WSGP Coal Seam Gas Water Management Plan

Document Number:

SENEX-WSGP-EN-PLN-008

Revision: 1

Position	Name	(tick one column only)		Signature	Date
		Approve	Review		
Environment Manager	T. Jensen	☒	☐	T Jensen	7 / 12 / 17

TABLE OF CONTENTS

Figures

Tables

REVISION HISTORY

Revision	Revision Date	Document Status	Revision Comments	Author	Approved By
A	April 5, 2017	Issued for Review	Document creation	CK, KCB	CS, CD, KCB
B	May 5, 2017	Issued as Final	Revised following review	CK, KCB	CS, KCB
C	May 23, 2017	Final	Revised following review	CK, KCB	CS, KCB
0	June 5, 2017	Final		KCB	T. Jensen
1	December, 4, 2017	Final	Revised following IESC Comments	KCB	T. Jensen

1. EXECUTIVE SUMMARY

Senex have developed a Coal Seam Gas Water Management Plan (CWMP) to set out their objectives, strategies and proposed management and monitoring practices associated with managing coal seam gas (CSG) produced water from the Western Surat Gas Project (WSGP).

The WSGP covers an area of approximately 915 km^2 and comprises ATP767, ATP795, and ATP889. These tenements are approximately 30 km north of the Warrego Highway, between the townships of Roma and Wallumbilla. The CSG production target for the WSGP is the Walloon Coal Measures (WCM) of the Surat Basin.

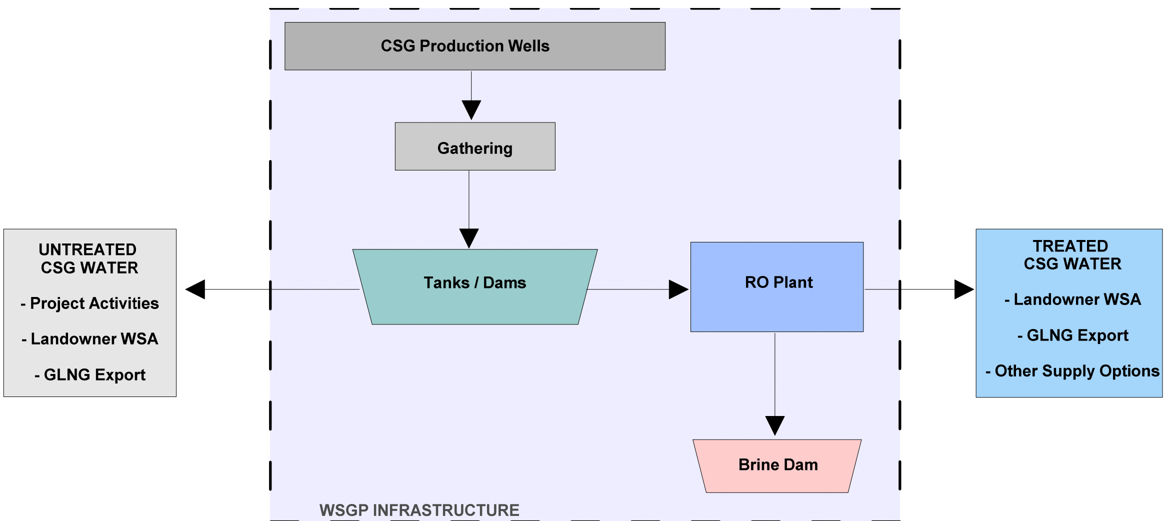
Activities for exploration and appraisal (including pilot production trials) have been authorised under the previous Environmental Authority (EA) (EPPG00651513). Senex applied for a major amendment of that EA to authorise the proposed production activities, which was granted 5 December 2017. This CWMP outlines how CSG water will be managed during production activities.

CSG water production over the Project duration (~47 years) is currently forecast to be approximately 35 GL, with a peak production rate of 6.5 ML/d predicted to occur in 2022. CSG water is collected from CSG production wells via a gathering system and delivered to water storage facilities (tanks / dams).

Senex have developed their strategy for CSG water management, based on the DEHP Prioritisation Hierarchy. The DEHP Hierarchy is presented in the Coal Seam Gas Water Management Policy, DEHP 2012 (CSGWMP). CSG water management options for the WSGP, as presented in Figure 1.1, have been developed to maximise the beneficial use of water. These options include providing CSG produced water for the following activities:

- Project activities, such as drilling and completions, dust suppression, etc.; and
- Landowner Water Supply Agreements (WSA), including water for irrigation, stock watering.

Figure 1.1 Water Management Infrastructure Schematic for the WSGP



Senex's preferred brine and salt management strategy aims to avoid the need to store brine in a regulated brine storage dam, where practicable, by utilising beneficial uses that do not produce brine. Where it is necessary to desalinate produced water, the brine will be stored in a regulated dam, constructed to contain the entire production of brine from the Project. Evaporation of the brine in the storage facility will be conducted over time to concentrate the brine and to produce salt. Once produced, the salt will be disposed in a regulated waste facility. Senex will continue to investigate cost effective and / or commercial saline disposal uses.

Senex will implement all CSG produced water and brine management strategies in accordance with the applicable EA conditions and in a manner that protects and maintains all relevant EVs. Senex have developed management criteria to monitor and assess the effectiveness of the management of all CSG produced water and saline waste associated with the activity.

Senex will undertake an annual review of the monitoring undertaken in accordance with the CWMP and EA conditions and report to government, as required. A review and update of the CWMP will be periodically undertaken to capture changes to the WSGP description that influences the management of CSG water and / or optimisation of the CSG water and brine management.

2. INTRODUCTION

2.1. Western Surat Gas Project – Project Description

Stuart Petroleum Cooper Basin Gas Pty Ltd ACN 130 588 055 (the Applicant) has prepared this plan to accompany the amendment application under Section 224 of the *Environmental Protection Act 1994* (EP Act) for Environmental Authority EPPG00651513. The Applicant is a wholly-owned subsidiary of Senex Energy Limited ACN 008 942 827.

Senex is planning to develop a gas project within petroleum tenures ATP 767, 795 and 889, referred to collectively as the Western Surat Gas Project (WSGP)[1]. The WSGP is located approximately 30 km northeast of Roma, in Queensland's Surat Basin. The location of the WSGP is presented in Figure 2.1.

Senex intends to produce and supply raw or treated gas to domestic markets and neighbouring operators (third parties) and distribute gas via existing pipelines and LNG processing facilities. Applications for Petroleum Lease (PL) 1022, 1023 and 1024, have been made to the Department of Natural Resources and Mines (DNRM). These PL's will form the 'Production Area', as shown on Figure 2.1.

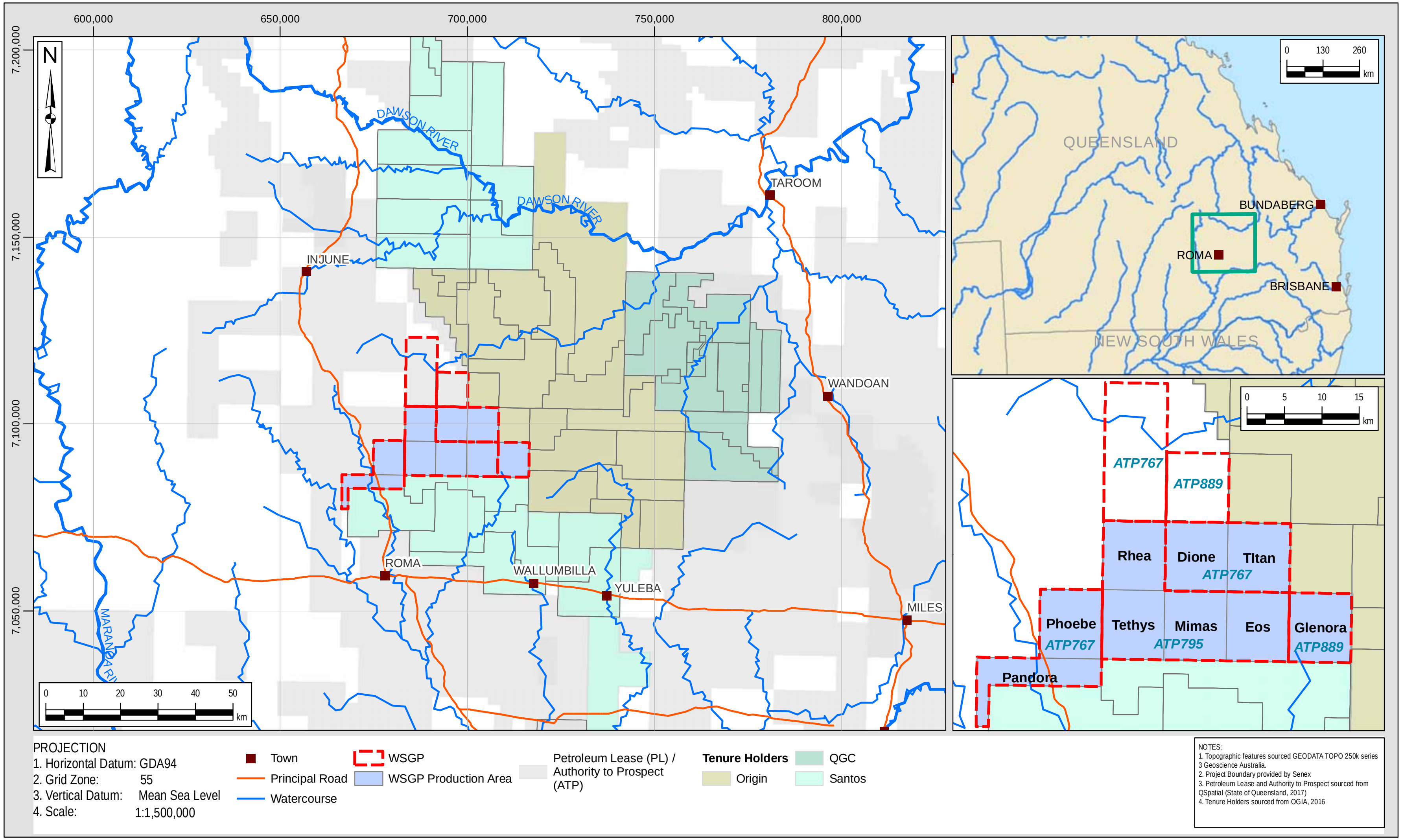
Proposed production activities include the following components:

- Up to 425 CSG production wells
- Gas and water gathering lines
- Field compressor facilities
- Medium pressure infield pipelines
- Central processing facility
- Water storage and water management facilities
- Access roads and tracks
- Maintenance facilities, workshop, construction support and administration buildings (during construction and operation)
- Construction phase accommodation facilities
- Utilities – power generation, water supply
- Communications
- Borrow pits.

[1] The remaining blocks, being the Maisey and Hawkins blocks, located to the south of the Warrego Highway, all within ATP 889 (refer to Figure 2.1) are not part of the WSGP but are still covered by the WSGP EA.

Details of the project components, including location and size, will be determined progressively over the life of the WSGP project.

Figure 2.1 Location of the WSGP



2.2. Aims and Objectives of the CWMP

The Coal Seam Gas Water Management Plan (CWMP) covers all activities associated with managing produced water from the WSGP once the water has been recovered to the ground surface. It includes managing saline waste by-product (brine) from treating produced water.

The aim of the CWMP is to provide a tool to assist Senex personnel with the long-term management of produced water. The plan sets objectives to maximise the beneficial use of the water and identify any potential impacts that may require mitigating. Other key objectives of the CWMP include:

- providing a transparent document outlining Senex's philosophy and approach to water management;
- demonstrating adherence to regulatory policy;
- documenting the risks and challenges in relation to CSG water management;
- providing a strategic management tool adaptive to changes in:
    - source water quantity and quality;
    - demand location and volume;
    - technology;
    - environmental receptors/constraints; and
    - community concerns, and regulatory requirements.
- allowing for continual improvement and implementing good practice CSG water management.

The CWMP will consider managing CSG water for the lifetime of the WSGP and will be updated as required so that the most appropriate and effective management approach is applied.

2.3. Definitions and Acronyms

ATP	means authority to prospect granted under the *Petroleum Act 1923 (Qld) or the Petroleum Gas (Production and Safety) Act 2004*
CPF	central processing facility
CRWP	means Comet Ridge to Wallumbilla Pipeline
CSG	means coal seam gas where gas is stored within coal deposits or seams
CWMP	Coal Seam Water Management Plan (SENEX-WSGP-EN-PLN-008)
E&A	Exploration and Appraisal
EA	Environmental Authority
EV	Environmental Value
Exploration	means drilling, seismic or technical studies to identify and evaluate regions or prospects with the potential to contain hydrocarbons
FEED	means front end engineering and design
GLNG	means the Santos GLNG joint venture comprising Santos Limited, Total, PETRONAS and KOGAS
LNG	means liquefied natural gas, which is natural gas that has been liquefied by refrigeration for storage or transportation
Petroleum Act	means the *Petroleum Act 1923* (Qld), the *Petroleum Gas (Production and Safety) Act 2004* (Qld)
PL	means Petroleum lease granted under the *Petroleum Act 1923* (Qld) or the *Petroleum Gas (Production and Safety) Act 2004* (Qld)
PPL	means Petroleum Pipeline Licence granted under the *Petroleum Gas (Production and Safety) Act 2004* (Qld)
Production Area	means the area within the WSGP where CSG production will take place and will consist of Petroleum Leases 1022, 1023 and 1024
Project Area	means the coal seam gas field over approximately 915km^2 of Senex permits ATP 767, 795, 889
RO	means reverse osmosis, a water treatment technology
Senex	Senex Energy Limited, ABN 50 008 942 827
Surat Basin	means the sedimentary geological basin of Jurassic to Cretaceous in southern Queensland and northern New South Wales

TD	Total Depth
WCM	Walloon Coal Measures (the target gas production unit)
WSA	Water Supply Agreement
WSF	water storage facility
WSGP	Western Surat Gas Project

3. REGULATORY FRAMEWORK

This CWMP has been prepared in accordance with key policies and legislation in Queensland for managing CSG produced water. A summary of the key policies and legislation relevant to the development of the WSGP is provided in the following sections.

3.1. Petroleum and Gas (Safety and Production) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2017a) is an Act relevant to exploring for, recovering and transporting by pipeline, petroleum and fuel gas and ensuring the safe and efficient undertaking of those activities. The key purpose of this Act is to facilitate and regulate the undertaking of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry.

The Act identifies underground water rights for petroleum tenures, and states that the holder of a petroleum tenure may take or interfere with underground water in the area of the tenure if the taking or interference happens during the course of, or results from, the carrying out of another authorised activity for the tenure. There is no limit to the volume of water that may be taken under the underground water rights and the tenure holder may use associated water for any purpose within, or outside, the area of the tenure.

3.2. Environmental Protection and Biodiversity Conservation Act 1999

The *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)* (Commonwealth of Australia 2016) is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under this Act. Amendments to the EPBC Act have resulted in water resources being a MNES in relation to large coal mining and CSG development projects. As a result, the WSGP may have potential for impacts on water resources, and has been referred to the Department of the Environment and Energy (DotEE).

The regulatory guideline relevant to the WSGP, developed from the amendment to the EPBC Act identifying water resources as being a MNES is the *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DotEE 2013).

3.3. Water Act 2000

The *Water Act 2000* (State of Queensland 2017b) is intended to provide for the sustainable management of water and the management of impacts on underground water, among other purposes. The Act provides a framework for:

- the sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water;
- the sustainable and secure water supply and demand management for the south-east Queensland region and other designated regions;
- the management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- the effective operation of water authorities.

The Act covers water in a watercourse, lake or spring, underground water (or groundwater), overland flow water, or water that has been collected in a dam.

The *Water Act 2000* provides for managing impacts on underground water caused by the exercising underground water rights by resource tenure holders, which are regulated under the *Petroleum and Gas (Production and Safety) Act 2004.* The Act also outlines the requirements for make good agreements, associated with impacts to underground water.

3.4. Environmental Protection Act 1994

The *Environmental Protection Act 1994* (State of Queensland 2016a) has an objective to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

Table 3.1 presents the primary requirements for the management of CSG water from the *Environmental Protection Act 1994* and identifies the sections in this CWMP to address each requirement.

*Table 3.1 Environmental Protection Act 1994 (*State of Queensland 2016a*) Requirements (*S126*) and Sections addressed in this report*

EP Act 1994 S126 – Requirements for site-specific applications-CSG activities			**Section Reference**
1)	A site-specific application for a CSG activity must also state the following:		
	a)	the quantity of CSG water the applicant reasonably expects will be generated in connection with carrying out each relevant CSG activity;	Section 4.1
	b)	the flow rate at which the applicant reasonably expects the water will be generated;	Section 4.1
	c)	the quality of the water, including changes in the water quality the applicant reasonably expects will happen while each relevant CSG activity is carried out;	Section 4.2
	d)	the proposed management of the water including, for example, the use, treatment, storage or disposal of the water;	Section 5
	e)	the measurable criteria (the management criteria) against which the applicant will monitor and assess the effectiveness of the management of the water, including, for example, criteria for each of the following (i) the quantity and quality of the water used, treated, stored or disposed of; (ii) protection of the environmental values affected by each relevant CSG activity; (iii) the disposal of waste, including, for example, salt, generated from the management of the water;	Section 7 Section 6 & Section 7 Section 7
	f)	the action proposed to be taken, if any, if the management criteria are not complied with, to ensure the criteria will be able to be complied with in the future.	Section 7
2)	The proposed management of the water cannot provide for using a CSG evaporation dam in connection with carrying out a relevant CSG activity unless—		
	a) b)	the application includes an evaluation of— (i) best practice environmental management for managing the CSG water; and (ii) alternative ways for managing the water; and the evaluation shows there is no feasible alternative to a CSG evaporation dam for managing the water.	Not relevant as no CSG evaporation dams are proposed.

3.4.1 Environmental Protection (Water) Policy 2009

Under the *Environmental Protection Act 1994,* the *Environmental Protection (Water) Policy 2009* (State of Queensland 2016b) was established as subordinate legislation to achieve the objective of the Act in relation to Queensland Waters. The purpose of the *Environmental Protection (Water) Policy 2009* is achieved by:

- identifying environmental values and management goals for Queensland waters;
- stating water quality guidelines and water quality objectives to enhance or protect the environmental values;
- providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- monitoring and reporting on the condition of Queensland waters.

3.4.2 CSG Water Management Policy 2012

The CSG Water Management Policy 2012 (DEHP 2012) primary objective is with the management and use of CSG water under the *Environmental Protection Act 1994*. The role of the policy is to:

- clearly state the government's position on the management and use of CSG water;
- guide CSG operators in managing CSG water under their environmental authority; and
- ensure community understanding about the government's preferred approach to managing CSG water.

4. CSG WATER PRODUCTION

This section of the CWMP describes the volumes and quantities of CSG water, treated CSG water and brine expected to be produced as part of the WSGP.

4.1. CSG Water Production

CSG water production is required as part of the CSG extraction for the WSGP. Groundwater is removed via CSG production wells to depressurise the coal seams. This depressurisation generates gas flow, and maintains the target producing operational pressure.

Produced water volumes and rates are predicted using Senex's analytical modelling tool or reservoir model with probabilistic distributions applied to several key reservoir parameters (i.e. permeability, porosity and net coal). The predictions generate production profiles (type curves). These production profiles are used in field development planning to provide a water forecast. Some uncertainty is inherent in any analytical model. Reservoir models can initially over-predict water production, due to factors including sensitivity to assumed porosity. A key method for reducing uncertainty is to match the model results with historical production records. Senex's predicted water volumes have a very good match with the actual water production for the 74 CSG wells that are located within 5 km of the project area. As Senex acquires more production data, the model is enhanced with additional historical matching, and revised production forecasts are produced. These revised production forecasts will be incorporated into the water balance model (along with the actual observations of water disposal volumes, rainfall and dam levels). Senex has confidence this integrated and iterative approach will ensure that produced water is managed responsibly, and beneficial use will be optimised. Type curves are updated throughout the life of the project as more information becomes available.

Figure 4.1 presents the forecast CSG water production profile for the WSGP. The CSG water production profile indicates that:

- The peak CSG water production is predicted to occur in 2022 at a rate of 6.5 ML/day;
- Following the peak production rate, the production profile gradually decreases between 2022 and 2033 with fluctuations in the profile as a result of new wells being commissioned; and
- After 2034, the water production profile decreases for the remainder of the project lifetime.

Figure 4.1 WSGP Forecast Water Production Rate (All CSG Production Wells)

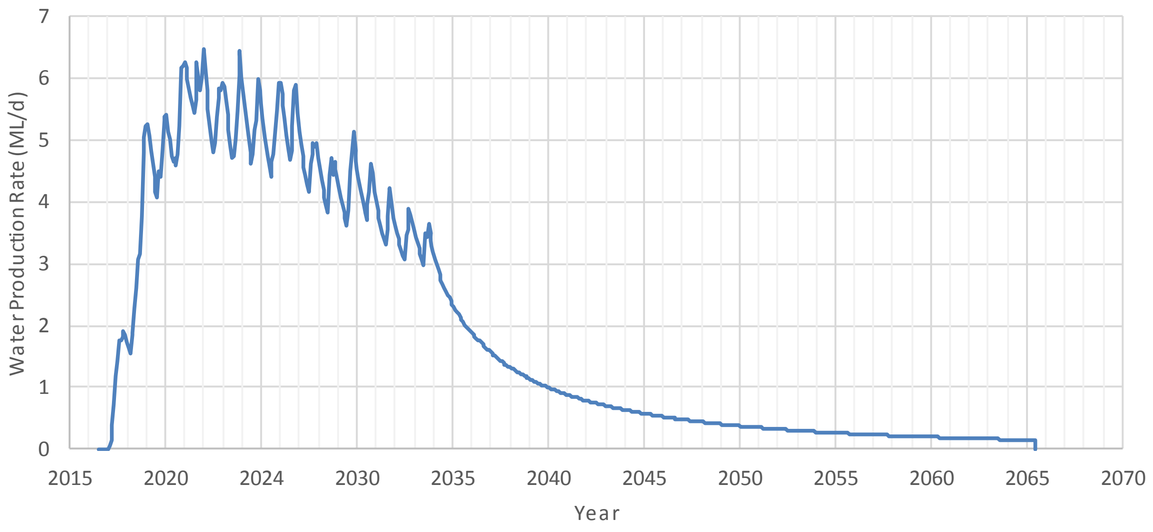
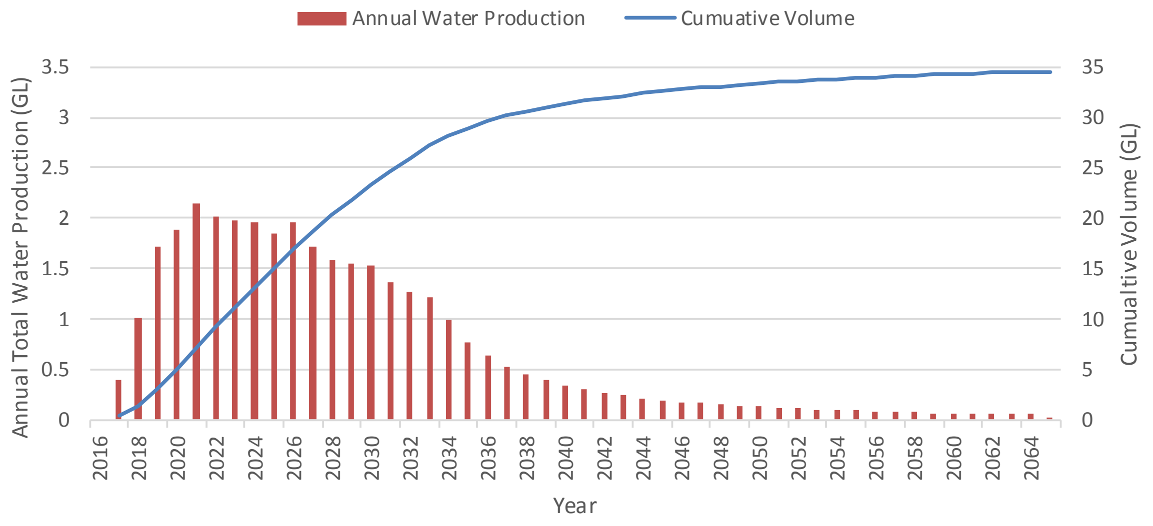


Figure 4.2 presents the total annual volumes of CSG water produced from the WSGP, based on the water production profile presented in Figure 4.1. The total volume of water forecast to be produced over the development lifetime (~47 years) is approximately 35 GL.

The CSG water production profile will be reviewed throughout project development and updated as new / additional data allows modelling inputs / assumptions to be progressively refined.

Figure 4.2 Annual Water Production and Cumulative Project Volume (Gigalitres – GL)



4.2. CSG Water Quality

The quality (TDS or EC) of produced water from the Walloon Coal Measures (WCM) across the Surat Basin can vary from fresh to saline. Specific to the WSGP, Table 4.1 presents the statistics of collected water analyses, comprising:

- Water samples taken from 16 CSG exploration and appraisal wells in the Eos, Mimas and Tethys blocks between April 2007 and April 2008 by Sunshine Gas, tenure holder of the WSGP during this period; and,
- Water samples collected from four Senex CSG pilot (exploration and appraisal) wells within the Glenora block in March, 2017.

Table 4.1: Summary of Walloon Coal Measures Water Chemistry Samples

Parameter	Unit	Number of Samples	20th Percentile	Median	80th Percentile
Acenaphthene	µg/L	4	<1.00	<1.00	<1.00
Acenaphthylene	µg/L	4	<1.00	<1.00	<1.00
Alkalinity (Bicarbonate)	mg/L	56	423	697	934
Alkalinity (Carbonate)	mg/L	5	88	108	134
Alkalinity (Hydroxide) as CaCO3	µg/L	4	1000	1000	1000
Alkalinity (total)	mg/L	52	3	494	776
Alkalinity (total) as CaCO3	mg/L	4	1019	1070	1084
Anions Total	meq/L	4	36.28	36.40	39.80
Anthracene	µg/L	4	<1.00	<1.00	<1.00
Arsenic	mg/L	4	0.001	0.001	0.002
Barium	mg/L	16	0.51	0.70	0.70
Benz(a)anthracene	µg/L	4	<1.00	<1.00	<1.00
Benzene	µg/L	4	<1.00	<1.00	<1.00
Benzo(a) pyrene	µg/L	4	<0.50	<0.50	<0.50
Benzo(b+j)fluoranthene	mg/L	4	<0.001	<0.001	<0.001
Benzo(g,h,i)perylene	µg/L	4	<1.00	<1.00	<1.00
Benzo(k)fluoranthene	µg/L	4	<1.00	<1.00	<1.00
Beryllium	mg/L	4	<0.001	<0.001	<0.001
Bicarbonate	mg/L	52	497	815	1119
Boron	mg/L	56	0.12	0.28	0.32
Cadmium	mg/L	4	<0.0001	<0.0001	<0.0001
Calcium	mg/L	56	3.00	4.00	8.00
Cations Total	meq/L	4	35.80	36.00	38.76
Chloride	mg/L	56	468	697	1270
Chromium (III+VI)	mg/L	4	0.01	0.02	0.03
Chrysene	µg/L	4	<1.00	<1.00	<1.00
Cobalt	mg/L	4	0.002	0.002	0.01
Copper	mg/L	56	<0.01	<0.01	0.07
Dibenz(a,h)anthracene	µg/L	4	<1.00	<1.00	<1.00
Ethylbenzene	µg/L	4	<2.00	<2.00	<2.00
Fluoranthene	µg/L	4	<1.00	<1.00	<1.00
Fluorene	µg/L	4	<1.00	<1.00	<1.00
Fluoride	mg/L	56	1.00	2.00	2.60
Hardness	mg/L	52	11.00	18.00	34.80
Hardness as CaCO3	mg/L	4	8.80	10.00	12.80
Indeno(1,2,3-c,d)pyrene	µg/L	4	<1.00	<1.00	<1.00
Ionic Balance	%	4	0.55	0.58	1.18
Iron	mg/L	52	0.01	0.12	0.80
Lead	mg/L	4	0.01	0.01	0.01
Magnesium	mg/L	56	0.90	2.00	3.00
Manganese	mg/L	56	0.01	0.01	0.08
Mercury	mg/L	4	<0.0001	<0.0001	<0.0001
Molybdenum	mg/L	52	0.04	0.04	0.05
Naphthalene	µg/L	4	<1.00	<1.00	<1.00
Nickel	mg/L	4	0.003	0.003	0.01
Nitrate (as N)	mg/L	52	0.90	0.90	1.00
Nitrite (as N)	mg/L	52	0.90	0.90	1.00
PAHs (Sum of total)	µg/L	4	<0.50	<0.50	<0.50
pH	pH_Units	56	8.20	8.40	8.60
Phenanthrene	µg/L	4	<1.00	<1.00	<1.00
Phosphorus	mg/L	52	0.90	0.90	1.00
Potassium	mg/L	56	2.00	3.00	22.00
Pyrene	µg/L	4	<1.00	<1.00	<1.00
Selenium	mg/L	4	<0.01	<0.01	<0.01
Silica	µg/L	12	8860	9800	11540

Parameter	Unit	Number of Samples	20th Percentile	Median	80th Percentile
Sodium	mg/L	56	569	739	1008
Sulphate	mg/L	56	0.90	0.90	1.00
Sulphur as S	mg/L	52	0.90	0.90	1.00
TDS	mg/L	56	1460	2087	2976
Toluene	µg/L	4	<2.00	<2.00	<2.00
Total BTEX	mg/L	4	<0.001	<0.001	<0.001
Vanadium	mg/L	4	<0.01	<0.01	<0.01
Xylene (m & p)	µg/L	4	<2.00	<2.00	<2.00
Xylene (o)	µg/L	4	<2.00	<2.00	<2.00
Xylene Total	µg/L	4	<2.00	<2.00	<2.00
Zinc	mg/L	55	0.01	0.04	0.13

5. CSG WATER MANAGEMENT AND INFRASTRUCTURE

5.1. CSG Water Management Strategy

Senex have developed their strategy for CSG water management at the WSGP, based on the DEHP Prioritisation Hierarchy. The DEHP Hierarchy is presented in the Coal Seam Gas Water Management Policy, DEHP 2012 (CSGWMP). The prioritisation hierarchy for managing and using CSG water is:

Priority 1 – CSG water is used for a purpose that is beneficial to one or more of the following:

- the environment;
- existing or new water users;
- existing or new water-dependent industries.

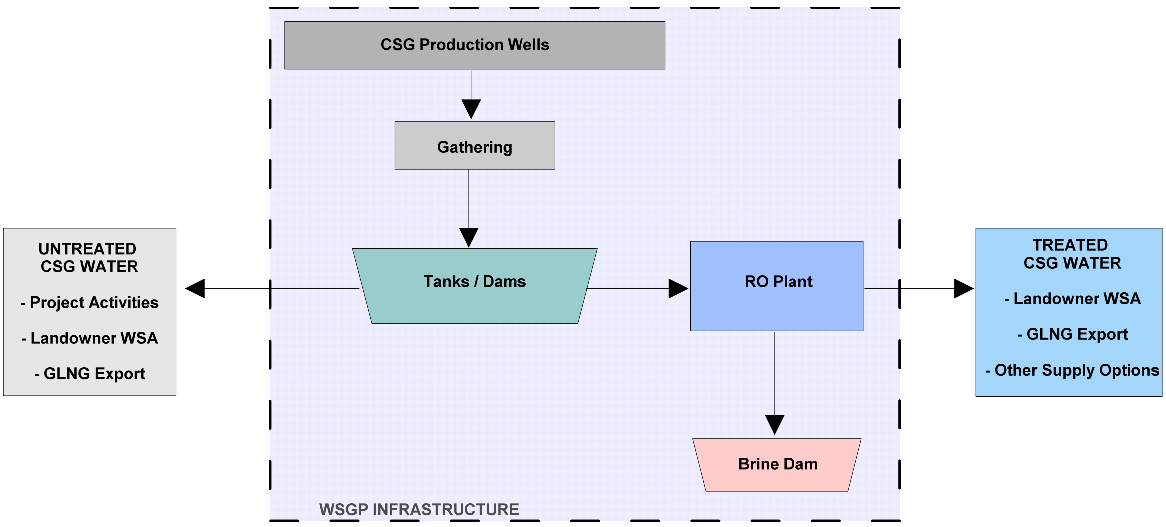
Priority 2 – After feasible beneficial use options have been considered, treating and disposing CSG water in a way that firstly avoids, and then minimises and mitigates, impacts on environmental values.

5.2. Water Management Infrastructure

5.2.1 Overview

This section provides an overview of the infrastructure required to transport, store, and treat CSG produced water for the WSGP. A schematic of the water management infrastructure is presented in Figure 5.1, with each component summarised in the following sections.

Figure 5.1 Water Management Infrastructure Schematic for the WSGP



5.2.2 WSGP Water Balance

Senex have developed a water balance model that incorporates the water production forecasts, current dam storage levels and rainfall as inputs. Outflows from the model are calculated or estimated, and include:

- Evaporation – based on BOM evaporation data and dam surface areas;
- Stock watering – based on predicted offtake volumes at any point in time;
- Construction use – based on predicted offtake volumes;
- Irrigation use – based on site-specific predicted offtake volumes for planned irrigation areas (based on technical work completed as part of an irrigation feasibility study); and
- Third party transfers – based on production plans.

It is understood that well performance will vary over time and the water balance model will be adapted and adjusted accordingly. The water balance model then provides a prediction of water levels in dams over time, which can be used for predicting when additional dams or irrigation areas may be required, or conversely when water is unlikely to be available for an offtake. Senex do not currently propose to discharge to streams, and would pursue an amendment to the State Environmental Authority, appropriately supported with site specific studies, should this disposal option be required at any time in future.

Any production peaks can be managed by transferring produced water to neighbouring proponents, under licence and existing commercial agreements. Plans for the initial phase are anticipated to allow disposal of ~1400 ML p.a. within the Glenora and Eos blocks alone.

Discussions with landowners will be ongoing to understand water consumption requirements (quality, quantity, profile) and to collaboratively plan produced water storage infrastructure. These beneficial use schemes will be expanded to suit the produced water volumes in those areas. Existing water use opportunities include small scale stock-watering, irrigation and feedlot water supply. The water modelling will be managed progressively as the fields are developed.

Senex water balance modelling does account for climatic or seasonal variations by taking monthly averages, then matching these to actual data, which is incorporated into the model to verify the model against actual production and monitoring records. Predicted irrigation volumes also account for seasonal variations.

5.2.3 CSG Production Wells, Water Gathering and Distribution System

To produce gas from a coal seam, the water in the reservoir must first be extracted from a production well using an artificial lift /pump installed in the well. This reduces the pressure (or head) within the coal seam, and liberates the adsorbed gas from the coal. Flow from the well is separated into water and gas by either: wellbore separation (where water is pumped up the tubing and produced gas flows to the surface in the annulus of the well); or where wellbore separation is ineffective, a surface separator may be installed. At the separation point, any hydrocarbons are also removed and processed through treatment designed accordingly for that purpose.

CSG production wells will be drilled and constructed in accordance with the 'Code of Practice for constructing and abandoning coal seam gas wells and associated water bores in Queensland' (DNRM 2013).

Gas and water from the wellsite will be delivered to the Field Compressors Facilities and water storage facilities, such as dams / tanks, via the Gas and Water Gathering System. The gathering system will transport gas and water at low pressure through separate High-Density Polyethylene (HDPE) pipelines installed underground. The HDPE gathering system shall be designed and installed in accordance with APGA Code of Practice Upstream Polyethylene Gathering Networks – CSG Industry Version 4.0.

All produced water will initially be collected from the water gathering systems into aggregation dams (Section 5.2.4).

5.2.4 Operational Water Storage Facilities

CSG produced water dams proposed for the WSGP include:

- dams for aggregating untreated CSG produced water;
- temporary tanks or dams for production pilots;
- dams for blending treated water; and
- dams for storage of brine.

Aggregation dams will generally be located at appraisal pilot locations, Field Compression Facilities or the Central Processing Facility. Aggregation dams will range from pre-engineered above ground tanks (approximately 25 ML capacity) to purpose-built earthen dams with impervious liners of up to 200 m x 200 m in dimension (up to 300 ML capacity).

CSG water storage dams will be assessed using the 'Manual for Assessing Hazard Categories and Hydraulic Performance of Structures' prepared by DEHP (2016a). If a dam is identified to be in the 'significant' or 'high-hazard' category, it is considered a regulated dam and detailed dam design reports must be submitted to DEHP following granting of the EA (that provides in principle approvals of dam construction).

The following will apply with respect to any regulated dams required for the project:

- Senex will design dams in accordance with relevant legislation and Queensland standards and DEHP guidelines;
- Senex will submit dam designs separately and specifically for registration;
- An independent third party will be engaged to certify dams to ensure design, construction and hydraulic performance meet design plan;
- Dams will be constructed under the supervision of a suitably qualified and experienced person and in accordance with the relevant DEHP schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements;
- Senex will employ a seepage monitoring program for water storage dams and tanks, where required. The seepage monitoring program will identify infrastructure and procedures that are in place to detect loss of containment as early as possible.

- Senex will routinely monitor water quality in dams, and in the respective dam's shallow groundwater monitoring bores, installed as part of the seepage monitoring program;
- Senex will monitor dam levels to provide early warning of overtopping and / or unidentified water losses; and
- Senex will monitor the integrity and assess the available storage of dams annually.

Any low-hazard dams required for CSG water storage will be designed in accordance with accepted engineering standards. The dams will be designed with a floor and sides made of material capable of containing the water for the life of the project.

5.2.5 Water Treatment

Treating produced water will depend on the end use as well as the water quality requirements:

- Produced water of moderately low salinity (<4,000 µS/cm) will generally be processed by calcium and pH amendment only; and
- Produced water of higher salinity (>4,000 µS/cm) will be treated using reverse osmosis (RO) as required. Generally, water treated by RO will be blended with untreated produced water to result in a water composition suitable for the intended end use, and to optimise the operation of water treatment facilities.

Senex's water management studies have indicated that treatment by RO meets water quality compliance requirements, but is the most expensive treatment option when brine costs are included. Blending of RO with untreated produced water or produced water with solid calcium amendment and pH adjustment will produce an irrigation water that meets the water quality compliance requirements; noting that at higher salinities (>4,000 µS/cm) soluble calcium amendment with RO blending has significant marginal economies over produced water with reverse osmosis permeate blending due to higher blending economies.

Senex has undertaken a preliminary assessment of the various technologies available for the treatment of CSG water. At the time of CWMP compilation, calcium amendment and pH adjustment has been selected as the primary amendment method for CSG produced water that is not able to be beneficially used when untreated. These amendment treatment plants are low impact facilities (in terms of disturbance and operation), and will be sited adjacent to selected aggregation dams, locations of which are to be confirmed.

Senex considers that treatment by RO may be necessary for some beneficial uses, and plans to construct a single RO treatment plant at the Central Processing Facility, when required. The RO facility is expected to have a capacity in the range of 2 ML/d to 5 ML/d.

5.3. CSG Water Management Options

CSG water management options for the WSGP (Figure 5.1), have been developed to maximise the beneficial use of water. These options include providing CSG produced water for the following activities:

- Project activities, such as drilling and completions, dust suppression, etc.; and
- Landowner Water Supply Agreements (WSA), including water for irrigation, stock watering.

5.3.1 Project Activities

Where practical, Senex will use untreated CSG produced water to support ongoing development / construction activities such as: dust suppression; drilling; well completions and workovers; facilities construction; hydro-testing gathering networks; and landscaping and rehabilitation. Any untreated produced water used as part of WSGP project activities will be undertaken in accordance with the *'General beneficial use approval: Associated water (including coal seam gas water)'* (DEHP 2014), the *'Streamlined Model Conditions for Petroleum Activities'* (DEHP 2016b), and Senex's Environmental Authority, particularly Schedule G (water) and Schedule B (waste), which provides specific conditions related to beneficial use for irrigation, dust suppression and construction.

The general beneficial use approval document establishes the criteria for using untreated CSG produced water for dust suppression, construction, and landscaping and vegetation requirements. Compliance with water quality criteria is required to use untreated produced water for landscaping and vegetation; however, such criteria are not specified for dust suppression and construction. Utilising CSG water for dust suppression and construction purposes will be undertaken with consideration to Senex's 'Environmental Management Plan' (SENEX-WSGP-EN-PLN-006).

The expected uses, and anticipated range of volumes, for untreated CSG produced water from the WSGP are provided below:

- Dust suppression –up to 90 ML/yr (or 0.25 ML/d)
- Construction of Wells and Facilities – up to 180 ML/yr (or 0.5 ML/d).

5.3.2 Landowner Water Supply Agreements

Senex anticipates further utilising the CSG produced water for beneficial use by establishing Landowner Water Supply Agreement (WSAs). An estimate of current groundwater use in the vicinity of the WSGP area is ~230 ML/year (see section 6.4.4), which includes groundwater abstraction for stock and domestic, stock intensive, irrigation and other agricultural purposes (OGIA 2017).

5.3.2.1. Irrigation and Commercial Stock Watering

Senex has concluded through studies (Verterra Ecological Engineering 2016) that there is sufficient suitable land available within the WSGP area to dispose of the CSG produced water volume from the project by sustainable irrigation practices.

Senex has commenced discussions with agricultural water users (i.e. irrigators and cattle producers) to confirm that local demand for water exceeds the WSGP's expected water production. As a result of seasonal variability and varying agricultural enterprises, Senex is aware that agricultural users have different water demand profiles and water requirements, with some requiring water for stock watering and others for irrigation. For these reasons, Senex plan to adopt a portfolio management approach to water management, identifying the opportunity to address beneficial use demands with anticipated produced water volumes.

5.3.3 Third party CSG Water Export

Senex currently has an agreement in place with GLNG until 2019 to export 0.5 ML/day from the Glenora pilot to GLNG.

Throughout the project life, Senex will continue to explore opportunities to provide CSG water to other neighbouring operator facilities.

5.4. Brine and Salt Management

The DEHP Hierarchy within the CSGWMP (DEHP 2012) also provides a prioritisation hierarchy for managing saline waste, which comprises:

Priority 1 – Brine or salt residues are treated to create useable products wherever feasible.

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

Senex's preferred brine and salt management strategy aims to avoid the need to store brine in a regulated brine storage dam, where practicable, by adopting beneficial uses that do not produce brine. It is unlikely that any brine will be produced, however the management of brine is addressed through the State Environmental Authority requirements in Schedule B (waste) and Schedule I (dams). These schedules also address spills, leaks, and seepage monitoring and management. Senex's approach to any brine management will remain consistent with industry best practice.

Where it is necessary to desalinate produced water, the brine will be stored in a regulated dam, constructed to contain the entire production of brine from the Project. Evaporation of the brine in the storage facility will be conducted over time to concentrate the brine and to produce salt. Once produced, the salt will be disposed in a regulated waste facility. Senex will continue to investigate cost effective and / or commercial saline disposal uses.

Site rehabilitation requirements are addressed in Schedule J (Rehabilitation) of the Environmental Authority. Senex will be responsible for the rehabilitation of any dams or infrastructure under that approval, ensuring legacy issues develop following the cessation of Project Production.

As stated in the PER, any brine produced would be disposed of at an appropriately licenced facility. Senex will also continue to investigate cost effective uses that may be developed over time should there be a commercially viable solution that presents. This is not a limiting aspect for the development of the WSGP.

6. EXISTING ENVIRONMENT AND ENVIRONMENTAL VALUES

6.1. Climate

The Surat Basin region is characterised by a subtropical climate. An overview of the climatic extremes as recorded by the Bureau of Meteorology (BoM) at the nearest meteorological station, Roma Airport, (located approximately 21 km south from the southern boundary of the WGSP) between the years 1985 to 2017 (BoM 2017) indicate:

- annual average rainfall of 579.2 mm, with average maximum rainfall of 86.7 mm in February and average minimum rainfall of 22.8 mm in July;
- average maximum temperature of 34.3°C in January and average minimum temperature of 3.8°C in July; and
- average maximum 9am humidity of 73% in June and average minimum 3pm humidity of 27% in September.

The local area is characterised by a distinct dry season between April and September and a wet season between October and March.

6.2. Land

6.2.1 Topography and Drainage

The low hilly landscape of the WSGP is predominantly composed of undulating to moderately undulating landforms. There are small level floodplains areas associated with minor streams (1% slopes), and some steeper areas where slopes are up to 88%. Slopes average 4.75% across the area. The undulating to steep landforms within the Production Area tend to have sand or sandy medium-textured surface soils which in many parts have been subjected to extensive grazing and grazing related land-use activities, such as the clearing of woody vegetation.

Elevations range from 308m AHD in the northern Kooringa block to 623 m AHD in the southern Mimas block. The Great Dividing Range forms a watershed between the catchments of the Fitzroy River (Eurombah Creek Basin) and the Murray Darling basin (Bungil Creek Basin), with an east west orientation through the Production Area.

6.2.2 Regional Geology

The WSGP lies within the geographical extent of the Surat Basin, a basin of Jurassic-Cretaceous age, which is underlain by the Permo-Triassic Bowen Basin. Cenozoic-age formations are present overlying the Surat Basin formations.

Cenozoic age formations cover much of the Surat Basin and generally comprise unconsolidated alluvial sediments, which have been deposited along pre-existing watercourses (OGIA 2016d).

The Surat Basin underlies approximately 180,000 km^2 of south-east Queensland and is connected to the Eromanga Basin in the west, the Clarence-Moreton Basin in the east and Mulgildie Basin to the north-east (KCB 2016). The Surat Basin is bounded to the north-east by the Auburn Arch and to the south-east by the Texas Block. The northern margin of the basin has been exposed and extensively eroded, and the sediments generally dip in a south-westerly direction (OGIA 2016d).

The Surat Basin has a maximum sediment thickness of 2,500 m. Generally, deposition was relatively continuous and widespread. Deposition in the basin commenced with the onset of a period of passive thermal subsidence of much of eastern Australia. During the Early Jurassic, deposition was mostly fluviolacustrine, while by the Middle Jurassic coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued (Geoscience Australia 2017; OGIA 2016d).

The Bowen Basin is elongated, trending north-south, and extends from central Queensland, south beneath the Surat Basin, into New South Wales where it eventually connects with the Gunnedah and Sydney basins. It contains Permian to Triassic age sediments with a maximum thickness of about 9,000 metres (OGIA 2016d; Cadman, Pain, and Vuckovic 1998).

The depositional history of the Bowen Basin is complex and individual formations are not always laterally extensive or easy to correlate across the basin (Draper 2013). Deposition in the basin began during the Early Permian, with river and lake sediments and volcanics being deposited in the east, and a thick succession of coals and non-marine sedimentary rocks in the west. These sediments were then overlain by mostly fine-grained sediments such as mudstone and siltstone of marine origin (OGIA 2016d).

6.2.3 Soils

The undulating to strongly undulating plains of the Production Area are dominated by texture contrast soils (i.e. Sodosols, Chromosols and Kurosols). These soils are characterised by abrupt textural changes between the typically sandy loam to loam topsoils and the medium to heavy clay subsoils. Subsoils are often sodic and dispersive and highly erodible if exposed.

Areas of cracking (Vertosols) and non-cracking (Dermosols) clay soils are present along flat alluvial plains and gently undulating plains, with some areas of cracking clays strongly gilgaied. These soils are utilised for improved pasture and cropping, with agricultural development having taken place on the deeper, more fertile cracking and non-cracking clay soils within the Production Area. Agricultural production on profiles formed on tertiary weathered sediments however, is usually limited due to subsoil constraints of excessive salinity, chloride and sodicity.

Areas of undulating to steep hill country are dominated by eucalypt woodland, and iron bark and occurs predominantly within and on either side of the Great Dividing Range. Soil profiles in these areas are typically shallow and rocky, with areas of rock outcrop on slopes in excess of 5%. Little or no profile development evidenced as Rudosols and Tenososls has occurred within these areas and soil profiles are shallow, moderately to strongly acid, and excessively well drained.

Remaining areas consist of coarse textured, structureless to poorly structured alluvial soils (i.e. Tenosols and Kandosols), red and yellow earths, or uniform coarse-textured soils (Tenosols). These soils are acidic and very well drained with a low plant available water capacity and they are prone to erosion with the disturbance or removal of riparian vegetation.

There are no known acid-sulfate soil-prone areas or acid-bearing rock formations within the vicinity of the Production Area.

6.2.4 Land Use

Land use within and surrounding the Production Area is predominantly focused on primary resources. Rural/agricultural production associated with cattle grazing and feed-lotting and petroleum activities are the dominant land uses within the region.

Of the 119 properties within the Production Area, 100 are freehold (84% of land area), 12 are leasehold (10% of land area), three are reserve (2.5% of land area), three are State forest (2.5% of land area) and one is State land (0.8% of land area).

Several CSG projects are located within the vicinity of the WSGP and include the Santos Gladstone LNG Project to the immediate south and the Australia Pacific LNG Project (Origin) to the northwest. There are a range of mining projects present in the greater region, which are at varying stages of development, as well as exploration tenements over the Production Area.

A relatively small portion of the Production Area is mapped as a Strategic Cropping Land (an "area of regional interest" under the *Regional Planning Interests Act 2014* (State of Queensland 2015). There are no other areas of regional interest located within the Production Area.

Commercial timber production from native forests occurs within the Rhea, Tethys and Phoebe and Dione sub-blocks. These areas contain Gubberamunda State Forest 1, Gubberamunda State Forest 2 and Gubberamunda State Forest 3, totalling an area of 3,541 ha, approximately 5% of the Production Area.

Areas of remnant vegetation within the Production Area are mainly associated with waterway riparian zones and isolated patches or tracts left uncleared.

6.2.5 Environmentally Sensitive Areas

Within the Production Area, there are Category B and C Environmentally Sensitive Areas (DEHP 2016c). This is summarised in *Table 6.1*.

Table 6.1: Environmentally Sensitive Areas within the Production Area

ESA Matter	Comment
Category B ESA that are 'endangered' regional ecosystems	There are areas of remnant and regrowth vegetation that are endangered regional ecosystem (biodiversity status) within the Production Area. Some of these areas are associated with riparian areas.
Category C ESA that are 'essential habitat', 'essential regrowth habitat', or 'of concern' regional ecosystems	There is essential habitat mapped in ATP795. There are 'of concern' regional ecosystems (biodiversity status) within the Production Area. There is no essential regrowth habitat mapped within the Production Area. Some of these areas are associated with riparian areas.
Category C ESA that are 'state forests' or 'timber reserves'	There is state forest within the Production Area – Gubberamunda State Forest. Some of these areas are associated with riparian areas. There is no timber reserve mapped within the Production Area.

6.3. Surface Water

6.3.1 Watercourses

The Production Area overlaps two catchments, the Upper Dawson River sub-basin (within the Fitzroy Basin), and the Upper Balonne River sub-basin (within the Condamine-Balonne Basin). Watercourses in these sub-basins are mostly ephemeral, with the exception of major watercourses such as the eastern portion of the Dawson River and parts of the Condamine River. Both catchments are heavily influenced by anthropogenic pressures including land use, riparian management, water infrastructure and point source pollution. The catchments are also highly modified as a result of agricultural and grazing practices.

The catchment boundary runs north-west to south-east across the Production Area along the Great Dividing Range. North of the Great Dividing Range, Eurombah Creek flows from ATP 767 northeast off tenure. South of the Great Dividing Range, Bungil and Blyth Creeks flow south from the Production Area to join the Balonne River near the town of Surat.

Several other smaller drainage lines are present within the Production Area. Creeks on the tenure include DEHP mapped stream orders (Strahler 1975) 1 to 5 with the majority comprising Stream Order 1 and 2.

In addition to waterways, there are a number of landholder dams located across the landscape.

6.3.2 Hydrology and Geomorphology

The hydrology of the Production Area is directly influenced by the distinct seasonal rainfall and the subsequent highly variable streamflow patterns. Watercourses within the WSGP area are largely ephemeral in nature, only flowing during or immediately after significant rainfall events and subjected to relatively rapid flow recessions. Peak stream discharges usually occur during the wet season months of December to February when rainfall is highest.

Watercourses in the Production Area exhibit a wide range of fluvial geomorphologic characteristics and typically show a moderate to high level of impact from the effects of land clearance for grazing and cropping, stock access and removal of riparian vegetation. These watercourses can also experience periodic, high energy flood events that may cause rapid adjustments to channel morphology. Flood plains are mapped (DNRM 2017) associated with the main channels of Blyth and Bungil creeks. Land use in the Production Area have also greatly increased the vulnerability of stream banks to erosion during high energy floods, which result in downstream movement of large volumes of sediment (Senex 2017).

6.3.3 Aquatic Ecology

Waterway flows, as described above, are considered to be largely associated with runoff events in response to significant rainfall. As a result, within the Production Area there are limited watercourse aquatic ecosystems. The waterways instead provide drainage paths and intermittent habitat for aquatic species.

The DEHP waterbody mapping identifies a number of small lacustrine waterbodies scattered across the landscape. Many of these are associated with the farm dams and water storages and would not be considered natural aquatic habitats, however would be expected to provide refuge and other habitat values to fauna moving through the area.

Field surveys revealed very few observations of aquatic flora and fauna and confirmed the overall paucity of permanent water. Those survey sites where water was present were found to be significantly impacted by grazing, vegetation clearing and erosion in some locations. Instream habitat was generally uniform and highly dependent on the presence of bars, and woody debris (Senex 2017). The field assessment results were largely consistent with the stream health ratings reported by Telfer (1995; cited in Senex 2017).

Pools were rarely observed, and where present were shallow and limited in size (a few metres) suggesting they do not provide significant refuge for biota. Grasses and other vegetation were commonly reported within first order stream beds suggesting less than annual occurrence of significant scouring flow (Senex 2017).

There is potential that these watercourses provide limited values for aquatic biota, particularly given the overall paucity of permanent water courses within the Production Area.

6.4. Hydrogeology

6.4.1 Hydrostratigraphy

The Surat Basin forms part of the Great Artesian Basin (GAB) which comprises a number of aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source for water used for stock supply, public water and domestic supply. Figure 6.1 presents the hydrostratigraphic sequence of the Surat Basin.

The main aquifers within the GAB, from the deepest to the shallowest, are the Precipice Sandstone, Hutton Sandstone, Springbok Sandstone, Gubberamunda Sandstone, Mooga Sandstone and Bungil Formation. These aquifers are typically laterally continuous on a regional scale, have significant water in storage largely under confined conditions, and are extensively developed for water supply.

However, in some areas, they have more of the character of aquitards than aquifers (OGIA 2016b). Minor discontinuous aquifers include the Orallo Formation and Wallumbilla Formation. The major aquitards are the Evergreen Formation, Walloon Coal Measures, Westbourne Formation, and Griman Creek Formation.

The WSGP is located in the area where several Surat Basin units outcrop, these include the Bungil Formation, Mooga Sandstone, Orallo Formation, Gubberamunda Sandstone, Westbourne Formation, Springbok Sandstone, Walloon Coal Measures, and Eurombah Formation, with the Hutton Sandstone outcropping to the north of the Project.

Quaternary alluvial deposits are also mapped as occurring within the Project area, generally with the most extensive alluvium associated with the major watercourses.

Table 6.2 presents a summary of each hydrostratigraphic unit within the Surat Basin (from oldest to youngest).

Figure 6.1 Regional Hydrostratigraphy (after OGIA, 2016)

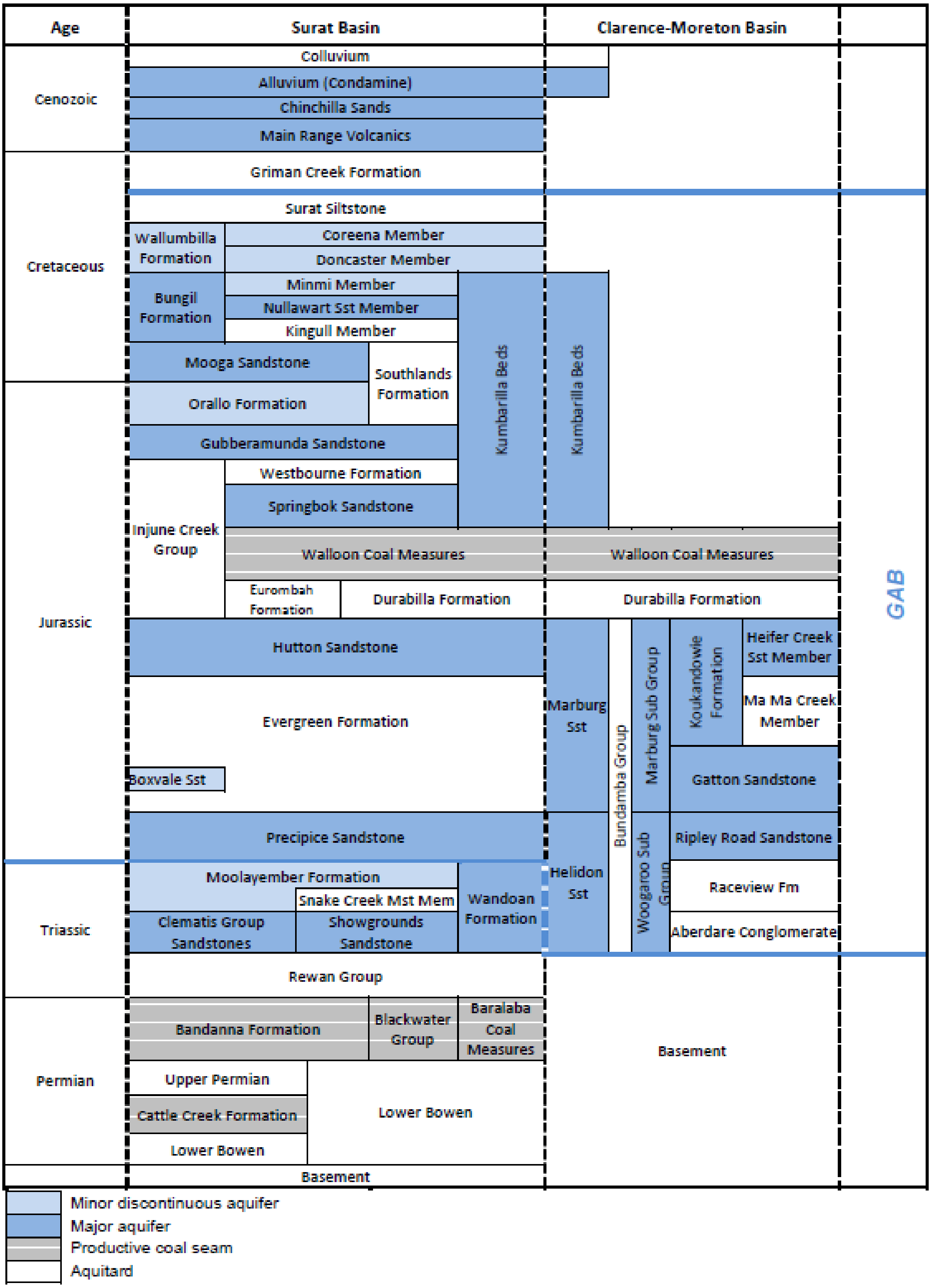


Table 6.2: Description of Relevant Surat Basin Hydrostratigraphic Units

Formation	Aquifer / Aquitard	Description
Precipice Sandstone	Major Aquifer	The Precipice Sandstone is the basal unit of the Surat Basin. It overlies the Moolayember Formation and sedimentary sequences of the Bowen Basin. Lower and upper subunits are recognised, often separated by a siltstone or shale unit. The layers with the coarsest grain sizes were deposited by transverse bars in a braided stream system and the sediment layers with finer grain sizes were deposited in a lower energy fluviatile meandering system (Martin 1981). The lower subunit, also known as the Precipice Braided Stream Facies (or Precipice BSF), consists of white, fine to very coarse-grained, in part pebbly, thin to very thickly bedded, porous, quartz rich sandstone with a white clay matrix (Exon 1976)
Evergreen Formation	Aquitard	The Evergreen Formation overlies the Precipice Sandstone and separates the Precipice Sandstone from the Hutton Sandstone, both major aquifers. The Evergreen Formation is considered an aquitard and generally consists of mudstones laminated with fine-grained sandstone, siltstone and shale (Green 1997).
Hutton Sandstone	Major Aquifer	The Hutton Sandstone was deposited in a non-marine environment by meandering streams on a broad floodplain (Exon 1976) and consists mainly of sandstone with interbedded siltstone, shale, minor mudstone, and coal. The sandstone is white to light grey, fine to medium-grained, well sorted, generally quartz-rich, partly porous with some pebble bands, shale, and siltstone clasts in the lower part. Siltstones and shales are light to dark grey, micaceous, carbonaceous and commonly interlaminated with very fine-grained sandstone (Green 1997). It is highly heterogeneous, with sand bodies limited in vertical and lateral extent.
Eurombah Formation	Aquitard	The Eurombah Formation, often referred to as the Durabilla Formation, conformably overlies the Hutton Sandstone. The depositional environment for this unit was fluvial with periods of rapid sedimentation. It is often difficult to differentiate the Eurombah Formation from the WCM. It is more restricted in extent than either the Hutton Sandstone or the WCM (Green 1997). The Eurombah Formation is considered an aquitard, consisting of siltstone, mudstone and fine to medium-grained poorly sorted sandstone, with almost no coal and consequently, little permeability (OGIA 2016b). The Eurombah Formation outcrops in the north of the WSGP area.
Walloon Coal Measures	Productive Coal Seam	The Walloon Coal Measures (WCM) is the target formation for CSG production. This formation conformably overlies the Eurombah Formation. It was deposited in a low-energy meander-belt river system with the coal layers deposited mainly in an overbank environment (Exon 1976). The WCM consist of very fine to medium-grained argillaceous sandstone, siltstone, mudstone, and coal with minor calcareous sandstone, impure limestone, and ironstone (Swarbrick 1973). Typically, the coal layers are positioned in the upper half to three-quarters of the coal measures, with mudstones, siltstones and lithic sandstones dominant in the lower part. The WCM are considered an aquitard. The WCM also outcrops to the north of the WSGP area, south of the Eurombah Formation.
Springbok Sandstone	Major Aquifer	The Springbok Sandstone overlies the WCM. It was deposited by streams and includes overbank and swamp deposits in the upper part of the unit which indicates streams became less energetic with time (Exon 1976). The Springbok Sandstone consists mostly of feldspathic sandstones, commonly with calcareous cement (Green 1997). At the basin scale, the sandstones range from very fine to coarse-grained, although some very coarse-grained, poorly sorted pebbly beds also occur. Minor interbedded siltstones, mudstones, and thin coal seams are also present, primarily in the upper part. Within the GAB, the Springbok Sandstone is considered a usable aquifer, however it is highly variable in hydraulic properties and yield across the Basin. The Springbok Sandstone also has a very high content of mudstone and siltstone at many locations with very low permeability (OGIA 2016b).

Formation	Aquifer / Aquitard	Description
Westbourne Formation	Aquitard	The Westbourne Formation overlies the Springbok Sandstone. It was deposited in an environment with characteristics consistent with a low energy, lacustrine deltaic plain (Green 1997). The Westbourne Formation comprises predominately siltstone layers with thick interbeds of fine to medium grained sandstone and minor mudstone. Small coal fragments, lenses and lamina are common throughout the formation. Within the GAB sequence, the Westbourne Formation is considered an aquitard.
Gubberamunda Sandstone	Major Aquifer	The Gubberamunda Sandstone overlies the Westbourne Formation. It was deposited by braided and meandering stream systems draining surrounding highlands (Exon 1976). Consistent with a fluvial depositional environment, repeated packages of siltstone and fine to coarse sandstone were deposited. Deposits of carbonaceous shale along with minor coal fragments are typically present. Aquifers within fluvial depositional environments frequently demonstrate a non-homogenous and anisotropic character resulting in variable permeability. Within the GAB, the Gubberamunda Sandstone is considered a usable aquifer.
Orallo Formation	Minor discontinuous aquifer	The Orallo Formation overlies the Gubberamunda Sandstone. It was deposited in a relatively low energy fluvial environment with local ponding (Green 1997). The Orallo Formation consists of fine to coarse grained sandstone interbedded with clay, siltstone, silty mudstone, bentonite clay, and coal. The Orallo Formation is considered a minor discontinuous aquifer and outcrops across the southern extent of the WSGP area.
Mooga Sandstone	Major Aquifer	The Mooga Sandstone overlies the Orallo Formation. Deposits tend toward fine to medium grain size sand, although siltstones, mudstones, and shale are present (Exon 1976). Three subunits are recognised. The upper Mooga Sandstone and lower Mooga Sandstone are considered aquifers. The middle Mooga Sandstone consists of siltstones, mudstones, and shale and is considered an aquitard.
Bungil Formation	Major Aquifer	The Bungil Formation overlies the Mooga Sandstone. This unit is comprised of interbedded fine-grained lithic sandstones, siltstones and mudstones with minor quartzose sandstone present. The Bungil Formation functions as an aquitard due to the dominance of mudstones and the massive character of the unit.
Wallumbilla Formation	Minor discontinuous aquifer	The Wallumbilla Formation overlies the Bungil Formation and outcrops to the south of the WSGP area. The Wallumbilla Formation consists of mudstones and siltstones interbedded with minor lenticular sandstones, conglomerates, concretionary limestones, coal, and coquinites (Green 1997). The Wallumbilla Formation is an aquitard and is sub-divided into the Coreena and Doncaster Members.

6.4.2 Recharge

The Project is located within in an area where diffuse aquifer recharge will occur. Diffuse recharge is the process by which rainfall infiltrates directly though outcropping aquifers (Kellett et al. 2003). Recharge rates estimated by OGIA (2016a) range between 1.1 and 26.5 mm/yr depending on hydrostratigraphic unit.

6.4.3 Groundwater Quality

Groundwater chemistry across the WSGP area has been considered using data collected during baseline monitoring, during appraisal well trials, and from literature sources.

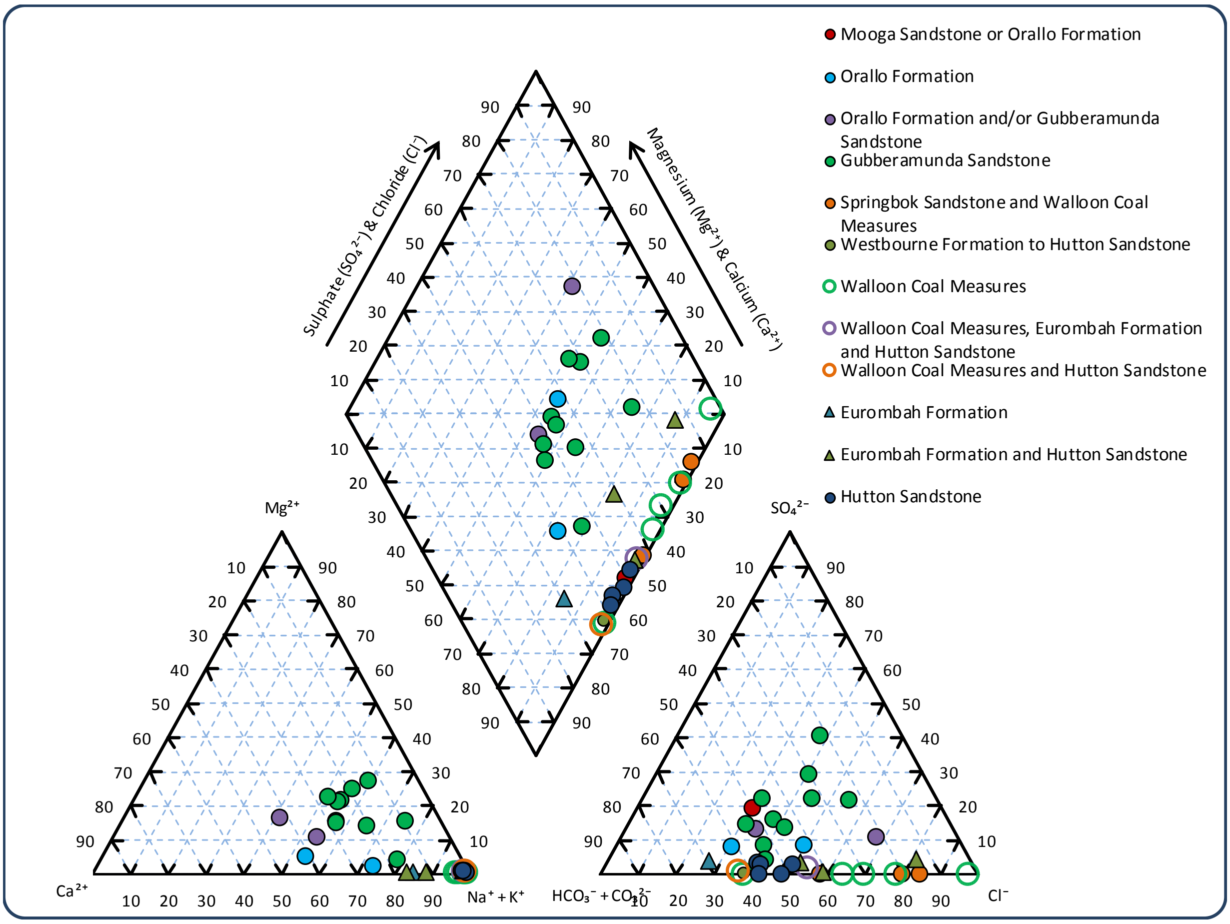
Table 6.3 presents a summary of the regional groundwater chemistry associated with each hydrostratigraphic unit occurring within the WSGP area from OGIA (2016c). Generally, the range of Total Dissolved Solids (TDS), used as an indicator of salinity, has a broad range across the Basin.

Table 6.3: Summary of Groundwater Chemistry for each Hydrostratigraphic Units

Hydrostratigraphic Unit	OGIA (2016c) Description
Bungil Formation	Fresh to brackish water. Mean TDS of 450 mg/L with a range of between 70 and 7,500 mg/L.
Mooga Sandstone	Fresh to brackish water. Mean TDS of 450 mg/L with a range of between 70 and 7,500 mg/L. Mooga Sandstone is fresh to brackish and dominated by Sodium-Bicarbonate, but becomes Chloride-rich in the north.
Orallo Formation	Fresh to saline conditions with TDS ranging from 75 to 20,000 mg/L, mean of 1,700 mg/L.
Gubberamunda Sandstone	Fresh to brackish water. Mean TDS of 450 mg/L with a range of between 70 and 7500 mg/L. Mean TDS ranges between 480 to 1,160 mg/L, depending on location category.
Westbourne Formation	Characterised by fresh to saline groundwater (TDS mean of 1,500 mg/L), ranging from 150 to 19,000 mg/L.
Springbok Sandstone	Fresh to brackish water quality, with a mean TDS of 1,000 mg/L (ranging between 200 and 7,000 mg/L).
WCM	Fresh to saline groundwater, TDS ranges from 30 to 18,000 mg/L, with a mean TDS of around 3,000 mg/L.
Hutton Sandstone	TDS ranges from 70 to 16,000 mg/L, with a mean TDS of around 1,600 mg/L, low-salinity calcium and magnesium bicarbonate type water in the recharge areas, to a relatively high-salinity sodium-chloride type water in discharge areas.
Evergreen Formation	Low salinity (TDS) and concentrations of sodium and chloride, TDS ranges from 80 to 670 mg/L, with a mean TDS of around 260 mg/L
Precipice Sandstone	Precipice Sandstone has the freshest groundwater in the Surat CMA, salinity ranges from 50 to 850 mg/L with a mean salinity (TDS) of 193 mg/L

Figure 6.2 presents a Piper diagram for each of the formations sampled within the baseline assessment. There is generally a distinction between the water chemistry for the formations overlying the WCM (Orallo Formation, Gubberamunda Sandstone) and the other formations presented, which show a strong sodium-chloride signature, while the upper formations indicate a sodium-bicarbonate water type.

Figure 6.2 Piper Diagram of Groundwater Chemistry within the WSGP



6.4.4 Groundwater Use

Groundwater within the vicinity of the Project is used for a range of purposes. Key bore purposes (OGIA 2017) include:

- Stock and Domestic (S&D)
- Agriculture, including: agriculture (any), irrigation and stock intensive;
- Town Water Supply;
- Industrial.

Groundwater abstraction for stock and domestic is the dominant water use purpose within the vicinity of the Project. OGIA (2017) estimate that 100 bores within the WSGP area abstract groundwater from Surat Basin units, with annual abstraction totalling 232 ML/year.

Thirty-nine of these bores are considered to at least partially[2] access groundwater from the WCM (Senex baseline assessment and OGIA aquifer attribution).

[2] It is common for water bores to be screened across multiple formations, with thirty-nine bores considered to at least partially or fully access groundwater from the WCM.

6.4.5 Groundwater Dependent Ecosystems

Surface expression Groundwater Dependent Ecosystems (GDEs) are defined as:

'ecosystems dependent on the discharge of groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. Surface expression GDEs include drainage lines, spring wetlands and regional ecosystems that have some groundwater dependency' (DSITI 2015).

In the GAB, these are referred to as Spring Vents / Complexes and Watercourse Springs. Table 6.4 presents a summary of springs and watercourse springs within the vicinity of the Project, with their locations presented on Figure 6.3.

Table 6.4: Surface expression GDEs within the vicinity of the Project

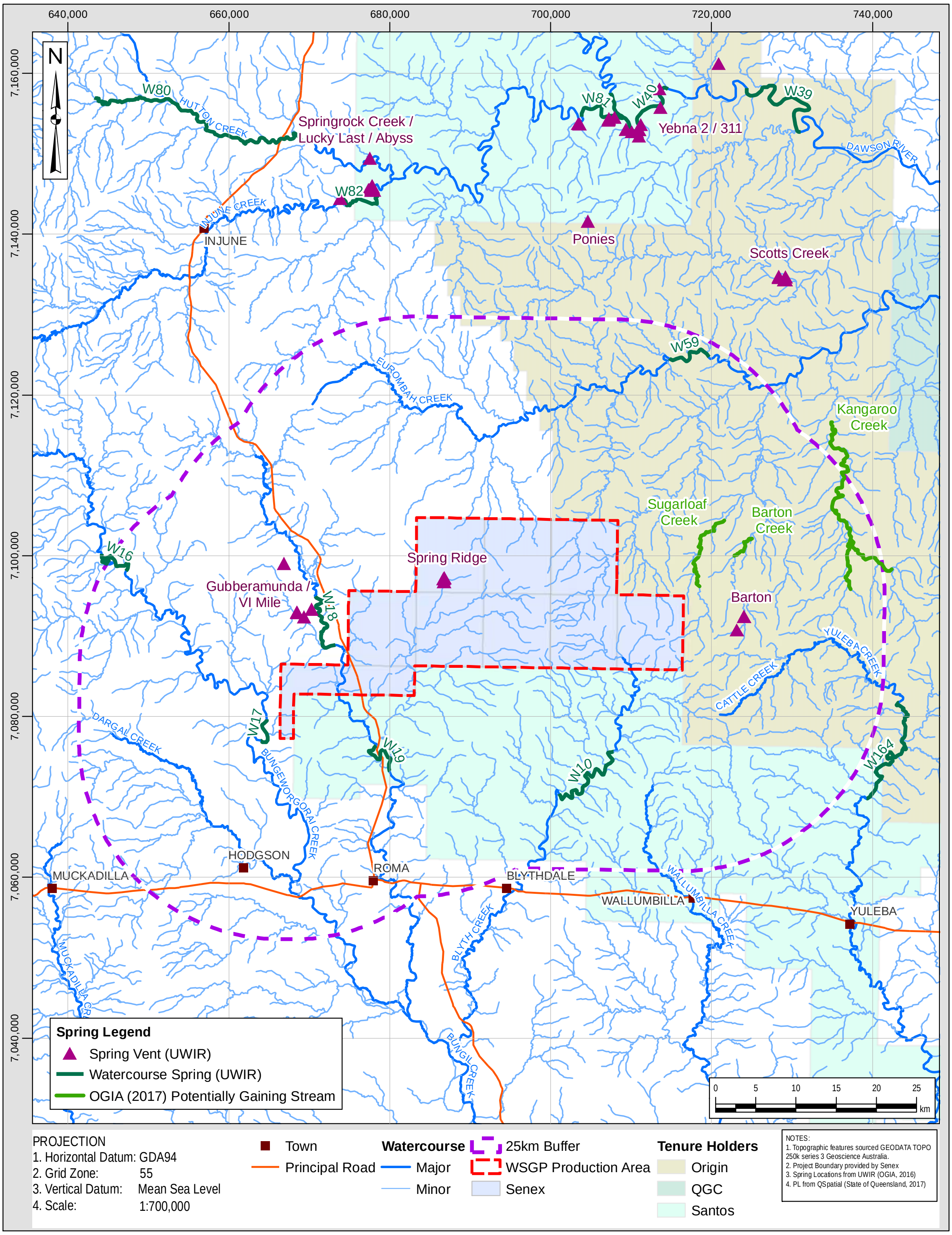
GDE Type	Complex / Site Number	Name	Vent	Source Aquifer	Distance from the Project Boundary
Spring Vents	506	Spring Ridge	184.1, 185.1, 186.1	Gubberamunda Sandstone	Within Project (Rhea Block)
	283	Barton	702.1, 703.1	Gubberamunda Sandstone	6.7 km east
	358	Gubberamunda (VI Mile)	187.1, 679.1, 680.1, 680.1.1	Gubberamunda Sandstone	5.0 km west
Watercourse Springs	W10	Blyth Creek	N/A	Mooga Sandstone, Orallo Formation	10 km south
	W16	Bungeworgorai Creek		Gubberamunda Sandstone	22.6 km
	W17	Bungeworgorai Creek		Mooga Sandstone	1.6 km west
	W18	Bungil Creek		Gubberamunda Sandstone	1.6 km west
	W19	Bungil Creek		Mooga Sandstone	6.3 km south
	W59	Eurombah Creek		Upper Hutton Sandstone	22.8 km

Recent work by OGIA (2017b), published since the UWIR, to re-map gaining streams (or baseflow-fed reaches, watercourse springs) has identified three further reaches of creeks, within the vicinity of the WSGP, as potentially gaining streams. Details of the three further reaches are provided in *Table **6-5***, with their locations shown on *Figure **6.3***. Blyth Creek (W10) and Eurombah Creek (W59) were also included in the assessment.

Table 6-5: Details of Potentially Gaining Streams (Watercourse Springs) from OGIA (2017b)

Name	Potential Source Aquifer	Distance from WSGP Boundary	Information Source
Sugarloaf Creek	Alluvium / Westbourne Formation / Springbok Sandstone / WCM	4.2 km	OGIA (2017b)
Barton Creek	Alluvium / Springbok Sandstone	10.6 km	OGIA (2017b)
Kangaroo Creek	Gubberamunda Sandstone / Westbourne Formation / Springbok Sandstone	23.8 km	OGIA (2017b)

Figure 6.3 Location of Spring Complexes / Vents and Watercourse Springs



6.5. Environmental Values and Water Quality Objectives

6.5.1 Environmental Values – Water

The *Environmental Protection Act 1994* (State of Queensland 2016a) defines an Environmental Value (EV) as:

- a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or
- another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

Under the *Environmental Protection Act 1994,* the *Environmental Protection (Water) Policy 2009* (State of Queensland 2016b) is established as subordinate legislation to achieve the objective of the Act in relation to Queensland Waters. The purpose of the *Environmental Protection (Water) Policy 2009* is achieved by:

- identifying environmental values and management goals for Queensland waters;
- stating water quality guidelines and water quality objectives to enhance or protect the environmental values;
- providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- monitoring and reporting on the condition of Queensland waters.

The WSGP area straddles two river basins; the Fitzroy Basin and Queensland Murray-Darling and Bulloo Basin. EVs have been prepared for each river basin / sub-basin independently. The sub-basins, plans and sub-catchments applicable to the WSGP area shown in Figure 6.4 and summarised below:

- EVs for the Fitzroy Basin are outlined in the 'Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment' (DEHP 2011). Specific EVs applicable to the WSGP area include the Upper Dawson River waters (WQ1308), which are separated into the Upper Dawson – Taroom Area and Upper Dawson – Injune Area.
- The EVs within the Queensland Murray Darling and Bulloo Basin relevant to the WSGP area are within the Maranoa-Balonne sub-basin, however this basin is not currently included in Schedule 1 of the Environmental Protection (Water) Policy 2009 (State of Queensland 2016b).Draft consultation materials have been published for consultation. The draft EVs are detailed in 'Maranoa Balonne Rivers Basin Groundwater Environmental Values, Draft.' (DSITI 2017a) and 'Maranoa Balonne Rivers Basin Surface Water Environmental Values, Draft' (DSITI 2017b) and have been considered as part of the CWMP. The EVs will be updated in this CWMP when the final EVs are available.

EVs, for both basins, are presented in *Table 6.6*, and includes both the values for surface water and groundwater.

Figure 6.4 Environmental Values Sub-Basins and Sub-Catchments

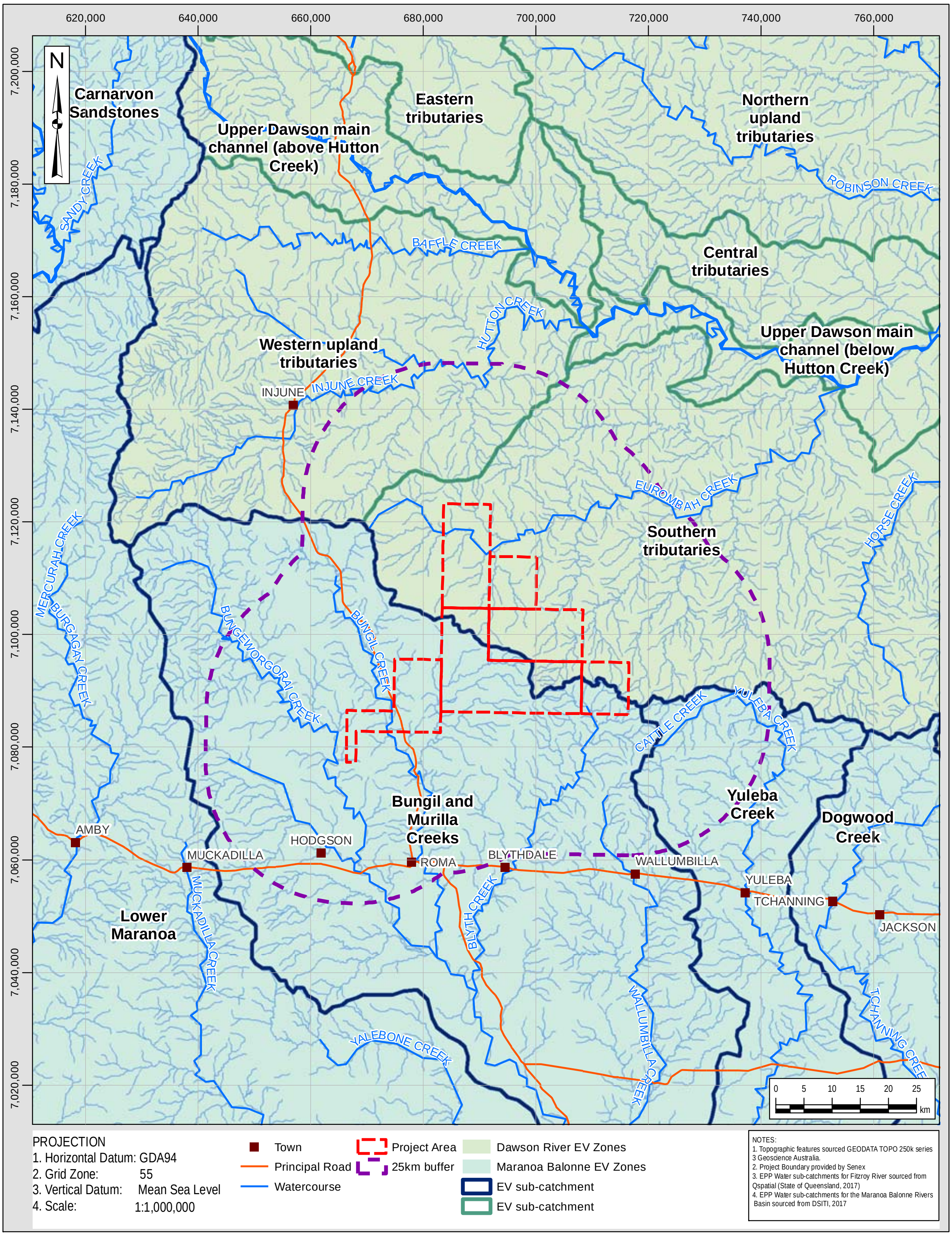


Table 6.6: Environmental Values for Groundwater and Surface waters within the vicinity of the WSGP (DEHP 2011)

Water		**Environmental Values**											
		Aquatic Ecosystem	**Irrigation**	**Farm Supply / Use**	**Stock Water**	**Aquaculture**	**Human consumer**	**Primary recreation**	**Secondary recreation**	**Visual recreation**	**Drinking water**	**Industrial use**	**Cultural and spiritual values**
Upper Dawson—Injune area (WQ1308)													
Upper Dawson main channel (upstream of Hutton Creek junction)—developed areas		✓			✓		✓	✓	✓	✓	✓		✓
Western upland tributaries—developed areas		✓			✓		✓	✓	✓	✓	✓		✓
Groundwater	Shallow groundwater (e.g. windmill bores)	✓	✓	✓	✓						✓		✓
	Precipice sandstone bores	✓	✓	✓	✓	✓	✓	✓			✓		✓
	Coal seam gas layer	✓	✓	✓	✓						✓	✓	✓
	Hutton sandstone (Injune town)	✓		✓	✓			✓			✓		✓
Undeveloped areas		✓			✓		✓	✓		✓	✓		✓
Upper Dawson—Taroom area (WQ1308)													
Upper Dawson main channel (downstream of Hutton Creek junction)—developed areas, including Glebe Weir		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Northern upland tributaries—developed areas		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
Central tributaries—developed areas		✓		✓	✓		✓	✓	✓	✓	✓		✓
Southern tributaries—developed areas		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Groundwater		✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
Undeveloped areas		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Maranoa Balonne - Groundwater													
Yuleba Creek		✓	✓	✓	✓						✓		
Bungil and Murilla Creeks		✓	✓	✓	✓						✓		

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values
Maranoa Balonne – Surface Water												
Yuleba Creek	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
Bungil and Murilla Creeks	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓

✓ means the EV is selected for protection. Blank indicates that the EV is not chosen for protection.

6.5.1.1. Water Quality Objectives

Water Quality Objectives (WQOs) for groundwater are also outlined (DEHP 2011) to protect EVs. A summary of the WQOs for groundwater in the Upper Dawson are provided below. WQOs for the Maranoa-Balonne sub-basin have not been defined, but will be incorporated into the CWMP once defined by DEHP.

- WQOs for aquatic ecosystems applicable to groundwater, where groundwater interacts with surface water, the groundwater quality should not compromise identified EVs and WQOs for those waters.
- For drinking water, local WQOs exist which relate to before and after water treatment and are based on a number of guidelines / legislation including the Australian Drinking Water Guidelines (NHMRC 2011).
- WQOs to protect or restore indigenous and non-indigenous cultural heritage should be consistent with relevant policies and plans.
- For irrigation, WQOs exist for metals, pathogens and other indicators in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000).
- For stock watering, objectives exist for faecal coliforms, total dissolved solids, metals, and other objectives based on guidelines presented in ANZECC & ARMCANZ (2000).
- For farm use / supply, objectives are as per the guidelines in ANZECC & ARMCANZ (2000).

6.5.2 Environmental Values – Other

There are no declared environmental values relating to land for the Production Area. The environmental values of the land, relevant to CSG water management within the Production Area to be protected or enhanced are:

- the integrity of undisturbed land and ecosystems within the Production Area;
- the integrity of the topsoil as a resource to be used in rehabilitation;
- the stability of disturbed land and ensuring it is non-polluting;
- the integrity of soil stability and structure for erosion protection;
- the suitability of the land for continued agricultural use post-closure;
- the integrity of regional ecosystem communities and the habitat values they provide within the Production Area;
- the integrity of habitat for endangered, vulnerable, near threatened and special least concern species;
- the integrity of Category B and C ESAs; and
- the integrity of movement corridors provided by riparian zone vegetation.

7. MANAGEMENT, COMPLIANCE AND MONITORING

7.1. Management and Compliance

Senex will implement all CSG produced water and brine management strategies in accordance with the applicable EA conditions and in a manner that ensures protection and maintenance of all relevant EVs.

The Environmental Protection Act 1994 requires that a site-specific application for a CSG activity must include measurable criteria (termed 'management criteria'), against which the applicant will monitor and assess the effectiveness of the management of all CSG produced water and saline waste associated with the activity. Senex has developed criteria that addresses this requirement (the criteria has been developed following guidance outlined in the DEHP factsheet ‘CSG water management: Measurable criteria’ (DEHP 2017).

The management criteria addresses:

- the quantity and quality of the water:
  - used,
  - treated,
  - stored, or
  - disposed of;
- protection of EVs affected by each relevant CSG activity; and
- the disposal of waste generated from the management of water.

Table 7.1: WSGP Water Management Criteria

Objective	Environmental Values	Tasks	Performance Indicator
No unauthorised disturbance of environmentally sensitive areas due to CSG water management activities	▪ Land (see Section 6.5.2 ▪ Surface water (see Table 6.6)	Secure disturbance approvals by implementing the 'Environmental Management Plan' (SENEX-WSGP-EN-PLN-006) and Environmental Constraints Protocol for Planning and Field Development' (SENEX-WSGP-EN-PRC-002). Finalise infrastructure locations to identify area and location of disturbances. Comply with EA conditions related to disturbance, biodiversity values and environmentally sensitive areas.	Site specific Ecology Assessment Reports Site specific Desktop constraints reports Compliance with extent of approved disturbance
No unauthorised releases to the environment from the gathering network	▪ Groundwater (see Table 6.6) ▪ Surface water (see Table 6.6)	Select gathering routes by implementing the 'Environmental Constraints Protocol for Planning and Field Development' (SENEX-WSGP-EN-PRC-002). Implement the Environmental Management Plan' (SENEX-WSGP-EN-PLN-006) Develop and implement operation and maintenance plans for gathering networks. Ensure plans includes: ▪ operational procedures for infrastructure associated with isolation, leakage detection and venting / draining for the CSG production wellhead and gathering network; and ▪ monitoring procedure for wellhead and gathering network infrastructure. Implement Senex Incident Reporting and Investigation Procedures.	Recorded volume of unauthorised leaks / spills Recorded number of incidents and associated investigations

Objective	Environmental Values	Tasks	Performance Indicator
No unauthorised releases to the environment from non-regulated structures storing CSG water	▪ Groundwater (see Table 6.6) ▪ Surface water (see Table 6.6))	Tanks – construction and maintenance in accordance with EA conditions; install remote monitoring equipment for water levels; and implement leak detection monitoring and site inspections. Ponds – implement site inspection / leak detection monitoring program in accordance with EA requirements (surface water and groundwater seepage). Implement Senex Incident Reporting and Investigation Procedures	Recorded volume of unauthorised leaks / spills Recorded detection of unauthorised leaks (i.e. groundwater level rise, groundwater quality changes) Recorded number of incidents and associated investigations
No unauthorised releases to the environment from regulated structures storing CSG water	▪ Groundwater (see Table 6.6) ▪ Surface water (see Table 6.6)	Design, construct and operate all regulated structures in accordance with the requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (DEHP 2016) Develop and maintain a regulated structure register. Develop and implement a monitoring program to assess structure integrity and groundwater seepage. Develop and implement a rehabilitation plan for specific regulated structures, including, if required, a brine and salt management plan. Undertake assessment and reporting in accordance with EA requirements	Recorded volume of unauthorised releases from regulated structure Compliance with requirements of the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* DEHP 2016) Recorded detection of unauthorised leaks (i.e. groundwater level rise, groundwater quality changes) Recorded number of incidents and associated investigations

Objective	Environmental Values	Tasks	Performance Indicator
Maximise the beneficial use of CSG water	▪ Groundwater (see Table 6.6) ▪ Surface water (see Table 6.6) ▪ Land (see Section 6.5.2)	Maintain the numerical reservoir model to predict the quantity and quality of water over the duration of WSGP development. Develop and maintain a project water balance model to optimise the size of water management infrastructure and predict changes in water quality to support the water management strategy. Prioritise water use in accordance with the hierarchy defined in the *CSG Water Management Policy* (DEHP 2012). Develop and implement a Water Quality Monitoring Program to confirm if water is fit for beneficial use. Determine requirement for a Water Treatment Facility.	Volume of untreated CSG water beneficially used Volume of treated CSG water beneficially used
Optimise CSG water and brine management	▪ Groundwater (see Table 6.6) ▪ Surface water (see Table 6.6)	Maintain the numerical reservoir model to predict the quantity and quality of water over the duration of WSGP development. Develop and maintain a project water balance model to optimise the size of water management infrastructure and predict changes in water quality to support the water management strategy. Continue to investigate opportunities for CSG water and brine management and prioritise these options in accordance with the *CSG Water Management Policy* (DEHP 2012). Undertake ongoing assessments of optimisation options for CSG water and brine management.	Results from the project water balance identifying the preferred CSG water and brine management options.

7.2. Monitoring

7.2.1 CSG Water and Treated CSG Water Quality Monitoring

Untreated CSG water quality will be monitored on a quarterly frequency. The water quality data from untreated CSG water will be used to:

- Inform the water treatment facility design and operation; and
- Ensure the water quality is suitable for the designated beneficial use and in accordance water quality objectives in the 'General beneficial use approval' (DEHP 2014) and conditions provided in the 'Streamlined Model Conditions for Petroleum Activities' (DEHP 2016b) that are aligned with the general beneficial use approval.

Treated CSG water quality will be monitored on a weekly frequency. The water quality data from treated CSG water will be used to:

- Ensure the water quality is suitable for the designated beneficial use or water supply arrangement and in accordance water quality objectives in the 'General beneficial use approval' (DEHP 2014); and
- Confirm the water treatment method is effectively treating the CSG water.

7.2.2 Water Storage Pond Monitoring

Senex will undertake inspections and monitoring associated with the water storage pond structures to assess integrity of the structures and monitor any potential impacts to environmental values. The monitoring requirements are provided in *Table 7.2.* Event-based monitoring will also be undertaken as and when required.

Table 7.2: Water Storage Pond Monitoring Requirements

Activity	Frequency	Reporting
Monitoring and Inspections		
Seepage Monitoring Program and dam water quality	Water and quality levels – quarterly	Any evidence of seepage reported in accordance with EA conditions (See Section 7.2.3.1)
Regulated structure water quality monitoring	Annually	Provided to DEHP in accordance with relevant EA conditions and Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (DEHP, 2013)
Dam embankments and spillways inspection	Annually	Any evidence of deterioration reported in accordance with relevant EA conditions
Dam compliance inspection	Annually and 5 yearly	Inspection report submitted to DEHP in accordance with relevant EA conditions
Documentation		
Regulated structure register	Completed as dams are constructed	Regulated structure register

7.2.3 Groundwater Monitoring

7.2.3.1. Seepage Monitoring Program (Shallow Groundwater)

Installation and monitoring of shallow groundwater bores surrounding water storage ponds will be undertaken to monitor for dam seepage in accordance with the relevant EA conditions, and *'Streamlined Model Conditions for Petroleum Activities'* (DEHP 2016b). This will be conducted in conjunction with monitoring the water quality within the water storage pond. The seepage monitoring program will be designed to:

- Be undertaken by a suitably qualified person, and in accordance with 'Groundwater Sampling and Analysis – A Field Guide' (Sundaram et al. 2009);
- Be undertaken on a quarterly basis;
- Ensure all water quality samples are analysed / tested at a laboratory with NATA accreditation;
- Identify water quality associated with the water stored within the dam;
- Identify the background groundwater quality in the vicinity of the dam as a reference site;
- Provide information to develop trigger levels and detection limits associated with dam seepage; and
- Be documented and updated should new containment facilities be constructed.

7.2.3.2. Regional (deep) Groundwater Monitoring

Regional groundwater monitoring in relation to CSG water production by Senex will be undertaken, however this is outside the scope of this CWMP in relation to the management of CSG water.

7.2.4 Land and Soils Monitoring

Senex will undertake land and soil monitoring where CSG water management activities have the potential to significantly impact on EVs.

7.3. Reporting

7.3.1 Monitoring Results

An annual review of the monitoring undertaken in accordance with the CWMP and EA conditions will be completed.

Water quality results will be reviewed following sampling events against the relevant water quality guidelines and EA conditions and reported to the appropriate administering authority.

7.3.2 Reviews

A review and update of the CWMP will be periodically undertaken to capture changes to the WSGP description that influences the management of CSG water and / or optimisation of the CSG water and brine management.

8. REFERENCES

ANZECC & ARMCANZ. 2000. 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality'. Prepared by the Australian and New Zealand Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). https://www.environment.gov.au/system/files/resources/53cda9ea-7ec2-49d4-af29-d1dde09e96ef/files/nwqms-guidelines-4-vol1.pdf.

BOM. 2017. 'Climate Statistics for Roma Airport, Site Number 043091'. *Bureau of Meteorology*. http://www.bom.gov.au/.

Cadman, SJ, L Pain, and V Vuckovic. 1998. 'Bowen and Surat Basins, Clarence-Moreton Basin, Gunnedah Basin, and Other Minor Onshore Basins, Queensland, NSW and NT'. 11. Australian Petroleum Accumulations. Canberra: Bureau of Resource Sciences.

Commonwealth of Australia. 2016. *Environment Protection and Biodiversity Conservation Act 1999*.

DEHP. 2011. *Environmental Protection (Water) Policy 2009. Dawson River Sub-Basin Environmental Values and Water Quality Objectives Basin No. 130 (Part), Including All Waters of the Dawson River Sub-Basin except the Callide Creek Catchment*.

2012. 'Coal Seam Gas Water Management Policy'. State of Queensland, Department of Environment and Heritage Protection.

2014. 'General Beneficial Use Approval - Associated Water (Including Coal Seam Gas Water)'. State of Queensland, Department of Environment and Heritage Protection, Prepared by: Energy Regulation and Implementation. https://www.ehp.qld.gov.au/assets/documents/regulation/wr-ga-associated-water.pdf.

2016a. 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures. Version 5.00'. ESR/2016/1933. State of Queensland, Department of Environment and Heritage Protection, Prepared by: Resource Sector Regulation and Support. https://www.ehp.qld.gov.au/assets/documents/regulation/era-mn-assessing-consequence-hydraulic-performance.pdf.

2016b. 'Streamlined Model Conditions for Petroleum Activities: Guideline, Environmental Protection Act 1994'. State of Queensland, Department of Environment and Heritage Protection.

2016c. Information sheet - *Environmental Protection Act 1994* - How to address environmentally sensitive areas and offset requirements in an application for an environmental authority for resource activities

2017. 'CSG Water Management: Measurable Criteria'. State of Queensland, Department of Environment and Heritage Protection. https://www.ehp.qld.gov.au/assets/documents/regulation/rs-is-csg-water-measurable-criteria.pdf.

DNRM. 2013. 'Code of Practice for Constructing and Abandoning Coal Seam Gas Wells and Associated Bores in Queensland - Edition 2'. State of Queensland, Department of Natural Resources and Mines. https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0011/119666/code-of-practice-csg-wells-and-bores.pdf.

2017. Queensland Floodplain Assessment Overlay. https://data.qld.gov.au/dataset/queensland-floodplain-assessment-overlay/resource/8a8e77fa-0914-4f94-8184-b50fd715b5c8.

DotEE. 2013. ‘Significant Impact Guidelines 1.3: Coal Seam Gas and Large Mining Developments – Impact on Water Resources’. Commonwealth of Australia, Department of the Environment and Energy.

Draper, JJ. 2013. ‘Bowen Basin’. In *Geology of Queensland*, 371À384. Brisbane: Geological Survey of Queensland.

DSITI. 2015. ‘Queensland Groundwater Dependent Ecosystem Mapping Method: A Method for Providing Baseline Mapping of Groundwater Dependent Ecosystems in Queensland’. Version 1.1. Brisbane: State of Queensland, Department of Science, Information Technology and Innovation.

2017a. ‘Maranoa Balonne Rivers Basin Groundwater Environmental Values. Draft for Discussion’. Environmental Protection (Water) Policy 2009. DRAFT for Discussion. State of Queensland, Department of Science, Information Technology and Innovation.

2017b. ‘Maranoa Balonne Rivers Basin Surface Water Environmental Values. Draft for Discussion’. Environmental Protection (Water) Policy 2009. DRAFT for Discussion. State of Queensland, Department of Science, Information Technology and Innovation.

Exon, NF. 1976. ‘Geology of the Surat Basin, Queensland’. Bulletin 166. Bureau of Mineral Resources, Geology and Geophysics.

Geoscience Australia. 2017. ‘Surat Basin’. *Surat Basin*. http://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/surat-basin.

Green, P. 1997. ‘The Surat and Bowen Basins, South-East Queensland’. Queensland Department of Mines and Energy.

KCB. 2016. ‘Hydrogeological Assessment of the Great Artesian Basin: Characterisation of Aquifer Groups - Surat Basin’. Prepared for the Queensland Government Department of Natural Resources and Mines. Brisbane: Klohn Crippen Berger Ltd.

Kellett, JR, TR Ransley, J Coram, J Jaycock, D Barclay, G McMahon, L Foster, and J Hillier. 2003. ‘Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland’. NHT Project# 982713. Bureau of Rural Science, Natural Resources and Mines, Queensland.

Martin, KR. 1981. ‘Deposition of the Precipice Sandstone and the Evolution of the Surat Basin in the Early Jurassic’. *The APEA Journal*, no. 21: 16–23.

NHMRC. 2011. ‘Australian Drinking Water Guidelines (2011)’. National Health and Medical Research Council. https://www.nhmrc.gov.au/guidelines-publications/eh52.

OGIA. 2016a. ‘Hydrogeological Conceptualisation Report for the Surat Cumulative Management Area’. State of Queensland, The Office of Groundwater Impact Assessment, Department of Natural Resources and Mines.

2016b. ‘Underground Water Impact Report for the Surat Cumulative Management Area’. Brisbane: State of Queensland, The Office of Groundwater Impact Assessment, Department of Natural Resources and Mines.

2017. 'Surat CMA Aquifer Attribution and Water Use Estimate (Senex_WU_Formations_23032017.xlsx)'. State of Queensland, The Office of Groundwater Impact Assessment, Department of Natural Resources and Mines.

Senex. 2017. Western Surat Gas Project Baseline Ecological Assessment.SENEX-WSGP-EN-REP-023.

State of Queensland. 2015. *Regional Planning Interests Act 2014*.

2016a. *Environmental Protection Act 1994*.

2016b. *Environmental Protection (Water) Policy 2009, Environmental Protection Act 1994*.

2017a. *Petroleum and Gas (Production and Safety) Act 2004*.

2017b. *Water Act 2000*.

Strahler. 1975. Physical Geography Fourth Edition - Chapter 27 Quantitative Analysis of Erosional Landforms, John Wiley and Sons Inc.

Sundaram, Baskaran, Andrew J Feitz, Patrice de Caritat, Aleksandra Plazinska, Ross S Brodie, Jane Coram, and Tim Ransley. 2009. 'Groundwater Sampling and Analysis - A Field Guide'. GeoCat# 68901. Commonwealth of Australia, Geoscience Australia, Department of Resources, Energy and Tourism.

Swarbrick, CFJ. 1973. 'Stratigraphy and Economic Potential of the Injune Creek Group in the Surat Basin'. Report 79. Geological Survey of Queensland.

Telfer, D.1995. State of the Rivers Dawson River and Major Tributaries, Department of Natural Resources, Brisbane.

Verterra Ecological Engineering. 2016. 'Western Surat Gas Project Irrigation Feasibility Study'. Prepared for Senex Energy Limited.