Santos
GLNG Project

October 2013

Santos GLNG Project

CSG Water Monitoring and Management Plan

Summary Plan – Stage 2 Revision 2

GLNG is a Santos PETRONAS Total KOGAS project.

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Abbreviations

CSG	Coal Seam Gas
CWMMP	Stage 1 and Stage 2 CSG Water Monitoring and Management Plans
CWMP	CSG Water Management Plans
DEHP	Department of Environment and Heritage Protection (was DERM)
EA	Environmental Authority
EMPI	Environmental Monitoring Plan
EMRS	Environmental Monitoring and Reporting Strategy
EPBC	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
GAB	Great Artesian Basin
GLNG	Gladstone Liquefied Natural Gas
JIP	Joint Industry Plan for the Management and Monitoring of EPBC Springs
LNG	Liquefied Natural Gas
RO	Reverse Osmosis
SEWPaC	Former Commonwealth Department of Sustainability, Environment, Water, Population and Communities, now the Department of the Environment
QWC	Queensland Water Commission (now Office of Groundwater Impact Assessment)

1 Introduction

1.1 Overview

1.1.1 Santos Gladstone Liquefied Natural Gas (GLNG) is a project that will convert coal seam gas (CSG) to liquefied natural gas (LNG) for export to global markets. In May 2010, the Queensland Coordinator-General approved the project under the State Development and Public Works Organisation Act 1971. In October 2010, the Minister of Sustainability, Environment, Water, Population and Communities (SEWPaC) (now the Department of the Environment) granted approval under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) (EPBC), with various conditions, in particular:

- Condition 49 requires the submission and approval of a Stage 1 Coal Seam Gas Water Monitoring and Management Plan within 6 months of project approval; and
- Condition 52 requires the submission and approval of a Stage 2 Coal Seam Gas Water Monitoring and Management Plan within 18 months of project approval.

Condition 49: Within 6 months from the date of the project approval, the proponent must submit for the approval of the Minister a Stage 1 Coal Seam Gas Water Monitoring and Management Plan (Stage 1 CSG WMMP).

Condition 52: Within 18 months from the date of the approval of the action the proponent must submit for the approval of the Minister, a Stage 2 Coal Seam Gas Water Monitoring and Management Plan (Stage 2 CSG WMMP).

1.1.2 Santos GLNG has prepared both Stage 1 and Stage 2 CWMMPs (CWMMP) within the specified timeframes to meet the requirements of these conditions. This document provides a clear and succinct overview of Santos GLNG's response to these conditions and technical comments from the Expert Panel[1] for major CSG projects on the Stage 1 and Stage 2 CWMMP's.

1.1.3 Santos GLNG has reviewed and aligned the CWMMP Stage 2 (revision 2) in response to further comments from the Expert Panel. These comments were informed by technical review and input from Geoscience Australia, University of New South Wales (Water Research Laboratory), SEWPaC (Office of Water Science), and Environmental Research Institute of the Supervising Scientist. The CWMMP Stage 2 (revision 2) also includes further commitments, detailed in Annex C, which include:

- Aquifer Connectivity Investigations;
- Hydraulic Fracturing Direct Toxicity Assessment (participation in joint industry work); and
- Joint Industry Plan for an early warning system for the monitoring and protection of EPBC springs.

1.1.4 It demonstrates that when the cumulative impacts of the GLNG Project and other approved CSG to LNG proposals are taken into account, the potential for impacts to Matters of National Environmental Significance is low. With appropriate mitigation measures in place, the GLNG Project can be developed and operated in a sustainable manner.

Annex A outlines the EPBC approval conditions 49, 52 and 53 and the location of responses within this Summary Plan, by referencing a page and paragraph number. Margin references within the document also identify where specific conditions are addressed.

1.1.5 **What is the purpose of the CWMMP?** It describes the water that will be produced from coal seams, how it will be used, what the impacts are expected to be, and how the impacts will be monitored and managed.

1.1.6 **When does the CWMMP apply?** The CWMMP covers the proposed management activities from the submission of the CWMMP in 2013 to the first LNG cargo scheduled for 2015. Specific detail on the program of work over this period, including water related infrastructure and associated monitoring, is set out in Annex B.

1.1.7 **What area is covered by the CWMMP?** The CWMMP covers three GLNG CSG fields that are proposed to be developed to varying degrees during this period: Roma, Fairview and Arcadia Valley.

[1] The Expert Panel provides expert hydrological and hydrogeological advice to the Minister and the Department of Sustainability, Environment, Water, Population and Communities (now Department of the Environment) for major coal seam gas proposals which are approved, or which require a decision on approval, under the ***Environment Protection and Biodiversity Conservation Act 1999***.

1.1.8 **What does the CWMMP demonstrate?**

- **Great Artesian Basin impacts minimised:** Groundwater flow modelling of the cumulative impact of CSG operations across the Surat Cumulative Management Area has been undertaken by the Queensland Water Commission (now Office of Groundwater Impact Assessment), with results reported in the Underground Water Impact Report[2]. This report finds that at five spring complexes, including 3 EPBC listed spring complexes, the decline in water levels as a result of cumulative CSG operations within the source aquifer is predicted to be more than 0.2 metres at the location of the spring, and therefore potentially requiring development of mitigation measures. Of these three EPBC listed complexes, two are on Santos GLNG's tenements: Lucky Last and Yebna 2 complexes.

  Santos GLNG will develop a Spring Impact Mitigation Strategy for those two springs, which will prevent any impact occurring to Matters of National Environmental Significance. Santos GLNG has identified the potential management/ mitigation options suitable to each of those two springs. These options will be studied in further detail, should impact propagation be observed. The management/ mitigation options will be implemented if impact to Matters of National Environmental Significance are confirmed. Mitigating controls, where necessary, might include managed aquifer recharge by injection of treated coal seam water to source aquifers, or virtual injection.

- **Environmental impacts minimised:** Santos GLNG has identified relevant Environmental Values and developed a comprehensive risk-based environmental monitoring program and rigorous management protocols to ensure that environmental impacts are minimised and any residual risks are managed to acceptable levels.

- **Many water reuse options:** Santos GLNG's portfolio of water reuse options encompasses beneficial uses including new water resources for rural communities and agricultural industries, as well as aquifer injection schemes, where feasible.

- **Hydraulic fracturing is safe:** Santos GLNG considers that hydraulic fracturing can be conducted safely and without adverse impact to human health or the environment. The process has been used safely for more than 60 years in the oil and gas industry.

- **Salt management aligns with policy:** Santos GLNG will manage salty water (referred to as brine, a by-product of water treatment) in accordance with the Queensland State Government policy for managing water extracted from coal seams and the conditions imposed under the EPBC approval relating to salt management.

- **EPBC Springs early warning system:** A collaborative joint monitoring plan (JIP) has been developed for the monitoring and management of impact to EPBC springs which provides a single approach for monitoring and management across the Proponents. Monitoring of impact propagation to EPBC springs and management of impact would be necessary as defined in the Joint Industry Plan for the Management and Monitoring of EPBC springs (JIP). A nominated network of monitoring bores will provide early warnings of propagation of impact through the EPBC springs source aquifers. Escalating levels of triggers and associated responses allow for the prevention of impact occurring to those springs.

1.1.9 **Santos GLNG's commitment:** Santos GLNG will carefully and sustainably manage the water extracted from coal seams, address potential impacts on soil and regional water resources, and develop long term solutions that benefit local communities and the environment. Santos GLNG commitments are included in Annex C.

1.1.10 **Future updates to the CWMMP:** Santos GLNG will update and resubmit the CWMMP three months before the start of any major stage of gas field development.

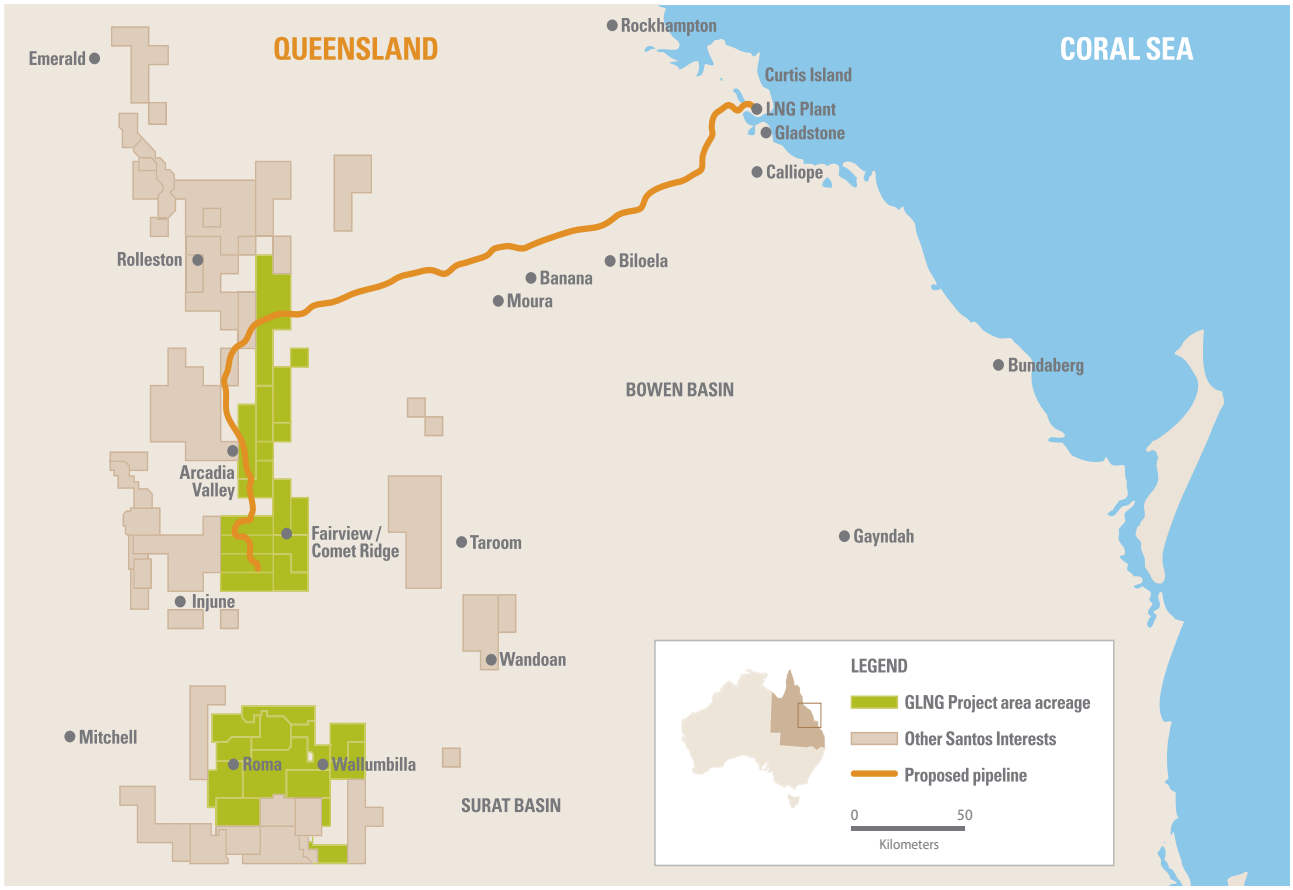
[2] *Queensland Water Commission, Underground Water Impact Report Surat Cumulative Management Area, December 2012.*

1.2 Project Description

1.2.1 GLNG is located in south east Queensland (Figure 1.1) and encompasses three major components:

- CSG fields in Roma, Fairview and Arcadia Valley;
- A 420 kilometre underground gas pipeline to transport the gas to Curtis Island, near Gladstone; and
- An LNG facility on Curtis Island, plus associated infrastructure.

Figure 1.1 Location and Components of GLNG



Fast Facts – Coal Seam Gas Development

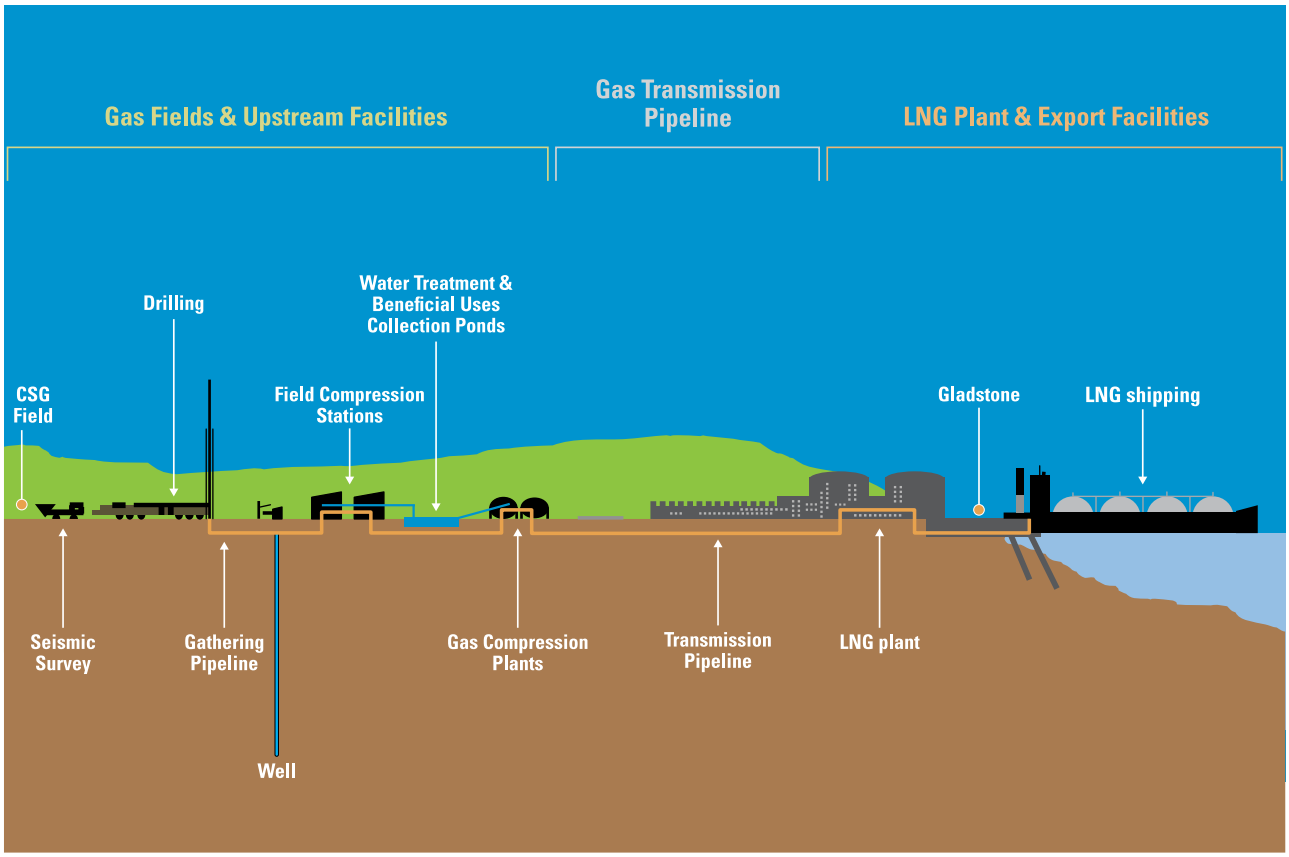
- Coal seam gas development involves drilling wells into underground coal seams to extract gas.
- Water is pumped out of the coal seams to reduce the pressure in the seam. This allows gas to flow through the well to the surface.
- The CWMMP explains how Santos GLNG will manage and use the produced water and address any associated environmental impacts.

1.2.2 The multibillion dollar Santos GLNG Project is a joint venture between: Santos Limited, Australia's largest domestic gas producer; PETRONAS, Malaysia's national oil and gas company and the second largest LNG producer in the world; French company Total, the world's fifth largest publicly traded integrated international oil and gas company; and KOGAS, the world's largest buyer of LNG. Santos is developing and operating the CSG fields on behalf of the joint venture.

1.2.3 GLNG will convert the CSG to LNG and prepare it for export, as illustrated in Figure 1.2. LNG is CSG that has been liquefied by cooling it to -161°C. This process significantly reduces the volume for shipping to overseas markets. The first cargoes of LNG for Santos GLNG are scheduled for 2015.

1.2.4 Santos GLNG is developing CSG fields in Roma, Fairview and Arcadia Valley to supply the LNG facility with natural gas. This involves drilling wells, constructing gathering systems and treatment facilities for the gas and water extracted from coal seams, and building gas processing facilities. The infrastructure will be placed and operated to minimise water treatment impacts on the environment (including Matters of Environmental Significance), landholders and the community.

Figure 1.2 The CSG to LNG Process



1.2.5 Developing a CSG reserve involves three phases:

- Exploration: This confirms the location, extent, thickness and quality of coal seams and the presence of gas (no water is extracted from coal seams);
- Appraisal: This assesses the gas potential of coal seams (and includes water production and gas flaring); and
- Production: This is undertaken once a gas resource is proven viable. This phase involves constructing gas and water pipeline gathering networks, gas processing facilities and water management and treatment infrastructure.

1.2.6 Different parts of a CSG field may be at different phases of CSG development at any one time. Over the period of the CWMMP (2013 until first LNG cargo in 2015) the Roma and Fairview fields will be in the production phase, and Arcadia Valley in the appraisal phase. Roma will also undergo some additional appraisal in currently undeveloped areas of the field, as shown in Table 1.1.

Table 1.1 Stages of CSG Field Development at GLNG

Field	Appraisal Commencement	Production Commencement	Existing Production (years)
Roma	Commenced	2014	0
Fairview	Commenced	Commenced	15
Arcadia Valley	Commenced	2017	0

1.2.7 Water is produced as part of the gas extraction process. Managing this water and its potential impacts on the environment is a key aspect of the GLNG Project. The CWMMP addresses all of the management activities associated with extracting water from coal seams for GLNG. This includes hydraulic fracturing of coal seams, the production, storage, transfer and treatment of the water extracted from coal seams, reuse of the water, and brine management, from 2013 to the first LNG cargo in 2015.

1.2.8 The CWMMP was developed in line with relevant legislation and explains how Santos GLNG proposes to meet all of the EPBC approval conditions, principally addressing:

- **Hydraulic fracturing:** Santos GLNG has conducted a detailed risk assessment of its hydraulic fracturing processes, which indicates that it can be conducted safely and without adverse impact on the environment. The process of hydraulic fracturing is engineered to be confined within the coal seams to ensure there is no impact on aquifers or spread of fluid to other geological formations.
- **Groundwater:** Santos GLNG will ensure that there are no unacceptable impacts from extracting water and gas from coal seams on other groundwater and associated environmental values.
- **Surface water:** Santos GLNG monitors surface water across GLNG and has appropriate response mechanisms in place to manage risks.
- **Storage, treatment and salinity:** Santos GLNG has appropriate plans in place to store and treat the water extracted from coal seams and manage the production of brine. These plans ensure the associated risks are managed.
- **Reuse of water from coal seams:** Santos GLNG has a range of programs in place to investigate how the water extracted from coal seams can be used beneficially, including the reinjection into drinking water aquifers. All of these programs focus on managing potential impacts, including any planned and authorised discharges.
- **Environmental protection:** Santos GLNG has set appropriate drawdown limits to protect Matters of National Environmental Significance related to GLNG. A comprehensive monitoring and management regime is in place and will be developed in accordance with the recommendations of the Surat Cumulative Management Area Underground Water Impact Report.
- **EPBC Springs:** Santos GLNG, together with QGC and Origin, has developed a joint regional approach for the management of EPBC springs. This approach defines the monitoring and management of impact to EPBC springs and ensures that any drawdown potentially propagating to an EPBC spring does not result in an impact to the spring.

1.2.9 Annex D provides a full list of supporting documents referenced in this Summary Plan.

[3] *URS, GLNG Project Environmental Impact Statement, 2009*

[4] *Coordinator - General's Evaluation Report for an Environmental Impact Statement, GLNG Project,* May 2010

Condition 49 (g) (xii) and Condition 53 (c) (vii) References to standards and relevant policies and guidelines.

1.3 Approvals

1.3.1 GLNG is subject to regulation and approval by the Queensland and Australian Governments. Table 1.2 provides an overview of relevant authorities and legislation relating to water, and details the status of approvals.

1.3.2 The Queensland Government declared the Santos GLNG Project to be a Significant Project under the State Development and Public Works Organisation Act 1971. As a result, Santos GLNG was required to produce an Environmental Impact Statement[3] and Supplementary Environmental Impact Statement, which were assessed by the Queensland Coordinator-General. In May 2010, the Coordinator-General approved the Santos GLNG Project subject to a number of conditions. The Coordinator-General's assessment and conditions of approval are described in the Evaluation Report[4].

1.3.3 In addition to this approval, Santos GLNG was required to obtain Environmental Authorities for each component of GLNG under the Environmental Protection Act 1994 (State), including the CSG fields.

1.3.4 The Australian Government referred GLNG for assessment under the EPBC Act. In October 2010, The Minister for Sustainability, Environment, Water, Population and Communities (now the Department of the Environment) granted approval to the project and imposed conditions to protect specific Matters of National Environmental Significance.

1.3.5 Through the approved GLNG Environmental Impact Statement and the Supplementary Environmental Impact Statement, Santos GLNG provided detailed information on the production and management of water extracted from coal seams in relation to Matters of National Environmental Significance. Subsequent technical reports satisfied the requirements of the EPBC conditions.

1.3.6 Annex A contains detailed information about the requirements of the conditions relating to the CWMMP.

Table 1.2 Overview and Status of State and Commonwealth Approvals

	Regulator	What is Regulated	How is it regulated	Outcomes / Plans	Fairview	Roma	Arcadia Valley
State	Department of Environment and Heritage Protection	Beneficial Uses Waste Management Management of impacts on the underground water	Beneficial Use Guidelines CSG Water Management Policy 2012 Environmental Protection Act 1994 Water Act 2000	Environmental Management Plans	✔[5]	✔[6]	✔[7]
				Environmental Authority	✔[8]	✔[9]	✔[10]
				CSG Water Management Plans	✔[11]	✔[12]	✔[13]
				Preventive Mitigation Options Report for Imported Springs (EPMOR)	✔	n/a	n/a
				Injection Management Plans	Submitted as circumstances require		
				Beneficial Use Approvals	Applied for as circumstances require		
				• Baseline assessment of water bores before commencing production, and to make good impairment of bore supplies now and into the future; • Monitoring activities to complete the regional water monitoring network outlined by the Underground Water Impact Report; and	Existing requirements under the Water Act 2000 have been met. Additional requirements related to the UWIR will be met in the timeframes specified following its approval by DEHP.		
	Department of Energy and Water Supply (Office of the Water Supply Regulator)	Supply of coal seam water directly or indirectly to a registered drinking water supply	Water Supply (Safety and Reliability) Act 2008	Recycled Water Management Plan or Exclusion Decision	Applied for as circumstances require		
	Department of Natural Resources and Mines (Office of Groundwater Impact Assessment)	Impacts on local groundwater users related to extraction of coal seam water	Water Act 2000	Surat Cumulative Management Area – Underground Water Impact Report	✔[14]		
Commonwealth	Department of the Environment	Impacts on Matters of National Environmental Significance	Environment Protection and Biodiversity Conservation Act 1999	Stage 1 CSG Water Monitoring and Management Plan	✔[15]		
				Specific conditions relating to monitoring Matters of National Environmental Significance triggers	✔		
				Modelled groundwater drawdown contour data and contour plots for each targeted aquifer.	✔		
				Stage 2 CSG Water Monitoring and Management Plan	✔		
				Cumulative Ground Water Model Subsidence monitouring	✔ (underway)		

[5] Santos, ***Fairview Project Area Environmental Management Plan***

[6] Santos, ***Roma Shallow Gas Project Area Environmental Management Plan***

[7] Santos, ***Arcadia Valley Project Area Environmental Management Plan***

[8] Santos, PEN100178208 (Revised EPPG00928713), ***Fairview Project Area Environmental Authority***

[9] Santos, PEN101578910 (Revised EPPG00898213), ***Roma Shallow Gas Project Area Environmental Authorities***

[10] Santos, PEN102125611 (Revised EPPG0084113), ***Arcadia Valley Project Area Environmental Authority***

[11] Santos, ***Fairview CSG Water Management Plan***, 2012

[12] Santos, ***Roma CSG Water Management Plan***, 2013

[13] Santos, ***Arcadia Valley CSG Water Management Plan,*** 2011

[14] Santos, ***Environmental Monitoring Plan,*** 2013

[15] Golder Associates, ***GLNG Project Stage 1: CSG Water Monitoring and Management Plan***, April 2011 and October 2011

Condition 49 (g) (i) Identification of the surface and aquatic ecosystems to be monitored and their environmental values, water quality, and environmental characteristics, and the rationale for selection.

1.4 Environmental Values

1.4.1 The Commonwealth and Queensland governments regulate GLNG's impact on the environment. This includes potential direct or indirect impacts to Matters of National Environmental Significance referenced under the EPBC Act, as well as Environmental Values under the Environmental Protection (Water) Policy 2009 (State). Table 1.3 details the presence and distribution of Environmental Values associated with GLNG.

1.4.2 Environmental Values determined to be relevant to all or part of the GLNG CSG fields include aquatic ecosystems, human consumption, agricultural purposes, recreational purposes, industrial purposes, cultural and spiritual values, Groundwater Dependent Ecosystems and sandstone aquifers of the Great Artesian Basin (GAB). The approved Environmental Management Plan for each CSG field outlines the relevant Environmental Values.

1.4.3 The GAB Groundwater Dependent Ecosystems are listed under the EPBC Act as Matters of National Environmental Significance. Of particular significance in the GAB are the Groundwater Dependent Ecosystems associated with springs and aquifers which typically support species listed as Matters of National Environmental Significance. Several such springs, water table springs and watercourse springs occur in the GLNG area and impact zone, whilst other springs occur at a limited number of locations within the GLNG area and impact zone, all of which are monitored accordingly. Current mapping by the Office of Groundwater Impact Assessment does not identify listed species under the EPBC as being present at water table and watercourse springs. Santos GLNG will also conduct detailed species surveys prior to any ground disturbance near the springs.

1.4.4 Santos GLNG is required, under its Project Approval, to have no impact on EPBC springs. As propagation and management of impact to springs extend outside of Santos GLNG tenement boundaries, a regional consultative approach is required. Santos GLNG, together with QGC and Origin, has developed a Joint Industry Plan for the monitoring and management of EPBC springs. This plan ensures appropriate measures to provide early warning of impact propagation to springs.

1.4.5 With appropriate measures in place, the GLNG Project can be developed and operated in a sustainable manner. This is because, in addition to the above, Santos GLNG has:

- Carefully located and designed the infrastructure associated with the water extracted from coal seams;
- Ensured the planned uses provide the best net environmental, social and economic outcomes planned for the region;
- Embraced an adaptive management approach; and
- Adopted rigorous management protocols to ensure that impacts are minimised and any residual risks are appropriately managed, specifically through Field Management Protocols, and the Environmental Monitoring and Reporting Strategy[16].

[16] Santos, ***Environmental Monitoring and Reporting Strategy,*** 2013

Table 1.3 Matters of National Environmental Significance in the GLNG Area

MNES		Species / GMA	EPBC Status	CSG Field		
				Fairview	Roma	Arcadia Valley
Matters of National Environmental Significance	Ecological Communities	Brigalow ecological community	Endangered	✔	✔	✔
		Semi-Evergreen Vine Thicket	Endangered	✔	✔	✔
		Weeping Myall Woodlands	Endangered	✔	✔	
		Coolibah Blackbox Woodlands	Endangered	✔	✔	
		Natural Grasslands of the Queensland Central Highlands and the Northern Fitzroy Basin	Endangered	✔	✔	
		GAB Groundwater Dependent Species including listed species (flora) at springs	Endangered	✔	✔	✔
	Listed Species	Northern quoll	Endangered	✔	✔	✔
		Large-eared pied bat, large pied bat	Vulnerable	✔	✔	✔
		Eastern long-eared bat (South-eastern form)	Vulnerable	✔	✔	✔
		Squatter pigeon (southern)	Vulnerable	✔	✔	✔
		Red goshawk	Vulnerable	✔	✔	✔
		Black-breasted button-quail	Vulnerable	✔	✔	✔
		Australian painted snipe	Vulnerable	✔	✔	✔
		Yakka skink	Vulnerable	✔	✔	✔
		Dunmall's snake	Vulnerable	✔	✔	✔
		Brigalow scaly-foot	Vulnerable	✔	✔	✔
		Ornamental snake	Vulnerable	✔	✔	✔
		Collared delma	Vulnerable	✔	✔	✔
		Boggomoss Snail	Critically Endangered			
	GAB Springs	Great Artesian Basin springs protected under EPBC Act	n/a	✔		✔ (adjacent to tenement)

Table 1.4 Environmental Values in the GLNG Area

Natural Resource	Environmental value	Fairview	Roma	Arcadia Valley	
Surface water	Aquatic ecosystems	Waterways exhibit slightly to moderately disturbed ecosystems. No rare or threatened aquatic flora recorded. Aquatic macro invertebrates indicative of poor to moderate habitat / water quality.	Waterways exhibit slightly to moderately disturbed ecosystems. Most fish species can tolerate a large range of water quality conditions. Aquatic macro invertebrates indicative of poor to moderate habitat / water quality.	No rare or threatened aquatic flora recorded Aquatic macro invertebrates indicative of poor to moderate habitat / water quality. Most fish species can tolerate a large range of water quality conditions.	
	Human consumption	Suitability for drinking water supplies (only relevant to the Dawson River at Theodore)	Suitability for drinking water supplies (only relevant to the Balonne River at and downstream of Surat)	Suitability for drinking water supplies	
		Agricultural purposes	Irrigation, water for farm use, and stock watering.	Irrigation, water for farm use, and stock watering.	Water for farm use, and stock watering.
		Recreational purposes	Recreational use (fishing, swimming, downstream of Glebe weir) & aesthetics (primary recreation with direct contact, secondary recreation and visual appreciation with no contact).	Recreational use (swimming and fishing along the Balonne River) & aesthetics (primary recreation with direct contact, secondary recreation and visual appreciation with no contact).	Recreational use (swimming and fishing) & aesthetics (primary recreation with direct contact, secondary recreation and visual appreciation with no contact).
		Industrial purposes	Industrial use.	Industrial use.	-
		Cultural and spiritual values	Cultural and spiritual values	Cultural and spiritual values	Cultural and spiritual values
Groundwater	Agricultural purposes	Irrigation, water for farm use, and stock watering.	Irrigation, water for farm use, and stock watering.	-	
	Human consumption	Groundwater commonly used for drinking water supply in this area rather than surface water.			
	Groundwater dependent ecosystems	Potential rivers receiving base flow are Dawson River and Hutton Creek. Aquifer source for a number of springs including 3 EPBC listed spring complexes: Yebna 2, Abyss, Lucky Last	Potential river system receiving base flow is the Condamine – Upper Balonne River system. No EPBC listed springs over the Roma CSG field.	A number of springs towards the north of Arcadia Valley. One EPBC listed spring close by (Elgin 2), to the east of Santos tenements.	
Groundwater continued		Sandstone aquifers of the GAB	Groundwater from Hutton, Precipice and Clematis Sandstone units suitable for potable use, irrigation, stock watering, Bandanna Formation generally unsuitable for potable use and irrigation; marginally suitable for stock watering.	Groundwater derived from Gubberamunda Sandstone aquifer which provide the only source of water for the town of Roma. Springbok aquifer not a viable source for Roma.	None present.
Land	Primary industries such as cropping and grazing	Cattle grazing is the predominant land use	Cattle grazing is the predominant land use, with cropping on alluvial floodplains and around watercourses	Cattle grazing is the predominant land use	
	Viability for flora and fauna	'Of Concern' regional ecosystems and listed species present	'Of Concern' regional ecosystems and listed species present	'Of Concern' regional ecosystems and listed species present	
		Cultural and spiritual values	Cultural and spiritual values	Cultural and spiritual values	Cultural and spiritual values

2 GLNG and Water

2.1 Groundwater

Fast Facts – Groundwater

- Hydraulic conductivity refers to the ability of a geological layer to allow water to pass through it.
- Hydraulic connectivity refers to the movement of water between geological layers.
- An aquifer is an underground layer of rock with high hydraulic conductivity that is capable of storing and transmitting water. Groundwater is held within the rock and moves very slowly through it. Water can be extracted from aquifers using a borehole or well.
- An aquitard is a layer of material with low hydraulic conductivity. Because water cannot easily move through aquitards, aquifers below become confined.

2.1.1 Geologically, the GLNG CSG fields are located in the Surat Basin (a sub-basin of the GAB) and the underlying Bowen Basin. These are structurally separate geological formations, but are considered to be hydraulically connected. The basins consist of alternating layers of water-bearing sandstones (aquifers) and non water-bearing siltstones and mudstones (aquitards). Aquitards hinder, but do not totally prevent, groundwater flow between aquifers.

2.1.2 Target coal seams in the Surat Basin are contained within the Walloon Coal Measures. The coal measures in the Bowen Basin are contained within the Bandanna Formation.

2.1.3 Groundwater in the three CSG fields is primarily extracted for stock and domestic purposes. The GAB aquifers are recharged by rainfall and streams, along the margins of the basin. The major aquifers in the GLNG Project area are defined and characterised in Table 2.1.

2.1.4 Santos GLNG does not draw groundwater from aquifers used by farmers in the Roma, Fairview and Arcadia Valley areas. The target coal seams for GLNG are typically 500 to 1,200 metres below the surface, well below bores drilled for stock or domestic use. CSG wells are lined with steel casing that is cemented to the side of the hole to isolate any aquifers that are intersected. In addition to the environmental imperatives, it is in Santos GLNG's commercial interest to keep aquifers separate from the coal seams. If water is allowed to flow ('leak') to the coal seam at significant rates, gas production will be compromised. Figures 2.1, 2.2 and 2.3 depict the hydrogeology of Roma, Fairview and Arcadia Valley and illustrate the locational difference between CSG wells and water bores.

Table 2.1 Definition and Characterisation of Major Aquifers in the GLNG Project Area

Aquifer	Location	Aquifer type	Thickness	Depth	Level of water supply development	Quality
Mooga Sandstone	Roma	Confined and unconfined aquifer (GAB)	Average: 86 m Range: 25 m to 200 m	At surface to the north and east of Roma CSG field. Approximately 80 m below surface in Roma east CSG field.	Important sandstone aquifer of the GAB used for drinking water town supplies in Roma, Wallumbilla and Yuleba town and stock supply. The Condamine – Upper Balonne River system receives baseflow from the aquifer.	Good quality
Orallo Formation	Roma	Confining bed/ aquitard	Average: 200 m Range: 140 m to 270 m	At surface to the north of Roma CSG field and to the east of the Wallumbilla Fault.	Assumed it is used for stock and domestic purposes. Generally considered to be an aquitard but sandstone layers observed to provide good stock and domestic water supply in some areas.	Limited data
Gubberamunda Sandstone	Roma	Major unconfined aquifer (GAB)	Average: 84 m Range: 45 m to 300 m	At surface to the north of Roma CSG field.	Most highly developed GAB sandstone aquifer in the Surat Basin. Used for Roma town water supply and stock supply.	Fresh
Springbok Sandstone	Fairview, Roma	Minor aquifer (GAB)	70 m	At surface north of the Roma CSG field, south of Fairview.	Limited due to its discontinuity and general low hydraulic conductivity. Used by groundwater users for stock and domestic purposes.	Limited data
Hutton Sandstone	Roma, Fairview	Major aquifer (GAB)	700 m	Outcrops in the southern part of Fairview, dips towards the south.	GAB sandstone aquifer, undeveloped in Roma but used within Fairview for stock and town supply. Dawson River and Hutton Creek (Fairview) receive baseflow from this aquifer.	Brackish, generally poor
Precipice Sandstone	Roma, Fairview, Arcadia Valley	Major aquifer (GAB)	Up to 80 m	At surface within the south of the Arcadia Valley field, at depth beneath Roma.	Important GAB sandstone aquifer, undeveloped in Roma but used within Fairview area and Injune for stock and town supply. Dawson River and Hutton Creek (Fairview) receive baseflow from this aquifer.	Good quality
Clematis Sandstone	Arcadia Valley	Confined aquifer (GAB)	Not present under GLNG CSG fields	Unknown	Major aquifer, moderate yield and good water quality. Important GAB sandstone aquifer, used for town water supply, domestic and stock use.	Good water quality, elevated dissolved metals found in some bores

Figure 2.1 Roma Hydrogeology

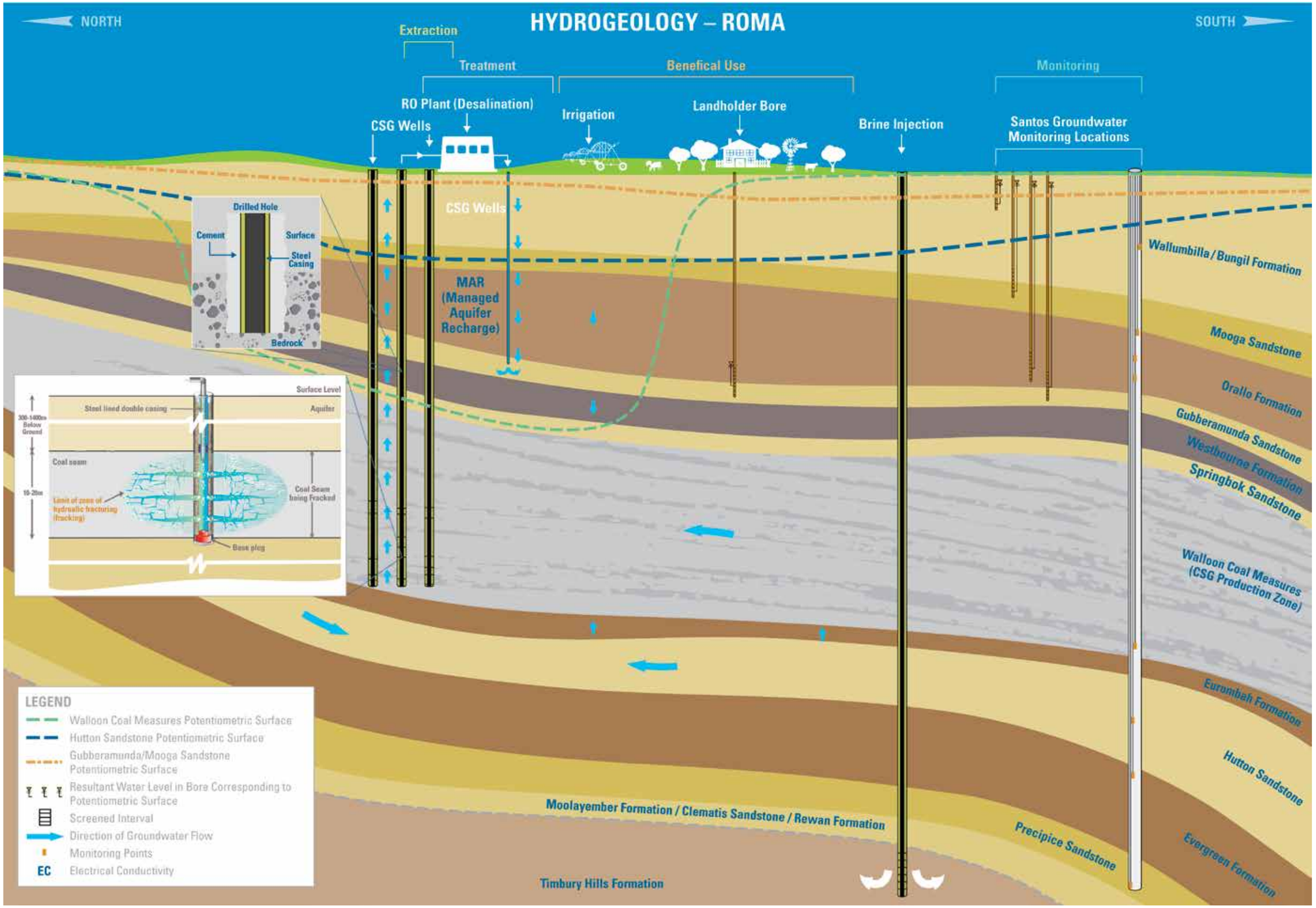


Figure 2.2 Fairview Hydrogeology

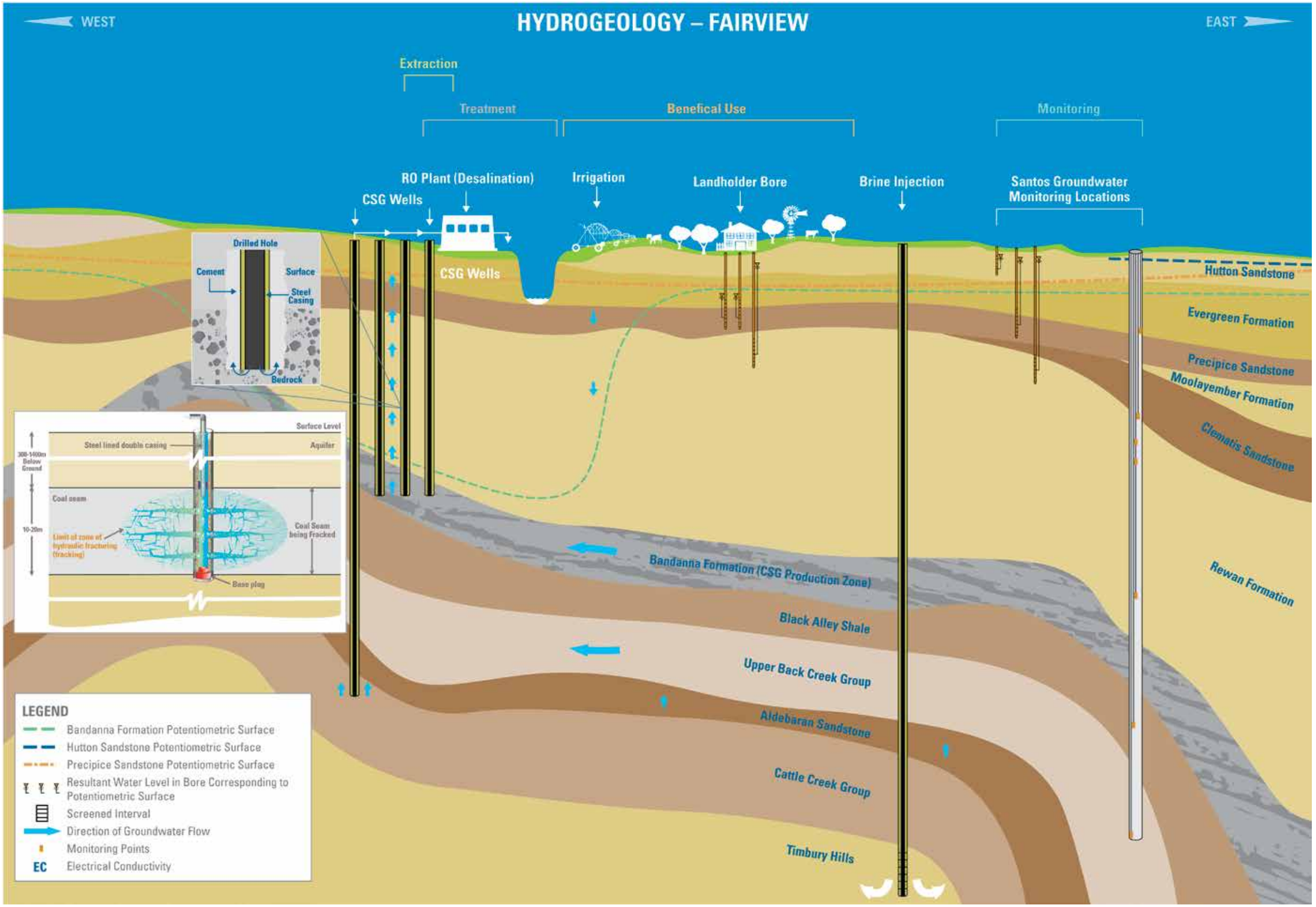
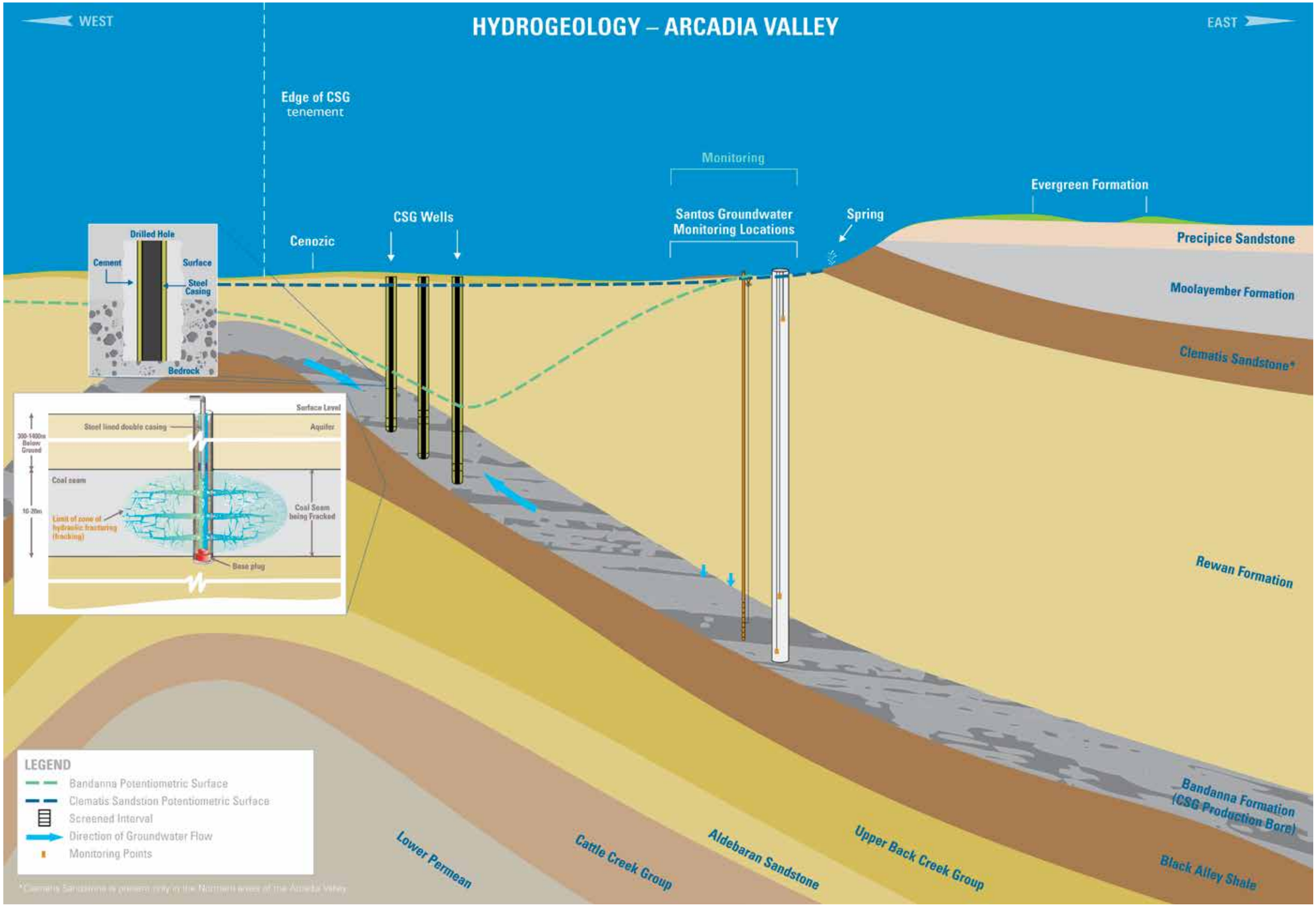


Figure 2.3 Arcadia Valley Hydrogeology



2.2 Surface Water and Aquatic Systems

2.2.1 The surface water systems in the GLNG CSG fields are illustrated in Figure 2.4, and summarised in Table 2.2.

Table 2.2 Summary of Surface Water Settings

CSG field	Basin that CSG field is part of	Relevant sub-catchment	Local watercourses draining field	Nature of watercourses
Roma	Murray-Darling Basin	Balonne River	Dargal Creek Bungil Creek Blyth Creek Wallumbilla Creek Yuleba Creek	Extensive meandering streams that are largely ephemeral
Fairview	Fitzroy Basin	Upper Dawson River	Hutton Creek Baffle Creek Dawson River	Extensive but largely ephemeral, with the exception of Yebna Crossing to east of field, which is perennial and maintained by spring flows below Dawsons Bend
Arcadia Valley	Fitzroy Basin	Located across Dawson River and Comet River	Comet River Dawson River Arcadia Creek	Extensive but largely ephemeral

2.2.2 The Office of Groundwater Impact Assessment has undertaken a region-wide spring survey to identify and characterise all springs in the region, and where possible identify the source aquifers for each spring. A parallel ecological and botanical survey of these springs was undertaken by the Queensland Herbarium.

2.2.3 Several springs occur in the GLNG area and impact zone and watercourse springs occur at a limited number of locations within the project area and predicted impact zone. All of these are monitored accordingly (see Section 7). Current mapping by the Office of Groundwater Impact Assessment does not identify listed species under the EPBC as being present at watercourse springs. A collaborative 'small footprint' monitoring scheme between Santos GLNG and the three other CSG operators in the southern Bowen and Surat Basins is being implemented to address potential drawdowns from CSG production areas toward EPBC-listed springs.

2.2.4 Santos GLNG is implementing ongoing river health monitoring on the Dawson River. In addition, Santos GLNG is implementing an adaptive management approach to improve stream salinity in catchments that contain irrigation projects. This involves using water from coal seams that has been treated extensively.

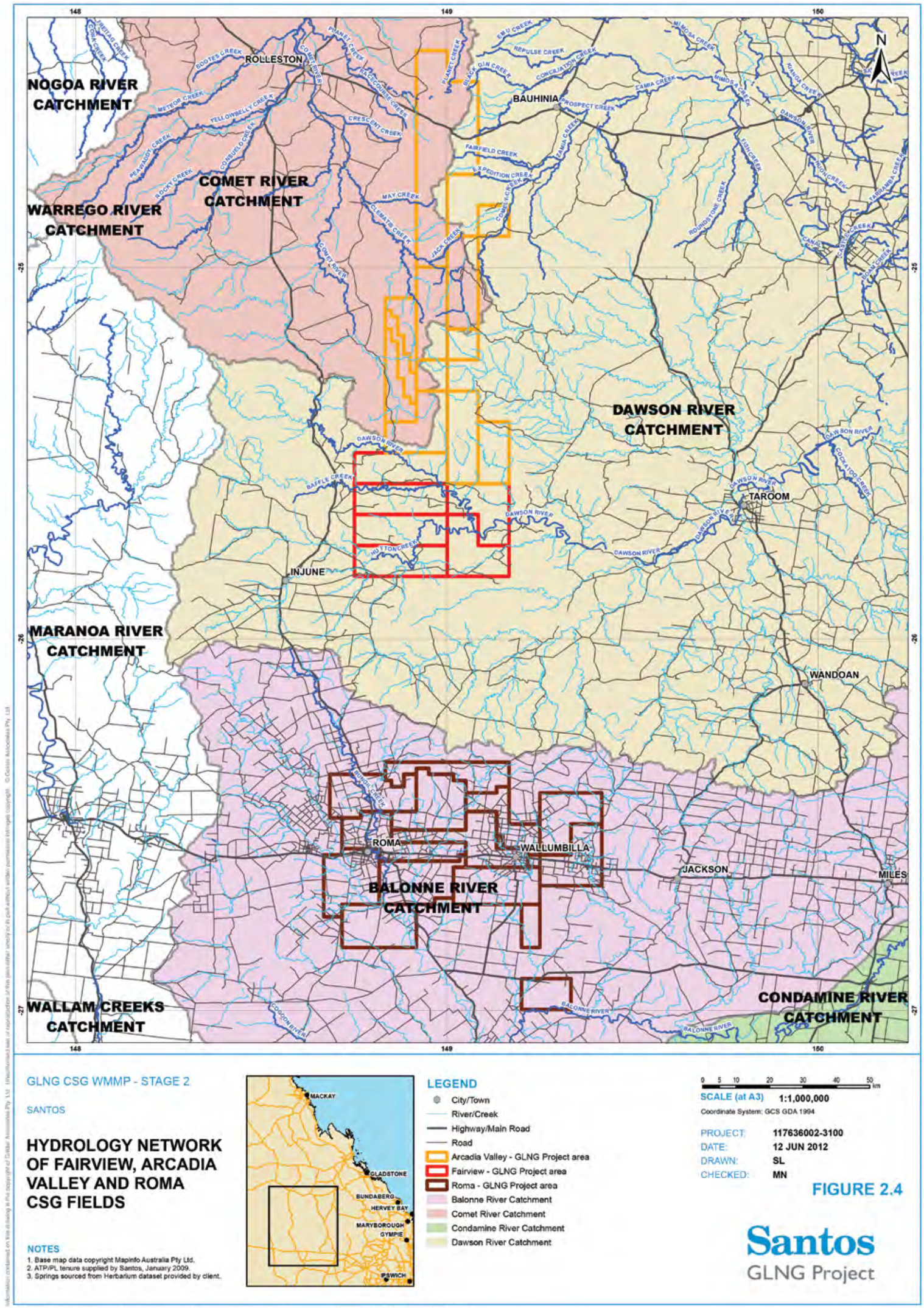


Figure 2.4 Surface Water Systems in the GLNG Fields

3 Conceptual Water Balance

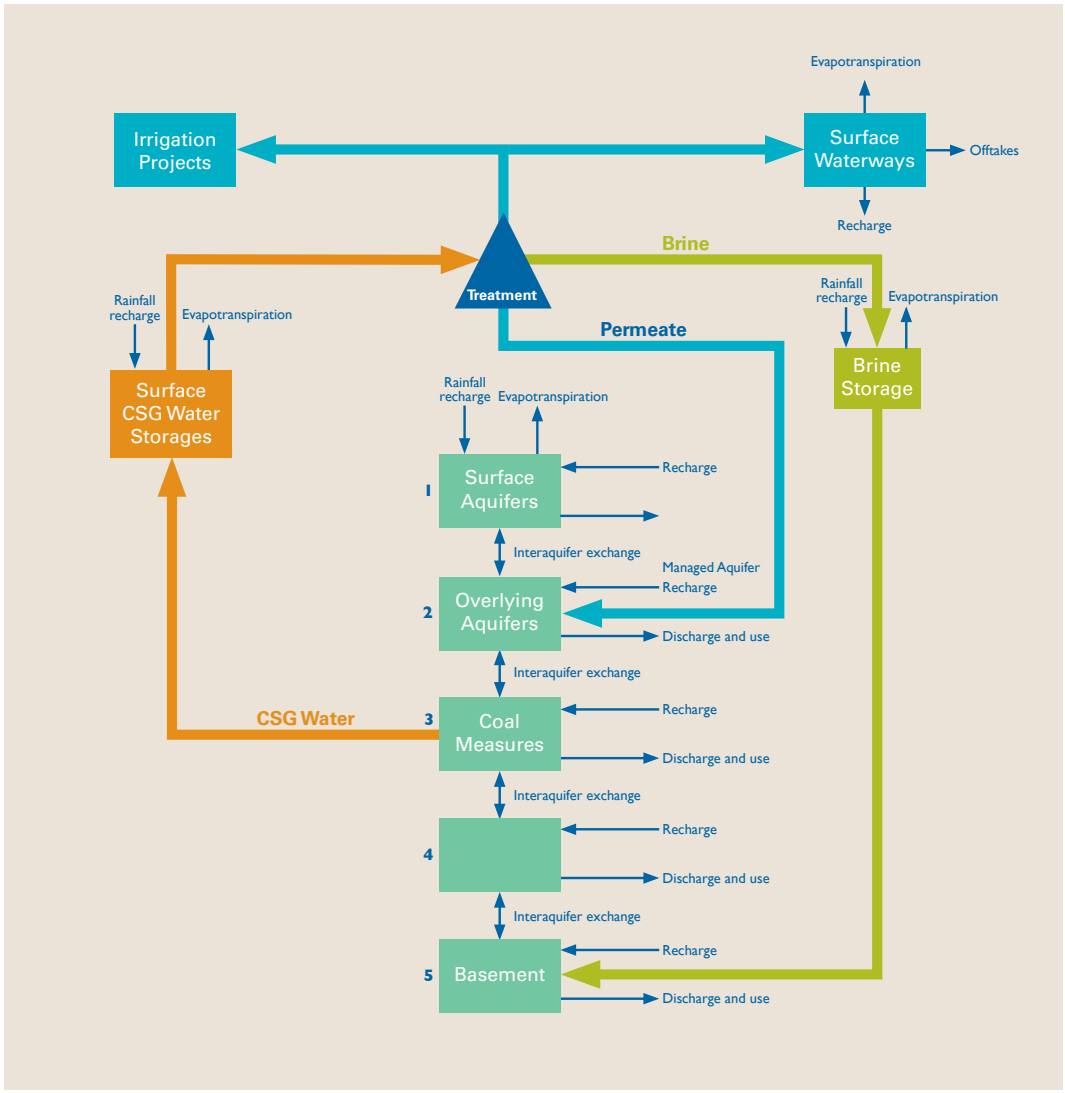
3.1.1 A water balance can be considered to be a 'water ledger' and describes, for a specified system, the water stores, flows and processes that occur during the operation of that system. In the case of GLNG, the water system is the collection of aquifers, storages (ponds), treatment plants, brine and other infrastructure associated with the reuse of water from coal seams.

3.1.2 Santos GLNG has developed conceptual water balance models to inform research, monitoring design and modelling for the GLNG Project. The conceptual water balance models in Annex E indicate how the water extracted from coal seams will be accounted for across GLNG.

3.1.3 The conceptual water balance models provide detail for peak water production within the Fairview, Roma and Arcadia Valley CSG fields over the life of the Santos GLNG Project.

3.1.4 Figure 3.1 illustrates how Santos GLNG has defined the conceptual water balance models. It also acts as a legend for the conceptual water balance models provided in Annex E.

Figure 3.1 GLNG Water Balance Schematic



4 Managing Water Extracted from Coal Seams

4.1 Introduction

4.1.1 Santos GLNG has developed CSG Water Management Plans[11,12,13] (CWMPs) for each of the GLNG CSG fields. These plans provide detail on how the water extracted from coal seams will be managed in a sustainable way over the life of GLNG. CWMPs are required by the Department of Environment and Heritage Protection (DEHP) (formerly the Queensland Department of Environment and Resource Management, DERM) under the Environmental Protection Act 1994 (State) as part of the approved Environmental Management Plans.

Santos GLNG CWMPs describe how Santos GLNG aims to maximise beneficial use opportunities for the community while minimising the potential for environmental harm. Developing viable long term CWMPs provide the best net environmental, social and economic outcomes for the region. The CWMPs define:

- The management of water extracted from coal seams through the gathering system;
- The portfolio of water reuse options and necessary treatments;
- The monitoring specification required to establish each field's baseline conditions and provide a framework for ongoing monitoring of impacts (both potential and actual); and
- Reporting requirements.

4.2 Water Production

4.2.1 The water extraction rate from coal seams is typically higher earlier in the life of a CSG well and declines as gas production increases.

4.2.2 CSG development is an incremental activity involving exploration, appraisal and establishment of producing gas wells. For this reason, the exact location, timing, quality and volume of coal seam water production is not known with certainty until investigations are complete. It is therefore important to note that water curves (a graph depicting the volume of water that will be produced throughout a field's development) provide a forecast of coal seam water production, where the shape of the curves in particular may be subject to change. Typically however, changes to the production plan do not result in changes to the cumulative amount of water produced. A variety of methods are used to develop the water curves, each of which is calibrated against field data.

4.2.3 The estimated water production forecast for the Fairview, Roma and Arcadia Valley CSG fields is shown in Figure 4.1. This demonstrates that the total GLNG peak production is expected to occur in 2018, when up to 48 ML/day of coal seam water will be produced. A total volume of some 200 GL is expected over the lifetime of GLNG development. The estimated volume and peak water production has significantly reduced from the Environmental Impact Statement, Supplementary Environmental Impact Statement and previous versions of the CWMMP due to refinement of water curves based on appraisal and production data.

4.2.4 Table 4.1 summarises the values shown in Figure 4.1 for the period covered by the CWMMP and over the life of the Santos GLNG Project.

Figure 4.1 GLNG Water Production Forecast

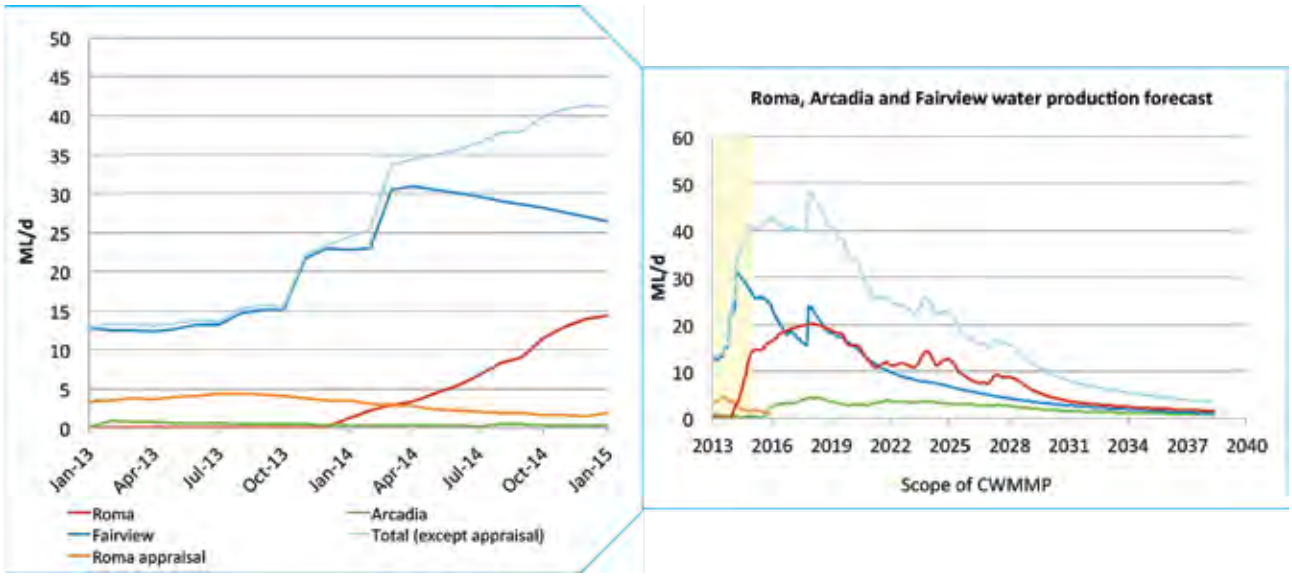


Table 4.1 Forecast CSG Water Production between 2013 and First Cargo and life of the GLNG Project

Basin	Surat	Bowen	
CSG field	Roma (incl Appraisal)	Fairview	Arcadia
Peak water production between 2013 and first cargo (ML/d)	16	30	1
Average water production between 2013 and first cargo (ML/d)	7	21	0.4
Average water production between 2013 and first cargo (ML/ year)	2,500	8,000	140
Total produced water between 2013 and first cargo (ML)	5,200	16,000	0.3
Peak water production for GLNG Project life (2018) (ML/day)	48		
Total water production for GLNG Project life	192		

Note: average values are calculated using producing years

[17] DEHP, *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*, February 2012

4.3 Water Quality

4.3.1 The quality of water extracted from coal seams primarily depends on the geology of the area in which the gas wells are located. The water from coal seams can be salty, which often precludes its direct use without treatment. As shown in Table 4.2, the water produced from Santos GLNG CSG wells typically contains between 20 and 8,900 parts per million of total dissolved solids.

Table 4.2 Water Quality Comparisons

Water Source	TDS (parts per million)
Rainwater	15 - 22ppm
Desalinated water	180 ppm
Brisbane tap water	240 ppm
Average groundwater bore in Fairview Qld	300 ppm
Average Roma tap water	800 ppm
Amended CSG water	1,800 ppm
Average CSG water	2,200 - 8,900 ppm
Livestock and watering	5,000 ppm
Saltwater swimming pool	6,000 ppm
Seawater	35,000 ppm

4.3.2 Santos GLNG continues to sample and analyse the water produced from GLNG CSG fields to establish the signature characteristics of the coal seam water in each location, in support of aquifer connectivity studies. To date, such water sampling has indicated that:

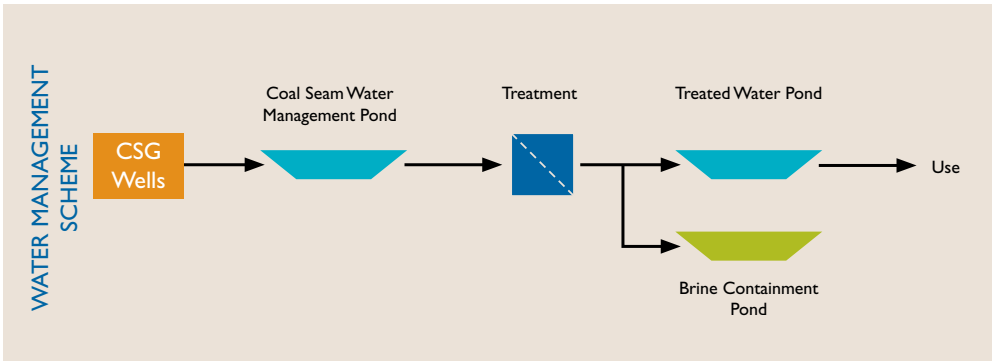
- Water extracted from coal seams at Fairview is variable, from fresh to saline;
- Water extracted from coal seams at Roma is mostly slightly brackish; and
- Water extracted from coal seams at Arcadia Valley is typically between brackish and saline.

4.4 Gathering System and Storage

Condition 49 (g) (viii) Water storage locations and volumes including any storage and volumes required to pilot or implement reinjection or other groundwater repressurisation techniques.

4.4.1 The gathering system includes all infrastructure (including pipelines and ponds) required to transfer the extracted water from CSG producing wells to coal seam water management ponds and treatment plants. This process is shown in Figure 4.2.

Figure 4.2 Conceptual Gathering and Treatment Process



4.4.2 A typical gathering system collects the extracted water from individual well pads using flowlines. A flowline from each well pad connects into a single gathering line that is connected to the corresponding compression facility. Multiple gathering systems flow into each compression facility.

4.4.3 The water received from the gathering flowlines is discharged into a management pond (which is co-located at the compression facility). This pond is sized to provide a minimum of 10 days' storage at the peak flow rate, determined from water balance modelling. Management ponds serve several purposes, including:

- Ensuring system reliability;
- Accommodating varying demand for use options; and
- Natural treatment (e.g. temperature, solids capture, oxidation).

4.4.4 These management ponds are designed with no external catchment and in accordance with the DEHP[17]. They are operated in accordance with the relevant field's approved Environmental Authority (EA). The DEHP guidelines for the management of regulated dams are rigorous and designed to protect the community, infrastructure and the local environment. Santos GLNG will comply with these regulations.

4.4.5 The gathering system includes the ability to transfer the extracted water between gathering catchments and treatment facilities to provide flexibility and contingency when production and/or quality exceeds the capacity of a specific treatment plant.

4.4.6 The water and brine storage locations are provided within the CWMPs, and illustrated in Figures 4.3 (Fairview), 4.4 (Roma) and 4.5 (Arcadia Valley). Table 4.3 provides the water and brine storage volumes.

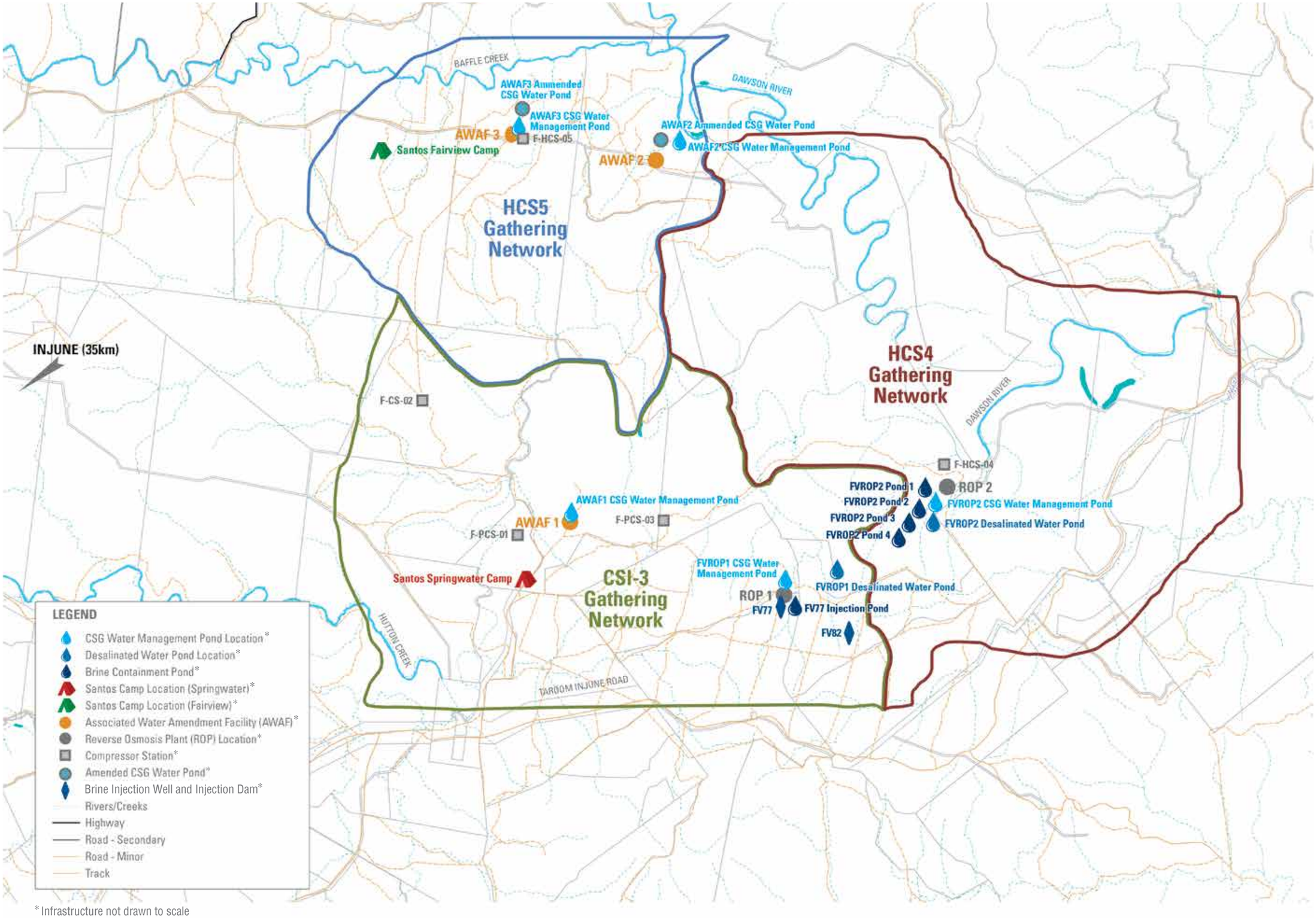
Table 4.3 CSG Water and Brine Storage Volumes

Name of Pond	Volumes – ML *	Status **	Pond Type
Fairview			
FV ROP1 CSG Water Management Pond	38	O	Coal seam water
FV ROP 1 Desalinated Water Pond	233	O	Desalinated water
AWAF1 CSG Water Management Pond	132	O	Coal seam water
AWAF2 CSG Water Management Pond	22	O	Coal seam water
AWAF2 Amended CSG Water Pond	17	O	Amended water
AWAF3 CSG Water Management Pond	35	UC	Coal seam water
AWAF3 Amended CSG Water Pond	43	UC	Amended water
FV ROP2 CSG Water Management Pond	200	F	Coal seam water
FV ROP2 Desalinated water pond	340	F	Desalinated water
Brine containment pond 1	350	UC	RO concentrate
Brine containment pond 2	350	UC	RO concentrate
Brine containment pond 3	350	UC	RO concentrate
Brine containment pond 4	350	UC	RO concentrate
Fairview 77 Injection Pond	3.6	O	RO concentrate
Fairview 82 Injection Pond	4	UC	RO concentrate
Roma			
Angry Jungle CSG Water Management Pond	176	O	Coal seam water
Ben Bow CSG Water Management Pond	165	O	Coal seam water
Coxon Creek East (also called Coxon Creek) CSG Water Management Pond	33	O	Coal seam water
Hermitage CSG Water Management Pond	230	O	Coal seam water
Mt Hope CSG Water Management Pond	140	O	Coal seam water
New Coxon Creek pond	195	O	RO concentrate
Pickanjinnie CSG Water Management Pond	195	O	Coal seam water
Pine Ridge CSG Water Management Pond	200	O	Coal seam water
Pleasant Hills CSG Water Management Pond	200	O	Coal seam water
Raslie CSG Water Management Pond	200	O	Coal seam water
Treville Downs CSG Water Management Pond	138	UC	Coal seam water
Washpool Creek CSG Water Management Pond	185	O	Coal seam water
ROMA ROP2 CSG Water Management Pond	116	F	Coal seam water
ROMA ROP2 Desalinated Water Pond	155	F	Desalinated water
Brine Containment Pond 1	300	F	RO concentrate
Brine Containment Pond 2	300	F	RO concentrate
Arcadia Valley			
Mt Kingsley CSG Water Management Pond	240	O	Coal seam water
Tarcoola CSG Water Management Pond	240	F	Coal seam water
Bottletree CSG Water Management Pond	240	O	Coal seam water

* Volume = Nominal Full Supply Volume (i.e. spillway level volume)

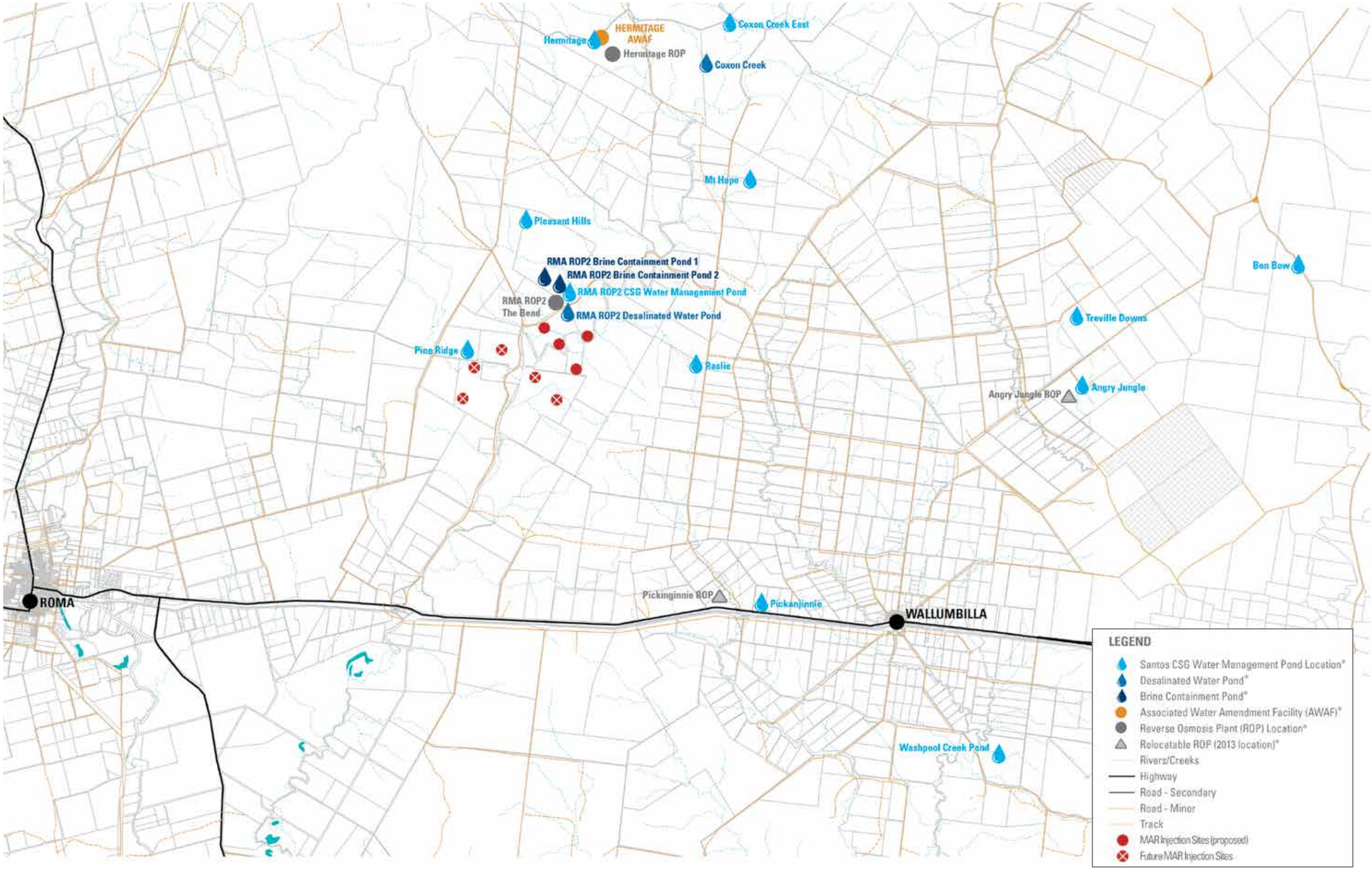
**Status: UC = under construction, O = operational, F = future

Figure 4.3 Water Infrastructure – Fairview



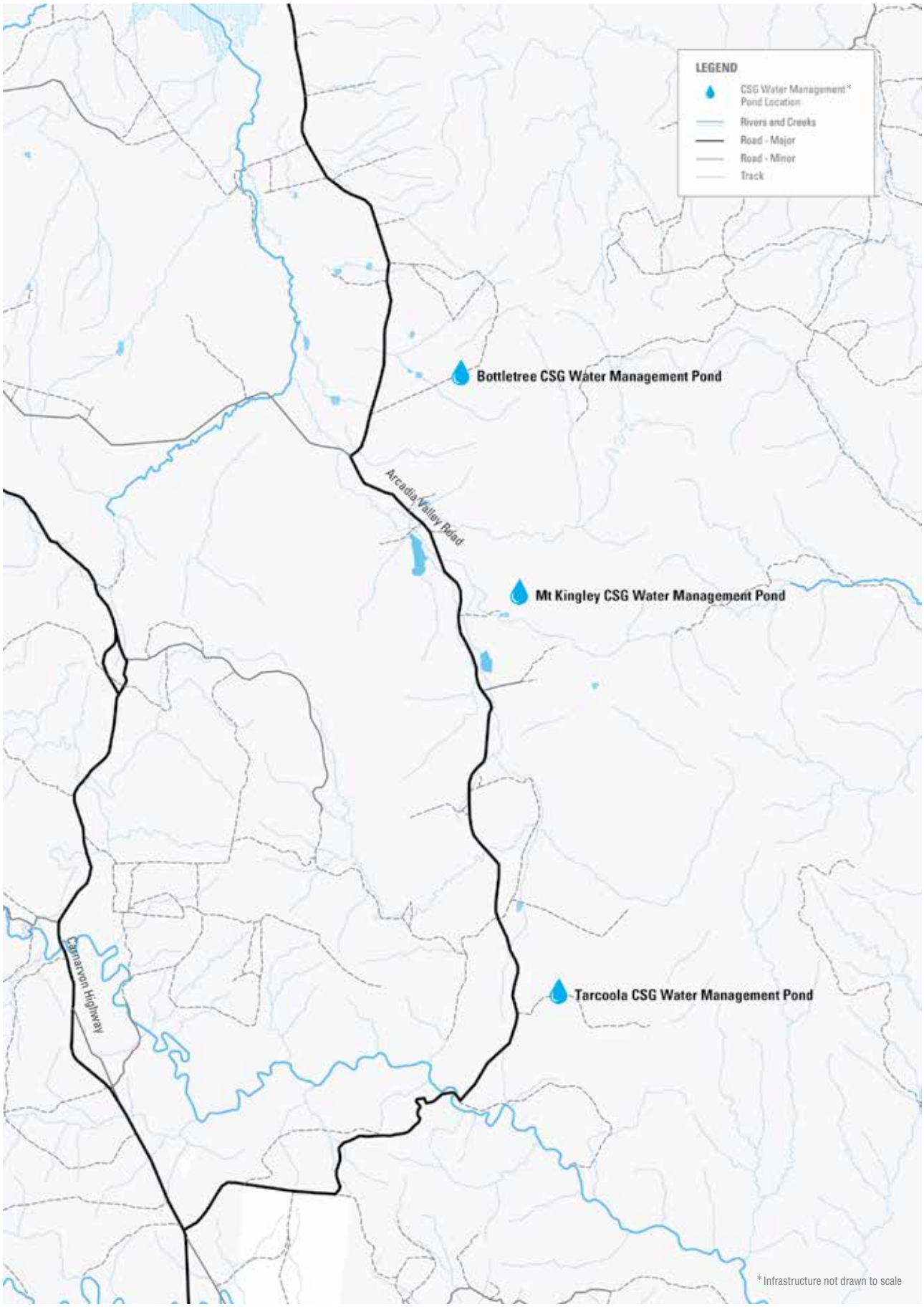
* Infrastructure not drawn to scale

Figure 4.4 Water Infrastructure – Roma



* Infrastructure not drawn to scale

Figure 4.5 Water Infrastructure – Arcadia Valley



Condition 49 (h) Mechanisms to avoid, minimise and manage risk of adverse impacts and response actions and timeframes that can be taken by the proponent if:

(2) there are any unforeseen emergency discharges

4.4.7 Santos GLNG's adaptive water management procedures are designed to prevent the need for any emergency discharge. There has been no emergency discharge required to date. All water management ponds and brine containment ponds are designed in accordance with DEHP's regulated dam guidelines[17]. This includes a requirement for the Design Storage Allowance, which is the 1 in 100 year, 3 month wet season rainfall volume, to be available on 1 November each year to contain the wet season rainfall. Santos GLNG has located ponds away from all known Matters of National Environmental Significance and Environmental Values. Combined with very low volumes and low numbers of ponds, Santos GLNG has addressed the Commonwealth Government request for no impact on Matters of National Environmental Significance or Environmental Values.

Condition 53 (d) (i) An exceedance response plan that includes: (4) any unforeseen emergency discharges

Condition 49 (g) (xi) Emergency discharges, their volumes and quality

4.4.8 The potential for emergency discharges could only occur under exceptional circumstances, outside the normal design parameters outlined above. Santos GLNG has therefore developed an Emergency Discharge Strategy, which:

- Identifies the exceptional scenarios in which emergency discharges may occur (either from storages, treatment facilities or pipelines);
- Identifies where the discharge locations would be;
- Identifies the volume and quality of the potential discharge;
- Outlines the emergency discharge risk management measures in place; and
- Outlines an Exceedance Response Plan which includes the residual risk management measures in place for monitoring, assessing, reporting and cleaning up in the unlikely event that an emergency discharge occurs.

4.4.9 Santos GLNG will manage any residual operational risk of emergency discharges through continuous water level monitoring and the use of site-based operational water balance models, to ensure that appropriate contingency storage is always maintained in the ponds.

4.4.10 Santos GLNG will report any unplanned discharges as described by the requirements set out by DEHP and the field's EA.

4.5 Treatment

4.5.1 Raw water from coal seams is 'brackish', which limits its direct use. It is only after treatment that this water can typically be used. Santos GLNG is therefore turning the water from coal seams, which is not suitable for drinking or agriculture, into a water resource for use within the community.

Condition 49 (g) (vii) Water treatment and amendment methods and standards.

4.5.2 All water extracted from coal seams in the GLNG area is treated by amendment and/or desalination. Desalination uses the process of reverse osmosis (RO) to separate salt from the water. Amendment alters the chemical balance of the water. The actual treatment process used to achieve the target water quality depends on the original quality of the water, its intended use and the required water quality objectives of each use in accordance with appropriate standards.

4.5.3 Desalination is used to remove total dissolved solids from water extracted from coal seams so that it may be used. Desalination of this water typically has five steps:

1. Pre-treatment;
2. Filtration;
3. Ion exchange (as required);
4. Desalination; and
5. Further treatment as required by final water use.

4.5.4 A desalinated water pond is located downstream of the RO plant, with the function of:

- Storing desalinated water from the RO plant;
- Accommodating varying demand for water reuse; and
- Ensuring system reliability.

4.5.5 Desalinated water ponds are designed with 15 days' retention time for the peak RO plant desalinated water production. They are designed with no external catchment, situated above the 1 in 100 year flood level and constructed according to agreed set back distances from environmentally sensitive areas.

4.5.6 Brine from the RO plant is sent to a brine containment pond. As with the management ponds for water from coal seams, the desalinated water ponds and brine containment ponds are designed in accordance with DEHP's regulated dam guidelines[17] and operated in accordance with the relevant field's approved EA.

4.5.7 Further details of brine management are provided in Section 4.8.

4.6 Injection of Treated Water from Coal Seams

4.6.1 A key objective of the groundwater component of the CWMMP is to maintain or restore pressure in affected aquifers (as described in Section 5) to levels that avoid the risk of adverse impacts on Matters of National Environmental Significance.

Condition 49 (c) A program and schedule for field piloting of aquifer reinjection of CSG water and other groundwater repressurisation techniques.

4.6.2 As part of its management options, Santos GLNG is in the process of evaluating three injection schemes across each field in across each field in accordance with the National Water Quality Management Strategy Australia Guidelines for Water Recycling Aquifer Recharge.

- **A Managed Aquifer Recharge** scheme is the injection of treated CSG water into an underground aquifer. A Managed Aquifer Recharge scheme in Roma aims to recharge the Gubberamunda Sandstone aquifer. The aquifer has already been subject to around 80 metres of aquifer pressure loss associated with pumping for town water supply over a period of around 100 years. Santos GLNG has assessed the feasibility of the project through injection trials at Hermitage. Pending approval, Santos GLNG plans to begin injection at The Bend of up to 9 ML/day of treated coal seam water into the Gubberamunda in late 2013, increasing up to 20 ML/day in 2014. This project will partly restore aquifer pressure depleted by local pumping and protect the Gubberamunda and overlying aquifers from impacts associated with depressurisation of the underlying coal seams.

  Santos GLNG conducted an injection feasibility study for the Fairview CSG field, undertaken in accordance with the National Water Quality Management Strategy Australian Guidelines for Water Recycling: Managed Aquifer Recharge. The study concluded that injection at this location would cause ephemeral catchments to become permanent flowing systems, with associated unacceptable impacts on the local ecology. For this and other feasibility reasons, injection at Fairview into suitable aquifers is therefore considered non-feasible.

  An injection feasibility study for the Arcadia Valley CSG field is currently being undertaken in accordance with National Water Quality Management Strategy Australian Guidelines for Water Recycling: Managed Aquifer Recharge. Early results from this study indicate that no aquifers suitable for Managed Aquifer Recharge for beneficial use are present in the Arcadia Valley. There is unlikely to be a need for large scale water reuse or depressurization impact management with the Arcadia areas within the timescale of this CWMMP.

Condition 53 (a) An ongoing CSG water treatment program to ensure that any water to be used for reinjection, or used for other groundwater repressurisation options, is treated at least equal to the water quality of the receiving groundwater system or environment.

- **Reinjection of coal seam water into disused coal seams** is not considered commercially, technically or environmentally viable for GLNG. Further, it is not even feasible to trial this option for at least 10 to 15 years.

[17] DEHP, ***Manual for Assessing Hazard Categories and Hydraulic Performance of Dams***, February 2012

4.6.3 Regulation of injection activities is managed through the Environmental Approval process currently administered by the State Government (DEHP). Approval to inject is provided by DEHP under operating conditions that are designed to monitor and manage potential impact to environmental values. These conditions are derived following DEHP assessment of a submitted Injection Management Plan, that details the potential impact of specific injection activities. All Injection Management Plans that are approved by DEHP shall be submitted to the Department of Environment (formerly SEWPAC).

4.7 Use of Water Extracted from Coal Seams

4.7.1 Santos GLNG aims to maximise re-use opportunities and minimise the potential for environmental harm. The company plans to do this by developing and implementing viable long term management plans that provide the best net environmental, social and economic outcomes for the region. Santos GLNG will develop the plans in response to the quality and quantity of water extracted and viability of management options at each location, as determined through feasibility studies.

Condition 49 (g) (ix) Water use or disposal options and methods (whether beneficial use or not) including frequency, volumes, quality and environmental values documented for each receiving catchment.

4.7.2 Santos GLNG has reviewed a wide range of water management options and considers that several combinations of options are available for the sustainable development of GLNG. Santos GLNG has conducted detailed assessments of local environmental settings, local land use and local water demands[19] to ensure that its management portfolios for each CSG field are achievable and realistic.

Fast Facts – CSG Water Utilisation

- **Managed Aquifer Recharge** is the injection of treated CSG water into an underground aquifer.
- **Dust** generated from unsealed roads presents an environmental risk to surrounding areas. Dust suppression is a required activity to minimise this risk and treated CSG water can be used for this purpose.
- Treated CSG water can be used to **irrigate crops.**

4.7.3 The *Environmental Protection (Waste Management) Policy* (2000) establishes a hierarchy of waste management practices, providing guidance on the preferred methods for dealing with wastes. The waste management hierarchy is simplified for managing the water extracted from coal seams.

4.7.4 The water reuse portfolios planned for Roma, Fairview and Arcadia Valley are presented in Table 4.4. A key aspect of the development of each CSG fields' water management profile is the selection of water use options that are sustainable both environmentally and economically. Santos GLNG intends to provide long-term benefit to the environment and community and leave a positive long-term legacy for the community after the water is no longer available.

[19] *Santos, Environmental Monitoring and Reporting Strategy, 2011*

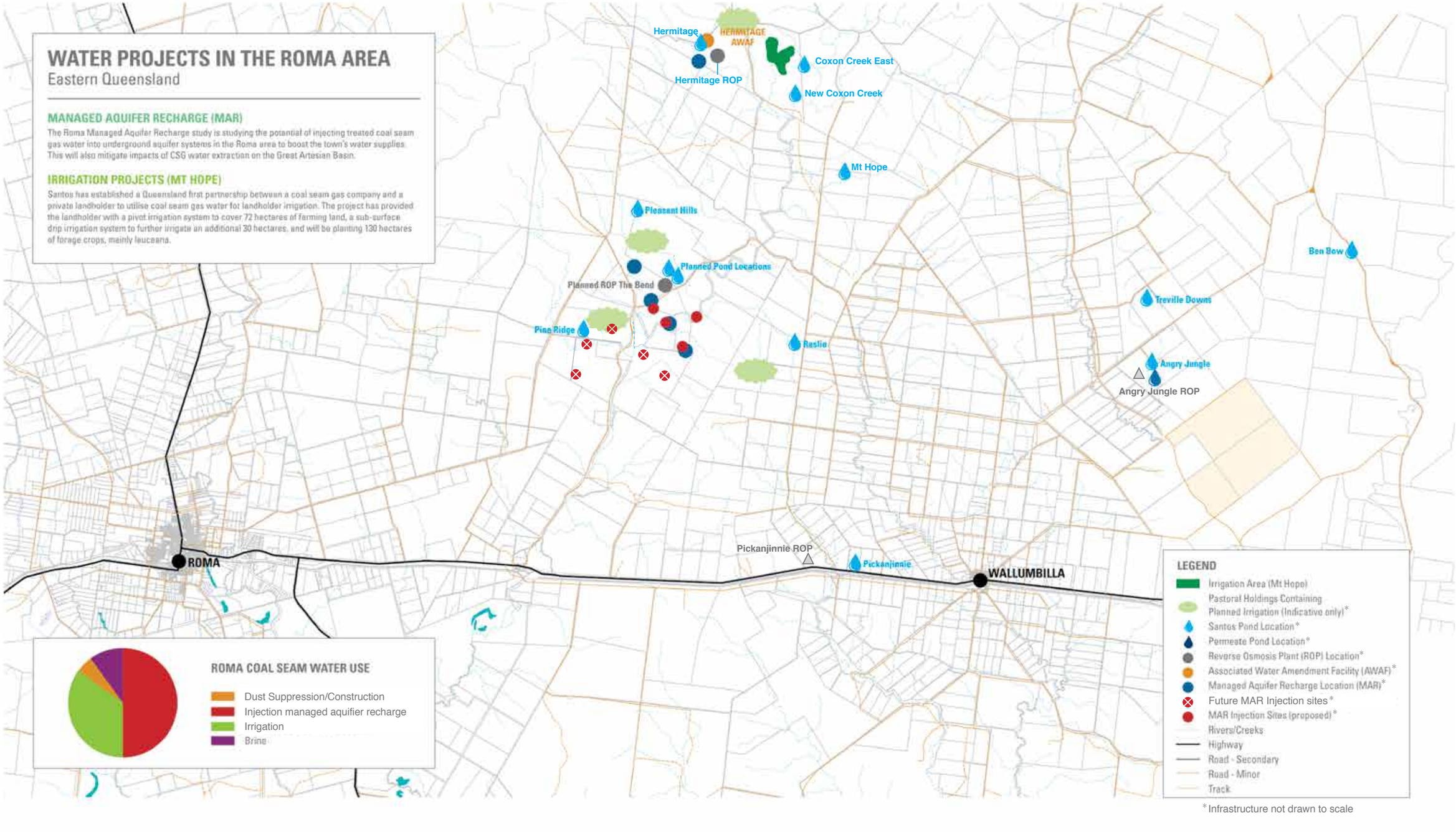
Table 4.4 Water Reuse Portfolios for Roma, Fairview and Arcadia Valley

Management Option		Roma	Fairview	Arcadia Valley*
Injection		✔ Gubberamunda Sandstone	✘ Not Feasible	? Under investigation
Beneficial use	Irrigation	✔ Mount Hope Irrigation Project Other irrigation projects planned	✔ Fairview Irrigation Project Other irrigation projects planned	✔ (Planned)
	Dust suppression	✔ (Minore use)	✔ (Minore use)	✔ (Minore use)
Discharge to surface waters		✘	✔ Release of treated CSG water to Dawson River planned	✘
CSG evaporation dam		✘	✘	✘

* Note: No CSG water treatment or uses are proposed in Arcadia Valley during the timeframe of this Plan.

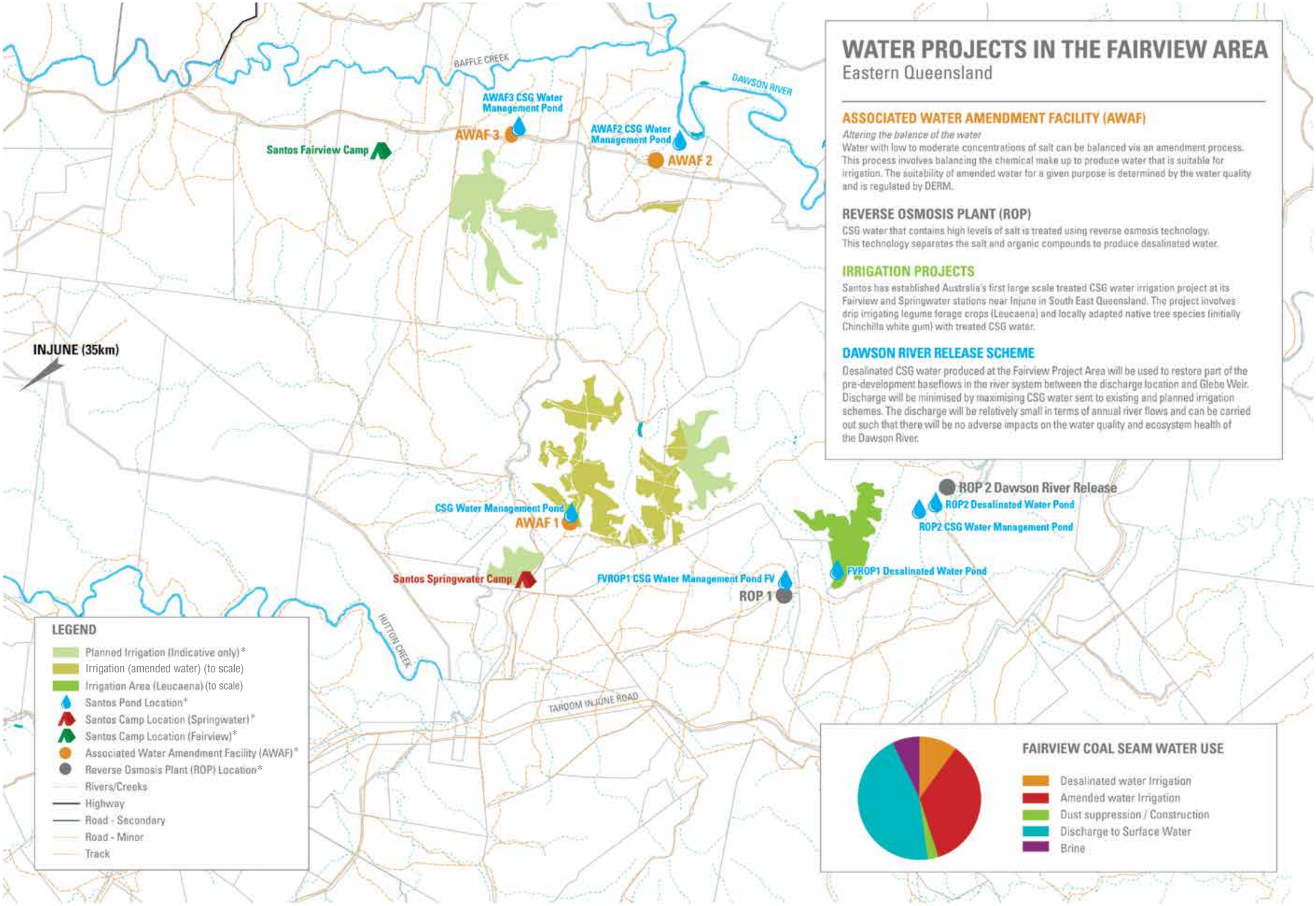
4.7.5 The water reuse portfolios for Roma and Fairview are illustrated in Figures 4.6 and 4.7 respectively. The quality of the water used for the different uses is achieved in accordance with the relevant field's approved EA, Beneficial Use Approval and DEHP's Minimum Standards for General Approval for Beneficial Use of CSG water. For each submission for beneficial use approval, Santos GLNG prepares extensive baseline information and specifies the precise management methods to be used.

Figure 4.6 Water Reuse Portfolio – Roma



*Infrastructure not drawn to scale

Figure 4.7 Water Reuse Portfolio – Fairview



*Infrastructure not drawn to scale

4.8 Brine Management

4.8.1 For the purposes of GLNG, brine is defined as the waste stream generated from the process of RO. Brine volumes are determined by the amount of water that an RO plant can recover from coal seam water. Santos GLNG designs its RO plants to be able to recover around 90% of desalinated coal seam water. This means that 10% of the total inflow volume will be produced as brine.

The estimated brine production is expected to peak in 2018 when up to 4.1 ML/day of brine will be produced. A total brine volume of some 17GL is expected over the lifetime of the Santos GLNG project. A total salt volume of 570,000 tonnes is expected over the life of the Santos GLNG project.

Condition 49 (g) (x) Brine storage locations and volumes, and brine crystal waste management.

4.8.2 Brine storage locations are provided in Figures 4.3 and 4.4. Brine storage volumes are provided in Table 4.3.

4.8.3 Santos GLNG's order of preference for brine management is in accordance with EPBC Condition 72:

Option 1. Brine injection in selected deep saline aquifers; and

Option 2. Solar and wind evaporation facilities to minimise the footprint of brine containment ponds and if required, assist with optimising evaporation and containment of the residual salt solids.

4.8.4 Santos GLNG investigations indicate that salt production will not be commercially viable for GLNG. At this stage, Santos GLNG anticipates that only Option 1 will need to be employed. This will take between two and five years to prove to the satisfaction of DEHP, and a range of brine deep injection studies are underway in support of this. Until then, Santos GLNG has the following interim arrangements in place for brine management:

- **Fairview:** Santos GLNG currently manages brine production from its existing reverse osmosis plant by reinjection into the deep, saline fractured basement rock of the Timbury Hills Formation, in accordance with Environmental Authority Conditions. Brine containment ponds will be required to buffer the system and contain all brine from the additional planned reverse osmosis treatment plant until sufficient extra injection capacity is developed over the next two years.
- **Roma:** As with Fairview, all brine generated at Roma will be temporarily stored in brine containment ponds prior to the commencement of future injection projects or brine crystalisation.
- **Arcadia Valley:** No brine will be produced in Arcadia Valley within the scope of this Plan.

4.8.5 As the GLNG CSG fields are further developed and expanded, additional brine management options or up-scaling of current options will be required. Santos GLNG is therefore assessing options for the long-term management of brine. Santos GLNG will develop brine management plans for each CSG field by the end of 2014 in accordance with State project approvals.

5 Predicted Groundwater Impacts

5.1 Groundwater Impact

5.1.1 To support the CWMMP (Stage 1) Santos GLNG commissioned the production of two numerical groundwater models:

- The Stage 1 Bowen Basin groundwater model; and
- The Stage 1 Roma groundwater model.

Neither model includes the effects of operations proposed by other CSG proponents.

5.1.2 The Queensland Water Commission (now office of Groundwater Impact Assessment) Underground Water Impact Report considers the cumulative impact of CSG water extraction in the Surat Cumulative Management Area. The report is supported by groundwater monitoring and its results supersede all regional underground water impact modelling undertaken by Santos GLNG to date. The Underground Water Impact Report is the statutory instrument under the Queensland Water Act 2000, and the obligations it requires of petroleum tenure holders will be enforceable by law.

5.1.3 The Underground Water Impact Report confirmed the results of studies that Santos GLNG had previously undertaken. This confirmed that the project will have a minimal but manageable impact. Santos GLNG has one landholder in the immediately impacted area and two in the long term impacted areas. Discussions have commenced with the immediately affected landholder. There are a number of factors to consider as individual circumstances need to be discussed before entering 'make good' arrangements, if the landholder's groundwater supply is in fact adversely affected.

5.1.4 With respect to impacts on Matters of National Environmental Significance, the main conclusions of the Underground Water Impact Report are as follows:

- There are 71 spring complexes (a total of 330 spring vents) and 43 watercourse springs in the Surat Cumulative Management Area. At five of the spring complexes, the decline in water levels within the source aquifer is predicted to be more than 0.2 metres at the location of the spring. Santos GLNG has been assigned as the 'responsible tenure holder' at three of these springs Lucky Last, Abyss and Yebna 2 complexes. As such, Santos GLNG is committed to producing a Spring Impact Mitigation Strategy for those springs, which addresses the Commonwealth Government requirement for no impacts to Matters of National Environmental Significance. Mitigating controls, where necessary, might include managed aquifer recharge by injection of treated CSG water to source aquifers, or virtual injection (using water for an outcome which reduces reliance on groundwater); and
- The report concludes there will be no impact on water pressures in aquifers supporting EPBC listed springs beyond 40 kilometres from the GLNG Project tenement boundaries.

5.1.5 Santos GLNG approval conditions require an assessment of all springs, with potential EPBC status, within a 100 kilometres buffer beyond the modeled limits of aquifer drawdown. A first survey was undertaken by Queensland Herbarium, the primary source aquifer for the EPBC springs visited in that survey are the Hutton Sandstone, Precipice Sandstone and Clematis Sandstone. A complementary survey was performed in 2013 to complete the spring survey requirement to the area required by SEWPaC. The field component of the work has now been completed, the report is being prepared and will be provided to the Department of the Environment upon completion.

5.1.6 Santos GLNG supports the approach adopted in the Underground Water Impact Report and will fully implement all of its approved recommendations. The findings and recommendations of the Underground Water Impact Report have been incorporated into the assessments, conclusions and proposed actions developed within this CWMMP.

5.2 Hydraulic Connectivity

5.2.1 The primary risk associated with coal seam depressurisation is the potential loss of pressure above and below the coal seams arising from leakage to the depressurised coals. It is important to understand the magnitude of potential hydraulic connectivity between the aquifers and the coal seams so that the potential for drawdown in neighbouring aquifers can be assessed.

There are no planned activities to investigate the connectivity that might be induced by specific CSG production wells. By following industry code of practice for constructing and abandoning CSG wells, Santos GLNG considers the true risk of induced hydraulic connectivity from the construction for gas production wells to be very low.

In addition to programs developed by Santos GLNG, all available data collected by the CSG industry has and will be interpreted by the State Government (Office of Groundwater Impact Assessment) during the preparation of all future Surat Basin Cumulative Impact models. The findings of this work will remain a key reference study that will guide the requirements of investigations into hydraulic connectivity between CSG coal seam and surrounding aquifers.

5.2.2 Aquifer connectivity studies undertaken to date:

- Indicate that there is minimal hydraulic connectivity between aquifers; and
- Support the modelling outcomes which indicate that, with appropriate mitigation measures in place, GLNG will not impact upon Matters of National Environmental Significance, the Murray-Darling Basin or the GAB Sustainability Initiative.

5.2.3 Santos GLNG has a program for re-injecting treated water from coal seams into suitable aquifers in the GLNG CSG fields as part of its water reuse portfolio (see Section 4.7). While there is minimal hydraulic connectivity between aquifers, aquifer injection provides Santos GLNG with a mechanism to manage or mitigate any potential depressurisation. Any such work is supported by approved groundwater hydrogeochemical models and undertaken in accordance with relevant Australian guidelines.

5.2.4 A summary of the baseline geological and hydrogeological setting of the three CSG fields, including evidence to support the conclusion that there is minimal hydraulic connectivity, is provided in Table 5.1.

Condition 53 (d) (ii) A program and timetable for repressurisation using re-injection of CSG water from hydraulically connected aquifers back into appropriate permeable aquifers and for other groundwater repressurisation options to re-establish pressure levels and water qualities to the satisfaction of the Minister on the advice of an expert panel, in conjunction with appropriate measures to forecast and proactively manage any short-term impacts.

Condition 53 (c) iv) baseline data for each monitoring site for comparison of monitoring results over the life of the project;

53 (b) The method, data and evidentiary standards necessary to support a conclusion that an aquifer from which CSG water is being extracted is not hydraulically connected to other aquifers.

Condition 49 (b) A program and schedule for aquifer connectivity studies and monitoring of relevant aquifers to determine hydraulic connectivity.

Table 5.1 Summary of Geological and Hydrogeological Setting

CSG field	Basin that CSG field is part of	Target coal seams	Relevant aquitard	Effectiveness of aquitard	Evidence of hydraulic connectivity
Roma	Surat Basin	Walloon Coal Measures	Westbourne Formation separates the Walloon Coal Measures from shallow aquifers used for stock and domestic purposes. Evergreen Formation separates the Walloon Coal Measures from deeper aquifers below (Hutton Sandstone and Precipice Sandstone).	Very effective due to the formation being thick and of near zero permeability.	Conservative groundwater modelling indicates that the Westbourne Formation will severely limit the potential for inter-aquifer transfer with some minor inter-aquifer transfer from the underlying Hutton Sandstone. Groundwater isotope analysis shows clear differences between the water from coal seams and main aquifers suggesting a lack of connectivity.
Fairview	Bowen Basin	Bandanna Formation	Rewan Formation separates the Bandanna Formation from overlying aquifers. The Black Alley shale separates the Bandanna formation from underlying aquifers.	Very effective due to the formation being very thick and of very low permeability.	Conservative groundwater fate and transport modelling indicate that there will be limited impact on groundwater quality, and a potential maximum impact of 3 m drawdown in the Precipice Sandstone in the south west of the Fairview CSG field in the vicinity of the contact zone between the Bandanna Formation and the Precipice Sandstone only. Groundwater isotope analysis shows clear differences between the water from coal seams and main aquifers suggesting a lack of connectivity.
Arcadia Valley	Bowen Basin	Bandanna Formation	Rewan Formation separates the Bandanna Formation from overlying aquifers. The Black Alley shale separates the Bandanna formation from underlying aquifers.	Very effective due to the formation being very thick and of very low permeability. There are no aquifers being used for town water supply and irrigation purposes.	Groundwater modelling shows that the risk to aquifers in the Arcadia Valley field is limited due the intended low levels of CSG development in this area, the spatial distribution of aquifers, and the presence of the Rewan Formation.

5.2.5 The water held in coal seams typically has a positive Dissolved Organic Carbon isotope ratio. Other aquifers and surface waters typically have a negative ratio. Analysing this ratio in groundwater can therefore provide a tool to trace water sources and to understand groundwater interactions. To date, Santos GLNG has taken 57 individual isotope samples from 22 different bores. All water samples taken from water bores to date (i.e. not coal seams) show negative isotope values, thereby indicating that there is no mixing and very low hydraulic connectivity between coal seams and aquifers. Additionally, the Office of Groundwater Impact Assessment has analysed 18 spring water samples, which were also shown to have negative isotope values, indicating no interaction with water from the coal seams.

5.2.6 Results to date support the conclusion that there is minimal connectivity between formations in the current environmental settings.

5.2.7 Table 5.2 provides detail on the current plans for continued hydraulic conductivity investigations for the next five years of the project life (2012-2017). Beyond this time, investigations will continue and be guided by the current program of studies.

Table 5.2 Activities to determine Hydraulic Connectivity of Aquifers

Study	Type of activity	Status
Wallumbilla Fault Program- Roma	Field program	In development
Contact Zone Program - Fairview	Field program	Progressing
Installation of deep monitoring bores	Field program	Progressing
Multi-level groundwater pressure monitoring	Field program and desktop assessment	Ongoing development, ongoing monitoring, ongoing assessment
Hydraulic vertical testing – Roma Coring and testing Program	Field program	Completed
Geological hydraulic conductivity mapping	Desktop assessment	Ongoing
Aquifer geochemical and isotopic signature	Field program and desktop assessment	Ongoing
Aquifer response – MAR testing	Field program	Completed
Aquifer response – private bores	Field program	Ongoing
Aquifer response – monitoring bores	Field program	Ongoing
Groundwater modelling	Desktop assessment	Ongoing

5.3 Subsidence

5.3.1 Depressurisation will be limited spatially and subject to strict monitoring to ensure any deviation from predictions are identified and if required, mitigated (as discussed in Section 5.2).

5.3.2 As the coal seams are depressurised and water is removed, the stress placed on the coal skeleton from the overlying rock increases. This can result in settlement of the formations, which manifests itself as subsidence at the surface. The maximum calculated subsidence is 0.28 metres for Roma, and 0.15m for Arcadia and Fairview. The risk that this amount of subsidence will impact surface water or groundwater flow is such a way as to impact upon Matters of National Envirnmental Significance is deemed extremely low.

5.3.3 Even though no impact is anticipated, Santos GLNG will conduct state of the art subsidence monitoring. This will include monitoring of pressure variations in aquifers and in the coal, and monitoring of ground surface displacement by satellite mapping. An exceedance response strategy is outlined within a ground motion monitoring and management plan that is submitted to the Department of the Environ,ent within this CWMMP.

Condition 65: In relation to subsidence, Santos is to provide: baseline and ongoing geodetic monitoring programs to quantify deformation at the land surface within the proponent's tenures; modelling to estimate the potential hydrological implications of the predicted surface and subsurface deformation, and measures for linking surface and sub-surface deformation arising from CSG activities.

Condition 53 (d) (iii) Subsidence or surface deformation occurs which impacts on surface or groundwater hydrology.

5.4 Hydraulic Fracturing

5.4.1 One hundred and twenty eight (128) wells out of 1,103 wells over the GLNG CSG tenements have been hydraulically fractured to date. Between 2012 and 2015, Santos GLNG plans to hydraulically fracture up to 200 wells over the three CSG fields. Whilst this number is not expected to be exceeded, there may be a need to undertake more or less hydraulic fracturing during this time, depending on the geology and permeability characteristics across the CSG fields.

Santos GLNG expects that approximately 70% of wells will be fractured over the remainder of the project in Fairview and Arcadia CSG fields and approximately 50% in the Roma CSG field

5.4.2 Santos GLNG adheres to strict State hydraulic fracturing procedures implemented by DEHP to ensure the process is undertaken safely and in a manner that does not impact upon the environment.

Condition 49 (e) The estimated number and the spatial distribution of boreholes where hydraulic fracturing may be necessary, an annual review of the estimate, and recording of actual use.

Fast Facts – Hydraulic Fracturing

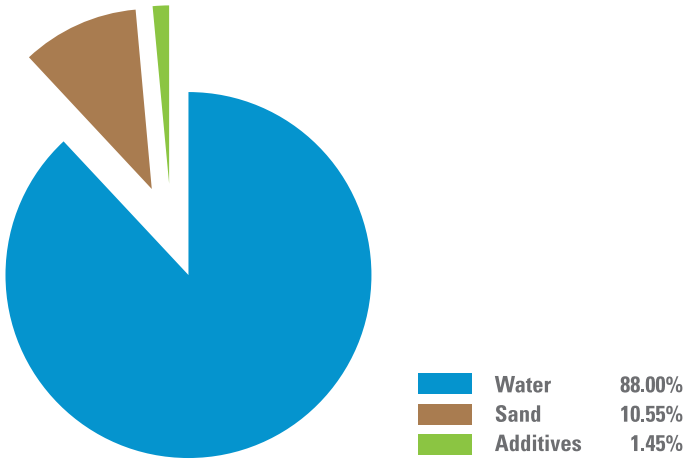
- Hydraulic fracturing is a process to safely open passageways into coal seams for the extraction of gas. It is not used for all wells.
- Hydraulic fracturing, or coal seam stimulation, reduces the number of required wells because it makes gas wells more productive.
- Fracturing fluid is pumped down a well at sufficient pressure to force open small passageways into the coal seam.
- Once the coal seam has been fractured, the fluid is pumped out of the well and only small amounts of diluted fluid remain in the coal seams, which are later recovered during gas production.

5.4.3 Hydraulic fracturing fluid includes around 99% water and sand and about 1% of a range of chemicals in minute, diluted quantities (refer Figure 5.1), which assist in carrying and dispersing the sand in the coal seam.

5.4.4 All of the chemicals Santos GLNG uses in the hydraulic fracturing process have been publicly disclosed on the DEHP website.

Figure 5.1 Composition of Hydraulic Fracturing Fluid

Condition 49 (f) Details of constituent components of any hydraulic fracturing agents and any other reinjected fluid(s), and their toxicity as individual substances and as total effluent toxicity and ecotoxicity, based on methods outlined in the National Water Quality Management Strategy.



5.4.5 Coal seam gas wells are lined with steel casing, which is cemented in place to isolate aquifers overlaying the coal seam. Pressure tests of casing and cement are conducted prior to hydraulic fracturing to guarantee the integrity of the well. Therefore, the risk of water contamination is minimal.

5.4.6 Chemicals used in the process are safe because they are used in very small quantities, typically at non toxic concentrations in the hydraulic fracturing fluid. They are handled in accordance with the appropriate legislation and have a minimal impact on the environment.

5.4.7 Santos GLNG has commissioned a range of assessments in relation to hydraulic fracturing, detailed in Table 5.3.

Table 5.3 Summary of Hydraulic Fracturing Assessments

Assessment	Scope	Key Results
Toxicological evaluation (human health and ecology)	Determine the toxicity of chemicals used in the hydraulic fracturing process	No "high" hazard-ranked chemicals were identified. Eleven chemicals were identified as chemicals of potential concern. Evaluation of the total toxicity of the mixed fracturing fluid has been evaluated through the application of a quantitative risk assessment approach based on fracturing and flow back monitoring data collected in 2011/2012. This quantitative assessment is constantly updated as new information becomes available.
Exposure pathways evaluation	Evaluate the potential exposure pathways on-site (i.e. within the drill pad) and off site (i.e. anything beyond the drill pad boundary)	The on-site assessment identified one complete exposure pathway - direct contact to the flow back water in the turkey's nest and mud pit for small native fauna (i.e. lizards and birds). All reasonable measures will be taken to discourage entry of small native fauna into the well pad area during hydraulic fracturing operations. The off-site exposure assessment was undertaken as a worst-case scenario. This found that potential exposures are unlikely when using Santos GLNG's operational and engineering controls. Fate and transport modelling found that the strong sorption capacity of the coal seam aquifers will significantly limit the transport potential of the organic hydraulic fracturing fluid components in coal seams. Migration was predicted to be less than 5 m beyond the hydraulic fracturing radius of influence.
Overall risk evaluation	Assess the risk of Santos GLNG's hydraulic fracturing practices, including an analysis of the chemicals used in the process and their potential impacts on both human health and the environment	Considering the operational controls implemented by Santos GLNG, the overall risk to human health and environment associated with the chemicals involved in hydraulic fracturing are evaluated to be Risk Category 1, and therefore considered to have no significant impact on Matters of National Environmental Significance. Key operational controls include: • Occupational health and safety procedures implemented during hydraulic fracturing operations; • Implementation of spill containment procedures during operations to prevent migration of and exposure to chemicals; • Santos GLNG operational procedures to ensure well integrity and design of fracture to stay within the target seam; and • Lining of mud pits and turkey's nests to prevent seepage of flow back water into underlying aquifers.

5.4.8 Santos GLNG has agreed with the Department of the Environment to undertake additional Toxicity Assessments as part of the joint industry Ecotoxicity Work Program. This program includes an ecotoxicological program, involving the testing of representative coal seam waters from wells to be fractured this year and testing hydraulic fracturing fluid and coal seam water as formulated for injection

5.4.9 Santos GLNG will provide routine updates to both the Queensland and Australian Governments, where significant deviations from the planned schedule occur. The need for hydraulic fracturing is subject to change and is affected by the progress of drilling and well completion activities, the availability of resources and field based information.

Condition 53 (c) (viii) mechanisms to monitor, avoid, minimise, manage, and respond to risks; and

Condition 43: Environmental measures to ensure CSG water has no significant impact on MNES during or beyond the life of the project. Where impacts arise, develop mitigation measures.

Condition 49 (d) early warning indicators where drawdown thresholds are being approached.

Condition 53 (c) (vi) groundwater drawdown threshold values and groundwater quality threshold values for each aquifer (based on regional groundwater modelling endorsed by the Minister) at which management actions (such as reporting or control line values for additional investigation, more intensive management action, make good, and cease operations) will be initiated to respond to escalating levels of risk, including increasing levels of drawdown, contamination of groundwater, or subsidence.

6 Environmental Risk Management

6.1.1 Santos GLNG has conducted a detailed, semi-quantitative risk assessment to evaluate the risks posed to Matters of National Environmental Significance from activities associated with extracting water from coal seams. This considered the findings of the Underground Water Impact Report and also covered the following CSG activities: drilling and well construction; production (depressurisation); gathering (pipelines, storage tanks and ponds); water reuse and brine management.

6.1.2 The Santos GLNG risk assessment framework complies with the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:2004). It rates risks using a five-point scale. A Category 1 risk is considered to be tolerable in its current state without the need for mitigation actions to reduce the risk. Category 1 risks are still monitored, but they generally represent risks that are either very unlikely to occur, or that would result in a minor or negligible consequence. Risks assessed as Category 2 to 5 may still be tolerable but require further evaluation of potential management or mitigation measures.

6.1.3 All risk ratings related to Matters of National Environmental Significance, post mitigation, were rated as Category 1 (zero or negligible). Any risks that were identified will be managed and/or mitigated by:

- Implementing environmental and operational monitoring;
- Implementing industry best practices;
- Implementing managed aquifer recharge by injection schemes or virtual injection; and
- Implementing adaptive management schemes.

6.1.4 The risk assessment has therefore identified that the potential risks to Matters of National Environmental Significance identified in the Underground Water Impact Report can all be appropriately mitigated by implementation of the above measures. It is therefore concluded that Santos GLNG have addressed the Commonwealth requirement for no impact on Matters of National Environmental Significance during and beyond the life of the GLNG project.

6.1.5 To identify potential future impacts, Santos GLNG has developed a series of early indicators, as per Condition 49 (d). This is discussed in Section 7 of this Summary Plan.

7 Monitoring and Response

7.1 Overview

7.1.1 Comprehensive monitoring provides assurance of predictions and early warning of unexpected impacts. Santos GLNG is investing in one of the most significant surface and groundwater monitoring programs in Australia. Through this program, Santos GLNG will be aware of potential groundwater changes several years in advance of their first appearance in local aquifers. This will allow the company to take appropriate groundwater management action to avoid these impacts, and 'make good' on potential adverse impacts.

7.1.2 The monitoring and management of EPBC springs will be undertaken through a Joint Industry Plan which will produce a collaborative Early Warning System Scheme for the monitoring and management of EPBC springs. The Joint Industry Plan relates to the management of risk and impact to EPBC springs in the southern Bowen and Surat Basins and includes Santos GLNG, APLNG and QGC. Arrow have been consulted and support the Joint Industry Plan. The Plan includes:

- The development of an EPBC spring 'early warning' monitoring scheme;
- Multiple spring monitoring exercises at the identified EPBC spring;
- Spring-specific triggers and a response system for early impact;
- A Response Plan; and
- A spring mapping exercise for the areas within 100km of the maximum predicted drawdown extent (Surat Basin Underground Water Impact Report, 2012).

Note: The assessment of spring mitigation options for a number of springs is currently underway, in response to Queensland regulatory requirements, for those on-tenement springs where an impact is predicted.

7.2 Joint Industry Plan for Early Warning System for the Monitoring and Management of EPBC Springs

7.2.1 Santos GLNG has initiated the Joint Industry Plan to address the risk of groundwater drawdown from the CSG production areas towards springs that host ecological communities listed as Matters of National Environmental Significance under the Environment Protection and Biodiversity Act 1999 (EPBC Act). The Joint Industry Plan addresses Santos GLNG EPBC conditions (69.b) i), iv) and v) and similar conditions that apply to QGC and APLNG. The approach to the Plan has been informed by comments from Geoscience Australia and SEWPaC (now the Department of the Environment). The SEWPaC (now the Department of the Environment) requirements include:

- a specific mechanism (ie. the Early Warning System) to avoid, minimise and manage risks and provide response actions;
- trigger values at which management actions will be initiated;
- a specific monitoring and response program; and
- analysis of the monitoring results, against baseline data, for the life of the project.

7.2.2 The Joint Industry Plan is based on the following key concepts:

- the monitoring of primary source aquifers only;
- the concept of impact propagation;
- the use of groundwater levels as a proxy to impact to an EPBC spring; and
- the use of the regional groundwater model definition in the Surat Underground Water Impact Report.

Condition 53 (c)
A groundwater quality and quantity monitoring plan to monitor the aquifers underlying the project area using a statistically and hydrogeologically valid best practice bore monitoring network across the project area.

Condition 49 (g) (ii)
Number and locations of monitoring sites upstream and downstream of proposed discharge of CSG water (whether treated water, amended water or raw water) including test and reference sites upstream and downstream and before and after proposed impacts.

Condition 49 (g) (vi)
threshold values that protect relevant MNES (such as reporting or control line values for additional investigation, more intensive management action, make good, and cease operations) at which management actions will be initiated to respond to escalating levels of risk and designed to protect water quality and the associated environmental values of surface and aquatic systems.

To address the management of EPBC springs, the Joint Industry Plan defines:

- an early warning system of monitoring bores located between the areas of CSG production and the EPBC spring;
- escalating levels of triggers which provide sufficient time to further assess or develop and implement a mitigation solution; and
- a response plan should one of the triggers be exceeded.

7.2.3 The work contained in the Joint Industry Plan to address the Department of the Environment requirements is in addition to joint industry studies that address:

- a 200 metre exclusion zone for on-tenement springs;
- a baseline analysis across a year to establish the seasonal presence or absence of springs; and
- ongoing monitoring of EPBC springs where an impact is predicted in the Surat area (every 6 months) over the life of the project.

7.3 Santos GLNG's Monitoring Framework

7.3.1 Santos GLNG's Environmental Monitoring and Reporting Strategy (EMRS) provides the framework for monitoring Environmental Values. The EMRS specifies monitoring requirements over the site and surrounding areas, including groundwater, surface water and spring monitoring. The EMRS is based on:

- The regulatory requirements;
- A risk assessment, defining the level of risk associated with each potential impact, and thus prioritising monitoring of higher risk ratings; and
- A pro-active monitoring approach aimed at early detection of any detrimental impacts.

7.3.2 Santos GLNG's EMRS commits to implementing the recommendations of the Underground Water Impact Report. The EMRS provides details on why monitoring is being conducted.

7.3.3 Santos GLNG has also developed an Environmental Monitoring Plan (EMPl). This document presents the monitoring requirements related to CSG infrastructure and activities at various locations within the Roma, Fairview and Arcadia CSG fields. By using this EMPl, field staff will be able to determine the type and frequency of sampling for a particular activity or monitoring site. The EMPl provies the details of what to monitor, where to monitor and when to monitor.

7.3.4 Santos GLNG is currently assessing and refining methodologies for statistical completeness of the collected monitoring data. These evaluations are being conducted in a manner consistent with the ANZECC (2000) and other monitoring system design guidelines, such that physical risks to aquifers are also considered in the design of the monitoring program. To-date, the statistical assessment of existing monitoring data suggests that:

- Temporally, the length of 'baseline' and 'operational' baseline periods should be at least 12 months, assuming a quarterly sampling period;
- Spatially, quarterly samples from 28 monitor bores are required to define a mean baseline concentration level with 95% confidence; and
- Statistical analysis will be used to identify natural variations and thus enable identification of non-natural variations including CSG induced impact.

7.4 Location and Frequency of Monitoring

7.4.1 Monitoring sites were selected to:

- Establish statistically significant baseline conditions; and
- Enable early detection of any detrimental impacts from Santos GLNG activities on the receiving environment so that preventative actions can be taken.

7.4.2 The aquifers that are / will be monitored are as follows:

- Mooga Sandstone;
- Orallo Formation;
- Gubberamunda Sandstone;
- Springbok Sandstone;
- Clematis Sandstone;
- Hutton Sandstone; and
- Precipice Sandstone.

Note: only the Hutton Sandstone, Precipice Sandstone and Clematis Sandstone are identified as primary source aquifers of EPBC springs.

7.4.3 The rationale for selection of these aquifers for detailed monitoring is that these aquifers are known to be mostly used for one or more of the following conditions:

- Local water supply;
- They support Groundwater Dependant Ecosystems; and
- They are referred to in the GAB Resource Plan.

7.4.4 Santos GLNG has specified the following target groundwater monitoring location spacing:

- One location per aquifer per 100 square kilometres (nominally 10 kilometres spacing between locations); and
- A maximum spacing of one location per aquifer per 200 square kilometres (nominally 14 kilometres spacing between locations).

7.4.5 This spacing was selected after considering regional groundwater modelling of the extent and gradient of maximum predicted drawdowns in the aquifer. Figures 7.1 and 7.2 illustrate the number and locations of existing and planned monitoring sites. Information obtained from Santos GLNG's baseline bore assessment and DEHP was used to determine the flow, pressure, head and water quality characteristics of each bore.

7.4.6 Once the spacing of monitoring locations was specified, Santos GLNG reviewed the existing (landholder) bores that were suitable for inclusion in a permanent network. Infill monitoring locations that were required to be established by Santos GLNG to meet the spacing specification were then defined. Santos GLNG plans to develop those new locations by:

- Drilling new monitoring bores;
- Converting abandoned conventional oil and gas wells to multi-stage monitoring locations; or
- Using exploration holes as multi-stage monitoring locations.

7.4.7 When developing the monitoring network, Santos GLNG took care to provide a number of locations where vertical groundwater gradients could be measured from monitoring locations within 500 meters of each other. This involves using vibrating wire piezometers in a single deep hole, supplemented by co-located boreholes where necessary. Data from these vertical gradient arrays will be valuable in the assessment of aquifer connectivity.

7.4.8 In addition to the Santos GLNG-developed monitoring network, the Underground Water Impact Report has specified groundwater monitoring locations. It includes the results of groundwater flow modelling and estimated drawdown, taking into account the cumulative effects of CSG operations in the Surat Cumulative Management Area.

7.4.9 Santos GLNG and its industry collaborators have assimilated the estimated drawdown from the Office of Groundwater Impact Assessment's model results in order to develop a systematic, 'small-footprint' approach to monitoring the cumulative impact of aquifer drawdown across the production tenements and adjacent impact areas. This monitoring system will focus on established Matters of National Environmental Significance values, including the EPBC-listed springs identified in the Queensland Herbarium's report[18] and will incorporate the latest recommendations made by Geoscience Australia to SEWPaC (now the Department of the Environment) in November 2012.

Condition 53 (c) (i) The aquifers to be monitored and the rationale for selection.

Condition 53 (c) (ii) The number and locations of monitoring bores and their flow, pressure, head and water quality characteristics.

Condition 49 (g) (i) Identification of the surface and aquatic ecosystems to be monitored and their environmental values, water quality, and environmental characteristics, and the rationale for selection.

Condition 49 (b) A program and schedule for aquifer connectivity studies and monitoring of relevant aquifers to determine hydraulic connectivity.

[18] *Queensland Herbarium, Ecological and Botanical Survey of Springs in the Surat Cumulative Management Area, 2012*

Condition 53 (c) (iii) The frequency of the monitoring and rationale for the frequency.

7.4.10 The frequency of water monitoring and the rationale for that frequency is defined in the EMRS[19] and provided on a site-specific basis in the EMPl. Table 7.1 provides a summary of groundwater monitoring frequency.

Table 7.1 Groundwater Monitoring Frequency

Recommended Monitoring by Agency	Groundwater Level	Water Quality Indicator (e.g., EC, Temp, pH)	Water Quality Physio and Chemical Parameters
Groundwater Sampling and Analysis – A Field Guide; Geo Sciences Australia (Basic resource monitoring)	Quarterly	Annual	As required
Groundwater Sampling and Analysis – A Field Guide; Geo Sciences Australia (sensitive site monitoring e.g., significant drawdown, groundwater quality impacts)	Daily	Monthly	Quarterly
DEHP Monitoring and Sampling Manual 2009. Section 2.2.3	No specification at discretion of sampling designer	No specification at discretion of sampling designer	No specification at discretion of sampling designer
UNSW Connected Waters (Shallow groundwater)	Weekly (during pumping) Monthly at other times	Monthly during pumping	Annually (for major ions)
Santos GLNG EMPl	Daily, continuous, monthly, quarterly	Continuous, monthly, quarterly, six monthly	Continuous, monthly, quarterly, six monthly

Condition 49 (g) (iv) baseline data for each monitoring site for comparison of monitoring results over the life of the project;

Condition 49 (g) (iii) The frequency of the monitoring and rationale for the frequency.

Condition 49 (g) (i) Identification of the surface and aquatic systems to be monitored and their environmental values, water quality, and environmental characteristics, and the rationale for selection.

7.4.11 The surface water monitoring locations are illustrated in Figures 7.1 and 7.2. These sites were selected to:

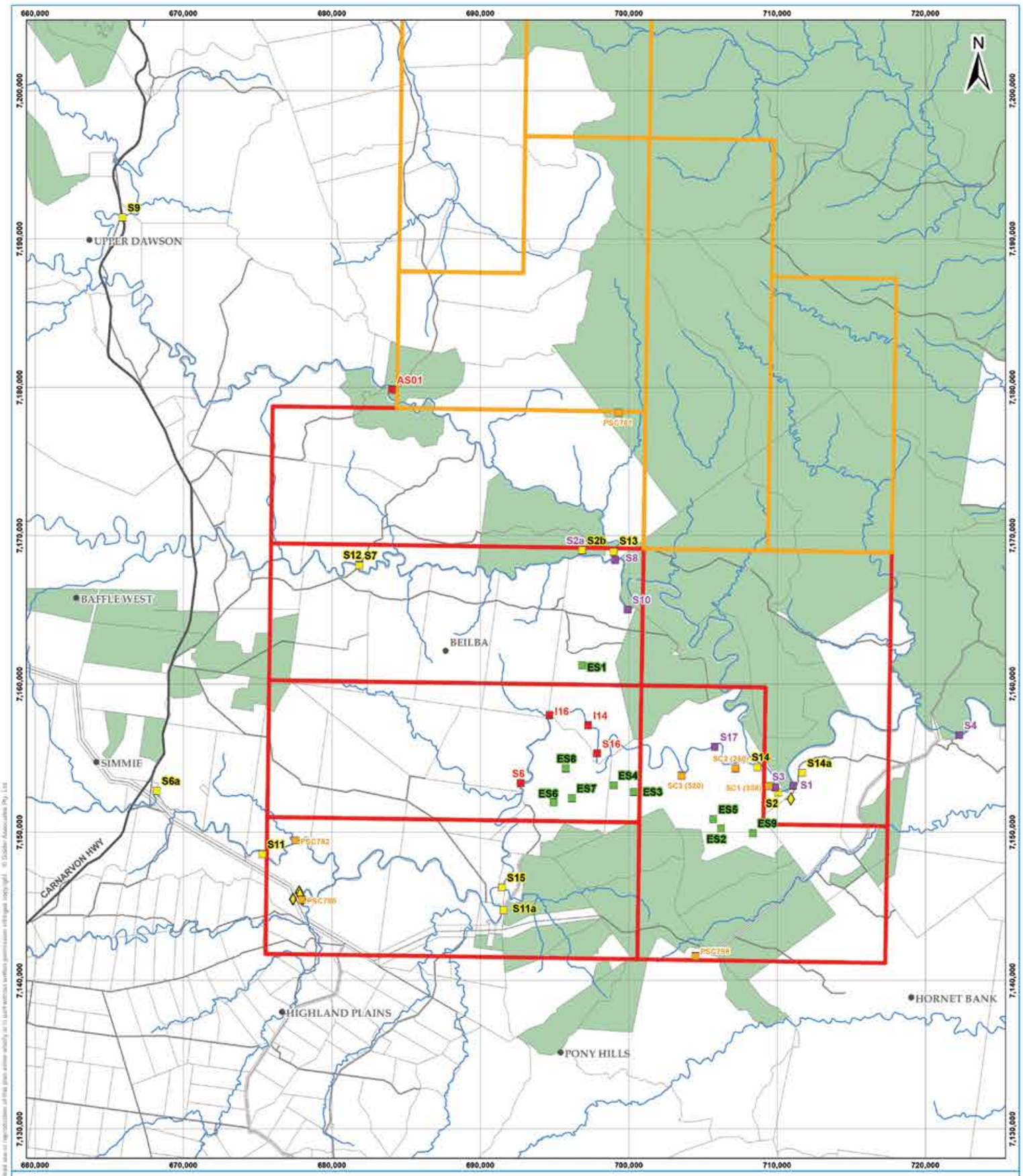
- Establish baseline conditions upstream and downstream of Santos GLNG planned activities (of which significant data has already been acquired, but is not expected to be complete until GLNG enters the full production phase); and
- Monitor potential impacts from Santos GLNG's planned activities, such as irrigation projects, on surface water systems.

7.4.12 In future, it is proposed that only treated water will be released to surface water from the Fairview CSG field. Santos GLNG has undertaken a Direct Toxicity Assessment to establish appropriate trigger values and define appropriate upstream and downstream monitoring locations for the proposed release to surface waters.

7.4.13 Santos GLNG will preserve the water quality in watercourses by implementing a groundwater and surface water monitoring program and adaptive management schemes. The water quality and environmental characteristics of the surface water systems are monitored and assessed against water quality objectives, defined to protect the Environmental Values associated with surface water systems. Of relevance to Matters of National Environmental Significance under the EPBC are the Groundwater Dependant Ecosystems associated with springs sourced from the GAB. Aquifers which typically support species listed as Matters of National Environmental Significance are addressed in the Joint Industry Plan (JIP). Non EPBC listed springs and watercourse springs occur at a limited number of locations within the project area and predicted impact zone, all of which will be monitored accordingly.

[19] *Santos, Environmental Monitoring and Reporting Strategy, 2011*

Figure 7.1 Surface Water Monitoring – Fairview



GLNG ENVIRONMENTAL MONITORING PLAN

SANTOS

SURFACE WATER MONITORING - FAIRVIEW

LEGEND

- Town
- EPBC Listed Spring

Monitoring Locations

- Springs
- Santos Ephemeral Surface Water Monitoring Location

Santos Perennial Surface Water Monitoring Locations

- Upstream
- Midstream
- Downstream

- Creek/River
- Highway / Main Road

ATP/ PL Field

- Arcadia Valley - GLNG Project area
- Fairview - GLNG Project area

0 1 2 4 6 8 10 km

SCALE (at A3) 1:250,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117636002-11000-003
DATE: MARCH 2013
DRAWN: SL/BAL
CHECKED: VA

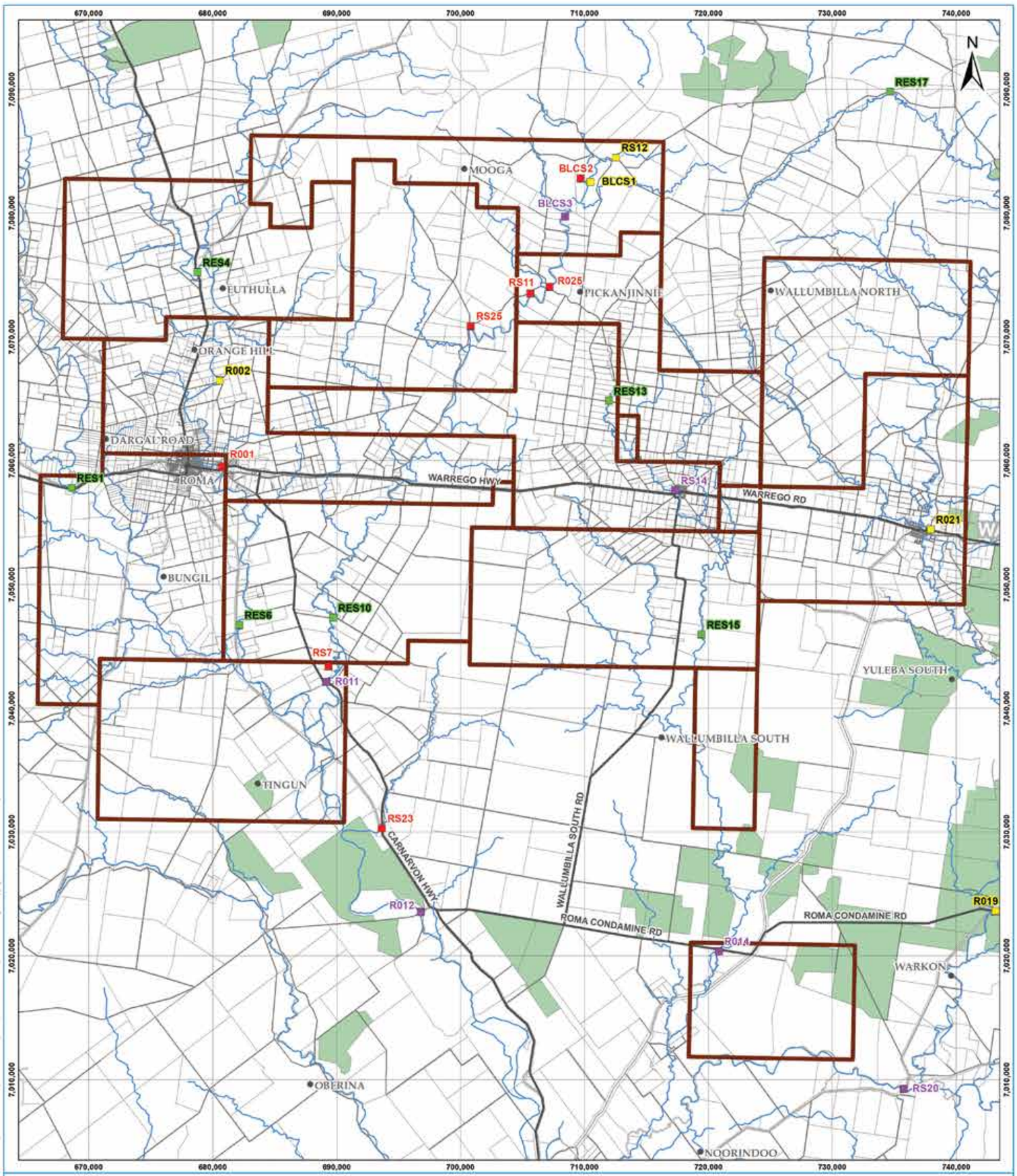
FIGURE B1

NOTES

1. Base map data copyright MapInfo Australia Pty Ltd.
2. ATP/PL tenure supplied by Santos, January 2009.
3. Springs sourced from Herbarium dataset provided by Santos.

Santos GLNG Project

Figure 7.2 Surface Water Monitoring – Roma



GLNG ENVIRONMENTAL MONITORING PLAN

SANTOS

SURFACE WATER MONITORING - ROMA

LEGEND

- Town
- Santos Ephemeral Surface Water Monitoring Location

Santos Perennial Surface Water Monitoring Locations

- Upstream
- Midstream
- Downstream
- Creek/River
- Highway / Main Road

ATP/ PL Field

- Roma - GLNG Project area

0 1 2 4 6 8 10 km

SCALE (at A3) 1:300,000

Coordinate System: GDA 1994 MGA Zone 55

PROJECT: 117636002-3100
DATE: MARCH 2013
DRAWN: SL/BAL
CHECKED: VA

FIGURE E2

NOTES

1. Base map data copyright MapInfo Australia Pty Ltd.
2. ATP/PL tenure supplied by Santos, January 2009

Santos GLNG Project

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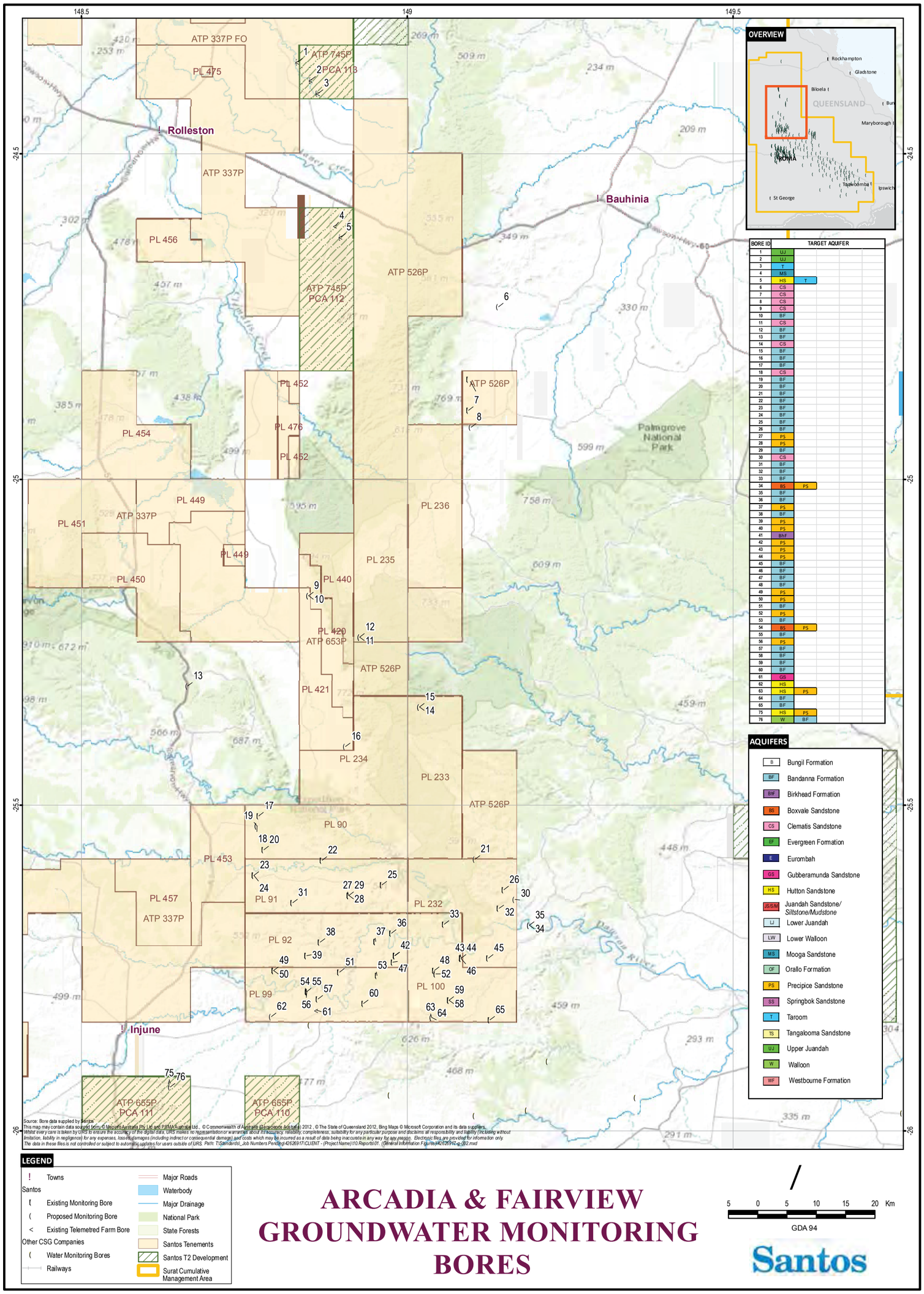
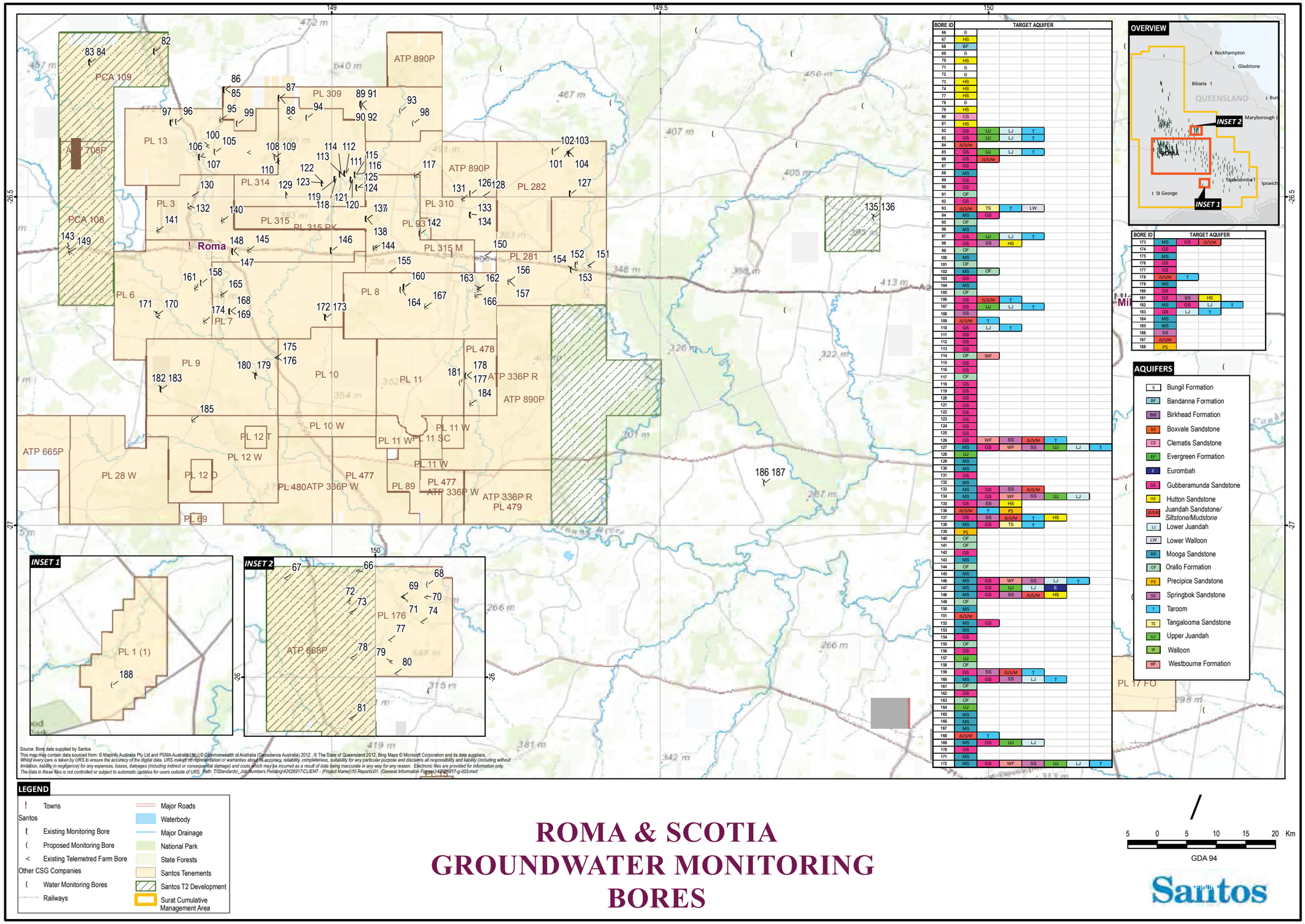


Figure 7.3 Groundwater Monitoring – Arcadia Valley and Fairview

Figure 7.4 Goundwater Monitoring – Roma and Scotia



7.5 Analysis and Trend Identification of Monitoring Results

Condition 53 (c) (v) The approach to be taken to analyse the results including the methods to determine trends to indicate potential impacts.

Condition 49 (g) (v) and Condition 53 (c) (v) The approach to be taken to analyse the monitoring results including the method to determine trends to indicate potential impacts.

7.5.1 Santos GLNG imports all monitoring data into a centralised database called EQuIS. This sophisticated database allows for automated trend analysis and comparison of data against baseline information and limit levels. Any exceedance above programmed thresholds triggers an automated alert. Any exceedance above programmed limit levels will cause an automated alert. Limit levels can be based on:

- Compliance limits;
- Early warning levels;
- Increase above pre-existing statistical norms;
- SEWPaC (now the Department of the Environment) 'Exceedance Levels';
- DEHP 'Trigger Levels'; and
- Others, as required.

7.5.2 Trend analysis will be used to remove natural variations from datasets. They will be applied after collection of a statistically representative dataset to initially define "reference values".

7.6 Groundwater Trigger and Drawdown Limits

Condition 53 (c) (vi) Groundwater drawdown threshold values and groundwater quality threshold values for each aquifer (based on regional groundwater monitoring endorsed by the minister) at which management actions (such as reporting or control line values for additional investigation, more intensive management action, make good, and cease operations) will be initiated to respond to escalating levels of risk, including increasing levels of drawdown, contamination of groundwater, or subsidence.

Condition 49 (d) early warning indicators where drawdown thresholds are being approached.

Condition 49 (h) Mechanisms to avoid, minimise and manage risk of adverse impacts and response actions and timeframes that can be taken by the proponent if: (1) threshold values for surface water quality and water environmental values specified in the CWMMP are exceeded.

Condition 49 (a) Groundwater drawdown limits for each targeted aquifer.

Condition 53 (c) (viii) mechanisms to monitor, avoid, minimise, manage, and respond to risks.

7.6.1 Santos GLNG has agreed to meet the environmental monitoring requirements set by both SEWPaC (now the Department of the Environment) and DEHP, and has defined a monitoring approach for each Environmental Value, as shown in Table 7.2. This includes three levels of Exceedance Levels' at EPBC springs (instructed by SEWPaC) (now the Department of the Environment) and 'Trigger Levels' at private bores (instructed by DEHP) which are set to provide an early warning of potential impacts, and inform the subsequent response. The approach gives early warning of potential loss of spring pressure. As such, it preserves the Matters of National Environmental Significance values of GAB springs to protect the springs' ecology and natural variation in spring flow.

7.6.2 Santos GLNG's impact monitoring program for Matters of National Environmental Significance will ensure that both Commonwealth and Queensland State requirements are met. In some cases in relation to groundwater, Santos GLNG has combined the outputs from SEWPaC (now the Department of the Environment) and DEHP guidance, and considered its own analysis, to derive conservative 'exceedance levels' that initiate mitigative action.

7.6.3 In respect to EPBC springs, groundwater triggers and drawdown limits are defined in the Joint Industry Plan. The exceedence levels are defined for a nominated set of monitoring bores located between the area of impact propagation and the spring. A set of exceedance values will be established for each bore based on the most recent cumulative groundwater model results.

7.6.4 Exceedence levels are defined for three escalating levels of impact:

- an investigation trigger;
- a management / mitigation trigger; and
- a drawdown limit.

Values of exceedences are derived from the Surat Underground Water Impact Report model results.

7.6.5 For private bores exceedance levels are set to provide an early warning of potential impacts. Because the impact itself would commence at a later time, exceedance of a trigger level would provide significant lead time to conduct corrective actions, such as 'make good'. This ensures the risk is manageable and therefore considered to be negligible.

7.6.6 Santos GLNG will also execute annual reviews of the data collected thought the extensive monitoring program, to continuously update knowledge on the potential to reach defined thresholds level.

Table 7.2 Environmental Monitoring Criteria and Response

Environmental Value / MNES	Number of Monitoring Points	Monitoring Details	Trigger and Threshold Levels as defined by DEHP/ SEWPAC
Surface Water			
Springs	3 spring clusters	• Continuous electrical conductivity, water level (when automated); • Event based sampling (automated) • Six-monthly field suite and surface water baseline suite	• 0.2m drawdown for active springs (DEHP) • Trigger exceedance levels and drawdown limit in primary aquifer source (SEWPAC).
	All springs	Spring survey (baseline, then ongoing)	
Intermittent springs	–	Inspection in January, April, July and October and following heavy rainfall.	
Ephemeral streams	16 locations	• Continuous electrical conductivity and water level (automated) • Event based sampling (automated) • Six-monthly field suite and surface water baseline suite	• 10% change in measured flow (DEHP) • 10% change in water chemistry parameters (DEHP)
Perennial streams	44 locations – 6 upstream & 1 downstream Fairview CSG field, 2 upstream & 4 downstream of Roma CSG field. Other locations are with the CSG fields.	• Continuous electrical conductivity, pH, dissolved oxygen, water level (when automated); • Event based sampling (automated) • Six-monthly field suite and surface water baseline suite	• 10% change in measured flow (DEHP) • 10% change in water chemistry parameters (DEHP)
Groundwater			
Regional groundwater	Private bore – 90 locations	Six-monthly for : • Baseline groundwater suite (quarterly initially) • Field suite • Water level	• 5m drawdown for consolidated aquifers such as a sandstone aquifer* • 10% change in water chemistry parameters • Trigger exceedance levels and drawdown limit in primary aquifer source (SEWPAC).
	Dedicated groundwater monitoring bores – 37 locations	Six-monthly for : • Baseline groundwater suite (quarterly initially) • Field suite • Water level Or daily if equipped with a logger	
	Multi-levels VWP – 122 locations	Daily water level as a minimum (automated)	
Hydraulic Fracturing	Exploration well where hydraulic fracturing is undertaken	Refer to Stimulation Impact Monitoring Program (essentially monitoring against baseline conditions) (as per DEHP EA requirements)	Assessed against baseline conditions (as per DEHP EA requirements)

8 Reporting

Condition 49 (i) and Condition 53 (c) (ix) Performance measures, annual reporting to the Department, and publication of reports on the internet.

8.1.1 Santos GLNG is focused on maintaining continual improvement in environmental performance. Santos GLNG acknowledges that regular reporting is critically important to that process.

8.1.2 Santos GLNG will publish the following reports on the Santos Water Portal (www.santoswaterportal.com.au)

- Link to the Surat Cumulative Management Area – Underground Water Impact Report
- Quality checked data from Santos GLNG's monitoring network will be published quarterly on the portal. This includes: groundwater levels and quality; surface water, levels, flows and quality; water pressure; climate data; water reuse figures; and contoured data of water levels and water quality.
- A Coal Seam Water Monitoring and Management Annual report will be developed. This will report on progress against commitments outlined in Annex C.
- The CWMMP (Stage 2 – Revised), following approval by the Department of the Environment.

8.1.3 The annual performance reports and impact statement updates will also be published on the Santos website (www.santos.com).

Annex A – EPBC Approval Conditions & Location of Response in Summary Plan

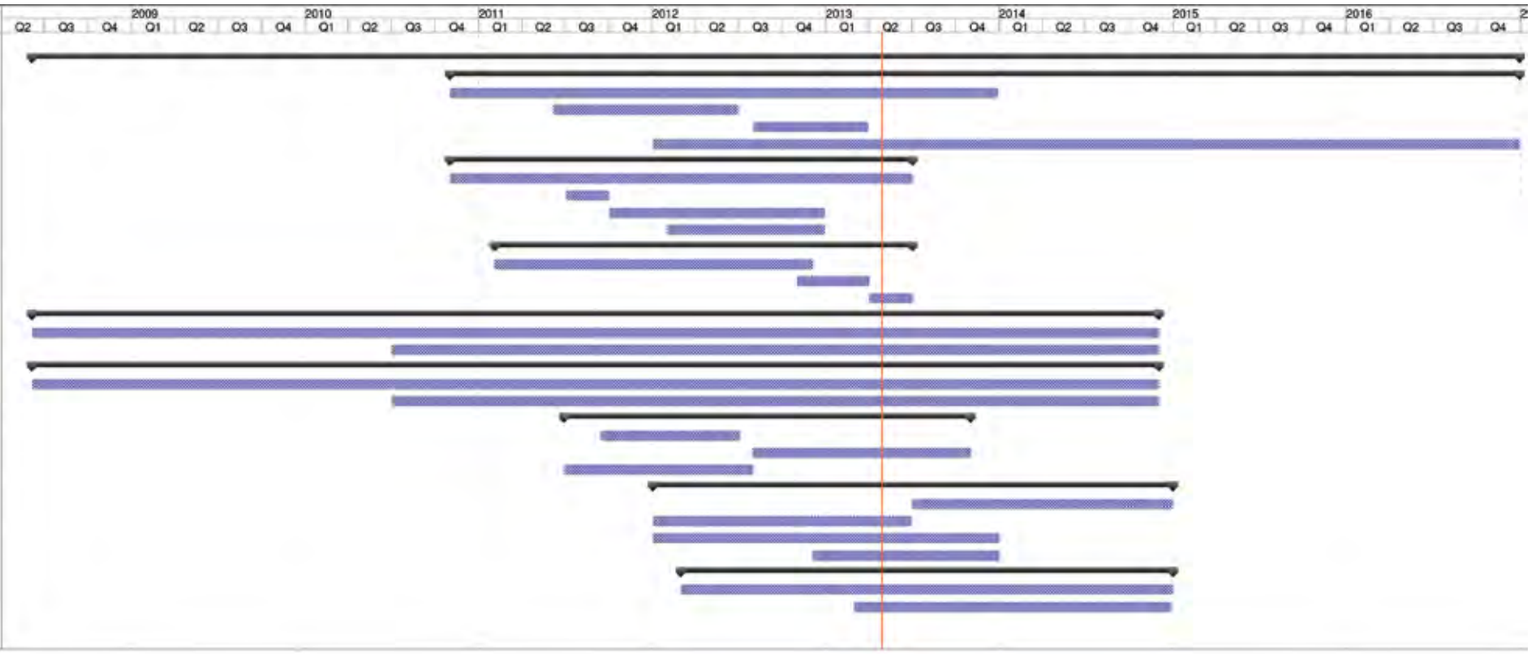
EPBC Approval Condition	Topic	CWMMP Summary Plan Reference	CWMMP Full Report Reference
		Section	Section
Stage 1 CSG Water Monitoring and Management Plan			
49	Within 6 months from the date of the project approval, the proponent must submit for the approval of the Minister a Stage 1 Coal Seam Gas Water Monitoring and Management Plan (Stage 1 CSG WMMP) which includes at least:	By submission	By submission
49 (a)	groundwater drawdown limits for each targeted aquifer;	Section 7.6 Table 7.2	Section 7.6, 7.7
49 (b)	a program and schedule for aquifer connectivity studies and monitoring of relevant aquifers to determine hydraulic connectivity;	Section 5.2, 7.4 Table 5.2	Section 7.6, 7.10, Appendix J
49 (c)	a program and schedule for field piloting of aquifer reinjection of treated CSG water and other groundwater repressurisation techniques;	Section 4.6	Section 4.8, 4.11.4, 4.12.4, 4.13.1, 5.2
49 (d)	early warning indicators where drawdown thresholds are being approached.	Section 7.6 Table 7.2	Section 7.6, 7.7 Appendix I
49 (e)	the estimated number and the spatial distribution of boreholes where hydraulic fracturing may be necessary, an annual review of the estimate, and recording of actual use;	Section 5.4	Section 4.5
49 (f)	details of constituent components of any hydraulic fracturing agents and any other reinjected fluid(s), and their toxicity as individual substances and as total effluent toxicity and ecotoxicity, based on methods outlined in the National Water Quality Management Strategy;	Section 5.4 Table 5.3 Figure 5.1	Section 5.4, Appendix C
	An ongoing water quality and quantity surface water monitoring plan that includes at least:	Section 7	Section 7.5
	i) identification of the surface and aquatic systems to be monitored and their environmental values, water quality, and environmental characteristics, and the rationale for selection;	Section 1.4 and 7.4 Table 1.3,1.4 Table 7.2 Figure 7.1, 7.2	Section 3.4, 3.8, 7.4, 7.5
	ii) the number and locations of monitoring sites upstream and downstream of proposed discharge of CSG water (whether treated water, amended water or raw water), including test and reference sites upstream and downstream and before and after any proposed impacts;	Section 7.4 Figure 7.1, 7.2, 7.3, 7.4 Table 7.1, 7.2	Section 4.9, 7.5.1
	iii) the frequency of the monitoring and rationale for the frequency;	Section 7.4 Table 7.1	Section 7.5 Appendix F and G
	iv) baseline data for each monitoring site for comparison of monitoring results over the life of the project;	Section 7.4	Section 7.4.1, Appendix H
	v) the approach to be taken to analyse the results including the methods to determine trends to indicate potential impacts;	Section 7.5	Section 7.11
49 (g)	vi) threshold values that protect relevant MNES (such as reporting or control line values for additional investigation, more intensive management action, make good, and cease operations) at which management actions will be initiated to respond to escalating levels of risk and designed to protect water quality and the associated environmental values of surface and aquatic systems;	Section 7.2, 7.5, 7.6	Section 7.51, 7.5.2, Appendix F and G
	vii) water treatment and amendment methods and standards;	Section 4.5	Section 4.7, 4.11.3, 4.12.3, 4.13
	viii) water storage locations and volumes including any storage and volumes required to pilot or implement reinjection or other groundwater repressurisation techniques;	Section 4.4 Table 4.3 Figure 4.3, 4.4 and 4.5	Section 4.6, 4.11.2, 4.11.6, 4.12.2, 4.12.6, 4.13, Table 4-12, 4-22, 4-28

EPBC Approval Condition	Topic	CWMMP Summary Plan Reference	CWMMP Full Report Reference
		Section	Section
	ix) water use or disposal options and methods (whether for beneficial use or not) including frequency, volumes, quality and environmental values documented for each receiving environment;	Section 4.7 Table 4.4 Figure 4.6 and 4.7	Section 3.4, 3.8, 4.8, 4.9, 4.11.4, 4.11.5, 4.12.4, 4.12.5, 4.13, Appendix D.
	x) brine storage locations and volumes, and brine crystal waste management;	Section 4.8 Table 4.3 Figure 4.3 and 4.4	Section 4.10, 4.11.6, 4.12.6, 4.13.2, Table 4-20, 4-26
	xi) emergency water discharges, their volumes and quality; and	Section 4.4.7, 4.4.8	Section 4.14, Appendix E
	xii) references to standards and relevant policies and guidelines.	Section 1.3	Section 2.4, References in Section 10 cited throughout CWMMP
49 (h)	mechanisms to avoid, minimise and manage risk of adverse impacts and response actions and timeframes that can be taken by the proponent if:		Section 6.2
	1) threshold values for surface water quality and water environmental values specified in the CSG WMMP are exceeded	Table 7.2 Section 7.6	Section 7.5.2, 7.8 Appendix I
	2) there are any unforeseen emergency discharges.	Section 4.4.7, 4.4.8	Section 4.14, Appendix E
49 (i)	performance measures, annual reporting to the Department, and publication of reports on the internet.	Section 8	Section 8.1, 8.2, 8.3, Table 1-4
Stage 2 CSG Water Monitoring and Management Plan			
53	In addition to the matters in the Stage 1 CSG WMMP, the Stage 2 CSG WMMP must also include:	By submission	By submission
53 (a)	an ongoing CSG water treatment program to ensure that any water to be used for re-injection, or used for other groundwater repressurisation options, is treated at least equal to the water quality of the receiving groundwater system or environment;	Section 4.6, 4.7	Section 4.7, 4.8, Table 3-5
53 (b)	the method, data and the evidentiary standards necessary to support a conclusion that an aquifer from which CSG water is being extracted is not hydraulically connected to other aquifers;	Section 5.2. Table 5.1, 5.2	Section 7.10, Appendix J
53 (c)	a groundwater quality and quantity monitoring plan to monitor the aquifers underlying the project area using a statistically and hydrogeologically valid, best practice bore monitoring network across the project area addressing at least;	Section 7	Section 7.6.1, 7.7
	i. the aquifers to be monitored and the rationale for selection;	Section 7.4	Section 7.6.1, 7.7, Appendix F and G
	ii. the number and locations of monitoring bores and their flow, pressure, head, and water quality characteristics;	Section 7.4 Figure 7.1, 7.2, 7.3, 7.4	Section 7.6.1, 7.7, Table 7-6, Appendix F and G
	iii. the frequency of the monitoring and rationale for the frequency;	Section 7.4 Table 7.1	Section 7.6.1, 7.7, Table 7-6, Appendix F and G
	iv. baseline data for each monitoring site for comparison of monitoring results over the life of the project	Section 5.2	Section 3.7, 7.4.3, 7.4.4, Appendix H
	v. the approach to be taken to analyse the results including the methods to determine trends to indicate potential impacts;	Section 7.5	Section 7.11
	vi. groundwater drawdown threshold values and groundwater quality threshold values for each aquifer (based on regional groundwater modelling endorsed by the Minister) at which management actions (such as reporting or control line values for additional investigation, more intensive management action, make good, and cease operations) will be initiated to respond to escalating levels of risk, including increasing levels of drawdown, contamination of groundwater, or subsidence;	Section 7.6	Section 7.6, 7.7, 7.8, Table 7.9

EPBC Approval Condition	Topic	CWMMP Summary Plan Reference	CWMMP Full Report Reference
		Section	Section
	vii. references to standards and relevant policies and guidelines;	Section 1.3	Section 2.4 References in Section 10 cited throughout CWMMP
	viii. mechanisms to monitor, avoid, minimise, manage, and respond to risks; and	Section 7.6, Table 7.2	Section 6.2
	ix. performance measures, annual reporting to the Department, and publication of reports on the internet;	Section 8	Section 8.1, 8.2, 8.3, Table 1-4
53 (d)	an exceedance response plan that includes:		
	i. mechanisms to avoid, minimise and manage risk of adverse impacts and response actions and timeframes that can be taken by the proponent if:	Table 7.2	Section 6.2
	I. threshold values for surface water quality and water environmental values specified in the CSG WMMP are exceeded;	Section 7.6 Table 7.2	Section 7.8 Appendix I
	II. threshold values specified in the CSG WMMP for aquifer drawdown or groundwater contamination are exceeded;	Section 7.6	Section 7.8, Appendix I
	III. subsidence or surface deformation occurs which impacts on surface or groundwater hydrology;	Section 5.3	Section 5.3.6 Appendix K
	IV. there are any unforeseen emergency discharges; and	Section 4.4.7, 4.4.8	Section 4.14, Appendix E
	ii. a program and timetable for repressurisation using re-injection of CSG water from hydraulically connected aquifers back into appropriate permeable aquifers and for other groundwater repressurisation options to re-establish pressure levels and water qualities to the satisfaction of the Minister on the advice of an expert panel, in conjunction with appropriate measures to forecast and proactively manage any short-term impacts.	Section 4.6, 4.7, 5.2	Section 4.8, 4.11.4, 4.12.4, 4.13

Annex B – Program of Water Activities and Monitoring

ID	Task Name	Approval / Condition
1	**Fairview**	
2	**1. EPBC Monitoring Implementation Schedule**	
3	**Monitoring of Matters of National Environmental Significance - GAB Springs**	**Condition 49A, 49D**
4	Isotopic Analysis at Springs	
5	EPBC Springs Identicication and Survey by OGIA	
6	EPBC Springs Identification and Survey Within 100km of Maximum Predicted Impact	
7	Installation of Monitoring Equipment for the Early Warning System network	
8	**Hydraulic Connectivity Monitoring**	**Condition 49B, 53B, 53D**
9	Isotopic Analysis - Existing Bores	
10	Hydraulic Conductivity Modelling	
11	Formation Coring and Multi-level Vibrating Wire Piezometer Installations	
12	Geotechnical Testing of Aquifer / Aquitard Cores	
13	**Formation Drawdown and Aquifer Quality Monitoring**	**Condition 49B**
14	Installation of Monitoring Bores and Equipment	
15	Formation Coring and Multi-level Vibrating Wire Piezometer Installations	
16	Geotechnical Testing of Aquifer / Aquitard Cores	
17	**Surface Water Monitoring**	**Condition 49G**
18	Background Baseline Monitoring	
19	Installation of Monitoring Facilities / Equipment	
20	**Groundwater Water Monitoring**	**Condition 53C**
21	Background Baseline Monitoring	
22	Installation of Monitoring Facilities / Equipment	
23	**Regional Subsidence Monitoring**	**Condition 65, 69**
24	Due Date Survey	
25	Installation of Control Survey Points	
26	Installation of Vibrating Wire Piezometer	
27	**2. Infrastructure Development (project development phase)**	
28	Coal Seam Water Production	
29	Ponds	
30	Treatment Facilities	
31	Pumping Facilities	
32	Beneficial Uses	
33	Irrigation	
34	Dawson River Release Scheme	
35		
36		

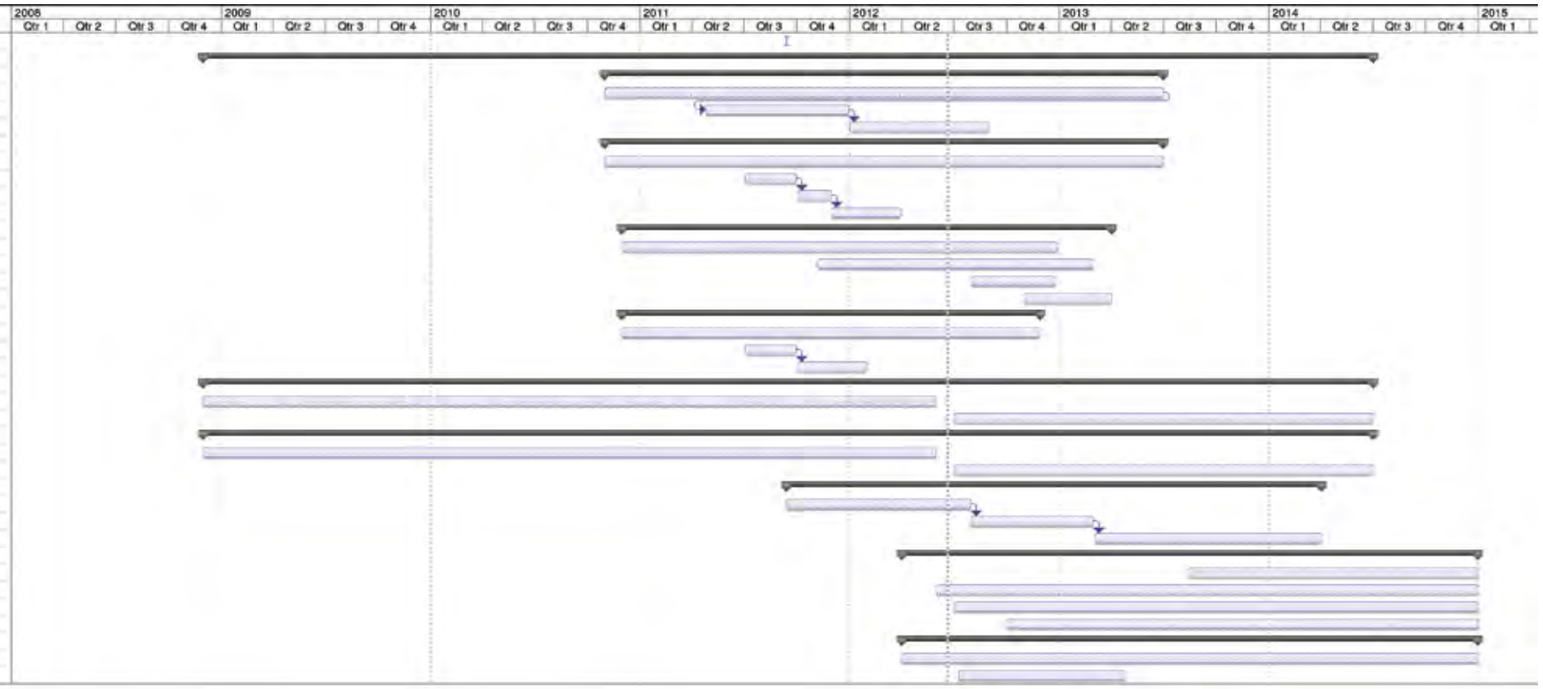


Project: EPBC Gant Chart
Date: Mon 29/04/13

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Progress
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Deadline

Annex B – Program of Water Activities and Monitoring

ID	Task Name	Approval / Condition
35	**Roma**	
36	**1. EPBC Monitoring Implementation Schedule**	
37	**Monitoring of Matters of Environmental National Significance (MENS) - GAB Springs**	**Condition 49A**
38	Isotopic Analysis	
39	EPBC Springs Identification and Survey	
40	Installation of Monitoring Equipment in the 20 km radius / 2 Meter Drawdown Zone	
41	**Hydraulic Connectivity Monitoring**	**Condition 49B, 53B, 53D**
42	Isotopic Analysis	
43	Formation Coring and Multi-level Vibrating Wire Piezometer Installations	
44	Geotechnical Testing of Aquifer / Aquitard Cores	
45	Hydraulic Conductivity Modelling	
46	**Managed Aquifer Recharge (MAR)**	**Condition 49C**
47	Geochemical Analysis and Monitoring	
48	Installation of Monitoring Bores and Equipment (Sectors 1 and 3)	
49	Formation Coring and Multi-level Vibrating Wire Piezometer Installations	
50	Geotechnical Testing of Aquifer / Aquitard Cores	
51	**Formation Drawdown and Aquifer Quality Monitoring**	**Condition 49D**
52	Installation of Monitoring Bores and Equipment	
53	Formation Coring and Multi-level Vibrating Wire Piezometer Installations	
54	Geotechnical Testing of Aquifer / Aquitard Cores	
55	**Surface Water Monitoring**	**Condition 49G**
56	Background Baseline Monitoring	
57	Installation of Monitoring Facilities / Equipment	
58	**Groundwater Monitoring**	**Condition 53C**
59	Background Baseline Monitoring	
60	Installation of Monitoring Facilities / Equipment	
61	**Regional Subsidence Monitoring**	**Condition 65**
62	Due Date Survey	
63	Installation of Control Survey Points	
64	Installation of Vibrating Wire Piezometers	
65	**2. Infrastructure Development (project development phase)**	
66	CSG Water Production	
67	Ponds	
68	Treatment Facilities	
69	Pumping Facilities	
70	Beneficial Uses	
71	Irrigation	
72	Managed Aquifer Recharge (MAR)	



Project: EPBC Gant Chart
Date: Tue 19/06/12

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Page 2

Annex C – Table of Commitments

SEWPaC Condition	Commitment	Target Completion Date
49a 49d 53c.vi	**Groundwater Drawdown**	
	Drawdown limits are now defined for the source aquifer at selected locations. These limits are subject to periodic updates.	Completed
	Installation of Early Warning Spring (EWS) monitoring network	End 2016
	Ground truthing of a selection of springs to assess the presence of EPBC listed species and EPBC communities	On tenement springs have been completed (with the exception of macroinvertebrates). On and off spring baseline initiated as part of the Joint Industry program, to be reported in April 2015.
	Santos will assume responsibility of mitigation (if required) for on-tenement springs and those off-tenements springs as will be assigned by the Surat Underground Water Impact Report (UWIR)/SEWPaC.	Ongoing
	Comparison of drawdown to UWIR predictions will occur on a quarterly basis.	Quarterly Graphic comparisons will be provided in the Santos GLNG Annual Report for Early Warning System bores that Santos GLNG is responsible for.
49b 53b 53d(i)4)	**Aquifer Connectivity**	
	Santos GLNG commits to provide further characterisation on the level of connectivity between the formations, including undertaking the following upcoming and ongoing hydraulic connectivity programs. Note that the results will be presented in future updates to the CWMMP	
	Multi-level monitoring bores	Ongoing monitoring and data assessment, as per Appendix J.
	Contact Zone Program	Ongoing after installation
	Wallumbilla Fault Program	Installation planned for 2014, scope currently under development.
	Aquifer Response	Ongoing, as per Environmental Monitoring Plan (Appendix G)
	Isotope and geochemical signature	Ongoing, as per Environmental Monitoring Plan (Appendix G)
	Pumping response observations and assessments	Annually from 2014
49c 53a 53d)ii	**Aquifer Re-injection**	
	Santos GLNG has developed a Managed Aquifer Recharge (MAR) piloting program and schedule for CSG field piloting of aquifer reinjection	
	Fairview CSG Field Stage 1– Desktop Study	Completed March 2012
	Roma CSG Field Stage 1– Desktop Study	Completed in January 2011
	Roma CSG Field Stage 2 – Investigations and Assessment	Completed in January 2011
	Roma CSG Field pilot trial (Hermitage) Stage 3 – Construction and Commissioning	Completed in Q1/Q2 2012
	Roma CSG Field pilot trial (Hermitage) Stage 4 – Operation	Completed Q4 2012
	Roma CSG Field (The Bend) Stage 3 – Construction and Commissioning	Due for completion Q3 2014
	Roma CSG Field (The Bend) Stage 4 – Operation	Due to commence Q3/Q4 2013
	Arcadia CSG Field Stage 1 – Desktop Study	Completed September 2013
	All approved Injection Management Plans will be submitted to the Department of the Environment annually, as they become available	Ongoing

SEWPaC Condition	Commitment	Target Completion Date
49e	**Hydraulic Fracturing**	
	As part of respective Annual Report requirements to both the State and Federal Governments, Santos GLNG will provide a projection of the anticipated number of wells to be hydraulically stimulated during each year (up to and including 2015) as well as the number of hydraulic stimulations completed in the proceeding year. Additional details to be reported will also include location information and the depth of each respective hydraulic stimulation.	Annually, submitted within the first quarter of each year (i.e. the 2013 annual report will be submitted to the Department of the Environment in Q1 2014), together with updated plan of future hydraulic fracturing.
49f	Santos GLNG has agreed with the Department of the Environment to undertake additional Direct Toxicity Assessment that will include: • an ecotoxicological program, involving, for example, a comparison of (i) coal seam water, (ii) coal seam water with fraccing chemicals, and (iii) fraccing chemicals in freshwater; • assessing the toxicity of individual fraccing chemicals of concern; and • assessing contribution of fraccing chemicals to toxicity of fraccing fluids and flowback waters (mixture toxicity). Santos is committed to undertaking these assessments as part of the joint industry Ecotoxicity Work Program; the result of which will be provided to the Department of the Environment upon completion.	December 2013
49.g.iv)	**Surface Water Baseline**	
	Ongoing collection of surface water baseline data up to	End of 2013
	EPBC spring hydrogeological conceptual model	Existing conceptual models to be provided in November 2013. All conceptual models will be provided at completion of spring baseline assessment (April 2015).
	Atmospheric pressure monitoring – 1 installation (barrologger or other) at each EPBC spring complex or cluster of spring complexes	Completed
43.g.vi)	Surface water Threshold Values – Collection and reviewing 2 years of baseline data and development of upper and lower confidence levels (threshold levels) for key parameters (relevant to MNES). These threshold values will be provided in the next revision of the CWMMP.	End of 2014
49.g.x)	Brine Management Plans – Provision of Brine Management Plans developed for Arcadia Valley, Roma and Fairview CSG Fields as a State Government requirement within the respective CSG field's Environmental Authorities. These will be provided in the next revision of the CWMMP	December 2014

SEWPaC Condition	Commitment	Target Completion Date
49i, 53c)ix)	**Reporting**	
	A Coal Seam Water Monitoring and Management Annual Report will be developed for each calendar year and submitted to the Department of the Environment within the first quarter of the following year.	31 March 2013
	Digital data can be provided to the Department of the Environment on request	Ongoing
	Santos GLNG will publish the following reports on the internet (via the Santos Water Portal): • Coal Seam Water Monitoring and Management Annual Report • Link to the latest Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR)	31 March 2013
	Santos GLNG will regularly publish data from all aspects of the water monitoring network on the Santos GLNG Water Portal	Ongoing
55	The next revision of the CWMMP is currently planned to be submitted to the Department of the Environment 3 months prior to first LNG cargo	3 months prior to first LNG cargo in 2015.
53.c)iv)	**Groundwater Baseline**	
	Groundwater baseline data collection completion	End of 2014
	Santos GLNG, in collaboration with the other proponents (APLNG and QGC), will by the end of 2013 develop a statistical methodology to enable definition of significant exceedences from the baseline water pressure and water quality levels. The establishment of this methodology can only reasonably be commenced once the three Projects all have sufficient confirmation of their EPBC conditions being met by the respective CWMMPs	Completed
53.d.i.III	**Subsidence**	
	The Subsidence Management Plan provides a response plan into any exceedance of the defined subsidence trigger. The Subsidence Management Plan describe the monitoring undertaken to establish variation of ground level over time.	Completed
	Subsidence baseline	Completed
	Monitoring through satellite measurements	Ongoing

Annex D – Reference List

ANZECC, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000

EPBC Condition Report – Coordinator Generals Evaluation Report for an Environmental Impact Statement, GLNG Project, May 2010

DEHP, Manual for Assessing Hazard Categories and Hydraulic Performance of Dams, February 2012

DEHP, Revised Arcadia Project Area Environmental Authority (EPPG00841113, formerly PEN102125611), 2013

DEHP, Revised Fairview Project Area Environmental Authority (EPPG00928713, formerly PEN100178208), 2013

DEHP, Revised Roma Shallow Gas Project Area East Environmental Authority (EPPG00662213, formerly PEN103814911), 2013

DEHP, Revised Roma Shallow Gas Project Area Environmental Authority (EPPG00898213, formerly PEN101578910), 2013

DERM, Preparing an environmental management plan for coal seam gas activities, Environmental Protection Act 1994, March 2010

DERM, Queensland Water Quality Guidelines, 2009

Queensland Environmental Protection Act 1994, Environmental Protection (Waste Management) Policy, 2000

Golder Associates, Coal Seam Hydraulic Fracturing Fluid Environmental Risk Assessment, 2011

Golder Associates, GLNG Project: CSG Water Monitoring and Management Plan, April 2011

NHMRC and ARMCANZ, Australian Drinking Water Guidelines, 1996

National Water Quality Management Strategy Australian Guidelines for Water Recycling: Managed Aquifer Recharge, 2009.

Queensland Herbarium, Ecological and Botanical Survey of Springs in the Surat Cumulative Management Area, 2012

Office of Groundwater Impact Assessment, Draft Underground Water Impact Report: Surat Cumulative Management Area, May 2012.

Santos, Arcadia CSG Water Management Plan, 2011

Santos, Arcadia Valley Environmental Management Plan, 2011

Santos, Environmental Monitoring Plan, 2013

Santos, Environmental Monitoring and Reporting Strategy, 2013

Santos, Fairview CSG Water Management Plan, 2012

Santos, Fairview Environmental Management Plan, 2012

Santos, Impact of CSG Water Management on Matters of National Environmental Significance, 2010

Santos, Roma CSG Water Management Plan, 2013

Santos, Roma Environmental Management Plan, 2010

URS, GLNG Project Environmental Impact Statement, 2009

Annex E – Conceptual Water Balance Assessment – Roma

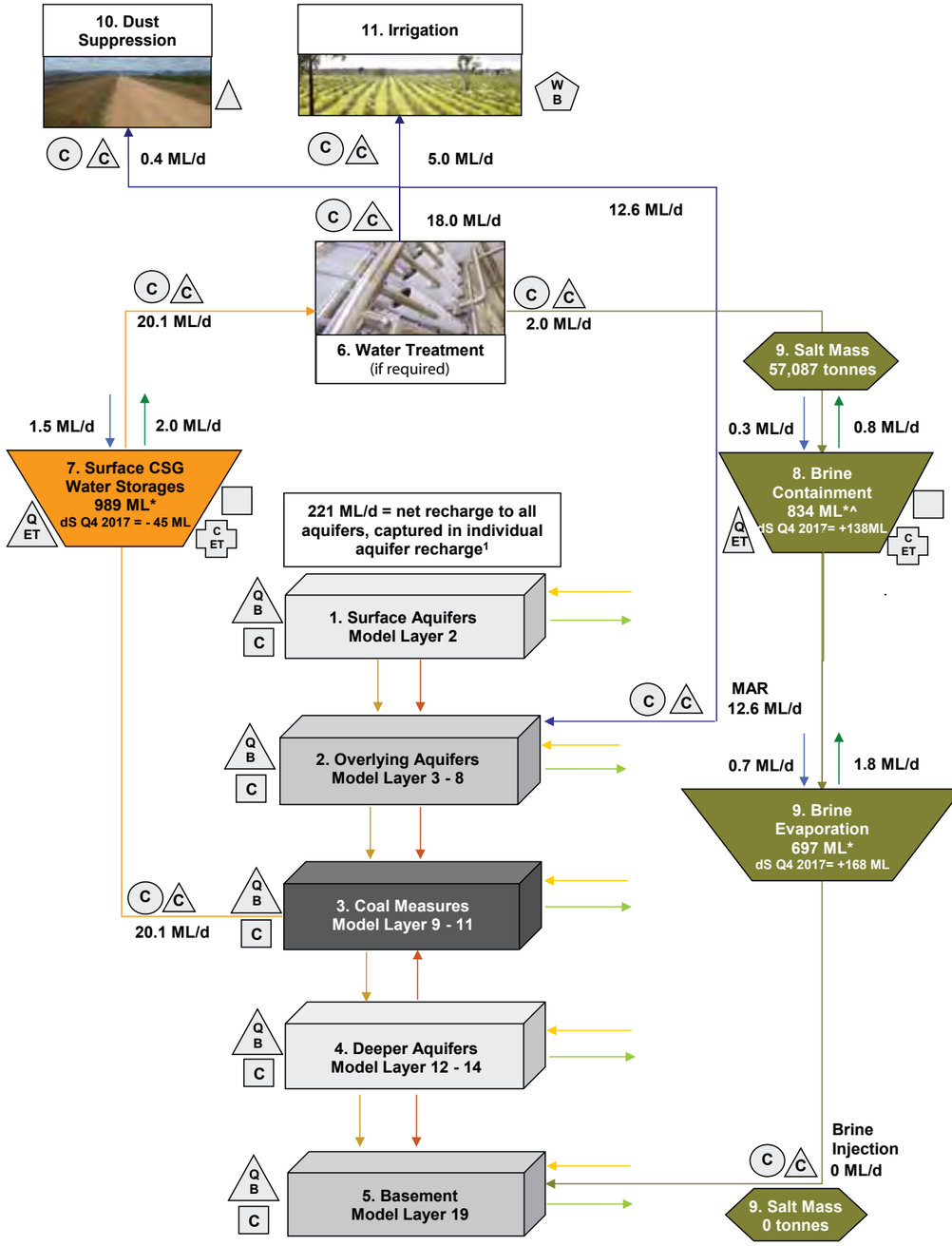
MONITORING LEGEND

Quality	C - continuous
Level and/ or pressure	W - weekly
Environmental	Q - quarterly
Seepage	B - bi-annually
Flow	A - annually
Stratification	ET - event triggered

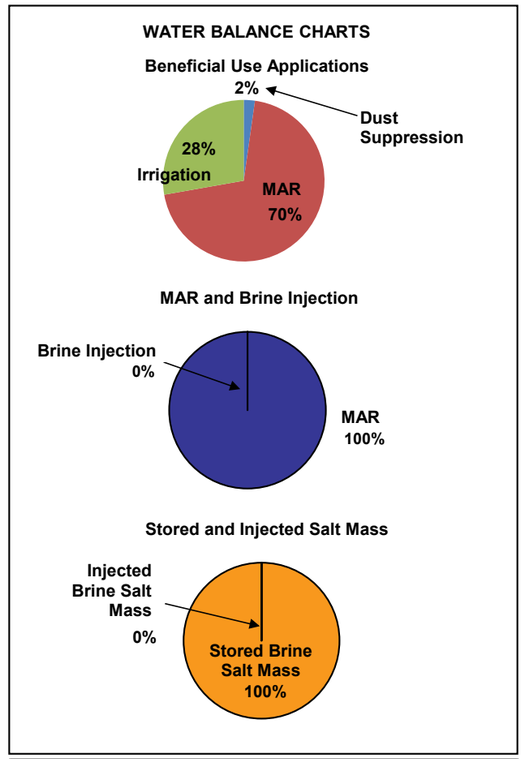
WATER BALANCE LEGEND

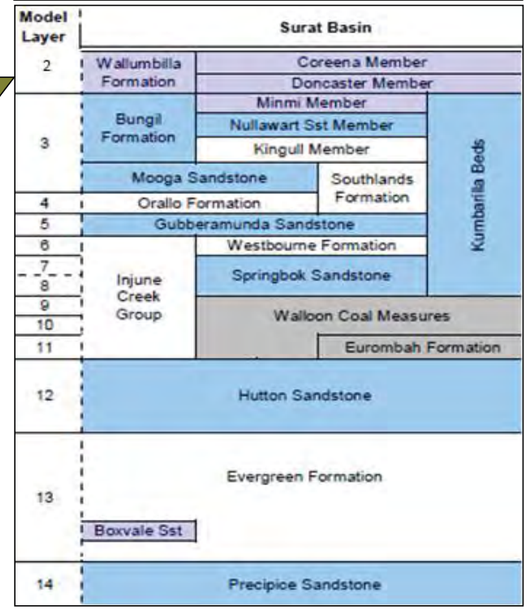
- CSG water
- Permeate
- Brine
- Rainfall
- Evaporation
- Net rainfall recharge (to all aquifers)
- Inter-aquifer transfer
- Change in inter-aquifer transfer due to CSG activities
- Recharge
- Discharge and use

[1] Table 17, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012



* Pond volume is calculated from expected storage during Q4 2017. Change in storage shown is the variance in inflow and outflow during Q4 2017.
^ Additional brine pond to be constructed prior to Q4 2017 providing additional 240 ML storage.





[2] Table 2, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012

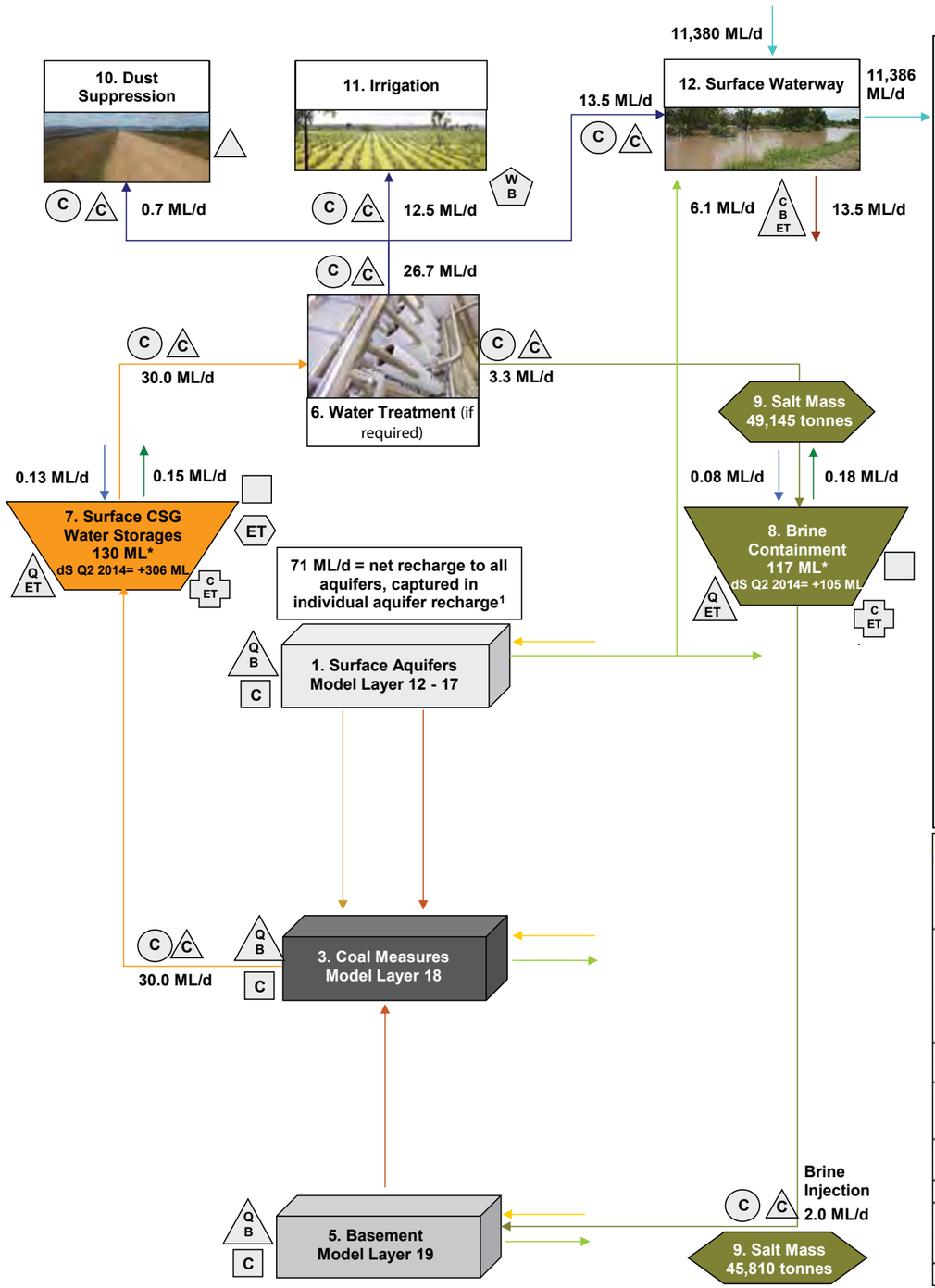
Annex E – Conceptual Water Balance Assessment – Fairview

MONITORING LEGEND

Quality	C - continuous
Level and/ or pressure	W - weekly
Environmental	Q - quarterly
Seepage	B - bi-annually
Flow	A - annually
Stratification	ET - event triggered

WATER BALANCE LEGEND

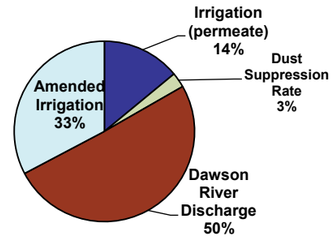
- CSG water
- Permeate
- Brine
- Rainfall
- Surface waterway flow
- Evaporation
- Offtake
- Net rainfall recharge (to all aquifers)
- Inter-aquifer transfer
- Change in inter-aquifer transfer due to CSG activities
- Recharge
- Discharge and use



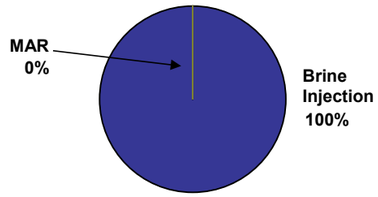
* Pond volume is estimated for Q2 2014 and mass balance of inflow and outflow during Q2 2014. Change in storage shown is the variance in inflow and outflow during Q2 2014.

WATER BALANCE CHARTS

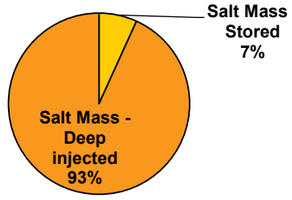
Beneficial Use Applications

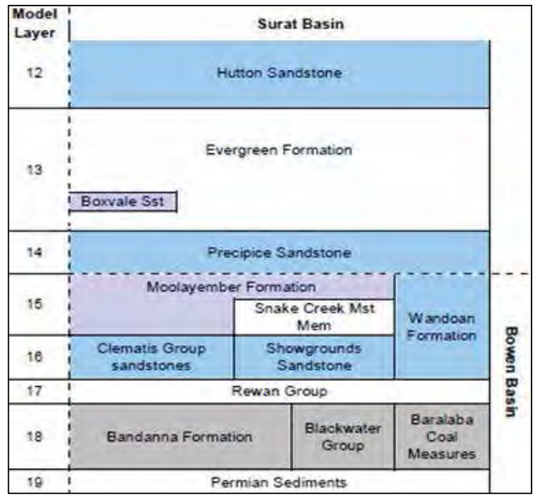


MAR and Brine Injection



Stored and Injected Salt Mass





[1] Table 17, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012

[2] Table 2, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012

Annex E – Conceptual Water Balance Models – Arcadia

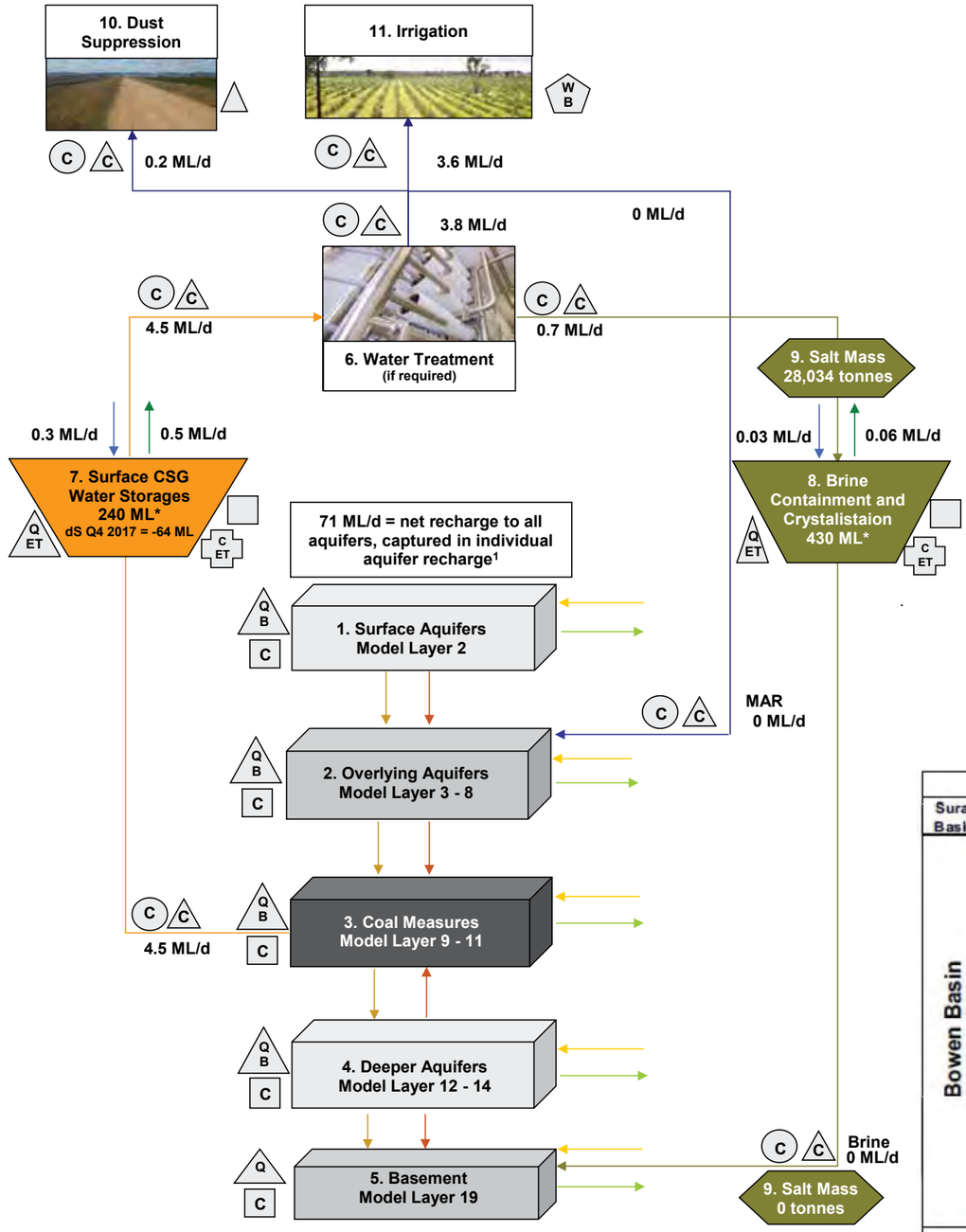
MONITORING LEGEND

Quality	C - continuous
Level and/ or pressure	W - weekly
Environmental	Q - quarterly
Seepage	B - bi-annually
Flow	A - annually
Stratification	ET - event triggered

WATER BALANCE LEGEND

- CSG water
- Permeate
- Brine
- Rainfall
- Evaporation
- Net rainfall recharge (to all aquifers)
- Inter-aquifer transfer
- Change in inter-aquifer transfer due to CSG activities
- Recharge
- Discharge and use

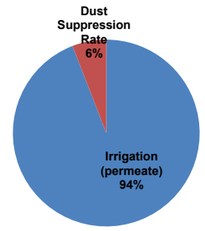
[1] Table 17, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012



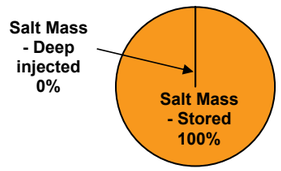
* Pond volume is calculated from expected storage during Q4 2017. Change in storage shown is the variance in inflow and outflow during Q4 2017.

WATER BALANCE CHARTS

Beneficial Use Applications



Stored and Injected Salt Mass



Arcadia Litho-stratigraphy

Surat Basin		Precipice Sandstone
Bowen Basin		Moolayember Formation
	Mimosa Group	Clematis Sandstone
		Showgrounds sandstone
		Rewan Formation
	Blackwater Group	Bandanna Formation
		Black Alley Shale
	Back Creek Group	Peawaddy Formation
		Catherine Sandstone
		Ingelara Formation
		Freitag Formation
		Aldebaran Sandstone
		Cattle Creek Group
		Reids Dome Beds
		Timbury Hills Formation

[2] Table 2, QWC Surat Cumulative Management Area Groundwater Model Report, May 2012

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