APPENDIX C

Groundwater Report

STRATEGIC MINERALS
CORPORATION

REPORT ON

BIG VEIN SOUTH GOLD PROJECT GROUNDWATER REPORT

For: Strategic Minerals Corporation

Project number: 4090

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Big Vein South Gold Project - Groundwater Report

Prepared for

Strategic Minerals Corporation

1. Introduction

hydrogeologist.com.au was commissioned by Strategic Minerals Corporation Pty Ltd (SMC) to complete a groundwater impact assessment as part of the Environmental Assessment Report (EAR) for the Big Vein South Gold (BVS) Project (the project).

1.1. Project description

The project involves the construction and operation of an open cut gold mine on a greenfield site in north Queensland. The project site covers an area of 2,281 hectares (ha) and is located approximately 100 km north of Richmond and 380 km west of Townsville (Figure 1).

Open cut mining will be conducted using excavators and trucks. Gold ore will be processed on site to produce gold dore (solid bars containing gold alloy). The mine's peak production rate will be up to 1.95 million tonnes per annum (Mtpa) of run of mine (ROM) gold ore, yielding up to 100,000 ounces of gold dore per annum. The mine life will be approximately 11 years.

The following mining and ore processing activities will be undertaken as part of the project:

- Developing three open cut pits:
    - The main Big Vein South Pit (BVS Pit), located in the centre of the project site (Figure 2). Waste rock from this pit will be hauled by truck and stored in the Central and Southern Waste Rock Dumps (WRDs).
    - Two smaller satellite pits, BV1 Pit and BV2 Pit, located in the northern part of the project site (Figure 2). Waste rock from these pits will be stored in the Northern WRD.
- Transporting mined ore in haul trucks from the open cut pits to the ROM area ore stockpiles, located near the mine processing facilities at the southern end of the project site (Figure 2).
- Processing ore from the BV1 and BV2 pits in the first two years of mining using heap leach pads and gold elution. Processing ore mined from the BVS Pit in an on-site Carbon In-Leach (CIL) Plant from Year 3 onwards. The heap leaching process will generate spent heap leach residues. These residues will be reprocessed in the CIL Plant over the life of the mine. The CIL Plant will generate wet tailings and dewatered tailings. Wet tailings will be pumped to a tailings storage cell. Dewatered tailings will be stored with waste rock in the Central and Southern WRDs.
- Transporting dore bars from the site via plane to a refinery.

The majority of the infrastructure will be located at the southern end of the project site (Figure 2). Key mine infrastructure will include ore processing facilities, workshop, warehouse, administration buildings, haul roads and access roads, vehicle servicing, refuelling and wash down facilities, fuel storage facilities, diesel and solar power station, water supply and water management infrastructure. Workforce accommodation and a private airstrip will also be located at the southern end of the project site.

1.2. Scope of assessment

The scope of work for this groundwater assessment includes:

- A review of relevant reports to develop an appreciation of the hydrogeological setting of the project.
- A review of the relevant geology data including 3D geology models, databases and exploration drilling data provided by the proponent.
- A review of government databases for relevant hydrogeological data.
- A census of water supply bores to confirm the bore locations, use and groundwater quality.
- A site-specific groundwater field investigation to develop a detailed understanding of the groundwater regime at the project site. The groundwater investigation included the drilling and installation of dedicated monitoring bores and vibrating wire piezometers (VWPs), the measurement of groundwater levels and groundwater quality, and the testing of aquifer hydraulic parameters.
- The development of a conceptual model of the groundwater regime of the project site and its surrounds, based on all available data.
- The development of a 3D numerical model for the predictive simulation of the scale and extent of the project's effects on groundwater levels.
- An assessment of the groundwater impacts and development of feasible mitigation and management strategies, where necessary.
- The development of a groundwater monitoring program for the project.

1.3. Report structure

This report is structured as follows:

- Section 1 – Introduction: provides an overview of the project, the assessment scope and report structure.
- Section 2 – Regulatory Framework: describes the regulatory setting relating to groundwater.
- Section 3 – Project Setting: describes the environmental and geological setting of the project including relevant land uses, local topography and drainage, climate, and local stratigraphy.
- Section 4 – Methodology: describes the assessment method including the collection of relevant data, the groundwater field investigation and numerical groundwater modelling.
- Section 5 – Existing Groundwater Regime: describes the existing groundwater regime for the project site and surrounding area.
- Section 6 – Impact Assessment: provides a detailed description of the proposed mining activities and the predicted effects of the project activities on the local groundwater regime. This section also presents an assessment of the potential impacts on groundwater users and sensitive environmental features.
- Section 7 – Groundwater Monitoring and Management: describes the proposed groundwater monitoring program and management measures for the project.
- Section 8 – Conclusions.
- Sections 9 to 11 comprising references, abbreviations, and a glossary.

Appendix A summarises the registered bores located within 5 km of the project site.

Appendix B summarises the groundwater quality at the project site.

Appendix C presents the drilling logs and permeability test results for the groundwater monitoring bores and VWPs installed at the project site.

Appendix D provides a detailed description of the numerical modelling undertaken for the project, including details on model construction, calibration, predictive simulations, and sensitivity analyses.

2. Queensland regulatory framework

2.1. Overview

The *Mineral Resources Act 1989* (Qld) (MR Act) entitles the holder of a mining lease (ML) or mineral development licence (MDL) to take or interfere with underground water (i.e., groundwater) as part of approved mining operations. This entitlement is termed the mining lease holder's 'underground water rights'.

Groundwater that is taken or interfered with while exercising the underground water rights is termed 'associated water'. The holder of the ML or MDL is entitled to use associated water for any purpose. In order to exercise the underground water rights for the project, the proponent must:

- Obtain an Environmental Authority (EA) under the *Environmental Protection Act 1994* (Qld) (EP Act).
- Comply with the notification requirements under Section 334ZP(6) of the MR Act by notifying the Department of Environment and Science (DES) of the exercise of its underground water rights.
- Comply with its monitoring and reporting obligations under Section 334ZP(5) of the MR Act and Chapter 3 of the *Water Act 2000* (Qld) (Water Act). Section 334ZP(5) of the MR Act requires that the volume of associated water taken is measured and reported. The proponent's obligations under Chapter 3 of the Water Act will include undertaking baseline assessments of the groundwater regime and water supply bores, providing ongoing assessment and reporting of groundwater take and, where necessary, entering into 'make good agreements' with owners of affected water supply bores.

These requirements are discussed in the following sections.

2.2. EP Act requirements to obtain an Environmental Authority

In order to obtain an EA, Section 126A(2) of the EP Act requires that the EA application for the project must be supported by the following specific information on the exercise of underground water rights:

- any proposed exercise of underground water rights during the period in which resource activities will be carried out under the relevant tenure;
- the areas in which underground water rights are proposed to be exercised;
- for each aquifer affected, or likely to be affected, by the exercise of underground water rights:
    - a description of the aquifer;
    - an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers and surface water;
    - a description of the area of the aquifer where the water level is predicted to decline because of the exercise of underground water rights; and
    - the predicted quantities of water to be taken or interfered with because of the exercise of underground water rights during the period in which resources activities are carried out.
- the environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values;
- any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out; and
- strategies for avoiding, mitigating, or managing the predicted impacts on the environmental values or impacts on the quality of groundwater.

The supporting information required under the EP Act is provided in this report. The conceptual groundwater model, including relevant aquifers and the movement of groundwater is discussed in Section 5. The proposed exercise of underground water rights is discussed in Section 6. The predicted effects of the project including changes in groundwater levels and groundwater take are also discussed in Section 6. Groundwater monitoring and management are discussed in Section 7.

2.3. MR Act notification requirements

In accordance with the requirements of the MR Act, the proponent will notify the DES of its exercise of underground water rights on the project site immediately after it starts exercising the rights. The proponent will report the annual associated water volume taken to the Department of Resources (DoR) in accordance with the Queensland guideline *Quantifying the volume of associated water taken under a mining lease or mineral development licence* (Department of Natural Resources, Mines and Energy, 2020).

2.4. Water Act monitoring and reporting obligations

In accordance with the requirements of Chapter 3 of the Water Act, the proponent will prepare an initial Underground Water Impact Report (UWIR). The main purpose of the UWIR is to describe the groundwater take due to mining (and any associated impacts) over a three-year period. The UWIR will also include a process for annual review and reporting.

The initial UWIR will be prepared in accordance with Section 376 of the Water Act and the DES guideline *Underground water impact reports and final reports* (the UWIR guideline) (DES, 2021), where relevant. Consistent with the UWIR guideline, the UWIR will be based on the information presented in this report. This information will be updated as necessary as part of the UWIR preparation. The proponent will then consult on the draft UWIR and notify relevant landholders. The draft UWIR will be provided to DES for approval, prior to the proponent exercising its underground water rights.

To ensure that the UWIR remains current throughout the duration of the groundwater take, the Water Act requires that the proponent must:

- update the UWIR on a three-yearly basis, in accordance with the UWIR guideline;
- review and update the UWIR in response to any material changes to the EA groundwater conditions to ensure alignment between the UWIR and EA groundwater conditions; and
- undertake an annual review of the accuracy of the groundwater model, as required by Section 376(1)(e) of the Water Act. The annual review process will comprise:
    - an initial review of any new geology or groundwater data or changes to the mine plan, to identify potentially significant departures from the data used in the UWIR to develop the drawdown mapping;
    - where potentially significant departures are identified, the potential effect of these departures on the drawdown mapping will be investigated; and
    - if the investigation concludes that the drawdown predictions are likely to have been under-estimated and additional impacts are likely, additional groundwater modelling will be undertaken to update the drawdown predictions.

The outcome of each annual review will be reported to the DES and the Queensland Office of Groundwater Impact Assessment (OGIA) following completion of each annual review. The OGIA is an independent entity established under the Water Act. The OGIA is responsible for assessing and managing the impacts of groundwater take for resource activities and provides expert advice on UWIRs and groundwater modelling to the DES. The reported outcomes will include a statement of whether there has been a material change in the information or predictions used to prepare the maps.

2.5. Other groundwater legislation and approvals

2.5.1. Water resource planning

The water resource planning process under the Water Act provides a framework for the development of catchment specific Water Plans. A Water Plan, along with subordinate protocols and operations manuals, provides a management framework for water resources in a plan area, and includes outcomes, objectives, and strategies for maintaining balanced and sustainable water use in that area.

The project site is located within the *Water Plan (Gulf) 2007* (the Gulf Water Plan) and *Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017* (the GABORA Water Plan) areas as shown in Figure 3. Both water plans are applicable to the project.

The GABORA Water Plan area comprises several 'groundwater units' and their component 'groundwater sub-areas'. A groundwater unit is the groundwater that is present within the geological formations that are listed within Schedule 3 of the GABORA Water Plan and are located within the areal extents of the groundwater unit. The groundwater units (and sub-areas) present at the project site are as follows:

- Eromanga North Hooray groundwater sub-area of the Hooray groundwater unit; and
- Eromanga Hutton groundwater sub-area of the Hutton groundwater unit.

The Gulf Water Plan is divided into several 'groundwater management areas'. The project site is located within the Great Artesian Basin Groundwater Management Area. The Gulf Water Plan is applicable to groundwater that is not 'GAB water' (i.e., groundwater that is not regulated as a groundwater unit under the GABORA Water Plan).

The project impacts on regulated groundwater resources are addressed in Section 6.3.1.

2.5.2. Water entitlements

As discussed in Section 2.3, the proponent has the right to take associated water under the MR Act. Hence, a water entitlement under the Water Act (e.g., a water allocation or water licence) is not required for associated water take.

Groundwater taken for 'consumptive' non-mining purposes (such as construction work and supplying accommodation camps) is not associated water. Hence, it is not authorised under the MR Act and would require a water entitlement. The project does not involve groundwater take for consumptive non-mining purposes and therefore a water entitlement is not required.

2.5.3. Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water) provides a framework for the protection of environmental values (i.e., uses) associated with Queensland aquifers. Under this framework, environmental values for specific catchments and drainage basins have been formalised through a process of statutory declaration. Environmental values formalised in this way are listed in Schedule 1 of the EPP Water. For other waters, a site-specific assessment of the potential environmental values is required.

The project site and its surrounds are not located within a catchment or aquifer that is listed in Schedule 1 of the EPP Water. Therefore, a site-specific assessment of the potential environmental values is required.

The groundwater users and sensitive environmental features within the project site and its surrounds are described in Section 4.1.3 and Section 6.3. Based on the information presented in this report, the environmental values for groundwaters in the project site and its surrounds are limited to agricultural use (stock watering).

Environmental values associated with other human uses of groundwater[1] are not relevant because these uses are not undertaken or currently planned within the project site or its surrounds. There are no known significant cultural or spiritual values associated with the local groundwater regime.

The EPP Water also establishes water quality objectives (WQOs) to protect the relevant environmental values for groundwater. WQOs comprise water quality indicators and corresponding water quality guidelines. The water quality indicators are the physical, chemical, or biological properties that can be quantitatively measured, while the water quality guidelines are the quantitative measure for an indicator. Water quality guideline values may be derived from assessment of environmental effects (i.e., toxicity testing) and/or reference site data.

WQOs have been established for the same catchments and drainage basins that have been formally assigned environmental values (through the process described above). WQOs that have been formalised in this way are listed in Schedule 1 of the EPP Water. For other waters (not listed in Schedule 1 of the EPP Water), WQOs are determined in accordance with:

- the Queensland guideline *Environmental Protection (Water and Wetland Biodiversity) Policy 2019: Deciding aquatic ecosystem indicators and local water quality guideline values* using site-specific information;
- the *Queensland Water Quality Guidelines* (Department of Environment and Heritage Protection [DEHP], 2009);
- the National Water Quality Management Strategy (NWQMS) guidelines;
- the *Australian and New Zealand guidelines for fresh and marine water quality* (Australian and New Zealand Environment and Conservation Council [ANZECC] and Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ], 2000);
- the *Australian drinking water guidelines* (National Health and Medical Research Council, 2011 updated 2018);
- the *Guidelines for managing risks in recreational waters* (National Health and Medical Research Council, 2008);
- *Deciding aquatic ecosystem indicators and local water quality guideline values* (DES, 2022); and
- *Using monitoring data to assess groundwater quality and potential environmental impacts* (DES, 2021).

WQOs have not been declared for the local groundwater regime. In the absence of declared WQOs, water quality objectives must be derived from a set of site-specific water quality guideline values for all relevant indicators that will protect the environmental values of the groundwater.

Interim site-specific water quality guideline values have been developed using local groundwater quality data, and supplemented by relevant published guideline values, where applicable. The interim site-specific water quality guidelines that meet the management intent of the EPP Water for protection of aquatic ecology and agricultural water supplies are presented in Table 1. The interim guideline values have been prepared in accordance with the *Queensland Water Quality Guidelines* (DEHP, 2009), the Queensland guidelines *Deciding aquatic ecosystem indicators and local water quality guideline values* (DES, 2022) and *Using monitoring data to assess groundwater quality and potential environmental impacts* (DES, 2021), and the Australian and New Zealand guidelines for fresh and marine water quality (Australian and New Zealand Governments [ANZG], 2018). This involved the following approach:

- Interim guideline values have been calculated using the baseline groundwater quality monitoring data discussed in Section 4.3.4.
- Interim guideline values have been calculated for all quality characteristics with at least eight monitoring results above the limit of reporting. Interim guideline values have not been calculated for quality characteristics with less than eight monitoring results above the applicable limit of reporting.

[1] Environmental values associated with the human use of groundwater include human consumption of aquatic foods, aquaculture, intensive agriculture, recreational uses (including swimming and aesthetic values), drinking water supply and industrial use.

- The dataset used to calculate the interim guideline values was adjusted for non-detections (i.e., results that are below the applied limit of reporting). For quality characteristics with a low proportion of non-detects, each non-detection was assigned a value of 50% of the applied limit of reporting. For quality characteristics with a high proportion of non-detections, each non-detection was removed from the dataset. Outliers were also removed from the dataset.
- Interim guideline values were calculated using the 80th (Limit A) and 95th percentile (Limit B) for each groundwater quality characteristic.

Section 4.3.4 describes the baseline groundwater quality and Section 6.4 provides an assessment of the project's effects on groundwater quality.

Table 1 Interim site-specific water quality values

Quality characteristic[1]	Unit	Limit type	Interim guideline value Limit A	Interim guideline value Limit B
pH	pH units	Range	6 - 8[3]	
TDS	mg/L	Maximum	8529[4]	10438[5]
Sulphate	mg/L	Maximum	144[4]	1515[5]
Aluminium	mg/L	Maximum	0.02[4]	0.04[5]
Arsenic	mg/L	Maximum	0.015[4]	0.027[5]
Boron	mg/L	Maximum	0.21[4]	0.29[5]
Cadmium	mg/L	Maximum		0.01[2]
Chromium	mg/L	Maximum		1[2]
Cobalt	mg/L	Maximum	0.011[4]	0.017[5]
Copper	mg/L	Maximum		1[2]
Iron	mg/L	Maximum	2.33[4]	8.68[5]
Lead	mg/L	Maximum	0.0012[4]	0.0015[5]
Manganese	mg/L	Maximum	3.41[4]	12.46[5]
Mercury	mg/L	Maximum		0.002[2]
Molybdenum	mg/L	Maximum	0.010[4]	0.016[5]
Nickel	mg/L	Maximum	0.010[4]	0.013[5]
Selenium	mg/L	Maximum		0.02[2]
Zinc	mg/L	Maximum	0.025[4]	0.043[5]
Other major ions	mg/L		For interpretive purposes	

Notes *:[1] All metals and metalloids must be measured as 'dissolved' (from analysis of a field filtered sample).*

[2] ANZECC (2000) trigger value from the livestock (cattle) drinking water guidelines.

[3] ANZECC (2000) Table 3.3.4 for lowland rivers.

[4] 80th percentile bore data (20th and 80th percentiles for pH)

[5] 95th percentile bore data (5th and 95th percentiles for pH)

3. Project setting

This section describes the project's environmental setting, including its location and land use, climate, topography and drainage, and geology.

3.1. Location and land use

The project site covers an area of 2,281 hectares (ha) and is located approximately 100 km north of Richmond and 380 km west of Townsville (Figure 1). Surrounding land use is predominantly cattle grazing.

There are no other current or proposed mining operations within 50 km of the project site. The potential for cumulative groundwater impacts due to the project and surrounding land uses is discussed in Section 6.3.7.

3.2. Climate

The climate at the project site is hot and semi-arid, and is characterised by hot, wet summers and mild, dry winters.

An interpolated site-specific dataset was downloaded from the DES Scientific Information for Land Owners (SILO) database for the project site (at location -19.75'S 143.45'E). The data is a grid point data set, meaning that the data has been interpolated for this location from station data.

A summary of average temperatures, rainfall and evaporation from the SILO dataset is shown below in Table 2.

Table 2 Climate averages

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean min temp (°C)	22.5	22.1	20.7	17.7	14.0	10.6	9.7	10.9	14.7	18.4	21.0	22.2	17.0
Mean max temp (°C)	35.3	34.3	33.6	31.9	28.7	26.1	26.0	28.3	31.8	35.1	36.5	36.7	32.0
Mean rainfall (mm)	158.2	131.6	73.8	19.8	10.7	12.2	7.2	2.9	4.7	14.9	36.9	87.8	561.2
Mean evaporation (mm)	108.4	103.7	88.6	49.7	29.0	21.4	21.0	28.0	36.5	51.0	65.6	86.3	690.1

The average annual rainfall for the area is approximately 560 mm, and the annual average evaporation is 690 mm. Rainfall predominantly occurs between December and March. Monthly evaporation rates exceed monthly rainfall for most months of the year (March to November), highlighting a net evaporative loss over a year.

3.3. Topography and drainage

The local topography and surface drainage are shown in Figure 4.

The regional topography is dominated by the Woolgar River and its tributaries. Rivers and creeks in the region have eroded the landscape, leaving behind isolated, elevated plateaus. Within the project site and its surrounds, the terrain is generally flat with an elevated plateau (approximately 100 m high) located to the east of the project site. Drainage over the project site flows to the west towards the Woolgar River (Figure 4).

The project site is bounded to the north and west by the Woolgar River, which discharges into the Stawell River approximately 73 km downstream of the project site boundary. Several minor un-named tributaries of the Woolgar River cross the project site. The Woolgar River and its tributaries are all ephemeral, with surface water flows typically restricted to the wet season (i.e., December to March).

3.4. Geology

The project site and its surrounds have a long history of geological exploration. Exploration activities commenced in the 1950s and have continued at intervals until the present day. On this basis, the geology of the project site and its surrounds is well understood.

The project site is located at the northern margin of the Eromanga Basin, a sedimentary basin that was deposited in the Mesozoic era. Locally, the Eromanga Basin overlies a Proterozoic basement. The Proterozoic basement is part of the North Australian Craton, one of Australia's major mineral provinces.

The Eromanga Basin and Proterozoic basement have been extensively modified by weathering and erosion. The weathered profile extends to depths of up to 40 m below ground level in the project site.

The surface geology in the project site and its surrounds is shown in Figure 5. Figure 6 shows typical geological cross-sections through the project site (the alignments of the cross sections are shown in Figure 5).

The project site stratigraphy includes the following (from youngest to oldest):

- alluvium associated with the Woolgar River and its floodplain;
- the weathered in-situ rocks of the Eromanga Basin and Proterozoic basement (herein called the 'weathered profile');
- fresh (i.e., unweathered) Jurassic strata of the Eromanga Basin; and
- fresh Proterozoic basement rocks, including the target gold ore.

The Woolgar River alluvium is a sand and gravel deposit that forms the Woolgar River floodplain. The floodplain alluvium is confined within a narrow valley. The floodplain alluvium thickness typically ranges from a few centimetres at the edge of the floodplain up to approximately 10 m on the riverbanks (Figure 7). The river channel is typically incised approximately 4 m into the floodplain alluvium. The base of the alluvium is located approximately 6 m below the riverbed.

The weathered profile comprises poorly consolidated, fine-grained, clay-bound sands and silts. The weathered profile is present across the entire project site. The weathered profile is typically located at the ground surface, except where it is overlain by the alluvium. The weathered profile is up to approximately 40 m thick in the lower lying areas and is typically thinner in the elevated parts of the project site (approximately 0.5 m thick). The weathered profile is between 4 m and 25 m thick in the open cut mining areas (Figure 8).

Historical bore logs show that the fresh Jurassic strata forms a single, undifferentiated sedimentary rock formation, comprising mainly sandstone, with minor conglomerate, siltstone, and claystone. Where present within the project site, the fresh Jurassic strata underlies the weathered profile (Figure 5) and ranges in thickness up to approximately 70 m. The fresh Jurassic sediments are between 0 m and 30 m thick in the open cut mining areas (Figure 9).

Exploration data from the project site shows that the Proterozoic basement comprises folded metamorphic rocks (e.g., amphibolite), granite and intrusive (dolerite and rhyolite) dykes. The Proterozoic basement typically underlies the weathered profile and the fresh Jurassic sediments (where present) (Figure 6). Within the open cut mining areas, the top of the Proterozoic basement is located at depths of between 10 m and 60 m below the ground surface (Figure 10). The Proterozoic basement is estimated to be several kilometres thick in the open cut mining areas.

The gold ore has been deposited in a deformation (or shear) zone within the Proterozoic basement. The shear zone is orientated along a south-southwest to north-northeast axis and extends across the project site. Exploration data from the project site shows that the shear zone has been completely mineralised.

4. Methodology

This section describes the groundwater assessment methodology, including the desktop study, groundwater field investigation, data analysis and conceptualisation, and numerical groundwater modelling.

4.1. Desktop study

The desktop study comprised the review and collation of site-specific and regional data to inform the conceptual understanding of the groundwater regime. The data accessed during the desktop study is described in the following sections.

4.1.1. Groundwater bore database searches

A search of relevant Australian and Queensland groundwater databases was undertaken. The purpose of this search was to identify the presence of current and historical groundwater bores and collate drilling records and groundwater level, yield and quality data from relevant bores.

The following databases and mapping were searched:

- The Department of Regional Development, Manufacturing and Water (DRDMW) groundwater database of registered water bore data from private water bores and Queensland Government groundwater investigation and monitoring bores. Data stored on the database includes bore location, groundwater levels, construction details, stratigraphic logs, hydrogeological testing, and groundwater quality.
- The Queensland Spatial Catalogue (Qspatial), via Queensland Globe. Records of petroleum and CSG exploration, production and monitoring wells are contained within this database.

The database search area included the project site and its surrounds within a radius of 5 km. The database search area was selected because it is suitably representative of the geological and hydrogeological conditions relevant to the project and includes the full extent of the projects effects on groundwater. The proponent undertook a bore census between 2017 and 2018 to confirm the status of the bores identified in the database searches and to identify any additional unregistered bores within the database search radius.

The database searches and bore census confirmed that there are no recorded bores within the project site. A total of six historical or existing groundwater bores have been recorded within a 5 km radius of the project site boundary (as shown in Figure 11 and summarised in Appendix A), including:

- Four historical bores, comprising:
    - Three registered historical water supply bores (RN 51011, RN 109879, and RN 109881). Database records for these bores show that they have all been abandoned and destroyed.
    - One registered historical bore (RN 163268). Site inspections undertaken as part of the bore census show that this bore is no longer present. The landholder is not aware of this bore having been installed or used as a water supply bore historically.
- Two existing bores, comprising:
    - One registered water supply bore (RN 163296). Database records show that this bore was drilled in 2019 and targets the Jurassic strata. It is understood to be an existing bore equipped for stock watering supply purposes. RN 163296 is located 3 km to the west of the project site boundary.
    - One unregistered water supply bore locally referred to as the 'Mt Norman Rockspear Bore'. The Mt Norman Rockspear Bore is currently equipped with a solar pump and provides stock watering supply to the landholder. Based on the location of the bore it is assessed that this bore intersects the weathered profile. The Mt Norman Rockspear Bore is located 2 km to the west of the project site boundary.

The available data from these six bores were collated (Appendix A) and used to assess site geology, groundwater levels, and groundwater quality. This information has been used to inform the conceptual understanding of the groundwater regime and the numerical groundwater model discussed in Sections 5 and 6, respectively.

4.1.2. Springs database searches and publications

A search of relevant Australian and Queensland groundwater databases/records was undertaken to identify groundwater springs. The following information sources were searched:

- springs shown on the Queensland Watercourse Identification Map of springs as defined in the Water Act;
- the Queensland Springs Database of active and inactive springs (DES, 2018);
- springs listed on the GABORA Water Plan (Water Management Protocol) Groundwater Dependent Ecosystem Register; and
- springs listed in the Queensland Groundwater Dependent Ecosystems Database.

There are no registered springs within the project site.

The only registered spring within 5 km of the project site boundary is Spring 377-Sowpit (as recorded on the Queensland Springs Database and GABORA Water Management Protocol). Spring 377 is located 900 m east of the project site boundary (Figure 11). The database records show that Spring 377 is an active spring that is part of the Sourpot spring complex within the Flinders River Spring Supergroup.

The proponent has also identified two unregistered springs approximately 600 m and 400 m to the east of the project site boundary (Figure 11).

The weathered profile forms the surface geology at the springs. At Spring 377 the groundwater table is located approximately 30 m below ground level within the underlying Proterozoic basement. At the unregistered springs, the groundwater table is located 45 m and 10 m below ground level within the underlying Jurassic strata. Hence, these springs are fed by perched groundwater seepage from the weathered profile. There is no hydraulic connection between the springs and the underlying groundwater table located within the Jurassic strata and Proterozoic basement.

A detailed description of the springs is provided in Section 5.3.

4.1.3. Other database searches and government mapping

Supporting data was also collected from a search of the following databases and maps:

- Queensland state geological mapping and explanatory notes;
- Queensland Globe and Qspatial mapping for information on the location of water plans and groundwater management units;
- DES climate data online (precipitation and evapotranspiration data);
- Geoscience Australia regional Great Artesian Basin datasets including the base of the Hooray Sandstone (GA, 2013a) and the Injune Creek Croup (GA, 2013b), and the water table elevation within the Great Artesian Basin (GA, 2013c);
- Geoscience Australia Hydrogeological Atlas of the Great Artesian Basin (GA, 2015); and
- Queensland government Water Monitoring Information Portal (DRDMW, 2022) for stream discharge records from state gauging stations.

4.1.4. Literature review and previous groundwater studies

A review of available literature and relevant groundwater studies was undertaken to collect hydrogeological data. This was undertaken to support the development and validation of the hydrogeological setting of the project site (Section 5).

Due to the remote location of the project site and the lack of historical mining activities, there are no previous groundwater studies of the local groundwater regime. Regional groundwater studies that were reviewed included the following:

- AGE (2005) – Great Artesian Basin Water Resource Plan – Potential river baseflow from aquifers of the GAB.
- Klohn Crippen Berger (2016) – Hydrogeological Assessment of the Great Artesian Basin – Characterisation of aquifer groups in the Eromanga Basin.
- CSIRO (2012) – Water resource assessment for the Central Eromanga region.

4.2. Groundwater field investigation

A site-specific groundwater investigation program was undertaken by the proponent in stages between October 2017 and November 2021. The purpose of the groundwater investigation program was to characterise the hydrogeological conditions within the project site and its surrounds.

The groundwater field investigation involved:

- Drilling and installing a dedicated groundwater monitoring network comprising 14 groundwater monitoring bores at seven sites (Table 3 and Figure 11). The 14 monitoring bores were installed as pairs of shallow and deep bores at each of the seven sites. The bores target the key hydrogeological units that form the local groundwater regime, including the Woolgar River alluvium, weathered profile, Jurassic strata, and the Proterozoic basement.
- Drilling and installing three vibrating wire piezometer (VWP) arrays (Table 3 and Figure 11). The VWP arrays were installed within the footprint of the BVS Pit. The VWP arrays were installed to measure groundwater levels in the Jurassic strata and Proterozoic basement and enable calculation of vertical hydraulic gradients between these units.
- Installing automatic water level loggers (dataloggers) in each groundwater monitoring bore following bore development and completion.
- Installing dataloggers at each VWP array.
- Permeability testing in monitoring bores and recording a standing water level.
- Measuring static groundwater levels in each groundwater monitoring bore. Initial measurements were collected following bore completion and development. Ongoing measurements have been collected by the proponent during the dry season when the project site is accessible.
- Sampling and testing groundwater quality in bores that contain sufficient water. Initial measurements were collected following bore completion and development. Ongoing measurements have been collected by the proponent during the dry season when the project site is accessible.
- Undertaking a targeted creek and alluvium investigation. The creek and alluvium investigation objectives included ground-truthing the extents of bed sediments and alluvium within the project site and its surrounds, where present confirming the depth/thickness of bed sands and alluvium, and identifying any other relevant landform features relevant to the local groundwater regime. The creek and alluvium investigation layout are shown in Figure 11. The investigation involved:
    - Locating the four groundwater monitoring sites within areas of mapped alluvium on the Queensland state geological mapping (i.e., MB1 to MB4). These bores were located close to the Woolgar River channel and the channels of drainage features traversing the project site.
    - Excavating seven test pits within the Woolgar River and overbank areas (sites A1, A1(X), A2, A3, A9, A12 and A27).

- Excavating 17 test pits in and adjacent to the drainage features that traverse the project site.
- Undertaking a detailed topographic/landform assessment based on high resolution aerial photography and detailed LiDAR data for the project site and its surrounds.

- Conducting a bore census to collect information on all relevant water supply bores within the bore census area. The results of the bore census are summarised in Section 4.1.1 and Appendix A.
- Conducting a spring inspection at the springs identified from the DES (2018) spring database and during the bore census. The results of the spring inspection are summarised in Section 4.1.1.

The location, target formation and depths of the installed groundwater monitoring bores and VWPs are shown below in Table 3.

Table 3 Summary of project monitoring bores and VWPs

Bore ID	Easting	Northing	Target formation	Bore depth (mbgl)	VWP depths (mbgl)
MB1A	738457	7807635	Proterozoic	6	-
MB1B	738457	7807635	Proterozoic	25	-
MB2A	739429	7810282	Jurassic strata	24	-
MB2B	739429	7810282	Proterozoic	70	-
MB3A	735824	7808079	Alluvium	5	-
MB3B	735824	7808079	Weathered profile	34	-
MB4A	740288	7805620	Weathered profile	13	-
MB4B	740288	7805620	Proterozoic	60	-
MB5A	738609	7805178	Jurassic strata	40	-
MB5B	738609	7805178	Proterozoic	90	-
MB6A	737645	7806506	Weathered profile	11	-
MB6B	737645	7806506	Proterozoic	84	-
MB7A	740129	7803932	Jurassic strata	33	-
MB7B	740129	7803932	Proterozoic	90	-
LR0290	739679	7806809	Proterozoic	292	60.0; 120.0; 180.0
LR0309	739480	7806379	Proterozoic	202	48.0; 120.0; 160.0
LR0272	739345	7805352	Jurassic strata; Proterozoic	322	48.5; 118.5; 169.0

Appendix B provides the groundwater quality monitoring data. Appendix C provides the data collected by the proponent during the groundwater field investigation, including bore/VWP logs, permeability testing results, and creek and alluvium inspection results.

4.3. Data analysis and conceptualisation

All relevant data was collated and analysed to develop an understanding of the conceptual groundwater regime. The conceptual groundwater regime is discussed in Section 5 and has been developed in consideration of the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012).

The following sections describe the data collation and analysis and development of the key datasets that underpin the conceptual groundwater regime, including geology data, groundwater flow data, hydraulic data, and groundwater quality data.

4.3.1. Geology

The regional and local geology data was used to identify the strata relevant to the conceptual groundwater regime. The proponent's exploration geology database was then integrated into the project dataset to produce detailed 3D geological surfaces representing the following strata:

- alluvium associated with the Woolgar River and its floodplain;
- the weathered profile of the Jurassic strata and Proterozoic basement;
- fresh (i.e., unweathered) Jurassic strata of the Eromanga Basin; and
- fresh Proterozoic basement rocks.

The geological model forms the basis for the conceptual groundwater regime described in Section 5 and provides the structural framework for developing a 3D numerical groundwater model, as summarised in Section 4.4.

4.3.2. Groundwater flow

Groundwater level data has been collected from the site-specific groundwater monitoring network and includes the following:

- Ten manual groundwater level monitoring rounds from April 2018 through to November 2021 (44 months duration). The monitoring has generally been carried out on a quarterly frequency.
- Groundwater level logger data captured from the monitoring bores and VWPs at a 6 hourly frequency from November 2017 through to November 2021 (49 months duration). Groundwater level monitoring is on-going.

Figure 12 to Figure 15 present the groundwater level hydrographs from the groundwater monitoring bores and VWP arrays for the period November 2017 to May 2021.

These groundwater level data were used to characterise groundwater flow directions and gradients. The data was plotted spatially to assess groundwater level flow directions and where data permits (e.g., VWPs) was assessed to determine vertical hydraulic gradients.

Temporal variations in groundwater level were used to interpret the rate and distribution of recharge/discharge, and pre-development variability in groundwater level. The groundwater level hydrographs were compared against rainfall and climatic trends to assess recharge/discharge characteristics. The bores were also considered in respect of their location to watercourses and drainage features.

The groundwater level data provides a reliable long-term, continuous record of groundwater level behaviour at the project site and is suitable to use as the basis for the development of the conceptual groundwater regime.

4.3.3. Hydraulic parameters

Hydraulic testing was carried out on the monitoring bore network. This hydraulic testing included falling head tests and rising head tests. The hydraulic data was then interpreted to calculate a hydraulic conductivity value for the screened interval at each monitoring bore. This includes data for the weathered profile, Jurassic strata and Proterozoic basement units within the project site and its surrounds. The hydraulic conductivity values collated are presented in Appendix C.

Five monitoring bores were dry throughout the monitoring period. Conventional falling head tests were unable to be carried out on these bores given the unsaturated conditions. Constant head tests were undertaken on the dry monitoring bores. The constant head tests show that the permeability of the screened strata is higher than could practically be measured using field pumping equipment (i.e., higher than 1 m/d).

The site-specific hydraulic conductivity data was considered in relation to regional studies and incorporated into the conceptual groundwater regime.

4.3.4. Groundwater quality

The groundwater quality data collected for the project comprises 109 samples from nine monitoring bores within the vicinity of the project site (from April 2018 to November 2021). Appendix B presents the groundwater quality results.

Groundwater quality data was used to:

- Establish baseline groundwater quality within each hydrostratigraphic unit (as described in Section 5).
- Develop interim groundwater quality guideline values (as discussed in Section 2.5.3).
- Identify and distinguish between groundwater types. Major ion data for the project monitoring bores are summarised in a Piper plot (Figure 16), which categorises water type based on the normalised, relative proportion of each major cation and anion. Piper plots are useful for assessing groundwater mixing and evolution (e.g., through water-rock interaction) and identifying potential zones of groundwater recharge and discharge.

Salinity is a key constraint to the usability of groundwater resources for productive applications such as potable supply, irrigation, stock watering and industrial applications. For the purposes of this report, the United Nations Food and Agriculture Organisation (FAO, 2013) categorisation scheme for salinity has been used to describe salinity. The salinity categories are presented in Table 4.

Table 4 Salinity classification (FAO 2013)

Salinity classification	TDS concentration (mg/L)
Fresh water	<500
Brackish (slightly saline)	500 to 1,500
Moderately saline	1,500 to 7,000
Saline	7,000 to 15,000
Highly saline	15,000 to 35,000
Brine	>35,000

A histogram of the average TDS for each monitored hydrostratigraphic unit from the groundwater monitoring network is presented in Figure 17.

4.4. Numerical modelling

A 3D numerical groundwater flow model was developed using MODFLOW-USG software to represent the conceptual groundwater regime discussed in Section 5. A detailed description of the modelling methodology is provided in Appendix D. The model was developed in accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012).

The model represents the key geological units using four model layers and extends approximately 15 km northeast-southwest and 8 km northwest-southeast. The project open cut mining areas are located in the centre of the model domain. As recommended in Barnett *et al.* (2012), the model domain covers the entire area of interest with a spatial buffer large enough to ensure that the limits of the model domain are sufficiently remote to reduce any impact of boundary conditions on the model results.

The physical structure of the groundwater model was based on the detailed geological model discussed in Section 3.4.

The available groundwater monitoring dataset was sufficiently large to enable a transient (time-variant) calibration to be undertaken. The transient calibration allowed the model to fully consider the change in groundwater levels and flow during the pre-mining conditions from 2017 through to 2021.

The groundwater flow model was calibrated to groundwater levels from 12 observation sites; including seven monitoring bores and five individual VWP gauges installed during the project field investigation. A detailed description of the calibration method is provided in Appendix D. The calibration was conducted in accordance with Barnett *et al.* (2012).

The calibration achieved a 9.81% scaled root mean squared (SRMS) error which is within acceptable limits (i.e., 10%) as recommended by Barnett *et al.* (2012). Furthermore, the calibrated groundwater levels, vertical gradients, flow patterns and mine inflows replicate measured data and groundwater trends. The model calibration is therefore robust.

The calibrated groundwater model was used to predict groundwater inflows and changes in groundwater levels in response to the open pit mining for the project.

The sensitivity of the model predictions to the input hydrogeological parameters was tested. This involved varying key model parameters in isolation and assessing the influence the change made of predictions of drawdown and mine inflow. Key model parameters were selected based on their potential to most influence model predictions. Sensitivity analysis included testing of the following parameters, which covers the range of likely uncertainty in key parameters:

- the hydraulic conductivity and specific storage of the Proterozoic basement;
- the river cell conductance term representing the Woolgar River; and
- the rainfall recharge rate across the model domain.

The changes used to test the model sensitivity include extremes in the potential parameter ranges and encompass the full range of relevant measured values for these parameters. This is in line with the method outlined in Barnett *et al.* (2012).

Appendix D provides a detailed discussion of the sensitivity analyses undertaken. The following sections describe the predictions of the groundwater model.

5. Existing groundwater regime

5.1. Overview

The conceptual groundwater regime is illustrated in Figure 18 and comprises:

- localised alluvium associated with the Woolgar River;
- a weathered profile which exhibits variable permeability and is typically dry and unsaturated;
- localised and disconnected residual areas of fresh Jurassic strata; and
- fresh Proterozoic basement aquiclude, comprising a dry crystalline and metamorphosed rock mass with occasional disconnected cracks that can contain groundwater.

The local groundwater regime is heavily influenced by the local topography. The local topography transitions from elevated rocky plateaus to the flatter, low-lying terrain of the Woolgar River floodplain. Several plateaus and associated ridgelines extend into the eastern portion of the project site.

These elevated landforms are formed on thin residual areas of Jurassic strata that is capped by a thin weathered profile. The residual areas of Jurassic strata within the project site and its surrounds are located approximately 60 km west of the thicker Jurassic strata which form productive GAB aquifers. The residual areas of Jurassic strata within the project site and its surrounds are therefore hydraulically disconnected from the productive Jurassic aquifers of the GAB. These distant GAB aquifers will therefore not be potentially impacted by the project and are not relevant to the groundwater assessment.

Seasonal rainfall and runoff concentrate on the upper surfaces and slopes of the elevated landforms, enhancing infiltration in these areas. A portion of the surface water infiltration moves through the unsaturated weathered profile and Jurassic strata to recharge the underlying regional groundwater table.

Locally, groundwater flows west from the elevated plateau recharge areas towards the surrounding lower-lying areas. Figure 19 to Figure 22 show the change in groundwater elevation across the local groundwater regime and the direction groundwater flow.

In the lower-lying areas, the groundwater table extends from the Jurassic strata into the adjacent Proterozoic strata and the overlying weathered profile. Figure 23 and Figure 24 show the extent and thickness of the saturation in the weathered profile and the Jurassic strata. The Proterozoic basement contains groundwater in disconnected cracks but does not form a continuous, saturated aquifer.

Figure 25 shows the spatial variations in the groundwater table depth due to changes in topography. The groundwater table is generally deeper in elevated areas and shallower in the vicinity of the incised rivers and creeks. In the elevated plateau areas, the groundwater table is typically located 50 m below ground level.

In discrete areas below the Woolgar River channel, where the alluvium is thickest, the base of the alluvium may intersect the groundwater table. In these localised and discontinuous areas, the base of the alluvium is likely to be partially saturated and recharged by the regional groundwater flows. The distribution and thickness of saturated alluvium is shown in Figure 26. In other areas, the base of the alluvium is typically located several metres above the regional groundwater table, and therefore in these areas the alluvium is typically dry and unsaturated. These areas are also shown in Figure 26. In the areas of unsaturated alluvium, the regional groundwater regime does not significantly contribute to recharge of the alluvium.

Ephemeral surface water flows in the Woolgar River recharge the underlying groundwater regime and result in small seasonal variations in groundwater table depth. The groundwater table immediately below and adjacent to the river channel typically rises by approximately 0.5 m, and up to approximately 2 m in response to ephemeral river flows. The groundwater table is typically at its highest (i.e., closest to ground level) during flow events in the river. At this time, the groundwater table may intersect the ground surface in the Woolgar River bed. As surface water flows recede, the depth to groundwater increases rapidly and the shallow alluvium dries quickly. At this time, the groundwater table is typically located between 2 m, and up to 6 m, below the riverbed. The groundwater table does not intersect the riverbed for the remainder of the year.

Groundwater discharge also occurs regionally through a range of processes, including discharge via evaporation from the alluvium and discharge via transpiration from the woodland vegetation that is present across the majority of the project site and its surrounds.

In the elevated plateau areas, shallow groundwater may also occur in thin permeable layers within the weathered profile. Where this occurs, the shallow groundwater is located above the regional groundwater table. Hence, the shallow groundwater and regional groundwater table are hydraulically disconnected.

Groundwater is typically slightly acidic to slightly alkaline and fresh to saline, with low concentrations of metals, metalloids, and other solutes. Local and regional groundwater is therefore generally unsuitable for potable or irrigation uses. Where groundwater quality is suitable for stock watering, yields are generally very low. There are two water supply bores located within 5 km of the of the project site boundary (see Figure 11).

The hydrogeology of each component of the groundwater regime is described in the following sections.

5.2. Alluvium

5.2.1. Groundwater distribution

The Woolgar River alluvium is a sand and gravel deposit that forms the Woolgar River floodplain. The floodplain alluvium is confined within a narrow valley. The floodplain alluvium thickness typically ranges from a few centimetres at the edge of the floodplain up to approximately 10 m on the riverbanks. The river channel is typically incised approximately 4 m into the floodplain alluvium. The base of the alluvium is located approximately 6 m below the riverbed.

The floodplain alluvium is located above the groundwater table in the vicinity of the project site. This means that the floodplain alluvium is dry and unsaturated.

Below the riverbed, the alluvium extends below the groundwater table in localised and discontinuous areas. In these localised areas, the riverbed alluvium is partially saturated by the groundwater table. There is up to 4 m of saturation in the riverbed alluvium. The upper profile of the riverbed alluvium is typically dry and unsaturated. The extent and thickness of saturation in the alluvium is shown in Figure 26.

There is no difference in the saturated extent of the alluvium between the wet and dry seasons.

Groundwater does not provide baseflow to any watercourses in the vicinity of the project site. This is supported by the highly ephemeral nature of the Woolgar River (i.e., no baseflow).

5.2.2. Hydrogeological parameters

The hydraulic conductivity of the alluvium is well understood from numerous regional studies (as discussed in Section 4.1.4).

No measured hydraulic conductivity values are available within the project extent as the alluvium monitoring bore has been dry since installation. The constant head tests show that the permeability of the target strata is higher than could practically be measured using field pumping equipment (i.e., higher than 1 m/d).

Alluvial sediments typically have relatively high hydraulic conductivity values with an estimated range between 1 m/day and 10 m/day common in similar geological settings.

5.2.3. Recharge, flow and discharge

Recharge to the alluvium predominantly occurs via localised and episodic recharge during intermittent flow or flood events in the Woolgar River. Discharge from the alluvium occurs laterally downgradient through the alluvial sediments, and vertically into the underlying weathered profile.

The alluvium is a high permeability unit, with water travelling quickly through the alluvium and recharging the underlying weathered profile. Monitoring bore MB3A is screened outside the saturated extent of the alluvium (Figure 26) and has been consistently dry since installation. This supports the conclusion that the extent of saturation in the alluvium does not noticeably expand during the wet season.

Groundwater flow within the alluvium occurs (where saturated) to the south-west along the flow direction of the Woolgar River (Figure 19).

5.2.4. Groundwater quality

RN 51011 is an abandoned and destroyed bore that was installed on a mid-channel bar within the Woolgar River, approximately 3 km to the west of the BVS Pit. The bore report for RN 51011 describes potable water quality. There is no other documented groundwater quality data for the alluvium.

However, where present, groundwater within the alluvium is expected to be similar to groundwater in the connected weathered profile, i.e., brackish to saline, and pH neutral with typically low concentrations of dissolved metals.

Intermittent river flows will recharge the alluvium and will reduce the salinity of the groundwater in the alluvium.

5.2.5. Groundwater yield and use

There are no groundwater supply bores targeting the alluvium within the project site or the surrounding 5 km. This is expected given that the alluvium is typically thin and dry with disconnected areas of partial saturation. Hence, the alluvium does not form a developed aquifer or a reliable, high yielding groundwater supply.

5.3. Weathered profile

5.3.1. Groundwater distribution

The weathered profile is extensive over the project site and within the vicinity of the proposed open pits is between 4 m and 25 m thick (Figure 8). The thickness of the weathered profile decreases and thins on the elevated plateau that occurs to the north-east and east of the project site.

The weathered profile is typically unsaturated over much of the project site with saturation occurring in proximity to the Woolgar River and beneath the southernmost drainage feature that extends through the central part of the project site. The extent and thickness of saturation in the weathered profile is shown in Figure 23.

5.3.2. Hydrogeological parameters

The weathered profile has a measured hydraulic conductivity of 1.7 m/d within the project site. This hydraulic conductivity is derived from monitoring bore MB3B which intersects groundwater within the weathered profile above the Proterozoic basement. The two other monitoring bores constructed within the weathered profile (MB4A and MB6A) are consistently dry.

5.3.3. Recharge, flow and discharge

Recharge to the weathered profile occurs via diffuse recharge from rainfall during periods where rainfall exceeds evaporation (December to February). Short-duration recharge may also occur via localised seepage from the overlying alluvium (where present).

The groundwater level hydrographs for the weathered profile monitoring bores are shown in Figure 12. Monitoring bores MB4A and MB6A are consistently dry however monitoring bore MB3B is located to the north-west of the project site immediately adjacent to the Woolgar River and shows a cyclic pattern in groundwater levels in response to flow events in the river.

Groundwater flow within the weathered profile occurs (where saturated) to the south-west, closely following topography (Figure 20).

Discharge from the weathered profile occurs vertically into the underlying Jurassic strata or Proterozoic basement (Figure 5).

Localised discharge from the weathered formation also occurs via Spring 377 and the unregistered springs located to the east of the project site boundary (Figure 11). These springs are outcrop springs of the Flinders River Spring Supergroup. The Queensland government has documented the hydrogeology of outcrop springs (including these springs) in the Flinders River Spring Supergroup as part of its Lake Eyre Basin Springs Assessment (LEBSA) Project reporting (DSITI, 2015). The LEBSA Project reporting provides a conceptual model of these springs (Figure 27) and describes the hydrogeology of these springs as follows:

- The outcrop springs occur in elevated areas where Jurassic sandstone outcrops (i.e., before the rocks dip underground). The springs are commonly associated with side gullies and/or footslopes of the elevated sandstone areas.
- A small percentage of rainwater that falls on the elevated area infiltrates into the ground. The infiltrating groundwater becomes perched when it reaches a less impermeable layer.
- Groundwater drains out of the elevated rocks under gravity or through the intersection of the ground surface with saturated rocks (rather than welling upwards under artesian pressure). Hence, outcrop springs have markedly different characteristics from discharge (artesian) springs that are typically located on low lying plains.
- Groundwater flows from outcrop springs can change dynamically in response to recent rainfall events. Hence, the groundwater has a relatively short residence time in the rock and tends to be neutral to slightly acidic, with low levels of dissolved solids.

Specifically, Spring 377 and the unregistered springs to the east of the project site are fed by seepage from perched groundwater within the weathered profile in the elevated plateau area. The springs emanate from stratigraphic weaknesses associated with gullies on the slopes of the elevated plateau area.

Spring 377 is located at an elevation of 432 mAHD. The regional groundwater table is located approximately 30 m below ground level (in the Proterozoic basement) at the Spring 377. Unregistered spring no. 1 is located at an elevation of 430 mAHD. The regional groundwater table is located approximately 45 m below ground level (in the fresh Jurassic strata) at unregistered spring no. 1. Unregistered spring no. 2 is located at an elevation of 397 mAHD. The regional groundwater table is located approximately 10 m below ground level (in the fresh Jurassic strata) at unregistered spring no. 2. Hence, there is no connection between these springs and the regional groundwater table. This is consistent with the Queensland government's assessment of the hydrogeology of these springs.

5.3.4. Groundwater quality

Groundwater in the weathered profile is typically fresh, with measured TDS values ranging from 118 ppm to 198 ppm (Figure 17). The observed low salinity is due to the permeability of the weathered profile and the short duration of groundwater residency in this formation.

Groundwater is typically slightly acidic to neutral (6.1 to 7.1 pH) with low concentrations of dissolved metals and minerals.

5.3.5. Groundwater yield and use

There are no groundwater supply bores targeting the weathered profile within the project site.

One water supply bore is located within 5 km of the project site (Mt Norman 'Rockspear Bore') within the weathered profile (Figure 11). This bore is currently utilised for stock watering.

5.4. Jurassic strata

5.4.1. Groundwater distribution

The Jurassic strata has a highly variable distribution across the project site and within the vicinity of the proposed open pits has a maximum thickness of 30 m (Figure 9). The thickness of the Jurassic strata increases on the elevated plateaus on the eastern and north-eastern margin of the project site.

The Jurassic strata is saturated in isolated areas to the north and east of the project site, corresponding to the location of the elevated plateaus. The extent and thickness of saturation in the Jurassic strata is shown in Figure 24.

As discussed in Section 2.5.1, the Jurassic strata within the project site and its surrounds are located approximately 60 km west of the main Jurassic strata that form productive GAB aquifers. The areas of Jurassic strata within the project site and its surrounds are hydraulically disconnected from the productive Jurassic aquifers of the GAB. There is no plausible mechanism by which the distant and hydraulically disconnected GAB aquifers located 60 km south of the project site could potentially be impacted by the project and therefore these aquifers are not relevant to the groundwater assessment.

5.4.2. Hydrogeological parameters

The Jurassic strata has variable hydraulic conductivity, ranging from 7×10^{-2} m/d to 5 m/d within the project site. This hydraulic conductivity is derived from monitoring bores MB2A and MB7A which intersect groundwater within the Jurassic strata. The other monitoring bore constructed within the Jurassic strata (MB5A) is consistently dry, as is the shallow VWP gauge at LR0272 (located within the footprint of the BVS Pit).

5.4.3. Recharge, flow and discharge

Recharge to the Jurassic strata occurs via diffuse recharge migrating vertically through the overlying weathered profile. Typically, this occurs during periods where rainfall exceeds evaporation (December to February).

Discharge from the Jurassic strata occurs vertically into the underlying Proterozoic basement.

The groundwater level hydrographs for the Jurassic strata monitoring bores are shown in Figure 13. Monitoring bore MB5A is consistently dry, as is the shallow VWP gauge at LR0727 which is located within the footprint of the BVS Pit. MB2A is located to the north of the project site adjacent to the Woolgar River and shows a cyclic recharge pattern in groundwater levels. This recharge response is muted by the overlying alluvium and weathered profile, with the recharge peak generally occurring between March through to July, four months after the flow event peak observed in the Woolgar River.

MB7A is located in the south-eastern portion of the project site. The monitoring bore is screened in the Jurassic strata directly above the Proterozoic basement. The hydrograph (Figure 13) illustrates a relatively flat and static groundwater trend at monitoring bore MB7A. The groundwater level at MB7A is regularly observed at approximately 28 mbGL (353 mAHD). The recharge responses observed at MB2A are not seen in MB7A. MB7A is located approximately 5 km from the Woolgar River and is not influenced by the localised recharge that occurs during flood or flow events of the Woolgar River.

Groundwater flow within the Jurassic strata occurs to the south-west, closely following topography (Figure 21).

5.4.4. Groundwater quality

Groundwater in the Jurassic strata is typically fresh to brackish, with measured TDS values ranging from 220 ppm to 699 ppm (Figure 17). The observed low salinity is due to the relatively high rates of recharge and short residence times of groundwater in this formation, which result in low solute contribution from the rock mass to groundwater.

Groundwater is typically neutral to slightly alkaline (6.7 to 8.8 pH) with low concentrations of dissolved metals and minerals.

5.4.5. Groundwater yield and use

No groundwater supply bores target the Jurassic strata within the project site.

One groundwater supply bore is located within 5 km of the project site (RN 163296) within the Jurassic strata (Figure 11). This bore is currently utilised for stock watering.

5.5. Proterozoic basement

5.5.1. Groundwater distribution

The Proterozoic basement is an aquiclude that is present across the entire project site (Figure 10). The rock mass is essentially a dry crystalline and metamorphosed rock mass with occasional disconnected cracks that can contain groundwater. On that basis, while the Proterozoic basement is partially or completely saturated across the project site, the groundwater within this formation does not form a single, connected, or pervasive aquifer.

5.5.2. Hydrogeological parameters

The Proterozoic basement is crystalline, with very low permeability. Monitoring bores MB2B, MB4B, MB5B and MB7B show slow recharge responses following groundwater sampling events and the recovery curves have been used to assess hydraulic conductivity values. The groundwater recovery data indicates very low hydraulic conductivity values in the range of 1×10^{-5} m/d to 4×10^{-5} m/d.

Higher hydraulic conductivity values (in particular from MB1B) are indicative of permeability associated with secondary porosity (i.e., localised and discontinuous fractures). As discussed in Section 5.5.1, these higher hydraulic conductivity values are not representative of the overall permeability of the rock mass.

5.5.3. Recharge, flow and discharge

Recharge to the Proterozoic basement occurs via diffuse recharge migrating vertically through the overlying weathered profile and Jurassic strata (where present) where these units are unsaturated. Typically, this occurs during periods where rainfall exceeds evaporation (December to February). Slow, downward seepage from areas of the weathered profile and the Jurassic strata that are saturated also recharge the Proterozoic basement year-round.

The groundwater level hydrographs for the Proterozoic basement monitoring bores are shown in Figure 14. Monitoring bore MB1A is consistently dry, however monitoring bore MB1B (located to the north-west of the project site) shows a subdued cyclic recharge pattern in groundwater levels. This recharge response is muted by the overlying weathered profile and Jurassic strata, with the recharge peak occurring between March to June.

The same subdued recharge response is visible within the three VWP hydrographs at LR0272, LR0290 and LR0309, located within the footprint of the BVS Pit (Figure 15).

The groundwater level hydrographs for monitoring bores MB2B, MB4B, MB6B and MB7B show a flat, or static, groundwater level over time, while MB5B shows a long, gradual recovery in groundwater level. The slow recovery at MB5B is a result of the very low hydraulic conductivity within the Proterozoic basement.

Groundwater flow and discharge from the Proterozoic basement occurs to the south-west, closely following topography (Figure 22). However, given the very low primary hydraulic conductivity of the Proterozoic basement, the rate of discharge is very low.

5.5.4. Groundwater quality

Groundwater in the Proterozoic basement is typically fresh to saline, with measured TDS values ranging from 442 mg/L to 10,740 mg/L (Figure 17).

Groundwater is typically slightly acidic to slightly alkaline (6.7 to 8.8 pH) with generally low concentrations of dissolved metals and minerals.

5.5.5. Groundwater yield and use

There are no groundwater supply bores targeting the Proterozoic basement within 5 km of the project site. This is expected given that the Proterozoic basement is low yielding with variable salinity, and as such does not provide a reliable groundwater supply.

6. Impact assessment

6.1. Project activities and potential groundwater effects

The project involves the development of three open cut pits and associated mining infrastructure within the project site (Figure 2). The open cut mining methods are described in Section 1.1.

6.1.1. BVS Pit

The depth of open cut mining in BVS Pit ranges up to approximately 220 m below ground level (150 mAHD). The proposed BVS Pit will intersect the weathered profile, Jurassic strata, and Proterozoic basement. In the BVS Pit footprint, the groundwater table is located within the weathered profile, Jurassic strata and Proterozoic basement at depths ranging from 5 m to 38 m below ground level (365 mAHD to 332 mAHD). Hence, the base of the BVS Pit will extend below the groundwater table and will result in a reduction in groundwater pressure or level in the vicinity of the pit. A reduction in groundwater pressure or level is referred to as 'drawdown' (or 'depressurisation' when referring to a confined groundwater table). The affected area is referred to as the 'zone of drawdown (or zone of depressurisation)'.

As discussed in Section 4.4, a numerical groundwater model was developed to predict the drawdown around BVS Pit. The extent and magnitude of drawdown around BVS Pit depends in part on the properties of the Proterozoic basement and the other surrounding strata. The magnitude of the drawdown is also influenced by distance from BVS Pit, with the greatest drawdown occurring adjacent to the pit and gradually reducing with distance from the pit.

The mining schedule and mine plan dictate the occurrence (extent and magnitude) of groundwater drawdown at each stage of the mine development, and this sequencing has been captured in the groundwater modelling.

Section 6.2 presents the predicted changes to groundwater levels due mining in BVS Pit and Section 6.3 describes the associated impacts. Section 6.4.1 describes the expected groundwater quality effects of BVS Pit and the associated impacts.

6.1.2. BV1 Pit and BV2 Pit

BV1 Pit will extend to a maximum depth of 35 m below ground level (390 mAHD). The groundwater table is located at depths of 55 m below ground level (370 mAHD) at BV1 Pit. Hence, the base of BV1 Pit is located approximately 20 m above the groundwater table and therefore BV1 Pit will not intersect the groundwater table. Mining activities in BV1 Pit that occur above the groundwater table will not result in groundwater drawdown.

Similarly, BV2 Pit will have a maximum depth of 10 m below ground level (370 mAHD). This depth is approximately 15 m above the groundwater table (355 mAHD) at this location and will not intersect the groundwater table or result in drawdown.

In both BV1 Pit and BV2 Pit, the base of the open cut pit is located in the Proterozoic basement. The Proterozoic basement is an aquiclude that is essentially a dry crystalline and metamorphosed rock mass with occasional disconnected cracks that can contain groundwater. It has very low permeability that will effectively prevent seepage of intermittent pit water to the underlying groundwater table. Hence, the BV1 Pit and BV2 Pit are expected to have negligible effect on groundwater levels.

Section 6.4.2 describes the expected groundwater quality effects of BV1 and BV2 the associated impacts.

6.1.3. Mine infrastructure

The key potential sources of groundwater contamination from the mine infrastructure include:

- seepage from WRDs;
- seepage from ore stockpiles;
- seepage from the tailings storage cell;
- seepage from the heap leach pads; and
- the use of hydrocarbons and chemicals.

The groundwater quality effects, and associated impacts of these sources are discussed in Section 6.4.

6.2. Groundwater modelling predictions

This section describes the predicted changes to groundwater levels due to the project, the corresponding volume of groundwater take from the groundwater regime and any associated changes in surface water flows. The associated impacts on groundwater users and the surrounding environment are described in Section 6.3.

6.2.1. Drawdown predictions

Groundwater assessments are typically based on the zone of drawdown at the end of mining operations, as this represents the cessation of mine dewatering, and this scenario typically represents the maximum drawdown associated with mining. This approach is appropriate and conservative for assessing the effects of mining on the groundwater regime and ensures that the potential worst-case impacts on groundwater users and sensitive environmental features are assessed.

For the purposes of the project groundwater assessment, the limit of the zone of drawdown is conservatively defined by a predicted 1 m change in the piezometric surface level. A 1 m change in the piezometric surface level was adopted in defining the limit of the zone of drawdown as it represents the reasonable limit of precision that can be inferred from groundwater modelling.

Figure 28 to Figure 30 show that localised drawdown is predicted around the BVS Pit.

The Proterozoic basement is predicted to experience up to approximately 65 m of drawdown around the pit margins (Figure 30). The zone of drawdown within the Proterozoic basement is predicted to extend up to approximately 1.4 km to the north-west of the BVS Pit, 1 km to the south-west, 550 m to the south-east and 1.5 km to the north-east and generally remains localised within the project site. The zone of drawdown extends up to approximately 430 m outside the eastern boundary of the project site.

Drawdown extends into the partially saturated Jurassic strata and weathered profile that overlie the Proterozoic basement around the BVS Pit (Figure 28 and Figure 29). This results in localised drawdown of up to approximately 3 m in the Jurassic strata (Figure 29) and 6 m in the weathered profile at the pit margins (Figure 28). Drawdown in the Jurassic strata extends approximately 760 m east of the BVS Pit, while drawdown in the weathered profile is concentrated in the area within 1.5 km to the north-west of the BVS Pit. Drawdown in these formations is almost entirely localised within the project site.

Within the zone of drawdown, the groundwater table is located within the weathered profile, Jurassic strata, and Proterozoic basement. The predicted drawdown on groundwater levels within these formations will result in a corresponding lowering of the groundwater table. The predicted drawdown on the groundwater table (irrespective of formation) is shown in Figure 31. Figure 31 shows that the groundwater table is predicted to be lowered by up to 70 m around the BVS Pit. The extent of groundwater table drawdown shown in Figure 31 corresponds to the combined extent of drawdown in the weathered profile, Jurassic strata, and Proterozoic basement formations.

No drawdown in the alluvium is predicted as it is located well beyond the maximum extent of drawdown on the groundwater table.

Post mining (i.e., following the cessation of mine dewatering) groundwater levels around the BVS Pit final void will recover in line with the establishment of a final void lake. The establishment of the final void lake is described in the EAR Surface Water Report. The water level within the BVS Pit final void is predicted to recover to a quasi-equilibrium elevation of 230 m AHD. Hence, the predicted final void lake elevation is approximately 120 m lower than the baseline pre-mining groundwater level at the BVS Pit. This difference in groundwater elevation means that there will be a post mining hydraulic gradient that induces groundwater flow towards the final void. On this basis, the final void will remain a permanent groundwater sink. There will be a zone of drawdown around the final void in perpetuity and groundwater flow within this zone will be towards the final void.

Groundwater monitoring will be undertaken during mining operations and post mining to confirm the groundwater drawdown predictions and identify any unexpected changes in groundwater levels. Section 7 describes the proposed groundwater monitoring program and management measures.

6.2.2. Predicted groundwater take

Figure 32 shows a hydrograph of predicted groundwater inflows to BVS Pit. The predicted groundwater take will peak at approximately 746 m^3/day (272 ML per annum) during the initial years of mining in BVS Pit. Predicted groundwater take then gradually decreases over the life of the project to a rate of approximately 570 m^3/day (208 ML per annum) at the end of the mining operations.

The predicted groundwater inflow rates represent the theoretical volume of groundwater take from the groundwater regime. The actual volume of groundwater pumped from the BVS Pit (requiring consideration in the site water management system) will be less than the inflow predicted by the numerical model, as a component of the groundwater will be lost to evaporation and retained moisture within the mined ore and waste rock. The model inflow rates presented in Figure 32 do not account for the abovementioned losses. A loss factor of approximately 40% is typically applied to groundwater model inflow rates to account for these losses in the calculation of mine dewatering rates.

There is likely to be negligible residual post mining groundwater take associated with evaporative losses from the final void lake surface. The EIS Surface Water Report provides a full assessment of the final void water balance.

There is no predicted groundwater take from the BV1 and BV2 Pits.

6.3. Project impacts

The predicted effects of mining on groundwater levels were used to assess the potential impacts of the project on groundwater users and groundwater dependent features of the surrounding environment. Potential impacts include:

- impacts on the regulated groundwater resources;
- impacts on groundwater supply bores;
- impacts on surface drainage;
- impacts on wetlands;
- impacts on Groundwater Dependent Ecosystems;
- impacts on springs; and
- cumulative impacts (i.e., due to operation of the project and other groundwater users) on creeks, surface water features, ecosystems, and groundwater resources and users.

Sections 6.3.1 to 6.3.7 describe potential impacts related to predicted changes in groundwater levels.

The groundwater assessment also investigated potential impacts on groundwater quality. These potential impacts are discussed in Section 6.4.

6.3.1. Impacts on groundwater resources

The regulated groundwater resources within the project site and its surrounds are listed in Section 2.5.1, and include:

- Groundwater within the Jurassic strata of the Hooray and Hutton groundwater units, as defined in the GABORA Water Plan; and
- Groundwater within all other formations as described in the Gulf Water Plan.

The project's total groundwater take from the GABORA Water Plan regulated groundwater resources (i.e., the Jurassic strata comprising the Hooray and Hutton groundwater units) is 0.04 ML (i.e., 40,000 L) over the life of the project. This represents a negligible proportion (0.00019%) of the 21,000 ML held within the general and state reserves for these groundwater units.

Post mining there will be negligible groundwater take from the GABORA Water Plan regulated groundwater resources. As discussed in Section 5.4.1, the Jurassic strata within the project site and its surrounds are hydraulically disconnected from the productive Jurassic GAB aquifers that are located approximately 60 km south of the project site. The GAB formations outside the project site extent will therefore not be affected by the project.

The remainder of the project's groundwater take will occur from the Proterozoic basement and the overlying weathered formation. These formations are not regulated under the GABORA Water Plan and fall under the general groundwater management area of the Gulf Water Plan.

As explained in Section 2.5.2, the project groundwater take will be deemed associated water. The proponent has the right to take associated water under the MR Act. Hence, a water entitlement under the Water Act (e.g., a water allocation or water licence) is not required for associated water take. The take of associated water will be conducted in accordance with the applicable Queensland regulatory requirements as set out in the Water Act, the EP Act, and the MR Act.

Specifically, as discussed in Section 7, the proponent will be required to measure and report its actual groundwater take annually during the mine life in accordance with mandatory requirements of the MR Act.

In addition, any departure from the predicted groundwater take will be identified as part of the mandatory annual UWIR review process under the Water Act. The proponent will be obligated to investigate any departure from predicted groundwater take and assess the potential for any adverse environmental impacts arising from mining activities. The findings of this review would be reported to the DES and the OGIA annually.

6.3.2. Impacts on groundwater supply bores

A bore census was carried out to identify water supply bores that could potentially be impacted by the project. The bore census drew upon information gathered through consultation with relevant landholders, field inspections, advice from the proponent, and a search of the Queensland government's groundwater database.

The bore census was targeted towards water supply bores that could potentially be impacted by the project due to their proximity to proposed mining activities. The local hydrogeology was also taken into account in planning the bore census. The bore census included a conservative search radius of 5 km beyond the boundary of the project site.

The bore census confirmed that there is a general lack of water supply bores in the project site and surrounding area. This is to be expected, given the lack of agricultural, residential, or industrial development.

There are no water supply bores within the project site. The bore census identified two water supply bores within 5 km of the project site boundary, including:

- RN 163296 is constructed within the Jurassic strata 4.5 km west of the BVS Pit; and
- Mt Norman 'Rockspear Bore' is constructed within the weathered profile approximately 4 km west of the BVS Pit.

Figure 29 shows that RN 163296 is located outside the predicted extent of drawdown in the Jurassic strata from the project. Figure 28 shows that the Mt Norman 'Rockspear Bore' is located outside the predicted extent of drawdown from in the weathered profile from the project. Drawdown from the project is not predicted to affect these bores, and the operation of the bores is therefore not expected to be impaired as a result of the project.

6.3.3. Impacts on watercourses and drainage features

Figure 4 shows the surface drainage within and surrounding the project site.

The Woolgar River traverses the western boundary of the project site in a south-westerly direction (Figure 4). In the vicinity of the project site, the Woolgar River has a well-defined channel that is set within a narrow, discontinuous floodplain. The river channel contains a braided low flow channel with sand sheet deposits, bars and islands that have been formed by the extensive suspended sediment deposition during flow events.

The Woolgar River exhibits highly ephemeral, short duration, surface water flows that are typically restricted to the wet season (i.e., December to March). The Woolgar River flows for approximately four months per year, on average. The volume and timing of surface water flow in the river varies significantly between years depending on rainfall. On average, the majority of surface water flow occurs during the wet season between January and March. The Woolgar River is a locally significant watercourse, as defined under the *Water Act 2000* (Qld) (Water Act).

Several unnamed tributaries traverse the project site. These tributaries form on the slopes of the plateaus and ridgelines to the east of the project site (Figure 4). The unnamed tributaries coalesce on the flatter ground that is located between the plateaus and ridgelines and drain towards the Woolgar River valley. Surface water flow duration, frequency and quality in the drainage features have similar characteristics to the Woolgar River. That is to say, the drainage features exhibit highly ephemeral, short duration, surface water flows that contain elevated suspended sediment loads. This is expected given the catchment features and geology setting. The unnamed tributaries meet the Water Act definition of a 'drainage feature'.

This surface drainage overview is consistent with observations made during the groundwater site inspection and field surveys undertaken as part of the EAR Aquatic Ecology Report and EAR Terrestrial Ecology Report. It is also supported by surface water flow data collected from the Queensland government's surface water gauging stations located downstream on the Woolgar River, which indicate no perennial surface water flows in the vicinity of the project site.

As discussed in Section 5, the groundwater table is typically located between 2 m, and up to 6 m, below the riverbed. The groundwater table does not intersect the riverbed for the majority of the year.

Ephemeral surface water flows in the Woolgar River recharge the underlying groundwater regime and result in small seasonal variations in groundwater table depth. The groundwater table immediately below and adjacent to the river channel typically rises by approximately 0.5 m, and up to approximately 2 m in response to ephemeral river flows. The groundwater table is typically at its highest (i.e., closest to ground level) during flow events in the river. At this time, the groundwater table may intersect the ground surface in the Woolgar River bed.

Figure 31 shows that the Woolgar River is located outside the predicted extents of drawdown on the groundwater table due to the project.

Groundwater depth generally increases with distance from the Woolgar River. The groundwater table is typically located 12 m, and up to 66 m, below the bed of the drainage features that traverse the project site. Hence, the groundwater table does not intersect the ground surface in the drainage features and there is no groundwater seepage through the creek beds or banks to provide baseflow to the drainage features.

On that basis, the localised drawdown on the groundwater table is not predicted to have any effect on river baseflow or the natural flow regime in the Woolgar River or its tributaries. Hence, no change in surface water flows due to the drawdown associated with the project are predicted. On that basis, the project's effects on groundwater are not expected to give rise to adverse impacts on any aquatic habitats and ecosystems associated with the Woolgar River, nor any downstream surface water users (e.g., farm dams).

Groundwater monitoring will be undertaken during mining operations. Section 7 describes the proposed groundwater monitoring program and management measures.

6.3.4. Impacts on wetlands

The EAR Aquatic Ecology Report provides a description of the aquatic ecology values within, or in proximity to, the project site based on the findings of a desktop assessment and field survey results. The relevant aquatic ecology values include:

- The Woolgar River and its local tributaries; and
- Two farm dams within the project site.

As discussed in Section 6.3.3, the Woolgar River is located outside the predicted extents of drawdown on the groundwater table due to the project. Hence, the localised drawdown on the groundwater table is not predicted to have any effect on river baseflow or the natural flow regime in the Woolgar River.

Section 6.3.3 also explains that the groundwater table does not intersect the ground surface in the drainage features that traverse the project site. The farm dams are located on the drainage features that traverse the project site. There is no groundwater seepage through the creek beds or banks, and therefore groundwater seepage does not provide baseflow to the drainage features or the farm dams.

On this basis, the effects of the project activities on groundwater are not predicted to give rise to any significant impacts on aquatic ecology values.

6.3.5. Impacts on groundwater dependent ecosystems

The impacts on groundwater dependent ecosystems within, or in proximity to, the project site, are discussed in the EAR Groundwater Dependent Ecosystems Section.

6.3.6. Impacts on springs

As discussed in Section 5.3.3, there are three springs within 5 km of the project site boundary (Figure 11).

The springs (Spring 377 and two unregistered springs) are described in Section 5.3.3. These springs are fed by seepage from perched groundwater within the weathered profile in the elevated plateau area to the east of the project site. The regional groundwater table is located approximately 30 m below ground level (in the Proterozoic basement) at the Spring 377 and approximately 45 m and 10 m below ground level (in the fresh Jurassic strata) at unregistered spring no. 1 and no. 2. Hence, there is no connection between these springs and the regional groundwater table.

As discussed in Section 5.3.3, this is consistent with the published research on the hydrogeology of these springs. The Queensland Government has undertaken investigations on the springs and their hydrogeology and function are well-understood (DSITI, 2015).

In addition, Figure 31 shows that maximum extents of predicted drawdown on the groundwater table due to the project does not extend to the springs.

On that basis, any drawdown of the regional groundwater table due to the project is not predicted to have any effect on the springs. Hence, the project's effects on groundwater are not expected to give rise to adverse impacts on the spring function or any habitats and ecosystems associated with the springs.

6.3.7. Cumulative impacts

There are no approved resource projects in the vicinity of the project site that could potentially contribute to cumulative groundwater impacts with the project.

6.4. Impacts on groundwater quality

The key potential sources of groundwater contamination from the project include:

- seepage from the open cut pits and final pit voids;
- seepage from the WRDs;
- seepage from the ore stockpiles;
- seepage from the tailings storage cell;
- seepage from the heap leach pads; and
- the use of hydrocarbons and chemicals.

The groundwater quality effects, and associated impacts of these sources are discussed in the following sections.

Groundwater monitoring will be undertaken to confirm the groundwater quality throughout the proposed mine life and post closure. The groundwater monitoring program is described in Section 7 and has been designed to detect any unanticipated groundwater quality issues.

6.4.1. Seepage from the BVS Pit and final void

The BVS Pit will generate pit water comprising direct rainfall to the pit, runoff from the pit catchment and groundwater inflows. BVS Pit will be actively dewatered during mining operations. Dewatering will create a hydraulic groundwater gradient and induce groundwater flow in the area surrounding the pit towards the dewatered pit. The EAR Surface Water Report describes the management of mine water removed from BVS Pit during the project operations phase.

Post mining (i.e., following the cessation of mine dewatering) water levels within the BVS Pit final void are predicted to recover to a quasi-equilibrium level of approximately 230 m AHD. The final void water level predictions are presented EAR Surface Water Report. This difference in groundwater elevation means that there will be a post mining hydraulic gradient that induces groundwater flow towards the final void. On this basis, the final void will remain a permanent groundwater sink. There will be a zone of drawdown around the final void in perpetuity and groundwater flow within this zone will be towards the final void.

The final void lake will comprise runoff from the final void catchment, direct rainfall to the final void and groundwater inflows. The EAR Geochemistry Report characterised runoff from the materials that comprise the final void floor and walls. The Geochemistry Report concludes that these materials will generate runoff with pH neutral runoff with low salinity and low concentrations of metals and hence will be similar to regional groundwater. Runoff from the final void catchment will be mixed with, and diluted by, direct seasonal rainfall and inflows of natural groundwater to the pit.

Water will evaporate from the final void lake surface. Evaporation from the lake surface will concentrate salts in the lake slowly over time. The gradual increase in salinity will not pose a risk to the surrounding groundwater systems as the final void will remain a permanent groundwater sink. As a result, surrounding groundwater quality will not be impacted post closure.

6.4.2. Seepage from the BV1 and BV2 pits and final voids

As explained in Section 6.1.2, BV1 Pit and BV2 Pit (the satellite pits) will terminate 20 m and 15 m above the groundwater table, respectively. Hence, the satellite pits are located well above the groundwater table and will not receive groundwater inflows during the operations phase or post closure.

Section 6.1.2 also explains that the base of the satellite pits will be located in the Proterozoic basement. The Proterozoic basement is an aquiclude that is essentially a dry crystalline and metamorphosed rock mass with occasional disconnected cracks that can contain groundwater. It has very low permeability that will effectively prevent seepage of any pit water to the underlying groundwater table. Hence, the satellite pits are expected to have negligible effect on the underlying groundwater regime during the operations phase or post closure.

The satellite pits will generate limited volumes of pit water during mining operations due to direct rainfall to the pits and runoff from the pit catchments as the pits are relatively small and the pit catchments will be essentially limited to the pit crests. The satellite pits may also be used for temporary contingency storage for pit water from BVS Pit. Any pit water stored in the satellite pits during operations will be reused in the mine water management system as a water supply.

The geochemical testing results indicate that runoff from pit catchments will be pH neutral, with low salinity and low concentrations of metals and hence will be similar to regional groundwater.

During operations, the BVS Pit will function as a groundwater sink from the time the mining excavation descends below the groundwater table. This will occur during Year 1 of operations. The BVS Pit is located in the downgradient groundwater flow direction from the satellite pits (see Figure 21 and Figure 22). Hence, any unexpected pit water seepage from either BV1 Pit or BV2 Pit during operations would migrate very slowly (vertically) to the underlying groundwater table and would migrate very slowly (laterally) following the enhanced hydraulic gradient towards the BVS Pit to the south-west.

As discussed in Section 5.5.2, the Proterozoic basement (through which any seepage from the satellite pits would flow) has an extremely low permeability. This permeability was measured at an equivalent of between 3 mm/year and 15 mm/year. Given that the downgradient BVS Pit will be located more than 1 km to the south-west of the satellite pits and will function as a groundwater sink from Year 1 of operations, any unexpected water seepage from the BV1 Pit or the BV2 Pit would be captured in the BVS Pit. Hence, any potential effects on groundwater quality due to satellite pit seepage during the operations phase would be limited to the groundwater flow path between the satellite pits and the BVS Pit.

Post mining, a shallow pool of water may accumulate intermittently at the base of the BV1 Pit and/or the BV2 Pit final voids, following sustained rainfall. Evaporation from the water surface and will concentrate salts in these voids slowly over time.

A small amount of intermittent void water may dissipate via infiltration through the void floor. However, the volume and rate of infiltration will be limited by the low permeability and low porosity the Proterozoic basement. Hence, the proportion of water that infiltrates the void floor and recharges the local groundwater will be negligible and will not pose a risk to the surrounding groundwater quality.

As discussed in Section 6.4.3, the BVS Pit final void will be a permanent groundwater sink. The hydraulic groundwater gradient around the BVS Pit final void will induce groundwater flow in the area surrounding the pit towards the dewatered pit. The BV1 Pit and BV2 Pit final voids are located hydraulically upgradient of the BVS Pit final void and the associated groundwater sink. Hence, any limited water seepage from the satellite pit final voids into the underlying geology will therefore migrate towards the BVS Pit over time. This will further reduce the likelihood that any seepage from the BV1 and BV2 pit final voids will have any adverse effect on groundwater quality.

A groundwater monitoring program will be implemented that will detect any unexpected groundwater quality effects due to any seepage from the satellite pits/voids during the operations phase and post closure. The groundwater monitoring program will be detailed in a Groundwater Monitoring and Management Plan.

6.4.3. Seepage from the waste rock dumps

The Central and Southern WRDs will store approximately 130 million tonnes (Mt) of waste rock mined from the BVS Pit, co-disposed with approximately 12 Mt of dewatered tailings produced in the CIL Plant. The geochemical testing results presented in the EAR Geochemistry Report show that seepage from the WRDs is likely to be pH neutral to slightly alkaline, with low salinity and low concentrations of metals and metalloids. Seepage from the WRDs is therefore comparable to existing groundwater quality and is not expected to present any significant environmental risks to surrounding groundwater quality.

The Northern WRD will store approximately 1.45 Mt of waste rock mined from BV1 Pit and BV2 Pit. Geochemical test results presented in the EAR Geochemistry Report indicate that seepage from the Northern WRD will have similar characteristics to surface runoff and seepage from the Southern and Central WRDs.

As discussed in Section 6.4.3, mine dewatering during operations and the subsequent establishment of a post mining final void lake will create a hydraulic groundwater gradient and induce groundwater flow towards BVS Pit and its final void. Any water seepage from the WRDs into the underlying geology will therefore migrate towards the BVS Pit and its final void.

As a result, surrounding groundwater quality is highly unlikely to be impacted during mining operations or post closure.

6.4.4. Seepage from the ore stockpiles

Ore will be stockpiled on dedicated pads prior to processing during mining operations. Geochemical test results presented in the EAR Geochemistry Report indicate that seepage from the low-grade ore stockpiles is likely to be benign with low concentrations of metals. The low-grade ore will be stockpiled on dedicated pads within the project site. The pads will have a compacted base to minimise seepage and a perimeter drain to collect seepage (and runoff) from the stockpiles. Seepage and runoff from the low-grade ore stockpiles will be directed to sediment dams for removal of suspended sediments and passively released from site in accordance with an Erosion and Sediment Control Plan.

High-grade ore may also be stockpiled in the mine industrial area for processing during mining operations. The geochemical testing results presented in the EAR Geochemistry Report show that seepage from the high-grade ore stockpiles is likely to be benign with low concentrations of metals. The high-grade ore will be stockpiled on a dedicated pad within the mine industrial area catchment. The stockpile pad will have a compacted base to minimise seepage. A collection drain will be constructed around the perimeter of the pads to collect seepage (and runoff) from the stockpiles. Seepage and runoff from the stockpile will be collected in the mine industrial area dam. The mine industrial area dam is a dedicated containment dam that will have sufficient storage capacity to ensure nil discharge. Seepage and stormwater runoff from the ore stockpile that collects in the mine industrial area dam will be reused in the site water management system.

As discussed in Section 6.4.3, mine dewatering during operations will create a hydraulic groundwater gradient and induce groundwater flow towards BVS Pit. Any water seepage from the ore stockpiles into the underlying geology will therefore migrate towards the BVS Pit. As a result, surrounding groundwater quality is highly unlikely to be impacted during mining operations.

No ore will be present at mine closure.

6.4.5. Seepage from the tailings storage cell

The Tailings Storage Cell will be a lined containment structure that will store approximately 3.15 GL of tailings (settled solids) produced in the CIL Plant. The tailings storage cell will be constructed in the southern part of the project site, south of the BVS Pit.

Geochemical testing results show that water from the stored tailings will be pH neutral to slightly alkaline, with low salinity and low concentrations of metals and metalloids. Hence, water from the stored wet tailings will be similar to groundwater quality below the tailings storage cell.

The tailings storage cell liner will minimise the potential for seepage of water from the tailings storage cell to the underlying groundwater regime.

Water from the tailings storage cell will be collected in a pond within the tailings storage cell and returned to the CIL pant over the life of the mine. The tailings storage cell return water pond will have sufficient storage capacity to ensure nil discharge.

The tailings storage cell will be rehabilitated and decommissioned at mine closure. This will involve covering the stored dried tailings with benign capping material (e.g., suitable subsoil) and topsoil and shaping the capped surface to promote runoff and minimise infiltration. These measures, and the liner, will ensure that the stored tailings will not be a source of seepage to groundwater in the long-term following mine closure.

On this basis, seepage from the tailings storage cell is not expected to adversely impact groundwater quality.

6.4.6. Seepage from the heap leach pads

Ore mined from BV1 Pit and BV2 Pit during the first two years of mining will be processed on fully lined heap leach pads. The heap leaching process will produce spent heap leach residues.

The spent heap leach residues may have some inherent potential for acid generation, however, the geochemistry results to date indicate that these materials will generate pH neutral drainage with excess alkalinity. Hence, water from the spent heap leach residues will be similar to groundwater quality below the heap leach pads.

Seepage from the heap leach pads will be collected in dedicated fully lined containment ponds. The pond lining will ensure that there is no potential for seepage to groundwater. The heap leach ponds will have sufficient storage capacity to ensure nil discharge. Stormwater from the heap leach stormwater pond will be reused in the heap leach process and/or pumped to the tailings storage cell stormwater pond.

The spent heap leach residues will be fed through the CIL Plant over the life of the mine, producing approximately 1 Mt of dewatered tailings. Tailings produced by processing spent heap leach residues in the CIL Plant will be stored in the Central and Southern WRDs, along with the tailings produced from the processing of ore. Tailings produced from the spent heap leach residues will have similar geochemistry to the rest of the tailings produced by the CIL Plant and will be managed within the WRDs.

No spent heap leach residues will remain at the end of the mine life and hence, the heap leach pad areas will be decommissioned at mine closure. Hence, there will be no potential for post mining groundwater quality impacts from the spent heap leach residues.

6.4.7. Hydrocarbon and chemical storage

Hydrocarbon and chemical storage will be managed in accordance with standard practice at mine sites. Proposed management measures include adequate bunding or storage areas, and immediate clean-up of any spills. These measures are designed to prevent the contamination of groundwater. Given the limited hydrocarbon and chemical storage activities proposed, and the controls that will be adopted, the project is not expected to give rise to groundwater contamination as a result of hydrocarbon and chemical contamination.

7. Groundwater monitoring and management

The groundwater monitoring program will comprise:

- a pre-mining baseline groundwater monitoring program; and
- an operational compliance groundwater monitoring program.

These groundwater monitoring program components are described in Sections 7.1 and 7.2.

7.1. Baseline groundwater monitoring program

The proponent maintains a groundwater monitoring network comprising 14 monitoring bores and three VWPs located across the project (Figure 11). The groundwater monitoring network was designed to establish baseline groundwater levels and quality within the project site.

The groundwater monitoring network targets the groundwater table associated with the relevant hydrostratigraphic units at the project site.

Groundwater levels are recorded using continuous dataloggers, and this enables natural groundwater level fluctuations (such as seasonal responses to rainfall) to be characterised.

Groundwater quality monitoring is undertaken opportunistically, as site access permits. Groundwater quality samples are analysed for the following standard quality characteristics:

- pH, electrical conductivity, and total dissolved solids;
- major ions (Ca, Mg, Na, K, Cl and SO_4), fluoride, alkalinity, and hardness; and
- dissolved metals and metalloids (Al, As, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se and Zn).

Monitoring and sampling is conducted by suitable qualified personnel. The collection, storage, and transport of water quality samples for laboratory analysis is undertaken in accordance with the proponent's existing procedures, and in accordance with the relevant guidelines and Australian Standards. A National Association of Testing Authorities (NATA) accredited laboratory conducts the water quality analyses.

The baseline groundwater monitoring program will continue until a suitable pre-mining baseline groundwater level, and quality dataset has been collected. This will include a minimum of 18 samples collected over at least 12 (and preferably at least 24) months.

The baseline groundwater monitoring dataset will be used to refine the interim site-specific water quality guideline values into robust guideline values and to confirm baseline groundwater levels. The baseline groundwater levels and site-specific water quality guideline values will be used to derive compliance monitoring triggers in accordance with the Queensland guideline documents discussed in Section 2.5.3. These compliance monitoring triggers will be included in the EA groundwater conditions.

7.2. Operational compliance groundwater monitoring program

The EA groundwater conditions will specify the compliance groundwater monitoring program to be implemented throughout the life of the project to confirm the actual extent of groundwater impacts and validate the conservative groundwater modelling predictions presented in Section 6.2.

The compliance monitoring program will incorporate the existing groundwater monitoring network. The existing groundwater monitoring network includes bores located outside the maximum predicted zone of drawdown that can be used for monitoring background conditions in the aquifers. It also includes bores located within the predicted maximum zone of drawdown that can be used to validate the groundwater drawdown predictions. The groundwater monitoring network is therefore suitable for identifying and monitoring the effects of the project on the groundwater regime.

The EA groundwater conditions will also contain groundwater level and quality compliance triggers based on site-specific water quality objectives derived from baseline water quality data. Interim groundwater triggers have been provided in Section 2 of this report. The interim groundwater triggers will be updated and finalised following completion of the baseline groundwater monitoring program and collation of the final pre-mining baseline groundwater level and quality dataset (comprising a minimum of 18 samples collected over at least 12, and preferably at least 24, months). The groundwater triggers will be developed in accordance with the Queensland guidelines discussed in Section 2.5.3. The development of groundwater triggers will be undertaken in consultation with, and to the satisfaction of, the DES.

The proponent will be required to conduct an investigation into any exceedances of EA trigger levels within the required timeframes and notify DES if required. The EA will also require that any corrective actions identified as being required, are implemented to the satisfaction of the DES. This process ensures the early identification of any potential contamination or unexpected drawdown effects and allows the targeted application of corrective measures to minimise the potential for environmental harm to the groundwater regime.

In addition, the EA will condition a requirement for the proponent will undertake an annual review of the groundwater monitoring program and supporting data. This will include:

- Reviewing and updating the groundwater monitoring program to ensure it is fit for purpose.
- Reviewing the accuracy of the groundwater model. This will include a review of all new geology and groundwater data to identify any potentially significant departures from the baseline data and/or the data used to support the project approvals. Where potentially significant departures are identified, the potential effect of these departures on the drawdown mapping will be investigated. If the investigation concludes that the drawdown predictions are likely to have been under-estimated and additional impacts are likely, additional groundwater modelling will be undertaken to update the drawdown predictions.
- A review of the suitability of the groundwater triggers and EA groundwater conditions.

The outcome of each annual review will be reported to the DES following completion of each annual review. The reported outcomes will include a statement of whether there has been a material change in the groundwater information or modelling predictions.

8. Conclusions

The key conclusions of the groundwater assessment are as follows:

- the project will not impact surface water, sensitive environmental features, or alluvial aquifers because:
  - alluvium is absent from the majority of the project site and its surrounds;
  - the localised alluvium associated with the Woolgar River is thin and is generally located above the groundwater table and therefore is dry and unsaturated, except immediately below the riverbed;
  - the alluvium associated with the Woolgar River is located beyond the predicted maximum extent of groundwater drawdown from the project;
  - the groundwater table is typically located at significant depths below local drainage features;
  - the springs located to the east of the project site, beyond the predicted maximum extent of drawdown from the project, and are associated with a perched aquifer system with no connection to the regional groundwater table; and
  - there are no other areas within the project site or its surrounds where the groundwater table intersects the ground surface.
- there is negligible groundwater drawdown in the Jurassic strata;
- there are no groundwater users or other sensitive receptors predicted to be affected by groundwater drawdown or depressurisation and therefore no significant groundwater impacts are predicted as a result of the project;
- there are no other mining operations in proximity to the project and therefore no cumulative impacts are predicted as a result of the project; and
- there is a very low potential for groundwater contamination as a result of the project.

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10. Abbreviations

BoM: Bureau of Meteorology

BVS: Big Vein South

DES: Department of Environment and Science

DRDMW: Department of Regional Development, Manufacturing and Water

EA: Environmental Authority

EAR: Environmental Assessment Report

EC: Electrical Conductivity

EP Act: *Environmental Protection Act 1994*

EPP Water: Environmental Protection (Water and Wetland Biodiversity) Policy 2019

GABORA Water Plan: Water Plan (Great Artesian Basin and Other Regional Aquifer) 2017

GDE: Groundwater Dependent Ecosystem

GWDB: Groundwater Database, currently managed by the DRDMW

mAHD: metres (above) Australian Height Datum

mbGL: metres below ground level

MR Act: *Mineral Resources Act 1989*

NATA: National Association of Testing Authorities

OGIA: Office of Groundwater Impact Assessment

SILO: Scientific Information for Land Owners

SRMS: scaled root mean squared

TDS: total dissolved solids

The Project: Big Vein South Gold Project

UWIR: Underground Water Impact Report

VWP: vibrating wire piezometer

Water Act: *Water Act 2000*

WQO: water quality objective

11. Glossary

Aquifer: Permeable earth material such as porous sediments or fractured hard rock, saturated with groundwater. The permeability should be such that it is capable of conducting and yielding usable quantities of groundwater to a borehole(s) and / or springs. An aquifer is 'a geological formation which has structures or textures that hold water or permit appreciable water movement through them'.

Aquitard: A confining bed that retards but does not completely stop the flow of water to or from an adjacent aquifer. Although it does not readily release water to boreholes or springs, it may function as a storage chamber for groundwater.

Calibration: The process by which independent variables (e.g., hydraulic conductivity) within a model are varied in order to match a dependent variable (e.g., measured groundwater level within a monitoring bore).

Confined aquifer: An aquifer which is overlain by a confining layer of low permeability. The groundwater is confined under pressure greater than atmospheric pressure such that if the aquifer is penetrated the water level may rise above the top of the aquifer.

Confining layer/unit: Geologic material with little permeability or hydraulic conductivity.

Contamination: The introduction into the environment of any substance by the action of man.

Dewatering: The process of removing water from an underground mine or open pit, or from the surrounding rock or non-lithified materials.

Drawdown: Lowering of the water table within an unconfined aquifer, or the potentiometric surface within a confined aquifer caused by an induced stress on the groundwater system (e.g., pumping).

Geology: The study of the earth, its history and the changes that have occurred or are occurring and the rocks and non-lithified materials of which it is composed and their mode of formation and transformation.

Groundwater: The water in the aquifer; saturated zone below the water table.

Hydraulic conductivity: Describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, Ksat, describes water movement through saturated media.

Hydraulic gradient: The change in hydraulic head or water level over a distance.

Hydraulic head: The height above a datum (such as sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system.

Lithology: The systematic description of sediment and rocks, in terms of composition, texture and internal structure.

Model: A formalised expression of a theory, event, object, process, or system used for prediction or control; an experimental design based on a casual situation that generates observed data. A model can be viewed as a selective approximation which by the elimination of incidental detail, allows some fundamental, relevant, or interesting aspect of the real world to appear in a generalised form.

pH: The negative logarithm to the base 10 of the hydrogen ion activity [H+] in solution.

Recharge: The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

Saturated zone: That part of the geological stratum in which all the voids are filled with water under pressure greater than that of the atmosphere.

Specific Storage: Volume of water released form storage from a unit volume of aquifer, per unit decline in hydraulic head.

Specific Yield: The ratio of the volume of water a rock or spoil will yield by gravity drainage to the volume of the rock or soil. The upper bound of a specific yield value for a given material is equal to its porosity.

Storativity: The storage coefficient or storativity is a measure of the volume of water per volume of aquifer released as a result of a change in head. For confined aquifers, the storage coefficient is equal to the product of the specific storage and aquifer thickness.

Transmissivity: Transmissivity is the rate at which water is transmitted through a unit thickness of aquifer under a unit hydraulic gradient (Driscoll, 1986). It is the product of the hydraulic conductivity and the contributing thickness of the aquifer to flow.

Unconfined aquifer: An aquifer whose upper surface (water table) is free to fluctuate.

Unsaturated zone: That part of the geological stratum above the saturated zone in which the voids contain both air and water.

Water Table: The top of an unconfined aquifer, where the aquifer is fully saturated, and the water pressure is equal to atmospheric pressure. Usually measured in metres below ground level or below top of casing.

Weathering: The processes by which *particles, rocks* and *minerals* are altered on exposure to surface temperature and pressure and atmospheric agents such as air, water, and biological activity.

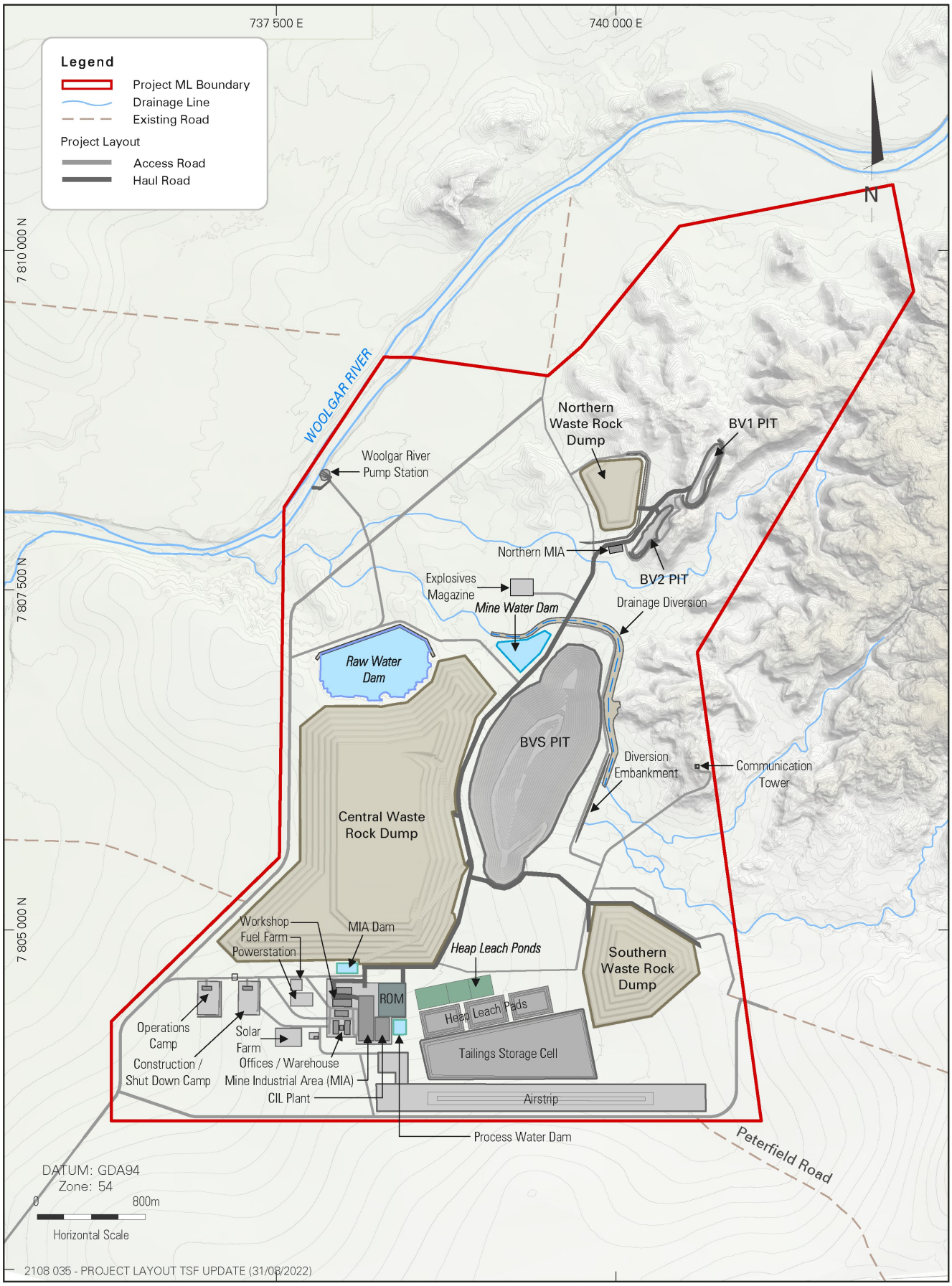


BIG VEIN SOUTH GOLD PROJECT

HANSEN ENVIRONMENTAL CONSULTING

Location Plan

FIGURE 1

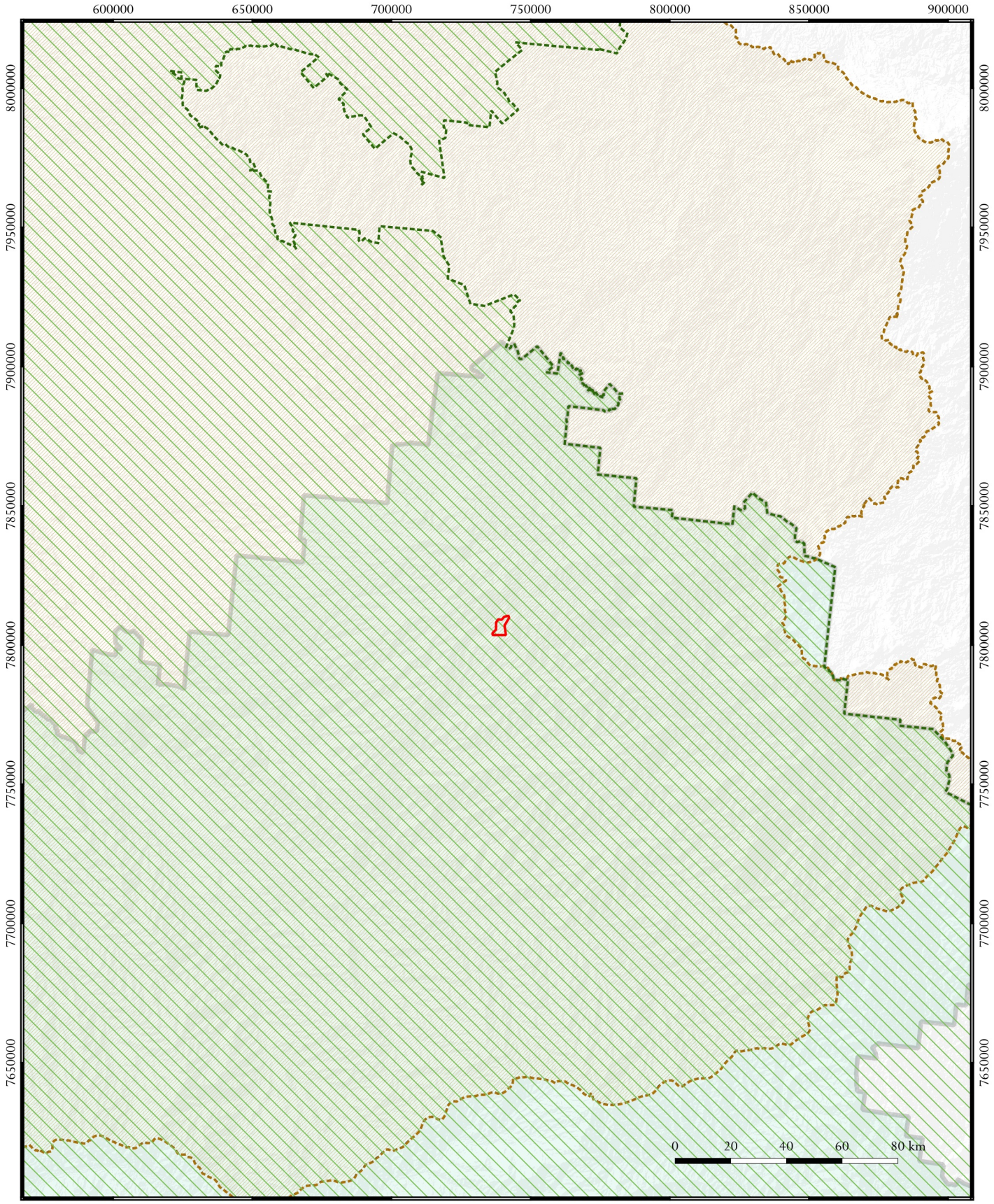


BIG VEIN SOUTH GOLD PROJECT

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Project Layout

FIGURE 2



LEGEND

- Project site boundary
- GABORA Water Plan area
- Gulf Water Plan area
- Eromanga Hutton/North Hooray groundwater sub-areas

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29/06/2022

GDA94, Zone 54
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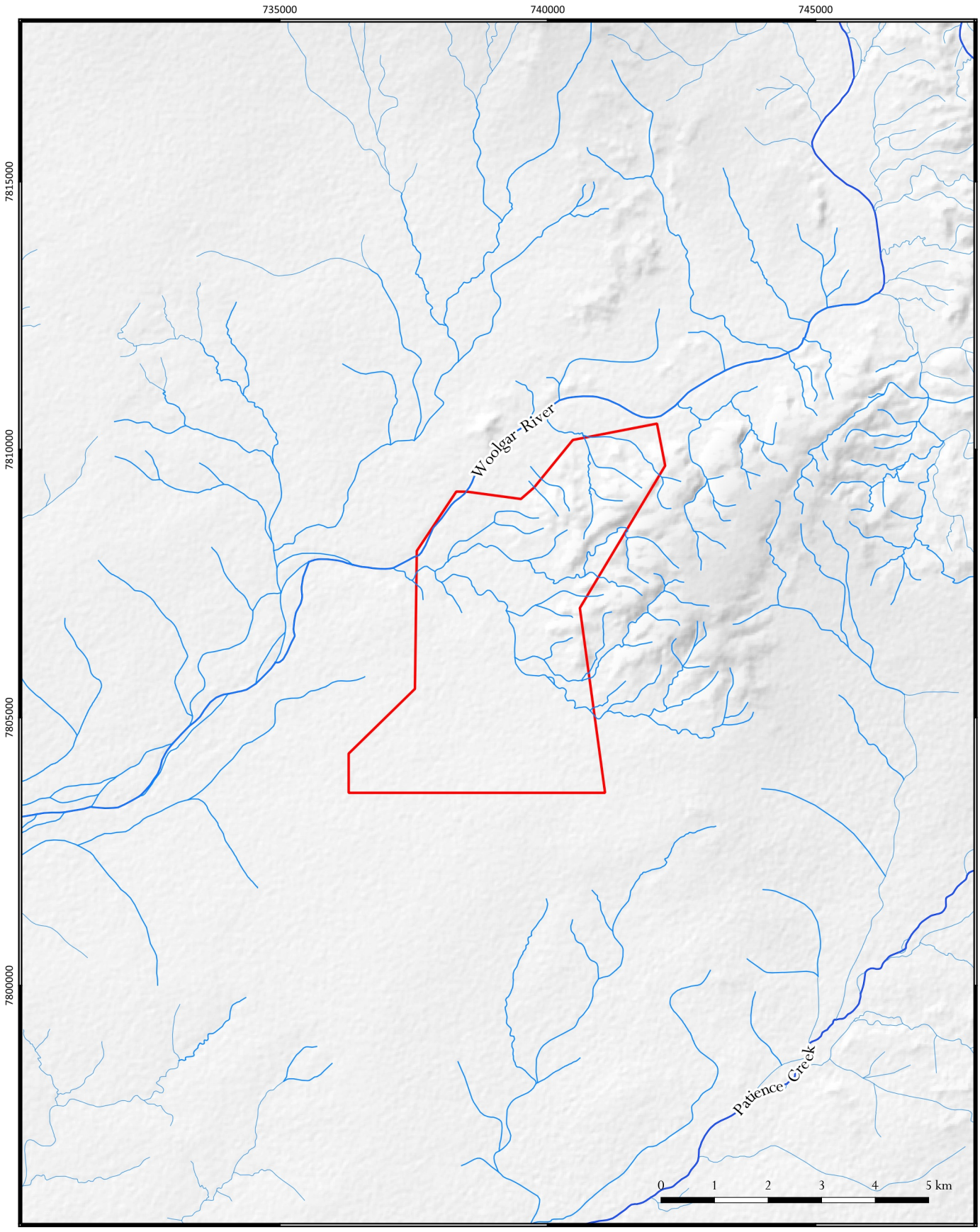
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Water Plan areas and groundwater sub-areas

FIGURE No.
3

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LEGEND

- Project site boundary
- Watercourses
- Drainage features

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05/09/2022

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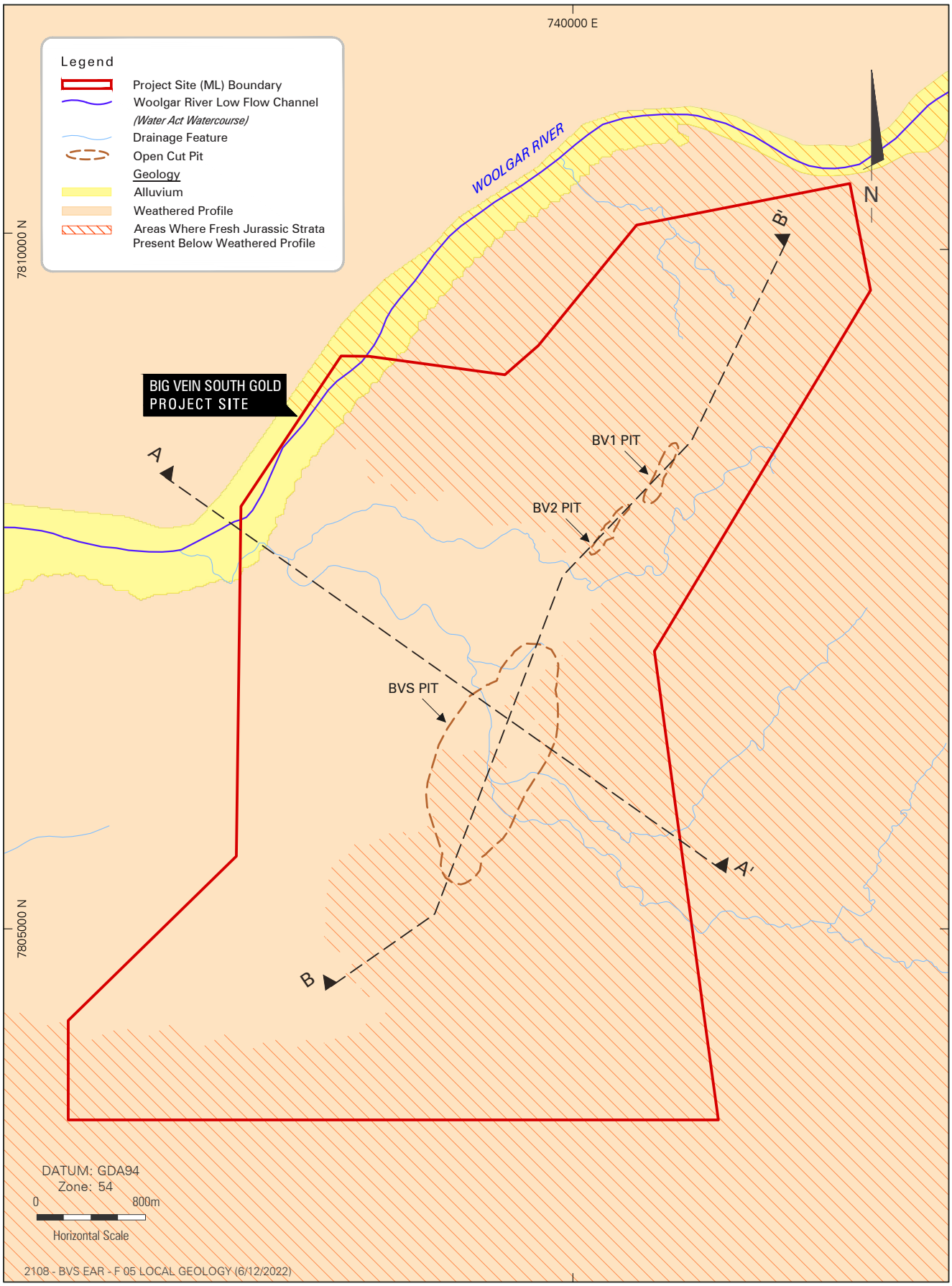
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Site topography and drainage

FIGURE No.
4

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BIG VEIN SOUTH GOLD PROJECT

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Local Geology

FIGURE 5

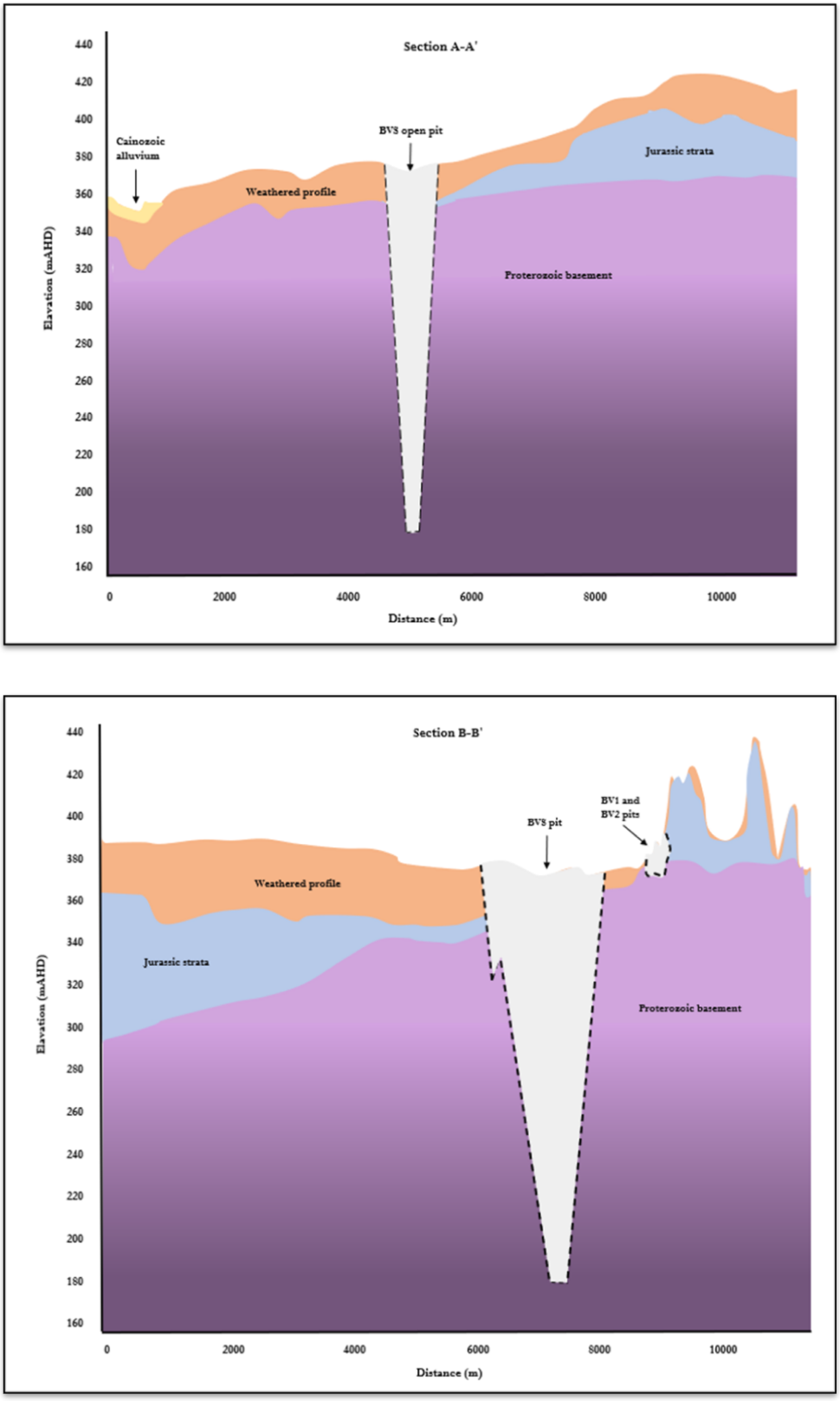
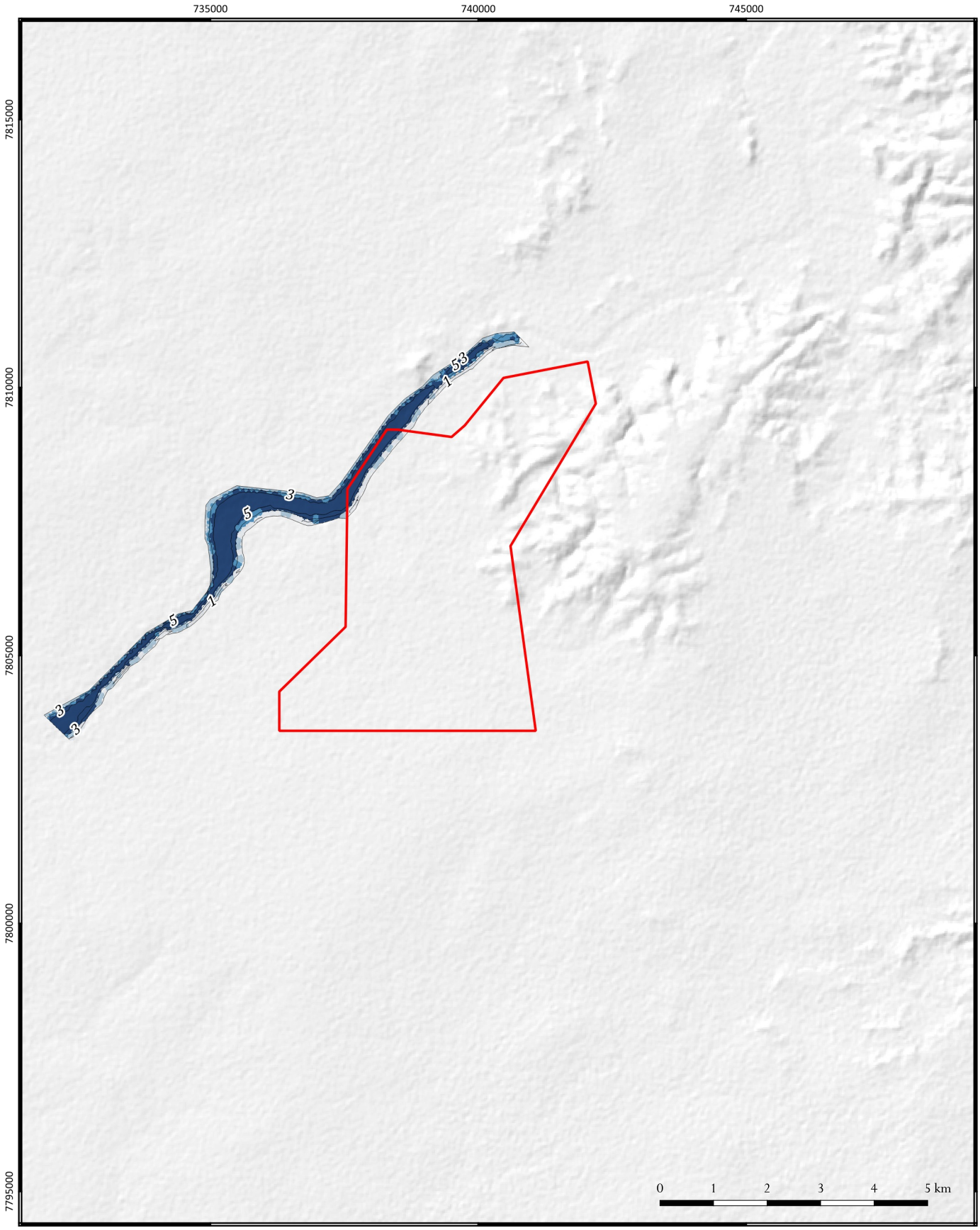


Figure 6 Geological cross-sections



LEGEND

Project site boundary

Thickness contour (m)

Layer thickness (m)

0 - 1 | >3 - 5

>1 - 3 | > 5

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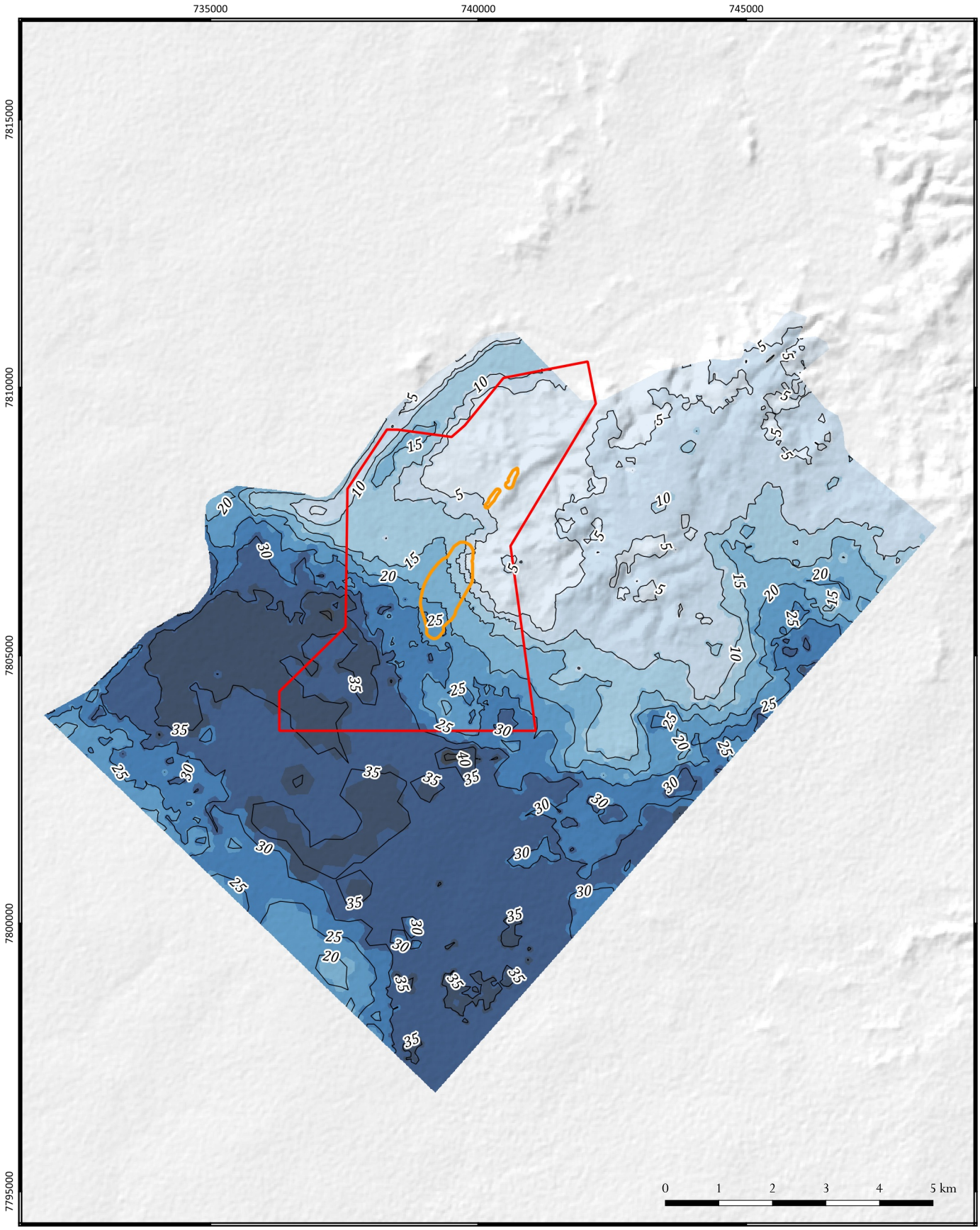
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Extent and thickness of the alluvium

FIGURE No.
7

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LEGEND

- Project site boundary
- Open cut pit
- Thickness contour (m)

Layer thickness (m)

0 - 5	>15 - 20	>30 - 35
>5 - 10	>20 - 25	>35 - 40
>10 - 15	>25 - 30	>40

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28/07/2022

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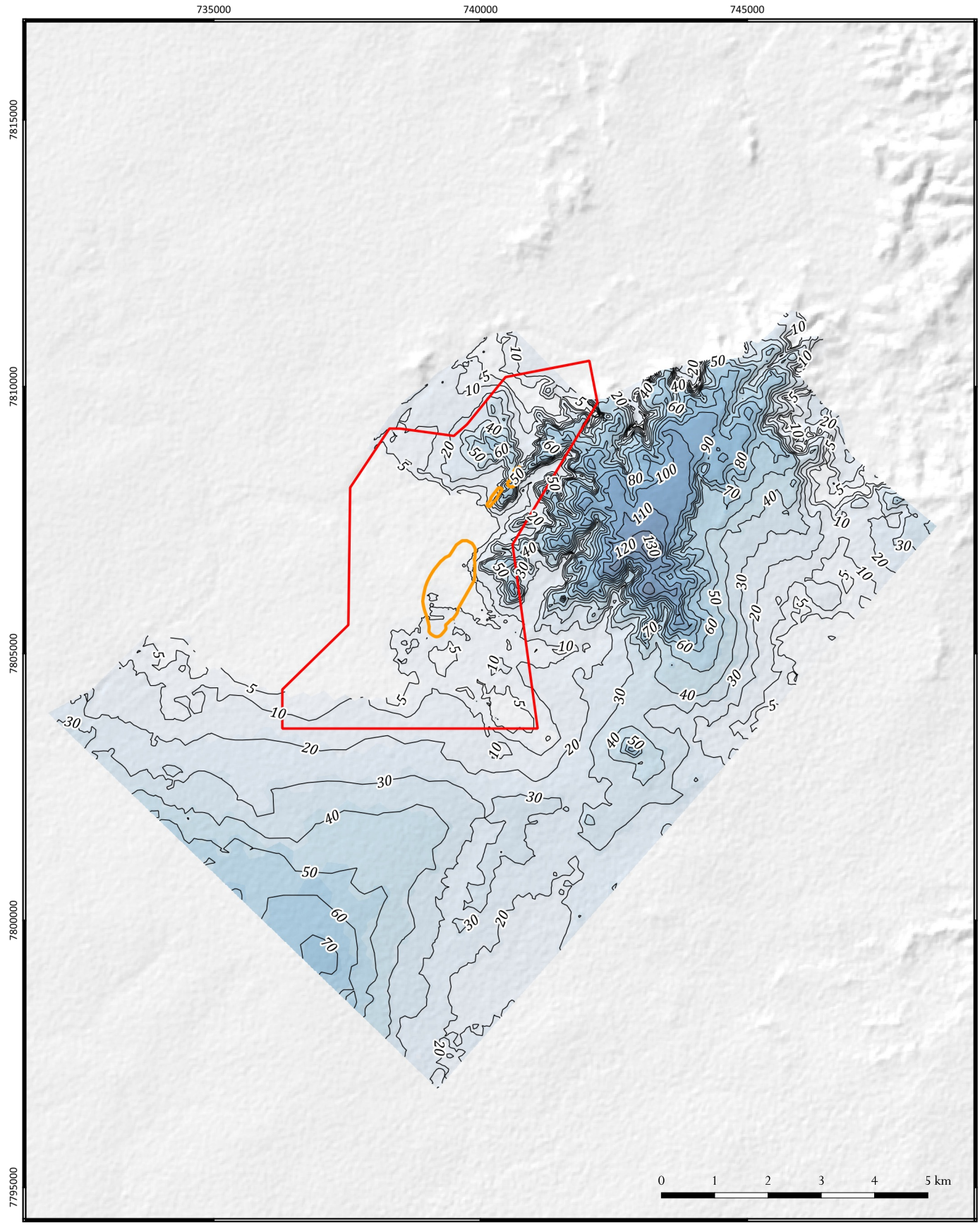
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Extent and thickness of the weathered profile

FIGURE No.
8

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LEGEND

Project site boundary

Open cut pit

Thickness contour (m)

Layer thickness (m)

0 - 5	>20 - 30	>50 - 60	>80 - 90	>110 - 120
>5 - 10	>30 - 40	>60 - 70	>90 - 100	> 120
>10 - 20	>40 - 50	>70 - 80	>100 - 110	

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29/07/2022

GDA94, Zone 54
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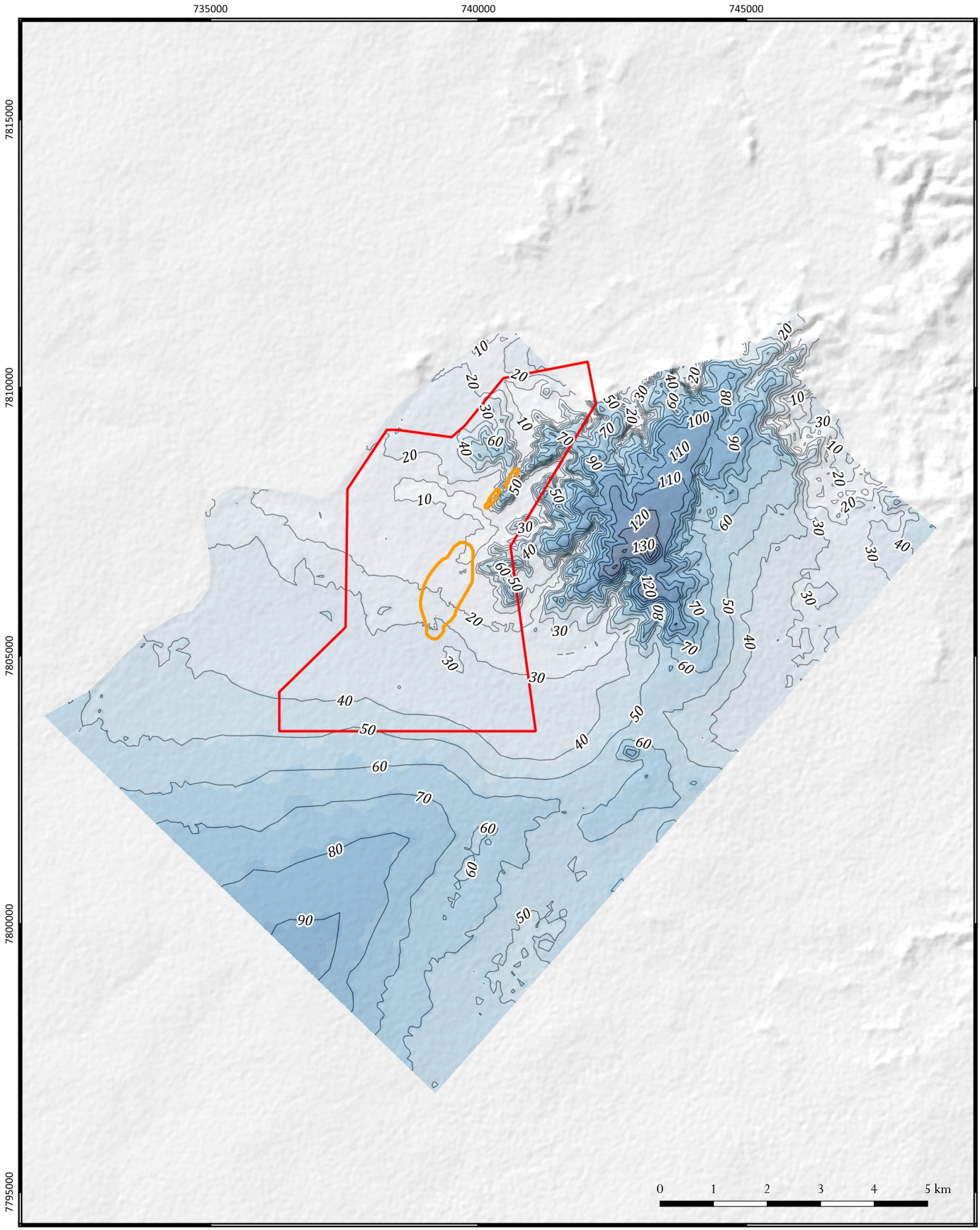
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Big Vein South Gold Project – Groundwater Report (4090)

Extent and thickness of the Jurassic strata

FIGURE No.
9

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LEGEND

- Project site boundary
- Open cut pit
- Depth to top of Proterozoic contour (m)

Layer elevation (mAHD)

0 -10	>30 - 40	>60 - 70	>90 - 100	>130
>10 - 20	>40 - 50	>70 - 80	>100 - 110	
>20 - 30	>50 - 60	>80 - 90	>110 - 120	

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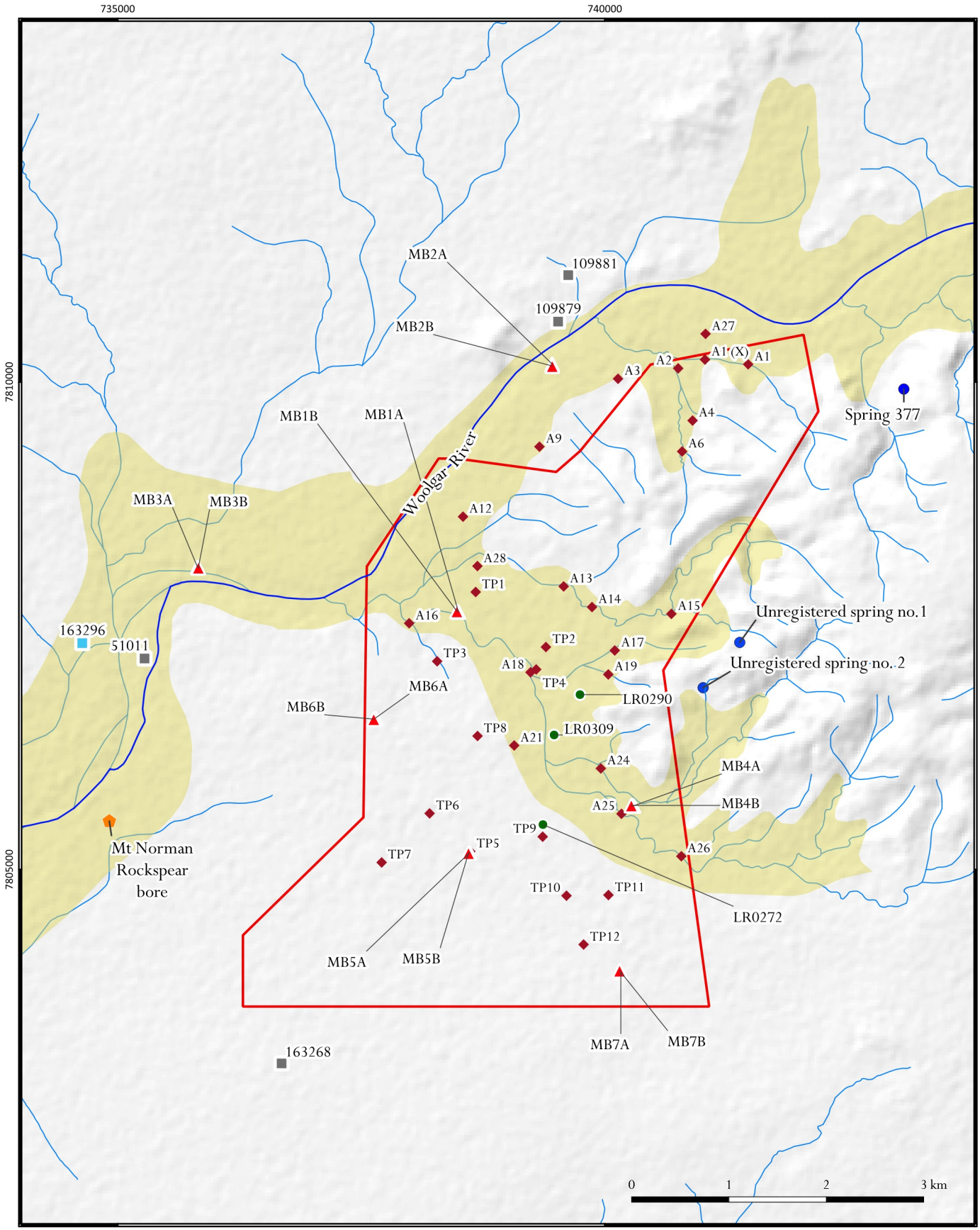
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Depth to the top of the Proterozoic basement

FIGURE No.
10

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LEGEND

Project groundwater monitoring network

- Project site boundary
- Project groundwater monitoring bore site (paired bores)
- Project groundwater VWP site
- Project test pit

Database records + Bore census

- Existing unregistered water supply bore
- Existing registered water supply bore
- Historical registered bores
- Government mapped alluvium

- Watercourse
- Drainage features
- Spring

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Groundwater bore locations

FIGURE No.

11

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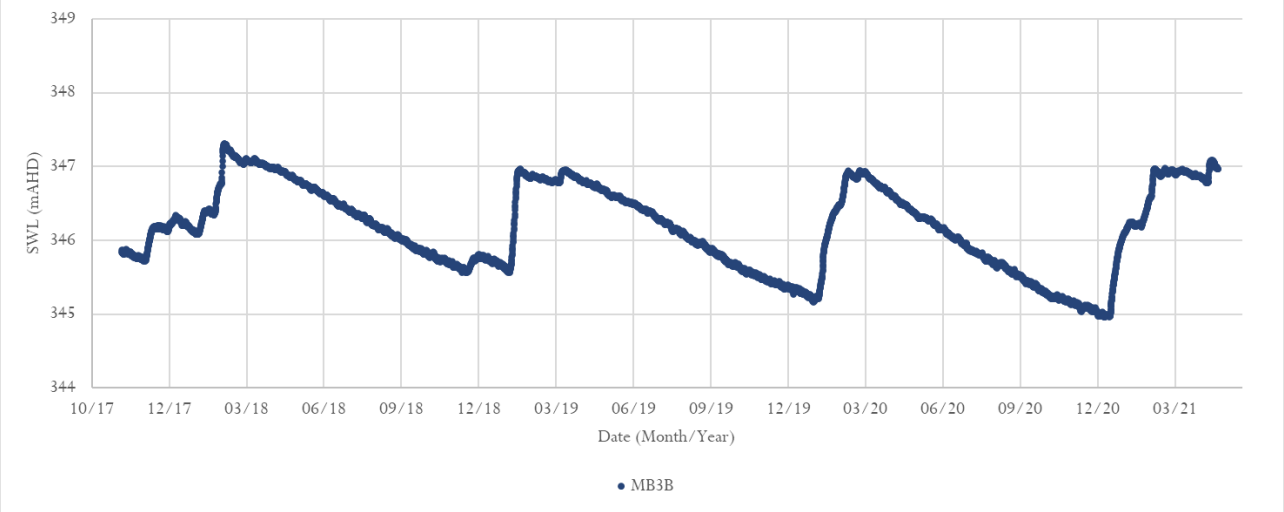


Figure 12 Groundwater level hydrographs – weathered profile

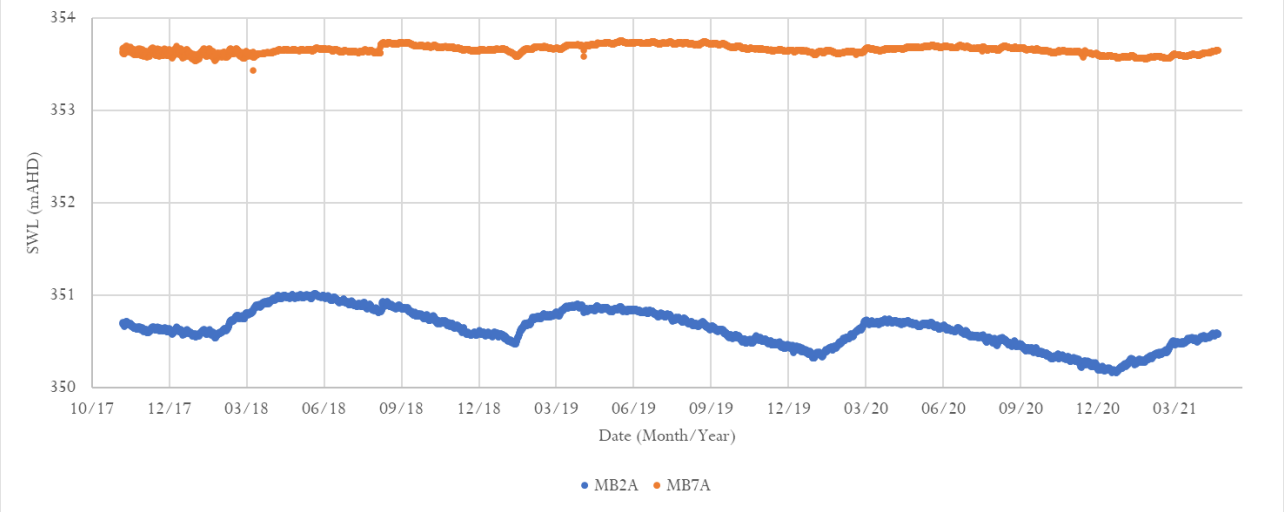


Figure 13 Groundwater level hydrographs – Jurassic strata

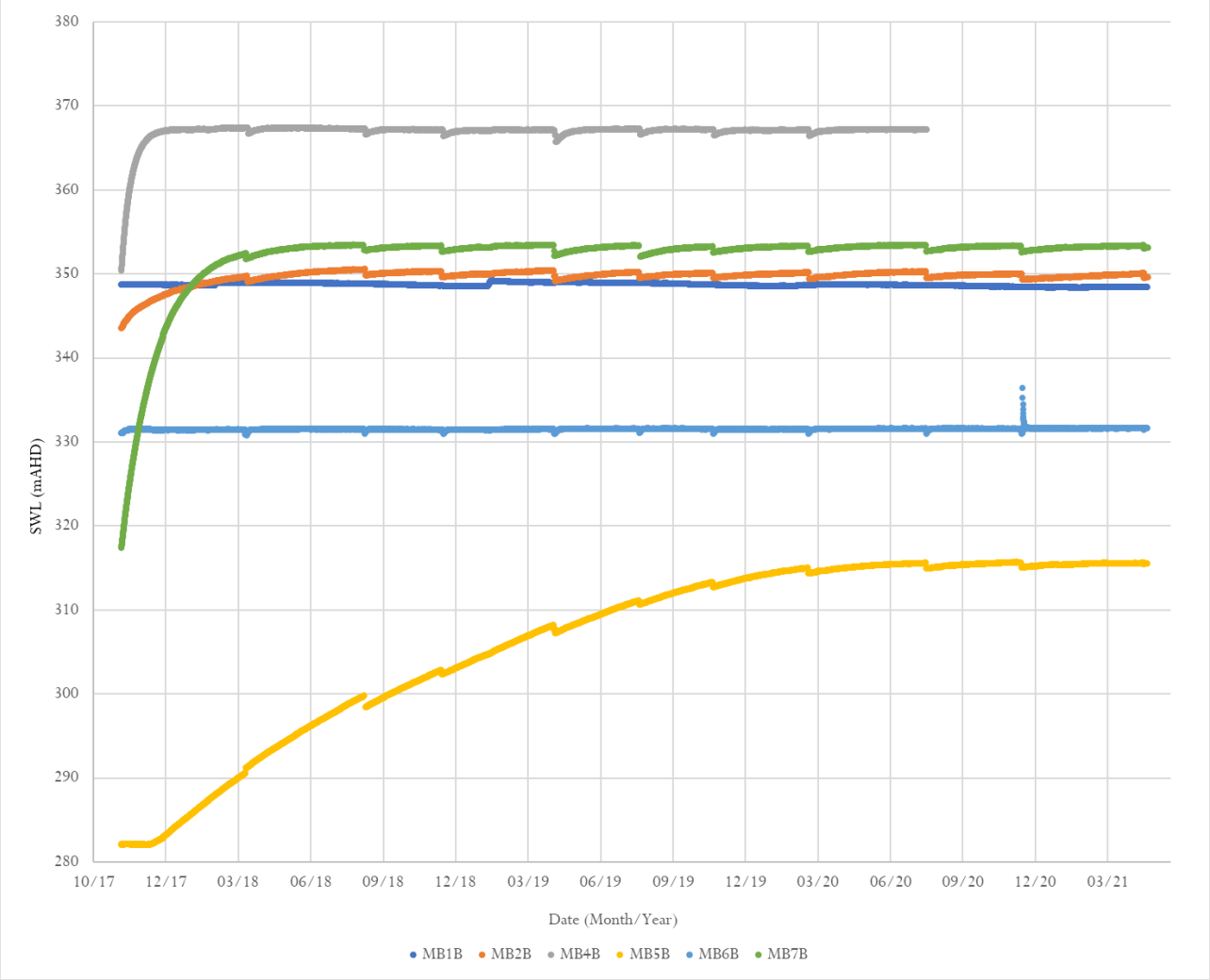
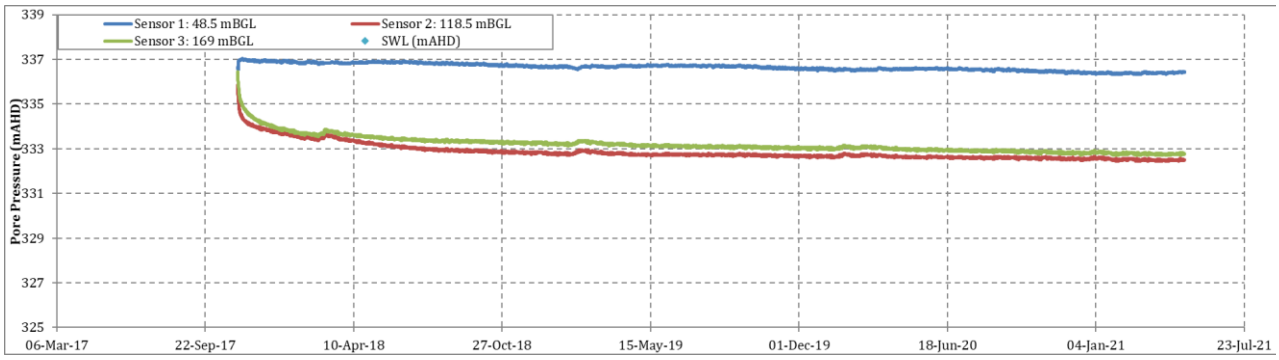
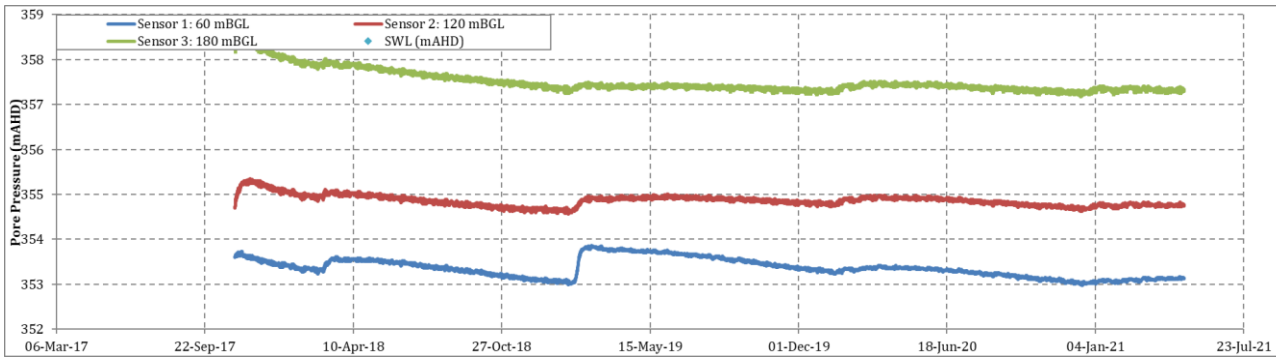


Figure 14 Groundwater level hydrographs – Proterozoic basement

LR0272



LR0290



LR0309

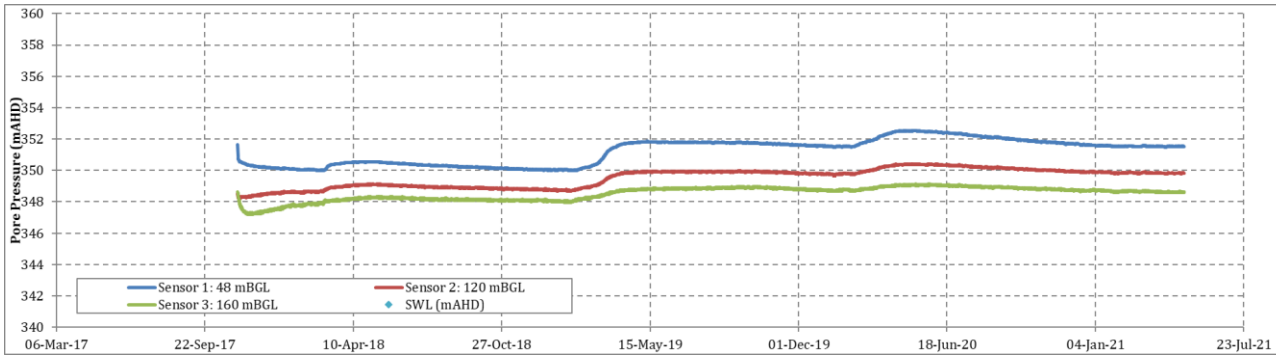


Figure 15 VWP hydrographs

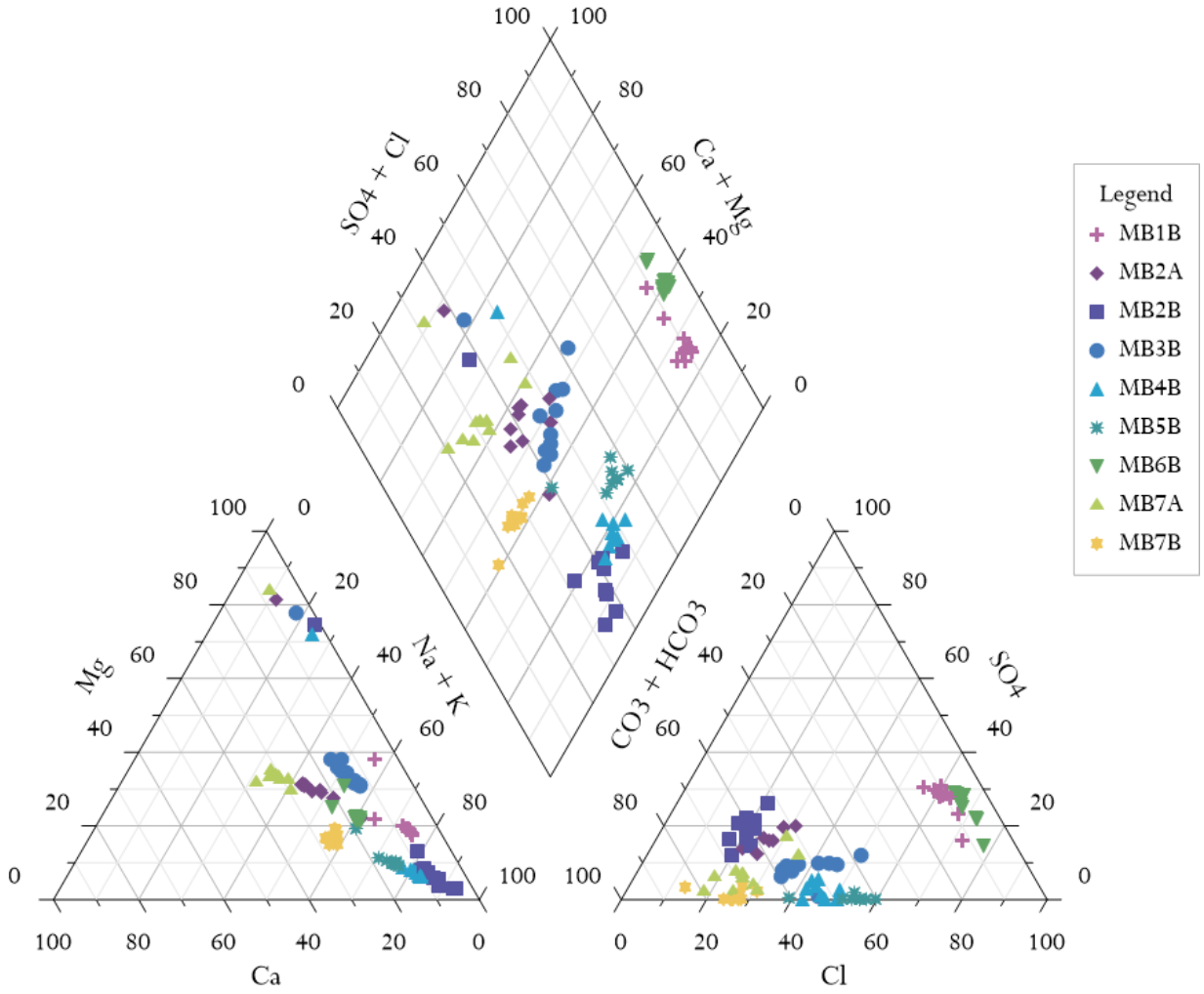


Figure 16 Water quality Piper diagram

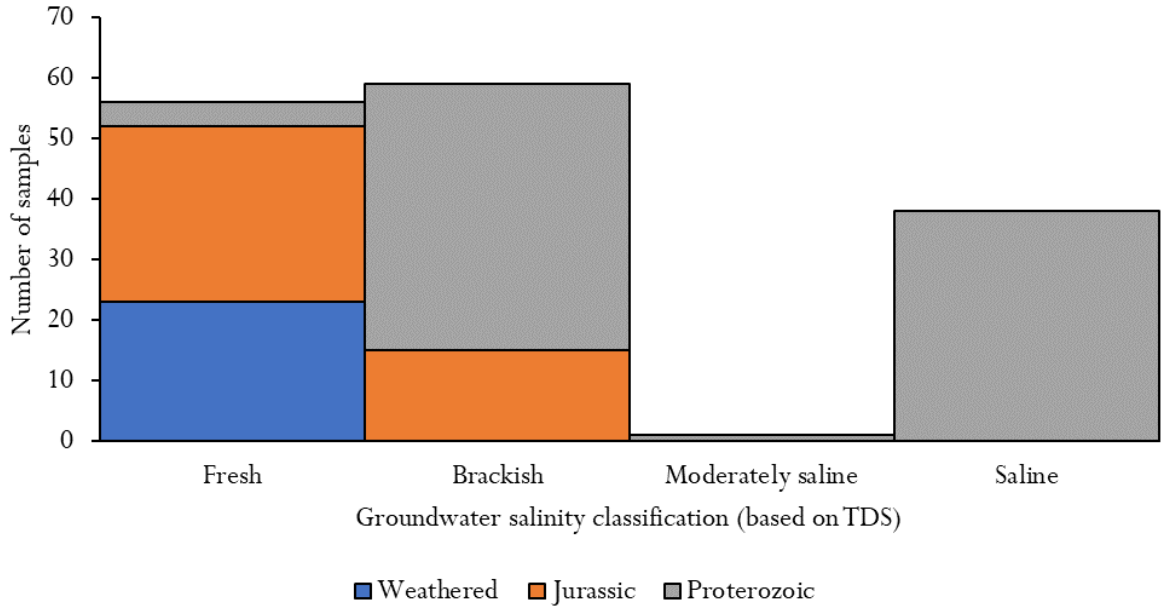
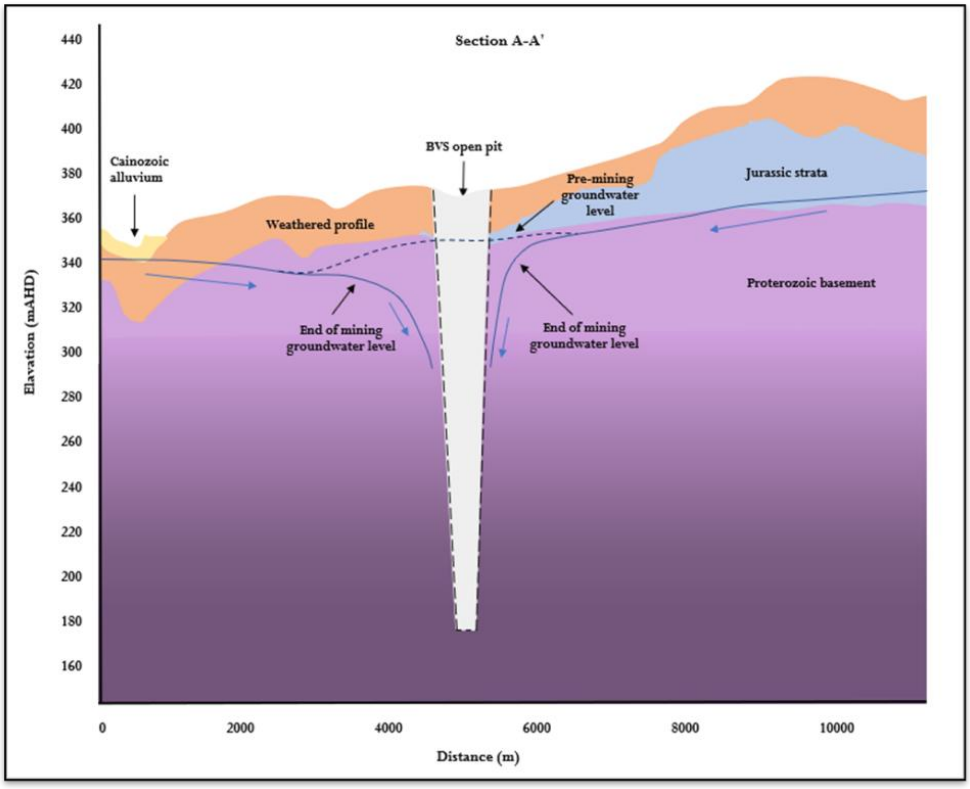


Figure 17 Salinity (as Total Dissolved Solids) histogram



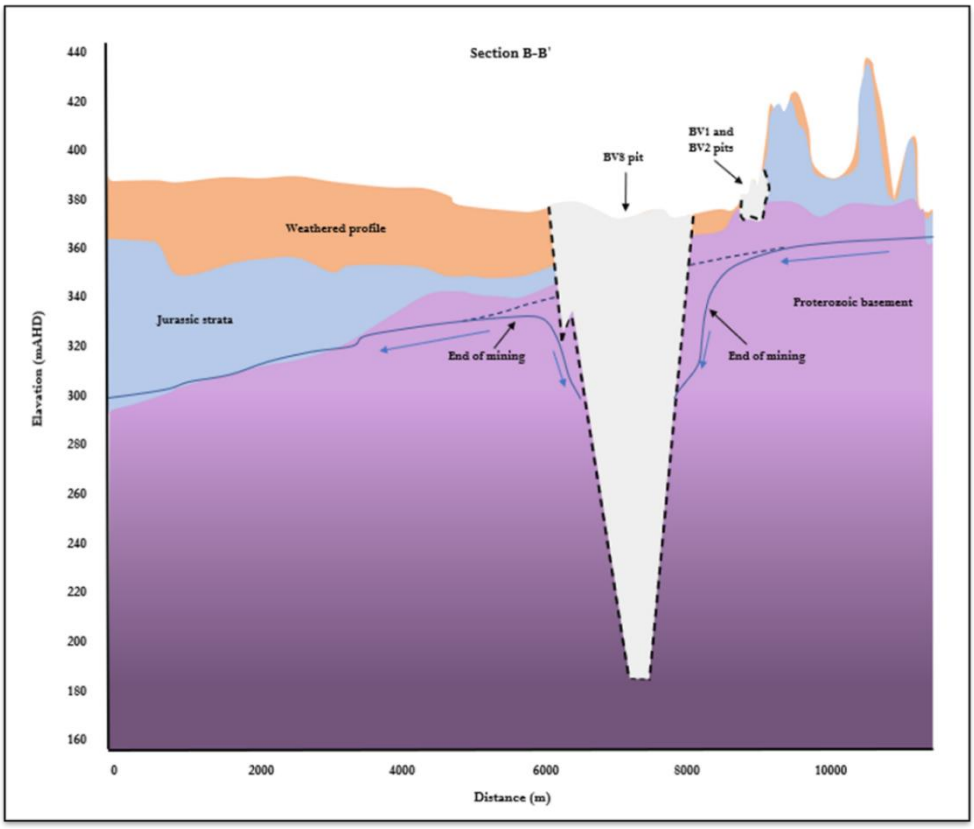
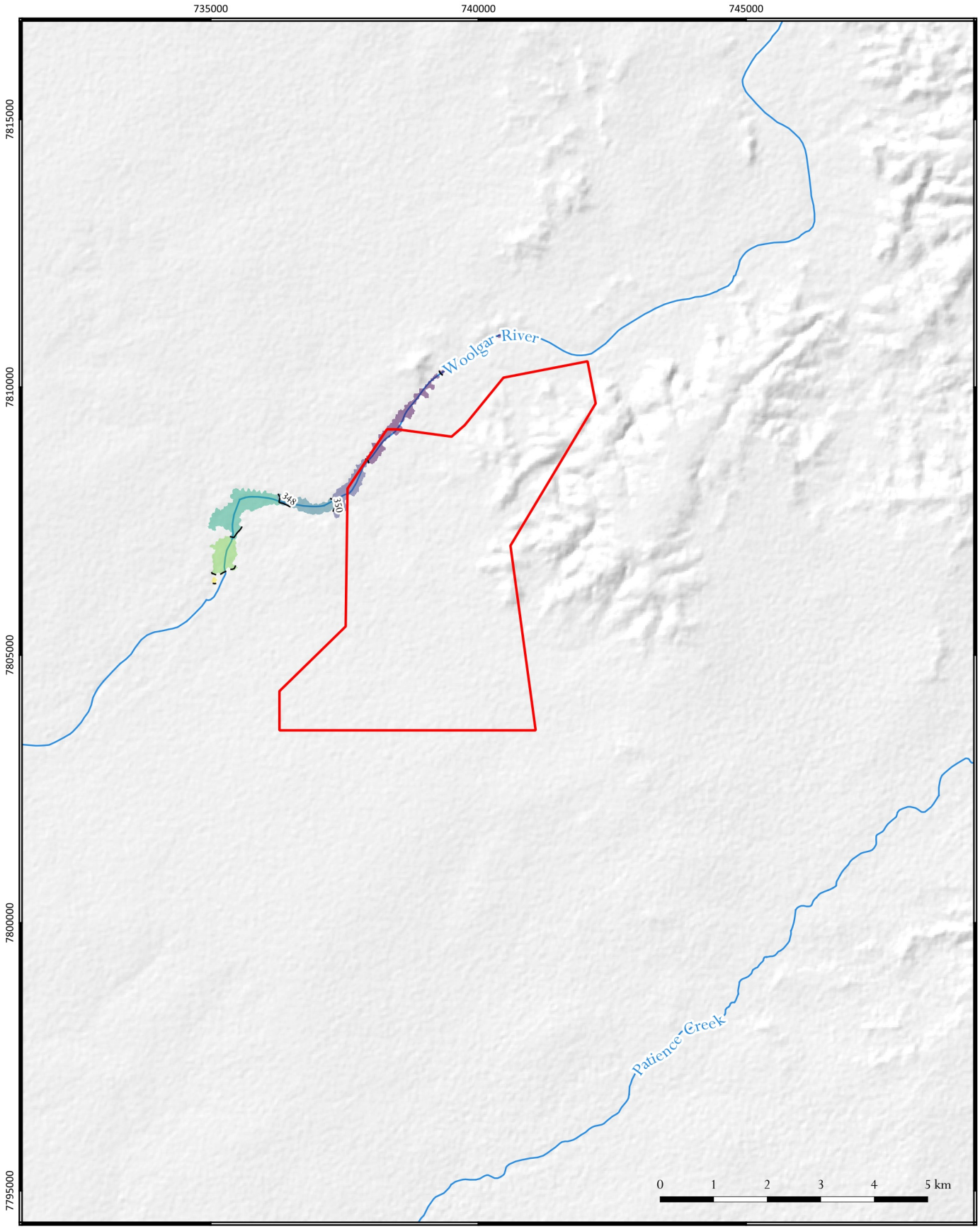


Figure 18 Conceptual groundwater regime cross-section



LEGEND

- Project site boundary
- Watercourses
- Elevation contour (mAHD)

Elevation (mAHD)

- >342 - 344
- >344 - 346
- >346 - 348
- >348 - 350
- >350 - 352
- > 354

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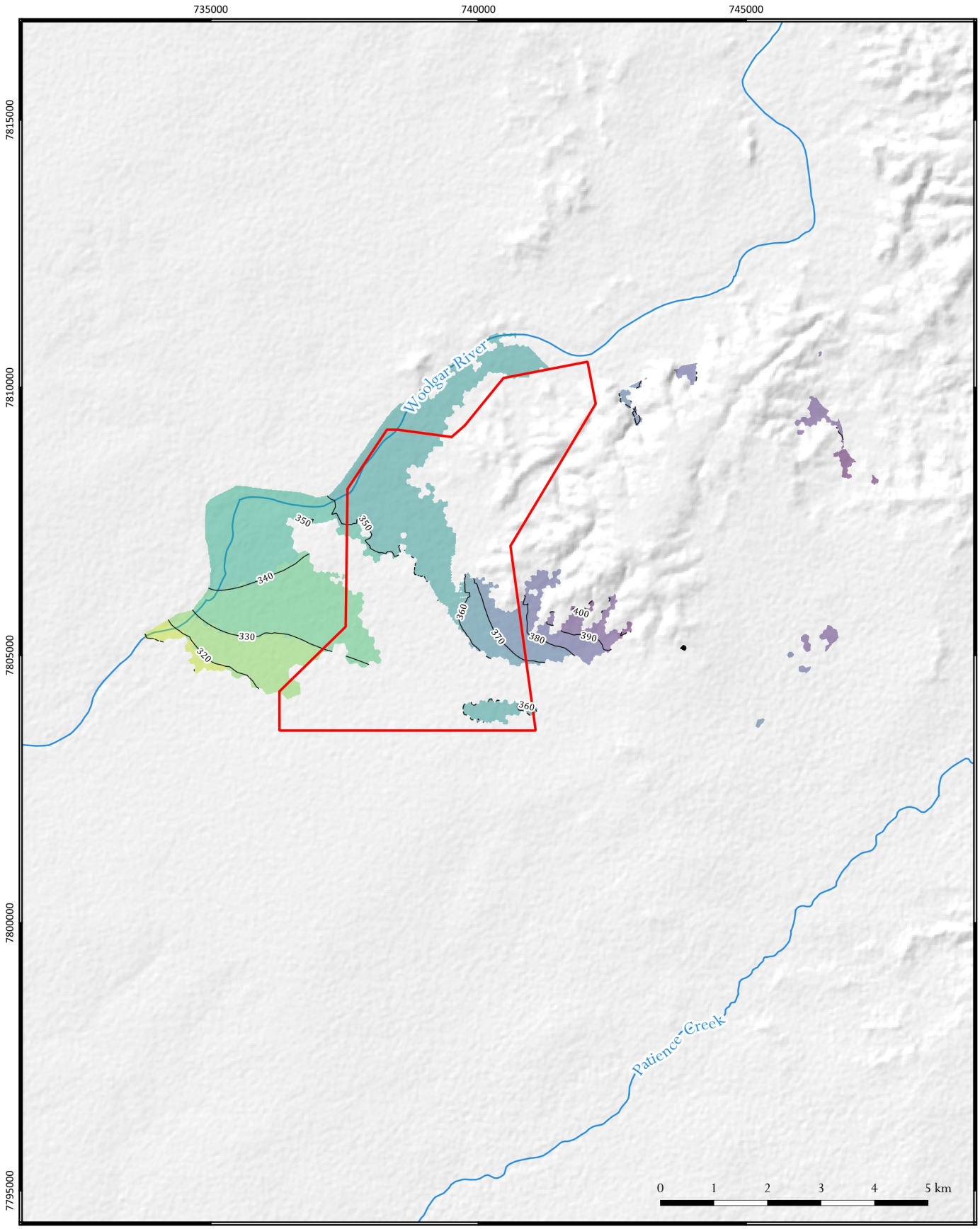
Groundwater elevation and flow within the alluvium

FIGURE No.
19

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LEGEND

- Project site boundary
- Watercourses
- Elevation contour (mAHD)

Elevation (mAHD)

310 - 320	>340 - 350	>370 - 380	> 400
>320 - 330	>350 - 360	>380 - 390	
>330 - 340	>360 - 370	>390 - 400	

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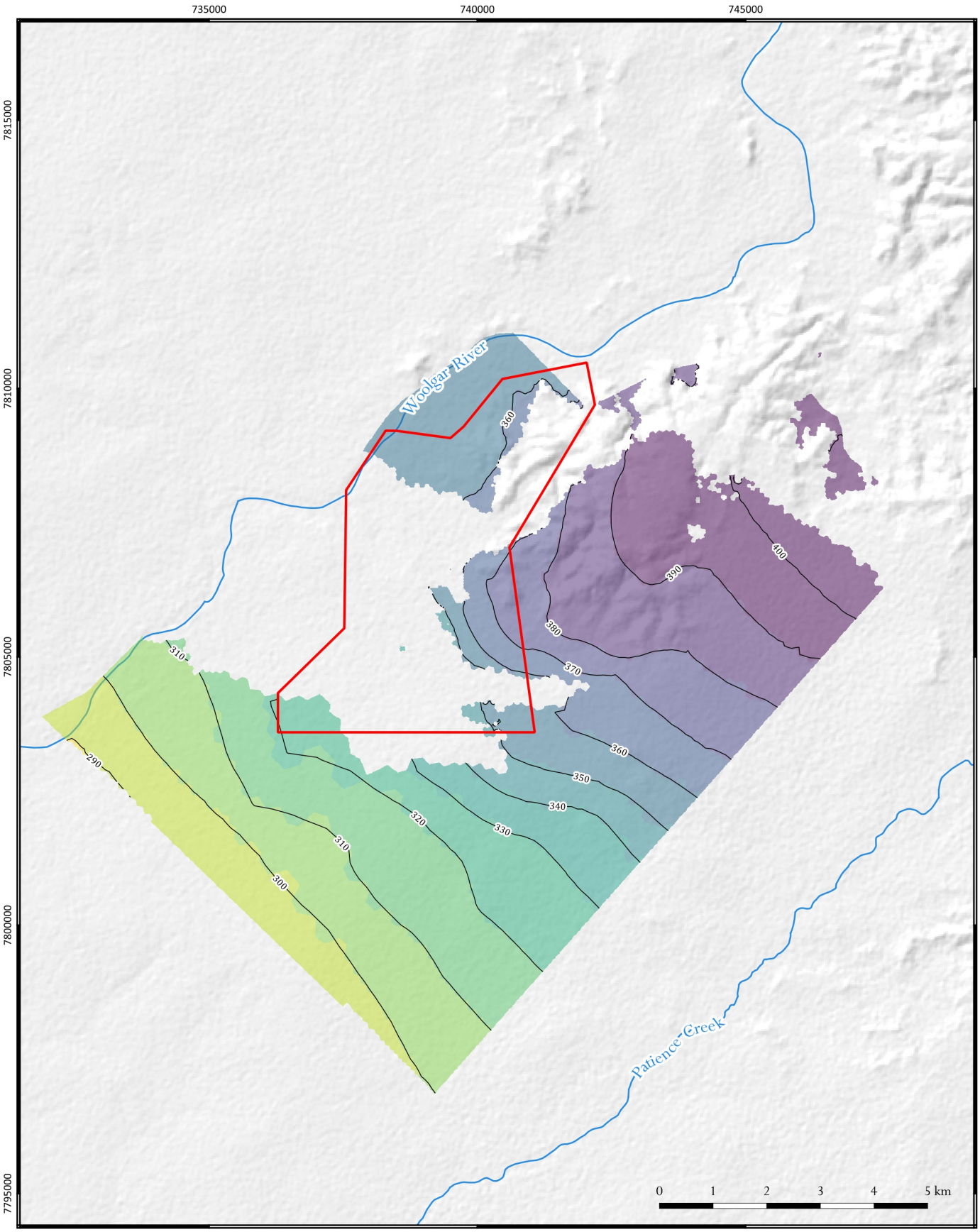
Groundwater elevation and flow within the weathered profile

FIGURE No.
20

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LEGEND

- Project site boundary
- Watercourses
- Elevation contour (mAHD)

Elevation (mAHD)

290 - 300	>320 - 330	>350 - 360	>380 - 390
>300 - 310	>330 - 340	>360 - 370	>390 - 400
>310 - 320	>340 - 350	>370 - 380	

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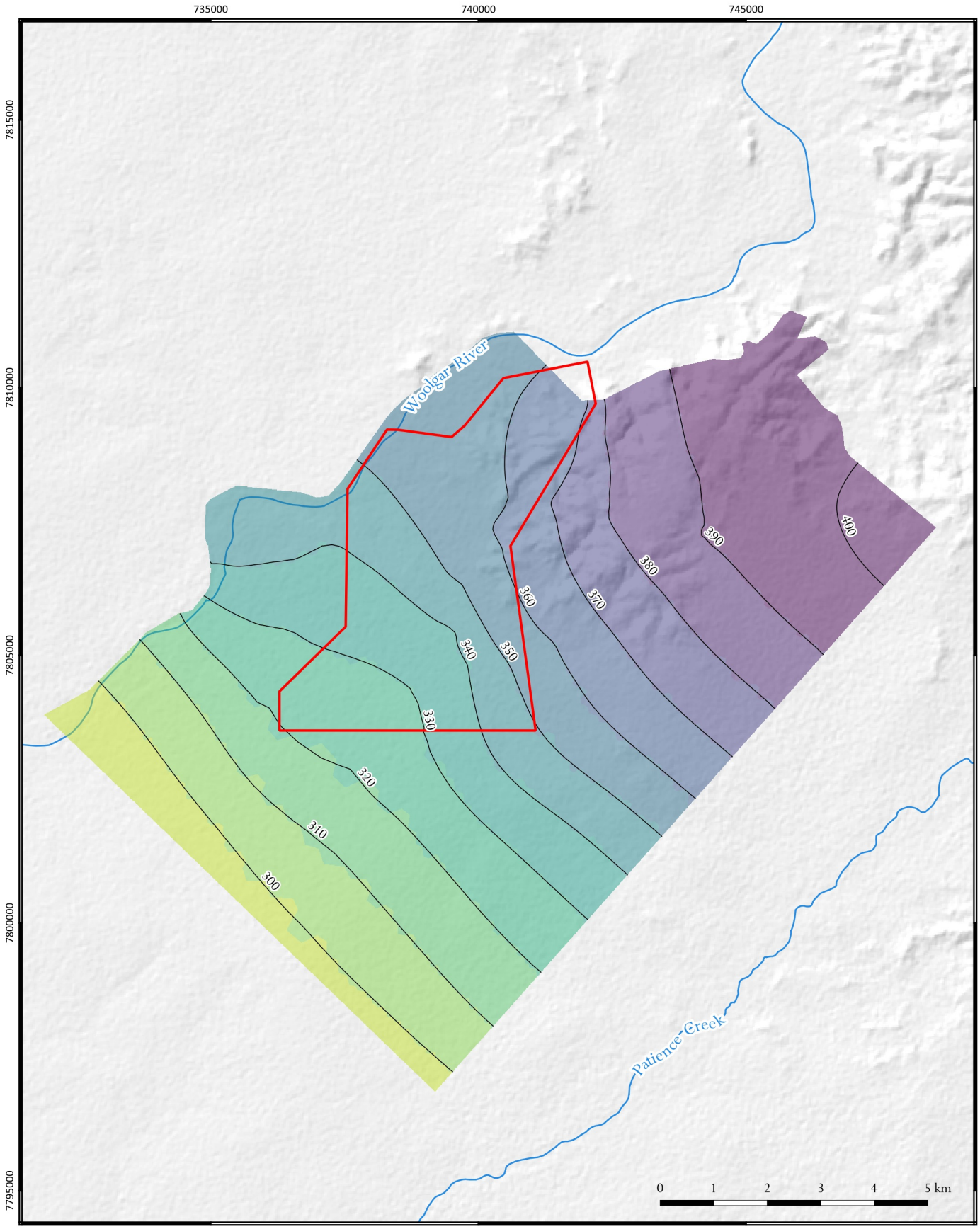
Groundwater elevation and flow within the Jurassic strata

FIGURE No.
21

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LEGEND

- Project site boundary
- Watercourses
- Elevation contour (mAHD)

Elevation (mAHD)

290 - 300	>320 - 330	>350 - 360	>380 - 390
>300 - 310	>330 - 340	>360 - 370	>400
>310 - 320	>340 - 350	>370 - 380	

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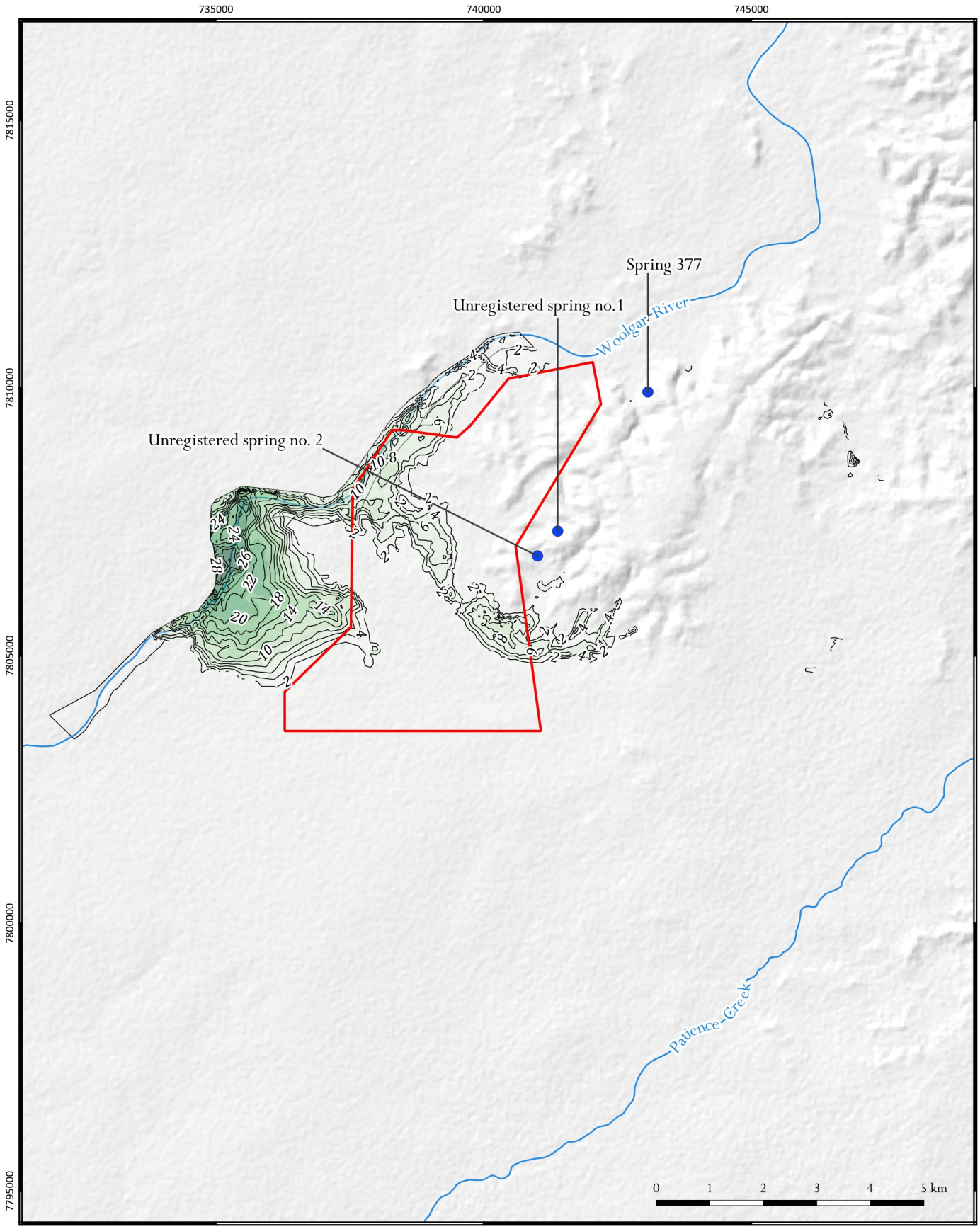
Groundwater elevation and flow within the Proterozoic basement

FIGURE No.
22

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LEGEND

- Project site boundary
- Watercourse
- Saturated thickness contours (m)
- Spring

Saturated thickness (m)

0 - 4	>12 - 16	>24 - 28
>4 - 8	>16 - 20	>28
>8 - 12	>20 - 24	

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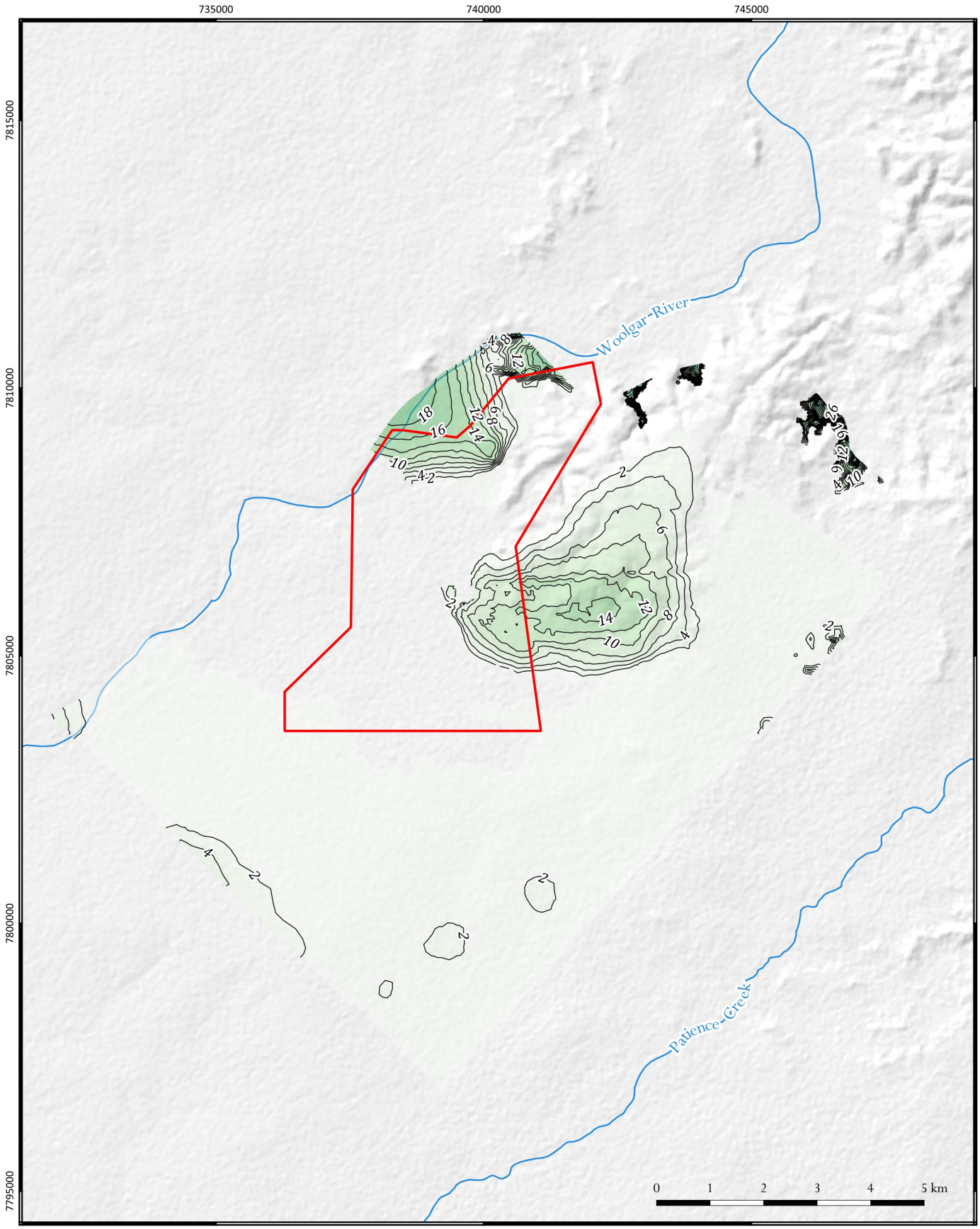
Extent and thickness of saturation in the weathered profile

FIGURE No.
23

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LEGEND

Project site boundary

Watercourse

Saturated thickness contour (m)

Saturated thickness (m)

0 - 2	>6 - 8	>12 - 14	>18 - 20	>24 - 26
>2 - 4	>8 - 10	>14 - 16	>20 - 22	>26
>4 - 6	>10 - 12	>16 - 18	>22 - 24	

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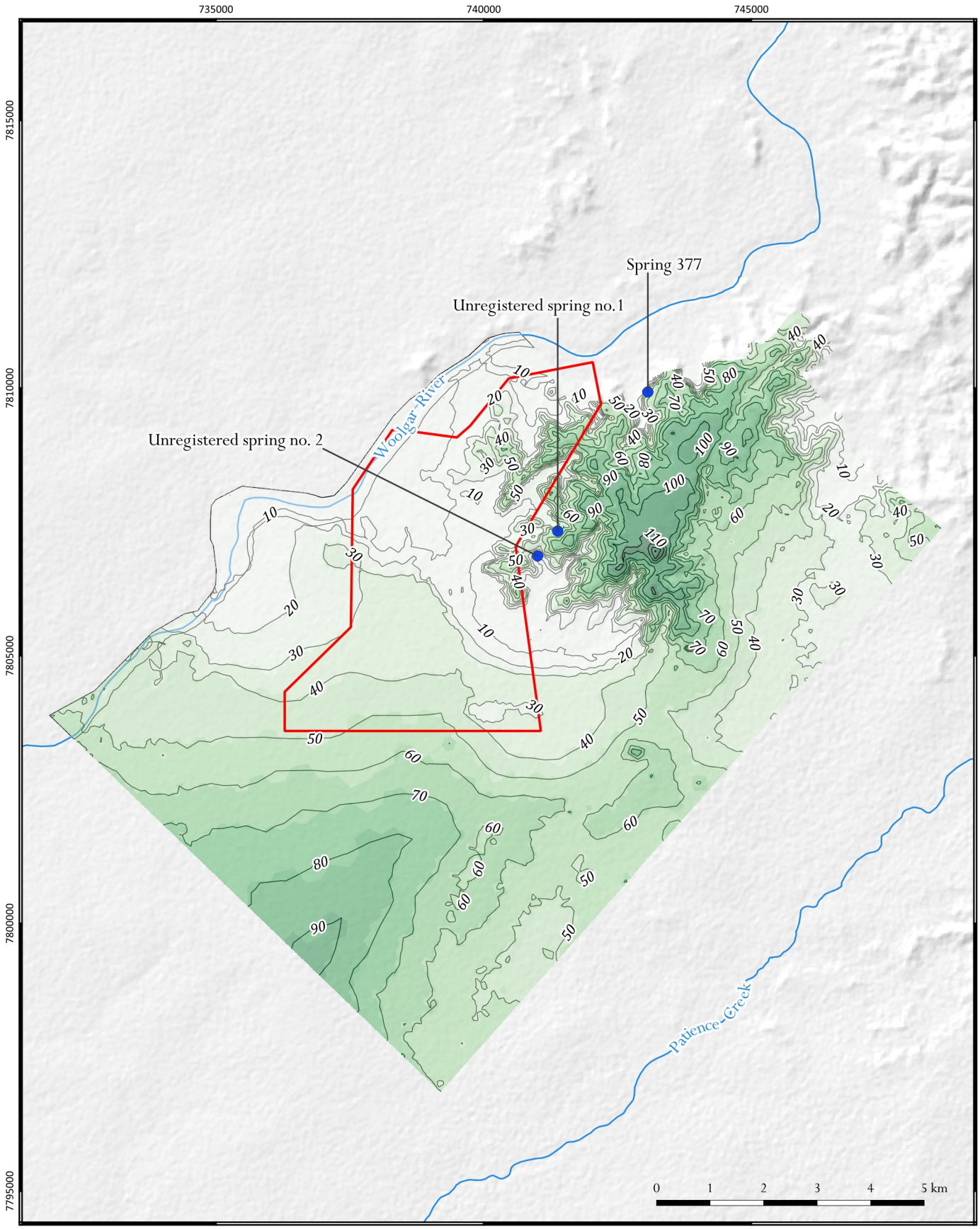
Extent and thickness of saturation in the Jurassic strata

FIGURE No.
24

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LEGEND

- Project site boundary
- Watercourse
- Depth to groundwater contours (m)
- Spring

Depth to groundwater (m)

0 - 20	>40 - 50	>70 - 80	>100 - 110
>20 - 30	>50 - 60	>80 - 90	>110 - 120
>30 - 40	>60 - 70	>90 - 100	

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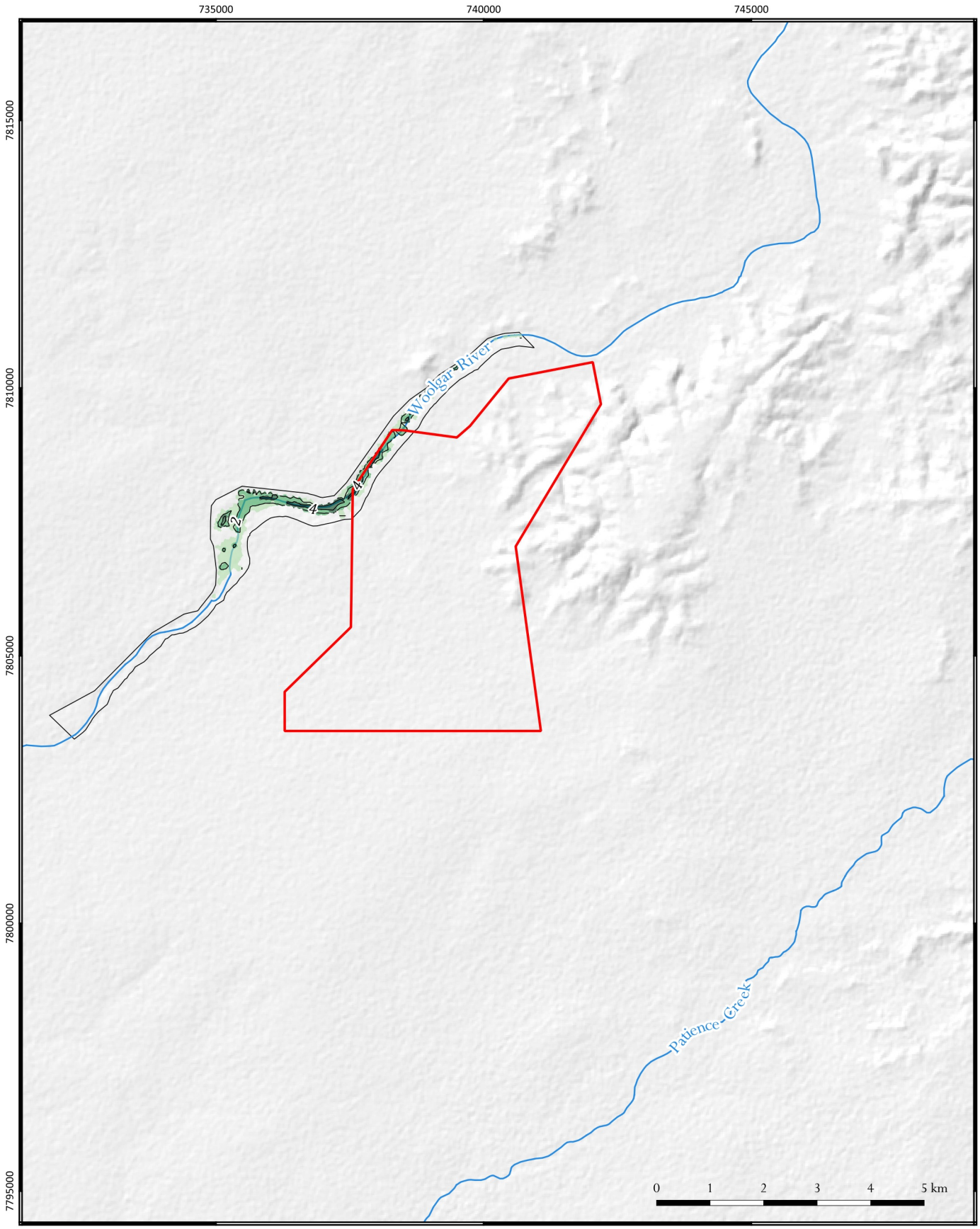
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Depth to groundwater table

FIGURE No.
25

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LEGEND

- Project site boundary
- Watercourse
- Saturated thickness contours (m)

Saturated thickness (m)

- 0
- >0 - 2
- >2 - 4
- >4

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Extent and thickness of saturation in the alluvium

FIGURE No.
26

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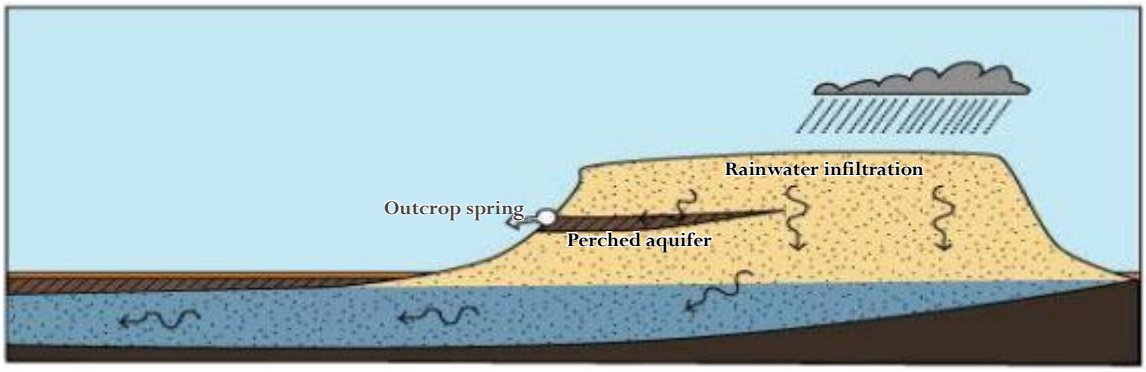
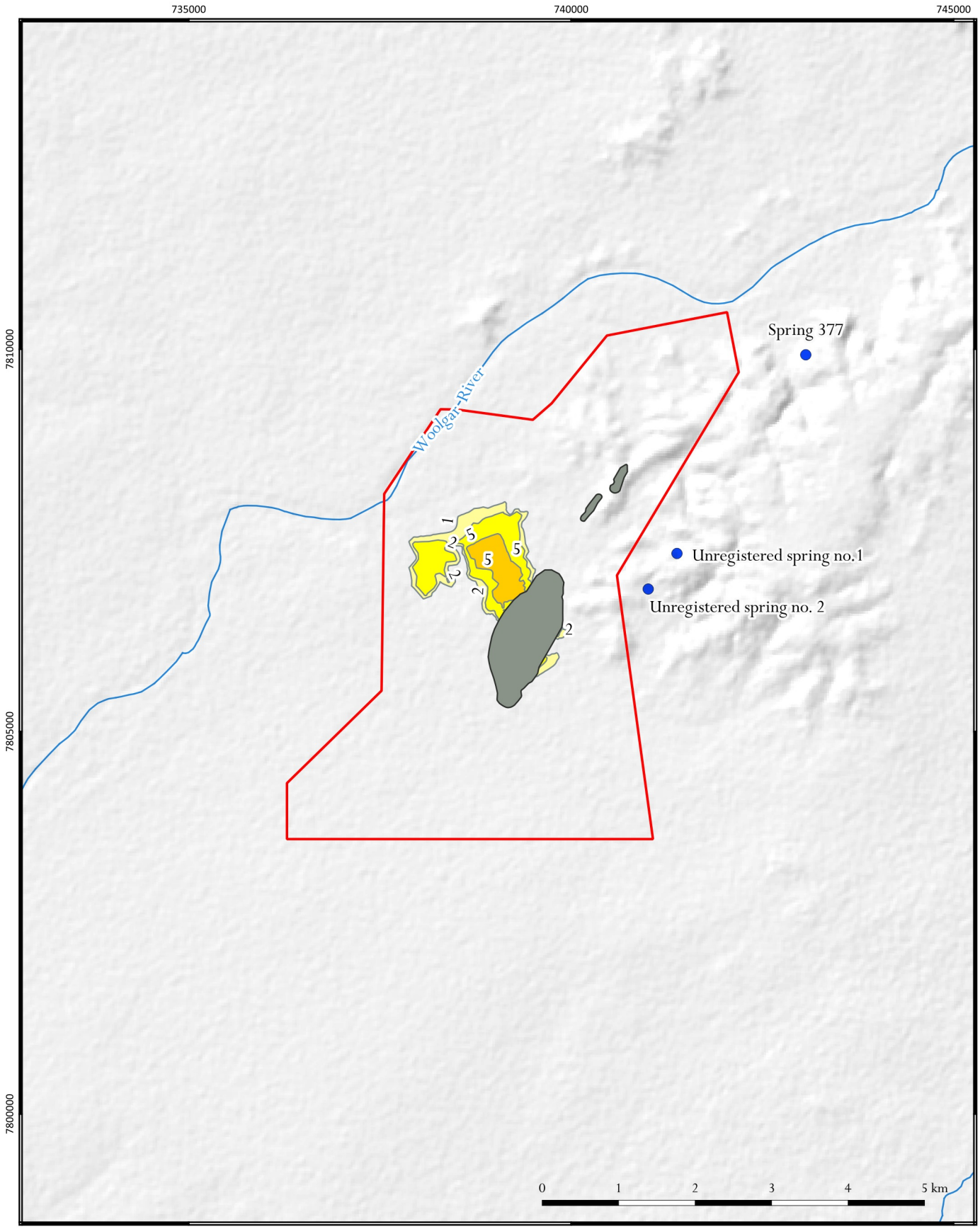


Figure 27 Conceptual diagram representing the outcrop springs (after DSITI, 2015)



LEGEND

- Project site boundary
- Open cut pit
- Existing unregistered water supply bore
- Watercourse
- Drawdown contour (m)
- Spring

Maximum drawdown (m)

- >1 - 2
- >2 - 5
- >5

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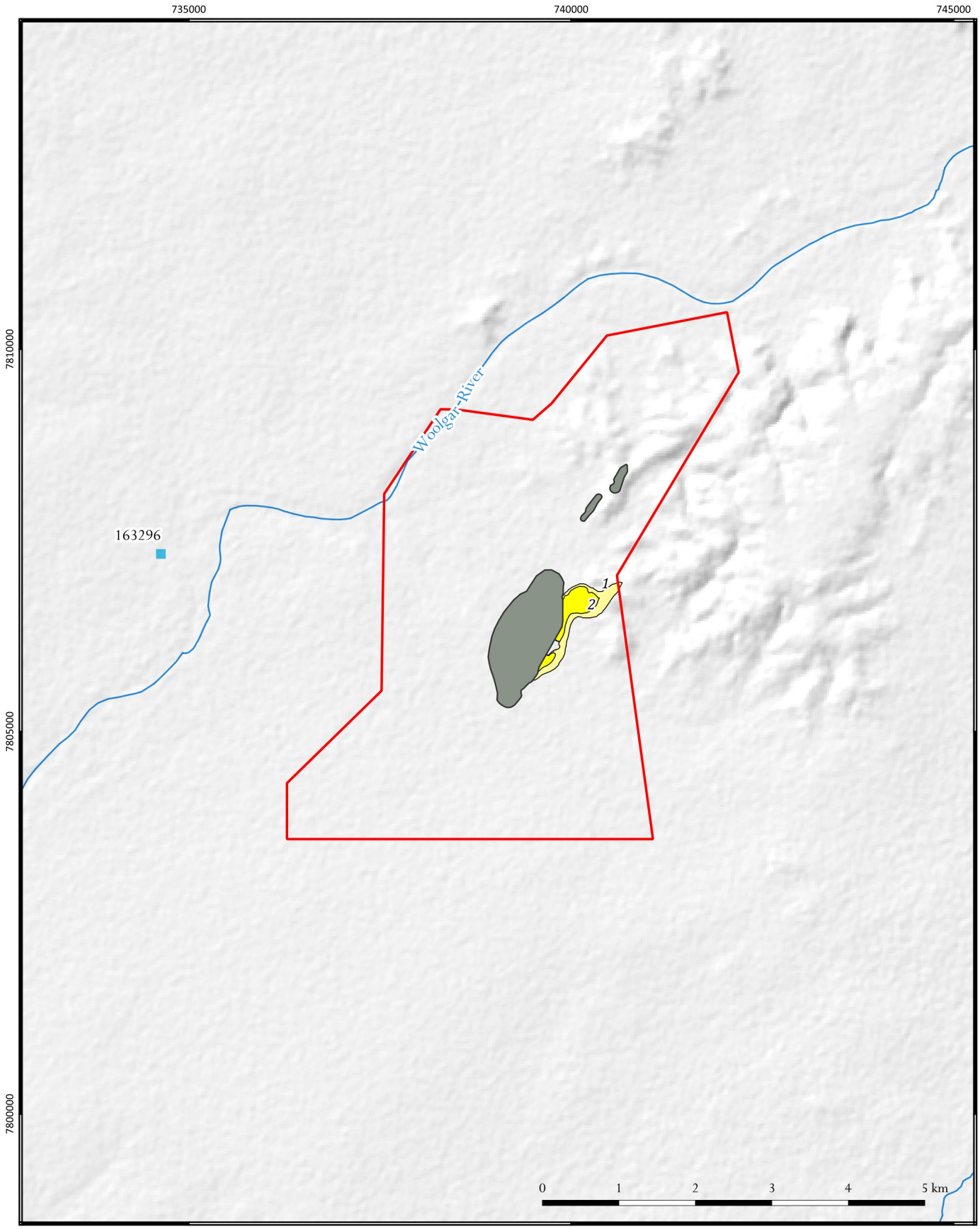
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Maximum predicted drawdown in the weathered profile

FIGURE No.
28

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LEGEND

- Project site boundary
- Open cut pit
- Existing registered water supply bore
- Watercourse
- Drawdown contour (m)

Maximum drawdown (m)

- >1 - 2
- >2 - 5

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1:70,000

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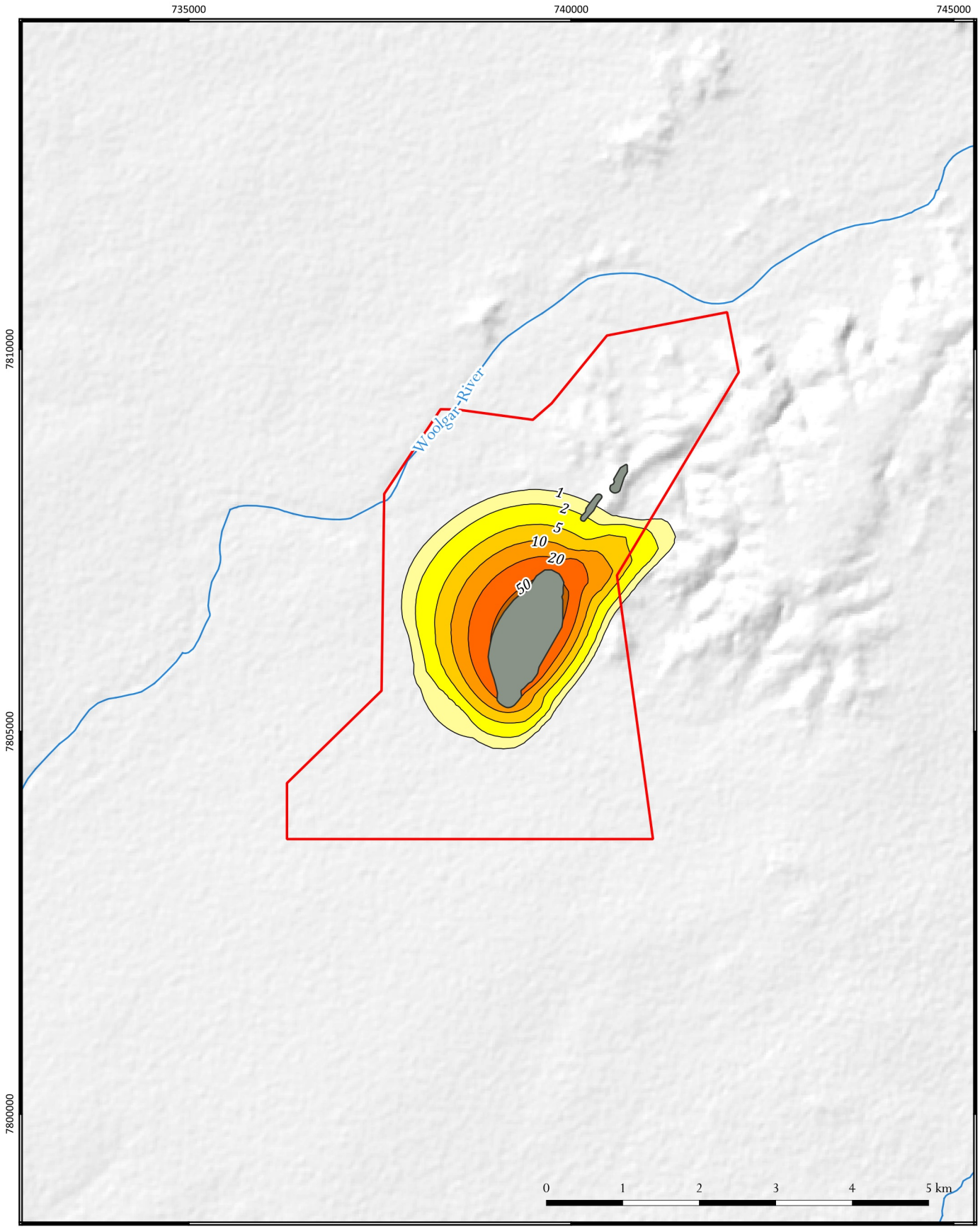
Maximum predicted drawdown in the Jurassic strata

FIGURE No.
29

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LEGEND

- Project site boundary
- Open cut pit
- Watercourse
- Drawdown contours (m)

Maximum drawdown (m)

>1 - 2	>10 - 20
>2 - 5	>20 - 50
>5 - 10	>50

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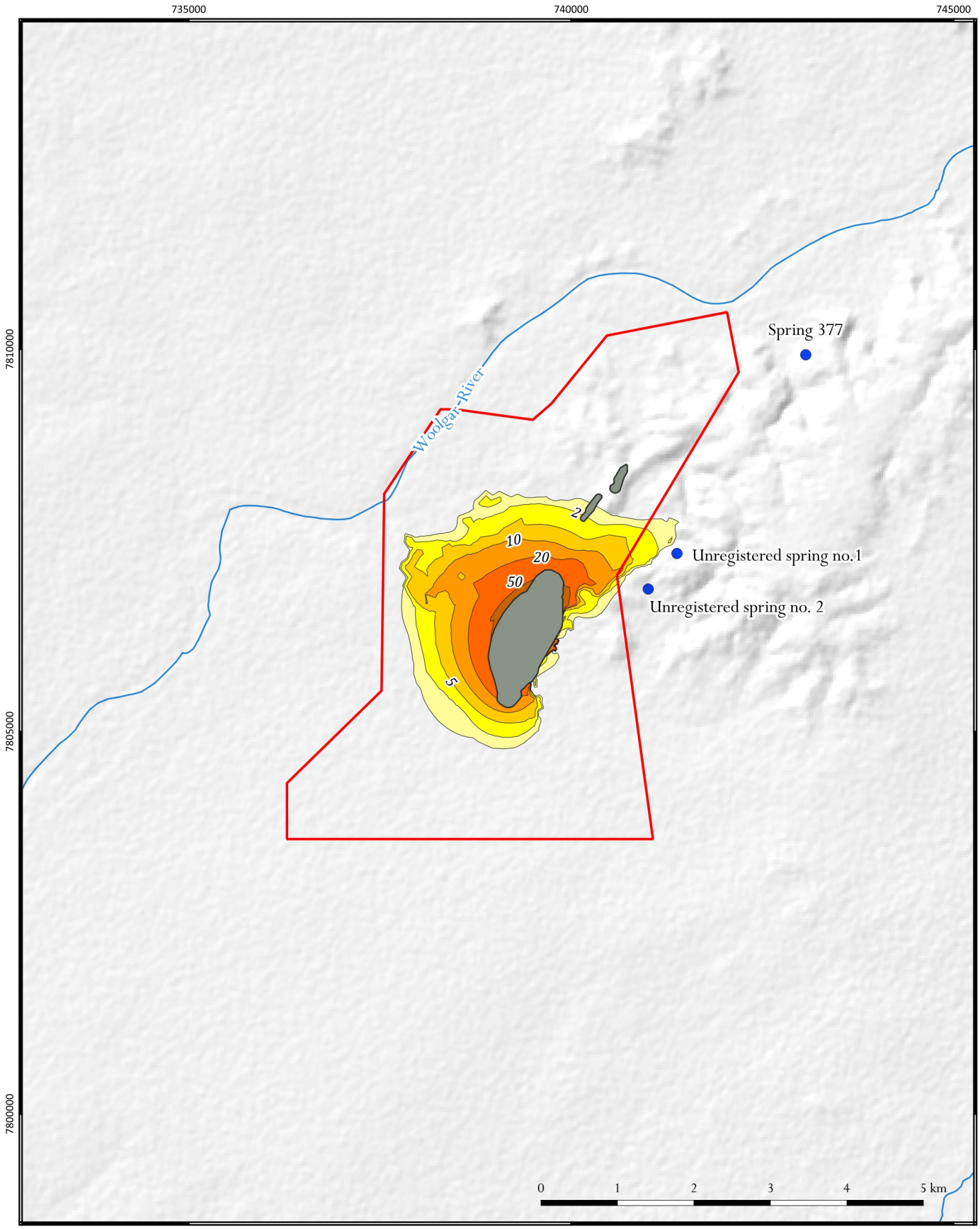
Maximum predicted drawdown in the Proterozoic basement

FIGURE No.
30

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LEGEND

- Project site boundary
- Open cut pit
- Watercourse
- Drawdown contour (m)
- Spring

Maximum drawdown (m)

>1 - 2	>10 - 20
>2 - 5	>20 - 50
>5 - 10	>50

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Predicted drawdown on the groundwater table

FIGURE No.
31

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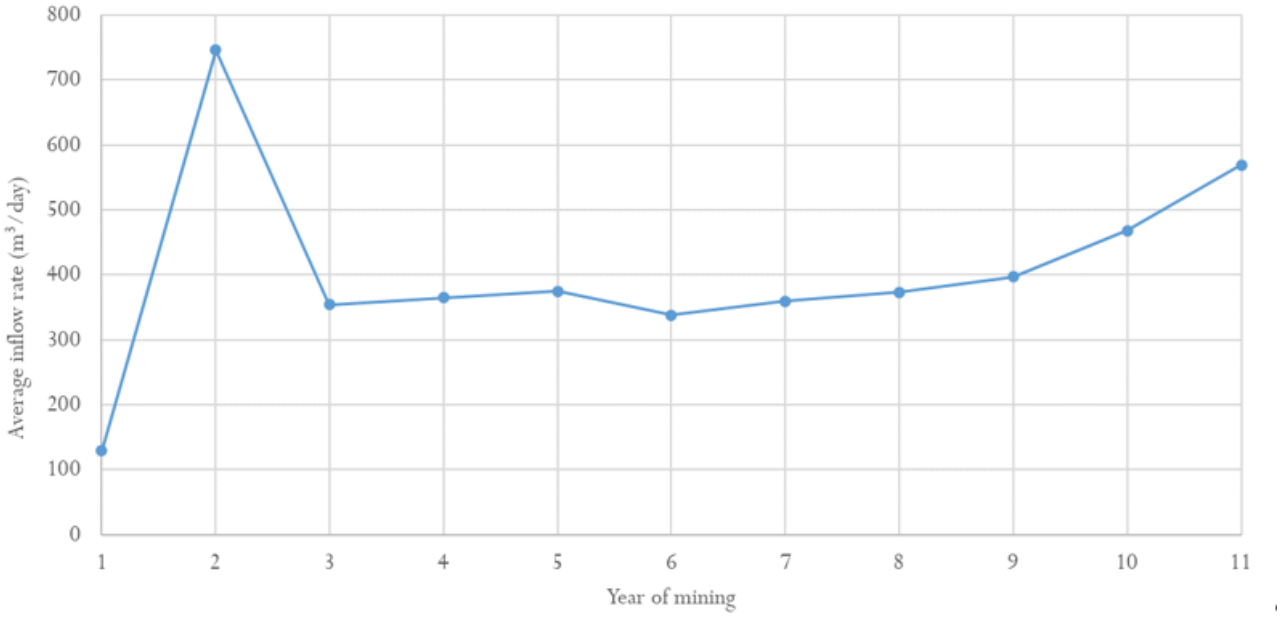


Figure 32 Predicted groundwater inflow rate during mining