Atlas Stage 3

Water Monitoring and Management Plan

Date:	March 2024
Document:	SENEX-ATLS-EN-PLN-017
Revision:	3

Table of Contents

List of Tables

List of Figures

Document Status

Revision History

Revision	Release Date	Document Status	Revision Comments	Author
0	Oct 2022	Final		KCB
1	July 2023		Updated to include new monitoring points.	KCB
2	Dec 2023	Final	Updated to include DCCEEW and IESC Comments.	KCB
3	Mar 2024	Draft	Updated to include DCCEEW comments	KCB

Document Approval

Originator	Name and role	**Signed**	Date
		Signed	
		Signed	
Reviewed by		**Signed**	
		Signed	
		Signed	
Approved by		**Signed**	
		Signed	
		Signed	

1. Introduction

Senex Energy Pty Ltd (Senex) (ABN 50 008 942 827), on behalf of its subsidiaries Senex Assets Pty Ltd and Senex Assets 2 Pty Ltd, is currently authorised to conduct petroleum exploration activities in accordance with its Environmental Authorities (EA), with Authority to Prospect (ATP) 2059 (EA0002524) and petroleum leases (PL 209) and PL 445 (P-EA-100112777).

Senex propose to develop, operate, decommission, and rehabilitate a coal seam gas (CSG) field within ATP 2059, PL 445, the northern portion of PL 209 and parts of PL 1037 in the central part of the Surat Basin, approximately 10 km southwest of Wandoan in southern Queensland (referred to herein as 'the Project').

Proposed production activities for the Project include installing up to 151 CSG production wells and their connection to gas and water gathering lines; ancillary activities to operate the field; and water management facilities, including aggregation dams, brine storage and irrigation.

CSG water production is required as part of the CSG extraction process. Groundwater is removed (pumped) from CSG production wells to depressurise the CSG target production coal seams. The removal of groundwater for this purpose is regulated under the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020b), where petroleum tenure holders can exercise underground water rights to take or interfere with underground water in the area of the tenure if the taking or interference occurs as a result of carrying out an authorised activity for the tenure.

1.1. Aim and Objectives of the Plan

This Water Monitoring and Management Plan (WMMP) has been prepared to outline Senex's monitoring, management, and mitigation measures to specifically address potential impacts to groundwater, surface water and potential groundwater dependent ecosystems (GDEs) as a result of the Project development.

This plan has been renewed and realigned to address the requirements of the IESC (31 August 2023, Reference IESC 2023-144) and includes a summary of Senex's baseline and ongoing monitoring commitments as per Table 1-1. Further detail is provided in Section 4.

Table 1-1 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 GDEs 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.

1.2. Regulatory and Policy Framework

1.2.1. Project Approval Status

Key State and Commonwealth legislation relevant to the Project include:

- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Commonwealth of Australia 2022);
- Petroleum and Gas (Production and Safety) Act 2004 (State of Queensland 2020b);
- Environmental Protection Act 1994 (State of Queensland 2022a); and
- Water Act 2000 (State of Queensland 2021c).

A summary of the Project's current approval status under these Acts is provided in Table 1-2.

Table 1-2 Summary of the Projects Approval Status under State and Commonwealth Legislation

Act / Policy	Approval Status
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Commonwealth of Australia 2022)	This plan is submitted to accompany preliminary documentation for the Project under the *EPBC Act* following a controlled action decision on 19 May 2023. PL 445 and PL 209 has received approval under the *EPBC Act* in 2011 as part of Australia Pacific LNG Pty Limited (**APLNG**) approval over a larger area '*to develop, construct, operate and decommission the coal seam gas field component of the Australia Pacifica 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.
Petroleum and Gas (Production and Safety) Act 2004 (State of Queensland 2020b)	PL 445 and PL 209 were purchased from APLNG in late 2021, the petroleum leases were originally granted to APLNG by Queensland Department of Natural Resources, Mines and Energy (**DNRME**, now Department of Resources) in December 2004. An Authority to Prospect was granted in October 2020 for ATP 2059 by Queensland DNRME (now Department of Resources).
Environmental Protection Act 1994 (State of Queensland 2022a)	Exploration activities are authorised under existing Environmental Authorities (**EA**) (EA0002524 for ATP 2059 and P-EA-100112777 for PL 209 and PL 445). Senex will apply for an amendment of the EA (EA0002524 for ATP 2059. The EA for PL 209 ad PL 445 (P-EA-100112777) already authorises the necessary activities and no amendment is required.
Water Act 2000 (State of Queensland 2021c)	The Project is located within the Surat Cumulative Management Area (**CMA**) and will be included in the next version of the Underground Water Impact Report (**UWIR**), due to be published in 2024. Any compliance obligations required under the Surat CMA UWIR will be as directed by the Office of Groundwater Impact Assessment (**OGIA**).

1.2.2. Surat Cumulative Management Area Underground Water Impact Report

Under the *Water Act 2000* (State of Queensland 2021c), where there is an area of concentrated development, a cumulative management area (CMA) can be declared. The Project is located within the Surat CMA, which was declared in 2011.

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. Specific to the Project, 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 2012) 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. The most recent UWIR was published by the OGIA in 2022 (OGIA 2021f).

A Water Management Strategy (WMS) is developed by OGIA as part of the Surat CMA UWIR which includes the specification of a groundwater monitoring network, tenure holder obligations for implementation of the network and reporting of data to OGIA.

The purposes of the WMS (OGIA 2022c) are to:

- Identify past groundwater impacts from Petroleum and Gas as well as coal mining development;
- Improve knowledge about the groundwater flow system, which improves OGIA's ability to predict impacts;
- Support the evaluation of UWIR impact management strategies; and
- Assign obligations relating to the WMS, which typically require actions such as installation of monitoring points, ongoing investigations, and mitigation actions.

Any requirements under these obligations by Senex will be provided by OGIA.

1.2.3. Joint Industry Framework

The purpose of the 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 Matters of National Environmental Significance (MNES) and is intended to reduce duplication between the regulation of groundwater at a Commonwealth and State level.

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.

Senex is committed to and will act in accordance with the JIF as required.

1.2.4. Environmental Values and Water Quality Objectives

1.2.4.1. Environmental Values

The *Environmental Protection Act 1994* (State of Queensland 2022a) 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 1-3.

Table 1-3 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 1-4 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 1-4 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* 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 1-5.

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 1-5 indicate that groundwater values extend to all categories listed, except for aquaculture, human consumption, and secondary recreation.

Table 1-5 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. Project Description

2.1. General Description

The Project covers an area of approximately 98 km^2 and is located approximately 10 km southwest of the township of Wandoan. The Project is located within ATP 2059, PL 445, the northern portion of PL 209 and parts of PL 1037 as shown in Figure 2.1.

The CSG target coal seams for the Project form part of the Walloon Coal Measures (WCM), which comprises thin-bedded, claystone, shale, siltstone, lithic and sublithic to feldspathic arenites, lithic to minor arkosic Sandstone, felsic tuff, siderite, coal seams and minor limestone.

The Project is located adjacent to Project Atlas (PL 1037), and other CSG tenure holders including QGC and APLNG, which are summarised in Table 2-1. 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 2021b). ML 50230 partially overlies PL 445.

Table 2-1 Adjacent CSG Tenure Holders (OGIA 2021c)

Tenure Holder	Tenure	Gas Field	Location	Commencement	Cessation
Senex	PL 1037	Atlas	Directly W	2018	2060 - 2065
QGC	PL 398	Polaris	NW	Prior to 2018	2060 - 2065
	PL 277	Mamdal	Directly W	Prior to 2018	2060 - 2065
	PL 276	Cam	Directly W	Prior to 2020	2050 - 2059
		Kathleen			2050 - 2059
		Mamdal			2060 - 2069
		Ros			2050 - 2059
		Woleebee Creek			2050 - 2059
	PL 510	Paradise Downs	Directly E	2020 - 2024	2060 - 2069
APLNG	PL 444	Sandpit	Directly N	Unknown	
	PL 470	Ramyard	Directly W	2020	2050 - 2055
	PL 469	Ramyard Central	Directly W	2025 - 2029	2050 - 2059

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;
- Installation, operation and maintenance of gas and water gathering flowlines;
- 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); and
- Installation, operation and maintenance of water storage and water management facilities.

Details of the project components, including location and size, will be identified progressively over the life of the Project. All infrastructure will be located in accordance with the Atlas Stage 3 Environmental Constraints Protocol (SENEX-CORP-EN-PRC-019).

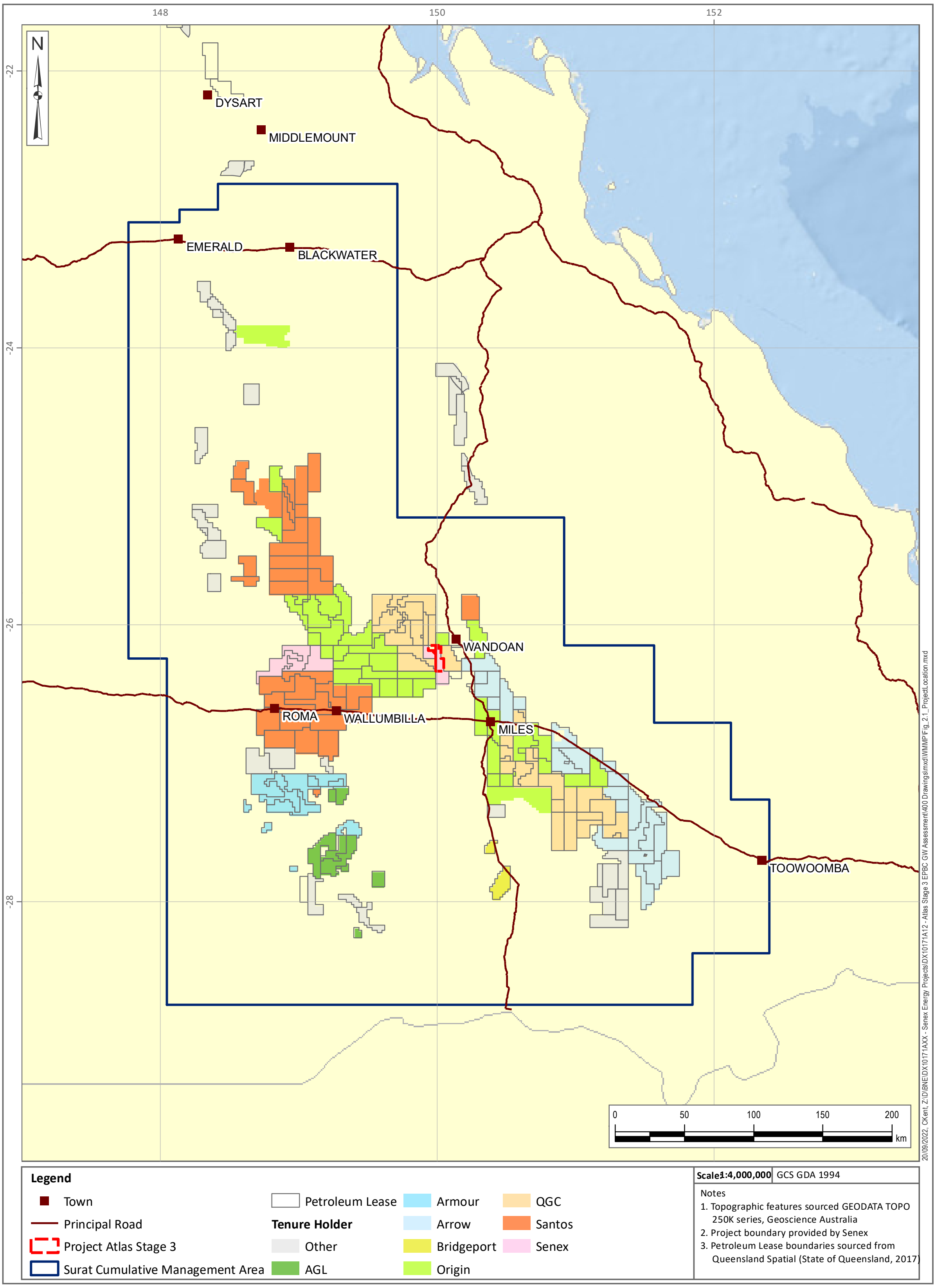


Figure 2.1 Location of Project

2.2. CSG Water Production

CSG water production is required as part of the CSG extraction process. Groundwater is abstracted (pumped) from CSG production wells to depressurise the target production coal seams. Depressurisation facilitates the desorption of gas, generating gas flow. Pumping, reduced over time, sustains a groundwater flow from the well to maintain the target producing operational pressure for each CSG production well. A summary of the proposed CSG production wells is provided in the following:

- CSG production wells will be drilled and constructed in accordance with the 'Code of Practice for 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.
- Hydraulic fracturing will not be undertaken 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 after 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 within each production well for gas to flow and approximately 18 months to reach optimum gas production. Once depleted of gas, wells will progressively be decommissioned and rehabilitated throughout the Project life (according to the Code of Practice).
- 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 50 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 and production history) become available.

Figure 2.2 presents the predicted water extraction rate for the Project. Peak CSG water production is predicted to occur in 2026 at an average daily rate of ~4.6 ML/day, 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.

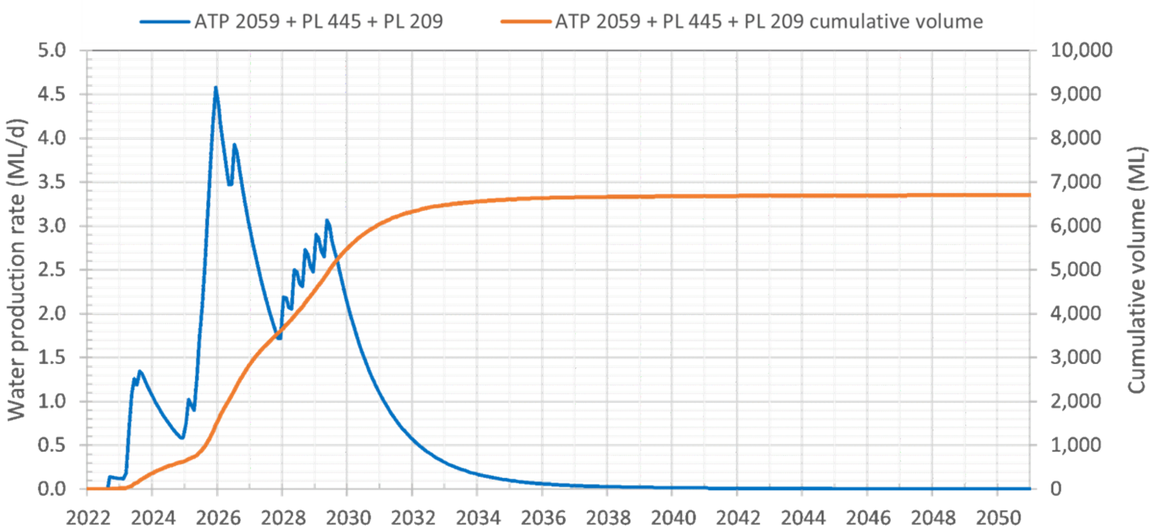


Figure 2.2 Proposed CSG Water Production Rate and Cumulative Volume for Atlas Stage 3 (151 CSG Production Wells)

2.3. CSG Water Management

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 on PL 1037. Such integration will maximise operational efficiency and reduce the impacts of the proposed action.

The water management process for the produced water will involve:

- New aggregation dams that will be established on PL 1037 and/or 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.
- The existing Project Atlas water treatment facility on PL 1037 will treat water from the proposed action. The existing water treatment facility is not part of the proposed action.
- 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 processing facility is part of the proposed action.
- Treated water will be transferred to existing and new third-party irrigation dam(s) (approximately 50-200 ML each) on PL 1037 and/or PL 209.
- Brine from the water treatment process will be stored in a new brine storage dam[1] (up to 300 ML) which will be developed on PL 1037 and is part of the proposed action. Additional brine storage (up to 300 ML) may also be required on PL 209 if a water treatment facility is established.

> Key project feature:
>
> Zero discharge to surface water is proposed.

- In total, up to 30 ha of brine storage and up to 30 ha water storage will be established as a result of the proposed action.
- The infrastructure and flow process associated with water management is provided in Figure 2.3.
- Senex's strategy for CSG water management for the Project has been developed based on the Department of Environment and Science[2] (DES) Prioritisation Hierarchy (DEHP 2012). The water management options have been developed to maximise beneficial use of 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-014) provide further information relating to the management of CSG water and associated water storage.

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

[2] Formerly the Department of Heritage and Environment Protection (DEHP)

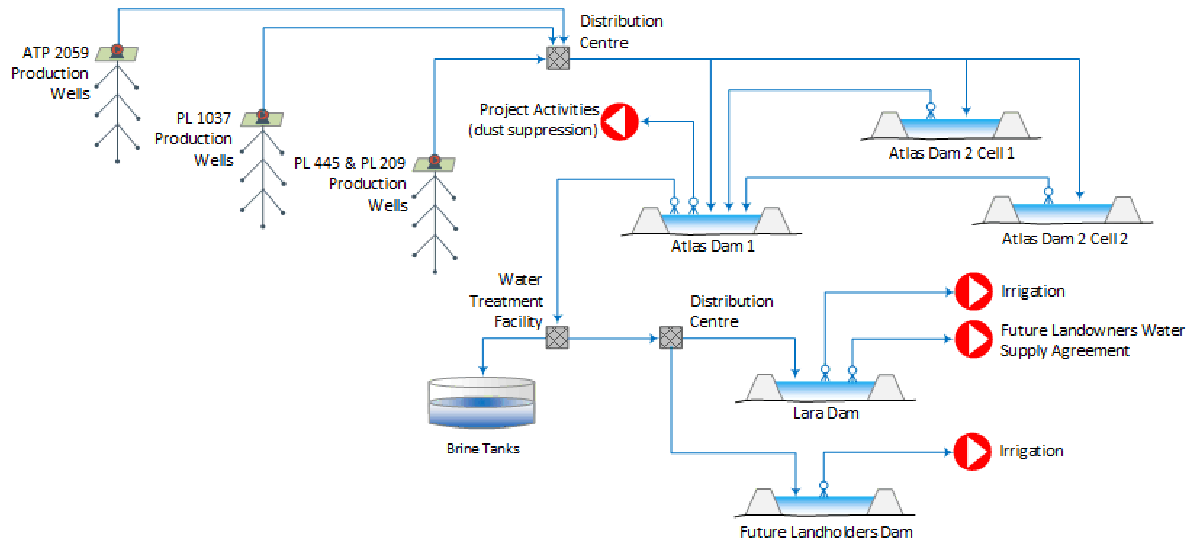


Figure 2.3 Water Management Infrastructure Schematic

Key project feature:

A 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. Site Setting

3.1. Climate

A summary of the climate statistics (sourced from the BoM) is detailed below for the climate station at Roma Airport[3] (43091), with rainfall statistics for Wandoan Post Office (35014):

- 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.
- In general, the highest rainfall occurs during December to February, with the lowest rainfall occurring during April to September.

3.2. Topography and Drainage

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. 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 externally drained 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. 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. The basin drains southwest into NSW.

Key watercourses (as shown on Figure 3.1) within the vicinity of the Project 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; and
- Hellhole Creek, a tributary to Woleebee Creek which flows north-west into Woleebee Creek across the southern portion of PL 209.

The watercourses across the Project area are ephemeral and typically flow only during significant runoff events likely due to being located in the higher reaches of the catchments with limited runoff area. Watercourses within the Project area is classified as Stream Orders 1 to 5 using the Strahler method, with the majority being Stream Order 1 (minor streams) (State of Queensland 2021a). Woleebee Creek is Stream Order 5.

Catchments within the Upper Dawson River sub-basin are influenced by anthropogenic activities including land use, riparian management, water infrastructure and point source releases.

---

[3] Temperature and evaporation data not available for Wandoan Post Office climate station

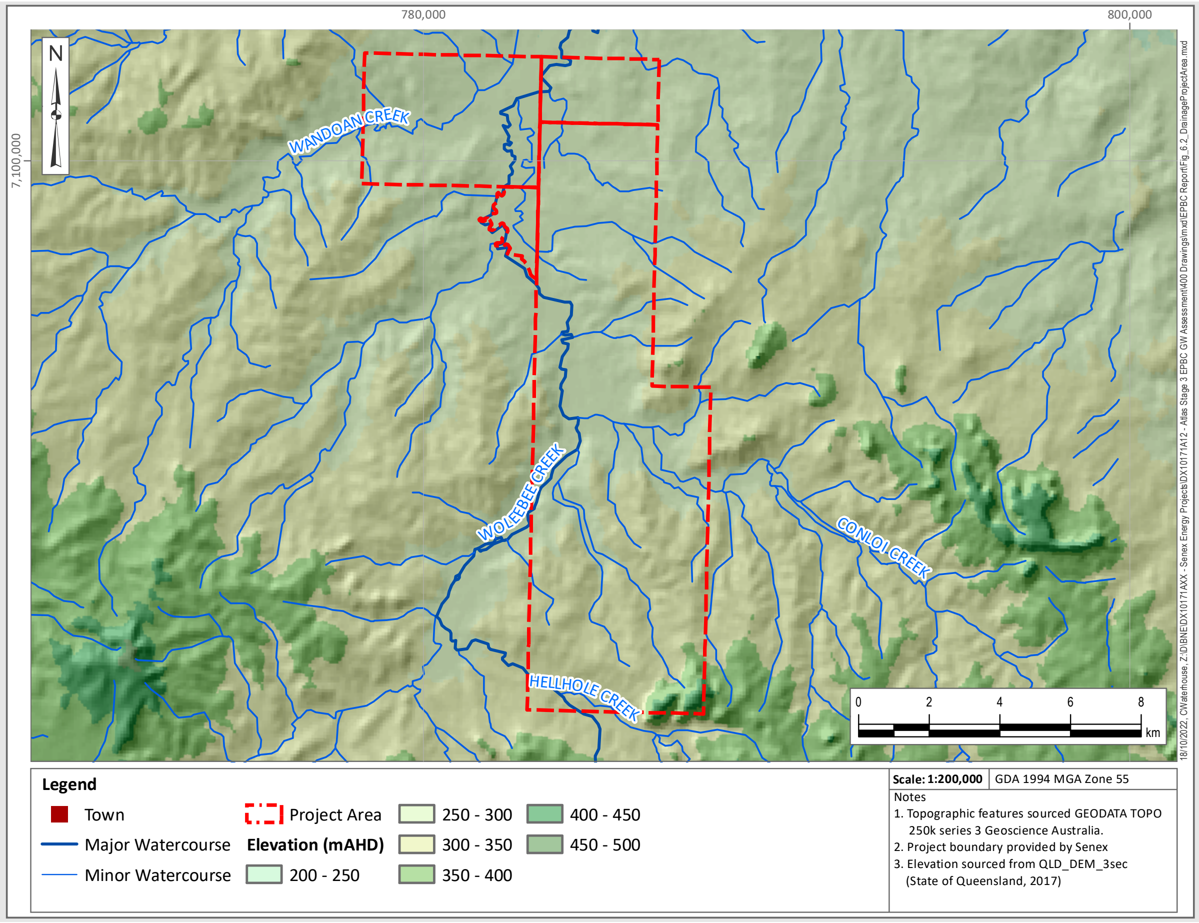


Figure 3.1 Drainage within the Project Area

3.3. Geological and Hydrogeological Overview

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. The surface geological map of the Project and surrounds is shown in Figure 3.2. Cenozoic-age formations cover much of the Surat Basin and generally comprise unconsolidated alluvial sediments, which have been deposited along pre-existing watercourses (OGIA 2016a).

The Surat Basin forms part of the Great Artesian Basin (GAB), which is comprised of several aquifers and confining aquitards. Aquifers of the Surat Basin are a significant source for water used for stock, public water, and domestic supply. OGIA (2016b) presents hydrostratigraphy of the Surat and Bowen Basin, included as Figure 3.3.

The main aquifers within the GAB, from the deepest to the shallowest, are the Precipice Sandstone, Hutton Sandstone, Springbok Sandstone, Gubberamunda Sandstone, Orallo Formation, Mooga Sandstone, and Bungil Formation. These aquifers are typically laterally continuous, have significant water storage, are permeable and are extensively developed for water supply. However, in some areas, they have more of the character of aquitards than aquifers (OGIA 2016b). The major aquitards are the Evergreen Formation, Durabilla Formation (formerly Eurombah Formation), Westbourne Formation, Surat Siltstone and Griman Creek Formation (Figure 3.3). The WCM, target formation for CSG production, is described as an interbedded aquitard.

The Project is situated in an area where the Orallo Formation, Gubberamunda Sandstone, Westbourne Formation, and Springbok Sandstone outcrop. The WCM outcrop is mapped as occurring ~14 km north of the Project.

Key units related to the Project are the Upper Springbok Sandstone, the Westbourne Formation, and the Gubberamunda Sandstone which outcrop across the majority of the Project area. The Springbok

Sandstone consists mostly of feldspathic sandstones, commonly with calcareous cement (Green 1997). At the basin scale, the sandstones range from very fine to coarse-grained, although some very coarse-grained, poorly sorted pebbly beds also occur within this unit. Minor interbedded siltstones, mudstones, and thin coal seams are also present, primarily in the upper part of the unit.

The Westbourne Formation comprises predominately siltstone layers with thick interbeds of fine to medium-grained sandstone and minor mudstone. Small coal fragments, lenses and lamina are common throughout the formation. The Westbourne Formation is a recognised aquitard (OGIA 2016a).

North-south and west-east oriented cross sections are presented in Figure 3.4 with the section locations provided on Figure 3.2. These sections show the hydrostratigraphic units dipping from the outcrop towards the south. Generally, all units are laterally extensive and continuous across the Project area.

Quaternary-age alluvium has been mapped as occurring within the Project area and is associated with Wandoan, Woleebee, Conloi, and Hellhole Creeks, as shown on Figure 3.2. The alluvium is mapped as relatively thin across the Project lease, with increased lateral extent towards the north as Wandoan Creek flows into Woleebee Creek.

Within the vicinity of the Project, groundwater recharge occurs as a result of direct rainfall on outcropping units, and localised recharge via discharge beneath watercourses and alluvial systems where sufficient saturation and hydraulic head allows water to infiltrate and migrate vertically into surficial aquifers and underlying units.

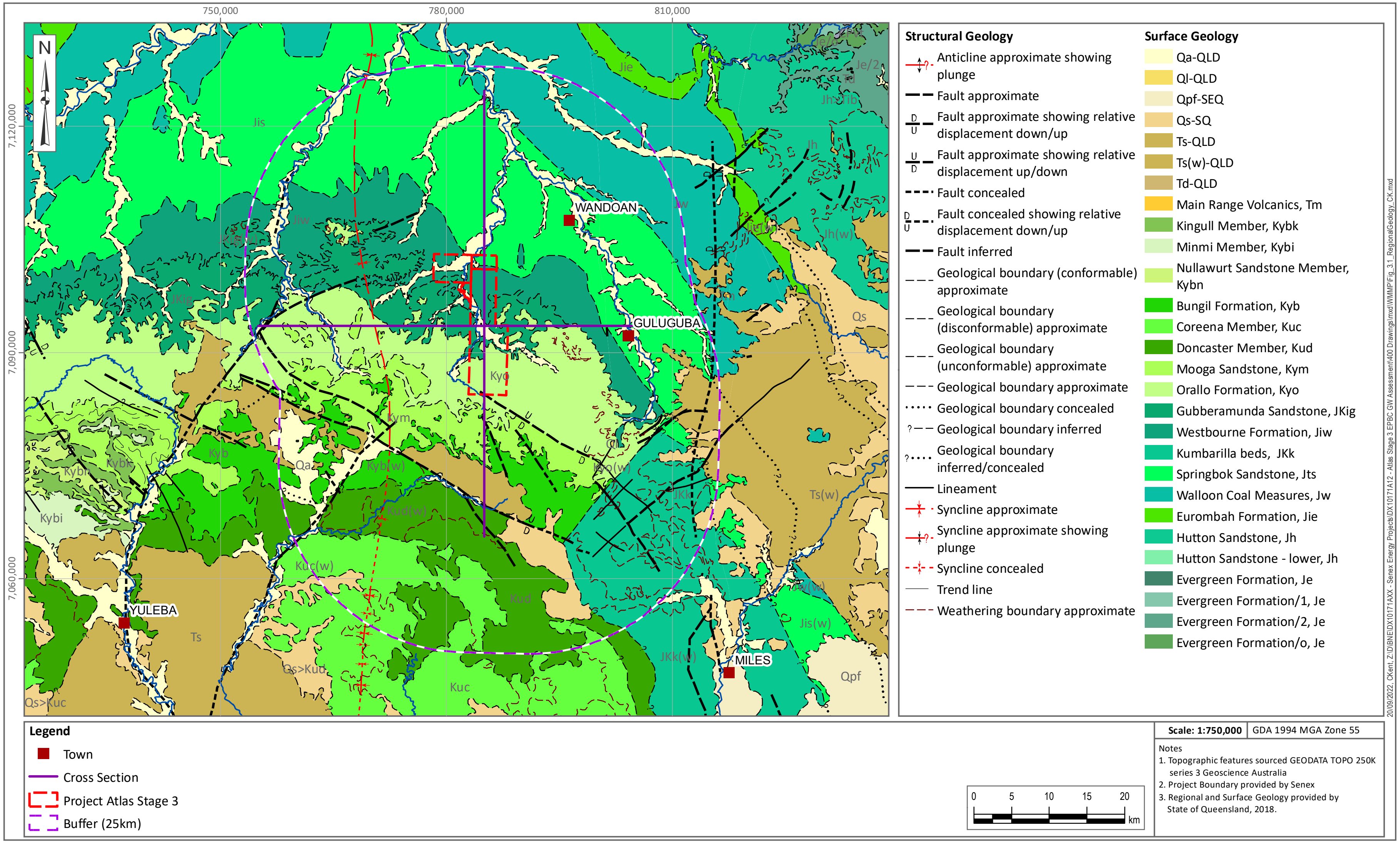


Figure 3.2 Regional Surface Geology Map

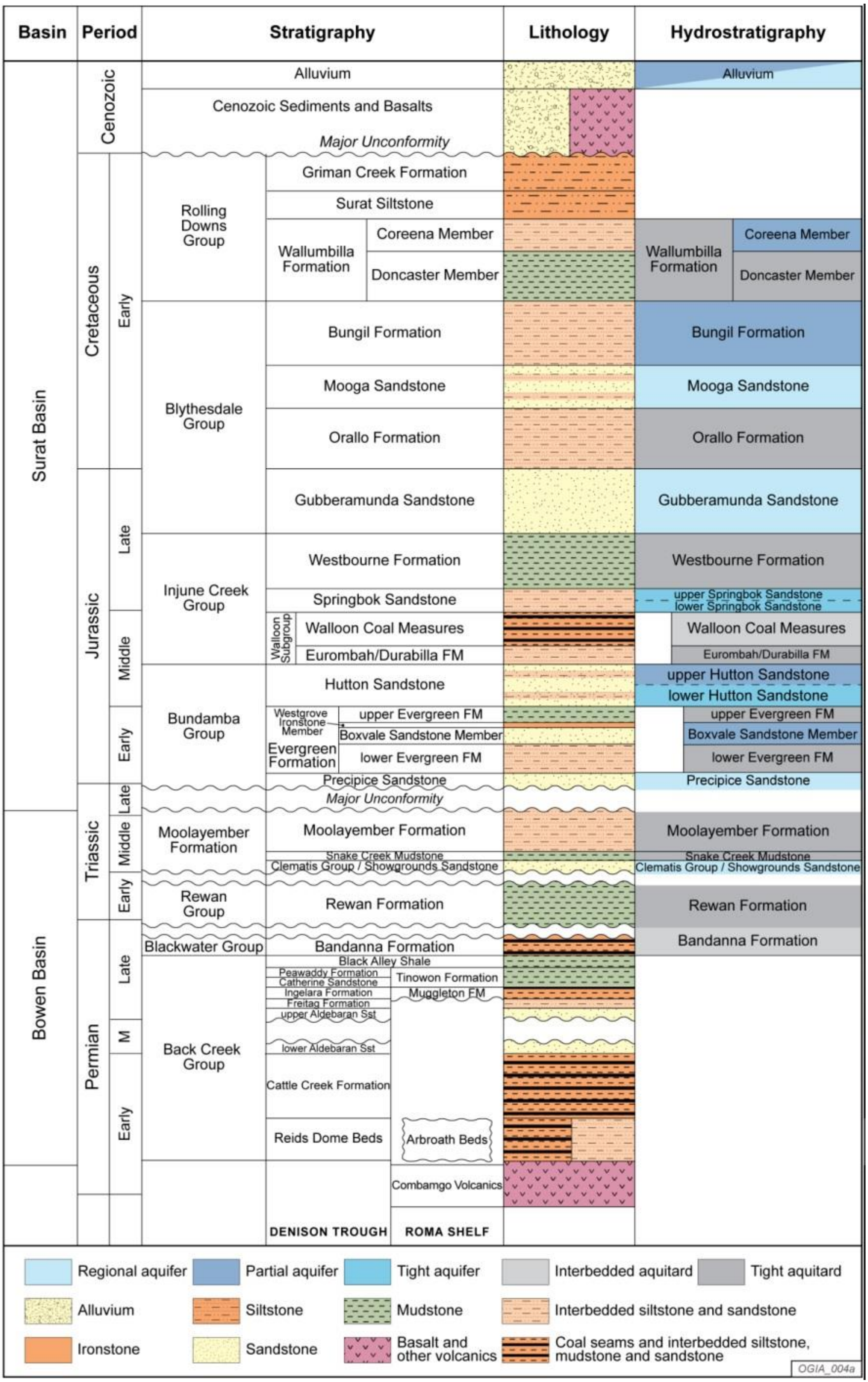


Figure 3.3 Regional Hydrostratigraphy (OGIA 2021f) with Relevant Hydrostratigraphic Units Indicated

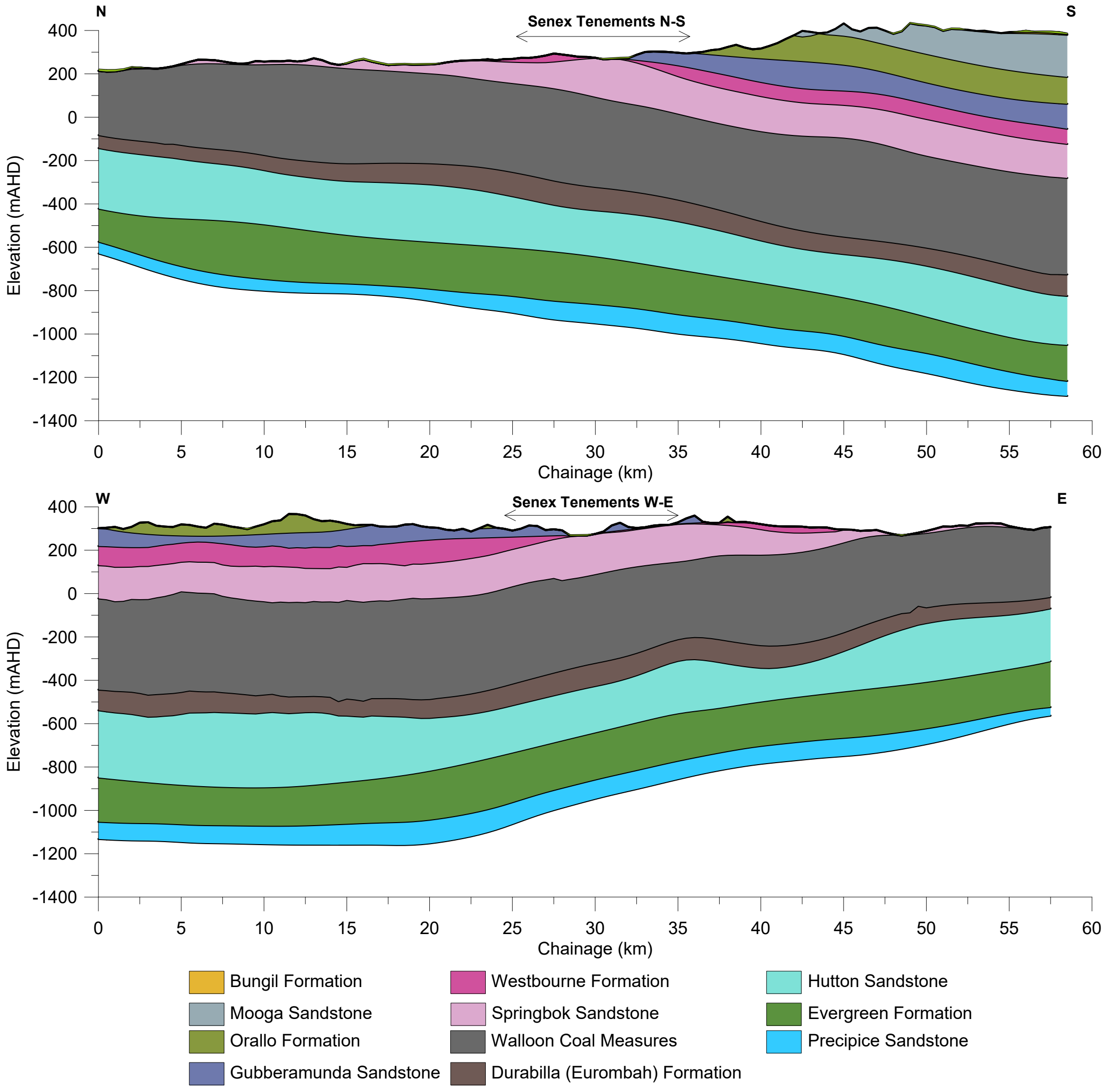


Figure 3.4 Geological Cross Sections based on the OGIA Model (Surat CMA Geological Model (OGIA 2021f))

3.4. Groundwater Assets

3.4.1. 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 2022c).

Of the 731 registered bores, 590 are existing, 12 are proposed and the remainder are abandoned but usable or decommissioned. A summary of registered bores is presented in Table 3-1, with their type and status, as derived from GWDB.

Table 3-1 GWDB Registered Bore Statistics for the Project and a 25 km 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	-		
Artesian	Ceased to Flow (AC)	3	-	5	-		
Artesian	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.

Of the 669 existing and unknown status bores (OGIA 2022):

- 410 bores have been identified as being used for water supply purposes (WS).
- 32 are potential water supply bores (PWS);219 are not used for water supply, they may be monitoring bores or not currently used for water supply (NWS); and eight are recent drills and the purpose is unknown.

The location of these bores is shown on Figure 3.5.

Groundwater abstraction for stock and domestic (S&D) use is the dominant water use purpose within the vicinity of the Project. There are five bores noted as town water supply and ten for intensive stock use.

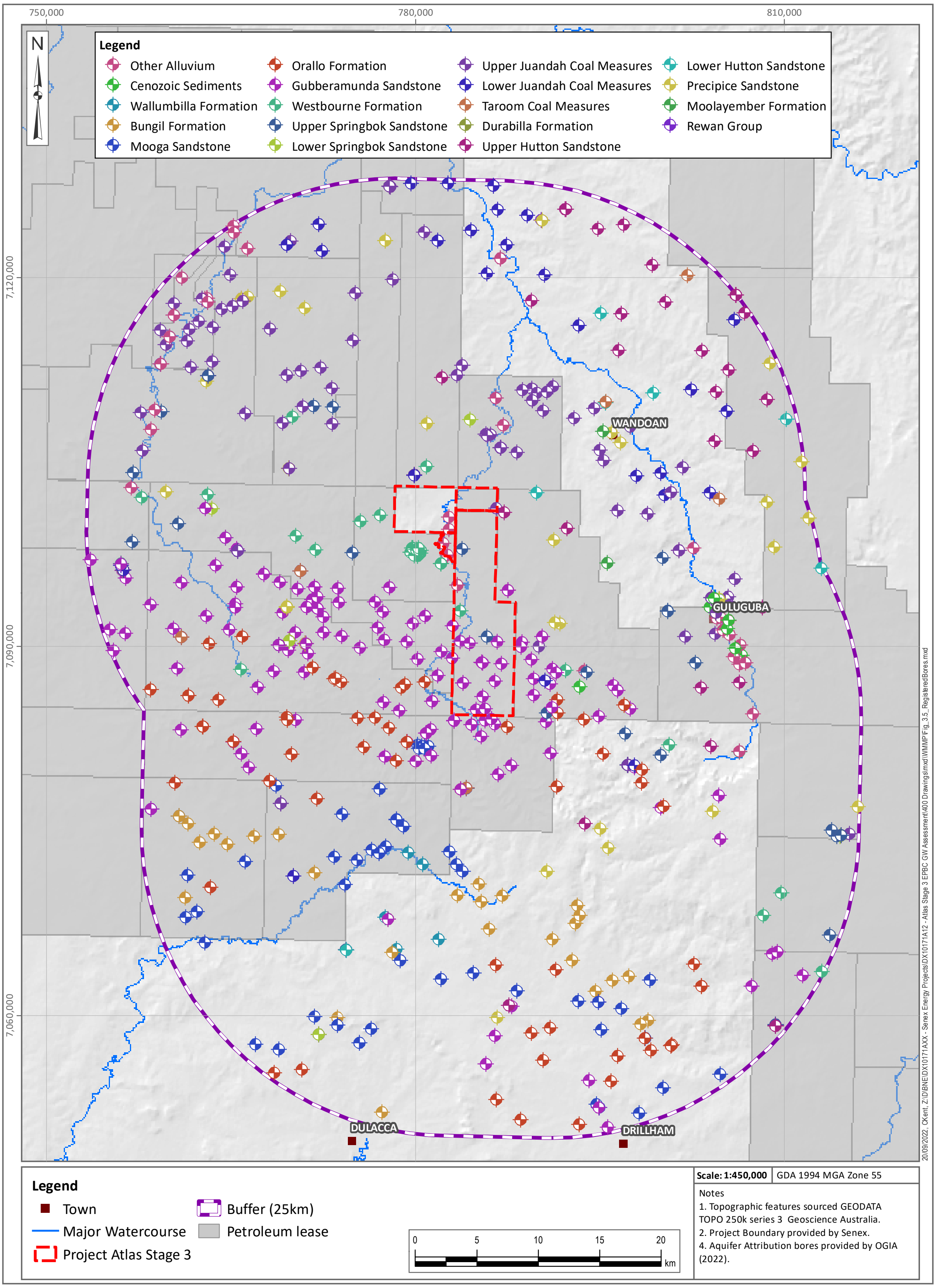


Figure 3.5 Location of Existing Registered Groundwater Bores within the vicinity of Project

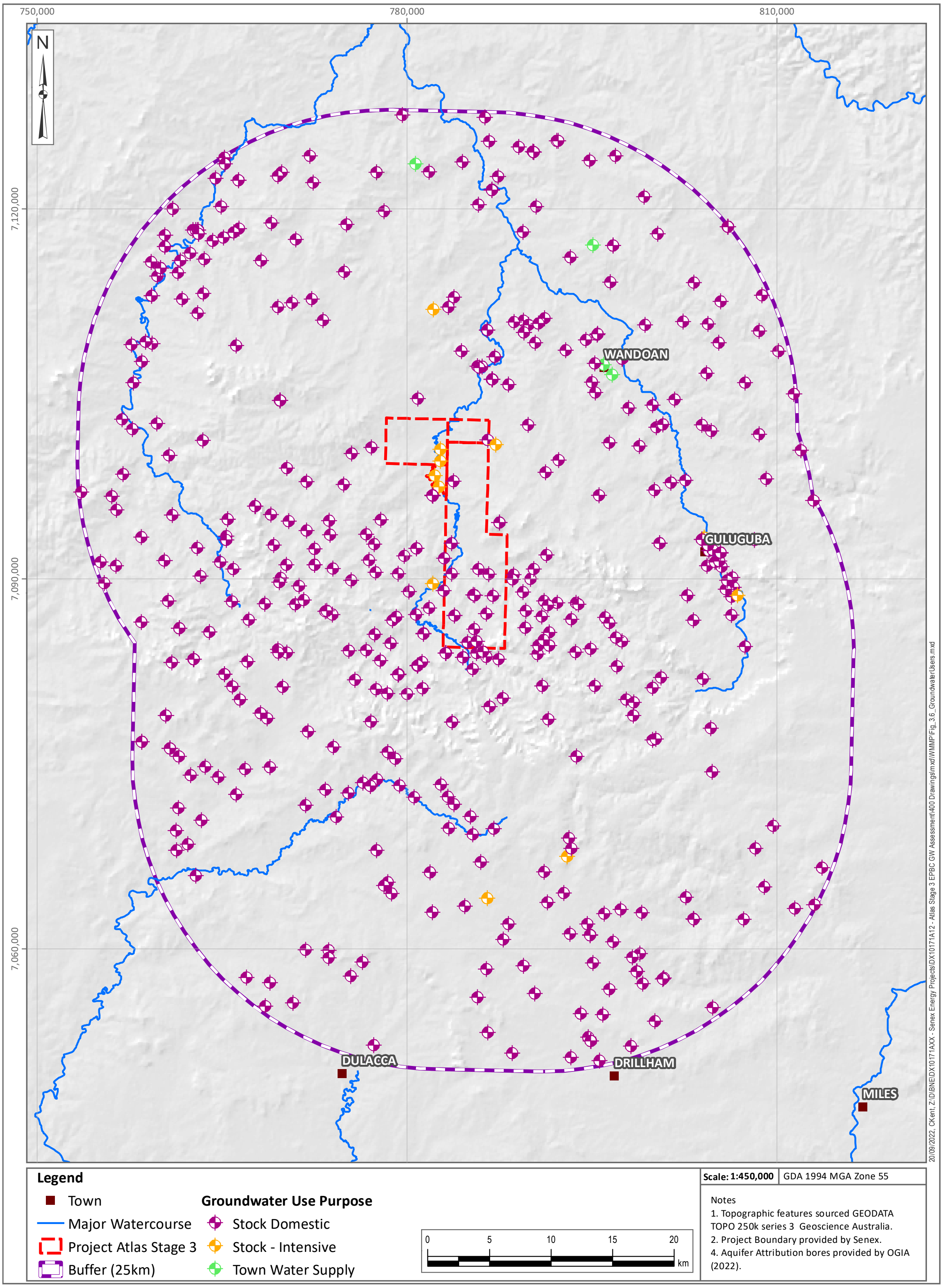


Figure 3.6 Location of Groundwater Users and Purpose of Use

3.4.2. Baseline Assessment

Under the *Water Act 2000*, petroleum tenure holders are required to undertake baseline assessment of water bores prior to commencement of CSG production. Assessments were undertaken in accordance with the 'Baseline Assessment Guideline' (State of Queensland 2021d) and the approved Baseline Assessment Plan (Senex 2022). The assessment was undertaken to obtain information such as:

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

Baseline assessment programs were undertaken by Senex as follows:

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

The location of the bores is presented on Figure 3.7.

In summary, 17 bores assessed as part of the baseline assessment were used for stock and domestic on private land (Table 3-2). Seven bores are not in use. Groundwater levels ranged from artesian (0.4 m above ground), to ~37 mbGL. 17 existing bores were screened in the Gubberamunda Sandstone with only two in the Upper Springbok Sandstone and one in the Orallo Formation. Hydrogeochemical 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 3-2). Beyond the Project area, groundwater is sourced from the deeper units for both stock and domestic purposes, and town water supply.

Table 3-2 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
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

RN	Facility Status	Groundwater Level (mbGL)[1]	Screened Aquifer	Bore Use
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	-	U. 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.

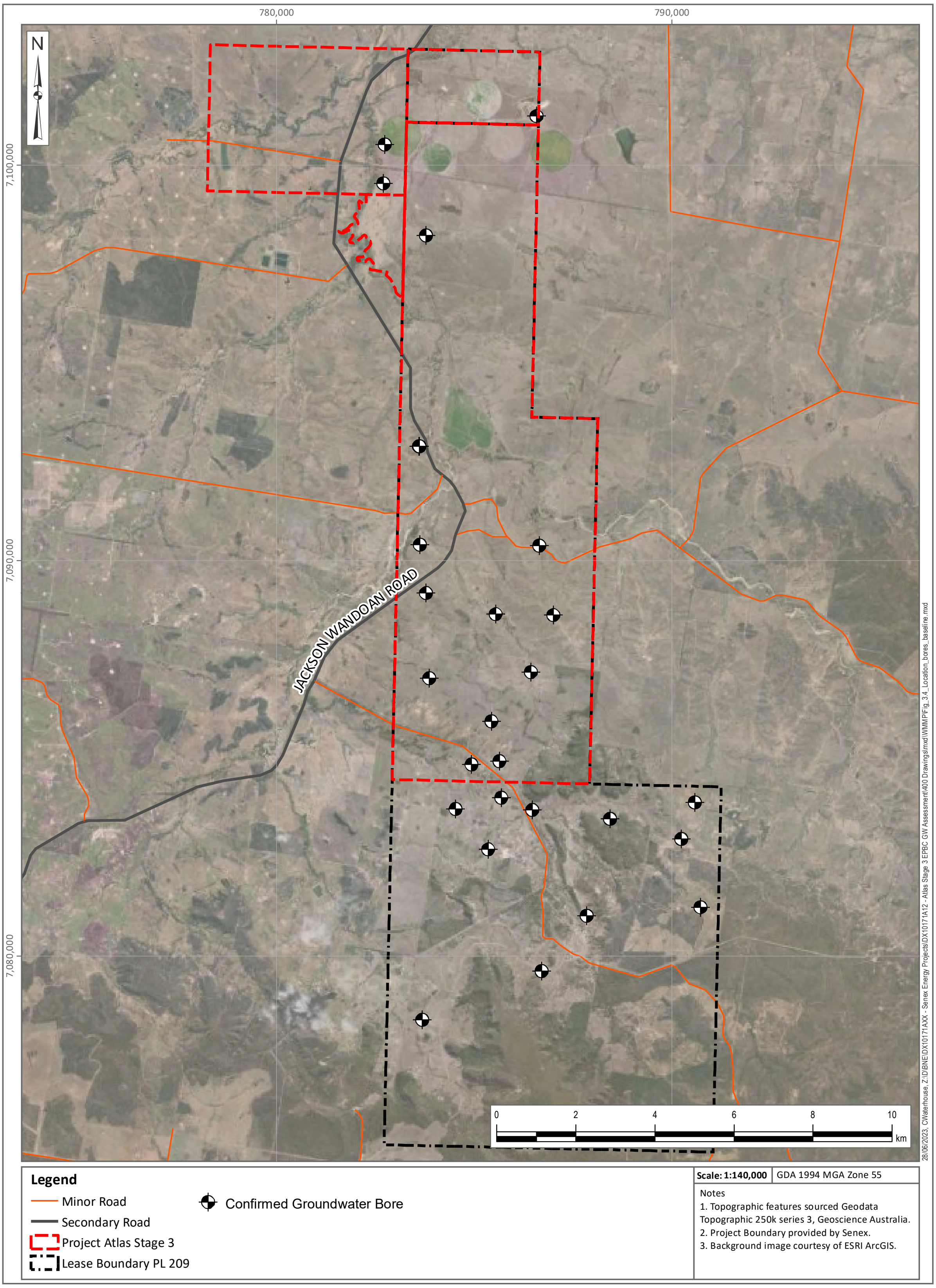


Figure 3.7 Location of Bores Confirmed/Existing During the Baseline Assessment for ATP 2059, PL 445, and PL 209

3.4.3. Groundwater Dependent Ecosystems

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 2018) as potentially being present in the vicinity of the Project (Figure 3.8). 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.

3.4.3.1. Potential Aquatic GDEs

There are no spring vents or complexes within the 25 km buffer of the Project.

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 more recently re-mapped watercourse springs within the Surat CMA for the 2021 UWIR report (OGIA 2021f), these are shown on Figure 3.8.

OGIA has identified three potential watercourse springs present within, or directly adjacent to, the Project area associated with Woleebee Creek (Table 3-3). 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 3-3 UWIR 2022 Watercourse Spring Details

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

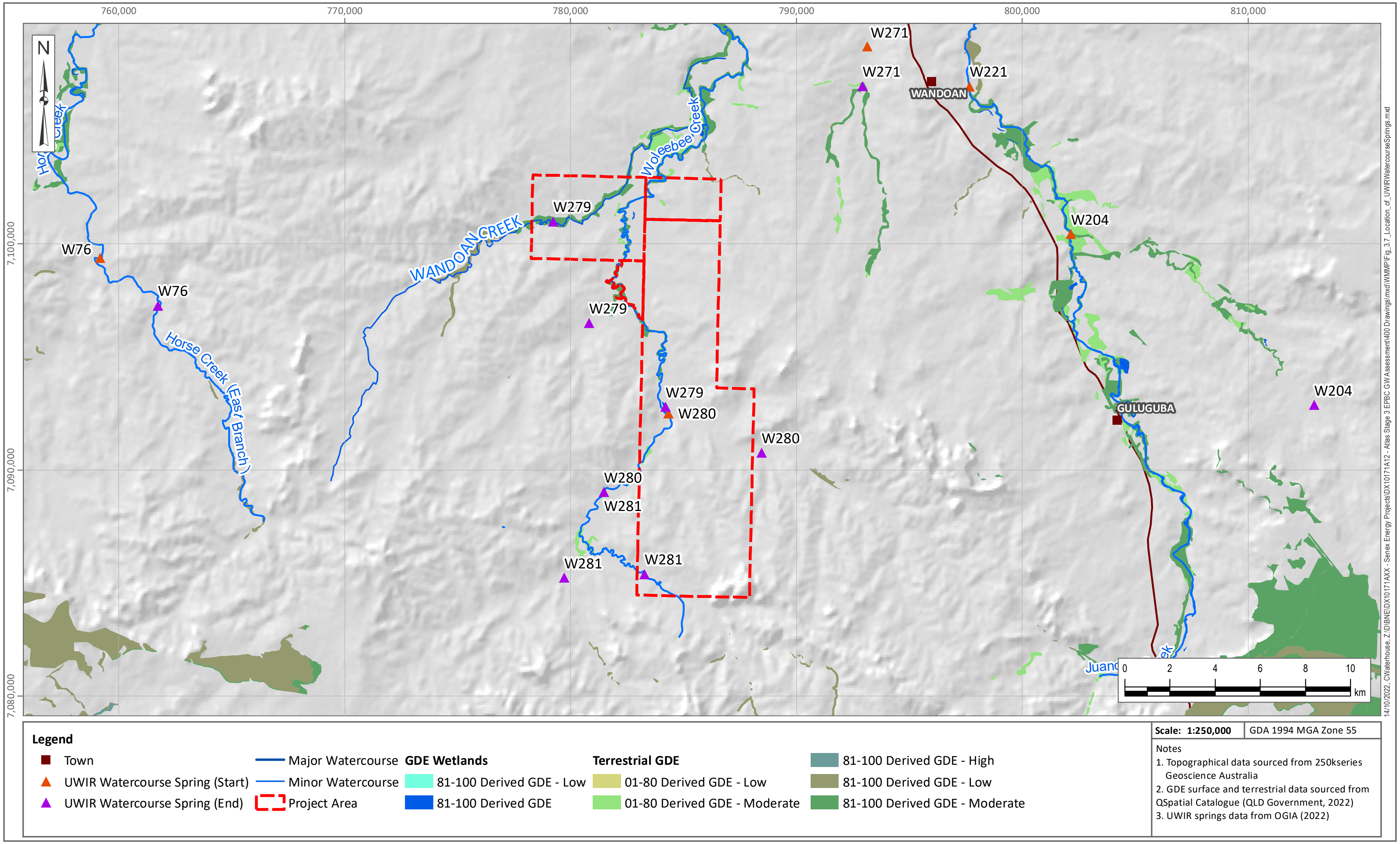


Figure 3.8 Location of UWIR Watercourse Springs and Mapped Potential GDEs (DES 2018b; OGIA 2021f)

The watercourses within the Project area, Wandoan and Woleebee Creeks, are characteristically ephemeral and typically flow only during significant rainfall events. Pooled water may remain after significant rainfall events, which provides a habitat for a limited number of aquatic species. Shallow pools were identified in the watercourses but were generally turbid with water quality results indicating that these pools are fresh and surface water sourced. 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.

Baseflow contributions from the alluvium and Surat Basin units to the watercourses are considered unlikely (the presence of watercourse springs has not been confirmed). This has been concluded through previous site verification in 2018 along these creek systems in PL 1037 from site observations and water quality analyses (freshwater quality but high turbidity) (KCB 2018). It is likely that the groundwater system in the alluvium is replenished by surface water during prolonged wet periods when the ephemeral creek system is flowing.

The alluvial systems present within the Project area are generally associated with Wandoan and Woleebee Creeks. Alluvial bank heights of up to 8 m have been observed along Woleebee Creek within PL 445. Alluvium thickness (encountered during the site investigation) varied across the Project from seven to 13 metres, with the thickness of the alluvium decreasing away from Woleebee Creek.

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. The groundwater quality from specific locations along the alluvium indicate that saline groundwater quality is present in isolated sections of the alluvium where evaporative concentration has likely increased the salinity (salinity of this alluvium is higher than both the Westbourne Formation and Springbok Sandstone). Both regional and site-specific alluvium water qualities are distinct from groundwater in the underlying Westbourne Formation or Springbok Sandstone.

Potential Terrestrial GDEs

Terrestrial GDEs have been identified and are generally associated with Wandoan and Woleebee Creek systems and their adjacent alluvial plains (Figure 3.8). The ecology survey identified flora and fauna that do not depend on the permanent presence of water (ERM 2022). 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.

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 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.

Eucalypts (including Forest Red Gums) have two rooting systems (known as a dimorphic rooting system), 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 potential terrestrial GDEs located along the creek systems may be groundwater dependent as they occur within an alluvial system (associated with creeks) and the ecosystem is associated with streamlines. This alluvial system, as discussed above, is replenished during prolonged wet periods when the ephemeral creek system is flowing and is considered to be disconnected from the Westbourne Formation and Upper Springbok Sandstone.

3.5. Hydrogeological Conceptualisation

The Project hydrogeological conceptual model is summarised below and presented in Figure 3.9 and Figure 3.10.

3.5.1. Geology and Hydrostratigraphy

The target for CSG production in the Project area is the WCM, which occurs from ~65 to 380 m below ground level; and is ~400 m to 450 m thick. The WCM forms part of the Great Artesian Basin (GAB) which is Australia’s largest freshwater basin (spanning four states), the GAB is a nationally important groundwater resource.

Surface geology (Figure 3.2) 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 Woleebee, Wandoan and Conloi Creek. 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 and Durabilla Formation, respectively.

Key hydrostratigraphic units are the Westbourne Formation (aquitard), Upper Springbok Sandstone (aquifer), Gubberamunda Sandstone (aquifer), and Quaternary alluvium (aquifer) (OGIA 2021d), which outcrop within the Project area and may support potential GDEs, these units are present above the WCM.

Alluvial bank heights of up to 8 m have been observed along Woleebee Creek and alluvial depths of up to 10 m were observed within PL 445 during the site investigation. The thickness of alluvial was relatively consistent at 7 to 10 m throughout the site, except to the south of PL 209 where a thickness of 13 m was observed in the vicinity of the creek above the Westbourne Formation.

3.5.2. Surface Water

Key watercourses within the Project area, Woleebee, Wandoan, Conloi, and Hellhole Creeks, are ephemeral and flow only during significant rainfall events. This has been confirmed from site walkovers during typical dry seasons, and groundwater site investigations undertaken following an unusually wet season where water was observed in Woleebee Creek.

When water is present in the watercourses, these creeks provide 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 hydrostratigraphic units.

3.5.3. Groundwater-Surface Water Interaction

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

- Groundwater level data from alluvium monitoring bores (collected during the wet season) indicate that groundwater level in alluvium near the creek is below the creek elevation; and,
- 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.

3.5.4. Groundwater Chemistry

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

- 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 regional 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 groundwater from the WCM and Springbok Sandstone.

3.5.5. Inter-aquifer Connectivity

Across the Project extent, there is potential for interaction between the 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 2021e) as being up to ~25 m thick across the Project area.

The Project is situated in an area where the Springbok Sandstone, Westbourne Formation, Gubberamunda Sandstone and Orallo Formation outcrop. Quaternary-age alluvium is mapped within the Project area and is associated with Woleebee and Wandoan Creeks above these Surat Basin units. The Westbourne Formation is mapped below Wandoan Creek; while the Gubberamunda Formation, Westbourne Formation and the Upper Springbok Sandstone is mapped below Woleebee Creek within the Project area. Interaction between the alluvium and underlying Surat Basin units is limited. There is both hydraulic and geochemical evidence to suggest a disconnection:

- Senex groundwater monitoring bores installed as paired sets in the alluvium and underlying Springbok Sandstone or Westbourne Formation displayed hydraulic separation between the units (see Section 4.1 for further details on these bores). Groundwater levels in both of these underlying units are below the base of the alluvium indicating that there is no hydraulic connection between 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. There may be losses from the alluvium to these deeper units during times of saturation in the alluvium (i.e., when the saturated thickness of groundwater in the alluvium is sufficient to facilitate vertical downward flow).
- 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.

3.5.6. Springs and GDEs

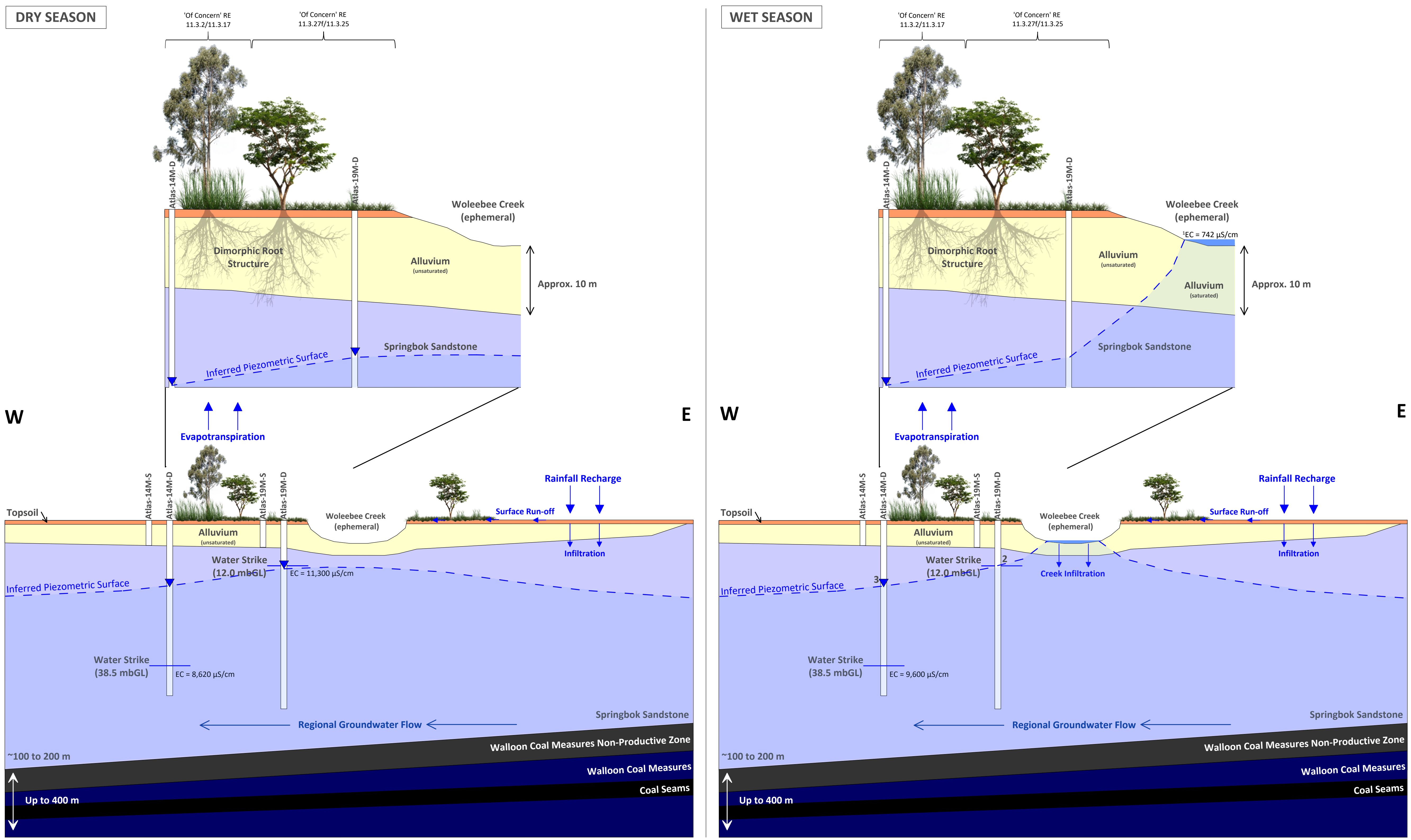
There are no spring vents or complexes within 25 km of the Project.

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 indicates that potential terrestrial GDEs away from the creeks are dependent on soil moisture.

Regional ecosystems close to the creek line, 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 3.9) 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 reported brackish to saline groundwater, which may be detrimental to plant growth over prolonged periods. It is reasonable to assume that healthy flora at the identified GDE locations do not source water from the deeper groundwater system, and instead sources water from soil moisture and rainfall recharge shallow units (i.e., alluvium following rainfall and streamflow recharge events) where salinity is much lower.

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 3.9 Hydrogeological Conceptual Model (Not to Scale)

3.6. Predicted Impacts

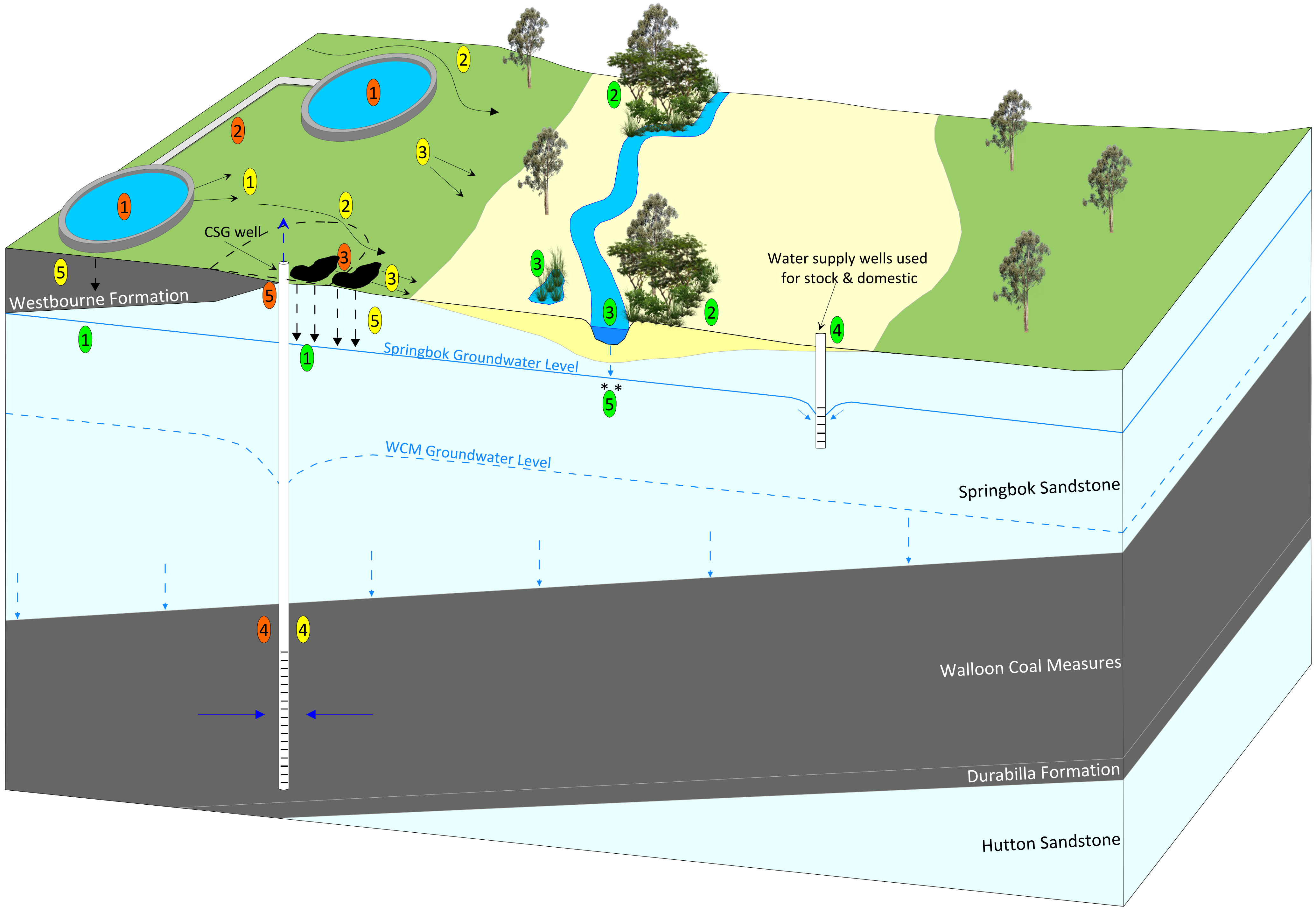
The proposed action may result in, but is not limited to, the following impacts, which are discussed in more detail in the following sections:

- 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 3.10) 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.



Source
1 Storage tanks, dams, waste disposals
2 Supply and discharge lines/hoses
3 Spills on the surface
4 Coal seam gas wells (deep groundwater)
5 Subsidence

Pathway
1 Overtopping
2 Diverted flow
3 Runoff to wetlands/creeks/TGDEs
4 Improperly constructed CSG wells
5 Seepage to groundwater

Receptor
1 Groundwater
2 TGDEs
3 Ephemeral watercourses/waterholes/farm dams
4 Private bore
5 Stygofauna

Aquitard
Aquifer
Alluvium
Grassland

Direction of flow
Seepage
Stygofauna
Subsidence

Figure 3.10 Source-Pathway-Receptor Impact Diagram for the Atlas Stage 3 Project

3.6.1. 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 drilling chemicals to be used as part of the CSG extraction during the Project development (KCB 2023a). The assessment examined the risks associated with use of drilling fluids and their associated chemicals. 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, and the eventual disposal of the drilling fluids.

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 highly unlikely to unlikely. 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 water-related MNES from chemical contamination has been assessed as low significance to insignificant.

Management and mitigation controls as discussed in the Chemical Risk Assessment Framework (CRAF) (KCB 2023) will be implemented to avoid or reduce potential risks associated with the use of drilling additives to as low as reasonably practicable.

3.6.2. Changes to Hydrological Regimes

Potential impacts to the watercourses are associated with the general construction and day to day operations of CSG surface facilities rather than CSG production; and, in the absence of Senex's mitigation and management measures, may 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 with the potential to impact surface water and associated ecosystems (overtopping and storage facility migration); and
- Potential unplanned release of fuel and chemicals used as part of the Project impacting surface water quality.

No discernible impacts to surface water and associated aquatic systems are predicted as a result of the Project development. The Project does <u>not</u> include any:

- Planned discharge to or 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.

Monitoring and mitigation measures have been implemented for accidental and unplanned impacts; these are discussed further in Section 4.

3.6.3. Changes to Water Quality

Potential changes to groundwater quality as a result of Project development activities may occur due 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. Impacts to groundwater quality will be monitored and mitigated through implementation of groundwater investigation trigger monitoring and trigger action response plans as discussed in Sections 4.3.6 and 4.3.7.

Based on the assessment results, changes to groundwater or surface water quality are not predicted as a result of the Project development.

3.6.4. Groundwater Drawdown and Associated Impacts

Abstraction of groundwater as part of CSG production may cause a drawdown in groundwater levels / pressure and therefore may impact existing water-dependent assets within the vicinity of the Project, such as groundwater bores, or GDEs.

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

The primary purpose of the model is to predict regional water pressure or water level changes in aquifers within the Surat CMA footprint in response to extraction / production 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.

At the request of Senex, OGIA has simulated an appraisal scenario using the 2021 groundwater model based on production plans provided by Senex. Outputs from this model were used as part of the EPBC water impact assessment (KCB 2023b). 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.

Potential impacts to groundwater bores were assessed against the *Water Act 2000* bore trigger threshold of 5 m for a consolidated aquifer and 2 m for an unconsolidated aquifer using maximum drawdown outputs from the UWIR model (KCB 2023b) and are discussed further in Section 3.6.4.1.

The results of the modelling for the Project only indicated that drawdown greater than 0.2 m (spring trigger threshold) is predicted in model layer 8 (Westbourne Formation) to model layer 18 (Durabilla Formation) and are discussed further in Section 3.6.4.2

3.6.4.1. Impacts to Third-Party Bores

Immediately Affected Bores

An 'Immediately Affected Area' is defined by *Water Act 2000* as an aquifer in the area within which water pressures are predicted to fall by more than the trigger threshold within three years. Bores within immediately affected areas are subject to make good arrangements under the *Water Act 2000*, as assigned by OGIA. There is currently one bore assigned to Senex within an immediately affected area in PL 445 (formerly assigned to Origin APLNG), see Section 4.3.1.

Long-Term Affected Bores

The prediction of long-term impacts to landholder bores within the Surat CMA are the responsibility of OGIA and published within revisions of the UWIR. As with the immediately affected bores, OGIA provide tenure holders with their make good obligations under the *Water Act 2000*.

The modelling results indicate that there are 23 landholder bores within the vicinity of the Project which are predicted to experience a water level decline greater than the *Water Act 2000* trigger threshold for the Project only. Of which two are located within the Project area. These bores are also cumulatively impacted without the presence of the Project.

Within the 25 km radius from the Project, 248 bores are triggered (i.e., >5 m drawdown) in the cumulative scenario. In comparison to the Project only scenario, five additional bores are triggered as a result of the cumulative scenario (i.e., the contribution of the drawdown associated with 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, none of the bores are located on-tenement and are all located off-lease 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 has been undertaken and confirmed that one of these bores is blocked and has not been used since 1996 (Arrow 2013).

3.6.4.2. GDE Impacts

Potential Aquatic GDEs

The predicted drawdown resulting from the Project development, at the location of aquatic GDEs of interest, is predicted to be less than the 0.2 m trigger. Further, it is unlikely that these potential aquatic GDEs are sourced from the underlying Surat Basin units of the Westbourne Formation and Upper Springbok Sandstone given the evidence from the field verification (discussed in Section 3.4.3.1).

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

Potential Terrestrial GDEs

Potential terrestrial GDEs are mapped along Wandoan Creek and Woleebee Creek, on mapped alluvium (Figure 3.8), with some areas located on the Springbok Sandstone outcrop within the 0.2 m Project only drawdown trigger extent. These potential terrestrial GDEs are all located along ephemeral creek systems. The likely source of water for these potential terrestrial GDEs is the alluvium and not the underlying consolidated aquifers.

The regional water quality of the alluvium indicates that groundwater in this aquifer is replenished by surface water during prolonged periods of rainfall, when the ephemeral creeks are flowing. The distinction between the alluvium water quality and underlying Westbourne Formation and Springbok Sandstone water quality, and groundwater levels in the alluvium and underlying formations, indicates that these units are disconnected. 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.

Based on the known characteristics of the GDE physiographic setting, it is interpreted that these potential GDEs may be intermittently supported by groundwater in the alluvium which is not predicted to experience drawdown. This alluvium aquifer is not considered to be connected to the Upper Springbok Sandstone which is predicted to experience drawdown. Based on this evidence, it is concluded that the contributing drawdown impacts from the Project to potential terrestrial GDEs are not significant.

Regardless of the potential GDE source aquifer the predicted risk to terrestrial GDEs is considered low because:

- The outcrops of the Westbourne Formation and Gubberamunda Sandstone, which underly the majority of the alluvium across the Project area, are not predicted to experience drawdown of more than 0.2 m.
- A maximum Project drawdown of 0.9 m is predicted to occur in the Upper Springbok Sandstone outcrop area (of approximately 0.7 km^2) on PL 445, approximately 7 years after the start of the development. According to the JIF Terrestrial GDE preliminary risk assessment (DCCEEW 2021), the magnitude (< 1 m) and timing of predicted exceedance (7 years) of the impact on the known GDEs, indicates that the risk of impact to potential terrestrial GDEs is low.

Baseline data gathered to date regarding the hydrogeological system across the Project area indicates that there is no hydraulic connection between the alluvium and underlying Surat Basin units. However, to further assess the potential for hydraulic connection, Senex propose to undertake a two-year GDE and groundwater level baseline and monitoring program (as specified in Section 4.1). Should a hydraulic connection be confirmed and drawdown likely to occur in identified in GDE dependent units, management measures including the development and implementation of a long-term GDE monitoring program will be initiated.

3.6.5. Subsidence

Depressurisation associated with CSG water extraction and gas desorption 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 which 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 compact, potentially 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 at depth, which is unlikely to be fully transferred to the surface (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 2021e). 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 2021e).

The potential subsidence for both ‘Project only’ and ‘Cumulative’ predictions have been calculated based on a methodology of applying a subsidence calculation based on the compaction at a specific location (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; and calculates compaction directly due to groundwater pressure changes in the geological unit at a given location. This was the same methodology adopted by Arrow Energy (Coffey 2018) and has been previously accepted by the OGIA.

The predicted cumulative induced subsidence (including the Project) has been estimated to be up to 0.063 m[4], 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).

3.6.5.1. Subsidence Risk Assessment

The predicted subsidence levels discussed above need to be contextualised for their potential impacts on environmental values (EVs) and assets with consideration to the absolute magnitude and the differential settlement. In general, areas predicted to experience subsidence of less than 0.2 m are considered to be of low risk to environmental values (OGIA 2019).

There may be potential impacts to human-use environmental values (EVs) (e.g., agricultural land and water bores), aquatic ecosystem EVs, such as watercourse springs and terrestrial GDEs, linear infrastructure (e.g., pipelines, roads, rail lines ad powerlines) and buildings and structures 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.

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.

---

[4] Cumulative estimation including surrounding projects.

- 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 associated 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.

The potential impacts on different types of assets are discussed in the following sections and broadly follow same approach adopted by Arrow Energy (Coffey 2018).

Linear Infrastructure

The sensitivity of various structures to subsidence including roads, rail lines and pipelines are discussed in Commonwealth of Australia (2014).

Table 3-4 Thresholds of adverse impact from ground movement – Linear infrastructure

Asset	Guideline	Potential impacts from Project induced subsidence
Roads and highways	0.3 % over a chord length of 10 m	Negligible
Pipelines	Tensile strain less than 2% Slope change less than 1/140 Sewer pipeline 0.4% grade change	Negligible

Buildings and Structures

Assessment of settlement impacts for buildings adopts the approach outlined in Coffey's (2018) subsidence technical memorandum for Arrow Energy. The approach adopts a deflection gradient (change in deflection per unit length) of 0.1% or 1/1000.

"Damage is a function of differential settlement rather than the absolute value and damage is also a function of horizontal strain.

As subsidence associated with Project arises from compression of geological units at depth the changes at the surface will be gradual and no measurable horizontal strain is anticipated at the ground surface. Rather than use of deflection ratio, use of differential settlement is adopted for assessment of the significance of differential movement for structures. For a uniform curvature the maximum differential settlement (the gradient of settlement) would be four times the deflection gradient. Taking a deflection ratio of 0.025% (half the limit for Class 0 damage (defined by Burland as negligible with hairline crack less than about 0.1 mm) this corresponds to a deflection gradient (change in deflection per unit length) of 0.1% or 1/1000. This is considered a conservative threshold for damage to buildings and other structures."

Water storages are present within or near the Project area (including produced water dams, treated water dams and brine dams). Tensile strains associated with CSG related subsidence, if excessive, could potentially result in cracking of embankment materials. For a compacted clay core, tensile strain of less than 0.5% is considered unlikely to have a material influence on its performance in a water retaining structure. Tensile strains approaching this magnitude are assessed as being highly unlikely to arise from subsidence induced by cumulative CSG extraction (Coffey 2018).

No major dams are present within or in proximity to the Project.

Rivers and Streams

The land surface falls from the south of the Project area on Woleebee Creek at approximately 275 m to 250 m in the north of the Project area over 9 km, with an overall topographic gradient of 2.8 m/km. Most of tributaries feeding Woleebee Creek are significantly steeper than this.

Using the existing topographic gradient as a guide it is assessed that predicted subsidence leading to the maximum change in ground slope of 20 mm/km is less than 1 % of the existing gradient (2.8 m/km) and would therefore be unlikely to have significant impact on the performance of the Woleebee Creek or tributary watercourses. To set a threshold for further investigation at a 5% change of watercourse gradient (Coffey 2018) would require a subsidence of 0.14 m/km (approximately seven times the expected CSG-induced subsidence).

Farm Irrigation Systems

Farm irrigation using centre pivots occurs in the Project area, however this type of irrigation system is not likely to be affected by CSG-induced subsidence, unlike flood irrigation systems that use furrows and drainage channels on laser levelled land. Subsidence occurring after farm levelling has taken place could potentially affect irrigation performance by changing the slope of the ground over which water is distributed throughout a crop.

Potential impacts on general farmland, small dams for movements of less than 100 mm over distance of 1 km are not considered likely to result in adverse impacts and these have not been considered further.

Aquatic Ecosystems

Potential impacts to aquatic ecosystems such as GDEs may occur as discussed in Section 3.6.4. Potential aquatic GDEs in the Project area include three potential watercourse springs in the Project area and ephemeral wetlands on floodplain associated with Woleebee Creek. Potential terrestrial GDEs are present in the Project area and are generally associated with Wandoan and Woleebee Creek systems and their adjacent alluvial plains.

Subsidence related impacts to GDEs may potentially occur if there are changes in the integrity of hydrological or hydrogeological connectivity resulting in changes to groundwater levels that the GDEs rely on. No specific subsidence thresholds are proposed for monitoring potential impacts to GDEs as the monitoring of groundwater levels for GDEs is more relevant (see Section 4.2.1 for Senex's ongoing groundwater monitoring commitments).

3.6.6. Cumulative Impacts with Other CSG Operations in the Region

Due to the close proximity of other CSG operations and coal mines through the Surat Basin, there are potential for cumulative impacts to occur. Potential cumulative impacts can result in:

- Additional groundwater drawdown
- Higher levels of subsidence

This can subsequently result in additional impacts to groundwater bores, GDEs and surface water systems.

Cumulative impacts are predicted due to the close proximity of Project Atlas on PL 1037 (a Senex project), immediately west of Project Atlas Stage 3, and the Wandoan open cut coal mine which is located immediately north of PL 445.

As part of the Surat CMA UWIR (OGIA 2021e), a regional groundwater flow model was developed by OGIA to predict groundwater pressure changes resulting from cumulative activities from planned future mining operations across multiple Petroleum and Gas tenure holders. The primary purpose of the 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.

The potential for cumulative impacts on third-party groundwater users and potential GDEs have been assessed within those specific impact assessments, the impacts of cumulative subsidence impacts have also been considered and are discussed in the sections above.

4. Monitoring, Mitigation and Management

Key Senex management plans and reports related to the monitoring and management of water include:

- The Water Monitoring and Management Plan (this report)
- 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

Table 4-1 provides a summary of the monitoring commitments made by Senex.

Table 4-1: Summary of Monitoring Requirements

Monitoring	Location	Purpose	Frequency	Response Trigger
Baseline Monitoring				
Groundwater Level	Senex Monitoring Bores (see Section 4.1.1)	Develop baseline	Quarterly	Yes – interim triggers
Groundwater Quality	Senex Monitoring Bores (see Section 4.1.1)	Develop baseline	Quarterly; parameters as listed in Section 4.1.1.3.	Yes – interim triggers
Surface water	Wandoan and Woleebee Creeks	Develop baseline	One completed; four additional events over minimum 2-year period	No
Terrestrial GDEs	~12 locations[5]	Develop baseline	Four over minimum 2 years	No
Aquatic GDEs	~20 locations[5]	Develop baseline	One completed; three additional over minimum 18 months	No
Subsidence/land surface elevation using InSAR	Across the full tenement	Develop baseline	Annually	No
Ongoing Monitoring				
Groundwater Level	UWIR WMS bores (see Section 4.2.1.1)	Monitor potential impacts	Hourly via SCADA	No
Production well water quality	ATLAS-61 (see Section 4.2.1.2)	Meet UWIR requirements	Annually	No
Groundwater quality	Seepage bores (see Section 4.2.1.2)	Identify potential impacts from surface water storage facilities	Quarterly	Yes

[5] These will be at representative locations across the site. Final location quantity subject to confirmation

Monitoring	Location	Purpose	Frequency	Response Trigger
Groundwater level	Seepage bores (see Section 4.2.1.2)	Identify potential impacts from surface water storage facilities	Quarterly	No
Groundwater level	Senex Monitoring Bores	Identify potential impacts associated with CSG production activities	TBC following 2 years of data collection and review	-
Surface water – erosion and sedimentation	Watercourse crossings	Monitor impacts during construction	As required	No
Regulated structure monitoring	Surface water structures	Provide data, assess performance, provide warning of loss of structural integrity	Dependent on monitoring activity	Yes
Subsidence	Across the full tenement	Identify changes to ground elevation due to the project	Annually	Yes

4.1. 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 season cycles (to include a wet and dry seasons) to be completed within two years of commencement, is proposed for:

- Groundwater level and quality;
- Groundwater dependent ecosystems; and
- Surface water quality.

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.

4.1.1. Groundwater

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. Details of these bores are provided in Table 4-2 and the location is provided on Figure 4.1.

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 coal seam gas 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 2 years. A data review will be undertaken annually by a suitably qualified person. After the collection of 2 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.

4.1.1.1. 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 considered to help place the new monitoring bore pair in the optimal location.

A geophysical survey will be undertaken as part of a mapping exercise to provide additional information in characterising the heterogeneity in the alluvium across this predicted drawdown area and improve the robustness of drawdown predictions and associated impact risks at the individual GDE-scale. The existing four paired monitoring bores will be used as verification points when analysing data obtained through this program.

These 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 area.

4.1.1.2. Groundwater Level/Pressure Monitoring Program

Groundwater level/pressure will be monitored at all active baseline monitoring network locations. Water level measurements will be carried out either manually, by automated pressure transducer data loggers

(PTDLs), or both. Data collected from PTDLs will be compared against manual measurements for data verification.

The frequency of monitoring is provided in Table 4-2.

4.1.1.3. Groundwater Quality Monitoring Program

Groundwater quality will be monitored in all active baseline monitoring network locations (Table 4-2).

The analytical parameters required to be analysed from groundwater samples collected from monitoring bores include, at a minimum:

- General field physiochemical parameters: (pH, EC, Turbidity, Dissolved Oxygen, Temperature, ORP), and Total Dissolved Solids (TDS), Suspended Solids
- Cations: Na^+, K^+, Ca^{2+}, Mg^{2+}
- Anions: Cl-, SO_4^{2-}, CO_3^{2-} Alkalinity, HCO_3^- Alkalinity and Total Alkalinity
- Ionic Balance
- Nutrients: Ammonia as N, Nitrite as N, Nitrate as N, Total N, Organic N, Total Phosphorous as P Sodium Adsorption Ratio (SAR)
- Halides: F-
- Total and Dissolved Metals: Al, Ag, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Ga, Hg, Li, Mo, Mn, Ni, Pb, Sb, Se, Sr, U V, Zn
- Total Organic Carbon
- Total Petroleum Hydrocarbons (TPH) (C6-C9 and C10-C36)
- Stable isotopes of water, oxygen 18 (δ18O) and deuterium (δ2H).

The frequency of sampling is provided in Table 4-2. Water quality will be sampled quarterly for two years until a sufficient baseline has collected, after which sampling frequency will be reviewed and long-term monitoring determined.

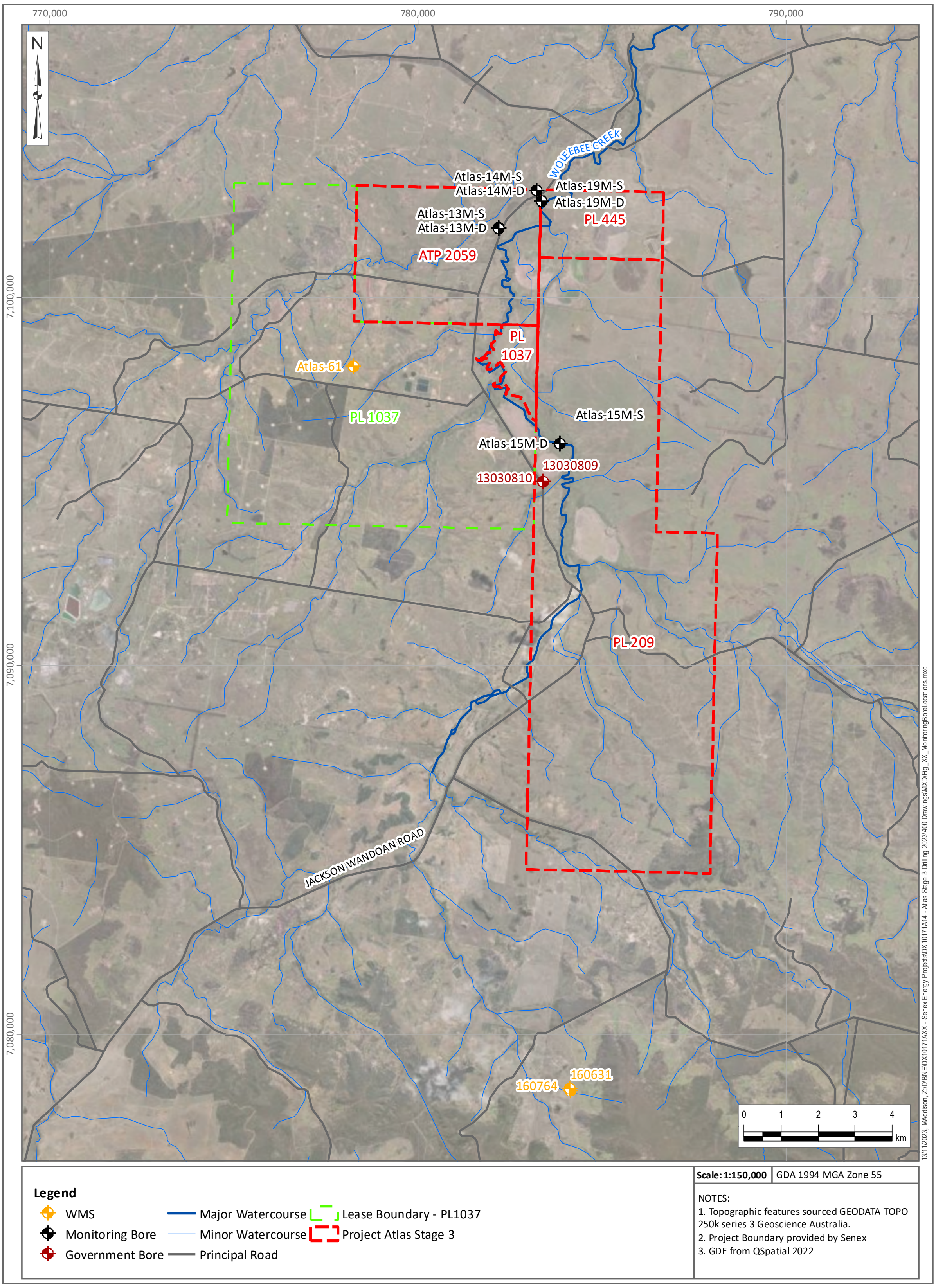


Figure 4.1 Location of Senex Baseline Monitoring Bores

Table 4-2 Baseline Groundwater Monitoring Bores

RN	Senex ID	Location	Screen Depth (mbGL)	Source Aquifer	Purpose	Instrumentation Equipped/Frequency of data logging	Manual Groundwater Measurements	Groundwater Sampling Regime
180128	Atlas 13M-D	ATP 2059	30.5 – 36.5	Westbourne Formation	Baseline Monitoring	PTDL/12-hourly	Quarterly[1]	Quarterly[1]
180127	Atlas 13M-S		6.0 – 9.0	Alluvium		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 14M-D		40.0 – 46.0	Springbok Sandstone		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 14M-S		7.0 – 10.0	Alluvium		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 15M-D	PL 209	29.0 – 35.0	Westbourne or Gubberamunda		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 15M-S		8.4 – 11.4	Alluvium		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 19M-D	PL 445	24.0 – 30.0 And 39.0 – 45.0	Springbok Sandstone		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
TBC	Atlas 19M-S		4.5 – 7.5	Alluvium		PTDL/12-hourly	Quarterly[1]	Quarterly[1]
13030810	-	PL 209	8.37 – 9.37	Alluvium	Baseline Monitoring (GWL only)	Manual Dip	Quarterly[1]	-
13030809	-		36.37 – 38.37	Springbok Sandstone		Manual Dip	Quarterly[1]	-
160631	Woleebee MB3-S	PL 209	378 – 420	Upper Springbok	WMS obligation (acquired from APLNG)	SCADA	Quarterly	-
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)	SCADA	Quarterly	-

PTDL – Pressure Transducer Data Logger

1. Quarterly sampling to occur until sufficient baseline of two years of data has been collected.

4.1.2. 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 (Figure 3.2). This baseline data will allow for improved design of monitoring, mitigation and management processes and plans.

Potential Terrestrial GDE Baseline Assessment

An initial round of Terrestrial GDE (TGDE) baseline field botanical surveys and vegetation community assessments was completed in March - June 2022 (Boobook 2022). A further four baselining survey events will be completed over a minimum two-year period (to enable enhanced understanding of any seasonal variation prior to any possible impact from the project).

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 be located adjacent the existing and proposed groundwater monitoring bores.

Baseline botanical surveys in the plots will describe dominant flora and vegetation community structure. Searches will be conducted for EPBC Act and NC Act listed threatened flora. If identified, the species, location and number of individuals will be recorded. Significant weed species, WoNS and Biosecurity Act Restricted Matters, will also be recorded.

BioCondition assessments have been and will be used to evaluate ecological functionality of vegetation communities in these areas. These assessments apply the methodologies described by *Eyre et al.*(2015). This involves the establishment of a 100 m x 50 m plot for measurements relating to canopy layer structure and diversity, a 100 m transect to measure canopy cover, a 50 m x 10 m subplot for measuring plant richness in shrub and ground layers, a 50 m x 20 m subplot for measuring coarse woody debris, and five 1 x 1 m quadrats to estimate ecological components of ground cover within the assessment area. These values are used as indicators of ecosystem function relative to minimally disturbed benchmark sites (Queensland Herbarium 2021) within the same vegetation type (AU).

BioCondition assessments will complement the vegetation community assessments.

The following information is recorded at each BioCondition site:

- Date;
- Observers;
- Description of location (bioregion, general description, co-ordinates for plot origin and centre, plot bearing and alignment);
- General habitat description and RE type;
- Median height for canopy, emergent and sub-canopy strata;
- Slope position/slope degree and slope aspect;
- Tree species richness (within 100 m x 50 m plot);
- Native plant species richness (within 50 m x 10 m plot);
- Non-native plant cover (within 50 m x 10 m plot);
- Total length of coarse woody debris (length >10 cm diameter and >0.5 m long within 50 m x 20 m plot);
- Number and average diameter at breast height (DBH) of large eucalypt and non-eucalypt trees (within 100 m x 50 m plot);
- Recruitment of canopy species (within the 100 m x 50 m plot);
- Tree and shrub canopy cover (within 100 m transect);

- Ground cover within 1 m x 1 m plots (native perennial grass and organic litter cover in the ground layer); and,
- Disturbances (severity, last event and observation type).

Site photographs will be taken using a digital camera in accordance with Eyre et al. (2015) (i.e. one photograph at plot origin and north, east, south and west photographs at the plot centre). Photograph numbers shall be recorded. Locations of BioCondition sites will be determined using a handheld Global Positioning System (GPS) and BioCondition assessment data will be captured by mobile GIS devices.

Scores for BioCondition sites will be calculated in accordance with Eyre et al. (2015) which compares the values obtained at each survey site with values in the benchmark document for that particular RE (Queensland Herbarium 2021).

Subscores will be awarded to each site are totalled and divided by the maximum possible score for that RE. This provides a numeric index along a continuum of biodiversity condition, where scores close to 0 indicate sites that are ecologically ‘dysfunctional’ and scores closer to 1 indicate increasing functional integrity.

Fauna surveys have and will include incidental and targeted searches to detect the presence of threatened vertebrate fauna. Incidental searches will consist of opportunistic active searches in suitable habitat while undertaking the vegetation community assessments. Targeted faunal survey techniques will include spotlighting for arboreal mammals and birds. Spotlighting surveys have already been undertaken in two sites, in riparian woodland along Wandoan Creek and in similar vegetation along Woleebee Creek, both within the northern part of the Project Area. Each spotlighting survey commenced one hour after sunset and consisted of a two-hour, approximately two-kilometre meandering transect through habitat suitable for arboreal mammals covering all vegetation strata along the route. Four further spotlighting surveys will be completed along these watercourses over the next two years.

Faunal habitat values will also be assessed within the same 50 m x 20 m plot used for vegetation assessments. Data has been and will continue to be collected for fauna habitat features and condition for threatened fauna. Features are assessed semi-quantitatively and include the presence and abundance of:

- Hollow-bearing live trees, stags and logs;
- Logs by size class;
- Leaf and woody litter, stone/rock and grassy ground cover;
- Rock outcrops, gilgais, termite mounds and burrows;
- Mistletoe and other potential food plants;
- Active or potential fauna breeding places are also recorded where found. Such places include;
- Decorticating trees and logs; and
- Hollow-bearing logs, live trees and stags.

Reference TGDE sites will also be established and assessed outside of the expected project impact area in comparable TGDEs. Reference sites will be as similar as possible to the ‘impact’ sites in their species composition, environmental setting and potential use of groundwater. It is recognised that reference site options are all likely to be within areas potentially affected by other gas and/or agricultural projects, however being outside of areas with any predicted potential for drawdown immediately underlying the alluvium, these reference sites will be best placed to contextualise any detected changes in the predicted ‘impact’ areas. Should TGDE monitoring be triggered in the future (through exceedance of groundwater trigger values established under the JIF), the data from the reference sites would be available to help indicate whether changes observed in potential TGDEs in the project ‘impact’ area exceed changes in the TGDEs in the broader area that may be explained by climate or other sources of variability.

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

An initial round of Aquatic GDE (AGDE) baseline field assessment has already be completed during the wet season of 2022 (14-21 March). A further three (3) baselining events will be completed over a minimum 18-month period (to enable enhanced understanding of seasonal variation prior to any possible impact from the project).

The aquatic ecology assessment sites will be located close to the existing and proposed groundwater monitoring bores. Reference sites will also be established.

To the extent that field conditions allow, field sampling of aquatic habitat values consists of:

- Habitat assessment;
- In situ water quality sampling;
- Macrophytes;
- Macroinvertebrate;
- Backpack electrofishing;
- Visual observations; and
- Fyke netting using large nets.

The aquatic habitat assessment is undertaken following the Australian River Assessment System (AusRivAS) protocols (DNRM 2001) by an AusRivAS accredited ecologist. The habitat assessment includes recording quantitative and qualitative measurements and observations of:

Substrate composition;

- Flow, water depth and wetted width, noting if surface water was connected or comprised of one or more disconnected pools in the channel;
- Channel morphology;
- Physical habitat features, such as large woody debris, undercut banks and aquatic plants;
- Riparian vegetation cover and condition;
- Any notable disturbances including bank erosion, cattle access to waterway and barriers;
- Associated with nearby road crossings or dams; and
- Other onsite features, such as presence of filamentous or benthic algae, surface scums, unusual sediment deposits, or fish kills.

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, including:

- Channel characteristics
  - Reach length, bankfull bank height, bankfull stream width, mean water depth, mean wetted width.
- Riparian vegetation characteristics
  - Riparian vegetation height (max.), riparian zone width (both banks), bare ground, grass, shrubs, trees (< 10 m and > 10 m), canopy cover.
- Mesohabitat composition (%)
  - Riffle, run, rocky pool, sandy pool, dry.
- Substrate composition (%)
  - Bedrock, boulder (>256 mm), cobble (64-256 mm), pebble (4-64 mm), gravel (2-4mm), sand (2-4 mm), silt/clay (<0.05 mm).
- Macrophytes (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)
  - Free floating, attached floating, submerged, emergent (as per section 3.5).
- In-stream wood (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)

- Detritus (leaves etc), sticks (<2 cm diameter), branches (<15 cm diameter), logs (>15 cm diameter).

- Microhabitat (None, Little 1-10%, Some 10-50%, Moderate 50-75%, Extensive >75%)
  - Periphyton, filamentous algae, submerged macrophytes, bank overhang vegetation, trailing bank vegetation, blanketing silt, substrate anoxia, bank undercuts.

Aquatic habitat will be assessed in accordance with Queensland Australian River Assessment System (AusRivAS) Sampling and Processing Manual (DNRM 2001). Habitat bioassessment score datasheets (from DNRM 2001) are used to numerically score nine criteria, which are then allocated to one of four categories (excellent, good, moderate and poor).

In situ water quality data is recorded at each AGDE assessment site using portable multiparameter water quality meters that have been calibrated in accordance with the manufacturer's specifications. Calibrations are regularly checked in the field. Parameters tested in situ are temperature, electrical conductivity (EC), pH, turbidity and dissolved oxygen (DO). In situ water quality testing is undertaken in conjunction with macroinvertebrate sampling to assist with the interpretation of results. All sample collection is completed in accordance with the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (DES 2018a) and *AS/NZ 5667.6:1998 Guidance on sampling of rivers and streams* (AS/NZS 1998).

Macrophyte surveys are undertaken following completion of the fish and macroinvertebrate surveys to increase the chance of observing macrophytes that were not abundant throughout the reach. All native and exotic macrophyte species at the site are recorded. The relative site coverage of each macrophyte species is recorded. Macrophyte species are categorised by growth form in accordance with definitions provided in Sainty and Jacobs (2003), as follows:

- Free floating – Species that are normally unattached and float on the surface but may become attached and rooted in drying mud when water levels drop.
- Floating attached – Species that are rooted in the substrate but normally have at least the mature leaves floating on the water surface.
- Submerged– Species rooted in the substrate or free floating submerged.
- Emergent – Species rooted in the bank substrate with stems, flowers and most of the.
- Mature leaves projecting above the water surface.
- No free floating or submerged macrophytes have been recorded to date.

Freshwater macroinvertebrates are also sampled in accordance with the Monitoring and Sampling Manual: Environmental Protection (Water) Policy (DES 2018a) which defaults to those methods adopted by the Australian River Assessment System (AusRivAS) Sampling and Processing Manual (DNRM 2001).Collected macroinvertebrates are sorted in the laboratory and identified to the family taxonomic level and relative abundance enumerated. Organisms are identified to family level with the exception of lower phyla (e.g., porifera, nematoda), oligochaetes (freshwater worms), acarina (freshwater mites) and microcrustacea (ostracoda, copeopoda and cladocera). Chironomids are identified to subfamily level in accordance with standard AusRivAS protocols (DNRM 2001).

Where sufficient water is present, fish and turtle sampling is conducted in line with the approach outlined in the Monitoring and Sampling Manual: Environmental Protection (Water) Policy (DES 2018a).

Sampling of frogs is restricted to opportunistic visual encounter surveys and call surveys. These are undertaken during general aquatic ecology surveys. At each site suitable habitat is searched for any frogs present. No frogs have been heard calling and no tadpoles have been recorded to date.

The AGDE assessment within and outside of the areas of predicted drawdown in the outcropping Upper Springbok will provide a baseline of the AGDE characteristics (including seasonal variability) within these areas prior to there being any potential for these AGDEs to be affected by the Project.

Stygofauna Baseline Assessment

A desktop stygofauna baseline assessment has been completed which considered a 50km radius area centred on the Project. Twelve landholder bores, all outside of the areas of predicted drawdown in the outcropping Upper Springbok (where >20cm drawdown is predicted at Upper Springbok outcrop at the

95% percentile), were sampled for stygofauna in June 2022. 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 alluvial monitoring bores these will be sampled for stygofauna. The non-alluvial bore of each monitoring bore pair will be sampled.

Groundwater bores are sampled for stygofauna in accordance with the methods defined in Queensland Environment Protection (Water) Policy 2009 – Monitoring and Sampling Manual for Biological Assessment (DES 2018a) and following established sampling techniques defined elsewhere in Australia and overseas (DSITI 2015; Hancock and Boulton 2008; Dumas and Fontanini 2001; WA EPA 2003; 2007).

Field samples are logged into a Laboratory Information Management System to record and track sample processing details. Stygofauna samples are then sorted under a stereomicroscope and all aquatic animals present are removed (stygofauna and non-stygofauna) and identified to Order/Family level (or lower taxonomic rank if visually possible) in accordance with standard Queensland Government Terms of Reference for an EIS.

Biannual groundwater quality sampling will also be conducted at each stygofauna sampling bore including for temperature (°C), pH (units), electrical conductivity (µS/cm), dissolved oxygen (mg/L) and turbidity (NTU) using a multiparameter water quality meter to provide a general estimate of standing groundwater quality, at the following bores:

- ATLAS-13-M-D/S
- ATLAS-14M-D/S
- ATLAS-15M-D/S
- ATLAS-19M-DS

Additional proposed monitoring bore pair.

Two of the existing monitoring bore pairs and the proposed monitoring bore pair are within the areas of predicted drawdown in the outcropping Upper Springbok while two monitoring bore pairs are upstream of these areas (reference sites). 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.

Groundwater 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 proposed sampling method locality and intensity is provided in Table 4-3 below. This program will be undertaken over a 2-years (4 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 asso ciated 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.

This intensive data collection will form a component of a baseline dataset.

Table 4-3 GDE Dependency Assessment Program Sampling Method Locality and Intensity

Sampling method	Sampling locality	Sampling Intensity
Pre-dawn leaf wetting potential (LWP)	Wandoan Creek	A minimum of 12 LWP assessment (tree) points across three monitoring sites extending from the inner benches of the creek to lower alluvial terraces.
	Woleebee Creek	A minimum of 20 LWP assessment (tree) points across five monitoring sites extending from the inner benches of the creek to the lower alluvial terraces.
	Wetland areas associated with the floodplain of Woleebee Creek	A minimum of 8 LWP assessment (tree) points across two monitoring sites within areas associated with the floodplain of Woleebee Creek.
Leaf area index (LAI)	Wandoan Creek	A minimum of 12 LAI capture (tree) points across three monitoring sites extending from the inner benches of the creek to lower alluvial terraces.
	Woleebee Creek	A minimum of 20 LAI capture (tree) points across five monitoring sites extending from the inner benches of the creek to the lower alluvial terraces.
	Wetland areas associated with the floodplain of Woleebee Creek	A minimum of 8 LAI capture (tree) points across two monitoring sites within areas associated with the floodplain of Woleebee Creek.
Stable Isotope	All localities	Sampling for stable isotopes will be completed at a minimum for: a) 40 trees proposed for assessment across 10 proposed GDE assessment sites. b) shallow groundwater stored in sand in the river channel (river sand aquifer) or intersected in deeper auger profiles located on alluvial terraces and sampled with a bailer. c) groundwater from alluvial monitoring bores where sampling with a bailer is suitable. d) groundwater from deeper monitoring bores installed into bedrock aquifers. e) soil samples from auger holes, including up to 6 auger holes up to 6m depth (two from Wandoan

Sampling method	Sampling locality	Sampling Intensity
		Creek, two from Woleebee Creek and two from AGDE wetlands.
NDVI Capture	Approximately 100km2 capture to cover the Project area and a suitable buffer.	Fresh capture WorldView 2 and GeoEye-1 (0.5m Resolution 4-8 band Pan) imagery coinciding with the field survey events will be used specifically as a measure of vegetation vigour as a baseline.

At the end of the two-year assessment period, a GDE Dependency Assessment Report will be prepared which includes identification of likely moisture sources utilised by targeted trees (and potential GDEs) at the time of assessment. Reporting will include a statistical analysis to identify trends and correlations between multiple datasets.

4.1.3. 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 (KCB 2023b).

The results indicated that isotope samples collected from surface water (Woleebee-Ck-N) show a “more evaporated” signature in comparison to the groundwater samples which did not show an evaporative signature. 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, as indicated in Table 4-4 below. 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).

Table 4-4 Surface Water Persistent Pool Baseline Sampling Locations

Location ID	GDA94 Zone 55		Water Source
	Easting (mE)	**Northing (mN)**	
Woleebee-Ck-N	785462	7104179	Woleebee Creek
Woleebe-Ck-S (near Atlas-15M-D/S)	TBC	TBC	Woleebee Creek
Wandoan-Ck	TBC	TBC	Wandoan Creek

Surface Water Sampling Suite

The analytical parameters required to be analysed from surface water samples collected from locations previously sampled include, at a minimum:

- General field physiochemical parameters: (pH, EC, Turbidity, Dissolved Oxygen, Temperature, ORP), and Total Dissolved Solids (TDS), Suspended Solids

- Cations: Na+, K+, Ca2+, Mg2+
- Anions: Cl-, SO42-, CO32- Alkalinity, HCO3- Alkalinity and Total Alkalinity
- Ionic Balance
- Sodium Adsorption Ratio (SAR)
- Halides: F-
- Total and Dissolved Metals: Al, Ag, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Ga, Hg, Li, Mo, Mn, Ni, Pb, Sb, Se, Sr, U V, Zn
- Stable isotopes of water, oxygen 18 (δ18O) and deuterium (δ2H).

Water quality will be sampled quarterly for two years until a sufficient baseline has collected, after which sampling frequency will be reviewed and long-term monitoring determined.

4.1.4. Subsidence Baselining

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 4.2.5 will be reviewed based on the findings of this baseline assessment.

4.2. Ongoing Monitoring

4.2.1. Groundwater

Groundwater monitoring should be undertaken where there is potential for adverse impacts to groundwater resources and related assets and ecosystems due to Project activities or where there is uncertainty about the potential risks to groundwater resources and related assets and ecosystems (IESC 2023).

Groundwater monitoring as part of the Project has been considered in relation to key legislation, policies, guidelines, and standards. These are outlined in Table 4-5.

Table 4-5 Key Legislation, Policies and Standards Applicable to Groundwater Monitoring

Type	Name
Legislation	*Water Act 2000* (State of Queensland 2021c) *Environmental Protection Act 1994* (State of Queensland 2022a) *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020b) *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth of Australia 2022)
Guidelines and Policies	Bore Baseline Assessments Guideline (DES 2022a) Queensland Water Quality Guidelines 2009 (DEHP 2013) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

Type	Name
	Monitoring and Sampling Manual: Environmental Protection (Water) Policy (DES 2018a) Australian and New Zealand Water Sampling Guidelines – Part 11 Guidance of sampling of groundwater (AS/NZS 5667.11 1998). Australian Groundwater's Sampling and Analysis – A Field Guide (Sundaram et al. 2009). Bore Assessments Guideline (DES 2022b)
Standards	Minimum Construction Requirements for Water Bores in Australia (NUDLC 2020) Minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland (State of Queensland 2017)
Reports	Underground Water Impact Report for the Surat Cumulative Management Area (OGIA 2021f) Groundwater Sampling and Analysis – A Field Guide (Sundaram et al. 2009)

Groundwater monitoring forms a key mechanism for early identification of the response to CSG water production within the WCM and other formations where groundwater receptors exist.

The groundwater monitoring requirements for CSG tenure holders within the Surat Cumulative Management Area (CMA) are specified in the Underground Water Impact Report (UWIR) Water Management Strategy (WMS) (OGIA 2021f) (see Section 1.2.2). The Department of Regional Development, Manufacturing and Water also design and maintain the Queensland Groundwater Monitoring Network. Groundwater monitoring data collected across the network supports a range of groundwater planning, management and investigation activities (RDMW 2022). Data is collected and stored and is publicly available through the Water Monitoring and Information Portal (WMIP) (State of Queensland 2022b).

A groundwater monitoring network and sampling and analysis program has been developed to monitor CSG related groundwater drawdown, to provide baseline data, and to enable the identification of early warning conditions as monitoring data are acquired over time. These bores form part of a wider regional groundwater monitoring network, the data is used to identify changes in groundwater level trends which may indicate a potential impact both from single projects and cumulatively.

The monitoring network utilises Senex's existing and planned monitoring locations as required by the Surat CMA UWIR WMS.

4.2.1.1. UWIR Monitoring

The Surat CMA UWIR sets out regional monitoring requirements for groundwater pressure and quality across the Surat CMA. Through this, a substantial network of groundwater monitoring locations has been established across the Surat CMA with the primary objectives to:

- Improve the understanding of system response within production areas.
- Identify pressure changes near specific areas of interest.
- Improve understanding of background trends in pressure.
- Provide sufficient data for model calibration.

Data collected from the greater UWIR monitoring network is considered to provide sufficient information to account for the heterogeneous nature of the system. The monitoring of these locations has resulted in the collection of a significant data set describing baseline groundwater pressure and quality and provides OGIA with periodic data for ongoing conceptualisation and calibration updates to its groundwater models.

Under the Surat CMA UWIR, Senex is assigned monitoring obligations. Senex is currently obligated to maintain and monitor two WMS monitoring points (a Springbok Sandstone and a multi-level WCM), located within the Project area (PL 209). Details of these monitoring points are provided in Table 4-5 monitoring of WMS points will follow any OGIA requirements (OGIA 2021a).

Senex will continue to comply with any updates to the WMS that may be required in any future updates of the Surat CMA UWIR.

Groundwater Level/Pressure Monitoring Program

Groundwater pressure will be monitored at all active monitoring network locations. The SCADA monitoring system records groundwater levels continuously at a frequency of one reading per hour (i.e. 24 readings per day) (OGIA 2021a)

Groundwater Quality Monitoring Program

ATLAS-61 is a production well monitored in accordance with the UWIR WMS for groundwater quality. This production well is sampled annually for the following parameters (OGIA 2021a):

- Field parameters: electrical conductivity, pH, Redox Potential, temperature, free gas at wellhead
- Major cations and anions: calcium, magnesium potassium, sodium, bicarbonate, carbonate, chloride, sulfate, and total alkalinity
- Metals (dissolved): arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, zinc
- Fluoride, TDS
- Gas (dissolved): Methane
- Isotopes: Strontium (87Sr/86Sr)
- Metals (dissolved): Strontium (Sr2+)

Report and Review

Senex is required to submit the following to OGIA every six months (following 1 April and 1 October each year) (OGIA 2021f):

- A WMS network implementation report that will include the current status of the groundwater monitoring points.
- A WMS water monitoring report that will include an explanation of any gaps in the monitoring record associated with maintenance issues or failure of a monitoring point.
- The monitoring records for the reporting period.
- The volume of water produced from all production wells is monitored against forecast results, any anomalous results are subject to the same sampling to confirm potential water sources.

Table 4-6 UWIR Monitoring

RN	Owner	Senex ID	Location	Screen Depth (mbGL)	Source Aquifer	Purpose	Instrumentation Equipped/Frequency of data logging	Manual Groundwater Measurements	Groundwater Sampling Regime
160631	Senex	Woleebee MB3-S	PL 209	378 – 420	Upper Springbok	WMS obligation (acquired from APLNG)	SCADA (hourly)	Quarterly	-
160764	Senex	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)	SCADA (hourly)	Quarterly	-
-	Senex	ATLAS-61	PL1037		WCM	WQ-PROD	SCADA (hourly)		Annually

Note: RDMW – Department of Regional Development, Manufacturing and Water

SCADA – Supervisory Control and Data Acquisition system

PTDL – Pressure Transducer Data Logger

mbGL – metres below ground level

1. Quarterly sampling to occur until sufficient baseline of two years of data has been collected and then ongoing monitoring as per approval conditions.
2. Note that Atlas-3M was replaced early 2023 with a replacement bore and is referred to as Atlas-3M-R.

4.2.1.2. *Seepage Monitoring*

Surface water and waste storage facilities have the potential to impact the shallow aquifer systems. 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 facility. The formation most likely to be affected by seepage from containment facilities is the Westbourne Formation which is considered a tight aquitard and unlikely to provide significant migration pathways.

The seepage monitoring program required under Condition 13 of the EA must include:

A. Identification of the containment facilities for which seepage will be monitored.

B. Identification of trigger parameters that are associated with the potential or actual contaminants held in the containment facilities.

C. Identification of trigger concentration levels that are suitable for early detection of contaminant releases at the containment facilities.

D. Monitoring of groundwater at each background and seepage monitoring bore at least quarterly for the trigger parameters identified in Condition 13b.

E. Seepage trigger action response procedures for when trigger parameters and trigger levels identified in conditions 13 b and 13c trigger the early detection of seepage, or upon becoming aware of any monitoring results that indicate potential groundwater contamination.

Investigation trigger values for Seepage Monitoring Bores have been developed together with a seepage emergency response procedure, which will be implemented following exceedance of quality trigger values (refer to Section 4.3.6.1 and 4.3.7.1). These trigger levels are considered interim values given the limited number of sample points available and will be reviewed when more data has been collected.

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. Details of these bores is presented in Table 4-7 with well locations provided in Figure 4.2.

Should any additional water structures for treated water or brine be constructed on PL 1037 or PL 209, Senex will assess the risks and consider installing additional monitoring bores or utilise existing water bores within the Project area. Where new monitoring bores are required, they will be drilled and installed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2020) and monitored in accordance with relevant Queensland regulations.

Groundwater Level Monitoring Program

Groundwater levels are manually measured quarterly.

Groundwater Quality Monitoring Program

Groundwater quality parameters have been categorised into three analytical suites (A, B, and C), with groundwater from the Seepage Monitoring Bores being analysed for all three suites until further analysis and comparison of groundwater samples to dam and brine tanks water have been undertaken. Once sufficient data has been collected to identify contaminant indicators, the frequency of testing for each suite will be amended. The three suites are presented in Table 4-8.

Table 4-7 Current Shallow Seepage Groundwater Monitoring Bores

RN	Owner	Senex ID	Location	Screen Depth (m below ground level)	Source Aquifer	Purpose	Manual Groundwater Measurements	Groundwater Sampling Regime
58824	Landholder bore	ATL-08	PL 1037	19 – 25	Westbourne Formation	Seepage background bore	Quarterly	Quarterly
180072	Senex	Atlas 1M		44 – 50		Atlas Dam Seepage Monitoring	Quarterly	Quarterly
180075	Senex	Atlas 2M		50 – 53			Quarterly	Quarterly
180073	Senex	Atlas 3M-R		39 – 45			Quarterly	Quarterly
180077	Senex	Atlas 4M		28 – 34			Quarterly	Quarterly
180079	Senex	Atlas 5M		9 – 15			Quarterly	Quarterly
180078	Senex	Atlas 9M		9 – 12			Quarterly	Quarterly
180080	Senex	Atlas 6M		9 – 15			Quarterly	Quarterly
180071	Senex	Atlas 7M		9 – 15			Quarterly	Quarterly
180076	Senex	Atlas 8M		9 – 12			Quarterly	Quarterly
180074	Senex	Atlas 12M		4.5 – 7.5			Quarterly	Quarterly
TBC	Senex	Atlas 16M		5.5 – 11.5			Quarterly	Quarterly
TBC	Senex	Atlas 17M		19.5 – 25.5			Quarterly	Quarterly
TBC	Senex	Atlas 18M		11 - 17			Quarterly	Quarterly

Table 4-8 Proposed Water Quality analysis Suites for Groundwater Seepage Monitoring

Suite	Description	Analytes
A	Parameters indicative of seepage from dams and/or brine tanks	pH, electrical conductivity (field and lab), dissolved oxygen, temperature, redox, TDS, TSS, SAR, major cations and anions, sulfate, fluoride, alkalinity, total and dissolved: barium, boron, lithium.
B	Required if parameters are detected in dam or brine tank samples	Total and dissolved: aluminium, arsenic, beryllium, chromium, cobalt, iron, lead, manganese, molybdenum, mercury, nickel, selenium, uranium, vanadium, zinc, nitrate, nitrite, total nitrogen, total phosphorus.
C	Monitor until demonstrated parameters are not an indicator	Total and dissolved: antimony, cadmium, copper, gallium, silver, strontium, gross alpha, gross beta activity, medium faecal coliforms, hydrocarbons (C_6 – C36).

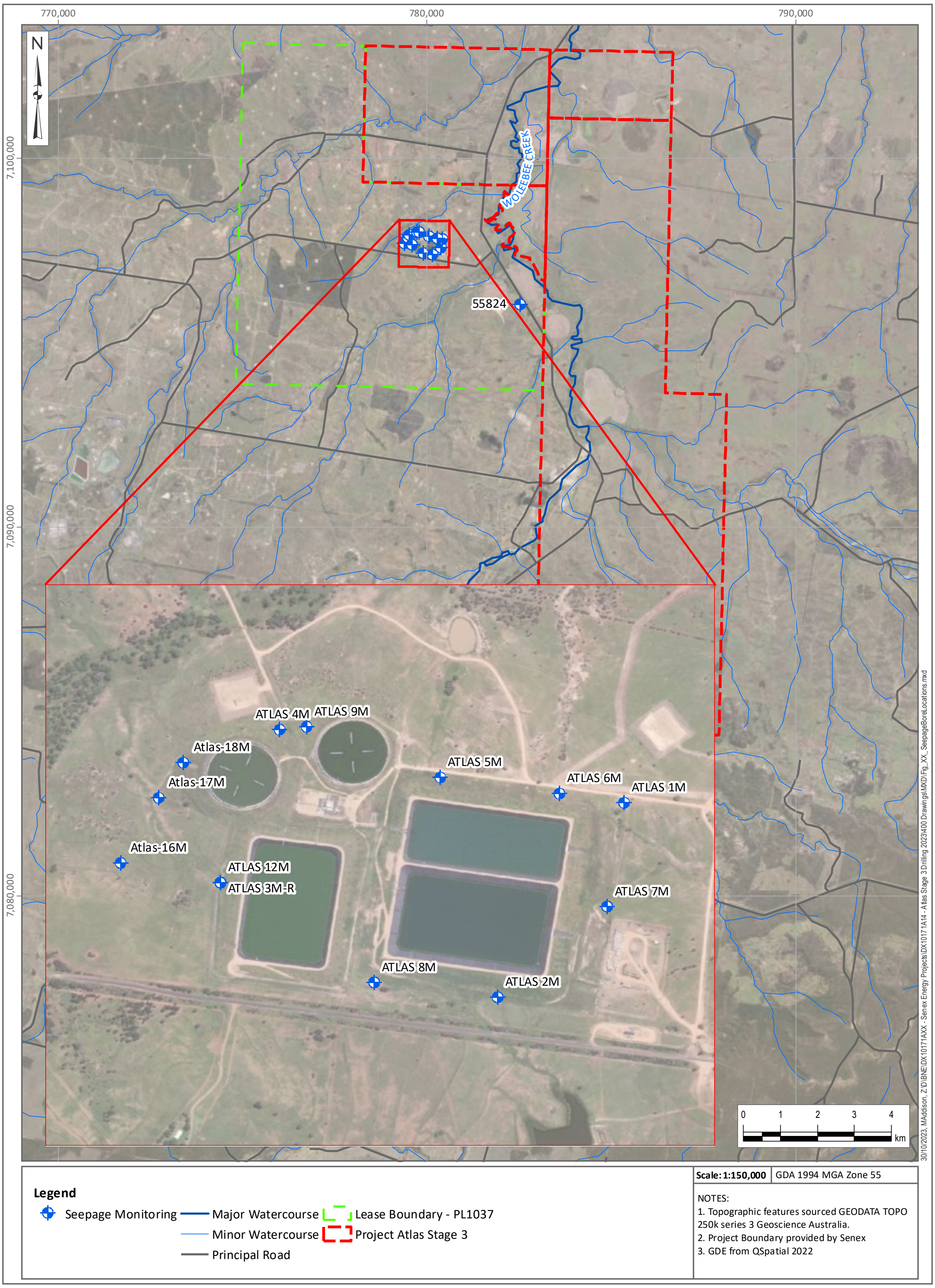


Figure 4.2 Location of Senex Monitoring Bores in the Vicinity of the Project

4.2.2. Surface Water

Monitoring of surface water systems is planned during the construction phase as follows:

- 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. Operational management/mitigation of potential impacts to surface water storage facilities are provided in section 4.2.3.
- There are no planned discharges to surface water from the proposed Project infrastructure (e.g., water storage facilities), therefore no ongoing monitoring of the surface water system is planned. Should this change, surface water monitoring will be undertaken prior to installation of infrastructure to confirm baseline conditions of the surface water system and to confirm potential impacts associated with discharge from the Project infrastructure.

4.2.3. Regulated Structure Monitoring

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.
- 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.
- 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 of the regulated structure includes:
- Produced water level.
- Produced water temperature.
- Produced water chemistry.
- Leakage detection via monitoring water in collection sump/s or flow rate through leakage recirculation pipes.
- Seepage detection via monitoring water level and chemical properties in shallow and deep groundwater bores surrounding the regulated structure.

The Atlas produced water dam monitoring requirements are presented in Table 4-9.

Table 4-9 Atlas Produced Water Dam Monitoring Requirements (as per OPS-QLD-OP-PLN-008)

Monitoring Activity	Data to be Acquired	Acquisition Method	Data Acquisition Frequency
Weather	Rainfall (mm) Evaporation (mm) Wind speed (m/s) Temperature (°C).	Weather station nearest to the regulated structure (BoM Station number 035014). Onsite weather stations.	Daily data provided by Bureau of Meteorology.
Water level	Water level in m.RL & %MOL.	Level transmitter with telemetry.	Minimum hourly recording.
Water chemistry	As required by the EA and as a minimum: • pH • Total Dissolved Solids • Total Alkalinity • Electrical Conductivity (EC)	Sample and test.	Quarterly
Leakage detection	Sump water level (m.RL or %Volume) and/or Total Leakage Recirculation Volume (m^3).	Flow totaliser or level transmitter via telemetry.	Hourly recording (level) Daily volume (flow totaliser).
Seepage detection	Groundwater level (m RL) in each monitoring bore and piezometer.	Manual measurement.	Same frequency as Routine Inspections.

4.2.4. Produced Water Quality Monitoring

The water quality of the produced water needs to be understood in order to identify potential impacts to the receiving environment should seepage, overtopping or emergency discharge to the environment occur. Water quality testing of produced water from Atlas production wells has been ongoing since 2018. Detailed chemical testing of produced water entering the Atlas Water Treatment plant has been occurring from October 2022. The quarterly analytical suite includes:

- Field parameters: pH, dissolved oxygen, temperature, oxidation reduction, EC, and TDS.
- pH.
- Electrical conductivity.
- Sodium adsorption ratio.
- Suspended solids.
- Alkalinity.
- Major ions (sodium, calcium, magnesium, potassium, sulfate, chloride, and fluoride).
- Total metals: barium, boron, lithium.
- The full suite of total metals is undertaken annually, and dissolved metals are tested if total concentrations are of concern.
- Total Organic Carbon.
- TRH volatiles/BTEX and TRH semi-volatile fraction are currently tested quarterly until there are eight complete datasets.

4.2.5. 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 suggest that additional monitoring occur 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 2021e).

Senex will identify areas, where they are the responsible tenure holder, 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. Subsidence monitoring frequency to be re-evaluated in 5 years.

Investigation of Potential CSG Related Subsidence

Where an annual subsidence rate has been identified, on land where Senex is the responsible proponent, that exceeds 10 mm/yr an assessment of the potential reason will be undertaken to identify if it 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 are likely to 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 2021e).

Trigger thresholds are presented below and have been developed based on the subsidence risk assessment undertaken in Section 3.6.5.

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 3.4.2.

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) (Sanderson 2012; Coffey 2018). 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.

4.3. Management and Mitigation

4.3.1. Data Management

Data management procedures have been established to ensure that data are recorded and handled in a consistent and organised manner and stored securely (Commonwealth of Australia 2023). Monitoring data will continue to be collated and stored in the Senex database.

The database will include but not be limited to the following information:

- Monitoring facility location details, aquifer and construction information;
- Landowner bore monitoring information from baseline assessments and the landowner bore monitoring program;
- Groundwater level/pressure monitoring data;
- Groundwater quality sampling results, including field measurements and laboratory analysis;
- Stratigraphic information (e.g., unit being monitored);
- Relevant CSG water production data (e.g., volumes / quality); and
- Climate data, including barometric pressure and rainfall.

4.3.2. Validation and Analysis of Monitoring Data

Senex have developed a procedure for review and analysis of groundwater monitoring data. A summary of the monitoring data analysis, to understand and review potential impacts as a result of project development, is provided in the following:

- Collect and review data.
  - Monitoring data will be collected / downloaded and reviewed by a qualified hydrogeologist. Data will be reviewed and validated through a visual assessment of the groundwater elevation hydrographs and any data quality issues will be identified. Missing data, unexpected values or variance from the historical range will be identified.
  - Monitoring results will be checked with appropriate QA/QC process adopted to verify the data by:
    - Reviewing and checking data and field documents to identify transcription errors.
    - Reviewing and checking the calibration of measurement equipment (for example data loggers and piezometers).
    - Barometric compensation of uncompensated logger data.
    - Obtaining further field data if necessary to confirm or clarify the results.
- Identify background or external influences / trends.
  - Groundwater elevations can be influenced by several factors, which can cause fluctuations and trends in groundwater elevations, both on a short-term (daily) or long-term (years or decades) scale. These may include:
    - Changes in barometric pressure;
    - Recharge following large precipitation events (short-term);
    - Longer term climatic response, such as wet / dry seasons as well as periods of drought or consecutive years of above average rainfall which overprint on season-to-season conditions;
    - Response to groundwater pumping; and

- Response to aquifer depressurisation.

Results of the monitoring program will be made available to OGIA for ongoing trend analysis and reporting, update to hydrogeological conceptualisation and modelling, and subsequently to inform the UWIR risk assessment.

4.3.3. JIF Risk Assessment Framework

Senex has committed to adopting the risk assessment and management framework defined in the JIF, which is applicable for this Project. The risk assessment and management frameworks defined in sections 3 to 7 of the JIF, relating to EPBC-listed springs, Water Supply Bores, Aquatic GDEs, Terrestrial GDEs and Subterranean GDEs will be implemented by Senex. These frameworks are based on defined risk thresholds for each of the above receptors, and associated risk assessment process. The risk thresholds are based on the predicted drawdown from the OGIA model at the location of the receptor that is caused by CSG development. A summary of the risk thresholds that are applicable for the Project are provided as follows:

- Water supply bores
  - Unconsolidated formation – 2 m drawdown
  - Consolidated formation – 5 m drawdown
- Terrestrial and Aquatic GDEs
  - 0.2 m drawdown
- Subterranean GDEs (stygofauna)
  - Over 2 m for unconfined hydrogeological units, dewatering of aquifer habitat for confined hydrogeological units (aquifer pressure in confined unit is reduced to the top of the hydrostratigraphic unit).

Should the above risk thresholds be exceeded based on the predicted results of the OGIA model, the applicable risk framework will be implemented for the assessment of potential impact along with identification of appropriate management/mitigation.

Actual mitigation or corrective actions would be determined during the JIF process. Examples of corrective actions include, but is not limited to:

- Cease groundwater extraction.
- 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.
- Reinjection of treated water to prevent drawdown in source aquifers.

Make Good Arrangements

The JIF water supply bore framework, adopted by Senex, is presented in Figure 4.3. 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.

Due to the Project being purchased from APLNG and the APLNG ‘Woleebee’ field being included in the 2021 Surat Basin UWIR, OGIA have identified one bore on Senex PL 445 (in the Upper Juandah Coal Measures) that requires make good arrangements[6] (Table 4-10). Senex are in negotiations with the landholder to include this bore in the Senex monitoring program.

[6] This bore is located in an immediately affected area (IAA)

Senex will comply with any updates to the make good arrangements in future UWIRs and continue to meet its make good obligations.

Senex will also respond to any complaints made from landowners in relation to potential unanticipated impacts. This will be undertaken through a bore assessment to establish whether a water bore has an impaired capacity, or is likely to have an impaired capacity, as a result of Atlas Stage 3. Any bore assessments will be undertaken in accordance with the DES *'Bore Assessments Guideline'* (DES 2022b).

Table 4-10 Bores Identified by OGIA for Make Good Arrangements (MGA) with the Project Area (OGIA 2021f)

RN	Latitude	Longitude	Intersected formations	Purpose	First identified	Current status
58910	-26.18	149.87	Upper Juandah Coal Measures	Stock and domestic	2019	In negotiation

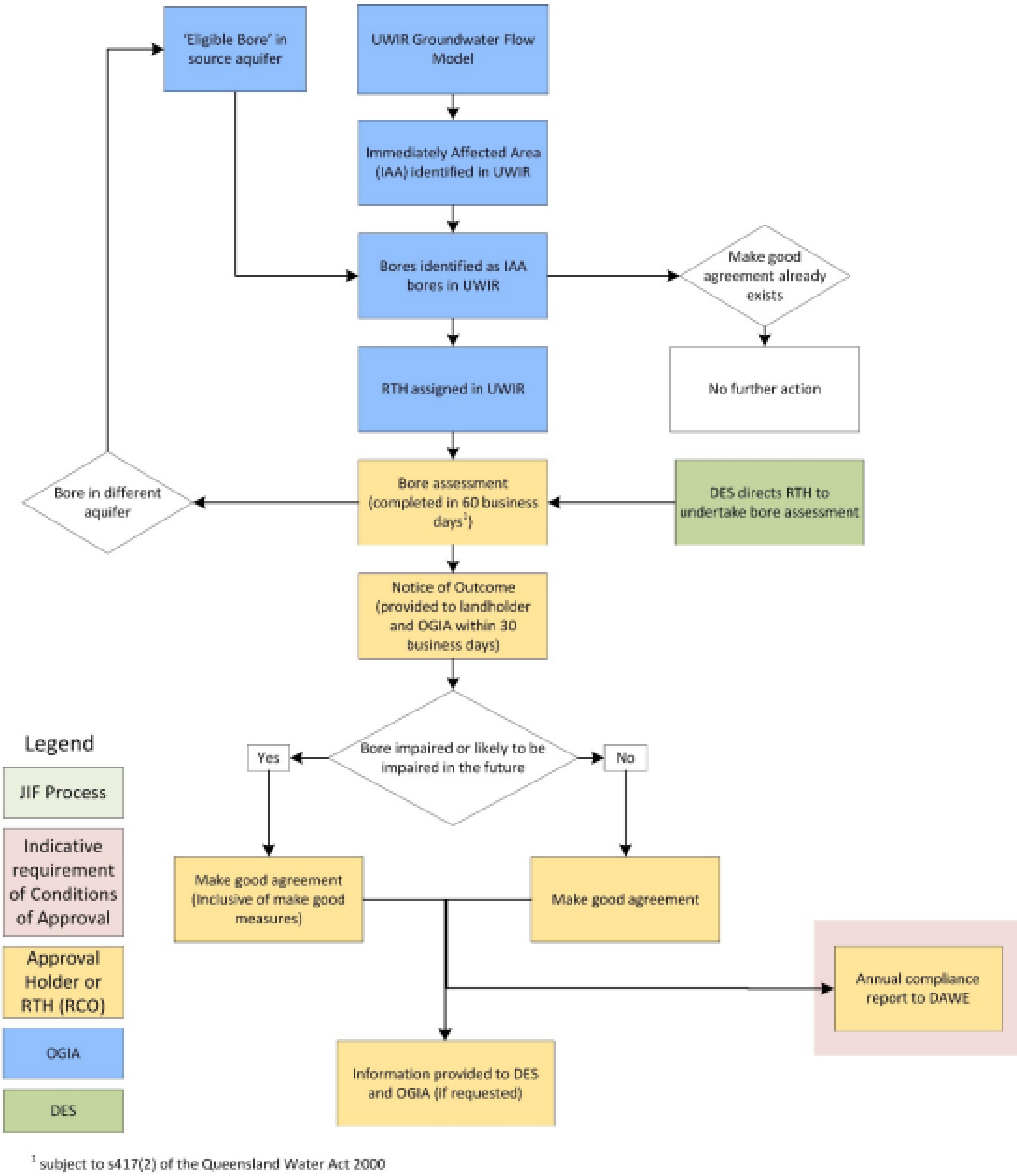


Figure 4.3 JIF Water Supply Bore Framework (DCCEEW 2021)

Terrestrial GDEs

The JIF risk framework for GDEs is presented in Figure 4.4. As per Section 3.6.1.2, it is interpreted that potential terrestrial GDEs may be intermittently supported by groundwater in the alluvium which is not predicted to experience drawdown due to its disconnect with the underlying GAB formations. The JIF preliminary risk assessment process has been followed assuming a potential connection of potential terrestrial GDEs to the GAB formations either directly or through the alluvium. The preliminary risk assessment suggests that the predicted risk to terrestrial GDEs from the Project are low because:

The outcrops of the Westbourne Formation and Gubberamunda Sandstone, which underlie the majority of the alluvium across the Project area, are not predicted to experience drawdown of more than 0.2 m due to the Project development.

A maximum Project only drawdown of 0.9 m is predicted to occur in the Upper Springbok Sandstone outcrop area (of approximately 0.7 km^2) on PL 445, approximately 7 years after the start of the development. According to the Joint Industry Framework (JIF) Terrestrial GDE preliminary risk assessment, the magnitude (< 1 m) and timing of predicted exceedance (7 years) of the impact on the known GDEs, suggests that the risk of impact to potential terrestrial GDEs is low.

Should a UWIR identify that the predicted drawdown or conceptual understanding has changed, Senex will re-evaluate the risk to the potential Terrestrial GDE and follow the JIF Terrestrial GDE framework (Figure 4.4).

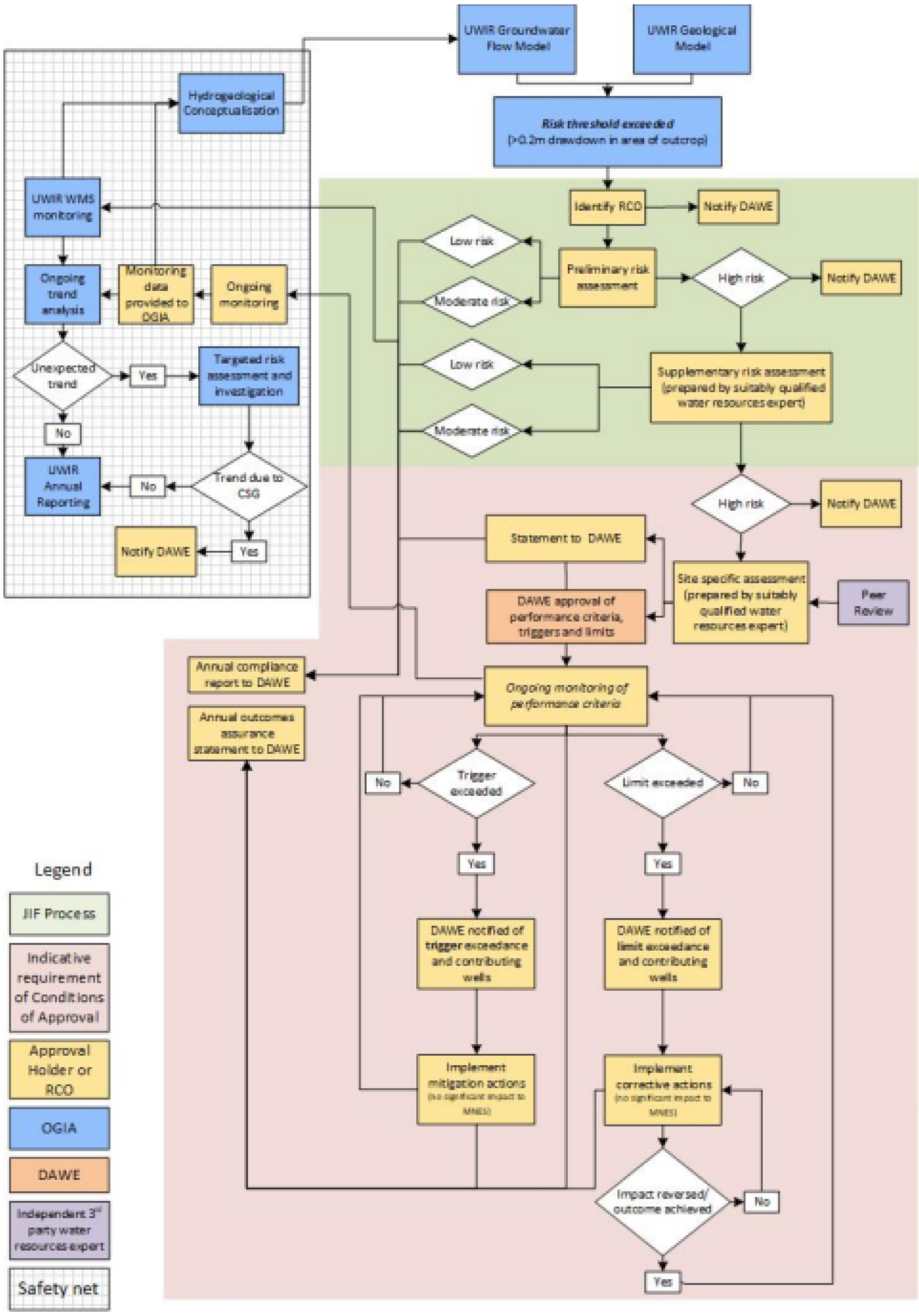


Figure 4.4 JIF Terrestrial GDE Framework (DCCEEW 2021)

Aquatic GDEs

The risk threshold for aquatic GDEs is based on a prediction from the UWIR groundwater model of a drawdown of 0.2m at the location of the Aquatic GDE that is caused by CSG development. The JIF risk process for aquatic GDEs, adopted by Senex, is presented in Figure 4.5.

The OGIA modelling does not predict a change of groundwater level in the location of aquatic GDEs within the Project area. However, if any future UWIR predicts an impact on an Aquatic GDE on a Senex tenement, Senex will follow the JIF risk assessment process as required.

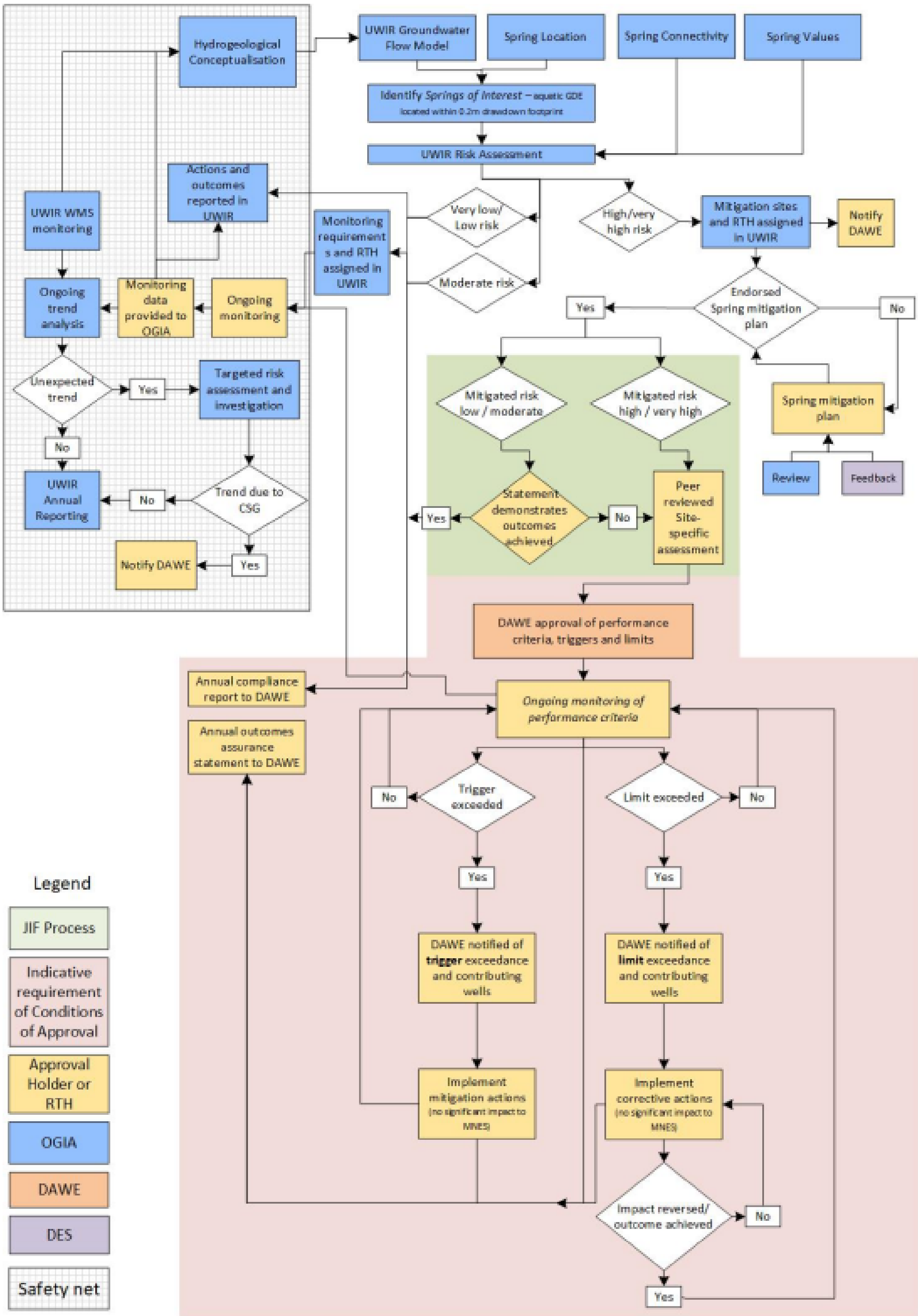


Figure 4.5 JIF Aquatic GDE Framework (DCCEEW 2021)

4.3.4. Validation and Analysis of GDE Baselining Program

The survey data collated from the GDE baseline assessments will be reviewed, validated, and analysed. A summary of the baselining data analysis, to understand and review potential impacts as a result of project development, is provided in the following:

- Collect and review data.
  - Baselining data will be collected / downloaded and reviewed by a qualified ecologist. Data will be reviewed and validated through a visual assessment of the data and any data quality issues will be identified. Missing data, unexpected values or variance from the historical range will be identified.
  - Monitoring results will be checked and QA/QC'd to verify the data by:
    - Reviewing and checking data and field documents to identify transcription errors.
    - Obtaining further field data if necessary to confirm or clarify the results.
- Identify background or external influences / trends.
  - Changes to the BioCondition, or faunal habitat value of the GDEs will be identified and any external influences identified. External influences could include land use and other land pressures due to cattle grazing. Groundwater levels in the underlying aquifers from nearby monitoring bores will be reviewed to identify any drawdown which may have resulted in a change to the condition.
  - Reference to the TGDE sites will be made to identify any similar changes and to identify other regional external influences such as climate.

A report will be produced, detailing the findings/outcomes of the GDE Baselining program. This report will be made available to DCCEEW upon request. Data and outcomes from this report will be used to update future iterations of this WMMP.

4.3.5. Seepage, Spills, and Overtopping

Seepage

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.

The seepage emergency response procedure is triggered through the following:

- The sudden or unexplained decrease in water level in the water storage facilities (identified through monitoring of automatic water level sensor data).
- Monitoring data indicating leakage rates which exceed trigger leakage rates.
- Exceedance of quality trigger values that have been derived for the shallow seepage groundwater monitoring bores as presented in Section 4.3.6.1 and 4.3.7.1.
- Monitoring data indicating unusual water level in leak detection sumps and/or shallow groundwater bores; and
- Surveillance inspection identifies evidence of seepage through the dam embankment or tank wall or foundations (e.g., springs, seeps, or boggy areas).
- Should the emergency response procedure be triggered, the following will occur:
- All inflows to the regulated structure shall be isolated/redirected.
- Reduce Produced Water level in the regulated structure (if practical).
- Undertake Special Inspection (refer to Section 5.5).
- Specify liner system remediation requirements.
- Undertake liner system remediation as required.
- Perform investigation of environmental harm.
- Provide report to relevant local authority on environmental harm, as required; and.
- Close-out emergency trigger response.

Spills

The Contingency Procedures for Emergency Environmental Incidents provides a framework for Senex to:

- Understand the risks of natural events and Senex activities to the integrity of infrastructure and the environment and safety of persons;

- Respond to emergency environmental incidents;
- Communicate with the appropriate parties in the event of emergency environmental incidents;
- Investigate the cause and impacts of emergency environmental incidents that have occurred; and
- Restore the environment or mitigate any environmental harm caused.

The Contingency Procedures for Emergency Environmental Incidents addresses a range of potential events including major spill of hazardous materials, CSG water release, pond failure leading to CGS water release, flooding/extreme weather events. The procedure sets out Senex's Emergency Response Process and response measures. The procedure is underpinned by the Spill Response Plan (SENEX-CORP-ER-PLAN-006) which includes standard protocols that will be utilised by Senex to respond in an appropriate and timely manner in the event of a spill. The procedure details the following steps:

- Prevention – takes actions to reduce or eliminate the likelihood of effects of an incident.
- Preparedness – takes steps before an incident to ensure effective response and recovery.
- Response – contain, control, or minimise the impacts of an incident.
- Recovery – takes steps to minimise disruption and recovery times.

Senex has adopted the 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.

Should a spill occur the Contingency Procedures for Emergency Environmental Incidents and the Spill Response Plan (SENEX-CORP-ER-PLAN-006) will be activated.

Overtopping

The 'significant consequence category dam operation plan' (OPS-QLD-OP-PLN-008), provides an emergency trigger for the imminent or actual regulated structure overtopping (i.e. spillway discharge). This is triggered through the exceedance of the mandatory reporting level (mRL) and the Bureau of Meteorology weather forecasts indicate heavy rainfall, or the regulated structure releasing water through the spillway. Should this occur, the emergency response procedure is triggered (OPS-QLD-OP-PLN-008).

Chemical Risk Assessment Framework

A separate Chemical Risk Assessment Framework (CRAF) report was undertaken to assess the risk of chemicals used in CSG operations (drilling and completion and water treatment) within the Atlas Stage 3 Project area (KCB 2024). Management and mitigation measures for identified risks as identified by the CRAF are reproduced in Table 4-11 .

Table 4-11 Management and Mitigation Measures for Identified Risks (reproduced from CRAF; KCB 2024)

Risk	Key Reference Documents.	Mitigation or Management Measure
Above ground chemical spills and leaks	▪ Environmental Management Plan (SENEX-ATLS-EN-PLN-001); ▪ Spill Response Plan (SENEX-ATLS-EN-PLN-001); ▪ AS 3780:2008 – The storage and handling of corrosive substances; ▪ AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers; and ▪ Senex Hazardous Substances and Dangerous Goods Procedure (SENEX-CORP-HS-PRC-010).	**Transportation of chemicals** ▪ In order to minimise the risk of spillage Senex will ensure that all hazardous materials are transported, stored and handled in accordance with AS1940, Australian Dangerous good Code and Environmental Protection Agency (EPA) guidelines. ▪ Bulk fuel tanks stored outside bunded areas must be contained within a self-bunded (double-skinned) tank with safety valves. ▪ The requirements for managing hazardous substance and dangerous goods at Senex sites are outlined in Senex Hazardous Substances and Dangerous Goods Procedure (SENEX-CORP-HS-PRC-010).
	▪ AS 3780:2008 – The storage and handling of corrosive substances; ▪ AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers; and ▪ Environmental Management Plan (SENEX-ATLS-EN-PLN-001).	**Chemical and fuel storage** ▪ 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 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers. AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers. ▪ Storage areas must be sealed, bunded, 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. ▪ Substances not in use are to be sealed and safely stored in a secure area. ▪ Containment bunds and/or sumps will be drained periodically of accumulated rainwater to prevent overflow and subsequent pollution of the surrounding land and watercourses. ▪ All chemical, oil and fuel storage areas are to be inspected at least monthly for temporary storage, and quarterly for permanent storage areas during the operating phase by the Contractor Site Supervisor and/or the Senex Site Supervisor. ▪ An inventory of all chemicals maintained on each site is to be maintained by the Senex Site Supervisor. ▪ Safety Data Sheets (SDS) are to be maintained on site at all times and for all chemicals. ▪ Minimise inventory volumes stored on site.
	▪ Incident Management Procedure (SENEX-CORP-PLN-006). ▪ Spill Response Plan (SENEX-ATLS-EN-PLN-001). ▪ Environmental Management Plan (SENEX-ATLS-EN-PLN-001).	**Emergency and Incident Support** ▪ 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 Manager as required to determine appropriate remediation options such as the removal of contaminated material. ▪ Incident reports must contain information required by the Senex Environment Manager and any relevant plans and procedures. ▪ 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. ▪ Emergency events will be managed in accordance with the contingency procedures in the Project Atlas Emergency Response Plan. ▪ Personnel who observe an environmental incident including a spill must immediately notify the Contractor Site Supervisor who will then notify the Senex Site Supervisor.
	▪ Environmental Protocol for Field Development and Constraints Analysis (SENEX-ATLS-EN-PRC-019).	**Well Siting** The Environmental Protocol for field development and constraints analysis prevents the siting of any CSG wells in locations which may result in the degradation of an environmental value. Petroleum activities must not occur in or within 200 m of a wetland of high ecological significance or a Great Artesian Basin Spring (DES 2016). This includes watercourse springs identified on the tenement.

Risk	Key Reference Documents.	Mitigation or Management Measure
	▪ Code of practice for Constructing and Abandoning Coal Seam Gas Wells and Associated.	**Well Construction** Standard Operating Procedures will be followed for sumpless drilling and mud mixing during the drilling process. These procedures will include the following: ▪ Sumpless drilling – drilling additives and mud are stored in portable, temporary tanks (no earthen pits); ▪ The use of bunds at surface; ▪ Regular site inspections, monitoring and recording mud returns, monitoring and recording mud volumes in tanks daily; and ▪ Undertaking daily drillers instructions.
	▪ Environmental Management Plan (SENEX-ATLS-EN-PLN-001). ▪ Atlas Stage 3 Water Monitoring and Management Plan (SENEX-ATLS-EN-PLN-017).	**Management of produced water/flow back water** Produced water will generally be collected from the water gathering systems into lined aggregation dam/s. Water for beneficial use, where treatment is not required, will be drawn from the aggregation dams. Where practical, Senex will use untreated CSG produced water to support ongoing development / construction activities such as dust suppression, drilling, construction and hydro-testing. Any untreated produced water used as part of Project activities will be undertaken in accordance with the End of Waste Codes (ENEW07546918 and ENEW07547018) produced water with moderately low salinities (<4 dS/m) will generally be processed by calcium addition and pH amendment only, however for higher salinities treatment by reverse osmosis (RO) or blending with available fresh water will be undertaken as required. Where suitable, water use options to be considered include stock watering and irrigation. Produced water may be used for dust suppression and construction purposes provided the use: ▪ Does not result in negative impacts on the composition and structure of soil or subsoils; ▪ Is not directly or indirectly released to waters; ▪ Does not result in runoff from the construction site; and ▪ Does not harm vegetation surrounding the construction site. Produced water may be disposed of for domestic purposes or stock purposes and must meet the irrigation or livestock watering criteria as relevant to those purposes in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018 revision; online resource). It must be disposed of in accordance with the BUAs where approved by Senex Site Supervisor having consulted with the Senex Environment Manager. All dams must be constructed, operated and maintained n accordance with accepted engineering standards; and be lined within impermeable geomembranes that will contain the wetting front and any entrained contaminants within the bounds of the containment system during both its operational life and including any period of decommissioning. Dams will be subject to a separate risk assessment. ▪ Visual inspection of areas where produced water is used will be undertaken during and post-application daily to ensure conditions are being met. ▪ Monitoring and inspections including of water levels, water quality and early signs of loss of structural or hydraulic integrity will be undertaken by a suitably qualified and experienced person to ensure conditions are being met. ▪ Dams and regulated structures must be monitored for early signs of loss of structural or hydraulic integrity as specified in the initial hazard assessment. ▪ Monitoring and reporting of groundwater to be undertaken as per the Atlas Stage 3 Water Monitoring and Management Plan [SENEX-ATLS-EN-PLN-017].
CSG production well construction / design / drilling / integrity results in contamination of aquifers	▪ Code of Practice for Constructing and Abandoning CSG Wells and Associated Bores in Queensland (DNRME 2019). ▪ Operations Geologist Standard Operating Procedure (OPS-QLDS-SB-PRC-001). ▪ CSG Basis of Well Design (SENEX-QLDS-DR-BOD-001).	**Well Construction** CSG production wells will be designed, constructed and decommissioned in accordance with the “Code of Practice for the construction and abandonment of coal seam gas and petroleum wells and associated bores in Queensland (DNRME 2019)”. 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 unlawful environmental harm.
	▪ Environmental Protocol for field development and constraints analysis (SENEX-ATLS-EN-PRC-019).	**Prevention of drilling fluid losses** Selecting the correct drilling additives based on the drilling conditions and formation to prevent excessive fluid losses in the well. Reference to the geological conditions encountered during the drilling of other nearby bores.

Risk	Key Reference Documents.	Mitigation or Management Measure
	▪ Environmental Protocol for Field Development and Constraints Analysis (SENEX-ATLS-EN-PRC-019).	**Well Siting** Sites for CSG production wells will be selected based on a good understanding of the local conditions and geology to prevent any potential for connections of target coal seam gas reservoirs and aquifers (i.e. avoiding the presence of known faults). Petroleum activities must not occur in or within 200 m of a wetland of high ecological significance or a Great Artesian Basin Spring (DES 2016). This includes watercourse springs identified on the tenement.
Inappropriate reuse / disposal of drill cuttings, additives and flowback water	▪ EA. ▪ Environmental Protection Act 1994 (State of Queensland 2022d). ▪ the Waste Reduction and Recycling Act 2011 (WRR Act)(State of Queensland 2021e); and ▪ Characterisation of Management of Drilling Fluids and Cuttings in the Petroleum Industry (DES 2019).	**Appropriate disposal of drilling additives** Waste solids will be disposed of to landfill. Drilling additives to be recycled where practicable. Disposed of on site by mix-bury-cover method if the residual drilling material meets the approved quality criteria as per EA requirements. Disposed of on site by land application following assessment and certification (by a suitably qualified third-party) that the quality and proposed application methods will not result in environmental harm. Records must be kept to demonstrate compliance with Condition Waste 15 and Waste 16 of the EA. The Department of Environment and Science (DES) regulates the management and disposal of wastes in Queensland under the provisions of the Environmental Protection Act 1994 (State of Queensland 2022d), the Waste Reduction and Recycling Act 2011 (WRR Act)(State of Queensland 2021e) and subordinate legislation. Further information on these regulations and management of drilling waste materials is provided in the Characterisation of Management of Drilling Fluids and Cuttings in the Petroleum Industry (DES 2019). Where onsite management options are proposed, state approvals require that the quality of material meet approved quality criteria and / or are assessed and certified by a suitably qualified third-party as being suitable for the application to land. If these options are to be used, Senex will undertake the appropriate assessments and develop management plans as per the requirements of the relevant state approvals. All waste generated in construction, operations and decommissioning must be stored, handled and transported in accordance with the waste and resource management hierarchy, waste and resource management principles, appropriate standards and regulatory requirements as outlined in the Senex Waste Management Procedure – Qld Operations [SENEX-QLDS-EN-PRC-022]. Only licensed waste contractors may collect, transport and dispose of regulated waste from the site.

4.3.6. 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.

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 adopted approach considers the site-specific conditions and is targeted towards understanding trends, that provides the Project with appropriate triggers to initiate additional monitoring, investigation, and actions, as well as providing a suitable level of protection for potential receptors. An overview of trigger values for seepage bores and of the proposed approach towards development of triggers for Senex Monitoring Bores are discussed below.

4.3.6.1. Groundwater Quality Triggers– Seepage Monitoring

Senex commissioned StreamlineHYDRO to develop trigger values for Seepage Monitoring Bores in 2023 (StreamlineHYDRO 2023). The trigger derivation report which includes the methodology and details of trigger development is included as Appendix A of this report. The site-specific and default water quality guidelines relevant to the water quality data at the Atlas Dam site are included in Appendix 2 of Appendix A and formed the basis for deriving trigger values against which water quality results can be compared to identify potential issues.

The seepage monitoring network, installed in the Westbourne Formation, consists of six existing shallow monitoring bores, four deep monitoring bores with one deemed to be a background bore and the nearest downstream landholders bore.

StreamlineHYDRO indicate that the compliance monitoring bores have been constructed to be fit for purpose, downgradient of potential sources and of a depth to monitor the appropriate hydrostratigraphic unit and flow pathways. The ongoing monitoring of these bores in conjunction with the monitoring of the leakage collection sumps and seepage monitoring inspections pursuant to the Atlas Project – Operation Management Plan for Regulated Structures (OPS-QLD-OP-PLN-008) will enable the detection of emerging issues on the site. These trigger levels are considered interim values given the limited number of sample points available and will be reviewed when more data has been collected.

A summary of site-specific groundwater quality trigger values for Seepage Monitoring Bores is represented in Table 4-12. The water quality guideline or objective has been adopted in instances where the site-specific 80th percentile value is not substantially different from default water quality guidelines, or if site-specific values cannot be determined due to insufficient data (as recommended by the Guideline). Where toxicant default guideline (ANZG, 2018) have been adopted, it is applied as a Value B not Value A.

Table 4-12 Site-specific Groundwater Quality Limits for Seepage Indicators at Specified Atlas Dam Monitoring Bores (StreamlineHYDRO 2023)

Indicator	Value type	Value A 80th Percentile	Value B 95th Percentile	Comment
pH – Atlas 1M, 2M, 3M-R	Range	7.70 –8.10	7.44 – 9.15	Site-specific 80th and 95th percentiles for bores.
pH – Atlas 4M, 9M	Range	7.07 – 7.39	6.93 – 7.56	Site-specific 80th and 95th percentiles for bores.
pH – Atlas 5M	Range	6.57 – 6.77	6.53 – 6.86	Site-specific 80th and 95th percentiles for bores.
Electrical Conductivity (µS/cm) –	Max	9,975	11,665	Site-specific 80th and 95th percentiles for Atlas 1M.

Indicator	Value type	Value A 80th Percentile	Value B 95th Percentile	Comment
Atlas 1M				
Electrical Conductivity (μS/cm) – Atlas 2M	Max	8,550	9,852	Site-specific 80th and 95th percentiles for Atlas 2M.
Electrical Conductivity (μS/cm) – Atlas 3M-R	Max	14,961	15,808	Site-specific 80th and 95th percentiles for Atlas 3M-R.
Electrical Conductivity (μS/cm) – Atlas 4M	Max	14,300	17,324	Site-specific 80th and 95th percentiles for Atlas 4M.
Electrical Conductivity (μS/cm) – Atlas 5M	Max	7,800	9,809	Site-specific 80th and 95th percentiles for Atlas 5M.
Electrical Conductivity (μS/cm) – Atlas 9M	Max	8,300	9,702	Site-specific 80th and 95th percentiles for Atlas 9M.
Sodium Adsorption Ratio – Atlas 1M, 2M, 3M-R	Max	77.96	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Sodium Adsorption Ratio – Atlas 4M, 5M, 9M	Max	61.89	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Fluoride (mg/L) – Atlas 1M, 2M, 3M-R, 4M	Max	1.195	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Fluoride (mg/L) – Atlas 5M, 9M	Max	0.769	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Boron – Total (mg/L) – Atlas 1M, 2M, 3M-R, 4M, 5M, 9M	Max	-	0.94	Site-specific values are less than the toxicant default guideline value (DGV).

4.3.6.2. Groundwater Quality Investigation Triggers– Senex Monitoring

As discussed in Section 4.1.1, a groundwater monitoring network has been established in the vicinity of predicted impact areas to monitor hydrostratigraphic units of interest. Monitoring commenced in December 2022. According to the Queensland Guideline sufficient spatially representative, good quality monitoring data at an adequate statistical distribution is required to calculate a 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.

Details pertaining to the proposed methodology and approach associated with trigger development for the Senex bores are included in Appendix B with extracts provided in this section.

Preliminary Indicator Parameters

Preliminary primary indicator parameters indicative of stored produced water, intra-formational flow, auxiliary infrastructure, and material handling and storage (including the use of drilling fluids) have been selected for Atlas Stage 3 as summarised in Table 4-14. Further information pertaining to the selection of indicator parameters are provided in Appendix B.

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. Parameters selected as representative indicators for identified drilling chemical groups are shown in Table 4-13.

Table 4-13 Selected Indicators Associated with Drilling Additives / Chemicals

Drilling Additive Group	Indicator Parameter Selected
Suspended Matter	None Not expected to be mobile in the groundwater environment
Salts and Ions	Total Dissolved Solids (TDS) Indicator of sulfate, calcium, chloride, sodium, phosphate, nitrate, ammonium, carbonate etc.
Organic Compounds	Total Organic Carbon A measure of the total amount of organic compounds present in a sample and would reflect impact from petroleum hydrocarbons, sugar solutions, carbon-based drilling fluids, etc.
Acid / Bases	pH pH would be affected by release of strong acids and bases

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 (refer to Section 4.3.7.2). Indicator parameters will be reviewed annually for representativity during the first two years of monitoring and updated as required by monitoring and investigation results.

Table 4-14 Preliminary Indicator Parameters for Groundwater Quality

Indicator	Parameter	Rationale	Potential Source
Primary (Trigger Levels)	pH	Standard measure for comparison to normal and acidic conditions.	Stored produced water / intra-formational flow
	Total dissolved solids (TDS)	Indicator of dissolved salts; variance may indicate a change in one of the major ions.	Stored produced water / intra-formational flow. Drilling additives.
	Chloride	Indicator of change in water quality.	Stored produced water / intra-formational flow
	Sodium	Indicator of change in water quality.	Stored produced water / intra-formational flow
	Total organic carbon (TOC)	Potential indicator of contamination associated with operational infrastructure including drilling fluid. TOC is a measure of the total amount of organic compounds present in a sample and would reflect impact from petroleum hydrocarbons, carbon-based drilling additives, etc.	Auxiliary infrastructure, drilling fluid, material / chemical handling and storage
Secondary (Trend Review)	Dissolved ions: calcium, magnesium, potassium, fluoride	Parameters to be reviewed in the event of trends occurring in the primary indicators to provide more information about the trends.	-
	Anions: nitrate / nitrite, ammonium, phosphate, fluoride, sulfate		
	Dissolved oxygen and ORP		
	Carbonate, and total alkalinity		
	Total suspended solids		
	Total petroleum hydrocarbons (C6-9, C10-C36)		
	Dissolved Metals: Aluminium, Silver, Arsenic, Boron, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Gallium, Mercury, Lithium, Molybdenum, Manganese, Nickel, Lead, Antimony, Selenium, Strontium, Uranium, Vanadium, Zinc		

Water Quality Investigation Triggers

Groundwater abstraction for stock and domestic use is the dominant water use purpose in the immediate vicinity of the Project, with intensive stock use also indicated. Bore baseline assessment indicate that most bores in use are attributed to the Gubberamunda Sandstone with one indicated to be present within the

Orallo Formation. Registered bores in the immediate vicinity of the Project are also indicated to be attributed to alluvium, the Westbourne Formation and the upper Springbok Sandstone. Groundwater contribution to surface water is not anticipated in the Project area.

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 (Section 1.2.4). Since site-specific trigger values cannot be calculated due to lack of data, it is recommended that monitoring 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). The proposed trigger includes 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 investigation triggers for pH based on default guideline values are presented in Table 4-15.

Table 4-15 Water Quality Investigation Trigger Value for pH

Parameter	Value A	Value B	Rationale
pH	<6.5 or >8.5	-	Value A is in line with the WQOs

4.3.6.3. Groundwater Level Investigation 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 bores to facilitate targeted impact monitoring and management. The groundwater level trigger strategy comprises two tiers as discussed in this section. The tiered trigger strategy system is adopted from APLNG 2012.

- Tier 1: Value A and B are based on the modelled maximum predicted drawdown at individual bore locations as summarised in Table 4-16. Value A is intended to provide an early warning and will trigger increased monitoring and observation of potential drawdown impacts when water levels drop to within 2 m of the maximum predicted drawdown. Value B (only) will apply in instances where the maximum predicted drawdown is less than 2 metres. 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 populate Table 4-16.)
- Tier 2: A second early warning trigger relates to hydrograph trend analyses and comparison of model predicted hydrographs to actual monitoring data per bore (refer to Section 4.3.7.3 for example charts). When Value A is triggered (or decreasing trends are identified for bores where Value A is not relevant), additional control chart assessment would be initiated / required as presented in the TARP (Section 4.3.7).

Table 4-16 Groundwater Level Investigation Trigger Levels

RN	Senex Bore ID	Bore Type	Formation	Location	Max. predicted drawdown	Value A - Monitoring Trigger (mAHD)	Value B – Reporting Trigger (mAHD)
180128	Atlas 13M-D	Senex Monitoring	Westbourne Formation	ATP 2059	0	-	TBC; maximum predicted drawdown
180127	Atlas 13M-S	Senex Monitoring	Alluvium		0.08	-	Dry bore – no trigger
TBC	Atlas 14M-D	Senex Monitoring	Springbok Sandstone		4.57	TBC; within 2m of model predictions	TBC; maximum predicted drawdown
TBC	Atlas 14M-S	Senex Monitoring	Alluvium		0.08	-	Dry bore – no trigger
TBC	Atlas 15M-D	Senex Monitoring	Westbourne or Gubberamunda	PL 209	0.00/0.01	-	TBC; maximum predicted drawdown
TBC	Atlas 15M-Sw	Senex Monitoring	Alluvium		0.09	-	TBC; maximum predicted drawdown
TBC	Atlas 19M-D	Senex Monitoring	Springbok Sandstone	PL 445	4.57	TBC; within 2m of model predictions	TBC; maximum predicted drawdown
TBC	Atlas 19M-S	Senex Monitoring	Alluvium		0.08	-	Dry bore – no trigger
New	New	Senex Monitoring	TBC	Wandoan Creek	TBC	TBC; within 2m of model predictions	TBC; maximum predicted drawdown
New	New	Senex Monitoring	TBC	Wandoan Creek	TBC	TBC; within 2m of model predictions	TBC; maximum predicted drawdown

TBC – To be confirmed. Maximum Predicted Drawdown to be extracted from the model results.

4.3.7. Trigger Action Response Plans - Groundwater Quality and Drawdown

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. This section details the actions that should follow the exceedance of a trigger value / identification of persistent trends. The methodology and framework utilised during the development of the Trigger Action Response Plans (TARPs) are included in Appendix B.

4.3.7.1. 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 as described in Section 4.3.5.

4.3.7.2. Groundwater Quality TARP

Senex will review the groundwater quality in monitoring bores for increasing trends on a biannual 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 4.6 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 4-17. 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.

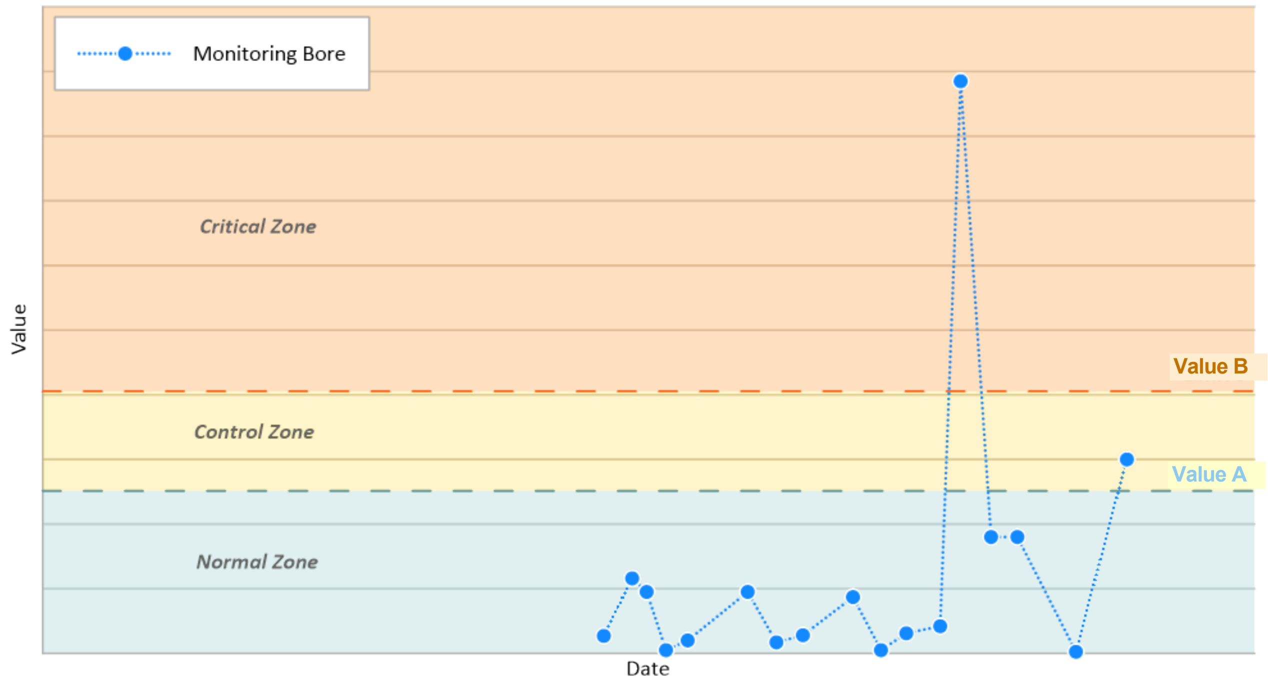


Figure 4.6 Example Control Chart

Table 4-17 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. ▪ Assess bore suitably and identify potential external influences.	▪ 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 other possible sources other than Project activities.	▪ 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%)
		▪ 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.	▪ 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 a 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.

4.3.7.3. Groundwater Level TARP

Senex will review groundwater levels and trends of monitoring bores in conjunction with the water quality trigger level review.

As discussed in Section 4.3.6.2, trigger levels for groundwater levels are based on the numerical model predictions by OGIA as listed in Table 4-16. To avoid false triggering, Value triggers for groundwater levels are defined to occur when average values dip below the groundwater trigger for three or more consecutive months.

Tier 1 Assessment

An example control chart is presented in Figure 4.7 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 (Table 4-18). 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. The TARP for exceedance of groundwater level triggers is provided in Table 4-18.

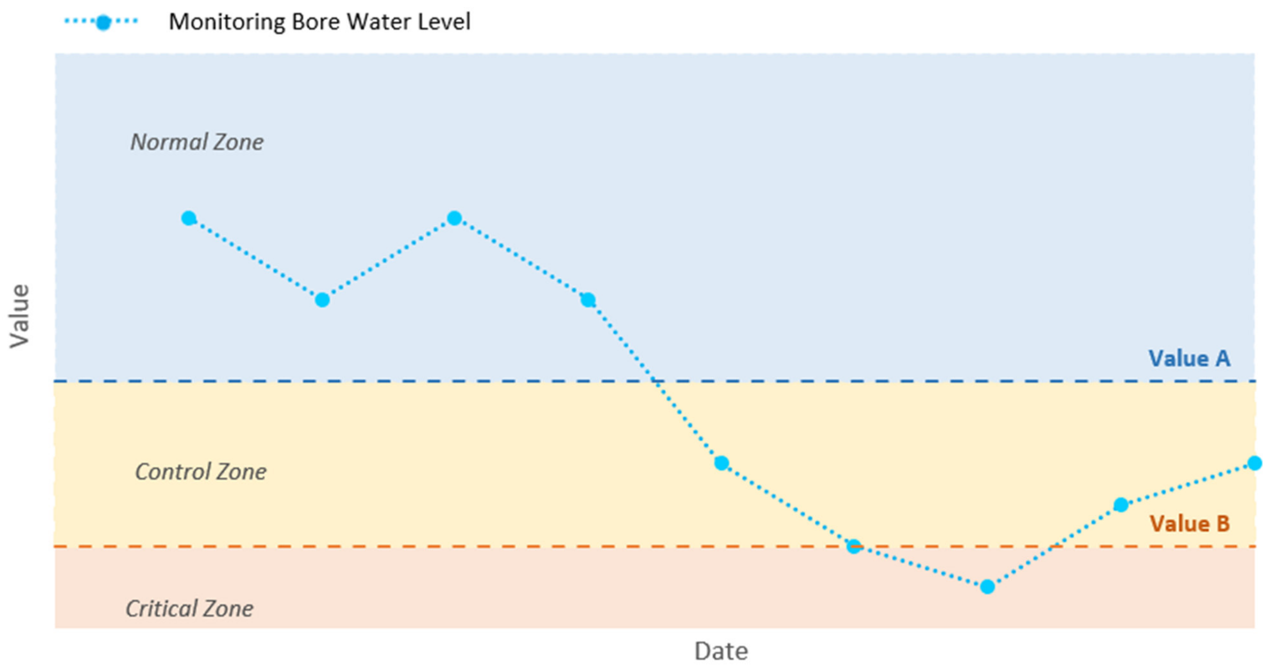


Figure 4.7 Tier 1 Example Control Chart

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.

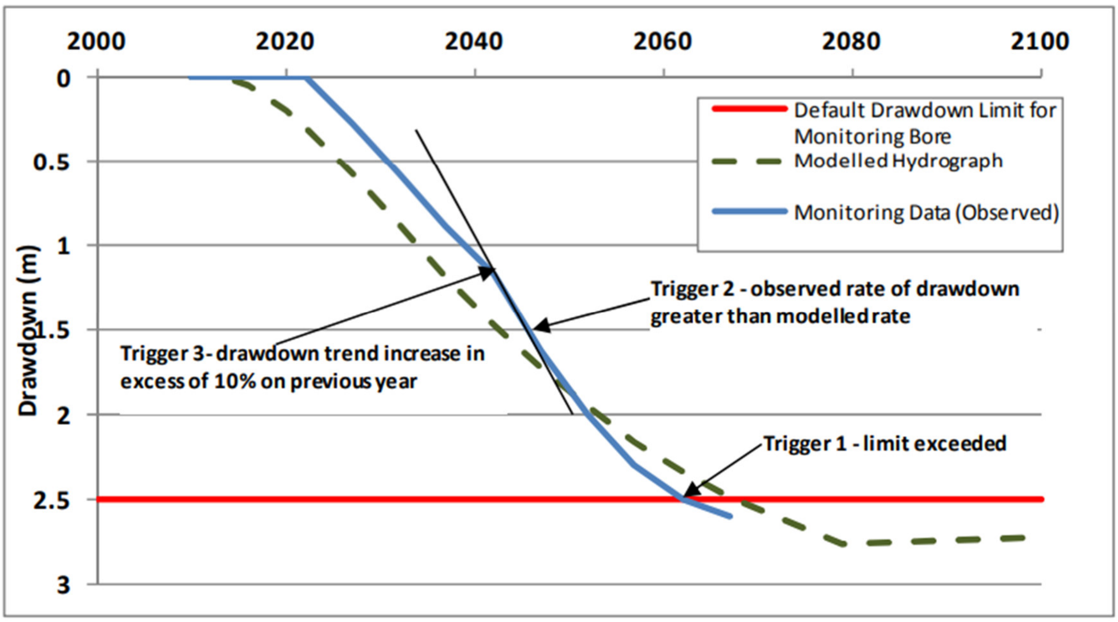


Figure 4.8 Schematic of Monitoring Trend Triggers to Initiate Follow-Up Response

1 *Table 4-18* *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.

4.3.8. Plan Review and Reporting

This Water Monitoring and Management Plan will be reviewed and updated after the first two years of operation, when new relevant information becomes available or as required.

The performance of the groundwater monitoring program will also be reviewed periodically throughout the Project life and any required amendments to the monitoring plan undertaken in consultation with the appropriate regulatory authorities and stakeholders. The annual groundwater report will provide commentary on the performance of the program and discuss/identify where updates may be required. The monitoring plan may also be revised based on:

- The findings of trigger investigation reports;
- The introduction of additional mitigation measures or controls;
- Changing environmental requirements;
- Changes in legislation; and
- Changes to the OGIA model predictions.

Senex will undertake all reporting as per the requirements under the State and Federal legislation, including to:

- OGIA as part of the UWIR requirements and in accordance with the Project's EA conditions.
- DCCEEW as part of the JIF annual compliance requirements.

5. References

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

ANZG. 2018. “Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian State and Territory Governments, Canberra ACT, Australia. Available at Www.Waterquality.Gov.Au/Anz-Guidelines.”

APLNG. 2012. “Australia Pacific LNG Upstream Phase 1 Groundwater Monitoring Plan Q-LNG01-10-MP-0005.”

Boobook. 2022. “Broadscale Ecological Assessment Report Senex Atlas 3 Gasfield Project - Survey of Terrestrial Ecological Values.”

CDM Smith. 2022. “Northern Development Area - GDE Management Plan. QGC. February 2022.”

Coffey. 2018. “SGP Stage 1 CSG WMMP: Subsidence Technical Memorandum Accessed from Https://Www.Arrowenergy.Com.Au/__data/Assets/Pdf_file/0006/30003/Appendix-K-Subsidence-Technical-Memorandum.Pdf, February 2023. Coffey Environments Australia Pty Ltd.”

Commonwealth of Australia. 2014. “Monitoring and Management of Subsidence Induced by Coal Seam Gas Extraction, Knowledge Report, Prepared by Coffey Geotechnics for the Department of the Environment, Commonwealth of Australia, Canberra.”

———. 2016. “Environment Protection and Biodiversity Conservation Act 1999.” 1999.

———. 2022. “Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Last Amended July 2022. Compilation Number 59.”

———. 2023. “Draft National Minimum Groundwater Monitoring Guidelines.”

DCCEEW. 2021. “Coal Seam Gas - Joint Industry Framework, Managing Impacts to Groundwater Resources in the Surat Cumulative Management Area under EPBC Act Approvals. March 2021. Department of Agriculture, Water and the Environment.”

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

———. 2013. “Queensland Water Quality Guidelines 2009.” State of Queensland, Department of Environment and Heritage Protection.

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

———. 2018a. “Monitoring and Sampling Manual: Environmental Protection (Water) Policy 2009.” Guideline. Queensland: Department of Environment and Science, Queensland Government.

———. 2018b. “Queensland Groundwater Dependent Ecosystems and Potential GDE Aquifer Mapping, Version 1.5.” State of Queensland, Department of Environment and Science. https://wetlandinfo.ehp.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/.

———. 2019. *Department of Environment and Science: Characterisation and Management of Drilling Fluids and Cuttings in the Petroleum Industry*. https://environment.des.qld.gov.au/__data/assets/pdf_file/0022/90580/rs-is-characterisation-management-drilling-fluids-petroleum.pdf.

———. 2022a. “Baseline Assessments: Guideline. Version 3.04, Effective July 2022.” ESR/2016/1999. State of Queensland, Department of Environment and Heritage Protection.

———. 2022b. “Bore Assessments: Guideline. July 2022.” ESR/2016/2005 Version 5.05. State of Queensland, Department of Environment and Heritage Protection.

DNRM. 2001. “Queensland Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual, August 2001, Queensland Department of Natural Resources and Mines, Rocklea.”

DNRME. 2019. “Code of Practice for the Construction and Abandonment of Petroleum Wells, and Associated Bores in Queensland - Version 2.” State of Queensland, Department of Natural Resources, Mines and Energy. https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0006/1461093/code-of-practice-petroleum-wells-bores.pdf.

DSITI. 2015. “Guideline for the Environmental Assessment of Subterranean Aquatic Fauna.”

Dumas and Fontanini. 2001. “Sampling Faunas in Aquifers: A Comparison of Net-Sampling and Pump-Sampling. Archiv Für Hydrobiologie 150(4): 661–676.”

ERM. 2022. “Atlas Stage 3 Gas Project Terrestrial and Aquatic Ecology Assessment Report. Report to Senex Energy Pty Ltd by Environmental Resources Management Australia Pty Ltd Level 15 309 Kent Street. Sydney NSW 2000. October, 2022.”

Eyre, Kelly, Neldner, Wilson, Ferguson, Laidlaw, and Franks. 2015. “BioCondition: A Condition Assessment Framework for Terrestrial Biodiversity in Queensland. Assessment Manual. Version 2.2. Department of Environment and Resource Management, Brisbane.”

Green, PM. 1997. “The Surat and Bowen Basins, South-East Queensland.” Queensland Department of Mines and Energy.

Hancock and Boulton. 2008. “Stygofauna Biodiversity and Endemism in Four Alluvial Aquifers in Eastern Australia. Invertebrate Systematics 22: 117-126.”

IESC. 2014. “Subsidence in Coal Seam Gas Extraction; Fact Sheet.”

KCB. 2018. “Project Atlas - EA Amendment, Water Resources Assessment Report.”

———. 2023a. “Atlas Stage 3: Chemical Risk Assessment for Drilling Fluids.”

———. 2023b. “Atlas Stage 3 EPBC Water Report. DCCEEW Update. November 2023.”

———. 2024. “Chemical Risk Assessment Framework - Atlas Stage 3.”

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

———. 2021. “Australian Drinking Water Guidelines (2011).” National Health and Medical Research Council. https://www.nhmrc.gov.au/guidelines-publications/eh52.

NUDLC. 2020. “Minimum Construction Requirements for Water Bores in Australia, Forth Edition.” ISBN 978-0-646-56917-8. National Uniform Drillers Licensing Committee.

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

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

———. 2017. “Identification of Gaining Streams in the Surat Cumulative Management Area; Hydrogeological Investigation Report.” State of Queensland, The Office of Groundwater Impact Assessment, Department of Natural Resources and Mines.

———. 2019. “Underground Water Impact Report for the Surat Cumulative Management Area, July 2019.”

———. 2021a. “Details of the Water Monitoring Strategy for the Underground Water Impact Report 2021.”

———. 2021b. “Existing and Proposed Coal Mining in the Surat Basin. A Snapshot Supporting the Surat Underground Water Impact Report 2021. November 2021.”

———. 2021c. “Status of Coal Seam Gas and Conventional Petroleum and Gas Development in the Surat Cumulative Management Area. A Snapshot Supporting the Surat Underground Water Impact Report 2021.”

———. 2021d. “Surat CMA and Its Groundwater Systems.”

———. 2021e. “Underground Water Impact Report 2021 for the Surat Cumulative Management Area. OGIA, Brisbane.”

———. 2021f. “Underground Water Impact Report for the Surat Cumulative Management Area’.” Brisbane, Queensland: The Office of Groundwater Impact Assessment,.

———. 2022. “OGIA Aquifer Attribution 2022. Provided June 2022.”

Queensland Herbarium. 2021. “BioCondition Benchmarks (Version 3.4).”

QWC. 2012. “Underground Water Impact Report for the Surat Cumulative Management Area.” State of Queensland, Coal Seam Gas Water, Queensland Water Commission.

RDMW. 2022. “Groundwater Monitoring Network Review Methodology Guideline. Department of Regional Development, Manufacturing and Water.”

Richardson, E, E Irvine, R Froend, P Book, S Barber, and B Bonneville. 2011. “Australian Groundwater Dependent Ecosystems Toolbox Part 2: Assessment Tools.” Canberra: National Water Commission.

Robertson. 2005. “Measurement and Modelling of Sorption-Induced Strain Data. PhD Dissertation, Colorado School of Mines.”

Sainty and Jacobs. 2003. “Waterplants In Australia: A Field Guide. Sainty and Associates.”

Sanderson. 2012. “Rock Behaviour. Chapter 18 of ICE Manual of Geotechnical Engineering.”

Senex. 2022. “Baseline Assessment Plan Atlas Stage-3 Gas Project (PL 209, PL 445 and ATP 2059), SENEX-ATLS-GW-GSU-002, July 2022.”

———. 2023. “Atlas Project - Operation Management Plan for Regulated Structures, OPS-QLDS-OP-PLN-008.”

State of Queensland. 2011. “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.” Environmental Protection (Water) Policy 2009. Queensland: Department of Environment and Science (DES); Previously Department of Environment and Heritage Protection (DEHP).

———. 2013. “WQ1308 - Upper Dawson River Sub-Basin - Part of Basin 130.” Central Queensland Map Series. Queensland: Department of Environment and Heritage Protection.

———. 2017. “Minimum Standards for the Construction and Reconditioning of Water Bores That Intersect the Sediments of Artesian Basins in Queensland.” State of Queensland, Department of Natural Resources and Mines.

———. 2018. “Queensland Groundwater Dependent Ecosystems and Potential GDE Aquifer Mapping, Version 1.5.1.” State of Queensland, Department of Science, Information Technology and Innovation. https://data.qld.gov.au/dataset/queensland-groundwater-dependent-ecosystems-and-potential-gde-aquifer-mapping/.

———. 2019a. “Code of Practice for Construction and Abandonment of Petroleum Wells and Associated Bores in Queensland.” State of Queensland, Department of Natural Resources and Mines.

———. 2019b. “Environmental Protection (Water and Wetland Biodiversity) Policy 2019. Subordinate Legislation 2019 No. 156. Made under the Environmental Protection Act 1994. Commences from 1 September 2019.”

———. 2020a. “Environmental Protection (Water and Wetland Biodiversity) Policy 2019 Maranoa-Balonne Rivers Basin Environmental Values and Water Quality Objectives Part of Basin 422, Including All Surface Waters of the Maranoa and Balonne Rivers Basin.” https://environment.des.qld.gov.au/__data/assets/pdf_file/0018/214227/Maranoa-Balonne-Rivers-Basin.pdf.

———. 2020b. “Petroleum and Gas (Production and Safety) Act 2004.” Queensland: Queensland Government.

———. 2020c. “Queensland Murray-Darling and Bulloo River Basins. Groundwater Environmental Values and Water Quality Objectives. All Groundwaters of the Queensland Murray-Darling and Bulloo River Basins.”

———. 2021a. “Stream Order Drainage. Queensland Globe, Assessed April 2021.”

———. 2021b. “Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts V2.”

———. 2021c. *Water Act 2000*.

———. 2021d. “Baseline Assessments: Guideline, Version 3.03.” ESR/2016/1999. Department of Environment and Science.

———. 2021e. *Waste Reduction and Recycling Act 2011*. https://www.legislation.qld.gov.au/view/html/inforce/current/act-2011-031.

———. 2022a. “Environmental Protection Act 1994.” Queensland: Queensland Government.

———. 2022b. “Queensland Government Water Monitoring Information Portal (WMIP). Supports the Water Assessment and Management Activities of the Department of Regional Development, Manufacturing and Water (RDMW).”

———. 2022c. “Queensland Registered Bore Database.”

———. 2022d. *Environmental Protection Act 1994*. https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-1994-062.

StreamlineHYDRO. 2023. “Atlas Dam Project - Seepage Monitoring Program 2020-2023.”

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

WA EPA. 2003. “Guidance for the Assessment of Environmental Factors (in Accordance with the Environmental Protection Act 1986). Sampling of Subterranean Fauna in Groundwater and Caves. Guidance Statement 54. Environmental Protection Authority, Western Australia.”

———. 2007. “Guidance for the Assessment of Environmental Factors (in Accordance with the Environmental Protection Act 1986). Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia. Guidance Statement 54a: Technical Appendix for Guidance Statement 54. Environmental Protection Authority, Western Australia.”

Appendix A
Seepage Monitoring Program 2020-2023

ATLAS DAM PROJECT

Seepage Monitoring Program 2020-2023

Commissioned by

Senex Energy

Document No. 2023095001-LTR-001
25 July 2023

Streamline Hydro Pty Limited

PO Box 77
Cleveland, QLD 4163
Australia

+61 7 3245 7050
info@streamlinehydro.com.au
ABN 77 121 102 725

Document Information

Project Name	Atlas Dam Project
Client Name	Senex Energy
Document Title	Seepage Monitoring Review 2020-2023
Document Number	2023095001-RPT-001
Document Date	25 July 2023
Prepared by	Rachael Johnson
Reviewed by	Roderick Bain
Approved by	Roderick Bain

Revision History

Rev	Document Number	Description	Issued to	Date Issued	Method of Issue
A	2023095001-RPT-001	Draft	Internal Review	-	-
B	2023095001-RPT-001	Draft	Internal Review	-	-
C	2023095001-RPT-001	Draft	L Gossmann	27/04/2023	Email
D	2023095001-RPT-001	Final draft	L Gossmann	29/05/2023	Email
0	2023095001-RPT-001	Final	L Gossmann	25/07/2023	Email

Contents

Appendices

Definitions and Acronyms

Definitions of terms, acronyms and chemical symbols contained in this report are provided below.

Definition of terms used in this report

Term	Definition
Analyte	A chemical parameter determined by either physical measurement at the bore head, or by laboratory analysis.
Aquifer	Aquifer has the meaning in Schedule 4 of the *Water Act* and means a geological structure, formation or formations that holds water in sufficient quantity to provide a source of water that can be tapped by a bore.
Drawdown	Drawdown means a lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by extraction of underground water from wells.
Produced water	Groundwater incidentally brought to the surface when coal seam gas (CSG) is extracted.
Water level	Water level of an aquifer has the meaning in section 362 of the *Water Act* and means: • if the aquifer were tapped by a sub-artesian bore - the level of the water in the bore.

Acronyms used in this report

Acronym	Term
AHD	Australian Height Datum
ANZG	Australian and New Zealand Guidelines
bGL	Below ground level
bREF	Below a specified reference point
CFU	Colony-forming unit
CMA	Cumulative Management Area
CSG	Coal seam gas
DEHP	Department of Environment, Heritage and Planning (former)
DES	Department of Environment & Science
EA	Environmental Authority
GL	Ground level
IESC	Independent Expert Scientific Committee
km	Kilometres
L/minute	Litres per minute
m	Metres
mg/L	Milligrams per litre

Acronym	Term
m/day	Metres per day
mm/year	Millimetres per year
NHMRC	National Health and Medical Research Council
NRMMC	National Resource Management Ministerial Council
OGIA	Office of Groundwater Impact Assessment
PL	Petroleum lease
RL	Relative level
RN	Registered number
SAR	Sodium adsorption ratio
SS	Suspended solids
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
UWIR	Under Ground Water Impact Report
WTP	Water treatment plant

Chemical symbols used in this report

Symbol	Term	Symbol	Term
Ag	Silver	HCO_3	Bicarbonate
Al	Aluminium	K	Potassium
As	Arsenic	Li	Lithium
B	Boron	Mg	Magnesium
Ba	Barium	Mn	Manganese
Be	Beryllium	Mo	Molybdenum
Ca	Calcium	Na	Sodium
Cd	Cadmium	Ni	Nickel
Cl	Chloride	Pb	Lead
Co	Cobalt	Sb	Antimony
CO_3	Carbonate	Se	Selenium
Cr	Chromium	SO_4^{2-}	Sulphate
Cu	Copper	Sr	Strontium
F	Fluoride	U	Uranium
Fe	Iron	V	Vanadium
Ga	Gallium	Zn	Zinc
Hg	Mercury		

1 Introduction

Senex Energy Limited (Senex) is the operator of the coal seam gas (CSG) petroleum lease PL 1037 located 20 km south-west of Wandoan in Queensland's Surat Basin as shown in **Figure 1.1**. In conjunction with its CSG operations at Atlas, Senex has established water storage infrastructure to manage the produced water extracted from the CSG wells and the brine from the onsite water treatment plant (WTP) at the Atlas Dam site on Lot 28 FT672 located on Sundown Road, Woleebee.

The Atlas Dam site currently consists of two dams and two brine tanks with a further two brine tanks proposed to be installed in 2023. The Atlas Dam site is located within the Woleebee Creek catchment, a tributary of the Dawson River Sub-basin which is in turn part of the larger Fitzroy Basin (DEHP, 2011a).

This document has been prepared to review the existing Seepage Monitoring Program and data collected between June 2020 and March 2023 to assess the effectiveness of the program and provide an updated Seepage Monitoring Plan to meet the requirements of Environmental Authority (EA) 0001207 for the Atlas Project effective 26 May 2020. This review has been conducted with regard to the environmental values and water quality objectives defined for the Dawson River Sub-basin by the Queensland government (DEHP, 2011a).

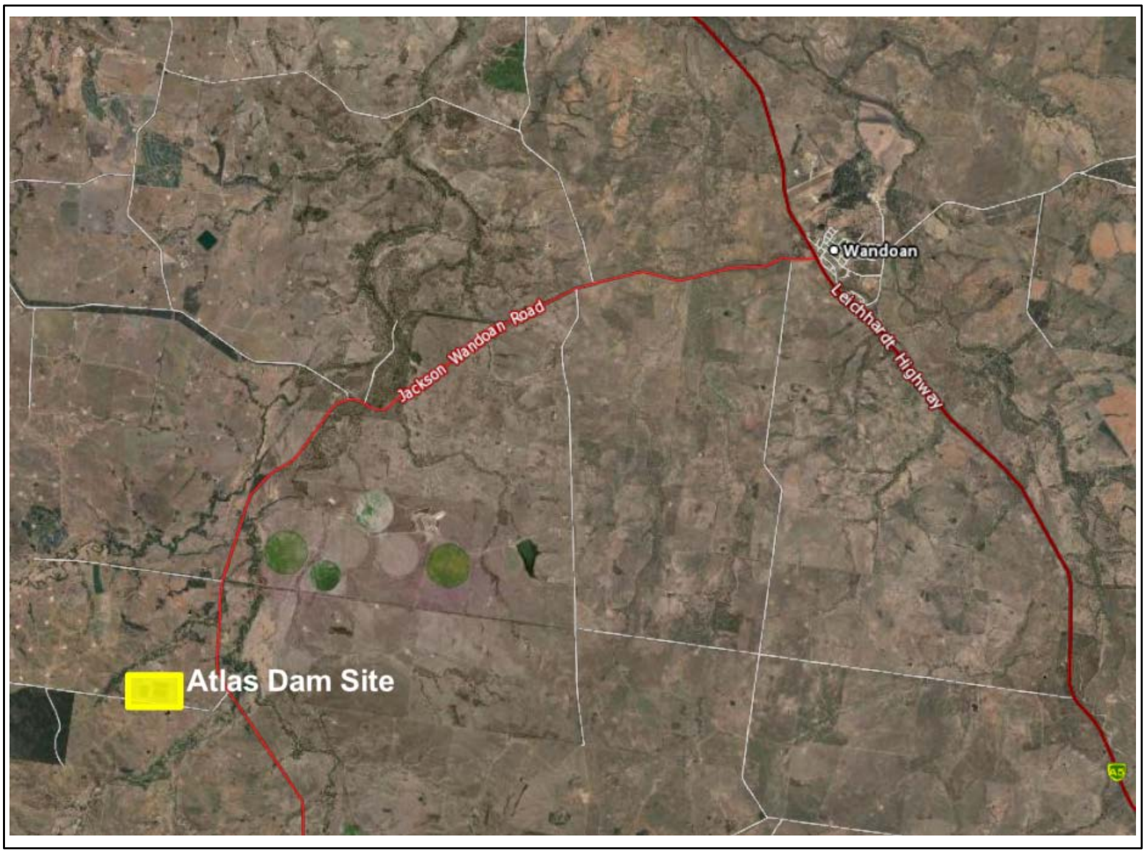


Figure 1-1 Atlas Dam site location

2 Regulatory Context

2.1 Relevant Legislation and Policy

The Queensland *Environmental Protection Act 1994* and the subordinate legislation, the *Environmental Protection Regulation 2019* and the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* provide the framework for protecting groundwater quality in Queensland.

The *Environmental Protection Regulation 2019* defines the following objectives with regards to groundwater:

Environmental Objective

The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.

Performance Outcomes

1) *Both of the following apply -*
   a) *there will be no direct or indirect release of contaminants to groundwater from the operation of the activity.*
   b) *there will be no actual or potential adverse effect on groundwater from the operation of the activity.*
2) *The activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.*

The purpose of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* is to achieve the object of the *Environmental Protection Act 1994* in relation to waters and wetlands by:

a) *identifying environmental values for waters and wetlands to be enhanced or protected; and*
b) *identifying management goals for waters; and*
c) *stating water quality guidelines and water quality objectives for enhancing or protecting the environmental values of waters; and*
d) *providing a framework for making consistent, equitable and informed decisions about waters; and*
e) *monitoring and reporting on the condition of waters.*

The assessment of groundwater quality is based on comparing measured indicators against default guidelines.

2.2 Default Water Quality Guidelines and Standards

The relevant default guidelines for this review include:

- *Queensland Water Quality Guidelines* (DEHP, 2013)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018)
- *Australian Drinking Water Quality Guidelines* (NHMRC, NRMMC 2011).

2.3 Relevant Water Quality Objectives

Pursuant to Schedule 1 of the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*, the Dawson River including all of the waters of the Dawson River sub-basin (other than the Callide Creek catchment) are subject to the *Dawson River Sub-basin Environmental Values and Water Quality Objectives* (DEHP, 2011a). This document outlines the environmental values and water quality objectives of the Dawson River sub-basin and applies to fresh surface water and groundwaters as indicated in the accompanying plans *WQ1308 – Upper Dawson Sub-basin Basin (Part of basin 130)* (DEHP, 2011b) and *WQ1310 - Fitzroy Basin Groundwater Zones (Basin 130)* (DEHP, 2011c).

2.4 Relevant EA Conditions

The Atlas Project is subject to Environmental Authority (EA) 0001207 and the relevant conditions are listed in **Table 2-1** below. Where these conditions have been wholly or partially satisfied by previous documents or programs is referenced in previous Senex reviews (Senex, 2022) or in conjunction with this review.

Table 2-1 EA Conditions and reference to where conditions have been addressed.

Condition Number	Condition	Reference to where condition has previously been addressed	Reference to where condition is addressed
(G12)	A seepage monitoring program must be developed by a suitably qualified person for regulated structures which requires and plans for detection of any seepage of contaminants to groundwater as a result of storing contaminants by no longer than 3 months from date of grant of this environmental authority.	Seepage Monitoring Plan (Golder, 2020a)	Seepage Monitoring Plan review (this document)
(G13)	The seepage monitoring program required by condition (G12) must include but not necessarily be limited to:		
	(a) identification of the containment facilities for which seepage will be monitored;	Seepage Monitoring Plan (Golder, 2020a)	Seepage Monitoring Plan review (this document)
	(b) identification of trigger parameters that are associated with the potential or actual contaminants held in the containment facilities;	Seepage Monitoring Plan (Golder, 2020a) Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	
	(c) identification of trigger concentration levels that are suitable for early detection of contaminant releases at the containment facilities;	Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	
	(d) installation of background seepage monitoring bores where groundwater quality will not have been affected by the petroleum activities authorised under this environmental authority to use as reference sites for determining impacts;	Atlas Dam Seepage Monitoring Bores Installation and Testing Report (Senex, 2020)	Previously addressed
	(e) installation of seepage monitoring bores that: i. are within formations potentially affected by the containment facilities authorised under this environmental authority (i.e. within the potential area of impact); ii. provide for the early detection of negative impacts prior to reaching groundwater dependent ecosystems, landholder's active groundwater bores, or water supply bores; iii. provide for the early detection of negative impacts prior to reaching migration pathways to other formations (i.e. faults, areas of unconformities known to connect two or more formations).	Seepage Monitoring Plan (Golder, 2020a); Atlas Dam Seepage Monitoring Bores Installation and Testing Report (Senex, 2020) Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Previously addressed
	(f) monitoring of groundwater at each background and seepage monitoring bore at least quarterly for the trigger parameters identified in condition (G13(b));	Atlas Dam Seepage Monitoring Bores Installation and Testing Report (Senex, 2020) Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Conducted quarterly and reported
	(g) seepage trigger action response procedures for when trigger parameters and trigger levels identified in conditions (G 13(b)) and (G 13(c)) trigger the early detection of seepage, or upon becoming aware of any monitoring results that indicate potential groundwater contamination;	Seepage Monitoring Plan (Golder, 2020a); Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Seepage Monitoring Plan review (this document)

Condition Number	Condition	Reference to where condition has previously been addressed	Reference to where condition is addressed
	(h) a rationale detailing the program conceptualisation including assumptions, determinations, monitoring equipment, sampling methods and data analysis; and	Seepage Monitoring Plan (Golder, 2020a); Atlas Dam Seepage Monitoring Bores Installation and Testing Report (Senex, 2020); Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Previously addressed in conjunction with Seepage Monitoring Plan review (this document)
	(i) provides for annual updates to the program for new containment facilities constructed in each annual return period.	Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Previously addressed for 2020 – 2021; Seepage Monitoring Plan review (this document)
(G14)	A bore drill log must be completed for each seepage monitoring bore in condition (G13) which must include: (a) bore identification reference and geographical coordinate location; (b) specific construction information including but not limited to depth of bore, depth and length of casing, depth and length of screening and bore sealing details; (c) standing groundwater level and water quality parameters including physical parameter and results of laboratory analysis for the possible trigger parameters; (d) lithological data, preferably a stratigraphic interpretation to identify the important features including the identification of any aquifers; and (e) target formation of the bore.	Atlas Dam Seepage Monitoring Bores Installation and Testing Report (Senex, 2020); Atlas Dam Groundwater Monitoring Report June 2020 – June 2021 (Senex, 2022)	Previously addressed

2.5 Existing Seepage Monitoring Program

Pursuant to clauses G12 and G13 of the EA 0001207, Senex commissioned the preparation of a Seepage Monitoring Plan (Golder, 2020a). The 2020 Plan was prepared prior to the establishment of the groundwater monitoring bore network and applied interim criteria until such time as sufficient data had been collected to enable further site-specific analysis.

The relevant sections of this Plan include:

- **Section 3.2.1** – Monitoring Parameters and Frequency

  The Plan notes that *the monitored parameters may be narrowed down to 'trigger parameters' considered to be potential or actual contaminants held in the containment facilities, which must be monitored quarterly.*

  In the absence of site-specific data, the Plan set trigger parameters based on the guidelines for proponents preparing CSG and large coal mining development proposals (IESC, 2018) and recommended baseline monitoring for 12 months after which resultant data would be reviewed to focus only on relevant water quality parameters for this project. The provisional trigger parameters defined were:

Physiochemical parameters	pH Electrical Conductivity Turbidity Dissolved Oxygen Temperature	Oxidation-Reduction Potential Total Dissolved Solids (TDS) Suspended Solids (SS) Sodium Adsorption Ratio (SAR)
Cations	Calcium, Magnesium, Potassium, Sodium	
Anions	Chloride, Sulphate, Carbonate, Bicarbonate and Total Alkalinity	
Nutrients	Ammonia, Nitrite, Nitrate, Total and Organic Nitrogen, Total Phosphorus	
Halides	Fluoride	
Total and dissolved metals	Al, Ag, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Ga, Hg, Li, Mo, Mn, Ni, Pb, Sb, Se, Sr, U, V, Zn.	
Hydrocarbons (TPH)	Total Petroleum Hydrocarbons (TPH) C6-C9 and C10-C36	
Bacteria	Median Faecal Coliforms	

- **Section 3.2.2** – Trigger Parameters and Concentration Levels

  The Plan specifies that until specific parameter trigger levels can be established, the following general 'triggers' should be considered:

  - *Detection of contaminants not normally present in groundwater from non-CSG formations.*
  - *Detection of one or more of the following parameters at concentrations greatly above concentrations in the background well: TDS, EC, pH and major ions.*
  - *Abrupt changes in parameters that could be present at very different concentrations between dam water and Surat Basin shallow groundwater, such as aluminium, boron, fluoride and radionuclides.*

- *Definitive and unaccounted for changes in dam water volume, as confirmed by short term water balance assessments.*

The Plan suggests caution in using these general guidelines as parameters can change with natural seasonal variation.

- **Section 3.3** – Site Specific Monitoring Details

  The Plan proposes the following to be included in the Atlas Dam monitoring program:

  Leakage collection sumps: sumps have been installed in dams to collect CSG produced water which may leak through the liner system. The sumps contain internal riser pipes and pumps which recirculate collected leakage water back into the dam.

  The primary function of the leakage collection sumps is to identify leakage and provide early warning of leakage into the surrounding environment.

  Background seepage monitoring bores: Background seepage monitoring bores were to be installed where groundwater quality would not have been affected by the petroleum activities to use as reference sites for determining impacts. The Plan required the installation and monitoring of Atlas 1M to be cross referenced and compared to registered groundwater bore RN58824, following which Atlas 1M would be used for seepage monitoring and RN58824 used to understand background groundwater quality.

  Seepage monitoring bores: At the time that the Plan was developed, groundwater depth and hydraulic gradient was unknown but presumed to follow regional surface water divides and drainage patterns to the northeast.

  The Plan identified that further hydrogeological investigation would be needed. Based on the available information, the Plan required the installation of:

  <u>Three deep seepage monitoring bores</u> to intersect the groundwater table to monitor potential impacts and assess hydraulic gradient in the area.

  <u>Five shallow seepage monitoring bores</u> downgradient of the containment structures and along nearby topographic drainage features. The intention of these bores is to identify the presence of dam seepage before seepage reaches groundwater.

  Seepage monitoring inspections: The Plan required visual inspections of the dam embankments and tank walls, and downstream of the dams and tanks to be conducted. Seepage indicators to act as performance triggers included: wet areas, increased drainage flows, significant surface erosion, deformations, cracks and sink holes.

- **Section 3.4.2** – The Plan established performance triggers and investigations in concert with the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b). The Seepage Monitoring Plan defined an exceedance of trigger values in groundwater or seepage monitoring bores or observation of seepage indicators as defined in the Section 3.3 of the Plan, as performance triggers requiring a performance investigation in accordance with the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b).

A review of the data was conducted by Senex following 12 months of monitoring and further site-specific and hydrogeological assessment undertaken. The *Atlas Dam Groundwater Monitoring Report June 2020 – June 2021* provides analysis of groundwater flow, hydraulic gradient, quality, hydrochemistry and groundwater-surface water interaction however there was still insufficient data to conduct statistical analysis to define 20^{th} and 80^{th} percentiles for each bore (Senex, 2022).

3 Seepage Monitoring Program Review Process

For the purpose of this review, the process outlined in the guiding document *Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impact* (DES, 2021) has been applied, being:

- Identify environmental values for groundwater and relevant default guidelines and water quality objectives.
- Describe site and bore characteristics.
- Analyse groundwater quality monitoring data.
    - **Step 1:** Determine summary statistics for each monitoring bore separately for all indicators using available data.
    - **Step 2:** Compare the composition of each bore.
    - **Step 3:** Graph and interpret data for each bore. Outliers, trends and peaks in the data should be identified and investigated.
    - **Step 4:** Adjust dataset and recalculate percentiles.
- Identify site-specific guidelines for groundwater quality.
    - **Step 1:** Are there sufficient good quality monitoring data and bores to calculate statistically robust site-specific groundwater guidelines?
    - **Step 2:** Compare 20th and 80th percentiles of monitoring data to relevant default guidelines.
    - **Step 3:** Determine site-specific guidelines for groundwater quality.
- Determine an appropriate compliance approach.
- Evaluate site-specific groundwater guidelines, triggers, limits and compliance approach.

In addition to the above process, the following standards and guidelines have been applied to the review of the collection of groundwater data at the Atlas Dam site:

- *Australian Standard for Water Quality - Sampling - Guidance on sampling of groundwaters* (AS/NZS 5667.11:1998).
- *Groundwater Sampling and Analysis – A Field Guide* (Sundaram *et al*., 2009).
- *Monitoring and Sampling Manual – Environmental Protection (Water) Policy* (DEHP, 2018).

4 Site Description

The Atlas Dam site was established in late 2019 / early 2020 with the construction of Atlas Dam 1 to manage produced water from CSG wells in the Atlas field (PL 1037) with a reverse osmosis water treatment plant (WTP), brine storage tanks and a network of seepage monitoring bores. An additional dam containing two separate cells (Atlas Dam 2 Cell 1 and Cell 2) was added in late 2020 / early 2021. The Seepage Monitoring Plan prepared in February 2020 includes the monitoring of the water storage infrastructure at the Atlas Dam site. As shown in **Figure 4-1**, the infrastructure consists of:

- Atlas Aggregate Dam #1 (AAD 1), a 300 ML produced water storage dam.
- Atlas Aggregate Dam #2 (AAD 2), an 800 ML produced water storage dam.
- Four 54 ML brine water storage tanks, two existing (Brine Tank 1 and Brine Tank 2) and two proposed to be installed in 2023 (Brine Tank 3 and Brine Tank 4).
- Ten existing groundwater monitoring bores ranging between 7.5 to 53 metres in depth. In addition to the ten purpose-built monitoring bores, Senex has also included water bore RN58824 as part of its groundwater monitoring network as a background bore.
- Three proposed groundwater monitoring bores up to 12 metres in depth to be installed in 2023 to monitor the two proposed new brine water storage tanks.

The Seepage Monitoring Plan (Golder, 2020) notes that:

- Natural ground elevation of the Atlas Dams and Brine Tanks 1 and 2 ranged from 285 to 305 mRL.
- A geotechnical investigation including the drilling of eight boreholes to 7.0 – 10.0 m bGL (metres below ground level) conducted by Butler Partners at the Atlas Dam site did not encounter groundwater in any of the boreholes.
- No groundwater was encountered during the construction of Atlas Dam 1, involving a maximum excavation depth of 9 m bGL.

4.1 Bore Details and Locations

The monitoring network for the Atlas Dam site consists of 10 monitoring bores and a landholder bore, RN58824 which was selected as the background bore as it is interpreted to be completed in the Westbourne Formation as per the OGIA aquifer attribution report (OGIA, 2021). Summary details of the background bore, and the Atlas Dam seepage monitoring bores are presented in **Table 4-1**.

Figure 4-1 Atlas Dam site layout.

Table 4-1 Summary of Atlas Dam Seepage Monitoring Bore Network

Bore ID	Total Depth (m bGL)	Top of Casing (m AHD)	Reference Height (m aGL)	Cased Depth (m bGL)	Screened Interval (m bGL)	Screened Lithology
Atlas 1M	53	290.604	0.659	53	44 – 50	sandstone, coal
Atlas 2M	56	287.492	0.635	56	50 – 53	sandstone
Atlas 3M	53	294.469	0.625	45	39 – 42	sandstone
Atlas 3M-R*	45	293.783	0.850	45	39 – 45	siltstone, sandstone
Atlas 4M	53	298.499	0.648	37#	28 – 34	sandstone
Atlas 5M	15	289.113	0.686	15	9 – 15	siltstone
Atlas 6M	15	292.781	0.692	15	9 – 15	siltstone
Atlas 7M	15	288.596	0.717	15	9 – 15	mudstone
Atlas 8M	15	294.354	0.605	15	9 – 12	mudstone, coal
Atlas 9M	15	289.377	0.631	15	9 – 12	sandstone, coal
Atlas 12M	7.5	294.473	0.675	7.5	4.5 – 7.5	mudstone
RN58824	25	267.785	0.235	25	19 – 25	shale, coal

Source: Senex Energy, 2022

* Atlas 3M-R was drilled as a replacement for Atlas 3M following damage to the bore in December 2021. Bore construction details for Atlas 3M-R were documented in a draft internal memo, *ATLAS 3M-R: Summary of works for drilling of replacement bore for Atlas-3M* dated 20/02/2023 (Senex, 2023). Top of casing elevation and reference height are based on manual levels measured from surveyed ground level.

- bore is plugged from 53 m bGL to 37 m bGL (Senex Energy. 2022; OGIA, 2021).

4.2 Rainfall

Long term rainfall data has been recorded at Bureau of Meteorology station Woleebee Nevasa (035081) situated approximately 8 km southwest of the site. Mean monthly rainfall from 1912 - 2023 has been plotted alongside actual monthly rainfall from June 2020 to March 2023 for this station as shown in **Figure 4-2** (Bureau of Meteorology, 2023). Senex has previously reported that it has also recorded local rainfall at the Atlas Dam commencing in October 2020, however data was not available at the time of reporting.

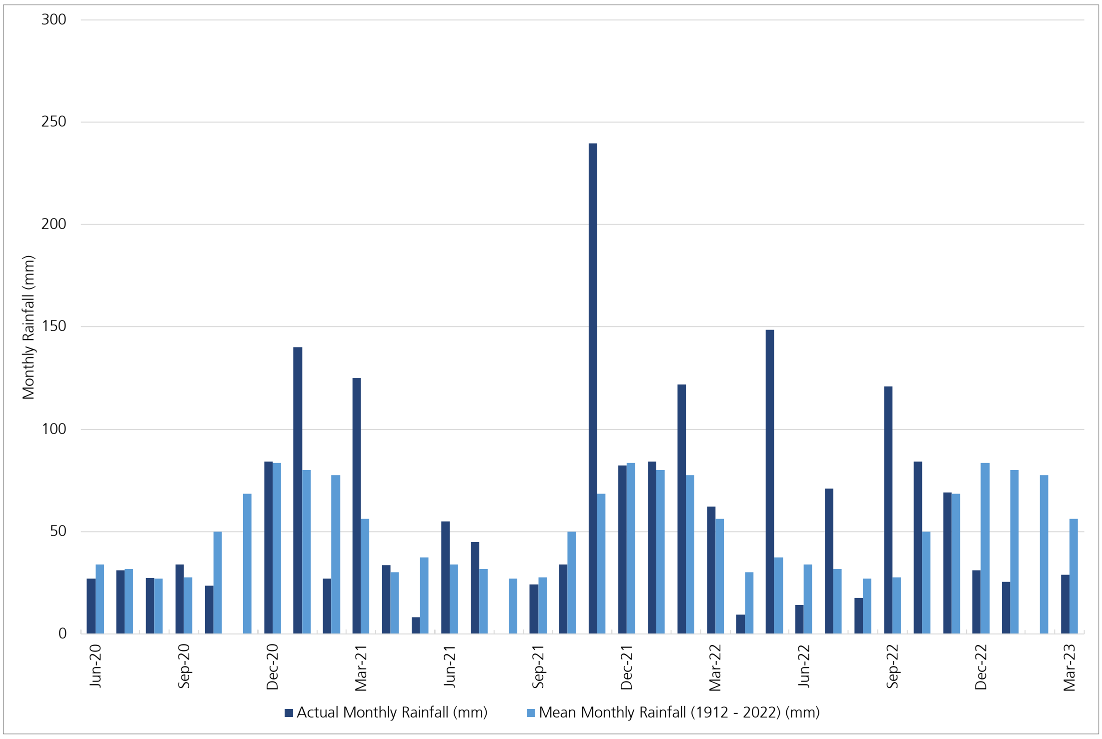


Figure 4-2 Woleebee Nevasa long-term monthly mean rain compared with actual monthly rainfall June 2020 to March 2023

4.3 Geology

Senex has previously confirmed that the Atlas Dam is located close to the contact between the Gubberamunda Sandstone and the Westbourne Formation as documented in the Project Atlas Environmental Approval Amendment (KCB, 2018). If the Gubberamunda Sandstone is present at the site, the formation is likely to be thin and not host significant quantities of groundwater (Senex, 2022). OGIA describes the Westbourne Formation as comprising mudstone, siltstone, sandstone, carbonaceous shale and coal and classifies the formation as a tight aquitard (Senex, 2022). The Westbourne is underlain by the Springbok Sandstone and is overlain by the Gubberamunda Sandstone to the south of the site, these formations dip to the south. Diffuse recharge to the Westbourne Formation across the Surat Cumulative Management Area (CMA) has been estimated to range from approximately 2.2 to 3.2 mm/year (OGIA, 2016).

4.4 Hydrogeology

Senex has previously defined the hydrogeology of the site and the findings are summarised as follows (Senex, 2022):

- The Westbourne Formation is known as a tight aquitard and as such is low yielding and is not heavily utilised in the Surat Basin.
- The hydraulic conductivity of the Westbourne Formation at the Atlas Dam site is estimated to range from 0.004 to 0.017 m/day from rising head tests conducted at Atlas 1M, Atlas 2M and Atlas 3M (Senex, 2020), with the higher value obtained from Atlas 1M. These results indicate the material tested is low permeability.

- There are no alluvial aquifers or springs mapped at or immediately adjacent to the Atlas Dam site.
- There are no known landholder bores at the Atlas Dam site, with the nearest bore being RN58824 located 1.9 km to the east southeast of the site is nominated as a background bore in the existing Seepage Monitoring Plan.
- The shallow groundwater system comprised a weathered profile logged and described from drill cuttings at each monitoring bore installed in 2020. The uppermost material comprised of stiff clays and cracks are clearly visible on the ground surface. It is likely these cracks facilitate rapid infiltration of rainfall-derived recharge resulting in unsaturated groundwater flow. The weathered profile would therefore effectively comprise a dual porosity system between the clay matrix and the cracks, with the latter being much higher permeability.
- Saturated groundwater flow may be within either intragranular pores, fractures and possibly coal cleats, where present.
- The deep groundwater system is confined with groundwater levels on site ranging from 256 to 266 mAHD. Flow in the deeper groundwater system is also likely to be through intragranular pores and coal cleats, where present. Potentiometric surface contours have been interpolated from groundwater elevation measured at the 3 deep monitoring bores (Atlas 1M, 2M and 3M), which indicated an east-south-easterly flow direction and is very consistent between the dry and wet seasons. The horizontal hydraulic gradient across the site has been calculated to be approximately 0.0077 from these contours.
- Based on the Senex assessment, the linear groundwater velocity at the site is considered to be low.

4.5 Groundwater-Surface Water Interaction

Senex has previously assessed groundwater-surface water interaction in conjunction with its project approvals which have been summarised in Senex's 2020 – 2021 monitoring review as follows (Senex, 2022):

- Assessments concluded that, based on field verification and water quality sampling of the Woleebee Creek, surface water likely represents rainwater and overland flow accumulating in the ephemeral creek channels as opposed to discharge of groundwater.
- Although potential terrestrial Groundwater Dependent Ecosystems (GDE) have been mapped along the Woleebee Creek and Wandoan Creek (DES, 2018), such features align with the creek channels and associated alluvium. There are no springs or alluvial aquifers at the Atlas Dam site and the nearest mapped GDE is located 1.65 km to the southeast (Ogle Creek).

Senex had further summarised that the nearest surface water drainage is located 220 – 240 metres to the northwest of the Atlas Brine Tanks. The base of this gully is shown to be at an elevation of approximately 282 m AHD. At the time of the 2020-2021 monitoring review, the water level in the closest monitoring bore Atlas 9M had not exceeded 279 m AHD supporting the previous assessment that the creeks and channels are not connected to shallow groundwater however with the significant rain events between November 2021 and November 2022, water level in the bore varied up to 288 m AHD, above the base level of the nearby gully. The water level has since declined back to the 2020 – 2021 levels of 275 m AHD.

As the water levels in the shallow monitoring bores can increase above the base of the nearest gully, it is possible that there may be periodic groundwater-surface water interaction dependent on climatic conditions. This would indicate that at times of high rainfall, the systems may connect for the duration such that water levels are elevated, however the surface water environment is not dependent on the groundwater supply.

4.6 Surrounding Groundwater Users

Senex has previously identified six known landholder bores located on PL 1037 and that these have previously been baselined by Senex with only one of the six bores in use at the time of the baseline assessment. The bore in use was completed in the Gubberamunda Sandstone formation and used for stock water (Senex, 2022). These bores are listed in **Table 4-2**.

There are three bores mapped on Queensland Globe on the Lara property, Lot 222 RP868424. These three registered bores, RN168129, 168346 and 168347 are recorded as not found during the Senex 2012 and 2018 baseline assessment programs.

Table 4-2 Existing registered bores within PL 1037

Bore RN	Distance from Atlas Dam (km)	Aquifer Attribution	Status
43482	3.5	Gubberamunda	In use
58009	5.0	Westbourne	Not in use
58609	4.1	Westbourne	Not in use
58824	1.95	Westbourne	Not in use
123244	2.5	Alluvium	Not in use
123245	2.7	Alluvium	Not in use

4.7 Potential Contamination Sources

The purpose of the seepage monitoring program is to provide an early detection of any seepage from the dams receiving CSG produced water (Atlas Dam #1 and Atlas Dam #2) and the brine tanks (Brine Tanks 1 to 4). As such, identifying parameters that are indicators of potential seepage from the dams and brine tanks into the underlying or adjacent groundwater is essential to targeting the monitoring program.

The dams receive CSG produced water and the brine tanks temporarily store the brine extracted by the water treatment plant prior to disposal at a regulated waste facility. The associated Environmental Authority (EA) identifies water quality parameters associated with the re-use and discharge of water which, in conjunction with water quality objectives (WQO) for the area, can be used to identify parameters to consider as follows:

- Parameters identified in the EA for assessment for water reuse are:
    - Electrical Conductivity
    - Sodium Adsorption Ratio (SAR)
    - pH
    - Heavy metals
- The water quality parameters which have been detected in analysis of water samples from the dams and brine tanks respectively are listed in **Appendix 1**.
- The water quality parameters which have been detected in the analysis of water samples from the monitoring bores have been reviewed and the statistical summaries and exceedances of relevant water quality guidelines and objectives are identified in **Appendix 2**.

4.8 Environmental Values

The Atlas Dam site is located within zone 32 as shown in WQ1310 – Fitzroy Basin Groundwater Zones – Central Queensland Map Series (DEHP, 2011) and classified as saline Na-Cl type. The Dawson River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) defines the environmental values and water quality objectives relevant to the Atlas Dam site. These environmental values and their relevance to the Atlas Dam site are summarised in **Table 4-3**.

Table 4-3 Environmental values for the Atlas Dam site.

Environmental Value	Site Relevance (Senex, 2022)
Aquatic ecosystems	There are no springs or groundwater dependent ecosystem (GDE) sourcing groundwater at or in the immediate vicinity of the Atlas Dam site. Groundwater at the site typically exceeds the usual limit of salinity for stygofauna (Hose et al, 2015).
Irrigation	The Sodium Adsorption Ratio (SAR) of the groundwater at the Atlas Dam site exceeds that suitable for irrigation and no nearby landholder bores were identified as used for irrigation during previous baseline assessments (Senex, 2022).
Farm supply / use	Of the existing landholder bores within PL 1079, none were identified as used for farm domestic supply during previous baseline assessments (Senex, 2022).
Stock water	Of the existing landholder bores within PL 1079, one bore was identified as used for stock water during previous baseline assessments (Senex, 2022).

Environmental Value	Site Relevance (Senex, 2022)
Primary and / or visual recreation	There are no known springs used for recreation purposes in the vicinity of Atlas Dam (Senex, 2022).
Drinking water	Groundwater in the Westbourne Formation, which underlies the Atlas Dam site, is not considered suitable for drinking water.
Industrial use	There are no known industrial activities in the vicinity of the Atlas Dam site (Senex, 2022).
Cultural and spiritual values	There are no known cultural or spiritual sites connected to groundwater in the vicinity of the Atlas Dam site (Senex, 2022).

5 Groundwater Sampling

The existing Seepage Monitoring Plan does not specify a groundwater sampling methodology for the Atlas Dam groundwater monitoring bores. Senex identifies low flow sampling as the most appropriate method due to the low permeability of the formation and the long fluid column length of the deep monitoring bores (Senex, 2022).

5.1 Methodology and Rationale

The low flow sampling method involves lowering a pneumatic bladder pump into the screened interval of the bore and water purges at a rate that minimises water level drawdown. Water level is monitored using an electronic water level meter and the water quality parameters monitored with a multiparameter meter for stabilisation.

Where bores have sufficient water column and permeability, the low flow method is utilised. This method has been applied consistently for quarterly monitoring of RN58824, Atlas 1M, Atlas 2M and either Atlas 3M or Atlas 3M-R. It is noted that the discharge rate for these bores is very low, needing to be less than 0.1 L/minute to minimise drawdown as far as practicable and obtain stabilisation of water quality parameters.

Despite the discharge rate for Atlas 3M-R being reduced to 0.02 L/minute, water level drawdown is observed during purging indicative of very low permeability. This observation should be taken into account when reviewing the groundwater monitoring data.

Where bores have insufficient water column or permeability to accommodate low flow sampling, the water column is purged as much as possible either with a bailer or a 12V sampling pump and a sample collected. None of the bores yield the recommended three or more well volumes, and some only permit a ‘grab’ sample to be collected. This should be taken into account when reviewing the groundwater monitoring data.

5.2 Sample Frequency and Numbers

The ten seepage monitoring bores and RN58824 have been monitored on a quarterly basis since June 2020, as weather and access conditions permitted, representing at least 12 monitoring events. Water quality samples have been obtained from RN58824 and three of the deep groundwater monitoring bores (Atlas 1M, Atlas 2M and Atlas 4M) on each of these monitoring events. Atlas 3M and Atlas 3M-R have a total of 8 water quality samples across the two bores. Water quality samples have also been collected from two shallow groundwater monitoring bores (Atlas 5M and Atlas 9M) in 9 monitoring events. Water quality samples have been obtained from Atlas 8M in four of the last five monitoring events. A single sample was collected from each of Atlas 6M and Atlas 7M in June 2020 which may have represented water added during bore construction as these bores have subsequently been dry or had insufficient water to sample (Senex, 2022). The total number of samples and sampling frequency for each bore is summarised in **Table 5-1**.

Table 5-1 Water quality monitoring events per bore from June 2020 and March 2023

Bore ID	TOTAL	Jun-20	Sep-20	Dec-20	Apr-21	Jun-21	Sep-21	Dec-21	Apr-22	Jul-22	Sep-22	Nov-22	Dec-22	Feb-23	Mar-23
Atlas 1M	**12**	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
Atlas 2M	**13**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Atlas 3M	**6**	✓	✓	✓	✓	✓	✓								
Atlas 3M-R	**2**													✓	✓
Atlas 4M	**12**	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
Atlas 5M	**9**	✓	Dry	Dry	✓	✓		✓	✓	✓		✓	✓		✓
Atlas 6M	**1**	✓	Dry	Dry	Dry	Dry		<	<	<		<	<		<
Atlas 7M	**1**	✓	Dry	Dry	Dry	Dry		Dry	Dry	<		Dry	<		<
Atlas 8M	**4**	Dry	Dry	Dry	Dry	Dry		<	✓	<		✓	✓		✓
Atlas 9M	**9**	Dry	✓	Dry	✓	✓		✓	✓	✓		✓	✓		✓
Atlas 12M	**0**	Dry	Dry	Dry	Dry	Dry		<	<			<	<	<	<
RN58824	**11**	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓

✓ Water quality sample collected and analysed
< Insufficient water level to collect a sample
Dry Bore was dry at the time of the visit

6 Data Analysis

Where monitoring bores have 8 to 13 water quality samples, statistical analysis can be utilised to specify site-specific trigger levels for potential indicators of seepage.

6.1 Groundwater Levels

As previously assessed by Senex and supported by subsequent data collection, there are two distinct groundwater systems monitored at Atlas Dam. Figure 6-1 and Figure 6-2 show the static water levels from June 2020 to March 2023. The shallow bores (Atlas 5M, 6M, 7M 8M, 9M and 12M) display a change in water level that coincides with the significant rainfall events between November 2021 and November 2022 as depicted in **Figure 4-2**.

The water levels in the deep monitoring bores (Atlas 1M, 2M and 3M-R) and the background bore RN58824 have remained stable. As previously reported by Senex, Atlas 4M comprises an isolated flow system distinct from the surrounding bores.

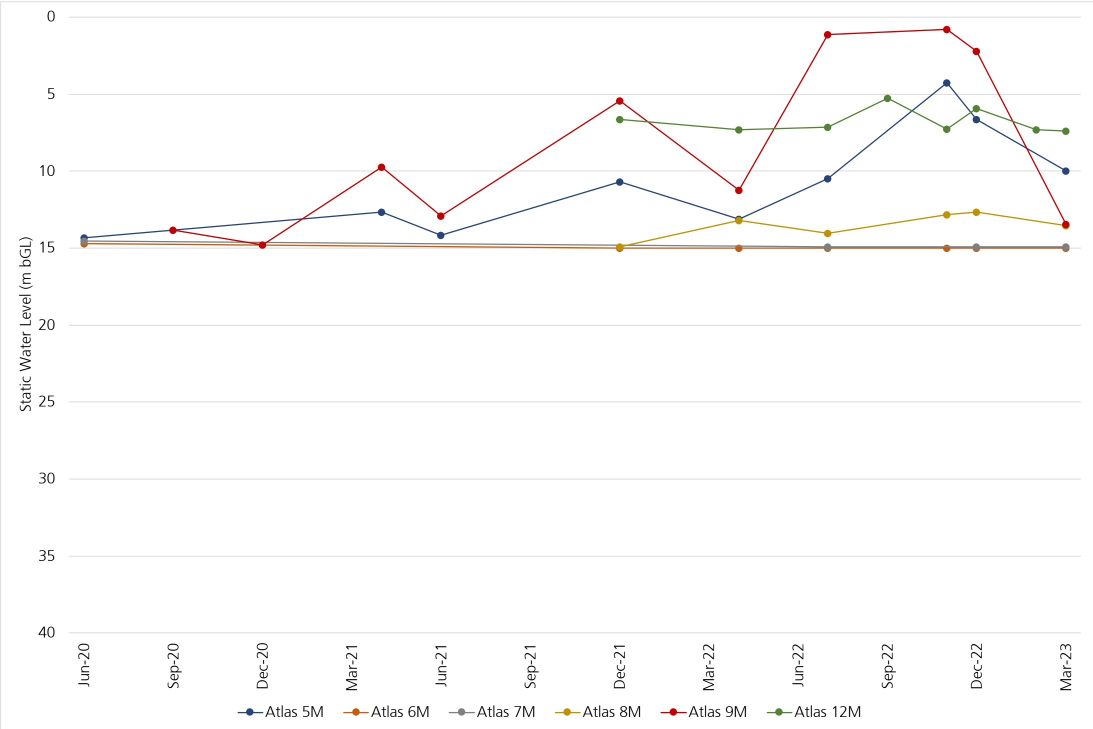


Figure 6-1 Static water levels (m bGL) within the Atlas Dam shallow monitoring bores.

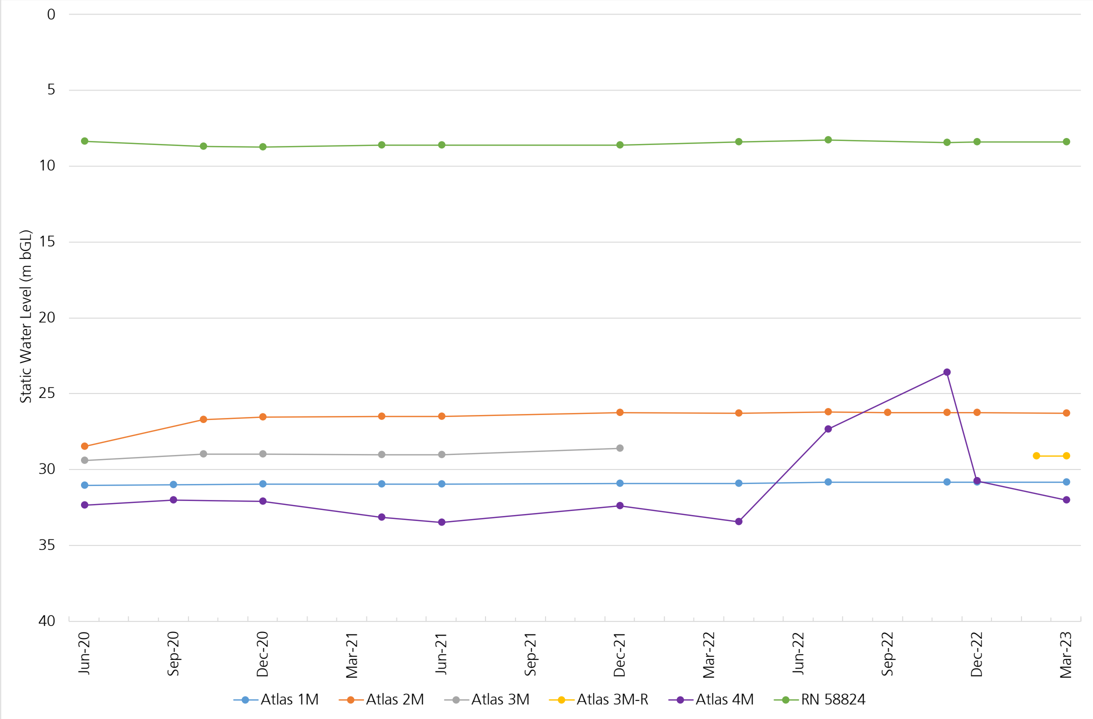


Figure 6-2 Static water levels (m bGL) within the Atlas Dam deep monitoring bores.

6.2 Summary Statistics

In order to monitor the impact of an activity on the water at the site and surrounding area, the ANZG 2018 recommends a minimum of two years of monthly baseline data to establish natural variability for surface water. DES (2021) suggest that a longer baseline period apply to groundwater as it typically moves at a slower rate. The Atlas Dam monitoring bores were installed after the establishment of Atlas Dam 1 and at the time of the commissioning of Atlas Dam 2. Water quality sampling has been conducted quarterly since the bores were installed and up to 12 monitoring events have been conducted between June 2020 and March 2023. Water quality samples have been obtained in most events for Atlas 1M, Atlas 2M, Atlas 4M and RN58824. Water quality samples have been collected from the remaining bores where sufficient water volume was obtainable for a sample. A minimum of 8 samples is recommended for statistical analysis when establishing site specific guidelines. To increase the number of samples, results from multiple bores may be combined for statistical analysis if they have similar direction and rate of groundwater flow, geology, soil types and ionic composition.

Data from each bore has been reviewed separately to identify trends and outliers. Where trends and outliers have been identified, each has been reviewed and investigated. The statistics for each parameter are summarised in **Appendix 2**.

- Where outliers are not able to be attributed to analysis or measurement variability or error, it must be retained however for the purposes of calculating percentiles, it should be excluded (DES, 2021).
- Where an increasing or decreasing trend is observed, a Mann-Kendall Test is used to identify the presence of a significantly increasing or decreasing trend.

- A simple adjustment has been applied to non-detection results in the datasets however it is noted that this can lead to biased estimates of the mean and variance when more than 10 – 15% of the of data are non-detection results particularly where the detected concentrations are recorded close to the reporting limits.

In general, the following should be taken into account when reviewing the groundwater monitoring data collected to date:

- pH data recorded for each of the groundwater bores is recorded in the field at the time of sample collection as pH has a holding time of just six hours which does not make laboratory analysis feasible. Currently only laboratory-analysed pH data for the water quality of the dams and tanks are available which would not have been analysed within holding time. While general comments are made regarding the comparison of the groundwater pH to the pH of the water in the dams and tanks, it is not currently possible to make a direct comparison until there is sufficient field pH records from the dams and tanks.
- Atlas 1M, Atlas 2M, Atlas 3M and 3M-R and RN58824 are all sampled by the low flow sampling method. It is noted that, due to the low yielding nature of this formation, water level drawdown is observed during sampling and as such, the water quality samples are influenced by stagnant water from the water column to varying degrees. Water level drawdown is minimised as far as is practicable.
- Atlas 4M, Atlas 5M, Atlas 8M and Atlas 9M are not able to produce a representative sample either via purging three or more well volumes or by low flow sampling. The samples are collected following purging of as much volume as possible prior to a sample being collected however these samples should be treated as a 'grab' sample and the results interpreted with this in mind.
- Atlas 6M and Atlas 7M have only been sampled on one occasion immediately following drilling and have since been dry. It is possible that the samples collected following drilling may have been influenced by water added during bore construction and not considered valid for water quality analysis.

Data from each bore has been plotted separately in a time series and box plot and included in **Appendix 3**. Based on plotting and assessing the data for each bore, the following findings are summarised:

- Atlas 6M, Atlas 7M, Atlas 8M and Atlas 12M were excluded from statistical analysis due to the low number or absence of data points. Trigger values are based on observations from other monitoring bores, or default water quality guidelines until sufficient data exists to establish bore specific values.
- A consistent peak in total metals was observed in Atlas 4M in the sampling and analysis conducted in December 2020. This peak was observed in Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Li, Pb, Mn, Ni, U, V and Zn. Ongoing baseline monitoring of this bore is recommended

however this peak has not been observed since and is not considered to represent the water quality of this bore.

- Increasing trends or observations in some metals (Al, As, Cr, Co, Cu, Fe, Ga, V and Zn) have been recorded for Atlas 5M and Atlas 9M. These increases coincide with increasing water level in these bores as a result of increased rainfall between November 2021 and November 2022. These bores do not yield a representative sample and 'grab' samples are collected for analysis. Ongoing baseline monitoring of these bores is recommended to investigate the relationship between the water level and metals concentrations.
- Trends calculated where results are frequently below the reporting limits or close to the reporting limit have been disregarded due to the likely bias of these results (DES, 2021), such as the trends calculated for Arsenic (As) in Atlas 1M and Cobalt (Co) in RN58824.
- There is a slight declining trend calculated for Fluoride in Atlas 1M which is recommended for ongoing monitoring. Fluoride has been identified as a seepage indicator for this site, due to the slight elevation in Fluoride in the dams and notably higher concentrations in the brine tanks. A declining trend in Atlas 1M would not be indicative of seepage, however verification of any trend would better inform the proposed trigger value guideline, which is consistent with the default water quality objectives for the area (DEHP, 2011a).
- Increasing trends have been calculated for Boron (B) in Atlas 1M and Atlas 4M. It is noted that Boron is a naturally occurring element in groundwater based on geology and exists in groundwater at a range of 0.05 – 2.9 mg/L (ANZG, 2021). Ongoing monitoring is recommended however current levels and proposed trigger value guidelines are below the toxicant default guideline for Boron (ANZG, 2018).
- Declining trends have been calculated or observed for Molybdenum (Mo) in Atlas 1M, Atlas 3M, Atlas 4M, Atlas 5M, Atlas 9M and the second sample from Atlas 3M-R was lower in Molybdenum than the initial sample following drilling. Molybdenum may be used in lubricants in drilling and declining trends would be consistent with a reduction in residual drilling residues over time.
- An increasing trend has been calculated for Molybdenum (Mo) in Atlas 2M. Ongoing baseline monitoring is recommended to verify any ongoing trend however current levels and proposed trigger value guidelines are below the toxicant default guideline (ANZG, 2018).
- Declining trends have been calculated or observed for Strontium (Sr) in Atlas 2M and Atlas 3M. Strontium may be used in lubricants in drilling and declining trends would be consistent with a reduction in residual drilling residues over time. Strontium is a naturally occurring element in groundwater and there are no default guideline values for Strontium. Ongoing baseline monitoring is recommended to verify any significant trends and better guide the site-specific water quality guidelines.

- Slight trends have been calculated for Barium (Ba) in Atlas 1M (increasing trend) and Atlas 2M (declining trend) which is recommended for ongoing monitoring. Barium has been identified as a seepage indicator for this site, due to the slight elevation in Barium in the dams and notably higher concentrations in the brine tanks. A declining trend in Atlas 2M would not be indicative of seepage, however verification of any trend would better inform the proposed trigger value guidelines. Barium is both naturally occurring in groundwater and may be used in lubricants in drilling. There are limited water quality guidelines for Barium, with only the Australian Drinking Water Guideline establishing a level of 2 mg/L for health reasons which is echoed by the US EPA guideline while the World Health Organisation (WHO) sets a guideline of 0.7 mg/L (NHMRC, 2011).
- Finally, a slight increasing trend in the presence of Nickel (Ni) in Atlas 2M has been calculated. Ongoing baseline monitoring is recommended to verify any trend however Nickel is not generally detected or is only detected at the limits of reporting in the dams and brine tanks and is therefore not indicative of seepage. The levels detected in Atlas 2M and the resultant proposed trigger value guideline are below the toxicant default guideline (ANZG, 2018).

6.3 Ionic Composition of Bores

Piper plots are tools for visualising and comparing the relative abundance of common ions (cations and anions) in water samples. This plot type is especially useful as it allows multiple samples to be presented on the same plot, thus allowing for grouping water samples by groundwater facies and other criteria. A piper plot is comprised of three components: a ternary diagram in the lower left representing cations (magnesium, calcium, and sodium plus potassium), a ternary diagram in the lower right representing anions (chloride, sulphate, and carbonate plus bicarbonate), and a diamond plot in the middle which is a matrix transformation of the two ternary diagrams. Each sample is normalised (sum of cations = 100 and sum of anions = 100), so the relative concentrations are on a percentage basis. In summary:

- Samples plotting in the top quadrant are calcium sulphate waters
- Samples plotting in the left quadrant are bicarbonate waters
- Samples plotting in the right quadrant are sodium chloride waters and
- Samples plotting in the bottom quadrant are sodium bicarbonate waters.

Utilising a Piper Plot to visualise the ionic composition of the bores, Senex previously assessed that the monitoring bores contained sodium chloride type water while RN58824, also plotting as sodium chloride type water comprised proportionately more sulphate, calcium and magnesium ions and consequently plotted slightly higher in the plot (Senex, 2022). This plot has been reproduced with the addition of samples collected from each bore since June 2021. The plot confirms the previous finding that the bores contain sodium-chloride type water with RN58824 plotting slightly higher. The updated piper plot is shown in **Figure 6-4**. The updated plot does indicate greater variance in the ionic composition of Atlas 5M and 9M, both of which are shallow bores with variable water level that coincides with rainfall events between November 2021 and November 2022 and are sampled as 'grab' samples due to low yield. In addition, greater variance is also observed in the deeper monitoring bore, Atlas 2M which showed variable data in December 2021 resulting in the lowest point plotted in the diamond diagram.

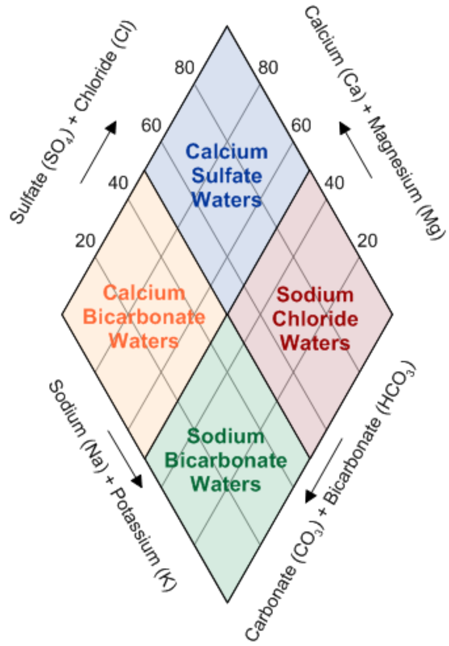


Figure 6-3 Water Classification from Piper Plots (sourced from https://support.goldensoftware.com/hc/en-us/articles/115003101648-What-is-a-piper-plot-trilinear-diagram-)

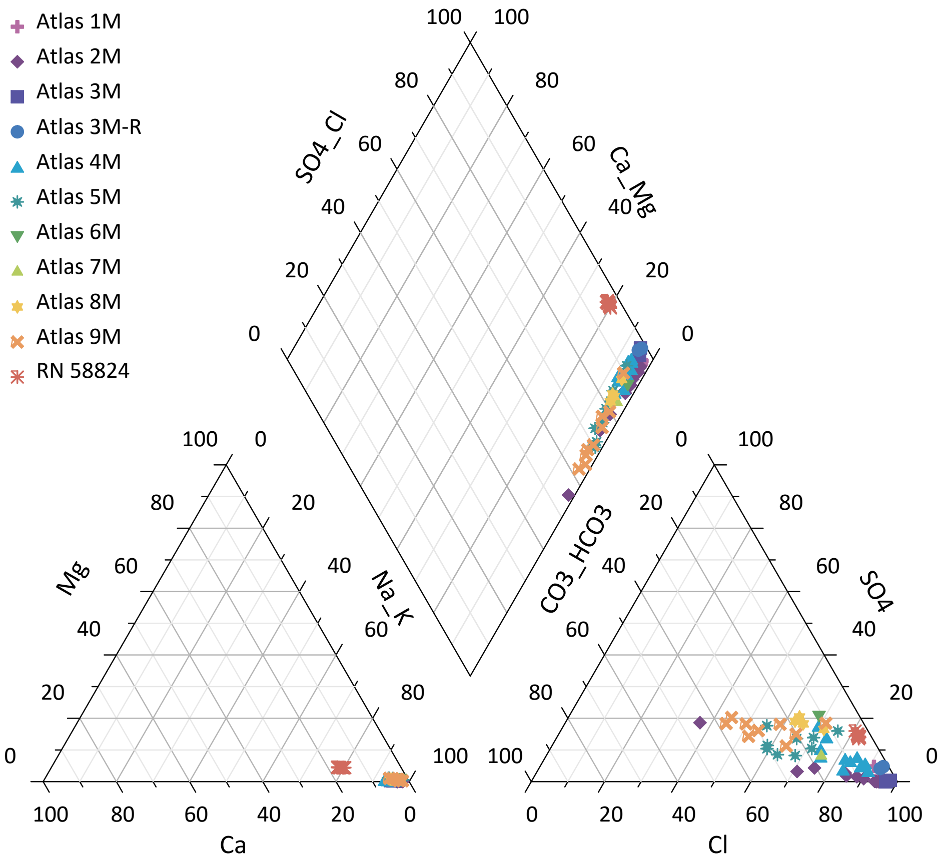


Figure 6-4 Trilinear diagram (Piper Plot) of major ions in 2020 – 2023 samples from all bores

6.4 Identification of Contaminants of Concern

Groundwater quality indicators for a specific site should be identified based on:

- The contaminants of concern for the activity being monitored.
- The Environmental Values (EV) and associated Water Quality Objectives (WQO) for the groundwater and relevant surface waters.

Regardless of activity, major anions and cations must be monitored to characterise groundwater (DES, 2021).

To identify contaminants of concern that may act as indicators of seepage from the dams and / or brine tanks into the surrounding area, the water quality results of the monitoring bores have been compared to that of the dams and brine tanks. Where the dams and / or brine tanks show higher concentrations of a particular analyte, this has been selected as an indicator of seepage and trigger limits specified accordingly, where sufficient data exists.

Water quality parameters have been divided into the following categories based on their role in understanding and monitoring of potential impacts of the activity on the site:

1. **General parameters** are analysed to provide basic water chemistry information. Some of these general parameters will also be indicators such as pH and electrical conductivity.
2. **Indicator parameters** are those described above where there are elevated concentrations at the source of contamination. Time series plots for the data of monitoring bores and dams and tanks have been compared and are included in **Appendix 4**.
3. **Baseline parameters** are analysed at a lesser frequency to maintain the baseline dataset against which any investigations can be assessed.
4. **Further data required,** where there is insufficient data to determine whether a parameter may be an indicator. It is recommended that further information be collected and that, based on that information, the parameter be assigned as an indicator or a baseline parameter.

As electrical conductivity and total dissolved solids are largely proportional, electrical conductivity has been selected as an indicator. In accordance with DES (2021), all metals analysis is total metals however analysis of dissolved metals in addition to total metals provides further analytical rigor.

The water quality analysis conducted at the dams and brine tanks has varied and further data is required to identify general water quality characteristics and variation over time. It is recommended that all parameters listed be analysed until a minimum of eight results from the dams and brine tanks are available for comparison.

When comparing the water quality results of the dams and tanks, the source of potential contamination, and the surrounding groundwater, the conclusions drawn for each parameter are summarised in **Table 6-1**.

Table 6-1 Summary of water quality parameters for seepage monitoring.

Parameter	Comment
General Parameters – To be analysed regardless of activity	
pH	Measured in the field during sampling – refer to indicator parameters.
Electrical conductivity	Measured in the field during sampling – refer to indicator parameters.
Temperature	Measured in the field during sampling
Dissolved oxygen	Measured in the field during sampling
Oxygen-Reduction Potential	Measured in the field during sampling
Total Dissolved Solids	Slightly elevated levels in dams compared to shallow groundwater bores. Elevated levels in brine tanks.
Ions	
Calcium	Major Cation
Chloride	Major Anion Elevated levels in brine tanks.
Magnesium	Major Cation
Potassium	Major Cation **Further data required for potential contaminant source.** Elevated level in brine tanks in previous sample.
Sodium	Major Cation Elevated levels in brine tanks.
Sulphate	Major Anion
Alkalinity (speciated)	Elevated levels in brine tanks.
Seepage Indicator Parameters	
pH	**Further data required for potential contaminant source**. Groundwater data is collected in the field at the time of water sample collection – as pH has a holding time of only six hours. Dams and brine tanks are sampled, and pH analysed in the laboratory beyond holding time. Dams and brine tanks are indicatively more alkaline than shallow monitoring bores, but comparable field data required for confirmation.
Electrical Conductivity	Slightly elevated levels in dams compared to shallow groundwater bores. Elevated levels in brine tanks.
Sodium Adsorption Ratio	Elevated levels in dams / concentrated in tanks.
Fluoride	Elevated levels in dams / concentrated in tanks.
Barium	**Further data required for potential contaminant source.** Slightly elevated levels in dams compared to groundwater. Elevated level in brine tanks in recent sample.
Boron	Elevated levels in brine tanks.
Cadmium	**Further data required for potential contaminant source**. Elevated levels in recent samples from brine tanks.
Copper	**Further data required for potential contaminant source**. Elevated levels in past samples from brine tank 1.
Lithium	Elevated levels in brine tanks.
Strontium	**Further data required for potential contaminant source.** Elevated level in brine tanks in recent sample.
Baseline Parameters	
Aluminium	Lower levels at potential contamination source than monitoring bores.
Arsenic	Lower levels at potential contamination source than monitoring bores.

Parameter	Comment
Beryllium	Not detected at potential contamination source.
Chromium	Not detected at potential contamination source.
Cobalt	Not detected at potential contamination source.
Iron	Lower levels at potential contamination source than monitoring bores.
Lead	Lower levels at potential contamination source than monitoring bores.
Manganese	Lower levels at potential contamination source than monitoring bores.
Mercury	Not detected at potential contamination source.
Molybdenum	Lower levels at potential contamination source than monitoring bores.
Nickel	Lower levels at potential contamination source than monitoring bores.
Selenium	Not detected at potential contamination source.
Uranium	Not detected at potential contamination source.
Vanadium	Not detected at potential contamination source.
Zinc	Lower levels at potential contamination source than monitoring bores.
Nitrate	Lower levels at potential contamination source than monitoring bores.
Nitrite	Low levels or not detected at potential contamination source.
Further Data Required – Status yet to be determined	
Antimony	No / low detection in groundwater bores. No detection in small number of dam / tanks samples.
Gallium	No comparative data for dams and brine tanks.
Silver	Not detected in monitoring bores / low detection in RN58824. No comparative data for dams and brine tanks.
Median Faecal Coliforms	No comparative data for dams and brine tanks. Source is likely surrounding land uses.
Total Nitrogen as N	No comparative data for dams and brine tanks. Source is likely surrounding land uses.
Total Phosphorus as P	No comparative data for dams and brine tanks.
Hydrocarbons BTEX / C6-9	No / low detection of BTEX and C6-9 in groundwater bores. No comparative data for dams and brine tanks.
Hydrocarbons C9-36	Detection of C9-36 Hydrocarbons in groundwater bores. No comparative data for dams and brine tanks.
Gross alpha radionuclides	No data

To provide the further information required, it is recommended that:

- Dams and brine tanks be analysed on at least a quarterly basis.
- The water quality analysis conducted on samples collected from the dams and brine tanks include all parameters listed for the groundwater monitoring bores until such time as the applicability of these additional parameters as indicators of seepage can be verified.

6.5 Establishing Site Specific Guidelines and Trigger limits for Contaminants of Concern

For the development of guideline values for this program, the following has been utilised:

- Where there is sufficient data for a parameter (eight or more values greater than the reporting limit), a site-specific guideline value equivalent to the 20th percentile (where a lower limit guideline is required such as pH) and the 80th percentile has been applied for slightly to moderately disturbed waters.

Although the monitoring bores at the Atlas Dam site have been monitored since June 2020, where bores have not contained sufficient water to sample, or where parameters are largely not detected in water quality analysis, site-specific guidelines and therefore trigger limits cannot be determined. Where this occurs, the following default water quality guidelines are applied (DES, 2021):

- The scheduled water quality objectives (WQO) for human use environmental values (stock watering and farm use / supply) as outlined in **Appendix 5** with reference to the ANZG (2018) where no bore specific guideline value can be determined.

- The toxicant default guideline values (DGV) for total metals (ANZG, 2018) as per the DES guideline (2021) where no bore specific guideline value can be determined.

To ensure that any changes in parameters identified as indicators of seepage can be adequately investigated, monitoring of these parameters are required consistently in the Atlas Dams, the Brine Tanks and the groundwater monitoring bores. It is noted that, if there are less than eight data points available, that are greater than the reporting limit, it is suggested that a default guideline or water quality objective be applied until sufficient data is collected to calculate a site-specific value (DES, 2021).

In accordance with the ANZG guidelines (2018), where possible, a hierarchy of chemical measurements (total then dissolved then bioavailable fractions) should be used for comparison with the default guideline values. As specified in the DES guideline (2021), total metals concentrations have been applied as the most likely use of groundwater in the project area is for stock watering and is therefore ingested.

7 Compliance Approach

In order for the Atlas Dam monitoring program to be effective, the associated compliance bores must be:

- Fit for purpose.
- Downgradient of potential sources.
- Monitor appropriate aquifers and flow pathways associated with potential sources.
- Detect emerging issues related to activities in a timely manner.

The existing Seepage Monitoring Plan specified the number and location of the compliance monitoring bores. The construction of the monitoring bores and the underlying hydrogeology has since been assessed by Senex (Senex, 2021; Senex 2022).

The monitoring network consists of six existing shallow monitoring bores, with three further shallow bores proposed, four deep monitoring bores with one deemed to be a background bore and the nearest downstream landholders bore.

The compliance monitoring bores have been constructed to be fit for purpose, downgradient of potential sources and of a depth to monitor the appropriate aquifer and flow pathways. The ongoing monitoring of these bores in conjunction with the monitoring of the leakage collection sumps and seepage monitoring inspections pursuant to the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b) will enable the detection of emerging issues on the site.

The site-specific and default water quality guidelines relevant to the water quality data at the Atlas Dam site are outlined in **Appendix 5** and are the basis for deriving trigger values or limits against which water quality results can be compared to identify potential issues.

DES (2021) recommend a compliance approach based on combining ANZECC 2000 methodology, adapted control charting approaches, and statistics around applying one or two limit types (or trigger). Suggested applications of this approach are -

- *Single Limit (95th percentile) – 3 consecutive test samples exceed the limit. If a toxicant default guideline (ANZG, 2018) is adopted, this can be applied as the limit.*
- *Limit A (80th percentile) and Limit B (95th percentile) – 5 consecutive test samples exceed the Limit A and 3 consecutive test samples exceed the Limit B. If toxicant default guideline (ANZG, 2018) is adopted, it should be applied as a Limit B not Limit A.*

Limit (and trigger) values are derived from default guidelines or site-specific data to derive site-specific groundwater guidelines. In general, the first limit (also referred to as Limit A) is the 80th percentile of site-specific groundwater data. Limit A is applied to 5 consecutive test samples. The second limit is the 95th percentile (also referred to as Limit B) of site-specific groundwater data and is applied to 3 consecutive test samples. Each limit is a set value for the period of the *compliance and would only be changed if the initial site-specific data used to derive the values was inadequate.*

If a toxicant default guideline was adopted, and is used as a limit, in line with the precautionary principle it should be applied as a Limit B not a Limit A. Where a default reference-based guideline is adopted as a limit, this would ideally be applied as Limit A.

Senex (2022) has previously recommended that the Limit A and Limit B approach is adopted. The specified limits are documented in **Table 7-1**. Where the site-specific 80th percentile value is not substantially different from default water quality guidelines, or if site-specific values cannot be determined due to insufficient data, it is recommended that the water quality guideline or objective is adopted (DES, 2021).

Table 7-1 Site-specific groundwater quality limits for seepage indicators at specified Atlas Dam monitoring bores

Indicator	Limit type	Limit A 80th Percentile	Limit B 95th Percentile	Comment
pH – Atlas 1M, 2M, 3M-R	Range	7.70 – 8.10	7.44 – 9.15	Site-specific 80th and 95th percentiles for bores.
pH – Atlas 4M, 9M	Range	7.07 – 7.39	6.93 – 7.56	Site-specific 80th and 95th percentiles for bores.
pH – Atlas 5M	Range	6.57 – 6.77	6.53 – 6.86	Site-specific 80th and 95th percentiles for bores.
Electrical Conductivity (µS/cm) – Atlas 1M	Maximum	9,975	11,665	Site-specific 80th and 95th percentiles for Atlas 1M.
Electrical Conductivity (µS/cm) – Atlas 2M	Maximum	8,550	9,852	Site-specific 80th and 95th percentiles for Atlas 2M.
Electrical Conductivity (µS/cm) – Atlas 3M-R	Maximum	14,961	15,808	Site-specific 80th and 95th percentiles for Atlas 3M-R.
Electrical Conductivity (µS/cm) – Atlas 4M	Maximum	14,300	17,324	Site-specific 80th and 95th percentiles for Atlas 4M.
Electrical Conductivity (µS/cm) – Atlas 5M	Maximum	7,800	9,809	Site-specific 80th and 95th percentiles for Atlas 5M.
Electrical Conductivity (µS/cm) – Atlas 9M	Maximum	8,300	9,702	Site-specific 80th and 95th percentiles for Atlas 9M.
Sodium Adsorption Ratio – Atlas 1M, 2M, 3M-R	Maximum	77.96	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Sodium Adsorption Ratio – Atlas 4M, 5M, 9M	Maximum	61.89	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Fluoride (mg/L) – Atlas 1M, 2M, 3M-R, 4M	Maximum	1.195	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Fluoride (mg/L) – Atlas 5M, 9M	Maximum	0.769	-	The site-specific 80th percentiles for the bores are not substantially different from the water quality objective (WQO), therefore the WQO is adopted.
Boron – Total (mg/L) – Atlas 1M, 2M, 3M-R, 4M, 5M, 9M	Maximum	-	0.94	Site-specific values are less than the toxicant default guideline value (DGV),

Indicator	Limit type	Limit A 80th Percentile	Limit B 95th Percentile	Comment
				however the source of contamination is higher that the DGV, therefore the DGV can be used for Limit B.
Lithium – Total (mg/L) – Atlas 1M	Maximum	0.095	0.101	Site-specific 80th and 95th percentiles for Atlas 1M.
Lithium – Total (mg/L) – Atlas 2M, 9M	Maximum	0.084	0.090	Site-specific 80th and 95th percentiles for bores.
Lithium – Total (mg/L) – Atlas 3M-R	Maximum	0.123	0.146	Site-specific 80th and 95th percentiles for Atlas 3M-R
Lithium – Total (mg/L) – Atlas 4M	Maximum	0.046	0.123	Site-specific 80th and 95th percentiles for Atlas 4M
Lithium – Total (mg/L) – Atlas 5M	Maximum	0.173	0.192	Site-specific 80th and 95th percentiles for Atlas 5M

8 Recommendations

The Seepage Monitoring Program at Atlas Dam is a comprehensive monitoring program incorporating:

1. Implementation of the monitoring outlined in the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b):

   Monitoring of leakage collection sumps:

   It is recommended that the monitoring of the leakage collection sumps associated with the brine tanks and dams be monitored on a quarterly basis in accordance with the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b) and the results (including null results) be documented.

   Seepage monitoring inspections around the brine tanks and dams:

   It is recommended that seepage monitoring inspections around the brine tanks and dams be conducted on a quarterly basis in accordance with the *Atlas Project – Operation Management Plan for Regulated Structures* (Golder, 2020b) and the results (including null results) be documented.

2. Water level and water quality monitoring:

   It is recommended that the water level in the groundwater bores and the water quality sampling of the groundwater bores, dams and brine tanks continue to be monitored on a **quarterly basis** ensuring that the water quality analysis of the dams and brine tanks include all parameters specified for the groundwater bores listed in the water quality analysis suites below to enable comparative analysis.

   The water quality analysis results are to be compared to the limits defined in **Table 7-1** and where exceedances are recorded in accordance with the specified compliance approach outlined in Section 7 above, an investigation is to be undertaken including comparative assessment with the dam and tank water quality analysis to identify any changes and/or patterns.

3. Water Quality Analysis Suites

   As defined in Section 6.4, water quality parameters have been analysed and compared with the potential source of seepage to identify those parameters that can indicate seepage. The parameters have been divided into three suites based on whether the parameter is indicative of seepage, recommended to maintain an ongoing baseline dataset and where additional information is required.

   As there is limited comparative data from the dams and brine tanks for some parameters, it is recommended that the full combination of analysis suites (Suites A, B and C) be collected quarterly from bores, dams and tanks until a minimum of 8 comparative sample results are available as an interim measure. Once there is sufficient data available to identify or confirm the indicator parameters selected, the frequency recommended below can be implemented.

The three suites are listed in **Table 8-1**:

- **Suite A** – Analysis of parameters indicative of seepage from dams and/or brine tanks to be collected on no less than a **quarterly** basis.
- **Suite B** – Analysis of parameters required if parameters are detected in dam or brine tank samples. Recommend analysing groundwater samples for Suite B on an **annual** basis to maintain a baseline data set.
- **Suite C** – Analysis of parameters to further verify applicability to this monitoring program. To be analysed quarterly until comparison with potential source of contamination demonstrates these parameters are not indicators.

Table 8-1 Proposed Seepage Monitoring Analysis Suites

Parameter	Suite A	Suite B	Suite C
Frequency	**Quarterly from bores, dams and tanks until a minimum of 8 comparative samples are available, then frequency specified below**		
	Quarterly	**Annual**	**Quarterly until determined not to be indicators**
pH (Field)	✓		
Electrical Conductivity (Field & Lab)	✓		
Dissolved Oxygen (Field)	✓		
Temperature (Field)	✓		
Oxidation-Reduction (Field)	✓		
Total Dissolved Solids	✓		
Total Suspended Solids	✓		
Sodium Adsorption Ratio	✓		
Calcium	✓		
Magnesium	✓		
Potassium	✓		
Sodium	✓		
Sulphate	✓		
Fluoride	✓		
Alkalinity (speciated)	✓		
Barium (total and dissolved)	✓		
Boron (total and dissolved)	✓		
Lithium (total and dissolved)	✓		

Parameter	Suite A	Suite B	Suite C
Frequency	**Quarterly from bores, dams and tanks until a minimum of 8 comparative samples are available, then frequency specified below**		
	Quarterly	**Annual**	**Quarterly until determined not to be indicators**
Aluminium (total and dissolved)		✓	
Arsenic (total and dissolved)		✓	
Beryllium (total and dissolved)		✓	
Chromium (total and dissolved)		✓	
Cobalt (total and dissolved)		✓	
Iron (total and dissolved)		✓	
Lead (total and dissolved)		✓	
Manganese (total and dissolved)		✓	
Molybdenum (total and dissolved)		✓	
Mercury (total and dissolved)		✓	
Nickel (total and dissolved)		✓	
Selenium (total and dissolved)		✓	
Uranium (total and dissolved)		✓	
Vanadium (total and dissolved)		✓	
Zinc (total and dissolved)		✓	
Nitrate		✓	
Nitrite		✓	
Total Nitrogen		✓	
Total Phosphorus		✓	
Antimony (total and dissolved)			✓
Cadmium (total and dissolved)			✓
Copper (total and dissolved)			✓
Gallium (total and dissolved)			✓
Silver (total and dissolved)			✓
Strontium (total and dissolved)			✓
Gross alpha			✓
Gross beta activity			✓
Median Faecal Coliforms			✓
Hydrocarbons (C6 – 36)			✓

Please note that further parameters may be included in the water quality analysis of the dams and tanks for operational purposes such as compliance with dam and tank liner design criteria, removal of additives for water treatment (i.e. Aluminium), surface water management of algae and register of regulated structures however these do not need to be added to the groundwater monitoring suite unless there is a potential risk to groundwater quality.

9 References

- ANZECC and ARMCANZ, 2000. *National Water Quality Management Strategy – Paper No. 4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1 – The Guidelines (Chapters 1-7).* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra
- ANZG, 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra
- ANZG, 2021. *Toxicant default guideline values for aquatic ecosystem protection Boron in freshwater.* Australian and New Zealand Guidelines for Fresh and Marine Water Quality. CC BY 4.0. Australian and New Zealand Governments and Australian state and territory governments, Canberra
- Bureau of Meteorology, 2023. Climate Statistics Woleebee Nevasa, Site Number 035081. Sourced from http://www.bom.gov.au/climate/data/ and verified on 12 April 2023.
- DEHP, 2011a. *Dawson River Sub-basin Environmental Values and Water Quality Objectives. Basin No. 130 (part), including all waters of the Dawson River Sub-basin except Callide Creek Catchment.* Environmental Policy and Planning, Department of Environment and Heritage Protection, State of Queensland, Brisbane (republished 2013)
- DEHP, 2011b. *Dawson River Sub-basin Environmental Values and Water Quality Objectives. Map Series WQ1308 – Upper Dawson River Sub-basin.* Environmental Policy and Planning, Department of Environment and Heritage Protection, State of Queensland, Brisbane (republished 2013)
- DEHP, 2011c. *Dawson River Sub-basin Environmental Values and Water Quality Objectives. Map Series WQ1310 – Fitzroy Bain Groundwater Zones.* Environmental Policy and Planning, Department of Environment and Heritage Protection, State of Queensland, Brisbane (republished 2013)
- DES, 2018. *Monitoring and Sampling Manual: Environmental Protection (Water) Policy*. Department of Environment and Science, State of Queensland, Brisbane
- DES, 2021. *Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts*. Version 2. Science and Technology Division Department of Environment and Science, State of Queensland, Brisbane
- Golder Associates, 2020a. *Seepage Monitoring Plan – Project Atlas Water Infrastructure*. Report prepared for Senex Energy, Brisbane
- Golder Associates, 2020b. *Atlas Project – Operation Management Plan for Regulated Structures*. Report prepared for Senex Energy, Brisbane
- Huynh T and Hobbs D, 2019. *Deriving site-specific guideline values for physico-chemical parameters and toxicants*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy
- Klohn Crippen Berger, 2018. *Project Atlas – EA Amendment – Water Report*. Report prepared for Senex Energy, Brisbane
- NHMRC, 2011. *National Water Quality Management Strategy - Australian Drinking Water Guidelines Paper 6* Version 3.5 Updated August 2018. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra
- Office of Groundwater Impact Assessment, 2016. *Hydrogeological Conceptualisation for the Surat Cumulative Management Area.* Department of Natural Resources and Mines, State of Queensland, Brisbane.
- Office of Groundwater Impact Assessment, 2021. *Bore Aquifer Attribution Report – RN58824.* Department of Regional Development, Manufacturing and Water, State of Queensland, Brisbane.
- Senex Energy, 2020. *Atlas Dam Seepage Monitoring Bores – Installation and Testing Report*. Internal document.
- Senex Energy, 2022. *Atlas Dam Groundwater Monitoring Report June 2020 – June 2021*. Internal document.

- Senex Energy, 2023. *Atlas 3M-R: Summary of works for drilling of replacement bore for Atlas-3M*. Internal document.
- Standards Australia Committee, 1998. *AS NZS 5667.11-1998 Water Quality - Sampling - Guidance on sampling of groundwaters*. Standards Australia, Homebush, New South Wales
- Sundaram, B, Feitz, A, Caritat, P. de, Plazinska, A, Brodie, R, Coram, J and Ransley, T, 2009. *Groundwater Sampling and Analysis – A Field Guide.* Geoscience Australia, Record 2009/27.
- State of Queensland, 1994, *Environmental Protection Act 1994.* Version 1 March 2023.
- State of Queensland, 2019. *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. Version 9 September 2022.
- State of Queensland, 2019. *Environmental Protection Regulation 2019.* Version 5 April 2023.

Appendix 1

Water Quality Data for Dam and Brine Tanks

Red text – Data is based on laboratory analysis which was conducted after the holding time had expired.
Bold text – Sufficient data exists for this parameter to provide comparison with monitoring bore data.
Unbold text – There have been sufficient sampling events for this parameter however it is not detected or only detected occasionally or at low levels.
Grey italicised text – Insufficient data for this parameter to provide adequate comparison with monitoring bore data.

Parameter	Units	Atlas Dam 1								Dam 2 - Cell 1						Dam 2 - Cell 2					Brine Tank 1				Brine Tank 2			
		Nov-19	Dec-20	Feb-21	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Feb-21	Mar-22	Feb-23	Dec-20	Apr-21	Mar-22	Feb-23
pH Value	pH Unit	8.23	8.93	8.95	9.14	9.24	9.19	8.91	8.91	8.85	9.02	9.00	9.07	9.02	9.05	8.44	8.99	9.06	8.93	8.93	9.36	9.33	9.30	9.15	9.15		9.29	9.02
Electrical Conductivity @ 25°C	µS/cm	8880	9680	9790	12400	10300	12000	11900	10400	9540	10000	10500	10500	10400	10300	8780	9980	9630	9650	9230	17600	19700	51800	47400	23800		56400	62600
Total Dissolved Solids (Calc.)	mg/L	5770		6360	8060		7800	7740	6760		6500		6820	6760	6700			6260	6270	6000		12800	33700	30800			36700	40700
Total Dissolved Solids @180°C	mg/L		5500	5630		5500	7000	6680	6240	5310		5600	5960	5870	6170	4830	5270	5560	5320	5670	10200	11700	35000	35600	14000	19000		47400
Suspended Solids	*mg/L*							*10*	*ND*					*ND*	*ND*				*ND*	*ND*				*6*				*11*
Bicarbonate Alkalinity as $CaCO_3$	mg/L	689	526	484	555	343	558	640	519	517	490	456	561	564	530	555	426	515	529	493	668	754	2030	2260	1130		2210	3200
Carbonate Alkalinity as $CaCO_3$	mg/L	ND	122	220	279	262	202	129	174	104	195	174	143	144	196	23	167	129	109	146	553	719	1680	1650	550		1880	1950
Hydroxide Alkalinity as $CaCO_3$	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND
Total Alkalinity as $CaCO_3$	mg/L	689	647	704	835	605	760	769	692	621	685	630	704	709	726	578	594	644	638	639	1220	1470	3710	3900	1680		4090	5160
Total Hardness as $CaCO_3$	*mg/L*	*64*			*52*						*51*																	
Bromide	*mg/L*	*7.6*			*11.6*						*9*																	
Calcium	mg/L	14	8	4	6	10	9	8	12	11	9	14	7	5	8	12	12	8	8	9	7	3	12	3	10	15	9	26
Chloride	mg/L	2680	3070	3140	3780	3050	3780	3690	3650	3030	3060	3160	3310	3220	3510	2750	2960	3020	3000	3180	5850	6700	16700	18200	8040	9920	18600	24800
Fluoride	mg/L	1.10	1.20	1.30	1.70	1.30	1.60	1.50	1.40	1.50	1.40	1.40	1.40	1.40	1.40	1.60	1.40	1.30	1.30	1.30	2.20	2.60	6.60	6.90	3.10		7.20	9.10
Iodide	*mg/L*	*0.6*			*1.3*						*0.7*																	
Magnesium	mg/L	7	7	7	9	6	7	8	7	6	7	7	6	6	7	6	7	6	6	6	14	14	33	32	19	25	40	50
Potassium	mg/L	38	54	47	62	43	75	42	30	15	16	22	36	21	21	13	16	30	19	19	129	133	516	303	160	194	535	328
Sodium	mg/L	1880	2160	2040	2730	2090	2270	2560	2370	2060	2180	2140	2020	2280	2300	1920	1960	1880	2090	2090	4060	4390	12000	14000	5780	7300	13600	17900
Sodium Adsorption Ratio	-	102	134	142	165	129	138	153	134	124	132	116	135	163	143	113	111	122	136	132	204	237	405	516	248	268	432	473
Sulphate as SO4 - Turbidimetric	mg/L	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ionic Balance	%	3.08	1.64	6.17	0.79	2.68	9.04	2.56	5.30	3.62	1.91	3.46	9.04	2.21	5.56	2.40	4.68	8.06	2.68	5.20	2.16	5.48	0.62	2.33	0.54		0.21	0.64

Parameter	Units	Atlas Dam 1								Dam 2 - Cell 1						Dam 2 - Cell 2					Brine Tank 1				Brine Tank 2			
		Nov-19	Dec-20	Feb-21	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Feb-21	Mar-22	Feb-23	Dec-20	Apr-21	Mar-22	Feb-23
Total Anions	**meq/L**	**89**	**100**	**103**	**123**	**98**	**122**	**119**	**117**	**98**	**100**	**102**	**107**	**105**	**114**	**89**	**95**	**98**	**97**	**102**	**189**	**218**	**545**	**591**	**260**		**606**	**803**
Total Cations	**meq/L**	**84**	**96**	**91**	**121**	**93**	**102**	**113**	**105**	**91**	**96**	**95**	**90**	**100**	**102**	**85**	**87**	**83**	**92**	**92**	**181**	**196**	**538**	**619**	**258**		**609**	**792**
Dissolved Metals																												
Mercury	*mg/L*	*ND*			*ND*						*ND*																	
Aluminium	*mg/L*	*ND*	*ND*		*0.01*	*ND*				*ND*	*ND*	*ND*				*ND*	*ND*				*ND*				*ND*			
Antimony	*mg/L*	*ND*																										
Arsenic	*mg/L*	*ND*			*0.002*						*0.002*																	
Barium	*mg/L*	*1.54*			*1.64*						*1.33*																	
Beryllium	*mg/L*	*ND*			*ND*						*ND*																	
Boron	**mg/L**	**0.33**	**0.36**		**0.34**	**0.40**				**0.28**	**0.31**	**0.40**				**0.26**	**0.39**				0.54				0.65			
Cadmium	*mg/L*	*ND*			*ND*						*ND*																	
Chromium	*mg/L*	*ND*			*ND*						*ND*																	
Cobalt	*mg/L*	*ND*			*ND*						*ND*																	
Copper	**mg/L**	**ND**	**0.00**		**0.035**	**0.004**				**0.001**	**0.002**	**0.002**				**ND**	**0.002**				0.002				0.006			
Iron	mg/L	0.07	ND		ND	ND				ND	ND	ND				0.06	ND				ND				ND			
Lead	*mg/L*	*ND*			*0.004*						*ND*																	
Manganese	mg/L	0.05	ND		ND	ND				ND	ND	0.002				0.009	ND				ND				0.003			
Molybdenum	mg/L	ND	0.01		ND	ND				0.002	ND	ND				0.002	ND				0.002				0.002			
Nickel	*mg/L*	*ND*			*ND*						*ND*																	
Selenium	*mg/L*	*ND*			*ND*						*ND*																	
Vanadium	*mg/L*	*ND*			*ND*						*ND*																	
Zinc	*mg/L*	*ND*			*0.013*						*ND*																	
Silver	*mg/L*	*ND*																										
Strontium	*mg/L*	*3.76*			*4.15*						*3.47*																	
Thorium	*mg/L*	*ND*																										
Uranium	*mg/L*	*ND*																										

Parameter	Units	Atlas Dam 1								Dam 2 - Cell 1						Dam 2 - Cell 2					Brine Tank 1				Brine Tank 2			
		Nov-19	Dec-20	Feb-21	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Feb-21	Mar-22	Feb-23	Dec-20	Apr-21	Mar-22	Feb-23
Total Metals																												
Mercury	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Aluminium	**mg/L**	**0.04**		**0.05**	**0.05**		**0.11**	**0.1**	**0.03**		**0.12**		**0.14**	**0.06**	**0.02**			**0.01**	**0.02**	**ND**		ND	ND	ND		ND	ND	ND
Antimony	*mg/L*	*ND*																										
Arsenic	mg/L	ND		0.00	0.002		ND	ND	0.001		0.002		0.001	0.001	0.002			ND	ND	0.001		0.002	0.006	0.006		ND	0.007	0.008
Barium	mg/L	1.71			1.67				1.66		1.34				1.46					1.41				7.67				11.2
Beryllium	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Boron	**mg/L**	**0.31**		**0.40**	**0.3**		**0.42**	**0.52**	**0.48**		**0.28**		**0.41**	**0.42**	**0.5**			**0.39**	**0.45**	**0.44**		**0.62**	**1.52**	**1.71**		**0.98**	**1.74**	**2.64**
Cadmium	mg/L	ND		ND	ND		ND	ND	0.0004		ND		ND	ND	0.0005			ND	ND	0.0004		ND	ND	0.0012		ND	ND	0.0041
Chromium	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Cobalt	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Copper	**mg/L**	**ND**		**0.001**	**0.040**		**0.005**	**0.036**	**0.008**		**0.003**		**0.004**	**0.004**	**0.004**			**0.003**	**ND**	**0.002**		**0.363**	**0.070**	**0.029**		**0.007**	**ND**	**0.018**
Iron	**mg/L**	**4.16**		**0.09**	**ND**		**0.23**	**0.10**	**0.09**		**0.07**		**0.10**	**0.06**	**ND**			**ND**	**ND**	**ND**		ND	ND	ND		0.07	ND	0.07
Lead	mg/L	ND		ND	0.004		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Lithium	**mg/L**			**0.13**			**0.127**	**0.14**	**0.12**				**0.112**	**0.116**	**0.134**			**0.106**	**0.114**	**0.109**		**0.254**	**0.611**	**0.664**		**0.402**	**0.674**	**1.06**
Manganese	mg/L	0.06		0.00	0.002		0.006	0.004	0.004		ND		0.001	0.001	0.001			ND	ND	ND		0.002	ND	ND		0.007	ND	ND
Molybdenum	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		0.002	ND	ND		ND	ND	ND
Nickel	mg/L	ND		ND	ND		ND	ND	0.004		ND		0.001	ND	0.006			ND	ND	0.002		ND	ND	ND		ND	ND	ND
Selenium	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Vanadium	mg/L	ND		ND	ND		ND	ND	ND		ND		ND	ND	ND			ND	ND	ND		ND	ND	ND		ND	ND	ND
Zinc	mg/L	0.01		ND	0.018		0.012	ND	0.009		ND		0.01	0.019	ND			ND	ND	ND		ND	0.026	0.035		0.027	0.026	0.059
Silver	*mg/L*	*ND*																										
Strontium	*mg/L*	*3.68*			*4.17*						*3.5*																	
Thorium	*mg/L*	*ND*																										
Uranium	mg/L	ND		ND			ND	ND					ND	ND				ND	ND			ND	ND			0.005	ND	

Parameter	Units	Atlas Dam 1								Dam 2 - Cell 1						Dam 2 - Cell 2					Brine Tank 1				Brine Tank 2			
		Nov-19	Dec-20	Feb-21	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Sep-21	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Dec-21	Mar-22	Oct-22	Feb-23	Dec-20	Feb-21	Mar-22	Feb-23	Dec-20	Apr-21	Mar-22	Feb-23
Nutrients																												
Ammonia as N	*mg/L*	*1.43*																										
Nitrate as N	mg/L	ND	ND	ND			ND	ND	0.01	0.08			ND	ND	ND	0.03		ND	0.02	ND	0.01	ND	ND	0.02	ND	0.02	0.01	ND
Nitrite + Nitrate as N	mg/L	ND	ND	ND			ND	ND	0.01	0.13			ND	ND	ND	0.03		ND	0.02	ND	0.01	ND	ND	0.02	ND	0.02	0.01	ND
Nitrite as N	mg/L	ND	ND	ND			ND	ND	ND	0.05			ND	ND	ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Kjeldahl Nitrogen as N	*mg/L*	*1.4*																									*41300*	
Total Nitrogen as N	*mg/L*	*1.40*																										
Reactive Phosphorus as P	*mg/L*	*ND*																										
Total Phosphorus as P	mg/L	0.02	0.02			0.08				ND		ND				0.08	ND				0.5				0.68			
Miscellaneous																												
Silicon	*mg/L*							*5.91*	*7.11*					*8.32*	*9.04*				*8.36*	*8.44*				*28.6*				*40*
Silicon as SiO2	*mg/L*							*12.7*	*15.2*					*17.8*	*19.4*				*17.9*	*18.1*				*61.3*				*85.7*
Reactive Silica	*mg/L*				*18.5*						*17.4*																	
Silicon as SiO_2 - Total	*mg/L*	*17.4*			*19.7*						*18*																	
Dissolved Organic Carbon	*mg/L*	*ND*																										
Total Organic Carbon	*mg/L*	*15*																										
Gross alpha	*Bq/L*			*0.26*																		*0.58*				*ND*		
Gross beta activity - 40K	*Bq/L*			*0.16*																		*0.10*				*2.19*		
Radium 226	*Bq/L*			*0.19*																		*0.15*				*0.09*		
Radium 228	*Bq/L*			*0.29*																		*0.26*				*0.08*		
Uranium	*mg/L*																					*0.02*				*0.002*		
Uranium 238	*Bq/L*																					*0.25*				*0.025*		

Appendix 2

Summary statistics and exceedances of Atlas Dam monitoring bores

(yellow)	- Value is below the lower guideline value for this parameter.
(orange)	- Value is above the upper guideline value for this parameter.
Red Text	- Percentage of results below the limits of reporting – insufficient data to permit statistical analysis.

		Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
pH Value (Field)	**7.60 – 8.60**	*Deep bores (Dawson River WQO - Zone 32)*						
	7.40 – 8.40	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		11	12	7	10	11	7	8
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		7.64	7.80	7.38	6.90	6.09	6.52	6.83
5th percentile		7.67	7.82	7.39	6.92	6.10	6.54	6.94
20th percentile		7.70	7.85	7.43	6.97	6.18	6.58	7.16
50th percentile		7.76	8.10	7.60	7.22	6.21	6.72	7.31
80th percentile		7.88	8.42	7.88	7.38	6.29	6.82	7.39
95th percentile		8.76	9.12	8.02	7.66	6.33	6.90	7.46
Maximum		9.53	9.64	8.08	7.88	6.34	6.93	7.49
Electrical Conductivity (µS/cm)	**0 – 5,165**	*Deep bores (Dawson River WQO - Zone 32)*						
	371 – 6,040	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		11	12	7	10	10	7	8
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		7,621	1,025	11,818	4,505	29,808	2,708	2,706
5th percentile		8,580	2,035	11,830	6,044	29,817	2,815	2,902
20th percentile		9,585	3,256	12,130	7,925	30,106	3,311	3,384
50th percentile		9,781	6,312	14,066	11,471	31,217	4,507	4,557
80th percentile		9,975	8,551	14,961	14,302	31,518	7,802	8,305
95th percentile		11,665	9,852	15,808	17,324	36,819	9,809	9,702
Maximum		12,817	10,691	16,085	17,530	41,082	10,362	10,107
Total Dissolved Solids (mg/L)	**0 – 5,000**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		3,980	658	6640	2,440	19,700	2,740	2,570
5th percentile		4,624	1,154	6658	3,795	19,850	2,904	2,794
20th percentile		5,262	1,836	6726	5,230	20,200	3,450	3,328
50th percentile		5,410	2,915	7125	6,180	21,700	4,460	3,950
80th percentile		5,466	4,378	8142	8,000	23,600	5,806	4,640
95th percentile		5,647	5,068	8669	9,980	23,850	7,612	5,036
Maximum		5,850	5,640	8840	10,400	23,900	8,280	5,300
Sodium Adsorption Ratio	**32.07 – 77.96**	*Deep bores (Dawson River WQO - Zone 32)*						
	5.67 – 61.89	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		63.80	26.30	58.00	43.30	35.30	36.40	35.40
5th percentile		64.41	31.97	58.56	44.90	35.65	37.92	37.76
20th percentile		66.20	38.12	59.60	48.60	37.30	41.16	41.48
50th percentile		67.60	61.30	60.40	55.60	38.00	43.70	48.70
80th percentile		68.66	68.92	61.38	58.30	39.00	48.40	54.78
95th percentile		70.44	72.76	63.26	59.75	39.95	51.16	59.88
Maximum		70.60	74.30	64.20	61.00	40.80	51.80	60.20

		Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
Alkalinity (mg/L as $CaCO_3$)	**-**	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		102.0	137.0	77.0	205.0	400.0	347.0	283.0
5th percentile		109.2	139.2	79.8	257.5	400.0	350.6	337.0
20th percentile		116.2	144.4	100.2	316.0	411.0	362.6	472.6
50th percentile		120.5	173.5	129.0	462.0	427.0	484.0	604.0
80th percentile		130.8	214.8	134.2	559.0	440.0	651.8	714.0
95th percentile		136.5	252.3	137.6	599.0	451.0	756.8	753.0
Maximum		142.0	288.0	139.0	601.0	460.0	802.0	757.0
Calcium (mg/L)	**1,000**	*Livestock Drinking Water Guidelines*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		34.0	4.0	97.0	29.0	1080.0	10.0	13.0
5th percentile		46.1	12.8	98.8	57.0	1110.0	12.8	13.8
20th percentile		57.0	21.2	102.4	88.0	1160.0	18.8	21.6
50th percentile		60.5	27.0	111.0	141.0	1200.0	61.0	37.0
80th percentile		62.0	38.8	148.0	176.0	1260.0	75.8	59.6
95th percentile		64.4	39.5	159.1	209.0	1315.0	97.4	75.2
Maximum		66.0	40.0	164.0	240.0	1340.0	105.0	84.0
Chloride (mg/L)	**185 – 2,476**	*Deep bores (Dawson River WQO - Zone 32)*						
	130 – 2,780	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	25%	0%	0%	0%	0%	0%
Minimum		2,340	160	3,820	1,120	9,100	693	490
5th percentile		2,764	508	3,880	1,795	9,275	705	552
20th percentile		3,242	880	4,058	2,790	9,850	932	894
50th percentile		3,315	1,675	4,260	3,550	10,100	1,620	1,090
80th percentile		3,420	2,580	4,770	4,530	10,300	2,278	1,960
95th percentile		3,481	2,744	4,863	5,405	10,450	2,992	2,224
Maximum		3,530	2,810	4,870	5,750	10,500	3,180	2,400
Fluoride (mg/L)	**0.200 – 1.195**	*Deep bores (Dawson River WQO - Zone 32)*						
	0.165 – 0.769	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		0.700	0.500	0.500	0.200	0.100	0.050	0.200
5th percentile		0.755	0.610	0.535	0.200	0.100	0.110	0.200
20th percentile		0.800	0.800	0.600	0.200	0.100	0.200	0.200
50th percentile		0.800	0.950	0.600	0.300	0.100	0.200	0.300
80th percentile		0.900	1.000	0.700	0.400	0.200	0.240	0.340
95th percentile		1.000	1.100	0.765	0.750	0.200	0.300	0.400
Maximum		1.000	1.100	0.800	0.900	0.200	0.300	0.400
Magnesium (mg/L)	**1 – 12**	*Deep bores (Dawson River WQO - Zone 32)*						
	2 - 30	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	25%	0%	0%	0%	0%	0%

	Guideline	Deep Monitoring Bores				Shallow Monitoring Bores		
		Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
Minimum		2.0	0.5	6.0	3.0	296.0	4.0	2.0
5th percentile		3.1	0.5	6.0	4.5	297.5	4.4	2.0
20th percentile		4.0	0.6	6.0	8.0	310.0	5.0	3.2
50th percentile		4.0	1.5	7.0	10.0	331.0	15.0	8.0
80th percentile		4.0	2.0	9.6	14.0	338.0	19.0	14.0
95th percentile		4.0	2.5	10.7	16.5	346.5	22.6	16.4
Maximum		4.0	3.0	11.0	19.0	347.0	23.0	18.0
Potassium (mg/L)	**-**	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		5.0	5.0	6.0	6.0	14.0	4.0	4.0
5th percentile		5.0	5.6	6.4	6.0	14.0	4.0	4.0
20th percentile		5.0	6.0	7.0	8.0	14.0	4.0	5.2
50th percentile		5.0	7.0	8.0	9.0	15.0	6.0	8.0
80th percentile		5.0	9.0	11.2	11.0	15.0	7.8	10.0
95th percentile		5.5	14.5	14.6	11.5	15.5	9.0	11.2
Maximum		6.0	15.0	16.0	12.0	16.0	9.0	12.0
Sodium (mg/L)	**360 – 1,802**	*Deep bores (Dawson River WQO - Zone 32)*						
	144 – 1,868	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	25%	0%	0%	0%	0%	0%
Minimum		1,440	210	2,230	917	5,260	699	551
5th percentile		1,688	428	2,234	1,294	5,265	713	633
20th percentile		1,950	672	2,276	2,000	5,480	875	909
50th percentile		2,020	1,235	2,450	2,290	5,790	1,260	1,330
80th percentile		2,046	1,612	2,902	2,860	6,030	1,720	1,680
95th percentile		2,105	1,675	2,957	3,295	6,160	2,008	1,914
Maximum		2,110	1,680	2,960	3,650	6,240	2,080	1,990
Sulphate (mg/L)	**0 – 34**	*Deep bores (Dawson River WQO - Zone 32)*						
	0 - 21	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	25%	0%	0%	0%	0%	0%
Minimum		0.5	0.5	0.5	152.0	1550.0	122.0	204.0
5th percentile		0.5	0.5	0.5	159.0	1615.0	129.6	240.0
20th percentile		0.5	0.5	0.5	195.0	1740.0	143.4	295.2
50th percentile		3.5	23.5	4.5	283.0	1800.0	321.0	345.0
80th percentile		15.4	36.8	132.4	388.0	1840.0	458.8	469.0
95th percentile		87.7	62.3	232.0	601.0	1855.0	614.2	536.8
Maximum		124.0	81.0	246.0	678.0	1870.0	671.0	556.0
Aluminium – Total (mg/L)	**5.00**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		0.04	0.06	0.02	0.12	0.03	0.06	0.33
5th percentile		0.07	0.11	0.07	0.40	0.03	0.28	0.37
20th percentile		0.15	0.18	0.27	2.67	0.03	16.80	3.12
50th percentile		0.17	0.46	0.58	14.40	0.09	54.10	24.60

		Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
80th percentile		0.31	1.36	0.77	23.80	0.35	103.40	62.92
95th percentile		0.45	2.34	8.24	123.75	0.65	119.60	137.68
Maximum		0.60	3.04	12.20	214.00	0.68	130.00	176.00
Antimony – Total (mg/L)	**0.0009**	*Toxicant Default Guideline Value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**92%**	**92%**	**38%**	**36%**	**91%**	**56%**	11%
Minimum		0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
5th percentile		0.0005	0.0005	0.0005	0.0005	0.0015	0.0005	0.0007
20th percentile		0.0005	0.0005	0.0005	0.0005	0.0025	0.0005	0.0010
50th percentile		0.0005	0.0005	0.0005	0.0020	0.0025	0.0005	0.0010
80th percentile		0.0005	0.0005	0.0016	0.0025	0.0025	0.0014	0.0030
95th percentile		0.0012	0.0012	0.0020	0.0030	0.0053	0.0026	0.0048
Maximum		0.0020	0.0020	0.0020	0.0030	0.0080	0.0030	0.0060
Arsenic – Total (mg/L)	**0.500**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**42%**	0%	0%	0%	0%	**22%**	0%
Minimum		0.001	0.002	0.004	0.023	0.003	0.001	0.004
5th percentile		0.001	0.002	0.004	0.023	0.003	0.001	0.004
20th percentile		0.001	0.002	0.004	0.023	0.003	0.004	0.006
50th percentile		0.002	0.003	0.006	0.029	0.003	0.013	0.013
80th percentile		0.002	0.005	0.016	0.034	0.008	0.028	0.024
95th percentile		0.008	0.006	0.021	0.093	0.009	0.035	0.033
Maximum		0.012	0.007	0.021	0.134	0.009	0.036	0.037
Barium – Total (mg/L)	**2.000**	*Australian Drinking Water (only existing guideline)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		0.446	0.038	0.950	0.559	0.058	0.050	0.033
5th percentile		0.643	0.096	0.952	0.592	0.059	0.054	0.034
20th percentile		0.834	0.212	1.082	0.697	0.060	0.193	0.061
50th percentile		0.869	0.347	1.315	0.932	0.063	0.552	0.112
80th percentile		0.903	0.551	1.666	1.370	0.072	0.640	0.296
95th percentile		0.947	0.613	1.910	3.145	0.083	1.323	0.309
Maximum		0.992	0.662	1.920	4.650	0.089	1.770	0.311
Beryllium – Total (mg/L)	**0.001**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**100%**	**88%**	**55%**	**100%**	0%	0%
Minimum		< LOR	< LOR	0.0005	0.0005	< LOR	0.0005	0.0005
5th percentile		< LOR	< LOR	0.0005	0.0005	< LOR	0.0005	0.0005
20th percentile		< LOR	< LOR	0.0005	0.0005	< LOR	0.0014	0.0005
50th percentile		< LOR	< LOR	0.0005	0.0005	< LOR	0.0030	0.0010
80th percentile		< LOR	< LOR	0.0005	0.0020	< LOR	0.0060	0.0024
95th percentile		< LOR	< LOR	0.0008	0.0130	< LOR	0.0060	0.0036
Maximum		< LOR	< LOR	0.0010	0.0220	< LOR	0.0060	0.0040
Boron – Total (mg/L)	**5.00**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%

	Guideline	Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
Minimum		0.24	0.13	0.44	0.19	0.28	0.11	0.18
5th percentile		0.34	0.22	0.45	0.27	0.29	0.12	0.20
20th percentile		0.46	0.32	0.49	0.36	0.32	0.18	0.24
50th percentile		0.49	0.47	0.51	0.42	0.36	0.26	0.34
80th percentile		0.54	0.56	0.53	0.56	0.40	0.31	0.39
95th percentile		0.59	0.57	0.55	0.57	0.43	0.39	0.48
Maximum		0.62	0.59	0.56	0.57	0.45	0.42	0.51
Cadmium – Total (mg/L)	**0.010**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**100%**	**88%**	**45%**	**91%**	**22%**	**67%**
Minimum		< LOR	< LOR	0.0001	0.0001	0.0001	0.0001	0.0001
5th percentile		< LOR	< LOR	0.0001	0.0001	0.0002	0.0001	0.0001
20th percentile		< LOR	< LOR	0.0001	0.0001	0.0003	0.0001	0.0001
50th percentile		< LOR	< LOR	0.0001	0.0001	0.0003	0.0002	0.0001
80th percentile		< LOR	< LOR	0.0001	0.0004	0.0003	0.0006	0.0002
95th percentile		< LOR	< LOR	0.0002	0.0021	0.0005	0.0007	0.0004
Maximum		< LOR	< LOR	0.0003	0.0033	0.0008	0.0008	0.0004
Chromium – Total (mg/L)	**1.000**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**42%**	17%	**38%**	9%	**100%**	11%	0%
Minimum		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
5th percentile		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
20th percentile		0.001	0.002	0.001	0.007	< LOR	0.015	0.002
50th percentile		0.001	0.004	0.001	0.019	< LOR	0.038	0.020
80th percentile		0.002	0.006	0.006	0.028	< LOR	0.062	0.041
95th percentile		0.002	0.008	0.019	0.145	< LOR	0.078	0.083
Maximum		0.003	0.009	0.025	0.222	< LOR	0.085	0.110
Cobalt – Total (mg/L)	**1.000**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**75%**	**50%**	0%	**64%**	0%	0%
Minimum		< LOR	0.001	0.001	0.002	0.003	0.002	0.001
5th percentile		< LOR	0.001	0.001	0.003	0.003	0.002	0.001
20th percentile		< LOR	0.001	0.001	0.004	0.003	0.009	0.003
50th percentile		< LOR	0.001	0.001	0.009	0.003	0.024	0.011
80th percentile		< LOR	0.001	0.002	0.033	0.007	0.041	0.031
95th percentile		< LOR	0.002	0.014	0.146	0.011	0.053	0.049
Maximum		< LOR	0.002	0.020	0.224	0.012	0.058	0.055
Copper – Total (mg/L)	**0.000 – 0.033**	*Deep bores (Dawson River WQO - Zone 32)*						
	0.000 – 0.010	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		33%	8%	**38%**	9%	**64%**	0%	0%
Minimum		0.001	0.001	0.001	0.001	0.003	0.004	0.002
5th percentile		0.001	0.001	0.001	0.001	0.003	0.005	0.002
20th percentile		0.001	0.002	0.001	0.005	0.003	0.024	0.003
50th percentile		0.001	0.005	0.001	0.022	0.003	0.077	0.020
80th percentile		0.002	0.008	0.004	0.033	0.010	0.123	0.038

	Guideline	Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
95th percentile		0.002	0.011	0.033	0.199	0.015	0.141	0.057
Maximum		0.002	0.012	0.048	0.311	0.018	0.151	0.064
Gallium – Total (mg/L)	**-**	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**92%**	**83%**	**88%**	18%	**100%**	**22%**	**33%**
Minimum		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
5th percentile		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
20th percentile		0.001	0.001	0.001	0.001	< LOR	0.004	0.001
50th percentile		0.001	0.001	0.001	0.006	< LOR	0.018	0.007
80th percentile		0.001	0.001	0.001	0.010	< LOR	0.032	0.016
95th percentile		0.001	0.001	0.005	0.052	< LOR	0.040	0.022
Maximum		0.001	0.002	0.007	0.086	< LOR	0.040	0.024
Iron – Total (mg/L)	**0.20**	*Deep bores (Dawson River WQO - Zone 32)*						
	2.35	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		33%	8%	**38%**	9%	**64%**	0%	0%
Minimum		0.03	0.17	0.44	1.00	10.50	0.05	0.88
5th percentile		0.12	0.19	0.60	1.73	11.10	0.33	0.90
20th percentile		0.26	0.28	0.91	5.66	13.00	17.16	0.93
50th percentile		0.30	0.59	1.24	18.40	14.30	64.30	16.40
80th percentile		0.43	1.10	1.61	43.40	15.00	95.78	44.68
95th percentile		0.58	3.25	25.01	261.00	16.35	107.60	59.92
Maximum		0.67	3.66	37.60	448.00	17.60	112.00	66.60
Lead – Total (mg/L)	**0.10**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**92%**	**42%**	**50%**	9%	**100%**	22%	**33%**
Minimum		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
5th percentile		0.001	0.001	0.001	0.001	< LOR	0.001	0.001
20th percentile		0.001	0.001	0.001	0.004	< LOR	0.014	0.001
50th percentile		0.001	0.002	0.001	0.016	< LOR	0.054	0.018
80th percentile		0.001	0.004	0.002	0.038	< LOR	0.095	0.040
95th percentile		0.001	0.004	0.018	0.192	< LOR	0.117	0.054
Maximum		0.001	0.004	0.027	0.313	< LOR	0.129	0.062
Lithium – Total (mg/L)	**2.500**	*Irrigation (LTV) (only existing guideline)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		0.046	0.020	0.091	0.014	0.549	0.087	0.012
5th percentile		0.063	0.029	0.092	0.016	0.577	0.095	0.024
20th percentile		0.079	0.040	0.095	0.032	0.624	0.111	0.048
50th percentile		0.090	0.062	0.107	0.041	0.683	0.139	0.066
80th percentile		0.095	0.083	0.123	0.046	0.782	0.173	0.079
95th percentile		0.101	0.085	0.146	0.123	0.809	0.192	0.095
Maximum		0.107	0.087	0.155	0.195	0.831	0.203	0.098
Manganese – Total (mg/L)	**0.033**	*Deep bores (Dawson River WQO - Zone 32)*						
	0.020	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9

		Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
% <LOR		0	0	0	0	0	0	0
Minimum		0.025	0.016	0.113	0.229	4.930	0.121	0.209
5th percentile		0.035	0.023	0.131	0.293	5.535	0.148	0.235
20th percentile		0.049	0.038	0.167	0.444	6.140	0.489	0.381
50th percentile		0.052	0.046	0.180	0.574	6.440	0.920	0.675
80th percentile		0.057	0.087	0.199	1.280	6.790	1.090	1.104
95th percentile		0.058	0.106	0.696	7.535	7.170	1.832	1.458
Maximum		0.059	0.120	0.961	12.900	7.400	2.180	1.670
Mercury – Total (mg/L)	**0.002**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**100%**	**100%**	**91%**	**100%**	**100%**	**100%**
Minimum		< LOR	< LOR	< LOR	0.00005	< LOR	< LOR	< LOR
5th percentile		< LOR	< LOR	< LOR	0.00005	< LOR	< LOR	< LOR
20th percentile		< LOR	< LOR	< LOR	0.00005	< LOR	< LOR	< LOR
50th percentile		< LOR	< LOR	< LOR	0.00005	< LOR	< LOR	< LOR
80th percentile		< LOR	< LOR	< LOR	0.00005	< LOR	< LOR	< LOR
95th percentile		< LOR	< LOR	< LOR	0.00018	< LOR	< LOR	< LOR
Maximum		< LOR	< LOR	< LOR	0.00030	< LOR	< LOR	< LOR
Molybdenum – Total (mg/L)	**0.150**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		25%	0%	0%	0%	**100%**	0%	0%
Minimum		0.001	0.002	0.002	0.016	< LOR	0.002	0.010
5th percentile		0.001	0.003	0.002	0.018	< LOR	0.002	0.010
20th percentile		0.001	0.004	0.003	0.019	< LOR	0.004	0.011
50th percentile		0.002	0.008	0.007	0.026	< LOR	0.006	0.013
80th percentile		0.011	0.011	0.065	0.043	< LOR	0.015	0.034
95th percentile		0.023	0.013	0.113	0.067	< LOR	0.020	0.043
Maximum		0.037	0.014	0.121	0.069	< LOR	0.021	0.048
Nickel – Total (mg/L)	**1.000**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		8%	17%	0%	0%	**64%**	0%	0%
Minimum		0.001	0.001	0.001	0.005	0.003	0.009	0.003
5th percentile		0.001	0.001	0.002	0.006	0.003	0.009	0.003
20th percentile		0.001	0.002	0.003	0.006	0.003	0.015	0.005
50th percentile		0.002	0.005	0.004	0.012	0.003	0.033	0.014
80th percentile		0.004	0.008	0.010	0.032	0.006	0.049	0.030
95th percentile		0.004	0.009	0.022	0.154	0.009	0.057	0.037
Maximum		0.005	0.010	0.028	0.234	0.011	0.062	0.039
Selenium – Total (mg/L)	**0.020**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Minimum		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
5th percentile		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
20th percentile		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
50th percentile		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
80th percentile		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR

	Guideline	Deep Monitoring Bores Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	Shallow Monitoring Bores RN58824	Atlas 5M	Atlas 9M
95th percentile		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
Maximum		< LOR	< LOR	< LOR	< LOR	< LOR	< LOR	< LOR
Silver – Total (mg/L)	**0.100**	*Australian Drinking Water (only existing guideline)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**100%**	**100%**	**100%**	**82%**	**100%**	**100%**
Minimum		< LOR	< LOR	< LOR	< LOR	0.003	< LOR	< LOR
5th percentile		< LOR	< LOR	< LOR	< LOR	0.003	< LOR	< LOR
20th percentile		< LOR	< LOR	< LOR	< LOR	0.003	< LOR	< LOR
50th percentile		< LOR	< LOR	< LOR	< LOR	0.003	< LOR	< LOR
80th percentile		< LOR	< LOR	< LOR	< LOR	0.003	< LOR	< LOR
95th percentile		< LOR	< LOR	< LOR	< LOR	0.007	< LOR	< LOR
Maximum		< LOR	< LOR	< LOR	< LOR	0.007	< LOR	< LOR
Strontium - Total	**-**	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		1.010	0.188	2.200	1.170	23.100	0.565	0.559
5th percentile		1.230	0.278	2.232	1.580	24.400	0.713	0.560
20th percentile		1.452	0.429	2.342	2.270	26.400	1.088	0.599
50th percentile		1.640	0.727	3.005	3.330	29.400	1.420	0.720
80th percentile		1.708	1.087	3.724	5.070	31.600	2.246	1.220
95th percentile		1.917	1.238	3.950	6.390	33.600	2.390	1.784
Maximum		2.010	1.260	4.030	7.080	33.900	2.450	2.020
Uranium – Total (mg/L)	**0.200**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**92%**	**75%**	**63%**	0%	**91%**	0%	0%
Minimum		0.001	0.001	0.001	0.003	0.003	0.007	0.004
5th percentile		0.001	0.001	0.001	0.003	0.003	0.007	0.004
20th percentile		0.001	0.001	0.001	0.004	0.003	0.007	0.004
50th percentile		0.001	0.001	0.001	0.007	0.003	0.008	0.005
80th percentile		0.001	0.001	0.006	0.008	0.003	0.011	0.005
95th percentile		0.001	0.002	0.009	0.030	0.003	0.019	0.007
Maximum		0.001	0.002	0.009	0.047	0.003	0.024	0.008
Vanadium – Total (mg/L)	**0.01**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**100%**	**67%**	**88%**	27%	0%	**22%**	**33%**
Minimum		< LOR	0.01	0.01	0.01	0.01	0.01	0.01
5th percentile		< LOR	0.01	0.01	0.01	0.02	0.01	0.01
20th percentile		< LOR	0.01	0.01	0.01	0.03	0.02	0.01
50th percentile		< LOR	0.01	0.01	0.03	0.03	0.08	0.03
80th percentile		< LOR	0.01	0.01	0.05	0.03	0.15	0.08
95th percentile		< LOR	0.02	0.02	0.26	0.03	0.17	0.21
Maximum		< LOR	0.02	0.03	0.43	0.03	0.17	0.28
Zinc – Total (mg/L)	**0.007 – 0.230**	*Deep bores (Dawson River WQO - Zone 32)*						
	0.000 – 20.000	*Shallow bores (Dawson River WQO - Zone 32)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	9%	0%	0%	0%

		Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
Minimum		0.012	0.009	0.020	0.003	0.031	0.028	0.009
5^{th} percentile		0.013	0.011	0.022	0.007	0.061	0.040	0.010
20^{th} percentile		0.015	0.015	0.064	0.027	0.092	0.143	0.017
50^{th} percentile		0.047	0.074	0.150	0.088	0.111	0.480	0.083
80^{th} percentile		0.085	0.140	0.236	0.254	0.142	0.633	0.173
95^{th} percentile		0.262	0.281	0.276	1.204	0.267	1.088	0.280
Maximum		0.404	0.300	0.296	1.830	0.279	1.370	0.334
Ammonia as N (mg/L)	**0.18 – 2.57**	*Toxicant Default Guideline Value (Subject to pH)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0%	0%	0%	0%
Minimum		1.460	0.790	2.160	0.640	1.490	0.080	0.030
5^{th} percentile		1.510	0.818	2.160	0.690	1.535	0.084	0.050
20^{th} percentile		1.636	0.856	2.168	0.800	1.660	0.114	0.080
50^{th} percentile		1.805	1.355	2.250	1.560	1.910	0.190	0.200
80^{th} percentile		1.922	1.630	2.418	2.620	2.260	0.532	0.692
95^{th} percentile		3.030	1.948	2.613	2.850	3.035	0.712	0.842
Maximum		4.300	2.190	2.700	3.020	3.410	0.740	0.910
Nitrate as N (mg/L)	**90.3**	*Livestock Drinking Water*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**58%**	**75%**	**88%**	18%	**64%**	11%	11%
Minimum		0.01	0.01	0.01	0.01	0.01	0.01	0.01
5^{th} percentile		0.01	0.01	0.01	0.01	0.01	0.40	0.53
20^{th} percentile		0.01	0.01	0.01	0.01	0.01	1.05	2.29
50^{th} percentile		0.01	0.01	0.01	0.02	0.01	6.04	7.44
80^{th} percentile		0.02	0.01	0.01	0.36	0.06	13.36	22.54
95^{th} percentile		0.02	0.01	0.01	2.64	0.63	23.88	29.08
Maximum		0.02	0.02	0.02	4.38	1.18	26.00	32.60
Nitrite as N (mg/L)	**-**	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**92%**	**100%**	**100%**	**55%**	**100%**	0%	**33%**
Minimum		0.005	<LOR	<LOR	0.005	<LOR	0.020	0.005
5^{th} percentile		0.005	<LOR	<LOR	0.005	<LOR	0.020	0.005
20^{th} percentile		0.005	<LOR	<LOR	0.005	<LOR	0.020	0.005
50^{th} percentile		0.005	<LOR	<LOR	0.005	<LOR	0.030	0.030
80^{th} percentile		0.005	<LOR	<LOR	0.020	<LOR	0.224	0.268
95^{th} percentile		0.034	<LOR	<LOR	0.020	<LOR	0.752	0.370
Maximum		0.070	<LOR	<LOR	0.020	<LOR	1.100	0.410
Nitrogen as N (mg/L)	**5**	*Irrigation (LTV) (only existing guideline)*						
Count (n)		12	12	8	11	11	9	9
% <LOR		0%	0%	0%	0	0	0	0
Minimum		1.60	1.50	2.20	2.90	1.60	5.50	1.60
5^{th} percentile		1.71	1.56	2.27	3.00	1.75	6.66	2.40
20^{th} percentile		1.80	1.60	2.40	3.20	2.00	8.76	4.80
50^{th} percentile		1.90	1.75	2.65	3.50	2.50	13.80	11.70
80^{th} percentile		2.18	2.04	2.94	4.20	3.00	21.28	30.14
95^{th} percentile		3.75	2.43	3.17	13.75	4.25	30.82	35.54

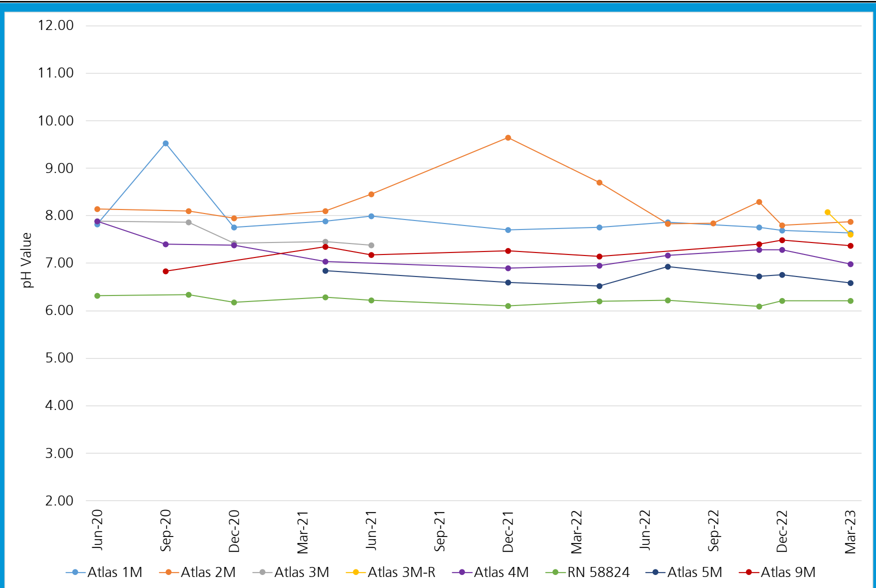
	Guideline	Deep Monitoring Bores				Shallow Monitoring Bores		
	Guideline	Atlas 1M	Atlas 2M	Atlas 3M / 3M-R	Atlas 4M	RN58824	Atlas 5M	Atlas 9M
Maximum		5.40	2.70	3.20	18.10	5.40	34.70	35.70
Phosphorus as P (mg/L)	**-**	*No default guideline value – Value of 0.05 for Irrigation (LTV) to manage bioclogging*						
Count (n)		12	12	8	11	11	9	9
% <LOR		25%	0%	**63%**	9%	9%	11%	0%
Minimum		0.010	0.020	0.005	0.025	0.025	0.005	0.040
5th percentile		0.010	0.031	0.010	0.038	0.038	0.015	0.060
20th percentile		0.020	0.044	0.022	0.100	0.080	0.222	0.102
50th percentile		0.023	0.070	0.025	0.330	0.120	1.430	0.340
80th percentile		0.029	0.088	0.028	0.890	0.140	2.074	0.878
95th percentile		0.044	0.113	0.297	3.615	0.210	2.560	2.084
Maximum		0.060	0.140	0.440	6.220	0.240	2.680	2.820
TPH (C10 – C36) (µg/L)	-	*No default guideline value*						
Count (n)		12	12	8	11	11	9	9
% <LOR		**42%**	**58%**	**88%**	9%	**100%**	11%	11%
Minimum		25	25	25	25	<LOR	25	25
5th percentile		25	25	25	103	<LOR	59	67
20th percentile		25	25	25	220	<LOR	236	136
50th percentile		110	25	25	370	<LOR	340	200
80th percentile		168	140	25	720	<LOR	456	356
95th percentile		185	370	54	1475	<LOR	2406	1514
Maximum		190	370	70	1550	<LOR	3670	2270
Faecal Coliforms (CFU/100 mL)	**<100**	*Dawson River WQO – Stock Watering (Table 3)*						
Count (n)		12	12	8	10	10	8	8
% <LOR		**92%**	**67%**	**100%**	**60%**	0%	**25%**	**50%**
Minimum		0.5	0.5	<LOR	5.0	0.5	22.0	5.0
5th percentile		0.5	0.5	<LOR	5.0	0.5	31.8	5.0
20th percentile		0.5	0.5	<LOR	41.0	2.1	50.0	5.0
50th percentile		0.5	0.8	<LOR	180.0	13.5	250.0	7.5
80th percentile		0.5	90.8	<LOR	442.0	298.0	1800.0	186.0
95th percentile		0.5	3107.5	<LOR	495.5	3482.5	6140.0	1405.0
Maximum		0.5	6600.0	<LOR	500.0	5800.0	8100.0	2000.0

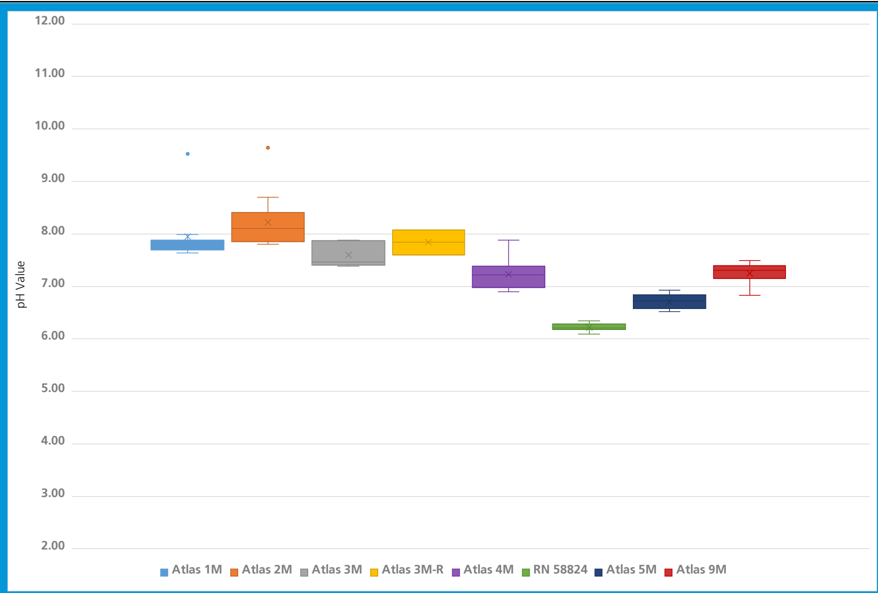
Where a parameter has not been detected, a simple adjustment has been applied (DES, 2021) – Refer to Section 6.2 of this report.

Appendix 3

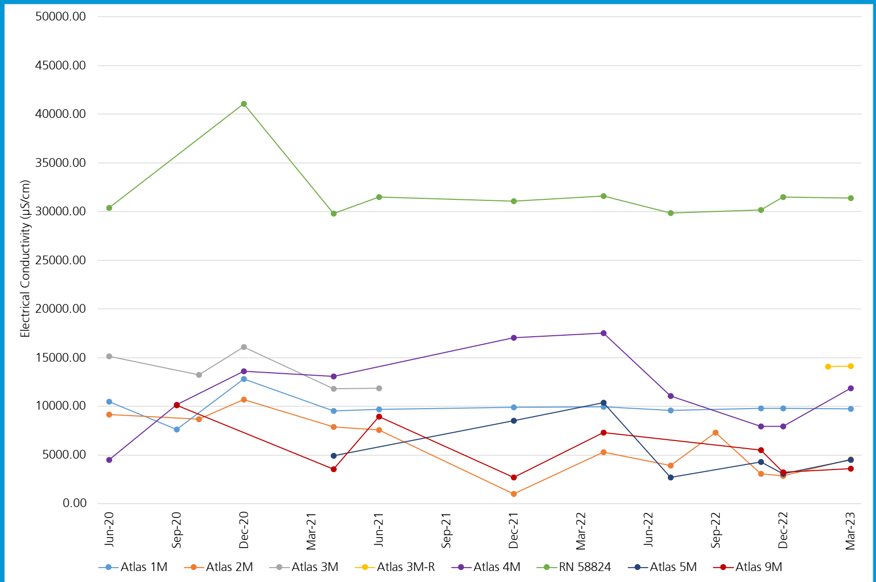
Time Series and Box Plots

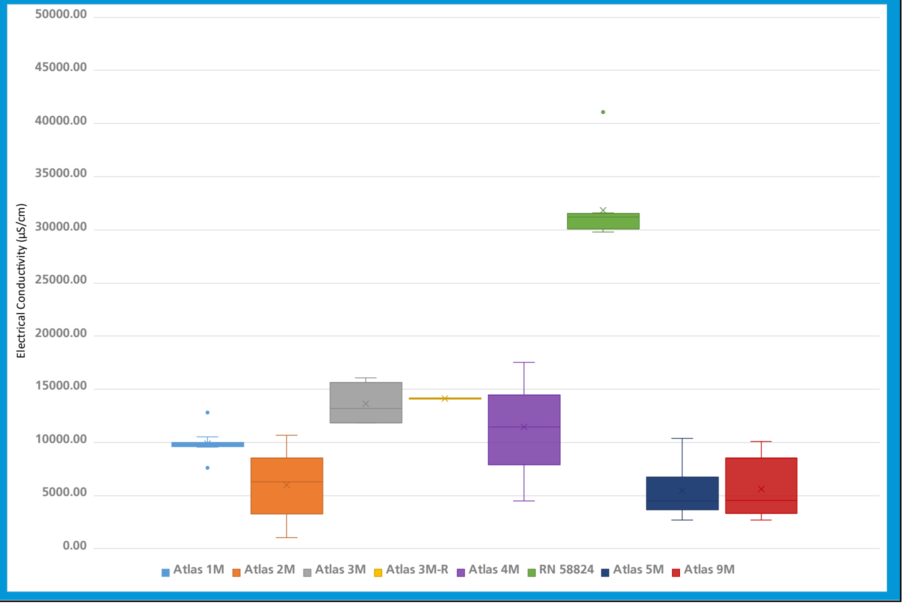
pH Value



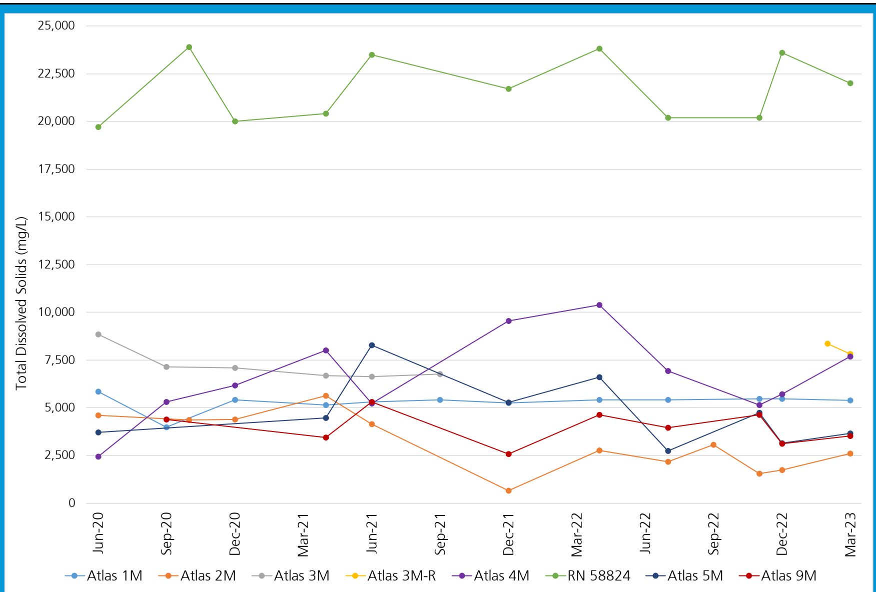


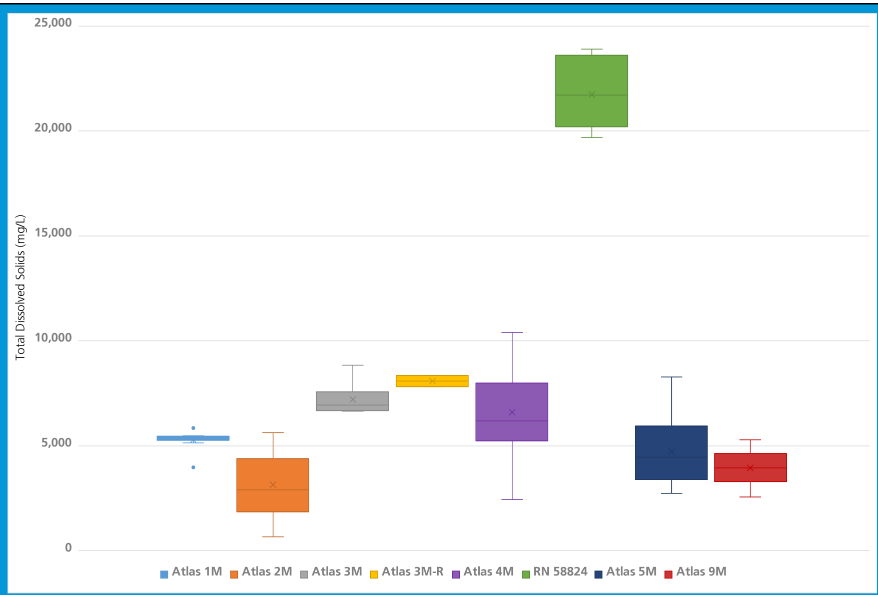
Electrical Conductivity (µS/cm)



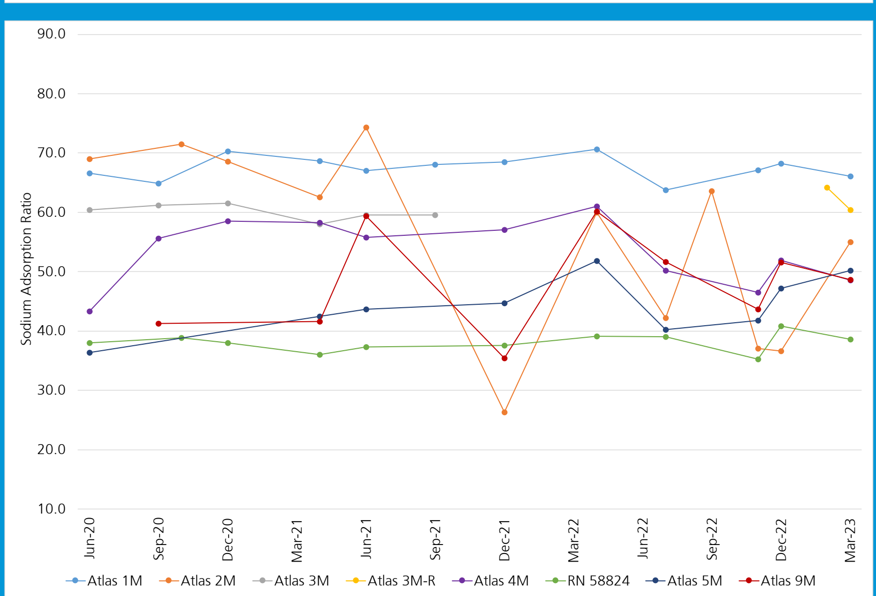


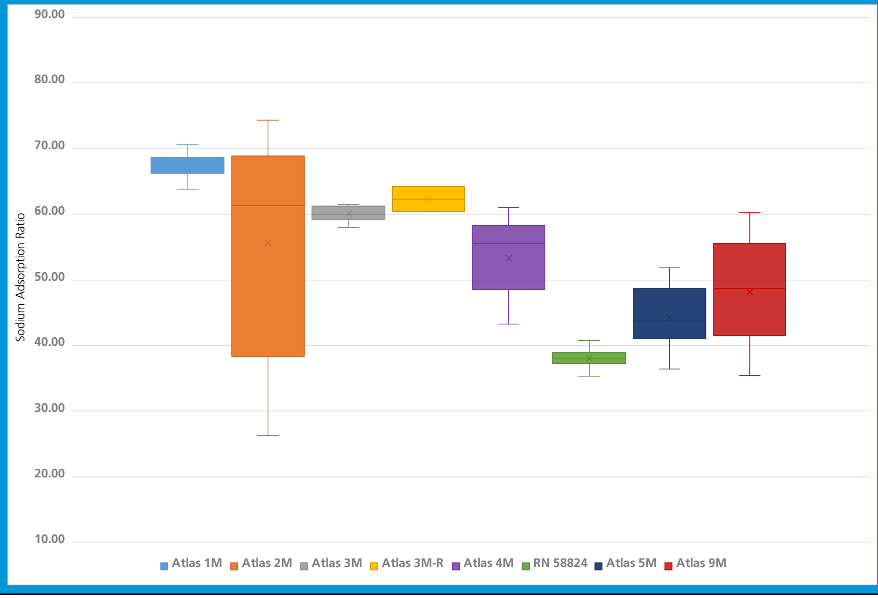
Total Dissolved Solids (TDS)



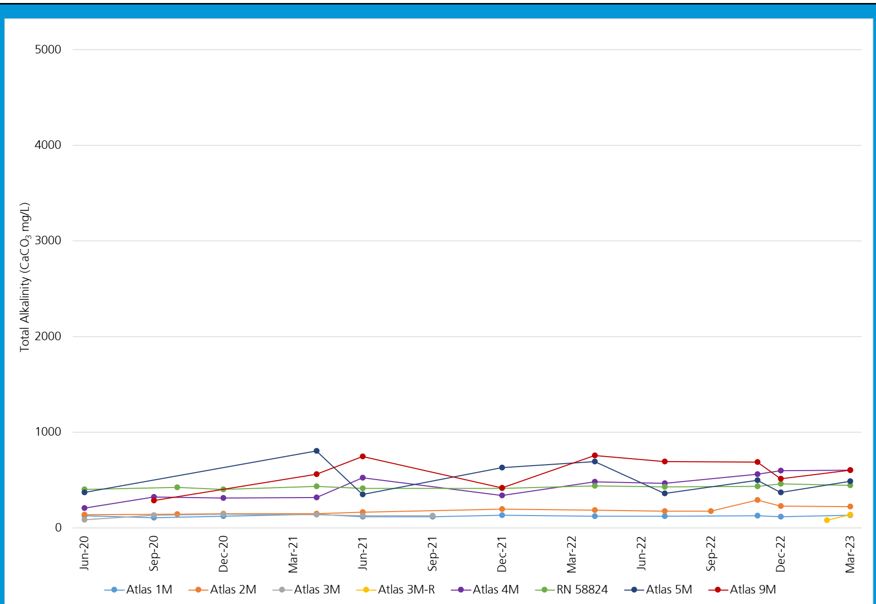


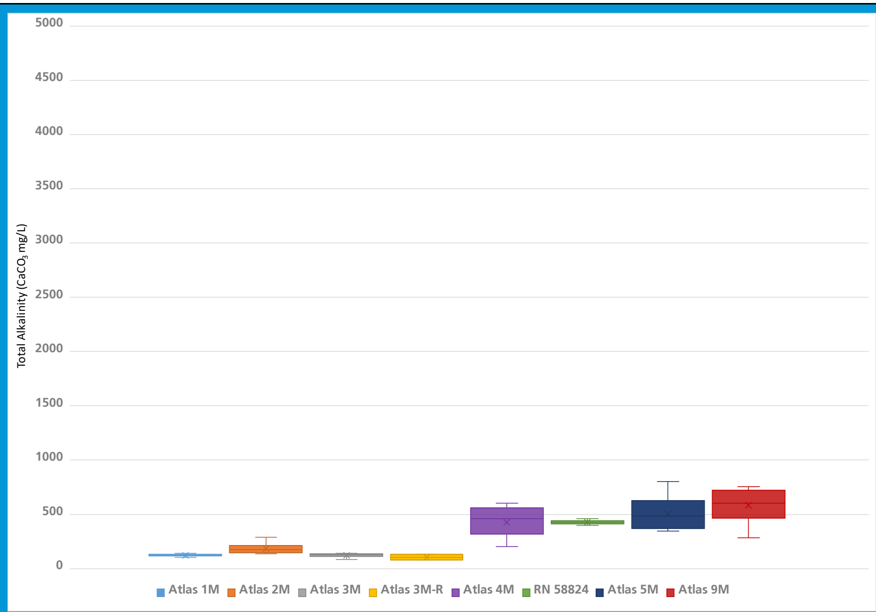
Sodium Adsorption Ratio



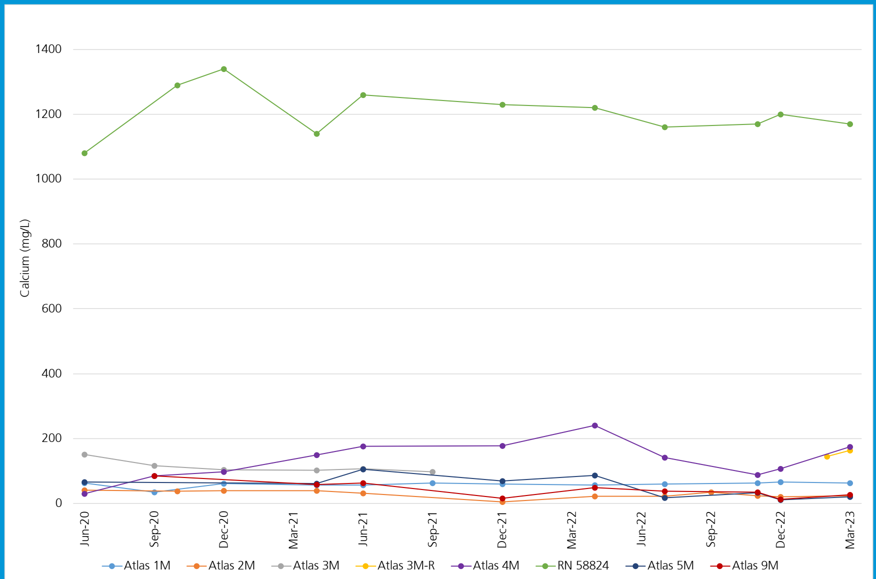


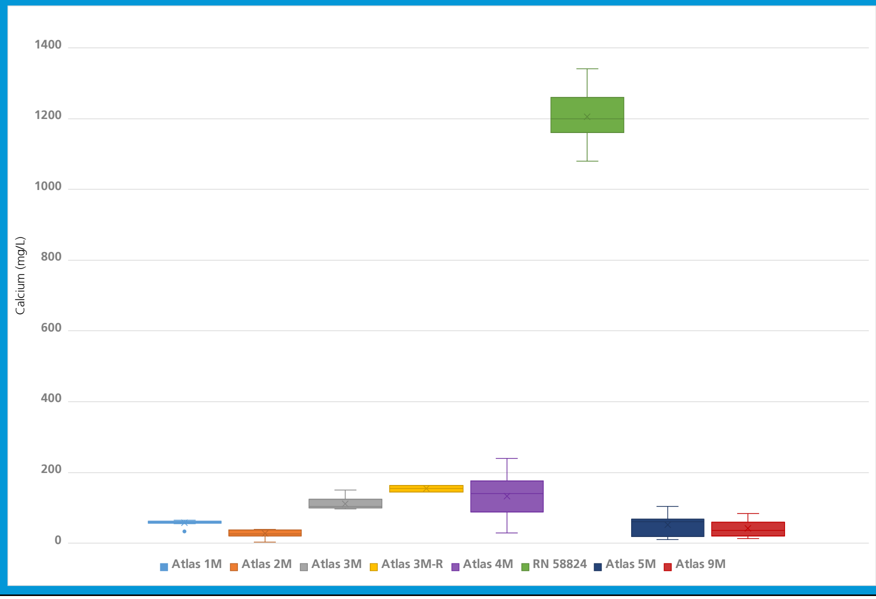
Total Alkalinity (mg/L as $CaCO_3$)



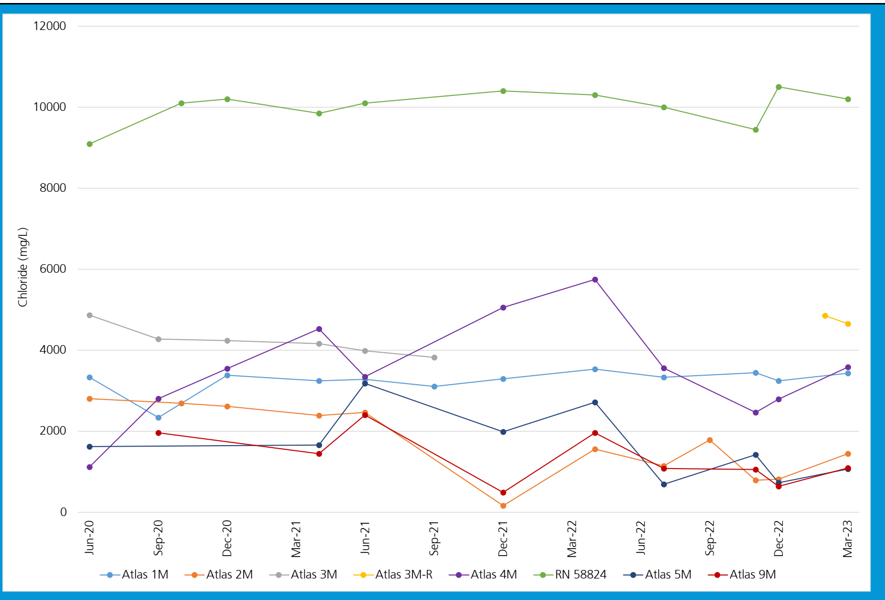


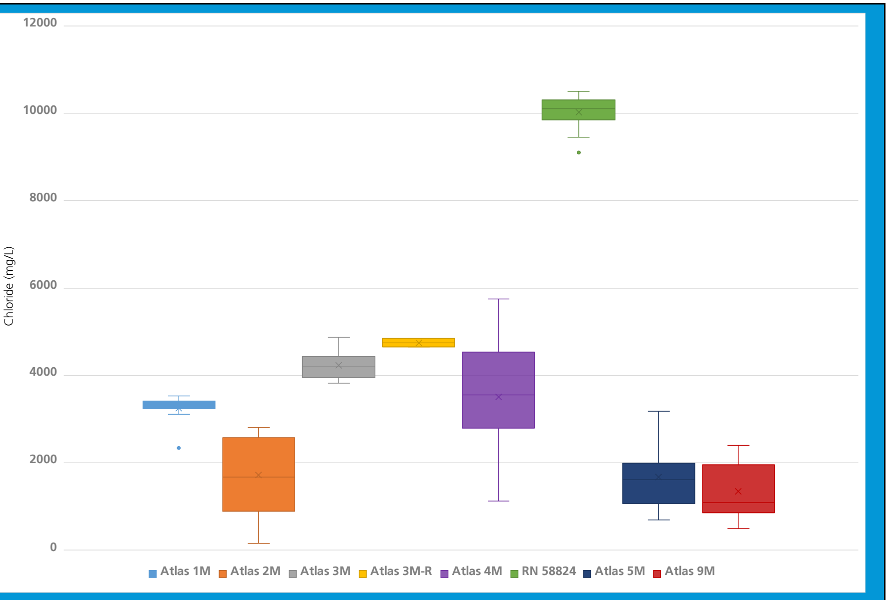
Calcium (mg/L)



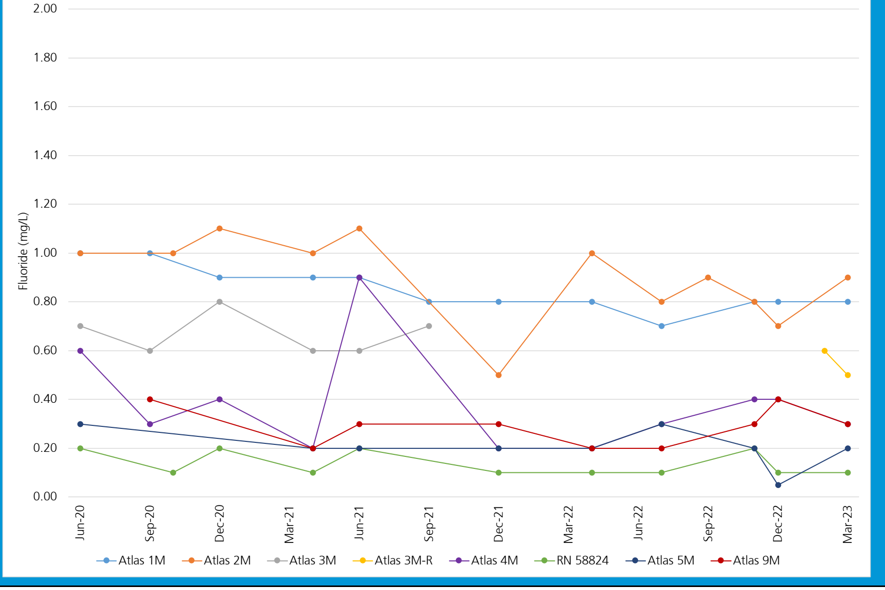


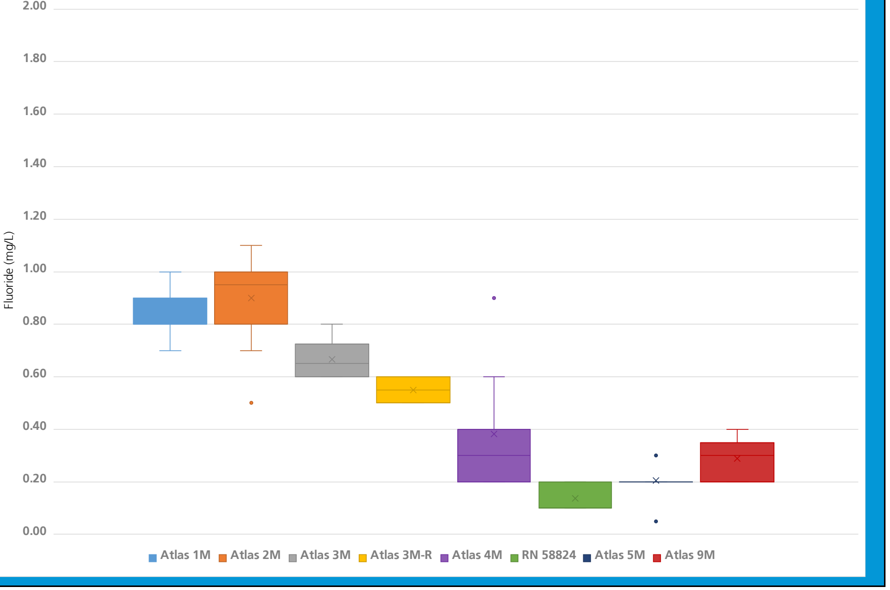
Chloride (mg/L)



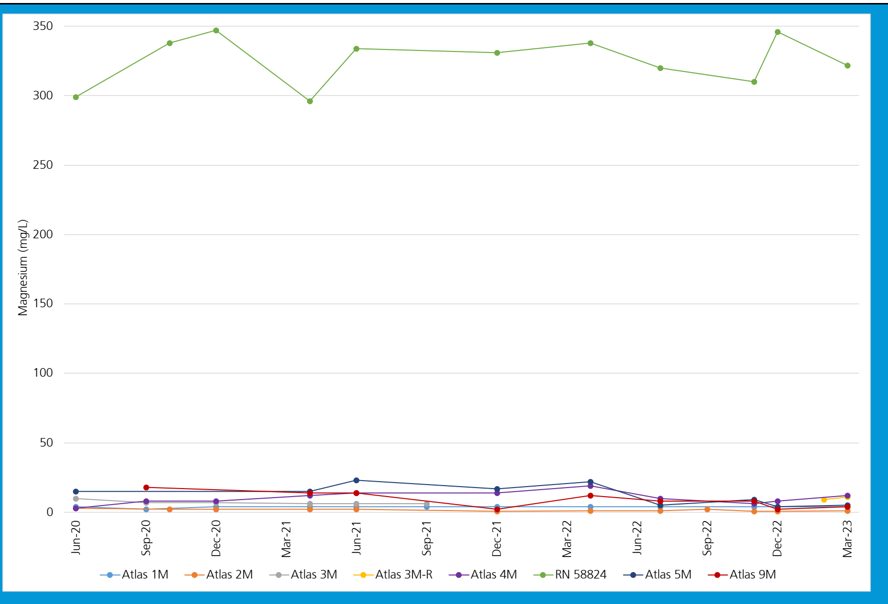


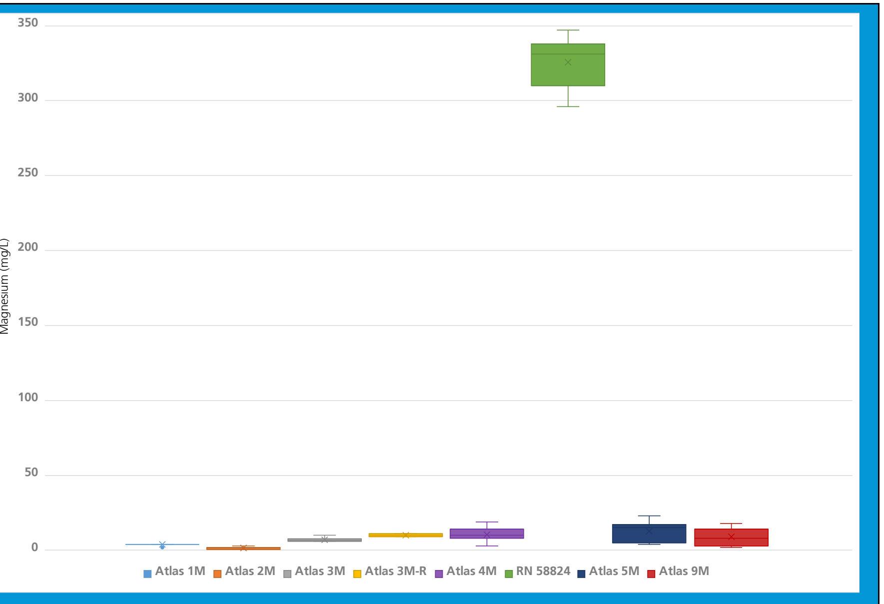
Fluoride (mg/L)



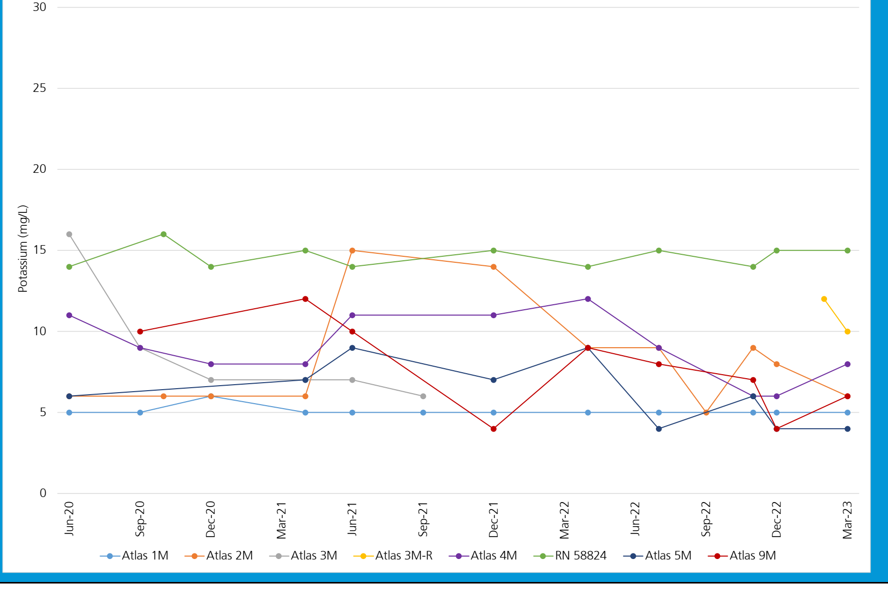


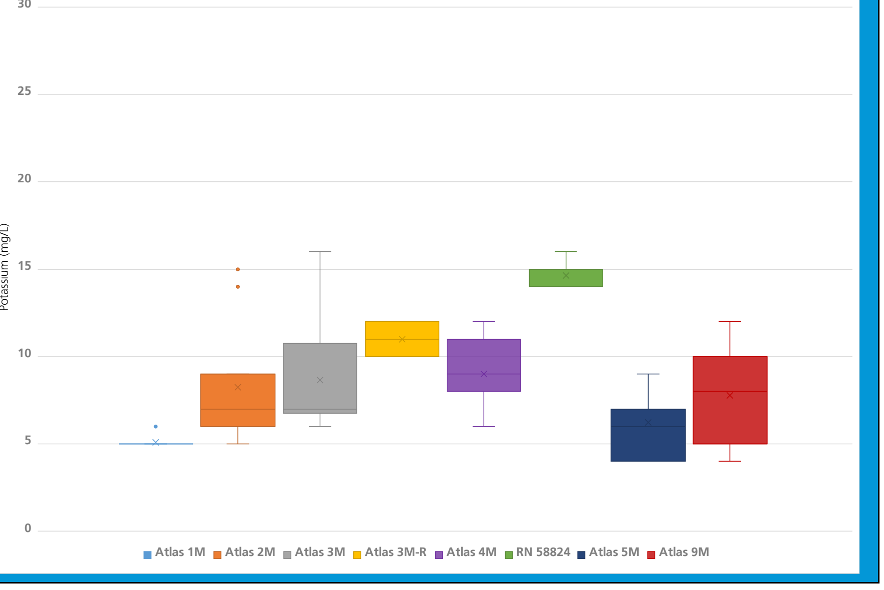
Magnesium (mg/L)



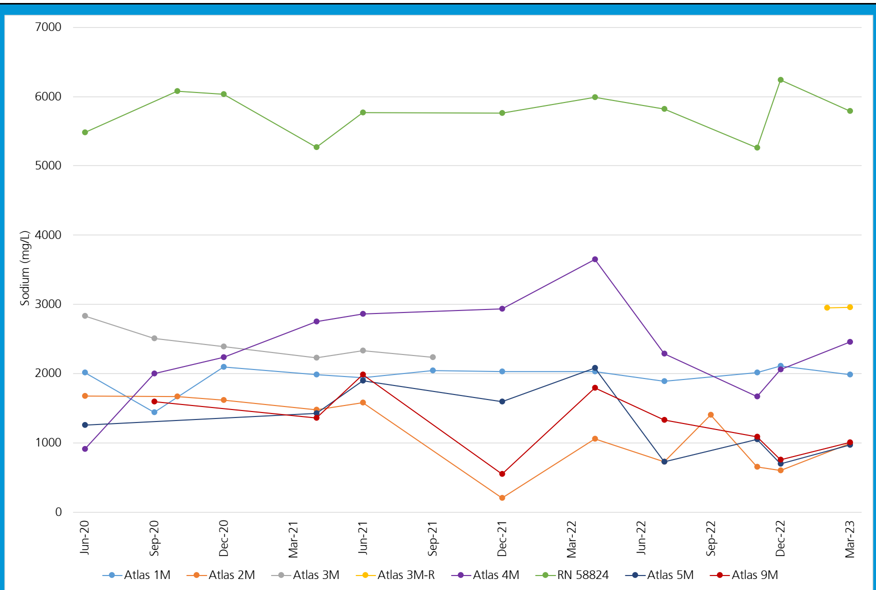


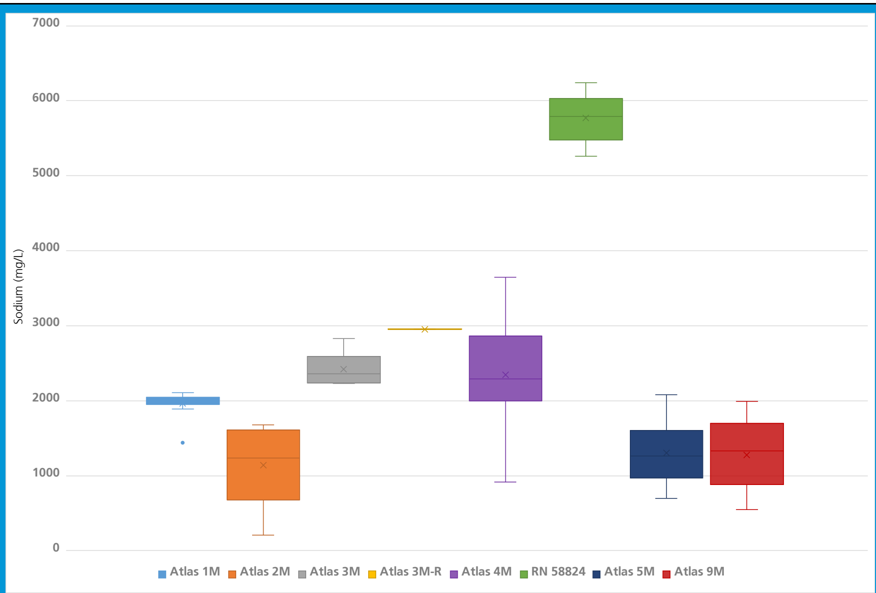
Potassium (mg/L)



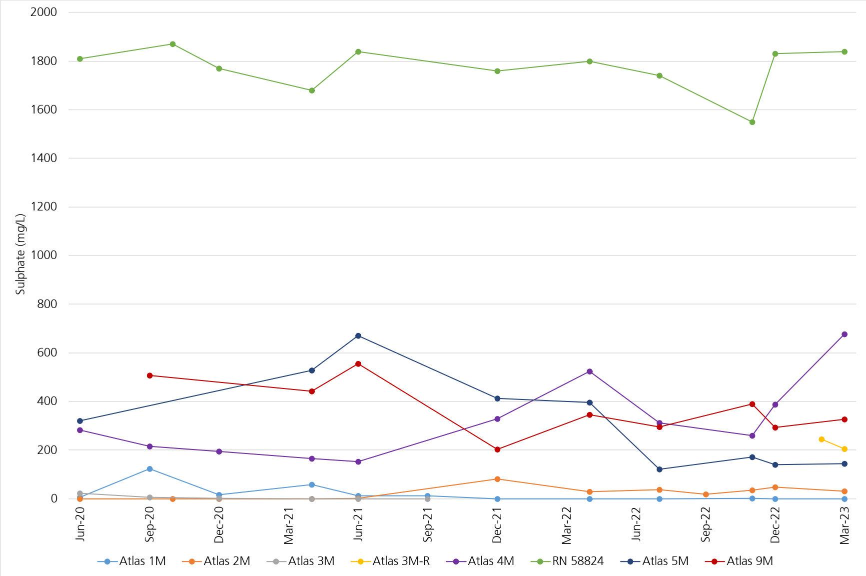


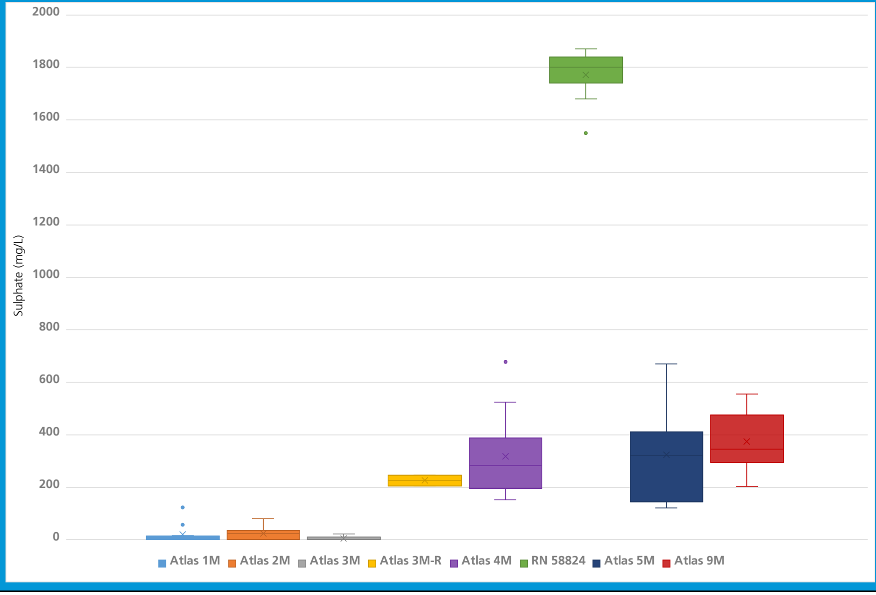
Sodium (mg/L)



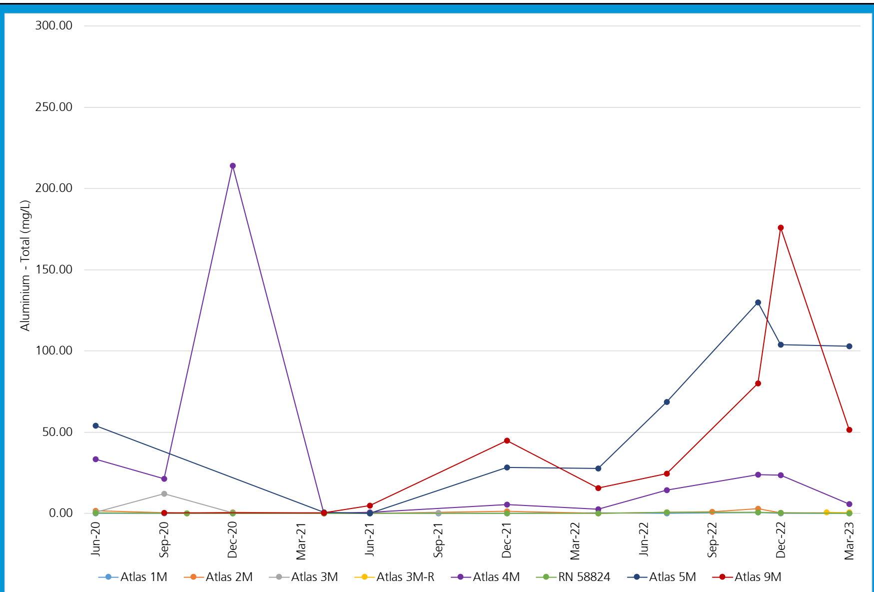


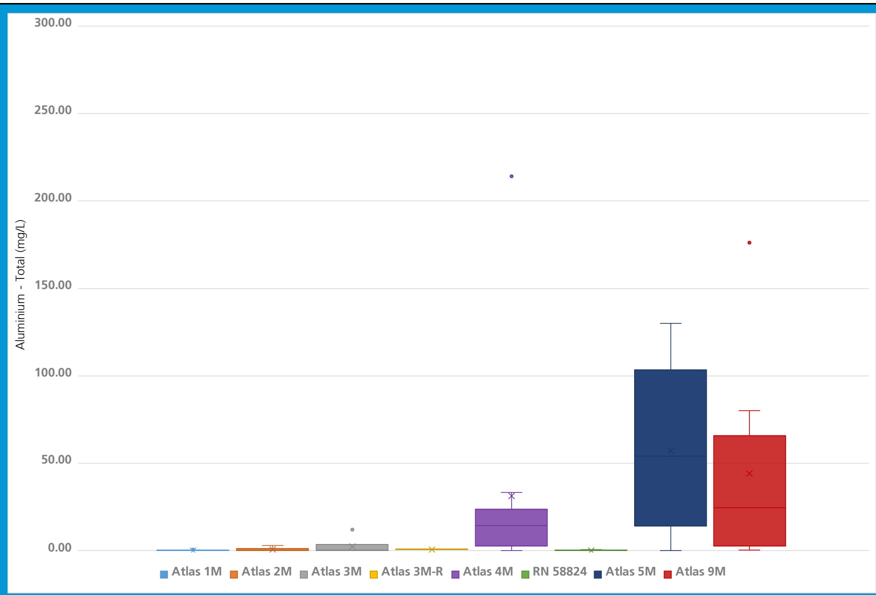
Sulphate (mg/L)



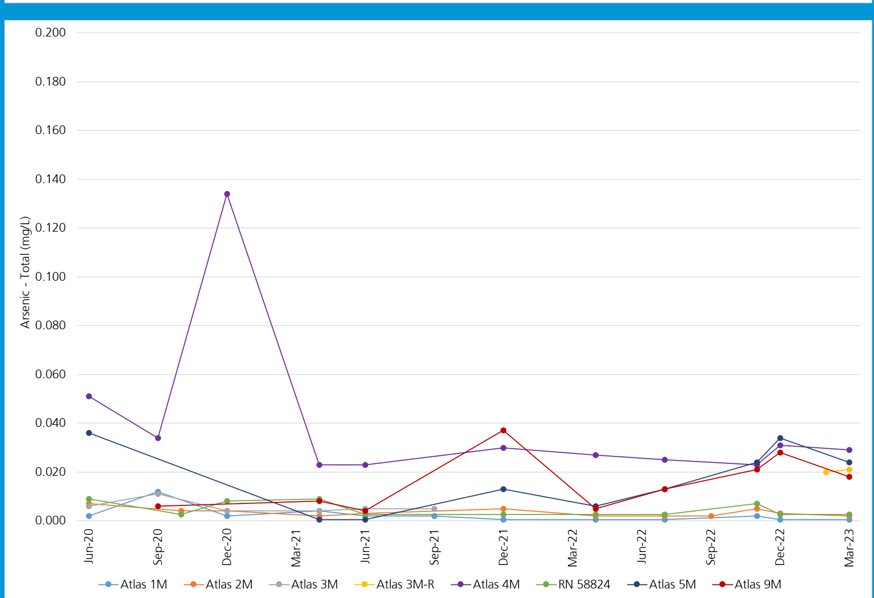


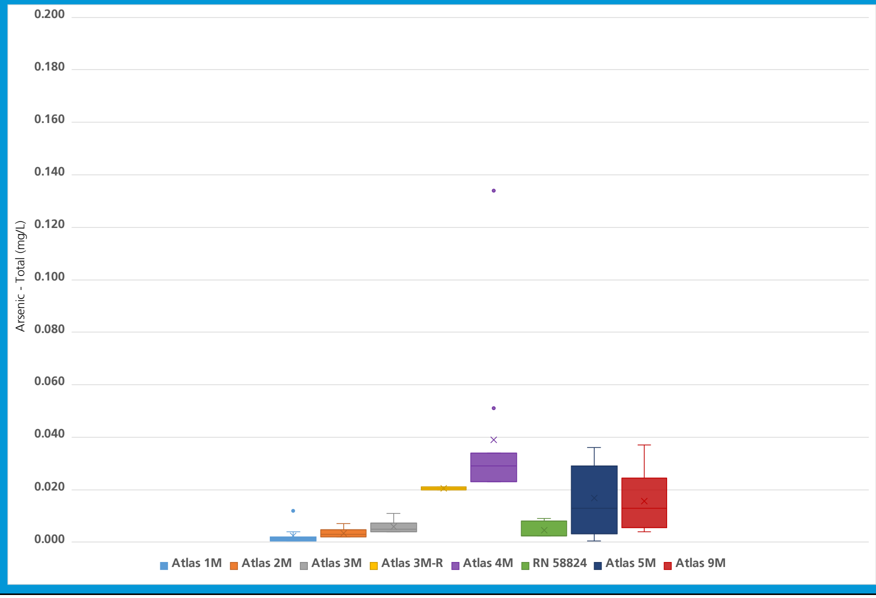
Aluminium – Total (mg/L)



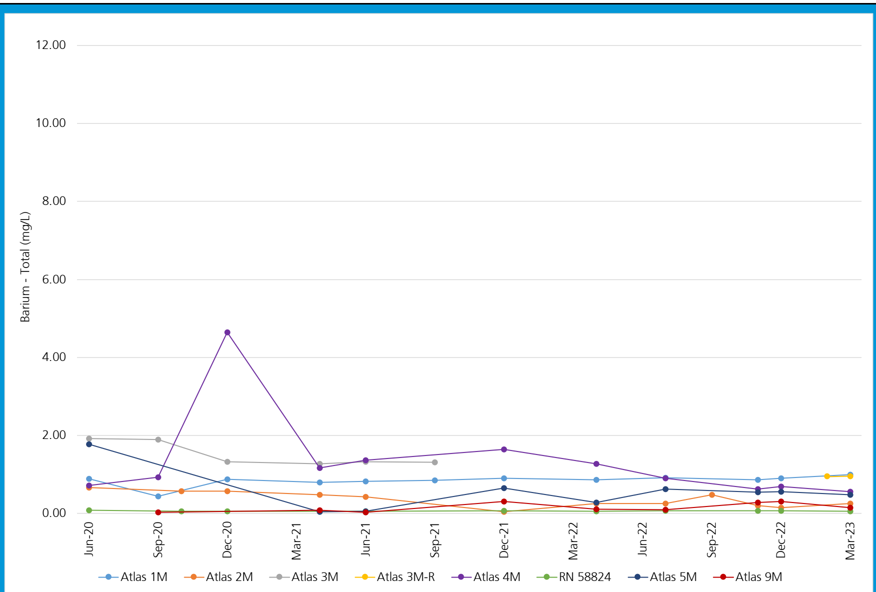


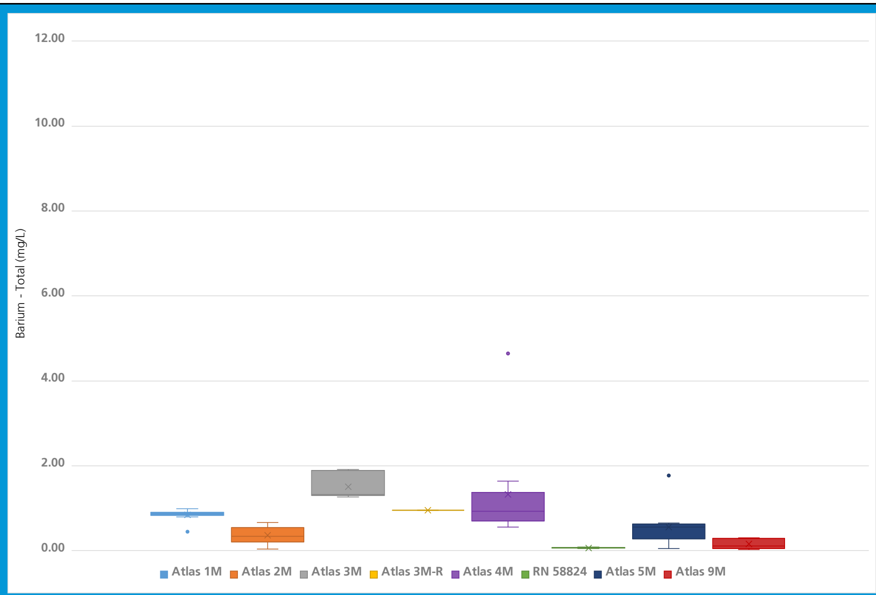
Arsenic – Total (mg/L)



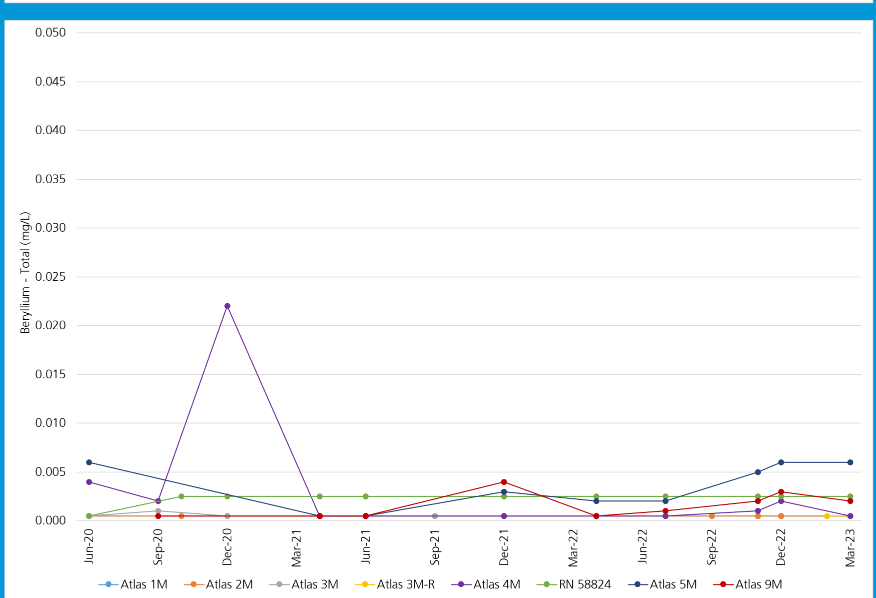


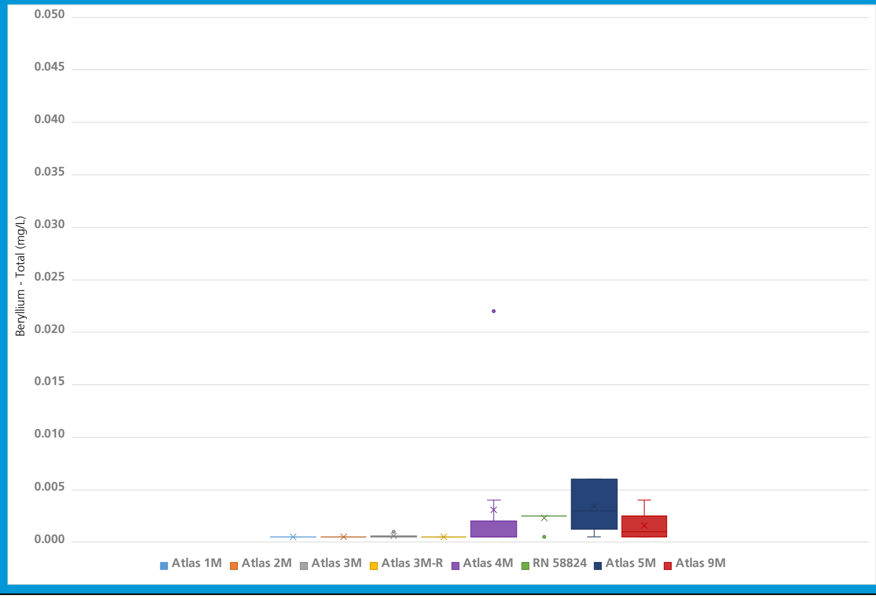
Barium – Total (mg/L)



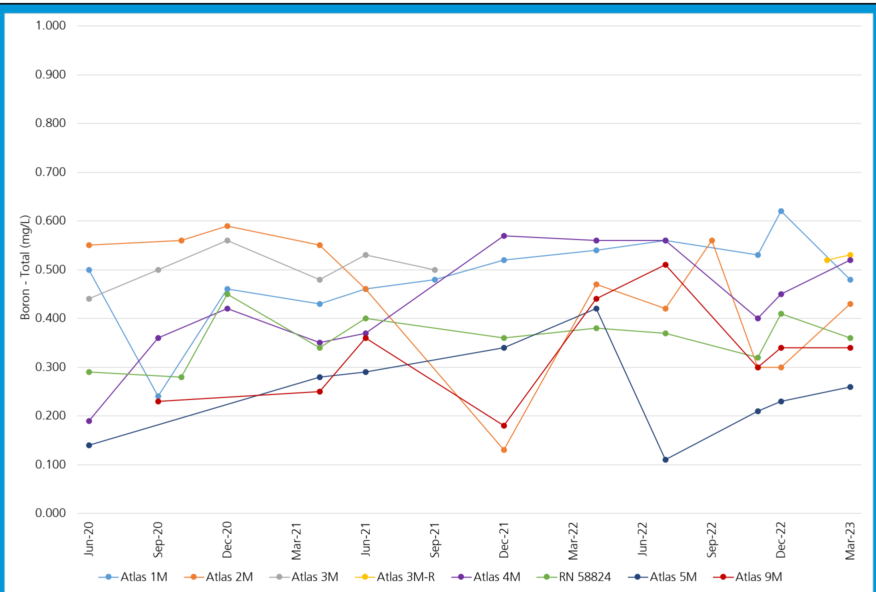


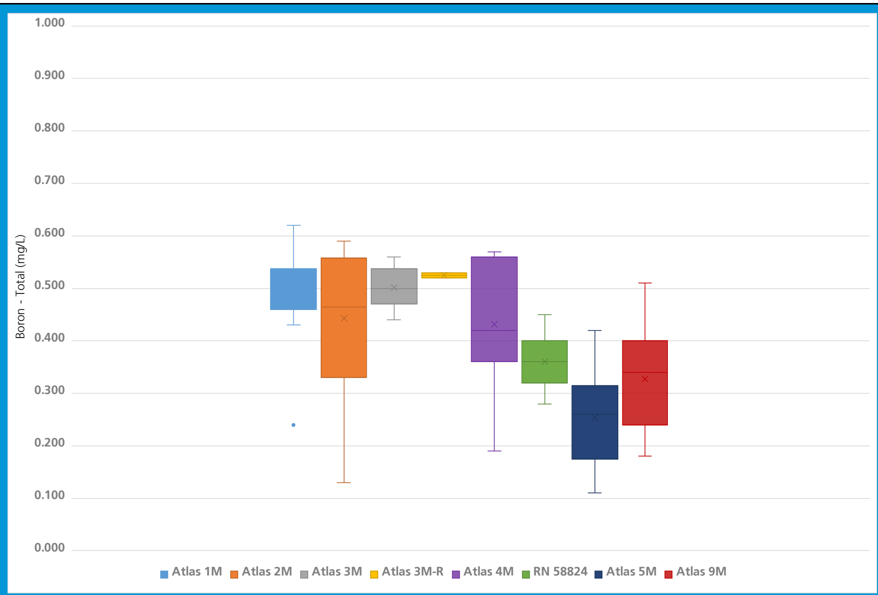
Beryllium – Total (mg/L)



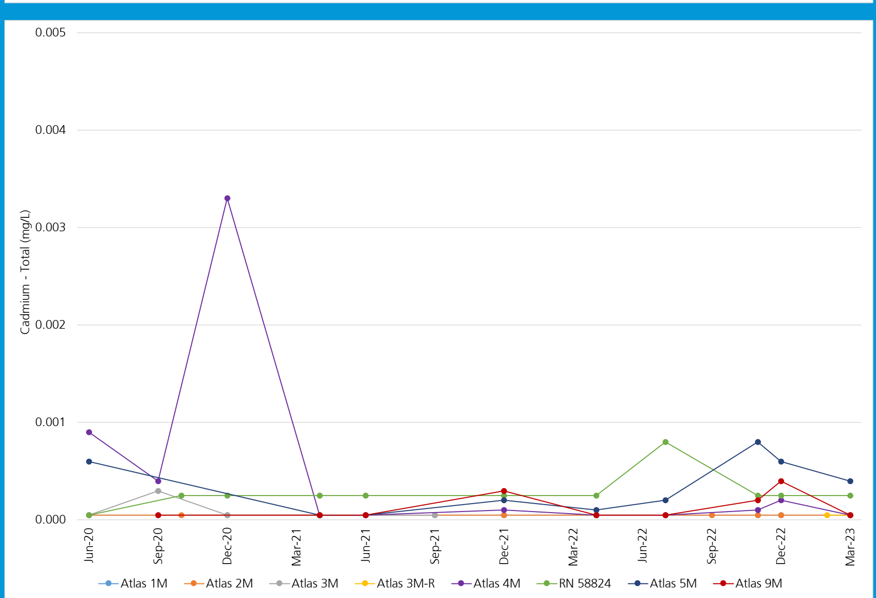


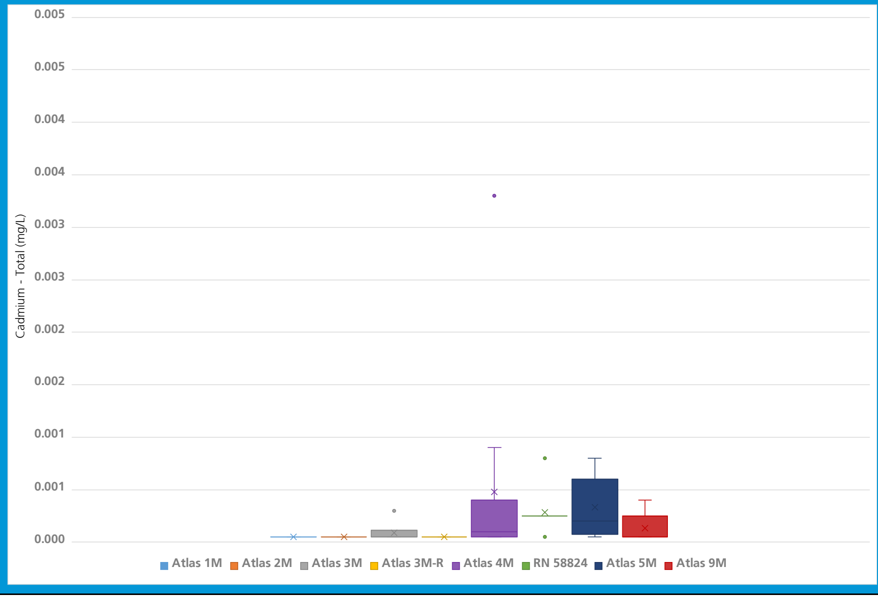
Boron – Total (mg/L)



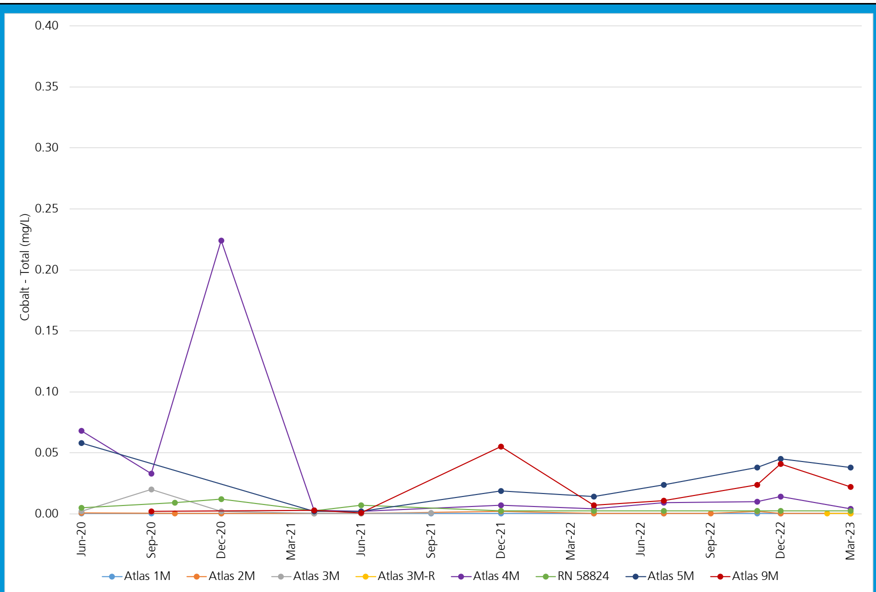


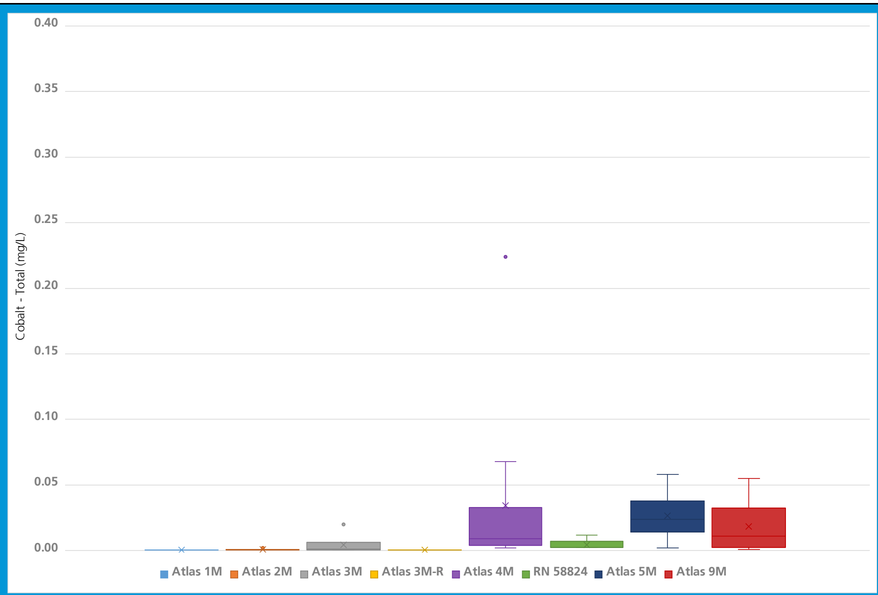
Cadmium – Total (mg/L)



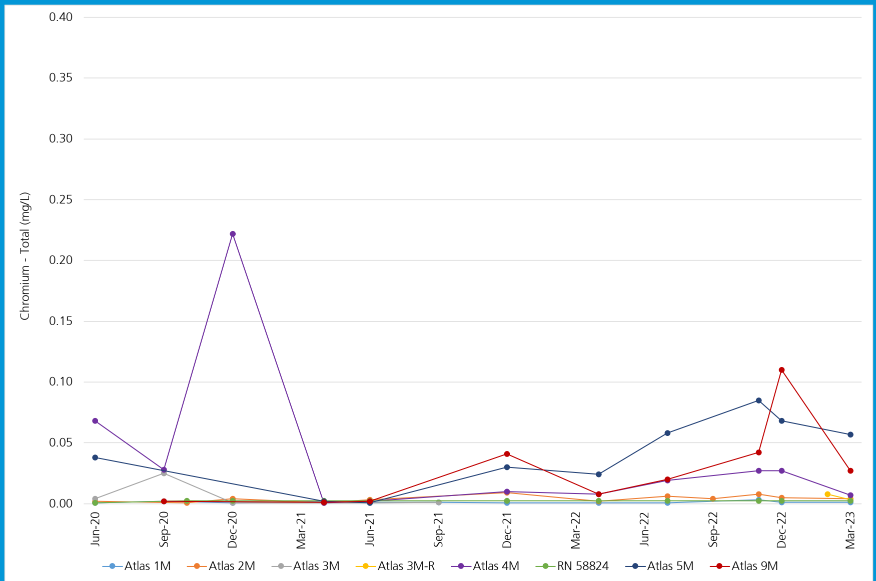


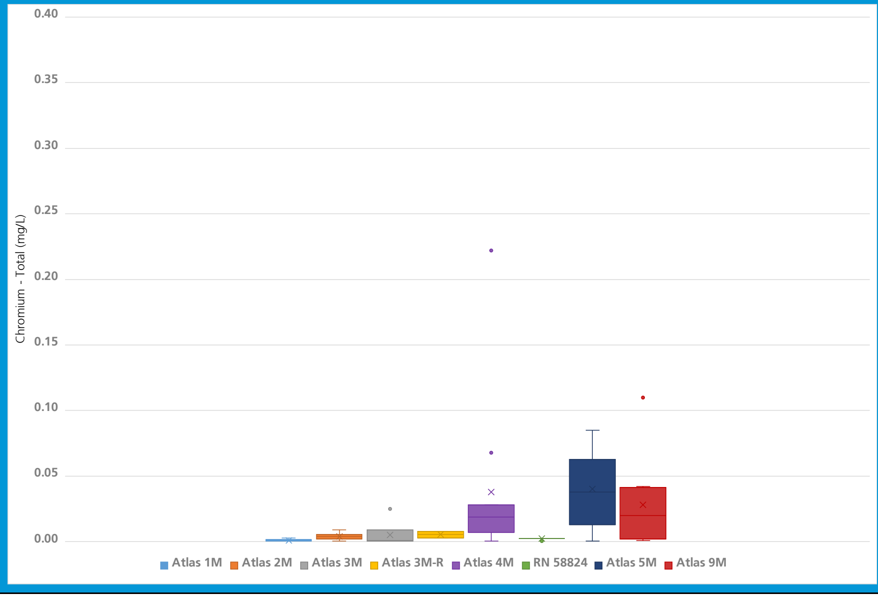
Cobalt – Total (mg/L)



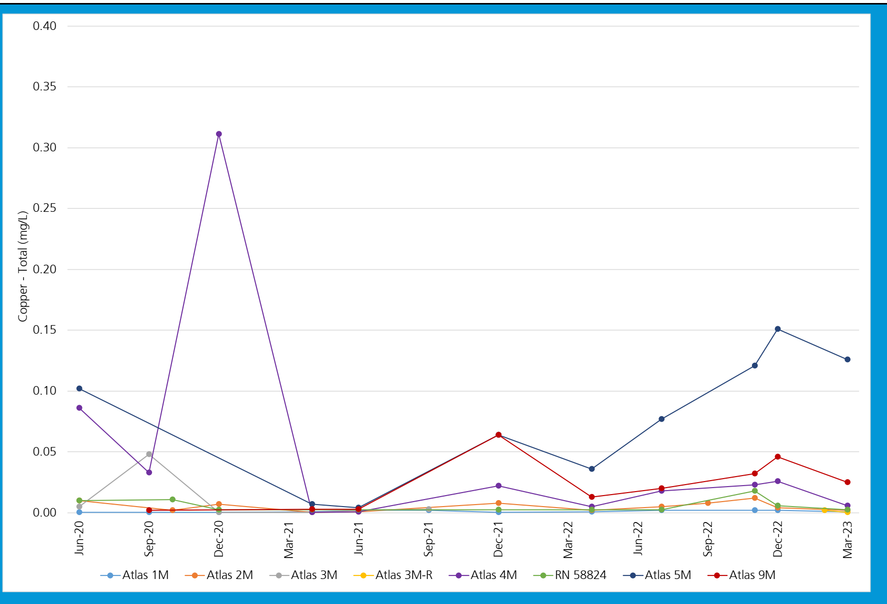


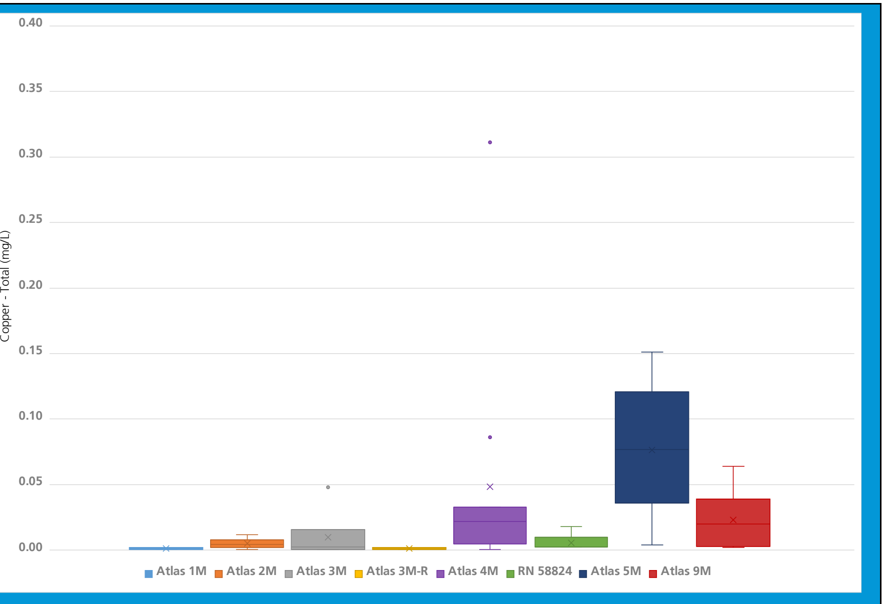
Chromium – Total (mg/L)



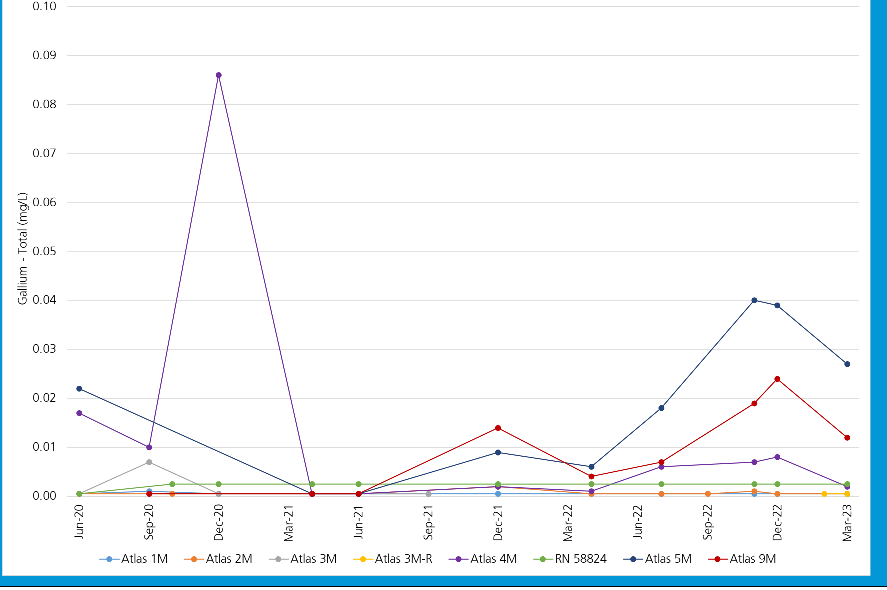


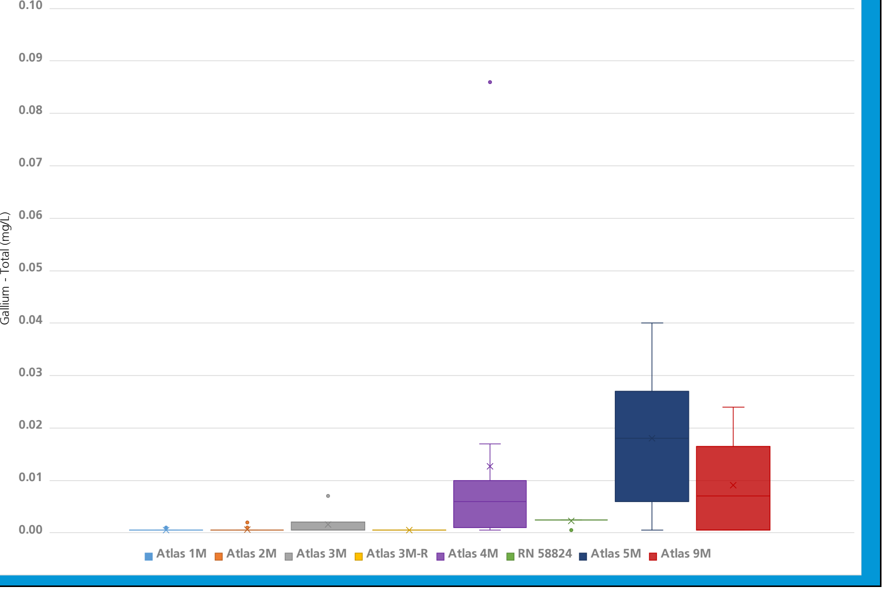
Copper – Total (mg/L)



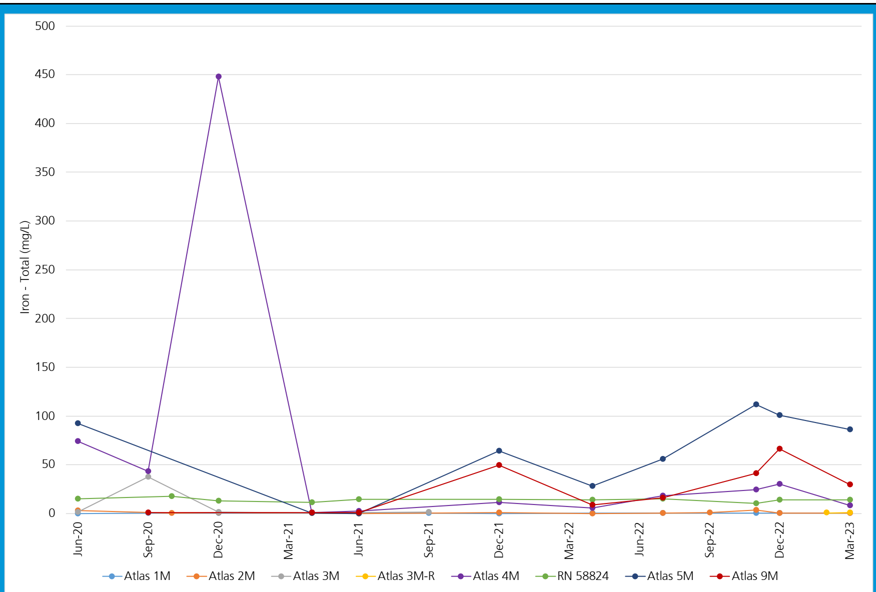


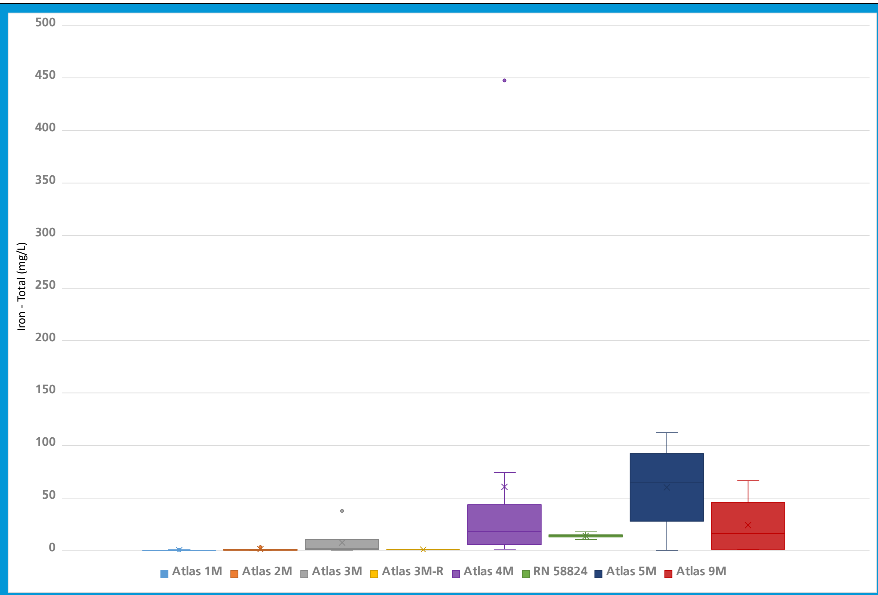
Gallium – Total (mg/L)



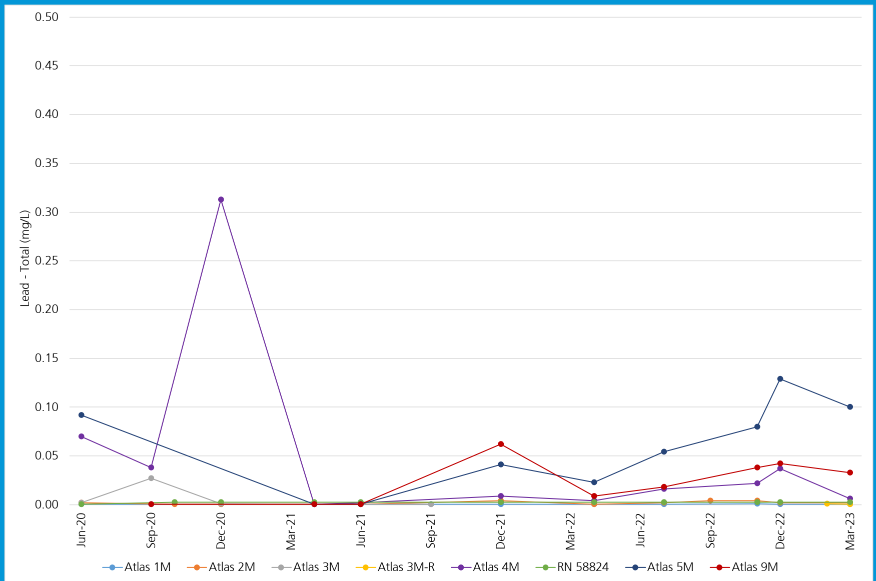


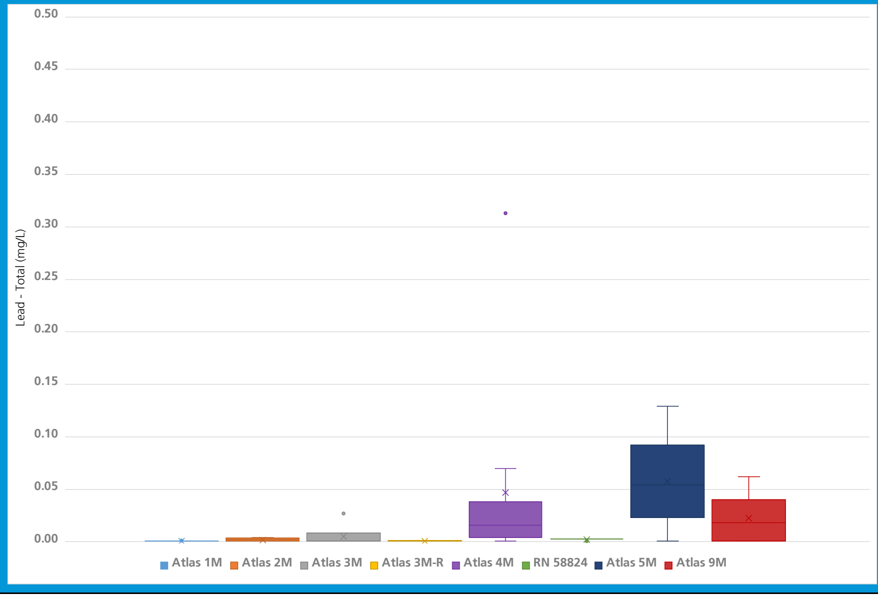
Iron – Total (mg/L)



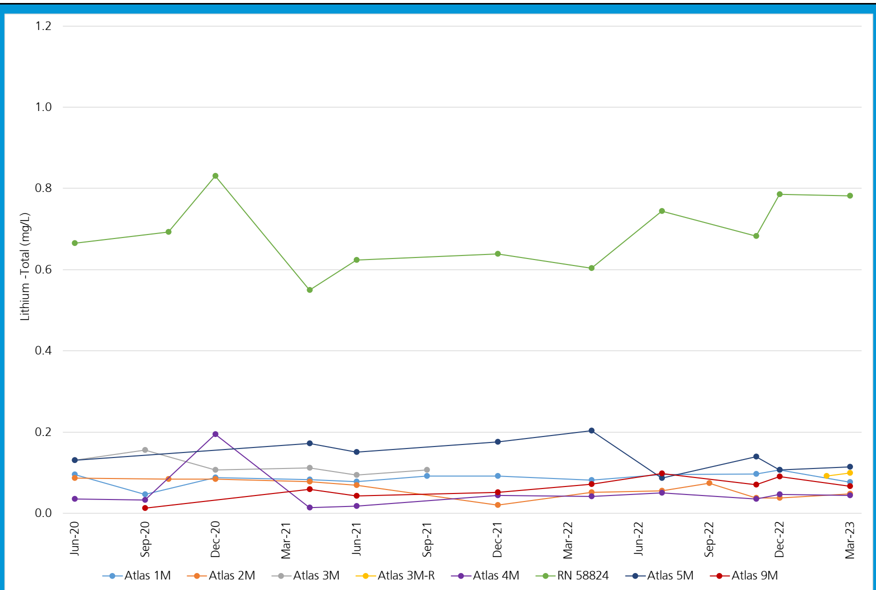


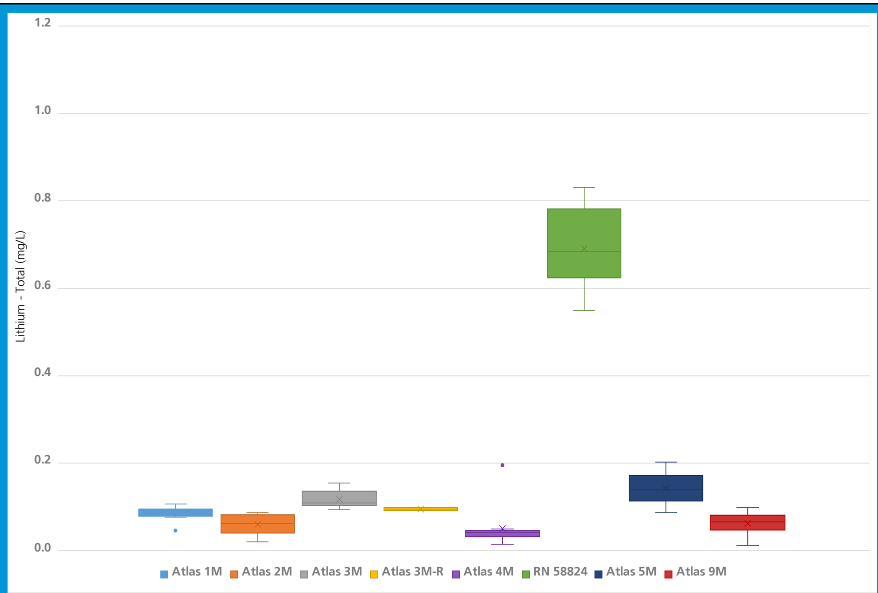
Lead – Total (mg/L)



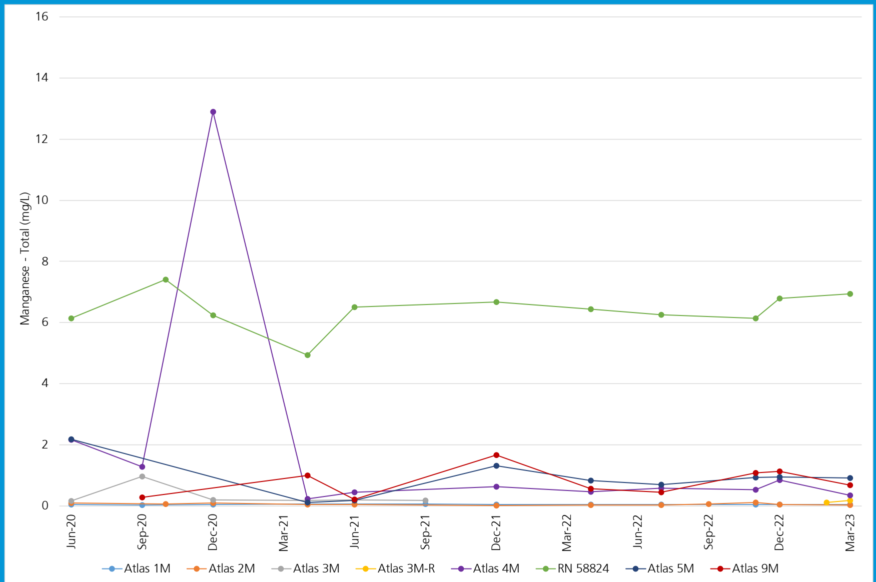


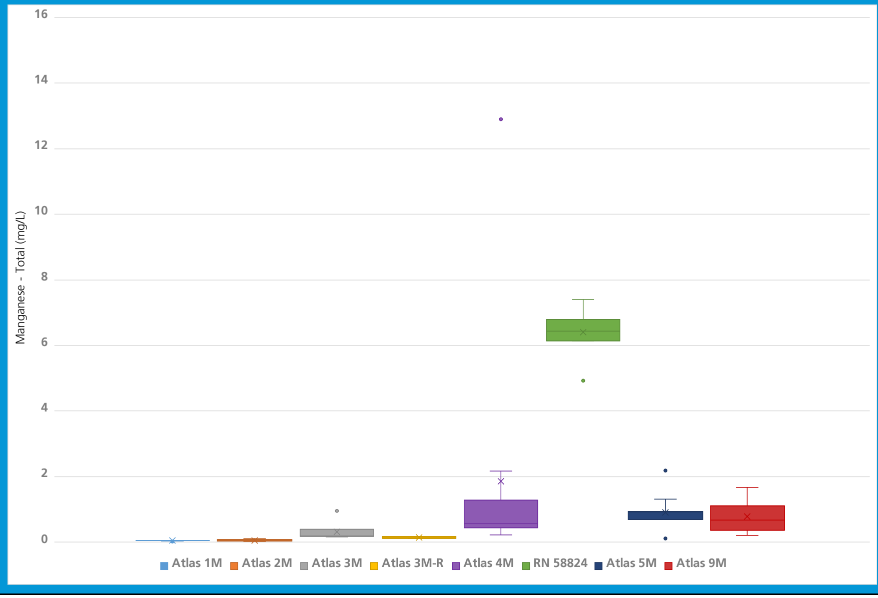
Lithium – Total (mg/L)



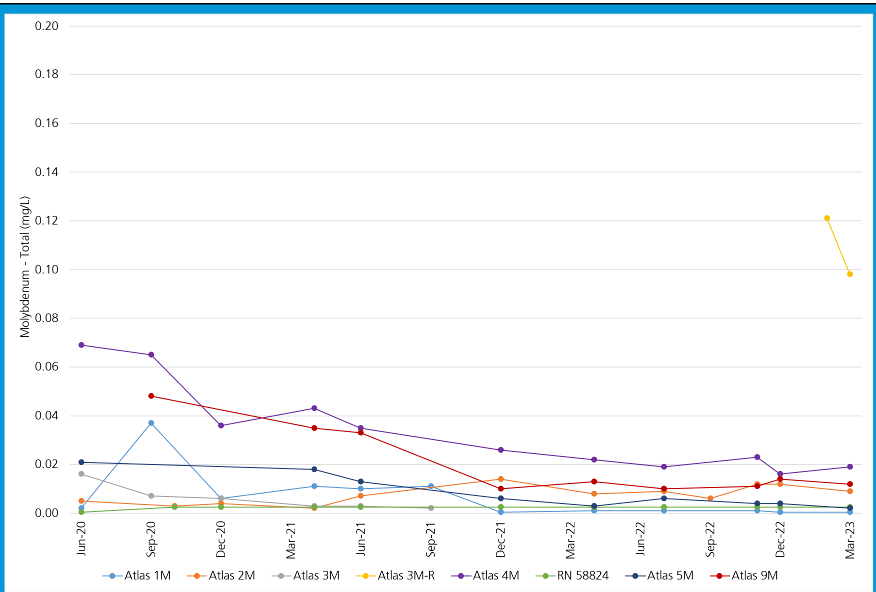


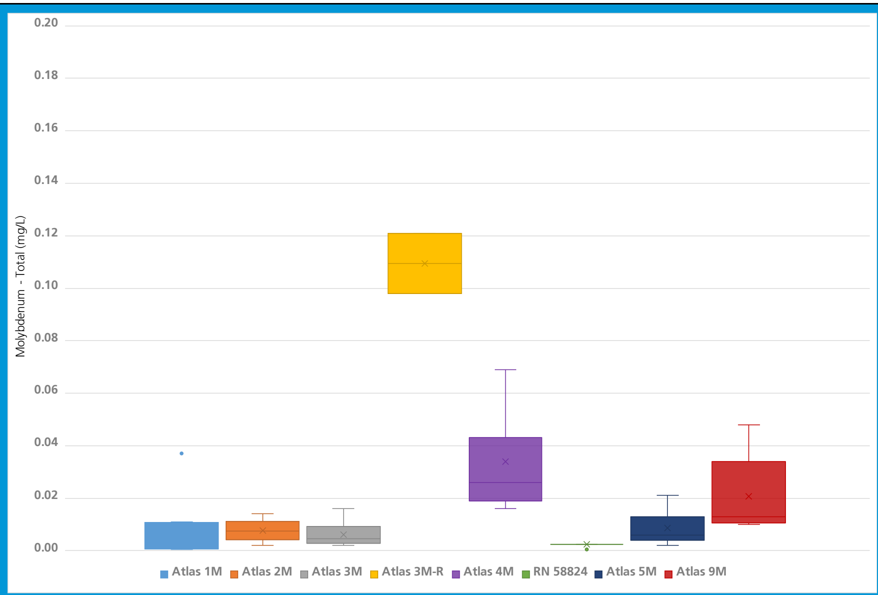
Manganese – Total (mg/L)



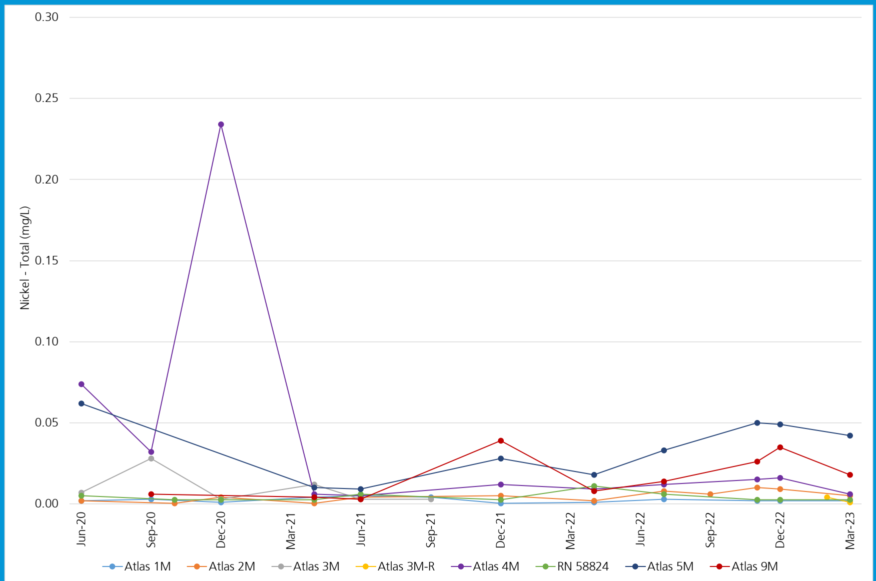


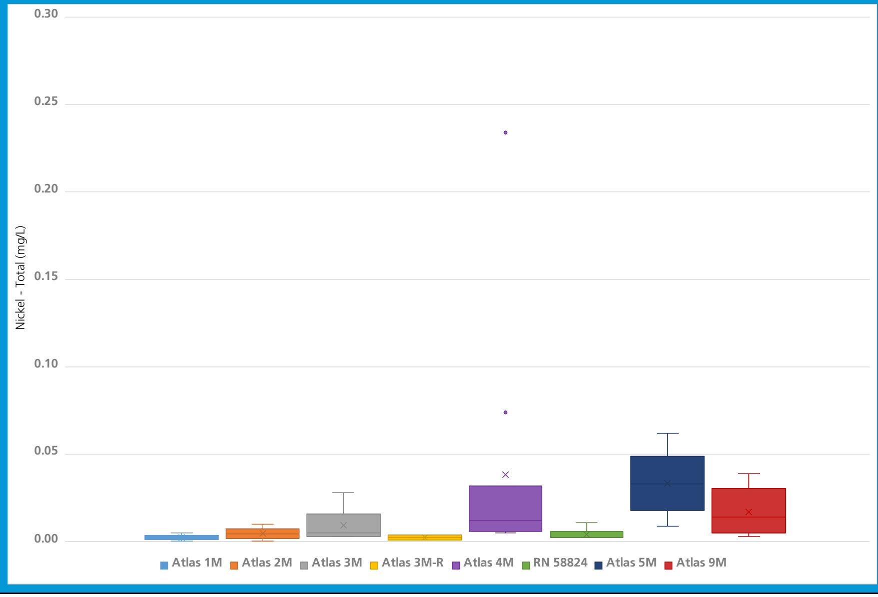
Molybdenum – Total (mg/L)



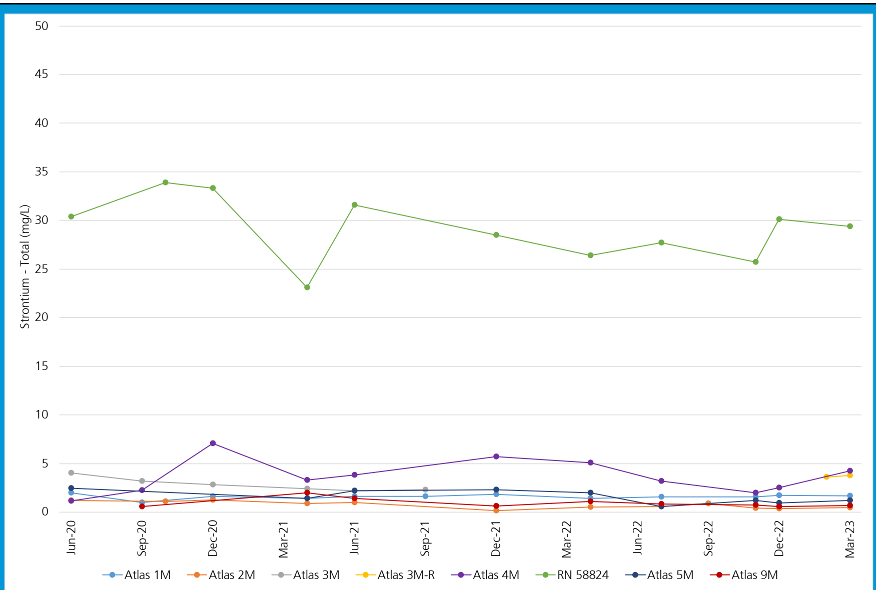


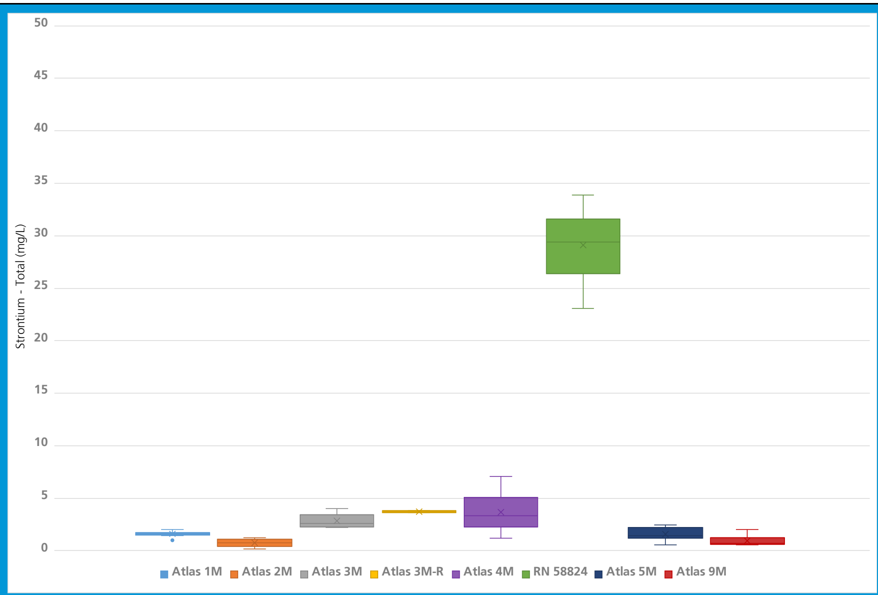
Nickel – Total (mg/L)



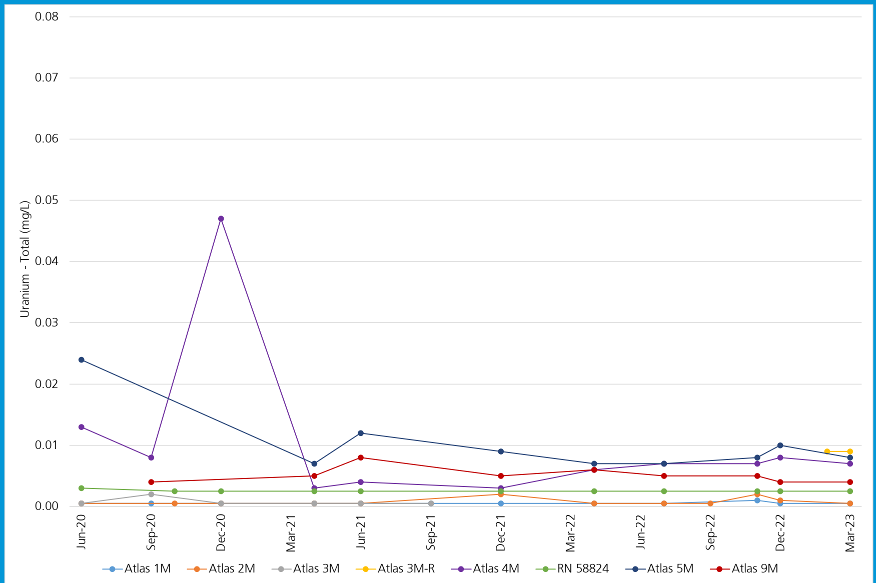


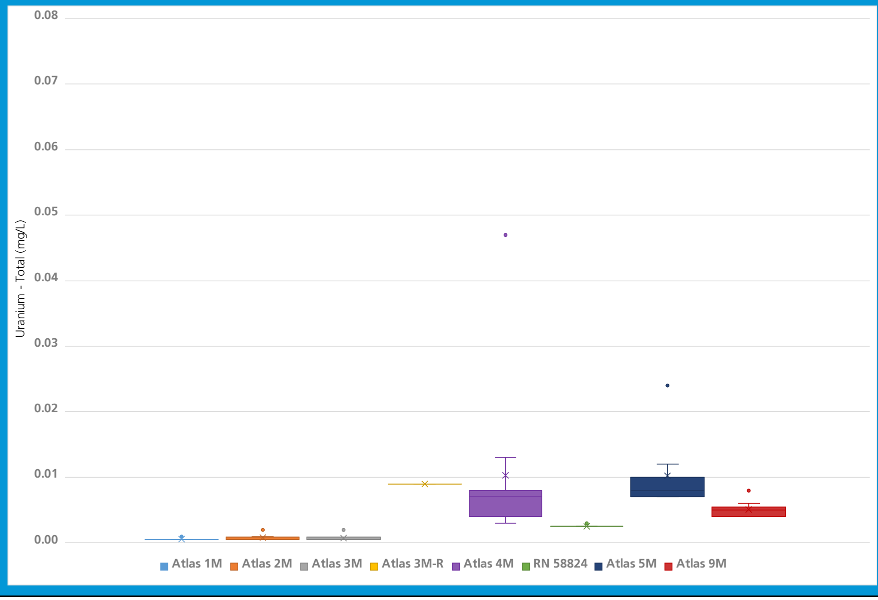
Strontium – Total (mg/L)



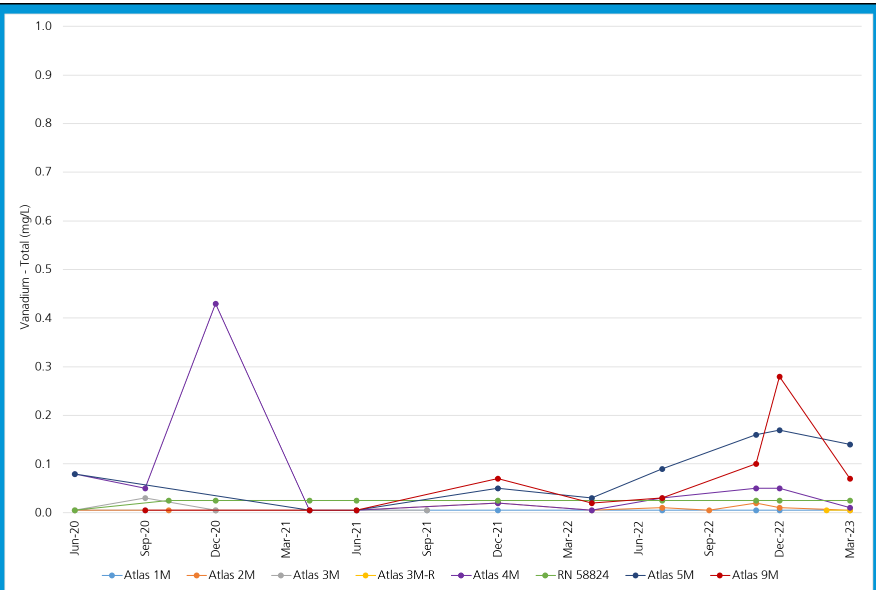


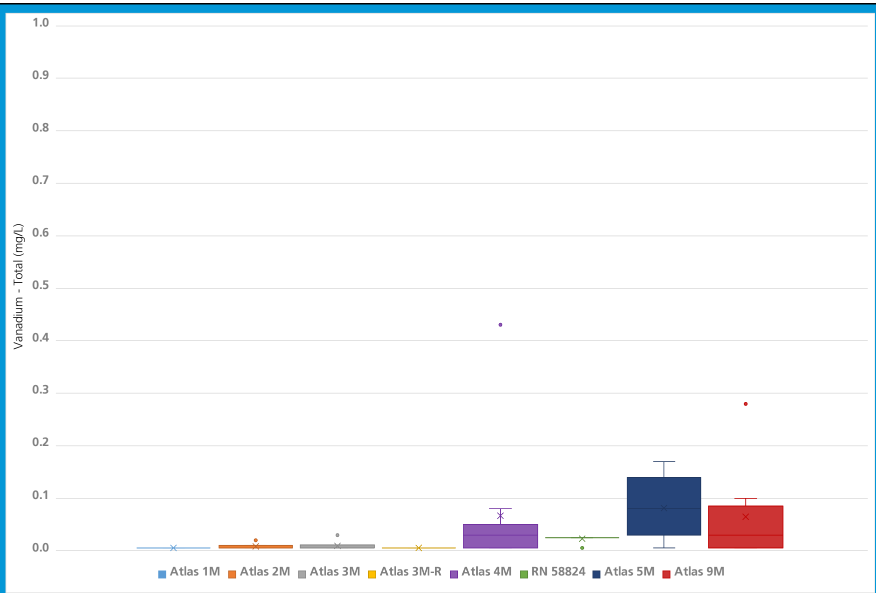
Uranium – Total (mg/L)



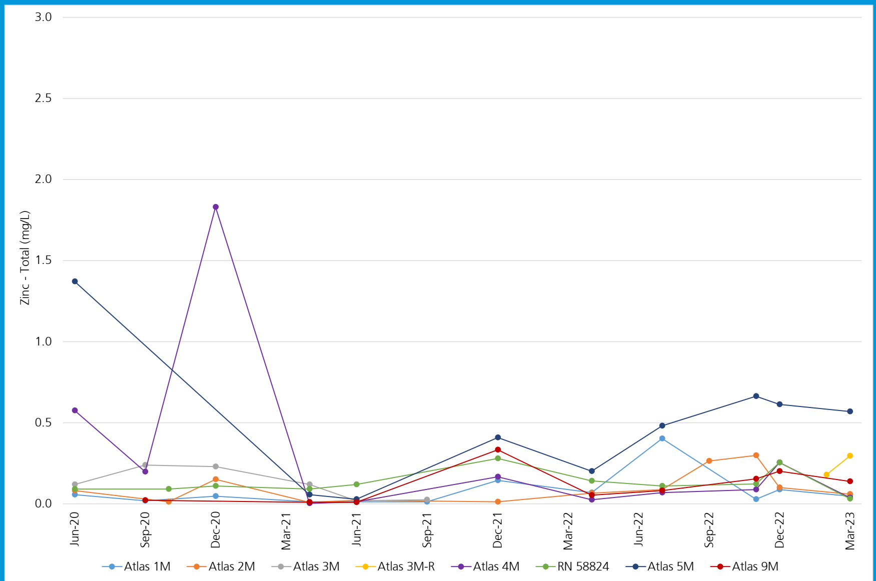


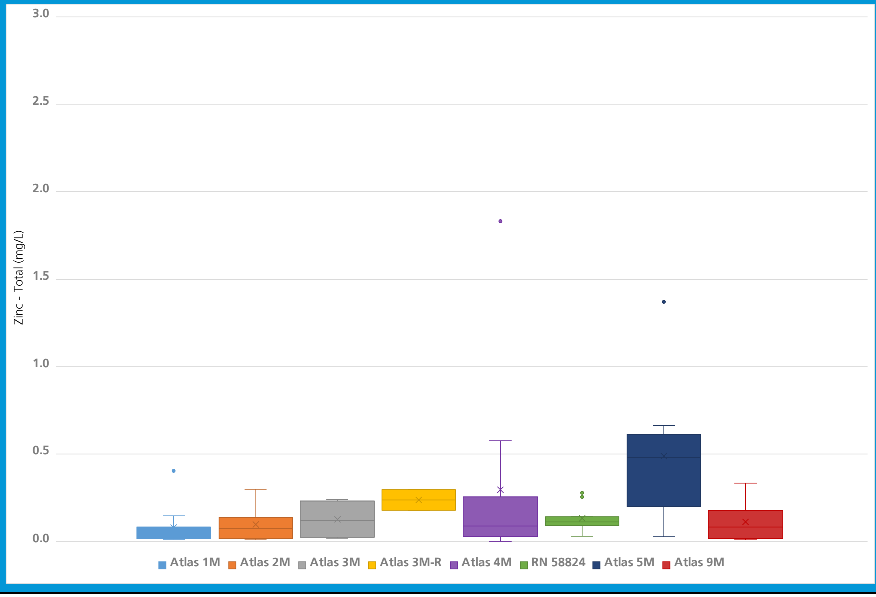
Vanadium – Total (mg/L)



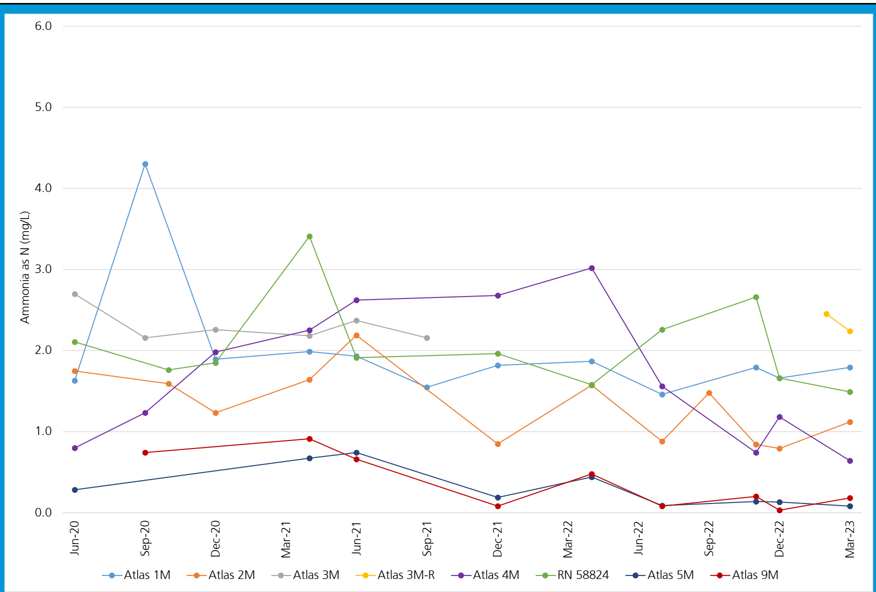


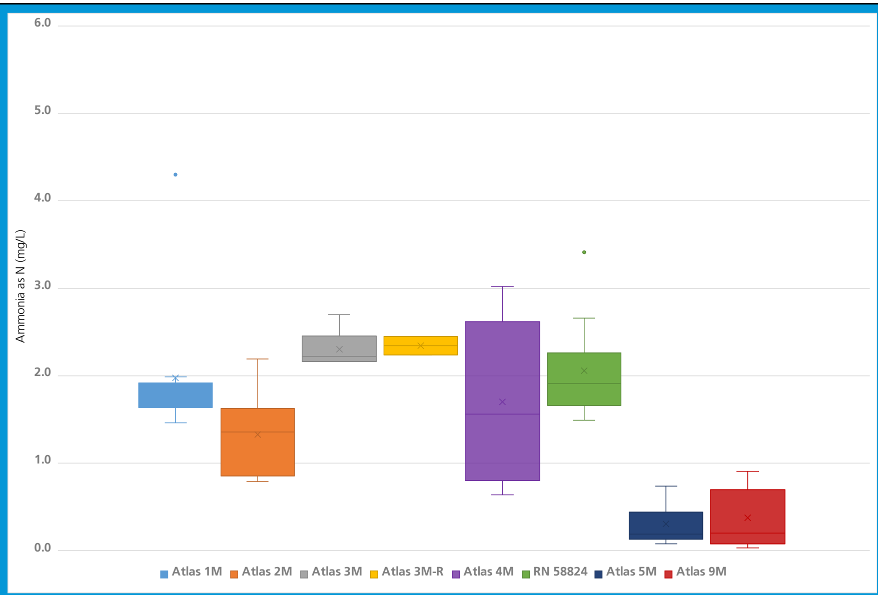
Zinc – Total (mg/L)



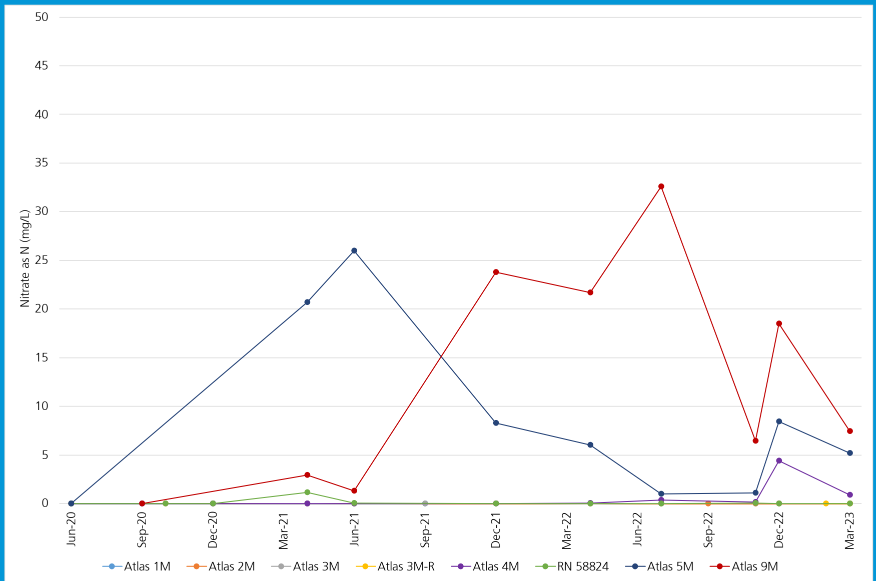


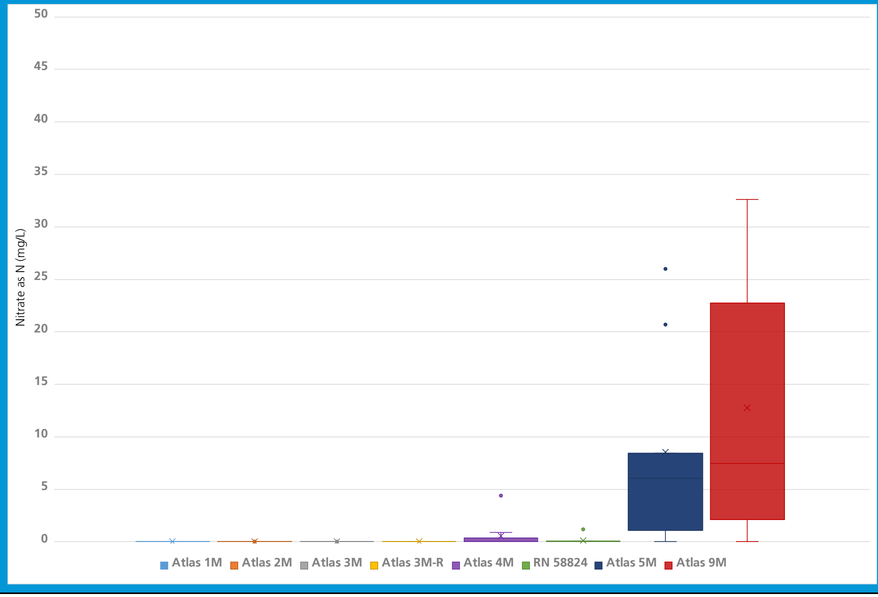
Ammonia as N (mg/L)



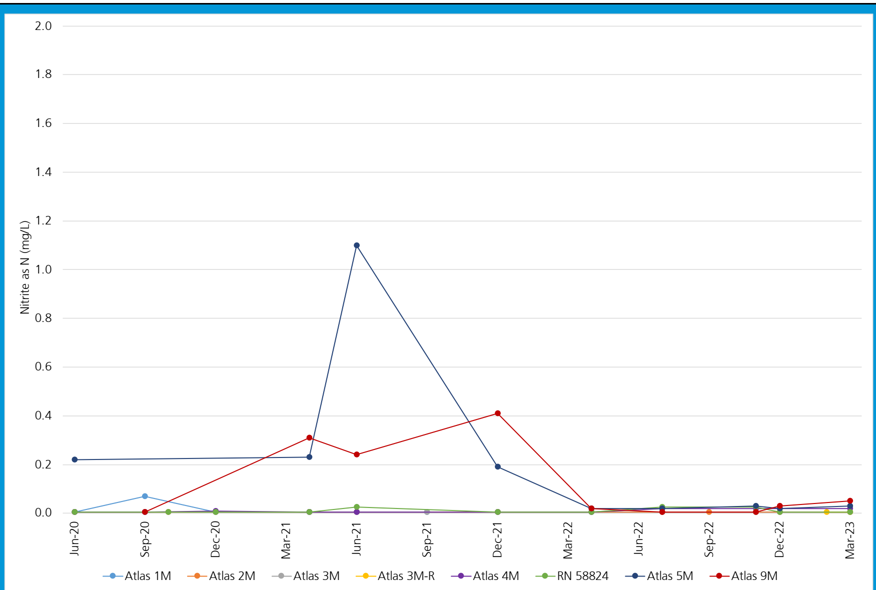


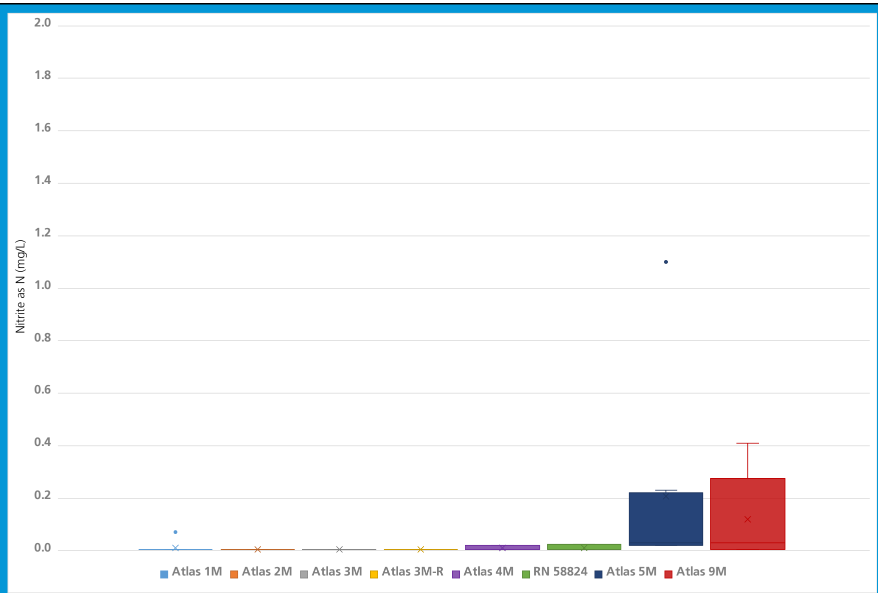
Nitrate as N (mg/L)



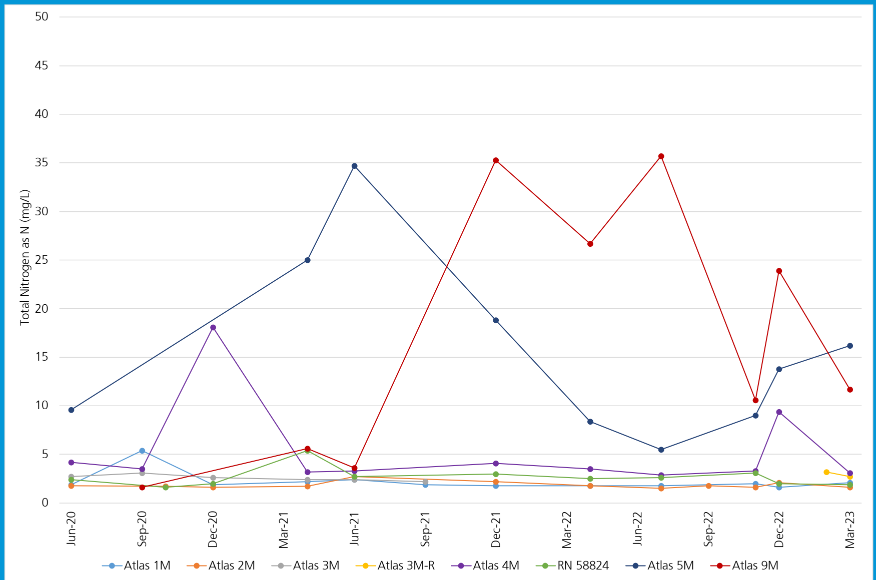


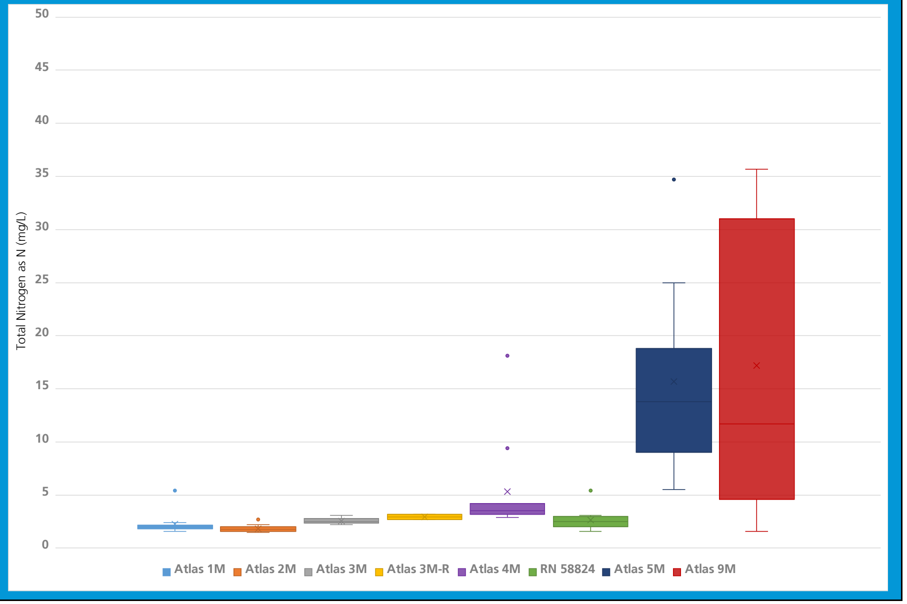
Nitrite as N (mg/L)



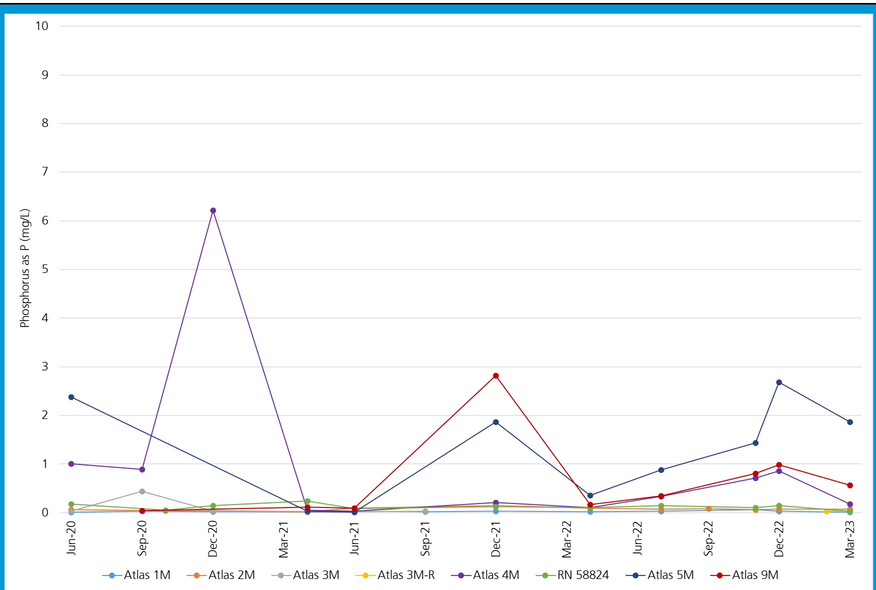


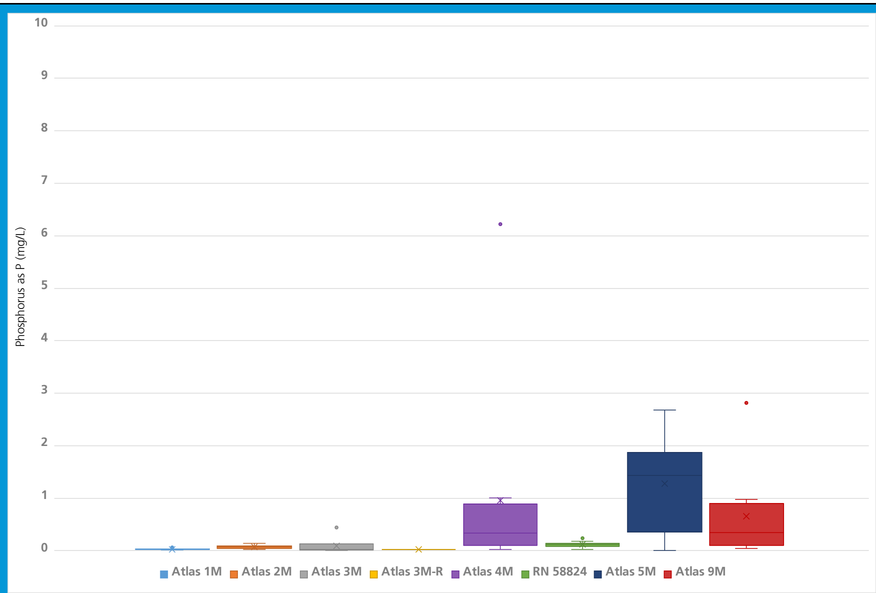
Total Nitrogen as N (mg/L)



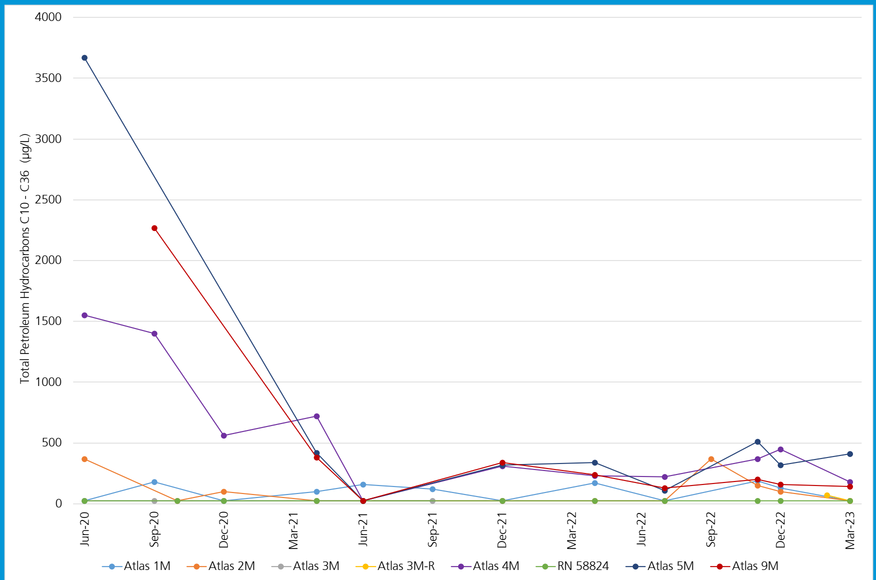


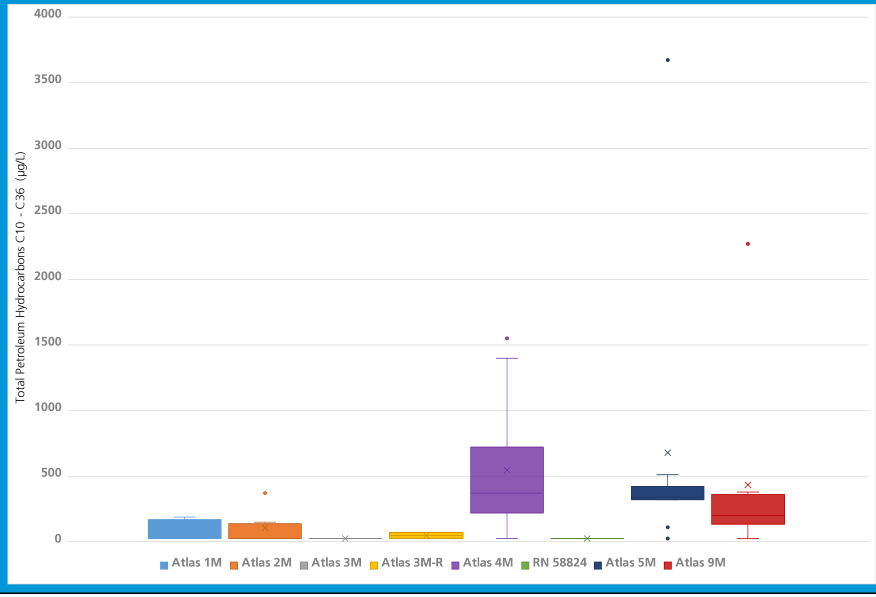
Total Phosphorus as P (mg/L)



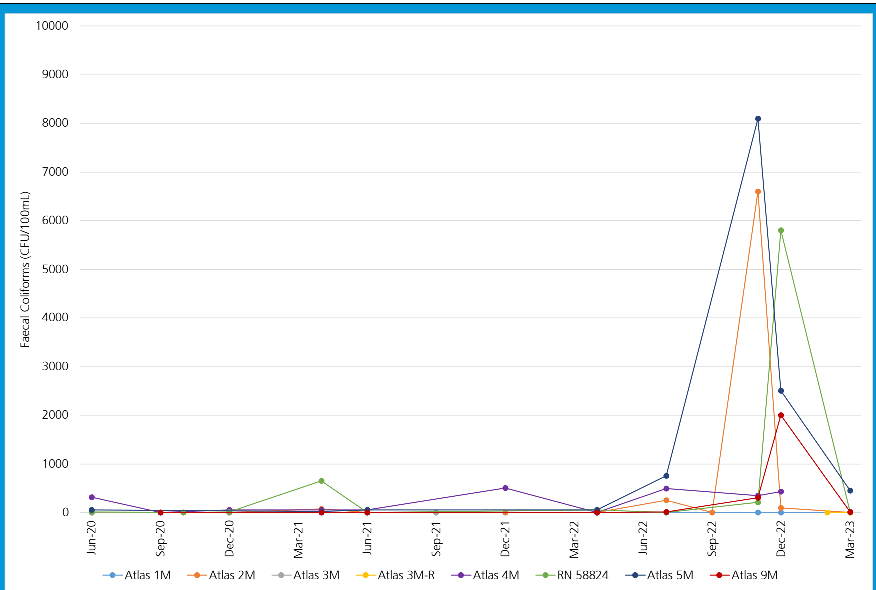


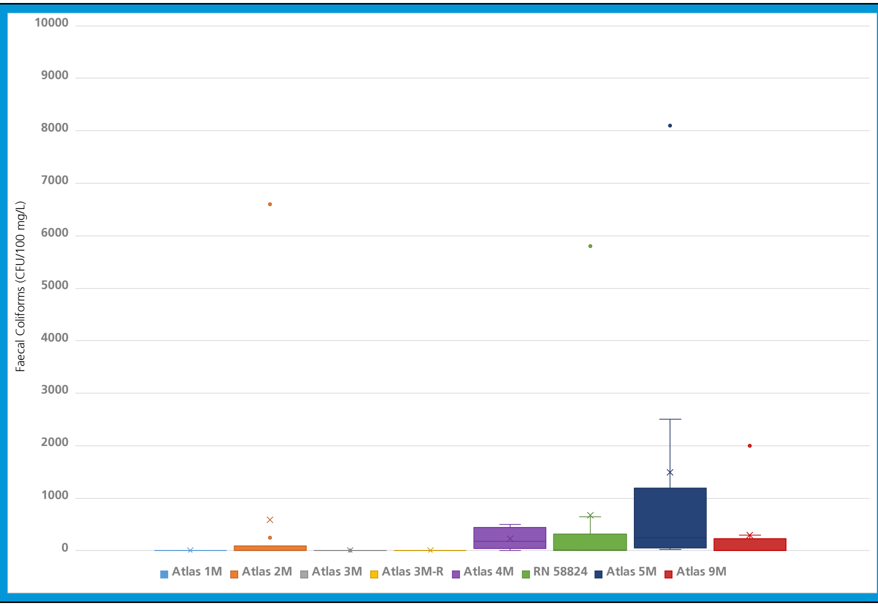
Total Petroleum Hydrocarbons C10-C36) (µg/L)





Median Faecal Coliforms (CFU/100mL)





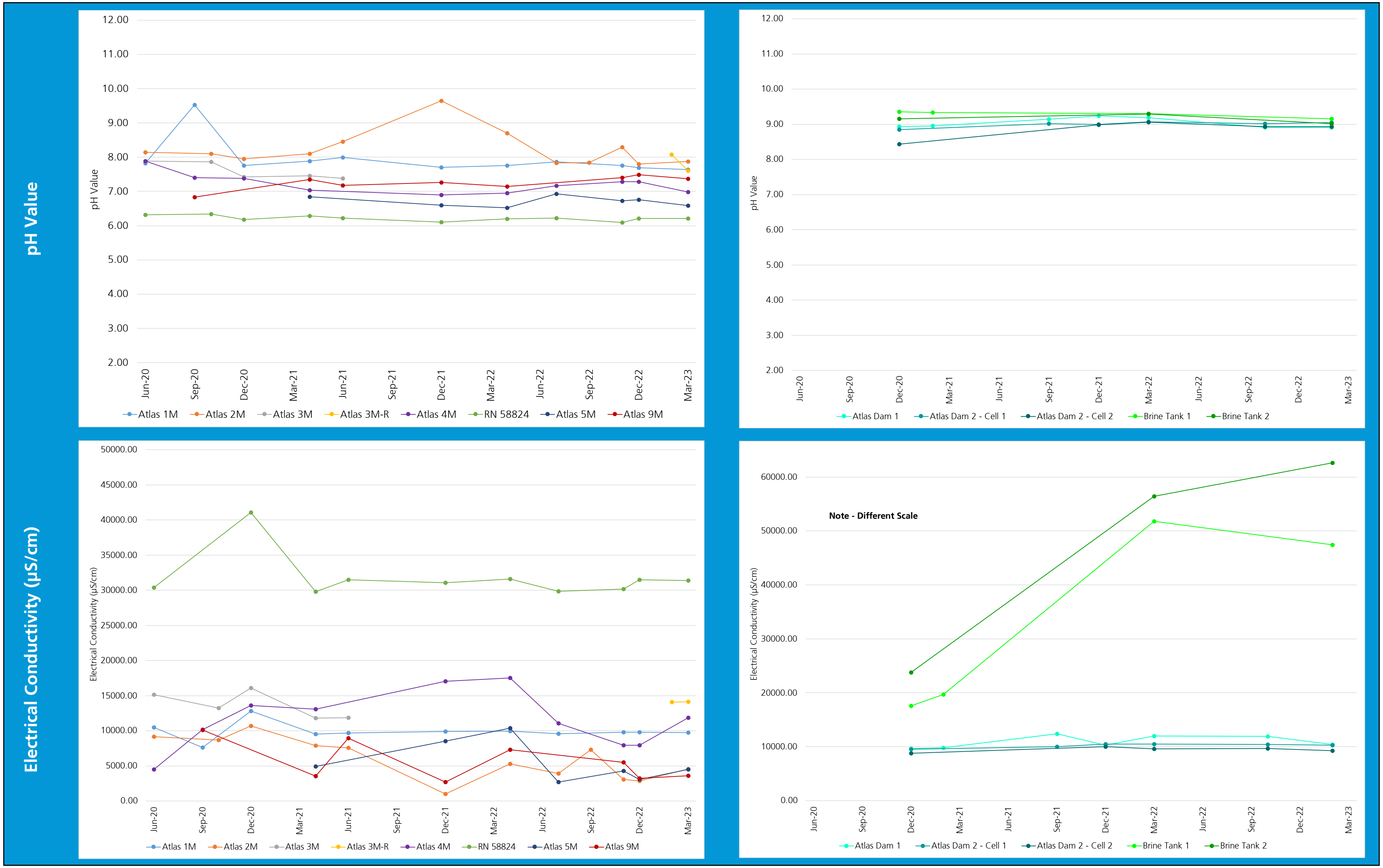
There are time series and box plots for those parameters that are not detected above reporting limits or have too few detections above reporting limits to permit statistical analysis to be conducted. These include:

- *Antimony - Total*
- *Mercury – Total*
- *Selenium - Total*
- *Silver - Total*
- *Total Petroleum Hydrocarbons (C6 – C9)*

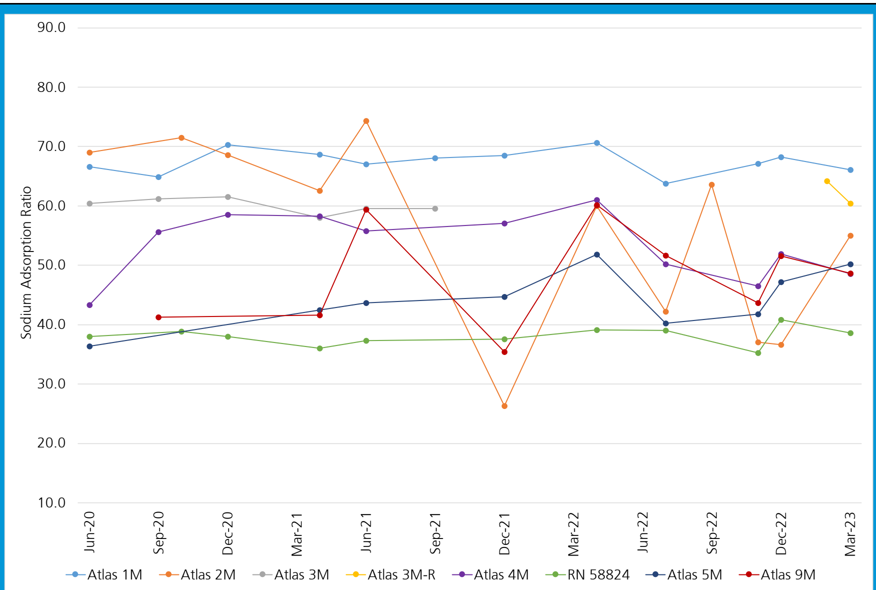
-

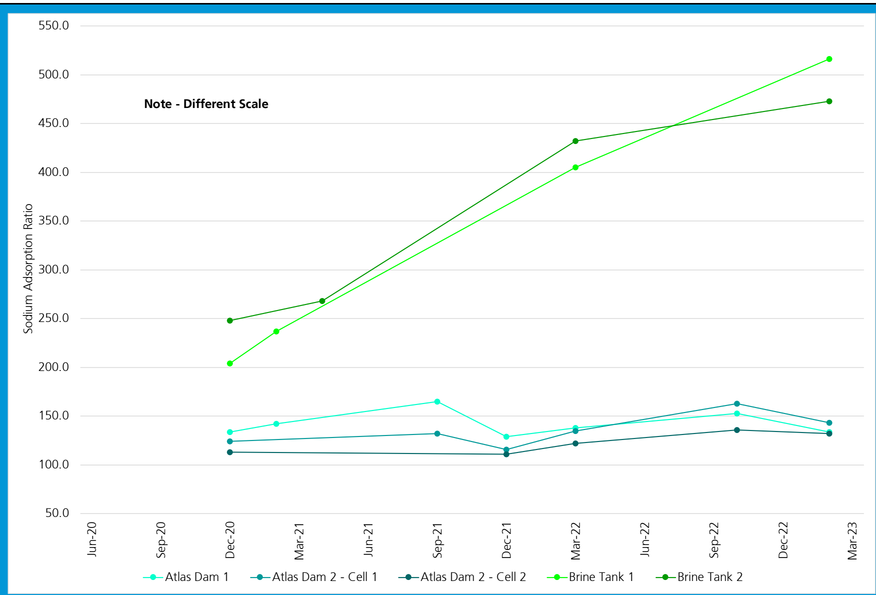
Appendix 4

Monitoring Bore vs Dam / Brine Tank Water Quality for Key Seepage Indicators

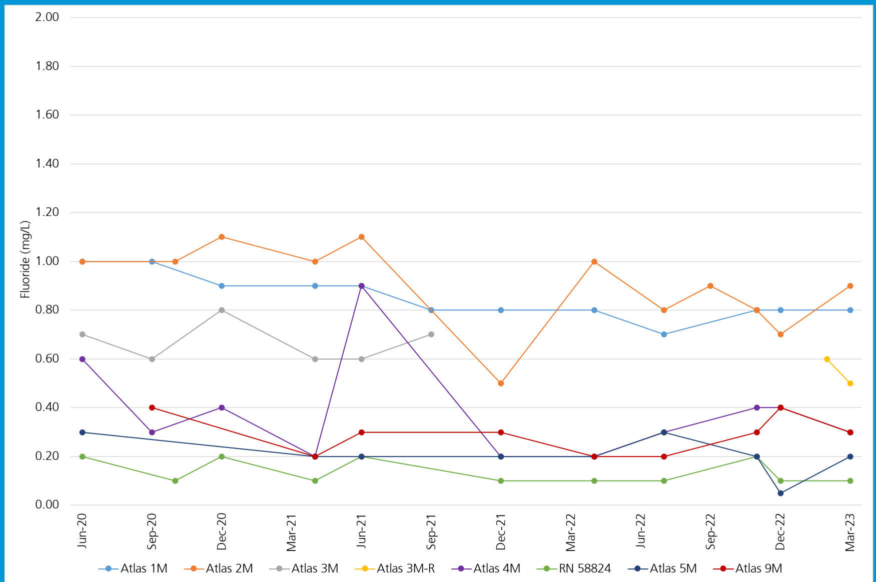

pH Value
pH Value
Atlas 1M
Atlas 2M
Atlas 3M
Atlas 3M-R
Atlas 4M
RN 58824
Atlas 5M
Atlas 9M
pH Value
Atlas Dam 1
Atlas Dam 2 - Cell 1
Atlas Dam 2 - Cell 2
Brine Tank 1
Brine Tank 2
Electrical Conductivity (µS/cm)
Electrical Conductivity (µS/cm)
Atlas 1M
Atlas 2M
Atlas 3M
Atlas 3M-R
Atlas 4M
RN 58824
Atlas 5M
Atlas 9M
Note - Different Scale
Electrical Conductivity (µS/cm)
Atlas Dam 1
Atlas Dam 2 - Cell 1
Atlas Dam 2 - Cell 2
Brine Tank 1
Brine Tank 2

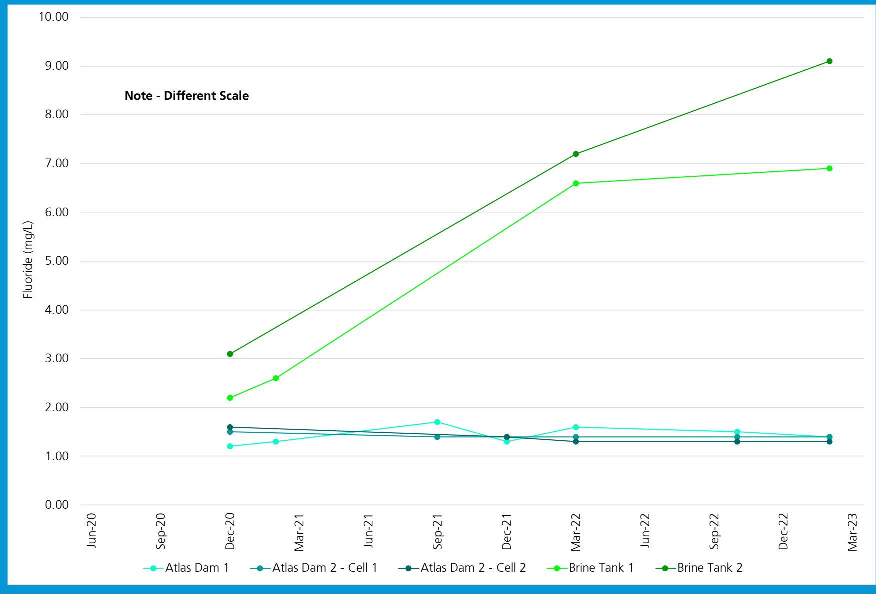
Sodium Adsorption Ratio



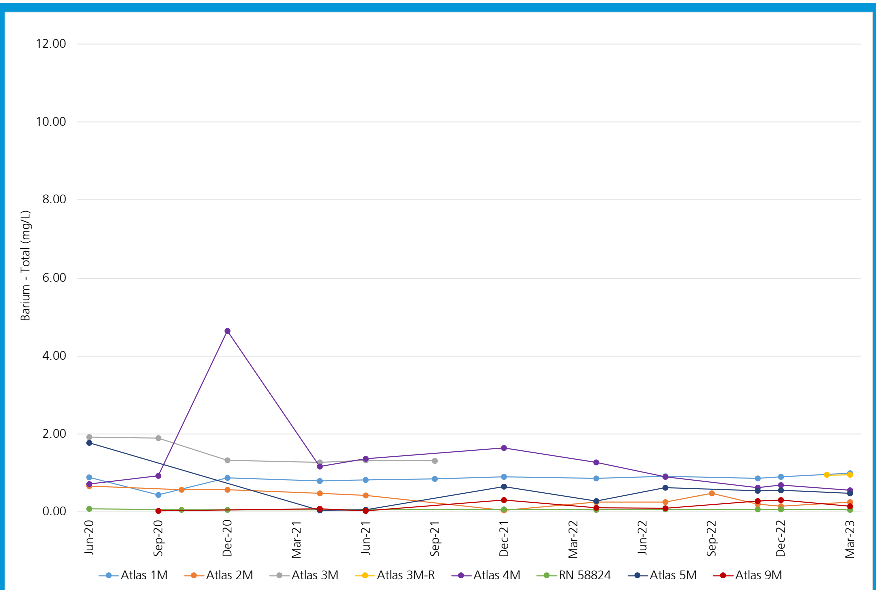


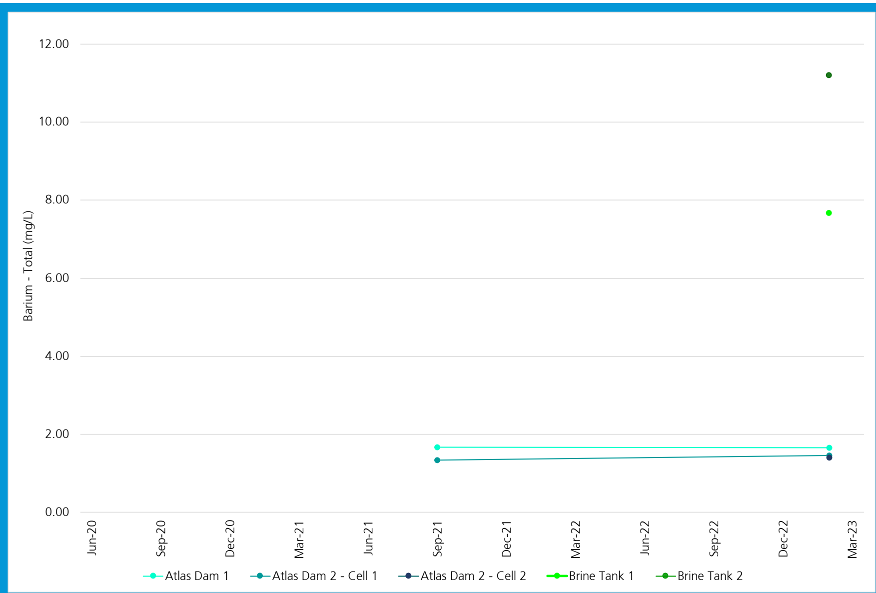
Fluoride (mg/L)



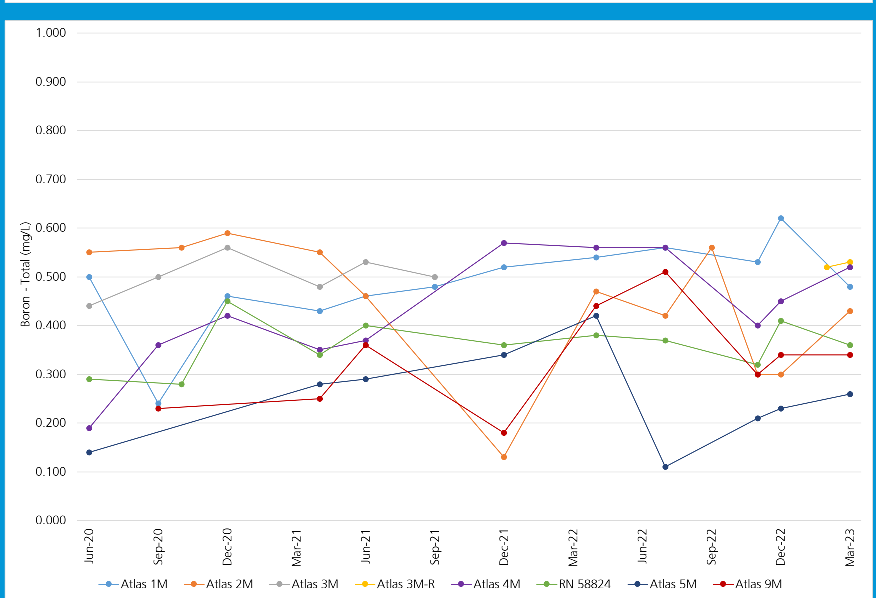


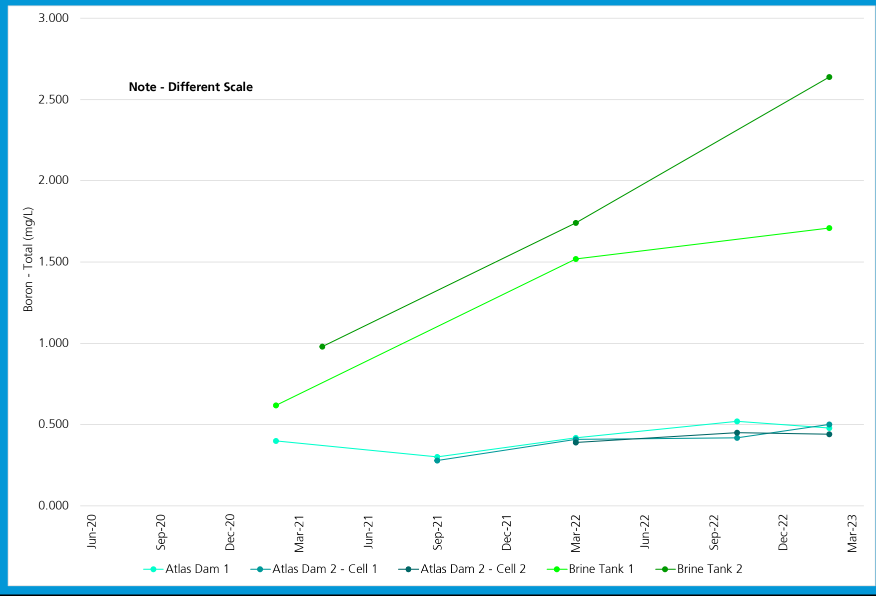
Barium – Total (mg/L)



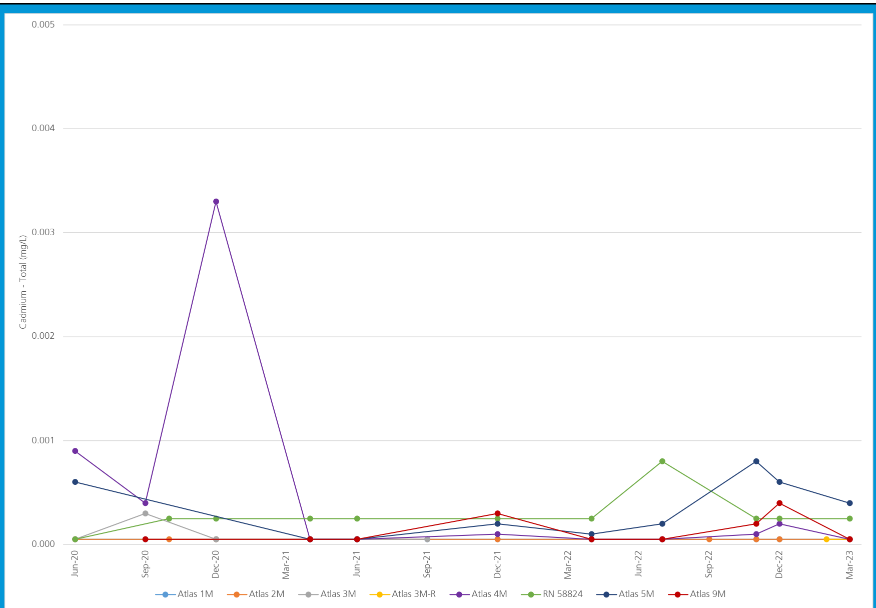


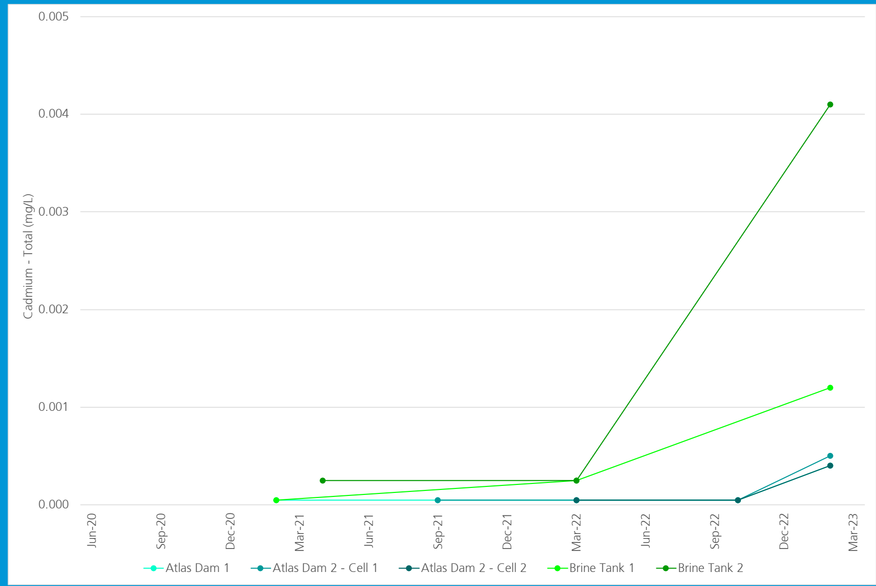
Boron – Total (mg/L)



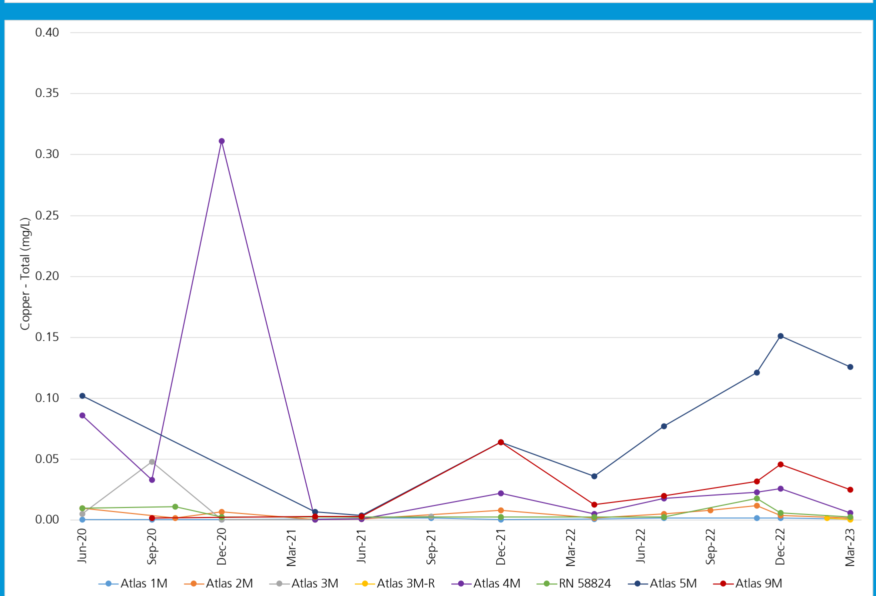


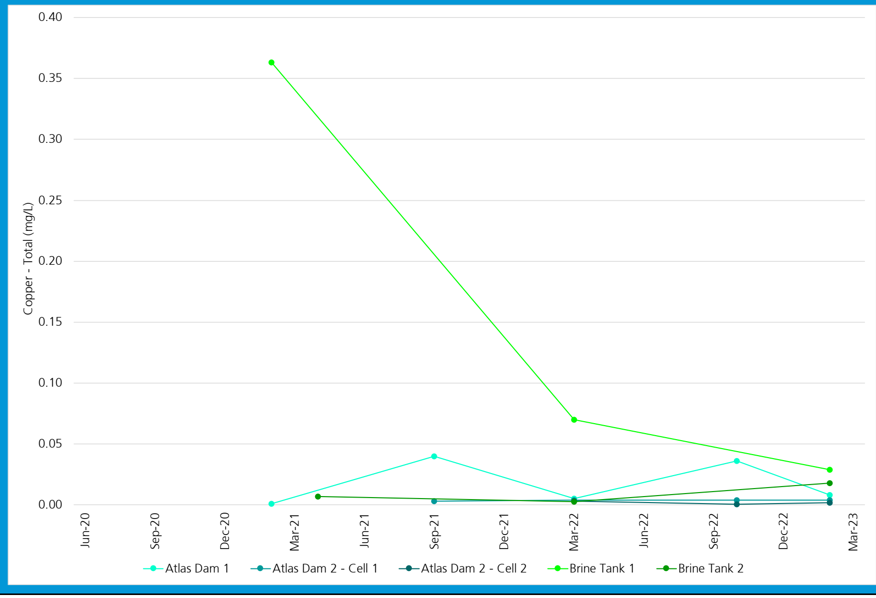
Cadmium – Total (mg/L)



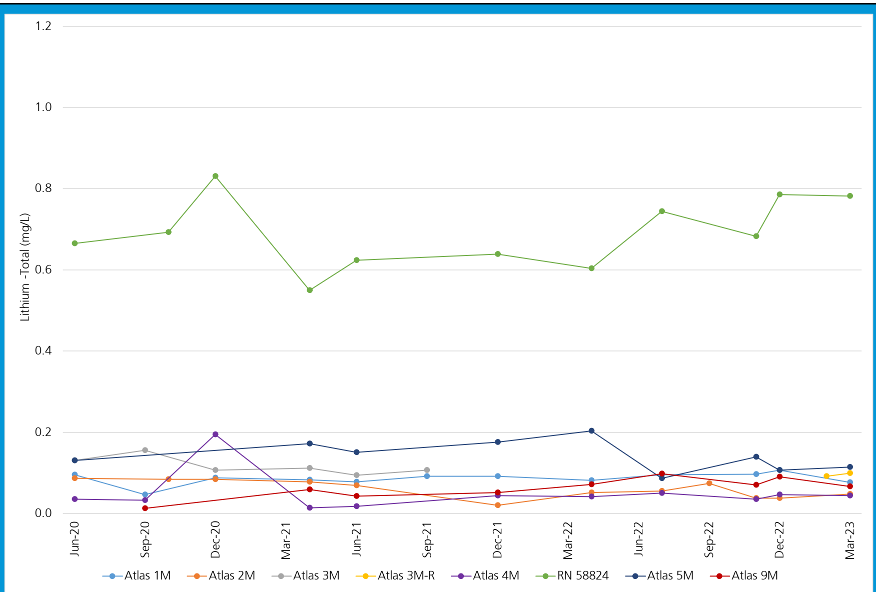


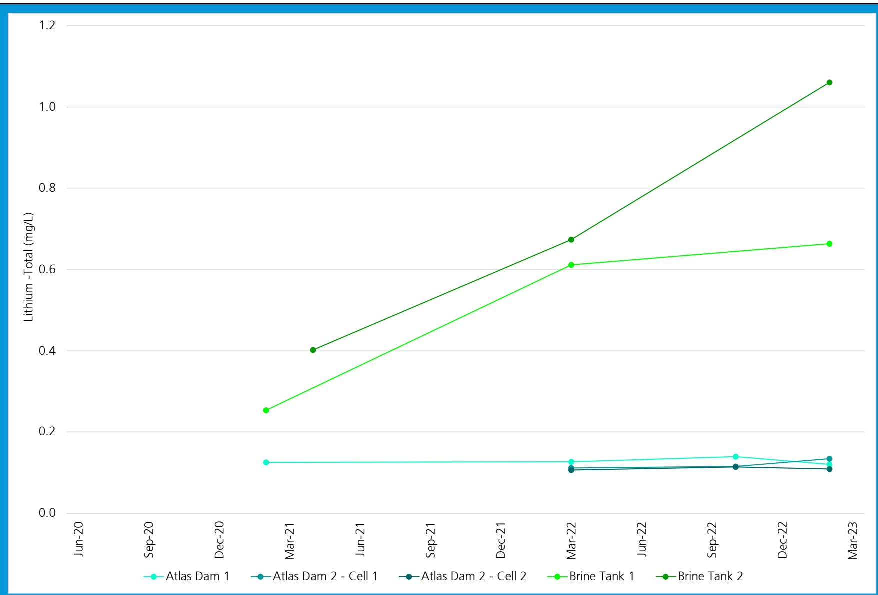
Copper – Total (mg/L)



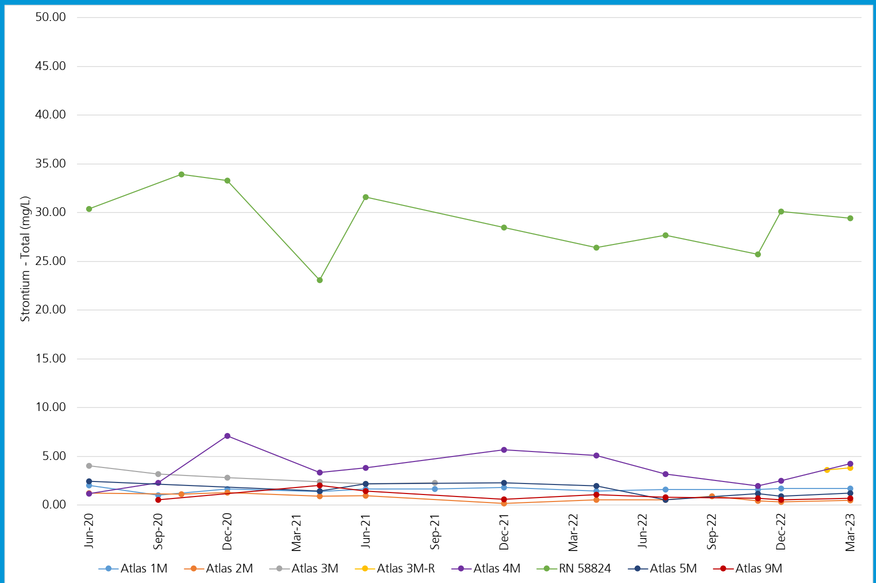


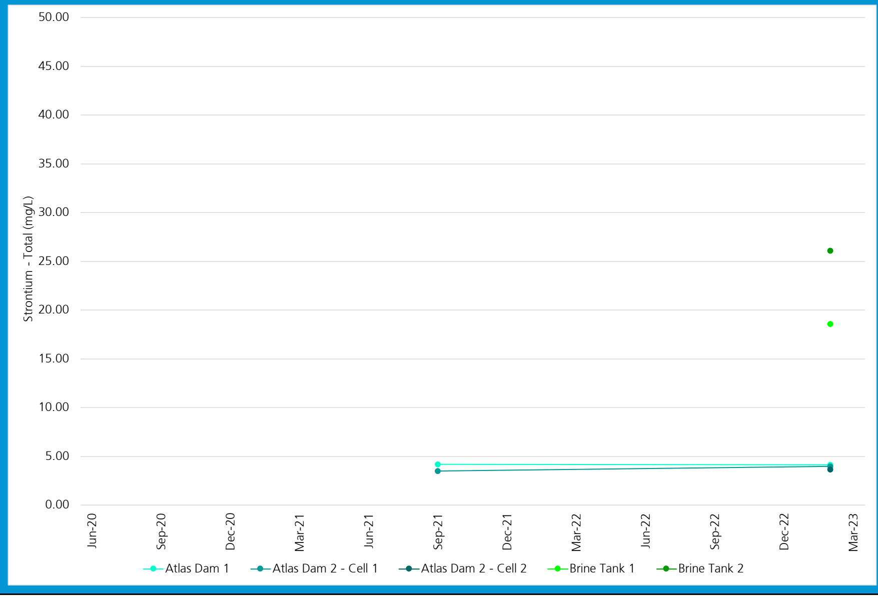
Lithium – Total (mg/L)





Strontium – Total (Mg/L)





Appendix 5

Water Quality Guidelines and Trigger Limits for Indicators

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
pH Value (Field)	Deep bores Shallow bores	6.0 - 8.5	6.0 - 8.5	-	-	7.60 - 8.60 7.40 - 8.40	7.60 - 8.60*	1M, 2M
							7.43 – 7.88	3M-R
							6.58 - 6.82	5M
							7.07 - 7.39	4M, 9M
							ID	All other monitoring bores
Electrical Conductivity (µS/cm)	Deep bores Shallow bores	-	-	-	-	0 - 5,165 371 - 6,040	9,975	Atlas 1M
							8,551	Atlas 2M
							14,961	Atlas 3M-R
							14,302	Atlas 4M
							7,802	Atlas 5M
							8,305	Atlas 9M
							ID	All other monitoring bores
Total Dissolved Solids (mg/L)	All bores	2,000 - 10,000	-	-	-	2,000 - 10,000	5,466	Atlas 1M
							4,378	Atlas 2M
							8,142	Atlas 3M-R
							8,000	Atlas 4M
							5,806	Atlas 5M
							4,640	Atlas 9M
							ID	All other monitoring bores
Sodium Adsorption Ratio	Deep bores Shallow bores	-	2 - 102[1]	-	-	32.07 - 77.96 5.67 - 61.89	68.16	1M, 2M, 3M-R
							51.66	4M, 5M. 9M
							ID	All other monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Calcium (Ca, mg/L)	Deep bores Shallow bores	1,000	-	-	-	3 - 46 7 - 74	62	1M
							3 – 46*	2M
							148	3M-R
							176	4M
							7 – 74*	5M, 9M
							ID	All other monitoring bores
Chloride (Cl, mg/L)	Deep bores Shallow bores	-	175 - 700	-	-	185 - 2,476 130 - 2,780	3,420	1M
							2,580	2M
							4,730	3M-R, 4M
							130 – 2,780*	5M, 9M
							ID	All other monitoring bores
Fluoride (F, mg/L)	Deep bores Shallow bores	2	1	1.5	-	0.200 - 1.195 0.165 - 0.769	0.200 - 1.195*	1M, 2M, 3M-R
							0.165 - 0.769*	4M, 5M, 9M
							ID	All other monitoring bores
Magnesium (Mg, mg/L)	Deep bores Shallow bores	2,000	-	-	-	1 - 12 2 - 30	1 - 12	1M, 2M, 3M-R
							2 - 30	4M, 5M, 9M
							ID	All other monitoring bores
Potassium (K, mg/L)	All bores	-	-	-	-	-	5.0 – 15.0	1M, 2M, 3M-R, 4M, 5M, 9M
							ID	All other monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Sodium (Na, mg/L)	Deep bores Shallow bores	-	115 - 460	-	-	360 - 1,802 144 - 1,868	2,046	1M
							360 - 1,802*	2M
							2,902	3M-R
							144 - 1,868*	5M, 9M
							2,860	4M
							ID	All other monitoring bores
Sulphate (SO_4^{2-}, mg/L)	Deep bores Shallow bores	1,000	-	-	-	0 - 34 0 - 21	0 - 37	1M, 2M
							134.4	3M-R
							388.0	4M
							469.0	5M, 9M
							ID	All other monitoring bores
Aluminium (Al, mg/L)	All bores	5	5	-	0.055	-	0.31	1M
							1.36	2M
							0.77	3M-R
							23.8	4M
							103.4	5M
							62.9	9M
							ID	All other monitoring bores
Antimony (Sb, mg/L)	All bores	-	-	0.003	0.009	-	0.003	9M
							ID	All other monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Arsenic (As, mg/L)	All bores	0.5	0.1	0.01	0.013	-	0.013*	2M
							0.016	3M-R
							0.034	4M
							0.024	9M
							ID	All other monitoring bores
Barium (Ba, mg/L)	All bores	-	-	2	-	-	0.90	Atlas 1M
							0.55	Atlas 2M
							1.67	Atlas 3M-R
							1.37	Atlas 4M
							0.64	Atlas 5M
							0.30	Atlas 9M
							ID	All other monitoring bores
Beryllium (Be, mg/L)	All bores	ND	0.1	0.06	-	-	ID	All monitoring bores
Boron (B, mg/L)	All bores	5	0.5	4	0.94	-	0.56	1M, 2M, 3M-R, 4M
							0.39	5M, 9M
							ID	All other monitoring bores
Cadmium (Cd, mg/L)	All bores	0.01	0.01	0.002	0.0002	-	ID	All monitoring bores
Chromium (Cr, mg/L)	All bores	1	-	0.05	0.0033	-	0.006	2M,
							0.028	4M
							0.062	5M
							0.041	9M
							ID	All other monitoring bores
Cobalt (Co, mg/L)	All bores	1	0.05	-	0.0014	-	0.04	4M, 5M, 9M
							ID	All other monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Copper (Cu, mg/L)	Deep bores Shallow bores	0.4 - 5.0	0.2	2	0.0014	0.033 0.010	0.12	5M
							0.033*	1M, 2M, 3M-R, 4M, 9M
							ID	All other monitoring bores
Gallium (Ga, mg/L)	All bores	-	-	-	-	-	ID	All monitoring bores
Iron (Fe, mg/L)	Deep bores Shallow bores	-	0.2	-	-	0.20 2.35	0.43	1M
							1.10	2M
							1.61	3M-R
							44.68	4M, 9M
							95.78	5M, 9M
							ID	All other monitoring bores
Lead (Pb, mg/L)	All bores	0.1	2	0.01	0.0034	-	0.038	4M
							0.095	5M
							ID	All monitoring bores
Lithium (Li, mg/L)	All bores	-	0.075 - 2.5	-	-	-	0.095	1M,
							0.084	2M, 9M
							0.123	3M-R
							0.046	4M
							0.173	5M
							ID	All other monitoring bores
Manganese (Mn, mg/L)	Deep bores Shallow bores	-	0.2	0.5	1.9	0.033 0.020	1.9*	1M, 2M, 3M-R, 4M, 5M, 9M
							ID	All other monitoring bores
Mercury (Hg, mg/L)	All bores	0.002	0.002	0.001	0.0006	-	ID	All monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Molybdenum (Mo, mg/L)	All bores	0.15	0.01	0.1	0.034	-	0.034*	1M, 2M, 5M, 9M
							0.065	3M-R
							0.043	4M
							ID	All other monitoring bores
Nickel (Ni, mg/L)	All bores	1	0.2	0.02	0.011	-	0.011*	1M, 2M, 3M-R
							0.032	4M
							0.049	5M
							0.030	9M
							ID	All other monitoring bores
Selenium (Se, mg/L)	All bores	0.02	0.02	0.01	0.011	-	ID	All monitoring bores
Silver (Ag, mg/L)	All bores	-	-	0.1	0.00005	-	ID	All monitoring bores
Strontium (Sr, mg/L)	All bores	-	-	-	-	-	1.7	1M
							1.1	2M
							3.7	3M-R
							5.1	4M
							2.2	5M
							1.2	9M
							ID	All other monitoring bores
Uranium (U, mg/L)	All bores	0.2	0.01	0.017	0.0005	-	0.01	4M, 5M, 9M
							ID	All other monitoring bores
Vanadium (V, mg/L)	All bores	ND	0.1	-	0.006	-	0.05	4M
							ID	All other monitoring bores

Parameters		Default Water Quality Guidelines and Objectives						
		Stock Drinking Water	Irrigation (LTV)	Drinking Water	Toxicant DGV	Dawson River WQO	Site Specific Guideline Values	Atlas Monitoring Bores
Zinc (Zn, mg/L)	Deep bores Shallow bores	20	2	3	0.008	0.007 - 0.230 ID	0.230*	1M, 2M, 3M-R
							0.254	4M
							0.633	5M
							0.173	9M
							ID	All other monitoring bores
Ammonia as N (mg/L)	All bores	-	-	0.5	0.9[2]	-	1.92	1M
							1.63	2M
							2.42	3M-R
							2.62	4M
							0.9*	5M, 9M
Nitrate as N (mg/L)	Deep bores Shallow bores	90.3	-	11.3	-	2.64 1.00	1.00*	4M
							13.36	5M
							22.54	9M
							ID	All other monitoring bores
Nitrite as N (mg/L)	All bores	-	-	-	-	-	0.224	5M
							ID	All other monitoring bores
Nitrogen as N (mg/L)	All bores	-	5	-		-	5*	1M, 2M, 4M
							30	5M, 9M
							ID	All other monitoring bores
Phosphorus as P (mg/L)	All bores	-	0.05[3]	-	-	-	0.03	1M
							0.09	2M
							0.89	4M, 9M
							2.07	5M
							ID	All other monitoring bores

ID = Insufficient data
ND = not detected
mg/L = milligrams per litre
LTV = long term trigger value
DGV = default guideline value
WQO = water quality objective
All metals are total concentrations as specified by the DES (2021) for consumptive uses.
Where no site-specific guideline value is denoted for a bore, the stock drinking water guideline value will apply as the water usage of the area.
** If the site-specific 80th percentile is not substantially different from the water quality objective (WQO) or toxicant default guideline value (DGV), the WQO or DGV is adopted.*
Unless denoted, site-specific trigger values are based on 20^{th} to 80^{th} percentile results for a specific bore or group of bores.
[1] range of values for Sodium Adsorption Ratio (SAR) are for extremely sensitive crops to highly tolerant crops (ANZECC, 2000)
[2] Toxicant value of Ammonia is dependent on pH and temperature. ANZG (2018) lists a default guideline value of 0.9 mg/L of Ammonia as N at a pH of 8.0. For this site with pH ranging from 6 to 9.6, the default guideline values range from 2.57 down to 0.18 mg/L.
[3] Irrigation LTV reported for Phosphorus is to minimise bio clogging of irrigation equipment only.

Appendix B
Senex Monitoring Bores Trigger Development Approach

1 INVESTIGATION TRIGGER DERIVATION OVERVIEW

The Queensland guideline, *using monitoring data to assess groundwater quality and potential environmental impacts* (State of Queensland 2021) (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. Conversely, limit values are typically the highest allowable concentration of an analyte that is permitted and should not be exceeded. Investigation trigger values should be fit for purpose and sufficiently conservative so as to provide an 'early warning'. Additionally, the Guideline states that, 'if trigger values are set too low, natural variability may be mistaken for contamination events and result in unnecessary reporting and investigation'.

The Guideline offers two alternative approaches: 'default values' or 'site-specific'. Where sufficient data is available, the site-specific approach is preferred. The site-specific approach has been adopted for the Project.

The Guideline explains that groundwater quality can be highly variable. The variability can be influenced by local geology, residence time in the aquifer and groundwater-rock interactions, which can result in naturally elevated concentrations (e.g. salinity), dissolved nutrients and metals. As groundwater quality can be variable, the Guideline states that the use of 'default' values, such as those derived from the Queensland Water Quality Guidelines (DEHP 2013), Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) for the protection of freshwater aquatic ecosystems or stock drinking water and the Australian Drinking Water Quality Guidelines (NHMRC 2018) 'may not always be appropriate' (page 1). In these cases, site-specific values should be calculated, which are aquifer-based and operational area-defined, as these are considered more representative.

The Queensland Guideline(State of Queensland 2021) identifies that:

> "*Trigger values should be fit for purpose and conservative enough such that, when applied, they provide an early warning of emerging potential impacts to groundwater. Applying triggers that are set too high may not be sensitive enough to identify current or emerging contamination issues. Conversely, if triggers and limits are set too low, natural variability may be mistaken for contamination events and result in unnecessary reporting and investigation."*

2 APPROACH

It is proposed that Investigation Trigger Values be derived in a manner that is consistent with the Queensland guidance document (State of Queensland 2021) and that an approach be adopted that considers the site-specific conditions and is targeted towards understanding trends, providing the Project with appropriate triggers to initiate actions and to provide a suitable level of protection for the potential receptors.

The Queensland Guideline recommend that groundwater quality assessment be based on comparing a number of consecutive sample tests at investigation trigger monitoring bores to a value based on percentile calculations. This approach is aimed at reducing the probability of a false positive while providing a method that is sufficiently sensitive to detect potential impacts.

2.1 Water Quality Investigation Trigger Value Development

2.1.1 Adoption of Percentiles

The percentiles approach 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 shorter term.

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, evaluate those changes, and take appropriate actions, which could include mitigation.

Control charting is a graphical tool that can be used to visualise the time series monitoring data and trigger values and track changes in measured data over time. Control charts will be utilised as part of the investigation trigger monitoring program.

2.1.2 Anticipated Impacts and Indicator Parameters

Potential changes to groundwater quality as a result of Project development activities may relate to:

- The use of drilling fluids during well installation;
- Seepage / overtopping from surface water storage facilities, and
- Incorrect installation of CSG wells, which could introduce mixing across geological units potentially altering the groundwater chemistry.

Groundwater in the Walloon Coal Measures (WCM) is characteristically rich in chloride, bicarbonate, and sodium, and poor in calcium, magnesium, potassium, and sulfate. Salinity typically ranges from less than 1,000 mg/L TDS (total dissolved solids) to more than 10,000 mg/L, with an average concentration of around 2,000 mg/L (OGIA 2023). Groundwater in hydrostratigraphic units above and below the WCM generally contain less saline groundwater, with chloride contributing to a lower proportion of TDS. Hydrostratigraphic units adjacent to the WCM occasionally show sulfate concentrations greater than 100 mg/L, while the WCM is typically contains less than 20 mg/L sulfate.

Preliminary primary and secondary indicator parameters representative of stored produced water, intraformational flow, auxiliary infrastructure, drilling fluids and material handling and storage are to be selected. Changes in indicator parameters would provide an indication of changing groundwater quality or hydrogeochemical conditions.

Indicator parameters should include dissolved concentrations (only) for metals. Dissolved concentrations are more appropriate for understanding the representative aquifer groundwater quality and therefore for the purpose of groundwater monitoring and the development of trigger values.

2.1.3 Baseline Monitoring and Triggers

As described in the WMMP, baseline monitoring is required to establish the conditions against which to monitor or assess whether, or not, the future development poses environmental risks.

It is noted that sufficient spatially representative good quality monitoring data at an adequate statistical distribution is required to calculate a robust site-specific groundwater trigger value. The guideline recommends 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. It is recommended that available data be assessed after 2 years of monitoring for statistical representativeness prior to value derivation.

Once triggers have been developed, the theoretical probability of false exceedances should be determined to be very low (<0.05%) prior to adoption of triggers.

It is anticipated that collected baseline data will be used as follows, to develop the water quality trigger levels:

- Anomalous values or outliers to be removed for individual bores prior to calculation of the trigger value (consistent with guidance provided by the Queensland Guideline(State of Queensland 2021) and (DSITI 2017).
- If more than 50% of the dataset are non-detects (under the Limit of Recognition (LoR)) the non-detect values to be set at half of the concentration of detection.
- If less than 50% of the dataset were non-detects (under the LoR), these values to be removed from the dataset before site-specific triggers are calculated on the remaining data.
- If there are less than eight (<8) data points available that are greater than LoR, the guidelines recommend continuing use of the default or WQO until sufficient data is available to calculate a site-specific value.
- If there are no default guidelines for a given analyte, comparable international guideline values may be adopted for use as the interim trigger value until sufficient data is collected to calculate a site-specific value.
- If the default guideline is less than the LoR, the LoR will be used as the interim trigger Value until sufficient data is collected to calculate a site-specific value.
- The Queensland guideline recognises that site-specific reference data may be more relevant and may be used.

Site-specific trigger levels will be developed once sufficient data has been collected to determine the natural water quality variability. In the interim, the guideline recommends that EVs and WQOs be reviewed, and conservative generic default guideline values be adopted to protect surface and groundwater. Where local reference conditions[1] are found to exceed published default guideline values for the protection of identified EVs, interim site-specific guidelines may be adopted that is greater than the default guideline (State of Queensland 2021).

[1] 'Local reference condition' refers to bores that are subject to minimal/limited disturbance and are not impacted by anthropogenic activity.

The guideline further indicates that in the event that a toxicant default guideline is adopted and is used as a trigger / value in line with the precautionary principle, it be applied as a Value B not a Value A. Where a default reference-based guideline is adopted as a trigger, such as for pH, this would ideally be applied as Value A. The guideline recognises that site-specific data is likely to be more relevant and may be used.

2.2 Water Level Investigation Trigger Value Development

Site-specific groundwater trigger levels with consideration to the potential drawdown resulting from the Project will be adopted for Senex bores to facilitate targeted impact monitoring and management.

2.2.1 Development Framework for Trigger Action Response Plan

TARPs for water quality and water levels to be developed based on the framework outlined in Figure 2.1.

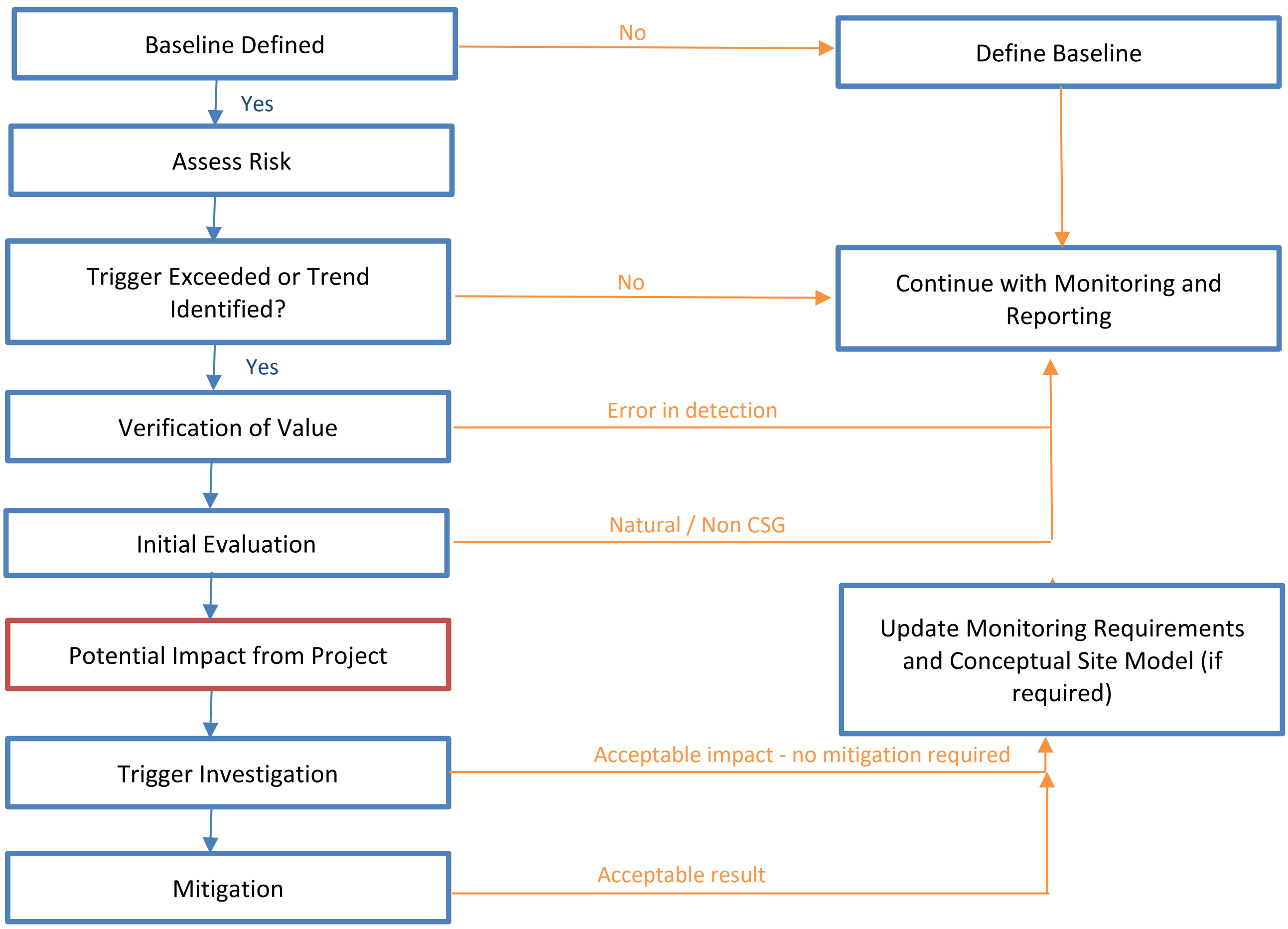


Figure 2.1 Investigation and Response Framework

REFERENCES

ANZG. 2018. 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian State and Territory Governments, Canberra ACT, Australia. Available at Www.Waterquality.Gov.Au/Anz-Guidelines'.

DSITI. 2017. 'Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts'. Version 1. Brisbane, Australia: State of Queensland, Department of Science, Information Technology and Innovation.

OGIA. 2023. 'Analysis of Groundwater Trends to Identify Impacts from Coal Seam Gas and Coal Mining in the Surat and Southern Bowen Basins V1'.

State of Queensland. 2021. 'Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts V2'.

Senex

Registered Office
Level 30, 180 Ann Street,
Brisbane Qld 4000

Postal Address
GPO Box 2233,
Brisbane Qld 4001

Phone: +61 7 3335 9000
Facsimile: +61 7 3335 9999
Web: senexenergy.com.au

Senex Energy Pty Ltd
ABN 50 008 942 827