Santos

NARRABRI GAS PROJECT

Groundwater Management Plan

PHASE 1

0041-150-PLA-0015

Date	Revision	Reason for Issue	Author	Checked	Approved
11 November 2022	0E	For approval	Eco Logical Australia / Onward Consulting	DG	TD

Santos

Prepared by:

Title	Name	Signature	Date
Senior Principal Hydrogeologist	Dr Richard Cresswell Eco Logical Australia		11 November 2022
Senior Environmental Manager	S. van der Meulen Onward Consulting		11 November 2022
Director	Mark Vile Onward Consulting		11 November 2022

Reviewed by:

Title	Name	Signature	Date
Principal Environmental Advisor | Hydrogeologist	David Gornall		11 November 2022

Approved by:

Title	Name	Signature	Date
Development Manager NSW	Todd Dunn		11 November 2022

This document has been prepared by Onward Consulting to comply with the Narrabri Gas Project conditions of consent and has relied upon the relevant information available at the time of writing and all findings, conclusions or recommendations contained herein are based thereon. This document is for the use of Santos Ltd and no responsibility will be taken for its use by other parties. Santos Ltd may, at its discretion, use this document to inform regulators and the public.

ONWARD CONSULTING

Onward document number:
NGP-001G-0E PLN

Document review history

In accordance with consent condition D4, this document has been reviewed as follows:

Review Date	Reason for review	Reviewed by	Revision required (Y/N)

Acronyms and abbreviations

Acronym	Description
°C	degrees Celsius
µg/L	micrograms per litre
AHD	Australian Height Datum
AIP	NSW Aquifer Interference Policy
ANSM	Australian National Seismograph Network
ANZECC	Australia and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS	Australian Standard/New Zealand Standard
BOM	Australian Bureau of Meteorology
cm	centimetre
CoA	Conditions of approval of EPBC 2014/7376
CoC	Conditions of consent of NGP SSD 6456
CSG	coal seam gas
Cth	Commonwealth
DCCEEW	Cth Department of Climate Change, Energy, the Environment and Water
DPE	NSW Department of Planning and Environment
DPE Water	The Water group within DPE
DPIE	The former NSW Department of Planning, Industry and Environment
EC	electrical conductivity
EIS	environmental impact statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2021
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
EPL	environment protection licence under the POEO Act
EQuIS	Environmental Quality Information System
GAB	Great Artesian Basin
GOB	Gunnedah-Oxley Basin
GBR	Groundwater Baseline Report
GIA	groundwater impact assessment
GIS	geographical information system
GL	gigalitre
GModP	Groundwater Modelling Plan
GMonP	Groundwater Monitoring Plan
GTP	gas transmission pipeline
ha	hectare

Acronym	Description
IEA	Independent Environmental Audit
InSAR	Interferometric Synthetic Aperture Radar
kg	kilogram
km	kilometre
L	litre
LOR	limits of recording
LSTU	less significant transmissive units
m	metre
m^2	square metre
ML	megalitre
mm	millimetre
mm/yr	millimetre per year
NTU	negligibly transmissive units
PAL	petroleum assessment lease under the PO Act
PEL	petroleum exploration licence under the PO Act
PJ	petajoules
PO Act	*Petroleum (Onshore) Act 1991* (NSW)
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POEO Regulation	Protection of the Environment Operations (General) Regulation 2009
PNTU	probable negligibly transmissive units
PPL	petroleum production lease under the PO Act
PPLA	petroleum production lease application under the PO Act
ppm	parts per million
SEPP	State Environmental Planning Policy
SMS	Santos Management System
STU	significant transmissive units
TARP	trigger action response plan
TDS	total dissolved solids
WAL	water access licence
WEP	Water Expert Panel
WM Act	*Water Management Act 2000* (NSW)
WMP	Water Management Plan
WSP	water sharing plan

Table of Contents

Tables

Figures

1. Introduction

1.1 Narrabri Gas Project

1.1.1 Background

Resource exploration has been occurring in the north-western area of NSW since the 1960s; initially for oil, but more recently for coal and gas. Santos NSW Pty Ltd began exploring for natural gas from coal seams in north-western NSW in 2008 and is currently conducting coal seam gas (**CSG**) exploration and appraisal activities within Petroleum Exploration Licence (**PEL**) 238, Petroleum Assessment Lease (**PAL**) 2 and Petroleum Production Lease (**PPL**) 3[1], located in the Gunnedah Basin about 20 kilometres (**km**) south-west of the town of Narrabri. Activities in PAL 2 have focussed on the Bibblewindi and Bohena CSG pilots, whilst recent activities in PEL 238 have focussed on the Dewhurst and Tintsfield CSG pilots.

The Narrabri Coal Seam Gas Utilisation Project (Wilga Park Power Station and associated infrastructure) operates under an existing Part 3A approval under the *Environmental Planning and Assessment Act 1979* (NSW) (**EP&A Act**). It was originally approved in 2008, with various modifications approved between 2011 and 2019. It encompasses a gas gathering system, a compressor and associated flare, a gas flow line from Bibblewindi to Wilga Park within a 10 metre (**m**) corridor with a riser at Leewood and an expansion of the existing Wilga Park Power Station from 12 to 40 megawatts.

1.1.2 Current Project

On 30 September 2020, Santos NSW (Eastern) Pty Ltd (**Santos**) obtained consent for State significant development (**SSD**) 6456 to develop the Narrabri Gas Project (**NGP**) (**the Project**). Approval EPBC 2014/7376 under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (**EPBC Act**) was granted on 24 November 2020.

The Project includes the progressive installation of up to 850 new gas wells on up to 425 new well pads over approximately 20 years and the construction and operation of gas processing and water treatment facilities. The Project area covers about 950 square kilometres (95,000 hectares) in size and the Project footprint will only directly impact about 1% of that area.

Four phases of development are defined under the consent, including:

- Phase 1 - exploration and appraisal;
- Phase 2 - construction activities for production wells and related infrastructure;
- Phase 3 - gas production operations; and
- Phase 4 - gas well and infrastructure decommissioning, rehabilitation and closure.

Phase 1 of the Project is defined in the consent as the phase of the development comprising ongoing exploration and appraisal activities in the Project area, including:

- seismic surveys;
- core and chip holes;
- construction and operation of pilot wells (up to 25 wells on up to 25 well pads across the Project area); and

[1] Refer to the Glossary for details on the titleholders for PEL 238, PAL 2 and PPL 3.

- pilot well ancillary infrastructure, including access tracks, gas and water gathering lines, water balance tanks, safety flaring infrastructure, utilities and services, and environmental monitoring equipment including groundwater monitoring bores.

Santos plans to continue exploration and appraisal of the resource in the near term until a final investment decision can be made. The exploration and appraisal activities will include continued operation of Santos' existing wells, infrastructure and facilities in PEL 238 and PAL 2, and construction and operation of new core holes, pilot wells and supporting infrastructure permitted under Phase 1.

Santos' existing exploration and appraisal activities in PEL 238 and PAL 2 include:

- Tintsfield Pilot;
- Bibblewindi East Pilot;
- Bibblewindi West Pilot;
- Dewhurst North Pilot;
- Dewhurst South Pilot;
- Dewhurst northern and southern flow lines;
- Leewood Water Management Facility including ponds, the water and brine treatment plant (WBTP) and irrigation area;
- Bibblewindi Facility, including gathering system, water balance tank, compressor and flare; and
- Bibblewindi to Leewood buried gas pipeline.

These exploration and appraisal activities will continue as part of the NGP. The initial, new-appraisal Phase 1 scope is a relatively minor extension to these existing exploration and appraisal activities.

The Phase 1 scope is planned to include the construction and operation of:

- 4 coreholes;
- 6 pilot wells;
- 2 deep reservoir monitoring bores (converted coreholes);
- new shallow water monitoring bores;
- associated linear infrastructure;
- seismic surveys (length and location to be determined); and
- continued operation of Santos' existing exploration and appraisal activities, including workover activities.

The full definitions of the approved activities for Phases 2, 3 and 4 of the Project are provided in the consent. Santos is not prevented from carrying out any or all of the phases concurrently, subject to the conditions of this consent.

Further details regarding the NGP, including a full overview of the regulatory framework and statutory provisions of the NGP and the current approvals, leases and licences are provided in the overarching Water Management Plan (**WMP**). Details regarding the staging of the works and the exact scope for each phase are as per the approved Field Development Plan.

1.2 Purpose and scope of the Groundwater Management Plan - Phase 1

The quantity and quality of groundwater produced varies considerably according to the hydrogeological setting, age and depth of the coal seam. It also varies during the life of the coal seam gas well. The potential effect of removal of this groundwater on other groundwater sources is predicted to vary spatially and temporally. Groundwater monitoring data will be used throughout the life of the Project to verify and improve predicted groundwater effects.

Santos has developed this Groundwater Management Plan (**GMP** or **Plan**) in accordance with the regulatory framework. Santos will implement all reasonable and feasible management measures and be strategic and proactive in the management of groundwater so that any potential impacts on the environment, including to groundwater dependent users and ecosystems, are avoided or minimised. It has been developed in accordance with the requirements of approval conditions of PEL 238, PAL 2, PPL 3, Environment Protection Licence (**EPL**) 20350, the conditions of consent (**CoC**) of SSD 6456 and the EPBC 2014/7376 conditions of approval.

This Plan forms part of a suite of documents prepared as part of the NGP Water Management Plan (**WMP**) under Condition B41(d), which consist of the following:

(i) An Erosion and Sediment Control Plan, prepared in accordance with the Blue Book and identifying details including but not limited to activities that could cause soil erosion, generate sediment or affect flooding; the location, function, and capacity of erosion and sediment control structures and flood management structures; and measures to manage any effects of soil erosion, sediment transport and flooding;

(ii) A Site Water Balance, which includes but is not limited to details of the inflows and outflows in the Project area; sources and security of water supply for the life of the Project; water storage and treatment capacity; water use and management, including sharing and transfers; licenced discharge points; and reporting procedures, including the annual preparation of an updated site water balance;

(iii) A Surface Water Management Plan, which includes but is not limited to specific details on baseline data on surface water flows and quality of watercourses; the surface water management system; detailed plans, design objectives and performance criteria for water infrastructure; performance criteria; a program and procedures for monitoring, evaluation and reporting; and plan to respond to any exceedances of the performance measures or performance criteria, and repair, mitigate and/or offset any adverse surface water impacts of the development;

(iv) A Groundwater Management Plan (**this Plan**);

(v) A Produced Water Management Plan (**PWMP**) that provides detailed baseline data on produced water yield and quality, and includes but is not limited to details regarding the produced water management system; performance criteria, including trigger levels; and a program and procedures for monitoring, evaluation and reporting;

(vi) An Irrigation Management Plan, for managing beneficial reuse of treated water for crop irrigation and stock watering, that includes but is not limited to details regarding site selection and assessment; agreements with third parties; baseline soil and groundwater conditions and quality; a protocol for operation of the irrigation management system; and measures to manage any effects on soils structure, erosion, groundwater quality and maintain a water balance;

(vii) A Dust Suppression Protocol for managing beneficial reuse of treated water for dust suppression and construction activities including but not limited to details of site selection and assessment; baseline soil and groundwater conditions and quality; a protocol for operation of the dust suppression system; and measures to manage any effects on soils structure, erosion, surface water runoff, groundwater quality and groundwater levels;

(viii) A Managed Release Protocol for managing disposal of treated water to Bohena Creek, that includes but is not limited to details of water flows, quality and health; predicted plume dispersal; a protocol and detailed procedures for managed release; and measures to manage any effects of water quality, stream and riparian health, erosion and sedimentation and downstream flooding. It is to be noted that it is not proposed to release to Bohena Creek during Phase 1 of the Project and as such this protocol will be developed for Phase 2 of the Project. A summary of the managed release is provided in section 6 of the PWMP;

(ix) A Salt Management Plan, which includes but is not limited to details of salt and other waste volumes and composition generated by the produced water management system; a program for investigating and implementing beneficial reuse options for the salt product; and a protocol and procedures for the full-cycle management of salt and salt-related waste products. It is to be noted that no salt will be generated during Phase 1 of the Project (only brine will be produced) and there is adequate storage in the existing facilities to manage this brine for Phase 1. Section 7 of the PWMP describes this proposed approach to salt management for the Project. A full Salt Management Plan will be developed prior to Phase 2 of the Project, based on the findings of the Produced Salt Beneficial Reuse and Disposal study required by condition B65;

(x) A Pollution Incident Response Management Plan, prepared in accordance with the Protection of the Environment Operations (General) Regulation 2009 and which includes detailed procedures for responding to incidents, spills and leaks associated with the produced water management system; and a Dam Safety Emergency Plan for managing potential incidents and emergencies associated with produced water storages, and

(xi) A protocol to report on the measures, monitoring results and performance criteria identified above, in the Annual Review referred to in Consent Condition D8.

A full list of the conditions applicable to this GMP is presented in section 3.1.4 and reproduced with section references at Appendix B. Consent conditions relevant to each of the other sub-plans listed above are provided in each of the sub-plan documents.

As required by CoC B42, Santos will implement the latest revision of this Plan once approved by the Planning Secretary.

1.3 Objectives

The objectives of this GMP are to provide the following:

- details of the relevant statutory requirements and a description of the measures to be implemented to comply with associated performance measures, as detailed in the Consent Conditions and other relevant codes and guidelines (section 3.2);
- details of any relevant commitments or recommendations identified in the Environment Impact Statement (EIS) for the Project;
- a program to monitor, evaluate and report on compliance with the requirements, obligations and performance measures and criteria, and
- a program to investigate and implement ways to improve the environmental performance of the groundwater management system over time.

Monitoring and management of extracted groundwater is described in the PWMP, including the monitoring and management of potential effects on groundwater due to, for example, monitoring the integrity of water storage ponds.

1.4 Performance measures

As required by consent condition B37, Santos will ensure that the Project complies with the water management performance measures in Table 7 [of the CoC]. Specifically, this GMP considers the following measures:

Feature	Performance measure

Namoi alluvial aquifers and Great Artesian Basin aquifers	• Negligible environmental consequences to the aquifers beyond those predicted in the EIS, including:
	  ▪ Negligible change in groundwater levels;
	  ▪ Negligible change in groundwater quality; and
	  ▪ Negligible impacts to other groundwater users
	• No exceedance of the minimal harm considerations in the Aquifer Interference Policy (DPI, 2012);
	• Negligible change to baseline methane levels in groundwater user bores.

Gunnedah Oxley Basin aquifers	• Drawdown and water take to be generally consistent with the 'base case' predictions and produced water profile in the EIS; • Negligible change in groundwater quality.
Riparian and aquatic ecosystems	• Negligible impact on groundwater dependent ecosystems (**GDEs**).

Further, as required by CoC B41(d)(iv), the Plan provides detailed performance criteria, including trigger levels, for identifying and investigating any potentially adverse impacts associated with the Project, on:

- regional and local aquifers and aquitards (alluvial and bedrock);
- ground subsidence and seismicity;
- groundwater supply and quality for other water users, including all potentially affected privately-owned licensed groundwater bores;
- GDEs; and
- aquatic habitat and stygofauna.

1.5 Consultation

For Phase 1, this GMP has been prepared by a suitably qualified and experienced person in consultation with the Water group within the NSW Department of Planning and Environment (**DPE**) (generally referred to as **DPE Water**), the NSW Environment Protection Authority (**EPA**) and the Water Technical Advisory Group (**WTAG**).

Minor comments were received from the EPA on the draft GMP (Revision A) and the attachments, with comments centred around potential expansion of the baseline data and the incorporation of recently completed Government coal basin monitoring bores. The WTAG provided extensive comments on the draft GMP (Revision A) and the attachments, with specific focus on groundwater extraction, groundwater sources drawdown and EIS predictions. Comments from DPE Water related to performance measures and timelines for the development of the groundwater model.

All consultation correspondence on the GMP, including attachments, and the responses to comments are provided in Appendix A.

1.6 Structure of this Plan

Together with the suite of documents listed in section 1.2, this Plan is a supporting document to the WMP. The WMP sets out the overall details how the documents are related and where information or details are located in the event of any overlap or commonality. Note that this Plan incorporates the following attachments:

- Groundwater Monitoring Plan (**GMonP**);
- Groundwater Baseline Report (**GBR**); and
- Groundwater Modelling Plan (**GModP**).

The GMonP provides for strategic and proactive management of any potential impacts on the environment, including to groundwater dependent users and ecosystems, as a consequence of extraction of CSG groundwater. It has been developed to support the GModP and provide early warning indicators of potential risks to groundwater resources in the region. It includes continued monitoring of existing monitoring bores, as well as development and monitoring at new bores designed to support the exploration and appraisal activities of Phase 1 and provide additional data to support further development of the groundwater model, as defined in the GMP.

The GBR provides a statement of the groundwater datasets that constitute the baseline groundwater monitoring for the NGP, and provides additional groundwater resource information to that as summarised in the GMP.

The GModP describes in detail how the groundwater model will be updated in the future, as required by CoC B39. Any update of the model (i.e., whether initiated by a trigger or as scheduled prior to Phase 2 of the Project) will incorporate new knowledge gathered since the previous model iteration. For example, geological and hydrogeological information provided by newly acquired well data or seismic surveys.

The structure of this Plan is as follows:

Section 1	Provides an introduction to the Project and the context, scope, purpose and objectives of this Plan. It further provides the performance measures related to groundwater as requested in the Conditions of Consent
Section 2	Defines the roles and responsibilities of personnel involved with the management of groundwater generated through NGP activities
Section 3	Outlines the statutory provisions relevant to the management of groundwater generated by development of the NGP
Section 4	Summarises the existing environment of the groundwater systems and matters of relevance to this GMP
Section 5	Describes the predicted groundwater effects concerning Phase 1 of the Project
Section 6	Summarises the monitoring principles and strategies used to assess potential groundwater impacts and the groundwater monitoring network implemented across the Project
Section 7	Describes the potential secondary effects of subsidence and seismicity

Section 8	Describes the groundwater performance criteria relevant to groundwater receptors and the trigger, action and response plans developed to assess and respond to unexpected conditions and to manage risks to operations and the environment
Section 9	Details the program to manage and/or monitor the potential impacts associated with groundwater management
Section 10	Provides details on the process that is implemented to manage data and records in a consistent, efficient and effective manner
Section 11	Details the actions required for incidents and non-compliances related to groundwater management, the unpredicted impact protocol, and the process to manage complaints
Section 12	Describes the reporting, evaluation and review process of this GMP
Section 13	References
Section 14	Glossary of terms
Appendix A	Consultation records
Appendix B	Approval conditions directly relevant to this GMP
Appendix C	InSAR Analysis of Baseline Ground Displacement

Attachment 1	Groundwater Monitoring Plan
Attachment 2	Groundwater Baseline Report
Attachment 3	Groundwater Modelling Plan

1.7 Distribution

A copy of the approved GMP is available to all Santos personnel via the Santos intranet. In accordance with consent condition D13, the latest copy of the Plan including all associated appendices, audits and reports, and summaries of all monitoring data (where relevant), can also be found on the Project website, once these have been approved by the Planning Secretary. This information will be kept up to date.

In accordance with specific licence, approval or code of practice conditions, a copy of this GMP is available at the Santos Operations Centre located at 300 Yarrie Lake Road in Narrabri. This is where operational and field staff commence and finish each workday.

Note that any printed copies of this GMP are uncontrolled.

2. Roles and responsibilities

All Santos employees and contractors involved in the Narrabri Gas Project are responsible for the environmental performance of their activities and for complying with all legal requirements and obligations. Project personnel will be required to comply with approval requirements of the activities they undertake and potential environmental impacts from all activities will be managed in accordance with the Project's relevant management plan(s).

In accordance with consent condition D1, the Environmental Management Strategy (**EMS**) sets out the role, responsibility, authority and accountability of all key personnel involved in the environmental management of the Project, including the requirements and obligations in this GMP. All roles, responsibilities and accountabilities have been assigned in accordance with Santos Management System *SMS-MS_14 People Management Standard*.

3. Regulatory requirements

The Project is permissible with development consent under the *State Environmental Planning Policy (Resources and Energy) 2021*, and is identified as a 'State significant development' under Section 4.38 of the EP&A Act and the *State Environmental Planning Policy (Planning Systems) 2021*.

The Project was subject to the State significant development assessment and approval provisions of Division 4.7 of Part 4 of the EP&A Act and was approved as a State significant development under the EP&A Act and the EPBC Act.

The Project will be carried out in accordance with the:

- relevant existing development consents and activity approvals;
- the conditions of relevant tenements including PEL 238, PAL 2, PPL 3, the provisions of the *Petroleum (Onshore) Act 1991* (NSW) (**PO Act**) and relevant codes of practice;
- EPL 20350 issued by the EPA and the provisions of the *Protection of the Environment Operations Act 1997* (**POEO Act**);
- conditions of consent for the NGP SSD 6456; and the
- conditions of approval of EPBC 2014/7376.

3.1 Compliance conditions

Compliance conditions associated with the following licence(s), lease(s) and consent(s) are relevant to this GMP:

- PEL 238, granted on 1 September 1980 and most recently renewed on 12 April 2022;
- PAL 2, granted on 30 October 2007;
- PPL 3, granted on 15 December 2003;
- PPLs 13, 14, 15 and 16, once issued;
- EPL 20350, as varied;
- State Significant Development SSD 6456: and
- EPBC 2014/7376.

3.1.1 PEL 238

There are no specific conditions or obligations in PEL 238 related to groundwater management.

3.1.2 PAL 2 and PPL 3

Lease condition 2 of PAL 2 and PPL 3 states that activities must only be carried out in accordance with a Petroleum Operations Plan (**POP**) which has been approved by the (then) Director-General of the Department of Primary Industries. Further, the POP must (i) identify how operations will be carried out on site in order to prevent and or minimise harm to the environment; and (ii) reflect conditions of approval under the EP&A Act, the POEO Act, and any other approvals relevant to PAL 2 and PPL 3.

This GMP supports the POP and satisfies condition 2 of PAL 2 and PPL 3 by providing information about how Santos manages all groundwater associated with the operation of its activities within PAL 2 and PPL 3.

3.1.3 EPL 20350

'Petroleum exploration, assessment and production' is a scheduled activity listed in Schedule 1 of the POEO Act. Under Section 48 of this Act, all scheduled activities are required to hold an environment protection licence. EPL 20350 is held for petroleum exploration, assessment and production in PEL 238, PAL 2 and PPL 3. Santos is required to prepare an Annual Return under the licence, including a Groundwater Monitoring Report for groundwater monitoring points identified in the licence which provides:

(a) an analysis and interpretation of monitoring results and

(b) actions to correct any identified adverse trends.

There are 37 groundwater quality monitoring points and six groundwater level monitoring points, located at the Bibblewindi, Dewhurst, Bohena, Leewood and Tintsfield/Wilga Park sites which require monitoring and reporting. Major and minor ions, metals and nutrients are required to be analysed and reported against any observed adverse trends in concentrations.

The volume of produced water being transferred to the Leewood water and brine treatment plant, as well as any discharge of water from the plant for irrigation purposes will also be reported. These are addressed in the Produced Water Management Plan and Irrigation Management Plan, respectively.

3.1.4 Development Consent SSD 6456

There are a number of SSD 6456 consent conditions directly relevant to groundwater management. However, since this version of the GMP is only applicable to Phase 1 of the Project, only the key conditions that are relevant to Phase 1 are provided in full below. Table B1 in Appendix B specifies where each of the requirements of all the consent conditions relevant to groundwater management are addressed in this Plan.

Consent condition B37 states that Santos must ensure that the development complies with the following groundwater management performance measures:

- for Namoi alluvial aquifers and Great Artesian Basin aquifers:
  - negligible environmental consequences to the Namoi alluvial aquifers and Great Artesian Basin aquifers beyond those predicted in the EIS, including:
    - negligible change in groundwater levels;
    - negligible change in groundwater quality; and
    - negligible impact to other groundwater users
  - no exceedance of the minimal harm considerations in the Aquifer Interference Policy (DPI, 2012); and
  - negligible change to baseline methane levels in groundwater user bores;
- for Gunnedah Oxley Basin aquifers:
  - drawdown and water take in Gunnedah Oxley Basin aquifers to be generally consistent with the 'base case' predictions and produced water profile in the EIS; and
  - negligible change in groundwater quality;
- for riparian and aquatic ecosystems:
  - negligible impact of GDEs.

Consent condition B39 states that Santos must periodically update the groundwater model for the development to the satisfaction of the Planning Secretary. The model update must:

(a) be prepared and peer reviewed by suitably qualified and experienced persons;

(b) be undertaken in consultation with DPE Water, EPA and the WTAG;

(c) be undertaken prior to the commencement of Phase 2, and at least every 3 years thereafter;

(d) be undertaken in accordance with the *Australian Groundwater Modelling Guidelines* (2012, or as updated) and other relevant guidelines including the IESC's *Information Guidelines Explanatory Note – Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018);

(e) improve the model prior to the commencement of Phase 2 to be generally in accordance with the features of a Class 3 confidence level model (as per the *Australian Groundwater Modelling Guidelines*) the features of which must be based on the WTAG's advice on appropriate development specific modelling objectives and criteria; and

(f) include:

(i) updated modelling objectives;

(ii) transient groundwater flow modelling;

(iii) updated geological modelling based on all available drill data and analysis, including:

- detailed structure assessment (including faulting) at best practice resolution;
- consideration of neotectonics and the stress field in the project area and surrounds;

(iv) updated hydrogeological modelling based on all well data, drilling data, hydrogeological analysis and water monitoring data for all aquifers and aquitards, including:

- consideration of impacts from the GABSI;
- consideration of leakage from the GAB to the Lower Namoi Groundwater Source using the heads predicted by the EIS model;

(v) updated predictions of groundwater drawdown and water take from all applicable groundwater sources as a result of the development; and

(vi) consideration of the predicted impacts against the:

- previous model predictions and monitoring results;
- water management performance measures in Table 7 [of the CoC];
- minimal harm considerations in the NSW Aquifer Interference Policy; and
- groundwater management response triggers in the Water Management Plan.

Consent condition B41 states that Santos must prepare a Water Management Plan for the NGP to the satisfaction of the Planning Secretary and that this plan must:

(a) be prepared by a suitably qualified and experienced person/s whose appointment has been endorsed by the Planning Secretary;

(b) be prepared in consultation with DPIE Water, EPA and the WTAG;

(c) describe the measures to be implemented to ensure that the Applicant complies with the water management performance measures (see Table 7 [of the CoC]);

(d) include a:

(iv) Groundwater Management Plan that includes:

- detailed baseline data of hydrogeology and groundwater levels, formation parameters (such as hydraulic conductivity, storage and yield) and quality for groundwater resources potentially impacted by the development (based on at least 3 years of monitoring data), including:
  - aquifer and aquitard health;
  - subsidence and seismicity, including a topographic baseline survey using interferometric synthetic aperture radar (or similar method as agreed by the Planning

Secretary);
    - groundwater supply and quality for other water users;
    - natural methane leaks and accumulations, including in privately-owned bores and monitoring bores; and
    - GDEs;
- a detailed description of the groundwater management and monitoring system, including a monitoring network that is capable of:
    - characterising temporal and spatial variations of all potentially affected water sources;
    - verifying actual direct and indirect water take;
    - providing an early warning of any impacts to potentially affected water sources, at varying depths in the geological profile;
    - providing data to improve the confidence level class of the groundwater model as soon as reasonable and feasible; and
    - integrating with any government monitoring networks in the area;
- detailed performance criteria, including trigger levels for identifying and investigating any potentially adverse impacts associated with the development, on:
    - regional and local aquifers and aquitards (alluvial and hardrock);
    - ground subsidence and seismicity;
    - groundwater supply and quality for other water users, including all potentially affected privately owned licensed groundwater bores;
    - GDEs; and
    - aquatic habitat and stygofauna;
- a program for baseline data acquisition (works and timing) for the required groundwater model updates;
- a program to monitor and evaluate:
    - compliance with the relevant performance measures listed in Table 7 [of the CoC], and the performance criteria established above;
    - groundwater flows, quality and yield in regional and local aquifers and aquitards (alluvial and hardrock),
    - ground subsidence and seismicity;
    - geological fracturing and heterogeneity;
    - water loss/seepage/leakage from water storages and Project-related infrastructure into the groundwater system;
    - potential cross-contamination of aquifers, including migration from lower aquifers to the Great Artesian Basin (**GAB**);
    - sub-surface leakage of methane, drilling fluids and saline groundwater;
    - groundwater inflows, outflows and storage volumes to inform the Site Water Balance;
    - the effectiveness of the groundwater management systems;
- reporting procedures for the results of the monitoring program; and
- a plan to respond to any exceedances of the groundwater performance criteria, and repair, mitigate and/or offset any adverse groundwater impacts of the development.

3.1.5 EPBC 2014/7376

Approval decision EPBC 2014/7376 was received on 24 November 2020, subject to a number of conditions of approval (**CoA**). The majority of the conditions either reflect or reinforce the SSD 6456 CoC, with CoA 1 stating that Santos must undertake the Project as described in and in accordance with the SSD 6456 consent conditions (referred to as the NSW approval). The general conditions related to the protection of water resources are addressed in the WMP. The specific conditions related to potential impact on groundwater resources during Phase 1 are listed below.

Table B2 in Appendix B specifies where each of the CoA requirements are addressed in this Plan.

Approval condition 7 states that Santos must establish an early warning monitoring system to detect groundwater pressure changes in deeper hydrostratigraphic units, so as to be able to take corrective actions in sufficient time to prevent impacts in shallow productive aquifers and GDEs. In addition to the monitoring requirements specified in the approved Groundwater Management Plan required under condition B41 of the NSW approval, Santos must:

(a) establish and maintain a network of groundwater monitoring bores across the Project area in the Napperby Sandstone. In the Project area where the Napperby Sandstone is in direct contact with the Namoi Alluvium, an appropriate network of groundwater monitoring bores must also be established and maintained in those areas in the Digby Formation. These monitoring bores must be installed prior to the commencement of Phase 2[2];

(b) monitor groundwater levels in these bores at a minimum of 3-monthly intervals from the commencement of Phase 1 or bore construction (whichever is first) until the completion of the Project; and

(c) publish all groundwater monitoring data from all bores, updated to add the most recent readings each quarter, on the website, and maintain that data on the website until the completion of the Project. The monitoring data must include hydrographs for all monitoring bores and explain what the data means in relation to the groundwater performance criteria specified in the NSW-approved Groundwater Management Plan.

Approval condition 8 states that if, at any time until the end date of this approval:

(a) Santos detects an exceedance of any groundwater performance criterion (including trigger levels), specified in the approved Groundwater Management Plan required by CoC B41 of the NSW approval; and/or

(b) the groundwater model, including any update required under CoC B39 of the NSW approval, predicts an exceedance of the groundwater performance criteria (including trigger levels), specified in the approved Groundwater Management Plan;

Santos must notify the Commonwealth Department of Climate Change, Energy, the Environment and Water (**DCCEEW**) of the exceedance within 10 business days of detecting or predicting the exceedance.

Approval condition 9 states that Santos must, within 6 months of detecting or predicting an exceedance as described in CoA 8, publish on the website a report describing:

(a) all potential and actual impacts to water resources arising from the exceedance;

(b) any further investigations undertaken to determine the cause of and remedy for the exceedance; and

(c) the mitigation and management measures that Santos has taken and proposes to take to reverse the exceedance, including data demonstrating the effectiveness of the mitigation and management measures.

[2] Note that this Groundwater Management Plan is for Phase 1 only.

Santos must notify DCCEEW within 2 business days of the report being published and retain the report on the website for the life of the approval.

Approval condition 10 states that if, after the implementation of CoA 9, Santos detects or predicts that the outcomes specified in CoA Appendix B cannot or will not be achieved, or the Minister considers that the outcomes specified in CoA Appendix B cannot or will not be achieved, then Santos must provide a site-specific assessment for the Minister's written approval within 3 months of making the prediction or of receiving a request from the Minister.

Approval condition 11 states that each site-specific assessment must incorporate data collected from the groundwater monitoring bores required by CoA 7 and be prepared by a suitably qualified water resources expert to derive a scientifically robust cease-work limit. Each site-specific assessment must include justification for how the outcomes specified in CoA Appendix B will be achieved and maintained and include:

(a) multiple lines of evidence and field data to support the assessment of the environmental value and groundwater-dependence of any potential GDEs identified in the area of predicted impact;

(b) conceptual modelling, including a review of all historical monitoring data to determine the stressor-response relationships for any potential GDEs and consideration of potential contributing activities; and

(c) local scale numerical modelling with consideration of potential contributing activities and identification of potential contributing well/s; and

(d) a peer review undertaken by an independent suitably qualified water resources expert including details of how Santos has addressed any inadequacies raised in the peer review.

Approval condition 12 states that Santos must publish each site-specific assessment approved by the Minister on its website within 5 business days of receiving approval for the site-specific assessment and for the remainder of the life of the Project.

Approval conditions 13 to 17 are related to the cease-work limits, and the continuation or recommencement of groundwater extraction. These conditions have been listed in full in Table B2 in Appendix B, which also identifies where the conditions have been addressed.

3.2 Relevant codes, standards, policies and guidelines

3.2.1 NSW Aquifer Interference Policy

The *Water Management Act 2000* (NSW) (**WM Act**) defines an aquifer interference activity as that which involves any of the following:

- the penetration of an aquifer;
- the interference with water in an aquifer;
- the obstruction of the flow of water in an aquifer;
- the taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- the disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The *NSW Aquifer Interference Policy* (DPI, 2012) (**AIP**) defines the regime for protecting and managing the impacts of aquifer interference activities on NSW's water resources. There are three key parts to the Policy:

- all water taken must be properly accounted for;
- the activity must address minimal impact considerations for impacts on water table, water pressure and water quality; and
- planning for measures in the event that the actual impacts are greater than predicted, including making sure that there is sufficient monitoring in place.

CoC Condition B39(f)(vi) requires that the NGP does not exceed the minimal harm considerations of the AIP. In this regard, the minimal harm considerations of the AIP will not be exceeded if the performance measures articulated in the CoC B37 [Table 7 of the CoC] are achieved. Further, the GMP states that the water extraction volumes from the GOB, which were authorised under the AIP, will not be exceeded.

3.2.2 NSW Groundwater Policy Framework

The main role of the *NSW Groundwater Policy Framework Document* (DLWC, 1997) is to ensure that the groundwater resources of the state are appropriately maintained and the sustainability of groundwater resources and their support functions to ecosystems are given explicit consideration in resource management decision making. The Groundwater Policy Framework has been constructed with the aid of two NSW policies:

- the *Groundwater Quality Protection Policy* (DLWC, 1998), which provides guidance on how to manage and protect groundwater quality against pollution; and
- the *State Groundwater Dependent Ecosystems Policy* (DLWC, 2002), which provides guidance on how to protect ecosystems that rely on groundwater, including their ecological processes and biodiversity.

3.2.3 NSW Policy for Managing Access to Buried Groundwater Sources

The *Policy for Managing Access to Buried Groundwater Sources* sets out a framework for how access to water will be managed in groundwater sources that are partly or completely buried. It outlines the limits to access water from storage in porous rock groundwater sources and also the licensing and approval requirements for the take of water from all contributing water sources.

Although not stated, this Policy provides a general and strategic approach for access to groundwater, whilst specific water sharing details are contained within the NSW water sharing plans.

3.2.4 ANZECC Guidelines

The Australian and New Zealand Environment Conservation Council (**ANZECC**) and Agriculture and Resource Management Council of Australia and New Zealand (**ARMCANZ**), published the revised *Australian and New Zealand guidelines for fresh and marine water quality* in 2000 (the **ANZECC Guidelines**).

Potential impacts of the Project on surface water quality were assessed in accordance with methodology from the guidelines and this is the accepted standard under which to manage environmental water quality in Australia. The ANZECC Guidelines provide a risk-based framework under which water quality data may be statistically interrogated, trends analysed, and site-specific trigger values may be derived.

Although the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (the **National Water Quality Guidelines**) were published in 2018 after a scientific review of the ANZECC Guidelines, both consent condition B37 (water management performance measures) and the treated water quality criteria in Appendix 6 of the CoC refer to the 2000 version of the ANZECC guidelines. As such, the 2000 version of the guidelines apply to the Project.

3.2.5 Water Quality Objectives

The NSW Government have published online the NSW Water Quality and River Flow Objectives (the **Objectives**). The Objectives are the agreed environmental values and long-term goals for NSW's waters, including for groundwaters that may be used for consumptive or environmental purposes, such as for stock and domestic requirements and to support GDEs. They set out:

- the community's values and uses for groundwater (i.e. healthy GDEs, water suitable for stock watering and domestic supply, and drinking water); and
- a range of water quality indicators to help assess whether the current condition of our groundwater supports those values and uses.

The Objectives are consistent with the agreed national framework for assessing water quality set out in the ANZECC Guidelines. The ANZECC Guidelines provide an agreed framework to assess water quality in terms of whether the water is suitable for a range of environmental values (including human uses). The Objectives provide environmental values for NSW waters and the ANZECC Guidelines provide the technical guidance to assess the water quality needed to protect those values. Refer to the note in section 3.2.4 that the ANZECC Guidelines have been superseded by the national Water Quality Guidelines.

3.2.6 Guidelines for Groundwater Documentation for SSD/SSI Projects

DPE Water has prepared updated guidelines specifically focused on the requirements of the NSW Government for the assessment of groundwater related matters and consideration of potential impacts of State significant development and State significant infrastructure projects in NSW. When used by proponents, the Guidelines will ensure consistency between proposals and ongoing compliance with their approvals

3.3 EIS commitments

In the EIS Chapter 31 and updated in Appendix B of the Response to Submissions Santos committed to implement a number of measures pending Project approval and a final investment decision. The EIS commitments relevant to surface water management have been reproduced below in Table 3.1, in accordance with consent condition D3(c) which states that Santos must ensure that (where relevant) the management plans include any relevant commitments or recommendations identified in the EIS.

Table 3.1 - EIS commitments relevant to groundwater management

Number	EIS commitment relevant to groundwater management	Section
1.2	A project-wide environmental management strategy, comprising a number of sub-plans to be used throughout the planning and design, construction, operation and decommissioning and rehabilitation stages of the project are described in Chapter 30 [of the EIS]. The sub-plans are:	Refer to the Groundwater Monitoring Plan, as Attachment 1
	• …. • Water Monitoring Plan • ….	
2.1	Drilling, completion and rehabilitation of wells in compliance with the *NSW Code of Practice for Coal Seam Gas - Well Integrity.*	Section 9.6 and 9.7
2.2	Extraction of groundwater in compliance with the NSW *Water Management Act 2000,* specifically the procurement of sufficient Water Access Licence (WAL) allocations.	Site Water Balance – section 4.1.3
2.3	The Water Monitoring Plan will be implemented.	Section 1.2
2.4	Groundwater monitoring bores will be installed in accordance with the *Minimum Construction Requirements for Water Bores in Australia.*	Section 9.6
2.5	Implementation of make good protocols in accordance with the requirements of the NSW *Aquifer Interference Policy.*	Section 8.5.1
2.6	Compliance with NSW and / or Commonwealth policies relating to drilling fluids.	Section 9.6

As described in section 12 of this Plan and section 8 of the EMS, this Plan will be subject to regular evaluation and review. This will include the EIS commitments to ensure they remain current, applicable, and generally improve the environmental performance of the Project.

4. Existing groundwater environment

This section provides a summary of the same information presented in the EIS. Additional information that has been gathered since the EIS comprises monitoring data which is reflected in the data sets presented in the GBR, and baseline measurements of ground motion which are described in section 4.3.

4.1 Climate and recharge

The climate of the region provides a background to guide recharge estimations for the numerical groundwater model as well as context for monitoring data interpretation. The climate is described as cool to temperate, with hot, wetter summers and cool, drier winters that result in high rates of evaporation and reduced recharge during summer months (November to March) and low rates, but enhanced recharge, during winter months (June and July). Mean annual rainfall within the Namoi Catchment is around 630 millimetres (**mm**), ranging from 1,300 mm in the eastern Barwon Highlands to 400 mm in the western part of the catchment varying significantly with altitude and relief. Long-term (91 years) rainfall data for Narrabri Climate Station 53026 (Mollee) also exhibits significant inter-annual climate variability, with rainfall ranging from 195 to 1,002 mm per year (**mm/yr**) over the historical record.

Spatial and temporal rainfall variability has the capacity to alter existing beneficial uses of water resources and critically affect the quantity and quality of recharge. For example, extended periods of drought may cause groundwater tables to decline due to reduced rates of recharge and increased consumptive use by irrigators, while recharge water may become more saline due to increased surficial recycling of salts.

Rainfall and temperature data sourced from the Bureau of Meteorology (**BoM**) will therefore be collated for the Groundwater Monitoring Plan (**GMonP**) provided in Attachment 1, to provide a climate context to groundwater recharge potential and trends in aquifer storage levels, as observed in the hydrographs of groundwater monitoring bores. Changes in rainfall patterns can also inform changes in consumptive water-use patterns to aid in interpretation of water level measurements.

4.2 Geology

The Project is located within the Namoi catchment, to the west of the Great Dividing Range, and the landscape is characterised by steep to undulating, mostly vegetated highlands in the east and south, which slopes toward low relief open floodplain in the west that is associated with the Namoi River. Elevations within the Project area range from approximately 400 m Australian Height Datum (**mAHD**) in the southeast down to approximately 250 mAHD in the northwest. Soils are typically clay and sandy- or clayey-loams.

The Project area is located on land where sediments (Orallo Formation and Pilliga Sandstone) of the GAB sub-crop or out-crop. The GAB sediments are locally overlain by alluvial and colluvial sediments associated with the Bohena Creek drainage system.

The Project area is located within two sedimentary geological basins:

- Coonamble Embayment (Jurassic-Cretaceous Age) which contains important aquifers of a sub-province of the GAB.
- Gunnedah Basin (Permo-Triassic Age) which contains the target coal seams for the Project.

Regional structure, and details within the NGP (and surrounds), has been primarily imaged via interpretation of local seismic lines. Thousands of kilometres of 2D seismic imagery form a broad 2-4-km spaced seismic grid across the main NGP development area. Key seismic horizons (including the Base Jurassic and Triassic unconformities, the Hoskisson's and Bohena Seams, and regional Basement) have been interpreted across the Bohena Trough with structure maps generated for each horizon. Faults have been mapped on each seismic line and incorporated into structural mapping.
The extent of the geological basins and the region over which they overlap can be seen in Figure 4.1. The deeper Gunnedah Basin underlies an area of more than 15,000 m^2 and links to the north and south to the Bowen and Sydney Basins, respectively. It contains up to 1,200 m of marine and nonmarine sediments that rest unconformably on basement rocks of Early Permian Age and older. The Permian Age sediments of the Sydney-Gunnedah-Bowen Basin system represent a major coal province in Australia.

Overlying the Gunnedah Basin are the mostly marine sediments of the Coonamble Embayment of the Surat Basin of the GAB, including the extensive Pilliga Sandstone aquifer, which is a significant groundwater source to the region. Overlying these basins are the recent unconsolidated, alluvial and colluvial sediments, including the important aquifers of the Namoi Alluvial groundwater source. Figure 4.2 shows a schematic section of these relationships.

The Project area is located on land where GAB sediments (Orallo Formation and Pilliga Sandstone) sub-crop or out-crop. The GAB sediments beneath the Project area are locally overlain by alluvial and colluvial sediments associated with the Bohena Creek drainage system.

Most faulting within the Project area is considered to be compressional and is believed to be associated with closure of the Bowen-Gunnedah-Sydney basinal system during the Middle Triassic. Multiple lines of evidence indicate most known faulting within the Project area is small scale and tight, hence restrictive of groundwater flow. Any potential impacts to groundwater flow due to faulting is currently considered to be negligible. Larger, possibly transmissive faults do occur on the margins of the basin and coincide with hydrostatic breaks and connections and these breaks have been included in the numerical groundwater model. There is no evidence that deep, Permo-Triassic faults extend into the overlying formations within the Project area.

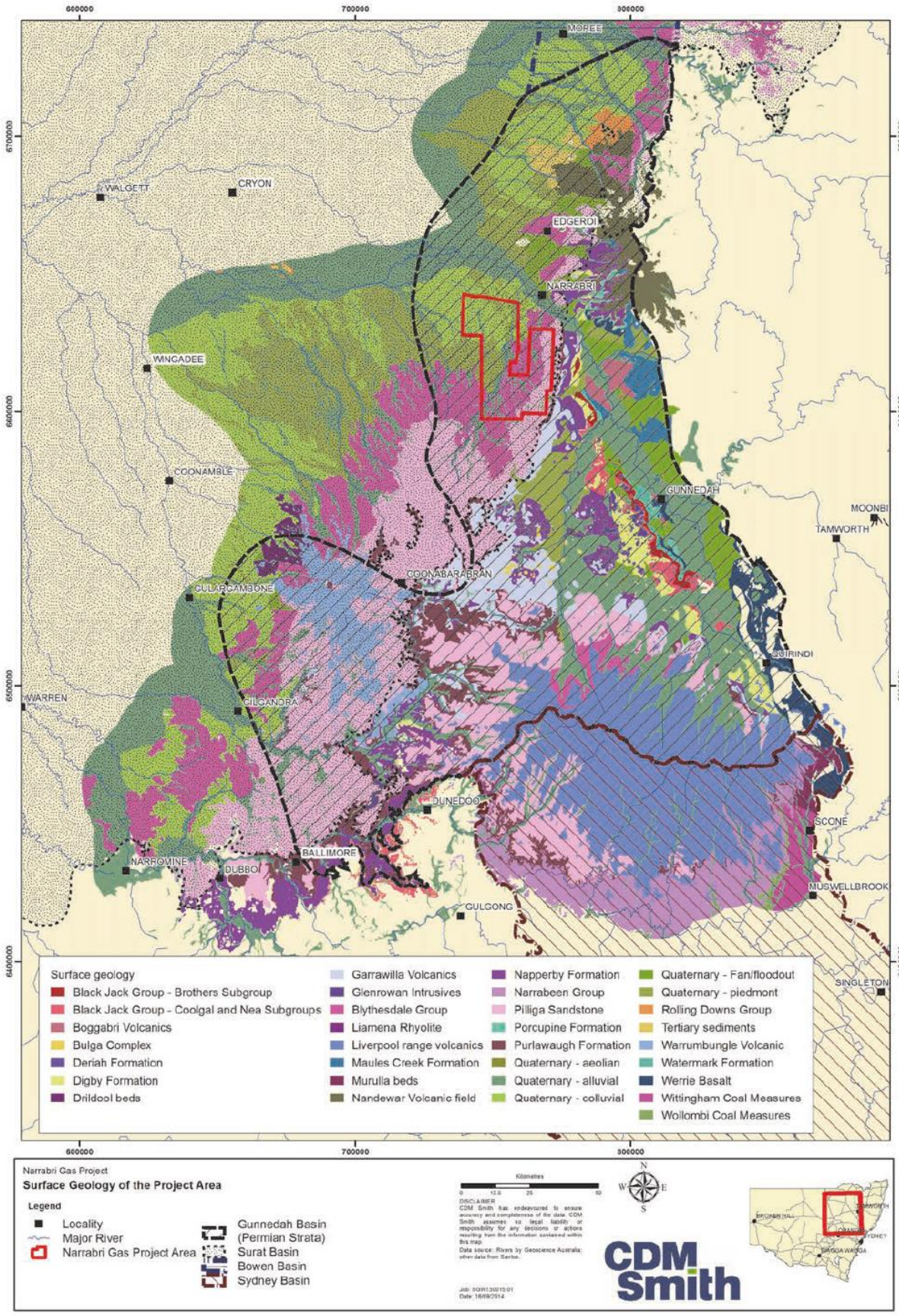


Figure 4.1 - Regional surface geology

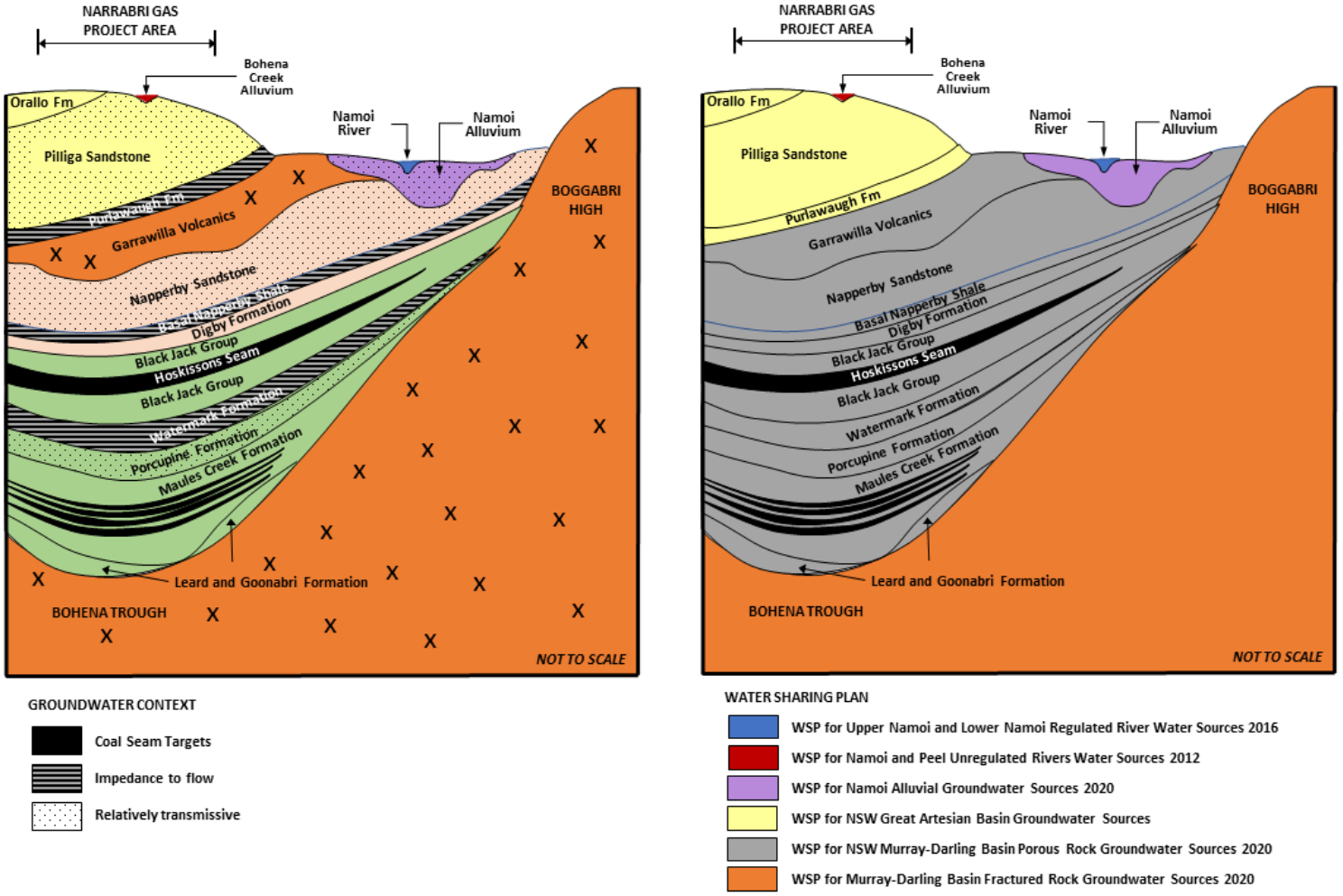


Figure 4.2 - Project area schematic showing lithology and water sharing plan relevance

4.3 Subsidence and seismicity

Santos has conducted a baseline monitoring program to quantify existing rates of deformation at the land surface within the Project area using interferometric synthetic aperture radar (**InSAR**[3]) and has undertaken an assessment of the potential for subsidence to arise from the NGP. The subsidence assessment and associated risk assessment form part of the groundwater impact assessment (**GIA**).

A baseline for ground motion across the Project area has been formed from data gathered using InSAR technology during the periods from January 2007 to March 2011, and from November 2014 to September 2020. The latter is further described in section 7, and is presented in Appendix C. The survey area was deemed stable with most of the region showing ± 7 mm/yr subsidence or uplift.

The Gunnedah Basin is an area of very low earthquake probability with only minor seismic activity recorded by the Australian National Seismograph Network (**ANSM**) to the east associated with the Mooki Thrust and no activity has been recorded (threshold magnitude 2 for the ANSM) across the NGP area since continuous records began in 1909.

An analysis of ground deformation (subsidence baseline survey) was carried out within the Project area using historical InSAR data for the period November 2014 to September 2020 (refer Appendix C). The analysis identified measurement points from objects on the ground and for each measurement point provides:

- position and elevation estimates;
- annual average displacement rate, measured along the line of sight, expressed in 'mm/yr'; and
- displacement time series representing the evolution of the measurement point's displacement for each acquisition date, expressed in 'mm'.

The analysis identified little baseline ground displacement, with low average acceleration rates (i.e. area where rates of subsidence or uplift are increasing or decreasing) throughout the Project area. Few localised seasonal trends were identified. These were concentrated over areas of vegetation and are expected to be associated with annual wetting and drying cycles.

Average time series were generated for deformation at four well pad locations. These indicated some localised depression in these areas (cumulative displacement ranging from -1.61 mm to -12.62 mm) which was beginning to recover over time. This can likely be attributed to soil compaction caused by heavy machinery used during well pad construction and drilling activities.

4.4 Aquifers and aquitards

The stratigraphic sequence in the area has been characterised based on the rocks' water storage and flow characteristics. Thus, hydrostratigraphic units have been attributed the following transmissivity classification:

- significant transmissive units (**STU**);
- less significant transmissive units (**LSTU**);
- probable negligibly transmissive units (**PNTU**); and
- negligibly transmissive units (**NTU**).

[3] A radar technology used in geodesy and remote sensing to assess motion of ground surface over time

This transmissivity classification is applied to the stratigraphic column in Figure 4.3.

Significantly transmissive units include the shallow alluvial units of the Namoi Alluvium, the sandstones of the Pilliga Formation in the Surat Basin and the various coal seams of the Permian. Negligibly transmissive units are identified immediately above and below the early Permian Coal Seams and at the base of the Triassic and Jurassic sequences. Overall, the hydrostratigraphic sequence consists of significant transmissive units at depth within the coal seams of the Gunnedah Basin, which are hydraulically isolated from the overlying Jurassic and recent transmissive units of the Pilliga Sandstone and Namoi Alluvium, respectively.

A Groundwater Baseline Report (**GBR**), provided as Attachment 2, has been prepared to accompany this report and includes monitoring data across a range of Santos and DPE Water groundwater monitoring sites including water level, water pressure data and hydraulic properties.

Province	Period / epoch	Division	Group	Sub-group	Formation	Lithology and hydrogeological classification	Trans-missivity classification
Namoi Alluvium	Pleistocene				Narrabri Fm	Clay and silt with sand lenses	LSTU
	Pliocene				Gunnedah Fm	Gravel and sand with clay lenses	STU
	Miocene				Cubbaroo FM	Gravel and sand with clay lenses	STU
Volcanics					Warrumbungle Volcanics	Basalt, dolerite	PNTU
	Eocene				Liverpool Range Volcanics	Basalt, dolerite	PNTU
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm	Clayey to quartzose sandstone, subordinate siltstone and conglmerate	NTU
		Early			Pilliga Ss	Fluvial, medium- to very coarse-grained, quartzose sandstone and conglomerate. Minor interbeds of mudstone, siltstone and fine-grained sandstone and coal	STU
	Jurassic	Late					STU
		Middle			Purlawaugh Fm	Fine to medium-grained sandstone thinly interbedded with siltstone, mudstone and thin coal seams	NTU
		Early	Garrawilla Volcanics			Dolerite, basalt, trachyte, tuff, breccia	LSTU
		Late					LSTU
Gunnedah Basin	Triassic	Middle			Deriah Fm	Sandstone	PNTU
					Napperby Fm	Interbedded fine sandstone, claystone and siltstone	PNTU
						Basal Napperby Shale	NTU
		Early			Digby Fm	Quartzose sandstone (Ulinda Ss)	NTU
						Lithic sandstone	NTU
						Lithic conglomerate (Bomera Congl.)	NTU
	Permian	Late	Black Jack	Nea	Trinkey FM	Coal measures - siltstone, fine sandstone, tuffs, stony coal	PNTU
					Wallala Fm	Conglomerate, sandstone, siltstone, minor coal bands	PNTU
				Coogal	Breeza Coal	Coal and claystone	PNTU
					Clare Ss	Medium- to coarse-grained quartzose sandstone, quartzose conglomerate	LSTU
					Hoes Hill Coal	Coal	PNTU
					Benalabi	Claystone, siltstone and sandstone, fining-up cycles; more sandy towards top	PNTU
					Hoskissons Coal	Potential target coal seam	STU
				Brothers	Brigalow Fm	Fining-up sequence of medium- to coarse-grained quartzose sandstone and siltstone	PNTU
					Arkarula Fm	Sandstone and siltstone	PNTU
					Melvilles Coal Mb	Coal	PNTU
					Pamboola Fm	Sandstone,siltstone, minor claystone and coal	PNTU
		Middle	Millie		Watermark Fm	Marine siltstone, shales and sandstone	NTU
					Porcupine Fm	Fining-up sequence of conglomerate and sandstone to mudstone	NTU
		Early	Bellata		Upper Mauels Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU
					Rutley Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Namoi Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Parkes Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Bohena Seam	Potential target coal seam	STU
					Lower Maules Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU
					Goonbri Fm	Siltstone, sandstone and coal	NTU
					Leard Fm	Flinty claystone	NTU
Basement			Werrie Basalt and Boggabri Volcanics (Basement)			Rhyolitic to dacitic lavas and ashflow	LSTU
						Tuffs with interbedded shale. Rare trachyte and andesite. Weathered basic lavas.	NTU
Colour code key:						STU - Significantly Transmissive Unit	
						LSTU - Less Significantly Transmissive Unit	
						PNTU - Probable Negligibly Transmissive Unit	
						NTU - Negligibly Transmissive Unit	

Figure 4.3 - Hydrostratigraphic classification of the rocks of the Project area

4.4.1 Hydraulic properties

Hydraulic properties for all formations have been determined during development of the numerical groundwater model and results of these studies were presented in Appendix F of the EIS.

Direct measurements have been made of the permeability of more than 30 rock samples from the Project area. These include three side-core samples recovered from one core hole in the Bando trough, south of the Project area, representing the Triassic aged Napperby Formation, the underlying Digby Formation and the deeper, Permian-aged, Porcupine Formation, and 25 samples collected from the Cretaceous-aged Orallo Formation, as well as the Jurassic-aged Pilliga Sandstone and the Purlawaugh Formation within the Bohena Trough, beneath the Project area. The cores consist of mixed lithologies and attest to the wide range of facies in the area, both laterally and vertically and do not capture the true range or distribution of hydraulic conductivity of these formations at spatial scales relevant to regional-scale assessments or the groundwater model.

In addition, indirect estimates have been made by interpreting drill stem tests performed almost exclusively on selected coal seams, and predominantly from the Early Permian-aged Maules Creek Formation within the Bohena Trough of the Project. Further indirect estimates have been derived from pumping tests conducted in the groundwater monitoring bores targeting the Pilliga Sandstone and Orallo Formation.

The collected and inferred data for vertical hydraulic conductivity for the formations in the Project area are summarised in Figure 4.4. A full listing, including formations with limited or no data, is provided in Table 4.1.

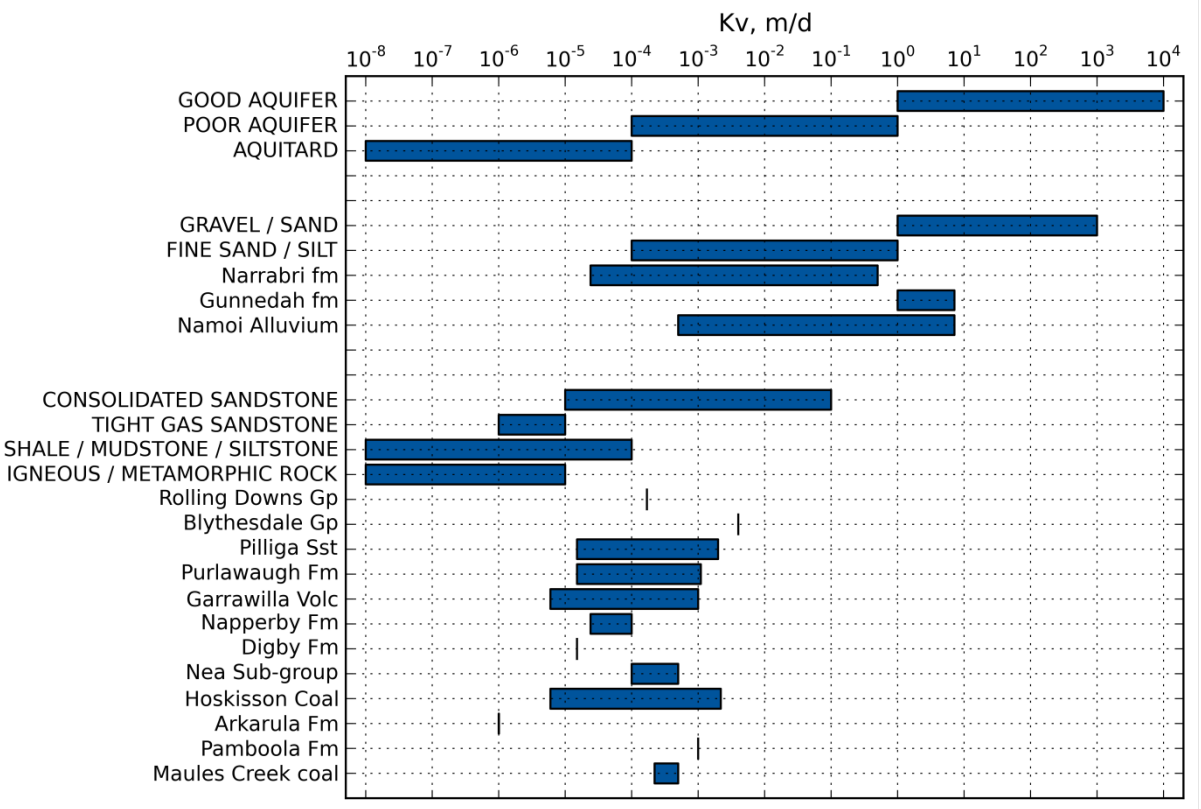


Figure 4.4 - Vertical hydraulic conductivity derived from multiple sources

Table 4.1 - Hydrogeological properties derived through direct and indirect measurement

Hydrostratigraphic Unit	K_h [m/d]	K_v [m/d]	S_y [1]	S_s [1/m]
Narrabri fm	0.1 – 30	-	0.005 – 0.1	-
	0.09 – 86	-	0.02 – 0.1	1E-5
	7	6.3E-2	0.05	5E-4
	5	5E-1	0.05	5E-4
	0.008 – 6	2.4E-5 – 2.4E-4	0.1	4E-5
	0.008 – 86	2.4E-5 – 5E-1	0.005 – 0.1	1E-5 – 1E-4
Gunnedah fm	0.05 – 30	-	-	1E-7 – 5E-4
	8.3	2.4	0.05	5E-4
	0.09 – 86	-	0.01 – 0.1	1E-5
	10	1	0.05	5E-4
	8.6 – 31	3.5 – 7.2	0.1 – 0.15	1E-4
	0.05 – 86	1 – 7.2	0.01 – 0.15	1E-7 – 5E-4
Namoi Alluvium	0.26 – 5	5E-4 – 5E-3	0.1	5E-6
	22 - 26	3.5 – 7.2	0.1	1E-4
	0.26 – 26	0.0005 – 7.2	0.1	5E-6 – 1E-4
Rolling Downs Gp	0.05	1.7E-4	0.03	4E-6
Blythesdale Gp (Keelind Beds)	0.12	4E-3	0.03	4E-6
Pilliga Ss	0.004 – 0.27	1.5E-5 – 2E-3	0.001	5E-6
Purlawaugh Fm	0.004 – 0.02	1.5E-5 – 1.1E-3	0.001	5E-6
Garrawilla Volcanics	0.001 – 0.04	6E-6 – 1E-3	0.002	5E-6
Deriah Fm	no estimates	no estimates	no estimates	no estimates
Napperby Fm	0.08 – 1.5	6.2E-1 – 7.1E-1	0.1	1E-4
	0.001 – 0.012	1E-4	0.001	5E-6
	0.004 – 0.04	2.4E-5	0.001	5E-6
	0.001 – 0.04	2.4E-5 – 1E-4	0.001	5E-6 – 1E-4
Digby Fm	0.0005 – 0.04	1.5E-5	0.001	5E-6
Trinkey and Wallala Fm	no estimates	no estimates	no estimates	no estimates
Nea Sub-group (Upper Black Jack Gp)	0.0002 – 0.0004	1E-4 – 5E-4	0.1	1E-4
Hoskissons Coal	0.005 – 0.04	6E-6	0.001	5E-6
	0.33 – 3.3	2E-4 – 2.2E-3	0.2	1E-4
	0.13 – 3.3	2.2E-4 – 2E-3	0.2	1E-4
	0.005 – 3.3	6E-6 – 2.2E-3	0.001 – 0.2	5E-6 – 1E-4
Brothers Sub-group (Lower Black Jack Gp)	no estimates	no estimates	no estimates	no estimates
Arkarula Fm	0.0005 – 0.04	1E-6	0.005	5E-6
Melvilles Coal Mb	no estimates	no estimates	no estimates	no estimates
Pamboola Fm	0.04	1E-3	-	-
Watermark Fm	no estimates	no estimates	no estimates	no estimates
Porcupine Fm	no estimates	no estimates	no estimates	no estimates
Maules Creek Fm	no estimates	no estimates	no estimates	no estimates
Maule Creek Coal	0.054	5E-3	0.001	1E-5
	0.13-3.3	2.2E-4 – 2E-3	0.01	1E-4
	0.054 – 3.3	2.2E-4 – 5E-3	0.001 – 0.01	1E-5 – 1E-4

4.4.2 Groundwater levels and pressures

Groundwater levels and pressures are presented in the Groundwater Baseline Report (**GBR**), provided as Attachment 2. Limited monitoring of coal seam groundwaters suggests generally stable groundwater conditions in the very deep formations, although water pressure loggers proved problematic over time in several deeper bores. Early data is supported, however, by recent manual measurements and shows flat trends in most deep formations of the Gunnedah Basin. One bore targeting the Porcupine Formation (at the Dewhurst 8 site) has shown a rising pressure trend over the last four years.

Bores targeting the Triassic-aged Napperby and Digby Formations also record flat water pressure trends over the period of monitoring, since 2014. Groundwater pressures in the Jurassic GAB formations are also mostly flat to slightly declining over the past 5 years. Groundwater pressures increase to the west and artesian conditions prevail at the western margin of the Project area.

Longer records for Government bores targeting the GAB aquifers reveal a muted climatic response with a general gradual decline in water levels in the region over the past 50 years. Inter-annual variability increases up to five metres in shallower bores, with artesian conditions to the west exhibiting significant variability up to 15 m year on year. A bore targeting the shallower Mooga Sandstone shows a long-term water level decline in excess of 10-12 m over the past 50 years.

Shallow groundwater tables in the unconsolidated Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year. There has been a long-term decline in water levels of several metres over 50 years in almost all monitored bores.

4.4.3 Groundwater quality

Baseline groundwater quality monitoring results are presented in the GBR, provided as Attachment 2.

Only intermittent sampling for the full chemistry suite has been undertaken for the target coal seams. Spot analyses indicate that the coal seam groundwater is relatively high in bicarbonate salts, averaging 2,400 parts per million (**ppm**) bicarbonate, resulting in elevated pH and salinities. Insufficient time-series at a single well has been collected to date, so trend analysis is not possible.

Bicarbonate is relatively high in all formations of the Gunnedah Oxley Basin and the groundwaters are relatively clean, that is, with low metal levels, low trace elements and low uranium. Methane can reach 20 ppm but is generally low (<10 ppm) and below limit of recording (**LOR**) in some samples. Water quality trends are flat across the region.

Groundwater in these Permo-Triassic strata of the Gunnedah Basin is distinguished from the overlying groundwaters in the Great Artesian Basin and alluvial groundwater sources by greater salinity and higher pH.

Water quality measured in baseline bores in the GAB has been good and stable at all bores, with generally low salinities dominated by sodium bicarbonate salts. Methane levels can reach 5 ppm but are generally below 1 ppm.

Most monitored bores in the alluvium aquifers also exhibit low salinity and are also dominated by sodium bicarbonate salts. Fewer water quality samples have been taken from these government-monitored bores, but where more than six samples have been taken, trends appear to be relatively flat. Water quality analyses from bores in the ephemeral Bohena Creek Alluvium revealed a chemistry very similar to the local GAB groundwaters. The short time series of four years suggests stable groundwater conditions with little variability despite the shallow and thin nature of these aquifers.

4.4.4 Natural methane leaks and accumulations

Baseline natural methane monitoring results in groundwater are presented in the GBR, provided as Attachment 2. In non-coal measures groundwaters of the Gunnedah Oxley Basin, methane is observed at levels up to 20 ppm, but is not ubiquitous and is generally below 10 ppm. In the sampled groundwaters of the GAB, methane levels can reach nearly 5 ppm, but are generally below LOR. Those samples recording methane (45 out of 121 analyses) returned an average level of about 1 ppm. The exceptions occur where previous exploration has targeted conventional gas reserves, such as those associated with PPL3, located in the north-west of the Project area.

The Namoi Alluvium is predominantly monitored by Government monitoring bores and methane is not routinely analysed at these locations. Local landholder bores accessing groundwater from the Namoi Alluvium have, however, previously been sampled by Santos (reported in Jacobs, 2014) and variable levels of methane were detected in these bores, with two bores reporting levels in excess of 1 ppm. Many recorded no methane, however, and the spatial distribution did not coincide with elevated levels measured in the underlying GAB aquifers. Stable isotope analyses suggest a mixed biogenic-thermogenic source for this gas.

All samples (n=10) from the Bohena Creek alluvial aquifer returned methane values greater than LOR, ranging from 0.5 to 1.6 ppm.

4.5 Groundwater resources

Groundwater resources are managed under several water sharing plans (**WSP**s), shown stylistically in Figure 4.2. WSPs set rules for water trading and dealing with access licences and access regimes for the extraction of water from groundwater and surface water systems and set out the overall limit on surface and ground water that can be extracted from the source and the circumstances in which access licences can be granted. The AIP is used to define the regime under which these rules apply. The relationship between the AIP and WSPs relevant to the NGP is outlined below.

4.5.1 Groundwater supply

The AIP classifies groundwater assets into ‘Highly Productive Groundwater Sources’ and ‘Less Productive Groundwater Sources’. Groundwater sources in the catchment are covered by a number of groundwater management areas associated with several WSPs:

- the ‘Highly Productive Groundwater Sources’ in the area include the alluvial aquifers associated with the Namoi River and the Pilliga Sandstone aquifer of the GAB:
  - the alluvial aquifers are high yielding and produce groundwater that is fresh to slightly brackish and suitable for multiple uses including town drinking supply, stock and domestic use and irrigation. Consequently, alluvial groundwater resources in the catchment are highly developed, with over 18,000 groundwater bores in the Namoi catchment, licenced to extract 343,000 megalitres per year, with 95 % used for irrigation. These aquifers are managed under the *Water Sharing Plan for the Namoi Alluvial Groundwater Sources Order 2020*;
  - the Pilliga Sandstone, within the GAB sedimentary sequence of the Coonamble Embayment, is highly porous and permeable, and locally produces high yields of good quality groundwater (Radke et al. 2000) suitable for domestic, stock and irrigation purposes where shallower alluvial groundwater is not available. The aquifer is managed under the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2020*;

- the ‘Less Productive Groundwater Sources’ in the area include the fractured and porous rock sequences associated with the Gunnedah-Oxley Basin strata, including sedimentary rocks that are the focus of coal mining and CSG exploration within the Namoi catchment:
    - groundwater associated with these sediments are managed under the *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources Order 2020* and the *Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources Order 2020*. The consolidated sediments are generally low yielding and discontinuous, and so do not form a major water resource in the Project area. Extractions from these strata generally only occur at locations where alluvial aquifers are absent.

4.5.2 Groundwater dependent ecosystems

GDEs are classified into the three broad types which are also recognised in the Namoi subregion bioregional assessment:

- Type 1 GDEs - aquifers and stygofauna ecosystems referring to ecosystems that reside within the spaces of caves and aquifers;
- Type 2 GDEs - ecosystems dependent on the surface expression of groundwater, referring to ecosystems that are connected to groundwater that comes to the earth’s surface, within wetlands, lakes, seeps, springs and river baseflow; and
- Type 3 GDEs - ecosystems dependent on the sub surface presence of groundwater, referring to ecosystems associated with terrestrial vegetation utilising the water table below the natural surface.

The study area for the GDE impact assessment is defined by the extent of maximum predicted depressurisation from the Project exceeding 0.5 m drawdown of hydraulic head which is then projected vertically to the land surface and extended in size by a buffer zone of 5 km. The resulting GDE study area shown in Figure 4.5 covers an area of approximately 3,950 km^2.

The GDE impact assessment found that potential Type 2 and Type 3 GDEs are present in the study area, but no Type 1 GDEs with potential to be impacted by the Project are present. Nine potential Type 2 GDEs that may be reliant on surface expression of groundwater are identified in the GDE impact assessment, and the Namoi River, Bohena Creek and Coghill Creek were identified in the GDE atlas as streams potentially receiving surface expression of groundwater.

Large areas of vegetation in the GDE atlas are mapped as having moderate potential for dependence on sub-surface expression of groundwater; however, detailed local vegetation mapping within the Project area has shown that the distribution of potential Type 3 GDEs is much smaller than was estimated using the methodology of the GDE Atlas. Vegetation communities with potential groundwater dependence are found to be concentrated in riparian areas, and include areas of:

- Rough-barked Apple - Red Gum - Cypress Pine woodland;
- Red gum - Rough-barked Apple with and without tea tree sandy creek woodland;
- Fuzzy Box Woodland; and
- a small area of Carbeen - White Cypress Pine - Curracabah - White Box tall woodland.

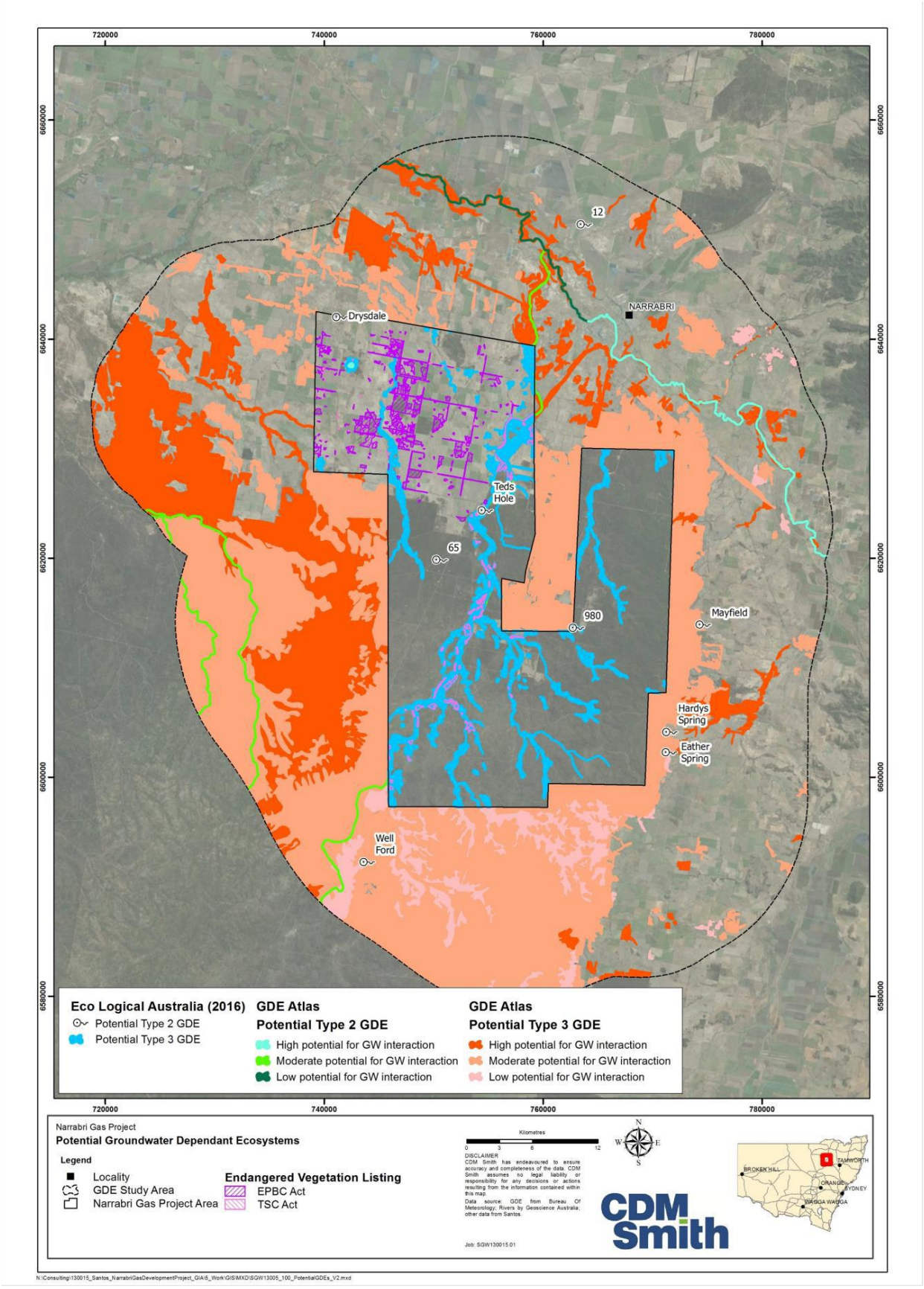


Figure 4.5 - Potential groundwater dependent ecosystems within the NGP study area

5. Predicted groundwater effects

5.1 Groundwater extraction

The predicted total water take from wells constructed prior to Phase 1 of the NGP, over the full gas production life of those wells, is shown in Figure 5.1. This shows a peak of up to 1.26 ML/day at approximately 2 years from the start of Phase 1, with cumulative predicted water take after three years approaching 1 gigalitre (**GL**). The model used to determine the potential groundwater impact from the Phase 1 operation was conservatively based on a 25-year operational life for the Phase 1 wells.

The location of the wells which are expected to be operational during Phase 1 of the Project are shown in Figure 5.2.

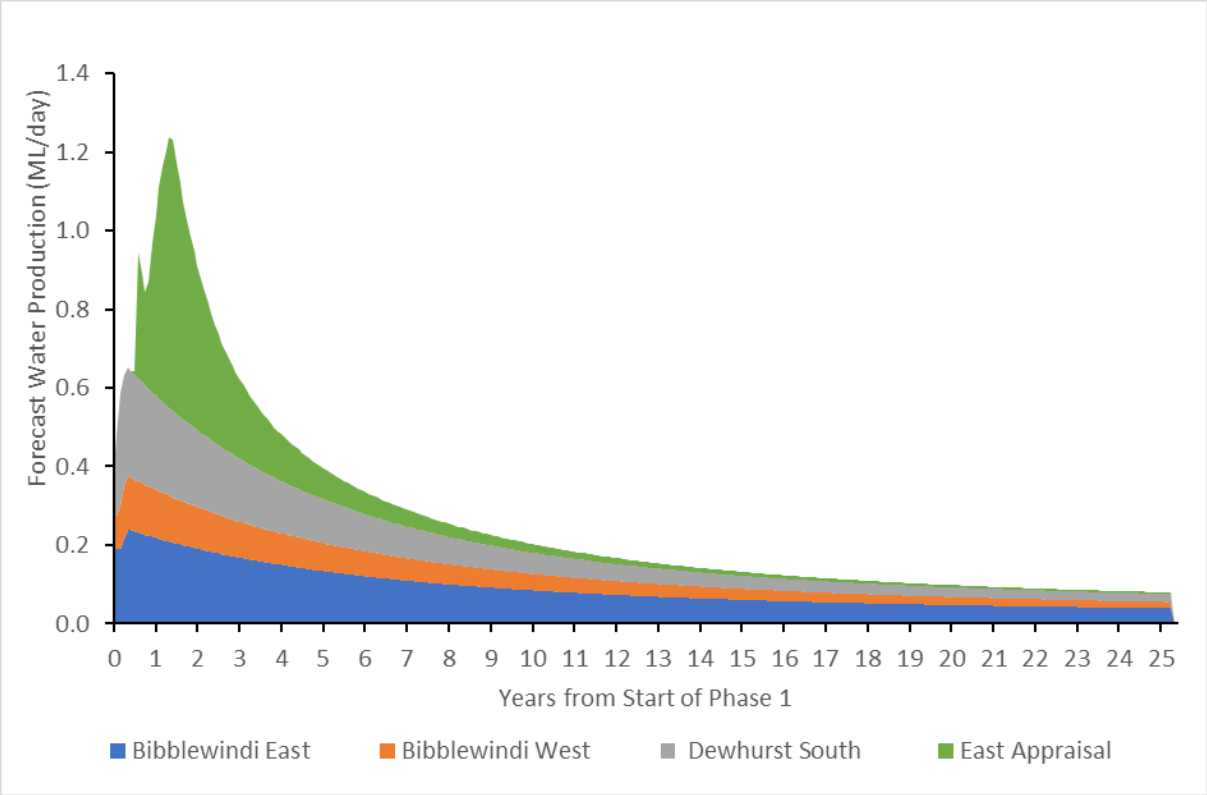


Figure 5.1 - Existing and Phase 1 water production forecast

All produced water from the Gunnedah Basin Coal Seams will be managed in accordance with the Produced Water Management Plan. Licensing for predicted produced water is described in the Site Water Balance. Extraction, transfer and treatment of produced water is not considered further in this GMP.

During Phase 1 of the NGP groundwater may be extracted from local aquifers in small quantities for ancillary activities (e.g. water for well drilling & completions or civil construction). Water licences and other necessary authorisation to extract that water will be acquired prior to use and in accordance with State water management policies. This is described further in the Site Water Balance. The effect of this abstraction on aquifers is not considered by this Plan as it will have already been assessed and reconciled by water planning policy instruments applied under the *Water Act 1912* (NSW) (**Water Act**).

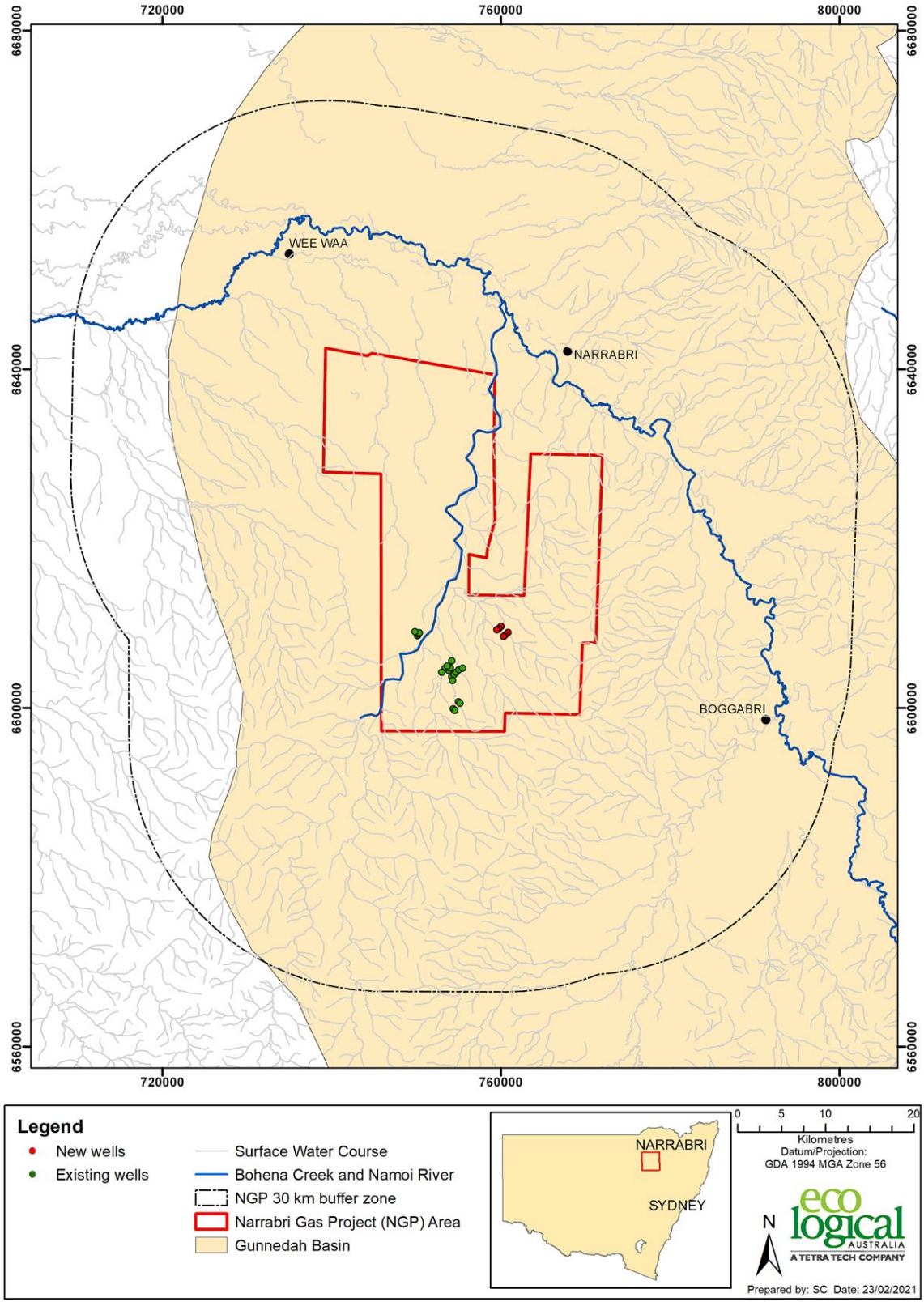


Figure 5.2 - Existing and proposed new gas exploration wells

5.2 Drawdown

Numerical groundwater modelling for the EIS modelled the extraction of groundwater throughout all phases of the Project. This showed that transfer of depressurisation from deep coal seams to the shallow high-valued groundwater sources will be impeded by thick aquitard sequences, resulting in small (if measurable) drawdowns in the high-valued groundwater sources many years after gas production ceases. This is presented in Table 5.1.

The EIS showed that the Project is not expected to cause an adverse reduction in the amount of water available in high-valued groundwater sources, neither for anthropogenic uses nor maintenance of dependent ecosystem function, throughout all phases of the Project and up to a maximum extraction of 37.5 GL.

There is no potential for deterioration of groundwater quality in the shallow high-valued groundwater sources because the direction of vertical groundwater flow induced by the Project is always downward and toward the coal seams, notionally only driving groundwater to flow from shallower formations of better quality into deeper formations of increasingly worse water quality.

Table 5.1 - Predicted maximum depressurisation and drawdown for the Project

Hydrostratigraphic unit	Maximum drawdown (m)	Time to maximum drawdown (years)
Regional Water Table away from alluvial aquifers	1 to 1.5	300 to 500
Namoi Alluvium	<0.5	300 to 500
Pilliga Sandstone	<0.5 to 0.6	200 to 250
GOB Triassic formations (e.g. Napperby and Digby Formations)	<0.5 to 5	200 to 1,000
GOB Late Permian coal seams (e.g. Hoskissons Coal Seam)	13 to 16	13 to 400
GOB Early Permian coal seams (e.g. Maules Creek Coal Seam)	93 to 128	3 to 500

Note:

Includes all phases of the Project, with data from the EIS numerical groundwater model.

5.3 Subsidence

The risk of subsidence within the Project area resulting from partial dewatering of the coal seams was investigated as part of the EIS. This included an assessment of (i) subsidence at depth due to compaction of the target coal seams and hydraulically connected strata caused by depressurisation, and (ii) potential subsidence at ground surface due to settlement of these compacted layers.

The assessment identified that the probable worst-case range of vertical compaction at depth, due to depressurisation of coal seams and surrounding strata, is 137-205 mm. This translates to negligible subsidence at the ground surface due to the large depth of the target coal seams and the presence and thickness of structurally competent rock formations within the overburden. The predicted maximum tilt at ground surface induced by subsidence is less than 0.08 millimetre per metre (<0.01%).

Such negligible subsidence is orders of magnitude smaller than subsidence predicted by the nearby Narrabri Coal Mine and only slightly larger than subsidence predicted from agricultural activities.

The risk of impacts to sub-surface infrastructure and groundwater resources due to potential subsidence at depth arising from the Project was assessed to be low to very low. The risk of impacts on surface infrastructure and surface water resources due to differential settlement and subsidence at ground surface was similarly assessed to be very low.

DPIE established an independent Water Expert Panel (**WEP**) to advise on land and water issues during assessment of the EIS. The WEP considered the risk of subsidence associated with the Project to be low but recommended that a subsidence baseline survey be undertaken, with periodic subsidence monitoring. This recommendation was incorporated into CoC B41(d)(iv).

6. Groundwater monitoring strategy

The Groundwater Monitoring Plan (**GMonP**), provided in Attachment 1, provides the details of the groundwater monitoring strategy. Performance measures and performance criteria (including trigger levels) that relate to the monitoring network defined in this plan are described in section 8.

Consent condition B41(d)(iv) requires that the groundwater monitoring network must be implemented and that it must be capable of:

1. characterising the temporal and spatial variations of all potentially affected water sources;
2. verifying actual direct and indirect water take;
3. providing an early warning of any impacts to potentially affected water sources, at varying depths within the geological profile;
4. providing data to improve the confidence level class of the groundwater model as soon as reasonable and feasible; and
5. integrating with any government monitoring networks in the area.

These capabilities are achieved through a combination of monitoring methods for targeted formations. Table 6.1 provides an overview of how specific monitored attributes of the various hydrostratigraphic units will meet the capabilities numbered 1 to 5 in the list above. Table 6.1 also links the requirements of CoC B41(d)(iv) to the hydrostratigrahic units in shown in Figure 6.1, providing an overview of the purpose of monitoring for each target hydrostratigraphic unit that will be monitored (coded A to D).

Table 6.1 - Monitoring network summary capabilities for Phase 1 of the Project

Target code	Monitored hydrostratigraphic unit	Groundwater quality	Groundwater pressure	Volume extraction by Project	Capabilities
A	Target coal seams (Maules Creek Formation)		✓	✓	1, 2, 3, 4
B	Deeper (early Permian-aged) formations of the Gunnedah Oxley Basin		✓		1, 2, 3, 4
C	Shallower (Triassic-aged) formations of the Gunnedah Oxley Basin		✓		1, 2, 3, 5
D	Great Artesian Basin and Namoi Alluvium aquifers	✓	✓		1, 5

A total of 105 groundwater monitoring points are nominated as part of the monitoring network, with all proposed monitoring points to be operational prior to the commencement of Phase 1 of the Project. A summary of the groundwater monitoring locations is provided in Figure 6.2, with the number of monitoring locations for each targeted unit summarised in Table 6.2.

Further details of the monitoring network are provided in section 4 and Appendix B of the GMonP.

Province	Period / epoch	Division	Group	Sub-group	Formation	Lithology and hydrogeological classification	Trans-missivity classification	Hydro-stratigraphic target
Namoi Alluvium	Pleistocene				Narrabri Fm	Clay and silt with sand lenses	LSTU	D
	Pliocene				Gunnedah Fm	Gravel and sand with clay lenses	STU	
	Miocene				Cubbaroo FM	Gravel and sand with clay lenses	STU	
Volcanics					Warrumbungle Volcanics	Basalt, dolerite	PNTU	
	Eocene				Liverpool Range Volcanics	Basalt, dolerite	PNTU	
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm	Clayey to quartzose sandstone, subordinate siltstone and conglmerate	NTU	
		Early			Pilliga Ss	Fluvial, medium-to very coarse-grained, quartzose sandstone and conglomerate. Minor interbeds of mudstone, siltstone and fine-grained sandstone and coal	STU	D
	Jurassic	Late					STU	
		Middle			Purlawaugh Fm	Fine to medium-grained sandstone thinly interbedded with siltstone, mudstone and thin coal seams	NTU	
		Early	Garrawilla Volcanics			Dolerite, basalt, trachyte, tuff, breccia	LSTU	
		Late					LSTU	
	Triassic	Middle			Deriah Fm	Sandstone	PNTU	
					Napperby Fm	Interbedded fine sandstone, claystone and siltstone	PNTU	C
						Basal Napperby Shale	NTU	
		Early			Digby Fm	Quartzose sandstone (Ulinda Ss)	NTU	
						Lithic sandstone	NTU	
						Lithic conglomerate (Bomera Congl.)	NTU	
Gunnedah Basin	Permian	Late	Black Jack	Nea	Trinkey FM	Coal measures - siltstone, fine sandstone, tuffs, stony coal	PNTU	
					Wallala Fm	Conglomerate, sandstone, siltstone, minor coal bands	PNTU	
				Coogal	Breeza Coal	Coal and claystone	PNTU	
					Clare Ss	Medium-to coarse-grained quartzose sandstone, quartzose conglomerate	LSTU	
					Hoes Hill Coal	Coal	PNTU	
					Benalabi	Claystone, siltstone and sandstone, fining-up cycles; more sandy towards top	PNTU	
					Hoskissons Coal	Potential target coal seam	STU	
				Brothers	Brigalow Fm	Fining-up sequence of medium-to coarse-grained quartzose sandstone and siltstone	PNTU	
					Arkarula Fm	Sandstone and siltstone	PNTU	
					Melvilles Coal Mb	Coal	PNTU	
					Pamboola Fm	Sandstone,siltstone, minor claystone and coal	PNTU	
		Middle	Millie		Watermark Fm	Marine siltstone, shales and sandstone	NTU	B
					Porcupine Fm	Fining-up sequence of conglomerate and sandstone to mudstone	NTU	
		Early	Bellata		Upper Mauels Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU	
					Rutley Seam	Potential target coal seam	STU	A
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Namoi Seam	Potential target coal seam	STU	
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Parkes Seam	Potential target coal seam	STU	
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Bohena Seam	Potential target coal seam	STU	
					Lower Maules Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU	
					Goonbri Fm	Siltstone, sandstone and coal	NTU	
					Leard Fm	Flinty claystone	NTU	
Basement			Werrie Basalt and Boggabri Volcanics (Basement)			Rhyolitic to dacitic lavas and ashflow	LSTU	
						Tuffs with interbedded shale. Rare trachyte and andesite. Weathered basic lavas.	NTU	
Colour code key:						STU - Significantly Transmissive Unit		
						LSTU - Less Significantly Transmissive Unit		
						PNTU - Probable Negligibly Transmissive Unit		
						NTU - Negligibly Transmissive Unit		

Figure 6.1 - Hydrostratigraphic classification of the Project area

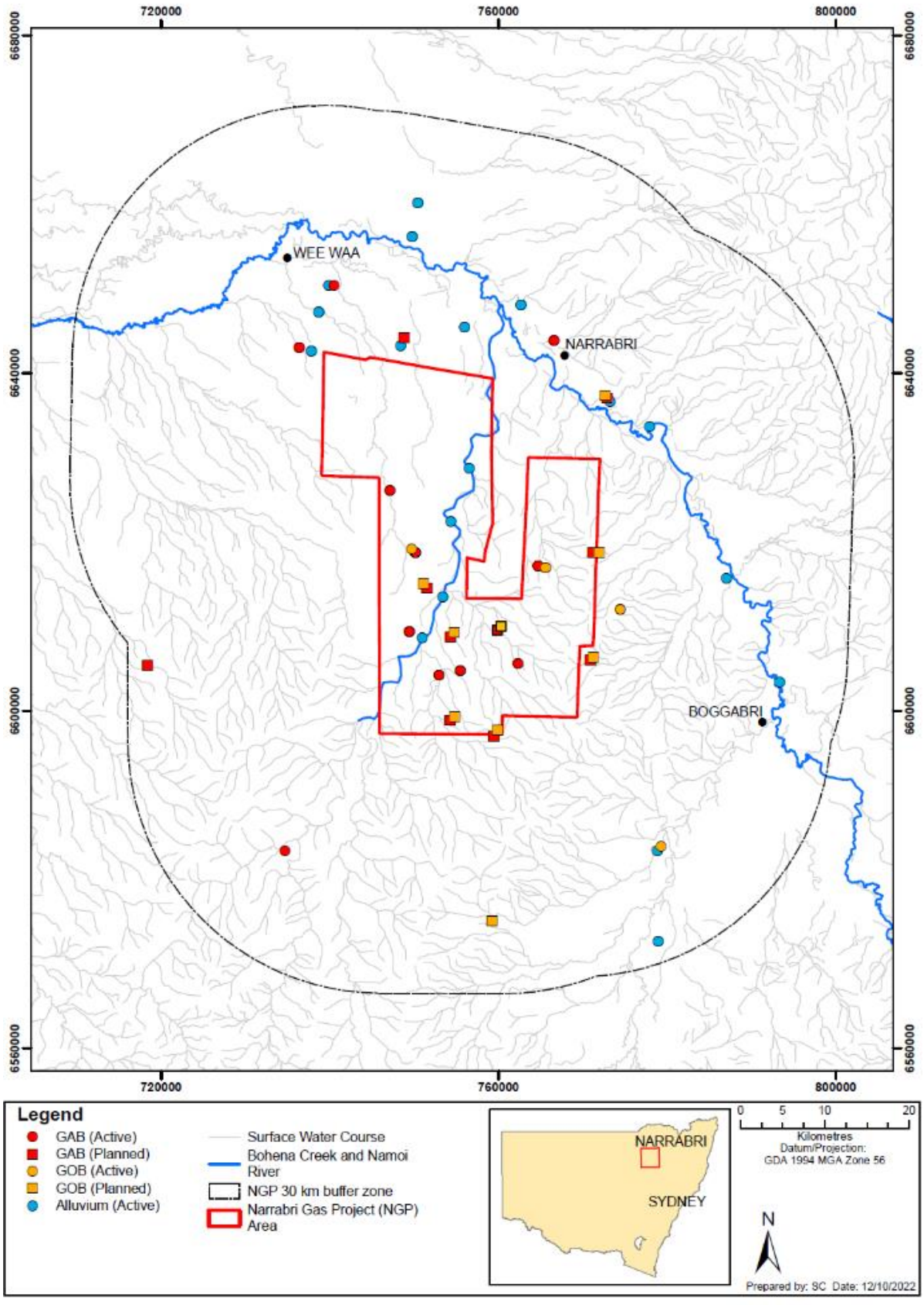


Figure 6.2 - Groundwater monitoring locations for Phase 1 of the Project

Table 6.2 - Summary of groundwater monitoring locations for Phase 1 of the Project

Hydrostratigraphic Unit	Monitored formations	Santos operated*		DPE operated
		Operational	To be constructed	Operational
Alluvial Aquifers	Bohena Creek Alluvium	4		
	Namoi Alluvium			27
Great Artesian Basin	Orallo Formation	3		
	Mooga Formation			1
	Pilliga Sandstone	12	5	7
	Purlawaugh Formation	2		4
Volcanics	Garrawilla Volcanics			1
Shallower Formations of the GOB	Napperby Sandstone	1		1
	Digby Formation	2	5	2
	Hoskisson Coal			2
	Black Jack Group			1
	Pamboola			1
Deeper Formations of the GOB	Porcupine Formation	1	5	1
	Arkarula Formation	1		
Target Coal Seam	Maules Creek Formation (Coal Seams)	1	15	

Notes:

Multiple monitoring points may be nested at the same monitoring site.
* Monitoring points shown in this table do not include monitoring of water production from CSG production wells.

The monitoring bore network used for setting trigger levels will be revised based on the following:

- increase the spatial representation of Gunnedah Oxley Basin (GOB) monitoring bores for trigger levels, with two sites set in proximity to the Phase 1 pilot wells (one near the existing wells and another at the proposed new cluster of pilot wells);
- a third or fourth monitoring bore site clustered with the existing Great Artesian Basin (GAB) monitoring bores. Several monitoring bores targeting the GAB bores are located between the existing and proposed pilot wells and have 10-years groundwater level data; and
- continued water quality monitoring throughout the life of the Project with performance triggers of electrical conductivity and methane concentrations forming a Level 3 target. The Level 3 target is to be set for the GAB only and in consultation with DPE Water.

7. Subsidence and seismic monitoring

Monitoring of subsidence involves use of InSAR techniques as detailed in Table 7.1. InSAR data acquisition will be undertaken every 48 days throughout Phase 1 and the data processed, analysed and compared to baseline assessment for each annual report.

Table 7.1 - Land subsidence monitoring program

Method	Measurement frequency
InSAR survey data collection	Every 48 days
InSAR survey summary report	Annual

InSAR is an aerial or satellite-based radar technology used in geodesy and remote sensing. The method uses two or more synthetic aperture radar images to generate maps of surface deformation or digital elevation by analysing differences in the phase of the waves returning to the satellite. The satellite-based geodetic survey is considered industry best practice and will identify cumulative subsidence for all contributing factors (such as agricultural extraction, seasonal variation, coal seam water extraction) to an accuracy of millimetres. Annual assessment will be compared to baseline conditions and assessed against the subsidence monitoring trigger described in section 8.6.

InSAR in the most appropriate technique for monitoring of change in ground elevation for the purpose of establishing trends and subsequent identification of subsidence. InSAR may have a limited application in areas that are heavily cultivated. However, the majority of the NGP is either uncultivated or only lightly cultivated and will be very suitable for long term monitoring using InSAR.

No seismic monitoring is proposed for this Project. Significant seismic activity (M>2) is continuously monitored by Geoscience Australia and reported on their live earthquake hazard map.

8. Groundwater performance criteria

8.1 Project phasing

The NGP comprises four defined phases of development, as described in section 1.1.2.

The groundwater performance criteria outlined in this section are only applicable to proposed activities of Phase 1, which comprises operation of up to 25 appraisal wells with expected peak water production of just 1.26 ML/day (see section5.1).

Prior to Phase 2, this Plan, including the groundwater performance criteria, will be reviewed, revised and approved via the Major Projects Portal to reflect:

- new knowledge and updated assessment;
- revised predictive modelling of Project effects on groundwater; and
- the extent and details of the proposed Phase 2 development.

8.2 Relevant measures and criteria

Condition B37, specifically Table 7 of the CoC, identifies a number of performance measures relevant to the management of groundwater. These are reproduced below in Table 8.1.

CoC B41(d)(iv) requires that the GMP provide detailed performance criteria, including trigger levels for identifying and investigating any potentially adverse impacts associated with the development. These are also shown in Table 8.1. Note that the prescribed performance criteria broadly align to the performance measures from CoC B37 that are relevant to groundwater.

CoA 5 states that Santos must achieve and maintain the performance measures in the NSW approval to demonstrate that the outcomes and sub-outcomes specified in CoA Appendix B are being achieved and maintained. These outcomes have been reproduced in Table 8.2.

Table 8.1 - Groundwater features, performance criteria and trigger levels

Feature	Performance measures and criteria	Verification method	Trigger levels	Trigger response
Condition B37 (Table 7)		• Current numerical groundwater model prediction • Groundwater monitoring data annual review	**Level 1** Produced water extraction triggers (see section 8.4.1) OR **Level 2** GOB aquifer (Napperby/Digby) pressure monitoring trigger (see section 8.4.2) OR **Level 3** GAB Aquifer (Pilliga Sandstone) water quality monitoring trigger	• Refer to Section 8.5
Namoi alluvial aquifers and GAB aquifers	• Negligible environmental consequences to aquifers beyond those predicted in the EIS including: ▪ Negligible change in groundwater levels; ▪ Negligible impact to other groundwater users; ▪ Negligible change in groundwater quality; • Negligible change to baseline methane levels in groundwater user bores;			
GOB aquifers	• Drawdown and water take to be generally consistent with the 'base case' predictions and produced water profile in the EIS; • Negligible change in groundwater quality			
Riparian and aquatic ecosystems	• Negligible impact on GDEs			
Condition B41(d)(iv)				
GMP must include performance criteria, including trigger levels for identifying and investigating any potentially adverse impacts associated with the development on:	• Regional and local aquifers and aquitards			
	• Groundwater supply and quality for other water users, including all potentially affected privately-owned licenced groundwater bores;			
	• Groundwater dependent ecosystems;			
	• Aquatic habitat and stygofauna			
	• Ground subsidence and seismicity	Subsidence monitoring annual review	Subsidence monitoring triggers (see section 8.6)	• Revise risk assessment • Develop management and mitigation measures

Table 8.2 - Outcomes for groundwater resources

Groundwater (CoA 5)				
Unconsolidated hydrogeological units				
Outcome	Conditions within unconsolidated hydrogeological units, including water level/pressure and water quality, maintain or improve ecosystem services and access by associated users.			
Associated users	**Water supply bores**	**Aquatic GDEs**	**Terrestrial GDEs**	**Subterranean GDEs**
Sub-outcome	Bore continues to supply water for its intended purpose or is made good.	No adverse effects on the function and environmental values due to CSG development.	No adverse effects on the function and environmental values due to CSG development.	Habitat is maintained or improved.
Consolidated hydrogeological units				
Outcome	Conditions within consolidated hydrogeological units, including water level/pressure and water quality, maintain or improve ecosystem services and access by associated users.			
Associated users	**Water supply bores**	**Aquatic GDEs**	**Terrestrial GDEs**	**Subterranean GDEs**
Sub-outcome	Bore continues to supply water for its intended purpose or is made good.	No adverse effects on the function and environmental values due to CSG development.	No adverse effects on the function and environmental values due to CSG development.	Habitat is maintained or improved.

8.3 Verification methods

The groundwater model is the primary tool for determining whether or not the Project will meet the performance measures at any time in the future. Predictions made by the model will be used to determine whether or not Phase 1 of the Project will meet the performance measures.

The use of a groundwater model as the primary verification tool is appropriate because:

- the model integrates all currently available and reliable information and knowledge regarding subsurface properties and the potential for impact to groundwater;
- changes to overlying formation pressures predicted by the model are not expected to be detectable until many decades into the future and will meet the performance measures; and
- the groundwater model is adaptive and continuously improved throughout the intervening period.

Santos will undertake groundwater monitoring to verify the model predictions are accurate and reliable. The monitoring triggers, which are described below, determine if the groundwater model needs to be revised. New data from a range of alternate sources may also lead to a review of the model.

Groundwater pressure monitoring provides the earliest possible method of detecting potential and unexpected groundwater connectivity throughout Phase 1. Further investigation and installation of new monitoring bores in the GOB throughout Phase 1 will confirm the presence of suitable groundwater quality monitoring sites for Phase 2. It is a practical limitation that, if a formation is not permeable enough, groundwater quality sampling has the potential to sustain drawdown in a monitoring bore over an extended periods which would negate the use of the bore for groundwater pressure monitoring.

8.3.1 Model updates

As required by CoC B39, Santos will update the groundwater model in the future. Santos will update groundwater model predictions prior to the commencement of Phase 2 of the Project, and at least every three years thereafter. The model update will be undertaken in consultation with DPE Water, the EPA, and the WTAG, and will be prepared and peer reviewed by suitably qualified and experienced persons.

The Groundwater Modelling Plan (**GModP**), provided as Attachment 3, describes in detail how the model will be updated. Any update of the model (i.e. whether initiated by a trigger or as scheduled prior to Phase 2) will incorporate new knowledge gathered since the previous model iteration. For example, geological and hydrogeological information provided by newly acquired well data or seismic surveys.

Once a model has been updated, the latest predictions will be used to determine if the performance measures are going to be met in the future.

8.4 Trigger levels

Three types of triggers have been identified, as described in the following sections. The location of the monitoring points against which these trigger levels will be applied is shown in Figure 8.1.

The triggers are ‘early warning’ triggers. Their occurrence does not necessarily mean that performance measures are not expected to be met, but rather trigger a reassessment of the risk of groundwater impact. This process is described in detail in the GModP.

The trigger response process is described in more detail in Section 8.5.
Throughout Phase 1, if the triggers are not exceeded, then current model predictions are considered reliable. This does not preclude periodic review, adaptation and improvement of the model throughout the current phase of the Project. This process is described in the GModP.

8.4.1 Level 1 trigger

A Level 1 trigger for Phase 1 is broadly described as the occurrence of greater than expected volume of water extracted from the coals. This trigger is expected to remain valid throughout all phases of the Project. A Level 1 triggers occurs if:

- one or more six-month periods in which the cumulative water production exceeds the modelled water production used to determine water licences reported in the Site Water Balance, as defined in CoC B28 (including both short-term, long-term and indirect water take).

Level 1 triggers are an upper limit based on the allowable water take from the GOB specific to the scale and timing of a specific Project phase. This cumulative water production not to be exceeded (the Limit) is defined for Phase 1 in Table 8.3, in accordance with Section 3 of the GModP. In Table 8.3, Year 1 comprises the first year since the start of water production as part of Phase 1, either from new wells constructed or from existing wells but following completion of well work-over activities.

Table 8.3 – Phase 1 nominated groundwater production take response triggers

Year	Limit (ML)	Year	Limit (ML)	Year	Limit (ML)
0.5	144	**9**	1786	**17.5**	2285
1	288	**9.5**	1827	**18**	2306
1.5	493	**10**	1867	**18.5**	2326
2	698	**10.5**	1903	**19**	2345
2.5	836	**11**	1939	**19.5**	2364
3	973	**11.5**	1972	**20**	2383
3.5	1075	**12**	2005	**20.5**	2401
4	1177	**12.5**	2035	**21**	2418
4.5	1259	**13**	2065	**21.5**	2435
5	1340	**13.5**	2093	**22**	2452
5.5	1409	**14**	2120	**22.5**	2468
6	1477	**14.5**	2146	**23**	2484
6.5	1536	**15**	2172	**23.5**	2500
7	1594	**15.5**	2196	**24**	2515
7.5	1645	**16**	2219	**24.5**	2530
8	1696	**16.5**	2242	**25**	2545
8.5	1741	**17**	2264		

.The wells which will be monitored to determine the cumulative groundwater extraction from the GOB have been presented previously in Figure 5.2 and comprise 25 CSG wells proposed to be operational during Phase 1.

The six-monthly review against the Level 1 trigger will also establish whether the actual number of operational CSG wells, or duration that wells are operational, is reasonably represented by the volume previously modelled as being extracted in the groundwater model for Phase 1.

Every second reporting period will be incorporated into the Annual Review.

8.4.2 Level 2 trigger

A Level 2 trigger for Phase 1 is broadly described as '*occurrence of greater than expected depressurisation of the Napperby Sandstone or Digby Formation*', which are some of the shallowest and youngest formations in the Gunnedah Oxley Basin sediments and above the target coal measures.

A Level 2 trigger occurs if groundwater level drawdown in the Napperby Sandstone or Digby Formation exceeds 0.5 m throughout Phase 1 of the Project. A drawdown trigger level of 0.5 m has been selected because:

- it represents the minimum feasibly detectable drawdown, and therefore represents a trigger of any recordable drawdown;
- the currently predicted time to peak drawdown is many decades away; and
- the predicted total maximum drawdown in these formations and across all phases of the Project is less than 5 m.

At least three years of groundwater level monitoring data will be collected at each bore location to establish baseline levels. The determination of baseline levels would not need to preclude the assignment of Level 2 triggers to monitored groundwater pressures as described above.

Predicted maximum drawdown within the Digby Formation for all phases of the Project is not predicted by the current groundwater model to exceed 2.4 m and the time until maximum drawdown occurs is predicted to be in excess of 190 years.

These triggers will be reviewed and where necessary, revised for subsequent phases of the Project, informed by groundwater model results:

- drawdown trigger levels will be reviewed and where necessary, revised to reflect the phase of the Project and the latest model predictions of drawdown; and
- trigger monitoring bores may be added to reflect adaptations to the monitoring network to align with the geographical extent of the subsequent phase of the Project.

The groundwater monitoring bores that will be used to monitor groundwater pressures against the Level 2 trigger described above are shown on Figure 8.1 and Table 8.4. Their proximity to the nearest CSG wells that will be operational in Phase 1 is also shown in Table 8.4. Additional information for these monitoring bores is provided in the GMonP.

Groundwater level triggers have not been defined for shallower aquifers of the GAB, nor for the Namoi Alluvium, because the maximum predicted water level change in these formations due to the Project will be imperceptible when compared to variability induced by climate and other groundwater users.

Groundwater level monitoring triggers in the Napperby and Digby Formations of the GOB will confirm if depressurisation of overlying shallower aquifers could occur in the future.

The Phase 1 Level 2 triggers will be set prior to extraction from any new pilot wells proposed under Phase 1.

Table 8.4 – Phase 1 nominated groundwater drawdown monitoring triggers (Level 2)

Monitoring point name	Monitored formation	Distance to nearest CSG well (km)
TULPRDGY02	Digby Formation	13.9
BHNS1PRDGY02	Digby Formation	5.8
BWD6PRDGY02	Digby Formation	3.1
DWH9PRDGY02	Digby Formation	0.9
DWH43PRDGY02	Digby Formation	2.6
GW971623-1	Digby Formation	9.7
DWH35PRDGY01	Digby Formation	0.5

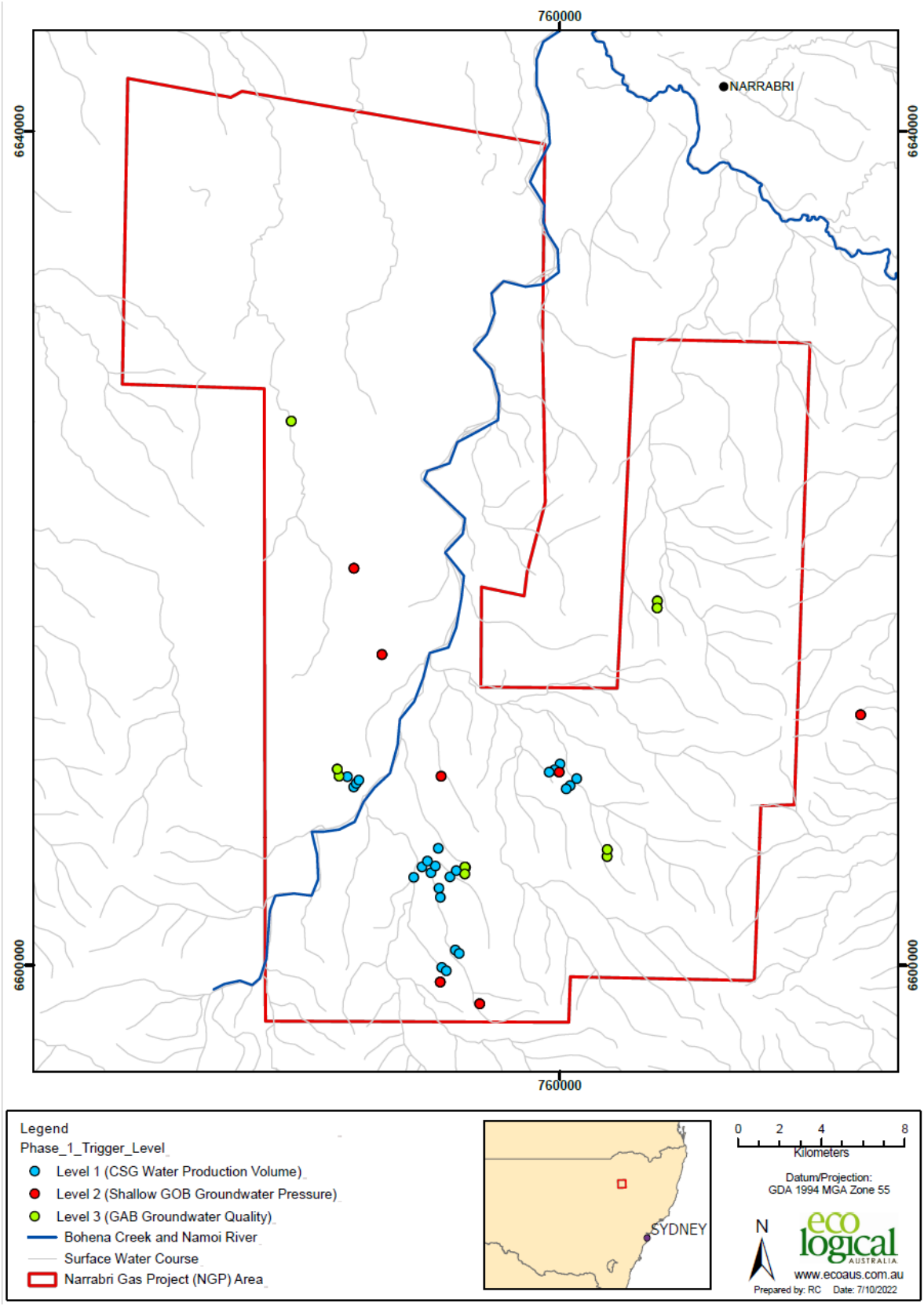


Figure 8.1 - Monitoring points against which trigger levels have been applied

8.4.3 Level 3 trigger

A Level 3 trigger for Phase 1 is broadly described as the occurrence of greater than expected change in groundwater quality in the Pilliga Sandstone, specifically the electrical conductivity (**EC**) and dissolved methane concentration. Trigger monitoring of electrical conductivity is useful because it provides a measure of the total amount of dissolved substances, chemicals, and minerals that may be present in the water.

Trigger monitoring of dissolved methane concentration has been selected because very small changes can be detected, and small changes in methane concentration may not lead to obvious changes in electrical conductivity.

The Level 3 trigger monitoring points for which these triggers have been derived comprise monitoring points that:

a) have existing monitoring data comprising at least eight monitoring results over at least 3 years (refer to Appendix B of the GBR), and
b) will be monitored throughout Phase 1 (refer to Appendix B of the GMonP).

The Level 3 trigger values have been derived from the existing monitoring data for each monitoring point. The Level 3 trigger value is derived from and equivalent to the previously highest detected value at that monitoring point, as published in Appendix B in the GBR.

Table 8.5 lists the Level 3 trigger monitoring points, the Level 3 trigger values and a reference for the derivation of those values within the GBR. The locations of the Level 3 trigger monitoring locations listed in Table 8.5 are summarised in Figure 8.1.

Table 8.5 – Phase 1 nominated groundwater quality monitoring triggers (Level 3)

Monitoring point name	Monitored formation	Trigger value EC lab (µS/cm)	Trigger value dissolved methane (ppm)*	Groundwater Baseline Report reference
DWH3PRUPS01	Upper Pilliga Sandstone	164	>LOR	Table B37
DWH3PRLPS02	Lower Pilliga Sandstone	215	0.042	Table B36
DWH14PRUPS01	Upper Pilliga Sandstone	721	>LOR	Table B35
DWH14PRLPS02	Lower Pilliga Sandstone	617	0.025	Table B34
BWD27PRUPS02	Upper Pilliga Sandstone	864	0.027	Table B33
BWD27PRLPS03	Lower Pilliga Sandstone	239	0.025	Table B32
BWD26PRUPS01	Upper Pilliga Sandstone	181	0.409	Table B31
BWD26PRLPS02	Lower Pilliga Sandstone	169	0.269	Table B30
BHN14PRUPS02	Upper Pilliga Sandstone	565	4.64	Table B29

* Where 1ppm is assumed to be 1000µg/L

8.5 Trigger response

This section describes the process to respond to any exceedances of the groundwater performance criteria which may result in management responses to repair, mitigate and/or offset any adverse groundwater impacts of the development.

8.5.1 Trigger action response plan

A trigger action response plan (**TARP**) is developed to identify, assess, and respond to unpredicted conditions and is implemented to manage risk to operations, personnel and the environment.

For Phase 1 of the Project, exceedance of the Level 1 trigger (exceedance of produced water volumes), Level 2 (exceedance of expected depressurisation of deep monitored aquifers) or Level 3 (exceedance of unexpected change in groundwater quality in the Pilliga Sandstone) will result in an initial data review and investigation. This may lead to an update of the numerical groundwater model assessment and a potential revision of the groundwater impact assessment as described in the GModP.

A flow chart of this TARP is presented in Figure 8.2 and summarised as follows:

- if the Level 1-3 monitoring triggers are not exceeded, then the Project is on track and it follows that the magnitude of observed effects from the Project is consistent with, or less than the approved magnitude of effects predicted in the EIS. This is the expected situation for the Project;
- if an exceedance of any trigger level is detected, then Santos will
    - notify DPE within 7 days and notify DCCEEW within 10 business days.
    - undertake a data review to determine whether the cause of trigger could possibly have been caused by the Project activities
- if the data review demonstrates that the trigger exceedance could possibly be due to CSG, then the within six months of an exceedance of any trigger level being detected, Santos will prepare a Risk Assessment Review Report for submission to DPE that describes:
    - all potential and actual impacts to water resources arising from the exceedance;
    - any further investigations undertaken to determine the cause of and remedy for the exceedance;
    - assessment of the risk of current or future non-compliance with the water management performance measures (refer to CoC B37, Table 7), and NSW Aquifer Interference Policy which defines considerations in assessing on whether more than minimal impacts might occur to a key water-dependent asset, employing a multiple lines of evidence approach,
    - the mitigation and management measures that have been or are proposed to be taken to reverse the exceedance, including incorporation of make good provisions compliant with the NSW Aquifer Interference Policy, including data demonstrating the effectiveness of the mitigation and management measures and
    - whether the currently approved WMP, or specific sub-plans included as part of that plan (e.g. the Groundwater Management Plan) needs to be revised to ensure that the water management performance measures (refer to CoC B37, Table 7) will be achieved.

Section 9.1 describes the management and reporting response in the event of trigger exceedances to ensure Project performance measures are achieved.

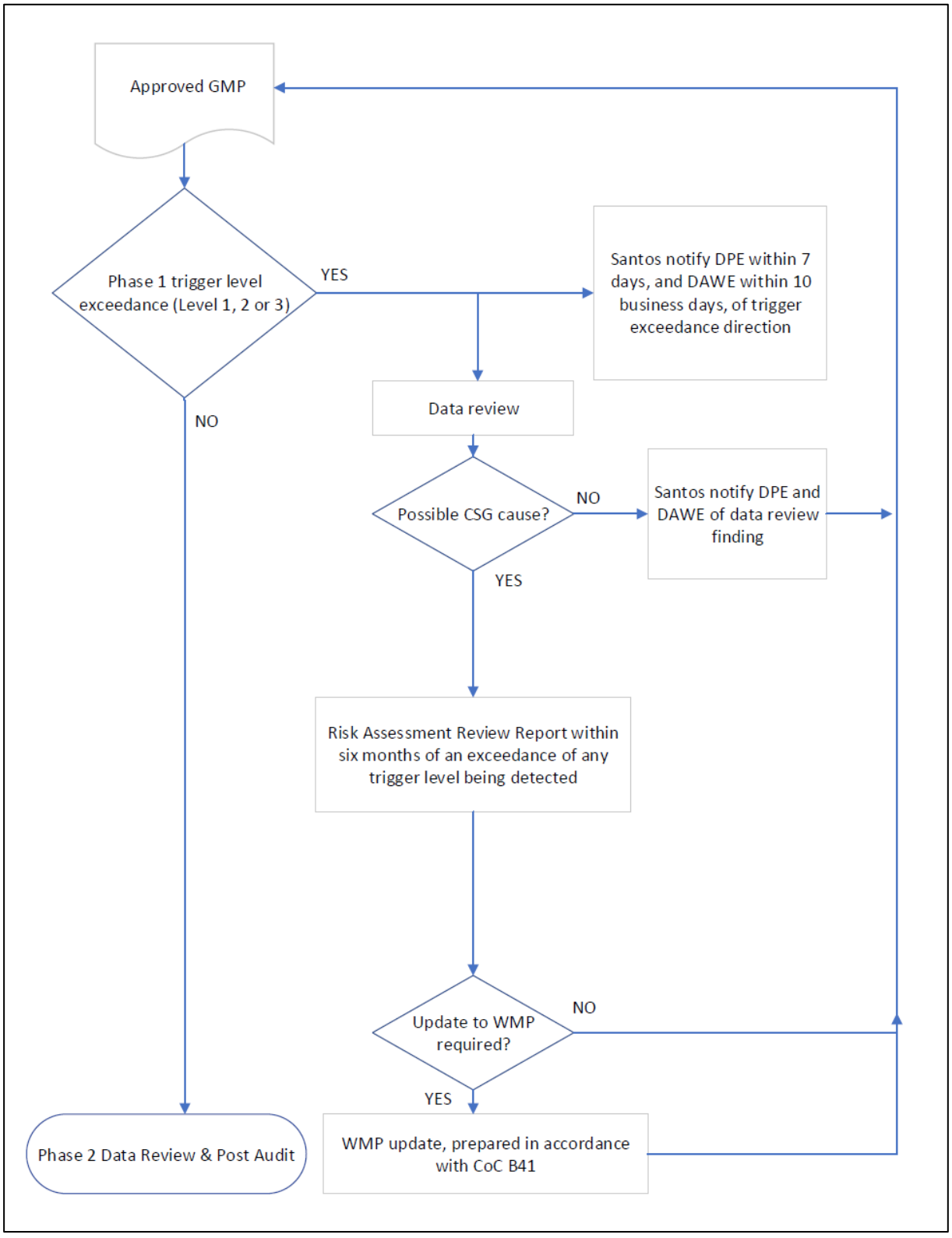


Figure 8.2 - Phase 1 trigger action response process

8.6 Subsidence monitoring trigger

InSAR monitoring techniques generate a large number of monitoring points across the Project area (e.g. typical density of 10,000 per km^2). Ground movement can be the result of many activities unrelated to CSG operations and data signals can have large intrinsic variability. For example, wetting and drying cycles in the soil due to climatic factors or land use change may result in ground deformation.

Additionally, due to the depth of the target coal seams and the competency of the overlying rocks, and the thickness and characteristics of the lithological material within the target coal formation and overlying formations, the risk of subsidence is considered low.

However, since the risk of subsidence due to CSG operations is related to depressurisation of the target coal seams, this risk will be highest in the areas adjacent to CSG wells. The trigger level for subsidence monitoring therefore comprises a coarse statistical analysis of all subsidence monitoring data points adjacent to CSG wells.

The subsidence monitoring trigger is exceeded if more than 50% of the monitoring points within 800 m of a CSG well (~0.5 km^2) show greater than 7 mm/yr subsidence.

Trend analysis, in this context, comprises the average trend across the large number of InSAR monitoring points over a given area of interest.

It is conservative to assign a trigger exceedance when only 50% of the monitoring points show >7mm/year subsidence because the average trend of all the same data (i.e. including all monitoring points including those showing <7mm/year subsidence) could show a trend of less than 7mm/year.

The nominated monitoring trigger level represents the minimum detectable rate of ground motion using the technique (i.e. 7mm/year) combined with a focus on the area where the risk of subsidence occurring is greatest, i.e. immediately adjacent to operating CSG wells where drawdown in the coal seam is earliest and greatest.

9. Monitoring and reporting

This section presents a program to monitor and report:

- compliance with the groundwater performance measures in CoC B37 and associated Table 7 [of the CoC] and the performance criteria established in Table 8.1;
- groundwater flows, quality and yield in regional and local aquifers and aquitards (alluvial and hardrock);
- ground subsidence and seismicity;
- geological fracturing and heterogeneity;
- water loss/seepage/leakage from water storages and Project-related infrastructure into the groundwater system;
- potential cross-contamination of aquifers, including migration from lower aquifers to the GAB;
- sub-surface leakage of methane, drilling fluids and saline groundwater;
- groundwater inflows, outflows and storage volumes to inform the Site Water Balance; and
- the effectiveness of the groundwater management systems.

In accordance with CoC D13, CoA 7, and as described in section 6 of the EMS, all groundwater monitoring data and associated reports will be made available on the Project website, for the duration of the Project.

9.1 Compliance with performance measures

Section 8 outlines how the Project will demonstrate compliance with the performance measures in CoC B37 and associated Table 7 [of the CoC] and the performance criteria using monitoring triggers.

If an exceedance or predicted exceedance of any water management performance measures (refer to CoC B37, Table 7), or an exceedance of any trigger level is detected, then Santos will, notify DPE within 7 days and notify DCCEEW within 10 business days.

Within six months of an exceedance or predicted exceedance of any groundwater performance criterion measure, or an exceedance of any trigger level, being detected, Santos will prepare a Risk Assessment Review Report for submission to DPE that describes:

- all potential and actual impacts to water resources arising from the exceedance;
- any further investigations undertaken to determine the cause of and remedy for the exceedance;
- assessment of the risk of current or future non-compliance with the water management performance measures (refer to CoC B37, Table 7), employing a multiple lines of evidence approach,
- the mitigation and management measures that have been or are proposed to be taken to reverse the exceedance, including data demonstrating the effectiveness of the mitigation and management measures and
- whether the currently approved WMP, or specific sub-plans included as part of that plan (e.g. the GMP) needs to be revised to ensure that the water management performance measures (refer to CoC B37, Table 7) will be achieved.

Santos will notify DCCEEW within 2 business days of the Risk Assessment Review Report being published on the Project website, and the report will remain on the website for the life of the Project.

If, after the implementation of mitigation and management measures as specified in the report, Santos detects or predicts that the outcomes cannot or will not be achieved, or the Minister considers that the outcomes cannot or will not be achieved, then Santos will provide a site-specific assessment for the Minister's written approval within 3 months of making the prediction or of receiving a request from the Minister. As outlined in Appendix B Table B2, each site-specific assessment is to provide a cease-work limit and is required to include multiple lines of evidence and field data; conceptual and numerical modelling; and be subjected to a peer review by a suitably qualified independent expert. Each approved site-specific assessment will be placed on the Project website.

CoA 13 to 17 generally relate to the cease-work limits in the site-specific assessments, and the suspension, continuation or recommencement of groundwater extraction. Based on the sufficiently conservative basis for the estimation of maximum predicted indirect water take as detailed in the GModP, and the fact that the forecast of Phase 1 water production will be regularly reviewed, and any estimates adjusted long before indirect water take peaks, it is highly unlikely that these conditions will be relevant to Phase 1. However, in the interest of completeness, they have been listed in full in Table B2 in Appendix B.

If an update to the WMP, or specific sub-plans included as part of the plan, is recommended by the Risk Assessment Review Report, the WMP will be updated to reflect recommendations of the report, and to meet the general requirements of the WMP that is specified by CoC B41.

9.2 Groundwater flow, quality and yield

Section 6 presents a summary of the groundwater monitoring strategy and further detail is provided in the GMonP.

No discernible changes to groundwater flow, quality or flux are expected during Phase 1, beyond the target Permian coal seams. This will be verified by ongoing assessment of monitoring data against monitoring triggers as described in section 8.4.

9.3 Ground subsidence and seismicity

On-going monitoring of ground surface deformation and subsidence will continue throughout Phase 1 via remote sensing of ground deformation using InSAR monitoring techniques. This is described in section 7. Subsidence monitoring triggers have been defined in section 8.6.

There is no planned collection of seismicity data in relation to the Project. Data collected from the ANSM may be reviewed as a management response to exceedance of subsidence monitoring triggers.

9.4 Geological fracturing and heterogeneity

Hydraulic fracture stimulation will not be carried out at any time during the Project. Hydraulic fracture stimulation is explicitly not an authorised activity according to CoC A17.

Heterogeneity in the sub-surface will continue to be assessed to inform future groundwater model updates. The GModP describes various methods and workflows for assessing sub-surface heterogeneity where it is relevant to the ongoing assessment of potential groundwater impacts.

9.5 Water seepage from water infrastructure

Monitoring of groundwater to detect potential for seepage from storage pond facilities is considered under the Produced Water Management Plan and is not considered further here. That plan describes how shallow groundwater monitoring bores monitor for any leaks and sub-surface changes to shallow perched groundwater systems.

The Project will design, construct and operate all water management infrastructure to strict water engineering standards to avoid unplanned loss of containment. The Pollution Incident Response Management Plan describes how the Project will detect, manage and respond to unplanned or accidental spillages of produced water and minimise risk to groundwater.

9.6 Cross-contamination of aquifers

No discernible changes to groundwater flow, quality or flux is expected beyond the target Permian coal seams. This will be monitored as described in sections 2.4, 3.2 and 5.2 of the GMonP and verified by ongoing assessment of monitoring data against monitoring triggers as described in section 8.

CSG wells and groundwater monitoring bores have potential to act as preferential flow pathways for groundwater between water bearing formations. Construction and rehabilitation of CSG wells, including the management of drilling fluids, will be undertaken in compliance with the *NSW Code of Practice for Coal Seam Gas - Well Integrity*. This includes requirements to record and report on well construction to maintain isolation between formations. Groundwater monitoring bores constructed under the Water Act will be constructed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (NUDLC, 2020).

9.7 Sub-surface leakage of methane

CSG wells have the potential to act as preferential flow pathways for gas between coal seam gas reservoirs and overlying water bearing formations. Construction and rehabilitation of CSG wells will be undertaken in compliance with the *NSW Code of Practice for Coal Seam Gas - Well Integrity*. This includes requirements to record and report on well construction to maintain isolation between formations.

Groundwater quality monitoring is described in section 3.3 of the GMonP. The suite of parameters includes methane, as per Table A1 of the GMonP.

9.8 Groundwater components of the water balance

The GModP describes how the groundwater model is used to derive groundwater components of the water balance. This will be reported in accordance with the Site Water Balance report required as part of the WMP.

10. Record keeping

Santos has a data management plan for the NGP 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. An overview of Santos' data management plan is presented in Figure B1 of Appendix B of the WMP, in the form of a data-management flow chart.

Santos uses a number of systems and platforms to manage the documentation and data associated with the activities under this Plan. These include Sharepoint for management plans, procedures and laboratory reports; Santos' EHS Toolbox for capturing inspections and field assessments; and EQuIS[4], an advanced environmental data management and decision support system, for capturing all data and any laboratory results.

Key records associated with this Plan and the associated sub-plans and protocols that will be stored and managed include:

- inspection and monitoring records;
- operational monitoring and performance data;
- water sampling and laboratory analytical reports;
- calibration records;
- records of implementation of any TARP;
- records of any reviews of this Plan and appendices; and
- annual inspection reports and/or certifications.

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. The GMonP outlines QA and QC protocols and procedures that ensure that data is accurate and usable.

Records are to be kept in a legible form for production to any inspector for a period of four years following the expiry or termination of a prospecting title, in compliance with Sections 97D and 97E of PO Act. Records associated with a code of practice may need to be kept for a longer period.

Specific record keeping requirements that may be required for any of the management plans or protocols are fully detailed and addressed in the respective documents.

[4] EQuIS (Environmental Quality Information System) is a proprietary software application.

11. Incidents, non-compliances and complaints

11.1 Incidents and non-compliances

Incident reporting and non-compliance notification will be in accordance with CoC D6 and D7 respectively, as described in section 6 of the EMS. Santos will notify the DPE and any other relevant agency via the Major Projects Portal immediately after becoming aware of an incident.

Within 7 days of becoming aware of a non-compliance with the CoC, Santos will notify the Department of the non-compliance via the Major Projects Portal. This notice will set out the non-compliance, the reasons for the non-compliance (if known) and what actions have been taken, or will be taken, to address the non-compliance. A non-compliance which has been notified as an incident will not be notified as a non-compliance.

As per CoA 8, Santos will notify DCCEEW of the exceedance within 10 business days of detecting or predicting the exceedance.

Where groundwater-related incidents or non-compliances are identified, Santos will:

- take steps to ensure that the incident or non-compliance ceases and does not reoccur;
- consider all reasonable and feasible options for remediation (where relevant) and submit a report to the relevant department(s) describing options and any preferred remediation measures or other courses of action; and
- implement remediation measures as directed by the relevant department(s).

As per CoA 9, Santos will, within 6 months of detecting or predicting an exceedance as described in CoA 8, publish on the Project website a report providing details of the exceedance or non-compliance. Santos will notify DCCEEW within 2 business days of the report being published. The report will remain on the website for the life of the EPBC approval.

11.2 Unpredicted impact protocol

It is considered unlikely that the Project exploration and appraisal activities during Phase 1 will result in any unpredicted or unforeseen adverse impacts in relation to groundwater management, and the compliance with performance measures and criteria. However, in accordance with CoC D3(f), the following strategy outlined in Table 11.1 will be adopted in the event where there is an unpredicted impact on groundwater flow, quality or flux.

Table 11.1 - Unpredicted impact protocol

Step	Strategy
1	Stop any groundwater disturbance works and implement immediate corrective actions to minimise the unpredicted impact
2	Review the unpredicted impact and consider the following: • recent or historical activities that may have triggered this event; and • relevant permit to work (or similar) or monitoring data.
3	Notify the relevant agencies and departments, as per section 11.1
4	Commission an investigation by a qualified groundwater specialist

Step	Strategy
5	Based on the results of the investigation, develop the appropriate amendment and amelioration methods
6	Implement the information from the investigation to review, and if necessary, update this Plan which will include any or all of the following: • a review the activities and actions that occurred or may have been taken prior to event; • a review and where required, revision and update of the groundwater management measures and groundwater monitoring strategy; • implement any relevant training based on the findings of the investigation and any revised management measures to avoid any recurrence of the unpredicted impact.

11.3 Complaint management

Santos has a documented *Complaint Management Procedure* that is communicated to all relevant staff members. Complaints can be directed to Santos via phone or email 24 hours a day, 7 days a week. Contact details are publicly available on the Project website and are presented in Appendix D of the EMS. All complaints are logged on a complaint form which includes the following details:

- date and time of the complaint;
- complainant details;
- details of the issue or complaint;
- actions taken to remediate the issue, if any;
- follow up actions required, if any;
- details of further liaison with complainant, if any; and
- closure date and time of the issue.

As per CoC D13, Santos maintains a complaint register which is updated as required and available on the Project website.

12. Reporting, evaluation and review

12.1 Annual Review

In accordance with condition D8 and as further described in section 6 of the EMS, Santos will review the performance and effectiveness of its groundwater management system for the previous calendar year and report the relevant results within the Annual Review, to the satisfaction of the Planning Secretary. The Annual Review will be submitted via the Major Projects Portal by the end of March each year and will, at a minimum provide the following information regarding:

- the effectiveness of the management measures to prevent, and if prevention is not reasonable and feasible, to minimise any impact to groundwater resources;
- the water extracted by the Project each year (direct and indirect), including water taken under each WAL as required by CoC B29; and
- any groundwater-related incidents or non-compliances.

Further, the annual review under consent condition D8 requires a number of items to be reviewed or assessed. In summary these are:

- monitoring results and complaints;
- non-compliances and incidents;
- compliance with performance measures and performance criteria;
- discrepancies between predicted and actual impacts; and
- measures to be implemented to improve environmental performance.

The Annual Review may also make recommendations for any additions, changes or improvements to the groundwater management process.

12.2 Independent environmental audits

Within one year of commencement of Phase 1 and every three years thereafter, Santos will commission an Independent Environmental Audit (**IEA**) of the operation, to be conducted in accordance with CoC D9. The audit team will be led by a suitably qualified auditor and include experts in groundwater, well integrity, hazards, and any other fields specified by the Planning Secretary.

The IEA process is further described in section 8.3 of the EMS.

12.3 Management Plan review and evaluation

As required by consent condition D4, Santos will review the suitability of existing strategies, plans and programs required under this consent, within two months of:

(a) the submission of an incident report;
(b) the submission of an Annual Review;
(c) the submission of an Independent Environmental Audit;
(d) the submission of a Field Development Plan;
(e) the submission of a Groundwater Model Update; or
(f) the approval of any modification of the conditions of this consent.

This is to ensure the GMP is updated on a regular basis and to incorporate any recommended measures to improve the environmental performance of the Project.

In view of the various conditions requiring annual reviews, suitability assessments and performance evaluations, this GMP will be reviewed and, if necessary, updated in at least the following circumstances:

- in accordance with any direction from the NSW EPA or the Minister administering the PO Act;
- before making any significant change to the management processes as described herein. If there is ambiguity in relation to whether there is a significant change, Santos will consult with the Planning Secretary to determine whether the GMP must be reviewed; and
- otherwise at intervals of no longer than one year.

The review history table in the front of this Plan provides the details of each review, conducted in accordance with condition D4.

As required by CoC D5, if the review under condition D4 determines that the strategies, plans and programs required under this consent require revision - to either improve the environmental performance of the development, cater for a modification or comply with a direction - then Santos will submit the revised document to the Planning Secretary for approval within 6 weeks of the review.

Further details on the reporting, evaluation and review of the GMP is provided in section 8 of the EMS.

12.4 Improvement measures

Santos will conduct a program to investigate and implement ways to improve the environmental performance regarding groundwater management over time, and implement a protocol for the periodic review of the suite of groundwater management plans, in accordance with CoC D3(g) and (i) respectively.

Measures to improve the environmental performance of the Project that will be implemented following review and evaluation include the following:

- audit of the groundwater management systems, and the review of current groundwater management measures;
- implementation of modifications to the groundwater management system; and
- additional monitoring and inspections.

The protocol for review is set out by consent conditions D8, D4 and D5, which have been addressed in sections 12.1 and 12.3 above.

In accordance with CoC D13 and as described in section 6 of the EMS, all relevant monitoring data and associated reports will be made available on the Project website, for the duration of the Project. This information will be kept up to date.

13. References

CDM Smith (2016a). *Narrabri Gas Project EIS Appendix F: Groundwater Impact Assessment*. Prepared for Santos Ltd.

CDM Smith (2016b). *GDE Impact Assessment*. Prepared for Santos Ltd.

DPI (2012) *NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities*. Department of Trade and Investment, Regional Infrastructure and Services. Publication Number 11445. ISBN: 978 1 74256 338 1

Drummond, B. (2013). *Background Paper on Seismicity*. NSW Chief Scientist and Engineer Review of Coal Seam Gas Activities in NSW.

Eco Logical Australia (2016), *Aquatic Ecology and Stygofauna Assessment*. Prepared for Santos NSW (Eastern) Pty Ltd.

GHD (2017). *Narrabri Gas Project Environmental Impact Statement*. Prepared for Santos Ltd.

Jacobs (2014) NGDP Hydrogeochemical Assessment of PEL238: Groundwater chemistry of the Narrabri Gas Project Area. Technical Report 1007419-5 for Santos Energy NSW 9 December 2014

Radke, B.M., Ferguson, J., Cresswell, R.G., Ransley, T.R. and Habermehl, M.A. 2000. Hydrochemistry and implied hydrodynamics of the Cadna-owie – Hooray Aquifer, Great Artesian Basin, Australia. Bureau of Rural Sciences, Canberra.

Welsh, W., Hodgkinson, J., Strand, J., Northey, J., Aryal, S., O'Grady, A., Slatter, E., Herron, N., Pinetown, K., Carey, H., Yates, G., Raisbeck-Brown, N. and Lewis, S. 2014. *Context statement for the Namoi subregion. Product 1.1 from the Northern Inland Catchments Bioregional Assessment*. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

14. Glossary

Term	Definition
Alignment	The line or lines that describe a linear-infrastructure route; it defines how linear infrastructure (such as a road, access track or pipeline) will be located in relation to the features encountered along the route
Alluvial	Sediments deposited following a decrease in velocity of flowing water
Alluvium	General term for unconsolidated fluvio-lacustrine deposits of inorganic materials (clay, silt, sand, gravel, and boulders) deposited following a decrease in velocity of flowing water
Alluvium aquifer	An aquifer formed within alluvium. See Alluvium.
Approved disturbance area	The disturbance areas shown in the EIS as modified by any approved Field Development Plan
Aquifer	A saturated permeable geologic unit that can transmit useful quantities of water
Baseline	A starting point used for future comparisons. Water baselines in context of the Narrabri Gas Project have been derived from long term water level and quality data presented in the Narrabri Gas Project Water Baseline Report.
Department	NSW Department of Planning and Environment (DPE)
Depressurisation	The extraction of coal seam water to facilitate gas production causes depressurisation of the target coal seams, which has the potential to propagate into surrounding formations.
Ecosystem	An interconnected biological community of organisms that interact with each other and their physical environment.
EIS	The Environmental Impact Statement titled Narrabri Gas Project Environmental Impact Statement, dated 31 January 2017, submitted with the development application, including the Applicant's response to submissions and supplementary response to submissions, and the additional information provided by the Applicant to the Department in support of the application
Exploration well	A petroleum well that is drilled to: a) Explore for the presence of petroleum or natural underground reservoirs suitable for storing petroleum, or b) obtain stratigraphic information for the purpose of exploring for petroleum. For clarity, an exploration well is not a production well
Feasible	Means what is possible and practical in the circumstances
Gas field infrastructure	All Project-related infrastructure, excluding the Leewood facility, Bibblewindi facility, Westport workers accommodation facility and the road upgrades required under SSD 6456
Gas well	Pilot wells and production wells
Gathering lines	Pipelines used to transfer gas and produced water from wells
Groundwater	Water contained in the interconnected pore spaces and voids of the saturated zone of sediments and rocks.
Groundwater dependent ecosystem	Ecosystems that have a species composition and natural ecological processes sustained to some extent by groundwater.
Groundwater level (or static / standing water level)	The depth to groundwater from some reference point (usually the natural surface)
Groundwater monitoring network	An arrangement of groundwater monitoring bores that is usually installed to monitor groundwater quantity and quality to inform how a groundwater system is responding to some applied stress, such as irrigation pumping and application, coal seam gas development, municipal water supply and climate

Term	Definition
	variability
Groundwater quality	A measure of groundwater value expressed in physio-chemical terms, such as acidity / alkalinity, dissolved oxygen, dissolved salts, ions and contaminants like hydrocarbons
Groundwater quantity	A measure of the amount of groundwater held within a groundwater system, usually expressed as groundwater head (elevation or pressure), volume or flux
Incident	An occurrence or set of circumstances that causes or threatens to cause material harm and which may or may not be or cause a non-compliance
InSAR	Interferometric Synthetic Aperture Radar - a radar technology used in geodesy and remote sensing to assess motion of ground surface over time
Linear infrastructure	Project related infrastructure of a linear nature including gas and water gathering lines, gas and water pipelines, access tracks, power lines, communication lines and other service lines
Major facilities	Leewood facility and Bibblewindi facility
Namoi Alluvium	The Upper Namoi Alluvium, an aquifer made of coarse-grained river gravels and sands. The Lower Namoi Alluvium, a hydrostratigraphic unit made of shallow alluvial fan deposits associated with the Namoi River. These units contain a significant resource of readily accessible, good quality groundwater that is heavily utilised for irrigation, public water supply, private water supply and livestock
Non-compliance	An occurrence, set of circumstances or development that is a breach of the SSD 6456 consent
Petroleum Assessment Lease 2 (PAL 2)	A PAL is required to hold the exclusive right to prospect for petroleum and to assess any petroleum deposit over a specified area of land in NSW. A lease allows the holder to maintain a title over a potential area, without having to commit to further exploration. The holder can, however, continue prospecting operations and to recover petroleum in the course of assessing the viability of commercial mining. • PAL 2 is held by Santos NSW Pty Ltd;
Petroleum Exploration Licence 238 (PEL 238)	Before exploring for minerals or petroleum in NSW, an explorer must first obtain a Petroleum Exploration Licence (PEL) under the *Petroleum (Onshore) Act 1991*. An exploration licence gives the licence holder exclusive rights to explore for petroleum or specific minerals within a designated area but it does not permit mining, nor does it guarantee a mining or production lease will be granted. PEL 238 is held by Santos NSW Pty Ltd;
Petroleum Production Lease 3 (PPL 3)	A petroleum production lease gives the holder the exclusive right to extract petroleum within the production lease area during the term of the lease. PPL 3 is held by the following titleholders: • Santos QNT Pty Ltd; • Santos NSW (Hillgrove) Pty Ltd; and • Santos NSW (Eastern) Pty Ltd;
Petroleum production lease application (PPLA)	A petroleum production lease gives the holder the exclusive right to extract petroleum within the production lease area during the term of the lease. Development consent under the *Environmental Planning and Assessment Act 1979* must be in place before a petroleum production lease can be granted. Santos, on behalf of its then joint venture partner lodged four petroleum production lease applications under the PO Act in May 2014 for the Project area, being PPLAs 13, 14, 15 and 16.

Term	Definition
	The ownership of the application is now held by Santos NSW Pty Ltd;
Pilot well	A well for gas and water extraction, for the purpose of exploration, appraisal and assessment of the gas field potential
Produced water	Any form of groundwater that is actively extracted from a borehole, well or excavation, excluding incidental groundwater mixed with drilling fluids
Production well	A well for gas and water extraction, for the purpose of commercial gas production and/or use
Project area	The area of approximately 95,000 hectares that encompasses the Project
Project footprint	The area of surface expression being about 1,000 hectares occupied by the infrastructure components of the Narrabri Gas Project
Project-related infrastructure	All infrastructure and other structures associated with the development. This includes linear infrastructure and non-linear infrastructure, surface infrastructure and subsurface infrastructure, major facilities, wells and well pads and other gas field infrastructure
Public infrastructure	Linear and related infrastructure that provides services to the general public, such as roads, railways, water supply, drainage, sewerage, gas supply, electricity, telephone, telecommunications, etc.
Reasonable	Means applying judgement in arriving at a decision, considering mitigation benefits, cost of mitigation versus benefits provided, community views and the nature and extent of potential improvements
Recharge spring	A spring supported by water that recharges sandstone sediments that outcrop on the margins of the Great Artesian Basin and discharge locally after relatively short residence times.
Spring	A naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the water table intersects the ground level.
Sediment	Particles derived from rocks or biological materials that have been transported by air or water
Sedimentation	Deposition or accumulation of mineral or organic matter deposited by air or water
Transmissivity	Rate in which water of a given density and viscosity is transmitted through a unit width of aquifer or aquitard under a unit hydraulic gradient.
Unacceptable risk	The level of risk at which mitigation actions are deemed to be warranted.
Water sharing plan	Legislated plans under the *Water Management Act 2000* that establish rules for sharing water between the environment and water users. Water licences are issued to water users in accordance with water sharing plans
Well	Pilot wells and production wells
Well pad	An area of up to 1 hectare in size upon which the gas wells are to be located, with the area decreasing to no more than 0.25 hectares following rehabilitation[5], or other area as may be approved in the Field Development Plan

[5] Workover activities will be contained within the operational area of the well pad area of around 0.2 ha, with an additional laydown area that could be approximately 0.2 ha in size.

Appendix A - Consultation records

Santos

Management Plan Consultation Feedback Form

DOCUMENT TITLE:	• **Groundwater Management Plan (Phase 1)** • **Groundwater Modelling Plan (Phase 1)** • **Groundwater Monitoring Plan (Phase 1)** • **Groundwater Baseline Report (Phase 1)**
STAKEHOLDER:	**New South Wales – Environment Protection Authority**
CONSULTATION RELEASE DATE:	
COMMENTS DUE DATE:	**7 February 2022**

General Feedback	
Key Issues	**Groundwater Management Plan:**
	Tullamullen groundwater monitoring site is nominated as a Level 2 investigation trigger in the Groundwater Management Plan. The Tullamullen groundwater monitoring site is known to have cumulative impacts from underground mining operations. It is noted that additional monitoring bores are proposed in the Napperby and Digby formations that would make suitable alternatives.
Suggestions for improvement	**Groundwater Monitoring Plan:**
	Suggest integrating new Government Coal Basin Monitoring Bores into Groundwater Monitoring Plan and Groundwater Modelling Plan. Table 4.1 in the Groundwater Monitoring Plan needs updating now that DPE Monitoring Bores have been constructed.
	Groundwater Baseline Report:
	Data presented extends up to July 2020. Report signed off December 2021. Further baseline data is available.

Plan	**Section**	**Specific Feedback** *Detail specific issues with certain sections in the document*
Groundwater Management Plan	8.4.2	The Tullamullen groundwater monitoring sites are known to monitor cumulative impacts from nearby underground mining operations and is outside the EPL Boundaries. It is noted that additional monitoring targeting interburden layers (Napperby and Digby) would make suitable targets for triggers once monitored and modelled into trigger points.
Groundwater Baseline Report	Chapter 3 introduction	While the instrumentation of Nyora groundwater monitoring site has ceased, the monitoring bores themselves have not been decommissioned.

Management Plan Consultation Feedback Form

Page 1 of 1

NSW GOVERNMENT

Department of Planning and Environment

David Gornall
Email: David.Gornall@santos.com

Contact: DPE Water Assessments
Email: water.assessments@dpie.nsw.gov.au
Our ref: OUT22/1852

4 March 2022

Dear Mr Gornall

Re: Narrabri Gas Groundwater Management Plans (SSD-6456)

I refer to your email of 7 December 2021 to the Department of Planning and Environment (DPE) Water about the above matter.

The Department of Planning and Environment - Water (DPE-Water) has reviewed the Groundwater Management Plans and recommends some improvements to the plans, in particular the Water Quality Performance Measure, Water Level Performance Measure, Water Take Performance Measure and recognition of structural geology in the groundwater model conceptualisation and uncertainty.

Should you have any further queries in relation to this submission please do not hesitate to contact DPE Water Assessments at water.assessments@dpie.nsw.gov.au.

Yours sincerely,

Mitchell Isaacs
Chief Knowledge Officer
Department of Planning and Environment - Water

4 Parramatta Square, 12 Darcy Street, Parramatta NSW 2150 | Locked Bag 5022, Parramatta NSW 2124 | dpie.nsw.gov.au

Attachment A

Detailed advice regarding the Narrabri Gas Groundwater Management Plans (SSD-6456)

1.0 Water Quality Performance Measure

1.1 Recommendation

- Performance measures need to include water quality targets for all on-lease monitoring bores screened in the Great Artesian Basin (GAB) formations and a commitment to on-going water quality monitoring.
- Performance measures for Gunnedah Oxley Basin Napperby and Digby Formations must be established from a representative baseline dataset prior to potential influences of Phase 1 expansion in Pilot wells, or failing this due to project timeframes, a statistical based steady trend in water quality be adopted as the performance measure.

1.2 Explanation

The Groundwater Monitoring Plan Section 3.3 states "*if the groundwater quality monitoring is consistent after 3 years or at least 6 samples have been taken (whichever is later), no further samples will be collected*".

The view that water quality risk is negligible needs to be substantiated through on-going monitoring. The conceptualisation that stratigraphic units in the Permo-Triassic sequence above the target the coal seams are hydrologically isolated from in the GAB needs demonstration from observation data, including both water level and water quality trends.

Elevated methane is reported in the geological formations that directly underlie the GAB, and within the GAB itself. These elevated methane levels suggest increased hydrological connection between the target coal seams of the Permo-Triassic Gunnedah-Oxley Basin (GOB) and the overlying GAB. These methane results conflict with the Santos' conceptualisation of hydrological isolation between the deeper target coal seams of the Permo-Triassic sequence with the overlying GAB. Geological features like folds and faults and the potential for increased hydrological connection between geological layers should form part of the Phase 1 groundwater impact evaluation.

The Groundwater Baseline report shows an off-lease monitoring bore (TULPRNAP01) with methane up to 20 mg/L detected in the Napperby Formation and 6.8mg in the Digby Formation. These are Triassic units, i.e. no coal. On-lease there are two bores (BHN14PRUPS02 and DWH14PRPUR03) screened in the GAB formations with methane concentrations exceeding 4.6 mg/L. At a level of 28 mg/L the water is considered fully saturated with methane and if there was a bore/well, the air space in the well is approaching the lower explosive limit. The presence of elevated methane is an indicator for potential conduit between geological layers that warrants ongoing monitoring as extraction increases.

The current closest bore (BWD6) to existing Phase 1 activities that is screened in the GOB was not monitored for water quality. There has been no water quality monitoring undertaken in the GOB formations in proximity to Phase 1 activities that would inform future trends during Phase 1 extraction. The baseline Water Management Plan (WMP) does not meet the requirements of the NSW Aquifer Interference Policy (AIP) in this respect.

Additionally, as peak extraction for Phase 1 is modelled to occur in Year 2, and as there is no current baseline data available on water quality in the GOB for bores close to Phase 1 activities, and as 3 years of data is required (Groundwater Management Plan p.44) to set a representative baseline dataset, the peak of extraction is modelled to have already occurred. This will compromise interpretations of impact change when establishing a performance target used to

evaluate if Santos activities have resulted in a change from baseline conditions. This issue must be reconciled prior to establishing performance targets for GOB Napperby and Digby formations.

DPE Water considers that cessation of water quality monitoring does not support the improved understanding risk of water quality changes with increasing groundwater take. It is noted that there are several GAB monitoring bores in proximity to Phase 1 activities that hold sufficient baseline data to move forward with establishing performance targets. However, the Draft WMP proposes that monitoring would be ceased. The monitoring bore sites screened in the GAB formations in proximity to Phase 1 Pilot Wells include:

- BDW26PRUPS01, BDW26PRLPS02,
- BWD27PRUPS02 BWD27PRLPS03
- BWD28QGLPS01, BWD28QGPUR01

To meet the objectives of the WMP water quality monitoring should continue in order to identify particular trends such as changes in methane. As a minimum, water quality performance measures must be established for the GAB aquifers that satisfy the 3 years or 6 samples minimum baseline data requirements documented in the Groundwater Management Plan. The baseline WMP does not comply with the NSW AIP and should be revised.

2.0 Water Level Performance Measure

2.1 Recommendation

- Performance measures need to include water level targets for all on-lease monitoring bores screened in the GAB formations.

2.2 Explanation

Santos reports they hold a total of 23 monitoring bores comprising:

- 16 screened in the GAB (8 of which are located on-lease and 3 of those are located in proximity to Phase 1 activities).
- 2 screened in the GOB
- 5 alluvial bores (privately owned bores)

The Draft WMP Performance Measure for water levels is a water level decline >0.5m in the Digby or Napperby Formations of the GOB. However, the only GOB screened bore (BWD6) in proximity to Phase 1 activities is reported in the Groundwater Baseline Report to be screened in the Porcupine Formation, not the Digby or Napperby Formations as the defined performance measure. The only other on-lease GOB monitoring bore is DWH8AQ which similarly is not screened in the Digby or Napperby Formations and there are no hydrographs available in the Groundwater Baseline Report. Logger failure is reported for Maules Formation at this bore site and may be the reason. Essentially, the WMP Level 2 performance proposes a management control which cannot be triggered due to the absence of relevant monitoring.

Santos proposes several nested monitoring bores sites to be constructed in 2022, including two of which will be screened in the Digby Formation in proximity to Phase 1. However, it is also reported that 3 years of baseline monitoring is required prior to consideration of establishing a performance measure. Figure 3-1 in the Groundwater Modelling Report presents modelled take, the peak of which occurs in Year 2, diminishing thereafter. It is apparent that any baseline data captured for the nominated bores may well be compromised and biased by extraction activities prior to establishment.

Representative water level targets must be established at sites with baseline data. This only applies to GAB monitoring bores as these have baseline monitoring results on-lease and in proximity to Phase 1 activities and predicted not to be impacted.

3.0 Water Take Performance Measure

3.1 Recommendation

Performance measures for water take proposed in the WMP should apply only to those appraisals proposed to date (as opposed to that permissible for Phase 1). Any increase of appraisal would require an update of the WMP to the satisfaction of the Secretary.

3.2 Explanation

A Level 1 trigger for Phase 1 is broadly described as occurrence of greater than expected volume of water extracted from the coals.

The year by year cumulative take up to year 25 for Phase 1 is presented in Table 8.4 of the Groundwater Management Plan. The management response to an exceedance is to initiate an immediate review of the groundwater model in accordance with the Groundwater Monitoring Plan, to establish whether the model should be immediately reviewed and potentially updated to reflect the new information provided by the trigger. That is, if the annual take exceeds the figures in Table 8.4 for the respective year of operation, then an update of the model will be considered.

Section 3.2 of the Groundwater Modelling Plan informs the modelled take is based on 25 pilot wells for Phase 1 with a peak take of 1.26 ML/d and the 2.9 GL over 25 years. There is a disparity (e.g 5 existing and 6 proposed pilot wells as opposed to the 25 modelled) for setting a performance measure.

It is highly plausible that prior to year 25 the application for Phase 2 will proceed. The cumulative take of water for 11 wells is likely to be much lower than the modelled 25. Uncorrected, the conclusion could be misrepresented that Phase 1 cumulative water take is trending considerably less than modelled at any given year lending support for minimal groundwater impact with Phase 2 expansion. The ramifications when upscaling to 850 wells would be a major risk if not based on comparative pilot wells.

4.0 Recognition of structural geology in the groundwater model conceptualisation and uncertainty

4.1 Recommendations

- Provide a timeline on how Phase 1 relates to Phase 2 and ensure the activities to inform the WMP and modelling plan for Phase 2 are approved prior to the start of Phase 2 and have sufficient time to be scoped and completed to meet the requirements of consent. Noting:
    a. a minimum of two years baseline is required on the monitoring locations to be used for Phase 2.
    b. additional monitoring to that proposed for Phase 1 will be required for Phase 2 to inform TARPS.
    c. the timeline needs to allow for scoping of the modelling requirement with DPE Water, agreement on the conceptualisation and development of the groundwater model.
- Define how Phase 1 WMP will investigate the geological structures that may influence hydrological connection between geological layers of the Gunnedah-Oxley Basin (GOB) and GAB that could result in preferential pathways for impacts. Elevated methane levels in geological layers above the coal seams and in the GAB itself have been identified from the baseline water quality monitoring. The results infer the potential for more enhanced hydrological pathways between geological layers than that currently conceptualised and warrant consideration in the design of the WMP prior to the large-scale expansion of Phases 2 and 3.

To improve confidence in the groundwater model predictive capacity leading into Phases 2 and 3, Phase 1 needs to demonstrate that either:

i. there are no structural features of significance within the Santos lease area warranting the need to explore uncertainty in Santos conceptualisation of hydrological isolation between the GAB and GOB;

or

ii. appraisal of known structural features with pilot wells and monitoring in proximity to these features.

Unless this uncertainty can be reconciled as part of Phase 1 investigations, the updated groundwater model comprising some additional calibration coincident with short-term transient conditions (extraction), will face significant challenges in meeting the Class 3 requirement specified in condition B39 (e). That is; as stated in Table 2-1 of the Australian Groundwater Modelling Guidelines, Class 3 requirement incorporates spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.

- Provide more detailed information on quality assurance procedures to demonstrate quality assurance.
- Provide detail on the program of formation characterisation and in-situ-permeability testing to improve hydraulic conductivity estimates.

4.2 Explanation

The WMP does not present any detail on geological structures that may influence hydrological connection between geological layers of the GOB and GAB. The spatial relationship between the location of the monitoring bores, pilot wells and any geological features of folds, faults and lineaments that may alter the model conceptualisation is not reported.

Elevated methane levels in geological layers above the coal seams and in the GAB itself have been identified from the baseline water quality monitoring. The results infer the potential for more enhanced hydrological pathways between geological layers than currently conceptualised and warrant consideration in the design of the WMP prior to the large-scale expansion of Phases 2 and 3.

The proponent must present spatial information of the known structural geology relative to Santos' existing and proposed pilot sites and their monitoring program demonstrating how such uncertainty in the model conceptualisation will be refined through measurable assessment criteria during Phase 1 activities.

End Attachment A

Department of Planning and Environment

Our ref: OUT22/19778

Wayne Jones

Dept Planning & Environment – Planning & Assessment

Email: wayne.jones@dpie.nsw.gov.au

8 November 2022

Subject: **Narrabri Gas Groundwater Management Plan - Revision 0D, 17 October 2022 (SSD-6456-PA-37)**

Dear Wayne Jones,

I refer to your request for advice received on 25/10/2022 to the Department of Planning and Environment (DPE) Water about the above matter.

The Department of Planning and Environment- Water considers the revisions made to the Groundwater Management Plan (GMP) have addressed most of DPE Water's comments on the previous version. Two recommendations prior to approval of the plan are included in this response. These relate to setting the Phase 1 Level 2 triggers prior to water extraction from new pilot wells, and revising the monitoring network to address potential limitations should issues with interpretation arise. Ongoing consultation with DPE Water to inform groundwater monitoring and modelling during Phase 1 implementation and preparation for Phase 2 is supported.

Please note detailed advice in Attachment A.

Should you have any further queries in relation to this submission please do not hesitate to contact DPE Water Assessments at water.assessments@dpie.nsw.gov.au

Yours sincerely,

Mitchell Isaacs

Chief Knowledge Officer
Department of Planning and Environment: Water

4 Parramatta Square, 12 Darcy Street, Parramatta NSW 2150
Locked Bag 5022, Parramatta NSW 2124

www.dpie.nsw.gov.au

Attachment A

Detailed advice regarding the Narrabri Gas Groundwater Management Plan (SSD-6456-PA-37) – Revision 0D, 17 October 2022

1.0 Monitoring and performance measures

1.1 Recommendation – Prior to plan approval

That the Groundwater Management Plan (GMP) state the Phase 1 Level 2 triggers will be set prior to extraction from any new pilot wells proposed under Phase 1.

1.2 Explanation

Consultation with the proponent since DPE Water's last submission on this plan clarified that the Groundwater Management Plan and the objectives for monitoring are developed commensurate to risk of impact with Phase 1 alone. The proponent has advised the performance target for groundwater drawdown (Level 2 trigger) can be set prior to the capture of 3 years of baseline data. A Water Technical Advisory Group representative suggested this reference trigger level could be established when pressure levels have stabilised after construction of the new monitoring bores, based on the presumption there are currently no other stresses. This position is acknowledged and accepted by the proponent and DPE Water.

1.3 Recommendation – Prior to plan approval

That the monitoring bore network used for setting trigger levels be revised based on the following:

- The GMP commits to increase the spatial representation of Gunnedah Oxley Basin (GOB) monitoring bores for trigger levels, with two sites set in proximity to the Phase 1 pilot wells (one near the existing wells and another at the proposed new cluster of pilot wells).
- That a third or fourth monitoring bore site would be highly beneficial when clustered with the existing Great Artesian Basin (GAB) monitoring bores. Several monitoring bores targeting the GAB bores are located between the existing and proposed pilot wells and have 10-years groundwater level data. However, DPE Water acknowledges the negotiated position between low likelihood of an impact being detected during Phase 1 and the financial commitment to increase the network during the appraisal stage.
- That the proponent continues water quality monitoring throughout the life of the project with performance triggers of electrical conductivity and methane concentrations forming a Level 3 target. The Level 3 target would be set for the GAB only and in consultation with DPE Water.

1.4 Explanation

Additional monitoring sites would help address limitations should an issue be detected at one or both monitoring bores. The ability to interrogate and compare the observations with another representative site could be constrained by the current large distances between the monitoring bores that target the GOB Digby/Napperby Formation.

In the event of a Level 2 trigger exceedance the proponent has acknowledged that they will carry an increased risk of dispute with interpretation given limited sites and baseline dataset.

1.5 Recommendation – post plan approval

That the proponent commits to consult with DPE Water on the monitoring and modelling requirements to support any future assessment of impact for Phase 2. The reviewed documents are appropriate to the risk associated with Phase 1 of the project only.

That the proponent includes an evidenced based process for assessment of impact for Phase 2 to substantiate the proponent's presumption that faulting in the area is 'restrictive of groundwater flow' and 'negligible' where major faulting and/or displacement is identified during the proposed seismic work.

1.6 Explanation

To support an application for Phase 2, further consultation will be necessary to ensure each of the conditions of approval can be satisfactorily addressed commensurate to the increased risk. Descriptive methods of model development, information requirements, a program of works and collation of evidence based supporting data would need to be expanded upon from that documented for Phase 1.

Condition B39 sets out the requirement for model development and uncertainty analysis in the numerical groundwater model. Whilst the position of the GMP is to satisfy monitoring and reporting requirements for Phase 1 scope of works, it also documents the process to identify any knowledge gaps, uncertainties and plausible alternative conceptual models for investigation in Phase 2.

> The GMP states: *"Most faulting within the Project area is considered to be compressional and is believed to be associated with closure of the Bowen-Gunnedah-Sydney basinal system during the Middle Triassic. Multiple lines of evidence indicate most known faulting within the Project area is small scale and tight, hence restrictive of groundwater flow. Any potential impacts to groundwater flow due to faulting is currently considered to be negligible. Larger, possibly transmissive faults do occur on the margins of the basin and coincide with hydrostatic breaks and connections and these breaks have been included in the numerical groundwater model. There is no evidence that deep, Permo-Triassic faults extend into the overlying formations within the Project area".*

The GMP presents six stages for review of the model in preparation for Phase 2. Stage three of the six stages presents the field data collection program. However, it is not transparent how the relative location of proposed works under Stage 3 contributes to the assessment of structural features and the assessment for hydrological connection across the GOB and GAB. CSIRO has concluded that there is little evidence of mixing of groundwater in the southern area of the Santos lease, but as noted in DPE Water's prior advice, structural influences increase towards the northern portion of the lease with evidence of some mixing. It is noted the Stage 3 field data collection program does not appear to cover the area identified by CSIRO where there is evidence of groundwater mixing due to structural influences. The work must also cover this area. If the program of works proposed under Stage 3 are not located close to known structural features, it is unclear how the presumption that faulting is *'restrictive of groundwater flow'* and *'negligible'* will be substantiated.

End of Attachment A

Groundwater Management Plan - EPA comments received on Revision A (draft)

Item	Section #	Section heading	Existing text	Comment	Final response
Groundwater Management Plan					
1	General	N/A	No specific text reference.	Tullamullen groundwater monitoring site is nominated as a Level 2 investigation trigger in the Groundwater Management Plan. The Tullamullen groundwater monitoring site is known to have cumulative impacts from underground mining operations. It is noted that additional monitoring bores are proposed in the Napperby and Digby formations that would make suitable alternatives.	Noted. No specific response required
2	8.4.2	Level 2 trigger levels	Nominated groundwater bores used to monitor groundwater pressures in the Gunnedah Basin formations are shown on Figure 8.1 of the Groundwater Management Plan. Bores proposed to monitor the GOB are currently established at the locations: GW-971623, DWH8A and TUL sites. Sites BHN1S, BWD6, DWH9 and DWH43 will be established as nested sites during 2022. Additional information for these sites is provided in the Groundwater Monitoring Plan.	The Tullamullen groundwater monitoring sites are known to monitor cumulative impacts from nearby underground mining operations and is outside the EPL Boundaries. It is noted that additional monitoring targeting interburden layers (Napperby and Digby) would make suitable targets for triggers once monitored and modelled into trigger points.	Noted. The development and monitoring of new bores is designed to support the exploration and appraisal activities of Phase 1 and provide additional data to support further development of the groundwater model, as defined in the Groundwater Modelling Plan.
Groundwater Monitoring Plan					
1	4.2	Groundwater monitoring network status	Table 4.1 - Summary of groundwater monitoring points for Phase 1 of the Project	Suggest integrating new Government Coal Basin Monitoring Bores into Groundwater Monitoring Plan and Groundwater Modelling Plan. Table 4.1 in the Groundwater Monitoring Plan needs updating now that DPE Monitoring Bores have been constructed.	The bore locations will be assessed and where relevant, will be incorporated into the next version of the relevant plan, when revised and updated.
Groundwater Baseline Report					
1	N/A	N/A	General comment	Data presented extends up to July 2020. Report signed off December 2021. Further baseline data is available.	The report is the latest and most up to date. DPE bores do not have any further data. The GBR provides a set point in time which will be used for annual reporting purposes.
2	3	Groundwater baseline data – pressure and levels	All listed bores satisfy the criteria for baseline data (at least three years of quality assured monitoring data) with the exception of NYOPRORA01 (targeting the Orallo Formation), NYOPRUPS02 (Upper Pilliga Sandstone), BWD6 (Porcupine) and DWH8AQGMCF04 (Maules Creek Formation). These bores suffered instrumentation failure and were decommissioned as monitoring bores in 2017. These targets will be recommissioned as part of the Phase 1 bore monitoring program.	While the instrumentation of Nyora groundwater monitoring site has ceased, the monitoring bores themselves have not been decommissioned.	The wording has been amended as follows, to clarify that the monitoring bores have not been decommissioned: … These bores suffered instrumentation failure, *which was decommissioned* ~~and were decommissioned as monitoring bores~~ in 2017. These targets will be recommissioned as part of the Phase 1 bore monitoring program.
Groundwater Modelling Plan					
				No comments provided on the Groundwater Modelling Plan	

Groundwater Management Plan – DPE Water comments received on Revision A (draft)

Item	Plan	Section heading	Existing text	Comment	Final response
1	GMP	Water Quality Performance Measure	"….if the groundwater quality monitoring is consistent after 3 years or at least 6 samples have been taken (whichever is later), no further samples will be collected".	Performance measures need to include water quality targets for all on-lease monitoring bores screened in the Great Artesian Basin (GAB) formations and a commitment to on-going water quality monitoring.	Santos can remove the commitment to cease groundwater quality monitoring throughout Phase 1, even after baseline has been established. Groundwater quality monitoring will continue throughout Phase 1. The performance criteria, comprising monitoring and evaluation of both coal seam water production (volume) and groundwater pressures in the deeper GOB formations (adjacent to the coals) are the best tool for assessing groundwater connectivity and the adequacy of the groundwater model in predicting short and long-term risk to shallower, high value aquifers. The performance criteria provide an early warning of any potential current or future impact, including demonstration that water quality performance measures are being achieved. This is because the first measurable indication that impact predictions are incorrect would be an excess of coal seam water production (water volumes) or greater groundwater drawdown immediately adjacent to the coals. The potential for impact on groundwater quality due to CSG water extraction is negligible. This is because changes in shallow aquifer groundwater quality could only occur after sustained period of coal seam water production or groundwater drawdown far in excess of that predicted/allowed. Direct measurement of these attributes is a suitable method for determining the risk of impact to shallow aquifers is negligible. This lack of potential for impact in this case is substantiated by monitoring, and not a "view that water quality risk is negligible (Section1.2, para 2)" per se. If all the drawdown is demonstrably constrained to the GOB, connectivity of the upper GOB with the GAB is inconsequential. If the drawdown in the GOB is greater than predicted, the GMP and the performance criteria will be updated (in consultation various stakeholders) and may then include water quality performance criteria for GAB aquifers if necessary.
2				Performance measures for Gunnedah Oxley Basin Napperby and Digby Formations must be established from a representative baseline dataset prior to potential influences of Phase 1 expansion in Pilot wells, or failing this due to project timeframes, a statistical based steady trend in water quality be adopted as the performance measure.	
3	GMP	Water Level Performance Measure	No specific text reference.	Performance measures need to include water level targets for all on-lease monitoring bores screened in the GAB formations.	The performance criteria, comprising monitoring and evaluation of both coal seam water production (volume) and groundwater pressures in the deeper GOB formations (adjacent to the coals) are the best tool for assessing groundwater connectivity and the adequacy of the groundwater model in predicting short and long-term risk to groundwater and shallower, high value aquifers. The performance criteria provide an early warning of any potential current or future impact, including demonstration that groundwater level performance measures are being achieved. This is because the first measurable indication that impact predictions are incorrect would be an excess of coal seam water production (water volumes) or greater groundwater drawdown immediately adjacent to the coals. Direct measurement of these attributes is a suitable method for determining the risk of impact to shallow aquifers achieves the performance measures articulated in the CoC B37 (Table 7). If all the drawdown is demonstrably constrained to the GOB, connectivity of the upper GOB with the GAB is inconsequential. If the drawdown in the GOB is greater than predicted, the GMP and the performance criteria will be updated (in consultation various stakeholders) and may then necessarily include performance criteria for GAB aquifers.
4	GMP	Water Take Performance Measure	No specific text reference.	Performance measures for water take proposed in the WMP should apply only to those appraisals proposed to date (as opposed to that permissible for Phase 1). Any increase of appraisal would require an update of the WMP to the satisfaction of the Secretary.	The relevant performance criteria articulated in the GMP (Section 8.4.1, Table 8.4) relates to all CSG wells that will be operated by Santos during Phase 1 of the NGP. This includes newly constructed wells, as well as operation of existing CSG wells. Any increase in the proposed number of appraisal wells, and therefore the predicted volume of water, would trigger an update of the GMP. Such an update would be needed to accommodate an increase the volumetric performance criterion for coal seam water production. It would be more critical to review relative water production if, for any reason, fewer wells were operating than expected. Throughout Phase 1, this will be assessed as stipulated in Section 11 of the GMP (e.g. within 2 months each Annual Review).

Item	Plan	Section heading	Existing text	Comment	Final response
5	GMP	Recognition of structural geology in the groundwater model conceptualisation and uncertainty	No specific text reference.	Provide a timeline on how Phase 1 relates to Phase 2 and ensure the activities to inform the WMP and modelling plan for Phase 2 are approved prior to the start of Phase 2 and have sufficient time to be scoped and completed to meet the requirements of consent. Noting: (a) a minimum of two years baseline is required on the monitoring locations to be used for Phase 2. (b) additional monitoring to that proposed for Phase 1 will be required for Phase 2 to inform TARPS. (c) the timeline needs to allow for scoping of the modelling requirement with DPE Water, agreement on the conceptualisation and development of the groundwater model.	The purpose of the GMP is to articulate monitoring and management of groundwater impacts during Phase 1. Santos cannot proceed with Phase 2 unless the Phase 2 WMP has been approved. The role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model and WMP. It is our expectation that advice received from WTAG members, including DPE-Water, will ensure that Santos has sufficient time to meet the requirements of consent.
6	GMP	Recognition of structural geology in the groundwater model conceptualisation and uncertainty	No specific text reference.	Define how Phase 1 WMP will investigate the geological structures that may influence hydrological connection between geological layers of the Gunnedah-Oxley Basin (GOB) and GAB that could result in preferential pathways for impacts. Elevated methane levels in geological layers above the coal seams and in the GAB itself have been identified from the baseline water quality monitoring. The results infer the potential for more enhanced hydrological pathways between geological layers than that currently conceptualised and warrant consideration in the design of the WMP prior to the large-scale expansion of Phases 2 and 3. To improve confidence in the groundwater model predictive capacity leading into Phases 2 and 3, Phase 1 needs to demonstrate that either: (i) there are no structural features of significance within the Santos lease area warranting the need to explore uncertainty in Santos conceptualisation of hydrological isolation between the GAB and GOB; or (ii) appraisal of known structural features with pilot wells and monitoring in proximity to these features.	The purpose of the GMP is to articulate monitoring and management of groundwater impacts during Phase 1, in accordance with COC. Investigations which are planned to improve model confidence prior to Phase 2 are summarised in the GMP (Attachment 3 - Groundwater Modelling Plan, Section 5.2 “Connectivity Studies Prior to Phase 2). The role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model and WMP. The planned investigations which will be executed during Phase 1 were developed in consultation with the WTAG and prior to submission of the GMP for review by the WTAG and DPE-Water. It is our expectation that advice received from WTAG members, including DPE-Water, helps Santos to ensure it has sufficient information to update and improve the groundwater model prior to Phase 2.
7	GMP	Recognition of structural geology in the groundwater model conceptualisation and uncertainty	No specific text reference.	Provide more detailed information on quality assurance procedures to demonstrate quality assurance.	It is not clear what this comment is specifically in relation to. In relation to monitoring quality assurance, refer to the GMP (Attachment 1 - Groundwater Monitoring Plan, Sections 3-5). The plan will be updated to reflect the fact that Santos proposes to use suitably qualified people to undertake monitoring, following best practice and relevant monitoring standards (e.g. *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (Department of Environment and Science Government, 2009) and *AS/NZS 5667.11:1998 Water quality – Sampling Part 11: Guidance on sampling of groundwaters* (Standards Australia, 1998). In relation to groundwater modelling quality assurance, refer to the GMP (Attachment 3 - Groundwater Monitoring Plan, Section 2). Santos proposes to use suitably qualified people to undertake groundwater modelling, following best practice and relevant modelling standards (e.g. *Australian Groundwater Modelling Guidelines* (NWC, 2012). Furthermore, the role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model. The development of the groundwater model during Phase 1 will be developed in consultation with the WTAG, including DPE-Water.
8	GMP	Recognition of structural geology in the groundwater model conceptualisation and uncertainty	No specific text reference.	Provide detail on the program of formation characterisation and in-situ-permeability testing to improve hydraulic conductivity estimates.	The purpose of the GMP is to articulate monitoring and management of groundwater impacts during Phase 1, in accordance with CoC. Investigations which are planned to improve model confidence prior to Phase 2 are summarised in the GMP (Attachment 3 - Groundwater Modelling Plan, Section 5.2 “Connectivity Studies Prior to Phase 2). The role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model and WMP. The planned investigations which will be executed during Phase 1 were developed in consultation with the WTAG and prior to submission of the GMP for review by the WTAG and DPE-Water.

Groundwater Management Plan Suite (Revision A) – DPE Water comments reconciliation

Overarching response comments:

DPE-Water Engagement with the WTAG

The role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model and WMP.

To facilitate preparation of the various management plans under the WMP, Santos has established a workflow comprising an initial introduction to each plan by Santos, a scheduled period of plan review by members, and then member submission of written feedback to Santos.

Following receipt of member feedback, any technical matters are discussed with all members of the WTAG at scheduled WTAG meetings. Santos discusses its proposed responses to feedback with all members, seeking broad endorsement from the members where possible. Members are then requested to review and comment on a final copy of Santos' written response to the written feedback received by members.

DPE-Water and WTAG members received a copy of the Groundwater Management Plan (GMP) on 7 December [2021]. The Chairperson of the WTAG asked members to provide feedback to Santos by 7 February [2022] and attend a WTAG meeting on 15 February [2022] to discuss that feedback. The meeting to discuss member feedback on the GMP was held on 18 February [2022]. It is unfortunate that the feedback on the GMP received from DPE-Water, received on 4 March [2022], has not been received in accordance with the schedule of WTAG meetings and therefore could not be discussed at those meetings.

DPE-Water representatives of the WTAG are proven experienced and knowledgeable technical experts in groundwater resource management and impact assessment. It is Santos' hope that DPE-Water representatives on the WTAG are sufficiently resourced so that they can engage with the WTAG to ensure that the Chairperson, Santos, and all members of the WTAG fully understand any technical matters raised on behalf of DPE-Water.

Terminology

Detailed advice regarding the NGP Groundwater Management Plan (SSD-6456) (Attachment A) provides advice following a review of the Groundwater Management Plan (GMP) for Phase 1 of the NGP.

The covering letter refers to the GMP received by DPE Water on 7 December [2022]. Attachment A refers to both the GMP and the WMP (Water Management Plan). For the purpose of our response, we have assumed any reference to the WMP is a reference to the GMP.

Attachment A recommends some improvements to the plan, in particular various performance measures. However 'performance measures' are articulated by the Conditions of Consent of NGP SSD 6456 (CoC), Condition B37 (Table 7) and cannot be amended. For the purpose of our response, where Attachment A refers to "performance measures", we interpret that to mean "performance criteria".

For context, the CoC Condition 41(d)(iv) requires that the GMP includes "detailed performance criteria, including trigger levels for identifying and investigating any potentially adverse impacts associated with the development, on…" the various groundwater values and "a program to monitor and evaluate…compliance with the relevant performance measures listed in Table 7, and the performance criteria established above".

Presence of methane

Section 1.2 and Section 4.2 of Attachment A [of the DPE Water consultation comments] assert that groundwater methane monitoring results provide evidence of potential connectivity that warrants ongoing monitoring as extraction increases.
There are many sources of methane within geological basins. The inference that coal is the only requisite for the presence of methane is incorrect. Under the correct conditions, thermogenic methane gas is produced within mud rock sediments for example. This may therefore include younger sediments of the GOB which are not necessarily hydraulically connected to the target coal seams of Phase 1 of the NGP.

Multiple lines of evidence will continue to be assessed throughout Phase 1 to inform groundwater modelling improvements prior to Phase 2. The GMP (Attachment 3 - Groundwater Modelling Plan, Section 5) commits to assessing all available evidence prior to development of the Phase 2 groundwater model.

A recent publication by GISERA (March 2022) assessed the same dissolved methane groundwater data discussed in Attachment A in the context of determining hydraulic connectivity across the NGP area. The publication does not report any evidence of connectivity between deeper formations of the GOB (i.e. the Maules Creek Coal which is the target coal during Phase 1) and the GAB. The report concludes that there may be some evidence of localised connectivity between the shallow GOB and the basal units of the GAB. This finding does not invalidate the performance criteria proposed in the GMP as a means of demonstrating the NGP achieves the performance measures.

Requirement to comply with the NSW AIP

Section 1.2 concludes that the WMP 'does not meet/comply with the requirements of the NSW AIP (para 5; para 8). The GMP has been prepared in order to comply with the CoC. Santos has already been granted right to extract groundwater in accordance with the NSW AIP, and therefore it is not clear how the AIP necessarily applies.

We note that the purpose of the AIP is to clarify requirements for obtaining water licences under NSW legislation and assists in the application and assessment of aquifer interference activities being applied for.

Section 2 of the AIP describes that "Water access licences are not to be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken under the licence".

CoC Condition B39(f)(vi) requires that the NGP does not exceed the minimal harm considerations of the AIP (DPI, 2012). In this regard, the minimal harm considerations of the AIP will not be exceeded if the performance measures articulated in the CoC B37 (Table 7) are achieved. Further, the GMP states that the water extraction volumes from the GOB, which were authorised under the AIP, will not be exceeded.

Groundwater Management Plan – WTAG comments received on Revision A (draft)

Comments received from Randall Cox, Jack Warnock and Michael Williams

Item	Section #	Section heading	Existing text	Comment	Final response
1	General	N/A	No specific text reference.	**[Jack Warnock]** The Plan outlines the process for measuring groundwater extraction, drawdown and subsidence in the Project area. Making this information available will be an important part of monitoring the impact of the Project on the local groundwater systems. There is no doubt that monitoring of subsidence will be important to inform the impact on the Project Area of the gas and water extraction. This information will need to be presented in a form which is readily understood and digested.	Section 9 describes: In accordance with CoC D13, CoA 7, and as described in section 6 of the EMS, all groundwater monitoring data and associated reports will be made available on the Project website, for the duration of the Project.
2	General	N/A	No specific text reference.	**[Jack Warnock]** The existing Groundwater environment describes the climate and recharge; Geology, Subsidence and seismicity, aquifers and aquitards, hydraulic properties, groundwater levels and pressures and quality, together with natural methane leaks and accumulation and so on. As a general observation, this document is highly technical and sometimes difficult to understand. In particular, the Technical Report "InSAR Analysis of Baseline Ground Displacement from 2014 to 2020 over the Narrabri Gas Project Area". I have not attempted to make comment on this particular report.	The document has been prepared by professional technical experts in order to meet the Plan requirements specified by the Project conditions of consent. Santos will continue to invite WTAG members to seek clarity where it is needed. The InSAR report has been provided as an appendix because it describes, in detail, how the baseline ground motion data has been interpreted.
3	General	N/A	No specific text reference.	**[Randall Cox]** There is inconsistency in the way the Gunnedah-Oxley Basin is called up. Sometimes it is 'Gunnedah-Oxley Basin', sometimes 'Gunnedah Basin'. I don't think it is a deliberate distinction. The abbreviation 'GOB' is usually used in tables but is also sometimes used in the text. The abbreviation is not called up in the 'Acronyms and Abbreviations on page (ii).	Generally, the references to the Gunndah Basin refer to the sedimentary geological basin, which contains the target coal seam for the Project. The references to the Gunnedah-Oxley Basins refer to the groundwater source, as referenced by NSW Government water planning policy documents. The GOB acronym has been added to the Acronyms and Abbreviations list.
4	General	N/A	No specific text reference.	**[Randall Cox]** Suggest there be some reconciliation of the Appendix References to 12-day InSAR data acquisition and the section 7 reference to 48-day acquisition	The data acquisition frequency for the InSAR Baseline Ground Displacement (Appendix B) was every 12 days. The data acquisition frequency for Phase 1, as detailed in Table 7.1, is every 48 days.
5	General	N/A	No specific text reference.	**[Randall Cox]** The acronym 'NGP' is abbreviated to 'the Project'. Review consistency in the way the terms are used.	Noted. A consistency review has been completed
6	General	N/A	No specific text reference.	**[Michael Williams]** The Plan requires an edit especially with regard to section references	All section references have been reviewed and corrections made.
7	4	Existing groundwater environment	No specific text reference.	**[Randall Cox]** Chapter 4 is mostly taken directly from the EIS. Perhaps at the beginning of the section there should be a statement that it is taken from the EIS unless there is some addition/variation or 'build' on the EIS noted in the text	The following text has been added as an introduction to section 4: *This section provides a summary of the same information presented in the EIS. Additional information that has been gathered since the EIS comprises monitoring data reflected in the data sets presented in the GBR, and baseline measurements of ground motion which are described in Section 4.3 and Appendix B.*
8	4.4	Aquifers and aquitards	No specific text reference.	**[Randall Cox]** Could the intro for Fig 4.3 say that this is Table 5.1 from the EIS, expanded here in the management plan to include the hydrostratigraphic classification. For ease of connecting to the text the last column of Figure 5.1 could be called 'hydrostratigraphic unit' rather than 'transmissivity' or if there is not room to say that then a footnote to make the connection.	The text in section 4.4 (first paragraph) has been amended as follows: The stratigraphic sequence in the area has been characterised based on the rocks' water storage and flow characteristics. Thus, hydrostratigraphic units have been ~~identified that follow~~ *attributed* the following *transmissivity* classifications: Figure 4.3 and Figure 6.1 have been amended to suit

Item	Section #	Section heading	Existing text	Comment	Final response
9	4.4.1	Hydraulic properties	No specific text reference.	**[Jack Warnock]** This is a very complex section of the Plan and would require a detailed explanation for someone like myself to understand.	This section was discussed in detail during the 16 February 2022 meeting (refer to meeting minutes and presentation). Santos appreciates the feedback and comments from WTAG members. Santos will continue to invite WTAG members to seek clarity where it is needed.
10	4.4.1	Hydraulic properties	Additional measurements have been made indirectly by interpreting drill stem tests performed almost exclusively on selected coal seams….	**[Randall Cox]** Third para says 'Additional measurements'. Perhaps this should be recast to …'In addition indirect estimates have been made..	The text has been amended as follows: ~~Additional measurements~~ *In addition, indirect estimates* have been made ~~indirectly~~ by interpreting drill stem tests performed almost exclusively on selected coal seams....
11	4.4.2	Groundwater levels and pressures		**[Randall Cox]** See comments on the GBR	See response to comments on the GBR.
12	4.4.2 para 4	Groundwater levels and pressures	Shallow groundwater tables in the unconsolidated Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year. There has been a long term decline in water levels of several metres over 50 years in almost all monitored bores.	**[Michael Williams]** There are multi-layer distributed parameter groundwater flow models for the Namoi Alluvium which are based on pumping tests and stable isotope studies with over 50 years of water level, groundwater usage and climate information. With current focus on CSG production, to date this information has largely been ignored.	The GBR has been updated to include a reference to existing studies that provide supporting evidence re: groundwater level/pressures, where data exists and whether or not the data supports our observations. Trends are comparable to those seen in alluvial bores elsewhere across the Namoi catchment.
13	4.4.3	Groundwater quality		**[Randall Cox]** First para – should 'WBR' be 'GBR'	The correction has been made.
14	4.4.3	Groundwater quality		**[Randall Cox]** See comments on the GBR	No response required.
15	4.4.3 para 6 last sentence	Groundwater quality	The short time series of four years suggests stable groundwater conditions with little variability despite the shallow and thin nature of these aquifers.	**[Michael Williams]** Elsewhere in other alluvial water sources in NSW it has been shown that the water quality can vary significantly through a water year due to pumping stresses and climate. Care that such variations are considered when setting groundwater quality targets.	The GBR has been updated to include a reference to existing studies that provide supporting evidence re: groundwater level/pressures, where data exists and whether or not the data supports our observations. Trends are comparable to those seen in alluvial bores elsewhere across the Namoi catchment.
16	4.4.4	Natural methane leaks and accumulations		**[Randall Cox]** First para – should 'WBR' be 'GBR'	The correction has been made and the rest of the document checked for similar errors.
17	5.1	Groundwater extraction		**[Jack Warnock]** On page 30 of this Plan there is Figure 5.1 Existing and Phase 1 water production forecast. This Figure has been presented elsewhere. The time frame for Phase 1 is from Year 0 to Year 10. However, on page 6 of the Groundwater Modelling Plan, Figure 3.1 represents a timeframe for Phase 1 from Year 0 to Year 25. Should there be more clarity in the timeframe for Phase 1 of the Project?	The text in section 5.1 has been amended as follows: *The model used to determine the potential groundwater impact from the Phase 1 operation was conservatively based on a 25-year operational life for the Phase 1 wells.* Figure 5.1 has been replaced with Figure 3.1 from the GModP.
18	5.1	Groundwater extraction	The predicted take of water from coal seams for Phase 1 of the NGP is shown in Figure 5.1.	**[Randall Cox]** The text and the figure label refer to water forecast for Phase 1. More correctly the data is total water forecast from wells constructed during Phase 1, over the full life of those wells.	Text in Section 5.1 has been amended as follows: The predicted *total water* take *from wells constructed prior to* Phase 1 of the NGP, *over the full gas production life of those wells*, is shown in Figure 5.1
19	5.3	Subsidence		**[Randall Cox]** The section first refers to the EIS predictions about minimal impact. The section then goes on to reference the Appendix B study, which is about monitoring not some geomechanical study leading to prediction. Suggest the reference to the Appendix B study be contained to Chapter 4 and be deleted from Section 5.3. Otherwise, there will be a tendency to think the Appendix B study contains something about prediction.	The last 3 paragraphs in section 5.3 have been moved to section 4.3. Section 4.3 established existing conditions of the site, including background subsidence – presented in detail in Appendix B.

Item	Section #	Section heading	Existing text	Comment	Final response
20	6	Groundwater monitoring strategy	These capabilities are achieved through a combination of monitoring methods for targeted formations. Table 6.1 provides an overview of how specific monitored attributes of the various hydro-stratigraphic units will meet the capabilities numbered 1 to 5 in the list above. Figure 6.1 provides an overview of the target hydro-stratigraphic units that will be monitored, highlighting the targeted units (A to D).	**[Randall Cox]** Difficult to see the relevance of Table 6.1 - See comments in the GMonP	The text in section 6 has been amended as follows: These capabilities are achieved through a combination of monitoring methods for targeted formations. Table 6.1 also links the requirements of CoC B41(d)(iv) to the hydrostratigrahic units in shown in Figure 6.1, providing an overview of the purpose of monitoring for each target hydrostratigraphic units that will be monitored (coded A to D).
21	6	Groundwater monitoring strategy	A summary of the groundwater monitoring locations is provided in Figure 6.2. Table 6.2 summarises the number of monitoring locations for each targeted unit. Further details of the monitoring network are provided in the GMonP.	**[Jack Warnock]** In Table 6.2 reference is made to the need to construct 23 Santos and 11 DPIE monitoring bores for Phase 1 of the Project. When are these bores expected to be constructed? Are they to be constructed prior to commencement of the Project?	The text in section 6 has been amended as follows: *A total of 98 groundwater monitoring points are nominated as part of the monitoring network, with all proposed monitoring points to be operational prior to the commencement of Phase 1 of the Project.* A summary of the groundwater monitoring locations is provided in Figure 6.2, with the number of monitoring locations for each targeted unit summarised in Table 6.2. Further details of the monitoring network are provided in section 4 of the GMonP.
22	7	Subsidence and seismic monitoring		**[Randall Cox]** The executive summary on page 2 of the Appendix B report says that 'image acquisition is currently ongoing with 12-day revisit frequency. However the 'summary and recommendations' in section 5 of the Appendix B report has a red strike out of the 'ongoing 12-day revisit' Section 7 first paragraph says 'InSAR data acquisition will be undertaken every 48 days throughout Phase 1' Has there been a change from 12-day to 48-day data? Does 48-day introduce a risk of seasonal changes being misinterpreted? Need to reconcile the references	The data acquisition frequency for the InSAR Baseline Ground Displacement (Appendix B) was every 12 days. The data acquisition frequency for Phase 1, as detailed in Table 7.1, is every 48 days.
23	8.1	Project phasing		**[Jack Warnock]** There are three references made that are represented by "Error! Reference source not found".	The corrections have been made.
24	Table 8.1 Column 3 Dotpoint 1	Groundwater features, performance criteria and trigger levels	• Current numerical groundwater model prediction	**[Michael Williams]** For Phase 1, the DPIE (Water) Namoi Alluvium model should independently report explicitly report of the impact from other water sources (in particular GABSI and Narrabri Gas activity. Appropriate integration should occur from the commencement of Phase 2 onwards.	This matter is relevant to development of the Phase 2 groundwater model or if a model revision is triggered by monitoring, which the Project conditions of consent require be undertaken in consultation with the WTAG at that time.
25	Table 8.1	Groundwater features, performance criteria and trigger levels		**[Randall Cox]** The table shows 'no specific trigger response' if there is more than 'negligible influence on GDEs'. It seems to me that the comment could have been left out and the line above the comment deleted so that the three dot points of 'trigger response' related to Condition 37 would apply to GDEs as well. The inclusion of the words 'no specific trigger response' seems to unnecessarily imply there is some sort of lack of attention to GDEs. Perhaps I am missing some legal technicality of consistency with condition B37?	The table has been updated to merge cells and include GDE with the three dot points describing the Trigger Response.
26	Table 8.1 Column 5	Groundwater features, performance criteria and trigger levels	Riparian and aquatic ecosystems	**[Michael Williams]** While I agree this is an unlikely occurrence from Phase 1 activity, this response should be inacceptable. If the ecosystems are in fact high value some action is required, even a simple referral should be acceptable.	The table has been updated to merge cells and include GDE with the three dot points describing the Trigger Response.
27	Table 8.2	Outcomes for groundwater resources		**[Randall Cox]** Suggest the table reference the source (CoA 5) as does Table 8.1	The reference to CoA 5 has been added to the table.

Item	Section #	Section heading	Existing text	Comment	Final response
28	8.3	Verification methods	Groundwater monitoring therefore provides a secondary method for verifying whether the Project is meeting performance measures throughout Phase 1 and is complementary to the primary method which relies on the validity of groundwater model predictions'.	**[Randall Cox]** See comments on the modelling GModP about model terminology around 'review' and 'update' Not sure if the text in the last paragraph is correct. Suggest the sentence be deleted. Suggest a sentence be added pointing out that new data from a range of sources could also lead to a review of the model.	The last paragraph of section 8.3 has been reworded as follows: Santos proposes to undertake groundwater monitoring to verify the model predictions are accurate and reliable. The monitoring triggers, which are described below, determine if the groundwater model needs to be revised. ~~Groundwater monitoring therefore provides a secondary method for verifying whether the Project is meeting the performance measures throughout Phase 1 and is complementary to the primary method which relies on the validity of groundwater model predictions~~*. New data from a range of alternate sources may also lead to a review of the model.*
29	8.3.1	Model updates and verification		**[Randall Cox]** Not sure that 'verification' in the title is relevant. Delete from title?	'Verification' has been deleted from the sub-title.
30	8.3.1 Para 1	Model updates and verification		**[Michael Williams]** The EIS model has is single set of aquifer parameters for each of the model layers. The activities proposed in Phase 1 aim to provide data from which heterogeneous layers will be developed for the model. Such information is currently available for the overlying water sources so consideration should be given as to how (or if) that information will be integrated into the Narrabri Gas groundwater flow model.	CoC B39 states that the model update must be undertaken prior to the commencement of Phase 2, and at least every 3 years thereafter. All relevant available information will be taken into consideration and integrated into the groundwater model. Paragraph has been amended: Santos will update the groundwater model in the future. In absence of a specific trigger to update it sooner, Santos will update groundwater model predictions ~~no sooner than the start~~ *prior to the commencement* of Phase 2 of the Project.
31	8.4 para 3	Trigger levels	If the triggers are not exceeded, then current model predictions are considered reliable. This does not preclude periodic review, adaptation and improvement of the model throughout the current phase of the Project. This process is described in the GModP.	**[Michael Williams]** Section 8.3 appears to indicate that this inference cannot be made?	The text has been amended as follows: *Throughout Phase 1*, if the triggers are not exceeded, then current model predictions are considered reliable.
32	8.4.1	Level 1 trigger	No specific text reference.	**[Jack Warnock]** The figures in Table 8.3 do not correspond to the figures in Table 8.4 for cumulative water production not to be exceeded. Please see Year 20: 32 GL versus 34.7 GL and Year 25: 37.5 GL versus 47.1 GL.	The heading for Table 8.3 has been revised as follows: Table 8.3 - *Maximum* ~~Nominated~~ groundwater production take ~~response triggers~~ *under SSD 6456* The heading for Table 8.4 has been revised as follows: Table 8.4 – *Phase 1* nominated groundwater production take response triggers
33	8.4.1	Level 1 trigger	'Trigger 1(b) is an upper limit based on the allowable water take from the GOB specific to the scale and timing of a specific Project phase. This cumulative water production not to be exceeded (the Limit) is defined for Phase 1 in Table 8.4, in accordance with section 5 of the GModP.'	**[Randall Cox]** Is the reference in the paragraph above table 8.4 to 'section 5 of the GModP correct? The referenced section is about data review.	The cross-reference has been corrected to section 3 of the GModP (Estimating direct water take).
34	8.4.2 para 7	Level 2 trigger	The maximum predicted water level change in these formations due to the Project will be imperceptible when compared to variability induced by climate and other groundwater users	**[Michael Williams]** While the water level changes may be imperceptible the resultant water volumes may be significant in terms of impact on the management of the GAB or Lower Namoi Alluvium water sources	The section is describing measurable attributes which can be used as management triggers. This statement is establishing the fact that it is challenging to develop monitoring triggers for shallow aquifers of the GAB or the Namoi Alluvium.
35	8.4.2	Level 2 trigger		**[Randall Cox]** Second bottom para p44. Refers to site 'BHNS1'. Figure 8.1 shows the location of site 'BHN1S' One of the references must be incorrect	The correction has been made. The well reference should be BHN1S.
36	8.4.2	Level 2 trigger		**[Jack Warnock]** On page 44 second last paragraph. Should Sites "BHNS1" actually be "BHN1S"?	Refer to comment above.
37	8.5	Trigger response		**[Randall Cox]** Second para refers to 'GMonP' – should it be 'GModP'	The correction has been made.

Groundwater Monitoring Plan – WTAG comments received on Revision A (draft)

Comments received from Randall Cox, Jack Warnock and Michael Williams

Item	Section #	Section heading	Existing text	Comment	Final response
1	General		No specific text reference.	**[Randall Cox]** There is inconsistency in the way the Gunnedah-Oxley Basin is called up. Sometimes it is 'Gunnedah-Oxley Basin', sometimes 'Gunnedah Basin'.	Generally, the references to the Gunnedah Basin refer to the sedimentary geological basin, which contains the target coal seam for the Project. The references to the Gunnedah-Oxley Basins refer to the groundwater source, as referenced by NSW Government water planning policy documents. The GOB acronym has been added to the Acronyms and Abbreviations list.
2	General		No specific text reference.	**[Randall Cox]** The acronym 'NGP' is abbreviated to 'the Project'. Review consistency in the way the terms are used.	Noted. A consistency review has been completed.
3	2		Figure 2.1 provides an overview of the target hydro-stratigraphic units that will be monitored, highlighting the targeted units (A to D). Table 2.1 provides an overview of how specific monitored attributes of the various hydro-stratigraphic units will meet the capabilities numbered 1 to 5 in the list above.	**[Randall Cox]** Section 2 introduces the concept of 'Target Code' and then uses that grouping to form a link with the 'capabilities' required under the Coc B41(d)(iv). The 'target code' is not used anywhere else. It is not clear to me what Table 2.1 is doing. It seems to me that it can be argued that the monitoring network does meet the required capabilities, and the Table 2.1 does not help in that regard.	The text in section 2 has been amended as follows: *These capabilities are achieved through a combination of monitoring methods for targeted formations.* Table 2.1 links the requirements of CoC B41(d)(iv) to the hydrostratigrahic units in shown in Figure 2.1, providing an overview of the purpose of monitoring for each target hydrostratigraphic units that will be monitored (coded A to D).
4	2.2	Deeper formations of the GOB	It is expected to take many years, and potentially decades, before changes in groundwater pressure in aquitards immediately overlying the Maules Creek coal seams (i.e. the deeper formations of the Gunnedah-Oxley Basin [**GOB**]) are predicted to be detectable by groundwater monitoring. Groundwater pressure monitoring of the Middle Permian age Porcupine Formation is therefore expected to provide the next most critical information after monitoring water extraction and groundwater levels in the target coal seam and is potentially useful for model validation prior to Phase 2 of the Project	**[Michael Williams]** If this proves to be the case, the impacts can still be assessed and the overlying water sources protected.	Noted. No response required.
5	2.3	Shallower formations of the GOB	These monitoring points would only provide model validation data prior to Phase 2 of the Project in the event that any groundwater level response due to Project activities is observed in these monitoring points throughout Phase 1.	**[Michael Williams]** If the GAB levels are rising due to GABSI water savings, the information from the pressure levels in this target would be useful to all Phases of the CSG project.	Noted. The sentence has been reworded as follows to better capture the intent of the monitoring points: *Although information obtained from the monitoring points will be valuable for all Project phases*, these monitoring points would only provide model validation data prior to Phase 2 of the Project in the event that any groundwater level response due to Project activities is observed in these monitoring points throughout Phase 1.
6	2.3	Shallower formations of the GOB	The groundwater model does not currently predict any change in groundwater pressures in these formations throughout Phase 1 of the Project. These monitoring points would only provide model validation data prior to Phase 2 of the Project in the event that any groundwater level response due to Project activities is observed in these monitoring points throughout Phase 1.	**[Randall Cox]** In the unlikely event that there was groundwater level response in these formations during Phase 1 then the data would be used for 'model review' rather 'model validation'. Suggest change 'validation' to 'review'.	The text in section 2.3 has been amended as follows: These monitoring points would only provide model ~~validation~~ *review* data prior to Phase 2 of the Project.…
7	2.4	High-value GA and alluvial aquifers	No specific text reference.	**[Randall Cox]** Section 2.4 is about high-value GAB and alluvial aquifers. If there is no Phase 1 water pressure impact in the GOB there will be no impact in the GAB or alluvium. Suggest follow the logic of section 2.3 and say that model does not predict any change during Phase 1. The fact that any later stage eventual water pressure impact will tend to be lost in background behaviour (paragraph 1) is a separate thought that is perhaps not necessary to include in the monitoring MP.	Noted. Section 2.3 states that the groundwater model does not currently predict any change in groundwater pressures in these formations throughout Phase 1 of the Project.

Item	Section #	Section heading	Existing text	Comment	Final response
8	2.4	High-value GA and alluvial aquifers	Therefore, groundwater quality monitoring will only be used to establish the initial baseline characteristics of groundwater quality high-value water resources of the GAB and Namoi Alluvium formations.	**[Michael Williams]** This is a reasonable way to manage the risk of claims of water quality change due to the CSG production.	Noted. No response required.
9	3.1	Types of groundwater monitoring infrastructure	**Multi-gauge completion**: this type of completion is required where there is potential for interaction with gas within the CSG reservoir. These monitoring points may be constructed to manage risks associated with the presence of flammable gas under pressure. Multiple monitoring gauges are installed within a single well, typically separated by hydraulic barriers such as swellable packers. Groundwater pressure is measured using water level loggers suspended inside the casing between the hydraulic barriers. Manual water level readings and water quality samples cannot be taken due to the presence of hydraulic barriers	**[Michael Williams]** I agree with approaching shown in Figure 3,1 using different piezometer type for Phase 1. However, in the longer term the matter that other piezometers have significantly longer design lives (e.g., due to transducer failure and record drift) will need to be addressed.	Piezometer quality/design life will be considered based on location, monitoring environment and depth. The operational maintenance of monitoring points will be an issue for Santos to manage throughout the life of the Project.
10	3.1	Types of groundwater monitoring infrastructure	No specific text reference.	**[Randall Cox]** Mentions multi-gauge completion but does not mention VWPs even though there are a number listed in monitoring network (Appendix A). The Surat experience is that VWPs can be problematic because they can drift and can't be maintained.	A footnote has been added to section 3.1: *No new cemented VWPs will be installed because they are difficult to maintain operational*.
11	Figure 3.1	Schematic of groundwater monitoring installation types	No specific text reference.	**[Randall Cox]** The figure does not include a VWP.	A footnote has been added to section 3.1: *No new cemented VWPs will be installed because they are difficult to maintain operational*.
12	3.3	Groundwater quality	Given that groundwater quality is usually very consistent temporally, if the groundwater quality monitoring is consistent after 3 years or at least 6 samples have been taken (whichever is later), no further samples will be collected. This requirement may be revised if management response to exceedance of performance criteria (including trigger levels) require this Plan to be updated. Inconsistent baseline data may require additional groundwater quality monitoring to determine the baseline groundwater quality.	**[Randall Cox]** The section proposes that water quality be sampled every 6 months but if quality is consistent after three years 'no further samples will be collected'. Perhaps it would be useful to have some long-term monitoring for bores close to CSG development. The resulting data may provide useful hydrochemical evidence in the long-term about the absence of leakage by showing that there has been no long-term evolution of the chemical character of one formation towards the chemical character of the overlying formation. That would be a line of evidence about the absence of leakage from above that is independent of modelling and monitored water pressure. That type of evidence has proved useful in the Surat where it has been shown that there is no hydrochemical evidence of upward migration of water from the Walloon Coal Measures into the alluvium after decades of low water levels in the alluvium due to irrigation extraction. The hydrochemical evidence provided one of several lines of evidence that there will be no significant downward migration when pressure differentials are reversed because of CSG development. Useful in building public confidence. Perhaps ongoing annual sampling of targeted bores could be considered?	The following text has been added to section 3.3: *Groundwater quality monitoring close to CSG development may provide useful hydrochemical evidence about the leakage from formations overlying the target coal seams e.g. evolution of chemical character towards that of the overlying formation. This line of evidence independent of modelling and monitored water pressure may be considered in Phase 2, pending the findings from Phase 1 which will initially further investigate the permeability of formations overlying the target coal seams.*
13	3.4	Volume extraction by the Project	Cumulative volume will be recorded by flow totalisers located on the water discharge line to each well.	**[Randall Cox]** Probably it is just a matter of expression. I assume 'to each well' means the same as 'from each well'. For modelling purposes water extraction data needs to be collected at least monthly, directly from each well. It should not be measured through a manifold system collecting from several wells then apportioned back to individual contributing wells.	The text has been amended as follows: The *daily water production and the* cumulative total volume of coal seam water extracted from each active CSG well will be recorded each day. Cumulative volume will be recorded by flow totalisers located on the water discharge line *connected* to each well. The data will be automatically uploaded to Santos operational data repository at least once each day.

Item	Section #	Section heading	Existing text	Comment	Final response
14	3.5	Climate data	Table 3.1 summarises the climate data that ~~will~~ be collated throughout Phase 1 of the Project. ~~Santos is not~~ responsible for the ongoing maintenance and any decision to continue monitoring at these locations. The data is useful for the groundwater model but in absence of data from these sites, alternative weather station data may be collated.	**[Randall Cox]** The first sentence says that the data will be collected. That gives the impression that Santos will ensure the data is collected. The second sentence says Santos is not responsible. I assume it is BOM responsibility. Suggest recast to say 'Table 3.1 summarises the data currently being collected by BOM (?) and this data collection can be expected to continue though Phase 1.	The wording has been amended as follows: Table 3.1 summarises the climate data that *is expected to* be collated throughout Phase 1 of the Project *by the Bureau of Meteorology* (**BOM**). *The BOM is* responsible for the ongoing maintenance and any decision to continue monitoring at these locations.
15	4		No specific text reference.	**[Jack Warnock]** In the last paragraph of this section "Section **Error! Reference source not found**	The correction has been made, with reference to section 5.
16	4	Groundwater monitoring network	No specific text reference.	**[Randall Cox]** Minor point. Check that terminology is OK. Existing bores are used as 'monitoring points' so is it better to refer to them as 'bores' or 'monitoring points' in the context of this management plan. The section is entitled 'monitoring network'. Appendix B is entitled 'monitoring infrastructure' and is a list of the 'monitoring points'. The figures in section 4 refer to 'monitoring bores'	The figures in Section 4 and in Appendix B have been updated to 'monitoring points'
17	4.1	Ownership and responsibility	On Santos notification of an inaccessible or non-operating site to DPIE Water, Santos will not return to monitor that site until DPIE has confirmed that the monitoring point is once again accessible and operational.	**[Randall Cox]** This sound unnecessarily combative. Suggest recast as follow.... 'Santos will recommence monitoring at the site when notified by DPIE that the monitoring point is made accessible and operational'	As suggested, the text has been amended as follows: ….., *Santos will recommence monitoring at that site when notified by DPE Water that the monitoring point is accessible and operational*.
18	4.1	Ownership and responsibility	No specific text reference.	**[Michael Williams]** This matter is extremely important so the Section reference should be added as a priority (I was unable to define find it).	The correction has been made, with reference to section 5.
19	Table 4.1	Summary of groundwater monitoring points for Phase 1	No specific text reference.	**[Jack Warnock]** When is it expected that the 23 Santos and 11 DPIE monitoring bores are to be constructed?	Section 4.2 already states the following: A number of monitoring points have yet to be constructed. All proposed monitoring points will be operational prior to the commencement of Phase 1 of the Project. In total, 98 groundwater monitoring points are nominated, as presented in Table 4.1. This is consistent with section 6 of the WMP.
20	5	Record keeping	No specific text reference.	**[Randall Cox]** Suggest that reasons for any outages be recorded	The text has been amended to include reference to outages: • operational monitoring and performance data (including outages and monitoring issues); The following sentence has been added (from item #22 below, section 5.3): *Data will be made available for any subsequent review or update of the groundwater model.*
21	5.3	Coal seam water production data	Groundwater take from the CSG wells will be monitored and recorded in accordance with the Produced Water Management Plan. Data will be made available to validate and update the groundwater model.	**[Randall Cox]** Not clear why this is included as monitoring of take from CSG wells will be in accordance with section 3.4 of the monitoring plan.	The text has been amended as follows: Groundwater take from the CSG wells will be monitored and recorded in accordance with the Produced Water Management Plan. Data will be made available to ~~validate~~ *review* and update the groundwater model.
22	5.3	Coal seam water production data	Data will be made available to validate and update the groundwater model.	**[Michael Williams]** If the proposal is to update the groundwater model around the coal seams then this is correct. If the proposal is to update outside the GOB then this sentence should be moved to the introduction of Section 5.	Following text added after last paragraph under Section 5: *Data will be made available for any subsequent review or update of the groundwater model.*

Groundwater Baseline Report – WTAG comments on Revision A (draft)

Comments received from Randall Cox, Jack Warnock and Michael Williams

Item	Section #	Section heading	Existing text	Comment	Final response
1	General		No specific text reference.	**[Randall Cox]** There is inconsistency in the way the Gunnedah-Oxley Basin is called up. Sometimes it is 'Gunnedah-Oxley Basin', sometimes 'Gunnedah Basin'.	Generally, the references to the Gunnedah Basin refer to the sedimentary geological basin, which contains the target coal seam for the Project. The references to the Gunnedah-Oxley Basin refer to the groundwater source, as referenced by NSW Government water planning policy documents. The GOB acronym has been added to the Acronyms and Abbreviations list.
2	General		No specific text reference.	**[Randall Cox]** The acronym 'NGP' is abbreviated to 'the Project'. Review consistency in the way the terms are used.	Noted. A consistency review of the full suite of groundwater management plans has been completed.
3	1.2	Objective		**[Randall Cox]** The objectives listed in section 1.2 simply talk about providing data. They do not include providing an analysis of trend. However, section 3 does provide comment on trend and I find some difficulties with the comments (as listed in later more specific comments). Suggest simplifying section 3 to providing comment about possible causes of unusual behaviour in the data and not attempt to draw conclusions about trend.	In response to other comments, described below, section 3 has been simplified to provide comment about possible causes of unusual behaviour in the data rather than attempt to draw conclusions about trend.
4	1.2	Objective	The objective of this Report is to: • provide detailed baseline data of hydrogeology and groundwater levels, formation parameters … and quality for groundwater resources potentially impacted by the development…	**[Randall Cox]** Consider if the objective in section 1.2 about water quality is appropriate	This objective is a replication of the requirement of CoC B41(d)(iv)
5	1.2	Objective	The objective of this Report is to: • identify which groundwater bores have sufficiently established groundwater quality, where no further groundwater quality sampling is required.	**[Randall Cox]** However, the baseline management plan presents data but does not argue that no further sampling is needed. Should the objective of this management plan include that limb?	The 3rd bullet has been amended as follows: - identify which groundwater bores have sufficiently established baseline groundwater quality, *(as defined in the Groundwater Monitoring Plan, section 3.3)* where no further groundwater quality sampling is required.
6	1.4.3	Southern Recharge and Surat Groundwater Sources		**[Michael Williams]** The report should identify the NSW GAB Shallow Groundwater Sources 2020 (here Surat) that cover the groundwater at less than 60 metres depth. The Bohena Creek alluvium is included in this water source.	The baseline report has been amended to clarify the status of the Bohena Creek Alluvium in section 1.4.1 The Bohena Creek Water Source is defined in the Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2012 *and includes all water occurring naturally on the surface of the ground, and all water in rivers, lakes and wetlands within the Bohena Creek catchment.* Within the subsurface, the Bohena Creek *Alluvial* Water Source includes all water below the surface of the ground and within the *boundary of the Southern Recharge Groundwater Source* defined in the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2020. The Bohena Creek Alluvium is laterally contiguous with the Lower Namoi Alluvial Groundwater Source.* ~~Above ground it includes all water occurring naturally on the surface of the ground, and all water in rivers, lakes and wetlands within the Bohena Creek catchment.~~
7	1.5	Hydrostratigraphic units	The stratigraphic units that are present within the area of baseline monitoring have been grouped into hydrostratigraphic units according to the capacities of the strata to transmit or inhibit the movement of groundwater.	**[Michael Williams]** Add "to the" regional "capacities of the strata …" For instance, the Mooga Sandstone is locally significant aquifer providing reasonable yields. It is also referred to as an aquifer to be monitored in the Groundwater Management Plan	The text has been amended as follows: The stratigraphic units that are present within the area of baseline monitoring have been grouped into hydrostratigraphic units according to the *regional* capacities of the strata to transmit or inhibit the movement of groundwater.

Item	Section #	Section heading	Existing text	Comment	Final response
8	2	Baseline bores	Table 2.1 - Overview of baseline data sources for groundwater hydraulic head Table 2.2 - Overview of baseline data sources for groundwater quality	**[Randall Cox]** Table 2.1 (hydraulic head) and Table 2.2 (quality) provide summary information about the number of monitoring points. A short explanation as to why there are differences in the lists would be useful. Presumably head has been measured in the deep Porcupine and Maules Cr formations using pressure gauges but samples for quality determination could not be taken from these types of installation. It seems odd that in the Mooga pressure has been monitored, but not water quality. It would be helpful to include some explanation.	New paragraph inserted in Section 2: *Bores monitored for hydraulic head were not all sampled for water quality. Some bores that have been sampled for water quality have no recorded static hydraulic head data. Table 3.1 (in section 3.1.5) and Table 4.1 (in section 4) distinguish which bores were measured for which attributes.* The reasons are varied and site-specific, e.g. not all bores are equipped with a pump to allow water quality sampling, or some wells are always pumped and so would not represent static water levels, or a bore might be equipped with a pump but not be accessible for water level monitoring. In simple terms, not all bores are suitable or equipped for monitoring both attributes.
9	2	Baseline bores	Table 2.1 - Overview of baseline data sources for groundwater hydraulic head	**[Michael Williams]** If the coal seams are not being monitored (head and volume), how can the impacts be assessed?	The GMonP describes how there will be monitoring points in the Maules Creek Formation prior to commencement of Phase 1. These pressures are expected to be stable, hence long time series are not required. The relative change in pressure induced by development will be dramatic and obvious (i.e. hundreds of metres change in water head), such that small scale variations and long-term trends are not critical.
10	Section 2.1 para 3	Private landholder bores	The exceptions are three bores targeting the Orallo Sandstone in the north of the Project area (Figure 2.2) and a single bore drawing domestic water from the Bohena Creek Alluvium. Data from these four bores are included in the summary statistics reported in section 4.	**[Michael Williams]** The Orallo Sandstone is defined as NTU but is clearly a significant aquifer in the region.	Text in Section 2.1 amended: The exceptions are *three stock and domestic* bores targeting the *low-yielding* Orallo Sandstone in the north of the Project area…
11	2.1	Private landholder bores	Figure 2.1 - Baseline monitoring locations in Alluvial Groundwater Sources	**[Michael Williams]** It is difficult to conceptualise the Narrabri Gas Project having a measurable impact on the Upper Namoi or Cox's Creek alluvium.	Noted. No response required.
12	2.1	Private landholder bores	Figures 2.1 to 2.3	**[Michael Williams]** While the figures are correct, it is confusing as the terms that govern the geographic distribution are being mixed. Section 1 are water sources and section 2 are hydrostratigraphic units. If would be clearer if the Figure titles in Section 2 removed the term "groundwater sources".	Tables 2.1 and 2.2. link the hydrostratigraphic units described in Section 2 to the Water sources described in Section1 and the titles of Figures 2.1 to 2.3. Table headings have been changed to reflect this.
13	3 Appendix A	Groundwater baseline data – pressure and levels		**[Randall Cox]** I had a difficulty relating the plots in Appendix A to the text in section 3. It would help if Appendix A was structured into geologic units to match the way Table 3.1 is structured.	The plots in Appendix A provide the same data as that in Table 3.1, with Table 3.1 structured into geologic units to assist interpretation. The sequence of the plots in Appendix A has been amended to follow the structure of Table 3.1.
14	3	Groundwater baseline data – pressure and levels		**[Jack Warnock]** A significant number of bores represented in Table 3.1 for the Namoi Alluvium have quite old data. Hopefully more recent data on groundwater head is available.	Although some bores have older data, it is only for five bores that the data is more than 5 years old (pre-2016).
15	3	Groundwater baseline data – pressure and levels		**[Randall Cox]** Consider the need to include conclusions about water level trend in section 3 – perhaps reduce to discussion about unusual data and general statements about trend rather than numerical conclusions.	The text has been reviewed to limit statements about numerical conclusions.
16	3	Groundwater baseline data – pressure and levels		**[Randall Cox]** It is difficult to connect some of the statements in section 3 with the plots in Appendix A. This is made more difficult because Appendix A is not clearly structured and labelled in follow the structure of Table 3.1.	Refer to response to item #13

Item	Section #	Section heading	Existing text	Comment	Final response
17	3.1.2	Deeper formations of the GOB	Water pressure loggers proved problematic over time in several deeper bores though early data is supported by recent manual measurements and shows flat trends in most deep formations of the Gunnedah Basin. One bore targeting the Porcupine Formation (at the Dewhurst 8 site) has shown a rising pressure trend over the last four years.	**[Randall Cox]** I can't find plots in Appendix A for the DWH8AQGMCF04 (Maules Cr) or DWH8AQDGDY01 (Porcupine fm) sites listed in Table 3.1. The opening paragraph of section 3 state that DWH8AQGMCF04 (Maules Cr formation) suffered instrumentation failure. Perhaps that is why they are not in Appendix A. The plot for BND6 does support stability but I can't see data to support the statement about rising pressure.	The plots in Appendix A have been reviewed and four missing plots have been added, including the plot for DWH8AQGMCF04. A footnote has been added stating that the bores suffered instrumentation failure, were decommissioned as monitoring bores in 2017 and will be recommissioned as part of the Phase 1 bore monitoring program. The plot for DWH8AQGMCF04 (Figure 4.1 in the Updated and Revised Water Baseline Report (December 2017) [as Appendix D of the Response to Submissions] shows instrumentation failure. It is assumed that the reference in the comment is to bore BWD6, not BND6. There is no BND6. Reference to the (incorrect) statement of rising trend in BWD6 has been removed.
18	3.1.3	Shallower formations of the GOB		**[Randall Cox]** Text refers to bores in Napperby and Digby formations, but the Table 3.1 does not list any bores in the Napperby. Text state 'bores record flat water level trends'. I can't locate plots for the two bores listed in Figure 3.1 for the Digby formation.	The plots in Appendix A have been reviewed and four missing plots have been added, including the plots for TULPRDGY02 and DWH8AQDGY01. These exhibit generally flat trends. No bores specifically target the Napperby Formation and this reference has been removed from the text.
19	3.1.2 and 3.1.3	Deeper/Shallower formations of the GOB		**[Randall Cox]** Would it be better to combine 3.1.2 and 3.1.3 as a single section for the GOB as there seems to be little data and therefore little that can be said?	Since there may be cross-references to sections 3.1.2 and 3.1.3 in other documents, it is more practical at this time to keep the sections separate.
20	3.1.4	High value GAB aquifers		**[Randall Cox]** I find it hard to see the basis for the statement here about falling trends in the GAB, but it is hard to check the correct plots because of the lack of structure in Appendix A. There seems to be a lot of erratic behaviour but falling trends are not obvious to me.	Text now reads "Groundwater pressures in the Jurassic GAB formations are mostly flat over the past 5 years with a couple of bores targeting the Upper Pilliga Sandstone slightly declining. Government bores with longer records show a general gradual decline in water pressures over the past 50 years. Inter-annual variability up to five metres is seen in shallower bores, with artesian conditions to the west exhibiting significant variability up to 15 m year on year. A bore targeting the Mooga Sandstone shows a long-term water-level decline in excess of 15 m over the past 50 years." Specifically, BWD26 & BWD27 are slightly declining. It should be noted that the GAB bores sampled are located in the southern recharge zone and are sub-artesian. Bores to the north are close to active pumping of shallower formations for irrigation and may reflect the influence of local drawdowns. Quoted declining trends are represented by the data for the respective bores.
21	3.1.4	High value GAB aquifers	Groundwater pressures in the Jurassic GAB formations are mostly flat to slightly declining over the past 5 years.	**[Michael Williams]** This is at odds with what DPIE (Water) indicated in the public consultations for the implementation of the NSW WSP GAB 2020 which 1. Allowed increased entitlement to be released in the Surat Basin and 2. Indicated significant water savings (i.e. pressure rises) due to GABSI activity.	As above. No obvious response in any monitored bores to the GABSI program.
22	3.1.5	High value alluvial aquifers	Groundwater ~~tables~~ in the Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year.	**[Michael Williams]** Change "Groundwater tables…" to Groundwater pressure levels ….	The text in section 3.1.5 has been amended as follows: Groundwater *pressure levels* in the Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year.

Item	Section #	Section heading	Existing text	Comment	Final response
23	3.1.5	High value alluvial aquifers	Groundwater tables in the Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year. There has been a long-term decline in water levels of several metres over 50 years in almost all monitored bores.	**[Randall Cox]** There is a falling trend, but I suggest there should be some comment about other features of the plots. Some bores show increasing variability over the years (GW036005-2) while others show less (GW025340-2). Very odd. Presumably there is more going on around many of these bores than seasonal variability.	The introduction to Appendix A of the Baseline Report states that: For shallow groundwater sources, such as the Namoi Alluvium, significant departures from the general trends generally represent the groundwater drawdown response to periodic and local extraction by other groundwater users. Text in Section 3.1.5 has been amended: Groundwater *pressure levels* in the Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year.
24	Table 3.1	Summary of baseline data for groundwater head		**[Randall Cox]** There seems to be some mismatches between Table 3.1 and Appendix A. Specific cases are noted in the later comments.	Noted. Refer to response to item #13
25	Table 3.1	Summary of baseline data for groundwater head		**[Randall Cox]** Structure and label Appendix A in the same was as Table 3.1 or cross-reference them in some way.	Noted. Refer to response to item #13
26	4	Groundwater baseline data - quality		**[Jack Warnock]** The DPIE water quality data for the Namoi Alluvium is quite old. One bore (GW030278-1) was sampled for quality once (21/11/1978). None have recorded data since 1999.	This is a correct observation and reflects the data that is available from DPIE.
27	4.2, 4.3 and 4.4	Shallow formations of the GOB		**[Randall Cox]** In the text methane is reported in 'ppm' while the table reports in 'µg/L'	Units of µg/L in the tables (as reported by laboratories) are converted to ppm for the purposes of providing units in the text comparable to mg/L as used for other analytes.
28	4.3	High value GAB aquifers		**[Michael Williams]** The groundwater quality is derived from a variety of sampling methods. Perhaps early in this section that should be acknowledged with a caveat that the information presented provides a guide that will be refined by future monitoring. It is arguable that the current data set is a baseline.	Section 1.2 states an objective of the Baseline Report is to: • provide a baseline groundwater report that may be periodically updated, for example prior to the next phase of the Project or prior to each groundwater model update.
29	4.4	High value alluvial aquifers		**[Randall Cox]** In Table 4.5 SAR is not included. But it is included in Table 4.6. Should there be an explanation?	A footnote has been added to Table 4.5" *SAR is rendered meaningless at very low dissolved ion concentrations.*
30	4.4		Water quality analyses from bores in the Bohena Creek Alluvium revealed a chemistry similar to the GAB groundwaters. The short time series of 4 years suggests stable groundwater conditions with little variability despite the shallow and thin nature of these aquifers	**[Michael Williams]** Is Bohena Creek alluvium considered a high value aquifer? While it is important in the operation of the Narrabri Gas Project, it was considered regionally significant so was included in the Lower Namoi Alluvium water source rather than the GAB Shallow.	The status of Bohena Creek alluvium has been clarified in section 1.4.3.
31	Table 4.5	Summary of baseline data for groundwater quality in Namoi alluvium		**[Michael Williams]** The groundwater analyses presented are from a range of sampling methods, using a variety of laboratories and no chain of custody provided. Subsequent sampling showed that many of the analyses (especially after pumping stress was applied) were not representative of the aquifer interval sampled.	Added comment under Section 4.5: *The groundwater analyses are from a range of sampling methods, using a variety of laboratories and generally low quality assurance and control. In a number of cases, subsequent sampling may show that the analyses may not be representative of the aquifer interval sampled, especially after pumping stress had been applied. As the details presented in Appendix B show, each bore may only be represented by one or two samples over the period of assessment.* Section 1.2 states an objective of the Baseline Report is to: • provide a baseline groundwater report that may be periodically updated, for example prior to the next phase of the Project or prior to each groundwater model update.

Item	Section #	Section heading	Existing text	Comment	Final response
32	Table 5.1	Summary status of groundwater sources in the Project area		**[Michael Williams]** The water pressure trends for the Namoi Alluvial and GAB are defined as “Declining” and “Flat to slight decline“ respectively. The Namoi is actively managed to the 10 year WSP with pressure levels being allowed to fluctuate due to pumping and climate influences with a strict lower limit when announced allocations are implemented. The trend is then actively managed. According to DPIE (Water) GAB pressure levels have been rising due to GABSI lowering water take. At the time of this report being published, GAB use has not increased so either GABSI is not effective in this region or there has been a ‘balancing loss’ in this region. One possible unconstrained loss could be the movement of GAB water into the Lower Namoi Alluvium water source which current EIS model does not adequately conceptualise.	There may be a case for assessment of all current DPIE monitoring bores to check if any show rising trends. All the bores monitored for the Project exhibit falling trends. Despite the best efforts of active management! GAB pressures are rising to the west, but there is no evidence that this has translated to the bores in the southern recharge zone. A current review could be carried out to determine where the closest responsive bores are located.
33	5.2	Ongoing groundwater monitoring	The GMonP for the Project establishes groundwater monitoring requirements throughout Phase 1 of the Project. This includes: • … • groundwater quality monitoring of GAB and shallow alluvial groundwater sources until stable groundwater quality baseline has been established.	**[Michael Williams]** For the shallow aquifer, given the seasonal variability and pumping impacts, is this achievable? (Add MDBC 2006 paper as monitoring was continuing).	Groundwater quality monitoring of GAB and shallow alluvial groundwater sources will continue into and most likely throughout Phase 2. The criteria for cessation of groundwater quality monitoring are described in the GMonP and bores that satisfy the objective are indicated in Section 4 (Table 4.1 and following text.
34	Appendix A	Groundwater level monitoring hydrographs		**[Jack Warnock]** It would be easier for the reader if all hydrographs • used the same vertical scale; • measured water level below surface; • recorded surface level in metres AHD; • grouped nested bore hydrographs together (eg; GW021266-3 is on page 29 and GW021266-4 is on page 35).	Due to the variability between vertical scales, the measured water levels and the RLs, this would not be possible. The sequence of the plots in Appendix A has been amended to follow the structure of Table 3.1.
35	Appendix B	Groundwater quality monitoring tables and time-series plots		**[Jack Warnock]** There are a number of bores with limited sample numbers, recent data and/or limited water quality measures.	This has been noted in the Baseline Report and reflects the available data.
36	Appendix B	Groundwater quality monitoring tables and time-series plots		**[Randall Cox]** Table B14 and B15 are for monitoring points BDW1WB and BWD5WB which are not listed in Table 4.1. However, Table 4.1 includes private bore 7707 that is not in Appendix B.	A number of monitoring points are not listed in Table 4.1 or in Appendix B. These have been added to both, where relevant. • Table 4.1 updated. • Bore 7707 has been added to Appendix tables.

Groundwater Baseline Report - WTAG comments on Revision B (draft)

Initial comments received from Narrabri Shire Council (NSC). Further comments received from Randall Cox and Michael Williams.

Item	Section #	Section heading	Existing text	Comment	Final response
37	1.1	Context	This Groundwater Baseline Report (GBR, or Report) has been prepared to support the Groundwater Management Plan (GMP) which is a sub-plan under the Water Management Plan (WMP) for the Narrabri Gas Project (NGP).	**[NSC]** Could be better described in a diagrammatical format showing interrelationships between the plans and their hierarchy.	The structure of the Water Management Plan, including the Groundwater Management Plan and its attachments, is provided in Figure 1.4 of the Water Management Plan.
38	1.4	Water sources	Table 1.1 - Groundwater sources within the area of baseline monitoring	**[Michael Williams]** The report should identify the NSW GAB Shallow Groundwater Sources 2020 (here Surat) that cover the groundwater in varying rock types at less than 60 metres depth overlying here the Surat Basin. The Bohena Creek alluvium is included in this water source.	Table 1.1 has been amended to include reference to the *Water Sharing Plan for the NSW Great Artesian Basin Shallow Groundwater Sources Order 2020*. A new section has been inserted before 1.4.3 to provide a description of this water source.
39	3.1	Summary of groundwater source condition	Table 3.1 - Summary of baseline data for groundwater head	**[Randall Cox]** Bore BWD28QGUPS01 is listed in the Table 3.1 but I can't find it among the Pilliga bores in Appendix A. However, Figure A35 in Appendix A gives a hydrograph for bore NYOPRORA01 (Orallo) but the number at the top of the graph gives the number BWD28QGUPS01 (Pilliga). Must be some mix-up here.	The title for Figure A35 in Appendix A has been corrected. It is for bore WD28QGUPS01 in the Pilliga Sandstone.
40	3.1.2	Deeper formations of the GOB	Water pressure loggers proved problematic over time in several deeper bores though early data is supported by recent manual measurements and shows flat trends in most deep formations of the Gunnedah Basin	**[NSC]** Recommend a brief explanation of why this has proved problematic	As detailed in the GMP and the GMonP, cemented VWPs are difficult to maintain operational.
41	3.1.3	Shallower formations of the GOB	Bores targeting the Digby Formations also record flat water pressure trends over the period of monitoring (since 2014).	**[NSC]** As above. A brief explanation of why this is the case.	Further information is provided in section 4 of the GMP.
42	3.1.4	High value GAB aquifers	Groundwater pressures in the Jurassic GAB formations are mostly flat over the past 5 years with a couple of bores targeting the Upper Pilliga Sandstone slightly declining.	**[NSC]** As above	Further information is provided in section 4 of the GMP. Also refer to response to item #43.
43	3.1.4	High value GAB aquifers	Groundwater pressures in the Jurassic GAB formations are mostly flat over the past 5 years with a couple of bores targeting the Upper Pilliga Sandstone slightly declining.	**[Randall Cox]** From Appendix A: • 9 bores show no trend, which is consistent with the comment 'mostly flat'; • 3 in the Pilliga are falling over the last approx. 5 years at 0.1 to 0.2m/yr (Fig A30, A31, A32); and • 1 in the Pilliga is rising at 0.6m/yr (Fig A34). Perhaps the sentence should end with '…, and one bore rising' Given that the Purlewaugh is closest to the underlying GOB and therefore the GAB aquifer that would feel any affect from depressurisation of underlying formations, perhaps the text could note that the two bores tapping that formation are declining at 0.1 to 0.3 m/yr over the last 5 years.	The existing text has been amended as follows: Groundwater pressures in the Jurassic GAB formations are mostly flat over the past 5 years, with a couple of bores targeting the Upper Pilliga Sandstone slightly declining, *and one bore rising*. *The two bores targeting the Purlewaugh Formation are declining at 0.1 m/yr and 0.3 m/yr over the last 5 years*.
44	3.1.4	High value GAB aquifer	A bore targeting the Mooga Sandstone shows a long-term water-level decline in excess of 15 m over the past 50 years.	**[Randall Cox]** Which bore is this comment referring to? The most significant fall I can find in Appendix A is bore GW025338-3 which shows a decline of approximately 10m over the past 50 years	The existing text has been amended as follows: The *DPE Water monitoring bore (GW025338-3)* targeting the Mooga Sandstone shows a long-term water-level decline of *approximately 10 m* over the past 50 years *(refer to Figure A26 in Appendix A)*.
45	3.1.5	High value alluvial aquifers	Trends are comparable to those seen in alluvial bores elsewhere across the Namoi catchment (NSW DoI, 2019)	**[NSC]** As above. What are the broad factors that this is attributable to	Further information is provided in section 4 of the GMP.

Item	Section #	Section heading	Existing text	Comment	Final response
46	4.2	Shallower formations of the GOB	No specific text reference	**[Randall Cox]** Methane is referred to in the text (here and in later sections) as 'ppm' but in the tables if it referred to as 'µg/L'	Refer to item #27 in the table above: Units of µg/L in the tables (as reported by laboratories) are converted to ppm for the purposes of providing units in the text comparable to mg/L as used for other analytes.
47	4.4	High value alluvial aquifers	Table 4.6 - Summary of baseline data for groundwater quality in Bohena Creek alluvium	**[Randall Cox]** 'pH lab' and 'SAR' are not in Table 4.6 but are in Table 4.5. Should there be a comment about this?	Refer to item #29 in the table above: A footnote has been added to Table 4.5" *SAR is rendered meaningless at very low dissolved ion concentrations, and a laboratory pH analysis was not conducted for these samples*.
48	Appendix A	Groundwater level monitoring hydrographs		**[Randall Cox]** P26 – 'Figure A-7 Hydrograph for monitoring bore BWD27PRLPS03 (Pilliga sandstone)' Suggest this may be a hydrograph for bore GW025343-1 (which is the number at the top of the graph) and would be for the Namoi Alluvium not the Pilliga Figure A-32 appears to be the correct hydrograph for BWD27PRLPS03	The correction has been made to Figure A7 in Appendix A.

Groundwater Modelling Plan - WTAG comments received on Revision A (draft)

Comments received from Randall Cox, Jack Warnock and Michael Williams

Item	Section #	Section heading	Existing text	Comment	Final response
1	General	N/A	No specific text reference.	**[Randall Cox]** The words 'update' and 'review' can get a little confusing. I think that a 'review' of the model leads to an 'updated' model. Some references as follows • In the early sections the references arise from the conditions of consent and reflect the language of the conditions – 'update' is commonly used • Section 4 is the 'review schedule'. Sect 4.2 says there is a requirement for a model 'update' prior to Phase 2 – (perhaps this could be 'review and update?) • Section 5 is about 'data review'. In the first para of 5.1 it refers to 'update' to be the outcome of a review. (Seems to me to be the right terminology) • Section 5.2 first para refers to studies that will 'inform the Phase 2 groundwater model update' (perhaps this could be 'inform the review and updating of the model) • Section 5.2 top of page 11 refers to 'review and update' of the geological model (seems to me to be the right terminology) The review and updating required before Phase 2 are really the same as the review and update required as a result of the exceedance of a trigger. Suggest carful use of language will avoid perceptions that there is a difference.	The text in section 4.1 has been amended as follows: During Phase 1, model reviews will be conducted by suitably qualified and experienced persons if triggered by exceedance of the impact response triggers described in the GMP, as otherwise directed by the Planning Secretary or *as a scheduled commitment prior to Phase 2*. *Contingent on the outcome, the review may result in a model update*. The Plan has been assessed and 'review' has generally been corrected to 'update' to be reflective of the consent conditions and the preceding statement.
2	General	N/A	No specific text reference.	**[Randall Cox]** There is inconsistency in the way the Gunnedah-Oxley Basin is called up. Sometimes it is 'Gunnedah-Oxley Basin', sometimes 'Gunnedah Basin'.	Generally, the references to the Gunndah Basin refer to the sedimentary geological basin, which contains the target coal seam for the Project. The references to the Gunnedah-Oxley Basins refer to the groundwater source. The acronym has been added to the Acronyms and Abbreviations list.
3	General	N/A	No specific text reference.	**[Randall Cox]** The acronym 'NGP' is abbreviated to 'the Project'. Review consistency in the way the terms are used.	Noted. A consistency review has been completed.
4	General	N/A	No specific text reference.	**[Michael Williams]** The Plan requires an edit as several of the referenced destination to other reports are missing.	All section references have been reviewed and corrections made.
5	1.2	Purpose and scope	The Model is also relevant to CoC B27 and B28 because the groundwater model is the ~~only tool currently available~~ to estimate inter-aquifer leakage (i.e. indirect water take) due to the Project, and therefore estimate the size of the water licences Santos must hold for the development.	**[Michael Williams]** GISERA used the Bioregional Model to estimate inter aquifer leakage volume envelopes. From the WTAG #4 meeting could be revised to …… the groundwater model "is the tool that will be used" to …..	As suggested, the text has been amended as follows: The Model is also relevant to CoC B27 and B28 because the groundwater model is the *tool that will be used* to estimate inter-aquifer leakage (i.e. indirect water take) due to the Project, and therefore estimate the size of the water licences Santos must hold for the development.
6	2.2	IESC information guidelines	With regard to model uncertainty, the Information Guidelines suggest: • assessments acknowledge uncertainties in modelling, identify the sources of errors (e.g. conceptual model and parameter uncertainty) and quantify the level of uncertainty.	**[Michael Williams]** Does Santos propose to examine the conceptual model uncertainty before the end of Phase 1?	The commitment to undertake conceptual model uncertainty analysis is detailed in section 6.5.4, as a subsection to the model prediction update.

Item	Section #	Section heading	Existing text	Comment	Final response
7	3.2	Phase 1 method statement	The water production rate at each site is estimated depending on its respective total forecasted volume over each period. The forecast of Phase 1 water production will be regularly reviewed and estimates, if necessary, will be adjusted long before indirect water take peaks, thus providing a sufficiently conservative basis for the estimation of maximum predicted indirect water take.	**[Michael Williams]** The Phase 1 program focusses on the CSG production. So, the maximum indirect take is likely to be the groundwater leaking from the surrounding GOB rather than from the other water sources. The distinction between production issues and regional impacts is important as a model that is fit for production processes may not be suitable to quantify regional impacts.	The following text has been added to the paragraph: ….. a sufficiently conservative basis for the estimation of maximum predicted indirect water take. *It should be noted that water production estimates are generated independently of groundwater impact predictions, and that water production is then used as a model input for the groundwater impact model*.
8	3.2	Phase 1 method statement	No specific text reference.	**[Jack Warnock]** As referenced elsewhere, the dates represented in Figure 3.1 Phase 1 annual water production forecast refer to 0 to 25 years from start of Phase 1, whereas other references are made to 0 to 10 years for Phase 1. Could the period of time for Phase 1 be clarified?	In line with the revised text in section 5.1 of the GMP, the text in section 3.2 has been amended as follows: *The model used to determine the potential groundwater impact from the Phase 1 operation was conservatively based on a 25-year operational life for the Phase 1 wells.* The Model *was* updated with the Phase 1 annual water production forecast as shown in Figure 3.1. The forecasted water production is 2.9 gigalitres (GL) over *the* ~~a period of~~ 25 year *period* with an expected production peak up to 1.26 megalitres (ML) per day (ML/day) approximately two years from the start of Phase 1.
9	4.3	Triggered model reviews	The requirement to conduct a model update prior to Phase 2 ~~will~~ be triggered by exceedance of response trigger levels …'	**[Randall Cox]** As already noted in Sect 4.2, there will be a scheduled update prior to Phase 2 (irrespective of triggers). Suggest change text in 4.3 to reinforce that the trigger may not happen, and use the 'review' terminology rather than the 'update' terminology. Suggest: 'Separately to the scheduled review prior to Phase 2, a review could be triggered by exceedance of response trigger levels…'	The text has been amended as follows: The requirement to conduct a model update prior to Phase 2 *could* be triggered by exceedance of response trigger levels defined in section 8 of the GMP.
10	4.3	Triggered model reviews	Project performance against the trigger levels is monitored and reported separately to the GModP through reporting procedures outlined in section 9.1 of the GMP.	**[Michael Williams]** The objective of these triggers is to ensure the impact from extraction on the surrounding confining beds is suitable for CGS production, NOT the impact overlying water sources. Section 8 in the GMP mentions the overlying water sources but the triggers are all GOB-based.	Appraisal well monitoring data alone would be insufficient to determine if the surrounding confining beds were suitable for CSG production. The triggers are designed to provide an early warning that the model and the model predictions need to be reassessed, far in advance of any potential impact on overlying water sources. The text has been amended as follows: *The objective of these triggers is to ensure the impact from extraction due to CGS production is limited to surrounding confining beds.* Project performance against the trigger levels is monitored and reported separately to the GModP through reporting procedures outlined in section 9.1 of the GMP.
11	5.1	Data review - Overview	A data review, whether to improve the model prior to Phase 2 or if triggered by the TARP, will be supported by the collection of Project information, hydrogeological data, and groundwater and surface water monitoring data over the Phase 1 period.	**[Michael Williams]** This review probably only needs to be cursory as the EIS model has previously been shown to be not suitable for Phase 2.	Noted. No response required.
12	5.3	Data sources for Model review	No specific text reference.	**[Michael Williams]** Consideration should be given to including in the review GAB WSP (2020), GABSI and Lower Namoi Alluvium WSP (model). Once the viability of the Narrabri Gas Project is established, the transfer of CSG impact to these water sources will be critical. It would be preferable for this to be carried out within the model review so that operational changes could be proposed that would keep any impacts within acceptable limits.	The text has been amended to include reference to the GAB WSP (2020), GABSI and Lower Namoi Alluvium WSP (model).
13	6.2	Objective review	If required, the updates to the modelling objectives may include the adjustments of criteria for assessing whether the model is generally in accordance with the features of a Class 3 confidence level model.	**[Michael Williams]** This is a reasonable approach as achieving a model that meets all the Class 3 criteria requires CSG production for several years so concurrent model improvement is a practical solution.	Noted. No response required.

Item	Section #	Section heading	Existing text	Comment	Final response
14	6.3	Model revision	Updates to the Project groundwater model will be informed by the model data review described in section 4 and guided by the current or updated modelling objectives	**[Randall Cox]** The section refers to 'model data review described in Section 4'. The reference should be to Section 5 not Section 4	The correction has been made.
15	6.4	Model calibration	The quality of the calibration match will be assessed using the scaled root mean square (**SRMS**) statistic of the residuals, which represent the differences between the measured and modelled values, however, other methods of assessing the quality of the calibration may also be used. The potential outcome of this review may involve re-calibration of the Model by adjusting the model parameters to improve the calibration match and SRMS value.	**[Randall Cox]** Second para says that a model review 'may' involve recalibration. Wouldn't it necessarily involve recalibration?	Section 6.4, second paragraph has been amended as follows: *The quality of the calibration match will be assessed through reference to the scaled root mean square (**SRMS**) error and other statistics, which analyse differences between the measured and modelled values. Where this review identifies that the calibration is deficient or have significantly deteriorated then the model will be recalibrated by adjusting the model parameters to better match observed hydraulic head records.*
16	6.5.2	Base case Project development	The base case predictive simulation will be designed to represent the effects of the Project on groundwater sources by considering only the Project-related stresses and removing background effects that may be unrelated to the Project (such as existing third-party groundwater abstractions)	**[Michael Williams]** Given the impact of GABSI, it may be more practical to assume that the increase of GAB pressure heads is a long-term background. There would be significant work required to remove that impact without a tangible benefit to the CGS project.	Rather than removing background effects the usual modelling approach for resource project impact assessment is to run two simulations both including other extractions etc and then compare heads and flows to assess the NGP impact. This matter is relevant to development of the Phase 2 groundwater model or if a model revision is triggered by monitoring, which the Project conditions of consent require be undertaken in consultation with the WTAG at that time.
17	6.5.4	Uncertainty analysis	No specific text reference.	**[Jack Warnock]** In last line of this section see: "Error! Reference source not found."	Correct reference to section 8.2 inserted.
18	6.5.5	Predictive results	The presentation of induced groundwater fluxes in the results is designed to inform assessment of Project water take from all sources and the associated water entitlement considerations.	**[Michael Williams]** It is unclear as to what purpose the predictive results will be applied. They will be useful for the assessment of local impact of CGS production but their utility to predict the impact on other water sources is limited by the EIS model conceptualisation.	The groundwater model is not required to be updated prior to Phase 1. This matter is relevant to development of the Phase 2 groundwater model or if a model revision is triggered by monitoring, which the Project conditions of consent require be undertaken in consultation with the WTAG at that time.
19	6.5.5	Predictive results	Presentation of pressure head drawdown results is designed to inform an updated assessment of the potential effects of the Project water extraction on hydraulic head and pressure withing groundwater resources, and potential effects on access to existing users of those resources'	**[Randall Cox]** Model output will relate to pressure heads, but impact of a predicted pressure head reduction on 'access to existing users' is a further dimension. Not sure this is intended. It would be straightforward where there are no detectable impacts on pressure. But if there are, then to what extent will the effect on access be assessed? A given lowering of pressure head could have a large or small impact on access depending on the characteristics of the individual water supply bore? Is that a matter for the modelling report?	This matter is relevant to development of the Phase 2 groundwater model or if a model revision is triggered by monitoring, which the Project conditions of consent require be undertaken in consultation with the WTAG at that time.
20	6.5.6	Impact assessment	No specific text reference.	**[Jack Warnock]** In last line of this section see: "Error! Reference source not found."	Correct reference to section 1.4 of the GMP inserted.
21	8	Review and evaluation	No specific text reference.	**[Randall Cox]** The Independent reviewer should be appointed early and be part of the journey. Late appointment is likely to lead to difficulties at a late stage.	This matter is relevant to development of the Phase 2 groundwater model or if a model revision is triggered by monitoring, which the Project conditions of consent require be undertaken in consultation with the WTAG at that time.
22	Appendix B	Table B1	No specific text reference.	**[Jack Warnock]** At the end of third paragraph reference is made to: " the base of the alluvium within the **eleven** Groundwater Management Area zones…" Should read "… within the **twelve** Groundwater Management Area Zones …"	The title of Table B1 has been changed to *Relevant Groundwater Management Area Zones*
23	Appendix B	Table B1	No specific text reference.	**[Jack Warnock]** GMA Zone 12 should be added to the Upper Namoi Groundwater Source.	The title of Table B1 has been changed to *Relevant Groundwater Management Area Zones*

Note:
The numbering of appendices may have changed between the draft and final versions of the Plan and attachments.

Appendix B - Compliance conditions relevant to the GMP

Table B1 - SSD 6456 consent conditions directly relevant to this GMP

SSD 6456 consent conditions directly relevant to this GMP	Section reference
Consent condition A1 In meeting the conditions of this consent, the Applicant must implement all reasonable and feasible measures to prevent and, if prevention is not reasonable and feasible, minimise any material harm to the environment that may result from the construction, operation or rehabilitation of the development.	Section 1.2
Consent condition A5 The Applicant may only undertake the development in the following stages:	Section 1.1.2 Section 1.2
a) Phase 1, comprising ongoing exploration and appraisal activities;	
b) Phase 2, comprising construction activities for production wells and related infrastructure;	
c) Phase 3, comprising gas production operations; and	
d) Phase 4, comprising gas well and infrastructure decommissioning, rehabilitation and mine closure.	
Consent condition A23 With the approval of the Planning Secretary, the Applicant may:	
a) prepare and submit any strategy, plan or program required by this consent on a staged basis (if a clear description is provided as to the specific stage and scope of the development to which the strategy, plan or program applies, the relationship of the stage to any future stages and the trigger for updating the strategy, plan or program)	Section 1.2
b) combine any strategy, plan or program required by this consent (if a clear relationship is demonstrated between the strategies, plans or programs that are proposed to be combined);	No combination proposed as part of this Plan
c) update any strategy, plan or program required by this consent (to ensure the strategies, plans and programs required under this consent are updated on a regular basis and incorporate additional measures or amendments to improve the environmental performance of the development); and	Section 1.2 Section 12.4
d) combine any strategy, plan or program required by this consent with any similar strategy, plan or program required by a consent or approval for an adjoining mine subject to common, shared or related ownership or management.	No combination proposed as part of this Plan
Consent condition B37 The Applicant must ensure that the development complies with the groundwater management performance measures in Table 7 [of the CoC]:	Section 8 Table 8.1
• Namoi alluvial aquifers and Great Artesian Basin aquifers:	
▪ Negligible environmental consequences to the Namoi alluvial aquifers and Great Artesian Basin aquifers beyond those predicted in the EIS, including:	Section 1.4 Section 5
• negligible change in groundwater levels;	Section 5.2 Section 8.4.2
• negligible change in groundwater quality; and	
• negligible impact to other groundwater users	

SSD 6456 consent conditions directly relevant to this GMP	Section reference
▪ No exceedance of the minimal harm considerations in the Aquifer Interference Policy (DPI, 2012); and	Section 3.2.1 Appendix A
▪ Negligible change to baseline methane levels in groundwater user bores;	Section 4.4.4 Section 3.3 of the GMonP Appendix A of the GMonP Appendix B of the GMonP
• Gunnedah Oxley Basin aquifers:	
▪ Drawdown and water take to be generally consistent with the 'base case' predictions and produced water profile in the EIS; and	Section 8.4
▪ Negligible change in groundwater quality;	Section 5.2 Table 8.1 Section 8.3 Section 8.5.1
• Riparian and aquatic ecosystems:	
▪ Negligible impact on groundwater dependent ecosystems.	Section 5.2 Section 8.2 Section 8.3
Consent condition B39 The Applicant must periodically update the groundwater model for the development, to the satisfaction of the Planning Secretary. The model update must:	The following refer to sections of the Groundwater Modelling Plan, provided as Attachment 3:
a) be prepared and peer reviewed by suitably qualified and experienced persons;	GModP GModP Section 5.1 GModP Section 6.1 GModP Section 8.1
b) be undertaken in consultation with DPE Water, EPA, and the Water Technical Advisory Group;	GModP Section 8.1
c) be undertaken prior to Phase 2 and every 3 years thereafter (unless the Planning Secretary agrees or directs otherwise);	GModP Section 4
d) be undertaken in accordance with the Australian Modelling Guidelines (2012, or as updated) and other relevant guidelines including the IESC's Information Guidelines Explanatory Note – Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (2018);	GModP Section 2.1 GModP Section 6.1
e) improve the model prior to the commencement of Phase 2 to be generally in accordance with the features of a Class 3 confidence level model (as per the *Australian Groundwater Modelling Guidelines*) the features of which must be based on the Water Technical Advisory Group's advice on appropriate development specific modelling objectives and criteria; and	GModP Sections 4,2 GModP Sections 5.1 and 5.2
f) include:	
(i) updated modelling objectives	GModP Section 6.2

SSD 6456 consent conditions directly relevant to this GMP	Section reference
(ii) transient groundwater flow modelling;	GModP Sections 6.4 Section 6.5
(iii) updated geological modelling based on all available drill data and analysis, including:	GModP Section 5.3
▪ detailed structure assessment (including faulting) at best practice resolution;	
▪ consideration of neotectonics and the stress field in the project area and surrounds;	
(iv) updated hydrogeological modelling based on all well data, drilling data, hydrogeological analysis and water monitoring data for all aquifers and aquitards, including:	GModP Section 6.5.3
▪ consideration of impacts from the GABSI;	
▪ consideration of leakage from the GAB to the Lower Namoi Groundwater Source using the heads predicted by the EIS model;	
(v) updated predictions of groundwater drawdown and water take from all applicable groundwater sources as a result of the development; and	GModP Section 6.5
(vi) consideration of the predicted impacts against the:	GModP Section 7
▪ previous model predictions and monitoring results;	
▪ water management performance measures in Table 7 of the CoC;	
▪ minimal harm considerations in the NSW Aquifer Interference Policy; and	
▪ groundwater management response triggers in the Water Management Plan.	
Consent condition B40 The Applicant must not commence Phase 2 of the development if the updated groundwater model for the development required under Condition B39 predicts an exceedance of the water management performance measures identified in Table 7 [of the CoC].	This Plan is for Phase 1.
Consent condition B41 Prior to the commencement of Phase 1, the Applicant must prepare a Water Management Plan for the development to the satisfaction of the Planning Secretary. This plan must:	Refer to the Water Management Plan
a) be prepared by a suitably qualified and experienced person/s whose appointment has been endorsed by the Planning Secretary;	Refer to section 1.5 and Appendix A of the Water Management Plan
b) be prepared in consultation with DPE Water, EPA and the Water Technical Advisory Group;	Appendix A
c) describe the measures to be implemented to ensure that the Applicant complies with the water management performance measures (see Table 7 [of the CoC]);	Section 8.2
d) include a	

SSD 6456 consent conditions directly relevant to this GMP	Section reference
(iv) Groundwater Management Plan that includes	This Plan
• detailed baseline data of hydrogeology and groundwater levels, formation parameters (such as hydraulic conductivity, storage and yield) and quality for groundwater resources potentially impacted by the development (based on at least 3 years of monitoring data), including:	Section 4 Attachment 2 - Groundwater Baseline Report Appendix C - InSAR Analysis of Baseline Ground Displacement
▪ aquifer and aquitard health;	
▪ subsidence and seismicity, including a topographic baseline survey using interferometric synthetic aperture radar (or similar method as agreed by the Planning Secretary);	
▪ groundwater supply and quality for other water users;	
▪ natural methane leaks and accumulations, including in privately-owned bores and monitoring bores; and	
▪ groundwater dependent ecosystems;	
• a detailed description of the groundwater management and monitoring system, including a monitoring network that is capable of;	Section 6 Section 9
▪ characterising temporal and spatial variations of all potentially affected water sources;	
▪ verifying actual direct and indirect water take;	
▪ providing an early warning of any impacts to potentially affected water sources, at varying depths in the geologic profile;	
▪ providing data to improve the confidence level class of the groundwater model as soon as reasonable and feasible; and	
▪ integrating with any government monitoring networks in the area;	
• detailed performance criteria, including trigger levels for identifying and investigating any potentially adverse impacts associated with the development, on:	Section 8
▪ regional and local aquifers and aquitards (alluvial and hardrock);;	
▪ ground subsidence and seismicity;	
▪ groundwater supply and quality for other water users, including all potentially affected privately-owned licensed groundwater bores;	
▪ groundwater dependent ecosystems; and	
▪ aquatic habitat and stygofauna;	
• a program for baseline data acquisition (works and timing) for the required groundwater model updates;	Attachment 1 - Groundwater Monitoring Plan
• a program to monitor and evaluate:	Section 9
▪ compliance with the relevant performance measures listed in Table 7 [of the CoC] and the performance criteria established above;	Section 9.1
▪ groundwater flows, quality and yield in regional and local aquifers and aquitards (alluvial and hardrock);	Section 9.2
▪ ground subsidence and seismicity;	Section 9.3
▪ geological fracturing and heterogeneity;	Section 9.4

SSD 6456 consent conditions directly relevant to this GMP	Section reference
▪ water loss/seepage/leakage from water storages and Project-related infrastructure into the groundwater system;	Section 9.5
▪ potential cross-contamination of aquifers, including migration from lower aquifers to the GAB;	Section 9.6
▪ sub-surface leakage of methane, drilling fluids and saline groundwater;	Section 6 Section 9.7 GMonP section 3.3
▪ groundwater inflows, outflows and storage volumes to inform the Site Water Balance;	Attachment 3 - Groundwater Modelling Plan Section 9.8
▪ the effectiveness of the groundwater management system;	Section 12.1 Section 12.3
• reporting procedures for the results of the monitoring program (including timely public reporting); and	Section 12
• a plan to respond to any probable or actual exceedances of the groundwater performance criteria, and repair, mitigate and/or offset any adverse groundwater impacts of the development.	Section 11.1
Consent condition D3 The Applicant must ensure that (where relevant) the management plans required under this consent include:	
a) a summary of relevant background or baseline data;	Attachment 2 – Groundwater Baseline Report
b) details of:	
(i) the relevant statutory requirements (including any relevant approval, licence or lease conditions);	Section 3
(ii) any relevant limits or performance measures and criteria; and	Section 8.2
(iii) the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the development or any management measures;	Section 8.4
c) any relevant commitments or recommendations identified in the documents listed in the NGP EIS;	Section 3.3
d) a description of the measures to be implemented to comply with the relevant statutory requirements, limits, or performance measures and criteria	Section 8.3
e) a program to monitor and report on the:	
(i) impacts and environmental performance of the development; and	Section 8.2
effectiveness of the management measures set out pursuant to paragraph (d);	Section 8.3
f) a contingency plan to manage any unpredicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible;	Section 11.2
g) a program to investigate and implement ways to improve the environmental performance of the development over time	Section 11

SSD 6456 consent conditions directly relevant to this GMP	Section reference
h) a protocol for managing and reporting any:	
(i) incident, non-compliance or exceedance of any impact assessment criterion and performance criterion	Section 11.1
(ii) complaint; or	Section 11.3
(iii) failure to comply with other statutory requirements; and	Section 11.1
i) a protocol for periodic review of the plan.	Section 12.3
Consent condition D4 Within 2 months of: (a) the submission of an incident report; (b) the submission of an Annual Review; (c)the submission of an Independent Environmental Audit; (d) the submission of a Field Development Plan; (e) the submission of a Groundwater Model Update; or (f) the approval of any modification of the conditions of this consent, the Applicant must review the suitability of existing strategies, plans and programs required under this consent.:	Section 12.3
Consent condition D5 If the review determines that the strategies, plans and programs required under this consent require revision – to either improve the environmental performance of the development, cater for a modification or comply with a direction - then the Applicant must submit the revised document to the Planning Secretary for approval within 6 weeks of the review. **Note**: *This is to ensure strategies, plans and programs are updated on a regular basis and to incorporate any recommended measures to improve the environmental performance of the development.*	Section 12.3
Consent condition D6 The Applicant must notify the Department and any other relevant agencies via the Major Projects Portal immediately after it becomes aware of the incident. This notice must describe the location and nature of the incident.	Section 11.1
Consent condition D7 Within 7 days of becoming aware of a non-compliance with the conditions of this consent, the Applicant must notify the Department of the non-compliance via the Major Projects Portal. This notice must set out the non-compliance, the reasons for the non-compliance (if known) and what actions have been taken, or will be taken, to address the non-compliance. **Note**: *A non-compliance which has been notified as an incident does not need to also be notified as a non-compliance*	Section 11.1
Consent condition D8 By the end of March each year, unless the Planning Secretary agrees otherwise, the Applicant must submit an Annual Review of the environmental performance of the development to the Department via the Major Projects Portal.	Section 12.1

SSD 6456 consent conditions directly relevant to this GMP	Section reference
Consent condition D9 Within one year of commencement of Phase 1 and every 3 years thereafter, unless the Planning Secretary directs otherwise, the Applicant must commission and pay the full cost of an Independent Environmental Audit of the development.	Section 12.2
Consent condition D13 From the commencement of Phase 1, until the completion of all rehabilitation required under this consent, the Applicant must:	
c) make copies of the following information publicly available on its website: (i) the document/s listed in condition A2(c); (ii) current statutory approvals for the development; (iii) approved strategies, plans and programs; (iv) detailed plans for the Phases of the development; (v) minutes of CCC and Advisory Group meetings; (vi) regular reporting on the environmental performance of the development in accordance with the reporting requirements in any plans or programs approved under the conditions of this consent; (vii) a comprehensive summary of the monitoring results of the development, reported in accordance with the specifications in any conditions of this consent, or any approved plans and programs; (viii) a summary of the current phase/s and progress of the development; (ix) contact details to enquire about the development or to make a complaint; (x) a complaint register, updated monthly; (xi) a record of all incidents and non-compliances; (xii) the Annual Reviews of the development; (xiii) audit reports prepared as part of any Independent Environmental Audit of the development and the Applicant's response to the recommendations in any audit report; and (xiv) any other matter required by the Planning Secretary; and	Section 1.7 Section 12.4
d) keep such information up to date.	Section 1.7 Section 12.4

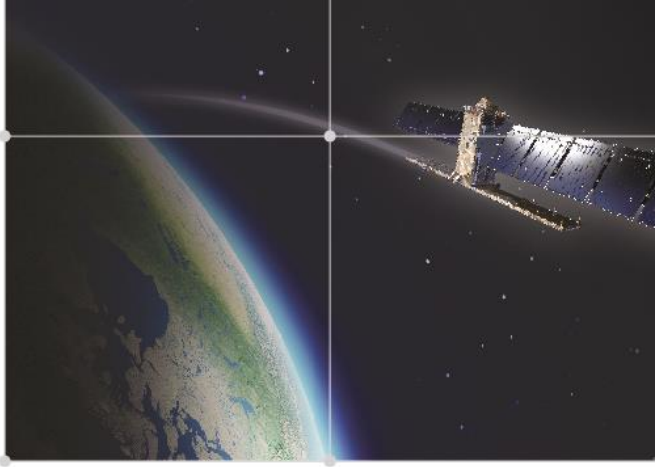
Table B2 - EPBC 2014/7376 approval conditions directly relevant to this GMP

EPBC 2014/7376 approval conditions directly relevant to this GMP	Section reference
Approval condition 7 The approval holder must establish an early warning monitoring system to detect groundwater pressure changes in deeper hydrostratigraphic units, so as to be able to take corrective actions in sufficient time to prevent impacts in shallow productive aquifers and GDEs. In addition to the monitoring requirements specified in the approved Groundwater Management Plan required under condition B41 of the NSW approval, Santos must:	GMonP section 2.3 and section 3.2
a) establish and maintain a network of groundwater monitoring bores across the Project area in the Napperby Sandstone. In the Project area where the Napperby Sandstone is in direct contact with the Namoi Alluvium, an appropriate network of groundwater monitoring bores must also be established and maintained in those areas in the Digby Formation. These monitoring bores must be installed prior to the commencement of Phase 2;	GMonP section 3.1
b) monitor groundwater levels in these bores at a minimum of 3-monthly intervals from the commencement of Phase 1 or bore construction (whichever is first) until the completion of the Project; and	GMonP section 3.2
c) publish all groundwater monitoring data from all bores, updated to add the most recent readings each quarter, on the website, and maintain that data on the website until the completion of the Project. The monitoring data must include hydrographs for all monitoring bores and explain what the data means in relation to the groundwater performance criteria specified in the NSW-approved Groundwater Management Plan.	Section 9 WMP section 5
Approval condition 8 If, at any time until the end date of this approval:	
a) the approval holder detects an exceedance of any groundwater performance criterion (including trigger levels), specified in the approved Groundwater Management Plan required by condition B41 of the NSW approval; and/or	Section 11.1
b) the groundwater model, including any update required under condition B39 of the NSW approval, predicts an exceedance of the groundwater performance criteria (including trigger levels), specified in the approved Groundwater Management Plan;	
the approval holder must notify DCCEEW of the exceedance within 10 business days of detecting or predicting the exceedance.	
Approval condition 9 The approval holder must, within 6 months of detecting or predicting an exceedance as described in condition 8, publish on the website a report describing:	Section 11.1
a) all potential and actual impacts to water resources arising from the exceedance;	
b) any further investigations undertaken to determine the cause of and remedy for the exceedance; and	
c) the mitigation and management measures that Santos has taken and proposes to take to reverse the exceedance, including data demonstrating the effectiveness of the mitigation and management measures.	

EPBC 2014/7376 approval conditions directly relevant to this GMP	Section reference
The approval holder must notify DCCEEW within 2 business days of the report being published and retain the report on the website for the life of the approval.	
Approval condition 10 If, after the implementation of condition 9 the approval holder detects or predicts that the outcomes specified in CoA Appendix B cannot or will not be achieved, or the Minister considers that the outcomes specified in CoA Appendix B cannot or will not be achieved, then the approval holder must provide a site-specific assessment for the Minister's written approval within 3 months of making the prediction or of receiving a request from the Minister.	Section 9.1
Approval condition 11 Each site-specific assessment must incorporate data collected from the groundwater monitoring bores required by CoA 7 and be prepared by a suitably qualified water resources expert to derive a scientifically robust cease-work limit. Each site-specific assessment must include justification for how the outcomes specified in CoA Appendix B will be achieved and maintained and include:	Section 9
a) multiple lines of evidence and field data to support the assessment of the environmental value and groundwater-dependence of any potential GDEs identified in the area of predicted impact;	
b) conceptual modelling, including a review of all historical monitoring data to determine the stressor-response relationships for any potential GDEs and consideration of potential contributing activities;	
c) local scale numerical modelling with consideration of potential contributing activities and identification of potential contributing well/s; and	
d) a peer review undertaken by an independent suitably qualified water resources expert including details of how the approval holder has addressed any inadequacies raised in the peer review.	
Approval condition 12 The approval holder must publish each site-specific assessment approved by the Minister on its website within 5 business days of receiving approval for the site-specific assessment and for the remainder of the life of the Project.	Section 1.7
Approval condition 13 The Minister may specify an interim cease-work limit to manage groundwater impacts where the Minister is not satisfied that the cease-work limit proposed by the approval holder in accordance with CoA 11 will ensure the outcome/s specified in CoA Appendix B will be, or are likely to be, achieved and maintained.	Section 9
Approval condition 14 If The approval holder detects or is informed that a cease-work limit has been exceeded, the approval holder must, in addition to the incident reporting requirements of CoA 35, provide in writing details of the contributing well/s to DCCEEW within 10 business days of the detection or of being informed.	Section 9

EPBC 2014/7376 approval conditions directly relevant to this GMP	Section reference
Approval condition 15 Unless otherwise notified by the Minister in writing, the approval holder must cease groundwater extraction associated with any contributing well/s within 10 business days of reporting the exceedance of a cease-work limit to DCCEEW. *Note: The Minister, in determining whether to give notice to the approval holder that it is not required to cease groundwater extraction, will consider all relevant information including but not limited to legislation and policy, information provided by the approval holder, and any other information available to the Minister at the time of the decision.*	Section 9
Approval condition 16 If the approval holder has been required to cease groundwater extraction pursuant to CoA 15, the approval holder must implement corrective actions so as to achieve and maintain the outcomes and sub-outcomes specified in CoA Appendix B.	Section 9
Approval condition 17 The approval holder must not recommence groundwater extraction from any contributing well/s until it can be demonstrated that the outcomes and sub-outcomes specified in CoA Appendix B are being achieved and the Minister approves in writing groundwater extraction from those contributing well/s. *Note: Approval to recommence groundwater extraction may be subject to conditions that the Minister considers reasonable*.	Section 9

Appendix C - InSAR analysis of baseline ground displacement



InSAR Analysis of Baseline Ground Displacement from 2014 to 2020 over the Narrabri Gas Project Area

Technical Report

December 2020

TRE ALTAMIRA

A CLS Group Company

Report Specifications

Client:	**Santos Limited**
Attention:	David Gornall
Address:	32 Turbot Street, Brisbane QLD 4000 Australia

Reference:	
Title:	InSAR Analysis of Baseline Ground Displacement from 2014 to 2020 over the Narrabri Gas Project Area
TRE ALTAMIRA Delivery Reference:	JO20-1287-CA REP 1.0
Client Reference (PO):	AU-0001

Prepared by:	**TRE ALTAMIRA Inc.**
Author(s):	Emma Cunningham
Verified by:	Vicky Hsiao
Approved by:	Giacomo Falorni
Date:	10 December 2020
Version:	1.0

Executive Summary

This report describes the results of the historical ground displacement InSAR analysis over the Narrabri Gas Project (NGP) area in Australia, for Santos Limited. TRE Altamira used its SqueeSAR® algorithm to process low-resolution Sentinel images and carry out a 1-D analysis of ground displacement over a period of 5 years and 10 months (01 November 2014 to 30 September 2020).

The following points summarize the key findings:

- Little ground displacement was identified within the NGP area.
- Localized seasonal trends were identified over areas of vegetation.

Sentinel image acquisitions over the site are currently proceeding with a 12-day revisit frequency.

Confidentiality disclaimer

Table of Contents

Acronyms and Abbreviations

AOI	Area of Interest
ATS	Average Time Series
CS	Cross-Section
DEM	Digital Elevation Model
DInSAR	Differential Interferometric SAR
DS	Distributed Scatterer(s)
GIS	Geographic Information System
InSAR	Interferometric Synthetic Aperture Radar
LOS	Line of Sight
MP	Measurement Point
NGP	Narrabri Gas Project
NR	Natural Reflector
PS	Permanent Scatterer(s)
SAR	Synthetic Aperture Radar
SNT	Sentinel Satellite
SqueeSAR®	The most recent InSAR algorithm patented by TRE
TCS	Temporary Coherent Scatterer
TS	Time Series

1. Introduction

Santos Limited contracted TRE Altamira Inc. (TREA) to carry out a historical InSAR analysis over the NGP area in New South Wales, Australia. TREA used its proprietary SqueeSAR algorithm and low-resolution Sentinel C-band imagery over the last 5 years and 10 months to identify ground movement at the site.

1.1. Area of Interest

The Narrabri Gas Project area is located approximately 550 km northwest of Sydney, Australia. The approximately 950 km^2 NGP area (Figure 1) includes a mixture of exposed, arid ground, vegetation, and man-made structures that make this a suitable location for InSAR.

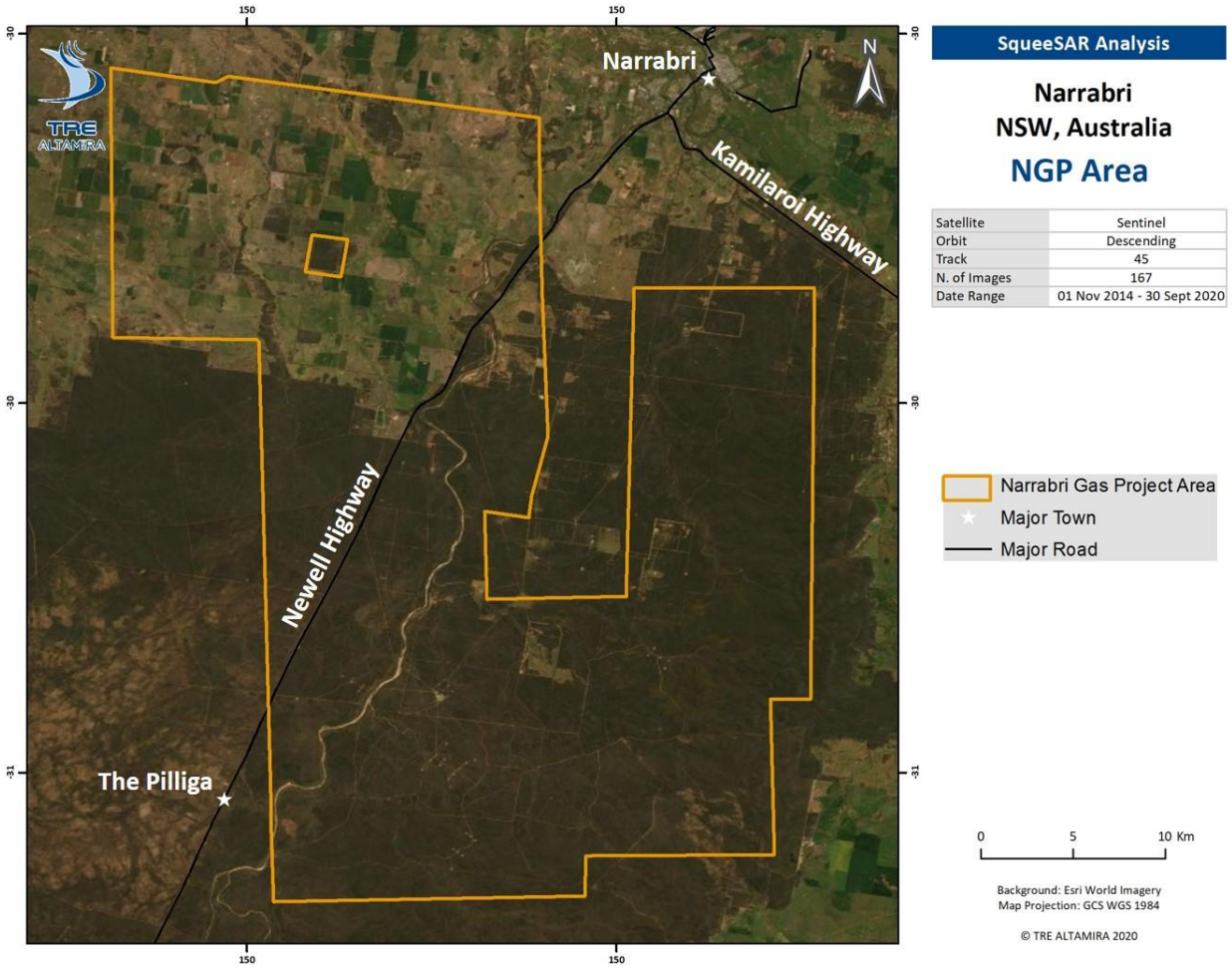


Figure 1: Narrabri Gas Project area of interest.

2. Radar Data

The radar data available over the Narrabri Gas Project area consists of low-resolution images acquired by the Sentinel satellite from a descending orbit (satellite travelling from north to south and imaging to the west) (Table 1). The 167-image data archive covers the period 01 November 2014 to 30 September 2020 (Figure 2 and Table 2). Sentinel image acquisitions over the site are ongoing with a 12-day revisit frequency. Appendix 2 provides additional information on the satellite acquisition parameters.

Table 1: Satellite acquisition parameters and image acquisition information.

Satellite	Pixel Resolution	Orbit	LOS Angle (Θ)	# of Images	Date Range
Sentinel	20 m x 5 m	Descending	36.7°	167	01 November 2014 – 30 September 2020

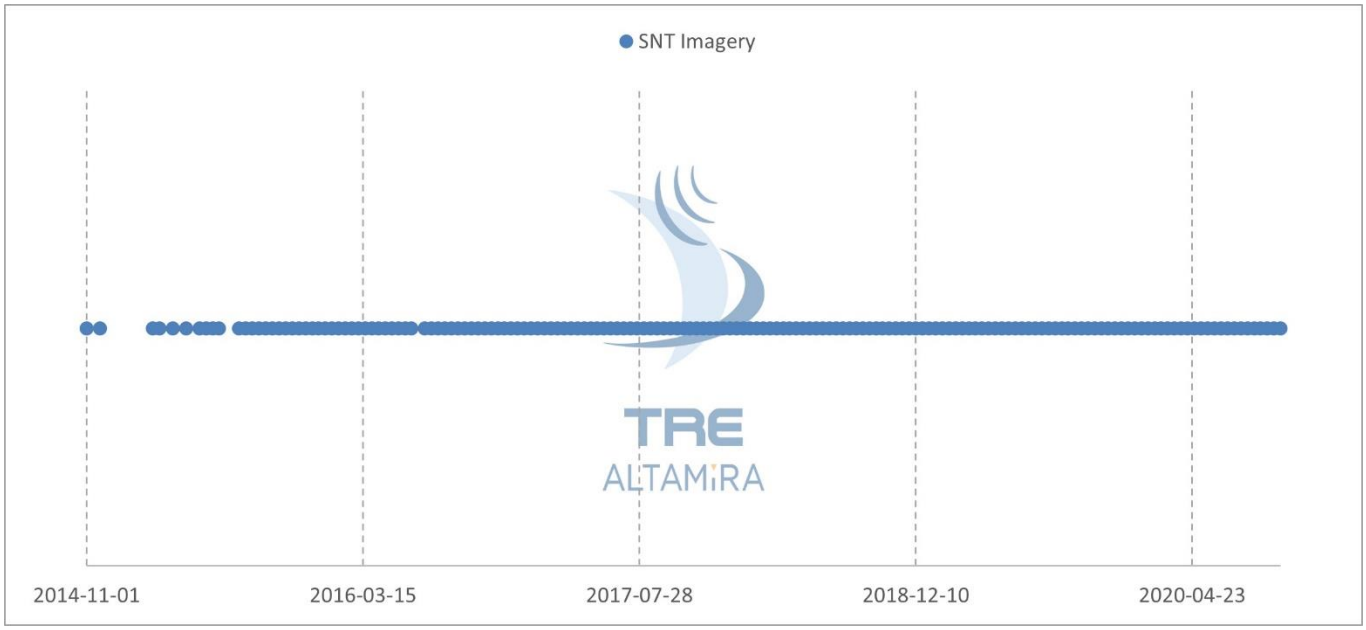


Figure 2: Temporal distribution of Sentinel radar images processed over the Narrabri Gas Project area.

3. Overview of Results

This section provides a summary of the techniques used and a general overview of the results, while Section 4 further describes areas of displacement in more detail. Refer to the Handbook for further details the technology and techniques used.

3.1. SqueeSAR Analysis

SqueeSAR identifies measurement points (MPs) from objects on the ground that display a stable return to the satellite in every image of an image archive. The MPs belong to two different categories (Figure 3):

- Permanent Scatterers (PS): point-wise radar targets characterized by highly stable radar signal return (e.g. buildings, rocky outcrops, linear infrastructures, etc.)

- Distributed Scatterers (DS): patches of ground exhibiting a lower but homogenous radar signal return (e.g. rangeland, debris fields, arid areas, etc.). DS therefore refer to small areas covering several pixels rather than to a single target or object on the ground. For clarity of presentation and ease of interpretation, DS are represented as individual points.

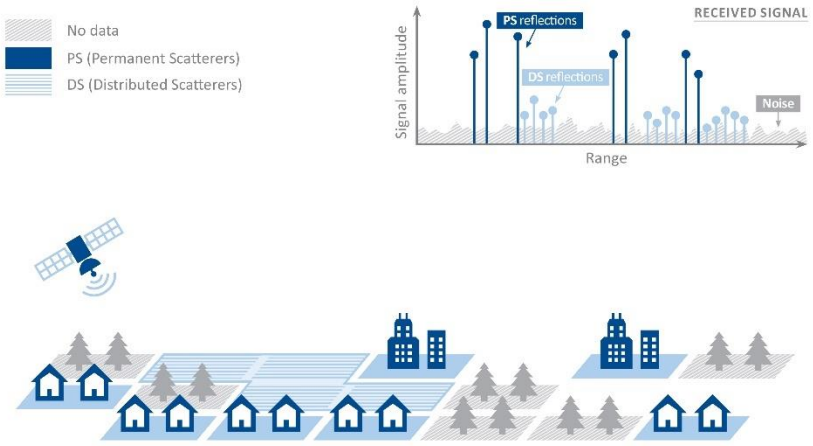


Figure 3: Schematic of PS and DS radar targets.

The density and distribution of the MPs is related to the resolution of the SAR images used and the surface characteristics of the area. In general, MP density increases with satellite resolution and the presence of man-made structures and decreases with the presence of vegetation. The highest density is reached over urban areas and arid ground, while it is lower over vegetated or agricultural areas, which are affected by reflectivity changes over time. No measurement points are obtained over water.

For each MP, SqueeSAR provides:

- Position and elevation estimated with respect to the WGS84 ellipsoid;
- Annual average displacement rate measured along the LOS, expressed in mm/yr, calculated over the observation period and referred to the reference point;
- Displacement time series (TS) representing the evolution of the MP's displacement for each acquisition date, expressed in inches [mm] and measured along the LOS direction.

When considering the DS type of MPs, the information provided by SqueeSAR refers to an area, rather than to a point.

In InSAR analyses, all measurements are 1-D readings along the sensor's line-of-sight (LOS) as the true vector of displacement is projected onto the LOS. The same displacement will produce different readings when viewed from different angles (Figure 4). Negative values (red) indicate surface displacement away from the satellite, while positive values (blue) indicate surface displacement towards the satellite.

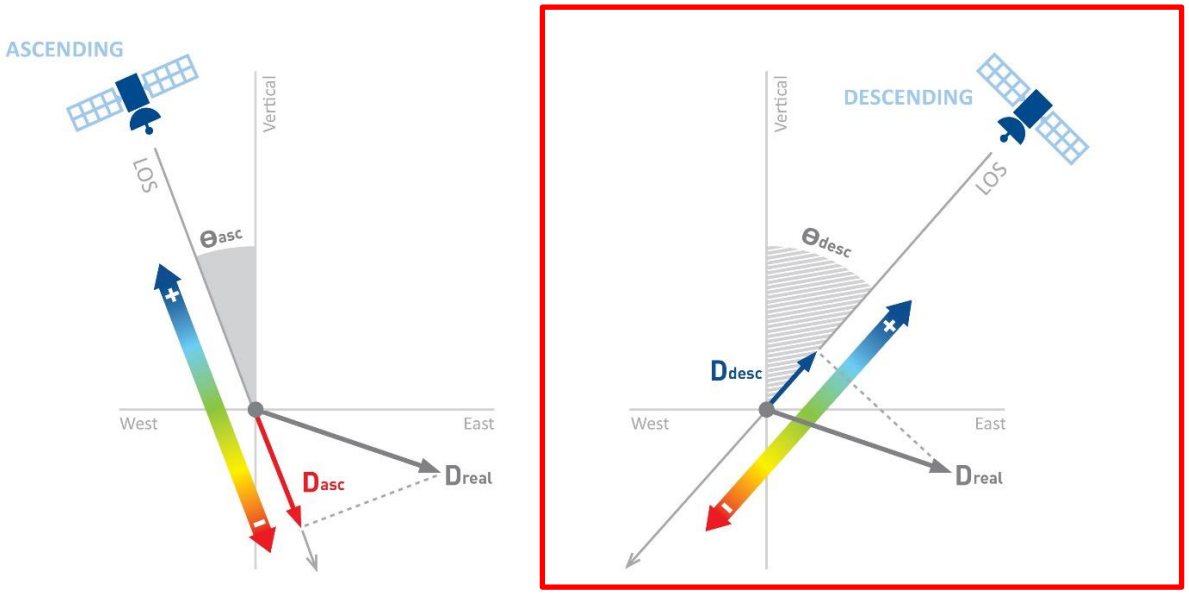


Figure 4: SqueeSAR measures the projection of real movement (D_{real}) onto the LOS. The same real movement (D_{real}) will produce a different value from a different LOS (different inclination or different orbits).

Displacement measurements obtained by the SqueeSAR algorithm are differential in space and time. Measurements are spatially related to the reference point (REF), and temporally to the date of the first available satellite image. The reference point is assumed to be motionless and for its radar properties to optimize the quality of the measurements.

Geographic coordinates of each MP depend on its SAR coordinates as well as its elevation, which are both estimated from the SqueeSAR analysis. The higher the spatial resolution of the satellite used in the analysis, the better the precision of the geocoding. The typical values of the location accuracy for SNT are reported in Table 2. Geocoding can be refined using a priori information but the absolute location of the REF with respect to the International Terrestrial Reference System (ITRS) can be verified only using an independent GNSS.

Table 2. Typical precision values (1 sigma) of the UTM coordinates of a MP at mid-latitudes. Values are referred to a MP less than 1 km from the REF in a data set of at least 30 images.

Direction	C-band SNT [m]
North	± 8
East	± 12
Vertical (elevation)	±8

SqueeSAR displacement measurements are provided with two precision indices:

- Displacement rate standard deviation, which provides an indication of the error bar of the annual displacement rate;
- Time series standard deviation, which provides an indication of the error bar of the displacement time series.

The displacement rate standard deviation characterizes the error associated with rate measurements with respect to the reference point. Given the standard deviation (σ), and assuming that the errors are normally distributed (or Gaussian), 95% of the values tend to be included in a ±2σ range.

The standard deviation of the displacement time series indicates how well an analytical model fits the displacement time series. The model is selected individually for each measurement point with an advanced Model Order Selection technique that also takes into account the quality of the image archive (number of processed images, time span covered by the archive and possible gaps in the acquisitions). The lower the standard deviation, the lower the average residual with respect to the analytical model. (i.e. the smaller the error bar of the time series).

3.2. Line-of-Sight Results

The LOS displacement rates measured in millimeters per year from the 5.8-year SNT descending archive (01 November 2014 to 30 September 2020) are shown in Figure 5. Further observations are described in Section 4.

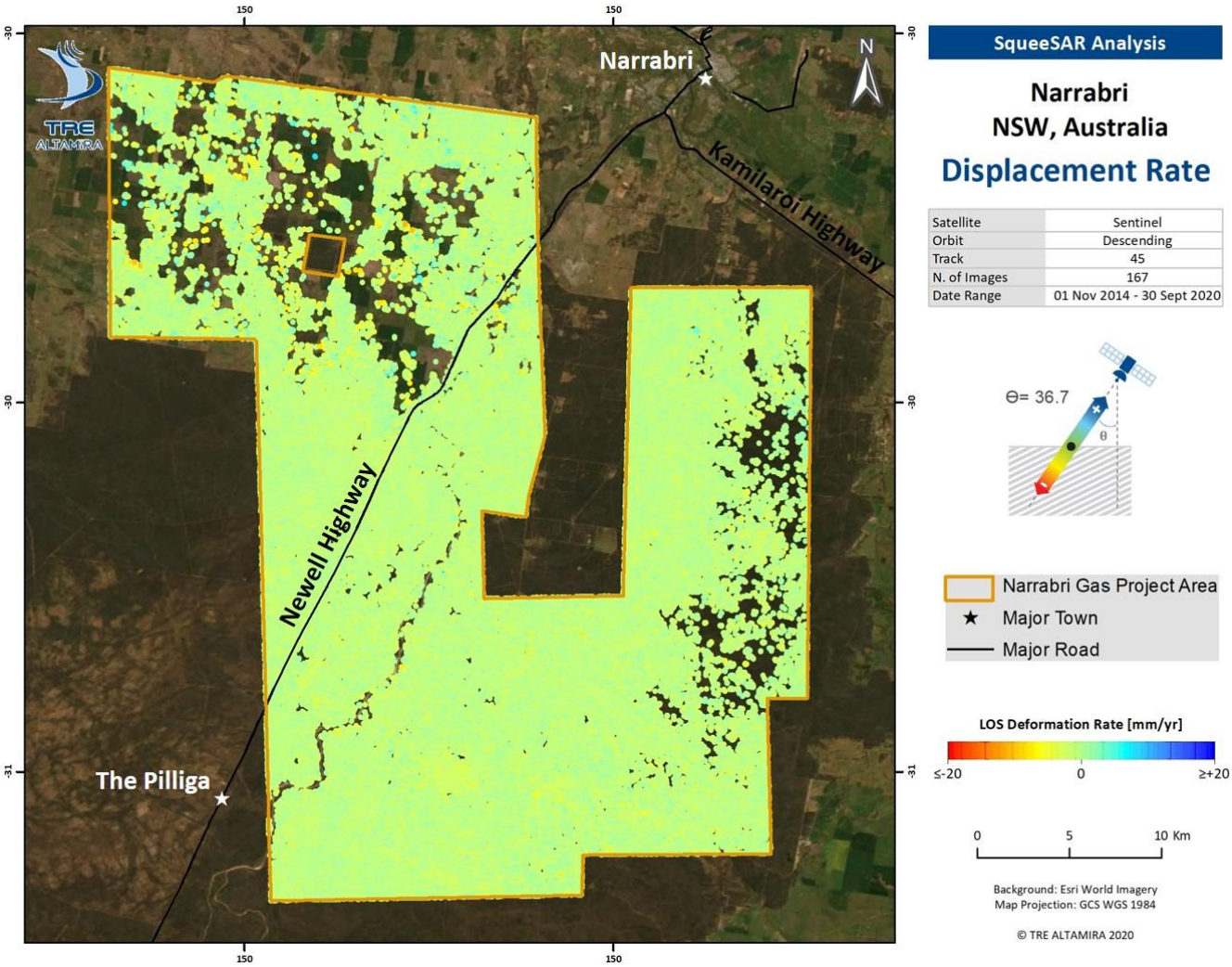


Figure 5. Annualized displacement rate over the Narrabri Gas Project area.

The Sentinel SqueeSAR analysis provided a density of 1,212 measurement points per square kilometer (Table 3). The precision of the measurements, as indicated by the average standard deviation values, is ±0.2 mm/yr. The density and precision of the Sentinel measurement points is expected to continue improving as more images are acquired.

Table 3: Properties of the SqueeSAR analysis.

Attribute	Descending
Date Range	01 Nov 2014 – 30 Sept 2020
N. of Images	167
Total points (PS + DS) **Number of PS** **Number of DS**	1,151,949 6,101 1,145,848
Average Point Density (pts/km^2)	1,212
Average Displacement Rate Standard Deviation (mm/yr)	±0.2
Average Time Series Error Bar (mm)	±3.5
Reference Point Location	X: 149.7764392 Y: -30.3257306

4. Observations

4.1. Acceleration

Acceleration rates [mm/yr^2], calculated from a second order model fitted to the deformation time series, help identify non-linear trends in the deformation time series (i.e. areas where the displacement rate is increasing or decreasing in the observed period). Negative accelerations are marked in red and indicate either an increase in subsidence rates or a decrease in uplift. Positive accelerations are displayed in blue and denote either an increase in the rate of uplift or a decrease in the rate of subsidence.

The average acceleration rate throughout the NGP area is low (Figure 6).

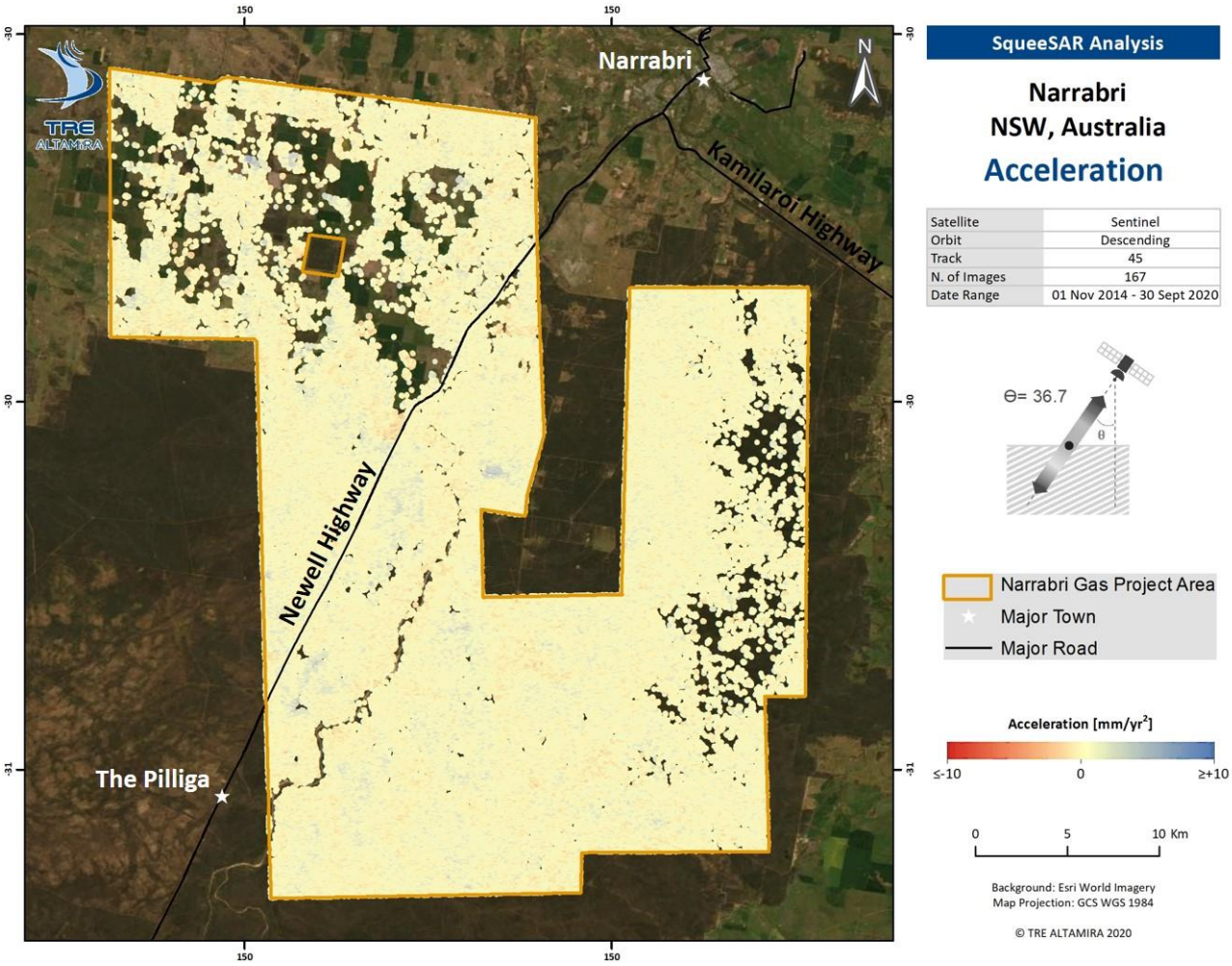


Figure 6. Acceleration rates over the Narrabri Gas Project area.

4.2. Seasonality

Seasonal deformation trends are assessed based on the seasonal amplitude [millimeters] of the deformation time series. The map in Figure 7 highlights the presence of few, localized seasonal trends concentrated mainly over areas of vegetation throughout the NGP area.

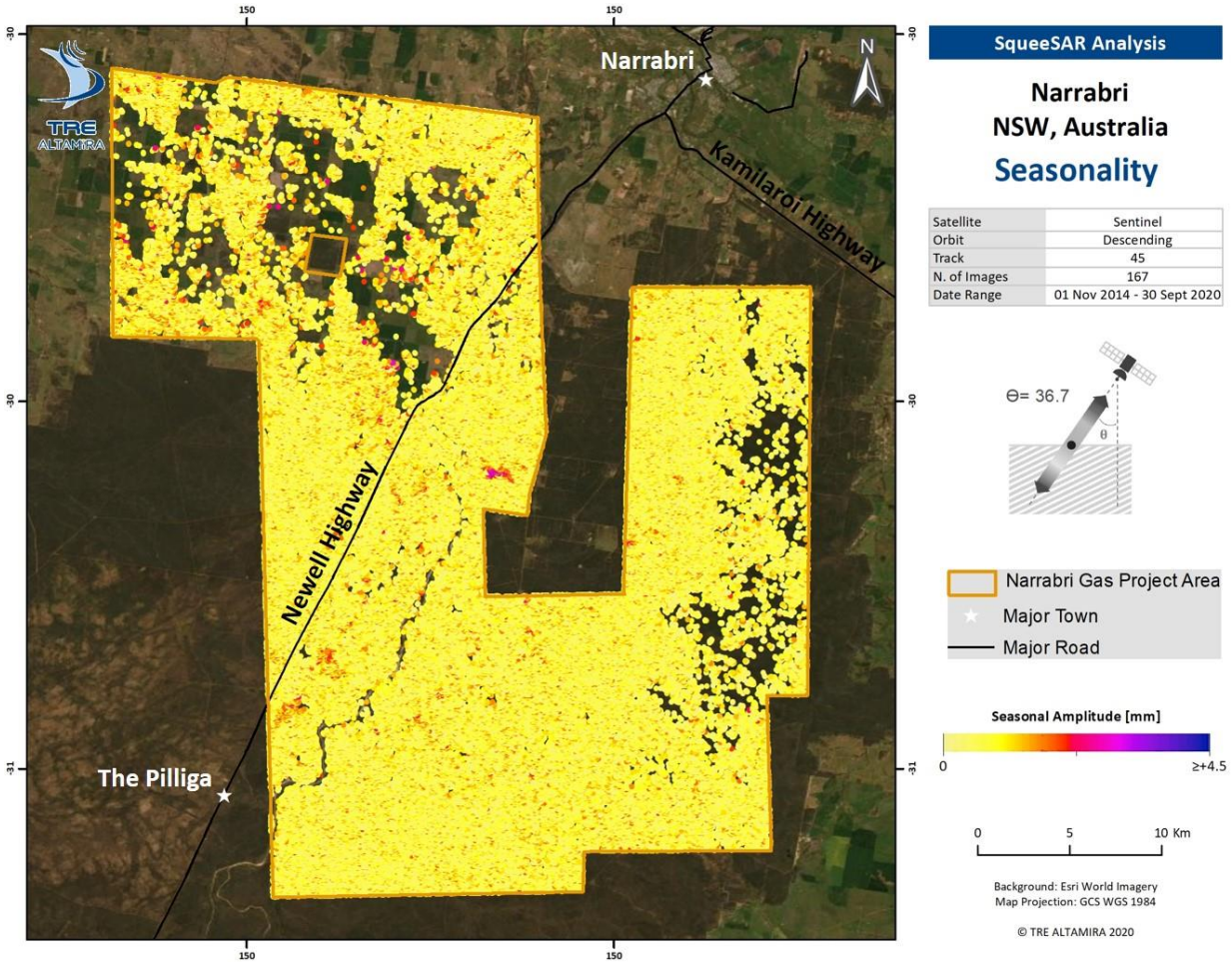


Figure 7. Seasonal amplitude over the Narrabri Gas Project Area.

4.3. Average Time Series over Wellpads

Average time series (ATS) are generated by averaging the time series of all measurement points located within selected areas of subsidence and uplift. Four ATS were generated over wellpads throughout the NGP area (Figure 8) and individual ATS are shown in Figure 9 and Figure 10.

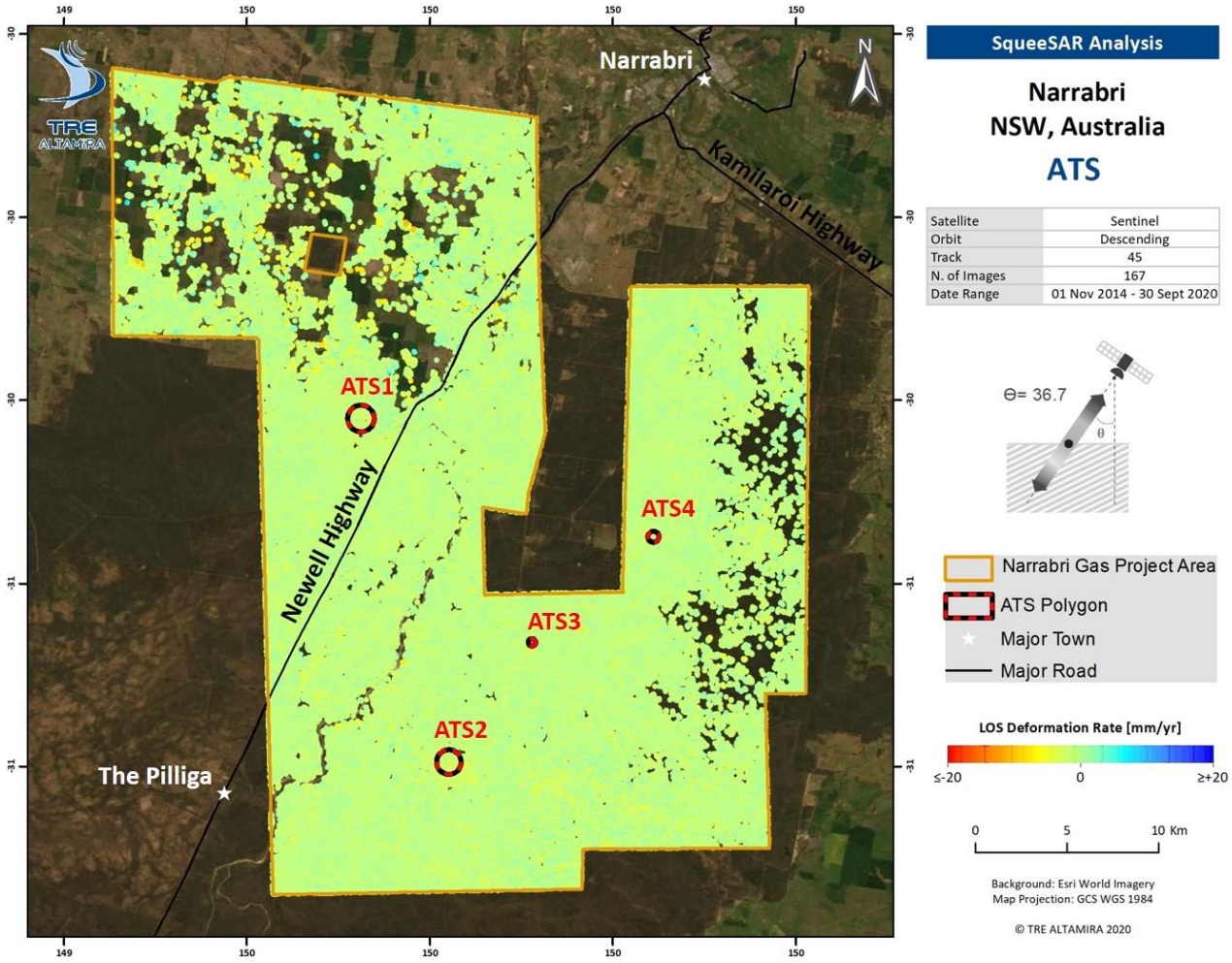


Figure 8. Locations of the ATS polygons within the Narrabri Gas Project area.

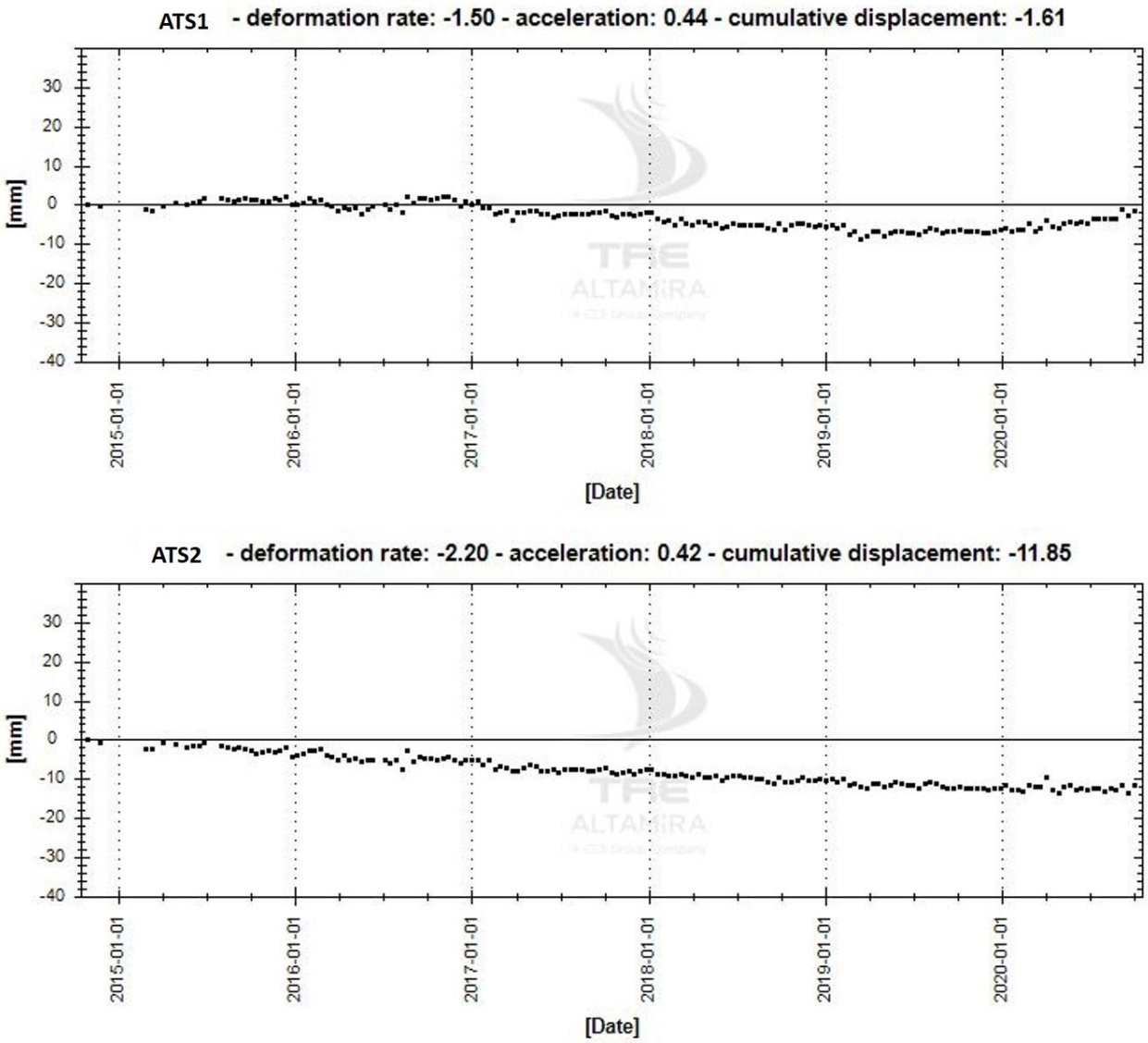


Figure 9. ATS of all measurement points identified within ATS1 (top) and ATS2 (bottom).

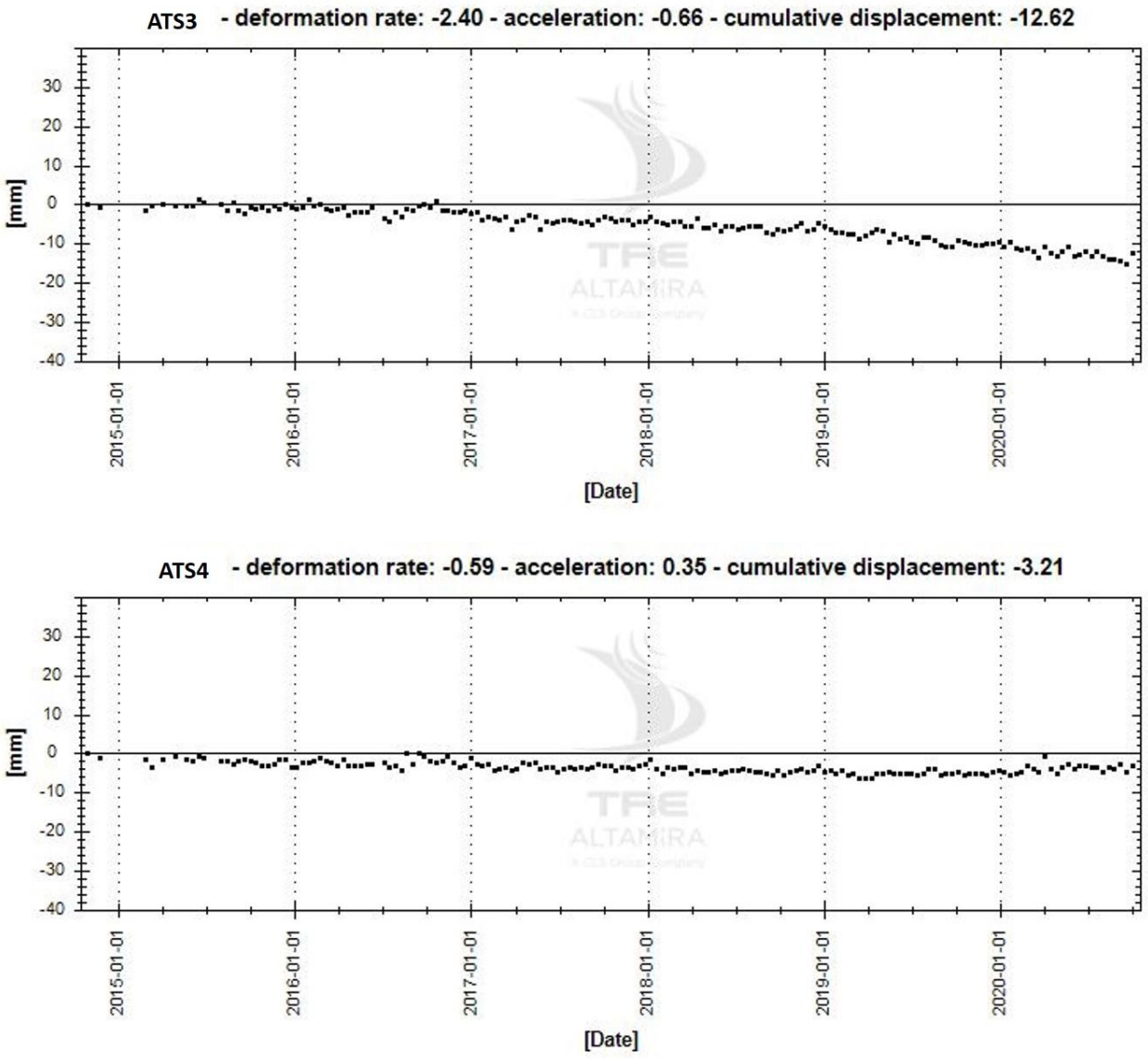


Figure 10. ATS of all measurement points identified within ATS3 (top) and ATS4 (bottom).

5. Summary and Recommendations

TREA carried out an analysis of ground deformation over the Narrabri Gas Project area using SNT imagery for the period 01 November 2014 to 30 September 2020. The results confirm relative stability throughout the NGP area.

Sentinel image acquisitions are currently ongoing with a 12-day revisit frequency. Ongoing monitoring over the NGP area is available with an annual update in 2021.

Appendix 1: Delivered Files

List of Deliverables

Table 4 list the deliverables including the present report, the InSAR data files and an updated version of the TRE toolbar, a software tool for assisting with the loading, viewing and interrogation of the data in ESRI ArcGIS 10.x software (For set-up procedure and functionalities, see the attached manual *TREToolbarSetup_5.0.pdf*).

Table 4: List of deliverables.

Description	File name
SqueeSAR Data	**Descending (LOS):** NARRABRI_SNT_T45_D_1_CA3136A1S.shp NARRABRI_SNT_T45_D_2_CA3136A1S.shp NARRABRI_SNT_T45_D_3_CA3136A1S.shp
MXD project file containing all the data (ESRI ArcGIS version 10.0 and 10.8)	Santos_Narrabri_SNT_Nov2020_v10.0.mxd Santos_Narrabri_SNT_Nov2020_v10.8.mxd
Technical Report	InSAR Analysis of Baseline Ground Displacement from 2014 to 2020 over the Narrabri Gas Project area.pdf
TRE Toolbar (ESRI® ArcGIS 10.x)	TREToolbar_5.0 TREToolbarSetup_5.0.pdf

Database Structure

The SqueeSAR vector data are delivered in a shapefile format and projected to WGS84 coordinates. The shapefile of each elaboration contains details about the measurement points identified, including displacement rate, elevation, cumulative displacement and quality index. The information associated within the database files (dbf) are described in Table 5.

Table 5: Description of the fields contained in the database of the vector data.

Field	Description
CODE	Measurement Point (MP) identification code.
HEIGHT	Topographic Elevation referred to WGS84 ellipsoid of the measurement point [m].
H_STDEV	Height standard deviation of the measurement point [m].
VEL	MP displacement rate [mm/yr]. • **Descending LOS:** Positive values correspond to motion toward the satellite (i.e. uplift and/or eastward movement); negative values correspond to motion away from the satellite (i.e. downward and/or westward movement).
V_STDEV	Displacement rate standard deviation [mm/yr].
ACC	Acceleration rate [mm/yr^2].
A_STDEV	Standard deviation of the acceleration value [mm/yr^2].
COHERENCE	Quality measure between 0 and 1.
STD_DEF	Displacement time series error bar [mm]
EFF_AREA	This parameter represents the effective extension of the area [m^2] covered by Distributed Scatterers (DS). For permanent scatterers (PS), its value is set to 0.
Dyyyymmdd	Series of columns that contain the displacement values of successive acquisitions relative to the first acquisition available [mm].

Appendix 2: Additional Radar Data Details

InSAR-based approaches measure surface displacement on a one-dimensional plane, along the satellite line-of-sight (LOS). The LOS angle varies depending on the satellite and on the acquisition parameters while another important angle, between the orbit direction and the geographic North, is nearly constant.

An ascending orbit denotes a satellite travelling from south to north and imaging to the east, while a descending orbit indicates a satellite travelling from north to south and imaging to the west. Table 6 lists the values of the angles for this study, while Figure 11 and Figure 12 show the geometry of the image acquisitions over the site for the ascending and descending orbits, respectively. The symbol Θ (theta) represents the angle the LOS forms with the vertical and δ (delta) the angle formed with the geographic north.

Table 6: Satellite viewing angles for the study.

Satellite	Wavelength	Orbit	Beam Mode/ Track	Symbol	Angle
Sentinel	C-Band 5.55 cm	Descending	45	**θ**	36.7°
				δ	16.4°

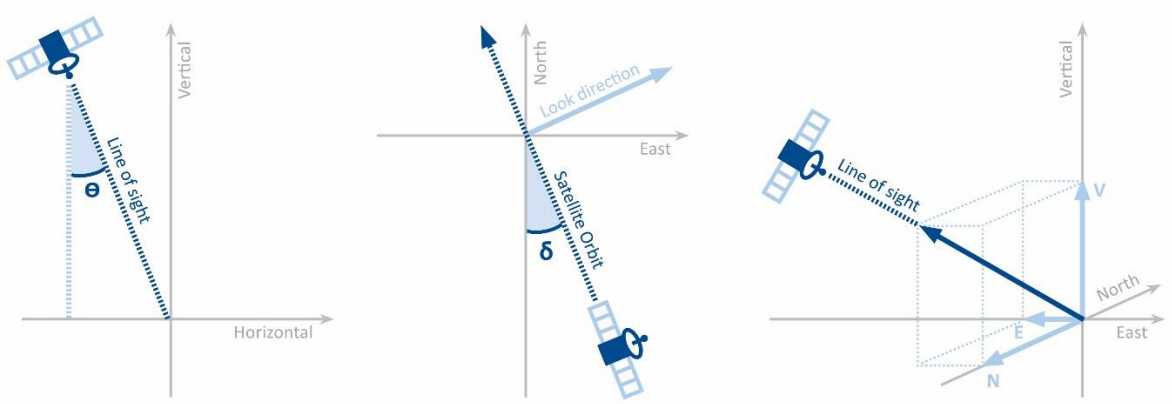


Figure 11: Geometry of the image acquisitions along the ascending orbit.

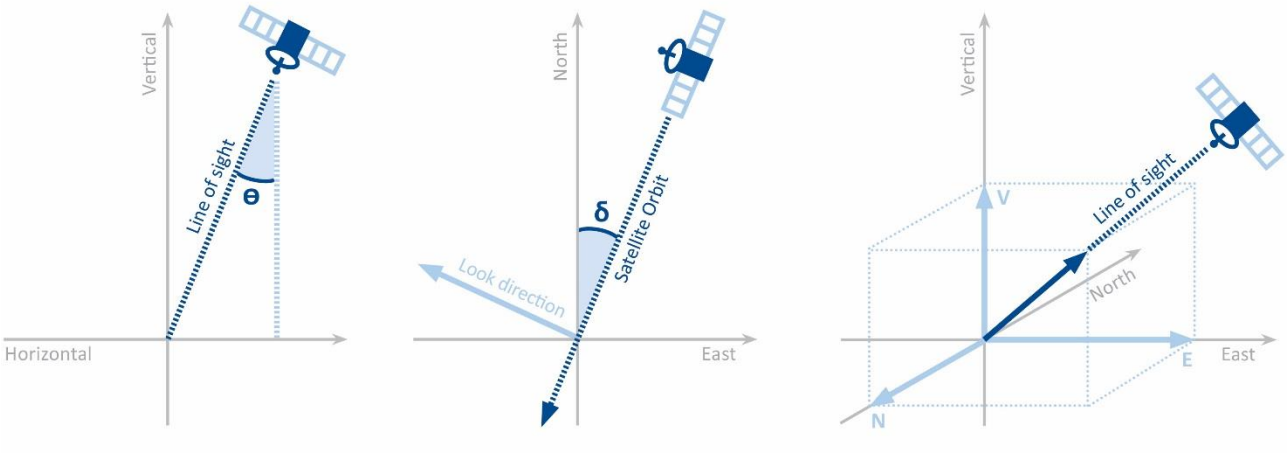


Figure 12: Geometry of the image acquisitions along the descending orbit.

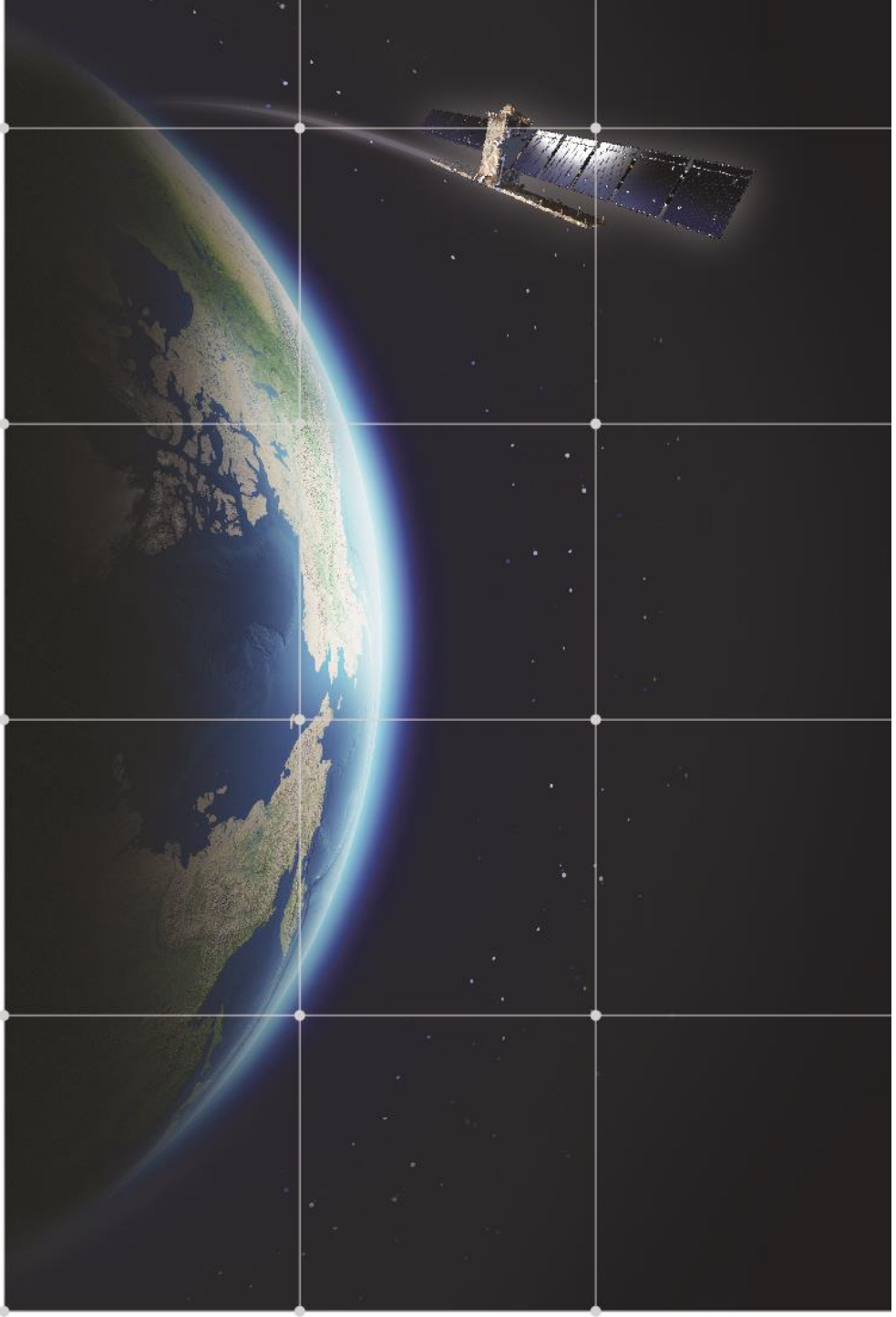
Table 7 lists all the radar images used for the data processing.

Table 7: Radar images acquired over the Narrabri Gas Project area by the Sentinel satellite.

SENTINEL Descending					
Count	**Image Date**	**Frequency**	**Count**	**Image Date**	**Frequency**
1	2014-11-01	12	**20**	2015-11-20	12
2	2014-11-25	24	**21**	2015-12-02	12
3	2015-03-01	96	**22**	2015-12-14	12
4	2015-03-13	12	**23**	2015-12-26	12
5	2015-04-06	24	**24**	2016-01-07	12
6	2015-04-30	24	**25**	2016-01-19	12
7	2015-05-24	24	**26**	2016-01-31	12
8	2015-06-05	12	**27**	2016-02-12	12
9	2015-06-17	12	**28**	2016-02-24	12
10	2015-06-29	12	**29**	2016-03-07	12
11	2015-08-04	36	**30**	2016-03-19	12
12	2015-08-16	12	**31**	2016-03-31	12
13	2015-08-28	12	**32**	2016-04-12	12
14	2015-09-09	12	**33**	2016-04-24	12
15	2015-09-21	12	**34**	2016-05-06	12
16	2015-10-03	12	**35**	2016-05-18	12
17	2015-10-15	12	**36**	2016-05-30	12
18	2015-10-27	12	**37**	2016-06-11	12
19	2015-11-08	12	**38**	2016-07-05	24

39	2016-07-17	12	**78**	2017-10-28	12
40	2016-07-29	12	**79**	2017-11-09	12
41	2016-08-10	12	**80**	2017-11-21	12
42	2016-08-22	12	**81**	2017-12-03	12
43	2016-09-03	12	**82**	2017-12-15	12
44	2016-09-15	12	**83**	2017-12-27	12
45	2016-09-27	12	**84**	2018-01-08	12
46	2016-10-09	12	**85**	2018-01-20	12
47	2016-10-21	12	**86**	2018-02-01	12
48	2016-11-02	12	**87**	2018-02-13	12
49	2016-11-14	12	**88**	2018-02-25	12
50	2016-11-26	12	**89**	2018-03-09	12
51	2016-12-08	12	**90**	2018-03-21	12
52	2016-12-20	12	**91**	2018-04-02	12
53	2017-01-01	12	**92**	2018-04-14	12
54	2017-01-13	12	**93**	2018-04-26	12
55	2017-01-25	12	**94**	2018-05-08	12
56	2017-02-06	12	**95**	2018-05-20	12
57	2017-02-18	12	**96**	2018-06-01	12
58	2017-03-02	12	**97**	2018-06-13	12
59	2017-03-14	12	**98**	2018-06-25	12
60	2017-03-26	12	**99**	2018-07-07	12
61	2017-04-07	12	**100**	2018-07-19	12
62	2017-04-19	12	**101**	2018-07-31	12
63	2017-05-01	12	**102**	2018-08-12	12
64	2017-05-13	12	**103**	2018-08-24	12
65	2017-05-25	12	**104**	2018-09-05	12
66	2017-06-06	12	**105**	2018-09-17	12
67	2017-06-18	12	**106**	2018-09-29	12
68	2017-06-30	12	**107**	2018-10-11	12
69	2017-07-12	12	**108**	2018-10-23	12
70	2017-07-24	12	**109**	2018-11-04	12
71	2017-08-05	12	**110**	2018-11-16	12
72	2017-08-17	12	**111**	2018-11-28	12
73	2017-08-29	12	**112**	2018-12-10	12
74	2017-09-10	12	**113**	2018-12-22	12
75	2017-09-22	12	**114**	2019-01-03	12
76	2017-10-04	12	**115**	2019-01-15	12
77	2017-10-16	12	**116**	2019-01-27	12

117	2019-02-08	12	**143**	2019-12-17	12
118	2019-02-20	12	**144**	2019-12-29	12
119	2019-03-04	12	**145**	2020-01-10	12
120	2019-03-16	12	**146**	2020-01-22	12
121	2019-03-28	12	**147**	2020-02-03	12
122	2019-04-09	12	**148**	2020-02-15	12
123	2019-04-21	12	**149**	2020-02-27	12
124	2019-05-03	12	**150**	2020-03-10	12
125	2019-05-15	12	**151**	2020-03-22	12
126	2019-05-27	12	**152**	2020-04-03	12
127	2019-06-08	12	**153**	2020-04-15	12
128	2019-06-20	12	**154**	2020-04-27	12
129	2019-07-02	12	**155**	2020-05-09	12
130	2019-07-14	12	**156**	2020-05-21	12
131	2019-07-26	12	**157**	2020-06-02	12
132	2019-08-07	12	**158**	2020-06-14	12
133	2019-08-19	12	**159**	2020-06-26	12
134	2019-08-31	12	**160**	2020-07-08	12
135	2019-09-12	12	**161**	2020-07-20	12
136	2019-09-24	12	**162**	2020-08-01	12
137	2019-10-06	12	**163**	2020-08-13	12
138	2019-10-18	12	**164**	2020-08-25	12
139	2019-10-30	12	**165**	2020-09-06	12
140	2019-11-11	12	**166**	2020-09-18	12
141	2019-11-23	12	**167**	2020-09-30	12
142	2019-12-05	12			



TRE
ALTAMIRA
A CLS Group Company

MILAN

Ripa di Porta Ticinese, 79
20143 Milano - Italy
Tel. +39.02.4343.121
Fax +39.02.4343.1230

BARCELONA

C/ Corsega, 381-387
E-08037 Barcelona Spain
Tel.: +34 93 183 57 50
Fax: +34 93 183 57 59

VANCOUVER

410 - 475 West Georgia Street
Vancouver, BC V6B 4M9 - Canada
Tel. +1.604.331.2512
Fax +1.604.331.2513

tre-altamira.com

Attachment 1 - Groundwater Monitoring Plan

Santos

NARRABRI GAS PROJECT

Groundwater Monitoring Plan

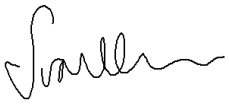
PHASE 1

0041-150-PLA-0011

Date	Revision	Reason for Issue	Author	Checked	Approved
11 November 2022	0E	For approval	Eco Logical Australia / Onward Consulting	DG	TD

Santos

Prepared by:

Title	Name	Signature	Date
Senior Principal Hydrogeologist	Dr Richard Cresswell Eco Logical Australia		11 November 2022
Senior Environmental Manager	S. van der Meulen Onward Consulting		11 November 2022
Director	Mark Vile Onward Consulting		11 November 2022

Reviewed by:

Title	Name	Signature	Date
Principal Environmental Advisor | Hydrogeologist	David Gornall		11 November 2022

Approved by:

Title	Name	Signature	Date
Development Manager NSW	Todd Dunn		11 November 2022

This document has been prepared by Onward Consulting to comply with the Narrabri Gas Project conditions of consent and has relied upon the relevant information available at the time of writing and all findings, conclusions or recommendations contained herein are based thereon. This document is for the use of Santos Ltd and no responsibility will be taken for its use by other parties. Santos Ltd may, at its discretion, use this document to inform regulators and the public.

ONWARD CONSULTING

Onward document number:
NGP-001I-0E-PLN

Acronyms and abbreviations

Acronym	Description
µg/L	micrograms per litre
BoM	Australian Bureau of Meteorology
Bq/L	Becquerel per litre
cm	centimetre
CoC	Conditions of consent for the NGP SSD 6456
CSG	coal seam gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPE	The former NSW Dept of Planning and Environment
DPI Water	The former Department of Primary Industries Water (formerly the NSW Office of Water; NOW)
DPE	NSW Department of Planning and Environment
DPE Water	The Water Group within DPE
DPI	The former NSW department of Primary Industries
DPIE	The former NSW Department of Planning, Industry and Environment
EMP	environmental management plan
EIS	environmental impact statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
EPL	environment protection licence under the POEO Act
EQuIS	Environmental Quality Information System
GAB	Great Artesian Basin
GABSI	Great Artesian Basin Sustainability Initiative
GBR	Groundwater Baseline Report
GIS	geographical information systems
GISERA	Gas Industry Social and Environmental Research Alliance
GL	gigalitre
GMP	Groundwater Management Plan
GModP	Groundwater Modelling Plan
GMonP	Groundwater Monitoring Plan (this document)
GOB	Gunnedah-Oxley Basin
IESC	Independent Expert Scientific Committee
ISO	International Organisation for Standardisation
km	kilometre

Acronym	Description
L	litre
mg/L	milligrams per litre
ML	megalitre
PAL	petroleum assessment lease under the PO Act
PEL	petroleum exploration licence under the PO Act
PO Act	*Petroleum (Onshore) Act 1991* (NSW)
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POEO Regulation	Protection of the Environment Operations (General) Regulation 2009
PPL	petroleum production lease under the PO Act
PPLA	petroleum production lease application under the PO Act
WM Act	*Water Management Act 2000* (NSW)
WMP	Water Management Plan
WRP	water resource plan
WSP	water sharing plan

Table of Contents

Tables

Figures

1. Introduction

1.1 Narrabri Gas Project

1.1.1 Background

Resource exploration has been occurring in the north-western area of NSW since the 1960s; initially for oil, but more recently for coal and gas. Santos NSW Pty Ltd began exploring for natural gas from coal seams in north-western NSW in 2008 and is currently conducting coal seam gas (**CSG**) exploration and appraisal activities within Petroleum Exploration Licence (**PEL**) 238, Petroleum Assessment Lease (**PAL**) 2 and Petroleum Production Lease (**PPL**) 3, located in the Gunnedah Basin about 20 kilometres (**km**) south-west of the town of Narrabri. Activities in PAL 2 have focussed on the Bibblewindi and Bohena CSG pilots, whilst recent activities in PEL 238 have focussed on the Dewhurst and Tintsfield CSG pilots.

The Narrabri Coal Seam Gas Utilisation Project (Wilga Park Power Station and associated infrastructure) operates under an existing Part 3A approval under the *Environmental Planning and Assessment Act 1979* (NSW) (**EP&A Act**). It was originally approved in 2008, with various modifications approved between 2011 and 2019. It encompasses a gas gathering system, a compressor and associated flare, a gas flow line from Bibblewindi to Wilga Park within a 10 metre (**m**) corridor with a riser at Leewood and an expansion of the existing Wilga Park Power Station from 12 megawatts to 40 megawatts.

1.1.2 Current Project

On 30 September 2020, Santos NSW (Eastern) Pty Ltd (**Santos**) obtained consent for State significant development (**SSD**) 6456 to develop the Narrabri Gas Project (**NGP**) (**the Project**). Approval EPBC 2014/7376 under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (**EPBC Act**) was granted on 24 November 2020.

The Project includes the progressive installation of up to 850 new gas wells on up to 425 new well pads over approximately 20 years and the construction and operation of gas processing and water treatment facilities. The Project area covers about 950 square kilometres (95,000 hectares) in size and the Project footprint will only directly impact about 1% of that area.

Four phases of development are defined under the consent, including:

- Phase 1 - exploration and appraisal;
- Phase 2 - construction activities for production wells and related infrastructure;
- Phase 3 - gas production operations; and
- Phase 4 - gas well and infrastructure decommissioning, rehabilitation and closure.

Phase 1 of the Project is defined in the consent as the phase of the development comprising ongoing exploration and appraisal activities in the Project area, including:

- seismic surveys;
- core and chip holes;
- construction and operation of pilot wells (up to 25 wells on up to 25 well pads across the Project area); and

- pilot well ancillary infrastructure, including access tracks, gas and water gathering lines, water balance tanks, safety flaring infrastructure, utilities and services, and environmental monitoring equipment including groundwater monitoring bores.

Santos plans to continue exploration and appraisal of the resource in the near term until a final investment decision can be made. The exploration and appraisal activities will include continued operation of Santos' existing wells, infrastructure and facilities in PEL 238 and PAL 2, and construction and operation of new core holes, pilot wells and supporting infrastructure permitted under Phase 1.

Santos' existing exploration and appraisal activities in PEL 238 and PAL 2 include:

- Tintsfield Pilot;
- Bibblewindi East Pilot;
- Bibblewindi West Pilot;
- Dewhurst North Pilot;
- Dewhurst South Pilot;
- Dewhurst northern and southern flow lines;
- Leewood Water Management Facility including ponds, the water and brine treatment plant (WBTP) and irrigation area;
- Bibblewindi Facility including gathering system, water balance tank, compressor and flare; and
- Bibblewindi to Leewood buried gas pipeline.

These exploration and appraisal activities will continue as part of the NGP. The initial, new-appraisal Phase 1 scope is a relatively minor extension to these existing exploration and appraisal activities.

The Phase 1 scope is planned to include the construction and operation of:

- 4 coreholes;
- 6 pilot wells;
- 2 deep reservoir monitoring bores (converted coreholes);
- new shallow water monitoring bores;
- associated linear infrastructure;
- seismic surveys (length and location to be determined); and
- continued operation of Santos' existing exploration and appraisal activities, including workover activities.

The full definitions of the approved activities for Phases 2, 3 and 4 of the Project are provided in the consent. Santos is not prevented from carrying out any or all of the phases concurrently, subject to the conditions of this consent.

Further details regarding the NGP, including a full overview of the regulatory framework and statutory provisions of the NGP and the current approvals, leases and licences are provided in the overarching Water Management Plan (**WMP**). Details regarding the staging of the works and the exact scope for each phase are as per the approved Field Development Plan.

1.2 Purpose and scope of the Groundwater Monitoring Plan

Santos has developed this Groundwater Monitoring Plan (**GMonP** or the **Plan)** in accordance with the requirements of the conditions of consent (**CoC**) of SSD 6456. It provides for strategic and proactive management of any potential impacts on the environment, including to groundwater dependent users and ecosystems, as a consequence of extraction of CSG groundwater. The GMonP forms an integral component of the Groundwater Management Plan (**GMP**) and has been developed to support the Groundwater Modelling Plan (**GModP**) and provide early warning indicators of potential risks to groundwater resources in the region. The GMP in turn forms part of a suite of documents prepared as part of the WMP under Condition B41.

This GMonP applies specifically to the monitoring of groundwater during the exploration and appraisal activities of Phase 1 of the Project and draws on the groundwater network established as part of the EIS to provide baseline information on groundwater conditions across the region. The GMonP includes continued monitoring of existing monitoring bores, as well as development and monitoring at new bores designed to support the exploration and appraisal activities of Phase 1 and provide additional data to support further development of the groundwater model, as defined in the GMP.

1.3 Objectives

The objective of this GMonP is to describe a monitoring network for the Project that supports **CoC** B41(d)(iv) which states that Santos must prepare a Groundwater Management Plan that includes a detailed description of the groundwater management and monitoring system.

Data from this monitoring network will be used to evaluate compliance with the relevant performance measures and definition of performance criteria (including development of trigger values) as required by the Conditions of Consent. This is described in more detail in the GMP.

1.4 Structure of this Plan

This GMonP is an attachment to the GMP, which sets out the overall details on how this GMonP relates to groundwater management and compliance with broader consent conditions relating to groundwater. The structure of this GMonP is as follows:

Section 1	Provides the context, scope and objectives of this Groundwater Monitoring Plan
Section 2	Provides a strategic overview of the groundwater monitoring network and why various groundwater attributes will be monitored
Section 3	Describes methods for how various groundwater attributes will be monitored
Section 4	Provides an overview of the monitoring network locations, ownership and construction status
Section 5	Describes the applicable quality assurance and control methods
Section 6	Details the record keeping and collection of monitoring data
Section 7	Glossary
Appendix A	Provides the suite of water quality parameters
Appendix B	Lists the Phase 1 groundwater monitoring points

2. Strategic overview

This GMonP describes the groundwater monitoring network only. Performance measures and performance criteria (including trigger levels) that relate to the monitoring network defined in this plan are described in the GMP.

CoC B41(d)(iv) requires that the groundwater monitoring network that must be implemented includes the following capabilities:

1. characterise the temporal and spatial variations of all potentially affected water sources;
2. verify the actual direct and indirect water take;
3. provide an early warning of any impacts to potentially affected water sources, at varying depths in the geological profile;
4. provide data to improve the confidence level class of the groundwater model as soon as reasonable and feasible; and
5. integrate with any government monitoring networks in the area.

These capabilities are achieved through a combination of monitoring methods for targeted formations. Table 2.1 links the requirements of CoC B41(d)(iv) to the hydrostratigrahic units in shown in Figure 2.1, providing an overview of the purpose of monitoring for each target hydrostratigraphic units that will be monitored (coded A to D).

A summary of the inter-relations and dependencies of the target units is provided in the following sections. A description of the hydrostatic units and the capacities of the strata to transmit or inhibit the movement of the groundwater is provided in section 1.5 of the Groundwater Baseline Report (**GBR**), provided as Attachment 2 to the GMP.

Table 2.1 - Monitoring network summary capabilities

Target code	Monitored hydrostratigraphic unit	Groundwater quality	Groundwater pressure	Volume extraction by Project	Capabilities
A	Target coal seams (Maules Creek Formation)		✓	✓	1, 2, 3, 4
B	Deeper (early Permian-aged) formations of the Gunnedah Oxley Basin		✓		1, 2, 3, 4
C	Shallower (Triassic-aged) formations of the Gunnedah Oxley Basin		✓		1, 2, 3, 5
D	Great Artesian Basin and Namoi Alluvium aquifers	✓	✓		1, 5

Province	Period / epoch	Division	Group	Sub-group	Formation	Lithology and hydrogeological classification	Trans-missivity	Hydro-stratigraphic target
Namoi Alluvium	Pleistocene				Narrabri Fm	Clay and silt with sand lenses	LSTU	D
	Pliocene				Gunnedah Fm	Gravel and sand with clay lenses	STU	
	Miocene				Cubbaroo FM	Gravel and sand with clay lenses	STU	
Volcanics					Warrumbungle Volcanics	Basalt, dolerite	PNTU	
	Eocene				Liverpool Range Volcanics	Basalt, dolerite	PNTU	
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm	Clayey to quartzose sandstone, subordinate siltstone and conglmerate	NTU	
		Early			Pilliga Ss	Fluvial, medium- to very coarse-grained, quartzose sandstone and conglomerate. Minor interbeds of mudstone, siltstone and fine-grained sandstone and coal	STU	D
	Jurassic	Late					STU	
		Middle			Purlawaugh Fm	Fine to medium-grained sandstone thinly interbedded with siltstone, mudstone and thin coal seams	NTU	
		Early	Garrawilla Volcanics			Dolerite, basalt, trachyte, tuff, breccia	LSTU	
		Late					LSTU	
	Triassic	Middle			Deriah Fm	Sandstone	PNTU	
					Napperby Fm	Interbedded fine sandstone, claystone and siltstone	PNTU	C
						Basal Napperby Shale	NTU	
		Early			Digby Fm	Quartzose sandstone (Ulinda Ss)	NTU	
						Lithic sandstone	NTU	
						Lithic conglomerate (Bomera Congl.)	NTU	
Gunnedah Basin	Permian	Late	Black Jack	Nea	Trinkey FM	Coal measures - siltstone, fine sandstone, tuffs, stony coal	PNTU	
					Wallala Fm	Conglomerate, sandstone, siltstone, minor coal bands	PNTU	
				Coogal	Breeza Coal	Coal and claystone	PNTU	
					Clare Ss	Medium- to coarse-grained quartzose sandstone, quartzose conglomerate	LSTU	
					Hoes Hill Coal	Coal	PNTU	
					Benalabi	Claystone, siltstone and sandstone, fining-up cycles; more sandy towards top	PNTU	
					Hoskissons Coal	Potential target coal seam	STU	
				Brothers	Brigalow Fm	Fining-up sequence of medium- to coarse-grained quartzose sandstone and siltstone	PNTU	
					Arkarula Fm	Sandstone and siltstone	PNTU	
					Melvilles Coal Mb	Coal	PNTU	
					Pamboola Fm	Sandstone,siltstone, minor claystone and coal	PNTU	
		Middle	Millie		Watermark Fm	Marine siltstone, shales and sandstone	NTU	B
					Porcupine Fm	Fining-up sequence of conglomerate and sandstone to mudstone	NTU	
		Early	Bellata		Upper Mauels Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU	
					Rutley Seam	Potential target coal seam	STU	A
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Namoi Seam	Potential target coal seam	STU	
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Parkes Seam	Potential target coal seam	STU	
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU	
					Bohena Seam	Potential target coal seam	STU	
					Lower Maules Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU	
					Goonbri Fm	Siltstone, sandstone and coal	NTU	
					Leard Fm	Flinty claystone	NTU	
Basement			Werrie Basalt and Boggabri Volcanics (Basement)			Rhyolitic to dacitic lavas and ashflow	LSTU	
						Tuffs with interbedded shale. Rare trachyte and andesite. Weathered basic lavas.	NTU	
Colour code key:						STU - Significantly Transmissive Unit		
						LSTU - Less Significantly Transmissive Unit		
						PNTU - Probable Negligibly Transmissive Unit		
						NTU - Negligibly Transmissive Unit		

Figure 2.1 - Hydrostratigraphic classification of the Project area

2.1 Target coal seams

Monitoring of coal seam water extraction volumes and corresponding groundwater pressures provides one of the most critical inputs for assessment of potential groundwater impacts early in the life and throughout Phase 1 of the Project. The data provides the earliest possible verification of the groundwater model attributes such as permeability of the coal and potential leakage from overlying aquitards. The monitoring data from target coal seams will provide critical information for model validation prior to Phase 2 of the Project.

2.2 Deeper formations of the GOB

It is expected to take many years, and potentially decades, before changes in groundwater pressure in aquitards immediately overlying the Maules Creek coal seams (i.e. the deeper formations of the Gunnedah-Oxley Basin [**GOB**]) are predicted to be detectable by groundwater monitoring. Groundwater pressure monitoring of the Middle Permian age Porcupine Formation is therefore expected to provide the next most critical information after monitoring water extraction and groundwater levels in the target coal seam and is potentially useful for model validation prior to Phase 2 of the Project.

2.3 Shallower formations of the GOB

The Napperby and Digby Formations represent important monitoring points that are purposefully located in between the deeper aquitard sequences of the GOB and the high value shallow water sources of the GAB and the Namoi Alluvium. In some areas, the Jurassic age Purlawaugh Formation may also be monitored. Monitoring of these formations will provide an early warning of any potential deviation from predicted groundwater pressure changes well in advance of any potential impact to the important shallow water resources.

The groundwater model does not currently predict any change in groundwater pressures in these formations throughout Phase 1 of the Project. Although information obtained from the monitoring points will be valuable for all Project phases, these monitoring points would only provide model review data prior to Phase 2 of the Project in the event that any groundwater level response due to Project activities is observed in these monitoring points throughout Phase 1.

2.4 High value GAB and alluvial aquifers

Monitoring groundwater pressure in these formations will characterise ongoing spatial and temporal trends in these important aquifers. The predicted change in groundwater pressures due to the project is unlikely to be detectable when compared to natural short-term and long-term variations in groundwater level, due to existing authorised water extraction and natural climate variability.

There is very little potential for adverse change in the quality of groundwater in shallow high-valued groundwater sources, such as the Bohena Creek Alluvium, Namoi Alluvium and Pilliga Sandstone, due to Project activities. Monitoring of groundwater pressure is the critical performance indicator for monitoring the potential impact to groundwater quality, since there cannot be any potential for change in water quality of shallow aquifers due to Project activities if there are no changes in groundwater levels due to Project activities. Therefore, groundwater quality monitoring will only be used to establish the initial baseline characteristics of groundwater quality high-value water resources of the GAB and Namoi Alluvium formations.

3. Monitoring methods

3.1 Types of groundwater monitoring infrastructure

A range of monitoring installation types have been[1] or will be constructed. Broadly, these fall into three categories of monitoring infrastructure:

- **Water supply bores**: water supply bores comprise bores specifically constructed to supply water and most are currently active. They can be useful monitoring points, particularly for monitoring water quality, but are less reliable for monitoring groundwater pressure due to the effect of pumping on bore water levels and the fact that they are designed to maximise yield and are often screened across multiple formations. Groundwater pressure data from water supply bores can be useful if the bore is pumped infrequently and recorded accurately, and the aquifer is well-defined and highly permeable. For example, if the bore is pumped only a few days each month and abstracts water from a productive aquifer such as the Gunnedah Formation.
- **Single aquifer piezometer**: these monitoring points have similar construction to modern water bores and are typically used in formations above the CSG reservoirs. The measurement of groundwater pressure is typically undertaken using a water level logger installed within the casing, however in some instances, manual water level readings may be taken instead. Single aquifer piezometers may be sampled for groundwater quality if a pump has also been installed. These piezometers may be nested, which means a number of single-aquifer piezometer bores that monitor different formations but are otherwise co-located.
- **Multi-gauge completion**: this type of completion is required where there is potential for interaction with gas within the CSG reservoir. These monitoring points may be constructed to manage risks associated with the presence of flammable gas under pressure. Multiple monitoring gauges are installed within a single well, typically separated by hydraulic barriers such as swellable packers. Groundwater pressure is measured using water level loggers suspended inside the casing between the hydraulic barriers. Manual water level readings and water quality samples cannot be taken due to the presence of hydraulic barriers.
- **CSG production wells**: production wells are useful for monitoring the volume of water extracted from the target coal seam and can provide samples for water quality. It is impractical to monitor groundwater pressures in an active CSG well.

Figure 3.1 provides a stylised schematic of groundwater monitoring installation types across a typical operating CSG field. It should be noted that there are no productive aquifers underneath the coal targeted by the Project. Hence, there are no hydrostratigraphic units beneath the coal seams of the Maules Creek Formation that will be monitored.

3.2 Groundwater pressure

A groundwater pressure reading will be taken at least once each day where automated groundwater level loggers are installed. Where level logger telemetry systems are installed, this data will be uploaded to a central Santos data repository each day. Where telemetry is not being used, for example where telemetry systems require maintenance and a temporary level logger must be deployed to ensure data continuity, level loggers may be employed which upload data to a local logger-memory system. Data from logger-memory systems will be manually downloaded at least once every three months. Manual water level readings will be taken whenever a level logger is serviced, or at least every three months in monitoring installations that do not have level-logging equipment installed.

[1] No new cemented VWPs will be installed because they are difficult to maintain operational.

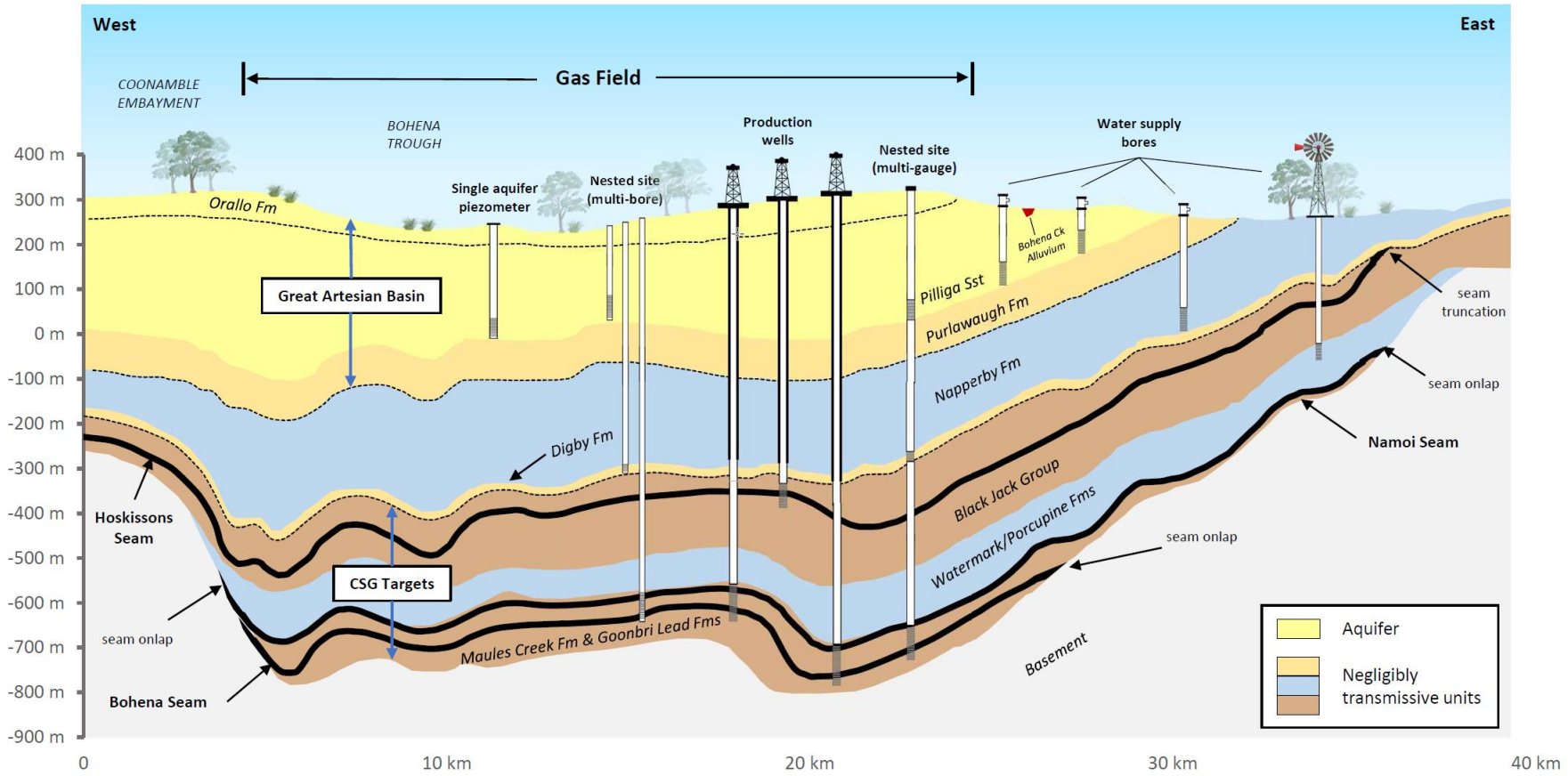


Figure 3.1 - Schematic of groundwater monitoring installation types

3.3 Groundwater quality

Groundwater quality will be sampled from nominated bores at least quarterly. Major ions, dissolved metals and field parameters are required to be measured from all existing and new monitoring points. The suite of water quality parameters is listed in Table A1 in Appendix A.

Given that groundwater quality is usually very consistent temporally, if the groundwater quality monitoring is consistent after 3 years or at least 6 samples have been taken (whichever is later), no further samples will be collected. This requirement may be revised if management response to exceedance of performance criteria (including trigger levels) require this Plan to be updated. Inconsistent baseline data may require additional groundwater quality monitoring to determine the baseline groundwater quality.

Groundwater quality monitoring close to CSG development may provide useful hydrochemical evidence about the leakage from formations overlying the target coal seams e.g. evolution of chemical character towards that of the overlying formation. This line of evidence independent of modelling and monitored water pressure may be considered in Phase 2, pending the findings from Phase 1 which will initially further investigate the permeability of formations overlying the target coal seams.

The GBR publishes all existing groundwater quality data and identifies which monitoring bores do not require further groundwater quality sampling where the baseline groundwater quality has been established.

3.4 Volume extraction by the Project

The daily water production and the cumulative total volume of coal seam water extracted from each active CSG well will be recorded each day. Cumulative volume will be recorded by flow totalisers located on the water discharge line connected to each well. The data will be automatically uploaded to Santos operational data repository at least once each day.

3.5 Climate data

Table 3.1 summarises the climate data that is expected to be collated throughout Phase 1 of the Project by the Bureau of Meteorology (**BOM**). The BOM is responsible for the ongoing maintenance and any decision to continue monitoring at these locations. The data is useful for the groundwater model but in absence of data from these sites, alternative weather station data may be collated.

Table 3.1 - Climate data required to complement the groundwater monitoring program

Climate parameter	Measurement
Temperature	Average daily for each month [1]
Rainfall	Monthly [2]
Notes: 1. BoM climate station 054038 (Narrabri Airport) 2. BoM climate stations 054120 (Narrabri Bowling Club), 053030 (Narrabri West Post Office), 054038 (Narrabri Airport) and 054026 (Narrabri Mollee), or other stations as appropriate	

4. Groundwater monitoring network

4.1 Ownership and responsibility

Appendix B provides a consolidated list of the proposed groundwater monitoring points throughout Phase 1 of the Project. These monitoring points are summarised in Figure 4.1 through Figure 4.4. It should be noted that the network comprises a combination of both monitoring points owned and operated by Santos, and monitoring points owned and operated by the Water group within the NSW Department of Planning and Environment (**DPE**) (generally referred to as **DPE Water**).

The nominated DPE Water monitoring points have been agreed with DPE Water based on the following criteria:

- monitoring points dedicated to monitoring (i.e. not used for water supply);
- expected to remain operational in the foreseeable future; and
- provide coverage proximal to historical CSG activities or where beneficial use of the shallow aquifers is at a premium.

The NSW Government is responsible for the maintenance of the DPE Water monitoring points. As such, Santos will rely on DPE Water for the provision of quality-assured groundwater pressure logger data from monitoring points that are owned and operated by DPE Water. It is assumed that DPE Water will ensure Santos is provided safe and practical access to be able to undertake groundwater quality monitoring of DPE Water-owned monitoring points as nominated in Appendix B. Santos will endeavour to communicate any site access or maintenance issues in a timely manner following discovery. On Santos notification of an inaccessible or non-operating site to DPE Water, Santos will recommence monitoring at the site when notified by DPE Water that the monitoring point is made accessible and operational.

Whilst every effort will be made to undertake the required monitoring at nominated locations, there may be occasions where it is not possible to access these locations to undertake monitoring (e.g. due to health and safety considerations, inclement weather), or data cannot be retrieved due to unplanned technical outages (e.g. logger or telemetry equipment failure). Section 5 Describes quality assurance and control procedures that will ensure timely equipment rectification and/or repeat sampling as required.

4.2 Network status

Figure 4.1 shows the 25 existing and proposed CSG wells which will be operational during Phase 1. Existing wells comprise CSG wells which have already been constructed and may already be operational. Proposed CSG wells are wells which will be constructed during Phase 1. Operational CSG wells will provide CSG water extraction volume data throughout Phase 1.

Figure 4.2, Figure 4.3 and Figure 4.4 present groundwater pressure and quality monitoring locations in the Namoi Alluvium, the GAB and the target formations of the GOB, respectively. Figure 4.5 shows the CSG wells which will be operational during Phase 1 and the groundwater monitoring points that are adjacent to them.

A number of monitoring points have yet to be constructed. All proposed monitoring points will be operational prior to the commencement of Phase 1 of the Project. In total, 98 groundwater monitoring points are nominated, as presented in Table 4.1.

Details of the monitoring network are provided in Appendix B.

Table 4.1 – Summary of groundwater monitoring points for Phase 1 of the Project

Hydrostratigraphic Unit	Monitored formations	Santos operated*		DPE operated
		Operational	To be constructed	Operational
Alluvial Aquifers	Bohena Creek Alluvium	4		
	Namoi Alluvium			27
Great Artesian Basin	Orallo Formation	3		
	Mooga Formation			1
	Pilliga Sandstone	12	5	7
	Purlawaugh Formation	2		4
Volcanics	Garrawilla Volcanics			1
Shallower Formations of the GOB	Napperby Sandstone	1		1
	Digby Formation	2	5	2
	Hoskisson Coal			2
	Black Jack Group			1
	Pamboola			1
Deeper Formations of the GOB	Porcupine Formation	1	5	1
	Arkarula Formation	1		
Target Coal Seam	Maules Creek Formation (Coal Seams)	1	15	

Notes:

Multiple monitoring points may be nested at the same monitoring site (refer to Appendix B).

***** Monitoring points shown in this table do not include monitoring of water production from CSG production wells.

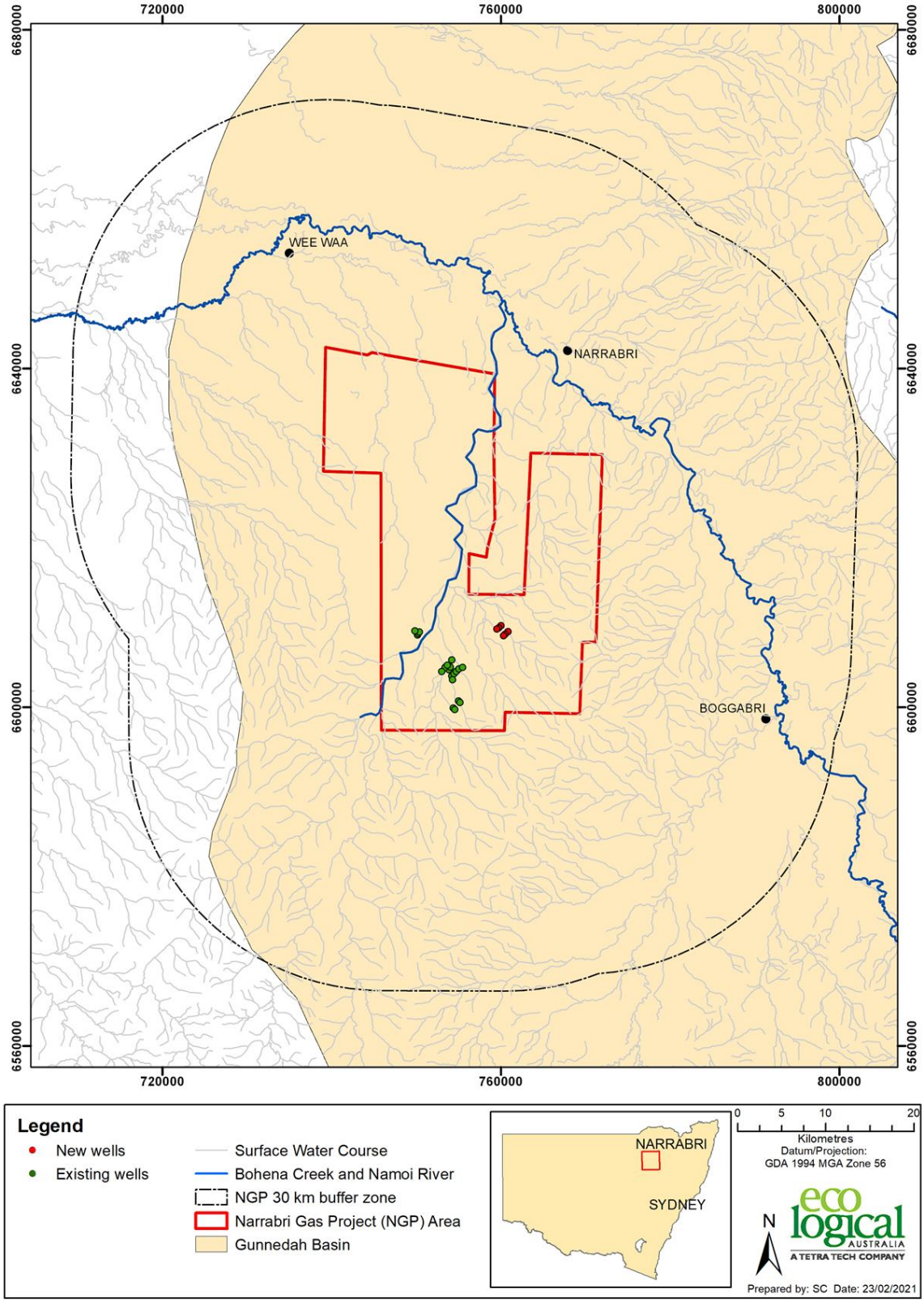


Figure 4.1 – CSG wells that will be developed during Phase 1 of the Project

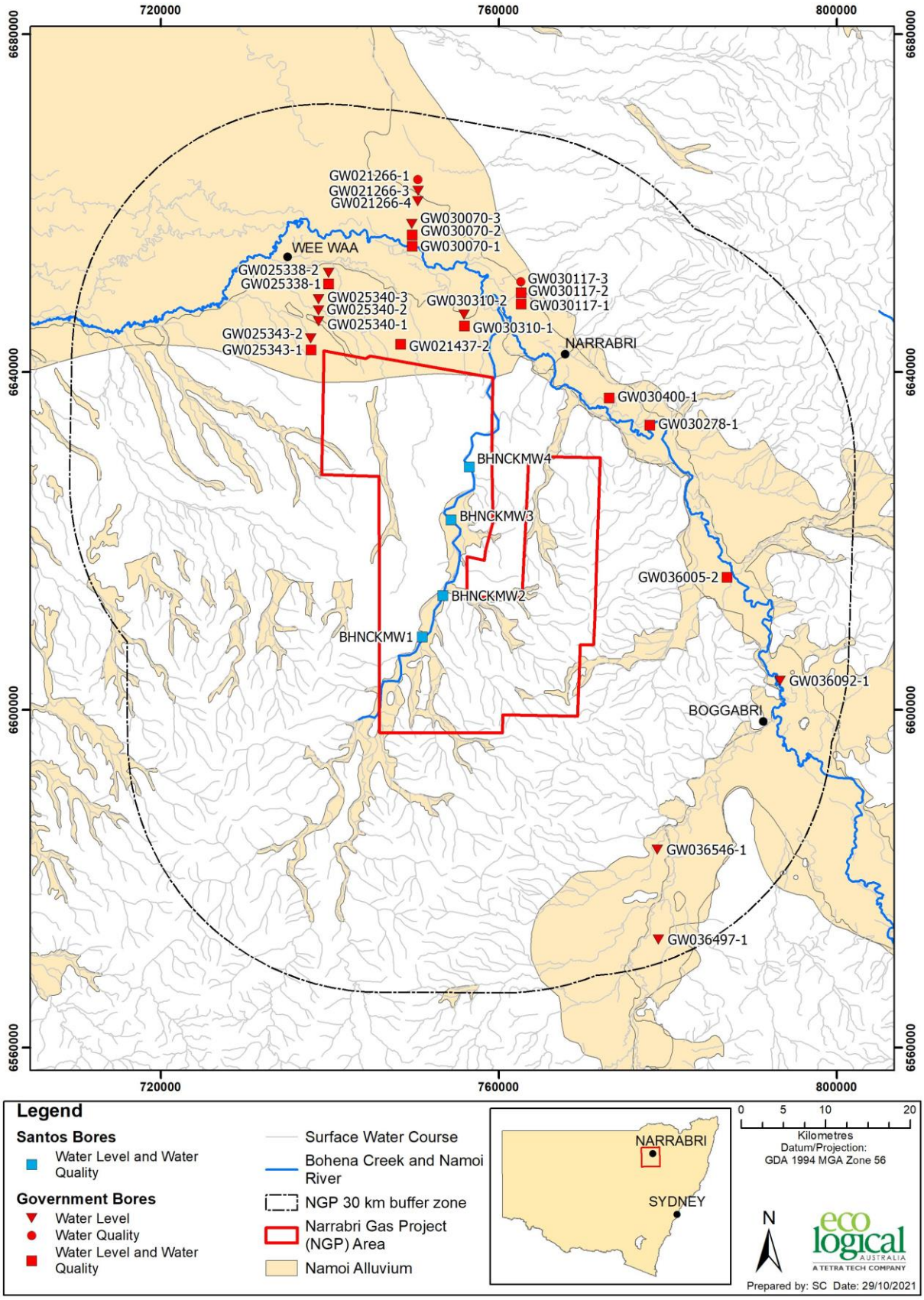


Figure 4.2 – Nominated alluvial aquifer groundwater monitoring points

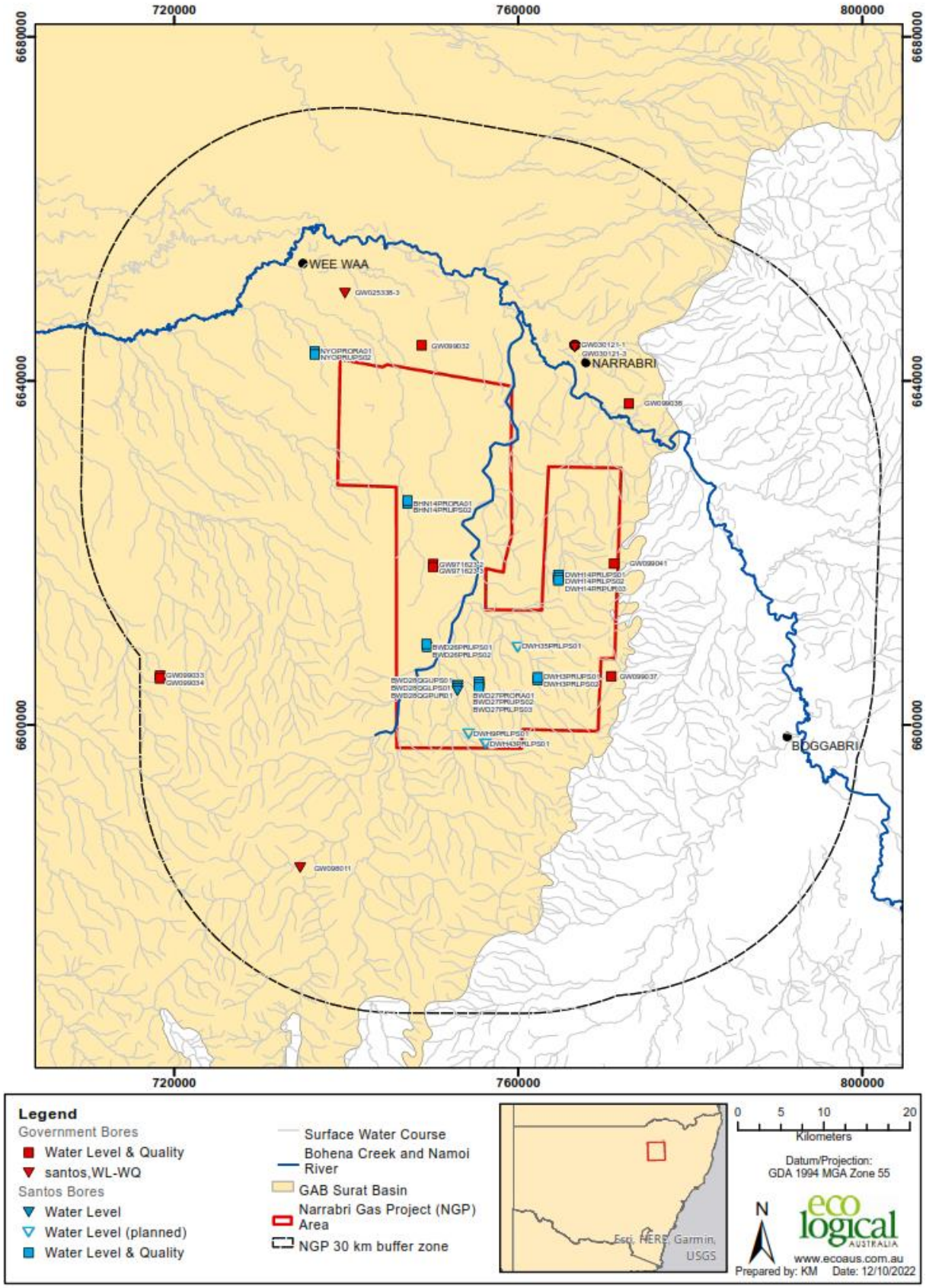


Figure 4.3 – Nominated GAB groundwater monitoring points

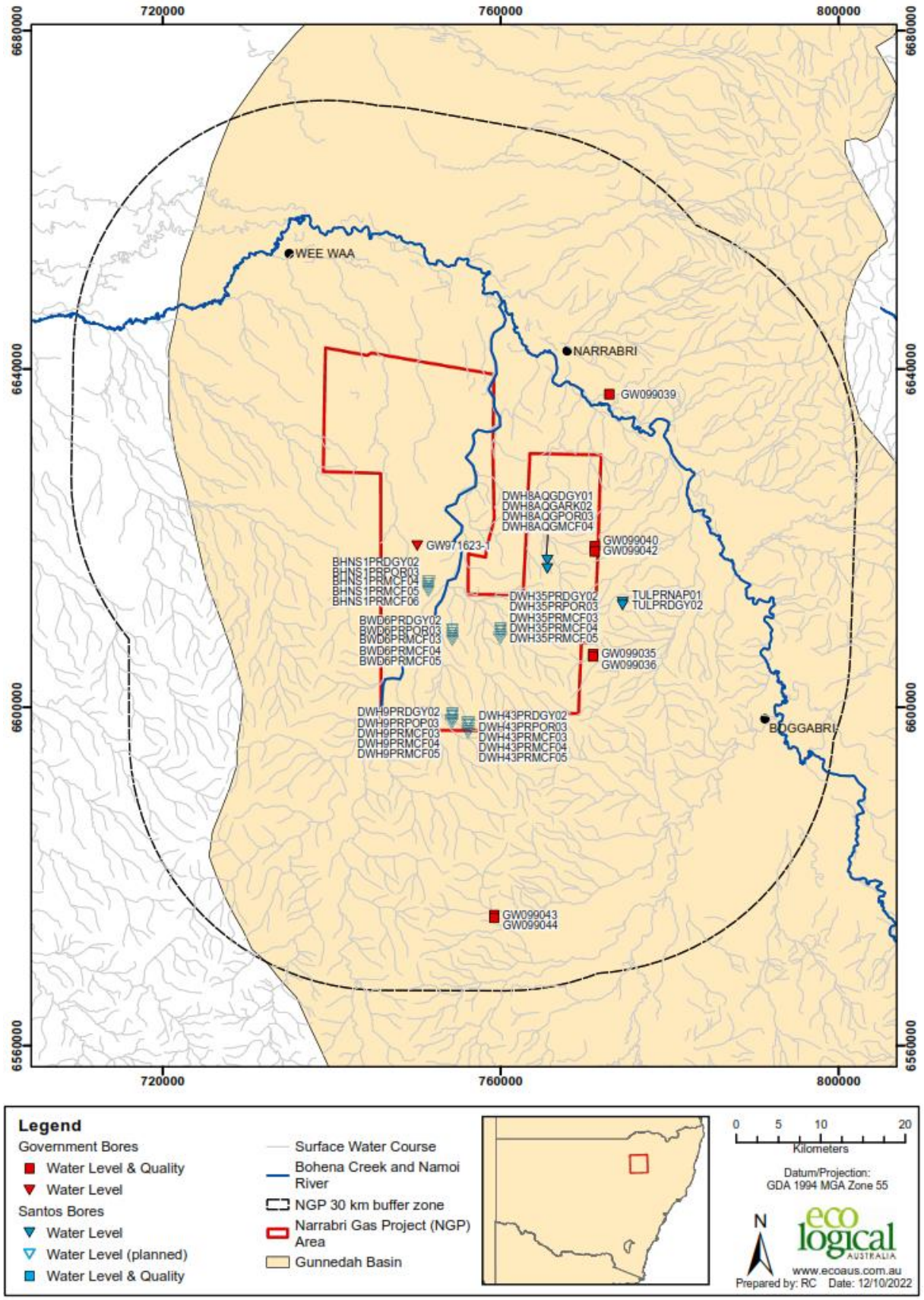


Figure 4.4 – Nominated Gunnedah-Oxley Basin groundwater monitoring points

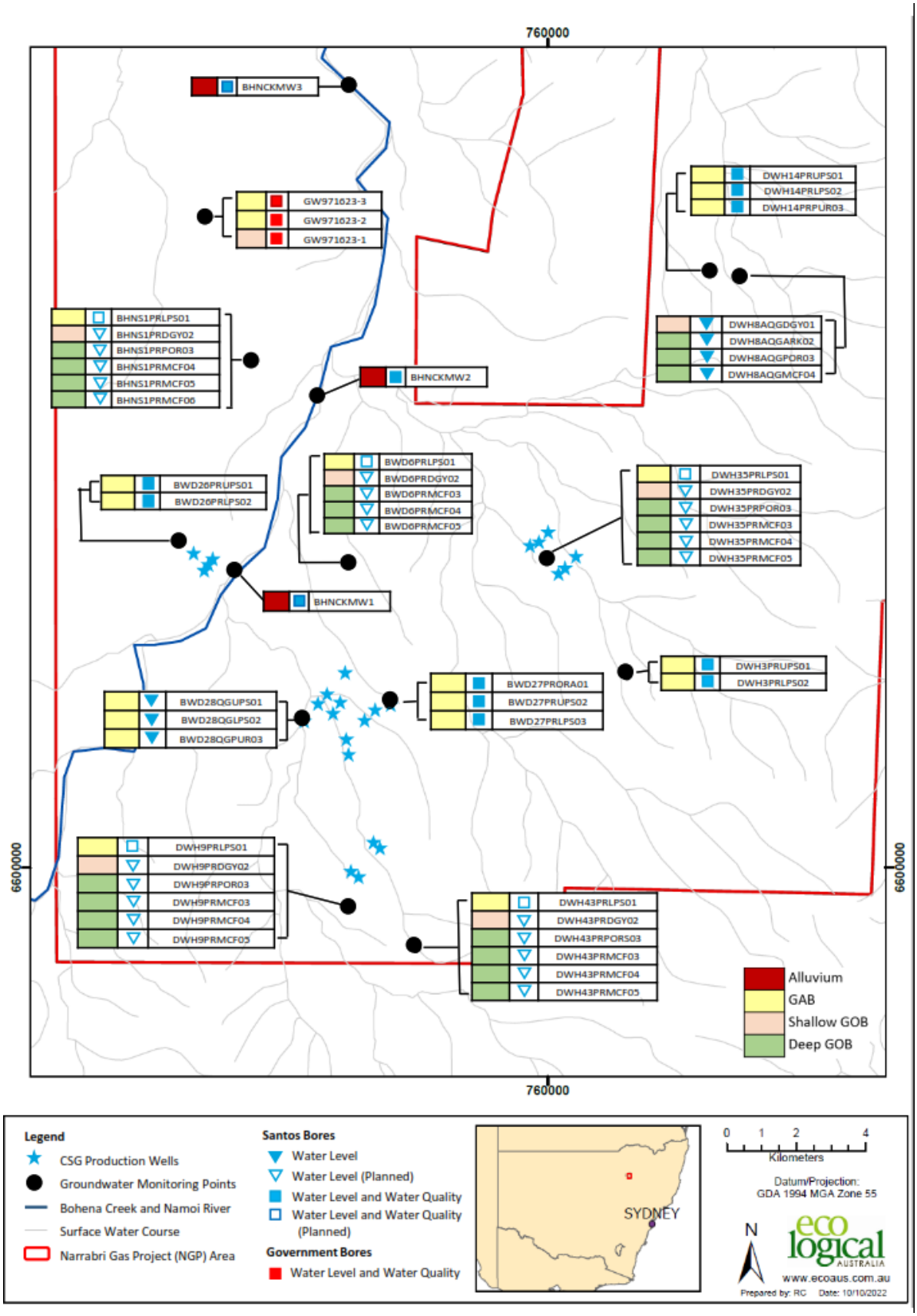


Figure 4.5 – Groundwater monitoring bores adjacent to active Phase 1 production wells

5. Record keeping

An overview of Santos' data management system is provided in Appendix B of the WMP in the form of a data management flow chart. The data management system covers all stages of data management from planning to archiving and includes setting of objectives for data collection; planning and scheduling of sampling activities; definition of field and laboratory protocols; data entry and automated completeness checking; data verification, validation and corrective action procedures; and data storage, backup and retrieval.

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

- records of any review of the GMonP;
- operational monitoring and performance data (including outages and monitoring issues); and
- water sampling and laboratory analytical reports.
- calibration records for field instruments and continuous water quality monitoring systems.

Data will be made available for any subsequent review or update of the groundwater model.

5.1 Groundwater quality monitoring data

Groundwater quality data collected as part of groundwater monitoring activities is stored and managed within Santos' environmental database, EQuIS[2], with web-based access to data entry and reporting and a full suite of technical procedures for data collection, workflow, reporting and other functions.

Monitoring data is subject to quality assurance and quality control protocols and procedures that ensure that data is accurate and usable. Data is subjected to consistent validation and verification procedures.

5.2 Groundwater pressure monitoring data

Groundwater pressures measured manually (e.g. using dip metres or air-lines) will be recorded and uploaded into the EQuIS database. Equipment maintenance schedules will be developed to reduce the likelihood of unplanned equipment failure and loss of telemetered monitoring data. However, across such an extensive telemetered monitoring network, it is inevitable that some unplanned equipment failures will occur.

Telemetered groundwater pressure monitoring data will be reviewed at least monthly. The purpose of the monthly review will be to ensure telemetered monitoring sites are still functioning. In the event that erroneous data is detected, site maintenance or site inspections may be scheduled as required and within practical timeframes.

5.3 Coal seam water production data

Groundwater take from the CSG wells will be monitored and recorded in accordance with the Produced Water Management Plan.

[2] EQuIS (Environmental Quality Information System) is a proprietary software application.

6. Evaluation and review

6.1 Plan review

As required by consent condition D4, Santos will review the suitability of existing strategies, plans and programs required under this consent, within two months of:

(a) the submission of an incident report;
(b) the submission of an Annual Review;
(c) the submission of an Independent Environmental Audit;
(d) the submission of a Field Development Plan;
(e) the submission of a Groundwater Model Update; or
(f) the approval of any modification of the conditions of this consent.

This is to ensure the GMonP is updated on a regular basis and to incorporate any recommended measures to improve the environmental performance of the Project.

The review history table in the front of this Plan provides the details of each review, conducted in accordance with condition D4.

Consent condition D5 in turn states that if the review under condition D4 determines that the strategies, plans and programs required under this consent require revision - to either improve the environmental performance of the development, cater for a modification or comply with a direction - then Santos must submit the revised document to the Planning Secretary for approval within 6 weeks of the review.

Note that in accordance with consent condition B42, Santos will implement the Water Management Plan (including the GMP and this GBR) once it has been approved by the Planning Secretary.

Further details on the reporting, evaluation and review of the GMP, and this GBR, is provided in section 8 of the EMS.

7. Glossary

Term	Definition
Alluvial	Sediments deposited following a decrease in velocity of flowing water
Alluvium	General term for unconsolidated fluvio-lacustrine deposits of inorganic materials (clay, silt, sand, gravel, and boulders) deposited following a decrease in velocity of flowing water
Alluvium aquifer	An aquifer formed within alluvium. See Alluvium.
Aquifer	A saturated permeable geologic unit that can transmit useful quantities of water
Baseline	A starting point used for future comparisons. Water baselines in context of the Narrabri Gas Project have been derived from long term water level and quality data presented in the Narrabri Gas Project Water Baseline Report.
Depressurisation	The extraction of coal seam water to facilitate gas production causes depressurisation of the target coal seams, which has the potential to propagate into surrounding formations.
Namoi Alluvium	The Upper Namoi Alluvium, an aquifer made of coarse-grained river gravels and sands. The Lower Namoi Alluvium, a hydrostratigraphic unit made of shallow alluvial fan deposits associated with the Namoi River. These units contain a significant resource of readily accessible, good quality groundwater that is heavily utilised for irrigation, public water supply, private water supply and livestock
Planning Secretary	Planning Secretary under the EP&A Act, or nominee
Produced water	Any form of groundwater that is actively extracted from a borehole, well or excavation, excluding incidental groundwater mixed with drilling fluids
Project area	The area of approximately 95,000 hectares that encompasses the Project
Project footprint	The area of surface expression being about 1,000 hectares occupied by the infrastructure components of the Narrabri Gas Project
Recharge spring	A spring supported by water that recharges sandstone sediments that outcrop on the margins of the Great Artesian Basin and discharge locally after relatively short residence times.
Response Trigger Process	The requirements for a groundwater model update outside the three-yearly review schedule that is triggered by exceedance of the Level 1 impact trigger
Spring	A naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the water table intersects the ground level.
Transmissivity	Rate in which water of a given density and viscosity is transmitted through a unit width of aquifer or aquitard under a unit hydraulic gradient.
Water sharing plan	Legislated plans under the *Water Management Act 2000* that establish rules for sharing water between the environment and water users. Water licences are issued to water users in accordance with water sharing plans

Appendix A - Water quality suite

Table A1 - Water quality suite

Parameter	Units	Limit of reporting / precision
Field parameters		
Static water level or pressure head	Metres below ground level	
Electrical conductivity	µS/cm	10 µS/cm
pH	pH units	0.1
Temperature	˚C	0.1 ˚C
Eh	mV	10 mV
Dissolved oxygen	ppm or % saturation	0.1 ppm
Laboratory analytes		
EC	µS/cm	1
pH	-	0.01
TDS	mg/L	1
Br	mg/L	0.01
Alkalinity	mg/L	1
Sulfate	mg/L	1
Chloride	mg/L	1
Sodium	mg/L	1
Calcium	mg/L	1
Magnesium	mg/L	1
Potassium	mg/L	1
Fluoride	mg/L	1
Dissolved metals: Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Rb, Se, Sr, U, V, Zn	mg/L	0.01 – 0.05 [U: 0.025 Bq/L]
Ammonia, nitrate, nitrite	mg/L	0.01
Reactive P	mg/L	0.01
Methane	µg/L	10

Appendix B - Phase 1 groundwater monitoring points

Monitoring point operator	NGP site ID	Site name	NGP monitoring point ID	Monitoring point name	Status / proposed year active	Trigger level assignment	Longitude	Latitude	Monitored formation	Hydro-stratigraphic unit	Water pressure monitoring	Water quality monitoring	Monitoring infrastructure type
						(refer to GMP)	(Zone 55J)	(Zone 55J)		(refer to Section 2)			(refer to Section 3)
Santos	1	Bohena Creek 1	1	BHNCKMW1	Active		149.618	-30.629	Bohena Creek Alluvium	ULNA	YES	YES	Single-aquifer piezometer
Santos	2	Bohena Creek 2	2	BHNCKMW2	Active		149.642	-30.584	Bohena Creek Alluvium	ULNA	YES	YES	Single-aquifer piezometer
Santos	3	Bohena Creek 3	3	BHNCKMW3	Active		149.65	-30.503	Bohena Creek Alluvium	ULNA	YES	YES	Single-aquifer piezometer
Santos	4	Bohena Creek 4	4	BHNCKMW4	Active		149.671	-30.446	Bohena Creek Alluvium	ULNA	YES	YES	Single-aquifer piezometer
Santos	5	Bohena 14	5	BHN14PRORA01	Active		149.574	-30.472	Orallo Formation	GAB	YES	YES	Single-aquifer piezometer
Santos	5	Bohena 14	6	BHN14PRUPS02	Active	3	149.574	-30.472	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	6	Bibblewindi 26	7	BWD26PRUPS01	Active	3	149.602	-30.622	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	6	Bibblewindi 26	8	BWD26PRLPS02	Active	3	149.601	-30.622	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	7	Bibblewindi 27	9	BWD27PRORA01	Active		149.666	-30.663	Orallo Formation	GAB	YES	YES	Single-aquifer piezometer
Santos	7	Bibblewindi 27	10	BWD27PRUPS02	Active	3	149.666	-30.663	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	7	Bibblewindi 27	11	BWD27PRLPS03	Active	3	149.666	-30.663	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	8	Bibblewindi 28	12	BWD28QGUPS01	Active		149.64	-30.668	Upper Pilliga Sandstone	GAB	YES	NO	Multi-gauge cemented VWP
Santos	8	Bibblewindi 28	13	BWD28QGLPS01	Active		149.64	-30.668	Lower Pilliga Sandstone	GAB	YES	NO	Multi-gauge cemented VWP
Santos	8	Bibblewindi 28	14	BWD28QGPUR01	Active		149.64	-30.668	Purlawaugh Formation	GAB	YES	NO	Multi-gauge cemented VWP
Santos	9	Dewhurst 3	15	DWH3PRUPS01	Active	3	149.737	-30.654	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	9	Dewhurst 3	16	DWH3PRLPS02	Active	3	149.737	-30.654	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	10	Dewhurst 14	17	DWH14PRUPS01	Active	3	149.759	-30.549	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	10	Dewhurst 14	18	DWH14PRLPS02	Active	3	149.759	-30.549	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	10	Dewhurst 14	19	DWH14PRPUR03	Active		149.759	-30.549	Purlawaugh Formation	GAB	YES	YES	Single-aquifer piezometer
Santos	11	Nyora	20	NYOPRORA01	Active		149.458	-30.321	Orallo Formation	GAB	YES	YES	Single-aquifer piezometer
Santos	11	Nyora	21	NYOPRUPS02	Active		149.458	-30.321	Upper Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	12	Tullamullen	22	TULPRNAP01	Active		149.862	-30.593	Napperby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	12	Tullamullen	23	TULPRDGY02	Active	2	149.862	-30.593	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	13	Bohena South 1C	24	BHNS1PRLPS01	Planned		149.622	-30.575	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	13	Bohena South 1C	25	BHNS1PRDGY02	Planned	2	149.622	-30.575	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	13	Bohena South 1C	26	BHNS1PRPOR03	Planned		149.622	-30.575	Porcupine Formation	Deep GOB	YES	NO	Multi-gauge packer
Santos	13	Bohena South 1C	27	BHNS1PRMCF04	Planned		149.622	-30.575	Maules Creek Formation (Namoi)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	13	Bohena South 1C	28	BHNS1PRMCF05	Planned		149.622	-30.575	Maules Creek Formation (Parkes)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	13	Bohena South 1C	29	BHNS1PRMCF06	Planned		149.622	-30.575	Maules Creek Formation (Bohena)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	14	Bibblewindi 6	30	BWD6PRLPS01	Planned		149.653	-30.627	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	14	Bibblewindi 6	31	BWD6PRDGY02	Planned	2	149.653	-30.627	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	14	Bibblewindi 6	32	BWD6PRPOR03	Planned		149.653	-30.627	Porcupine Formation	Deep GOB	YES	NO	Multi-gauge packer
Santos	14	Bibblewindi 6	33	BWD6PRMCF03	Planned		149.653	-30.627	Maules Creek Formation (Namoi)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	14	Bibblewindi 6	34	BWD6PRMCF04	Planned		149.653	-30.627	Maules Creek Formation (Parkes)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	14	Bibblewindi 6	35	BWD6PRMCF05	Planned		149.653	-30.627	Maules Creek Formation (Bohena)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	15	Dewhurst 9	36	DWH9PRLPS01	Planned		149.655	-30.716	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	15	Dewhurst 9	37	DWH9PRDGY02	Planned	2	149.655	-30.716	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer

Monitoring point operator	NGP site ID	Site name	NGP monitoring point ID	Monitoring point name	Status / proposed year active	Trigger level assignment	Longitude	Latitude	Monitored formation	Hydro-stratigraphic unit	Water pressure monitoring	Water quality monitoring	Monitoring infrastructure type
						(refer to GMP)	(Zone 55J)	(Zone 55J)		(refer to Section 2)			(refer to Section 3)
Santos	15	Dewhurst 9	38	DWH9PRPOP03	Planned		149.655	-30.716	Porcupine Formation	Deep GOB	YES	NO	Multi-gauge packer
Santos	15	Dewhurst 9	39	DWH9PRMCF03	Planned		149.655	-30.716	Maules Creek Formation (Namoi)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	15	Dewhurst 9	40	DWH9PRMCF04	Planned		149.655	-30.716	Maules Creek Formation (Parkes)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	15	Dewhurst 9	41	DWH9PRMCF05	Planned		149.655	-30.716	Maules Creek Formation (Bohena)	Deep GOB - Coal	YES	NO	Multi-gauge packer
Santos	16	Dewhurst 43	42	DWH43PRLPS01	Planned		149.675	-30.344	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	16	Dewhurst 43	43	DWH43PRDGY02	Planned	2	149.675	-30.344	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	16	Dewhurst 43	44	DWH43PRPOR03	Planned		149.675	-30.344	Porcupine Formation	Deep GOB	YES	NO	Multiple level packer
Santos	16	Dewhurst 43	45	DWH43PRMCF03	Planned		149.675	-30.344	Maules Creek Formation (Namoi)	Deep GOB - Coal	YES	NO	Multiple level packer
Santos	16	Dewhurst 43	46	DWH43PRMCF04	Planned		149.675	-30.344	Maules Creek Formation (Parkes)	Deep GOB - Coal	YES	NO	Multiple level packer
Santos	16	Dewhurst 43	47	DWH43PRMCF05	Planned		149.675	-30.344	Maules Creek Formation (Bohena)	Deep GOB - Coal	YES	NO	Multiple level packer
Santos	17	Dewhurst 8A	48	DWH8AQGDGY01	Active		149.768	-30.55	Digby Formation	Shallow GOB	YES	NO	Cemented VWP
Santos	17	Dewhurst 8A	49	DWH8AQGARK02	Active		149.768	-30.55	Arkarula Formation	Deep GOB	YES	NO	Cemented VWP
Santos	17	Dewhurst 8A	50	DWH8AQGPOR03	Active		149.768	-30.55	Porcupine Formation	Deep GOB	YES	NO	Cemented VWP
Santos	17	Dewhurst 8A	51	DWH8AQGMCF04	Active		149.768	-30.55	Maules Creek Formation (Upper)	Deep GOB - Coal	YES	NO	Cemented VWP
Santos	18	Dewhurst 35	52	DWH35PRLPS01	Planned		149.712	-30.624	Lower Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
Santos	18	Dewhurst 35	53	DWH35PRDGY02	Planned	2	149.712	-30.624	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
Santos	18	Dewhurst 35	54	DWH35PRPOR03	Planned		149.712	-30.624	Porcupine Formation	Deep GOB	YES	NO	Multiple level packer
Santos	18	Dewhurst 35	55	DWH35PRMCF03	Planned		149.712	-30.624	Maules Creek Formation (Namoi)	Deep GOB - Coal	YES	NO	Multiple level packer
Santos	18	Dewhurst 35	56	DWH35PRMCF04	Planned		149.712	-30.624	Maules Creek Formation (Parkes)	Deep GOB - Coal	YES	NO	Multiple level packer
Santos	18	Dewhurst 35	57	DWH35PRMCF05	Planned		149.712	-30.624	Maules Creek Formation (Bohena)	Deep GOB - Coal	YES	NO	Multiple level packer
DPIE Water	101	GW021266	500	GW021266-1	Active		149.6	-30.164	Namoi Alluvium	ULNA	NO	YES	Single-aquifer piezometer
DPIE Water	101	GW021266	501	GW021266-3	Active		149.6	-30.164	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	101	GW021266	502	GW021266-4	Active		149.6	-30.164	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	102	GW021437	503	GW021437-2	Active		149.583	-30.317	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	103	GW025338	504	GW025338-1	Active		149.493	-30.254	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	103	GW025338	505	GW025338-2	Active		149.493	-30.254	Namoi alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	103	GW025338	506	GW025338-3	Active		149.493	-30.254	Mooga Sandstone	GAB	YES	NO	Single-aquifer piezometer
DPIE Water	104	GW025340	507	GW025340-1	Active		149.481	-30.283	Namoi alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	104	GW025340	508	GW025340-2	Active		149.481	-30.283	Namoi alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	104	GW025340	509	GW025340-3	Active		149.481	-30.283	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	105	GW025343	510	GW025343-1	Active		149.473	-30.325	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	105	GW025343	511	GW025343-2	Active		149.473	-30.325	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	106	GW030070	512	GW030070-1	Active		149.594	-30.2	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	106	GW030070	513	GW030070-2	Active		149.594	-30.2	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	106	GW030070	514	GW030070-3	Active		149.594	-30.2	Namoi alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	107	GW030117	515	GW030117-1	Active		149.73	-30.271	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	107	GW030117	516	GW030117-2	Active		149.73	-30.271	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	107	GW030117	517	GW030117-3	Active		149.73	-30.271	Namoi alluvium	ULNA	NO	YES	Single-aquifer piezometer

Monitoring point operator	NGP site ID	Site name	NGP monitoring point ID	Monitoring point name	Status / proposed year active	Trigger level assignment	Longitude	Latitude	Monitored formation	Hydro-stratigraphic unit	Water pressure monitoring	Water quality monitoring	Monitoring infrastructure type
						(refer to GMP)	(Zone 55J)	(Zone 55J)		(refer to Section 2)			(refer to Section 3)
DPIE Water	108	GW030121	518	GW030121-1	Active		149.772	-30.308	Pilliga Sandstone	GAB	NO	YES	Single-aquifer piezometer
DPIE Water	108	GW030121	519	GW030121-3	Active		149.772	-30.308	Pilliga Sandstone	GAB	YES	NO	Single-aquifer piezometer
DPIE Water	109	GW030278	520	GW030278-1	Active		149.892	-30.397	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	110	GW030310	521	GW030310-1	Active		149.661	-30.296	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	110	GW030310	522	GW030310-2	Active		149.661	-30.296	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	111	GW030400	523	GW030400-1	Active		149.841	-30.369	Namoi Alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	111	3A Old Gunnedah Road	537	GW099038	Active		149.839	-30.368	Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	111	3A Old Gunnedah Road	538	GW099039	Active		149.839	-30.368	Napperby Formation	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	112	GW036005	524	GW036005-2	Active		149.992	-30.557	Namoi alluvium	ULNA	YES	YES	Single-aquifer piezometer
DPIE Water	113	GW036092	525	GW036092-1	Active		150.061	-30.666	Namoi alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	114	GW036497	526	GW036497-1	Active		149.919	-30.946	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	115	GW036546	527	GW036546-1	Active		149.915	-30.85	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	116	GW036546	528	GW036546-2	Active		149.915	-30.85	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	117	GW036546	529	GW036546-3	Active		149.915	-30.85	Namoi Alluvium	ULNA	YES	NO	Single-aquifer piezometer
DPIE Water	118	GW098011	530	GW098011-1	Active		149.454	-30.86	Pilliga Sandstone	GAB	YES	NO	Single-aquifer piezometer
DPIE Water	119	GW971623	531	Plumb Road @ Narrabri #1	Active	2	149.607	-30.538	Digby Formation	Shallow GOB	YES	NO	Single-aquifer piezometer
DPIE Water	119	GW971623	532	Plumb Road @ Narrabri #2	Active		149.607	-30.538	Purlawaugh Formation	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	119	GW971623	533	Plumb Road @ Narrabri #3	Active		149.607	-30.538	Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	120	1D Pilliga West	534	GW099033	Active		149.279	-30.664	Purlawaugh Formation	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	120	1D Pilliga West	535	GW099034	Active		149.279	-30.664	Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	121	2A Lower Namoi	536	GW099032	Active		149.587	-30.309	Pilliga Sandstone	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	122	4B Pilliga Scratch Road	539	GW099040	Active		149.826	-30.533	Black Jack Group	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	122	4B Pilliga Scratch Road	540	GW099041	Active		149.826	-30.533	Purlawaugh Formation	GAB	YES	YES	Single-aquifer piezometer
DPIE Water	122	4B Pilliga Scratch Road	541	GW099042	Active		149.826	-30.533	Porcupine Formation	Deep GOB	YES	YES	Single-aquifer piezometer
DPIE Water	123	5A Pilliga South East	542	GW099043	Active		149.713	-30.929	Hoskisson Coal Seam	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	123	5A Pilliga South East	543	GW099044	Active	2	149.713	-30.929	Digby Formation	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	123	5A Pilliga South East	544	GW099045	Active		149.713	-30.929	Garrawilla Volcanics	Volcanics	YES	YES	Single-aquifer piezometer
DPIE Water	124	14 Pilliga South	545	GW099035	Active		149.827	-30.648	Pamboola Formation	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	124	14 Pilliga South	546	GW099036	Active		149.827	-30.648	Hoskisson Coal Seam	Shallow GOB	YES	YES	Single-aquifer piezometer
DPIE Water	124	14 Pilliga South	547	GW099037	Active		149.826	-30.648	Purlawaugh Formation	GAB	YES	YES	Single-aquifer piezometer

Attachment 2 - Groundwater Baseline Report

Santos

NARRABRI GAS PROJECT

Groundwater Baseline Report

PHASE 1

0041-150-PLA-0013

Date	Revision	Reason for Issue	Author	Checked	Approved
11 November 2022	0E	For approval	Eco Logical Australia / Onward Consulting	DG	TD

Santos

Prepared by:

Title	Name	Signature	Date
Senior Principal Hydrogeologist	Dr Richard Cresswell Eco Logical Australia		11 November 2022
Senior Environmental Manager	S. van der Meulen Onward Consulting		11 November 2022
Director	Mark Vile Onward Consulting		11 November 2022

Reviewed by:

Title	Name	Signature	Date
Principal Environmental Advisor | Hydrogeologist	David Gornall		11 November 2022

Approved by:

Title	Name	Signature	Date
Development Manager NSW	Todd Dunn		11 November 2022

This document has been prepared by Onward Consulting to comply with the Narrabri Gas Project conditions of consent and has relied upon the relevant information available at the time of writing and all findings, conclusions or recommendations contained herein are based thereon. This document is for the use of Santos Ltd and no responsibility will be taken for its use by other parties. Santos Ltd may, at its discretion, use this document to inform regulators and the public.

ONWARD CONSULTING

Onward document number:
NGP-001H-0D REP

Acronyms and abbreviations

Acronym	Description
µg/L	micrograms per litre
AHD	Australian Height Datum
$CaCO_3$	calcium carbonate
CoC	SSD 6456 conditions of consent
CSG	coal seam gas
DPIE	The former NSW Department of Planning, Industry and Environment
DPE	NSW Department of Planning and Environment
DPE Water	The Water Group within DPE
EC	electrical conductivity
EIS	environmental impact statement
GAB	Great Artesian Basin
GMonP	Groundwater Monitoring Plan
GMP	Groundwater Management Plan
kg	kilogram
L	litre
LSTU	less significant transmissive units
LOR	limit of reporting
m	metre
mg/L	milligram per litre
mAHD	metres relative to AHD
NGP	Narrabri Gas Project
NTU	negligibly transmissive units
PNTU	probable negligibly transmissive units
ppm	parts per million (v/v)
SAR	sodium adsorption ratio
STU	significant transmissive units
TDS	total dissolved solids
WMP	Water Management Plan
WSP	water sharing plan

Table of contents

Tables

Figures

1. Introduction

1.1 Context

Santos NSW (Eastern) Pty Ltd (**Santos**) has been monitoring hydrogeological conditions in the project area since 2011. Hydrogeological measurements were initially collected to support Santos' exploration and appraisal activities, and more recently have been broadened to support the hydrogeological baseline for the Narrabri Gas Project (the **Project** or **NGP**). The groundwater data consist of observations in bores that are owned and maintained by Santos as well as a few private landholder bores that are sampled by Santos.

In addition to hydrogeological data held by Santos, the Water group within the NSW Department of Planning and Environment (**DPE**) (generally referred to as **DPE Water**) maintains an extensive network of groundwater monitoring bores across the area of the baseline monitoring. These data are available through DPE Water's PINNEENA[1] database and online data services through WaterNSW (WaterNSW Continuous water monitoring network).

This Groundwater Baseline Report (**GBR,** or **Report**) has been prepared to support the Groundwater Management Plan (**GMP**) which is a sub-plan under the Water Management Plan (**WMP**) for the Narrabri Gas Project (**NGP**). The GBR provides a statement of the groundwater datasets that constitute the baseline groundwater monitoring for the NGP. General contextual information on the water resources in the NGP area can be found in the WMP; additional groundwater resource information is contained in this GBR and summarised in the GMP. Information on surface waters, produced waters, treated waters and irrigation waters can be found in the Surface Water Management Plan, Produced Water Management Plan and the Irrigation Management Plan respectively, whilst the interchange between and through these water sources is described in the Site Water Balance.

The groundwater baseline monitoring comprises 51 monitoring bores with records of groundwater head and 41 monitoring bores with records of groundwater quality.

The baseline data are presented in graphs in the appendices and as summary tables that include statistical summaries of the data. Summaries are also presented in the GMP.

1.2 Objective

The objective of this Report is to:

- provide detailed baseline data of hydrogeology and groundwater levels, formation parameters (such as hydraulic conductivity, storage and yield) and quality for groundwater resources potentially impacted by the development (based on at least 3 years of monitoring data (SSD 6456 condition of consent (**COC**) B41(d)(iv));
- provide a baseline groundwater report that may be periodically updated, for example prior to the next phase of the Project or prior to each groundwater model update; and
- identify which groundwater bores have sufficiently established baseline groundwater quality (as defined in the Groundwater Monitoring Report section 3.3) where no further groundwater quality sampling is required.

[1] http://waterinfo.nsw.gov.au/pinneena/

1.3 Structure of this Report

The structure of this Report is as follows:

Section 1	Provides an introduction to the baseline monitoring and the context and scope of the baseline monitoring program within the groundwater resources relevant to the NGP
Section 2	Provides an overview of the baseline bores and characteristics
Section 3	Describes the groundwater data that constitute the groundwater head and level baseline
Section 4	Describes the groundwater data that constitute the groundwater quality baseline
Section 5	Describes how and when this Report may be updated
Section 6	References
Section 7	Glossary of terms
Appendix A	Presents the groundwater head data for the baseline bores
Appendix B	Presents the groundwater quality data for the baseline bores

1.4 Water sources

The area of baseline monitoring in the GBR contains five distinct water sources that are defined in four separate, but overlapping, water sharing plans (**WSPs**). The water sources and WSPs are listed in Table 1.1, with Figure 1.1 showing the relationships between stratigraphic units, WSPs and defined water sources, which are depicted in a schematic cross section through the Bohena Trough (Gunnedah Basin) and the on-lapping portion of the GAB and the Namoi alluvium.

Table 1.1 - Groundwater sources within the area of baseline monitoring

Water Source	Water Sharing Plan (WSP)
Bohena Creek Water Source	*Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2012*
Upper and Lower Namoi Groundwater Sources	*Water Sharing Plan for the Namoi Alluvial Groundwater Sources Order 2020*
Shallow Groundwater Sources	*Water Sharing Plan for the NSW Great Artesian Basin Shallow Groundwater Sources Order 2020*
Southern Recharge Groundwater Source Surat Groundwater Source	*Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2020*
Gunnedah–Oxley Basin MDB Groundwater Source	*Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources Order 2020*

The baseline data in this GBR are grouped by groundwater source, described below, and the groundwater baseline is sub-grouped by hydrostratigraphic unit (section 1.5).

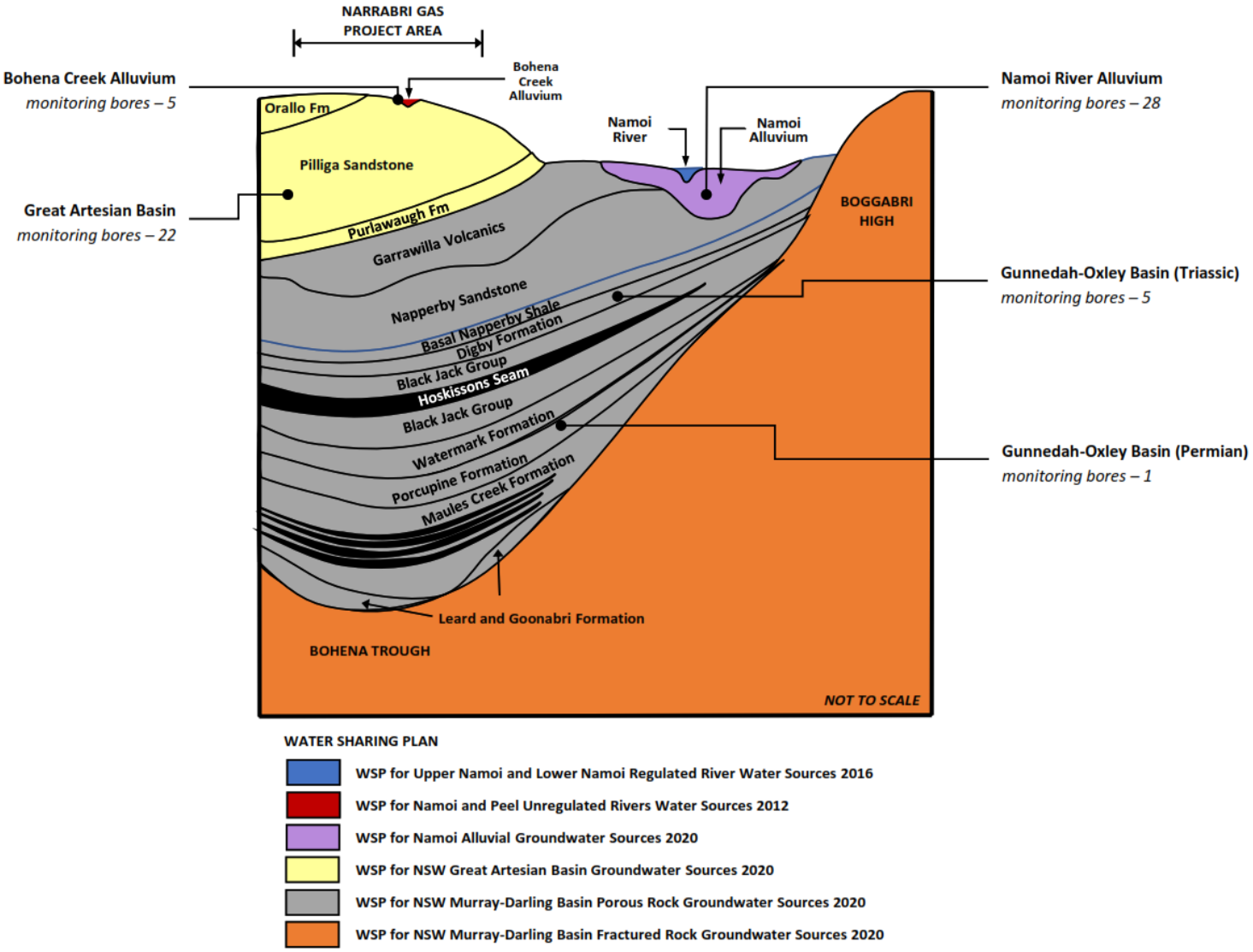


Figure 1.1 - Schematic of water sources in the area of baseline monitoring bore inventory

1.4.1 Bohena Creek Water Source

The Bohena Creek Water Source is defined in the *Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2012* and includes all water occurring naturally on the surface of the ground, and all water in rivers, lakes and wetlands within the Bohena Creek catchment. Within the subsurface, the Bohena Creek Alluvial Water Source includes all water below the surface of the ground and within the boundary of the Southern Recharge Groundwater Source defined in the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2020*. The Bohena Creek Alluvium is laterally contiguous with the Lower Namoi Alluvial Groundwater Source.

1.4.2 Upper and Lower Namoi Groundwater Sources

The Upper and Lower Namoi Groundwater Sources are defined in the *Water Sharing Plan for the Namoi Alluvial Groundwater Sources Order 2020*. They include all water contained in the unconsolidated alluvial sediment aquifers associated with the Namoi River and its tributaries and lying within the Namoi and Gwydir Water Management Areas.

1.4.3 Shallow Groundwater Sources

The Shallow Groundwater Sources are defined in the Water Sharing Plan for the NSW Great Artesian Basins Shallow Groundwater Sources Order 2020. They include the groundwater in varying rock types at less than 60 metres (**m**) depth overlying here the Surat Basin. The Bohena Creek alluvium is included in this water source.

1.4.4 Southern Recharge and Surat Groundwater Sources

The GAB Surat and Southern Recharge Groundwater Sources are defined within the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2020*. The Southern Recharge Groundwater Sources includes all water contained in all rocks of Cretaceous, Jurassic and Cenozoic age, and all unconsolidated alluvial sediments below the surface of the ground within the boundary defined in the Plan Map. The Surat Groundwater Source includes water contained in all rocks of Cretaceous and Jurassic age at a depth of more than 60 m below ground surface within the boundary of the Surat Groundwater Source defined in the Plan Map.

1.4.5 Gunnedah-Oxley Basin MDB Groundwater Source

The Gunnedah–Oxley Basin MDB Groundwater Source is defined in the *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources Order 2020*. The Plan includes all water contained in all rocks of Permian, Triassic, Jurassic, Cretaceous and Tertiary age within outcropped and buried areas, and all water contained in all alluvial sediments within the outcropped areas, and within the boundary of the Gunnedah–Oxley Basin defined in the Plan map. It excludes groundwater sources otherwise defined in the WSPs for the *Namoi Alluvial Groundwater Sources Order 2020* and the *NSW Great Artesian Basin Groundwater Sources 2020*.

1.5 Hydrostratigraphic units

Groundwater sources are typically classified with reference to the stratigraphic layer, or sequence of strata that contain the water. The stratigraphic units that are present within the area of baseline monitoring have been grouped into hydrostratigraphic units according to the regional capacities of the strata to transmit or inhibit the movement of groundwater. Figure 1.2 includes:

- significant transmissive units (**STU**);
- less significant transmissive units (**LSTU**);
- probable negligibly transmissive units (**PNTU**); and
- negligibly transmissive units (**NTU**).

These definitions identify the relative significance of each stratigraphic unit with respect to the expected hydrogeological response of the subsurface to coal seam gas development. Thus, a very conductive and high-yielding stratum is considered to be a STU, a low-yielding stratum is considered to be a LSTU, and leaky strata and aquitards are considered to be PNTUs and NTUs.

The purpose of Figure 1.2 is to provide a key to the names of specific stratigraphic and hydrostratigraphic units used elsewhere in the GBR.

Province	Period / epoch	Division	Group	Sub-group	Formation	Lithology and hydrogeological classification	Trans-missivity classification
Namoi Alluvium	Pleistocene				Narrabri Fm	Clay and silt with sand lenses	LSTU
	Pliocene				Gunnedah Fm	Gravel and sand with clay lenses	STU
	Miocene				Cubbaroo FM	Gravel and sand with clay lenses	STU
Volcanics					Warrumbungle Volcanics	Basalt, dolerite	PNTU
	Eocene				Liverpool Range Volcanics	Basalt, dolerite	PNTU
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm	Clayey to quartzose sandstone, subordinate siltstone and conglmerate	NTU
		Early			Pilliga Ss	Fluvial, medium- to very coarse-grained, quartzose sandstone and conglomerate. Minor interbeds of mudstone, siltstone and fine-grained sandstone and coal	STU
	Jurassic	Late					STU
		Middle			Purlawaugh Fm	Fine to medium-grained sandstone thinly interbedded with siltstone, mudstone and thin coal seams	NTU
	Triassic	Early	Garrawilla Volcanics			Dolerite, basalt, trachyte, tuff, breccia	LSTU
		Late					LSTU
		Middle			Deriah Fm	Sandstone	PNTU
					Napperby Fm	Interbedded fine sandstone, claystone and siltstone	PNTU
						Basal Napperby Shale	NTU
		Early			Digby Fm	Quartzose sandstone (Ulinda Ss)	NTU
						Lithic sandstone	NTU
						Lithic conglomerate (Bomera Congl.)	NTU
Gunnedah Basin	Permian	Late	Black Jack	Nea	Trinkey FM	Coal measures - siltstone, fine sandstone, tuffs, stony coal	PNTU
					Wallala Fm	Conglomerate, sandstone, siltstone, minor coal bands	PNTU
				Coogal	Breeza Coal	Coal and claystone	PNTU
					Clare Ss	Medium- to coarse-grained quartzose sandstone, quartzose conglomerate	LSTU
					Hoes Hill Coal	Coal	PNTU
					Benalabi	Claystone, siltstone and sandstone, fining-up cycles; more sandy towards top	PNTU
					Hoskissons Coal	Potential target coal seam	STU
				Brothers	Brigalow Fm	Fining-up sequence of medium- to coarse-grained quartzose sandstone and siltstone	PNTU
					Arkarula Fm	Sandstone and siltstone	PNTU
					Melvilles Coal Mb	Coal	PNTU
					Pamboola Fm	Sandstone,siltstone, minor claystone and coal	PNTU
		Middle	Millie		Watermark Fm	Marine siltstone, shales and sandstone	NTU
					Porcupine Fm	Fining-up sequence of conglomerate and sandstone to mudstone	NTU
		Early	Bellata		Upper Maules Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU
					Rutley Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Namoi Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Parkes Seam	Potential target coal seam	STU
					Interburden	Sandstone and conglomerate, siltstone and mudstone	PNTU
					Bohena Seam	Potential target coal seam	STU
					Lower Maules Creek Fm	Sandstone and conglomerate, siltstone, mudstone and coal	NTU
					Goonbri Fm	Siltstone, sandstone and coal	NTU
					Leard Fm	Flinty claystone	NTU
Basement			Werrie Basalt and Boggabri Volcanics (Basement)			Rhyolitic to dacitic lavas and ashflow	LSTU
						Tuffs with interbedded shale. Rare trachyte and andesite. Weathered basic lavas.	NTU
Colour code key:						STU - Significantly Transmissive Unit	
						LSTU - Less Significantly Transmissive Unit	
						PNTU - Probable Negligibly Transmissive Unit	
						NTU - Negligibly Transmissive Unit	

Figure 1.2 - Hydrostratigraphic classification of the Project area

2. Baseline bores

The groundwater baseline is compiled from hydrological data collected by Santos and DPE Water. An overview of the number of separate monitoring sites for hydraulic head and groundwater quality are provided in Table 2.1 and Table 2.2, respectively.

Table 2.1 - Overview of baseline data sources for groundwater hydraulic head

Targeted Stratigraphic Formation*	Groundwater Source**	Number of monitoring bores		
		Santos	DPE Water	Total
Namoi Alluvium	ULNA	0	25	25
Mooga Sandstone	GAB	0	1	1
Orallo Formation	GAB	2	0	2
Pilliga Sandstone	GAB	12	2	14
Purlawaugh Formation	GAB	2	0	2
Digby Formation	GOB	2	0	2
Porcupine Formation	GOB	2	0	2
Maules Creek Formation	GOB	1	0	1
TOTAL		**21**	**28**	**49**

Notes:

* *see* Figure 1.2; ** *see* Figure 1.1Figure 1.2
ULNA - Upper and Lower Namoi Groundwater Sources
GAB – Great Artesian Basin Surat and Southern Recharge Groundwater Sources
GOB - Gunnedah–Oxley Basin MDB Groundwater Source

Table 2.2 - Overview of baseline data sources for groundwater quality

Targeted Stratigraphic Formation*	Groundwater Source**	Number of monitoring bores		
		Santos†	DPE Water	Total
Bohena Creek Alluvium	BC	5	0	5
Namoi Alluvium	ULNA	0	16	16
Orallo Formation	GAB	5	0	5
Pilliga Sandstone	GAB	10	0	10
Purlawaugh Formation	GAB	1	0	1
Napperby Formation	GOB	1	0	1
Digby Formation	GOB	1	0	1
TOTAL		**23**	**16**	**39**

Notes:

* *see* Figure 1.2; ** *see* Figure 1.1; † includes private boresFigure 1.2
BC - Bohena Creek Water Source
ULNA - Upper and Lower Namoi Groundwater Sources
GAB - Great Artesian Basin Surat and Southern Recharge Groundwater Sources
GOB - Gunnedah–Oxley Basin MDB Groundwater Source

Bores monitored for hydraulic head were not all sampled for water quality. Some bores that have been sampled for water quality have no recorded static hydraulic head data. Table 3.1 (in section 3.1.5) and Table 4.1 (in section 4) distinguish which bores were measured for which attributes.

The locations of groundwater monitoring bores are shown in Figure 2.1 for alluvial water sources, in Figure 2.2 for the Great Artesian Basin and in Figure 2.3 for the Gunnedah-Oxley Basin.

The baseline for hydraulic head is compiled from observations in 49 groundwater monitoring bores, including 25 bores in the Namoi alluvium, 19 bores in the Great Artesian Basin and 5 bores in the Gunnedah-Oxley Basin.

The baseline for groundwater quality is compiled from water quality observations in 39 groundwater monitoring bores, including 16 bores in the Namoi alluvium, 5 bores in the Bohena Creek alluvium, 16 bores in the Great Artesian Basin, and 2 bores in the Gunnedah-Oxley Basin.

2.1 Private landholder bores

In addition to sampling the designated baseline groundwater bores, Santos has also sampled numerous private landholder bores on behalf of the landholders since 2011. While these data do not form part of the formal groundwater baseline, as active but largely unrecorded pumping on these bores strongly affects water levels and multiple screened intervals do not allow targeted water quality assessment, they nonetheless provide information about operating bore water levels and can provide indicative mixed water quality at each location.

These bores represent baseline data in as much as they have been located, sampled and described, though the water level and quality data generally did not pass quality assurance and control measures and hence the data is not recorded here.

The exceptions are three stock and domestic bores targeting the low-yielding Orallo Sandstone in the north of the Project area (Figure 2.2) and a single bore drawing domestic water from the Bohena Creek Alluvium. Data from these four bores are included in the summary statistics reported in section 4.

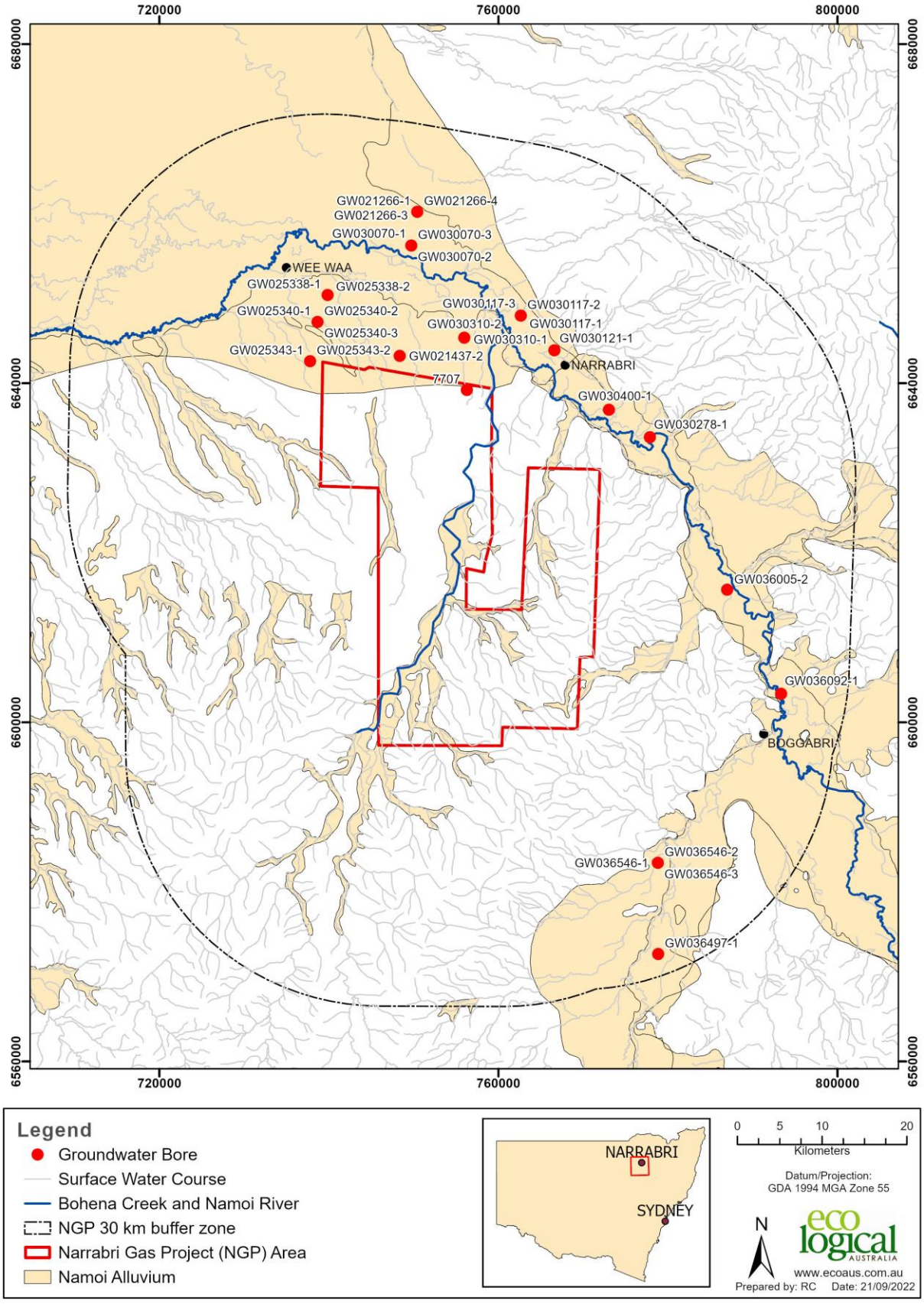


Figure 2.1 - Baseline monitoring locations in Alluvial Groundwater Sources

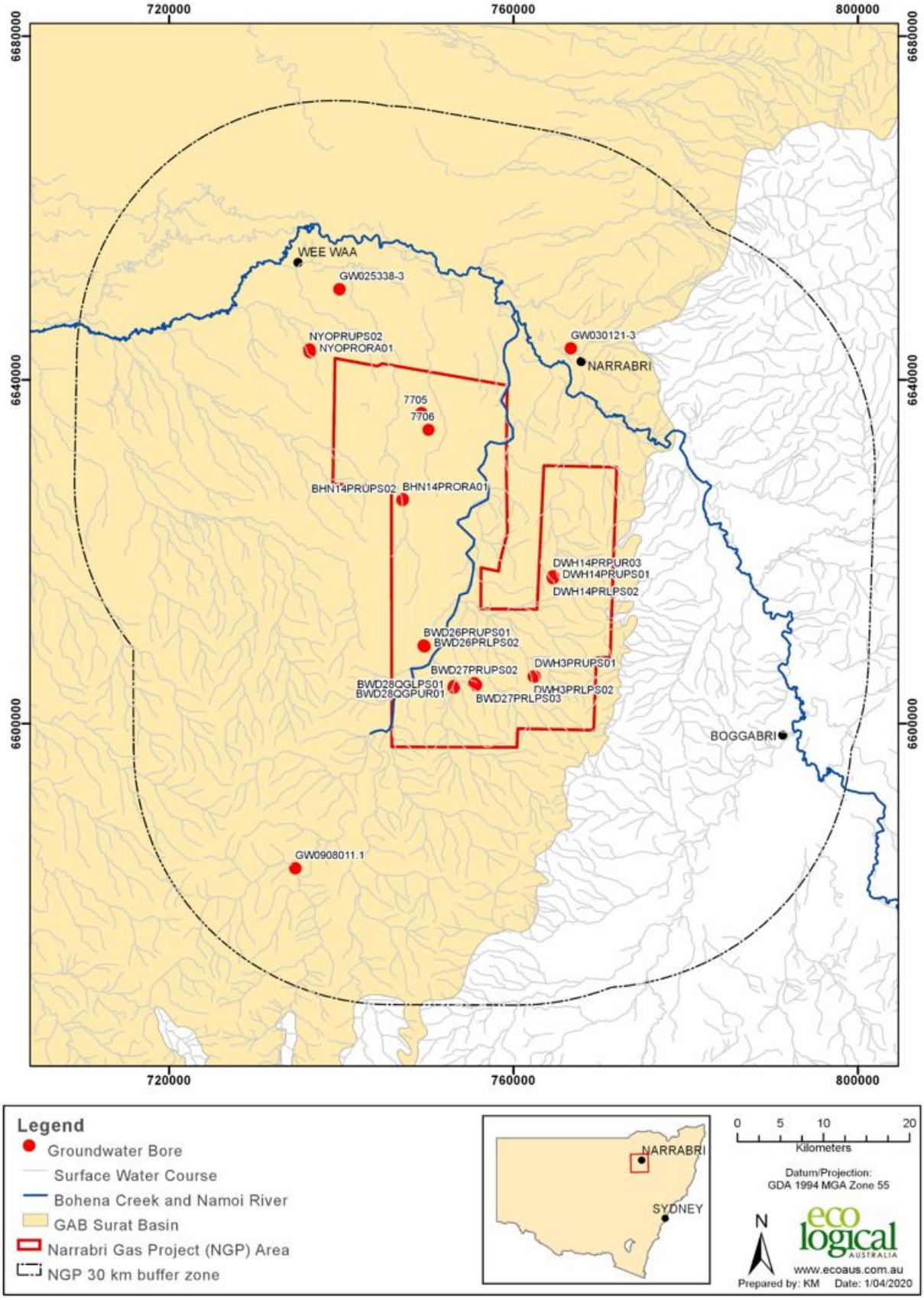


Figure 2.2 - Baseline monitoring locations in Great Artesian Basin Groundwater Sources

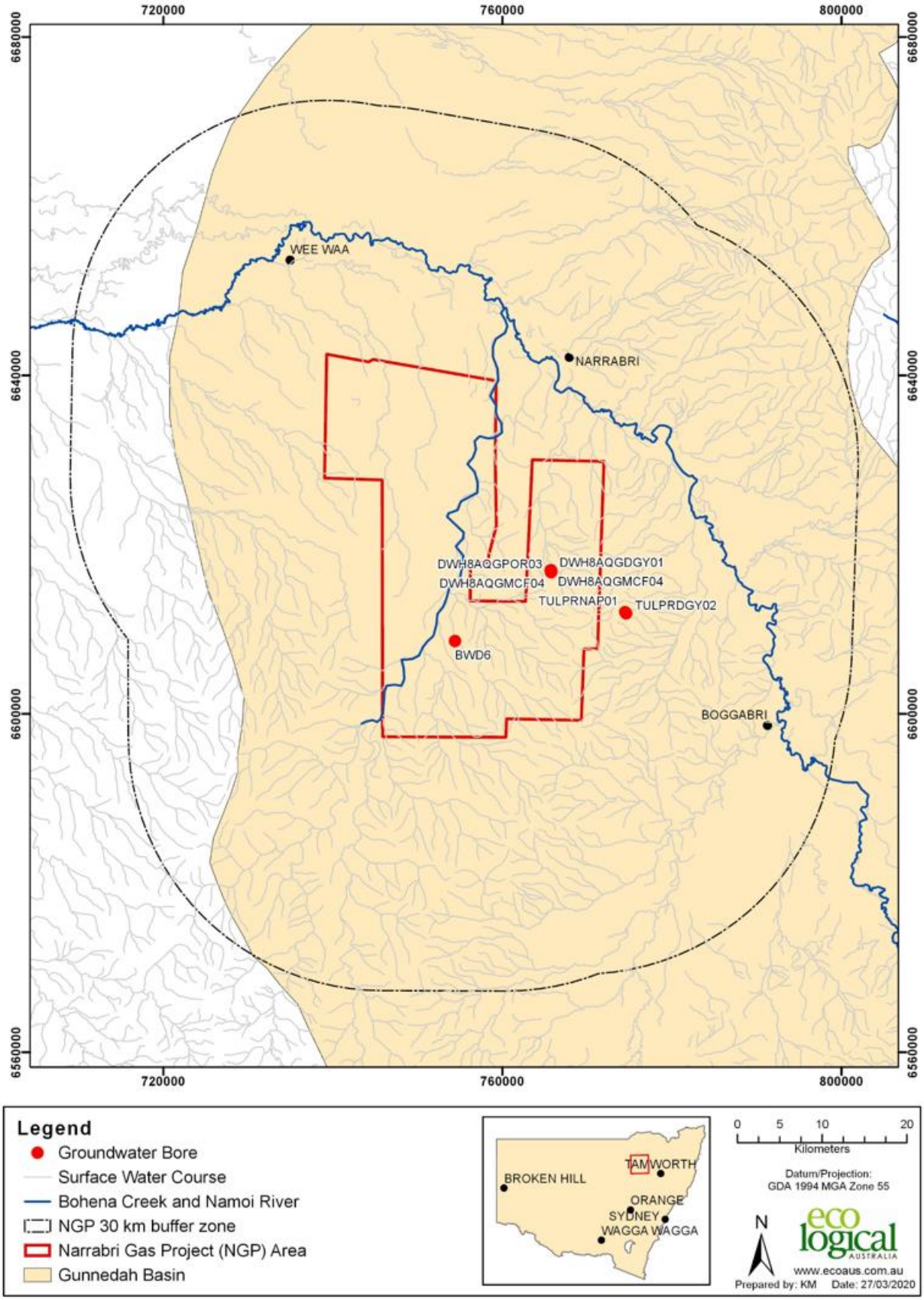


Figure 2.3 - Baseline monitoring locations in Gunnedah Oxley Basin Groundwater Sources

3. Groundwater baseline data - pressure and levels

Table 3.1 lists the 49 groundwater monitoring bores that constitute the baseline monitoring locations for groundwater hydraulic head. The table contains a simple statistical summary of the spread (minimum and maximum values) and central tendency (mean and median values) of measurements of hydraulic head in each bore. All listed bores satisfy the criteria for baseline data (at least three years of quality assured monitoring data) with the exception of NYOPRORA01 (targeting the Orallo Formation), NYOPRUPS02 (Upper Pilliga Sandstone), BWD6 (Porcupine) and DWH8AQGMCF04 (Maules Creek Formation). These bores suffered instrumentation failure which was decommissioned in 2017. These targets will be recommissioned as part of the Phase 1 bore monitoring program.

3.1 Summary of groundwater source condition

Hydrographs for each of the water bores listed in Table 3.1 are presented in Appendix A. A summary of water level or pressure trends is provided below.

3.1.1 Target coal seams

Limited monitoring of coal seam groundwaters (away from producing areas) suggests generally stable groundwater conditions, though problems with sealed loggers reduce the confidence in the data. Flat trends are observed where data is valid.

3.1.2 Deeper formations of the GOB

Water pressure loggers proved problematic over time in several deeper bores though early data is supported by recent manual measurements and shows flat trends in most deep formations of the Gunnedah Basin.

3.1.3 Shallower formations of the GOB

Bores targeting the Digby Formations also record flat water pressure trends over the period of monitoring (since 2014).

3.1.4 High value GAB aquifers

Groundwater pressures in the Jurassic GAB formations are mostly flat over the past 5 years, with a couple of bores targeting the Upper Pilliga Sandstone slightly declining, and one bore rising. The two bores targeting the Purlewaugh Formation are declining at 0.1 and 0.3 m/yr over the last 5 years. Government bores with longer records show a general gradual decline in water pressures over the past 50 years. Inter-annual variability up to five metres is seen in shallower bores, with artesian conditions to the west exhibiting significant variability up to 15 m year on year. The DPE Water monitoring bore (GW025338-3) targeting the Mooga Sandstone shows a long-term water-level decline of approximately 10 m over the past 50 years (refer to Figure A26 in Appendix A). Trends are comparable to those seen in alluvial bores elsewhere across the Namoi catchment (NSW DPIE, 2020).

3.1.5 High value alluvial aquifers

Groundwater pressure levels in the Namoi Alluvial aquifers show significant seasonal variability, in excess of 50 m in some bores, but generally 5-10 m each year. There has been a long-term decline in water levels of several metres over 50 years in almost all monitored bores. Trends are comparable to those seen in alluvial bores elsewhere across the Namoi catchment (NSW DoI, 2019).

Table 3.1 - Summary of baseline data for groundwater head

Bore	Owner	Unit	Water source	Hydraulic head (mAHD)						
				No. of records	First record	Last record	Min.	Max.	Mean	Median
GW021266-3	DPE	Namoi alluvium	ULNA	3630	6/73	08/19	131.0	185.8	166.1	172.5
GW021437-2*	DPE	Namoi alluvium	ULNA	1138	5/68	8/19	178	185.2	181.9	182.1
GW025338-1*	DPE	Namoi alluvium	ULNA	1089	12/69	12/18	170.4	181.8	175.4	174.9
GW025338-2	DPE	Namoi alluvium	ULNA	1089	12/69	12/18	161.8	181.6	174.1	174.1
GW025340-1	DPE	Namoi alluvium	ULNA	1085	4/70	9/18	169.7	180.5	172.8	172.8
GW025340-2	DPE	Namoi alluvium	ULNA	2208	4/70	9/18	169.5	180.5	172.0	170.8
GW025343-1*	DPE	Namoi alluvium	ULNA	1059	4/70	8/14	171.8	179.7	175.2	174.8
GW030070-1*	DPE	Namoi alluvium	ULNA	362	8/70	8/19	182.5	192.7	188.5	189.2
GW030070-2*	DPE	Namoi alluvium	ULNA	375	8/70	8/19	172.3	190.2	185.0	188.4
GW030070-3*	DPE	Namoi alluvium	ULNA	375	8/70	8/19	171.6	190.1	186.8	186.8
GW030310-1*	DPE	Namoi alluvium	ULNA	351	3/74	8/19	180.76	207.2	192.2	193.2
GW030117-1*	DPE	Namoi alluvium	ULNA	342	6/72	8/19	199.6	204.2	202.6	202.6
GW030117-2*	DPE	Namoi alluvium	ULNA	285	6/72	8/14	201.7	204.6	202.8	202.8
GW030278-1*	DPE	Namoi alluvium	ULNA	390	4/72	8/19	213.0	222.0	216.7	216.8
GW036005-2*	DPE	Namoi alluvium	ULNA	333	9/74	8/19	205.1	227.2	223.3	225.0
GW036092-1	DPE	Namoi alluvium	ULNA	339	12/74	9/18	230.9	234.4	232.3	232.4
GW036546-3	DPE	Namoi alluvium	ULNA	152	5/86	7/14	230.9	240.4	237.2	237.0
GW036546-1	DPE	Namoi alluvium	ULNA	172	5/86	7/19	233.6	240.4	238.2	237.6
GW036546-2	DPE	Namoi alluvium	ULNA	152	5/86	7/14	231.0	240.4	237.2	237.0
GW036497-1	DPE	Namoi alluvium	ULNA	182	6/84	7/19	254.3	257.3	255.9	255.6
GW030310-2	DPE	Namoi alluvium	ULNA	353	3/74	8/19	179.8	207.2	194.0	195.3
GW030400-1*	DPE	Namoi alluvium	ULNA	339	11/73	8/19	208.1	215.4	211.9	212.1
GW021266-4	DPE	Namoi alluvium	ULNA	363	6/73	8/19	128.0	186.7	169.7	175.6
GW025343-2	DPE	Namoi alluvium	ULNA	1059	1/70	8/14	171.9	179.8	175.2	174.9
GW025340-3	DPE	Namoi alluvium	ULNA	373	4/70	9/18	169.8	179.8	173.7	173.1
GW025338-3	DPE	Mooga Ss	GAB	1089	12/69	12/18	167	181.5	174.8	174.5
BHN14PRORA01*	Santos	Orallo Fm	GAB	1189	2/14	7/20	205.8	224.1	216.0	216.3
NYOPRORA01*	Santos	Orallo Fm	GAB	912	1/15	8/17	222.6	212.1	211.0	206.2
BHN14PRUPS02*	Santos	Pilliga Ss	GAB	1122	3/14	7/20	214.4	233.8	220.5	216.0
BWD26PRLPS02*	Santos	Pilliga Ss	GAB	939	3/14	7/20	246.8	248.3	248.1	248.0
BWD26PRUPS01*	Santos	Pilliga Ss	GAB	1279	12/13	7/20	238.2	250.1	246.7	247.2
BWD27PRLPS03*	Santos	Pilliga Ss	GAB	1043	3/14	7/20	244.5	264.5	255.2	254.0
BWD27PRUPS02*	Santos	Pilliga Ss	GAB	1018	3/14	7/20	243.9	262.2	253.4	253.4
BWD28QGLPS01	Santos	Pilliga Ss	GAB	1474	3/14	7/20	284.6	290.2	287.5	288.9
BWD28QGUPS01	Santos	Pilliga Ss	GAB	1249	3/14	8/17	270.1	283.2	282.0	282.2
DWH14PRLPS02*	Santos	Pilliga Ss	GAB	1205	3/14	7/20	225.9	245.9	232.5	234.9
DWH14PRUPS01*	Santos	Pilliga Ss	GAB	1260	12/13	7/20	42.3	62.3	57.0	53.6
DWH3PRLPS02*	Santos	Pilliga Ss	GAB	1258	3/14	7/20	240.7	260.7	251.4	249.7
DWH3PRUPS01*	Santos	Pilliga Ss	GAB	1237	12/13	7/20	241.6	261.6	252.8	250.0
NYOPRUPS02*	Santos	Pilliga Ss	GAB	1111	3/14	8/17	204.0	222.6	210.7	209.6
GW030121-3	DPE	Pilliga Ss	GAB	360	4/71	8/19	193.9	208.2	203.7	204.2
GW098011-1	DPE	Pilliga Ss	GAB	3374	12/12	10/17	305.1	306.5	305.3	305.3
BWD28QGPUR01	Santos	Purlawaugh Fm	GAB	1434	3/14	7/20	278.6	280.0	279.3	279.3
DWH14PRPUR03*	Santos	Purlawaugh Fm	GAB	413	3/14	7/20	235.2	237.2	236.8	236.9
DWH8AQGDGY01	Santos	Digby Fm	GOB	1542	6/15	7/20	327.5	330.2	329.6	329.7
TULPRDGY02*	Santos	Digby Fm	GOB	1223	4/14	7/20	228.9	250.4	242.4	240.3
DWH8AQGPOR03	Santos	Porcupine Fm	GOB	1541	6/15	7/20	348.8	362.3	356.3	356.3
BWD6	Santos	Porcupine Fm	GOB	427	5/15	6/16	354.2	369.7	362.3	362.6
DWH8AQGMCF04	Santos	Maules Creek Fm	GOB	800	6/15	8/17	379.4	1283.3	518.6	390.2

GOB – Gunnedah–Oxley Basin MDB Groundwater Source; GAB - Great Artesian Basin Surat and Southern Recharge Groundwater Sources; ULNA – Upper and Lower Namoi Alluvium Sources
Note: screened intervals of bores are listed in Appendix B
* Bores sampled for water quality analysis

4. Groundwater baseline data - quality

Table 4.1 lists the 41 groundwater monitoring bores that constitute the baseline monitoring locations for groundwater quality. Bore locations were previously shown in Figure 2.1, Figure 2.2 and Figure 2.3.

Table 4.1 - Summary of baseline data for groundwater quality

Bore	Owner	Stratigraphic Unit	Water Source	Date Range	
				First record	Last record
BHNCKMW1	Santos	BC alluvium	BC	17/07/13	25/10/13
BHNCKMW2	Santos	BC alluvium	BC	17/07/13	25/10/13
BHNCKMW3	Santos	BC alluvium	BC	17/07/13	25/10/13
BHNCKMW4	Santos	BC alluvium	BC	17/07/13	22/10/13
7707	Private	BC alluvium	BC	28/05/2012	24/06/14
GW021266-1†	DPE	Namoi alluvium	ULNA	01/04/66	21/09/99
GW021437-2*†	DPE	Namoi alluvium	ULNA	09/06/67	22/03/85
GW025338-1*†	DPE	Namoi alluvium	ULNA	14/11/69	11/11/99
GW025343-1*†	DPE	Namoi alluvium	ULNA	15/12/69	04/12/86
GW030070-1*†	DPE	Namoi alluvium	ULNA	22/05/70	02/06/99
GW030070-2*†	DPE	Namoi alluvium	ULNA	02/06/99	02/06/99
GW030070-3*	DPE	Namoi alluvium	ULNA	02/06/99	02/06/99
GW030117-1*†	DPE	Namoi alluvium	ULNA	07/03/72	28/05/99
GW030117-2*	DPE	Namoi alluvium	ULNA	28/05/99	28/05/99
GW030117-3	DPE	Namoi alluvium	ULNA	28/05/99	28/05/99
GW030278-1*	DPE	Namoi alluvium	ULNA	21/11/78	21/11/78
GW030310-1*†	DPE	Namoi alluvium	ULNA	16/08/76	31/05/99
GW036005-2*†	DPE	Namoi alluvium	ULNA	04/06/74	06/09/84
GW030121-1†	DPE	Namoi alluvium	ULNA	20/04/71	27/05/99
GW030310-2*†	DPE	Namoi alluvium	ULNA	27/02/85	30/05/99
GW030400-1*†	DPE	Namoi alluvium	ULNA	15/08/73	23/01/85
BHN14PRORA01*†	Santos	Orallo Fm	GAB	14/12/13	22/07/20
NYOPRORA01*†	Santos	Orallo Fm	GAB	30/11/13	22/07/20
7703	Private	Orallo Fm	GAB	25/05/12	07/05/14
7705	Private	Orallo Fm	GAB	25/05/12	07/05/14
7706	Private	Orallo Fm	GAB	25/05/12	25/06/14
BWD1WB	Santos	Pilliga Ss	GAB	17/10/12	23/10/13
BWD5WB	Santos	Pilliga Ss	GAB	08/10/12	18/10/12
BHN14PRUPS02*†	Santos	Pilliga Ss	GAB	12/12/13	22/07/20
BWD26PRLPS02*†	Santos	Pilliga Ss	GAB	19/09/13	28/07/20
BWD26PRUPS01*†	Santos	Pilliga Ss	GAB	27/07/14	28/07/20
BWD27PRLPS03*†	Santos	Pilliga Ss	GAB	15/11/13	28/07/20
BWD27PRUPS02*†	Santos	Pilliga Ss	GAB	29/07/13	28/07/20
DWH14PRLPS02*†	Santos	Pilliga Ss	GAB	27/10/13	14/07/20
DWH14PRUPS01*†	Santos	Pilliga Ss	GAB	07/11/13	14/07/20
DWH3PRLPS02*†	Santos	Pilliga Ss	GAB	30/09/13	15/07/20
DWH3PRUPS01*†	Santos	Pilliga Ss	GAB	02/10/13	15/07/20
NYOPRUPS02*†	Santos	Pilliga Ss	GAB	01/12/13	22/07/20
DWH14PRPUR03*†	Santos	Purlawaugh Fm	GAB	29/10/13	14/07/20
TULPRNAP01†	Santos	Napperby	GOB	09/07/14	08/07/20
TULPRDGY02*†	Santos	Digby Fm	GOB	13/01/15	08/07/20

Note:

* Bores also monitored for water level/pressure

† Bores that meet the water quality objective of an established baseline and will no longer be sampled for water quality unless required as a response in review of a monitoring trigger, as described in the GMP (Section 8)

All listed bores have sufficiently established baseline groundwater quality (as defined in the Groundwater Monitoring Report Section 3.3) where no further groundwater quality sampling is required, with the exception of: the Bohena Creek bores (due to dry, or low water level, bores, that prevent sample collection); a number of DPE bores that were only sampled at the time of development and have not been sampled since, and private landholder bores that were sampled over a period of two years only and require further permission from the landholder to continue sampling. All Santos baseline bores have been sampled and analysed for a minimum three years and six samples.

Summaries of the baseline data for each stratigraphic unit are presented below. Individual bores are presented in Appendix B. The tables contain statistical measures of the spread (minimum, maximum and percentiles values) and central tendency (median and mean values) of these data. The 16th and 84th percentiles are reported for large sample populations. As non-detect (or commonly the limit of reporting [**LOR**]) samples can result in biased results when reported in large proportions, samples with more than 15 % of results returning LOR have been excluded from percentile calculations. A sample size of at least six values greater than LOR is needed to statistically identify the 16th and 84th percentiles.

4.1 Target coal seams

Only intermittent sampling for the full chemistry suite has been undertaken for the target coal seams. Spot analyses indicate that the coal seam groundwater is relatively high in bicarbonate salts (averaging 2,400 parts per million [**ppm**] bicarbonate) resulting in elevated pH and salinities. Insufficient time-series at a single well has been collected to date, so trend analysis is not possible.

4.2 Shallower formations of the GOB

Bicarbonate is relatively high in all formations and the groundwaters are relatively clean, that is, with low metal levels, low trace elements and low uranium. Methane can reach 20 ppm but is generally low (<10 ppm). Water quality trends are flat across the region.

4.3 High value GAB aquifers

Water quality has been good and stable at all bores, with generally low salinities dominated by sodium bicarbonate salts. Methane levels can reach 5 ppm but are generally below 1 ppm and below LOR in many samples.

4.4 High value alluvial aquifers

Most monitored bores exhibit low salinity, also dominated by sodium bicarbonate salts. Where more than six samples have been taken, trends appear to be relatively flat.

Water quality analyses from bores in the Bohena Creek Alluvium revealed a chemistry similar to the GAB groundwaters. The short time series of 4 years suggests stable groundwater conditions with little variability despite the shallow and thin nature of these aquifers.

The groundwater monitoring analyses reported in Appendix B include historical monitoring undertaken by third parties. This monitoring employed a range of sampling and analytical methods. In a number of cases, subsequent monitoring has shown that the analyses are not representative of the aquifer interval sampled, especially if monitored after a significant pumping stress. Appendix B shows that some bores have only been monitored once or twice over the assessment period.

Table 4.2 - Summary of baseline data for groundwater quality in Permo-Triassic strata

Water quality measure	No. of Samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	13	13	0.013	3.3	1.7	0.49	3.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	13	10	1380	5200	2910	NA	NA
B (mg/L)	13	12	0.1	1	0.6	0.2	0.9
Ca (mg/L)	13	12	2	79	40	15	59
CO_3 alkalinity as $CaCO_3$ (mg/L)	13	3	292	427	348	NA	NA
Cl (mg/L)	13	13	33	866	425	40.5	854
EC (field) (µS/cm)	24	24	3126	10773	7282	6265	9499
EC @ 25C (lab) (µS/cm)	12	12	3640	10300	7732	7013	9410
F (mg/L)	13	13	0.5	1.6	1.1	0.68	1.4
Li (mg/L)	2	2	0.09	1	0.6	ISS	ISS
Mg (mg/L)	13	9	1	39	27	NA	NA
Mn (mg/L)	13	10	0.001	0.5	0.1	NA	NA
pH (field)	24	24	5.8	13	8	6.7	12
pH (lab)	12	12	6.9	12	8.5	6.9	12
K (mg/L)	13	12	2	305	103	34.6	288
Na (mg/L)	13	13	815	2260	1467	870	1766
Sodium adsorption ratio (SAR)	2	2	34	50	42	ISS	ISS
Sr (mg/L)	13	13	0.007	5.2	2.6	1.5	3.7
Sulfate as SO_4^{2-}	13	7	2	239	54.6	NA	NA
Methane (µg/L)	13	13	1100	20000	6300	1900	11000

Stratigraphic units: Digby and Napperby Formations
Date range: 29/10/2013 to 18/7/2017
ISS – insufficient sample size; NA – LOR > 15% sample size

Table 4.3 - Summary of baseline data for groundwater quality in the Pilliga Sandstone

Water quality measure	No. of Samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	92	91	0.02	1	0.3	0.06	0.5
HCO_3 alkalinity as $CaCO_3$ (mg/L)	97	95	6	637	92.7	11	197
B (mg/L)	92	24	0.05	0.2	0.1	NA	NA
Ca (mg/L)	97	63	1	45	7.9	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	97	10	2	43	25	NA	NA
Cl (mg/L)	97	97	5	61	30	19	42
EC (field) (µS/cm)	138	138	67.9	1390	302	121	479
EC @ 25C (lab) (µS/cm)	97	97	64	1520	306.8	124	464.2
F (mg/L)	96	37	0.1	1	0.35	NA	NA
Li (mg/L)	35	34	0.001	2	0.1	0.002	0.02
Mg (mg/L)	96	77	1	10	2.5	NA	NA
Mn (mg/L)	91	90	0.001	0.4	0.08	0.01	0.1
pH (field)	138	138	4.1	8.5	5.9	5.1	7
pH (lab)	97	97	4.1	9.5	6.6	5.8	7.5
K (mg/L)	96	96	2	14	5.4	2	7
Na (mg/L)	96	96	6	352	51.9	17	42
SAR	28	28	0.03	86	7.8	2.2	5
Sr (mg/L)	96	96	0.008	0.6	0.08	0.02	0.1
Sulfate as SO_4^{2-}	97	41	0.5	35	3.2	NA	NA
Methane (µg/L)	96	25	12	4600	850	NA	NA

Stratigraphic unit: Pilliga Sandstone
Date range: 20/4/1971 to 24/7/2017
ISS – insufficient sample size; NA – LOR > 15% sample size

Table 4.4 - Summary of baseline data for groundwater quality in the Orallo Formation

Water quality measure	No. of Samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	24	24	0.08	0.9	0.3	0.1	0.6
HCO_3 alkalinity as $CaCO_3$ (mg/L)	25	25	178	684	395	201	574
B (mg/L)	24	19	0.06	0.3	0.2	NA	NA
Ca (mg/L)	25	25	1	39	17	4	34
CO_3 alkalinity as $CaCO_3$ (mg/L)	25	11	3	89	25	NA	NA
Cl (mg/L)	25	25	25	721	108	32	81
EC (field) (µS/cm)	31	31	470	3079	1038	505	1343
EC @ 25C (lab) (µS/cm)	24	24	471	3280	1131	496	1360
F (mg/L)	24	21	0.2	1	0.7	0.2	1
Li (mg/L)	14	10	0.005	0.9	0.1	NA	NA
Mg (mg/L)	25	20	1	17	7.2	NA	NA
Mn (mg/L)	24	24	0.003	0.7	0.09	0.007	0.2
pH (field)	31	31	6.4	8.9	7.5	6.9	8.2
pH (lab)	24	24	7.3	8.9	8	7.5	8.5
K (mg/L)	25	25	1	13	5	2	8.2
Na (mg/L)	25	25	53	638	231	61	336
SAR	13	13	2.1	85	23	2.9	34
Sr (mg/L)	24	24	0.1	0.6	0.3	0.1	0.5
Sulfate as SO_4^{2-}	25	12	1	57	17	NA	NA
Methane (µg/L)	25	20	12	4200	1100	NA	NA

Stratigraphic unit: Orallo Formation
Date range: 25/5/2012 to 18/7/2017
ISS – insufficient sample size; NA – LOR > 15% sample size

Table 4.5 - Summary of baseline data for groundwater quality in Namoi alluvium

Water quality measure	No. of Samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	9	8	0.02	0.2	0.07	0.02	0.1
HCO_3 alkalinity as $CaCO_3$ (mg/L)	78	78	125	1190	436	181	797
B (mg/L)	9	9	0.03	0.2	0.1	0.04	0.2
Ca (mg/L)	9	9	1.7	55	19	3	48
CO_3 alkalinity as $CaCO_3$ (mg/L)	54	24	0.3	130	24	NA	NA
Cl (mg/L)	78	78	7.8	242	61.7	13	123
EC (field) (µS/cm)	47	47	248	2170	1006	376	1745
EC @ 25C (lab) (µS/cm)	32	32	318	2390	697	332	1082
F (mg/L)	10	10	0.05	2	0.9	0.3	1
Li (mg/L)	9	4	0.01	0.02	0.01	NA	NA
Mg (mg/L)	9	9	0.3	40	10	0.7	20
Mn (mg/L)	9	5	0.007	0.2	0.04	NA	NA
pH (field)	79	79	6.3	9.6	7.9	7.5	8.4
pH (lab)	-	-	-	-	-	-	-
K (mg/L)	77	75	0.08	23	3.2	1.2	6.2
Na (mg/L)	77	77	14.9	520	165	45	343
SAR	-	-	-	-	-	-	-
Sr (mg/L)	9	9	0.06	0.7	0.3	0.07	0.5
Sulfate as SO_4^{2-}	73	67	0.48	75	15	4.1	22
Methane (µg/L)	-	-	-	-	-	-	-

Stratigraphic unit: Namoi alluvium
Date range: 1/4/1966 to 11/11/1999
ISS – insufficient sample size; NA – LOR > 15% sample size; SAR is rendered meaningless at these very low dissolved ion concentrations; the pH was not analysed in the laboratory for these samples.

Table 4.6 - Summary of baseline data for groundwater quality in Bohena Creek alluvium

Water quality measure	No. of Samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	10	10	0.04	0.1	0.08	0.06	0.1
HCO_3 alkalinity as $CaCO_3$ (mg/L)	10	10	40	596	160	41.4	364
B (mg/L)	10	2	0.2	0.2	0.2	NA	NA
Ca (mg/L)	10	10	3	8	5.2	3	7
CO_3 alkalinity as $CaCO_3$ (mg/L)	10	1	19	19	19	NA	NA
Cl (mg/L)	10	10	18	58	32	20	46
EC (field) (µS/cm)	6	6	173	1388	576.2	174.6	1246
EC @ 25C (lab) (µS/cm)	10	10	137	1320	413.3	157	822
F (mg/L)	10	5	0.1	1.1	0.48	NA	NA
Li (mg/L)	10	2	0.03	0.03	0.03	NA	NA
Mg (mg/L)	10	9	2	9	5.7	3.3	7.7
Mn (mg/L)	10	9	0.002	0.8	0.5	0.3	0.6
pH (field)	10	10	6.2	7.9	6.8	6.4	7.4
pH (lab)	6	6	6.3	8.4	7.2	6.6	8.3
K (mg/L)	10	10	1	3	2.2	2	3
Na (mg/L)	10	10	12	321	77.2	14.9	179
SAR	10	10	0.9	47	8.7	1.1	17
Sr (mg/L)	10	10	0.07	0.2	0.1	0.08	0.1
Sulfate as SO_4^{2-}	10	1	2	2	2	NA	NA
Methane (µg/L)	10	10	550	1600	1100	680	1500

Stratigraphic unit: Bohena Creek alluvium
Date range: 24/5/2012 to 24/6/2014
ISS – insufficient sample size; NA – LOR > 15% sample size

4.5 Methane in groundwaters

In non-coal measure groundwaters of the Gunnedah Oxley Basin, methane is observed at levels up to 20 ppm, but is not ubiquitous and is generally below 10 ppm. In the sampled groundwaters of the GAB, methane levels can reach nearly 5 ppm, but are generally below limits of recording (LOR). Those samples recording methane (45 out of 121 analyses) returned an average level of about 1 ppm.

The baseline bores in the Namoi Alluvium are all Government monitoring bores and methane and trace analytes are not routinely analysed. Local landholder bores accessing groundwater from the Namoi Alluvium have previously been sampled by Santos (reported in Jacobs, 2014[2]) and variable levels of methane were detected in these bores, with two bores reporting levels in excess of 1 ppm. Many recorded no methane, however, and the spatial distribution did not coincide with elevated levels measured in the underlying GAB aquifers. Stable isotope analyses suggest a thermogenic source for this gas.

All samples from the Bohena Creek alluvial aquifer returned methane values greater than LOR, ranging from 0.5 to 1.6 ppm.

The groundwater analyses are from a range of sampling methods, using a variety of laboratories and generally low quality assurance and control. In a number of cases, subsequent sampling may show that the analyses may not be representative of the aquifer interval sampled, especially after pumping stress had been applied. As the details presented in Appendix B show, each bore may only be represented by one or two samples over the period of assessment.

[2] Jacobs (2014) NGDP Hydrogeochemical Assessment of PEL238: Groundwater chemistry of the Narrabri Gas Project Area. Technical Report 1007419-5 for Santos Energy NSW 9 December 2014

5. Updating the Groundwater Baseline Report

5.1 Summary groundwater source status

The status of the groundwater sources in the area can be assessed from the baseline data presented above and is summarised in Table 5.1.

Table 5.1 - Summary status of groundwater sources in the Project area

Groundwater source aquifers	Water levels / pressures		Water quality		
	Trend	Seasonality	Salinity / type	Trend	Methane in groundwater
Namoi Alluvial	Declining	Significant (10-50 m)	Fresh Sodium bicarbonate	Variable, mostly flat	Variable up to 2 ppm; generally <LOR
GAB	Flat to slight decline	Observed, but muted	Fresh Sodium bicarbonate	Flat	Variable up to 5 ppm; generally <LOR
Shallow GOB	Flat	Not observed	Brackish Sodium bicarbonate	Flat	Variable up to 20 ppm; generally <LOR
Deep GOB	Flat	Not observed	Brackish Sodium bicarbonate	Flat	Variable
Coal Seams	Flat	Not observed	Brackish Sodium bicarbonate	Flat	

5.2 Ongoing groundwater monitoring

The Groundwater Monitoring Plan (**GMonP**) for the Project establishes groundwater monitoring requirements throughout Phase 1 of the Project. This includes:

- ongoing groundwater pressure and level monitoring in all formations; and
- groundwater quality monitoring of GAB and shallow alluvial groundwater sources until stable groundwater quality baseline has been established.

5.3 Baseline report update

This report may be updated prior to any update of the GMonP. Examples of when the GMP may be updated include:

- at least prior to commencement of Phase 2;
- if groundwater performance criteria (including trigger levels) are exceeded; and
- if instructed by the regulator.

The revised baseline monitoring network is described in the GMonP and includes the majority of the groundwater baseline monitoring points as well as additional targets determined through discussion with DPE Water and to consolidate the existing baseline network prior to Phase 2 of the Project.

6. References

NSW Department of Industry (NSW DoI) (2019). *Namoi Alluvium Water Resource Plan – Groundwater Resource Description*. INT18/195450

NSW Department of Planning, Industry and Environment (NSW DPIE) (2020). *Groundwater Resource Description: NSW Great Artesian Basin*. PUB20/74

7. Glossary

Term	Definition
Alluvial	Sediments deposited following a decrease in velocity of flowing water
Alluvium	General term for unconsolidated fluvio-lacustrine deposits of inorganic materials (clay, silt, sand, gravel, and boulders) deposited following a decrease in velocity of flowing water
Alluvium aquifer	An aquifer formed within alluvium. See Alluvium.
Aquifer	A saturated permeable geologic unit that can transmit useful quantities of water
Artesian	An aquifer that is under sufficient pressure that water will rise above the land surface via a well that is drilled into it
Baseline	A starting point used for future comparisons. Water baselines in context of the Narrabri Gas Project have been derived from long term water level and quality data presented in the Narrabri Gas Project Water Baseline Report.
Department	NSW Department of Planning and Environment (DPE)
Great Artesian Basin (GAB)	A sequence of sedimentary formations of Jurassic and Cretaceous age that contain units that provide useful quantities of groundwater, with artesian conditions occurring to the west of the Project area. The GAB generally underlies the GOB.
Gunnedah Oxley Basin (GOB)	A sequence of sedimentary formations of Permian and Triassic age that contain units that have economic resources of coal and coal seam gas underlying the Project area. The GOB generally underlies the GAB.
Namoi Alluvium (ULNA)	The Upper Namoi Alluvium, an aquifer made of coarse-grained river gravels and sands and the Lower Namoi Alluvium, a hydrostratigraphic unit made of shallow alluvial fan deposits associated with the Namoi River. These units contain a significant resource of readily accessible, good quality groundwater that is heavily utilised for irrigation, public water supply, private water supply and watering livestock.
Project area	The area of approximately 95,000 hectares that encompasses the Project
Project footprint	The area of surface expression being about 1,000 hectares occupied by the infrastructure components of the Narrabri Gas Project
Project-related infrastructure	All infrastructure and other structures associated with the development. This includes linear infrastructure and non-linear infrastructure, surface infrastructure and subsurface infrastructure, major facilities, wells and well pads and other gas field infrastructure.
Unacceptable risk	The level of risk at which mitigation actions are deemed to be warranted.
Groundwater Management Plan	A document that provides a strategic and proactive framework for the management of groundwater so that any potential impacts on the environment are avoided or managed. Developed in accordance with approval and consent conditions for the Project.
Water Sharing Plan	Legislated plans under the *Water Management Act 2000* that establish rules for sharing water between the environment and water users. Water licences are issued to water users in accordance with water sharing plans.

Appendix A - Groundwater level monitoring hydrographs

Water pressure has been collected continuously and, where required, has been corrected for barometric changes. Data gaps in continuous logs indicate periods of probe instability and provide an indication of the competency of the respective probes.

Ground surface is provided as the reference level (**RL**), measured as metres relative to the Australian Height Datum (**mAHD**), effectively metres above mean sea-level. Where this is outside the plotted range, only the RL value is provided.

For shallow groundwater sources, such as the Namoi Alluvium, significant departures from the general trends generally represent the groundwater drawdown response to periodic and local extraction by other groundwater users.

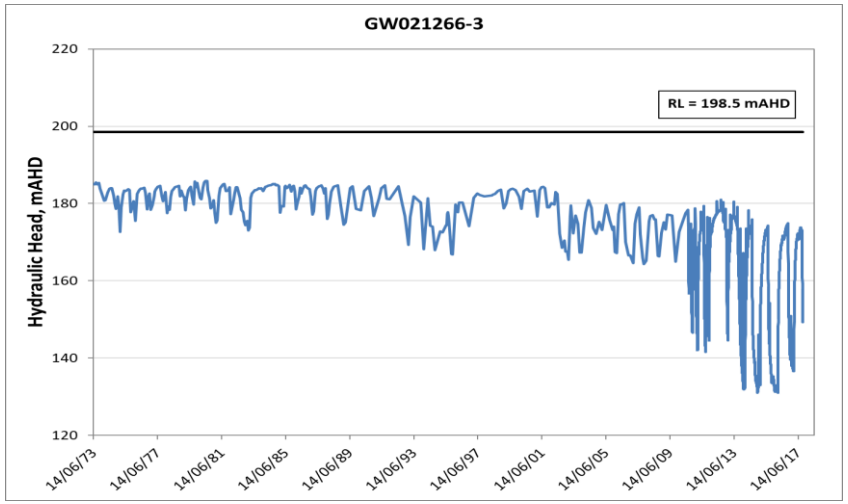


Figure A-1 Hydrograph for monitoring bore GW021266-3 (Namoi Alluvium)

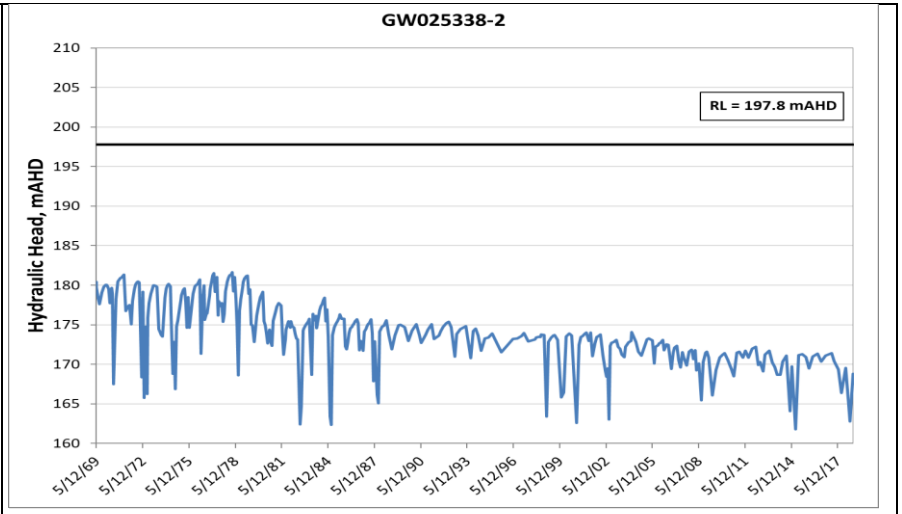


Figure A-3 Hydrograph for monitoring bore GW025338-2 (Namoi Alluvium)

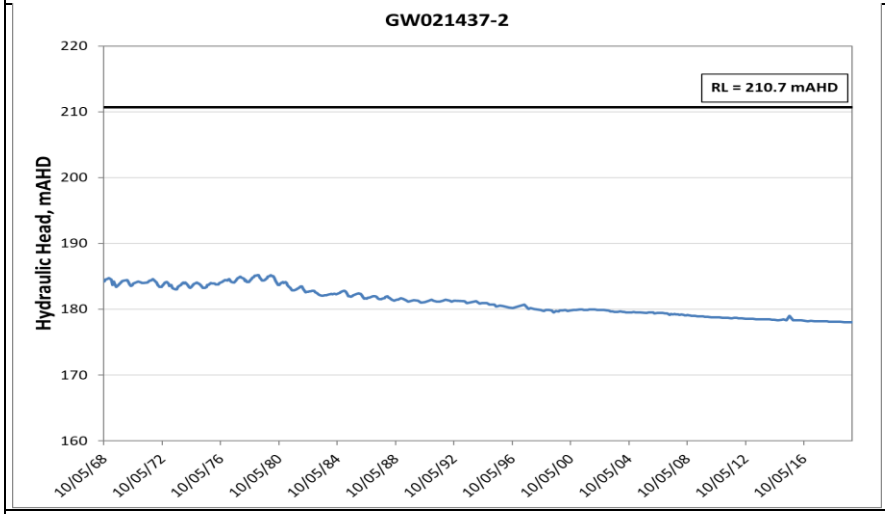


Figure A-2 Hydrograph for monitoring bore GW021437-2 (Namoi Alluvium)

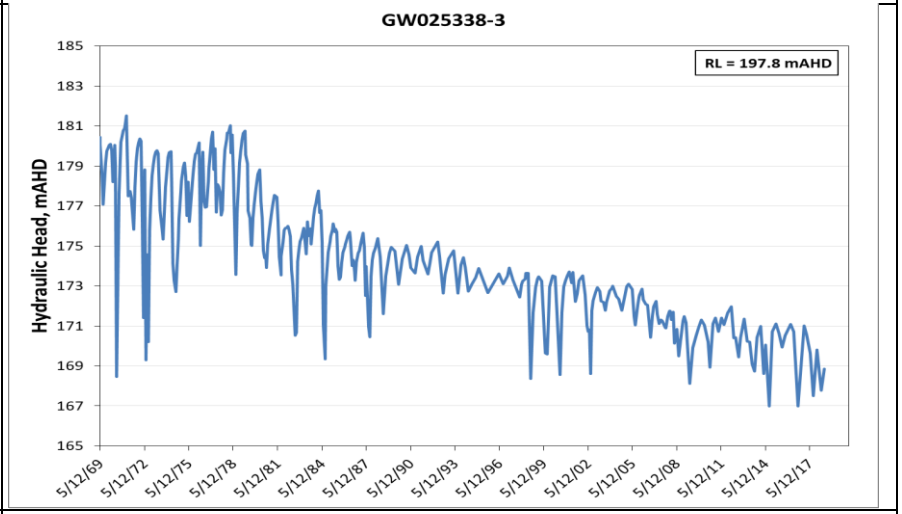


Figure A-4 Hydrograph for monitoring bore GW025338-3 (Namoi Alluvium)

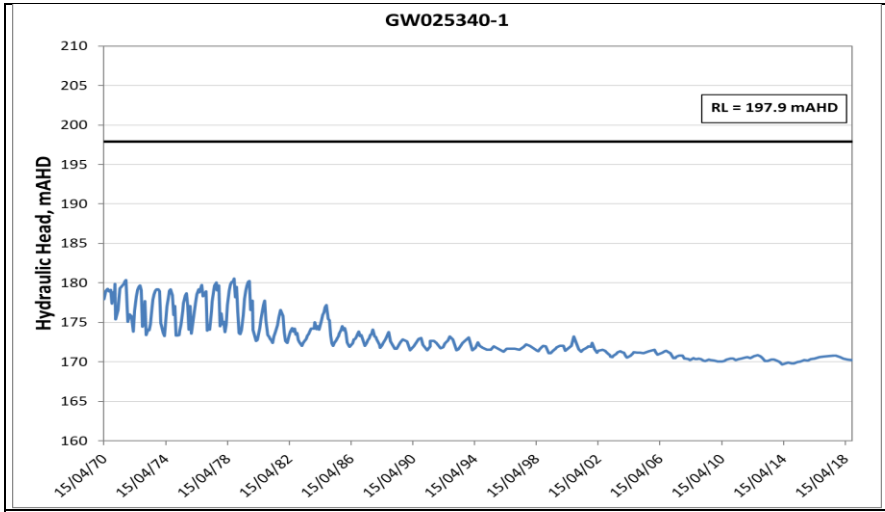


Figure A-5 Hydrograph for monitoring bore GW025340-1 (Namoi Alluvium)

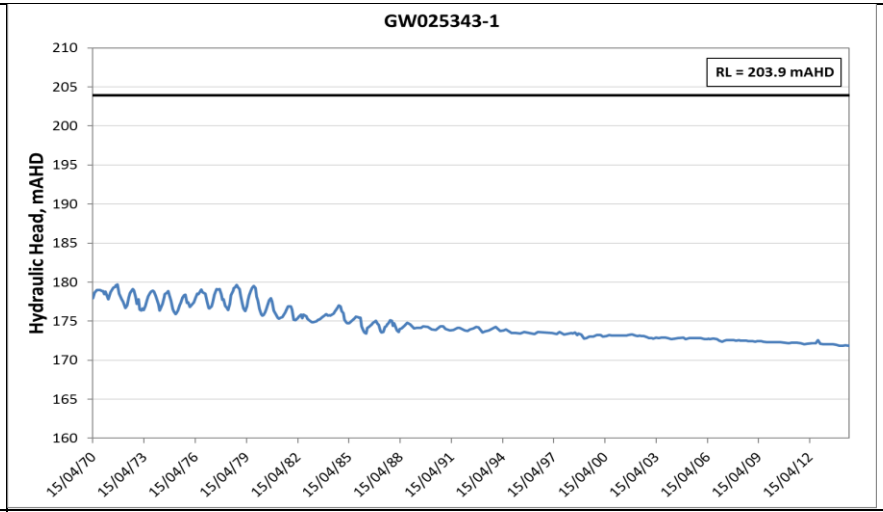


Figure A-7 Hydrograph for monitoring bore GW025343-1 (Namoi Alluvium)

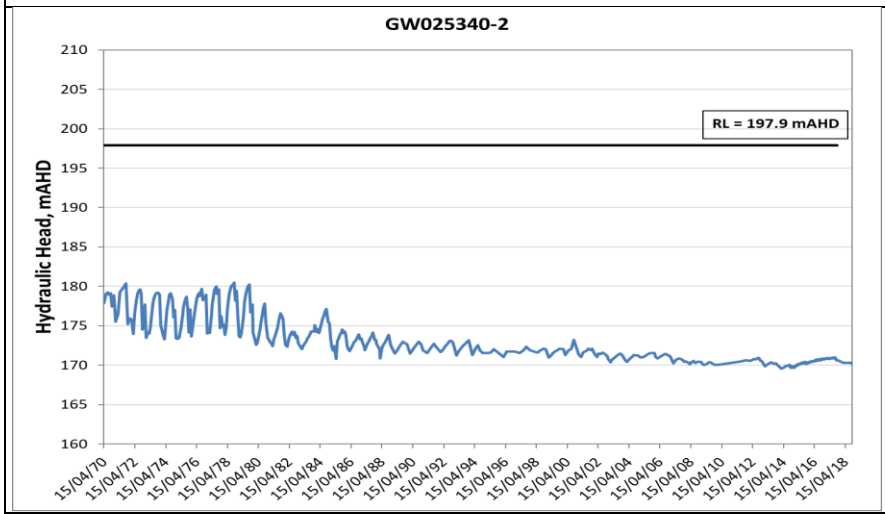


Figure A-6 Hydrograph for monitoring bore GW025340-2 (Namoi Alluvium)

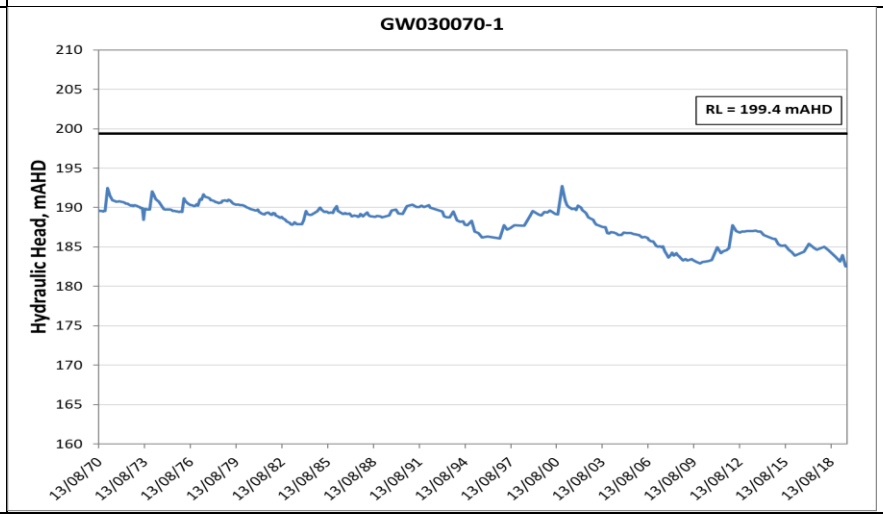


Figure A-8 Hydrograph for monitoring bore GW030070-1 (Namoi Alluvium)

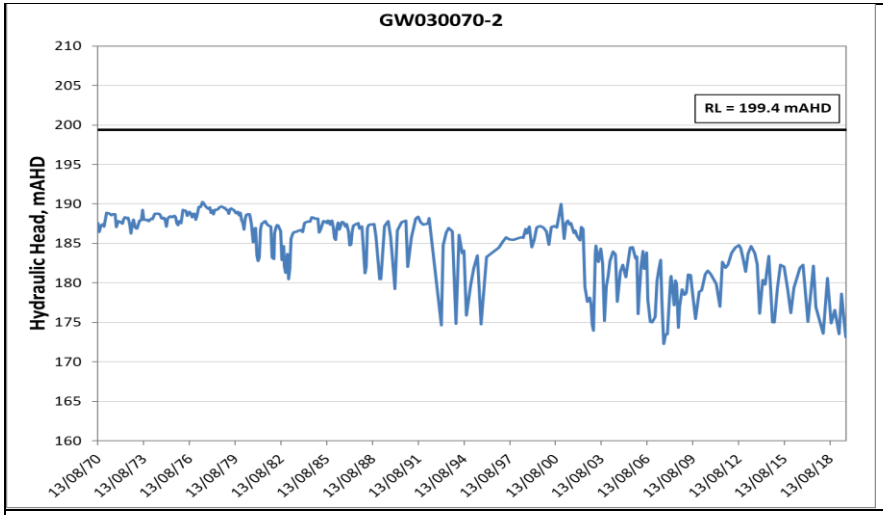


Figure A-9 Hydrograph for monitoring bore GW030070-2 (Namoi Alluvium)

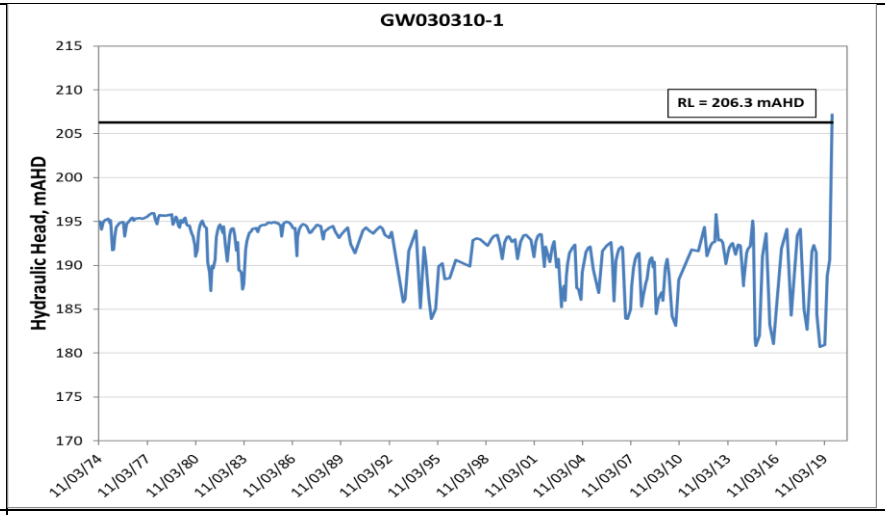


Figure A-11 Hydrograph for monitoring bore GW030310-1 (Namoi Alluvium)

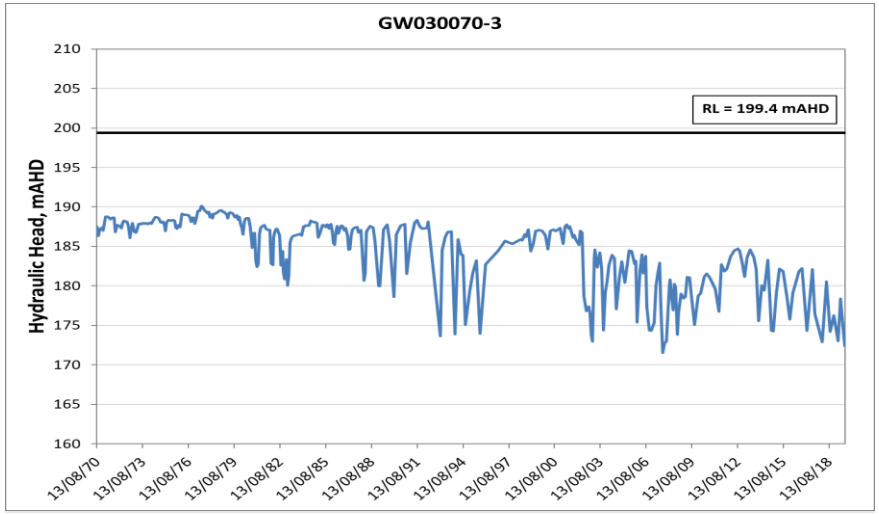


Figure A-10 Hydrograph for monitoring bore GW030070-3 (Namoi Alluvium)

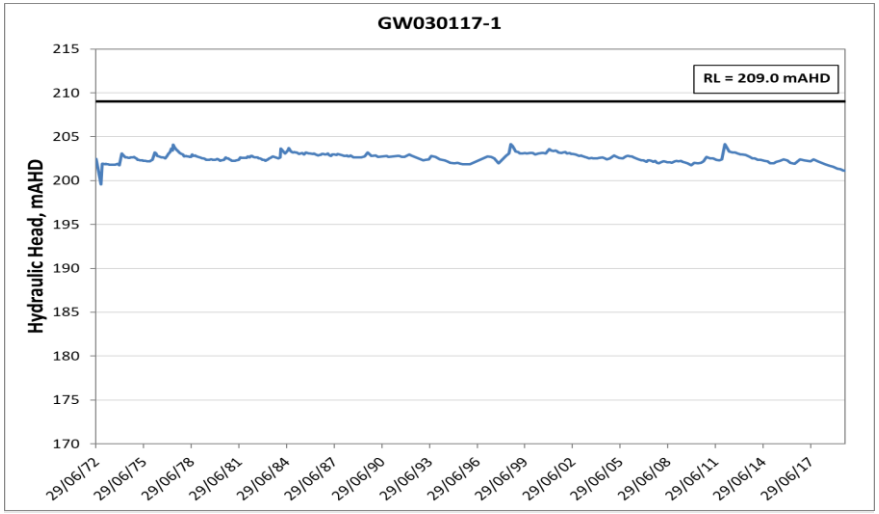


Figure A-12 Hydrograph for monitoring bore GW030117-1 (Namoi Alluvium)

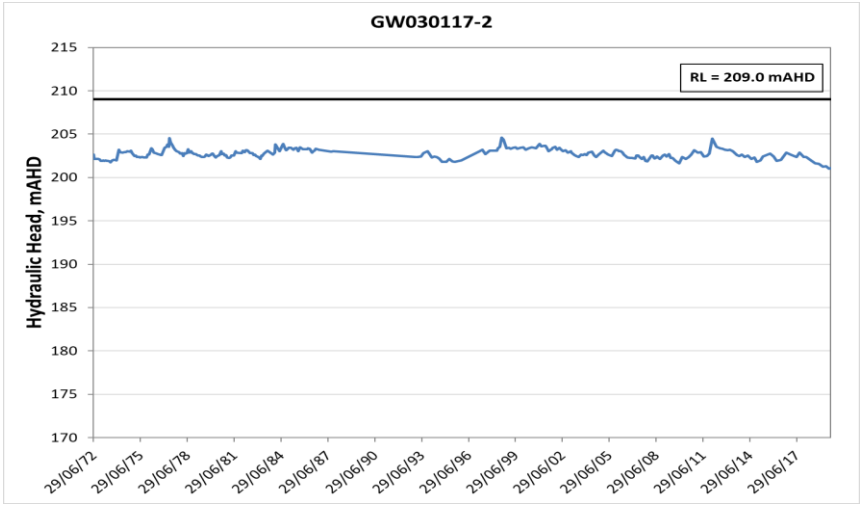


Figure A-13 Hydrograph for monitoring bore GW030117-2 (Namoi Alluvium)

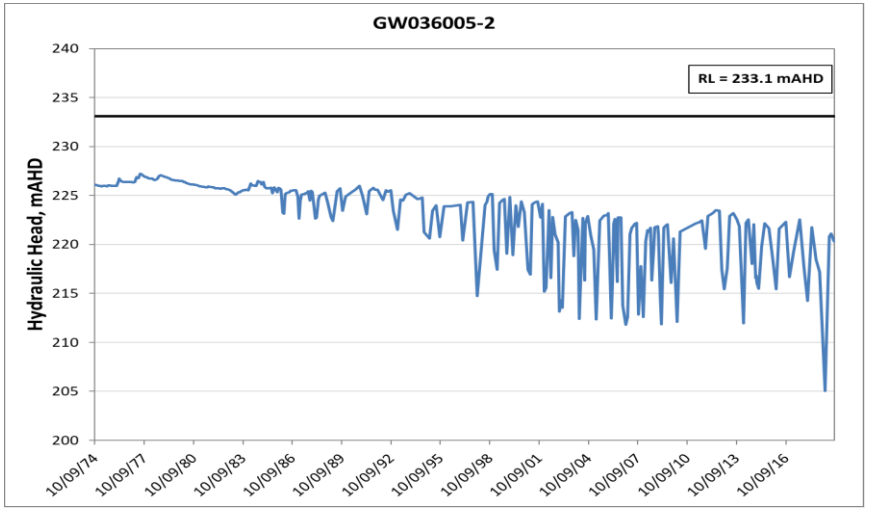


Figure A-15 Hydrograph for monitoring bore GW036005-2 (Namoi Alluvium)

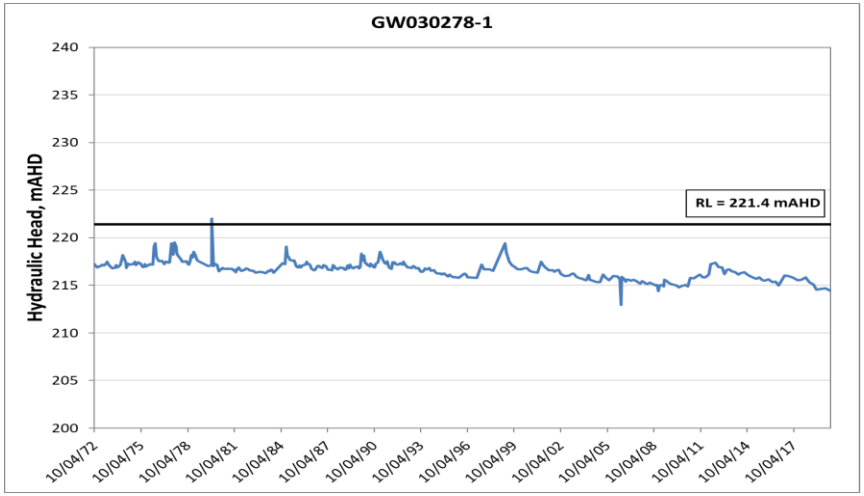


Figure A-14 Hydrograph for monitoring bore GW030278-1 (Namoi Alluvium)

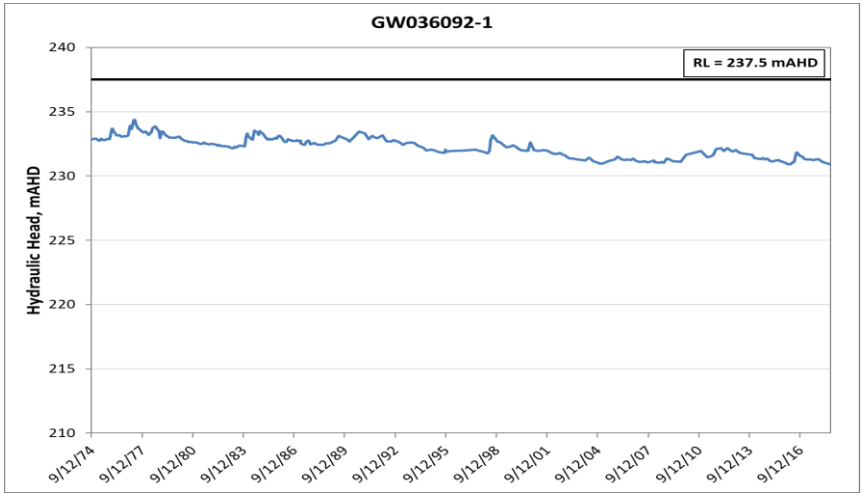


Figure A-16 Hydrograph for monitoring bore GW036092-1 (Namoi Alluvium)

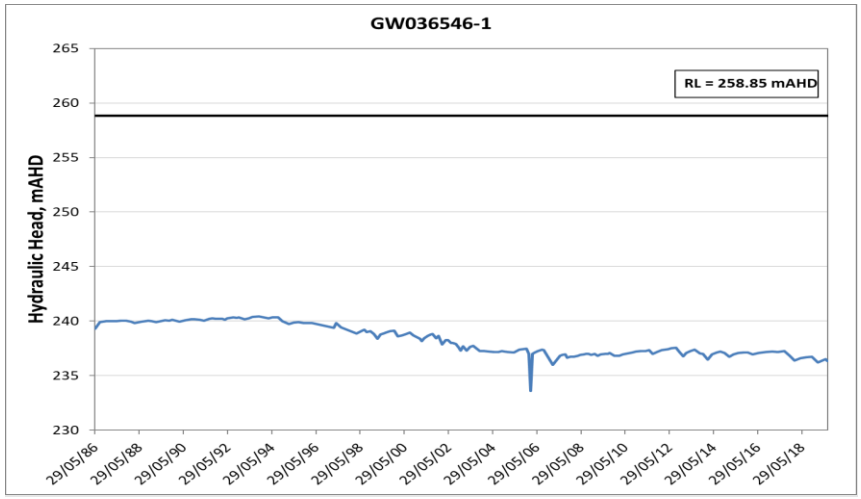


Figure A-17 Hydrograph for monitoring bore GW036546-1 (Namoi Alluvium)

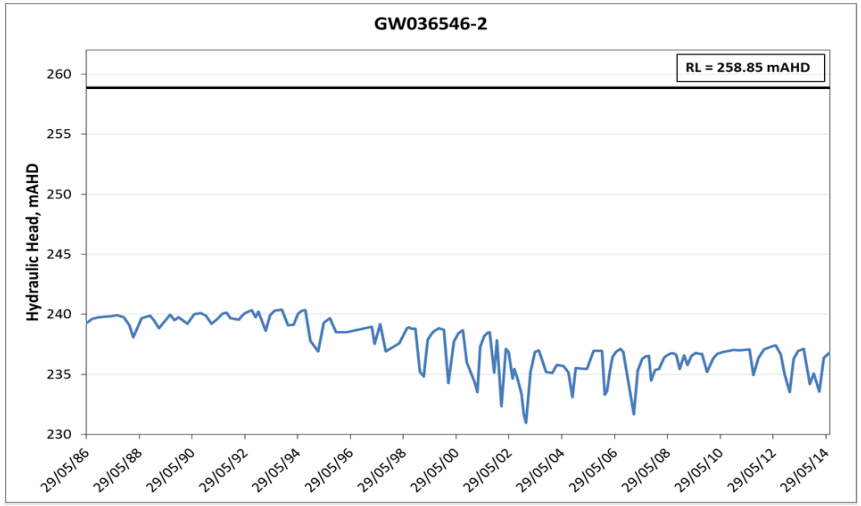


Figure A-18 Hydrograph for monitoring bore GW036546-2 (Namoi Alluvium)

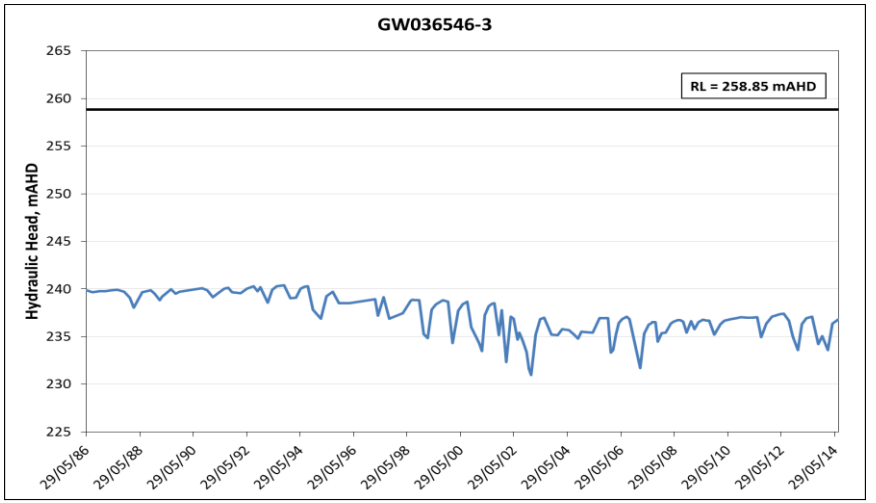


Figure A-19 Hydrograph for monitoring bore GW036546-3 (Namoi Alluvium)

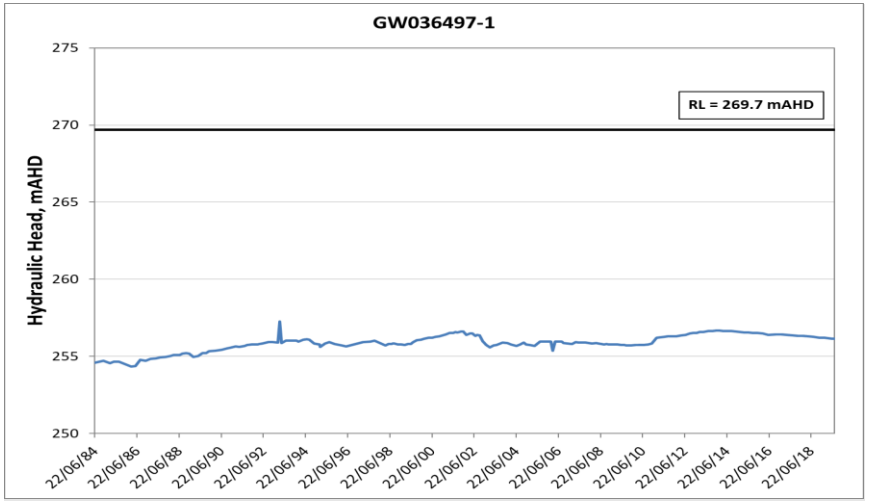


Figure A-20 Hydrograph for monitoring bore GW036497-1 (Namoi Alluvium)

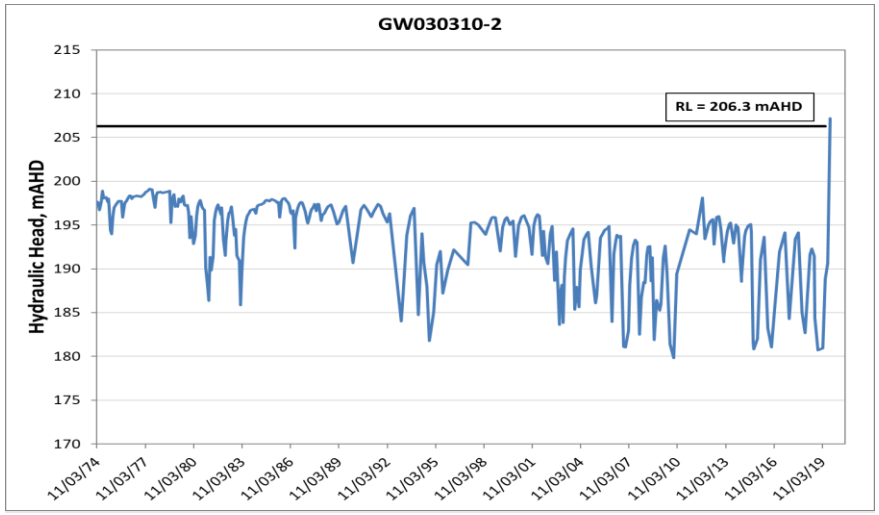


Figure A-21 Hydrograph for monitoring bore GW030310-2 (Namoi Alluvium)

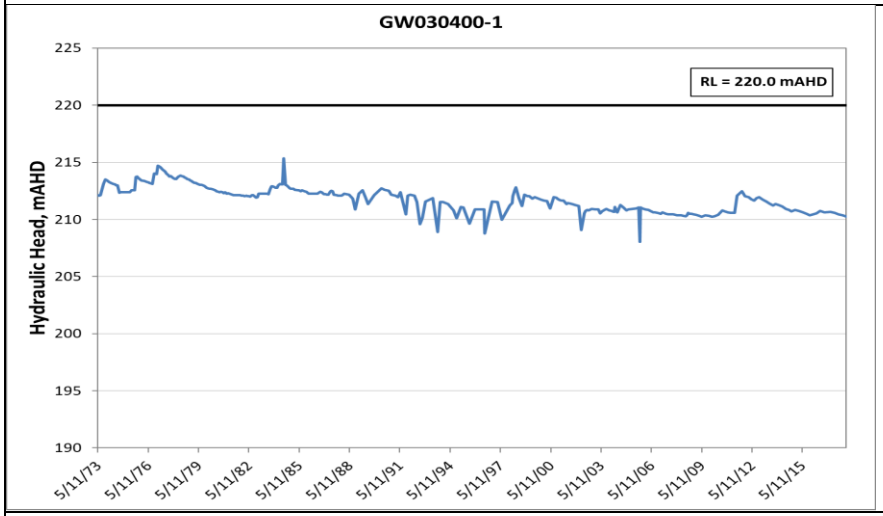


Figure A-22 Hydrograph for monitoring bore GW030400-1 (Namoi Alluvium)

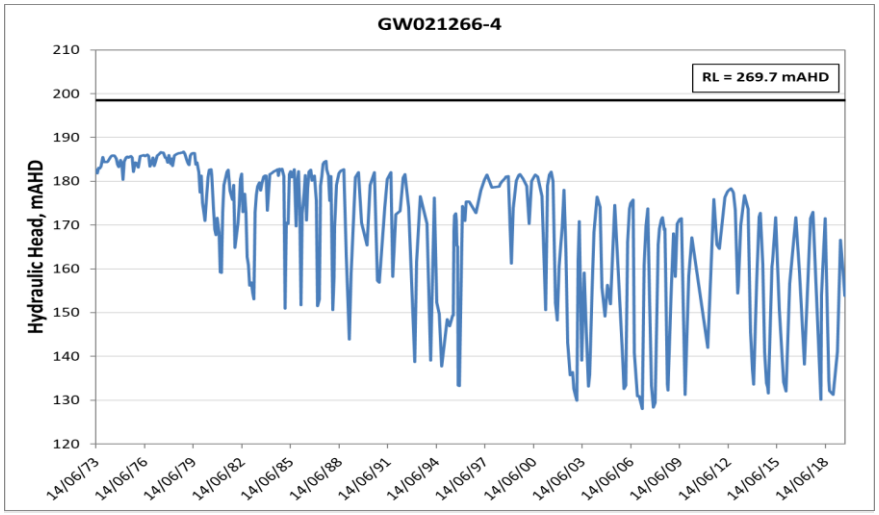


Figure A-23 Hydrograph for monitoring bore GW021266-4 (Namoi Alluvium)

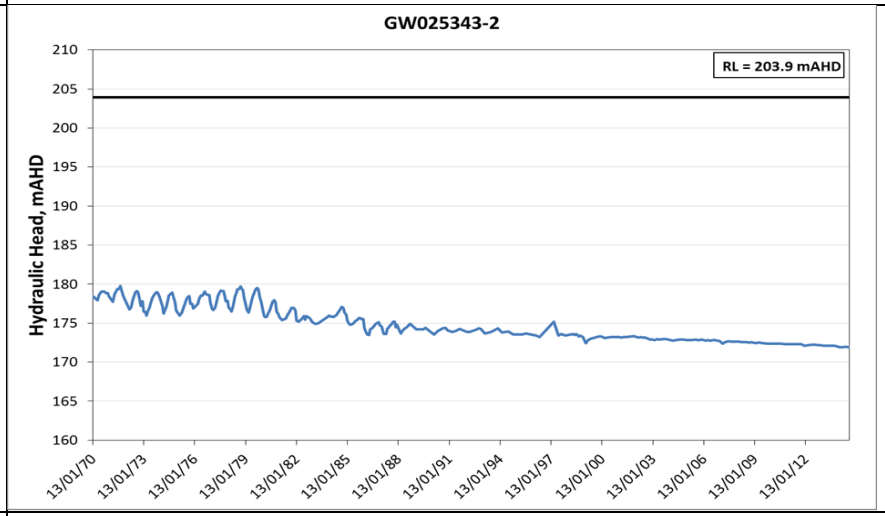


Figure A-24 Hydrograph for monitoring bore GW025343-2 (Namoi Alluvium)

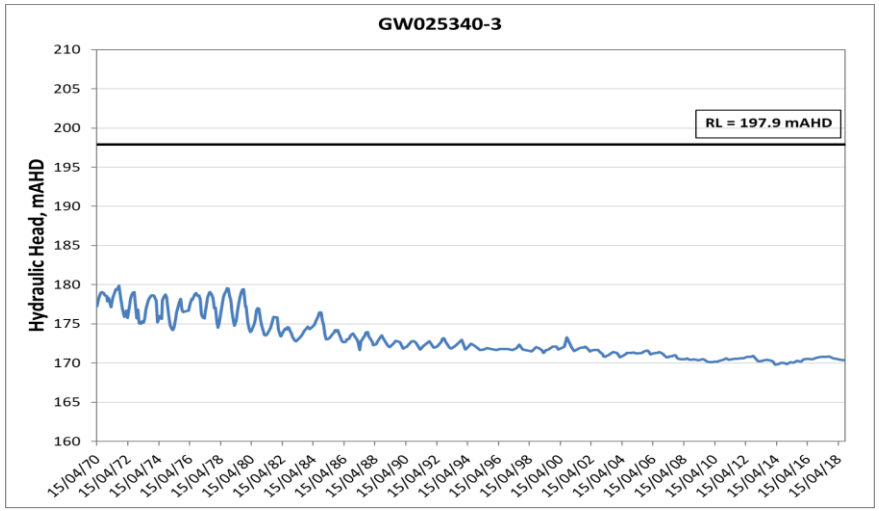


Figure A-25 Hydrograph for monitoring bore GW025340-3 (Namoi Alluvium)

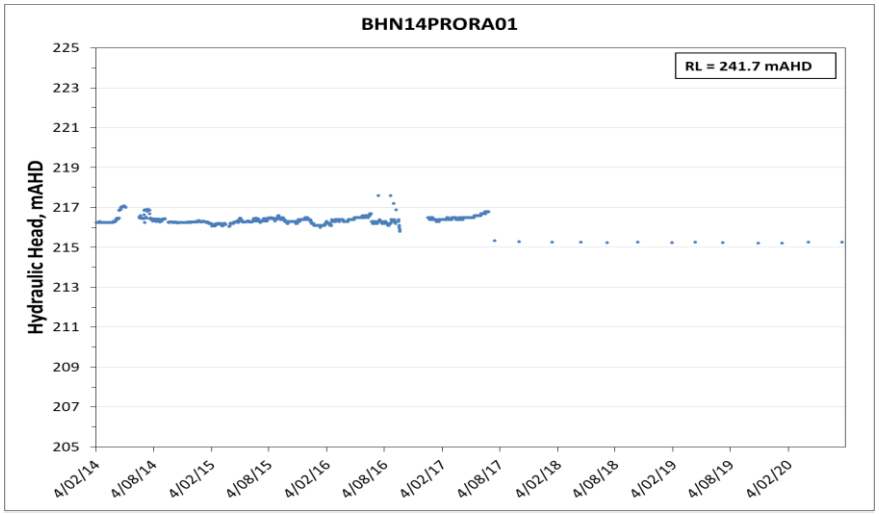


Figure A-27 Hydrograph for monitoring bore BHN14PRORA01 (Orallo Formation)

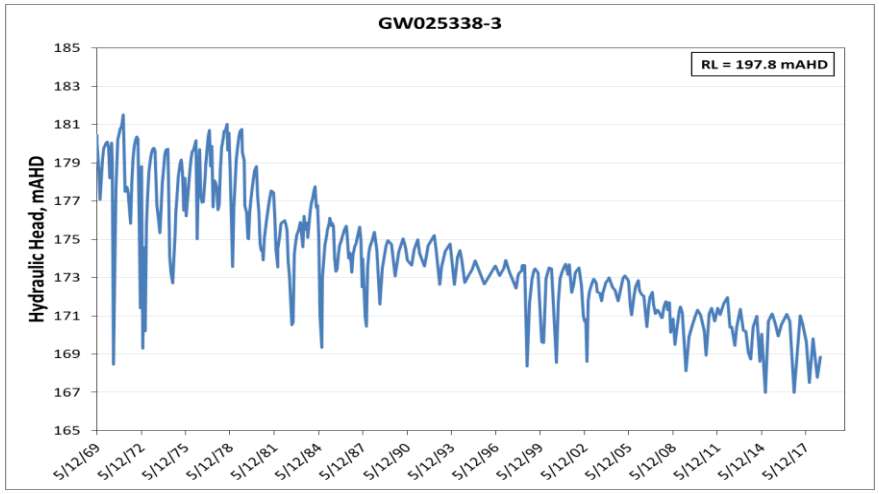


Figure A-26 Hydrograph for monitoring bore GW025338-3 (Mooga Sandstone)

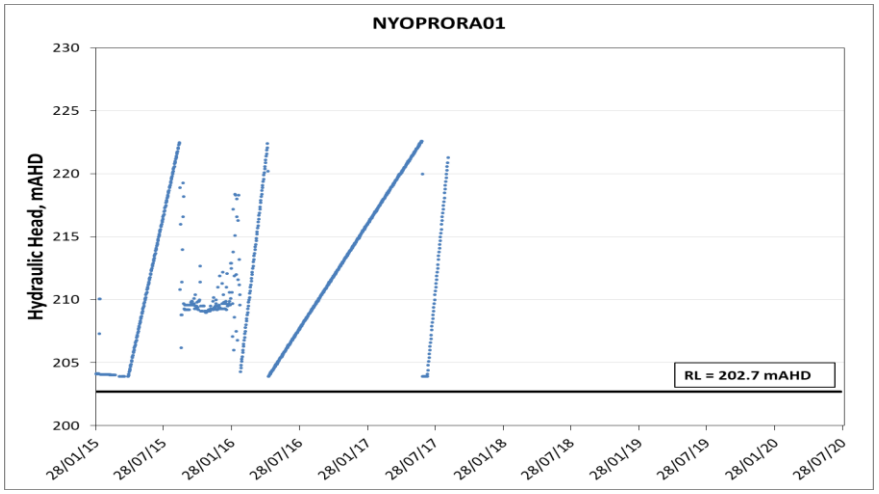


Figure A-28 Hydrograph for monitoring bore NYOPRORA01 (Orallo Formation)

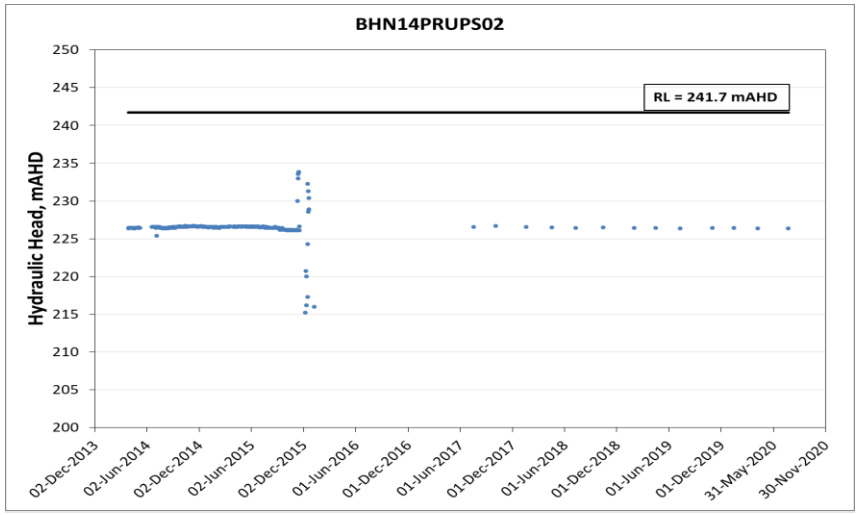


Figure A-29 Hydrograph for monitoring bore BHN14PRUPS02 (Pilliga Sandstone)

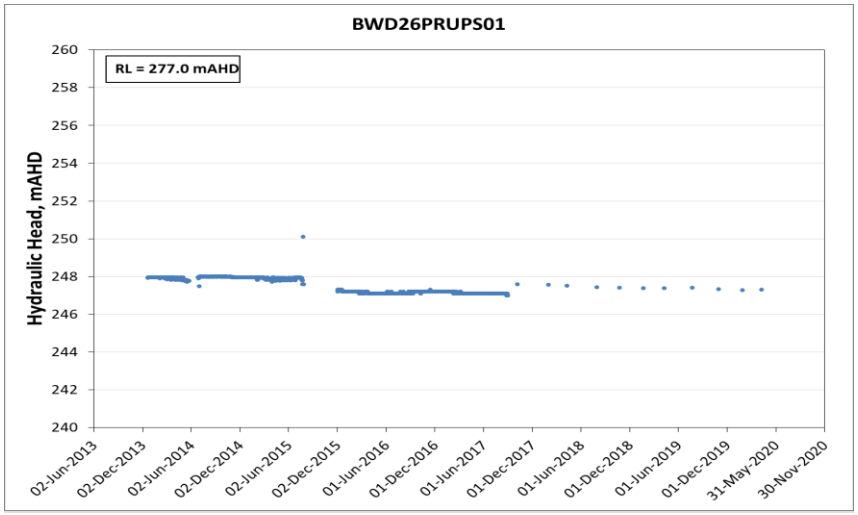


Figure A-31 Hydrograph for monitoring bore BWD26PRUPS01 (Pilliga Sandstone)

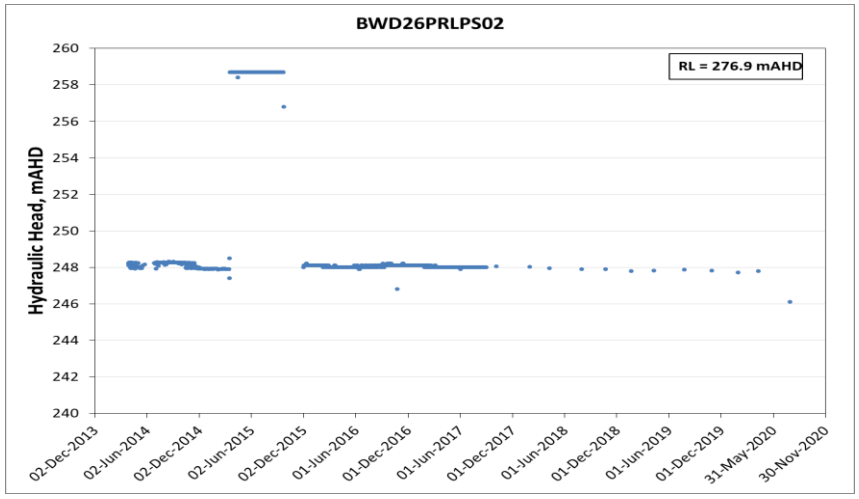


Figure A-30 Hydrograph for monitoring bore BWD26PRLPS02 (Pilliga Sandstone)

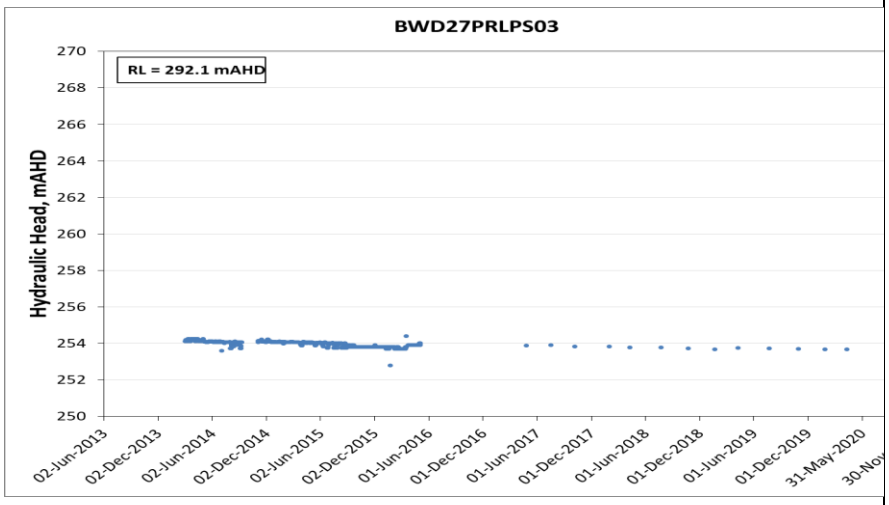


Figure A-32 Hydrograph for monitoring bore BWD27PRLPS03 (Pilliga Sandstone)

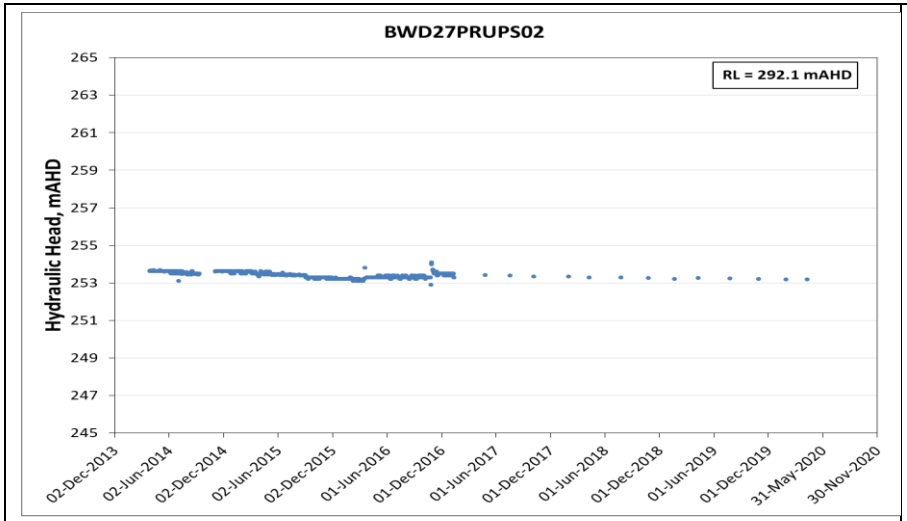


Figure A-33 Hydrograph for monitoring bore BWD27PRUPS02 (Pilliga Sandstone)

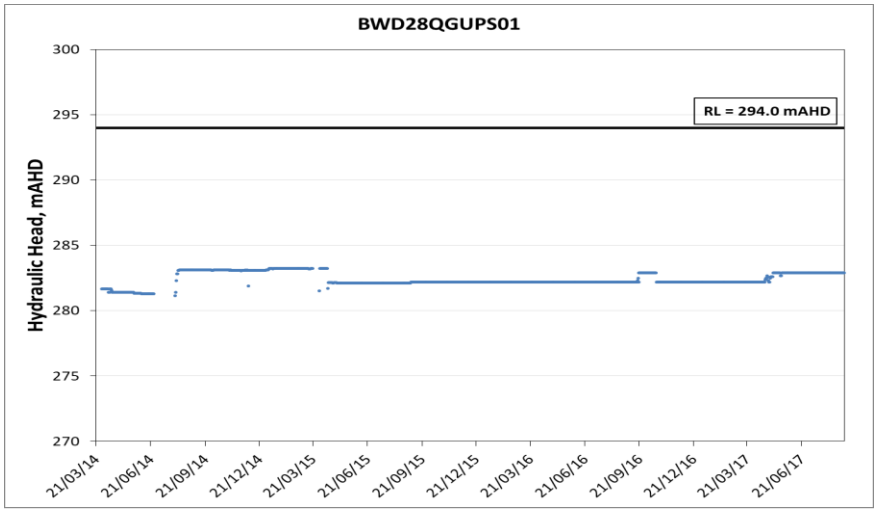


Figure A-35 Hydrograph for monitoring bore BWD28QGUPS01 (Pilliga Sandstone)

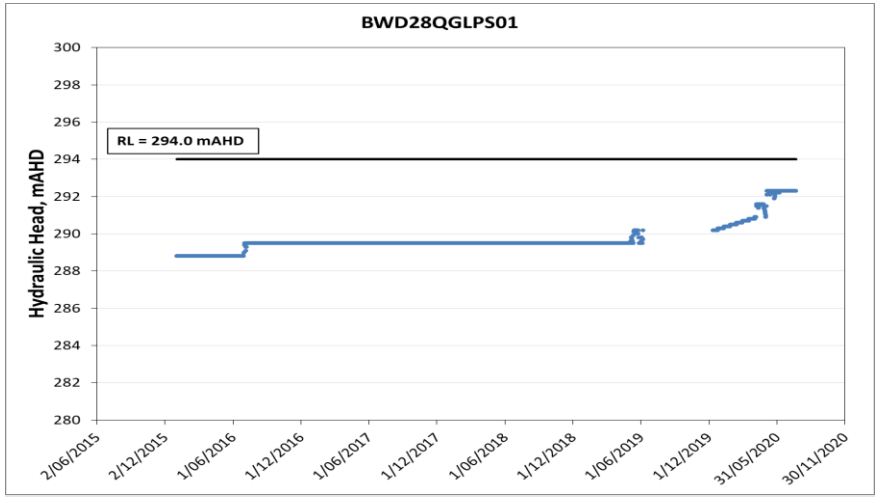


Figure A-34 Hydrograph for monitoring bore BWD28QGLPS01 (Pilliga Sandstone)

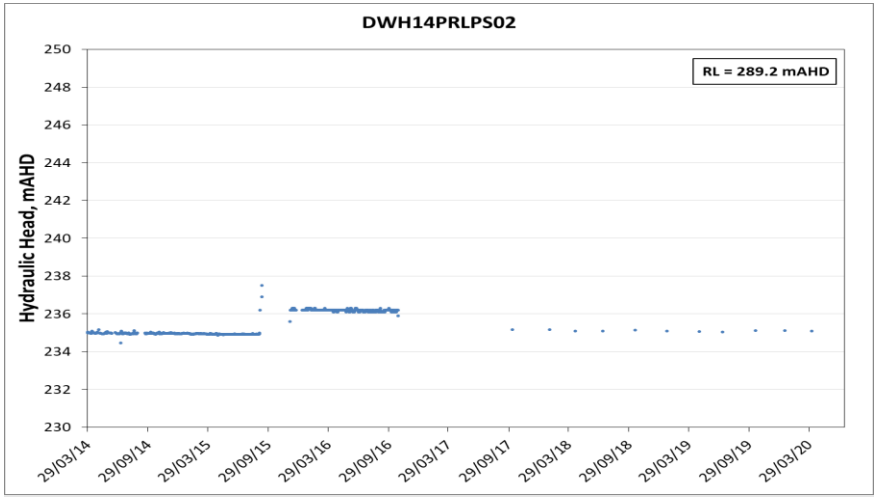


Figure A-36 Hydrograph for monitoring bore DWH14PRLPS02 (Pilliga Sandstone)

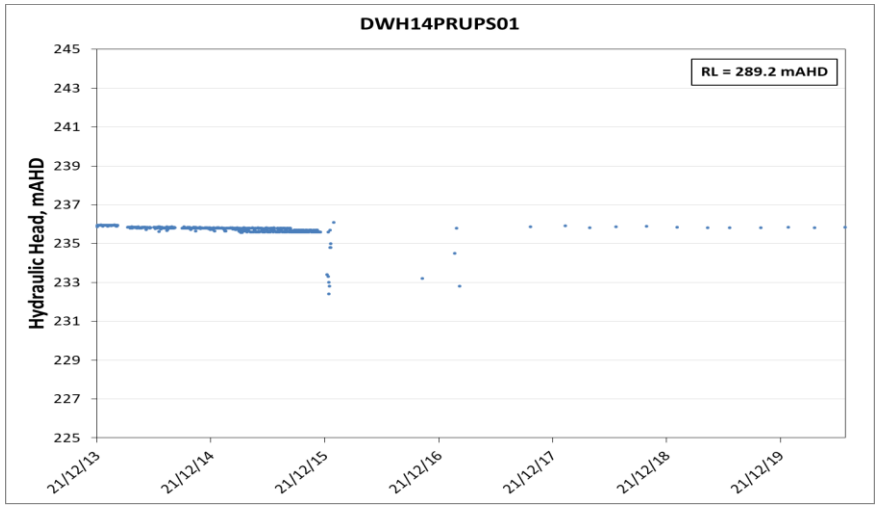


Figure A-37 Hydrograph for monitoring bore DWH14PRUPS01 (Pilliga Sandstone)

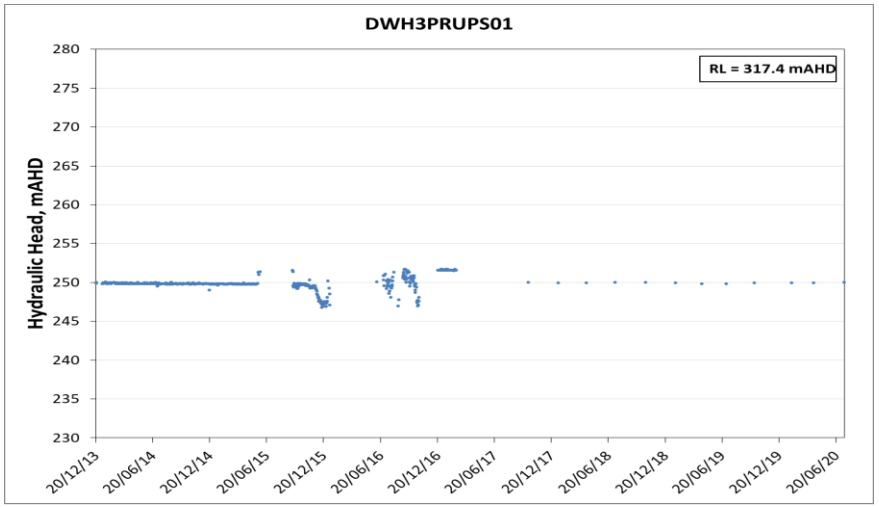


Figure A-39 Hydrograph for monitoring bore DWH3PRUPS01 (Pilliga Sandstone)

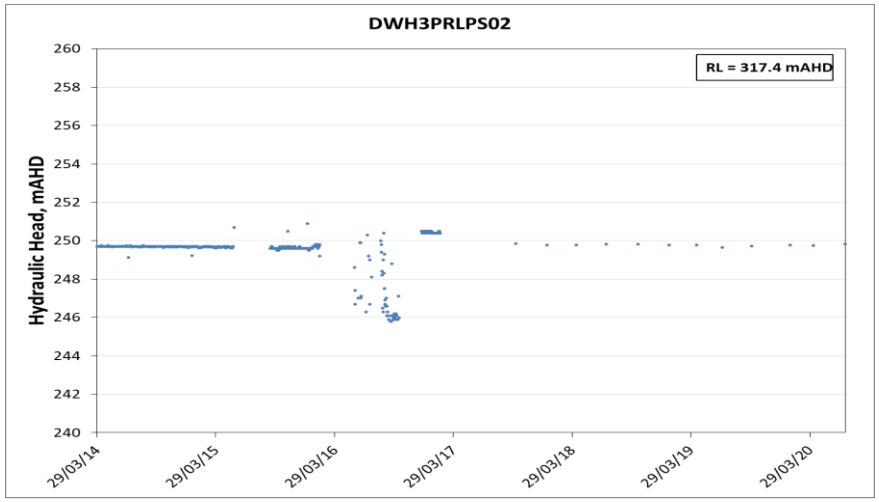


Figure A-38 Hydrograph for monitoring bore DWH3PRLPS02 (Pilliga Sandstone)

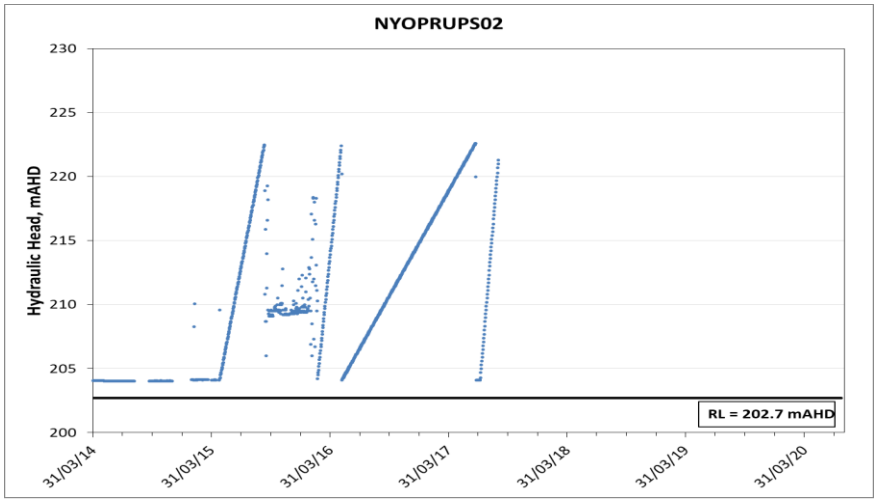


Figure A-40 Hydrograph for monitoring bore NYOPRUPS02 (Pilliga Sandstone)

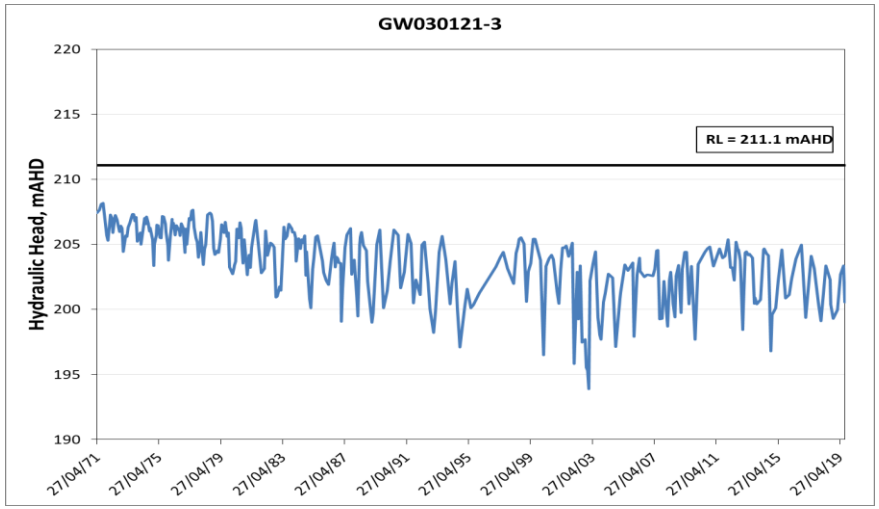


Figure A-41 Hydrograph for monitoring bore GW030121-3 (Pilliga Sandstone)

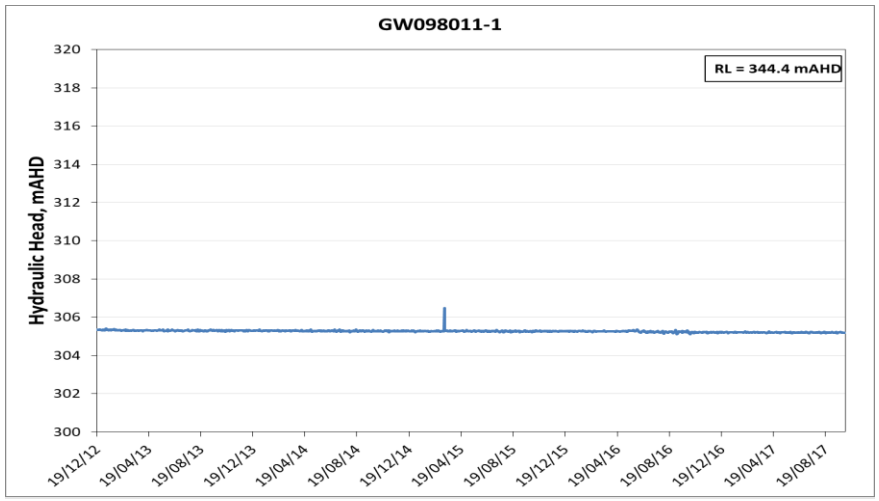


Figure A-42 Hydrograph for monitoring bore GW098011-1 (Pilliga Sandstone)

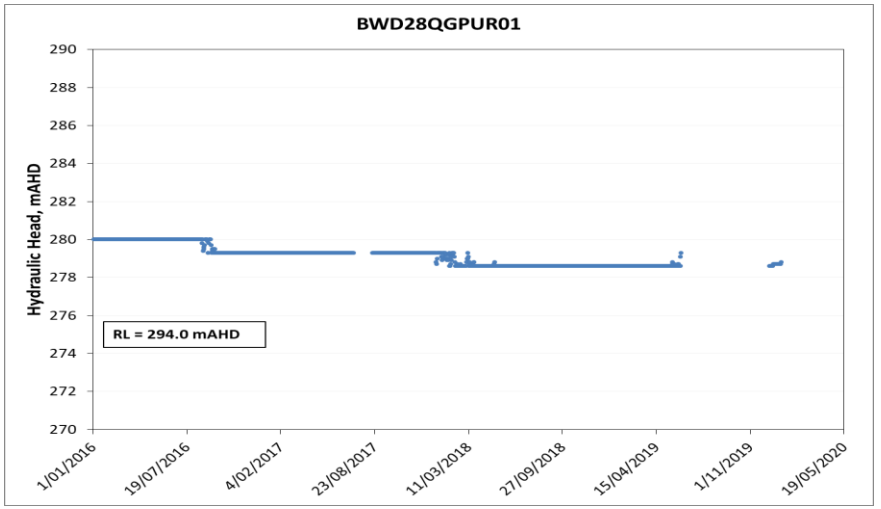


Figure A-43 Hydrograph for monitoring bore BWD28QGPUR01 (Purlawaugh Fm)

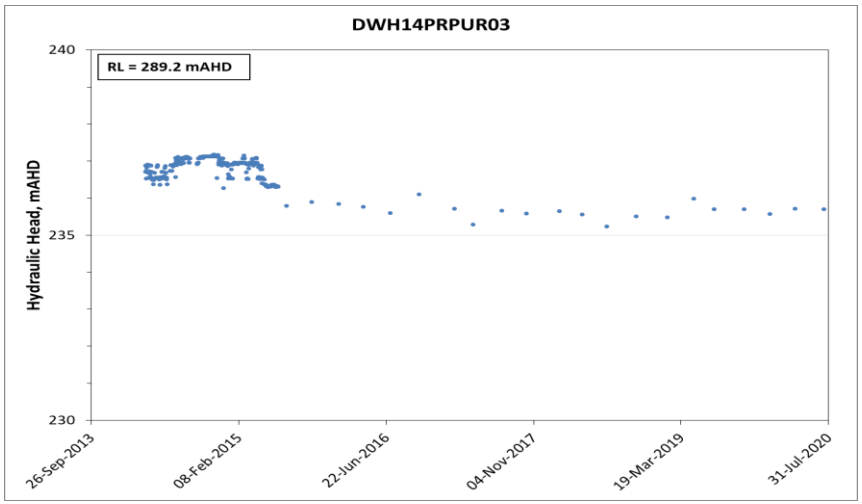


Figure A-44 Hydrograph for monitoring bore DW14PRPUR03 (Purlawaugh Fm)

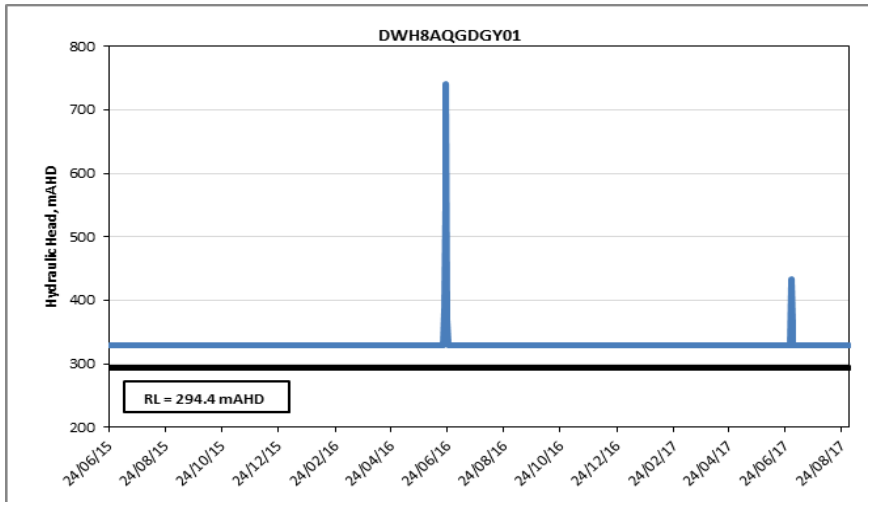


Figure A-45 Hydrograph for monitoring bore DWH8AQGDGY01 (Digby Fm)

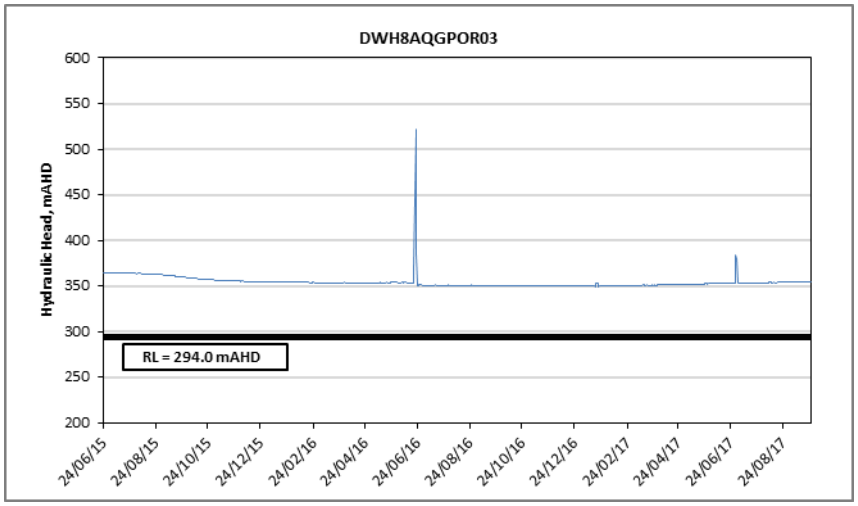


Figure A-47 Hydrograph for monitoring bore DWH*AQGPOR03 (Porcupine Fm)

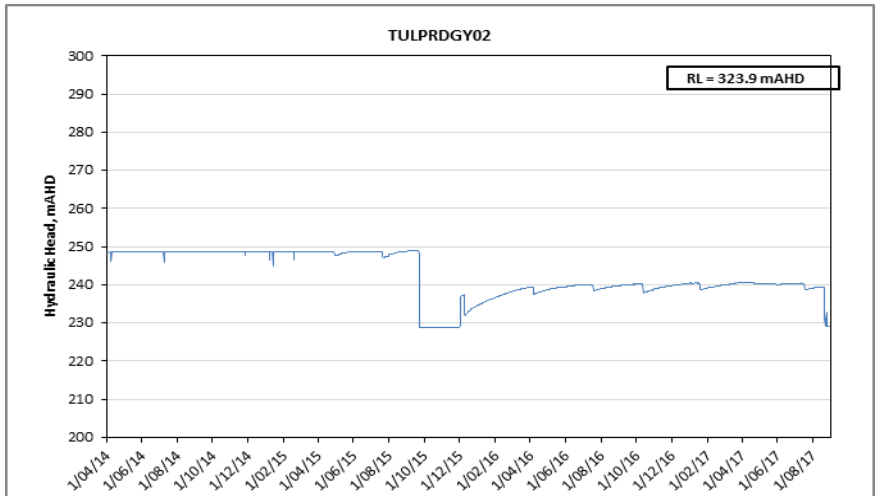


Figure A-46 Hydrograph for monitoring bore TULPRDGY02 (Digby Fm)

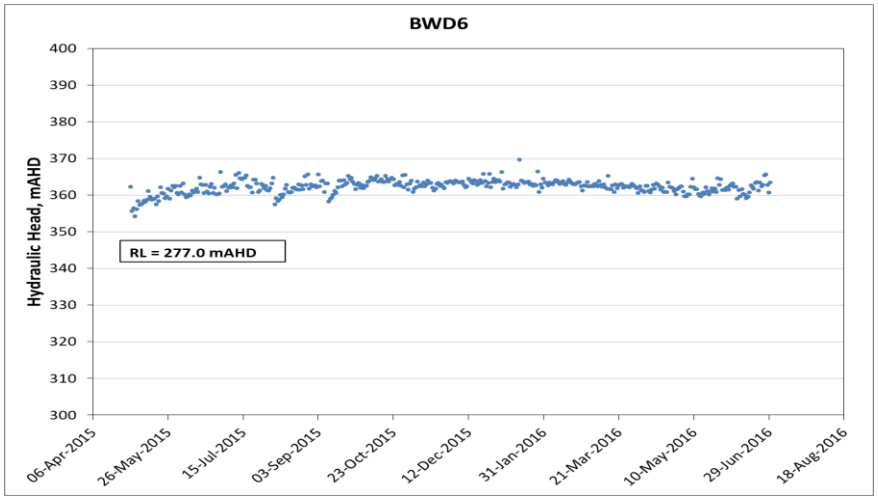


Figure A-48 Hydrograph for monitoring bore BWD6 (Porcupine Fm)

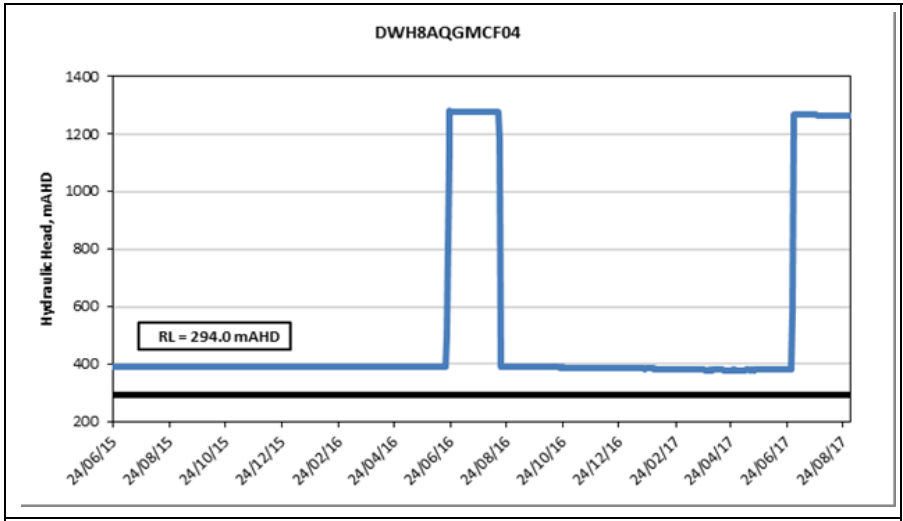


Figure A-49 Hydrograph for monitoring bore DWH8AQGMCF04 (Maules Creek Fm)

DWH8AQGMCF04 has been de-commissioned due to repeated instrument failure and will be re-commissioned a spart of the Phase 1 bore monitoring program

Appendix B - Groundwater quality monitoring tables and time-series plots

The tables and figures below show statistical summaries and time-series plots, respectively of indicative groundwater quality parameters for each of the water bores listed in Table 4.1.

Statistical measures of the spread and central tendency of the data are calculated for monitoring locations with more than two samples; however, these measures may not be statistically significant if the number of samples is small. A sample size greater than or equal to six is needed to identify the 16th and 84th percentiles.

The locations of monitoring bores are shown in Figures 2.1, 2.2 and 2.3.

Table B1 - Baseline data for groundwater quality monitoring at location BHNCKMW1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.06	0.06	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	42	50	ISS	ISS	ISS
B (mg/L)	2	0	-	-	-	-	-
Ca (mg/L)	2	2	7	7	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	-	-
Cl (mg/L)	2	2	28	34	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	240	240	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	200	207	ISS	ISS	ISS
F (mg/L)	2	2	0.1	0.1	ISS	ISS	ISS
Li (mg/L)	2	0	-	-	-	-	-
Mg (mg/L)	2	2	7	7	ISS	ISS	ISS
Mn (mg/L)	2	2	0.48	0.54	ISS	ISS	ISS
pH (field)	2	2	6.6	6.7	ISS	ISS	ISS
pH (lab)	1	1	6.9	6.9	ISS	ISS	ISS
K (mg/L)	2	2	2	2	ISS	ISS	ISS
Na (mg/L)	2	2	14	16	ISS	ISS	ISS
SAR	2	2	0.9	1.02	ISS	ISS	ISS
Sr (mg/L)	2	2	0.14	0.16	ISS	ISS	ISS
Sulfate as SO_4^{2-}	2	0	-	-	-	-	-
Methane (mg/L)	2	2	0.55	1.1	ISS	ISS	ISS

Stratigraphic unit: **Bohena Creek alluvium**
Date range: 17/7/2013 to 25/10/2013
ISS – insufficient sample size

Table B2 - Baseline data for groundwater quality monitoring at location BHNCKMW2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.09	0.1	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	40	52	ISS	ISS	ISS
B (mg/L)	2	0	-	-	-	-	-
Ca (mg/L)	2	2	3	5	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	-	-
Cl (mg/L)	2	2	18	20	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	175	175	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	137	171	ISS	ISS	ISS
F (mg/L)	2	0	-	-	-	-	-
Li (mg/L)	2	0	-	-	-	-	-
Mg (mg/L)	2	2	3	5	ISS	ISS	ISS
Mn (mg/L)	2	2	0.5	0.6	ISS	ISS	ISS
pH (field)	2	2	6.4	6.6	ISS	ISS	ISS
pH (lab)	1	1	6.7	6.7	ISS	ISS	ISS
K (mg/L)	2	2	2	3	ISS	ISS	ISS
Na (mg/L)	2	2	12	18	ISS	ISS	ISS
SAR	2	2	1.2	1.4	ISS	ISS	ISS
Sr (mg/L)	2	2	0.09	0.1	ISS	ISS	ISS
Sulfate as SO_4^{2-}	2	1	2	2	ISS	ISS	ISS
Methane (mg/L)	2	2	0.79	1.0	ISS	ISS	ISS

Stratigraphic unit: **Bohena Creek alluvium**
Date range: 17/7/2013 to 25/10/2013
ISS – insufficient sample size

Table B3 - Baseline data for groundwater quality monitoring at location BHNCKMW3

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.08	0.1	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	41	54	ISS	ISS	ISS
B (mg/L)	2	0	-	-	-	-	-
Ca (mg/L)	2	2	3	4	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	-	-
Cl (mg/L)	2	2	20	20	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	173	173	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	146	186	ISS	ISS	ISS
F (mg/L)	2	1	0.1	0.1	ISS	ISS	ISS
Li (mg/L)	2	0	-	-	-	-	-
Mg (mg/L)	2	2	4	6	ISS	ISS	ISS
Mn (mg/L)	2	2	0.2	0.5	ISS	ISS	ISS
pH (field)	2	2	6.2	6.4	ISS	ISS	ISS
pH (lab)	1	1	6.3	6.3	ISS	ISS	ISS
K (mg/L)	2	2	1	2	ISS	ISS	ISS
Na (mg/L)	2	2	16	22	ISS	ISS	ISS
SAR	2	2	1.4	1.6	ISS	ISS	ISS
Sr (mg/L)	2	2	0.07	0.09	ISS	ISS	ISS
Sulfate as SO_4^{2-}	2	0	-	-	-	-	-
Methane (mg/L)	2	2	1.4	1.6	ISS	ISS	ISS

Stratigraphic unit: Bohena Creek alluvium
Date range: 17/10/2013 to 25/10/2013
ISS – insufficient sample size

Table B4 - Baseline data for groundwater quality monitoring at location BHNCKMW4

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.04	0.08	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	56	88	ISS	ISS	ISS
B (mg/L)	2	0	-	-	-	-	-
Ca (mg/L)	2	2	6	8	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	-	-
Cl (mg/L)	2	2	32	35	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	270	270	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	236	290	ISS	ISS	ISS
F (mg/L)	2	0	-	-	-	-	-
Li (mg/L)	2	0	-	-	-	-	-
Mg (mg/L)	2	2	8	9	ISS	ISS	ISS
Mn (mg/L)	2	2	0.6	0.8	ISS	ISS	ISS
pH (field)	2	2	6.7	6.7	ISS	ISS	ISS
pH (lab)	1	1	6.8	6.8	ISS	ISS	ISS
K (mg/L)	2	2	3	3	ISS	ISS	ISS
Na (mg/L)	2	2	27	31	ISS	ISS	ISS
SAR	2	2	1.6	2	ISS	ISS	ISS
Sr (mg/L)	2	2	0.11	0.13	ISS	ISS	ISS
Sulfate as SO_4^{2-}	2	0	-	-	-	-	-
Methane (mg/L)	2	2	1.1	1.5	ISS	ISS	ISS

Stratigraphic unit: Bohena Creek alluvium
Date range: 17/7/2013 to 22/10/2013
ISS – insufficient sample size

Table B5 - Baseline data for groundwater quality monitoring at location 7707

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.06	0.07	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	581	596	ISS	ISS	ISS
B (mg/L)	2	2	0.23	0.24	ISS	ISS	ISS
Ca (mg/L)	2	2	3	6	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	0.5	19	ISS	ISS	ISS
Cl (mg/L)	2	2	55	58	ISS	ISS	ISS
EC (field) (µS/cm)	2	2	1240	1320	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	2	2	1.0	1.1	ISS	ISS	ISS
Li (mg/L)	2	2	0.03	0.03	ISS	ISS	ISS
Mg (mg/L)	2	2	0.5	2	ISS	ISS	ISS
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	0	0	-	-	-	-	-
pH (lab)	2	2	8.3	8.4	ISS	ISS	ISS
K (mg/L)	2	2	2	2	ISS	ISS	ISS
Na (mg/L)	2	2	29	47	ISS	ISS	ISS
SAR	2	2	29	47	ISS	ISS	ISS
Sr (mg/L)	2	2	0.07	0.08	ISS	ISS	ISS
Sulfate as SO_4^{2-}	0	0	-	-	-	-	-
Methane (mg/L)	2	2	0.6	0.9	ISS	ISS	ISS

Stratigraphic unit: **Bohena Creek alluvium**
Date range: 28/05/2012 to 24/06/2014
ISS – insufficient sample size

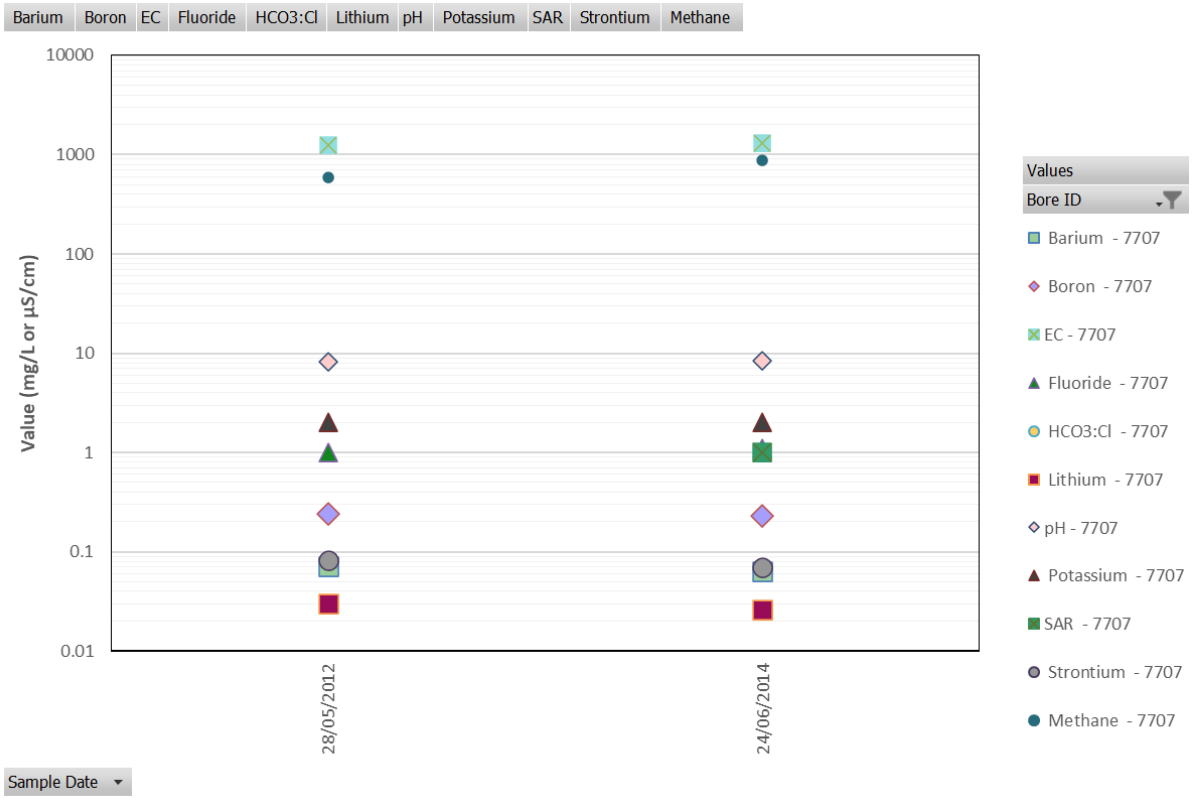


Table B6 - Baseline data for groundwater quality monitoring at location GW021266-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	19	19	164	1190	347	177	582
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	17	10	4.2	36	17	NA	NA
Cl (mg/L)	19	19	9.9	52	31	11	50
EC (field) (µS/cm)	0	0	-	-	-	-	-
EC @ 25C (lab) (µS/cm)	20	20	318	2390	661.4	329	1078
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	19	19	7.5	8.9	8.1	7.8	8.4
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	19	19	0.78	23	2.8	1.2	2
Na (mg/L)	19	19	36.1	244	93.7	47.9	206
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	18	18	0.96	23	9.9	3.4	17

Stratigraphic unit: **Namoi alluvium**
Date range: 1/4/1966 to 21/9/1999
NA – LOR > 15% sample size

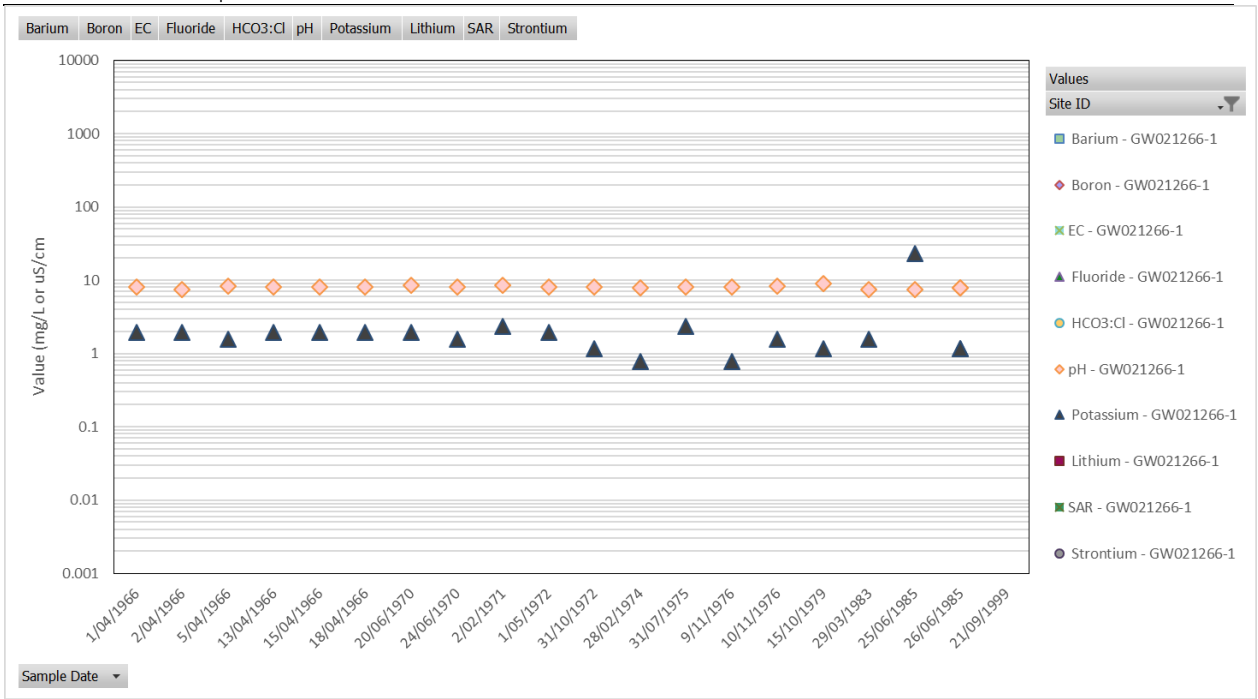


Table B7 - Baseline data for groundwater quality monitoring at location GW021437-2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	6	6	171	801	408	183	616
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	33.9	126	-	ISS	ISS
Cl (mg/L)	6	6	25.5	158	104	51.6	140
EC (field) (µS/cm)	0	0	-	-	-	-	-
EC @ 25C (lab) (µS/cm)	6	6	387	1370	1041	693.4	1370
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	6	6	7	9.6	8.2	7.8	8.5
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	6	6	1.6	5.5	3.6	1.9	5.2
Na (mg/L)	6	6	35.9	312	220	137	308
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	6	4	2.4	61	27	NA	NA

Stratigraphic unit: **Namoi alluvium**
Date range: 9/6/1967 to 22/3/1985
ISS – insufficient sample size
NA – LOR > 15% sample size

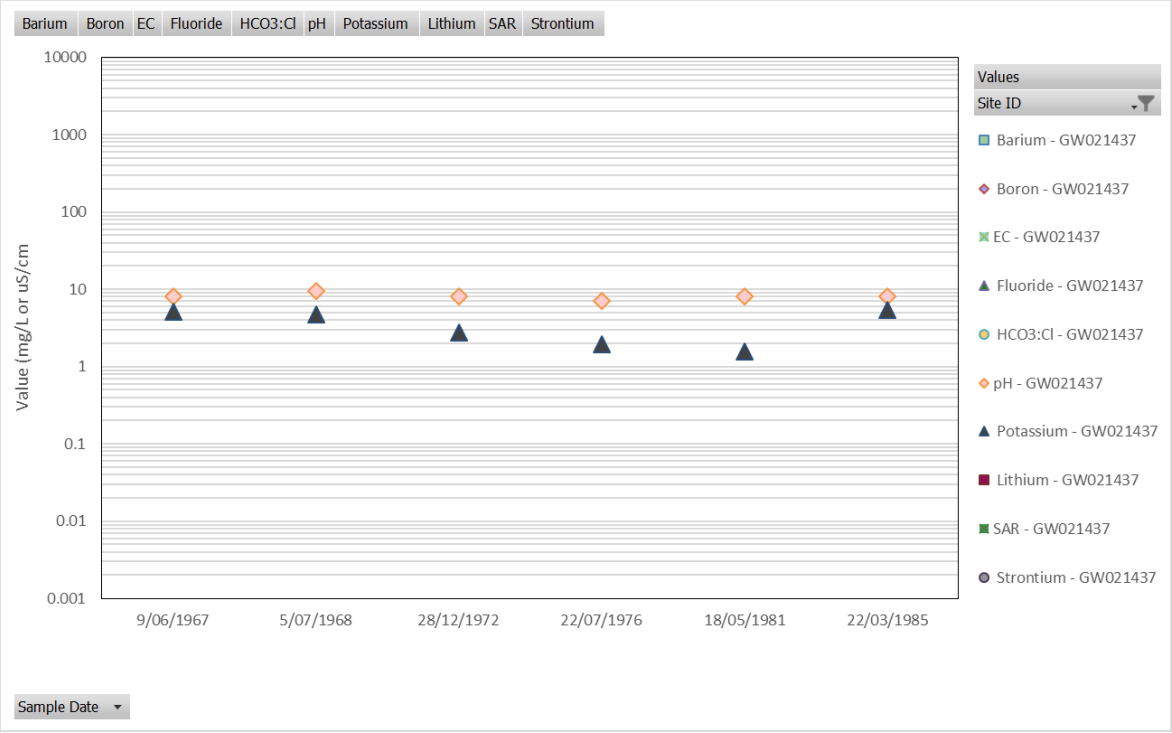


Table B8 - Baseline data for groundwater quality monitoring at location GW025338-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.1	0.1	-	ISS	ISS
HCO3 alkalinity as CaCO3 (mg/L)	7	7	209	289	248	211	289
B (mg/L)	1	1	0.07	0.07	-	ISS	ISS
Ca (mg/L)	1	1	54	54	-	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	6	2	2.1	9.6	5.9	NA	NA
Cl (mg/L)	7	7	13	146	39.8	13.8	44.3
EC (field) (µS/cm)	2	2	990	997	-	ISS	ISS
EC @ 25C (lab) (µS/cm)	6	6	367	580	470	397	548
F (mg/L)	1	1	0.4	0.4	-	ISS	ISS
Li (mg/L)	1	0	-	-	-	ISS	ISS
Mg (mg/L)	1	1	36	36	-	ISS	ISS
Mn (mg/L)	1	0	-	-	-	ISS	ISS
pH (field)	8	8	6.3	8.6	7.7	6.8	8.3
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	7	7	0.78	3.5	2	1.5	2.4
Na (mg/L)	7	7	68.1	123	94.4	69.8	113
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.7	0.7	-	ISS	ISS
Sulfate as SO_4^{2-}	6	6	4.1	75	20	4.1	29

Stratigraphic unit: **Namoi alluvium**
Date range: 14/11/1969 to 11/11/1999
ISS – insufficient sample size
NA – LOR > 15% sample size

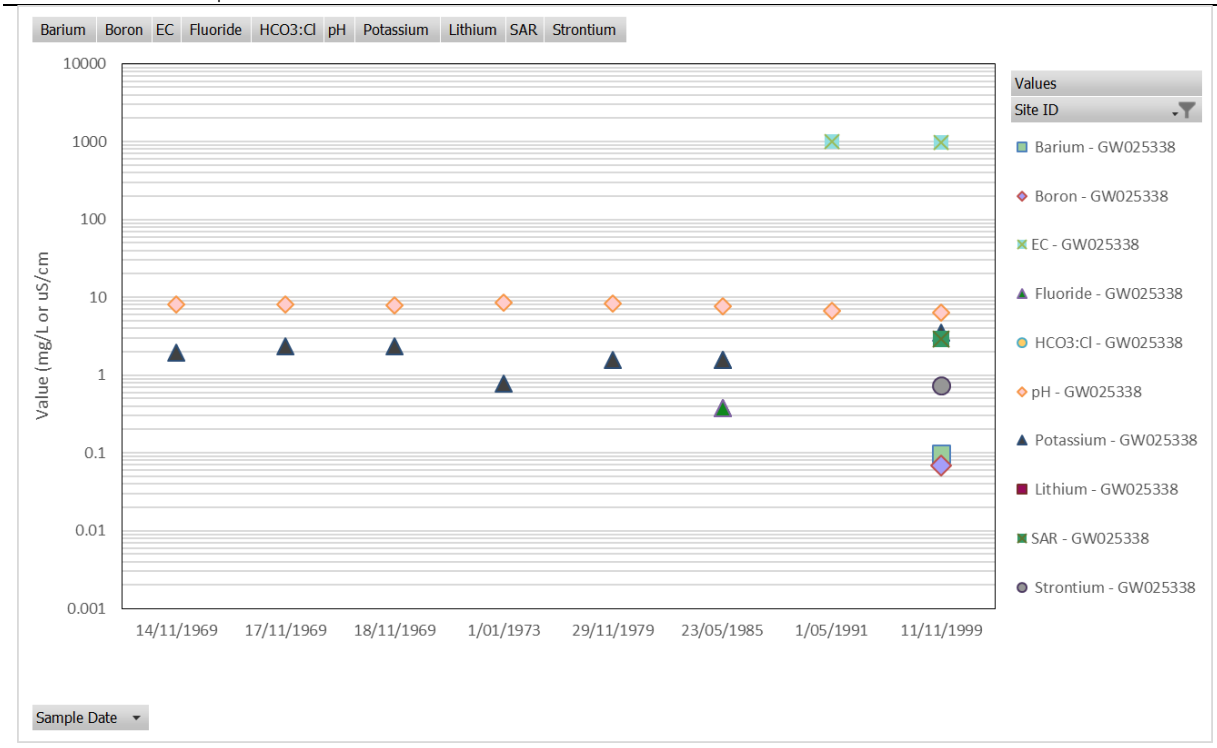


Table B9 - Baseline data for groundwater quality monitoring at location GW025343-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	10	10	794	1010	916	830	970
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	10	8	1	47	20	NA	NA
Cl (mg/L)	10	10	115	242	150	119	192
EC (field) (µS/cm)	10	10	1556	2170	1827	1701	2040
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	1	1	1	1	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	10	10	7.6	8.8	8.3	8.2	8.6
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	10	10	6.3	9.8	7.5	6.6	8.5
Na (mg/L)	10	10	366	520	426	390	450
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	10	10	3.7	60	12	4.8	9.6

Stratigraphic unit: **Namoi alluvium**
Date range: 15/12/1969 to 4/12/1986
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B10 - Baseline data for groundwater quality monitoring at location GW030070-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	0	-	-	-	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	14	14	125	671	221	138	255
B (mg/L)	1	1	0.03	0.03	-	ISS	ISS
Ca (mg/L)	1	1	34	34	-	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	8	2	0.3	3.6	2	NA	NA
Cl (mg/L)	14	14	7.8	96	39	9.6	66
EC (field) (µS/cm)	13	13	248	1190	518.2	285	729.1
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	3	3	0.05	0.5	0.3	0.1	0.5
Li (mg/L)	1	0	-	-	-	ISS	ISS
Mg (mg/L)	1	1	17	17	-	ISS	ISS
Mn (mg/L)	1	0	-	-	-	ISS	ISS
pH (field)	14	14	6.3	8.3	7.7	7.1	8.2
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	14	13	0.78	3.1	1.8	1.2	2.4
Na (mg/L)	14	14	15	240	56	23	64
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.4	0.4	-	ISS	ISS
Sulfate as SO_4^{2-}	13	13	6.2	41	18	8.5	29

Stratigraphic unit: **Namoi alluvium**
Date range: 22/5/1970 to 2/6/1999
ISS – insufficient sample size
NA – LOR > 15% sample size

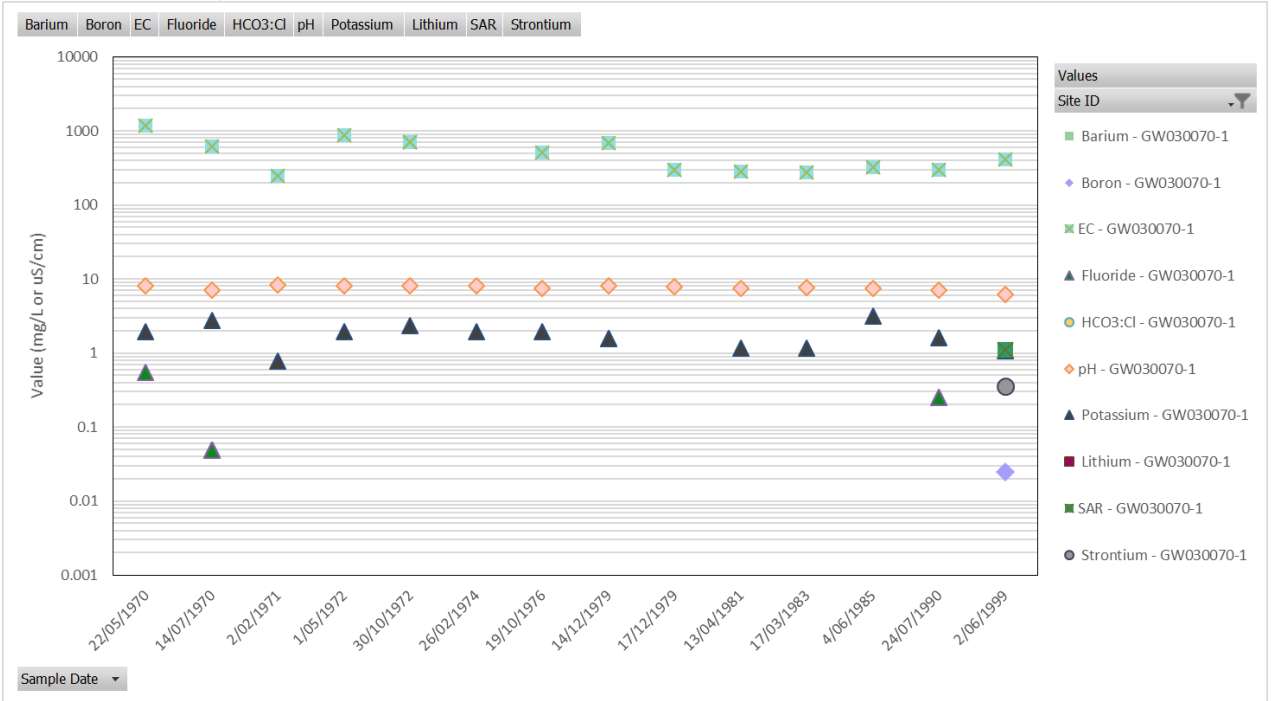


Table B11 - Baseline data for groundwater quality monitoring at location GW030070-2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.1	0.1	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	1	1	261	261	ISS	ISS	ISS
B (mg/L)	1	1	0.05	0.05	ISS	ISS	ISS
Ca (mg/L)	1	1	55	55	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	1	1	55	55	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	356	356	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	1	0	-	-	ISS	ISS	ISS
Mg (mg/L)	1	1	21	21	ISS	ISS	ISS
Mn (mg/L)	1	0	-	-	ISS	ISS	ISS
pH (field)	1	1	6.3	6.3	ISS	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	1	1	1.9	1.9	ISS	ISS	ISS
Na (mg/L)	1	1	68	68	ISS	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.5	0.5	ISS	ISS	ISS
Sulfate as SO_4^{2-}	1	1	48	48	ISS	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 2/6/1999 to 2/6/1999
ISS – insufficient sample size

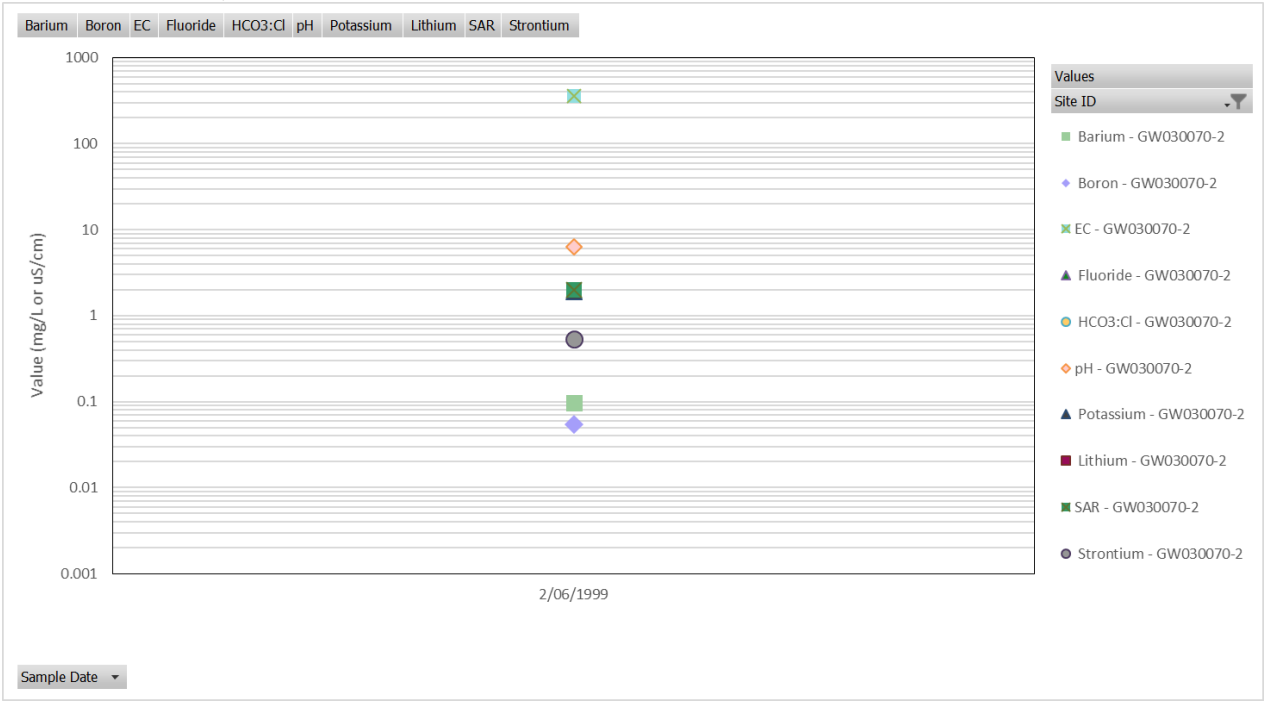


Table B12 - Baseline data for groundwater quality monitoring at location GW030070-3

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.03	0.03	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	1	1	178	178	ISS	ISS	ISS
B (mg/L)	1	1	0.04	0.04	ISS	ISS	ISS
Ca (mg/L)	1	1	7.1	7.1	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	1	1	13	13	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	308	308	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	1	0	0.001	0.001	ISS	ISS	ISS
Mg (mg/L)	1	1	-	-	ISS	ISS	ISS
Mn (mg/L)	1	1	0.01	0.01	ISS	ISS	ISS
pH (field)	1	1	6.4	6.4	ISS	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	1	1	0.66	0.66	ISS	ISS	ISS
Na (mg/L)	1	1	65	65	ISS	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.1	0.1	ISS	ISS	ISS
Sulfate as SO_4^{2-}	1	0	8.3	8.3	ISS	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 2/6/1999 to 2/6/1999
ISS – insufficient sample size

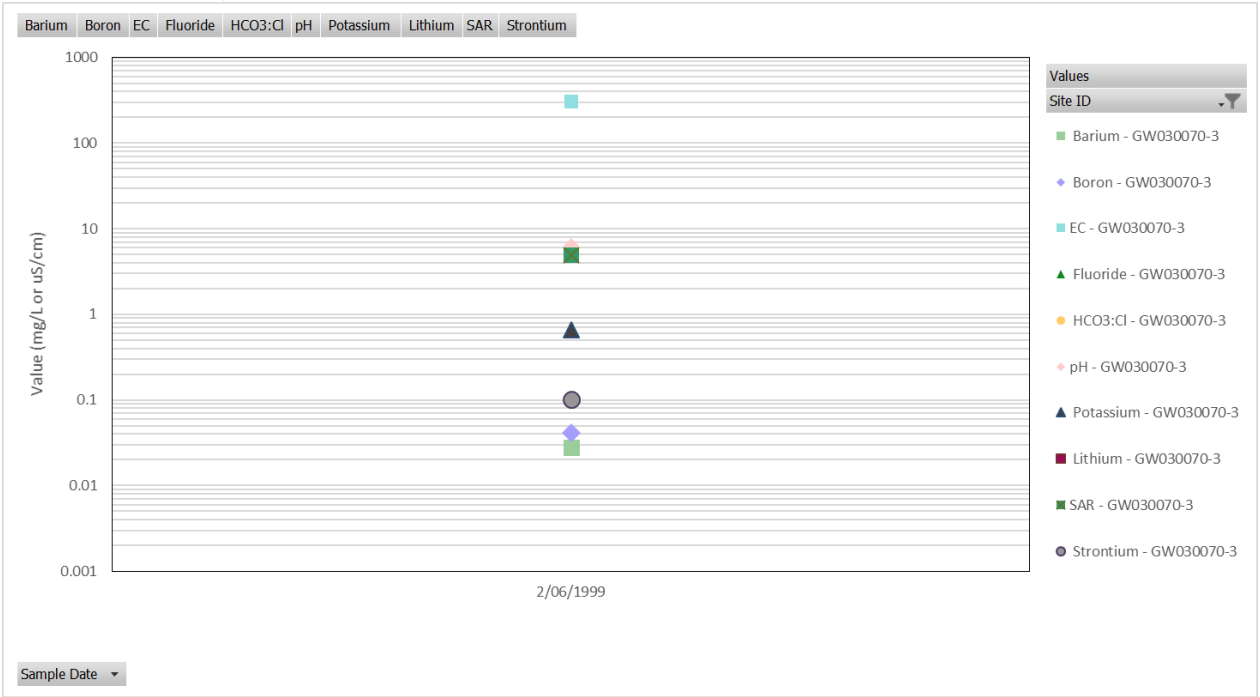


Table B13 - Baseline data for groundwater quality monitoring at location GW030117-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.02	0.02	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	5	5	319	583	479	ISS	ISS
B (mg/L)	1	1	0.1	0.1	ISS	ISS	ISS
Ca (mg/L)	1	1	1.7	1.7	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	3	1	24	24	24	ISS	ISS
Cl (mg/L)	5	5	44.3	167	72.4	ISS	ISS
EC (field) (µS/cm)	5	5	880	987	949	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	2	2	0.76	1.1	0.95	ISS	ISS
Li (mg/L)	1	1	0.01	0.01	ISS	ISS	ISS
Mg (mg/L)	1	1	0.3	0.3	ISS	ISS	ISS
Mn (mg/L)	1	1	0.007	0.007	ISS	ISS	ISS
pH (field)	5	5	7.6	8.5	8	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	4	4	0.08	7.8	3.1	ISS	ISS
Na (mg/L)	4	4	202	248	222	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.06	0.06	ISS	ISS	ISS
Sulfate as SO_4^{2-}	4	3	2.4	9.6	5.4	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 7/3/1972 to 28/5/1999
ISS – insufficient sample size

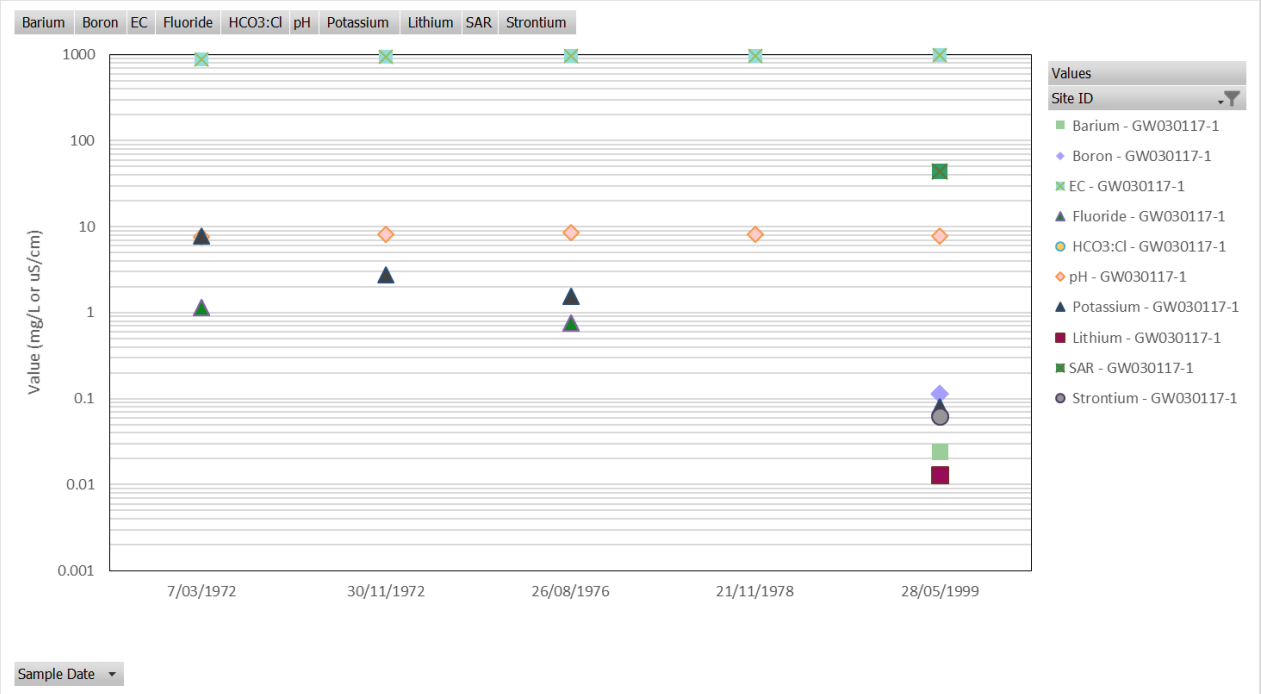


Table B14 - Baseline data for groundwater quality monitoring at location GW030117-2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.02	0.02	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	1	1	578	578	ISS	ISS	ISS
B (mg/L)	1	1	0.1	0.1	ISS	ISS	ISS
Ca (mg/L)	1	1	4	4	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	1	1	54	54	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	986	986	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	1	1	0.01	0.01	ISS	ISS	ISS
Mg (mg/L)	1	1	0.9	0.9	ISS	ISS	ISS
Mn (mg/L)	1	1	0.01	0.01	ISS	ISS	ISS
pH (field)	1	1	7.9	7.9	ISS	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	1	1	1	1	ISS	ISS	ISS
Na (mg/L)	1	1	273	273	ISS	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.06	0.06	ISS	ISS	ISS
Sulfate as SO_4^{2-}	1	0	-	-	ISS	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 28/5/1999 to 28/5/1999
ISS – insufficient sample size

Table B15 - Baseline data for groundwater quality monitoring at location GW030117-3

Water Quality Measure	No. of Samples	No. of Samples >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.03	0.03	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	1	1	486	486	ISS	ISS	ISS
B (mg/L)	1	1	0.1	0.1	ISS	ISS	ISS
Ca (mg/L)	1	1	2.7	2.7	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	1	1	37	37	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	815	815	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	1	1	0.01	0.01	ISS	ISS	ISS
Mg (mg/L)	1	1	0.7	0.7	ISS	ISS	ISS
Mn (mg/L)	1	1	0.02	0.02	ISS	ISS	ISS
pH (field)	1	1	7.9	7.9	ISS	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	1	1	0.39	0.39	ISS	ISS	ISS
Na (mg/L)	1	1	196	196	ISS	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.08	0.08	ISS	ISS	ISS
Sulfate as SO_4^{2-}	1	0	-	-	ISS	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 28/5/1999 to 28/5/1999
ISS – insufficient sample size

Table B16 - Baseline data for groundwater quality monitoring at location GW030278-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	1	1	235	235	ISS	ISS	ISS
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	1	1	43	43	ISS	ISS	ISS
EC (field) (µS/cm)	1	1	520	520	ISS	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	1	1	7.9	7.9	ISS	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	1	1	2.3	2.3	ISS	ISS	ISS
Na (mg/L)	1	1	37	37	ISS	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	1	1	2.4	2.4	ISS	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 21/11/1978 to 21/11/1978
ISS – insufficient sample size

Table B17 - Baseline data for groundwater quality monitoring at location GW030310-1

Water Quality Measure	No. of Samples	No. of Samples >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.2	0.2	ISS	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	5	5	711	907	767	ISS	ISS
B (mg/L)	1	1	0.2	0.2	ISS	ISS	ISS
Ca (mg/L)	1	1	8.5	8.5	ISS	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	4	1	60	60	60	ISS	ISS
Cl (mg/L)	5	5	53	96	64	ISS	ISS
EC (field) (µS/cm)	5	5	1227	1450	1340	ISS	ISS
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	3	3	1	2	2	ISS	ISS
Li (mg/L)	1	1	0.02	0.02	ISS	ISS	ISS
Mg (mg/L)	1	1	2.7	2.7	ISS	ISS	ISS
Mn (mg/L)	1	1	0.2	0.2	ISS	ISS	ISS
pH (field)	5	5	7.2	8.8	8.1	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	5	5	1.6	5.3	3.6	ISS	ISS
Na (mg/L)	5	5	268	375	323	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.2	0.2	ISS	ISS	ISS
Sulfate as SO_4^{2-}	4	3	0.48	7.2	3.7	ISS	ISS

Stratigraphic unit: **Namoi alluvium**
Date range: 16/8/1976 to 31/5/1999
ISS – insufficient sample size

Table B18 - Baseline data for groundwater quality monitoring at location GW036005-2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	6	6	327	379	339	329	344
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	4	0	-	-	-	ISS	ISS
Cl (mg/L)	6	6	32	60	42	34	51
EC (field) (µS/cm)	6	6	620	795	674	625	728
EC @ 25C (lab) (µS/cm)	0	0	-	-	-	-	-
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	6	6	7.4	8.1	7.8	7.6	8
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	6	5	1.2	3.5	2.1	NA	NA
Na (mg/L)	6	6	42	81	68	49	79
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	6	6	13	28	19	14	23

Stratigraphic unit: **Namoi alluvium**
Date range: 4/6/1974 to 6/9/1984
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B19 - Baseline data for groundwater quality monitoring at location GW030121-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	8	8	658	839	743	668	793
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	5	3	4.2	46	25	ISS	ISS
Cl (mg/L)	8	8	53	63	56	53	58
EC (field) (µS/cm)	0	0	-	-	-	-	-
EC @ 25C (lab) (µS/cm)	8	8	1200	1400	1273	1205	1326
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	8	8	6.2	8.7	7.9	7.9	8.3
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	8	8	4.7	7.4	5.8	5	6.9
Na (mg/L)	8	8	271	345	305	281	329
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	2	2	2.4	8.2	-	ISS	ISS
Methane (mg/L)							

Stratigraphic unit: **Namoi alluvium**
Date range: 20/4/1971 to 27/5/1999
ISS – insufficient sample size

Table B20 - Baseline data for groundwater quality monitoring at location GW030310-2

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	1	1	0.08	0.08	0.08	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	711	760	736	ISS	ISS
B (mg/L)	1	1	0.2	0.2	0.2	ISS	ISS
Ca (mg/L)	1	1	8.6	8.6	8.6	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	0	0	-	-	-	-	-
Cl (mg/L)	2	2	54	55	54	ISS	ISS
EC (field) (µS/cm)	0	0	-	-	-	-	-
EC @ 25C (lab) (µS/cm)	2	2	760.3	1250	1005	ISS	ISS
F (mg/L)	0	0	-	-	-	-	-
Li (mg/L)	1	1	0.03	0.03	0.03	ISS	ISS
Mg (mg/L)	1	1	1.5	1.5	1.5	ISS	ISS
Mn (mg/L)	1	1	0.005	0.005	0.005	ISS	ISS
pH (field)	2	2	7.4	8.3	7.8	ISS	ISS
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	2	2	2.3	2.4	2.4	ISS	ISS
Na (mg/L)	2	2	279	343	311	ISS	ISS
SAR	0	0	-	-	-	-	-
Sr (mg/L)	1	1	0.2	0.2	0.2	ISS	ISS
Sulfate as SO_4^{2-}	2	1	0.48	0.48	0.48	ISS	ISS
Methane (mg/L)							

Stratigraphic unit: **Namoi alluvium**
Date range: 27/2/1985 to 30/5/1999
ISS – insufficient sample size

Table B21 - Baseline data for groundwater quality monitoring at location GW030400-1

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	0	0	-	-	-	-	-
HCO_3 alkalinity as $CaCO_3$ (mg/L)	7	7	212	232	221	219	224
B (mg/L)	0	0	-	-	-	-	-
Ca (mg/L)	0	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	4	1	0.3	0.3	0.3	ISS	ISS
Cl (mg/L)	7	7	8.9	12	11	9.5	12
EC (field) (µS/cm)	0	0	-	-	-	-	-
EC @ 25C (lab) (µS/cm)	7	7	355	390	367	360	372
F (mg/L)	1	1	0.23	0.23	-	-	-
Li (mg/L)	0	0	-	-	-	-	-
Mg (mg/L)	0	0	-	-	-	-	-
Mn (mg/L)	0	0	-	-	-	-	-
pH (field)	7	7	7.2	8.2	8	7.9	8.2
pH (lab)	0	0	-	-	-	-	-
K (mg/L)	6	6	2	6.3	2.9	2	3.4
Na (mg/L)	6	6	24	34	27	25	28
SAR	0	0	-	-	-	-	-
Sr (mg/L)	0	0	-	-	-	-	-
Sulfate as SO_4^{2-}	6	6	3.8	14	8.3	4.6	12
Methane (mg/L)							

Stratigraphic unit: **Namoi alluvium**
Date range: 15/8/1973 to 23/1/1985
ISS – insufficient sample size

Table B22 - Baseline data for groundwater quality monitoring at location BHN14PRORA01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	7	7	0.6	0.9	0.6	0.6	0.6
HCO_3 alkalinity as $CaCO_3$ (mg/L)	8	8	178	262	207	182	220
B (mg/L)	7	6	0.07	0.2	0.1	0.08	0.1
Ca (mg/L)	8	8	21	36	31	25	34
CO_3 alkalinity as $CaCO_3$ (mg/L)	8	0	-	-	-	-	-
Cl (mg/L)	8	8	30	39	33	31	35
EC (field) (µS/cm)	13	13	480	930	552	493	585
EC @ 25C (lab) (µS/cm)	8	8	474	600	526	496	572
F (mg/L)	8	7	0.2	0.3	0.2	0.2	0.3
Li (mg/L)	2	2	0.005	0.02	0.01	ISS	ISS
Mg (mg/L)	8	8	7	11	8.6	8	9.9
Mn (mg/L)	7	7	0.05	0.7	0.3	0.2	0.2
pH (field)	13	13	6.7	7.4	7.1	6.9	7.2
pH (lab)	8	8	7.3	8.3	7.7	7.5	8
K (mg/L)	8	8	3	5	4.1	4	4.9
Na (mg/L)	8	8	53	89	66	61	72
SAR	2	2	3	3.3	3.2	ISS	ISS
Sr (mg/L)	8	8	0.4	0.6	0.5	0.5	0.5
Sulfate as SO_4^{2-}	8	7	2	11	5.4	3	9.1
Methane (µg/L)	8	7	170	649	350	217	421

Stratigraphic unit: **Orallo Formation**
Date range: 14/12/2013 to 18/7/2017
ISS – insufficient sample size

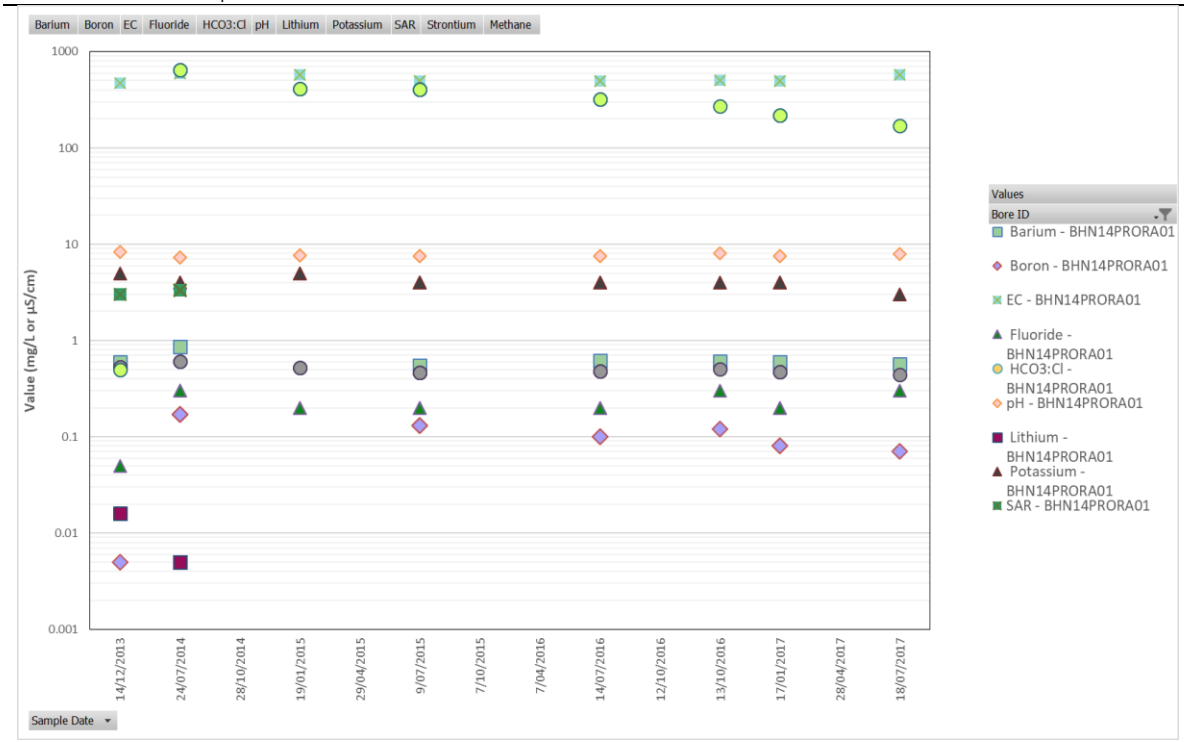


Table B23 - Baseline data for groundwater quality monitoring at location NYOPRORA01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	11	11	0.09	0.4	0.2	0.1	0.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	11	11	420	684	567	536	614
B (mg/L)	11	11	0.2	0.3	0.3	0.2	0.3
Ca (mg/L)	11	11	1	9	4.5	2.6	6
CO_3 alkalinity as $CaCO_3$ (mg/L)	11	11	3	89	25	7.6	37
Cl (mg/L)	11	11	48	63	56	52	60
EC (field) (µS/cm)	11	11	1194	1468	1327	1274	1385
EC @ 25C (lab) (µS/cm)	10	10	1090	1560	1336	1310	1360
F (mg/L)	10	10	0.9	1	1	1	1
Li (mg/L)	6	6	0.02	0.9	0.2	0.03	0.2
Mg (mg/L)	11	6	1	4	1.5	NA	NA
Mn (mg/L)	11	11	0.003	0.06	0.02	0.006	0.05
pH (field)	11	11	7.5	8.3	8	7.9	8.2
pH (lab)	10	10	8.3	8.9	8.5	8.3	8.6
K (mg/L)	11	11	1	12	3.3	2	4.2
Na (mg/L)	11	11	266	343	315	294	338
SAR	5	5	19	85	42	26	56
Sr (mg/L)	10	10	0.1	0.2	0.1	0.1	0.2
Sulfate as SO_4^{2-}	11	1	1	1	1	NA	NA
Methane (µg/L)	11	10	300	4180	1860	859	3150

Stratigraphic unit: **Orallo Formation**
Date range: 30/11/2013 to 17/7/2017
ISS – insufficient sample size

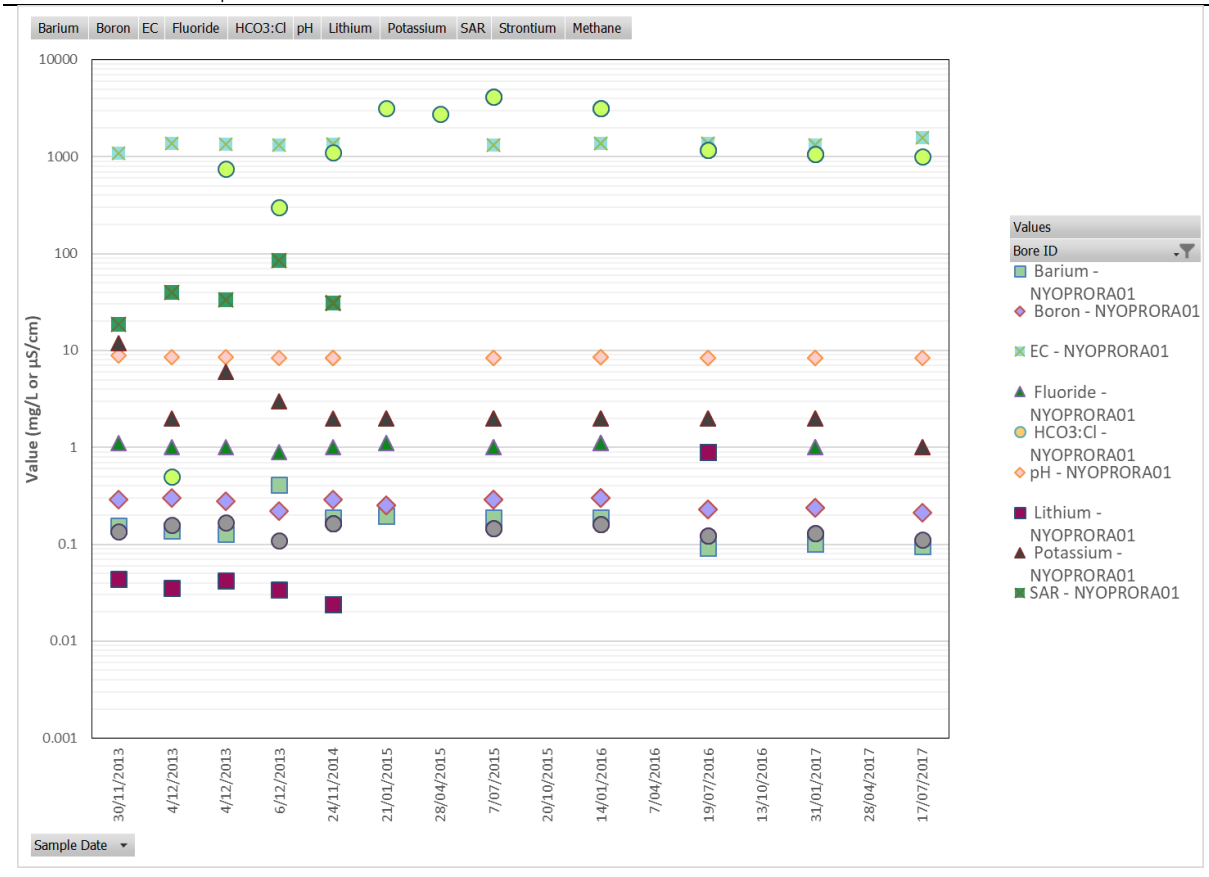


Table B24 - Baseline data for groundwater quality monitoring at location 7703

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.08	0.08	-	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	432	439	-	ISS	ISS
B (mg/L)	2	2	0.06	0.08	-	ISS	ISS
Ca (mg/L)	2	2	15	20	-	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	ISS	ISS
Cl (mg/L)	2	2	698	721	-	ISS	ISS
EC (field) (µS/cm)	2	2	2991	3079	-	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	2980	3280	-	ISS	ISS
F (mg/L)	2	2	0.6	0.6	-	ISS	ISS
Li (mg/L)	2	0	-	-	-	ISS	ISS
Mg (mg/L)	2	2	14	17	-	ISS	ISS
Mn (mg/L)	2	2	0.03	0.04	-	ISS	ISS
pH (field)	2	2	6.9	8.9	-	ISS	ISS
pH (lab)	2	2	7.7	7.8	-	ISS	ISS
K (mg/L)	2	2	12	13	-	ISS	ISS
Na (mg/L)	2	2	586	638	-	ISS	ISS
SAR	2	2	23	29	-	ISS	ISS
Sr (mg/L)	2	2	0.5	0.5	-	ISS	ISS
Sulfate as SO_4^{2-}	2	2	37	57	-	ISS	ISS
Methane (µg/L)	2	2	24	104	-	ISS	ISS

Stratigraphic unit: **Orallo Formation**
Date range: 25/5/2012 to 7/5/2014
ISS – insufficient sample size

Table B25 - Baseline data for groundwater quality monitoring at location 7705

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.1	0.1	0.1	ISS	ISS
HCO3 alkalinity as CaCO3 (mg/L)	2	2	327	343	335	ISS	ISS
B (mg/L)	2	0	-	-	-	ISS	ISS
Ca (mg/L)	2	2	9	12	11	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	ISS	ISS
Cl (mg/L)	2	2	175	180	178	ISS	ISS
EC (field) (µS/cm)	2	2	1141	1163	1152	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	1140	1220	1180	ISS	ISS
F (mg/L)	2	2	0.4	0.4	0.4	ISS	ISS
Li (mg/L)	2	0	-	-	-	ISS	ISS
Mg (mg/L)	2	2	8	10	9	ISS	ISS
Mn (mg/L)	2	2	0.004	0.01	0.009	ISS	ISS
pH (field)	2	2	6.4	8.3	7.4	ISS	ISS
pH (lab)	2	2	7.4	7.6	7.5	ISS	ISS
K (mg/L)	2	2	8	9	8.5	ISS	ISS
Na (mg/L)	2	2	220	236	228	ISS	ISS
SAR	2	2	11	14	13	ISS	ISS
Sr (mg/L)	2	2	0.2	0.2	0.2	ISS	ISS
Sulfate as SO_4^{2-}	2	2	30	37	34	ISS	ISS
Methane (µg/L)	2	0	-	-	-	ISS	ISS

Stratigraphic unit: **Orallo Formation**
Date range: 25/5/2012 to 7/5/2014
ISS – insufficient sample size

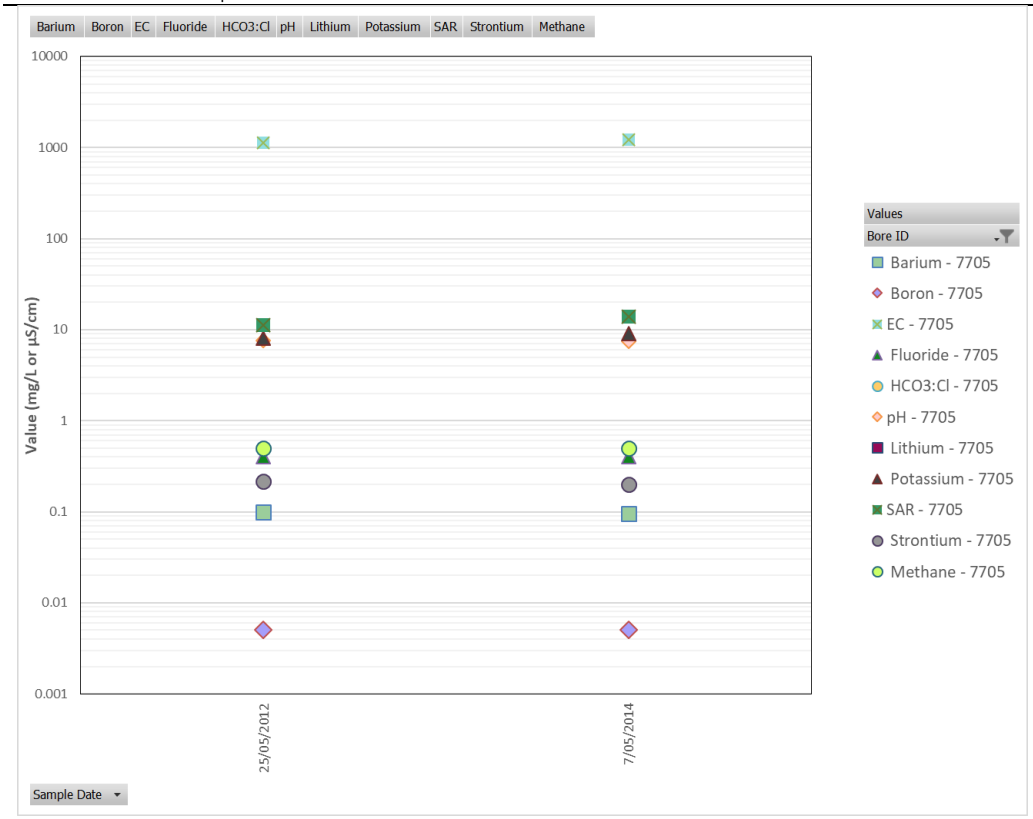


Table B26 - Baseline data for groundwater quality monitoring at location 7706

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.2	0.2	0.2	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	222	226	224	ISS	ISS
B (mg/L)	2	0	-	-	-	-	-
Ca (mg/L)	2	2	37	39	38	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	-	-
Cl (mg/L)	2	2	25	27	26	ISS	ISS
EC (field) (µS/cm)	2	2	470	531	501	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	471	486	479	ISS	ISS
F (mg/L)	2	0	-	-	-	ISS	ISS
Li (mg/L)	2	2	0.03	0.03	0.03	ISS	ISS
Mg (mg/L)	2	2	8	8	8	ISS	ISS
Mn (mg/L)	2	2	0.04	0.05	0.04	ISS	ISS
pH (field)	2	2	6.8	7.4	7.1	ISS	ISS
pH (lab)	2	2	7.9	8	7.9	ISS	ISS
K (mg/L)	2	2	6	8	7	ISS	ISS
Na (mg/L)	2	2	53	54	54	ISS	ISS
SAR	2	2	2.1	2.1	2.1	ISS	ISS
Sr (mg/L)	2	2	0.3	0.3	0.3	ISS	ISS
Sulfate as SO_4^{2-}	2	0	-	-	-	ISS	ISS
Methane (µg/L)	2	1	12	12	-	ISS	ISS

Stratigraphic unit: **Orallo Formation**
Date range: 25/5/2012 to 25/6/2014
ISS – insufficient sample size

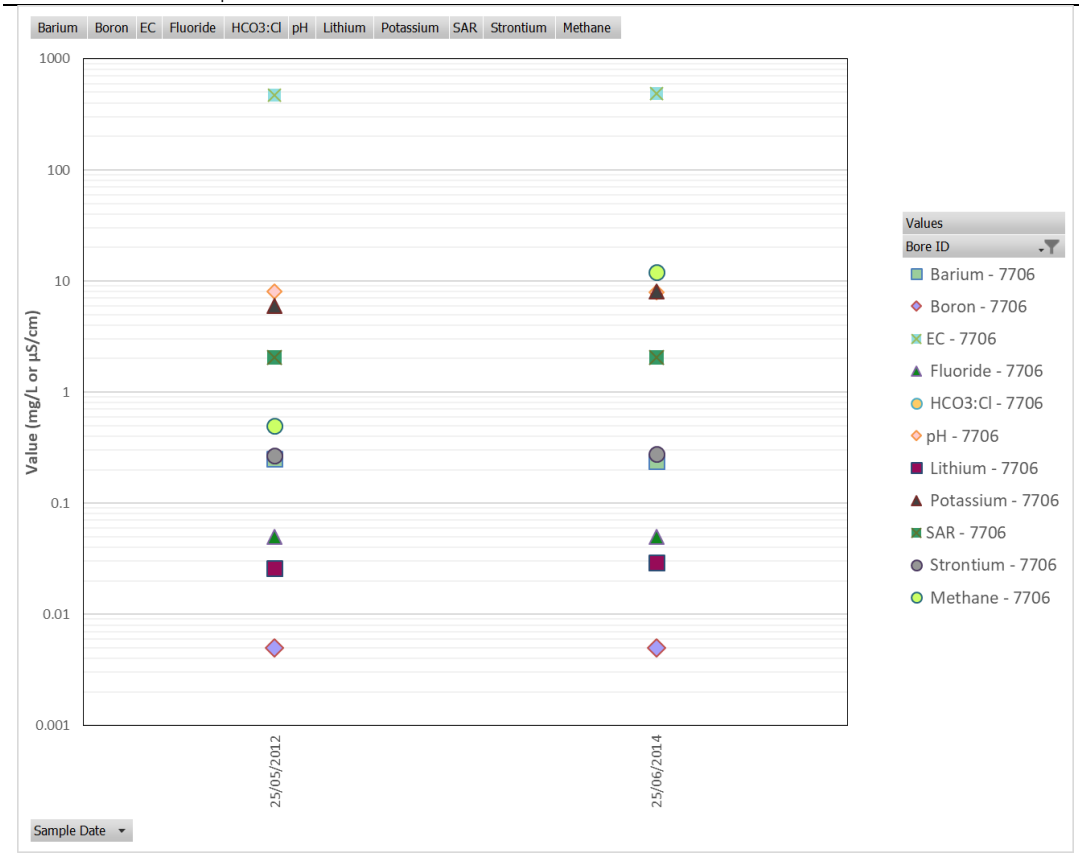


Table B27 - Baseline data for groundwater quality monitoring at location BWD1WB

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.08	0.09	-	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	6	6	-	ISS	ISS
B (mg/L)	2	0	-	-	-	ISS	ISS
Ca (mg/L)	2	0	-	-	-	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	ISS	ISS
Cl (mg/L)	2	2	27	31	-	ISS	ISS
EC (field) (µS/cm)	3	3	115	145	-	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	124	128	-	ISS	ISS
F (mg/L)	2	0	-	-	-	ISS	ISS
Li (mg/L)	2	2	0.002	0.003	-	ISS	ISS
Mg (mg/L)	2	1	2	2	-	ISS	ISS
Mn (mg/L)	1	1	0.006	0.006	-	ISS	ISS
pH (field)	3	3	5	6.9	-	ISS	ISS
pH (lab)	2	2	5.8	5.9	-	ISS	ISS
K (mg/L)	2	2	5	5	-	ISS	ISS
Na (mg/L)	2	2	17	17	-	ISS	ISS
SAR	2	2	2.7	3.6	-	ISS	ISS
Sr (mg/L)	2	2	0.01	0.02	-	ISS	ISS
Sulfate as SO_4^{2-}	2	0	-	-	-	ISS	ISS
Methane (µg/L)	2	1	16	16	-	ISS	ISS

Stratigraphic unit: **Pilliga Sandstone**
Date range: 17/10/2012 to 23/10/2013
ISS – insufficient sample size

Table B28 - Baseline data for groundwater quality monitoring at location BWD5WB

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	2	2	0.1	0.1	-	ISS	ISS
HCO_3 alkalinity as $CaCO_3$ (mg/L)	2	2	6	7	-	ISS	ISS
B (mg/L)	2	0	-	-	-	ISS	ISS
Ca (mg/L)	2	0	-	-	-	ISS	ISS
CO_3 alkalinity as $CaCO_3$ (mg/L)	2	0	-	-	-	ISS	ISS
Cl (mg/L)	2	2	30	33	-	ISS	ISS
EC (field) (µS/cm)	3	3	113	206	-	ISS	ISS
EC @ 25C (lab) (µS/cm)	2	2	124	129	-	ISS	ISS
F (mg/L)	2	0	-	-	-	ISS	ISS
Li (mg/L)	2	2	0.003	0.004	-	ISS	ISS
Mg (mg/L)	1	1	2	2	-	ISS	ISS
Mn (mg/L)	2	2	0.003	0.02	-	ISS	ISS
pH (field)	3	3	5.3	7.6	-	ISS	ISS
pH (lab)	2	2	5.6	6	-	ISS	ISS
K (mg/L)	1	1	5	5	-	ISS	ISS
Na (mg/L)	1	1	14	14	-	ISS	ISS
SAR	2	2	2.3	3.4	-	ISS	ISS
Sr (mg/L)	2	2	0.02	0.02	-	ISS	ISS
Sulfate as SO_4^{2-}	2	1	2	2	-	ISS	ISS
Methane (µg/L)	1	0	-	-	-	ISS	ISS

Stratigraphic unit: **Pilliga Sandstone**
Date range: 8/10/2012 to 18/10/2012
ISS – insufficient sample size

Table B29 - Baseline data for groundwater quality monitoring at location BHN14PRUPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	7	7	0.4	0.9	0.6	0.5	0.6
HCO_3 alkalinity as $CaCO_3$ (mg/L)	8	8	190	252	217	198	233
B (mg/L)	7	2	0.06	0.08	0.07	NA	NA
Ca (mg/L)	8	8	35	45	41	39	43
CO_3 alkalinity as $CaCO_3$ (mg/L)	8	1	2	2	2	2	2
Cl (mg/L)	8	8	16	23	20	18	22
EC (field) (µS/cm)	13	13	446	599	504	470	535
EC @ 25C (lab) (µS/cm)	8	8	456	565	495	459	542
F (mg/L)	7	6	0.2	0.3	0.2	0.2	0.2
Li (mg/L)	3	3	0.01	0.2	0.08	ISS	ISS
Mg (mg/L)	8	8	7	10	8.5	8	9
Mn (mg/L)	7	7	0.009	0.3	0.1	0.09	0.2
pH (field)	13	13	6.6	7.4	7	6.9	7.2
pH (lab)	8	8	7.3	8.3	7.6	7.3	8.1
K (mg/L)	8	8	5	7	6.1	6	6.9
Na (mg/L)	8	8	42	61	48	42	52
SAR	2	2	1.8	2.1	1.9	ISS	ISS
Sr (mg/L)	8	8	0.4	0.6	0.5	0.4	0.6
Sulfate as SO_4^{2-}	8	2	0.5	5	2.8	NA	NA
Methane (µg/L)	8	7	1680	4640	2300	1800	2460

Stratigraphic unit: **Pilliga Sandstone**
Date range: 12/12/2013 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B30 - Baseline data for groundwater quality monitoring at location BWD26PRLPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	8	8	0.2	0.6	0.5	0.3	0.6
HCO_3 alkalinity as $CaCO_3$ (mg/L)	9	9	31	39	35	32	38
B (mg/L)	8	2	0.07	0.2	0.1	NA	NA
Ca (mg/L)	9	9	1	3	1.7	1	2
CO_3 alkalinity as $CaCO_3$ (mg/L)	9	0	-	-	-	-	-
Cl (mg/L)	9	9	7	27	19	18	22
EC (field) (µS/cm)	15	15	131	293	168	141	190
EC @ 25C (lab) (µS/cm)	9	9	101	169	148	138	158
F (mg/L)	9	9	0.1	0.2	0.17	0.1	0.2
Li (mg/L)	2	2	0.001	0.003	0.002	ISS	ISS
Mg (mg/L)	9	9	1	2	1.7	1	2
Mn (mg/L)	8	8	0.008	0.2	0.1	0.05	0.1
pH (field)	15	15	5.3	7.7	6.1	5.8	6.3
pH (lab)	9	9	6.5	7.5	6.8	6.5	6.9
K (mg/L)	9	9	6	14	12	11	13
Na (mg/L)	9	9	12	21	15	13	17
SAR	2	2	1.4	3.6	2.5	1.8	3.2
Sr (mg/L)	9	9	0.04	0.05	0.05	0.04	0.05
Sulfate as SO_4^{2-}	9	5	1	10	3	NA	NA
Methane (µg/L)	9	5	42	269	148	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 19/9/2013 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B31 - Baseline data for groundwater quality monitoring at location BWD26PRUPS01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	7	7	0.2	0.5	0.2	0.2	0.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	8	8	23	58	30	23	35
B (mg/L)	7	5	0.05	0.2	0.08	NA	NA
Ca (mg/L)	8	5	1	3	1.8	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	8	0	-	-	-	-	-
Cl (mg/L)	8	8	5	19	7.3	5	6
EC (field) (µS/cm)	14	14	67.9	254	99.7	70.2	128
EC @ 25C (lab) (µS/cm)	8	8	64	181	90.6	76	89.2
F (mg/L)	8	2	0.1	0.3	0.2	NA	NA
Li (mg/L)	1	1	0.004	0.004	0.004	ISS	ISS
Mg (mg/L)	8	7	1	2	1.7	1	2
Mn (mg/L)	7	7	0.02	0.4	0.08	0.02	0.05
pH (field)	14	14	4.9	6.4	5.7	5.4	5.9
pH (lab)	8	8	6.2	6.9	6.5	6.2	6.8
K (mg/L)	8	8	6	12	6.9	6	6.9
Na (mg/L)	8	8	6	23	10	7	11
SAR	1	1	2.5	2.5	2.5	ISS	ISS
Sr (mg/L)	8	8	0.02	0.07	0.03	0.02	0.04
Sulfate as SO_4^{2-}	8	1	2	2	2	NA	NA
Methane (µg/L)	8	1	409	409	409	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 27/7/2014 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B32 - Baseline data for groundwater quality monitoring at location BWD27PRLPS03

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	8	8	0.05	0.1	0.09	0.08	0.09
HCO_3 alkalinity as $CaCO_3$ (mg/L)	9	8	10	41	29	14	36
B (mg/L)	8	1	0.06	0.06	0.06	NA	NA
Ca (mg/L)	9	5	1	2	1.2	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	9	0	-	-	-	-	-
Cl (mg/L)	9	9	35	46	40	37	45
EC (field) (µS/cm)	13	13	175	360	223	191	251
EC @ 25C (lab) (µS/cm)	9	9	182	239	207	192	215
F (mg/L)	9	2	0.1	0.1	0.1	NA	NA
Li (mg/L)	4	4	0.001	2	0.5	0.001	1
Mg (mg/L)	9	7	2	3	2.1	NA	NA
Mn (mg/L)	8	8	0.02	0.07	0.04	0.02	0.07
pH (field)	13	13	5.1	6.1	5.5	5.2	5.8
pH (lab)	9	9	4.1	6.4	5.9	5.8	6.3
K (mg/L)	9	9	3	5	4	4	4
Na (mg/L)	9	9	27	36	32	31	33
SAR	2	2	0.03	5.2	2.6	ISS	ISS
Sr (mg/L)	9	9	0.02	0.03	0.03	0.02	0.03
Sulfate as SO_4^{2-}	9	5	1	35	8	NA	NA
Methane (µg/L)	9	3	12	25	18	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 15/11/2013 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B33 - Baseline data for groundwater quality monitoring at location BWD27PRUPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	9	9	0.1	0.2	0.1	0.1	0.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	10	10	8	18	13	9.3	16
B (mg/L)	9	0	-	-	-	-	-
Ca (mg/L)	10	0	-	-	-	-	-
CO_3 alkalinity as $CaCO_3$ (mg/L)	10	0	-	-	-	-	-
Cl (mg/L)	10	10	23	33	29	28	32
EC (field) (µS/cm)	13	13	126	300	159	135	193
EC @ 25C (lab) (µS/cm)	11	11	129	864	203	131	146
F (mg/L)	10	1	0.1	0.1	0.1	NA	NA
Li (mg/L)	4	4	0.002	0.002	0.002	ISS	ISS
Mg (mg/L)	10	8	1	2	1.6	NA	NA
Mn (mg/L)	9	9	0.004	0.1	0.06	0.008	0.09
pH (field)	13	13	4.5	5.6	5.2	4.9	5.5
pH (lab)	11	11	5.8	8.8	6.4	5.8	6.7
K (mg/L)	10	10	6	7	6.2	6	6.6
Na (mg/L)	10	10	15	19	17	17	18
SAR	2	2	3.9	4.1	4	ISS	ISS
Sr (mg/L)	10	10	0.02	0.03	0.02	0.02	0.03
Sulfate as SO_4^{2-}	10	2	1	1	1	NA	NA
Methane (µg/L)	10	1	27	27	27	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 29/7/2013 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

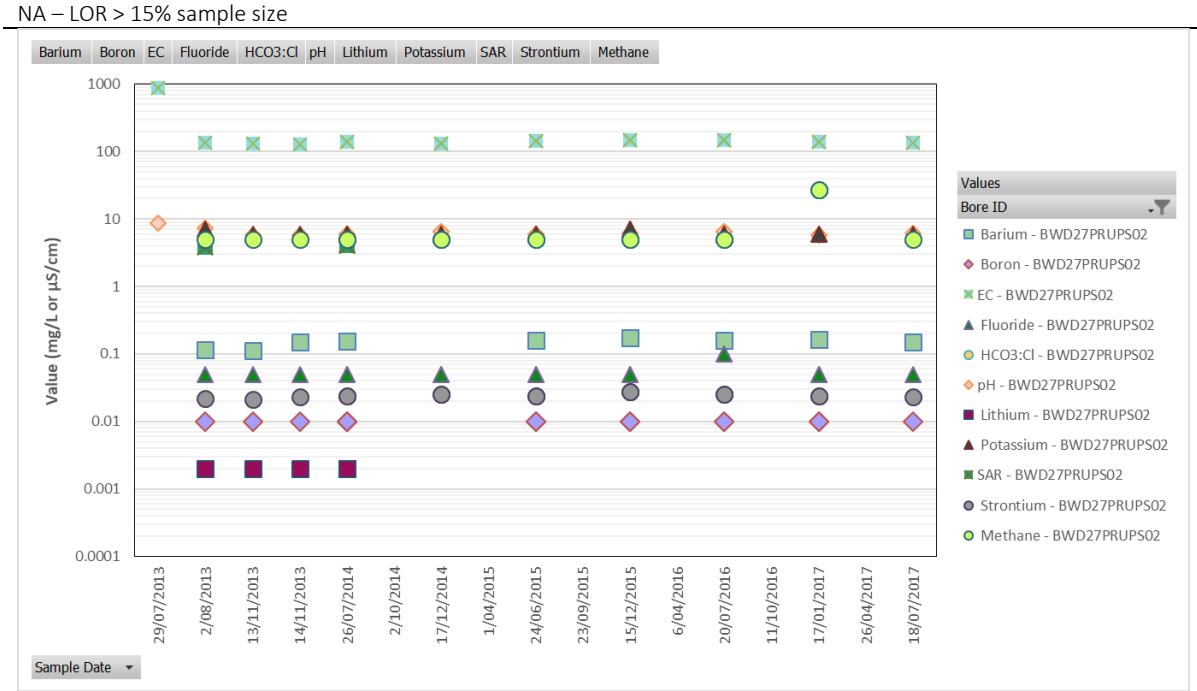


Table B34 - Baseline data for groundwater quality monitoring at location DWH14PRLPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	11	11	0.06	0.1	0.08	0.06	0.1
HCO_3 alkalinity as $CaCO_3$ (mg/L)	11	11	14	79	37	27	46
B (mg/L)	11	0	-	-	-	-	-
Ca (mg/L)	11	10	2	16	5.9	3	9.4
CO_3 alkalinity as $CaCO_3$ (mg/L)	11	0	-	-	-	-	-
Cl (mg/L)	11	11	31	43	37	33	42
EC (field) (µS/cm)	13	13	189	617	245	195	248
EC @ 25C (lab) (µS/cm)	10	10	181	299	205	187	209
F (mg/L)	11	3	0.1	0.1	0.1	NA	NA
Li (mg/L)	6	6	0.003	2	0.3	0.004	0.4
Mg (mg/L)	11	11	1	3	1.7	1	2
Mn (mg/L)	11	11	0.01	0.3	0.1	0.03	0.2
pH (field)	13	13	5	7.3	5.7	5.3	5.8
pH (lab)	10	10	6	7.5	6.5	6.1	7.3
K (mg/L)	11	11	4	6	4.5	4	5.4
Na (mg/L)	11	11	25	38	31	27	36
SAR	6	6	0.03	5.8	3.6	1.8	4.8
Sr (mg/L)	11	11	0.02	0.07	0.04	0.03	0.05
Sulfate as SO_4^{2-}	11	5	1	2	1.2	NA	NA
Methane (µg/L)	11	1	25	25	25	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 27/10/2013 to 20/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

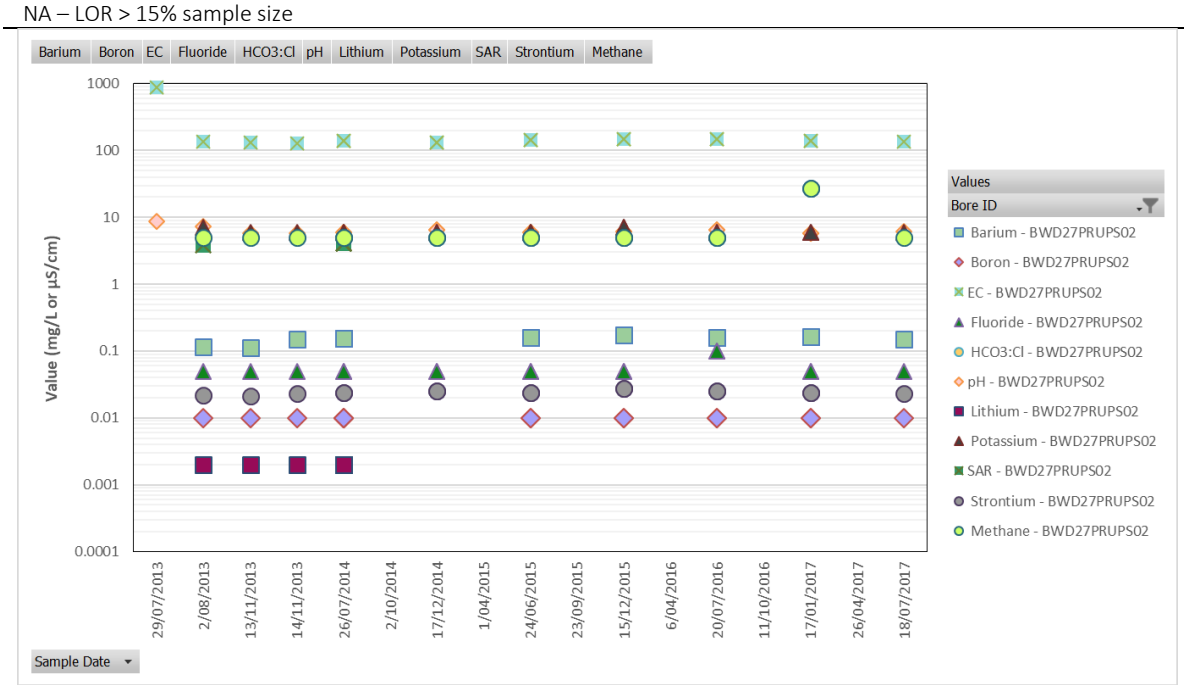


Table B35 - Baseline data for groundwater quality monitoring at location DWH14PRUPS01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	11	11	0.1	0.3	0.2	0.1	0.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	11	11	10	47	28	11	41
B (mg/L)	11	0	-	-	-	-	-
Ca (mg/L)	11	7	1	4	2.6	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	11	1	32	32	32	NA	NA
Cl (mg/L)	11	11	32	42	38	35	40
EC (field) (µS/cm)	13	13	196	450	235	205	258
EC @ 25C (lab) (µS/cm)	11	11	192	721	256	193	231
F (mg/L)	11	0	-	-	-	-	-
Li (mg/L)	5	5	0.005	0.009	0.006	ISS	ISS
Mg (mg/L)	11	11	2	4	3.2	2	4
Mn (mg/L)	11	11	0.007	0.4	0.2	0.01	0.3
pH (field)	13	13	5	6.8	5.7	5.2	6
pH (lab)	11	11	5.6	9.5	6.7	5.7	7.8
K (mg/L)	11	11	6	8	7.2	7	8
Na (mg/L)	11	11	23	34	27	25	30
SAR	5	5	2.5	5.2	3.8	ISS	ISS
Sr (mg/L)	11	11	0.02	0.1	0.05	0.03	0.08
Sulfate as SO_4^{2-}	11	0	-	-	-	-	-
Methane (µg/L)	11	0	-	-	-	-	-

Stratigraphic unit: **Pilliga Sandstone**
Date range: 26/10/2013 to 5/7/2016
ISS – insufficient sample size
NA – LOR > 15% sample size

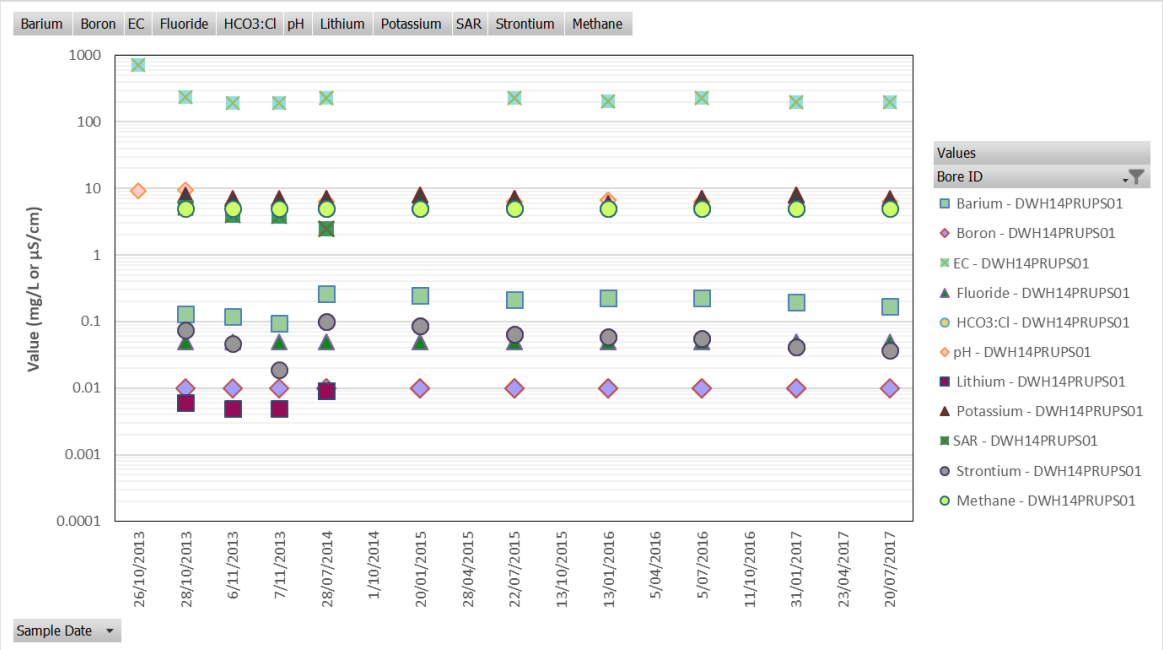


Table B36 - Baseline data for groundwater quality monitoring at location DWH3PRLPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	9	9	0.02	0.1	0.06	0.05	0.06
HCO_3 alkalinity as $CaCO_3$ (mg/L)	9	9	1	64	25	16	32
B (mg/L)	9	7	0.05	0.1	0.07	NA	NA
Ca (mg/L)	9	9	1	8	2.6	1	3.4
CO_3 alkalinity as $CaCO_3$ (mg/L)	9	4	1	1	1	NA	NA
Cl (mg/L)	9	9	22	32	25	23	27
EC (field) (µS/cm)	14	14	122	301	164	135	188
EC @ 25C (lab) (µS/cm)	9	9	122	215	151	133	167
F (mg/L)	9	5	0.1	1	0.3	NA	NA
Li (mg/L)	2	2	0.002	0.01	0.007	ISS	ISS
Mg (mg/L)	9	7	1	1	1	NA	NA
Mn (mg/L)	9	9	0.01	0.4	0.1	0.04	0.1
pH (field)	14	14	4.1	5.9	5.2	4.9	5.6
pH (lab)	9	9	4.2	7.1	6	5.9	6.4
K (mg/L)	9	9	2	6	3.2	2.3	3.7
Na (mg/L)	9	9	20	29	23	20	27
SAR	1	1	2.6	2.6	-	ISS	ISS
Sr (mg/L)	9	9	0.01	0.1	0.03	0.01	0.03
Sulfate as SO_4^{2-}	9	9	1	20	3.7	1	2
Methane (µg/L)	9	2	23	42	33	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 30/9/2013 to 24/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

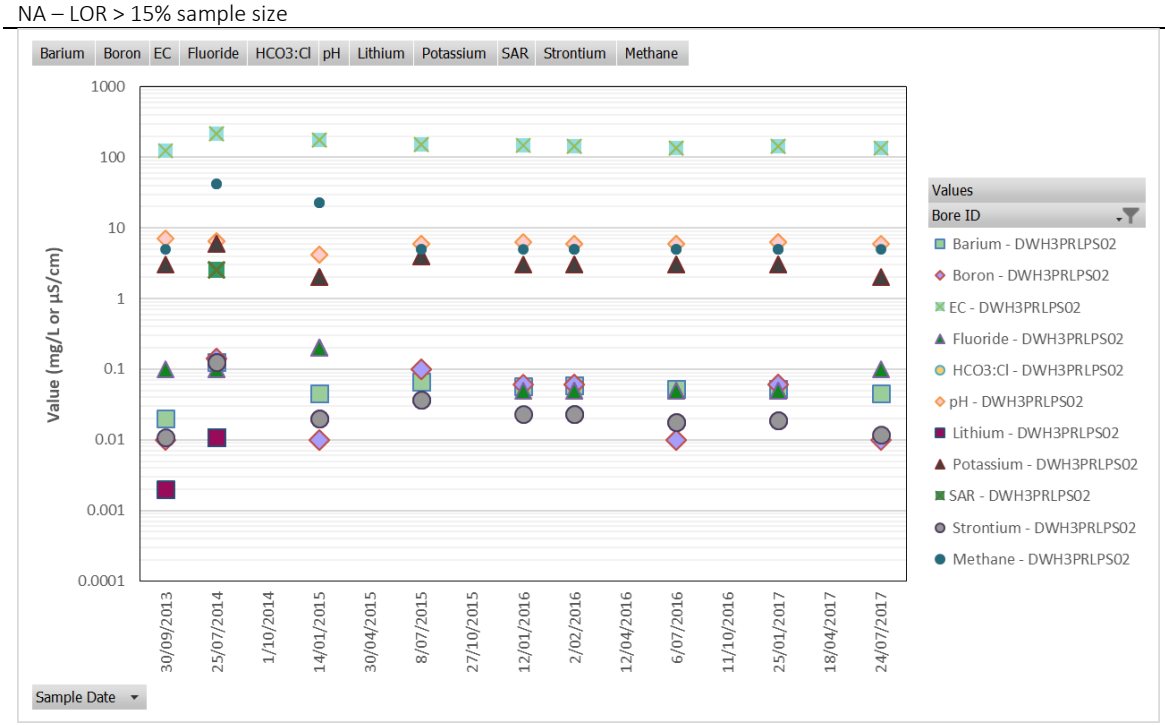


Table B37 - Baseline data for groundwater quality monitoring at location DWH3PRUPS01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	9	9	0.03	0.09	0.04	0.03	0.05
HCO_3 alkalinity as $CaCO_3$ (mg/L)	9	9	9	33	15	10	17
B (mg/L)	9	1	0.09	0.09	0.09	0.09	0.09
Ca (mg/L)	9	2	2	5	3.5	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	9	0	-	-	-	-	-
Cl (mg/L)	9	9	22	33	25	22	25
EC (field) (µS/cm)	14	14	112	293	139	119	160
EC @ 25C (lab) (µS/cm)	9	9	117	164	126	118	126
F (mg/L)	9	2	0.1	0.1	0.1	0.1	0.1
Li (mg/L)	2	2	0.002	0.002	0.002	ISS	ISS
Mg (mg/L)	9	8	1	2	1.1	1	1
Mn (mg/L)	9	9	0.008	0.2	0.05	0.02	0.05
pH (field)	14	14	4.1	6.5	5	4.6	5.4
pH (lab)	9	9	5.4	7.3	6.1	5.7	6.5
K (mg/L)	9	9	2	4	2.2	2	2
Na (mg/L)	9	9	18	25	21	18	24
SAR	1	1	3.5	3.5	-	ISS	ISS
Sr (mg/L)	9	9	0.008	0.06	0.02	0.01	0.02
Sulfate as SO_4^{2-}	9	9	2	3	2.2	2	2.7
Methane (µg/L)	9	0	-	-	-	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 2/10/2013 to 24/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

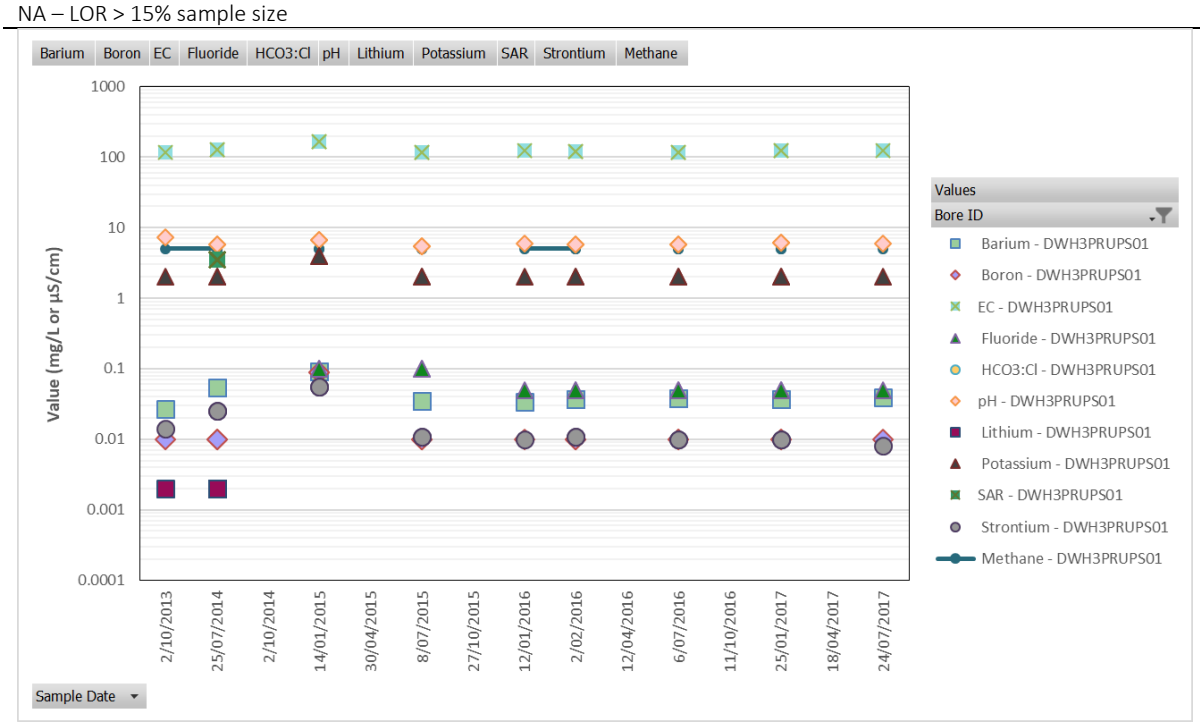


Table B38 - Baseline data for groundwater quality monitoring at location NYOPRUPS02

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	8	8	0.3	1	1	0.4	1
HCO_3 alkalinity as $CaCO_3$ (mg/L)	9	9	500	637	564	513	620
B (mg/L)	8	8	0.2	0.2	0.2	0.2	0.2
Ca (mg/L)	9	9	1	13	3.9	1	4
CO_3 alkalinity as $CaCO_3$ (mg/L)	9	8	12	43	27	14	40
Cl (mg/L)	9	9	47	61	55	52	59
EC (field) (µS/cm)	12	12	1127	1389	1266	1227	1307
EC @ 25C (lab) (µS/cm)	8	8	1270	1520	1324	1280	1319
F (mg/L)	9	9	0.9	1	0.97	0.9	1
Li (mg/L)	2	2	0.03	0.03	0.03	ISS	ISS
Mg (mg/L)	9	0	-	-	-	-	-
Mn (mg/L)	8	8	0.001	0.04	0.02	0.003	0.03
pH (field)	12	12	7.8	8.5	8.2	8.1	8.4
pH (lab)	8	8	8.3	8.7	8.5	8.4	8.6
K (mg/L)	9	9	2	2	2	2	2
Na (mg/L)	9	9	291	352	316	298	331
SAR	2	2	48	86	67	54	80
Sr (mg/L)	8	8	0.06	0.1	0.1	0.1	0.1
Sulfate as SO_4^{2-}	9	2	1	5	3	NA	NA
Methane (µg/L)	9	4	734	1180	989	NA	NA

Stratigraphic unit: **Pilliga Sandstone**
Date range: 1/12/2013 to 17/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

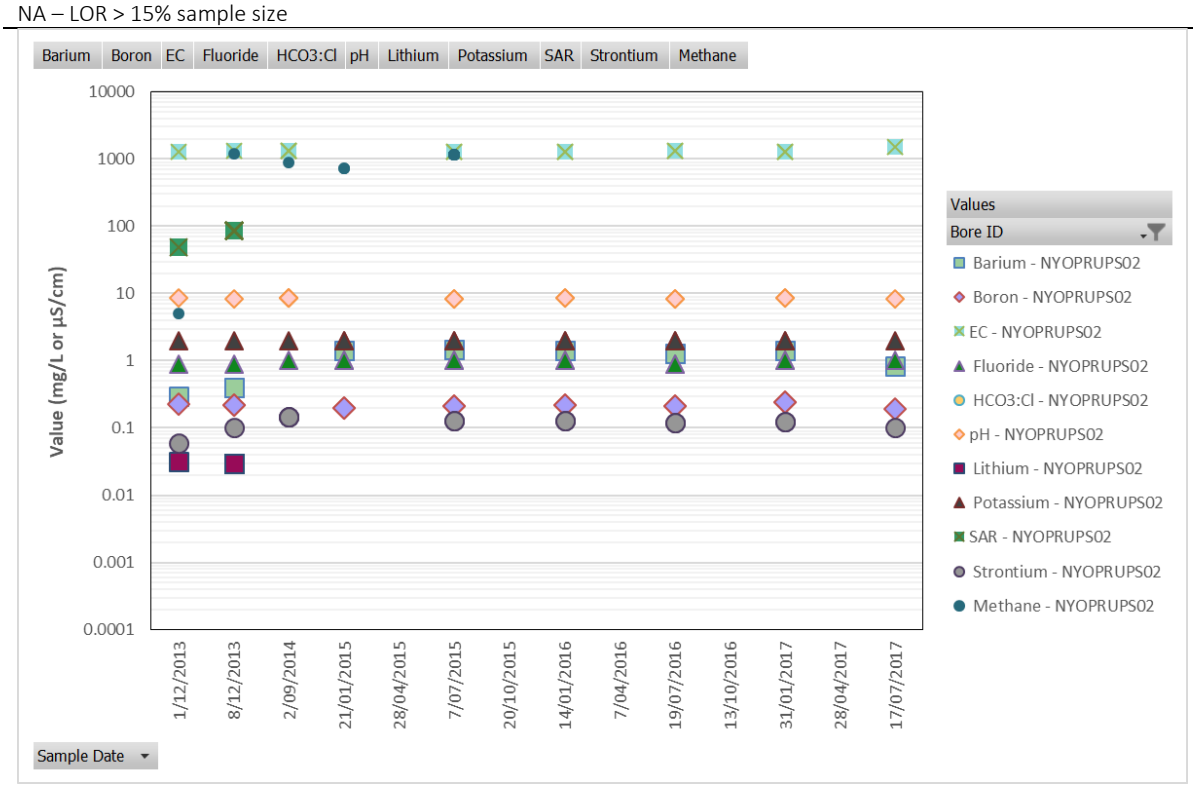


Table B39 - Baseline data for groundwater quality monitoring at location DWH14PRPUR03

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	7	7	0.088	0.13	0.11	0.11	0.12
HCO_3 alkalinity as $CaCO_3$ (mg/L)	7	7	7	159	62.1	8.92	120
B (mg/L)	7	3	0.05	0.11	0.08	NA	NA
Ca (mg/L)	7	7	1	7	3.29	1.96	4.12
CO_3 alkalinity as $CaCO_3$ (mg/L)	7	7	91	176	126	93.9	146
Cl (mg/L)	7	7	28	37	33.7	31.8	36
EC (field) (µS/cm)	10	10	407	778	651	549	752
EC @ 25C (lab) (µS/cm)	7	7	456	700	595	520	676
F (mg/L)	7	7	0.3	0.6	0.44	0.4	0.5
Li (mg/L)	1	1	0.03	0.03	0.03	ISS	ISS
Mg (mg/L)	7	0	-	-	-	-	-
Mn (mg/L)	7	5	0.002	0.01	0.004	NA	NA
pH (field)	10	10	9.01	11	10.1	9.58	10.5
pH (lab)	7	7	9.44	10.4	9.93	9.56	10.2
K (mg/L)	7	7	12	39	29.1	19.7	38
Na (mg/L)	7	7	78	120	100	79.9	115
SAR	1	1	27	27	27	ISS	ISS
Sr (mg/L)	7	7	0.075	0.26	0.21	0.2	0.24
Sulfate as SO42-	7	7	20	43	37.1	32.5	43
Methane (µg/L)	7	6	1390	4630	2620	NA	NA

Stratigraphic unit: **Purlawaugh Formation**
Date range: 29/10/2013 to 11/7/2018
ISS – insufficient sample size
NA – LOR > 15% sample size

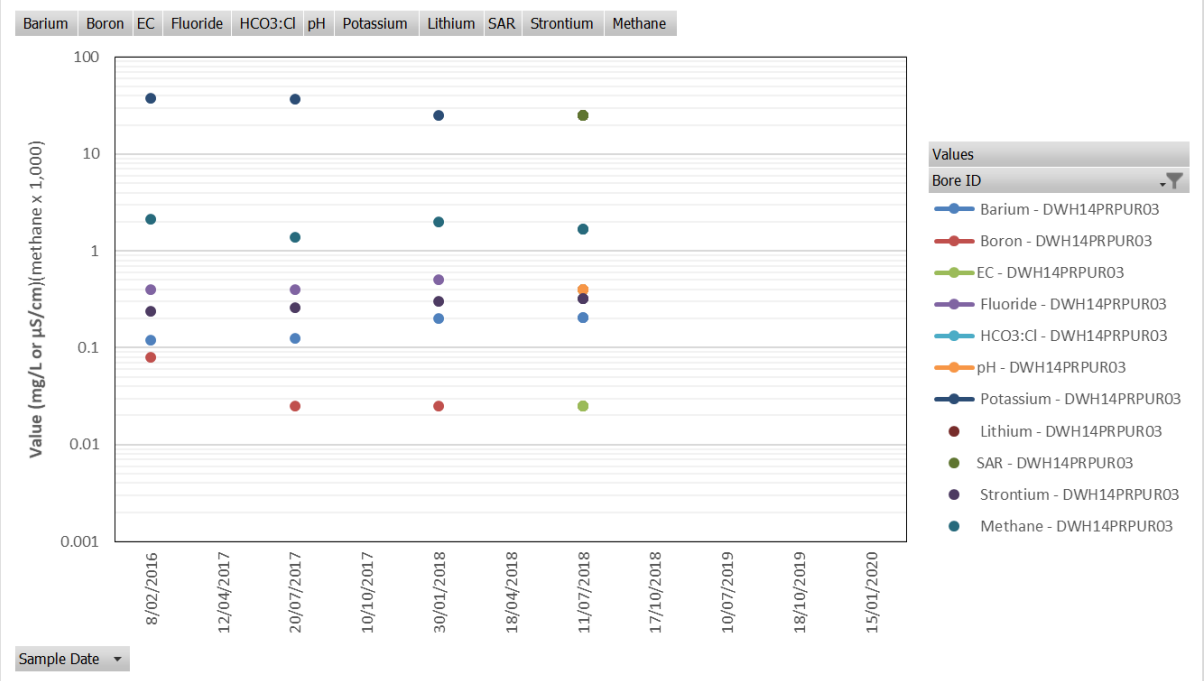


Table B40 - Baseline data for groundwater quality monitoring at location TULPRNAP01

Water quality measure	No. of samples	No. of sample >LOR	Min	Max	Mean	16th percentile	84th percentile
Ba (mg/L)	7	7	0.67	3.3	2	0.81	3
HCO_3 alkalinity as $CaCO_3$ (mg/L)	7	7	1380	2640	2271	2081	2592
B (mg/L)	7	7	0.14	1.2	0.64	0.27	0.91
Ca (mg/L)	7	7	2	53	39.1	28.9	52
CO_3 alkalinity as $CaCO_3$ (mg/L)	7	0	-	-	-	-	-
Cl (mg/L)	7	7	300	866	705	573	865
EC (field) (µS/cm)	13	13	3126	7488	6255	5294	7264
EC @ 25C (lab) (µS/cm)	6	6	3640	7820	6645	6120	7484
F (mg/L)	7	7	1	1.2	1.1	1.1	1.1
Li (mg/L)	1	1	0.09	0.09	0.09	ISS	ISS
Mg (mg/L)	7	7	1	34	24	12	33
Mn (mg/L)	7	7	0.008	0.54	0.16	0.024	0.41
pH (field)	13	13	5.8	7	6.7	6.7	6.9
pH (lab)	6	6	6.9	7.7	7.3	7	7.4
K (mg/L)	7	7	2	42	32.4	26	41
Na (mg/L)	7	7	866	1750	1518	1331	1712
SAR	1	1	33.8	33.8	33.8	ISS	ISS
Sr (mg/L)	7	7	1.2	5.2	3	1.5	4
Sulfate as SO_4^{2-}	7	5	5	239	69.4	NA	NA
Methane (µg/L)	7	7	1680	19900	9020	3410	13600

Stratigraphic unit: **Napperby Formation**
Date range: 9/7/2014 to 18/7/2017
ISS – insufficient sample size
NA – LOR > 15% sample size

Table B41 - Baseline data for groundwater quality monitoring at location TULPRDGY02

Water quality measure	No. of samples	No. of Sample >LOR	Min.	Max.	Mean	16th percentile	84th percentile
Ba (mg/L)	6	6	0.013	3.2	1.3	0.34	3.2
HCO_3 alkalinity as $CaCO_3$ (mg/L)	6	3	1	5200	2640	NA	NA
B (mg/L)	6	5	0.21	1.1	0.53	NA	NA
Ca (mg/L)	6	5	12	79	41.6	NA	NA
CO_3 alkalinity as $CaCO_3$ (mg/L)	6	3	292	427	348	NA	NA
Cl (mg/L)	6	6	33	166	97.7	34.6	160
EC (field) (µS/cm)	11	11	6714	10773	8496	6947	10280
EC @ 25C (lab) (µS/cm)	6	6	7220	10300	8820	7236	9996
F (mg/L)	6	6	0.5	1.6	1	0.5	1.5
Li (mg/L)	1	1	1.2	1.2	1.2	ISS	ISS
Mg (mg/L)	6	2	1	40	20	NA	NA
Mn (mg/L)	6	3	0.001	0.05	0.03	NA	NA
pH (field)	11	11	6.5	13	9.41	6.67	12.8
pH (lab)	6	6	6.88	12.4	9.68	6.95	12.4
K (mg/L)	6	5	60	305	201	NA	NA
Na (mg/L)	6	6	815	2260	1410	860	1920
SAR	1	1	50.2	50.2	50.2	ISS	ISS
Sr (mg/L)	6	6	0.007	2.5	2	1.9	2.5
Sulfate as SO_4^{2-}	6	2	1	33	12	NA	NA
Methane (µg/L)	6	6	1130	6830	3060	1770	3940

Stratigraphic unit: **Digby Formation**
Date range: 13/1/2015 to 17/7/2017
ISS – insufficient sample size; NA – LOR > 15% sample size

Attachment 3 - Groundwater Modelling Plan

Santos

NARRABRI GAS PROJECT

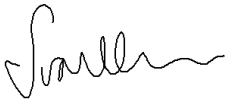
Groundwater Modelling Plan

PHASE 1

0041-150-PLA-0012

Date	Revision	Reason for Issue	Author	Checked	Approved
11 November 2022	0E	For approval	Eco Logical Australia / Onward Consulting	DG	TD

Prepared by:

Title	Name	Signature	Date
Senior Principal Hydrogeologist	Dr Richard Cresswell Eco Logical Australia		11 November 2022
Senior Environmental Manager	S. van der Meulen Onward Consulting		11 November 2022
Director	Mark Vile Onward Consulting		11 November 2022

Reviewed by:

Title	Name	Signature	Date
Principal Environmental Advisor | Hydrogeologist	David Gornall		11 November 2022

Approved by:

Title	Name	Signature	Date
Development Manager NSW	Todd Dunn		11 November 2022

Onward document number:
NGP-001J-0E PLN

Document review history

In accordance with consent condition D4, this document has been reviewed as follows:

Review Date	Reason for review	Reviewed by	Revision required (Y/N)

Acronyms and abbreviations

Acronym	Description
CoC	Conditions of consent for the NGP SSD 6456
CSG	coal seam gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPE	The former NSW Dept of Planning and Environment
DPI Water	The former Department of Primary Industries Water (formerly the NSW Office of Water; NOW)
DPE	The NSW Department of Planning and Environment
DPE Water	The Water Group within DPE
DPI	The former NSW department of Primary Industries
DPIE	The former NSW Department of Planning, Industry and Environment
EMP	environmental management plan
EIS	environmental impact statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
EPL	environment protection licence under the POEO Act
GAB	Great Artesian Basin
GABSI	Great Artesian Basin Sustainability Initiative
GBR	Groundwater Baseline Report
GIS	geographical information systems
GISERA	Gas Industry Social and Environmental Research Alliance
GL	gigalitre
GMA	Groundwater Management Area
GMP	Groundwater Management Plan
GModP	Groundwater Modelling Plan (this document)
GMonP	Groundwater Monitoring Plan
GOB	Gunnedah-Oxley Basin
IESC	Independent Expert Scientific Committee
ISO	International Organisation for Standardisation
ML	megalitre
PAL	petroleum assessment lease under the PO Act
PEL	petroleum exploration licence under the PO Act
PO Act	*Petroleum (Onshore) Act 1991* (NSW)
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)

Acronym	Description
POEO Regulation	Protection of the Environment Operations (General) Regulation 2009
PPL	petroleum production lease under the PO Act
PPLA	petroleum production lease application under the PO Act
RTL	response trigger levels
RTP	response trigger process
SRMS	scaled root mean square
WAL	water access licence
WM Act	*Water Management Act 2000* (NSW)
WMP	Water Management Plan
WRP	water resource plan
WSP	water sharing plan
WSPRA	water sharing plan reporting areas
WTAG	Water Technical Advisory Group

Table of contents

Tables

Figures

1. Introduction

1.1 Narrabri Gas Project

1.1.1 Background

Resource exploration has been occurring in the north-western area of NSW since the 1960s; initially for oil, but more recently for coal and gas. Santos NSW Pty Ltd began exploring for natural gas from coal seams in north-western NSW in 2008 and is currently conducting coal seam gas (**CSG**) exploration and appraisal activities within Petroleum Exploration Licence (**PEL**) 238, Petroleum Assessment Lease (**PAL**) 2 and Petroleum Production Lease (**PPL**) 3, located in the Gunnedah Basin about 20 kilometres (**km**) south-west of the town of Narrabri. Activities in PAL 2 have focussed on the Bibblewindi and Bohena CSG pilots, whilst recent activities in PEL 238 have focussed on the Dewhurst and Tintsfield CSG pilots.

The Narrabri Coal Seam Gas Utilisation Project (Wilga Park Power Station and associated infrastructure) operates under an existing Part 3A approval under the *Environmental Planning and Assessment Act 1979* (NSW) (**EP&A Act**). It was originally approved in 2008, with various modifications approved between 2011 and 2019. It encompasses a gas gathering system, a compressor and associated flare, a gas flow line from Bibblewindi to Wilga Park within a 10 metre (**m**) corridor with a riser at Leewood and an expansion of the existing Wilga Park Power Station from 12 to 40 megawatts.

1.1.2 Current Project

On 30 September 2020, Santos NSW (Eastern) Pty Ltd (**Santos**) obtained consent for State significant development (**SSD**) 6456 to develop the Narrabri Gas Project (**NGP**) (**the Project**). Approval EPBC 2014/7376 under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (**EPBC Act**) was granted on 24 November 2020.

The Project includes the progressive installation of up to 850 new gas wells on up to 425 new well pads over approximately 20 years and the construction and operation of gas processing and water treatment facilities. The Project area covers about 950 square kilometres (95,000 hectares) in size and the Project footprint will only directly impact about 1% of that area.

Four phases of development are defined under the consent, including:

- Phase 1 - exploration and appraisal;
- Phase 2 - construction activities for production wells and related infrastructure;
- Phase 3 - gas production operations; and
- Phase 4 - gas well and infrastructure decommissioning, rehabilitation and closure.

Phase 1 of the Project is defined in the consent as the phase of the development comprising ongoing exploration and appraisal activities in the Project area, including:

- seismic surveys;
- core and chip holes;
- construction and operation of pilot wells (up to 25 wells on up to 25 well pads across the Project area); and
- pilot well ancillary infrastructure, including access tracks, gas and water gathering lines, water balance tanks, safety flaring infrastructure, utilities and services, and environmental monitoring equipment including groundwater monitoring bores.

Santos plans to continue exploration and appraisal of the resource in the near term until a final investment decision can be made. The exploration and appraisal activities will include continued operation of Santos' existing wells, infrastructure and facilities in PEL 238 and PAL 2, and construction and operation of new core holes, pilot wells and supporting infrastructure permitted under Phase 1.

Santos' existing exploration and appraisal activities in PEL 238 and PAL 2 include:

- Tintsfield Pilot;
- Bibblewindi East Pilot;
- Bibblewindi West Pilot;
- Dewhurst North Pilot;
- Dewhurst South Pilot;
- Dewhurst northern and southern flow lines;
- Leewood Water Management Facility including ponds, the water and brine treatment plant (WBTP) and irrigation area;
- Bibblewindi Facility including gathering system, water balance tank, compressor and flare; and
- Bibblewindi to Leewood buried gas pipeline.

These exploration and appraisal activities will continue as part of the NGP. The initial, new-appraisal Phase 1 scope is a relatively minor extension to these existing exploration and appraisal activities.

The Phase 1 scope is planned to include the construction and operation of:

- 4 coreholes;
- 6 pilot wells;
- 2 deep reservoir monitoring bores (converted coreholes);
- new shallow water monitoring bores;
- associated linear infrastructure;
- seismic surveys (length and location to be determined); and
- continued operation of Santos' existing exploration and appraisal activities, including workover activities.

The full definitions of the approved activities for Phases 2, 3 and 4 of the Project are provided in the consent. Santos is not prevented from carrying out any or all of the phases concurrently, subject to the conditions of this consent.

Further details regarding the NGP, including a full overview of the regulatory framework and statutory provisions of the NGP and the current approvals, leases and licences are provided in the overarching Water Management Plan (**WMP**). Details regarding the staging of the works and the exact scope for each phase are as per the approved Field Development Plan.

1.2 Purpose and scope of the Groundwater Modelling Plan

Santos has developed this Groundwater Modelling Plan (**GModP** or the **Plan)** in accordance with the requirements of the conditions of consent (**CoC**) of SSD 6456. It sets out the procedures for review and update of the groundwater model (the **Model**) and model predictions during the exploration and appraisal activities of Phase 1 of the Project.

This Plan is an attachment to the Groundwater Management Plan (**GMP**) and comprises an important component of an overarching adaptive framework for the monitoring and management of the potential for impact to underground water resources. The GMP in turn forms part of a suite of documents prepared as part of the NGP Water Management Plan (**WMP**) under CoC B41.

Consent condition B39 provides specific conditions relating to a Groundwater Model. It states that Santos must periodically update the groundwater model for the development, to the satisfaction of the Planning Secretary. The model update must:

(a) be prepared and peer reviewed by suitably qualified and experienced persons;

(b) be undertaken in consultation with DPE Water, EPA and the Water Technical Advisory Group;

(c) be undertaken prior to the commencement of Phase 2, and at least every 3 years thereafter;

(d) be undertaken in accordance with the Australian Groundwater Modelling Guidelines (2012, or as updated) and other relevant guidelines including the IESC's Information Guidelines Explanatory Note – Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (2018);

(e) improve the model prior to the commencement of Phase 2 to be generally in accordance with the features of a Class 3 confidence level model (as per the *Australian Groundwater Modelling Guidelines*) the features of which must be based on the Water Technical Advisory Group's advice on appropriate development specific modelling objectives and criteria; and

(f) include:

(i) updated modelling objectives;

(ii) transient groundwater flow modelling;

(iii) updated geological modelling based on all available drill data and analysis, including:

- detailed structure assessment (including faulting) at best practice resolution;
- consideration of neotectonics and the stress field in the Project area and surrounds,

(iv) updated hydrogeological modelling based on all well data, drilling data, hydrogeological analysis and water monitoring data for all aquifers and aquitards, including:

- consideration of impacts from GABSI;
- consideration of leakage from the GAB to the Lower Namoi Groundwater Source using the heads predicted by the EIS model;

(v) updated predictions of groundwater drawdown and water take from all applicable groundwater sources as a result of the development; and

(vi) consideration of the predicted impacts against the:

- previous model predictions and monitoring results;
- water management performance measures in Table 7 [of the CoC];
- minimal harm considerations in the NSW Aquifer Interference Policy; and
- groundwater management response triggers in the Water Management Plan.

The Model is also relevant to CoC B27 and B28 because the groundwater model is the tool that will be used to estimate inter-aquifer leakage (i.e. indirect water take) due to the Project, and therefore estimate the size of the water licences Santos must hold for the development.

Consent condition B27 states that Santos must ensure that it has enough water for all stages of the development, and if necessary, adjust the scale of the development to match its available water supply.

Consent condition B28 states that prior to the commencement of each Phase of the development, Santos must demonstrate that it has adequate water licenses to account for the maximum predicted water take for the applicable Phase (including both short term and long term direct and indirect water

take) to the satisfaction of the Planning Secretary. It is to be noted that the maximum predicted water take will be based on the most recent update of the groundwater model.

Consent conditions B27 and B28 are further addressed in the Site Water Balance, as Attachment 2 to the overarching WMP.

1.3 Objectives

A groundwater flow model can be used to assess potential effects of CSG projects on underground water resources, mainly in terms of potential effects on groundwater pressures and inter-aquifer leakage. These groundwater models synthesise a range of hydrogeological information available at the time of model development to minimise predictive uncertainty. Such models may be periodically updated or improved over time as more data become available.

The objectives of this GModP are to provide the following:

- describe how Santos will comply with the Groundwater Model requirements as set out in CoC B27, B28 and B39;
- define various approaches for testing of model concepts, verification and potential updating of the Model on exceedance of a relevant performance criteria or monitoring trigger (refer to the GMP); and
- a process to improve the reliability of the modelling predictions over time.

1.4 Structure of this Plan

The structure of this Plan is as follows:

Section 1	Provides an introduction to the Project and the context, scope, purpose and objectives of this Plan. It further provides relevant performance measures related to aquifers
Section 2	Outlines the guidelines relevant to groundwater modelling in NSW
Section 3	Details the method for estimating indirect water take from aquifers for licencing
Section 4	Describes the review schedule for the groundwater model
Section 5	Provides details of the periodical review of data acquired during the Project
Section 6	Details the procedure for model updates that are undertaken following each model data review
Section 7	Outlines the reporting documentation of the groundwater model review
Section 8	Describes the evaluation and review process of this GModP
Section 9	References
Section 10	Glossary
Appendix A	Water Sharing Plan Reporting Areas

2. Relevant codes, standards and guidelines

2.1 Groundwater Modelling Guidelines

The 2012 *Australian Groundwater Modelling Guidelines* (**Modelling Guidelines**) aims to promote a consistent and sound approach to groundwater flow and solute transport modelling in Australia. The guidelines are a point of reference for best practice for the development, application and review of groundwater models, and seek to provide direction, scope and approaches common to modelling projects. They promote an approach to model development that is underpinned by a progression through a series of interdependent stages with frequent feedback loops to earlier stages.

A model review framework is a key element of the guidelines, with reviews recommended at key stages throughout a modelling program: conceptualisation, model plan and design, calibration/verification, prediction, and report completion.

The guidelines define a system to classify the confidence level for groundwater models based on the following factors:

- available data;
- calibration procedures;
- calibration and prediction consistency; and
- level of stress (hydraulic stress in the model).

Models are classified as Class 1, 2 or 3 in order of increasing confidence, with characteristics and indicators for the model confidence level classification listed in Table 2.1 of the modelling guidelines.

2.2 IESC Information Guidelines Explanatory Note – Uncertainty analysis

The *Information Guidelines Explanatory Note – Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (**Information Guidelines**) published by IESC in 2018 aims to provide proponents and their consultants with a high-level introduction and strategic overview of uncertainty analysis relating to groundwater modelling for environmental impact assessment. It is intended to provide initial guidance on the value of, and need for, uncertainty analysis in groundwater modelling and outlines some common methods for quantifying uncertainty in groundwater modelling.

Some guidance is also provided on engagement with regulators and communication of uncertainty.

With regard to model uncertainty, the Information Guidelines suggest:

- modelling results be presented to show a range of possible outcomes based on uncertainty analysis;
- assessments of potential impacts outline the quality of, and the risks and uncertainty inherent in, the background data and the modelling, particularly with respect to predicted potential scenarios; and
- assessments acknowledge uncertainties in modelling, identify the sources of errors (e.g. conceptual model and parameter uncertainty) and quantify the level of uncertainty.

The IESC guidelines are meant to complement the Modelling Guidelines.

3. Estimating indirect water take

3.1 Overview

The Model is used to estimate maximum predicted water take (including both short-term and long-term indirect water take) due to the Project, and therefore estimate the size of the water licences Santos is required to hold for the development in accordance with CoC B27 and B28.

For the purposes of estimating Phase 1 water licence requirements, the volume of water from one Water Sharing Plan Reporting Area (**WSPRA**) to another WSPRA is estimated using the most recent update of the Model. The maximum predicted water take, maximum short-term and maximum long-term indirect water take will be based on model predictions of the water balance as outlined in the section 3.2.

3.2 Phase 1 method statement

The model used to determine the potential groundwater impact from the Phase 1 operation was conservatively based on a 25-year operational life for the Phase 1 wells. The Model was updated with the Phase 1 annual water production forecast as shown in Figure 3.1. The forecasted water production is 2.9 gigalitres (**GL**) over the 25-year period with an expected production peak up to 1.26 megalitres (**ML**) per day (**ML/day**) approximately two years from the start of Phase 1. Water abstraction is planned from the following operational CSG wells which target the Early Permian coal seams of the Maules Creek Formation:

- 4 wells located in Bibblewindi West;
- 11 wells located in Bibblewindi East;
- 4 wells located in Dewhurst South; and
- 6 wells located in Dewhurst East.

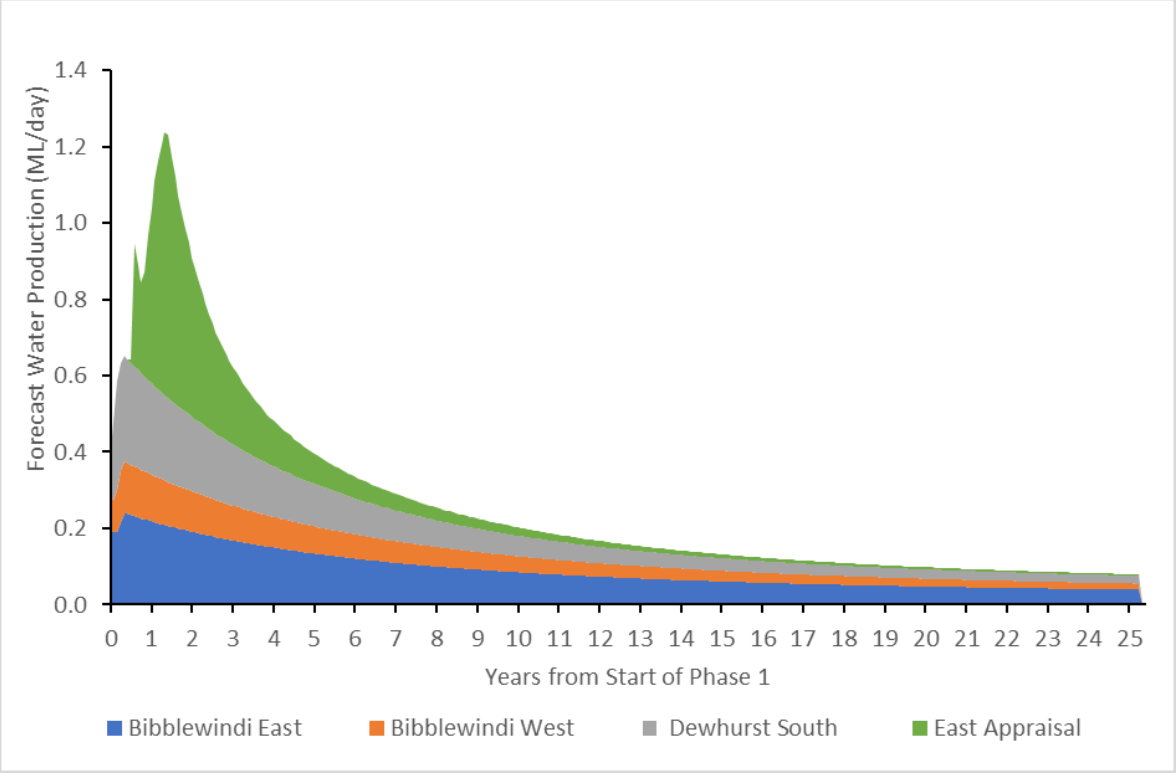


Figure 3.1 - Phase 1 annual water production forecast

The water production rate at each site is estimated depending on its respective total forecasted volume over each period. The forecast of Phase 1 water production will be regularly reviewed and estimates, if necessary, will be adjusted long before indirect water take peaks, thus providing a sufficiently conservative basis for the estimation of maximum predicted indirect water take. It should be noted that water production estimates are generated independently of groundwater impact predictions, and that water production is then used as a model input for the groundwater impact model.

Table A1 in Appendix A identifies 21 areas that are used as the basis for simulating inter-formation flows and annual volume exchange between recognised groundwater sources. The extents of these areas are based on the groundwater source areas defined in four water sharing plans that cover the model area. Maps of the water sharing plan reporting areas used in the Model are illustrated in Figure A1 in Appendix A.

Annual indirect water take due to coal seam water production for each water sharing plan reporting area is estimated as the difference between the annual volume exchange from the reporting area to another during an annual simulation period and the initial flow rate. The initial flow rate is the value of the flow rate prior to coal seam water production commencing and corresponding to the model's initial conditions. The maximum predicted water take represents the largest deviation of the annual volume exchange from the initial value due to coal seam water production.

4. Review schedule

4.1 Overview

During Phase 1, model reviews will be conducted by suitably qualified and experienced persons if triggered by exceedance of the impact response triggers described in the GMP, as otherwise directed by the Planning Secretary or as a scheduled commitment prior to commencement of Phase 2.

Contingent on the outcome, any review may result in a model update. However, the model review prior to Phase 2 will require an update to the groundwater model.

4.2 Scheduled model reviews

CoC B39(e) specifically requires that Santos improve the groundwater model prior to the commencement of Phase 2, to the satisfaction of the Planning Secretary, to be generally in accordance with features of a Class 3 confidence level model.

The following Sections outline the proposed groundwater model improvement workflow prior to Phase 2. It comprises six stages, compliant with all the requirements of CoC B39 which is described in Section 1.2.

Santos will prepare reports that will facilitate the communication of findings at Stages 1, 2, 5 and 6 to DPE Water, EPA and the WTAG. The feedback received by DPE Water, EPA and the WTAG on these reports will comprise a record of the consultation mandated by CoC B39(c).

The workflow may vary from that which is prescribed below, depending particularly on the advice received from stakeholders (e.g. DPE Water, EPA and the WTAG) throughout the model improvement process. However, the scope outlined in the Sections below is likely to comprise the minimum scope that will be completed.

The timeline for groundwater model improvement workflow prior to Phase 2 will be subject to review throughout the model improvement process. The timeline may vary for various reasons, such as changes to the schedule for the commencement of Phase 1 or Phase 2 or due to feedback received during stakeholder consultation.

An initial schedule of the groundwater model improvement workflow prior to Phase 2 is outlined below:

Table 4.1 - Schedule for groundwater model improvement prior to Phase 2

Model improvement stage	Description	Timeline
1	Review model objectives	October to November 2022
2	Initial model conceptualisation	November 2022 to January 2023
3	Data collection	January 2022 to March 2023
4	Data interpretation	February to June 2023
5	Model conceptualisation and review	June to September 2023
6	Updated impact assessment modelling and interpretation	August to December 2023

4.2.1 Stage 1 – Review modelling objectives

Stage 1 will review the modelling objectives. The aim will be to ensure stakeholder consensus regarding the target model confidence level classification.

A target model confidence class will be based on realistic expectations of:

- the data that is available prior to improve the model
- the manner in which the model will be calibrated, and
- how predictions are expected to be formulated.

Stakeholder consultation will comprise, as a minimum, separate technical workshops with the WTAG and DPE Water, and stakeholder feedback on a draft report. Following receipt of feedback, a final report will be prepared that summarises the modelling objectives.

4.2.2 Stage 2 – Initial model conceptualisation

Stage 2 will comprise a desktop review of information that will be used to inform the conceptualisation of the groundwater model prior to Phase 2. As a minimum this will comprise a desktop assessment of the structural geology and hydrogeological characterisation.

The desktop assessment of structural geology will review knowledge of the following geological structures as they pertain to the potential groundwater model domain:

- the termination of the Maules Creek Coal at the basin margins;
- extent, thickness and termination of Permian aquitards immediately above the Maules Creek Coal;
- extent, thickness and termination of aquitards throughout the Gunnedah Basin;
- the juxtaposition of strata across geological unconformities;
- location, extent and orientation of faults in Permian aged strata;
- location, extent and orientation of faults across the Permian, Triassic and Jurassic aged strata; and
- the location, extent and orientation of geological intrusions throughout the Permian, Triassic and Jurassic aged strata.

The desktop assessment of hydrogeological characterisation will review:

- the existing NGP groundwater model conceptualisation;
- more recent research findings (e.g. Suckow et al (2018), Raider & Suckow (2019), Iverach et all (2020) and Raiber et al (2022));
- groundwater monitoring data collected since 2016; and
- Narrabri Coal Mine groundwater assessment.

Stakeholder consultation will comprise, as a minimum, separate technical workshops with the WTAG and DPE Water, and stakeholder feedback on a draft report. Following receipt of feedback, a final report will be prepared that summarises the initial model conceptualisation.

4.2.3 Stage 3 – Data collection

Field data collection will comprise, as a minimum:

- Acquisition of core of target coal, coal interburden and the Watermark Formation aquitard overlying Maules Creek Formation coal seams;
- Analysis of core properties at high-frequency intervals (e.g. every 10 metres) for permeability, porosity, lithology and geophysical properties;
- Employment of geophysical data collection methods in the cored well, for example nuclear magnetic resonance (NMR) which provides continuous profile of permeability indicators;
- In-situ permeability testing, such as modular dynamic test, across more permeable zones where core could not be acquired and rising/falling head tests in single-zone monitoring bores;
- Review of CSG pilot data, including extraction rates and offset reservoir pressures;
- Interpretation of new seismic surveys to bolster exiting seismic survey in and around proposed Phase 2 development area.

Other data that will be collated at this stage is described in Section 5.2.

4.2.4 Stage 4 – Data interpretation

Stage 4 will interpret data from previous stages. The overarching aim will be to improve the groundwater model commensurate with the agreed model objectives at Stage 1.

Stratigraphic modelling will comprise a review and improvement of the geological model based on the initial conceptual model developed at Stage 2 and any new data acquired during Stage 3. The objective will be to reduce the conceptual uncertainty that relates to groundwater flow paths that are represented within the groundwater model.

Lithofacies modelling provides a means of reducing uncertainty relating the hydraulic parameterisation of the aquitards that overly the target coal seams. This is likely to comprise:

- Reinterpret geophysical data from both new and existing wells to derive lithofacies models and permeability profiles across the Phase 2 development area;
- Experimental small-scale 3D groundwater models developed from lithofacies models which focus on the Maules Creek Formation coal seams and immediately overlying aquitards which can be calibrated to pilot test data;
- Develop a range of upscaled upscaled parameters from the small-scale modelling (see above) and determine likely ranges of parameters for other formations based on the improved geophysical data.

Other interpretive methods that may be incorporated prior to Phase 2 are described in Section 5.3.

4.2.5 Stage 5 – Model conceptualisation and review

Stage 5 will update the hydrogeological conceptual model drawing on data and other information collected during Stages 1-4. It will specifically address changes to the conceptual model developed at Stage 2, identify any knowledge gaps, uncertainties and plausible alternative conceptual models for investigation in Phase 2.

A model review will be undertaken, as described in Section 5.3 and 5.4.

Stakeholder consultation will comprise, as a minimum, separate technical workshops with the WTAG and DPE Water, and stakeholder feedback on a draft report. Following receipt of feedback, a final report will be prepared that summarises the model conceptualisation prior to Phase 2.

4.2.6 Stage 6 - Updated impact assessment modelling and interpretation

Stage 6 will comprise running the groundwater model as required by CoC B39.

The updated model predictions which will be generated are described in Section 6.5.

Modelling objectives will be assessed and reported in the context of the target model confidence level classification derived in Stage 1. A model report will be prepared as described in Section 7.

Santos will seek regulatory approval of the Phase 2 Water Management Plan once a final report has been prepared that summarises the model improvement process, the updated predictions of drawdown and water take, and an interpretation of the findings.

4.3 Triggered model reviews

The requirement to conduct a model update prior to Phase 2 could be triggered by exceedance of response trigger levels defined in Section 8 of the GMP.

The objective of these triggers is to ensure the impact from extraction due to CGS production is limited to surrounding confining beds. Project performance against the trigger levels is monitored and reported separately to the GModP through reporting procedures outlined in Section 8 and Section 9 of the GMP.

5. Data review

5.1 Overview

A review of the Model triggered by exceedance of response trigger levels will comprise test of concept, verification and potential update of the Model and model predictions.

In absence of a trigger, the groundwater model will be improved prior to Phase 2 to be broadly in accordance with the features of a Class 3 confidence level model. The workflow proposed to achieve this is outlined in Section 4.2.

The role of the WTAG it is to provide advice on project-related water management issues, including preparation and implementation of the groundwater model and WMP. The planned investigations which will be executed during Phase 1 were developed in consultation with the WTAG and prior to submission of the GMP for review by the WTAG and DPE-Water.

A data review triggered by the TARP will be supported by the collection of Project information, hydrogeological data, and groundwater and surface water monitoring data.

Broad objectives for model improvement prior to Phase 2 comprise:

- increase groundwater model certainty, particularly the hydraulic properties of the aquitards immediately overlying the target coal seams
- Model results to optimise monitoring network design for Phase 2 to ensure high data-worth of monitoring points to continue to improve model confidence over time
- Model results to derive effective performance criteria applicable to Phase 2 of the Project.

Model data reviews as described in Section 4 will be conducted by a suitably qualified and experienced person/s and are reported under the GModP reporting procedures in Section 7.

5.2 Data sources for model review

Data sources which will support the model review process described in Section 4 will typically include the following:

- publicly available information including:
  - relevant scientific research results published in peer reviewed journals;
  - data and technical reports published through the Bioregional Assessment Project - Namoi subregion on-line Information Platform; and
  - outcomes of hydrogeological research published by the Gas Industry Social and Environmental Research Alliance (**GISERA)**;
  - water resource management plans and publications;
- reports of studies conducted by Santos within the Project;
- well data cards for coal seam gas production wells and appraisal drill holes including:
  - geological logs of subsurface samples;
  - geophysical wireline logs and log interpretations;
  - formation fluid pressure survey data;
  - drill stem test data;
  - flow test data;
  - water analysis data; and

    - well location survey data;
- geological logs, monitoring bore construction logs, borehole permeability test results and laboratory test results of subsurface samples from groundwater monitoring bores;
- the historical pattern of field development at the time of review, including the number, locations, depths and times of commissioning of coal seam gas production wells;
- the latest Field Development Plan at the time of review, including the planned development pattern and timing for commissioning of future coal seam gas production wells;
- historical water production at the time of review, including water production rates and volumes within the collector network;
- the latest forecast of future water production at the time of review;
- hydraulic head (formation pressure) and water quality parameter time series records from the groundwater monitoring program; and
- meteorological data and data records from surface water monitoring conducted by Santos.

Additional data may be sourced from publicly available data sources including the Northern Inland Catchments Bioregional Assessment. Refer to the GMP for details associated with the collection and management of the above data sources.

5.3 Data analysis and interpretation for Model review

The latest datasets will be analysed, interpreted and reviewed for consistency with the conceptual hydrogeology on which the project groundwater model is based. These additional datasets are considered within the context of the historical datasets and hydrogeological knowledge at the time of review. The potential outcomes of this review may involve revision of the conceptual hydrogeology, which could require changes to the following elements of model representation:

- hydrostratigraphy;
- geological material hydraulic properties;
- fault structures; and
- field development and water production.

5.3.1 Hydrostratigraphy

Additional information on formation tops and thicknesses will be compared against the existing representation of hydrostratigraphic formation tops and thicknesses. The potential outcome of this review may involve adjustment of the geological model layers (e.g., changes to the number of layers and / or their top elevations and thicknesses) to better represent all available hydrostratigraphic information in the areas of additional data.

5.3.2 Rock and soil hydraulic parameters

Revision or addition of data and information related to rock and soil hydraulic properties will be analysed, including:

- hydraulic conductivity and transmissivity of aquifers and aquitards;
- intrinsic permeability of coal seams;
- specific yield and storativity of aquifers and aquitards.

These data sets may become available from data sources listed in Section 5.3.

Methods for estimating rock and soil hydraulic properties developed as part of studies (e.g. Turnadge et al, 2018) conducted for the Northern Inland Catchments Bioregional Assessment and GISERA will also be reviewed. These methods may be applied, when practical, to review typical permeability value estimates used in the model for the various hydrostratigraphic units and to improve estimates for upper and lower permeability values of hydrostratigraphic units for model calibration.

5.3.3 Fault Structures

Revisions and update to the geological structural model including:

- detailed structure assessment;
- consideration of neotectonics and the stress field in the project area and surrounds; and
- consideration of faulting, and exclusion of faulting.

The structural model will be constructed within a three-dimensional geological modelling framework and will be based on a combination of geological datasets including historical and most recent drilling and seismic data.

5.3.4 Field development and water production

The review of field development and water production considers both the historical and planned future development of the Project coal seam gas field at the time of review.

The historical pattern of field development and water production will be compared against the representation of field development in the Model, including the number, locations, depths and times of commissioning of coal seam gas production wells and water production rates. The expected outcome of this review will be the adjustment of the historical pattern of water extraction in the model to better represent the pattern of field development since the previous model review.

The latest field development plan and water production forecast at the time of review will be compared against the representation of future field development in the Model. The potential outcome of this review may involve adjustment of future water extraction in the Model to better represent the planned field development over the remaining life of the Project.

6. Model review

6.1 Overview

Model reviews will be undertaken by a suitably qualified and experienced person/s following each model data review and therefore occur with the same frequency. A model review process flow may include the following steps:

- objective review;
- model revision; and
- prediction updates.

Model reviews will be undertaken in accordance with the relevant guidelines listed in Section 2 and reported under the GModP reporting procedures in Section 7.

6.2 Objective review

Modelling objectives may need to be reviewed in consultation with Water group within the NSW Department of Planning and Environment (**DPE**) (generally referred to as **DPE Water**), the NSW Environment Protection Authority (**EPA**) and the Water Technical Advisory Group. If required, the updates to the modelling objectives may include the adjustments of criteria for assessing whether the model is generally in accordance with the features of a Class 3 confidence level model.

6.3 Model revision

Updates to the Project groundwater model will be informed by the model data review described in Section 4 and guided by the current or updated modelling objectives.

If required, the updates to the model may include, but are not necessarily limited to, the following adjustments to:

- Model layers to improve the representation of hydrostratigraphy;
- Model's lateral resolution to increase level of spatial details of hydrogeological structures and sink/source terms represented in the model;
- the approach of modelling the effect of fault structures on inter-aquifer flows and groundwater heads;
- boundary conditions to better represent the historical and future patterns of field development at the time of review; and
- boundary conditions and model parameters to better represent historical and forecast future water production at the time of review.

6.4 Model calibration

The quality of the calibration match will be assessed through reference to the scaled root mean square (**SRMS**) error and other statistics, which analyse differences between the measured and modelled values. Where this review identifies that the calibration is deficient or have significantly deteriorated then the Model will be recalibrated by adjusting the Model parameters to better match observed hydraulic head records.

6.5 Prediction update

6.5.1 Overview

The potential impacts of the Project will be re-assessed following each update of the Model using the updated model version.

The updated estimates of induced aquifer interflow and change in groundwater heads will be conducted for the following predictive simulations:

- base case project development;
- base case project development and cumulative impacts (historical and predicted) of other mining activities; and
- predictive uncertainty analysis.

Predictive simulations will be run out to several thousand years after Project completion to capture maximum effects beyond the life of the Project and to show predicted post-production recovery of formation pressures.

The updated model predictions will be reported under the GModP reporting procedures outlined in Section 7.

6.5.2 Base case Project development

The base case predictive simulation will be designed to represent the effects of the Project on groundwater sources by considering only the Project-related stresses and removing background effects that may be unrelated to the Project (such as existing third-party groundwater abstractions). The base case simulation will use the latest model version and calibrated model parameters, and will simulate the following project activities:

- historical water production from appraisal activities up to the time of review (e.g., pilot wells);
- historical field development and water production up to the time of review; and
- planned field development and forecast water production for the remaining life of project.

6.5.3 Base case cumulative impacts

The base case cumulative impacts simulation will predict the potential cumulative impacts from the base case Project development and third-party groundwater extractions and injections associated with significant mining activities within the Project area. Third-party mining activities will be represented in the modelling as equivalent groundwater extractions at the locations of the mining activities. The simulations will not attempt to directly model the mining activities.

Cumulative impacts will be included in the simulation if data on groundwater extractions and injections are available from third parties, including the impacts from the Great Artesian Basin Sustainability Initiative [**GABSI**]) and the consideration of leakage from the GAB to the Lower Namoi Groundwater Source using the heads predicted by the EIS model. These data need to include the historical extractions and injections of the mining operation at the time of review as well as the modelled or forecast future extractions and injections.

6.5.4 Uncertainty analysis

The purpose of the predictive uncertainty simulations will be to provide information about uncertainties in the conceptualisation and model simulations that help decision makers to understand the effects of uncertainty on Project objectives and risk.

Middlemis et al. (2019) presented eleven guiding principles for designing a model workflow to assess uncertainty in groundwater modelling projects. Two pertinent principles to this GModP include:

> *"Uncertainty analysis results should be: (i) carefully tailored to decision makers' needs (i.e. based on consultation), (ii) focussed on the messages that are most likely to be relevant to their decisions; and (iii) presented in plain and clear (precise, non-jargon) language;* and
>
> *Project workflow should be iterative, revisiting objectives, assumptions, conceptualisations and simulations, as well as the risk assessment (with consideration of any risk treatments applied to mitigate impacts), in a process of engagement between proponents, water managers (agencies) and their technical experts and reviewers that begins at Project inception."*

Within this context, the details of uncertainty simulations conducted following a model update will not be prescribed in the GModP. Instead, they will be designed through consultation at the time of a model update. For details on consultation see Section 8.2.

6.5.5 Predictive results

Results of predictive simulations will typically be presented as predicted drawdown of hydraulic head (depressurisation) and induced change in groundwater fluxes from, and between, groundwater sources. They include, but are not limited to, the following formats:

- maximum drawdown and time of maximum drawdown value in all model cells of pertinent hydrostratigraphic units, including the Namoi Alluvium, Pilliga Sandstone and Late and Early Permian coal seam targets;
- maximum predicted indirect water take between Water Sharing Plan reporting areas (presented in Appendix A) and times of the maximum predicted indirect water take values; and
- annual rates of induced storage release (net induced water take) from all declared groundwater sources in Water Sharing Plans, including the Gunnedah-Oxley Basin, GAB Southern Recharge, GAB Surat, Lower Namoi Alluvium, Upper Namoi Alluvium, Liverpool Ranges Basalt and Warrumbungle Basalt groundwater sources.

Presentation of pressure head drawdown results is designed to inform an updated assessment of the potential effects of the Project water extraction on hydraulic head and pressure within groundwater sources, and potential effects on access to existing uses of those sources.

The presentation of induced groundwater fluxes in the results is designed to inform assessment of Project water take from all sources and the associated water entitlement considerations.

Results in other formats may also be provided as requested through consultation.

6.5.6 Impact assessment

Results of predictive simulations will be interpreted in the context of groundwater performance measures outlined in Table 7 [of the CoC]. This will include, for example:

- impact assessment update – an updated assessment of the significance of re-predicted impacts and implications for project risk, including implications in relation to:

  - comparison with previous model predictions and monitoring results;
  - groundwater management response triggers in Table 8.1 of the GMP;
  - minimal harm considerations in the NSW *Aquifer Interference Policy*; and
- relevant water management performance measures listed in Section 1.4 of the GMP.

7. Reporting

Each model review will be documented in a groundwater model review report prepared by Santos.

The content of any model review report includes, but is not limited to, the following Sections:

- introduction - context for the model review and type of model review;
- model data review - results of the review, analysis and interpretation of model datasets, as described in Section 5 of this Plan;
- model post-review - results and recommendations of the model review, as described in Section 6 of this Plan;
- impact assessment update - an updated assessment of the significance of re-predicted impacts and implications for project risk and groundwater performance criteria specified in the CoC; and
- statement of the model assumptions and limitations.

The content for a model review report may vary and will not include reporting on transient model calibration for the case of a Level 1 Trigger Response model revision as described in Section 4.3. As required by CoC B39(f)(vi), the model review report will consider the predicted impacts:

- previous model predictions and monitoring results;
- water management performance measures in Table 7;
- minimal harm considerations in the NSW Aquifer Interference Policy; and
- groundwater management response triggers in the Water Management Plan.

8. Evaluation and review

8.1 Independent peer review

Each model review report will be reviewed by an independent peer reviewer appointed by Santos. The independent reviewer will be a suitably qualified and experienced person/s whose appointment has been endorsed by the Planning Secretary and in consultation with DPE Water, EPA and the Water Technical Advisory Group. The independent model reviews will be guided by the recommendations for numerical groundwater model reviews as described in the Modelling Guidelines.

8.2 Plan review

Consent condition D4 states that Santos must review the suitability of existing strategies, plans and programs required under this consent, within two months of:

(a) the submission of an incident report;
(b) the submission of an Annual Review;
(c) the submission of an Independent Environmental Audit;
(d) the submission of a Field Development Plan;
(e) the submission of a Groundwater Model Update; or
(f) the approval of any modification of the conditions of this consent.

This is to ensure the GModP is updated on a regular basis and to incorporate any recommended measures to improve the environmental performance of the Project.

The review history table in the front of this Plan provides the details of each review, conducted in accordance with condition D4.

Consent condition D5 in turn states that if the review under condition D4 determines that the strategies, plans and programs required under this consent require revision - to either improve the environmental performance of the development, cater for a modification or comply with a direction - then Santos must submit the revised document to the Secretary for approval within 6 weeks of the review.

This GModP will be reviewed as mandated in accordance with the groundwater TARP outlined in the GMP. The GModP may be reviewed to allow the components and procedures of the Plan to be adjusted and adapted to potentially changing circumstances over the lifetime of the Project. The review includes appraisal of the adequacy of the model review triggers defined in Section 4.3.

Review of the GModP (including the model update) will be conducted by a suitably qualified and experienced person/s whose appointment has been endorsed by the Planning Secretary and in consultation with DPE Water, EPA and the WTAG.

The outcome of the review of the GModP may involve changes to the approach and procedures within the strategy.

9. References

GHD (2017). *Narrabri Gas Project Environmental Impact Statement*. Prepared for Santos Ltd.

Middlemis H and Peeters LJM (2018). *Uncertainty analysis—Guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

Middlemis H, Walker G, Peeters L, Richardson S, Hayes P, Moore C. (2019). *Groundwater modelling uncertainty – implications for decision making*. Summary report of the national groundwater modelling uncertainty workshop, 10 July 2017, Sydney, Australia. Flinders University, National Centre for Groundwater Research and Training, Australia.

Turnadge C, Esteban L, Emelyanova I, Nguyen D, Pervukhina M, Han T and Mallants D (2018). *Multiscale aquitard hydraulic conductivity characterisation and inclusion in groundwater flow models: Application to the Gunnedah Basin, New South Wales*. Prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra.

10. Glossary

Term	Definition
Alluvial	Sediments deposited following a decrease in velocity of flowing water
Alluvium	General term for unconsolidated fluvio-lacustrine deposits of inorganic materials (clay, silt, sand, gravel, and boulders) deposited following a decrease in velocity of flowing water
Alluvium aquifer	An aquifer formed within alluvium. See Alluvium.
Aquifer	A saturated permeable geologic unit that can transmit useful quantities of water
Baseline	A starting point used for future comparisons. Water baselines in context of the Narrabri Gas Project have been derived from long term water level and quality data presented in the Narrabri Gas Project Water Baseline Report.
Depressurisation	The extraction of coal seam water to facilitate gas production causes depressurisation of the target coal seams, which has the potential to propagate into surrounding formations.
Namoi Alluvium	The Upper Namoi Alluvium, an aquifer made of coarse-grained river gravels and sands. The Lower Namoi Alluvium, a hydrostratigraphic unit made of shallow alluvial fan deposits associated with the Namoi River. These units contain a significant resource of readily accessible, good quality groundwater that is heavily utilised for irrigation, public water supply, private water supply and livestock
Planning Secretary	Planning Secretary under the EP&A Act, or nominee
Produced water	Any form of groundwater that is actively extracted from a borehole, well or excavation, excluding incidental groundwater mixed with drilling fluids
Project area	The area of approximately 95,000 hectares that encompasses the Project
Project footprint	The area of surface expression being about 1,000 hectares occupied by the infrastructure components of the Narrabri Gas Project
Recharge spring	A spring supported by water that recharges sandstone sediments that outcrop on the margins of the Great Artesian Basin and discharge locally after relatively short residence times.
Response Trigger Process	The requirements for a groundwater model update outside the three-yearly review schedule that is triggered by exceedance of a performance trigger
Spring	A naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the water table intersects the ground level.
Transmissivity	Rate in which water of a given density and viscosity is transmitted through a unit width of aquifer or aquitard under a unit hydraulic gradient.
Water sharing plan	Legislated plans under the *Water Management Act 2000* that establish rules for sharing water between the environment and water users. Water licences are issued to water users in accordance with water sharing plans

Appendix A - Water Sharing Plan Reporting Areas

Table A1 and Figure A1 present the Water Sharing Plan reporting areas (WSPRAs) used as the basis for reporting groundwater fluxes between declared groundwater sources. The extents of the WSPRAs are derived from the groundwater source areas defined in the four water sharing plans falling within the model area.

The Lower Namoi alluvium (*WSP for the Namoi Alluvial Groundwater Sources Order 2020*) is divided into two WSPRAs representing vertical groundwater fluxes from the base of the alluvium to the Southern Recharge Groundwater Source and to the Surat Groundwater Source (*WSP for the NSW Great Artesian Basin Groundwater Sources 2020*).

The Upper Namoi alluvium is southeast of the Lower Namoi alluvium and overlies the Gunnedah-Oxley Basin groundwater source (*WSP for the NSW Murray-Darling Basin Porous Rock Groundwater Sources Order 2020*). The Upper Namoi alluvium is sub-divided into eleven WSPRAs representing vertical groundwater flux from the base of the alluvium within the eleven Groundwater Management Area (**GMA**) zones located within the groundwater model domain.

WSPRAs 14 and 15 define the area of vertical groundwater flux from the base of the Liverpool Ranges Basalt groundwater source (*WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources Order 2020*) to the Gunnedah-Oxley Basin groundwater source. These two WSPRAs represent the respective sub-crop areas of the Oxley Basin and Gunnedah Basin.

WSPRA 16 defines the area of vertical groundwater flux from the base of the Warrumbungle Basalt groundwater source (*WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources Order 2020*) to the Surat groundwater source.

WSPRAs 17 and 18 define the area of vertical groundwater flux from the Gunnedah-Oxley Basin to the Late Permian coal seam targets from above. WSPRA 17 corresponds to the areal projection of the Oxley Basin onto the Late Permian targets and WSPRA 18 corresponds to the areal projection of the Gunnedah Basin onto the Late Permian targets.

WSPRA 19 defines the area of vertical groundwater flux from the Gunnedah-Oxley Basin to the Early Permian coal seam targets from above.

WSPRAs 20 and 21 define the area of vertical groundwater flux from the base of the Pilliga Sandstone, and provide an approximation of vertical groundwater flux from the Southern Recharge and Surat Groundwater Sources to the Gunnedah-Oxley Basin groundwater source.

Table A1 – Relevant Groundwater Management Area Zones

Water Sharing Plan	Groundwater Source	WSPRA	Description
Namoi Alluvial Groundwater Sources Order 2020	Lower Namoi	1	Flux from base of alluvium to GAB Surat
		2	Flux from base of alluvium to GAB Southern Recharge
	Upper Namoi	3	Flux from base of alluvium to GOB in GMA zone 1
		4	" " " " GMA zone 2
		5	" " " " GMA zone 3
		6	" " " " GMA zone 4
		7	" " " " GMA zone 5
		8	" " " " GMA zone 6
		9	" " " " GMA zone 7
		10	" " " " GMA zone 8
		11	" " " " GMA zone 9
		12	" " " " GMA zone 10
		13	" " " " GMA zone 11
NSW MDB Fractured Rock Order 2020	Liverpool Ranges Basalt	14	Base of basalt to Oxley Basin
		15	Base of basalt to Gunnedah Basin
	Warrumbungle Basalt	16	Base of basalt to GAB Southern Recharge
NSW MDB Porous Rock Order 2020	Gunnedah-Oxley Basin	17	Oxley Basin to Late Permian coal seam targets
		18	Gunnedah Basin to Late Permian coal seam targets
		19	Gunnedah Basin to Early Permian coal seam targets
NSW Great Artesian Basin 2020	Southern Recharge	20	GAB Southern Recharge to Gunnedah Basin
	Surat	21	GAB Surat to Gunnedah Basin

Notes:

GAB - Great Artesian Basin
GOB - Gunnedah-Oxley Basin

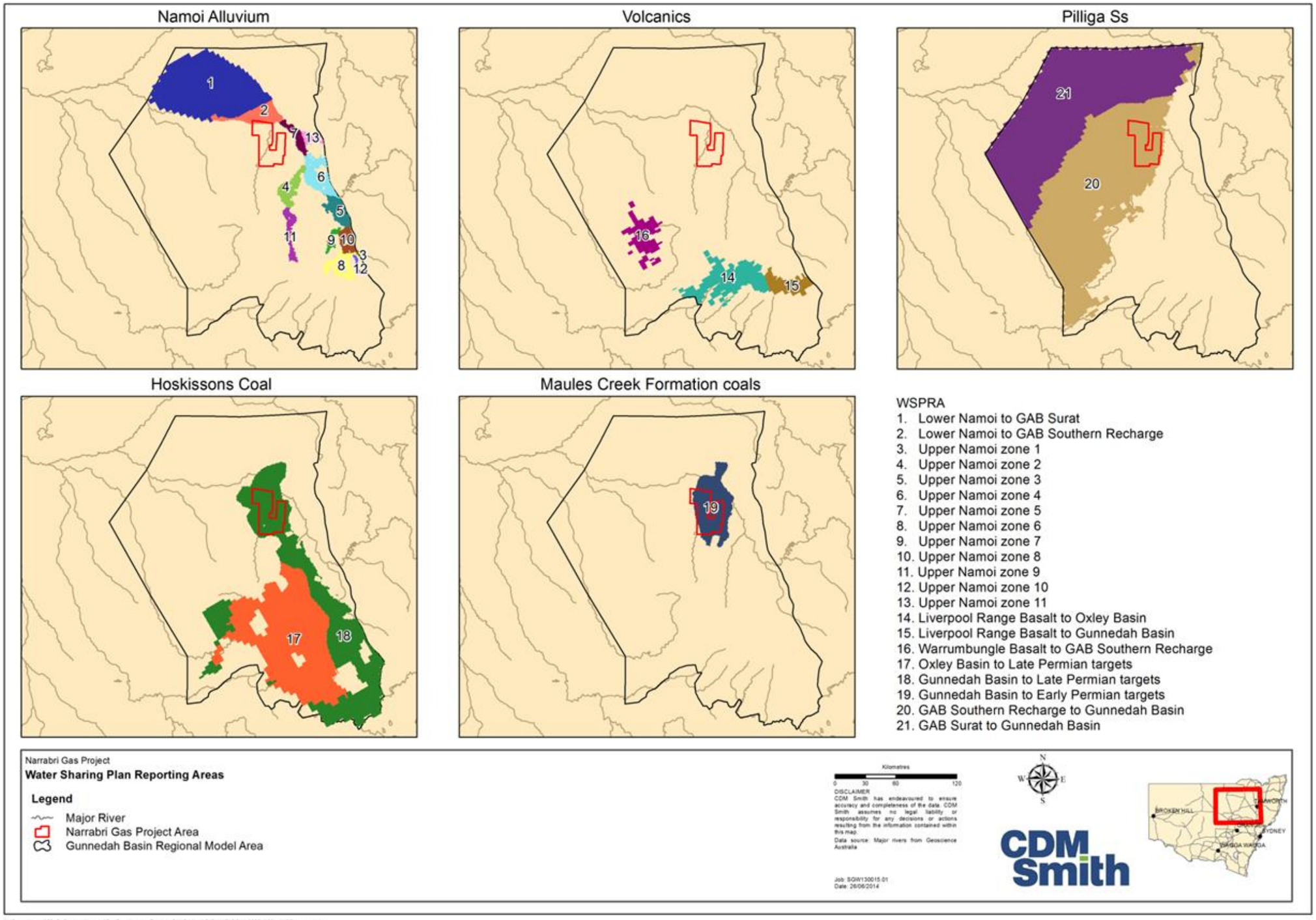


Figure A1 - Water Sharing Plan reporting areas