Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

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Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Coastwide Materials Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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1.0 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Coastwide Materials Pty Ltd (Coastwide) to provide a Groundwater Assessment to support the Hillview Quarry Environmental Impact Statement (EIS).

1.1 Purpose of this Report

The purpose of this report is to present the Groundwater Assessment for the Hillview Hard Rock Quarry project, from here on, termed 'the Project'. This report details the baseline groundwater conditions around the Project, assesses the potential impacts to groundwater as a result of the Project, and recommends mitigation measures required to address these impacts.

The Project is a State Significant Development (SSD) under the *Environmental Planning and Assessment Act 1979* as the Project will extract more than 500,000 tonnes of extractive materials per year. A SSD refers to developments that are significant to the State in which they are based. A SSD must be accompanied by an EIS.

This EIS, as well as meeting the minimum form and content requirements in clauses 6 and 7 of Schedule 2 of the Environmental Planning and Assessment Regulation 2021, must fulfil any Secretary's Environmental Assessment Requirements (SEARs) that the Project is subject to (detailed further in **Section 3.0**).

1.2 Project Description

Coastwide intends to seek development consent for a new hard rock quarry within a rural area known as Booral in the Great Lakes Region of New South Wales (NSW). The Project will be undertaken over seven stages during which approximately 45 million tonnes of resource material is proposed to be extracted at a rate of up to 1.5 million tonnes per annum (Mtpa) over 30 years. The total area of the subject site is approximately 400 hectares (ha); however, the total quarry footprint is considerably smaller comprising approximately 48 ha.

The plan view extent of each stage of the Project is shown in **Figure 1**. Quarry extraction of rhyolite will be from 205 metres Australian Height Datum (mAHD) down to final Relative Level (RL) of 95 mAHD.

Stage 1 (between years 0-5 of Project)

Stage 1 will result in a land disturbance area of 9.5 ha, it will broadly comprise commencing of construction of the haul road from Maytoms Lane to the processing pad. During this stage, the 14 m wide haul road will be pegged out and cleared as much as possible to expose underlying hard rock. A face will be created on the north side of the spur road with clearing to take place along the eastern underside to facilitate commencement of the processing pad where mobile plant will initially be set up.

Stage 2 (between years 0-5 of Project)

Stage 2 will result in a land disturbance area of 2.4 ha, it will broadly comprise increasing the size of the processing pad, continuing the slot and haul road southward, and upgrades to Maytoms Lane and the intersection with Bucketts Way.

Blasting and drilling will be required to advance the slots southwards. Two weighbridges will be constructed during Stage 2 as well as other ancillary structures and uses required for the proposal including offices and maintenance shed. Construction of the intersection at Maytoms Lane and The Bucketts Way will be commenced by way of vegetation removal and expansion of the road envelope to accommodate the intersection.

Stage 3 (between years 0-5 of Project)

Stage 3 will result in a land disturbance area of 10.6 ha, it will broadly comprise finalising the processing pad and haul road to Maytoms Lane, completion of Maytoms Lane upgrades and the intersection with Bucketts Way and commencing construction of the internal haul road to the new Run of Mine (ROM) pad to be located 10 m above processing pad.

Stage 3 will see the levelling of the main processing pad completed. The processing pad will accommodate the space required for the main processing area dam and sand processing plant dam; tertiary and secondary crushers; sand wash plant; site office; and final product stockpiles which will be constructed or installed as part of Stage 3.

Stage 4 (between years 0-5 of Project)

Stage 4 will result in a land disturbance area of 1.1 ha, it will broadly comprise continued construction of the haul road and ROM pad. Construction of the internal haul road which commenced in Stage 3 will continue to facilitate access to parts of the site which will comprise extraction areas associated with Stage 5, Stage 6, and Stage 7 as well as the ROM pad.

Stage 5 (Years 5-10 of Project)

Stage 5 will result in a land disturbance area of 5.4 ha and will involve extraction and processing of material. Material will be extracted from the highest point of the proposal before excavation commences downward in a north-westerly direction. Initial dozer and track drilling will occur at RL 206 mAHD.

Stage 6 (Years 10 to 25 of Project)

Stage 6 will result in a land disturbance area of 9.6 ha and comprise of continued extraction. Extraction will continue down the eastern face.

Stage 7 (Years 25 to 30 of Project)

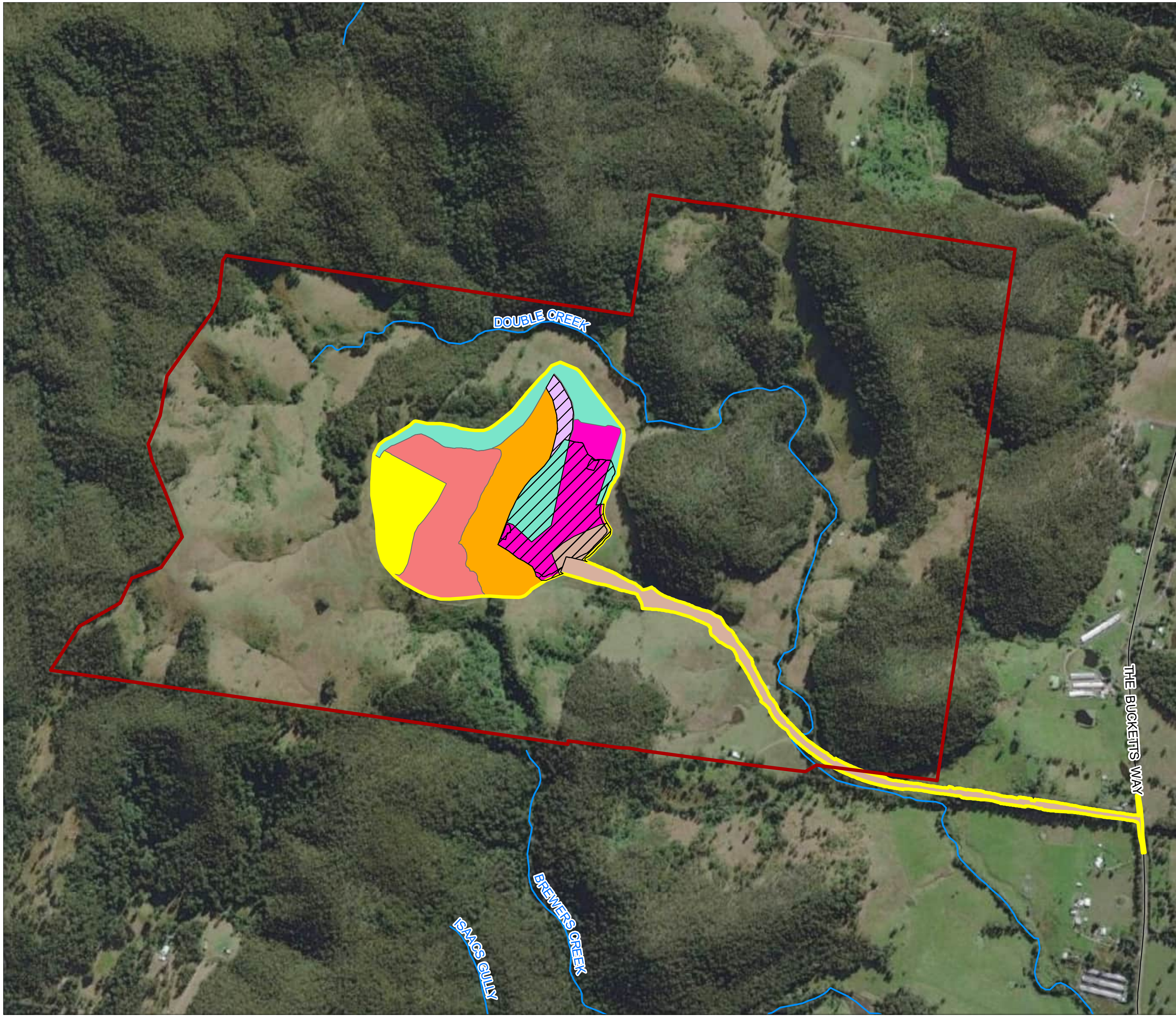
Stage 7 will result as the final landform, extraction will continue ultimately down to 95 mAHD, which is the same level as the processing pad constructed as part of Stage 3.

When excavation works are finalised at the end of the life of the Project, the final landform design will be a self-draining void.

HILLVIEW QUARRY EIS GROUNDWATER ASSESSMENT

Project Description

FIGURE 1



Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:16,000 at A4
Project Number:	630.12117
Date:	09-Nov-2023
Drawn by:	LF

SLR

2.0 Regulatory Framework

2.1 General Legislation, Policy, and Guidelines

General legislation and regulatory guidelines relevant to this water resources assessment are provided in **Table 1**.

Table 1 Legislation and Policy Context

Legislation/Policy	Description
Environmental Planning and Assessment Act (1979) / Environmental Planning and Assessment Amendment Act (2017)	Principles to guide planning authorities in making decisions for designated developments: • to promote the social and economic welfare of the community and a better environment via the proper management, development and conservation of the State's natural and other resources; • to facilitate ecologically sustainable development by considering economic, environmental and social factors in planning decisions; • to promote the best use of land; • to promote the delivery and maintenance of affordable housing; • to protect threatened and other species of plants and animals, and habitats; • to promote sustainable management of heritage sites; • to promote the good design and amenity of the built environment; • to promote the proper construction and maintenance of buildings; • to promote sharing of planning responsibility between different levels of government; and • to allow better community participation in environmental planning and assessment.
NSW Water Management Act (2000)	The NSW Department of Planning and Environment (DPE) Water Management Act of 2000 (WM Act) is the primary legislation regulating groundwater resources in NSW. The main purpose of the WM Act is to provide for the sustainable and integrated management of water sources in the State, and a means to manage and safeguard the existence of rivers and aquifers for commercial purposes. The WM Act also governs the issue of water licences across the State.
NSW Water Management (General) Regulation 2018 (NSW Government, 2018)	The WM Act requires water users to hold and comply with the conditions of a water access licence (WAL). WALs must be obtained for any activity involving the take of water from a surface water or groundwater source unless an exemption under the Water Management (General) Regulation 2018 is applicable.
NSW Water Sharing Plans	The WM Act is enacted under a framework of catchment specific Water Sharing Plans (WSPs). These WSPs set out the rules for water trading (buying and selling of water licences as well as water allocations), so that the equitable sharing of water and resources can occur sustainably and under a strict licensing and approvals process. Each WSP is split into several Water Sources; water can only be traded within a Water Source, and these act as the primary zones of water management.

Legislation/Policy	Description
NSW Aquifer Interference Policy (2012)	The purpose of the Aquifer Interference Policy 2012 (AIP) is to clarify the role and requirements of the administering authority of the water licensing and assessment processes for any activity that can be classed as an aquifer interference under the WM Act. Furthermore, the AIP aims to clarify the requirements for licensing for aquifer interference activities to ensure that any groundwater take is accounted for in the water budget and water sharing arrangements. Within the AIP, "Minimal Impact Considerations for Aquifer Interference Activities" are provided for different Water Sources, there are limits as to the allowable groundwater drawdown (water table and/or water pressure) of this source without the need to undertake additional studies to prove the long-term viability of GDEs, culturally significant sites, or water supply works.
NSW Protection of the Environment Operations Act (1997)	The Protection of the Environment Operations Act 1997 (POEO Act) seeks to manage pollution impacts for a variety of operations in NSW. The main objects of the POEO Act are to protect and restore the quality of the environment, to promote ecologically sustainable development and environmental protection, and strengthen the regulatory framework for environmental protection.
NSW State Groundwater Policy Framework Document (1997)	The NSW State Groundwater Policy Framework Document 1997 sets out the direction of groundwater management in NSW. Three component policies are under this Framework and provide a basis for decision making to achieve sustainable natural resource management: Groundwater Quantity Protection (DLWC, 1998), Groundwater Quality Protection (DLWC, 1998), and Groundwater Dependent Ecosystems (DLWC, 2002). The framework document (DLWC, 1997) outlines the following policy principles with respect to groundwater management in NSW: • An ethos for the sustainable management of groundwater resources should be encouraged in all agencies, communities and individuals who own, manage or use these resources, and its practical application facilitated; • Non sustainable resource uses should be phased out; • Significant environmental and/or social values dependent on groundwater should be accorded special protection; • Environmentally degrading processes and practices should be replaced with more efficient and ecologically sustainable alternatives; • Where possible, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored; • Where appropriate, the management of surface and groundwater resources should be integrated; • Groundwater management should be adaptive, to account for both increasing understanding of resource dynamics and changing community attitudes and needs; and • Groundwater management should be integrated with the wider environmental and resource management framework, and also with other policies dealing with human activities and land use, such as urban development, agriculture, industry, mining, energy, transport and tourism.
Risk Assessment Guidelines for	The risk assessment guidelines are used to manage land and water use activities that pose a potential threat to groundwater dependent

Legislation/Policy	Description
Groundwater Dependent Ecosystems (2012)	ecosystems. The guidelines consist of four volumes that include the conceptual framework, worked examples, identification of high potential groundwater dependent ecosystems and their ecological value for coastal aquifers, and the risk of groundwater extraction on the coastal plains of NSW.
NSW State Environmental Planning Policy (Resilience and Hazards) 2021	The *NSW State Environmental Planning Policy (Resilience and Hazards) 2021* has consolidated and repealed *SEPP (Coastal Management) 2018, SEPP 33 – Hazardous and Offensive Development, SEPP 55 – Remediation of Land (SEPP 55).* This SEPP contains planning provisions: • for land use planning within the coastal zone, in a manner consistent with the objects of the Coastal Management Act 2016 • to manage hazardous and offensive development • which provides a state-wide planning framework for the remediation of contaminated land and to minimise the risk of harm. • The SEPP promotes an integrated and co-ordinated approach to land use planning in the coastal zone in a manner consistent with the objects of the Coastal Management Act 2016, including the management objectives for each coastal management area, by • managing development in the coastal zone and protecting the environmental assets of the coast, and • establishing a framework for land use planning to guide decision-making in the coastal zone, and • mapping the 4 coastal management areas that comprise the NSW coastal zone for the purpose of the definitions in the Coastal Management Act 2016.
Department of Agriculture and Water Resources (2018): National Water Quality Management Strategy (NWQMS)	Water quality management in Australia is guided by the NWQMS that provides a nationally consistent approach. The main policy objective is to achieve sustainable use of the nation's water resources by protecting and enhancing their quality, while maintaining economic and social development.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) (ANZECC, 2000)	The purpose of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality is to achieve the sustainable use of Australia's and New Zealand's water resources by protecting and enhancing their quality while maintaining economic and social development. The Water Quality Objectives provide environmental values for NSW waters and the ANZECC 2000 Guidelines provide the technical guidance to assess the water quality needed to protect those values.
National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Australian and New Zealand Environment and Conservation Council, 1995)	The Guidelines for Groundwater Protection in Australia (ARMCANZ and ANZECC, 1995) are part of the National Water Quality Management Strategy and have been considered for preparation of this groundwater assessment. The guidelines provide a framework for protecting groundwater from contamination in Australia and involve the identification of specific beneficial uses and values for major aquifers. The guidelines outline several protection strategies to protect each aquifer, and all involve groundwater monitoring.

Legislation/Policy	Description
Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012)	The Australian Groundwater Modelling Guidelines provide a benchmark for best industry practice and are almost universally referenced by environmental regulators and model developers.

2.2 Water Sharing Plans

The NSW Government defines water-sharing arrangements in NSW through Water Sharing Plans (WSPs). The following WSPs are relevant to the Project:

- North Coast Fractured and Porous Rock Groundwater Sources 2016 (New England Fold Belt Coast Groundwater Source); and
- Lower North Coast Unregulated and Alluvial Water Sources 2022 (Karuah River Water Source and Lower North Coast Coastal Floodplain Alluvial Groundwater Source Extraction Management Unit – the latter associated with the alluvial deposits along the Karuah River).

2.2.1 Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016

The WSP covers 13 fractured and porous rock groundwater sources, extending from the Hawkesbury River north to the border of NSW and Queensland, and inland to the Murray-Darling Basin.

At the time of the WSP's commencement, within the New England Fold Belt Coast Groundwater Source, the share component for this groundwater source is estimated to be 14,840 ML/a in local water utility access licences and 11,023 ML/a in aquifer access licences.

The WSP includes rules for managing individual access licences for select groundwater sources, rules for water supply works located near groundwater dependent ecosystems and groundwater dependent culturally significant sites, and rules for the replacement of groundwater works. For fractured and porous rock groundwater sources, the minimal impact considerations are shown in **Table 2.**

2.2.2 Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources 2022

The alluvial deposits in the vicinity of the Project are regulated under the WSP for the Lower North Coast Unregulated and Alluvial Water Sources 2022, and form part of the Karuah Estuarine Management Zone under the Karuah River Water Source.

At the time of the WSP's commencement, the share component of aquifer access licences that are authorised to take water from groundwater sources is estimated to be 1,275.5 unit shares.

The WSP includes access rules for taking groundwater. The WSP also includes rules for water supply works taking groundwater including replacement groundwater work, high priority groundwater dependent ecosystem and groundwater dependent culturally significant sites, and water supply work approvals for groundwater.

2.3 Aquifer Interference Policy (AIP)

The NSW AIP divides groundwater into "highly productive" and "less productive" groundwater sources. Highly productive groundwater is defined in this policy as having:

- Total dissolved solids of less than 1,500 mg/L.
- Contains water supply works that can yield water at a rate greater than 5 L/sec.

Based on this the groundwater sources at the Project are considered to be 'less productive' due to fractured rock typically having yields of less than 1 L/sec and groundwater electrical conductivity being in the range of 1,000 to 4,000 mg/L TDS. The alluvium adjacent to the Project area (alluvial valley and alluvial high stand facies) are also considered to be less productive aquifers due to their limited spatial extent and depth, and therefore limited yield. The characteristics and water quality for each aquifer unit is detailed further in **Section 5.0**.

The minimal impact considerations for less productive aquifers are detailed in **Table 2**.

Table 2 Minimal Impact Considerations for Less Productive Alluvial and Fractured Rock Groundwater Sources

Level	Water Table	Water Pressure	Water Quality
1	1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan.; or A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and (b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above. (c) No quarrying activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three-dimensional extent of the alluvial material - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".
2	2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post- water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site;	2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that	2. If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister's

Level	Water Table	Water Pressure	Water Quality
	listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work, then make good provisions should apply	the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. If condition 1(c) is not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that: - there will be negligible riverbank or high wall instability risks; - during the activity's operation and post closure, levee banks and landform design should prevent the Probable Maximum Flood from entering the activity's site; and - low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed, and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.

2.4 Groundwater Flow and Quality Objectives

Relevant groundwater quality objectives for the Project are the ANZECC & ARMCANZ (2000) guidelines for marine water or fresh water. Any monitoring plan implemented should adhere to the water quality guidelines and trigger values mentioned in this document. **Table 3** shows the guideline values for livestock watering, and aquatic freshwater ecosystems that are the main uses of groundwater in the Project vicinity.

Table 3 ANZECC Guidelines

Parameter	ANZECC Guideline Values	
	Livestock Watering	Aquatic Freshwater Ecosystems (Slightly-Moderately Disturbed)
Field pH (pH units)	6.0 to 8.5	6.5 to 8.0
EC (µS/cm)	NA	350
TDS (mg/L)	2000	NA
Sulphate (mg/L)	1000	NA
Calcium (mg/L)	1000	NA
Magnesium (mg/L)	2000	NA
Nitrate (mg/L)	NA	0.7
Total Phosphorous (mg/L)	NA	0.01
Aluminium (mg/L)	5	0.055
Arsenic (mg/L)	0.5	0.013

Parameter	ANZECC Guideline Values	
	Livestock Watering	Aquatic Freshwater Ecosystems (Slightly-Moderately Disturbed)
Boron (mg/L)	5	NA
Cadmium (mg/L)	0.01	0.0002
Chromium (mg/L)	1	0.001
Copper (mg/L)	0.4	0.0014
Lead (mg/L)	0.1	0.0034
Manganese (mg/L)	NA	1.9
Mercury (mg/L)	0.002	6×10^{-5}
Molybdenum (mg/L)	0.15	NA
Nickel (mg/L)	1	0.011
Selenium (mg/L)	0.02	0.005
Zinc (mg/L)	20	0.008

3.0 Secretary's Environmental Assessment Requirements (SEARs)

The NSW Department of Planning and Environment (DPE) has reissued the Planning Secretary's Environmental Assessment Requirements (SEARs) for the preparation of the required EIS (dated 3 June 2024; original dated 27 April 2022). The scope of the groundwater assessment has been developed to address the SEARs concerned with groundwater impacts. It is understood that no SEARs were provided from the Natural Resources Access Regulator (NRAR) for the Project.

Table 4 SEARs for Groundwater Assessment

SEARS relevant to this technical report	Where addressed in this technical report
Planning Secretary's Environmental Assessment Requirements (Soil and Water) – June 2024	
~~1. A detailed site water balance, including description of site water demands, water disposal methods (inclusive of volume and frequency of site water discharges), water supply infrastructure and water storage structures.~~	Addressed in the surface water assessment appendix.
2. Identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000.	Section **10.0**
3. Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP).	Section **10.0**
4. A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP.	Section **10.0**
~~5. An assessment of any likely flooding impacts of the development.~~	Addressed in the surface water assessment appendix.
6. An assessment of the likely impacts on the quality and quantity of existing ~~surface and~~ groundwater resources, ~~including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives~~.	Sections **7.0**, **8.0**, and **9.0** Water discharge addressed in the surface water assessment appendix.
7. An assessment of the likely impacts of the development on aquifers, watercourses~~, riparian land~~, water-related infrastructure, and other water users.	Sections **7.0**, **8.0**, and **9.0**
8. A detailed description of the ~~proposed water management system (including sewage),~~ groundwater monitoring program and other measures to mitigate ~~surface and~~ groundwater impacts.	Section **9.0**
Department of Planning, Housing and Infrastructure (Water and Soils) – June 2024	
1. The EIS must map the following features relevant to water and soils including: a) Acid sulphate soils	a) Section **5.2**

SEARS relevant to this technical report	Where addressed in this technical report
b) Rivers, streams, estuaries c) Wetlands d) Groundwater e) Groundwater dependent ecosystems ~~f) Proposed intake and discharge locations.~~	b) Section **5.4** c) Section **5.8.3** d) Section **5.7** e) Section **5.8.3** f) Addressed in the surface water assessment appendix.
2. The EIS must describe background conditions for any water resource likely to be affected by the development, including: a) Existing ~~surface and~~ groundwater ~~b) Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations~~ c) Water Quality Objectives including groundwater as appropriate that represent the community's uses and values for the receiving waters d) Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) guidelines and/or local objectives, criteria or targets endorsed by the NSW Government.	Surface water components are addressed in the surface water assessment appendix. a) Section **5.7** b) Addressed in the surface water assessment appendix. c) Sections **2.4**, **5.7.4** d) Sections **2.4**, **5.7.4**
3. The EIS must assess the impacts of the development on water quality, including: a) The nature and degree of impact on receiving waters for ~~both surface and~~ groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. ~~This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.~~ b) Identification of proposed monitoring of water quality.	Surface water components are addressed in the surface water assessment appendix. a) Sections **8.1.2**, **8.2.2, 9.0** b) Section **9.0**
4. The EIS must assess the impact of the development on hydrology, including: a) Water balance including quantity, quality and source. b) Effects to downstream rivers, wetlands, ~~estuaries, marine waters and floodplain areas~~ c) Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems. ~~d) Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow,~~	Surface water components are addressed in the surface water assessment appendix. a) Section **7.0** b) Sections **8.0**, **9.0** c) Sections **8.0**, **9.0** d) Addressed in the surface water assessment appendix. e) Sections **8.0**, **9.0, 10.0** f) Addressed in the surface water assessment appendix. g) Section **9.0**

SEARS relevant to this technical report	Where addressed in this technical report
~~aquatic connectivity and access to habitat for spawning and refuge.~~ e) Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water. ~~f) Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.~~ g) Identification of proposed monitoring of hydrological attributes.	

* Note, all strikethrough text is not covered in this Groundwater Assessment and will be covered by other specialist studies in the EIS. All surface water aspects are addressed in the Surface Water Assessment appendix.

4.0 Assessment Methodology

The methodology undertaken for this groundwater assessment was as follows:

- A baseline desktop hydrogeological characterisation that defines the existing environment at the Project site.
- A numerical groundwater model risk assessment that predicts if groundwater is likely to be intercepted by the Project, including an estimation of groundwater inflows (groundwater take) for the Project, and radius of impact.
- Predicted groundwater take in relation to the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 and the Lower North Coast Unregulated and Alluvial Water Sources 2022 (came into effect in July 2022) in terms of construction dewatering and dewatering during long-term operation.
- An impact assessment detailing the groundwater impacts from all elements of the Project that may interact with the water environment, to address the SEARs.
- Proposed mitigation measures during both the construction/ operation and post closure phases of the Project.

4.1 Baseline Desktop Analysis

A baseline groundwater assessment was conducted for the Project using available data from the following public sources:

- The NSW Seamless Geology datasets of local and regional geology (DRNSW, 2020) including the geological stratigraphy and structural features in the vicinity of the Site.
- The Department of Planning and Environment (DPE) Water Sharing Plan (WSP) for the North Coast Fractured and Porous Rock Groundwater Sources 2016 and WSP for the Lower North Coast Unregulated and Alluvial Water Sources 2022. These WSPs detail the groundwater sources in the area and the legislation and water management for each of these groundwater sources.
- The Bureau of Meteorology (BOM) Groundwater Atlas that details information on potential Groundwater Dependent Ecosystems (GDEs) and anthropogenic groundwater use.
- The BOM climate data and rainfall statistics (BOM, 2022).
- SILO rainfall data.
- NSW Government Spatial Services Digital Elevation Model (DEM) data for the Dungog region with a 1 m resolution.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) that provides information on water quality guidelines and trigger values.
- NSW plant community type map (NSW Government, 2022a).

4.2 Impact Assessment

4.2.1 Approach

Quantitative and qualitative methods will be adopted to assess the potential impacts of the Project on the groundwater environment. This assessment will focus on the following:

- Groundwater levels, flows, and quality.

- Existing groundwater users.
- Groundwater Dependent Ecosystems (GDEs).

4.2.2 Impact significance

The devised matrix of significance for this Project is shown in **Table 5**; this compares the value of the water receptor against the potential magnitude of impact to that receptor from the Project.

Table 5 Matrix of Effect Significance

Magnitude of Impact	Value of Receptor			
	Very High	High	Moderate	Low
Major	Major adverse - significant	Major adverse - significant	Moderate adverse - significant	Minor adverse - not significant
Moderate	Major adverse - significant	Moderate adverse - significant	Moderate adverse - significant	Minor adverse - not significant
Minor	Moderate adverse - significant	Moderate adverse - significant	Minor adverse - not significant	Negligible - not significant
Negligible	Negligible - not significant	Negligible - not significant	Negligible- not significant	Negligible - not significant

Table 6 shows the value classification system for a water feature or receptor, whilst **Table 7** demonstrates the magnitude of impact classification that will be adopted in this assessment.

The Environmental Receptor Value evaluation is influenced by the following criteria:

- Condition of the environmental value, i.e., how far it is understood to have already been changed from its original natural form or state.
- How unique or rare the condition or value or its dependent ecological receptors are.
- How sensitive the dependent receptor/s is to changes.

The *Magnitude of Impact* evaluation is influence by the following criteria:

- Expected duration of impact: temporary vs. long-lasting/permanent.
- Expected extent of impact: Local vs. regional/widespread.
- Estimated degree of change from pre-development conditions.

Table 6 Environmental Receptor Value Classification

Classification	Value Criteria
Low	Receptor of low condition/ quality and/ or rarity.
Moderate	Receptor of moderate condition/ quality and/ or rarity.
High	Locally significant attribute of high value.
Very High	Nationally/ state significant attribute of high value.

Table 7 Magnitude of Impact Classification

Classification	Consequence Criteria
Negligible	Negligible change to receptor. OR Change to receptor that is less than the minimal impact considerations specified under local policy.
Minor	Measurable decrease (greater than minimal impact considerations specified in local policy) in the integrity of receptor in the short-term (temporary). AND/OR Measurable decrease (greater than minimal impact considerations specified in local policy) to a receptor in the long-term (permanent) but will not adversely influence upon overall integrity of attribute.
Moderate	Measurable decrease (greater than minimal impact considerations specified in local policy) in the integrity of a receptor in the long-term (permanent). AND/OR Loss of a receptor in the short-term (temporary).
Major	Loss of a receptor in the long-term (permanent).

4.2.3 Modelling methodologies

A numerical model assessment has been carried out to inform the risks to the groundwater environment during operation and long-term closure of the Project. This is presented in **Section 7.0**.

4.3 Recommendation of Mitigation Methods

Appropriate mitigation and management measures have been identified to ensure protection of the groundwater environment during both construction/ operation and post closure of the Project.

5.0 Existing Groundwater Environment

5.1 Climate

The Bureau of Meteorology (BoM) database was used to identify the nearest climate observation stations to the Project. The identified stations were used to determine the most representative set of records for use in this groundwater assessment. The results are summarised in Table 8.

Table 8 Climate Monitoring Stations

Data Source	Distance to Project (km)	Elevation (mAHD)	Active Years	Mean Annual Precipitation (mm)
Stroud Post Office (61071)	10.5	44	Sep 1889-present	1,143.8
Clarencetown (Mill Dam Falls) (61339)	14.0	10	2000-present	826.1
Dungog (Monkerai Hill (Urimbirra)) (61106)	18.1	91	2001-present	1,110.1
Clarence Town (Prince St) (61010)	18.2	24	1885-present	1,069.9
SILO dataset (-32.50°N 151.90°E)	NA	NA	1889-present	1,152.6

Due to the mean annual precipitation at the SILO data point being comparable to that of the BoM stations, as well as the lack of actual evapotranspiration data at the BoM stations, local climate statistics for the Project site have been obtained through the SILO database (Jeffrey *et al*., 2001). The summary of mean monthly rainfall, evaporation, and evapotranspiration from the beginning of the SILO dataset (1889) to the end of 2022 is shown in **Figure 2**.

The average annual rainfall is 1,153 mm with rainfall being generally higher in the summer months (January to March), and lowest in the winter months (July to September). Average rainfall is higher than average evapotranspiration over the February to July months.

The annual total rainfall records between 1889 and 2022 are shown in **Figure 3Figure 3**. Review of the historical data suggests the site experiences a large range of rainfall conditions, with drier years, such as 2019 receiving less than 750 mm, and wetter years such as those experienced over the recent 2021 to 2022 period receiving over 1,500 mm.

Figure 2 Mean Monthly Rainfall, Evaporation (EV), and Evapotranspiration (EVT) at SILO Point Lat: -32.50S/ Long: 151.90E

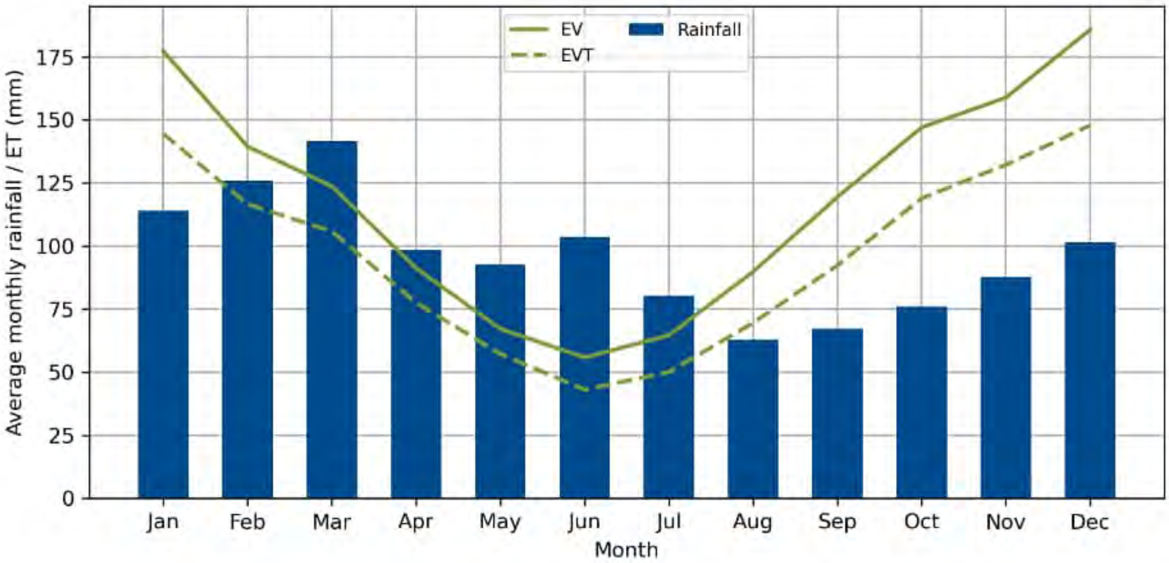
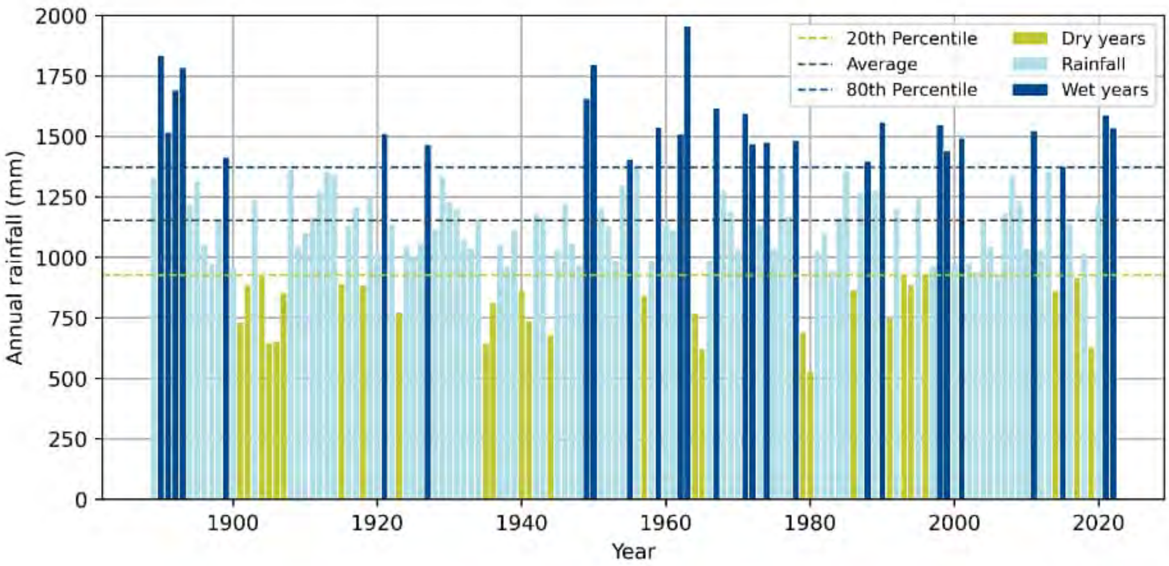


Figure 3 Average Annual Rainfall from 1889 to 2022



5.2 Land Use and Soil Type

Land use in the vicinity of the Project is predominantly rural, with areas of urbanisation associated with nearby townships of Booral (4.1 km northeast) and Stroud (10 km northeast). The Project site itself comprises an established grazing property with numerous existing farms dams. Most of the land has been cleared for cattle grazing. There are some areas of remnant bushland.

According to the Australian Soils Classification, the soils that are situated within the Project footprint are composed of Rudosols and Tenosols as well as Natric Kurosols. Rudosols and Tenosols are soils that are rudimentarily, or weakly, developed. In comparison, Kurosols are soils that display a strong textural contrast between surface (A) horizons and subsoil (B) horizons (CSIRO, 1960). The spatial distribution of these soils in the Project boundary is shown in **Figure 4**.

To the east of the Project site, there is the presence of Alluvial Tenosols associated with Karuah River and downgradient Double Creek and Brewers Creek. These are weakly developed alluvial soil profiles. Along the Karuah River there is also the presence of Dermosols, a diverse soil group lacking strong textural contrast between surface (A) horizons and subsoil (B) horizons (CSIRO, 1960).

No acid sulphate soils are mapped within the Project footprint or adjacent areas; accordingly, the risk of encountering acid sulphate soils is considered to be very low since there are no known occurrences of acid sulphate soils on lands near the Project.

5.3 Topography

NSW Government Spatial Services Digital Elevation Model (DEM) data for the Dungog region with a 1 m resolution was acquired from the public ELVIS website.

The Project site is generally traversed by ridgeline systems which trend to the northwest from the higher land along the southern boundary with elevations up to 220 m. The ridgeline systems include a number of hills and saddles which are steep sided and characterised by slopes of between 15 to 35 %. The topography dips strongly towards the north and east at the Project location, towards the local watercourses of Double Creek and Karuah River.

The topography at the Project is shown in **Figure 5**.

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GROUNDWATER ASSESSMENT

Soils - Statewide Land and Soil Mapping: ASC Classification

FIGURE 4

Project Site
Quarry Footprint
Watercourses
Roads

Dominant ASC - Order

Kurosols - natric (KUn)
Rudosols (RU)

Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)
ASC Mapping:
Department of Planning, Industry and Environment, 2021, Australian Soil Classification (ASC) Soil Type map of NSW, Version 4.5

0 200 400 m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:16,000 at A4
Project Number:	630.12117
Date:	07-Nov-2023
Drawn by:	JG/LF

SLR

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GROUNDWATER ASSESSMENT

Topography and Drainage

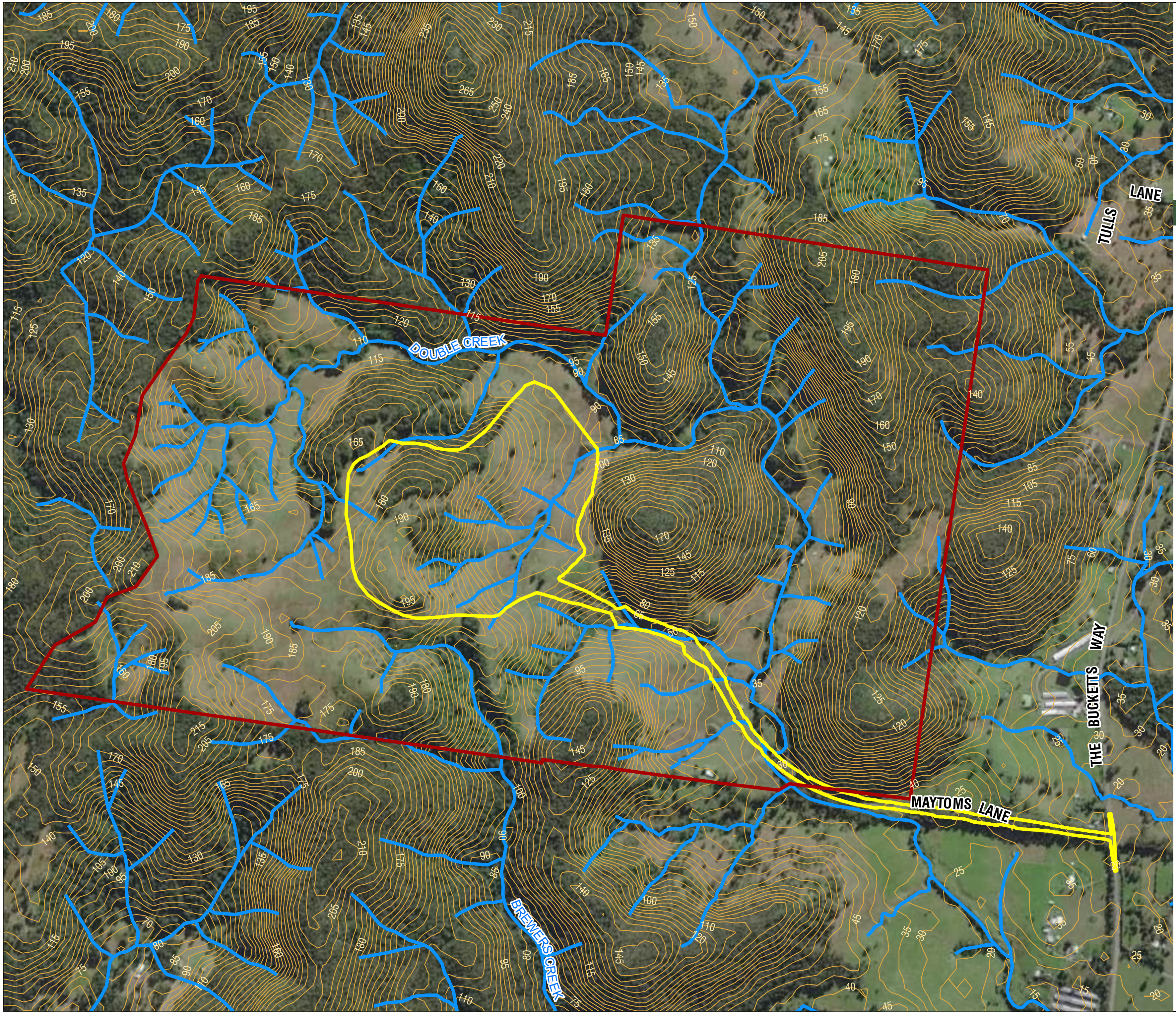

FIGURE 5

- Project Site
- Disturbance Footprint
- Watercourses
- Contour (5m Interval)

Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)

0 250 500 m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:16,000 at A4
Project Number:	630.12117
Date:	09-Nov-2023
Drawn by:	LF

SLR

5.4 Hydrology

The Project is located within the catchment of the Karuah River, and its tributary Double Creek. The majority of the proposed extraction area falls within a single valley which drains northwards towards Double Creek. The extraction area has a total area of approximately 44 ha and falls from an elevation of 206 mAHD to 90 mAHD. Rainfall runoff from this central valley reports to a series of existing farm dams. The largest existing farm dam is located approximately 150 m upstream of Double Creek. The drainage pattern is shown in **Figure 5**.

Karuah River is a Schedule 3 major river and is located 1.1 km to the northeast (4 km downstream along river course) of the Project footprint. Karuah River is situated in the valley depression mentioned in **Section 5.3**, a marked break of slope is consistent with the Karuah River valley.

Double Creek, a fourth order Schedule 2 minor watercourse, flows in a generally easterly direction to the north of the Project extraction area, before turning in a south to south-easterly direction through the south-eastern corner of the Project. In addition, a third order Schedule 2 watercourse, Brewers Creek, flows in an easterly direction 450 m south of the Project. Double Creek discharges to Cromarty Creek downgradient of the Project site (a tributary of Karuah River). Brewers Creek flows into Double Creek, before the latter’s confluence with Cromarty Creek. These are shown in relation to the Project in **Figure 5**.

Within the Project footprint, an unnamed tributary of Double Creek lies within the ‘central valley’ of the proposed quarrying site. The watercourse runs along the floor of the valley and is a third order Schedule 2 watercourse. This watercourse has been previously modified as it has a large existing farm dam approximately 150 m upstream of the confluence with Double Creek. Another unnamed tributary of Double Creek (2) runs through a valley to the north-western extent of the Project. This is a first order Schedule 2 watercourse.

There are a number of upper creeks at the Project site. Unless previously specified, all other watercourses on the upper slopes comprise first- or second-order Schedule 1 waterways. These are generally very steep and shallow watercourses with low sinuousity. The beds typically have good vegetative cover, with some natural armouring by the natural rock.

Further information on the surface hydrology and catchments in the Project is detailed in the *Hillview Quarry: Surface Water Assessment*.

Any surface watercourses that lie on steep hillslopes are considered to not be in connection with groundwater due to a groundwater being at depth beneath the hillslopes. Only the rivers mentioned above that lie within topographical values are considered likely to have a groundwater baseflow component in the vicinity of the Project.

5.5 Regional Geology

As per the NSW Seamless Geology Map (DRNSW, 2020), the geology surrounding the Project site typically consists of Quaternary deposits overlying Permo-Triassic and Carboniferous igneous and sedimentary bedrock.

5.5.1 Stratigraphical setting

The Project is located within the Stroud-Gloucester Trough (syncline orientated north-south) within the Myall Block that is part of the Tamworth Fold Belt. Carboniferous rocks are exposed across the western part of the section with Permian infilling of synclines. The Myall Block is bounded by the Gresfold Block to west, with the Williams River Fault acting as the boundary between the two. To the east, the Myall Block is bounded by the Gloucester Basin, with the Tarean Fault acting as the boundary between the two. The stratigraphy within the Project vicinity is shown in **Table 9**.

Initial folding occurred in Myall Block in the Early Permian Period, with syndepositional faulting in the Late Permian. Intensification of folding occurred in late Permian and again in Triassic periods.

Table 9 Regional Stratigraphy

Period	Group / Stratigraphic Unit	Description	Proximity to Project
Quaternary	Alluvial channel deposits – subaqueous (QHac)	Fluvially deposited sand, gravel, silt, clay.	Along Karuah River.
	Alluvium (Qa)	Unconsolidated grey to brown to beige humic (±) micaceous silty clay, quartz-(±)lithic silt, fine- to medium-grained quartz-rich to quartz-lithic sand, polymictic pebble to cobble gravel (as sporadic lenses); sporadic palaeosol horizons.	Alluvial deposits concentrated in valley along Karuah River and downstream reaches of the larger tributaries such as Double Creek and Cromarty Creek in the vicinity of the project.
	Alluvial Valley Deposits (Qav)	Silt, clay, (fluvially deposited) lithic to quartz-lithic sand, gravel.	Alluvial deposits along upstream reaches of Double Creek, Brewers Creek, and Cromarty Creek.
	Alluvial Floodplain Deposits (QHaf)	Silt, very fine- to medium-grained lithic to quartz-rich sand, clay.	Alluvial deposits concentrated in valley along Karuah River and downstream reaches of Cromarty Creek in the vicinity of the project.
	Alluvial Levee Overbank Deposits (Qal)	Fluvially deposited fine- to medium-grained lithic to quartz-rich sand, silt, clay.	Alluvial deposits along Karuah River where meanders are present.
	Alluvial Terrace Deposits - High Stand Facies (CZath)	High-level terrace deposits of sand and gravel.	Alluvial deposits concentrated in valley along Karuah River and downstream/ upstream reaches of the larger tributaries such as Double Creek, Brewers Creek, and Cromarty Creek in the vicinity of the project.
Triassic	Stroud Mountain Microgranite (Tugs)	Pink to grey, porphyritic microgranite.	North-west of Project on the other valley side of the Tarean Fault.
Permian	Alum Mountain Volcanics (Puma, Cua)	Flows of black to dark-green albitised alkaline-olivine basalt; massive to flow-banded (to porphyritic to spherulitic) rhyolite, and rhyolitic ignimbrites; interbedded pebble	North-west of Project on the other valley side of the Tarean Fault.

Period	Group / Stratigraphic Unit	Description	Proximity to Project
		conglomerate, sandstone, mudstone, tuff, breccia and basal coal seams.	
Carboniferous	Ungrouped Tamworth Belt Units (Cut) includes: Mount Johnstone Formation (Cutj)	Siliclastic, carbonate, volcaniclastic and volcanic units	Other side of Cromarty Creek to Project.
	Ungrouped Myall Block units (Cum) includes: Johnsons Creek Conglomerate (Cumj) McInnes Formation (Cumm) Booral Formation (Cumr) Karuah Fomration (Cumh) Nerong Volcanics (Cumn) Wootton beds (Cumo)	Siliclastic rocks with minor volcanic and carbonate rocks	Nerong Volcanics (Gilmore Volcanic Group?) in project footprint. Heavy faulted in vicinity.
	Ungrouped Gresford Block units (Cug) includes: Flagstaff Formation (Cugf) Bonnington Siltstone (Cugo)	Siliclastic and volcaniclastic units	Mostly to the west of the Williams River Fault in the Gresford Block but also situated to the east adjacent to this the Faultline.
	Gilmore Volcanic Group (Cgi) includes: Ararat Formation (Cgia) Vacy Ignimbtire Member (Cginv)	Green to brown, thick- to medium-bedded lithic sandstone, lensoidal units of grey cross-bedded oolitic and crinoidal limestone, cobble conglomerate, minor mudstone, and occasional ignimbrite.	Mostly to the west of the Williams River Fault in the Gresford Block but also situated to the east adjacent to this the Faultline.

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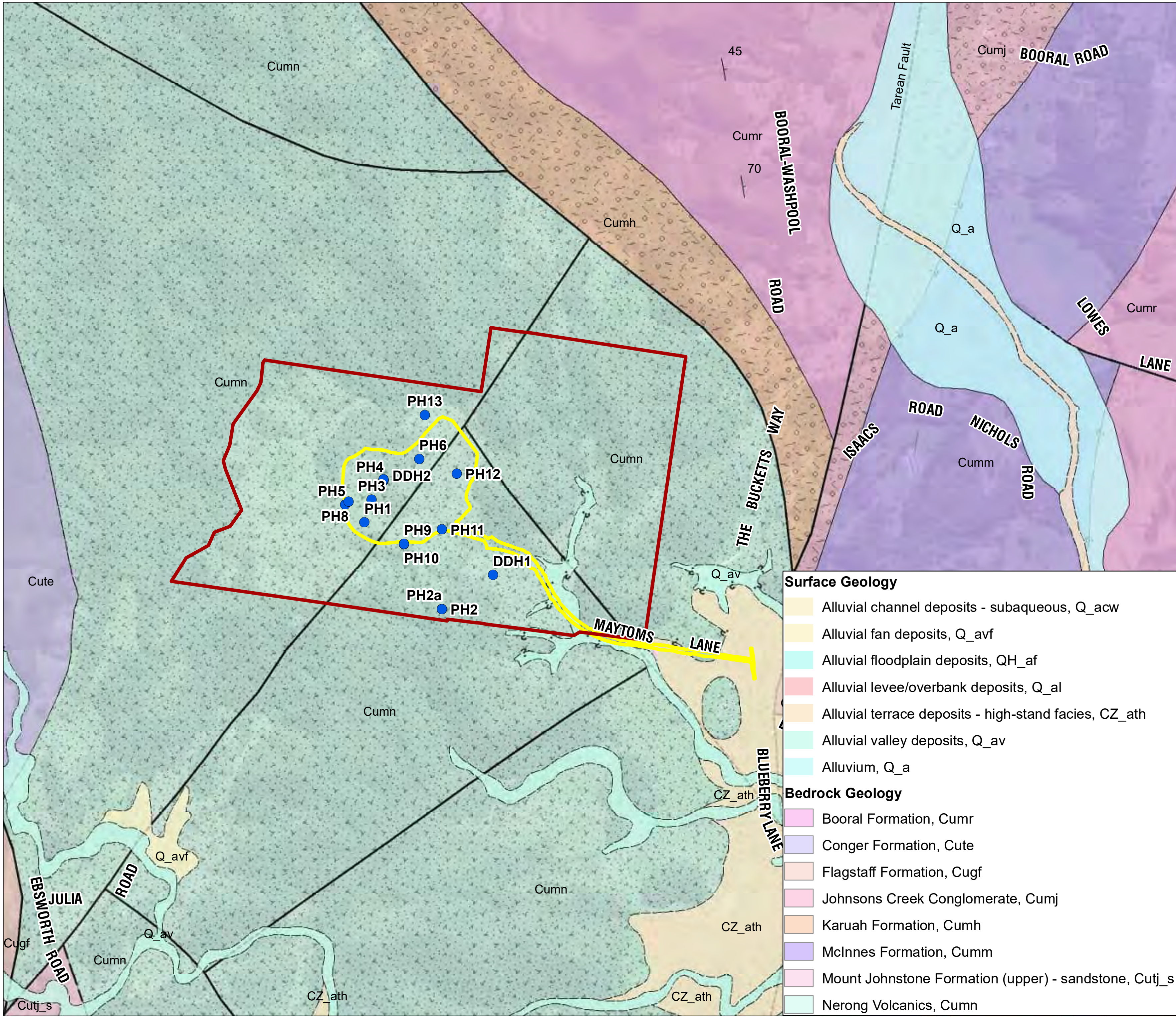
GROUNDWATER ASSESSMENT

Geology

FIGURE 6



- Project Groundwater Monitoring Bore
- Project Site
- Disturbance Footprint
- Geological boundary, inferred
- Geological boundary, position accurate
- Geological Boundary
- Fault, concealed
- Fault, inferred
- Fault, position accurate
- Fault, position approximate

Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)

0 250 500
m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:30,000 at A4
Project Number:	630.12117
Date:	20-Nov-2023
Drawn by:	RB

SLR

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5.5.2 Structural geology

Two major north-south trending faults are found in the area; the first, Tarean Fault is located 6 km to the east of the Project, with the second, the Williams River Fault is located 8.3 km to the west. These are associated with the north-south Stroud - Gloucester Syncline and are axial faults related to folding.

The Williams River Fault is steeply dipping and downthrown to the west. The southeastern limb of the Stroud-Gloucester Syncline is disrupted by the Tarean Fault which originates west of Port Stephens and extends roughly north as far as Mammy Johnsons River near Weismantels. This fault is downthrown to the east.

Table 10 Major Fault Structure Interpretation (from Robinson and Phillips, 2015)

Fault	Interpretation
Williams River Fault	Steep west-dipping reverse fault >100 km strike length. Interpreted deep penetrating (15 to 22 km) due to strike extent and cross cutting of all other faults along strike. Terminates south of Manning fault near Carboniferous-Carboniferous/Devonian boundary. Likely intersecting basal decollement (Hunter Thrust).
Tarean Fault	N-S trending Steep east-dipping reverse fault with >80km of strike length. Bounds the eastern margin of the southern half of the Gloucester Basin. The northern end of the fault is offset by a series of small E-W or NNE trending faults. The fault is interpreted to a hanging wall splay to or is cut off by a west-dipping fault zone to the east of the Gloucester Basin. South of the Gloucester basin the produces major apparent dextral offsets and is inferred to extend to greater depth due to the increased relative offsets observed.

5.6 Local Geology

5.6.1 Ground investigation

Ground investigation was carried out within the Project footprint in December 2016 by VGT, when 16 investigation bores were drilled; these are shown in **Table 11**. Geological bore logs for these are shown in **Appendix A**.

Table 11 On Site Investigation Bores

Bore	Easting (GDA 94 MGA Z56)	Northing (GDA 94 MGA Z56)	TOC Elevation, (mAHD)	Total Depth (m)	Screened Geology	Comments
PH1	398559	6404551	206.6	123	Rhyodacite, not weathered	Not cased and not used in monitoring.
PH2	399020	6404034	113.11	68	Mudstone	Monitoring infrastructure installed.
PH2a	399021	6404035	112.39	Unknown	Unknown	Monitoring infrastructure installed.
PH3	398601	6404686	194.42	114	Rhyolitic tuff, weathered	Upper cased with lower open hole,

Bore	Easting (GDA 94 MGA Z56)	Northing (GDA 94 MGA Z56)	TOC Elevation, (mAHD)	Total Depth (m)	Screened Geology	Comments
						but not used in monitoring.
PH4	398672	6404799	190.16	140	Rhyolitic tuff, slightly weathered	Monitoring infrastructure installed.
PH5	398444	6404656	185.58	90	Rhyolitic tuff/ dyke, some weathering and veining	Monitoring infrastructure installed.
PH6	398887	6404928	150.11	60	Unknown	Proposed bore, not drilled.
PH7	398674	6404804	189.81	40 to 46	Rhyolitic tuff/ dyke, some weathering and veining	Monitoring infrastructure installed.
PH8	398464	6404673	181.13	40 to 46	Rhyolitic tuff, calcite veining	Monitoring infrastructure installed.
PH9	398795	6404421	158.12	30 to 36	Rhyolitic tuff/ dyke, calcite and pyrite veining	Monitoring infrastructure installed.
PH10	398796	6404422	157.99	69 to 75	Rhyolitic tuff/ dyke, calcite precipitation	Monitoring infrastructure installed.
PH11	399020	6404508	113.58	17.5 to 23.5	Rhyolitic tuff, weathered	Monitoring infrastructure installed.
PH12	399109	6404840	88.79	14 to 20	Rhyolitic tuff, calcite veining	Monitoring infrastructure installed.
PH13	398919	6405190	100.21	20	Rhyolitic tuff/ dyke, some weathering, calcite precipitation	Monitoring infrastructure installed. Not capped.
DDH1	399325	6404237	101.77	34	Sandstone	Not cased and not used in monitoring.
DDH2	398674	6404805	189.73	95 to 101	Rhyolitic tuff, calcite veining	Monitoring infrastructure installed.

5.6.2 Alluvial deposits

The Quaternary alluvial deposits in the vicinity of the site are composed of a number of different mapped lithologies, as shown in **Table 9**. No on-site bores penetrate the alluvial deposits. The nearest registered bore that intercepts the mapped alluvials is GW202804, which is 6 km south-east of the Project. This bore log shows 9 m of clay at surface, though it is not known if this corresponds to alluvial deposits or weathered residual deposits (see **Section 5.6.3**).

5.6.3 Residual deposits

As seen from the logs in **Appendix A**, a weathered profile of the rhyolitic tuff is present across the Project site, ranging from 0.2 m thick at PH7 to greater than 23 m at PH11. The weathered material is commonly of a clay composition, with some coarser grained silt in places. This is sporadic and not mapped on the local geological mapping (DRNSW, 2012).

5.6.4 Myall Volcanic Group

Rhyolite bedrock will be intercepted over the Project footprint. As seen from the logs in **Appendix A**, most bores are characterised by rhyolitic tuff, or rhyodacite at surface, which is frequently fractured or broken, with dykes of approximately 10 m thickness occurring throughout geological profile.

5.6.5 Structural geology

Two smaller fault structures associated with the larger fault features detailed in **Section 5.5.2** directly intersect the Project footprint. The largest of these two faults is orientated in a southwest-northeast direction across the Project footprint with the smaller in southeast-northwest direction. There is overall, a lack of information about small-scale faults. The Myall block is extensively faulted, folding is generally tighter, and the trend of fold axes is more variable (Robinson and Phillips, 2015).

5.7 Hydrogeology

5.7.1 Regional hydrogeology

The Project lies within the Myall Block and is hydraulically separated from geological formations to the east within the Permo-Triassic Gloucester Basin, that contains the Alum Mountain Volcanics, Dewrang Group, and Gloucester Coal Measures (BioRegional Assessments, 2022), and therefore there is anticipated to be limited interaction between the Permo-Triassic bedrock in the Gloucester Basin and the Carboniferous bedrock at the Project location.

In addition, the Permo-Triassic basins in the Hunter subregion to the south of the Project are also not considered in connection with the Carboniferous bedrock at the site is not considered to have any groundwater connections with areas to the north-east due to the geological basin divides that define its boundary (BioRegional Assessments, 2022)

5.7.2 Groundwater monitoring network

The monitoring network at the Project consists of eleven screened monitoring bores. Monitoring bores at the Project are shown in **Table 11** and shown spatially in **Figure 6**.

Manual dips were taken at PH4, PH5, PH7, PH8, PH9, PH10, PH11, PH12, PH13, and DDH2 over the period from February 2019 to December 2020. Continuous water level dataloggers were installed at PH2a, PH4, PH7, and PH13 on 13 December 2022 for the purposes of this groundwater assessment. A barologger was also installed in PH13. Hydrographs with both the manual and logger data are shown in **Appendix B**.

5.7.3 Groundwater occurrence, recharge, and flow

5.7.3.1 Key aquifers

The four main hydrostratigraphic units within the study area are:

- Alluvial valley deposits. These are likely to exist as unconfined, perched aquifers predominantly recharged by rainfall and stream flow infiltration (where a favourable head gradient exists).
- Alluvial high-stand facies. These are predominantly sand and are likely to exist as unconfined, perched aquifers recharged by rainfall and stream flow infiltration (where a favourable head gradient exists).
- Alluvial floodplain and alluvial channel deposits associated with the Karuah River. These are predominantly recharged by rainfall and stream flow infiltration. Typically, they are high-yielding aquifers (albeit of limited areal extent and depth), with several water bores drilled directly into these deposits.
- Rhyolitic bedrock of the Myall Volcanic Group – a unconfined to semi-confined (likely becoming confined with depth).

The first three aquifers (alluvial) are associated with the Karuah Estuarine Management Zone of the Karuah River Water Source (part of the Lower North Coast Unregulated and Alluvial Water Sources 2022), whilst the Rhyolite is regulated as part of the New England Fold Belt Coast Groundwater Source (North Coast Fractured and Porous Rock Groundwater Sources 2016).

The weathered profile (residual deposits) of the rhyolitic bedrock is not considered a significant aquifer due to their predominant clay content and are likely to form a barrier to the underlying bedrock where a significant thickness of clay exists at surface.

5.7.3.2 Alluvial valley deposits

The alluvial valley deposits are situated along the upstream portions of Double Creek and Cromarty Creek. Due to their clay and silt composition, they are likely to form a series of discontinuous unconfined perched aquifers. Due to the limited spatial and vertical extent of these deposits, small groundwater baseflow contributions to receptors are envisaged, with this aquifer supporting groundwater features on a local scale. It is noted that no registered bores in the area abstract from these alluvial valley deposits and therefore the aquifer potential of this deposit is considered limited.

There is mapped alluvial valley deposits (DRNSW, 2020) downgradient of the Project around Double Creek and Brewers Creek; however, this is of limited spatial extent and the deposits are not present on the upland slopes directly adjacent to the Project. This deposit may be sporadically saturated, but due to its extent the resource is considered minor and not a major baseflow contributor to groundwater features.

5.7.3.3 Alluvial high stand facies

The alluvial high-stand facies are a sand-dominated lithology around Karuah River and the lower reaches of Double Creek, Brewers Creek, and Cromarty Creek. Due to their sand content, they are likely to form a permeable aquifer of an unconfined nature, receiving recharge from direct rainfall and runoff from the high topographical points to west. Similar to the alluvial valley deposits (**Section 5.7.3.2**), this deposit may be sporadically saturated, but due to its extent the resource is considered minor and not a major baseflow contributor to groundwater features.

5.7.3.4 Alluvial floodplain/ alluvial channel deposits

This aquifer is likely recharged by rainfall where clay layers are limited in depth or spatial extent, and by stream flow infiltration from the Karuah River along reaches where a favourable head gradient exists. Conversely, discharge to Karuah River is expected where groundwater levels are higher than the adjacent watercourse level. Regional groundwater flow is expected to be a subdued reflection of topography and regional surface water flow, with connection of groundwater in these deposits likely with the Karuah River and larger tributaries.

5.7.3.5 Rhyolitic bedrock

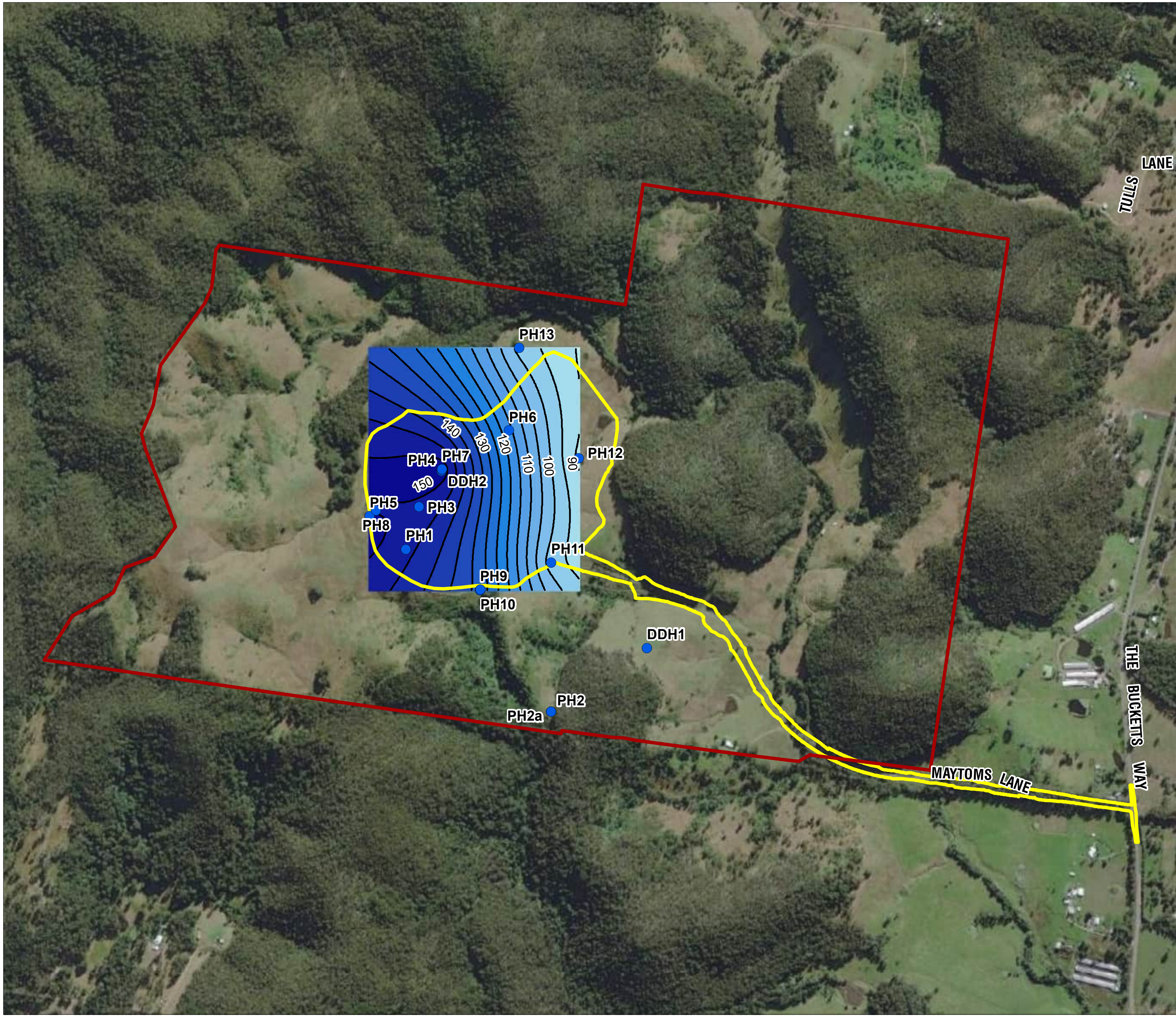
All monitoring bores with groundwater data are located in rhyolitic tuff geology, which is the predominant geological unit found across the Project; groundwater hydrographs are shown in **Appendix B**. This forms part of the New England Fold Belt Coast Groundwater Source that is dominated by fractured rock aquifers where groundwater is intersected in secondary fracture porosity associated with the folding and faulting of the rock.

According to NSW DPE (2016b), yields from the New England Fold Belt Coast Groundwater Source are typically low, being around 1 L/s. Maximum yields of up to 10 L/s may be obtained from highly fractured and connected fault systems. Groundwater is typically recharged by direct rainfall infiltration. No yield information is available within the vicinity of the Project footprint and therefore, the range of yields to be expected is currently unknown.

Monitoring in the on-site bores shows flow across the Project footprint is predominantly in an easterly to north-easterly direction (**Figure 7**) with groundwater direction heavily influenced by topography, flowing from high topographical recharge areas and discharging to low topographical areas and major surface water expressions (such as Karuah River).

Based on a one-off on-site survey by ADW Johnson, the base of Double Creek is at elevations of 110.3 to 79.3 mAHD along the northern extent of the Project. PH13, the closest bore to Double Creek shows groundwater levels of between 92.5 to 98.0 mAHD, suggesting groundwater is above the base of the Creek in the vicinity of the Project, and therefore likely in connection and discharging to the Creek. Therefore, Double Creek is likely to be baseflow supported during times of high groundwater. There is likely to also be groundwater baseflow to the reaches of Double Creek to the east of the Project, due to the break in slope here.

A number of surface watercourses including Double Creek, unnamed tributary of Double Creek, unnamed tributary of Double Creek 2, and Cromarty Creek are likely to be fed by groundwater springs issuing from the rhyolite, with groundwater discharges where valleys and topographical breaks in slope exist.



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Observed Groundwater Flow across Project

FIGURE 7

Interpolated groundwater contours – December 2020
Project Site
Disturbance Footprint

Groundwater (m)

80 - 85
85 - 90
90 - 95
95 - 100
100 - 105
105 - 110
110 - 115
115 - 120
120 - 125
125 - 130
130 - 135
135 - 140
140 - 145
145 - 150
150 - 155

Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)

0 250 500 m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:16,000 at A4
Project Number:	630.12117
Date:	20-Nov-2023
Drawn by:	RB

SLR

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5.7.4 Groundwater quality

Water quality was monitored at the Project site between January 2019 and December 2020. A water type analysis has not been completed, as bicarbonate and carbonate ions were not monitored at the site during this time at either groundwater or surface water monitoring locations.

Time series charts for water quality in the groundwater monitoring bores are presented in **Appendix B**. A summary of the significant values and trends are:

- pH over the monitoring period is within the range of 6.2 to 7.6 pH units. The deeper bores (PH4, DDH2) show a greater variability in pH, with a decrease in pH (more acidic change) over time.
- Bores PH9 and PH10 to the south of the Project show stable, low electrical conductivities throughout monitoring. Bores PH7 and PH12 have the highest electrical conductivity measurements but experience the greatest variability; no obvious correlation between depth or location and conductivity exists.
- High conductivity is linked to high sodium and chloride measurements, which are the dominant ions in the groundwaters.
- DDH2 shows high concentrations of aluminium and beryllium.
- PH13 despite being shallow does not observe same high concentrations of nitrate, as other shallow bores.
- The following show prolonged exceedances of the ANZECC guidelines which are highlighted in **Table 3**:
  - Aluminium in PH4 and DDH2. Not observed in the shallower PH7 at same location. Potentially linked to deep flow paths and longer residence time/ interaction with rock minerals of groundwater with depth.
  - Manganese in PH4, PH10, PH12, PH13, and DDH2. No obvious correlation with spatial location or depth.
  - Nitrate in PH9. Note adjacent bore PH10 does not show this level of nitrate and may mean that nitrates are not observed at depth (PH9 shallower than PH10), and therefore linked to local land practices.
  - Total phosphorous in PH7, PH9, PH11, PH12, and PH13. These are all shallow bores, deeper bores do not show high phosphorous suggesting land practices are causing high total phosphorous.
  - Salinity (electrical conductivity) is higher in all Project bores than that tolerated by aquatic freshwater environments.

Two water quality monitoring points along Double Creek were monitored over the period from January 2019 to December 2020. Full details are provided in *Hillview Quarry: Surface Water Assessment*, but are summarised here for completeness:

- pH at the upstream monitoring location varies between 6.5 to 7.75 pH units; the downstream location is more alkaline and ranges between 7.0 to 8.0 pH units.
- Electrical conductivity at the upstream and downstream points remains similar throughout monitoring, with downstream consistently slightly higher. Maximum downstream concentrations reached approximately 2,250 µS/cm in late 2019. No measurements were taken at the upstream location during this time and the corresponding upstream concentration is therefore unknown.

- Total suspended solids (TSS) are typically within the range of 0 to 10 mg/L. Peaks in the upstream TSS concentrations in the range of 20 to 30 mg/L are not seen at the downstream monitoring point.

It is noted that the conductivity measurements in Double Creek show similar values and trends to that of groundwater bore P13, which is the closest bore to the river, thereby implying some level of surface water-groundwater connection in proximity to this bore. In addition, water quality monitoring undertaken in the Karuah River Catchment by the Gloucester Water Study Project, Baseline Water Survey (Great Lakes Council, 2015) during 2014, likewise found elevated manganese, aluminium, and iron levels, as well as elevated turbidity levels in Wards River and Mammy Johnsons River. These metals are naturally occurring within the landscape associated with the underlying geology and soil types of the catchment and a likely exported to the river bound to sediment. The similarities between water quality parameters suggests a level of hydraulic connection between the shallow bedrock and the surface watercourses.

5.7.5 Hydraulic properties

Hydraulic conductivity is a property of soil or rock which describes the ease at which water can move through pore spaces or fractures.

A literature review (summarised in **Table 12**) has been carried out to identify the potential range of hydraulic parameters for the geological units intercepted by the Project.

Table 12 Literature Parameters for the Site Deposits

Geology	Lithological Description	Hydraulic Conductivity (m/s)			Specific Yield		Specific Storage (m^{-1})
		Domenico and Schwartz, 1990 (from Aqtesolv, 2022)	Freeze and Cherry, 1979	Bouwer, 1978 from Krusema n and de Ridder, 1992)	Heath, 1983 (from Aqtesolv , 2022)	Morris and Johnson , 1967 (from Aqtesolv , 2022)	Domenic o and Mifflin, 1965 (from Aqtesolv, 2022)
Alluvial deposits/ Weathered colluvium	Deposits in area assumed to be silty and sandy clay due to underlying bedrock composition.	1×10^{-11} (fine clay) to 2×10^{-5} (silt)	1×10^{-12} (fine clay) to 1×10^{-5} (silt)	1×10^{-10} (clay) to 1×10^{-6} (sandy clay)	0.02 (clay) to 0.22 (sand)	0.06 (clay) to 0.32 (medium sand)	8.5×10^{-5} (medium clay) to 1.9×10^{-5} (dense sand)
Rhyolite bedrock	Rhyolite (igneous)	8×10^{-9} to 3×10^{-4} (fractured igneous and metamorph ic rocks)	1×10^{-10} to 1×10^{-4} (fractured igneous and metamorphi c rocks)	Negligible flow to 1×10^{-3} (fractured or weathered rock)	-	0.08 (basalt) to 0.21 (tuff)	3.1×10^{-7} to 6.4×10^{-6} (fissured rock)

In addition, on-site slug tests were carried out by SLR in the rhyolite bedrock at the Project site on 16 March 2023. The results are shown in **Table 13** and further information including methodology is shown in **Appendix C**.

Table 13 Slug Test Results

Bore	Geology	Test Type	Hydraulic Conductivity (m/d)	
			Hvorslev Analysis	Bouwer and Rice Analysis
PH4	Rhyolitic tuff, slightly weathered	Rising Head	0.00233	0.00233
PH8	Rhyolitic tuff, calcite veining	Falling Head	10.65	13.33
PH10	Rhyolitic tuff/ dyke, calcite precipitation	Rising Head	0.0307	0.0329
PH11	Rhyolitic tuff, weathered	Rising Head	0.00356	0.00378
PH13	Rhyolitic tuff/ dyke, some weathering, calcite precipitation	Rising Head	0.00324	0.00418

As observed in **Table 13**, hydraulic conductivities at the Project site span five orders of magnitude and range from 0.0023 m/d (observed in PH4) to 13.33 m/d (observed in PH8). It is likely that the low end of the conductivities is representative of the volcanic rock matrix and/ or smaller scale fractures, whilst the conductivities observed in PH8 are indicative of a larger fault zone, with enhanced fracture permeability. This fault zone does not directly correlate with those that are mapped, and therefore it is considered likely that smaller scale faults that are not mapped are present across the Project.

5.8 Groundwater Users

5.8.1 Registered groundwater bores

There is one third-party registered bore within 2 km of the Project. This bore (GW050664) is located near the proposed entrance to the Project on a property fronting the Buckets Way.

Table 14 Third-party Water Supply Bores

Bore	Easting (GDA 94 MGA Z56)	Northing (GDA 94 MGA Z56)	Ground Elevation (mAHD)	Total Depth (mbgl)/ Screened Depth (mbgl)	Screened Geology	Yield
GW050664	400791	6403456	27.8	51.8 (7.6 to 51.8)	Shale/ Mudstone	23 m at 0.19L/s 45 m at 0.13L/s

Based on this bore accessing a water bearing horizon at 45 m depth (-17.2 mAHD), this is considered to be extracting from a deeper confined unit in the Myall Block Volcanics than that the Project intersects (base of quarry to 95 mAHD) and is not considered in direct hydraulic connection with the Project.

5.8.2 Water availability

The number of water access licences (WALs), total share component, and total usage for the last five years for the New England Fold Belt Coast Groundwater Source are shown in **Table 15**.

Table 15 Groundwater Usage in the New England Fold Belt Coast Groundwater Source (NSW Water Register – WaterNSW, 2023)

Groundwater Source	Access Licence Category	No. of WALs/Total Share Component/Total Usage (ML/a)* by Water Year				
		2022/23	2021/22	2020/21	2019/20	2018/19
New England Fold Belt Coast	Aquifer	630 16,512 84.8	606 15,642 96.5	591 13,016 106.9	562 13,016 177.3	558 12,911 66.7
	Local Water Utility	2 240 0	2 240 36.6	2 240 199.2	2 240 199.2	2 240 0

*ML/a = megalitre per year

The long-term average annual extraction limit (LTAAEL) for the New England Fold Belt Coast Groundwater Source is 60,000 ML/a. Data in **Table 15** shows that the total share component is less than the LTAEEL, and therefore, groundwater is available for use in the catchment.

5.8.3 Groundwater dependent ecosystems

Ecosystems that rely on groundwater to maintain their structure and function are classified as Groundwater Dependent Ecosystems (GDEs). The GDE Atlas developed by the Bureau of Meteorology (BoM) provides high level mapping for surface and sub-surface GDEs, based on national-scale analysis and regional studies. The Atlas (BoM, 2012) contains information about three types of ecosystems:

- Aquatic ecosystems are ecosystems that rely on the surface expression of groundwater. This includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands, and springs. Marine and estuarine ecosystems can also be groundwater dependent, but these are not mapped in the Atlas.
- Terrestrial ecosystems are ecosystems that rely on the subsurface presence of groundwater–this includes all vegetation ecosystems.
- Subterranean ecosystems, includes cave and aquifer ecosystems (stygofauna).

The first two categories may overlap in riparian zones where vegetation may access groundwater in the subsurface but also via its surface expression during overbank flooding of streamflow sourced from baseflow.

For vegetation to access groundwater in the subsurface, the roots must be able to reach the capillary zone above the water table at some time during the plant's life cycle. A widely adopted rule of thumb is that vegetation use of groundwater is likely where depth to groundwater is 0 to 10 mbgl, possible at depths of 10 to 20 mbgl, and unlikely at depths of >20 mbgl (Doody, 2019).

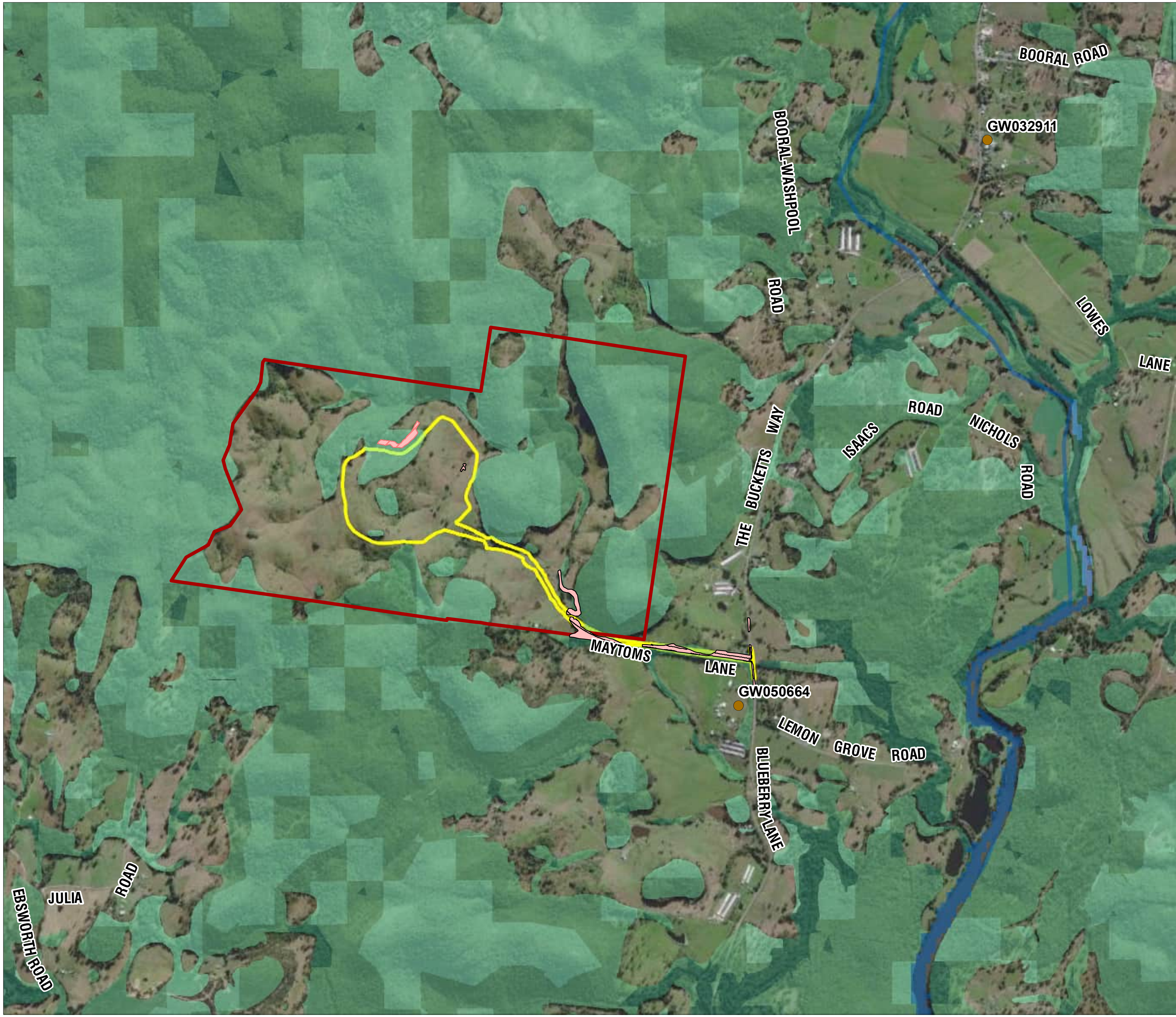
The BoM GDE Atlas (BoM, 2012) shows there to be isolated patches of high potential terrestrial GDEs associated with the alluvial deposits running along Karuah River and major tributaries including Double Creek, Brewers Creek, and Cromarty Creek. Along Double Creek and Brewers Creek in the direct vicinity of the Project, these high potential ecosystems have been mapped from regional studies and are highly disconnected from one another as well as small in spatial extent. Areas of moderate and low potential GDE are also associated with the riparian zones along Double Creek and Brewers Creek as well as the Volcanic Permian and Carboniferous deposits.

According to the Lower North Coast Unregulated and Alluvial WSP, the nearest high-priority GDE is associated with Karuah River Wetlands, 4.75 km south-east of the Project. These are also designated as coastal wetlands and are protected under the SEPP (Resilience and Hazards) 2021 legislation. These are outside the catchment and radius of influence of the Project and are not included further in this groundwater assessment. No GDEs are associated with the North Coast Fractured and Porous Rock WSP (New England Fold Belt Coast Groundwater Source) in the vicinity of the Project.

A site survey conducted by SLR ecologists (see *Hillview Quarry: BDAR* for further details) shows the presence of a Eucalypt River Flat Forest located along Double Creek that correlates to the high potential GDEs along this river on the BoM database and is protected as a threatened ecological community under the Biodiversity Conservation Act (BCA), 2016.

In addition, there is high value Lower Hunter Valley Dry Rainforest habitat to the adjacent northwest of the Project footprint, situated along the unnamed tributary of Double Creek 2, and is protected as a threatened ecological community under the BCA, 2016. It is noted that this habitat is not mapped as a GDE in either the BoM Atlas or the WSP and therefore its groundwater dependency is considered to be limited.

All potential GDEs are shown in **Figure 8**.



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Groundwater Users

FIGURE 8

- Registered Bore
- Project Site
- Disturbance Footprint

BCA Act Protected Habitat

- Whalebone
- Eucalypt

Aquatic GDE

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

Terrestrial GDE

- High potential GDE - from regional studies
- Moderate potential GDE - from regional studies
- Low potential GDE - from regional studies

Data Sources:
NSW Spatial Information Exchange
ESRI Basemap world imagery (May 2023)

0 250 500 m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:30,000 at A4
Project Number:	630.12117
Date:	20-Nov-2023
Drawn by:	RB

SLR

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6.0 Hydrogeological Conceptual Model

6.1 Conceptual Model

The Project will directly intersect the Myall Volcanic Group, a predominantly rhyolite geology that forms an aquifer of secondary (fracture) permeability with minimal primary (matrix) permeability. Recharge to this aquifer is predominantly through rainfall recharge with discharge to surface watercourses in the topographical valleys and groundwater levels a subdued reflection of topography. Based on the elevation of surface watercourses in the vicinity and the unknown interconnectedness and degree of fracturing with depth, the aquifer close to surface is considered to be unconfined and in likely connection with surface watercourses and riparian GDEs, becoming confined with depth.

Hydraulically downgradient of the Project lies alluvial valley deposits, a clayey silt lithology associated with downgradient reaches of Double and Brewers creeks. This deposit is likely temporally saturated and limited in spatial and vertical extent; therefore, acting as a minor perched aquifer temporally supporting local flow and habitats including the high and moderate priority riparian GDE systems along the surface watercourses. High-stand alluvial facies also lie downgradient of the Project, these are composed of sand and gravel.

As observed in the monitoring bores on site, the groundwater levels follow closely with the antecedent rainfall conditions. Higher groundwater levels are observed underneath the topographical high points with groundwater in the valleys, near Double Creek and Brewers Creek (and associated minor tributaries) being close to surface with groundwater discharging to the surface watercourses themselves.

Figure 9 and **Figure 10** show schematic conceptual cross-sections through the Project in a west to east and south to north direction respectively.

Figure 9 Schematic Conceptual Model of Groundwater Flow (W-E) – a) Pre-Development and b) During Development

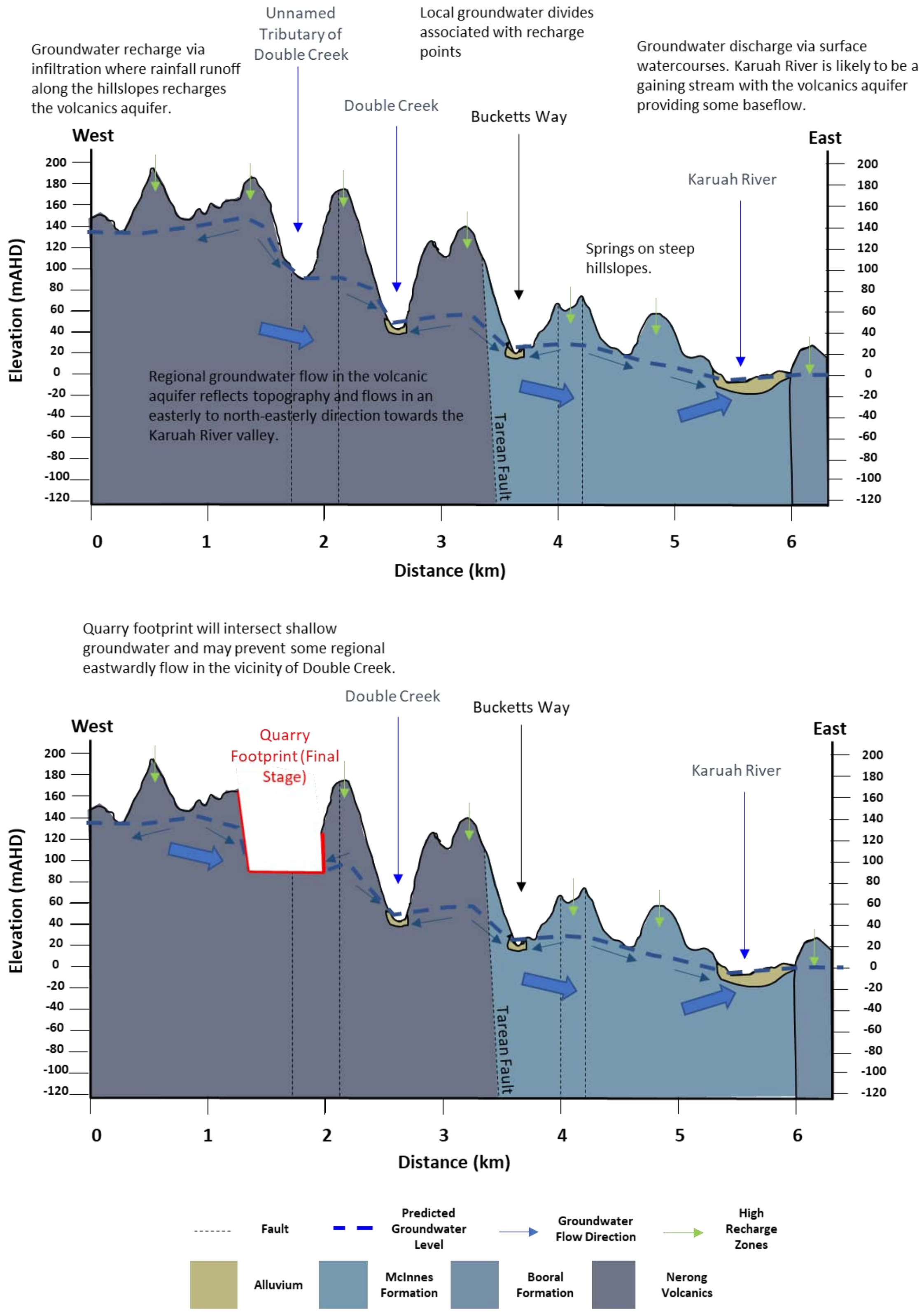
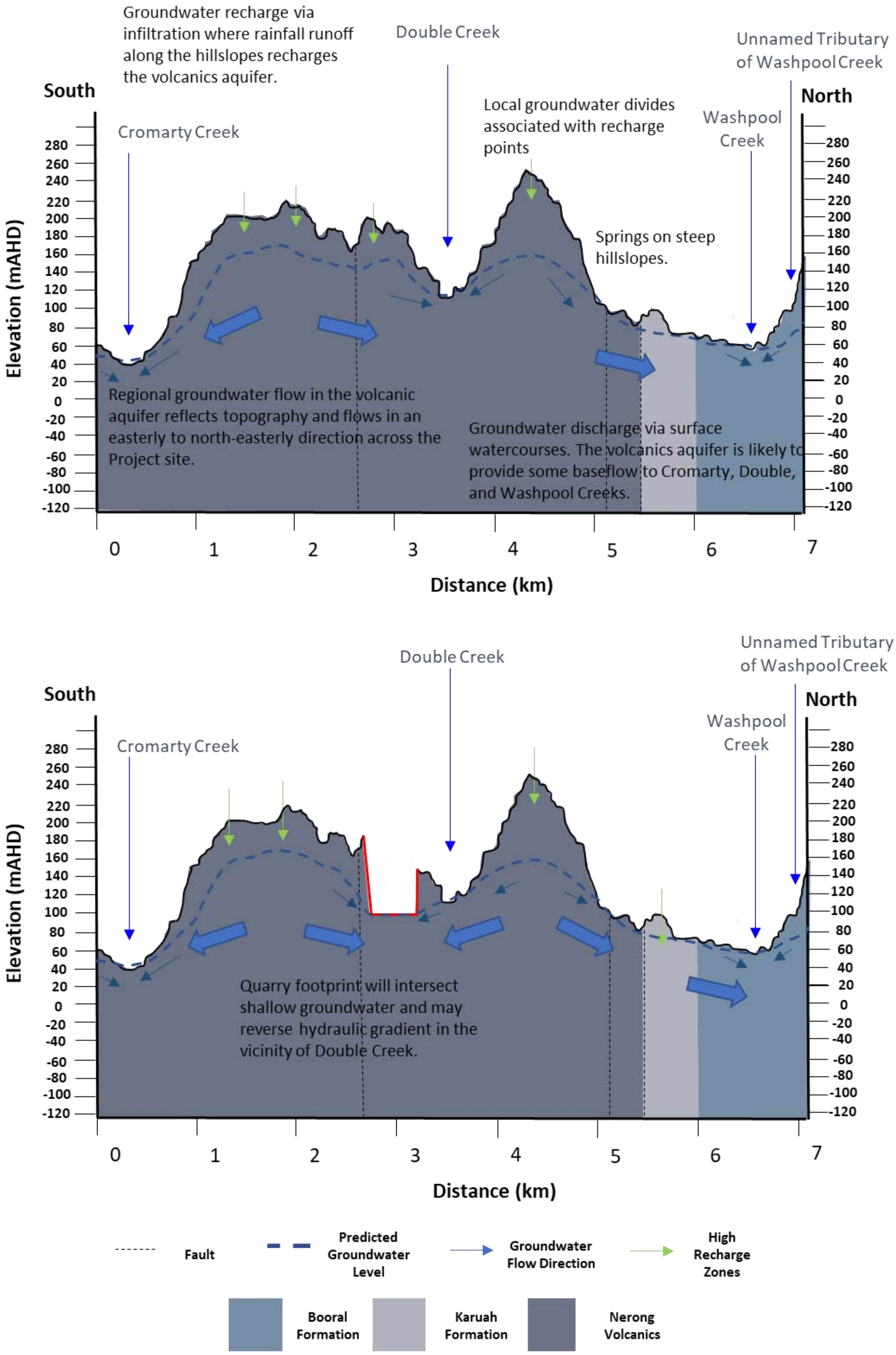


Figure 10 Schematic Conceptual Model of Groundwater Flow (S-N) – a) Pre-Development and b) During Development



6.2 Receptor Identification

Based on the conceptual model and understood hydrological and hydrogeological catchments at the Project, the key receptors that will be included in the model domain and will be assessed against in the impact assessment are outlined in **Table 16**.

Table 16 Groundwater Receptors

Receptor	Type	Distance to Project (m)	Receptor Value
Grouped Myall Block volcanic deposits	Aquifer	Within footprint	Moderate – unconfined to semi-confined aquifer that supports small-scale baseflow to rivers and GDEs. Low yielding.
Alluvial valley deposits	Aquifer	Within footprint (haul road)	Low – unconfined to semi-confined aquifer that supports small-scale baseflow to rivers. Limited in spatial extent and depth and predominantly clay based thereby limiting yield and aquifer potential.
Alluvial terrace deposits - high-stand facies	Aquifer	Within footprint (haul road)	Moderate – unconfined to semi-confined aquifer that supports small-scale baseflow to rivers and GDEs.
Unnamed tributary of Double Creek (located within 'central valley' of proposed quarrying site)	Third order, or above, surface watercourse	Within footprint	Low – heavily modified watercourse with a large existing farm dam approximately 150 m upstream of confluence with Double Creek.
BoM moderate potential with patches of high potential riparian GDE associated with Brewers Creek.	Environmental GDE (potential)	5 S	Low – moderate potential GDE determined from national studies, with isolated patches of high potential GDE. Not specified in any specific legislation such as the *Biodiversity Conservation Act (BCA) 2016*, WSP, or SEPP.
Lower Hunter Valley Dry Rainforest along unnamed tributary of Double Creek 2	Environmental GDE (potential)	30 NW	High – potential GDE, habitat is considered rare in the Hunter region and protected under the *BCA 2016* state legislation. Threatened species found within habitat.
Eucalypt River-Flat Forest along Double Creek	Environmental GDE (potential)	71 E	High - potential GDE correlating with high potential GDE from BoM (2012), habitat is considered rare in the Hunter region and protected under the state legislation *BCA 2016*.
Brewers Creek	Third order, or above, surface watercourse	85 S	Moderate - natural watercourse supporting local ecosystems.
Double Creek	Third order, or above, surface watercourse	92 N and W	Moderate - natural watercourse supporting local ecosystems.
BoM moderate potential with patches of high potential	Environmental GDE (potential)	100 NE	Low – moderate potential GDE determined from national studies. These studies suggest that the GDE

Receptor	Type	Distance to Project (m)	Receptor Value
riparian GDE associated with Double Creek (outside of mapped Eucalypt River Flat Forest)			has a limited spatial extent and connectiveness with other GDE habitats. Not specified in the BCA, WSP, or SEPP.
GW050664	Anthropogenic bore	2,000 SE (quarry) 270 S (haul road)	Moderate – presumed stock and domestic bore providing up to 3 ML/a of supply.
Cromarty Creek	Third order, or above, surface watercourse	2,350 S	Moderate – natural watercourse supporting riparian ecosystems.
BoM high and moderate potential riparian GDE associated with Cromarty Creek	Environmental GDE (potential)	2,350 S	Moderate – high and moderate potential GDEs determined from national studies. Not specified in the BCA, WSP, or SEPP.
Alluvial floodplain deposits	Aquifer	3,070 SE (quarry) 1,220 E (haul road)	High – unconfined to semi-confined aquifer that supports regional-scale baseflow to rivers and GDEs.
Karuah River	Third order, or above, surface watercourse	3,300 E 1,700 E (haul road)	Very High – natural river supporting WSP and SEPP wetlands.
BoM high and moderate potential riparian GDE associated with Karuah River	Environmental GDE (potential)	3,300 E 1,700 E (haul road)	Moderate – high and moderate potential GDE determined from national studies. Not specified in the BCA, WSP, or SEPP in vicinity of Project.
Alluvial levee/ overbank deposits	Aquifer	3,300 E 1,700 E (haul road)	High – unconfined to semi-confined aquifer that supports regional-scale baseflow to rivers and GDEs.

Note, only GDEs outside of the Project boundary have been included as a receptor in this groundwater impact assessment, as all habitats intersected directly by the Project will be lost and mitigated as standard by the *Hillview Quarry: BDAR*.

6.3 Model Design Assumptions

Based upon the conceptualisation and the objectives of the modelling, it is proposed that the numerical model should be designed in a manner that:

- Focuses on the Myall Block volcanic deposits and excludes both the Permo-Triassic Gloucester Basin (to east) and Hunter Region (to south) that are regionally acting as their own isolated groundwater basins.
- Replicates the rhyolitic tuff geology with intrusive dykes, and the alluvial deposits where they are present. As no obvious geological laying is present in the rock from existing studies, layering in the model should be appropriate and of sufficient vertical resolution to represent pit advancement.

- Includes the surface watercourses of Karuah River, Double Creek, Brewers Creek, and Cromarty Creek that act as key groundwater discharge areas.
- Considers the mapped extensive faulting across the area. Although on-site slug testing observed the potential for additional unmapped fault, only mapped faults will be modelled due to the uncertainty regarding these unmapped features.
- Uses literature review and on-site slug testing results for initial and constrained calibration ranges.

7.0 Numerical Model

7.1 Model Details

7.1.1 Model objectives

The overall objectives of the numerical groundwater modelling for the Project are to:

- Predict groundwater levels during the lifecycle of the Project (operation and closure).
- Predict the extent of maximum groundwater drawdown/ depressurisation due to the Project, presented in maps for the key stratigraphic units or aquifers.
- Quantify time-varying pit inflows.
- Predict the change in groundwater levels at, and fluxes to, identified groundwater receptors (i.e., surface watercourses, registered bores, landholder bores, and GDEs) during the lifecycle of the Project.
- Predict the induced changes in water budgets including groundwater fluxes to and from alluvial sediments during operation and closure (via the use of zone budgets).
- Predict the change in surface water flow due to the proposed operations (i.e., the reduction in baseflow to or induced leakage from watercourses).
- Identify areas of potential risk where groundwater impact mitigation/ control measures may be required.

7.1.2 Groundwater system conceptualisation

Conceptualisation of the groundwater regime and the calibration of the model against observed data are key to achieving a reliable numerical model. Conceptualisation is a simplified overview of the groundwater regime (i.e., the distribution and flow of groundwater) based on available data and experience. Consistency between numerical model results and the conceptual understanding of the groundwater regime increases the credibility of the numerical model predictions. Therefore, the Project numerical groundwater model has been built based on the conceptual groundwater model presented above in **Section 6.0**.

Confidence in the numerical model is increased by calibration of numerical model results against observed data. A well calibrated model has demonstrated the ability to simulate groundwater levels that approximate observed levels at specific locations.

7.2 Model Design

The numerical model was developed using a Geographic Information System (GIS) in conjunction with MODFLOW-USG, which is distributed by the United States Geological Survey (USGS). MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the USGS. MODFLOW is the most widely used code for groundwater modelling and has long been considered an industry standard.

7.2.1 Model extent and mesh

The groundwater model boundary is shown in **Appendix D, Figure D1**. The model is approximately 8 by 13 km. The groundwater model extent was designed to prevent boundary influence on potential model drawdowns.

The eastern boundary follows the Karuah River, whilst the western boundary follows the Williams River Fault, and are considered to be regional flow divides in the area. The northern and southern boundaries both follow known faults away from the Project area (**Section 5.5.2**).

To allow stable numerical modelling of the large spatial area of the model domain, an unstructured grid with varying Voronoi cell sizes was designed using Algomesh (HydroAlgorithmics, 2014). Varying Voronoi cell sizes allowed refinement around areas of interest, while a coarser resolution elsewhere reduces the total cell count to a manageable size. The model domain was vertically discretised into eight layers, each layer comprising a cell count of a maximum of 26,953. The total number of cells in the model is 98,860. This is after pinching out areas in layers 2 to 8 where a layer is not present.

The following features have been included in the grid design and refinement and are shown on **Appendix D, Figure D1**.

- 20 m resolution around the Project quarry pit, haul road, and monitoring bores.
- 50 m resolution along Karuah River.
- 100 m resolution in alluvium in the north near pit extents.
- 20 m resolution along Double Creek.
- 150 m resolution along the remaining surface watercourses.
- 50 m resolution along the faults.

7.2.2 Layers and features

The model domain is discretised into eight layers representing the alluvium and regolith (Layer 1) and underlying bedrock (Layers 2 to 8). The bedrock was discretised into seven layers. Layers 2 to 6 represent the stages of operation of the quarry pit in the Project area, with the bottom of Layers 2 to 6 at the elevation of the base of each quarry stage (see **Section 1.2**). Layers 7 and 8 represent the bedrock below the pit.

Some areas of layers 2 to 7 are ‘pinched out’ where a layer is not present. This happens in areas away from the pit where the topography is lower than the base of a quarry stage. Over the eight layers, with pinch-out areas (where a layer is not present) in layers 2 to 7, the total cell count for the model is 98,860.

The model layer structure is presented in **Table 17**. The top of Layer 1 was based on LIDAR data and the Digital Elevation Model from the NSW government. The extent of the alluvium was based on the geological map from the NSW Seamless Geology Map (DRNSW, 2020). The depth of alluvium and depth of regolith (bottom of Layer 1) were based on the CSIRO (2015) regolith depth map.

Table 17 Model Layering

Model Layer	Geologic Formation	Hydrogeologic Unit	Average Thickness (m)
1	Alluvium, Colluvium, Regolith	Alluvium, surface cover	5
2	Pyroclastic rock, Sedimentary rock	Fractured bedrock	24
3	Pyroclastic rock, Sedimentary rock	Fractured bedrock	14
4	Pyroclastic rock, Sedimentary rock	Fractured bedrock	13
5	Pyroclastic rock, Sedimentary rock	Fractured bedrock	14
6	Pyroclastic rock, Sedimentary rock	Fractured bedrock	26
7	Pyroclastic rock, Sedimentary rock	Fractured bedrock	53

Model Layer	Geologic Formation	Hydrogeologic Unit	Average Thickness (m)
8	Pyroclastic rock, Sedimentary rock	Fractured bedrock	50

Different geologies in different layers on the model are presented using hydraulic properties zones.

27 hydraulic property zones were defined based on geological properties and depth (layer). In each hydraulic property zone unique values of vertical hydraulic conductivities (Kx), vertical hydraulic conductivity (Kz), specific yield (Sy), and specific storage (Ss) were defined. These were then refined during the calibration process (see **Section 7.3**).

As discussed in **Section 3.6**, there are a number of small faults that occur within the Project area. There is very limited information regarding these faults, and it is unclear if they act as a hydraulic conduit or barrier to groundwater flow. These faults have been simulated in the groundwater model domain as separate hydraulic zones. The hydraulic properties of the fault zones were adjusted during the model calibration. Mesh refinement used along fault lines allowed for isolated changes of hydraulic properties (e.g., increased vertical permeability) along faults zones during calibration.

The hydraulic property zones are summarized in **Table 18** and shown on **Appendix D, Figure D2a** to **D2g** for each layer of the model**.**

Table 18 Hydraulic Property Zones

Hydraulic zone number	Layer – Geology Unit	Layer
1	L01 – Pyroclastic rock (regolith)	1
2	L01 - Sedimentary rock (regolith)	1
3	L01 – Alluvium high production	1
4	L01 – Alluvium low production	1
5	L01 – Alluvium medium production	1
6	L01 – Fault zone	1
7	L02 – Pyroclastic rock	2
8	L02 - Sedimentary rock	2
9	L02 – Fault zone	2
10	L03 – Pyroclastic rock	3
11	L03 - Sedimentary rock	3
12	L03 – Fault zone	3
13	L04 – Pyroclastic rock	4
14	L04 - Sedimentary rock	4
15	L04 – Fault zone	4
16	L05 – Pyroclastic rock	5
17	L05 - Sedimentary rock	5
18	L05 – Fault zone	5
19	L06 – Pyroclastic rock	6

Hydraulic zone number	Layer – Geology Unit	Layer
20	L06 - Sedimentary rock	6
21	L06 – Fault zone	6
22	L07 – Pyroclastic rock	7
23	L07 - Sedimentary rock	7
24	L07 – Fault zone	7
27	L07 - weathered pyroclastic rock along creeks	7
25	L08 – Pyroclastic rock	8
26	L08 - Sedimentary rock	8

7.2.3 Boundary conditions

7.2.3.1 Evapotranspiration

Evapotranspiration from the shallow water table was simulated using the evapotranspiration package (EVT). Evapotranspiration was represented in the upper most cells of the model domain, down to an extinction depth of 10 m. The extinction depth usually varies between 0 and 10 m in the Hunter region (Herron *et al*., 2018) and was assigned during the calibration process. A maximum rate of evapotranspiration was set based on the data from the SILO Grid Point observations for the Project (see **Section 5.1** for more information).

7.2.3.2 No flow boundaries

No flow boundaries were set on the northern, southern, and western boundaries.

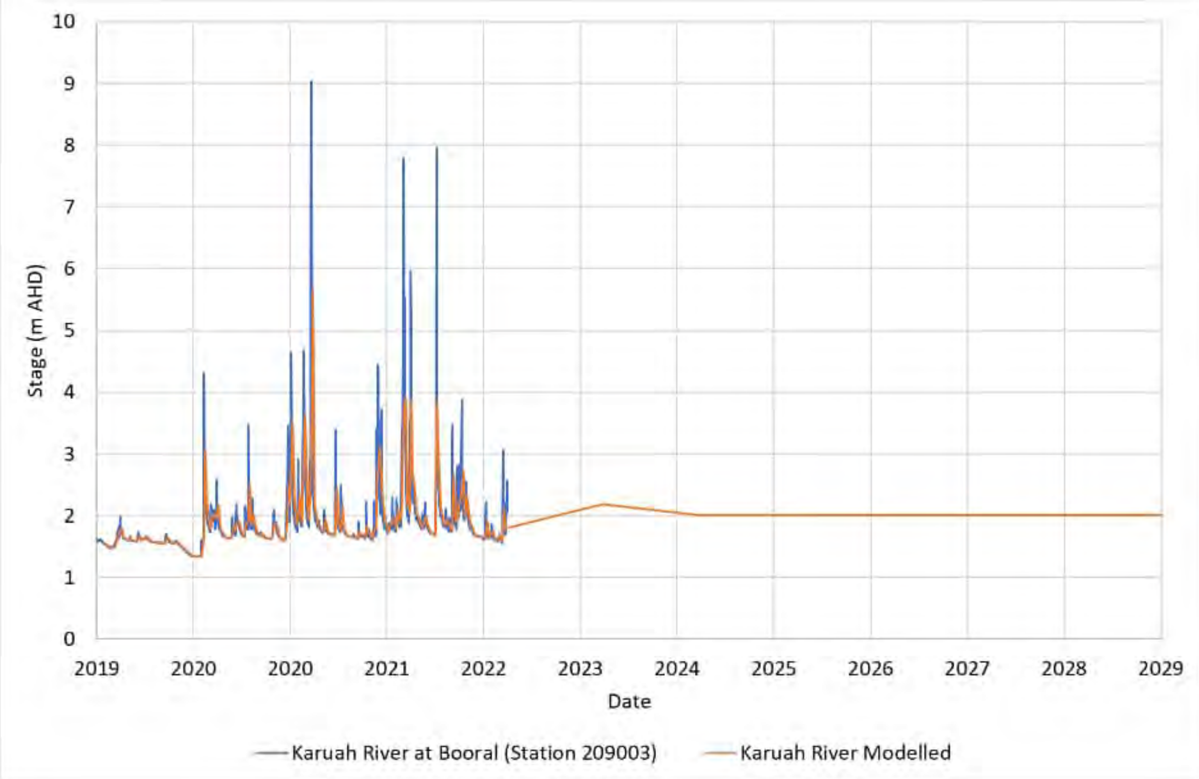
7.2.4 Stresses

7.2.4.1 Watercourses

Karuah River and other surface watercourses in the model area were represented in the model using the MODFLOW River (RIV) package shown on **Appendix D, Figure D3** in the model area and shown on **Appendix D, Figure D4** in the Pit area. Surveyed river stage data was available at the BoM gauge station 'Karuah River at Booral' (BoM station number 209003), located 3 km northeast of the Project.

Karuah River is represented with a time-varying stage to allow recharge of the underlying groundwater system. The observed river stages are shown with the representation of the river stages used in the model on **Figure 11**. The other surface watercourses in the model area are modelled using the RIV package, but the model stage is set equal to the base of the riverbed, so they act as drains. This allows groundwater to discharge to the drainage lines as baseflow but does not allow these watercourses to recharge the underlying groundwater system.

Figure 11 Karuah River Observed versus Modelled Stages



The riverbed conductance of Karuah River and other creeks is calculated based on the area of the cells and vertical hydraulic conductivity and varies between 0.004 and 140 m^2/d (**Table 19**). The vertical hydraulic conductivity was estimated during the calibration process.

The rivers are set with the riverbed 1 m below the surrounding topography to represent the steep-banked incised channels. The river widths were assumed to be fixed for each river in the model.

Table 19 Representation of Watercourses in the Model

Boundary	Width (m)	Conductance (m^2/d)	Riverbed Vertical Hydraulic Conductivity (m/d)
Double Creek	1	0.04-13	0.19
Karuah River	1	2.3 - 67	3.17
Brewers Creek	0.5	16 - 100	2.44
Cromarty Creek	0.5	3.1 - 57	1.38
Isaacs Gully	0.5	0.83 – 17	0.30
Armsleys Gully	0.5	1.3 – 4.4	0.08
Camerons Creek	0.5	0.004 – 1.0	0.01
Deep Creek	0.5	0.11 – 9.8	0.14
Washpool Creek	0.5	10 – 15.0	0.24
Cedar Tree creek	0.5	0.58 – 8.1	0.12

Boundary	Width (m)	Conductance (m^2/d)	Riverbed Vertical Hydraulic Conductivity (m/d)
Small creeks outside project area	0.5	0.01 – 7.1	0.13
Tributaries to Double Creek	0.5	1.1 - 250	0.23 – 1.5

7.2.4.2 Pumping

There is one third-party registered bores within 2 km of the Project. This bore (GW050664) is located near the proposed entrance to the Project on a property fronting the Bucketts Way (construction details shown in **Table 14**). It is unknown if groundwater is currently being extracted from this bore and has therefore not been included as an extraction bore in the numerical model.

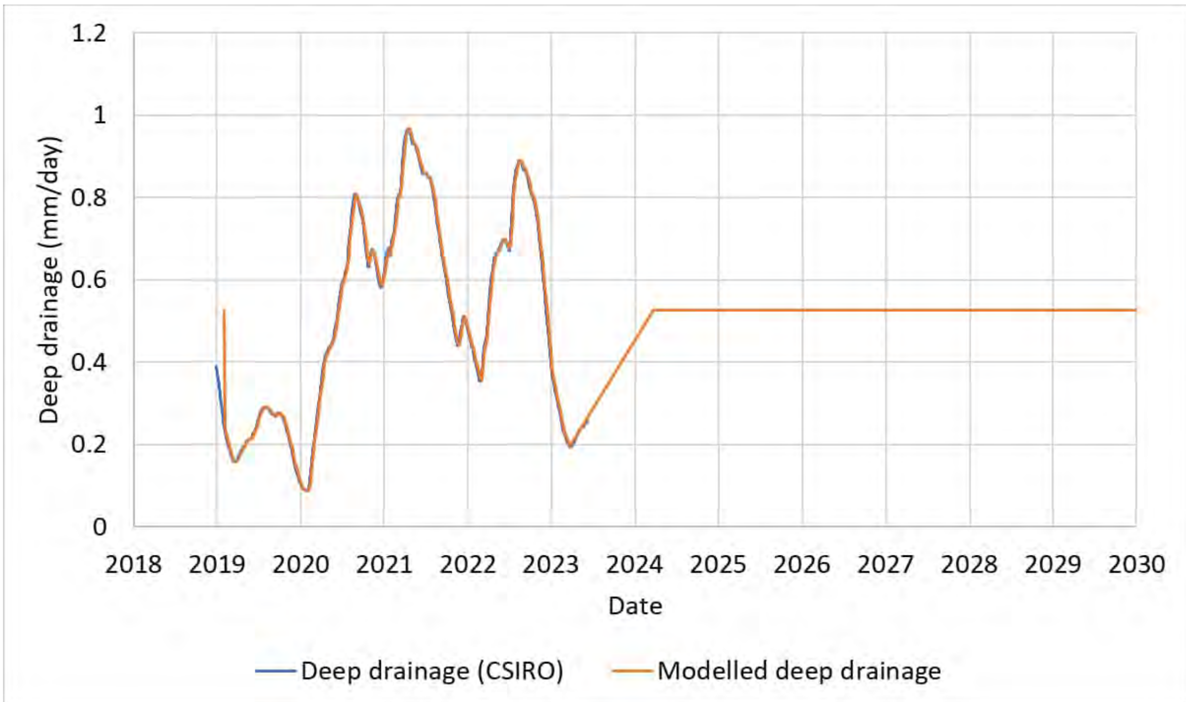
Coastwide have acquired an aquifer Water Access Licence (number 44439) for 100 units from the New England Fold Belt Coast Groundwater Source. This is not currently linked to any bores. As no pumping has commenced, this has not been included in the model.

7.2.4.3 Recharge and Evapotranspiration

The dominant mechanism for recharge to the groundwater system is through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. Diffuse rainfall recharge to the model was represented using the MODFLOW-USG recharge package (RCH).

The recharge rates were established through the calibration process, with bounds based on the conceptual understanding of the system and comparing them with other groundwater models prepared for the region. Recharge was imposed as a percentage of deep drainage from the CSIRO ALRA-Model (Frost et al., 2018). Deep drainage values for the Project area and values used in the model are shown on **Figure 12**.

Figure 12 Historical Deep Drainage Recharge (CSIRO, 2023)



The model includes six recharge zones as presented in **Appendix D, Figure D3**:

- Alluvium channel and valley deposits along Karuah River.
- Alluvium fan deposits and floodplain deposits.
- Alluvium deposits along higher order creeks.
- Regolith (pyroclastic rock).
- Regolith (sedimentary rock).
- Regolith fault zone.

7.2.4.4 Quarrying

The MODFLOW Drain (DRN) package was used to simulate quarry dewatering in the model the proposed open pit and access road. Drain boundary conditions allow a one-way flow of water out of the model. The modelled progression and timing are presented in **Appendix D, Figure D5**, and the timing is summarised in **Table 20**. The quarrying progression was as provided by Coastwide and simplified into five stages.

Table 20 Summary of Quarrying Progression

Stress Period	Description
Stage 1/2 of operation	Haul road and eastern side of processing pad
Stage 3/4 of operation	Finalise processing pad and install internal haul road
Stage 5 of operation	Extraction of western side of pit to an elevation of 158 m AHD
Stage 6 of operation	Continue extraction to an elevation of 126 m AHD
Stage 7 of operation	Continue extraction to an elevation of 95 m AHD

7.2.4.5 Model timing

The model has a total of 260 stress periods (i.e., time slices):

- 217 to represent weekly time-slices between 2019 and 2023 prior to quarrying.
- 29 monthly time-slices between 2023 and 2053 during the quarrying period.
- 13 slices between 5 and 100 years for the post-quarrying period.

Weekly stress periods were used during the calibration period to allow fluctuations in groundwater levels in response to rainfall, and river levels to be replicated.

To assist the model in overcoming the numerical difficulties, MODFLOW-USG Adaptive Time-Stepping (ATS) option was used. The ATS option of MODFLOW automatically decreases time-step size when the simulation becomes numerically difficult and increases it when the difficulty passes. The minimum time step size used in the simulations was one day.

Table 21 summarises the model timing and stresses. The first stress period is steady-state to initialise the heads leading into the transient run.

Table 21 Summary of Stress Periods in Model

Stress Period	Date From	Date To	Length of Stress Periods	Description
1	01/02/2019	02/02/2019	Not applicable	Steady-state run

Stress Period	Date From	Date To	Length of Stress Periods	Description
2 -217	02/02/2019	24/03/2023	1 week	Pre-quarrying calibration period
218-219	25/03/2023	24/03/2025	1 year	Stage 1/2 of operation
220- 223	25/03/2025	24/03/2029	1 year	Stage 3/4 of operation
224 -231	25/03/2029	21/03/2037	1 year	Stage 5 of operation
232 - 240	22/03/2037	19/03/2045	1 year	Stage 6 of operation
241 – 247	20/03/2045	17/03/2053	1 year	Stage 7 of operation
248 - 260	18/03/2053	24/11/2522	5 years to 100 years	Post-quarrying closure

7.3 Model Calibration

Automated calibration utility PEST++ (Doherty, 2019) and manual calibration were used to match the available transient water level data from February 2019 to December 2022. Monitoring bores included in the calibration are shown in **Appendix D, Figure D1**.

The model variables included in the calibration were:

- Aquifer parameters including horizontal and vertical hydraulic conductivity, specific storage, and specific yield.
- Faults horizontal and vertical hydraulic conductivity, specific storage, and specific yield.
- Recharge rates.
- Evapotranspiration rate and extinction depth.

7.3.1 Calibration statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) is expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^{\ 2}\right]^{0.5}$$

where: n = number of measurements

ho = observed water level

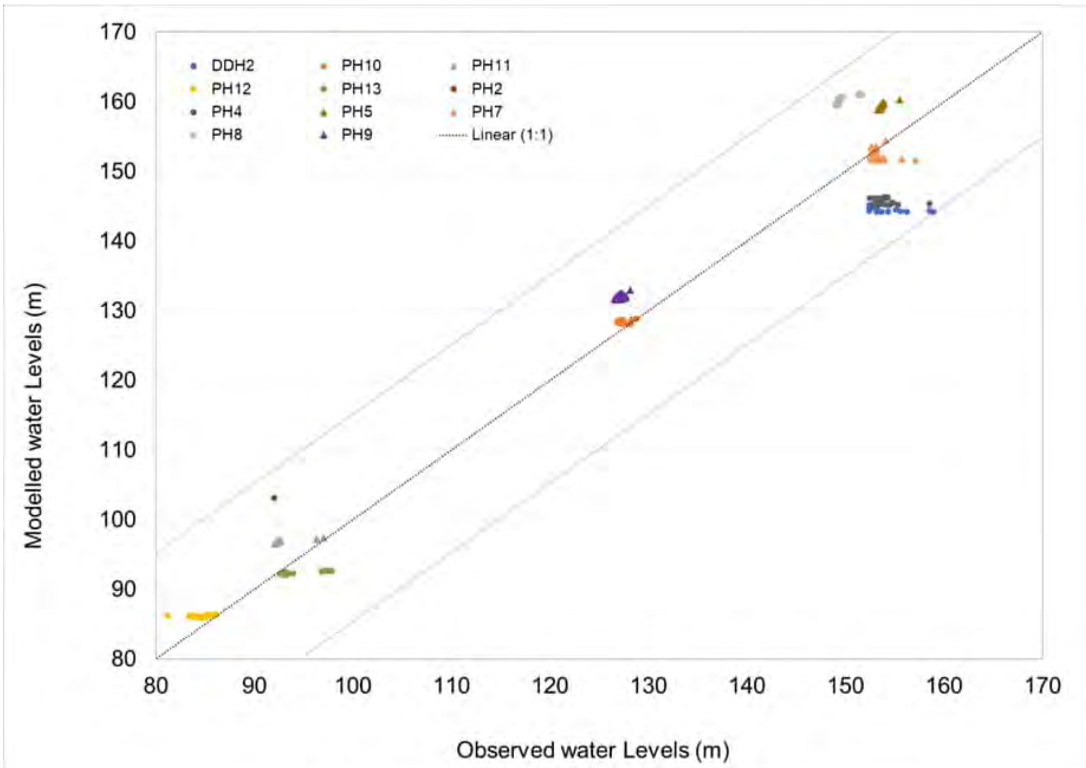
hm = simulated water level

RMS is considered to be the best measure of error if errors are normally distributed. The RMS error calculated for the calibrated model is 6.1 m. In accordance with Barnett *et al.* (2012), another option for measuring the goodness of fit is the Scaled Root Mean Squared error (SRMS).

SRMS is computed by dividing the RMS by the range of measured heads and expressing it as a percentage. When the goal is to fit historical measurements of heads, SRMS provides a valuable indicator of the goodness of fit (Barnett *et al*., 2012). This is primarily due to its ability to compare errors in the model against the total head changes in the system. If the errors are small relative to the total head change, they can be considered negligible. The total measured head change across the model domain is 77.7 m; therefore, the ratio of RMS to the total head loss (SRMS) is 7.9 %. While there is no recommended universal SRMS error, the Australian Groundwater Modelling Guidelines suggests that setting Scaled RMS targets such as 5 or 10 % may be appropriate in some circumstances (Barnett *et al.,* 2012).

Figure 13 presents the observed and simulated groundwater levels graphically as a scattergram for the initial and historic transient calibration (2019 to 2023). **Appendix D, Figure D6** shows the average head residual in each bore in the model.

Figure 13 Calibration Scattergram – Modelled vs Observed Groundwater Levels



The key calibration statistics are shown in **Table 22**. The key statistic is 7.9 % Scaled Root Mean Square Error (SRMS), which is consistent with the groundwater modelling guideline value of 5 to 10 % (MDBC, 2001; Barnett *et al*., 2012) for acceptable model calibration.

Table 22 Transient Calibration Statistics

Statistic	Value
Sum of Squares (m^2)	24,086
Mean of Squares (m)	38.1
Total Number of observations	631
Square Root of Mean of Squares (RMS) (m)	6.18
Scaled Root Mean Square (SRMS) (%)	7.9%
Range in Observations	77.7
Sum of Residuals (m)	3,492.5
Mean Residual (m)	5.5

7.3.2 Calibration hydrographs

Transient calibration hydrographs showing modelled and observed heads over time for all monitoring locations are shown in **Figure 14**. The locations of all monitoring bores are shown in **Appendix D, Figure D1**.

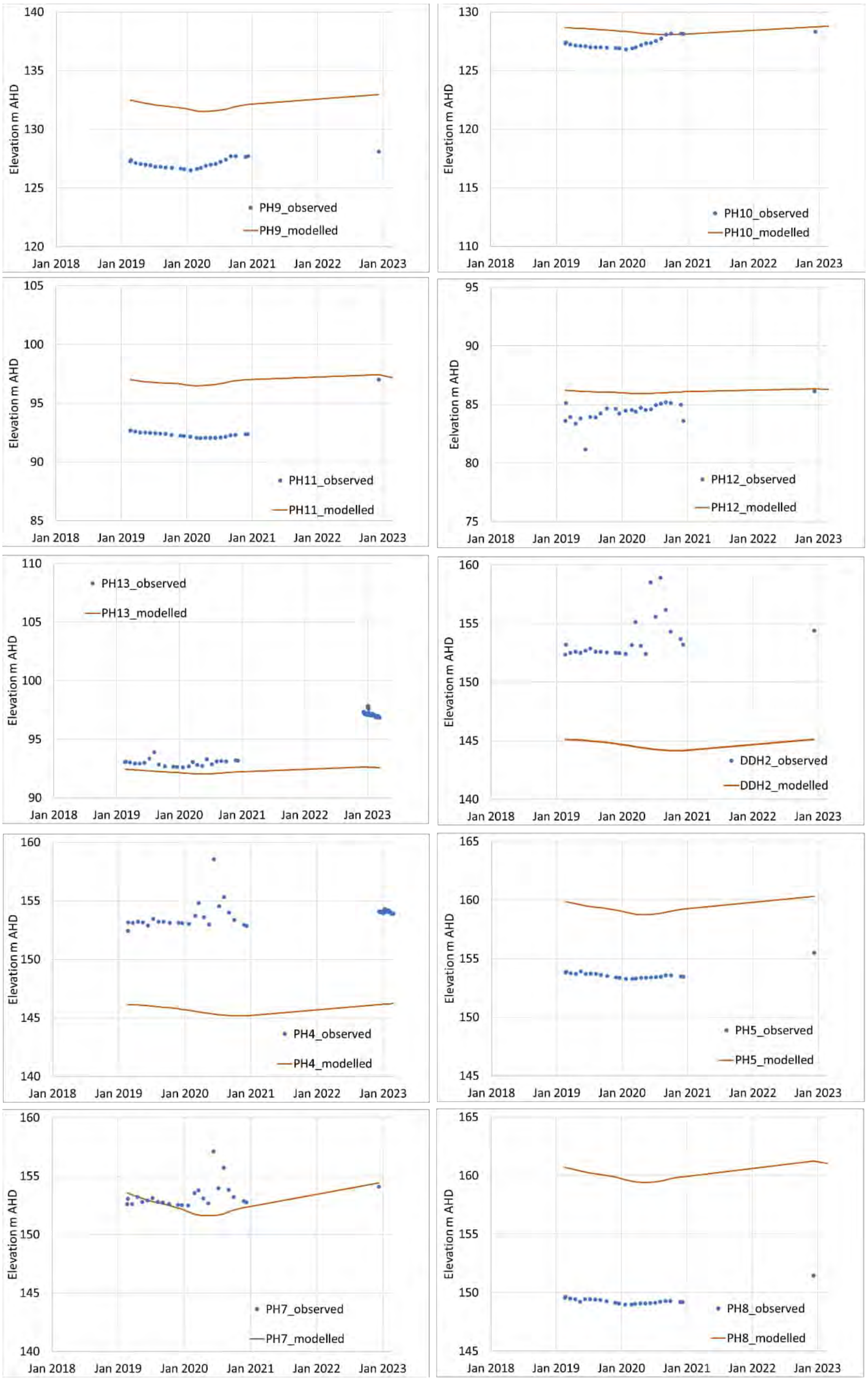
The model is able to replicate seasonal variation and groundwater level elevation at PH7, PH12 and PH10 but overestimates groundwater levels at PH9, PH11, PH5 and PH8 and underestimates groundwater levels at PH4 and DDH2.

The difficulty in replicating observed groundwater level elevations reflects the challenge in building a simplified model to simulate a complex groundwater system. Potential sources of errors that may lead to discrepancies between simulated and observed groundwater levels include:

- Oversimplification of the geological and structural model. The structure of the geology within the quarry area is based on mapped geology and existing ground investigation at the Project, which is limited to bores drilled exclusively within the bedrock.
- Structural simplifications in the model (i.e. the vertical and horizontal discretization of the model): the model cell sizes being too large to represent steep hydraulic gradients. For example, strong vertical gradients may mean that a model, which predicts average water levels for a cell, will struggle to replicate an observed water level if that water level is from the upper or lower portion of that layer. For a layer that is 50 m thick and where the gradient is 1 in 10, this leads to errors of ± 2.5 m.
- Use of hydraulic zones and recharge zones to represent the hydraulic properties and recharge in the groundwater model that are simplified representation of the complex stress system.

Despite the discrepancies with some observed groundwater levels, the model is deemed fit for the purpose in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012) as presented in Section **7.3.2**.

Figure 14 Calibration Hydrographs



7.3.3 Calibrated water levels

The simulated depth to water table at the end of the transient calibration is presented in **Appendix D, Figure D7**. This figure shows the depth to groundwater within the alluvium generally ranges between 1 to 10 m and varies spatially. In some places the alluvium is dry.

The simulated groundwater levels in the unconsolidated (alluvium and regolith) and for the bedrock aquifer for the end of the calibration period (2023) are presented in **Appendix D, Figure D8** and **Appendix D, Figure D9** respectively.

Figure D8 shows that groundwater levels in the alluvium flow generally follows topography. In the area of Karuah River groundwater levels in the alluvium flow north to south. In the area of the Project, modelled groundwater level elevations within the alluvium along Double Creek range from approximately 104 mAHD close to PH13 to 20 mAHD at the eastern part of the Haul Road.

In the area of the pit, groundwater levels flow in a general southwest to northeast direction (**Figure D9**) consistent with inferred groundwater flow direction onsite (see **Section 5.0**).

7.3.4 Water balance

The water balance at the end of the steady and transient calibration period across the entire model area is summarised in **Table 23** and **Table 24** respectively.

In steady-state, the average inflow (recharge) to the groundwater system is approximately 51.8 ML/d split between rainfall recharge (79 %) and leakage from streams to the groundwater system (21 %). The average outflow is approximately 51.1 ML/day split between evapotranspiration (87 %) and loss of groundwater to the creeks (13 %).

During the transient calibration there is a net loss in storage of approximately 0.1 ML/d over the calibration period (**Table 23**).

The mass balance error for the steady-state calibration is less than 0.5 %, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012), and indicating the model is stable and achieves an accurate numerical solution.

Table 23 Steady-state Water Balance

Component	Inflow (ML/day)	Percent of Total Inflow (%)	Outflow (ML/day)	Percent of Total Outflow (%)
Recharge (RCH)	41.0	79	0	0
ET (from GW) (EVT)	0	0	44.5	87
SW-GW Interaction Karuah River	10.8	21	6.6	13
Quarry	0	0	0	0
Storage	0	0	0	0
Total	51.8	100	51.1	100

Table 24 Average Transient Water Balance

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Recharge (RCH)	40.3	75	0	0
ET (from GW) (EVT)	0	0	44.0	81
SW-GW Interaction Karuah River	11.2	21	7.6	14
Quarry	0	0	0	0
Storage	2.4	4	2.4	4
Total	54.0	100	54.0	100

7.3.5 Calibrated hydraulic properties

Table 25 shows the calibrated values for horizontal hydraulic conductivity (Kx) and vertical to horizontal hydraulic conductivity ratio (Kz/Kx), specific storage (Ss), and specific yield (Sy).

Overall, the horizontal hydraulic conductivity is consistent with the estimates obtained from the slug testing carried out onsite ranged between 0.0023 and 0.0307 m/d. This excludes the slug test carried out at PH8 where a hydraulic conductivity of 13 m/d was estimated.

No site-specific values for Ss and Sy were estimated in the on-site testing. The calibrated values were therefore compared with the values obtained from the literature review (**Section 5.7.5**) and are considered consistent with these.

Table 25 Calibrated Hydraulic Properties

Zone	Layer – Geology Unit	Kx (m/day)	Kz/Kx	Sy	Ss(1/m)
1	L01 – Pyroclastic rock	0.01	0.4	0.05	$2.3x10^{-06}$
2	L01 - Sedimentary rock	0.01	0.08	0.05	$1.2x10^{-06}$
3	L01 – Alluvium high production	8.0	0.02	0.19	$2.3x10^{-05}$
4	L01 – Alluvium low production	0.04	0.01	0.05	0.0006
5	L01 – Alluvium medium production	7.7	0.2	0.04	$3.4x10^{-05}$
6	L01 – Fault zone	0.05	0.5	0.05	0.00018
7	L02 – Pyroclastic rock	0.008	0.4	0.05	$1.00x10^{-06}$
8	L02 - Sedimentary rock	0.006	0.18	0.05	$1.13x10^{-06}$
9	L02 – Fault zone	0.002	0.4	0.05	$1.05x10^{-06}$
10	L03 – Pyroclastic rock	0.008	0.4	0.05	$6.96x10^{-06}$
11	L03 - Sedimentary rock	0.004	0.4	0.05	$5.83x10^{-06}$
12	L03 – Fault zone	0.001	0.4	0.05	$1.89x10^{-06}$
13	L04 – Pyroclastic rock	0.009	0.5	0.04	$1.49x10^{-06}$
14	L04 - Sedimentary rock	0.004	0.1	0.04	$1.24x10^{-06}$
15	L04 – Fault zone	0.001	0.4	0.04	$1.41x10^{-06}$

Zone	Layer – Geology Unit	Kx (m/day)	Kz/Kx	Sy	Ss(1/m)
16	L05 – Pyroclastic rock	0.009	0.35	0.04	8.66×10^{-06}
17	L05 - Sedimentary rock	0.004	0.2	0.04	1.02×10^{-06}
18	L05 – Fault zone	0.001	0.4	0.04	1.00×10^{-06}
19	L06 – Pyroclastic rock	0.009	0.35	0.025	1.62×10^{-06}
20	L06 - Sedimentary rock	0.003	0.5	0.03	1.18×10^{-06}
21	L06 – Fault zone	0.001	0.5	0.03	7.77×10^{-06}
22	L07 – Pyroclastic rock	0.0001	0.9	0.025	6.49×10^{-06}
23	L07 - Sedimentary rock	0.0001	0.9	0.03	1.00×10^{-06}
24	L07 – Fault zone	0.00007	0.6	0.03	1.00×10^{-06}
25	L08 – Pyroclastic rock	0.00001	0.8	0.03	1.31×10^{-06}
26	L08 - Sedimentary rock	0.00001	0.8	0.03	1.04×10^{-06}
27	L07- weathered pyroclastic rock along creeks	0.005	0.5	0.025	4.89×10^{-06}

7.3.6 Calibrated recharge rates

Diffuse infiltration of rainfall through the soil profile and subsequent drainage to underlying hydrostratigraphic units is the primary method of groundwater recharge. In alluvial zones, river leakage can also provide recharge to groundwater systems, as detailed in **Section 6.0**. Model recharge zones and their corresponding annual recharge rates are summarised in **Table 26**.

Table 26 Calibrated Recharge Rates

Layer – Geology Unit	Rate (%)	Long-term Average Rainfall Recharge (mm/yr)
Alluvium channel and valley deposits along Karuah River	1.24	14.3
Alluvium fan deposits and floodplain deposits	0.99	11.4
Alluvium deposits along higher order creeks	1.30	15.0
Regolith (pyroclastic rock)	0.6	6.9
Regolith (sedimentary rock)	0.7	8.1
Regolith fault zone	0.8	9.2

7.4 Predictive Modelling

7.4.1 Timing and quarrying

Transient predictive modelling was used to simulate the proposed Project open pit and haul road. The predictive model comprises yearly stress periods in the quarrying period, starting from 2023 until 2053.

Two numerical model scenarios were run to assess the groundwater impacts of the Project:

- Null Quarrying Scenario – A scenario without any quarrying.
- Hillview Quarrying Scenario – A scenario with the proposed quarrying with the Project Open Pit and Haul Road (as described in **Section 1.2**).

7.4.2 Water balance

Table 27 and **Table 28** present average flow rates for water transfer in and out of the predictive model periods (2023 to 2053) for the two predictive scenarios. The mass balance error for both scenarios was 0.0% indicating that the model was stable and achieved an acceptable numerical solution.

Simulated recharge for the Hillview Quarrying Scenario and the Null Scenario is equal. Evapotranspiration is 0.1 ML/day higher in the Null Scenario compared to the Hillview Quarrying Scenario. The loss to evapotranspiration happens where the water table is within 10 m of the land surface across the model domain, when the open pit is being mined evapotranspiration does not occur through the area of the footprint of the open pit and haul road. The reduction in evapotranspiration outflow reflects the reduction in evapotranspiration area.

Net river exchange flux for the Hillview Quarrying Scenario and the Null Scenario are positive suggesting that Karuah River is losing water to the groundwater system. The quarrying at the Project will have minimal impact to the surface water groundwater interactions in the vicinity of Karuah River.

Quarrying outflows are modelled at 0.3 ML/d representing 0.6 % of the total mass balance.

Table 27 Average Simulated Water Balance over the Prediction Periods (2023 – 2053)

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Recharge (RCH)	41.0	77.9	0.0	0.0
ET (from GW) (EVT)	0.0	0.0	44.7	85.1
SW-GW Interaction Karuah River	11.4	21.6	7.6	14.8
Quarry	0.0	0.0	0.3	0.6
Storage	0.2	0.4	0.06	0.1
Total	52.7	100	52.7	100

Table 28 Average Simulated Water Balance – Null Run (2023 – 2053)

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Recharge (RCH)	41.0	78.2	0	0.0
ET (from GW) (EVT)	0.0	0	44.8	85.3
SW-GW Interaction Karuah River	11.4	21.7	7.7	14.6
Quarry	0.0	0.0	0	0.0
Storage	0.04	0.1	0.06	0.1

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Total	52.5	100	52.5	100

7.4.3 Predicted groundwater levels

Predicted groundwater level elevations at the end of quarrying at the Project are presented in **Appendix D, Figure D10** and **Appendix D, Figure D11**.

Figure D10 and **Figure D11** indicate that away from the Project pit, the modelled groundwater table generally reflects the topography and surface drainage. The model predicts the groundwater level elevation within the alluvium is generally similar to results for the current calibrated groundwater conditions presented in **Figure D10**.

Figure D11 shows that within and immediately around the quarry footprint the simulated groundwater levels in the bedrock are influenced by excavation of the Project.

7.4.4 Predicted drawdowns

The process of quarrying directly removes water from the groundwater system and reduces water levels in surrounding groundwater units. The extent of the zone affected is dependent on the properties of the aquifers/ aquitards and is referred to as the zone of drawdown.

Maximum drawdown refers to the drawdown impact associated with the Project open pit and is obtained by comparing the difference in predicted aquifer groundwater levels for the Hillview Quarrying Scenario and the Null Quarrying Scenario at matching times. The maximum drawdown represents the maximum drawdown values recorded at each model cell at any time over the model duration.

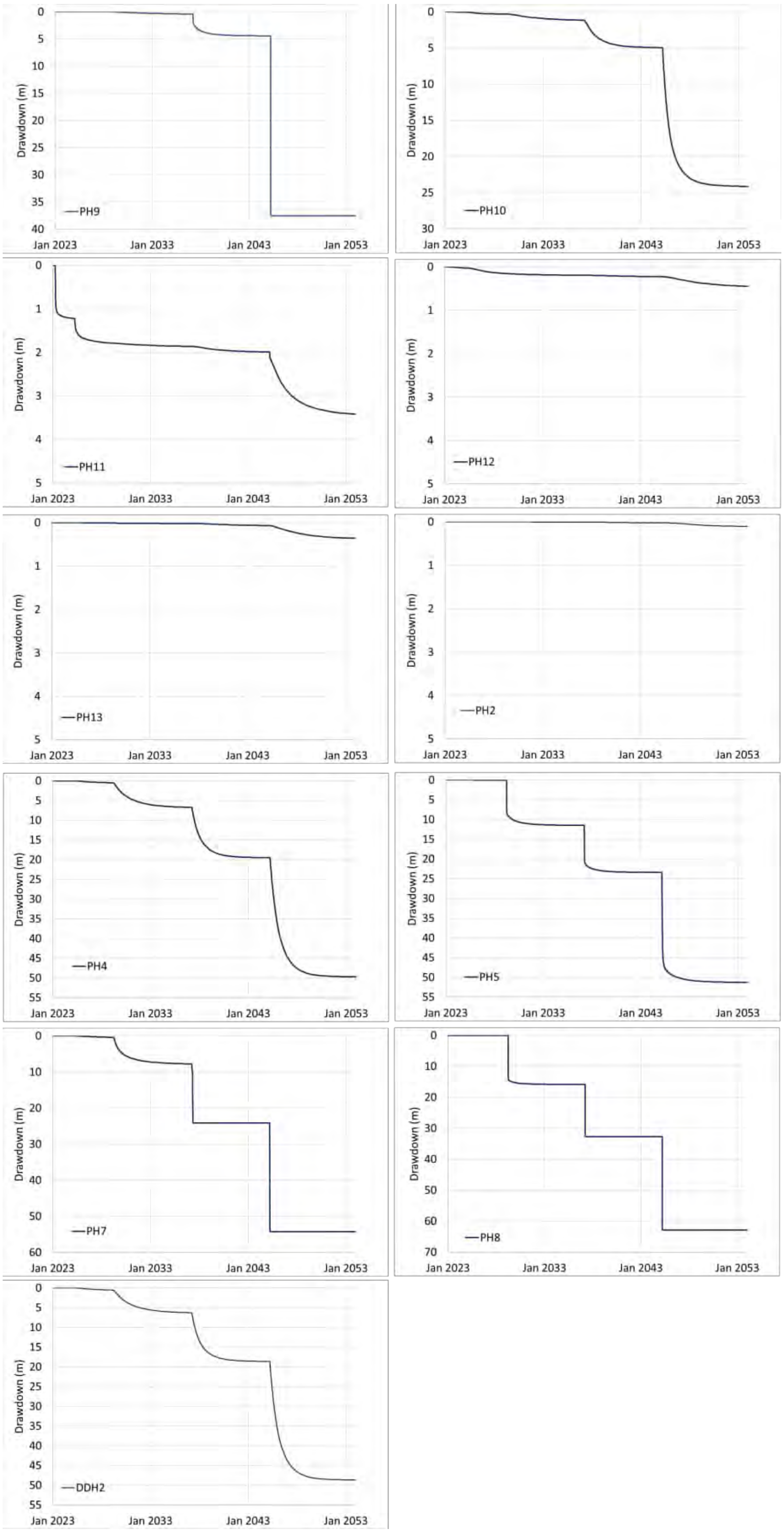
A map of predicted maximum drawdowns is presented in **Appendix D, Figure D12** for the bedrock. **Figure 15** presents predicted drawdown hydrographs at the monitoring bores due to the Project.

Figure D12 shows the maximum drawdown modelled within the pit and the 1 m drawdown cone is observed to extend approximately 260 m north of pit, 450 m west of the pit and 380 m south of the pit.

Drawdown is also expected along the footprint of the haul road, the 1 m drawdown is expected to extend 100 m north and south of the haul road (**Figure D12**).

Drawdowns of up to 62 m are observed in the monitoring bores located within the pit footprint (PH8, PH7, PH5, PH4, PH9, PH10 and DDH2). Maximum drawdowns varying between 0.1 and 2 m are modelled in the bores located outside the footprint of the site (PH11, P12, PH13 and PH2) (Figure D-19).

Figure 15 Predicted Drawdown at Monitoring Bores



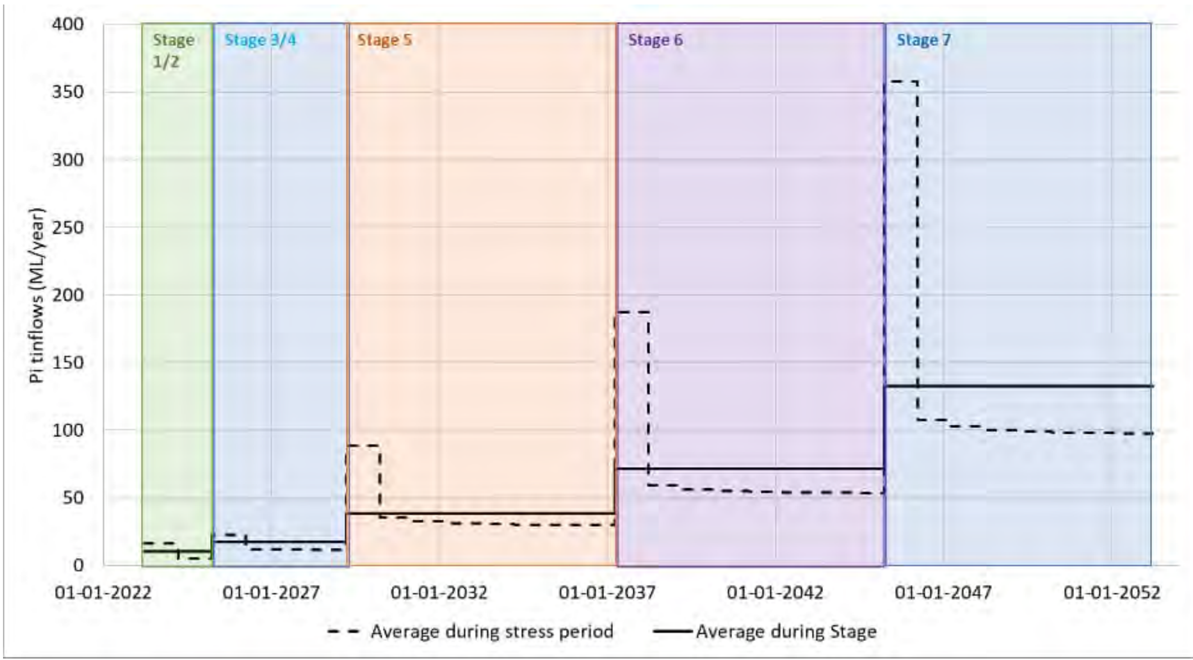
7.4.5 Predicted groundwater take

The Project groundwater inflow volumes have been calculated as time weighted averages of the outflow reported by ZoneBudget software for model drain cells representing quarrying at the Project. The predicted groundwater inflows for each stage of quarrying at the Project are presented in **Figure 16**.

Figure 16 shows the average Project inflows are estimated to vary between 11 ML/a during Stage 1/2 to 133 ML/a (0.9 ML/d) during Stage 7.

It should be noted that this total volume includes water removed in rock material with quarrying, as well as water evaporated from the pit surface. It is therefore considered an over-estimate of water that could report to the site water balance.

Figure 16 Predicted Groundwater Inflows to Project



7.4.6 Incidental water impacts

7.4.6.1 Influence on alluvium

The change in alluvial water resources was calculated by comparing water budgets for alluvial zones using the scenarios of the predictive model that included and excluded the Project respectively.

In the Project area, alluvial deposits are limited to the downstream reaches of Double Creek and Brewers Creek. The model predicts that there will be an insignificant loss (<0.01 ML/a) of water to the alluvium due to quarrying at the Project.

7.4.6.2 Influence on surface water flow

The change in leakage and baseflow in Karuah River and other surface watercourses within the model area due to the Project was calculated by comparing the river flow budgets in the Hillview Quarrying Scenario against the Null Quarrying Scenario.

The model predicts that:

- There will be no change to inflows and outflows from Karuah River due to Project operation.
- There will be a decrease of 9.43 ML/a (7 %) in the discharge of groundwater to Double Creek and tributaries due to the excavation of the Project.
- There will be a decrease of 4.50 ML/a (16 %) in the discharge of groundwater to Brewers Creek and tributaries due to the excavation of the Project.

7.5 Model Performance and Limitations

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al*. 2012), the Murray Darling Basin Committee (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) and the released IESC Explanatory Note for Uncertainty Analysis (IESC, 2018). These are mostly generic guides and do not include specific guidelines on special applications, such as open pit modelling.

7.5.1 Model performance

The 2012 Australia Groundwater Modelling Guidelines has replaced the model complexity classification of the previous MDBC guideline by a "model confidence level" (Class 1, Class 2, or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design, and construction.
- Calibration procedures that are undertaken during model development.
- Consistency between the calibration and predictive analysis.
- Level of stresses applied in predictive models.

It is generally expected that a model confidence level of Class 2 is required for quarrying environmental impact assessments; the 2012 Australian Groundwater Modelling Guidelines state that a Class 2 model may be used for assessing impacts associated with quarry dewatering (Barnett *et al*., 2012).

Table 29 summarises the subjective qualitative criteria allowing model classification, per Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines. The classification of the Project model, as presented in **Table 29**, has been assessed subjectively by a SLR Principal Groundwater Modeller. The assessment shown in **Table 29** indicates that the Project groundwater model can be classified primarily as a Class 2, with some items meeting Class 1 criteria and some items meeting Class 3 criteria. This is considered an appropriate level for the Project groundwater impact assessment context.

Table 29 Groundwater Model Classification

Class	Model Characteristics					
		Data		Calibration		Prediction
1		Few or poorly distributed data points		Not possible	✓	Predictive timeframe >> calibration timeframe
		Unavailable or sparse data in areas of greatest interest		Unacceptable levels of error		Temporal discretisation is different to calibration
	✓	No metered groundwater extraction data		Inadequate distribution of data		Transient prediction but steady state calibration
		Remote climate data		Targets incompatible with model purpose		Unacceptable validation

Class	Model Characteristics					
		Data		Calibration		Prediction
		Little or no useful data on land-use, soils, or river flows and stage elevations				
2	✓	Some data but may not be adequate throughout domain	✓	Reasonable calibration statistics with errors in parts of the model	✓	Predictive timeframe > calibration timeframe
		Some metered groundwater extraction data		Long-term trends not replicated in all parts of domain	✓	Long stress periods compared to calibration
	✓	Streamflow and stage measurements are available at some points		Transient calibration not extending to present day		New stresses not in calibration
		Reliable irrigation application data available in part	✓	Weak seasonal replication		Poor validation
				No use of calibration targets compatible with model purpose		
			✓	Validation not undertaken		
3		Spatial and temporal distribution of data adequate	✓	Scaled RMS error or other calibration statistics are acceptable		Predictive timeframe ~ calibration timeframe
		Clearly defined aquifer geometry	✓	Long-term trends adequately replicated where important		Temporal discretisation in predictive model consistent with transient calibration
		Reliable metered groundwater extraction data		Seasonal fluctuations adequately replicated		Similar stresses to those in calibration
		Rainfall and evaporation data is available	✓	Transient calibration is current		Steady state prediction consistent with steady state calibration
		Aquifer testing data to define key parameters		Model is calibrated to heads and fluxes		Model validation suggests calibration is appropriate
	✓	Good quality and adequate spatial coverage of DEM		Key modelling outcomes dataset used in calibration		Steady-state predictions when the model is calibrated in steady-state
		Streamflow and stage measurements are available at many points				
		Reliable land-use and soil-mapping data available				
		Reliable irrigation application data available				

1. Refer Table 2.1 of the 2012 Australian Groundwater Modelling Guidelines (Barnett et al. 2012)

2. Green highlighted cells = model has been subjectively assessed to meet the classification criteria for that Class

7.5.2 Model limitations

It is important to note that groundwater models have inherent uncertainties that should be quantified and reduced where required and possible. The limitations and uncertainty associated with the model are discussed below. The IESC *Uncertainty analysis – Guidance for groundwater modelling within a risk management framework* (2018) identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural/ conceptual.

- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of uncertainty have been qualitatively assessed with regards key aspects of the project groundwater model, as presented in **Table 30**.

Overall, the model is considered fit for purpose to achieve the objectives of the EIS groundwater assessment based on the available data and the project timeframe. **Table 30** includes a detailed summary of the model setup and capabilities, demonstrating that the model is fit for purpose, as well as some recommendations if future updates to the model should be required.

Table 30 Groundwater Model and Data Limitations and Potential Recommended Updates

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose.	The model has an unstructured Voronoi grid that includes detailed cell refinement around the Project quarry and haul access road, as well as mapped faults and along drainage features. The groundwater model extent was designed to prevent boundary influence on modelled Project drawdowns.
	Layers	Fit for purpose. Potential for further assessment.	Top of Layer 1 incorporates site LiDAR data. Representation of alluvium and regolith based on publicly available mapped geology and CSIRO (2015) regolith mapping. Model vertical resolution is sufficient to represent relevant geological units and unstructured grid allows layer pinch out where units not present. Model structure could be refined based on more ground investigation at the siter.
	Conceptualisation – Geological Structure	Fit for purpose. Potential for further assessment.	The structure of the geology with the quarry area is based on mapped geology and existing ground investigation at the Project, which is limited to bores drilled exclusively within the bedrock. Further ground investigation at the site could improve the conceptualisation of the presence, thickness, and composition of the alluvial deposits. However, it is unlikely that these will be drilled as part of the Project, due to the alluvial deposits not being within land owned by Coastwide.
	Conceptualisation – GDEs	Fit for purpose. Potential for further assessment.	High potential GDEs are indicated in the BoM GDE Atlas (BoM, 2012) along parts of Double Creek, Brewers Creek, and their tributaries but there have been no field studies to confirm the actual presence of GDEs, their dependence on groundwater, or their resilience to changes in groundwater levels.
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose. Potential for further assessment.	Key groundwater–surface water interaction is related to drainage features and associated alluvium and the main drainage feature within the model of Double Creek, Brewers Creek, and the associated alluvial deposits. Further investigations and monitoring could help assess whether the alluvium is dry, and the creeks are ephemeral / losing during occasional flow events.
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose. Future improvements could be made.	There are no monitoring bores in the alluvium. If any additional monitoring is carried out in these deposits, it could verify the presence or absence of groundwater in this deposit.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose. Future improvements could be made.	Limited site-specific hydraulic conductivity data (horizontal and to a lesser extent vertical) was available. Additional data (if available) should be utilised to verify and update the modelled change with depth, and to refine model calibration and predictions.

Type	Part	Status	Comment
	Rivers	Fit for purpose. Improvements possible.	Further investigations and monitoring could help assess whether the creeks are ephemeral / losing during occasional flow events.
	Recharge	Fit for purpose.	Recharge zonation is based on mapped surface geology and calibrated percentage of Deep drainage from the CSIRO ALRA-Model. Soil mapping and site water quality data could be further utilised to base recharge rates.
Measurement Error	Observation Data Quality	Fit for purpose.	Incorporation of any new groundwater level monitoring to refine the groundwater model in future.
	Landholder Bore Data Quality	Fit for purpose.	No known landholder bores are present in the vicinity of the site
	Temporal spread	Fit for purpose. Future improvements possible.	Timeseries water level data with varying resolution has been used in the calibration from the site. There were no regional groundwater level measurements were available to be included in the calibration. If regional groundwater levels become available, they could be used to refine the model calibration and predictions in the future.
Scenario Uncertainties Future stresses/ conditions	Calibration	Fit for purpose. Future improvement possible.	A transient calibration model was run and calibrated to observed groundwater levels (2001- December 2022) using PEST ++ automated calibration. Using shorter time slices (monthly instead of quarterly) in the model would allow climate seasonality to be better represented in the model. The model calibration could be further refined if additional monitoring bores are installed, and more data is collected.
	Predictive	Fit for purpose.	Model captures open cut quarrying progression and timing at the Project based on data provided by Coastwide.
	Sensitivity and uncertainty	Fit for purpose. Future improvements may be required.	Predictive uncertainty analysis was carried out. Additional work to test the uncertainty of the model parameters may be required if more site-specific data becomes available. This includes differences in hydraulic properties of the in-situ strata. As well the influence of recharge on model predictions.

7.6 Sensitivity and Uncertainty Analysis

7.6.1 Calibration identifiability

Identifiability describes a parameter's capability to be constrained by the model calibration. Identifiability values range from zero to one. As identifiability approaches one, the parameter is increasingly able to be constrained. Conversely, as values approach zero the parameter is increasingly unable to be constrained by the calibration and uncertainty of model results is not reduced through calibration.

The PEST utility GENLINPRED was used to provide an estimate of parameter identifiability for each of the model parameters. Estimated identifiability values for the calibrated parameters horizontal hydraulic conductivity, anisotropy, specific yield, recharge evapotranspiration rate, and evapotranspiration extinction depth are summarised in **Figure 17** through **Figure 21**.

Figure 17 indicates that in general the calibration process was relatively successful in constraining the horizontal conductivity of the pyroclastic rock in Layers 5 to 7 (identifiability values above 0.5). The horizontal hydraulic conductivities of the alluvium and sedimentary rock layers are not well constrained by calibration. This is to be expected as all the monitoring locations are installed in the pyroclastic rock and within Layers 4 to 7.

Identifiability of hydraulic conductivity anisotropy for model zones is presented in **Figure 18**. Anisotropy in the interburden at Layer 7 has a high identifiability value (>0.9) indicating this can be constrained by the calibration. All other zones feature low values (equal to and below 0.20) and are not well constrained by calibration.

In general, specific yields and specific storages of most zones in the model domain have low identifiability (**Figure 19** and **Figure 20**). **Figure 20** shows that the specific yield in the pyroclastic rock in Layer 7 was somewhat constrained by the model (identifiability >0.6).

Figure 21 shows the identifiability of the hydraulic conductivity of the riverbed sediments, recharge zones, evapotranspiration rate and evapotranspiration extinction depth. The hydraulic conductivity of all rivers and creeks in the model, including Karuah River and Double Creek and its tributaries, are not well constrained by the model. The recharge in all zones show low identifiability and are not well constrained by the model. The evapotranspiration rate shows low identifiability and is not well constrained by the model. The evapotranspiration extinction depth shows high identifiability and is well constrained by the model.

Figure 17 Identifiability – Horizontal Conductivity

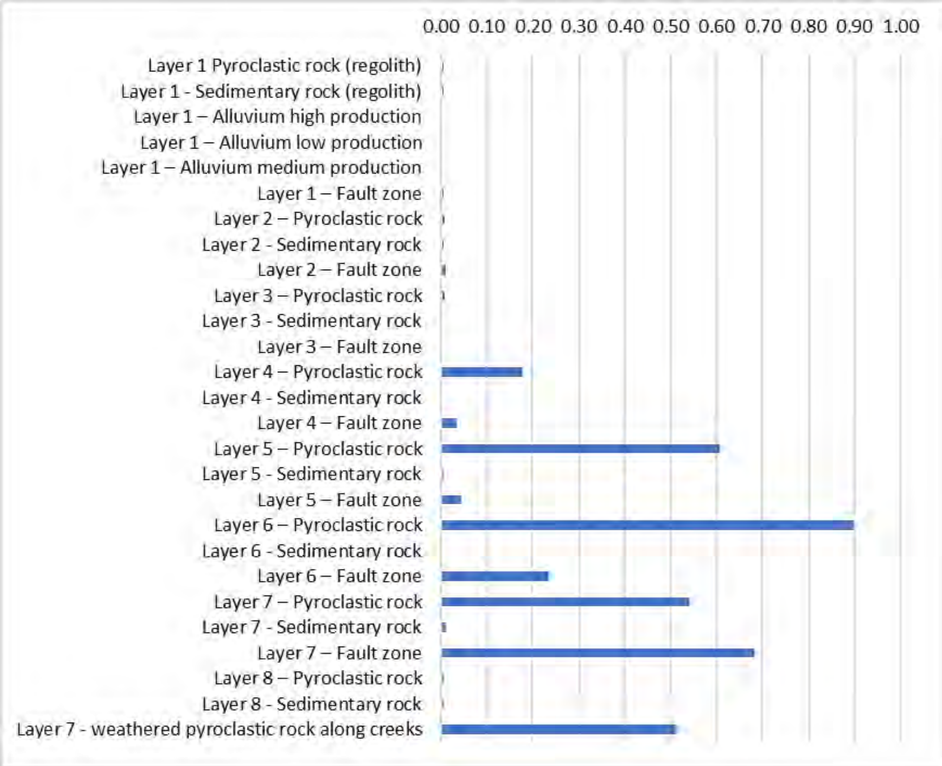


Figure 18 Identifiability – Anisotropy

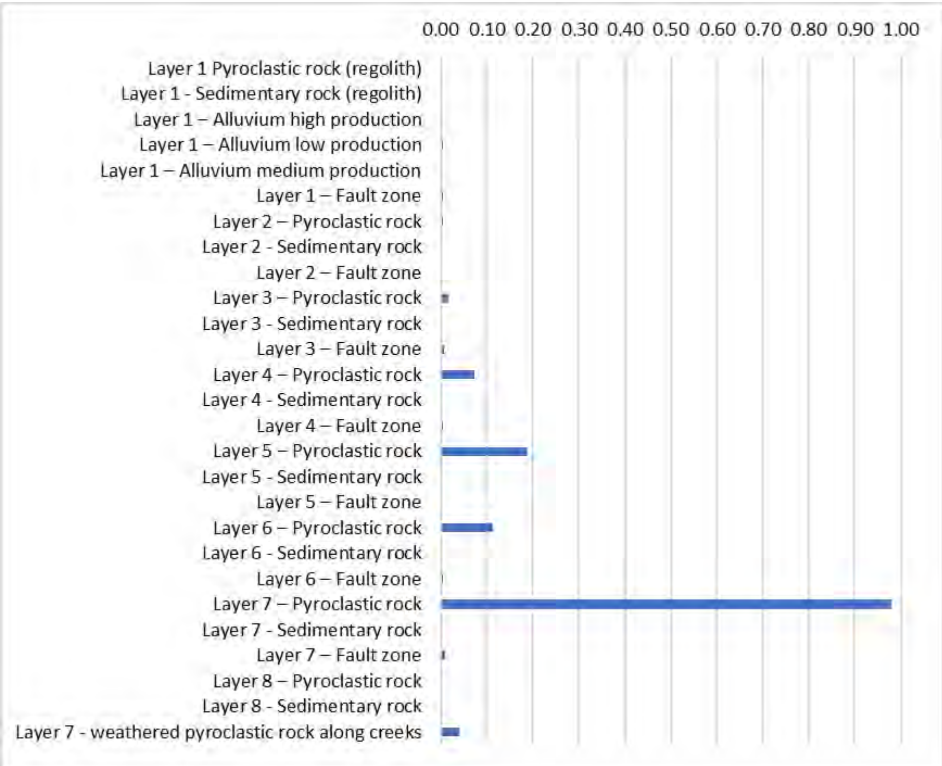


Figure 19 Identifiability – Specific Yield

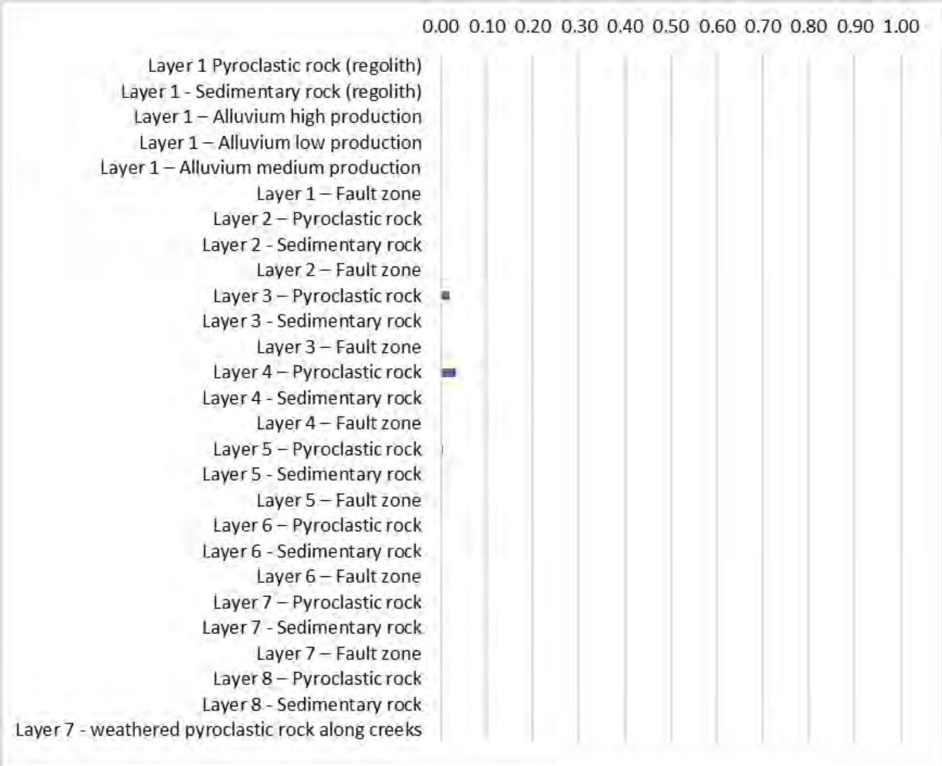


Figure 20 Identifiability – Specific Storage

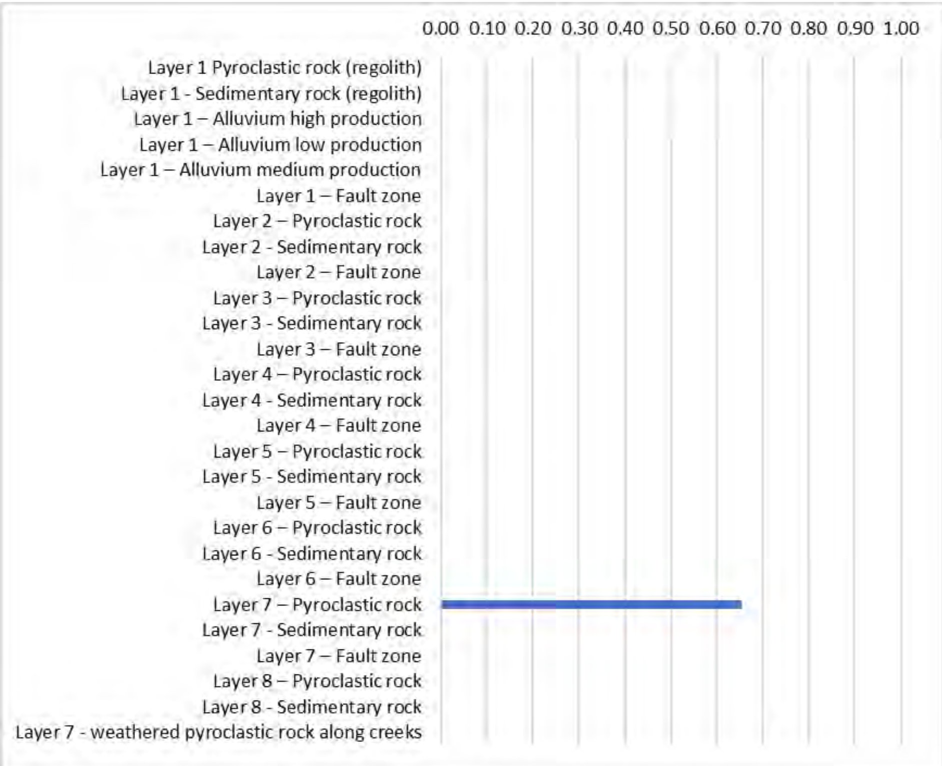
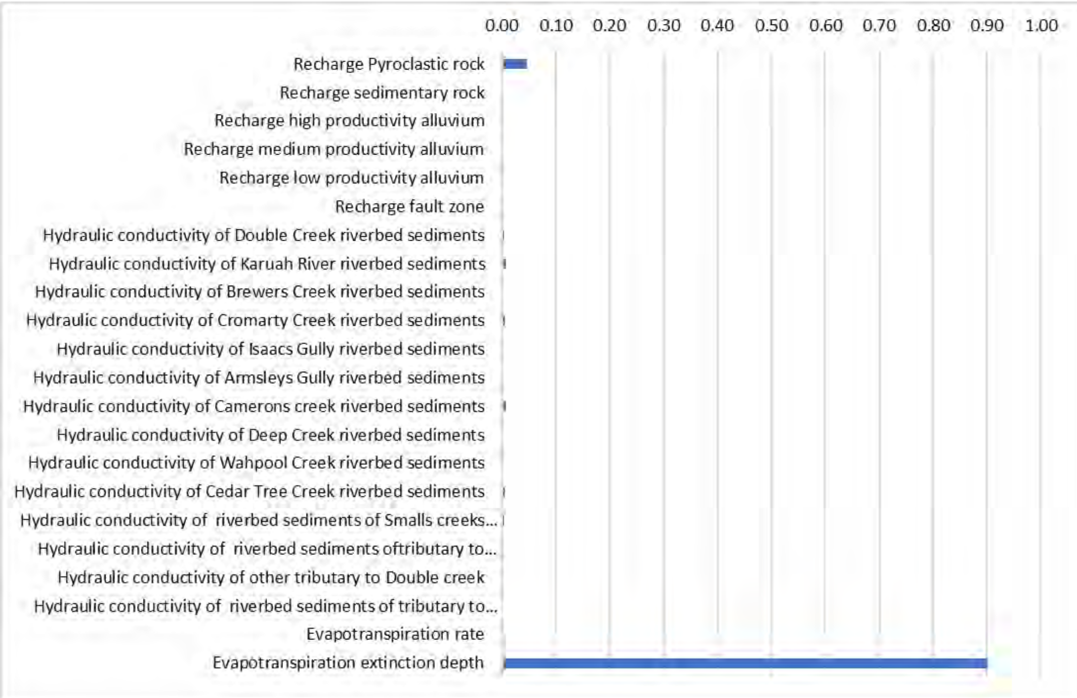


Figure 21 Identifiability – Riverbed Hydraulic Conductivity, Recharge, Evapotranspiration Rate, and Extinction Depth



7.6.2 Uncertainty analysis

A Type 3 Monte Carlo uncertainty analysis (IESC, 2018) was undertaken to estimate the uncertainty in the future impacts predicted by the model. This method operates by generating numerous alternative sets of input parameters to the deterministic groundwater flow model (realisations), executing the model independently for each realisation, and then aggregating the results for statistical analysis.

The first step in Monte Carlo analysis is to define the parameter distribution and range. For this project, the parameters are assumed to be log-normally distributed around the optimum value derived from the calibration and the standard deviation attributed to the log (base 10) of parameter is 0.5 or 1. The distribution for each parameter were checked and constrained such that upper or lower ranges do not go beyond ranges in literature for physical constraints.

Instead of simple random sampling, the Latin Hypercube Sampling (LHS) method was used to create random realisations from parameter distribution. LHS aims to spread the sample points evenly across all possible values. In doing so, it divides parameter space into N intervals of equal probability and chooses one sample from each interval. The generated random numbers derived from LHS approach is distributed sufficiently across the parameter space even at the small sample size. The main advantage of LHS over simple random sampling is that a lower number of realisations are needed to obtain a reasonable convergence of the uncertainty results.

6,000 model realisations were generated each with unique parameter distributions. Parameters were assumed to possess a log-normal distribution, with the Latin Hypercube Sampling (LHS) method used to create random realisations from parameter distribution. 376 of the realisations met calibration criteria (SRMS <8 %) after running through the calibration model and so were adopted for the uncertainty analysis.

Appendix E compares the prior parameter distribution for the initially generated realisations (6,000 parameters) against the posterior parameter distribution from the 376 realisations that met the calibration criteria and were adopted for uncertainty analysis Additionally, the graphs in **Appendix E** demonstrate how the values from the best-calibrated model, reported in **Section 7.3**, align with the overall distribution.

7.6.2.1 Number of realisations

As discussed above, 376 realisations met the calibration criteria and were selected as calibrated realisations. The predictive model was run using the 376 parameters sets. The results from the predictive model were used to conduct statistical analyses to assess if additional realisations were likely to provide results that would significantly change the reported predictive results. The 95 % confidence interval was calculated for the quarry inflows from the Hillview Quarry and the maximum drawdown in the fractured rock.

Figure 22 and **Figure 23**, show the 95 % confidence intervals of the median and predicted discharge quarry inflow and water table drawdowns, as well as the variance of the median and maximum for these two model outputs as more realisations are added to the uncertainty analysis. For example, the 95% confidence interval for the simulated quarry inflow is calculated by first estimating the inflow for each realisation and then calculating the 95 % confidence interval of the simulated quarry inflow as each realisation is added to the dataset. Additional realisations are unlikely to significantly increase or decrease the confidence intervals of predictions of simulated quarry inflow and the maximum incremental drawdown.

Figure 22 95 % Confidence Interval for Predicted Quarry Inflows

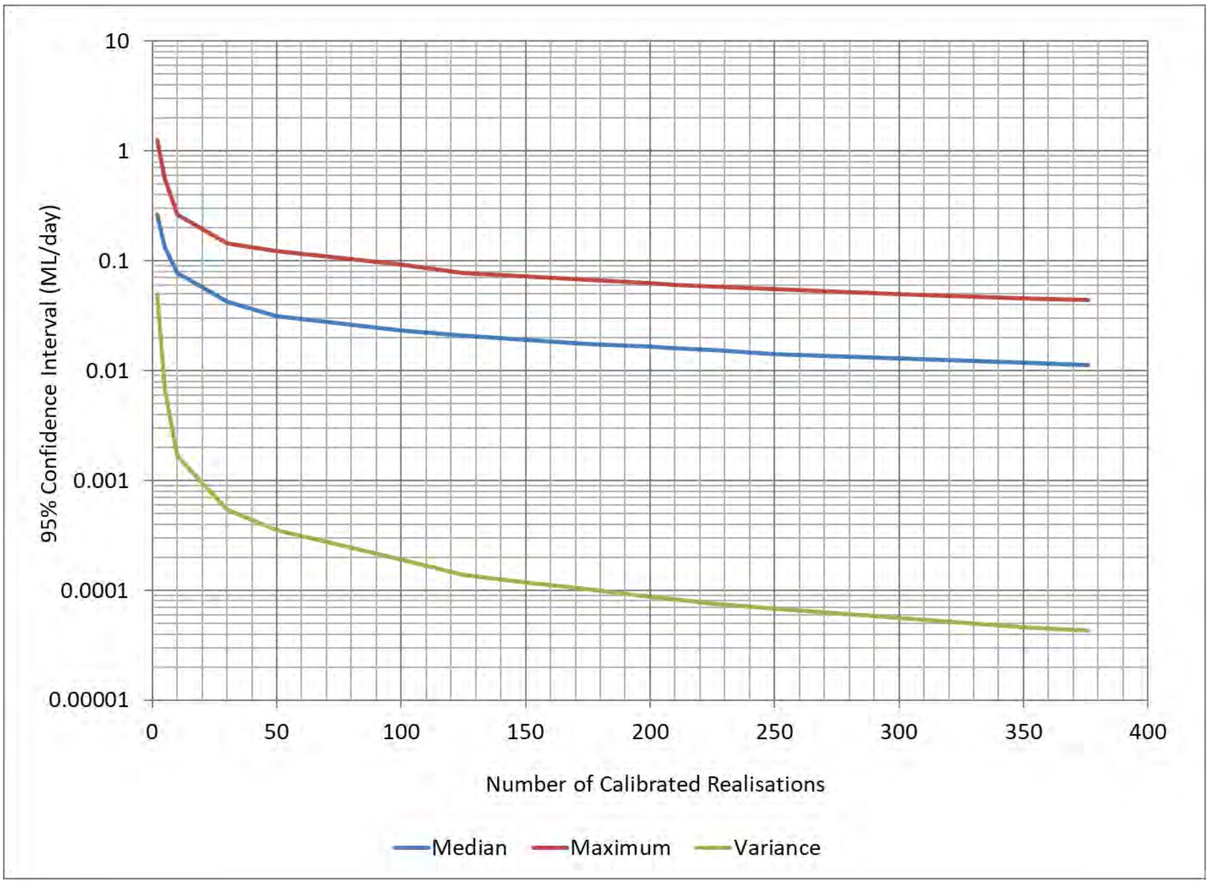
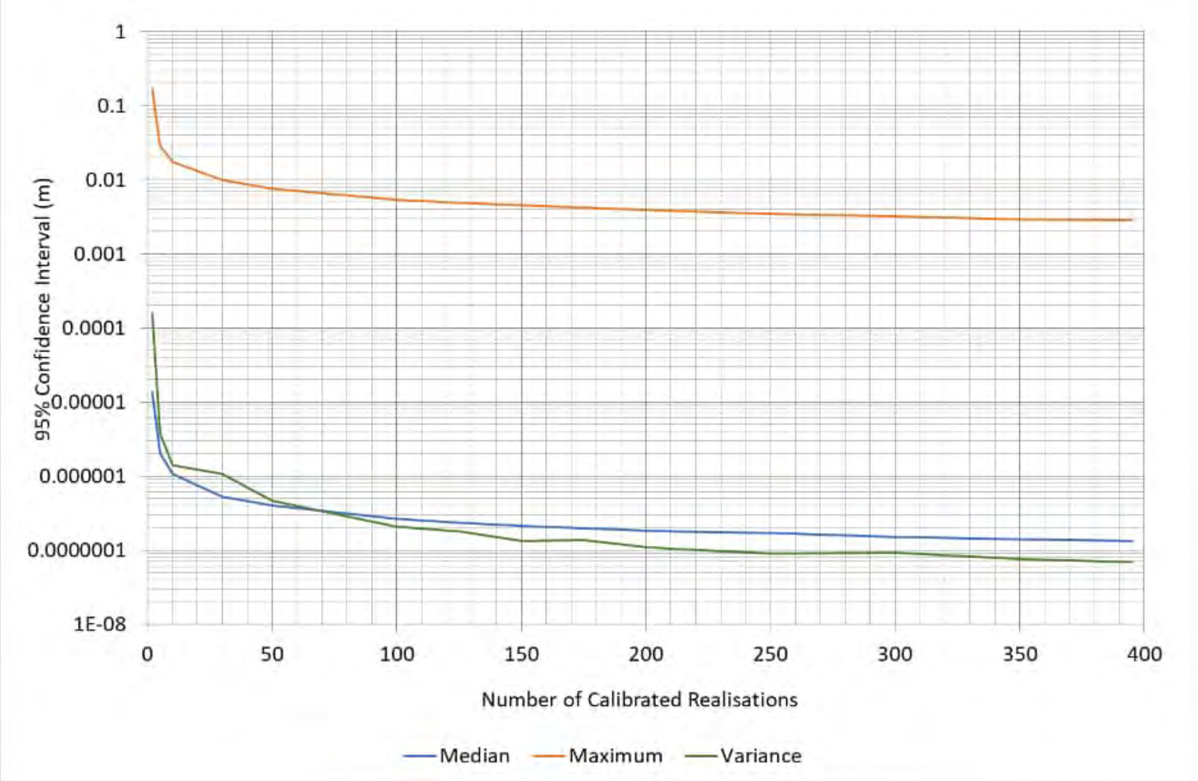


Figure 23 95 % Confidence Interval for Maximum Drawdown



7.6.2.2 Uncertainty of quarry inflows

Figure 24 presents the uncertainty of predicted groundwater inflows to the Project that have been extracted from the Hillview Quarrying Scenario. The figure shows the predicted inflows for the calibrated prediction model and different percentiles including 5th, 33rd, 50th, 66th, and 95th prediction bounds. Based on the IESC (2018) guidelines these represent:

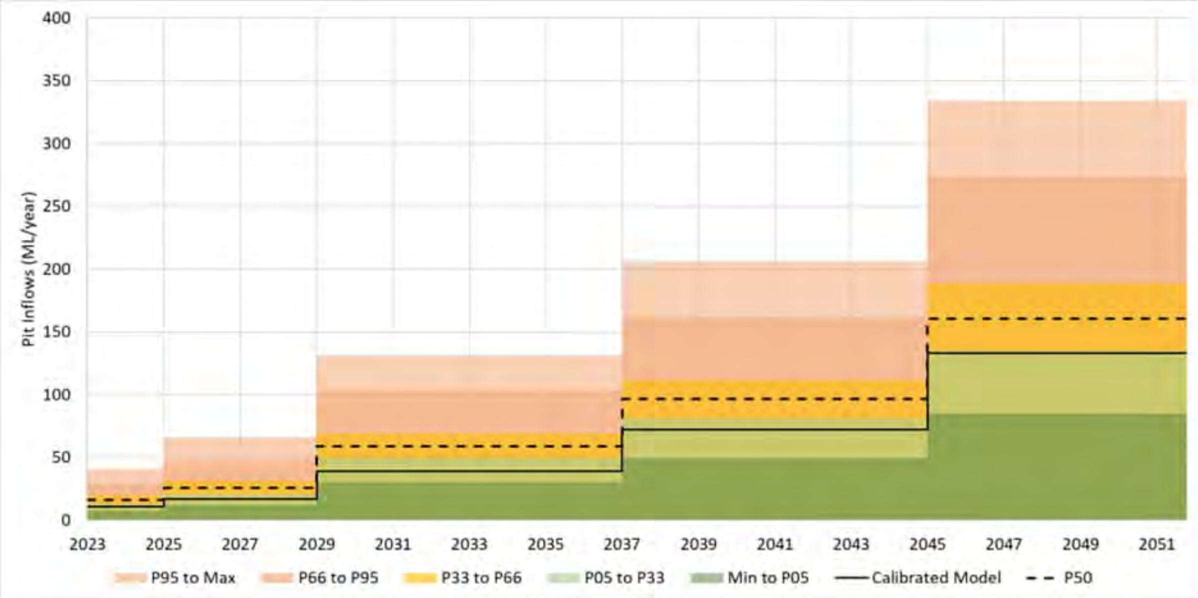
- 5th percentile indicates it is very likely the outcome is larger than this value.
- 5th - 33rd indicates it is likely that the outcome is larger than this value.
- 33rd - 66th indicates it is as likely as not that the outcome is larger or smaller than this value.
- 66th - 95th indicates it is unlikely that the outcome is larger than this value.
- 95th percentile indicates it is very unlikely the outcome is larger than this value.

Figure 24 shows that the predicted inflow in the calibrated prediction model is lower than the 50th percentile predicted inflow (calibrated prediction model is very close to the 50th percentile).

As shown in **Figure 24**, the 50th percentile inflow is larger than the calibration prediction model predicted values. As shown in **Appendix E**, some of the insensitive model parameters identified through the sensitivity analysis (**Section 7.6.1**) were adjusted (i.e., recentred in the distribution curves) to allow more extreme values for these parameters to be explored in the analysis. This adjustment in parameter values in uncertainty analysis is the likely reason for difference in 50th percentile and the calibration prediction model lines to be different.

The maximum quarry inflow in the uncertainty analysis is 333 ML/a for 2053 (unlikely outcome is larger than this value). The 5th to 95th range in quarry inflows for the year 2053 was 85 to 274 ML/a.

Figure 24 Uncertainty Analysis for the Predicted Inflows



7.6.2.3 Uncertainty of surface water flow

Table 31 and **Table 32** show the uncertainty range in loss of groundwater discharge to surface water in Double Creek and Brewers Creek respectively.

The uncertainty results indicate that the 95th percentile loss of groundwater discharge to Double Creek is 29 ML/a at the end of Stage 7 and the 95th percentile in loss of groundwater discharge to Brewers Creek is 11 ML/a at the end of Stage 7.

The 50th percentile loss in groundwater discharge to Double Creek and Brewers Creek is close to the values for the calibrated prediction model (the value given by the calibrated prediction model is a likely outcome).

Table 31 Uncertainty of Flux Change (ML/a) to Double Creek

Year	5th Percentile	50th Percentile	Calibrated Prediction Model	95th Percentile
2025 (end of Stage ½)	0.04	0.49	0.04	1.52
2029 (end of Stage ¾)	0.20	1.37	0.12	3.61
2037 (end of Stage 5)	1.35	5.34	2.20	12.07
2045 (end of Stage 6)	2.80	9.09	5.57	20.27
2053 (end of Stage 7)	4.20	12.81	9.43	29.43

Table 32 Uncertainty of Flux Change (ML/a) to Brewers Creek

Year	5th percentile	50th percentile	Calibrated Prediction Model	95th percentile
2025 (end of Stage 1/ 2)	0.00	0.00	0.00	0.01
2029 (end of Stage3/ 4)	0.00	0.01	0.00	0.04
2037 (end of Stage 5)	0.05	0.21	0.09	0.67
2045 (end of Stage 6)	0.65	2.12	1.47	4.61
2053 (end of Stage 7)	1.54	4.84	4.50	10.77

7.6.2.4 Uncertainty of groundwater drawdowns

To illustrate the level of uncertainty in the extent of predicted drawdown due to the Project, the maximum extent of the 1 m predicted drawdown in the fractured rock for the 5th, 50th, and 95th percentiles was compared to the maximum extent of the 1 m drawdown from the calibrated prediction model.

The 95th percentile lines on **Figure D14** show the predicted maximum drawdown extent exceeded by 5 % of tested realisations (drawdown extent greater than the 95th percentile area is an unlikely outcome). The 5th percentile lines in the figures show the predicted maximum drawdown extent exceeded by 95 % of tested realisations (it is highly likely that the actual extent will be greater than that shown for the 5th percentile). The 50th percentile lines show the predicted maximum drawdown extent exceeded 50 % of tested realisations. These predictions are considered as likely outcomes.

Figure D14 shows the uncertainty in the extent of predicted 1 m maximum drawdown in the fractured rock. The figures show that the 95th percentile drawdown in the fractured rock extends to approximately 250 m southwest from the Hillview pit. **Figure D14** shows consistency between the calibrated prediction model and the 50th percentile predicted drawdown.

7.7 Predictive Post Quarrying Modelling

This section described the post quarrying groundwater modelling and the modelled long term post quarrying groundwater levels in the vicinity of the Project.

7.7.1 Model setup

Transient modelling was used to simulate the groundwater responses during post-quarrying conditions. Transient predictive models of 500 years duration post-quarrying have been developed for two scenarios:

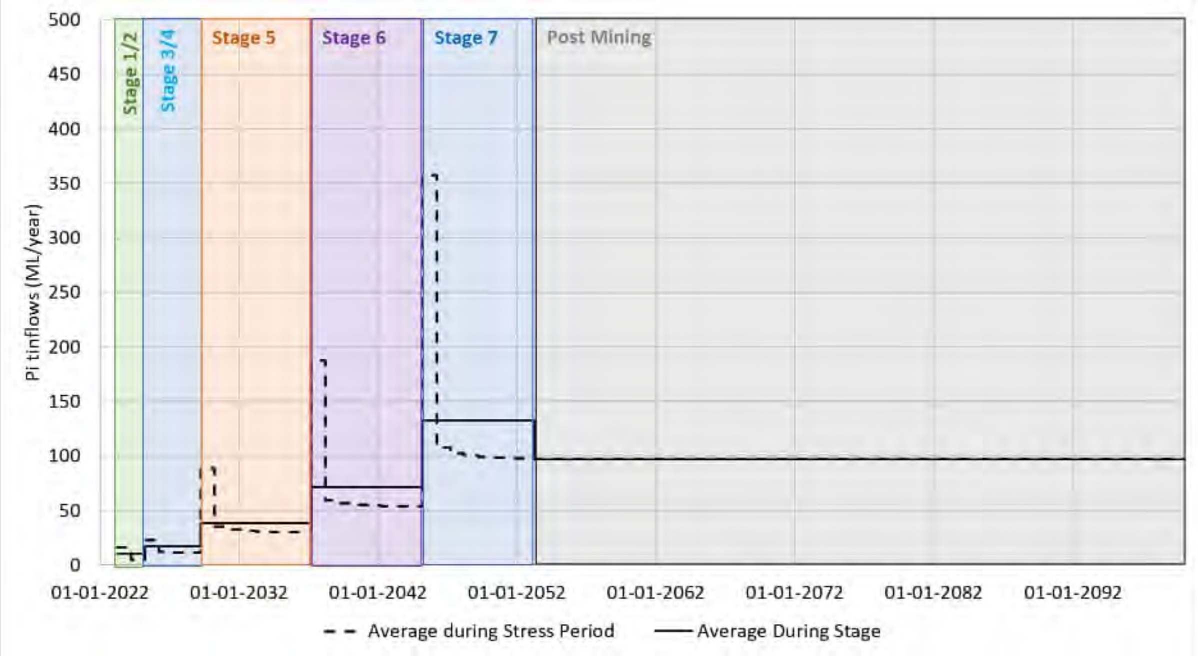
- Null Quarrying Scenario – A scenario without any quarrying.
- Hillview Quarrying Scenario– A scenario with the proposed quarrying and final landform set to run 500 years after quarrying ceases (i.e., until 2522).

The proposed Project final landform, provided by Coastwide, is a self-draining void (floor at 95 mAHD). Climate related boundary conditions (i.e., recharge and evapotranspiration) in the post-quarrying model were set constant for the duration using the long-term averages. The MODFLOW drain package used to represent quarrying at the Project was continued to represent the final landform.

7.7.2 Groundwater inflows

The groundwater inflows to the pit predicted by the groundwater model are shown in **Figure 25**. The groundwater inflows to the pit are predicted to stabilise during operation of Stage 7 at approximately 97 ML/a.

Figure 25 Simulated Post-Quarrying Pit Inflows



7.7.3 Post-quarrying groundwater levels and drawdown

Predicted equilibrium groundwater levels for the alluvium and fractured rock are shown in **Figure D15** and **Figure D16**.

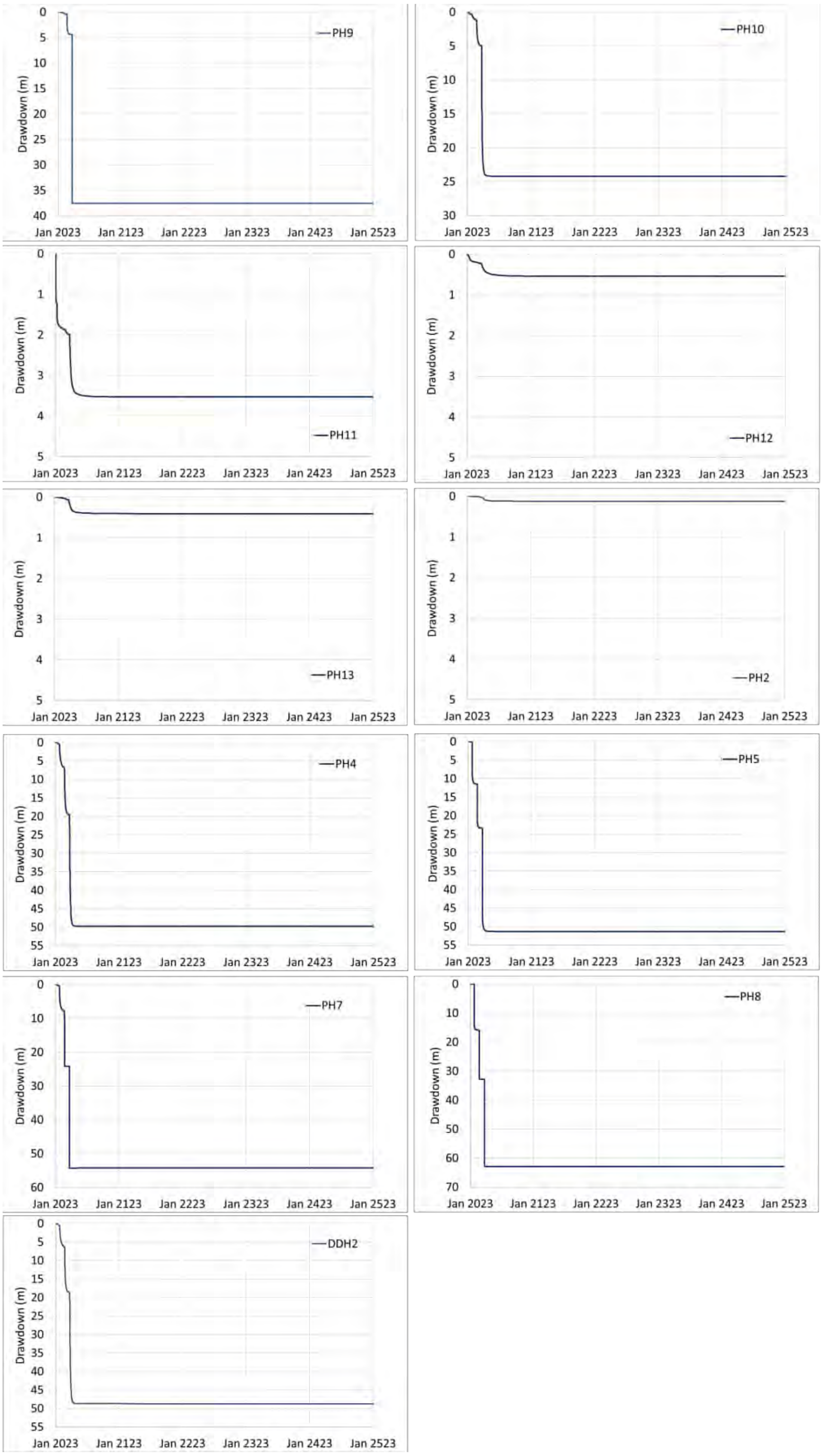
Figure D15 shows groundwater levels in alluvium in post-quarrying conditions. The model predicts that groundwater level elevations within alluvium in the vicinity of the pit generally ranges between 1 m to 10 m post-quarrying, similar to results for the current (calibrated) groundwater conditions presented in **Figure D8**.

Predicted groundwater levels in the bedrock presented in **Figure D16**, indicate that groundwater levels are predicted to remain depressed in the long term, driven by the groundwater discharge to the Project open pit which is controlled by the elevation of the pit floor (95 m AHD).

Residual drawdown refers to the remaining groundwater level drawdown post-quarrying compared to pre-quarrying groundwater levels and is obtained by subtracting the predicted equilibrium post-closure groundwater levels in the Hillview Quarrying Scenario from the Null Quarrying Scenario. The post-quarrying drawdown is therefore a comparison of groundwater levels between a 'quarrying and closure' situation, and a 'no quarrying' situation. Long-term drawdowns in Layer 1 and Layer 7 are shown in **Figure D17** and **Figure D18.**

Residual drawdown at monitoring bores is shown on the hydrographs on **Figure 26**. Maximum drawdown and equilibrium are reached during the operation of Stage 7 (i.e., the model does not predict that further drawdown will be expected in post quarrying conditions).

Figure 26 Predicted Residual Drawdown at Groundwater Monitoring Bores



7.7.4 Water balance

Table 33 and **Table 34** present average flow rates for water transfer in and out of the predictive model periods (2053 to 2522) for the Hillview Quarrying Scenario and the Null Quarrying Scenario respectively.

Table 33 Average Simulated Water Balance during the Post-Quarrying Period (2053 – 2500)

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Recharge (RCH)	41.04	77.9%	0.00	0.0%
ET (from GW) (EVT)	0.00	0.0%	44.53	85.1%
SW-GW Interaction	11.35	21.6%	7.60	14.8%
Mine	0.00	0.0%	0.27	0.6%
Storage	0.00	0.0%	0.00	0.0%
Total	**52.70**	**100.0%**	**52.70**	**100.0%**

Table 34 Average Simulated Water Balance during the Post-Quarrying Period – Null Run (2053 – 2500)

Component	Inflow (ML/d)	Percent of Total Inflow (%)	Outflow (ML/d)	Percent of Total Outflow (%)
Recharge (RCH)	41.04	78.2%	0.00	0.0%
ET (from GW) (EVT)	0.00	0.0%	44.75	85.3%
SW-GW Interaction	11.35	21.7%	7.65	14.6%
Mine	0.00	0.0%	0.00	0.0%
Storage	0.04	0.1%	0.06	0.1%
Total	**52.40**	**100.0%**	**52.40**	**100.0%**

7.7.5 Incremental water impacts

7.7.5.1 Influence on alluvium

The model predicts that there will be an insignificant loss (<0.001 ML/a) of water to the alluvium deposits located in the downstream reaches of Double Creek and Brewers Creek due to the quarrying at the Project.

7.7.5.2 Influence on surface water flow

The change in leakage and baseflow in Karuah River and the creeks within the model area due to the Project was calculated by comparing the river flow budgets in the Hillview Quarrying Scenario against the Null Quarrying Scenario.

The model predicts that:

- There will be no change to inflows and outflows from Karuah River to the creeks in the long-term due to closure of the Project.

- There will be a decrease of 9.43 ML/a (7 % of total baseflow) in the discharge of groundwater to Double Creek and its tributaries during closure of the Project.
- There will be a decrease of 4.50 ML/a (16 % of total baseflow) in the discharge of groundwater to Brewers Creek and its tributaries during closure of the Project.

7.8 Conclusions

A regional model centred around the Project has been developed with eight layers, the upper layer represents the unconsolidated alluvium and regolith, whilst the lower seven layers represent the bedrock. Key groundwater receptors, including the surface watercourses have been included in the model to evaluate the changes to these features as a result of the Project.

The transient model has been calibrated to seven monitoring bores at the Project site with water levels from 2020 to 2022. Overall, the model shows a good fit to observed water levels, with an RMS error of 6.1 m and SRMS of 7.9 % with a calibration that is considered reasonable under the 2012 Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012).

During operation, the quarry will cause drawdown in the Myall Volcanics aquifer with maximum drawdowns of 68 m at the quarry face predicted under the calibrated model scenario. Drawdowns between the 5th, 50th, and 95th percentile remain relatively consistent with the biggest drawdown impacts occurring to the southwest, away from the main groundwater receptors.

Average maximum inflows under this calibrated scenario are anticipated to be on the order of 100 ML/a during Stage 7 of the Project, whilst the 95th percentile shows inflows could be up to 333 ML/a during this Stage. Due to the Project quarry pit being engineered to be a long-term self-draining feature, groundwater levels are predicted to depressed in the long-term as per the steady-state Stage 7 drawdowns.

The uncertainty analysis shows there will be a negligible impact to Karuah River and associated alluvial sediments from the Project during either operation or closure. Under the calibrated scenario, the nearer watercourses of Double Creek and Brewers Creek will experience a reduction in baseflow of up to 9.4 and 4.5 ML/a, which equates to 7 and 16 % of their total bedrock groundwater baseflow respectively. The uncertainty shows the 95th percentile could result in a greater reduction of 29.4 and 10.8 ML/a respectively to these watercourses.

Overall, the model can be classified as a Class 2 model, under the 2012 Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) and is suitable for use in assessment of impacts from quarrying activities. The model could be improved through additional ground investigation and groundwater monitoring at the Project site, especially in relation to localised surface water-groundwater interactions. The groundwater should be validated if more groundwater data is acquired at the Project site.

8.0 Pre-Mitigation Impact Assessment

Groundwater impacts associated with the Project have been identified and an assessment of groundwater impacts has been undertaken, in alignment with the scope of the Project SEARs (**Section 3**). No additional below ground infrastructure exists in the near hydrogeological catchment and therefore this impact assessment only assesses the impacts as a result of this Project (i.e., no cumulative impacts).

The significance of any potential impact from the Project components on the local groundwater receptors have been determined by considering the value and sensitivity of the receptor related to the magnitude of the expected change, as described in **Section 4.2**. The following sections highlight the potential pre-mitigation impacts from both the construction and operation phase (from here on referred to as the operation phase) as well as the rehabilitation and long-term closure phase of the Project.

Numerical modelling, as provided in **Section 7.0,** was undertaken to predict the extent and magnitude of impact of the Project on the groundwater environment. The impact assessment has been based on the calibrated scenario, noting that the impact radius is similar for both the calibrated and 95th percentile (**Appendix D, Figure D14**). A review of both scenarios demonstrates that the impacts and effect significance to each receptor will not change between the calibrated and 95th percentile scenarios. The calibrated scenario from the numerical model (**Section 7.4**) has been used as the indication of 'most likely' impacts to the groundwater environment.

The impact to each identified receptor from all Project activities is shown in **Appendix F**.

8.1 Assessment of Potential Operational Impacts

The following section assesses the potential operational impacts of the Project on groundwater and associated receptors.

The Project will be operated over a period of 30 years; during this time the following Project activities will be undertaken:

- Staged excavation of approximately 45 million tonnes of hard rock (rhyolite) at a rate of up to 1.5 Mtpa;
- Site preparation and earthworks, including;
  - vegetation clearing.
  - road upgrade works.
  - access road construction and use (including receipt of concrete waste from off-site location).
  - site servicing infrastructure installation and operation.
  - Ancillary site infrastructure installation and operation.
- Concrete batching plant installation and operation (including receipt of sand, cement and fly ash from off-site location);
- Overburden stockpiling and removal; and
- Material transport to off-site location.

The main risks to the groundwater environment from operation of the Project include:

- Groundwater dewatering and direct drawdown to receptors as a result of below ground excavation from the Project quarry and haul road cut within the Myall Block Volcanics.

- Reduction in groundwater to, or through, a receptor as a result of below ground excavation and active dewatering in the upgradient Myall Block Volcanics.
- Contamination of groundwater from accidental spills, poor water management, or other operational activities.

8.1.1 Impact on groundwater levels, flow, and connectivity

The proposed quarry pit of the Project will intersect the groundwater table. Any excavation below the water table has the potential to influence the groundwater regime. Therefore, potential changes to groundwater levels, flow, and surface water-groundwater interactions are likely to occur during operation of the Project.

8.1.1.1 Impact on aquifers

The Myall Block Volcanic deposits is the predominant unit found across the Project and during operation this formation will be the target material during quarrying. Excavation and direct dewatering of this deposit will occur causing a lowering of groundwater levels during operation of the quarry to maintain safe working conditions. Under the calibrated scenario. a maximum drawdown of up to 68 m is predicted at the quarry face during Stage 7, as shown in **Appendix D, Figure D12** and **Table 35**.

Table 35 Drawdown in the Myall Volcanics at End of Each Quarry Stage

End of Stage	Time into Project (years)	Maximum drawdown at Quarry Face (m)	Maximum ROI to 0.1 m (m)	New Receptors in Drawdown
1/ 2	2	6.9	165	Unnamed tributary of Double Creek Moderate potential GDEs along Double Creek to east
3/ 4	6	7.1	190	Lower Hunter Valley Dry Rainforest
5	16	21.8	240	Double Creek
6	24	37.0	610	Brewers Creek Moderate and high potential GDEs along Brewers Creek to south
7	30	67.8	855	Moderate potential GDEs along Double Creek to north

Flow paths in the vicinity of the excavation will change in the Myall Block Volcanics due to the targeted dewatering. In the context of the wider volcanic aquifer, this change will be relatively local and minor, and will not result in a measurable decrease to the integrity of the regional aquifer. Flow paths to local downgradient receptors may change within this aquifer due to the dewatering and drawdown in the aquifer. These changes have been assessed individually to each receptor in the following sections.

The Project is located adjacently upgradient of the alluvial valley and alluvial high stand facies deposits. As the alluvial valley deposits do not lie within the radius of dewatering impact the Project, there is likely to be a negligible drawdown impact to the aquifer associated with the deposits. However, dewatering in the upgradient catchment may result in a change to the groundwater flow paths discharging from the Myall Block Volcanics to these aquifers and reduce flow to the alluvial aquifer systems. However, the potential flow impact is anticipated to be exclusive to the local alluvial valley and alluvial high stand facies deposits which are situated close to the Project, with no long-term impact to regional alluvial aquifer flows and integrity expected.

As predicted by the numerical model (**Section 7.4.6.1**), the Project is not likely to have a significant impact on groundwater levels or flow in the alluvial floodplain deposits aquifer associated with the Karuah River. This is supported conceptually, since the dewatered area is predicted to contribute a relatively limited volume of groundwater throughflow to the alluvial floodplain deposits, in comparison to the contribution of other groundwater recharge process across the catchment.

8.1.1.2 Impact on surface watercourses (baseflow)

This groundwater impact assessment is limited to the potential impacts of the Project on baseflow to surface watercourses. All other surface water impacts are discussed in the *Hillview Quarry EIS: Surface Water Assessment*.

The Project could result in the following impacts to the contribution of groundwater baseflow to surface water in the vicinity of the Project:

<u>Unnamed tributary of Double Creek</u>

- The unnamed tributary of Double Creek will be lost as this watercourse lies within the footprint of the Project processing pad, constituting an overall major impact to this watercourse. Therefore, changes to baseflow are not deemed relevant as this feature will be lost; and this watercourse has not been assessed further in this groundwater assessment. Further significance and required mitigation for loss of this watercourse are detailed in the *Hillview Quarry: Surface Water Assessment*.

<u>Double Creek</u>

- The reaches of Double Creek to the north of the Project may experience a potential minor drawdown impact as they lie within the Project radius of drawdown during Stages 5, 6, and 7 of the Project. This is considered a minor impact as the maximum drawdown (Stage 7) in the vicinity of Double Creek is less than 1 m.
- The downstream reaches of Double Creek to the east of the Project, may also experience a moderate baseflow impact due to dewatering in the upgradient catchment that is likely to significantly reduce throughflow to this surface watercourse. These downstream reaches will not experience direct dewatering impacts as the elevation of Double Creek is lower than the base of the proposed quarry footprint and outside the radius of drawdown predicted by the numerical model.
- The calibrated numerical model predicts an overall baseflow loss of up to 9.43 ML/a (7 %) to Double Creek during Stage 7 due to excavation and dewatering of the Project.
- Based on the moderate receptor value of Double Creek (see **Section 6.2** for more information), the potential moderate baseflow impact from operation of the Project on this receptor could lead to a moderate baseflow adverse effect, which is significant. Further impact significance and required mitigation for these adverse baseflow impacts to this watercourse are detailed in the *Hillview Quarry: Surface Water Assessment*.

Brewers Creek

- Brewers Creek to the south of the Project may experience a potential minor drawdown impact as the watercourse lies within the radius of drawdown during Stages 6 and 7 of the Project. This is considered a minor impact as the maximum drawdown (Stage 7) in the vicinity of Brewers Creek is less than 1 m.
- Downstream reaches of Brewers Creek may also experience a moderate baseflow impact due to dewatering in the majority of its upgradient catchment that is likely to significantly reduce baseflow to the upgradient portions of this watercourse.
- The calibrated numerical model predicts an overall baseflow loss of 4.5 ML/a (16 %) to Brewers Creek during Stage 7 due to excavation and dewatering of the Project.
- Based on the moderate receptor value of Brewers Creek, the potential moderate baseflow impact on this receptor could lead to a moderate adverse baseflow effect, which is significant. Further impact significance and required mitigation for these adverse baseflow impacts to this watercourse are detailed in the *Hillview Quarry: Surface Water Assessment*.

Cromarty Creek

- Cromarty Creek will not experience a drawdown or baseflow impact as the groundwater contours show that groundwater at the Project does not discharge to this watercourse, which lies in a different hydrogeological catchment.
- Maximum drawdown during Stage 7 extends into the Cromarty Creek hydrogeological catchment, however, this drawdown extent is limited and not significant in context of wider groundwater catchment of this watercourse.
- No significant adverse baseflow effects are anticipated to Cromarty Creek because of operation of the Project.

Karuah River

- There is likely to be negligible drawdown and baseflow impacts to the Karuah River. Karuah River is a major river that is located over 1 km away from the Project footprint. Karuah River does not lie within the radius of drawdown of the Project and lies at lower elevations than that of the Project so will not be directly dewatered.
- The numerical model predicts that the volume of groundwater baseflow contributed to Karuah River will not change because of the Project. This is due to the Project intercepting a relatively small area of the Karuah River catchment in comparison to other inputs to the watercourse from across the watercourse's catchment (hydrological and hydrogeological).
- No significant adverse baseflow effects are anticipated to Karuah River because of operation of the Project.

8.1.1.3 Impact on groundwater users

One anthropogenic bore, GW050664, is located downgradient of the Project, near the confluence of Brewers Creek and Double Creek, and is understood to extract from the Myall Block aquifer. No significant adverse effects are anticipated to this groundwater user because of the Project due to the bore accessing a deeper water-bearing horizon at -17.2 mAHD than that intersected by the Project.

8.1.1.4 Impact on GDEs

Within the vicinity of the Project, several ecosystems rely on the alluvial groundwater deposits to maintain their structure and function. No high priority GDEs are mapped within the vicinity of the Project, though a number of potential GDEs are present. The current extent of groundwater dependency of these ecosystems is unknown but have been assessed as being reliant, at least partially, on groundwater flow for a conservative assessment unless there is strong evidence otherwise. These potential GDEs with the potential impacts are as follows:

<u>Lower Hunter Dry Rainforest</u>

- Operation of the Project is likely to have a major impact on groundwater level and flow pertinent to the Lower Hunter Valley Dry Rainforest ecosystem (located 30 m to the north-west of the Project). This potential GDE lies within the radius of drawdown of the Project, with up to 25 m drawdown anticipated. This drawdown will also create a major flow impact to the potential GDE as the long-term reduction in water level will cause groundwater baseflow to no longer discharge to this habitat. This could result in a long-term loss of this receptor if the potential GDE is solely or predominantly groundwater-fed.
- Based on the high receptor value of the Lower Hunter Valley Dry Rainforest ecosystem, the potential major baseflow impact on this receptor could lead to a major adverse baseflow effect. The ecological significance to this habitat because of this groundwater baseflow impact is assessed in *Hillview Quarry: BDAR*.

<u>Eucalypt River Flat Forest</u>

- The Eucalypt River Flat Forest does not lie within the radius of drawdown of the Project, and therefore, there is predicted to be a negligible direct drawdown impact to this potential GDE.
- A moderate flow impact is anticipated to the Eucalypt River Flat Forest along Double Creek as dewatering will occupy most of the upgradient hydrogeological catchment of this potential GDE. This may cause a measurable long-term decrease of flow to the potential GDE and could impact on integrity of the receptor if the potential GDE is solely or predominantly groundwater-fed.
- Based on the high receptor value of the Eucalypt River Flat Forest ecosystem, the potential moderate baseflow impact on this receptor could lead to a moderate adverse baseflow effect. The ecological significance to this habitat because of this groundwater baseflow impact is assessed in *Hillview Quarry: BDAR*.

<u>Moderate potential riparian GDE associated with Brewers Creek</u>

- Operation of the Project is likely to have a major impact on groundwater levels and flow pertinent to the BoM potential riparian GDE associated with Brewers Creek, due to this potential GDE lying within the radius of drawdown of the Project, with up to 20 m drawdown anticipated. This drawdown will also create a major flow impact to the potential GDE as the long-term reduction in water level will cause groundwater baseflow to no longer discharge to this habitat. This could result in a long-term loss of this receptor if the potential GDE is solely or predominantly groundwater-fed.
- Based on the low receptor value of the Brewers Creek riparian ecosystem, the potential major impact on this receptor could lead to a minor baseflow adverse effect, which is not considered significant.

<u>Moderate potential riparian GDE associated with Double Creek</u>

- The potential GDE does not lie within the radius of dewatering impact the Project, there is likely to be a negligible drawdown impact to these riparian GDEs.
- The Project is likely to have a moderate impact on groundwater flow pertinent to the BoM potential riparian GDE associated with Double Creek due to groundwater dewatering in the upgradient catchment. This may cause a measurable long-term decrease of flow to the potential GDE and could impact on integrity of the receptor if the potential GDE is solely or predominantly groundwater-fed.
- Based on the low receptor value of the Double Creek riparian ecosystem, the potential moderate baseflow impact on this receptor could lead to a minor adverse baseflow effect, which is not considered significant.

<u>High and moderate potential riparian GDE associated with Cromarty Creek and Karuah River</u>

- Operation of the Project is predicted to have a negligible impact on groundwater level and flow pertinent to the high and moderate potential riparian GDEs associated with Cromarty Creek and Karuah River. As predicted by the numerical model. these GDEs do not lie within the radius of drawdown of the Project, and flow changes to the alluvium and rivers supporting these features will not significantly change (**Section 7.4.6.1**). Conceptually, the proposed dewatering area is likely to contribute relatively limited water in support of these potential GDEs, in comparison to other water sources across the catchment.
- No significant adverse effects are anticipated to the riparian ecosystems associated with Cromarty Creek or Karuah River because of operation of the Project.

8.1.2 Impact on groundwater quality

There is potential for infiltration and contamination of groundwater as a result of accidental spills (e.g., chemical and/ or fuel), disturbance of sediment, and/ or stormwater mismanagement during the operational phase of the Project. Any accidental spill that interacts with the neighbouring groundwater environment could result in a degradation of groundwater quality.

The quarry is predicted to act as a regional sink in the water table, and therefore offsite migration of concentrations within the quarry footprint is generally considered low risk to groundwater. However, any contamination of groundwater outside of the groundwater drawdown radius (i.e., in vicinity of haul road) could migrate through the subsurface to downgradient water receptors.

Where quality impacts exist, they are anticipated to be minor due to the short-term (temporary) nature of quality impacts in the water environment where attenuation is anticipated. The following downgradient receptors are vulnerable to adverse effects from any quality issues that may arise at the Project:

- Eucalypt River Flat Forest ecosystem.
- Double Creek.
- Moderate potential riparian GDE associated with Double Creek.
- Alluvial floodplain deposits.
- Alluvial levee/ overbank deposits.
- Karuah River.

- High and moderate potential riparian GDE associated with Karuah River.

8.2 Assessment of Potential Closure and Rehabilitation Impacts

After closure of the quarry, the quarry structure will be left as an open cut pit as per operation (i.e., no backfill) and will be engineered to be gravity self-draining (to the on-site water management system), and then topsoiled and vegetated. No spoil emplacement will be left at the Project after closure, with all material removed from the Project site during operation.

8.2.1 Impact on groundwater levels, flow, and connectivity

The operation phase of the Project is anticipated to be completed after 30 years. At the end of operation, the groundwater table will remain depressed and not be allowed to recover, remaining self-draining. Numerical modelling has shown that the long-term drawdown and inflow during the rehabilitation stage is the same as that at the end of quarrying (after 30 years) and therefore the pre-mitigation impacts of the rehabilitation phase will be the same as the worst case of the operation phase, albeit longer-term (permanent), as described in **Section 7.1**.

8.2.2 Impact on groundwater quality

Post-closure, quality impacts are expected to be less than that during operation as all the activities and materials that pose a water quality risk will be removed from the Project site.

Any groundwater inflow to the pit will be engineered to be self-draining and will not accumulate in quarry shell, which prevents the formation of a pit lake and evapo-concentration of salts within the pit lake and potential salinity increases and acid mine drainage issues.

8.3 Pre-Mitigation AIP Minimal Impact Considerations

A summary of the predicted impacts to the groundwater environment pre-mitigation throughout the lifecycle of the Project against the NSW AIP Minimal Impact Considerations legislation for less productive alluvial as well as porous and fractured rock groundwater sources is provided in **Table 36**.

Table 36 Minimal Impact Considerations – Pre-Mitigation

Minimal Impact Consideration Level	Level 1 Acceptable Criteria	Response
Water Table	*Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:* *(a) high priority groundwater dependent ecosystem; or*	No high priority groundwater dependent ecosystems are described in the relevant WSPs for the Project. However, the following two ecosystems protected under the Biodiversity Conservation Act (2016) legislation and are located along topographical valleys that could have a component of groundwater flow. • Eucalypt River-Flat Forest located along Double Creek that correlates to the high potential GDEs along this river on the BoM database.

Minimal Impact Consideration Level	Level 1 Acceptable Criteria	Response
		• Lower Hunter Valley Dry Rainforest located along unnamed tributary of Double Creek 2. **Level 1 acceptable criteria exceeded.**
	(b) high priority culturally significant site listed in the schedule of the relevant water sharing plan; or	No known high priority culturally significant sites lie within the Project influence. Level 1 acceptable criteria not exceeded.
	A maximum of a 2 m decline cumulatively at any water supply work.	No drawdown greater than 2 m is anticipated at any bore. Level 1 acceptable criteria not exceeded.
Water Pressure	*A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.*	No impact to water pressure aquifers is anticipated because of the Project as occurring on a hillslope and geological profile in an unconfined aquifer. Level 1 acceptable criteria not exceeded.
Water Quality	*(a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and*	Beneficial use of Myall Block Volcanics groundwater in the area is limited, this is due to the high metal and nutrient concentrations as well as high salinity. Potential component of baseflow from Myall Block Volcanics to downgradient freshwater GDE ecosystems. Any contamination of groundwater could impact on the groundwater quality in this aquifer due to activity in the upgradient catchment. **Level 1 acceptable criteria exceeded.**
	(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. *Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above.*	The salinity of the Myall Block Volcanics shows that the groundwater is generally brackish to fresh. Changes to salinity are not predicted as a direct impact of the Project; a surface water management system will be designed so that no water will be left to accumulate and form evapo-concentrate. Level 1 acceptable criteria not exceeded.
	(c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three-dimensional extent of the alluvial material - whichever is the lesser distance) of a highly	No highly connected surface watercourse (Schedule 3 and above) or alluvial material exists within 200 m laterally or 100 m vertically of the quarrying activity. Brewers Creek and Double Creek are 85 and 110 m from the Project respectively but are considered Schedule 2

Minimal Impact Consideration Level	Level 1 Acceptable Criteria	Response
	connected surface water source that is defined as a "reliable water supply".	minor rivers, and not considered a reliable water supply. Level 1 acceptable criteria not exceeded.

To be within the Level 1 acceptable impact considerations, mitigation measures will need to be put in place to prevent groundwater quality issues arising downgradient of the Project as well as prevent significant drawdown or flow impacts at the following receptors:

- Eucalypt river-flat forest located along Double Creek that correlates to the high potential GDEs along this river on the BoM database.
- Lower Hunter Valley Dry Rainforest located along unnamed tributary of Double Creek 2.

9.0 Environmental Management Measures and Residual Impacts

This section provides a summary of the pre-mitigation operational and rehabilitation impacts, as described in **Section 7.7.4**, and the appropriate measures to mitigate these risks.

9.1 Environmental Management Measures

9.1.1 Environmental Management Plan

There is low risk from operation and closure of the Project of mitigation of contaminants and/ or degradation of groundwater quality due to the Project quarry acting as a sink for groundwater. However, an Environmental Management Plan (EMP) will be developed to mitigate for all foreseeable water quality or contamination risks to the aquifer environment during operation and closure of the Project. This will include:

- A Dewatering Management Plan to outline responsibilities, controls, and procedures to mitigate potential environmental impacts with operational dewatering. A Water Access Licence (WAL) will need purchasing as part of the Project during the later stages to cover inflow above the existing WAL of 100 ML/a, as detailed further in **Section 10.0**.
- An appropriate Soil and Water Management Plan, detailing:
    - Preventative measures for accidental spills with appropriate response protocols. Storage of fuels, oils, and chemicals will be isolated from the water environment.
    - Preventative measures for stormwater control in a Stormwater and Erosion Control Management sub-plan. This is detailed further in the *Hillview Quarry: Surface Water Assessment*.
    - Management of groundwater inflows, treatment, and discharge. Any groundwater intersected by the Project will be collected by the surface water management system and retained in sedimentation dams before being discharged to Double Creek. More information and environmental management measures about the surface water drainage system are discussed in the *Hillview Quarry: Surface Water Assessment*.

9.1.2 Groundwater Management Plan

A Groundwater Management Plan (GWMP) will be required to prescribe groundwater level and quality monitoring at site and the method of reporting and analysis of data. Interpretation and presentation of data will be required internally and for reporting to government agencies.

- It is recommended that additional baseline data is collected in all existing monitoring bores prior to establishment of a full GWMP to allow for the development of appropriate water level and quality triggers and response plans.
- Additional bores are also likely to be needed at the Project, outside the quarry footprint to measure dewatering performance and monitor for long-term groundwater changes in the vicinity of key receptors. The locations of these should be specified in the GWMP considering the dewatering design and key local receptors. It is recommended that dataloggers in existing bores that will be mined out are reassigned to these new bores outside the Project quarry footprint.
- During operation, groundwater levels should continue to be recorded and downloaded in the on-site dataloggers. They should be downloaded on at least a

quarterly basis to confirm data quality. Bores without groundwater loggers should be manually dipped on this quarterly basis.

- Water quality should be measured on a monthly basis during the first two years of operation, after which a quarterly basis should be adopted. The analytes to be analysed are as per **Table 37** below.

Table 37 Analytes for Groundwater Quality Monitoring

Testing Suite	Parameters
Petroleum Hydrocarbons	TPH, TRH, BTEX
Phys-chemical	pH, Electrical Conductivity, Total Dissolved Solids
Nutrients	Nitrates, Total Nitrogen, Phosphorous, Ammonia
Major Ions	Alkalinity (including Bicarbonate, Carbonate, Hydroxide, and Total), Calcium, Chloride, Magnesium, Potassium, Sodium, Sulphate, Anions, Cations, Ionic Balance
Metals	Aluminium, Arsenic, Boron, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Iron, Manganese, Mercury, Nickel, Lead, Selenium, Vanadium, Zinc

- Annual reports should be conducted to fulfil the requirements of the GWMP and should include:
  - Review of publicly available rainfall data to understand climatic variation and controls on groundwater levels.
  - Presentation and analysis of water levels and water quality in the on-site groundwater monitoring wells in comparison to the triggers and responses in the GWMP.
  - Conclusions from monitoring and required changes to the monitoring network and/ or monitoring schedules.
- It is recommended that the GWMP for the rehabilitation stage is constructed at a later point when the operation impacts and need for long-term groundwater monitoring are better understood.

9.1.3 Additional mitigation measures

In addition, work will need to be done to mitigate for the impact to potential GDEs that may be adversely impacted from the Project. This includes the high value Lower Hunter Valley Dry Rainforest and Eucalypt River Flat Forest ecosystems. Monitoring and mitigation for the biodiversity habitats and plant species within these GDEs is outlined in further detail in **Appendix F** and the *Hillview Quarry: BDAR*.

- Additional bores may be needed at the Project, outside of the Project footprint, to monitor for long-term groundwater changes in the vicinity of these ecosystems. Baseline groundwater level data will need to be collected to understand groundwater flow and level dynamics in the vicinity of these ecosystems prior to quarrying.
- If these ecosystems are understood to be groundwater dependent, then a trigger action response plan (TARP) will be included within the GWMP (see **Section 9.1.2**) to monitor any adverse impacts on these ecosystems from the removal of groundwater.

- A Biodiversity Management Plan (BMP) will also be developed to response to monitor the ecological condition during the Project; further information is included in *Hillview Quarry: BDAR*.

9.2 Post-Mitigation (Residual) Impacts

After implementation of the mitigation measures outlined in **Section 9.1,** residual drawdown and flow impacts will still exist for the potential GDE habitats as specified in **Table 38**.

With the adoption of an Environmental Management Plan and appropriate subsidiary plans, no residual impacts are anticipated to groundwater quality.

Table 38 Minimal Impact Considerations – Post-Mitigation

Minimal Impact Consideration Level	Level 1 Acceptable Criteria	Response
Water Table	*Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:* *(a) high priority groundwater dependent ecosystem*	No high priority groundwater dependent ecosystems are described in the relevant WSPs for the Project. However, the following two ecosystems protected under the Biodiversity Conservation Act (2016) are predicted to be significantly adversely impacted by the Project: • Eucalypt River-Flat Forest located along Double Creek that correlates to the high potential GDEs along this river on the BoM database. • Lower Hunter Valley Dry Rainforest located along unnamed tributary of Double Creek 2. Mitigation will be put in place to monitor groundwater levels prior to, and during, operation to understand groundwater changes and monitor the ecological condition of the two habitats. However, residual impacts may occur if the habitats are solely, or highly, dependent on groundwater and surface water flow cannot sustain water requirements of the plant species. **Level 1 criteria still exceeded.**
Water Quality	*(a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity*	With the adoption of an Environmental Management Plan and appropriate subsidiary plans, no residual impacts are anticipated to groundwater quality. Level 1 criteria not exceeded after implementation of the mitigation measures outlined above.

Despite mitigation to monitor and assess for the significant drawdown and flow to the potential GDEs of the Eucalypt River Flat Forest and Lower Hunter Valley Dry Rainforest, residual impacts may occur if the habitats are solely, or predominantly, dependent on groundwater and surface water flow cannot sustain water requirements of the plant species and habitats. Further mitigation (i.e., biodiversity offsetting) may be needed to offset the loss of these habitats. This additional mitigation is detailed further in the *Hillview Quarry: BDAR*.

10.0 Licencing Requirements

Groundwater inflows per year during operation and after operation, as per the calibrated groundwater model are shown in **Table 39**.

Table 39 Licencing Requirements by Year

Stage	Year/s	Licencing Requirements (Calibrated) (ML/a)
1/ 2	1	17
	2	5
3/ 4	3	23
	4 to 6	12
5	7	89
	8 to 14	36
6	15	188
	16 to 22	60
7	23	360
	24	108
	25	103
	26	101
	27 to 30	99
After Operation	Long-term	97

The maximum quarry inflow in the uncertainty analysis is 333 ML/a for 2053 (unlikely outcome is larger than this value). The 5th to 95th range in quarry inflows for the year 2053 was 85 to 274 ML/a.

All groundwater take will be from the Myall Volcanics rhyolite bedrock. This aquifer is regulated under the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources. Under this water sharing plan, the quarry is located within the New England Fold Belt Coast Groundwater Source of which approximately 40,000 ML/a is unassigned. No groundwater take is anticipated from the alluvial deposits and therefore no licence will be required under the WSP for the Lower North Coast Unregulated and Alluvial Water Sources 2022.

Coastwide have acquired an aquifer Water Access Licence (number 44439) for 100 units from the New England Fold Belt Coast Groundwater Source. This is not currently linked to any works. This licence will be adequate until Stage 6 of the Project to cover groundwater inflows to the quarry pit. A further water allocation is likely to be required at this stage to cover transient inflows. During operation, it is recommended that seepage to the Project should be metered and compared to predictions to allow for groundwater access licences to be amended accordingly.

11.0 Conclusions

This Groundwater Assessment forms part of the EIS for the Hillview Quarry Project. A full conceptual and numerical groundwater model has been carried out to understand impacts and provide mitigation to reduce these impacts on the groundwater environment. The Project will involve the progressive quarrying over a period of 30 years, after which time the quarry will go into closure and rehabilitation.

The Project will directly intersect the Myall Volcanic Group, a predominantly rhyolite geology that forms an aquifer of secondary (fracture) permeability with minimal primary (matrix) permeability. Recharge to this aquifer is predominantly through rainfall recharge with discharge to surface watercourses in the topographical valleys and groundwater levels a subdued reflection of topography.

Hydraulically downgradient of the Project lies alluvial valley deposits, a clayey silt lithology associated with downgradient reaches of Double Creek and Brewers Creek. This deposit is likely temporally saturated and limited in spatial and vertical extent; therefore, acting as a minor perched aquifer temporally supporting local flow and habitats including the high and moderate priority riparian GDE systems along the surface watercourses. High-stand alluvial facies also lie downgradient of the Project, these are composed of sand and gravel.

A regional numerical groundwater model centred around the Project has been developed with eight layers; the upper layer represents the unconsolidated alluvium and regolith, whilst the lower seven layers represent the bedrock. Key groundwater receptors, including the surface watercourses have been included to evaluate the Project impacts to these features.

The transient model has been calibrated to seven monitoring bores at the Project site with water levels from 2020 to 2022. Overall, the model shows a good fit to observed water levels, with an RMS error of 6.1 m and SRMS of 7.9 % with a calibration that is considered reasonable under the 2012 Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012).

- During operation and closure, the quarry will cause drawdown in the Myall Volcanics aquifer with maximum drawdowns of 68 m at the quarry face predicted under the calibrated model scenario. The drawdown extent into the groundwater environment between the 5th, 50th, and 95th percentile remain relatively consistent.
- The maximum radius of influence to 0.1 m under the calibrated scenario is approximately 855 m into the Myall Block volcanics. This occurs during Stage 7 of the quarry progression and has been used to conservatively assess impacts to receptors over the project lifecycle.
- Average maximum inflows under the calibrated scenario are anticipated to be on the order of 100 ML/a during Stage 7 of the Project, whilst the 95th percentile shows inflows could be up to 333 ML/a during this Stage and post-closure. Groundwater levels are predicted to be depressed in the long-term due to the Project being engineered to be a self-draining pit upon closure.
- The uncertainty analysis shows there will be a negligible impact to Karuah River and associated alluvial sediments from the Project during either operation or closure. Under the calibrated scenario, the nearer watercourses of Double Creek and Brewers Creek will experience a reduction in baseflow of up to 9.4 and 4.5 ML/a, which equates to 7 and 16 % of their total bedrock groundwater baseflow respectively. The uncertainty analysis shows the 95th percentile could result in a greater baseflow reduction of 29.4 and 10.8 ML/a respectively to these watercourses. This amounts to a significant change of baseflow to Double Creek and Brewers Creek.

The Project is located in the New England Fold Belt Coast Groundwater Source and regulated under the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources. Coastwide have acquired an aquifer Water Access Licence (number 44439) for 100 units from the New England Fold Belt Coast Groundwater Source. Based on the calibrated inflow predictions for Stages 6 and 7 (the final and deepest stages of quarry operations), Coastwide would be required to obtain an additional Water Access Licence for up to approximately 260 ML/a to cover transient inflows at the start of both Stages 6 and 7.

A summary of the pre-mitigation impacts with the required mitigation, along with any residual impacts are detailed in **Table 40**.

Table 40 Summary of Environmental Management Measures to Mitigate Groundwater Impacts

Mitigation Number	Risks and Associated Impacts	Mitigation	Timing	Potential Residual Impact after Implementation of Management Measures	Comment on how any Residual Impacts would be Managed
GW1	Licencing requirements for operational and long-term aquifer inflow.	**Dewatering Management Plan (DMP)** Outline responsibilities, controls, and procedures to mitigate potential environmental impacts with operational dewatering. Acquire a **Water Access Licence** to cover the inflow from the Myall Volcanics.	Develop the mitigation during the pre-operation phase. Implement the mitigation during the operation and rehabilitation stage.	Negligible	None required.
GW2	Groundwater drawdown and flow reduction in the environment during quarry operation and closure of the Project. Significant impact to: - Lower Hunter Valley Dry Rainforest potential GDE -Eucalypt River Flat Forest potential GDE -Brewers Creek -Double Creek	A **Water Management Plan (WMP)** with **Groundwater Management Plan appendix (GWMP)** will be created prior to operation to provide appropriate mitigation for the groundwater environment and to prevent significant adverse impacts.	Develop the mitigation during the pre-operation phase. Implement the mitigation during the operation and closure/rehabilitation stage.	Despite mitigation to monitor and assess groundwater levels surrounding the potential GDEs of the Eucalypt River Flat Forest and Lower Hunter Valley Dry Rainforest, residual impacts may occur if the habitats are solely, or highly, dependent on groundwater and surface water flow cannot sustain water requirements of the plant species.	Further mitigation for the reduction in baseflow to surface watercourses is detailed in *Hillview Quarry: Surface Water Assessment*. Further mitigation for the GDE habitats is detailed in *Hillview Quarry: BDAR*.
GW3	Risk of water quality impacts due to the mobilisation of contaminants, accidental spills, disturbance of sediment and/or stormwater mismanagement during the	Develop and implement an **Environmental Management Plan (EMP)** to sufficiently manage the risk of water quality impacts, including the mobilisation of contaminants, accidental spills, disturbance of sediment and/or stormwater mismanagement during the construction/operational and	Develop the mitigation during the pre-operation phase. Implement the mitigation during the operation and closure/rehabilitation stage.	Negligible potential residual quality impact – implementation of the mitigation will reduce the likelihood of mobilisation of contaminants, accidental spills, disturbance of sediment and/or stormwater mismanagement during the	None required.

Mitigation Number	Risks and Associated Impacts	Mitigation	Timing	Potential Residual Impact after Implementation of Management Measures	Comment on how any Residual Impacts would be Managed
	construction/operational and rehabilitation phase of the Project. Associated impact is a potential minor to moderate impact to quality, depending on the proximity of the receptor to the Project.	rehabilitation phase of the Project, such that there is a negligible impact to water quality. The EMP will include appropriate sub-plans for Soil and Water Management and Stormwater and Erosion Control Management. These sub-plans will identify all reasonably foreseeable risks relating to water pollution, soil erosion and stormwater pollution associated with the Project, describe how these risks will be managed and minimised during construction, and include arrangements for managing pollution risks associated with contamination, spillage, soil erosion and stormwater management within the vicinity of the Project. These Plans and their requirements are detailed further in Hillview Quarry: Surface Water Assessment.		construction/operational and rehabilitation phase of the Project. The ongoing and correct implementation of the mitigation will result in a negligible magnitude of residual quality impact, due to the low likelihood of risk event occurrence after implementation of the mitigation.	

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Appendix A Geological Bore Logs

Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Auger	190	0								Hematized Rhyolitic Tuff- brown,grey to pink, weathered, porphrytic	Becoming competent
			60	0.74	0.76		2				
Diamond Drill	189	1	95				5				
	188	2	100	10.11	5.62		>5				
	187	3	100				3				
	186	4	95	8.95	8	215	3			Hematized Rhyolitic Tuff- dark red to pink, porphrytic	
	185	5									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	**Checked By: SK**	**Version: 3430_HQ_GA_DDH2_V2**

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vgt Environmental Compliance Solutions

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Diamond Drill			95				6				
	184	6		7.08	7.59						
			95				>4				
	183	7									
			95				10				
	182	8		8.67	5.75						
			95				6				
	181	9									
			95				6*			Dyke- grey to dark grey, aphanitic	Pyrite crystallisation
	180	10								Hematized Rhyolitic Tuff-	

Other information:
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Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill				9.54	5.28					dark red to pink, porphyritic	
			95				4*			Hematized Rhyolitic Tuff- dark red to pink, porphyritic	Feldspathic veining
	179	11									
			95	4.51	2.85		5			Hematized Rhyolitic Tuff- orange to pink, weathered, porphyritic	Plagioclase alteration
										Dyke- grey to dark grey, aphanitic	Some pyrite crystallisation
										Hematized Rhyolitic Tuff- dark red to pink, porphyritic	Some weathering on upper contact
	178	12									
			100				7			Hematized Rhyolitic Tuff- dark red to pink, porphyritic	Feldspathic veining
	177	13									
			95				1*			Hematized Rhyolitic Tuff-dark red, porphyritic	
	176	14		9.65	8.76						
			95				>6				
	175	15								Hematized Rhyolitic Tuff-	

Other information:
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Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95	3.54	3.09		6			orange, weathered, friable, porphrytic	
										Hematized Rhyolitic Tuff- dark red to pink, porphrytic,	
	174	16	85				>6			Hematized Rhyolitic Tuff- orange, weathered, friable, porphrytic	
				6.79	5.54					Dyke- grey to dark grey, aphanitic	Some pyrite crystallisation
	173	17	95				7			Hematized Rhyolitic Tuff- dark red to pink, porphrytic	Some feldspathic veining
	172	18	85	10.39	7.26		6				
	171	19	95				7			Hematized Rhyolitic Tuff- grey to dark red, porphrytic	
										Hematized Rhyolitic Tuff- dark red to pink, porphrytic	
	170	20									

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Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Lithological Description	Additional Information
Diamond Drill			80	0.29	0.17		8	Dyke- grey to dark grey, aphanitic	Dyke, some pyrite crystallisation, weathered at base
	169	21							
			90				7*	Hematized Rhyolitic Tuff- dark red to pink. porphrytic	
	168	22							
			90	11.82	9.71		4*		
	167	23							
			95				11	Hematized Rhyolitic Tuff- grey to dark red, porphrytic	
	166	24							
			95	9.44	9.72	209	4*	Hematized Rhyolitic Tuff- dark red to pink, porphrytic	
	165	25							

Other information:
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Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95				10			Hematized Rhyolitic Tuff- grey to pink, porphyrytic	Calcite veining
										Hematized Rhyolitic Tuff- dark red to pink, porphyrytic	
	164	26									
										Dyke- grey to dark grey, aphanitic	Dyke, some pyrite crystallisation, weathered at base
			90				>5				
	163	27									
				6.05	4.15						
			90				6				
	162	28								Hematized Rhyolitic Tuff- dark red to pink, porphyrytic	Weathered at base
			75	11.85	7.32		3				
	161	29									
			90				7				
	160	30									

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*: Sub Vertical Joint
>1: Rubble zone with multiple joints

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Diamond Drill			90	7.06	6.37		5			Dyke- grey to dark grey, aphanitic	Weathered at top contact, Hematized Rhyolitic Tuff inclusions at base of sequence
	159	31	95				10				
	158	32								Hematized Rhyolitic Tuff- dark red to pink, porphrytic	Weathered at base
			75	3.33	1.94		>5			Dyke- grey to dark grey, aphanitic	Some pyrite crystallisation, weathered at top contact
	157	33	100				2				
	156	34	100				4				
	155	35									

Other information:
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>1: Rubble zone with multiple joints

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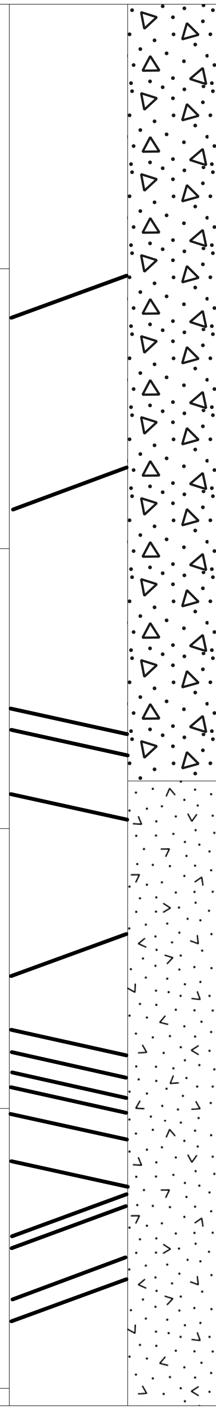
Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			100	11.82	4.14		0			Hematized Rhyolitic Tuff- dark red to grey, porphyritic	Machine fractures at 35-36m
	154	36	100				2				
	153	37	100	9.26	7.85		3				
	152	38	95				5				
	151	39	90	11.79	6.95		6				
	150	40									



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vgt Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95				2*			Rhyolitic Tuff- dark grey to grey, porphrytic	Hematized Rhyolitic Tuff inclusions?, weathered 39.1-39.26
	149	41									
			97	11.79	9.14		4*				
	148	42									
			100				2				
	147	43		1.06	1.42					Rhyolitic Tuff- orange to brown, weathered, porphrytic	
			97				11			Rhyolitic Tuff- dark grey to grey, porphrytic	Calcite veining
	146	44									
			90				9			Rhyolitic Tuff- orange to brown, porphrytic	Calcite veining
	145	45		5.12	4.97	201					

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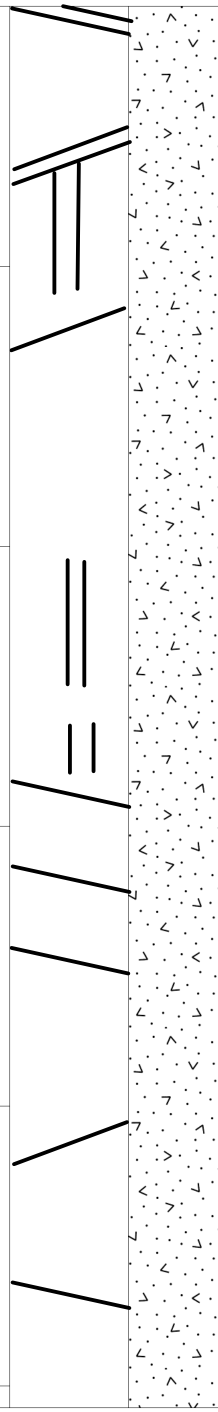
Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95				5*				
	144	46									
			95				3*				
				3.3	2.02						
	143	47									
			95				3*				
	142	48									
			100				2				
	141	49		8.85	5.75	137					
			100				2				
	140	50									



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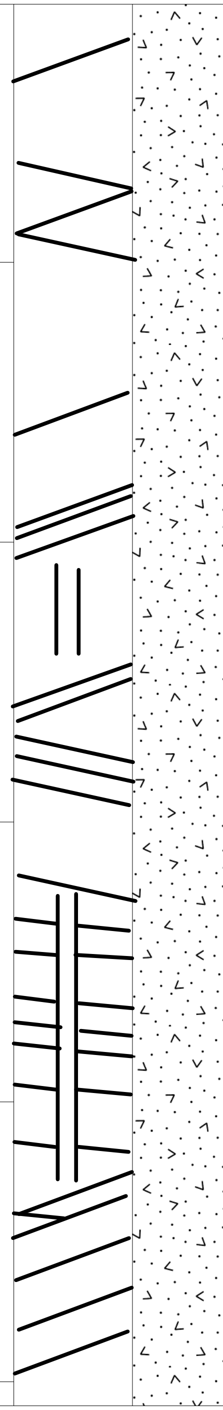
Diamond Drill			100				5			Rhyolitic Tuff- grey to blue, porphrytic,	Calcite veining, machine fractures at 46-47m
	139	51		7.67	5.29						
			100				4				
	138	52									
			95				8*				
	137	53		11.79	10.4 3						
			95				8*				
	136	54									
			95				8*				
	135	55									



Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	Checked By: SK	Version: 3430_HQ_GA_DDH2_V2

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill				5.57	5.81						
			95				1				
	134	56									
			90				>5				
	133	57		9.95	8.76						
			85				4*				
										Rhyolitic tuff- grey to blue, Porphrytic, significant calcite veining	Rubble zone present
	132	58									
			90				3*				
										Rhyolitic Tuff- grey to blue, porphrytic, heavily veined	
	131	59		6.9	3.98						
			85				>8				
	130	60									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	**Checked By: SK**	**Version: 3430_HQ_GA_DDH2_V2**

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			80				>7			Rhyolitic Tuff- grey to blue, porphrytic, calcite veining	Rubble zone present
	129	61									
				1.27	1.45					Rhyolitic Tuff- grey to blue, porphrytic, heavily veined	
			95				3				
	128	62									
			95				4				
	127	63		11.79	8.34						
			100				0				
	126	64									
			95				3				
	125	65									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	Checked By: SK	Version: 3430_HQ_GA_DDH2_V2

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill				5.09	4.45					Rhyolitic Tuff- grey to blue, porphyritic, some veins	Machine fractures at 63-64m
			95				3				
	124	66									
			95				1				
	123	67									
				9.1	9.25						
			100				0				
	122	68									
			100				1				
				10.55	4.09						
	121	69									
			90				3			Rhyolitic Tuff- grey to blue, porphyritic, heavily veined	
	120	70									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	Checked By: SK	Version: 3430_HQ_GA_DDH2_V2

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95				3*				
				5.41	1.67						
	119	71	90				2*				
	118	72	90				6*				
				9.69	1.07						
	117	73	95				2*				
	116	74	95				0				
	115	75									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95	8.5	3.98		2			Rhyolitic Tuff- grey to blue, porphrytic, some veins	Machine fractures 78-81.4m
	114	76	100				4				
	113	77	100	9.89	5.25		3*				
	112	78	95				1*				
	111	79	100	9.63	3.7		2*				
	110	80									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK | **Checked By: SK** | **Version: 3430_HQ_GA_DDH2_V2**

BOREHOLE LOG

Hillview

Name of Hole: DDH2

Project Number: 3430

Client: Tricon Mining Equipment

Project: Geological Assessment

Location: Off Maytoms Lane, Booral

Logged by: MA/SK

Date Logged: 03/01/2017

Date Commenced: 08/12/2016

Date Completed: 13/12/2016

Surface RL: 189.5 AHD

Coordinates: E:398674 N:6404805

Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			100				0				
				11.82	1.46						
	109	81	95				1*			Rhyolitic Tuff- grey to blue, porphrytic, heavily veined	
	108	82	95	7.51	2.52		7*				
	107	83	95				4*				
	106	84	95	7.49	5.94		3*				
	105	85									

Other information:

Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.

*: Sub Vertical Joint

>1: Rubble zone with multiple joints

Prepared By: MA/SK

Checked By: SK

Version: 3430_HQ_GA_DDH2_V2

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			100				0			Rhyolitic Tuff- grey to blue, porphrytic, some veins	
	104	86	100				0				
				9.2	3.9						
	103	87	85				>4*				
	102	88	95				3*				
	101	89		10.29	8.13						
			100				1				
	100	90									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	Checked By: SK	Version: 3430_HQ_GA_DDH2_V2

BOREHOLE LOG

Hillview

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			95	9.78	9.16		1				
	99	91	100				2				
	98	92	90				4*				
				1.82	0.36					Rhyolitic Tuff- grey to blue, porphrytic, heavily veined	
	97	93	100				2				
	96	94	100	9.95	5.29		1				
	95	95									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK **Checked By: SK** **Version: 3430_HQ_GA_DDH2_V2**

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			100				2			Rhyolitic Tuff- grey to blue, porphyritic, some veins	
	94	96	100				1				
	93	97	100	10.69	10.6 5		4				
	92	98	100				0				
	91	99	100	11.85	7.2	228	2				
	90	100									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK	**Checked By: SK**	**Version: 3430_HQ_GA_DDH2_V2**

BOREHOLE LOG

Name of Hole: DDH2

Project Number: 3430
Client: Tricon Mining Equipment
Project: Geological Assessment
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Logged: 03/01/2017
Date Commenced: 08/12/2016
Date Completed: 13/12/2016
Surface RL: 189.5 AHD
Coordinates: E:398674 N:6404805
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drilling Method	Elevation (RL)	Depth (m)	Core Recovery (%)	Diametral Strength (Mpa)	Axial Strength (Mpa)	UCS Strength (Mpa)	Fracture Frequency /m	Fracture Log	Graphic Log	Lithological Description	Additional Information
Diamond Drill			85				0				
	89	101								Hole Terminated at Target Depth	
	88	102									
	87	103									
	86	104									
	85	105									

Other information:
Data included within this log have been sourced from field observations and geotechnical data collected and provided by Qualtest Laboratories.
*: Sub Vertical Joint
>1: Rubble zone with multiple joints

Prepared By: MA/SK | **Checked By: SK** | **Version: 3430_HQ_GA_DDH2_V2**

BOREHOLE LOG

Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

vgt Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
	194	0					
	193	1				Weathered Hematized Rhyolitic Tuff - Dark Red/Red, porphyritic.	
	192	2					
	191	3					
	190	4				Weathered Hematized Rhyolitic Tuff- Dark Red/Red, porphyritic	Carbonate clay
	189	5					
	188	6					
	187	7					
	186	8				Weathered Hematized Rhyolitic Tuff- Dark Red/red, porphrytic	
	185	9					
Hammer	184	10					
	183	11					
	182	12					
	181	13					
	180	14					
	179	15					
	178	16					
	177	17					
	176	18				Hematized Rhyolitic Tuff- dark purple/grey,	Some weathering
	175	19					
	174	20					

Other Information: No Piezometer installed

Logged By: MA/SK	**Checked By: SK**	**3430_TH_GA_LOG_PH3_V2**

BOREHOLE LOG

Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
Hammer	173	21					
	172	22					
	171	23					
	170	24					
	169	25					
	168	26				Rhyolitic Tuff, dark purple/grey, porphyritic	
	167	27	<				
	166	28					
	165	29					
	164	30					
	163	31					
	162	32					
	161	33					
	160	34					
	159	35				Hematized Rhyolitic Tuff/ Dyke-light grey to dark grey, porphrytic to aphanitic	Calcite precipitation
	158	36				Dyke- dark grey to blue, aphanitic	Pyrite crystalisation, magnetic,calcite precipitation
	157	37					
	156	38				Weathered Rhyolitic Tuff- dark blue/grey, porphyritic	
	155	39					
	154	40					

Other Information: No Piezometer installed

Logged By: MA/SK	**Checked By: SK**	**3430_TH_GA_LOG_PH3_V2**

BOREHOLE LOG

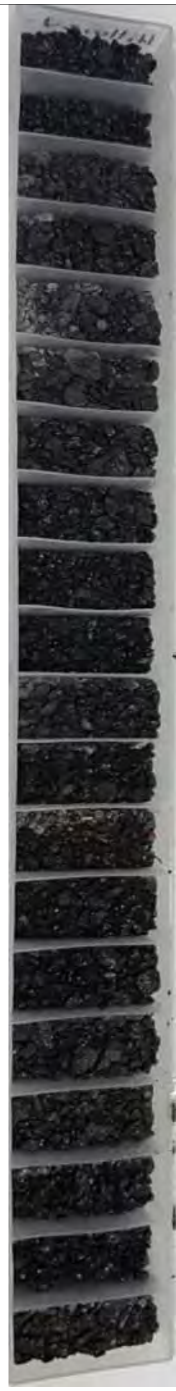
Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

Environmental Compliance Solutions



Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
	153	41					
	152	42					
	151	43					
	150	44					
	149	45					
	148	46				Rhyolitic Tuff, dark blue/grey, porphyritic	
	147	47					
	146	48					
	145	49					
Hammer	144	50					
	143	51					
	142	52					
	141	53				Weathered Rhyolitic Tuff- dark blue/grey, porphyritic	
	140	54					
	139	55					
	138	56					
	137	57					
	136	58					
	135	59					
	134	60					

Other Information: No Piezometer installed

Logged By: MA/SK	**Checked By: SK**	**3430_TH_GA_LOG_PH3_V2**

BOREHOLE LOG

Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
Hammer	133	61				Rhyolitic Tuff- Grey/blue to red, porphyritic.	
	132	62					
	131	63					
	130	64					
	129	65					
	128	66					
	127	67					
	126	68					
	125	69					
	124	70					
	123	71					
	122	72					
	121	73					
	120	74					
	119	75					
	118	76					
	117	77					
	116	78					
	115	79					
	114	80					

Other Information: No Piezometer installed

Logged By: MA/SK	**Checked By: SK**	**3430_TH_GA_LOG_PH3_V2**

BOREHOLE LOG

Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
Hammer	113	81					
	112	82					
	111	83					
	110	84					
	109	85					
	108	86					
	107	87				Rhyolitic Tuff- Grey/blue to red, porphyritic.	Some weathering, magnetic, calcite veining
	106	88				Rhyolitic Tuff, dark blue/grey, porphyritic	
	105	89					
	104	90					
	103	91					
	102	92					
	101	93					
	100	94					
	99	95				Rhyolitic Tuff Grey/blue to red, porphyritic.	Some weathering, magnetic, calcite veining
	98	96				Rhyolitic Tuff, dark blue/grey, porphyritic	
	97	97					
	96	98					
	95	99					
	94	100					

Other Information: No Piezometer installed

Logged By: MA/SK	Checked By: SK	3430_TH_GA_LOG_PH3_V2

BOREHOLE LOG

Name of Hole: PH 3

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced:27/09/2016
Date Completed: 29/09/2016
Surface RL: 194m AHD
Coordinates: E: 398601 N:6404686
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Water Level	Photo Log	Graphic Log	Description	Additional Information
Hammer	93	101				Rhyolitic Tuff, dark blue/grey, porphyritic	Possible sample contamination, weathered chip draw down
	92	102					
	91	103					
	90	104					
	89	105					
	88	106					
	87	107					
	86	108					
	85	109					
	84	110					
	83	111					
	82	112					
	81	113					
	80	114				Hole terminated due to difficult drilling conditions	
	79	115					
	78	116					
	77	117					
	76	118					
	75	119					
	74	120					

Other Information: No Piezometer installed

Logged By: MA/SK	**Checked By: SK**	**3430_TH_GA_LOG_PH3_V2**

BOREHOLE LOG

Name of Hole: PH 4

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	190	0				Weathered Hematized Rhyolitic Tuff- Cream to red in colour, porphrytic.	Clayey
	189	1					
	188	2				Hematized Rhyolitic Tuff/Dyke- red to grey/black aphanitic to porphrytic	
	187	3				Hematized Rhyolitic Tuff- Red to purple, porphrytic	
	186	4					
	185	5					
	184	6					
	183	7					
	182	8				Hematized Rhyolitic Tuff/Dyke- red to grey/black aphanitic to porphrytic	Dykes, magnetic
	181	9					
	180	10					
	179	11				Hematized Rhyolitic Tuff- red/purple, porphrytic	
	178	12					
	177	13					
	176	14					
	175	15					
	174	16					
	173	17					
	172	18				Fines- brown to cream in colour, isolated fragments of Rhyolitic Tuff	Magnetic, possible fault/shear zone?
	171	19					
	170	20					

Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Name of Hole: PH 4

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	169	21				Hematized Rhyolitic Tuff- red/purple, porphrytic	Minute traces of calcite
	168	22					
	167	23					
	166	24					
	165	25					
	164	26				Hematized Rhyolitic Tuff/Dyke- red to grey/black aphanitic to porphrytic	Dyke, magnetic
	163	27	<				
	162	28				Hematized Rhyolitic Tuff- red to purple porphrytic	
	161	29					
	160	30				Hematized Rhyolitic Tuff/Dyke- red to grey/black aphanitic to porphrytic	
	159	31				Dyke- black to dark grey, fine crystal size, aphanitic texture.	Pyrite crystallisation
	158	32				Hematized Rhyolitic Tuff/Dyke- red to grey/black aphanitic to porphrytic	Calcite precipitation at 35-36m, magnetic
	157	33					
	156	34					
	155	35					
	154	36					
	153	37				Hematized Rhyolitic Tuff - red in Colour, porphrytic	Calcite precipitation, magnetic
	152	38					
	151	39				Rhyolitic Tuff- grey/blue to brown,	
	150	40					

Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	Checked By: SK	Version: 3430_TH_LOG_PH4_V2

BOREHOLE LOG

Name of Hole: PH 4

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Description	Additional Information
Hammer			Altered, porphrytic,	
	149	41	Rhyolitic Tuff- grey to blue in colour, porphrytic	Magnetic
	148	42	Rhyolitic Tuff- grey to blue in colour, porphrytic	Magnetic, calcite precipitation
	147	43	Rhyolitic Tuff- grey blue to red, slightly weathered, porphrytic	Magnetic, calcite precipitation, some quartz veining
	146	44		
	145	45		
	144	46	Rhyolitic Tuff- grey to blue in colour, porphrytic	Calcite precipitation, magnetic, some quartz veining
	143	47		
	142	48		
	141	49		
	140	50		
	139	51		
	138	52		
	137	53		
	136	54		
	135	55		
	134	56		
	133	57		
	132	58		
	131	59		
	130	60		

Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Name of Hole: PH 4

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	129	61				Rhyolitic Tuff- grey blue to red, slightly weathered, porphrytic	Quartz Veining, magnetic, calcite precipitation
	128	62					
	127	63					
	126	64					
	125	65					
	124	66					
	123	67					
	122	68					
	121	69					
	120	70					
	119	71					
	118	72					
	117	73				Rhyolitic Tuff- grey to blue in colour, porphrytic	Possible fault
	116	74					
	115	75					
	114	76					
	113	77					
	112	78					
	111	79					
	110	80					

Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Name of Hole: PH 4

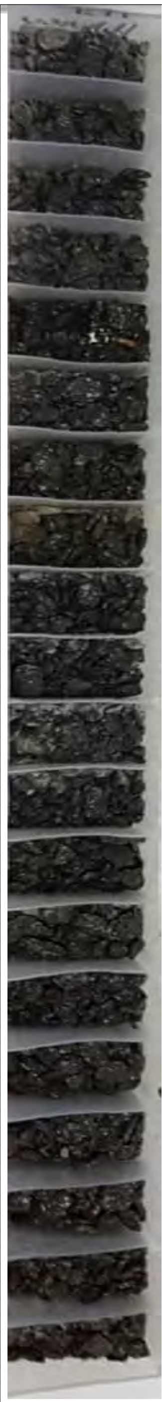
Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	109	81					
	108	82					
	107	83					
	106	84					
	105	85					
	104	86					
	103	87					
	102	88					
	101	89					
	100	90					
	99	91					
	98	92					
	97	93					
	96	94					
	95	95					
	94	96					
	93	97				Rhyolitic Tuff- grey to blue/ red, porphrytic	Slight weathering, quartz veined, calcite precipitation, magnetic
	92	98					
	91	99					
	90	100					



Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Name of Hole: PH 4

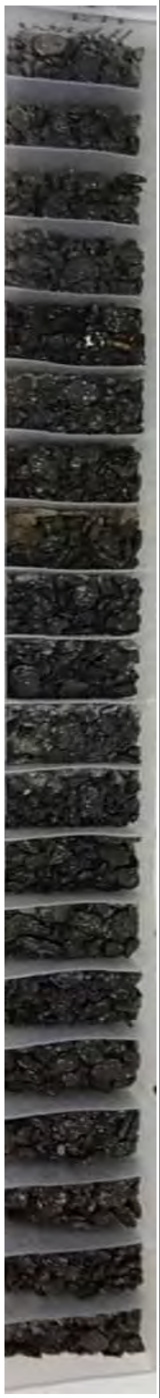
Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

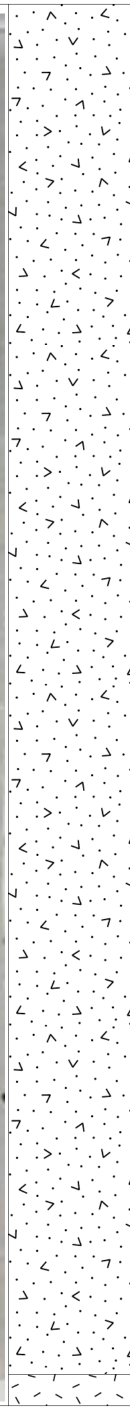
Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

vgt Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	89	101					
	88	102					
	87	103					
	86	104					
	85	105					
	84	106					
	83	107					
	82	108					
	81	109					
	80	110					
	79	111					
	78	112					
	77	113					
	76	114					
	75	115					
	74	116					
	73	117					
	72	118					
	71	119					
	70	120					





Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Name of Hole: PH 4

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 04/10/2016
Date Completed: 11/10/2016
Surface RL: 190 AHD
Coordinates: 398673 6404805
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	69	121				Dyke- black to dark grey, aphanitic	Calcite veining, magnetic
	68	122					
	67	123				Rhyolitic Tuff- grey to blue slightly red, porphrytic	Slight Weathering, quartz veined, magnetic
	66	124					
	65	125					
	64	126					
	63	127					
	62	128					
	61	129					
	60	130					
	59	131					
	58	132					
	57	133					
	56	134					
	55	135					
	54	136					
	53	137					
	52	138					
	51	139					
	50	140					

Other Information: Hole Drilled to 140m, Piezo Installed to RL 123m due to blockage.

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_LOG_PH4_V2**

BOREHOLE LOG

Hillview

Name of Hole: PH 5

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Date Commenced: 12/10/2016
Date Completed: 27/10/2016
Surface RL:180 m AHD
Coordinates: E: 398470 N: 6404669
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	180 – 177	0 – 3				Weathered Hematized Rhyolitic Tuff- orange to red, porphrytic,	Clayey
Hammer	177 – 164	3 – 16				Hematized Rhyolitic Tuff-Red to orange, porphrytic	Magnetic, some weathering
Hammer	164 – 160	16 – 20				Hematized Rhyolitic Tuff- orange, red to blue, dark grey, porphrytic	Magnetic, some weathering

Elevation (RL): 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167, 166, 165, 164, 163, 162, 161, 160

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Other Information: N/A

Logged By: MA

Checked By:SK

Version: 3430_TH_GA_LOG_PH5_V2

BOREHOLE LOG

Name of Hole: PH 5

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 12/10/2016
Date Completed: 27/10/2016
Surface RL:180 m AHD
Coordinates: E: 398470 N: 6404669
Drilling Contractor: Total Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	159	21					
	158	22					
	157	23					
	156	24					
	155	25					
	154	26					
	153	27					
	152	28				Hematized Rhyolitic Tuff- orange red to purple, porphrytic	Magnetic, some weathering
	151	29					
	150	30					
	149	31	<				
	148	32					
	147	33					
	146	34					
	145	35					
	144	36					
	143	37					
	142	38					
	141	39					
	140	40					

Other Information: N/A

Logged By: MA | **Checked By:SK** | **Version: 3430_TH_GA_LOG_PH5_V2**

BOREHOLE LOG

Name of Hole: PH 5

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 12/10/2016
Date Completed: 27/10/2016
Surface RL:180 m AHD
Coordinates: E: 398470 N: 6404669
Drilling Contractor: Total Drilling

vgt Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	139	41					
	138	42					
	137	43					
	136	44					
	135	45					
	134	46					
	133	47					
	132	48					
	131	49					
	130	50					
	129	51					
	128	52					
	127	53					
	126	54					
	125	55					
	124	56					
	123	57					
	122	58				Rhyolitic Tuff-grey/blue to orange, porphrytic	Magnetic, some weathering, possible hole contamination
	121	59					
	120	60					

Other Information: N/A

Logged By: MA

Checked By:SK

Version: 3430_TH_GA_LOG_PH5_V2

BOREHOLE LOG

Name of Hole: PH 5

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 12/10/2016
Date Completed: 27/10/2016
Surface RL:180 m AHD
Coordinates: E: 398470 N: 6404669
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	119	61					
	118	62					
	117	63					
	116	64					
	115	65					
	114	66					
	113	67					
	112	68					
	111	69					
	110	70					
	109	71					
	108	72					
	107	73					
	106	74					
	105	75					
	104	76					
	103	77					
	102	78					
	101	79					
	100	80					

Other Information: N/A

Logged By: MA

Checked By:SK

Version: 3430_TH_GA_LOG_PH5_V2

BOREHOLE LOG

Name of Hole: PH 5

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 12/10/2016
Date Completed: 27/10/2016
Surface RL:180 m AHD
Coordinates: E: 398470 N: 6404669
Drilling Contractor: Total Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	99	81				Hematized Rhyolitic Tuff/Dyke - Red to dark grey/dark blue, porphrytic to anphinitic	Possible fault/shear zone, some weathering
	98	82					
	97	83					
	96	84					
	95	85					
	94	86					
	93	87					
	92	88					
	91	89					
	90	90					

Other Information: N/A

Logged By: MA	**Checked By:SK**	**Version: 3430_TH_GA_LOG_PH5_V2**

BOREHOLE LOG

Name of Hole: PH7

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 07/12/2016
Date Completed: 07/12/2016
Surface RL: 190m AHD
Coordinates: E:398674 N:6404804
Drilling Contractor: D and E Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Auger	190	0				Weathered Rhyodacite- pink to brown, Porphyritic	20cm topsoil
Hammer	189	1					
	188	2					
	187	3					
	186	4				Hematized Rhyolitic Tuff- Pink to orange, porphyritic	Some weathering
	185	5					
	184	6					
	183	7					
	182	8				Hematized Rhyolitic Tuff, pink, purple to orange, porphrytic	Slight weathering,
	181	9					
	180	10					
	179	11				Hematized Rhyolitic Tuff/ Dyke- pink, purple to dark grey/blue, porphrytic to aphanitic	Multiple small dykes?,magnetic
	178	12					
	177	13					
	176	14					
	175	15				Hematized Rhyolitic Tuff- pink, purple to orange, porphrytic	Slight weathering
	174	16					
	173	17				Hematized Rhyolitic Tuff/ Dyke- pink, purple to dark grey/blue, porphrytic to aphanitic	Hematite nodule?, dykes, magnetic
	172	18				Hematized Rhyolitic Tuff- pink to purple, porphrytic	
	171	19					
	170	20				Hematized Rhyolitic Tuff/ Dyke- pink, purple	

Other Information: N/A

Logged By: MA | **Checked By: SK** | **Version: 3430_TH_GA_LOG_PH7_V2**

BOREHOLE LOG

Name of Hole: PH7

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 07/12/2016
Date Completed: 07/12/2016
Surface RL: 190m AHD
Coordinates: E:398674 N:6404804
Drilling Contractor: D and E Drilling

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log
Hammer	169	21			
	168	22			
	167	23			
	166	24			
	165	25			
	164	26			
	163	27			
	162	28			
	161	29			
	160	30			
	159	31			
	158	32			
	157	33			
	156	34			
	155	35			
	154	36			
	153	37			
	152	38			
	151	39			
	150	40			

Description	Additional Information
to dark grey/blue, porphyritic to aphanitic	Dyke
Weathered Hematized Rhyolitic Tuff- pink to brown, porphyritic	
Hematized Rhyolitic Tuff- pink to purple, porphyritic	
Hematized Rhyolitic Tuff- pink, purple to orange, porphyritic	Some weathering
Hematized Rhyolitic Tuff/ Dyke- pink, purple to dark grey/blue, porphyritic to aphanitic	Magnetic
Hematized Rhyolitic Tuff, pink, purple to orange, porphyritic	Some weathering
Hematized Rhyolitic Tuff/ Dyke- pink, purple to dark grey/blue, porphyritic to aphanitic	Dyke
Dyke- dark grey to dark blue, aphanitic	Magnetic
Hematized Rhyolitic Tuff/ Dyke- pink, purple to dark grey/blue, porphyritic to aphanitic	Dyke

Other Information: N/A

Logged By: MA	Checked By: SK	Version: 3430_TH_GA_LOG_PH7_V2

BOREHOLE LOG

Name of Hole: PH7

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 07/12/2016
Date Completed: 07/12/2016
Surface RL: 190m AHD
Coordinates: E:398674 N:6404804
Drilling Contractor: D and E Drilling

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Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	149	41				Rhyolitic tuff/Dyke- Dark grey to dark blue, porphrytic to aphanitic	Dyke
	148	42					
	147	43				Rhyolitic tuff - dark grey/blue to orange, Porphrytic	Quartz veining, some weathering, some water intercepted @ 44m
	146	44					
	145	45					
	144	46				Hole Terminated at Target Depth	
	143	47					
	142	48					

Other Information: N/A

Logged By: MA	Checked By: SK	Version: 3430_TH_GA_LOG_PH7_V2

BOREHOLE LOG

Name of Hole: PH 8

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 13/12/2016
Date Completed: 13/12/2016
Surface RL: 181m AHD
Coordinates: E:398464 N: 6404673.
Drilling Contractor: D and E Drilling

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Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	181	0					
	180	1					
	179	2				Weathered Hematized Rhyolitic Tuff- orange to brown, porphrytic	Dyke, Some weathering
	178	3					
	177	4					
	176	5				Hematized Rhyolitic Tuff- brown to orange, porphrytic	Some weathering
	175	6					
	174	7					
	173	8				Weathered Dyke/Hematized Rhyolitic Tuff- orange, brown to grey, porphrytic to aphanitic	Magnetic
	172	9					
	171	10					
	170	11					
	169	12					
	168	13					
	167	14				Hematized Rhyolitic Tuff- dark purple, grey to orange, porphrytic	Slight weathering
	166	15					
	165	16					
	164	17					
	163	18					
	162	19				Rhyolitic Tuff- dark grey to blue, porphrytic	
	161	20					

Other Information:N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH8_V2**

BOREHOLE LOG

Name of Hole: PH 8

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 13/12/2016
Date Completed: 13/12/2016
Surface RL: 181m AHD
Coordinates: E:398464 N: 6404673.
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Description	Additional Information
Hammer	160	21			
	159	22		Rhyolitic Tuff- dark blue, grey to orange, porphrytic	Some weathering
	158	23			
	157	24			
	156	25		Weathered Rhyolitic Tuff- brown to orange, porphrytic	
	155	26			
	154	27			
	153	28		Rhyolitic Tuff- dark blue, grey to orange, porphrytic	Some weathering
	152	29			
	151	30			
	150	31	<		
	149	32			
	148	33		Rhyolitic Tuff- dark grey to blue, porphrytic	Some weathering, calcite veining
	147	34			
	146	35			
	145	36			
	144	37			
	143	38			
	142	39			
	141	40			

Other Information:N/A

Logged By: MA | **Checked By: SK** | **Version: 3430_TH_GA_LOG_PH8_V2**

BOREHOLE LOG

Name of Hole: PH 8

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 13/12/2016
Date Completed: 13/12/2016
Surface RL: 181m AHD
Coordinates: E:398464 N: 6404673.
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	140	41				Rhyolitic Tuff- dark blue, grey to orange, Porphrytic	Some calcite veining
	139	42					
	138	43					
	137	44					
	136	45					
	135	46				Hole Terminated at Taget Depth	
	134	47					
	133	48					

Other Information:N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH8_V2**

BOREHOLE LOG

Name of Hole: PH 9

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 15/12/2016
Date Completed: 15/12/2016
Surface RL:158.2m AHD
Coordinates: E: 398795 N: 6404421
Drilling Contractor: D and E Drilling

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Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information

Drill Type: Auger; Hammer

Elevation (RL)	Depth (m)
158	0
157	1
156	2
155	3
154	4
153	5
152	6
151	7
150	8
149	9
148	10
147	11
146	12
145	13
144	14
143	15
142	16
141	17
140	18
139	19
	20

Description:

- Weathered Hematized Rhyolitic Tuff- pink to orange, porphyritic
- Fines- orange to dark orange, silty, some coarse quartz fragments
- Weathered Hematized Rhyolitic Tuff- orange to brown, porphyritic, some fines
- Fines- orange to dark orange, silty, some coarse quartz fragments and black aphanitic textured fragments
- Weathered Hematized Rhyolitic Tuff pink to orange, porphyritic
- Fines- orange to dark orange, silty, some coarse quartz fragments
- Weathered- pink to orange, porphyritic
- Fines- orange to dark orange, silty, aphanitic textured fragments
- Weathered Hematized Rhyolitic Tuff- orange to brown, porphyritic
- Weathered Hematized Rhyolitic Tuff- orange to brown, porphyritic

Other Information: N/A

Logged By: MA | **Checked By: SK** | **Version: 3430_TH_GA_LOG_PH9_V2**

BOREHOLE LOG

Name of Hole: PH 9

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hillview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 15/12/2016
Date Completed: 15/12/2016
Surface RL:158.2m AHD
Coordinates: E: 398795 N: 6404421
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	138						
	137	21					
	136	22					
	135	23				Hematized Rhyolitic Tuff- orange to dark purple, porphrytic	Some weathering
	134	24					
	133	25					
	132	26					
	131	27					
	130	28				Weathered Hematized Rhyolitic Tuff- orange, brown to dark blue, porphrytic to aphanitic	Calcite precipitation, Dyke
	129	29				Dyke-dark blue to black, aphanitic	Calcite precipitation, Pyrite crystallisation
	128	30					
	127	31					
	126	32				Hematized Rhyolitic Tuff- dark purple to pink, Porphyritic	Calcite precipitation
	125	33					
	124	34					
	123	35				Dyke-dark blue to black, aphanitic	Calcite precipitation, Pyrite crystallisation
	122	36				Hole Terminated at Target Depth	
	121	37					
		38					

Other Information: N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH9_V2**

BOREHOLE LOG

Name of Hole: PH 10

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 14/12/2016
Date Completed: 14/12/2016
Surface RL: 158m AHD
Coordinates: E: 398796 N:6404422
Drilling Contractor: D andE Drilling

Environmental Compliance Solutions

Drill Type: Hammer

Elevation (RL)	Depth (m)	Description	Additional Information
158–155	0–3	Weathered Hematized Rhyolitic Tuff- brown, red to light orange, porphyritic	
155–153	3–5	Weathered Hematized Rhyolitic Tuff- brown, red to light orange, porphyritic	
153–152	5–6	Weathered Hematized Rhyolitic Tuff/ Dyke- red, orange to dark grey, porphyritic to aphanitic	
152–150	6–8	Weathered Hematized Rhyolitic Tuff/ Dyke- red, orange to dark grey, porphyritic to aphanitic	Calcite precipitation
150–143	8–15	Weathered Hematized Rhyolitic Tuff- brown, red to light orange, porphyritic	Hardness increasing @12m
143–139	15–19	Weathered Hematized Rhyolitic Tuff- brown, red to light orange, porphyritic	
139–138	19–20		

Other Information: N/A

Logged By: MA	Checked By: SK	Version: 3430_TH_GA_LOG_PH10_V2

BOREHOLE LOG

Name of Hole: PH 10

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 14/12/2016
Date Completed: 14/12/2016
Surface RL: 158m AHD
Coordinates: E: 398796 N:6404422
Drilling Contractor: D andE Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	137 – 130	21 – 28				Hematized Rhyolitic Tuff- orange to dark red, porphrytic	Some weathering
	130 – 129	28 – 29				Weathered Hematized Rhyolitic Tuff/ Dyke-orange, red to grey, blue, porphrytic to aphanitic	Calcite precipitation
	129 – 128	29 – 30				Dyke- dark grey to blue, aphanitic	Pyrite crystalation, calcite precipitation
	128 – 123	30 – 35				Hematized Rhyolitic Tuff- dark red to light purple, porphrytic	Some weathering
	123 – 120	35 – 38				Weathered Hematized Rhyolitic Tuff/ Dyke-dark red, purple to dark grey, porphrytic to aphanitic	Calcite precipitation
	120 – 118	38 – 40					

Elevation (RL): 137, 136, 135, 134, 133, 132, 131, 130, 129, 128, 127, 126, 125, 124, 123, 122, 121, 120, 119, 118

Depth (m): 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

Other Information: N/A

Logged By: MA

Checked By: SK

Version: 3430_TH_GA_LOG_PH10_V2

BOREHOLE LOG

Name of Hole: PH 10

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 14/12/2016
Date Completed: 14/12/2016
Surface RL: 158m AHD
Coordinates: E: 398796 N:6404422
Drilling Contractor: D andE Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)
Hammer	117	41
	116	42
	115	43
	114	44
	113	45
	112	46
	111	47
	110	48
	109	49
	108	50
	107	51
	106	52
	105	53
	104	54
	103	55
	102	56
	101	57
	100	58
	99	59
	98	60

Piezometer Design

Photo Log

Graphic Log

Description	Additional Information
Hematized Rhyolitic Tuff- dark purple to dark grey, porphrytic	Calcite precipitation, some weathering
Rhyolitic Tuff- light grey to blue, porphrytic	Calcite precipitation
Dyke- dark grey to blue, aphanitic	Pyrite crystalisation, magnetic, calcite precipitation
Rhyolitic Tuff- light grey, porphrytic	
Dyke- dark grey to blue, aphanitic	Dyke, pyrite crystalisation, magnetic, calcite precipitation
Hematized Rhyolitic Tuff/ Dyke- light grey to dark grey, porphrytic to aphanitic	Magnetic, calcite precipitation
Rhyolitic Tuff- light grey, porphrytic	Water intersected
Rhyolitic Tuff/ Dyke- light grey to dark grey, porphrytic to aphanitic	Magnetic, calcite precipitation
Dyke- dark grey to blue, aphanitic	Dyke, pyrite crystallisation, magnetic, calcite precipitation, some

Other Information: N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH10_V2**

BOREHOLE LOG

Name of Hole: PH 10

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 14/12/2016
Date Completed: 14/12/2016
Surface RL: 158m AHD
Coordinates: E: 398796 N:6404422
Drilling Contractor: D andE Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Description	Additional Information
Hammer				weathering
	97	61	Rhyolitic Tuff/ Basalt- light grey to dark grey, porphrytic to aphanitic	Magnetic, calcite precipitation
	96	62		
	95	63	Rhyolitic Tuff- dark purple to grey, porphrytic	
	94	64		
	93	65		
	92	66		
	91	67		
	90	68		
	89	69		
	88	70		
	87	71		
	86	72		
	85	73	Rhyolitic Tuff/ Basalt- light grey to dark grey, Porphrytic to aphanitic	Magnetic, calcite precipitation
	84	74		
	83	75	Hole Terminated at Target Depth	
	82	76		

Other Information: N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH10_V2**

BOREHOLE LOG

Name of Hole: PH 11

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 19/12/2016 (Collected)
Date Completed: 19/12/2016
Surface RL: 113m AHD
Coordinates: E:399020 N:6404508
Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	113	0				Hematized Rhyolitic Tuff- orange to brown, porphrytic	
	112	1					
	111	2					
	110	3					
	109	4					
	108	5					
	107	6					
	106	7					
	105	8					
	104	9					
	103	10					
	102	11				Weathered Rhyolitic Tuff/ Dyke-orange, brown to dark grey, porphrytic to aphanitic	Calcite precipitation
	101	12					
	100	13					
	99	14					
	98	15					
	97	16				Weathered Rhyodacite- orange to	
	96	17					
	95	18					
	94	19					
	93	20					

Other Information: N/A

Logged By: MA | **Checked By: SK** | **Version: 3430_TH_GA_LOG_PH11_V2**

BOREHOLE LOG

Name of Hole: PH 11

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 19/12/2016 (Collected)
Date Completed: 19/12/2016
Surface RL: 113m AHD
Coordinates: E:399020 N:6404508
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
						brown, porphyritic	
	92	21					
	91	22					
	90	23					
	89	24				Hole Terminated	
	88	25					
	87	26					

Other Information: N/A

Logged By: MA | **Checked By: SK** | **Version: 3430_TH_GA_LOG_PH11_V2**

BOREHOLE LOG

Name of Hole: PH 12

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 19/12/2016 (collected)
Date Completed: 19/12/2016
Surface RL: 89m AHD
Coordinates: E: 399109 N: 6404840
Drilling Contractor: D and E Drilling

Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)	Piezometer Design	Photo Log	Graphic Log	Description	Additional Information
Hammer	89	0				Weathered Rhyolitic Tuff - brown to purple	
	88	1				Weathered Hematized Rhyolitic Tuff- brown, dark purple to orange, porphrytic	
	87	2					
	86	3					
	85	4				Hematized Rhyolitic Tuff-dark purple to orange, porphrytic	Some weathering
	84	5					
	83	6					
	82	7				Fines- brown, some isolated fragments of weathered Hematized Rhyolitic Tuff	Possible fault or shear zone?
	81	8				Hematized Rhyolitic Tuff-dark purple to orange, porphrytic	Some weathering, some calcite veining
	80	9					
	79	10					
	78	11					
	77	12					
	76	13					
	75	14					
	74	15					
	73	16					
	72	17					
	71	18					
	70	19					
	69	20					

Other Information: N/A

Logged By: MA

Checked By: SK

Version: 3430_TH_GA_LOG_PH12_V2

BOREHOLE LOG

Name of Hole: PH 13

Project Number: 3430
Client: Tricon Mining Equipment
Project: Hilview Geological Investigation
Location: Off Maytoms Lane, Booral
Logged by: MA/SK

Hillview

Date Commenced: 19/12/2016 (Collected)
Date Completed: 19/12/2016
Surface RL: 100m AHD
Coordinates: 398919 6405190
Drilling Contractor: D and E Drilling

vgt Environmental Compliance Solutions

Drill Type	Elevation (RL)	Depth (m)
Hammer	100	0
	99	1
	98	2
	97	3
	96	4
	95	5
	94	6
	93	7
	92	8
	91	9
	90	10
	89	11
	88	12
	87	13
	86	14
	85	15
	84	16
	83	17
	82	18
	81	19
	80	20

Piezometer Design

Photo Log

Graphic Log

Description	Additional Information
Weathered Hematized Rhyolitic Tuff- pink, orange to brown, porphrytic	Clay, possible joints?
Weathered Hematized Rhyolitic Tuff- pink, orange to brown, porphrytic	Some Clay, possible joints?
Hematized Rhyolitic Tuff/ Dyke- dark red, purple to grey, dark grey, porphrytic to aphanitic	Calcite precipitation
Hematized Rhyolitic Tuff- dark red, purple to orange, porphrytic	Some Weathering
Hematized Rhyolitic Tuff/ zdyke- dark red, purple to grey, dark grey, porphrytic to aphanitic	Calcite precipitation
Hematized Rhyolitic Tuff- dark red, purple to orange, porphrytic	Some Weathering
Dyke- dark grey, aphanitic, some calcite veining	Calcite precipitation, some pyrite mineralisation

Other Information: N/A

Logged By: MA	**Checked By: SK**	**Version: 3430_TH_GA_LOG_PH13_V2**

Appendix B Groundwater Hydrographs

Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024

Figure B1 Logger Hydrograph of PH2A (December 2022 to March 2023)

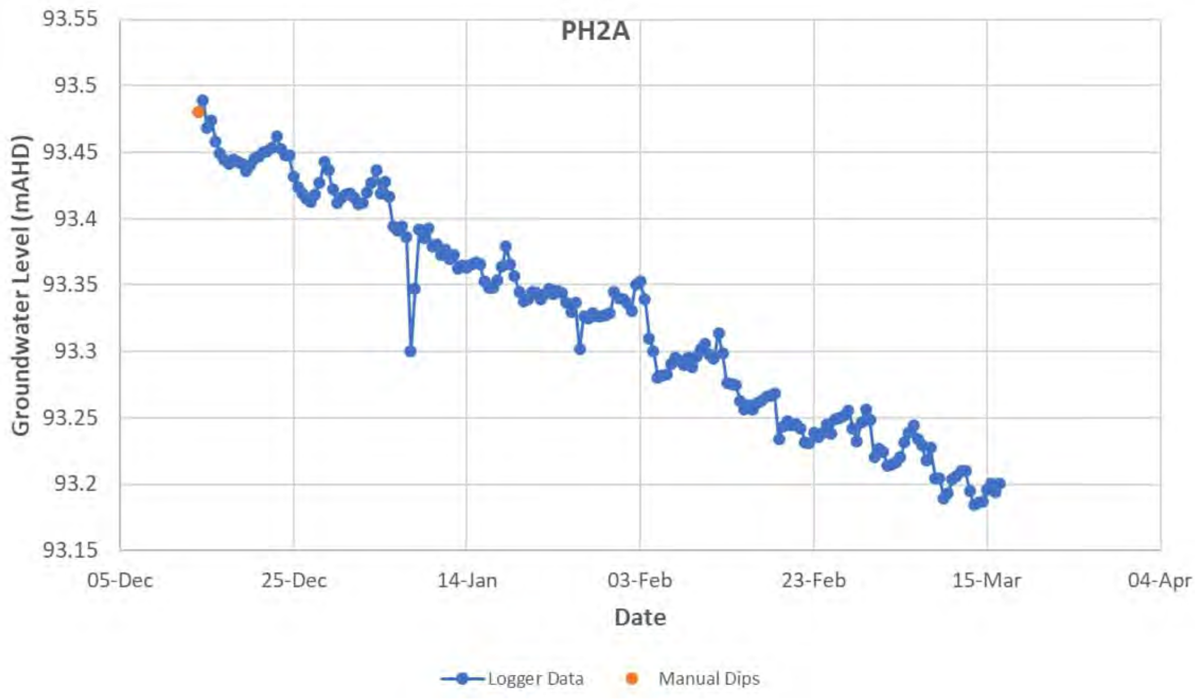


Figure B2 Logger Hydrograph of PH4 (December 2022 to March 2023)

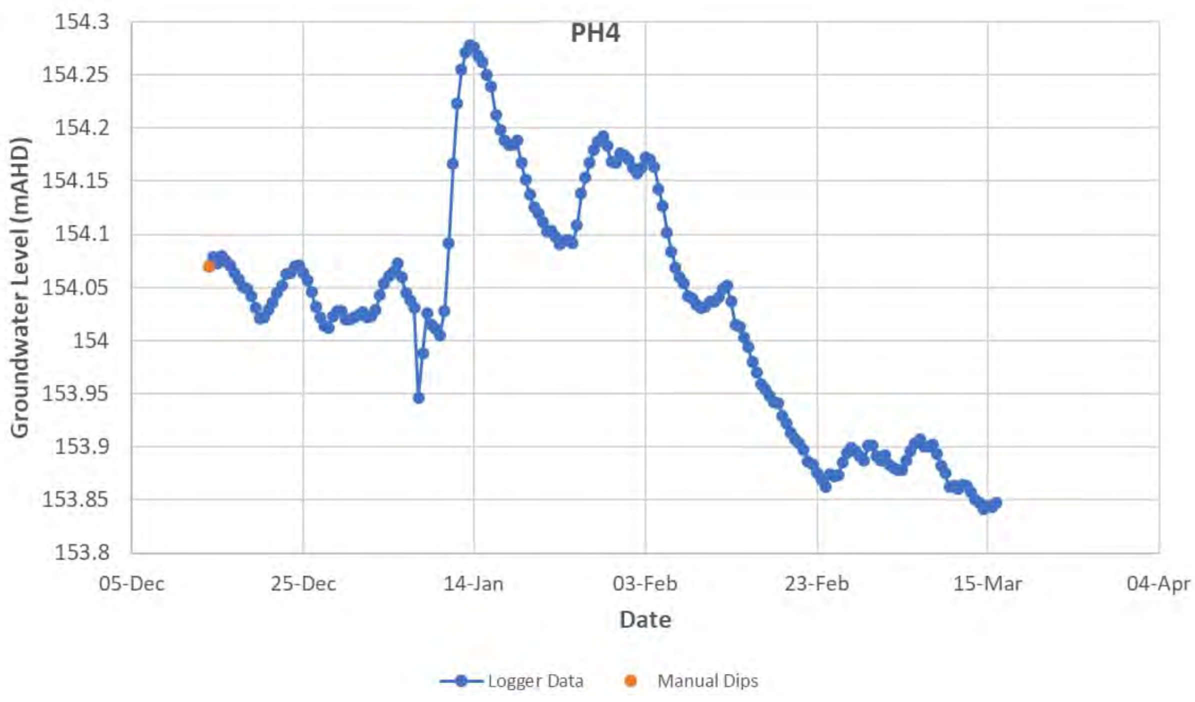
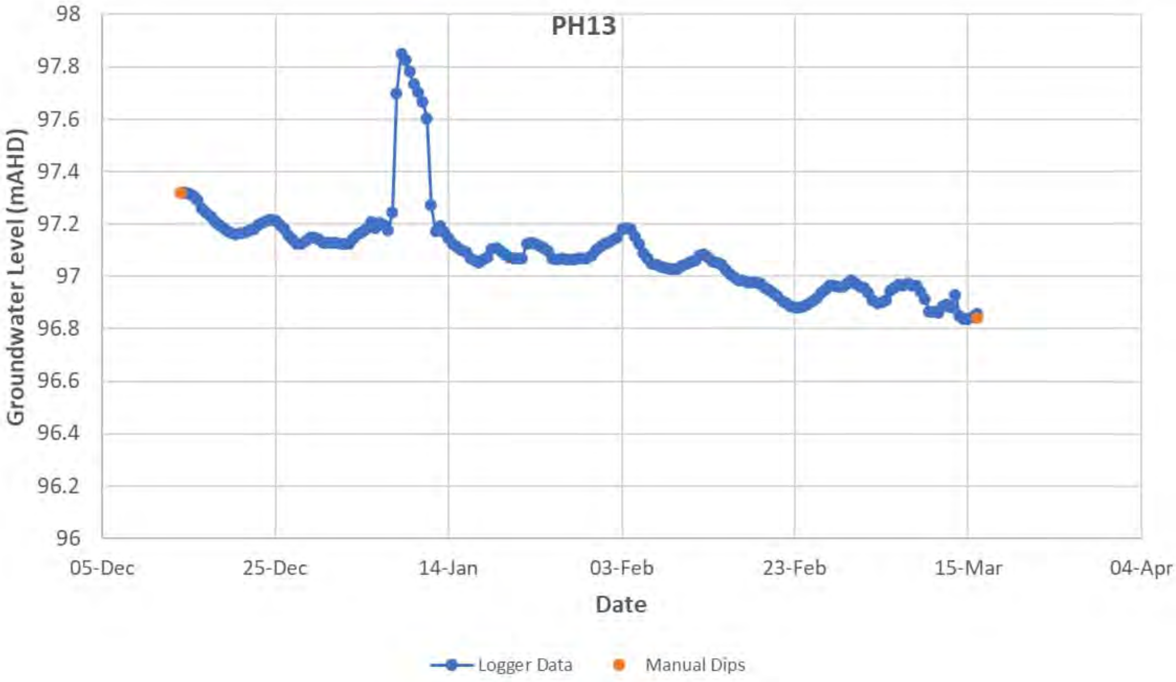
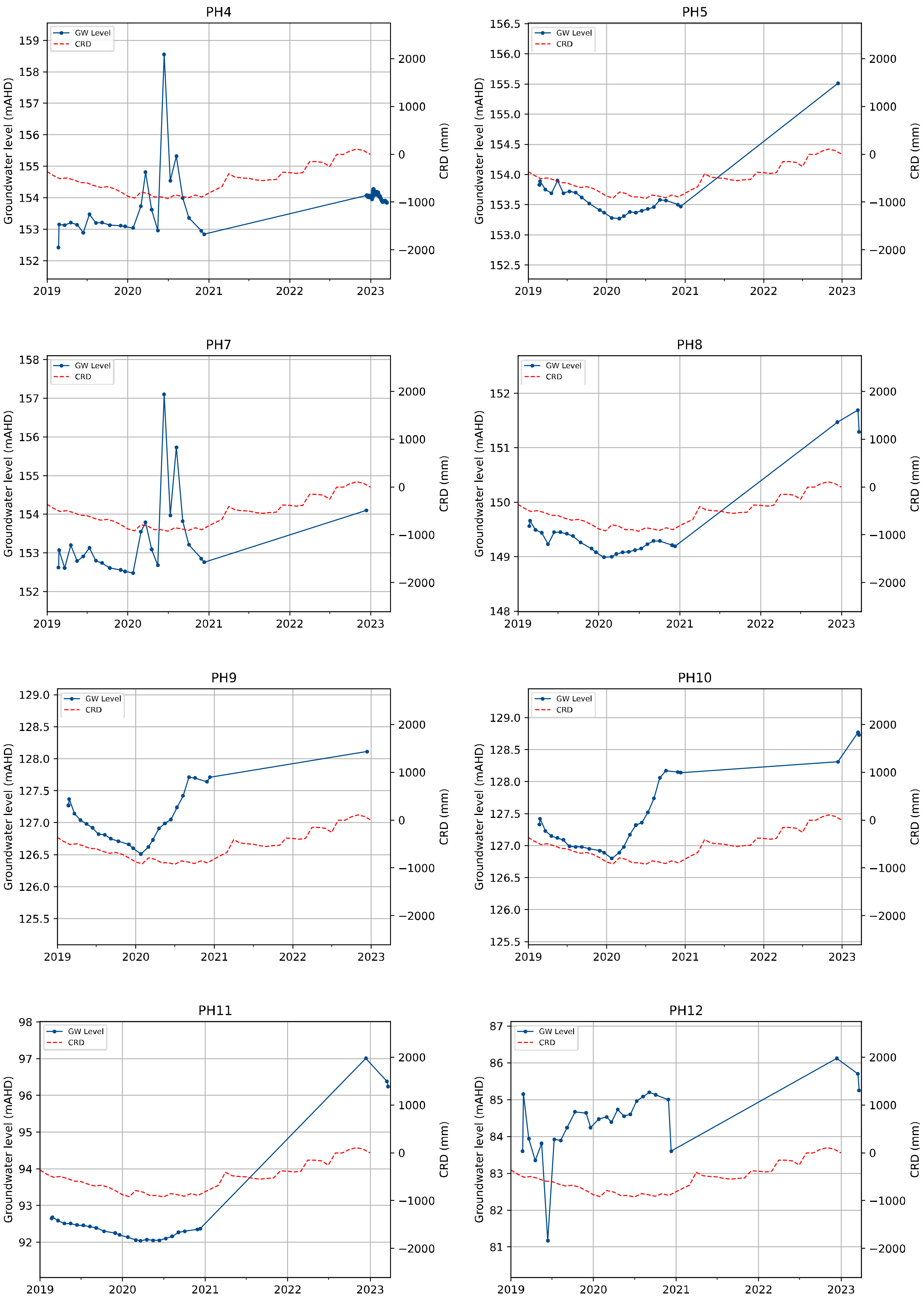
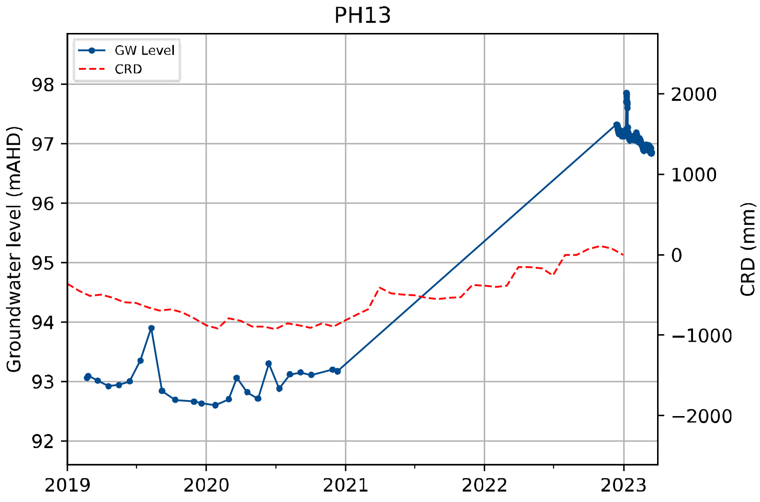


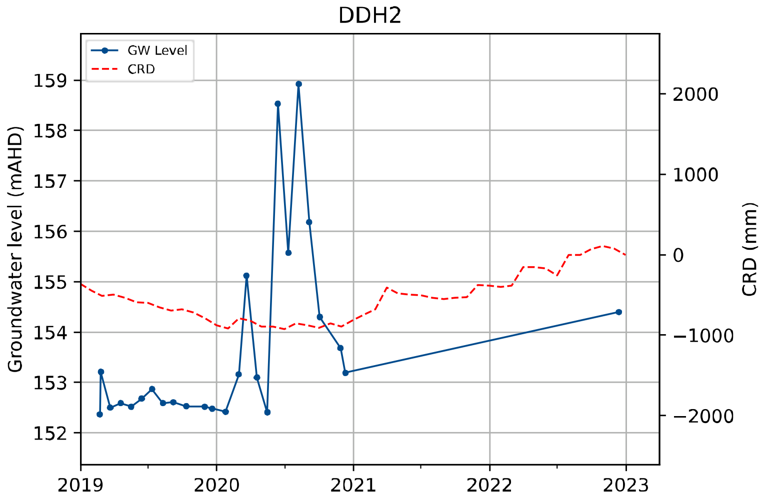
Figure B3 Logger Hydrograph of PH13 (December 2022 to March 2023)

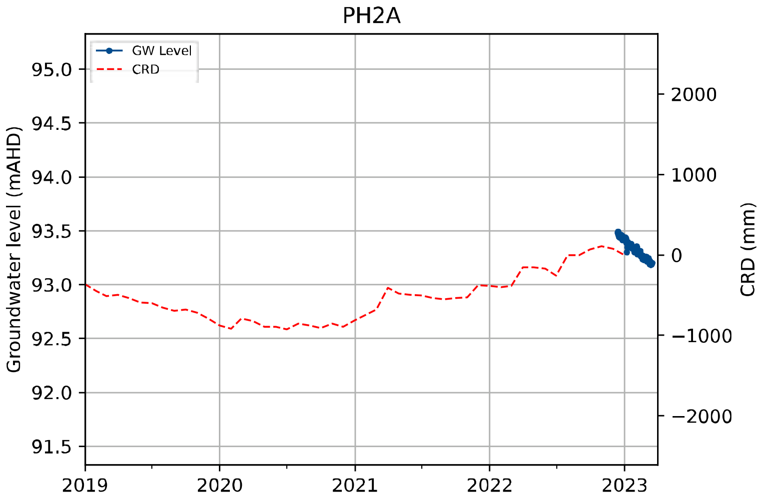


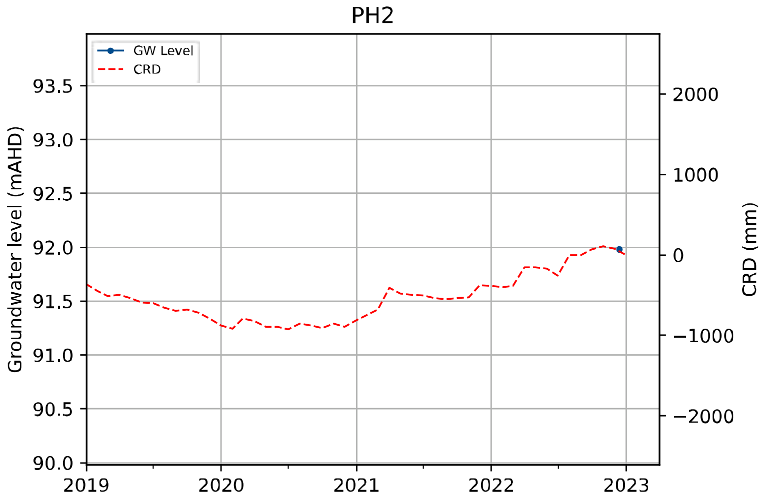


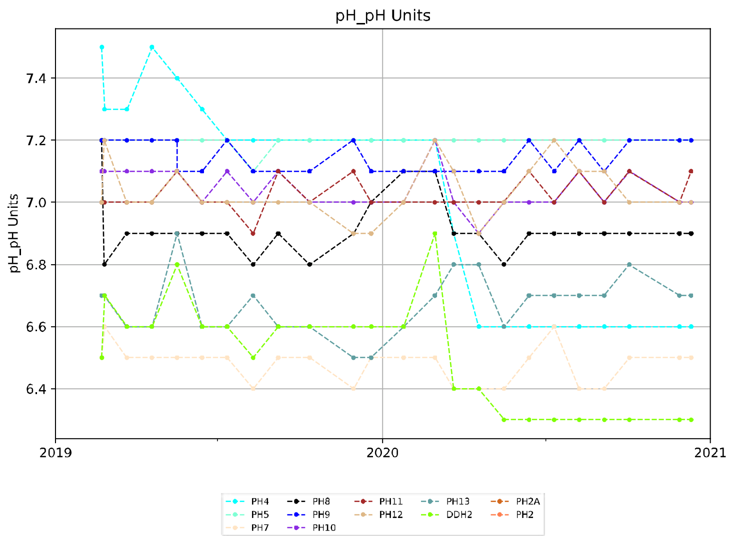
PH4
PH5
PH7
PH8
PH9
PH10
PH11
PH12
GW Level
CRD
Groundwater level (mAHD)
CRD (mm)
2019
2020
2021
2022
2023

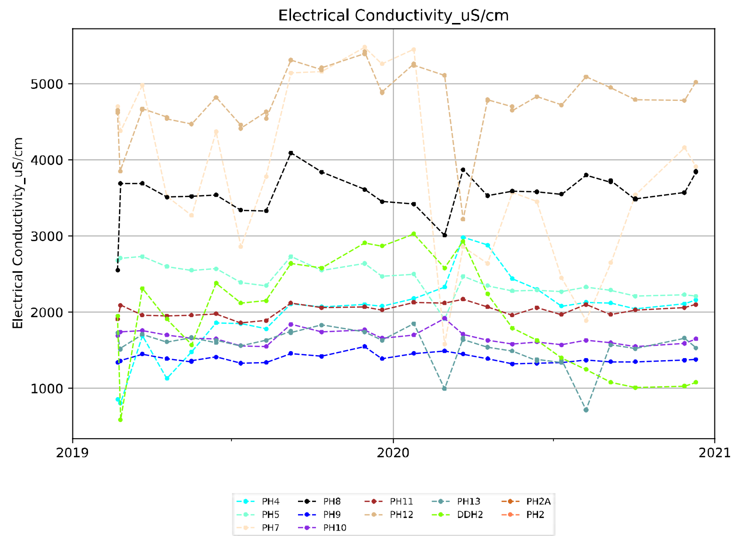

PH13
GW Level
CRD
Groundwater level (mAHD)
CRD (mm)

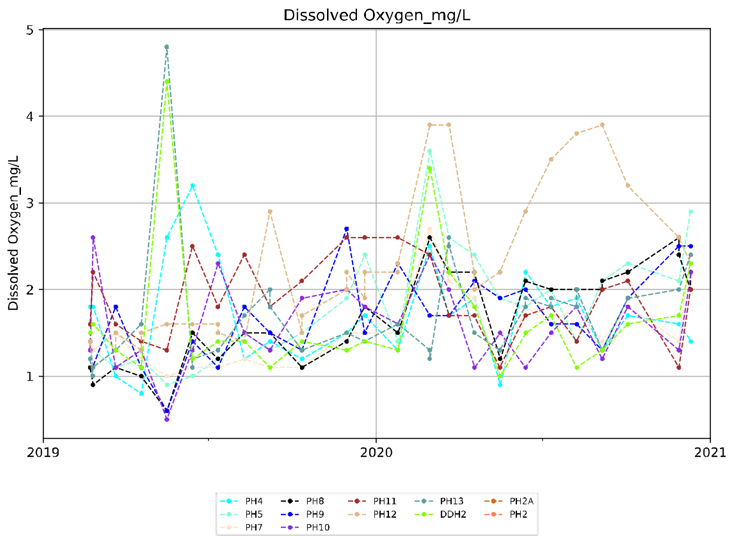

DDH2
GW Level
CRD
Groundwater level (mAHD)
CRD (mm)

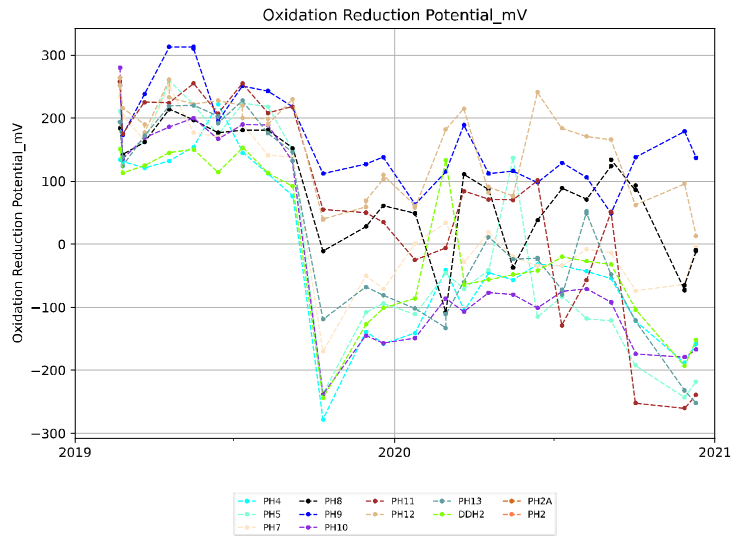

PH2A
GW Level
CRD
Groundwater level (mAHD)
CRD (mm)

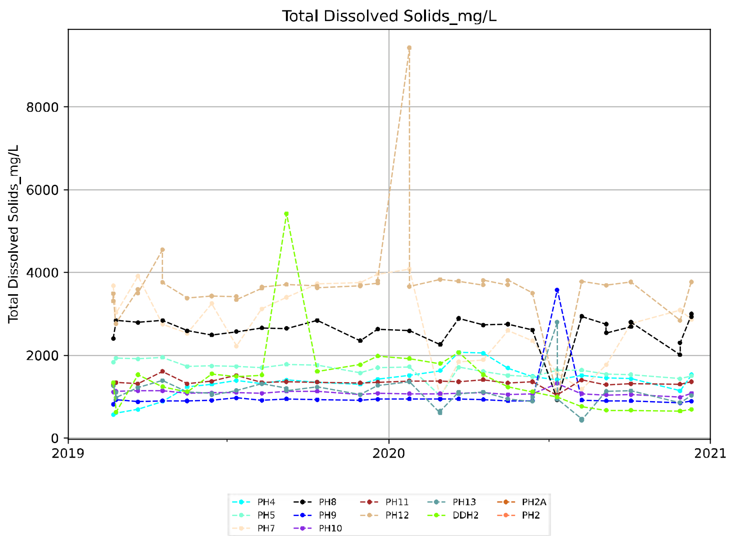

PH2
GW Level
CRD
Groundwater level (mAHD)
CRD (mm)

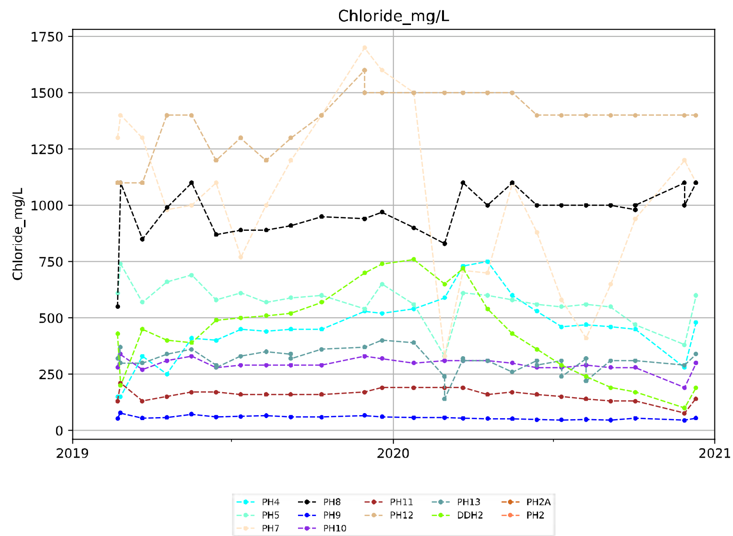

pH_pH Units
pH_pH Units
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

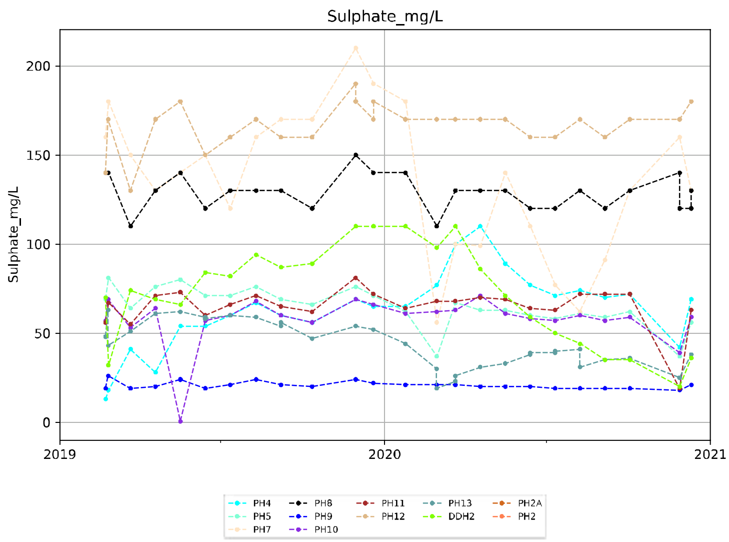

Electrical Conductivity_uS/cm
Electrical Conductivity_uS/cm
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

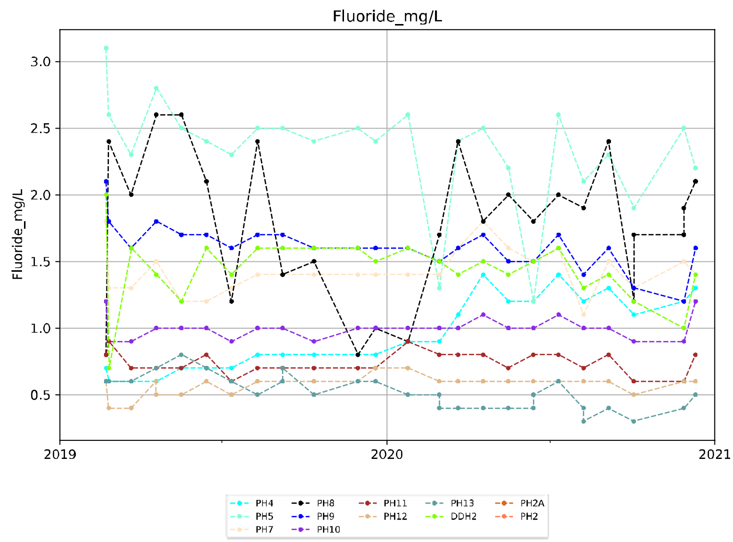

Dissolved Oxygen_mg/L
Dissolved Oxygen_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

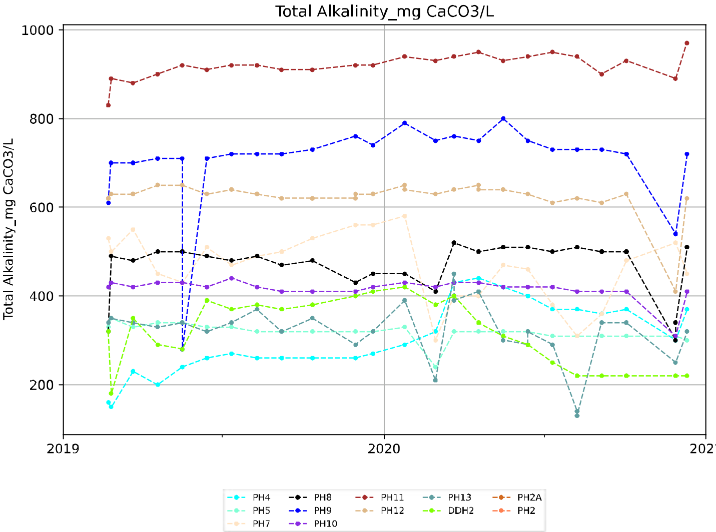

Oxidation Reduction Potential_mV
Oxidation Reduction Potential_mV
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

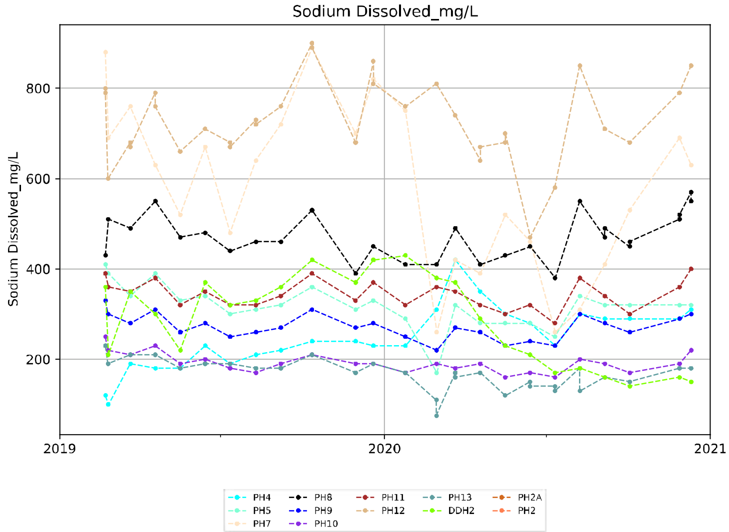

Total Dissolved Solids_mg/L
Total Dissolved Solids_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

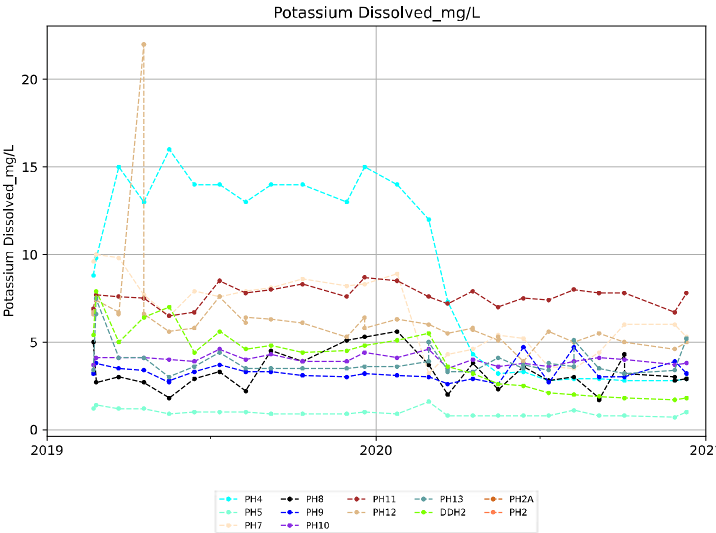

Chloride_mg/L
Chloride_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

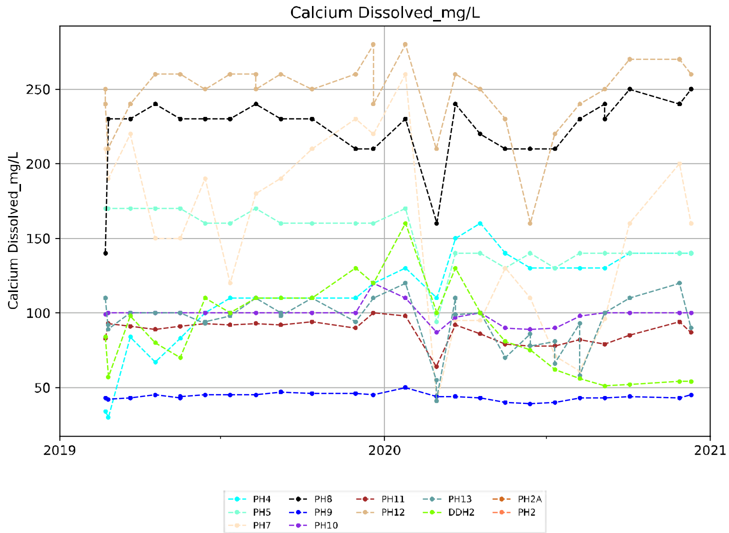

Sulphate_mg/L
Sulphate_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

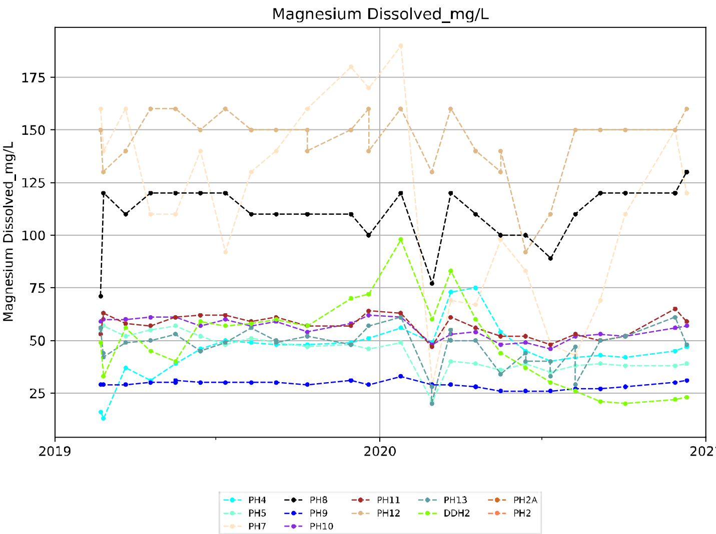

Fluoride_mg/L
Fluoride_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

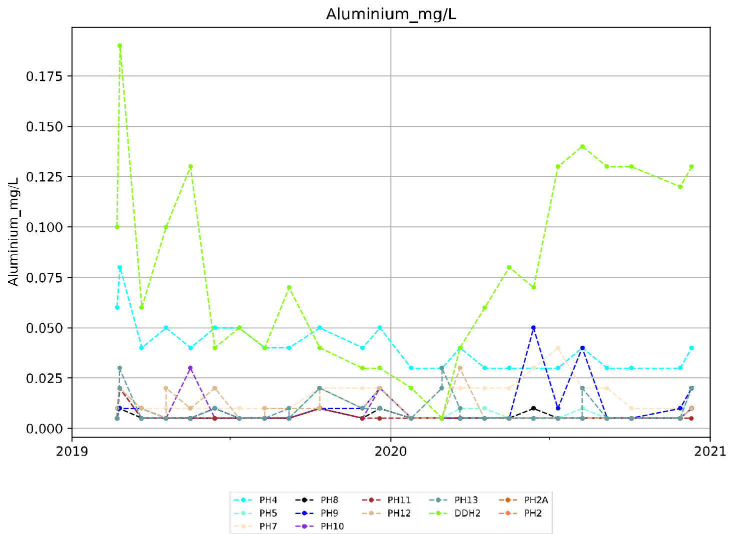

Total Alkalinity_mg CaCO3/L
Total Alkalinity_mg CaCO3/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

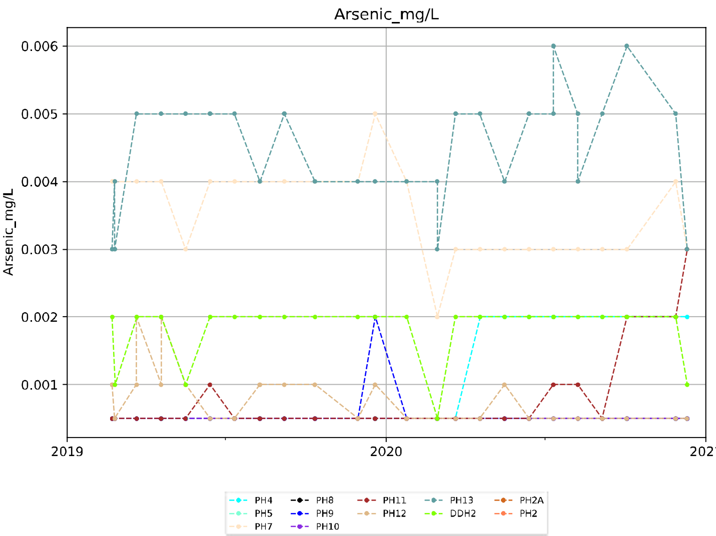

Sodium Dissolved_mg/L
Sodium Dissolved_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

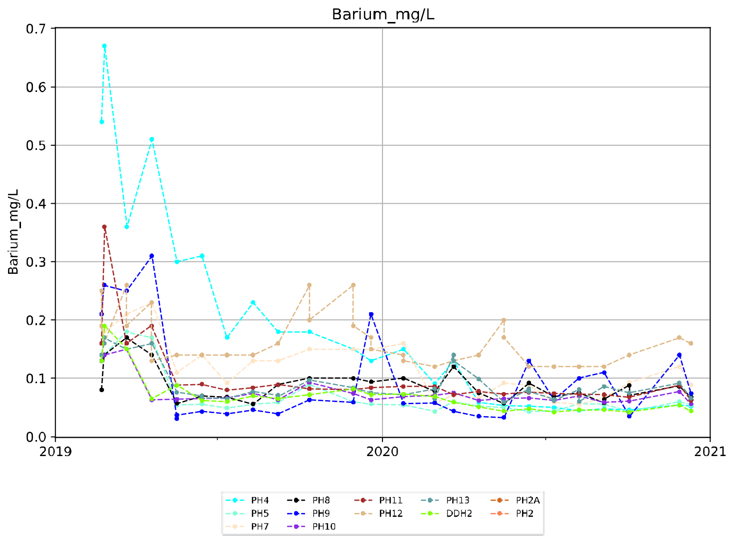

Potassium Dissolved_mg/L
Potassium Dissolved_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

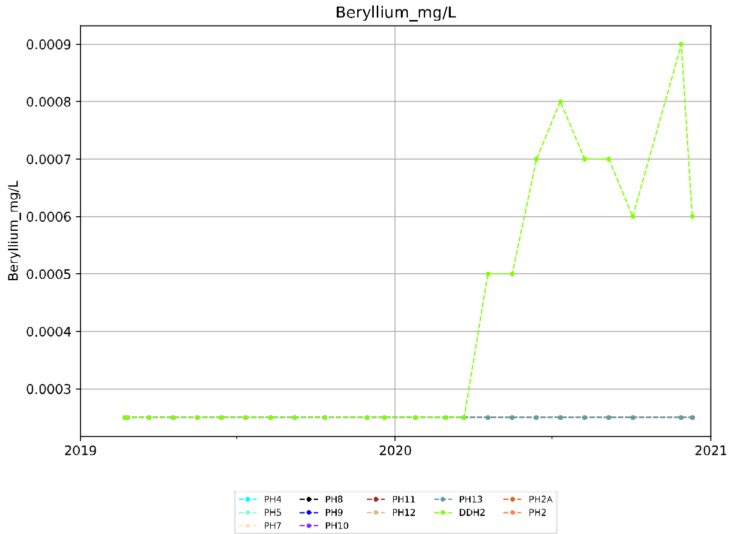

Calcium Dissolved_mg/L
Calcium Dissolved_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

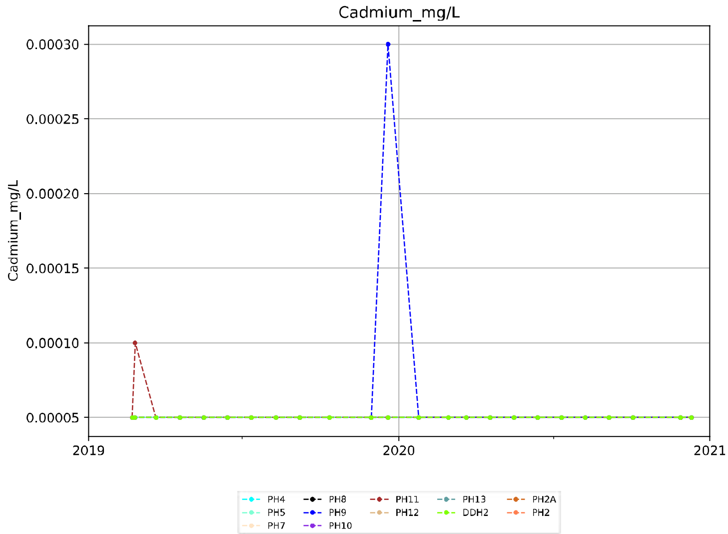

Magnesium Dissolved_mg/L
Magnesium Dissolved_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

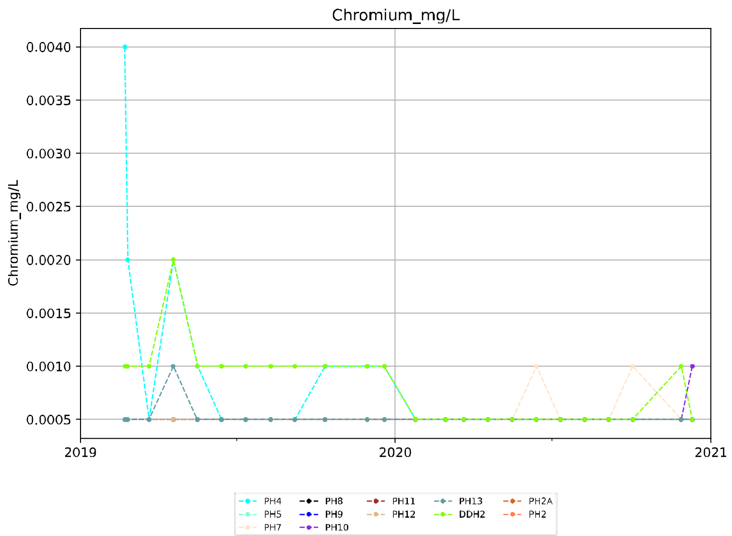

Aluminium_mg/L
Aluminium_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

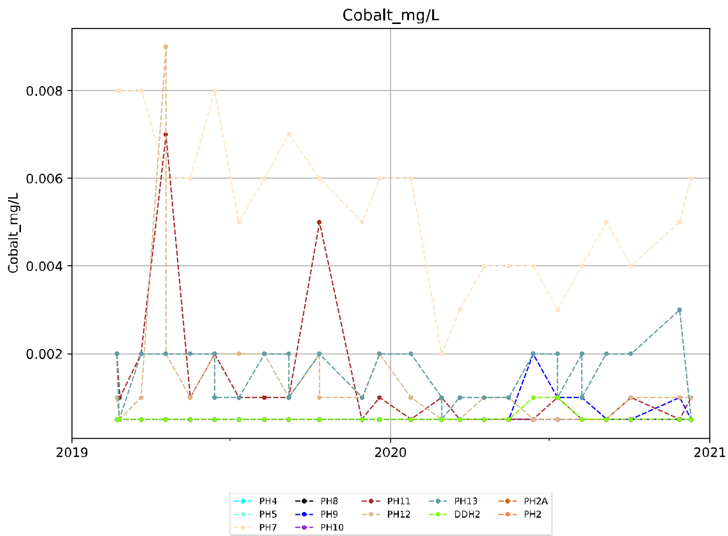

Arsenic_mg/L
Arsenic_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

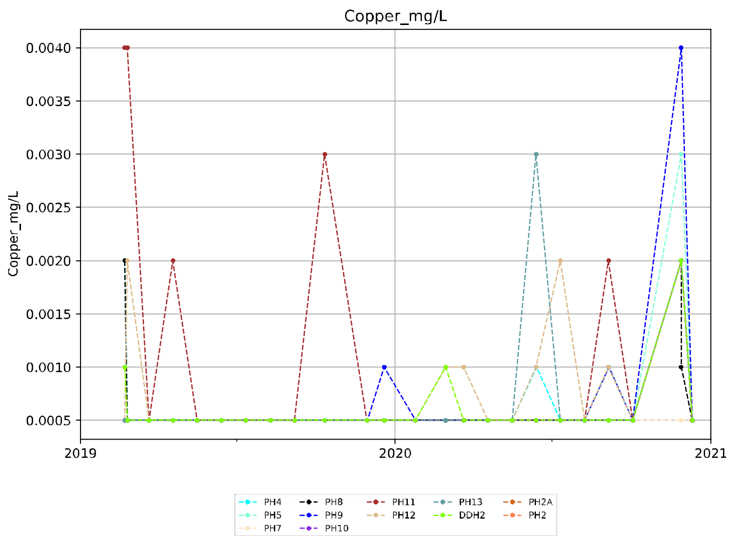

Barium_mg/L
Barium_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

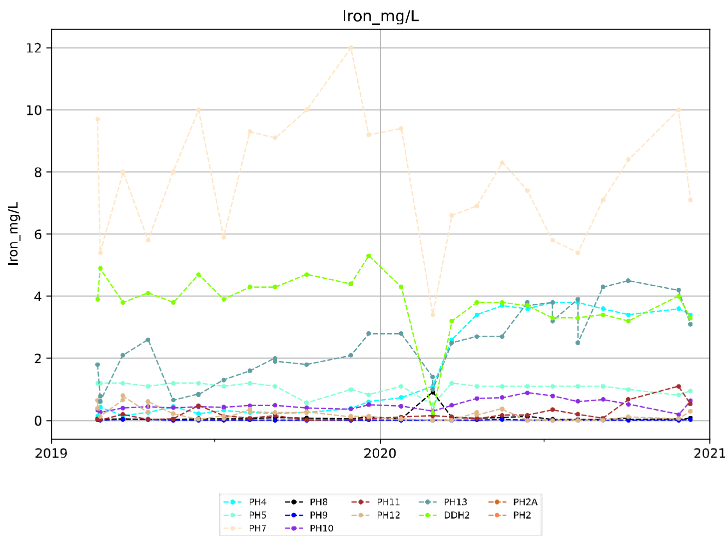

Beryllium_mg/L
Beryllium_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

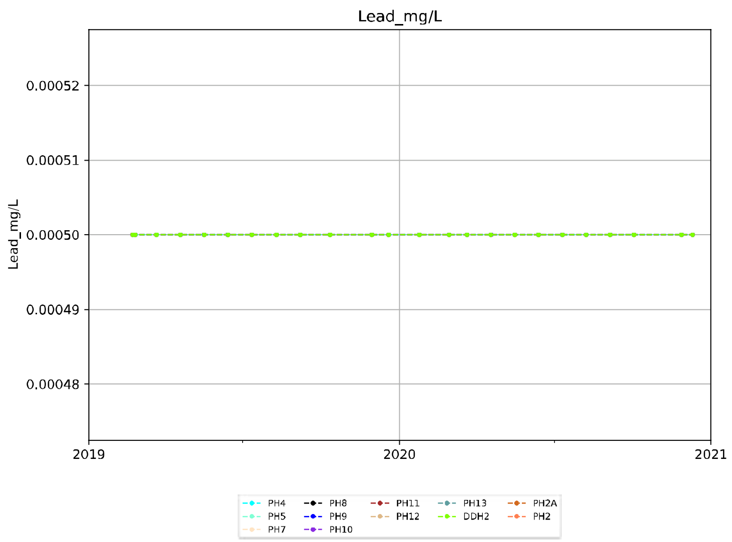

Cadmium_mg/L
Cadmium_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

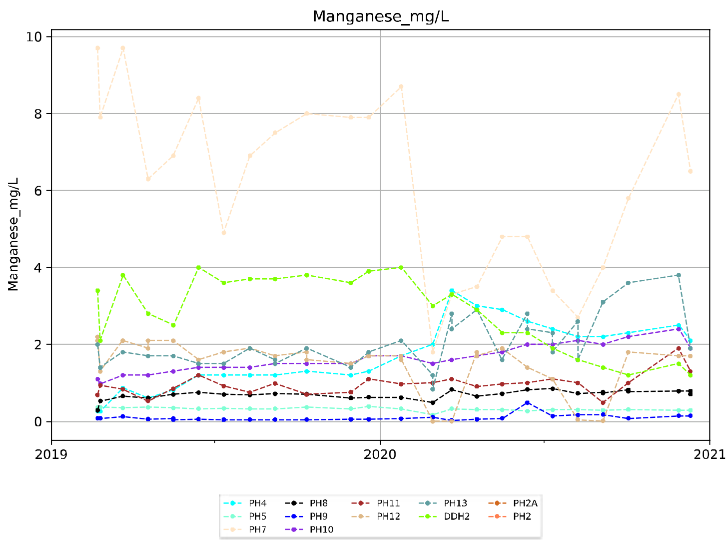

Chromium_mg/L
Chromium_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

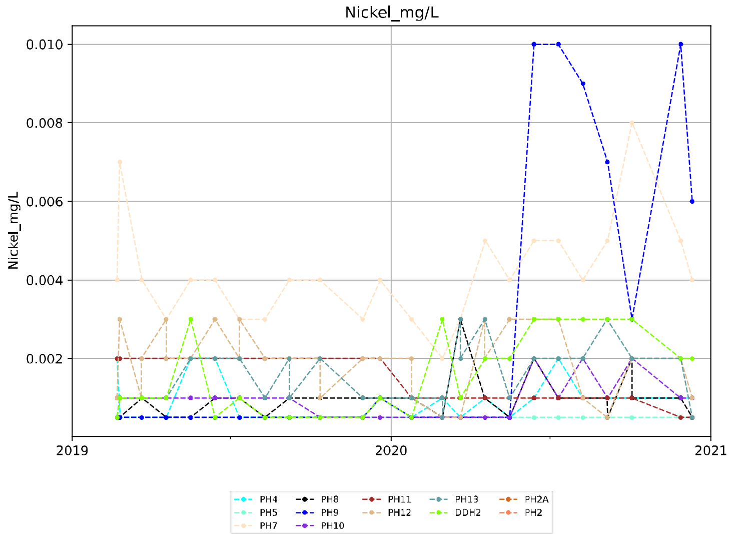

Cobalt_mg/L
Cobalt_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

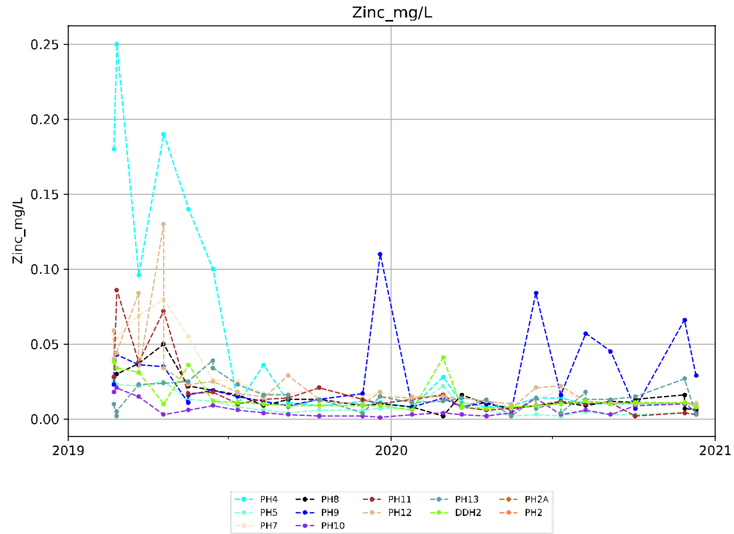

Copper_mg/L
Copper_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

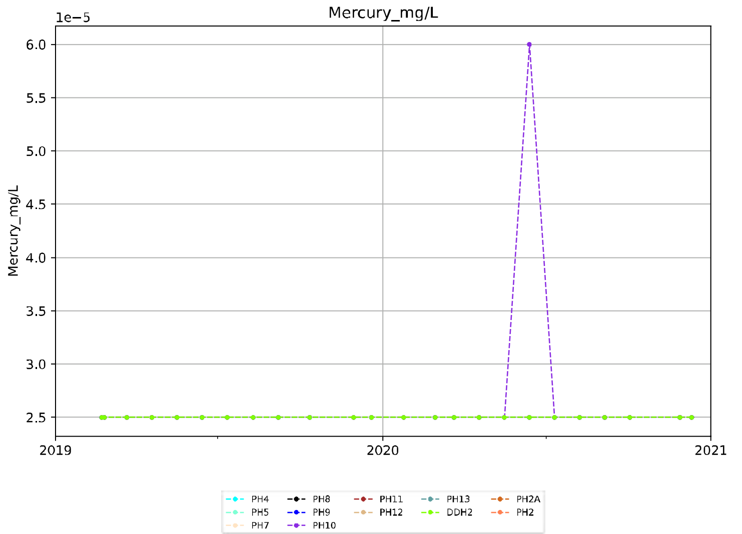

Iron_mg/L
Iron_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

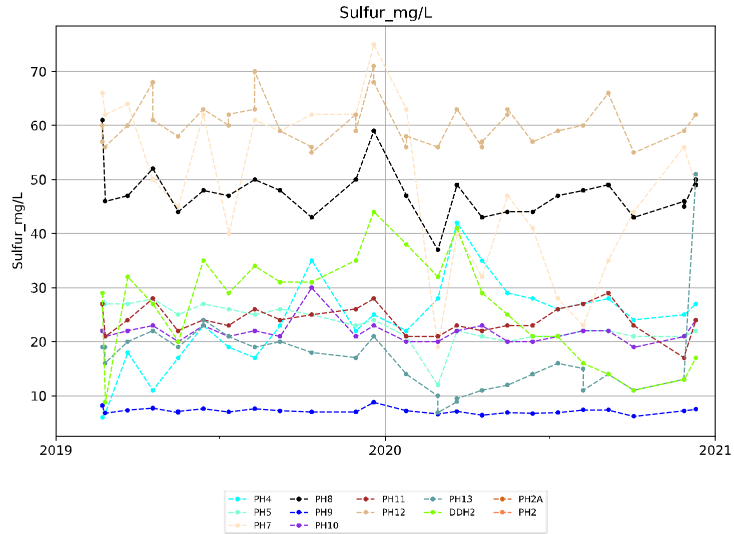

Lead_mg/L
Lead_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

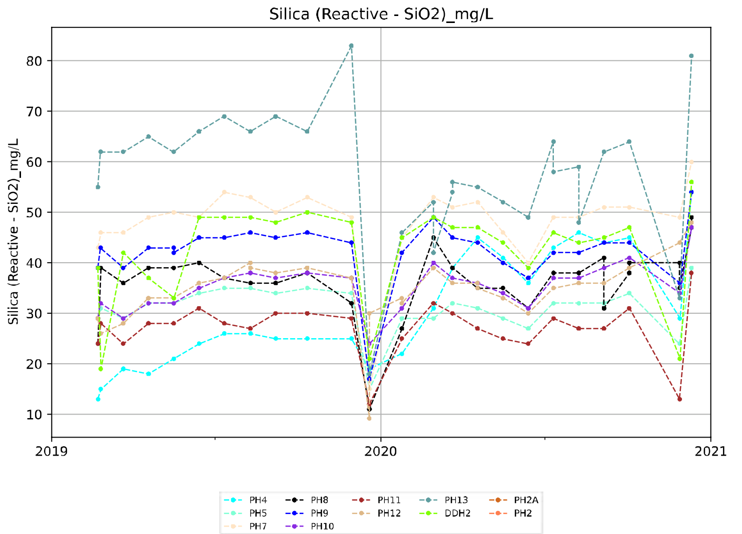

Manganese_mg/L
Manganese_mg/L
2019
2020
2021
PH4 PH8 PH11 PH13 PH2A
PH5 PH9 PH12 DDH2 PH2
PH7 PH10

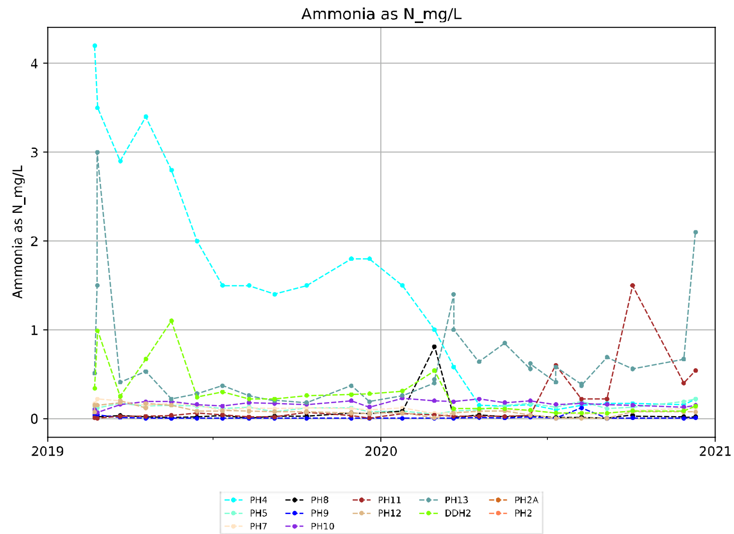

Nickel_mg/L
Nickel_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2

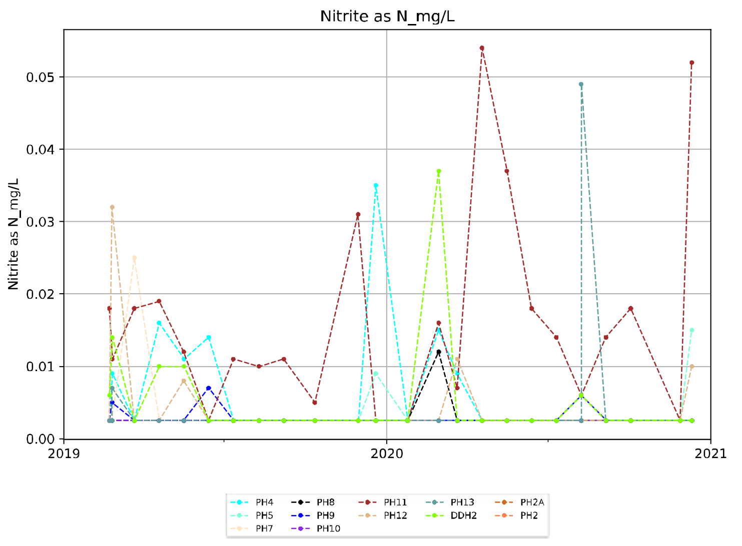

Zinc_mg/L
Zinc_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2

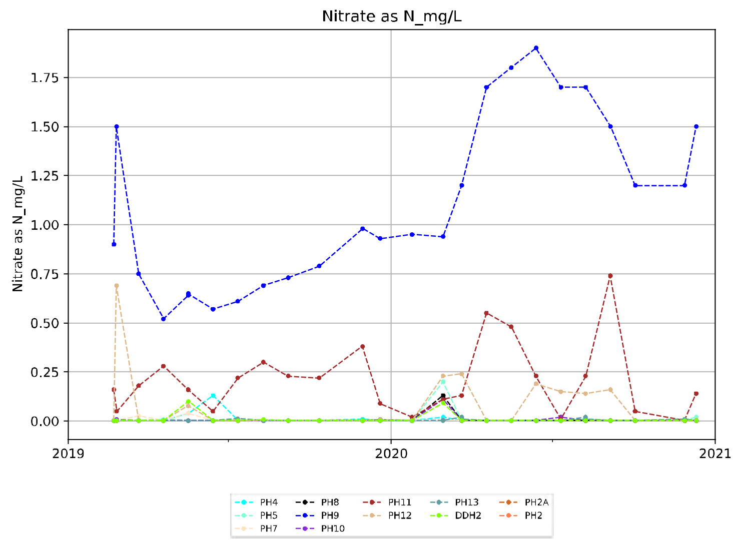

Mercury_mg/L
Mercury_mg/L
1e−5
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2

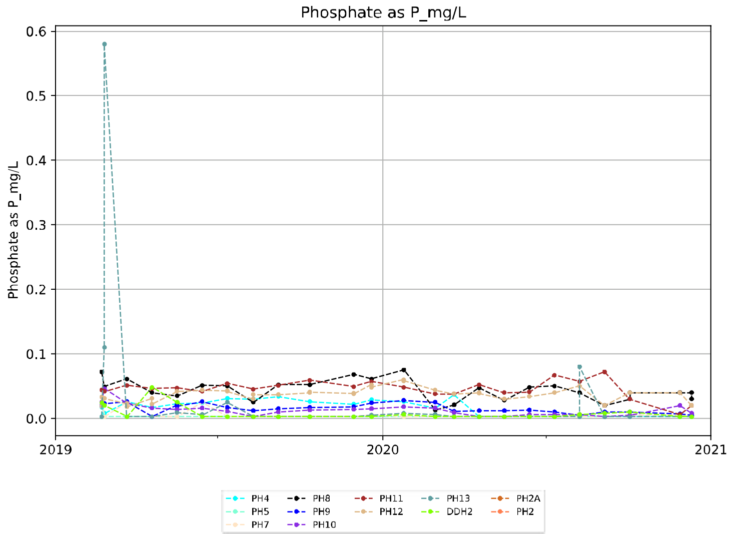

Sulfur_mg/L
Sulfur_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2


Silica (Reactive - SiO2)_mg/L
Silica (Reactive - SiO2)_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2

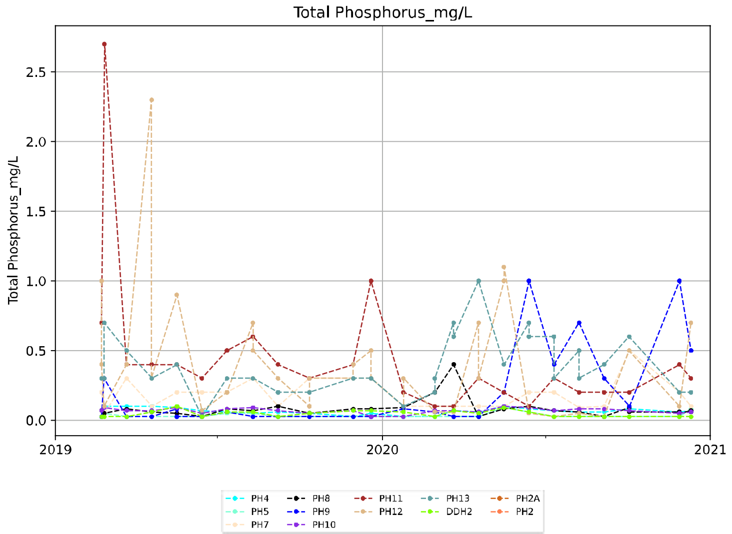

Ammonia as N_mg/L
Ammonia as N_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2


Nitrite as N_mg/L
Nitrite as N_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2


Nitrate as N_mg/L
Nitrate as N_mg/L
2019
2020
2021
PH4 PH5 PH7 PH8 PH9 PH10 PH11 PH12 PH13 DDH2 PH2A PH2



Phosphate as P_mg/L
Phosphate as P_mg/L
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2019
2020
2021
PH4
PH5
PH7
PH8
PH9
PH10
PH11
PH12
PH13
DDH2
PH2A
PH2



Total Phosphorus_mg/L
Total Phosphorus_mg/L
2.5
2.0
1.5
1.0
0.5
0.0
2019
2020
2021
PH4
PH5
PH7
PH8
PH9
PH10
PH11
PH12
PH13
DDH2
PH2A
PH2

Appendix C Slug Test Results

Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024

C.1 Introduction and Objectives

As part of the groundwater assessment to support the Environment Impact Statement (EIS), a suite of slug tests was recommended at the Hillview Quarry Project site to understand the hydraulic properties, specifically the hydraulic conductivity, of the aquifers within the study area. This information will be used to inform the groundwater model construction and calibration to constrain the range of uncertainty and fulfil the Secretary Environment Assessment Requirements (SEARs).

Accordingly, SLR Consulting Australia Pty Ltd (SLR) have been commissioned by Coastwide Materials Pty Ltd (Coastwide) to undertake this suite of slug tests at the Hillview Quarry Project. These were carried out by SLR hydrogeologists over the period from 16 to 21 March 2023.

C.2 Slug Test Methodology

An aquifer slug test is a controlled field experiment used to estimate the hydraulic properties, specifically the hydraulic conductivity, of an aquifer. Slug tests involve the insertion or removal of a slug (e.g., solid slug, bailer, pneumatic pressure) into a bore with the purpose of displacing the water within the hole and recording the water level change over time as the level recovers back to pre-test conditions.

C.2.1 Bore Information

The on-site monitoring bores that were chosen to be slug tested at the Project and their bore information are provided in **Table C1**. These bores were chosen to cover a great spatial extent across the Project site to observe the hydraulic conductivity across the entire proposed Project footprint.

Table C1 Hillview slug test bore information

Bore ID	Eastings	Northings	Elevation (TOC)	Stick Up (m)	Total Depth (m)	Screened Geology
PH4	398672	6404799	190.16	0.69	140	Rhyolitic tuff, slightly weathered
PH8	398464	6404673	181.13	0.62	40 to 46	Rhyolitic tuff, calcite veining
PH10	398796	6404422	157.99	0.81	69 to 75	Rhyolitic tuff/ dyke, calcite precipitation
PH11	399020	6404508	113.58	0.87	17.5 to 23.5	Rhyolitic tuff, weathered
PH13	398919	6405190	100.21	0.10	20	Rhyolitic tuff/ dyke, some weathering, calcite precipitation

C.2.2 Site Work Schedule

Site work to inform the groundwater assessment was conducted in three phases:

- **<u>Phase 1 (13 December 2022):</u>** Initial site inspection to install water level loggers into bores PH4 and PH13. A barometric pressure logger was also installed into PH13.

- **Phase 2 (16 March 2023):** Second site inspection to download water level and barometric pressure loggers from the Phase 1 bores. Additional installation of temporary dataloggers in PH8, PH10, and PH11 the purposes of slug testing. Slug testing on all bores was carried out.
- **Phase 3 (21 March 2023):** Return visit to download water level and barometric pressure data from all loggers for analysis.

C.2.3 Slug Test Type

There are two types of slug tests that can be conducted on bores:

- A rising-head test is initiated by rapidly lowering the water level in the control well and then taking measurements of the rising water level in the well.
- A falling-head test is conducted by rapidly raising the water level in the control well and subsequently measuring the falling water level.

For the bores at the Project location a rising head test was conducted using a Waterra pump to remove a slug of water.

For PH8 an initial rising head test was conducted; however, recovery was rapid and could not be accurately recorded, and it was decided that a falling head test (slug insertion of water) should be conducted to provide a meaningful result due to the capacity of the pump on-site.

C.2.4 Data Recording

Groundwater elevations were recorded throughout the use of Solinst dataloggers, with an accompanying barologger for atmospheric pressure correction. Dataloggers were set to record every 5 seconds, with a 0.5 second recording schedule in PH8, to capture the rapid responses observed in this bore. Manual groundwater level dips were also taken before the slug test to capture the pre-test static water level as well as at regular intervals during the tests to validate the datalogger levels. The adjusted datalogger groundwater levels with manual dips during each slug test are provided in **Attachment C1**.

C.3 Slug Test Analysis

The analysis of the results was conducted for each bore to determine the hydraulic conductivity. This analysis was conducted using the aquifer test software, Aqtesolv (HydroSOLVE, Inc).

C.3.1 Conceptual and Mathematical Model

The bores are all screened in the volcanic deposits at varying depths. These volcanics form part of the New England Fold Belt Coast Groundwater Source that is dominated by fractured rock aquifers where groundwater is intersected in secondary fracture porosity associated with the folding and faulting of the rock. Due to this fracture network, for simplicity, any bore that is less than 30 m in depth is conceptualised to be accessing the unconfined upper portion of the volcanic deposits, whilst any bore deeper than 30 m is conceptualised as accessing a lower confined aquifer.

Bouwer and Rice (1976) and Hvorslev (1951) equations were chosen to analysis the slug test data in Aqtesolv software. Both of these mathematical models can be used on both unconfined and confined aquifer conditions and therefore were considered appropriate for the conceptual model above. Both equations were used in the analysis on each bore to provide a comparison of the results between the two methods.

C.3.2 Hydraulic Parameter Results

The hydraulic parameters were determined through the analysis of the logger data during the slug testing. The hydraulic conductivity is the main parameter determined during the test, the value for each bore is provided in **Table C2**. The Aqtesolv output reports are shown in **Attachment C2**.

Attempting to match straight-line methods such as Bouwer and Rice (1976) and Hvorslev (1951) to slug test data with curvature leads to ambiguity. Therefore, to reduce this uncertainty the analysis was matched to the part of the curve that satisfies the internal Aqtesolv normalised head range for line-matching; these head ranges are shown on the graphs in **Attachment C2**.

Table C2 Hydraulic conductivity results

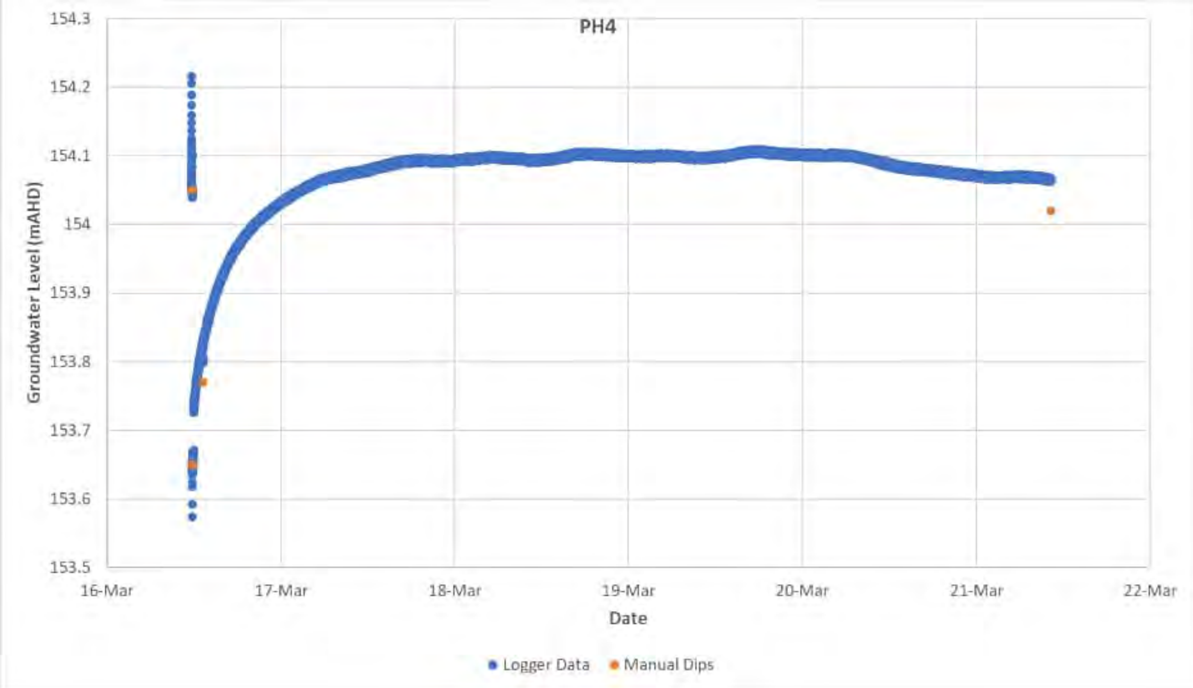
Bore ID	Equation Applied	Hydraulic Conductivity, K (m/d)
PH4	Bouwer-Rice	0.0023
	Hvorslev	0.0023
PH8	Bouwer-Rice	10.65
	Hvorslev	13.33
PH10	Bouwer-Rice	0.031
	Hvorslev	0.033
PH11	Bouwer-Rice	0.0036
	Hvorslev	0.0038
PH13	Bouwer-Rice	0.0032
	Hvorslev	0.0042

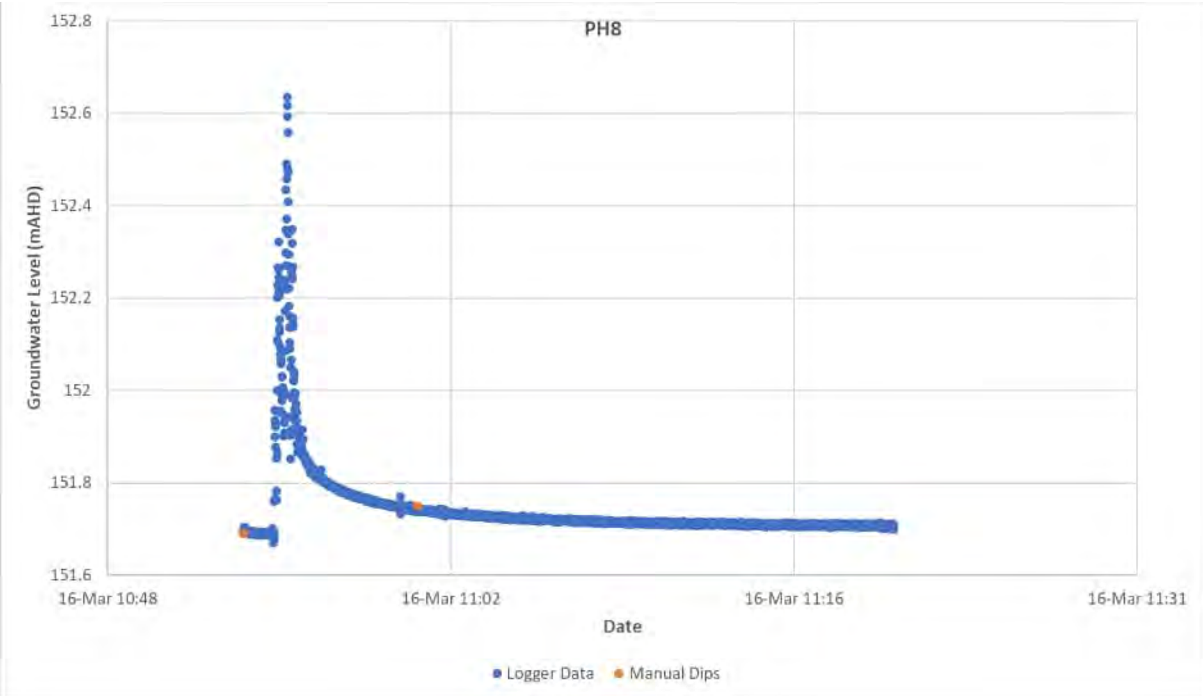
C.3.3 Hydraulic Parameter Discussion

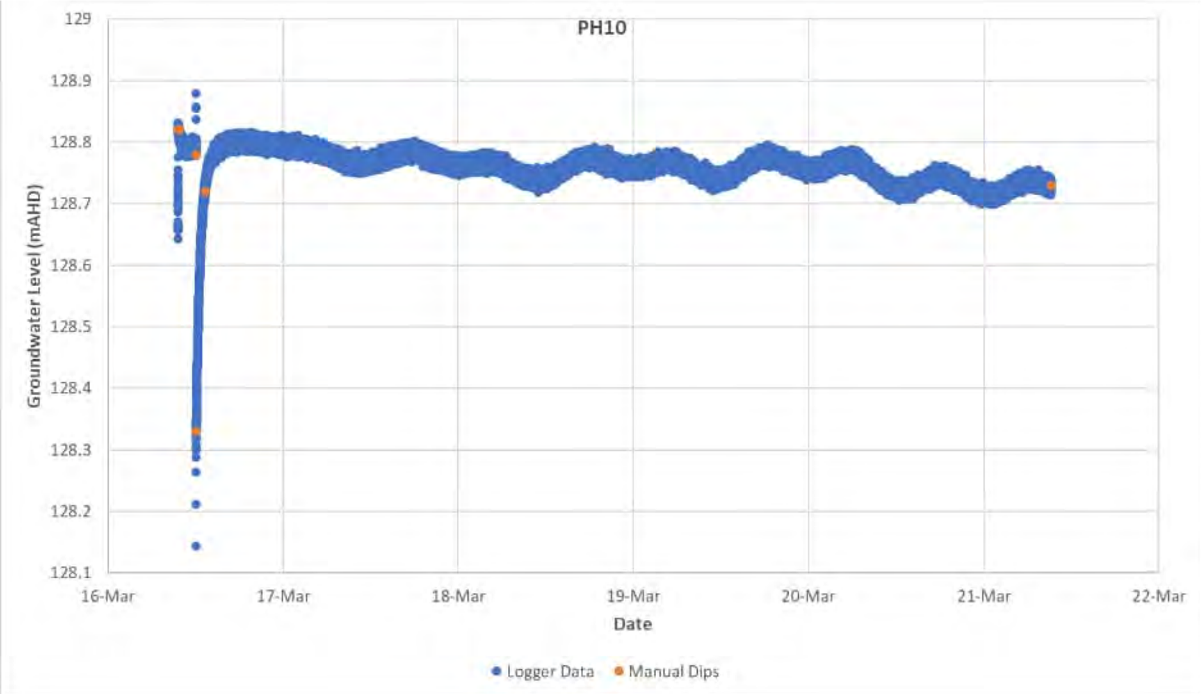
As observed in **Table C2,** hydraulic conductivities at the Project site span five orders of magnitude and range from 0.0023 m/d (observed in PH4) to 13.33 m/d (observed in PH8). It is likely that the low end of the conductivities is representative of the volcanic rock matrix and smaller fracture networks, whilst the conductivities observed in PH8 are indicative of a fault zone, with enhanced fracture permeability.

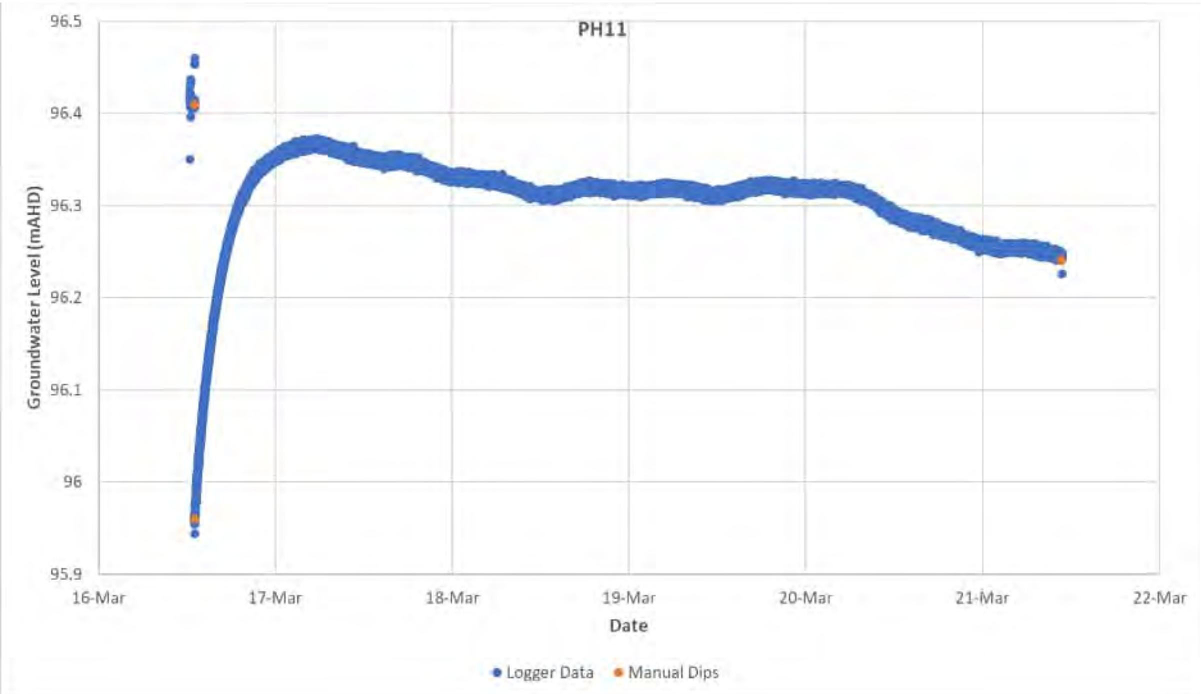
These values will be used to inform the groundwater model construction and calibration.

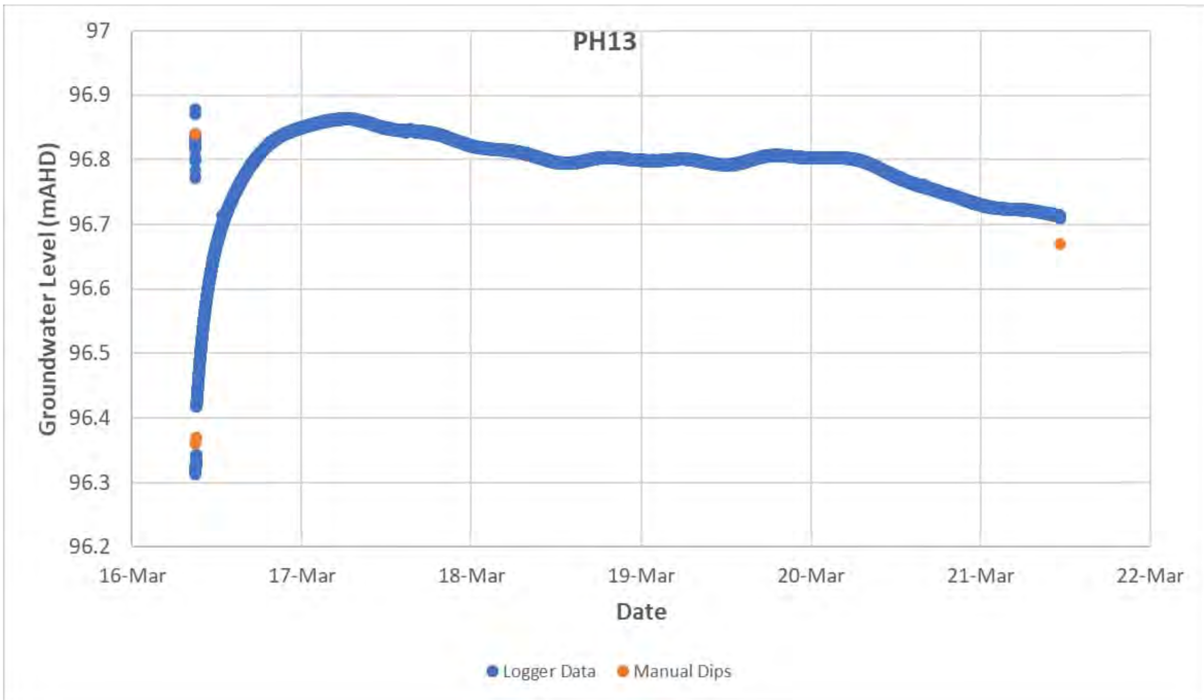
Attachment C1: Slug Test Hydrographs



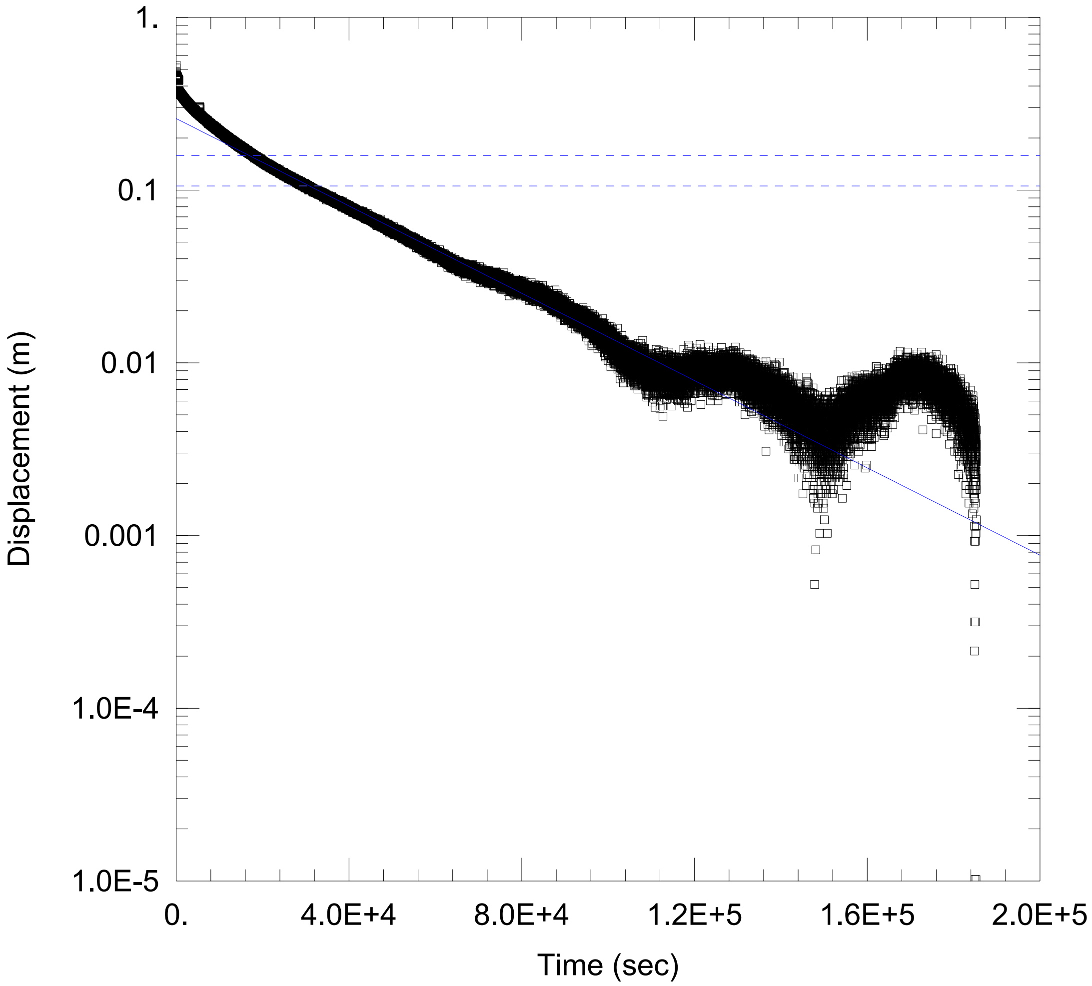



PH10
Groundwater Level (mAHD)
129
128.9
128.8
128.7
128.6
128.5
128.4
128.3
128.2
128.1
16-Mar
17-Mar
18-Mar
19-Mar
20-Mar
21-Mar
22-Mar
Date
Logger Data
Manual Dips


PH11
Groundwater Level (mAHD)
96.5
96.4
96.3
96.2
96.1
96
95.9
16-Mar
17-Mar
18-Mar
19-Mar
20-Mar
21-Mar
22-Mar
Date
Logger Data
Manual Dips


PH13
Groundwater Level (mAHD)
97
96.9
96.8
96.7
96.6
96.5
96.4
96.3
96.2
16-Mar
17-Mar
18-Mar
19-Mar
20-Mar
21-Mar
22-Mar
Date
Logger Data
Manual Dips

Attachment C2: Aqtesolv Outputs



WELL TEST ANALYSIS

Data Set: H:\...\PH4_Bouwer.aqt
Date: 03/24/23 Time: 10:51:47

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH4
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 85.86 m
Anisotropy Ratio (Kz/Kr): 1.

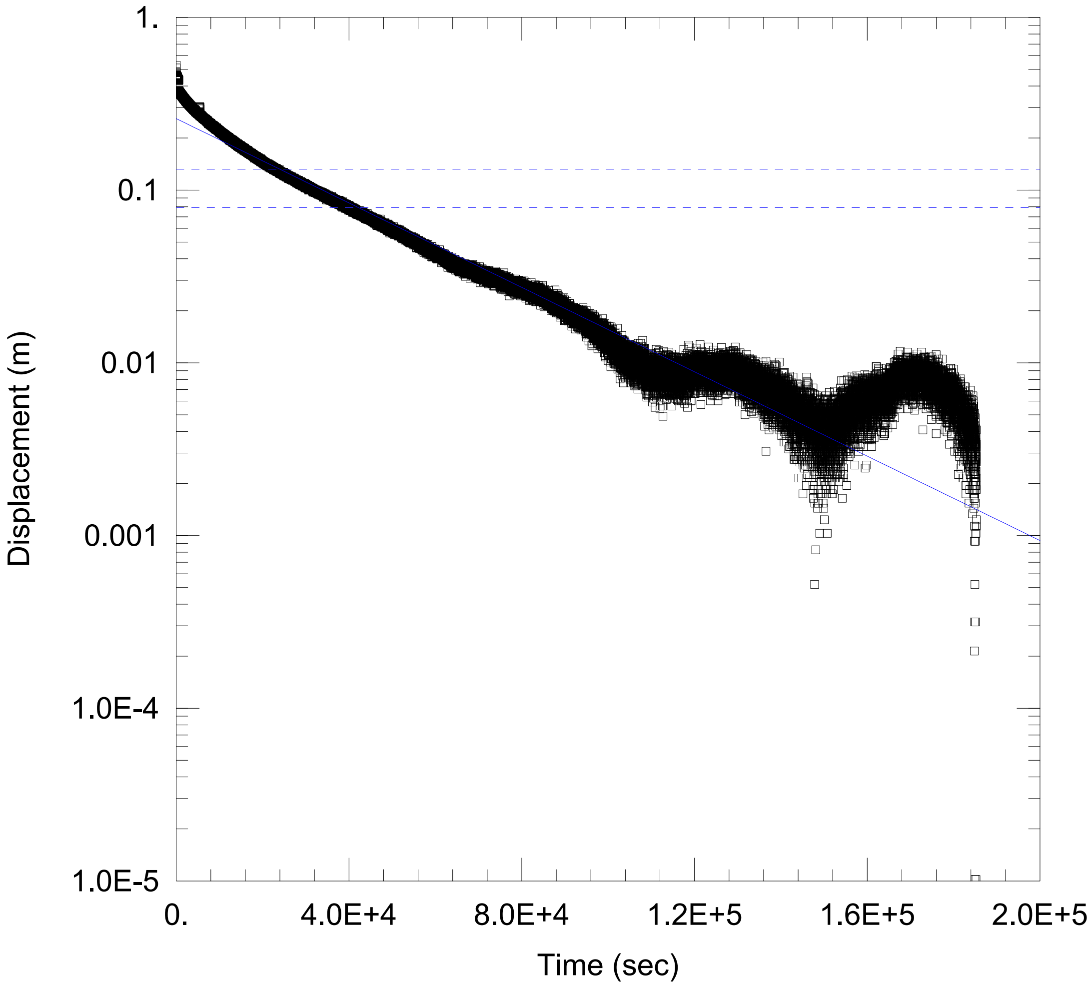
WELL DATA (PH4)

Initial Displacement: 0.528 m
Total Well Penetration Depth: 85.86 m
Casing Radius: 0.05 m
Static Water Column Height: 85.86 m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 0.00233 m/day
y0 = 0.2592 m



WELL TEST ANALYSIS

Data Set: H:\...\PH4_Hvorslev.aqt
Date: 03/24/23 Time: 10:52:44

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH4
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 85.86 m Anisotropy Ratio (Kz/Kr): 1.

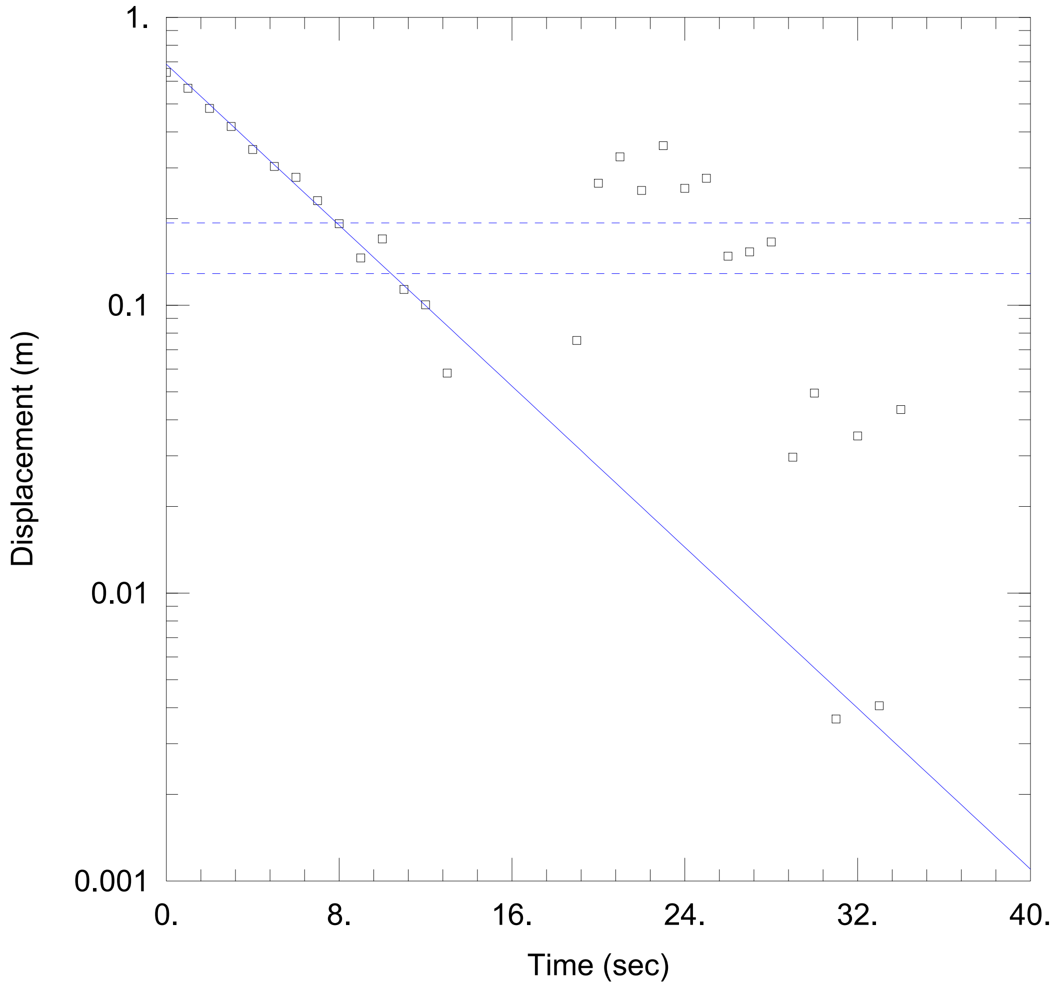
WELL DATA (PH4)

Initial Displacement: 0.528 m Static Water Column Height: 85.86 m
Total Well Penetration Depth: 85.86 m Screen Length: 6. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev

K = 0.00233 m/day y0 = 0.2592 m



WELL TEST ANALYSIS

Data Set: H:\...\PH8_Bouwer.aqt
Date: 03/24/23 Time: 10:53:34

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH8
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 17.78 m
Anisotropy Ratio (Kz/Kr): 1.

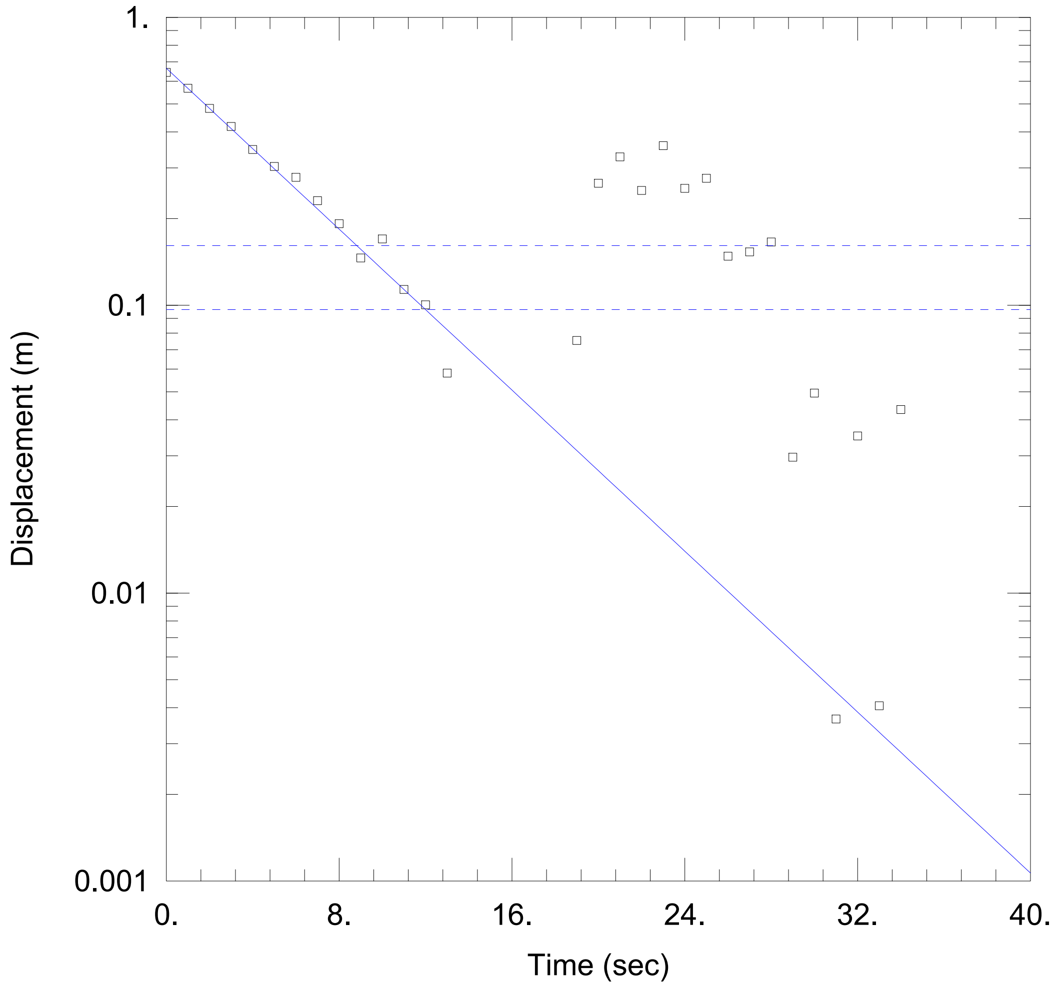
WELL DATA (PH8)

Initial Displacement: 0.644 m
Total Well Penetration Depth: 17.78 m
Casing Radius: 0.05 m
Static Water Column Height: 17.78 m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 10.65 m/day
y0 = 0.6871 m



WELL TEST ANALYSIS

Data Set: H:\...\PH8_Hvorslev.aqt
Date: 03/24/23 Time: 10:54:52

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH8
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 17.78 m
Anisotropy Ratio (Kz/Kr): 1.

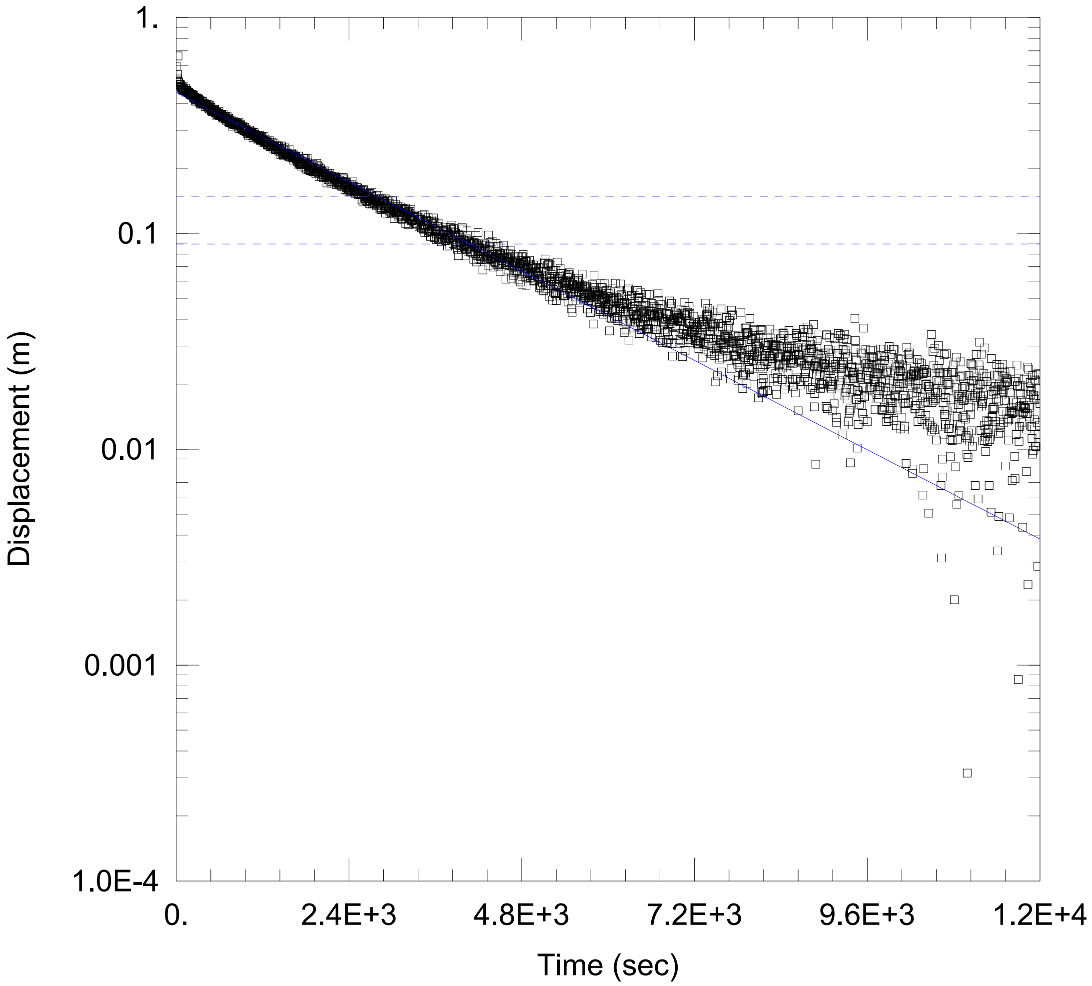
WELL DATA (PH8)

Initial Displacement: 0.644 m
Static Water Column Height: 17.78 m
Total Well Penetration Depth: 17.78 m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 13.33 m/day
y0 = 0.6655 m



WELL TEST ANALYSIS

Data Set: H:\...\PH10 Hvorslev.aqt
Date: 03/24/23 | Time: 11:00:28

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH10
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 48.42 m | Anisotropy Ratio (Kz/Kr): 1.

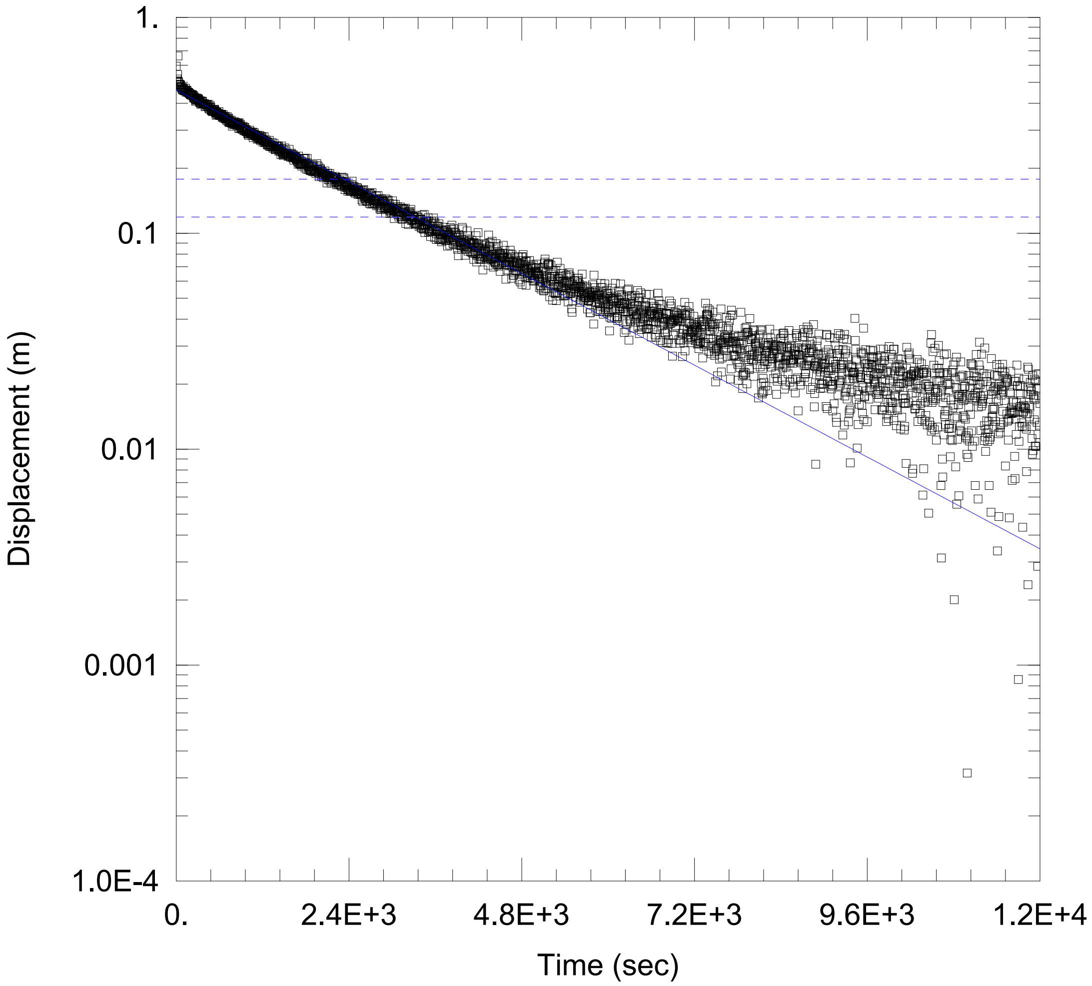
WELL DATA (PH10)

Initial Displacement: 0.594 m | Static Water Column Height: 48.42 m
Total Well Penetration Depth: 48.42 m | Screen Length: 6. m
Casing Radius: 0.05 m | Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined | Solution Method: Hvorslev

K = 0.03289 m/day | y0 = 0.4485 m



WELL TEST ANALYSIS

Data Set: H:\...\PH10_Bouwer.aqt
Date: 03/24/23 Time: 10:58:39

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH10
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 48.42 m Anisotropy Ratio (Kz/Kr): 1.

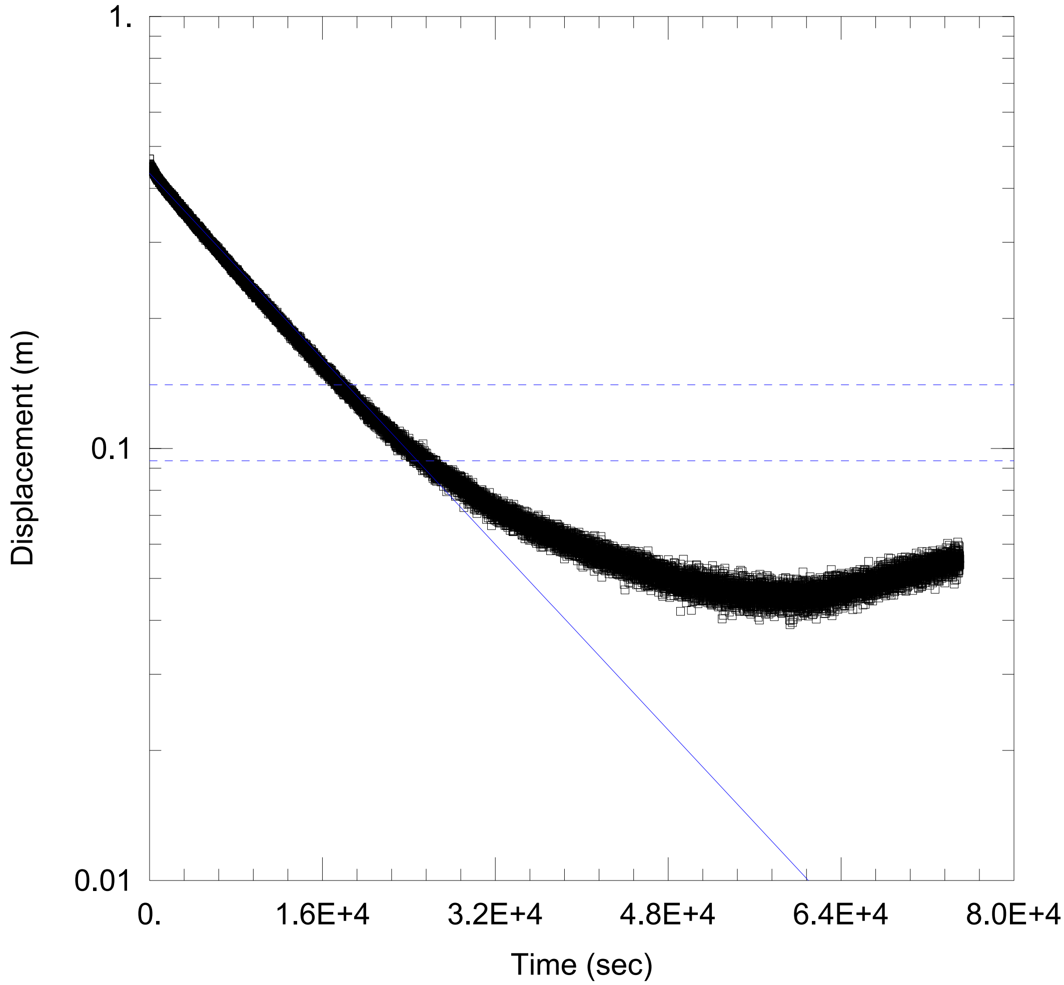
WELL DATA (PH10)

Initial Displacement: 0.594 m
Total Well Penetration Depth: 48.42 m
Casing Radius: 0.05 m
Static Water Column Height: 48.42 m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.03068 m/day y0 = 0.4623 m



WELL TEST ANALYSIS

Data Set: H:\...\PH11_Bouwer.aqt
Date: 03/24/23 | Time: 11:03:09

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH11
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 7.132 m
Anisotropy Ratio (Kz/Kr): 1.

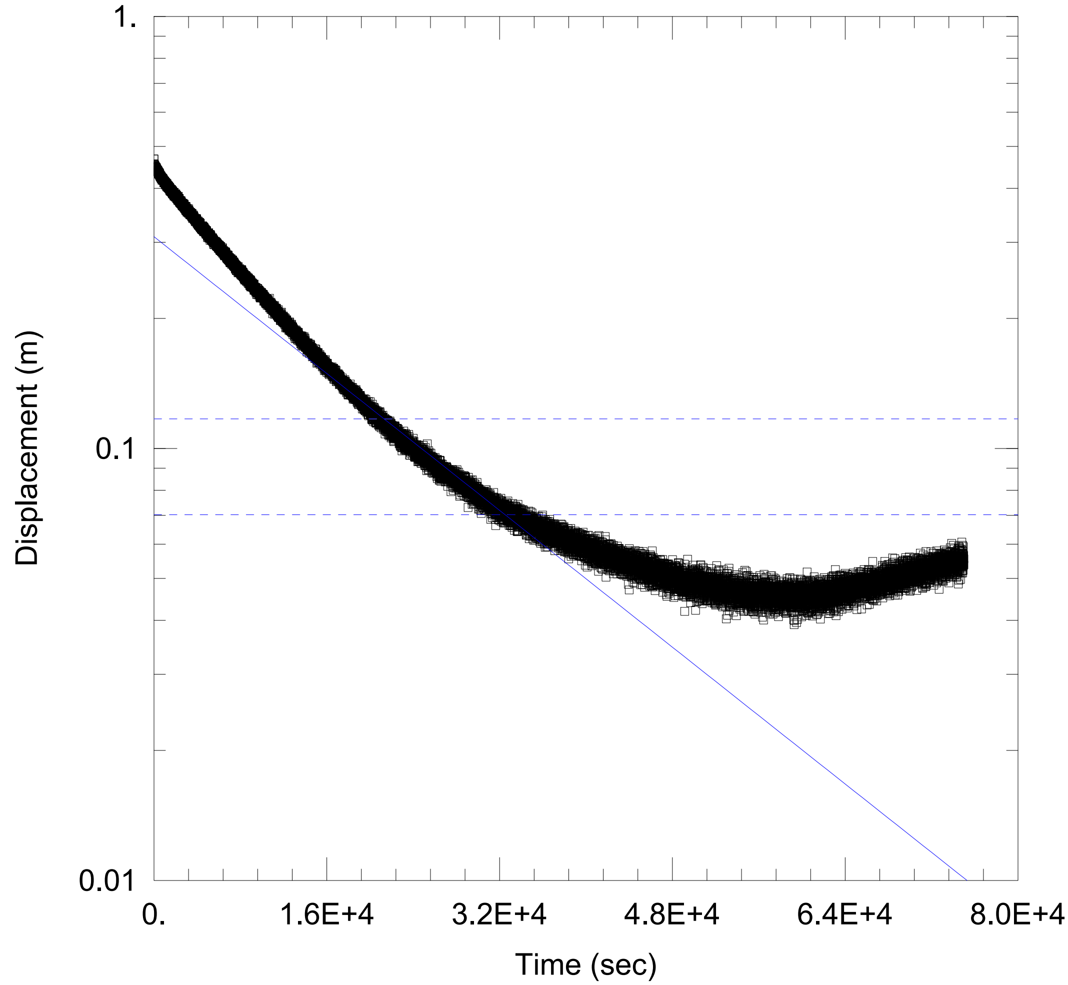
WELL DATA (PH11)

Initial Displacement: 0.468 m
Total Well Penetration Depth: 7.132 m
Casing Radius: 0.05 m
Static Water Column Height: 7.132 m
Screen Length: 6. m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 0.003555 m/day
y0 = 0.4332 m



WELL TEST ANALYSIS

Data Set: H:\...\PH11_Hvorslev.aqt
Date: 03/24/23 Time: 11:03:49

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262.00000
Location: Stroud
Test Well: PH11
Test Date: 16-03-2023

AQUIFER DATA

Saturated Thickness: 7.132 m Anisotropy Ratio (Kz/Kr): 1.

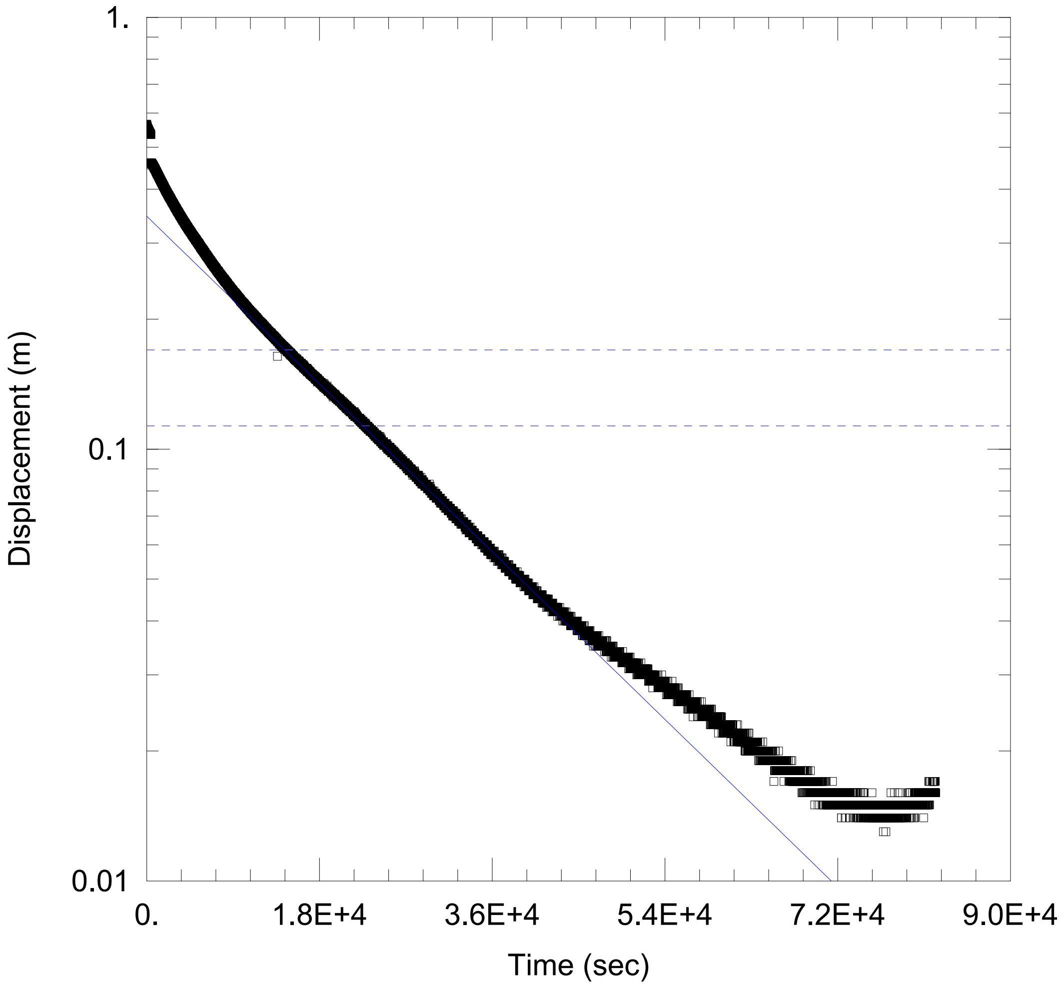
WELL DATA (PH11)

Initial Displacement: 0.468 m Static Water Column Height: 7.132 m
Total Well Penetration Depth: 7.132 m Screen Length: 6. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.003777 m/day y0 = 0.3091 m



WELL TEST ANALYSIS

Data Set: H:\...\PH13_Bouwer.aqt
Date: 03/24/23 Time: 10:50:28

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262
Location: Stroud
Test Well: PH13
Test Date: 16/03/2023

AQUIFER DATA

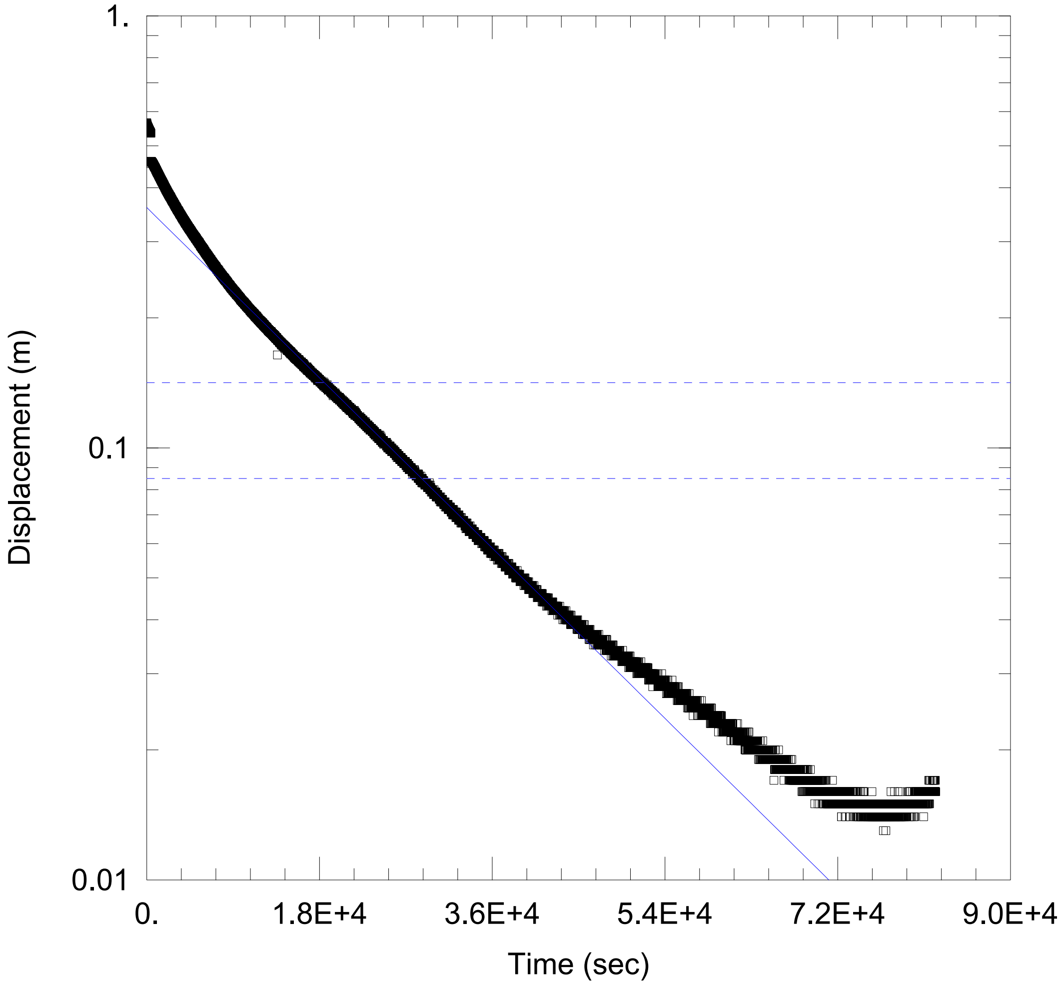
Saturated Thickness: 15.87 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PH13)

Initial Displacement: 0.566 m Static Water Column Height: 15.87 m
Total Well Penetration Depth: 15.87 m Screen Length: 6. m
Casing Radius: 0.05 m Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice
K = 0.003237 m/day y0 = 0.3462 m



WELL TEST ANALYSIS

Data Set: H:\...\PH13_Hvorslev.aqt
Date: 03/24/23 Time: 10:49:48

PROJECT INFORMATION

Company: SLR Consulting
Client: Coastwide Materials Pty Ltd
Project: 660.30262
Location: Stroud
Test Well: PH13
Test Date: 16/03/2023

AQUIFER DATA

Saturated Thickness: 15.87 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PH13)

Initial Displacement: 0.566 m
Static Water Column Height: 15.87 m
Total Well Penetration Depth: 15.87 m
Screen Length: 6. m
Casing Radius: 0.05 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.004179 m/day
y0 = 0.36 m

Appendix D Numerical Model Figure Book

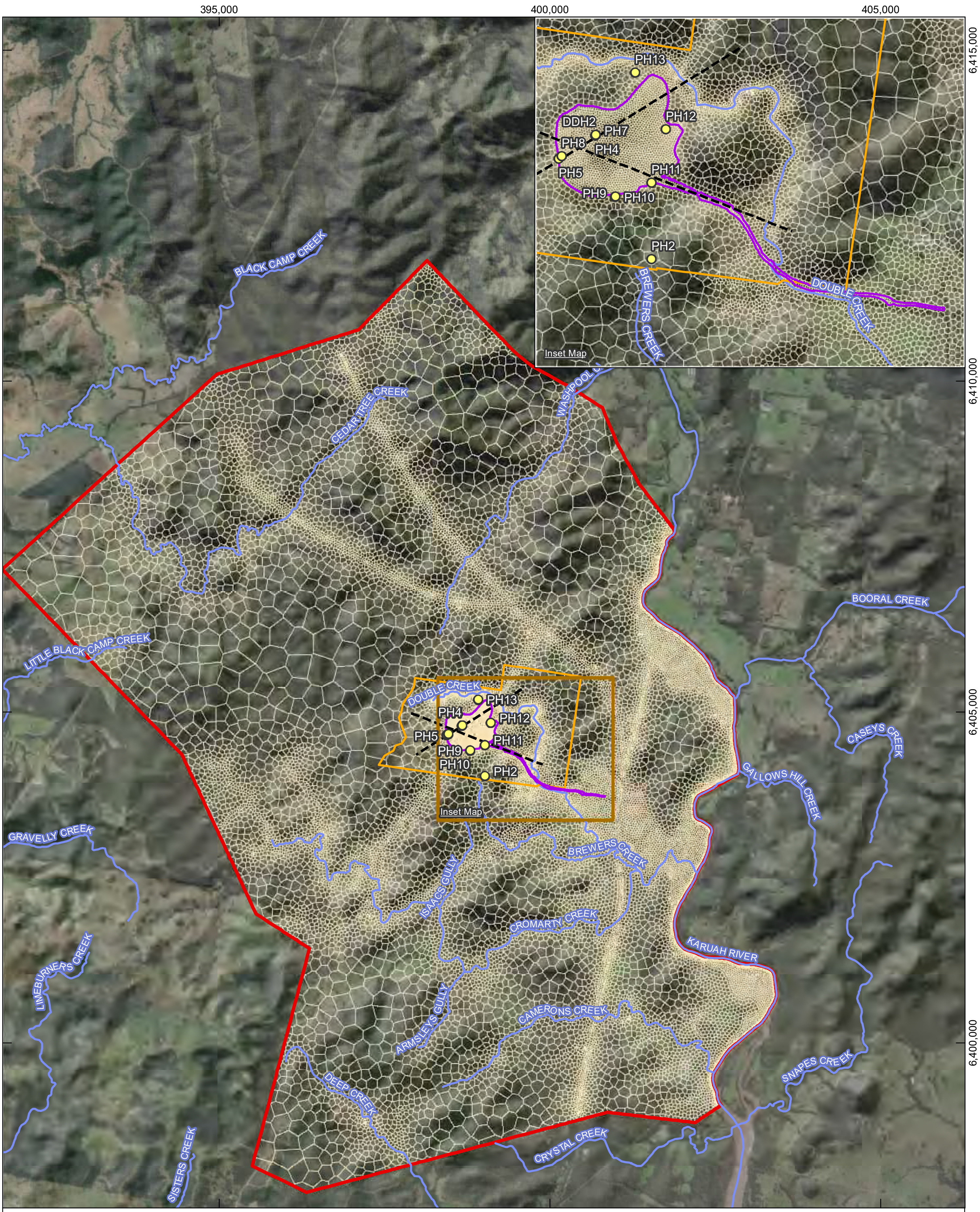
Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024



0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:75,000 at A4
Project Number: 660.30262
Date: 04-Aug-2023
Drawn by: NT/RB

SLR

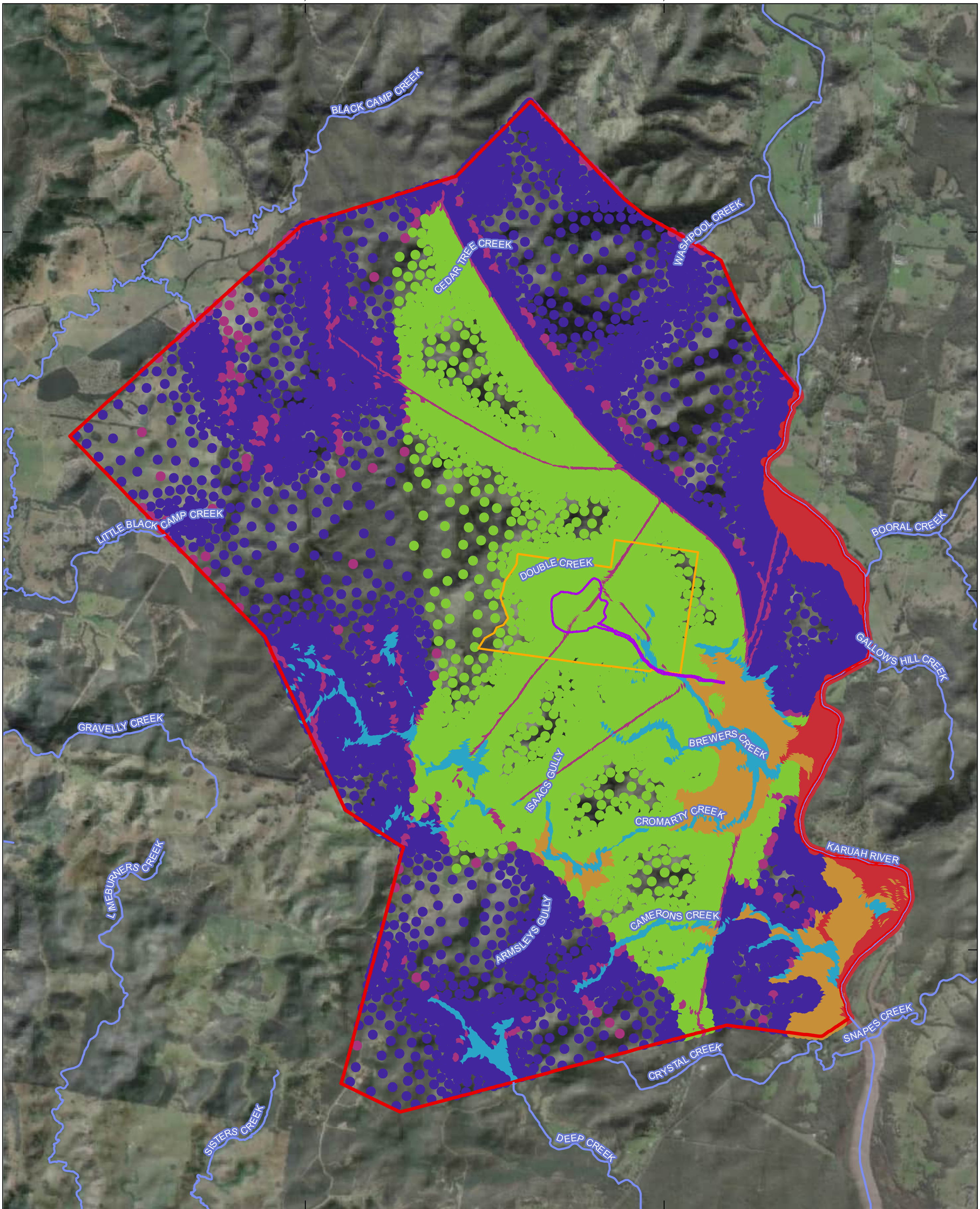
- Observation Bore
- Watercourse
- Cross Section
- Quarry Extent
- Site Boundary
- Model Extent
- Model Grid

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL EXTENT AND MESH

FIGURE D-1

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-1_Model Mesh Extent.mxd



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2a_Model Geological Zones Layer 1.mxd

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	RB

SLR

- Watercourse
- Quarry Extent
- Site Boundary
- Model Extent

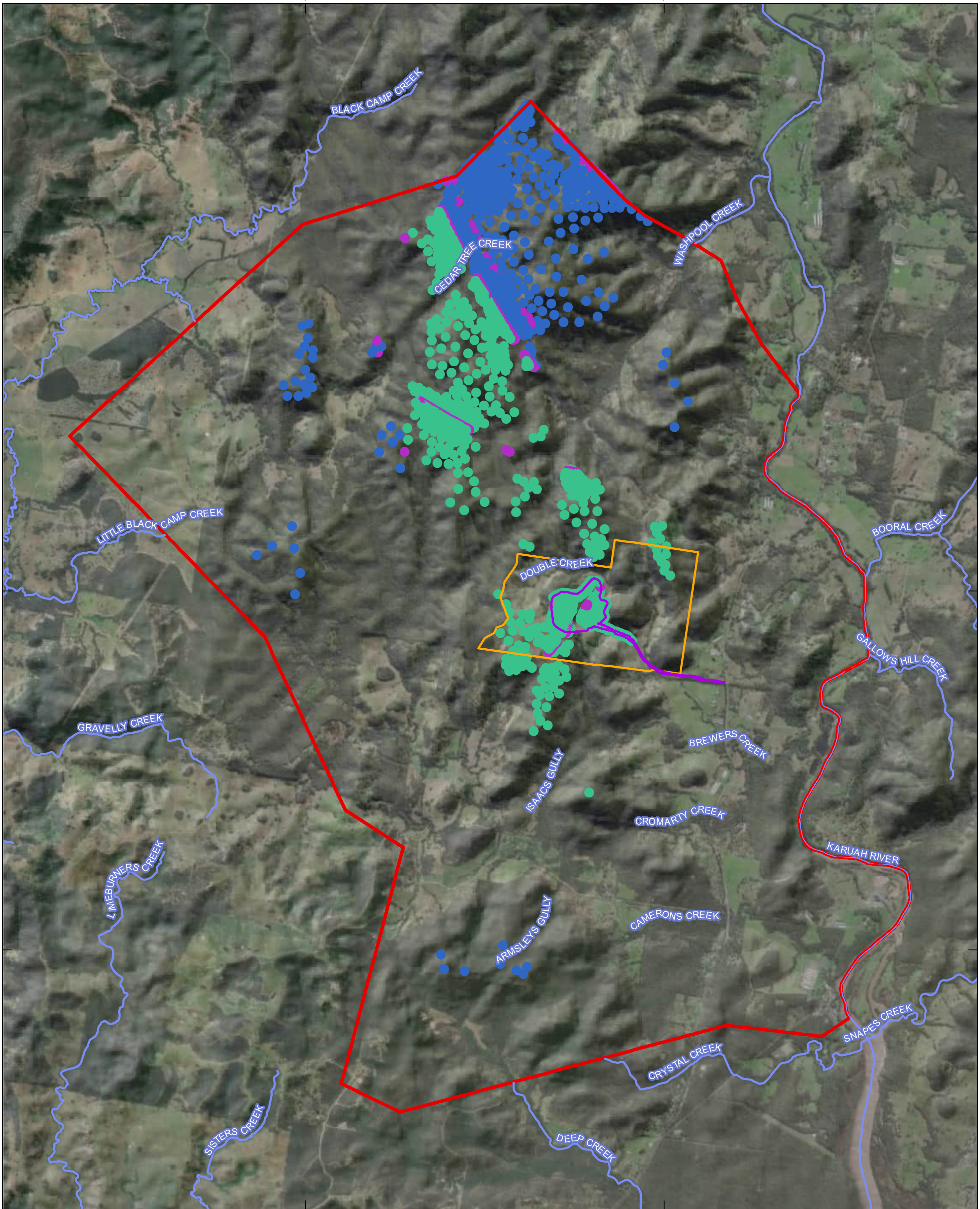
Geological Zone

- 1 - Pyroclastic rock (regolith)
- 2 - Sedimentary rock (regolith)
- 3 - Alluvium high production
- 4 - Alluvium low production
- 5 - Alluvium medium production
- 6 - Fault zone

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 1

FIGURE D-2a



N

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	RB

Watercourse
Quarry Extent
Site Boundary
Model Extent

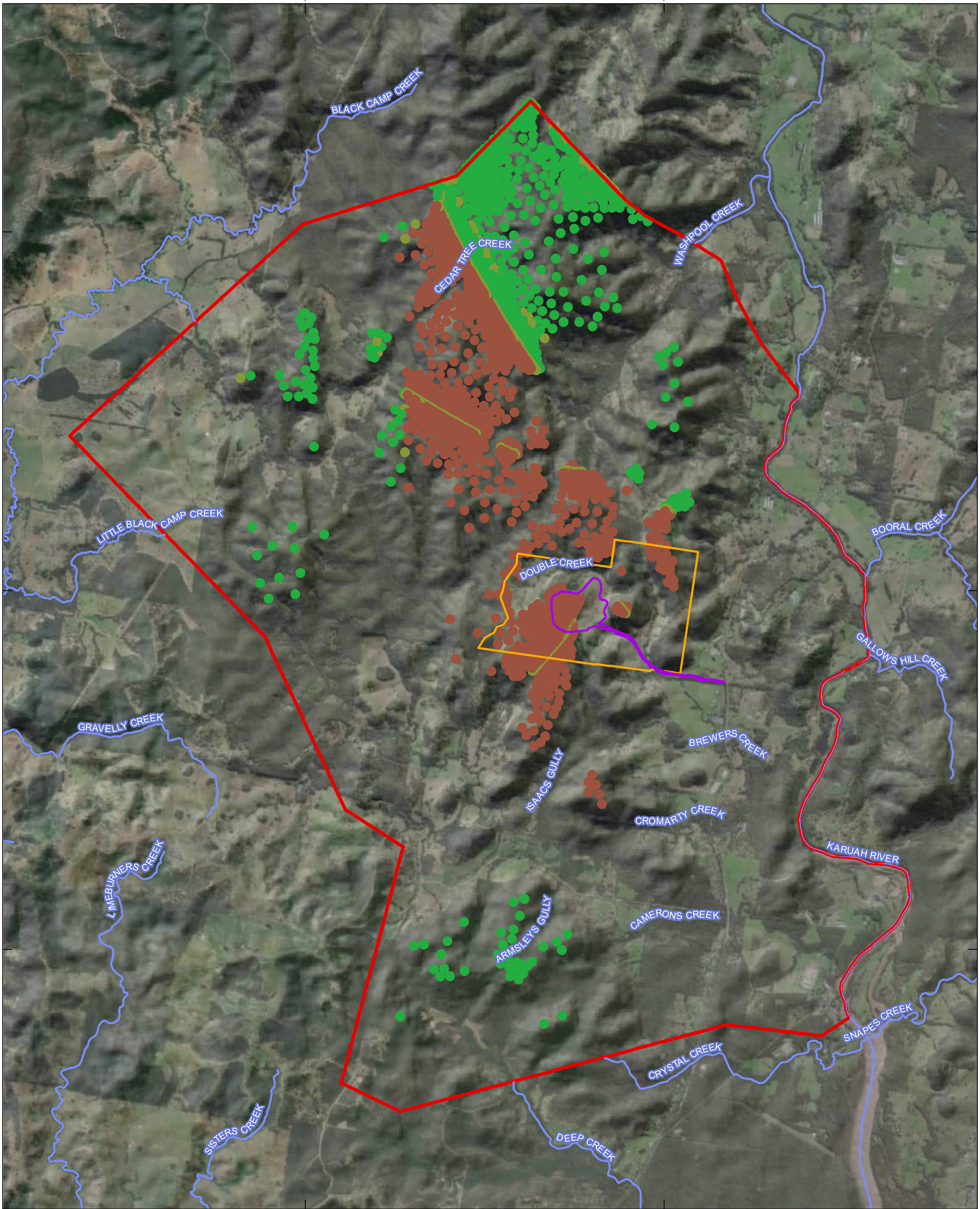
Geological Zone
- 7 - Pyroclastic rock
- 8 - Sedimentary rock
- 9 - Fault zone

HILLVIEW QUARRY
GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 2

FIGURE D-2 b

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2b_Model Geological Zones Layer 2.mxd



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2c_Model Geological Zones Layer 3.mxd

N

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	23-Oct-2023
Drawn by:	RB

- Watercourse
- Quarry Extent
- Site Boundary
- Model Extent

Geological Zone

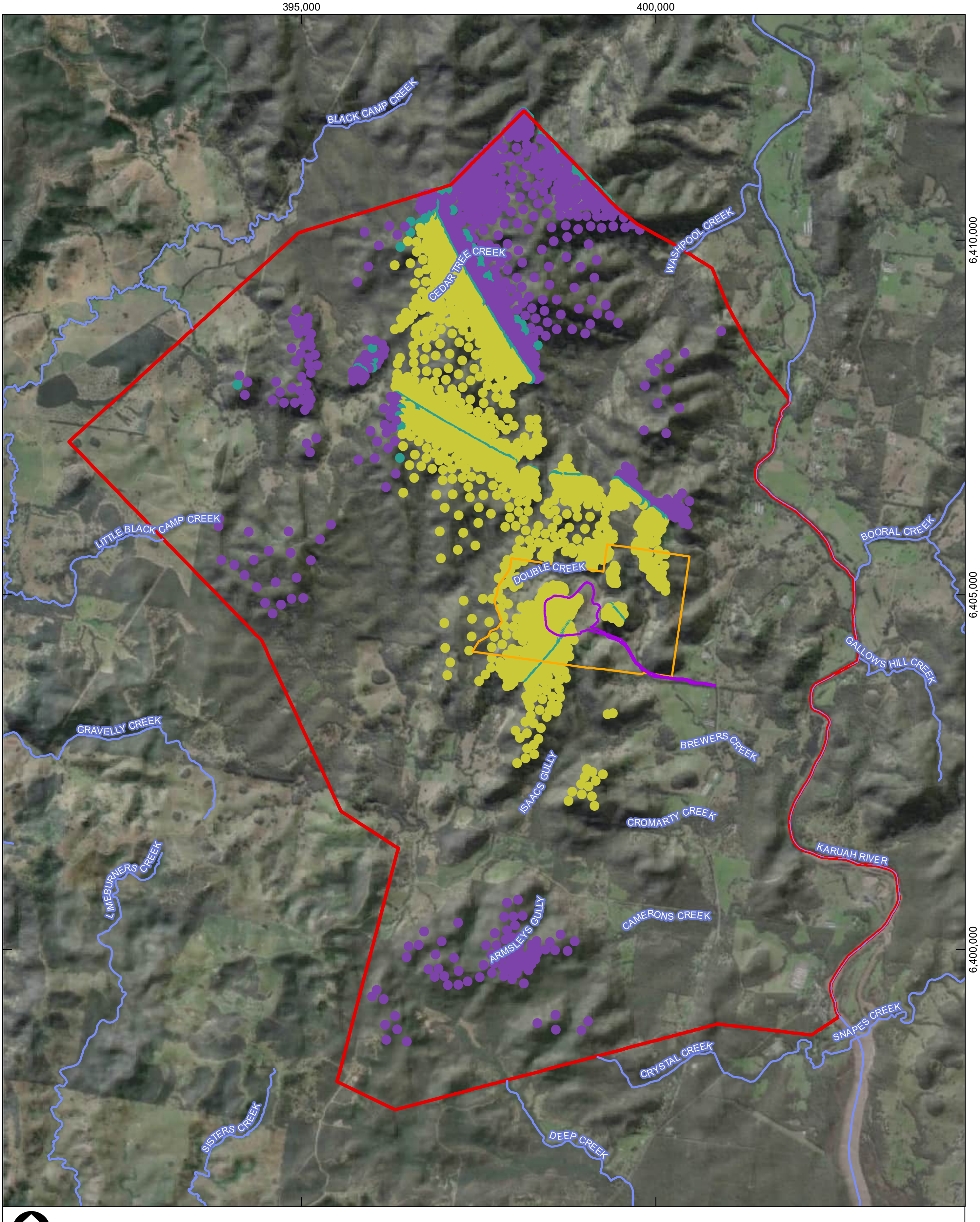
- 10 - Pyroclastic rock
- 11 - Sedimentary rock
- 12 - Fault zone

SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 3

FIGURE D-2c



0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:70,000 at A4
Project Number: 660.30262
Date: 23-Oct-2023
Drawn by: RB

Watercourse
Quarry Extent
Site Boundary
Model Extent

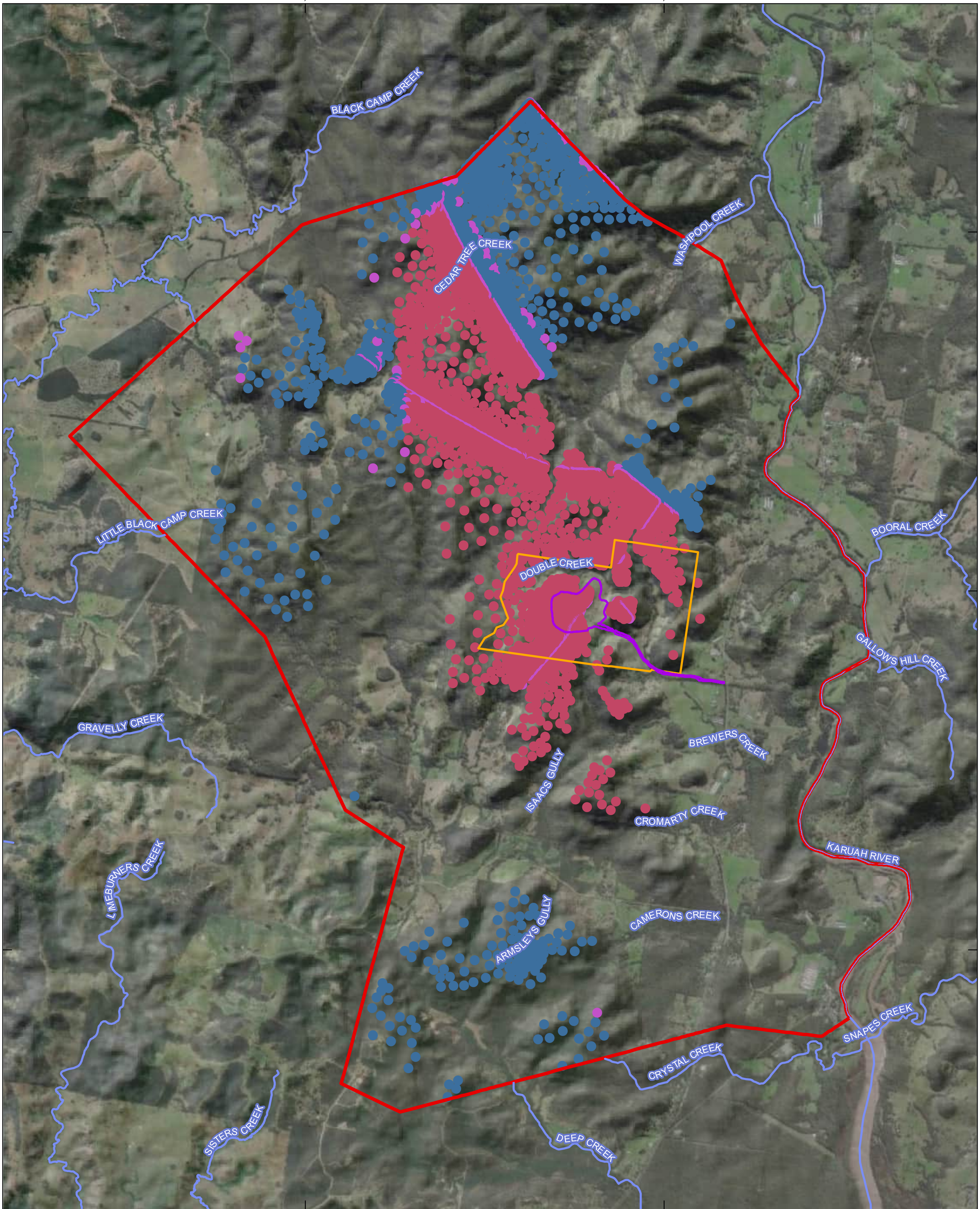
Geological Zone

13 - Pyroclastic rock
14 - Sedimentary rock
15 - Fault zone

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 4

FIGURE D-2d



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2e_Model Geological Zones Layer 5.mxd

N

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	23-Oct-2023
Drawn by:	RB

- Watercourse
- Quarry Extent
- Site Boundary
- Model Extent

Geological Zone

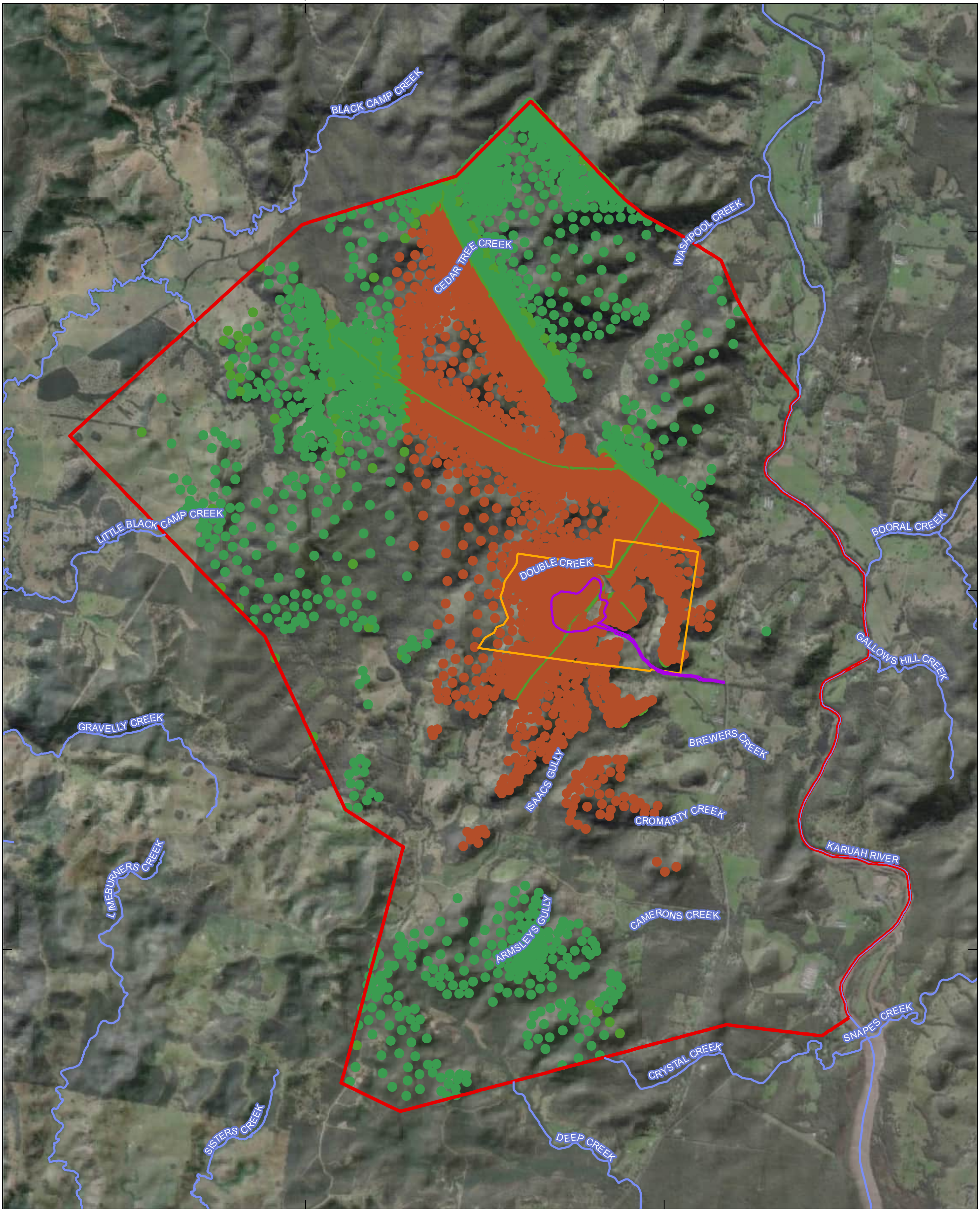
- 16 - Pyroclastic rock
- 17 - Sedimentary rock
- 18 - Fault zone

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 5

SLR

FIGURE D-2e



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2f_Model Geological Zones Layer 6.mxd

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	23-Oct-2023
Drawn by:	RB

- Watercourse
- Quarry Extent
- Site Boundary
- Model Extent

Geological Zone

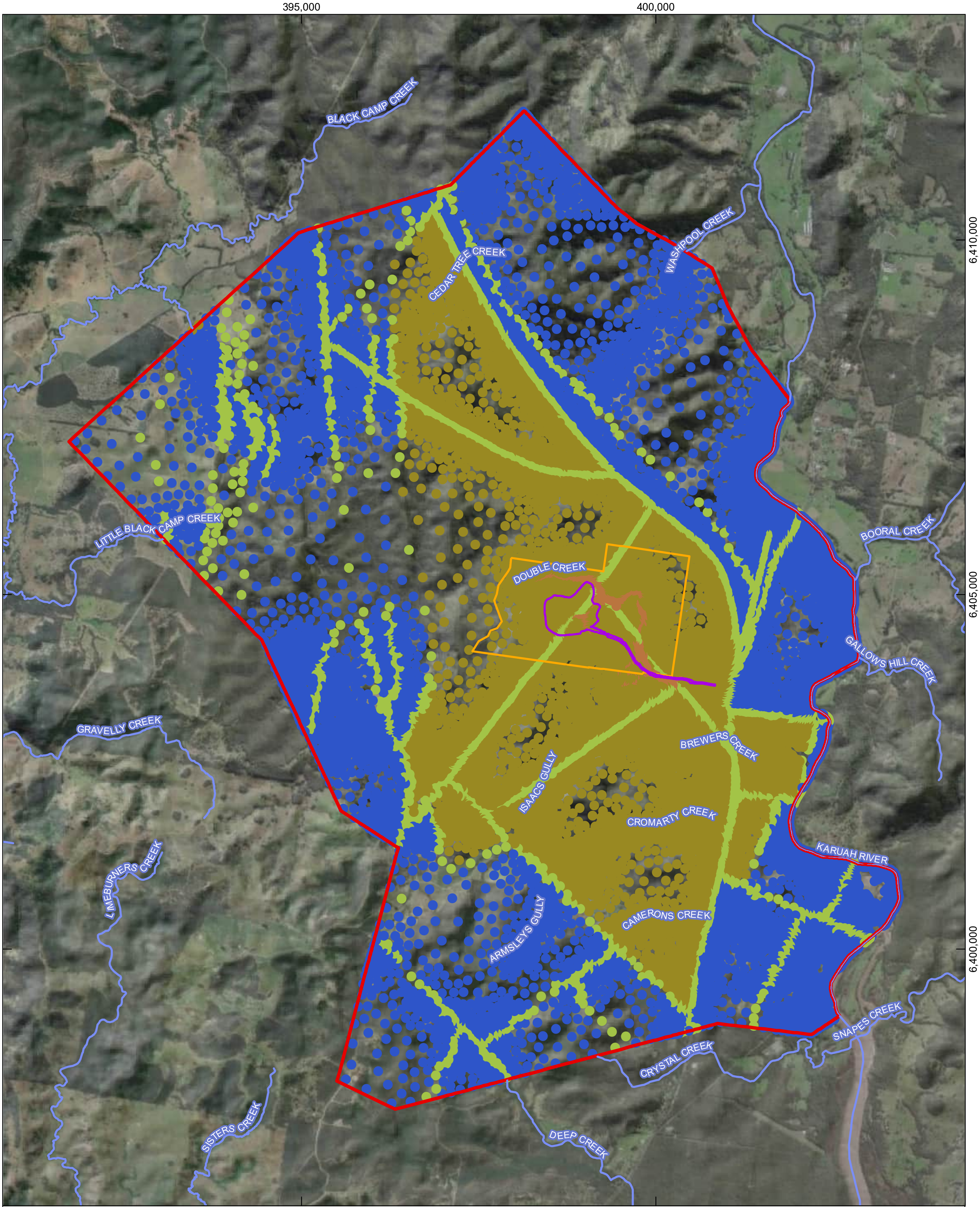
- 19 - Pyroclastic rock
- 20 - Sedimentary rock
- 21 - Fault zone

SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 6

FIGURE D-2f



0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:70,000 at A4
Project Number: 660.30262
Date: 23-Oct-2023
Drawn by: RB

Watercourse
Quarry Extent
Site Boundary
Model Extent

Geological Zone
- 22 - Pyroclastic rock
- 23 - Sedimentary rock
- 24 - Fault zone
- 27 - weathered pyroclastic rock along creeks

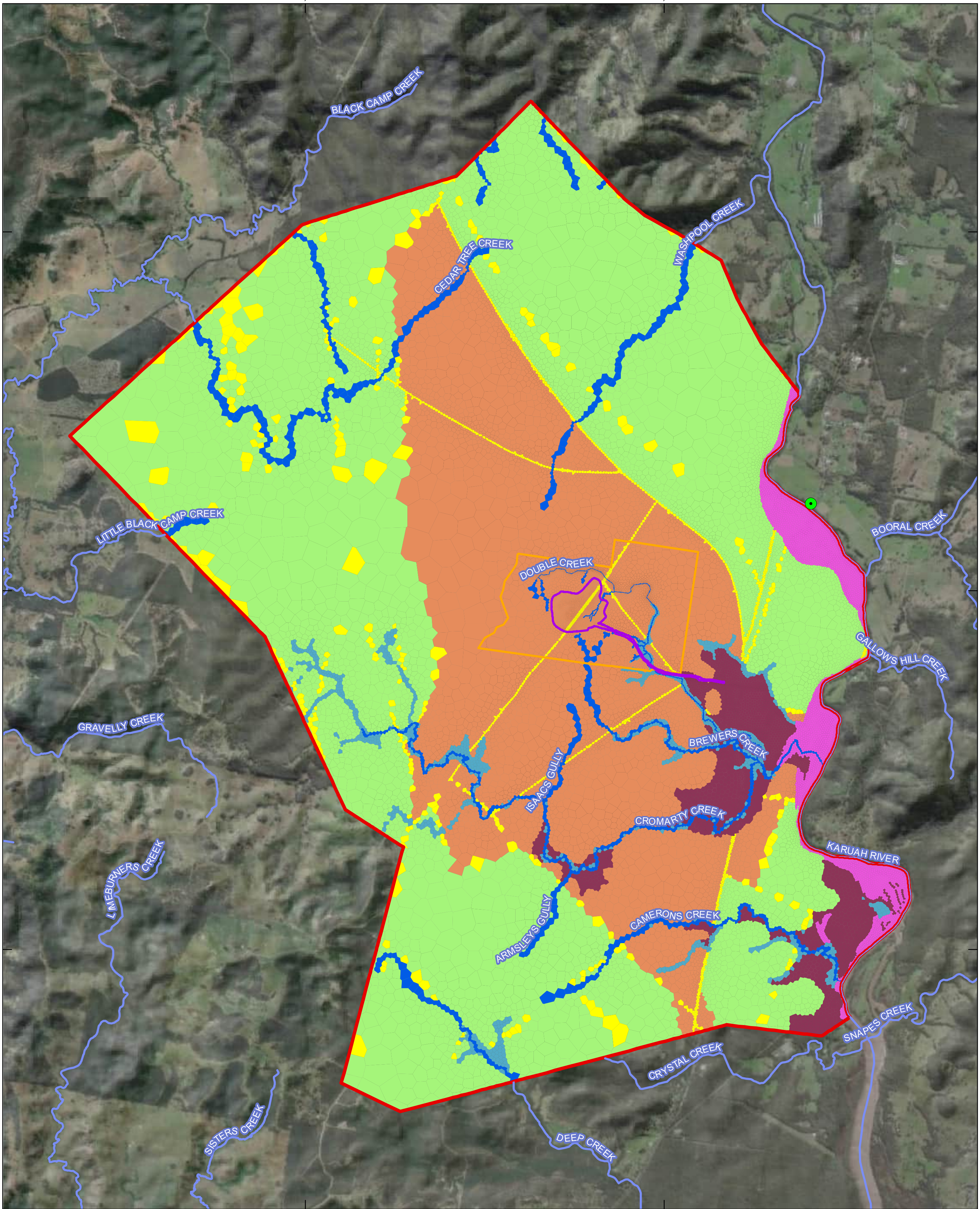
SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODEL GEOLOGICAL ZONES – LAYER 7

FIGURE D-2g

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-2g_Model Geological Zones Layer 7.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:70,000 at A4
Project Number:	660.30262
Date:	03-Aug-2023
Drawn by:	NT/RB

SLR

- BOM Station - Karuah River at Booral
- Watercourse
- River Cell
- Quarry Extent
- Site Boundary
- Model Extent

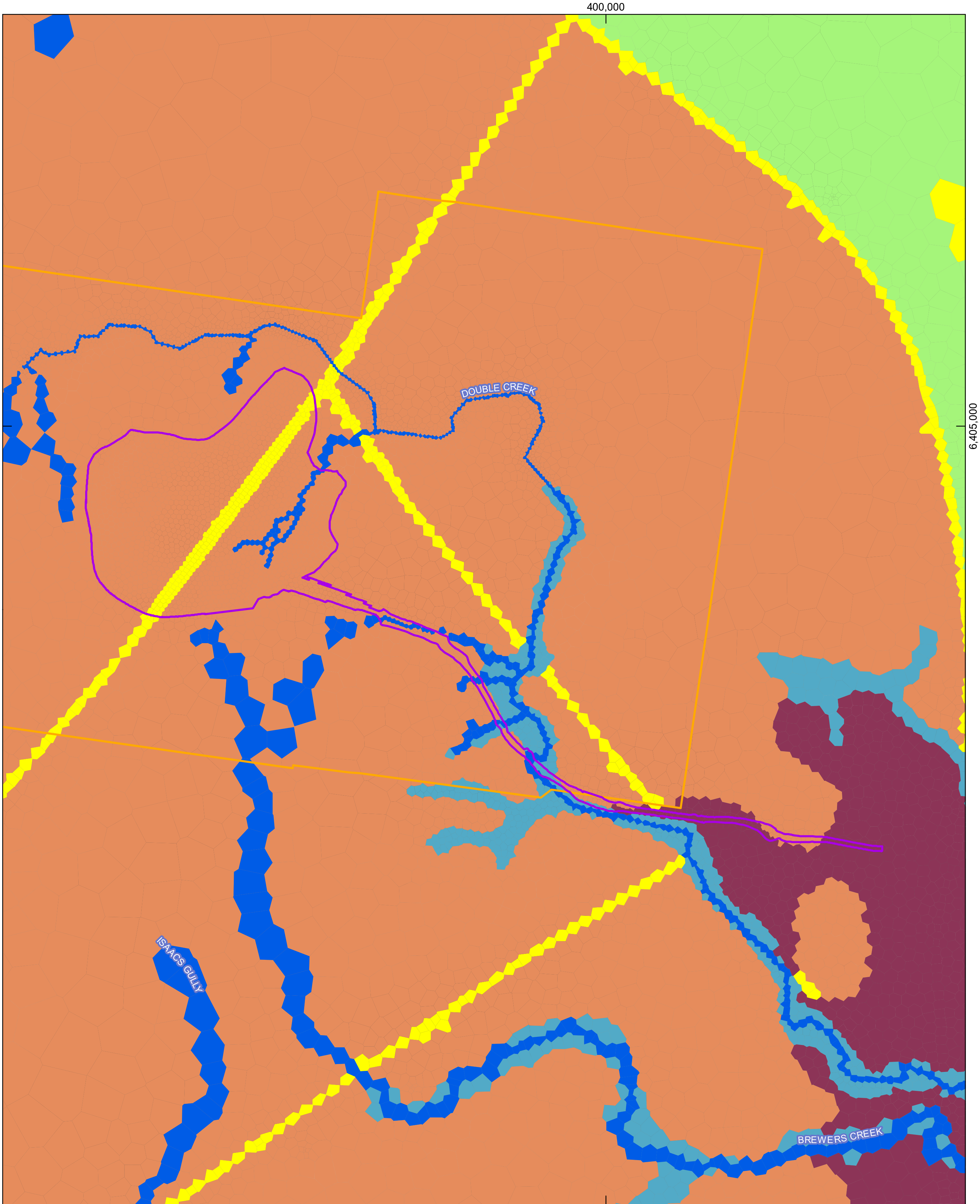
Recharge Zone
- Regolith (Pyroclastic rock)
- Regolith (Sedimentary rock)
- Alluvium high productivity
- Alluvium medium productivity
- Alluvium low productivity
- Regolith (Fault zone)

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODELLED RECHARGE ZONES AND RIVER CELLS IN MODEL AREA

FIGURE D-3

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-3_Recharge Zones River Cells in Model Area.mxd



0 0.25 0.5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:15,000 at A4
Project Number:	660.30262
Date:	03-Aug-2023
Drawn by:	NT/RB

SLR

- Watercourse
- River Cell
- Quarry Extent
- Site Boundary

Recharge Zone

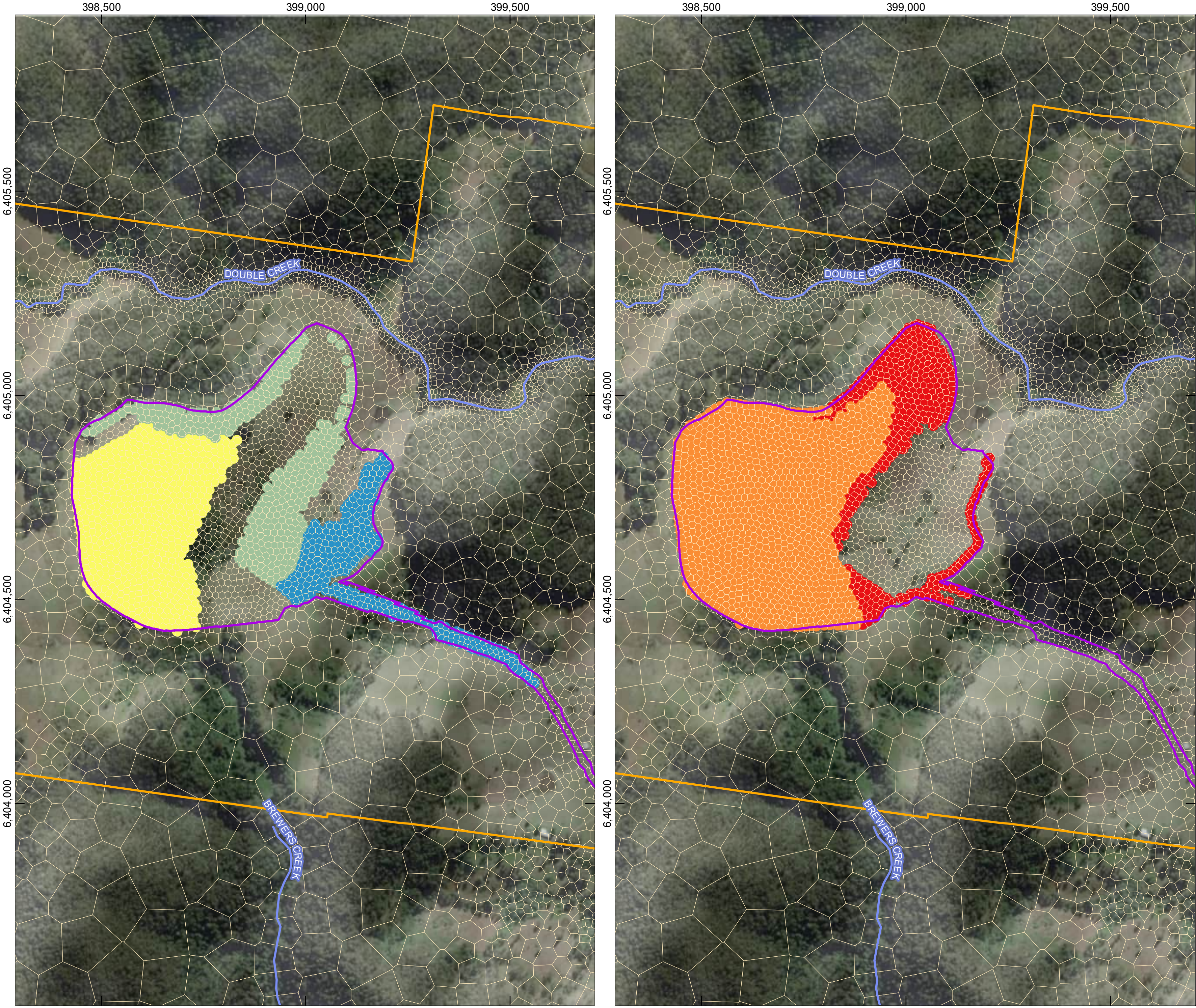
- Regolith (Pyroclastic rock)
- Regolith (Sedimentary rock)
- Alluvium high productivity
- Alluvium medium productivity
- Alluvium low productivity
- Regolith (Fault zone)

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODELLED RECHARGE ZONES AND RIVER CELLS IN PIT AREA

FIGURE D-4

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-4_Recharge Zones River Cells in Pit Area.mxd



HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MINING PROGRESSION

FIGURE D-5

Watercourse
Quarry Extent
Site Boundary
Model Extent
Model Grid

Mining progression

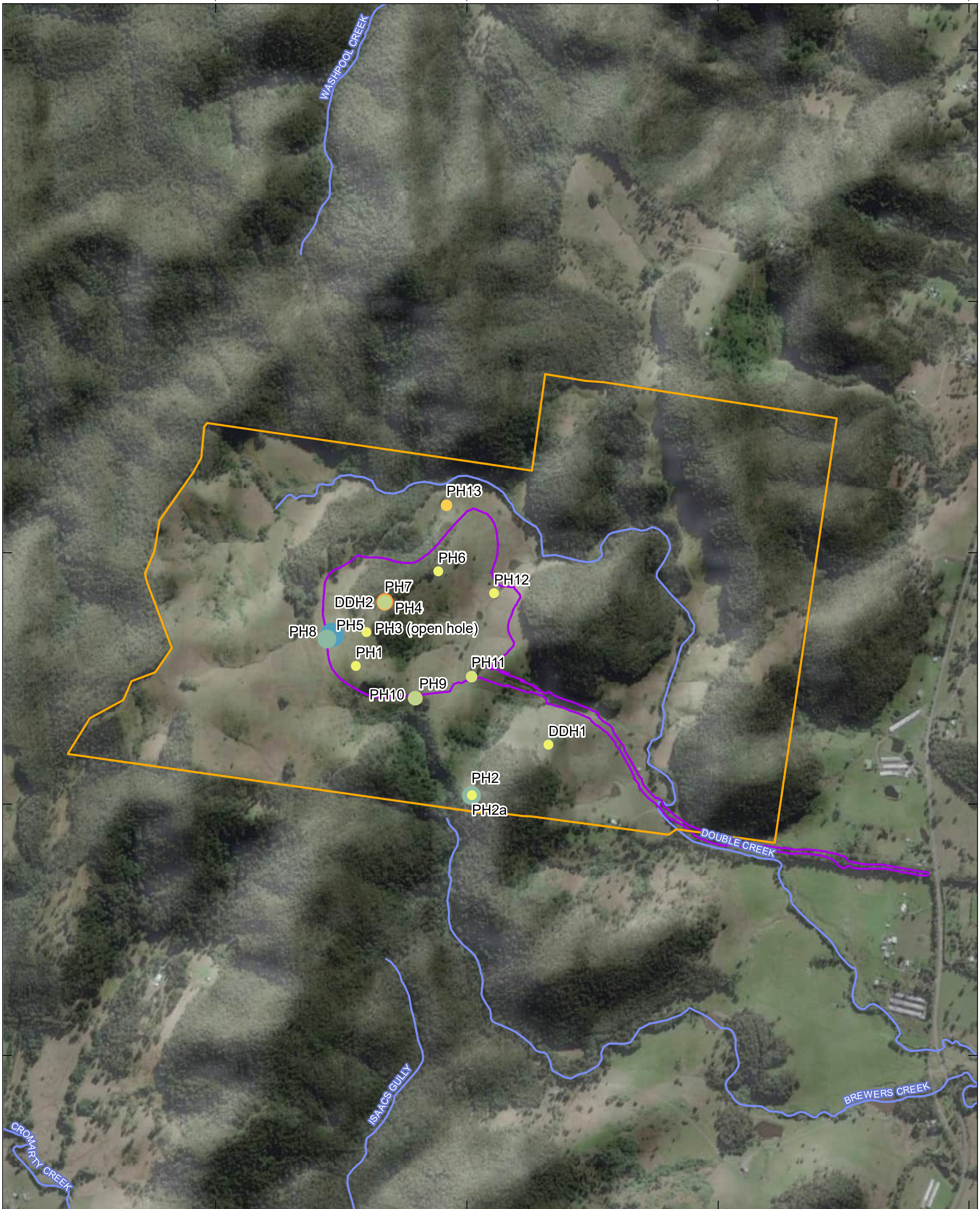
Stage 1/2
Stage 3/4
Stage 5
Stage 6
Stage 7

0 100 200 M

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:12,500 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	NT/RB

SLR

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-5_Mine Progression.mxd



0 250 500 m

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:20,000 at A4
Project Number:	660.30262
Date:	04-Aug-2023
Drawn by:	NT/RB

SLR

Watercourse
Quarry Extent
Site Boundary
Model Extent

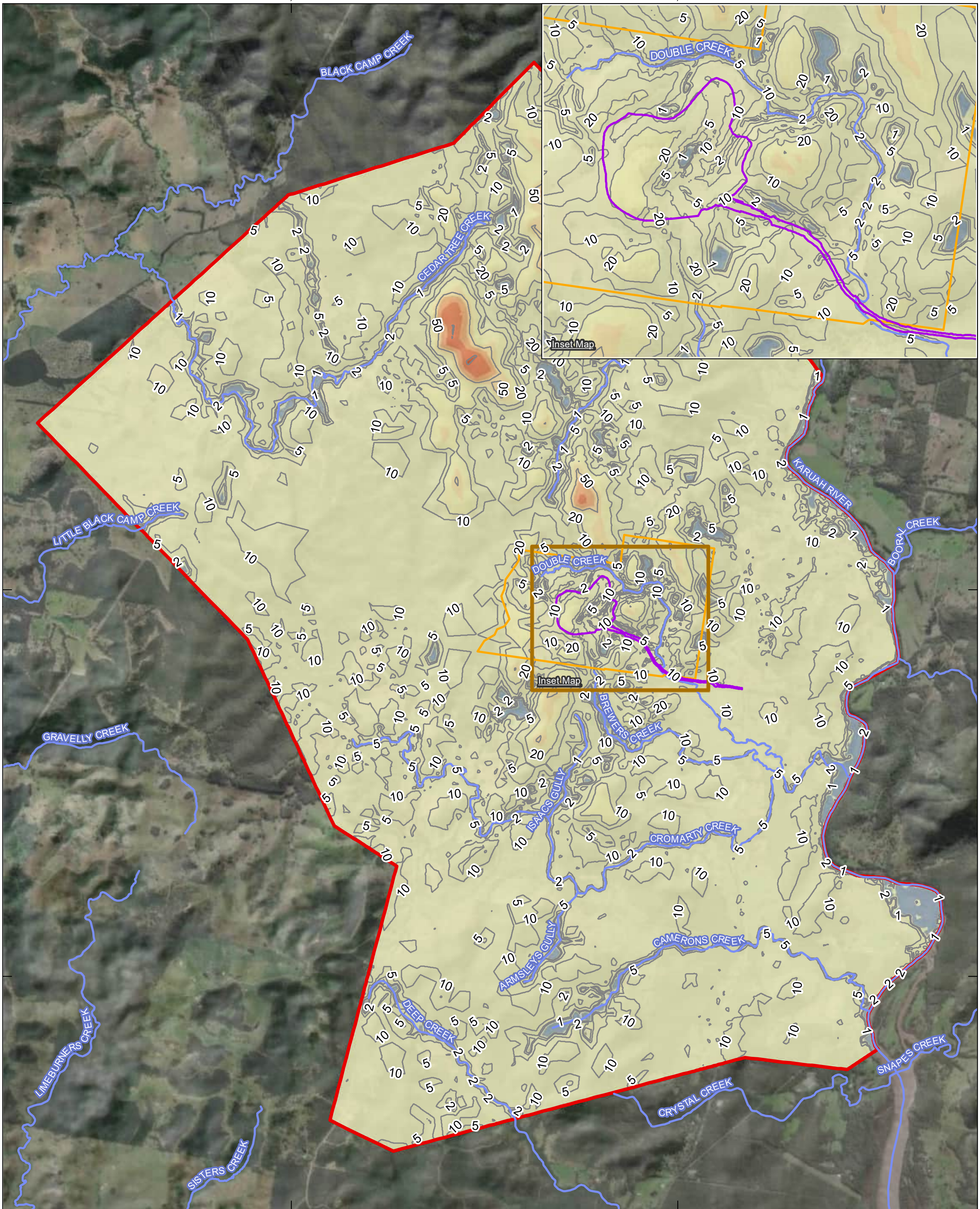
Residual (m)
-14 - -12
-12 - -10
-10 - -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

TRANSIENT CALIBRATION AVERAGE HEAD RESIDUALS

FIGURE D-6

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-6_Transient Calibration Residuals.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	04-Aug-2023
Drawn by:	NT/RB

Depth Contour (m)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Depth to Water Table (m)

-60 - -40	40 - 60
-40 - -20	60 - 80
-20 - 0	80 - 100
0 - 20	100 - 120
20 - 40	120 - 140

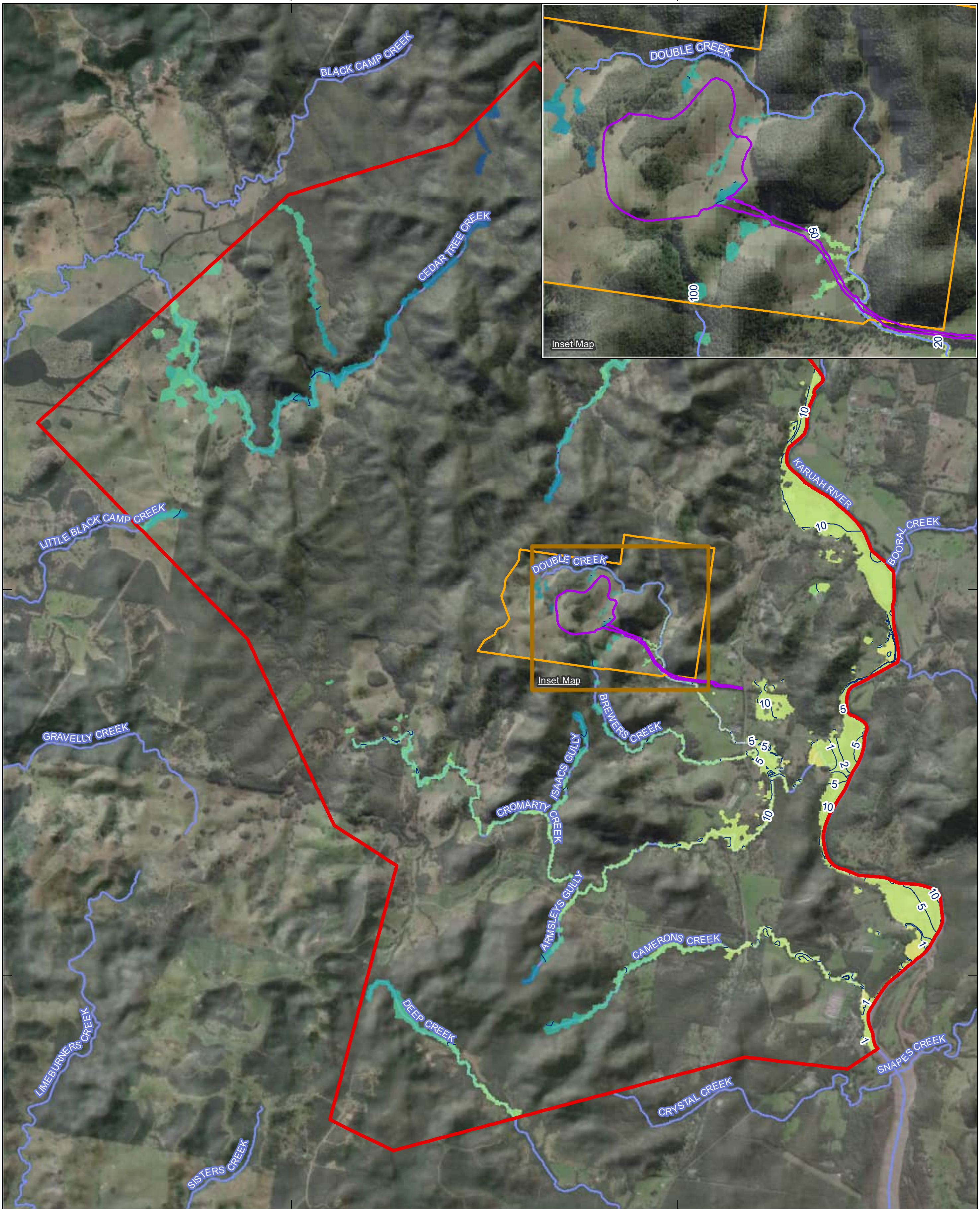
SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

SIMULATED DEPTH TO WATER TABLE – END OF CALIBRATION (2023)

FIGURE D-7

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-7_Simulated Depth to WT.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	NT/RB

SLR

Groundwater Contour (mAHD)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Groundwater Elevation (mAHD)

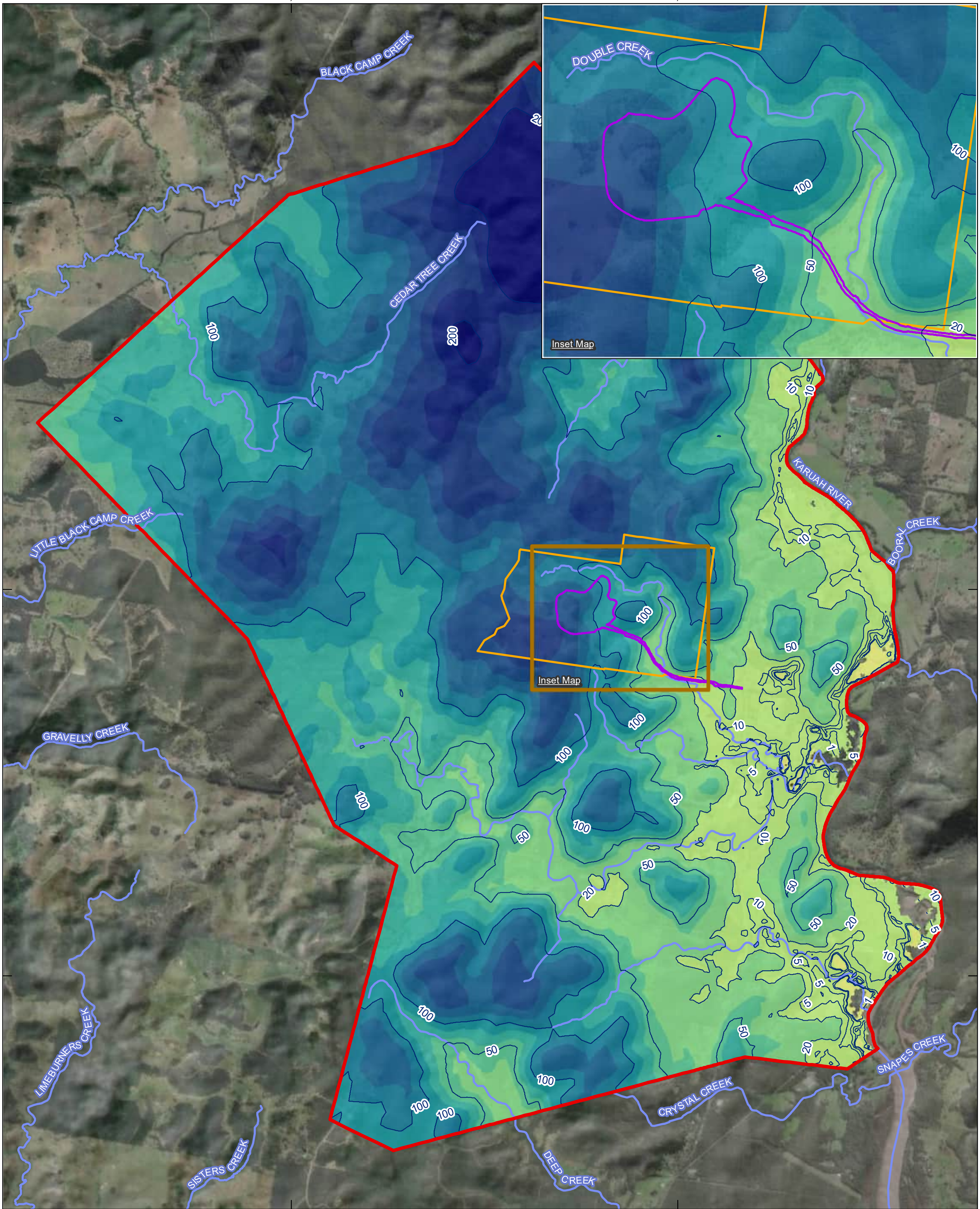
-10 - 0	140 - 160
0 - 20	160 - 180
20 - 40	180 - 200
40 - 60	200 - 220
60 - 80	220 - 240
80 - 100	240 - 260
100 - 120	260 - 280
120 - 140	

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MODELED GROUNDWATER LEVELS ALLUVIUM AND REGOLITH – END OF CALIBRATION (2023)

FIGURE D-8

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-8_Modeled GWL Alluvium and Regolith EoCal.mxd



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-9_Modeled GWL Bedrock EoCal.mxd

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	04-Aug-2023
Drawn by:	NT/RB

SLR

- Groundwater Contour (mAHD)
- Watercourse
- Quarry Extent
- Site Boundary
- Model Extent

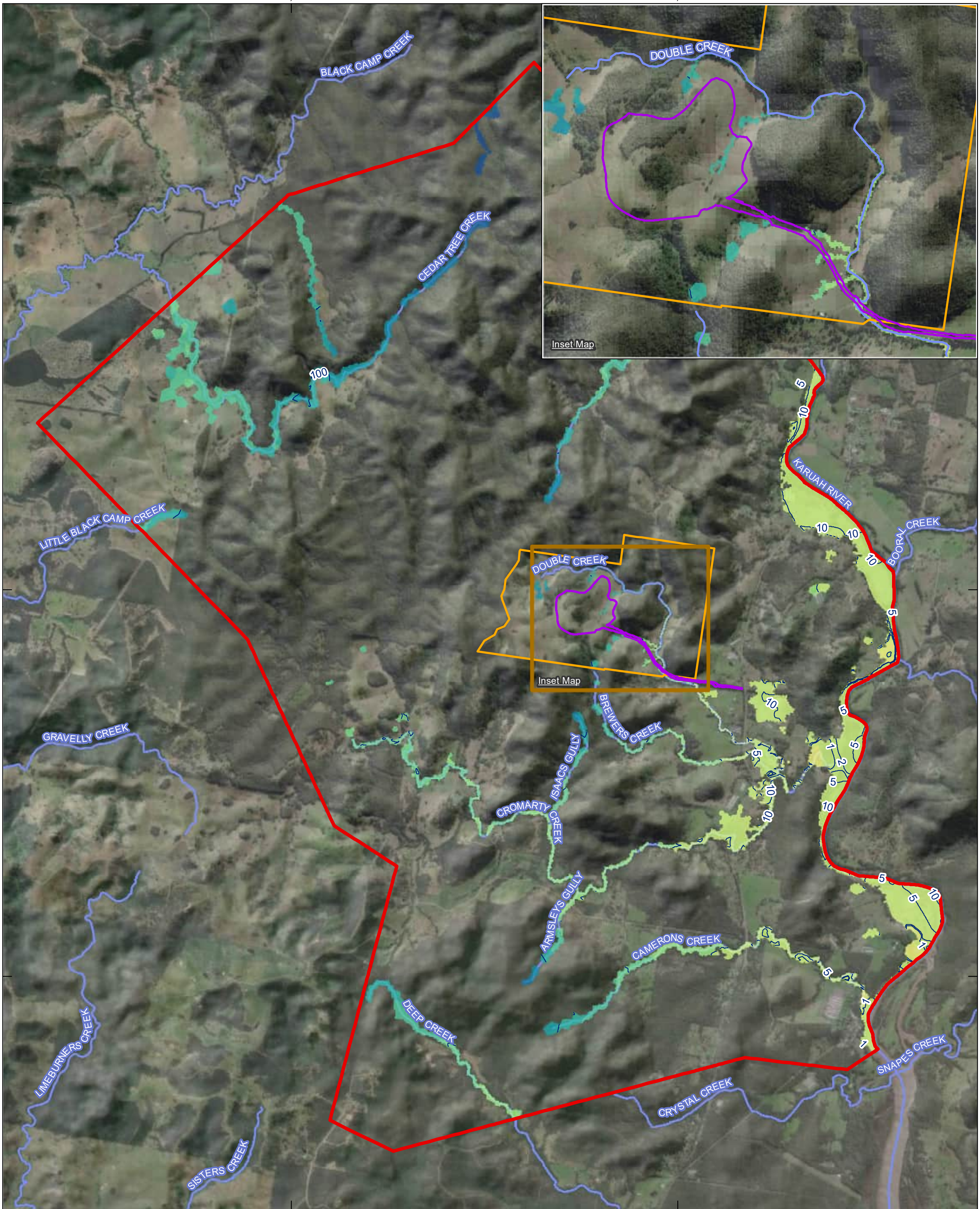
Groundwater Elevation (mAHD)

-10 - 0	100 - 120
0 - 20	120 - 140
20 - 40	140 - 160
40 - 60	160 - 180
60 - 80	180 - 200
80 - 100	200 - 220

HILLVIEW QUARRY
GROUNDWATER ASSESSMENT

MODELED GROUNDWATER LEVELS IN BEDROCK – END OF CALIBRATION (2023)

FIGURE D-9



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	04-Aug-2023
Drawn by:	NT/RB

SLR

Groundwater Contour (mAHD)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Groundwater Elevation (mAHD)

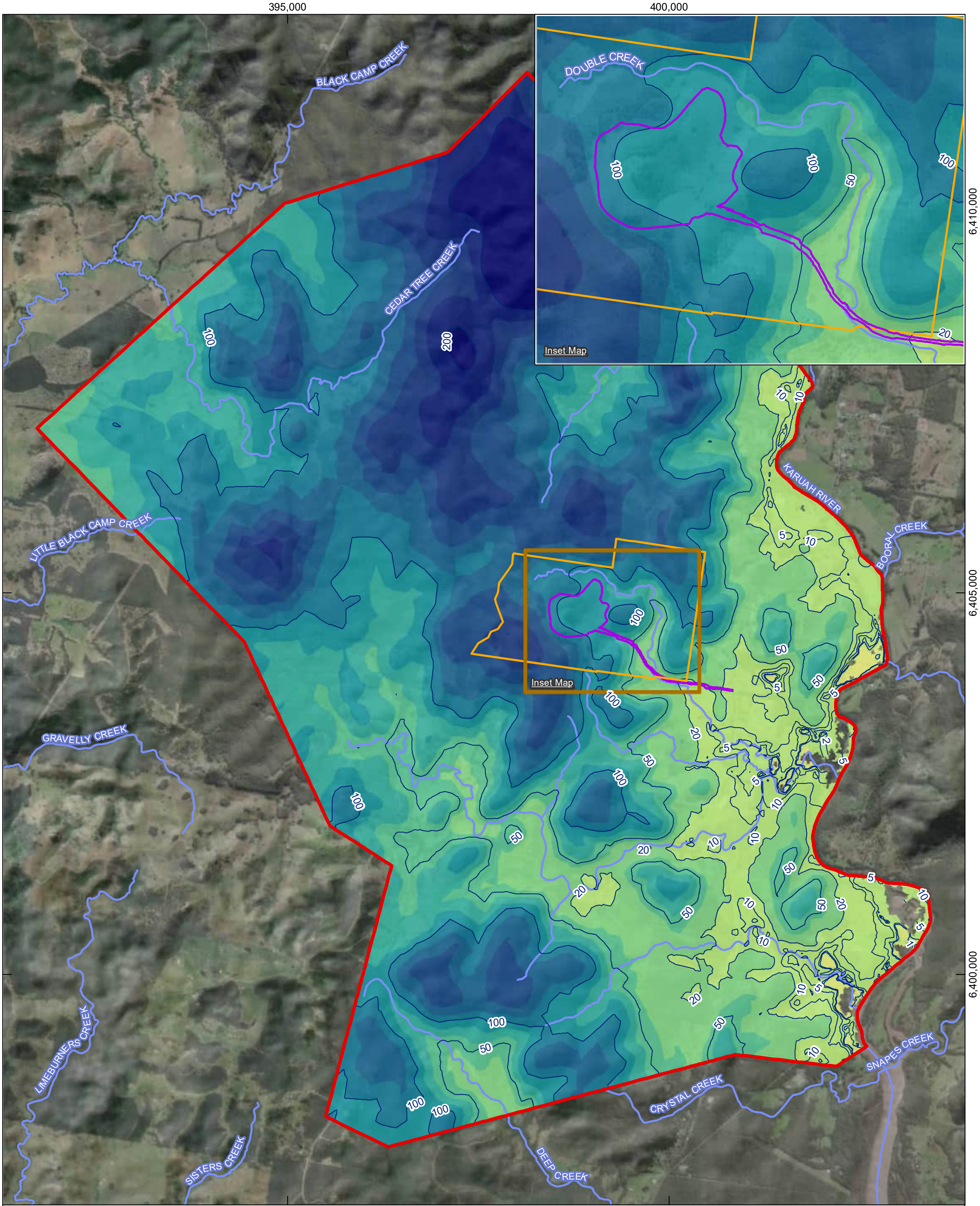
-10 - 0
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140
140 - 160
160 - 180
180 - 200
200 - 220
220 - 240
240 - 260
260 - 280

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

SIMULATED GROUNDWATER LEVELS IN THE ALLUVIUM AND REGOLITH – END OF MINING (2053)

FIGURE D-10

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-10_Simulated GWL Alluvium and Regolith EoM.mxd



Groundwater Contour (mAHD)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Groundwater Elevation (mAHD)

-10 - 0	100 - 120
0 - 20	120 - 140
20 - 40	140 - 160
40 - 60	160 - 180
60 - 80	180 - 200
80 - 100	200 - 220

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	NT/RB

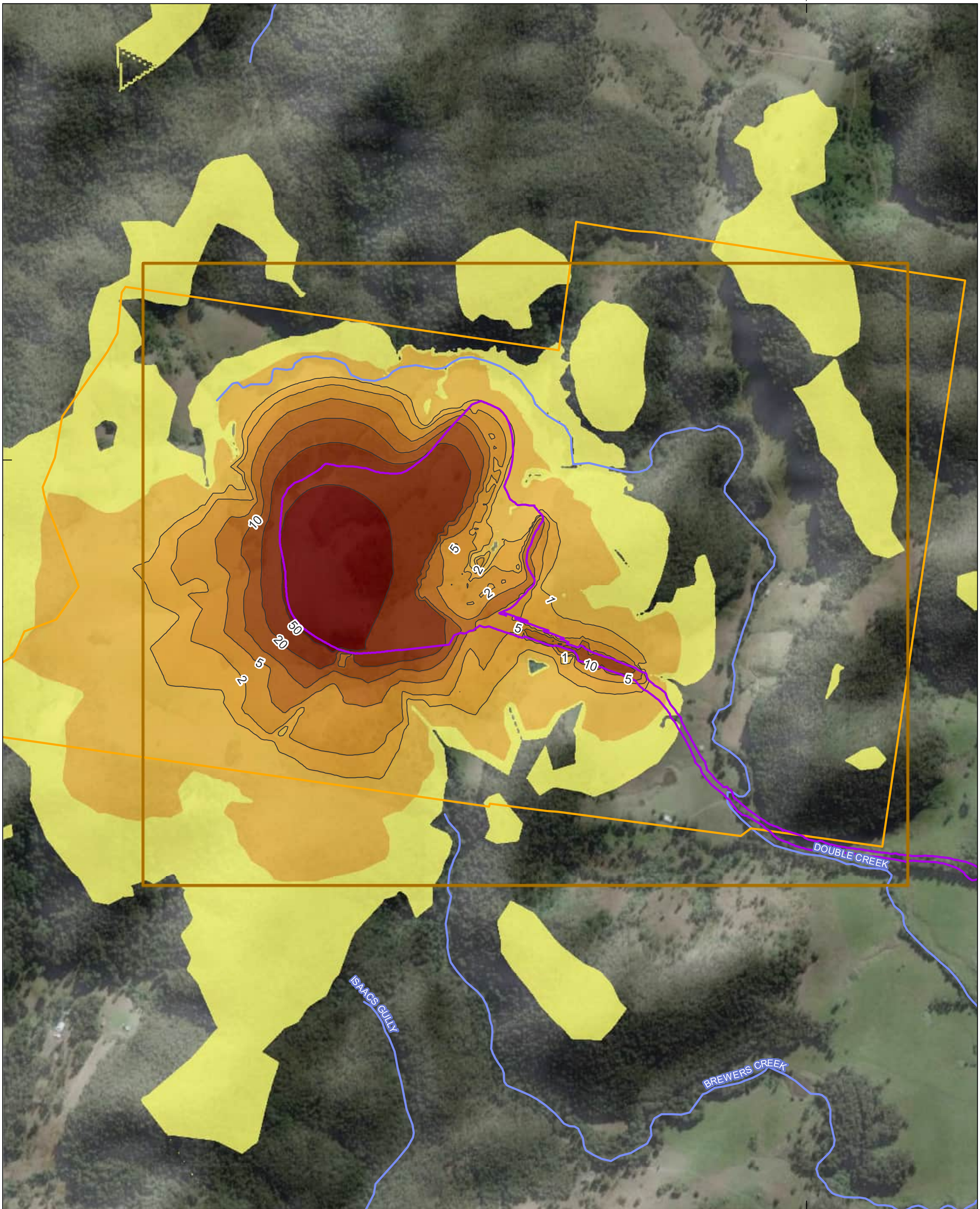
SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

SIMULATED GROUNDWATER LEVELS IN BEDROCK – END OF MINING (2053)

FIGURE D-11

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-11_Simulated GWL Bedrock EoM.mxd



0 0.25 0.5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:15,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	NT/RB

SLR

Drawdown Contour (m)
Watercourse
Quarry Extent
Site Boundary
Model Extent

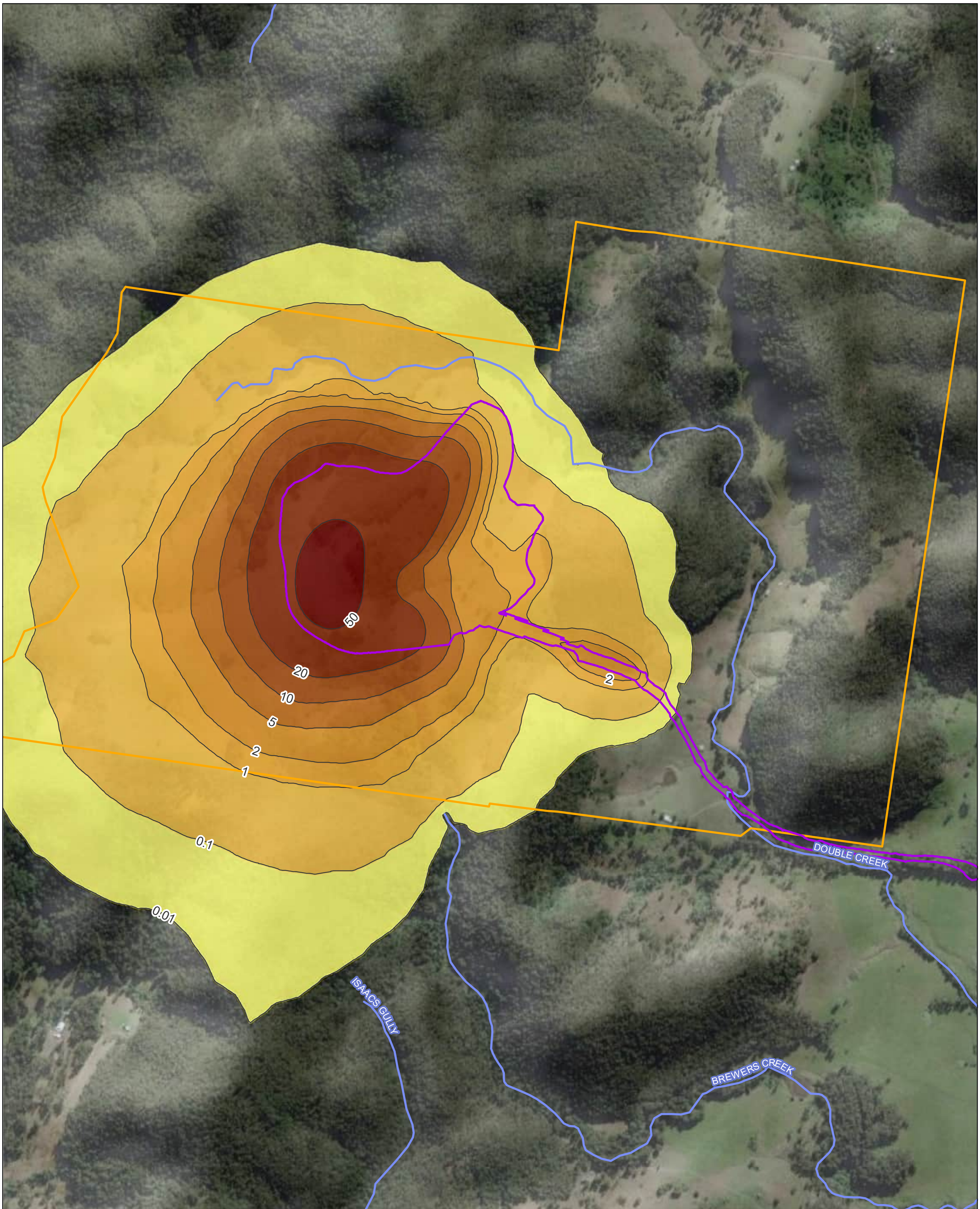
Drawdown (m)
0.01 - 0.1
0.1 - 1
1 - 2
2 - 5
5- 10
10 - 20
20 - 50
> 50

HILLVIEW QUARRY
GROUNDWATER ASSESSMENT

MAXIMUM DRAWDOWN
IN BEDROCK
– END OF MINING (2053)

FIGURE D-12

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-12_Max Drawdown Bedrock EoM.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:15,000 at A4
Project Number:	660.30262
Date:	20-Nov-2023
Drawn by:	NT/RB

SLR

Drawdown Contour (m)
Watercourse
Quarry Extent
Site Boundary
Model Extent

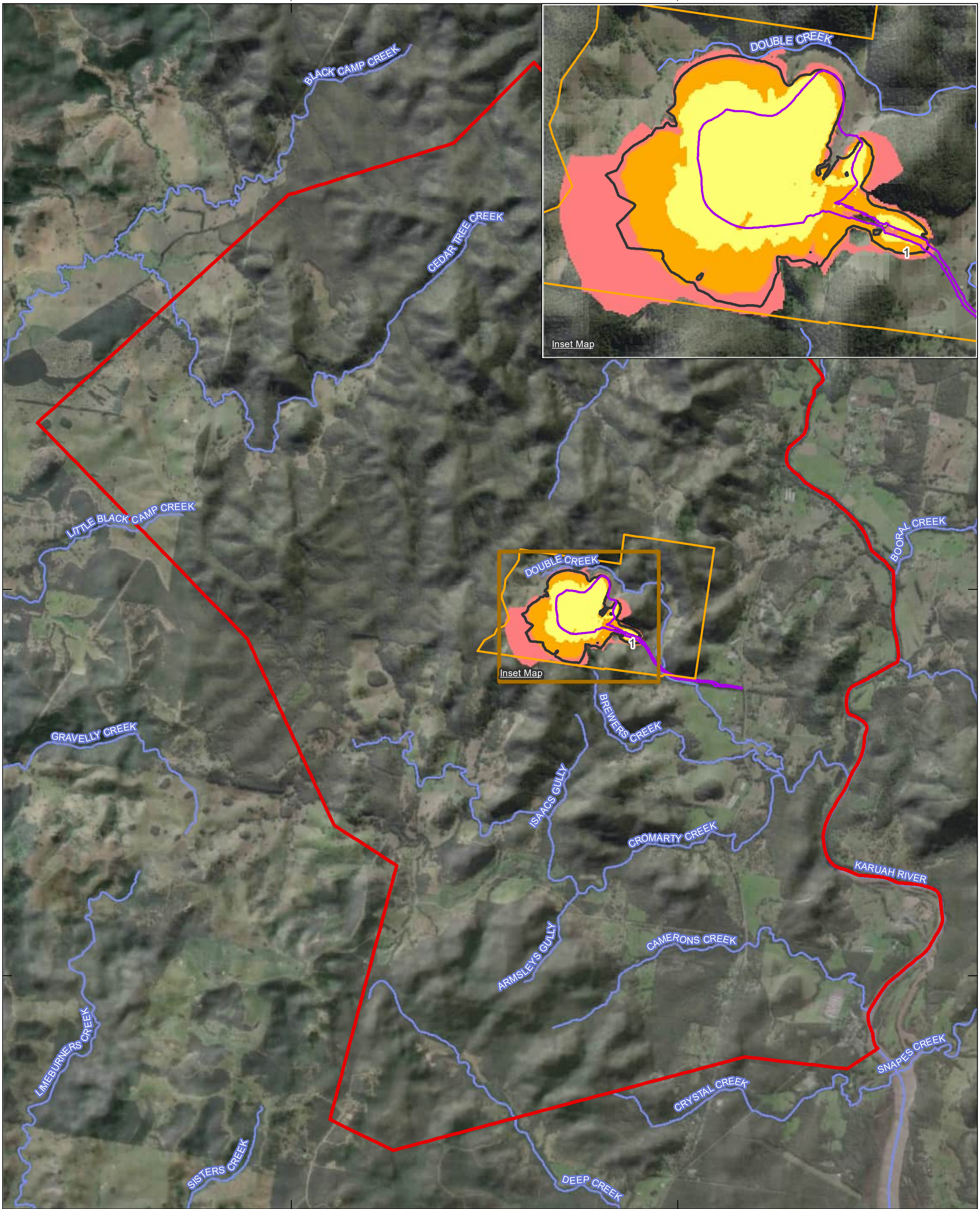
Drawdown (m)
0.01 - 0.1
0.1 - 1
1 - 2
2 - 5
5- 10
10 - 20
20 - 50
> 50

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MAXIMUM DRAWDOWN IN BEDROCK (LAYER 7) – END OF MINING (2053)

FIGURE D-13

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_XX_Max Drawdown Bedrock Layer 7 EoM.mxd



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-13_Uncertainty in Predicted 1 m maximum drawdown in fractured rock.mxd

0 1 2 km

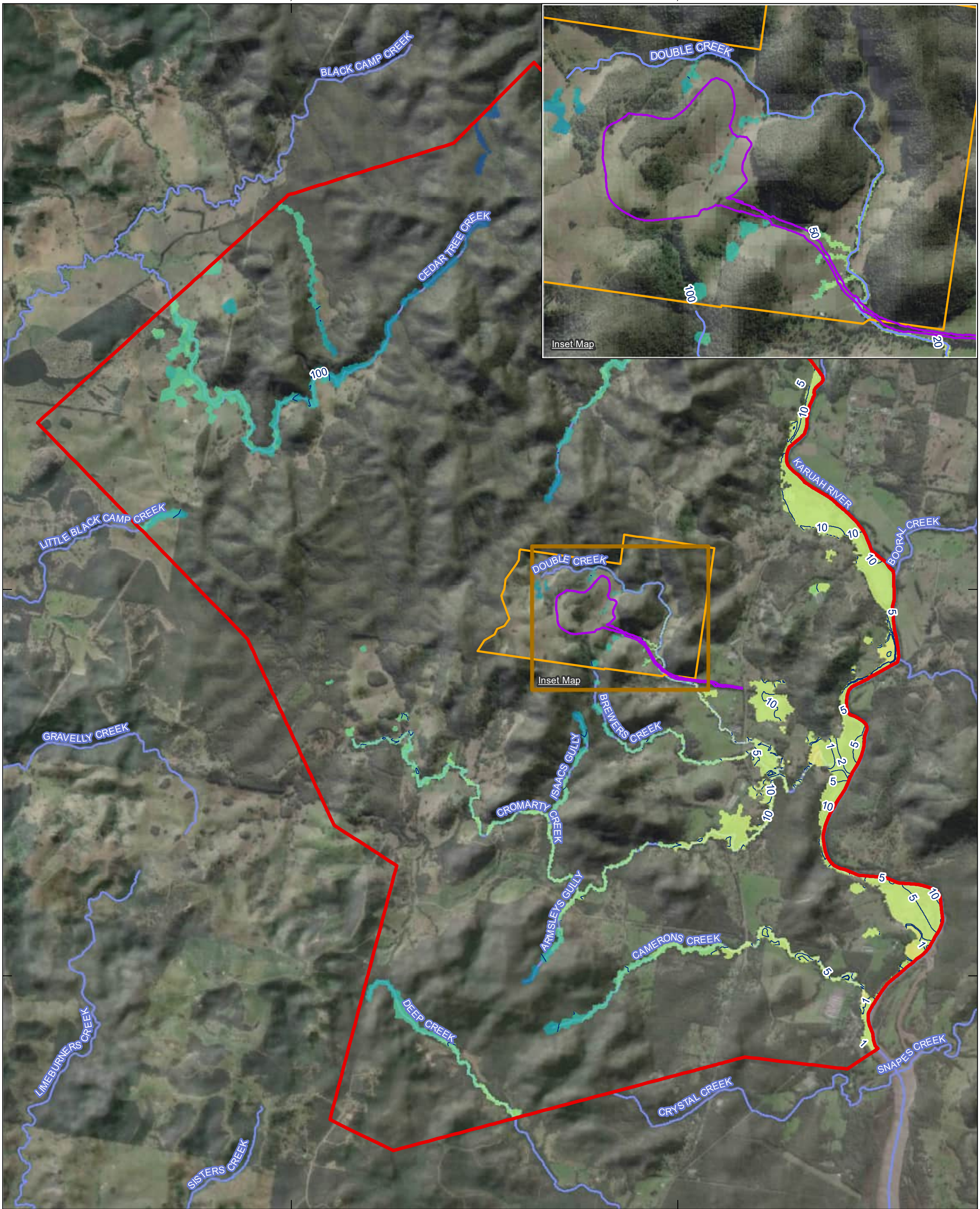
Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	19-Oct-2023
Drawn by:	RB

Watercourse
Quarry Extent
Site Boundary
Model Extent
Calibrated Predicted Model
5th Percentile
50th Percentile
95th Percentile

HILLVIEW QUARRY
GROUNDWATER ASSESSMENT

UNCERTAINTY IN PREDICTED 1 M MAXIMUM DRAWDOWN IN FRACTURED ROCK (LAYER 1)

FIGURE D-14



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	07-Aug-2023
Drawn by:	RB

0 1 2 km

Groundwater Contour (mAHD)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Groundwater Elevation (mAHD)

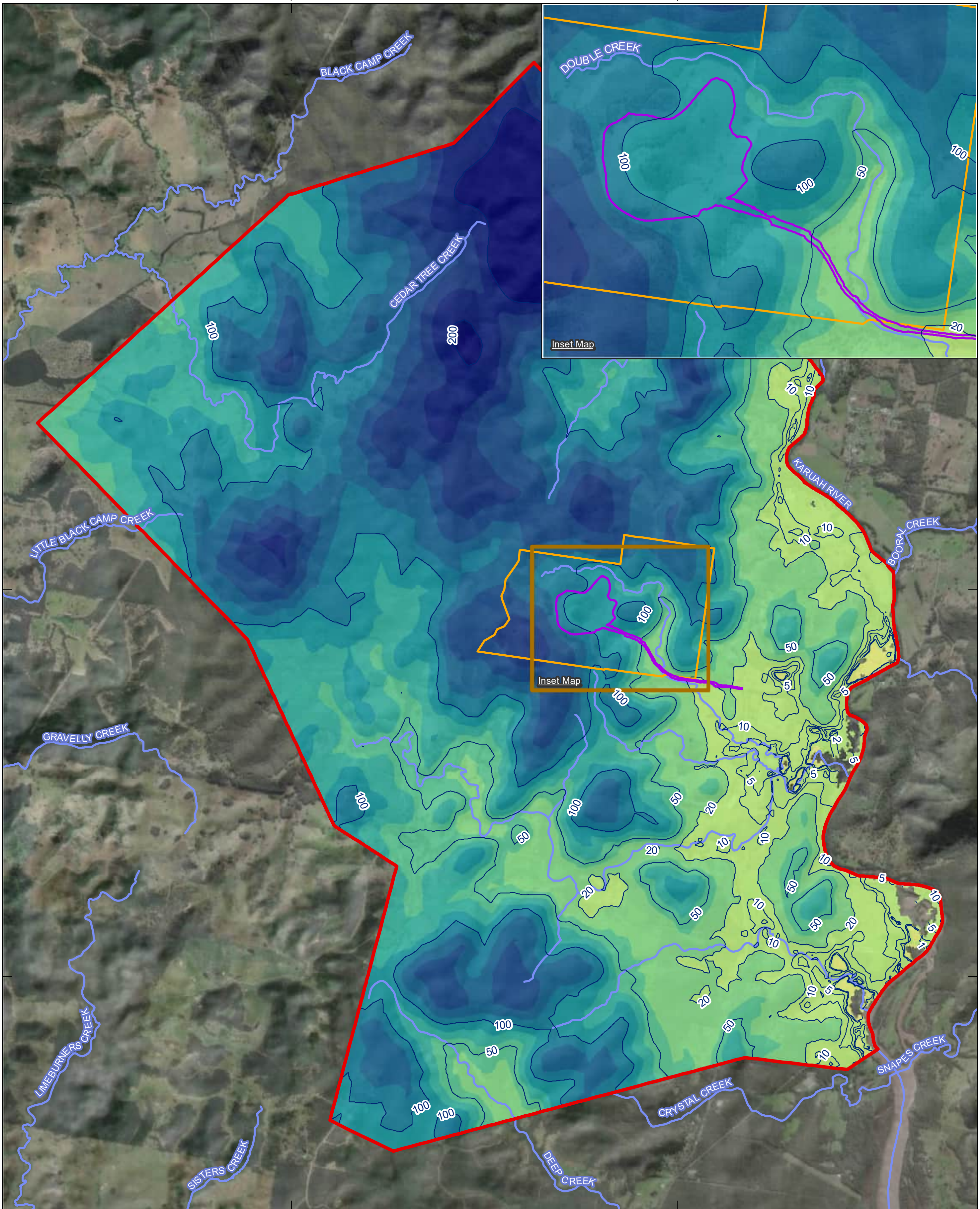
-10 - 0	140 - 160
0 - 20	160 - 180
20 - 40	180 - 200
40 - 60	200 - 220
60 - 80	220 - 240
80 - 100	240 - 260
100 - 120	260 - 280
120 - 140	

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

PREDICTED GROUNDWATER LEVELS ALLUVIUM – POST MINING EQUILIBRIUM

FIGURE D-15

H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-14_Predicted GWL Alluvium and Regolith Post Mining Equilibrium.mxd



H:\Projects-SLR\660-SrvWOL\660-WOL\660.30262.00000 Hillview Quarry Groundwater Assessment\06 SLR Data\01 CADGIS\GIS\Appendix\66030262_Appendix_D-15_Predicted GWL Bedrock Post Mining Equilibrium.mxd

0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	660.30262
Date:	04-Aug-2023
Drawn by:	RB

Groundwater Contour (mAHD)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Groundwater Elevation (mAHD)

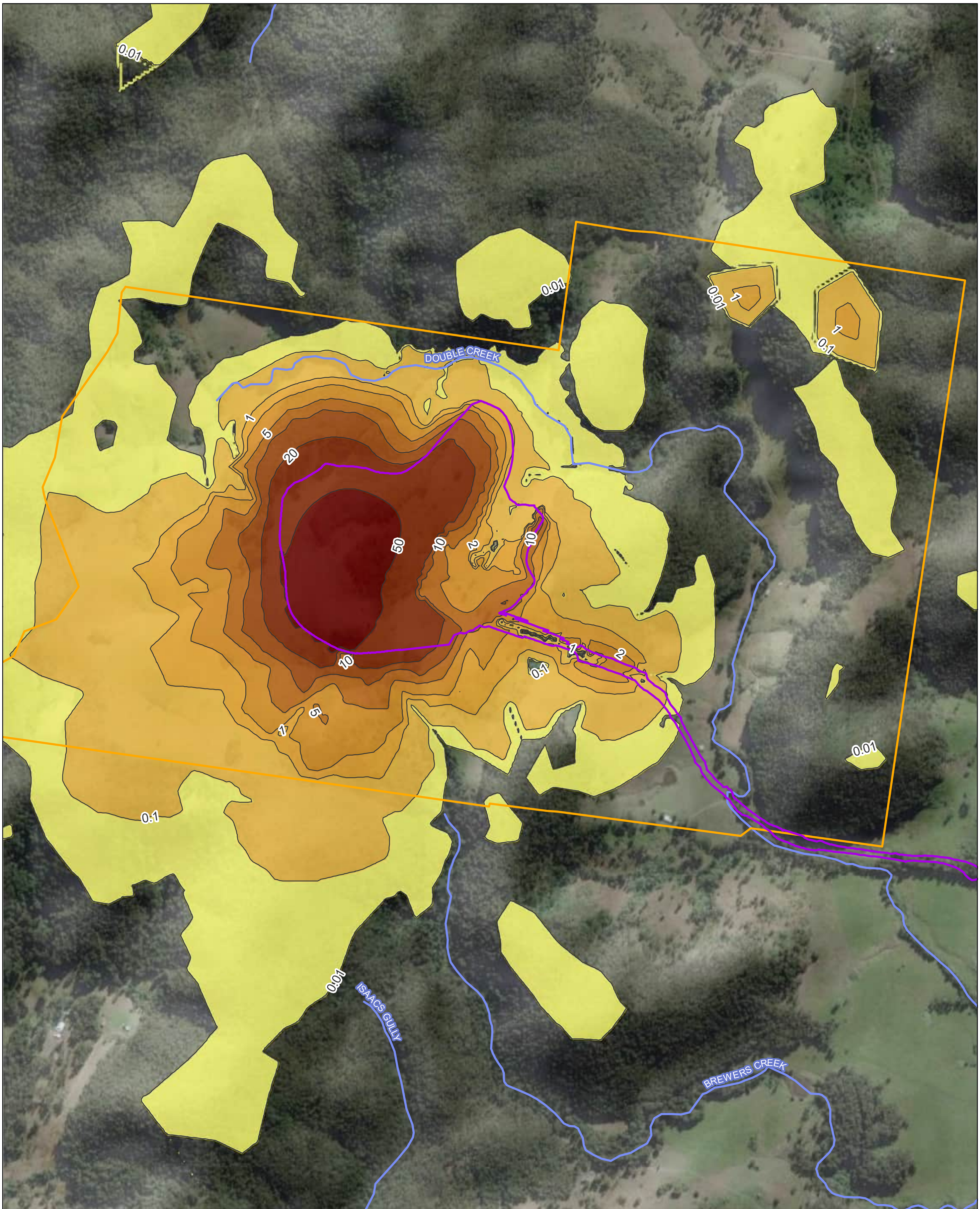
-10 - 0
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140
140 - 160
160 - 180
180 - 200
200 - 220

SLR

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

PREDICTED GROUNDWATER LEVELS IN BEDROCK – POST MINING EQUILIBRIUM

FIGUR E D 16



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0 0.25 0.5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:15,000 at A4
Project Number:	660.30262
Date:	20-Nov-2023
Drawn by:	NT/RB

SLR

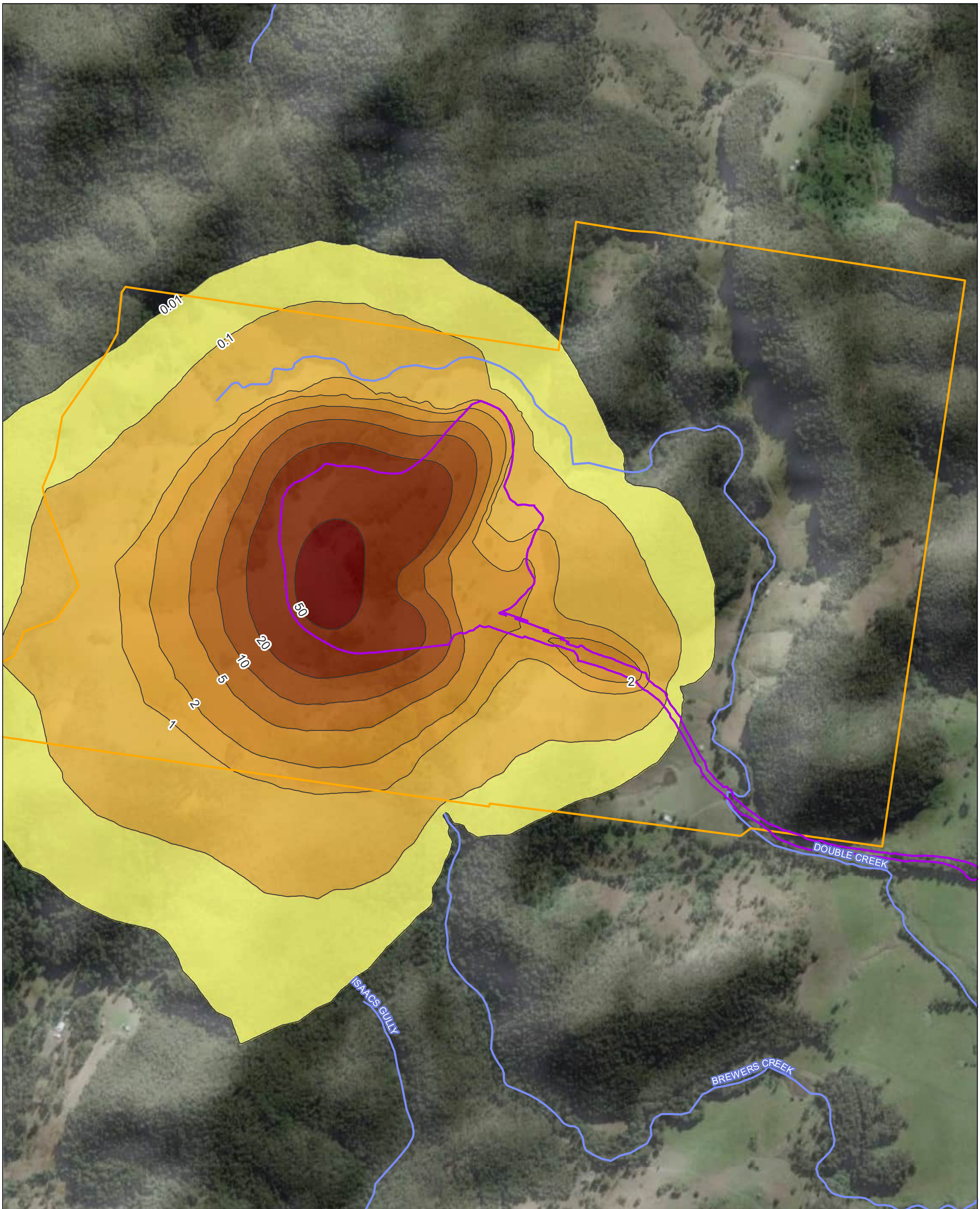
Drawdown Contour (m)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Drawdown (m)
- 0.01 - 0.1
- 0.1 - 1
- 1 - 2
- 2 - 5
- 5- 10
- 10 - 20
- 20 - 50
- > 50

HILLVIEW QUARRY
GROUNDWATER ASSESSMENT

MAXIMUM DRAWDOWN IN BEDROCK (WATER TABLE) – POST QUARRYING (2522)

FIGURE D-17



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0 0.25 0.5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:15,000 at A4
Project Number:	660.30262
Date:	20-Nov-2023
Drawn by:	NT/RB

SLR

Drawdown Contour (m)
Watercourse
Quarry Extent
Site Boundary
Model Extent

Drawdown (m)
- 0.01 - 0.1
- 0.1 - 1
- 1 - 2
- 2 - 5
- 5- 10
- 10 - 20
- 20 - 50
- > 50

HILLVIEW QUARRY GROUNDWATER ASSESSMENT

MAXIMUM DRAWDOWN IN BEDROCK (LAYER 7) – POST QUARRYING (2522)

FIGURE D-18

Appendix E Uncertainty Analysis Realisations

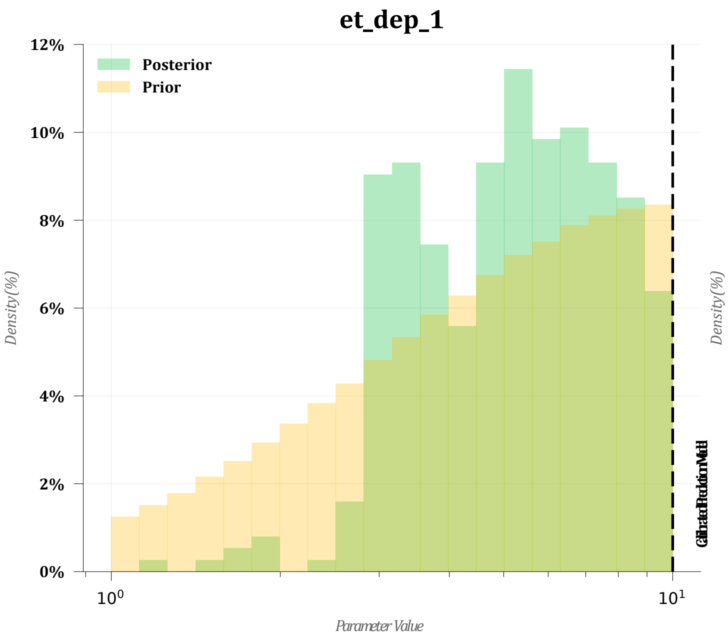
Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024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Prior
Density(%)
Parameter Value
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6%
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12%
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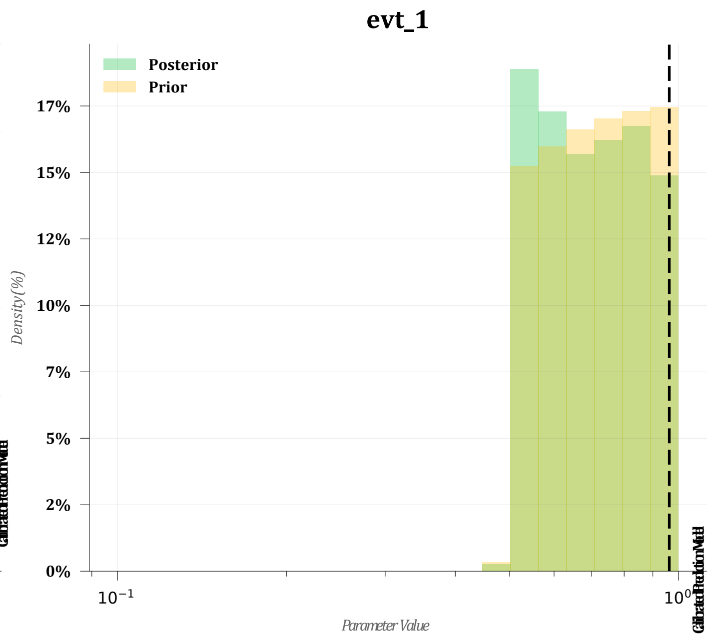
10^1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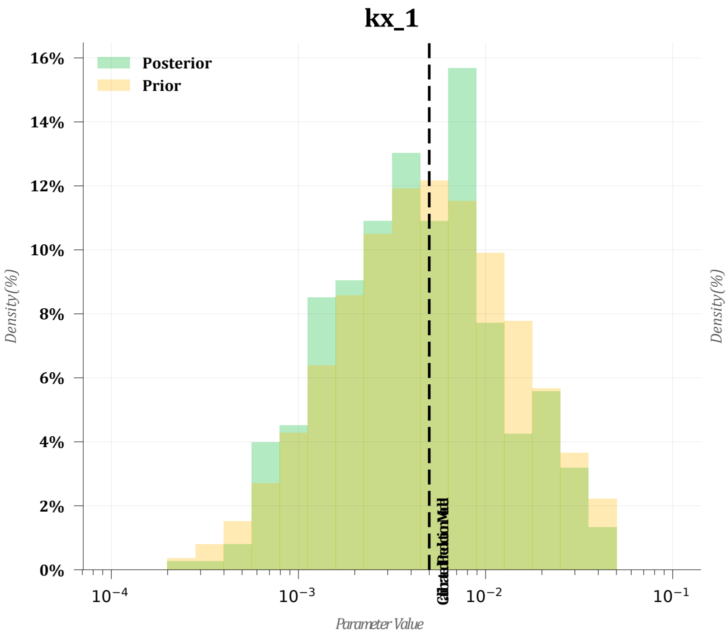
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Prior
Density(%)
Parameter Value
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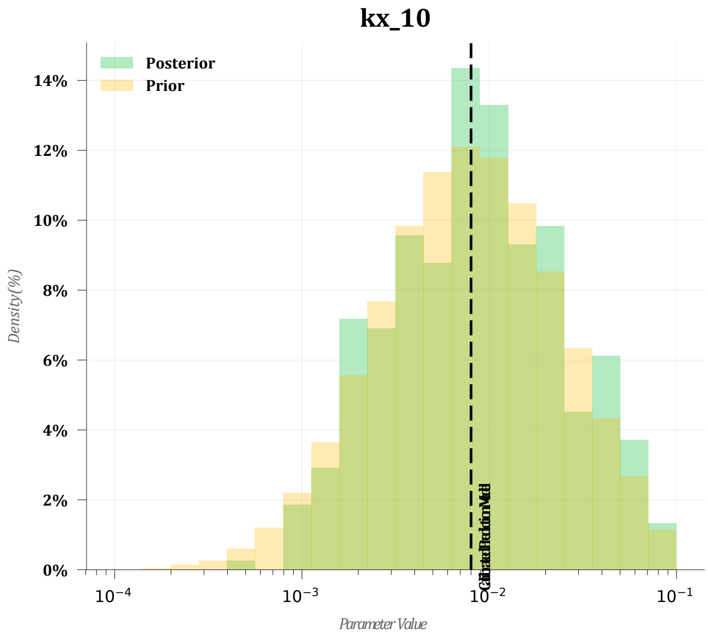
10^{-3}
10^{-2}
10^{-1}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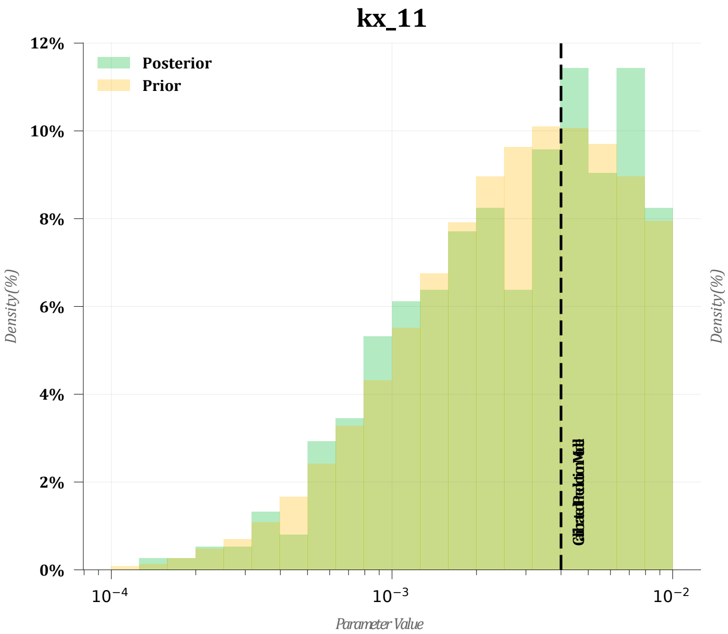
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Prior
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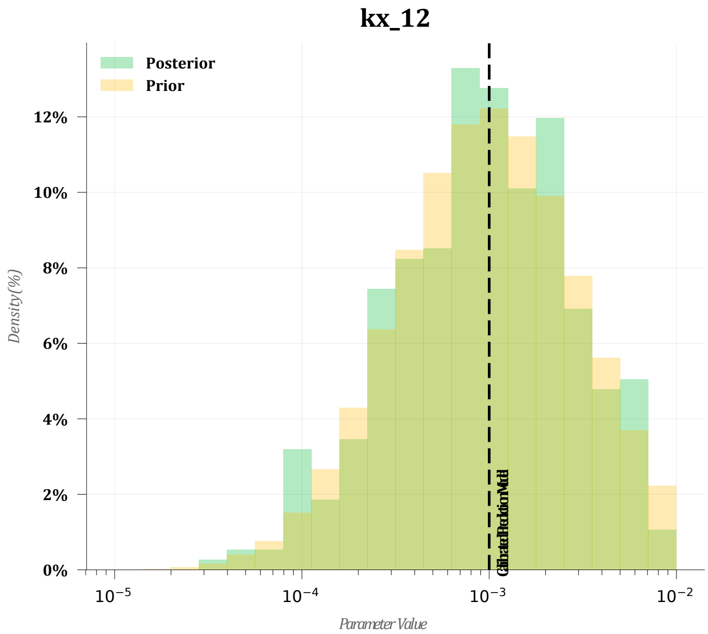
10^{-2}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Prior
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Parameter Value
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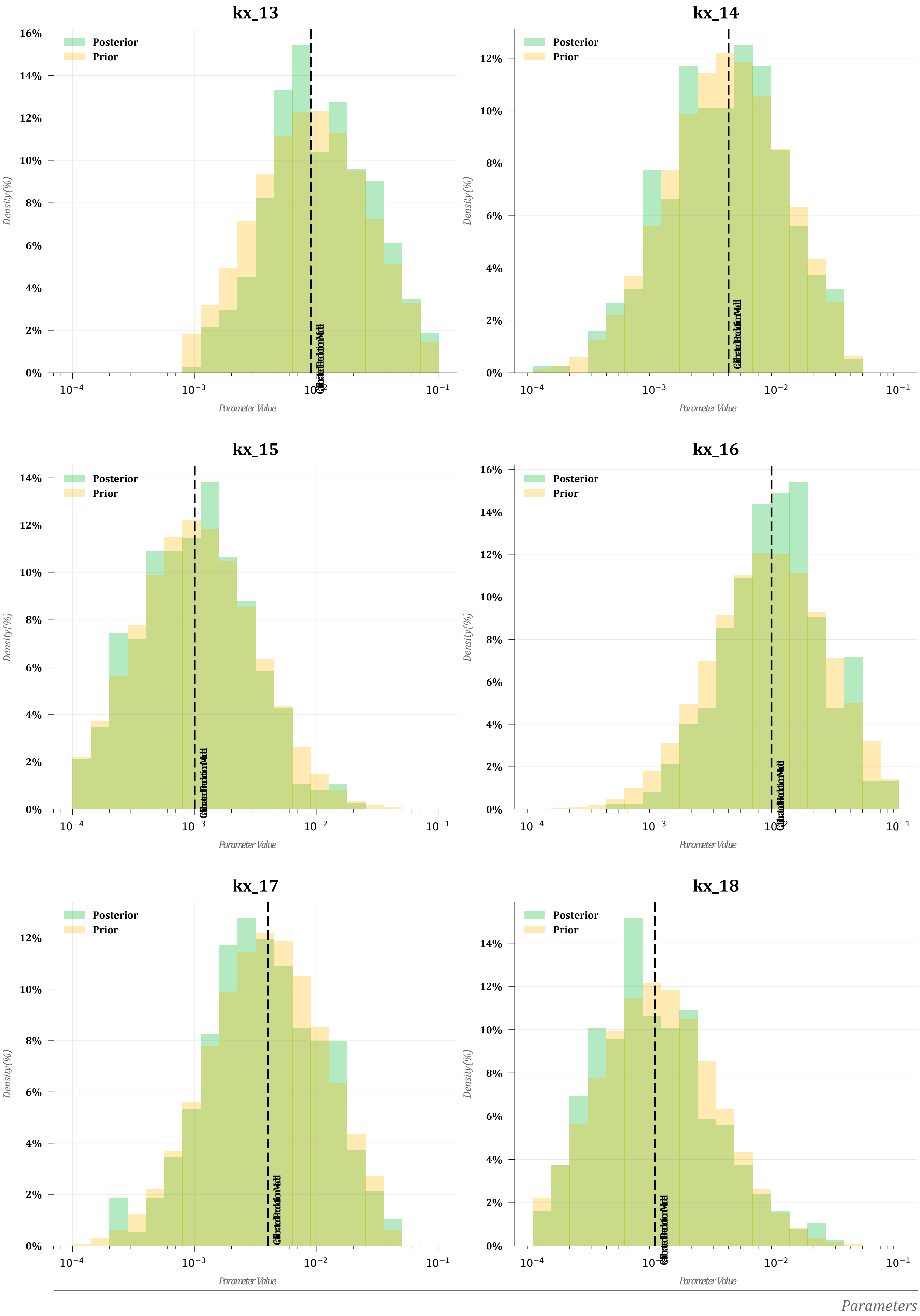
10^{-3}
10^{-2}

Parameters



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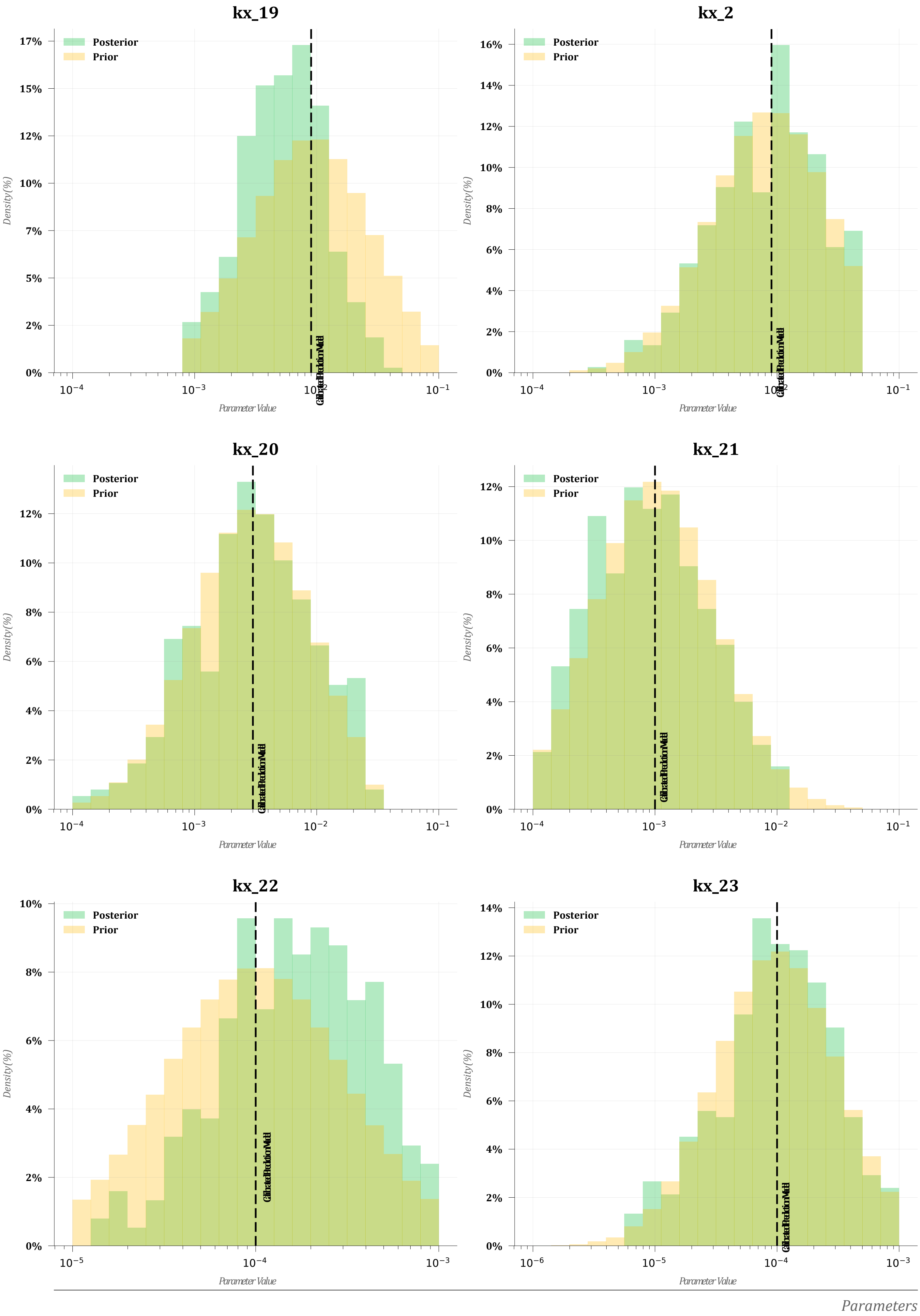
kx_15
kx_16
kx_17
kx_18
Posterior
Prior
Density(%)
Parameter Value
Parameters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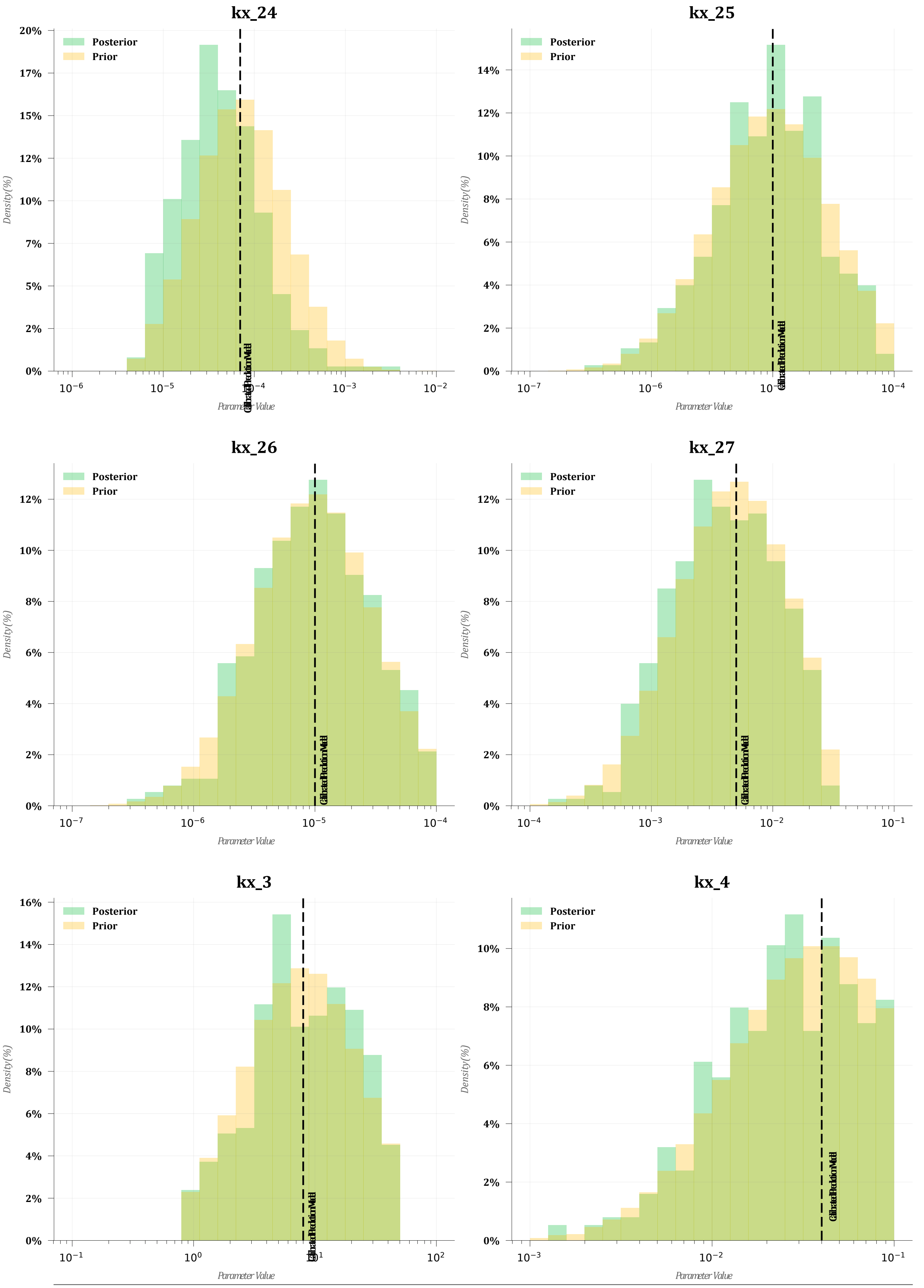
Prior
Density(%)
Parameter Value
Parameters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kx_4
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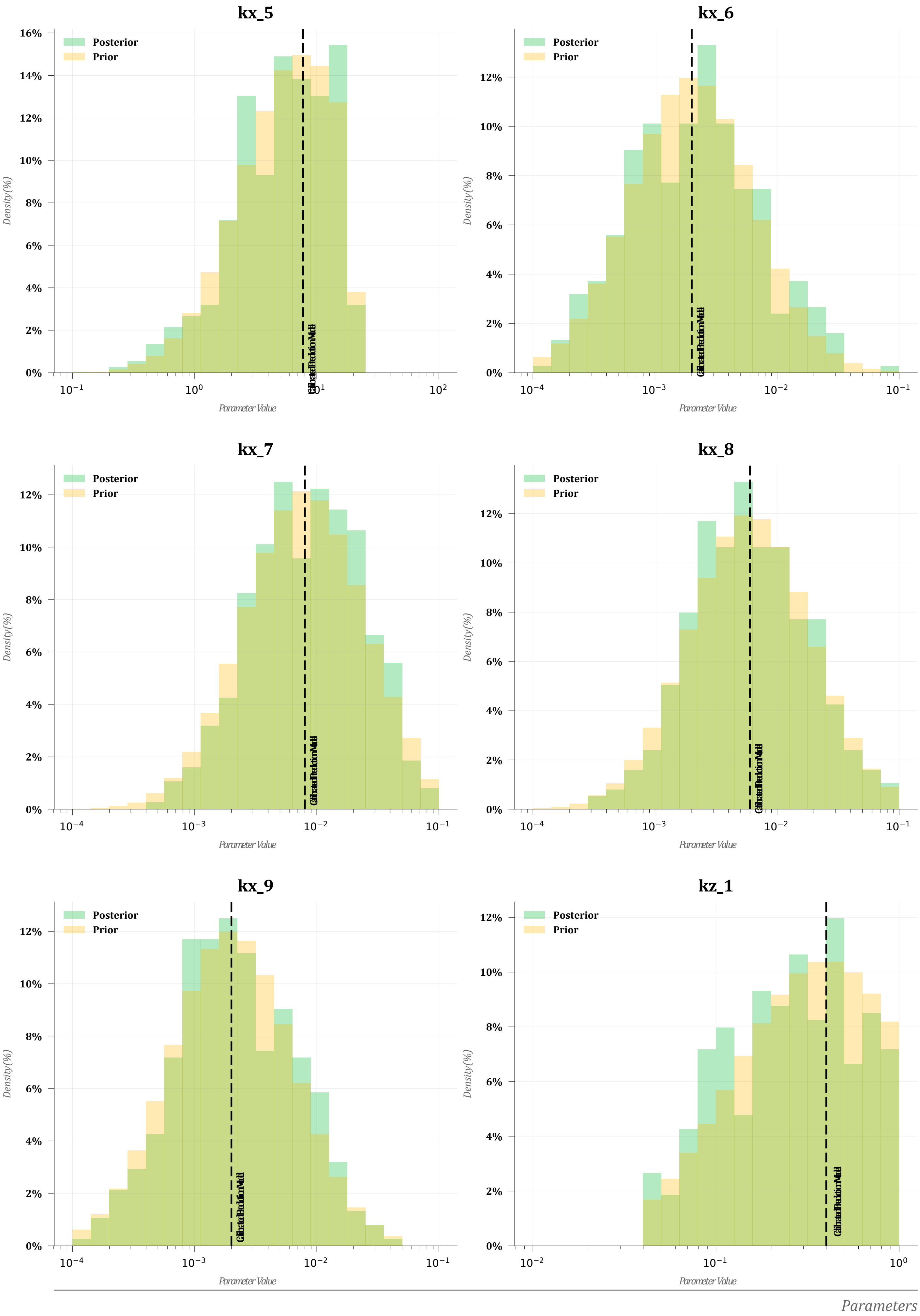
Prior
Density(%)
Parameter Value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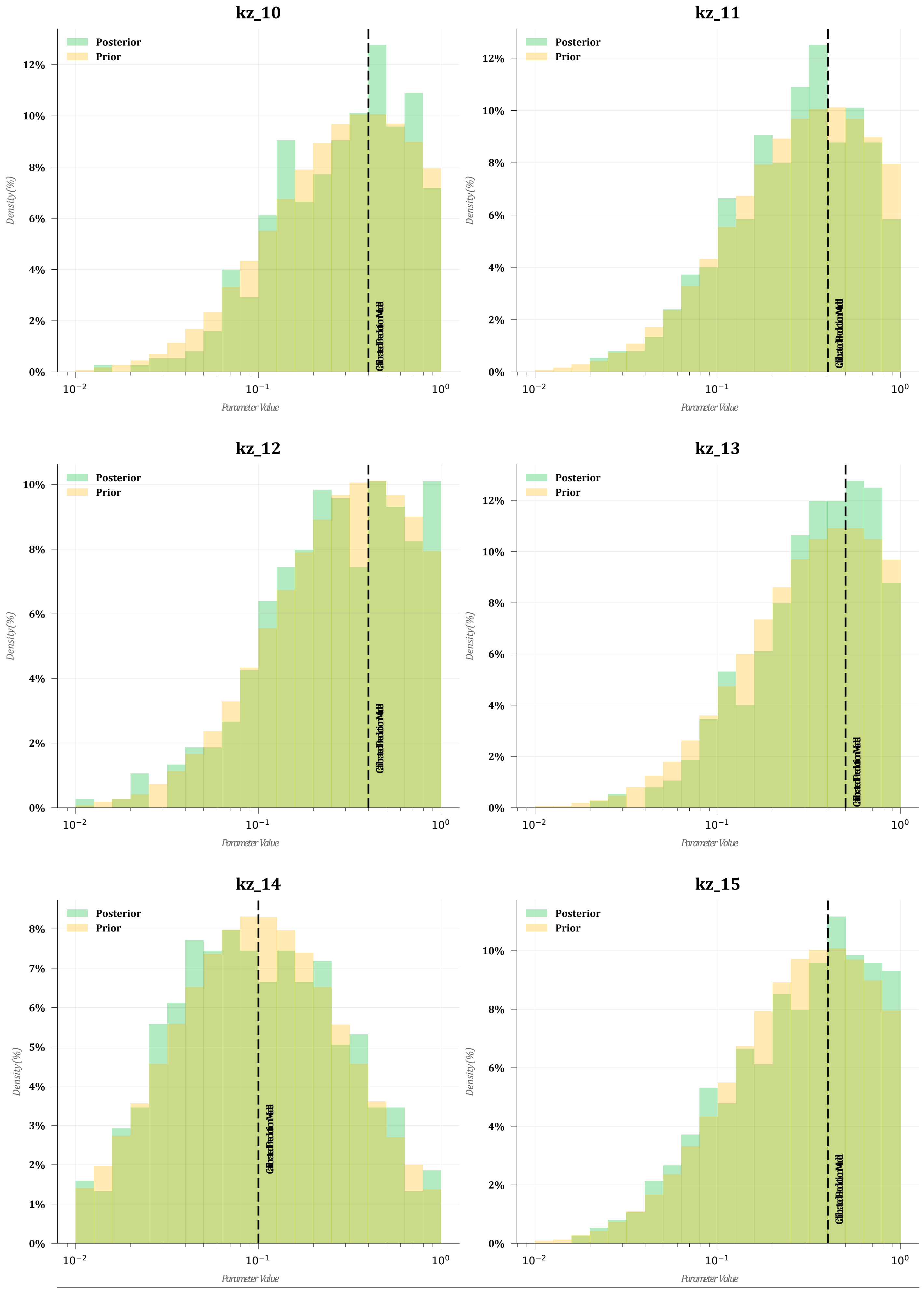
kx_7
kx_8
kx_9
kz_1
Posterior
Prior
Density(%)
Parameter Value
Parameters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kz_12
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kz_14
kz_15
Posterior
Prior
Density(%)
Parameter Value
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10^{-1}
10^{0}
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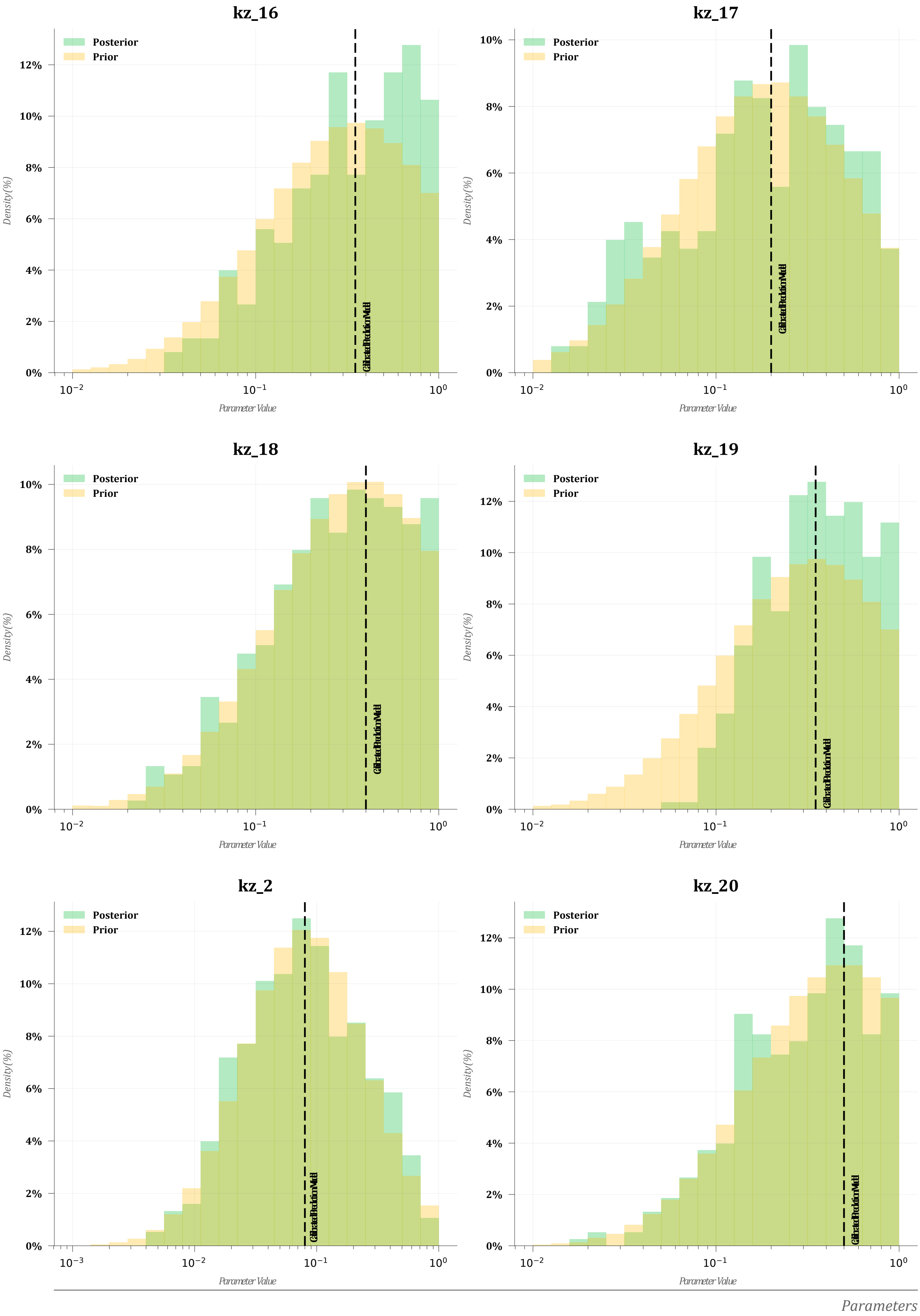
2%
4%
6%
8%
10%
12%
1%
3%
5%
7%

Parameters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Density(%)
Parameter Value
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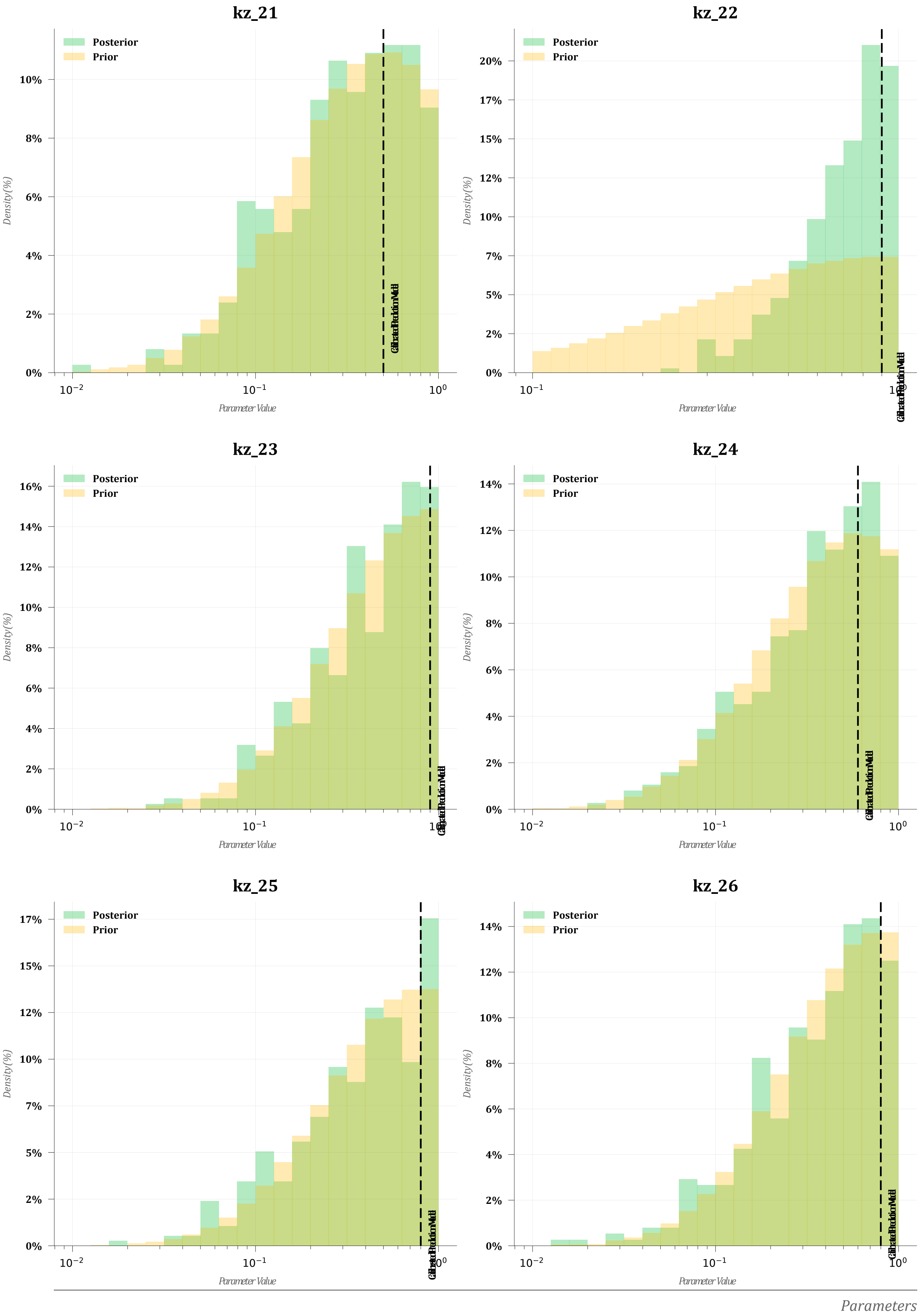
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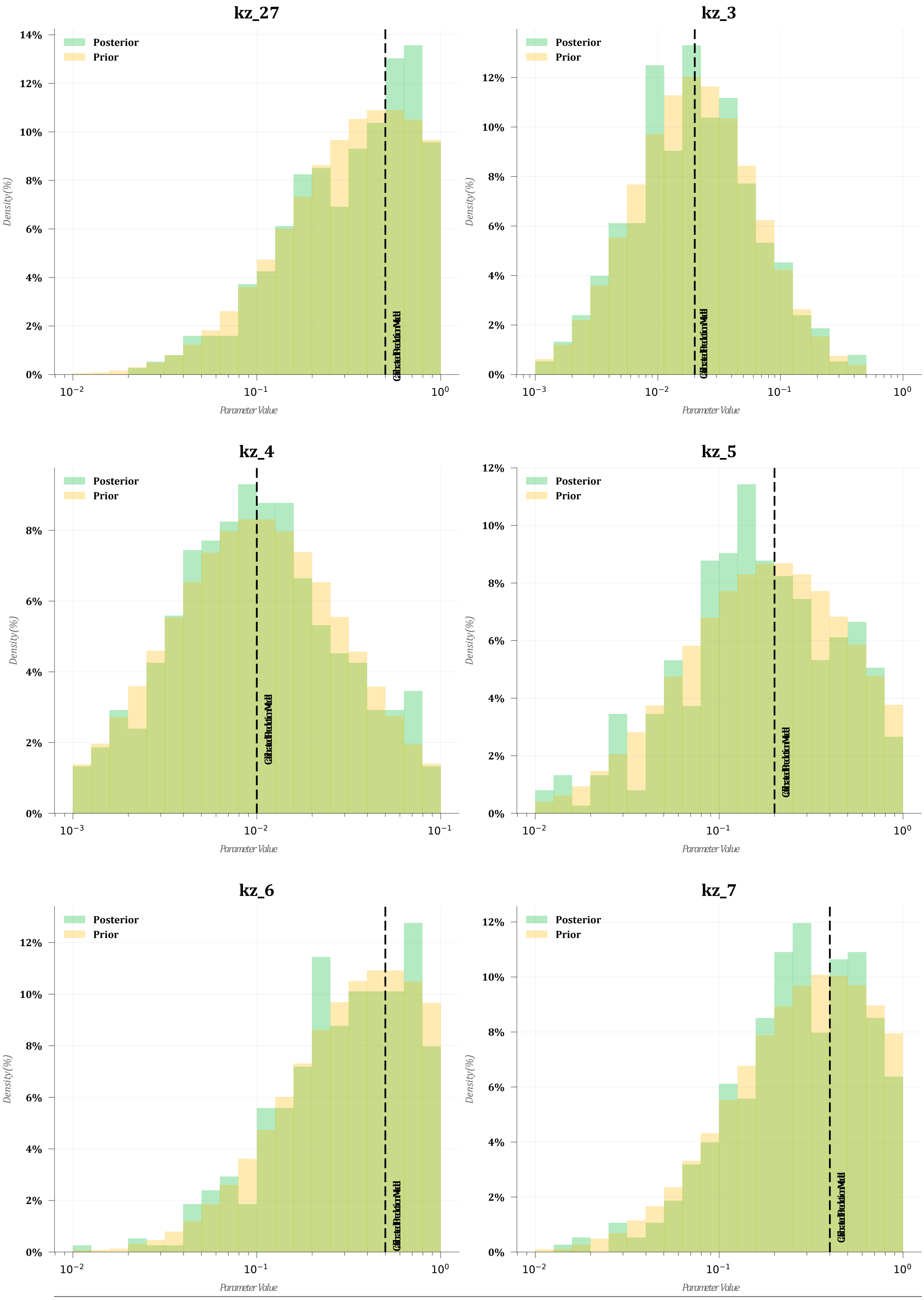
Density(%)
Parameter Value
Parameters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Density(%)
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12%
14%
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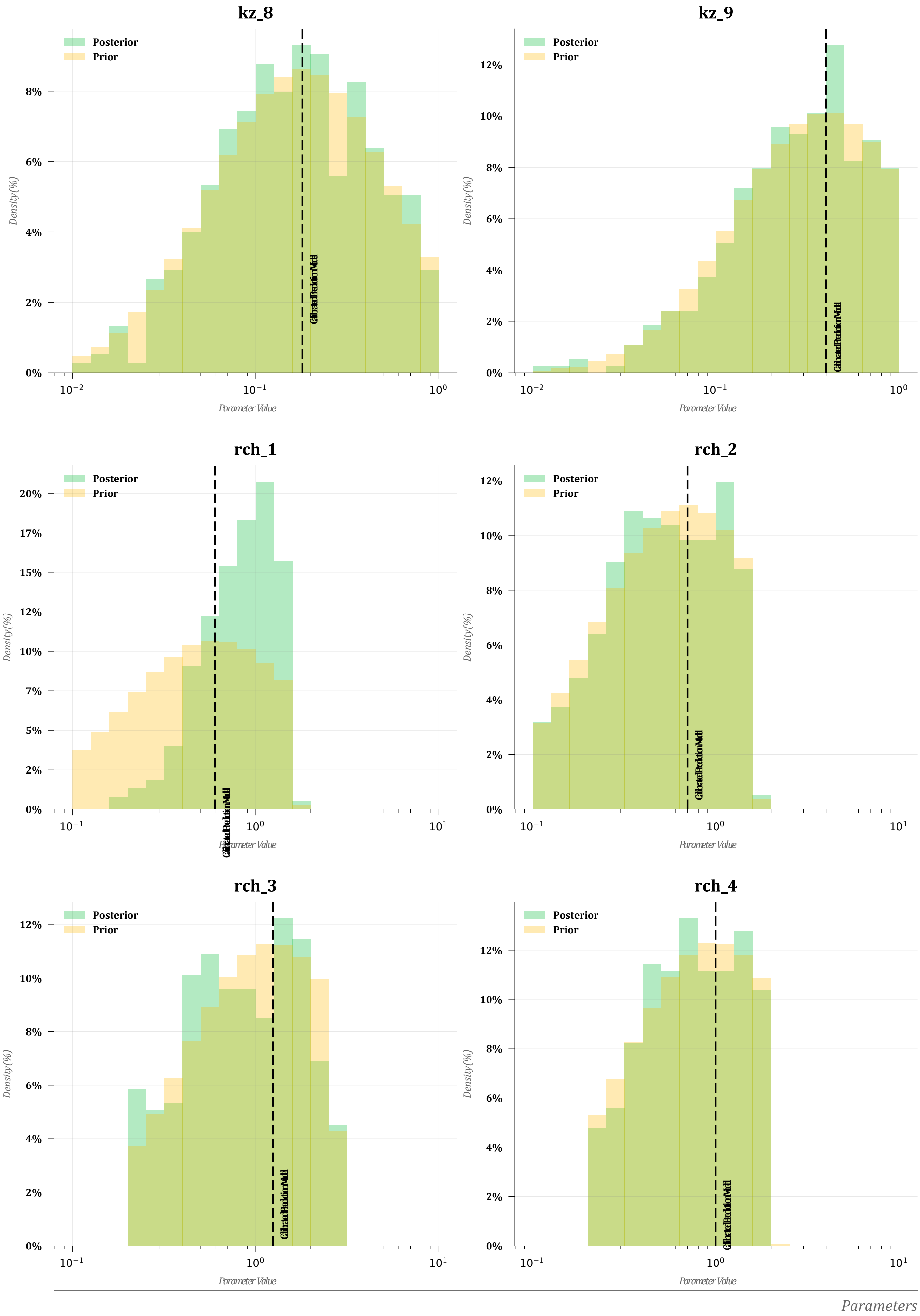
10^{-2}
10^{-1}
10^{0}

Parameters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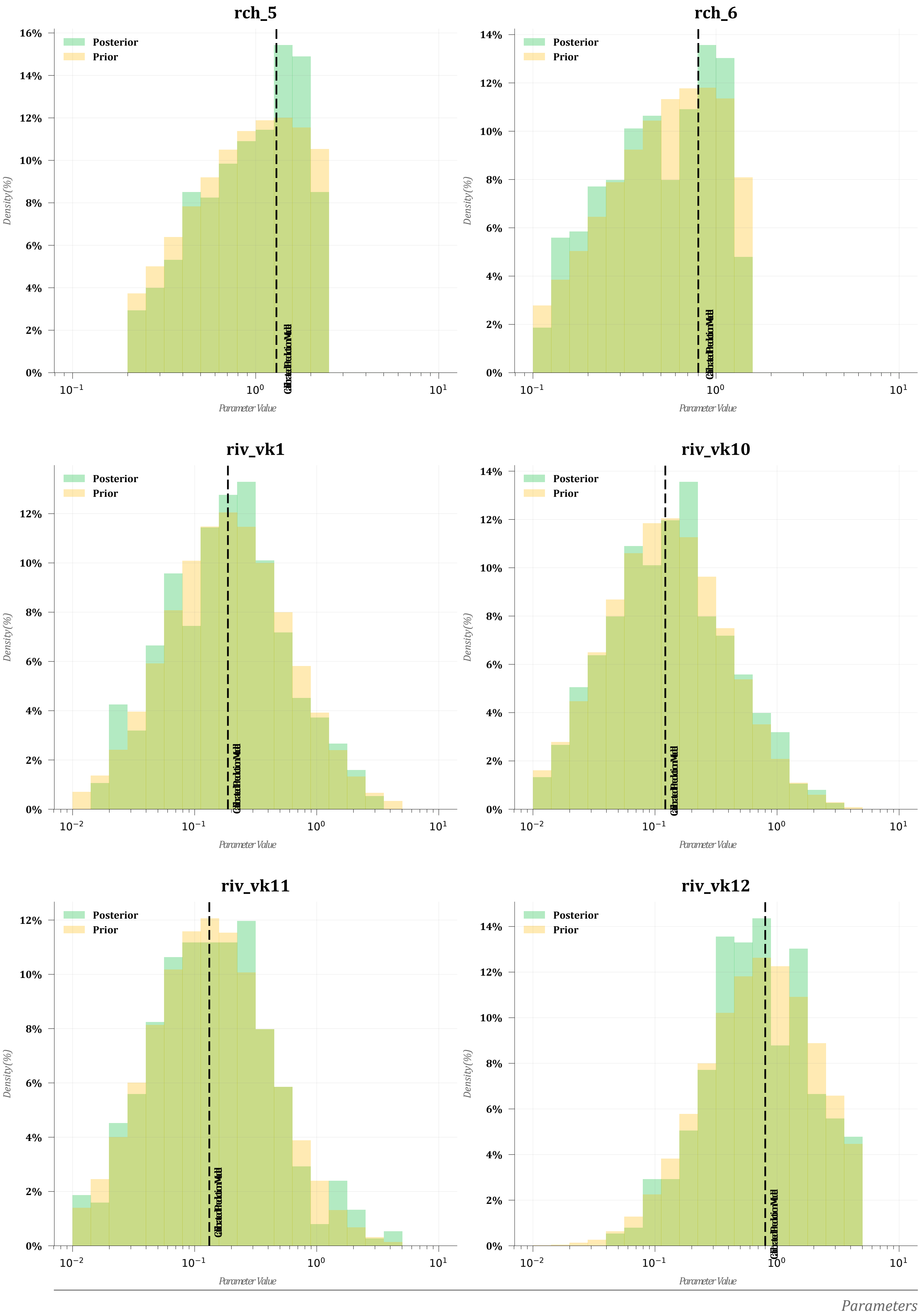
Posterior
Prior
Density(%)
Parameter Value
Parameters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riv_vk11
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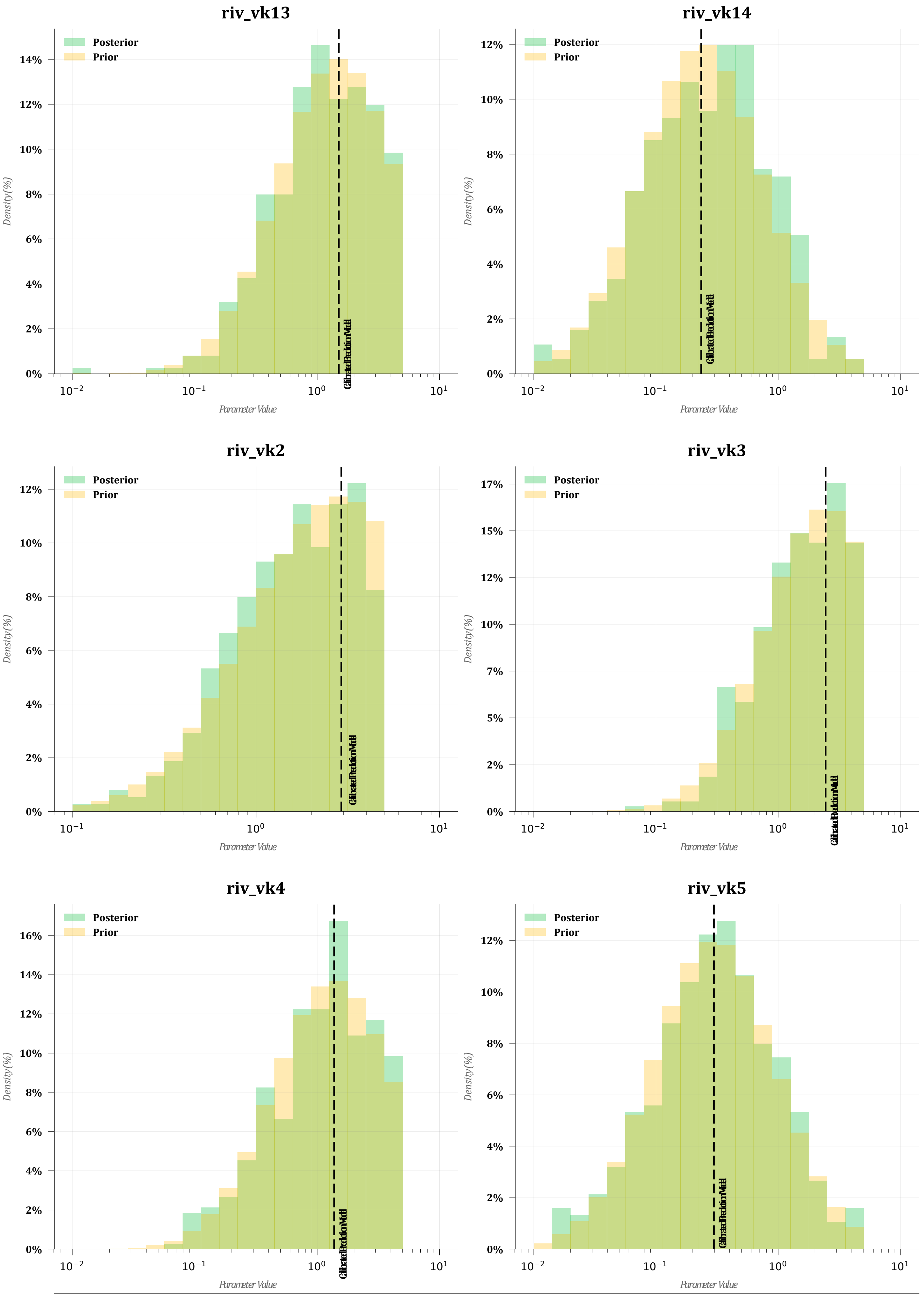
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Density(%)
Parameter Value
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Prior
Density(%)
Parameter Value

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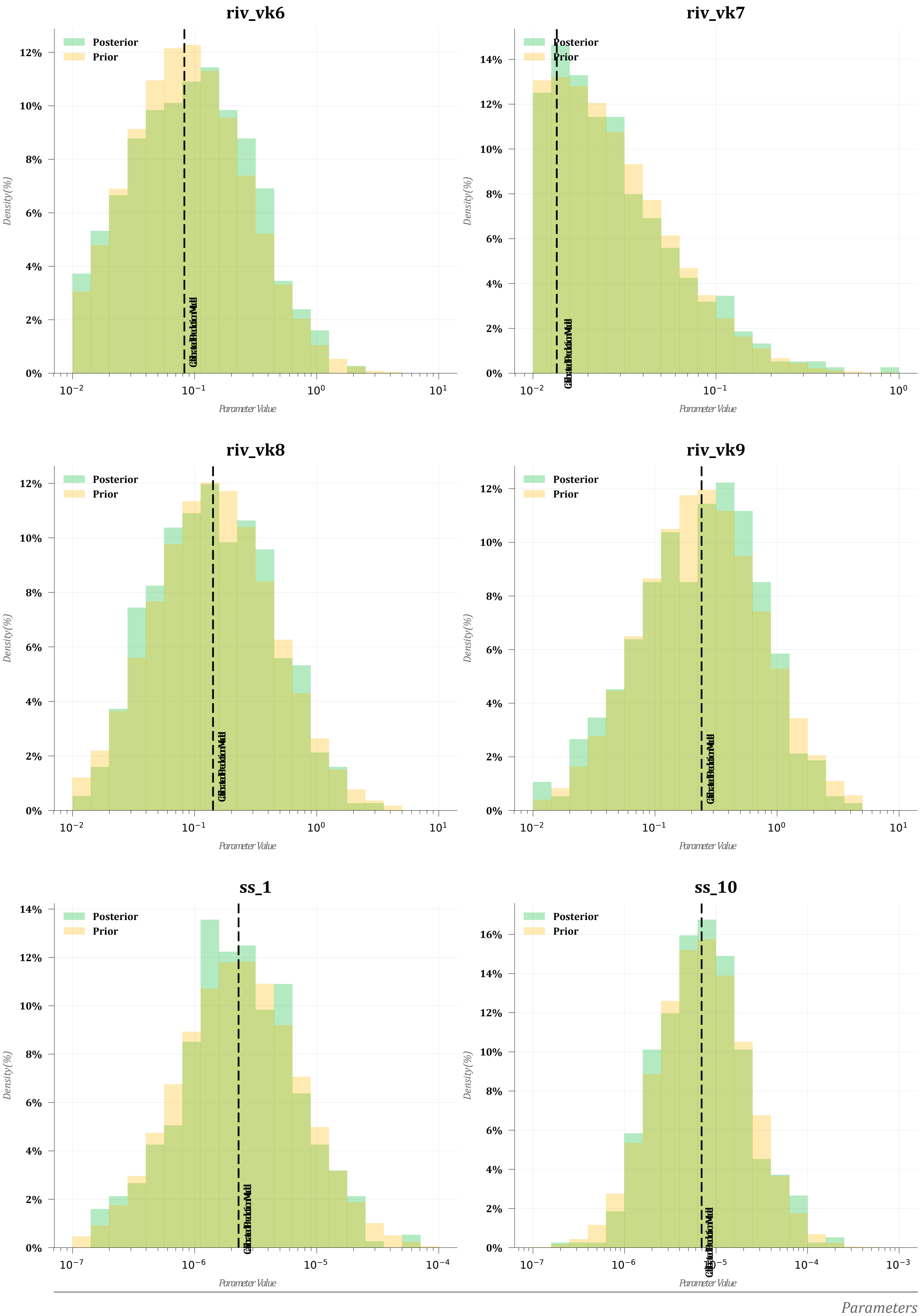
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Density(%)
Parameter Value
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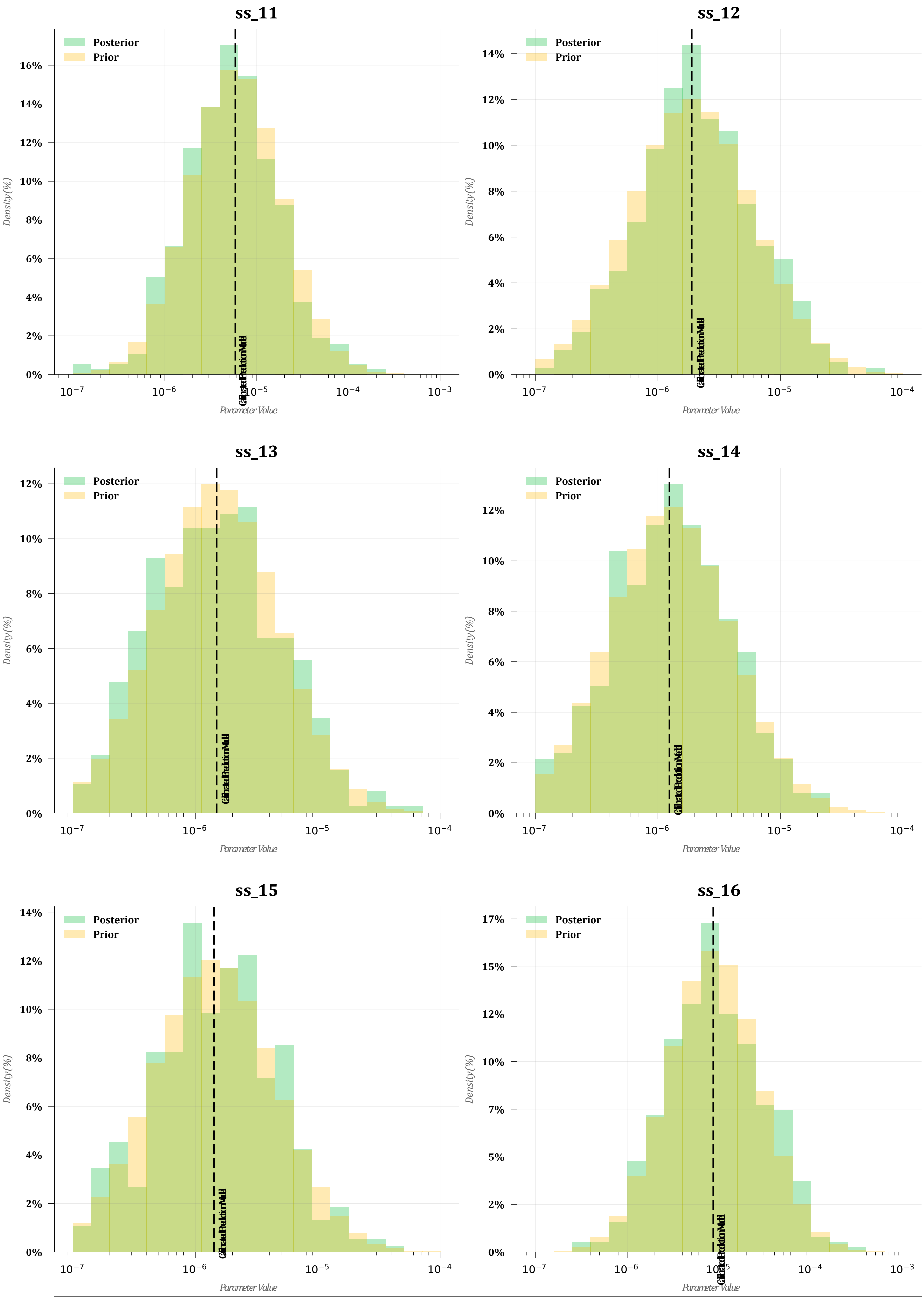
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Density(%)
Parameter Value

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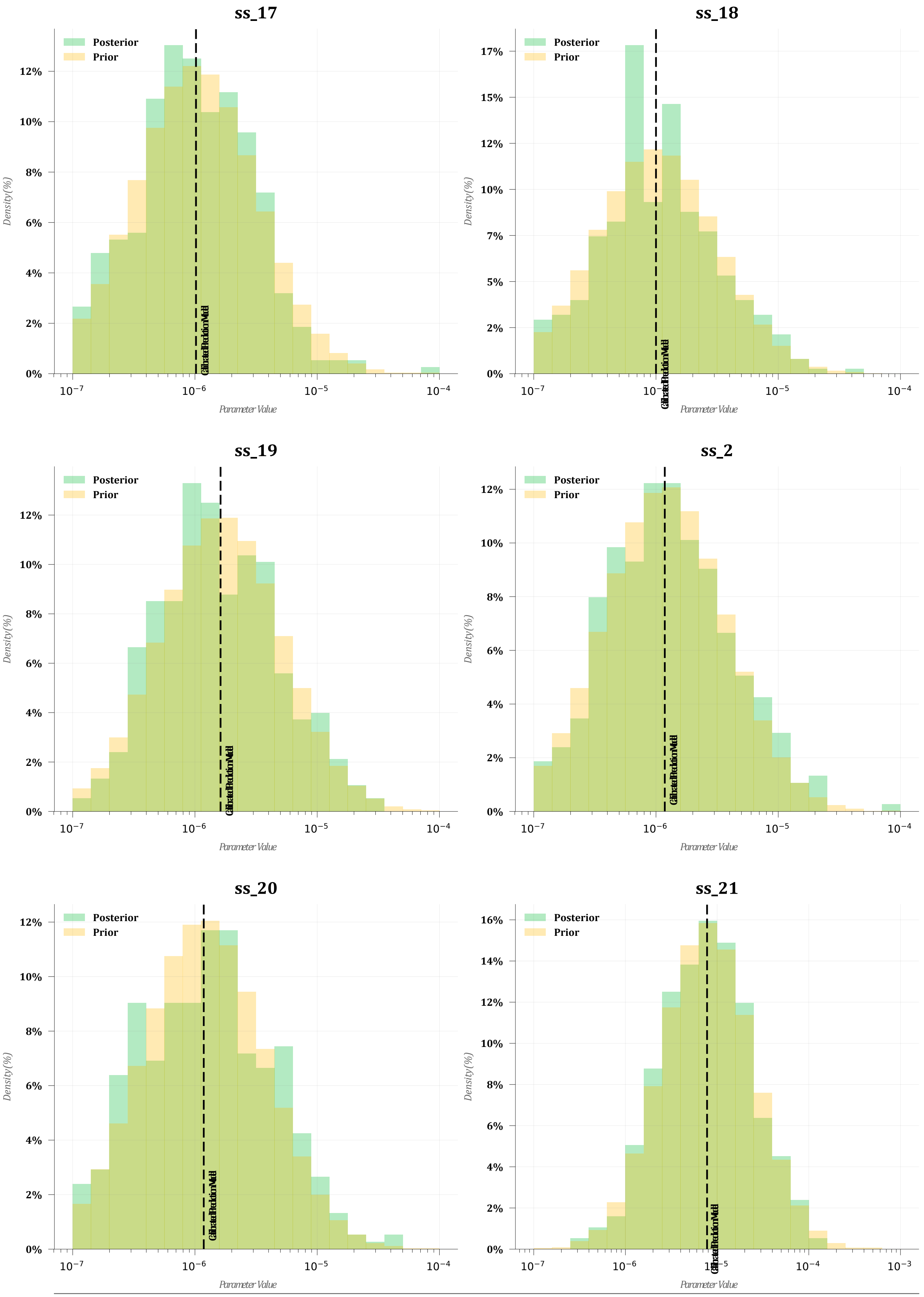
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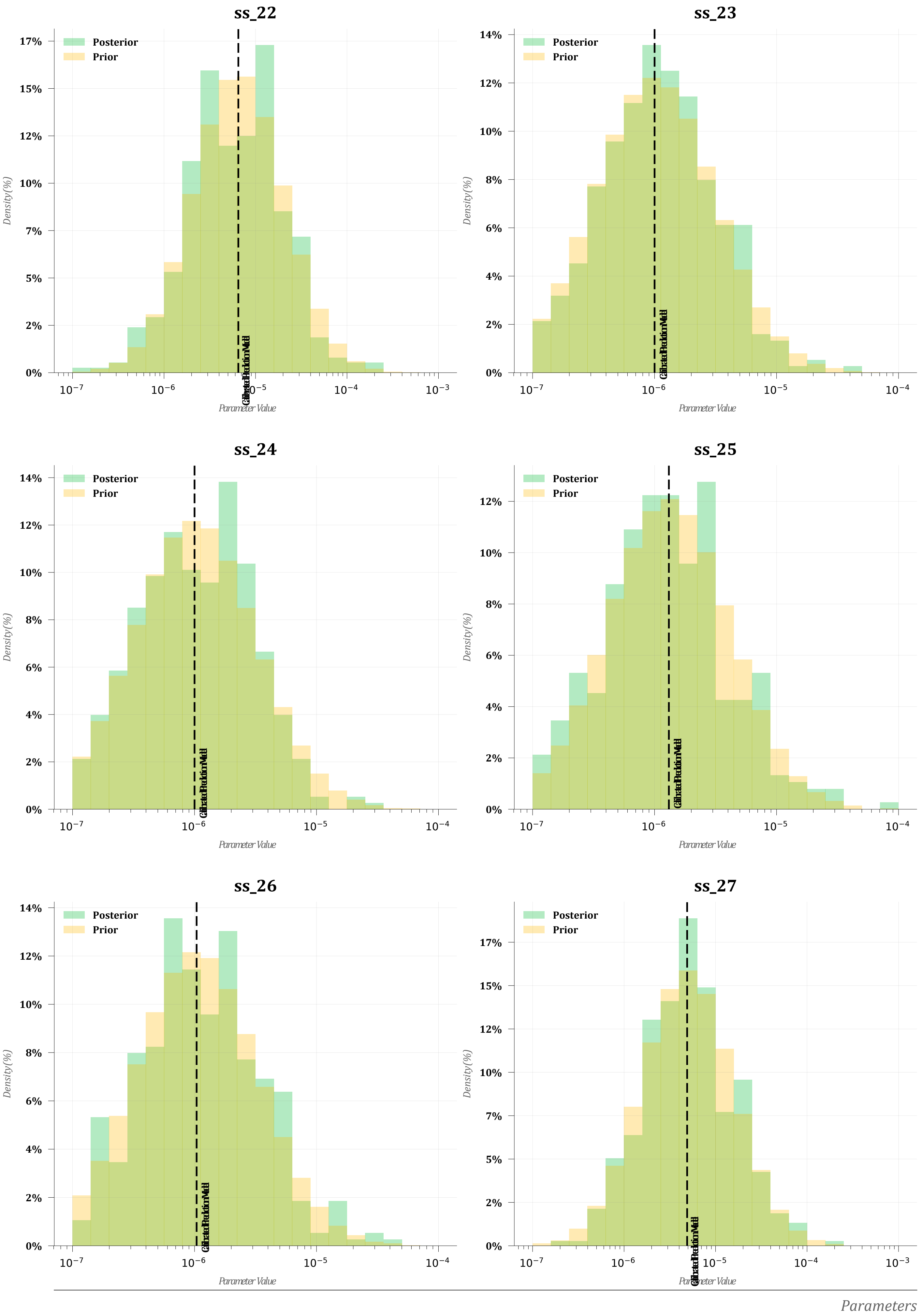
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Density(%)
Parameter Value
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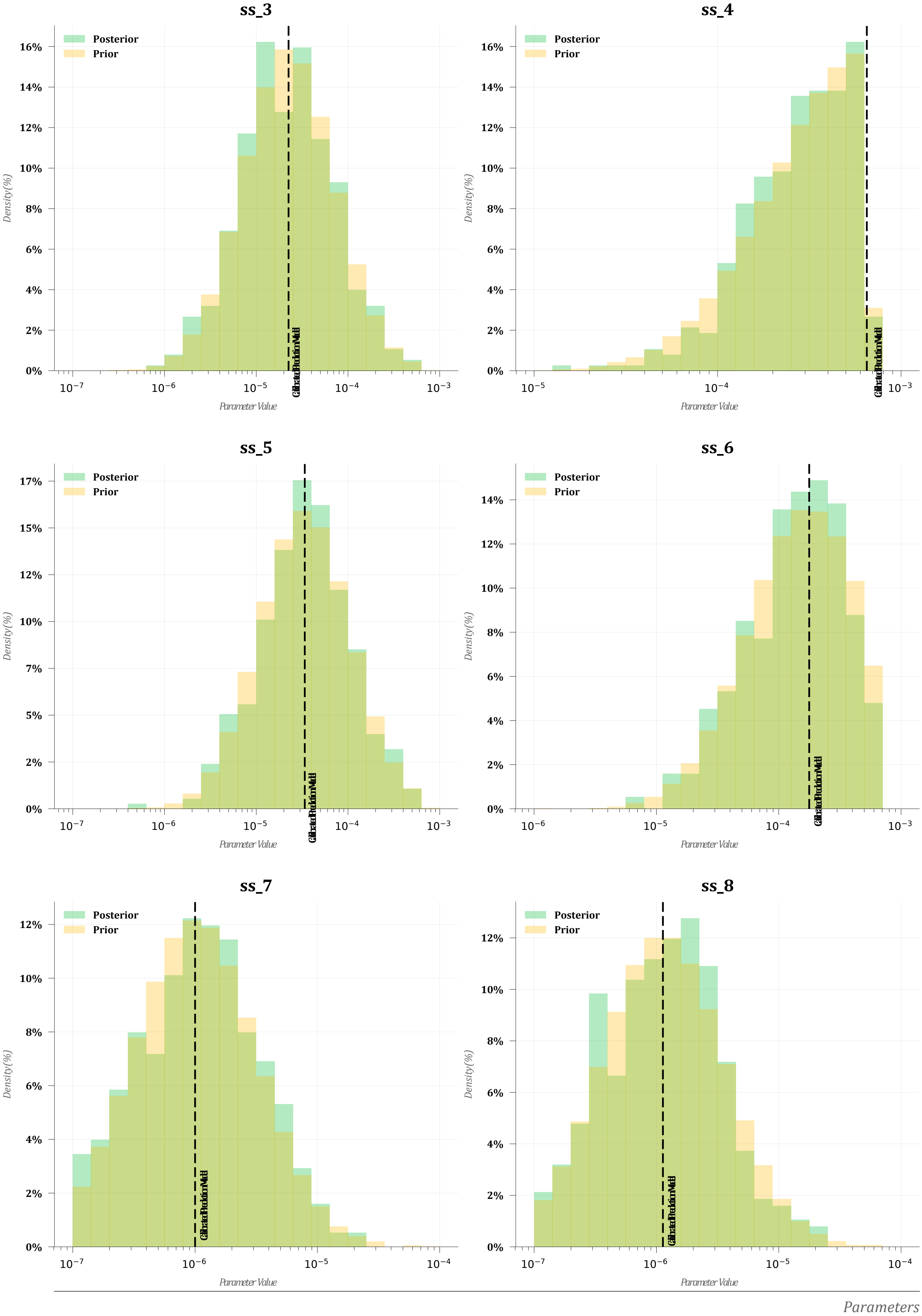
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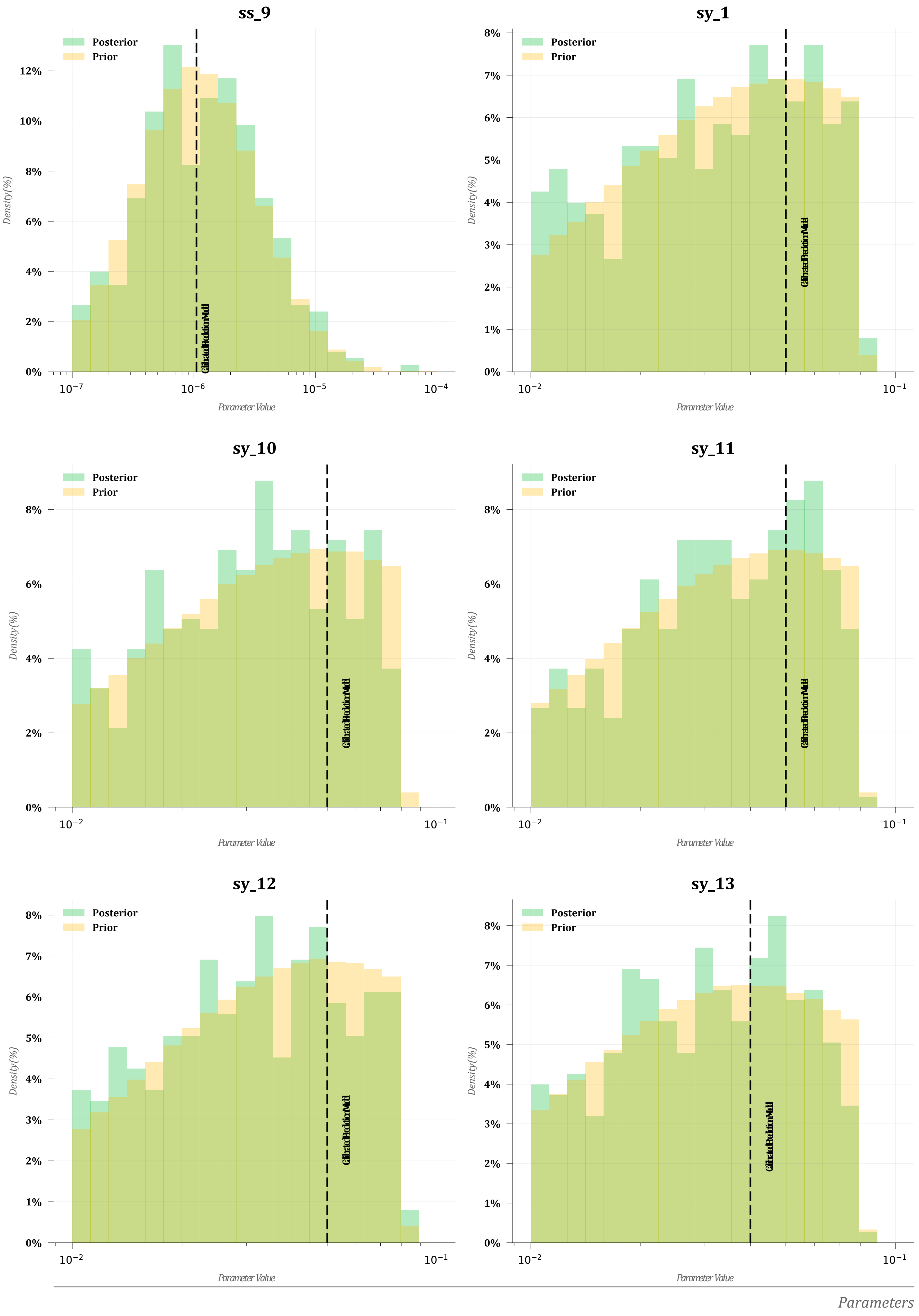
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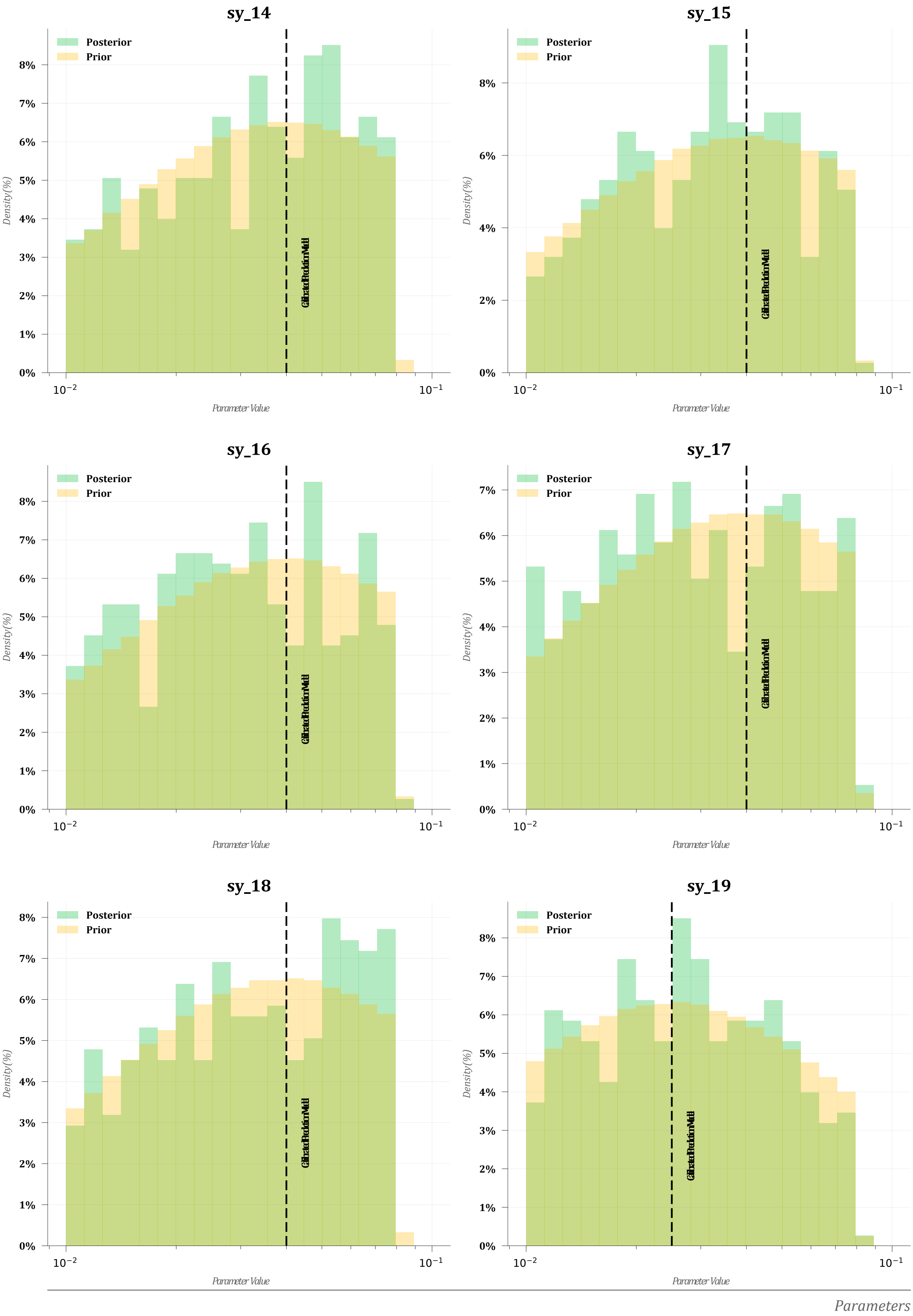
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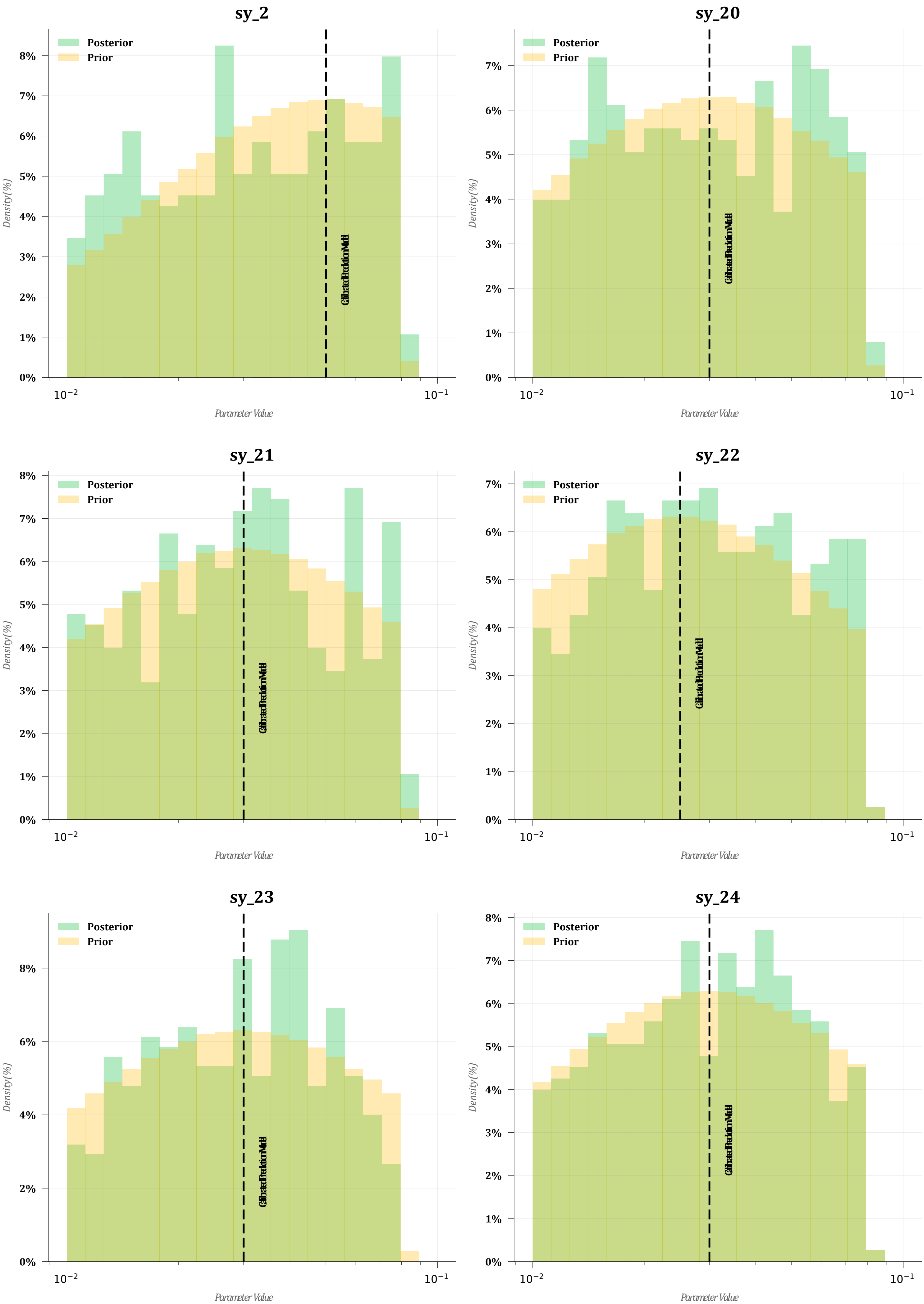
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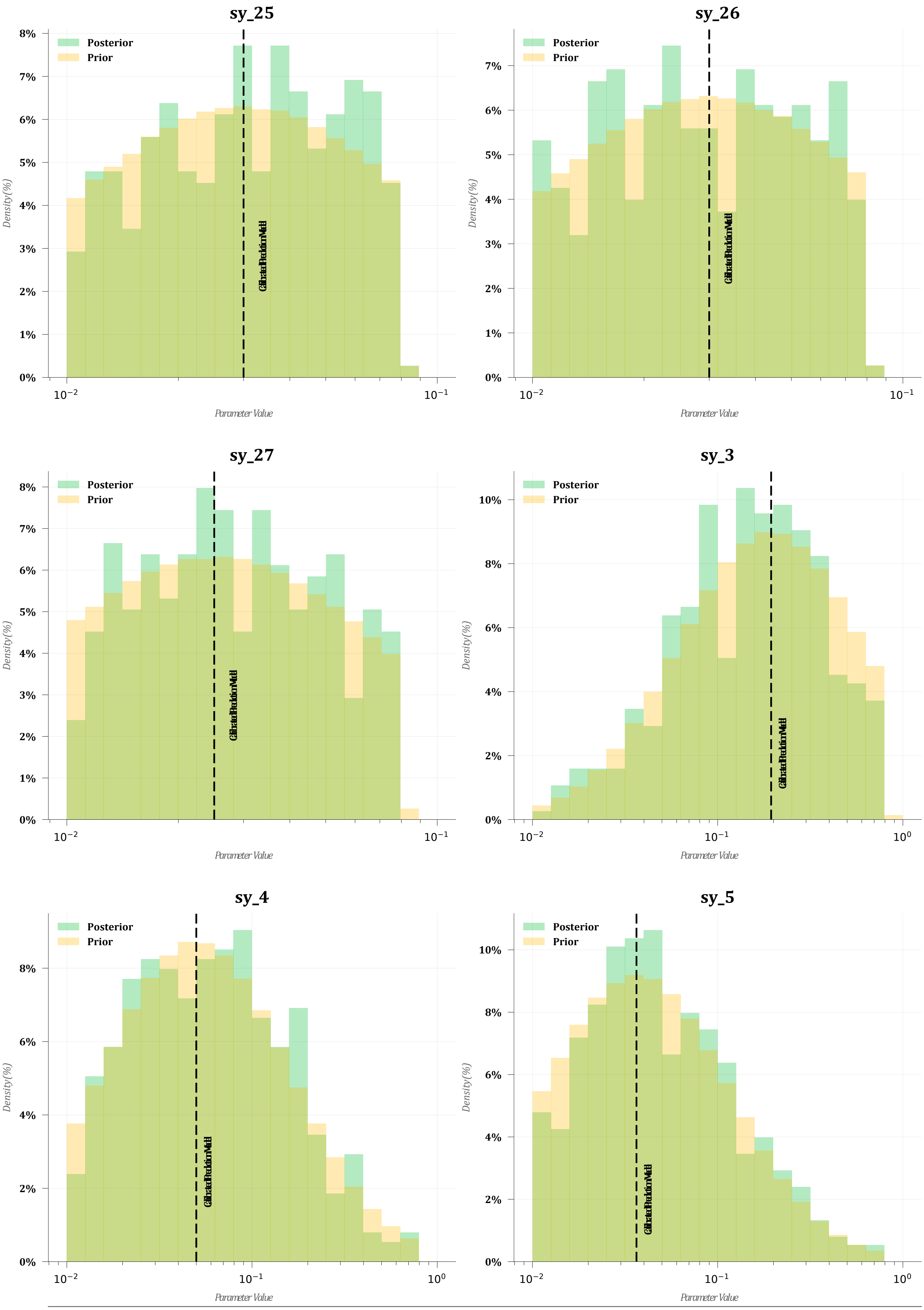
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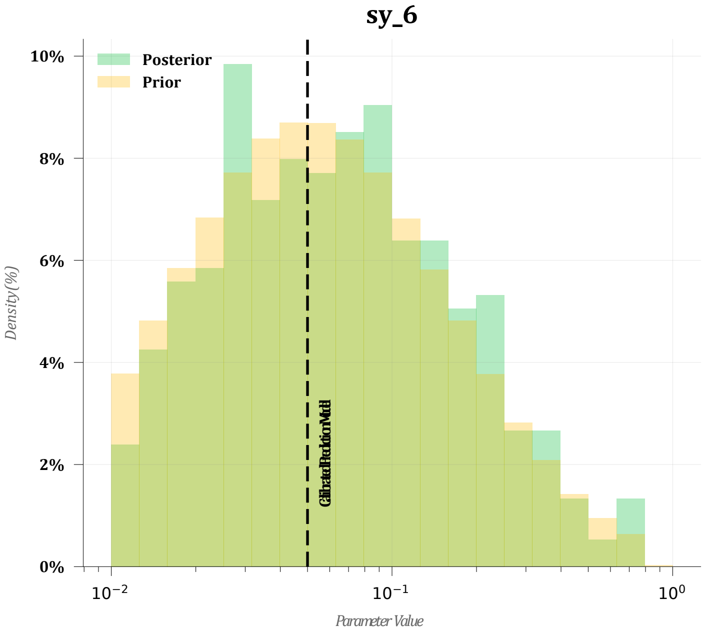
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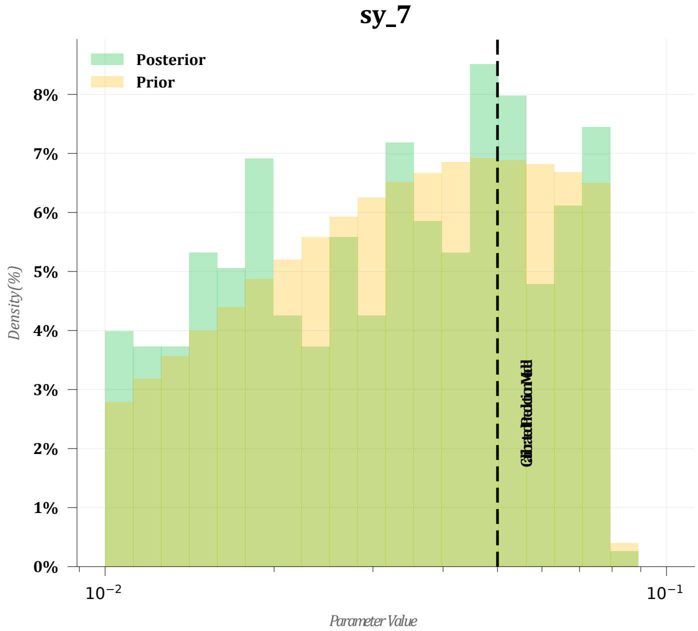
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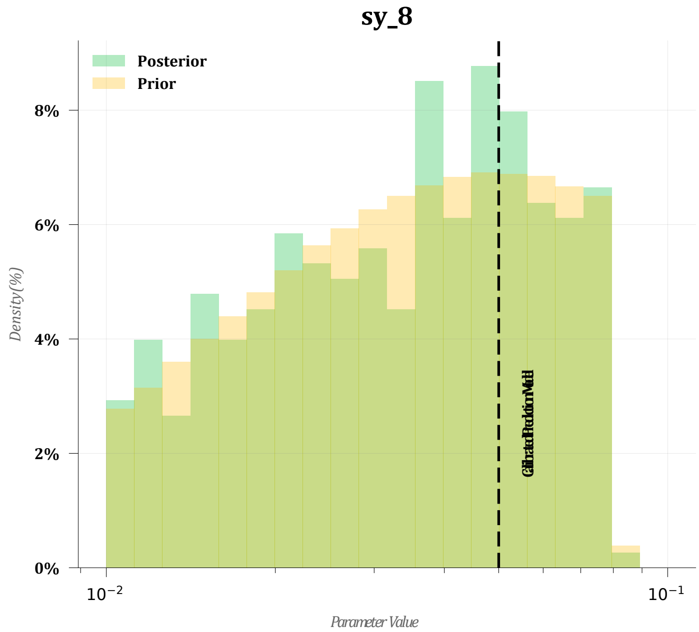
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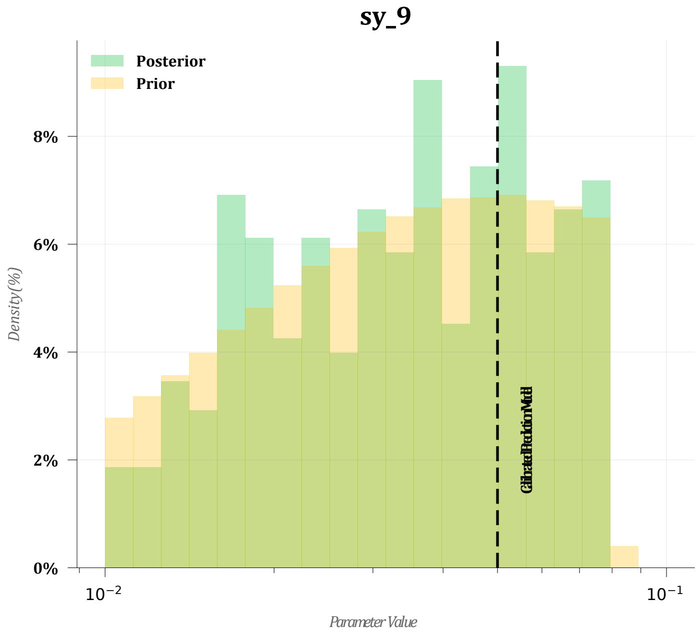
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Parameter Value

Appendix F Impact Assessment by Receptor

Hillview Quarry EIS

Groundwater Assessment

Coastwide Materials Pty Ltd

SLR Project No.: 660.30262.00000

21 June 2024

Table F1 Summary of construction/operation and rehabilitation impacts to receptors with proposed mitigation and residual impacts

Receptor	Receptor Type	Receptor Value (see Section 5.9)	Summary of Pre-Mitigation Impacts	Magnitude of Pre-Mitigation Impact	Pre-Mitigation Effect Significance	Proposed Mitigation and Summary of Post-Mitigation Impacts	Magnitude of Post-Mitigation Impact	Post-Mitigation Effect Significance
Grouped Myall Block volcanic deposits	Aquifer	Moderate	Potential long-term drawdown impact as the deposits will be directly dewatered as part of the Project. Maximum drawdown of 68 m in this deposit is predicted at the quarry face. Calibrated radius of influence extends out 650 m into aquifer (to the south-west). Potential flow impact to the deposits is predicted in the aquifer immediately adjacent to the proposed Project footprint. However, both flow and drawdown impacts are likely to be minor and limited to a local scale in context of the regional volcanic aquifer and will not impact on overall integrity of aquifer.	Minor (drawdown, flow)	Minor adverse – not significant	None required.	Minor (drawdown, flow)	Minor adverse – not significant
			Potential quality impact to the deposits due to the deposits lying within the footprint of the Project. Any quality impact is likely to be short-term and impact locally in the context of the regional aquifer and will not impact on overall integrity of aquifer.	Minor (quality)	Minor adverse – not significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality).	Negligible – not significant
Alluvial valley deposits	Aquifer	Low	Negligible drawdown impact to the deposits as they do not lie within the calibrated radius of drawdown of the Project. Potential minor baseflow impact to a small local area of the deposits along Double Creek and Brewers Creek that the Project is located upgradient of. Will not impact on overall integrity of aquifer.	Minor (flow)	Negligible – not significant	None required.	Minor (flow)	Negligible – not significant
			Potential quality impact to the deposits due to the deposits lying within the footprint of the Project (haul road). Any quality impact is likely to be short-term and impact locally in the context of the regional aquifer and will not impact on overall integrity of aquifer.	Minor (quality)	Negligible – not significant	None required.	Negligible (quality).	Negligible – not significant
Alluvial terrace deposits - high-stand facies	Aquifer	Moderate	Negligible drawdown impact to the deposits as they do not lie within the calibrated radius of impact of dewatering of the Project. Potential minor baseflow impact to a small local area of the deposits along Double Creek and Brewers Creek which the Project is located upgradient of. Will not impact on overall integrity of aquifer.	Minor (flow)	Minor adverse – not significant	None required.	Minor (flow)	Minor adverse – not significant
			Potential quality impact to the deposits due to the deposits lying within the footprint of the Project (haul road). Any quality impact is likely to be short-term and impact locally in the	Minor (quality)	Minor adverse – not significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality).	Negligible – not significant

Receptor	Receptor Type	Receptor Value (see Section 5.9)	Summary of Pre-Mitigation Impacts	Magnitude of Pre-Mitigation Impact	Pre-Mitigation Effect Significance	Proposed Mitigation and Summary of Post-Mitigation Impacts	Magnitude of Post-Mitigation Impact	Post-Mitigation Effect Significance
			context of the regional aquifer and will not impact on overall integrity of aquifer.					
Unnamed tributary of Double Creek (located within 'central valley' of proposed quarrying site)	Third order, or above, surface watercourse	Low	This surface watercourse will be lost as the majority lies within the footprint of the Project quarry and processing pad constituting an overall major impact. Therefore, changes to groundwater baseflow and quality are not deemed relevant as feature will be lost.	Refer to *Hillview Quarry: Surface Water Assessment* for impact significance of loss of this watercourse and required mitigation.				
BoM moderate potential with patches of high potential riparian GDE associated with Brewers Creek	Environmental GDE (potential)	Low	Major drawdown impact to the potential GDE with calibrated drawdown between 20 and 0.1 m in the long-term during operation and closure. This will cause a permanent reduction in baseflow to this ecosystem due to groundwater no longer discharging near ground at this habitat. This may cause a permanent loss, or degradation, of this receptor if predominantly fed by groundwater.	Major (drawdown, baseflow)	Minor adverse – not significant	None required.	Major (drawdown, flow)	Minor adverse – not significant
			Local to this receptor, the Project (quarry) is expected to act as a groundwater sink, therefore limiting the offsite migration of contaminants through the groundwater environment to this receptor.	Negligible (quality)	Negligible – not significant	None required.	Negligible (quality).	Negligible – not significant
Lower Hunter Valley Dry Rainforest ecosystem along Unnamed tributary of Double Creek 2	Environmental GDE (potential)	High	Potential major drawdown and flow impact to the potential GDE as it lies within the radius of impact of dewatering of the Project. Maximum drawdown in the vicinity of the potential GDE is predicted to be up to 26 m in the southern portion of the potential GDE and will be a long-term drawdown during operation and closure. This will cause a major reduction in baseflow to this ecosystem due to groundwater no longer discharging near ground at this habitat. This may cause a permanent loss, or degradation, of this receptor.	Major (drawdown, baseflow)	Refer to the *Hillview Quarry: BDAR* for pre-mitigation ecological impact significance and further mitigation required to this habitat from potential reduction in water level and baseflow.	A Water Management Plan will be constructed that includes appropriate monitoring, with a Trigger Action Response Plan, to monitor changes in groundwater around this habitat. Other mitigation measures, specific to preserving the ecological features of the habitat if adverse changes to groundwater levels and flow were to occur, are specified in the *Hillview Quarry: BDAR*.	Major (drawdown, baseflow)	Refer to the *Hillview Quarry: BDAR* for post-mitigation ecological impact significance and further mitigation required to this habitat from potential reduction in water level and baseflow.
			Local to this receptor, the Project (quarry) is expected to act as a groundwater sink, therefore limiting the offsite migration of contaminants through the groundwater environment to this receptor if predominantly fed by groundwater if predominantly fed by groundwater.	Negligible (quality)	Negligible – not significant	None required.	Negligible (quality).	Negligible – not significant
Eucalypt River Flat Forest along Double Creek	Environmental GDE (potential)	High	Negligible drawdown impact to the high potential GDEs that lie outside the radius of drawdown and at lower elevations than the Project. Potential moderate baseflow impact to the potential GDE as the area of long-term dewatering during operation and closure will be	Moderate (baseflow)	Refer to the *Hillview Quarry: BDAR* for pre-mitigation ecological impact significance and further mitigation required to this	A Water Management Plan will be constructed that includes appropriate monitoring, with a Trigger Action Response Plan, to monitor changes in groundwater around this habitat. Other mitigation measures, specific to preserving the ecological features of the habitat if adverse changes	Moderate (baseflow)	Refer to the *Hillview Quarry: BDAR* for post-mitigation ecological impact significance and further mitigation required to this habitat from

Receptor	Receptor Type	Receptor Value (see Section 5.9)	Summary of Pre-Mitigation Impacts	Magnitude of Pre-Mitigation Impact	Pre-Mitigation Effect Significance	Proposed Mitigation and Summary of Post-Mitigation Impacts	Magnitude of Post-Mitigation Impact	Post-Mitigation Effect Significance
			most of the upgradient portion of this hydrogeological catchment. This may cause a measurable permanent decrease in baseflow to the habitat and impact upon the integrity of the receptor if predominantly fed by groundwater.		habitat from potential reduction in baseflow.	to groundwater levels and flow were to occur, are specified in *Hillview Quarry: BDAR*.		potential reduction in baseflow.
			Potential minor, short-term quality impact to the potential GDE due to the receptor lying within the Project footprint (haul road).	Minor (quality)	Moderate adverse –significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality).	Negligible – not significant
Double Creek	Third order, or above, surface watercourse	Moderate	Potential minor drawdown impact as the creek to the north of the Project lies within the radius of drawdown of the Project. Maximum drawdown in the vicinity of the creek is predicted to range from approximately 0.1 to 1 m of drawdown. East of the Project, the elevation of the base of the creek is lower than the base of the proposed quarry footprint, therefore no direct drawdown impacts are anticipated. Potential moderate baseflow impact to the creek as the area of dewatering will be most of the upgradient portion of this hydrogeological catchment. This may cause a measurable permanent decrease in baseflow to the creek and impact upon the integrity of the receptor if predominantly fed by groundwater.	Moderate (flow), Minor (drawdown)	Moderate adverse –significant	A Water Management Plan will be constructed that includes appropriate monitoring, with a Trigger Action Response Plan, to monitor changes in groundwater around this surface watercourse. Other mitigation measures, specific to preserving and monitoring the surface water flow are specified in *Hillview Quarry: Surface Water Assessment*.	Refer to the *Hillview Quarry: Surface Water Assessment, Section 12.1* for impact significance and mitigation for this watercourse from potential reduction in water level and baseflow.	
			Potential minor, short-term quality impact to the creek due to the creek lying downgradient and in the vicinity of the Project (haul road).	Minor (quality)	Minor adverse – not significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality).	Negligible – not significant
BoM moderate potential with spots of high potential riparian GDE associated with Double Creek (outside of mapped Eucalypt River Flat Forest)	Environmental GDE (potential)	Low	Negligible drawdown impact to the high potential GDEs that lie outside the radius of drawdown and at lower elevations than the Project. Potential moderate baseflow impact to the GDE as the area of dewatering will be most of the upgradient portion of this hydrogeological catchment. This may cause a measurable permanent decrease in baseflow to the habitat and impact upon the integrity of the receptor if predominantly fed by groundwater.	Moderate (flow), Negligible (drawdown)	Minor adverse - not significant	None required.	Moderate (flow), Negligible (drawdown)	Minor adverse - not significant
			Potential minor, short-term quality impact to the Creek due to the Creek lying downgradient and in the vicinity of the Project (haul road).	Minor (quality)	Negligible – not significant	None required.	Minor (quality	Negligible – not significant
Brewers Creek	Third order, or above,	Moderate	Potential minor drawdown impact as the creek to the south of the Project lies within the radius	Moderate (flow), Minor (drawdown)	Moderate adverse –significant	A Water Management Plan will be constructed that includes appropriate monitoring, with a Trigger Action	Refer to the *Hillview Quarry: Surface Water Assessment,*	

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	surface watercourse		of drawdown of the Project during Stages 6 and 7. Maximum drawdown in the vicinity of the creek is predicted to range from approximately 0.1 to 1 m of drawdown. Potential moderate baseflow impact to the creek as the area of dewatering will be most of the upgradient portion of this hydrogeological catchment. This may cause a measurable permanent decrease in baseflow to the creek and impact upon the integrity of the receptor if predominantly fed by groundwater.			Response Plan, to monitor changes in groundwater around this surface watercourse. Other mitigation measures, specific to preserving and monitoring the surface water flow are specified in *Hillview Quarry: Surface Water Assessment*.	*Section 12.1* for impact significance and mitigation for this watercourse from potential reduction in water level and baseflow.	
			Local to this receptor, the Project (quarry) is expected to act as a groundwater sink, therefore limiting the offsite migration of contaminants through the groundwater environment to this receptor.	Negligible (quality)	Negligible – not significant	None required.	Negligible (quality).	Negligible – not significant
GW050664	Anthropogenic bore	Moderate	Negligible drawdown impact to the bore as it does not lie within the radius of impact of dewatering of the Project. Negligible flow impact to the bore as it is understood to extract from the volcanic deposits/ fractured rock aquifer at greater depths than that intersected by the Project.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant
			Potential minor, short-term quality impact to the bore from being located downstream of, though at distance from, the Project (haul road).	Minor (quality)	Minor adverse – not significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality)	Negligible – not significant
Cromarty Creek	Third order, or above, surface watercourse	Moderate	Negligible drawdown impact to the creek as it does not lie within the radius of drawdown of the Project. Negligible flow impact to the creek as Project and project drawdown is outside the hydrogeological catchment of the creek.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant
			Negligible quality impact to the creek as Project is outside the hydrogeological catchment of the creek.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant
BoM high potential riparian GDE associated with Cromarty Creek	Environmental GDE (potential)	Moderate	Negligible drawdown impact to the GDE as it does not lie within the radius of impact of dewatering of the Project. Negligible flow impact to the GDE as Project and project drawdown is outside the hydrogeological catchment of the GDE.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant
			Negligible quality impact to the GDE as Project is outside the hydrogeological catchment of the GDE.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant

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Alluvial floodplain deposits	Aquifer	High	Negligible drawdown impact to the deposits as it does not lie within the radius of impact of dewatering of the Project. Negligible baseflow impact to the deposits as the proposed dewatering area is likely to contribute relatively limited groundwater throughflow to the deposits, in comparison to other recharge processes across the catchment of these alluvial deposits.	Negligible	Negligible – not significant	None required.	Negligible	Negligible – not significant
			Potential minor, short-term quality impact to the creek from being located downstream of, though at distance from, the Project (haul road).	Minor (quality)	Moderate adverse – significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality).	Negligible – not significant
Karuah River	Third order, or above, surface watercourse	Very High	Negligible drawdown impact to the river as it does not lie within the radius of drawdown of the Project. Additionally, the river lies in at a lower elevation than that of the Project so no direct drawdown will occur. Negligible flow impact to the river as the volume of baseflow contributed to the river by groundwater is relatively low, in comparison to other inputs to the river across the catchment. (i.e., the water balance is predicted to be surface water driven). It is predicted that the water balance remains unchanged by the Project, with the Project not likely to result in an impact to the existing surface water/groundwater interactions.	Negligible (drawdown, flow)	Negligible – not significant	None required.	Negligible (drawdown, flow)	Negligible – not significant
			Potential minor, short-term quality impact from being located downstream of, though at distance from, the Project (haul road).	Minor (quality)	Moderate adverse – significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality)	Negligible – not significant
BoM high potential riparian GDE associated with Karuah River	Environmental GDE (potential)	High	Negligible drawdown impact to the GDE as it does not lie within the radius of drawdown of the Project. Negligible flow impact to the GDE as the proposed dewatering area is likely to contribute relatively limited water in support of the GDE, in comparison to other water sources across the catchment.	Negligible (drawdown, flow)	Negligible – not significant	None required.	Negligible (drawdown, flow)	Negligible – not significant
			Potential minor, short-term quality impact from being located downstream of, though at distance from, the Project (haul road).	Minor (quality)	Moderate adverse – significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality)	Negligible – not significant

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Alluvial levee/ overbank deposits	Aquifer	High	Negligible drawdown impact to the deposits as it does not lie within the radius of impact of dewatering of the Project. Negligible flow impact to the deposits as the proposed dewatering area is likely to contribute relatively limited groundwater throughflow to the deposits, in comparison to other recharge processes across the catchment.	Negligible (drawdown, flow)	Negligible – not significant	None required.	Negligible (drawdown, flow)	Negligible – not significant
			Potential minor, short-term quality impact to the creek from being located downstream of, though at distance from, the Project (haul road).	Minor (quality)	Moderate adverse – significant	Develop an Environmental Management Plan (EMP) with appropriate subplans to sufficiently manage the risk of groundwater quality impacts (e.g., mobilisation of contaminants and/or accidental spills) such that there is a negligible impact to water quality.	Negligible (quality)	Negligible – not significant

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