6.7 Associated Water Management

6.7.1 Introduction

The primary objective of this study is to develop an adaptive long-term Associated Water Management Strategy that (i) considers a range of water management options, (ii) recognises variability of associated water produced in different areas and (iii) allows for continual improvement in best practice water management for coal seam gas operations (see full report in Appendix Q).

The guiding principle of the strategy is to maximise use for beneficial purposes and minimise the potential for environmental harm, in line with Queensland Government Environmental Protection Agency (EPA) Operational Policy for associated water and Queensland Government Department of Infrastructure and Planning (DIP) Policy (Queensland Coal Seam Gas Water Management Policy).

A key foundation of the strategy has involved the development of a knowledge base of advantages, disadvantages and risks of various water management options and a framework to select appropriate water management approaches at various stages of the GLNG Project life (see Appendix Q for the full technical report). It is envisaged that the strategy will allow informed decisions to be made throughout the lifetime of the field and help meet the needs for regulatory approvals, negotiations, and compliance with EPA requirements.

The specific objectives of the strategy are therefore:

1) To assess the technical, economic, environmental, social and regulatory viability of a number of associated water management options;
2) To develop the best net environmental, social and economic outcomes for the region;
3) To develop a consistent and transparent decision support tool to assist Santos' internal management processes and aid negotiations with regulatory authorities throughout the EIS period and beyond;
4) To develop an adaptive associated water management strategy that can be updated periodically and continually improved with new monitoring data and with advances in science and technology (e.g. emerging water treatment technologies);
5) To promote and, where practical, adopt EPA preferred uses of associated water; and
6) To maximise opportunities for local community use of associated water and, where ever practical, add value to the local environment and economy.

It should be noted that the strategy is based on the current Coal Seam Gas (CSG) field development scenarios, as described in Section 3, and is in accordance with the phased approach of the EIS for the CSG fields (refer to Section 6.1).

6.7.2 Methodology

For the purpose of this strategy the GLNG CSG fields have been divided into three sub-regions, namely Fairview, Roma and Arcadia Valley (reasonably foreseeable development (RFD) area). Given the distinct geographical physical and socio-economic characteristics of the three field areas, the associated water management strategy has been developed on a field-by-field basis. The strategy sets out specific performance measures and goals to maximise the beneficial use of associated water and minimise the generation or emissions of potential containments to the receiving environment (refer to Appendix Q for the full strategy).

The steps in developing the strategy and meeting the needs of the Terms of Reference (ToR) for the GLNG EIS are shown in Figure 6.7.1 and described in more detail in Sections 6.7.2.1 through 6.7.2.4.

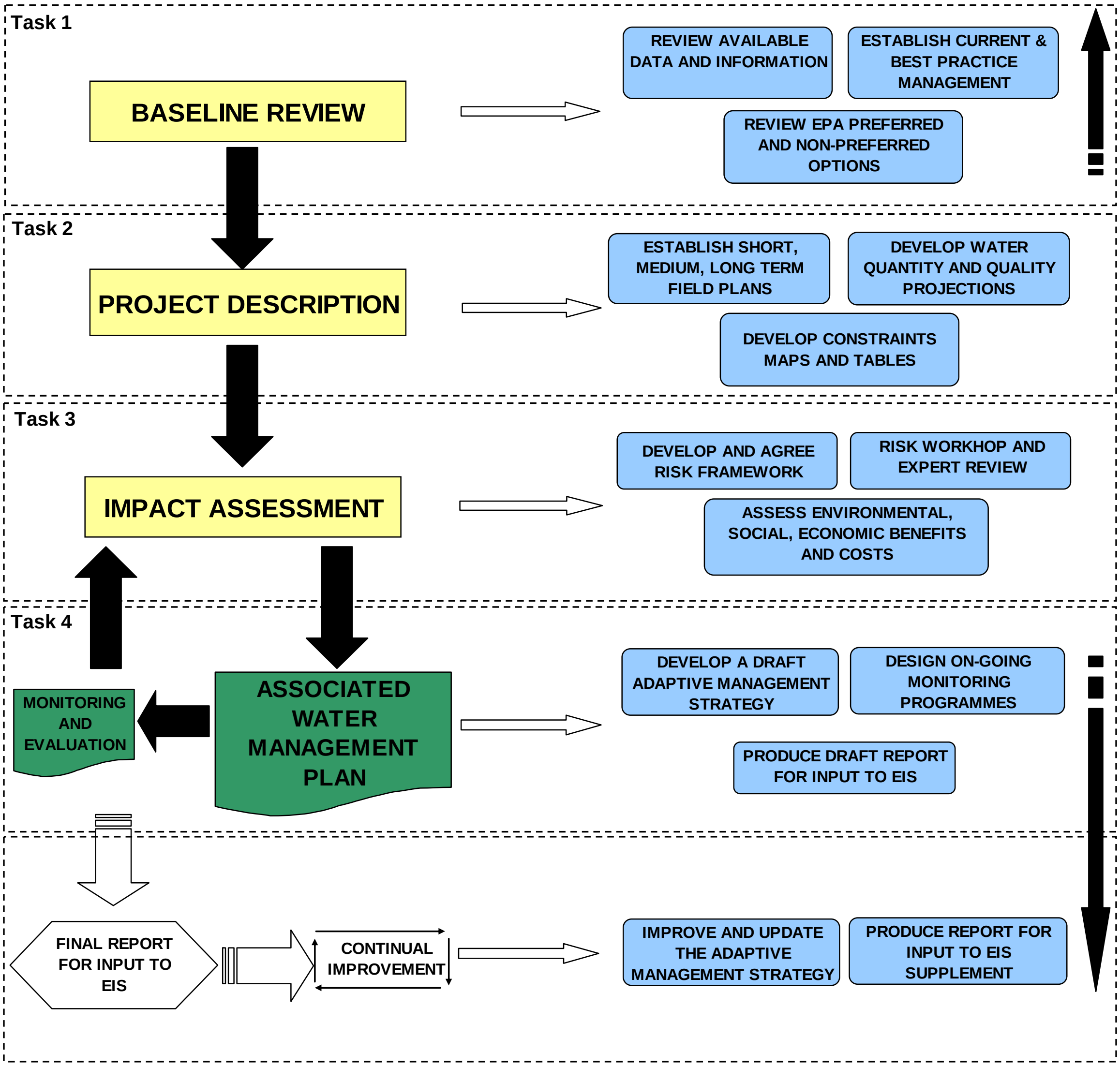

Figure 6.7.1 Strategy Development Process

6.7.2.1 Task 1 - Baseline Review

Tasks included:

- Carrying out a desktop review of existing operations, management practices/studies and a review of similar projects beyond Santos operations;
- Identifying missing data through gap analysis and defining additional data needs (monitoring programs) and working assumptions;
- Identifying and quantifying existing beneficial use demands and identifying the potential for additional uses above current demand;
- Undertaking an initial assessment of associated water management options, including identifying key opportunities and constraints to implementation; and
- Undertaking a series of meetings with key Santos and URS personnel to explain the objectives, methodology and desired outcomes and their role in the strategy development process.

6.7.2.2 Task 2 - Project Description

Tasks included:

- Consulting with Santos to develop agreed long term scenarios for the projected development of the three CSG fields from 2010 to 2034; and
- Estimating the change to water quantity production rates and quality over the lifetime of the CSG fields.

6.7.2.3 Task 3 - Impact Assessment

Tasks included:

- Developing a quantitative risk assessment methodology to provide a comprehensive, rigorous and defensible platform from which Santos can reasonably determine their preferred water management strategy, identifying which risk issues are significant, and which risk issues need further investigation to comply with organisational policies, standards and external criteria;
- Using an experienced and qualified panel of experts during a 2-day workshop to identify the risks to the initial strategy, including commercial and legal liabilities, political and reputation impacts, human health and safety impacts and environmental impacts. The workshop participants used their collective expert knowledge and experience to quantify (estimate) the likelihood (frequency of occurrence) and the consequences (expressed in terms of environmental, social, health and safety and economic impacts) of the relevant issues; and
- Developing an adaptable risk assessment framework which can be updated throughout the lifetime of the CSG fields as more data and information becomes available from monitoring programs and modelling studies. The outputs from the risk modelling provides a consistent and transparent basis on which to compare the economic, social and environmental benefits and costs of associated water management options, and support the decision making process.

6.7.2.4 Task 4 – Draft Associated Water Management Strategy

Tasks included:

- Developing a draft long term water management strategy (combination of preferred options) for each CSG field. The strategy has been designed to provide a flexible decision support framework which can be adapted to the likely schedule of water production and changes in water quality; and
- Providing recommendations for additional longer term water studies and monitoring programs which will be required to refine and continually improve the water management strategy.

The draft associated water management strategy and the Environmental Management Plan (EMP) are both required as part of the CSG fields operation approvals process. The two documents are written to complement one another and are linked through referencing. The two document strategy allows for specific attention required for the associated water issues, which then can be referenced in the EMP.

6.7.3 Regulatory Framework

Key legislation governing the management of associated water identified with regards to the proposed CSG fields of the GLNG Project includes:

- *Water Act 2000 (Qld);*
- *Water Supply (Safety and Reliability) Act 2008 (Qld);*
- *Environment Protection Act 1994 (Qld);*

- *Environmental Protection (Waste Management) Policy 2000 (Qld);*
- *Environmental Protection (Water) Policy 1997 (Qld)*[1]*;*
- *Petroleum and Gas (Production and Safety) Act 2004 (Qld);*
- *Petroleum Act 1923 (Qld);*
- *Water Resource (Great Artesian Basin) Plan 2006, Queensland; and*
- *Water Resource (Fitzroy Basin) Plan 1999, Queensland.*

6.7.3.1 Water Act 2000

The *Water Act 2000* (Qld) (Water Act) provides a framework for the sustainable management of water and related resources. It regulates the taking, use and allocation of water through (among other things) water resource plans and resource operations plans. It sets out permitting and licensing requirements for taking or interfering with water, quarry material and other resources. Development approval under the IP Act is also required in respect of certain Water Act activities (including operational works and removing quarry material from a watercourse).

Where water used is not associated water under the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G (PS) Act), or is not water necessarily produced as a result of the carrying out authorised activities under the *Petroleum Act 1923* (Qld) (Petroleum Act), a water licence, which regulates the taking or interfering with water from a watercourse or overland flowwater, will be required for those activities. A water licence is also required to authorise the access to/supply of treated or untreated associated water to any third party, other than for domestic or stock watering purposes.

6.7.3.2 Water Supply (Safety and Reliability) Act 2008

The *Water Supply (Safety and Reliability) Act 2008* (Qld) (WS (S&R) Act) aims to provide for the safety and reliability of water supply in Queensland. It provides for water service provider registration and sets out service provider obligations. It also determines what dams are referrable dams for which a failure impact assessment will be required. A failure impact assessment must be accepted by the DNRW before the construction of any referrable dam occurs.

A further ramification of the (WS (S&R) Act) is that if the petroleum tenure holder is granted a water licence, it may not charge for the on-supply of water unless it is also registered as a water service provider. Development approval under the IP Act is also required in respect of certain (WS (S&R) Act) activities (including operational work that is the construction of a referrable dam).

6.7.3.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (Qld) (EP Act) aims to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (being ecologically sustainable development).

6.7.3.4 Environmental Protection (Water) Policy 1997

The *Environmental Protection (Water) Policy 1997* (Qld) (EPP (Water) aims to achieve the object of the EP Act in relation to Queensland waters by providing a framework for identifying environmental values, stating water quality guidelines and objectives to enhance or protect the environmental values, making consistent and equitable decisions about Queensland waters that promote their efficient use and best

[1] Note that at the time of technical report preparation (December 2008) the EPP Water policy was still in force. However, on 1 January 2009 the Environmental Protection Act 1994 Environmental Protection (Water) Amendment Policy (No.1) 2008 came into effect. The Amendment allowed for the identification of additional environmental values, with respect to water. The shallow groundwater resources have been evaluated according to the updated criteria.

practice environmental management and providing for community consultation and education. Legislative amendments to the EPP Water that took effect on 1 January 2009 were considered during preparation of this EIS.

6.7.3.5 Environmental Protection (Waste Management) Policy 2000

The *Environmental Protection (Waste Management) Policy 2000* (Qld) (EPP Waste) aims to achieve the object of the EP Act in relation to waste management by identifying environmental values to be enhanced or protected, providing a framework for the making of consistent and fair decisions in relation to waste management and minimisation, providing for the preparation of waste management programs and industry waste reduction programs and providing for government planning for waste management. Legislative amendments to the EPP Waste that took effect on 1 January 2009 were considered during preparation of this EIS.

6.7.3.6 Petroleum and Gas (Production and Safety) Act 2004

The P&G (PSA) Act also regulates petroleum and natural gas in Queensland. It aims to facilitate and regulate the carrying out of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry. It aims to achieve this in a way that minimises land use conflicts and encourages responsible land use management (among other measures). The project will require a range of consents and approvals under the P&G (PSA) Act.

The P&G (PSA) Act allows the holder of a petroleum tenure to take, interfere with and use an unlimited amount of underground water (referred to as 'associated water') that arises during the course of, or results from, activities that are authorised activities under the terms of the petroleum tenure.

6.7.3.7 Petroleum Act 1923

The Petroleum Act regulates petroleum and natural gas in Queensland in relation to certain petroleum tenements granted prior to 2004. The Petroleum Act deals with authorities to prospect and leases, and provides for the ownership of pipelines and equipment.

6.7.3.8 Water Resource (Great Artesian Basin) Plan 2006

The Water Resource (Great Artesian Basin) Plan 2006 (GAB WRP) defines the availability of water in the plan area and provides a framework for sustainably managing and taking that water. The plan also identifies priorities and mechanisms for dealing with future water requirements.

The Great Artesian Basin Resource Operations Plan 2006 (GAB ROP) implements the objectives and outcomes specified in the GAB WRP.

6.7.3.9 Water Resource (Fitzroy Basin) Plan 1999

The Water Resource (Fitzroy Basin) Plan 1999 (Fitzroy Basin WRP) provides a framework for sustainably managing water, and the taking of water within the plan area. The Plan also provides a framework for establishing water allocations and the regulation of the taking of overland flow water. The Fitzroy Basin Resource Operations Plan 2006 (Fitzroy Basin ROP) provides guidance on the allocation and management of water to implement the objectives set out in the Fitzroy Basin WRP.

6.7.4 Existing Environmental Values

6.7.4.1 Associated Water Quantity and Quality Estimates

The quality and quantity of associated water is primarily dependent upon the geology of the area in which the gas wells are located, and therefore the management strategies for dealing with the water generally need to be site specific. However, throughout the CSG industry, the presence of total dissolved solids (TDS) is the primary constituent of concern which dictates water management strategies. CSG freshwater with sodium, bicarbonate and chloride being the primary constituents (typical TDS concentrations of associated water within the GLNG CSG fields are between 400 and 6,000 mg/L, with an average of approximately 1,200 to 2,000 mg/L). Other key water quality parameters of concern in associated water include fluoride and boron. In addition, due care needs to be taken to manage pH, dissolved oxygen, suspended solids, temperatures and sodium adsorption ratios (SAR).

Across the entire CSG fields there are expected to be up to approximately 2,650 wells installed over the project life, producing a large quantity of associated water (see Section 3).

Figure 6.7.2 provides an overview of the volume of associated water expected from the reasonable foreseeable development (RFD) area over the life of the project. It must be noted that the volumes identified below have a substantial range of uncertainty because of the significant subsurface uncertainty. Detailed volume estimates will be better defined during later stages of field development.

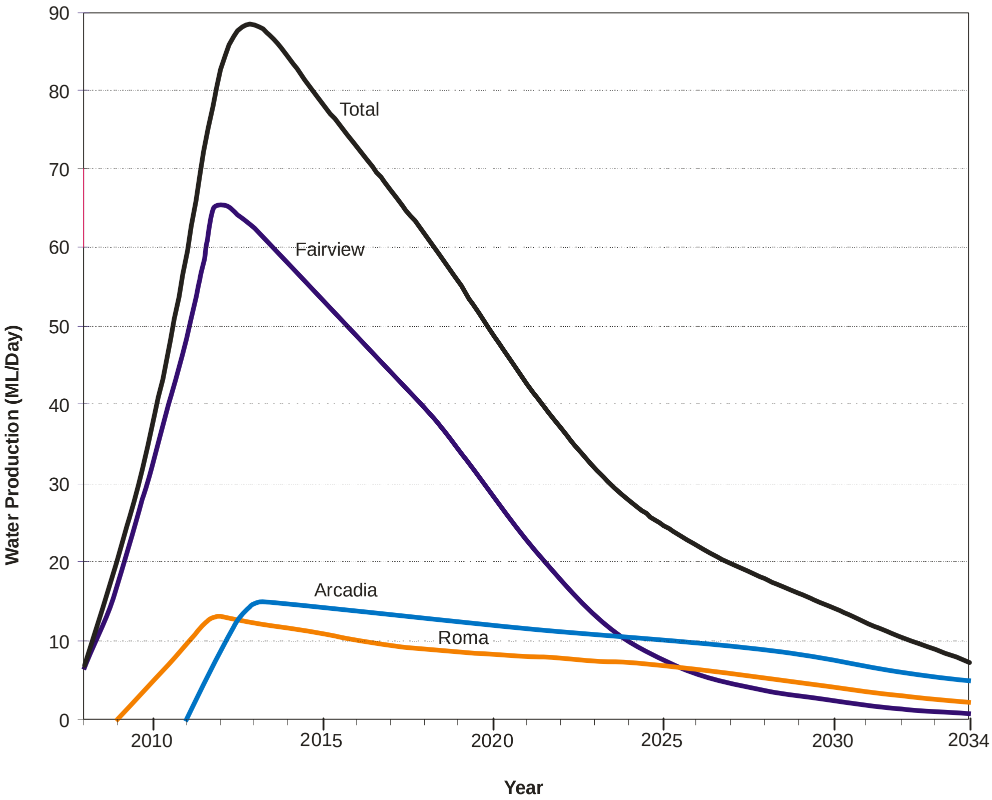

Figure 6.7.2 Estimated Associated Water Production from the RFD Area

Based on the upper bound water quantity estimates, 70 % of the total volume of water is expected to originate from the Fairview CSG field, with Roma and Arcadia Valley producing around 20 % and 10 %, respectively. In terms of water quality, the available monitoring data suggests that the key contaminants of concern for the likely re-use options are TDS, Fluoride and SAR (i.e. relative concentrations of sodium, calcium and magnesium). Concentrations of these contaminants are generally above trigger values for most beneficial re-use options. As such, it is likely that some form of treatment will be required for the majority of the associated water, in the form of desalination (such as Reverse Osmosis) and dosing to reduce SAR, if beneficial use can be implemented.

A detailed assessment of predicted associated water quantities and qualities for each CSG field is provided in Appendix Q.

6.7.4.2 Management Options

Various options were considered for the long term management of associated water such as piping it through to the coast. However this option was discounted on the basis of pipeline/pumping costs, loss of water resource for the local communities being impacted by the GLNG Project, need for licensing under the Integrated Planning Act (IPA), risk to environment as a result of possible discharge, compensation to landholders, and potential need for future remediation.

Other options that were investigated have been categorised as follows:

- **Municipal use -** including potable water supply, community uses (e.g. irrigation of sports fields/open spaces);
- **Agricultural use -** including small to large scale irrigation schemes, stock watering, local farm uses;
- **Industrial use -** coal mine/s, feedlots, cooling tower water;
- **Injection -** of associated water or brine stream (following treatment) into underground formations being either the aquifer from which the water was extracted or another formation with appropriate characteristics to receive the water;
- **Water management dams -** store and release, constructed wetlands, brine containment ponds, recreation (note, evaporation of associated water is both non-preferred and not permitted); and
- **Surface discharge -** to surface water systems either via direct discharge or via overland flow paths.

Different solutions (and levels of water treatment, principally to reduce TDS) will be appropriate for different areas depending on the quantity and quality of associated water, and the intended use. It is therefore likely that water management options will be site-specific and constrained by some or all of the following factors:

- Location of production area and proximity to communities, industries and agricultural lands;
- Confidence in the water production rates that can be guaranteed for beneficial use;
- Water quality and treatment facility requirements and costs;
- Environmental sensitivity of surroundings/receiving environment;
- Quantification of risks associated with various uses;
- Responsibility for costs for beneficial use schemes; and
- Regulatory guidance, in particular from the Queensland EPA.

Table 6.7.1 summarises the constraints to the water management options in each CSG field on the basis of the information provided in Appendix Q.

Table 6.7.1 Water Management Options Constraints Summary

Water Management Option	CSG Field		
	Roma	Fairview	Arcadia Valley
Potable use	Green	Red	Red
Other municipal uses	Green	Red	Red
Agricultural use	Green	Green	Green
Industrial use	Green	Red	Red
Injection into overlying formations – brine stream or associated water	Red	Red	Red
Injection of associated water into CSG formations	Red	Red	Red
Injection into underlying formations – associated water	Red	Green	Amber
Injection into underlying formations – brine stream	Amber	Green	Amber
Temporary storage of associated water in dams (2,00ML – 1,000ML)	Green	Green	Green
Evaporation ponds for associated water	Red	Red	Red
Brine containment ponds	Green	Green	Green
Treated discharge to surface water	Amber	Amber	Amber
Untreated discharge to surface water	Red	Red	Red

Key to Constraint Levels: (**Green** – Low, **Amber** – Medium, **Red** – High)

The least constrained area is the Roma field as a result of its proximity to sizeable communities with a demand for additional water to support existing potable, municipal, industrial and agricultural supplies, and interest in exploring added value uses of water. There is also i) potential for treated discharge to surrounding creeks, although this requires further investigation to ensure that potential impacts can be adequately mitigated, and ii) potential for injection of brine stream into underlying aquifers, although this requires additional hydrogeological studies to be carried out (refer to Section 6.7.4.4 for a more detailed description of the preferred options).

The Fairview field is constrained largely by the absence of any nearby end users which renders all municipal and industrial uses uneconomic. However, a favourable condition at Fairview is the significant area of freehold land owned by Santos, which is potentially suitable for large scale irrigation schemes, and the potential to use the Dawson River to transport water to downstream users (which includes agricultural and industrial users). Coupled with this is the availability of existing injection well infrastructure, which can be used to manage the resultant brine stream (refer to Section 6.7.4.5 for a more detailed description of the preferred options).

The most constrained area, from a water management perspective, is the Arcadia Valley field. This is due to the lack of any significant municipal or industrial water demand. Furthermore, all streams in the vicinity of the development area are ephemeral, which presents challenges with respect to ecologically approved discharge of treated. Within the Arcadia Valley CSG field, however, it could be viable to provide treated water for irrigation both within the valley and further downstream (refer to Section 6.7.4.6 for a more detailed description of the preferred options).

It is likely that treatment will be required for the majority of associated water from the Arcadia Valley and Roma CSG fields, given the sensitivity of the receiving environment and options for beneficial use. Also, given the technical and regulatory constraints to injection it is highly likely that brine containment ponds will be required to manage brine prior to its safe disposal (crystallisation and encapsulation or transfer to licensed landfill sites).

6.7.4.3 Community Engagement

Following the review of various water management constraints and opportunities, and their relevance to the three CSG fields, local communities were engaged to identify local water needs and consider issues. The underlying aim of the long term associated water management strategy is to economically dispose of associated water in an environmentally sustainable manner and where ever possible add value to the local environment and economy and develop opportunities for local community use of associated water. As such, this first step, and the ongoing process of community engagement throughout the duration of the development program for the CSG fields is considered fundamental to achieving the objective.

Roma and Wallumbilla Communities

Roma Town Water Opportunity Workshops

Santos engaged a cross-section of stakeholders during two workshops held in Roma on 2 and 16 September 2008, to identify and evaluate a range of potential water uses within Roma Township and the surrounding area. These workshops involved representatives from Roma Regional Council, Queensland Murray-Darling Commission, AgForce Queensland, Commerce Roma, Uniting Church, as well as selected individual local landholders. The main objectives of the workshops were to:

- listen to and work with a representative cross-section of the community to understand their expectations and potential water needs;
- explore and identify opportunities and mechanisms for providing water to the community (in line with best practice and current legislative guidance); and
- provide the community with a central contact for all issues relating to associated water.

The workshop identified and then undertook a screening exercise to identify a range of water management options and then determine the preferred options in order of priority. The following beneficial end uses (considered high priority) were identified as potentially viable from a technical, social, economic and environmental perspective (see Section 6.7.4.4).

1) Provide potable water to Roma Township;
2) Provide treated water for local municipal, industrial and intensive agricultural uses (feedlots, saleyards, truck washdowns and Council road works);
3) Augment water levels within Lake Campbell (using treated water) to allow recreation and fishing, with opportunistic release to Bungil Creek during the wet season (and eventual supply to Surat Weir);
4) Provide water for the irrigation of existing and new crops;
5) Provide water for injection into potable aquifers for later use; and
6) Provide water to establish new agroforestry projects.

Wallumbilla Town Water Opportunity Workshop

A water opportunity workshop was also held in Wallumbilla with local community representatives on the 18 October 2008 to identify possible water demands in Wallumbilla and Yuleba townships, which are located off the Warrego Highway approximately 40 - 60km east of Roma Township. The following options were identified:

1) Provide potable water for Wallumbilla Township;
2) Provide water for irrigating local food crops (melons, grapes, vegetables);
3) Supply water to local industry (fertilizer plant and sand washing facility) and a newly proposed feedlot; and
4) Treated discharge to Wallumbilla and Yuleba Creeks to aid environmental flows and improve supply to downstream users.

Fairview Community

A significant proportion of water produced from the Fairview CSG field could be managed within the land already owned by Santos. This would likely be achieved by irrigation of crops and tree plantations (see Section 6.7.4.5). The process of engaging the local community has been ongoing since Santos purchased the Fairview CSG field and there are already established uses of associated water for stock watering and other local uses (e.g. road construction, dust suppression). Whilst this only constitutes a small proportion of the expected water volume, Santos will endeavour to continue the supply for local small scale farm uses, subject to regulatory approval. In addition, supply to the town of Injune is being investigated, and options for treated discharge to the Dawson River for the benefit of downstream users are currently being assessed.

Arcadia Valley Community

Santos engaged local landholders, via a survey, to identify a range of potential water uses within the Arcadia Valley and surrounding area. The following options were identified:

1) Irrigate existing and new Chinchilla White Gum plantations;
2) Irrigate existing and new Leucaena and Cereal crops;
3) Discharge to surface waters and augmentation of Lake Nuga Nuga for environmental and recreational uses;
4) Provide water for stock watering; and
5) Supply water for road works.

Of these, the first three are considered potentially feasible, and have been adopted as preferred options for long term water management (see Section 6.7.4.6). Whilst opportunities such as providing water for road works and stock watering could be pursued, they are unlikely to have a combined demand of more than 1 ML/d and would therefore only be a small component of the overall long term associated water management strategy. The distance to, and size of the nearest communities (Rolleston to the north and Injune to the south west) largely preclude opportunities for large scale municipal and industrial beneficial use options.

6.7.4.4 Roma Water Strategy Overview

Roma Town Beneficial Uses

The current population of Roma Township is approximately 6,800. This is unlikely to change significantly over the next 20 years, according to the Queensland Government Department of Infrastructure and Planning. The town’s drinking and municipal water supply is currently provided by a network of 12 groundwater bores. Of the 12 bores used, 7 pump directly into the distribution network without treatment.

The bore pumps run continuously during peak demand (summer) and there is very little spare capacity in the system. Approximately 3 ML/d of wastewater is produced by the town which is all treated and used to irrigate the golf course and local Lucerne crops.

The water demand in Roma varies significantly depending on the season. Peak demand during summer is in the order of 14 ML/d. This reduces to just 2 ML/d during the winter. Such significant variance presents a challenge in terms of providing water for potable use. The Council currently distributes 40 % of its water to residential/commercial users and 60 % to public spaces in the summer (this is seasonal and reverses in winter).

Additional uses for the water include other council uses (such as road works), existing and planned feedlots (10,000 Standard Cattle Units are planned for a new feedlot in Roma), an existing truck washdown facility, an existing saleyard, and existing and a new industrial subdivision. The basis for this option will involve the construction of a water gathering network (assuming a total of 100 km in length for costing purposes) and main water pipeline and pumps (20 km in length) to transport water from the CSG field to the eastern outskirts of Roma.

The preferred current option is to construct water treatment plants with a combined peak treatment capacity of up to 20 ML/d, constructed at locations convenient to the water supply and overall field layout. It is planned that the water treatment plants will be located close to a compressor station (or power station) to reduce pumping costs, limit the environmental impacts of brine reject on the receiving environment, reduce noise, offer opportunities for waste heat recycling and provide opportunities for other users who are located out of town.

An option under consideration is that all raw water is treated to potable water standard for a range of high value uses, which could also include irrigation and discharge to surface waters. The existing groundwater bores which supply the network would likely be put on standby duty until such a time that CSG water supply is no longer sustainable, or potentially adapted to inject water of suitable quality into receiving formations.

The base case for brine management is to construct compacted clay and high density polyethylene (HDPE) lined water management ponds to contain the brine, which will be located next to each water treatment plant. Depending on the outcome of more detailed studies, the brine may be i) injected into suitable formations (such as Precipice and Showground formations) and/or ii) naturally crystallised and encapsulated or transferred to a suitable landfill.

In summary, the option of providing potable quality water to the town of Roma for a variety of municipal and industrial uses could use between 20 % and 80 % of the peak associated water volume, depending on the season and adopted strategy for replacing Roma town water supply. The significant seasonal variation means that additional water management options are likely to be required particularly for the winter months during which there will be an excess of water.

Wallumbilla and Yuleba Township Uses

Wallumbilla and Yuleba townships have populations of around 300 and 200, respectively. These populations have declined over recent years and it is unlikely that they will increase over the duration of the CSG field development program. There are several possible beneficial end users within the regions surrounding the towns, including local industry and small scale agriculture. The maximum demand from this area is in the order of 2 ML/d. It is likely that all stated uses would require treated water with a TDS of less than 500 mg/L, to avoid contamination of the environment and meet water quality standards for the stated uses. To service this need, water could be treated at a local water treatment plant and piped to the town for appropriate beneficial use.

Lake Campbell and Opportunistic Release to Bungil Creek

Lake Campbell is located approximately 5 km to the east of Roma on the north side of the Warrego Highway. It is situated around 500 m to the west of the existing Roma town water supply storage tanks.

The lake is man-made and has a 4 m high; 500 m long earth bund (most likely constructed using material excavated from the centre of the lake) and provides approximately 300 ML of storage. From a visual inspection, the embankment shows little or no sign of erosion, differential settlement or instability. To the west of the dam is a lower spillway section, approximately 50 m in length.

A committee is responsible for maintaining the lake and it is occasionally used for water skiing and jet skiing, when water levels permit. Adjacent to the lake, and overlooking it, is Campbell Park (community events are held here in the summer), which includes a rest area containing toilets and cold water shower facilities.

The lake has a limited catchment area and receives minimal overland flow. Water to fill the lake is sourced via an existing pump and pipeline connecting the lake to Bungil Creek, located around 2.5km to the west of the lake. Under the existing operational rules, water can only be pumped from Bungil Creek when flows are above a certain threshold in the creek. Bungil Creek is predominantly ephemeral and therefore opportunities to fill the Lake are restricted to periods within the wet season (November to February). As a result of this, the Lake is either empty or has very low levels for the majority of the year (especially in the winter).

There is a potential opportunity to improve the amenity, recreational and environmental value of this area. The basis of this option is as follows:

- Raise the embankment (and spillway section) by up to 2 m to provide an increase in the operational storage capacity;
- Supply water from the nearest water treatment plant to fill the lake during the dry winter months (around seven months of the year); and
- During the wet season (or around five months of the year) investigate opportunities to discharge treated water from the lake to Bungil Creek as and when flows within the creek permit this activity, or via a permanent but regulated flow to a section of the creek with permanent flow. For recreational purposes and in order to undertake managed release, the water will need to be treated to a TDS concentration of around 400 mg/L.

A key element of the scheme is the ability to discharge treated water to Bungil Creek. Bungil Creek is a tributary to the Balonne River, which flows to the Surat Weir some 60 km downstream. From the detailed surface water discharge studies undertaken for the Balonne-Condamine catchment (refer to Appendix O1, it appears that minor treated discharge to grade could be undertaken (at rates of up to 5 ML/d) with minimal impact on the receiving watercourse salinity regime (although a more detailed site specific study will be required to confirm this). However, it should be noted that this is a Category 2 non-preferred option (as defined by the EPA) so justification will need to be provided on why this option is required and what additional benefits it may bring to the surrounding area.

Santos is currently exploring opportunities to use Bungil Creek to transport treated water to Surat weir to supplement environmental or “pass flows” at that location as requested by recent updates to the Water Resources Plan.

Irrigation of Crops

This option would involve providing treated water to local landholders to irrigate their crops, replacing existing or providing new irrigation supplies. The water demand from cereal crops is in the order of 4 - 5ML/ha/yr, and therefore to manage the peak water production from the Roma area (16 ML/d of permeate), around 1,100 ha of land would be required (around a quarter of the available land area). It is expected that the demand would vary according to season.

This option could be readily integrated with the other suggested water management options (i.e. Lake Campbell and Roma Town supply), and would provide the overall system with more overall capacity and flexibility (since the Roma Township and discharge to Bungil Creek water demands are constrained by population/existing industrial activity, and the sensitivity of the creek to altered flow regimes, respectively).

Santos will also provide treated water to local farmers (for irrigation use / farm uses) as part of land access agreements. This is expected to provide additional demand for treated water.

Irrigation of New Agroforestry Initiatives

Agroforestry is an agricultural approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy and sustainable land-use systems.

The proposed scheme would use the same principles as set-out in the irrigation of crops option. High value treated water from the desalination plant could be provided to the landholder and piped to the relevant irrigation area. Additional treatment may then be required to reduce the SAR to an acceptable level, depending on the specific needs of selected crops and trees. Agroforestry may also provide the opportunity to use untreated associated water, although this will be subject to further investigation.

The success of the proposed agroforestry initiative would be largely dependent on the willingness of landholders to change existing land uses from crops to mixed uses. The most effective form of information, knowledge and skill development that leads to practice change will be to provide landholders with regular exposure to regional / national models of agroforestry / multiple land use options and to practitioners who already manage such systems. There are significant properties (each >500 ha) located alongside the riparian zones of Bungil Creek and Blyth Creek. Cypress Pine and Sandalwood are grown locally and these could be planted around these as part of the scheme. The average water demands for these are in the order of 2.4 ML/ha/yr, and therefore around 2,500 ha of land would be required to manage the peak water production rates of 16 ML/d. Santos is currently developing concept plans for agroforestry schemes for offer to the local landholder community.

Preferred Option Combinations

A risk assessment model was developed and used to assess a number of option combinations based on the available beneficial end-uses as detailed above (for full details refer to Appendix Q). Following risk optimisation and careful consideration of the constraints, the following preferred option and one alternative option were identified for progression to the Concept Selection stage (see Table 6.7.2 and Figure 6.7.3). These options are cost effective and pose an acceptable risk to the wider environment.

It should be noted that these options are preliminary and will require further examination and optimisation. Furthermore, they are based on assumed water production schedules which are likely to change as the CSG field development plans are developed and refined, and additional monitoring data becomes available. In order to manage the uncertainty and changing water availability, it is also likely that different priorities will be established for the various demands. This is currently under investigation by Santos, and is being progressed via on-going consultation with potential end-users.

Table 6.7.2 Roma Associated Water Management Options (% distribution[1])

Option	Town Supply	Industrial Supply	Irrigation (Crops or Agroforestry)	Treated Discharge to Watercourse
Preferred	22 %	12 %	66 %	0 %
Alternative 1	22 %	12 %	51 %	15 %
Alternative 2	0 %	0 %	100 %	0 %

[1]The % distributions provided in the table above are indicative only and are based on estimated peak flows and potential end-user demands. As such, it is likely that relative proportions will change with time following more detailed demand studies and progression of the field development plans (and water quantity estimates).

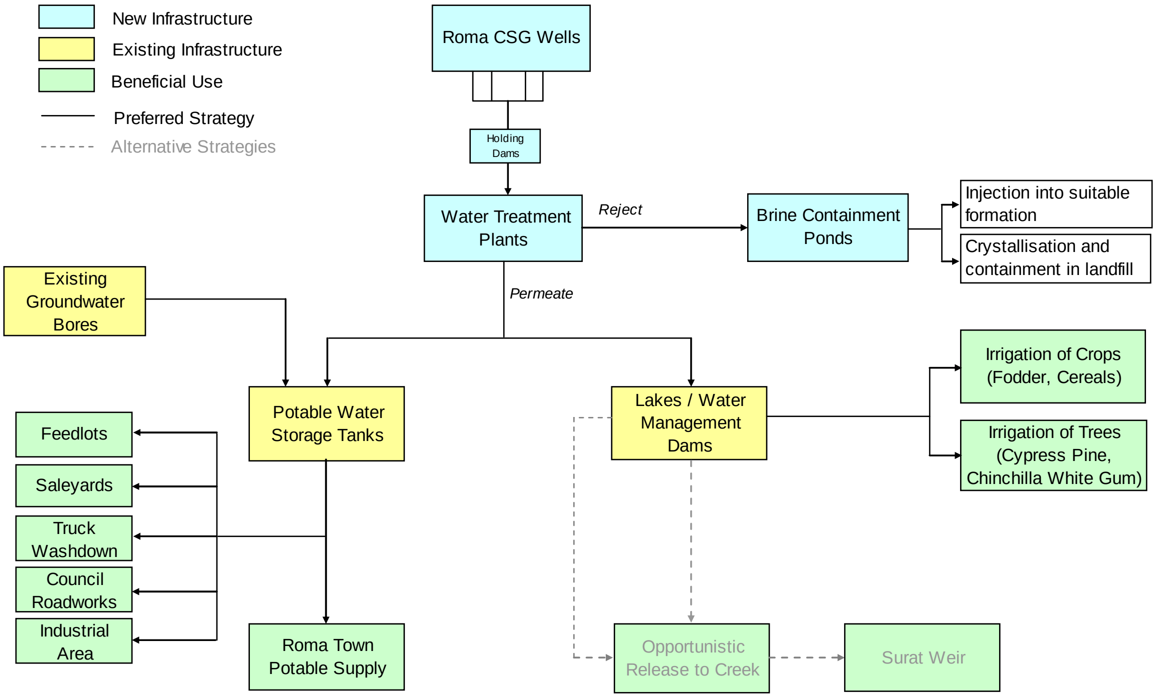

Figure 6.7.3 Roma Water Management Conceptual Model

The preferred and alternative strategies are broadly in line with the recently published Queensland Government EPA Operational Policy entitled *'Management of water produced in association with petroleum activities (associated water)'* and the Queensland Government DIP Policy, *Queensland Coal Seam Gas Water Management Policy*. They are all Category 1 options (i.e. preferred uses), with the exception of the option to store and release water to Bungil Creek (Alternative 1) which is classified as Category 2 (i.e. non-preferred) by the EPA.

6.7.4.5 Fairview Water Strategy Overview

Fairview Irrigation Scheme

Santos owns freehold land of around 18,000 ha within the Fairview and Springwater properties, of which approximately 3,437 ha is suitable for plantation establishment on the plateau areas of Springwater and Fairview, and 1,555 ha is potentially suitable in the valley areas (land less than 4 degree slope and suitable soils).

Santos has recently submitted a Resource Utilisation Plan (RUP) for beneficial use of approximately 65 GL of associated water produced from CSG development activities to irrigate approximately 2,000 ha of plantation eucalypt forest and 234 ha of Leucaena-pasture grass-fodder crop over the next 10 years. The current projected maximum peak water production during this period would be in the order of 32 ML/d. The water would be treated for irrigation of *Eucalyptus argophloia* (Chinchilla white gum) plantations and desalinated and treated for irrigation of Leucaena dominant forage crops used for grazing and forage harvesting. It is proposed that the Fairview Irrigation Scheme will be extended for the entire duration of the CSG field development.

A brief description of each component of the scheme is provided below.

Trees

Chinchilla White Gum trees are native to the Chinchilla region and were selected due to their relatively high tolerance to drought, frost, salinity, insect pests and diseases, as well as their economic value as a commercial hardwood timber species.

Under normal, rainfall induced leaching conditions, long-term irrigation with untreated associated water is not predicted to substantially change subsoil salinities, but without management would substantially increase soil sodicity, leading to soil structural decline. To mitigate this risk, the associated water will be treated with calcium and magnesium sulphates (2:1 cation ratio) to reduce SAR from 100 to around 25. Associated water will also be treated with sulphuric acid to reduce irrigant pH to 6 and carbonates by 50 % to about 400 to 500 mg/l to minimise precipitation of calcium carbonates in soils. Combined with a mean TDS concentration of around 2,000 mg/L, this will ensure that the integrity of the soil structure and plant health is maintained.

Partly to avoid the need for construction of winter storage, and partly to minimise total salt loads, the operation will be based on "under irrigation' aimed at capturing 'salts' in soils and in strata below the root zone in a controlled manner. This allows continuous daily irrigation.

Modelling highlights the robustness of the forest plantation system. Irrigating of treated associated water using median 2,000 - 3,000 µS/m electrical conductivity irrigant at 4 ML/ha with no leaching (an highly conservative assumption), would require approximately 5 years of continuous irrigation before mean soil salinity levels rise from 2 to 5 dS/m, thereby initiating a low level of salinity induced yield loss.

The under-irrigation strategy of an average 2.4 ML/ha/yr or 40 % of long-term rainfall will ensure that forest plantation soils maintain high soil capacity to absorb water at a constant daily rate, including maximum planned daily rates of up to 4.5 ML/ha/yr. The selected irrigation rate strategy has additional benefits of:

- Minimising salt load per unit land area;
- Reduced land impact;
- Slow rate of change in soil properties;
- Greater irrigation volume flexibility; and
- Minimising surface run-off and release to local watercourses.

A 1.4 m wide area surrounding each tree row is wet by drip irrigation. SALF (salt and leaching fraction) modelling based on an irrigation rate of 400 mm/yr (compared with the long-term average of 240 mm/yr) and a TDS concentration of 2,000 mg/L predicts no change in the average root zone salinity for Springwater soils and only a slight increase in root zone salinity for Fairview plateau soils. No salinity impact on inter-row native and improved grasses is expected - these ground covers comprise 65 % of the total system area.

Forage Crops

The area of land proposed for the Leucaena dominant forage system is currently constrained by the available water treatment plant capacity at Pony Hills, which is 4.5 ML/d. Leucaena system total water demand is 7 ML/ha/year and therefore a maximum area of approximately 234 ha can be irrigated, until further treatment capacity is installed.

The desalination process removes most chemical elements from the associated water, but may leave a small residual quantity of sodium (up to 140 mg/l). Because of the very low calcium in this water, SAR is relatively high (approximately 38). Therefore, further treatment of the desalinated water will be required by addition of calcium and magnesium to reduce the SAR to between 2 and 6. As the sodium concentration of the desalinated water is very low, the total load over time is low, and no significant impacts on soil structural integrity are anticipated.

The reject from the water treatment process (brine stream) is proposed to be injected into the Timbury Hills formation (basement) using existing borehole infrastructure located at Fairview 77 and Fairview 82. Each injection well has a capacity of around 1.2 ML/d, although there is uncertainty over whether these capacities can be maintained in the long term. As a result, in the long term it may also be necessary to consider compacted clay and HDPE lined brine containment ponds to manage the brine, prior to natural crystallisation, and encapsulation or transfer to a suitable landfill.

To provide a feed buffer and allow for variation of water application in line with plant water-use demand (which varies between wet and dry seasons), desalinated water will be stored in a 220 ML water management pond prior to irrigation. In years of unseasonal high rainfall (90th percentile rainfall 866 mm), the key management option would be to divert excess feed water via drip irrigation to eucalypt forests. This may be achieved given the under-irrigation strategy applied to this crop, and maintenance of a large soil water storage capacity.

In summary, the available area of suitable plantation and crop (forage) land within the Fairview and Springwater properties is sufficient to manage the maximum water production rates and volumes from the Fairview CSG field. Santos are also undertaking trials on other trees and forage types, as well as combined tree-forage plantations.

Discharge to Upper Dawson River

To support the long term water management strategy under the GLNG Project, an extensive catchment hydrological modelling study has been undertaken to assess potential changes in hydrology, salinity and temperature that may arise in-stream under a range of discharge to surface water scenarios (refer to Appendix O1). This has included establishing the baseline conditions of streams in proximity to the Fairview CSG field, which are briefly summarised below:

- The Upper Dawson River has been observed to be ephemeral with period of no flow at certain times of the year (mainly winter), and furthermore, the base flow within the stream is often very low; in the order of a few mega litres per day;
- Salinity monitoring at the Utopia Downs gauging station over the last 10 years indicates that the upper Dawson River has a relatively low average TDS concentration of 200 mg/L; and
- The ambient stream temperature ranges between 17 °C to 22 °C in the winter and 22 °C to 27 °C in the summer.

The hydrological model indicates that water treatment would be required to a background level similar to the receiving watercourses, to avoid detrimental environmental impacts.

The basis of this option is to discharge treated (i.e. desalinated) associated water to the Hutton Creek, Baffle Creek and Dawson River. It is proposed that associated water would be captured via a water gathering network, piped to a water management pond prior to treatment and then discharged to stream locations with spring flows (or further downstream on the Dawson River to reaches with higher baseflow) to minimise alterations to flow, temperature and salinity regimes. Water would be treated to a high standard with a TDS concentration similar to background stream levels.

In summary, treated water discharges to perennial watercourses (or springflow locations) at relatively low discharge rates, should not substantially impact upon stream water quality or geomorphology (refer Appendix O1). Furthermore, the option to discharge treated water to grade is considered to add flexibility to the overall long term associated water management strategy for Fairview. It could provide a useful alternative to the Fairview irrigation scheme should actual volumes of associated water be significantly higher than expected. This is especially important since there are no other significant alternative beneficial use options within the immediate area (i.e. no community or industrial demand). The extent of its implementation will be largely constrained by sensitivity of the ecosystem to changes in the flow, temperature and salinity regime of the receiving watercourses.

Preferred Option Combinations

A risk assessment model was developed and used to assess a number of option combinations based on the available beneficial end-uses as detailed above (for full details refer to Appendix Q). Following risk optimisation and careful consideration of the constraints, the following preferred option and one alternative option were identified for progression to the Concept Selection stage (see Table 6.7.3 and Figure 6.7.4). These options are cost effective and pose an acceptable risk to the wider environment.

Table 6.7.3 Fairview Associated Water Management Options (% distribution[1])

Option	Treated and Desalinated Irrigation (Leucaena)	Treated (for SAR) Irrigation (Chinchilla White Gum)	Treated Discharge to Watercourse	Other Local Uses[2]
Preferred	12 %	88 %	0 %	0 %
Alternative	12 %	68 %	10 %	10 %

[1] The % distributions provided in the table above are indicative only and are based on estimated peak flows and potential end-user demands. As such, it is likely that relative proportions will change with time following more detailed demand studies and progression of the field development plans (and water quantity estimates).

[2] Other local uses relate to stock watering, road construction and dust suppression. The total demand has been calculated on the basis of existing water uses from the Fairview CSG field (i.e. at around 5 ML/d).

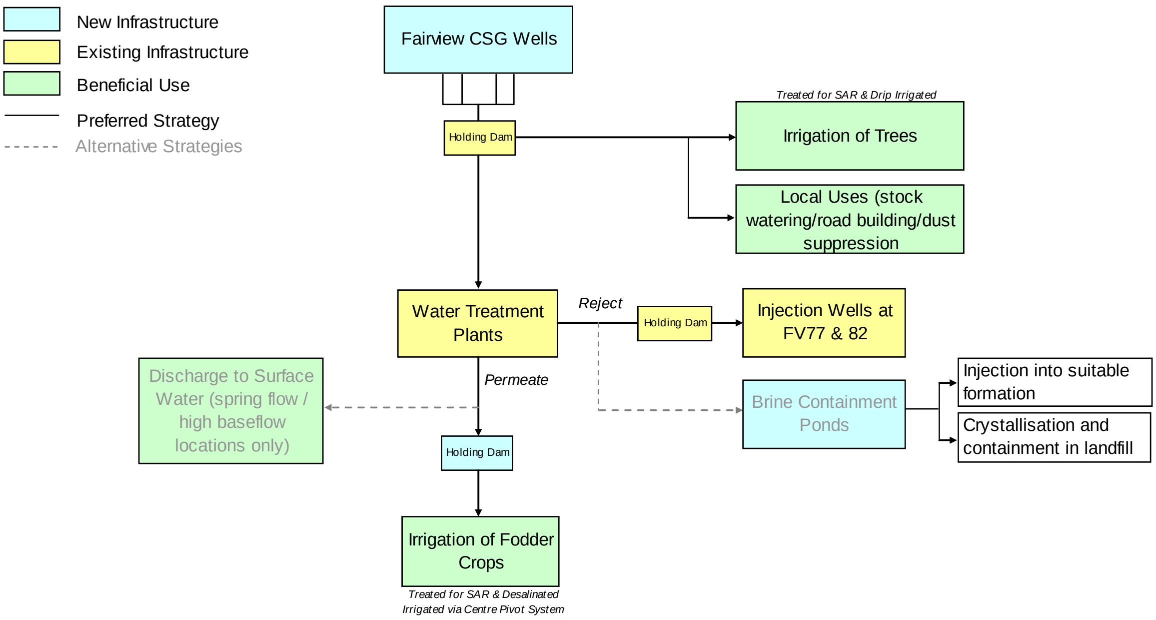

Figure 6.7.4 Fairview Water Management Conceptual Model

The main options put forward for the Fairview CSG field include; irrigation, discharge to grade, and other local agricultural (e.g. stock watering) and municipal uses (e.g. road building and dust suppression), with treatment. Notably, the area provides very little opportunity for local community or industrial use (as compared to Roma), and therefore, in line with the EPA's waste-hierarchy it is considered that the most attractive long term water management solution is to implement and expand the Fairview irrigation scheme as outlined above, whilst continuing to develop opportunities to supply water to users at locations downstream of the Dawson River.

This scheme has the capacity to manage all of the associated water and can be scaled according to actual schedules of water production. It is classified as a Category 1 option (i.e. preferred) by the EPA. As a back-up option, however, the option of treated discharge to local watercourses should be kept, although it will given the likely impact on the flow and temperature regime of this activity, it is likely that only a small proportion of associated water could be managed in this way, and for a relatively short time period only.

6.7.4.6 Arcadia Valley Water Strategy Overview

Irrigation of Crops and Trees

Unlike the Fairview and Springwater plateau areas, the Arcadia Valley is characterised by a dense ephemeral surface water drainage network. The baseline water quality within Arcadia Creek, which flows northwards through the valley towards Lake Nuga Nuga, is high, with an average TDS concentration of 146 mg/L (and maximum of 270 mg/L). As such, to avoid contamination of surface water and groundwater resources, as well as soil profiles, any sustainable long term water management option for the area will require treatment (i.e. desalination and SAR reduction) to a high standard similar to background levels.

Within the Arcadia Valley, both existing and new irrigation schemes could be supplied with treated and desalinated associated water. There are at least 20 properties (a mixture of freehold and leasehold) greater than 1,500 ha. Key landholders have indicated that they would be keen to use the water to irrigate existing crop and tree plantation areas, as well as expand operations to include other high value food crops. Current productivity within the Arcadia Valley is limited by the lack of water. CSG field development in this area may allow this constraint to be removed for a period of 10 - 15 years, during which significant volumes of water will be produced in this region.

It is proposed that a combination of tree plantations and crops could be irrigated with treated water (note: there would be nominally 21.5 ML/d of permeate available for the irrigation scheme assuming a water treatment plant efficiency of 80 %).

It is also proposed that a water gathering network would be developed and linked to a temporary holding pond prior to being fed to one or more water treatment plants (locations dependent on the layout of the development wells) with a capacity to treat up to 27 ML/d of raw water. This would produce around 21.5 ML/d of permeate, assuming 80 % water treatment facilities efficiency. Additional pipelines would then potentially be required to transfer the water to the irrigation areas.

This treatment process removes most chemical elements from the associated water, but may leave a small residual quantity of sodium. Because of the likely low calcium in this water, SAR would be expected to be relatively high. Further treatment of the desalinated water would therefore be required by addition of calcium and magnesium to reduce the SAR to below 10. Given comprehensive soil surveying and the selection of soil types suitable for irrigation, long term irrigation would not change subsoil salinities or impact the integrity of the soil structure.

The base case for brine management is to construct compacted clay and/or HDPE lined brine containment ponds to manage the brine, which will be located next to each water treatment facility. Depending on the outcome of more detailed studies being undertaken by Santos, the brine may be i) injected into suitable formations and/or ii) naturally crystallised, evaporated and encapsulated or transferred to a suitable landfill.

In summary, the available area of suitable plantation and crop land within the Arcadia Valley is sufficient to manage the maximum water production rates and volumes from the Arcadia Valley CSG field. The main challenge will be the safe disposal of the brine stream from the desalination process, and the ability to manage the likely seasonal variation in irrigation water demand for the suggested crops. Given the significant uncertainty of the likely quantities of associated water over the lifetime of the project however, the ability to scale the water management option is seen as a considerable advantage.

Discharge to Arcadia Creek & Lake Nuga Nuga

The basis of this option is to discharge treated associated water to Arcadia Creek, which flows northwards through the middle of the Arcadia Valley into Lake Nuga Nuga, before joining the Comet River. The Comet River and headwater catchments form part of the Fitzroy Basin, which flows into the Great Barrier Reef Lagoon at Rockhampton.

To inform the viability of this option, an extensive catchment hydrological modelling study has been undertaken to assess potential changes in hydrology and salinity that may arise in-stream under a range of discharge to surface water scenarios (refer to Appendix O1). This included establishing the baseline conditions of streams in proximity to the Arcadia Valley CSG field, which are briefly summarised below:

- The Arcadia Creek is ephemeral and only flows for around 3 - 4 months of the year (in the wet season); and
- Salinity modelling indicates that water quality in the Arcadia Valley region is high, with an average TDS concentration of 146 mg/L and maximum TDS concentration of 270 mg/L.

A further review of Lake Nuga Nuga has been undertaken since this water body is listed in the Directory of Important Wetlands in Australia and is classified as a Wetland of 'National Importance'. The key features of Lake Nuga Nuga are as follows:

- Located in the broad valley between the Expedition and Carnarvon ranges, with Mount Warrinilla located at its northern end. It is located on Arcadia Creek and is constructed with levees at its northern most extent. It is managed by Bauhinia Shire Council;
- It has a maximum surface area of 2,070 ha, with a depth ranging between 2 m and 9 m. The available storage in the lake is in excess of 103 GL. The volume of water in Lake Nuga Nuga varies considerably from year to year, depending on rainfall totals. Lake Nuga Nuga is classified as semi-permanent;
- Current water uses include extraction for irrigation, stock watering and recreation (camping, boating, fishing);
- The lake provides important refuge for dependent flora and fauna. Significant use of the lake is made by waterbirds such as pelicans and cormorants. Aquatic bed communities are dominated by Nymphaea sp. Flora species such as Acacia harpophylla and Casuarina cunninghamiana occur on the margins of the lake;
- The lake is known to suffer from algal blooms as a result of drought, water extraction for irrigation, stock consumption, runoff and erosion from fertilized agricultural areas (resulting in phosphorous loading) and regulation of rivers upstream of the lake and by the levee itself; and
- Continued and intensified grazing is considered a threat to the lake ecosystem.

The hydrological model of Arcadia Creek indicates water treatment would be required to a background level similar to the receiving watercourses, to avoid detrimental environmental impacts.

It is proposed that associated water would be captured via a water gathering network, piped to a water management pond, prior to water treatment (TDS <200 mg/L). Treated discharge to Arcadia Creek would be undertaken on a constant basis or, if required, via store and release schemes.

In summary, the option to discharge treated water to grade is considered to add flexibility to the long term associated water management strategy for the Arcadia Valley CSG field, which is likely to be focused upon irrigation of crops and trees. It could provide a useful alternative (or contingency) to the proposed irrigation scheme should actual volumes of associated water be significantly higher than expected or high annual rainfalls exceed the capacity of the irrigation demand. The extent of its implementation will be largely constrained by the sensitivity of the ecosystem to changes in the water balance, flow and temperature regimes of Arcadia Creek and Lake Nuga Nuga.

Preferred Option Combinations

A risk assessment model was developed and used to assess a number of option combinations based on the available beneficial end-uses as detailed above (for full details refer to Appendix Q). Following risk optimisation and careful consideration of the constraints, the following preferred option and one alternative option were identified for progression to the concept selection stage (see Table 6.7.4 and Figure 6.7.5). These options are cost effective and pose an acceptable risk to the wider environment.

Table 6.7.4 Arcadia Valley Associated Water Management Options (% distribution[1])

Option	Treated and Desalinated Irrigation	Treated Discharge to Watercourse	Untreated Discharge to Watercourse	Other Local Uses (road works, stock watering)
Preferred	100 %	0 %	0 %	0 %
Alternative	80 %	20 %	0 %	0 %

[1]The % distributions provided in the table above are indicative only and are based on estimated peak flows and potential end-user demands. As such, it is likely that relative proportions will change with time following more detailed demand studies and progression of the field development plans (and water quantity estimates).

The main options put forward for the Arcadia Valley CSG field include irrigation, discharge to grade and minor local agricultural and municipal uses (such as stock-watering and road building). All of these options require treatment, as a result of the sensitivity of the receiving environment to changes in salinity inputs.

Notably, the area has minimal opportunity for local community or industrial use (as compared to Roma), and therefore (in line with the EPA's waste-hierarchy) it is considered that the most attractive long term water management solution is to implement the irrigation scheme as outlined above. This has the capacity to manage all of the associated water, can be scaled according to actual schedules of water production and is in line with EPA and DIP policies on associated water (i.e. a Category 1 preferred option).

As a back-up option, however, the option of treated discharge to grade could be kept, although given the likely impact on the flow and temperature regime of this activity, it is likely that only a small proportion of associated water could be managed in this way, and for a relatively short time period only.

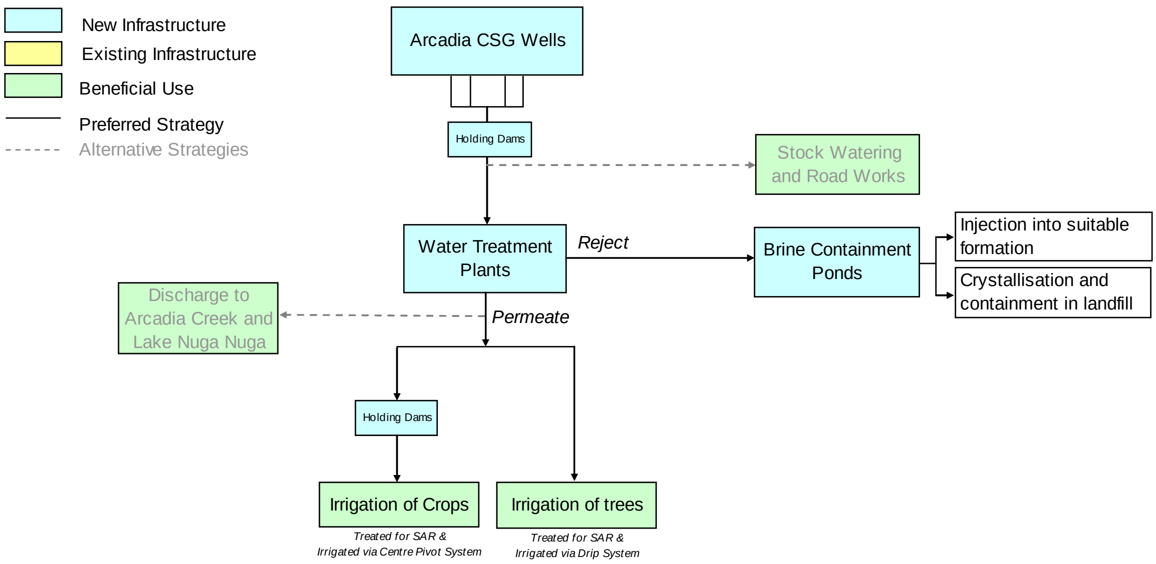

Figure 6.7.5 Arcadia Valley Water Management Conceptual Model

6.7.5 Potential Impacts and Mitigation Measures

The potential impacts and mitigation measures for the preferred preliminary water management strategies are outlined in Table 6.7.5 (refer to Appendix Q for a full description). During subsequent phases of the GLNG Project, which will include the production of detailed EMPs and the preparation of a detailed adaptive associated water management plan, further detailed assessments of potential impacts will be undertaken. Appropriate mitigations measures, including specific monitoring plans, will then be defined and implemented for each of the CSG fields.

6.7.5.1 Cumulative Impacts

Section 1 identifies other CSG development projects planned for the surrounding region. Some of these projects are up to 100 km from the GLNG Project CSG field areas and some may be within the GLNG Project FD area. There is limited information available as to the planned development of those projects or the quantity and timing of the development of the wells or associated infrastructure; however, a qualitative assessment can be made of the possible cumulative impacts.

Santos will develop the CSG fields in accordance with the EIS. There will be no other development by other petroleum producers in the tenements described in the CSG fields. Infrastructure impacts will not exceed those stated in the project description.

It is however, possible that other companies may develop CSG facilities within the CSG fields FD area as part of their planned CSG development projects in addition to the existing CSG domestic supply facilities. This will mean that there will be more CSG development in the FD area than the Santos project. As an area is developed, the number of wells will increase, but the spacing of wells will not intensify.

At the height of field development, each CSG field could potentially produce large volumes of associated water. However, it is likely that other CSG field development projects would involve the management of associated water in accordance with current Queensland EPA and DIP policies, as well as include some or all of the proposed mitigation measures outlined, thereby minimising the cumulative impacts on the receiving environment.

The associated management plans of other CSG producers are likely to involve significant amounts of desalination coupled with local/regional beneficial use of permeate to meet local and regional agricultural, municipal and industrial water demands. The management of brine (reject) is therefore potentially a key issue across the region. The Australian Petroleum Production & Exploration Association (APPEA) has recently commissioned a study to undertake a technical and economic feasibility study for the aggregation of associated water from CSG members from across the region. The outcomes of this study will be available by May 2009 and will further address issues of water treatment, local and regional demands and the management of brine.

Table 6.7.5 provides a summary of potential associated water impacts and mitigation measures for the CSG fields.

Table 6.7.5 Potential Associated Water Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Roma Field Associated Water Strategy			
Construction of water gathering networks and pipelines.	Construction activities could cause erosion, mobilise sediment and alter flow and in-stream water quality characteristics.	• Minimise the number of watercourse crossings. • Use trenching techniques to cross watercourses to minimise impacts on the flow regime. • Design and implement an erosion and sediment control plan. • Install stormwater management infrastructure prior to commencing construction nearby watercourses. • Minimise disturbance by heavy earthmoving equipment.	Minimise impact on existing watercourses.
Storage of associated water in water management dams.	Contamination (elevated salinity) of soil and shallow groundwater due to seepage and uncontrolled releases. Potential for harm due to catastrophic failure or longer term contamination of potable/stock water supplies. Inadequate rehabilitation at end of project.	• Adopt appropriate design, construction, operation and maintenance, decommissioning/rehabilitation techniques. • Appropriately site the dam above EPA agreed flood levels away from sensitive areas. • Use HDPE lining and clay liner to limit seepage and potential contamination of soil profiles and shallow groundwater. • Establish a monitoring system of the performance of the dam and the effectiveness of environmental management controls. • Explore opportunities to transfer dams to landholders and/or convert to surface water harvesting dams.	Minimise impacts of water management dams.
Storage of brine in brine containment dams.	Same impacts as associated water management dams, plus; • Air pollution (salts) caused when water levels in the evaporation pond decrease. • Odour due to algae or bacterial growth. • Potentially more significant contamination of soil and shallow groundwater due to seepage of highly saline water; and	Same as for associated water management dams, plus; • Use heat exchange system to recover waste heat from compressors, maximise evaporation rates and limit footprint of water management dam. • Implement wind breaks to reduce salt spray. • Include toe drains to capture seepage. • Remediate impacted areas and/or clay cap, mound and divert surface water away from the water management dam footprint area. • Establish a monitoring system off performance of dam and the	Minimise impacts of water management dams.

Aspect	Potential Impact	Mitigation Measures	Objective
	• Potential property devaluation, loss of farming land and limitations to the future use of the land, following decommissioning.	effectiveness of environmental management controls. • Explore potential to transfer dams to landholders following the project.	
Discharge to Bungil Creek via Campbell Lake or discharge line.	Alteration of the flow regime by introducing additional flows, potentially changing long term stream morphology and sediment and erosion patterns. Alteration of riparian vegetation and aquatic species through increased/altered environmental flows and differences in water quality. Localised erosion and scour at the point of discharge, if suitable controls are not put in place.	• Treatment of water to background levels prior to discharge to surface waters. • Discharge to grade limited to flow periods only or at downstream locations where sufficient baseflow exists. • Establish water quality and river health monitoring program to detect environmental change outside of agreed limits (physical, chemical and biological change). • Monthly inspection and water quality sampling at the location of discharge and up to two kilometres downstream. • Implement erosion controls at the point of discharge.	Minimise impacts on surface water environment.
Injection of brine stream into suitable formations.	Contamination of ground water in interconnected formations.	• Develop regional bore inventory to establish existing groundwater users and baseline conditions (groundwater flow and level). • Undertake studies to identify underlying aquifers suitable for injection (i.e. poor quality and unlikely to be of beneficial use). • Establish monitoring and reporting program on response of the receiving reservoir and nearby aquifers, which may be impacted (also to include pre-injection monitoring to ascertain baseline).	To ensure local water supply is not affected by injection activities.
Fairview Field Associated Water Strategy			
Construction of water gathering networks	Refer to Roma – Construction of water gathering networks.		
Storage of associated water in water management dams.	Refer to Roma - Storage of associated water in water management dams.		
Storage of brine in brine containment dams	Refer to Roma - Storage of brine in brine containment dams.		

Aspect	Potential Impact	Mitigation Measures	Objective
Injection of brine stream into suitable formations.	Refer to Roma - Injection of brine stream into suitable formations.		
Irrigation of trees using Associated Water.	• Localised development of perched water tables and water logging and build up of salinity. • Transport of excess water, potentially at an elevated salinity, to springs at the cliff faces surrounding the irrigation areas; • Localised tree or plant death as a result of water logging or excess salinity. • Soil structural decline (soil sodicity). • Increased erosion potential. • Loss of productive agricultural land.	• Implement an adaptive irrigation and groundwater management plan to guide the ongoing modification, and where necessary re-direction of the irrigation. • Undertake regular monitoring of in soil chemistry and structure appropriate management actions. • Reduce SAR to an appropriate level prior to application to maintain soil structure.	Ensure irrigation scheme does not adversely impact environment.
Irrigation of fodder crops (treated for SAR and desalinated)	• Localised development of perched water tables/water logging and build up of salinity. • Localised tree or plant death as a result of water logging or excess salinity. • Soil structural decline (soil sodicity). • Increased erosion potential. • Loss of productive agricultural land.	• Treat all associated water to high standard reduce SAR to an appropriate level prior to application. • Implement an adaptive irrigation and groundwater management plan.	Ensure irrigation scheme does not adversely impact the receiving environment.
Treated discharge to Dawson River	• Altering the flow regime by introducing additional flows, potentially changing long term stream morphology and sediment	• Treat water to background levels prior to discharge. • Discharge only to locations with consistent wet and dry season spring flows, or further downstream where there are higher baseflows.	Minimise changes to receiving watercourses.

Aspect	Potential Impact	Mitigation Measures	Objective
	and erosion patterns. • Alteration of riparian vegetation and aquatic species through increased/altered environmental flows and differences in water quality. • Changes to the temperature regime of up to 10 °C at the point of discharge, extending several kilometres downstream. • Localised erosion and scour at the point of discharge, if suitable controls are not put in place.	• No discharges at source during zero flow periods whenever possible. • Establish water quality and river health monitoring program. • Undertake regular inspection and water quality sampling at the location of discharge and up to two kilometres downstream. • Implement erosion controls at the point of discharge.	
Arcadia Valley Field Associated Water Strategy			
Construction of water gathering networks	Refer to Roma – Construction of water gathering networks.		
Storage of associated water in water management dams.	Refer to Roma - Storage of associated water in water management dams.		
Storage of brine in brine containment dams	Refer to Roma - Storage of brine in brine containment dams.		
Injection of brine stream into suitable formations.	Refer to Roma - Injection of brine stream into suitable formations.		
Treated irrigation of crops and trees	Refer to Fairview – Treated irrigation of fodder crops.		
Treated discharge to Arcadia Creek and Lake Nuga Nuga	Altering the flow regime by introducing additional flows, potentially changing long term stream morphology and sediment and erosion patterns. Alteration of riparian vegetation and	• Treat water to background levels prior to discharge; • Discharge to grade only during periods of flow. **Note 1**: Given the highly ephemeral nature of Arcadia Creek, this would likely require the potential use of water management (store	Minimise changes to receiving watercourses and wetlands.

Aspect	Potential Impact	Mitigation Measures	Objective
	aquatic species through increased/altered environmental flows and differences in water quality. Changes to the in-stream temperature regime. Localised erosion and scour at the point of discharge.	and release) dams, especially if reasonably significant quantities of water are managed in this way. **Note 2**:Treated water could be piped directly to Lake Nuga Nuga from a water management dam. This would remove the potential impacts associated with altering the flow/temperature regime and potentially allow for year-round constant discharge. • Establish water quality and river health monitoring program. • Undertake regular inspection and water quality sampling at discharge and up to two kilometres downstream. • Implement erosion controls at the point of discharge.	

6.7.6 Summary of Findings

The primary objective of this study has been to develop an adaptive long-term associated water management strategy that (i) considers a range of water management options, (ii) recognises variability of associated water produced in different areas and (iii) allows for continual improvement in best practice water management for CSG operations (see full report in Appendix Q). The guiding principle of the strategy has been to maximise use for beneficial purposes and minimise the potential for environmental harm, in line with Queensland Government *EPA Operational Policy* for associated water and Queensland Government *Departure of Infrastructure and Planning (DIP) Policy* (Queensland Coal Seam Gas Water Management Policy).

Separate associated water management strategies have been developed for the Roma, Fairview and Arcadia Valley CSG fields. At this preliminary stage of the project (Phase 1 of the CSG fields assessment, refer to Section 6.1), the preferred scenarios include:

- Roma CSG field: Potable use, industrial re-use, treated irrigation and treated discharge to lakes/watercourses;
- Fairview CSG field: Treated irrigation, untreated irrigation and treated discharge to watercourses (for downstream users);
- Arcadia Valley CSG field: Treated irrigation and treated discharge to lakes/watercourses;
- All CSG fields; construction of compacted clay and/or HDPE lined brine containment ponds to manage the brine stream following treatment, which is then i) injected into suitable formations and/or ii) naturally crystallised and encapsulated or transferred to a suitable landfill.

The selection of the preferred scenarios has considered the risk to the wider environment, practicality, cost effectiveness and site specific constraints. There are a number of on-going studies exploring other opportunities for associated water management. The results of these will inform an adaptive management plan.

The selected preliminary strategies are considered to:

1) Promote and adopt EPA preferred uses of associated water and only use non-preferred uses as a temporary/back-up measure.

2) Maximise opportunities for local community use of associated water and, where practical, add value to the local environment and economy.

In summary, throughout the CSG fields, associated water will be managed through a portfolio of options, to ensure that impacts to receiving environments are managed and mitigated. Historical operations provide a guide to the consistency and predictability of associated water flows; typically water quality remains relatively stable throughout the production period, but volumes vary. The associated water *management* strategy allows for beneficial use of water by the community, as well as accommodating variability in flows both seasonally and over time. An adaptive management strategy has been adopted to ensure the best environmental outcomes are achieved, by regular review, ongoing monitoring, continuing consultation with stakeholders and engagement with regulators.