



Chapter 7

Produced water management

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Chapter 7 Produced water management

7.1 Introduction

This chapter outlines the way in which produced water would be managed under the Narrabri Gas Project. In summary, produced water would be managed in accordance with the regulatory framework. Once treated, the project intends to beneficially reuse produced water for irrigation, stock watering, dust suppression, construction and drilling across the project area, and minimise the potential for impacts to the environment to occur.

This chapter also describes how the Produced Water Management Plan would be implemented for the project, including:

- the regulatory and policy environment within which the project would implement the Produced Water Management Plan
- the modelled produced water volumes for the project
- the various water qualities the project would expect to manage
- the proposed water treatment process that the project would use to enable produced water to achieve a quality suitable for its beneficial re-use
- the suite of beneficial reuse options available under the project to manage the reassimilation of the treated and amended water into the environment—within the regulatory framework
- salt loads and their management under the project.

The Produced Water Management Plan described in this chapter utilises the experience and understanding of produced water management that the proponent has gained through previous projects.

The produced water management approach and corresponding impact assessment demonstrate that effective and efficient produced water management can be achieved, with minimal environmental impact. The chapter explains how a combination of water storage facilities, and beneficial reuse options including irrigation, stock watering, dust suppression, construction and drilling would manage the produced water once treated. It also explains how the option of managed release to Bohena Creek under specified natural flow conditions would be utilised.

The treated water quality proposed for the beneficial reuses is similar to water sources currently accessed and used for irrigation in the region. Water used for irrigation would be treated to an appropriate quality and would be applied in accordance with normal irrigation procedures which would be outlined in an Irrigation Management Plan. Importantly, the beneficial reuse of treated water would result in reduced demand on other water sources for drilling, construction and dust suppression.

Complementing these beneficial uses would be the option for managed release of treated water to Bohena Creek when the flow in the creek equals or exceeds 100 megalitres per day.

An assessment of the potential environmental impacts from beneficially reusing treated and amended water, and the Bohena Creek managed release option is presented in Chapters 12 (Surface water quality), 13 (Hydrology and geomorphology) and 14 (Soils and land contamination). Potential impacts from extracting the produced water are addressed in Chapter 11 (Groundwater and geology).

The project would implement monitoring to ensure that the beneficial reuse of treated water is occurring in accordance with the project commitments and management plans.

7.2 What is ‘produced water’?

As discussed in Chapter 1, depressurising coal seams by the removal of water present in the coal seam is a fundamental step in the extraction of natural gas. As water is extracted, pressure within the coal seams is lowered and natural gas begins to flow. ‘Produced water’ is the industry and regulatory term used in NSW for water that is removed in this way. Figure 1-3 showed that the volume of produced water reduces over time from gas well.

The quality of water extracted from a coal seam, like many forms of groundwater, can vary depending on a range of factors including age, depth and the type of geological formation. The average salinity of produced water generated during exploration and appraisal activities within the project area to date from the Maules Creek Formation and Black Jack Group is around 14,000 micro Siemens per centimetre. This level of salinity is approximately 30 per cent of the salinity of seawater, which is around 50,000 micro Siemens per centimetre.

Produced water may be managed using a range of options, including being reused, recycled or disposed of in accordance with the regulatory framework. In NSW, the management of produced water is regulated through a system of permits and approvals (refer to Section 7.3).

The following technical reports for the EIS have informed the produced water management approach that is documented in this chapter:

- Groundwater Impact Assessment (Appendix F)
- Managed Release Study (Bohena Creek) (Appendix G1)
- Irrigation General Concept Design (Appendix G2)
- Water Monitoring Plan (Appendix G3)
- Water Baseline Report (Appendix G4).

7.3 Regulatory framework

An extensive regulatory framework governing groundwater users is in place at both Commonwealth and State levels. The proponent has developed its Produced Water Management Plan in accordance with this regulatory framework. In this respect, the project would be subject to the same rules that apply to all licensed users of groundwater including irrigators, water utilities and other resource developers.

Under these frameworks, both the Commonwealth and NSW Governments have set limits on how much groundwater can be sustainably extracted from groundwater sources, and under what conditions. These limits define the long-term average volume of water that can be sustainably extracted from groundwater sources.

Groundwater extraction during the construction and operation of the project would occur in accordance with a water access licence granted under the NSW regulatory framework. Refer to Chapter 11 for further information on water access licencing.

The key legislation, policies and guidelines regarding produced water management are provided below.

7.3.1 Commonwealth

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the principal piece of environmental legislation administered by the Commonwealth Government, providing for the protection a number of matters of national environmental significance. The project is a controlled action under the EPBC Act with the relevant controlling provisions being listed threatened species, a water resource in relation to coal seam gas development, and Commonwealth land. The project is to be assessed under the assessment bilateral agreement between the Commonwealth Government and NSW Government. The controlling provision of most relevance to produced water management is 'a water resource in relation to a coal seam gas development'. This controlling provision is commonly referred to as the 'water trigger'.

The Commonwealth Government has developed the *Significant Impact Guidelines 1.3 – Coal seam gas and Large Coal Mining Developments – Impacts on Water Resources* (Commonwealth Government 2013b) to help proponents determine if they are likely to have a significant impact for the water trigger. The guidelines determine that an action is likely to have a significant impact if there is a real or not remote possibility that it will change the hydrology or quality of a water resource at sufficient scale or intensity to reduce its utility to third party users, including environmental outcomes.

The Commonwealth Government also established the Independent Expert Scientific Committee to provide scientific advice to regulators on the impact of coal seam gas and large coal mining development on water resources. In deciding whether to approve a proposed action that is likely to have a significant impact with regard to the water trigger, the Minister for the Environment and Energy must obtain advice from the Independent Expert Scientific Committee in accordance with Section 131AB of the EPBC Act.

The Independent Expert Scientific Committee have also developed the *Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (IESC 2015). The guidelines set out the information required by the committee to provide robust scientific advice to regulators regarding the impact of coal seam gas and large coal mining proposals. As such, the guidelines are an important determinant of the information presented in environmental assessments under the EPBC Act—including this EIS.

The provisions of the EPBC Act and associated guidelines have been given due consideration in planning for produced water management and supporting technical assessments, including:

- groundwater impact assessment (see Appendix F)
- managed release of treated water to Bohena Creek (see Appendix G1)
- irrigation of treated and amended water (see Appendix G2)
- hydrology and geomorphology assessment (see Appendix H).

The project assessment and approval process under the EPBC Act is explained further in Chapter 5.

Water Act 2007

The *Water Act 2007* (Water Act) regulates the management of the water resources of the Murray-Darling Basin, and establishes an independent Murray-Darling Basin Authority (MDBA) with the functions and enforcement powers needed to ensure that Murray-Darling Basin water resources are managed in an integrated and sustainable way. A key function of the MDBA includes the preparation of The Murray-Darling Basin Plan (the Basin Plan).

The Basin Plan is guided by the Water Act, which specifies measures that the Basin Plan must contain to guide management of the water resources of the Murray-Darling Basin. A key feature of the Basin Plan is the recommendation that the health of the Murray-Darling Basin be improved by setting a long-term environmentally sustainable level of water extraction from its rivers of 10,873 gigalitres per year, and a volume of 3,324 gigalitres per year for groundwater.

Under the Basin Plan, the Commonwealth and State governments are required to cooperate in the development of water resource plans that consider the requirements of the Basin Plan. The purpose of water resource plans is to establish arrangements for users to share water for consumptive use. They also establish rules to meet environmental and water quality objectives that take into account potential and emerging risks to water resources. Under the Basin Plan, water resource plans have been established. These plans impose a range of management and monitoring requirements on the use of water resources that have the potential to impact on surface water and groundwater in the water resource plan area. The development and implementation of individual water resource plans under the Water Act does not alter the need for the project to meet relevant State water approvals, as well as licensing and management requirements.

The Basin Plan establishes the limits on water that can be taken from the Murray-Darling Basin. These limits are known as long-term average sustainable diversion limits and include transitional arrangements to support their implementation. The sustainable diversion limits refer to the amount of water available for consumptive purposes (such as drinking water, industry, irrigation and agriculture) after environmental needs have been met. This is described in the Water Act as the 'environmentally sustainable level of take'.

Within the Basin Plan, the Commonwealth Government has identified sustainable diversion limits for all water sources located within the Murray-Darling Basin, including the Gunnedah-Oxley Basin. The extent of the Gunnedah-Oxley Basin water source identified by the MDBA is generally consistent with the volume used by the NSW Office of Water for its water sharing plan. Under the Commonwealth regime, the Gunnedah-Oxley Basin water source (within which the target coal seams for the project are located) is part of the Murray-Darling Basin (MDB) Porous Rock Water Resource Plan Area (identified as GS17 under the Basin Plan). Figure 7-1 presents a schematic of the water sharing plans relevant to the project and how they relate to the geology in the project area.

The sustainable diversion limits identified in the plans, referred to as the long-term average annual extraction limit by NSW water sharing plans, are based on a percentage of the average annual rainfall recharge for the groundwater source. It is important to note that the sustainable diversion limits identified under the NSW and Commonwealth regimes for the Gunnedah-Oxley Basin differ from one another. This is discussed further in Chapter 11—Groundwater and geology.

Under the terms of the *Water Act 2007*, the sustainable diversion limits identified by the Commonwealth will take effect on 1 July 2019 and will replace limits identified in the relevant State water sharing plans.

Both the Commonwealth and the NSW plans also protect water for environmental purposes. Under the NSW Water Sharing Plan for the Gunnedah-Oxley Basin, the volume for environmental purposes is around 50 per cent of the long-term average annual rainfall recharge in those areas that are not high environmental value areas. In areas of high environmental value, the volume set aside for environmental purposes is 100 per cent of the long-term average annual rainfall recharge, and 99.998 per cent of the long-term groundwater storage.

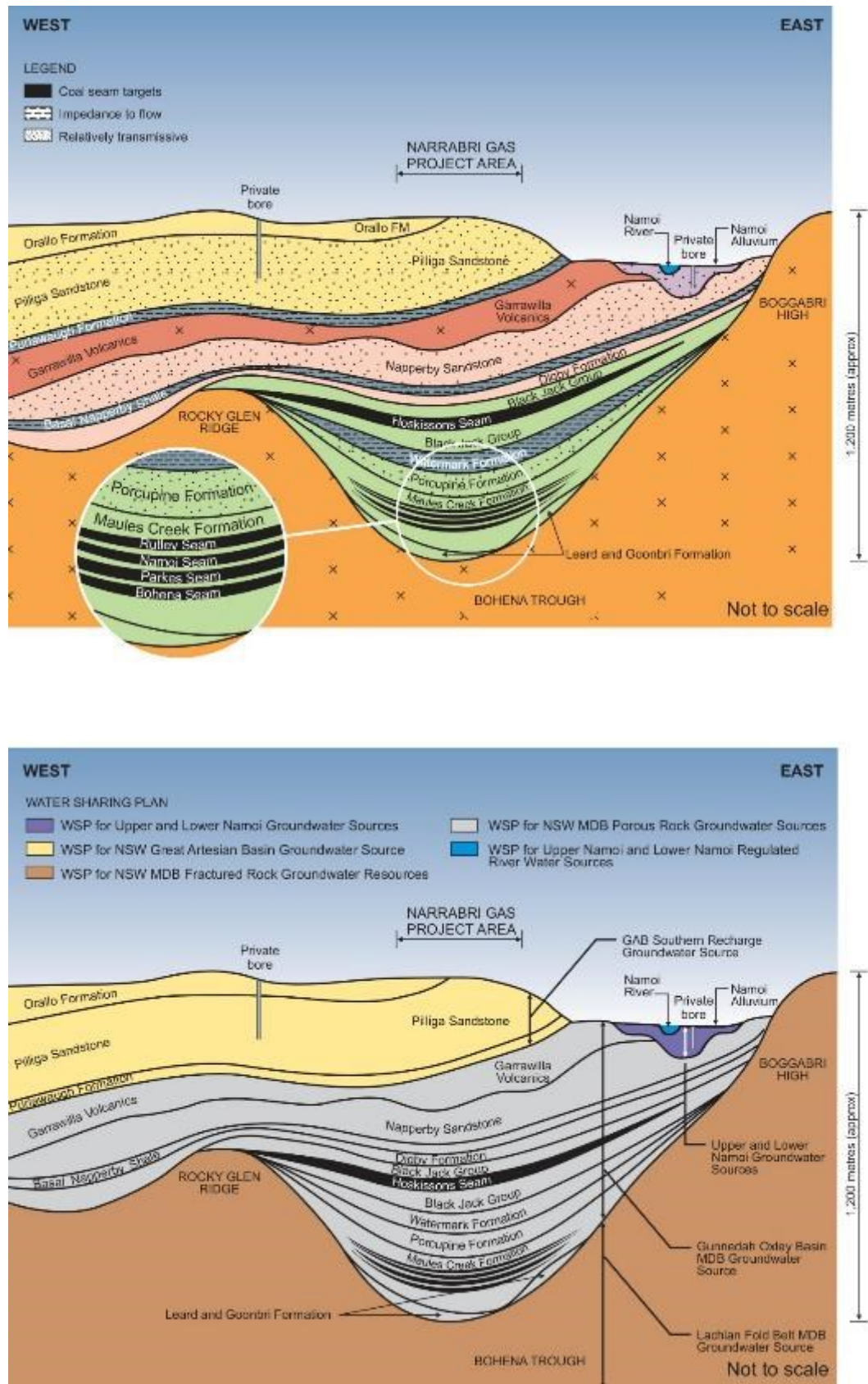


Figure 7-1 Water sharing plans applicable to the project

The current water access rights and water access licences for the Gunnedah-Oxley Basin that have been made available to the market amount to 23.1 gigalitres per year. This amount can only be increased if the NSW Government chooses to release more water through a statutory process (a controlled allocation under the NSW *Water Management Act 2000*). The 23.1 gigalitres of water currently allowed to be extracted from the Gunnedah-Oxley Basin represents around 20 per cent of the maximum sustainable diversion limit (114.5 gigalitres) identified by the Commonwealth Government, or around 11 per cent of the long term average annual extraction limit set under NSW legislation.

National Water Quality Management Strategy

The *National Water Quality Management Strategy* is a joint national approach to improving water quality in Australian and New Zealand waterways. The strategy aims to protect water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development.

A key output of the strategy is the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000). The document identifies water quality guidelines targeted at the protection of specific environmental values, such as aquatic ecosystems and recreational water use. As described in the guidelines, once the relevant water quality guidelines and environmental values are identified for a given activity, these can be formalised between stakeholders as water quality objectives.

Using ANZECC/ARMCANZ (2000) terminology, Bohena Creek would not be classified as a 'highly disturbed system', particularly in the area immediately within the Pilliga State Forest. It does, however, receive runoff from land disturbed to varying degrees by agriculture. Indicative of this, pesticides have been detected in surface water samples collected from Bohena Creek, and exotic species are common (refer to Appendix G1). Under these circumstances and in accordance with ANZECC/ARMCANZ (2000), the level of protection that is considered appropriate for meeting the management goal of maintenance or improvement of ecological conditions is termed a 'slightly to moderately disturbed system'.

It is expected that water quality objectives for the project would be formalised in licence and approval conditions, particularly under the *Protection of the Environment Operations Act 1997* (refer to Section 7.3.2). Surface water and groundwater monitoring for the project would be undertaken with reference to those objectives.

7.3.2 State

Petroleum (Onshore) Act 1991

The *Petroleum (Onshore) Act 1991* regulates onshore petroleum exploration and production in NSW through a system of petroleum titles (licences and leases). A proponent would generally apply for a petroleum exploration licence (PEL) over an area and subsequently apply for a petroleum assessment lease (PAL) and / or petroleum production lease (PPL) to further develop the resource.

Under Section 23 of the *Petroleum (Onshore) Act 1991*, a petroleum title is subject to conditions prescribed under regulations and additional conditions prescribed by the Minister. The *Code of Practice for Coal Seam Gas: Well Integrity* (DTIRIS 2012) is enforced in this manner. Santos is the holder of PEL 238 over the project area, which would require a PPL following project approval. Four PPL applications (PPLAs) were lodged under the *Petroleum (Onshore) Act 1991* for the project area.

Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* regulates development in NSW. Section 89C of the Act defines a subset of development termed 'State significant development'. Development may be declared State significant development through a State environmental planning policy or ministerial declaration.

The project is State significant development as it meets a definition included in Schedule 1 of *State Environmental Planning Policy (State and Regional Development) 2011*, namely that it is 'development for the purpose of petroleum production'.

Under Section 78A of the *Environmental Planning and Assessment Act 1979*, a development application for State significant development is to be accompanied by an environmental impact statement. Under Section 115Y of the Act, the Secretary of the department administering the Act must prepare environmental assessment requirements (refer to Appendix A). The Secretary's environmental assessment requirements for the project include a waste management strategy to cover wastes such as produced water and drilling fluids.

Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* regulates pollution through the control of environment protection licences (EPLs). Activities requiring an EPL are listed in Schedule 1 of the Act and include petroleum exploration, assessment and production.

Santos is the holder of EPL 20350 for its current petroleum activities in the Narrabri area. The EPL would be varied to reflect all project related gas development and production activities, following project approval. The variation application would include a request for an authorised release point at Bohena Creek during appropriate flow conditions with the implementation of toxicity-based assessment criteria to manage and monitor the release.

The EPL could be amended to include a licence condition that prescribes the allowable chemistry of project-related treated water release to the receiving environment. This approach would be consistent with the Environment Protection Authority Licensing Fact Sheet: *Using Environment Protection Licensing to Control Water Pollution* (NSW EPA 2013).

A comprehensive environmental assessment of the proposed treated water release has been undertaken for this EIS, including ecological risk assessment, direct toxicity assessment, aquatic ecology and stygofauna impact assessment and mixing zone analysis (refer Appendix G1).

Water Management Act 2000

The *Water Management Act 2000* regulates the allocation of water between consumptive users and the environment in NSW through the establishment of water sharing plans and associated access licences. Water sharing plans set long-term average annual extraction limits to safeguard surface water and groundwater resources.

One of the water sharing plans that applies to groundwater resources in the project area is the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater – Gunnedah Oxley Basin Groundwater Source* (refer to Figure 7-1). The project would extract groundwater from this groundwater source, which is regulated under this water sharing plan. The proposed extraction of groundwater would therefore require a water access licence to cover the volume to be taken.

The long-term average annual extraction limit for the Gunnedah-Oxley Basin Groundwater Source, as defined in the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater*, is

205.6 gigalitres per year. As noted above, the current water access rights and water access licences for the Gunnedah-Oxley Basin that have been made available to the market by the NSW Government amount to 23.1 gigalitres per year. This amount can only be increased if the NSW Government chooses to release more water through a statutory process under the *NSW Water Management Act 2000*.

It is estimated that the project would extract around 1.5 gigalitres per year on average over 25 years, equalling about 0.7 per cent of the long-term annual extraction limit of around 205.6 gigalitres per year. This average extraction rate would total around 37.5 gigalitres over the life of the project. The proponent would seek a licence to extract this volume of water.

Code of Practice for Coal Seam Gas: Well Integrity

The *Code of Practice for Coal Seam Gas: Well Integrity* (DTIRIS 2012) (the Code) is an industry guideline administered by the NSW Government and enforced under the *NSW Petroleum (Onshore) Act 1991*. The code and practice defines the standards for well design and construction to prevent environmental harm, particularly to groundwater resources.

Wells constructed as part of the project would comply with the code. With regard to produced water, the Code states that wells must be designed 'to ensure all fluids produced from the well travel directly from the production zone to the surface without contaminating groundwater.'

Under the Code, wells must be designed to ensure the safe and environmentally sound production of gas by (DTIRIS 2012):

- preventing interconnection between hydrocarbon-bearing formations and aquifers
- ensuring that gas is contained within the well and associated pipework and equipment without leakage
- ensuring zonal isolation between different aquifers and water-bearing zones is achieved
- not introducing substances that may cause environmental harm.

Section 6.5.2 presents further information on gas well construction.

NSW Aquifer Interference Policy

The *NSW Aquifer Interference Policy* (NSW Government 2012a) guides water assessment and licensing processes for aquifer interference activities under the *NSW Water Management Act 2000*. The extraction of groundwater for the project would involve aquifer interference activities as defined in the policy and the *NSW Water Management Act 2000*, including:

- the penetration of an aquifer
- the taking of water from an aquifer
- the disposal of water taken from an aquifer.

The policy describes the requirements for proponents seeking water access licences. Considerations include the volume of the proposed extraction of groundwater, the variability of the extraction over time, uncertainty around potential impacts, and strategies for monitoring volumes. The aquifer access licence sought for the project would be required to, and would comply with, the proponent's responsibilities for holding licences.

Refer to Chapter 11 for additional information and an assessment of the project against the minimal impact considerations outlined under the *NSW Aquifer Interference Policy*.

Beneficial Reuse of Treated Water by Irrigation

The *Use of Effluent by Irrigation* (DEC 2004) guidelines define the required practices for managing effluent by irrigation in NSW. The guidelines set out a range of environmental performance objectives including:

- protection of surface water and groundwater
- protection of lands from soil deterioration, salinisation and erosion
- beneficial reuse, including development of agronomic systems.

To achieve these objectives, the guidelines discuss necessary site characteristics, design and operation of irrigation systems, and management of effluent (water) quality.

The selection and assessment of sites for the beneficial reuse of treated water for crop irrigation undertaken as part of the project would be carried out with due consideration to the *Use of Effluent by Irrigation*.

Irrigation of treated water would be undertaken in accordance with an Irrigation Management Plan, which would seek to ensure that:

- the structure, stability and productive capacity of the soils are maximised
- erosion is minimised
- effective surface water and stormwater runoff controls are implemented.

Irrigation would also include a program of regular and appropriate monitoring. The irrigation schedule would be adjusted, as needed, to address trends identified through the monitoring program.

7.4 Produced water volumes

7.4.1 Basis of produced water estimates

Estimations of gas and water to be recovered under the project have been based on the exploration and appraisal program.

Based on financial and technical considerations, and incorporating learnings from other natural gas from coal seam projects Santos has operated, the modular Leewood central water treatment plant will have a maximum design capacity of 14 megalitres per day during the produced water peak, thereby catering for around 50 per cent more produced water than expected from subsurface modelling. The water treatment plant would likely be downsized as produced water volumes decreased over time, whilst retaining contingency processing capacity over modelled produced water yields.

It is expected that produced water volumes will peak at around 10 megalitres per day in at around years two to four, gradually declining over the life of the project. The long term average would be around four megalitres per day, which equates to some 1.5 gigalitres per year over the 25-year assessment period. The estimated total volume of produced water over the project assessment period is around 37.5 gigalitres. Figure 7-2 shows an indicative produced water profile for the project.

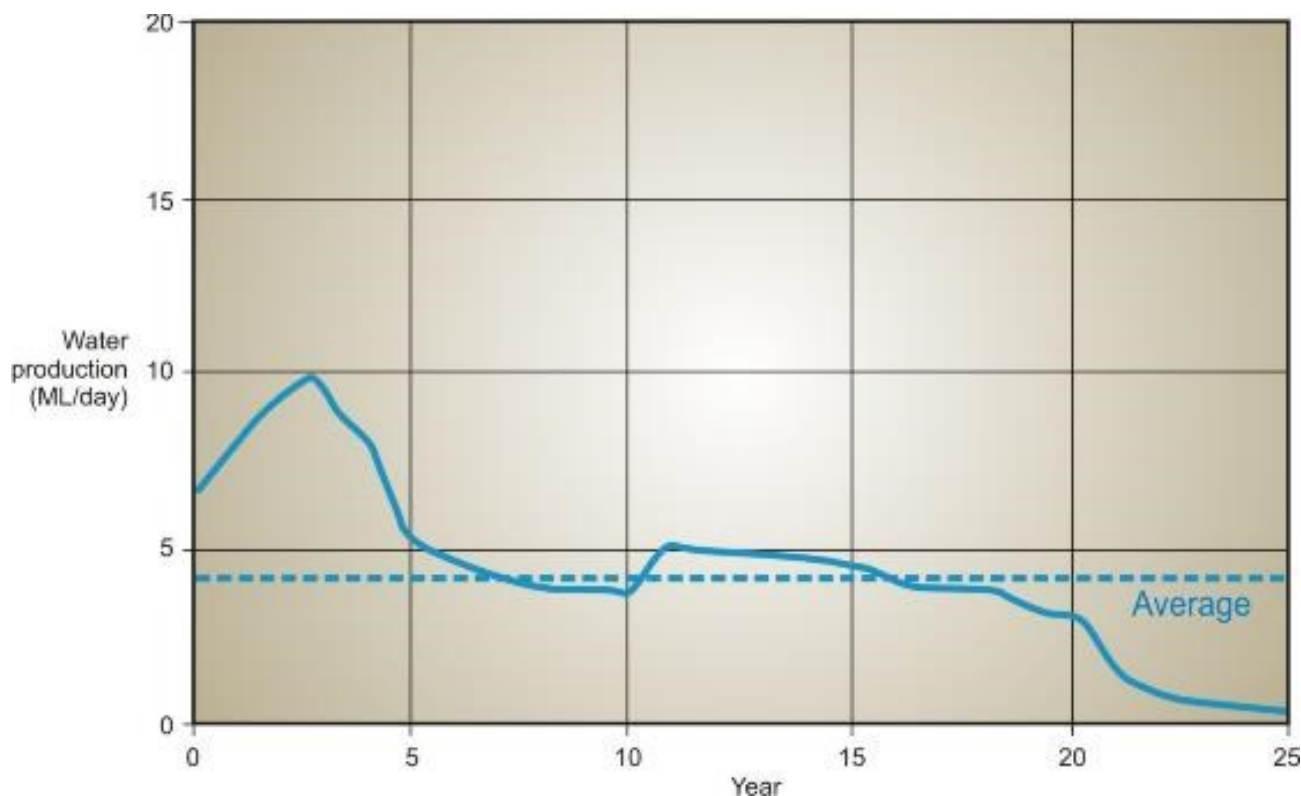


Figure 7-2 Indicative produced water profile

7.4.2 Produced water volumes in context

Regulatory framework

Section 7.3 provides an overview of the regulatory framework as related to the policy environment within the region of the Gunnedah Basin. All produced water extracted during the project would be as a licenced user within a well-established policy framework overseen in NSW by the Department of Primary Industries – Water (DPI Water). This basis for this policy framework includes assessment of the volume of water in the Gunnedah-Oxley Basin, with allocation limits established for users and the environment as a subset of the long-term average annual extraction limit. The project would become another regulated water user along with existing irrigators, industrial users, and other resource developments drawing under licence.

Water availability and use in the Gunnedah-Oxley Basin

The project would represent a small overall portion of the licensed water users in the Gunnedah-Oxley Basin. The water would be extracted from a deeper source than that targeted by other licensed users. Based on available groundwater licencing information, there are no known water users taking water from the coal seams targeted by the project within the project area.

Figure 7-3 shows that the predicted annual produced water extraction under the project would be around 1.5 gigalitres per year. This is a relatively small amount when considered against the following water metrics for the Gunnedah-Oxley Basin:

- The annual average rainfall recharge for the groundwater source is around 415 gigalitres per year.
- Currently allocated water access licences total 23.1 gigalitres per year, representing around 5.6 per cent of the average annual rainfall recharge, and 11.2 per cent of the long-term average annual extraction limit.
- Currently allocated water access licence holders are from a broad range of industries and hold the licences for a broad range of uses. These licence holders are accessing shallower and higher quality water within the Gunnedah-Oxley Basin water source, and not the deep coal seams that would be accessed under the project.
- The long-term annual extraction limit is around 206 gigalitres per year. This is around half of the annual average rainfall recharge for the groundwater source of around 415 gigalitres per year.
- The environmental water allocation is around 207 gigalitres per year; approximately half of the annual average rainfall recharge for the groundwater source of around 415 gigalitres per year. (The environmental water allocation is the volume of water set aside during the water allocation planning process undertaken by DPI Water to maintain the environmental sustainability of the water source).
- The Gunnedah-Oxley Basin has an overall water storage capacity of approximately nine million gigalitres.

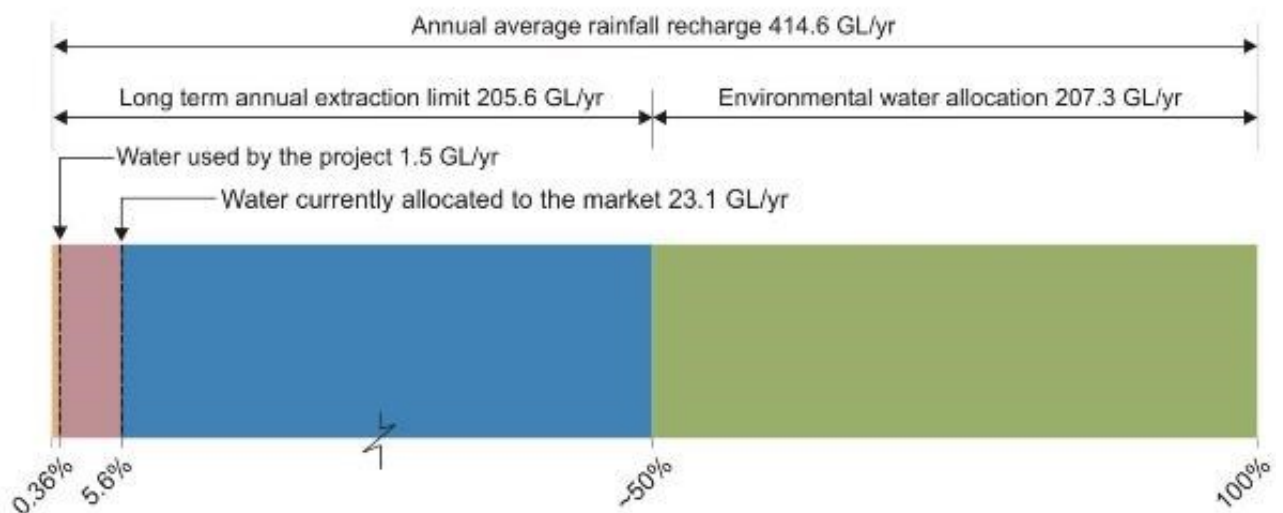


Figure 7-3 Forecast annual produced water extraction for the project in context

Produced water from the project

The project's annual forecast produced water extraction of around 1.5 gigalitres represents approximately:

- 0.4 per cent of the annual average rainfall recharge for the groundwater source of around 415 gigalitres per year
- 0.7 per cent of the long-term annual extraction limit of around 206 gigalitres per year
- 6.5 per cent of the current water access licences of 23.1 gigalitres per year.

The produced water that would be extracted under licence would be treated and beneficially reused, primarily for agricultural irrigation. Around 82 per cent of treated water would be beneficially re-used in irrigation during the produced water peak and around 71 per cent would be beneficially re-used in irrigation during average produced water production.

The project would comply with the same regulatory regime as applies to activities that extract water from a regulated water source in NSW. As such, the required water allocations would be purchased and the relevant water access licences sought and operated under.

Future Commonwealth sustainable diversion limit

Under the terms of the Commonwealth *Water Act 2007*, the sustainable diversion limit identified by the Commonwealth will take effect on 1 July, 2019, replacing limits identified in the relevant State Government water sharing plans, including the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater – Gunnedah Oxley Basin Groundwater Source*.

The Commonwealth sustainable diversion limit is 114.5 gigalitres per year, which would replace the NSW Government's long-term annual extraction limit of 205.6 gigalitres per year. When this occurs, the project's annual average produced water volume would represent around 1.3 per cent of the annual sustainable extraction, rather than 0.7 per cent, which would still be a relatively small component of the total volume allocated for extraction.

Summary of water volumes

Table 7-1 summarises the produced and treated water volumes used throughout this EIS. Section 7.7 details the rationale for assessing the management options for a volume of treated water in excess of that estimated during the produced water peak in around years two to four.

Table 7-1 Summary of project water volumes

Parameter	Volume (megalitres per day)	Comment
Installed infrastructure capacity	14	Refer to Table 6-2 in Chapter 6
Estimated produced water	Peak (~years 2 to 4): around 10 25-year average: 4.1	Refer to Section 7.4.1
Estimated treated / amended water	Peak (~years 2 to 4): around 9.5 25-year average: 3.9	The treatment process reduces water volumes marginally by evaporation, and also through water retained in the final salt product
Assessed treated / amended water	Peak (~years 2 to 4): around 12 25-year average: 3.9	A conservative approach used in this EIS (refer to Chapters 11, 12, 13 and 14) to allow for operational flexibility during project operation

7.5 Produced water management operating system

7.5.1 Overview and capacity

The project would include infrastructure to manage and treat produced water to a quality suitable for its end use. Produced water extracted at each production well would be transferred to Bibblewindi and Leewood via a network of water gathering lines and in-field balance tanks. Produced water would be stored in double-lined ponds at Bibblewindi and Leewood, before undergoing treatment at the Leewood central water treatment facility. The treated water would then be managed through beneficial reuse or managed release to Bohena Creek under appropriate flow conditions (refer to Section 7.7).

The produced water life-cycle components for the project would be:

- a number of coal lithological units containing water
- aboveground water storages for the produced water
- a treatment plant and other water management infrastructure
- activities associated with treated water management and use
- the management and disposal of waste generated in the operation of the system (this would primarily be salt).

Figure 7-4 presents the produced water process flow diagram for the estimated peak produced water flow of around 10 megalitres per day. It includes the peak daily volumes expected around years two to four, along with the longer-term average daily volume of produced water, being slightly over four megalitres per day, calculated over the 25-year assessment period.

As noted above, the water management system has been engineered to have sufficient capacity to manage the peak produced water volume of around 10 megalitres per day—through a treatment plant design capacity of 14 megalitres per day. Water storage capacity both before and after the treatment process, in addition to the suite of beneficial use options and managed release; provide further flexibility in the system to sustainably manage the water associated with the project.

7.5.2 Produced water treatment

Figure 7-4 shows the indicative movement and quantity of produced water through the treatment process at the Leewood central water treatment plant. As shown, peak produced water production would be around 10 megalitres per day and average produced water production would be slightly over four megalitres per day over the life of the project.

The key stages of water treatment are as follows:

- Stage 1: Removal of solids using dissolved air flotation, strainer and microfiltration / ultrafiltration (membrane) technologies. This stage would use ion exchange technology to remove certain cations that can otherwise interfere with reverse osmosis (refer to Stage 2). Biocide would be used to control the growth of organisms through the treatment process.
- Stage 2: Removal of salt using reverse osmosis technology. About two-thirds of produced water would exit reverse osmosis as treated water (permeate), with the remaining one-third being brine.
- Stage 3: Recovery of treated water (distillate) from brine using thermal evaporation technologies. The distillate would be recombined with the treated water.

- Stage 4: Removal of a solid salt product from concentrated brine using salt crystallisation technology. The solid salt product would be stored on site prior to being removed for off-site disposal at a licensed facility. Residual distillate would also be recovered by thermal evaporation and recombined with the treated water.
- Stage 5: Removal of ammonia by chlorination. This would be followed by dechlorination and pH adjustment.
- Stage 6: Amendment of the treated water. Calcium sulfate would be added to adjust the sodium adsorption ratio.

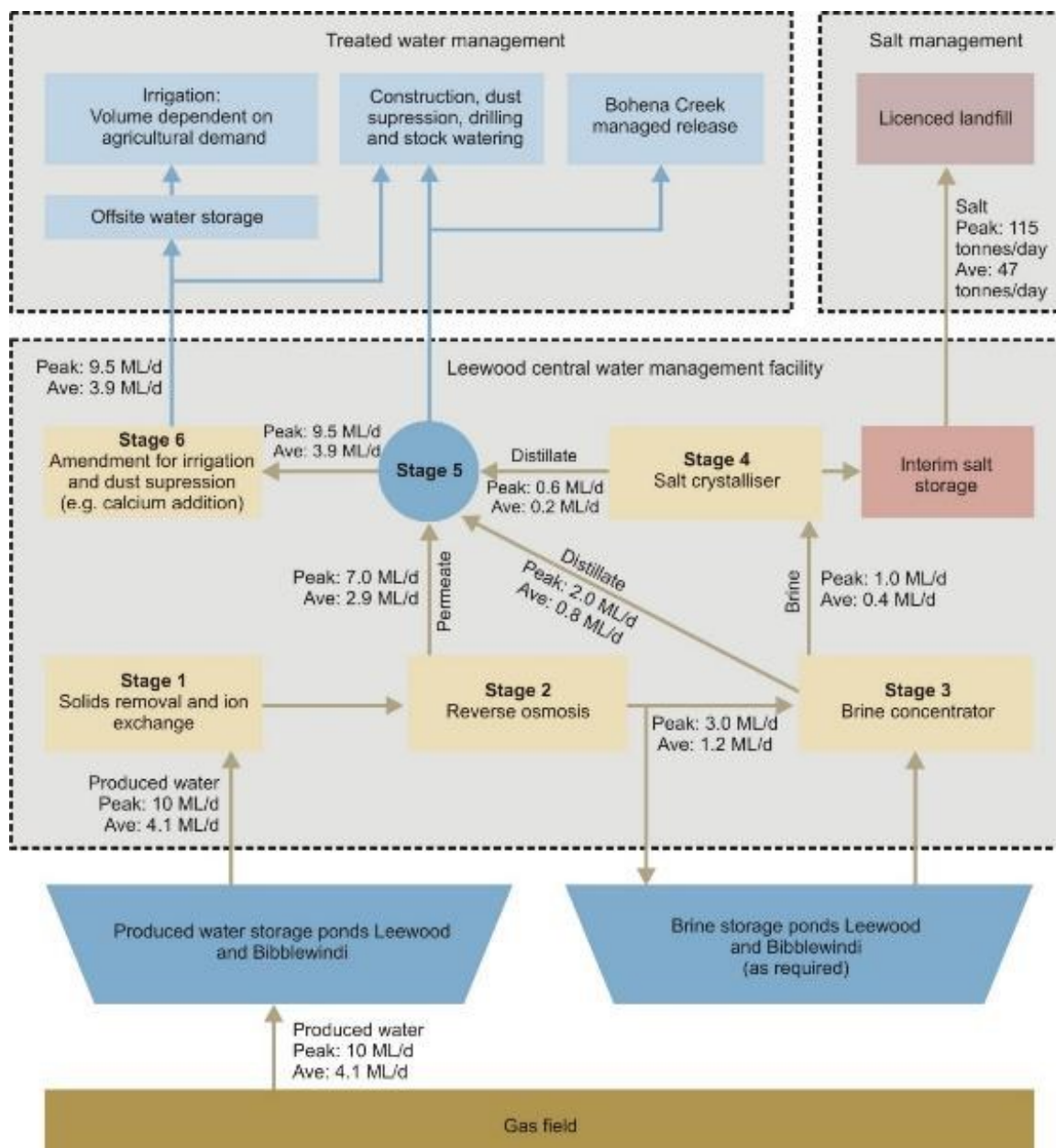


Figure 7-4 Overview of the water treatment process

7.5.3 Treated water use

Post Stage 5 of water treatment

After Stage 5 (refer to Figure 7-4), the treated water would be suitable for beneficial reuse in:

- irrigating local soils in forested areas on non-agricultural land
- stock watering
- dust suppression
- construction
- drilling.

The treated water would also be available for managed release to Bohena Creek under appropriate flow conditions (refer to Section 7.7.1).

Post Stage 6 of water treatment

After Stage 6 (refer to Figure 7-4), the treated water would be suitable for beneficial reuse in:

- irrigating local soils on agricultural land
- suppressing dust on roads, access tracks, well pads and construction and operational areas in non-forested areas that comprise certain soil types.

The amendment of treated water would maintain the permeability and structural longevity of the soil by encouraging aggregate stability of soil particles through reduction of the sodium adsorption ratio of the amended water. The sodium adsorption ratio of irrigation water is the ratio of sodium in solution compared to the average of the sum of magnesium and calcium in solution. If the sodium adsorption ratio of irrigation water is too high (that is, there is too much sodium relative to the mean of the sum of calcium and magnesium), it can tend to disperse the receiving soil. The amendments would prevent these issues by balancing sodium levels through addition of calcium and sulfate salts such as gypsum.

In comparison, water used across NSW in agricultural irrigation typically has a similar salinity to that of the amended water proposed for irrigation within the project area—that is, an average value of 368 milligrams per litre total dissolved solids (refer to Figure 7-6). For example:

- water drawn from the Calivil Formation in the Lower Murrumbidgee Water Sharing Plan has a median total dissolved solids concentration of around 400 milligrams per litre (Parsons Brinckerhoff 2011)
- water drawn from the Gunnedah Formation within the Upper Namoi Alluvium Zone 3 Water Sharing Plan has been reported as having a median total dissolved solids concentration of around 680 milligrams per litre (Parsons Brinckerhoff 2011).

Both examples are comparable to the project's predicted amended water quality of around 368 milligrams per litre total dissolved solids that would predominantly be used for agricultural irrigation (refer to Figure 7-6).

The strategy for re-using treated and amended water from the project is outlined in Section 7.7.

Operational considerations

There will be a high level of control and operational flexibility to vary the volume of treated water being produced to meet environmental conditions. If there is limited opportunity for beneficial reuse of the treated water (e.g. in extended significant rainfall conditions preventing irrigation or other beneficial uses), and Bohena Creek is not flowing at equal to or greater than 100 megalitres per day to allow for managed release, then the produced water storage ponds can be used as storage buffers.

As is the case for all water treatment plants, including those producing drinking water, chemicals are used within the process for treatment, cleaning, conditioning, anti-scaling and disinfection. Many of these chemicals are similar to those used for household cleaning and pool treatment. The biocides used to inhibit the growth of organisms in piping, equipment and the membranes themselves are reactive and rapidly degrade. This, when combined with the high rate of biocide removal by the reverse osmosis system, ensures the treated water is of an appropriate quality for beneficial use and managed release.

7.6 Water quality

The water produced by the project would be treated to ensure it is of a standard that is suitable for all planned beneficial reuses including irrigation, construction, stock watering, dust suppression and drilling. Produced water typically contains varying concentrations of dissolved salts (refer to Section 7.8), and therefore requires a level of treatment suitable for its proposed end use. This is discussed in Section 7.5.

Table 7-2 compares indicative target water qualities for the project to various national water quality guidelines. Table 7-2 includes:

- Target treated water quality (following Stage 5 on Figure 7-4). The treated water would be beneficially used for irrigation, stock watering, dust suppression, construction (including rehabilitation) and drilling (and also made available for firefighting at Leewood and Bibblewindi), and would also be available for managed release to Bohena Creek under appropriate flow conditions.
- Target amended water quality (following Stage 6 on Figure 7-4). The amended water would be beneficially used for irrigation, rehabilitation and dust suppression on certain soil types. These beneficial uses are the predicted long-term operating scenario for the project under average produced water generation rates (refer to Section 7.8).
- Australian drinking water quality guidelines (NHMRC 2011).
- Short term irrigation guidelines (ANZECC / ARMCANZ 2000).
- Stock watering guidelines (ANZECC / ARMCANZ 2000).

Table 7-2 shows that prior to, and following, the addition of gypsum to adjust the sodium adsorption ratio, target treated and amended water quality is better than accepted guidelines for drinking water, irrigation and stock watering.

There will be two forms of treated water monitoring to ensure appropriate water quality is maintained. Continuous monitoring for pH and electrical conductivity would be undertaken using real time on-line equipment. If the treated water quality does not meet the required specifications, the dedicated control system will ensure the water is re-treated.

In addition to the automated monitoring system, samples of the treated water would be analysed on a monthly basis by a National Association of Testing Authorities (NATA) accredited laboratory. A broad range of parameters would be analysed including compounds indicative of the chemicals used for treatment, cleaning and disinfection such as total residual chlorine.

The treated water monitoring program is included within the Water Monitoring Plan (refer to Appendix G3).

Table 7-2 Indicative target concentrations for treated and amended water quality

Parameter	Australian Drinking Water Guidelines (NHMRC 2011)	ANZECC / ARMCANZ (2000) Irrigation Guidelines (Short Term < 20 years)	ANZECC / ARMCANZ (2000) Stock watering	Treated water ^a	Amended water ^b
(mg/L unless stated)			Target (mg/L unless stated)		
pH (pH units)	6.5 – 8.5	6.0 -9.0	Not referenced	7.1	7.1
Electrical conductivity (laboratory) (µS/cm)	Not referenced	Crop specific – Lucerne (2,700 in loamy soils)	Not referenced	357	566
Total dissolved solids	Health: Not referenced Aesthetic as follows: <600 Good quality 600-900 Fair quality 900-1,200 Poor quality >1,200 Unacceptable	Crop specific – Lucerne (1,273 – 3,015)	No adverse effects to: Beef cattle, pigs and horses 4,000 Sheep 5,000	232	368
Sodium (filtered)	Health: Not referenced Aesthetic: 180	Crop specific – Lucerne (230 - 460)	Not referenced	77	77
Magnesium (filtered)	Not referenced	Not referenced	Not referenced	<0.01	<0.01
Aluminium	Health: Not referenced Aesthetics: 2	20	5	<0.001	<0.001
Silica (SiO ₂) (µg/L)	900	Not referenced	Not referenced	23	0.15
Potassium (filtered)	Not referenced	Not referenced	Not referenced	0.8	0.8
Calcium (filtered)	Health: Not referenced Aesthetic as follows: <60 Soft 60-200 Good quality >200 Increased scaling	Not referenced	1,000	0.01	40.01
Chromium (III+VI)	0.05	1 (Cr ^{VI})	1	<0.001	<0.001

Parameter	Australian Drinking Water Guidelines (NHMRC 2011)	ANZECC / ARMCANZ (2000) Irrigation Guidelines (Short Term < 20 years)	ANZECC / ARMCANZ (2000) Stock watering	Treated water ^a	Amended water ^b
(mg/L unless stated)			Target (mg/L unless stated)		
Manganese	0.5	10	Not sufficiently toxic	<0.001	<0.001
Iron	<1	10	Not sufficiently toxic	<0.001	<0.001
Boron	4	Crop specific 0.5 (sensitive) to 15 (very tolerant)	5	0.12	0.12
Cobalt	Not referenced	0.1	1	<0.001	<0.001
Nickel	0.02	2	1	<0.001	<0.001
Copper	2	5	0.4 (sheep) 1 (cattle) 5 (pigs)	<0.001	<0.001
Zinc	Health: Not referenced Aesthetic: 3	5	20	<0.001	<0.001
Arsenic	0.01	2	0.5 – 5	<0.001	<0.001
Selenium	0.01	0.05	0.02	<0.001	<0.001
Molybdenum	0.05	0.05	0.15	<0.001	<0.001
Cadmium	0.002	0.05	0.01	<0.001	<0.001
Barium	2	Not referenced	Not referenced	<0.001	<0.001
Mercury	0.001	0.002	0.002	0.0000067	<0.001
Lead	0.017	5	0.1	<0.001	<0.001
Uranium	0.017	0.1	0.2	<0.0028	<0.0028
Alkalinity (total as CaCO ₃)	Not referenced	Not referenced	Not referenced	139	139
Ammonia (as N)	Health: Not referenced Aesthetic: 0.5	Crop specific as N (25 – 125)	Not referenced	0.005	0.005
Nitrate (as N)	50	Crop specific as N (25 – 125)	400	0.005	0.005
Total N	Not referenced	25 - 125	Not referenced	0.005	0.005
Sulfate	500	Not referenced	1,000	0.003	95.9

Parameter	Australian Drinking Water Guidelines (NHMRC 2011)	ANZECC / ARMCANZ (2000) Irrigation Guidelines (Short Term < 20 years)	ANZECC / ARMCANZ (2000) Stock watering	Treated water ^a	Amended water ^b
(mg/L unless stated)			Target (mg/L unless stated)		
Chloride	Health: Not referenced Aesthetics: 250	Crop specific – Lucerne (350 – 700)	Not referenced	15	15
Fluoride	1.5	2	Not referenced	0.08	0.08
Total phosphorous	Not referenced	Crop specific – (0.8 – 12)	Not referenced	0.01	0.01

^a For managed release into Bohena Creek, and beneficial reuse in certain dust suppression scenarios, drilling, stock watering and construction. Post Stage 5 of treatment in Section 7-5.

^b For beneficial reuse in irrigation, and certain dust suppression scenarios. Post Stage 6 of treatment in Section 7-5.

7.7 Produced water management

7.7.1 Treated water beneficial reuse options

Following treatment, the water would be beneficially re-used for either:

- crop irrigation
- stock watering
- dust suppression
- construction (including rehabilitation and drilling).

Although not included in Figure 7-4, water would also be made available at Leewood and Bibblewindi for firefighting as required.

The treated water would also be available for managed release to Bohena Creek during flow conditions equal to, or greater than, 100 megalitres per day as measured at the Newell Highway gauging station.

The beneficial reuse options are shown schematically in Figure 7-5. They represent a subset of the more detailed produced water management figure shown as Figure 7-4. Each beneficial reuse option is discussed in the following sections.

As outlined in Table 6-2, and discussed in Section 7.5.1, the proposed water treatment plant would be designed to have capacity to treat up to 14 megalitres per day of produced water, and would likely be downsized as produced water volumes decrease over time.

The estimated produced water volumes would peak during the early years of the project (around the first two to four years) at around 10 megalitres per day and then gradually decline over the life of the project. The long-term produced water average would be slightly over four megalitres per day. This is equivalent to about 1.5 gigalitres per year, which equates to an estimated total volume of around 37.5 gigalitres over the 25-year assessment period.

The assessment of beneficial reuse options in this EIS has assumed the use of up to 12 megalitres of treated and amended water per day, which is well above the estimated quantity to be produced of around

10 megalitres per day. This conservative assumption would ensure that the peak produced water volumes could be effectively managed, whilst also providing operational flexibility.

The average of treated (and amended) water volume over the life of the project of around 3.9 megalitres per day has also been assessed in the EIS.

A summary of project water volumes is provided in Table 7-1.

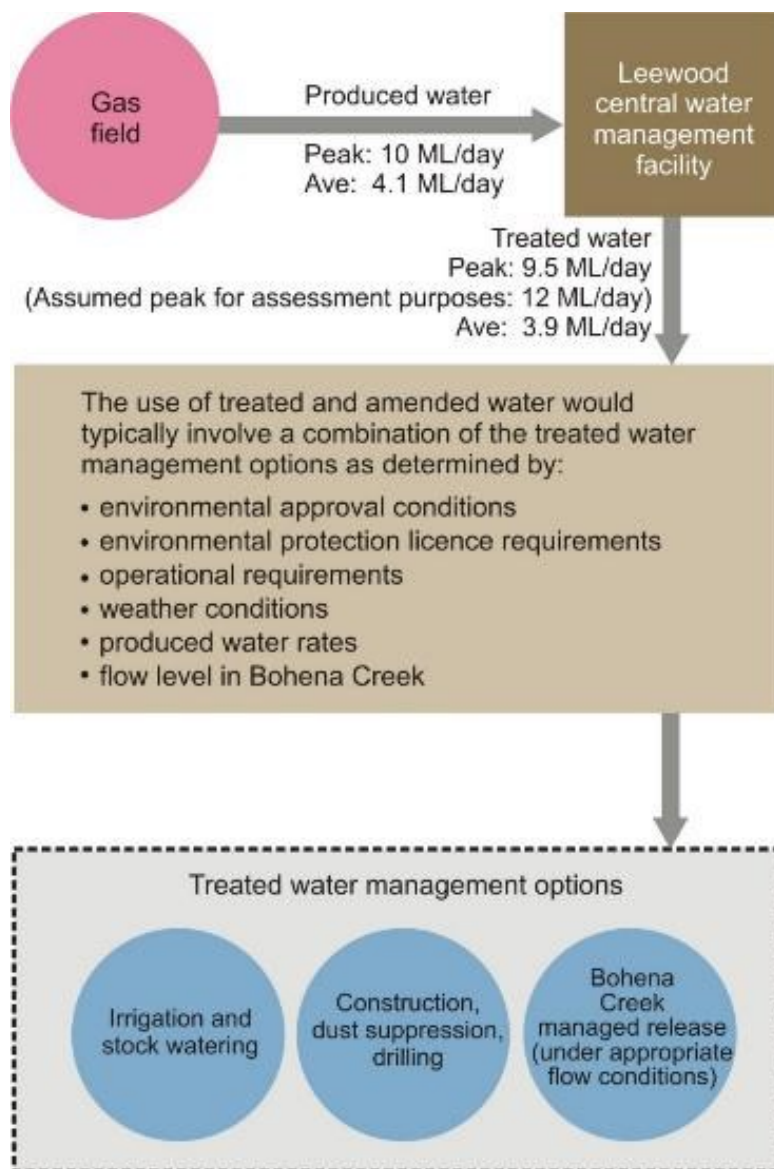


Figure 7-5 Treated water beneficial reuse options

Beneficial reuse for crop irrigation and stock watering

Treated water would be beneficially re-used for irrigating agricultural land. Site selection and assessment would be in accordance with the *Environmental Guidelines: Use of Effluent by Irrigation* (DEC 2004). To provide operational flexibility, the irrigation scheme would be designed to have the capacity to beneficially re-use 12 megalitres per day, which is slightly in excess of the peak treated water production of around 10 megalitres per day.

Modelling was undertaken to assess the sustainability of the irrigation scheme to manage the expected peak volumes of amended water (refer Appendix G2). The model used a nominal irrigation area of 500 hectares. The results showed that up to 60 megalitres of treated water per day could be beneficially re-used on the 500 hectares of agricultural land.

A soil survey undertaken for the project (also reported in Appendix G2) identified around 9,000 hectares of suitable irrigation land within a 20 kilometre radius of the Leewood water treatment plant. Therefore, a larger irrigated area than that modelled would be available to beneficially re-use the treated water. When selecting an irrigation site, the following factors would be considered:

- site selection - a relatively flat or gently sloping site
- crop selection - the crop would be selected based on soil conditions, seasonality, crop water demand, potential positive effects on soil structure, economic yield, and the stage of the produced water profile. To date, modelling has shown lucerne to be the likely preferred crop (Appendix G2)
- soil quality
- design of the irrigation area
- the potential for runoff or salinisation.

The irrigation of amended water would be undertaken in accordance with an Irrigation Management Plan, which would seek to ensure:

- the structure, stability and productive capacity of the soils are maintained
- erosion is minimised
- there are effective surface water and stormwater runoff controls.

Irrigation would also include a program of regular monitoring, with the irrigation schedule being adjusted as needed to address trends identified through the monitoring system.

Treated water would also be used for stock watering with both the treated and amended water being of suitable quality for this beneficial reuse (see table 7-2).

Beneficial reuse for dust suppression, construction, and drilling

Treated and amended water would be beneficially re-used for construction, dust suppression, and drilling in the project area. During the initial construction phase of the project, treated and amended water for construction would be sourced from existing, previously approved central water management facility at Leewood. Water would also be sourced from licensed water bores. Following the initial construction phase, treated and amended water would be sourced from the water management facility at Leewood.

On average, up to around four megalitres of treated water per day could be used for dust suppression, construction and drilling over the 25-year assessment period for the project. This would depend on a range of variables including the extent of construction activities, drilling activity, and seasonality (there would be greater demand for treated water during the warmer, drier months). An average long-term rate of one to two megalitres has been assumed for these beneficial reuse activities.

Treated and amended water would be used for dust suppression during construction, operations and decommissioning. Water would be applied to roads and operating areas including Leewood, Bibblewindi and other trafficked areas including well sites undergoing maintenance and rehabilitation in the project area, to suppress dust as required. No produced water would be used for dust suppression without first undergoing treatment, and where necessary, amendment. Treated water used for dust suppression within the State Forest areas would be of a quality consistent with that of the managed release to Bohena

Creek, while water used for dust suppression within agricultural areas would be treated and amended to a quality consistent with the irrigation water (refer to Appendix G2 for context).

Only treated, amended or bore water will be used for dust suppression and rehabilitation. Dust suppression and rehabilitation activities will take into consideration:

- managing spraying to avoid ponding and runoff of water
- avoiding spraying during significant rainfall events
- adjusting application rates based on surface conditions and frequency of application
- routine visual inspections to check for ponding or runoff.

Treated water would also be made available for firefighting at Leewood and Bibblewindi. The beneficial reuse of water for firefighting would be a seasonal activity.

Managed release to Bohena Creek

Complementing the beneficial uses described above would be the managed release of treated water to Bohena Creek during appropriate flow conditions via a pipeline from Leewood with a suitably designed diffuser.

Studies on Bohena Creek have found that at flow conditions of at least 100 megalitres per day the release of up to 12 megalitres per day of treated water would have an insignificant to low impact on the creek. The managed release of treated water to Bohena Creek is most likely to be required during peak water production (around years two to four); particularly during extended wet weather when the volume of treated water generated exceeds demand for the beneficial reuse activities. Irrigation modelling indicates that during the period of peak water production, there is on average, 18 days per year where the capacity of the modelled irrigation scheme is exceeded (refer to Appendix G2).

It would be unlikely that managed release would be required under the long-term average water production scenario which would occur for the majority of the project life following the initial peak water production period. Irrespective of this, approval is being sought for the managed release facility to be available for the life of the project to enable operational flexibility.

Based on historic rainfall and stream gauging data from the years 1995 to 2005, it is estimated that flow in Bohena Creek would exceed 100 megalitres per day at the Newell Highway gauging station on around 44 days per year (refer to Appendix G1). Data suggests that Bohena Creek typically flows only following periods of heavy rainfall and subsequent saturation of the surficial alluvial deposits within Bohena Creek (refer to Appendix G1).

If wet weather or another scenario limits demand for the beneficial reuse options outlined in this EIS, and the flow in Bohena Creek remains less than 100 megalitres per day, treated water would be managed within the existing produced water storage infrastructure.

Managed release would not occur to Bohena Creek when flow rates are below 100 megalitres per day as measured at the Newell Highway gauging station.

The managed release activity would be undertaken in a manner that does not cause material erosion of the bed and banks, nor result in material aggradation of sediments in Bohena Creek.

To assess the performance of the managed release scheme, water monitoring would be undertaken in accordance with the Water Monitoring Plan (refer to Appendix G3). Monitored parameters would include flow rates, water quality and toxicity assessment upstream and downstream of the water release point.

Detailed impact assessment of the proposed managed release activity has been conducted (refer to Appendix G1), with the findings discussed in further detail in Chapters 12 (Surface water quality) and 13 (Hydrology and geomorphology).

7.8 Salt management

Produced water from the Maules Creek Formation contains around 30 per cent of the salinity of seawater. It therefore requires a level of treatment commensurate with its proposed beneficial reuse, as discussed in Section 7.7.

The treatment process would produce a saline waste stream that would be further concentrated, crystallised into a solid salt product, and transported and disposed of to an off-site licensed landfill in accordance with regulatory requirements. As part of ongoing development of brine and salt management, options for alternative disposal methods, including potential commercial arrangements, would be investigated.

Salt management for the project is outlined below.

7.8.1 Salt volumes

As noted in Section 7.1, the average salinity of produced water generated during exploration and appraisal activities within the project area to date from the Maules Creek Formation and Black Jack Group is around 14,000 micro Siemens per centimetre.

To determine the volume of solid salt product the project would generate, laboratory work was undertaken to imitate the Leewood water treatment process (explained in Section 6.2.1 of Chapter 6), using conditions likely to achieve a similar level of decomposition. Specifically, the produced water was heated in the laboratory to 180 degrees Celsius to simulate the thermal process used during water treatment. During heating, some salt in the produced water decompose, while the remainder become a solid salt product. After taking into account decomposition resulting from heating, the typical mass of salt produced is 11,700 milligrams per litre of water fed to the water treatment process. This factor has been used to determine the estimated salt production rates below.

Produced water volumes are predicted to peak within years two to four of production at around 10 megalitres per day; therefore, estimated salt volumes are also expected to peak around that time. Forecasts indicate that the estimated salt quantities in produced water would be as follows:

- For the peak period in around years two to four - around 117 tonnes per day of which 115 tonnes per day would be extracted through the treatment process and disposed of off-site to a licensed landfill. This is the equivalent of around two and a half B-double truckloads of salt per day. The residual two tonnes of salt per day would be contained within the treated water used for beneficial reuse activities (refer to Table 7-3). Approximately 145 tonnes of salt product per day would be generated and transferred to a licensed landfill under a scenario where 12 megalitres per day of treated water is generated.
- The long-term average over the 25-year assessment period - around 48 tonnes per day of which around 47 tonnes per day would be extracted through the treatment process and disposed of off-site to a licensed landfill. This is the equivalent of just over one B-double truckload of salt per day. The residual one tonne of salt per day would be contained within the treated water used for beneficial use activities as shown in Table 7-3.

7.8.2 Annual salt volume estimates

Table 7-3 shows annual modelled salt volumes associated with routine project operations. It is based on treating around 10 megalitres per day during the peak produced water period in around years two to four, and around four megalitres per day as the long term average over the 25-year assessment period. Actual quantities would be dependent on a number of factors including crop requirements for irrigation, demand for stock watering, soil and weather conditions and the level of construction, and drilling and rehabilitation activities taking place at the time. Note that total salt volumes from stock watering activities have been excluded from Table 7-3 as their contribution is considered negligible in context.

The model provides that almost forty per cent of the dissolved salts that would be applied to land through irrigation water would be calcium sulfate that has been added during Stage 6 of the water treatment process (amendment of treated water) to reduce sodium adsorption ratios (refer to Figure 7-6). These calcium sulfate salts (or a similar salt product) would be added to improve the soil's cationic balance and agricultural productivity by reducing the soil's sodicity.

Further information on salt balances during peak and average water production periods are provided in Chapter 12.

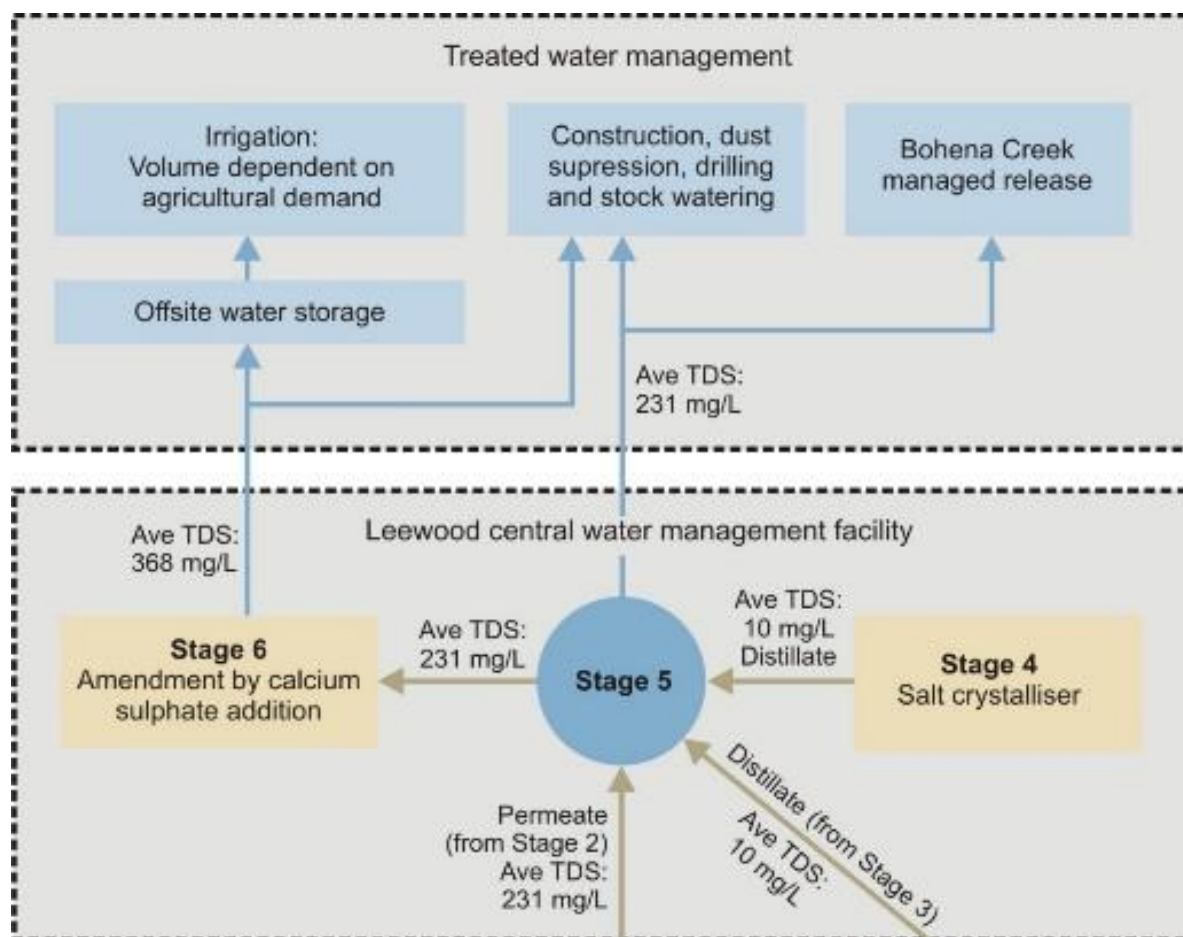


Figure 7-6 Stage 6 amendment by calcium sulfate (gypsum) addition

Table 7-3 Annual average and peak salt estimates

Produced water	Solid salt to licensed landfill	Irrigation	Dust suppression, drilling and construction	Managed release to Bohena Creek (under appropriate flow conditions)
Average: 1.5 GL per annum (~4.1 ML/day produced water over 25 years)	~47 tonnes per day or around 17,200 tonnes per year ^a	~371 tonnes per annum in around 1,009 ML per year of amended water ^b	~122 tonnes per annum ^c	Assumes managed release not required although option retained for operational flexibility
Peak: 3.65 GL per annum (years 2 to 4) (~10 ML/day produced water for years 2 to 4)	~115 tonnes per day or around 41,975 tonnes per year ^a	~874 tonnes per annum in around 2,376 ML per year of amended water ^d	~206 tonnes per annum ^e	~97 tonnes (max.) per year (a daily average of around 2.2 tonnes for each of the assumed 44 days of managed release) ^f

^a Removed initially during Stages 2, 3 and 4 of water treatment (refer to Figure 7-4)

^b Equivalent to the use of 365 days per annum of amended water averaging around 2.75 ML/day noting that managed release assumed to not be required).

^c Equivalent to the use of 365 days per annum of treated and amended water (half on forested land and half on non-forested land). Assumes a dust suppression rate of 1 ML/day on 100 kms of road. Assumes drilling for 365 days per annum using treated water using 0.15 ML/day.

^d Equivalent to the use of at least 321 days per annum of amended water averaging around 7.4 ML/day (assumes 44 days where managed release occurs based on historic Bohena Creek flow data from the years 1995 to 2013 (refer to Appendix G1).

^e Equivalent to the use of 321 days per annum of treated and amended water (half on non-forested land and half on forested land). Assumes a dust suppression rate of 2 ML/day on 100 kms of road (aligns with increased construction and drilling activities during years 0 to 4 – refer to Chapter 6; Section 6.1.4). Assumes drilling for 365 days per annum using treated water using 0.15 ML/day.

^f Assumes 44 days of release per year based on historic Bohena Creek flow data from the years 1995 to 2013 (refer to Appendix G1) at a rate of around 9.4 ML/day.

