Nolan Consulting Pty Ltd

Little River Quarry (Work Authority No. 453) Work Plan Variation Hydrogeological Assessment

Mountain View Quarries

(A division of the Barro Group Pty Ltd)

June 2023

A143-14

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1 Introduction

The Barro Group Pty Ltd (Barro Group) owns the land associated with Work Authority 453 (WA 453). This land is about 10 km north of Lara and north of the You Yangs (Appendix A: Figure 1.1). The locality plan is Appendix A: Figure 1.2.

Mountain Views Quarry, a division of the Barro Group, operates a quarry within WA453. The Barro Group propose to extend and deepen this quarry (see Appendix A: Figure 2.1 for proposed extraction boundary).

1.1 Purpose of this report

Nolan Consulting has been engaged by the Barro Group to prepare this hydrogeological assessment report as supporting information for the WA453 Work Plan variation. Nolan Consulting has been assisted by Valenza Engineering who has undertaken the site investigations (see Section 6).

1.2 Key assessment elements

This hydrogeological assessment report:

1. Describes the work plan variation including post closure
2. Presents the
   - site investigation outcomes
   - conceptual hydrogeological model
3. Addresses take and use licence considerations
4. Presents an impact assessment
5. Proposes a groundwater management plan (including contingency arrangements).

1.3 Definitions

For the purposes of this report the term "site" refers to the land within the proposed extraction boundary as shown in Figure 1.2 and Figure 2.1.

1.4 Site activities

Site inspections have been undertaken.

An inspection was conducted in December 2020 in the company of representatives of the Barro Group, Mansfield Crushing and BCA Consulting. Mansfield Crushing operate the quarry on behalf of the Barro Group and BCA Consulting is the Barro Group's resource consultant. At the inspection the following was observed:

- quarry pit including quarry pit sump
- surface drainage system
- dams.

1.5 Site investigations

Site investigations have been undertaken. These are described in Section 5 and Section 6.

2 Entitlements to take water

2.1 Registration licence BEE030364 – harvest surface water

Registration licence BEE030364 allows the Barro Group to harvest up to 74.7 ML/year from four off-waterway dams (see Section 3.2 for details). The locations of these dams are shown in Figure 3.1 (Existing Water Management Map).

2.2 Entitlement BEE072352 - take and use groundwater

Entitlement BEE072352 allows the Barro Group to take and use 44 ML/year of groundwater up to 30 June 2029. Related Licence to Operate Works WLE060541 provides details of the well/shaft which is licenced works WRK081946 (Appendix C). The well/shaft is the quarry pit sump.

3 Current water management

Under current arrangements surface water is captured in four on-site registered dams and used for quarry consumptive uses. Runoff from rainfall within the pit, stormwater runoff from two local catchments and groundwater captured within the quarry pit is also used for quarry consumptive uses.

The current surface management system is shown diagrammatically in Figure 3.1.

3.1 Water supply for consumptive uses

Water for consumptive uses is taken from Dam 1, Dam 4A, the quarry pit sump and the water tank. Water for consumptive uses is also imported during dry periods.

3.2 Dams

Registration licence BEE030364 (Appendix B) allows the Barro Group to harvest up to 74.7 ML/year from four off-waterway dams within WA453. The licensed uses are industrial or commercial as well as stock and domestic.

This registration licence has four extraction points (dams) and related licence to operate works WLE036219 (Appendix B).

Licence to Operate Works WLE036219 includes works ID, works location, dam capacity, maximum annual volume and use for each dam. The works ID, location, dam capacity and maximum annual volume as well as dam number allocated by the Barro Group are listed in Table 3-1.

Table 3-1: Registered dam capacity, maximum annual volume and use

Dam Number	Works ID	Easting	Northing	Dam capacity (ML)	Maximum annual volume (ML)
1	WRK033599	273,707	5,800,443	110.9	65
3	WRK036394	273,504	5,799,386	0.7	0.7
4A	WRK037757	272,643	5,799,791	2.2	2.0
4B	WRK038326	272,700	5,799,580	7.0	7.0
Total					74.7

Condition 12 of Licence to Operate Works WLE036219 is:

> The licence holder must keep all works, appliances and dams associated with this licence, including outlet pipes and valves, in a safe and operable condition and free from obstacles and vegetation that might hinder access to works.

The locations of the registered dams are shown in Appendix A: Figure 3.1 (Existing Water Management Map).

3.2.1 Dam 1

Dam 1 is located on a former drainage line through the north-west boundary of WA453. Its base is suspected to be the You Yang granites.

It has a surface area of about 1.3 ha at the freeboard level of about 165 m AHD. The freeboard level is 0.5 m from the lowest dam crest level. The dam's average water depth is about 1.5 m and its maximum water depth is about 4.5 m. These depths are to the freeboard level.

Dam 1 receives inflows from:

- stormwater runoff, via a channel located above the northern section of the quarry pit
- stormwater runoff, via piped culverts, from the sales/stockpile area within the southern section of the catchment
- haul roads
- Dam 3 and Dam 4A
- quarry pit sump (which are pumped to the channel located above the northern section of the quarry pit).

The stormwater runoff is managed by swale drains, bunding and sediment traps.

Losses from Dam 1 are from:

- net evaporation (evaporation less rainfall)
- seepage
- consumption
- discharge to Dam 4A (when the Dam 1 level is near its freeboard level).

The Mansfield Crushing's quarry manager advised:

- overflows from Dam 1 have not been observed
- Dam 1 was dry in the 2018 summer.

The water level was close to the freeboard level when inspected on 15 December 2020.

The water level has been close to the freeboard level since June 2022. During this wet period water from Dam 1 has been pumped to the quarry pit to maintain the freeboard level without discharging off-site. [At shown in Section 7.1.1 the Little River meteorological station recorded monthly rainfalls of 140.8 mm in October 2022 and 90 mm in November 2022. During these months recorded peak daily rainfalls were 28 mm on 26 October 2022 and 30 mm on 14 November 2022].

3.2.2 Dam 2

Dam 2 is east of the current quarry. It is about 0.15 ha in area at an elevation of about 195 m AHD. It is not registered and is not used as a water supply source.

3.2.3 Dam 3

Dam 3 is located along the southern boundary of WA453. This dam has a surface area of about 0.18 ha and is at an elevation of about 170 m AHD. The dam is often dry. Water from this dam is piped to Dam 1 (see Appendix A: Figure 3.1).

3.2.4 Dams 4A and 4B

These dams are south-west of the quarry. Both dams are at an elevation of about 158 m AHD.

Water from Dam 4B is transferred to Dam 4A.

Dam 4A is 5 m deep. It was close to full when inspected on 15 December 2020. It is flocculated two to three times a year. Water to this dam is supplied from catchment runoff and Dam 1 (when the water level in Dam 1 is near the freeboard level). Water from Dam 4A is piped to Dam 1 and pumped to the water cart.

3.2.5 Dam 5

Dam 5 is near the western boundary of WA453. It is not registered and is not used as a water supply source.

3.3 Quarry pit sump

The quarry pit sump is in the northern part of the current quarry pit (Appendix A: Figure 2.3).

3.3.1 Inflows

The quarry pit sump receives inflows from:

- groundwater - seeps within the pit wall
- in-pit runoff – rainfall falling within the pit
- surface water - via two drains from the small catchment in a low lying area to the east of the quarry pit and from the plant and stockpile area to the south
- Dam 1 when it is at or close to the freeboard level.

Away from the seeps the quarry pit wall is dry.

Surface water inflows to the two drains to the east of the pit traverse over disturbed ground Stormwater runoff to the pit occurs following large rainfall events. Since late 2022 the lower level of the quarry pit has been flooded. This followed a wet period with monthly rainfalls of 140.8 mm in October 2022 and 90 mm in November 2022 including peak daily rainfalls of 28 mm on 26 October 2022 and 30 mm on 14 November 2022. (See Section 7.1.1).

3.3.2 Outflows

Outflows from the quarry pit sump are:

- used for dust suppression and aggregate wetting
- discharged to Dam 1.

Water has not been abstracted from the quarry pit sump since June 2022.

Discharge from the sump is required to be metered under the take and use licence approved by Southern Rural Water. The Barro Group has notified Southern Rural Water that it wishes to install a meter on the discharge line and has provided details of possible meters. It is awaiting Southern Rural Water approval to install a meter.

3.3.3 Water level

The quarry pit sump's water level was estimated as:

- 131.0 m AHD – 13 January 2021
- 125.7 m AHD – 2 March 2023.

The floor level of the quarry floor was surveyed on 13 January 2021 to be 131.5 m AHD. It remained at this level until April 2021. Shortly after April 2021 the floor level was lowered to 118.5 m AHD. Water abstraction from the quarry pit sump occurred up to June 2022 when the quarry pit floor was flooded.

3.4 Water tank

A water tank is adjacent the haul road to the south of the quarry. It is filled by the water cart and from Dam 4A. Water from the tank is used within the plant and stockpile area.

3.5 Water consumption

The average water consumption from the site is about 100 ML/year. It is comprised of:

- dust suppression
  - haul roads 40%
  - around quarry 20%
  - crushing and screening 20%
- wetting of aggregate stockpiles (prior to sale) 20%

3.6 Groundwater mitigation measures

At present:

- fuelling occurs as follows:
  - mobile vehicles - outside of the quarry pit
  - crushers - within the crushing pads
  - track machines - in the quarry pit
- service vehicles carry a spill kit
- servicing occurs as follows:
  - mobile plant - outside of the quarry pit in the workshop area
  - crushers - within the crushing pads
  - track machines - in the quarry pit
- oils and greases are bunded in the workshop area
- drains have sediment control
- domestic / non-industrial waste is separated, placed in bins and removed from site
- there is a septic tank at the drivers lounge and the site office.

4 Work Plan variation

This description of the work plan variation is based upon Nolan Consulting's understanding as of April 2023.

4.1 Background

4.1.1 Site location, ownership and access

WA453 is within 250 Drysdale Road, Little River and north of the You Yangs Regional Park (Appendix A: Figure 1.2). It is owned by the Barro Group.

The site will be accessed from Sandy Creek Road to the west (as currently occurs).

4.1.2 Title details

WA453 is within the following allotments:

- Lot 2 Plan of Subdivision 344713R
- Crown Allotment 13, Sec 11 Parish of Wurdi-Youang.

The Barro Group hold grazing licences over three Crown land road reserves adjacent to WA453.

4.2 Site layout

The site layout plan for Stage 4 is presented in Appendix A: Figure 2.2. The site will include a weighbridge, office, amenities, workshop and plant and stockpile area. The plant area will be at 165m AHD, some 10 m below the current stockpile area.

4.3 Extraction, production and processing

4.3.1 Resource extraction method

The extraction process is:

- soil removed and used in progressive rehabilitation or potentially stored in temporary stockpiles within the disturbance area
- overburden removed and placed in storage mounds within the excavation area, or used directly in progressive rehabilitation where possible
- resource extracted and hauled to the processing plant.

Both excavator and dozer techniques will be employed to remove overburden and highly weathered granite. Drill and blast methods will be employed to extract the harder, fresher granite.

4.3.2 Staging

The extraction stages are:

- Stage 1 expansion of upper pit area to the north-east at a level of 165 m AHD with a quarry pit sump floor level of 120 m AHD and a mobile plant
- Stage 2 expansion of 165 m AHD level to south and south-east with an expanding quarry floor level of 120 m AHD and the establishment of fixed plant at the 165 m AHD
- Stage 3 deepening of quarry, a quarry floor level of 90 m AHD and a fixed plant

- Stage 4 deepening and widening of quarry floor level of 60 m AHD, a quarry pit sump level of 55 m AHD and a fixed plant.

Stages 1 and 2 provide a shielded area for the fixed plant.

4.3.3 Production rate

The production rate will be determined by market forces and is expected to be approximately 750,000 tonne/year which is similar to the current rate.

The life expectancy of the quarry is in excess of 80 years.

4.3.4 Processing

Excavated material will be hauled to and processed at a crushing and screening plant. This will be mobile for Stages 1 and 2 and fixed for Stages 3 and 4 (see Appendix A: Figure 2.2). The fixed plant will be within a hard stand area.

Washing will not be undertaken. Wetting of aggregate will occur (See Section 3.3.2 and Section 3.5).

4.4 Dam 1 relocation

Dam 1 will be relocated within the quarry pit and its storage capacity is intended to remain as per the BEE030364 registration at 110.9 ML. (See Appendix A: Figure 2.2 and Figure 4.1).

During its excavation its water and inflows will be stored within the quarry pit and will be returned to the dam once it is constructed.

4.5 Quarry floor level and water level

The proposed quarry floor levels are presented in Section 4.3.2. The lowest floor level of 60 m AHD is proposed to occur in Stage 4 (see Appendix A: Figure 2.2). This is about 60 m below the proposed Stage 1 floor level.

The quarry pit sump water level will be maintained at the quarry pit floor level at all stages.

4.6 Water consumption and supply

4.6.1 Consumption

The total water consumptive demand for the proposed Work Plan variation will not change from the current demand.

4.6.2 Supply

The future water supply will be sourced from groundwater seepage into the quarry pit and Dam 1, Dam 3, Dam 4A and Dam 4B. Registration licence BEE030364 allows for harvesting of up to 74.7 ML/year. Take and use licence BEE0072352 allows for the take and use of 44 ML/year from quarry pit sump.

Dam 1 will be relocated within the expanded quarry and will act as the quarry pit sump.

The source of surface water inflows to Dam 1 will be the current inflows (see Section 3.2.1) less most of the runoff from the northern catchment which will be directed into the Sandy Creek tributary.

Minor runoff from the north-eastern catchment area immediately above the terminal crest will be directed to the relocated Dam 1 due to topographic constraints. These flows will be directed to rock-lined chutes and drains constructed in the upper benches.

Stormwater from the south-west slopes will continue to be captured in Dam 3 and will be a supplementary water supply. The catchment area for this dam will be reduced from the existing catchment area due to the expanding quarry.

The Dam 1/quarry pit sump is expected to meet the consumptive use requirements throughout the life of the quarry given the average operational consumption of 100 ML/year, predicted groundwater inflows, and registered dam storage capacity.

It is likely that the reliance of flows from Dam 3 and Dam 4A to Dam 1 will diminish as the depth of the quarry increases. Overflows from these dams will discharge into the catchments via constructed spillways.

4.6.3 Wet and dry conditions

4.6.3.1 Wet conditions

Water abstracted from the quarry pit sump will be consumed on-site. In particularly wet periods excess water will to stored in the pit avoiding the need for an off-site discharge.

4.6.3.2 Dry conditions

The need to import water during dry periods for consumptive use will diminish as the quarry deepens and the volume of groundwater abstracted increases.

4.7 Natural runoff to Sandy Creek

An exclusion zone to the north-east of the quarry provides protection of the waterways and drainage lines as per Melbourne Water's letters to BCA Consulting of 7 October 2021 and 18 October 2022 (Appendix D). This exclusion zone does not include the north-eastern catchment area immediately above the terminal crest as it is low lying (see Section 4.6.2).

Within the exclusion zone clean runoff outside the excavation will be directed to the Sandy Creek tributary via grassed swale drains and other surface water management control features. Flow from this tributary will enter Little River. These works will be managed to ensure the water quality of flows into the Sandy Creek tributary will be consistent with the Victorian Government (2021) "*Environment Reference Standard*" surface water environmental values for inland waters.

The runoff from the slopes south-west of the pit is collected in Dam 3 for use under Registration licence BEE030364.

4.8 Groundwater quality control

The following controls to minimise the risk of unacceptable groundwater quality impacts will be undertaken:

- keep fuel and fuelling operations clear of the quarry pit as far as practicable
- keep a spill kit available for when mobile equipment is being refuelled or any minor servicing and/or simple maintenance tasks are undertaken
- conduct major servicing / repairs on a workshop hardstand fitted with an interceptor trap
- bund the oils and grease storage areas
- drain processing and stockpile areas through a sediment pit/trap
- contain domestic / non-industrial waste in bins and regularly remove from site
- utilise approved septic tank/toilet system.

4.9 Land to the east of current quarry

An inspection of aerial photographs indicates the land to the east of current quarry had ceased acting as a fertiliser storage area by 2004.

This area has been subject to site investigations (see Section 6.3). It will be incorporated into the expanded quarry area. The management of this area will be undertaken to ensure that stormwater runoff associated with the work plan variation meets the Victorian Government (2021) "*Environment Reference Standard*" surface water environmental values for inland waters.

The steps are described below.

4.9.1 During Stage 1

The fill will be covered and sealed with clay overburden as soon as practicable.

4.9.2 Prior to removal in Stage 2

A Soil Management Plan as recommended by Senversa (2021) will be developed (see Section 6.3.4).

4.9.3 During Stage 2

The fill will be transferred and encapsulated to below the fixed plant's hardstand area where it will be sealed from above and below.

4.10 Post closure

The proposed end use for the site as stated in the Rehabilitation Plan is for ongoing use by Barro, as:

- agriculture (animal husbandry)
- service industry / rural industry
  - maintenance depot for road trucks, quarry plant/equipment and farm equipment
- warehousing, which may include:
  - core store, for drill core / drill cuttings storage, sampling and logging
  - road truck parking
  - quarry equipment storage
  - mobile plant storage
  - mobile crushing equipment storage
  - quarry plant / equipment storage.

After quarrying ceases the water level in the quarry pit will rise as water abstraction from the quarry will be substantially less than that which currently occurs. The post closure water use will likely be limited to minor extraction for agricultural and industrial uses.

A discussion of the water level to which the quarry pit is likely to recover to and the timeframe for this recovery is provided in Section 8.3. A discussion of the post closure water quality of the quarry pit is provided in Section 9.2.2.

4.11 Cultural Heritage

No works are proposed in the south-east corner which is mapped as an area of Aboriginal Cultural Heritage Sensitivity.

5 On-site bores installed prior to site investigations

Information from on-site bores which had been installed prior to the site investigations is presented below.

5.1 Former groundwater observation bores

Bores 105530 to 105533 are identified in the Department of Energy, Environment and Climate Action (DEECA) "*Water Measurement Information System*" (WMIS) and the Visualising Victoria's Groundwater databases (see Appendix A: Figure 2.3 and Figure 5.3). They were drilled to a depth of 35 m. The driller's logs for these bores are presented in Appendix G. Based on their coordinates and uses these bores are assumed to be bores 1, 2, 3 and 4 which were installed as a requirement of EPA licence SW4238.

The bores have cemented headworks with metal plate (covers) and are without locks. Information recorded in 2012 is presented in Table 5-1.

Table 5-1: Former groundwater observation bore information

Former groundwater observation bores	WMIS No.	Bore depth (mbgl)	Depth to water (mbgl)	Water quality parameters			Location with respect to current quarry
				TDS (mg/l)	pH	Temp (°C)	
Bore 1[1]	105531	4.75	0.45	6,740	5.26	21.7	East
Bore 2[1]	105532	33.60	2.78	7,140	6.43	19.9	East
Bore 3	105533	5.40	Dry	-	-	-	North-west
Bore 4[1]	105530	7.13	Dry	-	-	-	West
[1] Bores 1, 3 and 4 have collapsed							

As Bore 1 and Bore 2 have damaged headworks and are likely to suffer from surface water ingress the gauged depth to waters found in these bores is not given weight.

5.2 Resource investigations bores

5.2.1 1990

Resource investigation bores OPT-1, OPT-2, OPT-3 and OPT-4 were drilled in 1990. Their locations are shown Figure 2.3 and the logs are presented in Appendix H.

The bores were augered through the colluvial sands prior to its removal and then cored through the granite. The depth of the colluvial sands and the granite at these bores are presented in Table 5-2.

Table 5-2: Geological logs of Bores OPT-1 to OPT-4 colluvial sand/granite intersections

Bore	Colluvial sands (mbgl)		Granite (mbgl)	
	From	To	From	To[1]
OPT-1	0.0	7.3	7.3	>21.0
OPT-2	0.0	1.7	1.7	>12.0
OPT-3	0.0	Not logged	Not logged	>13.5
OPT-4	0.0	Not logged	Above 14.4	>31.7
[1] base of hole				

5.2.2 2013

In 2013 BCA Consulting supervised the drilling and undertook the logging of:

- 56 percussion holes (YY13-01 to YY13-56)
- five diamond cored holes (D13-01 to D13-05).

The percussion holes were drilled to about 29 m in depth. Four of the five diamond cored holes were drilled to a depth of 50 m to 51 m. Most of these holes were drilled to the east of the current quarry. Granitic soil from the surface was found in most of these bores with a typical thickness of 1.8 m and a maximum thickness of 7.2 m.

An electromagnetic survey was conducted as part of these investigations.

6 Site investigations

Site investigations were undertaken from:

- February 2021 to August 2021
- August to September 2021
- December 2022 to February 2023.

The February 2021 to August 2021 investigations included the installation and testing of groundwater observation bore BH01 and the sampling and analysis of water from Dams 1 and 2, observation bore BH01 and the quarry pit sump. This is reported in Valenza Engineering (2021) "*Little River Quarry, Surface Water, Groundwater and Soil Sampling Factual Report*".

The December 2022 to February 2023 investigations included the installation and testing of groundwater observation bores BH02, BH03 and BH04. This is reported in Valenza Engineering (2023) "*Little River Quarry Well Installation and Hydraulic Testing Report*".

All groundwater observation bores are understood to have been installed in accordance with DEECA Licences to Construct Works. Licence to Construct Works WLE080609 applies to observation bore BH01 and Licence to Construct Works WLE084568 applies to observation bores BH02, BH03 and BH04. Both licences to construct are included in Appendix I.

The August 2021 to September 2021 investigations undertaken by Senversa (2021) were of the land to the east of the current quarry. These investigations are described in Section 6.3.

6.1 Groundwater observation bores

6.1.1 Locations

Four groundwater observation bores have been installed around the perimeter of the quarry (Appendix A: Figure 2.3). Table 6-1 presents their locations with respect to the current quarry pit.

Table 6-1: Location of groundwater observation bores with respect to current quarry pit

Groundwater observation bore	Direction from current quarry	Approximate Distance from current quarry (m)
BH01	South	468
BH02	South-west	500
BH03	North-west	270
BH04	East	520

6.1.2 Installation

6.1.2.1 Drilling

Observation bore BH01 was diamond core drilled by Statewide Drilling on 10 March 2021. The core was logged by a BCA Consulting geologist. Observation bores BH02, BH03 and BH04 were air hammer drilled by Star Drilling between 21 December 2022 and 16 January 2023.

6.1.2.2 BH01 installation

Installation details were provided to Valenza Engineering by the driller. The details are:

1. Hole diameter — 96 mm (HQ) – surface to 39 m bgl
75.7 mm (NQ) - 39 m bgl to150 m bgl
2. Casing diameter — 50 mm

3.	Casing material	Class 12 uPVC
4.	Screen type	Machine slotted, 0.4 mm aperture, 5 mm spacing
5.	Screen length	12 m (138 m bgl to 150 m bgl)
6.	Filter pack	Nil
7.	Sump	Nil
8.	Caps	PVC endcap and Jcap
9.	Seal / Seal placement	Rubber seal at 3m bgl, bentonite to surface Bore cemented from 3 m bgl to 39 m bgl
10.	Completion	Concrete pad at surface and monument

The bore was drilled with drilling mud. The Valenza Engineering log (with installation details) and the BCA Consulting log of the cores are provided in Appendix J.

6.1.2.3 BH02, BH03 and BH04 installations

The installation details are:

1.	Hole diameter	175-225 mm
2.	Casing diameter	50 mm
3.	Casing material	Class 18 PVC
4.	Screen type	Machine slotted, 0.4 mm aperture, 5 mm spacing
5.	Screen length	45 m (BH2: 100 m bgl to 145 m bgl) 18 m (BH3: 102 m bgl to 120 m bgl) 18 m (BH4: 142 m bgl to 160 m bgl)
6.	Filter pack	1.5 mm grade washed sand
7.	Sump	Nil
8.	Caps	PVC endcap and Jcap
9.	Seal / Seal placement	Bentonite pellets/ 2 m minimum above filter pack Cement grout mixed with 4% to 7% bentonite powder from bentonite seal to surface
10.	Completion	Pre-cast galvanised steel monument

Bores BH02 and BH03 were drilled without water. Bore BH04 was drilled with water due to high dust generation. The Valenza Engineering logs are provided in Appendix J.

6.1.2.4 Survey of observation bores and screened intervals

Table 6-2 lists the top of casing and ground surface surveyed levels and screened interval. All bores are screened to their base.

Table 6-2: Groundwater observation bores - depth, surveyed levels and screened interval

Bore	Surveyed levels (m AHD)		Screened interval (m bgl)	
	TOC	Ground surface	Top	Bottom
BH01	203.03	202.15	138.0	150.0
BH02	203.32	202.53	100.0	145.0
BH03	172.13	171.28	102.0	120.0
BH04	220.55	219.99	142.0	160.0

The survey was undertaken by Landair Surveys. All bores are screened within the You Yang Granites.

The driller of observation bore BH01 advised that water strikes occurred at fractures however due to the drilling method the precise location of these fractures could not be determined. Due to the down hole hammer drilling method, the water strikes at observation bores BH02, BH03 and BH04 could not be identified.

6.1.3 Development

Development of all observation bores was undertaken by the driller under the supervision of a Valenza Engineering field hydrogeologist. Development of all bores occurred using a HDPE pipe with air lifting and surging to remove sediment and fines disturbed during drilling and construction of the boreholes.

Prior to the development of observation bore BH01 drilling mud was present in the casing up to about 9 m from ground level. The observation bore BH01 development objective was to remove drilling mud as well as sediment and fines. Its development took place on the 21 April 2021 over 5 hours. The elimination of all drilling fluid from this bore was not possible due to the absence of a filter pack, limited groundwater inflow and the slow recovery.

Observation bore BH02 was developed with sufficient water to maintain a modest flow at the surface.

Observation bores BH03 and BH04 were developed without water.

6.1.4 Hydraulic conductivity tests

All four observation bores are screened across the You Yang granites where the hydraulic conductivity is mainly associated with the fractures and weathered zones.

Falling head and rising head hydraulic tests of the screened intervals were undertaken at all observation bores after development. The observation bore BH01 tests entailed water level monitoring during post-development recovery. Observation bore BH02, BH03 and BH04 tests entailed water level monitoring after the introduction of a slug (falling head test) and then after removal of a slug (rising head test). The slugs have a 1.73 L volume (0.88 m of a 50 mm diameter casing). No water was added during these tests.

The hydraulic conductivities and test completion dates are presented in Table 6-3. The test plots with solutions are provided in Appendix K.

Table 6-3: Groundwater observation bore hydraulic test results

Parameter	BH01	BH02	BH03	BH04
- *McElwee-Zenner*	*NA*	*0.70 - 1.36*10^{-8}*	*0.04 – 0.06*10^{-8}*	*0.22 - 1.58*10^{-9}*
- *Bouwer-Rice*	*NA*	*0.58 - 1.41*10^{-8}*	*0.02 – 0.04*10^{-8}*	*0.13 - 1.03*10^{-9}*
- *Cooper-Bredehoeft-Papadopulos*	*1.23*10^{-3}*	*NA*	*NA*	*NA*
- *Butler-Zhan*	*1.23*10^{-3}*	*NA*	*NA*	*NA*
- *Barker-Black*	*0.86*10^{-3}*	*NA*	*NA*	*NA*
- *KGS Model*	*1.28*10^{-3}*	*0.01- 6.45*10^{-7}*	*0.02 – 0.03*10^{-8}*	*0.21- 1.04*10^{-9}*
Mean hydraulic conductivity (m/day)	1.4*10^{-3}	10^{-8}	*0.04*10^{-8}*	0.08*10^{-8}
Test completion date	7/07/2021	23/02/23	23/02/23	23/02/23

The median mean hydraulic conductivity is 10^{-8} m/s. This is at the low end of the range for fractured igneous rocks [The BH04 observation bore results are not included as Valenza (2023) suggests a low reliability].

6.1.5 Water levels

The groundwater observation bore depths at which wet cuttings were observed during drilling, gauged levels, and projected stabilised levels are presented in Table 6-4.

Table 6-4: Gauged levels at groundwater observation bores

Date	BH01 (203.03 m TOC)		BH02 (203.32 m TOC)		BH03 (172.13 m TOC)		BH04 (220.55 m TOC)	
	Depth bTOC (m)	Level (m AHD)	Depth bTOC (m)	Level (m AHD)	Depth bTOC (m)	Level (m AHD)	Depth bTOC (m)	Level (m AHD)
Wet cuttings during drilling	NA	NA	68.0(4)	134.5	78.0(4)	93.3	-	-
21 April 2021	82.95(1)	120.08(1)	NA	NA	NA	NA	NA	NA
27 April 2021	64.66	138.37	NA	NA	NA	NA	NA	NA
5 August 2021	19.51	183.52	NA	NA	NA	NA	NA	NA
24 August 2021	18.09	184.94	NA	NA	NA	NA	NA	NA
24 November 2022	12.60	190.43	NA	NA	NA	NA	NA	NA
14 February 2023(2)	NA	NA	16.71	186.61	9.11	163.03	23.67	196.88
22 February 2023(3)	12.41	190.63	16.35	186.97	8.47	163.67	20.71	199.84
22 March 2023	12.38	190.65	15.63	187.69	7.43	164.70	16.50	204.05
26 April 2023	12.24	190.79	14.24	188.08	6.87	165.26	13.79	206.77
Projected stabilised level	-	190.8	13.4	188.9	6.4	165.7	12.5	208.1
Installation completion	10 Jan 2021		21 Dec 2022		16 Jan 2023		16 Jan 2023	

(1) Following development

(2) Gauged prior to hydraulic conductivity testing

(3) Gauged prior to taking of field parameters

(4) m below ground level

The cause of the rise in gauged levels at the groundwater observation bores shown in Table 6-4 is considered to be due to a very low hydraulic conductivity and dewatering during bore development.

The projected stabilised levels presented in Table 6 4 have been determined based upon the continuation of the level trends at each bore.

6.1.5.1 Observed levels

Observation bores BH01 and BH02 are located at similar surface levels to the south and south-west of the quarry.

The material description in the BH01 log (Appendix J) is of highly weathered granite to a depth of 32.5 m, and a water level of 64.66 mbTOC (138.37m AHD) on 27 April 2021. This was over 1 month after the bore was completed. The water level has stabilised at about 190.7 m AHD.

The material description in the BH02 log (Appendix J) is of dry granite to a depth of about 34 m bgl, moist granite from 34 m bgl to 65 m bgL and wet granite from 65 m bgl to the base of hole at 145.0 m bgl. A water level of 16.71 mbTOC (186.61 m AHD) was recorded on 14 February 2023. This was almost 2 months after the bore was completed. This level increased to 188.1 m AHD on 26 April 2023.

Observation bore BH03 is located to the north-west of the quarry and at the lowest elevation of the four observation bore. The material description in the BH03 log (Appendix J) is of dry granite to a depth of about 35 m bgl and moist granite from 35 m bgl to the base of hole at 120 m bgl.

Observation bore BH04 is east of the existing quarry and at the highest elevation of the four observation bores. The material description in the log (Appendix J) is of dry granite to a depth of 160 m. The significant increase in gauged level shown in Table 6-4 is suspected to be due the bore's proximity to the ridge to the east which may be a groundwater divide, its location in a cleared area and the response to the significant rainfall events in October and November 2022.

6.2 Laboratory analysis

Sampling and analysis has been undertaken in accordance with the methods described in the Groundwater Management Plan (Appendix P).

6.2.1 Laboratory analysis sampling schedule

The sites and dates of sampling events for laboratory analysis by a NATA accredited laboratory are listed in Table 6-5.

Table 6-5: Sampling event dates

Monitoring site	Date			
	24 February 2021	**29 April 2021**	**5 August 2021**	**24 November 2022**
BH01	x	√	√	x
Dam 1	√	x	√	x
Dam 2	√	x	√	x
Quarry pit sump	√	x	√	√

Observation bores BH02, BH03 and BH04 have been sampled and analysed in the field.

6.2.2 Laboratory analysis analytical results

Table 6-6 summarises the NATA accredited laboratory results.

Table 6-6: Water quality laboratory results

Parameter	Sampling point								
	BH01		Dam 1		Dam 2		Pit Sump		
Date	29/04/21	5/08/21	24/02/21	5/08/21	24/02/21	5/08/21	24/02/21	5/08/21	24/11/22
pH (dimensionless)	8.34	8.12	9.14	8.88	9.26	9.35	8.21	7.89	8.04
TDS (mg/L)	1,350	5,520	990	951	15,100	12,200	2,080	1,620	826
turbidity (NTU)	NA	76.6	6.1	10.5	134	540	267	251	76
bicarbonate alkalinity as $CaCO_3$ (mg/L)	164	164	102	175	84	111	217	230	114
sulphate as SO_4 (mg/L)	108	100	119	114	8,350	6,500	147	237	101
chloride (mg/L)	646	3,170	379	377	1,900	1,640	513	621	271
calcium (mg/L)	75	481	14	18	619	486	21	48	17
magnesium (mg/L)	18	142	33	35	760	597	29	52	18
sodium (mg/L)	340	1,160	266	259	2,300	1,730	424	427	208
potassium (mg/L)	18	32	17	16	2,200	1,810	20	20	11
manganese (mg/L)	0.045	1.06	<0.001	0.002	0.191	0.078	0.093	0.177	0.006
iron (mg/L)	0.20	0.26	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
ammonia as N (mg/L)	0.96	1.35	0.09	0.004	0.10	0.10	1.56	1.99	0.21
nitrate as N (mg/L)	-	0.01	18.7	13.5	<0.01	<0.01	46.9	36.2	17.3
TKN as N (mg/L)	-	3.2	1.9	0.8	15.8	26.6	1.9	2.2	2.4
Total Nitrogen as N (mg/L)	-	3.4	21.1	14.4	15.8	26.6	50.7	39.2	20.0
Total Phosphorus as P(mg/L)	-	0.04	<0.01	0.01	2.81	4.16	0.08	0.04	0.32

The 29 April 2021 analysis of observation bore BH01 is likely to have been impacted by fluid introduced during drilling (see Section 6.1.3).

The 24 February and 5 August 2021 total N (as N) and total P (as P) concentrations at Dam 1, Dam 2 and the quarry pit sump are repeated in Table 6-7.

Table 6-7: 2021 total N and total P concentrations at Dam 1, Dam 2 and the quarry sump

Analyte	Dam 1	Dam 2	Quarry sump
Total N (as N) – mg/L	14.4 - 21.1	15.8 - 26.6	39.2 - 50.7
Total P (as P) – mg/L	<0.01 - 0.01	2.8 4.2	0.04 - 0.08

The total N concentrations at all of the above sites are above 10 mg/L suggesting an impact from a nitrogen rich source. As most total N reports as nitrate at Dam 1 and the quarry sump, nitrification has occurred. Nitrification has not occurred at Dam 2 as most total N reports as ammonia.

The total P concentrations at Dam 1 and the quarry pit sump are both low (less than 0.1 mg/L) indicating a low mobility of phosphorus in surface runoff. The total P concentration at Dam 2 of 2.8 mg/L to 4.2 mg/L is indicative of a nearby source.

6.2.3 Observation bores BH02, BH03 and BH04 field analysis

Table 6-8 presents the 22 February 2023 field water quality analysis at observation bores BH02, BH03 and BH04.

Table 6-8: 22 Feb 2023 field parameters

Bore	EC (mS/cm)	Turbidity (NTU)	TDS (mg/L)	pH	Redox (mV)	DO (mg/L)	Temperature (°C)
BH02	3.82	177	2,489	8.12	-123	1.42	18.26
BH03	5.82	251	3,854	10.77	-275	0.40	17.86
BH04	5.86	540	3,848	9.68	-479	0.37	18.39

6.3 Land to the east of current quarry - preliminary assessment

A preliminary assessment of the land to the east of the current quarry identified that fertiliser product had been stockpiled in this area [Senversa (2021) "*Preliminary Site Investigation Part of 250 Drysdale Road, Little River*"]. This land was subject to EPA licencing as described below.

6.3.1 Historical licencing

The historical EPA licencing is described below.

6.3.1.1 Issue of licence in 1982

EPA licence SW4238 was issued on 30 April 1982. It was transferred to Transwest Haulage Pty Ltd (Transwest) on 10 August 1984.

Selected conditions on this licence were:

Condition 1

> directly to an unnamed tributary of the Little River, Lara, via discharge via a 150 mm diameter PVC pipe, from the western boundary of Crown Allotment 7, Parish of Wurdi Youang, County of Grant, at a point denoted by the red cross in the attached plan.

This pipe appeared to be from Dam 1 to the unnamed tributary of the Little River. The Barro Group has advised that this pipe does not exist.

Condition 7 set limits of 80 grams/m^3 (mg/L) for suspended solids and 1,000 grams/m^3 (mg/L) for total dissolved solids (TDS) for discharges from the discharge point referred to in Condition 1.

Condition 10 (a) required quarterly monitoring (February, May, August and September.

6.3.1.2 Licence amendments

6.3.1.2.1 <u>26 August 2003</u>

The amended licence of 26 August 2003 included new Conditions 12 to 15 which are groundwater specific. Selected conditions on this amended licence are:

Condition 12

> The licence holder must maintain groundwater monitoring bores ("the Bores) in operation at the location shown on the attached plan showing bore locations at the site.

Condition 15

> Samples of water must be taken from the bores on at least once in every period of twelve months and be analysed or tested for
>
> a) pH, TDS,
>
> b) fluoride (as fluoride)
>
> c) phosphate (as phosphorus)
>
> d) sulphate (as sulphate).

6.3.1.2.2 <u>21 May 2010</u>

Amended EPA licence SW4238 of 21 May 2010 stated the premises is scheduled by the Regulations as C01 - Extractive Industry and Mining. The licence condition and obligations included:

> The licence holder operates a quarry. This licence allows for discharges of treated wastewater to a tributary of Little River.

General condition DW2 set limits of 80 mg/L for suspended solids and 1,000 mg/L for TDS for any discharge to '*tributary of Little River*'. This amended licence did not include specific groundwater conditions.

6.3.1.3 Licence surrender in 2013

The EPA advised that the licence had been surrendered on 6 February 2013. This followed the Barro Group advice to the EPA of 10 August 2012:

> We understand that the licence relates to an earlier fertiliser treatment activity undertaken by Incitec Pivot; an earlier owner of the property. It is also understood that this activity ceased in the early to mid-2000's.
>
> The Barro Group intends to use the site for sand and gravel quarrying activities only and does not foresee the need for any water discharge from the property.

6.3.1.4 EPA Victorian Landfill Register

The site is shown on the EPA Victorian Landfill Register as a landfill (10506) that closed in 2003. The waste accepted is shown on the register as prescribed industrial waste and chemical gypsum.

This closed landfill' is considered to be related to the fertiliser product stockpiling as described by Senversa (2021).

6.3.2 Scope of site investigations

A site investigation of this land was undertaken as part of the preliminary assessment. This involved sampling at depths up to 2.0 m at 10 locations and targeted sampling at a depth of 0.1 m from 5 locations. These investigations found silty sand, gravelly silty sand and gravel fill ranging from 0.0 m to 1.2 m in thickness overlying plastic lining.

Samples were analysed for metals, sulphur, major cations, ammonia, nitrite, nitrate, total kjeldahl nitrogen, total nitrogen, total and reactive phosphorus.

6.3.3 Preliminary assessment conclusions

The preliminary assessment found:

- soil concentrations were below the environmental values for commercial and industrial land use except for zinc at one central sampling location
- the zinc concentrations at the central sampling location (SB06) at depths of 0.5 m to 0.6 m and 1.0 m to 1.1 m were slightly above the Category D leachable concentration of 150 mg/L [EPA (2021) "*Waste Disposal Categories – Characteristics and Thresholds*", EPA Publication 1828.2] of March 2021. Table 7.2 of Senversa (2021) states

  > In the context of the localised zinc concentration, the future use of the site (quarry) the highly modified nature of the site, surface and shallow fill soils are not considered to pose an unacceptable risk.

- the fill is provisionally categorised as Category D
- measurable concentrations of nitrate, total nitrogen and phosphorous for which there are no reference values in the National Environmental Council (1999) "*National Environment Protection (Assessment of Site Contamination) Measure 1999*" as amended in 2013. were detected including:
  - nitrate ranging from 0.1 to 1,860 mg/kg.
  - total nitrogen ranging from 50 mg/kg to 19,300 mg/kg
  - phosphorus ranging from 72 mg/kg to 15,200 mg/kg
- the presence of elevated nitrogen and phosphorous in soil represents a risk to surface waters at the site and further investigation should be considered to assess the potential for site and downstream impact in surface waters.

6.3.4 Preliminary assessment recommendation

Senversa (2021) recommended:

> a Soil Management Plan (SMP) be developed to manage the impacted material identified on-site that will become surplus during future quarry extension works. This should include development of a suitable on-site management strategy. This would likely comprise segregation and stockpiling of the impacted soil within the site boundary and capping of the stockpile with a clay-rich soil cover and vegetation cover system to minimise rainwater infiltration.

7 Conceptual hydrogeological model

This conceptual hydrogeological model considers the climate, land use, topography, geology, hydrogeology, surface water, springs and groundwater dependent ecosystems.

7.1 Climate

7.1.1 Rainfall

The nearest meteorological stations to the expanded quarry are Little River (No. 087033) and Mount Rothwell (No. 087048). Little River (No. 087033) is about 9 km south-south-east at an elevation of 20 m AHD. Mount Rothwell (No. 087048) is 2 km north an elevation of 110 m AHD. [The ground surface at the expanded quarry ranges from 230 m AHD to 170 m AHD).

Rainfall has been recorded at Little River since 1906 and at Mount Rothwell since 1882. The annual rainfall recorded at both stations over the past 20 years is presented in Table 7-1.

Table 7-1: Annual rainfall at nearby meteorological stations

Year	Rainfall (mm)		Year	Rainfall (mm)	
	Little River	Mount Rothwell		Little River	Mount Rothwell
2003	399	377	2013	454	NA
2004	NA	503	2014	NA	NA
2005	496	NA	2015	374	392
2006	NA	NA	2016	500	459
2007	NA	NA	2017	501	NA
2008	319	307	2018	370	342
2009	400	389	2019	402	NA
2010	585	NA	2020	576	571
2011	701	703	2021	539	NA
2012	524	489	2022	693	NA

At the Little River station, the mean rainfall is 487 mm/yr and the 5 and 95 percentile rainfalls are 284 m/yr and 691 mm/yr respectively. At the Mount Rothwell station, the mean rainfall is 469 mm/yr and the 5 and 95 percentile rainfalls are 316 mm/yr and 663 mm/yr respectively. A mean annual rainfall of 478 mm/yr has been adopted.

Mean monthly rainfall is presented for Little River rather than Mount Rothwell as it has a more complete data set. The monthly rainfall for the Little River meteorological station is shown in Table 7-2 as means and for 2022.

Table 7-2: Monthly rainfall at the Little River meteorological station (No. 087033)

Month	Rainfall (mm)		Month	Rainfall (mm)	
	Mean	2022/23(1)		Mean	2022(1)
January	33.2	24.6	July	36.3	34.4
February	37.8	22.6	August	40.2	45.4
March	33.7	24.2	September	45.5	49.0
April	38.3	78.2	October	49.0	140.8

Month	Rainfall (mm)		Month	Rainfall (mm)	
	Mean	2022/23[1]		Mean	2022[1]
May	39.5	22.8	November	46.9	90.0
June	37.5	36.5	December	45.3	35.4
[1] *January to March are from 2023, and all other 2022/23 monthly rainfalls are from 2022.*					

The monthly rainfall recorded at the Little River meteorological station in October 2022 and November 2022 was significantly above the long term mean monthly rainfall. This is expected to result in increased infiltration in the recharge areas. The rainfall over the first three months of 2023 was below the long term mean.

7.1.2 Surface water evaporation

Class A pan evaporation has been recorded at the Laverton RAAF Airbase meteorological station (No. 087031) from 1976 to 1999. The mean daily Class A pan evaporation ranges from 1.6 mm in June to 7.5 mm in January and is 4.3 mm/day over a year (1 570 mm/yr).

The evaporation from surface water bodies is expected to be at least 60% of the Class A pan evaporation (942 mm/yr). This allows for a loss in evaporation associated with high salinity (which is not expected).

7.1.3 Net loss of water from Dam 1/sump

The mean net loss of water from Dam 1/sump is evaporation from surface water less rainfall. This is estimated to about 455 mm/yr (942 mm – 487 mm).

7.2 Land use – WA453

7.2.1 Historical

The site was a supplier of road and construction sands from the early 1970's.

The site including the quarry and the fertiliser storage facility to the east of the current quarry was operated by Pivot Limited (formerly the Phosphate Co-operative Company of Australia Limited) from May 1980 to April 2003.

Transwest Haulage Pty Ltd purchased the site from Pivot Limited in 2003 and continued the sand and gravel supply activity and also the supply of unwashed concrete sand to others.

Kalari Pty Ltd purchased the site from Transwest Haulage Pty Ltd in February 2007.

7.2.2 Current

Barro Group purchased the site from Kalari Pty Ltd in July 2012.

7.3 Land use – surrounding

Surrounding land uses are shown in the locality plan (Appendix A: Figure 1.2).

7.3.1 Farming

The land to the north is zoned Farming (FZ) under the City of Geelong Planning Scheme.

The dominant surrounding land use is farming. Other surrounding land uses are described below.

7.3.2 Commercial

Nearby commercial land uses are:

- Ford You Yangs vehicle proving ground – west-north-west
- rifle range and paint ball complex – north east
- extractive industry
  - WA437 - south-west (Davegale Pty Ltd)
  - WA188 - south of WA437 (Davegale Pty Ltd)
  - WA1532 – west (Bisinella)
  - WA006830 - west.

7.3.3 Regional Park

The You Yangs Regional Park is located to the south.

7.3.4 Dwellings

There are five dwellings within 2 km of WA453 to the east. The closest dwelling is approximately 1,000 m from the proposed extraction boundary.

7.4 Topography

There are two granite ridges within WA453 near the proposed extraction boundary (Appendix A: Figure 2.1).

The southern ridge runs in a north-easterly direction south of the current quarry pit. This ridge contains two hills, with the eastern most hill, at about 270 m AHD, being the highest point within WA453. Between these hills is a north-west trending valley. The valley falls from about 200 m AHD to 160 m AHD.

The northern ridge runs in a north-westerly direction along the north-western boundary of WA453. It is north of the proposed extraction boundary.

7.5 Geology

7.5.1 Regional

The outcropping geology, sourced from Geological Boundaries Vicmap 2014, is shown in Appendix A: Figure 7.1. The nomenclature, stratigraphic units and lithology are presented in Table 7-3.

Table 7-3: Stratigraphy

Nomenclature	Unit	Lithology
G277	You Yang granites (Devonian)	Intrusive granites
Qc4	Colluvium – granite derived (Holocene to Pliocene)	Hillwash; gravel, sand, silt
Neo	Newer Volcanics (Quaternary)	Basalt with minor scoria and ash
Nbb	Brighton Group (Tertiary)	Fluvial, gravel and silts
Nxr	Darley Gravel (Holocene to Pliocene)	Silt, sand, minor gravel
Nbb	Black Rock Sandstone (Holocene)	Gully alluvium, colluvium, gravel, sand and silt

The Devonian aged You Yang granites and its colluvium outcrop within WA453.

The You Yang granites form the You Yangs ranges.

The colluvium is granitic sand outwash found in gullies and low-lying areas. Its thickness generally increases down slope; however, the underlying granite profile can be irregular. It has been extracted over much of the current quarry.

The Newer Volcanics basalts do not outcrop in WA453. It is shown as outcropping to the north and west of the You Yang granites and its colluvium. The nearest eruption points are the low hills to the west at Anakie. There were also lava flows from Bald Hill and Spring Hill to the north.

The Darley Gravel and the Black Rock Sandstone outcrop to the west of WA453.

7.5.2 Local

The BCA Consulting log of BH01 shows granite from the surface as follows:

- highly weathered granite with clay to a depth of 32.5 m
- moderately with slightly weathered and fresh granite to a depth of 138.5 m
- fresh granite to 150.0 m (base of hole).

The colluvium has been extracted within the footprint of the current quarry by past quarrying and appears to be absent outside of this footprint and hence is restricted to the south-west corner of WA453. It is shown as absent in the logs of the four groundwater observation bores (Appendix J).

The colluvium is typically 70% to 80% sand, 15% to 25% fines and 5% gravel.

7.6 Aquifers

The main regional aquifers are the You Yang granites, colluvium, Newer Volcanics basalts, Black Rock sandstone and Darley Gravels.

The main local aquifer within WA453 is the You Yang granites. The Newer Volcanics basalts, Black Rock sandstone, Darley Gravels appear to be absent within WA453. The colluvium has been extracted within the footprint of the current quarry by past quarrying and appears to be absent outside this footprint.

A north-west to south-east hydrogeological section is shown in Appendix A: Figure 7.2.

7.7 Groundwater within You Yang granites

7.7.1 Aquifer parameters

The groundwater within the You Yang granite is considered to be confined as the water levels in the groundwater observation bores are above the screened interval.

The median mean hydraulic conductivity is 10^{-8} m/s. This is at the low end of hydraulic conductivities for fractured igneous rock aquifers.

7.7.2 Yield

The yield is estimated by Leonard (1992) to be less than 1.26 L/s.

7.7.3 Recharge

Recharge is considered to be controlled by topography, fractures and shear zones.

7.7.4 Depth to groundwater

7.7.4.1 Information

7.7.4.1.1 *VVG database*

The depth to groundwater is shown in the Visualising Victoria's groundwater (VVG) database as greater than 20 m from the surface.

7.7.4.1.2 *Senversa (2021) investigation bores*

The Senversa (2021) holes to refusal (assumed rock, up to 1.5 m deep) were dry in August 2021.

7.7.4.1.3 *Percussion holes*

Water intersections were recorded in 20 of the 56 percussion holes drilled to a depth of about 29 m in 2013 (see Section 5.2.2). These water intersections appear to be along a WNW trending shear zone along the axis of the valley through the extraction boundary. Water in these bores was intersected at 10 m to 15 m below ground surface which is below the granitic sands. While the volumes were generally low, a moderate flow was obtained from a depth of about 22 m at percussion hole YY13-31.

7.7.4.1.4 *Observation bores*

Table 6-4 shows the monitored water levels within the four groundwater observation bores.

Figure 7.2 is a schematic cross-section through quarry (prior to quarrying, current and projected at the completion of Stage 4).

7.7.4.2 Interpretation

The primary source of information on groundwater depths and levels is the four groundwater observation bores (Appendix J). Water levels from these bores is provided in Table 6-4. These bores are screened in the You Yang granites.

7.7.4.2.1 *Pre-quarry*

The pre-quarry mean potentiometric surface level of the four groundwater observation bores screened within the You Yang granites around the existing quarry surface is estimated to be 188.4 m AHD. These potentiometric surface at these bores is inferred to be outside of the quarry pit’s cone of depression (see Section 8.1.4).

The potentiometric surface level within the granite aquifer is inferred to be a subdued reflection of the topography. This suggests the pre-quarry potentiometric surface level of the You Yang granites below the existing pit was less than 188.4 m AHD.

7.7.4.2.2 *Current*

Most of the colluvium within the current pit has been extracted leaving the You Yang granites. The logs of groundwater observation bores BH01, BH02, BH03 and BH04 do not show colluvium This indicates the colluvium is absent and perched water is unlikely to occur.

The interpolated stabilised current groundwater level at the four groundwater observation bores is presented in Table 6-4. The mean interpolated level is 188.4 m AHD. The larger rise in the gauged levels at observation bore BH04 is inferred to be due to its proximity to the southern granite ridge to its east.

Further water level gauging at these observation bores would increase the level of confidence in this interpolation.

7.7.5 Flow direction

The inferred regional flow direction is towards Port Phillip Bay to the south-east. This flow direction has been disrupted by the outcrop of the You Yang granites.

The gauged levels at the four groundwater observation bores confirm local groundwater flow within the You Yang granites is to the north-west towards Little River. A cone of depression within this aquifer emanates from the quarry pit sump (Section 8.1.4).

7.7.6 Segment and environmental values

7.7.6.1 Groundwater segment

Part 5, Division 2 – Groundwater of the Environmental Reference Standard (ERS) characterises groundwater into segments defined by the background total dissolved solids (TDS). Environmental values apply to each segment. These are listed in Table 5.3 of the ERS and are repeated below in Table 7-4.

Table 7-4: Protected environmental values of groundwater segments

Environmental values	Segment (mg/L)						
	A1 (0-600)	A2 (601 - 1,200)	B (1,201 - 3,100)	C (3,101 - 5,400)	D (5,401 - 7,100)	E (7,101 - 10,000)	F (>10,000)
Water dependent ecosystems and species	√	√	√	√	√		
Potable water supply (desirable)	√						
Potable water supply (acceptable)		√					
Potable mineral water supply	√	√	√				
Agriculture & irrigation (irrigation)	√	√	√				
Agriculture & irrigation (stock watering)	√	√	√	√			
Industrial and commercial	√	√	√	√	√		
Water-based recreation (primary contact recreational)	√	√	√	√	√	√	√
Traditional Owner cultural values	√	√	√	√	√	√	√
Cultural and spiritual values	√	√	√	√	√	√	√
Buildings and structures	√	√	√	√	√	√	√
Geothermal properties	√	√	√	√	√	√	√

The salinity as total dissolved solids at groundwater observation bores BH01 to BH04 ranges from 2,489 mg/L to 5,520 mg/L and has an arithmetic mean of 3,928 mg/L. [The analysis of BH01 of 29 April 2021 is not included as this sample is likely to have been influenced by fluid introduced during drilling]. This places the background groundwater within Segment B to Segment D based upon individual measurements and Segment C based upon the arithmetic mean.

7.7.7 Nearby groundwater bores

Information on groundwater users within 5 km of WA453 has been sourced from a search of the WMIS for bores. The search identified 38 bores.

The location of these bores are shown in:

- Figure 5.1 – Bores with consumptive uses
- Figure 5.2 – Stock and domestic bores
- Figure 5.3 – Other (observation and dryland salinity) bores

7.7.7.1 Consumptive use bores

The bores with take and use licences are:

- stock, domestic & commercial WRK046909
- irrigation WRK040659
- industrial WRK081946, WRK031865, WRK039056, WRK081920

In this report bores with take and use licences are referred to as consumptive uses. They include bore WRK046909 as it has a commercial use as well as a stock and domestic use.

Bore WRK046909 is about 5 km to the north, and bore WRK040659, an irrigation bore, is about 4 km to the east of WA453.

Industrial bore WRK081946, the quarry pit sump within WA453, accesses groundwater from the You Yang granites.

Summary details of the three other industrial bores are presented in Table 7-5.

Table 7-5: Off-site licensed bores with consumption uses

Bore ID	Old Bore No	Depth	Licence No.	Licensed Volume	Yield (l/s)	Screened Interval (m)	SWL (m)
WRK039056	75053	83	BEE025488	50	7.0	65-70	50
WRK031865	105540	116	BEE022192	14	0.5	96-116	96
WRK081920		110	-	-		Unknown	

Bore WRK039056 appears to be within WA1532 about 2.4 km to the south-west and immediately west of a southerly flowing watercourse. The log of this bore is presented in Appendix E. It is also referred to as bore PB#1 and was drilled in 1986. It was gamma logged and physically logged by a geologist (see Appendix F).

This bore intersected clayey sands and gravels up to a depth of 43 m. Clean sands and granitic gravels were found between 43 m to 85 m below ground surface. These coarser sediments are not found within the proposed extension area. The bore was constructed with 200 mm diameter PVC casing with stainless steel screens from 62 m to 65 m and 70 m to 74 m. The bore is understood to have collapsed. The yield was 7 L/s and the depth to water is listed as 50 m below ground.

Bores WRK081920 and WRK031865 are about 1.9 km south-south-west of WA453. They appear to be within WA1988.

7.7.7.2 Stock and/or domestic bores

There are 21 stock and/or domestic bores within 5 km and at greater distances than 2 km from WA453 with the exception of 105529 and 105535. Bore 105529 is near the northern boundary of WA453. The drillers log for this 37.5 m deep bore is shown in Appendix G. The Barro Group has not witnessed this bore. Bore 105535 is south-west of WA453 and appears to be located in WA437. It is 25 m deep and is screened across granites.

The depth, yield and static water level of two stock and domestic bores screened in the Black Rock Sandstone and Darley Gravels to the west-south-west of WA453 are presented in Table 7-6.

Table 7-6: Bore depth, yield & static water levels of two stock and domestic bores

Bore	Use	Bore depth (m bgl)	Yield (L/s)	Depth to static water level (m bgl)
75047	Stock & domestic	66.6	0.3	58.7
75048	Stock & domestic	48.8	0.4	42.2

The logs of these bores are presented in Appendix E.

7.7.7.3 Other bores

The other (observation and dryland salinity) bores, with numbers, are:

- unknown 5
- dryland salinity observation 2
- observation (within property) 4

7.7.8 Groundwater management unit

WA453 is within an unincorporated groundwater management unit.

7.8 Surface water

A water management map for Stage 2 is shown in Appendix A: Figure 4.1

The area within the proposed extraction boundary falls towards Little River. Little River is within the Port Phillip and Westernport Catchment Management Authority area. WA453 is also within the Hovells Creek catchment which is within the Corangamite Catchment Management Authority area.

7.8.1 Regional

7.8.1.1 Little River

The former drainage line has a confluence with Sandy Creek, an easterly flowing tributary of the Little River located about 4 km to the north of Dam 1. Little River flows south-easterly and then in a southerly direction towards Port Phillip Bay below its confluence with Sandy Creek.

7.8.1.1.1 <u>Values and objectives</u>

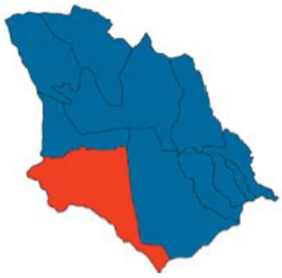
The *Port Philip and Westernport Healthy Waterways Strategy 2018-28* identifies Little River as having the values and objectives shown in Table 7-7.

Table 7-7: Little River values and objectives

Value Type	Value
Regional importance:	Moderate
Management objective:	Improve condition and enhance social values
Current social value:	High
Target social value:	High
Current conditions:	Moderate

Target conditions:	Moderate

The conditions of the river are shown in Table 7-8.



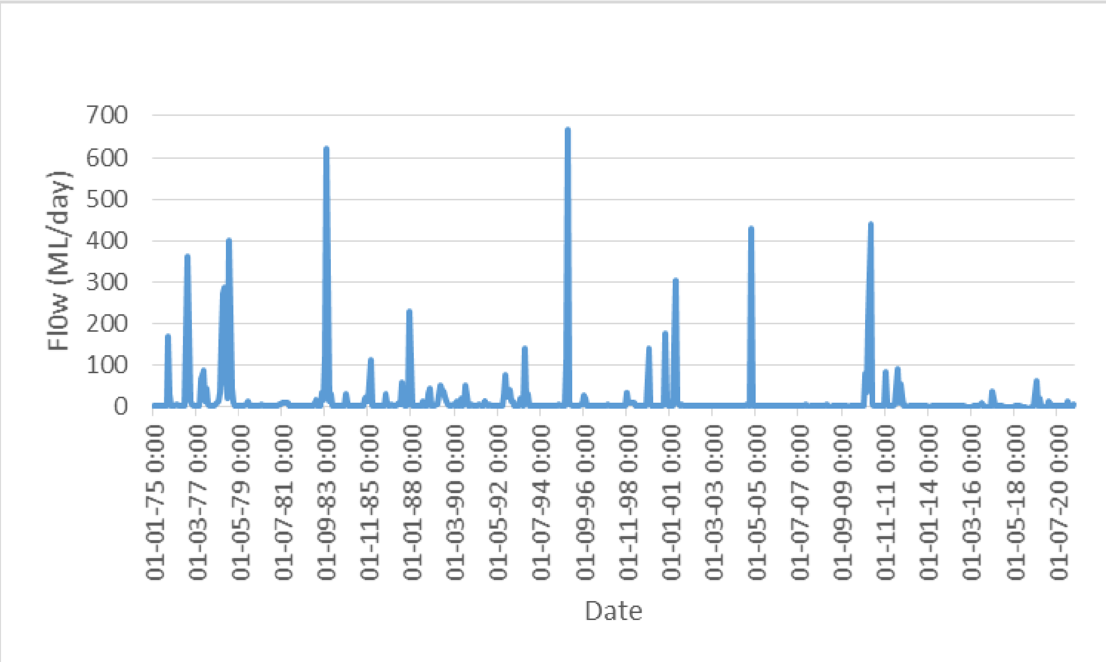
	Water quality	Aquatic life	Habitat & stability	Vegetation	Flow
Excellent					●
Good	●	●		●	
Moderate				●	
Poor			●		
Very poor					

Table 7-8: Little River conditions

The Little River estuary has high environmental values as it flows through an internationally recognised wetland and migratory bird habitat. The major threats are changes to water flow, stock access and expansion of both Werribee and Little River townships.

7.8.1.1.2 Flow

Flows at Little River gauging station 232200 from 1975 to 2021 are shown in Plot 7.1.



Plot 7-1: Average monthly flows in the Little River - 1975 to 2021

The Little River average flow ranges from 4 ML/day in March to 57 ML/day in October.

7.8.1.2 Hovells Creek

Hovells Creek forms part of the Moorabool River Basin and flows in a southward direction from the You Yangs to Limeburners Bay, near Geelong. The south-west portion of the WA453 drains into Hovells Creek via south-easterly flowing tributaries.

The values and threats are listed in Table 7-9.

Table 7-9: Hovells Creek values (Corangamite Waterway Strategy 2014-2022)

Value Type	Description
Key values	Rare and threatened species Bird and amphibian species Recreation. Including picnicking, walking tracks and boating
Key threats	Urban expansion Recreational us Water quality Algal bloom Degraded riparian vegetation Livestock access

Several ephemeral tributary streams flow into Hovells Creek.

7.8.2 Local

7.9 Springs

Springs have not been identified.

7.10 Groundwater dependent ecosystems

The Bureau of Meteorology's Groundwater Dependent Ecosystems (GDE) Atlas was interrogated in Senversa (2021) and as part of this assessment in 2023 to identify aquatic and terrestrial GDE's within the vicinity of the site. Aquatic and terrestrial GDEs at and near WA453 as sourced from the Bureau of Meteorology's GDE Atlas are shown in Appendix M.

7.10.1 Aquatic GDE

Aquatic GDEs identify the potential for groundwater interaction for rivers, springs, and wetland ecosystems.

High potential aquatic GDE (national assessment) identified are:

- Little River
- two swamps.

These high potential aquatic GDEs (national assessment) are over 3 km from WA453.

An unclassified potential GDE (national assessment) is shown about 1,300 m south-east of the quarry pit floor at closure and 265 m south of WA453. This potential GDE is within the You Yang Regional Park. The regional geology map (Appendix A: Figure 7.1) indicates this area has been underlain by colluvium.

The site photo plan (Figure 2.1) indicates this area is:

- south of the southern ridge which is south of the final stage of the proposed quarry expansion
- below 140 m AHD.

Appendix B of Senversa (2021) includes historical aerial photos and topographic maps which indicates that this area was an active quarry.

The above evidence indicates that the colluvium has been quarried and hence this area is unlikely to be a GDE.

7.10.2Terrestrial GDE

Terrestrial GDEs are vegetation ecosystems that rely on the subsurface presence of groundwater.

Moderate potential GDEs have been identified outside of the current quarry activity areas from a national assessment [see Appendix M for the extent shown in Senversa (2021)]. Two small areas of high potential GDE has been identified about 1 km to the north on Sandy Creek tributaries.

8 Prediction of operating and post closure levels

The quarry pit receives inflows from:

- groundwater
- within pit runoff
- natural catchment runoff.
- inflow from Dam 1 during very wet periods.

The quarry pit loses water via pumping from Dam 1/sump and excess evaporation (evaporation less rainfall) from Dam 1/sump.

These inflows and losses (outflows) change over time.

This section estimates/predicts:

- quarry pit inflows
- quarry pit outflows
- quarry pit water levels
- potentiometric surface cone of depression

for the existing, end of quarrying (end of Stage 4) and post closure.

Figure 7.2 is a schematic north-west to south-east cross-section through the quarry (prior to quarrying, current and projected at the completion of quarrying (Stage 4).

These estimates/predictions are based upon an interpretation of the available data and modelling. Refinement of these estimates may be undertaken once long term data becomes available through the groundwater management plan (Appendix P).

8.1 Current

Current is as of June 2023.

8.1.1 Inflows

The quarry pit receives groundwater, within pit runoff, natural catchment runoff and inflows from Dam 1 during very wet periods

8.1.1.1 Groundwater

8.1.1.1.1 Estimate

The current groundwater seepage into the quarry pit is estimated to be 20.7 ML/year. This estimate is based on the method set out below.

8.1.1.1.2 Method

To estimate the groundwater seepage collected in the quarry pit sump, a period was selected in which the catchment rainfall was low and hence the diversion of sump water to Dam 1 would be negligible. The selected period is 21April 2021 to 25 June 2021. At this time the water level within the pit was about 131 m AHD.

During this period the water cart was filled from the quarry pit sump on 237 occasions. The water cart was filled in week days only. Based upon the water cart capacity of 30 kL, about 108 kL/day was pumped from the quarry pit sump.

A spreadsheet with daily water cart trips and rainfall was established. This spreadsheet was used to estimate the groundwater sourced volumes. As an example if there was no rainfall on the day and preceding days all water cart trips were allocated to groundwater.

48.1% of the water pumped to the water cart is estimated to be groundwater seepage sourced. This is equivalent to 18.9 ML/year. This estimate is considered to be an upper estimate as pit has steep benched batters without vegetation which suggests the estimate of the internal runoff contribution may be low.

As the current water level within the quarry pit is 125.7 m AHD, and the mean projected stabilised groundwater level outside of the cone of depression is estimated to be 188.4 m AHD (the interpolated mean potentiometric level of the four groundwater observation bores surrounding the current pit and screened within the You Yang granites), the current groundwater seepage into the pit is estimated to be 20.7 ML/year [18.9 * (188.4 - 125.7)/(188.4 - 131.0)].

8.1.1.2 Within quarry pit runoff

8.1.1.2.1 *Estimate*

The mean current within quarry pit runoff is estimated to range between 3.5 ML/yr and 17.6 ML/yr. This estimate is based on the method set out below.

8.1.1.2.2 *Method*

HARC (Appendix N) estimated the quarry pit impervious to range between 0.1 and 0.5. The pit area at the surface is about 7.4 ha and the mean annual rainfall is 478 mm/yr.

8.1.1.3 Natural catchment runoff

The quarry pit receives stormwater inflows from the two drainage lines in the south-east and from the plant and stockpile area to the south.

8.1.1.3.1 *Estimate*

The mean current natural catchment runoff is estimated to about 5 ML/yr. This estimate is based on the method set out below.

8.1.1.3.2 *Method*

HARC (Appendix N) estimated the mean natural catchment runoff to be about 3 ML based upon a catchment areas of 12 ha. The current natural catchment areas is estimated to be 20 ha.

8.1.2 Outflows

The outflows are the pumped volumes from the quarry pit sump.

8.1.2.1 Estimate

The mean of the current total outflows are estimated to be 29.2 ML/yr to 43.3 ML/yr. This estimate is based on the method set out below.

8.1.2.2 Method

Total of groundwater, within pit runoff and natural catchment runoff. As the sump area is small no allowance is included for net evaporation.

8.1.3 Pit water level

The current pit water level is 125.7 m AHD. This is 62.7 m below the interpolated stabilised groundwater level of 188.4 m AHD (the interpolated mean potentiometric level of the four groundwater observation bores surrounding the current pit and screened within the You Yang granites).

8.1.4 Cone of depression

8.1.4.1 Estimate

The current cone of depression from the quarry pit floor is estimated to be less than 468 m (see Figure 7.2) and possibly less than 270 m. This is consistent with the low hydraulic conductivity. This estimate is based on the method set out below.

8.1.4.2 Method

Groundwater observation bore BH01 was gauged for level prior to and after the lowering of the pit floor to 118.5 m AHD. It is about 468 m from the current quarry pit floor (Table 6-1). As the water level in this bore did not fall during the lowering of the pit floor, this bore is considered to be beyond the cone of depression.

Groundwater observation bore BH03 is about 270 m from the current quarry pit floor. The potentiometric surface level at this bore of 165.26 m AHD on 26 April 2023. As the water level in this bore is high post lowering of the pit floor this bore is likely to be beyond the cone of depression.

8.2 At the completion of quarrying

Quarrying will be completed at the end of Stage 4 when the floor of the quarry is at 60 m AHD and the base of the sump is at 55 m AHD. The within quarry pit groundwater level is at 60 m AHD to maintain a dry floor level.

8.2.1 Inflows

The quarry pit will receive groundwater, within pit runoff and natural catchment runoff.

8.2.1.1 Groundwater

8.2.1.1.1 Estimate

The groundwater inflow is estimated to be 42.4 ML/year. This estimate is based on the method set out below.

8.2.1.1.2 Method

The groundwater inflows will increase as the quarry pit floor level decreases. The extent of the increase is dependent upon:

- floor level
- floor area
- vertical profile of granite
- hydraulic conductivity of granite.

A linear increase in inflows with depth is assumed. This is based upon a hydraulic conductivity reduction with depth balancing out non-linear increases.

The groundwater inflow is estimated to be 42.4 ML/year [20.7 (188.4 - 60)/(188.4 - 125.7)] at the Stage 4 floor level of 60 m AHD. This is slightly less than the BEE072352 groundwater take and use entitlement of 44 ML/year.

8.2.1.2 Within quarry pit runoff

8.2.1.2.1 Estimate

The mean within quarry pit runoff at the completion of Stage 4 is estimated to range between 38.6 ML/yr and 124.9 ML/yr. This estimate is based on the method set out below.

8.2.1.2.2 Method

The quarry pit runoff increases as the pit area expands.

HARC (Appendix N) estimated the quarry pit impervious to range between 0.1 and 0.5. The model (Appendix N) estimates the mean annual quarry pit runoff.

8.2.1.3 Natural catchment runoff

8.2.1.3.1 Estimate

The surface water inflow at the completion of Stage 4 is estimated by HARC (Appendix N) to be about 3 ML/year (Appendix N). This estimate is based on the method set out below.

8.2.1.3.2 Method

At the completion of Stage 4 the quarry pit:

- will receive mean natural stormwater runoff of about 3 ML/yr (HARC; Appendix N) from the north-eastern catchment area of 12 ha immediately above the terminal crest (HARC; Appendix N).
- will not receive natural stormwater runoff from the current two stormwater drainage lines from the south-east as the quarry expansion will incorporate these drainage lines.

8.2.2 Outflows

The outflows will be the pumped volumes from the quarry pit sump.

8.2.2.1 Estimate

The mean of the current total outflows are estimated to be 84 ML/yr to 173 ML/yr. This estimate is based on the method set out below.

8.2.2.2 Method

Total of groundwater, within pit runoff and natural catchment runoff. As the sump area is small no allowance is included for net evaporation.

8.2.3 Quarry pit level

The pit water level at the completion of Stage 4 will be 60 m AHD. This is 128.4 m below the estimated stabilised groundwater level of 188.4 m AHD (The interpolated mean potentiometric level of the four groundwater observation bores surrounding the current pit and screened within the You Yang granites).

8.2.4 Cone of depression

8.2.4.1 Estimate

The cone of depression from the quarry pit floor is estimated to be less than 958 m (see Figure 7.2) and possibly less than 553 m. This estimate is based on the method set out below.

8.2.4.2 Method

This is calculated on a pro-rata basis from the current quarry where the cone of depression is estimated to be less than 468 m from the pit floor for a drawdown of 62.7 m.

The estimate of less than 958 m is 468*(128.4/62.7). The estimate of less than 553 m is 270*(128.4/62.7).

This cone of depression is unlikely to extend beyond 958 m due to the influence of recharge.

8.3 Post closure

8.3.1 Inflows and outflows

The inflows will diminish from the maximum described in Section 8.2.2.1 as the quarry pit water level rises due to a reducing groundwater gradient and a reduced in pit catchment area as the ponded area increases.

The outflows will increase as the quarry pit water level rises due to an increase in the ponded area and hence an increase in the net evaporation from the ponded water.

8.3.2 Quarry pit static level

8.3.2.1 Estimate

The estimated post closure quarry pit equilibrium water levels for a range of scenarios is presented in Table 8-1 together with the estimated years to reach the equilibrium level.

Table 8-1: Estimated post closure quarry pit equilibrium water levels

Water balance output	Net evaporation					
	4.55 ML/ha		3.00 ML/ha		6.00 ML/ha	
	Imp 0.5	Imp 0.1	Imp 0.5	Imp 0.1	Imp 0.5	Imp 0.1
Equilibrium level (m AHD)	118	77	146	99	101	72
Years to reach equilibrium level	>187	>185	>396	>263	>133	>30

The best estimate of the equilibrium level is 118 m AHD. This is based upon a net evaporation rate of 4.55 ML/ha and an imperviousness of 0.5. The upper equilibrium level estimate is 146 m AHD which is below the lowest crest level of the final pit (i.e. 165 m AHD).

This estimate is based on the method set out below.

8.3.2.2 Method

The water level within the quarry pit will rise (recover) after quarrying ceases and pumping from the quarry pit sump is discontinued. The equilibrium (static water) level to which the water will rise to will be influenced by:

- pre-quarry potentiometric surface level at the pit
- the in-pit runoff

- natural surface water runoff of about 3 ML/yr from the north-eastern catchment
- net evaporation from the water within the pit (Dam 1/sump).

A water balance model has been developed to estimate the post closure water equilibrium level within the quarry pit and the time taken to reach the equilibrium level from the time of quarry closure. This model assumes no post closure extraction of water.

Imperviousness's of 0.1 and 0.5 have been used as per the HARC surface water study (Appendix N) and net evaporation rates of 3.00, 4.55 and 6.00 ML/ha have been applied. An imperviousness of 0.1 occurs when the rainfall losses within the catchment are high.

The net evaporation rate of 4.55 ML/ha is the mean estimate described in Section 7.1.3. The net evaporation rates of 3.00 ML/ha and 6.00 ML/ha are upper and lower bounds provided as part of the sensitivity study. The results of the post closure water balance study are presented in Appendix O.

8.3.3 Cone of depression

The cone of depression will diminish as recovery occurs. There will be a permanent localised cone of depression once the water level stabilises. This will be considerably less than the current cone of depression from the quarry pit floor which is estimated to be less than 468 m and possibly less than 270 m (see Section 8.1.4).

9 Impact assessment

This impact assessment is of the quarry as described in Section 4. It assesses the following impacts during operations and post closure:

- drawdown
  - interference at other bores
  - aquatic groundwater dependent ecosystems (GDEs)
    - Sandy Creek and Little River
    - former quarry to south-east
    - two swaps to north
  - terrestrial groundwater dependent ecosystems (GDEs)
  - springs
- groundwater quality
- soil.

9.1 Drawdown

The worst case for drawdown impacts is towards the end of quarrying when the extent of the cone of depression is greatest. The current cone of depression is discussed in Sections 8.1.4.

9.1.1 Bore interference

Take and use licenced (consumptive use) and stock and domestic bores are shown in figures 5.1 and 5.2 respectively. The nearest of these bores outside of the Work Authority is about 2 km from the quarry pit (see Section 7.7.6.1).

Adverse bore interference effects on these bores is not anticipated as they are beyond the estimated maximum cone of depression of 958 m from the quarry pit floor.

9.1.2 Aquatic groundwater dependent ecosystems

The aquatic groundwater dependent ecosystems (GDEs) within the vicinity of WA453 are shown in Appendix M.

9.1.2.1 Sandy Creek and Little River

Sandy Creek and Little River are shown as High Potential aquatic GDEs (national assessment).

Adverse bore interference effects on these GDEs are not anticipated as these streams are beyond the estimated maximum cone of depression of 958 m from the quarry pit floor.

9.1.2.2 Former quarry to south-east

The former quarry to the south-east is shown as an unclassified potential aquatic GDE. It is about 1,300 m south east of the quarry pit floor at closure. Further details are provided in Section 7.10.1.

Adverse bore interference effects on this GDE are not anticipated as this former quarry is beyond the estimated maximum cone of depression of 958 m from the quarry pit floor and the colluvium is likely to have has been removed hence this former quarry is unlikely to be a GDE (see Section 7.10.1).

9.1.2.3 Swamps to north

The two swamps to the north of the quarry are high potential aquatic GDEs (national assessment). They are over 3 km from WA453 and outside the estimated maximum cone of depression.

9.1.3 Terrestrial groundwater dependent ecosystems

Moderate potential terrestrial groundwater dependent ecosystems (national assessment) have been identified outside of the current quarry activity areas and two small area of high potential GDE has been identified about 1 km to the north of WA453 on Sandy Creek tributaries.

The moderate potential terrestrial GDEs (national assessment) within the site are unlikely to be impacted by this work plan variation as the potentiometric surface is below the ground surface at groundwater observation bore BH03 and hence is expected to be below the vegetation's root zone.

9.2 Water quality

9.2.1 During operations

Groundwater quality during operations is unlikely to be adversely impacted based upon the controls listed in Section 4.8 and the proposed management of the former fertiliser stockpile site to the east of the current quarry. Fill at the former fertiliser stockpile will be managed during operations such that stormwater within WA453 will meet the environmental values for surface water. The method by which this will be achieved is described in Section 4.9.

9.2.2 Post closure

The quarry pit's post closure salinity will be influenced by the relative inflow contributions and the net evaporation. The stabilised salinity will be above the mean salinity of the inflows as the stabilised level will occur when inflows are balanced by the net loss of water from the pit due to excess evaporation.

Assuming a runoff salinity of 1,000 mg/L and a mean groundwater salinity of 3,928 mg/L, the quarry pit's post closure salinity when the equilibrium level is reached is estimated to range between at least 1,400 mg/L and 2,200 mg/L. The post closure quarry pit salinity is expected to rise by 60% to 80% within twenty years after the equilibrium level has been reached due to excess evaporation. The rate of salinity increase will diminish thereafter.

9.3 Springs

No springs have been observed on-site or off-site,

If they are present they are anticipated to be on low lying land beyond the cone of depression both during operations and post closure.

9.4 Soil

No soil impact is anticipated as substantial irrigation is not proposed during operations and post closure.

10 Groundwater management plan

A stand-alone Groundwater Management Plan is provided in Appendix P.

11 References

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