11 ASSOCIATED WATER MANAGEMENT

11.1 INTRODUCTION

Chapter 11 describes QGC's approach to Associated Water, a primary by-product of coal seam gas (CSG) production, generated in the Gas Field Component of the Queensland Curtis LNG (QCLNG) Project. The chapter, which is based on QGC's water management strategy, describes the following key aspects of Associated Water management:

- background information about the division of QGC tenements into regions
- applicable legislation
- QGC's water management strategy
- estimated Associated Water quality and quantity
- constraints to beneficial use options
- options for beneficial use of Associated Water
- options analysis and preferred options
- potential requirements for water management infrastructure
- water treatment options
- waste management options
- potential impacts of Associated Water management
- investigations and trials QGC is currently undertaking or intends to undertake for management of Associated Water.

Associated Water is generated when hydrostatic pressure from a coal seam is reduced by the extraction of groundwater. Associated Water typically contains mainly salts of sodium chloride and sodium bicarbonate with a sodium adsorption ratio (SAR) typically from 60 to 120. Other minor ions, salts and metals are present. These substances exist primarily at or near detection levels. Associated Water does have hydrocarbons but these are generally negligible or below the level of detection.

Due to the salinity and volumes of Associated Water production (approximately 160 ML/day), appropriate management of Associated Water is important to minimise environmental harm and maximise benefits from the beneficial use of Associated Water.

Accordingly, QGC has developed a strategy for the responsible management of Associated Water. This includes future plans for optimising beneficial use, water treatment methods including reverse osmosis, maintaining a commitment to water quality monitoring, and commitment to trial injection into aquifers below the Walloon Coal Measures.

At the time of drafting this Environmental Impact Statement (EIS), a final option or set of options had not been decided for Associated Water management. Given the complexity of environmental, social, economic, commercial, technical and regulatory aspects affecting Associated Water management, QGC will adopt a rigorous approach, including field trials, to selecting final options. Currently QGC is conducting further research into forestry (tree cropping), agricultural, industrial and community uses; as well as investigating options for reinjection. If managed appropriately, Associated Water can provide social, environmental and economic benefits.

The Project environmental objectives for Associated Water are to:

- maximise the beneficial use of Associated Water
- treat and manage Associated Water so as not to contaminate other waters and lands, or compromise ecological health, public amenity or safety.

11.2 BACKGROUND

QGC currently produces CSG in the Surat Basin. Data from historic production records and monitoring of existing QGC wells has been used as a basis to develop the Water Management Strategy and water production estimation models used in this chapter.

11.2.1 Regional Areas

For the purposes of planning and development, Gas Field tenements are divided into three regional areas, the:

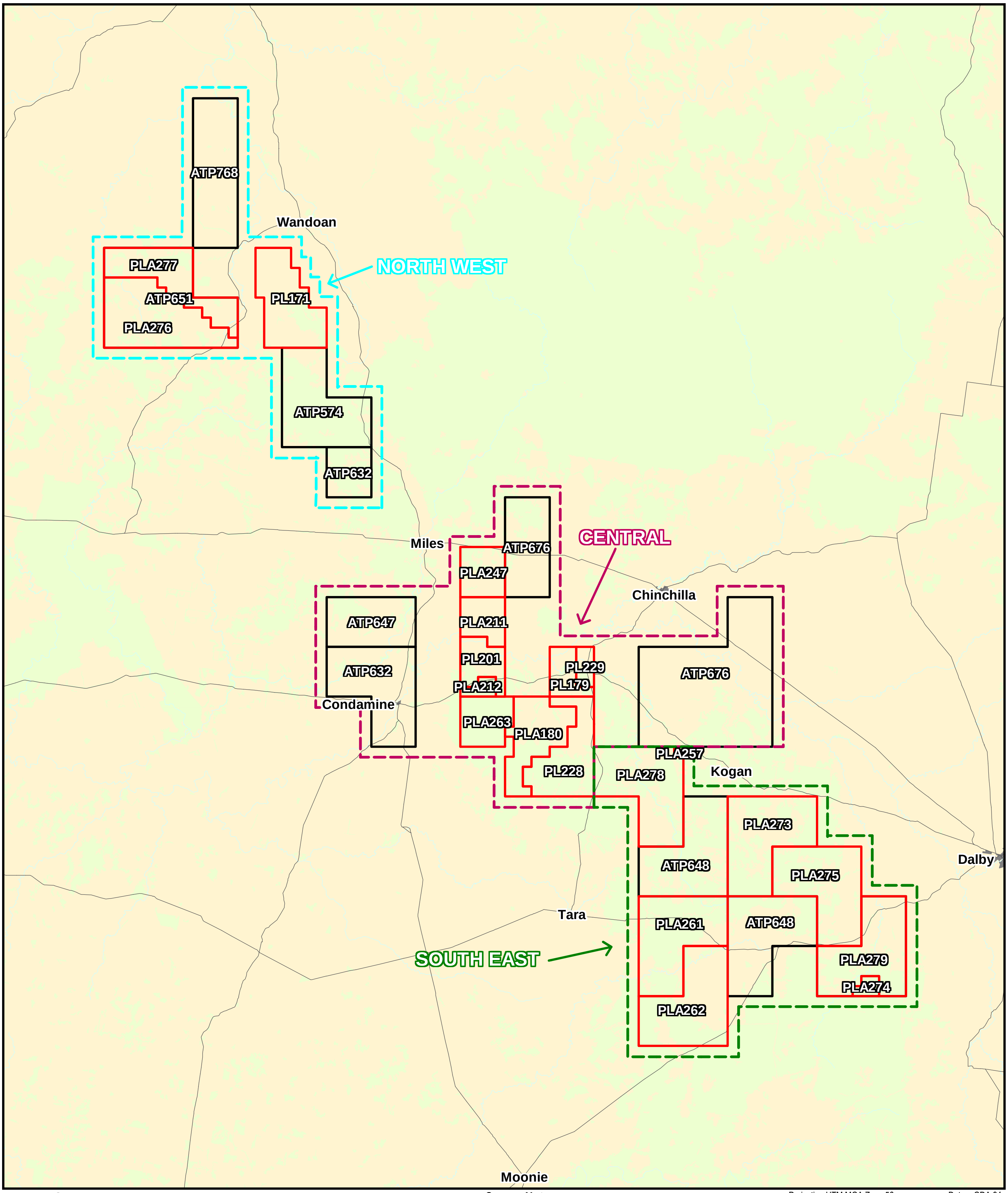
- North West Development Area (NWDA)
- Central Development Area (CDA); and
- South East Development Area (SEDA).

Figure 3.11.1 shows the three regions.

The current QGC domestic gas production and Associated Water production is sourced from the CDA. These arrangements will continue and operate under existing approvals. QCLNG Project gas production and Associated Water production will be sourced from the NWDA, CDA and SEDA. Gas production from the CDA for the QCLNG Project is covered by this EIS. CDA gas production for existing domestic contracts is not covered by this EIS.

11.3 STATUTORY REQUIREMENTS AND POLICIES

Water for any use is a resource controlled by the State, with the exception of petroleum tenement holders who are granted access to Associated Water with their right to produce gas.



Legend:

Gas Fields - Petroleum Lease/Petroleum Lease Application

Gas Fields - Authority to Prospect

Source Note:
DCDB data copyright State of Queensland (2008)
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Projection UTM MGA Zone 56 — Datum GDA 94

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QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	**Queensland Curtis LNG Project**	Title	**Regional Areas for Water Management**
Client	**QGC - A BG Group business**		
Drawn: Mipela	**Volume** 3 **Figure** 3.11.1	Disclaimer: Maps and Figures contained in this Report may be based on Third Party Data, may not be to scale and are intended as Guides only. ERM does not warrant the accuracy of any such Maps and Figures.	
Approved: CDiP	File No: QC02-T-MA-00090		
Date: 10.06.09	Revision: A		

Water produced in the Gas Field is regulated by the Queensland State Government, through the Department of Employment, Economic Development and Innovation (DEEDI) (formerly Department of Mines and Energy) and Department of Environment and Resource Management (DERM) which contains the former Environmental Protection Agency and depending on its use, the Department of Natural Resources and Water.

11.3.1 Legislation, Policy and Guidelines

The controlling pieces of legislation, policy and guidelines applicable to the management of Associated Water are detailed in *Figure 3.11.1.*

11.3.1.1 Petroleum and Gas (Production and Safety) Act 2004 (Qld) *(P&G Act)*

The authorised uses of Associated Water under the *P&G Act* include supply to adjacent landholders for stock and domestic purposes (quality dependent) and uses in association with petroleum activities, such as civil construction. ''Domestic purposes'' includes irrigating a garden, not exceeding 0.25 ha, being a garden cultivated for domestic use and not for the sale, barter or exchange of goods produced in the garden. "Stock purposes" means watering stock of a number that would normally be depastured on the land on which the water is, or is to be, used.

Under section 250 of the *P&G Act* a petroleum tenement holder is obliged to make good any adverse impacts resulting from exerting underground water rights, by either taking restoration measures to restore the supply of water to any Water Act bore owners, or compensating the owner of affected bore(s).

11.3.1.2 Water Act 2000 (Qld)

If the proposed use of Associated Water is not authorised for stock or domestic or petroleum activities, under s185 or s186 of the *P&G Act*, a water licence under the *Water Act* is required. Any taking of water or interference with water is managed under this Act. Licences that may be required under this Act include:

- a Riverine Protection Permit under Part 8 of the Water Act (exemptions exist)
- a Water Licence permitting the use of Associated Water outside of those uses permitted under the P&G Act for beneficial use; and
- a discharge licence permitting the release of Associated Water for beneficial use to land or waters (including reinjection to aquifers).

Table 3.11.1 Legislation and Standards Relevant to Associated Water Management

Issue	Legislation/Standard	Key Requirements
General	*Environmental Protection Act 1994*	Requirements for Environmental Authorities (EAs) for petroleum authorities, which will contain conditions regarding the management of Associated Water.
	Environmental Protection Regulations 2008	Prescribes environmentally relevant activities.
	Petroleum and Gas (Production and Safety) Act 2004	Requirements for approval and management of petroleum activities, including linkages with environmental authorities and the Water Act.
Water quality	*Environmental Protection (Water) Policy 1997*	Prevention of contamination of water and stormwater runoff.
	Australian and New Zealand Guidelines for Fresh and Marine Water Quality, ANZECC, 2000	Water quality criteria, including those for domestic stock and irrigation use.
Contaminated Land	*Environmental Protection Act 1994*	Processes for notification and management of ''notifiable activities'' and contaminated land.
	Draft Guidelines for the Assessment and Management of Contaminated Land. 1998	Guidelines for the implications of contaminated land requirements of the *Environmental Protection Act 1994*. Relevant to any identified areas of contamination at decommissioning.
Waste Management	*Environmental Protection (Waste Management) Policy 2000*	Waste management hierarchy and principles, and environmental management decisions concerning waste.
	Environmental Protection (Waste Management) Regulation 2000	Describes process for applying for the consideration of a waste as a resource for beneficial use.
Water Usage	*Water Act 2000*	Requirements or approval of water extraction, usage and associated infrastructure outside that authorised under the *P&G Act*.
	EPA's Operational policy: Management of water produced in association with petroleum activities (Associated Water)	Describes preferred management of Associated Water and general approval conditions.

11.3.1.3 Environmental Protection (Waste Management) Regulation 2000

Applications for the beneficial use of Associated Water under *Environmental Protection (Waste Management) Regulation 2000* (Qld) may be required to utilise Associated Water, depending on the proposed use. A permit under this regulation is likely to be issued for each use, rather than an overarching beneficial use permit.

11.3.1.4 Environmental Protection Regulations 2008 (EP Regulations)

Associated Water is considered a regulated waste under Schedule 7 of the EP

Regulations (non-toxic salts, including for example, saline effluent). Waste disposal is listed as an environmentally relevant activity (ERA 60) in the EP Regulations. Treatment of a regulated waste is listed as ERA 58.

11.3.1.5 Existing Environmental Authorities

Under existing Environmental Authorities (EAs), QGC is permitted to construct and operate ponds for the storage of Associated Water with a maximum area of 800 ha.

11.3.2 Government Policy

The former Environmental Protection Agency produced an "Operational Policy for Management of water produced in association with petroleum activities (Associated Water)" in December 2007. This operational policy outlines the preferred and non-preferred management options for Associated Water and states that the order of preferred management options is:

- reinjection;
- direct use of untreated water; and
- treatment and beneficial use.

The Policy states that non-preferred management options for Associated Water are:

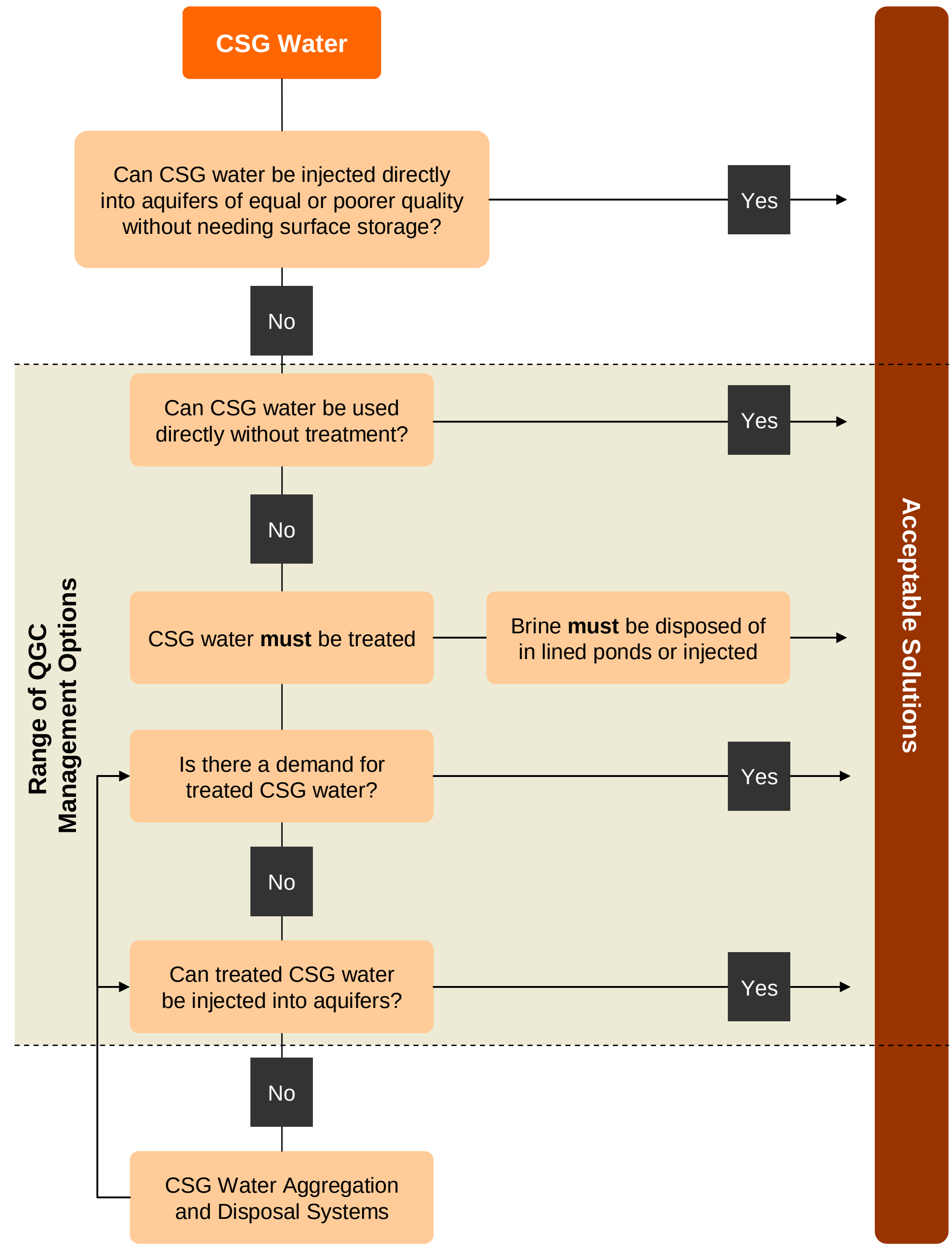
- disposal via evaporation ponds;
- reinjection to aquifers with better water quality than the Associated Water; and
- disposal of untreated or treated water via discharge to surface waters.

The Department of Infrastructure and Planning (DIP) released a fact sheet in 2008 on ''The Management of Coal Seam Gas Water'' outlining a whole of government perspective on the management of Associated Water.

An overview of the DIP CSG Water Management Policy is detailed in *Figure 3.11.2*[1].

1 http://www.dip.qld.gov.au/images/coal-seam-gas-water-management.gif

Figure 3.11.2 Coal Seam Gas Water Management Policy Overview



Source: DIP

These policies communicate to the CSG industry the Queensland Government's preference for options in managing Associated Water to achieve sustainable outcomes across the State. At the time of preparing this EIS, the draft policy was open to public and industry consultation, hence there may be changes as a result of this process. QGC is currently preparing an Associated Water Management Plan (AWMP) in accordance with the CSG Water Policy requirements.

11.3.3 QGC Alignment with Government Policy

QGC has developed a water management strategy for Associated Water. This strategy has been developed to ensure QGC can employ the best available technology (which includes economic considerations) for sustainable management of Associated Water. This strategy will inform the AWMP.

The strategy sets out the preferred options for Associated Water management in the short-term and long-term. The strategy acknowledges that the water being produced on QGC tenements needs to be of suitable quality for the intended beneficial use. This will require water to be treated, blended and, in some instances, used raw depending upon the water quality requirement for the intended purpose.

Associated Water will be managed, as far as reasonably practical, in accordance with the EPA Operational Policy (2007) and the DIP Coal Seam Gas Water Management Policy (2008). The management strategy considers the beneficial use of Associated Water with regard to the preferred and non-preferred uses detailed in the EPA Operational Policy (2007).

11.4 ASSOCIATED WATER QUALITY

Options for the direct use of Associated Water in a raw state are limited due to the amount of total dissolved solids (TDS), fluoride and potassium in the water, coupled with a high Sodium Adsorption Ratio (SAR). This means raw water uses need to be specifically targeted (such as for industrial purposes or for injection to saline aquifers) otherwise Associated Water may require some level of treatment before use.

11.4.1.1 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) represents the total amount of solids (milligrams per litre) remaining when a water sample is evaporated to dryness. In principle, it is the sum of all dissolved elements. On average the TDS of the water within the Gas Field is 3,600mg/L. However the TDS of the water varies across regions, with 5,500mg/L in the NWDA, 2,800mg/L in the CDA and 4,700mg/L in the SEDA. In comparison potable water is <500mg/L TDS and seawater is >30 000mg/L TDS.

A summary of the Australia and New Zealand Environment and Conservation Council (ANZECC) guidelines[2] for TDS levels in water for livestock is presented in *Table 3.11.2* and guidelines for irrigation water are presented in *Table 3.11.3.*

2 Australian and New Zealand Environment Conservation Council, October 2000, Australian and New Zealand Guide to Fresh and Marine Water Quality, 2000

Table 3.11.2 TDS Guidelines for Livestock

Animal	No adverse effect (mg/L)	No loss of production (mg/L)	Loss of production, illness (mg/L)
Beef cattle	0-4000	4000-5000	5000-10000
Dairy cattle	0-2500	2500-4000	4000-7000
Sheep	0-5000	5000-10000	10000-13000
Horses	0-4000	4000-6000	6000-7000
Pigs	0-4000	4000-6000	6000-8000
Poultry	0-2000	2000-3000	3000-4000

Table 3.11.3 TDS Guidelines for Irrigation Water

TDS (mg/L)[1]	Water Salinity rating	Plant Suitability
<435	Very Low	Sensitive crop
435 to 870	Low	Moderately sensitive crop
870 to 1,940	Medium	Moderately tolerant crop
1,940 to 3,480	High	Tolerant crop
3,480 to 5,430	Very high	Very tolerant crop
< 5,430	Extreme	Generally too saline.

Note 1: Adapted from ANZECC Guidelines which are stated in ds/m

As indicated in *Table 3.11.2,* in general, the TDS in QGC Associated Water will not result in a loss of production if consumed by most varieties of livestock. However (as indicated in *Table 3.11.3*), for irrigation purposes the Associated Water salinity is rated as high to extreme and only tolerant or very tolerant plants can be irrigated.

11.4.1.2 Sodium Adsorption Rate (SAR)

The Sodium Adsorption Ratio (SAR) is a measure of the proportion of sodium to magnesium and calcium in water. When applied to clay soils, Associated Water with an elevated SAR is likely to make these soils dispersive. Over time this may create an impermeable soil crust, which inhibits water migration. Sodic soils are also dispersible and thus vulnerable to erosion. If water with a high SAR is applied to soils, this is likely to increase the sodicity of the soil and hence make the soils less suitable for irrigation purposes.

The average SAR of Associated Water in the Gas Field is approximately 110. *Table 3.11.4* shows the ANZECC guidelines for SAR in irrigation water. As evidenced by the guidelines, the acceptable SAR ratio is dependent on the soil type and clay mineralogy.

Table 3.11.4 SAR Guidelines for Irrigation Water

Clay Content (%)	Soil Texture	Permissible irrigation water SAR				
		Clay mineralogy expressed as CCR[1] (mole/kg)				
		<0.35	0.35 - 0.55	0.55 - 0.75	0.75 - 0.95	> 0.95
<0.15	Sand, sandy loam	>20	>20	>20	>20	>20
15 – 25	Loam, Silty loam	20	11	10	10	8
25 – 35	Clay loam	13	11	8	5	6
35 – 45	Light clay	11	8	5	5	5
45 - 55	Medium clay	10	5	5	5	5
55 – 65	Medium Heavy clay	5	5	5	4	4
65 – 75	Heavy clay	-	4	4	4	4
75 – 85	Heavy clay	-	-	4	5	5

Note 1: Cation Exchange Concentration to Clay Ratio

Depending on the soil type, the SAR of QGC's Associated Water is between five and 25 times the recommended maximum limit for irrigation. The SAR level can be reduced by blending magnesium and calcium (gypsum) into the water and adding acid to lower the pH. This process is referred to as ''amendment'' and will assist in preventing long-term soil damage. Additionally treated Associated Water from a reverse osmosis plant (known as permeate) may need to be added to prevent long-term soil damage.

11.4.1.3 Salinity and SAR Combinations

One potential option for beneficial use of Associated Water under investigation by QGC is the irrigation of trees and other crops. QGC is preparing to trial and monitor irrigation in small areas to determine if amended and blended water is suitable for this purpose.

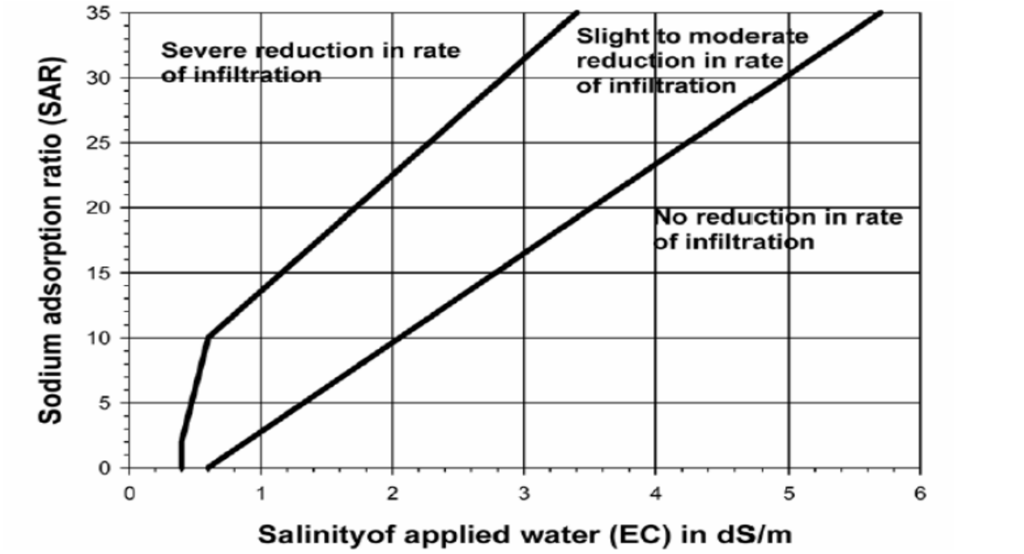
Irrigation water salinity and SAR combinations that cause soil structure instability vary significantly depending on the soil type. In the Gas Field there are significant variations in soil type, hence it is not possible to provide a single salinity and SAR combination that would be optimal for all soil types. In general however better quality agricultural land tends to be less prone to soil structure instability. Approximately 184 000 ha or 39 per cent of the land within the Gas Field is classified as Good Quality Agricultural Land (GQAL) (refer to *Volume 3, Chapter 4*). Most of the land owned by QGC is not classified as GQAL.

Some native tree species are relatively well adapted to salinity and some species are particularly tolerant to relatively high levels of salinity. In general the current commercially grown agricultural crops and pasture grown in the area are not particularly salt tolerant. However there are other species that could be grown that are significantly more salt tolerant.

QGC has undertaken significant research on the salinity and SAR of irrigation water and the effect this water has on soil structure and hence agricultural production. However, trials are required to rigorously define the optimal salinity and SAR combination that could sustain agriculture in the long term while minimising the amount of water treatment required for an acceptable solution.

Figure 3.11.3 shows the effect that a combination of SAR and salinity, in water applied to soils, has on the permeability of soils. The greater the reduction in permeability the less desirable is the water for irrigation.

Figure 3.11.3 Salinity and SAR Combinations



Source: R.S. Ayers and D.W, Westcot (1994)

Water quality that falls to the left of both lines is likely to induce degradation of soil structure and corrective management will be required such as the application of lime or gypsum to reduce the SAR, or desalination through reverse osmosis (RO).

Water that falls between the lines is of marginal quality. Water compositions that occur to the right of the lines are considered satisfactory for irrigation, provided the SAR is not so high that severe dispersion of the surface soil water will occur following rainfall.

An electrical conductivity (EC) value of 4dS/m is approximately equal to TDS of 2 700mg/L. QGC are currently trialling the irrigation of soils with water having various combinations of TDS (EC) and SAR that fall along the line separating marginal quality water from good quality water.

Reductions in salinity can be achieved through desalination. Reduction in the SAR can be achieved by amending untreated Associated Water with gypsum. Combinations of SAR and TDS can be achieved by blending desalinated water with amended water.

The desalination process results in the production of saline brine waste. Further details about water treatment and waste management are provided in *Section 11.9* and *Section 11.10* respectively.

11.4.1.4 Other Chemical Components

Table 3.11.5 provides a summary of the quality of Associated Water from existing production wells and ponds in comparison to the ANZECC Guidelines for stock watering, short and long-term irrigation and aquatic ecosystem protection. These criteria provide a reasonable representation of existing uses of groundwater in the regional area and an indication of the impact of in the event of Associated Water release to aquatic ecosystems.

When applied continuously and with no treatment for stock watering, irrigation and aquatic ecosystems, raw Associated Water has elevated levels, according to the above ANZECC guidelines, of the following:

- potassium
- fluoride
- aluminium
- cobalt
- boron
- copper
- pH
- TDS.

The following analytes exceed aquatic ecosystem water quality guidelines only (but do not exceed stock watering and irrigation guidelines):

- arsenic
- cadmium
- lead
- mercury
- nickel
- nitrate
- selenium
- zinc.

Table 3.11.5 Associated Water Quality

Analyte Element	Production Wells Average (mg/L)	ANZECC 2000		ANZECC 2000	
		Aquatic Guidelines (mg/L)	Livestock Guidelines (mg/L)	Irrigation LTU [1](mg/L)	Irrigation STU [2](mg/L)
Aluminium	14.73	0.027	5	5	20
Arsenic (III)	0.014	0.001	0.5	0.1	2
Benzene	<0.0010	0.6	NG	NG	NG
Bicarbonate alkalinity	1857.3	NG	NG	NG	NG
Boron	1.08	0.09	5	0.5	0.5 -15
Cadmium	<0.01	0.00006	0.01	0.01	0.05
Calcium	5.15	NG	<1000	NG	NG
Carbonate alkalinity	271.78	NG	NG	NG	NG
Chloride - non wells	935.9	NG	NG	NG	NG
Chloride - wells	861.1	NG	NG	NG	NG
Cobalt	0.058	n/a	1	0.05	0.1
Copper	2.5	0.001	0.4-5 (animal dependent)	0.2	5
Fluoride	3.3	NG	2	1	2
Lead	0.07	0.001	0.1	2	5
Magnesium	4.32	NG	n/a	NG	NG
Mercury	0.0008	0.00006	0.002	0.002	0.002
Nickel	0.15	0.008	1	0.2	2
Nitrate	0.044	0.017	NG	NG	NG
Nitrite	0.013	NG	NG	NG	NG
pH	8.6	NG	6.5-8.5	6.0-9.0	6.0-9.0
Phenol	<0.0010	0.085	NG	NG	NG
Potassium	12.19	NG	NG	0.05	0.8
Selenium	0.0103	0.005	0.02	0.02	0.05
Sodium - non wells	1975.9	NG	NG	NG	NG
Sodium - wells	1081.5	NG	NG	NG	NG
Sulphate	6.23	NG	<1000	NG	NG
Suspended solids (turbidity)	2243.3	NG	NG	NG	NG
TDS (Salinity)	3558.1	NG	max 3000-6000 (animal dependent)	<1000g/L (revegetation)	NG
TOC (total organic carbon)	1.32	NG	NG	NG	NG
Toluene	<0.003	NG	NG	NG	NG
Total Iron	9.49	n/a	n/a	NG	NG
Zinc	1.49	0.024	20	2	5

Notes:
1. in irrigation water (long term use — up to 100 yrs)
2. in irrigation water (short term use — up to 20 yrs)
3. NG = no guideline available

QGC does not intend to release untreated Associated Water to watercourses. Further, QGC expects that analytes in excess of the above guidelines will be substantially removed from Associated Water through the desalination process. QGC will further test the quality of Associated Water for the above analytes during desalination trials. This will be used as a guide to the degree of treatment required to make water fit for its intended purpose.

At the same time, QGC will develop its own water quality guidelines to understand and monitor environmental values and local water quality and to validate the ANZECC national guidelines. Local surface water testing on trace values (identified above) will be undertaken to establish a local guideline value. (*Volume 3, Chapter 9* and the assessment contained in *Appendix 3.3* have not sought to establish these values).

11.5 ASSOCIATED WATER PRODUCTION ESTIMATES

11.5.1 Existing Production Volumes

QGC's existing domestic commitments and exploration and appraisal requirements currently generate 17 ML per day of Associated Water.

11.5.2 Water and Gas Production Rates

The initial quantity of Associated Water extracted from production wells ranges from 0.4 to 0.8 ML per well per day. This level decreases to approximately 0.1 ML per well per day over a period of six months to a few years. The volume per well is markedly variable and is based on permeability, hydrostatic pressure, proximity to other wells and local geological and hydrological conditions.

Water production volumes peak at the commencement of well operation, while gas production peaks after the initial one-to-two years of well operation. A generalised example of water production versus gas production per well is depicted in *Figure 3.11.4.*

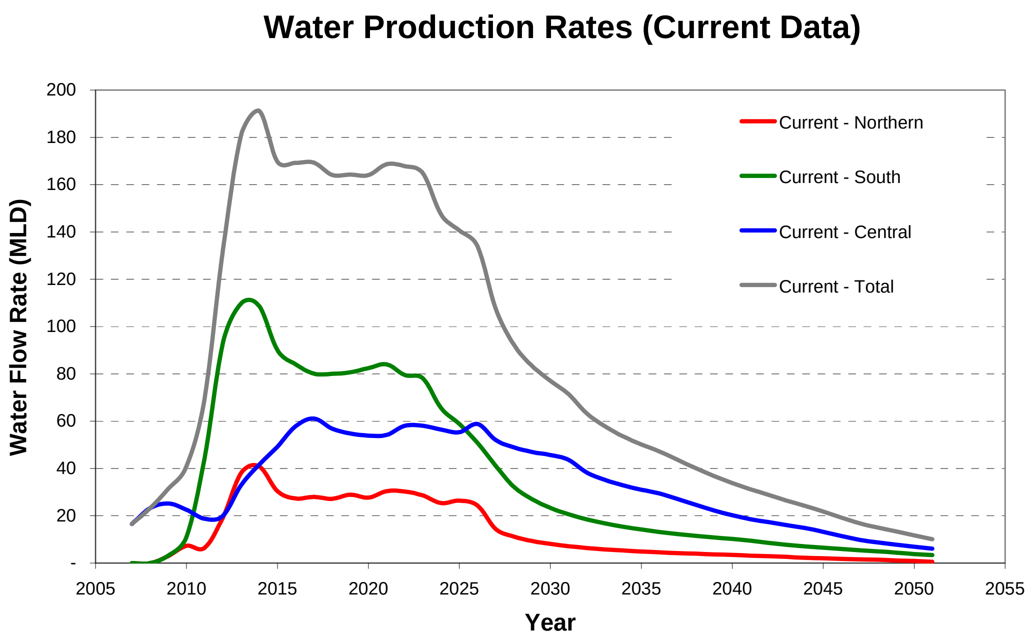
Figure 3.11.4 Water Production versus Gas Production (for a Typical Well)

11.5.3 Projected Water Volumes

Current estimates predict the total volume of Associated Water generated over the life of the Project to be approximately 1,200,000ML. Based on current estimates, the volume of Associated Water generated is projected to peak at approximately 190ML/per day in 2013/2014, with average production in the order of 165ML per day between 2015 and 2025. The estimated water volumes may be reduced by up to 30 per cent as these figures are conservative with recent testing and modelling indicating a lower figure is likely. Further analysis will be conducted to enable more accurate predictions of potential water volumes.

The formulation of an Associated Water Management Plan (refer *Section 11.6.3.12*) will consider the variable nature of production estimates as water management infrastructure must be in place prior to the full development of a particular region. *Figure 3.11.5* shows the estimated volumes of water produced by area and in total, based on best available current estimates.

Figure 3.11.5 Water Production by Area and in Total (ML/d)



At peak production the current conservative estimates are that the:

- CDA (Central) will produce approximately 61ML/per day
- NWDA (Northern) will produce approximately 40 ML/per day
- SEDA (Southern) will produce approximately 110 ML/per day.

The peak production periods for each area do not coincide.

11.6 BENEFICIAL USE OPTIONS

QGC are reviewing several options for the management of Associated Water in the CDA, SEDA and NWDA. The following options for beneficial use of Associated Water are discussed in detail below.

- QGC petroleum activities during construction and operation
- stock and domestic purposes
- tree cropping (forestry)
- irrigation of crops (agriculture)
- wetland creation
- supply of water to mines
- urban (municipal) water supply
- supply of water to industries
- reinjection to groundwater aquifers

- aggregation of CSG waters with other CSG producers
- surface water discharge
- coastal discharge
- evaporation ponds.

11.6.1 Regulatory Considerations

A permit to consider a regulated waste a resource may be required from the DERM before a beneficial use activity can proceed.

The approvals and permits required for individual beneficial uses depend on the activity being undertaken, the quality of water being used and whether the activity is proposed on a QGC petroleum tenement.

Treatment will require QGC to seek approval to undertake certain Environmentally Relevant Activities (ERAs) related to water treatment. Where the beneficial use option is an authorised activity under the *P&G Act*, additional approvals are unlikely to be required. Where the beneficial use option is not an authorised activity under the *P & G Act*, a specific beneficial use permit may be required under the *EP Act* and a water licence or permit required under the *Water Act*. Should the proposed beneficial use comply with the general conditions of the EPA Operational Policy “Management of Water Produced in Association with Petroleum Activities”, a specific beneficial use permit may not be required.

The permitting requirements for beneficial use options are summarised in *Table 3.11.6.*

Table 3.11.6 Permitting Requirements for Options for Water Uses

Proposed Use of Associated Water	Is the proposed use on QGC Tenure?	Will the water be treated?	Treatment Permitting Requirements	Beneficial Use Permitting Requirements			
			EP Act	P&G Act	EP Act		Water Act
			EA must include ERAs 56, 58 and 60	Authorised petroleum activity	Specific Beneficial use Permit	Complies with General Approval	Water Licence or Permit
QGC petroleum activities - dust suppression, construction and washdown	✓	✓	✓	✓		✓	
QGC petroleum activities - potable	✓	✓	✓	✓		✓	
QGC petroleum activities - hydrotest	✓			✓			
					✓		✓
Stock and domestic purposes within QGC tenements	✓	✓	✓	✓		✓	
	✓			✓		✓	
Tree cropping and irrigation of crops	✓	✓	✓		✓		✓
Wetlands	✓	✓	✓		✓		✓
	✓				✓		✓
Supply of water to mines					✓		✓
Urban water supply		✓	✓		✓		✓
		✓	✓			✓	✓
Supply of water to industries and feedlots		✓	✓		✓		✓
						✓	✓
Reinjection to groundwater aquifers	✓	✓	✓	✓	✓		
	✓			✓	✓		
Surface water discharge		✓	✓		✓		✓
Coastal discharge					✓		✓
Evaporation ponds	✓			✓			
Transport of Associated Water to central CSG industry aggregation site		✓	✓		✓		✓
					✓		✓

Assumptions:
1 - All water treatment on QGC tenure
2 -Treated water is suitable for end use (complies with General Notice)

11.6.2 *Constraints to Beneficial Use*

Each beneficial use option described is constrained by the:

- respective regulatory approvals framework
- quality of water required for the respective use and hence level of treatment required
- total quantity of water that can be received by users
- fluctuations in quantity that are required by users over time
- ability to source other water supplies once supply from QGC ceases
- social and community implications of each water use option
- distance from the source of water to the final destination and hence cost of infrastructure.

The cost and technical feasibility of supplying a certain quantity of water at a particular standard needs to be determined for each beneficial use. Any final decision will be justified against the environmental and social benefits offered by that option.

11.6.2.1 *Quality*

Raw water quality represents the major constraint in management of Associated Water. Beneficial uses may require treatment to improve the water quality to a suitable standard for each specific use. Specific treatment methods can be employed to treat Associated Water to the required quality. In general, the better the quality of water required, the greater the cost of treatment.

11.6.2.2 *Quantity*

Due to the geographic spread of CSG production sites, and the significant and varying volume of Associated Water produced, no single beneficial user will be able to receive all the Associated Water. Hence, water will be supplied to a range of uses and may be treated by more than one method.

Each beneficial use may have fluctuating water requirements for various reasons, including seasonal variations in rainfall and fluctuating demand. This demand for water stands in contrast to the continuous production of water by QGC. Storage pond infrastructure will be required to balance the difference between constant supply and fluctuating demand.

11.6.2.3 *Long-Term Supply*

QGC will be able to supply water at a decreasing rate for the next 20 to 40 years. However, some beneficial users will maintain demand for water over longer periods and may not be able to source additional water supplies once supplies from QGC decline or are no longer available.

11.6.2.4 *Distribution*

Infrastructure such as pipelines and pumping stations will be required for the transport of Associated Water from wells to water treatment facilities and beneficial users. This poses both economic and technical constraints for each beneficial use option.

11.6.3 *Beneficial Use Options*

Figure 3.11.6 illustrates some of the potential beneficial use options investigated by QGC.

11.6.3.1 *QGC Petroleum Activities*

Associated Water may be utilised for a number of petroleum activities including construction, dust suppression, hydrotesting of pipelines, weed washdown facilities and accommodation facilities.

The quality of Associated Water required for each petroleum activity varies. This is further complicated by the variation in water quality across the tenements.

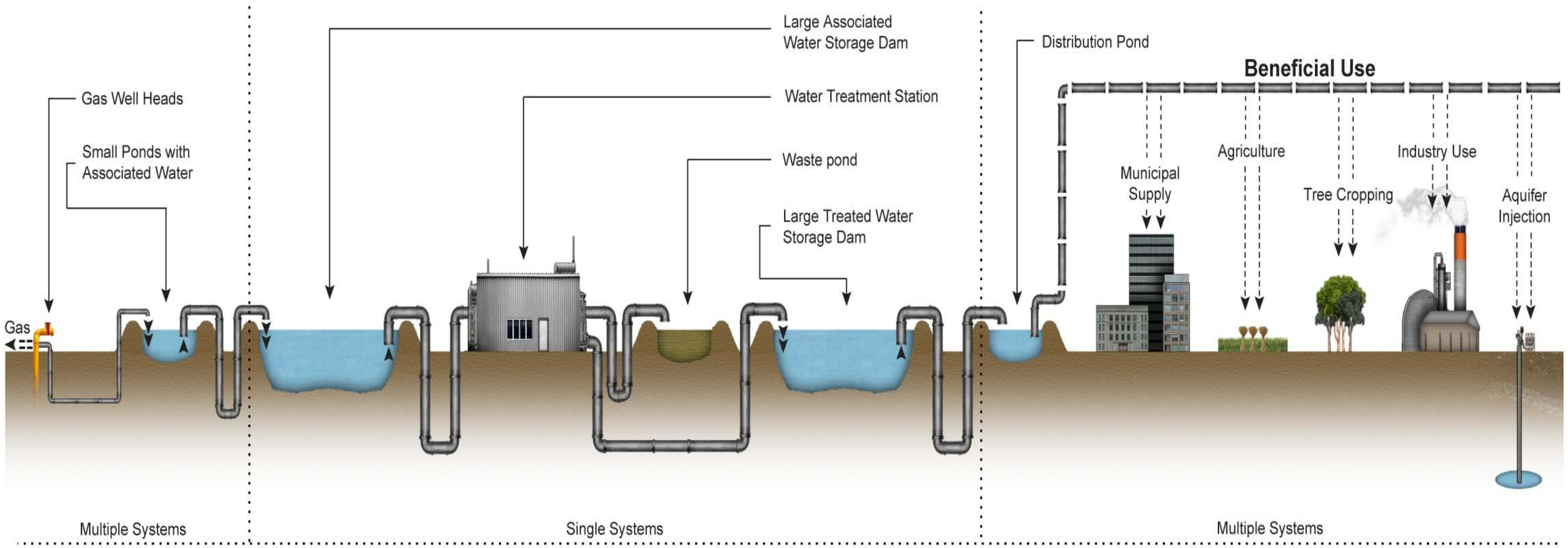
Table 3.11.7 details the water quality and approximate water quantity required during construction and operations for various petroleum activities.

Table 3.11.7 Petroleum Activities

Water Use	Key Water Quality Parameters	Quantity (ML) per day -Construction	Quantity (ML) per day - Operations
Dust suppression	< 2000 mg/L TDS	1.0	0.75
Construction[1]	< 2000 mg/L TDS	0.2	n/a
Hydrotesting	< 2000 mg/L TDS	0.1	n/a
Washdown	< 2000 mg/L TDS	0.05	0.05
Accommodation	UN potable water standard	0.45	0.16
Total		**1.80**	**0.96**

[1] Exemptions may be required and will be sought separately

Figure 3.11.6 The Potential Beneficial Use Options being Investigated by QGC



NOT TO SCALE

It is estimated that daily water requirements will be 1.8 ML per day during construction and 0.96ML per day during operations. This represents between 0.1 and 1.0 per cent of daily Associated Water production.

QGC will use, wherever feasible, treated and untreated Associated Water for petroleum activities to minimise the impact on other water sources such as groundwater and river supplies. However, other options for beneficial use will be required to match expected production volumes.

11.6.3.2 Stock and Domestic Purposes

Water Quality

Associated Water would generally require treatment prior to use for stock and domestic purposes.

Water Quantity

Under the *P&G Act*, QGC can supply Associated Water to adjacent landholders for stock and domestic purposes. However, there are limitations on the volume that can be supplied, namely:

- irrigating a maximum of 0.25 ha
- watering stock of a number that would normally be depastured on the land.

The demand available from this option is anticipated to be less than 5% of the Associated Water available.

Distribution

A large number of distribution pipelines would need to be constructed to potentially thousands of properties. The cost of these pipelines is potentially prohibitive. In addition, demand from users would vary according to fluctuations in rainfall or existing water supplies. QGC requires a demand for water to match the constant supply produced.

Long-Term Supply

The supply of Associated Water will decrease rapidly after 20 to 30 years. Communities may become dependent on a water supply that is not sustainable in the long term.

Conclusion

Given the above constraints, it is unlikely that the large scale supply of Associated Water for stock and domestic purposes will result in a feasible solution for Associated Water management. However, the supply of some water for stock and domestic purposes is being further investigated.

11.6.3.3 *Tree Cropping*

Pending agreement with landholders and the purchase of suitable properties if required, there is likely to be a significant portion of land within the Gas Field which may be available and suitable for irrigated tree cropping.

Aside from providing an adequate and reliable option of beneficial use of Associated Water, tree plantings may provide other benefits. These benefits include:

- improved biodiversity through the planting of local indigenous species
- greenhouse gas biosequestration
- harvestable timber if commercially viable, otherwise forest replenishment (currently under determination).

It is proposed to plant a mixture of local, indigenous species. The majority of trees (between 80 and 95 per cent) would be Chinchilla White Gums (*Eucalyptus argophloia*). Other local species would be planted during the forest's life to enhance biodiversity.

QGC will further investigate the potential for using tree plantings as greenhouse gas offsets and to understand the biodiversity value of the plantings. The method of measurement of carbon biosequestration and the national regulatory framework for recognition of greenhouse gas offsets are still under development.

Water Quality

The average raw Associated Water quality from QGC's wells can be classified as highly-to-extremely saline for irrigation purposes. In addition, the balance of salts in the water is poor for irrigation, with the water exhibiting an average SAR of approximately 110.

QGC has targeted local native tree species which already cope with existing sodic soils that are frequently degraded and low in nutrients. Within the project area native tree species are relatively well adapted to salinity and some species are particularly tolerant to relatively high levels of salinity.

The suitability of specific sites for irrigation will need to be assessed in detailed research plots before establishing an irrigation scheme. This research will also take account of alternative uses for the land and it is not intended to displace current cropping land with tree cropping.

For tree cropping, desalinated water would be blended with amended or untreated water to produce water which is suitable for irrigation. The blending ratio would depend on the water quality achieved by the desalination process and the quality of the local Associated Water supply (noting that quality varies by location).

QGC is trialling irrigation of water with various combinations of SAR and TDS levels, as discussed in *Section 11.4.1.3*. As a general indication a target irrigation water quality of 1 200 – 2 000 mg/L TDS, and SAR 6 – 20 may be suitable for irrigation of a sufficiently broad range of soils to enable QGC to use the majority of its Associated Water within the Gas Field. To achieve this water quality, a blend ratio in the order of 1:1 to 1:4 (untreated to treated) water would be required.

Further field trials will seek to verify that water with a TDS of 2 500 mg/L and SAR up to 20 is suitable for long-term irrigation. This level of TDS and SAR would reduce the blend ratio below 1:4 (untreated to treated), and possible as low as 1:1. Lower blend ratios result in a reduction in the required water treatment capacity and volume of salt to be disposed of through mechanical and evaporation processes. The level of treatment required to achieve a quality of water which is suitable for irrigation has not been confirmed. Irrigation water quality will also need to demonstrate that it would not have a negative impact on groundwater quality and water table levels.

Technology required for water treatment is discussed in *Section 11.9.* Feasible and reliable technology is available for water treatment.

Water Quantity

Water consumption by tree cropping is dependent on a range of factors including variations in rainfall, evaporation, soil types, water quality, the method of irrigation application and tree species.

Site specific assessment is needed to confirm the irrigation rates required for sites within the Gas Field. Based on an evaluation of the available information regarding average irrigation conditions which are likely to be present within irrigation sites, the application rates in *Table 3.11.8* may be applicable for trees and other crops irrigated with blended water:

Table 3.11.8 Potential Irrigation Rates

Water Quality Type	Key Water Quality Parameters	Treatment required to achieve Water Quality	Irrigation Application Rate (ML/ha/year)	Regulatory Constraints
A	TDS 1200 mg/L, SAR 6	Desalination and amendment	6	Low
B	TDS 1600 mg/L, SAR 10	Blending desalinated & untreated water, with gypsum amendment	6	Low
C	TDS 2000 mg/L, SAR 20	Blending desalinated & untreated water, with gypsum amendment	6	Moderate, requiring trial success and modelling
D	TDS 2500 mg/L, SAR 25	Amendment of untreated water, with pH correction	2 or less	Demonstration of trial sustainability required before approval.

Based on these estimates of irrigation rates, the area of irrigation required to dispose of water with the range of qualities has been investigated.

At peak water production, under various treatment options, Associated Water may be used for irrigation of approximately 10,000 ha. These figures are initial estimates only. Extensive field investigations will be required to identify and assess the suitability of specific sites for irrigation and confirm the quality of water required.

Given sufficient available land of suitable soil quality, QGC will be able to match the irrigation rates to the production rates of Associated Water. This will assist in minimising the volume of storage ponds required to balance water supply and demand.

Regulations

The approval of Associated Water for irrigation purposes is regulated by the DERM (formerly EPA) and DEEDI (formerly DPIF) in Queensland. Based on previous experience, regulators have permitted irrigation with water with a salinity of below 2 dS/m (TDS of 1200 mg/L) and a SAR of 6. The DERM generally will not approve irrigation with water of salinity greater than 4 dS/m (TDS of 2500 mg/L) and a SAR of 15 without strong evidence that irrigation will not cause harm to soils and the environment. Usually, obtaining this evidence involves undertaking trials or extensive desktop studies using detailed soil and water chemistry balance modelling before irrigating the sites proposed for broadscale application of the water. Details of the trials QGC is currently undertaking are provided in *Section 11.11.1.*

Distribution

Irrigation of tree crops is feasible in and around the Gas Field. It is probable that suitable irrigation sites of the required size can be found within distances of the water treatment sites that are economically feasible for infrastructure construction.

Long-Term Supply

Irrigation of tree species peaks during the early and maturing years of tree growth. However, as water production declines over time the requirement for irrigation water by mature tree species will decrease.

Conclusion

Water quality can be adjusted to meet irrigation requirements and environmental constraints. Irrigation of tree crops offers a potential constant source of demand for the entire volume of Associated Water produced. Irrigation trials will be conducted to confirm the constraints and requirements to enable irrigation of tree crops. These investigations will focus on site-specific areas, landforms, soil types and profiles, and other environmental impacts.

QGC is also considering other beneficial uses and injection, with some options the subject of trials.

11.6.3.4 *Cropping (Agriculture)*

Pending agreement with landholders, there is likely to be a significant portion of land within the Gas Field which may be available and suitable for irrigation of various crops. However there are several significant limitations to this option as being a viable means of utilising Associated Water.

Water Quality

Agricultural crops are generally quite sensitive to salinity in irrigation water. The salinity of the untreated water, containing an average TDS concentration is in the range of 2,800mg/L to 5,500 mg/L, is high to extreme (refer *Section 11.4.1.1)* for irrigation purposes. Water with these classifications is not suitable for irrigation. Irrigation water with elevated salinity should only be used for salt tolerant crops on soils which are free draining and with careful management of soil salinity.

In general the current commercial agricultural crops and pasture grown in the area are not particularly salt tolerant, however there are other species that could be grown that are more salt tolerant.

The SAR of the untreated water from wells is approximately 110 and is unsuitable for irrigation without prior chemical amendment. SAR levels higher than six can be sustained if the water has higher salinity levels and the soil is free draining.

Given these constraints, the Associated Water will need to be treated to reduce its salinity and amended to reduce the SAR before it can be used for irrigation of agricultural crops.

Water Quantity

Irrigation water demand varies considerably for different crops. Demand is seasonal, as crops are planted, grow, mature and are harvested; and at frequent times there will be no demand for irrigation (e.g. during fallow periods and during rainfall). This demand fluctuation can be reduced to a limited degree by careful coordination of crop rotation and crop types, however, it cannot be removed. This means that large storage dams would be required to balance the constant daily inflow from the Gas Field with the highly variable irrigation demand.

Distribution

Within the Gas Field approximately 56,000 ha (12 per cent) is currently used for cropping. The limited extent of cropping is mainly due to the poor quality of the soils. As discussed in *Volume 3, Chapters 4* and *5*, the majority of cropping land is in the CDA in pockets adjacent to the Condamine River, and in the NWDA west of Wandoan.

Given the fragmented nature of suitable cropping land, irrigation of crops with Associated Water is likely to be impractical due to the cost of distributing water to a number of small sites. It may be possible to install small-scale cropping irrigation areas on QGC-owned land adjacent to some water collection and treatment facilities. However given the extent of QGC's existing land holdings, this is likely to utilise only a very small portion of the total volume of treated water.

To achieve irrigation disposal of all of the treated water, it would be necessary to deliver the water to private irrigators or purchase more land. As discussed in *Volume 3, Chapter 5* (refer *Figure 3.5.3*), there is currently very limited irrigated cropping within the Gas Fields. Delivery of water to irrigators would require a significant distribution network and involve considerable cost.

Long-Term Supply

Irrigation of crops by third party irrigators using QGC Associated Water will be limited by the life of the Project. A water use agreement will be required to acknowledge the duration of supply so that an irrigator can plan mitigation measures of socio-economic impacts once the rate of water production declines.

Conclusion

Beneficial use of untreated Associated Water for agricultural irrigation is subject to multiple constraints. Associated Water would need significant treatment prior to irrigation of crops. Due to the high treatment and potential distribution costs and the need to provide large balancing water storages, this option may not be economically feasible. QGC may seek future opportunities for irrigation of crops with treated Associated Water. Should this option proceed, QGC would establish a transparent and robust process for determining the conditions under which water for irrigation would be provided.

11.6.3.5 Wetlands

The utilisation of artificial wetland systems for desalination is a relatively new concept. QGC is investigating a biological filtration system which includes a constructed wetland and forest plantations. The wetland would consist of multiple filtration sections, separated by a number of ponds. Wetlands would comprise flora species that grow within the salinity range of untreated Associated Water. The objective of the system is to allow salt tolerant species to take up the salt and other contaminants from the water. The biomass would be harvested to remove the salt load from the system. Harvested biomass could be used as silage.

The total reduction of TDS levels after the wetland treatment of the water to levels acceptable for discharge to surface water is not well understood. Depending on the water salinity after passing through the wetland, either further desalination may be required or the water may be suitable (with amendment) for beneficial uses such as irrigation of tree crops.

An alternative use for wetlands is water polishing of permeate combined with small amounts of untreated water to be released to local waterways. The wetland would be used adjust treated water to mimic the biological water quality of the watercourse, and hence not be a threat to the aquatic ecological values.

Wetland trials are currently being tested and trialled under laboratory conditions with potential to expand to small scale field trials if the laboratory trial results are favourable. Wetland trials are discussed in *Section 11.11.1*.

At the time of drafting this EIS, there is insufficient information about the:

- quality and quantity of water that can be desalinated through a wetland
- species composition for wetlands of varying salinity
- construction requirements for a wetland system
- regulations involved in establishing a wetland
- potential locations for wetlands.

11.6.3.6 Mine Water Supply

There are several proposed coal mines located in the region. All these have a requirement for water in their operations. QGC will explore supply opportunities to these proposed mines. Other mines have existing commercial water supply arrangements, so while there is some prospect that they may require additional future water supplies, the timing of that demand is uncertain.

Distribution

To gather and transport water to a mining operation will require the development and operation of a water pipeline system.

Quality

The level of treatment required for mining depends on the user's requirements. Generally, it is anticipated that mines would accept untreated water. The ability of these users to accept untreated water would result in lower treatment costs to QGC.

Quantity

The volumes of water required for mining are unlikely to meet the supply available from Associated Water production. A coal mine producing approximately 30 million tonnes per annum of coal would require approximately 10,500 ML of water per annum, which would represent about 15 per cent of the Associated Water produced in the early stages of the QCLNG Project.

Long-Term Supply

The life of a mine, and hence its demand for water in the future may not coincide with the supply of Associated Water from QGC. In addition, there is a risk that water users may opt out of water supply arrangements during the Project, leaving QGC without sufficient demand for Associated Water.

Due to the rapid rate of increase in water production in the initial years of the Project, major supply arrangements would be needed by 2011 at the latest. This may limit the number of mines that would be in a position to enter agreements to receive Associated Water.

Conclusion

There are significant advantages for supply of untreated Associated Water to mines. However, it is unlikely that mines will have sufficient demand to match the forecast supply of Associated Water. There is also uncertainty about which potential mining projects will proceed. In addition there are commercial risks in supplying water to mines.

11.6.3.7 Council Water Supply

Supply to adjacent towns within the Gas Field area may provide social, community and environmental benefits as the supply of the potable water to towns would enable these communities to decrease their current dependence on existing surface water and groundwater resources.

Distribution

QGC has discussed supply of Associated Water to the townships of Miles (population 1,500) and Chinchilla (population 3,000). Other potential council water users include the towns of Kogan (population 1,000), Dalby (population 10,000), Roma (population 4,000), and Tara (population 3,900). When assessing the possible opportunities a key issue will be the distance over which water must be transported to the township.

Council water supply is dependent on treated water delivery pipelines coinciding with the council water supply points. If dedicated pipelines are required, the infrastructure cost to supply small quantities of water, may be prohibitive.

Quality

Water supplied for urban (potable) uses must meet standards in the Australian Drinking Water Guidelines (ADWG). These water quality standards are particularly stringent and are generally higher than the standards for water quality required for other beneficial use options. A detailed assessment of water quality requirements and the social impacts of supplying water for potable use will be undertaken before proceeding with this option.

Should QGC supply Associated Water to a standard that does not meet the ADWG for council water supply, the local authority would need to treat water further to achieve potable (ADWG) standards. This aspect has not been resolved in discussions with local councils.

Quantity

The quantity of water required by the township of Miles and Chinchilla is less than 3 per cent of the volume of Associated Water produced. *Table 3.11.9* shows the estimated daily and annual water demand for Chinchilla and Miles. Should other towns in the region require Associated Water, this may drive demand for an additional estimated 5 - 10ML per day. ‘

Table 3.11.9 Estimated Municipal Water Demand

Town	Daily Water Demand (ML/day)	Annual Water Demand (ML/year)
Miles	1	365
Chinchilla	3 (estimated)	1,095

The relatively small volume of Associated Water required for council use requires other options to be considered for beneficial use.

Long-Term Supply

Municipalities may seek long-term solutions to water supply. The volume of water that QGC can supply may decline in a timeframe that councils consider to be too short.

Conclusion

Council water supply faces a number of constraints through the quality of water required, limited demand for water, high distribution costs and long-term social implications of a declining water supply. Any consideration for supply will require significant community and council support before a decision is made.

11.6.3.8 Industrial Supply

There are currently no industrial users, other than power stations, in or adjacent to the Gas Field which could accept Associated Water in viable quantities. The Condamine Power Station will be a beneficial user of Associated Water when it is commissioned in the third quarter of 2009.

There are a number of new power stations due to commence operations in the region. There is an opportunity for supply of Associated Water to these power stations. The locations of mines and power stations that may use Associated Water are shown in *Figure 3.11.7.*

Distribution

To gather and transport water to industry will require the development and operation of a water pipeline system. Commercial arrangements could be negotiated to share the costs of distributing water, including planning, construction, operations and maintenance costs.

Quality

The quality of water required for each industrial use may be specific to that industry. For food-related industries, the water must be of potable standard. For other activities such as metal processing, near potable quality water is also required. For some industrial uses (like wash water), lower quality water can be utilised. However, it generally needs to be of a reasonably good standard to maintain the operability of plant and equipment.

Given this, it is likely that Associated Water supplied for many industrial purposes will need to be treated to remove salts and other analytes. Depending on individual agreements with the relevant organisation, treatment may be performed by either QGC or another entity.

Quantity

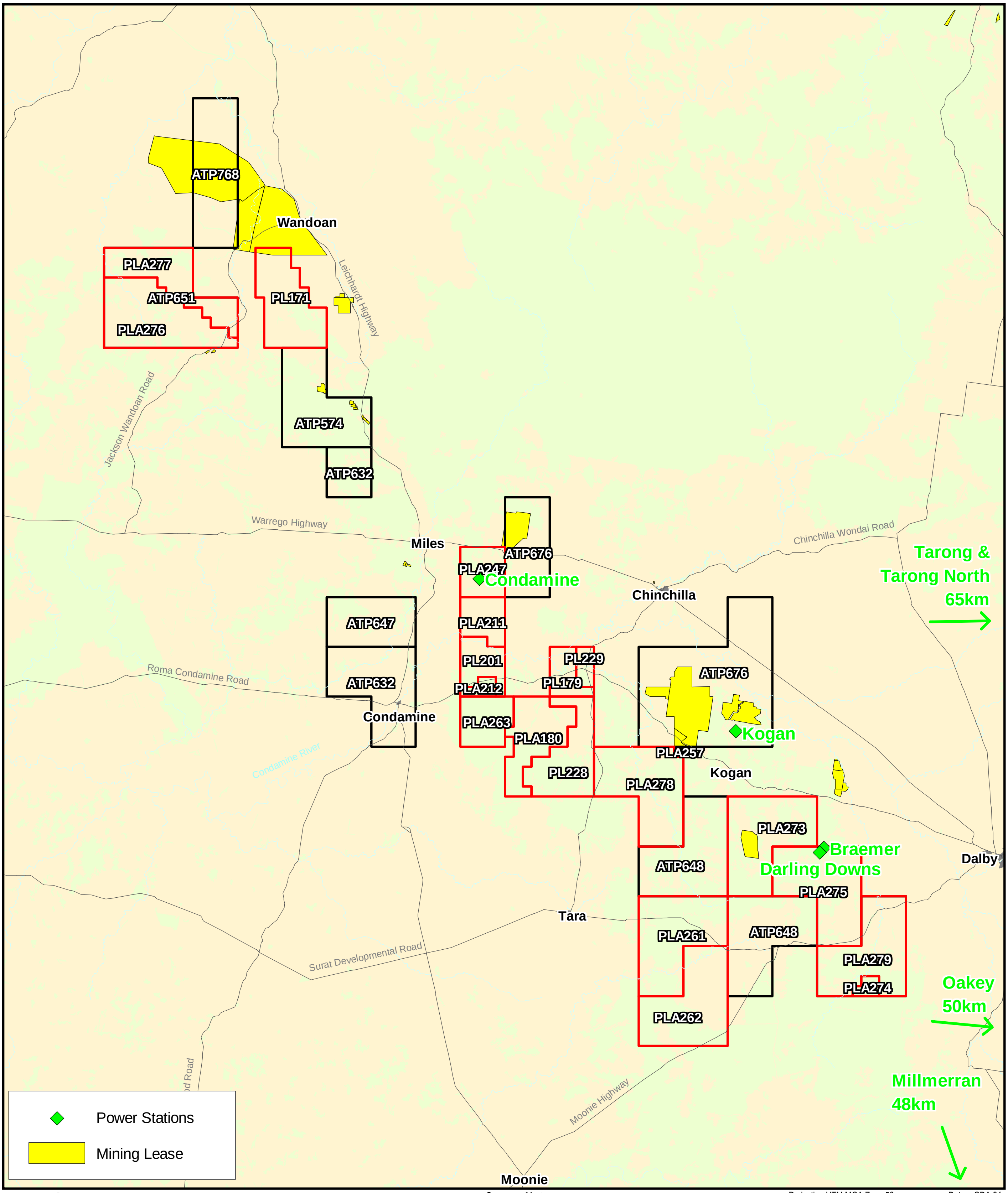
It is anticipated that industry, particularly power stations, could receive a portion of the Associated Water. Further investigations would need to be conducted to determine a realistic volume of water that is required by industries in the region. However, the volume of Associated Water that industry may require in future may be substantially less than the overall volume of water consumed, given the existence of prior long-term water supply arrangements.

The Condamine Power Station is likely to consume approximately 6 ML per day. Other projects have committed to receiving approximately 4 ML per day from QGC.

Long-Term Supply

Power stations are generally intended to have a long service life (50-80 years) in comparison to the relatively short-term water supply (20-30 years) which could be offered by QGC. Diminishing rates of supply, as well as the potential cost of funding water infrastructure may make using Associated Water commercially unfeasible for power stations.

Contractual arrangements will need to be negotiated for the long-term supply of Associated Water. However, there is a risk that water users may opt out of arrangements during the Project, leaving QGC without sufficient demand for Associated Water.



Legend:

Gas Fields - Petroleum Lease/Petroleum Lease Application

Gas Fields - Authority to Prospect

Source Note:
1:250,000 Topographic vector copyright Geoscience Australia
Power stations sourced from Geoscience Australi
Mining Leases sourced from Dept Mines and Energy

Projection UTM MGA Zone 56 Datum GDA 94

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QUEENSLAND CURTIS LNG
A BG Group business

ERM
Environmental Resources Management Australia Pty Ltd

Project	Queensland Curtis LNG Project		
Client	QGC - A BG Group business		
Drawn	Mipela	**Volume** 3	**Figure** 3.11.7
Approved	CDiP	File No:	QC02-T-MA-00113
Date	10.06.09	Revision	A

Title **Power Stations & Mining Leases**

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Conclusion

Industrial water supply, by virtue of the volumes it consumes, remains a possible option for QGC. However, industrial water supply faces water quality and high distribution cost constraints. QGC will remain flexible about entering any future water supply arrangements. QGC will keep a watching brief on local development and, where viable, will continue to assess supply of water to local industries as a potential alternative use for Associated Water.

11.6.3.9 Reinjection

Reinjection refers to the placement of Associated Water in subsurface strata. There are essentially four options for the strata used for reinjection:

- near-surface aquifers
- non coal related aquifers
- depleted coal seams
- localised subsurface voids.

The Queensland Government's preferred position is that reinjected water is at least the same as, or better quality than, the water in the aquifer.

Near-surface aquifers

Near-surface aquifers are nominally located within 50 m of the ground surface. They are usually associated with local watercourses, may only be a few metres deep and there is usually a direct hydraulic connection between surface water and groundwater in the aquifer.

These aquifers are a primary source of water for local communities, agriculture, stock watering and domestic purposes. In some areas, aquifers are used for irrigation; however irrigated cropping is unusual within the locality of the Gas Field (refer *Volume 3, Chapter 5*).

The water quality of near-surface aquifers is likely to be significantly better than the quality of the untreated Associated Water. Water will need to be treated prior to reinjection in near-surface aquifers.

It is probable that suitable near-surface aquifers for reinjection only occur in some areas of the Gas Field and the volumes of water that could be injected into these aquifers is likely to be limited.

Non coal related aquifers

Reinjection into non-coal related aquifers situated below the coal seams may offer large reinjection volumes if aquifers are regionally extensive and of comparable water quality. The technical feasibility of reinjection to deep aquifers is under investigation.

QGC has commissioned a study on reinjection of Associated Water into the deep aquifers situated below the coal seams. There are two possible stratigraphic aquifer reinjection targets, the Hutton and Precipice formations. Local testing has indicated locations where these aquifers have water of a similar quality to untreated Associated Water. Indications are that these formations offer sufficient permeability to accept large volumes of Associated Water.

In terms of minimising impacts on background groundwater use, potential mixing of water quality and the effects of increased aquifer pressure, the Precipice is considered as the highest priority target for water injection, although this would not preclude further investigation of other strata. Field testing is required to improve the understanding and confidence in the hydrogeology of the Precipice. Data acquisition, including water sampling for water quality compatibility, and uptake of reinjection volumes is critical for progression of reinjection as an option for beneficial use.

Depleted coal seams

It may be possible to reinject Associated Water back into the coal seams from which it was drawn once wells have passed their useful productive life. This reinjection option would attempt to use the existing well infrastructure for reinjection.

Associated Water from various wells is likely to be mixed in storage ponds prior to reinjection. However, water is unlikely to be distributed between the three Gas Field regions. Assuming evaporation of stored water is minimised, the Associated Water quality that is reinjected should be very similar to the aquifer water quality from which it was drawn.

Field testing of Associated Water reinjection into the coal seams has not been conducted on a QGC site. While reinjection into coal seams is conceptually feasible, it has not been successfully trialled locally.

This option could not be considered until wells were no longer productive. Given that the average well has a life span of approximately 15 years, large volume of Associated Water would need to be stored before reinjection to coal seams could commence. As such, it is unlikely that this is a feasible option.

Localised subsurface voids

There may be sub-surface voids, such as deep, fractured basement formations, which are available for reinjection. Such formations are somewhat unusual.

However, it is not known if there is a suitable sub-surface formation within the bounds of the Gas Field. The cost of exploration to locate a suitable formation and then further test the formations' injectivity does not appear economically feasible.

Conclusion

The quantity of water that could be injected may equal the supply of Associated Water. Treatment of the Associated Water is unlikely to be required for deep aquifers.

There are a number of issues that could affect the success of a long-term reinjection program. Further investigation to establish the viability of reinjection as a beneficial use option is required for the:

- ability of the reinjection reservoir to accept and store reinjection water over a long period
- chemical compatibility of untreated or blended Associated Water in comparison to the receptor formation geochemistry and existing pore water chemistry
- hydraulic aspects of the proposed reinjection program, such as the number of wells, well field configuration, well interference, well longevity, and the radius of influence of enhanced permeability and storage.

QGC has commissioned independent experts to determine the prospects for both reinjection and the impact on receiving aquifers from injecting Associated Water.

11.6.3.10 Coastal Discharge

It is technically possible to deliver Associated Water, collected from the Gas Field, to an ocean outfall at the coast. A pipeline, approximately 325 km long, would be required. Details of potential pipelines required to deliver untreated Associated Water, brine (following treatment of the raw Associated Water) and concentrated brine are summarised in *Table 3.11.10 .*

Table 3.11.10 Coastal Discharge Pipeline Requirements

Water Type	Average Salinity (TDS mg/L)	Annual Volume[1] (ML/year)	Daily Flowrate[2] (L/s)	Pipe Diameter (mm)	Pumping Requirements
Untreated	4,500	54,750	1,900	DN1250	3 pump stations approx. 6.8mW each.
Brine[3]	18,000	13,700	475	DN600	3 pump stations approx. 1.7mW each
Concentrated Brine[4]	100,000	2,466	85	DN300	6 pump stations approx. 200KW each

Notes:

1. Volumes based on Associated Water production rate of 150 ML/day.
2. Flowrates based on pumping 22 hours per day, 365 days per year. Assumed flow velocity 1.5m/s.
3. Brine assumed to be 25 per cent of raw water inflow to treatment plant.
4. Concentrated brine assumed to be 4.5 per cent of the raw water inflow.

Once the pipeline has delivered the water to the coast, it would need to be discharged into the ocean via an outfall. This outfall would probably consist of a deep shaft on the coast, feeding a tunnelled pipeline in the range of 1.5 to 2.5 m diameter extending into the ocean by about 1.3 km and dispersing the water into the ocean via a diffusion structure. The design of the outfall is a complex undertaking and its configuration could vary considerably depending on a range of factors.

There are a number of contaminants in untreated Associated Water that may be deleterious to the ocean environment. A detailed investigation of impacts on marine environments would be required if this option was pursued. Approval may be granted to discharge treated Associated Water to the ocean. Should this option be pursued, QGC will engage with the DERM and other authorities to confirm the requirements for treatment.

A large number of approvals and land access agreements would be required to implement this option. The pipeline would cross a number of landscapes, interact with services and infrastructure owned by others, and traverse public and private properties. For a pipeline of this length, the approvals and agreements could take one to two years to finalise.

The potential cost of ocean disposal is likely to be high, the risk of the environmental harm is significant and the likelihood of obtaining approval is low. On this basis, ocean disposal is not considered a viable option for management of Associated Water.

11.6.3.11 Surface Water Discharge

The majority of the Gas Field is within the catchment of the Condamine and Balonne rivers. The CDA and SEDA are located along the southern catchment of the Condamine River between Dalby and Miles, with a section of the NWDA located north of the Condamine River between Miles and Wandoan. The balance of the NWDA lies in the Dawson-Fitzroy Basin catchment.

Distribution

The location of the Gas Field provides the possibility of discharging Associated Water into the Condamine River or its tributary creeks. A number of pipes, approximately 30 km in length would be required between water treatment facilities and the watercourses.

Water Quality

Given the salinity levels and other water quality limitations of Associated Water, discharge of untreated Associated Water to watercourses is not considered by QGC to be environmentally sustainable. It is possible that a licence could be obtained from the DERM to discharge treated Associated Water to the Condamine River. The EPP (Water) objective is to rehabilitate ‘disturbed’ streams and regulators may require that the treated Associated

Water be not worse than the water quality of the background river water quality.

A water quality standard for surface water discharge of treated Associated Water has not been established by the authorities; however the DERM typically applies the principles in the ANZECC guidelines and other relevant sources. In essence, these guidelines require that the water being discharged match, as closely as possible, the quality of the receiving water across a wide range of chemical and physical parameters such as pH, temperature, salinity, salt balance, mineral content and background element content. Release of lesser quality waters must be demonstrated to have no negative impact on the environment or other users.

Given that the Condamine River is the proposed receiving watercourse in this case, the quality of water in the river can be considered to be the baseline quality required for treated Associated Water proposed for discharge. Water quality parameters for the Condamine River vary over time. Data obtained by QGC is summarised in *Table 3.11.11* and compared with the quality of untreated Associated Water from QGC's three Gas Field regions.

Table 3.11.11 Summary of Water Quality by Region

Analyte	Units	Condamine River[2]	South-East Development Area[1]	Central Development Area[1]	North-Western Development Area[1]
Total Dissolved Solids	mg/L	200	4,748.0	2,817.0	5,518.0
SAR	-	1.5	108.0	113.0	no data
Fluoride	mg/L	0.2	1.7	3.43	1.4
pH	-	7.8	8.49	8.55	8.49
Soluble Iron (as Fe^{2+})	mg/L	0.19	3.0	3.9	23.0

Notes:
1. Source (QGC data): QGC
2. Source (Condamine River Data): QGC (from NRW)

This data shows that Associated Water requires considerable treatment to bring it to a quality which could be discharged into the Condamine River. Given the range of analytes which need to be treated, including large concentrations of salt, some form of desalination treatment will be required for this option. Following desalination, there is potential to flow treated water through a constructed wetland system prior to release to surface waters. This wetland system would be designed to yield water that approximates the water quality of the Condamine River.

Water Quantity

Discharge of water into a watercourse will change the flow regime of the receiving watercourse. The lowest cost and simplest method of discharge would be to pipe water from the treatment plants at the plant output rate. However, even large watercourses of inland Australia, such as the

Condamine River, are ephemeral, so a constant discharge rate from the water treatment plants would change the current flow regime and impact on aquatic ecosystems. Ideally discharges would be maximised during the wettest times of the year when natural peak flow occurs, and minimised during times of low flow.

The key consideration is whether the proposal would substantially change the river regime compared with its historic regime before the catchment was developed for agricultural use. If the Condamine River had a constant base flow before the catchment was developed, this would build a case for discharging treated water at a constant rate. A second consideration would be to evaluate the downstream extent of the treated water flow and whether this would be ecologically and socially sustainable.

In this context, it is possible that QGC could obtain a permit to discharge treated water to the Condamine River with the condition that the release be timed to coincide with high flows in the river. To achieve this, QGC would need to provide very large water storages, equipped with release spillways, to enable significant volumes of stored treated water to be released in a short space of time in a controlled manner. The cost of these storages and high-volume release structures would be very high.

Further studies will be needed to determine the ecological values of the watercourse and appropriate temporal discharge.

Long-Term Supply

As water production rates decrease, the supply of water to the watercourse will decrease. Ecosystems and species that may have become dependent on additional water supplies may not survive the decline in water volumes. Hence only an appropriate amount of water should be released over the life of the Project. The relative contribution of QGC's Associated Water flows to the Condamine River Catchment would need to be investigated in greater detail to determine the likely long term environmental impacts.

Increased river flows are likely to benefit agricultural users in the short term. Certain agricultural practices may become dependent on increased river flows and suffer socio-economic stress when water volumes decline.

Release to Existing Dams

A variation of releasing water to a watercourse would be to release water to an existing dam. The water quality requirements for this option would depend upon the intended use of the water, and the current water quality, size and purpose of the dam. However, release to a dam has the advantage, over release to a watercourse, that it is unlikely to change stream flow regimes or impact on the aquatic environment outside the dam.

Options for this form of release include Cooby Dam (north of Toowoomba) and Beardmore Dam (north of St George). Both of these sites are some distance (more than 150 km) from the Gas Field.

QGC will continue to pursue release of treated Associated Water to dams with the relevant government departments.

Conclusion

Surface water discharge is technically feasible, and may require treatment of large volumes of Associated Water depending upon the end use. There are significant piping and pumping costs in supplying water to dams. Additionally, social and environmental impacts would need to be considered for any intended use.

11.6.3.12 Evaporation Ponds

Evaporation ponds are not a preferred option of the EPA Operational Policy on management of Associated Water (2007). The policy requires the preparation of an Associated Water Management Plan (AWMP). The AWMP will require companies to demonstrate how they intend to phase out and transition away from the use of evaporation ponds.

QGC currently uses evaporation ponds for management of Associated Water from existing gas production. Evaporation ponds will be transitioned into water storage ponds, required for the balancing of water before and after treatment. It is proposed that this transition will be initiated after close consultation with the DERM and taking account of the technical and economic viability of alternatives.

Water Quantity

There are some technical limitations to using ponds for evaporation. The performance of evaporation ponds is determined largely by the balance between evaporation (which is relatively constant but varies slowly between seasons), and rainfall (which varies considerably over all scales of time). To evaluate the efficiency of evaporation ponds, water balance modelling is required. Using a simple assessment of the difference between average monthly or annual evaporation and rainfall to determine the long-term performance (and therefore the correct size) of evaporation ponds results in significant errors.

Regulations and Licensing

The DIP issued a policy document on the management of CSG Associated Water in 2008 which cites "widespread concerns about evaporation ponds and the long-term legacy of salt stored in them". Key features of the policy include discontinuing the use of evaporation ponds as a primary means of disposal for Associated Water, and making CSG producers responsible for treating and disposing of Associated Water.

QGC will minimise the construction of evaporation ponds for untreated Associated Water. Note that this does not preclude the company being able to obtain additional licences for the construction of dams to store treated water, brine or water from exploration and appraisal wells.

Pond Decommissioning

Appropriately designed and certified evaporation ponds are relatively expensive to construct. However, the long-term cost of decommissioning evaporation ponds can be even greater.

QGC will need to rehabilitate or convert its evaporation ponds to satisfy regulatory requirements. It will never-the-less almost certainly require raw water storage ponds for balancing water flows, which will be deeper and have a smaller footprint than evaporation ponds.

Rehabilitation of evaporation ponds is likely to involve:

- pumping any remaining highly saline water to small HDPE lined ponds to reduce the footprint of salt affected soils
- allowing ponds to dry out (an activity which will be largely dictated by rainfall patterns, not pre-determined schedules)
- encapsulating, in-situ, any saline soils, using a capillary break layer, clay capping and appropriate depth of growth medium

QGC will adopt water management strategies which minimise the area of evaporation ponds.

Conclusion

The primary method of disposal of Associated Water via evaporation ponds is not feasible for QGC's operation in the long term. In the short term, evaporation ponds are likely to be required while other water management infrastructure is constructed.

Storage dams will continue to play a role in QGC's long-term water strategy for balancing of water flows between the Gas Fields, treatment facilities and beneficial users. Small evaporation ponds may be required to evaporate concentrated brine from treatment processes.

11.6.3.13 Aggregation

Aggregation refers to combining, in a central location, Associated Water from the various CSG operations in the Surat Basin. This may result in some shared cost savings on the one hand, whilst markedly increasing piping and pumping costs on the other. The methods of water treatment, waste disposal and the options for beneficial use of the water are essentially the same as those described in this chapter.

Any cost savings achieved by aggregation are likely to be outweighed by the cost of piping the water to central locations for aggregation, treatment and distribution, and the costs associated with treating water to potable standard. A separate study is currently being conducted by Australian Petroleum Production and Exploration Association (APPEA) and various industry groups, including QGC, to assess whether there are any economic and environmental benefits achievable by aggregation of Associated Water. If the outcome of this study is favourable for aggregation, QGC would consider pursuing this option further. However, at the time of this EIS, there is no framework in place within the CSG industry to enable such coordination of water management, so QGC cannot rely on an aggregation scheme to resolve its water management issues in the short-term. It appears unlikely that such aggregation can be implemented within the required timeframes for the QCLNG Project.

According to the recently released former EPA Policy on CSG water management, the Queensland Government has a preference for aggregation when Associated Water is in excess of that required for on-site disposal. There is an awareness among the stakeholders involved that aggregation needs to be economically viable for CSG projects to progress towards government's preference.

11.6.4 Options Selection

11.6.4.1 Criteria for Options Analysis

The following criteria have been used to assess each beneficial use option:

- environmental impacts
- social impacts
- technical constraints
- economic constraints
- commercial constraints
- regulatory constraints

Environmental impacts encompass an assessment of the positive and negative impacts of Associated Water management options on:

- soil character, fertility and productivity
- land contamination
- waste management
- surface water quality and hydrology
- shallow aquifer water quality
- groundwater quality and hydrodynamics

- air quality
- visual amenity
- noise levels
- biodiversity.

Potential impacts are discussed in greater detail in *Section 11.11.2.*

Environmental impacts are dependent on the quality, quantity and duration of water supplied to the environment, the quantity of waste that requires disposal and the infrastructure required for management of Associated Water.

Social impacts encompass an assessment of the positive and negative impacts of water management options on:

- existing land use
- disruption to communities
- social infrastructure benefits
- community and individual landholder access to water
- community expectations.

Technical constraints refer to the degree to which the technology required to implement an option is proven and available.

Economic constraints are based on assessment of the cost of infrastructure required to implement an option. Cost is dependent on the:

- quality of water required for the beneficial use where the better the quality of water the greater the costs of water treatment and waste management
- distribution network, where the greater the length of the distribution network per ML of water transferred, the greater the cost.

Commercial constraints refer to the:

- degree of reliance that QGC will be required to place on third parties for each option, where the greater the reliance the less feasible the option
- volume of water that can be received by an option, where the greater the volume the more feasible the option.

Individual contracts can be complex and have a risk of non-performance by the third party. In addition QGC may not be able to supply the desired quality or quantity of water for the required period to a third party. The greater the degree of reliance on third parties the greater the risk of an option underperforming.

The volume that can be received by a beneficial use is a critical constraint. Options that do not have demand equivalent to the estimated supply have to be supplemented by other options, irrespective of the level of environmental and social impacts of that option. Thus, options that have the potential to receive a significant percentage of produced water are favoured, with mitigation measures to be implemented to reduce the potential environmental and social impacts of those options.

Regulatory constraints refer to the potential complexity of the approvals process required for each option. The greater the complexity the less feasible it is to obtain regulatory approval.

Table 3.11.12 provides a ranking of the potential impacts from each option and the constraints facing each option. Impacts can be both positive and negative and are ranked as high, medium or low. Constraints are ranked as high, medium or low. The greater the potential impacts and constraints, the less desirable is the option. An overall ranking is then assigned to each option.

11.7 PREFERRED OPTIONS

Based on the above qualitative impacts and constraints ranking, the preferred set of beneficial use options is:

- tree cropping
- supply of water to mines
- reinjection.

Both tree cropping and reinjection offer the possibility of supplying the majority of Associated Water to beneficial use. The potential social and environmental impacts of tree cropping will be investigated to determine the magnitude of potential impacts and the mitigation measures required to reduce those impacts. Impacts will be minimised by the use of trials conducted on QGC's land and through the use of extensive monitoring.

In the short term, evaporation ponds remain a preferred option prior to the establishment of infrastructure to support the longer term options.

Table 3.11.12 Ranking of Beneficial Use Options

Criteria Beneficial Use Option	Environmental Impact	Social Impact	Technical Constraints	Economic Constraints	Commercial Constraints	Regulatory Constraints	Impact / Constraints Ranking
QGC Petroleum Activities	Medium	Medium	Low	Low	High	Low	Medium
Stock and Domestic Purposes	Low	Low (+ve)	Low	High	High	Low	Medium / High [2]
Tree Cropping	Medium[1]	Medium	Medium	Medium	Low	Medium	Low / Medium
Cropping	Medium	Medium	Medium	High	High	High	High [2]
Wetlands	High[1]	Medium	High	Low	Medium	High	High [3]
Mine Water Supply	Low	Low	Low	Low	Medium	Medium	Low
Council Water Supply	Medium	High (+ve)	High	High	High	High	High
Industrial Supply	Medium	Low	Medium	Medium	High	Medium	Medium
Reinjection	Low	Low	High	Medium	Low	Low	Low
Coastal Discharge	High	High	High	High	Low	High	High
Surface Water Discharge	High1	Low	Medium	Medium	Low	High	Medium
Evaporation Ponds	High	High	Low	Low	Medium	High	High
Aggregation							

Notes: 1 based on uncertainty prior to impact assessment of option
2. QGC may pursue individual agreements, where the volume of water or cost of delivery is the primary constraint
3. Wetlands for permeate polishing may be pursued

Reinjection is likely to have low social and environmental impacts, is a preferred option of regulators, but faces high technical and medium economic constraints. Further field trials will be conducted to determine the technical feasibility of reinjection.

Supply of water to mines offers a low environmental and social impact option with low economic and technical constraints, but will only result in the supply of a small percentage of Associated Water produced.

Those options assessed which have a medium ranking for impacts and constraints are:

- QGC petroleum activities
- supply to industry
- surface water discharge.

These options are or will be the focus of further investigations by QGC to determine their feasibility.

The major constraint facing use of Associated Water for QGC's petroleum activities is very limited volume demanded by this option. However, this option remains attractive as a means to source water for the Gas Field activities, with minimal requirements for water from other sources.

Supply to industry is less certain than supply to mines due to commercial and economic constraints, but remains a reasonable option should an industrial supply option emerge.

Surface water discharge may have high environmental impacts, and is not a preferred option under regulatory policy. However, surface water discharge of treated water has the potential to receive all of the Associated Water produced.

Those options assessed which have a high ranking for impacts and constraints are:

- stock and domestic purposes
- cropping
- wetlands
- council water supply
- coastal discharge
- evaporation ponds.

These options are not precluded, but QGC will place less emphasis on these as the long-term solutions to water management.

Supply of water for stock and domestic purposes will utilise a very limited volume of water while posing high economic constraints in distributing small volumes of water to multiple users, each with fluctuating demand. Individual supply agreements would be entered on a case by case basis.

Supply of water for cropping is likely to be constrained by high costs of distributing water to areas suitable for cropping and the fluctuating demand for water as rainfall changes.

Treatment of water through wetlands is an unproven technology on the scale required by QGC and has potential for high environmental impacts.

Municipal water supply, while providing social benefits, faces high economic, commercial and regulatory constraints to supply small volumes of very high quality water across long distances.

Coastal discharge may have high environmental and social impacts, be costly and is unlikely to receive regulatory approval.

Evaporation ponds are favoured as a short-term solution as they are not economically and technically constrained. As a long-term solution they are not preferred due to high environmental and social impacts.

11.7.1 Conclusion

At the time of preparation of this EIS, it is anticipated that approximately 15 ML per day of untreated water will be utilised for QGC petroleum activities and supply to mines and industrial users. The balance of Associated Water, approximately 165 ML per day at peak production may be reinjected, used for irrigation of tree crops or discharged to surface waters.

The option that, at the time of drafting the EIS, was most progressed and hence more likely to be implemented in the next two to three years is irrigation of tree crops. As discussed in *Section 11.6.3.3*, water for irrigation will be sourced from a blend of desalinated water and amended or untreated water. The blend ratio will depend on the outcomes of trials to determine the sustainable water quality required for irrigation.

Should circumstances affecting any of the options change in the future, QGC will evaluate those options in the light of new information.

11.8 WATER MANAGEMENT INFRASTRUCTURE

The infrastructure required for the various beneficial use options for Associated Water is summarised in *Table 3.11.13*.

Table 3.11.13 Infrastructure Required per Beneficial Use

Use	Treatment	Treatment Facilities	Pipelines	Brine Treatment[1]
QGC Petroleum Activities	Untreated , desalinated and amended	Water treatment plants (WTP) with desalination and amendment	• Possible pipelines between camps and storage ponds.	• Brine treatment required
Tree or Crop Irrigation	Blended or desalinated and amended	Three desalination WTPs with combined capacity of 105 ML/day (conservative figure) Water storage ponds – approximately 400ha	• Gathering pipelines to treatment plants (360km) • Pipelines to irrigation areas (150km)	• Brine concentration treatment at each water treatment plant • Multi-cell solar evaporation basins at each water treatment plant • Salt landfill in CDA and SEDA
Stock and Domestic Purposes	Desalinated and blended	Treatment plants (desalination and amendment) and storage ponds	• Pipelines between treatment facilities and local landholders (length undetermined)	• Brine treatment required
Mine Water Supply	Untreated	Nil	• Gathering pipelines in central locations near CPPs (length undetermined) • Pipelines to water user as required	• Nil
Discharge of Water to Ocean	Untreated or Partial treatment	Pre-treatment facility with capacity of 180 ML/day.	• Pipeline between site and coast approximately 325km long. At least three booster pump stations required. Discharging through an outfall pipeline with dissipaters into the ocean.	• Solid waste landfill at CDA and SEDA.
Council Water Supply	Potable water standards	Desalination and other treatment facilities. Capacity dependent on volume of water delivered for urban water supply.	• Gathering pipelines to treatment plants (360km) • Pipelines to urban centres (length undetermined)	• Brine concentration treatment at each water treatment plant. • Multi-cell solar evaporation basins at each water treatment plant. • Salt landfill in CDA and SEDA

Use	Treatment	Treatment Facilities	Pipelines	Brine Treatment[1]
Industrial Supply	Untreated or Treated	Desalination WTPs. Capacity dependent on volume of water delivered for industrial use.	• Gathering pipelines to treatment plants (360km) • Pipelines to water users as required	• Brine concentration treatment at each water treatment plant. • Multi-cell solar evaporation basins at each water treatment plant. • Salt landfill in CDA and SEDA
Reinjection	Untreated	Pre-treatment facility	• Gathering pipelines to central locations or reinjection sites (length undetermined) • Reinjection system (pipelines to reinjection bores, pumps, balancing storages)	• Not required
Surface Water Discharge	Blended of desalinated and amended	• Three desalination WTPs with combined capacity of up to 180ML/day. • Continuous discharge system: outfall structure at river for each WTP • Flood-timed discharge system: Large water balancing dam with large release gates for each WTP. • A wetland may be required for water polishing prior to discharge	• Gathering pipelines to treatment plants (length undetermined). • Pipelines to surface water discharge locations (approximately 25km long for each WTP).	• Brine concentration treatment at each water treatment plant. • Multi-cell solar evaporation basins at each water treatment plant. • Salt landfill in CDA and SEDA.
Wetlands	Untreated or desalinated	Wetland ecosystem, including constructed ponds and water channels	• Likely from storage ponds to wetlands	• Brine treatment required
Evaporation ponds	Untreated	Ponds, designed to applicable pond standards	• Required from wells to ponds	• Not required

Note 1: Brine treatment discussed in more detail in *Section 11.10*.

A case for irrigation has been developed and is presented below. The proposed infrastructure required is further detailed in *Table 3.11.14.* Note that this infrastructure assumes all water is to be amended or treated for tree crop agriculture and does not consider the reduction in plant size should injection prove feasible. It is also conservative in that it does not consider possible forecast water reduction of up to 30 per cent.

When considering this infrastructure the quantity of water desalinated per day for irrigation is dependent on:

- the volume of untreated water that is beneficially used (e.g. for supply to mines, industry and dust suppression)
- a function of the blend ratio of desalinated water and amended water.

It is anticipated that QGC will supply approximately 15 ML per day of untreated water to various beneficial users in the short-term, with the intention to increase this volume in the long term.

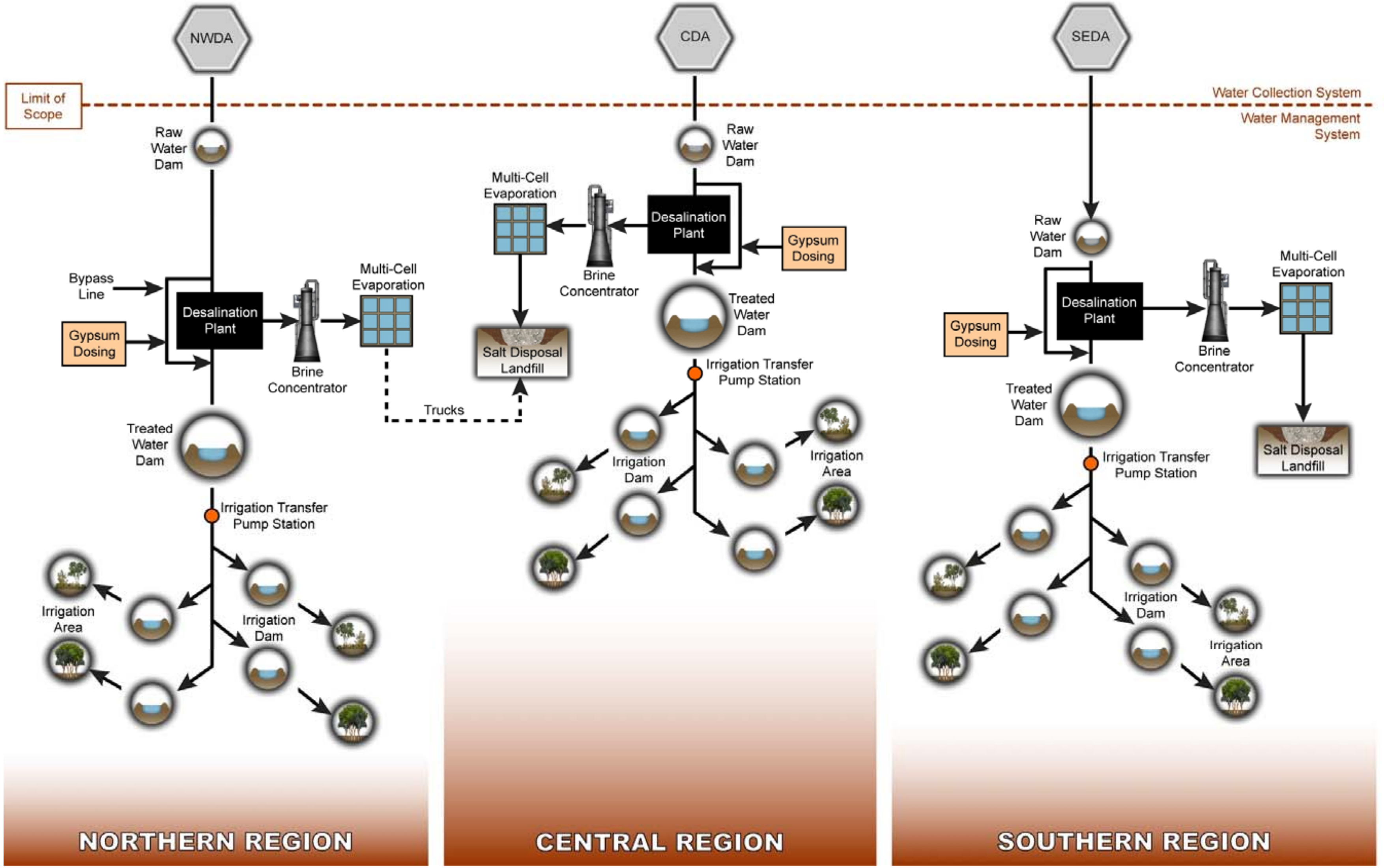
QGC believe that a blend ratio of 1:1 to 4:1, depending upon the input water quality and soil requirements, is likely to be achievable. At peak water production, this equates to blending approximately 105 ML per day of desalinated water with 55 ML per day of amended water. QGC will vary the volume of water requiring desalination, and hence the infrastructure required, depending on the outcome of trials to establish an optimal blend ratio that achieves a balance between minimising desalination infrastructure and sustainable irrigation.

Further details of the proposed infrastructure that is required for irrigation is summarised in *Volume 2, Chapter 7 and 11.* A schematic diagram of the configuration of the water management system for irrigation is provided in *Figure 3.11.8.*

Table 3.11.14 Proposed Water Treatment Infrastructure for Irrigation of Tree Crop Option

NWDA	CDA	SEDA
• 20 ML/day Desalination plant • Untreated water collection and storage ponds (2,000 ML) • 2 feed pump stations • Pre-treatment and reverse osmosis treatment plant • Brine concentration plant • Raw water dosing (amendment) and blending system • Brine holding dam (100ML) • Multi-cell evaporation basin • 2 discharge pump stations • Treated water dam (400ML)	• 30 ML/day Desalination plant • Untreated water collection and storage ponds (2,600 ML) • 5 feed pump stations • Pre-treatment and reverse osmosis treatment plant • Brine concentration plant • Raw water dosing (amendment) and blending system • Brine holding dam (200ML) • Multi-cell evaporation basin • 4 discharge pump stations • Treated water dam (300ML)	• 55 ML/day Desalination plant • Untreated water collection and storage ponds (3,950ML) • 7 feed pump stations • Pre-treatment and reverse osmosis treatment plant • Brine concentration plant • Raw water dosing (amendment) and blending system • Brine holding dam (400ML) • Multi-cell evaporation basin • 7 discharge pump stations • Treated water dam (1,200ML)
	Salt disposal landfill	Salt disposal landfill
Irrigation Transfer pumping station and 15km pipeline to irrigation area(s)	Irrigation Transfer pumping station and 15km pipeline to irrigation area(s)	Irrigation Transfer pumping station and 15km pipeline to irrigation area(s)
Mixed crop irrigation areas comprising: • 950 ha plantation with surface drip irrigation system • 4 x75ML balancing storages • 4 x irrigation filtration systems. • Soil and climate monitoring systems.	Mixed crop irrigation areas comprising: • 5,000 ha plantation with surface drip irrigation system • 4 x 300ML balancing storages • 4 x irrigation filtration systems. • Soil and climate monitoring systems.	Mixed crop irrigation areas comprising: • 4,500 ha plantation with surface drip irrigation system • 4 x 300ML balancing storages • 4 x irrigation filtration systems. • Soil and climate monitoring systems.
		Transfer pipeline from SW region (15km).

Figure 3.11.8 Schematic Diagram –Water Management System for Irrigation of Tree Crops



Anticipated daily rates of Associated Water consumption for the various anticipated beneficial uses are summarised in *Figure 3.11.9.* A summary of the anticipated cumulative usage of Associated Water through the Project life is provided in *Figure 3.11.10*.

Figure 3.11.9 Daily Associated Water Use

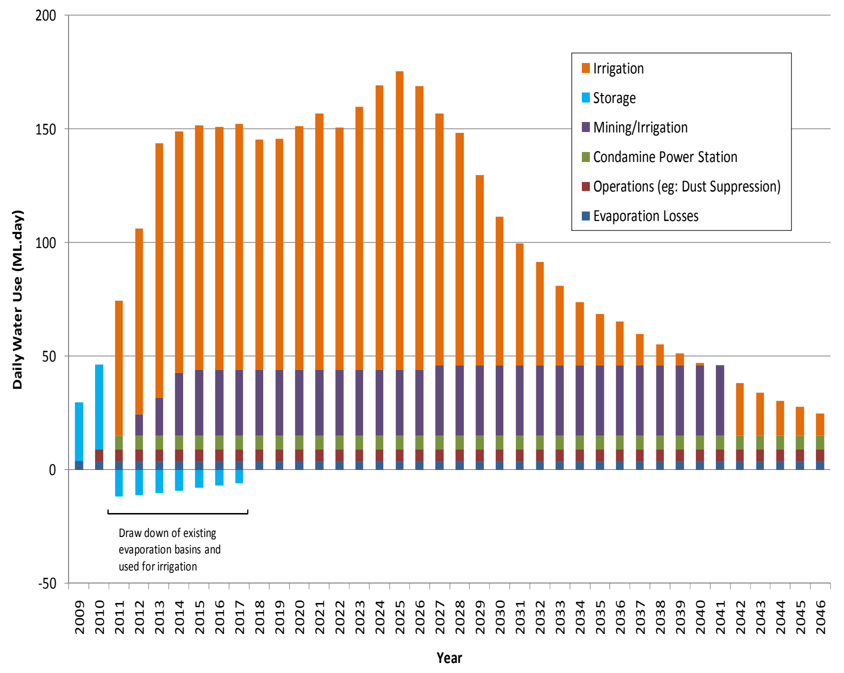
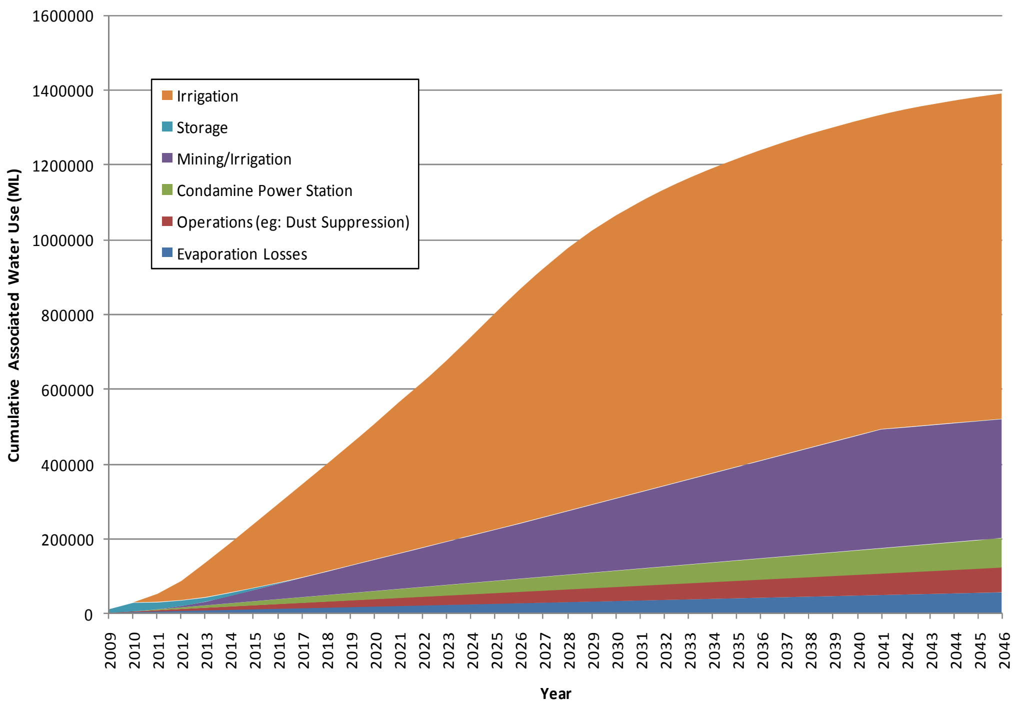


Figure 3.11.10 Cumulative Associated Water Use



11.8.1 Water Management Strategy

The QGC water management strategy proposes the following short-term (present to 2013) and long-term (2014 onwards) strategies for Associated Water management. In the short term, proven technologies with minimal lead times for construction and commissioning will be necessary to manage Associated Water. In the long term, the options which satisfy the above options selection criteria will be preferred.

11.8.2 Short-Term Water Management

Short-term water management requires early planning and implementation to manage water derived from the early ramp-up phase of the Project. Water volumes in the period 2010 to 2013 will increase rapidly from approximately 40 ML per day to 180 ML per day.

The aims of short term water management are to:

- establish sufficient capacity for management of water in short timeframes; and
- investigate alternative technologies and methods of water management which offer potential future environmental, economic, social, technological and commercial benefits.

The implementation strategy involves:

- undertaking detailed planning and scope definition of the required water management system

- advancing the design and procurement of the water treatment plants (WTPs) required to be commissioned in 2011
- continuing the use of evaporation ponds and constructing additional untreated water storage capacity to be used as part of the post 2011 WTP system
- providing small (1 - 3 ML/d), localised WTPs to cope with increasing water volumes until the primary WTPs are operational
- trialling injection and wetlands for improving water quality
- establishing small pasture irrigation plots until primary WTPs and irrigation areas are operational
- establishing a 20 ML/d blended treatment capacity and tree irrigation area.

QGC is currently seeking permitting and approvals for a permanent water treatment plant. It is intended that this facility will have approximately 30 ML per day capacity and use ultra filtration reverse osmosis technology. This facility will process Associated Water from QGC's domestic gas production activities in the CDA.

Approval will also be sought for a number of modular mobile Reverse Osmosis (RO) units with a brine concentrator with approximately 1 - 3 ML per day treatment capacity. These modular RO units are intended to provide treatment for water generated in remote field locations from well exploration and appraisal.

11.8.3 Long-Term Water Management

Long-term water management requires progressive expansion of the capacity of water management infrastructure.

The aims of long-term water management are to:

- manage the expansion of the water management system to match Associated Water production rates and quality requirements
- implement alternative technologies and methods of water management which offer potential future environmental, economic, social, technological and commercial benefits.

Based on the preferred options, the implementation strategy involves:

- expanding desalination water treatment capacity to approximately 105 ML per day in the three regions (North: 20 ML per day, Central: 30 ML per day and South: 55 ML per day)
- progressively reducing the blending ratio of desalinated and amended water to untreated water
- monitoring the effect of the resulting change in water quality on the sustainability of irrigation

- providing additional water treatment capacity and/or irrigation area if required, to ensure the environmental sustainability of the irrigation scheme
- injection on a large scale if proven feasible
- continuing the use of evaporation ponds where this is the only feasible option.

11.9 *Water Treatment Options Analysis*

Associated water qualities from across the Gas Field are variable and are high in TDS and SAR relative to regional waterways. The level to which the water will require treatment will depend on the type of beneficial use.

The two treatment methods that will produce the range of water qualities required for beneficial use are desalination and amendment. The SAR can be reduced in a treatment process that involves the addition of calcium (in the form of gypsum), commonly called ‘amendment’. Amendment achieved by dissolving the gypsum in water and mixing it with the Associated Water.

Desalination removes nearly all of the salts dissolved in the Associated Water. Hence a range of water qualities can be achieved by blending the desalinated water with amended or untreated Associated Water.

11.9.1 *Desalination Treatment Options*

The following water treatment technologies are being considered by QGC and are briefly described in subsequent sections:

- Membrane technologies (e.g. Reverse Osmosis (RO), Electrodialysis Reversal (EDR) and Nanofiltration (NF))
- Flow Through Capacitor (FTC)
- Ion Exchange (IE)
- Wetland system, forestation and polyploids
- Distillation
- Localised Mechanical Vapour Compression Evaporators (MVC).

11.9.1.1 Available Technology Review

A summary of the treatment technologies for Associated Water appears in *Table 3.11.15*

Desalination technologies will have a significant reduction on the SAR of water. However, following the utilisation of one of the above technologies, it is possible to further reduce the SAR of untreated Associated Water by adding gypsum or similar products.

11.9.1.2 *Parameters and Selection Criteria*

The most appropriate water treatment infrastructure for QGC's preferred beneficial use options has been determined based on the following selection criteria:

- capable of peak treatment of approximately 150 to 200 ML per day of Associated Water
- targeted water quality of 1,000 mg/L TDS
- high energy efficiency equipment to minimise site power requirements and air emissions
- proven, robust and utilises reliable equipment design
- built in redundancy to achieve high reliability and availability to ensure continuous uninterrupted operation
- modular WTP designs that are easily interchangeable between facilities
- reduction in the variety of maintenance inventory.

Table 3.11.15 Summary of Treatment Technologies for Associated Water

Treatment Technology	Advantage	Disadvantage	Constraints or data requirements
Reverse Osmosis (RO)	Proven technology. Effective removal of bacteria, salts, sugars, proteins, particles, dyes and other constituents that have a molecular weight of greater than 150 – 250 daltons. Minimal post treatment required to produce potable water quality. Multiple technology suppliers facilitating competition in the market.	Significant pre-treatment may be required to prolong membrane efficiency. Potential for fouling and cleaning of membranes. Recovery rate dependant on TDS concentration in the feed water. Waste stream management. A concentrated waste stream requires disposal or further processing to reduce volume. Moderate energy requirements.	Relatively expensive with significant operating and maintenance costs.
Electrodialysis Reversal (EDR)	Requires a lower level of pre-treatment compared to RO and thus lower associated capital costs. Less concern with fouling of membranes. Lower operational cost than RO for TDS < 3000 mg/L.	Typically less cost effective than RO for TDS >3000 mg/L. Higher capital cost of EDR plant than RO. Does not provide removal of constituents other than charged ions. High volume waste stream. A concentrated waste stream requires disposal or further processing to reduce volume.	Relatively expensive with significant operating and maintenance costs.
Flow Through Capacitor (FTC)	Less concern with fouling according to technology providers. Typically requires less pre-treatment. Removes charged ions.	Technology in development phase and requires further verification. Commercial cost is unconfirmed. As for EDR it does not provide removal of constituents other than charged ions.	Effectiveness, capital and operational cost still to be verified. Further development and refining of technology required.
Ion Exchange (IE)	Provides softening of water or removal of salts.	Does not provide removal of constituents other than charged ions. Product water typically requires chemical dosing to adjust SAR due	

Treatment Technology	Advantage	Disadvantage	Constraints or data requirements
	Limited requirements for pre-treatment. Lower volume waste stream than RO.	to preferential removal of divalent ions. Large quantities of regenerating chemicals required. Waste stream, although lower in volume, contains significant higher salt load than RO and EDR.	
Wetland system, forestation etc	Takes up salt and reduces salt content in water. Utilises all Associated Water. Potential carbon credits and carbon sink. Timber resource for local industry. Low operating cost.	Technology still in development and testing phase. Process sensitive to water quality, flow rate and seasonal variations. No redundancy. Potential long term liability. Sensitive to higher salt loads.	Sizing of wetland system largely dependent on plant transpiration rates and plant salt uptake capacity. This still needs to be verified under field conditions and seasonal variations. The long-term effects of salt loads are not known.
Distillation	Provides removal of all constituents except those with similar boiling points to water such as some organics and volatile solvents. Nominal pre-treatment required.	Very energy intensive. High maintenance.	Only cost effective when low-cost energy source is available.
Mechanical Vapour Compression (MVC)	Low waste volume. Small footprint required. Mobile plant. Nominal pre-treatment required.	High maintenance. Labour intensive. Long lead time required.	

11.9.2 *Option Selection*

Due to the relatively short timeframe in which to implement the initial water treatment solution, and the criticality of these plants operating successfully, only well-proven technologies can be contemplated for selection. In later years, with experience gained from the initial treatment plants and more time for trials and development, other emerging technologies can be pursued. It is for these reasons that RO technology will be utilised in the first instance as a means of managing Associated Water treatment.

The RO process is sensitive to the feed water quality. Hence the correct pre-treatment process is essential to promote the membrane lifespan and increase the process efficiency. It is essential to conduct pilot-plant trials over at least three months to ascertain actual field performance of the numerous options for pre-treatment chemicals, processes, membrane types for pre-treatment and the main plant requirements.

The system proposed for treatment of Associated Water and its subsequent waste involves the following processes; pre-treatment, ultra filtration, RO, brine concentration and brine evaporation.

The pre-treatment process will be based on feed water quality and RO pilot studies performed in the past. Ongoing trials are proposed to optimise the pre-treatment system. The pre-treatment system is likely to consist of a settling pond (raw water storage ponds), screen, ultra filtration membranes and the addition of chemicals to reduce the impacts of untreated Associated Water on RO membranes. Ultra filtration (UF) membranes have been widely accepted in the CSG industry as part of the pre-treatment process to protect RO membranes from physical and biological fouling.

QGC will reassess water treatment technologies throughout the life of the Project to ensure the most robust, efficient and proven technologies are being utilised.

It is proposed to incorporate a three-stage RO process to achieve a recovery rate of approximately 90 per cent, leaving approximately 10 per cent brine. The multistage RO process will be followed by brine concentration and evaporation ponds for concentrated brine. The multistage RO is included in the core treatment step, but is often also considered as a brine treatment step in that it significantly reduces the brine disposal volume. To reduce the brine evaporation pond footprint, a brine concentrator will be utilised. Exposed evaporation ponds are recommended to enhance the evaporation rate and reduce the operational period of the brine disposal site.

This desired water quality for irrigation will be achieved by blending desalinated and amended or untreated water. The required capacity of the treatment plants is dependent on the TDS of the feed water and the blend ratio. Because this parameter varies between regions, the treatment plant capability required in each region to achieve the targeted blended water quality will be slightly different. *Table 3.11.16* details the WTP requirements for each of the QGC field areas, assuming treatment technology is utilised to treat water for irrigation.

Table 3.11.16 Water Treatment Plant Capacity Requirements

Region / WTP	Associated Water Peak Production Rate (ML/day)	Water Treatment Plant Capacity (ML/day)	
		Nominal Target 1200 mg/L TDS	Nominal Target 2500 mg/L TDS
NWDA	40	26	20
CDA	61	40	30
SEDA	110	72	55
Total		**138**	**105**

11.9.3 Reverse Osmosis Treatment Process

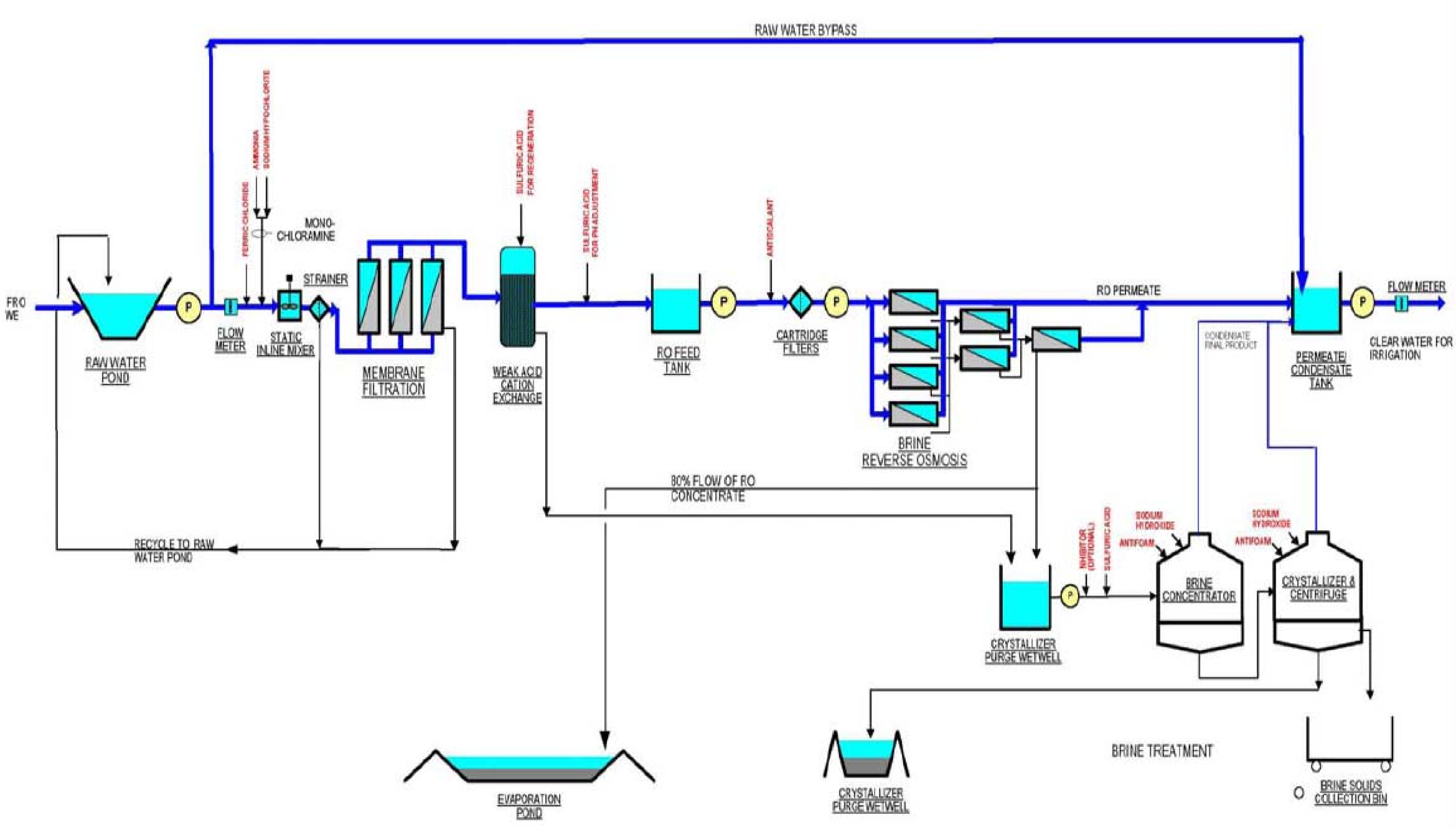
Reverse osmosis (RO) is a proven process for the removal of dissolved solids from brackish or saline feed water. This process uses pressure to ‘‘force’’ water through a semi-permeable membrane, leaving the ions behind. A clean water stream and a concentrated brine solution result. RO is capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, chemical elements and other constituents that have a molecular weight of greater than 150-250 daltons.

RO is particularly effective as it can treat water to the variety of qualities that may be required for various beneficial uses. RO has the ability to produce treated water with a very low TDS concentration. However, greater reduction in TDS comes at an increasing financial cost and lower rates of increase in the recovery ratio. As a general rule the larger the required reduction in TDS the more expensive an RO plant is in terms of capital and operating expenditure. Generally, a recovery ratio of between 50 per cent and 80 per cent can be achieved with a single stage RO plant. Recovery ratios can be increased up to 95 per cent with a multiple stage RO, thereby greatly reducing the waste stream volume. QGC aims to achieve a recovery rate of approximately 90 per cent.

11.9.3.1 Process Description

Figure 3.11.11 shows a water management process flow diagram, with the various preferred treatment technologies.

Figure 3.11.11 CSG Water Treatment Schematic Diagram



Note: Excerpt from the CH2M Hill Document – RO Based Water Plant

11.9.3.2 Chemicals required for Water Treatment Process

Typical chemicals which form part of the treatment process include:

- coagulant, e.g. ferric chloride
- disinfectant, e.g. sodium hypochlorite
- bio fouling inhibitor, e.g. sodium hypochlorite, aqueous ammonia
- pH adjustment, e.g. sulphuric acid, sodium hydroxide
- scale inhibitor.

The chemicals detailed in *Table 3.11.17* are required for pre-treatment of Associated Water. The approximate volume on hand for treatment of 100 ML per day is provided in *Table 3.11.17.*

Table 3.11.17 Pre-treatment Chemicals

Chemical	Function	Volume Required		Volume on Hand (kg)
		WTP 20ML/d In kg/ day	WTP 40ML/d In kg/ day	Based on treating 100ML/day
Ferric Chloride	Coagulant	156	312	23 400
Sodium Hypochlorite	Biofouling and Disinfection	158	315	23 700
Aqueous Ammonia	Biofouling	19	37	2 850
Sulphuric Acid	pH adjustment	2000	3400	300 000
Scale Inhibitor	Scaling control	30	59	4 500
Sodium Hydroxide	pH adjustment	17	33	2 630

Water treatment chemicals will be stored in appropriately designed and bunded storage tanks. Further details regarding dangerous goods, including water treatment chemicals, and mitigation measures for handling and storage of dangerous goods are provided in *Volume 3, Chapter 17*.

11.10 WASTE MANAGEMENT

Associated Water treatment generates a significant volume of saline residue which will require management over the life of the Project. Waste streams will require careful management due to their high concentrations of dissolved salts. The quality and quantity of the waste stream can vary significantly depending on the pre-treatment process and the feed water quality.

11.10.1 Waste Characterisation

Under Schedule 7 of the EP Regulations, Associated Water is classified as a regulated waste. Therefore brine from Associated Water treatment would also be classified as a regulated waste.

Since the concentration of chemical elements in the Associated Water varies between the three regions of the Gas Field, it is probable that the chemical elements of the waste streams will also vary by region.

Indicative brine water quality is presented in *Table 3.11.18*. This data has been derived by concentrating the Associated Water analyte data from the CDA based on a recovery rate of 85 per cent from a reverse osmosis treatment system. In practice the actual recovery rate may be up to 95 per cent. There will also be some chemical addition through the RO treatment system which will affect some of the parameters. Given this and the fact that actual water quality will vary across QGC's tenements, the data presented in the table below is only broadly indicative of the anticipated brine water quality. This data will be refined as the actual quality of brine is tested.

Table 3.11.18 Indicative Brine Water Quality

Analyte	Indicative Brine Water Quality[2]
Aluminium (mg/L)	98.2
Aromatic hydrocarbons	ND
Arsenic (mg/L)	0.094
Barium	ND
Benzene (ug/L)	
Bicarbonate alkalinity (mg/L)	12382
Boron (mg/L)	7.2
Cadmium (mg/L)	0.066
Calcium (mg/L)	34.34
Carbonate alkalinity (mg/L)	1811.9
Chloride – wells (mg/L)	5740.7
Chloride - non wells (mg/L)	6239.4
Cobalt (mg/L)	0.387
Copper (mg/L)	16.7
Fluoride (mg/L)	22
Lead (mg/L)	0.5
Magnesium (mg/L)	28.8
Mercury (mg/L)	0.0060
Nickel (mg/L)	1
Nitrate (mg/L)	0.294
Nitrite (mg/L)	0.087
pH	8.6
Phenol (µg/L)	-

Analyte	Indicative Brine Water Quality[2]
Potassium (mg/L)	81.3
Selenium (mg/L)	0.069
Sodium – wells (mg/L)	7210
Sodium – non well (mg/L)	13172.7
Total Iron (mg/L)	63.3
Sulphate	41.6
Suspended solids (mg/L)	14955.4
Toluene (µg/L)	18.8
Total dissolved salts (mg/L)	23720.7
TDS (excluding Ponds) (mg/L)	20412
TOC (total organic carbon) (mg/L)	8.8
Zinc (mg/L)	9.94

Typically, brine contains TDS of 20,000 to 30,000 mg/L.

Assuming treatment technology is utilised to treat water for irrigation, at peak Associated Water production, approximately 10 ML per day of brine will be produced. Over the life of the Project approximately 65,000 ML of brine will be produced.

11.10.2 Waste Minimisation

Volumes of brine waste can be reduced by a combination of the following strategies:

- Maximise beneficial use of untreated Associated Water. This will reduce the volume of water to be treated and therefore the volume of brine and salt which requires disposal. Untreated Associated Water will only be delivered to users who have a salt management strategy for their existing operations
- Minimise production of brine from the water treatment facility. The water treatment process can be designed to maximise the percentage of Associated Water which is converted to clean product water, and therefore reduce the quantity of brine produced. However, the quantity of salt produced will remain the same
- Concentrate brine into a crystallised salt. This reduces the quantity of waste product to approximately 10 to 15 per cent of the original brine volume by converting brine to a solid product (salt) and removing the majority of the water. However, the quantity of salt produced will remain the same

QGC will adopt a combination of the above strategies to minimise brine production.

11.10.3 *Waste Recycling/Use Opportunities*

QGC is currently pursuing opportunities for a third party to establish a processing plant to convert brine into commercial salt products, such as soda ash. If this proceeds, the processing plant could be co-located with QGC's water treatment plants or located on another site with brine delivered via a pipeline.

11.10.4 *Waste Treatment Options*

There are a number of options available for treatment of brine. All options are targeted toward separating the water from the dissolved solids so that the volume of waste is reduced and a solid waste is produced. As the volume of the solid waste is substantially less than the original brine volume, disposal may be easier. QGC has undertaken a comparative assessment of potential brine treatment systems to determine the optimal process for inclusion in its water management strategy. A summary of the outcomes of that assessment is provided in the *Table 3.11.19*.

Several other technologies such as Wind Aided Intensified eVaporation (WAIV), DewVaporation and Freeze Desalination are being developed which promise some advantages and efficiencies over currently available technologies and which may be available in the future. There is potential to partially treat brine using a constructed wetland system. This wetland would comprise flora species that grow in highly saline waters and which take up salt. Wetland species could then be harvested. However at this time, these methods are either still experimental or have not been proven at a commercial scale. QGC therefore will not utilise these processes for the initial stages of its water treatment facilities, but will continue to monitor their development.

Based on the assessment, the preferred brine treatment process is brine concentration followed by evaporation in multi-cell solar evaporation ponds. Brine concentration is a well established, reliable and well understood process.

Brine concentration is a relatively simple process which involves evaporating water from the brine in a heated tank. This process produces highly saline slurry with typical TDS of 100,000-150,000 mg/L.

Energy consumption for brine concentration increases as the salinity of the water increases, making brine concentration progressively more expensive at higher salt concentrations. It is likely that solar evaporation will be utilised to complete the salt crystallisation process. The brine slurry will be evaporated in specially constructed ponds, resulting in a solid crystallised salt. Over the life of the Project approximately 6,500 ML of concentrated brine (10 per cent of total produced brine) or 4,500,000 tonnes of salt will be produced.

Table 3.11.19 Summary of Brine Treatment Options

Treatment Technology	Advantages	Disadvantages	Conclusion
Evaporation ponds and solar ponds	Low operational cost. Uncomplicated, proven process. Viable option in dry climates with high net evaporation rate.	Requires large area. Very dependent on evaporation rate. Not viable in areas with a low or negative net evaporation rate.	Solar evaporation is a viable final treatment step.
Wind Aided Intensified eVaporation	Increased evaporation rate. Less dependent on the net evaporation rate and may possibly be applied in areas with a low net evaporation rate. Low operational cost. Reduced pond area requirement.	Not commercially available. Further verification required. Highly dependent on sufficient wind (regular saturated air displacement is important).	Not currently viable. Monitor for use in future treatment system expansions.
DewVaporation	Recovery of high quality water. Significantly reduced brine stream. Reduced pond area requirement for final concentrated brine disposal.	Requires energy input. Only viable if low cost or waste heat is available. Commercially available only in small-scale units. Further verification on site specific water quality required.	Not currently viable. Monitor for use in future treatment system expansions.
Freeze desalination	Small footprint required. Significantly reduced brine stream. Reduced pond area requirement for final concentrated brine disposal.	Technology only proven for production of ice from seawater and on small scale. Further testing required. Unknown operational costs when used for brine concentration.	Not currently viable. Monitor for use in future treatment system expansions.
Deep well reinjection	Reduces or eliminates the need for surface storage.	High capital and operational cost. Aquifer quality and interaction testing and modelling required.	Viable, but unproven strategy. Monitor for use in future treatment system expansions.
Brine Concentrators	Concentration of brine independent of climate. High recovery rate.	High capital and operational cost. Energy intensive.	Adopt as first stage brine treatment step.
Crystallisers	Concentration of brine to crystal slurry and dewatering of the crystals independent of climate.	High capital and operational cost Extremely energy intensive.	Viable but energy intensive and expensive. Possible alternative strategy.
Compact Evaporation Desalination	Produces crystallised salt. Not sensitive to feed water quality. Minimal maintenance required. Waste heat can increase economical viability of process.	High power consumption. Very new technology. Single source provider. Requires high capital investment for development units.	Viable but energy intensive and expensive. Possible alternative strategy.
Dynamic Vapour Recompression	Low energy consumption. Modular units allowing small and large scale installations. High recovery rate, 99%.	Technology not commercialised. Overseas supplier.	Not currently viable. Monitor for use in future treatment system expansions.
Multi Stage Desalination	Increased recovery rate. Reduced brine stream. Reduced surface storage area requirement. Proven technology. Can be implemented in stages.	Increased capital and operational cost. Additional pre-treatment will be required for additional stages.	Viable but energy intensive. Possible alternative strategy.

The solar evaporation process will require construction of multi-cell evaporation basins. These are open-top earth ring dams which will be double lined with HDPE to prevent seepage. Each cell would be partially filled with concentrated brine and left to evaporate over time. Performance of the system may be improved by pumping brine between cells. Because the evaporation basins are open, they will collect rainwater. The design of the basins will account for this by providing capacity within each cell for rainwater to be stored and evaporated over time. When the water has been evaporated, the remaining solid salt product will be removed and deposited in an engineered landfill.

A landfill site for the purposes of salt storage will be selected on the basis of having all, or the majority of, the following characteristics:

- a deep natural groundwater table that will minimise the risk of groundwater interfering with the integrity of the landfill sealing liner and the associated risk of salt leaching from the landfill into groundwater
- suitable clay materials for sealing the landfill will be present onsite. These clays would ideally cover the landfill site to a depth at least 500 mm below the finished floor level
- the landfill will not be located on a surface watercourse or intersect a buried streambed
- topography will be conducive to construction with minimum earthworks
- the site will have stable geology and landscape morphology
- the landfill will not be located on good quality agricultural land and will be accessible via all-weather roads
- the landfill will be located as close as possible to the water treatment facilities.

The landfill will be constructed as a waste management facility and be engineered to applicable Australian and DERM standards.

Nominally, the design would consist of an excavation which would be sealed with a combination of double-layered liners (such as a clay liner and a plastic liner). The landfill would be filled in segments. Once each segment is full, it would be capped with a double sealing system similar to the excavation base.

The cell-system of segmenting the landfill ensures that if a breach develops in any one of the cells, it will not compromise the integrity of the entire landfill. It also simplifies the process of identifying the location of the problem and simplifies the repairs.

QGC will install and maintain appropriate monitoring systems at the landfill site such as groundwater sampling bores. This information will provide early indications of any leak developing from the landfill site.

Landfills will be recorded on the Contaminated Land Register as necessary.

11.10.4.1 Treatment Chemicals

The feedwater to the brine concentrator may need to be seeded with calcium sulphate crystals to achieve the desired performance. Due to the alkalinity of the brine, it may also be necessary to dose the water feeding the brine concentrator with sulphuric acid.

Chemical handling facilities for acid and calcium sulphate are therefore likely to be required and will be designed and operated in accordance with relevant standards. Further details about water treatment chemicals are provided in *Section 11.9.3.2*.

11.10.5 Waste Disposal Options

The quality and quantity of the waste stream can vary significantly depending on the pre-treatment process and on the feed water quality.

This waste stream can be disposed of by:

- pumping to ocean outfall
- reinjection to deep sub-surface aquifers
- brine treatment and disposal to landfill.

Ocean discharge and reinjection have been rejected as feasible options for the following reasons:

- brine water quality is likely to be worse quality than ocean water or subsurface aquifers. Environmental impacts are unknown, but are potentially high
- the cost may be very high, particularly in the case of ocean outfall
- there are likely to be long lead times for obtaining approvals and constructing the required infrastructure
- technologies are unconfirmed, particularly in the case of the reinjection to deep subsurface aquifers.

As a result, QGC intends to treat the brine and dispose of the solid salt waste in purpose-built engineered landfills. It is likely that two salt landfill sites will be required. These would nominally be located at the WTP in the CDA and the WTP in the SEDA.

11.11 IMPACT ASSESSMENT

As a final set of options has not been decided for water management, the potential impacts of beneficial use options have not been fully assessed.

In some cases, potential treatment systems and beneficial uses need testing to verify their long-term viability. In other cases, trials are required to confirm the design parameters for the long-term development of the water management system.

QGC's intention is to construct and operate water management systems for treatment and beneficial uses throughout the life of the Project. In the early stages of the Project this will involve utilising well-established, reliable methods which can be installed in the timeframes required and with low risk to the environment.

In the long term QGC will take advantage of treatment and beneficial use systems which may have advantages such as reduced energy consumption, reduced emissions, reduced waste streams and lower costs. Many of these technologies and methods are not sufficiently matured to provide a reliable outcome during the early implementation phase (pre 2014) of the Project. However, in the future they may become viable options. QGC will investigate these alternatives and where possible will undertake trials to verify their feasibility.

Table 3.11.20 shows, for environmental and social values, whether an impact is expected on that value and whether a technical study of impacts is required.

11.11.1 Investigations of Impacts

QGC is currently focusing its investigations and trials on QGC-owned and operated land. Studies undertaken to date have investigated options for using untreated and treated water for applications on QGC-owned land.

QGC has commissioned an investigation of the feasibility and impacts of reinjection. Investigations in the second quarter of 2009 have confirmed that reinjection options will proceed to trials. Investigations of the receiving aquifers will need to be performed before this option is considered viable.

RO technology will be tested using smaller (1 - 3 ML per day) RO plants at well exploration sites.

The feasibility of using wetlands is being tested under laboratory conditions. Depending on research outcomes, this trial may move to field testing.

The details of trials now being proposed and implemented can be found in *Table 3.11.21.*

Table 3.11.20 Impacts of Associated Water Management

Analysis of Potential Impacts from Beneficial Use Options — Value Impacted	Soil Character, Fertility & Productivity	Land Contamination	Waste Management	Surface Water quality and hydrology	Shallow Aquifer Water Quality	Groundwater Quality and Hydrodynamics	Airshed	Visual Amenity	Noise	Biodiversity	Land use	Disruption to communities	Infrastructure benefits	Access to Water	Community Expectations
Beneficial Use Option															
QGC Petroleum Activities	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red
Stock and Domestic Purposes	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Orange
Tree Cropping	Red	Red	Red	Red	Yellow	Green	Yellow	Yellow	Yellow	Green	Red	Yellow	Green	Green	Yellow
Cropping	Red	Red	Red	Red	Yellow	Green	Green	Green	Yellow	Green	Yellow	Green	Orange	Green	Red
Wetlands	Red	Yellow	Red	Red	Red	Green	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Red
Supply to Mines	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Council Supply	Green	Yellow	Red	Green	Green	Green	Green	Green	Yellow	Green	Green	Orange	Orange	Orange	Orange
Supply to Industry	Green	Yellow	Red	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green
Reinjection	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Green	Yellow	Green	Green	Green	Green	Orange	Green
Coastal Discharge	Green	Green	Red	Red (*Note1*)	Green	Green	Yellow	Green	Yellow	Red	Green	Green	Green	Green	Red
Surface Water Discharge	Green	Yellow	Red	Red	Yellow	Green	Green	Green	Yellow	Red	Green	Yellow	Yellow	Orange	Green
Evaporation Ponds	Yellow	Red	Red	Yellow	Yellow	Green	Green	Yellow	Green	Green	Yellow	Green	Green	Red	Red

Note 1: Applies to impacts on coastal waters

Key to potential impacts and studies required:

- Red: Impact expected, technical study required
- Yellow: Impact unknown, technical investigation required
- Green: No impact expected, technical study not required
- Orange: Positive impact

Table 3.11.21 Investigations and Trials for Beneficial Use of Associated Water

Trial name	Description	Aim	Implementation Plan
Woodlot and pasture cropping trials	Irrigate a large trial plot with blended water. Different blend ratios will be used in different areas. The trial will extend across a broad range of soil types.	Establish irrigation area design parameters for irrigation with various qualities of blended water on various soil types.	Develop a large trial woodlot and pasture plot in the CDA in 2009.
Wetland treatment system trial	Develop a wetland treatment system including specialised wetland plants.	Establish the quality of the final water product produced by the wetland and how this is affected by variable inflow water quality and different detention times. Establish design parameters.	Develop a small-scale trial wetland treatment system in the CDA Region in 2009/10.
Amended CSG water irrigation trial	Irrigate small woodlot and crop trial plot with water which has been amended only by acid and gypsum to reduce its SAR.	Establish whether irrigation with amended Associated Water is sustainable.	Undertake a small-scale trial in the CDA in 2009.
Treatment Systems	Establish pilot plants and undertake laboratory testing for likely treatment processes. Expected to use RO systems in the short term, but others are also possible.	Verify the treatment system design parameters and process requirements.	Establish pilot plant trials for shortlisted treatment systems

Trials may be constrained for the following reasons:

- there may be difficulty in finding sufficient land suitable for irrigation and locating of water treatment facilities
- low quality water (TDS > 1200 mg/l and SAR >6) has disadvantages for use in irrigation as it may have detrimental impacts on soil
- based on existing forecasts, QGC will need to manage approximately 40 ML per day by August 2010. Trials need to demonstrate feasibility for use of large volumes of water in a short timeframe.

Tree crop trials will include a selection of species to assist in maintaining the biodiversity of the region. Perennial plantings may be preferable to annuals as soils disturbance is minimised.

11.11.2 Preliminary Impact Assessment

This section briefly discusses the potential impacts that management and beneficial use of Associated Water have on environmental and social values. Detailed impact studies have not currently been conducted as the final options for beneficial use have not been decided. A high level overview of potential impacts and mitigation measures in presented below. The following environmental values may be impacted:

- soil character, fertility and productivity
- land contamination
- waste disposal
- surface water hydrology
- shallow aquifer water quality
- groundwater quality and hydrodynamics
- air quality
- visual amenity
- noise levels
- biodiversity

The following social values may be impacted:

- land use
- disruption to communities
- social benefits and values, including access to water.

11.11.2.1 Soil Character / Land Contamination

Beneficial use options involving dispersal of untreated or amended Associated Water to land surfaces may result in increased salinity and SAR of soils. The use of treated water for irrigation and surface water discharge is likely to mitigate this impact. Ponds used for storage of untreated water are likely to accumulate salts over their life. Decommissioning and rehabilitation of storage ponds will require appropriate management of contaminated soils.

The release of water treatment chemicals has the potential to contaminate land. Appropriate storage techniques will be employed to minimise this risk.

11.11.2.2 Waste Disposal

Waste, in the form of saline brine or highly saline concentrated brine has the potential to impact on the environment should it be poorly managed. Waste management systems will be designed to minimise the risk of environmental harm from the release of brine and accumulation of salt.

11.11.2.3 Surface Water Hydrology

Discharge of treated water to watercourses may have a significant impact on surface water hydrology. Potential impacts would be mitigated through treatment of Associated Water prior to release and regulation of water flows to mimic natural variations.

Establishment of a wetland is likely to have a significant impact on surface water hydrology. The magnitude of the impact will depend on the location of the wetland and the salinity of the water.

11.11.2.4 Shallow Aquifer Water Quality

Water from irrigation, evaporation ponds or wetlands may infiltrate shallow aquifers. Investigations and monitoring would be required to determine if impacts on shallow aquifers from these beneficial uses is significant. Appropriate management methods would seek to mitigate possible impacts.

11.11.2.5 Groundwater Quality and Hydrodynamics

Reinjection of untreated Associated Water may have a significant impact on the quality of water in the aquifer into which it is injected. If aquifer water quality is better then Associated Water quality, Associated Water can be treated prior to reinjection. The impact of reinjection on groundwater hydrodynamics and hydrogeochemistry is unknown.

11.11.2.6 Air quality

Vehicle emissions and dust generated by vehicles traversing the site are the only sources of air quality pollution expected during the construction phase.

Power requirements for Associated Water infrastructure may result in emissions of air pollutants. Preliminary estimates indicate that these emissions will be minor in comparison to emissions from compressors. As per *Volume 3, Chapter 12*, emissions from compressors are not expected to exceed air quality guidelines.

At peak water production, greenhouse gas emissions from water treatment facilities are expected to be approximately 97,000 tonnes per annum, which is approximately 6 per cent of greenhouse gas emission from other Gas Field infrastructure. These emissions may be offset by sequestration of carbon in tree plantations.

No odour generation is expected when using water treatment infrastructure.

11.11.2.7 Visual Amenity

Visual impacts are expected to be low during the construction phase. As discussed in *Volume 3, Chapter 15*, the visual impact of infrastructure is likely to be minor and suitable mitigation measures can be implemented to reduce impacts. Water management infrastructure including water storage ponds, brine solar evaporation ponds, salt disposal facilities and water treatment facilities is likely to have a lesser visual impact than water treatment infrastructure.

11.11.2.8 Noise Levels

Temporary noise impacts may be experienced during the construction phase due to the movement of heavy machinery and vehicle traffic.

The sound power levels of water treatment infrastructure are expected to be significantly lower than the noise levels of compressors, and hence are unlikely to contribute to cumulative noise impacts from the Gas Field. Further noise studies will be conducted to determine the impacts on sensitive receptors within the vicinity of water treatment infrastructure, and any mitigation measures required.

11.11.2.9 Biodiversity

Depending on the species cultivated for tree cropping, there may be benefits to biodiversity from habitat creation. Surface water discharge may impact on biodiversity along watercourses. This impact may be positive or negative and investigations and monitoring would be required to determine possible impacts.

The direct footprint of water infrastructure will be approximately 25 ha for water treatment infrastructure and approximately 400 ha for water storage facilities and waste disposal facilities. The impact of this footprint area will depend on the existing condition of biodiversity at the locations selected for infrastructure. Locations will, as far as reasonably practical, be sited to minimise impacts on biodiversity.

11.11.2.10 Land Use

Landholder agreements will be established before any water management activities occur on another party's land. Pond and waste disposal infrastructure will, in the majority of instances, be located on QGC-owned land.

11.11.2.11 Disruption to Communities

Negative impacts during construction and operation will be felt mainly as disturbance to traffic, noise pollution, safety and security issues and visual impact. Positive impacts may be generated through employment, and local capital investment.

11.11.2.12 Community Expectations

Local communities have high expectations about access to, and benefits from, Associated Water. They have also expressed concerns over the potential impacts associated with the uptake and release of water during the extraction of CSG (refer to *Volume 8*). The potential benefits and impacts on social values will depend on the beneficial use option selected and the water treatment strategy underpinning that option.

The following is a summary of some of the potential social issues:

- There may be a perceived or actual impact on bore water levels resulting from Associated Water production. QGC will be required to compensate bore owners for the loss of the water and possibly the livelihood impacts resulting from drawdown of bores. Alternatively, QGC may supplement bores through reinjection of treated Associated Water to local aquifers.
- Options involving irrigation may create a perception that QGC is competing for good quality agricultural land. QGC is unlikely to select crops that are normally grown within the region and is seeking to conduct irrigation on land that is not classified as GQAL.
- Brine and salt will be managed to minimise the area of land that will potentially be sterilised.
- QGC will have access to a ready supply of water at all times, including during periods of drought. Pending agreement with landholders and regulators, water may be made available to local landholders and townships during droughts.

These issues will be addressed as part of the Associated Water Social Impact Assessment and the outcomes included in a detailed community relations plan that will be developed by QGC for the whole of the QCLNG Project.

11.12 CONCLUSION

QGC will produce large volumes of saline Associated Water as part of the Gas Field Component of the Queensland Curtis LNG (QCLNG) Project. The application of this Associated Water presents both opportunities and potential impacts for environmental and social values.

There are a number of potential options for beneficial use of Associated Water. Selection of the optimal combination of beneficial uses will depend on environmental, social, economic, technical, commercial and regulatory aspects. Based on the options analysis presented above, the preferred option for the short term is evaporation ponds and for the long term, irrigation of tree crops and injection (subject to trials). Both short- and long-term options will be supplemented by supply to industry and QGC petroleum activities.

Each beneficial use option will require different levels of water quality, which creates a need for alternative technologies for water treatment. Water treatment results in the creation of brine waste, which will be managed to minimise impacts on land. The preferred treatment option is desalination complemented by brine concentration, with concentrated brine waste disposed of in specially constructed landfills.

QGC will undertake further detailed investigations of Associated Water management options. Investigations will focus on determining the likely impact of beneficial use options on environmental and social values.

It is recognised that preferred options for Associated Water management may change over the life of the QCLNG Project. The water management strategy will guide the formulation of an Associated Water management plan. QGC will revise the water management plan to optimise the management of Associated Water over time. A summary of the impacts outlined in this chapter is provided in *Table 3.11.22* below.

Table 3.11.22 Summary of Impacts for Associated Water

Impact assessment criteria	**Assessment outcome**
Impact assessment	Negative, potential positive
Impact type	Direct
Impact duration	Long term
Impact extent	Local
Impact likelihood	High

Overall assessment of impact significance: moderate.