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Atlas Stage 3 Gas Project

EPBC Water Resource Impact Assessment

Revision 3

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EXECUTIVE SUMMARY

Senex Energy Pty Ltd (Senex), on behalf of its subsidiaries Senex Assets Pty Ltd and Senex Assets 2 Pty Ltd, is proposing to develop, operate, decommission, and rehabilitate new coal seam gas (CSG) wells and associated infrastructure on Authority to Prospect (ATP) 2059, Petroleum Lease (PL) 445, the northern portion of PL209 and parts of PL1037 in the central part of the Surat Basin, Queensland (the proposed action). An assessment has been undertaken to consider the potential impact to water resources and water-dependent assets under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) (Commonwealth of Australia 2022a) as a result of the proposed Project activities. The assessment has been conducted with reference to the '*Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources*' (Commonwealth of Australia 2022b), *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Commonwealth of Australia 2013) and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) information guidelines for proponents preparing coal seam gas and large coal mining development proposals (IESC 2018a).

This assessment was prepared for submission to accompany Senex's *EPBC Act* Referral for Project Atlas to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW).

On the May 19, 2023, the delegate for the Minister for the Environment and Water decided that the development associated with PL 445, PL 209 and ATP 2059 is a 'Controlled Action' and requires approval under the EPBC Act. On June 6, 2023, a request for further information (RFI) detailing additional information requirements to be included in the Preliminary Documentation (PD) was issued by DCCEEW. This assessment has been updated in response to the RFI from DCCEEW.

Description of the Project

The Atlas Stage 3 Gas Project (the Project) covers an area of approximately 98 km^2 and is located approximately 10 km southwest of the township of Wandoan. Proposed production activities include the installation of up to 151 CSG wells and their connection to gas and water gathering lines, water separation and treatment facilities, water management facilities and associated infrastructure.

Surface Water Context

The Project is located within the Upper Dawson River sub-basin, which is part of the Fitzroy River Basin. Key watercourses within the Project area include Woleebee Creek, Wandoan Creek, Conloi Creek and Hellhole Creek. Watercourse flows in the Project area are characteristically ephemeral and episodic in nature, and typically generated only due to significant runoff events. This is likely a consequence of the Project area being in the uppermost reaches of the catchments, with limited runoff area. There are no identified third-party surface water users in the vicinity of the Project.

Groundwater Context and Groundwater Dependent Assets

The target units for CSG production for the Project is the Walloon Coal Measures (WCM), a formation within the Surat Basin. The Surat Basin forms part of the Great Artesian Basin (GAB), which comprises several aquifers and aquitards.

Aquifers of the Surat Basin are a significant source of water used for public water, agricultural, stock and domestic supply, with the majority of use in the vicinity of the Project for stock and domestic purposes. There are 669 registered existing potential groundwater bores within the Project boundary and in the 25 km buffer zone outside of the Project.

Groundwater Dependent Ecosystems (GDEs) within the Project area include stygofauna, and potential terrestrial GDEs associated with the alluvium. GDEs are identified within the Project area including potential watercourse springs and potential terrestrial GDEs. There are no spring vents or complexes in the vicinity of the Project.

Connectivity Between the Alluvium and Underlying Surat Basin Units

To assist Senex with the understanding of the hydraulic connection between the alluvium and the underlying Surat Basin units, drilling and monitoring bore installations were completed across the Project area between December 9, 2022, and September 9, 2023. Eight monitoring bores were installed as adjacent pairs at four locations. Four of those were installed in alluvium, and four in underlying Surat Basin units (Springbok Sandstone and Westbourne Formation). The bores have been monitored for groundwater quality and groundwater levels since installation.

The alluvium is not recognised to be connected to the Surat Basin units in the Project area. The field investigations provided both hydraulic and hydrochemical evidence to support the interpretation that these units are disconnected. Primary evidence includes water level data and water quality/isotope data:

- Vertical separation of water levels in the alluvium and the Springbok Sandstone was evident. The alluvium was confirmed to be dry in the majority of monitoring bores, and groundwater levels within the underlying units were found to be below the base of the alluvium during site investigations and during ongoing monitoring.
- There is a distinction between regional alluvium groundwater quality (bores from surrounding adjacent projects) and the underlying Westbourne Formation and Springbok Sandstone groundwater quality (which is more saline). Alluvium groundwater quality is comparable to surface water quality, indicating the alluvium is recharged/replenished by the surface water systems during flow events.

Impact Assessment

The Project is located within the Surat Cumulative Management Area (CMA), which was declared in 2011. The Office of Groundwater Impact Assessment (OGIA) was established under the *Water Act 2000* and is responsible for predicting regional impacts on water pressures in aquifers, developing water monitoring and spring management strategies; and assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within the Surat CMA. These predictions, strategies and responsibilities are set out in the Surat CMA Underground Water Impact Report (UWIR), prepared, refined, and maintained by OGIA.

Outputs from the Surat CMA numerical model have been used to predict drawdown impacts to groundwater. Based on the information provided by Senex, OGIA have modelled a Project only scenario, which includes only CSG water production from the Project and a Cumulative scenario, which includes the simulation of Senex CSG water production as well as all current and proposed developments for Origin, QGC, Arrow and Santos.

For the Project only scenario, the predicted long-term drawdown impacts associated with the Project are limited to the Westbourne Formation, Springbok Sandstone, WCM and Durabilla Formation. The cumulative model scenario drawdown results indicate drawdown within the vicinity of the Project area for the Westbourne Formation, Springbok Sandstone, WCM and Hutton Sandstone. The majority of the drawdown occurs towards the west of the Project and is associated with neighboring CSG developments and geological (fault) features. Drawdown also occurs to the southeast, where other CSG proponents are also operating.

Potential impacts to water-dependent assets have been considered with respect to the Queensland *Water Act 2000* water level trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the Project only and Cumulative predictive model scenarios.

Third-Party Bores

For the Project only scenario, 23 third-party groundwater bores in the WCM are predicted to experience a decline greater than the 5 m trigger threshold. These groundwater bores are predicted to be already triggered by adjacent developments (without contribution from the Project). There are five additional bores triggered as part of the cumulative scenario (i.e. the contribution of the Project development results in five additional bores being triggered in the cumulative scenario; these bores would not have been triggered without the presence of the Project). Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. Of the five additional bores, no bores are located within the Project tenement and all bores are located to the east of the Project. One of these bores is noted as “Abandoned and destroyed”, two are noted as “Monitoring bores (and not water supply bores)”, and two are noted as “Existing bores”. Of the existing bores, a bore baseline assessment confirmed one of these bores is blocked and has not been used since 1996 (Arrow 2013). The maximum Project only contribution to drawdown, the only existing usable bore is 1.3 m (26% of the cumulative drawdown).

Groundwater Dependent Ecosystems

The Project was assessed to not have a significant impact to GDEs. Based on the available characteristics of the GDE physiographic setting, it is interpreted that the potential GDEs may be intermittently supported by groundwater in the alluvium (which is not predicted to experience drawdown). There is no predicted drawdown in the alluvium for both the Project only and the cumulative scenarios. These potential terrestrial GDEs are considered to be resilient and adapt well to stress, with the larger eucalypts (including Forest Red Gums) having a dimorphic root system and are well adapted to the drying and wetting ephemeral setting associated with the creek systems.

Considering the GDEs through the source-pathway-receptor conceptualisation:

- The presence of the Project results in a predicted drawdown of >0.2 m in the Upper Springbok Sandstone underlying alluvium in the far north of the Project area in PL 445 (the source). This may impact an area of approximately 70 ha, of which 7 ha of terrestrial GDEs are present along Woleebee Creek (the receptor).
- There is a potential pathway for impact to the GDEs (the receptor) should a connection between the Springbok Sandstone and alluvium be present, resulting in drawdown in the Springbok Sandstone to induce flow from the alluvium. The alluvium is the most likely a water source for the GDEs given the depth to groundwater in the Springbok Sandstone (>13 m). However, there are two lines of evidence to support the argument that there is no connection:
  - Hydraulic Data – vertical separation of water levels in alluvium and Springbok Sandstone was evident across all groundwater monitoring events. Springbok Sandstone water levels were found to be below the base of the alluvium during site investigations.
  - Hydrochemical data - Springbok Sandstone water quality differs to that of the regional alluvium; Springbok Sandstone groundwater is more saline; therefore, alluvium is not hydraulically connected to the Upper Springbok Sandstone.
- The disconnect between the Springbok Sandstone and the alluvium infers there is no pathway for drawdown in the Springbok Sandstone (the source) to propagate into the alluvium, and no significant impacts to GDEs (the receptor) are predicted.

The Joint Industry Framework preliminary risk assessment suggests that should a connection exist the risk to GDEs is low as Project only drawdown is <1 m and is predicted to occur seven years after the CSG field is brought into production.

Surface Water

CSG activities may potentially result in non-drawdown related impacts to water resources. These may include impacts associated with drilling and construction of CSG production wells, CSG produced water storage facilities including the proposed brine storage on PL 1037, localised incidental CSG activities such as fuel spills or improper storage of chemicals and beneficial use activities, such as irrigation and stock watering. These potential impacts have been assessed and are mitigated and managed by adopting the appropriate standards and implementing appropriate controls. A chemical risk assessment of the drilling fluids and associated chemicals indicated that they are unlikely to highly unlikely to adversely affect matters of national environmental significance (MNES), due to the controls in place during drilling and the protocols/management practices in place if a spill should occur. These controls have been proven and successfully implemented at the adjacent Project Atlas tenement.

Direct impacts to surface water are not anticipated. Proposed activities of the Project do not include direct abstraction from or discharges to watercourses.

Subsidence

The potential subsidence based on the both the Project only and the cumulative model scenario groundwater level drawdown predictions, have been based on a methodology of applying a subsidence calculation based on the potential for compaction at a specific location (Sanderson 2012; Coffey 2018). The predicted cumulative induced subsidence (including the Project) has been estimated to be up to 0.063 m[1], with a range of 0.006 to 0.063 m across the Project (cumulative). The Project only subsidence is predicted to be between 0.002 and 0.058 m. The maximum change in ground slope from CSG-induced subsidence is expected to be less than 0.002% (20 mm over a km). Areas predicted to experience subsidence of less than 0.2 m are considered to be of low risk to environmental values (OGIA 2019b). A review of the land use within the Project area and near vicinity identified the following types of assets that may be impacted by subsidence:

- Linear infrastructure – roads, pipelines and power lines.
- Buildings and structures - farmhouses and other small buildings and dams (including small farm dams and lined CSG water dams).
- Rivers and streams - Woleebee Creek and its tributaries.
- Farm irrigation systems - centre pivot irrigation areas.
- Aquatic ecosystems – potential aquatic GDEs present as watercourse springs and potential terrestrial GDEs are known to occur in the Project area.

Based on a risk assessment of the predicted cumulative CSG-induced subsidence and the potential impact on the land uses and assets in the Project area it is unlikely that the adopted investigation thresholds will be exceeded.

When assessing against the significant impact criteria, it is concluded that the proposed development will not have a significant impact on water resources.

Monitoring, Mitigation and Management

To minimise the predicted potential impacts from the Project, Senex will adopt a number of mitigation, management, and monitoring measures.

As part of their CSG Water Management Strategy, Senex plan to beneficially use produced water through landholder water supply agreements. Senex will adhere to relevant environmental authority (EA) conditions as well as mandatory requirements and guidelines, including the '*Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 2'* (State of Queensland 2019a), applicable Australian Standards for storing and handling applicable materials, *'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures'* (DES 2016a), and *'Streamlined Model Conditions for Petroleum Activities'* (DES 2016b).

[1] Cumulative estimation including surrounding projects.

Groundwater monitoring will be undertaken in accordance with the requirements provided as part of the UWIR Water Monitoring Strategy (WMS) (OGIA 2021f) and Senex's Water Monitoring and Management Plan (WMMP) (SENEX-ATLS-EN-PLN-017). A seepage monitoring program has been developed to monitor for seepage associated with the existing water storage facilities on PL 1037, and any additional monitoring will be designed and established where required in accordance with the relevant EA conditions.

Senex have installed a site-specific monitoring bore network within the Project area, which consists of four sites with paired monitoring bores screened in the alluvium and underlying Surat Basin units. These bores are used for monitoring water level and quality in each of the associated hydrostratigraphic units. Additional groundwater monitoring bores are proposed to be installed adjacent to Woleebee Creek to monitor groundwater levels in the vicinity of potential GDEs that may be sourcing water from the alluvium associated with Woleebee Creek.

Groundwater trigger values are an important tool in identifying changes to the groundwater system which may potentially be related to the Project. Trigger values for water quality and water levels will be developed for Senex monitoring bores. Groundwater quality triggers have already been derived for the seepage monitoring bore network and will be derived for the wider Senex network once sufficient data has been collected. Trigger values are to be set statistically, based on monitoring data, and should guide the management of the site to detect changes in water quality and water levels, evaluate those changes, and take appropriate actions, which could include mitigation. The percentiles approach for water quality trigger derivation is based on combining the ANZECC 2000 methodology, adapted control charting approaches, and statistics. The approach includes the calculation of the following:

- Value A (80th percentile) of existing time series monitoring data.
- Value B (95th percentile) of existing time series monitoring data.

Value A is a level for detecting gradual change over the medium term (i.e. 1 to 2 years). Value B provides an indication of change over a longer term. Groundwater level triggers are derived from the maximum predicted drawdown as estimated by the OGIA cumulative groundwater model for the Surat Basin.

Groundwater triggers are simply a threshold value, above / below which some further consideration of the data should be given to determine the potential for environmental harm from the Project activities. The trigger values are not a pass or fail assessment; rather they act as a warning system that initiates further investigation.

A trigger action response plan (TARP)s for water quality and water levels has been developed. Where investigations following trigger value exceedance determines that impacts are likely to be Project related and present an unacceptable risk of harm to human health or the environment, appropriate mitigation / remediation actions may be required. The need for appropriate mitigation should be evaluated and implemented as required to mitigate the risk of unacceptable harm. The TARPs for groundwater quality and level changes are presented in the WMMP (SENEX-ATLS-EN-PLN-017).

Senex will undertake all regulatory reporting as per the requirements under State and Commonwealth legislation and manage impacts to groundwater resources in the Surat Cumulative Management Area under EPBC Act approvals under the Joint Industry Framework (JIF). The JIF reflects and adopts relevant aspects of the regulatory environment administered by the Queensland Government. This includes obligations to OGIA as part of the UWIR requirements. Senex will also undertake all regulatory requirements and obligations in accordance with the Project's EA conditions.

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CLARIFICATIONS REGARDING THIS REPORT

This report is an instrument of service of KCB Australia Pty Ltd (KCB). The report has been prepared for the use of Senex Energy Ltd Pty (Client) for the specific application to the Atlas Stage 3 Gas Project and may be published or disclosed by the Client to the Department of Climate Change, Energy, Environment and Water (DCCEEW).

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TABLE OF ABBREVIATIONS

ACA	Aquatic Conservation Assessments
AEP	Annual exceedance probability
AGDE	Aquatic Groundwater Dependent Ecosystem
ALUM	Australian Land Use and Management
ANZECC	Australian and New Zealand Conservation Council
API	American Petroleum Institute
APLNG	Australia Pacific LNG Pty Limited
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ATP	Authority to Prospect
ATW	Authority to Work
BOT	Back on Track
CBAS	Chemicals and Biotechnology Assessments Section
CMA	Cumulative Management Area
CRD	Cumulative rainfall departure
CSG	Coal seam gas
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEE	Department of the Environment and Energy
DEHP	Department of Environment and Heritage Protection
DES	Department of Environment and Science
DSITI	Department of Science, Information Technology, and Innovation
DST	Drill stem tests
EA	Environmental authority
EC	Electrical Conductivity
EOW	End of Waste
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERA	Environmentally relevant activity
ESA	Environmentally sensitive areas
EV	Environmental Value
EVNT	Endangered, vulnerable, and near threatened
GAB	Great Artesian Basin

GDEs	Groundwater dependent ecosystems
GWDB	Groundwater Database
HEV	High Ecological Value
JIF	Joint Industry Framework
KCB	Klohn Crippen Berger
MNES	Matters of national environmental significance
MSES	Matters of state environmental significance
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NSMC	Null space Monte Carlo
NWQMS	National Water Quality Management Strategy
OECD	Organisation for Economic Co-operation and Development
OGIA	Office of Groundwater Impact Assessment
PL	Petroleum Lease
QFAO	Queensland Floodplain Assessment Overlay
QWC	Queensland Water Commission
RDMW	Regional Development, Manufacturing and Water
RE	Regional ecosystem
RN	Registered number
ROP	Resource Operations Plan
RoW	Right-of-way
SDS	Safety Data Sheets
TDS	Total Dissolved Solids
TDGE	Terrestrial Groundwater Dependent Ecosystem
UWIR	Underground Water Impact Report
Water Act	*Water Act 2000*
WCM	Walloon Coal Measures
WMS	Water Monitoring Strategy
WQO	Water quality objectives
WSA	Water Supply Agreements

1 INTRODUCTION

KCB Australia Pty Ltd (KCB) has been commissioned by Senex Energy Pty Ltd (Senex), to undertake an assessment of water-related impacts for the proposed development of Atlas Stage 3 Gas Project (the Project); a coal seam gas (CSG) project in the Surat Basin, Queensland.

The objective of this assessment is to assess potential impacts to water resources and water-dependent assets under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth of Australia 2022a) resulting from proposed activities associated with the Project. This assessment is conducted with reference to the following guidelines:

- Department of Climate Change, Energy, the Environment and Water (DCCEEW) Significant Impact Criteria provided in 'Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources' (Commonwealth of Australia 2022b) (Section 2.1);
- DCCEEW Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (Commonwealth of Australia 2013) (Section 2.1); and
- The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) '*Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*' (IESC 2018b).

This assessment was prepared for submission to accompany Senex's *EPBC Act* Referral for Atlas Stage 3 to the DCCEEW. On the May 19, 2023, the delegate for the Minister for the Environment and Water decided that the development associated with PL 445, PL 209 and ATP 2059 is a 'Controlled Action' and requires approval under the EPBC Act.

On 6 June 2023, a RFI detailing additional information requirements to be included in the Preliminary Documentation (PD) was issued by DCCEEW. This assessment has been updated in response to the Request for Further Information (RFI), received from DCCEEW June 6, 2023.

1.1 Project Overview

Senex, on behalf of its subsidiaries Senex Assets Pty Ltd and Senex Assets 2 Pty Ltd, is proposing to develop, operate, decommission and rehabilitate new CSG wells and associated infrastructure on Authority to Prospect (ATP) 2059, Petroleum Lease (PL) 445, the northern portion of PL 209 and parts of PL 1037 in the central part of the Surat Basin, Queensland (the proposed action) (Location shown on Figure 1.1). The parts of PL 1037 that will contain infrastructure include the part that is east of Woleebee Creek as well as one as yet unconfirmed site for a new Atlas Stage 3 brine storage within previously cleared parts of eastern PL 1037, proximate to the existing water management facilities. The proposed action will provide natural gas for domestic and international markets.

The proposed action is referred to as the Atlas Stage 3 Gas Project (referred to herein as 'the Project'). The Project covers an area of approximately 98 km^2 and is located approximately 10 km southwest of the township of Wandoan. The target gas producing unit for the Project is the Walloon Coal Measures (WCM) of the Surat Basin.

Gas field production activities are planned to commence in 2023 (pending-approval). The Project will involve the progressive development of gas infrastructure and will include the following activities:

- Drilling, installation, operation, and maintenance of up to 151 CSG production wells (all vertical), targeting the WCM;
- Installation, operation and maintenance of a gas and water gathering system;
- Installation, operation, and maintenance of associated supporting infrastructure (e.g. temporary workforce accommodation, access roads, power and communication systems, laydowns, stockpiles, and storage areas);
- Decommissioning and rehabilitation of infrastructure and disturbed areas; and
- Installation, operation and maintenance of water storage and water management facilities (if required).

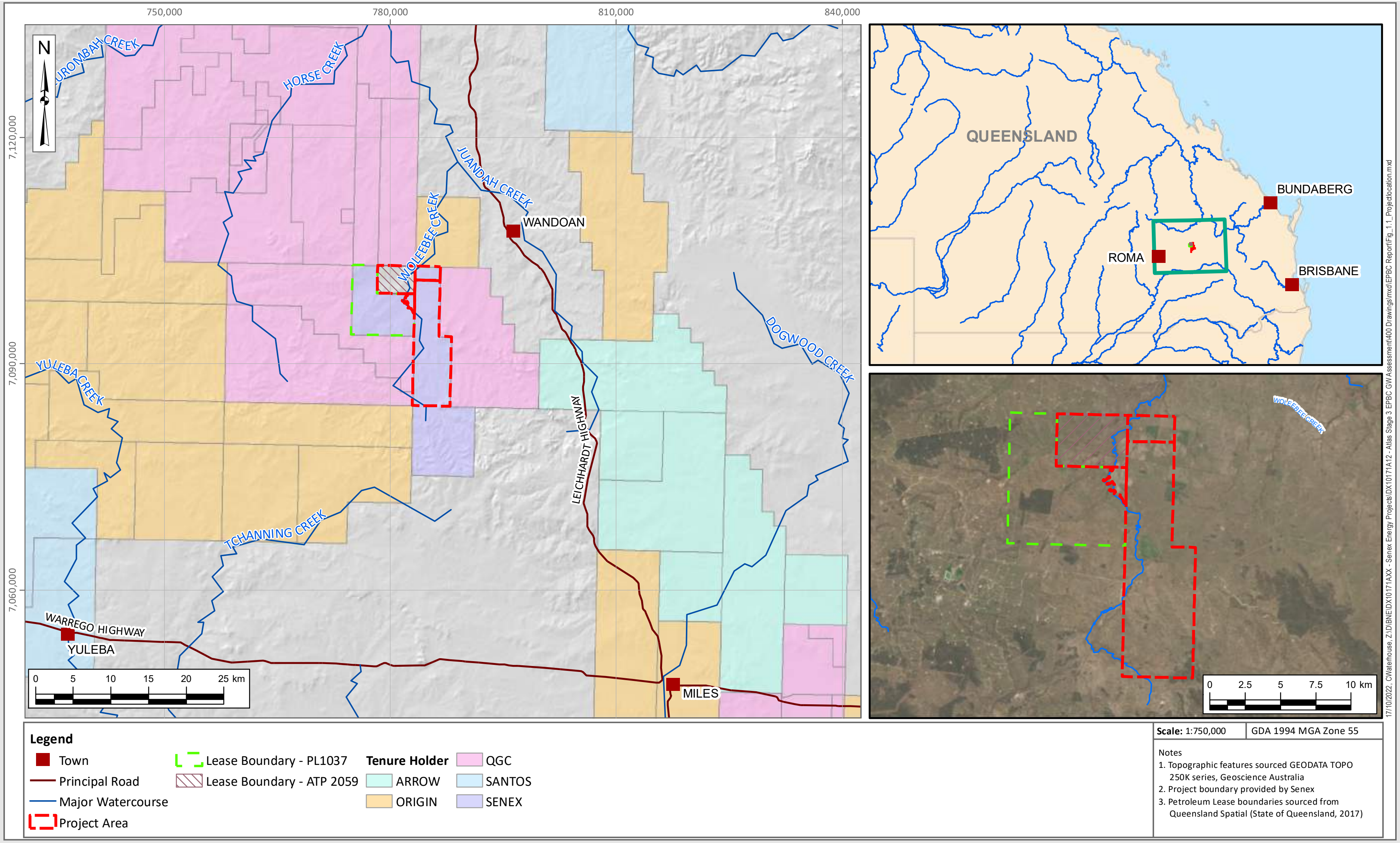


Figure 1.1 Project Location

1.2 Report Structure

This report has been prepared to accompany the Atlas Stage 3 Gas Project *EPBC Act 1999* revised Preliminary Documentation to be submitted to DCCEEW. This report is structured to include:

Section 1: Introduction to the Project, report purpose, and structure.

Section 2: Statutory Context, including an overview of the relevant Commonwealth and Queensland legislation related to water and gas development/ production.

Section 3: Proposal Description, including project approval status.

Section 4: Assessment Methodology, including the existing environment and environmental values, as well as potential project impacts.

Section 5: Existing Environment, including a review of the topography, climate, and land use.

Section 6: Hydrological Context and Conceptualisation.

Section 7: Hydrogeological Context and Conceptualisation.

Section 8: Numerical Groundwater Modelling, including predicted extent of drawdown.

Section 9: Impact Assessment.

Section 10: Mitigation, Management, and Monitoring.

Section 11: Assessment against the Significant Impact Criteria.

1.2.1 IESC Checklist

The IESC is a statutory body under the EPBC Act (Commonwealth of Australia 2022a). The IESC's key function in relation to this Project is to provide scientific advice to the Commonwealth Environment Minister and relevant State ministers in relation to CSG or large coal mining development proposals that have or are likely to have a significant impact on water resources.

To allow the IESC to provide robust scientific advice to government regulators on water-related impacts of CSG, an information guideline (IESC 2018b) has been developed outlining the specific information considered necessary for the IESC to undertake the relevant assessment. Table 1.1 provides the information checklist and the relevant sections of this report that addresses each checklist item. It should be noted that some items in the guideline are not required for this Project, including final landform and voids – coal mines, acid-forming materials and other contaminants of concern, and checklist items related to hydraulic stimulation for CSG (no hydraulic stimulation is proposed for the Project).

This assessment has been undertaken using the Office of Groundwater Impact Assessment's (OGIA) assessment and associated modelling tools to identify project specific risks and impacts and to make reference to cumulative assessment and management in the Surat Cumulative Management Area (CMA) Underground Water Impact Report (UWIR) (OGIA 2021f) (further detail is provided in Section 2.2.2).

This assessment has been updated to address comments received from DCCEEW, which included advice from the IESC dated August 31, 2023 and received by Senex on September 1, 2023.

Table 1.1 IESC Checklist and Section Addressed in this Report

Checklist Title	Checklist Item	Section Addressed
Description of the Proposal		
Description Of The Proposal	Provide a regional overview of the proposed project area including a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, present, and reasonably foreseeable coal mining and CSG developments.	Section 3.1
	Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Section 3
	Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations.	Section 2 and Section 3.2
	Describe how impacted water resources are currently being regulated under State or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Risk Assessment		
Risk Assessment	Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	Section 9 and 11
	Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.	
	Assess risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	
	The risk assessment should include an assessment of: ▪ All potential cumulative impacts which could affect water resources and water-related assets; and ▪ Mitigation and management options which the proponent could implement to reduce these impacts.	
Groundwater		
Context and Conceptualisation	Describe and map geology at an appropriate level of horizontal and vertical resolution including: ▪ Definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross sections, and any relevant field data. ▪ Geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	Section 7
	Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	
	Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge, or recharge. ▪ Site-specific studies (e.g. geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g. damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). ▪ Discussion on how these fits into the fault's potential influence on regional-scale groundwater conditions should also be included.	
	Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	
	Provide site-specific values for hydraulic parameters (e.g. vertical, and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In-situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	
	Describe the likely recharge, discharge, and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	
	Provide time series level and water quality data representative of seasonal and climatic cycles.	

Checklist Title	Checklist Item	Section Addressed
	Assess the frequency (and time lags if any), location, volume, and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	
Analytical and Numerical Modelling	Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Section 8 and Surat CMA UWIR (OGIA 2021f)
	Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	
	Undertaken groundwater modelling in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al. 2012), including independent peer review.	
	Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	
	Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	
	Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	
	Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	
	Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	
	Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	
	Undertake an uncertainty analysis of model construction, data, conceptualisation, and predictions (see Middlemis and Peeters [in press]).	
	Describe the various stages of the proposed project (construction, operation, and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	
	Provide a program for review and update of models as more data and information become available, including reporting requirements.	
	Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	
	Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	
	Undertake model verification with past and/or existing site monitoring data.	
Impacts to Water Resources and Water-Dependent Assets	Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: ▪ Any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. ▪ The effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. ▪ The potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units. ▪ The possible fracturing of and other damage to confining layers. ▪ For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	Section 8, Section 9 and Surat CMA UWIR (OGIA 2021f)
	Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open-cut mining and/or underground mining.	Section 6 and 7

Checklist Title	Checklist Item	Section Addressed
	For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 9
	Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Section 2.3
	Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 9
	Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 9.9
Data and monitoring	Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 7
	Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Section 7
	Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge, and discharge processes, and identifying changes over time.	Section 9.9 and Water Monitoring and Management Plan (WMMP) (SENEX-ATLS-EN-PLN-017)
	Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated State protocols (e.g. QLD Government 2013).	Section 9.9
	Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining groundwater dependent ecosystems (GDEs), the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Section 9.9
Surface Water		
Context and Conceptualisation	Describe the hydrological regime of all watercourses, standing waters and springs across the site including: ▪ Geomorphology, including drainage patterns, sediment regime and floodplain features. ▪ Spatial, temporal, and seasonal trends in streamflow and/or standing water levels. ▪ Spatial, temporal, and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids, and radionuclides); and ▪ Current stressors on watercourses, including impacts from any currently approved projects.	Section 6
	Describe the existing flood regime, including flood volume, depth, duration, extent, and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth, and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	
	Provide an assessment of the frequency, volume, seasonal variability, and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	
Analytical and Numerical Modelling	Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Not undertaken, refer to Section 8
	Describe and justify model assumptions and limitations and calibrate with appropriate surface water monitoring data.	
	Use methods in accordance with the most recent publication of *Australian Rainfall and Runoff* (Ball et al. 2016).	
	Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	
	Develop and describe a program for review and update of the models as more data and information becomes available.	
	Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	

Checklist Title	Checklist Item	Section Addressed
Impacts to water resources and water-dependent assets	Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: ▪ Impacts on streamflow under the full range of flow conditions. ▪ Impacts associated with surface water diversions. ▪ Impacts to water quality, including consideration of mixing zones. ▪ The quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets. ▪ Landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway, and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 9
	Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 2.2
	Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Not undertaken, refer to Section 8
	Propose mitigation actions for each identified significant impact.	
	Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	
	Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present, and reasonably foreseeable) are considered in combination.	
	Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	
Data And Monitoring	Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	
	Develop and describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions and assess the effectiveness of mitigation and management measures. The program will: include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals); comparison of physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available; and, identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	
	Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated State protocols (e.g. QLD Government 2013).	
	Describe the rationale for selected monitoring parameters, duration, frequency, and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	
	Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	
	Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	
	Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	
Water-dependent assets		
Context and Conceptualisation	Identify water-dependent assets, including: ▪ Water-dependent fauna and flora and provide surveys of habitat, flora, and fauna (including stygofauna) (see Doody et al. [in press]). ▪ Public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	Section 6 and 7
	Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody et al. [in press]).	

Checklist Title	Checklist Item	Section Addressed
	Identify the hydrogeological units on which any identified GDEs are dependent (see Doody et al. [in press]).	
	Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in identification of GDEs (see Doody et al. [in press]).	
	Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	
	Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance, and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	
	Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	
Impacts, risk assessment and management of risks	Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody et al. [in press]).	Section 9
	Provide estimates of the volume, beneficial uses, and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	
	Describe the potential range of drawdown at each affected bore, and clearly articulate of the scale of impacts to other water users.	
	Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	
	Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	
	Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	
	Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	
	Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	
Data and monitoring	Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions, and test potential responses to impacts of the proposal (see Doody et al. [in press]).	Section 9.9
	Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody et al. [in press]).	
	Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody et al. [in press]).	
	Describe the proposed process for regular reporting, review, and revisions to the monitoring program.	
	Ensure ecological monitoring complies with relevant State or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	
Water and salt balance, and water quality		
Water And Salt Balance, And Water Quality	Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Section 3.3,CSG Water Management Plans and WMMP.
	Provide estimates of the quality and quantity of operational discharges under dry, median, and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	
	Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	
	Provide salt balance modelling that includes stores and the movement of salt between stores and takes into account seasonal and long-term variation.	
Cumulative Impacts		
Context and	Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 8 and Section

Checklist Title	Checklist Item	Section Addressed
Conceptualisation	Consider all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	9 and Surat CMA UWIR (OGIA 2021f)
Impacts	Provide an assessment of the condition of affected water resources which includes: ▪ Identification of all water resources likely to be cumulatively impacted by the proposed development. ▪ A description of the current condition and quality of water resources and information on condition trends. ▪ Identification of ecological characteristics, processes, conditions, trends, and values of water resources. ▪ Adequate water and salt balances; and ▪ Identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	
	Assess the cumulative impacts to water resources considering: ▪ The full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically, and laterally. ▪ All stages of the development, including exploration, operations, and post closure / decommissioning. ▪ Appropriately robust, repeatable, and transparent methods. ▪ The likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and ▪ Opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	
Mitigation, Monitoring And Management	Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	
	Identify cumulative impact environmental objectives.	
	Identify measures to detect and monitor cumulative impacts, pre- and post-development, and assess the success of mitigation strategies.	
	Describe appropriate reporting mechanisms	
	Propose adaptive management measures and management responses.	
Subsidence – underground coal mines and coal seam gas		
Subsidence – Underground Coal Mines And Coal Seam Gas	Provide predictions of subsidence impact on surface topography, water-dependent assets, groundwater (including enhanced connectivity between aquifers) and the movement of water across the landscape (See CoA 2014b; CoA 2014c). Consider multiple methods of predictions and apply the most appropriate method. Consider the limitations of each method including the adequacy of empirical data and site-specific geological conditions and justify the selected method.	Section 9
	Describe subsidence monitoring methods, including the use of remote or on-ground techniques and explain the predicted accuracy of such techniques.	
	Provide an assessment of both conventional and unconventional subsidence. For project expansions, an evaluation of past or current effects of geological structures on subsidence and implications for water resources and water-dependent assets should be provided.	
	Consider geological strata and their properties (strength/hardness/fracture propagation) in the subsidence analysis and/or modelling. Anomalous and near-surface ground movements with implications for water resources and compaction of unconsolidated sediment should also be considered.	
CSG Well Construction And Operation		
CSG Well Construction And Operation	Describe the scale of fracturing (number of wells, number of fracturing events per well), types of wells to be stimulated (vertical versus horizontal), and other forms of well stimulation (cavitation, acid flushing).	Not applicable. No hydraulic fracturing planned to be undertaken.
	Describe proposed measuring and monitoring of fracture propagation.	
	Identify water source for drilling and hydraulic stimulation and outline the volume of fluid and mass balance (quantities/volumes).	Section 9
	Describe the rules (e.g. water sharing plans) covering access to each water source used for drilling and hydraulic stimulation and how the project proposes to comply with them.	

Checklist Title	Checklist Item	Section Addressed
	Quantify and describe the quality and toxicity of flowback and produced water and how it will be treated and managed.	
	Assess the potential for inter-aquifer leakage or contamination.	
	The use of drilling and hydraulic fracturing chemicals should be informed by appropriately tiered deterministic and/or probabilistic hazard and risk assessments, based on ecotoxicological testing consistent with Australian Government testing guidelines (see CoA 2012; MRMMC-EPHC-NHMRC 2009).	
	Propose waste management measures (including salt and brines) during both operations and legacy after closure.	
	List the chemicals proposed for use in drilling and hydraulic stimulation including: ▪ Names of the companies producing fracturing fluids and associated products. ▪ Proprietary names (trade names) of compounds (fracturing fluid additives) being produced. ▪ Chemical names of each additive used in each of the fluids. ▪ Chemical abstract service (cas) numbers of each of the chemical components used in each of the fluids. ▪ General purpose and function of each of the chemicals used. ▪ Mass or volume proposed for use. ▪ Maximum concentration (mg / l or g / kg) of the chemicals used. ▪ Chemical half-life data, partitioning data, and volatilisation data. ▪ Ecotoxicology; and ▪ Any material safety Data Sheets for the chemicals or chemical products used.	
	Chemicals for use in drilling and hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (that is, confirmed by NICNAS as being listed in the Australian Inventory of Chemical Substances) (see CoA 2017b).	

2 STATUTORY CONTEXT

This water resource impact assessment report has been prepared with consideration to key policies and legislation from the Commonwealth of Australia and the State of Queensland. This section provides an overview of applicable legislation / policies to this assessment.

2.1 Commonwealth Legislation

2.1.1 Environment Protection and Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* (Commonwealth of Australia 2022a) is the central piece of environmental legislation at the Commonwealth level. It provides for the protection of environmental values, including matters of national environmental significance (MNES). Actions that are likely to have a significant impact on MNES are subject to the assessment and approval process under this Act. Water resources in relation to large coal mining and CSG development projects are a MNES. The Project may have potential to have a significant impact on water resources, and as such is being referred to the DCCEEW.

The regulatory guideline relevant to the Project, developed from the amendment to the *EPBC Act* identifying water resources as being a MNES, is the *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (Commonwealth of Australia 2022b).

Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments

The 'Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources' (Commonwealth of Australia 2022b) identify a 'significant impact' as *"an impact which is important, notable, or of consequence, having regard to its context or intensity*".

Section 4.2 and 4.3 of the guidelines, identify that for a water resource a 'significant impact' may occur where, as a result of the action, one of the following changes to the hydrological characteristics of a water resource are of a sufficient scale or intensity to significantly reduce the current or future utility of the water resource for third-party users, including environmental and other public benefit outcomes:

a) Changes in the water quantity, including the timing of variations in water quantity.

b) Changes in the integrity of hydrological or hydrogeological connections, including structural damage (e.g. large-scale subsidence); and

c) Changes in the area or extent of a water resource.

DCCEEW have identified the following aspects that may need to be considered when assessing the above hydrological characteristics:

- Flow regimes (volume, timing, duration, and frequency of surface water flows);
- Recharge rates to groundwater;
- Aquifer pressure or pressure relationships between aquifers;

- Groundwater table and potentiometric surface levels;
- Groundwater-surface water interactions;
- River-floodplain connectivity;
- Inter-aquifer connectivity; and
- Coastal processes including changes to sediment movement or accretion, water circulation patterns, permanent alterations in tidal patterns, or substantial changes to water flows or water quality in estuaries.

The Significant impact guidelines 1.3, Section 4.4, provide guidance on changes to water quality which state that a significant impact on a water resource may occur where (as a result of the action):

- There is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action:
  - Creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality;
  - Substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality;
  - Causes persistent organic chemicals, heavy metals, salt, or other potentially harmful substances to accumulate in the environment;
  - Seriously affects the habitat or lifecycle of a native species dependent on a water resource; or
  - Causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource.
- There is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives); or
- High quality water is released into an ecosystem which is adapted to a lower quality of water.

Both changes to the hydrological characteristics and water quality, as a result of the proposed activities, have been assessed as part of this assessment for the identification of potential impacts.

Matters of National Significance: Significant Impact Guidelines 1.1

The Significant Impact Guidelines 1.1 (Australian Government 2013) identify a ‘significant impact’ as an “impact which is important, notable, or of consequence, having regard to its context or intensity”. A ‘significant impact’ on a critically endangered and endangered species, may occur where, as a result of the action, there is a real chance or possibility that it will:

- Lead to a long-term decrease in the size of a population;
- Reduce the area of occupancy of the species;
- Fragment an existing population into two or more populations;

- Adversely affect habitat critical to the survival of a species;
- Disrupt the breeding cycle of a population;
- Modify, destroy, remove, isolate, or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
- Introduce disease that may cause the species to decline; or
- Interfere with the recovery of the species.

For ecological communities, a 'significant impact' may occur, where, as a result of the action, there is a real chance or possibility that it will:

- Reduce the extent of an ecological community.
- Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines.
- Adversely affect habitat critical to the survival of an ecological community.
- Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns.
- Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting.
- Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to:
  - Assisting invasive species, that are harmful to the listed ecological community, to become established; or
  - Causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community.
- Interfere with the recovery of an ecological community.

Coal Seam Gas – Joint Industry Framework

Managing Impacts to Groundwater Resources in the Surat Cumulative Management Area Under EPBC Act Approvals

The purpose of the Joint Industry Framework (JIF) is to establish a consistent post-approval framework for the management of impacts on groundwater caused by CSG developments within the Surat CMA that are subject to approvals under the *EPBC Act*. The JIF provides a risk management framework to achieve stated outcomes for relevant MNES and is intended to reduce duplication between the regulation of groundwater at a Commonwealth and State level.

The JIF applies to CSG development that are within the Surat CMA that are the subject of an *EPBC Act* approval with:

- One or both of the following controlling provisions:
  - Listed threatened species and ecological communities (sections 18 and 18A *EPBC Act*), which include the community of native species dependent on natural discharge of groundwater from the Great Artesian Basin or other listed threatened species and ecological communities that are supported by springs (EPBC-listed springs); and
  - A water resource (section 24D and 24E *EPBC Act*), in respect of groundwater; and
- Conditions that reference one or more outcomes and risk management frameworks under the JIF due to a potential impact on EPBC-listed springs and/or a water resource.

The JIF reflects and adopts relevant aspects of the regulatory environment administered by the Queensland Government.

The framework for groundwater management in the Surat CMA is provided by the Surat UWIR, prepared in accordance with the Queensland Water Act. The UWIR reports on the groundwater impacts of the exercise of underground water rights by resource tenure holders in the Surat CMA and establishes:

- Strategies to manage the predicted impacts; and
- Responsibilities for implementing various aspects of the strategies.

Further details on the Surat UWIR are provided in Section 2.2.2.

Once an approval is granted with conditions referencing one or more JIF outcomes and management frameworks, the approval holder must comply with each of its obligation under the JIF and the approval conditions, including the various notification and reporting requirements outlined in the management frameworks and conditions. The JIF defines the process to be used by approval holders to determine the risk level of a particular impact on EPBC-listed springs and/or GDEs and understand their related obligations under approval conditions. The approval holder's management actions and the regulatory involvement in those management actions will be commensurate to the level of risk to the EPBC-listed spring or associated user, and the level of regulation at a state level.

JIF management frameworks, and associated risk thresholds, have been established to achieve protection of EPBC-listed springs and water resources. Where CSG development impacts exceed a risk threshold (based on OGIA model drawdown prediction), approval holders are required to implement the relevant risk management framework. Where a risk threshold has not been exceeded, and/or is not predicted to be exceeded, the CSG development is taken not to have impacted the protected matters and approval holders are not required to undertake risk management in order to comply with their approval conditions. Section 3 to 7 of the JIF (Australian Government 2021) provides details of the management frameworks and risk thresholds for the EPBC-listed springs and water resources.

2.2 State Legislation

2.2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020b) is an Act relevant to exploring for, recovering and transporting by pipeline, petroleum and fuel gas, and ensuring the safe and efficient undertaking of those activities. The key purpose of this Act is to facilitate and regulate the undertaking of responsible petroleum activities and the development of a safe, efficient, and viable petroleum and fuel gas industry.

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

The Act prescribes mandatory compliance with the '*Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 2'* (State of Queensland 2019a). The purpose of this code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained, and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and gas and the protection of groundwater resources.

2.2.2 Water Act 2000

General Purpose of the Water Act

The *Water Act 2000* (State of Queensland 2021e) is an Act to provide for the sustainable management of water and the management of impacts on underground water, among other purposes. This Act provides a framework for:

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

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

Water Act and CSG Related Activities

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

Chapter 3 of the *Water Act 2000* (Water Act) has a stated purpose to provide for the management of impacts on underground water caused by the exercise of underground water rights by resource tenure holders, which includes petroleum tenure holders. To achieve the stated purpose, a regulatory framework is provided which requires:

- Resource tenure holders to monitor and assess the impacts of the exercise of underground water rights on water bores and to enter into make good agreements with the owners of the groundwater bores as necessary;
- The preparation of UWIR that establish underground water obligations, including obligations to monitor and manage impacts on aquifers and springs; and
- Managing the cumulative impacts of the activities of two or more resource tenure holders' underground water rights on underground water.

The Project is located within the Surat under the Water Act. Under this regulatory framework a CMA can be declared where there is an area of concentrated development if the chief executive considers an area containing two or more resource tenures may be affected by the exercise of underground water rights by the tenure holders. The OGIA was established under the *Water Act 2000* and is responsible for predicting regional impacts on water pressures in aquifers; developing water monitoring and spring management strategies; and, assigning responsibility to individual petroleum tenure holders for implementing specific parts of the strategies within CMAs. These predictions, strategies and responsibilities are set out in the Surat CMA UWIR, prepared, and maintained by OGIA.

The Surat CMA UWIR was first published by Queensland Water Commission (QWC) in 2012 (QWC 2012a) to assess the cumulative impacts to the Surat and southern Bowen Basin, as a result of the expansion of CSG production by multiple, adjacent developers. An updated UWIR was published by the OGIA in May, 2022 (OGIA 2021f).

OGIA also provide tenure holders with their obligations to comply with the Surat CMA UWIR Water Monitoring Strategy (WMS). The WMS includes:

- Installation, maintenance, and collection of data from the groundwater monitoring network including water pressure and water chemistry;
- Monitoring of associated water volumes;
- A program for baseline assessment; and
- Tenure holder reporting of the data and activities relating to the above components.

OGIA has provided Senex with groundwater modelling outputs from the 2021 UWIR numerical model to inform this assessment, which is detailed further in Sections 4.2.4 and 8.

Trigger Thresholds

Under Section 362 of the *Water Act 2000*, a bore trigger threshold for a consolidated aquifer of 5 m applies (2 m for an unconsolidated aquifer). The 5 m threshold represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holders' activities, prior to triggering an investigation into the water level decline and an assessment to establish whether a bore has, or is likely to have, an impaired capacity because of a petroleum tenure holder exercising their underground water rights.

Under Section 379 of the *Water Act 2000* a spring trigger threshold for an aquifer applies. This includes vent springs / complexes and watercourse spring (i.e. gaining streams). This threshold value (0.2 m) represents the maximum allowable decline in the water level of an aquifer in connection with a spring (at the spring location) prior to triggering an investigation into the water level decline. The threshold value may change for an area if a regulation or prescribed threshold exists. There are no prescribed spring trigger threshold applicable in the Project area.

2.2.3 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (State of Queensland 2022b) is an Act with the objective to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).

This Act states that 'to carry out an Environmentally Relevant Activity (ERA) an environmental authority (EA) is required'. A resource activity, specifically a petroleum activity, is defined as an ERA.

2.2.3.1 Existing Environmental Authorities

Senex currently holds Environmental Authorities (EA) for appraisal scale activities at ATP 2059 (EA0002524), and for production activities at PL 209 and PL 445 (P-EA-1001127770 and PL 1037 (EA0001207). These EA conditions require activities to avoid, minimise and mitigate impacts to vegetation and other areas of ecological significance.

Senex will be applying for a new Environmental Authority aligning with ATP 2059 being progressed to a PL. The EA will facilitate development of up to 31 CSG production wells and associated infrastructure under the *Environmental Protection Act 1994.* These 31 wells will form part of the 151 CSG production wells and associated infrastructure being developed for the Atlas Stage 3 Gas Project.

2.2.4 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The purpose of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019b) is to achieve the object of the *Environmental Protection Act 1994* in relation to waters and wetlands; protecting Queensland's water environment while allowing for development that is ecologically sustainable.

2.2.4.1 CSG Water Management Policy 2012

The primary objective of the Coal Seam Gas Water Management Policy 2012 (State of Queensland 2012) relates to the management and use of CSG water under the *Environmental Protection Act 1994*. The role of the policy is to:

- Clearly state the government's position on the management and use of CSG water;
- Guide CSG operators in managing CSG water under their EA; and
- Ensure community understanding about the government's preferred approach to managing CSG water.

The '*General beneficial use approval: Associated water (including coal seam gas water)*' (State of Queensland 2014), *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b) supports the objective of the CSG Water Management Policy 2012, by specifying what standards need to be met where associated water is to be used for beneficial purposes.

2.2.5 Water Supply (Safety and Reliability) Act 2008

The *Water Supply (Safety and Reliability) Act 2008* (State of Queensland 2017b) is an Act that provides for the safety and reliability of water supply. The purpose of this Act is achieved primarily by providing:

- A regulatory framework for providing water and sewerage services in the State, including functions and powers of service providers;
- A regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health;
- The regulation of referable dams;
- Flood mitigation responsibilities; and
- The protect the interests of customers of service providers.

The key component of the Act relevant to the Project relates to the regulation of referable dams.

2.3 Environmental Values and Water Resource Management

2.3.1 Environmental Values

The *Environmental Protection Act 1994* (State of Queensland 2022b) defines an Environmental Value (EV) as:

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

Under the *Environmental Protection Act 1994* (EP Act 1994), the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019b) is established as subordinate legislation to achieve the object of the Act in relation to Queensland waters. The purpose of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* is achieved by:

- Identifying EVs and management goals for Queensland waters;
- Stating water quality guidelines and water quality objectives to enhance or protect the EVs;
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters; and
- Monitoring and reporting on the condition of Queensland waters.

Surface Water Environmental Values

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019b) provides defined EVs and water quality objectives (WQOs) for surface and groundwater under Schedule 1 of the policy. The catchments of relevance of the Project are:

- The Dawson River sub-basin (State of Queensland 2011); and
- The WQ1308 plan (State of Queensland 2013) that accompanies the policy indicates that the Project area is located on the southern tributaries of the Upper Dawson.

Relevant EVs for surface water are presented in Table 2.1.

Table 2.1 Environmental Values for the Dawson River Sub-Basin and Maranoa-Balonne Rivers Basin waters within the Vicinity of the Project (State of Queensland 2011)

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Drinking Water	Industrial Use	Cultural And Spiritual Values
Dawson River Sub-Basin												
Upper Dawson southern tributaries	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Undeveloped areas	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓

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

Water Quality Objectives – Surface Water

WQOs for surface water (State of Queensland 2011; 2020a) are also outlined to protect EVs. A summary of the relevant WQOs for surface water in the Upper Dawson and Dogwood Creek are provided below:

- Where the aquatic ecosystem has high ecological value the WQO is to maintain the existing water quality, habitat, biota, flow, and riparian areas.
- For the Upper Dawson River sub-basin waters and main trunk, the aquatic ecosystem is described as moderately disturbed and specific water quality guidelines have been produced (Table 2 of State of Queensland 2011).
- For the protection for human consumption, objectives as per the Australian drinking water guidelines (ADWG) (NHMRC 2011) and Australia New Zealand Food Standards Code (Commonwealth of Australia 2016).
- For suitability for industrial use there are no WQOs as water quality requirements vary within the industry.
- For secondary contact and visual recreation, objectives as per NHMRC (NHMRC 2011).

- For drinking water, local WQOs exist which relate to before and after water treatment and are based on several guidelines / legislations including the ADWG (NHMRC 2011).
- WQOs to protect or restore indigenous and non-indigenous cultural heritage should be consistent with relevant policies and plans.
- For irrigation, WQOs exist for metals, pathogens, and other indicators in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).
- For stock watering, objectives exist for faecal coliforms, Total Dissolved Solids, metals, and other objectives based on established guidelines (ANZG 2018).
- For farm use / supply, objectives are as per the guidelines in (ANZG 2018).
- For primary contact recreation objectives as per NHMRC (NHMRC 2011) and for fresh water objectives exist for cyanobacteria or algae.

There are no surface water entitlements in the Project area.

Table 2.2 outlines relevant objectives to protect aquatic ecosystem EVs under baseflow and (where specified) high flow conditions. These objectives are largely related to the main river channel of the Upper Dawson, and do not necessarily present appropriate objective for ephemeral tributary systems that form the main habitat within the Project area.

Table 2.2 Objectives to Protect Aquatic Ecosystem Environmental Values Under Baseflow, and Where Specified, High Flow Conditions (State of Queensland 2011)

Water Area / Type	Management Intent	Objectives to Protect Aquatic Ecosystem EVs
Waters in HEVa2155 and HEVa2156	Aquatic ecosystem – high ecological value	Achieve effectively unmodified water quality (20th, 50th and 80th percentiles of HEV waters), habitat, biota, flow, and riparian areas. Note: there is insufficient information available to establish effectively unmodified water quality for these waters. Refer to QWQG for details on how to establish a minimum water quality data set for deriving local 20th, 50th and 80th percentiles.
Upper Dawson River Sub-basin waters (WQ1308)	Aquatic ecosystem – moderately disturbed	Macroinvertebrates: –Taxa richness (composite): 12–21 –Taxa richness (edge habitat): 23–33 –PET taxa richness (composite): 2–5 –PET taxa richness (edge habitat): 2–5 –SIGNAL index (composite): 3.33–3.85 –SIGNAL index (edge habitat): 3.31–4.20 –% tolerant taxa (composite): 25–50% –% tolerant taxa (edge habitat): 44–56%
Upper Dawson River Sub-basin main trunk*	Aquatic ecosystem - moderately disturbed	Native fish species observed/expected (O/E) ratio ≥ 1. Native species found to be present in ≥ 50% of sampling events in main river trunks/channels in this catchment are outlined below (additional native species may also be present): –*Nematolosa erebi* –*Macquaria ambigua oriens* –*Tandanus tandanus* –*Leiopotherapon unicolor* –*Melanotaenia splendida* –*Ambassis agassizii* –*Hypseleotris* sp. –*Pseudomugil signifer*

Water Area / Type	Management Intent	Objectives to Protect Aquatic Ecosystem EVs
		Exotic fish species: no increase in number of exotic species relative to current number of exotic species identified in main channel. Current sampled species: –*Carassius auratus* –*Gambusia holbrooki* –*Poecilia reticulate*

*While these native fish ratios are observed/expected for main trunk of Upper Dawson River, useful to compare to catch with that of the Project area.

Groundwater Environmental Values

Groundwater EVs for the Upper Dawson are presented in Table 2.3.

The WQ1308 plan for the Upper Dawson (State of Queensland 2013) that accompanies the policy provides groundwater EV status for groundwaters in the southern tributaries. The EVs presented in Table 2.3 indicate that groundwater values extend to all categories listed, except for aquaculture, human consumption, and secondary recreation.

Table 2.3 Groundwater Environmental Values for the Dawson River Sub-Basin within the Vicinity of the Project (State of Queensland 2011; 2020c)

Water	Environmental Values											
	Aquatic Ecosystem	Irrigation	Farm Supply / Use	Stock Water	Aquaculture	Human Consumer	Primary Recreation	Secondary Recreation	Visual Recreation	Drinking Water	Industrial Use	Cultural And Spiritual Values
Dawson River Sub-Basin												
Groundwater	✓	✓	✓	✓			✓		✓	✓	✓	✓

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

Water Quality Objectives – Groundwater

A summary of the Water Quality Objectives (WQOs) for groundwater in the Upper Dawson are provided below:

- For WQOs of aquatic ecosystems applicable to groundwater where groundwater interacts with surface water, the groundwater quality should not compromise identified EVs and WQOs for those waters.
- For drinking water, local WQOs exist which relate to before and after water treatment and are based on a number of guidelines and legislation including the ADWG (NHMRC 2021).
- WQOs to protect or restore indigenous and non-indigenous cultural heritage should be consistent with relevant policies and plans.
- For irrigation, WQOs exist for metals, pathogens and other indicators in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).
- For stock watering, objectives exist for faecal coliforms, Total Dissolved Solids, metals, and other objectives based on guidelines presented in ANZG (2018).
- For agricultural use or supply, objectives are as per the guidelines in ANZG (2018).

2.3.2 Water Resource and Resource Operations Plans

Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017

Groundwater in the Great Artesian Basin is managed within the *Water Plan (Great Artesian Basin and Other Regional Aquifers - GABORA) 2017* (State of Queensland 2017a), under the *Water Act 2000*. The purpose of the GABORA plan is:

- To define the availability of water in the plan area;
- To provide a framework for sustainably managing water and the taking of water in the plan area;
- To identify priorities and mechanisms for dealing with future water requirements; and
- To provide a framework for reversing, if practicable, the degradation of groundwater dependent ecosystems.

Water Plan (Fitzroy Basin) 2011 (Currently Under Replacement)

The surface water resource of the Upper Dawson sub-basin is managed under the Queensland Water Resource Plan framework as part of the *Water Plan (Fitzroy Basin) 2011* (State of Queensland 2021d). The purpose of the plan is to:

- Define the availability of water in the plan area;
- Provide a framework for sustainably managing water and the taking of water;
- Identify priorities and mechanisms for dealing with future water requirements;
- Provide a framework for establishing water allocations;
- Provide a framework for reversing, where practicable, degradation in natural ecosystems;
- Regulate the taking of overland flow water; and
- Regulate the taking of groundwater.

The Project is within the Carnarvon Groundwater Management Area.

Fitzroy Basin Resource Operations Plan

The Fitzroy Basin Resource Operations Plan (ROP) (State of Queensland 2015a) provides the process to implement the *Water Plan (Fitzroy Basin) 2011* (State of Queensland 2021d). The key function of the ROP is to provide the operating and environmental management rules and monitoring requirements to resource operations licence holders.

3 PROPOSAL DESCRIPTION

3.1 Project Overview

3.1.1 Project Location and Regional Overview

Atlas Stage 3 Gas Project covers an area of approximately 98 km^2 and is located approximately 10 km southwest of the township of Wandoan. Atlas Stage 3 is located within ATP 2059, PL 445, northern PL 209, and parts of PL 1037, as shown in Figure 1.1. Additionally, the location is still to be confirmed for a new Atlas Stage 3 Gas Project brine storage dam which is being planned within previously cleared parts of eastern PL 1037, proximate to the existing water management facilities.

A summary of the regional project setting is provided below, with further detail (as indicated below) included in the remainder of the report:

- The CSG target coal seam for the Project is the WCM, of the Jurassic-Cretaceous Surat Basin, which is underlain by the Permo-Triassic Bowen Basin (Section 7.1).
- The Project is located towards the headwaters of the Upper Dawson River Sub-Basin, which is part of the larger Fitzroy Basin (Section 6).
- The Surat Basin forms part of the Great Artesian Basin (GAB), which comprises several aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source of water used for stock, public water and domestic supply (Section 7.1 and 7.12).
- Water-dependent assets identified in the Project area include third-party groundwater bores, potential terrestrial GDEs, subterranean and aquatic fauna (Section 7.12 and 7.11).

3.1.2 Other Developments

The Project is located directly adjacent to Project Atlas (occupying much of PL 1037), and other CSG tenure holders including QGC and APLNG, which are summarised in Table 3.1 and presented in Figure 3.1.

Table 3.1 Adjacent CSG Tenure Holders (OGIA 2021e)

Tenure Holder	Tenure	Gas Field	Location	Commencement	Cessation
Senex	PL 1037	Atlas	Directly W	2018	2060 - 2065
QGC	PL 398	Polaris	NW	Prior 2018	2060 - 2065
	PL 277	Mamdal	Directly W	Prior 2018	2060 - 2065
	PL 276	Cam Kathleen Mamdal Ros Woleebee Creek	Directly W	Prior to 2020	2050 - 2059 2050 - 2059 2060 - 2069 2050 - 2059 2050 - 2059
	PL 510	Paradise Downs	Directly E	2020-2024	2060 - 2069
APLNG	PL 444	Sandpit	Directly N	Application – not indicated	
	PL 470	Ramyard	Directly W	2020	2050 - 2055
	PL 469	Ramyard Central	Directly W	2025 - 2029	2050 - 2059

The Project is adjacent to the proposed Wandoan Coal Project (tenure holder: Glencore), which was granted Mining Lease (ML) 50229, 50230 and 50231 in 2017 (OGIA 2021a). ML 50230 partially overlies PL 445 (see Figure 3.1. The Wandoan Coal Project is a proposed open-cut thermal coal mine targeting the Juandah Coal Measures of the WCM. The anticipated start year is 2024 with peak development (all mining areas in operation) expected around 2056 (OGIA 2021a). Development of the mine is currently on hold subject to market conditions (OGIA 2021a).

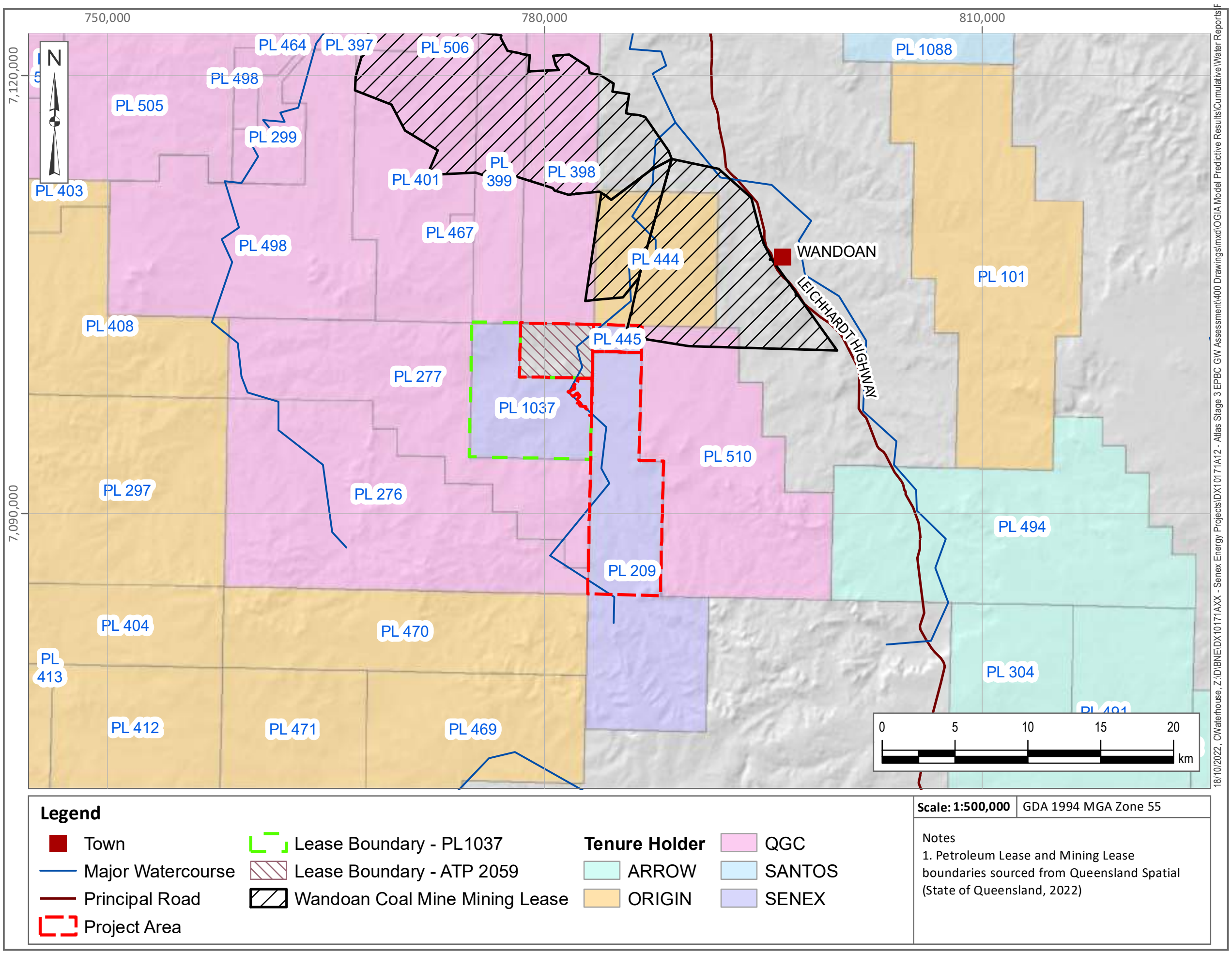


Figure 3.1 Neighbouring Petroleum and Mining Leases

3.2 Project Approval Status

The *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020e) identifies underground water rights for petroleum tenures, and in summary, states that the holder of a petroleum tenure may take or interfere with underground water. Senex intends to exercise its underground water rights for the Atlas Stage 3 Gas Project.

A summary of the Project's approval status within the legislative / regulatory framework is provided in the following:

- Senex has been authorised to conduct petroleum exploration activities in accordance with its EA EA0002524 for ATP 2059, P-EA-100112777 for PL 209 and PL 445 and EA0001207 for PL1037 under the *Environmental Protection Act 1994* (State of Queensland 2022b).

- An application to convert ATP 2059 from an ATP to a PL under the *Queensland Petroleum and Gas (Production and Safety) Act 2004* will be lodged with the Queensland Government under the *Environmental Protection Act 1994* to authorise production activities.
- PL 445 and PL 209 were purchased from Australia Pacific LNG Pty Limited (APLNG) in late 2021. The Environmental Authorities for these PLs were transferred to Senex in early 2022 as part of the purchase. Development of these PL areas by APLNG has received approval under the *EPBC Act* in 2011 as part of APLNG's approval over a larger area 'to develop, construct, operate and decommission the coal seam gas field component of the Australia Pacific LNG Project in the Walloons gas fields within the Surat Basin in south central Queensland' (EPBC 2009/4974). However, the *EPBC Act* does not allow the partial transfer of a component of a larger project to a new proponent.
- The Project was self-referred to the DCCEEW for consideration under the *EPBC Act* (Commonwealth of Australia 2022a) in November 2022. This assessment report was initially prepared to support Senex's referral under the *EPBC Act*.
- On May 19, 2023, a delegate of the Minister for the Environment and Water determined that the Atlas Stage 3 Gas Project is a "controlled action" due to likely impacts to a water resource in relation to a coal seam gas development and large coal mining development (sections 24D and 24E) under Part 3 of the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). Further information required for assessment by preliminary documentation was requested by DCCEEW on June 6, 2023.
- DCCEEW referred the application to the IESC for independent advice. This report provides the response to DCCEEW's comments and IESC's advice.

3.3 Project Components

Gas field production activities, planned to commence in 2023, will include the following:

- Drilling, installation, operation, and maintenance of up to 151 CSG production wells (all vertical), targeting the WCM. There will be no hydraulic stimulation;
- Installation, operation and maintenance of gas and water gathering systems;
- Installation, operation, and maintenance of associated supporting infrastructure (e.g. temporary workforce accommodation, access roads, power and communication systems, laydowns, stockpiles, and storage areas);
- Decommissioning and rehabilitation of infrastructure and disturbed areas (the disturbance area is anticipated to be up to 530 ha of the total Project area of 98 km^2); and
- Installation, operation and maintenance of water storage and water management facilities and brine storage.

Details of the Project components, including location and size, will be identified progressively over the life of the Project.

3.3.1 Project Activities and Infrastructure

3.3.1.1 CSG Production Wells and Water Production

Groundwater abstraction is required as part of the gas production process. Groundwater is abstracted (pumped) from production wells to depressurise the target production coal seams. Depressurisation generates gas flow through desorption, while groundwater flow from the well is sustained to maintain the target producing operational pressure for each production well. A summary of the proposed production wells is provided in the following:

- Production wells will be drilled and constructed in accordance with the 'Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 1' (State of Queensland 2019a). The purpose of this code is to ensure that all petroleum wells, CSG wells and associated bores are constructed, maintained, and abandoned to a minimum acceptable standard resulting in long-term well integrity, containment of petroleum and the protection of groundwater resources.
- Hydraulic fracturing is not planned as part of the Project.
- Water and gas will be produced from all CSG production wells.
- Subject to relevant approvals, gas production and its associated water extraction will commence in 2024, and the gas field will be progressively developed over a period of approximately 5 to 10 years.
- Senex estimate that up to six months will be required to reduce groundwater levels in each production well for gas to flow and approximately 18 months to reach optimum gas production. Once depleted of gas, wells will be progressively decommissioned and rehabilitated throughout the Project life. Decommissioning of individual wells is not expected to occur until after the well has been producing for at least 15 years and may be much longer (anticipated to be between 20 and 35 years).

Produced water volumes and rates are predicted using an analytical modelling tool, developed by Senex, with probabilistic distributions applied to several key reservoir parameters (i.e. permeability, porosity, and net coal). The model predictions generate production profiles (type curves). These production profiles are used in field development planning to provide a water forecast. Type curves are updated during the life of the Project as more information (e.g. key reservoir parameters) becomes available.

Figure 3.2 presents the predicted water forecast, as total water production rate per day, for the Project. Peak CSG water production is predicted to occur in 2026 at an average daily rate of ~4.6 ML/d, the daily produced water rate is expected up to a maximum rate of 6.5 ML/day. It is estimated that ~6,800 ML of groundwater will be produced during the Project life.

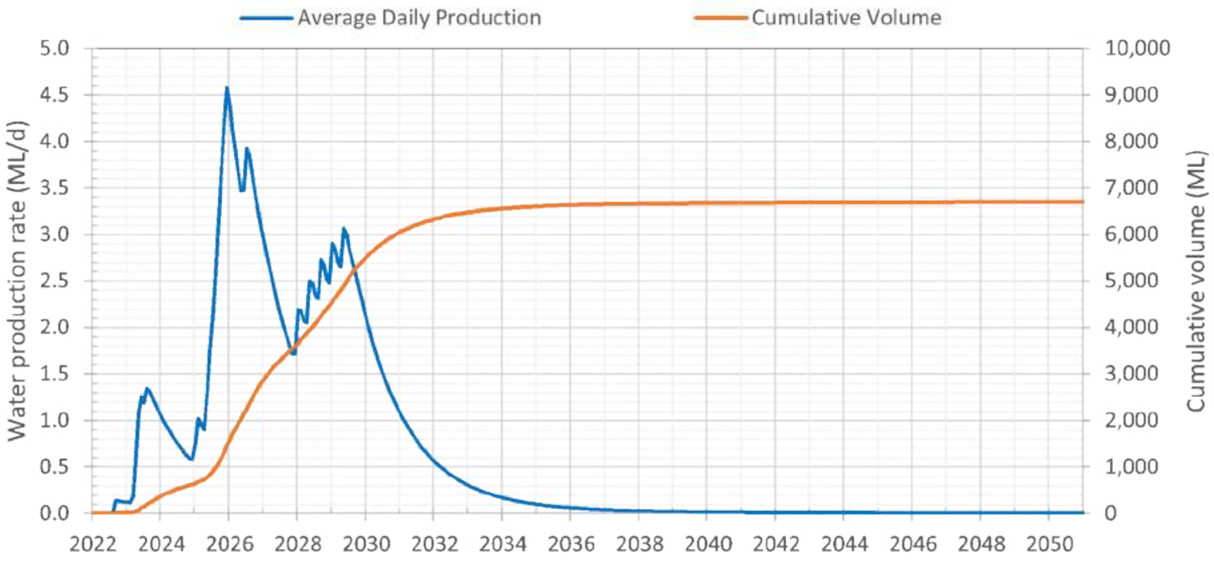


Figure 3.2 Proposed CSG Water Production Rate for Atlas Stage 3 (151 CSG Production Wells)

3.3.1.2 CSG Water Management

A water balance model has been developed using industry standard software (GoldSim) to determine timing for the long-term water management strategy for the Project. The model has been designed and configured to simulate the operation of the existing PL 1037 water management system (as shown in Figure 3.3) with the ability to incorporate additional water management infrastructure as/if required due to the increased water production forecasts.

The water balance model uses a probabilistic simulation approach where long-term daily climate data for the region from 1889 to 2021 is adopted in the model. This results in 108 distinct solutions for each time step within the 26-year simulation period, with statistics used to present the results in terms of exceedance percentiles. For example, P5 represents the 5th percentile of non-exceedance; where there is a 5% chance of water volumes being less because of dry climate conditions (or a 95% chance of volumes being greater); P50 represents the 50th or median percentile because of average climate conditions; and P95 represents the 95th percentile non-exceedance where there is a 95% chance of water volumes being less because of wet climate conditions (or a 5% chance of volumes being greater). This evaluates the resilience of the model under different climatic conditions.

The water balance model is based on a daily timestep and considers the changing volume over time in the aggregation dams, brine tanks and irrigation dam. Storage curves are referenced to determine the changing free water surface and corresponding daily evaporation rate, with Morton's lake evaporation rates (SILO 2022) from the wet surface areas, considered in each time step.

The water balance model provides a prediction of stored water volumes over time using the water production forecast and can be used to estimate the timing that additional storage or beneficial use applications may be required.

CSG produced water for the Project will be collected via water gathering systems. Where practicable, and to the extent authorised by current and future approvals, the proposed action will integrate with infrastructure constructed as part of Project Atlas within PL 1037. Such integration will maximise operational efficiency and reduce the impacts of the proposed action.

The water management process for the produced water is expected to involve:

- New aggregation dams that will be established on PL 209 to service produced water from the up to 151 wells of the proposed action. Where additional aggregation storage is required, measures will range from pre-engineered above ground tanks to purpose built earthen dams with impervious liners and leakage detection/collection systems as required.
- Water will be treated through the existing Project Atlas water treatment facility (not part of this action) which has adequate treatment capacity of approximately 4.5ML/d throughput. Subject to water production rates and other field development characteristics, an additional water treatment facility may also be constructed on PL 209. This potential water treatment facility is part of the proposed action.
- Treated water will be transferred to third party irrigation dam(s) (approximately 50-200 ML each) on PL 1037 and/or PL 209 under existing agreements.
- Brine from the water treatment facility will be stored in a new Atlas Stage 3 brine storage dam[2] (up to approximately 300 ML) which will be developed (constructed and operated) on previously cleared parts of eastern PL 1037 (proximate to the existing water treatment facility and Project Atlas' existing 100 ML of bring storage and planned additional 200 ML of brine storage) and is part of the proposed action. Additional brine storage is anticipated (up to approximately 300 ML) on PL 209 if a water treatment facility is established. Based on a median salt concentration of 5,176 mg/L Total Dissolved Solids (TDS), it is anticipated that approximately 5 tonnes of salt per mega litre of produced water will be generated.

In total, up to approximately 30 ha of Atlas Stage 3 brine storage and up to approximately 30 ha water storage will be established as a result of the proposed action.

The infrastructure and process flow associated with water management is provided in Figure 3.3.

Zero discharge to surface water is proposed.

Senex's strategy for CSG water management for the Project has been developed based on the DES Prioritisation Hierarchy (DEHP 2012). The water management options have been developed to maximise beneficial use of produced water.

The Atlas Stage 3 CSG Water Management Plans (ATP 2059: SENEX-ATLS-EN-PLN-013; PL 445 and PL 209: SENEX-ATLS-EN-PLN-14) provide further information relating to the management of CSG water and associated water storage.

[2] The treatment of CSG produced water using desalination technologies results in brine.

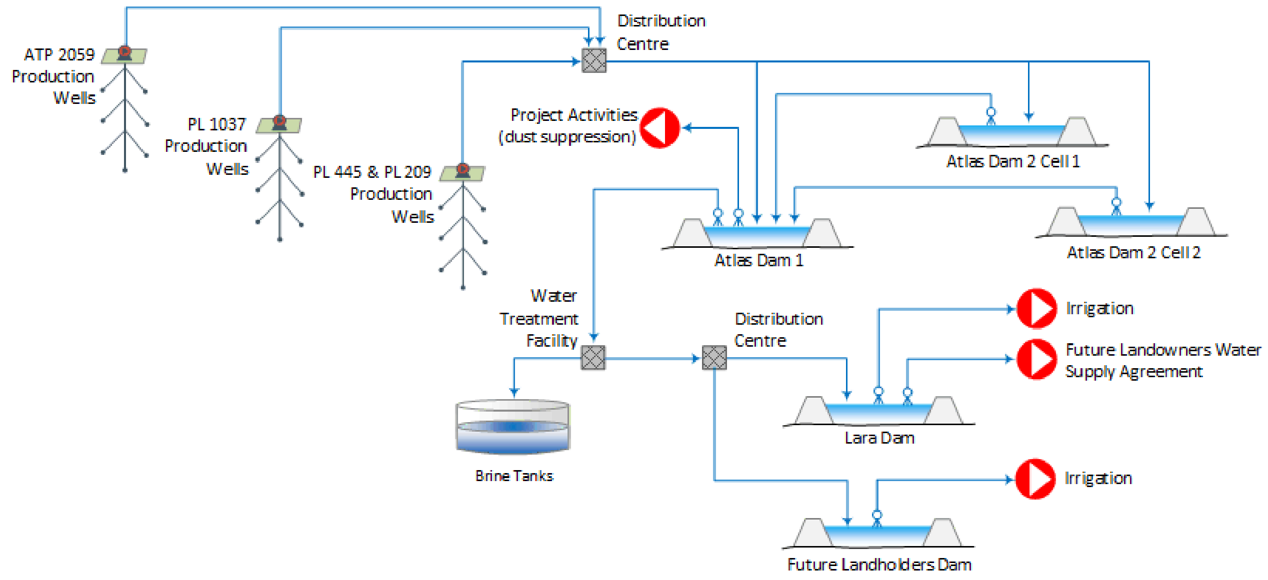


Figure 3.3 Water Management Infrastructure Schematic

A shallow groundwater (seepage) monitoring network has been established for existing surface water storage facilities and will be expanded for new facilities. Operations and Management plans are in place.

3.3.1.3 Infrastructure Location Planning

The exact locations of water management infrastructure within the Project area, as well as proximate to the existing water management facilities in PL 1037, are still to be finalised. The unconfirmed Atlas Stage 3 brine storage location in PL 1037 will be located within areas that have been subject to earlier ecology assessments for Senex's existing Project Atlas (EPBC 2018-8329). The potential impacts to water resources from this proposed brine storage facility has been included in this assessment. To support well field layout for all surface infrastructure, including wells and gathering pipelines, and to avoid, minimise and manage potential impacts across the Project area, Senex will implement the 'Atlas Stage 3 Environmental Constraints Protocol for Planning and Field Development' (OPS-ATLS-EN-PLN-001; Senex 2023a) (the Constraints Protocol). The Constraints Protocol aims to ensure that infrastructure siting:

- Considers biodiversity values and environmental constraints, such as sensitive receptors, when selecting preferential locations, and aligning with planning principles to avoid, minimise, mitigate, and then manage potential environmental impacts; and
- Identifies any additional external environmental approvals required and that those are secured prior to the commencement of construction activities.

With respect to EVs, the protocol addresses avoiding or minimising and managing potential impacts to:

- Biodiversity values contributing to environmentally sensitive areas (ESA), matters of state environmental significance (MSES) and MNES;
- Habitat for wildlife, including threatened MSES and MNES threatened communities, flora and fauna; and

- Wetlands, watercourses, springs and GDEs.

The Constraints Protocol also recognises that, in addition to environmental constraints, landholder, engineering and cultural heritage constraints must be considered during infrastructure siting.

The process involves a desktop constraints analysis, site surveys, post-survey environmental constraints analysis and preparing a report that includes a list of site-specific environmental conditions and associated constraints maps. These are included in the final Access to Work (ATW) documentation, issued upon sign-off by the Project Manager to relevant staff and contractors prior to commencing construction.

Further field investigations may be undertaken to confirm the suitability and baseline conditions prior to finalising the locations of infrastructure.

Surface Water Storage

The undulating topography of the Project area results in the presence of numerous drainage features and low stream order watercourses, together with a limited number of higher stream order (SO ≥4) watercourses (e.g. Wandoan and Woleebee Creeks). The government 1% AEP flood mapping over the Project area is relatively granular, especially for low order watercourses (SO 1) and may not be relied upon for finer scale field development planning.

Where necessitated by location constraints, diversion drains may be constructed around water storages (dams) to re-establish drainage lines and stream order 1 watercourses away from the water storages. For higher order watercourses (SO ≥2), Senex will avoid locating regulated structures (as defined under the EP Act 1994) within the mapped 1% AEP zone (or as subsequently calculated by SQPs).

At a State level, the design of a Dam is stringently regulated through the imposition of conditions of approval, generally following the form used in the DES guideline: *Structures which are dams or levees constructed as part of environmentally relevant activities (ESR/ 2016/1934)*. Dam design is required to be in accordance with a Dam Design Plan prepared and certified by a Registered Professional Engineer of Queensland (RPEQ). An RPEQ must also oversee the construction of the proposed Dam.

Of particular relevance, model condition X8 covers design and construction in relation to dam integrity:

(X 8) **Regulated structures** must:

a) be designed and constructed in compliance with the Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933[8]);

b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of:

*i) floodwaters from entering the **regulated dam** from any **watercourse** or drainage line; and*

ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line.

In addition, the capacity of a water storage classified as high or significant consequence under the DES guideline: *Manual for assessing consequence categories and hydraulic performance of structures (ESR/2016/1933)* must include a:

- Design Storage Allowance (DSA) – a volume that must be available at 1 November every year to allow for wet season rainfall without overtopping;
- Mandatory Reporting Limit (MRL) – the level at which the operator must report to the regulator, and at which point measures may be required to reduce or manage water levels; and
- Extreme Storm Storage (ESS) - a storm storage allowance to allow for waves within the dam and brief heavy rainfall without overtopping.

Senex will line proposed water stores with an appropriate geo-synthetic impermeable liner and install relevant seepage detection (below the liner and monitoring bores) in accordance with the likely State conditions of approval.

4 ASSESSMENT METHODOLOGY

4.1 Assessment Methodology

The description of the existing environment across the Project area was compiled through a desktop assessment to establish the baseline groundwater conditions, EVs and potential receptors. This was further supported with the undertaking of a field program to collect site-specific information. This identification of baseline conditions included a review of the data collected for the directly adjacent Project Atlas (within PL 1037) including the area of the proposed new brine storage dam which is in the vicinity of the existing water treatment facility.

The assessment area for the purposes of this report includes the surface water features within and adjacent to the Project area, hydrostratigraphic units underlying the Project within the Surat Basin and overlying Quaternary deposits. For the identification of groundwater receptors relevant to this Project, a 25 km buffer around the Project area was established to capture potential adjacent groundwater receptors that may be impacted by the proposed development. The 25 km buffer extends from the PL boundaries, and the southern extent of PL 209[3].

Primary data and information utilised in this assessment is listed in the following section.

4.1.1 Information and Data Sources

A preliminary desktop assessment utilised data and information provided by Senex, OGIA and publicly available reports and data. Primary information utilised in this assessment includes:

Datasets:

- 1:100 000 scale geological maps for the Surat Basin, including the Detailed Surface and solid Geology – Queensland (State of Queensland 2018b).
- 2021 Surat CMA regional geological model (OGIA 2021b), Groundwater modelling report for the Surat CMA (OGIA 2021c; 2019c) and model predictions.
- Queensland groundwater bore database (GWDB) for registered bore construction data from private water bores and Queensland Government groundwater investigation and monitoring bores (State of Queensland 2022c).
- OGIA aquifer attribution (OGIA 2022).
- Department of Science, Information Technology, and Innovation (DSITI) Queensland Groundwater Dependent Ecosystem Mapping (State of Queensland 2018c), which indicates the locations of potential GDEs at a catchment scale (both surface expression and terrestrial).
- The Queensland Spring Database provides a comprehensive catalogue of springs and potential GDEs at fixed locations in Queensland. The Queensland Spring Database is updated annually (Queensland Herbarium 2021).
- CSG monitoring bore data and information, sourced from the Queensland Globe.
- OGIA subsidence assessment undertaken for the Surat Basin 2019 CMA UWIR.

[3] Note that only the northern portion of PL 209 is being developed.

- Groundwater monitoring dataset (level and quality) from neighbouring proponent.

Reports

- Underground Water Impact Report for the Surat CMA 2021 and associated technical documents and appendices (OGIA 2021f).
- Hydrogeological Conceptualisation Report for the Surat CMA (OGIA 2016c).
- Springs in the Surat CMA (OGIA 2016b).
- Identification of Gaining Steams in the Surat CMA; Hydrogeological Investigation Report (OGIA 2017).
- Environmental Protection Policy (Water) 2009 – Dawson River Sub-Basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek Catchment (State of Queensland 2011).

4.1.2 Site Specific Investigations

Field programs were undertaken to refine the description of the existing environment and confirm environmental values across the Project. A summary of these programs is provided in the following sections.

4.1.2.1 Field Investigation

Drilling and monitoring bore installation was completed within the Project area between December 9, 2022, and September 9, 2023. Eight monitoring bores were installed at four locations to assist with understanding site-specific hydrogeology and provide long-term monitoring locations. Monitoring bore locations were selected both adjacent to the creek and away from the creek in the alluvial plains to provide a broader understanding of groundwater occurrence across the whole alluvial system. This variety of locations, particularly adjacent to the creek, provides increased confidence in the hydrogeological conceptual model of the area. Further information on the field investigation is provided in Appendix X and XI. A monitoring bore location plan is provided in Figure 4.1 and further information is provided in Table 4.1.

The following activities were undertaken as part of the field investigation:

- The installation of four monitoring bores in the alluvium, and four in the hydrostratigraphic unit underlying alluvium at the first water strike (total of eight bores) adjacent to the alluvium bores. Bores were drilled using dry air rotary techniques.
- Development of all bores via airlifting technique following installation, groundwater sampling at the end of development followed by a period of stabilisation and aquifer hydraulic testing.
- Hydraulic testing of each bore (where water was present) via variable head (solid slug) testing methods.
- The installation of Solinst Pressure Transducer Dataloggers (PTDL) in each bore and recording of groundwater levels at 12-hour intervals.

- Quarterly groundwater samples collected from each bore (where water was present) at least four weeks after installation. The baseline water quality results are presented in Appendix I.
- The installation of a PTDL in a former government alluvium monitoring bore RN13030810 (March 1, 2023).
- Collection of a surface water sample from Woleebee Creek where it flows within alluvium above the Springbok Sandstone.

The rationale for the selected locations of the Senex monitoring bores included:

- Locations on the alluvium to allow installation of a paired monitoring bore in the shallow alluvium and deeper Surat Basin units. Monitoring bore pairs allowed for assessment of the hydraulic connection between these units through comparisons of groundwater level and groundwater quality.
- The Westbourne Formation and the Upper Springbok Sandstone were targeted for monitoring as the sub-crop beneath most of the Project area and the alluvium located along Woleebee and Wandoan Creeks.
- Locations as close to potential terrestrial GDEs on the Upper Springbok Sandstone on PL 445.

Actual bore locations were selected in consultation with Senex field representatives but dictated by access conditions including land access, the ability to access during wet conditions, rig accessibility and landholder agreements.

Senex were unable to install monitoring bores off-tenement, however, have data sharing agreements with the tenement holders directly north of ATP 2059, PL 445 and PL 209 to allow the collation and review of data from these areas.

Table 4.1 Senex Site Specific Monitoring Bores

<table>
<tr><th rowspan="2">Senex ID</th><th rowspan="2">Installation Date</th><th rowspan="2">Distance to Woleebee Creek (m)</th><th colspan="2">GDA94 Zone 56</th><th colspan="2">Screen (mbGL)</th><th rowspan="2">Source Aquifer</th><th rowspan="2">Rationale</th><th rowspan="2">Location</th></tr>
<tr><th>Easting (mE)</th><th>Northing (mN)</th><th>From</th><th>To</th></tr>
<tr><td>ATLAS-13M-D</td><td>10/12/22</td><td>395</td><td>782185</td><td>7101921</td><td>30.5</td><td>36.5</td><td>Westbourne Formation</td><td>▪ Characterise lithological profile and monitor groundwater in Westbourne Formation near Woleebee Creek.
▪ Investigate potential for hydraulic connection with overlying alluvium.</td><td rowspan="4">ATP 2059</td></tr>
<tr><td>ATLAS-13M-S</td><td>10/12/22</td><td>395</td><td>782184</td><td>7101917</td><td>6.0</td><td>9.0</td><td>Alluvium</td><td>▪ Characterise lithological profile and monitor groundwater in Alluvium above the Westbourne Formation near Woleebee Creek.
▪ Investigate potential for hydraulic connection with underlying Westbourne Formation.</td></tr>
<tr><td>ATLAS-14M-D</td><td>24/01/23</td><td>298</td><td>783221</td><td>7102910</td><td>40.0</td><td>46.0</td><td>Springbok Sandstone</td><td>▪ Characterise lithological profile and monitor groundwater in Springbok Sandstone near Woleebee Creek.
▪ Investigate potential for hydraulic connection with overlying alluvium.</td></tr>
<tr><td>ATLAS-14M-S</td><td>24/01/23</td><td>298</td><td>783217</td><td>7102907</td><td>7.0</td><td>10.0</td><td>Alluvium</td><td>▪ Characterise lithological profile and monitor groundwater in Alluvium above the Springbok Sandstone near Woleebee Creek.
▪ Investigate potential for hydraulic connection with underlying Springbok Sandstone.</td></tr>
<tr><td>ATLAS-15M-D</td><td>20/01/23</td><td>68</td><td>783871</td><td>7096028</td><td>29.0</td><td>35.0</td><td>Westbourne Formation</td><td>▪ Characterise lithological profile and monitor groundwater in bedrock near Woleebee Creek.
▪ Investigate potential for hydraulic connection with overlying alluvium.</td><td rowspan="2">PL 209</td></tr>
<tr><td>ATLAS-15M-S</td><td>19/01/23</td><td>74</td><td>783869</td><td>7096012</td><td>8.4</td><td>11.4</td><td>Alluvium</td><td>▪ Characterise lithological profile and monitor groundwater in Alluvium above the Surat Basin unit near Woleebee Creek.
▪ Investigate potential for hydraulic connection with underlying bedrock.</td></tr>
<tr><td rowspan="2">ATLAS-19M-D</td><td rowspan="2">08/09/23</td><td rowspan="2">40</td><td rowspan="2">783359</td><td rowspan="2">7102620</td><td>24.0</td><td>30.0</td><td rowspan="2">Springbok Sandstone</td><td rowspan="2">▪ Characterise lithological profile and monitor groundwater in Springbok Sandstone immediately adjacent to Woleebee Creek and potential terrestrial GDEs.
▪ Investigate potential for hydraulic connection with overlying alluvium.</td><td rowspan="3">PL 445</td></tr>
<tr><td>39.0</td><td>45.0</td></tr>
<tr><td>ATLAS-19M-S</td><td>09/09/23</td><td>40</td><td>783356</td><td>7102616</td><td>4.5</td><td>7.5</td><td>Alluvium</td><td>▪ Characterise lithological profile and monitor groundwater in Alluvium above the Springbok Sandstone immediately adjacent to Woleebee Creek and potential terrestrial GDEs.
▪ Investigate potential for hydraulic connection with underlying Springbok Sandstone.</td></tr>
</table>

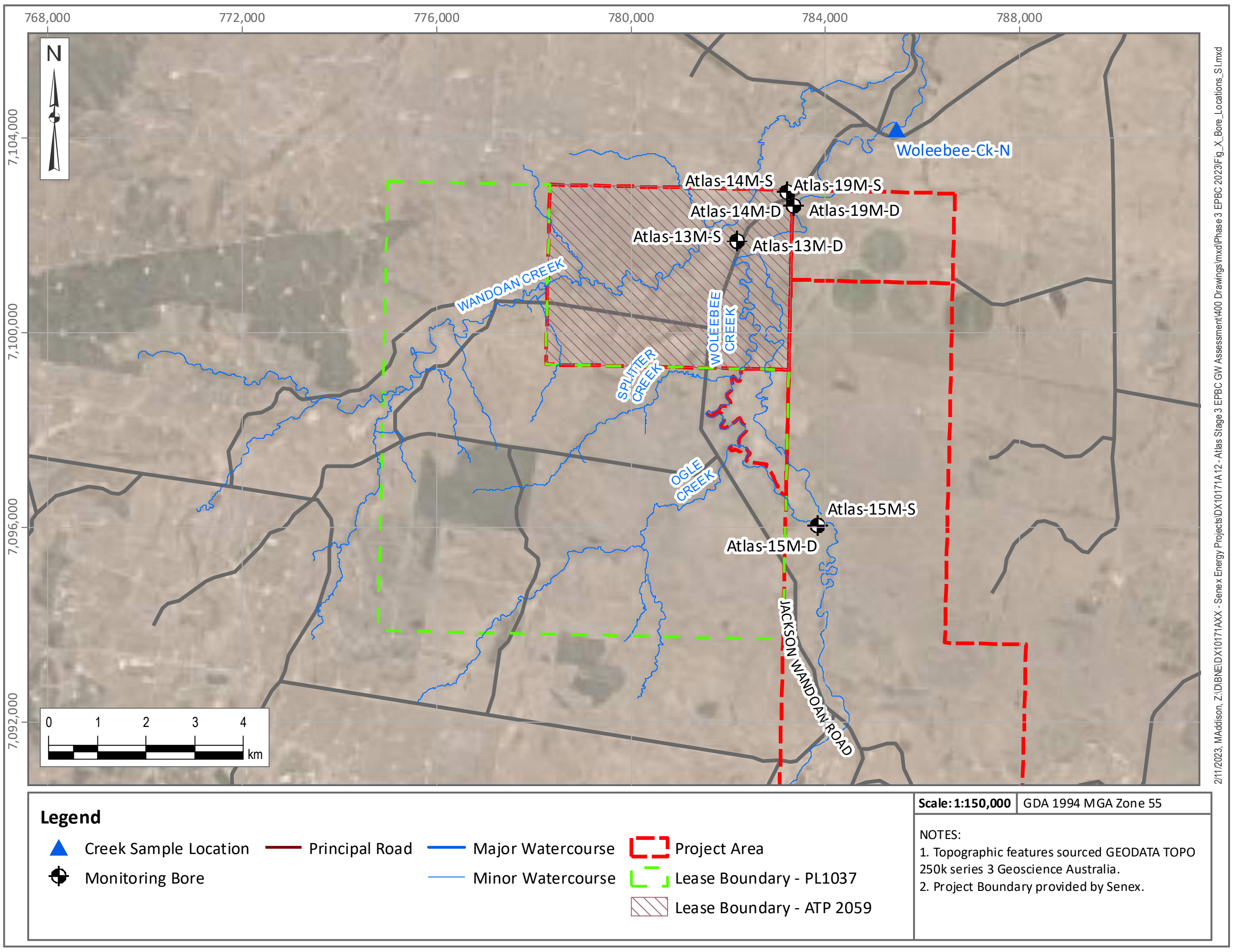


Figure 4.1 Site Investigation Bore Locations

4.1.2.2 Isotope Analysis

Five water samples, consisting of four groundwater and one surface water sample, including from bores drilled during the field investigation were collected in February 2023 by a KCB hydrogeologist. Water samples were sent to the GNS Science Laboratory in New Zealand for analysis of hydrogen and oxygen isotopes using an Isoprime Mass Spectrometer. The results of the isotope sampling are provided in Section 7.7.2

4.1.2.3 Baseline Assessment

Baseline assessments were required to be undertaken by Senex, as part of the *Water Act 2000*, on all existing water bores within ATP 2059, PL 445, PL 209, and PL 1037 tenures. The baseline assessments were undertaken in accordance with the requirements and methodology outlined in the Department of Environment and Science (DES) 'Baseline Assessment Guideline' (State of Queensland 2022a) and as stipulated in the approved Baseline Assessment Plan (BAP) prepared by Senex (Senex 2022b). The information collated during the baseline assessments is presented in Section 7.12.2.

4.1.2.4 Field Verification Mapping

Surface water and groundwater features mapped within the Project area include several watercourses, alluvium associated with the watercourses, a potential baseflow-fed reach (watercourse spring) and potential terrestrial GDEs.

Due to wet weather, field verification across the Project area could not be undertaken. However, field verification mapping has been undertaken for neighbouring PL 1037 in 2018 for EPBC approvals (KCB 2018c) (Appendix IX). The 2018 field verification included upstream Woleebee and Wandoan Creek catchments, which are present in the Project area. The 2018 field verification program included:

- Field mapping and surface water sampling (where possible) of Wandoan Creek and Woleebee Creek;
- Data collection and observations related to the nature and extent of the alluvium, creek flow, groundwater-surface water interconnectivity and assessment of inferred hydrogeological conditions in the areas of mapped potential GDEs (DES 2018d); and
- Groundwater and surface water sample collection in the area of Woleebee Creek, a potentially gaining stream (identified in OGIA (2017)), to assist in the assessment of any potential watercourse springs and identification of the source aquifer.

4.1.2.5 Ecological Survey and GDE Mapping

Terrestrial and aquatic ecology field surveys were undertaken by ERM (ERM 2022b) and Freshwater Ecology (Freshwater Ecology 2022a). These surveys included the mapping of potential GDEs within the Project area and verification of vegetation communities which may be reliant on groundwater (ERM 2022a). Further details of these surveys are provided in Appendix VIII.

4.1.2.6 GDE Subterranean Fauna

Sampling for subterranean fauna was undertaken at 12 existing landholder bores within the Project area. The sampling was undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b). Sampling was undertaken by Freshwater Ecology (Freshwater Ecology 2022b, see Appendix VII).

Biota sorting and identification were completed by Blue Earth Environmental. In-situ groundwater quality was considered high and suitable for the presence of stygofauna. Samples were taken from the Upper Springbok Sandstone (one), Westbourne Formation (one), Gubberamunda Sandstone (seven) and the Orallo Formation (three).

Stygofauna sampling was undertaken by Hydrobiology on neighbouring PL 1037 at four existing landholder bores. The sampling was undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b).

4.1.2.7 Aquatic Ecology Survey

Aquatic ecology surveys were undertaken by ecologists from Freshwater Ecology (Freshwater Ecology 2022a).

Aquatic Habitat Assessment

Aquatic habitat assessment was undertaken in accordance with the Queensland AUSRIVAS Sampling and Processing Manual (DNRM 2001b) describing each survey reach and its immediate surrounds. Planform and cross-sectional sketches recorded bank full height, bank full width, depth, wetted width, and normal width, as well as key habitat features. Georeferenced photographs including upstream, downstream, left bank, and right bank directions were taken at each site, and throughout lengths of the dry creek sections traversed. A record was kept of condition and micro- and macro-habitat features of the creek sections between sites.

To assist with interpreting habitat classification, the River Bioassessment Program scores (bioassessment scores; out of 135) were calculated for all sites based on nine AUSRIVAS categories, including:

- Habitat availability (pool/riffle, run/bend ratio);
- Bank stability;
- Streamside cover;
- Bed substrate composition and embeddedness;
- Channel alteration; and
- Presence of scouring and/or deposition.

From these scores, an aquatic habitat condition rating was calculated and categorised into 'Poor', 'Fair', 'Good' or 'Excellent' habitat conditions.

Aquatic Flora

An inventory of aquatic flora species identified during the field program was compiled based on visual observation and identification. Species were identified in the field using available literature, and the presence and site coverage (i.e. extensive, moderate, some or little) of aquatic flora were determined within the study reach. Species were categorised by growth form (i.e. free floating, floating attached, submerged or emergent).

Macroinvertebrates

Macroinvertebrate sampling was undertaken using a combination of AUSRIVAS protocols and replicated samples, to assess which method may provide the most representative understanding of macroinvertebrate communities in the Project area. AUSRIVAS protocols are intended to be used at a catchment or regional scale, whereas for smaller scale studies, control and replicate sites are likely to be more appropriate. Samples were obtained from each site for each of the aquatic habitats present:

- Edge habitat – sample collected by sweeping a 250 µm mesh dip-net along bank habitat, proportionally incorporating the spatial occurrence of key microhabitats present within the sampled stream reach; and
- Bed habitat – benthic (bed) samples were obtained using the kick-sampling method, which consisted of kicking and disturbing the bed and sweeping the disturbance with a 250 µm mesh dip-net to capture dislodged macroinvertebrates.

Habitat conditions were recorded, detailing macroinvertebrate habitat conditions, including physical characteristics (width, depth, velocity), substrate composition (silt, sand, mud, gravel) and microhabitat structure (detritus, sticks, logs, plants).

For Queensland, live-picking macroinvertebrates from the sample is the method required for the Queensland AUSRIVAS modelling program (DNRM 2001b). AUSRIVAS sampling protocols require that a habitat type should be sampled if it accounts for more than 10% of the study reach. Macroinvertebrates were collected from both the edge and bed habitats (where available) at all sites from freshwater watercourses (impoundments and wetlands are not appropriate comparisons).

All picked specimens were placed into sample jars and preserved with 70% ethanol for later identification.

All preserved samples were processed under laboratory conditions by AUSRIVAS-accredited scientists, who performed identification and enumeration of macroinvertebrates. Organisms were generally identified to family level, with the exception of lower phyla (nematoda, nemertea etc.), oligochaetes (freshwater worms), acarina (mites) and microcrustacea (ostracoda, copepoda and cladocera). Chironomids were identified to sub-family level, in accordance with standard AUSRIVAS protocols (DNRM 2001b).

Fish, Macrocrustaceans and Turtles

Fish surveys were conducted in line with the approach outlined in the Monitoring and Sampling Manual: Environmental Protection (Water) Policy (DES 2018a). All electrofishing sampling was undertaken by senior electrofishing operators and in accordance with the Australian Code of Electrofishing Practice (NSW Fisheries 1997).

Sampling methods at each site included fyke nets, backpack electrofishing and unbaited boxes. Fish were identified to species level, enumerated, measured, and assessed for obvious wounds, lesions, or deformities. After completion of processing, all native species were released at the point of capture.

Unbaited box trapping is a passive fish sampling technique that targets small bodied pelagic and benthic species. Five to ten unbaited box traps were strategically placed at all sites for between 30 minutes and 2 hours.

Backpack Electrofishing

Backpack electrofishing was undertaken in waterways that held water, using a LR20B electrofishing unit. Sampling was carried out over a site reach spanning at least 100 m (where sufficient water was available), with care being taken to sample all macro and microhabitat types. Settings for the backpack electrofisher varied between sites, depending on water conductivity, depth, fish size and species. All electrofishing was undertaken in compliance with the Australian Code of Electrofishing Practice (NSW Fisheries 1997) with the minimum power setting used to effectively attract and stun the fish.

Fyke Netting

Fyke nets were deployed at sites that had sufficient water levels. Nets were deployed with sufficient breathing area above the water for air-breathing fauna that might be captured (i.e., turtles).

4.2 Impact Assessment Methodology

4.2.1 Chemical Contamination

Potential chemical contamination may occur due to the storage and use of drilling fluids, and seepage, overtopping or release of produced water or brine from surface water storage facilities.

A chemical risk assessment has been undertaken for chemicals to be used as part of the CSG extraction during the Project development. The assessment examined the risks associated with use of drilling fluids and their associated chemicals. The chemical risk assessment follows the Chemical Risk Assessment Framework (CRAF). The chemical risk assessment is undertaken in accordance with leading industry practice risk assessment methodologies both internationally and domestically, which meets the DCCEEW “best practice” requirement. The best practice national and international standards and guidelines include:

- The Organisation for Economic Co-operation and Development (OECD) Manual for Assessment Toolkit (OECD 2014).
- AS/NZS 4360:2004: Risk Management and AS/NZS ISO 31000:2009 Risk Management – Principals and Guidelines (AS/NZS 2004; 2009).

Current “best practice” guidance includes:

- Exposure Draft: Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction (DoEE 2017).
- Industrial Chemicals Notifications and Assessment Scheme (NICNAS) and approach used for industrial chemicals.

The aim of the chemical risk assessment framework is to enable:

- Evaluation of the potential risks and effects of chemicals used during CSG operations (drilling and completions, and water treatment) to MNES.
- Evaluation of the potential risks and effects of geogenic chemicals to MNES that may be present in recovered drilling fluids and produced waters during CSG operations.

The objective of the risk assessment is to:

- Demonstrate that the potential risks to MNES associated with the chemicals used in CSG operations have been eliminated or reduced as much as practically possible.

In assessing the environmental impact from drilling fluid chemicals, the following stages of the chemical lifecycle were considered:

- Transport to and storage on the drilling site;
- Processing on-site at the CSG production well head prior to use;

- During use down-hole; and
- Disposal of the fluid.

4.2.2 Changes to Hydrological Regimes

The IESC checklist identifies that analytical and/or numerical modelling is to be undertaken for the assessment of impacts to surface water. The proposed Project does not include any discharges to surface water or interaction with surface water bodies, and therefore, direct impacts to surface water are not anticipated. On this basis, modelling was not deemed necessary as part of this assessment. Indirect impacts to surface water systems, such as unplanned releases and overtopping are dealt with through monitoring, management and mitigation of the surface water storage facilities.

A review of other potential impacts to surface water as a result of the Project are discussed in Section 9. Relevant mitigation, management, and monitoring measures to address these potential impacts are provided in Section 9.9.

Aquatic ecosystems have been considered within this mitigation, management and monitoring framework.

4.2.3 Changes to Water Quality

Potential changes to groundwater quality as a result of Project development activities may relate to the use of drilling fluids and seepage from water storage facilities.

Potential changes to surface water quality from Project activities relate to the use of drilling fluids, surface spills, localised transport of suspended sediment to waters during construction or site works, or unplanned releasees from water storage facilities.

Impacts to water quality related to the use of chemicals by the Project are discussed in the Chemical Risk Assessment (discussed in Section 4.2.1 above).

4.2.4 Groundwater Drawdown and Associated Impacts

OGIA simulated the predictive model scenario for Senex using the regional groundwater flow model that underpins the Surat CMA UWIR (OGIA 2021f), and based on the proposed development information provided by Senex (e.g. number and location of wells, production scheduling, water forecasts, and durations).

Modelling included simulations to provide impact predictions from the Project as well as cumulative impact predictions from other approved and foreseen CSG developments as well as coal mines, as defined in the 2021 UWIR for the Surat CMA (OGIA 2021f). Outputs from the modelling have been processed by KCB and considered as part of this assessment (Section 8).

The assessment criteria used to consider the groundwater drawdown impacts associated with the Project refers to the *Water Act 2000*, groundwater and springs trigger thresholds, as outlined in Section 2.2.2:

- Bore trigger threshold, represents the maximum allowable groundwater level decline in a groundwater bore, due to petroleum tenure holders exercising their water rights, prior to triggering an investigation into the water level decline / impairment of water bore capacity.

- For a consolidated aquifer – 5 m.
- For an unconsolidated aquifer – 2 m.

- Spring trigger threshold represents the maximum allowable decline in the water level of an aquifer in connection with a spring, at the spring location, prior to triggering an investigation into the water level decline.
  - Spring – 0.2 m.

Potential impacts to the source aquifers for GDEs and spring complexes (watercourse springs) have been assessed using the predicted drawdown from the Surat CMA UWIR numerical model with consideration to hydrogeological conceptual understanding of the system. Groundwater and surface water interactions have also been considered through the conceptual understanding of the system.

Other potential impacts associated with the Project in relation to groundwater are presented in Section 9, with the relevant mitigation, management, and monitoring measures to address these potential impacts provided in Section 9.9.

4.2.5 Subsidence

KCB have undertaken an assessment of the potential subsidence for both Project only and cumulative predictive model scenario drawdown predictions by applying a subsidence calculation based on the compaction at a specific location method (Sanderson 2012; Coffey 2018). This method considers the axial compression of lateral strain using Poisson's Ratio with Young's Modulus to calculate a coefficient of volume compressibility. It calculates compaction directly due to groundwater pressure changes in the geological unit at a given location. This was the same methodology applied by Arrow Energy (Coffey 2018) and has been previously accepted by the OGIA.

The *Compaction at a Specific Location* method considers the ratio of axial compression to lateral strain using Poisson's Ratio with Young's Modulus to calculate a coefficient of volume compressibility. This methodology has been adopted for the calculation of Project only and cumulative drawdown scenario subsidence for the Project. This methodology was previously adopted by Arrow (Coffey 2018) and has been accepted by OGIA.

Compaction (δ) directly due to groundwater pressure changes in the geological unit at a given location is given by (Sanderson 2012; Coffey 2018):

Equation 1 Subsidence Equation (Sanderson 2012)

$$\delta = \int_{z=\infty}^{z=0} \delta u \, \alpha \frac{(1+v')(1-2v')}{(1-v')E'} dz$$

Where:

δ	is the subsidence at the ground surface
z	is the depth below the ground surface

δu	is the pore pressure change at depth z below the ground surface
ν'	is the Poisson's ratio of the ground at depth z
α	is the Biot's coefficient of the ground at depth z
E'	is the drained Young's modulus of the ground at depth z

The values adopted in the calculation for the parameters above are provided in Table 4.2.

Table 4.2 Parameters Used in Settlement Calculations

Parameter	Description	Value	Rationale
E' – Young's modulus	Describes the elastic property of the rock, which represents the rock type.	7.8 GPa	Conservative calculation taken from Arrow which was calculated from observed subsidence versus drawdown in Arrow's Daandine CSG field. Considers the mixture of coal, sandstone and mudstone in the WCM.
α – Biot's coefficient	Relates to the effective stress in the rock.	0.85	Parameter value adopted from Arrow (Coffey 2018). Sandstone usually varies from 0.75 to 0.9
ν' – Poisson's ratio	The deformation (expansion or contraction) of a material in directions perpendicular to the specific direction of loading. An increased Poisson's Ratio reduces the amount of subsidence predicted.	0.25	IESC, 204
dz – Depth below the ground surface	Depth to top of the coal measures.	Varies	Depth provided by OGIA.
δu – Pore pressure change at depth z below the ground surface	Groundwater level depressurisation.	Varies	Drawdown provided for Project only and cumulative by OGIA. Varies across the Project area.

This equates to:

$$\delta = \frac{dz\ x\ 0.85\ x\ \delta u\ (1 + 0.25)(1 - 2\ x\ 0.25)}{7.8\ GPa \qquad\qquad (1 - 0.25)}$$

Depth to the coal seam (dz) and pore pressure change (δu) varies across the Project area and are unique to location. Therefore, these values were derived from the OGIA groundwater model data and predictions made specifically for the Project. These results were gridded as per the OGIA groundwater model grids (1.5 km x 1.5 km) across the Project area.

4.2.6 Cumulative Impacts

Due to the proximity of other CSG operations and coal mines in the Surat Basin to the Project area, there are potential for cumulative impacts to occur.

Both 'Project only' and cumulative impact model scenario predictions used for the Project were considered within the assessments above: chemical contamination, groundwater drawdown, and associated impacts and subsidence.

4.3 Risk Assessment

The IESC checklist identifies that a risk assessment should be conducted from an early stage of the Project area. Throughout the assessment, risks and uncertainties associated with the Project area have been considered and appropriate mitigation and management strategies developed. Section 9.8 presents the risk assessment results with both pre- and post-mitigation risks assessed.

5 EXISTING ENVIRONMENT

5.1 Topography

The topography of the Project area is presented in Figure 5.1. Elevations across the area range between 250 mAHD (metres above Australian Height Datum) and 420 mAHD. Topographic highs are present in the south of the Project area and form the surface water (Fitzroy Basin) and groundwater (GAB) divides. The Project is located within the Upper Dawson River sub-basin, which is part of the Fitzroy River Basin.

5.2 Climate

The Project area is classified under the modified Köppen classification system (BOM. 2005) as subtropical with no dry season. Climate statistics for Roma Airport weather station (43091) and rainfall statistics for Wandoan Post Office weather station (35014) are presented in Table 5.1. Mean maximum temperatures range between 34.6°C in the summer months and 20.4°C in the winter months. Mean minimum temperatures range between 20.1°C in the summer months and 3.8°C in the winter months. Daily evaporation rates are generally high and exceed rainfall throughout the year. The highest rainfall occurs during December to February, with the lowest rainfall occurring during April to September.

Table 5.1 Climate Statistics for Roma Airport and Wandoan Post Office, Site Numbers 43091 and 35914 (BOM 2022a; 2022b)

Statistic Element	Roma Airport (43091)				Wandoan Post Office (35014)	SILO
	Mean maximum temperature (°C)	Mean Minimum temperature (°C)	Mean Daily evaporation (mm)	Mean Rainfall (mm)	Mean Rainfall (mm)	Mean Monthly Evaporation (mm)
Period of Record	*1992 to 2022*	*1992 to 2022*	*1992 to 2022*	*1985 to 2022*	*1955 to 2022*	*1960 to 2023*
January	34.6	21.0	10.3	66.9	83.4	236.9
February	33.0	20.0	8.6	89.6	76.3	190.0
March	31.6	17.5	7.8	58.9	53.9	187.1
April	28.2	12.4	6.2	31.9	36.4	139.5
May	23.9	7.6	4.4	32.1	35.4	99.2
June	20.5	5.2	3.2	29.0	33.7	74.9
July	20.4	3.8	3.5	21.3	28.9	81.2
August	22.8	4.7	4.6	22.4	26.9	113.0
September	26.8	9.3	7.0	25.2	28.9	157.0
October	30.0	13.6	8.6	49.8	51.7	200.5
November	32.3	17.2	9.2	60.4	64.7	217.8
December	33.6	19.4	9.7	77.6	94.7	238.7
Annual	**28.1**	**12.6**	**6.9**	**47.1**	**51.2**	**161.3**

Note: Roma Airport statistics to 27 February 2022, Wandoan Post Office Statistics to 27 February 2022 (Accessed 08 June 2022).

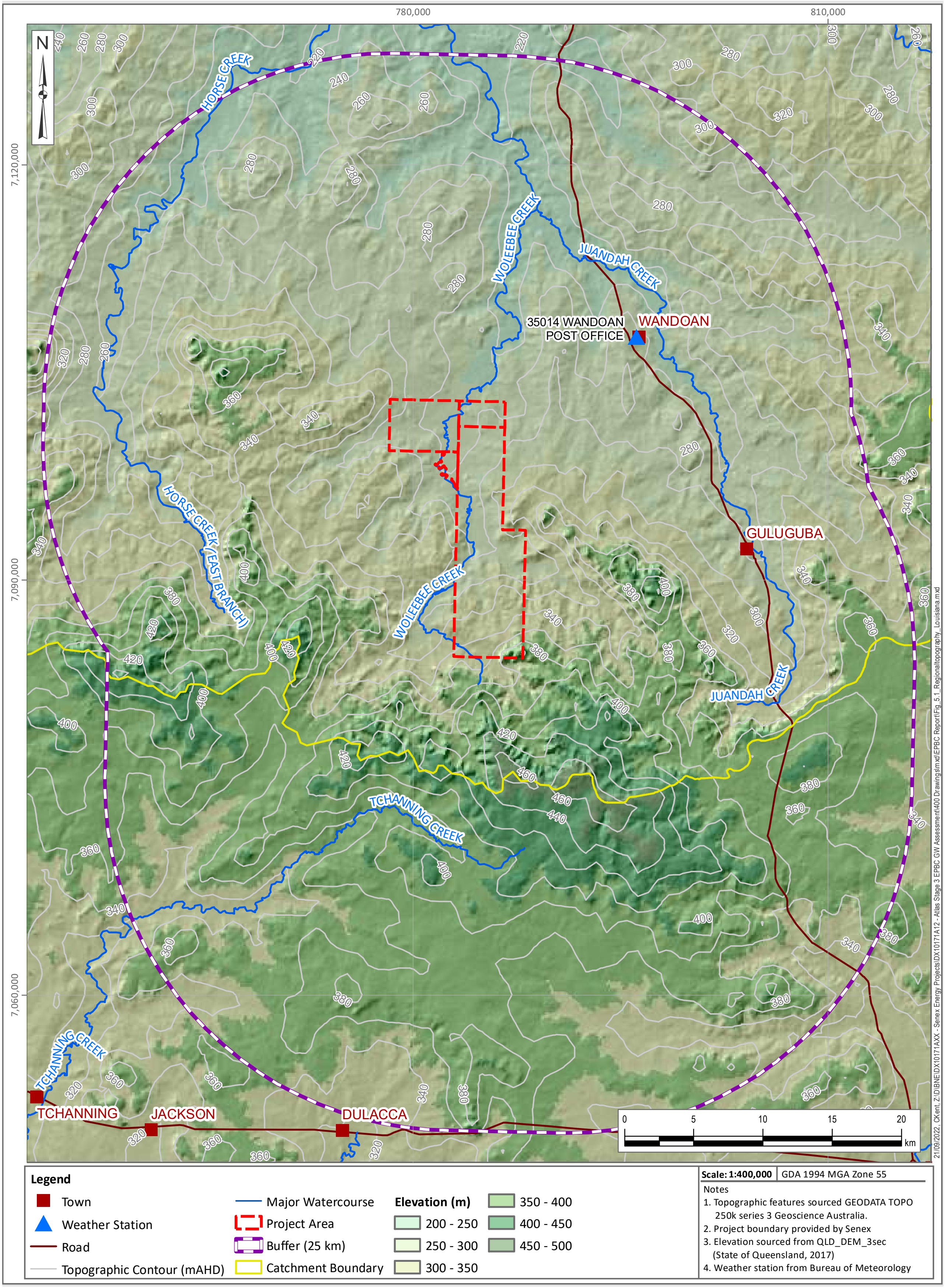


Figure 5.1 Project Area Regional Topography

Synthetic rainfall data were used to analyse rainfall trends due to incomplete rainfall data for the Project area (SILO 2022). SILO is an enhanced synthetic climate database that provides daily time series data for point locations and comprises actual station records augmented by interpolated estimates where observed data are missing.

Figure 5.2 presents daily rainfall between 1960 and 2022, as well as a cumulative rainfall departure (CRD) trend for the same period. CRD trends represent a running deviation of long-term actual rainfall against the overall average. This provides season-scale identification of trends (wet / dry) as well as longer term (e.g. decadal) deviation from average conditions. CRDs are useful for correlating rainfall events to aquifer responses. Observations from the CRD trend include:

- The overall rainfall trend is characterised by the cycle between the wet and dry seasons, with annual fluctuations of approximately 200 mm evident across the record.
- The trend shows a period of increasing rainfall between 1960 and 1986, a decline to below average conditions between 1986 and 1994, an increasing period to 1999 and a declining period to 2009.
- Between 2010 and 2012, a series of large rainfall events dominate the record, resulting in above average rainfall conditions, which is followed by a period of decline to 2019. Since 2020 there has been above average rainfall recorded to present day.

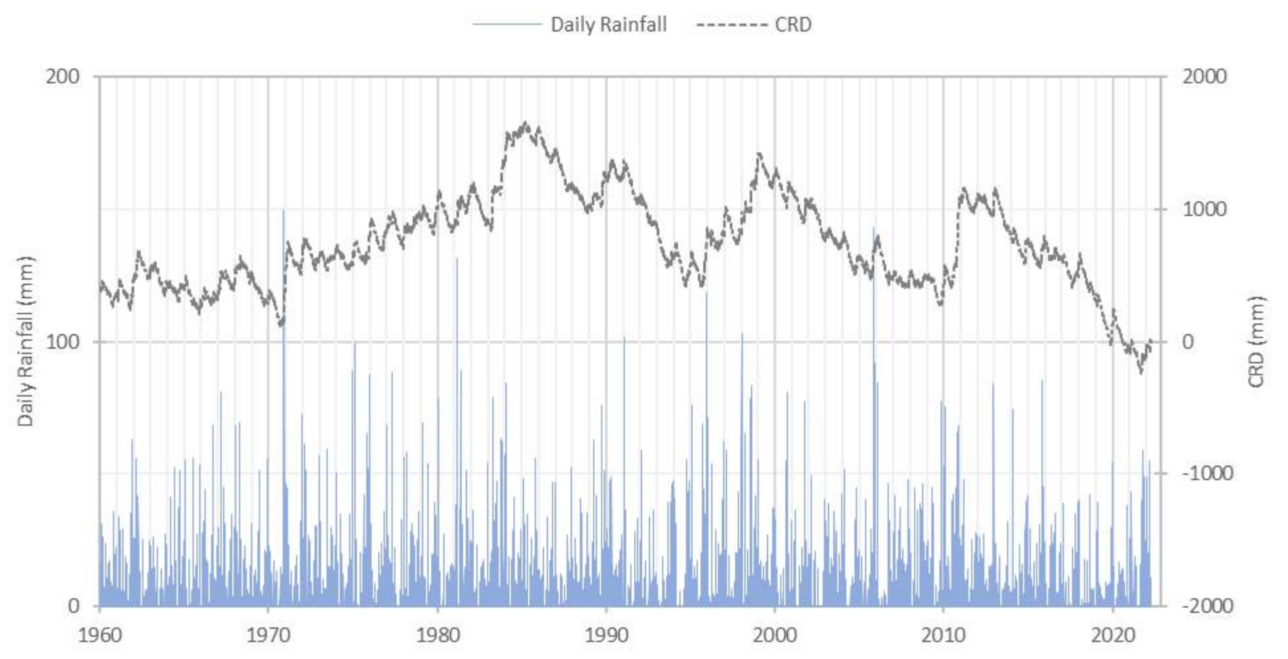


Figure 5.2 Daily Rainfall and CRD Trend for SILO grid location -26.15, 149.90 (SILO 2022)

5.3 Land Use

Land use information specific to the Project area was sourced from the Queensland Government DSITI (State of Queensland 2016a).

The land use dataset classifies land use type using the Australian Land Use and Management (ALUM) Classification system which provides a nationally consistent method to collect and present land use information in Australia. This classification system categories 32 land use classes and subclasses. There are six primary classes used in the ALUM classification system and these are further divided into secondary and tertiary classes. A description of the primary classes (ABARES 2010) is detailed below:

- Conservation and natural environments – Land is used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
- Intensive uses – Land is subject to substantial modification, generally in association with closer residential settlement, commercial or industrial uses.
- Production from dryland agriculture and plantations – Land is used mainly for primary production, based on dryland farming systems.
- Production from irrigated agriculture and plantations – Land is used mainly for primary production, based on irrigated farming.
- Production from relatively natural environments – Land is used mainly for primary production based on limited change to the native vegetation.
- Water – Although primarily land cover types, water features are regarded as essential to the classification.

Figure 5.3 presents land use across the Project area.

A summary of the land use distribution (area and percentage) directly within the Project area is provided in Table 5.2. There are five primary land use types within the Project area. The dominant land use is 'production from relatively natural environments', specifically grazing native vegetation. Production forestry and cropping is also present in the Project area.

Table 5.2 Summary of the Project Current Land Use

Land Use Category			Area (km^2)	Percentage of Total Area
Primary	Secondary	Tertiary		
Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	86.94	88.68%
Production from dryland agriculture and plantations	Cropping	Cropping	10.27	10.48%
Intensive uses	Intensive animal production	Cattle feedlots	0.21	0.22%
Water	Lake	Lake	0.07	0.07%
	Reservoir/dam	Reservoir/dam	0.49	0.51%
Conservation and Natural Environments	Other Minimal Use	Other Minimal Use	0.05	0.04%
		TOTAL	**98.03**	**100%**

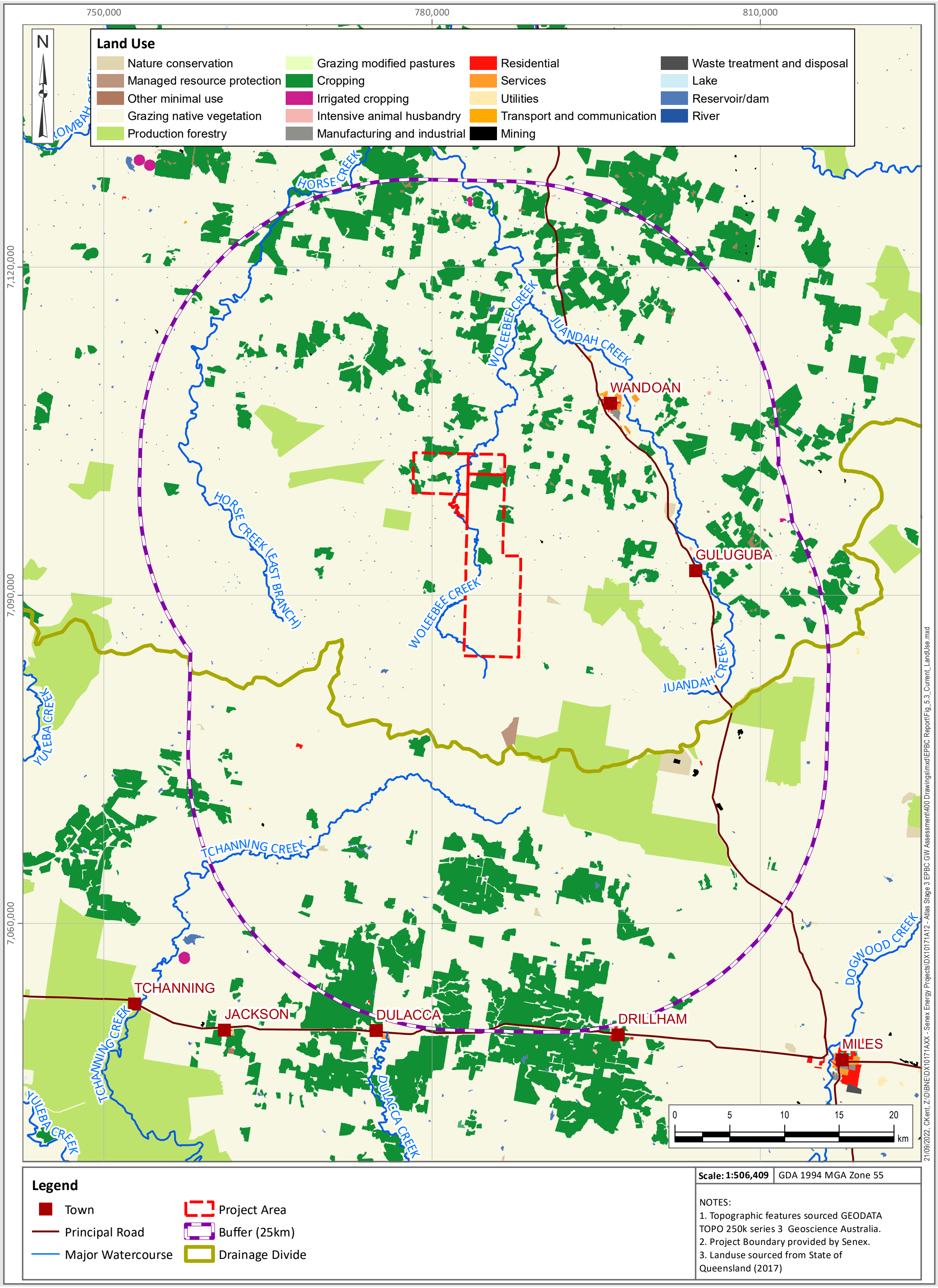


Figure 5.3 Land Use within the vicinity of the Project

6 HYDROLOGICAL CONTEXT AND CONCEPTUALISATION

6.1 Location and Catchment Context

The Project is located within the Upper Dawson River sub-basin, which is part of the Fitzroy River Basin. The Fitzroy River Basin is the second largest drainage basin in Australia and the largest on the eastern coast of the continent. Covering an area of 150,000 km^2, the basin contains several significant tributaries, including the Nogoa, Comet, Mackenzie, and Dawson Rivers. The basin discharges into the Coral Sea east of Rockhampton.

The divide between the Upper Dawson sub-basin and the Condamine-Balonne Rivers sub-basin is located at the southern extent of PL 209, ~8 km south of the Project area (Figure 5.1). The Maranoa-Balonne Rivers sub-basin is part of the Balonne-Condamine River Basin which contains several significant tributaries including the Balonne River and the Maranoa River.

6.2 Key Surface Water Bodies

6.2.1 Streams

Key watercourses (as shown on Figure 6.1) within the Project study area (25 km buffer) include:

- Woleebee Creek, which flows north from its headwaters flanking the southwestern boundary of the PL 209, and north along the boundaries of PL 445 and ATP 2059, to join Juandah Creek to the northeast;
- Wandoan Creek, a headwater tributary of Woleebee Creek, present within ATP 2059 to the west of PL 445;
- Conloi Creek, a tributary to Woleebee Creek, which flows west across the central portion of PL 209 (Figure 6.2); and
- Hellhole Creek, a tributary to Woleebee Creek which flows north-west into Woleebee Creek across the southern portion of PL 209.

Watercourses within the Project area have been classified using the Strahler method as stream orders 1 to 5, with the majority being stream order 1 (minor streams) (State of Queensland 2022d). Woleebee Creek is stream order 5.

Other watercourses of interest in the 25 km buffer include:

- Horse Creek and Horse Creek-East Branch, located to the southwest of PL 445 and PL 209, flows in a general northerly direction to join Juandah Creek in the north; and
- Juandah Creek, which flows towards the north to join the Dawson River, 3 km south of Taroom. Juandah Creek is joined by Woleebee Creek, Horse Creek (from the south) and Bungaban Creek from the east before joining the Dawson River.

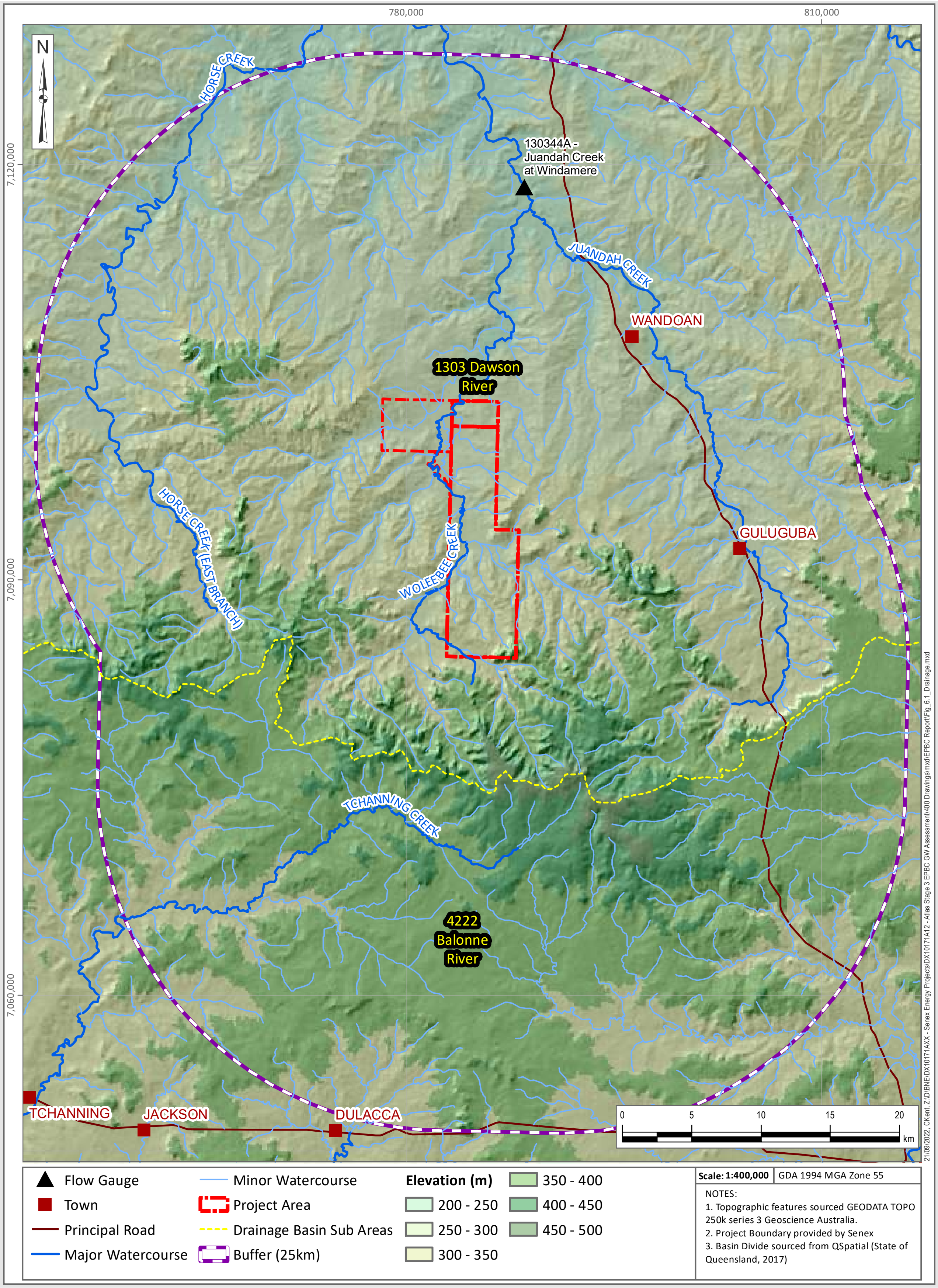


Figure 6.1 Regional Drainage and River Basin Divide

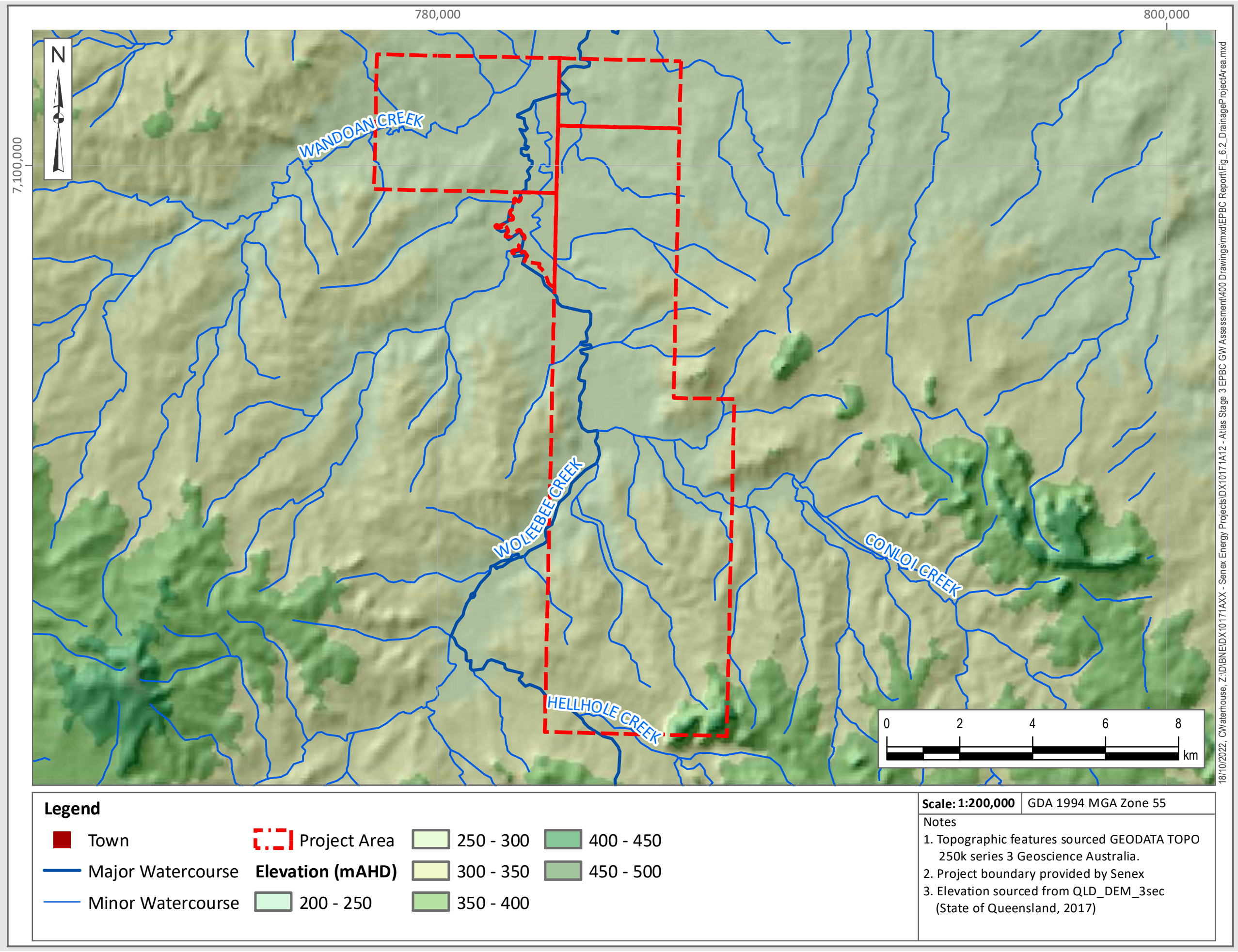


Figure 6.2 Drainage within the Project Area

6.2.2 Wetlands

There are no Ramsar Wetlands within the 25 km buffer of the Project. The nearest Ramsar Wetland is over 300 km to the east of the Project (Great Sandy Strait).

The Directory of Important Wetlands in Australia (Environment Australia 2001) lists two nationally important wetlands in the Dawson River sub-basin:

- Boggomoss Springs is approximately 95 km downstream of the Project (northeast): a 400-ha lacustrine / palustrine wetland with approximately one-third of its area artificially or highly modified, and the remainder of the area riverine.
- Palm Tree and Robinson Creeks wetland areas (50,274 ha) comprise 155 lacustrine and palustrine wetlands with approximately 4% of the area classified as lacustrine, 48% palustrine and 48% riverine. These wetland areas are located 80 km north of the Project, and upstream of the Dawson River.

A review of the Project area on the DES ‘Wetland Info’ website (State of Queensland 2022e) was undertaken. The mapping identifies the following within the Project area:

- Palustrine wetlands (vegetated, non-riverine or non-channel systems) mainly associated with floodplains;

- Lacustrine wetlands (dominated by open water) identified as mainly artificial or modified dams or weirs in channels; and
- Subdominant wetlands along Wandoan and Woleebee Creeks (comprising of 50% or less of the area), identified as Coastal/ Sub-coastal floodplain tree swamps (Melaleuca and Eucalypt).

The location of these wetlands is shown on Figure 6.3.

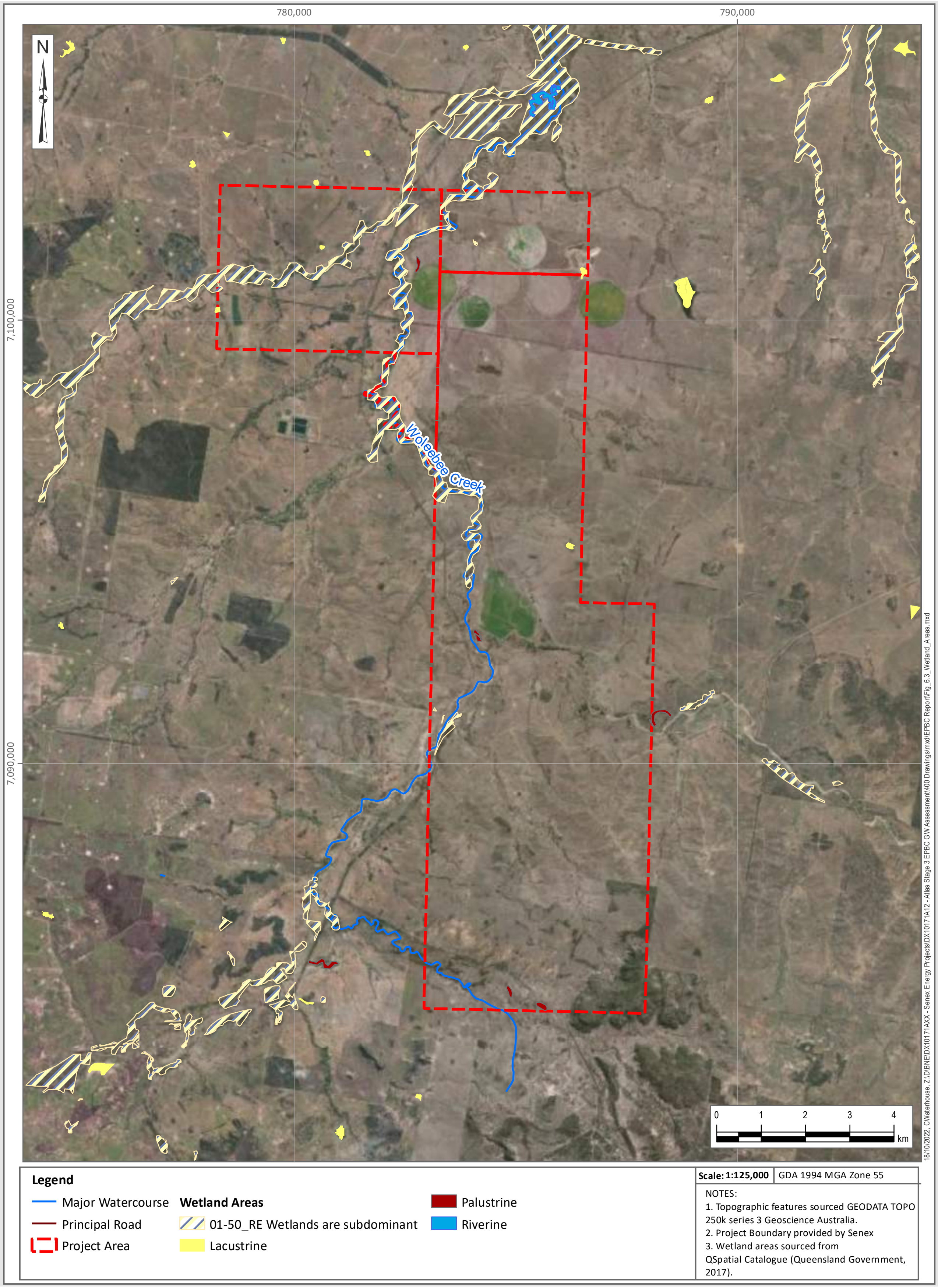


Figure 6.3 Location of Government Mapped Potential Wetlands in Relation to the Project

6.3 Geomorphology

Information related to the geomorphology of the creeks in the vicinity of the Project area is sourced from previous studies within the Project area (e.g. Golder Associates 2009a) and the field verification program undertaken for Project Atlas approvals (within PL 1037, see Appendix IX). The geomorphology of Conloi and Hellhole Creeks has not been assessed due to access issues / restrictions, but they are expected to have similar characteristics as Woleebee Creek, typical of ephemeral creek systems.

Woleebee Creek

Woleebee Creek flows north along the eastern boundary of PL 209 and dissects PL 445 and PL 209 where the lease boundary is shared. It is ephemeral, classified as stream order 5 (major streams) and has been identified as a potential gaining stream (OGIA 2017). Typical creek profiles are shown in Figure 6.4. The banks and channel comprise silty clay.

Woleebee Creek was assessed in 2009 as part of environmental assessments for QGC on QGC tenements (Golder Associates 2009a). The creek was assessed to be stable. Woleebee Creek was described as having a low width to depth ratio indicating lower potential energy for erosion and bank scouring although some evidence of minor erosion was present on the banks despite vegetation being present. Debris was present in the channel but assessed to be fallen limbs from trees growing in the channel and on the banks. The banks and channel were described as comprising silty clay.

The 2022 aquatic ecology survey of Woleebee Creek identified creek bank heights of 2.5 m in the upper reaches in the southern area of PL 209, to 7 m in the north of PL 445 just south of the confluence with Wandoan Creek. In all instances the creek beds are described as predominantly consisting of alluvial sand.

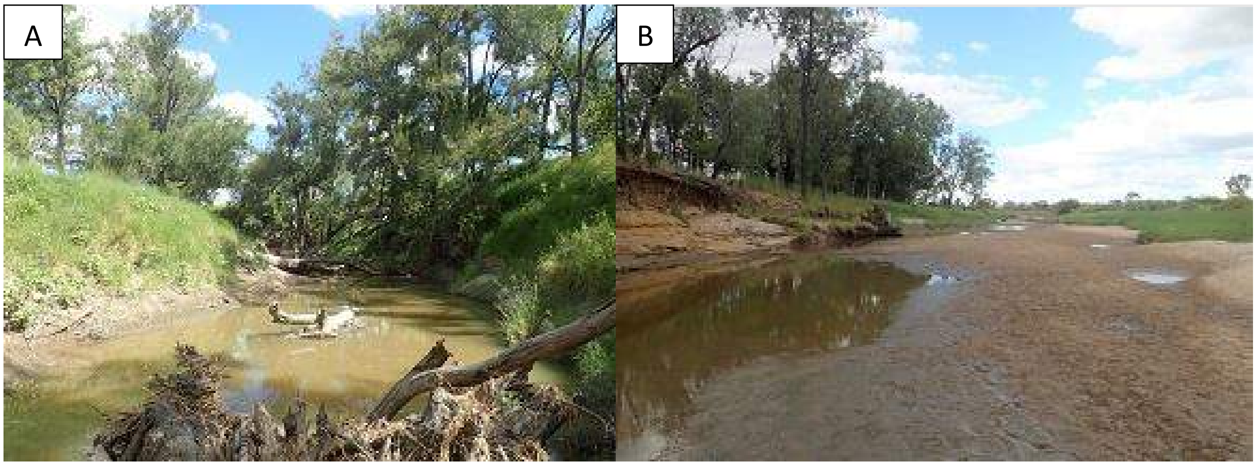


Figure 6.4 Banks Gently Sloping towards the river and evidence of pooling in Woleebee Creek (A), Woleebee Creek at Aquatic Ecology sampling location LAQ9 in PL 445 (B) Woleebee Creek at Aquatic Ecology Sampling Location LAQ7 in PL 209. See Figure 6.9 for Locations

Wandoan Creek

Wandoan Creek flows through the Project area from the west to the northeast through ATP 2059, and into Woleebee Creek downstream of the Project area, approximately 6.5 km northeast. Upstream, within PL 1037 to the west of ATP 2059, the creek is very shallow, narrow, and highly vegetated.

Wandoan Creek is classified as stream orders 1 to 4, with stream orders 3 and 4 (DNRME 2018) occurring within the Project area. The creek is ephemeral. The catchment comprises a large alluvial floodplain gently sloping towards the creek channel. The floodplains have largely been cleared for beef cattle grazing with some remnant riparian vegetation present along the creek lines.

Field verification indicated that the general creek characteristics comprise shallow creek banks (1 to 2 m high), is highly meandering and is 10 to 15 m wide. Upstream, within the vicinity of the western Project area boundary, the creek is very shallow, narrow, and highly vegetated.

Figure 6.5 shows photographs of Wandoan Creek where pooling water was observed; and, scouring of the creek banks and debris within the creek. The aquatic ecology assessment undertaken by Freshwater Ecology (2022a) identified that pooled water in Wandoan Creek was mostly turbid and less than 1 m deep. Bank heights were identified at approximately 5 m at three sites along Wandoan Creek, the creek bed substrate consisting mainly of sand (Freshwater Ecology 2022a).

Wandoan Creek, downstream of the Project area, was assessed in 2009, as part of environmental assessments for QGC (Golder Associates 2009a). The report described the creek as moderately stable with the creek bed and bank well vegetated with grasses and woody trees. The stream had a low width to depth ratio indicating lower potential energy for erosion and bank scouring although some debris and scouring was present downstream.

Figure 6.5 Banks gently sloping towards Wandoan Creek and evidence of pooling (A) (KCB 2018c), Wandoan Creek at Aquatic Ecology Sampling Location TAQ1 (B) (Freshwater Ecology 2022a). See Figure 6.9 for locations.

6.4 Flood Regime

Floodplain mapping sourced from the Department of Regional Development, Manufacturing and Water (RDMW) is presented in Figure 6.6. This presents the Queensland Floodplain Assessment Overlay (QFAO), which estimates areas potentially at threat of inundation by flooding. The mapping indicates that creeks within the Project area, such as Woleebee Creek, are potentially at threat of inundation by flooding.

Flood modelling maps are available through Queensland Globe (State of Queensland 2021c). Flood modelling mapping for a 1% annual exceedance probability (AEP) or 1 in 100-year flood are available. For a 1 in 100-year flood event, flooding may occur in all main channels and tributaries. In upper tributaries, flood depths for a 1 in 100-year flood event are generally less than 0.5 m, with flood depth between 1 to 2 m mapped within Woleebee Creek and Wandoan Creek.

6.5 Surface Water Flow

6.5.1 Watercourse Classification

Hydrologic flow can be classified into three regimes: permanent, semi-permanent, and ephemeral based on Kennard et al. (2010):

- Permanent: Stream discharge persists during both high rainfall (typically summer wet season) and low rainfall (typically winter dry season) periods. During drought years, some cease to flow periods may occur, however non-flowing, connected pools will persist throughout the waterway channel.
- Semi-Permanent: A watercourse that contains water for more than 70% of the time on average. These watercourses experience high discharges during heavy rainfall periods (i.e., summer wet season), however are typically reduced to a series of disconnected, nonflowing series of pools during the dry season.
- Ephemeral: These watercourses will typically only experience surface water flow during or immediately after heavy or sustained rainfall events (i.e. summer wet season). Following periods of flow surface water will persist in the form of non-flowing, disconnected pools separated by dry / exposed stream bed. Surface water (flowing or non-flowing) is only present for a small part of the hydrological cycle.

Watercourses across the Project area are characteristically ephemeral and typically flow only during significant runoff events. This is likely a consequence of the catchments being in the upper most reaches with limited runoff area.

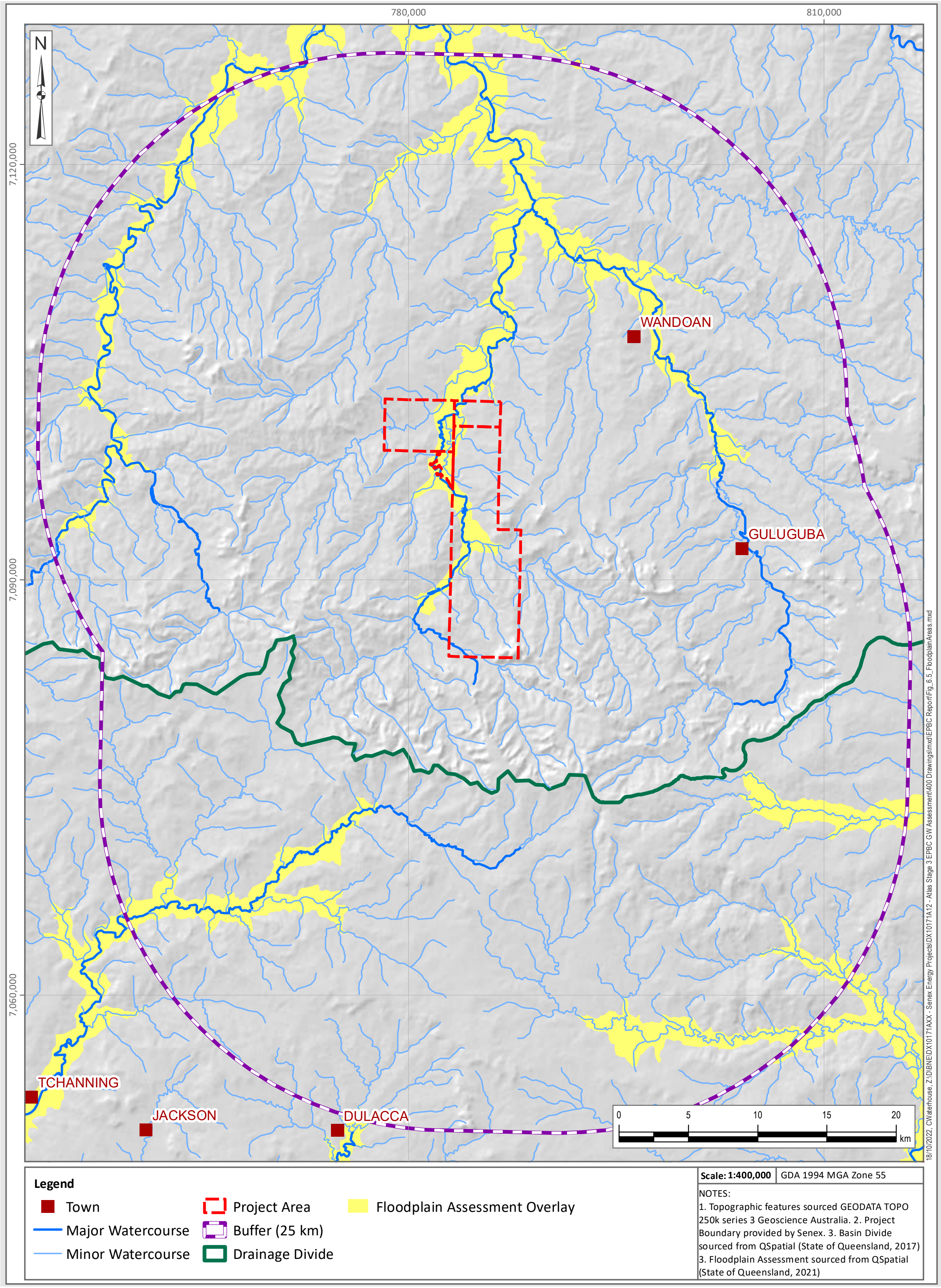


Figure 6.6 Extent of Floodplain Areas

6.5.2 Flow and Discharge

Field verification has been undertaken for sections of Woleebee Creek and Wandoan Creek for the Atlas Project on PL 1037 (KCB 2018a, Appendix IX). During the 2018 field verification program, undertaken during winter dry season, no surface water flow was observed in any of the watercourses surveyed (Woleebee Creek and Wandoan Creek). This is consistent with the ephemeral nature of these watercourses. This was also observed in the aquatic ecology assessment undertaken in March 2022 (Freshwater Ecology 2022a). This is consistent with the ephemeral nature of these watercourses.

There are no Queensland Government surface water flow gauges within the Project area, however one flow gauge (130344A – Juandah Creek at Windamere) is located ~16 km north of the Project area within Juandah Creek (Figure 6.1), downstream of the confluence between Woleebee Creek and Juandah Creek.

Gauge data were available from October 1974 to June 2022. The highest average daily flows occur between November and February each year with the lowest flows in June to August. Figure 6.7 shows the cumulative exceedance probability for the average daily recorded flow and indicates that flows are present ~40% of the gauged period, and the discharge is greater than 500 ML/day for ~5% of the gauged period. This data highlights the ephemeral nature of Juandah Creek and that it is likely to flow only during and after significant runoff events. Woleebee and Wandoan Creeks and their tributaries are observed to behave similarly to Juandah Creek.

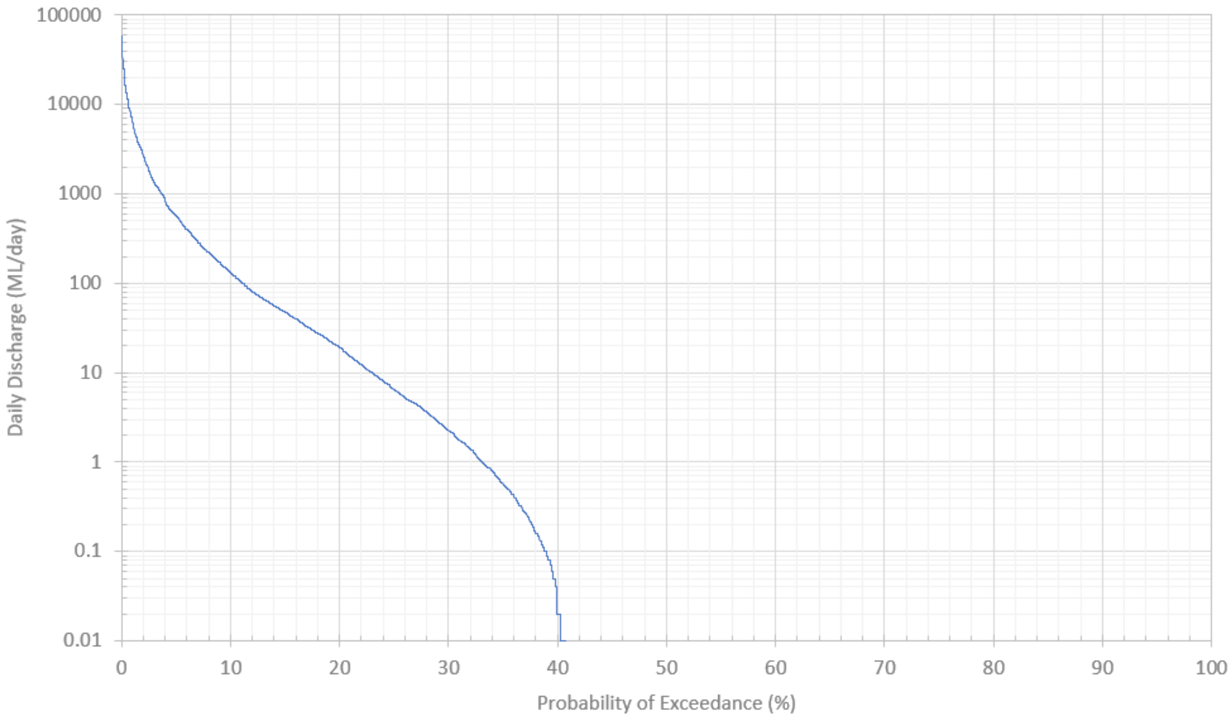


Figure 6.7 Cumulative Exceedance Probability for Recorded Daily Discharge at Juandah Creek (130344A – Juandah Creek at Windamere)

6.6 Surface Water Quality

Available surface water quality data has also been sourced from the Queensland Government for the gauge at Juandah Creek (at Windermere). Data are available between 1985 and 2022 and summarised in Table 6.1 (location shown on Figure 6.1).

Table 6.1 Summary of Water Quality Measured at Juandah Creek at Windermere (130344A), Wandoan Creek and Woleebee Creek

Parameter	Juandah					Wandoan Ck Sample	Woleebee Ck Sample
	Count	Min	Max	Mean	Standard Deviation		
Conductivity @ 25°C (field)	23	108	865	307	220	498	742
Turbidity (NTU) (field)	13	11	2000	379	543	-	-
Colour True (Hazen units)	15	5	86	32	22	-	-
pH (pH units) FLD	16	6.8	8.2	7.6	0.4	8.4	8.41
Total Alkalinity as $CaCO_3$ (mg/L)	22	36	264	100	72	210	204
Total Diss. Solids (mg/L)	22	77	588	192	138	324	482
Calcium as Ca soluble (mg/L)	22	5	53	17	15	25	32
Chloride as Cl (mg/L)	22	8	165	33	38	21	101
Magnesium as Mg soluble (mg/L)	22	1	13	4	3	7	8
Potassium as K (mg/L)	22	3	10	6	2	14	13
Sodium as Na (mg/L)	22	13	148	42	35	68	109
Sulfate as SO_4 (mg/L)	22	2	22	7	5	4	6
Aluminium as Al soluble (mg/L)	12	0.0	4.2	0.4	1.2	1	0.86
Boron as B (mg/L)	17	0.00	0.20	0.06	0.05	0.06	0.09
Copper as Cu soluble (mg/L)	14	0.000	0.050	0.030	0.020	0.002	0.003
Fluoride as F (mg/L)	21	0.05	0.20	0.12	0.05	0.2	0.2
Iron as Fe soluble (mg/L)	21	0.00	11.50	1.22	2.65	0.82	1.05
Manganese as Mn soluble (mg/L)	16	0.00	0.07	0.02	0.02	0.15	0.39
Silica as SiO_2 soluble (mg/L)	21	12	44	21	7	-	-
Zinc as Zn soluble (mg/L)	14	0.000	0.080	0.020	0.020	0.006	0.021

A water quality sample was taken by Senex from a flowing section of Woleebee Creek on February 28, 2023, north of PL 445 along the Jackson-Wandoan Road (location shown on Figure 4.1).

Based on the available water quality data from the RDMW gauge downstream of the Project, and the Woleebee Creek surface water sample, Piper and Durov diagrams have been prepared. These are presented in Figure 6.8.

The Woleebee Creek surface water chemistry corresponds with the surface water chemistry from Juandah Creek. The surface water from both the RDMW gauge, Woleebee Creek, and pools at Wandoan Creek are characterised as a sodium-bicarbonate water type, with some sodium enrichment. The electrical conductivity (EC), as shown on the Durov plot (Figure 6.8), ranges between ~110 µS/cm and 865 µS/cm, with a median value of 307 µS/cm.

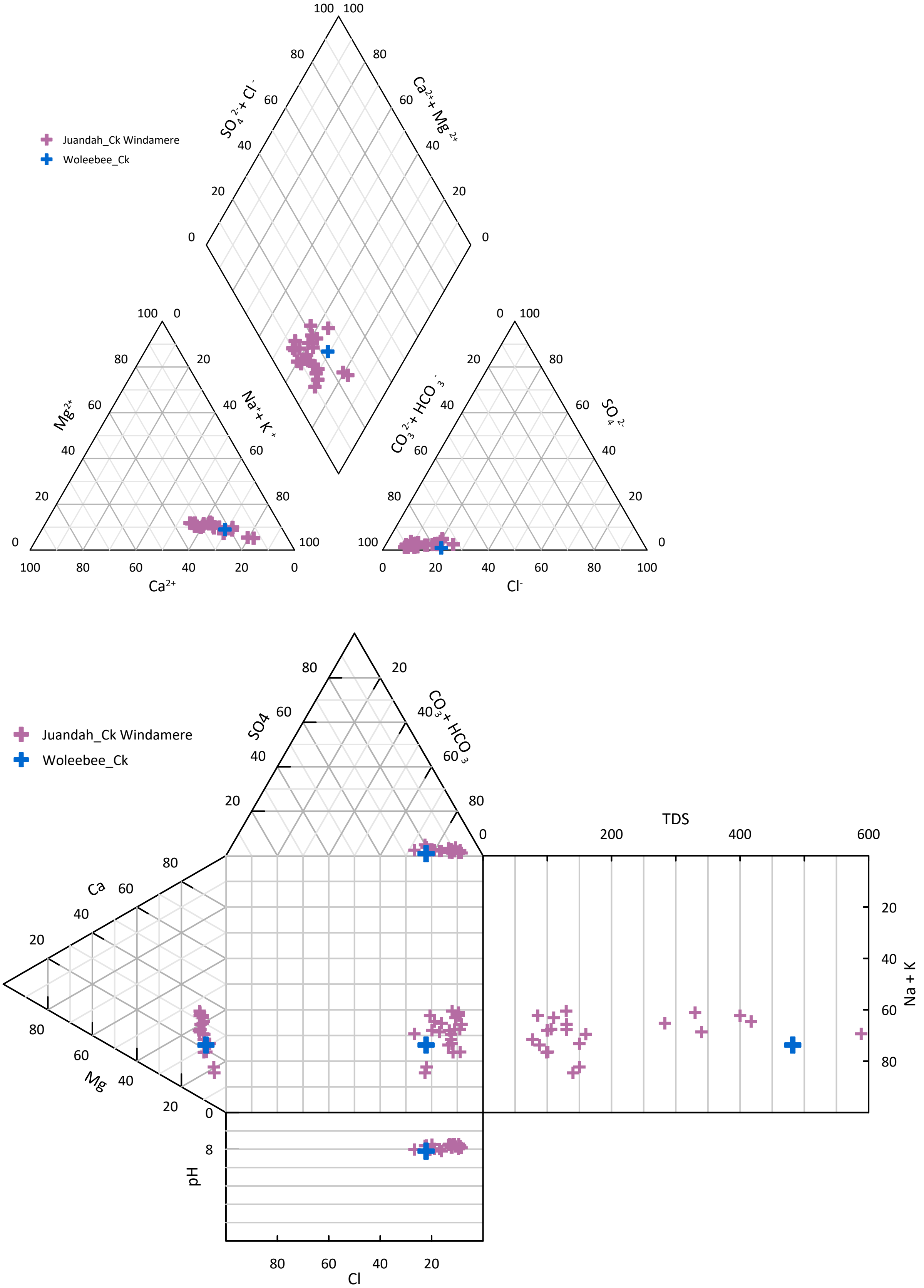


Figure 6.8 **Piper Diagram (top) and Durov Diagram (bottom) for Surface Water Samples from Juandah Creek (130344A – Juandah Creek at Windamere) and Woleebee Creek**

6.7 Current Surface Water Stressors

The Dawson River sub-basin is heavily influenced by anthropogenic pressures including land use, riparian management, water infrastructure and point source pollution; and is also highly modified as a result of agricultural and grazing practices.

Since circa 1850, the primary land use in the Dawson River sub-basin has been sheep and cattle grazing. The State of River report (Telfer 1995) lists indicators of the physical conditions of the Dawson River and its tributaries. The “Southern Tributaries” catchment identified by Telfer (1995) is of most relevance to this report as the upper reaches are located within ATP 2059.

The condition of land immediately adjacent to reaches within the State of River study (Telfer 1995) is typically rated as being in poor to moderate condition (89% of reaches). Subjective assessments of disturbance reflect these ratings with 9% moderately disturbed, 43% highly disturbed, 31% very highly disturbed, and 15% extremely disturbed. Major factors contributing to disturbance were identified as grazing (94% of sites), roads (37%), bridges or culverts (20%), ford and ramp structures (13%) and forestry (4%) (Telfer 1995).

6.8 Existing Surface Water Users

Under the Fitzroy Basin ROP (State of Queensland 2015b), creeks within the Project area are managed within the Dawson Valley Water Management Area. Within this management area Woleebee, Horse and Juandah Creeks are a tributary of the Dawson N Zone, along the AMTD reach 356.5 to 428.0 (km); and, is described as ‘Upstream limit of Glebe Weir and Eurombah Creek Junction’.

There are no resource operations licence holders in the Dawson N Zone of the Dawson Valley Water Management Area (State of Queensland 2021a). No other surface water users or water entitlements have been identified within the vicinity of the Project.

6.9 Aquatic Ecology

An aquatic ecology assessment was undertaken by ERM (2022b) and Freshwater Ecology (Freshwater Ecology 2022a). This included surveys of Woleebee and Wandoan Creeks. Aquatic ecology surveys were also undertaken by Hydrobiology on PL 1037 in 2018 along reaches of Woleebee Creek and Wandoan Creek (KCB 2018c).

As detailed in previous sections, the Project area lies within the southern tributaries of the Upper Dawson. This is part of the ‘Central Freshwater Biogeographic Province’, based on its broad patterns in the natural distribution of aquatic faunal communities, being broadly similar to other coastal flowing catchments in the central part of Queensland (DES 2018b).

As detailed in Section 4.1.2.7, an aquatic ecology field survey was undertaken within the Project area. Details of the identified habitats, aquatic species and assessment of baseline aquatic values are provided in the following section.

6.9.1 Habitat Description

Waterways across the Project area are all ephemeral, with most waterways anecdotally drying completely during dry periods and few waterways retaining refugial pools. Twenty-three of the 32 sites inspected during the field survey held water in March 2022 while all other sites were dry.

At the time of sampling most waterways had already ceased surface flows with disconnected pools noted along the watercourses, although subsurface flow was apparent at sites along most creeks with sandy substrates. Along the watercourses with clay substrates the disconnection between pools was often separated by open grassland and poorly defined channels. The riparian vegetation density along the sites varied from moderate to non-existent, with most sites having a relatively low coverage of riparian vegetation.

In-stream habitat, using habitat bioassessment, was mostly found to be in 'fair' condition across all sites sampled (17 of the 24 sites). The remaining seven sites were determined to be in 'poor' condition.

The location of the surveyed sites is shown on Figure 6.9, while site profiles are provided in Table 6.2.

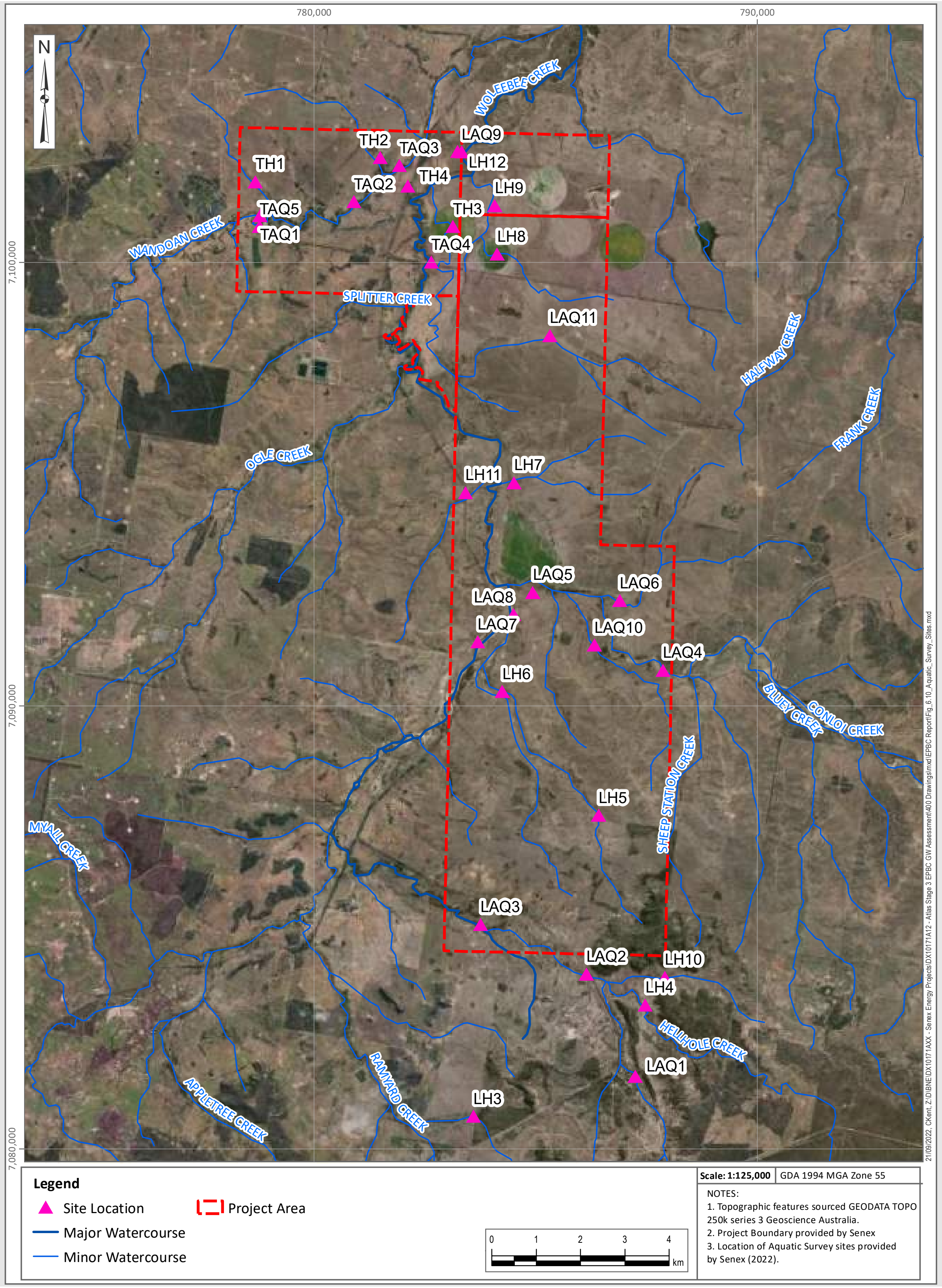


Figure 6.9 Location of Aquatic Survey Sites (Freshwater Ecology 2022a)

Table 6.2 Habitat Description and Photographs for Selected Aquatic Ecology Sites Surveyed in March 2022 (Freshwater Ecology 2022a)

Site	Feature	Site Photo	
Wandoan Creek			
TAQ1	**Location: W**ater body in Wandoan Creek on ATP 2059 **Waterbody**: Subsurface flows expressing in some reaches. Uncertain whether these were hyporheic or groundwater expressions. Shallow and highly ephemeral. **Wetland type:** Riverine **Stream order:** 4 **Macrocrustaceans:** Palaemonidae (freshwater prawns) and Paratacidae (freshwater crayfish) **Amphibians:** Green-stripe frog recorded. **Habitat bioassessment score**: Poor/fair condition		
Woleebee Creek			
LAQ7	**Location:** Main channel of Woleebee Creek on PL 209. **Waterbody**: Likely to retain subsurface (hyporheic flows) for some time after the cessation of heavy rainfall. **Wetland type:** Riverine **Stream order:** 5 **Macrocrustaceans:** Palaemonidae (freshwater prawns) **Habitat bioassessment score**: Poor condition		

Site	Feature	Site Photo	
LAQ9	**Location:** Main channel of Woleebee Creek on PL 445. **Waterbody**: Likely to retain subsurface (hyporheic flows) for some time after the cessation of heavy rainfall. **Wetland type:** Riverine **Stream order:** 5 **Macrocrustaceans:** Palaemonidae (freshwater prawns) and Paratacidae. **Turtles:** An eastern long-necked turtle was captured (and released). **Habitat bioassessment score**: Fair condition		
Conloi Creek			
LAQ5	**Location: U**nnamed billabong off the main channel of Conloi Creek. **Waterbody**: Possibly a permanent waterhole. **Wetland type:** Palustrine **Stream order:** - **Macrocrustaceans:** Atyidae (glass shrimp), Palaemonidae (freshwater prawns) and Paratacidae (freshwater crayfish) **Amphibians:** Green-stripe frog recorded. **Habitat bioassessment score**: Fair condition		

Site	Feature	Site Photo	
Hellhole Creek			
LAQ3	**Location:** Main channel of Hellhole Creek on PL 209. **Waterbody**: Dry site, unlikely to hold water for extended periods immediately following heavy rainfall. **Wetland type:** Riverine **Stream order:** 4 **Habitat bioassessment score**: poor condition		

6.9.2 Aquatic Invertebrates

The field survey identified the following in terms of aquatic invertebrates (Freshwater Ecology 2022a):

- A total of 53 macroinvertebrate taxa (mainly family level) were collected from the four sites that held water across the Project area. In addition to the macroinvertebrates recorded, three groups of microcrustacea (Cladocera, Copepoda, Ostracoda) were recorded. Overall, there is a low abundance of aquatic macroinvertebrates across the Project area. The low abundances are likely to be due to the largely ephemeral nature of the waterways. taxa diversity across all samples ranged from 6 to 28 (with a mean of 16.4 taxa across all samples) and was typically higher in edge samples than bed samples. These results are also typical for ephemeral streams in central Queensland.
- Macrocrustaceans were collected during both macroinvertebrate and fish sampling. Three families of macrocrustacean were detected across the Atlas Stage 3 Project Area: Atyidae (glass shrimp), Palaemonidae (freshwater prawns) and Paratacidae (freshwater crayfish). The Palaemonidae species was Macrobrachium australiense, a common and widespread species across eastern Australia. Freshwater prawns are opportunistic scavengers that forage on detritus, algae, invertebrates, and small fish and are very hardy.

6.9.3 Fish Community

The field survey identified the following in terms of fish community (Freshwater Ecology 2022a):

- 2,192 fish individuals from eight species were recorded from the 14 sites that were sampled, five of which are relatively widespread.
- Eight of the species of fish recorded were native species, with the only introduced specie (tilapia – *Oreochromis mossambicus*) recorded as juveniles at a single site. Tilapia is a restricted noxious fish under the Biosecurity Act 2014.
- The most abundant species was spangled perch (*Leiopotherapon unicolor*) which accounted for nearly half of all fish recorded was found at all sites sampled for fish. Other widespread species recorded were Agassiz's glassfish (*Ambassis agassizii*), Midgely's carp gudgeon (*Hypseleotris bucephala*), eastern rainbowfish (M*elanotaenia splendida*) and bony bream (*Nematalosa erebi*) which were recorded at 79%, 79%, 71% and 50% of sites sampled respectively. Single specimens of eel-tailed catfish (*Tandanus tandanus*) and sleepy cod (*Oxyeleotris lineolata*) were recorded in the March 2022 sampling.
- All the native fish species recorded are relatively common and widespread across their distributions.

6.9.4 Aquatic Fauna

A single specimen of eastern long-necked turtle (*Chelodina longicollis*) was captured at site LAQ9. This species is capable of moving long distances overland between waterholes, particularly after heavy rainfall. Given the disconnected nature of these habitats, any turtle use of these areas is likely to be transitory, particularly given turtles prefer deeper pool habitats connected by riffle areas.

No platypus (*Ornithorhynchus anatinus*) was recorded in the March 2022 surveys. Considering the generally poor habitat suitability and the distance from existing records it is considered unlikely that platypus would occur across the Project area.

Only three species of frog were recorded in the March 2022 sampling. The green-stripe frog (*Cyclorana alboguttata*) was recorded at sites (LAQ5, LAQ11, TAQ1, TAQ2, TAQ3, TAQ4 and TAQ5). The specimen at site TAQ4 was observed being consumed by a keelback snake (*Tropidonophis mairii*). The broad-palmed rocket frog (*Litoria latopalmata*) was recorded only at site TAQ1. Cane toads (*Rhinella marina*) were recorded at sites LAQ11 and TAQ1.

6.9.5 Aquatic Values

An overall aquatic value rating of Low, Moderate or High, was assigned to watercourse of Strahler stream order three or greater within the Project area based on the summation of all available information from the desktop assessment and field survey. The criteria used to define each category are provided in Table 6.3. These aquatic value ratings are also discussed below in the context of geographic significance, that is, in terms of State, regional, catchment and local significance.

Table 6.3 Criteria Used for Assigning Overall Aquatic Values Rating

Aquatic values rating	Criteria
High value	Aquatic endangered, vulnerable and near threatened (EVNT) species are confirmed or likely to occur (i.e., recording/sighting recorded within 5 km of the proposed alignment) and suitable habitat available), and Flow and/or permanent water present (e.g., refugia), and/or In-stream habitat conditions in near natural or good condition (an Excellent or Good habitat bioassessment score)
Moderate value	Aquatic EVNT species could possibly occur (i.e., marginal habitat), and Priority* species are confirmed or likely to occur (i.e., suitable habitat available), and/or High diversity of non-conservation significant native aquatic fauna and or flora, and/or Presence of permanent or persistent refugial waterholes, and/or In-stream habitat conditions in moderate to good condition (a Good or Fair habitat bioassessment score)
Low value	Aquatic EVNT and Priority species are unlikely to occur and Drainage feature without refugial waterholes, and/or Presence of non-conservation significant native aquatic fauna and or flora, and/or May have some in-stream aquatic habitat value (a Fair or Good habitat bioassessment score)

*Priority species for conservation identified in the Back on Track (BOT) actions for Biodiversity in the Fitzroy NRM Region (DERM 2010) and those identified in the Expert Panel Report for the ACA of the Riverine and non-Riverine wetlands of the GBR catchments (Inglis and Howell 2009; Rollason and Howell 2011).

Watercourses transecting the Project area were rated as Moderate value, at a local level, primarily due to the presence of permanent or persistent pools. These provide critical dry season refugia for the aquatic life that use them, to sustain them until the rains, which is significant on a local tributary scale. These ecosystems are recognised as Aquatic Ecosystems Environmental Values under *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (State of Queensland 2019b), which fulfils the *Environmental Protection Act 1994*. On a catchment scale, aquatic value of these watercourses would be Low, as the more permanent main channel of the Dawson and its larger tributaries support much more diverse aquatic communities.

All sites surveyed were scored as low or fair habitat, had presence (but low diversity) of non-conservation significant native aquatic fauna and flora.

Following the field surveys an assessment on the likelihood of occurrence for aquatic Endangered, Vulnerable and Near Threatened (EVNT) species was undertaken, suitable habitat was not identified. All EVNT species identified in an initial desktop assessment were considered unlikely to occur within the Project area (ERM 2022b; Freshwater Ecology 2022a).

7 HYDROGEOLOGICAL CONTEXT AND CONCEPTUALISATION

7.1 Regional Geology

The Project is located within the Surat Basin, a basin of Jurassic-Cretaceous age, which is underlain by the Permo-Triassic Bowen Basin. Cenozoic-age formations are present overlying the Surat Basin formations. A surface and solid geological map of the Project and its surrounds is shown in Figure 7.1.

Cenozoic-age formations generally comprise unconsolidated alluvial sediments, which have been deposited along pre-existing watercourses (OGIA 2021f).

The Surat Basin, some 300,000 km^2 in extent, underlies approximately 180,000 km^2 of southeast Queensland; and is connected to the Eromanga Basin to the west, the Clarence-Moreton Basin to the east, and the Mulgildie Basin to the northeast. The Surat Basin is bounded to the northeast by the Auburn Arch and to the southeast by the Texas Block. The northern margin of the basin has been exposed and extensively eroded. The Surat Basin sediments generally dip southwest (OGIA 2021f).

The maximum thickness of the Surat Basin is ~2,500 m, which occurs in the Mimosa Syncline west of the Project area. Generally, sediment deposition was continuous and widespread within the basin. Deposition in the basin commenced with a period of passive thermal subsidence over much of eastern Australia. During the Early Jurassic, deposition was mostly fluvio-lacustrine, while by the Middle Jurassic coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued (Geoscience Australia 2017; OGIA 2021f).

7.2 Regional Hydrostratigraphy

The Surat Basin forms part of the hydrogeologically conceptualised GAB, which comprises several aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source of water used for stock, public water, and domestic supply. Conversely, aquitards of the Surat Basin do not transmit water easily and do not represent good sources of water.

Aquifers are a body of permeable rock which can contain or transmit groundwater which are used extensively for groundwater abstraction (OGIA 2021h). Aquitards are formations which do not readily transmit groundwater (semipervious in nature), resulting in slower groundwater flow (UNSW 2017).

OGIA classified GAB aquifers and aquitards into five types, based on their ability to store and transmit groundwater (which is a function of lithological composition and aquifer hydraulic properties). Those classifications are presented in Table 7.1. Examples of project-relevant units were included with their respective classifications.

Table 7.1 OGIA Hydrostratigraphic Unit Classifications (OGIA 2021h)

Type	Classification	Definition	Example Formation
Aquifer	Regional Aquifer	High transmissivity, bore yields that are vertically and laterally consistent at a regional scale	Gubberamunda Sandstone
	Partial Aquifer	Medium transmissivity, bore yields that are vertically and laterally inconsistent at a regional scale and exhibiting a high degree of heterogeneity	Alluvium
	Tight Aquifer	Medium to low transmissivity, bore yields that are regionally inconsistent and exhibiting a high degree of heterogeneity	Upper Springbok Sandstone
Aquitard	Interbedded Aquitard	Similar to a tight aquifer but with thin, spatially limited water-yielding zones are interbedded in an otherwise tight aquitard	Walloon Coal Measures
	Tight Aquitard	Predominantly low permeability, regionally extensive and thick formations	Westbourne Formation

Formations within the Surat Basin represent laterally continuous depositional layers which means where an aquitard occurs, groundwater beneath is confined by the overlying formation. For example, the Westbourne Formation is a tight aquitard which overlies the Upper Springbok Sandstone which is a tight aquifer (Table 7.1), and thus confines groundwater in the Upper Springbok Sandstone leading to artesian conditions in part of the Upper Springbok Sandstone.

OGIA presented the hydrostratigraphy of the Surat and Bowen Basin (OGIA 2021f), which is included in Figure 7.2. A summary of each of the hydrostratigraphic units within the Surat Basin and of relevance to the Project is provided in the following sections (from oldest to youngest).

The Precipice Sandstone *Aquifer*

The Precipice Sandstone is the basal unit of the Surat Basin, which overlies the Moolayember Formation and sedimentary sequences of the older Bowen Basin. Lower and upper subunits are recognised, often separated by a siltstone or shale unit. The layers with the coarsest grain sizes were deposited by transverse bars in a braided stream system and the sediment layers with finer grain sizes were deposited in a lower energy fluviatile meandering system (Martin 1981). The lower subunit, also known as the Precipice Braided Stream Facies (or Precipice BSF), consists of white, fine to very coarse-grained, in part pebbly, thin to very thickly bedded, porous, quartz-rich sandstone with a white clay matrix (Exon 1976a).

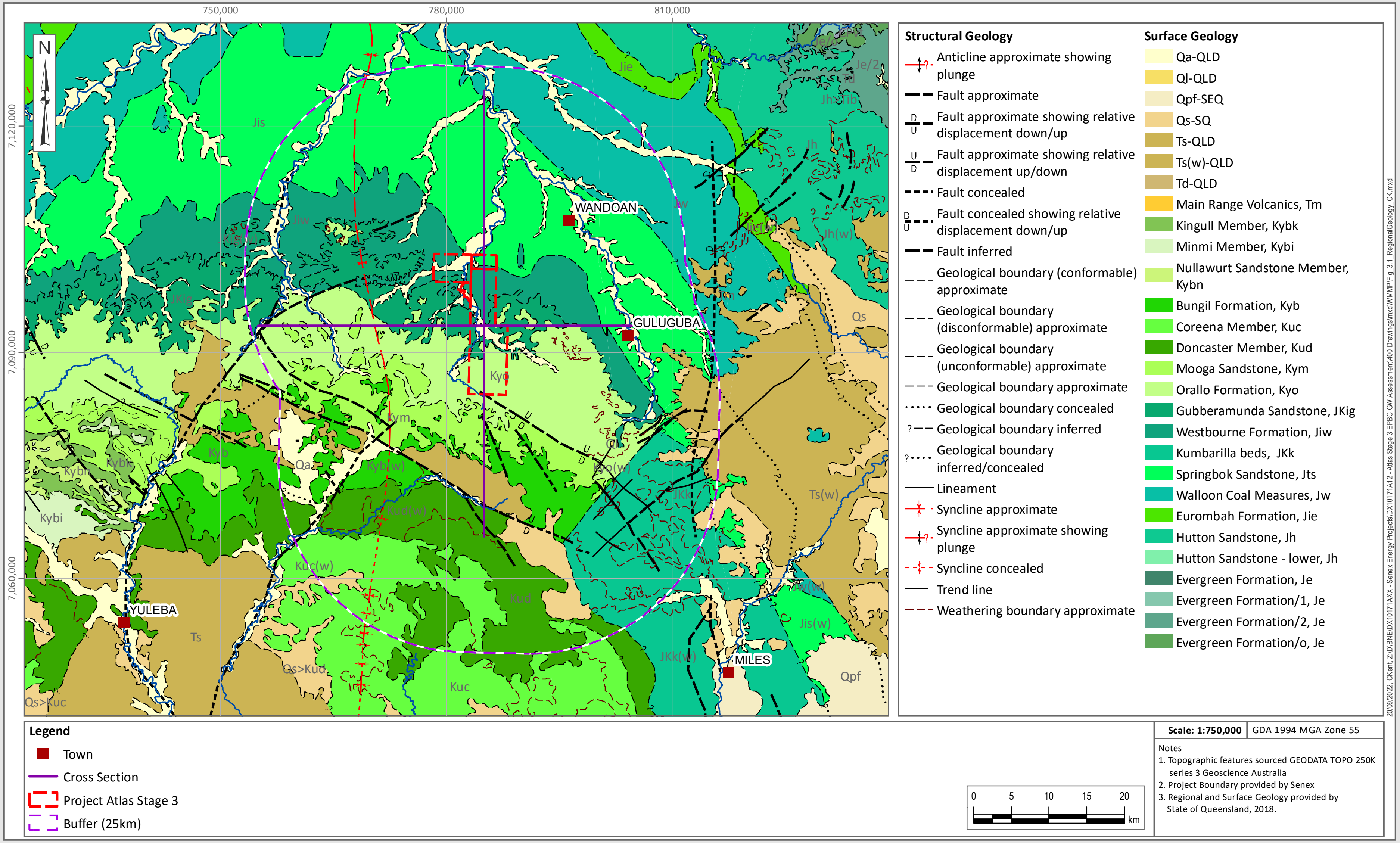


Figure 7.1 Regional Surface Geology Map

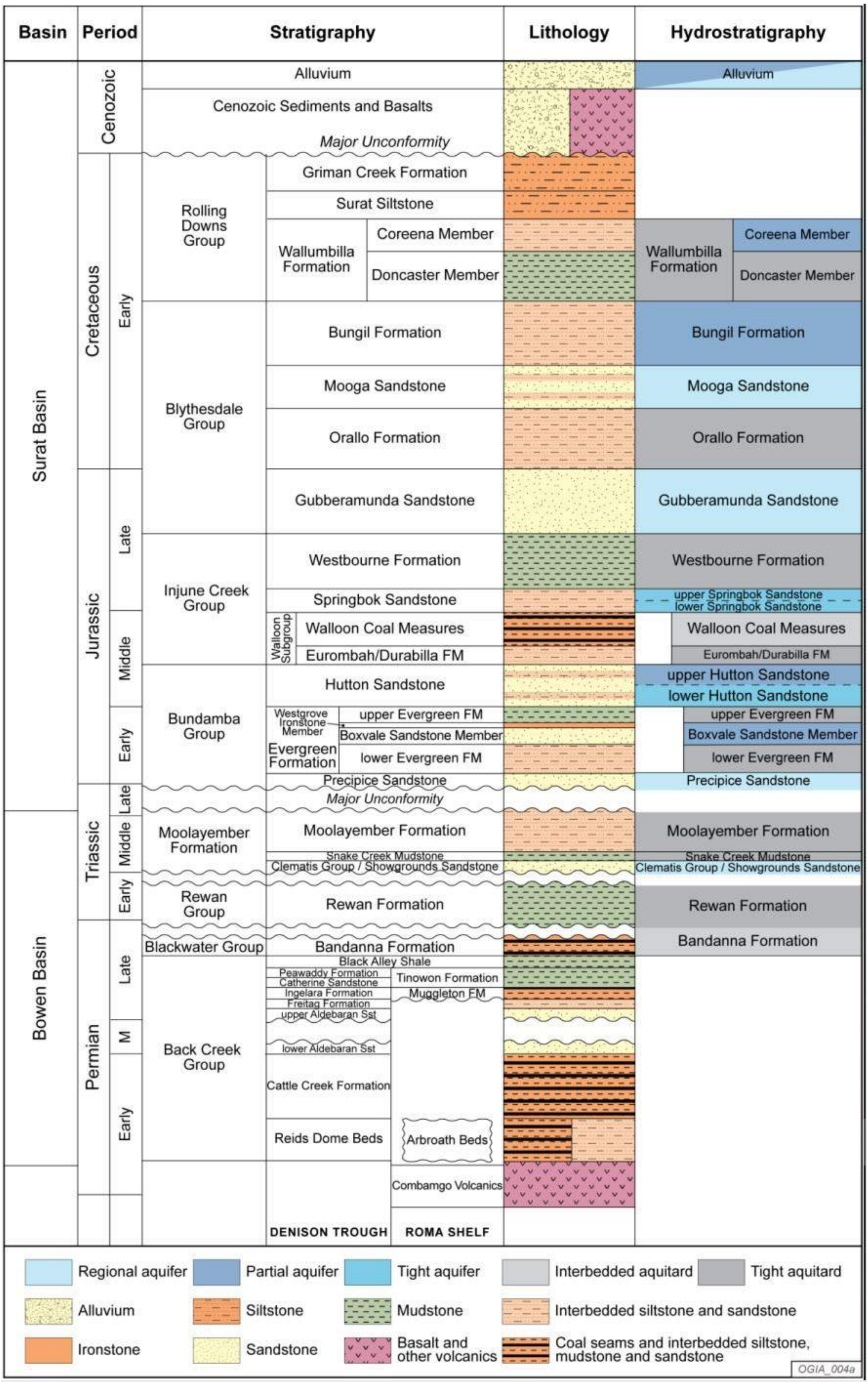


Figure 7.2 Regional Hydrostratigraphy (OGIA 2021f)

The Evergreen Formation *Aquitard*

The Evergreen Formation conformably overlies the Precipice Sandstone and separates the Precipice Sandstone from the Hutton Sandstone. The Evergreen Formation is considered an aquitard and generally consists of mudstones laminated with fine-grained sandstone, siltstone and shale (PM Green 1997).

The Hutton Sandstone *Aquifer*

The Hutton Sandstone was deposited in a non-marine environment by meandering streams on a broad floodplain (Exon 1976a) and consists mainly of sandstone with interbedded siltstone, shale, minor mudstone, and coal. The sandstone is white to light grey, fine to medium-grained, well sorted, generally quartz-rich, partly porous with some pebble bands, shale, and siltstone clasts in the lower part. Siltstones and shales are light to dark grey, micaceous, carbonaceous, and commonly interlaminated with very fine-grained sandstone (PM Green 1997). It is highly heterogeneous, with sand bodies limited in vertical and lateral extent.

Durabilla (Eurombah) Formation *Aquitard*

The Durabilla Formation (informal), often referred to as the Eurombah Formation (formal), conformably overlies the Hutton Sandstone. The depositional environment for this unit was fluvial with periods of rapid sedimentation. It is often difficult to differentiate the Durabilla Formation from the WCM. It is more restricted in extent than either the Hutton Sandstone or the WCM (P Green 1997). The Durabilla Formation is considered an aquitard, consisting of siltstone, mudstone and fine to medium-grained poorly sorted sandstone, with almost no coal and consequently, little permeability (OGIA 2016d).

The Walloon Coal Measures *Productive Coal Seam*

The WCM is the target sub-group for the Project. This sub-group conformably overlies the Durabilla Formation. It was deposited in a low energy meander-belt river system, with the coal layers deposited mainly in an overbank environment (Exon 1976b). The WCM consists of thin-bedded, claystone, shale, siltstone, lithic and sublithic to feldspathic arenites, coal seams and partings; minor limestone (Geoscience Australia 2023). Typically, the coal layers are positioned in the upper half to three-quarters of the coal measures, with mudstones, siltstones, and lithic sandstones dominant in the lower part. At a regional-scale the WCM is considered as a leaky aquitard (OGIA 2016c). The stratigraphy of the WCM is presented in Figure 7.3

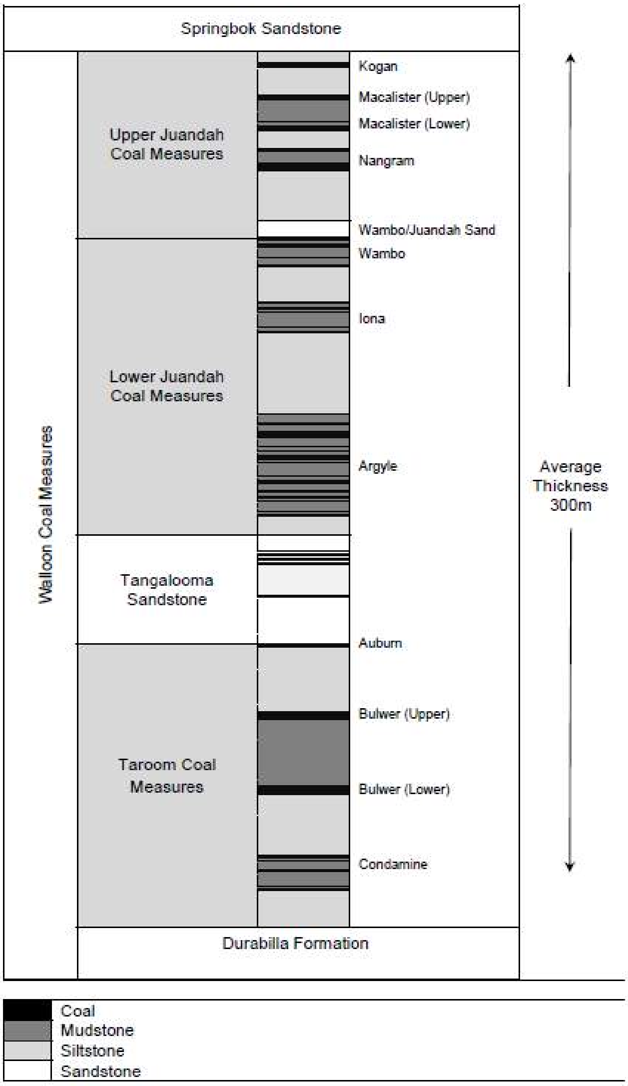


Figure 7.3 Stratigraphy of the WCM (OGIA 2021f) after (Hamilton, Esterle, and Sliwa 2014))

The Springbok Sandstone *Aquifer*

The Springbok Sandstone unconformably overlies the WCM and was deposited by streams and includes overbank and swamp deposits in the upper part of the unit which indicates streams becoming less energetic with time (Exon 1976a). The Springbok Sandstone consists mostly of feldspathic sandstones, commonly with calcareous cement (PM Green 1997). At the basin scale, the sandstones range from very fine to coarse-grained, although some very coarse-grained, poorly sorted pebbly beds also occur. Minor interbedded siltstones, mudstones, and thin coal seams are also present, primarily in the upper part of the unit. Within the Surat Basin, the Springbok Sandstone is considered a usable water source, however this heterogeneous unit has highly variable hydraulic properties and yield across the basin. The Springbok Sandstone also has a very high content of mudstone and siltstone at many locations with very low permeability (OGIA 2021f).

The Westbourne Formation *Aquitard*

The Westbourne Formation conformably overlies the Upper Springbok Sandstone. It was deposited in an environment with characteristics consistent with a low energy, lacustrine deltaic plain (PM Green 1997). The Westbourne Formation comprises predominately mudstone and siltstone layers with thick interbeds of fine to medium-grained sandstone. Small coal fragments, lenses and lamina are common throughout the formation. Within the GAB sequence, the Westbourne Formation is considered a 'tight' aquitard (Table 7.1). The Westbourne Formation contains the highest proportion of mudstone and the lowest proportion of sandstone in all of the Surat Basin formations, thus making it one of the main aquitards in the Surat CMA (OGIA 2021h). Two monitoring bores drilled into the Westbourne Formation within the Project area reported standing water levels 21 m above the water strike (Appendix X), which is an indicator of a tight formation with confining layers, indicative of an aquitard and confined conditions.

The Gubberamunda Sandstone *Aquifer*

Regionally, the Gubberamunda Sandstone conformably overlies the Westbourne Formation, but locally is disconformable, particularly around the margins of the basin (PM Green 1997). It was deposited by braided and meandering stream systems draining surrounding highlands (Exon 1976a). Consistent with a fluvial depositional environment, repeated packages of siltstone and fine to coarse sandstone were deposited. Deposits of carbonaceous shale along with minor coal fragments are typically present. Within the GAB, the Gubberamunda Sandstone is considered a usable aquifer.

The Orallo Formation *Minor Discontinuous Aquifer*

The Orallo Formation conformably overlies the Gubberamunda Sandstone. It was deposited in a relatively low energy fluvial environment with local ponding (PM Green 1997). The Orallo Formation consists of fine to coarse-grained sandstone interbedded with clay, siltstone, silty mudstone, bentonite clay, and coal. The Orallo Formation is considered a minor discontinuous aquifer.

The Mooga Sandstone *Aquifer*

The Mooga Sandstone generally conformably overlies the Orallo Formation, with local disconformities (Exon 1976a). Deposits tend towards fine to medium grain size sand, although siltstones, mudstones, and shale are present (Exon 1976a). Three subunits are recognised. The upper Mooga Sandstone and lower Mooga Sandstone are considered aquifers. The middle Mooga Sandstone consists of siltstones, mudstones, and shale and is considered an aquitard.

The Bungil Formation *Aquifer*

The Bungil Formation conformably overlies the Mooga Sandstone. This unit is comprised of interbedded fine-grained lithic sandstones, siltstones, and mudstones with minor quartzose sandstone present. The Bungil Formation is considered an aquifer.

7.3 Local Hydrogeology

7.3.1 Surat Basin Units

The Project is situated in an area where the Springbok Sandstone, Westbourne, and Gubberamunda Formations outcrop. Two cross sections, oriented North-South and West-East, through the Project area, are shown on Figure 7.4. The cross sections were prepared using the OGIA Surat CMA geological model (OGIA 2021g). The sections indicate that the WCM occurs at ~220 to 300 m below ground level; and is ~400 m thick.

Table 7.2 presents the mean thickness within the Project area for each of the underlying hydrostratigraphic units. Isopachs for the key hydrostratigraphic units are presented in Figure 7.5, with the top of the unit elevations shown in Figure 7.6.

Table 7.2 Aquifer / Aquitard Thicknesses within the Project (after (OGIA 2021g))

Hydrostratigraphic Unit	Aquifer / Aquitard	Mean Thickness (m)
Orallo Formation	Minor Discontinuous Aquifer	26
Gubberamunda Sandstone	Aquifer	43
Westbourne Formation	Aquitard	41
Springbok Sandstone	Aquifer	104
Walloon Coal Measures	Productive Coal Seams	413
Durabilla Formation	Aquitard	87
Hutton Sandstone	Aquifer	236
Evergreen Formation	Aquitard	203
Precipice Sandstone	Aquifer	73

Exploration wells drilled in the southern extent of PL 209 (WOLEEBEE EAST 4) encountered 152 m of Westbourne Formation, 83 m of Springbok Sandstone, and the top of the Upper Juandah Formation at 474 mbGL.

There are no mapped major geological structures (e.g., faults) within the vicinity of the Project. The nearest major fault is the Burunga Fault which is located approximately 26 km to the east of PL 209, 17 km east of Wandoan.

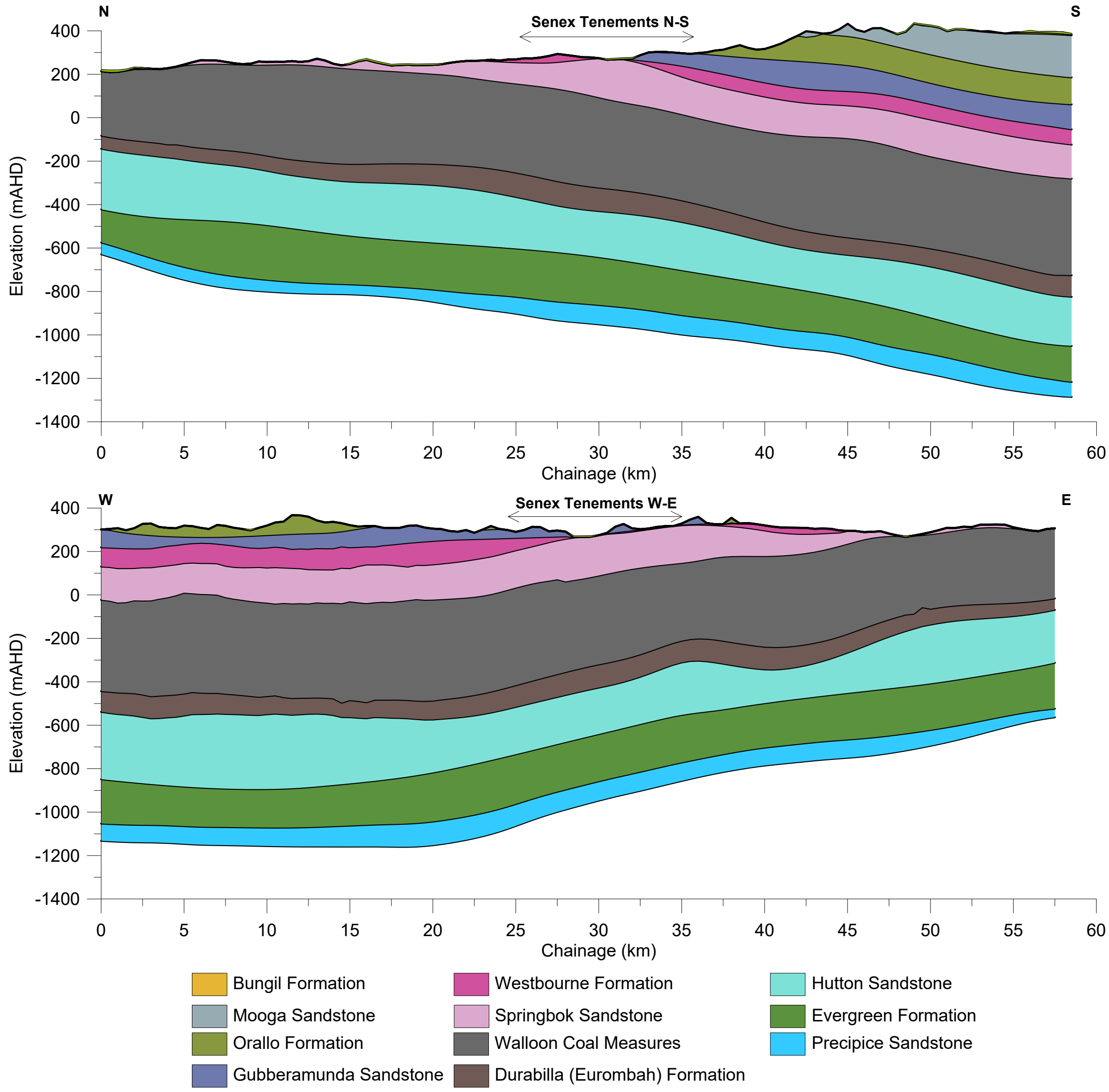


Figure 7.4 Geological Cross Sections Surat CMA Geological Model (OGIA 2021f)

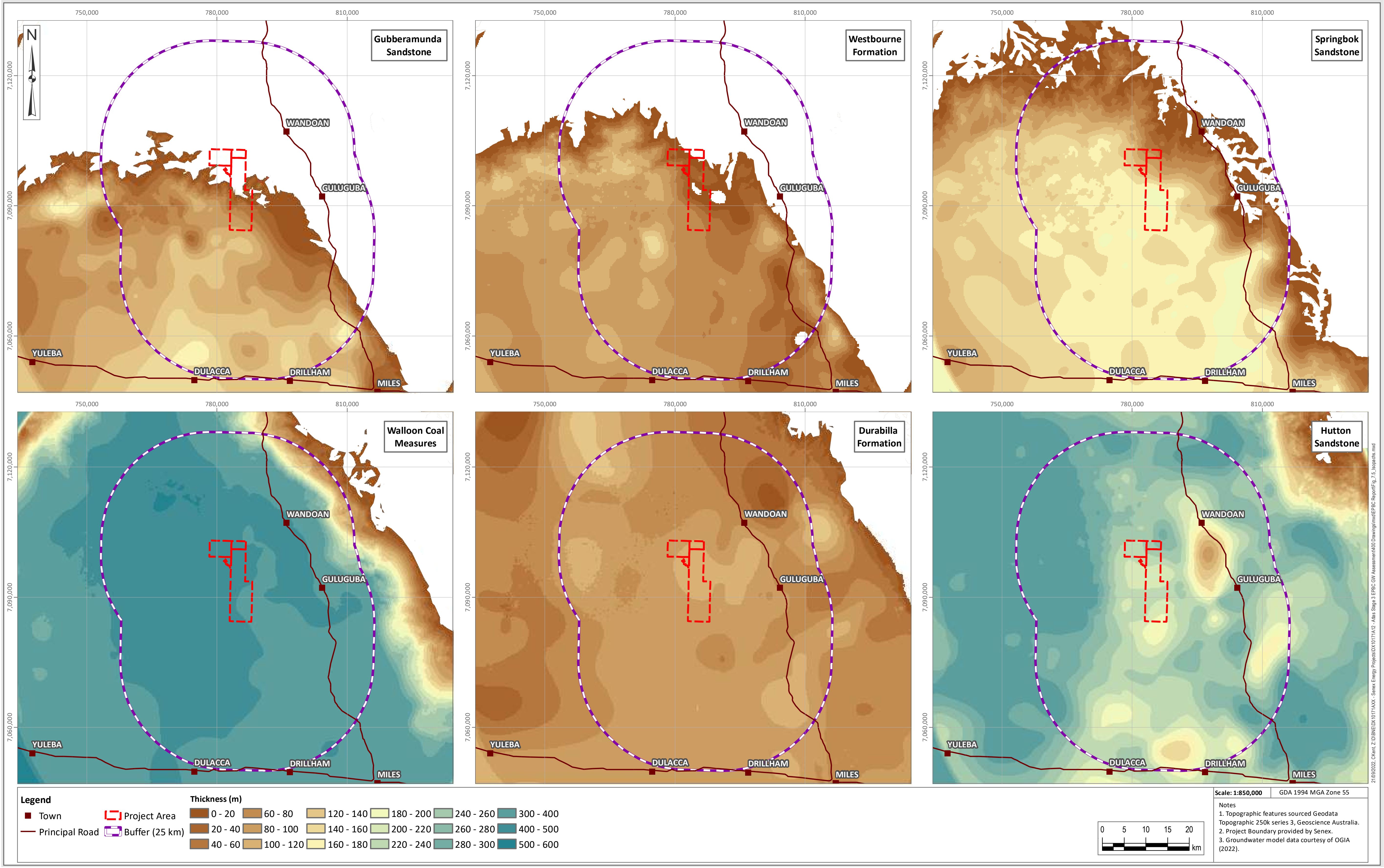


Figure 7.5 Formation Isopachs for Relevant Surat Basin Units (OGIA 2021f)

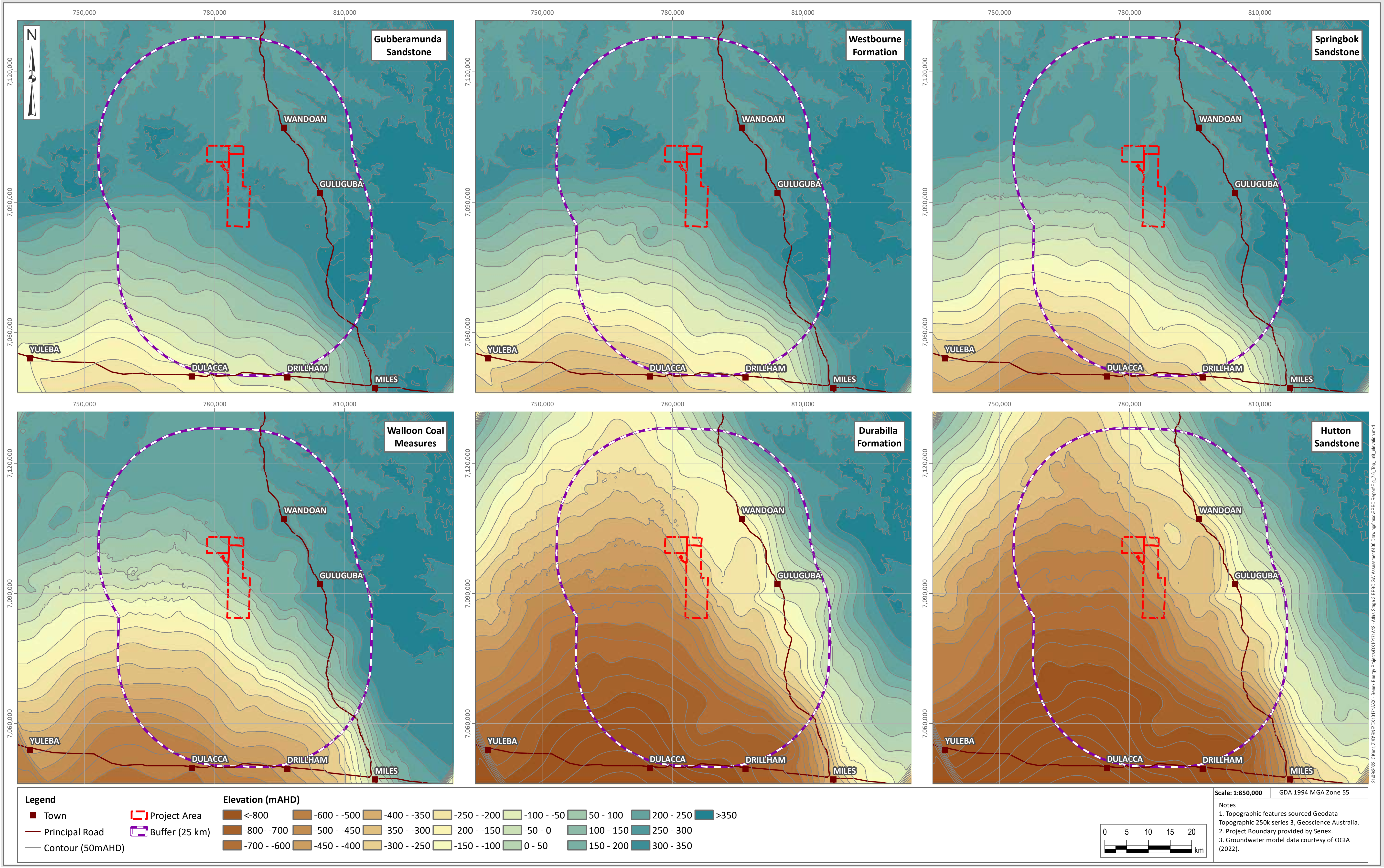


Figure 7.6 Top of Unit Elevation for Relevant Surat Basin Units (OGIA 2021f)

7.3.2 Alluvium

Quaternary-age alluvium is mapped (1:100,000 scale) within the Project area and is associated with Woleebee and Wandoan Creeks, as shown on Figure 7.7. The alluvium is mapped along the Wandoan and Woleebee creeks, the lateral extent of the alluvium increases towards the north of the Project area where Wandoan Creek flows into Woleebee Creek.

Alluvial thickness associated with Woleebee Creek, within the Project area, ranges between 7 to 10 m above the Springbok Sandstone sub-crop, and up to 13 m above the southern outcrop of the Westbourne Formation (Appendix X and XI).

Monitoring bores were installed by Senex in the Project area between December 9, 2022, and September 9, 2023 at four strategic locations across the Project area (location shown on Figure 4.1), four of which were screened in alluvium Three were dry during installation and have been found (using dataloggers) to have been consistently dry throughout the period of monitoring to date. (see Section 7.6.2).

Observations of the alluvium in Woleebee and Wandoan Creek were made in the field verification for Project Atlas (KCB 2018c), close to and within the Project area. A summary of the observations and interpretations from the field verification is provided below, the full report can be found in Appendix IX.

Woleebee Creek Alluvium

In the upper reaches of Woleebee Creek the creek bed is sandy. The sand is coarse-grained and considered to be associated with the Gubberamunda Sandstone (which outcrops upstream). Further downstream, beyond the confluence with Ogle Creek, where the creek is underlain by the Westbourne Formation, the creek bed sediments become siltier and more clay-rich.

A rock outcrop was identified in the upper reaches of the creek close to the border of PL 1037 and PL 209 (and photograph A on Figure 7.8, as shown on Figure 7.7). This indicates the discontinuous nature of the alluvium. The base of the outcrop contained mudstones considered to be part of the Westbourne Formation, which is overlain by an ‘ironstone’ and is interpreted to have been formed by the chemical precipitation of iron and manganese. Overlaying the ironstone is a fine gravel conglomerate which in turn is overlain with coarse-grained sandstone with crossbedding. The coarse-grained sandstone is typical of the Gubberamunda Sandstone. The outcrop is considered to show the conformable contact between the Gubberamunda Sandstone and the underlying Westbourne Formation.

Other rock outcrops were observed downstream, an example of the discontinuous nature of the alluvium which is likely to affect groundwater flow and storage.. These consisted of mudstones and fine-grained sandstone associated with the Westbourne Formation. These rocks were weak and friable.

The change in bedrock geology between the Westbourne Formation and the Gubberamunda Sandstone could have resulted in the change in the meandering nature of the creek. The presence of the more competent coarse-grained Gubberamunda Sandstone may have resulted in a straighter creek channel upstream, with the weak and friable mudstones of the Westbourne Formation resulting in a meandering form downstream.

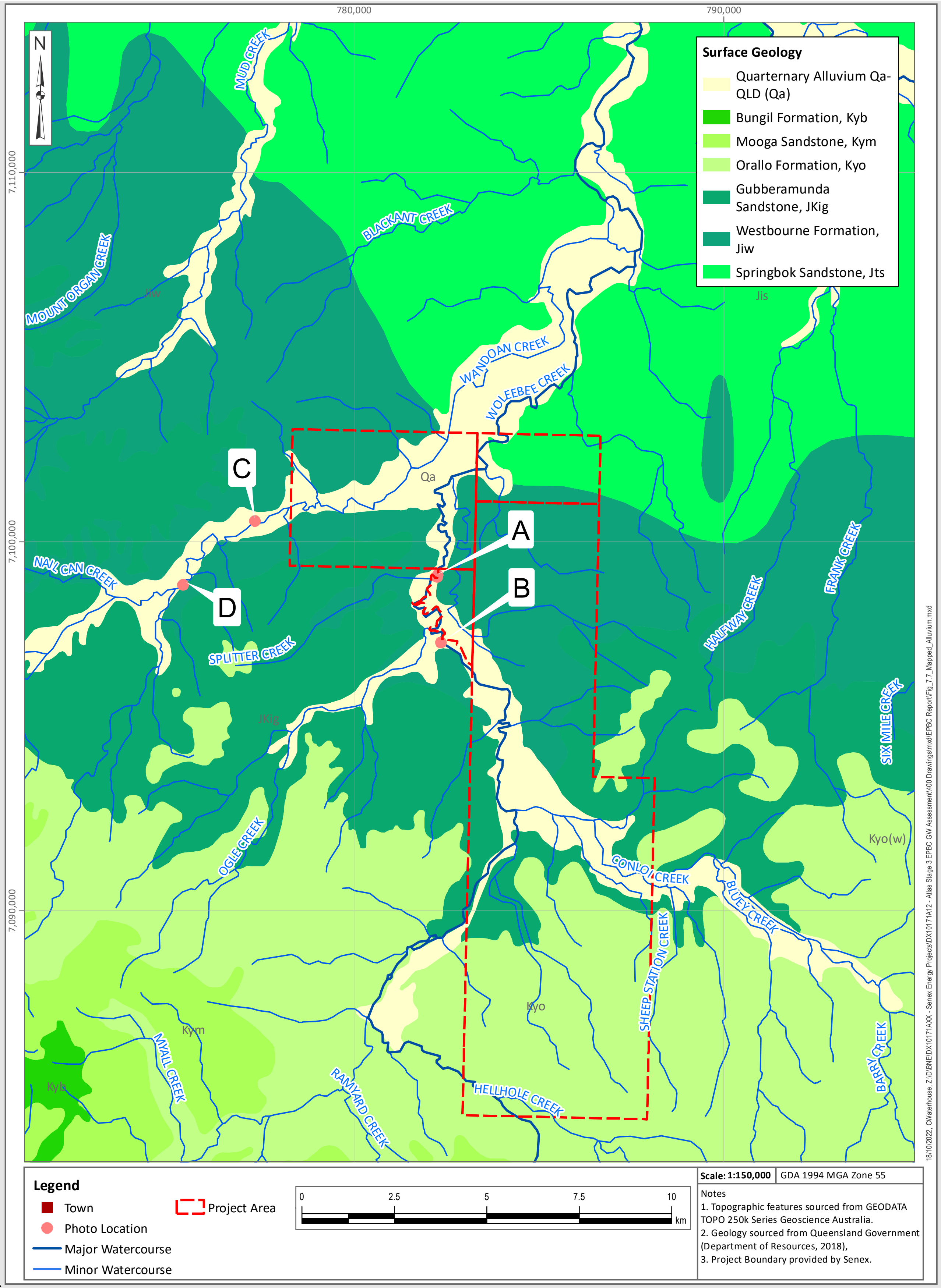


Figure 7.7 Location of Mapped Alluvium in the vicinity of the Project

Figure 7.8 Bedrock and superficial geology encountered at Woleebee Creek on the border of PL 1037 and ATP 2059 A) Outcrop of fine-grained sandstone and mudstone (Westbourne Formation); B) Typical sandy creek bed (see Figure 7.7 for location)

Wandoan Creek Alluvium

- The bedrock geology beneath Wandoan Creek across the Project is the Westbourne Formation.
- The Gubberamunda Sandstone outcrops further upstream, outside of the Project area, to the west.
- The creek bed generally consists of silt / silty sand. The creek bed is generally sandier upstream where the creek is closer to the Gubberamunda Sandstone outcrop and becomes silty and clayey downstream consistent with the underlying geology (Westbourne Formation).
- One small rock outcrop was identified (an example of the discontinuous nature of the alluvium). This is described as a fine-grained sandstone, which was friable and considered to be a lithological unit of the Westbourne Formation. This unit had been eroded by surface water flow within the creek (Figure 7.9).
- Alluvial sand was encountered approximately 400 m from the creek bed, just south of Weldons Road, which passes north of Wandoan Creek (north of photo point C on Figure 7.7). This is consistent with the geological mapping.

Figure 7.9 Bedrock and superficial geology encountered at Wandoan Creek C) Outcrop of fine-grained Sandstone; D) Sandy creek bed in the Upstream Sections of the Creek (see Figure 7.7 for locations)

7.4 Aquifer / Aquitard Hydraulic Properties

A number of hydraulic tests, to determine aquifer hydraulic parameters, have been conducted across the Surat Basin on formations overlying and underlying the WCM.

Hydraulic Conductivity

OGIA (OGIA 2016a) presented a range of hydraulic conductivity estimates from core drill stem tests (DSTs) and pumping tests within the Surat CMA. Those values are provided on Figure 7.10. The data was compiled from a range of sources including the GWDB, Queensland Petroleum Exploration Database (QPED), GAB Water Resource Assessment (Smerdon et al. 2012) and public domain sourced investigations undertaken by other CSG proponents including QGC, APLNG and Arrow Energy.

Ranges of horizontal hydraulic conductivity values from these tests, together with the OGIA model calibrated values indicate that the Gubberamunda and Precipice Sandstones are the most permeable consolidated formations in the Surat CMA (Figure 7.10) (OGIA 2019b).

Limited site-specific hydraulic parameter values are available for the alluvium within the Project area. A hydraulic conductivity of between 0.2 and 1.4 m/d was reported for the alluvium associated with Horse Creek (AGE 2012), which is located in an adjacent catchment to the Project. Four monitoring bores have been installed by Senex in alluvium (see section 4.1.2.1), of which three were dry and one had water (ATLAS-15M-S), which allowed for a hydraulic test to be undertaken. The hydraulic conductivity for the alluvium was determined to be between 0.12 to 0.16 m/d (note that this bore is suspected to be intersecting an isolated pocket of groundwater within the alluvium). This is lower than the hydraulic conductivity associated with Horse Creek (AGE 2012) and suggests that the aquifer hydraulic properties of the alluvium is highly variable.

Four deeper monitoring bores were drilled and installed into the underlying Surat Basin units, adjacent to the shallow alluvium monitoring bores. Screened intervals for these monitoring bores targeted the Westbourne Formation (ATLAS-13M-D; ATLAS-15M-D) and Upper Springbok

Sandstone (ATLAS-14M-D; ATLAS-19M-D). Hydraulic conductivity estimates from slug tests for these formations were as follows:

- Westbourne Formation: 0.001 – 0.002 m/d
- Upper Springbok Sandstone: 0.002 – 0.31 m/d

Site-specific hydraulic conductivity estimated from hydraulic tests completed on the new monitoring bores in the Westbourne Formation and Springbok Sandstone are within the same ranges as the OGIA hydraulic conductivity data presented in Figure 7.10.

Storage

Estimates of storage parameters are presented in documentation for the neighbouring QGC tenures (Golder Associates 2009b). Storage (storativity) is reported to range between 5 x 10^{-3} and 5 x 10^{-4} for all hydrostratigraphic units.

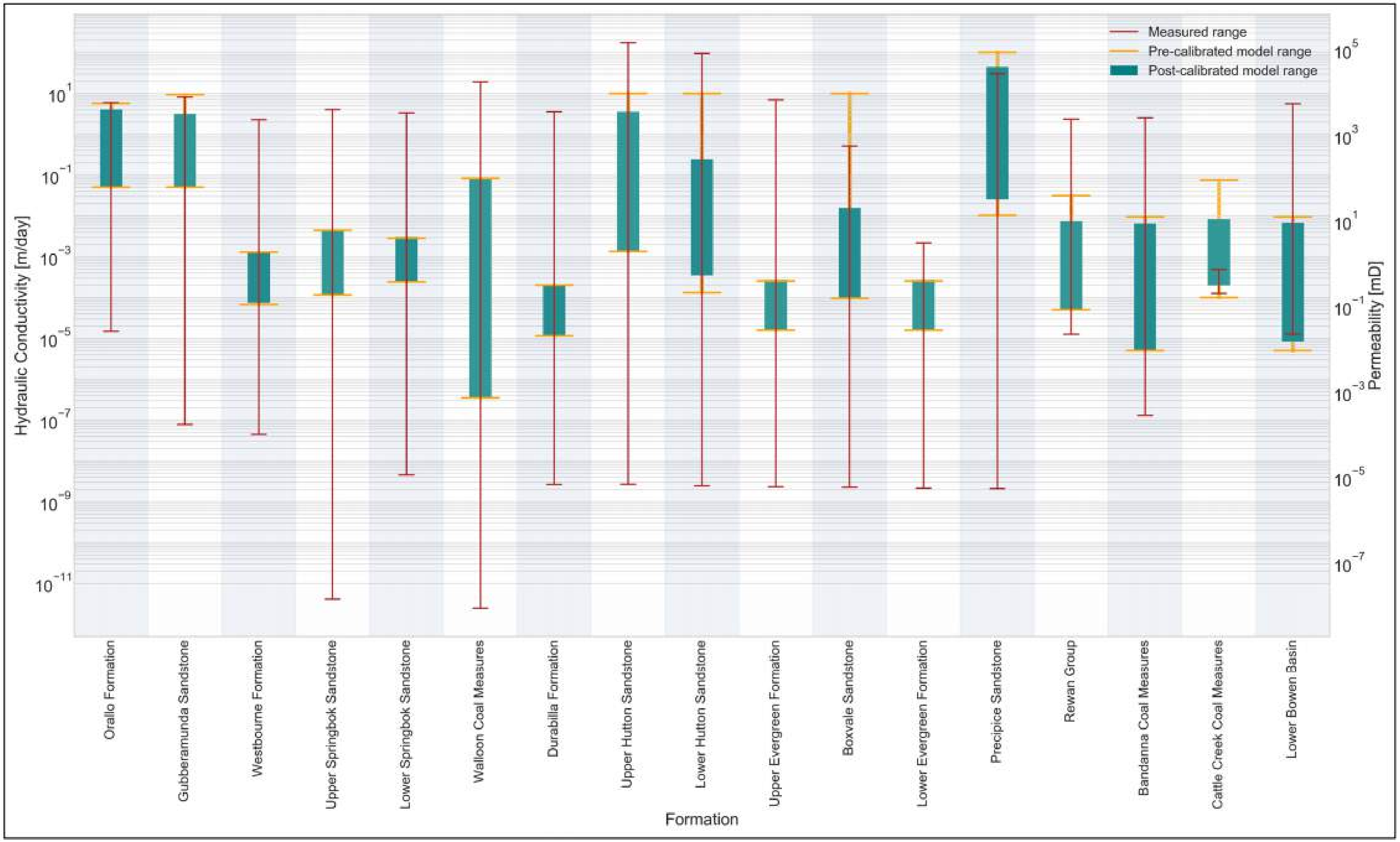


Figure 7.10 Hydraulic Conductivity Values for Surat Basin Units (after OGIA 2019b)

7.5 Groundwater Recharge

Groundwater recharge processes within the Surat Basin are summarised in the *Hydrogeological Conceptualisation Report for the Surat Cumulative Management Area* (OGIA 2016c) and based on Kellett et al. (2003), and *Regional flow systems and potentiometry in Queensland's Surat and Southern Bowen Basins* (OGIA 2021d). Key processes of recharge include localised recharge, preferential pathway flow and diffuse recharge:

- Localised recharge occurs beneath drainage features including rivers, creeks, and alluvial and tertiary groundwater systems where there is sufficient saturation and hydraulic head to allow water to infiltrate into aquifers. Areas of localised recharge are considered limited in extent in the GAB (Kellett et al. 2003).
- Preferential pathway flow arises from changes in permeability within aquifers and in overlying regolith, providing conduits for water to infiltrate. Zones of higher permeability may include fissures, faults, joints, tree roots and high-permeability beds within individual formations and along bedding planes (Kellett et al. 2003; Sucklow et al. 2016). This mechanism is considered the dominant recharge process in the GAB (Kellett et al. 2003).
- Diffuse discharge is the process by which rainfall infiltrates directly though outcropping aquifers. This is expected to occur within all outcrop areas and therefore this process applies to the largest spatial extent (Kellett et al. 2003).

Within the vicinity of the Project, groundwater recharge is likely to occur as a result of localised recharge occurring beneath watercourses and alluvial systems where sufficient saturation and hydraulic head allows water to infiltrate into surficial aquifers. Recharge will also occur as diffuse recharge with rainfall infiltrating directly through outcropping aquifers, such as the Springbok Sandstone which outcrops across the majority of PL 445.

Long-term average recharge rates were estimated previously (OGIA 2019a) using the chloride mass balance recharge method:

- Orallo Formation (outcrops to the south) – 2.4 mm/year.
- Gubberamunda Sandstone (outcrops in the Project area) – 3.4 mm/year.
- Westbourne Formation (outcrops in the Project area) – 1.6 mm/year.
- Springbok Sandstone (outcrops to the northeast) – 1.3 mm/year.

7.6 Groundwater Levels and Flow

7.6.1 Regional Groundwater Flow

Basin scale groundwater flow within the Surat Basin is typically north to south from northern outcrop areas. There is a recognised groundwater to flow towards the north (towards Taroom) on the northern side of the Great Dividing Range with groundwater discharging into the Dawson River catchment (OGIA 2016d; 2021d). This is consistent with the surface water drainage, as higher heads are present in the south at the catchment divide. South of the Range, groundwater flow is generally southward, broadly consistent with the dip of the formation (OGIA 2021d).

Groundwater movement is slow in the GAB with flow velocities estimated at 1 to 5 m/yr. (Habermehl 1980). Generally, groundwater flow and movement occurs as sub-horizontal flow, with limited vertical leakage across formations, where pressure differences may exist (OGIA 2016d). Local groundwater flow conditions may be different from regional flow conditions with potential steeper gradients and increased velocities in response to hydraulic stresses such as groundwater abstraction.

7.6.2 Groundwater Elevation and Monitoring Bores

There are 71 active regional monitoring bores at 47 sites within the 25 km buffer (State of Queensland 2021b) (Figure 7.11 and Table 7.3), 91 including the Senex monitoring bores. These monitoring bores likely include bores installed by resource companies as part of the Surat CMA UWIR Groundwater Monitoring Network and other programs, such as Groundwater Online or Groundwater Net, coordinated by the Queensland Government. In addition, there are:

- Ten seepage monitoring bores installed by Senex in the Westbourne Formation, for monitoring of potential seepage from established development infrastructure as required by the EA.
- Three privately owned monitoring bores to the north of the Project area in the alluvium (see Figure 7.12 for location).
- Eight newly drilled Senex monitoring bores in ATP 2059 and PL 445. Four of these bores are screened in alluvium, two in the Springbok Sandstone, and two in the Westbourne Formation. Baseline data from the eight Senex monitoring bores collected to date is presented in Appendix I.

Individual maps of monitoring bore locations, for each formation, are provided in the following sections. It should be noted that some of the monitoring bore data is not currently available through the GWDB, which may be a function of recent installation, or the frequency of data entry into the GWDB. Aquifer attributions for the monitoring bores have been determined by OGIA as part of their 2021 Surat CMA numerical groundwater model update (OGIA 2022).

Table 7.3 Groundwater Monitoring Bores Within 25 km Buffer

Formation	No. of Monitoring Bores
Alluvium	7
Wallumbilla Formation	1
Mooga Sandstone	3
Gubberamunda Sandstone	11
Westbourne Formation	13
Upper Springbok Sandstone	9
Lower Springbok Sandstone	2
Upper Juandah Coal Measures	9
Lower Juandah Coal Measures	11
Taroom Coal Measures	7
Durabilla Formation	2
Lower Evergreen Formation	1
Upper Hutton Sandstone	8
Lower Hutton Sandstone	3
Precipice Sandstone	4
Total:	**91**

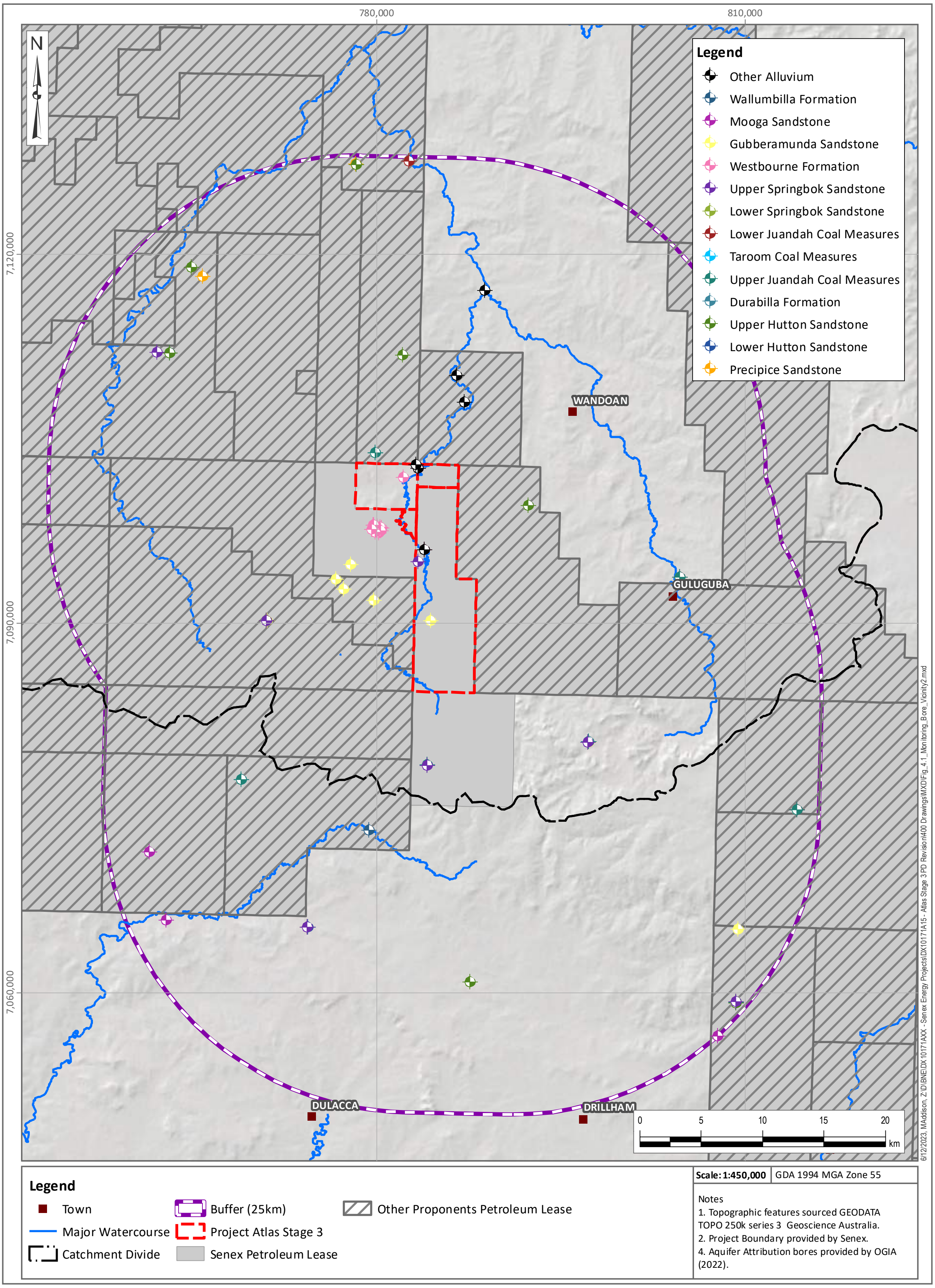


Figure 7.11 Location of Monitoring Bores within the Vicinity of the Project

Alluvium Monitoring Bores

There are seven monitoring bores screened in alluvium within the 25 km buffer zone of the Project. Bore locations are presented in Figure 7.12, and a groundwater elevation hydrograph is presented for those bores on Figure 7.13.

Observations from data include:

- Four out of the seven alluvium bores were dry as, indicated in Figure 7.12 (in orange).
- Groundwater elevations in the alluvium range between ~230 and ~275 mAHD, with highest elevations corresponding to highest ground elevations in the southeast. ATLAS15M-S exhibits the highest groundwater elevation, located in PL 209.
- Groundwater levels are relatively stable but do show some seasonal variability as seen for RN 180145 and RN 180147 further downstream (Figure 7.13).

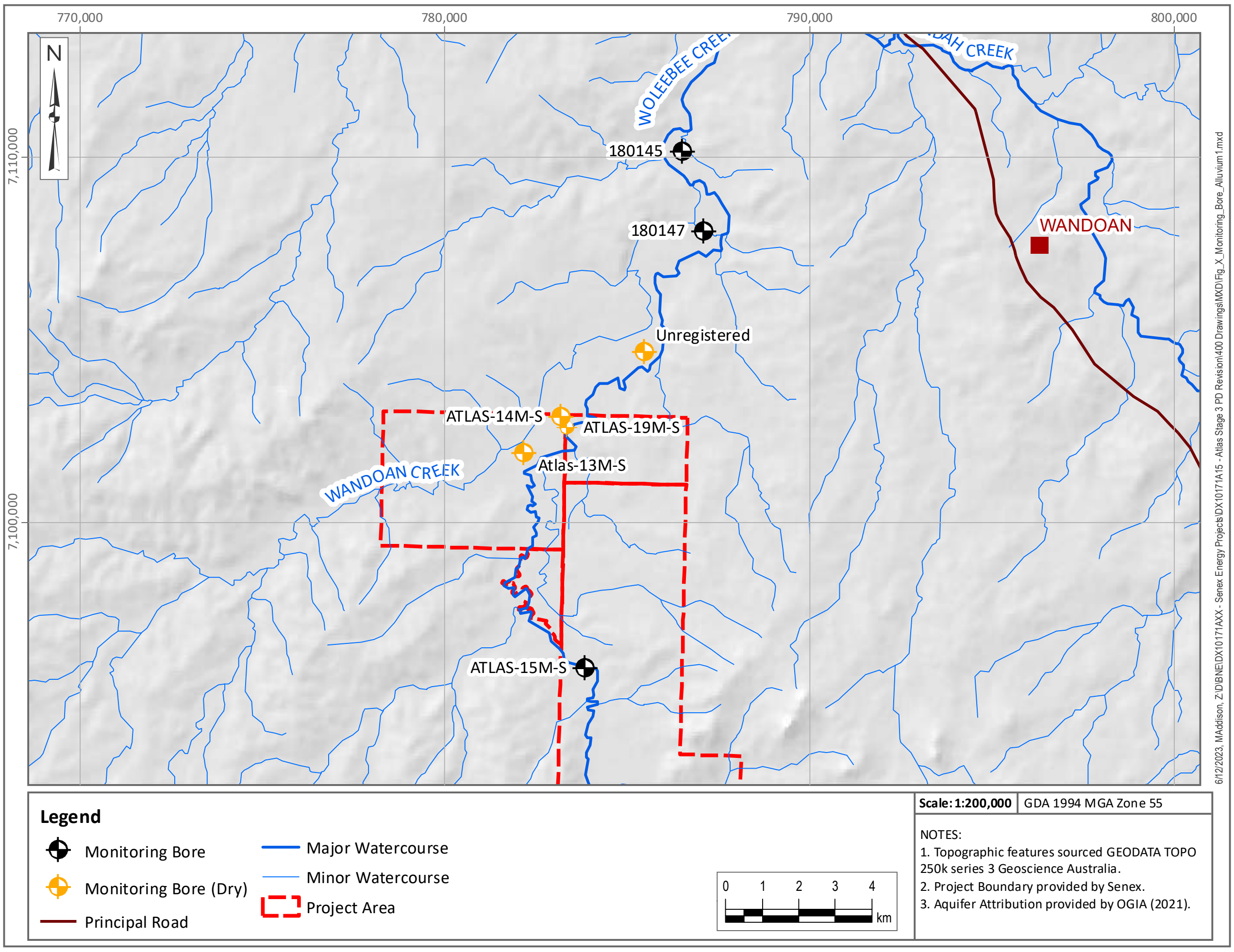
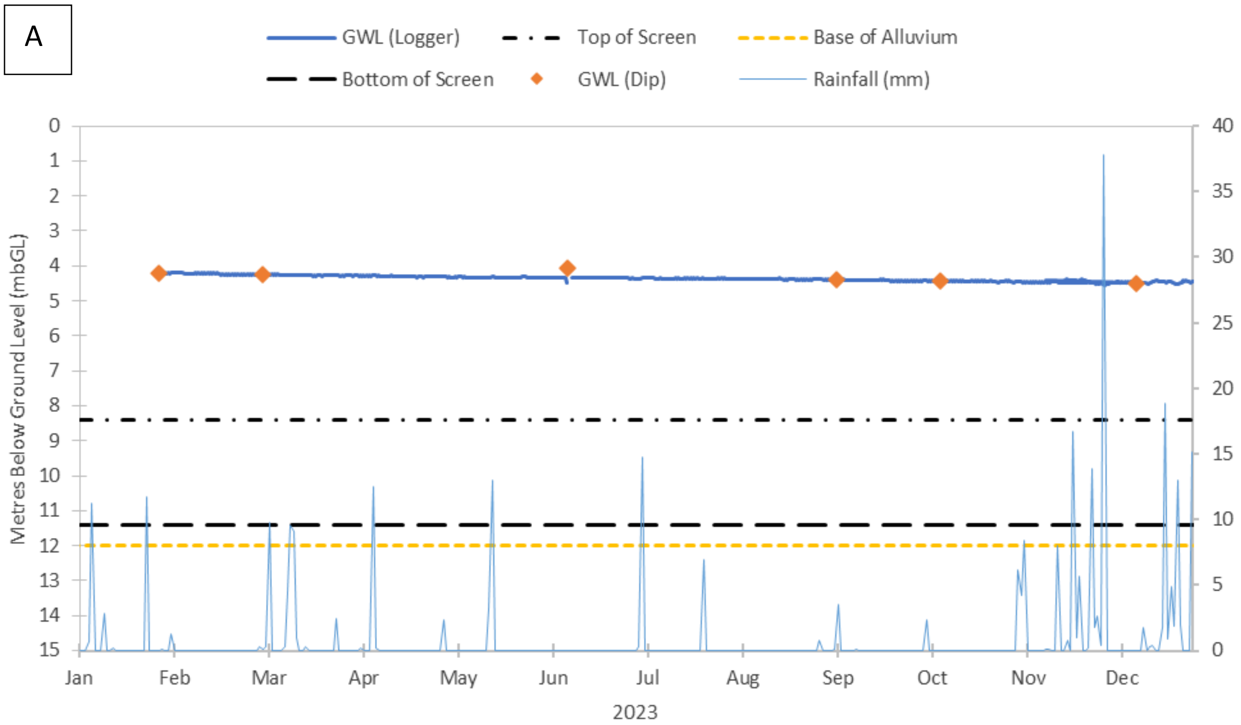


Figure 7.12 Location of Alluvium Monitoring Bores



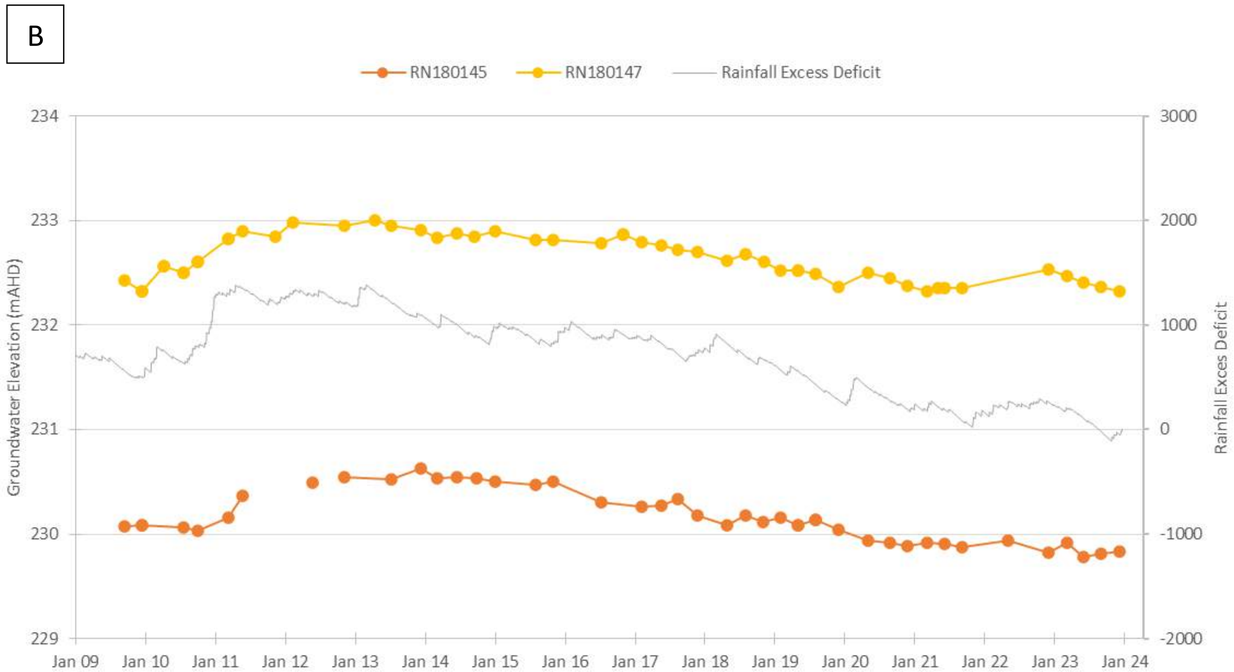


Figure 7.13 Groundwater Elevation Hydrograph – Alluvium. (A) Monitoring Bore ATLAS-15M S; (B) RN 180145 and 180147 north of PL 445 along Woleebee Creek.

Gubberamunda Sandstone Monitoring Bores

There are 11 Gubberamunda Sandstone monitoring bores within the Project 25 km buffer zone. Bore locations are shown on Figure 7.14, and a groundwater elevation hydrograph is presented for those bores on Figure 7.15.

Observations from available data include:

- Groundwater elevations range between ~269 and ~314 mAHD, with highest elevations corresponding to highest ground elevations in the southeast. RN 43482 exhibits the lowest groundwater elevation, located immediately to the west of PL 445 within ATP 2059.
- Groundwater levels in most bores are either stable (particularly shallow bores) or exhibit slightly declining trends. RN 160522 (located due west of PL 445) has seen a steep decline from 2012, followed by an increase to 2016 after which levels stabilised. This observation is supported by rainfall CRD, indicating some degree of climatic influence at that location. RN 123553 has seen periodic water level increases and decreases of +/- 12 m since 2016 and may be influenced by pumping. RN 13030808 located in PL 209 remains stable since pre-2010 with an elevation of ~282 mAHD.
- Inferred groundwater flow within the Gubberamunda Sandstone is northwest and south from a high point at RN 160704. This observation corresponds with expected groundwater flow directions on either side of the river basin divide at the southern extent of PL 209.

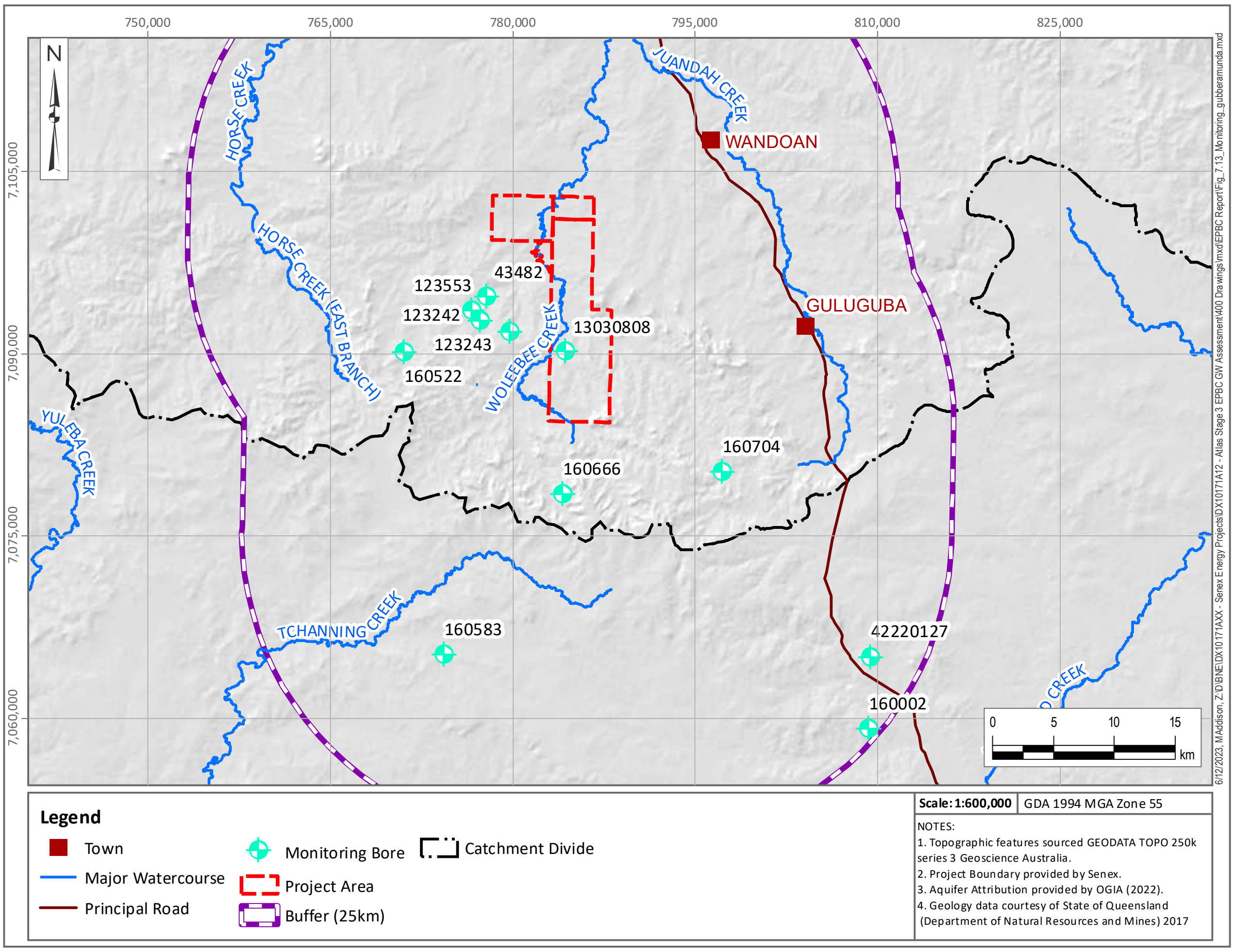


Figure 7.14 Location of Gubberamunda Sandstone Monitoring Bores

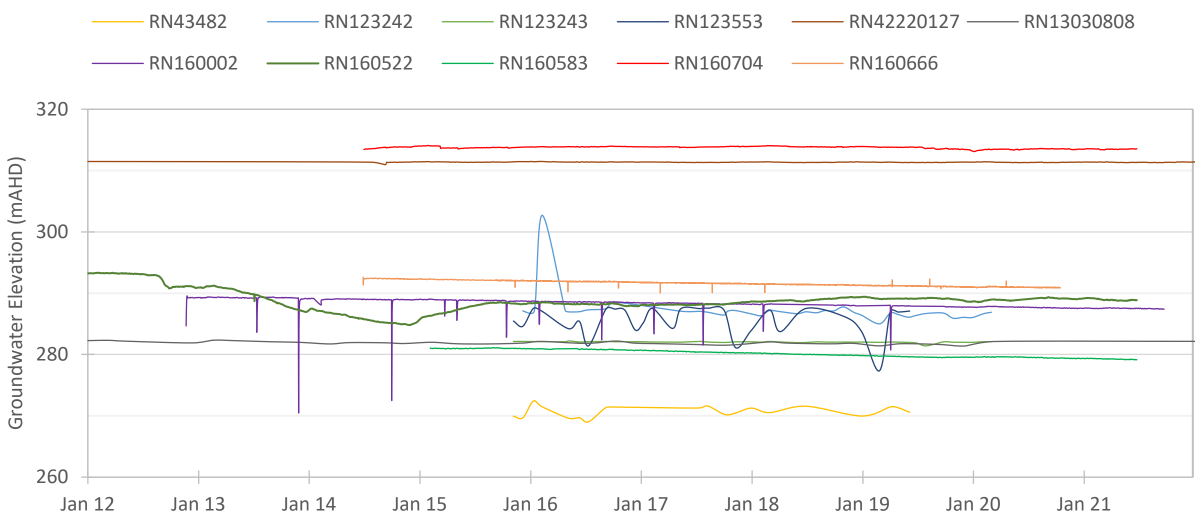


Figure 7.15 Groundwater Elevation Hydrograph – Gubberamunda Sandstone

Westbourne Formation Monitoring Bores

There are twelve monitoring bores on the Project Atlas tenure screened within the Westbourne Formation, with the locations shown on Figure 7.16. The majority of the bores were installed by Senex for seepage monitoring of Project Atlas produced water dams. Two of which are new Senex bores (ATLAS 13M-D and ATLAS 15M-D) that were installed between between December 9, 2022, and January 25, 2023, as part of the site-specific field investigation.

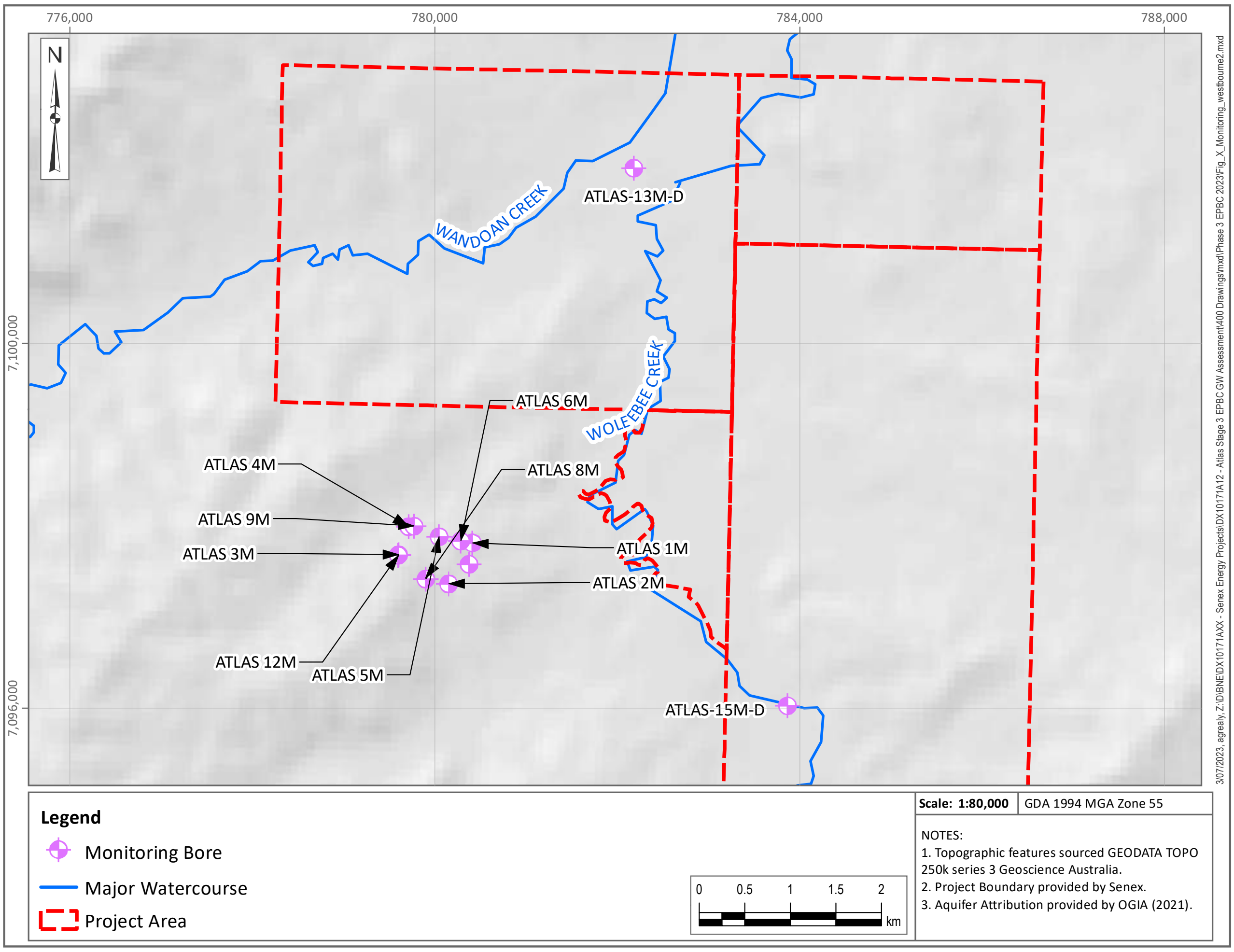


Figure 7.16 Location of Westbourne Formation Monitoring Bores

Of the ten bores seepage bores, only six are monitored regularly, with four being consistently dry (ATLAS 6M, 7M, 8M, and 12M). The seepage bores have been monitored from June 2020 and were installed by Senex.

Figure 7.17 presents groundwater levels for nine of the 12 bores screened within the Westbourne Formation. The new monitoring bores (ATLAS-13M-D and ATLAS-15M-D) were installed between December 9, 2022, and January 25, 2023, by Senex and have loggers installed in them for short-term periodic groundwater level monitoring. Standing groundwater levels in the Westbourne Formation range between ~2 and ~35 mbGL. Groundwater levels in these bores have remained relatively stable across the monitoring period, with the exception of a rise of approximately 3 m observed in monitoring bore Atlas 2M.

Groundwater within the Westbourne Formation at the Atlas produced water dams occur in shallow unconfined and deeper confined groundwater systems. In the deeper Westbourne Formation, flow direction is towards the east-southeast with a low horizontal hydraulic gradient across the site (Senex 2022a).

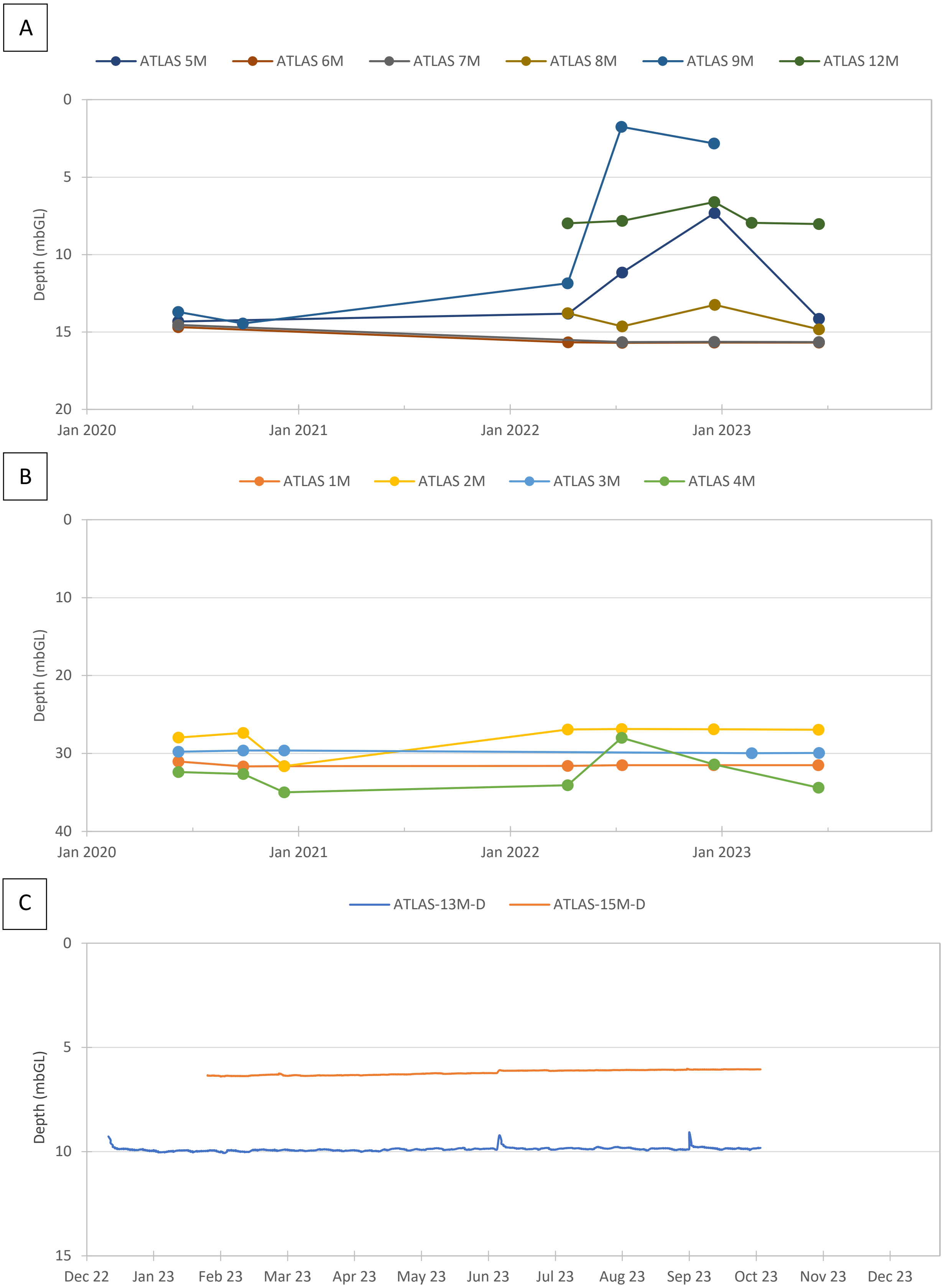


Figure 7.17 Groundwater Levels – (A) Deeper Westbourne Formation; (B) Shallow Westbourne Formation; (C) New Westbourne Monitoring Bores

Upper Springbok Sandstone Monitoring Bores

There are nine Upper Springbok Sandstone monitoring bores within the 25 km buffer zone. Bore locations are shown on Figure 7.18, and a groundwater elevation hydrograph is presented for those bores on Figure 7.19.

Observations from available data include:

- Groundwater levels in this unit range between ~9 and ~74 mbGL.
- RN 160694 and RN 160812 exhibit periodic pumping and recovery trends associated with landholder pumping which is common in Springbok Sandstone bores. Slow and frequently incomplete recovery trends indicate homogeneity and low permeability within the Springbok Sandstone (OGIA 2021f).
- Groundwater levels in most bores have remained stable since 2016.
- RN 160431 (located ~12 km due west of PL 209) has seen a steep decline from 2012 until 2019 when levels stabilised. The overall decline for this bore was ~36 m over 10 years. A moderate concentration of groundwater use has been noted in this area and is considered to be contributing locally to drawdown (OGIA 2021d).
- Inferred groundwater flow within the Upper Springbok Sandstone is northwest from a high point at RN 160193, this aligns with observations from OGIA (OGIA 2021d).

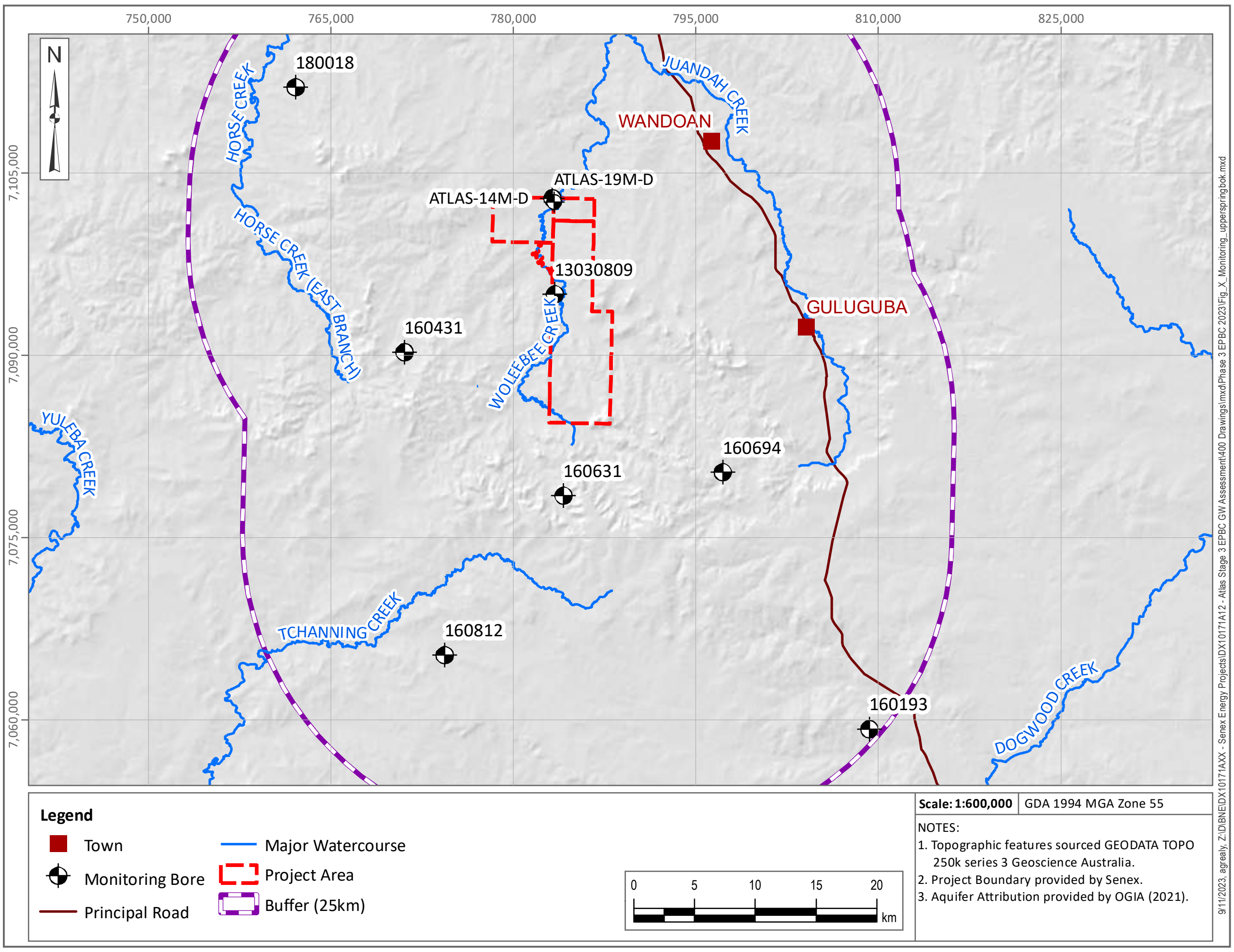


Figure 7.18 Location of Upper Springbok Sandstone Monitoring Bores

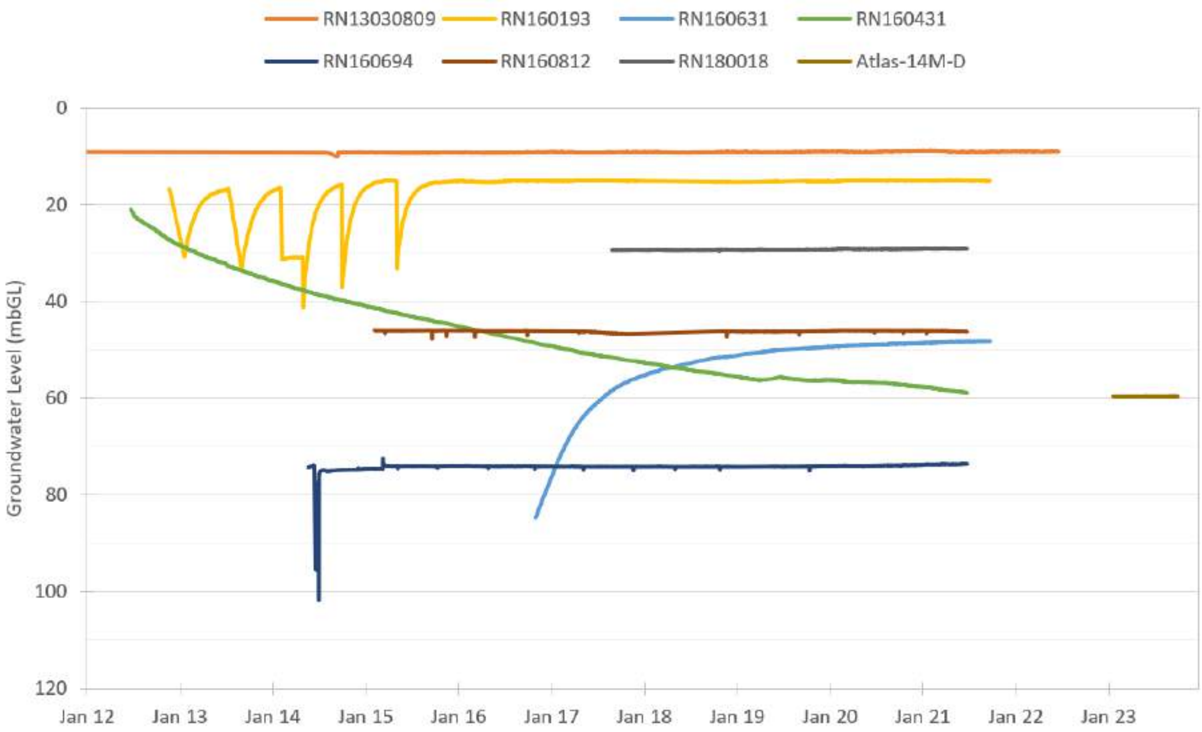


Figure 7.19 Groundwater Hydrograph – Upper Springbok Sandstone (A) Artesian Upper Springbok (B) Upper Springbok Monitoring Bore ATLAS-14M-D (non-artesian)

Lower Springbok Sandstone Monitoring Bores

There are two Lower Springbok Sandstone monitoring bores, at two locations, with groundwater elevation data available in the vicinity of the Project area. The location of these bores is shown in Figure 7.20.

There are two Lower Springbok Sandstone monitoring bores within the 25 km buffer zone, a groundwater elevation hydrograph is presented for those bores on Figure 7.21.

Observations from available data include:

- Groundwater elevations range between ~269 mAHD and ~277 mAHD. Groundwater levels in RN 160853 have remained stable, however RN 160430 may be influenced by pumping in the Upper Sandstone (OGIA 2021d).

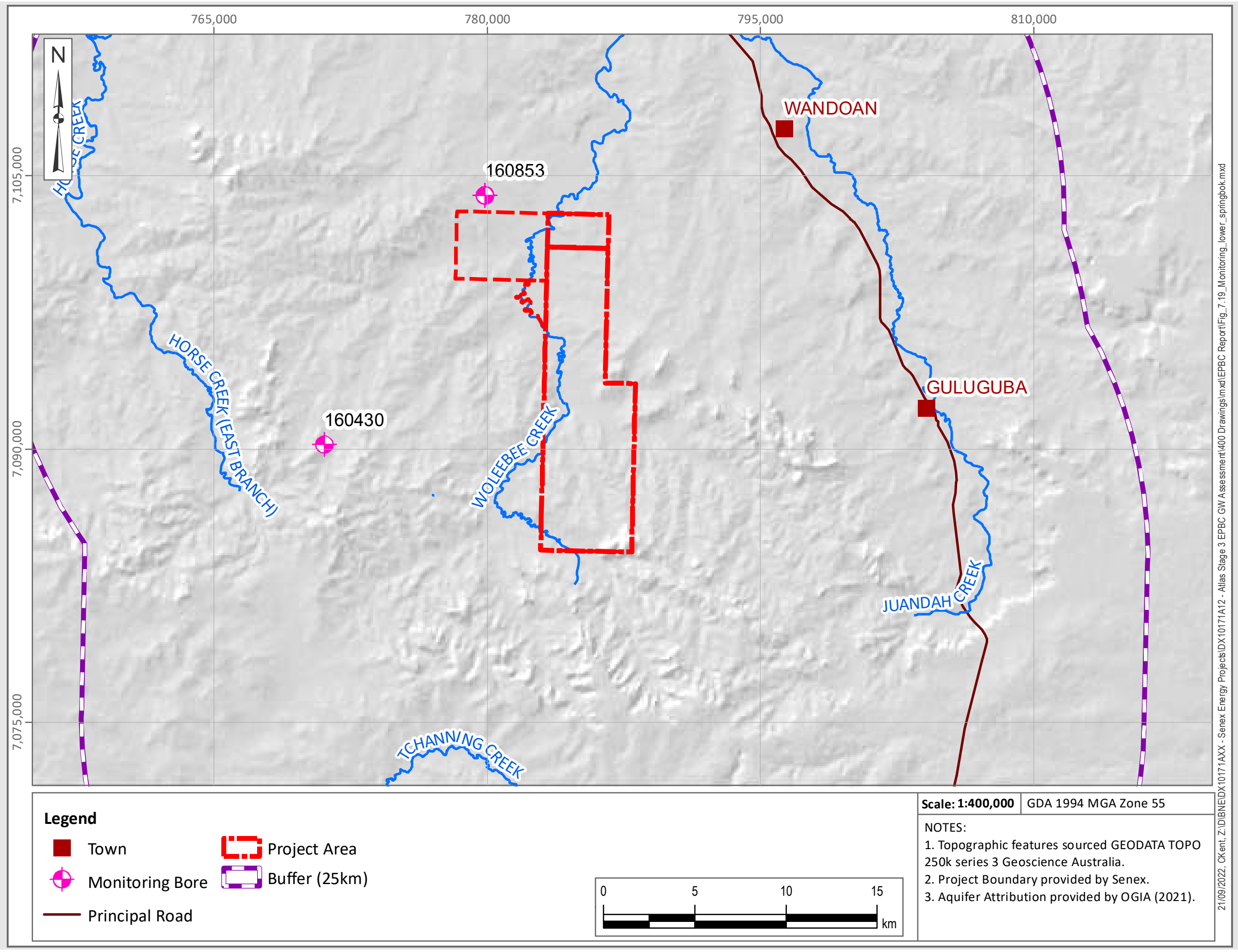


Figure 7.20 Location of Lower Springbok Sandstone Monitoring Bores

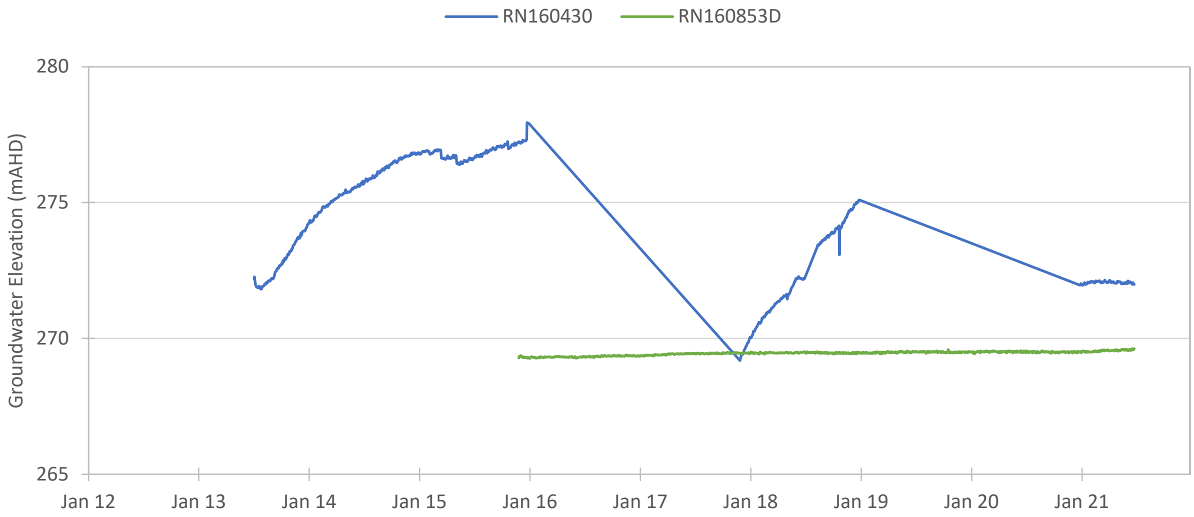


Figure 7.21 Groundwater Elevation Hydrograph – Lower Springbok Sandstone

Walloon Coal Measures Monitoring

There are 27 WCM monitoring bores at ten locations within the vicinity of the Project area. The majority of these locations include multi-unit monitoring bores across the different coal seams of the WCM. These bores include:

- Nine in the Upper Juandah Coal Measures;
- Eleven in the Lower Juandah Coal Measures; and
- Seven in the Taroom Coal Measures.

These locations are shown on Figure 7.22.

Monitoring records are presented in Figure 7.23, Figure 7.24, and Figure 7.25. These monitoring locations are likely operated by neighbouring CSG tenure holders and show a variety of responses which are likely due to depressurisation or testing which has commenced in these areas. Groundwater elevations within the WCM range between ~340 mAHD and 70 mAHD.

Groundwater flow in the WCM is generally south to north towards Taroom, however CSG development in the area result in localised variations to this regional flow direction (OGIA 2021d). The observed drawdown in the CSG development areas is steep, with little drawdown observed outside of the operating fields. This is likely to reflect the discontinuous nature of the coal seams in these gas fields and low effective horizontal permeabilities (OGIA 2021d). This explains the variety of responses in the groundwater elevations.

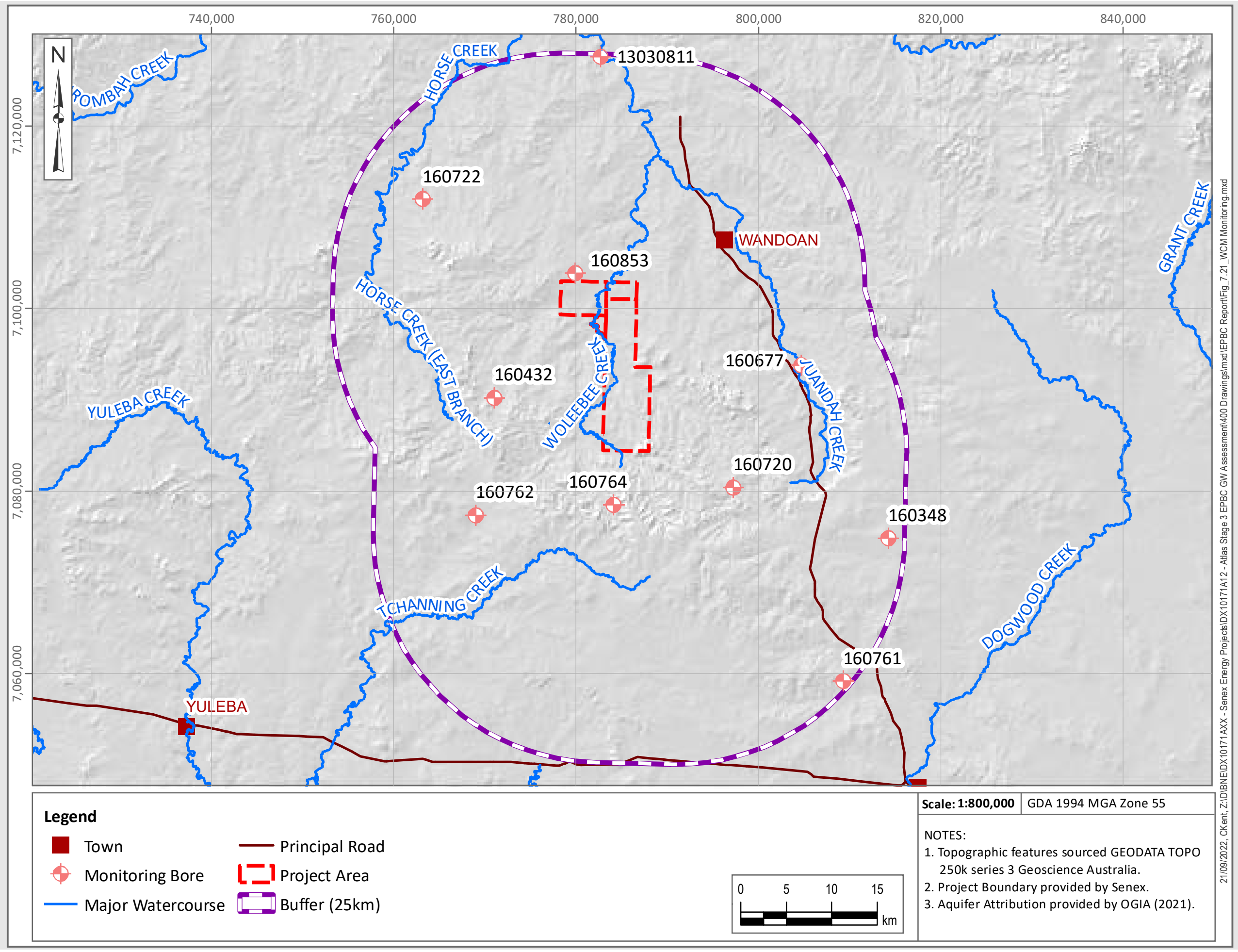


Figure 7.22 Location of WCM Monitoring Bores

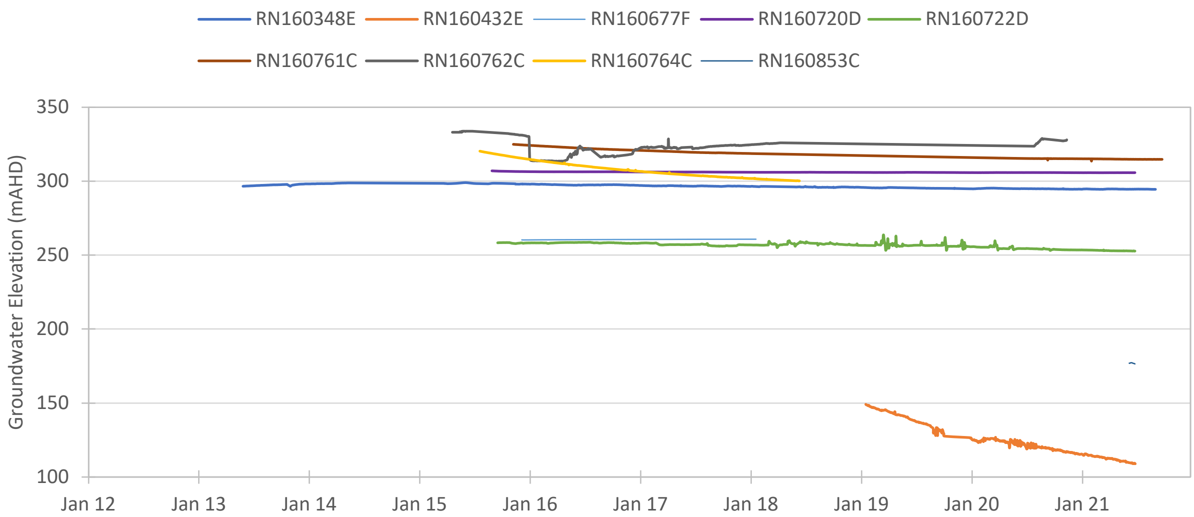


Figure 7.23 Groundwater Elevation Hydrograph for WCM – Upper Juandah Coal Measures

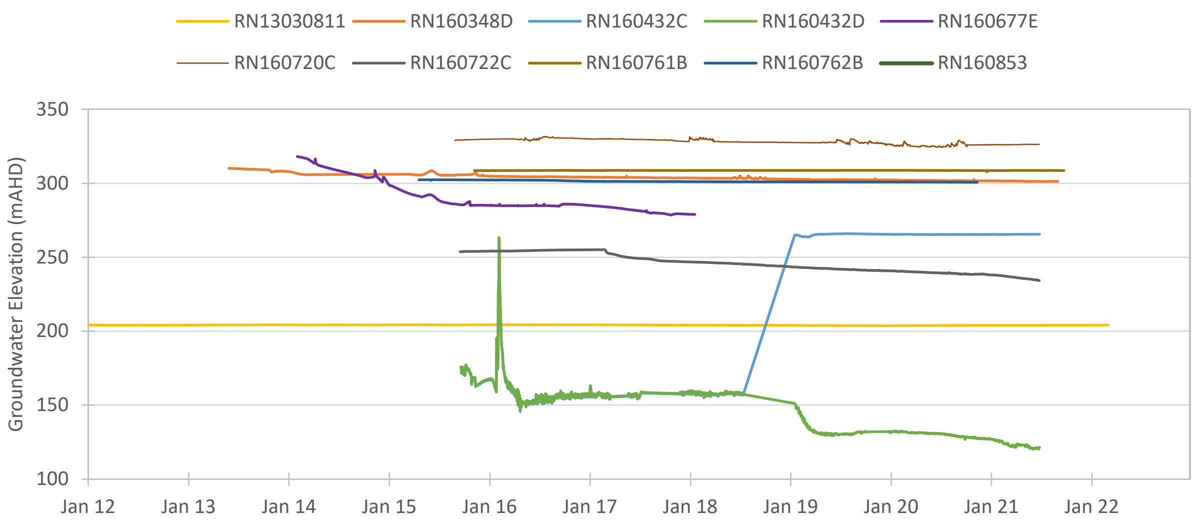


Figure 7.24 Groundwater Elevation Hydrograph for WCM – Lower Juandah Coal Measures

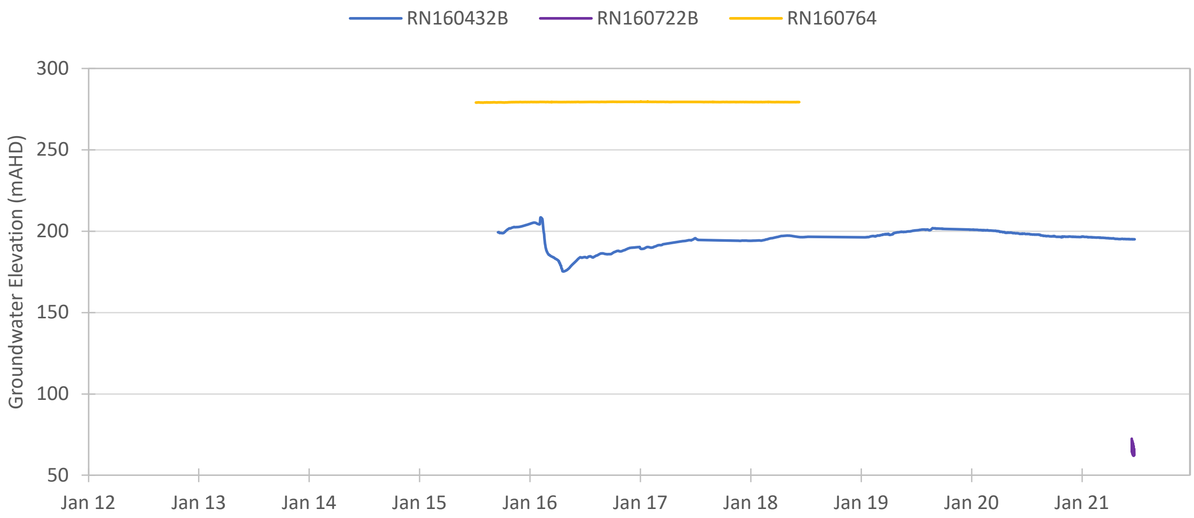


Figure 7.25 Groundwater Elevation Hydrograph for WCM – Taroom Coal Measures

Upper Hutton Sandstone Monitoring Bores

Temporal groundwater elevations for the Hutton Sandstone, within the vicinity of the Project, are available for eight sites. The location of these sites is shown on Figure 7.26 with the groundwater elevation hydrograph presented on Figure 7.27.

The range of groundwater elevation from these monitoring bores is between ~235 mAHD and 287 mAHD. Generally, most groundwater level records present relatively static groundwater levels with the exception of RN 160807 and RN 160505 which show a gradual decline. The monitoring record for RN 58133, located north of the Project, indicates a response to local pumping. RN 160722 and RN 44000 may also be responding to local water use.

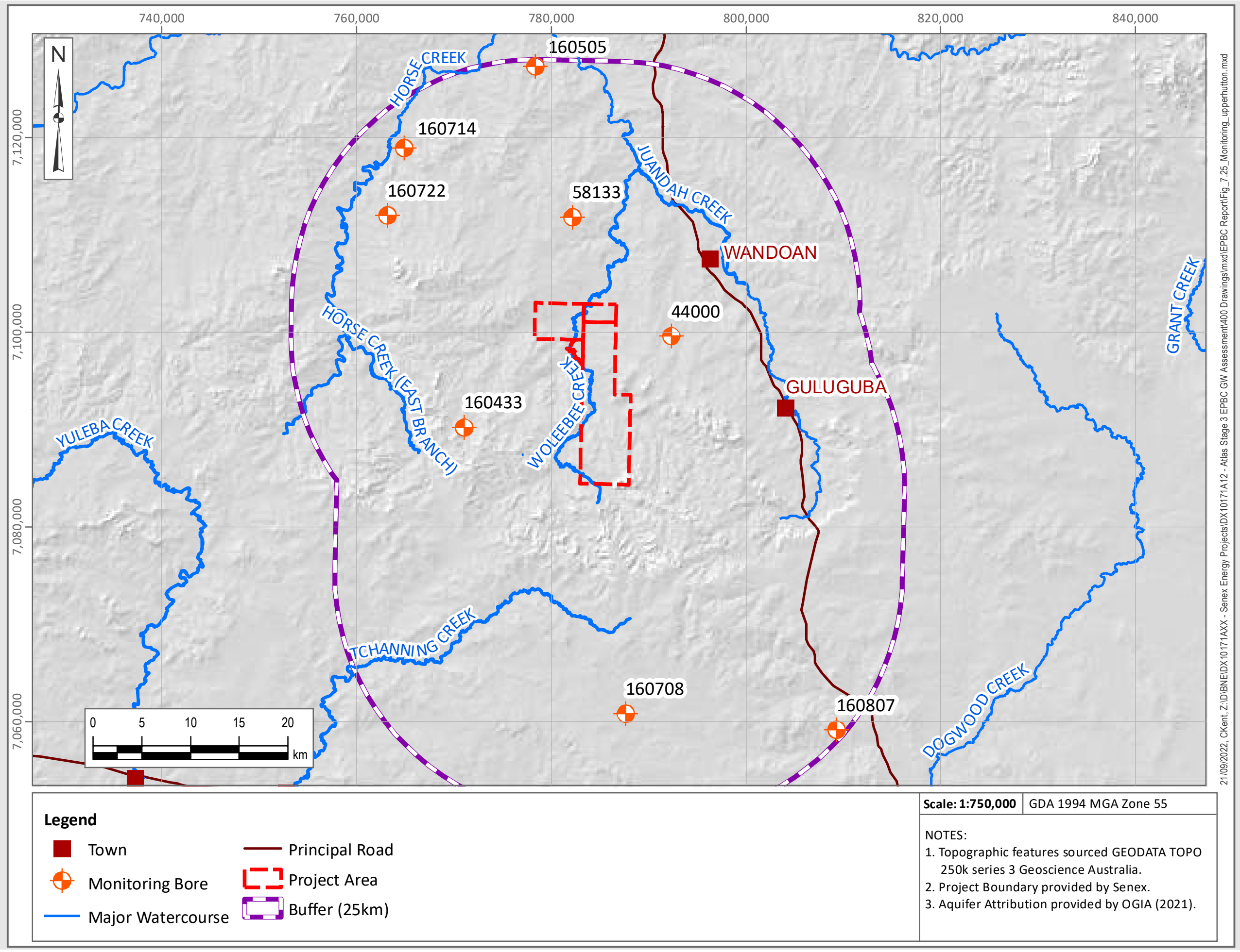


Figure 7.26 Location of Upper Hutton Sandstone Monitoring Bores

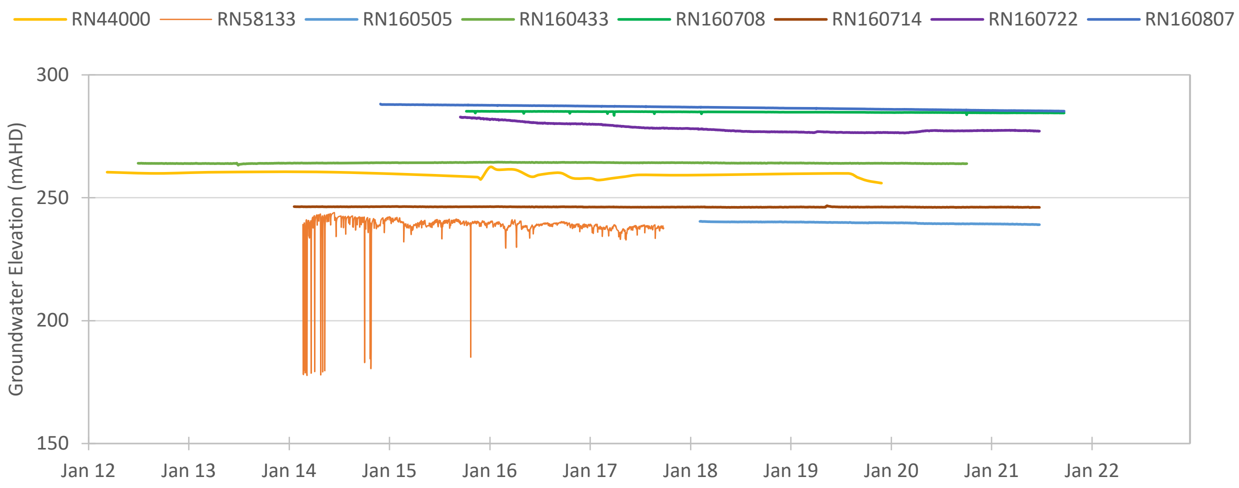


Figure 7.27 Groundwater Elevation Hydrograph – Upper Hutton Sandstone

Lower Hutton Sandstone Monitoring Bores

Three Lower Hutton Sandstone monitoring bores are located within the Project 25 km buffer zone (Figure 7.28). Groundwater hydrographs for these bores are presented in Figure 7.29.

Observations from available data include:

- Groundwater elevations range between ~277 and ~285 mAHD.
- Groundwater elevations are generally stable in RN 160813. RN 160348 experienced a decrease of ~1.5 m in 2016 where the water level remained stable for approximately two years, then increased to previous levels. This pattern repeated in 2019 to 2020. This may be due to issues with the pressure transducer at this bore. The bore exhibits an overall slightly declining trend of 1.2 m over ~7 years, RN 160677 exhibits a similar trend.
- Inferred groundwater flow within the Lower Hutton Sandstone is north towards Taroom (recognising limited data) which aligns with OGIA's potentiometric map for the Hutton Sandstone (OGIA 2021d).

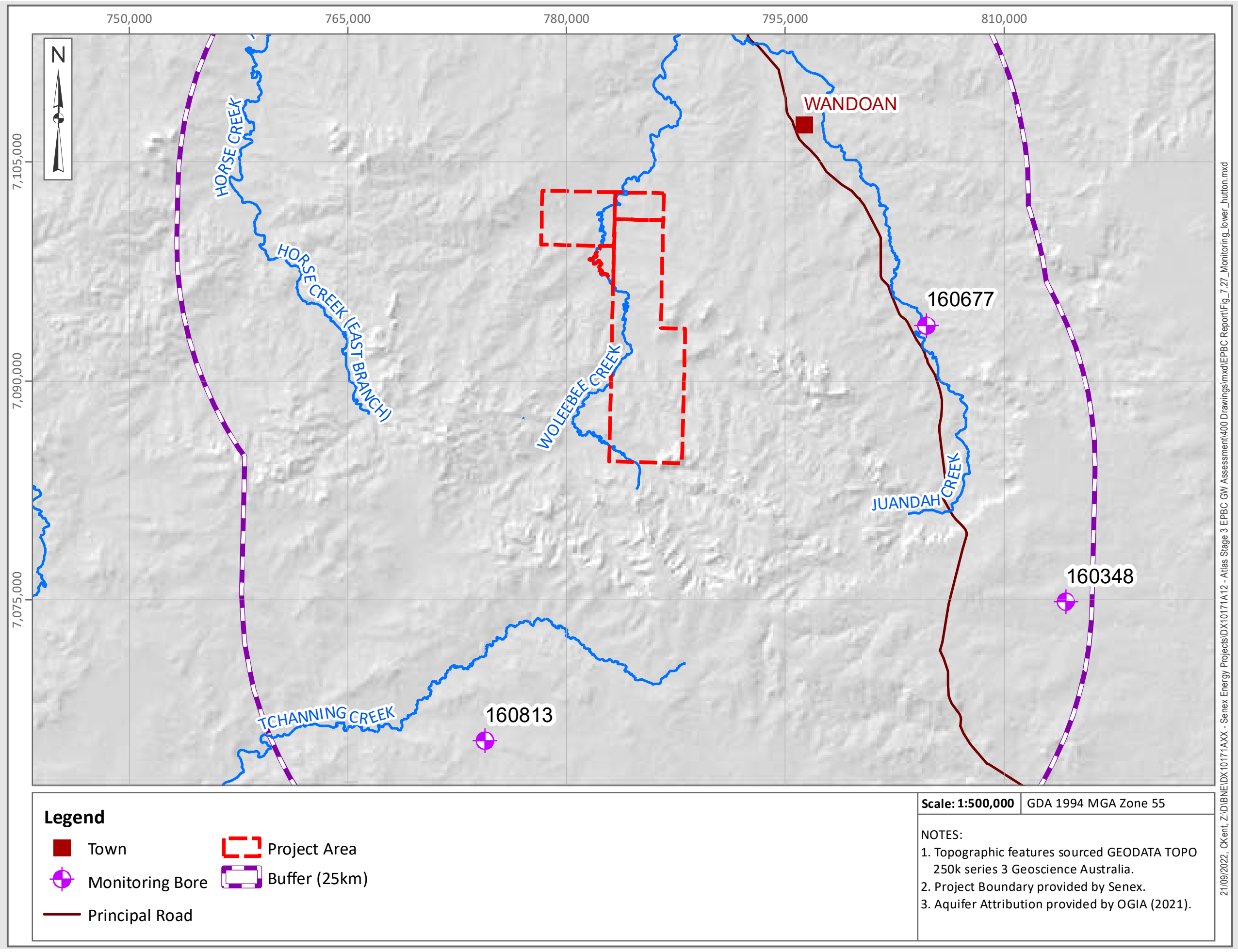


Figure 7.28 Location of Lower Hutton Sandstone Monitoring Bores

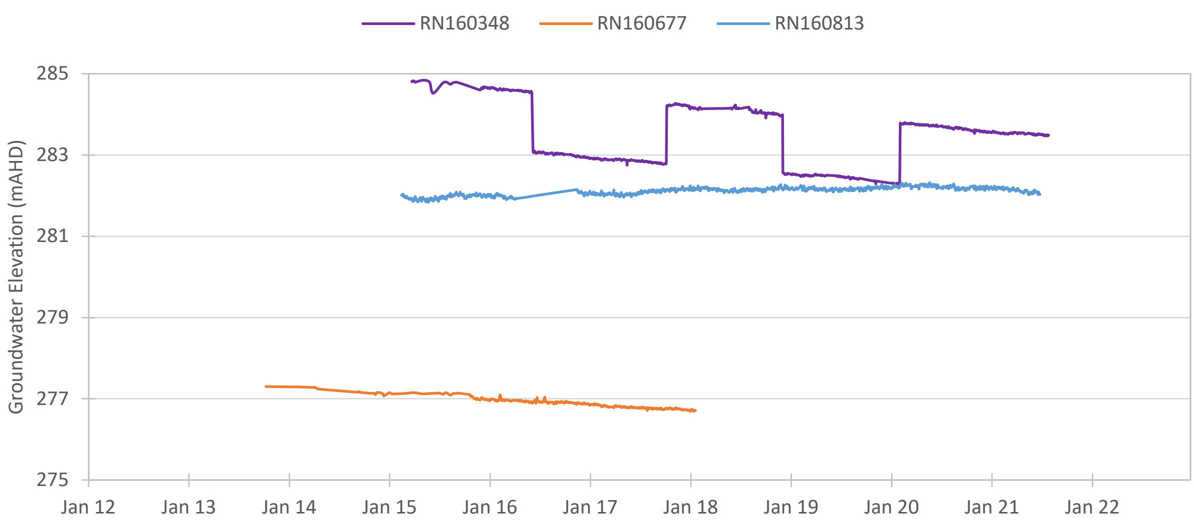


Figure 7.29 Groundwater Elevation Hydrograph – Lower Hutton Sandstone

Evergreen Formation Monitoring Bores

There is one bore (RN 160686) monitoring the Evergreen Formation located approximately 18 km east of the Project, as shown in Figure 7.30. Hydrographs for this monitoring bore is presented in Figure 7.31.

This bore is a multi-level monitoring point and includes monitoring of both the Evergreen Formation (Pipe B) and Precipice Sandstone (Pipe D).

The groundwater hydrograph for the Evergreen Formation bore, presented in Figure 7.31 indicates that the groundwater elevation is ~282 mAHD. The groundwater level in this bore has remained within a range of approximately 2 m.

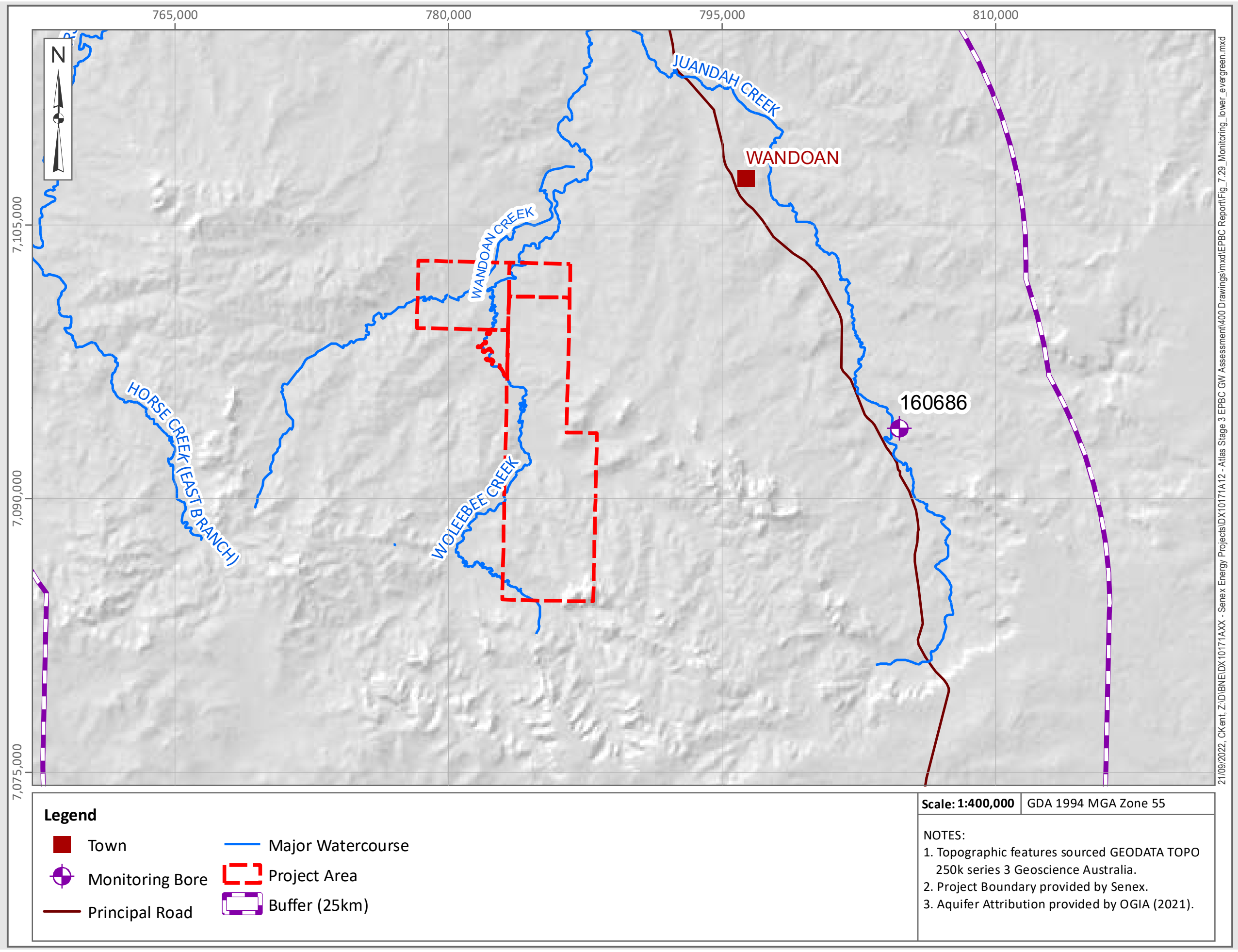


Figure 7.30 Location of Evergreen Monitoring

Figure 7.31 Groundwater Elevation Hydrograph – Evergreen Formation

Precipice Sandstone Monitoring Bores

There are four bores monitoring the Precipice Sandstone within the vicinity of the Project area, as shown in Figure 7.32. Hydrographs for the monitoring bores are presented in Figure 7.33.

The hydrographs indicate that the groundwater elevation in the Precipice Sandstone at RN 160441 has been rising since mid-2015 and is likely a function of an aquifer injection scheme occurring ~80 km to the west of the Project at Reedy Creek (OGIA 2021d).

RN 160863 is located ~20 km to the northwest of the Project and monitors the Precipice Sandstone at depth (top of Precipice Sandstone ~1,100 mbGL). The groundwater level in this bore has been rising which is likely due to the Reedy Creek and Spring Gully aquifer reinjection schemes, with trials having commenced in December 2012.

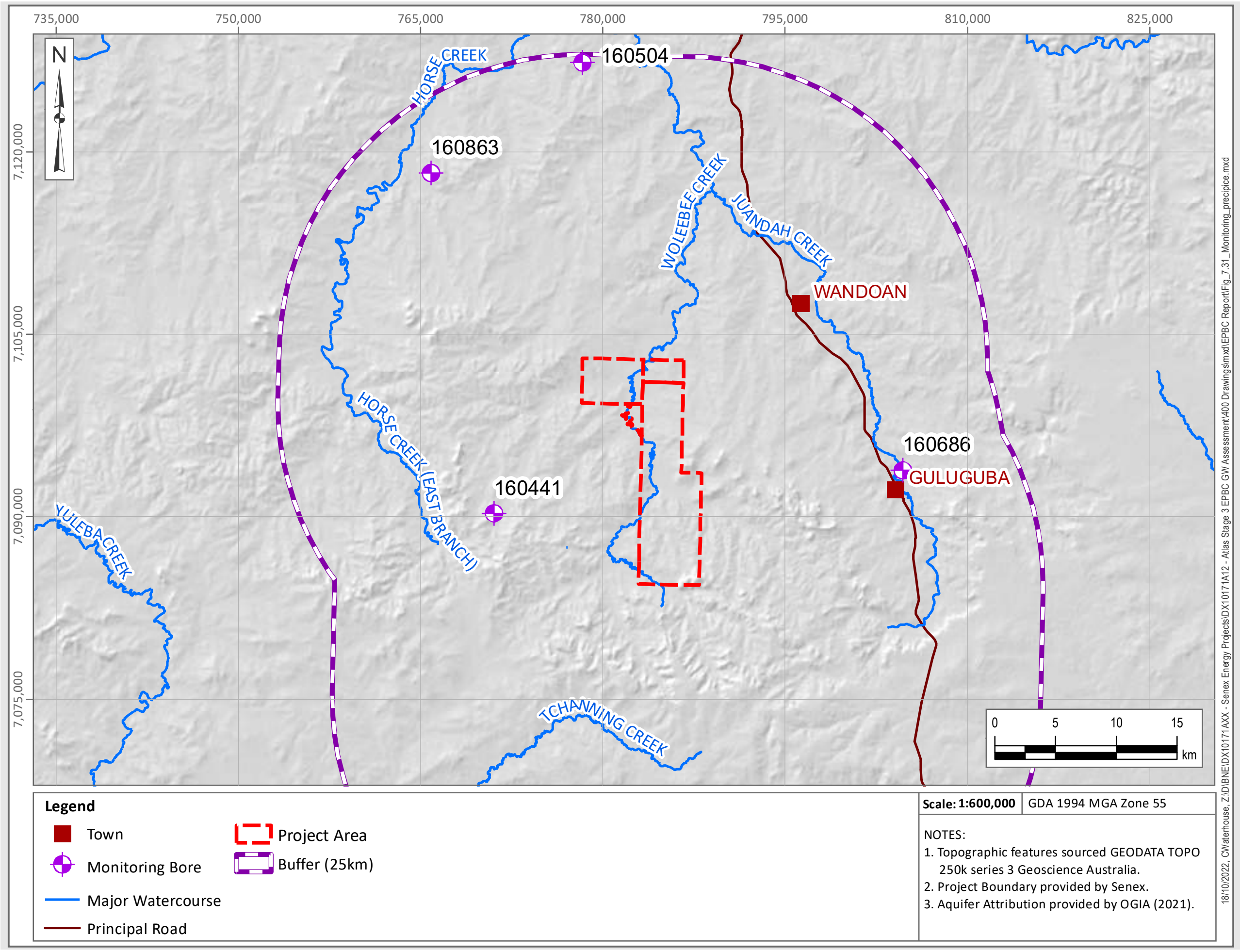


Figure 7.32 Location of Precipice Sandstone Monitoring

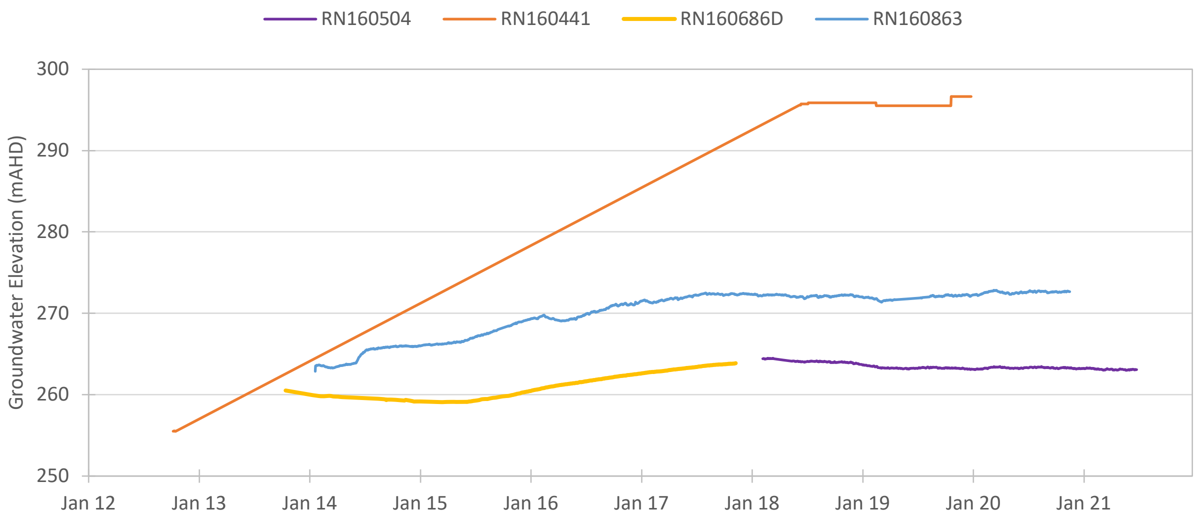


Figure 7.33 Groundwater Elevation Hydrograph –Precipice Sandstone

7.7 Groundwater Chemistry

Groundwater chemistry within the Surat Basin was considered using information provided in the Hydrogeological Conceptualisation Report which supports the UWIR (OGIA 2016a). Table 7.4 presents a summary of the regional groundwater chemistry associated with each hydrostratigraphic unit occurring within the Project area from OGIA (OGIA 2016a). Generally, the TDS, used as an indicator of salinity, presents as a broad range across the hydrostratigraphic units of the basin.

Table 7.4 Summary of Regional Groundwater Chemistry for Each Hydrostratigraphic Unit from OGIA (OGIA 2016a)

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

Additional hydrochemical data were sourced from the GWDB for bores within a 25 km buffer of the Project. Locations of bores with hydrochemical data and attributed aquifers using OGIA's aquifer attribution (OGIA 2022). There are 102 bores within this area which have corresponding hydrochemical data. GWDB records are often limited to major cation / anions analysis, with few samples analysed for metals.

Figure 7.34 presents a Piper plot and Durov diagram for each relevant hydrostratigraphic unit from the GWDB records. The following observations were made:

- All samples from the Surat Basin bedrock units (regardless of formation) reflect either sodium-chloride or sodium-bicarbonate water types.
- Groundwater samples from bores screened in the alluvium (associated with Woleebee and Juandah Creek) have different signatures to the Surat Basin bedrock units, with a stronger sodium-bicarbonate signature.

Fresher groundwater is observed in the samples from the alluvium, Gubberamunda Sandstone, and Hutton Sandstone. EC was higher in samples measured from the WCM and Springbok Sandstone.

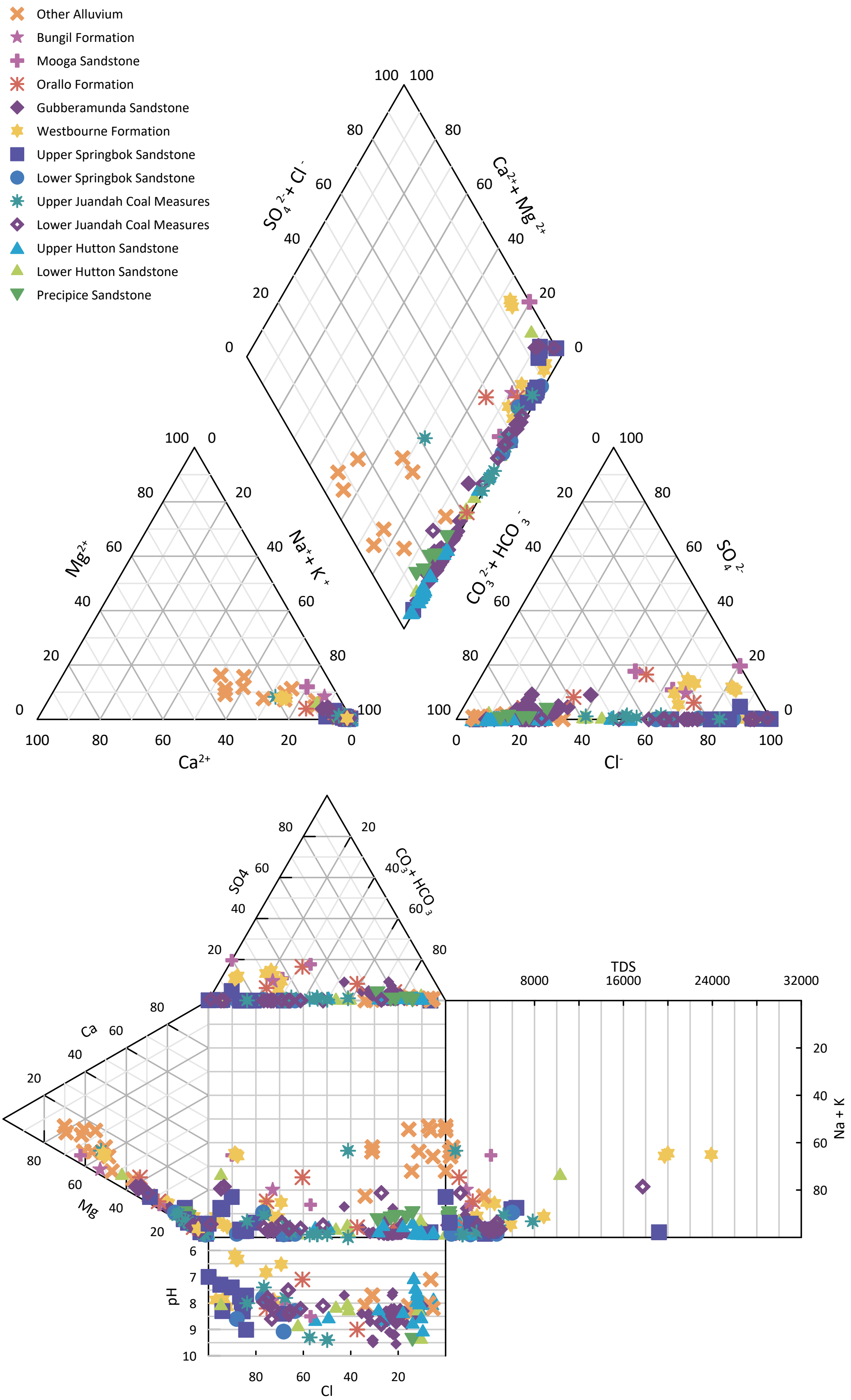


Figure 7.34 Piper and Durov Diagram of GWDB Hydrochemical Records from Bores within a 25 km Buffer of the Project

7.7.1 Site Specific Water Quality

Site specific hydrogeochemical data were collated from the baseline assessment, neighbouring landholder's monitoring bores, and the site investigation report (Appendix I).

Piper and Durov diagrams for the corresponding hydrostratigraphic units are presented in Figure 7.35. The samples from the deeper hard rock units reflect sodium-chloride or sodium-bicarbonate water types. This is similar to that of the regional data from the GWDB. The alluvium samples from the site-specific data have a strong sodium -chloride signature which is different when compared to the GWDB data that indicated a sodium-bicarbonate signature.

The alluvium samples from Atlas-15M-S do not group with other alluvium samples and may not be representative of typical alluvium groundwater quality at the Project. Higher salinity and chloride concentrations (than would be expected) for alluvium were encountered in samples collected from this bore. Geologically isolated pockets of alluvium at this location may contribute to anomalous water quality concentrations observed in this bore. Limited groundwater movement in an isolated pocket leading to long residence time.

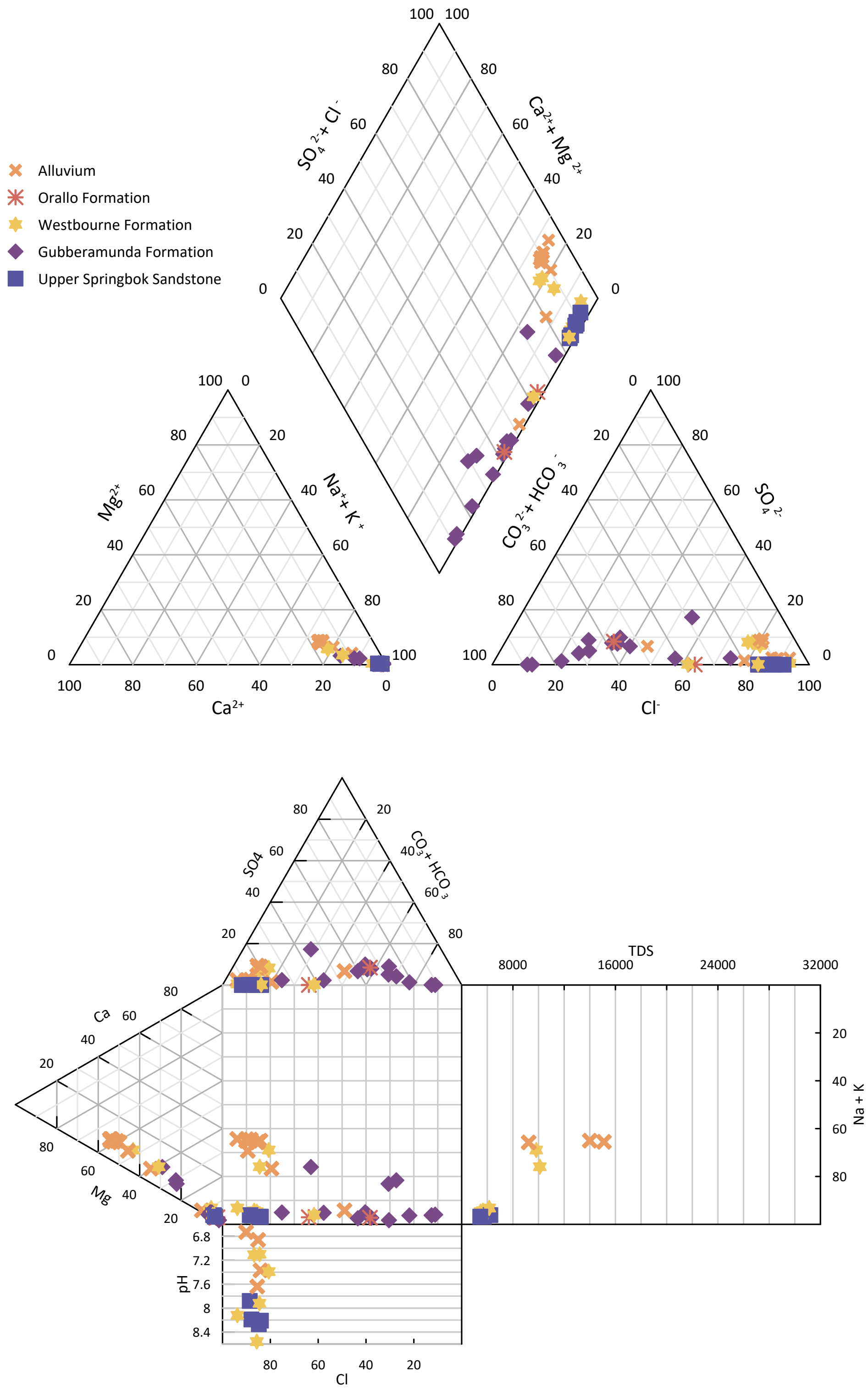


Figure 7.35 Piper and Durov Diagrams of Site-Specific Groundwater Quality from Bores within the Project Boundary

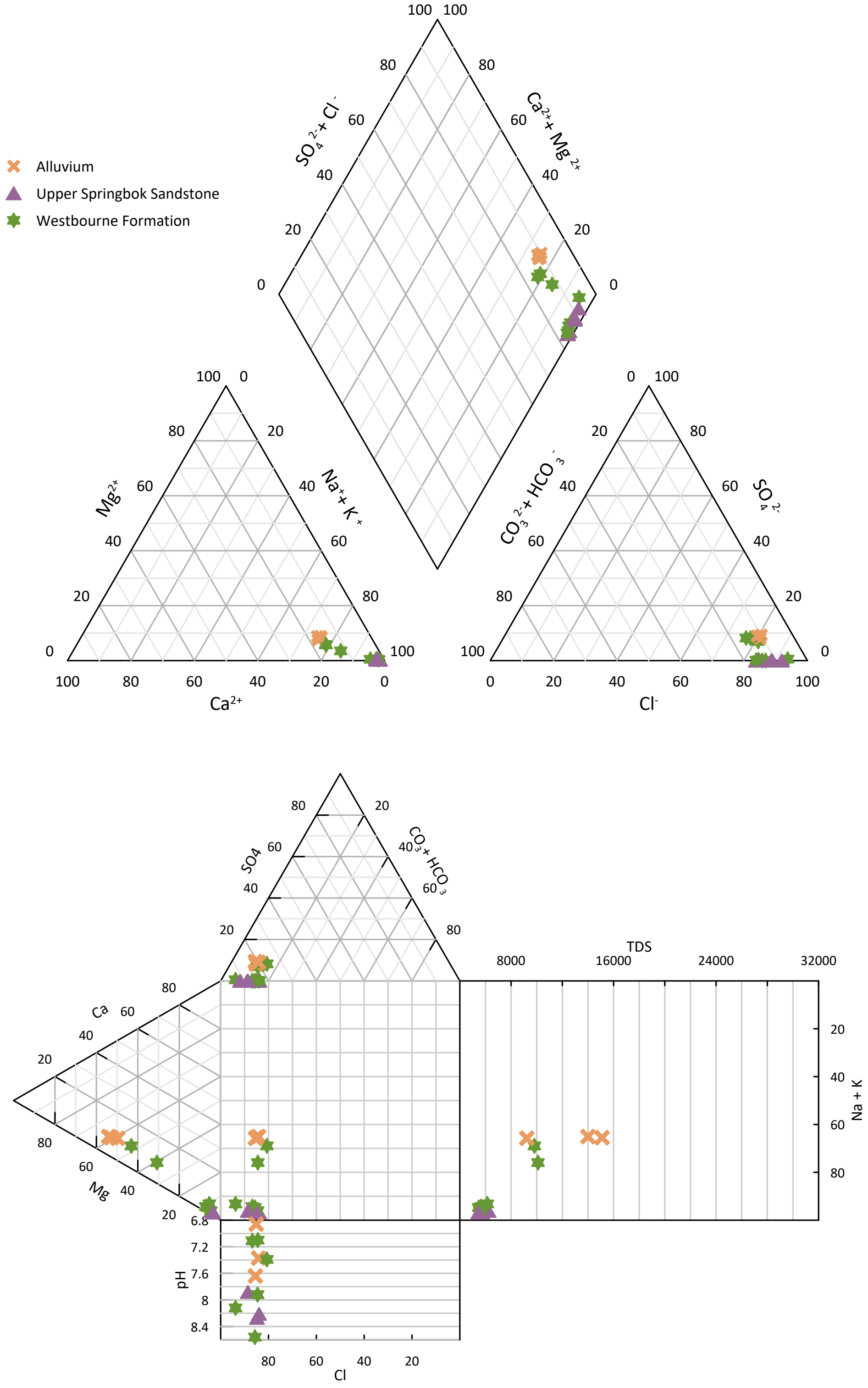


Figure 7.36 **Piper and Durov Diagrams of Site-Specific Groundwater Quality for Monitoring Bores drilled at Senex**

7.7.2 Isotopes

Five water samples, consisting of groundwater and surface water, were collected in February 2023 by a KCB hydrogeologist.

The stable isotopes of water (^2H and ^{18}O) are regularly used to assist in distinguishing water sources, where evaporation may have occurred on the water source. Isotopes naturally fractionate due to evaporation and result in different signatures that can be used to identify different water bodies.

Craig (1961) identified that when the stable isotopes (δ^2H/deuterium and $\delta^{18}O$) of water have not undergone evaporation (rainwater), a linear relationship between the relative deuterium and oxygen enrichment can be obtained and approximated by:

$$\delta^2 H = 8\ \delta^{18}O + 10$$

The equation approximating this relationship is referred to as the Global Meteoric Water Line (GMWL) and was developed based on isotope analysis data from precipitation from across the globe. A Local Meteoric Water Line (LMWL) is usually developed from precipitation data collected from either a single location or a set of locations within a localised area of interest.

The analysis results are presented in Table 7.5 and plotted alongside the GMWL and the LMWL in Figure 7.37.

There were no isotope data for local rainfall for the Project area therefore the LMWL developed by Hollins et al. (2018) for Brisbane (B MWL) and Charleville (C MWL) was used in combination with the GMWL for isotope analysis.

Table 7.5 Isotope Analytical Results

Sample ID	Type	$\delta\ ^2H$ (‰)	$\delta\ ^{18}O$ (‰)
ATLAS-13M-D	Groundwater	-35.5	-5.76
ATLAS-14M-D	Groundwater	-37.6	-6.05
ATLAS-15M-D	Groundwater	-31.1	-4.69
ATLAS-15M-S	Groundwater	-29.4	-4.43
Woleebee-Ck-N	Surface water	28.1	5.99

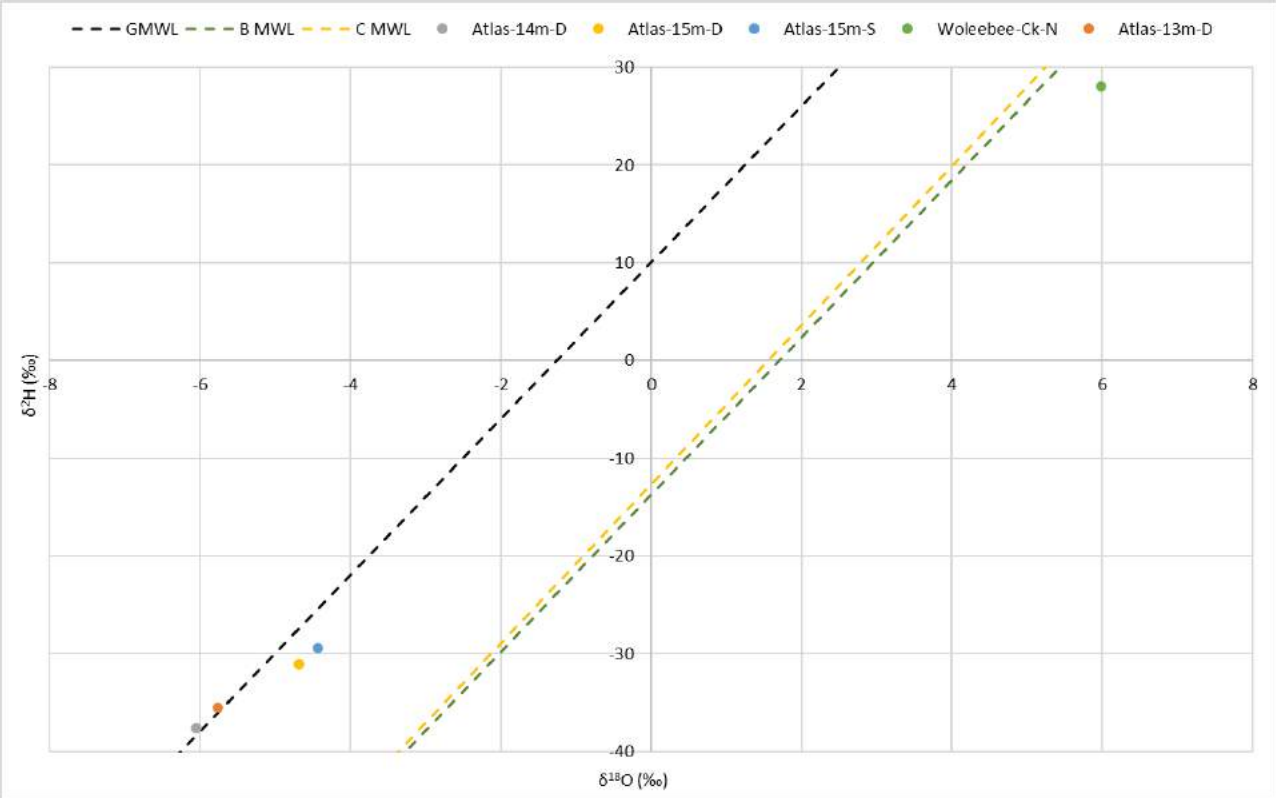


Figure 7.37 Stable Water Isotopes Results

The water isotope results indicate:

- The stable water isotope samples collected from surface water (Woleebee-Ck-N) show a "more evaporated" signature indicated by a more positive deuterium and oxygen isotope values and therefore plots towards the top right corner on the right side of all three MWL used.
- The four groundwater (three bedrock and one alluvium groundwater) samples all plot on, or close to, the GMWL. The groundwater does not show an evaporated signature as it plots to the bottom left of the graph and also to the left of the B MWL and C MWL.

These findings strongly support the interpretation that the surface water does not connect to the bedrock groundwater in the area.

7.8 Surat Basin Units Aquifer Inter-Connectivity

The Surat Basin comprises layers of aquifers and aquitards of varying hydraulic properties. The formations predominantly comprise fluvial sedimentary deposits that have formed stratifications of sand, silt and clay within and across hydrostratigraphic formations (OGIA 2016c). Groundwater flow within the Surat Basin hydrostratigraphic units is predominantly horizontal, as vertical flow is restricted by the spatial extent and continuity of aquitards, by lower permeability horizons within the aquifers (OGIA 2016c) and horizontal hydraulic conductivity being generally higher than vertical hydraulic conductivity.

Across the Project extent, there is potential for interaction between the WCM and aquifers above and below, specifically the overlying Springbok Sandstone and underlying Hutton Sandstone (separated from the WCM by the Durabilla Formation). The Durabilla Formation is mapped across the entire Project area, with a mean thickness of 87 m (Figure 7.38), recognised on resistivity and spontaneous potential logs, which provides a significant vertical barrier between the WCM and underlying Hutton Sandstone. An upper WCM aquitard has been mapped by OGIA (the Walloon Coal Measures non-productive zone, OGIA 2021f) as being up to ~25 m thick across the Project area, with ~40 m of thickness in the central west of PL 209, separating the WCM coal seams from the overlying Springbok Sandstone.

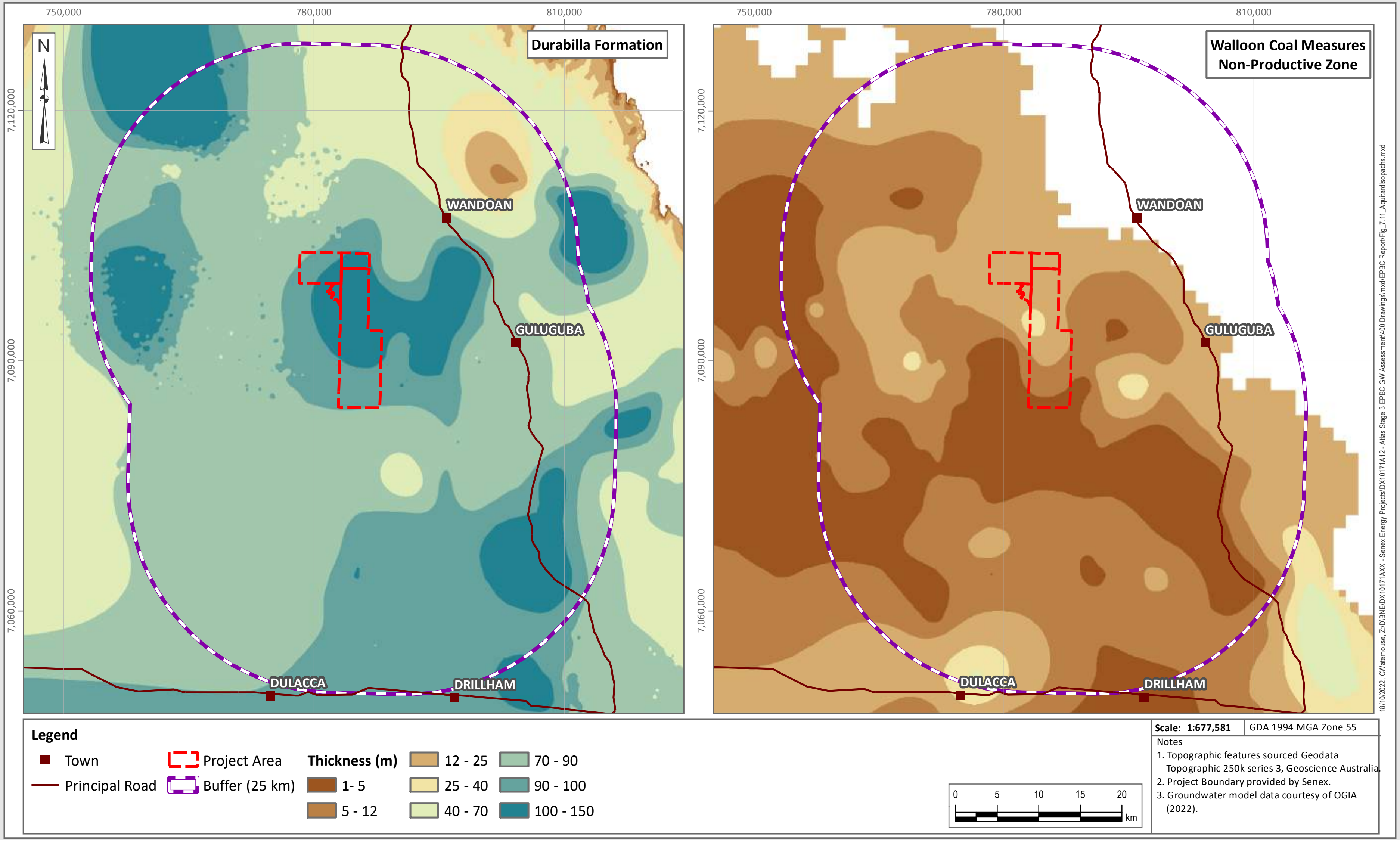


Figure 7.38 Aquitard Isopachs (after (OGIA 2021f))

7.9 Alluvium and Surat Basin Unit Connectivity

The Project is situated in an area where the Springbok Sandstone, Westbourne Formation, and Gubberamunda Sandstone outcrop. Quaternary-age alluvium is mapped within the Project area and is associated with Woleebee and Wandoan Creeks. The alluvial flood plains are sizeable and extend from Woleebee Creek to Wandoan Creek in ATP 2059 (Figure 7.7). Although mapped as continuous on the geological mapping, site specific data from the 2018 creek validation survey identified bedrock outcrops within the mapped alluvium, which influences continuity, flow and storage of the alluvium. In the northeast of ATP 2059, and within PL 445, the alluvium directly overlies the Upper Springbok Sandstone. Potential terrestrial GDEs have been identified along Woleebee Creek on the alluvium which directly overlies the Upper Springbok Sandstone which is predicted to experience minor drawdown greater than the 0.2 m trigger due to the presence of the Project. The hydraulic connection between the Springbok Sandstone, and other Surat Basin units, with the overlying alluvium must be understood to assess the potential for propagation of drawdown from these units into the alluvium.

The following section assesses the potential hydraulic connection between the Surat Basin units and the alluvium, incorporating additional information collected during field investigations undertaken by Senex and monitoring data from neighbouring monitoring bores.

Evidence from drilling and sampling during the site investigations demonstrates a high level of confidence that hydraulic connection between shallow alluvium and underlying Surat Basin units is unlikely in the Project area. Hydraulic data definitively support a disconnection at all paired monitoring bore sites. Supporting water quality data also support a disconnect. It should be noted that no amount of investigation and monitoring can completely rule out the possibility of discrete zones of connectivity at the Project scale, however, any potential residual risk will be addressed by the implementation of an industry accepted monitoring and mitigation plan duration Project operation.

Key observations which support hydraulic disconnection between surficial alluvium and underlying bedrock units are discussed in the next section.

The alluvium groundwater quality from Senex bore ATLAS-15M-S is not comparable with the groundwater quality from other regional alluvium groundwater bores (Section 7.7.1). This bore also exhibits higher salinity and chloride concentrations (than would be expected compared to regional alluvium water quality from the Juandah Creek alluvium) and higher than the underlying Westbourne Formation and other Surat Basin units. An alluvium bore with similar groundwater chemistry has been identified to the north of the Project area on a neighbouring site along Woleebee Creek. It is considered that hydrogeologically isolated pockets of high clay content alluvium must be present along Woleebee Creek which would limit groundwater movement and cause increased groundwater salinity (i.e., reduced throughflow, negligible rainfall recharge, and longer residence times resulting in elevated TDS). The geochemistry of the water in these isolated pockets is also distinct to the underlying Surat Basin units, with the alluvium having a higher salinity.

7.9.1 Stratigraphy and Groundwater Level Observations

Groundwater Levels

Vertical separation between surface water and groundwater level in the Surat Basin units relevant to the Project was evident during the site investigation. This evidence identified limited connectivity between the alluvium and the Surat Basin units in the Project area.

During dry air-rotary percussion drilling of the Upper Springbok Sandstone monitoring bore (ATLAS-14M-D), the Springbok Sandstone was encountered from 10 mbGL and the formation remained dry until the main water strike at 38.5 mbGL. There was 28.5 m of dry rock between the base of alluvium and the water strike within the Upper Springbok Sandstone. Following bore installation, the groundwater level within the monitoring bore rose and eventually equilibrated overnight to 14.0 mbGL (~ 4 m below the base of the alluvium), indicating that the Springbok Sandstone at this location is a confined system and has no hydraulic connection with the overlying alluvium.

Groundwater level in the Springbok Sandstone was 3 m below the base of alluvium, during the wet season, at Atlas-14M-D. The groundwater level in the Springbok Sandstone was 2 m below the base of alluvium next to the creek at monitoring bore Atlas-19M-D during the dry season. The water level in Atlas-19M-D is yet to be measured during the wet season.

Groundwater level in the Westbourne Formation reflects water pressure, as opposed to 'free' water level (due to water levels being much higher than water strikes). The unit is also a tight aquitard, so any shallow alluvial groundwater above that unit would behave independently and would be unaffected by Project-related drawdown due to low hydraulic conductivity (aquitard) in the Westbourne Formation.

Unsaturated Alluvium Monitoring Bores

During drilling of the four Senex alluvium monitoring bores, the observed thickness of alluvium encountered adjacent to Woleebee Creek varied from 7 m to 10 m above the Springbok Sandstone sub-crop, and up to 13 m thick above the Westbourne Formation sub-crop to the south. At the time of drilling and data collection for Atlas-13M, 14M, and 15M, it was the wet season and water was still present in Woleebee Creek. However, groundwater was not encountered in two of the bores installed: ATLAS-14M-S (above the Upper Springbok Sandstone) and ATLAS-13M-S (above the Westbourne Formation), approximately 250 m from Woleebee Creek). These two bores have remained dry across the wet and dry season since installation.

Atlas-19M bores were drilled during the dry season when Woleebee Creek was dry. Atlas-19M-S (alluvium bore) was also dry after drilling. Groundwater level is this bore is yet to be observed during the wet season due to the timing of the drilling. A total of three alluvium monitoring bores have been drilled and have been consistently dry since installation.

The only alluvium monitoring bore to encounter groundwater was ATLAS-15M-S, installed above the Westbourne Formation, approximately 50 m from Woleebee Creek channel with standing water level measured at 4.2 mbGL. Drilling fluids were not used during drilling of this bore; therefore, the encountered water can only be natural groundwater.

In addition, neighbouring private monitoring bores to the north screened in the alluvium were also found to be dry. Long-term monitoring data for these three bores were obtained and assessed (see Section 7.6.2 – Alluvium). Data indicated that one of these monitoring bores is dry while the other two bores (RN 180147 and RN180145) indicated a saturated thickness of ~2 m for the alluvium at their respective locations. The distance from the bores to Woleebee Creek is approximately 500 m.

7.9.2 Groundwater Quality Observations

Site specific groundwater sampling was undertaken and has been reviewed against regional water qualities to determine if there is a difference between the Surat Basin units, in particular the Springbok Sandstone, and the alluvium. A Piper diagram representing these groundwater qualities is provided in Figure 7.39. Figure 7.39 indicates:

- The groundwater qualities observed from the Springbok Sandstone are distinct from the groundwater quality of the alluvium with the Springbok Sandstone groundwater showing a proportionally higher chloride concentration in comparison with the regional alluvium groundwater which show a proportionally higher carbonate-bicarbonate concentration. This difference in proportional anion concentrations indicates a lack of connection between the units (i.e., the underlying Springbok Sandstone does not discharge into the alluvium). The Springbok Sandstone groundwater sample (ATLAS-14M-D) is grouped with other samples for that unit, illustrating the sample is representative of the Upper Springbok Sandstone. The underlying Springbok Sandstone is generally brackish to saline.
- The water quality of the regional alluvium is very similar to the quality of surface water sampled from Wandoan, Woleebee, and Juandah Creeks. The comparable water qualities of the surface water and alluvium provides further evidence that the alluvium is recharged/replenished by, and in connection with, the surface water systems during flow events following prolonged rainfall events.
- The alluvium sample from ATLAS-15M-S does not group with other alluvium samples and is not representative of typical alluvium groundwater quality at the Project site. Higher salinity and chloride concentrations (than would be expected) for alluvium were encountered in samples collected from this bore. Hydrogeologically isolated pockets of alluvium at this location may contribute to anomalous water quality concentrations observed in this bore; limited groundwater movement in a clay dominated isolated pocket would increase groundwater salinity.

Figure 7.39 shows that there is a marked difference in water quality between alluvium and the Upper Springbok Sandstone which indicates the samples are from different groundwater systems. These data indicates that there is no hydraulic connection between the Springbok Sandstone and overlying alluvium.

Marked differences in groundwater quality between alluvium and the Upper Springbok Sandstone indicates the groundwater samples are from different hydrostratigraphic units.

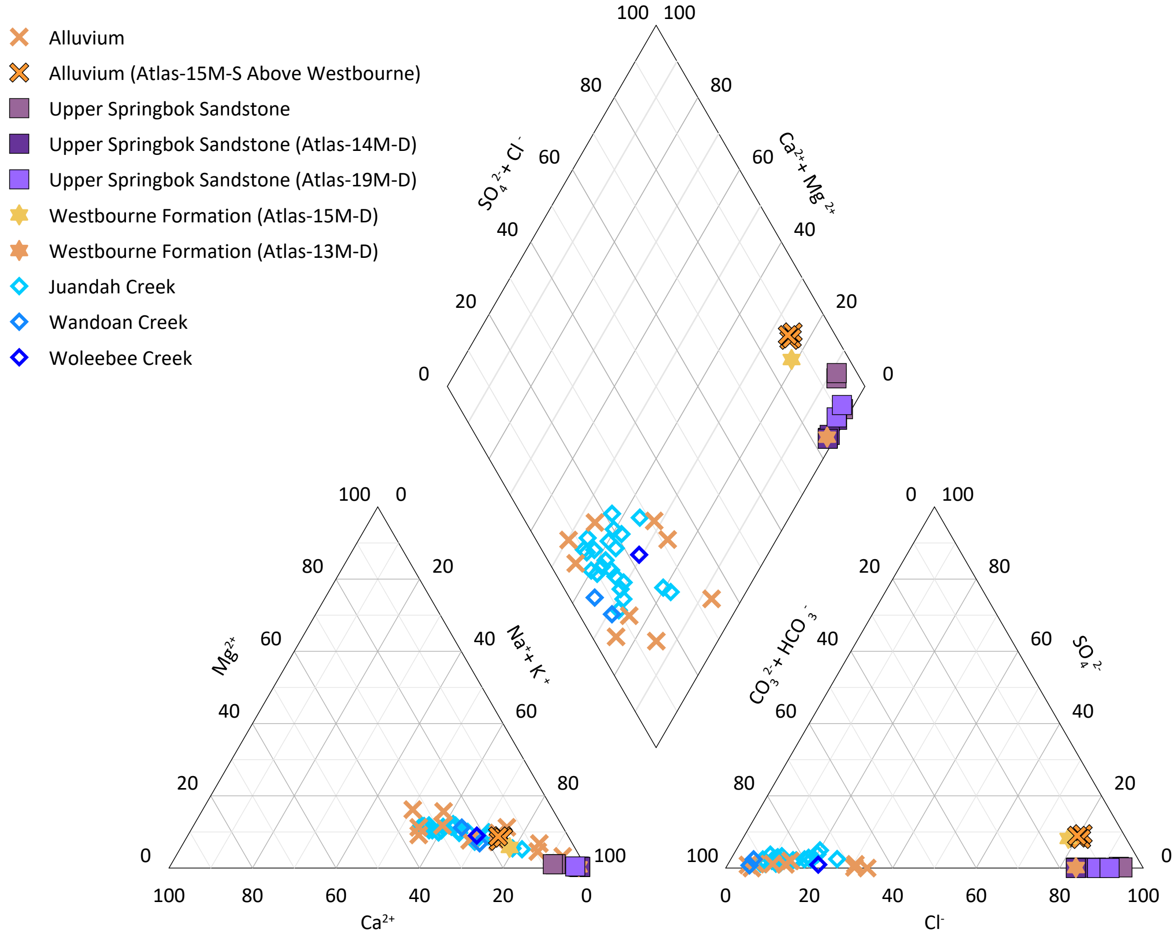


Figure 7.39 Water Quality Data for Alluvium and Springbok Sandstone (groundwater); and Surface water at Atlas Stage 3

7.10 Groundwater-Surface Water Interaction

Groundwater-surface water interaction within the Project area may occur from two key processes, where surface water systems are either gaining or losing, or both along the drainage systems:

- Discharge of groundwater to watercourses as baseflow; and
- Recharge to aquifers as leakage from watercourses.

Recharge to groundwater systems from watercourses may occur across the Project area, however as discussed in Section 7.5, there must be sufficient saturation and hydraulic head to allow water to infiltrate into aquifers.

A discussion on baseflow fed reaches of watercourses, or watercourse springs, and the groundwater-surface water interaction is provided in Section 7.11.1.

7.11 Springs and Groundwater Dependent Ecosystems

GDEs are defined as 'Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services' (Richardson et al. 2011).

There are three categories of GDEs:

- **Aquatic GDEs**, which are ecological communities dependent on the surface expression of groundwater, including springs other than EPBC-listed springs, river baseflow systems (watercourse springs), riparian ecosystems and wetlands.
- **Terrestrial GDEs,** which are surface ecosystems dependent on the subsurface presence of water (i.e., terrestrial vegetation accessing the water table below ground), including ecosystems that are intermittently and permanently dependent on groundwater; and
- **Subterranean GDEs**, which are subterranean ecosystems dependent on the permanent presence of subsurface water. For the purposes of this document, this includes vertebrates and invertebrates only (i.e., excludes unicellular and simple multicellular organisms).

Potential surface expression GDEs and subsurface GDEs are mapped by DES (State of Queensland 2018a) as potentially being present in the vicinity of the Project (Figure 7.42). These generally correspond with the location of the mapped alluvium associated with Woleebee Creek within the Project area and Wandoan Creek, Horse Creek and Juandah Creek further afield.

There are no mapped or registered spring vents or complexes within the vicinity of the Project.

7.11.1 Potential Aquatic GDEs

Baseflow-fed reaches of watercourses, or watercourse springs, are sections of a watercourse where groundwater from an aquifer enters the stream through the streambed (OGIA 2021f). A report published by OGIA in 2017 re-maps potential gaining streams (or baseflow-fed reaches, watercourse springs) within the Surat CMA (OGIA 2017). This report identified sections of Woleebee Creek as a potentially gaining stream. OGIA have re-mapped watercourse springs within the Surat CMA for the 2021 UWIR report (OGIA 2021f), these are shown on Figure 7.40 with the details of the springs summarised in Table 7.6.

OGIA has identified three potential watercourse springs present within the Project area associated with Woleebee Creek. These watercourse springs are identified as being associated with the alluvium, Gubberamunda Sandstone, and the Orallo Formation. These are noted as springs of interest but not currently affected or listed as a mitigation site (OGIA 2021f).

Table 7.6 UWIR Watercourse Spring Details

Site Number	Name	Source Aquifer
W279	Woleebee Creek	Alluvium
W280	Woleebee Creek	Alluvium/Gubberamunda
W281	Woleebee Creek	Alluvium/Orallo Formation

Reaches of Woleebee Creek within PL 1037 were assessed during the field verification program in 2018 (KCB 2018b, Appendix IX). The following observations were made regarding Woleebee Creek as a gaining stream:

- The assessment was conducted during the dry season and no flow was observed within the areas surveyed.
- Pools of water were encountered in the lower reaches of Woleebee Creek (within the PL), which were rainfall derived surface water based on the turbid appearance and the field measured EC of 547 µS/cm.
- Based on the difference between the field water quality measured at Woleebee Creek pools, field observations and groundwater elevation monitoring data from the alluvium and Gubberamunda Sandstone, it is considered that Woleebee Creek is not a baseflow-fed reach. (i.e. it is a losing stream).

The verification program considered it unlikely that Woleebee Creek is a baseflow-fed reach. This aligns with observations made during the 2022 ecology surveys and the assessment undertaken by CDM Smith for QGC relating to tenements to the north, which concluded the ephemeral creeks feeding Juandah Creek (which includes Woleebee Creek) are not 'gaining' from alluvial groundwater (CDM Smith 2022).

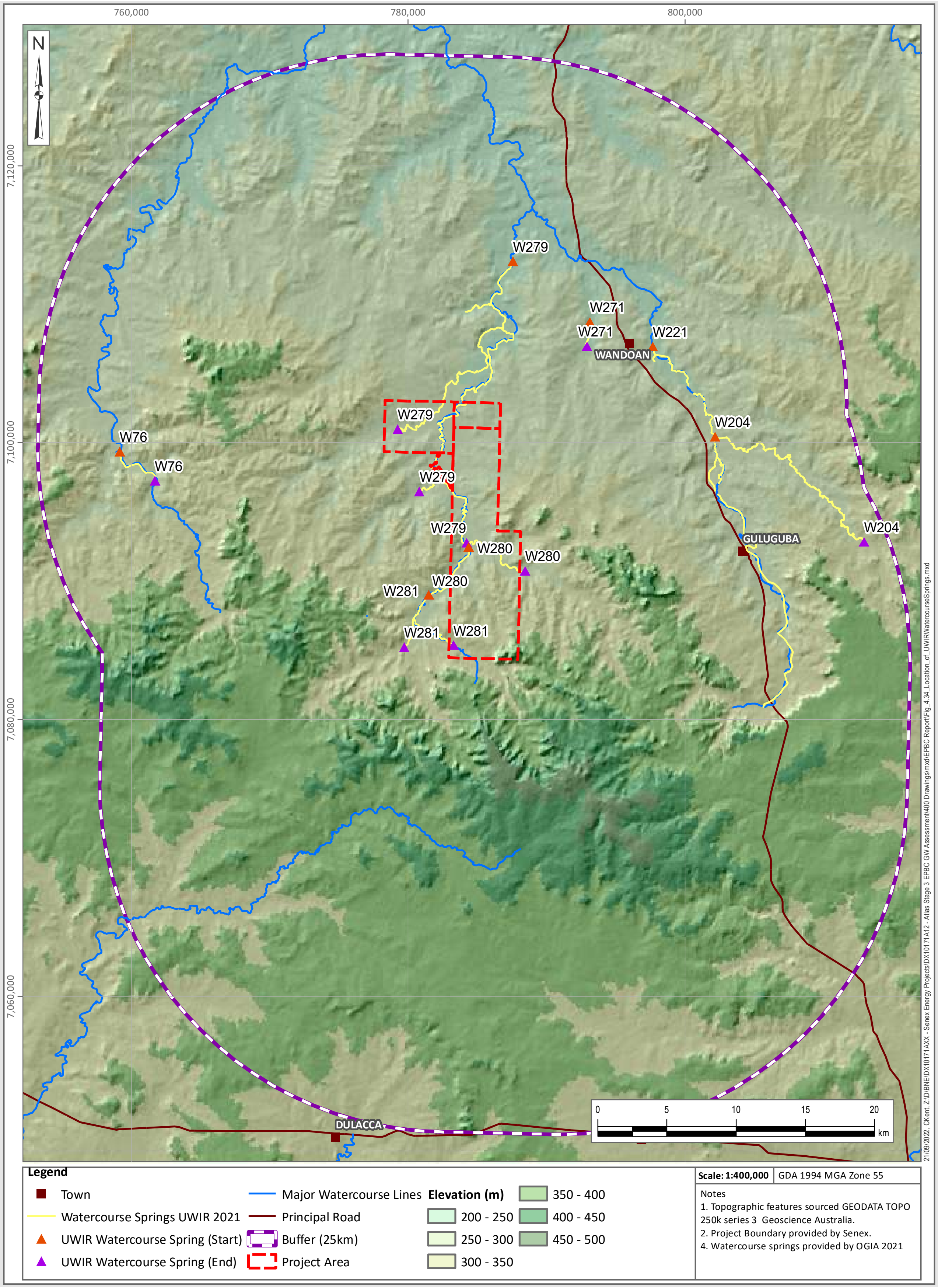


Figure 7.40 Location of Potential Watercourse Springs (OGIA 2021f)

A water quality review of the following data has been undertaken which is supported by a piper diagram presented in Figure 7.41 and comprises:

- Surface water samples collected locally in Wandoan Creek and from Juandah Creek to the northeast (at the Juandah Creek RDMW gauge);
- A surface water sample from Woleebee Creek north of PL 445;
- Groundwater samples collected locally in PL 209, PL 445, PL 1037, and ATP 2059 (note only two alluvium water quality samples are available locally and these bores are also screened across the Westbourne Formation); and
- Alluvium water quality samples collected within the 25 km buffer of the Project area.

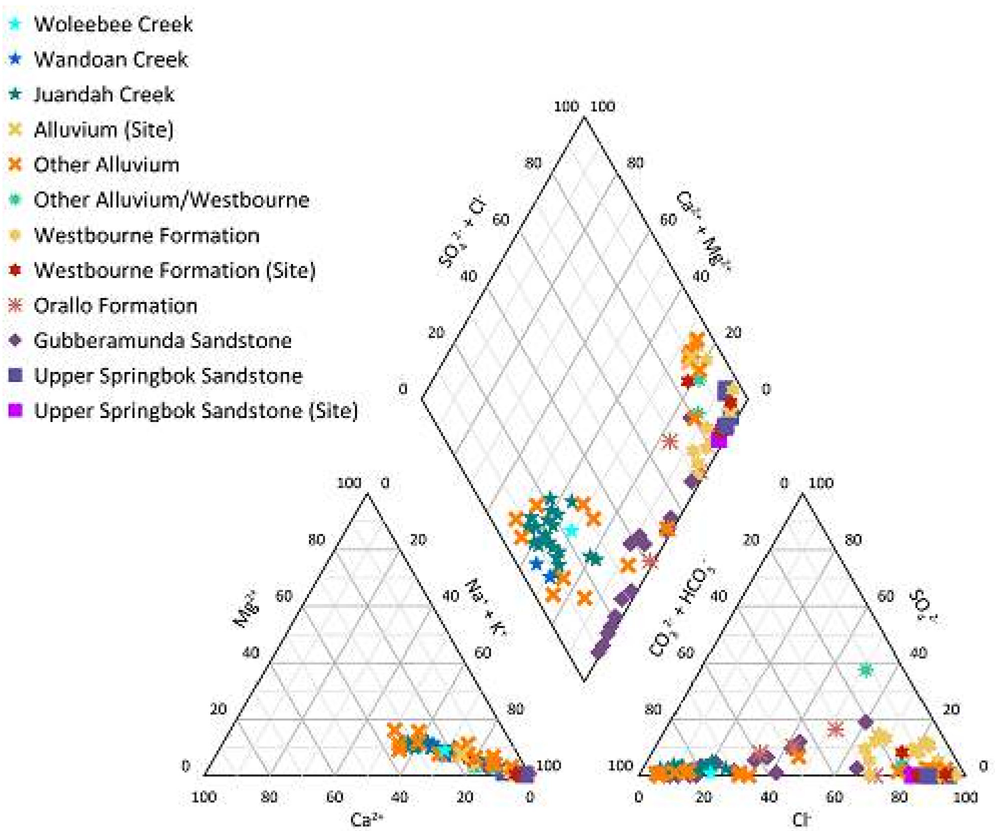


Figure 7.41 Piper Diagram showing Surface Water and Groundwater Samples from Alluvium Bores

Figure 7.41 shows the difference between the water quality of the alluvium and the underlying GAB units. The water quality of the alluvium (in orange) is very similar to the surface water qualities of Wandoan, Woleebee and Juandah Creeks. The water qualities of the Westbourne Formation and Springbok Sandstone are distinct from the water quality of the alluvium, indicating a lack of connection between the units (i.e. the underlying Westbourne Formation and Springbok Sandstone do not discharge into the alluvium). The underlying GAB units generally have a higher salinity than the alluvium (discussed further in Section 7.7 above).

The comparable water qualities of the surface water and regional alluvium indicates that the regional alluvium is recharged/replenished by the surface water systems during flow events following prolonged rainfall event/s.

The alluvium sample from Senex bore ATLAS-15M-S does not group with other regional alluvium samples. This bore also exhibits higher salinity and chloride concentrations (than would be expected) for alluvium and the underlying Westbourne Formation (which is not predicted to incur drawdown of >0.2 m). An alluvium bore with similar groundwater chemistry (RN 180147) has been identified to the north of the Project area on a neighbouring site along Woleebee Creek. It is considered that hydrogeologically isolated pockets of low permeability, high clay content, alluvium must be present along Woleebee Creek which would limit groundwater movement and cause increased groundwater salinity. The chemistry of the groundwater in these isolated pockets of alluvium is distinct to the underlying Surat Basin units, with the alluvium having a higher salinity.

7.11.2 Potential Terrestrial GDEs

The DES dataset identifies potential terrestrial GDEs within the Project area (State of Queensland 2018d). These GDEs are present in the vicinity of Wandoan and Woleebee Creeks. An assessment of those GDEs was performed by ERM (Appendix III, ERM 2022a). A summary of the findings is provided in this section.

The assessment was conducted in two stages. Firstly, a desktop analysis was performed to identify potential terrestrial GDEs based on available GDE mapping. A field survey was then performed to verify these potential terrestrial GDEs identified during the desktop assessment and collect data to assess their condition and identify other potential ecological values.

Within the Atlas Stage 3 Project Area, the majority of the terrestrial and aquatic GDEs are associated with watercourses and adjacent alluvial plains. This includes the named creeks; Woleebee Creek, Wandoan Creek, Conloi Creek and Hellhole Creek, as well as several unnamed creeks and hydrological features.

Using terminology developed as part of the DES GDE mapping, the following potential terrestrial and aquatic GDE types have been identified as occurring within the Project area:

1. Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow; and
2. Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow.

These potential GDE types correspond with regional ecosystem (RE) types that occur on alluvial landscapes, associated with watercourses and the adjacent floodplain areas. Based on the DES GDE mapping rule sets, these vegetation communities rely on alluvial aquifers that form from sediments such as gravel, sand, silt and/or clay deposited by fluvial processes in river channels or on floodplains. These deposits store and transmit water to varying degrees through inter-granular voids, pore spaces, fractures and other weathered zones of the rock material (ERM 2022a).

Potential GDE Wetlands and potential terrestrial GDEs within the vicinity of the project are presented on Figure 7.42 with additional context for each confidence rating presented in Table 7.7.

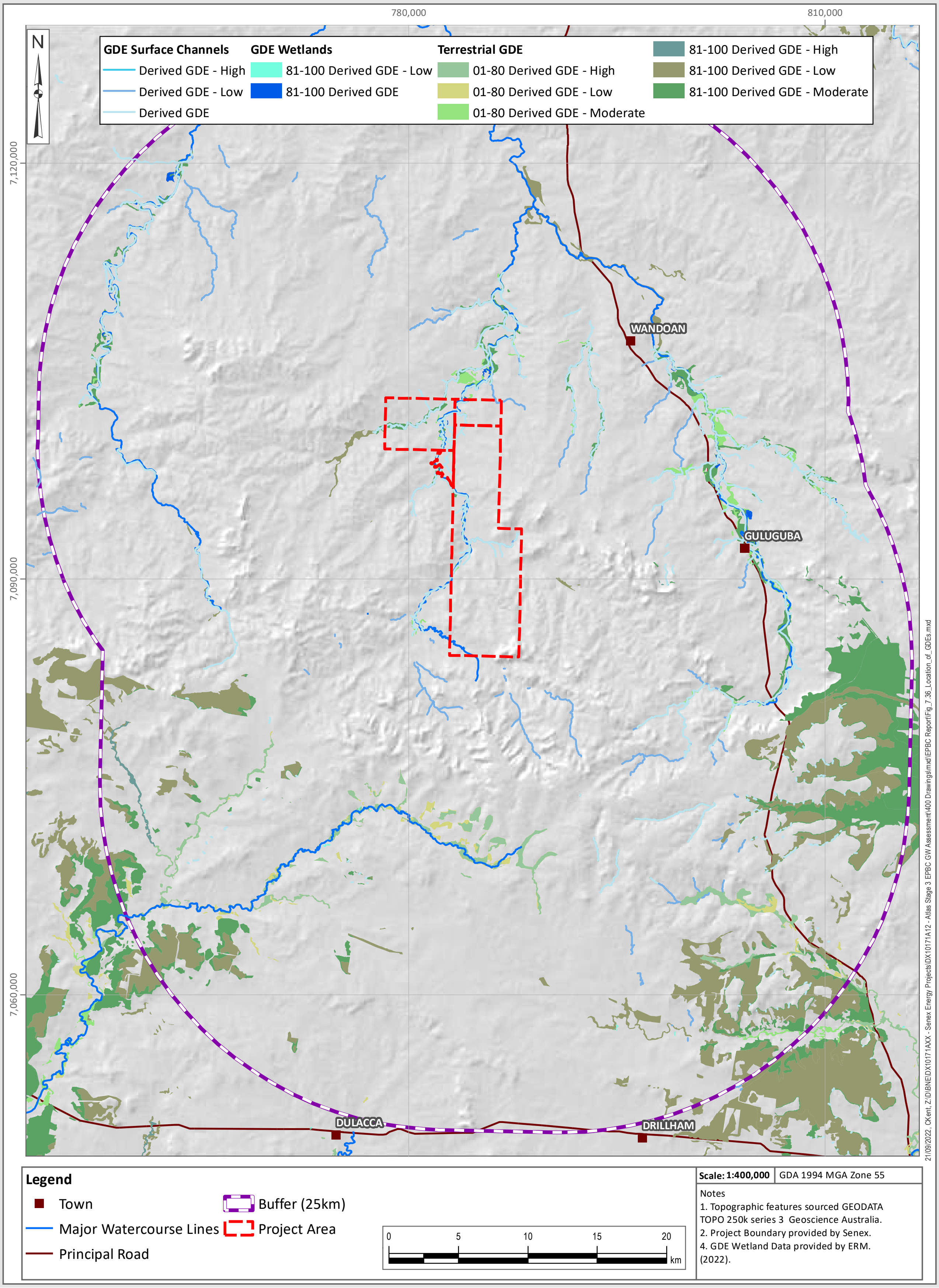


Figure 7.42 Location Mapped Potential GDEs

Table 7.7 Mapped Potential GDEs with Confidence Rating Descriptors

GDE Confidence Rating	Descriptor
Known GDE	According to expert knowledge and supporting evidence (e.g., field validation), the mapped ecosystem has been accurately identified as having some degree of groundwater dependence.
Derived GDE – High Confidence	According to expert knowledge, there is a high confidence in the mapping rule set and therefore in the prediction that the mapped ecosystem has some degree of groundwater dependence.
Derived GDE – Moderate Confidence	According to expert knowledge, there is a moderate confidence in the mapping rule set and therefore in the prediction that the mapped ecosystem has some degree of groundwater dependence.
Derived GDE – Low Confidence	According to expert knowledge, there is a low confidence in the mapping rule set and therefore in the prediction that the mapped ecosystem has some degree of groundwater dependence.
Unknown Confidence	According to expert knowledge, the confidence in the mapping rule set is yet to be determined and therefore the confidence in the prediction that the mapped ecosystem has some degree of groundwater dependence is yet to be determined.

7.11.2.1 RE Verification

The GDEs identified within the Project area have been described in relation to three key areas delineated based on general characteristics and condition within the Project area:

1. North: Wandoan and Woleebee Creeks;
2. Central: Woleebee and Conloi Creeks; and
3. South: Hellhole Creek.

All three areas are comprised of mosaics of remnant and regrowth REs of varying patch sizes and ecological conditions. RE 11.3.25 (Forest Red Gum *Eucalyptus tereticornis* or River Red Gum *Eucalyptus camaldulensis* woodland fringing drainage lines) is the most widely abundant vegetation community identified that has the potential to be a GDE, however interconnected patches of other REs are present. Historic land clearing is known to have occurred throughout the Project area that has impacted the condition of terrestrial GDEs, particularly along creek lines and water courses. Grazing pressure is also likely to influence the ecological condition of RE patches and their value for maintaining biodiversity levels.

A description of the field verified REs is provided below, and the locations are presented in Figure 7.43 and Figure 7.44.

<u>North: Wandoan and Woleebee Creeks</u>

The northern section of the Project area is dominated by RE 11.3.25: (Tall woodland of *Eucalyptus tereticornis* with *Angophora floribunda* and *Casuarina cunninghamiana*; tree species present in the field are typically *Eucalyptus tereticornis*, *Angophora floribunda*, *Brachychiton X turgidulus*, *Brachychiton populneus* var. *trilobum*, *Citrus glauca*, *Acacia salicina*, *Atalaya hemiglauca*, *Geijera parviflora*, *Notelaea microcarpa*, E. *populnea*, *Casuarina cunninghamiana*).

The following are also present in smaller more fragmented patches within a wider landscape of modified pastures, cropping and grazing land (ERM 2022a): RE 11.3.2 (E*ucalyptus populn*ea open grassy woodland on floodplain between braided stream channels: tree species present in the field are typically *Eucalyptus populnea*, *Acacia excelsa*, *Casuarina cristata*, *Geijera parviflora*, *Alectryon oleifolius*); 11.3.27f (Tall woodland of *Eucalyptus tereticornis* with *Eucalyptus populnea* and *Angophora floribunda* around floodplain billabongs with *Vachellia farnesiana* shrubs and ground layer of Carex, native and introduced grasses. Trees species present in the field are typically *Eucalyptus tereticornis*, *Eucalyptus populnea*, *Angophora floribunda*, *Acacia salicina*, *Geijera parviflora, Casuarina cristata*), and 11.3.17 (Poplar Box woodland with Brigalow *Acacia harpophylla* and/or Belah *Casuarina cristata* on alluvial plains).

Central: Woleebee and Conloi Creeks

The mapped GDEs within the central area of Woleebee and Conloi Creeks are also dominated by RE 11.3.25 (Forest Red Gum woodland fringing drainage lines). These patches have been confirmed to largely be remnant communities although some regrowth is also present. Forest Red Gum woodlands fringing water courses are confirmed to be present following field surveys with other *Eucalyptus spp*. Such as Poplar Box and Silver-leaved Ironbark *Eucalyptus melanophloia* also present throughout the area. Unlike the northern area, REs that occur in riparian zones and on alluvium in the centre of the Project area are considerably smaller in size and influenced by increased fragmentation.

South: Hellhole Creek

The southern area around Hellhole Creek is dominated almost exclusively with RE 11.3.25 (Forest Red Gum woodland fringing drainage lines). A combination of regrowth and remnant vegetation is found in the southern area with the majority of patches confirmed to be remnant. Much like the central area, many patches found in the southern area are highly fragmented and restricted to thin bands of riparian vegetation.

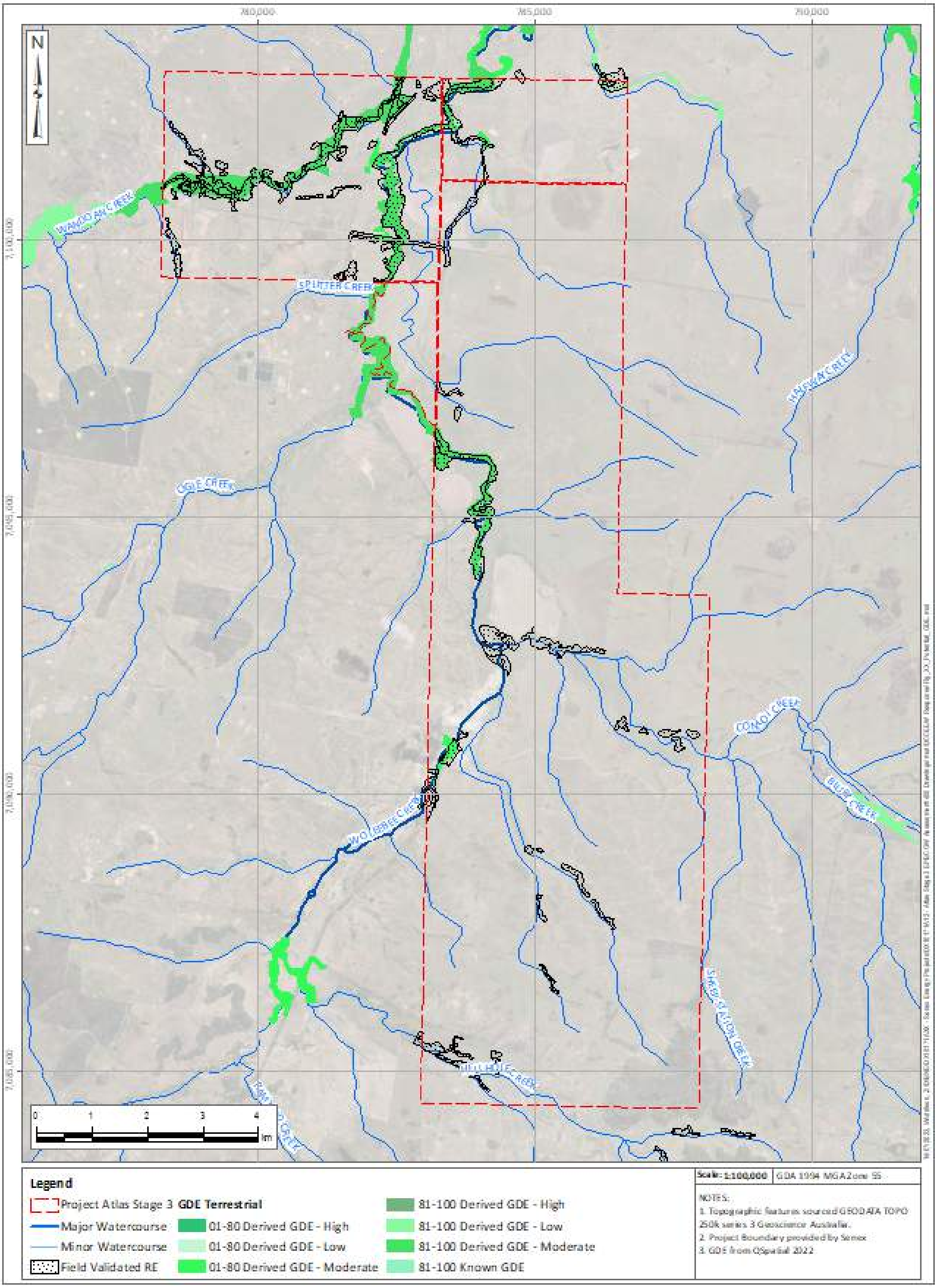


Figure 7.43 Mapped Potential GDEs in the Project Area and Field Verified REs

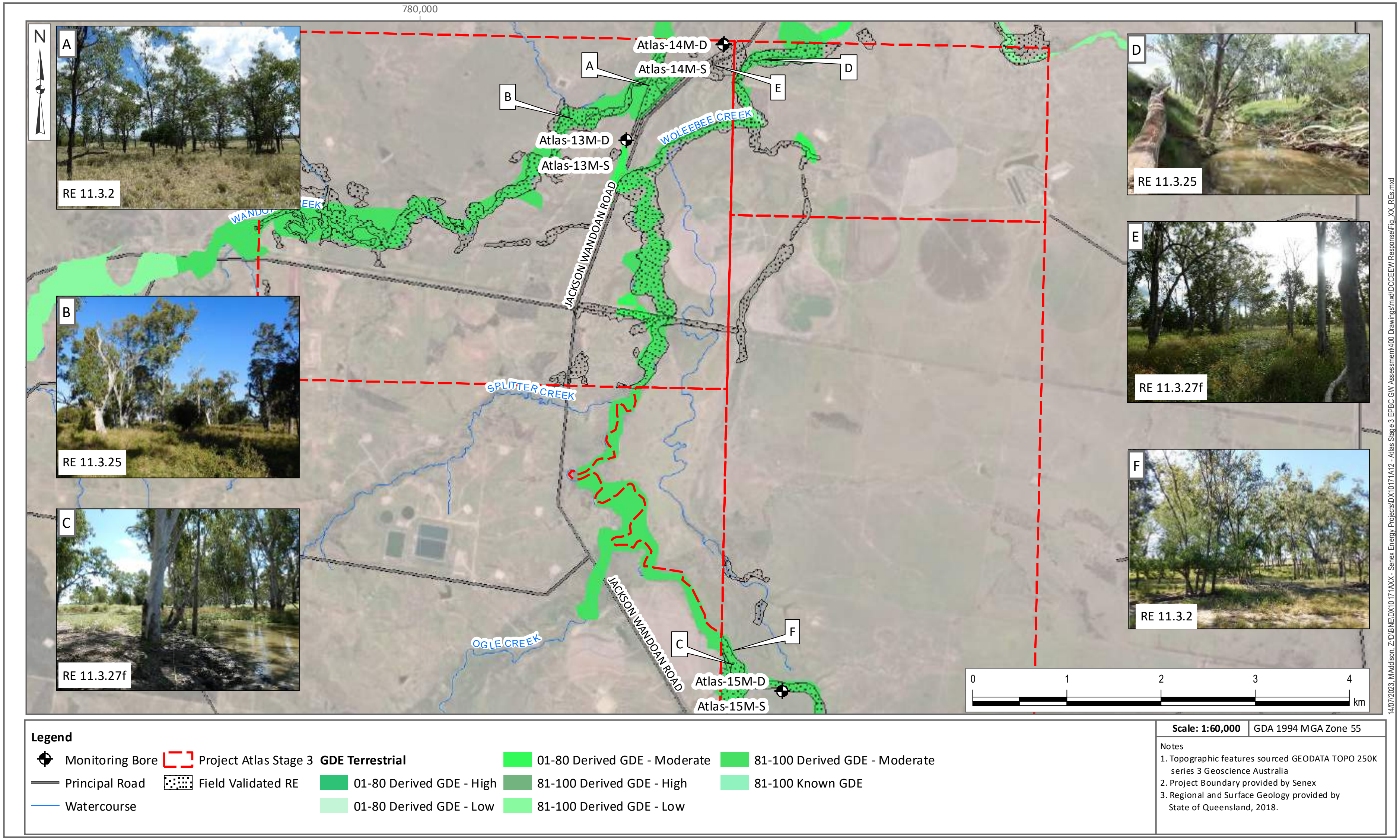


Figure 7.44 Locations of Identified REs

7.11.2.2 Groundwater Dependence

Groundwater dependence of potential terrestrial GDEs in the Project area have been assessed considering all information presented in this report.

The following lines of evidence are referred:

- Plant rooting depth and morphology.
- Evaluation of surface water – groundwater interaction.

The dominant ecosystem, RE 11.3.25, is known to include both ephemeral and permanent wetlands, so aquatic vegetation present will vary depending on the presence of permanent, open water. However, permanent open water/wetlands were not recorded /mapped within the Project area. The ecology survey identified flora and fauna that do not depend on the permanent presence of water. The ephemeral nature of these creek systems, which follow the episodic cycle of wetting and drying, with dry periods followed by wet periods in which the creek system flows, support the high resilience in these vegetation communities.

Whilst the presence of tree species that inhabit wetter environments indicate some potential for groundwater use, the leaf water potential and isotope data, from studies undertaken by QGC directly north of the Project area on similar REs along creek tributaries to Juandah Creek, demonstrated that trees are sourcing water largely from soil moisture stores which fluctuate with rainfall (CDM Smith 2022). This is considered to be a function of the dimorphic rooting systems which access water at multiple depths. In this study, depth profiles of soil moisture show that most trees were accessing water at relatively shallow depths (and several metres above the water table) where soil moisture is high.

The potential GDEs source water largely from soil moisture stores (mainly shallow), a function of their dimorphic rooting system.

A review of available literature on tree rooting depth for those dominant species present in each of the ground-truthed REs has been completed to understand how dependent these species may be on groundwater (ERM 2022a). Table 7.8 presents the REs identified within the Project area, their associated rooting depths, and a comparison of this to observed groundwater levels and commentary on groundwater dependency.

In summary:

- The field investigations confirmed a lack of groundwater in alluvium within the alluvial plains away from the immediate creek vicinity (during the wet season). The confined groundwater in the units below the alluvium is substantial (water strike at 38.5 mbGL in the Springbok Sandstone), with the Springbok Sandstone being dry above this depth. This indicates that REs within the alluvial plains away from the immediate creek vicinity do not depend on groundwater. The REs away from the immediate creek vicinity must be reliant on surface water and soil moisture.
- While the presence of tree species that inhabit wetter environments indicate some potential for groundwater use, the leaf water potential and isotope data, from studies undertaken by QGC directly north of the Project area, on similar REs along creek tributaries

to Juandah Creek, demonstrate that trees are sourcing water largely from soil moisture stores which fluctuate with rainfall (CDM Smith 2022). This is considered to be a function of the dimorphic rooting systems which access water at multiple depths.

- The average rooting depth for species of Eucalyptus present at the Project area is known, based on literature reviews, to range from 9 to 22.6 mbGL, depending on the species and the interactions between geomorphology and plant physiological traits. The dimporphic rooting system of the Eucalypts (including Forest Red Gums), provides them with the ability to access deep groundwater during periods of time where shallower soil moisture is limited, they have shown physiological responses allowing them to adapt to water stress (CDM Smith 2022). The depth to the confined groundwater strike in the Springbok Sandstone is 38.5 m, with the Springbok Sandstone being dry above this depth, indicating that these Eucalypts are not accessing the water within the Springbok Sandstone.
- In the vicinity of the creeks, groundwater is assumed to be present in the alluvium during the wet season. Although this has not been confirmed through groundwater monitoring to date, as the majority of the alluvium has been confirmed as unsaturated. Only potential GDEs in the vicinity of the creeks have access to groundwater or pore water within the unsaturated alluvium. They may have moderate dependency on the pore water in the unsaturated alluvium. However, as the evidence has shown there is no hydraulic connection between the Upper Springbok Sandstone and the alluvium. The predicted drawdown in the Upper Springbok Sandstone will not impact GDEs dependent on pore water in the unsaturated alluvium.

Table 7.8 Potential GDEs, Vegetation Description and Tree Rooting Depth (ERM 2022a)

Regional Ecosystem Code and Names	GDE Type	Dominant Flora Species	Field Verified Condition	Groundwater Dependence and Rooting Depth	Observed Groundwater Levels	Dependence on Groundwater	Representative Site Photographs (ERM 2022a)
11.3.2 *Eucalyptus populnea* woodland on alluvial plains	Treed regional ecosystems on alluvial overlying sandstone ranges with fresh, intermittent flow.	Poplar Box *Eucalyptus populnea.*	Majority of this RE and potential GDE is in a remnant condition. Occurs on **alluvial plains** adjacent to riparian vegetation.	12.6 - 22.6 m for Poplar Box	▪ Alluvium in the alluvial plain is dry. ▪ Groundwater is assumed to be present in the alluvium close to the creek system, however this has not been confirmed through observations. ▪ Springbok Sandstone is confined at depth, top of sandstone is dry to 38.5 m.	Nil – groundwater is not present in the alluvial plains. Springbok Sandstone dry to 38.5 mbGL.	
11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow.	Forest Red Gum.	Largely confined to **fringing riparian vegetation along watercourse** and is the most common RE and GDE type within the Project area. Varying condition, ranging from advanced regrowth to remnant.	At least 9 m and assumed to reach groundwater reservoirs (Forest Red Gum) 12.1 - 22.6 m (*E. camaldulensis).*		Moderate – groundwater is assumed to be present in the alluvium close to the creek system. Alluvium is fed by the surface water system.	
11.3.27 Freshwater Wetlands.	Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow.	Variable freshwater vegetation ranging from open water to fringing sedgelands and eucalypt woodlands. Forest Red Gum.	Occurs largely in closed depressions or oxbows adjacent to watercourses or on adjacent alluvial plains.	*Eucalyptus camaldulensis*- 12.1-22.6 m Forest Red Gum- at least 9 m *Eucalyptus coolabah* possibly at least 7-8 m.		Moderate – groundwater is present in the alluvium close to the creek system. Alluvium is fed by the surface water system.	

Regional Ecosystem Code and Names	GDE Type	Dominant Flora Species	Field Verified Condition	Groundwater Dependence and Rooting Depth	Observed Groundwater Levels	Dependence on Groundwater	Representative Site Photographs (ERM 2022a)
11.3.17 *Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plain	Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow.	Poplar Box Brigalow *Acacia harpophylla* Belah *Casuarina Cristata.*	Identified as majority remnant vegetation and occurs on adjacent alluvial floodplains, usually connected to the adjacent riparian zone.	Poplar Box - 12.6-22.6 m (Kath, et al., 2014) Brigalow - Unknown Belah - Unknown		Nil – groundwater is not present in the alluvial plains. Depth to groundwater in Springbok Sandstone >38.5 m.	
11.3.19 *Callitris glaucophylla, Corymbia* spp. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains	Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow.	White Cypress Pine *Callitris glaucophylla*; *Corymbia spp.* And/or Silver-leaved Ironbark Eucalyptus melanophloia	Occurs on alluvial floodplains adjacent to riparian zone in the southern third of the Project Area 10km south of the Springbok Sandstone outcrop area).	Up to 6 m (*Callitris glaucophylla*) (Eberbach, 2003) Silver-leaved Ironbark - Unknown but likely potential to be similar to Forest Red Gum.			

Table 7.9 Groundwater Dependence Assessment for Potential Terrestrial GDEs Associated in the Project Area (Serov, Kuginis, and Williams 2012)

Groundwater Dependence	Northern Section: Wandoan Creek and Woleebee Creek	Central Section: Woleebee Creek and Conloi Creek	Southern Section: Hellhole Creek
General			
Is the ecosystem identical or like another that is known to be groundwater dependent?	There is potential for the identified REs to access groundwater, but this has not been confirmed. The relative reliance on groundwater could not be identified for some of these dominant species, it is likely that the Eucalyptus species present are resilient to changes in groundwater availability due to their dimorphic root structure. For other dominant flora species, such as Brigalow and Belah, at least an indirect reliance on groundwater availability through water discharge should be assumed.	There is potential for the identified REs to access groundwater, but this has not been confirmed. The dominant tree species in this section of the Project Area are Eucalyptus spp., with Forest Red Gum, Poplar Box and Silver-leaved Ironbark the most common species. The known rooting depth for these species, as identified from literature reviews, is between 9 m and 22.6 m with a reliance on groundwater known for at least Forest Red Gum.	There is potential for the identified REs to access groundwater, but this has not been confirmed. The relative reliance on groundwater could not be identified for some of these dominant species, it is likely that the Eucalyptus species present are resilient to changes in groundwater availability due to their dimorphic root structure. For other dominant flora species, such as Brigalow and Belah, at least an indirect reliance on groundwater availability through water discharge should be assumed.
Does the community contain species known to require permanent saturation such as within aquifers, karsts, or mound springs or some wetlands?	No	No	No
Is the distribution of the ecosystem consistently associated with known areas of groundwater discharge, e.g. springs, mound springs or groundwater seeps in terrestrial and/or near shore marine environments?	No. Standing water present but not considered to be groundwater and it is unlikely that groundwater would express as baseflow or watercourse springs along these creeks.	No. Standing water present but not considered to be groundwater and it is unlikely that groundwater would express as baseflow or watercourse springs along these creeks.	No. Standing water present but not considered to be groundwater and it is unlikely that groundwater would express as baseflow or watercourse springs along these creeks.
Is the distribution of the ecosystem typically confined to locations where groundwater is known or expected to be shallow? For example, topographically low areas, major breaks of topographic slope, i.e. cliffs or escarpments, alluvial and coastal sand beds aquifers, gaining streams?	Yes. The vegetation is located within the area of sandy alluvium associated with the watercourse. However, these creeks are not considered to be gaining streams, and therefore, not connected to the regional groundwater system of the bedrock.	Yes. The vegetation is located within the area of sandy alluvium associated with the watercourse. However, these creeks are not considered to be gaining streams, and therefore, not connected to the regional groundwater system of the bedrock.	Yes. The vegetation is located within the area of sandy alluvium associated with the watercourse. However, these creeks are not considered to be gaining streams, and therefore, not connected to the regional groundwater system of the bedrock.

Groundwater Dependence	Northern Section: Wandoan Creek and Woleebee Creek	Central Section: Woleebee Creek and Conloi Creek	Southern Section: Hellhole Creek
Terrestrial GDEs			
Is the water table level near or at the surface or within the root zone of the surrounding vegetation? If roots can reach a source of fresh water, it is generally true that this water will be absorbed by the roots and transpired by the canopy.	Yes. There are two registered bores accessing the alluvium on Woleebee Creek in ATP 2059. Measurements at these bores record groundwater at ~7.5 mbGL (April 2022). Average root depth for species of Eucalyptus present is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits (ERM 2022a).	Yes. There are two registered bores accessing the alluvium on Woleebee Creek in ATP 2059. Measurements at these bores record groundwater at ~7.5 mbGL (April 2022). Average root depth for species of Eucalyptus present is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits (ERM 2022a).	Yes. One monitoring bore is located in alluvium on Woleebee Creek in PL 209. Measurements at this bore records groundwater at 9.05 mbGL (2014). Average root depth for species of Eucalyptus present is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits (ERM 2022a).
Is the vegetation community composed of species known to require permanent saturation (wet rainforest or wet sclerophyll forests) or high soil moisture levels (dry rainforest)?	No.	No.	No.
Does the vegetation in a particular community occur along streamlines?	Yes. Field verified REs are associated with water courses and the adjacent alluvial plains.	Yes. Field verified REs are associated with water courses and the adjacent alluvial plains.	Yes. Field verified REs are associated with water courses and the adjacent alluvial plains.
Is the vegetation community known to function as a refuge for more mobile fauna during times of drought?	No. Wandoan and Woleebee Creeks are ephemeral and therefore would not likely have permanent water during the dry season or periods of limited rain.	No. The creeks are ephemeral and therefore would not likely have permanent water during the dry season or periods of limited rain.	No. The creek is ephemeral and therefore would not likely have permanent during the dry season or periods of limited rain.

7.11.3 Subterranean Fauna

Stygofauna are known to occur in alluvial, limestone, fractured rock, calcrete aquifers and coal seams in Australia. Stygofauna are subterranean aquatic animals that live in groundwater. Communities are often dominated by crustacean invertebrates, also containing oligochaetes, insects, other invertebrate groups and occasionally fish. Where stygofauna are abundant, for example in alluvial aquifers, they are likely to contribute to improvement of water quality through processes such as biochemical filtration (Hancock, Boulton, and Humphreys 2005).

The prospective habitat for subterranean fauna is dependent on the presence of underground voids of suitable size and connectivity, to satisfy biological requirements. Subterranean faunae were previously believed to be restricted to alluvial or karst landscapes (limestone or calcrete dominated systems) which provided optimal habitat conditions. In more recent years, subterranean faunae have been found to occur in various types of non-karstic geological units and aquifer systems that exhibit suitable voids for colonisation, including alluvial, fractured rock, calcrete aquifers and coal seams, in addition to limestone (Hose et al. 2015; EPA 2016a).

The extent of subterranean habitat present is dependent on the interconnection of subsurface crevices, fractures, and voids, within suitable geological units and aquifer systems, in addition to connectivity to recharge areas and sources of particulate organic matter for food.

Stygofauna have previously been recorded in the Wandoan area, where sampling of groundwater from Horse Creek alluvium to the west of the Project, and WCM near Wandoan (close to the WCM outcrop) recorded several stygofauna taxa (Xstrata 2008; Hose et al. 2015; State of Queensland 2016b). Stygofauna are rarely found more than 100 m below the surface and are usually most abundant within the top 30 m from below ground surface (Hose et al. 2015). Stygofauna are found across a range of water quality conditions (from fresh to saline), but most common in fresh and brackish water (electrical conductivity less than 5,000 µS/cm) (Hose et al. 2015).

Sampling for subterranean fauna was undertaken at 12 existing landholder bores within the Project area. The sampling was undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b). Sampling was undertaken by Freshwater Ecology (Freshwater Ecology 2022b). Only two specimens of one potential stygofauna (from a single bore) were recorded in the 12 samples collected. Given the location of the bore, it is likely that these two specimens are stygofauna, but they could not be formally identified. No stygofauna (stygobites or stygophiles) were recovered from the other 11 bores sampled, although large numbers of stygoxenes[4] (both whole and heavily decomposed) were recorded from most bores.

Stygofauna sampling was undertaken on neighbouring areas of PL 1037 at four existing landholder bores. The sampling was undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b). Sampling was undertaken by Hydrobiology (KCB 2018c). Stygofauna were recorded at two bores, the first of which is estimated to be screened across both the Westbourne Formation and Gubberamunda Sandstone (Table 7.10). A review of the groundwater bore database (GWDB) bore card and drilling log, and the groundwater chemistry results suggest that the majority of the water inflow is likely to be from the Gubberamunda Sandstone.

[4] Animals found accidentally in groundwater.

The Gubberamunda Sandstone is inferred to be present between 19 and 25 mbGL within this bore. The stygofauna found were two Cyprididae species (Cyprinopsinae sp.) and three nematode species (Nematoda sp.).

The second bore is screened within the Upper Springbok Sandstone with depth to water recorded as 18.37 mbGL. Despite the higher EC (20,948 µS/cm), stygofauna were found to occur in this bore.

In the context of the WCM within the Project area, it is unlikely that stygofauna will be present within the target coal seams. Although there is reported occurrence within coal seams of the Surat Basin, near Wandoan; these were in shallow bores (Xstrata 2008). All CSG production within the Project area will occur from coal seams deeper than 250 mbGL, which is deeper than any known occurrence of stygofauna in the Surat Basin.

Table 7.10 Summary of Stygofauna Sampling Results (KCB 2018c)

Bore	Aquifer Attribution*	Bore Depth (mbGL)	EC (µs/cm)	Stygofauna Present
Bore 1	Gubberamunda Sandstone / Westbourne Formation	67.4	3,724	Yes
Bore 4	Upper Springbok Sandstone	25.0	20,948	Yes

*Aquifer attribution from OGIA (2017e) and Senex baseline assessment (KCB 2018c)

There are no threatened stygofauna species listed in Queensland under the EPBC Act.

7.12 Existing Third-Party Groundwater Users

7.12.1 Registered Groundwater Bores

Within a 25 km buffer of the lease boundaries of the Project, there are 810 groundwater bores present with aquifer attributions provided by OGIA (OGIA 2022). Of these 810, 79 bores are not recorded in the registered groundwater bores database (GWDB)(State of Queensland 2022b).

Of these 810 bores, 590 are existing bores, including water supply or monitoring bores, with the remainder being either abandoned or decommissioned. A summary of registered bores is presented in Table 7.11 along with their type and status, as derived from GWDB.

Table 7.11 GWDB Registered Bore Statistics Within the 25 km Project Buffer (State of Queensland 2022c; OGIA 2022)

Type		Abandoned and Destroyed (AD)	Abandoned but Usable (AU)	Existing (EX)	Proposed (PR)	Unknown	Total
Artesian	Condition Unknown (AB)	-	-	6	-		
	Ceased to Flow (AC)	3	-	5	-		
	Controlled Flow (AF)	5	-	14	-		
Sub-Artesian (SF)		116	5	565	12		
Unknown		-	-	-	-	79	
	Total	**124**	**5**	**590**	**12**	**79**	**810**

AB: artesian condition unknown; AF: bores that are under artesian pressure and capped to control free flow; AC: bores that have been artesian in the past but have now become sub-artesian due to a reduction in artesian pressure; AB: likely artesian bores, however their current pressure condition is unknown; SF: bores which do not flow under any condition and where active pumping is required to abstract water.

7.12.2 Baseline Assessment

Under the *Water Act 2000*, petroleum tenure holders are required to undertake baseline assessment of water bores prior to commencement of production. A bore baseline assessment program within the Project area was undertaken in June 2022. Assessments were undertaken in accordance with the 'Baseline Assessment Guideline' (State of Queensland 2022a) and as stipulated in the approved Baseline Assessment Plan (BAP) prepared by Senex (Senex 2022b). The assessment was undertaken to obtain information such as:

- Bore status, type and purpose;
- Information related to the construction of the bore, including depth installed, screen interval and source aquifer;
- Groundwater level and quality and field gas measurement; and
- Bore equipment including pump depth, pumping frequency and flow rate.

Senex were required to undertake baseline assessments for two bores within ATP 2059, and 32 bores within PL 445 and PL 209 tenures.

Baseline assessment programs were undertaken by Senex as follows:

- ATP 2059 – April 2022 – two registered bores;
- PL 445 – June 2022 – one registered bore; and
- PL 209 – June 2022 and March 2023 – 27 registered bores and one unregistered bore.

In summary, 17 bores assessed as part of the bore baseline assessment program were used for stock and domestic purposes on private land (Table 7.12). Seven bores were not in use. Groundwater levels ranged from artesian (0.4 m above ground), to ~37 mbGL. Seventeen existing bores were screened in the Gubberamunda Sandstone with only two in the Upper Springbok Sandstone and one in the Orallo Formation. Hydro-geochemical composition of all units is dominated by Na, Cl and HCO_3. The majority of samples collected (76%) represent the Gubberamunda Sandstone.

Groundwater use within the Project area is limited to the shallowest units of the Gubberamunda Sandstone, Westbourne Formation, and Springbok Sandstone where bores are typically used for stock and domestic purposes (Table 7.12). Beyond the Project area, groundwater is sourced from the deeper units for both stock and domestic purposes, and town water supply.

Table 7.12 Baseline Assessment Bore Summary of Bores Visited

RN	Facility Status	Groundwater Level (mbGL)[1]	Screened Aquifer	Bore Use
11600	EX	-	Gubberamunda Sandstone	Stock & Domestic
12712	A&D	-	-	-
13884	EX	-0.40	Upper Springbok Sandstone	Not in use
14192	EX	-	Gubberamunda Sandstone	Stock & Domestic

RN	Facility Status	Groundwater Level (mbGL)[1]	Screened Aquifer	Bore Use
14193	EX	-	Gubberamunda Sandstone	Stock & Domestic
15500	EX	-	Gubberamunda Sandstone	Stock & Domestic
15501	EX	37.18	Gubberamunda Sandstone	Stock & Domestic
32880	A&D	-	-	-
33443	EX	-	-	Not assessed – off-tenement
43483	EX	-	Gubberamunda Sandstone	Stock & Domestic
43869	EX	-	Gubberamunda Sandstone	Stock & Domestic
44001	EX	27.65	Gubberamunda Sandstone	Not in use
44006	A&D	31.90	Upper Springbok Sandstone	Not in use
44040	EX	-	Upper Springbok Sandstone	Not in use
44278	EX	-	Gubberamunda Sandstone	Not in use
48818	EX	9.05	Gubberamunda Sandstone	Stock & Domestic
48835	EX	-	Gubberamunda Sandstone	Stock & Domestic
48836	EX	26.76	Gubberamunda Sandstone	Stock & Domestic
48837	EX	16.18	Gubberamunda Sandstone	Stock & Domestic
58028	-	-	-	-
58276	EX	-	-	Stock & Domestic
58494	EX	-	-	-
58495	EX	30.10	Orallo Formation	Stock & Domestic
58786	EX	33.51	Westbourne Formation	Not is use
58842	EX	-	-	-
58910	EX	-	Upper. Juandah Coal Measures	-
123021	EX	-	Gubberamunda Sandstone	Not in use
168139	EX	-	-	-
168167	EX	-	Gubberamunda Sandstone	Stock & Domestic
168264	EX	-	Gubberamunda Sandstone	Stock & Domestic
168286	EX	-	-	-
168350	EX	-	Gubberamunda Sandstone	Stock & Domestic
Unregistered	EX	-	-	Stock & Domestic

EX = Existing, A&D = Abandoned and Destroyed, mbGL = metres below ground level
1. Groundwater levels are recorded where there was access to the bore.
- no data

7.12.3 Groundwater Users and Purpose

Of the 669 existing or unknown status bores in Table 7.11 (OGIA 2022):

- 410 bores have been identified as being used for water supply purposes (WS);
- 32 are potential water supply bore (PWS);
- 219 are not a water supply bore, some are monitoring bores or not currently used for water supply (NWS); and

- Eight are recent drills and the purpose is unknown.

The locations of these existing bores are shown on Figure 7.45.

Groundwater abstraction for stock and domestic use is the dominant water use purpose in the vicinity of the Project. There are five bores noted as town water supply and ten for intensive stock use. The location of the bores with their purpose indicated is shown on Figure 7.46.

A summary of aquifer attribution is presented in Table 7.13 (OGIA 2022). OGIA have designated all bores with a primary source aquifer, which has been used to populate the table.

Table 7.13 Summary of Aquifer Attribution, 25 km Buffer of the Project (OGIA 2022)

Formation	Number of Bores (EX, AU or Unknown) *
Other alluvium	41
Cenozoic Sediments	8
Wallumbilla Formation	5
Bungil Formation	27
Mooga Sandstone	50
Orallo Formation	61
Gubberamunda Sandstone	145
Westbourne Formation	33
Upper Springbok Sandstone	30
Lower Springbok Sandstone	15
Upper Juandah Coal Measures	100
Lower Juandah Coal Measures	48
Taroom Coal Measures	20
Durabilla Formation	5
Upper Hutton Sandstone	37
Lower Hutton Sandstone	10
Upper Evergreen Formation	1
Lower Evergreen Formation	1
Precipice Sandstone	34
Moolayember Formation	2
Rewan Group	1
Total	**674**

*Includes abandoned but usable (AU), existing (EX) and status unknown bores are included.

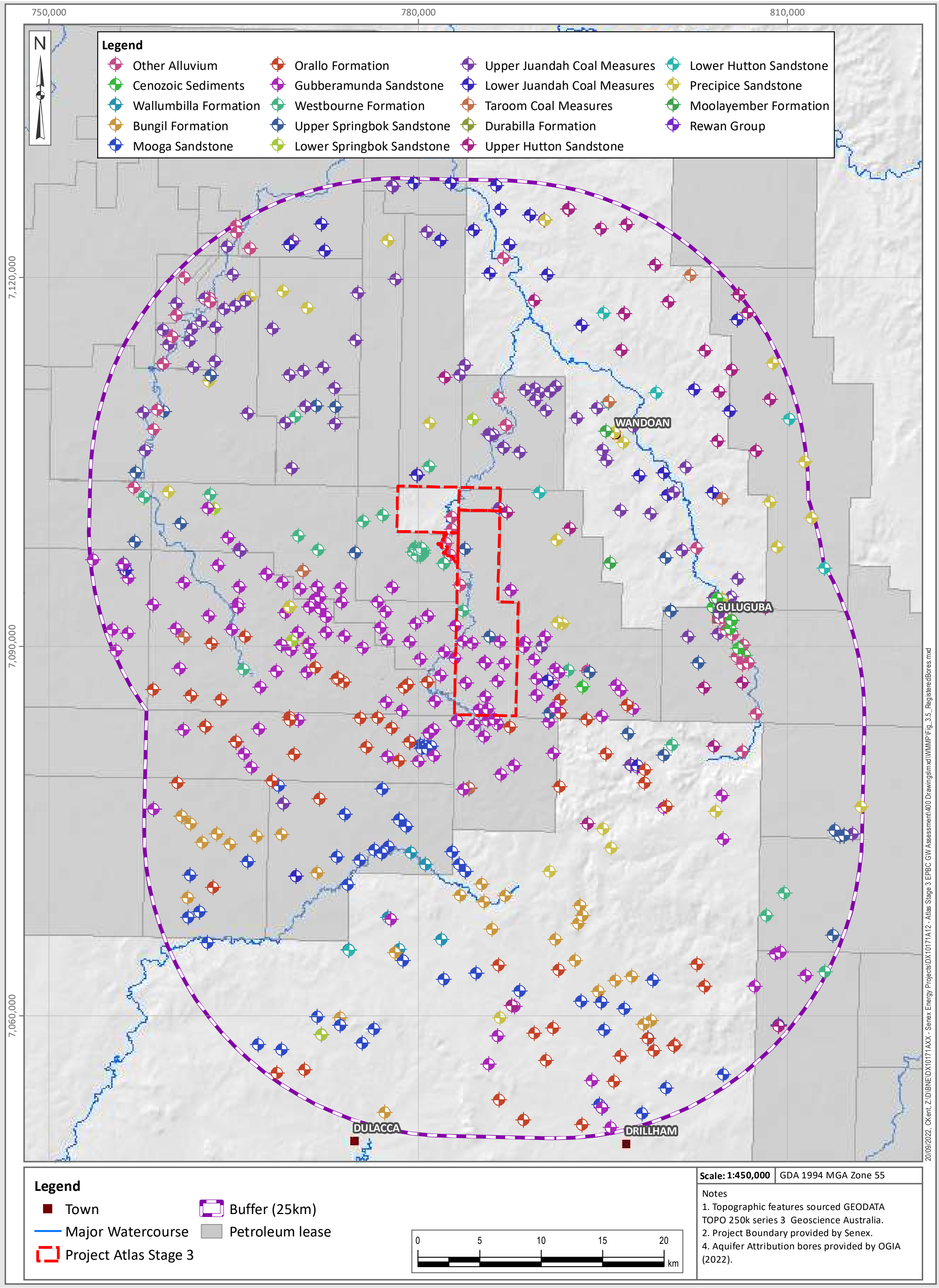


Figure 7.45 Location of Registered Groundwater Users within the Vicinity of the Project

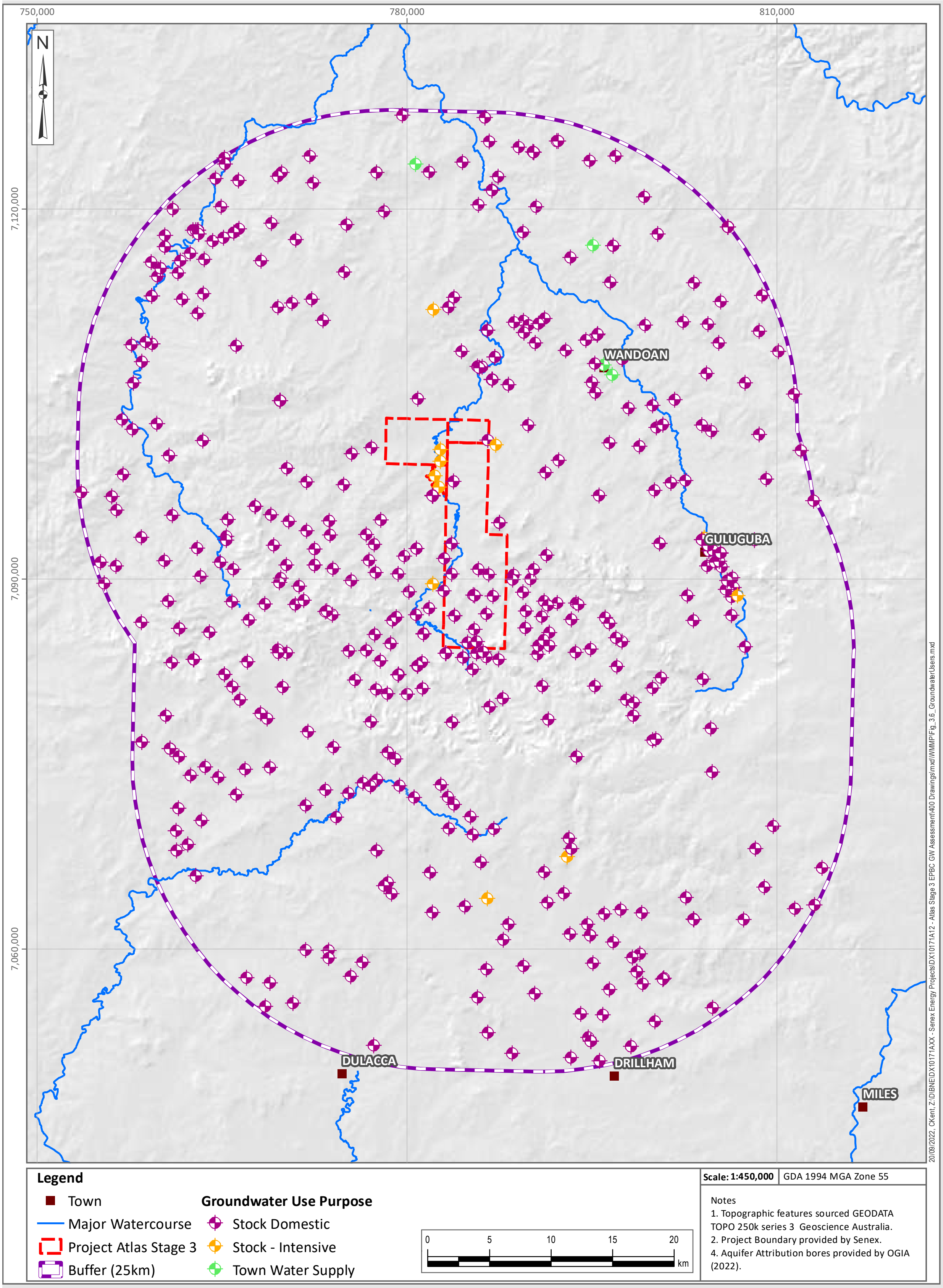


Figure 7.46 Location of Groundwater Users and Purpose of Use

7.13 Hydrogeological Conceptual Model Summary

The Project hydrogeological conceptual model is summarised below and presented in a schematic in Figure 7.47.

Geology and Hydrostratigraphy

The target for CSG production is the WCM, which occurs at ~220 to 300 m below ground level; and is ~400 m thick. The WCM forms part of the Surat Basin.

Surface geology within PL 209 comprises outcrops of the Gubberamunda Sandstone and Westbourne Formation of the Surat Basin. The Upper Springbok Sandstone outcrops within the northern extent of PL 445. Quaternary-age alluvium is present along the Woleebee, Wandoan and Conloi Creek systems.

The WCM outcrops 14 km to the north and northeast of the Project area, while the Orallo Formation outcrops ~ 1 km to the south. The WCM is separated from overlying and underlying aquifers by aquitard layers of the Upper WCM aquitard and Durabilla Formation, respectively.

Key hydrostratigraphic units in the vicinity of the Project are the Westbourne Formation (aquitard), Upper Springbok Sandstone (aquifer), Gubberamunda Sandstone (aquifer), and Quaternary alluvium (a discontinuous perched aquifer).

The alluvium present within the Project area is generally associated with Wandoan and Woleebee Creeks. Alluvium bank heights of up to 8 m have been observed along Woleebee Creek and alluvium depths of up to 10 m were logged within PL 445 during the site investigation. Alluvium thickness was relatively consistent at 7 to 10 m throughout the Project area, except further south at Atlas-15M where 13 m of alluvium was logged close to the creek above the Westbourne Formation.

Surface Water

Key watercourses within the Project area, Woleebee, Wandoan, Conloi, and Hellhole creeks, are characteristically ephemeral and typically flow only during and after significant rainfall events. This has been confirmed through site walkovers during typical dry seasons (in 2018), and groundwater site investigations undertaken following an unusually wet season where rainfall was above average (late 2022) where water was observed in Woleebee Creek.

When water is present in the creek systems, it provides a habitat for a limited number of aquatic species. Shallow pools identified in the watercourses during the 2018 dry season were generally turbid with water quality results indicating that these pools are fresh and surface water sourced and had a contrasting water quality to the groundwater in the underlying Surat Basin units.

The identified aquatic ecosystems are generally of low to fair habitat and had presence (but low diversity) of non-conservation significant native aquatic fauna and flora.

Groundwater Chemistry

Site specific groundwater chemistry was available from the Senex monitoring bore network and the bore baseline assessment. Surface water samples have also been taken from pools in Wandoan Creek and a flowing section of Woleebee Creek.

A review of the groundwater chemistry from bores across the Project, indicates the following:

- All samples from the Surat Basin units (regardless of formation) reflect either sodium-chloride or sodium-bicarbonate water types.
- The alluvium samples from Atlas-15M-S do not group with other regional alluvium water quality and may not be representative of typical alluvium groundwater quality at the Project. Higher salinity and chloride concentrations (than would be expected) for alluvium were encountered in samples collected from this bore. Geologically, isolated pockets of alluvium at this location may contribute to anomalous water quality concentrations observed in this bore; as limited groundwater movement in an isolated pocket may promote long residence times which would increase groundwater salinity.
- Groundwater samples from bores screened in the regional alluvium (associated with Woleebee and Juandah Creeks) have different water chemistry signatures to the Surat Basin units (Upper Springbok Sandstone and Westbourne Formation) observed at the Project, with a stronger sodium-bicarbonate signature.
- Fresher groundwater is observed in the samples from the regional alluvium, Gubberamunda Sandstone, and Hutton Sandstone. EC was higher in groundwater from the WCM and Springbok Sandstone.
- The groundwater qualities observed from the Springbok Sandstone are distinct from the groundwater quality of the alluvium, with the Springbok Sandstone groundwater showing a proportionally higher chloride concentration. This difference in proportional anion concentrations indicates a lack of connection between the units (i.e., the underlying Springbok Sandstone does not discharge into the alluvium). The Springbok Sandstone groundwater sample (Atlas-14M-D) is grouped with other samples for that unit, illustrating the sample is representative of the Upper Springbok Sandstone.

Inter-aquifer Connectivity

Across the Surat CMA, there is potential for interaction between the CSG production target formation, WCM, and hydrostratigraphic units above and below the WCM, specifically the Springbok Sandstone and Hutton Sandstone (separated from the WCM by the Durabilla Formation), respectively. The Durabilla Formation is mapped across the entire Project area, with a mean thickness of 87 m, which provides a significant low permeability barrier between the WCM and underlying Hutton Sandstone. An upper WCM aquitard has been mapped by OGIA (the Walloon Coal Measures non-productive zone, OGIA 2021f) as being up to ~25 m thick across the Project area, with ~40 m of thickness in the central west of PL 209, separating the WCM coal seams from the overlying Springbok Sandstone.

The Project is situated in an area where the Springbok Sandstone, Westbourne Formation, and Gubberamunda Sandstone outcrop. Quaternary-age alluvium is mapped within the Project area and is associated with Woleebee and Wandoan Creeks above these Surat Basin units. Interaction between the alluvium and underlying units has not been identified. There is both hydraulic and geochemical evidence to identify a disconnection between the alluvium and the Surat Basin units:

- Senex groundwater monitoring bores installed as paired sets in the alluvium and underlying Springbok Sandstone or Westbourne Formation displayed hydraulic separation between the units. Groundwater levels in both of these underlying units are below the base of the alluvium indicating that there is no contribution from these deeper units to the shallower alluvium. The groundwater level in the Springbok Sandstone was 3 m below the base of alluvium during the wet season in Atlas-14M-D. There may be losses from the alluvium to these deeper units during times of saturation in the alluvium.

- The groundwater qualities observed in the Springbok Sandstone and Westbourne Formation are distinct from the groundwater quality observed in the alluvium. The deeper units show a proportionally higher chloride concentration in comparison with the Juandah Creek alluvium groundwater which show a proportionally higher carbonate-bicarbonate concentration.

Groundwater-Surface Water Interaction

The ephemeral Wandoan and Woleebee Creeks are 'losing' streams whereby surface water is lost to groundwater via the alluvium at the base of the creek during times of flow within the Project. Baseflow contributions from the groundwater system to the watercourses is not identified at the Project. There are two lines of evidence which support this theory:

- Groundwater level data from alluvium monitoring bore ATLAS-15M-S (collected during the wet season) indicate that groundwater level in alluvium near the creek is below the creek elevation.
- A comparison of water quality of pooled water within Wandoan and Woleebee Creeks, during the dry season versus the groundwater in underlying hydrostratigraphic units, indicates that the pooled water within the creek was rainfall derived as the pooled water was turbid and of a lower salinity; which is distinct from the underlying groundwater.

Springs and GDEs

There are no spring vents or complexes within the vicinity of the Project.

Potential terrestrial GDEs have been identified and are generally associated with Wandoan and Woleebee Creeks. These potential GDEs are considered to be sourcing water from shallow soil systems and the alluvium along the watercourses.

The unsaturated nature of the alluvium at a distance from the creek banks, confirmed through groundwater monitoring of ATLAS-13M-S, ATLAS-14M-S, and ATLAS-19M-S, suggests that potential terrestrial GDEs are dependent on soil moisture.

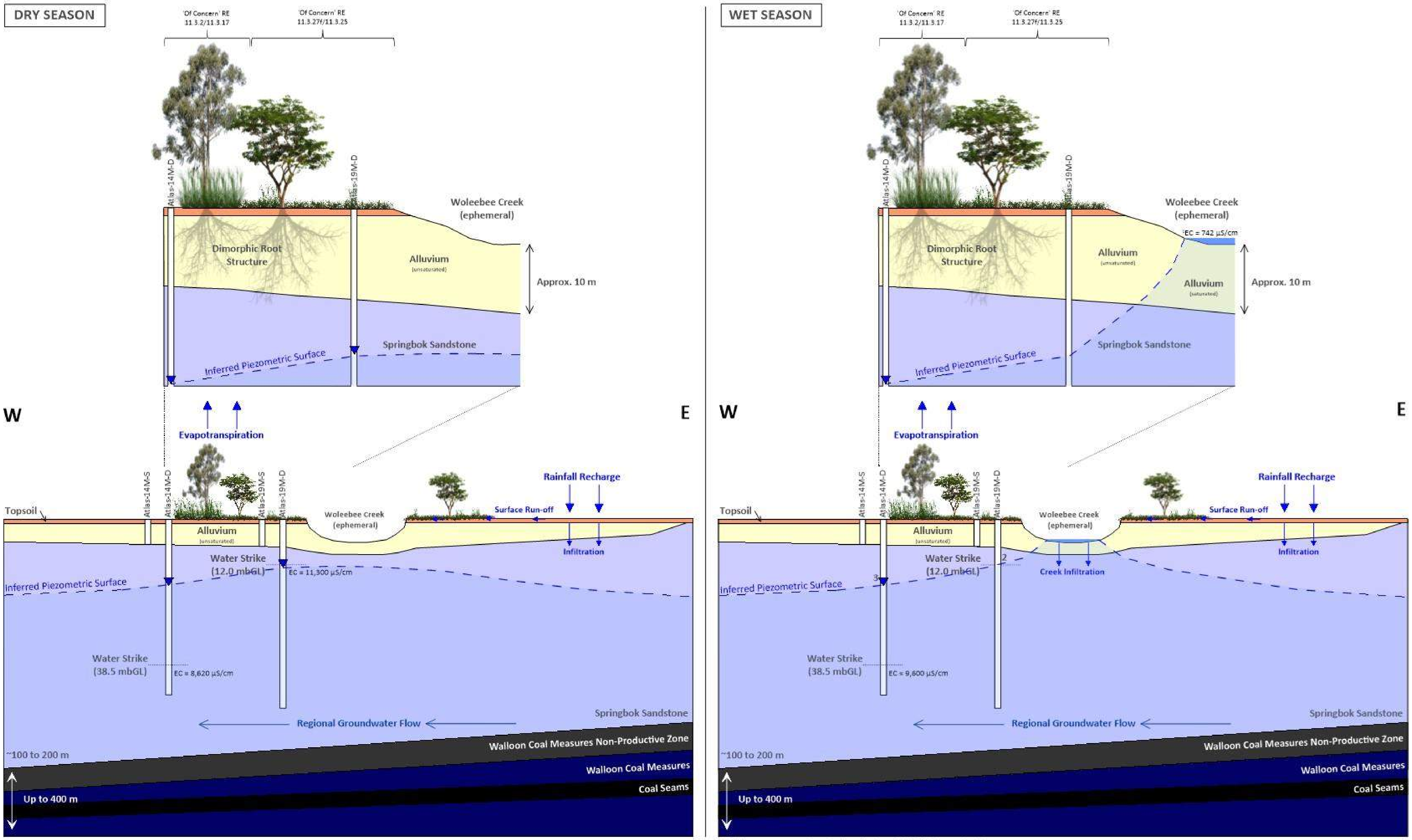
Regional ecosystems close to the creek lines, where there is more likely to be groundwater present in the alluvium, may be partially dependent on groundwater, however, this would only apply to larger trees with deeper root systems due to a low water table in alluvium (~10-12 mbGL in the wet season). Due to the ephemeral nature of the alluvial system, these trees cannot be fully dependent on groundwater and would need to be resilient and adapt well to stress. The larger eucalypts (including Forest Red Gums) have dimorphic root systems (Figure 7.47) and are well adapted to the dry/wet environment associated with ephemeral creek systems.

Water quality samples from monitoring bores installed in the Springbok Sandstone and Westbourne Formation displayed brackish to saline groundwater qualities, which may be detrimental to terrestrial GDE survival over prolonged periods. It is reasonable to assume that healthy flora at the identified terrestrial GDE locations do not source water from the deeper groundwater system, and instead source water from soil moisture and rainfall recharge to the alluvium (following rainfall and stream flow recharge events) where salinity is much lower.

Third-Party Groundwater Users

A baseline assessment has been conducted on registered bores within the Project area. Groundwater use within the Project area is limited to the shallowest units of the Gubberamunda Sandstone, Westbourne Formation, and Springbok Sandstone where bores are typically used for stock and domestic purposes. Further afield, groundwater is also accessed from the deeper units for both stock and domestic purposes, and town water supply (Section 7.12).

NOT TO SCALE



1. This measurement was taken during a 2023 site investigation
2. Water level and EC in Atlas-19M-D are yet to be observed during wet season
3. Water level in Atlas-14M-D remains consistent between dry and weat seasons

Figure 7.47 Hydrogeological Conceptual Model (Not to Scale)

8 NUMERICAL GROUNDWATER MODELLING

8.1 Overview

As detailed in Section 2.2.2, the Project is located within the Surat CMA, which was declared under the *Water Act 2000*, as a result of concentrated development by multiple tenure holders.

The Project area is located adjacent to other active and proposed CSG developments. As groundwater is removed via CSG production wells to depressurise the coal seams, there will be a degree of interaction between the individual tenure holders. There is also the potential for planned future mining operations in the area to contribute to the cumulative groundwater impacts.

OGIA, established under the *Water Act 2000*, is responsible for predicting regional impacts on water pressures in the hydrostratigraphic units of the Surat CMA and identifying potentially impacted groundwater bores and springs as presented in the UWIR, which is updated and published every three years.

As part of the Surat CMA UWIR (OGIA 2021f), a regional groundwater flow model was developed by OGIA to predict groundwater pressure impacts resulting from cumulative activities from multiple petroleum and gas tenure holders and mining. The model was first developed and utilised as part of the 2012 UWIR (QWC 2012b). An updated UWIR and updated numerical groundwater model was published by OGIA in September, 2016 (OGIA 2016d), July, 2019 (OGIA 2019b) and most recently May 2022 (OGIA 2021f).

The primary purpose of the regional groundwater model is to predict regional water pressure or water level changes in aquifers within the Surat CMA footprint in response to extraction of water from the various producing coal seams. In particular, the OGIA numerical groundwater model is used to assess potential impacts to landholder groundwater bores and springs relative to the *Water Act 2000* trigger thresholds.

The current OGIA groundwater model is the agreed basis for assessment for all Surat Cumulative Management Area CSG impacts, even at the scale of individual bores for make good investigation purposes, therefore, also appropriate to use at the GDE scale for this assessment where it applies to non-alluvial units.

The Surat CMA UWIR is updated periodically (every three years), therefore, the OGIA numerical groundwater model for the Surat CMA is also updated periodically to support the UWIR. Key updates to the model include recalibration of the model based on monitoring data provided by proponents operating within the CMA, extraction records, and the incorporation of newly approved CSG developments within the CMA. Therefore, each update to the OGIA model results in the additional incorporation of site data and an update of the predicted cumulative drawdown impacts across the CMA.

The model domain includes the extent of the Surat CMA, with hydrostratigraphic units from the Surat Basin as well as interconnected basins (Bowen Basin and Clarence-Moreton Basin). The model domain is shown in Figure 8.1. The 2021 UWIR model consists of 35 layers, of which seven layers represent the WCM, as shown in Figure 8.2.

A summary of key aspects of the model is presented in Table 8.1, with further detail provided in the following sections.

Table 8.1 Summary of the OGIA Regional Groundwater Flow Model (OGIA 2021c)

Model Component	Description
Modelling Platform	MODFLOW-USG
Model Domain	Model covers the entire Surat CMA (Figure 8.1), including all coal seam formations and potentially connected aquifers in the Surat, southern Bowen, and Clarence-Moreton Basins.
Model Layers	Model consists of 35 layers (Figure 8.2).
Grid Spacing	Model grid spacing is 1.5 km x 1.5 km
Parameterisation	Initial parameters for use in the Surat CMA model were developed using an innovative workflow, developed by OGIA, centred around a suite of detailed numerical permeameters. This workflow was initially developed for use in the 2016 regional groundwater flow model and has been further enhanced for the current model. This approach extracts full value from the large geological and hydraulic parameter dataset available for the CMA. Outputs from this process include formation scale horizontal and vertical permeabilities that are then used as inputs to the regional groundwater flow model for further calibration against water level and other observed data.
Water Production Simulation	Simulated using the MODFLOW-USG 'drain' boundary condition. Multiple MODFLOW-USG drains are assigned to each well; these descend over time as pressures in the CSG well are reduced.
Calibration	Calibration of the groundwater flow model in three stages: 'pre-development' (1947) to replicate conditions that existed prior to the commencement of any groundwater extraction; pre-CSG extraction conditions commensurate with 1995; and a transient simulation to replicate the period from January 1995 to December 2020, during which CSG extraction commenced initially from the Bandanna Formation and then from the WCM.

The key changes to the 2021 regional groundwater model include:

- The introduction of an additional layer in the WCM to better represent the geological subdivision of this formation and improve representation of flow between units of the WCM.
- Representation of coal mines where overlapping impacts with CSG development are likely to occur, this included the Wandoan Coal Project located directly north of the Project area.

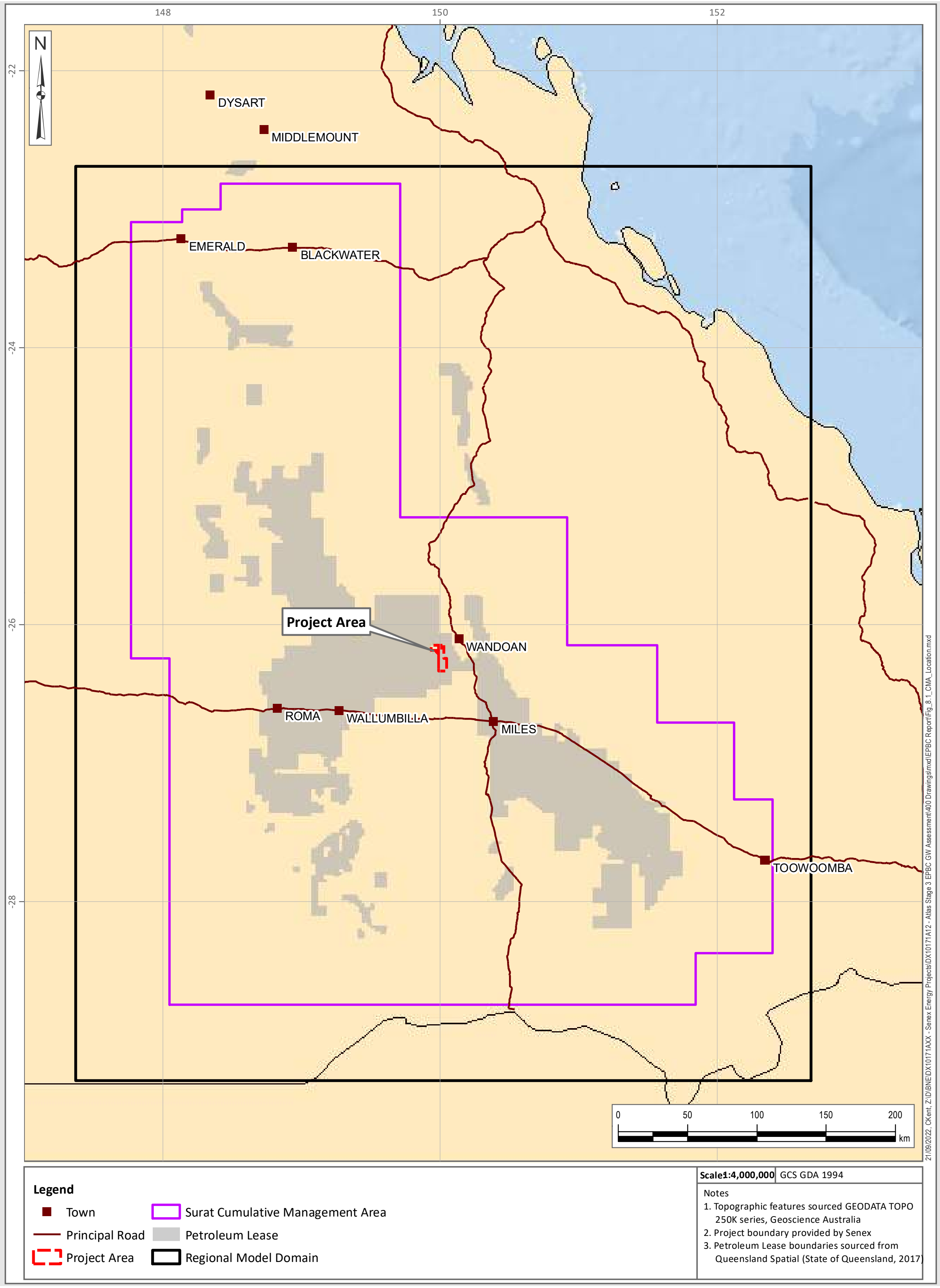


Figure 8.1 Location of the Surat CMA Regional Flow Model and the Project

Model layer	Formation	Basin
1	All Alluvium and Basalt (including Main Range Volcanics)	Cenozoic
2	Upper Cretaceous (Griman Creek Formation & Surat Siltstone) and the Condamine-Walloon transition zone	Surat & Clarence-Moreton basins
3	Wallumbilla Formation	
4	Bungil Formation	
5	Mooga Sandstone	
6	Orallo Formation	
7	Gubberamunda Sandstone	
8	Westbourne Formation	
9	Upper Springbok Sandstone	
10	Lower Springbok Sandstone	
11	Walloon Coal Measures non-productive zone	
12	Upper Juandah Coal Measures - Layer 1	
13	Upper Juandah Coal Measures - Layer 2	
14	Lower Juandah Coal Measures - Layer 1	
15	Lower Juandah Coal Measures - Layer 2	
16	Lower Juandah Coal Measures - Layer 3	
17	Taroom Coal Measures	
18	Durabilla Formation	
19	Upper Hutton Sandstone	
20	Lower Hutton Sandstone	
21	Upper Evergreen Formation	
22	Boxvale Sandstone	
23	Lower Evergreen Formation	
24	Precipice Sandstone	
25	Moolayember Formation	Bowen Basin
26	Clematis Group	
27	Rewan Group	
28	Bandanna Formation non-productive zone	
29	Upper Bandanna Formation	
30	Lower Bandanna Formation	
31	Lower Bowen 1	
32	Cattle Creek Formation non-productive zone	
33	Upper Cattle Creek Formation	
34	Lower Cattle Creek Formation	
35	Lower Bowen 2	

Regional aquifer | Partial aquifer | Tight aquifer | Interbedded aquitard | Tight aquitard

OGIA_017

Figure 8.2 Model Layers and Corresponding Hydrostratigraphic Units Represented in the OGIA Regional Groundwater Flow Model (OGIA 2021c)

8.2 Model Parameters, Boundary Conditions and Calibration

The information provided in the following sections has been summarised from the *Groundwater Modelling Report for the Surat Cumulative Management Area* (OGIA 2016d), *Underground Water Impact Report for the Surat CMA* (OGIA 2021f), and *Modelling of cumulative groundwater impacts in the Surat CMA: approach and methods* (OGIA 2021c).

8.2.1 Model Parameters

OGIA improved their approach to assigning initial numerical groundwater model parameters as part of the update to the regional model for the 2016 UWIR (OGIA 2016d) and have continued to further refine the model for the 2021 UWIR (OGIA 2021f).

The approach included three steps, as described in OGIA (2019d):

- Initial values of hydraulic conductivity for each of six lithology types (clean sand, dirty sand, siltstone, mudstone, carbonaceous shale, and coal) from geophysical logs are derived from expert knowledge, literature, and analysis of geophysical logs.
- These initial values are then input to a stochastic permeability model and calibrated (or 'conditioned') through comparison with around 13,000 hydraulic test results at three different scales (i.e. pump tests, core test and geophysical measurement).
- Once calibrated, these values are then used to populate numerical permeameters – detailed 21 x 21 km numerical models of each stratigraphic unit, generated using lithological data for about 6,000 CSG wells and covering the full extent of the 12 stratigraphic units modelled. In total, more than 138,000 model runs were carried out during this part of the process.'

8.2.2 Groundwater Abstraction – Boundary Conditions

Optimal flow conditions for gas production are typically achieved when water pressures within the production well are equivalent to 25 to 80 m of water head (OGIA 2019d). To simulate water production, OGIA have used the MODFLOW-USG 'drain' boundary condition, with multiple drains assigned to each production well descending over time as pressures in the CSG production well reduce. The simulation using the drain boundary condition, is based on the sequencing of development and production well spacing provided by tenure holders across the model domain. Water is removed from the model to achieve the optimal head conditions (25 to 80 m), rather than removing a volume predicted using a modelling tool (e.g. estimated abstraction volume in Section 3.3.1.1).

Groundwater abstraction for non-petroleum and gas purposes, such as stock and domestic, are simulated using the MODFLOW-USG 'well' boundary condition.

8.2.3 Model Calibration

Calibration of the 2021 model was achieved using a three-stage simulation (OGIA 2021c). The first was a pre-development (1947) simulation was to replicate conditions that existed prior to the commencement of any groundwater extraction, for petroleum, gas, or other purposes. The second simulation was to replicate pre-petroleum and gas extraction conditions in 1995 to provide starting or initial conditions for the third and final stage.

The third stage was a transient simulation to replicate the period from January 1995 to December 2020, during which petroleum and gas production commenced initially from the Bandanna Formation and then from the WCM.

The calibration was undertaken using the automated calibration software PEST, with a range of qualitative and quantitative measures used to assess each calibration iteration, consistent with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012).

8.3 Senex Model Scenarios

At the request of Senex, OGIA has simulated a gas field development scenario using the 2021 groundwater model based on production plans provided by Senex. Outputs from this model were used to inform this assessment. The original 2021 UWIR model included the approved APLNG ‘Woleebee’ gas field in PL 445 and PL 209, therefore, this gas field was removed for the modelled scenarios.

These outputs have been provided for use and processed as part of this assessment. All processing and analysis of model outputs was undertaken by KCB based on raw model outputs provided by OGIA.

The modelled scenarios completed by OGIA comprised:

- Cumulative CSG Development without the Project:
  - Cumulative drawdown associated with all CSG and coal mining but *excluding* the Project (ATP 2059, PL 209, and PL 445) and the cancelled APLNG Woleebee gas field.
- Project Development scenarios (2023 until 2045):
  - Drawdown associated with 31 wells on ATP 2059 and 120 wells on PL 445 and PL 209 (total of 151 wells) (Project only) (see section 8.5.1).

Total cumulative drawdown of the Project, plus all other CSG and coal mining projects, is calculated by adding the individual drawdown predicted by the Project only, to the cumulative without project scenario, resulting in a cumulative drawdown scenario for the project development scenario. The modelling results are discussed in section 8.5.2.

8.4 Assumptions and Limitations

Assumptions and limitations of the regional groundwater model are provided in OGIA (2016e). Key assumptions and limitations of the model associated with its use for this assessment are provided as follows:

- Since the model is required to cover the full extent of the Surat CMA and all aquifers potentially impacted by petroleum and gas water extraction within the Surat CMA, groundwater numerical model cell sizes are relatively large in lateral extent (1.5 km × 1.5 km). One outcome of the large cell size is that shallow, unconfined groundwater systems, and the interaction of these systems with deeper systems, can be simulated only approximately.
- Model cell sizes are large in vertical extent. Other than the WCM, most stratigraphic layers in the Surat and Bowen Basins are represented by only one or two model layers. Vertical

head gradients within these layers, and geological details which lead to variations of these gradients, are only an approximation for the entire stratigraphic thickness (i.e. heterogeneity of the stratigraphic unit is not fully captured in the numerical model although considerable efforts were made to generate upscaled parameters and test that the model could replicate impact predictions made using highly detailed models with minimal upscaling).

- Depressurisation of coal measures leading to desorption of gas, and hence the resulting dual phase flow (gas and water), is simulated using a van Genuchten function in which water saturation is a function of pressure alone. This is a simplification of more complex processes that include desorption of gas, and then flow of gas together with water towards extraction centres. Buoyant potential up-dip movement of gas, not captured in CSG production wells, is also not represented.
- The effect of local faulting and abandoned and poorly constructed wells on vertical propagation of drawdown to stratigraphic units adjacent to the WCM units is not currently considered. However, major regional fault systems are represented in both the model structure and parameterisation and hence their effects on impact propagation are considered.
- Limited site-specific hydraulic parameter data is available and therefore the values utilised in the model in the vicinity of the Project have been inferred and calibrated through reference to data outside of the Project area, which may increase / decrease the effects of CSG production, and associated groundwater abstraction, within the Project area.
- CSG production is represented by drain boundary conditions with elevations set for optimal gas production. As a result, the produced volume of water from the drain cells may not necessarily represent actual CSG water production due to localised variability in aquifer hydraulic parameters. The model, however, has been calibrated to historic actual production data and is able to replicate production in most current fields to a high degree of accuracy.

8.5 Modelling Results

8.5.1 Project Only Scenario Results

Numerical model outputs provided by OGIA, for the scenarios detailed in the previous section, have been used by KCB to assess the potential extent and magnitude of drawdown related to CSG production from the Project.

Appendix III includes the predicted drawdown for the individual model layers, which represent the modelled hydrostratigraphic units (detailed in Figure 8.2). The figures in Appendix III present the drawdown during field development and post-development. Summary figures are presented in Figure 8.3 and Figure 8.4 showing the maximum Project only predicted drawdown (for the model duration). Observations include:

- Drawdown greater than 0.2 m (spring trigger threshold) is predicted in model layer 8 (Westbourne Formation) to model layer 18 (Durabilla Formation).
- Drawdown greater than 5 m (consolidated bore trigger threshold) is predicted in model layers 10 to 18 (Lower Springbok Sandstone to Durabilla Formation).

- The highest drawdown is predicted in model layer 17, which represents the Taroom Coal Measures.
- Drawdown within the Upper Juandah Coal Measures Layer 2 (model layer 13) has the widest drawdown extent: 13.1 km beyond of the Project area extent.

As indicated, Appendix III presents the predicted drawdown during field development and post-development. The post-development timesteps presented are for 2060 (~10-years since end of CSG production), 2100 (50-years since end of CSG production) and 2300 (250-years since end of CSG production. These figures show groundwater level recovery within the WCM, and in the later timesteps, the propagation of drawdown in the overlying / underlying layers.

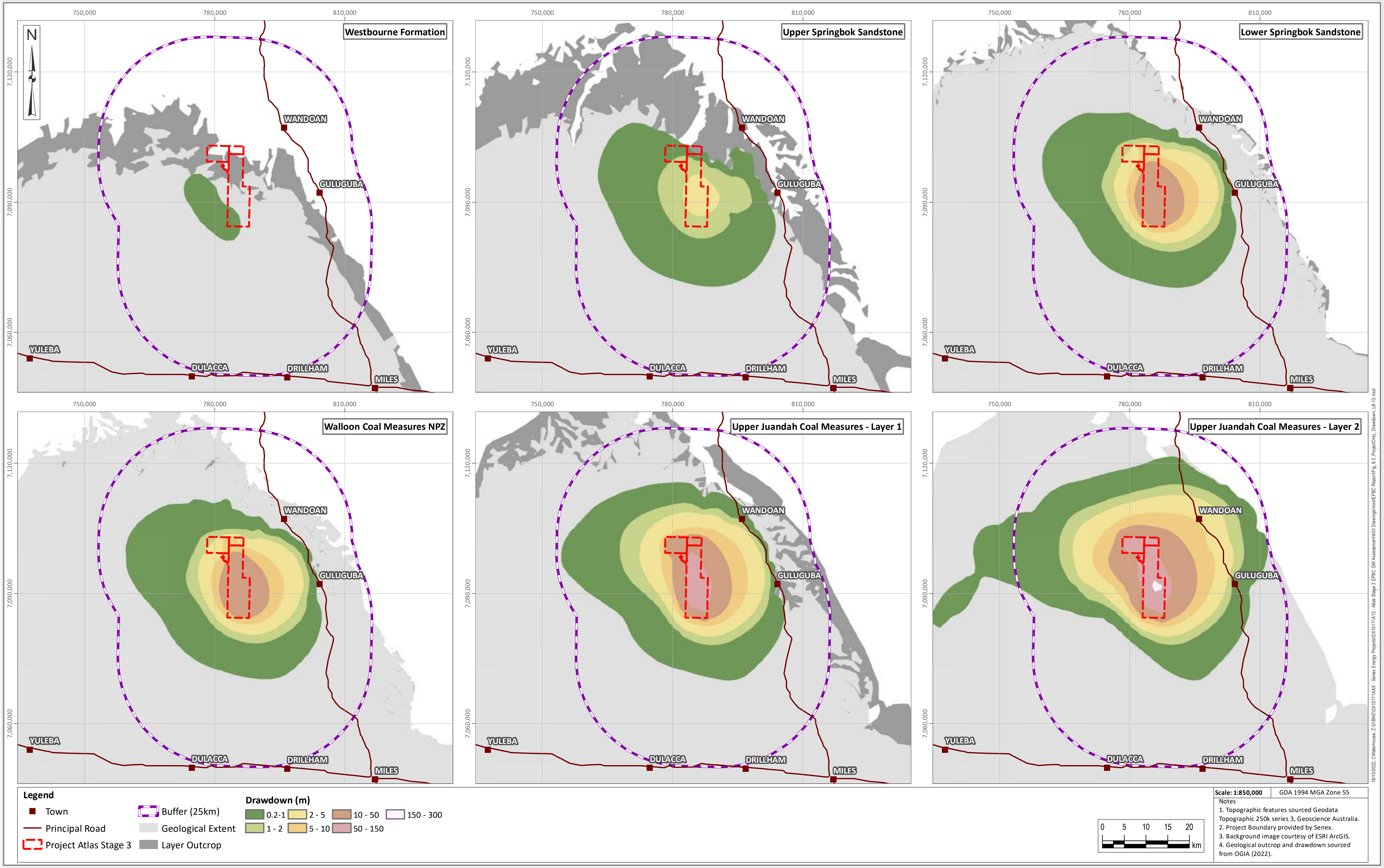


Figure 8.3 Extent of Project Only Maximum Predicted Drawdown for Model Layers 8 to 13 – Westbourne Formation to Upper Juandah Coal Measures – Layer 2

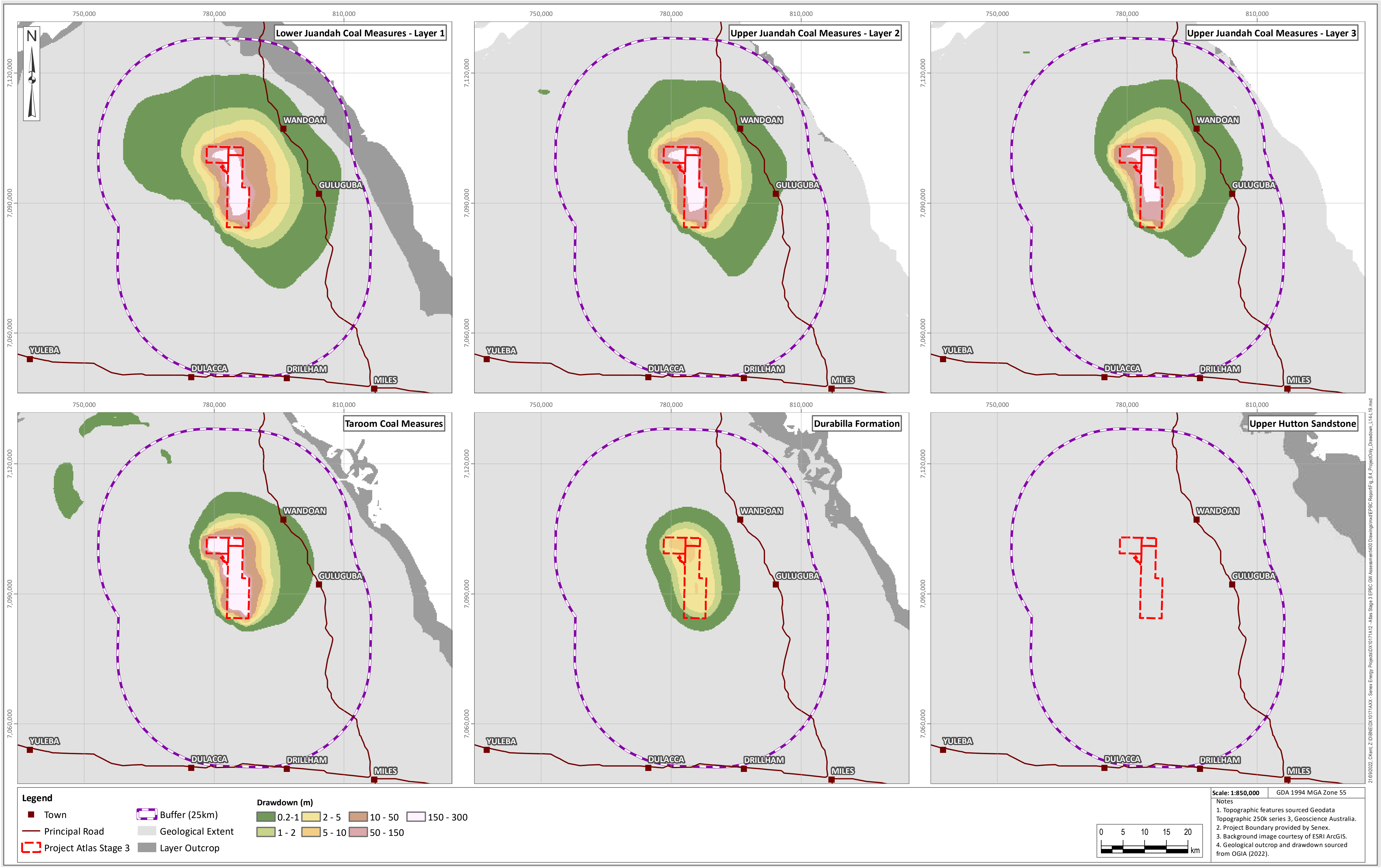


Figure 8.4 Extent of Project Only Maximum Predicted Drawdown Model Layers 14 to 19 – Lower Juandah Coal Measures – Layer 1 to Upper Hutton Sandstone

8.5.2 Cumulative Scenario Results

Drawdown results for the cumulative scenario, focused on the Project area, are presented in Appendix IV for individual modelled hydrostratigraphic units. Summary figures for the cumulative scenario are presented in Figure 8.5 and Figure 8.6. These figures show the maximum predicted cumulative drawdown for the modelled duration.

The cumulative drawdown results indicate drawdown within the vicinity of the Project area for the Westbourne Formation, Springbok Sandstone, WCM and Hutton Sandstone. The majority of the drawdown occurs towards the west of the Project, associated with neighbouring CSG developments. Drawdown also occurs to the southeast, where other CSG proponents are also operating.

The post-development timesteps for cumulative drawdown for the various hydrostratigraphic units are presented in Appendix IV. These timesteps include 2060 (10-years since end of CSG production), 2100 (50-years since end of CSG production) and 2300 (250-years since end of CSG production). Like the Project only, the figures show groundwater level recovery within the WCM; and, in the later timesteps, the propagation of drawdown in the overlying / underlying layers.

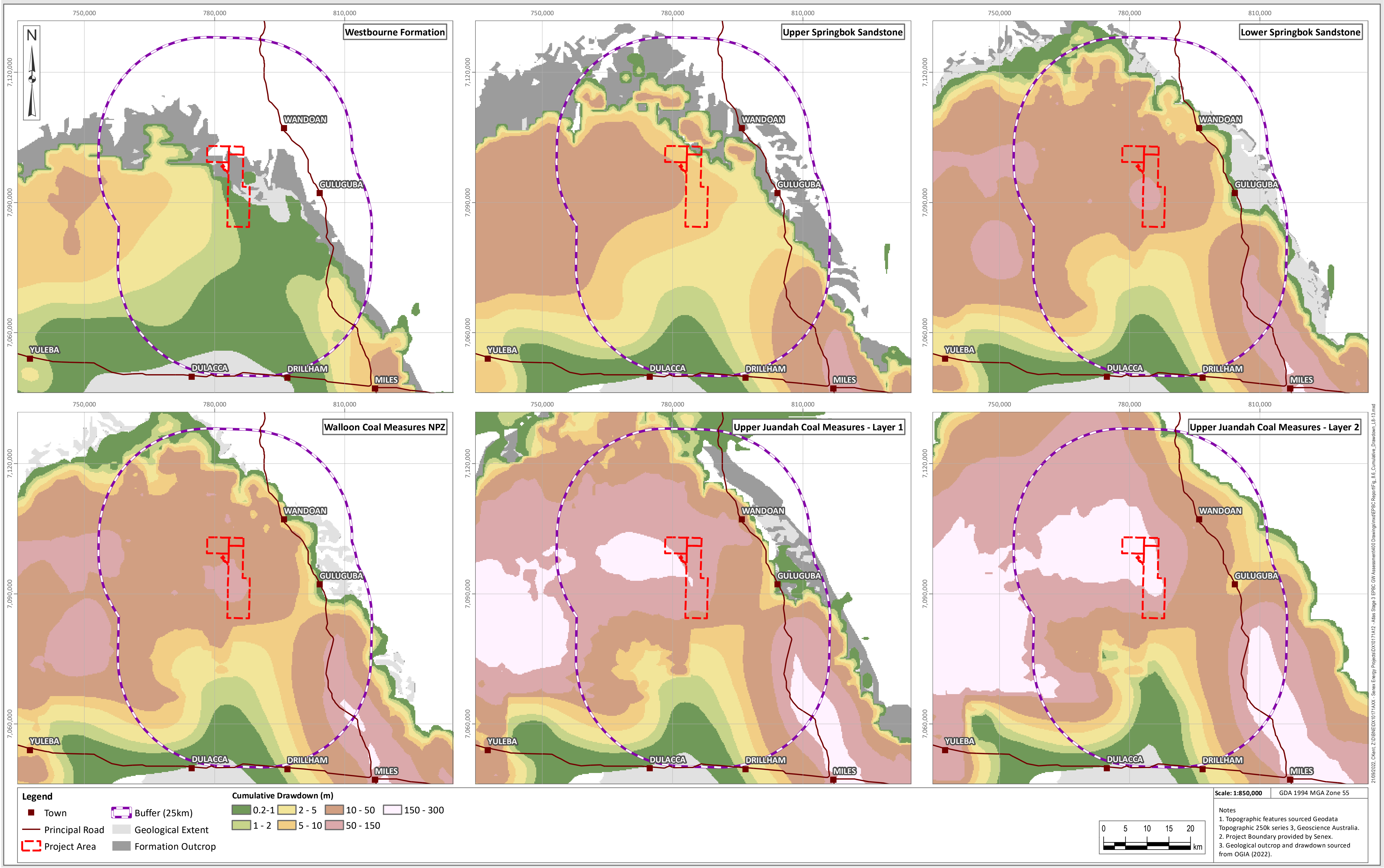


Figure 8.5 Extent of Cumulative Maximum Predicted Drawdown for Model Layers 8 - 13 Westbourne Formation to Upper Juandah Coal Measures – Layer 2

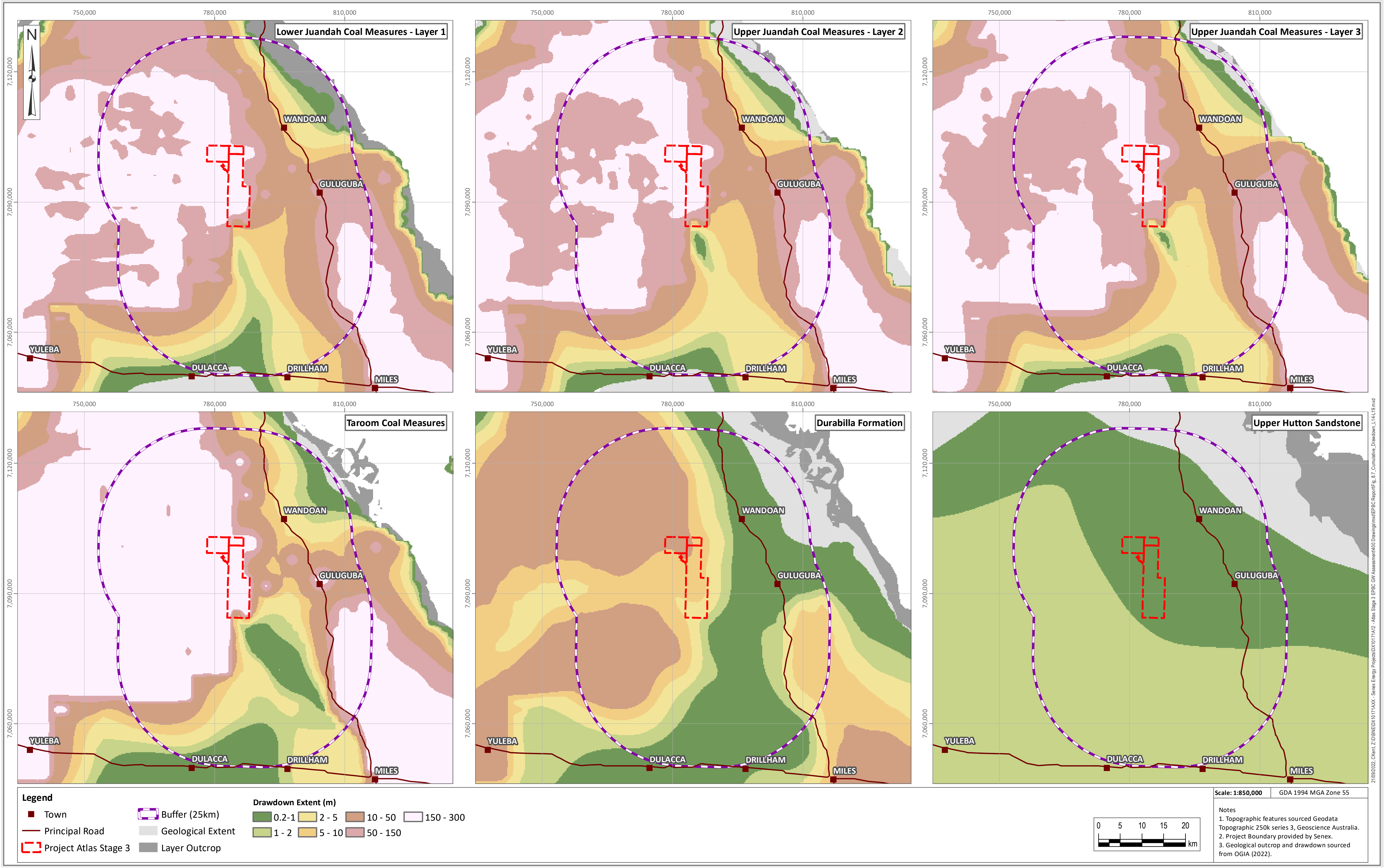


Figure 8.6 Extent of Cumulative Maximum Predicted Drawdown for Model Layers 14 to 19 – Lower Juandah Coal Measures – Layer 1 to Upper Hutton Sandstone

Project Contribution to Cumulative Scenario

The proportion of cumulative drawdown which can be attributed to the Project was quantified (Figure 8.7). Most areas with >10% contribution to cumulative drawdown is restricted to the Project and immediate surrounding areas. The greatest contribution from the Project is in the vicinity of, and directly east of PL 209.

The formations other than the WCM which are expected to exhibit the largest proportion to cumulative drawdown (up to 80%) are the Lower Springbok Sandstone and the Durabilla Formation. The formations which are expected to exhibit the smallest proportion to cumulative drawdown (up to 30%) are the Upper Springbok Sandstone and the Westbourne Formation.

The majority of areas within the 25 Km buffer zone are expected to contribute <10% to regional cumulative drawdown.

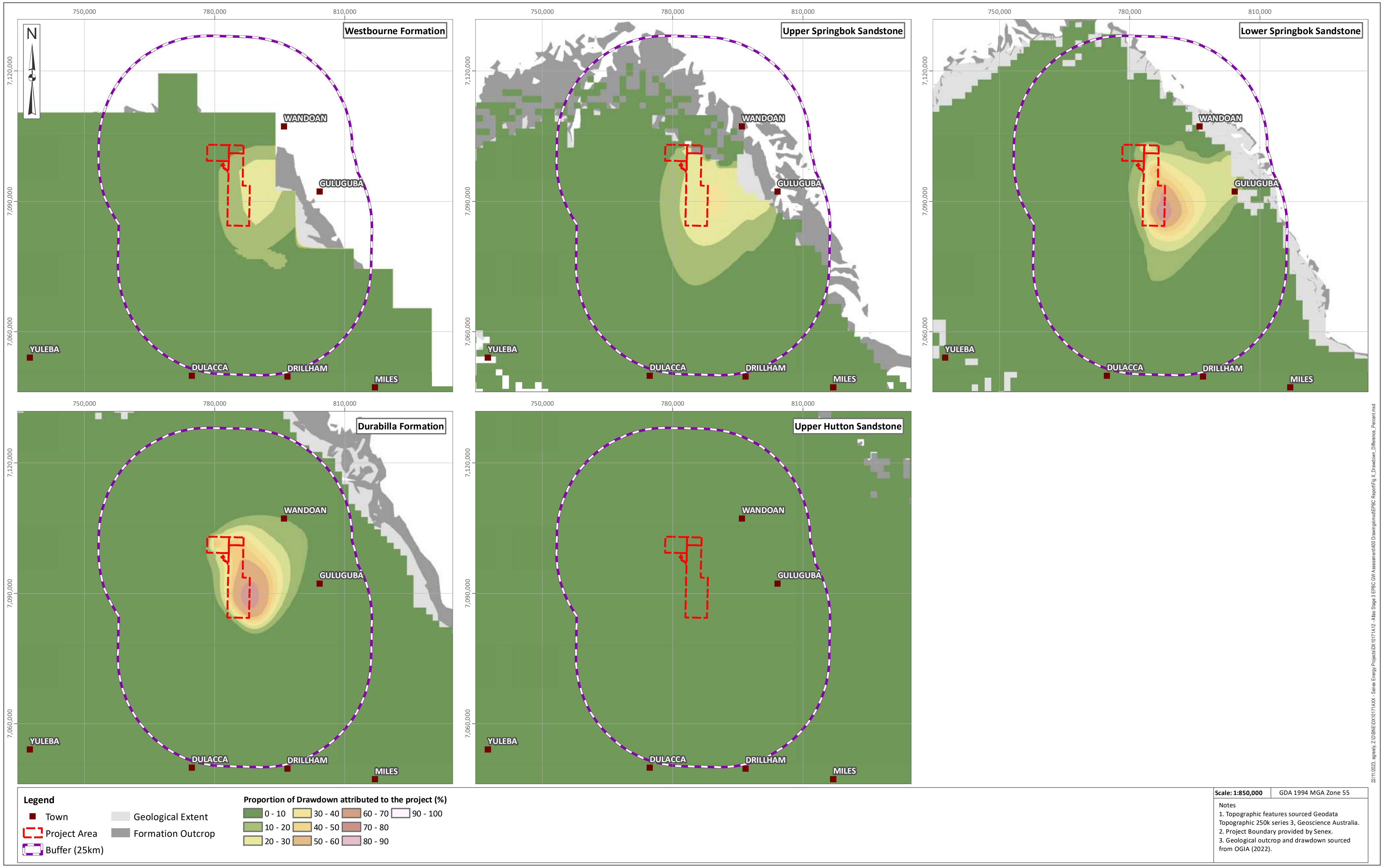


Figure 8.7 Proportion of Cumulative Drawdown which can be Attributed To the Project

8.6 Uncertainty Analysis

As part of the 2021 UWIR model, OGIA have undertaken predictive uncertainty analysis on the model simulations. Potential uncertainties in groundwater flow model predictions have been assessed using a 'null space Monte Carlo' (NSMC) methodology, which is identified in the IESC explanatory note (Middlemis and Peeters 2018) as being the most complex of the three levels of uncertainty analysis outlined. This methodology involves the development of a suite of 550 parameter fields, constrained to the parameter calibration range, and were applied to the model resulting in 550 NSMC simulations. The maximum simulated drawdown from each model cell was determined for each of the 550 NSMC simulations to assess the drawdown impacts for the proposed development. Statistical analyses of the 550 NSMC simulations were undertaken to identify the 5th percentile (P5), median (P50) and 95th (P95) percentile maximum impact drawdown from the Project.

The maximum drawdown maps for key model layers in the vicinity of the Project tenure for P5, P50, and P95 NSMC simulation results are presented in Appendix V[5]. For clarification, the P5 maximum impact drawdown represents a drawdown level where, conceptually, there is a 5% probability that the maximum impact drawdown will be lower than these values; and, for the P95 maximum impact drawdown, there is a 95% probability that the maximum impact drawdown will be less than these values.

The uncertainty analysis identifies:

- There is no incremental change in the cumulative or project specific long-term affected area drawdowns predictions for the Gubberamunda Sandstone or the Westbourne Formation.
- Drawdown predicted in the alluvium and Upper Hutton Sandstone is <0.2 m.
- The key formation of interest is the Upper Springbok Sandstone (Layer 9), due to the presence of potential GDEs on the outcrop. These potential GDEs are located within PL 445 and to the northeast of the Project area and are considered to be supported by groundwater and/or pore water in the alluvium (as discussed in Section 7.10).
    - In comparison to the P50 drawdown, the P95 drawdown in the Upper Springbok Sandstone extends further to the south (where the Springbok Sandstone is present at depth) and to the northeast.
    - The P95 scenario predicts additional drawdown, in comparison to the P50 drawdown, at potential GDE locations on the Springbok Sandstone outcrop, with a maximum drawdown of 1.6 m on PL 445 (P50 scenario predicts 0.9 m of drawdown at this location). This location is predicted to experience up to 4.57 m of cumulative drawdown for the P50 prediction.

[5] The WCM non-productive zone (Layer 11) and the Durabilla Formation (Layer 18) uncertainty drawdown results were not provided by OGIA as they are classed as aquitards and are not targeted for water supply or sustain GDEs.

9 IMPACT ASSESSMENT

9.1 Key Potential Impacts

A detailed assessment of impacts to water resources, both directly and indirectly from the proposed Project, has been undertaken. The proposed action may result in the following impacts:

- Chemical contamination;
- Changes to hydrological regimes;
- Changes to water quality;
- Groundwater drawdown and associated impacts on:
  - Groundwater dependent ecosystems; and
  - Third-party bores;
- Subsidence; and
- Cumulative impacts with other CSG operations in the region.

These impacts have been assessed and are discussed in more detail in the following sections.

A 'Source-Pathway-Receptor' impact pathway diagram was developed for the Project (Figure 9.1) which includes the following potential impacts to water receptors:

- Groundwater depressurisation – drawdown of groundwater levels in landholder bores and at GDEs.
- Surface water storage facilities – seepage to shallow groundwater systems, leaks, overtopping to surface water systems.
- Use of chemicals through drilling – spills to surface water systems, invasion risks to shallow and deeper groundwater systems.
- Subsidence – change to ground level which may result in altered overland flows and changes to surface water systems and ecosystems.
- Presence of infrastructure – alteration to overland flow and flood flows.

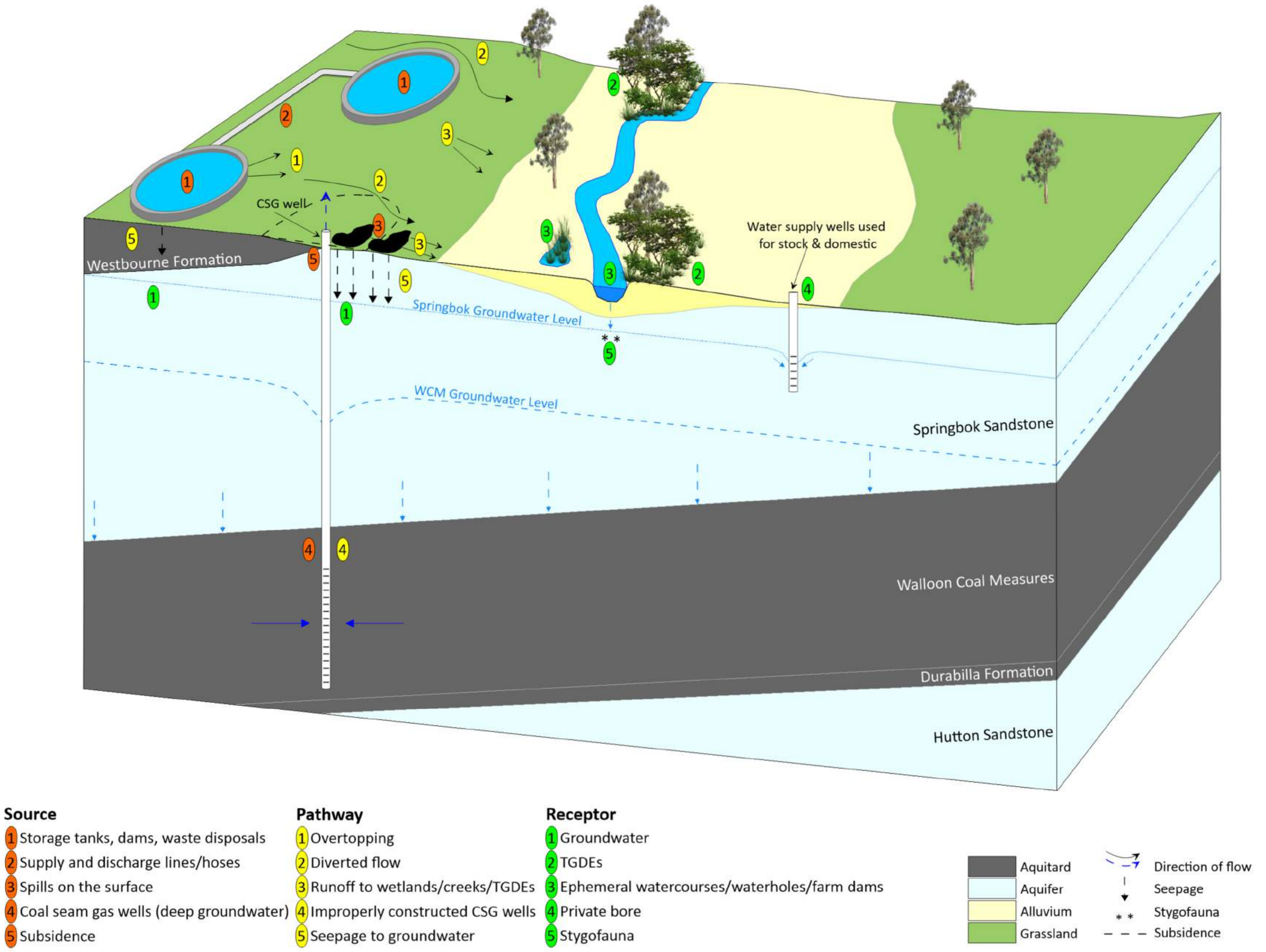


Figure 9.1 Source-Pathway-Receptor Impact Diagram for the Atlas Stage 3 Project

9.2 Chemical Contamination

Potential chemical contamination may occur due to the use of drilling fluids, and seepage of produced water or brine from water storage facilities.

A chemical risk assessment has been undertaken for chemicals to be used as part of the CSG production during the Project development (KCB 2023a). The assessment examined the risks associated with the use of drilling fluids and their associated chemicals and followed the chemical risk assessment framework (CRAF). It was determined that the risk to the MNES receptors from drilling fluids were limited to above ground chemical spills, the infiltration of chemicals to aquifers below ground (downhole) during well installation, operation, and abandonment, and the eventual disposal of the drilling fluids.

Hydraulic fracturing is not proposed for this Project.

The risk to MNES receptors from drilling fluids was determined both prior to, and following, mitigation and management measures. The risk assessment concluded that the likelihood for a drilling fluid to adversely affect an MNES is unlikely to highly unlikely when management and mitigation protocols are followed. This is due to the proposed controls that will be implemented during drilling and the protocols in place if a spill should occur. The overall risk to MNES from chemical contamination has been assessed as low significance to insignificant.

The chemical risk assessment is undertaken in accordance with leading industry practice risk assessment methodologies both internationally and domestically, which meets the DCCEEW "best practice" requirement. The best practice national and international standards and guidelines include:

- The Organisation for Economic Co-operation and Development (OECD) Manual for Assessment Toolkit (OECD 2014).
- AS/NZS 4360:2004: Risk Management and AS/NZS ISO 31000:2009 Risk Management – Principals and Guidelines (AS/NZS 2004; 2009).

Current "best practice" guidance includes:

- Exposure Draft: Chemical Risk Assessment Guidance Manual: for chemicals associated with coal seam gas extraction (DoEE 2017).
- Industrial Chemicals Notifications and Assessment Scheme (NICNAS) and approach used for industrial chemicals.

A Chemical Risk Assessment Framework (CRAF) has been developed to assess the risk of chemicals used in CSG operations (drilling and completion and water treatment) within the Atlas Stage 3 Project area. The CRAF incorporates current leading industry practice risk assessment methodology for the assessment of the potential impacts of the chemicals proposed to be used in, or arising from, CSG operations on MNES.

MNES present in the Project area, and potential sensitive receptors, include threatened ecological communities such as Brigalow and Poplar Box Grassy Woodland. Nationally threatened fauna species confirmed to occur in the Project area include the Greater Glider (*Petauroides volans*), while threatened flora species include Ooline (*Cadellia pentastylis*). Several trees with scratches that may possibly have been caused by Koala (*Phascolarctos cinereus*) were also recorded in the Project area. An additional two threatened flora species and an additional two fauna species are likely to be present, and fourteen fauna species potentially occur in the Project area. Water resources of interest include the Surat Basin aquifers such as the Springbok Sandstone and the Gubberamunda Sandstone and their groundwater users, ephemeral surface water systems and GDEs.

It was determined that the risk to the MNES receptors from drilling fluids were limited to above ground chemical spills, the infiltration of chemicals to aquifers below ground, and the eventual disposal of the drilling fluids.

Flowback water is treated in the same way as produced water. On completion of the well, it is immediately connected to the main gathering system and is transported to the produced water facility at Lara where it is treated and stored.

Senex propose to apply a number of management and mitigation measures to reduce the risk to MNES. These include drilling protocols such as the *Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland* (State of Queensland 2019a), and environmental management practices such as the Atlas Stage 3 Environmental Constraints Protocol for Planning and Field Development (OPS-ATLS-EN-PLN-001; Senex 2023a), Environmental Management Plan (Senex 2023c), CSG Water Management Plan (ATP 2059: SENEX-ATLS-EN-PLN-013; PL 445 and PL 209: SENEX-ATLS-EN-PLN-14) and a Spill Response Plan (SENEX-CORP-ER-PLN-006; Senex 2017).The likelihood of chemical migration from the CSG production well is considered highly unlikely due to the following:

- Drilling, construction and well maintenance activities are short term and not persistant;
- Quantities are restricted to maintain optimal conditions;
- Drilling chemicals are designed to maintain CSG well integrity and limit fluid losses;
- Operational groundwater pumping associated with CSG extraction will develop a groundwater pressure gradient towards the well, inducing groundwater flow towards the well. For contaminant migration to occur, groundwater flow would need to be away from the well;
- Tight aquitard sediments of the Westbourne Formation, where present, act as a barrier to mitigate migration pathways downwards into more important aquifer systems.

The risk to MNES receptors from drilling fluids was determined both prior to, and following, mitigation and management measures. The final risk assessment determined that the likelihood for a drilling fluid to adversely affect an MNES is **highly unlikely** to **unlikely** due to the proposed controls that will be implemented during drilling and the protocols in place if a spill did occur. The overall risk to MNES has been assessed as **low significance** to **insignificant**.

9.3 Changes to Hydrological Regimes

Potential impacts likely to result from Project activities to the hydrological system are summarised below. These potential impacts are associated with the general construction and day to day operations of CSG surface facilities rather than CSG production; and could comprise:

- Localised transport of suspended sediment to waters during construction or site works, resulting in the potential to alter flow regimes and quality;
- Localised release of hydrotest water, effluent, or trench water to land (these fluids are not intended for release to the surface water system so has limited potential for any impact to surface water quality);
- Alteration of a watercourse character or changes to riparian buffers due to construction works;
- Unplanned releases from water storage facilities have the potential to impact surface water and associated ecosystems; and
- Fuel and chemicals will be used as part of the Project, with the potential for unplanned release that could impact surface water quality.

No discernible impacts to surface water and associated aquatic systems and environmental values from the Project are anticipated. The Project does not include any:

- Planned discharge to / abstraction from the surface water systems; or
- Surface water diversions.

There are no surface water users identified within the vicinity or immediately downstream of the Project. Therefore, no impacts to third-party surface water users are predicted as a result of the Project development.

Regardless of the low potential for impact, monitoring, mitigation and management plans will be implemented to address any risks that my develop during operations. Further discussion of these management plans is included in the Section 10.

9.3.1 Impacts to Third-Party Surface Water Users

There are no surface water users identified within the vicinity or immediately downstream of the Project, therefore, no impacts to third-party surface water users are predicted as a result of the Project development.

9.4 Changes to Water Quality

Potential changes to groundwater quality as a result of Project development activities may relate to the use of drilling fluids and seepage from water storage facilities.

Potential changes to surface water quality from Project activities relate to the use of drilling fluids, surface spills, localised transport of suspended sediment to waters during construction or site works, or unplanned releases (storage tank failure) or overtopping from water storage facilities.

Impacts to water quality related to the use of chemicals by the Project are discussed in the Chemical Risk Assessment (KCB 2023a). These impacts are managed through monitoring, mitigation and management discussed in Section 10. Based on the assessment results, changes to groundwater or surface water quality are unlikely and are not predicted as a result of the Project.

Impacts to water quality, related to the use of chemicals by the Project, are discussed in the Chemical Risk Assessment (KCB 2023a). Monitoring, management and mitigation measures are discussed in the Chemical Risk Assessment Framework (Appendix I of the Chemical Risk

Assessment). Management and mitigation controls will be implemented to ensure the potential risks with the use of drilling additives have been eliminated or reduced to as low as reasonably practicable. There are a number of key Senex management documents including the Environmental Protocol for Field Development and Constraints Analysis (SENEX-CORP-EN-PRC-019), the Environmental Management Plan (SENEX-ATLS-EN-PLN-001), the Spill Response Plan (SENEX-CORP-ER-PLN-006) and the Water Monitoring and Management Plan (SENEX-ATLS-EN-PLN-017). Based on the assessment results, changes to groundwater or surface water quality are not predicted as a result of the Project development. This is a proven approach based on the adjacent Project Atlas tenement.

9.5 Groundwater Drawdown and Associated Impacts

CSG water production occurs as part of the CSG production process. Groundwater is removed via CSG wells during the process of depressurisation of the coal seams, which then liberates gas flow. This depressurisation and gas flow sustains a groundwater flow from each well to maintain the target gas producing operational pressure.

Senex intend to exercise their underground water rights under the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020d) to produce CSG. Several other authorised petroleum lease holders are also exercising their underground water rights in the vicinity of the Project.

Potential impacts resulting from CSG water production include:

- Decline in groundwater level / pressure at water bores, reducing water availability and potentially impacting groundwater EVs.
- Reduction in groundwater head resulting in a reduction of groundwater discharge at spring complexes, potentially causing degradation of GDEs.
- Reduction of baseflow to watercourses, potentially resulting in degradation of GDEs and reduced water availability to potential users downstream.

These impacts have been quantitatively assessed in the following sections using modelling outputs from the UWIR 2021 numerical groundwater model. Potential impacts to water-dependent assets have been assessed based on the Queensland *Water Act 2000* trigger threshold for springs (0.2 m drawdown) and bores (5 m drawdown in consolidated aquifer; 2 m drawdown in unconsolidated aquifer) using the predicted drawdown for both the ‘Project only’ and ‘Cumulative’ scenarios.

Other potential impacts associated with groundwater are mitigated and managed by adopting the appropriate monitoring, management, and mitigation strategies. These impacts may include:

- Potential to introduce a connection between hydrostratigraphic units which were previously isolated units though drilling and construction of CSG production wells, resulting in the potential for alteration of flow regimes and quality.
- Drilling fluids are also used during the drilling process, which have the potential to impact groundwater quality.
- CSG produced water storage facilities also have the potential to impact groundwater levels and quality, through seepage from the storage dams.

- Localised incidental CSG activities have the potential to impact shallow groundwater systems, such as fuel spills or improper storage of chemicals.
- Beneficial use activities have the potential to impact shallow groundwater systems should over-irrigating occur, or the relevant beneficial use quality guidelines not be adhered to.
- Potential impacts such as an increased demand in groundwater use as a result of the Project (e.g. from the establishment of site camps) are not anticipated. Small camp facilities may be located within the Project area, however the majority of the personnel for the operations will utilise accommodation in Wandoan.

Monitoring, management, and mitigation practices associated with the above activities are discussed further in Section 9.9. A risk assessment, which considers these potential impacts is provided in Section 9.8.

9.5.1 Groundwater Dependent Ecosystems

Impacts to potential GDEs can occur if the following conditions are met:

- Potential GDEs have been identified in the area;
- The potential GDEs are located on a GAB aquifer outcrop/sub-crop;
- It is confirmed that the potential GDEs are sourcing water from the GAB aquifer or the GDEs are sourcing water from an alluvial system connected to a GAB aquifer. Evidence to suggest a connection include:
  - Hydraulic evidence including groundwater levels in the underlying GAB aquifer are in connection with the alluvium or there is sufficient water in the alluvium to support the potential GDE.
  - Water quality in the GAB aquifer is suitable for GDEs to survive.
- Drawdown of >0.2 m is predicted in the GAB aquifer due to the presence of the Project.

There are outcropping geological formations in the Project area which have the potential for connection to aquatic and terrestrial GDEs, either directly, or through connections to overlying alluvial deposits.

The areas of interest for assessment of impacts to GDEs are the outcrop areas of:

- Upper Springbok Sandstone – this unit outcrops under PL 445 and to the north / northeast of PL 445 and PL 209.
- Westbourne Formation – this unit outcrops under PL 445 and PL 209.
- Gubberamunda Sandstone – this unit outcrops under PL 209.

Areas of interest were identified by the 0.2 m drawdown or greater extent for each outcrop formation. Potential drawdown greater than 0.2 m in these outcropping geological units have been overlain with the locations of potential GDEs and watercourse springs from the Queensland GDE mapping (State of Queensland 2018a) and field verification by ERM ecologists for GDEs located within the Project area.

In summary:

- Drawdown of more than 0.2 m is not predicted for the Gubberamunda Sandstone for the Project only scenario, and cumulatively, the Project does not contribute to any additional potential GDE areas exceeding the 0.2 m trigger. Potential GDEs on the Gubberamunda Sandstone are not considered further in the GDE assessment.
- Project only drawdown in the Westbourne Formation is predicted to be less than 0.2 m on any Westbourne Formation outcrops. The Project does contribute cumulatively to additional drawdown in the outcrop area of the Westbourne Formation (<1%). This occurs in a small area of the Westbourne Formation outcrop in PL 1037 (Atlas) and neighbouring tenement PL 277 (QGC) to the west.
- The groundwater in the Upper Springbok Sandstone outcrop area is predicted to have a drawdown greater than 0.2 m due to the proposed Project development (Project only simulation), resulting in this formation being the main formation of concern for this GDE impact assessment.
- Drawdown <= 0.2 m in the underlying GAB units is insufficient to induce flow > 0.2 m from overlying units, including the alluvium.

Impacts to Watercourse Springs

OGIA has identified the potential for watercourse springs on-tenement along Woleebee Creek (Section 7.11). These locations and aquifer attributions are:

- W279 – alluvium;
- W280 – alluvium/Gubberamunda Formation; and
- W281 – alluvium/Orallo Formation.

These areas of potential watercourse springs have been assessed against the *Water Act 2000* spring trigger threshold of 0.2 m using the drawdown predictions from the UWIR numerical model. The Project only scenario does not result in drawdown at these locations in the potential source aquifers. The predicted cumulative drawdown is also <0.2 m. The results indicate that there is no drawdown predicted in the attributed source aquifer(s) at these locations and therefore the spring trigger threshold is not exceeded. Project only drawdown of more than 0.2 m is not predicted for OGIA watercourse springs identified along Juandah Creek 15 km east of PL 445.

Woleebee and Wandoan Creeks are not identified to be baseflow fed with hydraulic and geochemical evidence indicating that these creek systems are ‘losing streams’ to the underlying alluvium / bedrock outcrops within the creeks during periods of rainfall and creek flow.

No drawdown is predicted at the location of identified watercourse springs and therefore the spring trigger threshold is not predicted to be exceeded and no discernible impacts to the springs are predicted.

Impacts to Aquatic GDEs Areas

There are three potential aquatic GDEs of interest within, or close to, the Project area. These aquatic GDEs are defined by the Queensland GDE mapping as being sourced by Quaternary alluvial aquifers overlying sandstone ranges with fresh, intermittent groundwater connectivity;

and with moderate confidence in their presence (State of Queensland 2018a). The locations and summary of predicted drawdown is presented in Figure 9.2 and Table 9.1.

Two of the mapped aquatic GDEs located within the Project area are located on the Westbourne Formation outcrop which is not predicted to experience drawdown greater than 0.2 m (for any predictive model scenario) (No. 1 and No. 2 in Table 9.1 and Figure 9.2). The alluvium overlying the Westbourne Formation is also not predicted to drawdown greater than 0.2 m as the drawdown in the Westbourne Formation below the alluvium is not predicted to drawdown greater than 0.2 m.

The aquatic GDE to the north of PL 445, is located on the Springbok Sandstone outcrop. Without the development of the Project, drawdown in the Upper Springbok Sandstone, of up to 19.7 m, is predicted at this location due to surrounding resource development activities. This drawdown is predicted to be due to the proposed development of the Wandoan Coal Project. The GDE is located directly adjacent to a planned area of disturbance (Wandoan Coal Project lease area, see Figure 3.1). The alluvium overlying the Springbok Sandstone is not predicted to experience drawdown resulting from the development of the Project.

The predicted drawdown in the alluvium or Westbourne Formation from the development of the Project (only), at the location of aquatic GDEs of interest, is predicted to be less than the 0.2 m trigger.

Table 9.1 Predicted Drawdown at Aquatic GDEs Areas of Interest

No.	GDE Rule ID	Location	Source Aquifer[1]	Project Only Development Scenario Drawdown (m)	Cumulative with Project (m)	Proportional Drawdown Contribution of the Project (%)
1	SURAT_RS_01A	ATP 2059	Alluvium	0.00	0.08	-
			Westbourne Formation	0.00	0.00	-
2	SURAT_RS_01A	PL 209	Alluvium	0.00	0.09	-
			Westbourne Formation	0.00	0.00	-
3	SURAT_RS_01A	1.8 km north of PL 445	Alluvium	0.00	0.08	-
			Upper Springbok	0.12	19.71	0.6

1. Source aquifer as defined by the Queensland GDE mapping and GDE Rule ID dataset.

Based on site-specific groundwater data these potential aquatic GDE areas are not sourcing groundwater from the deeper GAB units of the Westbourne Formation and Upper Springbok Sandstone and are more likely to be dependent on the sporadic discontinuous saturation of alluvium. The alluvium is recharged and replenished by surface water during prolonged periods of rainfall and during periods of sustained creek flow; this theory is supported by both collected water quality and hydraulic data. This is discussed in Section 7 and discussed further below in the discussion on impacts to potential terrestrial GDEs.

Reaches of Woleebee Creek within PL 1037 were assessed during field verification in 2018 (KCB 2018b, Appendix IX). The 2018 field verification, and 2022/2023 groundwater monitoring bore drilling confirmed that baseflow to this creek is unlikely. As described in Section 6.9, these ephemeral creeks are of low diversity and of non-conservation significant aquatic fauna and flora, and further, lack suitable habitat for EVNT aquatic species.

Impacts to aquatic ecosystems are expected to be minimal and will be managed through implementation of the appropriate management, mitigation and monitoring practices associated with construction and operation, which are detailed in Section 9.9. Based on the characteristics of the aquatic GDEs present (as described in Section 6.9) a change of less than 0.2 m is unlikely to affect those species that are present or the ecological function of these ecosystems (ERM 2022a). Impacts to threatened EPBC-listed aquatic species are considered unlikely.

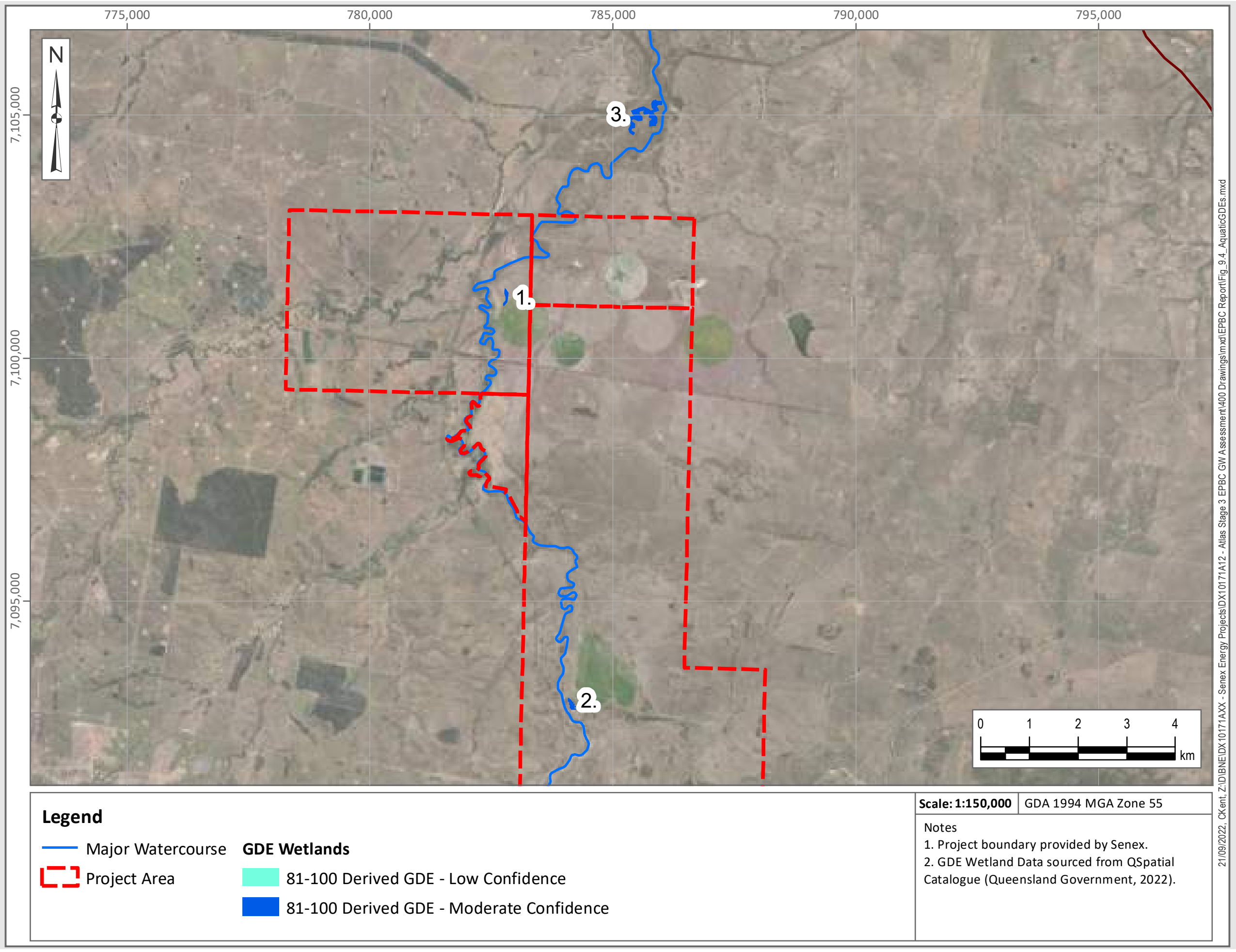


Figure 9.2 Aquatic GDEs of Interest within the Vicinity of the Project

Impacts to Terrestrial GDEs

Westbourne Formation

- There are no terrestrial GDEs mapped within the predicted 0.2 m **Project only** drawdown extent of the Westbourne Formation outcrop.

Drawdown of greater than the 0.2 m trigger at potential terrestrial GDE areas on the Westbourne Formation outcrop is not predicted for the Project (only) development.

- There is only one potential terrestrial GDE mapped on the Westbourne Formation outcrop within the predicted 0.2 m **cumulative** drawdown extent (Figure 9.3 and Table 9.2).

Predicted (Project Only and cumulative) drawdown in the alluvium, the likely source aquifer for the terrestrial GDE at this location, is less than the 0.2 m drawdown trigger. The underlying Westbourne Formation at the location of this potential GDE is predicted to experience drawdown of more than 0.2 m without the presence of the Project, with a predicted cumulative drawdown of 2.6 m. The Project contribution to this cumulative drawdown is ~6 %. Due to the nature of the Westbourne Formation, being an aquitard, any depressurisation of this unit is unlikely to propagate to the potential GDE at the surface.

This terrestrial GDE is located on PL 277 (QGC) ~2.7 km west of ATP 2059 and described as a 'treed regional ecosystem with alluvia on fresh, intermittent flow'. This GDE has an assigned GDE rule of Surat_RS_01C, and there is low confidence of its dependence on groundwater (State of Queensland 2018a). The dominant RE is identified as 11.3.25, which is *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines. The average rooting depth for species of Eucalyptus present at the Project area is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits. The groundwater source for this GDE is described as 'Quaternary alluvial aquifers with a fresh, intermittent groundwater connectivity regime' and 'shallow alluvial, local, unconfined, and unconsolidated'.

Table 9.2 Terrestrial GDEs within the Predicted >0.2 m Drawdown Extent on the Westbourne Formation Outcrop

Location	GDE Rule ID	Source Aquifer	Project Only Development Scenario Drawdown (m)	Cumulative with Project (m)	Proportional Drawdown Contribution of the Project (%)	Area Of Potentially Affected GDE (km²)
~2.7 km west PL 277	Surat_RS_01C	Alluvium	0.00	0.09	-	-
		Westbourne Formation	0.19	3.68	5.16	0.09
			0.16	2.60	6.15	0.27

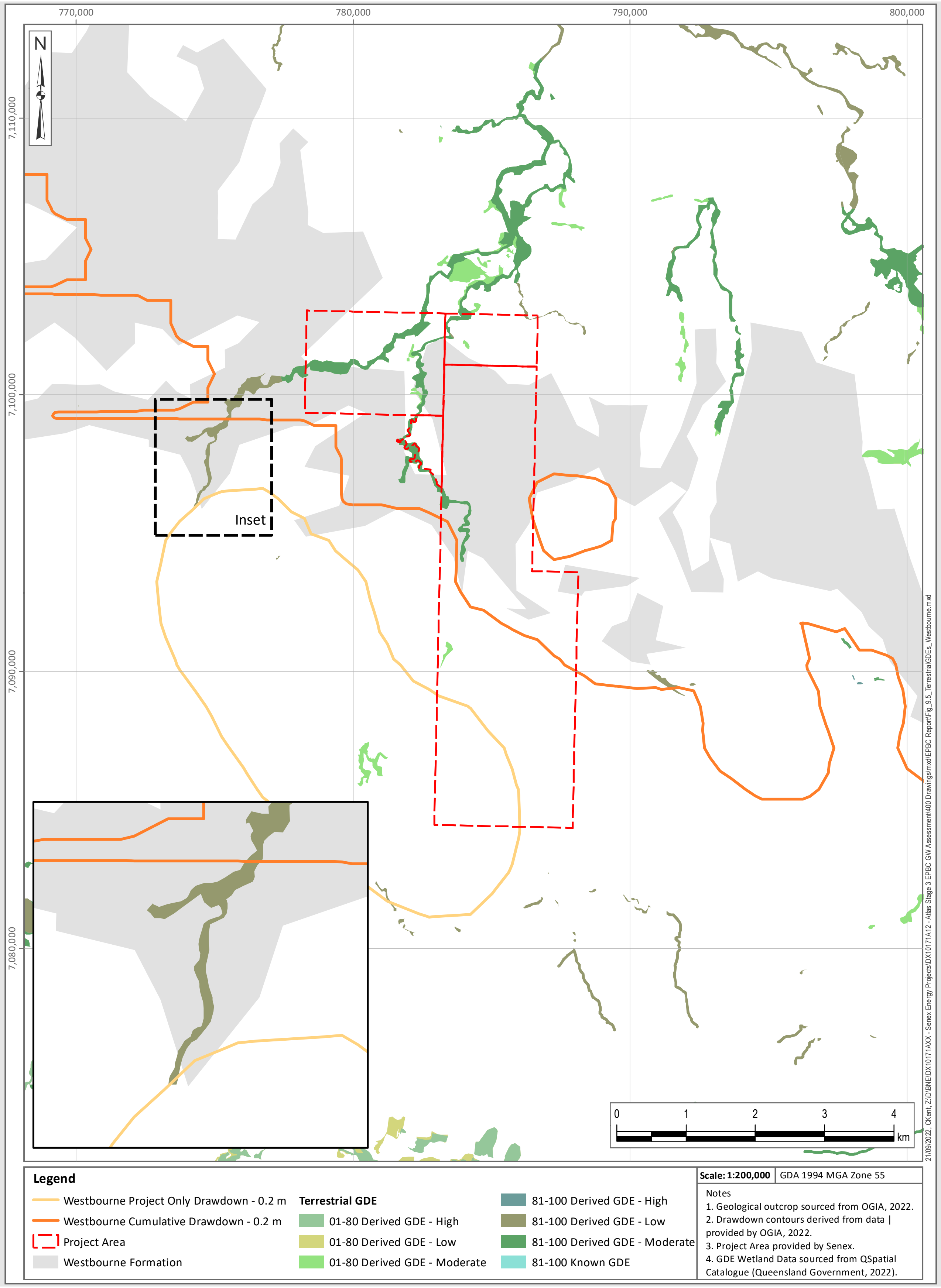


Figure 9.3 Mapped Potential Terrestrial GDEs and Predicted Drawdown Area – 0.2 m Contours Westbourne Formation

Springbok Sandstone

There are four potential terrestrial GDE areas located on the Springbok Sandstone outcrop within the >0.2 m Project only drawdown extent. These areas are shown on Figure 9.4, with the predicted drawdown summarised in Table 9.3. One of these potential GDEs is located on Senex tenement PL 445 (No. 1).

These GDEs are described as:

- Surat_RS_01A: Quaternary alluvial aquifers overlying sandstone ranges with fresh, intermittent groundwater connectivity regime (moderate confidence in GDE status).
- Surat_RS_03A: permeable consolidated sedimentary rock aquifers with fresh, intermittent groundwater connectivity regime (low confidence in GDE status).

Project only model scenario drawdown is not predicted in the overlying alluvium at these mapped GDE locations.

The four potential GDEs are cumulatively impacted by surrounding activities (without the presence of the Project). The Project contributes to the cumulative drawdown at these GDEs (see Table 9.3), with the highest contribution being at GDE No. 4 which is located ~12 km east of PL 209.

GDE No. 2 and 3 are located directly on, or close to, proposed areas of disturbance associated with the proposed Wandoan Coal Mine, with the Project contributing less than 6% of the predicted drawdown. The approved Wandoan Coal Project is planned to excavate both alluvium and Springbok Sandstone with open cut mine pit depths of 24 to 60 m. The Springbok Sandstone will likely be dewatered by the Wandoan Coal Project during pit excavation.

Table 9.3 Terrestrial GDEs within the Predicted >0.2 m Drawdown Extent on the Upper Springbok Sandstone Outcrop

<table>
<tr><th>No.</th><th>Location</th><th>GDE Rule ID</th><th>Source aquifer</th><th>Project Only Development Scenario Drawdown (m)</th><th>Cumulative with Project (m)</th><th>Proportional Drawdown Contribution of the Project (%)</th><th>Area Of Potentially Affected GDE (km²)</th><th>RE</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Within PL 445</td><td>Surat_RS_01A</td><td>Alluvium</td><td>0.00</td><td>0.08</td><td>-</td><td>-</td><td rowspan="2">11.3.25 (Forest Red Gum Eucalyptus tereticornis woodland fringing drainage lines) however areas of RE 11.3.2 (Poplar Box Eucalyptus populnea woodland on alluvial plains), RE 11.3.27 (Freshwater wetlands: Coolabah Eucalyptus coolabah and/or Forest Red Gum) open woodland to woodland fringing swamps) and RE 11.3.17 (Poplar Box woodland with Brigalow Acacia harpophylla and/or Belah Casuarina cristata on alluvial plains) are also present</td></tr>
<tr><td>Surat_RS_03A</td><td>Upper Springbok Sandstone</td><td>0.90</td><td>4.57</td><td>19.69</td><td>0.07</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">7.5 km east of PL 445</td><td>Surat_RS_01A</td><td>Alluvium</td><td>0.00</td><td>0.08</td><td>-</td><td>-</td><td rowspan="3">RE 11.3.25 Eucalyptus tereticornis or E. camaldulensis woodland</td></tr>
<tr><td rowspan="2">Surat_RS_03A</td><td rowspan="2">Upper Springbok Sandstone</td><td>0.28</td><td>5.12</td><td>5.47</td><td>0.17</td></tr>
<tr><td>0.48</td><td>8.42</td><td>5.70</td><td>0.05</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">10.5 km east of PL 445</td><td rowspan="2">Surat_RS_03A</td><td rowspan="2">Upper Springbok Sandstone</td><td>0.45</td><td>36.74</td><td>1.22</td><td>0.001</td><td rowspan="2">11.9.5/11.9.10</td></tr>
<tr><td>0.32</td><td>29.3</td><td>1.09</td><td>0.01</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">~12 km east of PL 209</td><td>Surat_RS_01A</td><td>Alluvium</td><td>0.00</td><td>0.07</td><td>-</td><td>-</td><td rowspan="2">RE 11.3.25 Eucalyptus tereticornis or E. camaldulensis woodland</td></tr>
<tr><td>Surat_RS_03A</td><td>Upper Springbok Sandstone</td><td>0.51</td><td>2.24</td><td>22.76</td><td>0.02</td></tr>
</table>

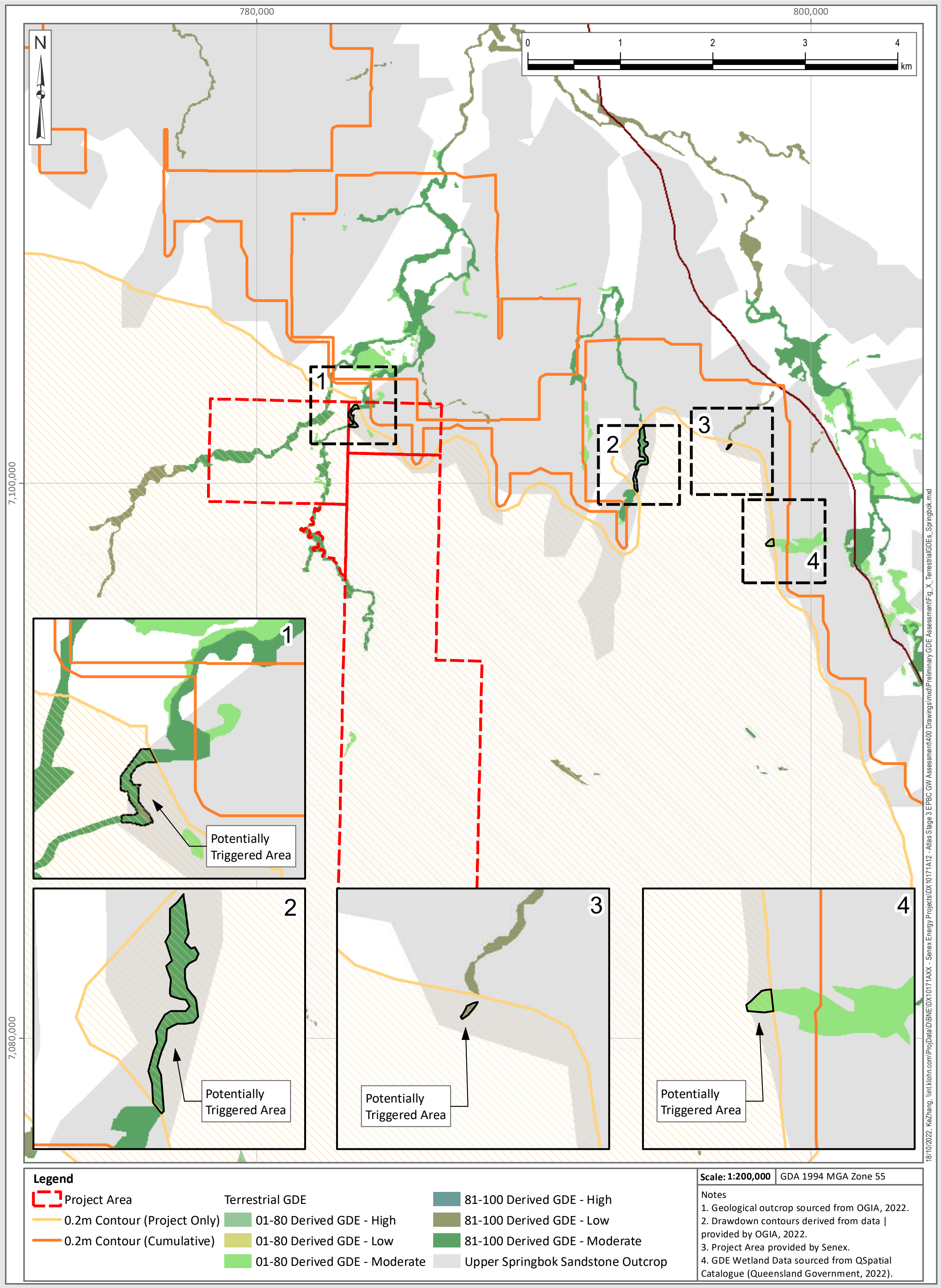


Figure 9.4 Mapped Potential Terrestrial GDEs and Predicted Drawdown Area – 0.2 m Contours Upper Springbok Sandstone Formation

A maximum Project only drawdown of 0.9 m is predicted to occur in the Upper Springbok Sandstone outcrop area, which corresponds to a location along Woleebee Creek on PL 445 where potential terrestrial GDEs are present. This drawdown is predicted to occur approximately 7 years after the start of the development (see Figure 9.5 for the area of concern). According to the terrestrial GDE preliminary risk assessment provided in the JIF (DCCEEW 2021), the magnitude (<1 m) and timing of predicted exceedance (7 years) of the drawdown at the potential GDEs, suggests that the risk of impact to potential terrestrial GDEs is low.

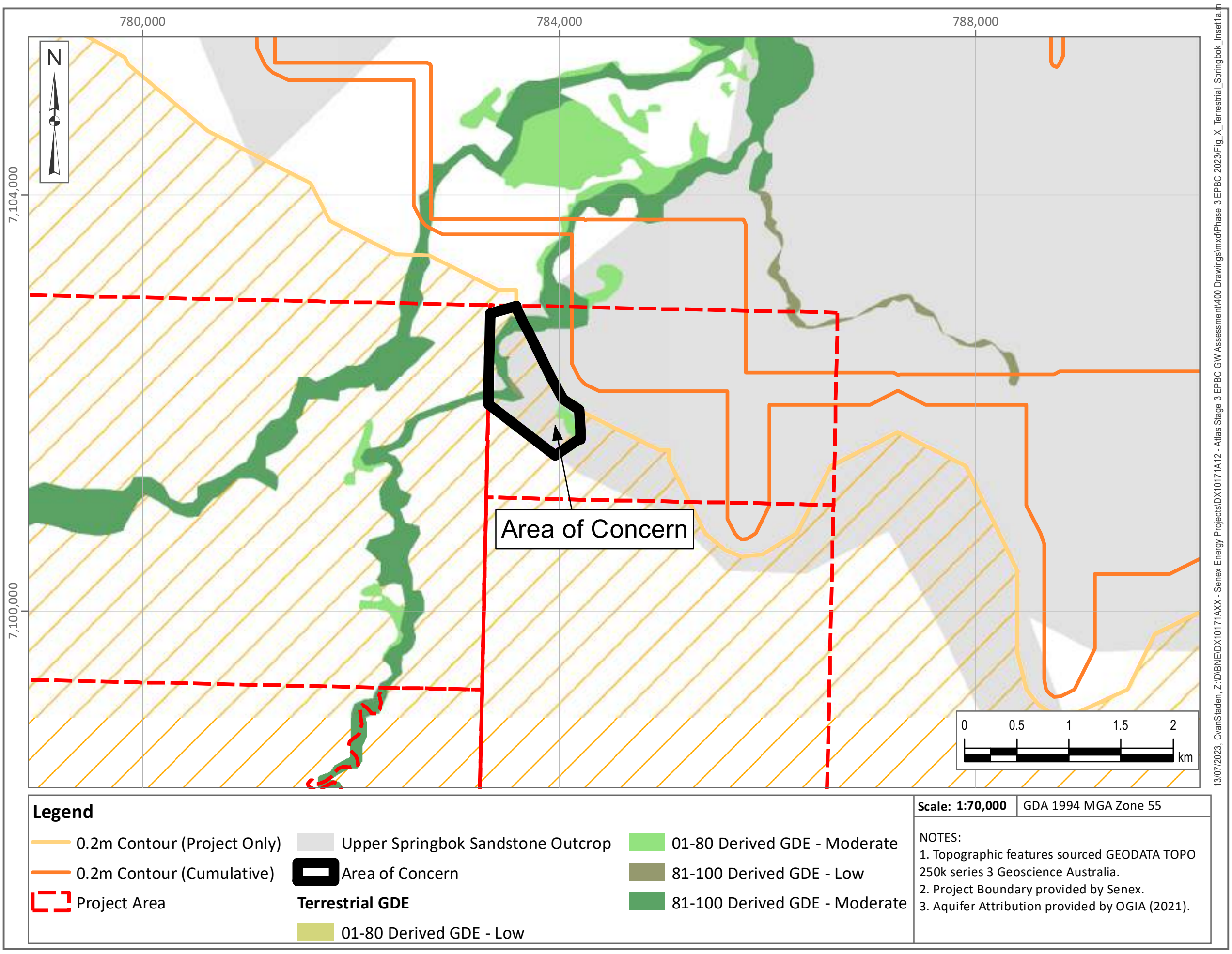


Figure 9.5 Area of Concern on the Upper Springbok Sandstone Outcrop

Potential for Alluvium as a Source Aquifer

These potential terrestrial GDEs are all located along ephemeral creek systems. Based on the available characteristics of the GDE physiographic setting, it is interpreted that the potential GDEs may be intermittently supported by groundwater in the alluvium. The regional water quality of the alluvium indicates that it is recharged and replenished by surface water during prolonged periods of rainfall and during periods of creek flow.

Connection of Alluvium to Springbok Sandstone

Field investigations have provided both hydraulic and hydrochemical evidence to support the argument that the alluvium and the underlying Upper Springbok Sandstone are disconnected (Section 7). This evidence includes water level, water quality and isotope data. There are two main lines of evidence that identified disconnection between the alluvium and the underlying Surat Basin formations:

1. Hydraulics – Groundwater monitoring bores installed by Senex as paired bore sets in the alluvium and underlying Springbok Sandstone or Westbourne Formation displayed hydraulic separation between the units. Monitored groundwater levels in both of these units underlying the alluvium have always been below the base of the alluvium indicating that there is no contribution from these deeper units to the shallower alluvium. The groundwater level in the Springbok Sandstone is ~3 m below the base of alluvium during the wet season in Atlas-14M-D. There may be losses from the alluvium to these deeper units, as a result of infiltration, during times of saturation in the alluvium.

2. Water quality – The water quality of the alluvium and underlying Surat Basin units is distinctly different. Fresher quality groundwater is observed in the groundwater samples of the alluvium (from the larger Jundah Creek catchment), Gubberamunda Sandstone and Hutton Sandstone. Electric Conductivity (EC) is generally higher in the WCM, Westbourne Formation and Springbok Sandstone.

The geochemical disconnect has been assessed through the comparison of alluvium and Upper Springbok Sandstone water quality and isotope analysis. The results show that:

- The water quality of the regional alluvium is very similar to the quality of surface water sampled from Wandoan, Woleebee, and Juandah Creeks. The comparable water qualities of the surface water and alluvium indicates that the alluvium is recharged/replenished by, and in connection with, the surface water systems during flow events following prolonged rainfall event/s.
- The groundwater qualities observed from the Springbok Sandstone are distinct from the groundwater quality of the regional alluvium with the Springbok Sandstone groundwater showing a proportionally higher chloride concentration in comparison with the alluvium groundwater which display a proportionally higher carbonate-bicarbonate concentration. This difference in proportional anion concentrations indicates a lack of connection between the units (i.e. the underlying Springbok Sandstone does not discharge into the alluvium). The Springbok Sandstone groundwater sample (ATLAS-14M-D) is grouped with other samples for that unit, illustrating the sample is representative of the Upper Springbok Sandstone. The underlying Springbok Sandstone generally comprises a higher salinity than the regional alluvium system.

Based on the available characteristics of the GDE physiographic setting (Figure 7.47), it is interpreted that these potential GDEs:

1. may be intermittently supported by groundwater in the alluvium which is not predicted to experience drawdown;
2. alluvium source aquifer is not interpreted to be connected to the Upper Springbok Sandstone which is predicted to experience drawdown; and
3. are being significantly impacted cumulatively by neighbouring activities without the presence of the Project (by the Wandoan Coal Project and other CSG activities).

Considering the GDEs through the source-pathway-receptor conceptualisation:

- The presence of the Project results in a predicted drawdown of >0.2 m in the Springbok Sandstone in the far north of the Project area in PL 445 (the source). This may impact an area of approximately 70 ha, of which 0.7 ha of terrestrial GDEs are present along Woleebee Creek (the receptor).
- The pathway for the potential impact to the potential GDEs (the receptor) is the connection between the Springbok Sandstone and the alluvium, and the potential for drawdown in the Springbok Sandstone to propagate into the alluvium. The alluvium is the most likely water source for the GDEs given the depth to groundwater in the Springbok Sandstone (>20 m).
- The alluvium is not considered to be hydraulically connected to the Upper Springbok Sandstone, as supported by both hydraulic and hydrochemical data. The water quality of the Springbok Sandstone is different to that of the regional alluvium water quality, with the Springbok Sandstone being a higher salinity. Water levels in the alluvium and Springbok Sandstone differ, with the Springbok Sandstone water level confirmed as being below the base of the alluvium in the site investigations.
- The disconnect between the Springbok Sandstone and the alluvium infers there is no pathway for drawdown in the Springbok Sandstone (the source) to propagate into the alluvium, and no significant impacts to GDEs (the receptor) are predicted.

Due to the lack of connection between the Upper Springbok Sandstone and the alluvium, there will be no discernible impacts to potential terrestrial GDEs due to drawdown in the underlying Upper Springbok Sandstone.

Impacts to Subterranean Fauna

Impacts to potential stygofauna habitats are limited to the unconfined outcrop areas, which have been identified in PL 1037 in the Gubberamunda Sandstone/Westbourne Formations and Upper Springbok Sandstone (KCB 2018c). The potential impact is summarised as follows:

- For ecological systems potentially reliant on groundwater within the shallow aquifers, the cumulative scenario does not predict any drawdown within the Gubberamunda Sandstone from the Project.
- For ecological systems potentially reliant on groundwater in the Westbourne Formation outcrop, the Project only drawdown in the Westbourne Formation is predicted to be less than 0.2 m. The results of the numerical modelling indicate that there is negligible (at most

2%) reduction in saturated thickness in the outcrop areas of the Westbourne Formation to the west and east of the Project area.

- Drawdown is predicted in the Upper Springbok Sandstone within outcrop areas to the north and northeast of the Project area. These areas are cumulatively impacted without the presence of the Project, with the Project contributing up to 0.9 m of drawdown within PL 445, which equates to a proportional drawdown contribution of the Project of ~20%. Given the overall thickness of the Springbok Sandstone of ~100 m, the reduction in saturated thickness from the Project only is negligible.

No discernible impacts to subterranean fauna as a result of the Project development are predicted.

9.5.2 Third-Party Groundwater Users

Potential long-term impacts to groundwater bores have been assessed against the *Water Act 2000* bore trigger threshold of 2 m for an unconsolidated aquifer (e.g., alluvium) and 5 m for a consolidated aquifer (e.g., Surat Basin units) using the outputs and drawdown predictions from the Surat CMA UWIR numerical model. The maximum predicted drawdown was used for this assessment, irrespective of the timing of predicted drawdown. Assumptions / limitations of this assessment include:

- Many groundwater bores within the vicinity of the Project were constructed to intersect multiple formations. OGIA have assigned each bore a dominant source aquifer, with this dominant aquifer used to assess potential drawdown at each bore. Appendix VI provides the attributed formation (or formations) as discussed in Section 7.11.3 and the formation used as part of the impact assessment.
- Forty-four bores were assigned as ‘screened within alluvium’. Where the OGIA model does not simulate alluvium at a bore location, predicted drawdown in the unit directly underlying the alluvium was considered for the impact assessment and assessed against the *Water Act 2000* bore trigger threshold of 2 m for an unconsolidated aquifer. Appendix VI details the unit assigned to those bores for impact assessment purposes.

A summary of the impacts to groundwater bores from the Project only simulation is presented in Table 9.4, with individual bore results presented in Appendix VI.

Table 9.4 indicates the number of bores assessed for each formation; the number of bores which are predicted to have any drawdown; the number of bores which exceed the groundwater bore trigger threshold of 5 m drawdown for consolidated aquifers; and the maximum drawdown modelled for all the bores attributed to that formation.

Table 9.4 Project Only – Summary of Impact Assessment Results for Groundwater Bores

Formation	Number of Bores	Number of Bores with Drawdown	Number of Bores Predicted to Exceed Trigger Thresholds	Maximum Drawdown Observed Across the Bores (m)
Bungil Formation	29	0	0	0.00
Mooga Sandstone	59	0	0	0.00
Orallo Formation	74	0	0	0.00
Gubberamunda Sandstone	148	62	0	0.01

Formation	Number of Bores	Number of Bores with Drawdown	Number of Bores Predicted to Exceed Trigger Thresholds	Maximum Drawdown Observed Across the Bores (m)
Westbourne Formation	38	13	0	0.11
Upper Springbok Sandstone	45	35	0	2.33
Lower Springbok Sandstone	15	14	0	1.11
Walloon Coal Measures	228	220	23	123.34
Durabilla Formation	5	2	0	0.02
Hutton Sandstone	47	3	0	0.01
Evergreen Formation	2	0	0	0.00
Precipice Sandstone	37	0	0	0.00

The results indicate:

- The groundwater bores triggered in the Project only scenario, are already triggered by adjacent developments (e.g. without any contribution from the Project).
- Predicted drawdown (of any magnitude) is observed in bores attributed to most hydrostratigraphic units, except the Bungil, Orallo and Evergreen formations, as well as the Mooga and Precipice sandstones. However, only bores in the WCM are predicted to experience a drawdown greater than 5 m.
- There are 23 bores in the WCM which have a predicted drawdown greater than 5 m. These bores are screened in the Upper Juandah Coal Measures (21 bores) and the Taroom Coal Measures (two bores). The maximum predicted drawdown in any one bore is 123.34 m (screened in the Upper Juandah Coal Measures).
- Of these 23 bores, 12 are noted by OGIA as water supply bores, ten bores are noted as ‘not water supply’, and one as ‘potential water supply’. The location of these bores, where the water level is predicted to drawdown greater than the trigger threshold, is presented in Figure 9.6.
- Five town water supply bores (discussed in Section 7.11.3) located near Wandoan and ~14 km to the north of the Project area are predicted to experience less than 0.1 m of drawdown. These bores are attributed to the Precipice Sandstone, the Lower Hutton Sandstone and the WCM.

Drawdown greater than the trigger level of 5 m in consolidated rock, is exceeded at twenty-three registered groundwater bores. These bores are predicted to exceed this trigger regardless of Project approval due to surrounding projects.

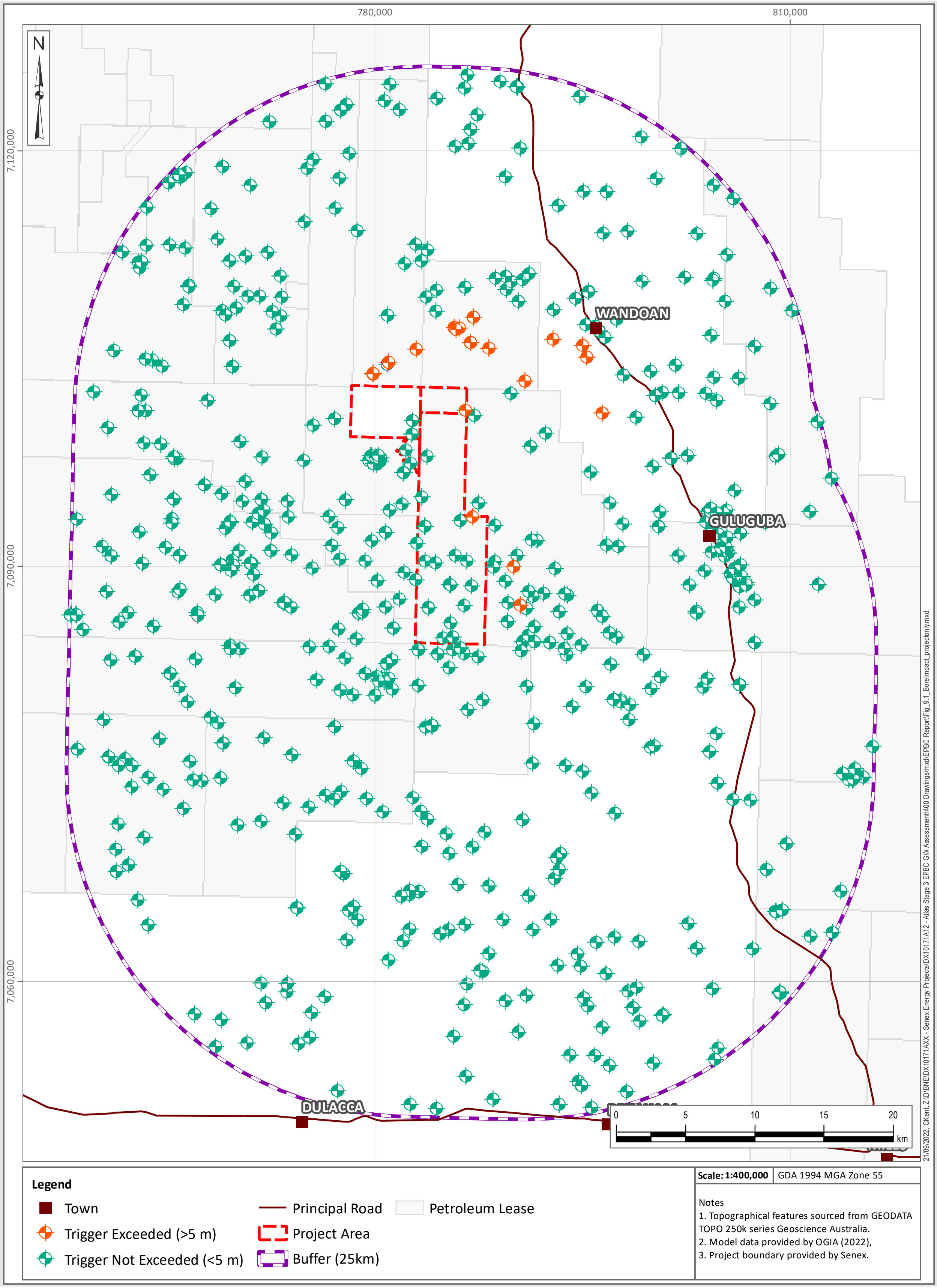


Figure 9.6 Summary of Impacts to Groundwater Bores – Project Only (23 Bores Impacted, not all Visible Due to Close Proximity)

9.6 Subsidence

Depressurisation associated with CSG water extraction from the WCM may result in the compaction of coal seams. Compaction generally occurs as water is removed from the pores of saturated, high porosity layers (such as clay and silt) (IESC 2014). Most of the compaction in response to depressurisation occurs in coal seams as they contain cleats and fractures and are relatively more compressible compared to interburden material (such as sandstone, siltstone and mudstone). These layers cannot maintain the increased vertical stress as water pressure reduces, and the layers can potentially compact, resulting in subsidence of the land surface (IESC 2014). Some of the compaction is elastic, allowing a degree of recovery and reversal of subsidence when groundwater pressure is returned (i.e. post-depressurisation).

Desorption of gas from the coal seams can result in additional compaction (IESC 2014). This compaction is minor and estimated to be approximately 1% of the coal thickness (Robertson 2005).

The potential for subsidence to occur is influenced by two primary factors: the magnitude of change in groundwater level; and the thickness and type of formations overlying the reservoir (OGIA 2021f). The greatest effect on CSG-induced subsidence is the magnitude of depressurisation, its pattern and how it develops over time across a gas field (OGIA 2021f).

Ground movement also occurs naturally (i.e. the ground movement caused by factors other than the CSG-induced subsidence) from the shrinking or expansion of high-clay-content soils due to changes in moisture content, depressurisation resulting from groundwater use in aquifers overlying the target coal formation and, land management practices, such as irrigation, tillage and land contouring. This must be factored into any monitoring and observation of CSG-induced subsidence.

The assessment of subsidence is within the legislative scope of the Underground Water Impact Report (UWIR) which is undertaken for the Surat Basin by OGIA. The UWIR is required to assess subsidence impacts that may have already occurred and are likely to occur in the future.

9.6.1 Project Related Subsidence

The subsidence resulting from the predicted cumulative drawdown scenario (including the Project) has been estimated to be up to 0.063 m[6], with a range of 0.006 to 0.063 m (cumulative). The subsidence estimated from the Project only drawdown scenario is predicted between 0.002 and 0.058 m. The maximum change in ground slope from CSG-induced subsidence is expected to be less than 0.002% (20 mm over a km). The cumulative and Project only drawdown subsidence predictions are provided in Figure 9.7.

It is understood that consolidated sandstone formations can attenuate potential subsidence impacts, as the strength of these consolidated formations are likely to result in a ‘bridging effect’ and reduce the degree to which compaction at depth in the coal measures manifests as subsidence at the ground surface (OGIA 2021f).

[6] Cumulative estimation including surrounding projects.

The presence of the Springbok Sandstone and the Gubberamunda Sandstone will assist with attenuating these impacts. Actual subsidence will most likely be less than that calculated.

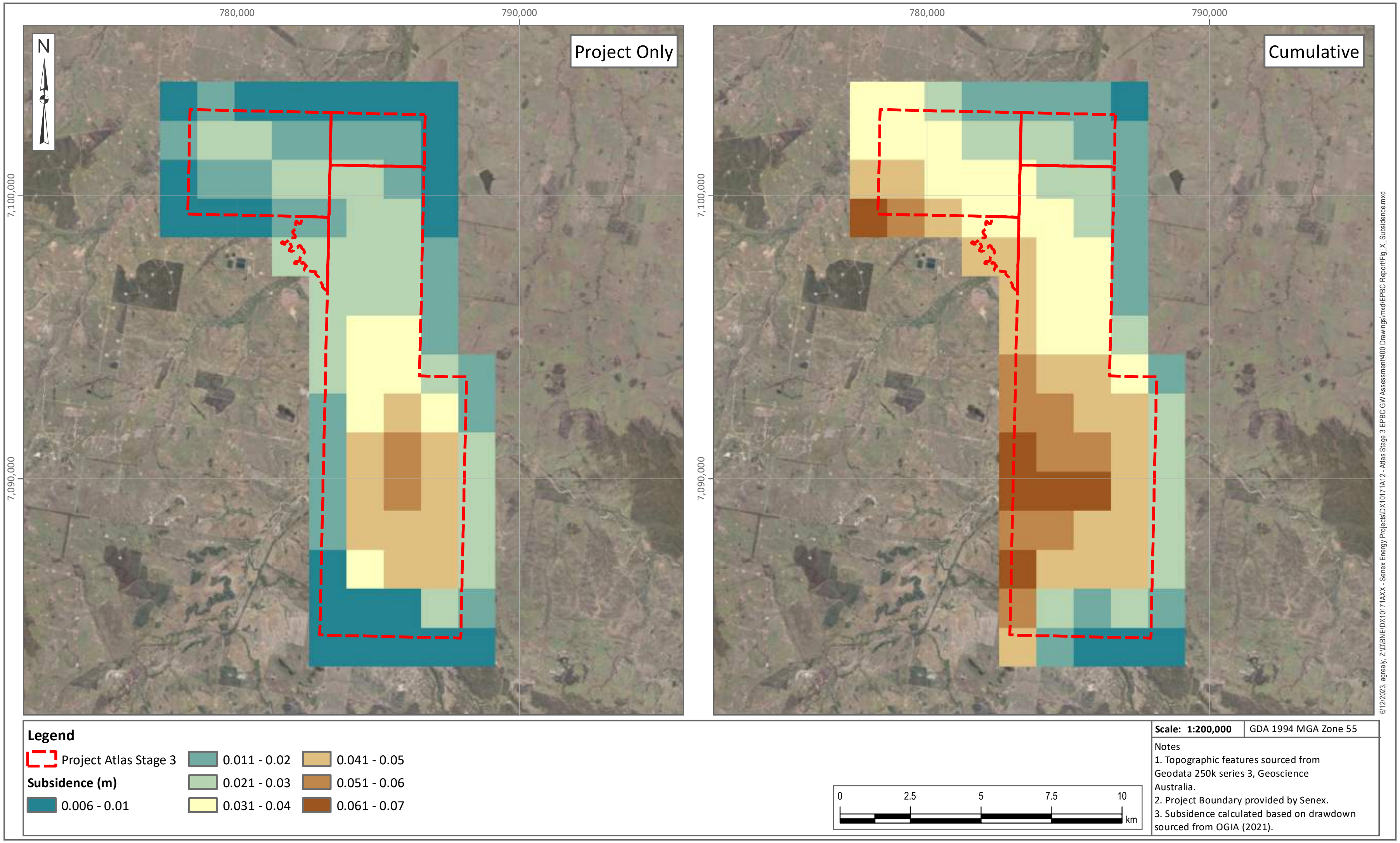


Figure 9.7 Predicted Project Only and Cumulative Subsidence

9.6.2 Subsidence Predictions by Others

Areas predicted to experience subsidence of less than 0.2 m are considered to be of low risk to environmental values (OGIA 2019b).

OGIA undertook a preliminary regional assessment of subsidence for the Surat CMA in the 2019 UWIR. The approach incorporated an assessment of the likelihood of subsidence and a description of the EVs located within risk areas. The likelihood of subsidence was assessed using two risk factors: an estimate of total compaction within the WCM using the predictions of groundwater level change; and the presence or absence of overlying consolidated sandstone formations that may attenuate any potential subsidence at the surface (OGIA 2021f).

For the more recent 2021 UWIR, OGIA developed an analytical model for the entire Surat Basin using an analytical equation integrating geomechanical rock properties and predicted depressurisation. The model calculates compaction in the WCM as a function of the change in pressure resulting from depressurisation, the thickness of the formation prior to compaction and the properties of the lithological units derived from downhole geophysical logs.

OGIA cumulative predictions, which include the Project (based on the historical APLNG Woleebee Gas Field of 240 wells), suggest:

- Subsidence between 0.007 to 0.111 m for the Project area.

The upper end of these predictions are slightly higher than the subsidence calculated in Section 9.6.1, which is likely due to the difference in the number of wells between the former APLNG Woleebee Project (240 wells) and the proposed Atlas Stage 3 Project (151 wells).

The maximum change in ground slope from CSG-induced subsidence in most areas of the Surat CMA is predicted to be less than 0.001% (10 mm over 1 km) but is up to 0.004% (40 mm over 1 km) in some areas (OGIA 2021f).

Estimations for subsidence have been conducted by neighbouring proponents and are summarised in Table 9.5. The predicted cumulative subsidence in the vicinity of the Project area ranges from 0.01 to 0.3 m (10 mm to 300 mm), with the highest amount of subsidence predicted by QGC for PL 398 and PL 399, to the north of ATP 2059.

9.6.3 Observations to Date

Available data indicate approximately 100 mm of CSG-induced subsidence has occurred since 2015 in some of the mature gas field areas in the vicinity of the Condamine Alluvium, approximately 150 km to the southeast of PL 209. The ground movement data indicates that the rate of subsidence is higher in the earlier stages of development, however, ground movement has slowed since 2020.

QGC reports that observations of subsidence in the area derived from InSAR satellite data analysis indicates that the observations are following the QGC subsidence model predictions (pers. comms. QGC).

Table 9.5 Predicted Subsidence at Surrounding Projects

Proponent	Distance from Atlas Stage 3	Comments on Subsidence	Predicted Subsidence (m)[1]
Shell/QGC	Adjacent to east of PL 445 and PL 209 Adjacent to north of ATP 2059	▪ A ground motion model was constructed using the OGIA UWIR 2016 drawdown predictions, using linear elastic theory to determine potential ground motion resulting from CSG activities. The model was run for the life of the QCG activities. ▪ The model predicts maximum cumulative settlements of: ♦ 0.02 to 0.05 m to the east PL 445 and PL 209; ♦ 0.1 to 0.3 m to the north of ATP 2059. ▪ Observations of subsidence in the area derived from InSAR satellite data analysis so far indicates that these model results are very close to what will eventuate (pers. Comms. Shell).	0.02 to 0.05 0.1 to 0.3
Arrow (Coffey 2018)	8.5 km east of PL 209	▪ Subsidence was calculated by reviewing records of subsidence versus drawdown to determine a site-specific effective Young's modulus for the WCM. This was used with predictions of maximum drawdown to calculate maximum subsidence. ▪ A Project only subsidence of <0.01 m was calculated. ▪ A cumulative subsidence of 0.01 to 0.05 m is predicted.	0.01 to 0.05
APLNG	Includes PL 209 and PL 445 (previously APLNG tenements)	▪ A simplified analytical model was coupled with the numerical groundwater flow model to calculate the potential compression that may occur. ▪ APLNG did not report on the potential estimated subsidence as compaction is unlikely to be expressed at the surface (as land subsidence) as the shallower consolidated and competent rock will, to some extent, operate as a bridge to prevent the downward movement (APLNG 2011). The distribution of the potential compaction was used to identify areas of the highest risk. These high risk areas are ~20 km south of PL 209. Note that PL 209 and PL 445, formerly the APLNG Woleebee Gas Field, are referenced in this document but it is unknown as to whether CSG wells on Woleebee were included in the subsidence predictions.	Unknown
Santos	Roma gas field ~75 km southwest	▪ Santos estimate a maximum subsidence of up to 0.28 m around the Roma gas field (Santos 2013), which relates to an average reduction in pressure of 700 m in the WCM. ▪ Maximum differential settlements at the surface of 0.06 m over a distance of 1. 5 km for the Roma gas field. Settlements of this scale were determined to be too small to cause changes to surface water or groundwater paths and as a result, no impact to groundwater EVs is expected (Santos 2013).	0.28

9.6.4 Potential Impact to Environmental Values

There may be potential impacts to human-use environmental values (EVs) (e.g. agricultural land and water bores) and aquatic ecosystem EVs, such as watercourse springs and terrestrial GDEs, depending on the magnitude of subsidence.

Large-scale subsidence can have the following consequences:

- Change in ground slope and aspect of the land (resulting from variation in ground movement) may affect surface water drainage directions; and
- Change in the integrity of hydrological or hydrogeological connectivity which may cause structural changes to geological units.

In 2019, OGIA undertook an initial assessment of the risk of subsidence to EVs in the 2019 Surat CMA UWIR (OGIA 2019b). OGIA's approach incorporated an assessment of the likelihood of subsidence occurring, and a description of EVs located within those areas. A moderate risk was assigned to areas where between 0.1 to 0.2 m of subsidence is predicted, and high risk for greater than 0.2 m of subsidence. In areas where there are consolidated formations overlying the CSG coal seams, the assigned level of risk to environmental values was reduced to a lower level (OGIA 2021f). OGIA assigned the Woleebee Creek area as an area of high risk[7]. Project only subsidence estimation of a maximum of 0.06 m (Section 9.6.1) would be classed as low risk under OGIAs classification.

OGIA identified that the observed and predicted subsidence across the Surat Basin is small and unlikely to materially change surface flows to watercourses. The process of depressurisation of the target formation has the potential to alter the porosity and permeability of the formation through compaction. This effect is likely to be inconsequential in surrounding aquifers, as these aquifer units have practically no coal and hence less prone to compaction compared to the CSG target formation. Where consolidated sandstone formations are located above the CSG target formation, these are likely to attenuate impacts, as the strength of these consolidated formations is likely to result in a 'bridging effect' and reduce the degree to which compaction at depth in the coal measures manifests as subsidence at the ground surface (OGIA 2021f).

The overall risk to EVs from subsidence is regarded as low.

9.7 Cumulative Impacts With Other CSG and Coal Mine Operations in the Region

Due to the proximity of other CSG operations and coal mines through the Surat Basin, there is potential for cumulative impacts to occur. Potential cumulative impacts can result in:

- Additional groundwater drawdown; and
- Higher levels of subsidence.

[7] The predictions completed by OGIA do not include the Senex Atlas Stage 3 Project, as it is assumed that the previously approved APLNG Woleebee Gas Project was modelled in the OGIA predictions which is understood to have consisted of more gas wells than is proposed for the Atlas Stage 3 Project.

This can subsequently result in additional impacts to groundwater bores, GDEs and surface water systems.

9.7.1 Chemical Contamination

Cumulative impacts related to chemical contamination were considered in the chemical risk assessment (KCB 2023a). Cumulative impacts can occur due to the proximity of CSG wells and the use of chemicals during their drilling and operation. Due to the distance between wells of 500 to 750 m, cumulative impacts due to the use of chemicals are not expected.

9.7.2 Changes to Hydrological Regime

Being located at the top of the Woleebee and Wandoan Creek catchments, there are no cumulative impacts resulting in a change to the hydrological regime due to water take or overtopping or unplanned/planned discharges from other proponents.

9.7.3 Changes to Water Quality

Being located at the top of the Woleebee and Wandoan Creek catchments, there are no cumulative impacts resulting in a change to water quality expected due to spills, overtopping or unplanned/planned discharges from other proponents.

9.7.4 Groundwater Drawdown and Associated Impacts

GDEs

The cumulative drawdown extent in aquifer outcrops was assessed with the Project only assessment and is discussed in Section 9.5.

There is only one potential terrestrial GDE mapped on the Westbourne Formation outcrop within the predicted 0.2 m **cumulative** drawdown extent. Predicted (Project only and cumulative) drawdown in the alluvium, the likely source aquifer for the GDE, at this location is less than the 0.2 m drawdown trigger. The underlying Westbourne Formation at the location of this potential GDE is predicted to experience drawdown of more than 0.2 m without the presence of the Project, with a predicted cumulative drawdown of 2.6 m. The Project contribution to this cumulative drawdown is ~6%.

Four potential terrestrial GDE areas are located on the Springbok Sandstone outcrop within the >0.2 m Project only drawdown extent. These four potential GDEs are cumulatively impacted by surrounding project activities (without the presence of the Project). The overall 0.2 m drawdown extent does not significantly extend with the presence of the Project and no additional GDE areas are predicted to be impacted.

Third-Party Groundwater Users

The cumulative impact assessment was undertaken using the same approach adopted for the Project only impacts (e.g. *Water Act 2000* trigger thresholds).

A summary of the cumulative impact results for groundwater bores is presented in Table 9.6, with results for individual bores presented in Appendix VI. The results indicate the following:

- Within the 25 km buffer from the Project, 248 bores are triggered (i.e. >5 m drawdown) in the cumulative scenario.
- The contribution of the Project development results in five additional bores being triggered in the cumulative scenario (i.e. these bores would not have been triggered without the presence of the Project). Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. The location of these bores is presented on Figure 9.8.
- Of the five additional bores, all are located off-tenure to the east of the Project. One of these bores is noted as abandoned and destroyed, two are noted as monitoring bores (and not water supply bores), and two are noted as existing bores. Of the existing bores, a bore baseline assessment confirmed one of these bores is blocked and has not been used since 1996 (Arrow 2013). The maximum Project only contribution to drawdown the only existing, usable bore is 26%.
- Of the 248 bores, the Project only contribution to drawdown of more than 1% occurs at 99 bores, and more than 10% at 36 bores. The maximum contribution from the Project is 81% to a bore that is located on PL 209 which has been confirmed as not existing through the 2022 Baseline Assessment (KCB 2023b).

Table 9.6 Cumulative Scenario – Summary of the Impact Assessment Results for Groundwater Bores

Formation	Number Of Bores Within 25 Km	Project Only – Number of Bores Triggered	Cumulative – Number of Bores Triggered
Bungil Formation	29	0	0
Mooga Sandstone	59	0	0
Orallo Formation	74	0	0
Gubberamunda Sandstone	148	0	0
Westbourne Formation	38	0	3
Upper Springbok Sandstone	45	0	22
Lower Springbok Sandstone	15	0	14
Walloon Coal Measures	228	23	205
Durabilla Formation	5	0	4
Hutton Sandstone	47	0	0
Evergreen Formation	2	0	0
Precipice Sandstone	37	0	0

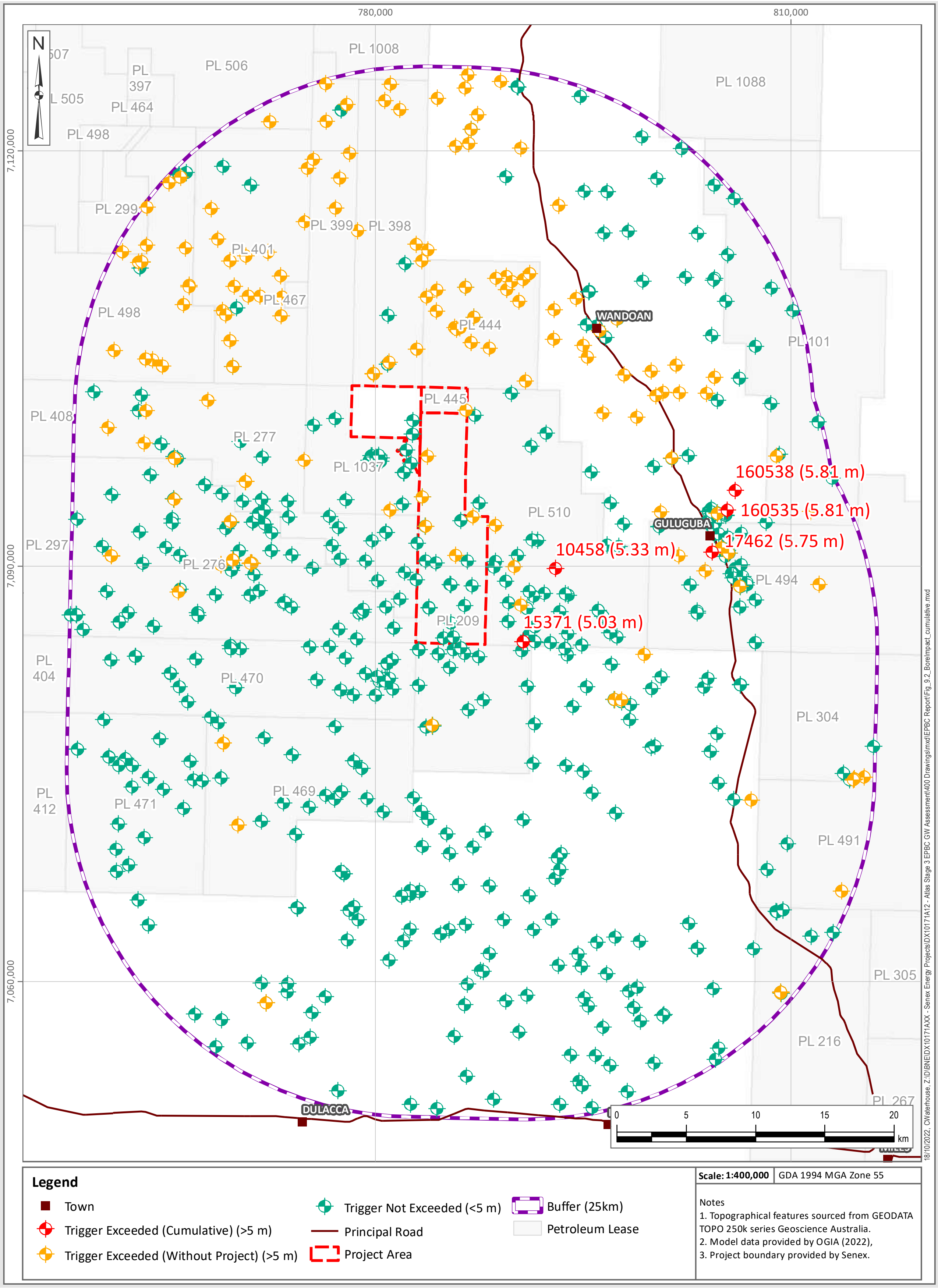


Figure 9.8 Summary of Impacts to Groundwater Bores – Cumulative Scenario

9.7.5 Subsidence

The OGIA cumulative groundwater drawdown predictions were used to predict the potential cumulative subsidence due to the presence of the Project and the surrounding tenements. The methodology is discussed in Section 4.2.5 and impacts from the Project in Section 9.6.

The subsidence resulting from the predicted cumulative drawdown scenario (including the Project) has been estimated to be up to 0.063 m[8], with a range of 0.006 to 0.063 m (cumulative). This is marginally higher than the subsidence estimated from the Project only drawdown scenario (0.002 and 0.058 m). As discussed in Section 9.6, the overall risk to EVs from subsidence, from both the Project only and cumulative scenarios is regarded as low.

9.8 Risk Assessment

A risk assessment has been conducted for the proposed Project activities. Based on the information presented in earlier sections, and the likelihood of occurrence and the consequence of risk tables presented in Table 9.7 and Table 9.8, the significance of the risks were identified using Table 9.9.

This risk assessment will be used as a live document to support infrastructure design, construction, operations and decommissioning to reduce risk and identify appropriate risk mitigation strategies. This approach is consistent with AS/NZS 4360:2004 – Risk Management and AS/NZS ISO 31000:2009 – Risk Management – Principals and Guidelines (AS/NZS 2009), with environmental consequence adapted from Ford et al. (2016). The significance of the risks is described below:

- **High significance:** Significant risk with high likelihood of impact. The risk is considered unacceptable or intolerable and may be irreversible or persistent.
- **Moderate significance:** Level of risk is not acceptable with moderate severity with impacts persisting over time but that can be mitigated.
- **Low significance:** The risk is low with any impacts short in duration and reversible; and
- **Insignificant:** An insignificant risk and any potential impacts are acceptable, and no risk treatment is necessary with the impact restricted to the immediate area of activity.

The results of the risk assessment are detailed in Table 9.10. The risk assessment results include pre-mitigated risk ratings, which consider the relevant statutory and legislative obligations for the specific activity / risk (e.g. Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland (State of Queensland 2019a)). Residual risk ratings, following application of the relevant mitigation and management controls to reduce the risk of an adverse impact to MNES, are also provided. Management controls are described further in Section 9.9.

[8] Cumulative estimation including surrounding projects.

Table 9.7 Likelihood of Risk (Criteria)

Rank	Likelihood	Description
1	Highly unlikely	An event that has not previously been experienced in the industry but may occur in exceptional circumstances
2	Unlikely	An event not likely to occur in the industry over 10 years
3	Possible	An event that may occur in the industry over 10 years
4	Likely	An event likely to occur more than once a year in the industry
5	Very likely	A common event that is likely to occur in the industry many times per year

Table 9.8 Consequence of Risk (Criteria)

Magnitude	Description
Negligible	Minimal impact on ecosystem; contained on petroleum lease, reversible in 1 year
Low	Moderate impact on ecosystem; contained on petroleum lease, reversible in 1 to 5 years
Moderate	Significant impact on ecosystem; impact contained on petroleum lease, reversible in ~10 years
High	Significant harm or irreversible impact (for example to World Heritage area); widespread, catchment area, long-term, greater than 10 years
Severe	Incident(s) due to unforeseen circumstances causing significant harm or irreversible impact (for example to World Heritage area); widespread, long-term

Table 9.9 Significance of Risk (Criteria)

		Likelihood				
		Highly Unlikely (1)	Unlikely (2)	Possible (3)	Likely (4)	Highly Likely (5)
Consequence	Severe	Insignificant	Low	High	High	High
	High	Insignificant	Low	Moderate	High	High
	Moderate	Insignificant	Low	Moderate	Moderate	Moderate
	Low	Insignificant	Low	Low	Low	Low
	Negligible	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant

Table 9.10 Risk Assessment Results

Potential Impact		Pre-Mitigated Risk Rating			Management Controls	Residual Risk Rating		
		Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating
Aquifer Depressurisation[1]	Decline in groundwater level / pressure at water bores, reducing water availability and potentially impacting groundwater EVs	3	Moderate	Moderate	▪ Surat CMA UWIR WMS (OGIA 2021f) ▪ Water Act 2000 baseline and bore assessments and make good requirements (DES 2022a) ▪ Joint Industry Framework (DCCEEW 2021) ▪ Coal Seam Gas Water Management Plans for ATP 2059 and for PL445 and PL 209 (SENEX-ATLS-EN-PLN-013 and 014) ▪ Atlas Stage 3 Water Monitoring and Management Plan (SENEX-ATLS-EN-PLN-017) ▪ Atlas Stage 3 Environmental Management Plan (SENEX-ATLS-EN-PLN-015) ▪ Code of Practice for the construction and abandonment of coal seam gas and petroleum wells, and associated bores in Queensland Version 1 (DNRME 2019) ▪ Queensland General beneficial use approval (DEHP 2014) ▪ Queensland CSG Water Management Policy (DEHP 2012) ▪ Queensland Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (DES 2016a) ▪ Queensland Streamlined Model Conditions for Petroleum Activities (DES 2016b) ▪ Queensland Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (State of Queensland 2019b) ▪ Queensland CSG water management: Measurable criteria (DES 2013)	3	Low	Low
	Reduction in groundwater head resulting in a reduction of groundwater availability, potentially causing degradation of GDEs	3	Moderate	Moderate		2	Moderate	Low
	Reduction of baseflow to watercourses, potentially resulting in degradation of GDEs and reduced water availability to potential users downstream	1	Moderate	Insignificant		1	Moderate	Insignificant
	Subsidence	1	Moderate	Insignificant		1	Moderate	Insignificant
Drilling and construction of CSG production wells	Potential to introduce a connection between hydrostratigraphic units, which were previously isolated units, through drilling and construction of CSG production wells, resulting in the potential for alteration of groundwater flow regimes and quality	3	High	Moderate		2	High	Low
	Drilling fluids are used during the drilling process, which have the potential to impact groundwater quality	2	High	Low		1/2	Moderate	Low/insignificant
CSG produced water storage facilities	CSG produced water storage facilities have the potential to impact groundwater levels and quality, through seepage or unplanned releases from surface storage dams	3	Moderate	Moderate		2	Moderate	Low
	Unplanned releases from water storage facilities	2	High	Low		2	High	Low
Beneficial use activities	Beneficial use activities, such as irrigation and stock watering, have the potential to impact shallow groundwater systems should over-irrigating occur, or the relevant beneficial use water quality guidelines are not adhered to	3	Moderate	Moderate		2	Moderate	Low
Construction activities	Localised transport of suspended sediment to waters during construction or site works, resulting in the potential to alter flow regimes and water quality and ecosystems	3	Low	Low		2	Low	Low
	Localised release of hydrotest water, effluent, or trench water to land	3	Low	Low		2	Low	Low
	Alteration of a watercourse character or changes to riparian buffers due to construction works	3	Low	Low		2	Low	Low
	Localised incidental CSG activities have the potential to impact shallow groundwater systems, such as fuel spills or improper storage of chemicals	3	Low	Low		2	Low	Low

1. Note that risks from impact will vary from aquifer to aquifer.

9.9 Impact Assessment Summary

A summary of the Project only and cumulative impacts on the following aspects is provided in Table 9.11:

- Chemical contamination;
- Changes to hydrological regimes;
- Changes to water quality;
- Groundwater drawdown and associated impacts on:
  - Groundwater dependent ecosystems; and
  - Third-party bores;
- Subsidence; and
- Cumulative impacts with other CSG operations in the region.

The impact assessment followed the methodology provided in Section 4.2. The monitoring, management and mitigation measures to be implemented by Senex to address the predicted impacts are detailed in Section 10.

Table 9.11 Summary of Project Only and Cumulative Impacts

Aspect	Assessment	Predicted Project Only Impact	Predicted Cumulative Impacts	Monitoring, Management and Mitigation
Chemical contamination	▪ Chemical risk assessment for drilling chemicals (KCB, 2023), following the chemical risk assessment framework (CRAF). ▪ The aim of the chemical risk assessment framework is to enable the evaluation of the potential risks and effects of chemicals used during coal seam gas operations (drilling and completions, and water treatment) to MNES. The goal of the chemical risk assessment was to demonstrate that the potential risks to MNES associated with the chemicals used in coal seam gas operations have been eliminated or reduced as much as practically possible.	▪ Risk to MNES receptors from drilling fluids is limited to above ground chemical spills, the infiltration of chemicals to aquifers below ground (downhole) during well installation, and the eventual disposal of the drilling fluids. ▪ The overall risk to MNES from chemical contamination has been assessed as low significance to insignificant.	▪ Cumulative impacts are not expected due to the distance between the drill pads.	Management and mitigation measures for chemical contamination are discussed in: ▪ Section 10.2.2 CSG Production well drilling and construction ▪ Section 10.2.5 Infrastructure location planning ▪ Section 10.2.6 Environmental management practices ▪ Section 10.2.7 Chemical and fuel storage ▪ Section 10.2.9 Emergency and incident response: Spills
Changes to hydrological regime	▪ Not directly assessed as the project does not include any planned discharge to / abstraction from the surface water systems, or surface water diversions.	▪ Potential impacts may include sediment from construction work, overtopping or seepage from surface water storage structures, unintended release of water or alteration of watercourse character due to construction works. ▪ No downstream users identified.	▪ Being located at the top of the Woleebee and Wandoan Creek catchments, there are no cumulative impacts resulting in a change to the hydrological regime due to overtopping or unplanned/planned discharges from other proponents.	Monitoring, management and mitigation measures related to changes in hydrological regime are discussed in: ▪ Section 10.1.2 ongoing monitoring for surface water and regulated structure seepage monitoring ▪ Section 10.2.3 CSG Water Management ▪ Section 10.2.5 Infrastructure location planning ▪ Section 10.2.6 Environmental management practices
Changes to water quality	▪ Impacts to water quality related to the use of chemicals by the Project are discussed in the Chemical Risk Assessment (KCB 2023a).	▪ Potential changes to groundwater quality as a result of Project development activities may relate to the use of drilling fluids, seepage from water storage facilities. ▪ Potential changes to surface water quality from Project activities relate to the use of drilling fluids, surface spills, localised transport of suspended sediment to waters during construction or site works, or unplanned releases or overtopping from water storage facilities.	▪ Being located at the top of the Woleebee and Wandoan Creek catchments, there are no cumulative impacts resulting in a change to water quality expected due to spills, overtopping or unplanned/planned discharges from other proponents.	Monitoring, management and mitigation measures related to changes in water quality are discussed in: ▪ Section 10.1.2 ongoing monitoring for surface water and regulated structure seepage monitoring ▪ Section 10.2.3 CSG Water Management ▪ Section 10.2.5 Infrastructure location planning ▪ Section 10.2.6 Environmental management practices ▪ Section 10.2.9 Emergency and incident response: Spills
Groundwater drawdown – GDEs	Impacts to potential GDEs can occur if the following conditions are met: ▪ Potential GDEs have been identified in the area. ▪ The potential GDEs are located on a GAB aquifer outcrop/sub-crop. ▪ It is confirmed that the potential GDEs are sourcing water from the GAB aquifer or the GDEs are sourcing water from an alluvial system connected to a GAB aquifer. Evidence to suggest a connection include: ▪ Hydraulic evidence including groundwater levels in the underlying GAB aquifer are in connection with the alluvium or there is sufficient water in the alluvium to support the potential GDE. ▪ Water quality in the GAB aquifer is sufficient for GDEs to survive. ▪ Drawdown of >0.2 m is predicted in the GAB aquifer due to the presence of the Project by the OGIA modelling.	▪ Drawdown of greater than the 0.2 m trigger at potential terrestrial GDE areas on the Westbourne Formation outcrop is not predicted for the 'Project only' development. ▪ Drawdown of greater than 0.2 m are predicted in the Upper Springbok Sandstone outcrop at an area of potential terrestrial GDEs. The potential terrestrial GDEs align with the presence of alluvium and based on the evidence provided above, it is likely that they are supported by the alluvium which is not considered to be connected to the Springbok Sandstone; and is therefore not predicted to experience drawdown as a result of the Project. ▪ It is concluded that the predicted impacts to potential terrestrial GDEs from the predicted drawdown resulting from the Project development are not significant. ▪ Impacts to potential stygofauna habitats are limited to the unconfined outcrop areas. These impacts have been identified in the Upper Springbok Sandstone. The Project contributes up to 0.9 m of drawdown within the Springbok Sandstone outcrop on PL 445. No discernable impacts to subterranean fauna, as a result of the Project development, are predicted.	▪ The cumulative impact of drawdown on the Springbok Sandstone has been assessed and four potential GDE locations have been identified. These locations are impacted without the presence of the Project.	Monitoring, management and mitigation measures related to changes in hydrological regime are discussed in: ▪ Section 10.1.1 baseline monitoring for potential GDEs and groundwater bores ▪ Section 10.1.2 ongoing monitoring for groundwater ▪ Section 10.2.5 Infrastructure location planning ▪ Section 10.2.6 Environmental management practices

Aspect	Assessment	Predicted Project Only Impact	Predicted Cumulative Impacts	Monitoring, Management and Mitigation
Groundwater drawdown - Bores	Potential long-term impacts to groundwater bores have been assessed against the Water Act 2000 bore trigger threshold of 2 m for an unconsolidated aquifer (e.g., alluvium) and 5 m for a consolidated aquifer (e.g., Surat Basin units) using the outputs and drawdown predictions from the Surat CMA UWIR numerical model.	▪ Twenty-three bores exceed the trigger threshold. These groundwater bores, are already triggered by adjacent developments (e.g. without any contribution from the Project) and are sourcing from the WCM.	▪ The contribution of the Project development results in five additional bores being triggered in the cumulative scenario. These bores would not have been triggered without the presence of the Project. Of these only two bores are existing water supply bores, and one has been identified as being blocked. ▪ Impacts to groundwater bores are mitigated through the requirements of the Water Act 2000 and the make good obligations of a resource tenure holder.	Monitoring, management and mitigation measures related to changes in hydrological regime are discussed in: ▪ Section 10.1.1 baseline monitoring for groundwater ▪ Section 10.1.2 ongoing monitoring for groundwater ▪ Section 10.2.2 Bore Impact Management Measures
Subsidence	subsidence calculation based on the compaction at a specific location method (Sanderson 2012; Coffey 2018) and using the OGIA groundwater model drawdown predictions for both Project only and cumulative scenarios.	▪ Project only subsidence is estimated to be between 0.002 and 0.058 m. ▪ Project only subsidence estimation of a maximum of 0.06 m (Section 9.6.1) would be classed as low risk under OGIAs classification. ▪ The overall risk to EVs from subsidence is regarded as low.	▪ The subsidence resulting from the predicted cumulative drawdown scenario (including the Project) has been estimated to be up to 0.063 m[9], with a range of 0.006 to 0.063 m (cumulative).	Monitoring, management and mitigation measures related to subsidence are discussed in: ▪ Section 10.1.1 baseline monitoring for subsidence ▪ Section 10.1.2 ongoing monitoring for subsidence

[9] Cumulative estimation including surrounding projects.

10 MITIGATION, MANAGEMENT AND MONITORING

This section provides details on Senex's proposed mitigation, management and monitoring practices for the Project that will be adopted to manage the risk of impacting water resources.

Key Senex management plans and reports related to the monitoring and management of water include:

- The Water Monitoring and Management Plan (SENEX-ATLS-EN-PLN-017)
- The Environmental Management Plan (SENEX-ATLAS-EN-PLN-015)
- The Atlas Project – Operation Management Plan for Regulated Structures (OPS-QLD-OP-PLN-008)
- Seepage monitoring plan (OPS-ATLW-CS-PLN-002)
- Atlas Dam – Seepage Monitoring Review 2020-2023_REV0 (Streamline Hydro, 25 July 2023, 2023095001-RPT-001)
- The CSG Water Management Plan (SENEX-ATLS-EN-PLN-013 and SENEX-ATLS-EN-PLN-14)
- Contingency Procedures for Emergency Environmental Incidences (SENEX-QLDS-EN-PRC-024)
- Spill Response Plan (SENEX-CORP-ER-PLN-006)

Other documents of importance:

- The Surat CMA Water Management Strategy (WMS) (OGIA 2021a)
- The Joint Industry Framework (DCCEEW 2021)
- The Atlas Stage 3 EPBC Water Report (this report)

10.1 Monitoring

A summary of Senex's baseline and ongoing-monitoring commitments is provided in Table 10.1 and more detail is provided below and in the WMMP (SENEX-ATLS-EN-PLN-017).

Table 10.1 Monitoring Commitments and Issues Addressed

Monitoring Commitment	Issues Addressed
Baseline monitoring of groundwater quality and levels	Understanding the groundwater baseline water quality and levels, and the relationship between hydrostratigraphic units. Monitoring of potentially impacted areas of GDEs to establish groundwater dependence. Establish vertical hydraulic gradients near potential watercourse springs and other GDEs.
Baseline monitoring of groundwater dependent ecosystems	Provide sufficient understanding of the baseline conditions of the GDE to enable identification of potential adverse effects in the future. Determine the likelihood of groundwater dependence.

Monitoring Commitment	Issues Addressed
Baseline monitoring of surface water systems	Provide sufficient understanding of the baseline conditions of the surface water system to enable the identification of potential adverse effects in the future. Establish further understanding of groundwater interaction, determine losing or gaining surface water systems.
Baseline monitoring of produced water quality	Provide an understanding of the typical produced water quality to assist with identifying potential groundwater or surface water impacts from seepage, spills or overtopping.
Ongoing groundwater level and quality monitoring	Inform the Joint Industry Framework (JIF) risk assessment processes. Identify changes in water level or quality which could indicate that the Project is potentially impacting the groundwater system.
Ongoing groundwater seepage monitoring	Monitor for potential seepage or spills from produced water or brine storage facilities constructed for the project through groundwater monitoring.
Ongoing monitoring of water storage facilities	Monitor water storage facilities to identify when a spill, seepage or overtopping event occurs which may impact groundwater or surface water systems.

10.1.1 Baseline Monitoring

Baseline monitoring is required to enable the establishment of a baseline condition against which to monitor or assess whether, or not, the future development poses environmental risks.

Baseline monitoring, for two years (to include two wet and dry seasons) to be completed within two years of commencement, is proposed for:

- Groundwater level and quality;
- Groundwater dependent ecosystems;
- Surface water quality; and
- Subsidence.

Ongoing baseline monitoring of produced water is occurring throughout the duration of Project Atlas (approved project on adjacent lease PL 1037). The proposed baseline monitoring is proposed in the following sections.

Ongoing baseline monitoring of produced water is occurring throughout the duration of Project Atlas (approved project on adjacent lease PL 1037).

Groundwater

Baseline Groundwater Monitoring Network

Senex have installed eight groundwater monitoring bores at four nested sites across PL 445 and PL 209. These bores were installed in late 2022 to mid-2023 to provide site specific hydrogeological characteristics and allow for the monitoring of groundwater levels and quality over time. Bore locations were selected to be in the vicinity of predicted impact areas and monitor hydrostratigraphic units of interest. These bores were installed in the alluvium and the underlying consolidated formations of the Springbok Sandstone and Westbourne Formation.

The purpose of these bores is to establish baseline conditions and seasonal trends, and to monitor for any changes in groundwater levels and quality in the alluvium and underlying Surat Basin units for at least two years, incorporating two wet/dry seasonal cycles; to provide sufficient temporal data sets, and; to validate and update the hydrogeological conceptual model.

Monitoring parameters have been selected based on information guidelines for proponents preparing CSG and large coal mining developments (IESC 2018). All of these parameters will be monitored in the baseline monitoring network and any future additional bore(s) for the first two years. A data review of the collated baseline data will be undertaken annually by a suitably qualified person. After the collection of two years of data the sampling suite and frequency will be reviewed, and it will be determined whether to extend the baselining or determine long-term monitoring.

Details of the bores to be used for the baseline program are provided in Table 10.2, with their location provided on Figure 10.1.

Table 10.2 Baseline Groundwater Monitoring Bores

RN	Senex ID	Location	Screen Depth (mbGL)	Source Aquifer	Purpose
180128	Atlas-13M-D	ATP 2059	30.5 – 36.5	Westbourne Formation	Baseline Monitoring
180127	Atlas-13M-S		6.0 – 9.0	Alluvium	
TBC	Atlas-14M-D		40.0 – 46.0	Springbok Sandstone	
TBC	Atlas-14M-S		7.0 – 10.0	Alluvium	
TBC	Atlas-15M-D	PL 209	29.0 – 35.0	Westbourne Formation or Gubberamunda Sandstone	
TBC	Atlas-15M-S		8.4 – 11.4	Alluvium	
TBC	Atlas-19M-D	PL 445	24.0 – 30.0 and 39.0 – 45.0	Springbok Sandstone	
TBC	Atlas-19M-S		4.5 – 7.5	Alluvium	
13030810	-	PL 209	8.37 – 9.37	Alluvium	Baseline Monitoring (GWL only)
13030809	-		36.37 – 38.37	Springbok Sandstone	
160631	Wolleebee MB3-S	PL 209	378 – 420	Upper Springbok	WMS obligation (acquired from APLNG)
160764	Woleebee MB1-W	PL 209	506 – 510 709 – 714 786 – 791	Upper Juandah Coal Measures Lower Juandah Coal Measures Taroom Coal Measures	WMS obligation (acquired from APLNG)

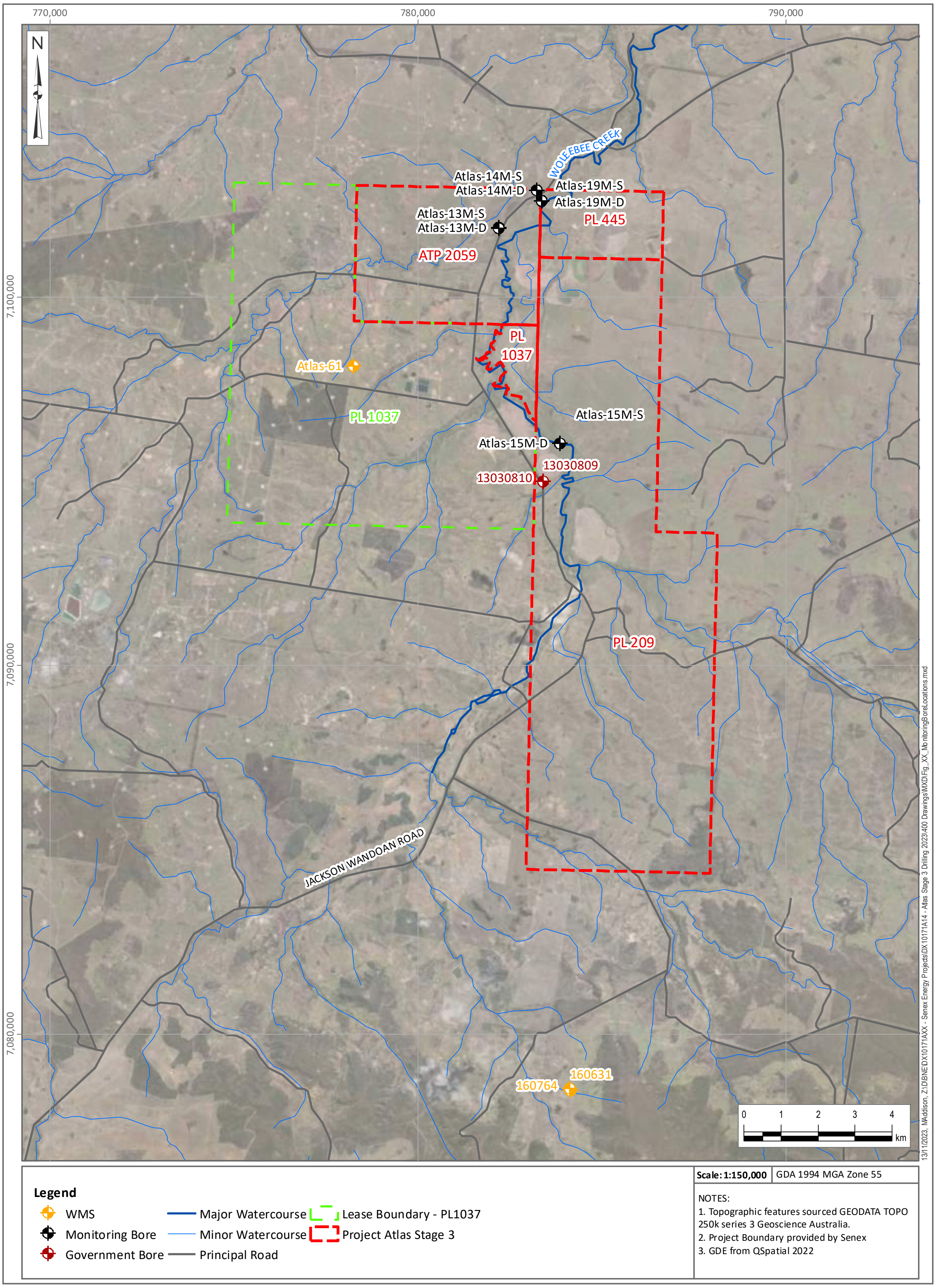


Figure 10.1 Location of Senex Baseline Monitoring Bores

Additional Baseline Monitoring Bores

To account for the spatial variability and extent of the alluvium, and further assess the connectivity between the Quaternary alluvium and the underlying Upper Springbok Sandstone, Senex will install an additional (5th) pair of monitoring bores in the vicinity of Wandoan Creek, within the area of predicted drawdown near the northern boundary of ATP 2059. Surface geophysical surveys (method to be determined) will be undertaken to help place the new monitoring bore pair in the optimal location.

A geophysical survey will be undertaken as part of an alluvium mapping exercise to provide additional information in characterising the heterogeneity in the alluvium across this predicted drawdown areas and improve the robustness of drawdown predictions and associated risks at the individual GDE-scale. The existing four paired monitoring bores will be used as verification points when analysing geophyscial data obtained through this program.

These additional monitoring bores will become part of the groundwater baseline monitoring bore network which will include monitoring of groundwater levels and quality and isotope sampling. The geological and hydrogeological data collected as part of this site investigation will be used to refine the hydrogeological conceptual model of the Project.

Groundwater Bore Baseline Assessments

Senex was required by DES to undertake bore baseline assessments for two bores within ATP 2059, and 32 bores within PL 445 and PL 209 tenures. These bore baseline assessments have been undertaken as detailed in Section 7.12.2.

Senex will comply with any updates to the bores required for baseline assessment as part of the WMS that may be required in any future updates of the UWIR. Any future baseline assessments will be conducted in accordance with the DES 'Baseline Assessment Guideline' (DES 2022a).

Groundwater Dependent Ecosystems

The purpose of the GDE baseline monitoring is to collect adequate baseline data to characterise the existing environment in areas where the OGIA model predicts (for the 95th percentile cumulative drawdown simulation) >0.2 m lowering of groundwater levels within the formations underlying the alluvium/GDEs (i.e. within the Upper Springbok Sandstone outcrop areas). This baseline data will allow for improved design of monitoring, mitigation and management processes and plans.

The GDE baseline monitoring will include:

- Potential Terrestrial GDE Baseline Assessment
  - The TGDE vegetation community assessments will be undertaken within 50 m x 20 m plots (0.1 ha) in representative locations (including at least one location in each identified RE and regrowth vegetation type) that make up the potential TGDEs within the areas of predicted drawdown in the outcropping Upper Springbok (where >0.2 m drawdown is predicted at Upper Springbok outcrop at the 95th percentile). Vegetation community assessment plots will, wherever possible, be located close to the existing and proposed groundwater monitoring bores.

  - BioCondition assessments and baseline botanical surveys will be undertaken.
  - Reference TGDE sites will also be established and assessed outside of the expected project impact area in comparable TGDEs.
  - The TGDE assessment within and outside of the areas of predicted drawdown in the outcropping Upper Springbok will provide a baseline of the TGDE characteristics (including seasonal variability) within these areas prior to there being any potential for these TGDEs to be affected by the Project.
- Potential Aquatic GDE Baseline Assessment
  - The aquatic ecology assessment sites will, wherever possible, be located close to the existing and proposed groundwater monitoring bores. Reference sites will also be established.
  - An aquatic habitat inventory is undertaken at each baselining location to assist in the interpretation of ecological data. This inventory includes a general description of the environment within, and immediately surrounding each site.
  - Aquatic habitat will be assessed in accordance with Queensland Australian River Assessment System (AusRivAS) Sampling and Processing Manual (DNRM 2001a).
- Stygofauna Assessment
  - It is proposed that stygofauna sampling be completed in Senex's recently installed and future proposed monitoring bores on at least four separate occasions (all at least three months apart) over two years. Where water is present in the alluvium monitoring bores these will be sampled for stygofauna. The non-alluvium bore of each monitoring bore pair will be sampled.
  - The sampling program will provide a baseline of the stygofauna characteristics (including seasonal variability) within these areas prior to there being any potential for these areas to be affected by the Project.

The proposed GDE baseline monitoring is further detailed in the WMMP (SENEX-ATLS-EN-PLN-017).

GDE Dependency Assessment Program

Senex will undertake a GDE Groundwater Dependency Assessment Program to assess the level of potential groundwater dependency of GDEs present in and upstream of the potentially 'impacted' areas.

The assessment will include the following:

1. Collection of biophysical data from trees from within areas mapped as Terrestrial or Aquatic GDEs within and upstream of the potentially 'impacted' area, including:

   a. Measurement of pre-dawn leaf water potential (LWP) from selected canopy trees at proposed assessment sites.
   b. Measurement of leaf area index (LAI) from trees assessed for LWP.
   c. Soil auger profiling and collection of downhole soil moisture potential (SMP) at selected assessment sites.
2. Analysis of stable isotope composition of surface waters, groundwater (from auger holes and dedicated monitoring bores), soil moisture and twig xylem to investigate the partitioning of moisture pools being utilised by woody vegetation within mapped GDE areas.
3. Consideration of the hydrochemical properties of all water samples, particularly salinity (EC) in groundwater samples as an indicator of suitability of the various moisture sources to support transpiration.
4. Acquisition and analysis of high resolution (World View_GEO Eye 50cm) NDVI imagery to form a component of a broader dataset applied for temporal monitoring of GDEs.

The program will be undertaken over a two-year (four sampling events) baseline period. The program will include the assessment of stable isotopes to determine the major water sources being utilised by riparian vegetation that is associated with potential TGDEs or AGDEs. Stable isotope analysis including sampling of twig xylem, soils, any surface water (plus groundwater intercepted in soil augers) over two seasonal cycles will allow for the identify any changes to vegetation moisture sources that occur during the baseline - particularly important in a drying climatic cycle where trees can switch abruptly from use of soil moisture to groundwater.

Further details on the assessment program, including sampling methods, locality and intensity are provided in the WMMP (SENEX-ATLS-EN-PLN-017).

This intensive data collection will form a component of a baseline dataset.

Surface Water

Surface water sampling has not been previously undertaken, apart from one sample that was collected and submitted for isotopic analysis for comparison with water samples collected from the paired monitoring bore network. The results were used to assist with determining the connection between surface water and the groundwater of the Quaternary alluvium (one bore) and the deeper Surat Basin units water samples.

In order to further establish baseline conditions of surface water, Senex will collect surface water samples from a minimum of three sites along Wandoan and Woleebee Creeks (at least one site on each creek), including a reference site near the monitoring bore pair Atlas-15M. Given the ephemeral nature of the surface water system, water quality sampling will need to include event-based sampling when watercourse flows occur.

Four baselining events will be completed over a minimum two-year period (to establish a better understanding of seasonal variation prior to any potential impact from the Project development), after which sampling frequency will be reviewed and long-term monitoring determined.

Subsidence Monitoring

Baseline analysis of the land surface elevation will be undertaken using interferometric synthetic aperture radar (InSAR) data available over the relevant time period prior to Project commencement. It is worth noting that natural or 'background' ground movement unaffected by CSG development is in the order of ±25 mm/year (OGIA 2021) due to a range of factors including the shrinking or expansion of high-clay-content soils due to changes in moisture content, depressurisation resulting from groundwater use in aquifers overlying the target coal formation and, land management practices, such as irrigation, tillage and land contouring.

The analysis of ground movement data will examine annual trends and discuss pre-CSG activity ground movements with post-CSG movement along with any potential impacts from adjacent tenement activities, where identified.

The monitoring trigger thresholds proposed in Section 10.1.2 will be reviewed based on the findings of this baseline assessment.

10.1.2 Ongoing Monitoring

Groundwater

Groundwater monitoring will serve as a key mechanism for the early identification of the changes in groundwater levels as a result of CSG water production, within the WCM and other formations where groundwater receptors exist.

OGIA Groundwater Monitoring

The groundwater monitoring requirements for CSG tenure holders within the Surat CMA are provided as part of the UWIR WMS (OGIA 2021f), which establishes baseline trends, identifies any changes within or near CSG development areas or locations of interest and informs future improvement of groundwater modelling.

The groundwater monitoring strategy is detailed in the Atlas Stage 3 WMMP (SENEX-ATLS-EN-PLN-017). This plan has been prepared to outline Senex's proposed monitoring, management and mitigation measures to specifically address impacts to water from the Project.

Senex is currently obligated to maintain and monitor two WMS monitoring points (a Springbok Sandstone and a multi-zone WCM), located within the Project area (PL 209). Senex also monitor one production bore for water quality under the WMS. Details of these monitoring points are provided in Table 10.3. Senex will continue to comply with any updates to the WMS that may be required in any future updates of the Surat CMA UWIR.

Table 10.3 Senex Groundwater Monitoring Network

RN	Senex ID	Owner	Source Aquifer	Location	Monitoring Status
160631	Woleebee MB3-S	Senex	Upper Springbok Sandstone	PL 209	Senex WMS obligation (acquired APLNG)
160764	Woleebee MB1-W	Senex	Upper Juandah Coal Measures Lower Juandah Coal Measures Taroom Coal Measures	PL 209	Senex WMS obligation (acquired from APLNG)
-	ATLAS-61	Senex	WCM	PL 1037	WMS Production quality bore

Seepage Monitoring

Surface water and waste storage facilities have the potential to impact shallow groundwater resources. As a result, shallow groundwater monitoring in the vicinity of water storage facilities has been established for the identification of potential seepage from the CSG water storage facilities, which includes produced water and brine. The formation most likely to be affected by possible seepage from containment facilities is the underlying Westbourne Formation aquitard.

Senex undertakes quarterly monitoring for potential seepage from the water storage facilities via thirteen shallow groundwater monitoring bores and one private landholder bore as required by the Queensland Environmental Authority (EA) requirements for PL 1037. This is in compliance with Senex existing obligations to the State.

Should any additional water structures for treated water or brine be constructed on PL 445, PL 209, or ATP 2059, Senex will assess the risks and the seepage monitoring bore network would be augmented to monitor for seepage. Where new monitoring bores are required, bores will be drilled (dry air-rotary-percussion) and installed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2020) and monitored in accordance with relevant Queensland regulations.

The existing shallow seepage monitoring bores are listed in Table 10.4 and shown in Figure 10.2.

Table 10.4 Current Shallow Seepage Groundwater Monitoring Bores

RN	Owner	Senex ID	Location	Screen Depth (m below ground level)	Source Aquifer	Purpose
58824	Landholder bore	ATL-08	PL 1037	19 – 25	Westbourne Formation	Seepage background bore
180072	Senex	Atlas 1M		44 – 50		Atlas Dam Seepage Monitoring
180075	Senex	Atlas 2M		50 – 53		
180073	Senex	Atlas 3M-R		39 – 45		
180077	Senex	Atlas 4M		28 – 34		
180079	Senex	Atlas 5M		9 – 15		
180078	Senex	Atlas 9M		9 – 12		
180080	Senex	Atlas 6M		9 – 15		
180071	Senex	Atlas 7M		9 – 15		
180076	Senex	Atlas 8M		9 – 12		
180074	Senex	Atlas 12M		4.5 – 7.5		
TBC	Senex	Atlas 16M		5.5 – 11.5		
TBC	Senex	Atlas 17M		19.5 – 25.5		
TBC	Senex	Atlas 18M		11 - 17		

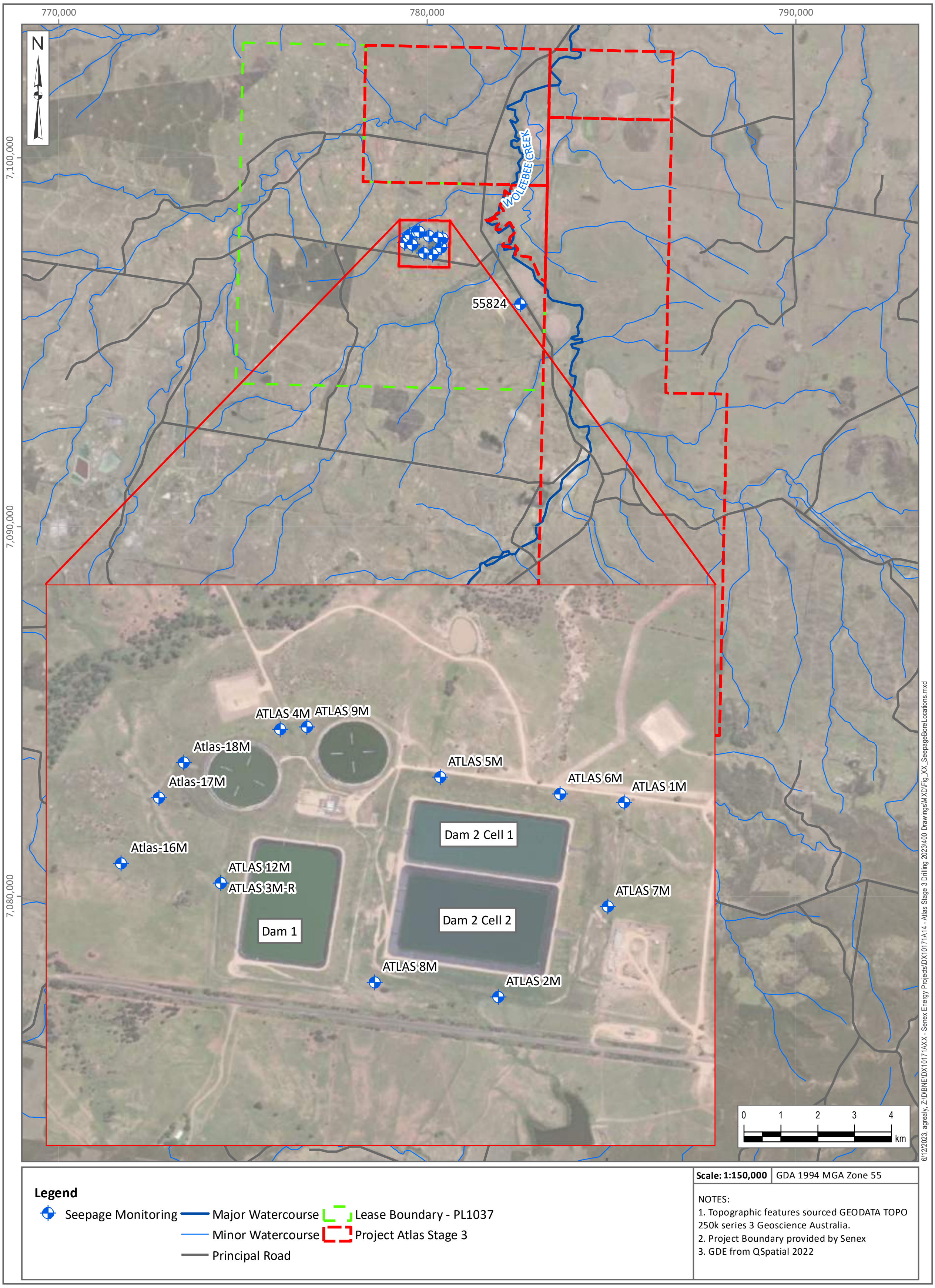


Figure 10.2 Location of Senex Seepage Monitoring Bores

Surface Water

Ongoing surface water monitoring of Woleebee and Wandoan Creeks is not proposed due to the low risk of impact to the surface water systems due to the mitigation and management measures in place. These measures include:

- Watercourse crossings will be monitored for erosion and sedimentation during construction, weekly during dry conditions, and daily inspections during rainfall of >50 mm in one day or >100 mm over 4 days or as soon as watercourse access is re-established after flooding. Locations of watercourse crossings are to be confirmed.
- Implementation of a significant consequence category dam operation plan (OPS-ATLW-CS-PLN-002), which provides an emergency response trigger and subsequent management procedure for the significant loss of regulated structure liner integrity or overtopping.
- Regulated structure monitoring to assess the performance of the structure liner system and to provide advanced warning of a loss of structural integrity of the regulated structure or overtopping.
- Implementation of a Spill Response Plan (SENEX-CORP-ER-PLAN-006) which provides the standard protocols that must be utilised in order for Senex to respond in an appropriate and timely manner in the event of a spill.

Regulated Structure Seepage Monitoring

CSG produced water and brine will be stored in storage facilities in the eastern area of PL 1037, and in the vicinity of the existing water treatment facility and in PL 209. These facilities have the potential to impact the shallow groundwater quality should over-topping or a breach of the facility liner occur. CSG water storage ponds will be constructed in accordance with the *'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures'* (DES 2016a) and relevant EA conditions. Water storage facilities will be monitored to ensure the operating water levels are maintained within the specifications of the dam design.

Any monitoring program will be designed and implemented to monitor for dam and brine tank seepage in accordance with the relevant EA conditions, and the requirements outlined in the *'Streamlined Model Conditions for Petroleum Activities'* (DES 2016b).

Produced water monitoring is ongoing at the Atlas Aggregation Dam #1 and #2, located on adjacent lease PL 1037 which are classed as regulated structures. The primary objectives for monitoring activities for the regulated structure are:

- To provide data on the produced water level within the storage facilities;
- To assess the performance of the regulated structure liner system and leak detection system;
- To provide advanced warning of a loss of structural integrity of the regulated structure embankment/wall;
- To comply with regulatory conditions, including EA conditions, relating to operation and monitoring of the regulated structures; and

- To comply with risk mitigation measures identified in the regulated structure design risk assessment and also residual risks identified as part of construction reporting and certification for each regulated structure.

Monitoring includes:

- Produced water level in the storage facilities;
- Produced water temperature;
- Produced water chemistry;
- Leakage detection via monitoring water in collection sump/s or flow rate through leakage recirculation pipes; and
- Seepage detection via monitoring water level and chemical properties in shallow and deep groundwater bores surrounding the regulated structure.

Produced Water Monitoring

As per the requirements outlined in the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020b), the volume of CSG water produced will be monitored and recorded and provided to the relevant authority as required.

Untreated CSG produced water quality will be monitored on a quarterly frequency or based on licensing requirements for the intended use (e.g. stock watering or irrigation). The water quality data from untreated CSG water will be used to:

- Inform the water treatment facility design and operation; and
- Monitor the water quality for suitability for the designated beneficial use and in accordance with water quality objectives in the *end of waste code associated water (including coal seam gas water)* (DES 2019a), and the *end of waste code irrigation of associated water (including coal seam gas water)* (DES 2019b), and conditions provided in the 'streamlined model conditions for petroleum activities' (DES 2016b) that are aligned with the beneficial reuse of produced water.

Water quality data from treated CSG water will be monitored regularly and used to:

- Confirm that the water quality is suitable for the designated beneficial use or water supply arrangement and in accordance with water quality objectives in the End of Waste (EOW) codes (as noted above); and
- Confirm the water treatment facility is effectively treating the CSG water.

Subsidence

InSAR is the most appropriate technique for ongoing monitoring of change in elevation for the purpose of establishing trends and subsequent identification of subsidence (OGIA 2021e). OGIA will acquire InSAR data directly from a supplier and make this dataset available to industry and stakeholders. Senex will process the acquired InSAR data annually to identify changes to ground elevation from the pre-Project baseline and establish trends. The general assessment process (outlined below) will involve the identification of potential Project related subsidence and further investigation to compare the subsidence assessment against trigger thresholds for different types of assets.

The results will be reported to DCCEEW in accordance with approval conditions.

Identification of potential CSG related subsidence

OGIA suggests that additional monitoring occurs where the observed trend in ground movement shows a decline of more than 10 mm/year over a 12-month period and there is CSG production within 2.5 km of the monitoring location (OGIA 2021f).

Senex will identify areas for further assessment where the annual rate of subsidence based on the InSAR monitoring over a 1 km by 1 km grid for 50% of the InSAR data points have an annual subsidence rate of more than 10 mm/yr. In these areas further assessment will be undertaken to assess if the trigger thresholds identified in the following section are exceeded.

Investigation of potential CSG related subsidence

Where an annual subsidence rate has been identified that exceeds 10 mm/yr an assessment of the potential reason will be undertaken to identify if was due to:

- Natural or anthropogenic causes; or
- CSG related due to depressurisation based on analysis of CSG wells and groundwater bores data.

Exceedances that are assessed to be Project related will be investigated to determine if any asset trigger thresholds are exceeded. Site specific investigations will then be carried out to identify and assess potentially affected infrastructure and watercourses. Site specific investigations may include additional monitoring consisting of LiDAR (or similar data) within 12 months of the decline and undertaking additional verification at agreed ground control points to further improve accuracy of the survey data (OGIA 2021f).

Trigger thresholds are presented below and have been developed based on the subsidence risk assessment undertaken.

Trigger thresholds:

- Buildings and structures - Differential settlement of built infrastructure of 0.001 m/m (Selected for buildings as most sensitive infrastructure. Not relevant to linear infrastructure as predicted differential settlement is well within tolerance).
- Flood flow in watercourses - Change of slope (natural features) of 140 mm/km (Only applies to the main channel of the Woleebee Creek and Wandoan Creek. Effects on flow to be reviewed using conventional survey to assess significance of the change).

These trigger thresholds will be reviewed based on the findings of the baseline assessment described in Section 10.1.1.

Subsidence Mitigation Action Plan

If the trigger thresholds are found to be exceeded for any of the assets identified above a Subsidence Mitigation Action Plan will be developed that will:

- Identify potential mitigation measures and response actions.
- Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude.
- Evaluate time frames within which impacts would be expected to occur and within which mitigation actions would need to be successful.
- Schedule mitigation implementation, with consideration for the anticipated timing of the indicated impact.
- Contain procedures to evaluate the effectiveness of the mitigation measures.

It is worth noting that a Subsidence Mitigation Action Plan is unlikely to be required because the predicted cumulative induced subsidence (including the Project) has been estimated to be 0.063 m across the Project with a maximum change in ground slope from CSG-induced subsidence of less than 0.002% (20 mm/km). This is well below the adopted investigation thresholds for protection of buildings, road, railways, pipelines of 1 in 1000 and for the flow in the Woleebee Creek of 140 mm/km.

10.2 Management and Mitigation

10.2.1 CSG Production Well Drilling and Construction

Measures to minimise impacts to groundwater quality and avoid introducing connectivity between formations during the construction of CSG production wells, include the following:

- CSG production wells will be designed, constructed and decommissioned in accordance with the "*Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 1*" (State of Queensland 2019a). This code outlines mandatory requirements and good practice to reduce the risk of environmental harm. CSG production wells will be designed to:
  - Prevent any interconnection between target hydrocarbon bearing formations and aquifers;
  - Ensure that gas is contained within the well and associated pipework and equipment without leakage;
  - Ensure zonal isolation between different aquifers is achieved; and
  - Not introduce substances that may cause environmental harm.

A chemical risk assessment has been undertaken for the Project (KCB 2023a), to consider drilling fluids used in CSG well drilling/installation. Drilling fluids and additives used during drilling activities will be water based, appropriate for the well design and local geological conditions, and will be used in accordance with the mandatory requirements and good practice guidelines outlined in the Code of Practice (State of Queensland 2019a), as well as the Safety Data Sheets

(SDS) provided with each fluid/additive. With relation to drilling fluids, the mandatory requirements include:

- Drilling fluids must be selected and managed to ensure all manufactured products used during well procedures on CSG wells are in accordance with the manufacturer's recommendations and relevant SDS; and
- The name, type and quantity of each chemical used on each well throughout the life of the well must be recorded.

Good industry practice for CSG drilling includes:

- Drilling fluid should be a carefully monitored and controlled mixture which is designed to:
  - Achieve best drilling results and ensure efficient removal of formation cuttings;
  - Control formation pressures; and
  - Minimise damage to formations.
- Petroleum tenure holders should ensure that the drilling fluid selected is appropriate for the well design to manage any locally experienced drilling problems and the geological conditions likely to be encountered;
- The use of biodegradable substances in the drilling fluid is preferred;
- The source of water for all well procedures (drilling, completion, workover, and abandonment) should be recorded for future well monitoring purposes;
- Products should be chosen, stored, and used at concentrations that minimise the risk of causing environmental harm;
- Personnel, including contractors, should be aware of the environmental impact and emergency spill procedures for the products and substances in use on-site; and
- Petroleum tenure holders should use established, effective drilling practices to achieve a stable, uniform and, as far as possible, in-gauge hole.

Drilling fluids will be disposed in accordance with EA conditions outlined in the waste schedules. Additionally, hydraulic fracture stimulation will not be undertaken as part of the Project.

Further details on the management practices associated with chemical and fuel storage are provided in Section 10.2.7.

10.2.2 Bore Impact Management Measures

The *Water Act 2000* outlines requirements for make good obligations of a resource tenure holder for a bore located in immediately affected areas. Tenure holders must carry out a bore assessment and enter into a make good agreement with the bore owner if the bores are located within an immediately affected area. The UWIR assigns bores to tenure holders located within immediately affected areas. There is currently one bore assigned to Senex within an immediately affected area in PL 445 (formerly assigned to Origin APLNG; RN 58910 in the Upper Juandah Coal Measures).

The results of the impact assessment to bores indicate that there would be five additional bores that may potentially experience water level decline greater than 5 m as a result of the cumulative scenario (i.e. the contribution of the Project development results in five additional bores being triggered in the cumulative scenario). Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. These bores are not located on Senex tenements and of the five, only one appears to exist and is in a 'usable' condition.

Senex will comply with any updates to the make good agreements required in future updates of the UWIR and undertake bore assessments as required as a result of make good obligations. Any required bore assessments will be undertaken in accordance with the DES 'Bore Assessment Guideline' (DES 2022b).

Senex have developed an Atlas Stage 3 Water Management and Monitoring Plan (Senex 2023b), which has been prepared to outline Senex's proposed monitoring, management and mitigation measures to specifically address impacts to groundwater from the Project. This includes process associated with undertaking bore assessments associated with make good obligations.

Senex has developed their CSG Water Management Strategy, outlined in the CSG Water Management Plans (ATP 2059: SENEX-ATLS-EN-PLN-013; PL 445 and PL 209: SENEX-ATLS-EN-PLN-14), and described in the following section, to maximise beneficial use of CSG water. To minimise impacts to landowner bores, Senex proposes to establish Landowner Water Supply Agreements (WSAs).

10.2.3 CSG Water Management

CSG water management will be undertaken in accordance with the Senex CSG Water Management Plan (ATP 2059: SENEX-ATLS-EN-PLN-013; PL 445 and PL 209: SENEX-ATLS-EN-PLN-14), which has been developed to meet the requirements of the CSG Water Management Policy (State of Queensland 2012).

10.2.4 Beneficial Use Activities

To minimise impacts to shallow groundwater quality, as a result of beneficial use activities such as third party irrigation, water quality will be monitored to confirm compliance with water quality objectives in the *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b), and conditions provided in the 'Streamlined Model Conditions for Petroleum Activities' (DES 2016b) that are aligned with the general beneficial use approval.

10.2.5 Infrastructure Location Planning

To avoid, minimise and manage potential impacts to MNES across the Project area, and to support well field layout for all surface infrastructure, including wells and gathering pipelines, Senex will implement a 'Atlas Stage 3 Environmental Constraints Protocol for Planning and Field Development' (OPS-ATLS-EN-PLN-001; Senex 2023a)(the Constraints Protocol). The Constraints Protocol is described in Section 3.3.1.3.

10.2.6 Environmental Management Practices

Senex have developed an Environmental Management Plan (SENEX-ATLAS-EN-PLN-015) that describes how Senex will manage potential environmental impacts associated with conducting gas production activities and to ensure compliance with EA conditions, industry guidelines and regulatory requirements. The relevant environmental controls relating to minimising the impact to groundwater and surface water are described below.

Watercourses and Riparian Ecosystems

Watercourses and riparian ecosystems, depending on their location, may be intersected by Right-of-way's (RoWs) for the gathering system, where they cannot be avoided. Impacts to these features have been considered as part of the Project impact assessment. Potential impacts that may result from these crossings during construction and operation include generation of suspended sediment in the watercourse, altered geomorphic watercourse characteristics (e.g. changes to bed and bank profile), changes to riparian buffers (vegetation clearing), construction in bed and/or banks of waterways, and habitat fragmentation. A number of mitigation and management measures are planned to limit the impact to waterways and riparian ecosystems. These include:

- **Site Selection** – During field planning for site selection, watercourse crossings are avoided where practicable because of environmental impacts (including impacts such as fragmentation and disruption of flows), and their associated additional construction requirements, including erosion and sediment control and monitoring. Where possible, existing watercourse crossings will be utilised to minimise land disturbance and impacts to riparian vegetation and associated habitat.
- **Construction Planning** – Overall, construction activities will aim to avoid interfering or blocking natural drainage. Stormwater will be allowed to pass through the sites in a controlled manner and at non-erosive flow velocities. Watercourse crossing points will be adequately stabilised to prevent erosion and the RoW construction period when working in waterways will be minimised.
- **Erosion and Sediment Control** – Erosion and sediment control structures will be implemented to address the risk of sediment release. These measures will be inspected periodically and after rain events and maintenance carried out where required.
- **Rehabilitation** – The scale of the initial disturbance for construction is generally planned to be 18 m wide for RoWs. This width will be reduced during the operating phase to a nominal area that will be rehabilitated directly over the pipeline to maintain pipeline integrity, and a 6 m access track will be maintained to access wells and infrastructure. Within the life of the well field, RoWs through watercourses may be rehabilitated sooner than the gas field life, depending on their location and the well's operational life.

To minimise the impacts of water quality in surface watercourses during construction and operation, the following measures will be implemented:

- Petroleum activities within any watercourse must be carried out in accordance with an approved Authority to Work (ATW). Watercourse crossings will be limited to those strictly necessary for construction or operation of infrastructure and only at locations approved in the ATW.
- Any waterway barrier works (works that pose a barrier to water flow) must only be undertaken where authorised under an ATW and only at the location specified.

- Where required, watercourse crossing points will be adequately stabilised to prevent erosion.
- 'No-go' areas will be GPS located and clearly marked.
- Construction activities must be managed to minimise interference with overland flow paths.
- Clean stormwater will be diverted around disturbed land wherever practicable.
- For linear infrastructure – construction or maintenance activities in a watercourse must be carried out under the authorisation of an ATW and under the supervision of a Senex environment representative to ensure conditions of the EA are achieved.

In addition, the following monitoring and reporting will be undertaken:

- Watercourse crossings must be monitored for erosion and sedimentation during construction, regularly during dry conditions, and daily inspections during rainfall of >50 mm in one day or >100 mm over 4 days or as soon as watercourse access is re-established after flooding.
- During periods of flow, surface waters downstream of construction areas near a watercourse area will be monitored for water quality as per the Environmental Management Plan (SENEX-ATLAS-EN-PLN-015).
- Records of all erosion and sediment control and water quality checks will be maintained by Senex staff.
- Construction or maintenance works on linear infrastructure in watercourses should be monitored by a Senex representative to ensure compliance with the EA conditions.

10.2.7 Chemical and Fuel Storage

To minimise the impacts of a chemical or fuel spill to surface or groundwater the following measures will be implemented:

- All fuel, oil and chemicals are to be stored, transported, and handled in accordance appropriate standards including AS 3780:2008 – The storage and handling of corrosive substances, AS 1940:2004 – The storage and handling of flammable and combustible liquids, AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers.
- Storage areas must be sealed, bunded (secondary containment), and adequately ventilated.
- Storage and refuelling areas will be preferentially located away from watercourses, sensitive areas and any source of ignition as determined by the Senex Site Supervisor.
- Containment bunds and/or sumps will be drained periodically of accumulated rainwater to prevent overflow and subsequent pollution of the surrounding land and watercourses.

In addition, the following monitoring and reporting will be undertaken:

- All chemical, oil and fuel storage areas are to be inspected regularly for temporary storage, and for permanent storage areas during the operating phase by the Contractor Site Supervisor and/or the Senex Representative.
- All spills are to be contained immediately and managed through the Senex Spill Response procedure (see Atlas Stage 3 Environmental Management Plan (SENEX-ATLAS-EN-PLN-015)).
- Emergency events will be managed in accordance with the contingency procedures in the Emergency Response Plan.
- Incident details must be recorded immediately and notified through the Senex Incident reporting systems, reported, and investigated.

10.2.8 Soil and Erosion Management

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

Senex will undertake Erosion and Sediment Control (ESC) on all significantly disturbed land with reasonable and practicable measures implemented depending on the relative risk of the works and the sensitivity of the receiving environment. The aim is to minimise soil loss and prevent impacts to watercourses and wetlands resulting from events that cause sediment release.

To minimise soil erosion, mass movement and gully erosion, the following measures will be implemented:

- Ensure stormwater passes through the site in a controlled manner and at non-erosive flow velocities. Divert clean water from the work site where practical.
- Minimise the duration that disturbed soils are exposed to the erosive forces of wind, rain and flowing water.
- Minimise work-related soil erosion and sediment runoff.
- Minimise negative impacts to land or properties adjacent to the activities (including roads).
- Inspect worksites periodically as required, before expected rainfall events, and after rain events and undertake maintenance where required as per the Erosion and Sediment Control Plan.

In addition, the following monitoring and reporting will be undertaken:

- Construction phase monitoring of soil erosion and sediment controls will be undertaken as required by project specific construction ESCPs;
- ESC monitoring during the operational phase of the Project will comprise monitoring of previously installed ESC controls and established groundcover to ensure that controls remain functional, and groundcover is not reduced;
- Records of all erosion and sediment control monitoring will be maintained by the Senex staff; and
- All monitoring and reporting will be in accordance with Environmental Authority conditions.

Where produced water has been applied to land (e.g. dust suppression), and adverse impacts have been identified such as surface crusting, scalding or poor vegetation growth, further assessment will be undertaken to assess the impacts and cause. Assessment will typically involve soil sampling and laboratory analysis of pH, electrical conductivity, chloride, sodicity (i.e. soil cations) and Emersons aggregate stability test. Depending on the findings, soil amelioration will be undertaken to address the issue. Amelioration and amendments may include addition of gypsum for sodicity, organic matter such as manures for poor structure and fertility, lime for strongly acid soils, elemental sulfur for highly alkaline soils or fertiliser for low nutrients.

10.2.9 Emergency and Incident Response: Spills

In the event of an environmental incident:

- Personnel who observe an environmental incident including a spill must immediately notify the Contractor Site Supervisor who will then notify the Senex Site Supervisor.
- In the event of a chemical, oil or fuel spill, the spill will be contained and cleaned up as outlined in the Senex Spill Response Plan.
- Contractors must have in place procedures for spill response which are in accordance with the Senex Spill Response Plan and will include details requirements for:
    - Minimising release;
    - Containing spilled material;
    - Raising the alarm and response;
    - Locations of spill kits; and
    - Management of contaminated material if necessary.
- Any spills will be assessed by the Senex Site Supervisor supported by the Senex Environment Representative as required to determine appropriate remediation options such as the removal of contaminated material.
- Incident reports must contain information required by the Safety Management Plan and Incident Reporting and Investigation Procedure.
- Emergency Response drills will be performed to ensure readiness and identify opportunities for improvement.

Senex requires that all incidents including spills are reported and fully investigated in accordance with their specific level of potential risk. The environmental emergency activation pathway as presented by the Spill Response Plan is shown in Figure 10.3.

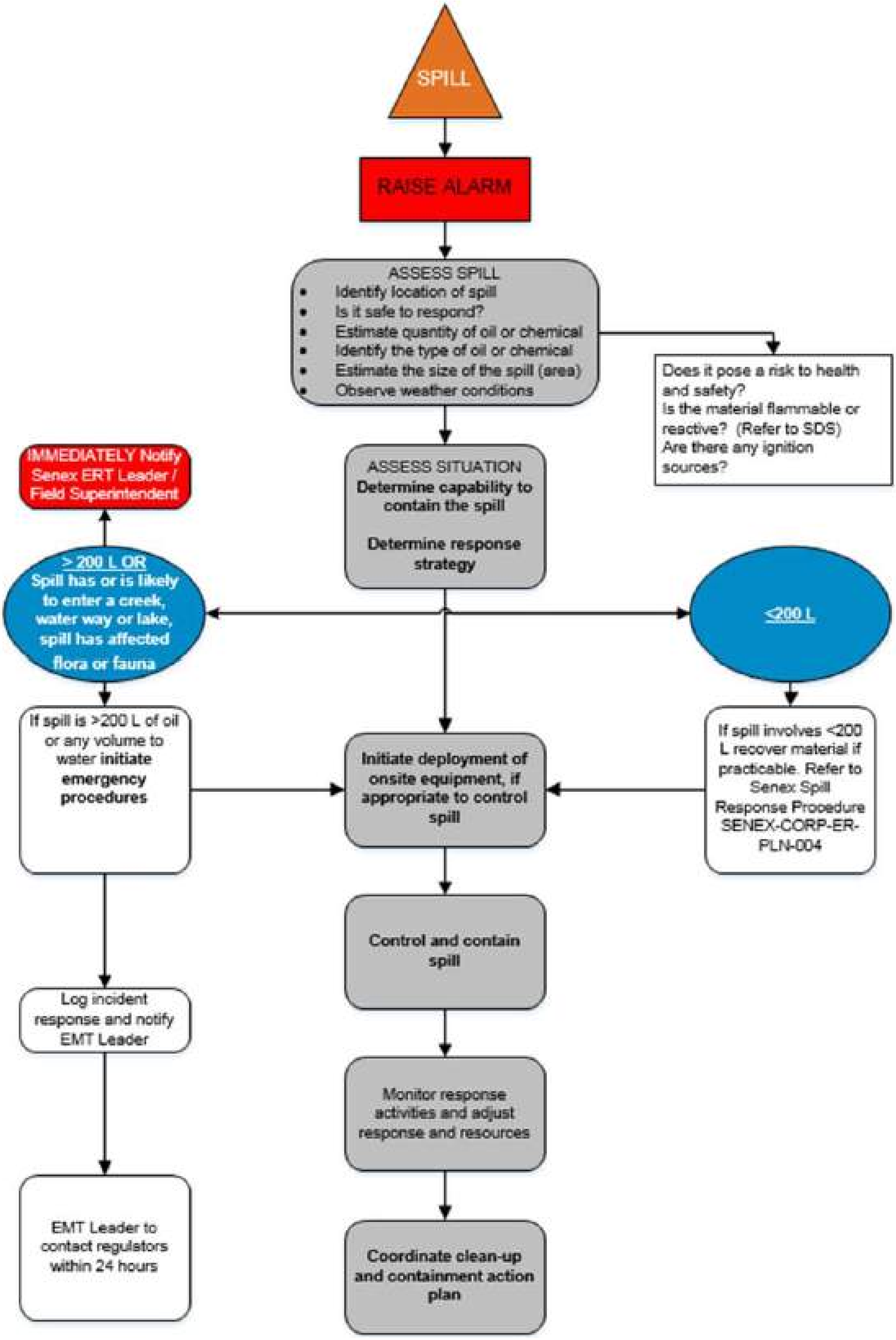


Figure 10.3 Senex Environmental Emergency Activation Pathway

Senex has adopted internationally accepted 'Tiered Response' classifications to describe different categories of spill events, based on severity and location. Tier classifications are determined based on spill volume, environmental sensitivity, potential social impacts and other factors specific to the event. The Spill Response Plan details tier event trigger limits and the appropriate response required to assist with effective mitigation and management of associated risk due to accidental spill events.

The chemical risk assessment and associated SDS will be adaptively used to inform the spill response associated with accidental release of a chemical to prevent adverse impacts to protected matters. The spill response plan uses information from the CRA and SDS throughout the response process (see Table 10.5).

Table 10.5 Spill Response Plan (Adapted from the Spill Response Procedure (SENEX-CORP-ER-PLN-006; Senex 2017)

Step	Assess the Spill
Assess the Spill	Use the SDS and CRA to: ▪ Inform personnel training requirements. ▪ Inform the selection of appropriate spill response kits and PPE located at chemical storage / handling locations. ▪ Identify the risk to personal health and safety by the type of pollutant. Determine whether the chemical is flammable or reactive. ▪ Determine whether the spill poses a threat to personnel, people, or the environment. ▪ Inform the severity assessment and assign the spill classification (Tier 1: emergency/crisis to Tier 3: minor event). ▪ The potential for impacts to nearby sensitive environmental areas.
Control the Spill	Use the SDS and CRA to inform spill containment and management. The documents can be consulted for advice on accidental release measures, personal precautions, protective equipment, and emergency procedures.
Clean-up Action Plan	Use the SDS and CRA to inform decisions on clean up and rehabilitation, including protective equipment, dependent on the type and nature of the chemical (as documented in the CRA). For chemicals the SDS is to be referred to for information on appropriate handling and transport.

10.2.10 Groundwater Quality and Drawdown Investigation and Reporting Triggers

The Queensland guideline, using *monitoring data to assess groundwater quality and potential environmental impacts* (State of Queensland 2021b) (the Guideline) provides a framework for site-specific development of groundwater investigation triggers. Trigger values are typically a numerical criterion that, if exceeded, provide an indication of a change that warrants further investigation.

Groundwater Quality Triggers

Site specific Investigation Trigger Values have been derived for Seepage Monitoring Bores (StreamlineHYDRO 2023). Trigger values will also be derived for Senex Monitoring Bores (once sufficient monitoring data has been collected), in a manner that is consistent with the Queensland guideline document (State of Queensland 2021b). The approach to be adopted is detailed in Senex's Water Monitoring and Management Plan (WMMP) (SENEX-ATLS-EN-PLN-017) It is proposed that site-specific conditions and trends be considered that will provide the Project with appropriate triggers to initiate additional monitoring, investigation, and actions, as well as providing a suitable level of protection for potential receptors.

According to the Queensland Guideline sufficient spatially representative, good quality monitoring data at an adequate statistical distribution is required to calculate robust site-specific groundwater trigger values. The Guideline recommends that estimates of 20th and 80th percentiles require a minimum of 18 samples over at least 12 and preferably 24 months. Although percentile estimates based on eight samples can be used to derive guidelines, this approach is not recommended. Site-specific trigger values should be developed once sufficient data has been collected to determine the natural water quality variability. It is proposed that available data be assessed after 2 years of monitoring for statistical representativeness prior to site-specific trigger value derivation.

In the interim, the guideline recommends that EVs and WQOs be reviewed, and preliminary conservative generic default guideline values be adopted to protect surface and groundwater. Where local reference conditions are found to exceed published default guideline values for the protection of identified EVs, the guideline states that interim site-specific guidelines may be adopted that is greater than the default guideline.

Assessment of water-related impacts for the proposed development of the Atlas Stage 3 Gas Project (KCB 2023b) indicate the water quality in these formations generally exceed relevant generic Water Quality Objectives and guideline values. Since site-specific trigger values cannot be calculated due to lack of data, it is recommended that monitoring of Senex bores be continued to establish the required dataset for trigger calculations. It is proposed that available data be assessed after 2 years of monitoring for statistical representativeness, prior to value derivation and adoption of triggers.

For this reason and as a preliminary approach, it is suggested that primary parameters during the first two years be monitored for increasing trends or concentration spikes, as opposed to, against a set trigger level (with the exception of pH, where investigation triggers in line with relevant WQOs have been chosen). The proposed interim trigger would include five or more data points that indicate an upward trend or a general increasing trend over a six-month period. Immediate resampling would be required where sharp concentration increases are detected (3 or more times above the dataset average). Where elevated levels are confirmed, immediate investigation pertaining to possible causes should follow.

Preliminary Indicator Parameters

Preliminary primary indicator parameters indicative of stored produced water, intraformational flow, auxiliary infrastructure, and material handling and storage (including the use of drilling fluids) have been selected for Atlas Stage 3. Selection of indicator parameters relevant to drilling additives and chemicals entailed the review of drilling additives proposed to be used at Atlas Stage 3. Drilling additives include a range of chemical groups including suspended clays and other solids, acids and bases, salts, ions and organic compounds. Changes in primary indicator parameters are most likely to provide an indication of changing groundwater quality or hydrogeochemical conditions. Preliminary secondary indicators are also provided. In the event of an exceedance of a primary indicator, a trend analysis of the secondary indicators would be required as per the TARP, in support of the investigation into the cause of a trigger exceedance.

Indicator parameters will be reviewed annually for representativity during the first two years of monitoring and updated as required by monitoring and investigation results. A list of preliminary primary and secondary indicator parameters and further details pertaining to their derivation are contained in the WMMP (SENEX-ATLS-EN-PLN-017). The WMMP is a living document that will be updated throughout the operational Project life.

Groundwater Level Triggers

Groundwater level triggers are not proposed to be developed for seepage monitoring bores.

Site-specific groundwater trigger levels with consideration to the potential drawdown resulting from the Project will be adopted for Senex monitoring bores to facilitate targeted impact monitoring and management. Hydrographs for each bore location will be requested from OGIA together with the maximum predicted drawdown water levels in mAHD, which will be used to derive early warning, investigation and reporting triggers as described in the WMMP (SENEX-ATLS-EN-PLN-017).

10.2.11 Groundwater Trigger Action Response (TARP)

Groundwater triggers are simply a threshold value, above / below which some further consideration of the data should be given to determine the potential for environmental harm from the Project activities. The trigger values are not a pass or fail assessment; rather they act as a warning system that initiates further investigation. It is anticipated that the most up to date relevant groundwater quality and water level triggers and action plans will be contained in the latest update of Senex's WMMP for Atlas Stage 3 throughout the Project life. This section details the actions that should follow the exceedance of a trigger value / identification of persistent trends (as at project start).

Seepage Bore TARP

The adopted compliance approach, which is aligned with the Queensland Guidelines, relevant to the seepage bores include:

- Five (5) consecutive values above the Value A (80th percentile) level trigger.
- Any three (3) consecutive exceedances above the Value B (95th percentile) level trigger.

Exceedance of these values will trigger the seepage emergency response procedure (refer Section 10.2.8).

Groundwater Quality TARP

Senex will review the groundwater quality in monitoring bores for increasing trends on a bi-annual basis until statistically robust triggers have been developed. Following this, monitoring results will be evaluated against prescribed groundwater quality trigger values after each quarterly monitoring round.

Monitoring data will also be added to a control chart for each bore, which includes the historical record. Control charts are a visual method of using monitoring data to determine if a management response is needed, therefore acting as an early warning system using control values identified by statistical methods on site-specific data.

An example control chart is presented in Figure 10.4 and shows the Value A and Value B performance indicators, as well as the Normal, Control and Critical Zones, which have actions defined in the TARP as presented in Table 10.6. If the data review identifies upward trends / exceedance of the groundwater quality trigger values, then the TARP will be used to determine the appropriate actions.

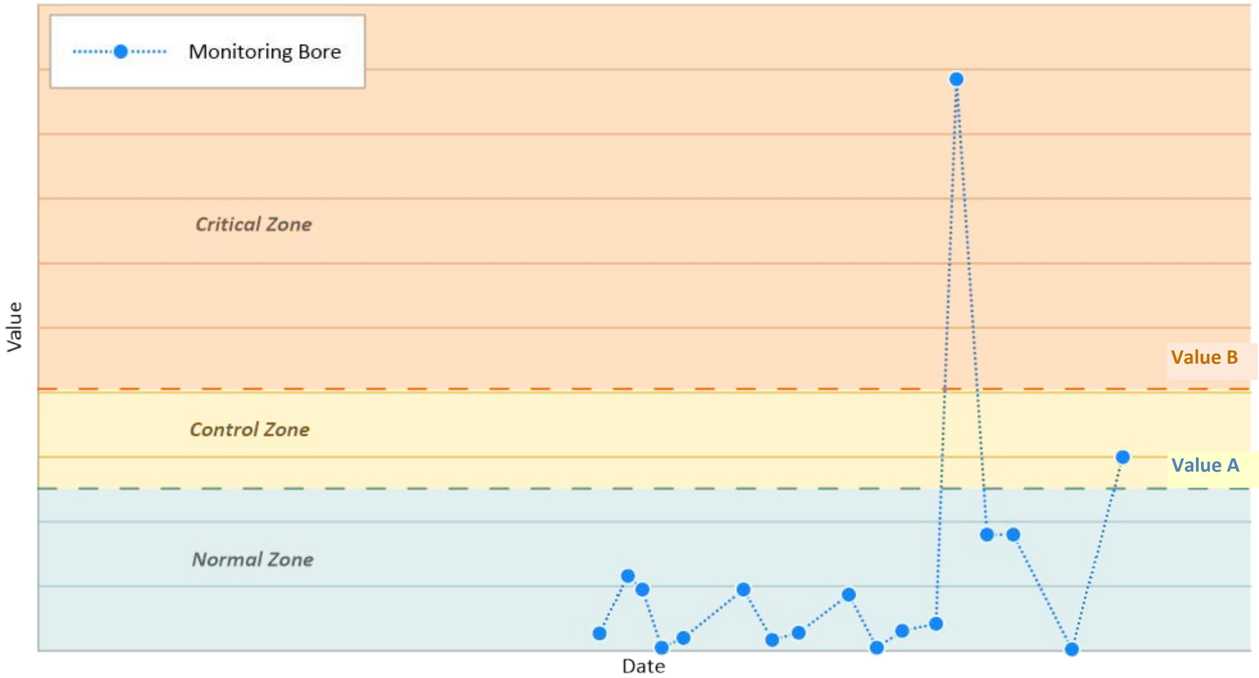


Figure 10.4 Example Control Chart

Table 10.6 Trigger Action Response Plan for Groundwater Quality

Actions	Normal Zone	Normal Zone With Upward Trend Below Value A Level but Upward Trends / Spikes	Control Zone Above Value A (80%) / Below Value B	Critical Zone Exceedance of Value B (95%)
Action Trigger	▪ All parameters below Value A. ▪ No persistent upward trends.	▪ Concentration increases more than 3 times above the dataset average. ▪ If five (5) or more data points indicate an upward trend (visual check) ▪ A general increasing trend over a 6-month period	▪ Five (5) consecutive values above the Value A (80%) level trigger	▪ Any three (3) consecutive exceedances above the Value B (95%) level trigger
Recommended Actions	▪ No actions apart from continued monitoring as per WMMP Groundwater Monitoring Plan.	▪ Confirm that the measured concentrations are correct (e.g., review laboratory, field notes and sample QA/QC results). ▪ For sharp concentration increases: resample within one week to confirm results. Where elevated levels are confirmed, immediate investigation pertaining to possible causes should follow. ▪ Confirm with site personnel any localised site activity or construction not noted in monitoring records. ▪ Increase frequency of monitoring as relevant following assessment of the trend.	▪ Confirm that the measured concentrations are correct (e.g., review laboratory, field notes and sample QA/QC results). ▪ Confirm trends or anomalies by resampling within 7 days. ▪ Commence Initial Investigation - perform trend analysis (Mann-Kendal Test) and review concentrations to identify a potential reason for the result. ▪ Monitor adjacent bores and/ or evaluate the need to install additional bores to increase robustness of monitoring program and coverage. ▪ Perform trend review of Secondary Indicator parameters. ▪ In instances where increases are isolated to one bore, investigate	▪ Resampling of measurement within 7 days of noting the exceedance. ▪ Notification of the exceedance to the environmental manager if the field parameters are confirmed. ▪ A Trigger Investigation report to be undertaken by a suitably qualified hydrogeologist to identify the cause of the water quality changes. ▪ Implement actions as recommended for the 'Control Zone' as relevant to support the investigation. ▪ Where an investigation determines that impacts are the result of the Project, evaluate and implement the appropriate mitigation actions.

Actions	Normal Zone	Normal Zone With Upward Trend Below Value A Level but Upward Trends / Spikes	Control Zone Above Value A (80%) / Below Value B	Critical Zone Exceedance of Value B (95%)
		▪ Assess bore suitably and identify potential external influences. ▪ Implement relevant mitigation actions should external influences be identified (e.g. prevention of surface water ingress). ▪ If upward trend is found to be potentially due to project activities / impacts, or if upward trend is likely to exceed Value A, follow Control Zone trigger actions.	other possible sources other than Project activities. ▪ If increases are not isolated to one bore commence initial investigation and evaluate the need for mitigation.	▪
Reporting Level	▪ None.	▪ Senex Environmental Manager.	▪ Senex Environmental Manager.	▪ Senex Environmental Manager ▪ Administering Authority within 4 months of receiving the analysis results.

Mitigation

Where investigations following trigger value exceedance determines that impacts are likely to be Project related and present an unacceptable risk of harm to human health or the environment, appropriate mitigation / remediation actions may be required. The need for appropriate mitigation should be evaluated, and implemented as may be required to mitigate the risk of unacceptable harm.

Examples of mitigation options include:

- Review of the design, construction, and operation of the surface water storage facilities to prevent seepage and overtopping. Update of relevant documentation (e.g. the Atlas Project - Operation Management Plan for Regulated Structures (Senex 2023) as required);
- Install contamination capturing bores or interception trenches to allow collection and as required treatment of the impacted water;
- Install dewatering bores to create a hydraulic barrier to prevent migration of contaminated water;
- Containment and subsequent remediation of identified point pollution sources;
- Decommissioning and sealing of incorrectly installed CSG wells; and
- Improvement of housekeeping, storage, handling and management procedures / facilities associated with potential pollution sources.

Remediation options could include:

- Source removal / stabilisation / degradation (aerobic /anaerobic, biological / chemically mediated);
- CSG bore rehabilitation where impacts are identified to be related to loss of drilling fluids / inter-formational flow / well failure; and
- Engineered cut-off or treatment trenches / interception systems / barriers, etc.

Additional monitoring bores are likely to be required to evaluate the flow paths and success of implementation in all the above cases.

Groundwater Level TARP

Senex will review groundwater levels and trends of monitoring bores in conjunction with the water quality trigger level review. Trigger levels for groundwater levels are based on the numerical model predictions by OGIA. To avoid false triggering, Value triggers for groundwater levels are proposed to occur when average values dip below the groundwater trigger for three or more consecutive months. The groundwater level trigger strategy comprises two tiers as follows:

Tier 1 Assessment

An example control chart is presented in Figure 10.5 which shows the Value A and Value B performance indicators, as well as the Normal, Control and Critical Zones, that have actions defined in the TARP. If the data review identifies exceedance of the groundwater level trigger values and criteria or a persistent decreasing trend, the groundwater level TARP will be used to determine the appropriate actions.

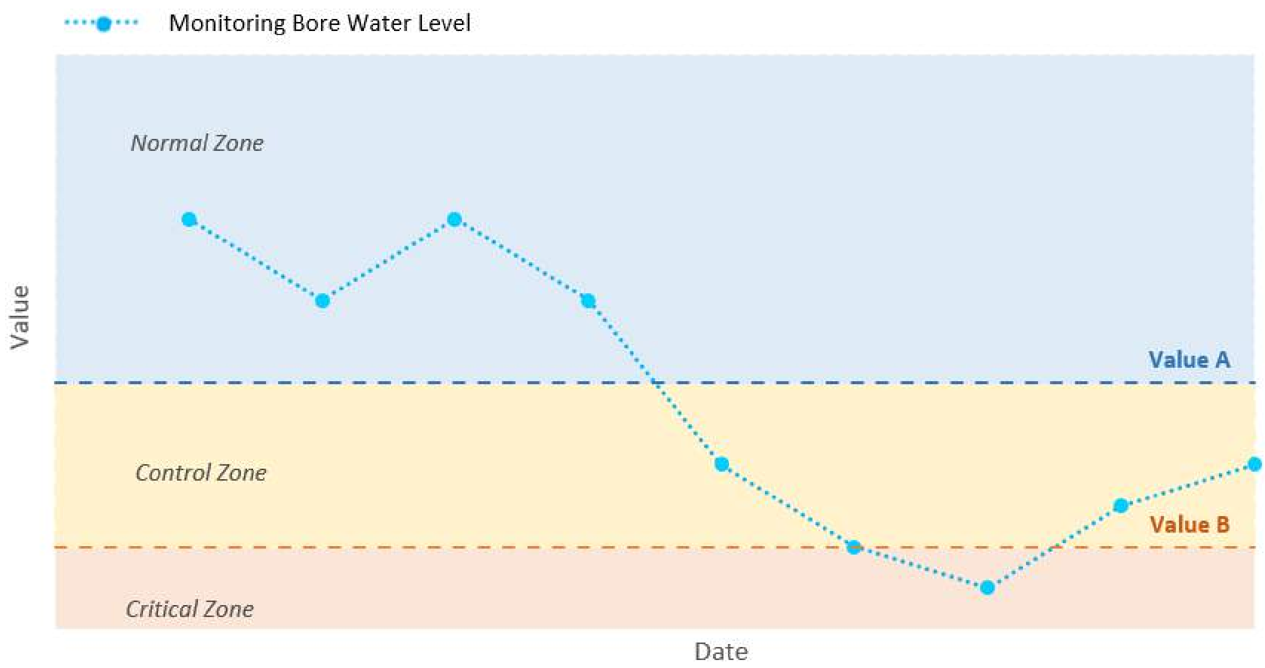


Figure 10.5 Tier 1 Example Control Chart

Tier 2 Assessment

Model predicted hydrographs will be generated for each monitoring bore. When the TARP requires Tier 2 assessment, actual monitoring bore data collected during the Project will be compared with model predicted hydrographs. If monitored trends exceed modelled trends, further investigation would be triggered as per the TARP.

As an extra precaution, an increase in drawdown trend in excess of 10% over the previous year has also been specified as a trigger for follow-up investigation as per the TARP.

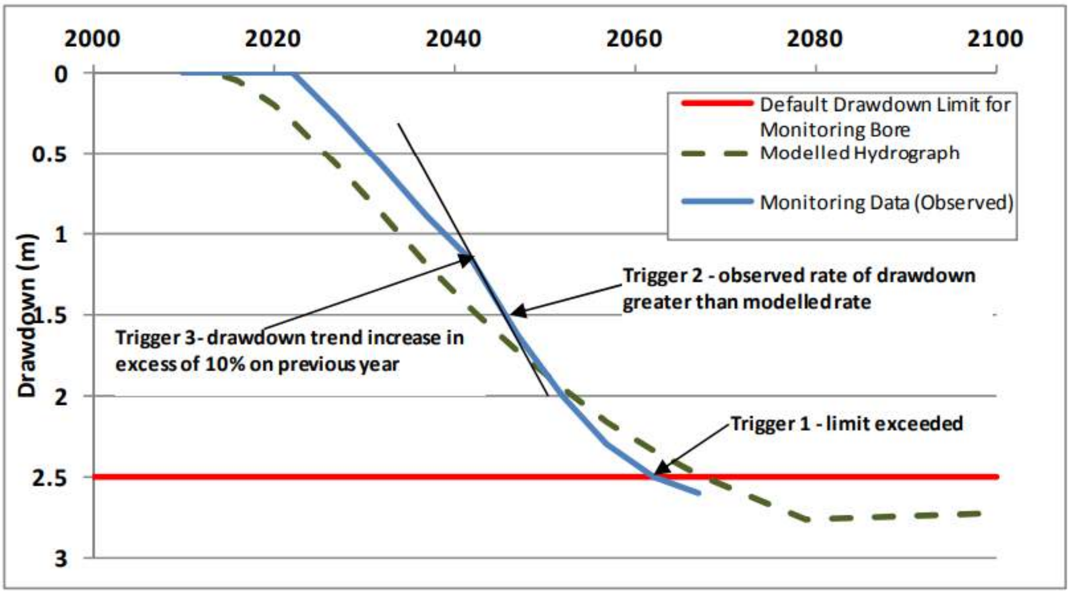


Figure 10.6 Schematic of Monitoring Trend Triggers to Initiate Follow-Up Response

Table 10.7 Trigger Action Response Plan for Groundwater Levels

	Normal Zone	Normal Zone - Increased Monitoring Values Display Decreasing Trend within 5m of / Within Control Zone.	Control Zone Early Warning: Below Value A / Above Value B	Critical Zone Below Value B
Action Trigger	All parameters above Value A. No decreasing trends.	▪ If monitoring over a 6-month period displays a decreasing trend (visual check) ▪ Any one or more recordings below Value A.	▪ Average groundwater level is below Value A and above Value B (within 2m of max. model predicted drawdown) for three or more consecutive months. ▪ Monthly average groundwater Level is >2 m different from the model prediction for three (3) consecutive months. ▪ Any one or more recordings below Value B.	▪ Average groundwater level is below Value B (max predicted model drawdown) for three or more consecutive months. ▪ Monthly average groundwater Level is >2 m different from the model prediction for six (6) consecutive months.
Recommended Actions	No actions apart from continued monitoring as per WMMP Groundwater Monitoring Plan.	▪ Confirm that the measured water levels are correct (e.g., review field notes QA/QC, validate logger values with hand readings, data handling etc.). ▪ Assess possible causes (e.g., climatic conditions, site activities) that may impact groundwater levels. ▪ Consider an increase in frequency of monitoring. ▪ Evaluate monitoring results and compare with modelled results as per Tier 2 control chart assessments. If model vs monitoring levels / trends are more than 10% different implement 'Control Zone' actions.	▪ Confirm that the measured water levels are correct (e.g., review field notes QA/QC, remeasure within 7 days, perform hand measurements, check loggers etc.). ▪ Evaluate monitoring results and compare with modelled results as per Tier 2 control chart assessments. If model vs monitoring levels / trends are more than 10% different commence Initial Investigation: ▪ Review differences in actual CSG development vs that included in the numerical model. ▪ Include trend analysis (Seasonal Kendal Test) to identify a potential reason for the change in groundwater levels for Trigger Bores.	▪ Confirm that the measured water levels are correct (e.g., review field notes QA/QC, remeasure within 7 days, perform hand measurements, check loggers etc.). ▪ A Trigger Investigation report should be undertaken by a qualified hydrogeologist to identify the cause of any changes. ▪ Where investigations indicate that cumulative CSG / mining impact is a likely cause, re-visit latest model predictions (if different than previous) and actual CSG (vs proposed) development plans to understand deviation from the original modelled water levels.

	Normal Zone	Normal Zone - Increased Monitoring Values Display Decreasing Trend within 5m of / Within Control Zone.	Control Zone Early Warning: Below Value A / Above Value B	Critical Zone Below Value B
			▪ The investigation analyses must account for the lag time between natural events and changes in groundwater levels. ▪ Assess possible causes (e.g., climatic conditions, site activities) that may impact groundwater levels. ▪ Compare tends with that of other bores. ▪ Increase frequency of monitoring (as determined by a specialist). ▪ If deviation (in excess of 10%) are not isolated to one bore, initiate assessment (refer to critical zone actions). ▪ Evaluate the need to install additional bores to expand monitoring network as determined by a specialist.	▪ Identify and evaluate mitigation measures (e.g. via model scenarios). ▪ Drill additional bores to support investigations as determined by a specialist. ▪ Where an investigation determines that Project impact exceed modelled results, determine appropriate mitigation actions. ▪ Consider undertaking geophysical survey of the alluvium to understand heterogeneity and saturation across the alluvium to assist with understanding potential impacts. ▪
Reporting Level	Senex Environmental Manager.	▪ Senex Environmental Manager.	▪ Senex Environmental Manager.	▪ Senex Environmental Manager. ▪ Notification of exceedance of Value B to Administering Authority within 28 days of receiving the results or as required by the Administrating Authority. ▪ Results of additional drilling and trigger investigation report to Administering Authority within 6 months of initial notification.

Mitigation

Where an investigation determines that Project impacts exceed modelled predictions, and present an unacceptable risk of harm, appropriate mitigation actions will be evaluated and may be implemented as required.

Examples of mitigation options include:

- Modifying the staging of CSG water production in areas that could influence drawdown in specific areas.
- Off-set source aquifer impact by retiring landholder’s groundwater use from the source aquifer and by introducing stock control measures to improve wetland condition and resilience to any potential impacts on the wetland.
- Artificial recharge of aquifers where water levels have dropped to unacceptable levels.
- Ceasing CSG production in the vicinity of impacted receptors or modifying the field plan.
- Sourcing alternative water to users where the water supply bores are affected due to the Project.
- Potentially off-set impacts to GDEs should unacceptable impact be indicated.
- Augmentation of surface water flow.

10.3 Reporting

Senex will undertake all reporting as per the requirements under the State legislation, including to OGIA as part of the UWIR requirements and in accordance with the Project’s EA conditions.

11 ASSESSMENT AGAINST THE SIGNIFICANT IMPACT CRITERIA

A water resource assessment of the Project has been undertaken to consider the potential impacts associated with the Project with respect to the *Environment Protection and Biodiversity Conservation Act* 1994 (Commonwealth of Australia 2022a). A summary of the findings of this assessment is provided, with consideration to the criteria outlined in the '*Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources'* (Commonwealth of Australia 2022b).

The *'Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources'* (Commonwealth of Australia 2022b) identify a 'significant impact' as *'an impact which is important, notable, or of consequence, having regard to its context or intensity'.*

The general criteria (5.2) (Commonwealth of Australia 2022b) identifies that an action is likely to have a significant impact on a water resource if there is a real, or not remote, chance or possibility that it will directly or indirectly result in a change to: the hydrology of a water resource, the water quality of a water resource, that is of sufficient scale or intensity as to reduce the current or future utility of the water resource for third-party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring.

The *Petroleum and Gas (Production and Safety) Act 2004* identifies underground water rights for petroleum tenures, and in summary states that the holder of a petroleum tenure may take or interfere with underground water. Senex intend to exercise their underground water rights for the Project.

The Project targets the WCM for CSG production. In the vicinity of Project, there are 810 groundwater bores of which 669 are considered to be groundwater users. Key environmental values directly relevant to the Project include agriculture, town water supply and stock water. Stock and domestic is the most common use purpose within this area. The results of the impact assessment indicate:

- Twenty-three bores in the WCM are predicted to experience a water level decline that exceeds the trigger threshold of 5 m for a consolidated aquifer as a result of the Project, however these bores are already triggered through existing and approved developments.
- There are five additional bores triggered as part of the cumulative scenario (i.e. the contribution of the Project development results in five additional bores being triggered in the cumulative scenario).
    - Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures.
    - These bores are not located on Senex tenements and are to the east of the Project area. One of these bores is noted as abandoned and destroyed, two are noted as monitoring bores (and not water supply bores), and two are noted as existing bores. Of the existing bores, a bore baseline assessment confirmed one of these bores is blocked and has not been used since 1996 (Arrow 2013). The maximum Project only contribution to drawdown the only existing, usable bore is 26%.

- These bores are protected under the *Water Act 2000* which outlines requirements for make good obligations of a resource tenure holder for a bore located in immediately affected areas.

The OGIA groundwater modelling predicts the potential for drawdown to exceed the *Water Act 2000* trigger of 0.2 m for a spring/GDE in the outcrop areas of the Upper Springbok Sandstone. This area of drawdown coincides with the presence of potential terrestrial GDEs along ephemeral creek systems. These terrestrial GDEs are considered to source groundwater from the alluvial aquifers present along the creeks in these locations and not the underlying Upper Springbok Sandstone.

The alluvium is not interpreted to be connected to the Upper Springbok Sandstone in the Project area. Field investigations undertaken have provided both hydraulic and hydrochemical evidence that these units are disconnected. This evidence includes transient water level, water quality and isotope data.

A maximum Project only drawdown of 0.9 m is predicted to occur in the Upper Springbok Sandstone outcrop area, which corresponds to the location of approximately 0.7 ha of potential terrestrial GDEs along Woleebee Creek on PL 445, approximately 7 years after the start of the development. According to the terrestrial GDE preliminary risk assessment provided in the JIF (DCCEEW 2021), the magnitude (< 1 m) and timing of predicted exceedance of the drawdown on the known GDEs, suggests that the risk of impact to these potential terrestrial GDEs is low. These GDEs are predicted to be cumulatively impacted by the surrounding developments without the presence of the Project.

Considering the GDEs through the source-pathway-receptor conceptualisation:

- The presence of the Project results in a predicted drawdown of >0.2 m in the Springbok Sandstone in the far north of the Project area in PL 445 (the source). This may impact an area of approximately 70 ha, of which 0.7 ha of terrestrial GDEs are present along Woleebee Creek (the receptor).
- The pathway for the potential impact to the potential GDEs (the receptor) is the connection between the Springbok Sandstone and the alluvium, and the potential for drawdown in the Springbok Sandstone to propagate into the alluvium. The alluvium is the most likely water source for the GDEs given the depth to groundwater in the Springbok Sandstone (>20 m).
- The alluvium is not considered to be hydraulically connected to the Upper Springbok Sandstone, as supported by both hydraulic and hydrochemical data. The water quality of the Springbok Sandstone is different to that of the regional alluvium water quality, with the Springbok Sandstone being a higher salinity. Water levels in the alluvium and Springbok Sandstone differ, with the Springbok Sandstone water level confirmed as being below the base of the alluvium in the site investigations.
- The disconnect between the Springbok Sandstone and the alluvium infers there is no pathway for drawdown in the Springbok (the source) to propagate into the alluvium, and no significant impacts to GDEs (the receptor) are predicted.

A summary of the potential impacts against the Significant Impact Criteria 1.3 (Commonwealth of Australia 2022b), Changes to Hydrological Characteristics has been provided in Table 11.1 and Significant Impact Criteria 1.4, changes to water quality provided in Table 11.2.

It is concluded that the proposed development will **not** have a significant impact on water resources.

Table 11.1 Summary of Potential Impacts Against the Significant Impact Criteria 1.3, Changes to Hydrological Characteristics (Commonwealth of Australia 2022b)

Parameter	Comments
Flow Regime (volume, timing, duration, and frequency of surface water flows)	The Project does not include any abstraction or discharges associated with surface water and watercourses. There are no direct impacts predicted. Indirect impacts may occur but will be managed through Senex management procedures including the Environmental Management Plan and the Constraints Protocol. CSG water production for the Project is limited to the coal seams of the WCM. Groundwater abstracted as part of the CSG production process will be transported, treated, and contained within Senex's current water management infrastructure, with additional infrastructure constructed as required. This infrastructure will be located within the planned Project area and the neighbouring PL 1037. The location of the infrastructure will be planned in accordance with Senex's 'Atlas Stage 3 Environmental Protocol for Planning and Field Development'. The flow regime of Woleebee Creek and its tributaries (volume, timing, and frequency) is not expected to change due to drawdown of groundwater in the underlying geological units or planned ancillary infrastructure. The OGIA have identified potential watercourse springs, present in the Project area along Woleebee Creek, are sourced from the alluvium, Gubberamunda and Orallo Formations. These formations do not have a predicted drawdown of more than 0.2 m and are therefore unlikely to significantly change the flow regime of any watercourse. Water quality analysis and field verification observations indicate that watercourses in the Project area are not baseflow fed but are likely to 'lose' water to the alluvial system during times of prolonged rainfall and creek flow. Therefore, the Project is not predicted to change the flow regime. The 'Atlas Stage 3 Environmental Protocol for Planning and Field Development' (OPS-ATLS-PLN-001; Senex 2023a) will be implemented to locate infrastructure, including gathering pipelines and wells, which will be located to avoid impacting the watercourses. The gas field layout will generally avoid watercourse crossings for right of ways, and other infrastructure will be located ensuring a buffer from watercourses, to minimise surface water discharge from the Project. Senex will also implement their Sediment and Erosion Control Plan (SENEX-QLDS-EN-PRC-003; Senex 2018d), which identifies measures to ensure Senex meets its regulatory obligations relating to managing disturbed land that has potential to release soil directly or indirectly to land or water on or adjacent to Senex work sites. Surface water volumes are not anticipated to be impacted as groundwater drawdown in potentially baseflow contributing formations is limited to negligible. The ephemeral creeks present in the Project area are not considered to be baseflow fed and 'lose' to the groundwater system during periods of creek flow (Section 7.11.1).

Recharge rates to groundwater	The Project is located in an area where the Upper Springbok Sandstone, Westbourne Formation and Gubberamunda Sandstone outcrop. These outcrop areas are considered to be the location where diffuse rainfall recharge occurs to the Surat Basin formations. There is no drawdown predicted in the outcrop areas of the Gubberamunda Sandstone. There is minor Project only drawdown of <0.2 m on a small area of the Westbourne Formation, and minor drawdown of >0.2 m in the Upper Springbok Sandstone outcrop. Impacts to recharge rates in these outcrop areas is not expected. Recharge to groundwater from surface water is unlikely to decrease as a result of the Project, as the Project does not include any abstractions from the creek systems.
Aquifer pressure or pressure relationship between aquifers. Groundwater table and potentiometric surface levels Inter-aquifer connectivity	CSG water production for the Project is limited to the coal seams of the WCM. The pressure reduction in the target coal formation may result in induce leakage into the depressurised (not dewatered) formation from overlying or underlying formations. The presence of the upper WCM non-productive zone (at the top of the WCM, 25 to 40 m thick) and the Durabilla Formation (beneath the WCM, ~87 m thick) provide a marked vertical barrier between the WCM and the overlying Springbok Sandstone and underlying Hutton Sandstone. Groundwater flow within the Surat Basin units is predominantly horizontal. While there is presence of barriers between the WCM and the overlying Springbok Sandstone and the underlying Hutton Sandstone, induced leakage may still occur as observed in the groundwater modelling outputs. CSG production wells are drilled and constructed in accordance with the Code of Practice for the construction and abandonment of petroleum wells and associated bores in Queensland (State of Queensland 2019a), API standards and Senex in-house protocols (developed and implemented successfully at the adjacent Atlas Project). This code outlines the mandatory requirements and good practice to reduce the risk of environmental harm throughout the drilling process from overlying aquifers, this includes preventing interconnection between formations and ensuring zonal isolation between different aquifers. Therefore, the impact to inter-aquifer connectivity is considered insignificant. The presence of the Project only (with no surrounding developments) results in the prediction of 23 groundwater bores exceeding the consolidated groundwater trigger of 5 m. These bores are sourcing the WCM and are already predicted to be triggered by adjacent developments (without the Project). There are five additional bores triggered as part of the cumulative scenario, two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. The maximum Project contribution to drawdown at these five bores is 29%. These bores are protected under the *Water Act 2000,* which outlines the requirement for make good arrangements to bores predicted to be impacted. Resource tenure holders are required to enter into make good agreements with the owners of the groundwater bores as necessary if a bore capacity is impaired.

Groundwater / surface water interactions River / floodplain connectivity	CSG water production for the Project is limited to the coal seams of the WCM. The Project does not involve any abstraction or discharge from / to watercourses. Groundwater abstracted as a result of CSG production from the Project will be treated / stored in site-specific infrastructure, which will be constructed and monitored in accordance with relevant standards / guidelines. Woleebee Creek and its tributaries are not considered to be baseflow fed creeks. Water quality analysis indicates that the surface water system and alluvium is disconnected from the Springbok Sandstone where the deepest Project related drawdown is predicted. Based on the results of the predictive groundwater modelling outputs provided by OGIA, drawdown is not predicted to occur in formations which are the possible source aquifers for potential watercourse springs along Woleebee Creek. Therefore, potential impacts to groundwater/ surface water interactions as a result of the Project are not anticipated and will not affect river/ floodplain connectivity.
Coastal processes	The Project is located in south central Queensland. Given the distance to the coast and no potential impacts to surface water from the Project, changes to coastal processes will not occur as a result of the Project.

Table 11.2 Summary of Potential Impacts Against the Significant Impact Criteria 1.4, Changes to Water Quality (Commonwealth of Australia 2022b)

<table>
<tr><th>Parameter</th><th>Comments</th></tr>
<tr><td>Create risks to human or animal health or to the condition of the natural environment as a result of the change in water quality</td><td rowspan="2">Potential changes to groundwater quality as a result of Project development activities may relate to the use of drilling fluids, seepage from water storage facilities.

Potential changes to surface water quality from Project activities relate to the use of drilling fluids, surface spills, localised transport of suspended sediment to waters during construction or site works, or unplanned releases or overtopping from water storage facilities.

Groundwater abstracted as a result of CSG production from the Project will be treated / stored in site infrastructure, which will be constructed in accordance with relevant standards / guidelines (e.g. the 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures' (DES 2016a)) and appropriately isolated to remove any potential human / animal interaction. The surface water facilities are managed and monitored to prevent seepage, overtopping or structural failure. The significant consequence category dam operation plan (OPS-ATLW-CS-PLN-002) provides an emergency response trigger and subsequent management procedure for the significant loss of regulated structure liner integrity. A seepage monitoring bore network has been established surrounding current structures and trigger values for key source analytes will be calculated once sufficient baseline data has been collected.

A chemical risk assessment for use of drilling chemicals has been undertaken. It was determined that the risk to the MNES receptors from drilling fluids were limited to above ground chemical spills, the loss of chemicals to aquifers below ground, and the eventual disposal of the drilling fluids. Senex apply a number of management and mitigation measures to reduce the risk to MNES including drilling protocols such as the Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland (State of Queensland 2019a), and environmental management practices such as the Atlas Stage 3 Environmental Protocol for Planning and Field Development (OPS-ATLS-EN-PLN-001), Environmental Management Plan (SENEX-ATLAS-EN-PLN-015), CSG Water Management Plans for ATP 2059 and for</td></tr>
<tr><td>Substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses which are dependent on water of the appropriate quality</td></tr>
</table>

Parameter	Comments
	PL445 and PL 209 (SENEX-ATLS-EN-REP-013 and SENEX-ATLS-EN-REP-014) and a Spill Response Plan (SENEX-CORP-ER-PLN-006). The risk to MNES receptors from drilling fluids was determined both prior to, and following, mitigation and management measures. The final risk assessment determined that the likelihood for a drilling fluid to adversely affect an MNES is highly unlikely to unlikely due to the controls in place during drilling and the protocols that would be implemented if a spill did occur. The overall risk to MNES has been assessed as low significance to insignificant. Changes to groundwater or surface water quality as a result of CSG water production are not anticipated. It is not likely that the Project would result in a risk to human or animal health, or to the condition of the environment as a result of a change in water quality.
Causes persistent organic chemicals, heavy metals, salt, or other potentially harmful substances to accumulate in the environment	Potential chemical contamination may occur due to the use of drilling fluids, and seepage of produced water or brine from water storage facilities. Groundwater abstracted as a result of CSG production from the Project will be treated / stored in site-specific infrastructure, which will be constructed and monitored in accordance with relevant standards / guidelines. Fuel and chemicals used during drilling and operations will be stored and handled in accordance with the relevant Australian Standards (e.g. AS 3780:2008, AS 1940:2004, AS 3833:2007) and regulatory requirements. Hydraulic stimulation is not planned to be undertaken as part of the Project and all CSG production wells will be designed, constructed and abandoned in accordance with *"Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 1"* (State of Queensland 2019a). This code outlines the mandatory requirements and good practice to reduce the risk of environmental harm. CSG production wells will be designed to prevent any interconnection between target CSG-bearing formations and aquifers, ensure that gas is contained within the well and associated pipework and equipment without leakage, ensure zonal isolation between different aquifers is achieved and not introduce substances that may cause environmental harm. Brine will be stored in accordance with the 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures' (DES 2016a) and relevant EA conditions, and additional groundwater monitoring bores will be installed if required. Any salt or salt slurry will be trucked from the site and disposed at a Regulated Waste Facility as per the CSG Water Management Policy (DEHP 2012), which provides a prioritisation hierarchy for managing saline waste. The brine storages will be designed and constructed under the supervision of a suitably qualified and experienced person and in accordance with the relevant Australian Standards relating to tank or dam design, construction, and inspection. Beneficial use activities such as irrigation, proposed as part of the Project, will be undertaken so that the WQOs in the *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b) are met, and to ensure that the quality and quantity of treated or blended CSG water is appropriate for the receiving environment. A chemical risk assessment has been undertaken for the use of all planned drilling chemicals. Activities associated with the Project are unlikely to introduce organic

Parameter	Comments
	chemicals, heavy metals, salt, or other potentially harmful substances to the environment.
Seriously affects the habitat or lifecycle of a native species dependent on a water resource	Native species habitats dependent on water resources in the Project area include aquatic ecosystems within the creek system, and potential aquatic and terrestrial GDEs which may have some degree of dependence on groundwater. A review of these potential GDEs indicate that these ecosystems are sourcing from the alluvial system which is disconnected from deeper Surat Basin units. Woleebee Creek and its tributaries are ephemeral and not considered to be gaining streams dependent on the contribution of groundwater (as per Section 7.11.1). A maximum Project only drawdown of 0.9 m is predicted to occur in the Upper Springbok Sandstone outcrop area, which corresponds to the presence of potential terrestrial GDEs located along Woleebee Creek on PL 445, approximately 7 years after the start of the development. According to the terrestrial GDE preliminary risk assessment provided in the JIF (DCCEEW 2021), the magnitude (<1 m) and duration (7 years) of the drawdown on the known GDEs, suggests that the risk of impact to the potential terrestrial GDEs is low. However, given the alluvium on which the GDEs are likely sourcing, is not considered to be connected to the underlying Springbok Sandstone there is no pathway for drawdown to the potential receptors. The groundwater modelling outputs provided by OGIA do not predict drawdown in the alluvial system or other Surat Basin units which have been identified as a potential source to watercourse springs in PL 209 (Gubberamunda Sandstone and Orallo Formation). Therefore, surface water baseflow volumes and species dependent on water resources are not predicted to be impacted. No changes to groundwater or surface water quality have been identified as a result of the Project. No changes to habitat or lifecycle of a native species dependent on a water resource are expected.
Causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful to the ecosystem function of the water resource	No changes to groundwater and surface water quality have been identified as a result of the Project. Therefore, no changes to the water resource that may cause the establishment of an invasive species (or the spread of an existing invasive species) are expected. Senex will prevent the spread of weeds or invasive species through adherence to the Environmental Management Plan (SENEX-ATLAS-EN-PLN-015) and the Biosecurity Management Plan Queensland Operations (SENEX-QLDS-EN-PLN-001).
There is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives)	Groundwater quality data sourced from the GWDB within the vicinity of the Project indicate there is generally a distinction between the water chemistry for shallower formations (alluvium, Gubberamunda Sandstone) and the other deeper formations (e.g. WCM, Springbok Sandstone), which show a sodium-chloride signature, while the upper formations indicate a calcium / magnesium-bicarbonate water type. All formations are currently used by third-party users and the water quality is considered appropriate for their uses. Surface water is not generally used as a sustainable water source due to the ephemeral nature of the watercourses, and no discharges are proposed to the surface water system. No changes to water quality have been identified as a result of the Project. Therefore, no significant worsening of local water quality is anticipated.

Parameter	Comments
High quality water is released into an ecosystem which is adapted to a lower quality of water	Groundwater abstracted as a result of CSG production from the Project will be treated / stored in site-specific infrastructure, which will be constructed and monitored in accordance with relevant standards / guidelines. Beneficial use activities such as irrigation, proposed as part of the Project, will be undertaken so that WQOs in the *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b) are met, to ensure that the quality and quantity of treated or blended CSG water is appropriate for the receiving environment. Surface water discharge from the Project infrastructure is not proposed. Therefore, no changes to ecosystem water qualities are anticipated.

12 CLOSING

We would like to thank you for the opportunity to work on this assignment. Should you have any questions, please do not hesitate to contact the undersigned.

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