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Santos NSW (Eastern) Pty Ltd

Coal Seam Gas Exploration and Appraisal

Produced Water Management Plan

PEL238 PAL2 PPL3

November 2018, Rev 1

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1. Introduction

1.1. Purpose

This Produced Water Management Plan (PWMP) has been developed in accordance with the requirements of condition 14 of Petroleum Exploration Licence (PEL) 238 and with the Department of Industry's *Exploration Code of Practice Produced Water Management, Storage and Transfer* (the Code). It is designed to provide information about how Santos NSW (Eastern) Pty Ltd (Santos) will manage produced water resulting from the operation of its coal seam gas (CSG) activities in the Narrabri area within PEL238, Petroleum Assessment Lease (PAL) 2 and Petroleum Production Lease (PPL) 3.

This PWMP supersedes the previous PWMP dated May 2017, that was approved by the NSW Department of Planning and Environment, Division of Resources and Geoscience on 26 June 2017.

1.2. Scope

Table 1-1 summarises the content requirements of condition 14 of PEL238 and where this information is provided in this PWMP.

Table 1-1 PEL 238, condition 14, PWMP content requirements

PWMP requirement under condition 14 of PEL238	Section reference
Expected sources and estimated quantities of produced water	Sections 3.1, 3.2
Proposed containment measures	Sections 4.1, 4.2
Proposed treatment measures	Section 4.3
Proposed beneficial reuse or disposal methods	Section 4.4
Controls to be implemented to prevent and/or minimise pollution	Sections 4.2, 5, 6
Record keeping for the quality, quantity, transport and disposal of produced water	Section 7
Staging process for implementation of the PWMP	Section 1.5

Table 1-2 sets out the key mandatory requirements of the Code and where this information is found in the PWMP. The mandatory requirements do not apply to existing infrastructure constructed prior to 2015.

Table 1-2 Mandatory requirements of the Code

No	Code of Practice PWMP content requirements	Section reference
1.1	Prior to commencing any activity that will require the management of produced water, the title holder must prepare a Produced Water Management Plan (PWMP). The PWMP must:	
	(a) set out a description of the activities associated with produced water to be carried out by the title holder.	Section 3
	(b) set out a description of management controls for those activities which ensure, so far as practicable, the effective prevention (or where that is not practicable, mitigation) of risks associated with produced water activities, and	Table 3-1, Table 4-1, section 5

No	Code of Practice PWMP content requirements	Section reference
	(c) set out measures which demonstrate compliance with the mandatory requirements of this Code and the requirements of any other relevant legislation.	Table 3-1, Table 4-1, section 5, Appendix B
1.3	The title holder must implement and comply with the PWMP, as revised from time to time in accordance with this Code.	Section 1
1.4	The PWMP must set out the risk assessment undertaken for the activity, including the characterisation, consideration of beneficial reuse and the fate of produced water.	Section 4
1.5	The PWMP must set out a site specific water balance to be maintained during activities. When multiple produced water activities are conducted under a single prospecting title, or as part of a broader exploration project area (under more than one prospecting title), the PWMP must provide a water balance model showing how these activities interrelate.	Section 3.5
1.6	The title holder must provide a copy of the PWMP to the Secretary no later than 14 days prior to conducting activities set out in the PWMP.	Section 8
1.7	The PWMP must be made available at the site of the produced water activities to all persons involved in those activities.	Section 1.4
2.1	The PWMP must set out an overview of how identified risks will be managed and mitigated.	Section 4
3	Produced water storage requirements.	Appendix A
4.1	The PWMP must include a Trigger Action Response Plan (TARP) that addresses the risks identified in clause 2.1 of this Code which require ongoing management controls.	Section 6
5.1	PWMP review requirements.	Section 8
6.1	Notification and reporting requirements.	Section 7

1.3. Background

Santos Limited and its subsidiary companies (including Santos NSW (Eastern) Pty Ltd) have been producing natural gas for more than 50 years and gas from coal seams for more than 17 years. Santos Limited began exploring for natural gas from coal seams in north-western NSW in 2008.

Santos is currently conducting CSG exploration and appraisal activities within PEL238, PAL2 and PPL3 in the Narrabri area. Figure 1-1 shows the location and context of PEL 238, PAL 2 and PPL3.

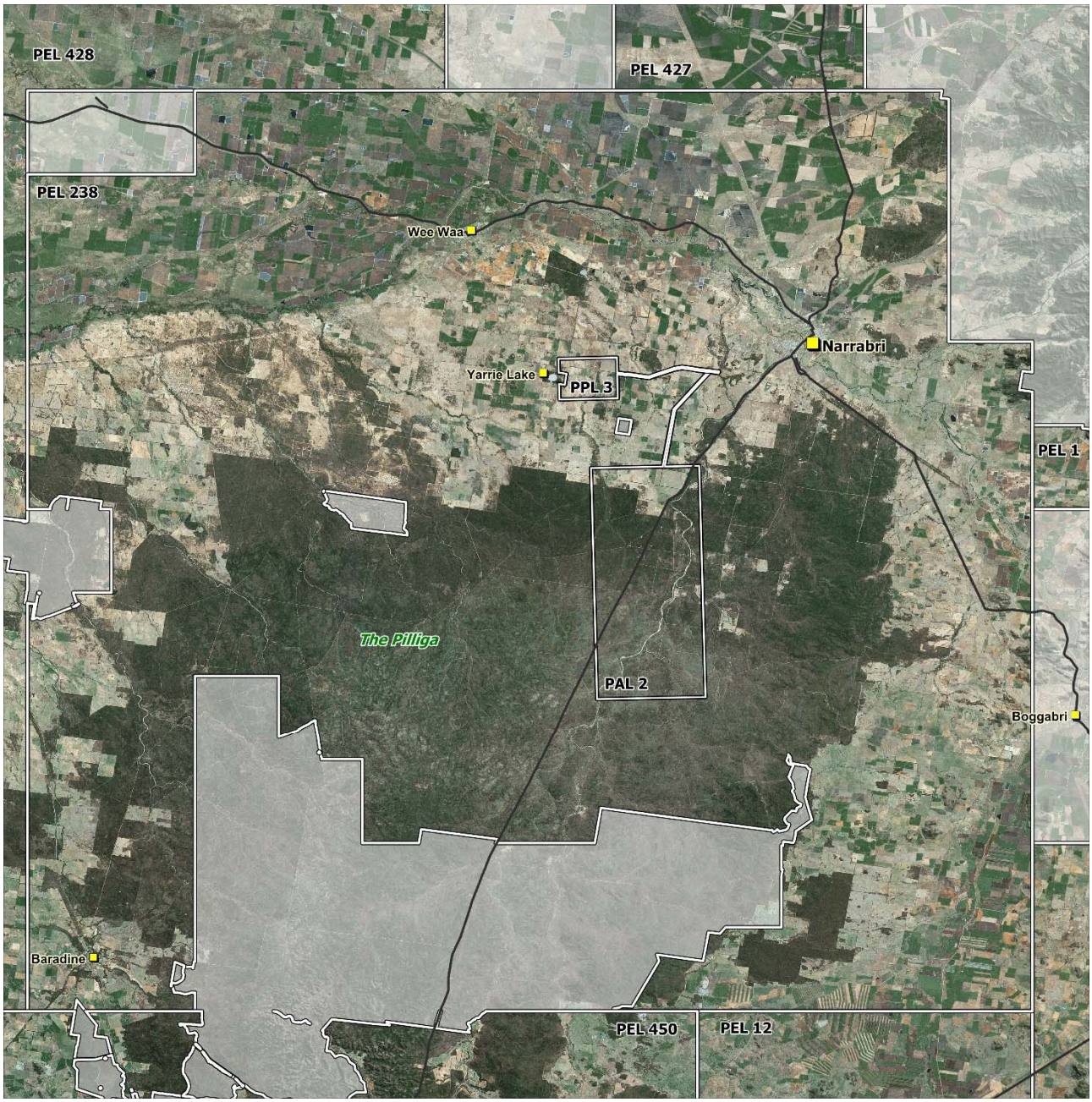

Figure 1-1 Location and context of PEL 238, PAL 2 and PPL3

Santos' main water management facilities are located at the Leewood property on the Newell Highway, approximately 24 kilometres south-west of Narrabri, within PAL2. Leewood hosts the following infrastructure to manage produced water and brine from Santos' exploration and appraisal activities:

- two double-lined produced water and brine storage ponds, each pond with two cells
- a water treatment facility to manage produced water and brine from exploration and appraisal activities
- a managed irrigation system
- a storage and utilities area, staff amenities and car parking.

Additional water management infrastructure is located at the Bibblewindi facility, on Garlands Road within the Bibblewindi State Forest, in PEL 238. This includes a 5 ML water balance tank used to manage produced water flows between the gas field and the water treatment plant at Leewood, a small capacity gas compression station (currently not in use), a safety flare, storage and utility areas, staff amenities and car parking. The facility also has two ponds—Bibblewindi Pond 2 and Pond 3—used to hold rainwater and/or bore water for construction and dust suppression purposes.

Two additional produced water ponds, known as Tintsfield Pond 1 and Pond 2, are located approximately 10 kilometres south-west of Narrabri, within PEL238. These accept produced water from the Tintsfield Pilot.

Table 1-3 summarises the field's key produced water assets and facilities, their status and relevant activity approvals. Figure 1-2 identifies the location of key assets and infrastructure.

Table 1-3 Summary of key produced water management assets within PEL238, PAL2 and PPL3

Asset/ facility	Ten-ure	Type	Status-Nov 2018	Relevant assessment documents	Approval reference and date	Approval period expiry date
Bibblewindi West Pilot	PAL 2	Appraisal Pilot	Operating – currently dewatering	*Review of Environmental Factors (REF) Narrabri Coal seam Gas Project Bibblewindi West Lateral Production Pilot, January 2009* *The Narrabri Coal Seam Gas Project REF Bibblewindi West Lateral Gas Pilot and Water Gathering System, March 2009*	PAL 2: Approval to conduct Narrabri Coal Seam Gas Project Bibblewindi West Lateral Production Pilot. Department of Primary Industries, 30 April 2009 PAL 2: Approval to conduct Narrabri Coal Seam Gas Project Bibblewindi West Lateral Pilot Gas and Water Gathering System (File 09/3009). Department of Primary Industries, 29 May 2009	None specified
Bibblewindi East Pilot	PAL 2	Appraisal Pilot	Operating – currently dewatering	*REF 2008 Narrabri Coal Seam Gas Lateral Program Lateral Production Pilot A* *2009 Narrabri Coal Seam Gas Project Bibblewindi Lateral Pilot Supplementary REF Bibblewindi Shield Laterals, July 2009* *The Narrabri Coal Seam Gas Project Operations and Water Management Plan, September 2008* *Supplementary REF – 2009 Narrabri Coal Seam Gas Project – Bibblewindi Lateral Pilot – ESP Installation & Extension of GGS to BW28H & 21H, May 2010*	PAL 2: Approval to conduct the Narrabri Coal Seam Gas Lateral Program, Lateral Production Pilot A, involving coal seam methane exploration well(s) Bibblewindi 18H, 12, 13, 14, 19H, 15, 16, 17. Department of Primary Industries, 12 August 2008 PAL 2: Approval to conduct Narrabri Coal Seam Gas Project Bibblewindi Lateral Pilot – Shield Laterals Supplementary (File 09/4500). Department of Primary Industries, 20 July 2009 PAL 2: Approval to conduct 2009 Narrabri Coal Seam Gas Project: Bibblewindi Lateral Pilot: ESP Installation & Extension of GGS to BW28H & 21H (File 09/4500). Department of Industry & Investment, 24 March 2011	None specified
Leewood Water Management Facility (ponds)	PAL 2	Ponds	Operational	*Leewood Produced Water & Brine Management Ponds REF, December 2012*	RE: PAL2 Approval to construct and operate Leewood produced water and brine management ponds (INT13/23812). Department of Resources & Energy, 19 March 2013	None specified
Leewood Produced Water	PAL 2	Plant, treated water	Suspended until	*Leewood Produced Water Treatment and Beneficial*	RE: Petroleum Assessment Lease (PAL) 2 Approval to undertake Leewood Produced Water	18 August 2020; rehabilitation

Asset/ facility	Ten-ure	Type	Status-Nov 2018	Relevant assessment documents	Approval reference and date	Approval period expiry date
Treatment and Beneficial Use Project		storage tank and irrigation infra-structure	September 2019	*Reuse Project REF, June 2015*	Treatment and Beneficial Reuse Project (MCV15/245#3, OUT15/16630). Division of Resources and Energy, 18 August 2015	by 18 August 2023.
Bibblewindi 5ML tank	PAL 2	Tank	Operational	*Leewood Produced Water & Brine Management Ponds REF, December 2012*	RE: PAL2 Approval to construct and operate Leewood produced water and brine management ponds (INT13/23812). Department of Resources & Energy, 19 March 2013	None specified
Bibblewindi to Leewood water flow line	PAL 2	Water flow line	Operational	*Leewood Produced Water & Brine Management Ponds REF, December 2012*	RE: PAL2 Approval to construct and operate Leewood produced water and brine management ponds (INT13/23812). Department of Resources & Energy, 19 March 2013	None specified
Bibblewindi to Wilga Park GRE gas flowline	PAL 2	Gas flow line	Operational. Can be used to transfer produced water if required.	*Narrabri Coal Seam Gas Utilisation Project Part 3A Environmental Assessment (Project Application 07_0023)* *Narrabri Coal Seam Gas Utilisation Project (MP 07_0023) Modification 3*	Project Approval for MP07_0023 (S07/00277). Minister for Planning, 2 December 2008. Notice of Modification to Project Approval (07_0023). Planning Assessment Commission, 18 July 2014.	None applicable as works are complete.
Dewhurst Northern Water and Gas Flow Lines	PAL 2/PEL 238	Water and gas flow lines	Water flow line installed	*Dewhurst Northern Water and Gas Flow Lines REF, June 2013*	RE: PEL 238 and PAL 2, Approval to undertake Dewhurst Northern Water and Gas Flow Lines construction program (MCV13/369, OUT 13/25591). Office of CSG, 18 September 2013	No specified end date in amended approval.
Dewhurst Southern Water and Gas Flow Lines	PAL 2/PEL 238	Water and gas flow lines	Water flow line installed; gas flow line under construction	*Dewhurst Southern Water and Gas Flow Lines REF, June 2013*	RE: PEL 238 and PAL 2, Approval to undertake Dewhurst Southern Water and Gas Flow Lines construction program (MCV13/370, OUT13/25677). Office of CSG, 18 September 2013	No specified end date in amended approval.
Tintsfield 2-7 Pilot	PEL 238	Appraisal Pilot	Operating – currently dewatering	*Recommencement of Tintsfield Pilot and flare PEL 238 and PPL 3, Gunnedah Basin NSW, Supplementary REF, August 2013*	RE: PEL 238 and PPL3, Approval to recommence Tintsfield Pilot and construct and operate associated flare (MCV13/588, OUT13/32001). Office of CSG, 25 October 2013	No specified end date in amended approval.
Dewhurst 13-18H Pilot	PEL 238	Appraisal Pilot	Shut in	*REF Dewhurst-8 Lateral Production Pilot, June 2009*	PEL 238: Approval to conduct Narrabri Coal Seam Gas Project Dewhurst – 8 Lateral Production Pilot (09/4409). Department of Primary Industries, 21 July 2009	None specified

Asset/ facility	Ten-ure	Type	Status-Nov 2018	Relevant assessment documents	Approval reference and date	Approval period expiry date
				EIS Dewhurst Gas Exploration Pilot Expansion SSD 6038	SSD – 6038 Dewhurst Gas Exploration Pilot Expansion Planning Assessment Commission,18 July 2014	18 July 2017
Dewhurst 22-25 Pilot	PEL 238	Appraisal Pilot	Shut in	*REF Dewhurst 22-25 Pilot Wells, March 2013*	RE: PEL 238 Approval to undertake Dewhurst 22-25 Pilot Wells exploration program (MCV13/204, OUT13/23530). Office of CSG, 16 August 2013	No specified end date in amended approval
Dewhurst 26-29	PEL 238	Appraisal Pilot	Operating – currently dewatering	*Dewhurst 26-29 petroleum wells REF, March 2013* *EIS Dewhurst Gas Exploration Pilot Expansion SSD 6038*	RE: PEL 238 Approval to undertake Dewhurst 26-29 Pilot Wells exploration program (MCV13/205, OUT13/23533). Office of CSG, 16 August 2013 SSD – 6038 Dewhurst Gas Exploration Pilot Expansion Planning Assessment Commission, 18 July 2014	No specified end date in amended approval 18 July 2017
Tintsfield pond 1 and 2	PEL 238	Ponds	Operational	*Tintsfield Water Management Plan, Narrabri Coal Seam Gas Project, February 2010*	PEL 238: 2009 Narrabri Coal Seam Gas Program, Approval of Tintsfield CSG Pilot Water Management Plan (OUT10/7377). Department of Industry and Investment, 25 May 2010	No specified end date in amended approval for Tintsfield 2-7 pilot (which identified use of Tintsfield ponds to manage water)

There are other approved pilots which are currently not producing water or gas. These pilots are the Bibblewindi 9 Spot pilot, the Coonarah wells in PPL3 and the Bohena Pilot. They will not be producing water for the period of this Produced Water Management Plan.

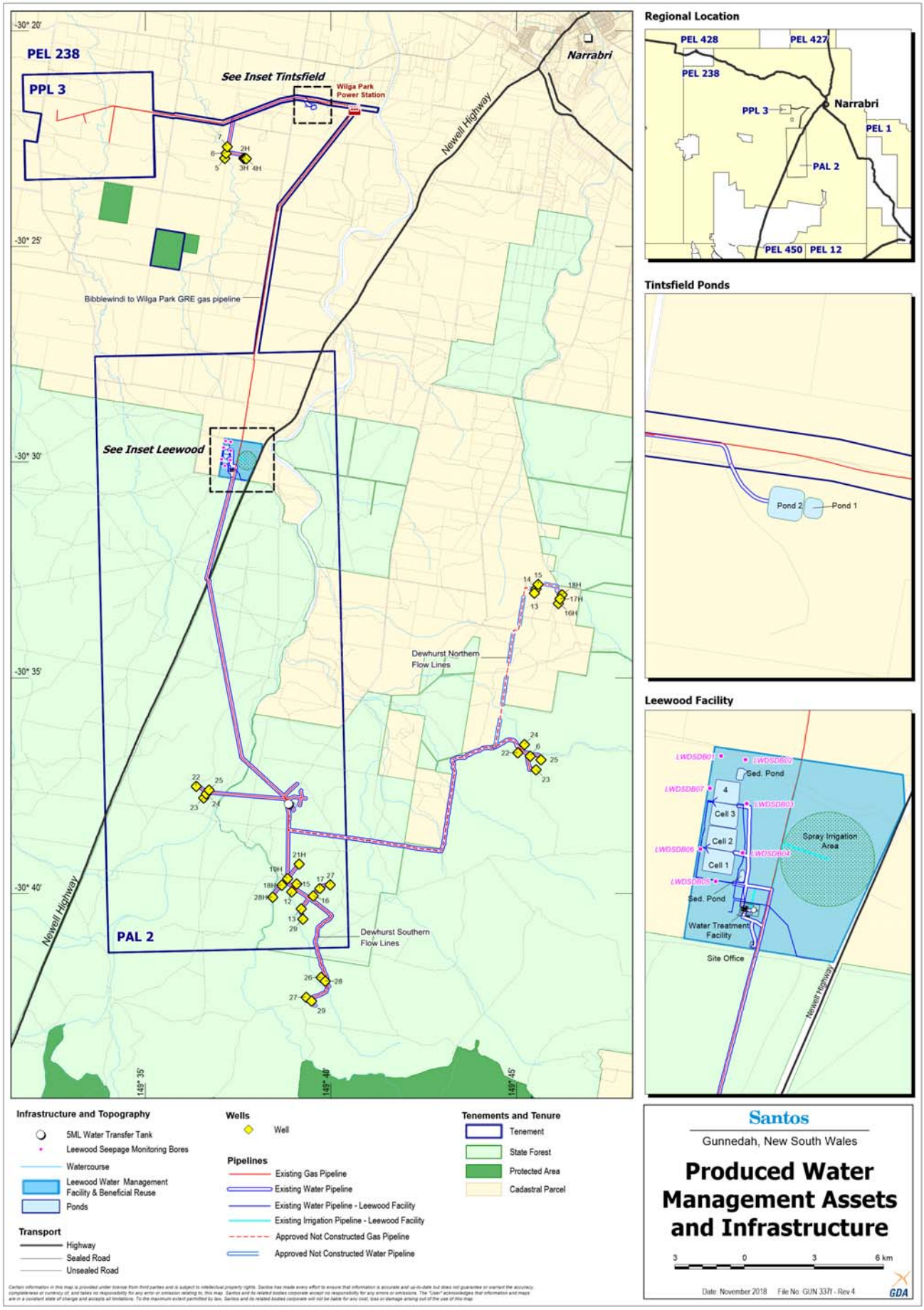

Figure 1-2 Key assets and infrastructure

1.4. Implementation of this Plan

This PWMP applies to the management of produced water generated during exploration and appraisal activities. A copy of this PWMP will be kept at Santos' Narrabri Operations Centre, 300 Yarrie Lake Road Narrabri, where operational and field staff commence and finish work each day.

2. Characterisation of produced water

2.1. Produced water source

CSG development will primarily target gas reserves associated with Early Permian coal seams of the Maules Creek Formation, located at depth in the northern portion of the Gunnedah Basin.

The primary target seams (Bohena, Parkes, Namoi and Rutley seams) of the early Permian Maules Creek Formation occupy the basal part of the Bohena Trough within the northern part of the Gunnedah Basin. The coal seams are generally moderately transmissive, exhibiting higher hydraulic conductivity than the adjacent units. However, these units are not utilised for water supply due to the depth and presence of the alluvium and Pilliga Sandstone closer to the ground surface. The coal seams are typically characterised by poor (saline) water quality.

Overlying the target seams are approximately 600 - 800 metres (m) of Permian and Triassic strata. Jurassic-age strata belonging to the Surat Basin, a south eastern extension of the Great Artesian Basin, overly the Permo-Triassic strata and are themselves overlain in part by more recent consolidated and unconsolidated alluvial sediments.

Gas trapped in coal is adsorbed onto the coal surface in cleats and joints or micro pores and held in place by reservoir and water pressures. To extract the gas it is necessary to reduce the pressure by first removing water (known as produced water). Typically, water production is higher earlier in the life of a CSG field and declines as gas production increases as demonstrated in Figure 2-1.

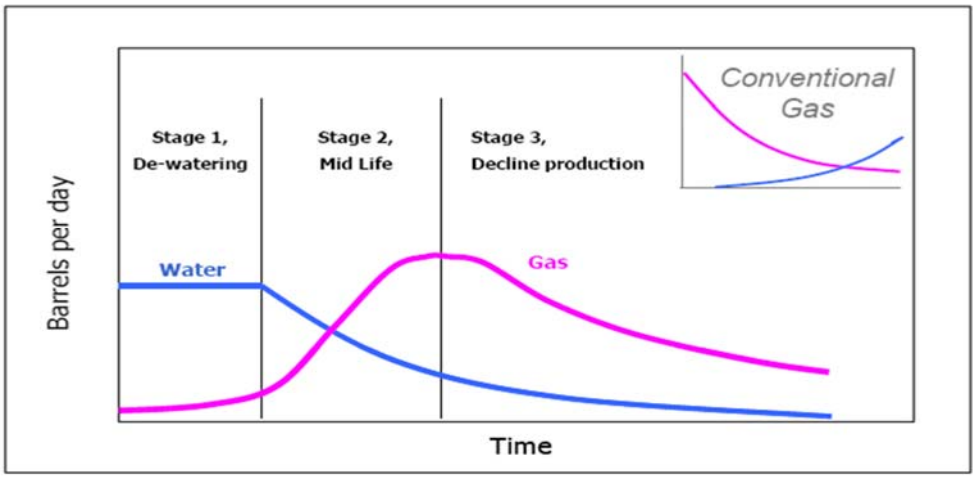

Figure 2-1: Stages of produced water and CSG production

2.2. Produced water quantity

Details of the estimated quantity of produced water associated with the operation of the pilots for exploration and appraisal activities in PEL238 and PAL2 is provided in Table 2-1.

Table 2-1 Estimated produced water volumes for exploration and appraisal activities within PEL238 and PAL2

Activity	Total estimated forecast volume of produced water December 2018 – November 2019.
Exploration and appraisal activities in PEL238 and PAL2.	185ML

The volume of water generated during the production phase is determined by the properties of the coal and the depressurisation targets that must be achieved to facilitate gas production. There is limited ability to reduce depressurisation targets (and associated water production) during appraisal testing as this impacts gas flow and volumes extracted and therefore reduces the information that can be gained during the testing period.

Table 2-2 identifies current produced water and brine volumes stored in PEL238 and PAL2.

Table 2-2 Current (November 2018) volumes of produced water and brine stored in PEL238 and PAL2

Storage name	Volume (ML) – November 2018	Water quality (field measurements) September 2018		
		pH	Temperature (c)	Electrical Conductivity (µS/cm)
Leewood Cell 1	41	9.63	17.8	80138
Leewood Cell 2	112.34	9.50	17.3	39041
Leewood Cell 3	112.33	9.18	17.8	18395
Leewood Cell 4	69.94	9.44	17.7	85370
Tintsfield Pond 1*	1.1	Dry	Dry	Dry
Tintsfield Pond 2*	5.66	9.79	17	50118

*Tintsfield Ponds to be operated in accordance with the Liner Integrity Monitoring Program set out in EPL20350.

2.3. Produced water quality

The quality of produced water is primarily dependent upon the geology of the area in which CSG wells are located and consequently, variability between wells can be high. Evidence suggests that the produced water quality from a single well is generally within a consistent range with fluctuations in the order of 20% (+/-) over the lifetime of a well.

Table 2-3 provides the average produced water quality at the well head and has been derived from over 300 samples from around 50 wells throughout PAL2 and PEL238 over a period of 16-years. Considering the spatial extent and long time-period over which samples were taken, Table 2-3 is considered to be representative of the conditions which could be encountered in the field.

Table 2-3 Average produced water quality at well head

Parameter	Units	LOR*	Number of analyses	Average	16th percentile	84th percentile
Physicochemical						
pH			321	8.0	7.3	8.6
Electrical Conductivity	µS/cm		319	14836	11284	18653
Solids (Dissolved)	mg/L	2	252	9765	7083	13000
Solids (Dissolved) @180	mg/L	2	82	11675	7971	14815
Dissolved anions						
Carbonate alkalinity as CaCO3	mg/L	1	227	378	1	779
Bicarbonate alkalinity as $CaCO_3$	mg/L	1	335	8518	5157	11800

Parameter	Units	LOR*	Number of analyses	Average	16th percentile	84th percentile
Bromide	mg/L	0.005	41	4.44	3.04	5.51
Chloride	mg/L	2	335	1396	1000	1673
Fluoride	mg/L	0.05	75	4.86	2.51	6.00
Sulphur as SO4	mg/L	0.1	258	45	1	34
Dissolved cations						
Calcium (Total)	mg/L	0.1	284	19	5	31
Magnesium (Total)	mg/L	0.01	166	6	3	7
Potassium (Total)	mg/L	0.2	331	213	41	156
Sodium (Total)	mg/L	1	334	4360	2858	5955
Hardness (Total)	mg/L	1	105	88	26	147
Nutrients						
Ammonia-Nitrogen	mg/L	10	57	10	4	16
Nitrate-Nitrogen	mg/L	0.1	167	2.56	0.05	3.00
Nitrite-Nitrogen	mg/L	0.01	75	0.04	0.01	0.02
Nitrogen (TKN)	mg/L	1	54	25.6	6.0	33.6
Nitrogen (Total)	mg/L	1	60	23.6	4.9	30.8
Ortho-Phosphorus	mg/L	0.18	34	<0.18	<0.18	<0.18
Phosphorus (Total)	mg/L	0.02	58	0.28	0.04	0.22
Total metals & trace elements						
Aluminium (Total)	mg/L	0.01	60	3.35	0.02	2.73
Antimony (Total)	mg/L	0.0001	59	0.0008	<0.0001	0.0011
Arsenic (Total)	mg/L	0.0001	57	0.0106	0.0047	0.0126
Barium (Ba)	mg/L	1	60	8.5	4.2	14.4
Beryllium (Total)	mg/L	0.001	55	<0.001	<0.001	<0.001
Boron (Total)	mg/L	0.2	60	0.6	<0.2	1.2
Cadmium (Total)	mg/L	0.0001	60	0.0107	<0.0001	0.0204
Chromium (Total)	mg/L	0.0005	60	0.0116	0.0008	0.0201
Cobalt (Total)	mg/L	0.0001	56	0.0017	<0.0001	0.0027
Copper (Total)	mg/L	0.0005	60	0.0503	0.0046	0.0438
Iron (Total)	mg/L	0.01	106	17.17	0.26	6.00
Lead (Total)	mg/L	0.0005	17	0.0199	<0.0005	0.0252
Lithium (Total)	mg/L	0.1	17	1.7	1.3	2.0
Manganese (Total)	mg/L	0.001	61	0.266	0.003	0.062
Mercury (Total)	mg/L	0.0001	58	0.0005	<0.0001	0.0005
Molybdenum (Total)	mg/L	0.0001	59	0.0047	0.0001	0.0043
Nickel (Total)	mg/L	0.0001	60	0.0065	<0.0001	0.0125
Selenium (Total)	mg/L	0.0005	58	0.0206	0.0039	0.0413
Strontium (Total)	mg/L	0.001	86	2.521	0.603	4.361
Tin (Total)	mg/L	0.0005	17	0.0018	<0.0005	0.0027
Uranium	mg/L	0.0001	58	0.0004	<0.0001	0.0005
Vanadium (Total)	mg/L	0.005	53	0.009	<0.005	0.012
Zinc (Total)	mg/L	0.0005	60	0.0531	0.0041	0.0575

*Limit of reporting

3. Produced water management

Produced water from exploration and appraisal activities within PEL238 and PAL2 is managed through a network of gathering, storage and treatment infrastructure. This infrastructure has been developed after extensive environmental impact assessment and approval and is operated in accordance with relevant approvals, tenure conditions and Santos Environment Protection Licence (EPL) 20350.

The produced water management infrastructure and processes are described in the sections below. Further detail of each aspect of the network can be found in the relevant Review of Environmental

Factors document (available on Department of Industry's DiGS website (http://digsopen.minerals.nsw.gov.au/), or environmental impact statement (EIS) available on the Department of Planning and Environment's Major Projects website (http://majorprojects.planning.nsw.gov.au/). Figure 4 provides a diagrammatic overview of the infrastructure.

3.1. Produced water gathering and transfer

At each pilot, produced water is pumped from through local water gathering lines to a centralised balance tank for that pilot (where installed). Produced water is then pumped from the balance tank (or directly from the pilot well where no balance tank is installed) via flowlines to the Bibblewindi facility 5ML balance tank and onto Leewood via the Leewood Water Pipeline. The only exception is produced water from the Tintsfield Pilot, which is transferred via flowlines to the Tintsfield Ponds.

The water pipeline/flowline network includes:

- the Leewood Water Pipeline between the Bibblewindi facility and the Leewood Water Management Facility
- the Dewhurst Northern Flowline between Dewhurst 22-25 Pilot and the Bibblewindi facility
- the Dewhurst Southern Flowline between Dewhurst 26-29 Pilot and the Bibblewindi facility
- water flowlines from Bibblewindi West Pilot to Bibblewindi facility
- water flowlines from Bibblewindi East Pilot (also known as the Multi-lateral Pilot) to the Bibblewindi facility
- water flowlines from the Tintsfield Pilot to Tintsfield ponds.

In addition, there is a buried gas pipeline between the Bibblewindi facility and Wilga Park Power Station that has an offtake at Leewood. This pipeline can be used to transfer water between Bibblewindi, Leewood and Tintsfield.

The design, construction and operation of the High Density Poly-Ethylene (HDPE) flowlines is undertaken in accordance with the Australian Pipeline Industry Association's *Code of Practice for Upstream Polyethylene Gathering Networks - CSG Industry* (March 2013). This includes detailed quality control measure requirements to ensure the integrity during the construction process. After construction and prior to commissioning, the entire flowline is required to be pressure tested and once operating, ongoing pressure monitoring using remote telemetry occurs.

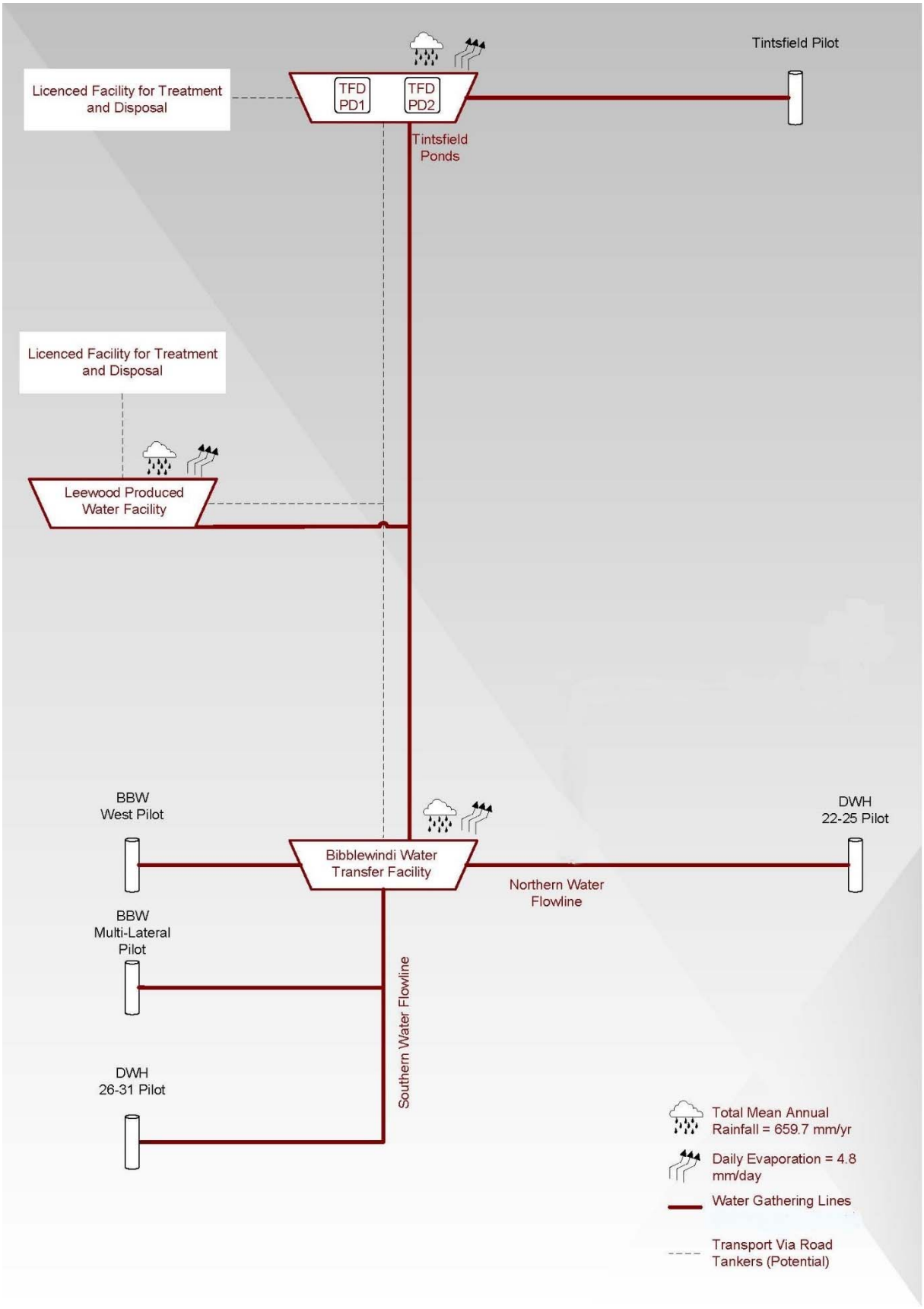

Figure 3-1: Produced water infrastructure schematic

3.2. Produced water storage facilities

A summary of the approved produced water storage facilities is presented in Table 3-1. The table includes information on storage volumes of each facility and controls to prevent and minimise pollution including pond liners and monitoring equipment installed. It does not include tanks within the Leewood Water Treatment Plant.

Table 3-1 Summary of produced water storage facilities

Storage name	Full supply level volume (ML)	Maximum operating level volume (ML)	Design life	Lining and leak detection system	Facility monitoring		
					Monitoring aspect	Frequency	Monitoring at facility
Bibblewindi Transfer Tank (produced water)	4	3.75	25 years	Galvanised steel panel tank with internal polypropylene bladder. Tank is also contained within an earthen bund underlain with a HDPE liner.	Water level	Continuous using sensors and remote monitoring. Tank is equipped with level instrumentation, alarms and trips, to ensure the tank does not over fill.	Network (13) of monitoring bores installed at the facility at varying depths located up-gradient, down-gradient and cross hydraulic gradient of the water infrastructure. These monitoring points were installed when there were three produced water storage ponds at Bibblewindi and pre-dated the construction of the Transfer Tank. The bores are designed to both monitor groundwater (chemical, physical and hydraulic) and intercept groundwater where this is found to be present. Additional perched water layers are monitored at a number of locations to assess any vertical migration of groundwater.
					Inflow and outflow	Continuous using flow meters and remote monitoring.	
Leewood Pond 1 (produced water)	389	300	25 years	Primary polyethylene geomembrane liner underlain by leak detection system underlain by a secondary liner. The secondary liner will be underlain by 300 mm of smooth clayey sub grade. The leak collection system transfers any produced water collected below the liner directly back into the pond. The	Water level	Continuous using sensors and remote monitoring	Network (7) of seepage detection bores (50mm diameter) installed around the Leewood ponds to a depth of 10 metres, with screening from 7 to 10 metres below ground level. Seepage detection bores are monitored biannually. Ten groundwater monitoring bores of varying depths are installed across the Leewood property. The monitoring bores are screened at a number of shallow perched water layers below the surface. Sampling of standard groundwater parameters is undertaken quarterly and results reviewed for any unexpected changes to physical and
					Inflow and outflow	Continuous using flow meters and remote monitoring	
					Embankment seepage	Monthly	
					Embankment erosion	Quarterly	
					Pond crest integrity and capping	Quarterly	
					Hydraulic structures	Quarterly	
					Pipework and valves	Weekly	
					Pond water quality	Quarterly for pH, DO and EC Six monthly grab sample for laboratory	

Leewood Pond 2 (produced water and brine)	403.1	300		operation of the sump pumps and sump levels is checked on a daily basis and data recorded. Ponds designed by a suitably qualified engineer and constructed on stable sub-base with each liner weld tested and associated QA documentation developed. The ponds also have a fauna proof fence installed to prevent terrestrial fauna from entering the pond area.		analysis in accordance with EPL 20350.	chemical water quality parameters and water levels.
					Rainfall and evaporation	Weekly	
					Pond liner condition	Monthly	
					Embankment deformation	Monthly	
					Vegetation growth	Quarterly	
					Wildlife management systems (fences etc.)	Quarterly	
Tintsfield Pond 1 (produced water) Tintsfield Pond 2 (produced water)	22.9 92.0	15.3 72.6	25 years	HDPE membrane thickness 2mm. Leak detection via shallow groundwater monitoring network surrounding ponds. Ponds operate on a duty and standby mode to enable full inspection of one liner each year. Ponds designed by a suitably qualified engineer and constructed on stable sub-base with each liner weld tested and associated QA documentation developed. The ponds also have a fauna proof fence installed to prevent terrestrial fauna from entering the pond area.	Water level	Continuous using sensors and remote monitoring.	Network (20) monitoring bores of monitoring bores installed at the facility at varying depths located up-gradient, down-gradient and cross hydraulic gradient of the water infrastructure. The monitoring bores are screened at a number of shallow perched water layers below the surface. Sampling of standard groundwater parameters is undertaken quarterly and results reviewed for any unexpected changes to physical and chemical water quality parameters and water levels.
					Inflow and outflow	Continuous using flow data from wellhead pumps, outflow pumps and remote monitoring.	
					Embankment seepage	Monthly	
					Pond crest integrity and capping	Quarterly	
					Hydraulic structures	Quarterly	
					Pipework and valves	Weekly	
					Pond water quality	Quarterly for pH, DO and EC Six monthly grab sample for laboratory analysis in accordance with EPL 20350.	
					Rainfall and evaporation	Weekly	
					Pond liner condition	Monthly	
					Embankment deformation	Monthly	
					Vegetation growth	Quarterly	
					Wildlife management (fences etc.)	Quarterly	

3.3. Produced water and brine treatment

The treatment and beneficial reuse of produced water and brine from exploration and appraisal activities has been assessed and approved under Part 5 of the *Environmental Planning and Assessment Act 1979* and the *Petroleum Onshore Act 1991*. Further information is available at the NSW Government website: https://search.geoscience.nsw.gov.au/report/R00070789

The Leewood Water and Brine Treatment Plant is currently suspended until September 2019. When operational, it has the capacity to treat up to 1.5 ML of produced water per day. Treatment processes include:

- **Pre-treatment** to enable the removal of solids and/or scale-causing compounds from the water. To remove solids and/or scale causing compounds, produced water first undergoes microfiltration/ultrafiltration to remove solids between 0.01 – 0.1 microns within the feed water. The final pre-treatment process involves using a biocide for bio-fouling control. This step controls the growth of microorganisms, both in the microfiltration/ultrafiltration and reverse osmosis (RO) stages.
- **Treatment by RO** where the produced water is pumped through a semi-permeable membrane, separating treated water into one stream and salts into another stream known as rejected concentrate or 'brine'. Feed water is pumped at high pressure through the membranes, typically separating over 99 per cent of the total dissolved solids from the water.
- **Post-treatment** which involves a series of steps in order to chemically balance the treated water prior to beneficial reuse (particularly for irrigation). This includes:
    - dechlorination by sodium bisulphate addition (this is dosed prior to the RO to protect the RO membranes from oxidation by chlorine)
    - addition of calcium and magnesium to lower the sodium adsorption ratio (SAR)
    - adjustment of pH by acid or caustic addition, if required.

When operational, brine from the reverse osmosis plant is sent to the brine treatment plant to further recover treated water and concentrated brines beyond the limit of the water treatment plant. A membrane brine concentrator within the brine treatment plant uses a high pressure membrane process to concentrate dissolved solids in solution by using reverse osmosis and recovering additional treated water. The main output from the membrane brine concentrator is concentrated brine which is then transferred to the brine storage cell.

3.4. Beneficial reuse of treated water and brine

When operational, the plant has the capacity to produce 1ML/day of treated water. Treated water from the plant is approved for use in a number of beneficial use applications, including a managed irrigation system on the Leewood property, dust suppression, construction and drilling activities, watering of landscaped and rehabilitation areas and firefighting.

Treated water from the plant is held in a 5ML treated water storage tank prior to its beneficial reuse. Monitoring of treated water from this tank is conducted in accordance with the conditions of EPL 20350 prior to irrigation.

The managed irrigation system includes a centre-pivot irrigator fitted with Variable Rate Irrigation (VRI) technology covering an area of approximately 49 hectares. The irrigation system has the capacity to utilise up to 6.5 ML/day though treated water availability would be limited to 6ML per day based on plant capacity and storage volumes.

The irrigation activities are operated under an Irrigation Management Plan (IMP) that includes soil and groundwater monitoring within the irrigation area, and in accordance with EPL 20350.

Santos is exploring opportunities to beneficially reuse brine from its water treatment operations. Over the next approximately 12 months, Santos is planning to transfer a quantity of brine stored at

Leewood to a third party mine for use in site trials as an alkalising agent. The third party mine operator is required to obtain all necessary approvals to use the brine. Transfer of the brine would be in accordance the *Protection of the Environment Operations (Waste) Regulation 2014* requirements including waste tracking.

3.5. Water balance model

A water balance model for the field was prepared as part of the Leewood Produced Water Management and Beneficial Reuse Project REF and supporting material. The schematic is provided in Figure 3-1.

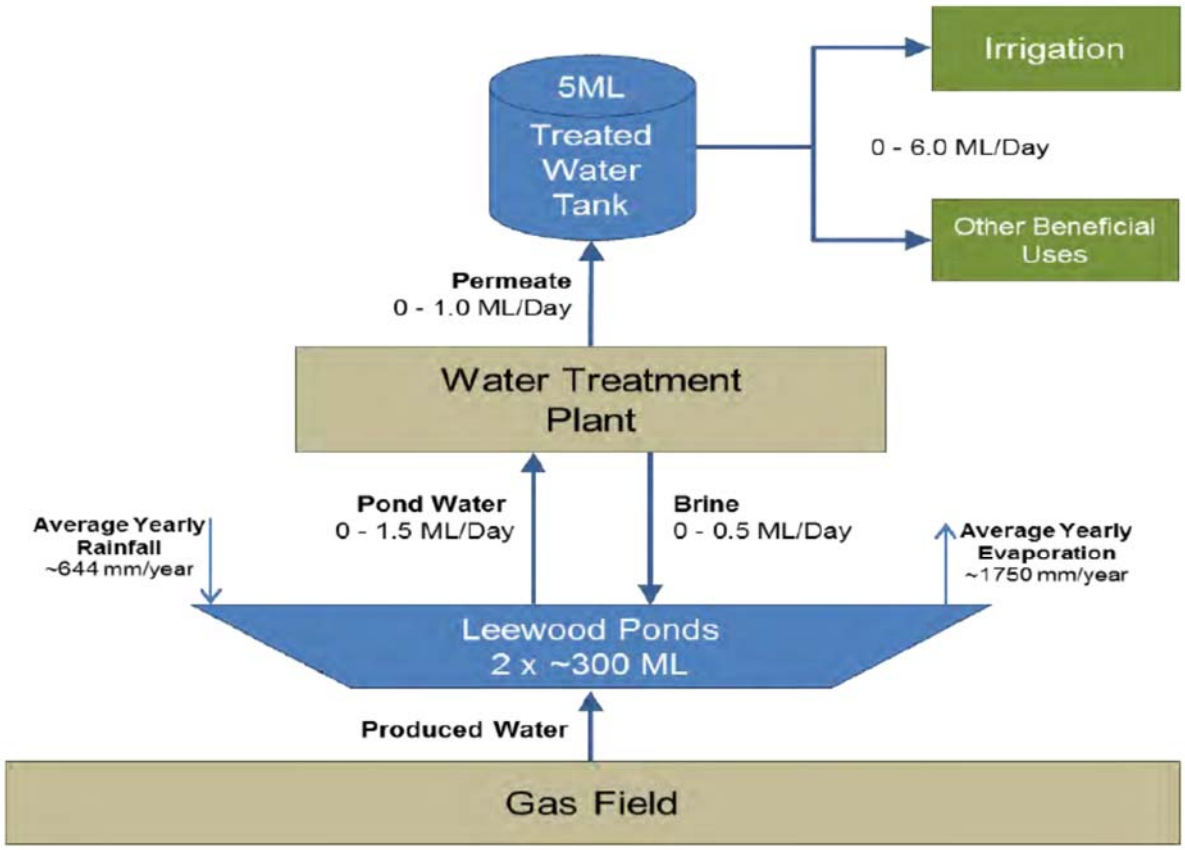

Figure 3-2 Water balance model schematic

4. Risk assessment and mitigation

The potential risks associated with construction, operation and decommissioning the activities covered by this PWMP were assessed, and mitigation measures described, in the various review of environmental factors documents listed in Table 1-3. Further risk assessment has been carried out during the implementation of these activities in accordance with Santos risk assessment standards. A summary of the key risks associated with produced water management, and measures to manage these risks, are provided in Table 4-1. The operational risk matrix used to determine risk levels is provided in Appendix B.

Table 4-1 Risk assessment and mitigation

Risk	Potential causes	Inherent design standards and operational practices	Initial risk			Site/activity specific mitigation measures/ management plans to reduce risk	Residual risk		
			Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Loss of containment of produced water from wellhead.	Equipment failure, operational error, tampering, impact from livestock	Wells are designed and constructed in accordance with the NSW Government *Code of Practice for Coal Seam Gas - Well Integrity*. Well leases are fenced.	C	IV	3	Pressure gauges are fitted to wellhead equipment and monitored remotely through a Supervisory Control and Data Acquisition (SCADA) system. Any change in pressure is investigated immediately and in the event of a leak, the well shut-in. Well head inspections are carried out on a daily basis for operational wells and quarterly for shut-in and suspended wells. Well integrity is monitored through a leak detection and repair program (LDAR) in accordance with EPL 20350.	B	IV	2
Loss of containment of produced water from flowline/pipeline	Excavation, overpressure, equipment failure	Pipelines are designed and constructed in accordance with Australian Pipeline Industry Association's *Code of Practice for Upstream Polyethylene Gathering Networks - CSG Industry* and pressure tested prior to commissioning.	D	IV	4	Mass balance calculations using wellhead data and produced water storage levels are carried out to determine if there are any losses of produced water along the pipeline network. In the event that a loss is detected, wellheads are able to be shut-in remotely.	C	IV	3
Loss of containment of produced water from storage tank (5ML or 40KL)	Faulty valve, operator error, tank failure or overflow	All produced water storage tanks are bunded to 110% capacity.	C	IV	3	Inflow and outflow of the Bibblewindi Transfer Tank and balance tanks is monitored continuously. Continuous level measurement of the Bibblewindi Transfer Tank is carried out in accordance with section 5.1. Balance tanks are inspected on a monthly basis.	B	III	2
Loss of containment of produced water from pond due to lining, pipe or wall failure, or overtopping	Improper design, construction or maintenance Operation outside design limits	All ponds are designed and operated according to appropriate engineering standards. The Leewood ponds have: • a spillway capacity designed to pass 0.01% Annual Exceedance Probability (AEP) flows • wet season design storage allowance (the volume between the MOL and FSL /spillway level) sized to provide storage for a volume	C	V	4	Continuous pond level measurement is carried out in accordance with section 5.1. Monitoring of other aspects of the ponds, such as embankment and liner condition, is carried out in accordance with Table 3-1. Level instrumentation and pond level forecasting is carried out.	B	V	3

Risk	Potential causes	Inherent design standards and operational practices	Initial risk			Site/activity specific mitigation measures/ management plans to reduce risk	Residual risk		
			Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
		equivalent to the 1:100 AEP and a storm event containment of 1:100 AEP 72 hour duration. • double lining and leak detection. Tintsfield Ponds are operated in duty standby mode in accordance with EPL 20350.				Trigger Action Response Plans (TARPs) have been developed for a range of potential circumstances.			
Loss of containment of produced water or chemicals from water treatment plant	Improper design, overpressure, operator error, equipment failure	The plant is designed and operated according to appropriate engineering standards.	C	IV	3	The plant is operated in accordance with the approved Water Treatment Plan. The plant is situated on a bunded area.	B	III	2

5. Infrastructure monitoring

An infrastructure monitoring program is implemented across the produced water and brine storage facilities and gathering and transfer infrastructure. A summary of the infrastructure monitoring measures and their frequency for each storage is included in Table 3-1. Additional monitoring is described in the sections below.

5.1. Produced water storages

Produced water storage facilities are monitored in accordance with Table 3-1 (section 3.2).

Water storage levels have been defined for each of the ponds for monitoring and management purposes. These definitions are based on the Queensland guidelines '*Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*' (Department of Environment and Resource Management, 2011), and include:

- Wet Season Containment (**Maximum Operating Level (MOL)**) – Includes a minimum spare storage capacity (Design Storage Allowance) required at the nominal start of the wet season (1 November each year) to give the regulatory agency confidence that wet season inputs can be managed without loss of containment (i.e. spillway discharge).
- Storm Event Containment (**Emergency Reporting Level (ERL)**) – The dam level at which loss of containment could potentially occur within a single storm event (72 hour duration event) triggering notifications and further action.
- Spillway Capacity (**Full Supply Level (FSL)**) – Sufficient spillway capacity is required to ensure that the design flood event can be conveyed by the spillway without causing overtopping of the dam embankment which could lead to catastrophic failure of the dam structure.

Water storage levels for each pond are identified in Table 6-1.

Table 5-1 Defined pond operating levels

Produced Water storage facility	Full Supply Level (FSL) (m AHD)	Emergency Response Level (ERL) (m AHD)	Maximum Operating Level (MOL) (m AHD)
Tintsfield Pond 1	225.84	225.46	224.57
Tintsfield Pond 2	225.84	225.53	224.85
Leewood Pond 1	250.4	249.92	249.59
Leewood Pond 2	249.85	249.41	249.03

Monitoring of storage levels is undertaken with the use of pressure sensors that continuously measure and record storage depth, volume and surface area based on hydrostatic pressure. These automated meters are submersed in the pond to a depth as close to the base of the pond as reasonably practicable, and are used in conjunction with surveyed data to determine the water level of the pond. Telemetry is used to allow for remote real-time monitoring of the pond levels and this is used to monitor storage capacity in conjunction with other parameters such as upstream pilot or wellhead water production data.

Field operators are required to record the pond level and volume on a daily basis. Other operating markers/indicators may also be used in conjunction with the pressure sensor monitoring, such as volume and MOL indicator markers on storage facility walls. The level sensors system used in the existing ponds undergoes regular assessment and, when necessary, recalibration occurs six monthly in order to ensure the accuracy of readings.

In addition to monitoring, regular forecasting of predicted water production will be undertaken to identify the potential for elevated levels as early as possible to allow strategies to be implemented to minimise the potential for pond levels to exceed the MOL.

5.2. Dam safety

In addition to the monitoring outlined for the Leewood Water Management Facility, the Leewood ponds are subject to the surveillance requirements for prescribed dams, including the preparation of a Surveillance Report. This report requires inspection and reporting of the condition of the ponds including embankment slopes, crest and spillway, presence of any erosion, vegetation, seepage and monitoring instrumentation.

A Dam Safety Emergency Plan has been provided to the NSW Dam Safety Committee in accordance with the requirements of the *Dams* Safety *Act 1978*. The plan provides emergency response procedures for the management of the Leewood ponds in the event of an imminent or actual uncontrolled release from the ponds.

5.3. Flowline and pipeline monitoring

Pipeline integrity management procedures are maintained to ensure flowline infrastructure remains fit for purpose at all times by implementing a systematic approach to operation, maintenance, testing and inspection activities. Periodic inspections are carried out to identify actual or potential problems that could affect the integrity of the pipeline and any maintenance required is carried out in a timely manner.

5.4. Groundwater monitoring

Santos also undertakes an extensive regional groundwater monitoring program to monitor groundwater in the region of its operations. This program is the subject of the Groundwater Monitoring and Modelling Plan prepared in relation to exploration and appraisal activities and approved by the (former) NSW Office of CSG in July 2013.

6. Trigger action response plans

Trigger Action Response Plans (TARPs) are developed to identify, assess and respond to abnormal conditions and are implemented to manage risk to operations, personnel and the environment. Two TARP documents have been developed to address the requirements of the Produced Water Code of Practice.

- Produced water storage pond level TARP provides the actions to be taken if defined pond management levels are reached.
- Leewood pond leakage management TARP provides actions to be taken if defined leakage rates are reached.

These TARP documents are stored on the Santos SharePoint site and are available to all Santos Operations personnel. In addition to the trigger points and associated actions to be undertaken, these documents also detail the delegation of responsibility at each trigger points and contact details for both internal and external notification requirements.

7. Record keeping

Santos has a comprehensive data management plan for the Narrabri Gas Field that outlines the policies and procedures that will be implemented to ensure that data is managed in a consistent, efficient and effective manner in order to provide accurate records of activity operations and enhance the value of the data collected.

Data collected as part of produced water management activities is stored and managed within Santos' environmental database, EQUIS, with web based access to data entry and reporting and a full suite of technical procedures for data collection, work flow, reporting and other functions.

Key records associated with this PWMP that are stored and managed include:

1. Inspection and monitoring records for facilities and dams (including leak detection monitoring);
2. Records of Construction Quality Assurance (CQA) program including person who prepared CQA program and records to demonstrate their certification by Engineers Australia (if applicable);
3. Records of pond design and construction;
4. Records of standards and quality control testing used for seam joining of geomembrane liners;
5. Records of groundwater levels or underdrainage measures where applicable;
6. Names of standard or code that is utilised for construction of pipeline and records of field pressure testing;
7. Record of pipeline leak detection testing;
8. Records of implementation of any TARP;
9. Records of any review of the PWMP;
10. Operational monitoring and performance data for treatment systems;
11. Water sampling and laboratory analytical reports;
12. Calibration records for field instruments and continuous water quality monitoring systems;
13. Waste Transportation and Disposal Certificates;
14. Annual Inspection reports and/or certifications of storages.

Monitoring data is subject to quality assurance (QA) and quality control (QC) protocols and procedures that ensure that data is accurate and usable. Data is subjected to consistent validation and verification procedures. Any data that fails QA and QC procedures is rejected for future use. QA and QC procedures include:

- For each batch of water quality samples sent to the laboratory, results are validated against the analysis requested on the chain of custody (COC) to ensure all results have been received;
- All results, including quality control samples (QCS) including method blanks, laboratory control samples, matrix spikes samples and surrogate samples must fall within the specific quality control limits. Appropriate field quality control samples (i.e. duplicates, field blanks, trip blanks and triplicate samples, etc.) will also be used to assist in the quality control of the data obtained from the monitoring programs;
- Program monitoring guidelines (minimum and maximum values) will likely be configured in the environmental database for each monitoring compliance requirement or to detect anomalous results. The guidelines act as quality control measures to verify that data falls within an acceptable range.

8. Review of PWMP

This PWMP will be reviewed annually and in the following circumstances:

- in accordance with any direction from the Minister administering the NSW *Petroleum (Onshore) Act 1991* or the NSW Environment Protection Authority

- if changes to produced water management practices are proposed which necessitate additional assessment under the *Environmental Planning and Assessment Act 1979*
- before making a significant change to the design or operation of a produced water storage or transfer facility
- in the event that the TARP trigger level 2 is activated (notification to regulator).

A copy of the PWMP will be provided to the Division of Resources and Energy a minimum of 14 days prior to commencing operation of any changed facility, or (where the PWMP is revised due to another event), no later than 14 days after that revision is complete.

9. APPENDIX A – COMPLIANCE WITH CODE OF PRACTICE MANDATORY REQUIREMENTS – PRODUCED WATER STORAGE

Note that the mandatory requirements for water storages do not apply to existing infrastructure constructed prior to 2015.

Requirement	Compliance	Comment
3.1 Evaporation ponds must not be used to manage produced water in connection with activities carried out under a prospecting title relating to petroleum.	Yes	No evaporation ponds are used. Produced water is stored in ponds prior to treatment at Leewood.
3.2 If the produced water being stored may have an adverse impact on the environment if released: a) the produced water storage must: i) be chemically compatible with the produced water being stored ii) not absorb or react with the produced water being stored, and iii) incorporate measures to prevent any overfilling or draining of the produced water being stored.	Yes	Refer to Table 3-1 for pond and tank liner systems and measures to prevent overfilling.
b) the title holder must not operate a produced water storage facility beyond its intended design life without prior approval from the Secretary. Materials utilised in the construction must have performance characteristics that exceed the anticipated conditions and length of time that the facility is intended to be in operation.	Yes	Refer to Table 1-3 for date each produced water storage facility was approved and Table 3-1 for design life of each produced water storage facility.
c) produced water storage facilities with the capacity to store more than five cubic metres of produced water must comprise a secondary containment, and	Partial (exempt)	The Leewood ponds are double lined. The Tintsfield ponds are operated in duty standby mode in accordance with EPL20350.
d) the produced water storage facility must have the capability to detect leaks of produced water through the primary containment (such as a tank or liner material) within one (1) month of the compromising event occurring.	Partial (exempt)	The Leewood ponds are designed and constructed to provide immediate identification and notification of leaks of produced water through the primary containment
3.3 If ponds are used to store produced water: a) the design and installation of the pond must comply with the requirements specified in a Construction Quality Assurance (CQA) program. The CQA program must be prepared by a person certified by Engineers Australia to provide those services, or such other organisation approved by the Secretary	Yes	Engineering design and construction QA program completed by certified engineer through Golders Associates
b) the pond must maintain an environmental containment freeboard capable of containing inflow from events up to and including a 1 in 100 year Annual Exceedance Probability (AEP) 72 hour rainfall event, without discharge, unless the operation of a freeboard for that pond is authorised by an EPL.	Partial (exempt)	The Leewood ponds have an environmental containment freeboard capable of containing events greater than the 1 in 100 year AEP 72 hour rainfall event. Refer to Table 4-1.
c) the ponds must be located and designed to be structurally stable in all events up to and including the probable maximum flood.	Partial (exempt)	Flood study completed by Golder Associates as part of the Engineering design for the Leewood Ponds with both the 1 in 50 year and 1 in 100 year flood events considered.
d) the ponds must not be located in any area that will increase flood risk to surrounding area land unless controls are implemented to effectively mitigate that risk.	Partial (exempt)	Flood study completed by Golder Associates as part of the Engineering design for the Leewood Ponds with both the 1 in 50 year and 1 in 100 year flood events considered.
e) the ponds must have spillway or overflow levels located above the 1 in 100 year ARI flood level	Partial (exempt)	The Leewood ponds have a spillway level above the 1 in 100 year ARI flood level. Refer to Table 4-1.
f) if geomembrane liners are used in the construction of the pond: i) liner seams and joins must be watertight and seamed over their full length in accordance with the manufacturer's standard procedures and any site-	Partial (exempt)	For the Leewood ponds, Engineering design and construction QA program completed by certified engineer through Golders Associates with

Requirement	Compliance	Comment
specific recommendations by a person certified by Engineers Australia to provide these services, or such other organisation approved by the Secretary. ii) quality control testing must be conducted over the full length of seams and joins prior to storing any produced water in the pond iii) liners must be installed on a stable soil sub-base, free of protrusions that have the potential to compromise the liner. The underside of the lowest liner (secondary containment) should be at least two (2) metres above the highest seasonal groundwater level, unless effective under-drainage measures are installed to prevent upward water pressure on the liner, and iv) controls must be implemented to prevent terrestrial fauna that have the potential to damage the liner from entering the pond.		all seams tested and associated QA documentation completed for all welds. The Leewood ponds have been constructed on a stable sub-base. The Leewood ponds are also fully fenced to discourage terrestrial fauna from entering and damaging the liner. For the Tintsfield ponds Engineering design and construction QA program completed by certified engineer through Aquatech Consulting with all seams tested and associated QA documentation completed for all welds. The Tintsfield ponds have been constructed on a stable sub-base. The Tintsfield ponds are also fully fenced to discourage terrestrial fauna from entering and damaging the liner.
3.4 If pipelines are used to convey produced water: a) the pipelines must be constructed and installed in accordance with *AS2885, AS/NZS2566* or the *APGA Code of Practice for Upstream Polyethylene Gathering Networks in the Coal Seam Gas Industry.* The licence holder must carry out field pressure testing to verify pipe integrity prior to commissioning the pipe, and	Yes	All pipelines are constructed in accordance with the *APIA Code of Practice for Upstream Polyethylene Gathering Networks in the Coal Seam Gas Industry* and pressure tested prior to commissioning. Refer to section 3.1.
b) computational pipeline monitoring (or some other leak detection system that provides equivalent or better leak detection than computational pipeline monitoring) must be implemented for any pipeline which conveys produced water at flow rates greater than one (1) megalitre per day.	Yes (exempt)	Flowlines/pipelines do not convey produced water at flow rates greater than 1 ML/day.

10. APPENDIX B – OPERATIONAL RISK MATRIX

	CONSEQUENCE		**Localised** and short term environmental or community impact – readily dealt with	**Localised and short term impact** to an area, plants or animals of environmental value. Readily treated.	**Localised and medium term impact** to areas, plants or animals of significant environmental value. Remediation may be difficult or expensive.	**Extensive and medium-term impact** to an area, plants or animals of recognised environmental value. Remediation possible but may be difficult or expensive.	**Destruction of an important population of plants or animals or of an area of significant environmental value**. Complete remediation not practical or possible.	**Regional and long term impact** on an area of significant environmental value. Destruction of an important population of plants and animals with recognised conservation value. Complete remediation impossible.
			I	II	III	IV	V	VI
LIKELIHOOD	**ALMOST CERTAIN** Occurs in almost all circumstances OR could occur within **days to weeks**	f	**2**	**3**	**4**	**5**	**5**	**5**
	LIKELY Occurs in most circumstances OR could occur within **weeks to months**	e	**2**	**3**	**4**	**4**	**5**	**5**
	OCCASIONAL Has occurred before in Santos OR could occur within **months to years**	d	**2**	**2**	**3**	**4**	**4**	**5**
	POSSIBLE Has occurred before in the industry OR could occur within the **next few years**	c	**1**	**2**	**2**	**3**	**4**	**5**
	UNLIKELY Has occurred elsewhere OR could occur **within decades**	b	**1**	**1**	**2**	**2**	**3**	**4**
	REMOTE Requires exceptional circumstances and is unlikely even in the long term OR only occurs as a **"100 year event"**	a	**1**	**1**	**1**	**2**	**3**	**3**