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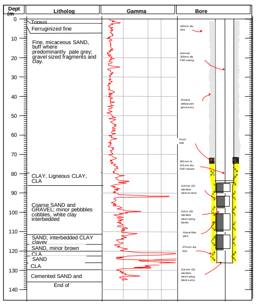

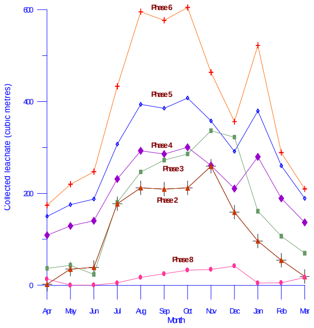

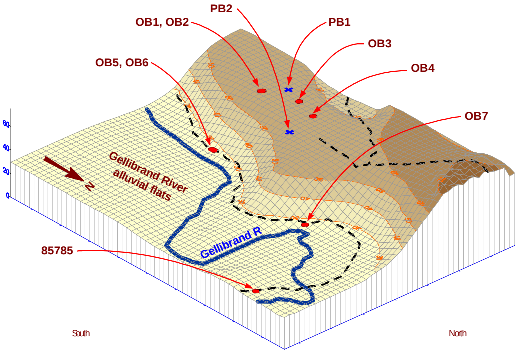

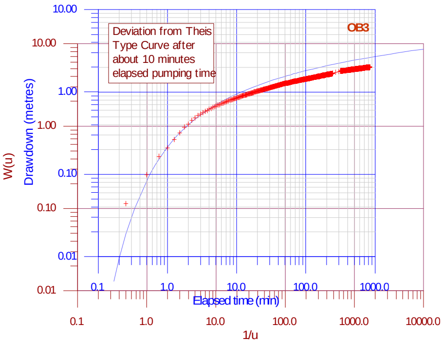

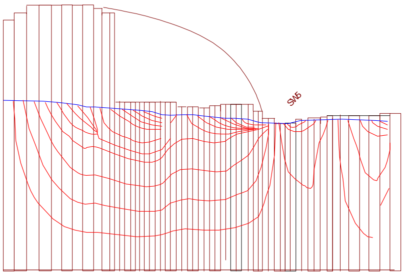

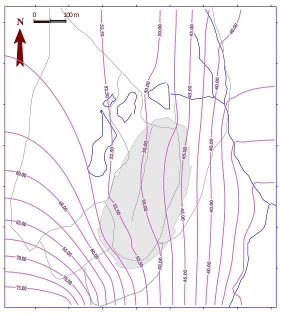

HYDROGEOLOGICAL ASSESSMENT, PROPOSED EXTENSION, YARRA VALLEY HARD ROCK QUARRY, McMAHON ROAD, LAUNCHING PLACE

February 2024

Ref. No.: GW-24/001

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1.0 INTRODUCTION

JOHN LEONARD CONSULTING SERVICES Pty Ltd (JLCS) was engaged by Dandy Premix Quarries Pty Ltd, (DPQ) trading as Yarra Valley Quarries (YVQ), to undertake a Hydrogeological Assessment (HA) of their hard rock quarry at McMahons Road, Launching Place (Figures 1.1, 1.2 and 1.3). The YVQ Launching Place quarry is operated under Extractive Industries Work Authority 375 (WA375) issued by the Department of Jobs, Precincts and Regions (DJPR). DPQ are seeking a Work Plan Variation (WPV) to expand the quarry into adjoining land owned by DPQ.

1.1 BACKGROUND

WA375 is quarried for fresh (unweathered) hornfels. Quarrying has occurred on the site for over 70 years. Prior to hard rock extraction and crushing, the site was used for timber production and hill gravel extraction. The current operation was established in 1987 as Warradoo Quarry, subsequently undergoing an ownership and name change in 1993 to YVQ. A further change of ownership occurred in 2007 when DPQ acquired the business.

WA375 embraces an area of about 130 ha and is located about 55 km ENE of the Melbourne CBD (Figure l.l) about 3 km northwest on Launching Place and 5 km northeast of Woori Yallock (Figures 1.2 and 1.3). The WA375 boundary is the boundary of land described as Plan PC364849, 130 McMahons Road, Launching Place, parish of Gracedale, Yarra Ranges Shire. DPQ propose to extend the existing quarry in a northwest direction onto the adjoining Lot50c (Figure 1.4) The extended quarry will cover an additional area of about 16 ha.

The sump in the floor of the current (mid 2022) pit is at an elevation of about 190 Australian Height Datum (m AHD) as surveyed by Landair. The 2022 pit topography is shown as filled 2D contours in Figure 1.5A and as mid-2022 Google Earth image draped over a “true” 3D terrain model in Figure 1.5B.

The proposed expanded extraction pit would be developed in four stages. Digital Elevation Models of the 4 pit stages are shown in Figure 1.6. The deepest areas of stages 1, 2 and 3 will all be at about 180 m AHD, but the terminal (Stage 4) pit floor will be about 70 m deeper at 110 m AHD.

The proposed quarry pit s will extend below the water table. Post-quarrying the pit void will be filled up to a spill-point elevation of 217 m AHD predominately by surface water with a lesser contribution by groundwater inflow (Figure 1.7). The lake will be a surface water dominated groundwater throughflow lake.

1.2 EXTRACTIVE INDUSTRY ASSESSMENT GUIDELINES

HAs are required for extractive industry WA variations as well as new Work Authorities. HAs are also required to support extractive industry rehabilitation plans (RPs).

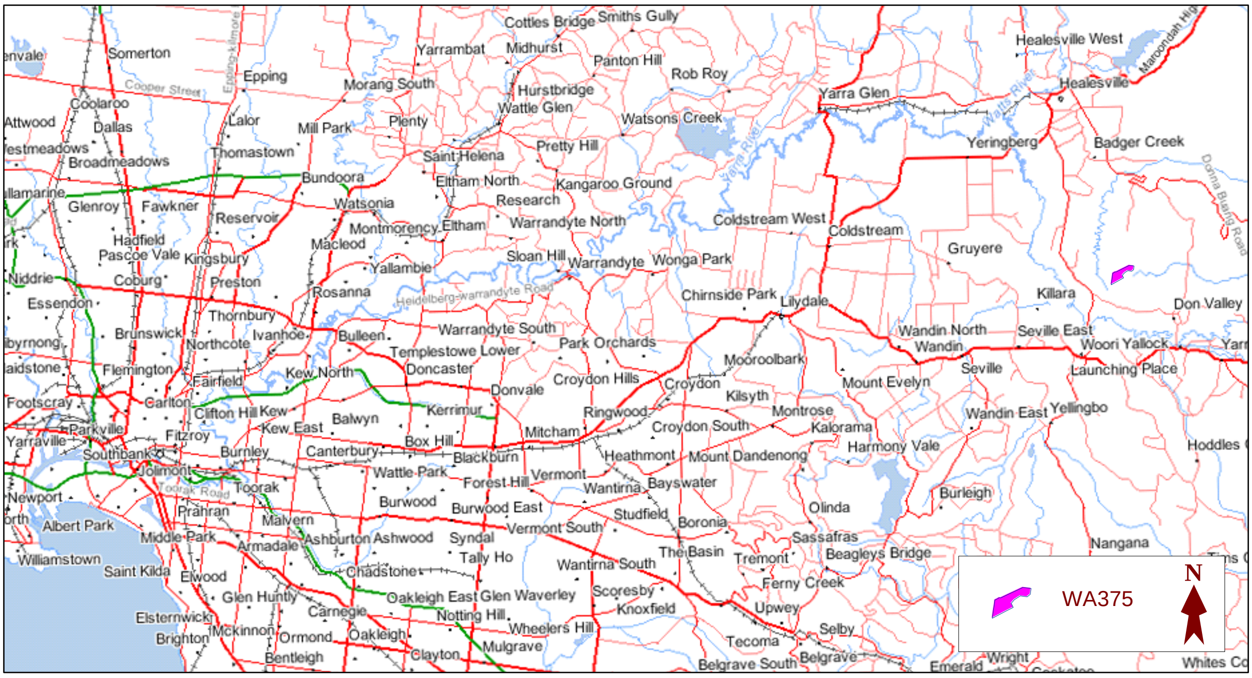

FIGURE 1.1 WA375 General Location

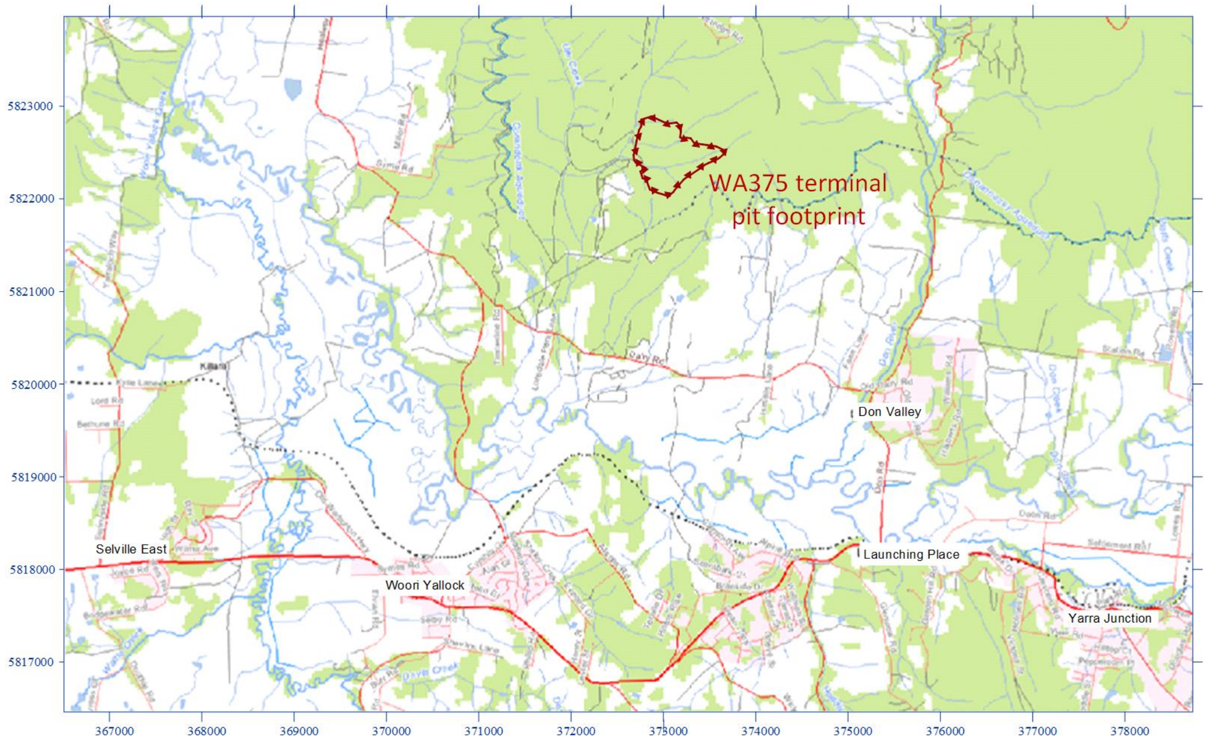

FIGURE 1.2 WA375 Location

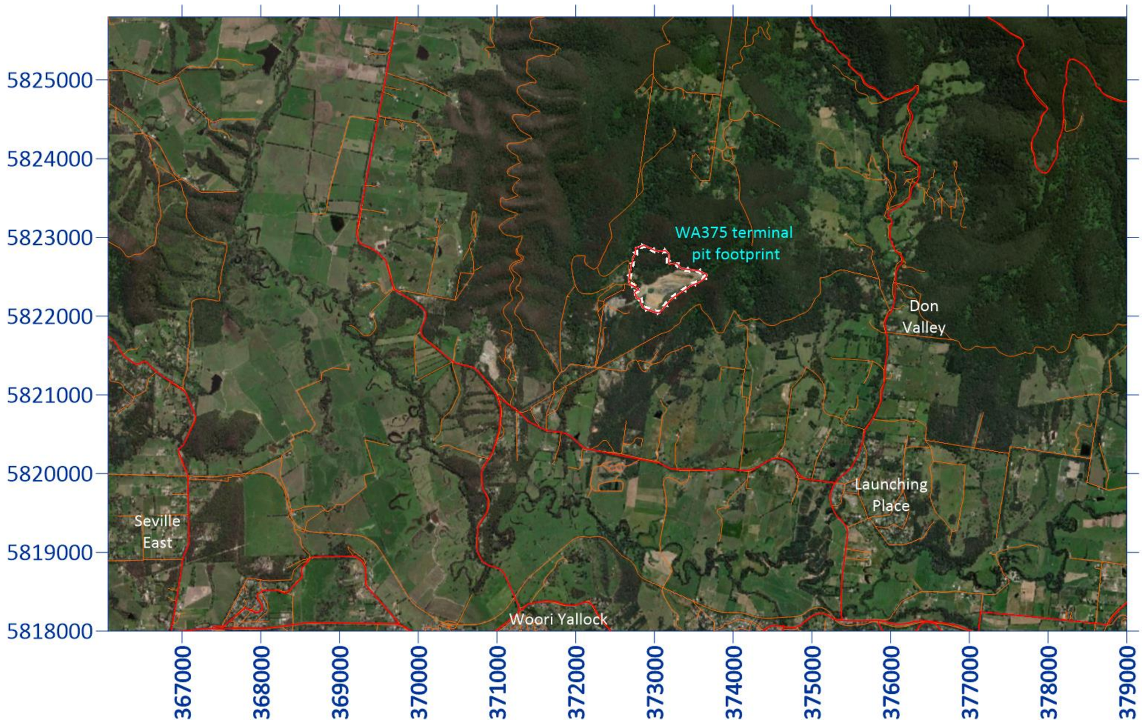

FIGURE 1.3 WA375 Location, Satellite Image Base

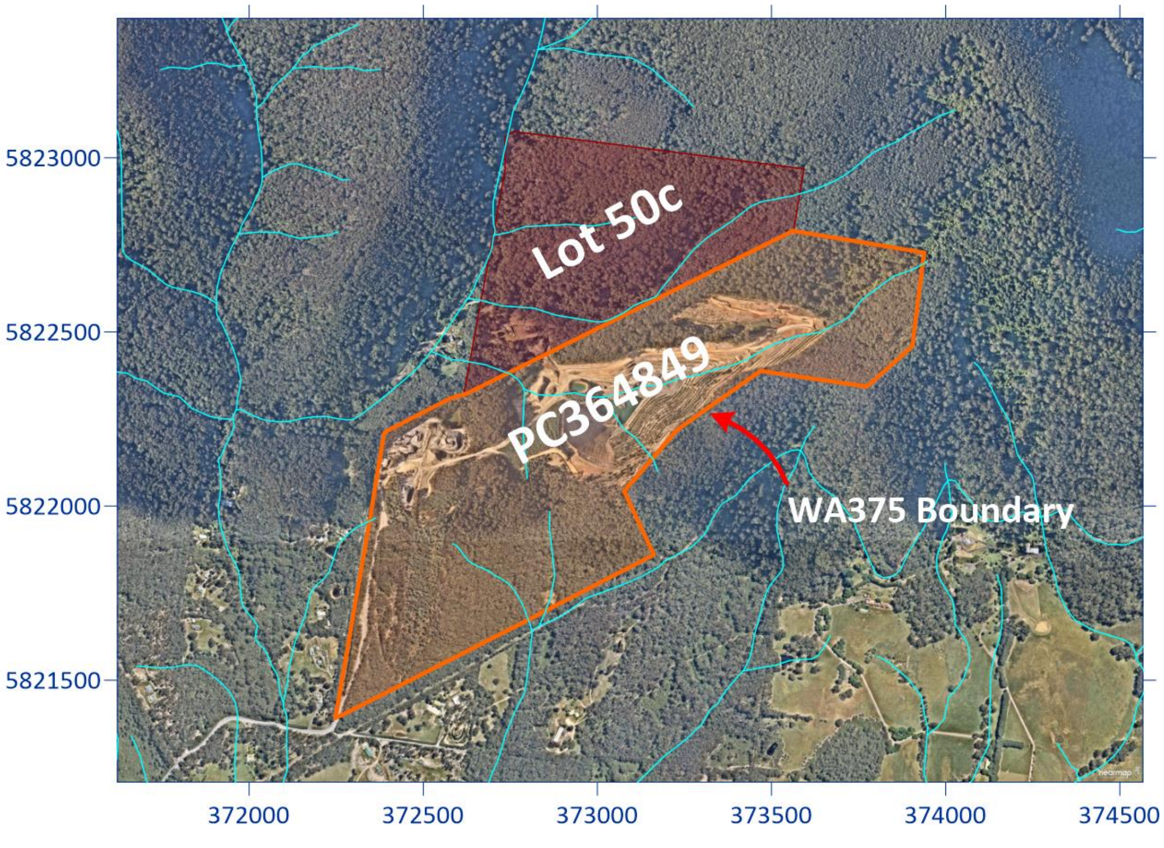

FIGURE 1.4 WA375 and Lot 50c Boundaries

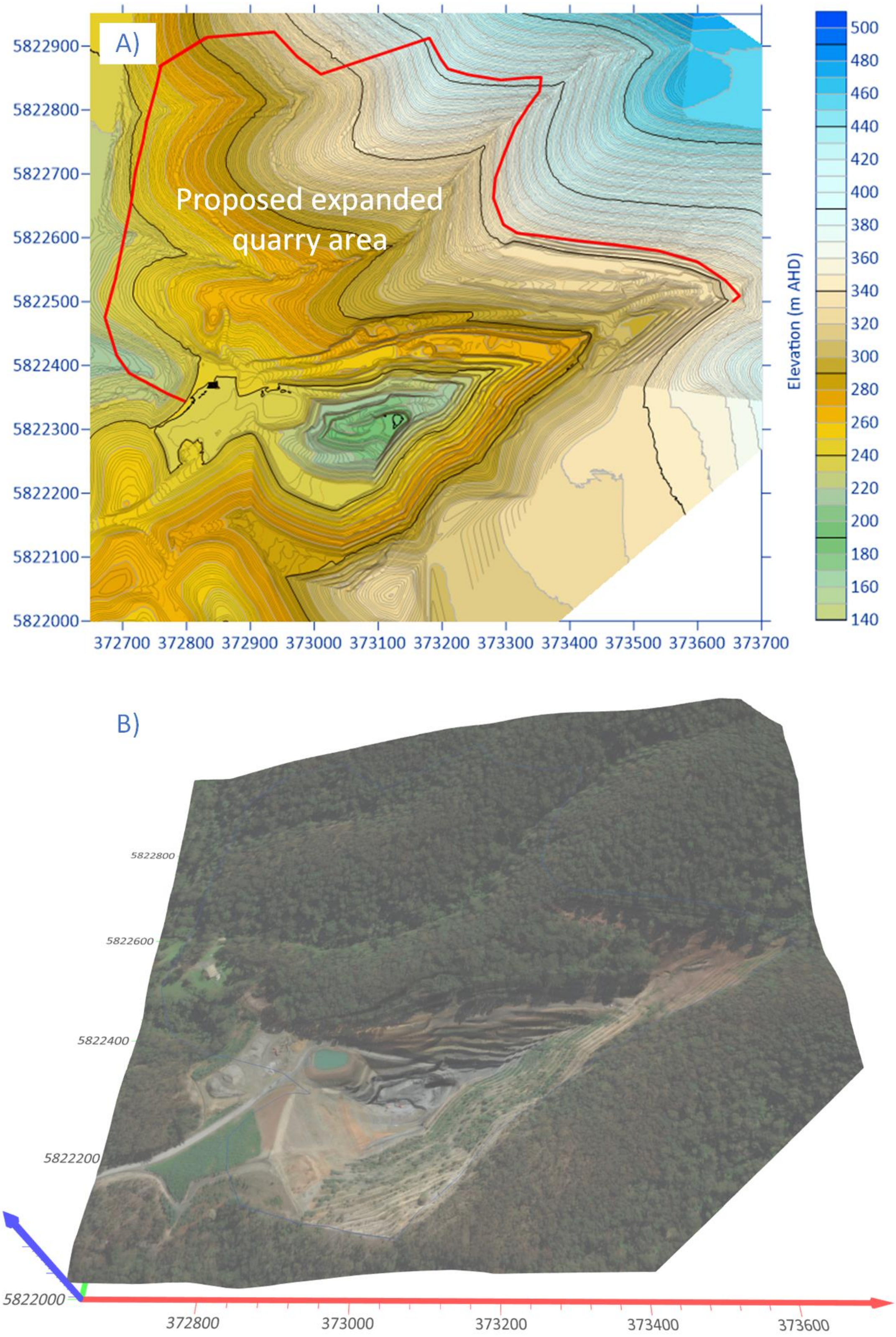

FIGURE 1.5 Visualization of the WA375 July 2022 Quarry, A) Filled 2D Contour Map, and B) Aerial Image Draped over True 3D Terrain Model

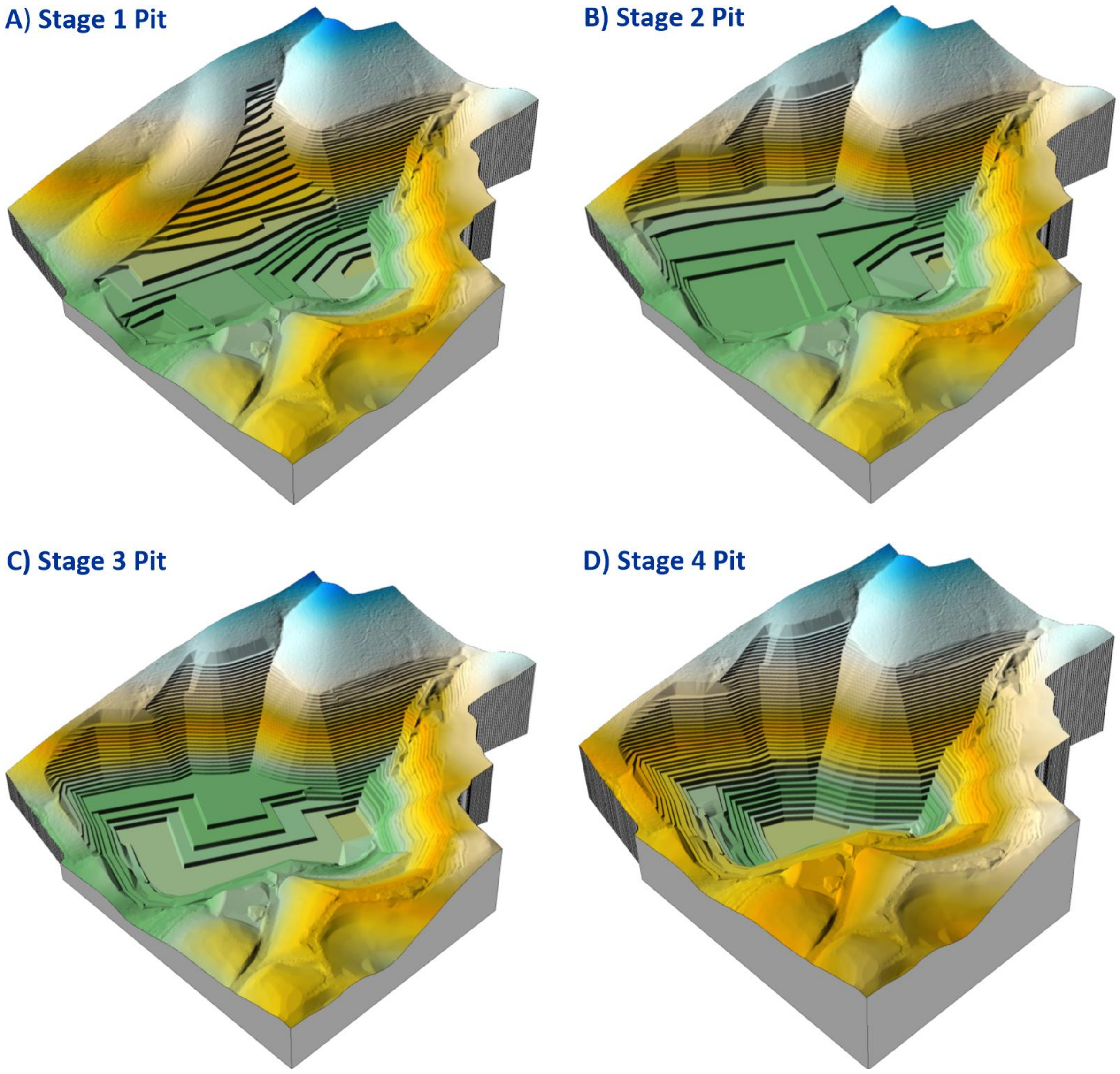

FIGURE 1.6 WA75 Work Authority Variation Proposed Quarry Pit Stages

Earth Resources Regulation (ERR), Department of Jobs, Precincts and Regions (DJPR) has developed two guideline documents to support Victorian extractive industry work authority holders to develop work plans, work plan variations and rehabilitation plans that meet regulatory requirements in Victoria including achieving sustainable rehabilitation outcomes.

1. "Preparation of Work Plans and Work Plan — Variations Guidelines for Mining Projects" (DJPR, V12, 2019).

2. "Preparation of rehabilitation Plans. Guidelines for Extractive Industry Projects" prepared by the Department of Jobs, Precincts and Regions (DJPR, 2021).

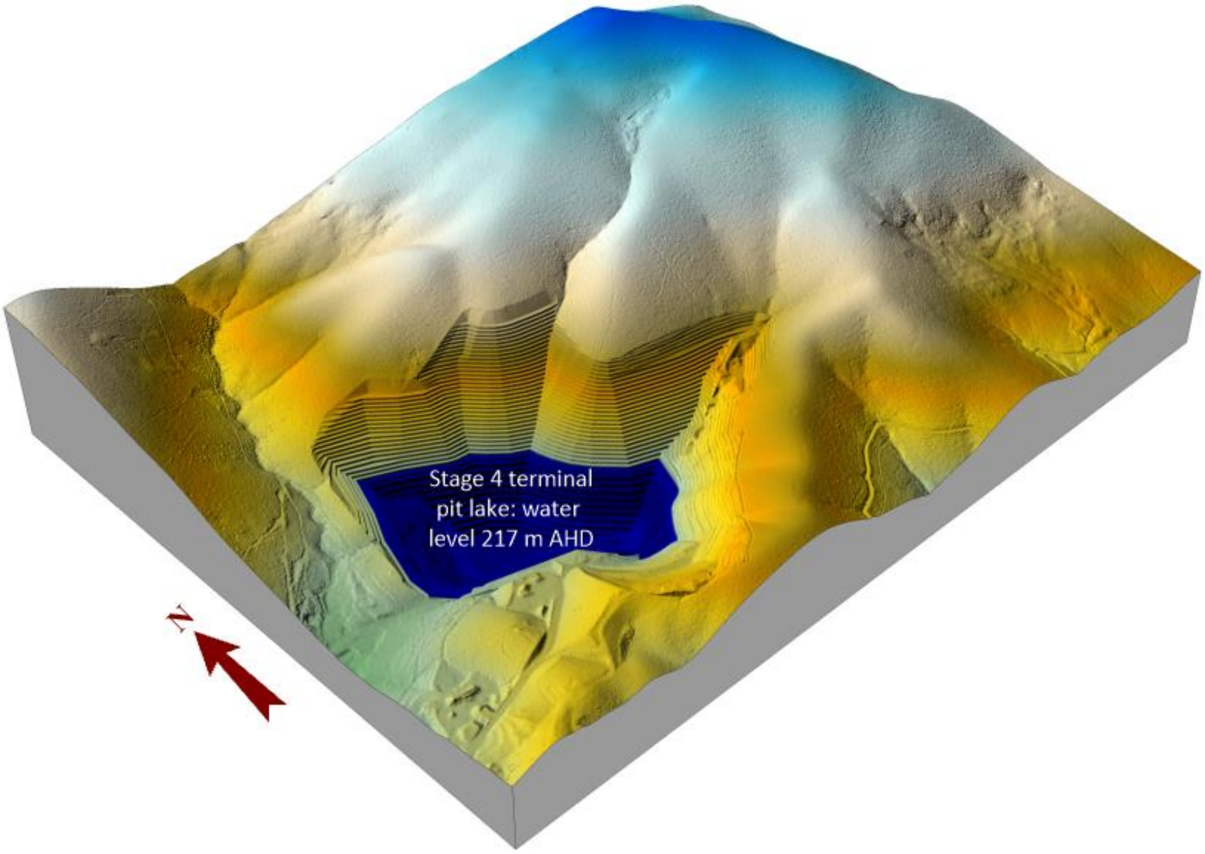

FIGURE 1.7 WA75 Stage 5 Terminal Pit Lake Digital Elevation Model

The guidelines set out what ERR expects to be included in work authority plans (WAPs) and rehabilitation plans (RPs). These guidelines identify descriptions that must be included in WAs/RPs documents including (but not limited to):

- local climate conditions and future projections for the area and its relevance to rehabilitation actions
- relevant details of the land (topography, geotechnical, seismic and hydrogeology), air, water (including surface and groundwater hydrology, water quality, ecological and beneficial uses), organisms, ecosystems, native and introduced fauna, habitats, vegetation communities
- key trends from data sets may be included and implications on rehabilitation planning requirements and outcomes
- geology (including regional and local geological structures and their characteristics) /geochemistry and soil materials characterization (topsoil, overburden, waste rock and tailings)
- catchment area water users
- aesthetics and other values of the site
- proximity to sensitive receptors.

Hydrogeological Assessments (HAs) that are required by ERR have to consider any auxiliary works, e.g., dewatering bores, and water treatment plant that could adversely impact local groundwater systems, 2) the location of sensitive hydraulically connected receptors such as water supply bores and Groundwater Dependent Ecosystems (GDEs) within two kilometres of the license boundary relevant to the new or changing works, and 3) an assessment of the risk of harm arising from the proposed changed operations to local groundwater users and hydraulically connected sensitive environmental segments such as wetlands or GDEs.

1.3 KEY CONCEPTUAL HYDROGEOLOGICAL MODEL COMPONENT

A robust, technically defensible conceptual hydrogeological model (CHM) is fundamental to all hydrogeological assessments. CHMs describe the geological setting and hydrogeological regime including the aquifer rock type and degree of groundwater confinement, movement of groundwater and contaminants, and the interactions between groundwater and the surface, and identifies potential receptors (groundwater users or environmental segments where groundwater discharges or can be accessed). CHMs provide a foundation for understanding potential uncertainties of the physical characteristics of groundwater systems which can be useful for identifying data gaps necessary to further refine the understanding of the hydrogeology. CHMs should be developed and periodically updated as part of an iterative process as data gaps are addressed, and new information becomes available.

Key considerations in developing a CHM include climate, topography, surface and subsurface geology, aquifer type and form, aquifer spatial distribution, and aquifer hydraulic parameters. Climate, especially rainfall and evaporation, control the amount of water available to recharge aquifer systems. The amount of recharge together with other stresses on groundwater systems and aquifer hydraulic parameters in turn control the depth to groundwater.

Topography is not only one of the main controls on surface water runoff but also has a significant influence on water table position; the water table configuration is a subdued reflection of the surface topography. The influence of topography is more pronounced in hilly and mountainous terrain with high relief. Direct groundwater discharge occurs where the water table intersects the ground surface or indirectly via evapotranspiration where the water table is close to the ground surface.

The geological history of an area controls the number and type of aquifers, their lateral and vertical extent, and configuration (depth, outcrop pattern), hydraulic properties and degree of interconnection. Surface/outcrop geology controls the recharge/discharge regime of aquifer systems whilst subsurface geology controls the distribution and flow of groundwater. Subsurface geology also controls possible development of perched water tables above the main regional water table.

1.4 GUIDELINES, DATA AND INFORMATION SOURCES

Information used in preparing the required HA was obtained from a number of sources including site-specific investigations. Key data and information sources are listed in the following sections.

1.4.1 Guidance Documents

- Preparation of Work Plans and Work Plan — Variations Guidelines for Mining Projects. Department of Jobs, Precincts and Regions, V12, 2019.
- Preparation of rehabilitation Plans. Guidelines for Extractive Industry Projects. Department of Jobs, Precincts and Regions, 2021.
- Environmental Reference Standard (ERS). Victoria Government Gazette, No. S 245 Wednesday 26 May 2021.

1.4.2 Data Sources

- Victoria Seamless Geology Mapping 2011-14, GSV, Earth Resources (Welsh et al., 2014); digital maps downloaded from the GeoVic online mapping application).
- Groundwater and geology public domain databases — Geological Exploration and Development Information System (GEDIS), Water Management Information System (WMIS) and Visualizing Victorian Groundwater (VVG).
- Detailed site contours of existing surface provided by Landair.
- DELWP Central Highlands Lidar Survey data, 1 m resolution.
- Regional 10 m contours digitised from published topographic maps and/or from maps downloaded from the DPI Explore Victoria Online website.
- ELVIS Topography data (https://elevation.fsdf.org.au/).
- Rock resource exploration bore logs provided by Bell Cochrane.
- Pit design drawings prepared by Bell Cochrane.
- Water level observations and tests on groundwater from 4 bores including 3 purpose-installed during January 2022.
- Site rainfall data for period 2009 to 2022 provided by Dandy Premix Quarries.
- Rainfall data, Bureau of Meteorology, Healesville Station 086229 and site data recorded by DPQ for period 2007-present.

1.4.3 Key Technical Reports

- Hydrogeological Assessment Proposed Extension to Yarra Valley Hard Rock Quarry, McMahon, Launching Place. Report prepared by John Leonard, John Leonard Consulting Services, July 2009.
- Launching Place WA375 Hydrology Assessment including Water Balance and Drainage Investigation. Water Technology, November 2023.
- Yarra Valley Quarry Desktop Review and Gap Analyses. Report prepared by GHD, January 2021.
- GHD (2022). Woori Yallock Quarry Geotechnical Assessment. Report prepared for Dandy Premix Quarries by GHD, 13 April 2022.

1.5 DATA COMPILATION AND MAPPING

JLCS compiled a project dataset from the various data sources. A number of regional, local and site two- and three-dimensional maps were prepared as background to developing a conceptual hydrogeological model of the quarry site and surrounding area. Digital elevation models (DEMs) were prepared for 1) the current quarry topography and 2) proposed quarry extension (maximum proposed depth and footprint).

The various maps produced for this report were georegistered to the UTM MGA94 coordinate system, and elevations referenced to the Australian Height Datum (AHD).

2.0 GROUNDWATER PROTECTION AND MANAGEMENT

The main Victorian legislation and policies related to consumptive use of groundwater including dewatering and groundwater extraction impacts (Groundwater Resource Management) and potential groundwater contamination (Groundwater Quality Protection) are briefly discussed in the following Sections.

2.1 GROUNDWATER RESOURCE MANAGEMENT

Groundwater resources ("quantity") management is achieved under the provisions of the Water Act 1989, as amended. Southern Rural Water (SRW) has delegated responsibility for managing groundwater resources across southern Victoria.

The provisions of the Water Act 1989 require that potential groundwater users obtain 1) a license to construct a bore, and 2) a separate licence to take and use groundwater for commercial uses. [Extracting groundwater for stock watering and/or domestic use is a statutory right under the Water Act and does not require an extraction licence.] Licensing authorities are also required to ensure that allocation of a new groundwater licence does not undermine environmental water reserves or surface water allocations. In considering applications for a groundwater extraction licences the Rural Water Authorities including SRW have to take a number of matters into consideration including, 1) the existing and projected availability of water in the area, 2) any adverse effect that the allocation or use of water under the entitlement is likely to have on existing authorised uses of water, a waterway or an aquifer, 3) the need to protect the environment, including the riverine and riparian environment, and 4) government policies concerning the preferred allocation or use of water resources.

WA375 is not located within any groundwater management area that is a Groundwater Management Area (GMA) or a Groundwater Supply Protection Area (GSPA). GMAs have been declared for geographic areas with high levels of groundwater development or development potential. Where groundwater in a GMA is identified as being under threat of overuse[1], the area is declared a Water Supply Protection Area (WSPA) and extractions are managed in accordance with an approved management plan. Areas of the state not covered by a GMA or WSPA are known as "unincorporated areas".

The closest GMA to the YVQ Launching Place site is the "Wandin Yallock Water Supply Protection Area" located more than 10 km southwest of the quarry. This area was incorporated in 1998 to manage groundwater extraction primarily from the Older Volcanics aquifer in the Seville-Wandin-Burleigh area.

2.2 GROUNDWATER QUALITY PROTECTION

Groundwater quality protection is achieved under the provisions of the Environment Protection Act 2017 (The Act). The Act and the Environment Protection Regulations 2021

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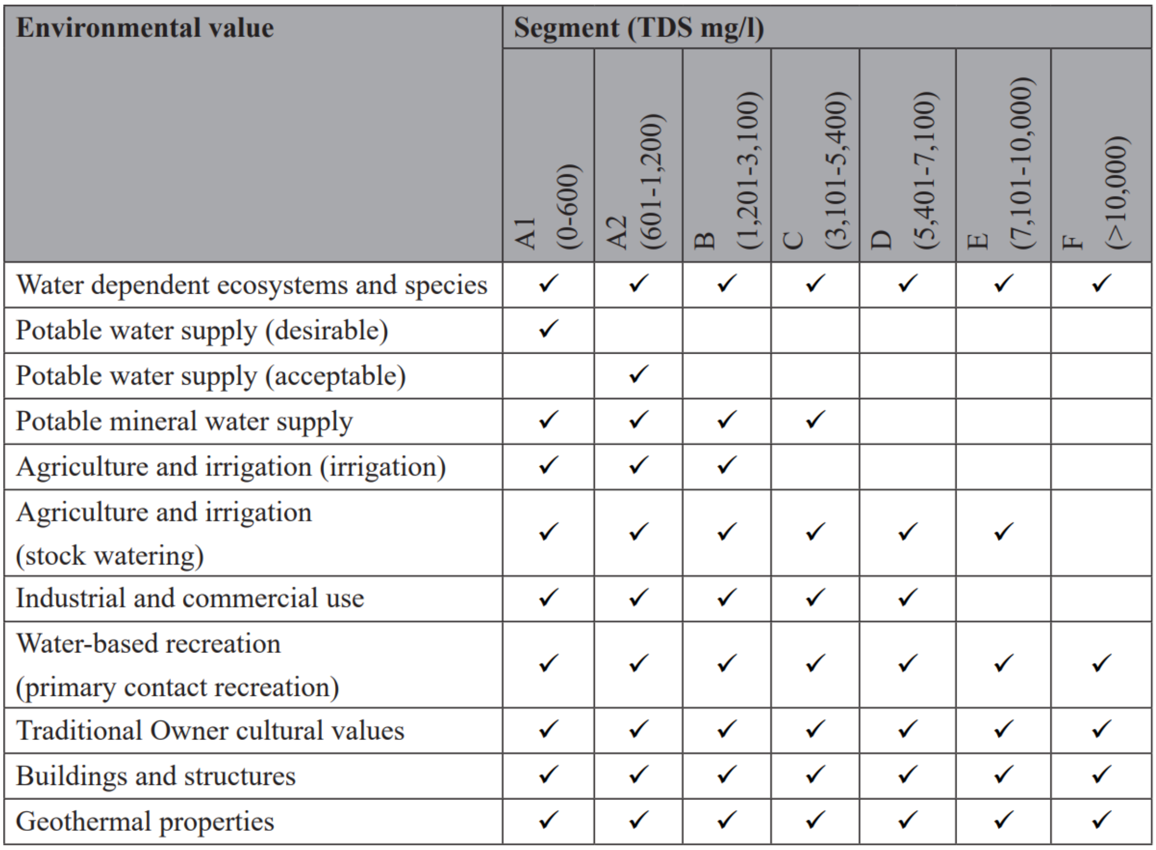
[1] When groundwater allocations exceed 70% of the PAV for a GMA, the area is declared a Water Supply Protection Area (WSPA). Rural Water Authorities were instructed not to issue any new groundwater extraction licenses (i.e., to cease allocating more groundwater) when allocations exceed 100% of the PAV.

introduced a new regulatory framework designed to prevent harm by eliminating or minimising risks of harm to human health and the environment. The EPA Act established general environmental duties (GEDs)– a set of obligations on duty holders. The GED 1) requires Victorians to understand and minimise their risks of harm from pollution and waste to human health and the environment, and 2) requires that “a person who is engaging in an activity that may give rise to risks of harm to human health or the environment from pollution or waste must minimize those risks, so far as reasonably practicable”.

The Environmental Values to determine monitoring and environmental quality objectives including groundwater and surface water quality are defined in the Environmental Reference Standard (ERS) (Victoria Government Gazette, No. S 245 Wednesday 26 May 2021), effective as of July 2021 which superseded the State Environmental Protection Policies (SEPPs) including the Waters of Victoria” SEPP. Environmental Values indicate potential amenity values of water, air, land, ambient noise and atmosphere. Environmental Values replaced Beneficial uses previously described in SEPPs. Environmental Values that apply specifically to groundwater segments are provided in Table 1. The various groundwater segments are based on the salinity of the natural/uncontaminated) groundwater and are determined by reference to the ERS Table 5.3 in Gazette No. S 245 as presented in Table 1. Indicators and objectives for the different Environmental Values are present in Table 2.1 (reproduced from Table 5.4 in Gazette No. S 245).

TABLE 2.1 Groundwater Environmental Values and Segments



Environmental value	Segment (TDS 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 and irrigation (irrigation)	✓	✓	✓				
Agriculture and irrigation (stock watering)	✓	✓	✓	✓	✓	✓	
Industrial and commercial use	✓	✓	✓	✓	✓		
Water-based recreation (primary contact recreation)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

Source: Table 5.3, Government Gazette No. S 245, 26 May 2021, Part 5 Division 2 - Groundwater

An environmental value may not apply to groundwater if a) there is insufficient aquifer yield to sustain the environmental value, having regard to variations within the aquifer and reasonable bore development techniques to improve yield; b) the application of that groundwater, such as for irrigation, may be a risk to the environmental values of land or the broader environment due to the soil properties; or c) the background water quality level exceeds (or is less than, in the case of indicators such as pH, dissolved oxygen and many biological indicators) the relevant objective specified in Table 2 and as a result the environmental value cannot be achieved.

TABLE 2.2 Indicators and Objectives for Groundwater

Environmental value	**Indicators**	**Objectives**
Water dependent ecosystems and species (in surface waters)	For groundwater that discharges to surface water, the indicators are the indicators applicable to the relevant surface water as specified in Division 3 of Part 5 of this ERS	The level that ensures the groundwater does not affect receiving waters to the extent that the level of any indicator in the receiving waters: exceeds the level of that indicator (if specified as an upper limit); or is less than the level of that indicator (if specified as a lower limit), specified for surface water in Division 3 of Part 5 of this ERS.
Water dependent ecosystems and species (in subterranean waters with a hydrogeological setting conducive to the presence of troglofauna and stygofauna)	Indicators that are relevant to the subterranean species of troglofauna and stygofauna, which may include TSS, salinity, toxicants in water, toxicants in sediment and dissolved oxygen	The level that ensures the groundwater quality does not adversely affect the troglofauna and stygofauna that depend on the groundwater
Potable water supply	Indicators specified in the ADWG	Health-related guideline value for each indicator specified in the ADWG. Aesthetic guideline value for each indicator specified in the ADWG.
Potable mineral water supply	Indicators specified in the ADWG	Health guideline values for each indicator specified in the ADWG. Aesthetic guideline values for each indicator set out in the ADWG.
Agriculture and irrigation (irrigation)	Indicators specified for irrigation and water for general on-farm use in the ANZG	Level of that indicator specified in the ANZG
Agriculture and irrigation (stock watering)	Indicators specified for livestock drinking water quality in the ANZG	Level of that indicator specified in the ANZG
Industrial and commercial	Indicators specific to the particular industrial or commercial activity and their use of water	Groundwater quality that is suitable for its industrial or commercial use
Water-based recreation	*E. coli*	10 E. coili 100 mL (if no human faecal contamination sources identified) 0 E. coli/100 mL (if human faecal contamination sources identified)
	Chemical hazards, aesthetic effects	Level of indicators (where specified) and descriptions in applicable guidance, in the Recreational Water Guidelines
Buildings and structures	pH, sulphate, chloride, redox potential, salinity or any chemical substance or waste that may have a detrimental impact on the structural integrity of buildings or other structures	Groundwater that is not corrosive to or otherwise adversely affecting structures or building
Geothermal	Temperature between 30 and 70 degrees Celsius	Geothermal properties of groundwater to be maintained for current and future users of the resource

Source: Table 5.3, Government Gazette No. S245, 26 May 2021, Part 5 Division 2 Groundwater.

3.0 REGIONAL SETTING AND PHYSICAL CHARACTERISTICS
&
3.1 LOCAL LAND USE

The land use within 1 km of the edge of the proposed Stage 4 (terminal) pit is mostly public bushland except for some small areas of partially cleared land west of McMahons Road and south of Parrot Road with residential buildings. The area between 1 to 2 km to the southwest, south southeast and northeast is mostly cleared open grazing land with a few scattered residences (Figure 3.1)

FIGURE 3.1 WA375 Local Land Use and Buffer Zones

3.2 CLIMATE

The climate in the Launching Place area is temperate with warm summers and cooler winters, and moderate rainfall generally received in most months. Monthly and average annual rainfall recorded on-site by DPQ over the period 2009 to 2022, inclusive are tabulated in Table 3.1. Key rainfall statistics are presented in Table 3.2.

TABLE 3.1 WA375 Monthly and Annual Rainfall 2009 to 2022, Inclusive

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	5	2	73	67	23	63	99	101	125	68	54	58	738.0
2010	59	72	78	90	63	109	79	144	71	180	133	180	1258.0
2011	119	230	81	111.5	111	88.5	100.5	51	128	90.5	171.5	134	1416.5
2012	50	88.5	75	70	122	126	0	120	96	71.5	29.5	41.5	890.0
2013	20	81.5	57	21.5	81.5	104.5	98	121.5	110.5	75.5	91.5	86	949.0
2014	38.5	28	44	134.5	108	139	113	49.5	78.5	64.5	67	61.5	926.0
2015	38	88.5	39	95	115.5	37	100.5	116	59	51	50	56.5	846.0
2016	100.5	15	76.5	73	96.5	113	81.5	111.5	117.5	152	47	81	1065.0
2017	58.5	93	61	100	47.5	27	56	81	98.5	72.5	49.5	193.5	938.0
2018	57	5	38	28	129	79.2	68.5	109.5	45	33.5	141	86	819.7
2019	5	2	73	67	23	63	99	101	125	68	54	58	738.0
2020	125	89.75	70	217.5	84.5	84	51.5	125.75	72	127	79.5	85	1211.5
2021	111	28	75.5	77	87.5	164	115	50.5	162.5	139	103.5	26.5	1140.0

TABLE 3.2 WA375 Rainfall Statistics

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	60.5	63.3	64.7	88.6	84.0	92.1	81.7	98.6	99.1	91.8	82.4	88.3	995.1
Lowest	5.0	2.0	38.0	21.5	23.0	27.0	0.0	49.5	45.0	33.5	29.5	26.5	738.0
5th %ile	5.0	2.0	38.6	25.4	23.0	33.0	30.9	50.1	53.4	44.0	40.0	35.5	738.0
10th %ile	8.0	2.6	40.0	35.8	27.9	42.2	52.4	50.6	61.4	53.7	47.5	44.5	754.3
Median	57.0	72.0	73.0	77.0	87.5	88.5	98.0	109.5	98.5	72.5	67.0	81.0	938.0
90th %ile	117.4	92.4	77.7	129.9	120.7	136.4	110.5	124.9	127.4	149.4	139.4	170.8	1248.7
95th %ile	121.4	147.8	79.2	167.7	124.8	149.0	113.8	133.1	141.8	163.2	153.2	185.4	1321.4
Highest	125.0	230.0	81.0	217.5	129.0	164.0	115.0	144.0	162.5	180.0	171.5	193.5	1416.5

Notes: temperature in °C; rainfall and evaporation in mm: Source: Commonwealth Bureau of Meteorology Website.

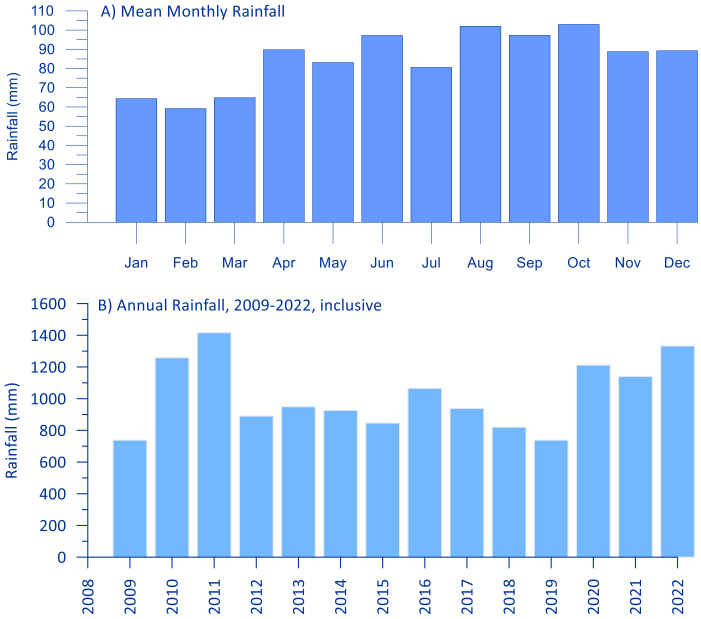


FIGURE 3.2 WA375 Mean Monthly and Annual Rainfall, 2009-2023

The monthly rainfall measured at WA375 over the period 2009 to 2022 varied between 2 mm and 230 mm (Table 3.1) and the average monthly rainfall for the same period varied between 60.5 mm and 99.1 mm (Table 3.2; Figure 3.1). The annual rainfall ranged from 738 to 1,416.5 mm (Figure 3.2) with the average for the 13-year period was about 995 mm.

Water Technology (2023) developed synthetical data set of daily rainfall for the period 1955 to 2020 present by merging data from two nearby Bureau of Meteorology (BoM) rainfall stations, located at Coranderrk (86219) about 5km north of the site, and Healesville (86229) 2.4 km west of the site. The former has continuous data from 1955 to 2015 and the latter has data available from 2007 to present. The mean annual rainfall from the merged data was 1,189 mm (compare to 995 from the WA375 site data).

Water Technology (2023) also estimated daily evapotranspiration data based on average monthly evaporation extracted from the L-AWRA model for WA375.

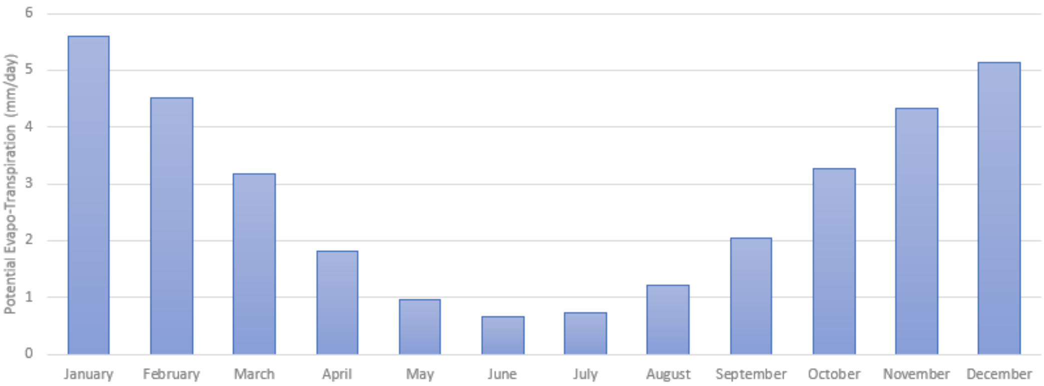


FIGURE 3.3 Average monthly evapotranspiration (from Water Technology, 2023)

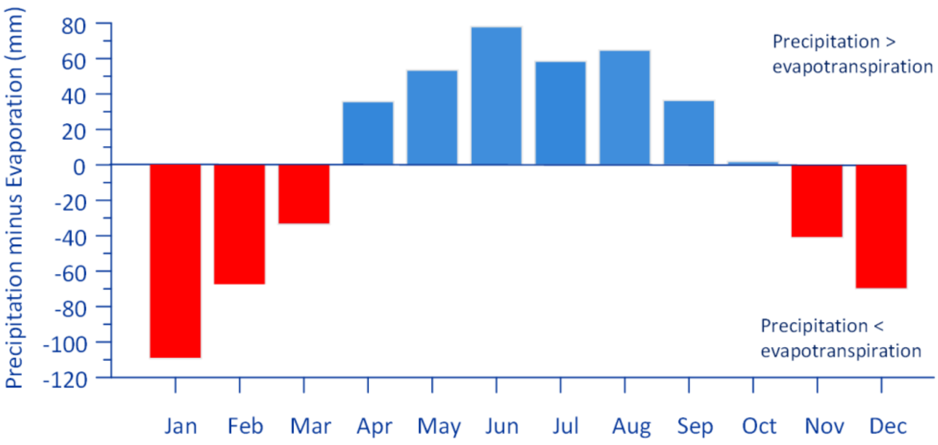


FIGURE 3.4 Average Monthly Precipitation Minus Evapotranspiration

3.3 GEOMORPHOLOGY

The geomorphology of an area (physiography, topography and drainage) together with geology control groundwater flow and provides an insight into likely groundwater flow systems in specific areas.

WA375 site is situated in the foothills of the Yarra Ranges on the southern margins of the Kinglake Plateau (part of the Kinglake Surface that also includes the Dandenong Ranges) physiographic unit near its junction with Nillumbik Terrain (Figure 3.5). The Kinglake Plateau is a dissected erosional surface along the drainage divide to the north and northeast of Melbourne. The plateau is characterized by gently undulating summits, generally deeply ferruginised regolith and steep erosional scarps to the adjoining Nillumbik Terrain. The elevation of the plateau is mostly between 400 and 1,000 m AHD with some ridges exceeding 1,500 m AHD. The main stream systems draining the plateau are the (upper) Yarra and Acheron, and the smaller Watts River.

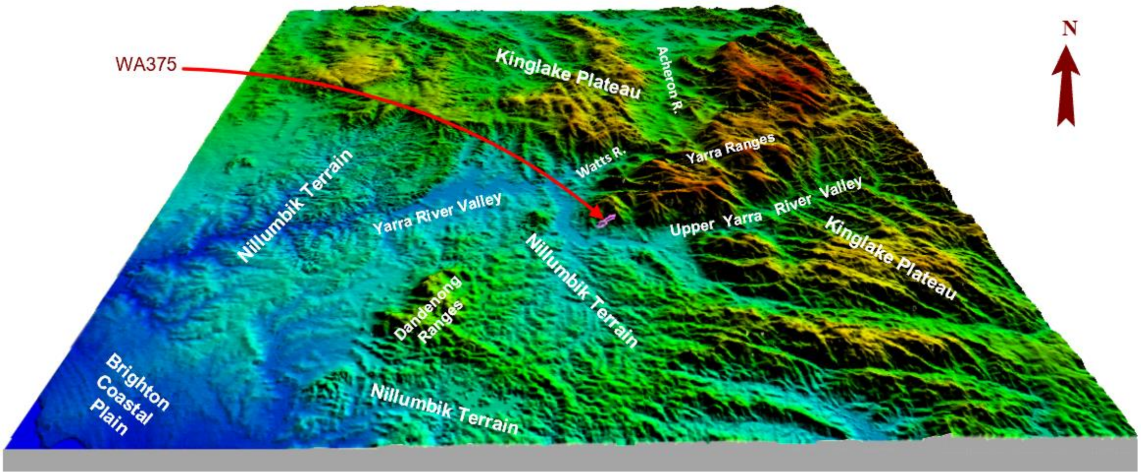


FIGURE 3.5 Regional Three-Dimensional Perspective View and Physiographic Units

The Nillumbik Terrain is a mildly dissected, plateau-like palaeosurface, formed on folded Silurian and Devonian sediments to south and southeast of the Kinglake Plateau. It is moderately uplifted and has relatively subdued relief ranging from less than 100 m AHD near Melbourne to about 300 m AHD where it terminates abruptly at the foot of the Kinglake Plateau. The surface of the Palaeozoic bedrock varies from deeply weathered regolith mantles of kaolinitic clay to fresher rock exposed by stripping. Streams of the Yarra system have cut into the surface and removed much of the cover of younger Tertiary sediments with the regional topography characterised by a series of ridges and moderate to deeply incised valleys on the old Silurian/Lower Devonian erosion surface.

The local topography varies from less than 100 m AHD along the flood plain of the Yarra River to more than 700 m AHD along the catchment divide at Mt Toole-Be-Wong about 2.4 km north of WA375 (Figure 3.6 and 3.7). The topography of the land in the foothills of the Yarra Ranges in the WA375 is characterised by a series of ridges separated by moderately incised valleys.

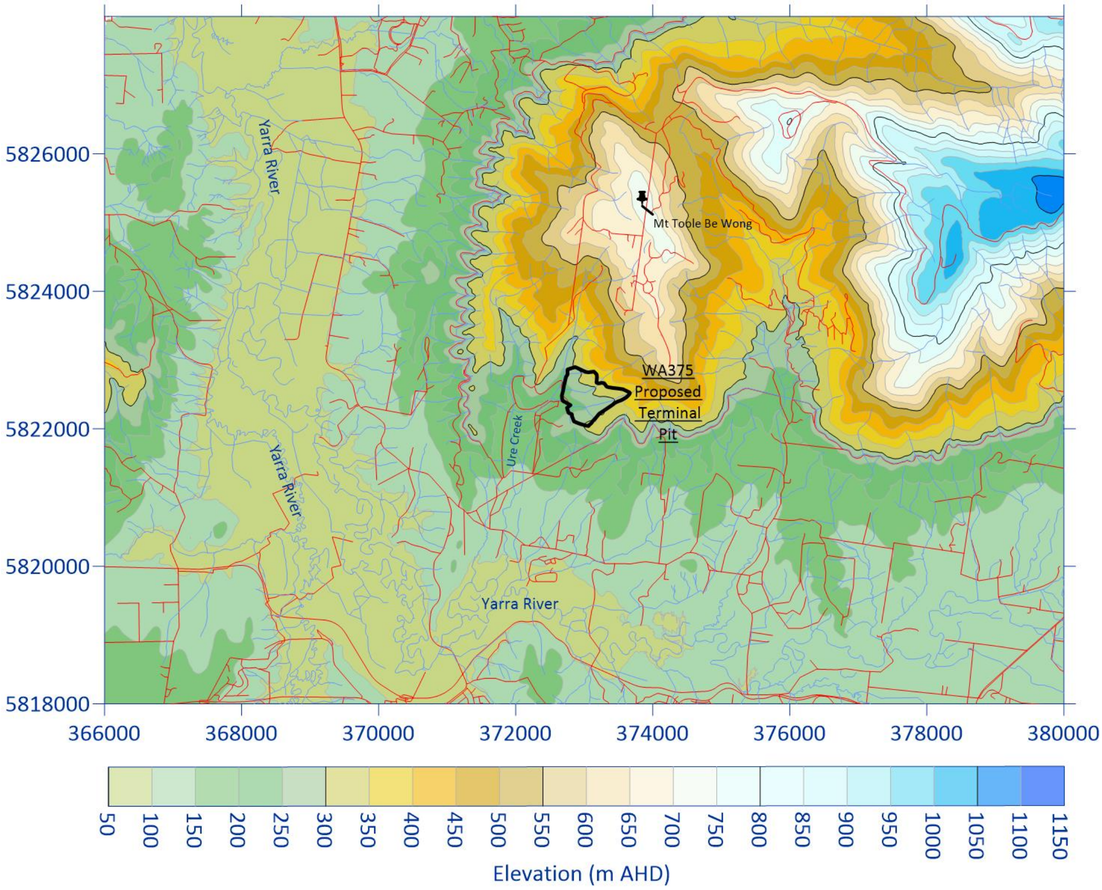


FIGURE 3.6 WA375 and Surrounds Filled 2D Topographic Contours

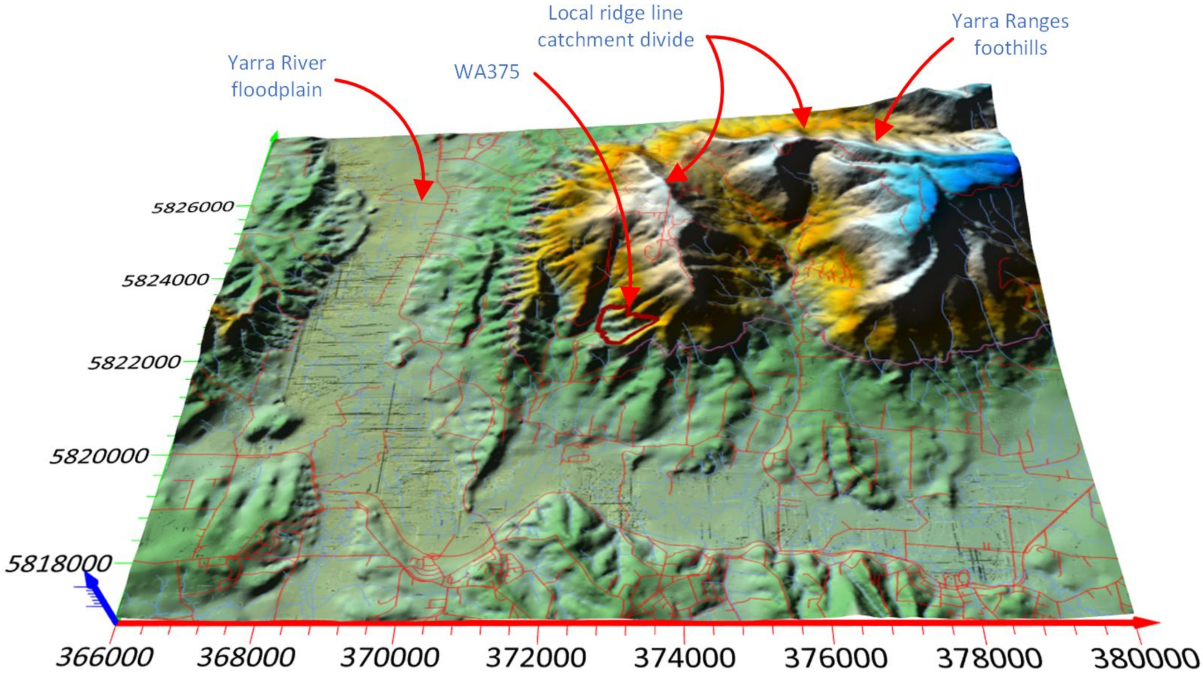


FIGURE 3.7 WA375 and Surrounds "True" 3D Terrain Model

3.4 DRAINAGE

The WA375 quarry is located within a sub-catchment of Ure Creek which is a tributary of the Yarra River. It is about 2.5 km north of the river at its closest point. Ure Creek flows generally north-south into the Yarra and is fed by flow along many unnamed tributaries that are shown as permanent streams on topographic maps, but flow is probably intermittent at least at higher elevations. The largest Ure Creek tributary is informally named the "Moora Tributary" (after the nearby road name) for report identification purposes. Three small, unnamed intermittent flowing tributaries of the Moora Creek (designated as Tributary 1, 2 and 3) cross WA375 (Figure 3.8).

Moora Creek runs along the western side of the WA375 quarry and joins Ure Creek about 750 m west of the quarry pit. The catchment area of the Moora Creek (Moora Creek sub-catchment) is about 2.2 times larger than the sub-catchment of Ure Creek upstream of their confluence (Figure 3.9) but is incised to about the same elevation (Figure 3.10).

The course of Tributary 1 has been partially removed by quarrying works. The lower tracts of Tributaries 2 and 3 will be removed by the proposed quarry expansion.

3.4 HIGH VALUE ECOSYSTEMS

Groundwater Dependent Ecosystems (GDEs) are ecosystem that are maintained at least in part by groundwater. GDEs include aquatic and terrestrial ecosystems defined as (BoM undated):

- Aquatic ecosystems that rely on the surface expression of groundwater — including surface water ecosystems which may have a groundwater component, such as rivers, wetlands, and springs.
- Terrestrial ecosystems that rely on the subsurface presence of groundwater—including vegetation ecosystems such as forests and riparian vegetation.

Two online web-based mapping applications, the Commonwealth Government GDE Atlas (BoM) and the Victorian Government MapShareVic Wetland interactive mapping tool (DELWP) were interrogated to identify potential GDEs in the area around WA375. Mapped GDEs of the GDE Atlas and their classifications are shown in Figures 3.11A (Aquatic) and Figure 3.11B (Terrestrial), and wetlands shown on the MapShare website in Figure 3.12.

3.4.1 GDE Atlas Mapping

Aquatic ecosystems

"Moderate Potential Aquatic GDEs" that have been mapped along the Yarra River floodplain are shown in Figure 3.11A. The moderate potential GDE areas are all more than 2,900 m from the outer edge of the proposed Stage 4 quarry pit.

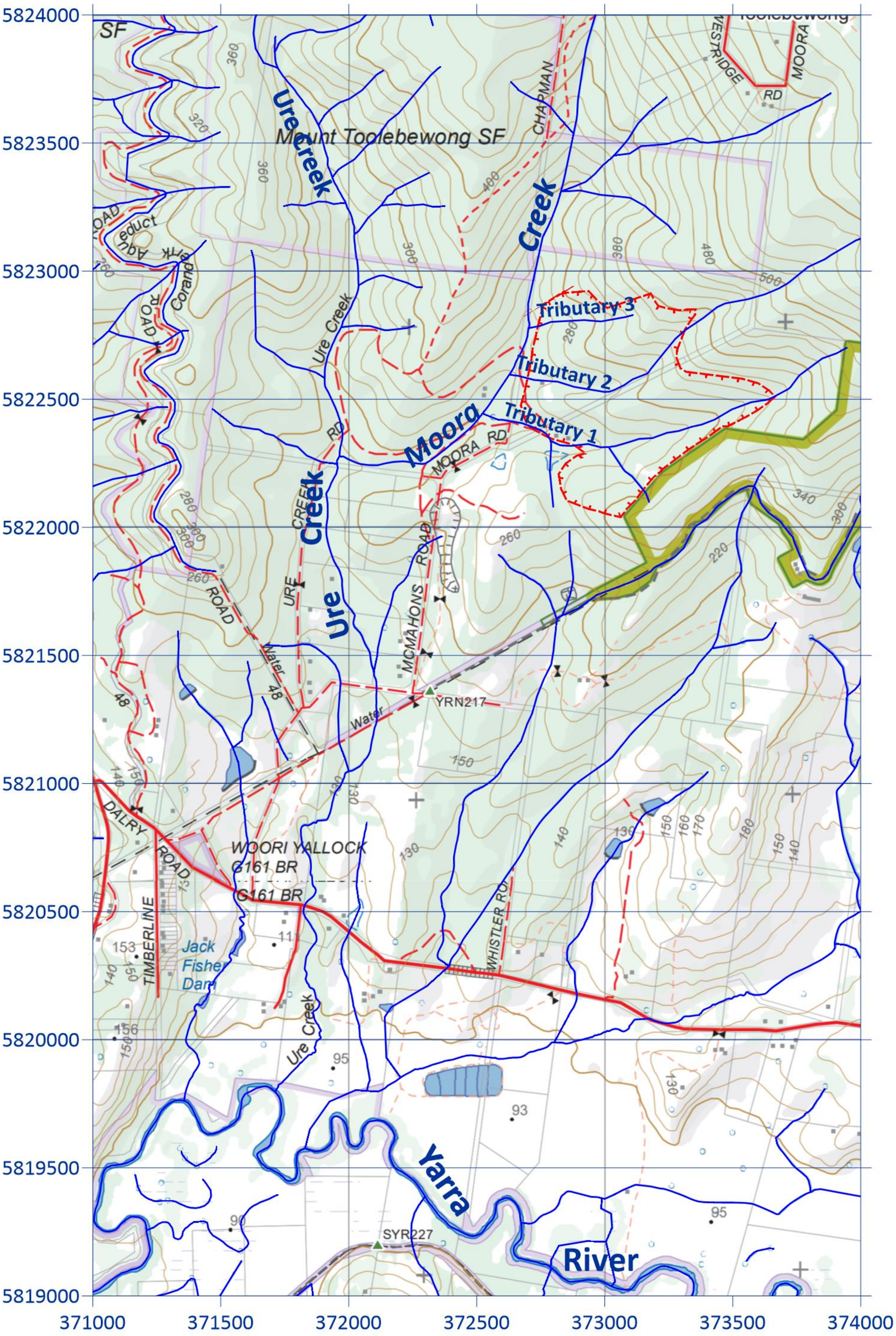


FIGURE 3.8 Local Drainage System

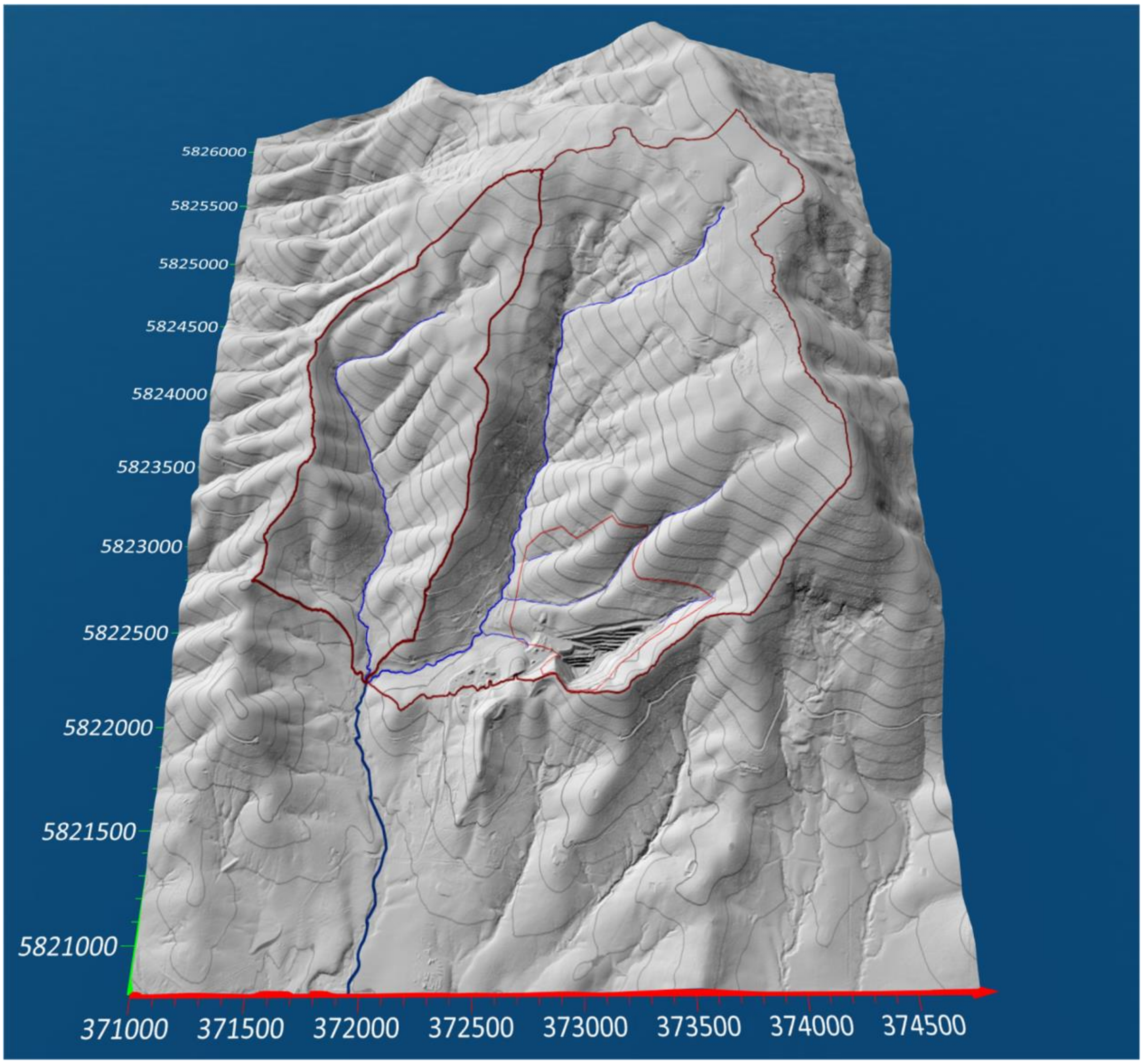


FIGURE 3.9 Three-Dimensional Visualisation, Upstream Ure Creek and Moora Creek Catchments

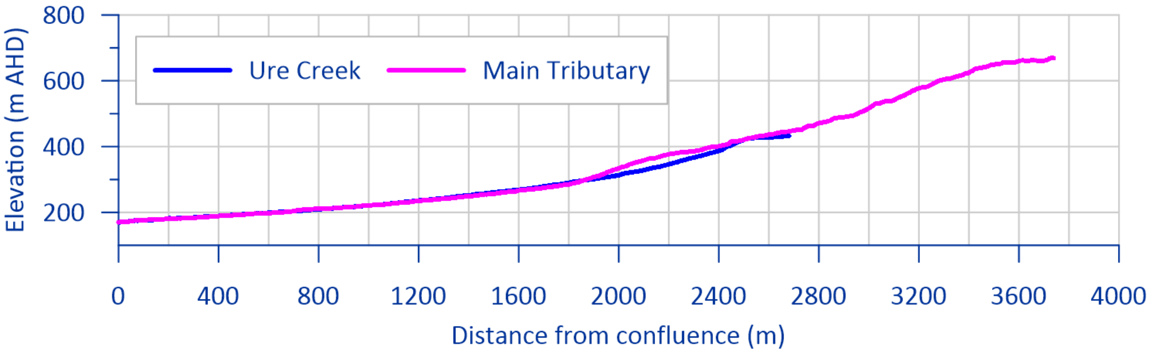


FIGURE 3.10 Ure Creek (Upstream) and Moora Creek Topographic Profiles

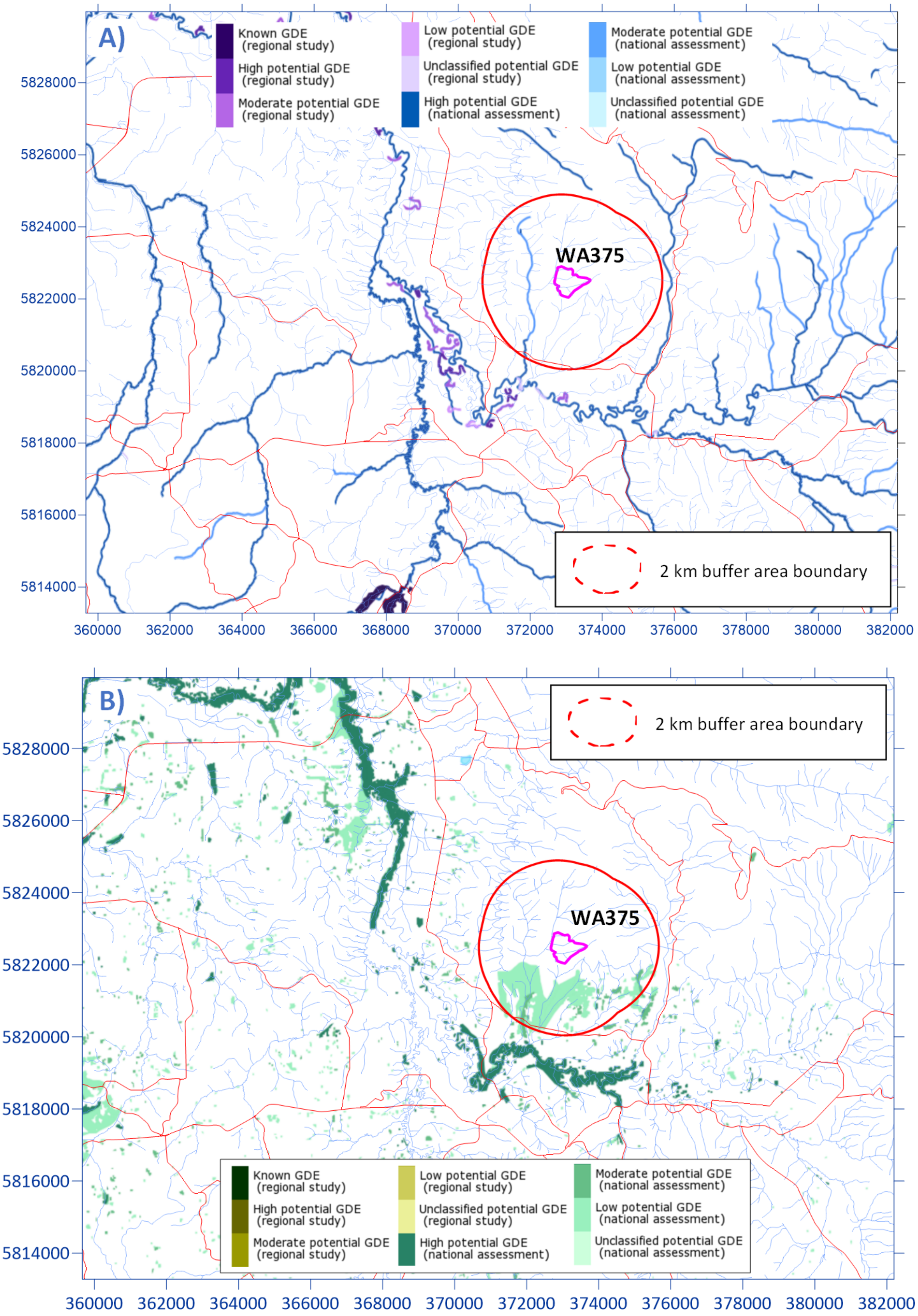


FIGURE 3.11 **A) Aquatic and B) Terrestrial GEDs (GDE Atlas accessed November 2022)**

Terrestrial ecosystems

High potential terrestrial GDEs have been mapped along the Yarra River flood plain along a roughly 8 km stretch more than 2,800 m south of WA375 Stage 4 pit (Figure 3.11B). Low potential terrestrial GDEs have been mapped over a relatively large area in the "valleys" of many of the Yarra River tributaries. The area closest to the Stage 4 quarry pit is about 600 m south.

3.4.2 MapShareVic Wetlands Mapping

Wetlands are mapped along the Yarra River tract from near Warburton (east) to North Warrandyte (west). (Figure 3.12) There are no Ramsar sites within about 55 km of WA375 (closest is Western Port about 56 km south).

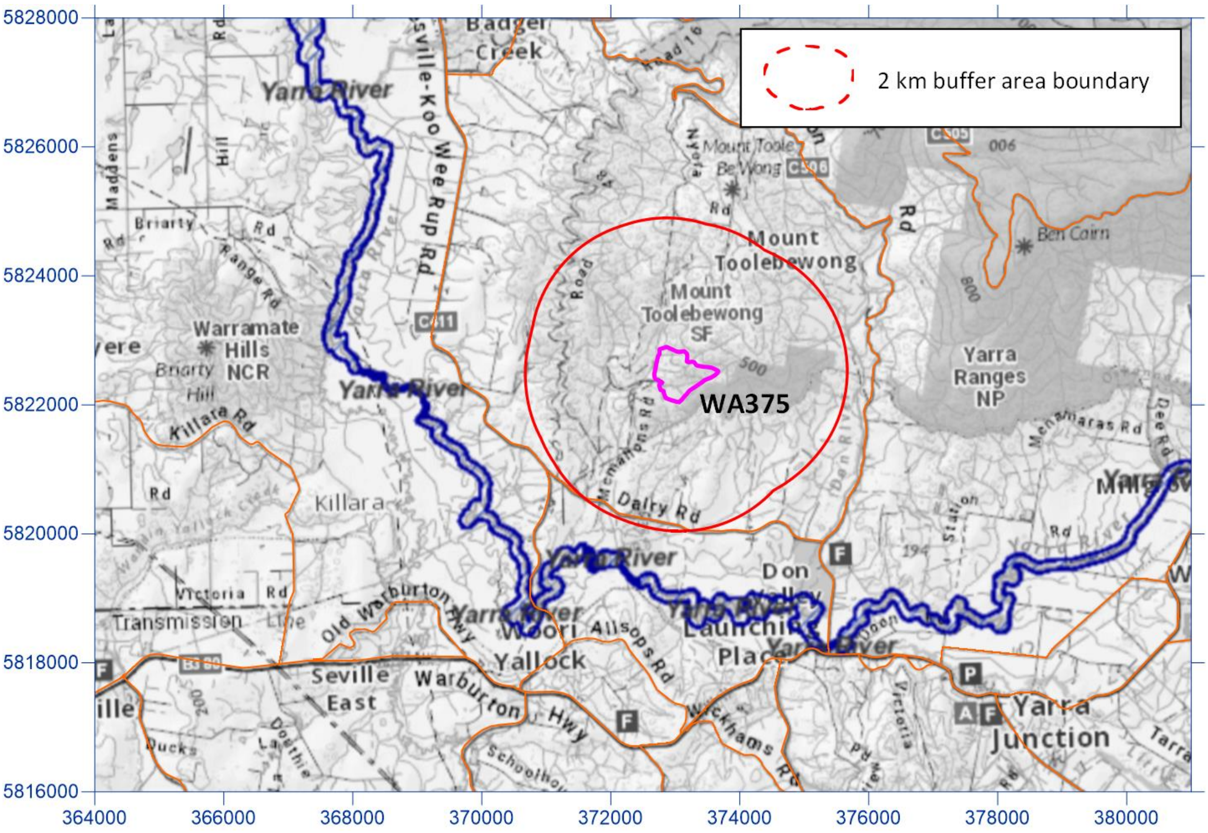


FIGURE 3.12 Mapped Wetlands, Launching Place Area (MapShareVic, accessed December 2022)

3.5 GEOLOGY

This Section provides a brief overview of the regional structural geological setting followed by more detailed descriptions of the local and site geology as necessary background for establishing the hydrogeological framework and developing an understanding of the potential impact of the proposed WA375 quarry extension on groundwater and potential impact of groundwater on quarry operations during both quarrying and post-quarrying. The descriptions are summarised from many published sources; key sources include VandenBerg *et al*. (1977, 1995), VandenBerg and Gray (1988), Moore et al. (1988), VandenBerg et al. (2000), Sandiford (2004), Welsh *et al*. (2011), Willam *et al*. (2002), Earp (2015), Camilleri and Warne (2014), and Clemens and Elburg (2015).

3.5.1 Geological Setting

Geological Survey geologists and/or University researchers have subdivided Victoria into three main structural rankings (based on rock ages and structural histories) consisting of twofold belts (Delamerian and Lachlan), two terranes in the Lachlan Fold Belt (Whitelaw and Benambra), and ten structural zones (Glenelg, Grampians-Stavely, Stawell, Bendigo, Melbourne, Tabberabbera, Omeo, Deddick, Kuark, Mallacoota) as shown in Figure 3.13A. The thrust faults that traverse the Palaeozoic basement are more or less parallel to the north–south structural grain.

WA375 is located within the Melbourne Zone in the Whitelaw Terrane of the Lachlan Fold Belt (Figure 3.13A). The Palaeozoic rocks of the Melbourne Zone overlie the Proterozoic Selwyn Block (Figure 3.13B). The Melbourne Zone lies between the west dipping Heathcote and east dipping Governor thrust faults and is composed of a thick imbricated pile of Cambrian to Ordovician (490 to 440 Ma) quartz-mica turbiditic rocks deposited into a deep marine environment along the eastern edge of the Australian craton. Two main depositional provinces have been recognized within the Melbourne Zone (Moore et al., 1988): the Darraweit Guim Province in the west, and the Mount Easton Province in the east (Figure 3.13). WA375 is positioned along the ill-defined boundary between the two provinces.

3.5.2 Folding and Faulting

These Melbourne Zone Palaeozoic rocks are steeply dipping predominantly siltstones with lesser sandstones and minor limestone. These rocks were folded into a series of anticlines and synclines in the Middle Devonian during a folding event called the Tabberabberan orogeny (about 380 mya). The axes of the folds trend approximately north-northeast to south-southwest. In the eastern part of the Melbourne Zone, the Palaeozoic sequence is disrupted by early formed bedding-parallel thrusts, which themselves are cut by late-formed westerly dipping thrust faults (VandenBerg and Gray, 1988; VandenBerg et al., 1995). In places, the Palaeozoic rocks are broken by faulting.

3.5.3 Major Regional Structures

Two “Shear Displacement Structures[2]” are mapped on the superseded Warburton 250,0000 Series Geological Maps and on the Earth Resources - GeoVic – Explore Victoria Online interactive website near WA375, namely 1) the Yellingbo Fault located about 500 m west of WA375 and 2) an unnamed fault here informally referred to as the “Don Valley Fault” about

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[2] A shear zone is described as a tabular to sheetlike, planar or curviplanar zone composed of rocks that are more highly strained than rocks adjacent to the zone They often occur at the edges of tectonic blocks and form important discontinuities to separate terranes. Shear zones may form zones of much more intense foliation, deformation, and folding. Shear zones widths vary from a few centimetres up to several kilometres wide (Davis and Reynolds, 1996).

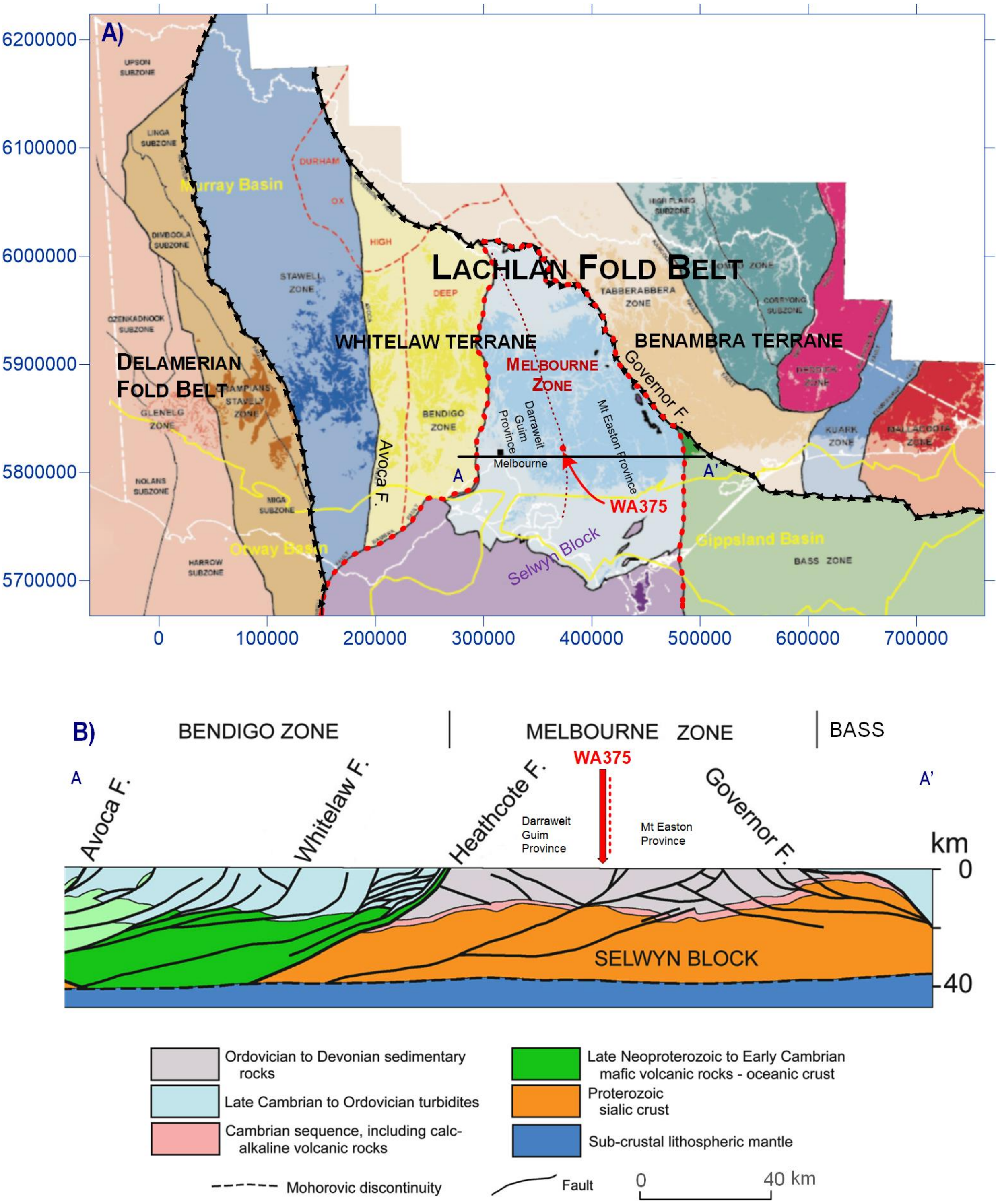


FIGURE 3.13 Victorian Geological Structural Zones

200 m to the east (Figures 3.13 and 3.14) on the Earth Resources - GeoVic – Explore Victoria Online interactive website. The two structures are sub-parallel with general north-south strikes. They roughly coincide with the edges of the intrusive Toole-Be-Wong Granodiorite

batholith indicating that the molten rocks were intruded into the older rocks along fault damage zones. A large area of igneous extrusive rocks occurs east of the two shear zones and the outcropping Toole-Be-Wong granodiorite in the Archeron Cauldron (part of the Marysville Igneous Complex). The Yellingbo Fault which is partly filled by a dyke (VandenBerg et al., 2000) links the Dandenong Ranges Igneous Complex cauldron with the Acheron Cauldron.

3.5.2 Stratigraphy

Many different stratigraphic units have been recognized within the Melbourne Zone, but most are not relevant in terms of the current Hydrogeological Assessment either because they are not present or overlain by thick sequence of younger rocks. The relevant stratigraphic unit is the Humevale Siltstone, referred to as "Humevale Formation in some reports. [The Humevale Siltstone is quarried at WA375.] Other nearby units include the Melbourne Formation, Toole-Be-Wong Granodiorite, Donna Buang Rhyodacite, and unnamed colluvial and alluvial deposits. The predominant lithologies of these units are listed in the legend on Figures 3.14 and 3.15.

The outcropping stratigraphic units within about 6 km from WA375 are mapped in Figure 3.14. A more detailed (larger scale) local geology map and true three-dimensional visualisation including the Stage 4 quarry pit are presented in Figure 3.15. The relevant stratigraphic units are described below (from oldest to youngest):

Melbourne Formation (Sxm)

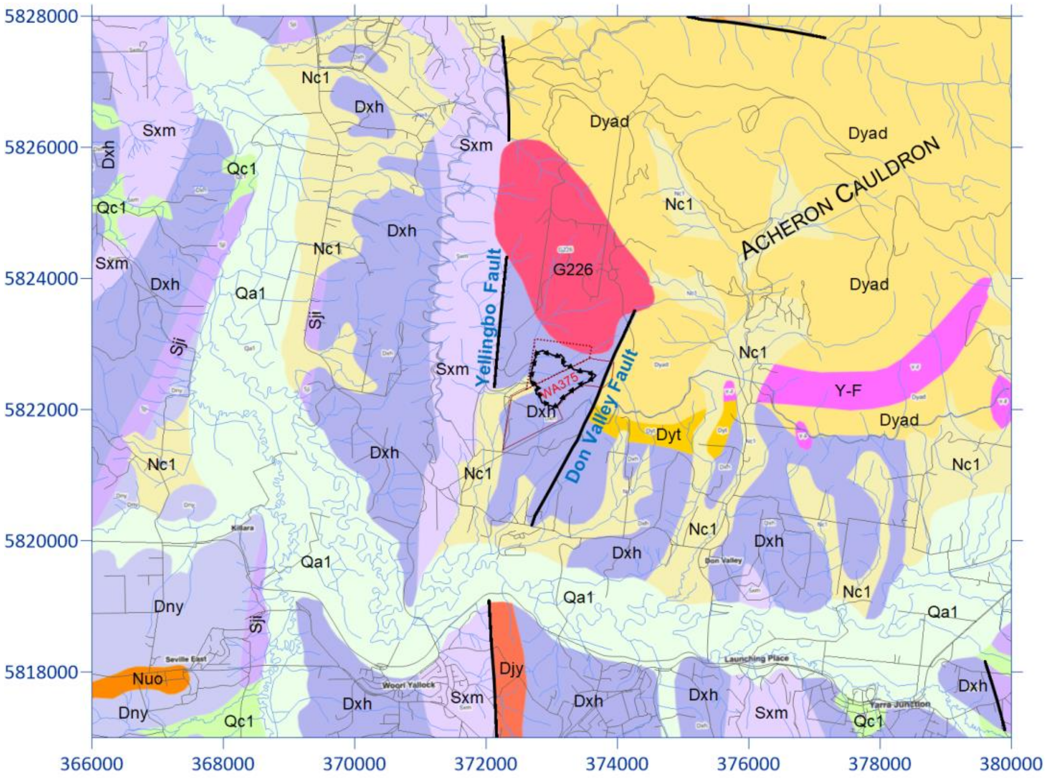
Relevance: Underlies Humevale Siltstone at depth; outcrops down hydraulic from WA375

The Silurian aged Melbourne Formation consists of a consolidated and fully lithified sequence of mainly thin-bedded, tightly folded siltstone and sandstone, commonly cross-bedded. The formation outcrops along a general north-south aligned roughly 1 km wide belt about 550 m west of the proposed WA375 expanded quarry on the western side of the Yellingbo Fault (Figure 3.13).

Humevale Siltstone (Sxm)

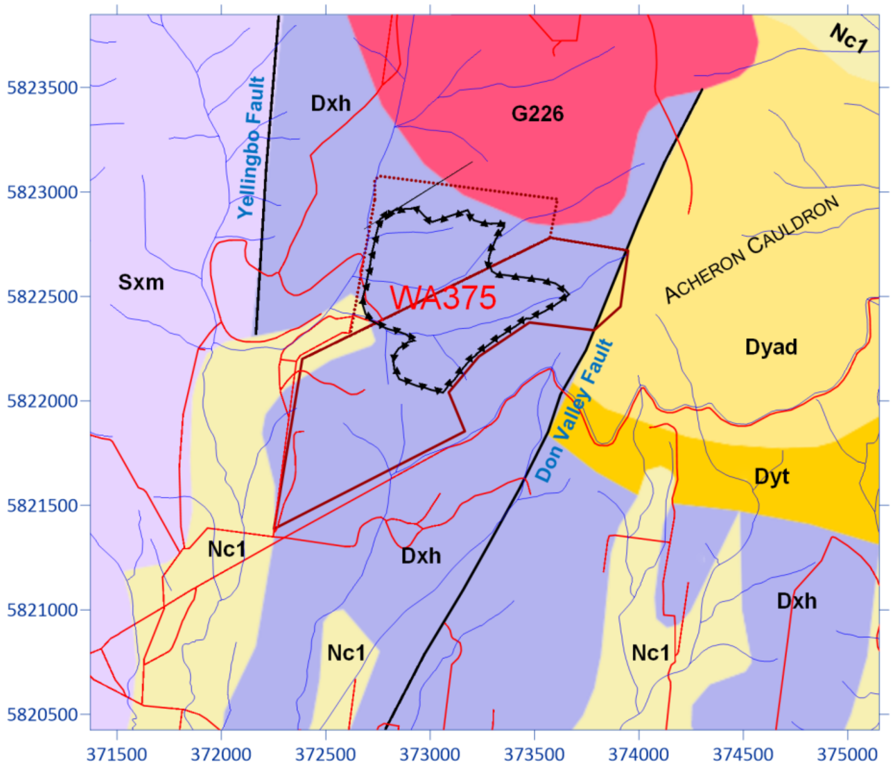
Relevance: WA375 quarried hard rock resource

The Humevale Siltstone (referred to as "Humevale Formation in some reports) occurs in the western part of the Melbourne Zone (Powell et al 2003), where it conformably overlies various late Silurian formations (Vandenberg et al., 2000; Vandenberg, 2003). The unit is Late Silurian to Early Devonian age and is estimated to be up to 3,800 m thick. It is composed composed primarily of siltstone with thin subordinate sandstone and mudstone beds (Garratt 1985, Vandenberg et al. 1988). Overall, the unit is a monotonous sedimentary sequence, with deposition resulting predominantly from dilute slurries and mudflows rather than settling from suspension (Vandenberg et al 2000, Vandenberg 2003). A contact metamorphic aureole on the ridge and western slopes of Mt. Toole-Be-Wong on the Nyora estate was described by Edwards (1932; Text Box 3.1) but is not mapped on the GSV seamless geology maps.



QUATERNARY	Pleistocene to Holocene	Qa1	Unnamed alluvium	Silt, clay, sand, gravel
	Pleistocene to Holocene	Qc1	Unnamed colluvium	Silt, clay, sand, gravel
	Pleistocene to Holocene	Nc1	Incised colluvium	Silt, clay, sand, gravel
TERTIARY	Miocene	Nuo	Monbulk Volcanic Group	Basalt, basaltic clay, tuff scoria
PALAEOZOIC	Late Devonian	Dyad	Donna Buang Rhyodacite	Rhyodacite
	Late Devonian	G226	Toole-Be-Wong Granodiorite	Granodiorite
	Late Devonian	Dxh	Humevale Siltstone	Siltstone, minor sandstone. Siltstone locally metophosed to hornfels
	Late Devonian	Djy	Yellingbo Porphyry	Quartz-feldspar porphyry
	Early Devonian	Dny	Woori Yallock Formation	Sandstone, siltstone, conglomerate
	Early Devonian	Sji	Wilson Creek Shale	Cordierite hornfels
	Devonian	Dyt	Taggerty Subgroup	Felsic ignimbrites, basalt and andesite lavas, conglomerate, sandstone.
	Silurian	Sxm	Melbourne Formation	Siltstone, sandstone, shale, limestone
	Silurian to Carboniferous	Y-F	Unnamed felsic dyke	Felsic dykes: glassy to porphyritic, quartz, feldspar, biotite and hornblende

FIGURE 3.14 Regional Outcrop Geology Map (Source Seamless Geology Victoria, 2011-2014; Earth Resources – GeoVic Explore Victoria Online)



QUATERNARY	Pleistocene to Holocene	Nc1	Incised colluvium	Silt, clay, sand, gravel
	Late Devonian	Dyad	Donna Buang Rhyodacite	Igneous extrusive: Rhyodacite and ignimbrite
	Late Devonian	Dyt	Taggerty Subgroup	Igneous extrusiveFelsic ignimbrites, basalt and andesite lavas, conglomerate, sandstone.
PALAEOZOIC	Late Devonian	G226	Toole-Be-Wong Granodiorite	Igneous intrusive: Granodiorite
	Early Silurian to Late Devonian	Dxh	Humevale Siltstone	Sedimentary: marine siltstone and minor sandstone; locally metophosed to hornfels
	Silurian	Sxm	Melbourne Formation	Siltstone, sandstone, shale, limestone

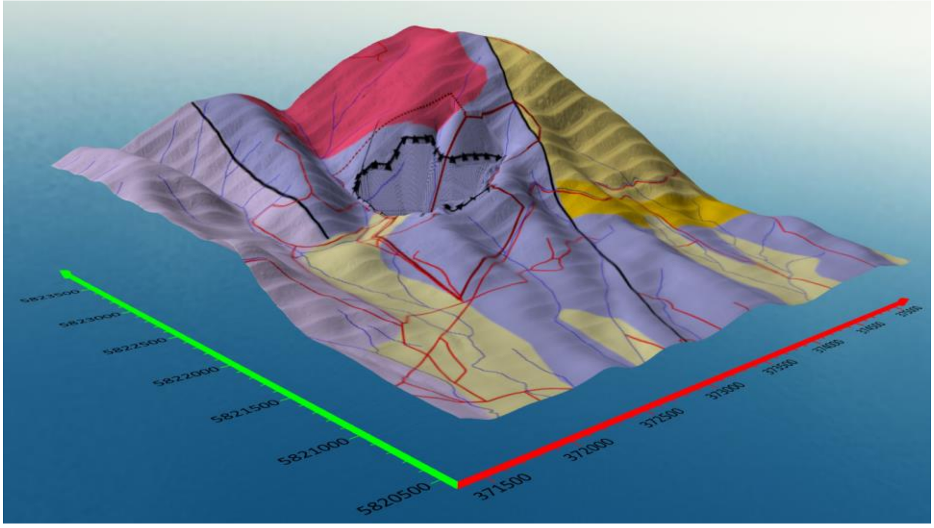
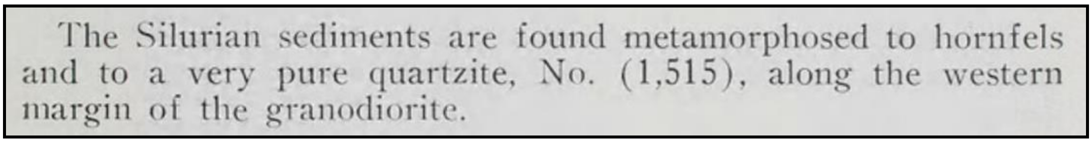


FIGURE 3.15 Local Outcrop Geology Map and "True" Three-Dimensional Visualisation



The Silurian sediments are found metamorphosed to hornfels and to a very pure quartzite, No. (1,515), along the western margin of the granodiorite.

TEXT BOX 3.1 Edwards (1932) Observations, Nyora Estate, Mount Toole-Be-Wong

Acheron Cauldron Igneous Rocks (Dyad, Dyt)

Relevance: Up topographic slope and hydraulic gradient from WA375

Extrusive volcanic rocks outcrop across the Acheron Cauldron northeast of WA375 to the east of the Don Valley Fault. The most extensive outcropping unit is the Donna Buang Rhyodacite a recrystallised (from its own heat) biotite hypersthene rhyodacite. VandenBerg et al. (2000) considered that the unit is up to 1,000 m thick (largely conjecture; VandenBerg, 1977) but as its local occurrence is along the edges of the cauldron deposit it is could be much thinner near WA375.

The Taggerty Subgroup is comprised of Felsic ignimbrites, basalt and andesite lavas, conglomerate, sandstone that outcrop in an irregular, discontinuous manner around the rim of the Acheron Cauldron including a small narrow band southeast of WA375.

Toole-Be-Wong Granodiorite (G226)

Relevance: Up topographic slope and Hydraulic gradient from WA375

The formation of the Acheron Cauldron was closely followed by intrusion of granitic rocks including the relatively small Tool-Be-Wong Granodiorite which is part as a thin ring dyke system around the western and southeastern edge of the Acheron Cauldron (VandenBerg, 1977). the Toole-Be-Wong Granodiorite, a sub-equigranular medium grained S-type biotite granodiorite, with abundant xenoliths (Welsh et al., 2011).The Toole-Be-Wong Granodiorite caused metamorphism along a sharp contact which as least in part fault-controlled.

Colluvium (Nc1)

Relevance: Down hydraulic gradient but thin and possibly mostly unsaturated

The colluvium derived from upslope "parent" rocks occurs along lower hillslopes and stream valleys including Ure Creek downslope from WA375. The colluvium is described as silt, sand, gravel that is generally poorly sorted and poorly rounded except within channels cut into colluvial material. The colluvial deposits are dissected to variable degrees. Colluvium is mapped close to the southwestern corner of the proposed WA375 terminal (Stage 4) quarry pit. These deposits are probably mostly unsaturated.

Alluvium (Qa1)

Relevance: Probable groundwater local and intermediate flow system discharge areas

Alluvium on the Yarra River floodplain consists of variably sorted, generally unconsolidated mixture of gravel, sand, silt and clay. The flood plain is more than 2.5 km from the WA375 quarry pit. It is locally between about 700 and 1,500 m wide. Shallow groundwater most likely discharges across the floodplain as well as into the Yarra River.

3.6 WA375 SITE GEOLOGY

The geology at the WA375 quarry has been investigated by BCA as part of a hard rock resource investigation program and by GHD (2007, 2009, 2021, 2022) for geotechnical assessments.

At the WA375 quarry site, the Humevale Siltstone has been metamorphosed to hornfels and quartzite by the intruded Toole-Be-Wong Granodiorite pluton that outcrops about one kilometre north of the current pit and only about 70 from the footprint of the proposed terminal Stage 4 quarry.

The irregular hornfels weathering profile is evident in the exposed northwestern pit wall panoramic photograph (Plate 3.1). GHD (2022) mapped three weathering zones (EW, extremely weathered: HW, highly weathered; and MW, moderately weathered) underlying residual soil and overlying fresh (FR) hornfels as shown in Figure 3.15. Steep dipping, varyingly fractured beds are evident in the less weathered rock faces (Plate 3.2). The higher grade hornfels are more brittle tending to be more fractured.

Plate 3.1 WA375 Northwestern Pit Wall Panoramic Photograph, 26 May 2022

GHD (2007, 2009, 2021, 2022) reported the presence of a few faults and shear structures associated with the local shear displacement structures. Numerous discontinuities in the quarry pit walls were also mapped. GHD (2007) observed a granitic dyke in the southwestern area of the then quarry wall.

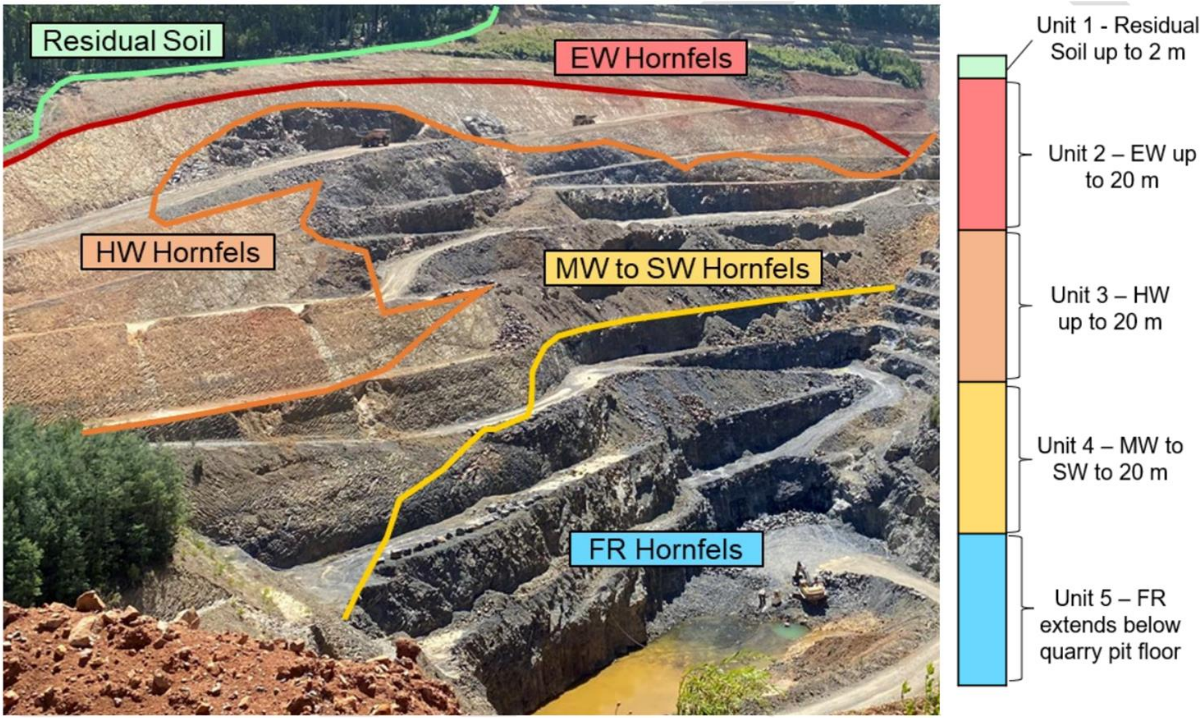


FIGURE 3.16 Hornfels Weathering Profile (GHD, 2022)

PLATE 3.2 Steeply Dipping Hornfels Exposed in Quarry Pit Wall (2009 photograph)

4.0 HYDROGEOLOGY

4.1 AQUIFER TYPE AND CHACARTERISTICS

The hornfels quarried at WA375 are part of an extensive aquifer system that includes all of the outcropping Silurian-Devonian bedrock in the Yarra catchment. The hydraulic characteristics of these rocks are broadly similar and are commonly grouped as “groundwater basement” in regional hydrogeological assessments.

Fresh (unweathered) bedrock generally behaves hydraulically as fractured rock aquifers with groundwater stored and transmitted predominantly through secondary joints and fractures. The groundwater storage and transmitting capacity of the fractured rocks depends on the frequency and openness of fractures and joints, roughness of fracture walls and the degree of interconnection of all discontinuities in the rock mass. Deeply weathered rock above the fresher rock can function as porous media type aquifers with groundwater movement through the interconnected pores in the rock mass.

The outcropping Siluro-Devonian rocks are commonly considered as a regional unconfined aquifer, but weathering generally forms thick fine grained, low permeability clay and silts that have high porosity but low specific yields that “confining” the groundwater to varying degrees forming semi-unconfined to at the extreme, confined aquifers. Lower permeability weathered profiles can restrict both recharge and discharges fluxes.

Hydraulic characteristics of the hornfels and the other fracture rocks in the WA375 area have not been tested but the various coefficients are expected to be small based on information on similar rocks elsewhere in Victoria and values reported in the scientific literature. Domenico and Schwartz (1990) reported a hydraulic conductivity (K) range for siltstone from 8.64×10^{-7} to 1.21×10^{-3} m/day. Morris and Johnson (1967) summarised analytical data from 42 USS States and determined that extreme minimum and maximum K values of 3.048×10^{-7} and 0.01219 m/day respectively, with likely range from 3.048×10^{-6} to 0.0015 m/day. The Port Phillip and Western Port regional groundwater flow models was calibrated with a hydraulic conductivity for the fractured bedrock of 0.03 m/day (GHD, 2010). A less extensive regional model for the East-West Link was calibrated with a hydraulic conductivity up to 0.07 m/day (SKM, 2013).

The permeability and porosity of fractured bedrock aquifers have been shown generally to decrease with depth (Daniel et al, 1997; Davis and Turk, 1964). Snow (1968) reported that the permeability of fractured bedrock aquifers tends to become exceedingly small at depths 60 to 90 m below land surface consequently the effective saturated thickness may be 60 to 90 m or less.

The local fractured bedrocks are generally low productivity aquifers with bore yields in the range 0.05 to 4 L/sec based on recorded yields from bedrock aquifers in the Yarra Catchment. Groundwater salinity varies from low (< 400 mg/LTDS) to moderate (1,600 mg/L TDS).

4.2 GROUNDWATER FLOW

Groundwater recharge is via direct infiltration of rainwater. The near-surface geologic materials and the structure and permeability of the underlying rock control direct infiltration and the generation of runoff, and whether basins are likely to be dominated by runoff or by infiltration and groundwater recharge directly. For example, infiltration into high permeability soils reduces the amount of runoff whereas low permeability rocks allow little infiltration creating greater potential for runoff. Large-scale geologic features and properties (e.g., faults and fractures), sloping strata, matrix permeability, and degree of weathering all influence deeper movement of water through the subsurface.

Groundwater in the WA375 area flows from recharge areas at higher elevations north and northeast of WA375 in a sub-radial direction towards the Yarra River which is the main discharge area of the local and intermediate flow systems that develop in the area (Figure 4.1). [Base flow which is the groundwater portion of total stream flow in the Yarra has been estimated to be as high as 69% of total stream flow ()]. Discharge probably also occurs into the depressions and the many small tributaries across the Yarra flood plain, and into the lower reaches of Ure Creek.

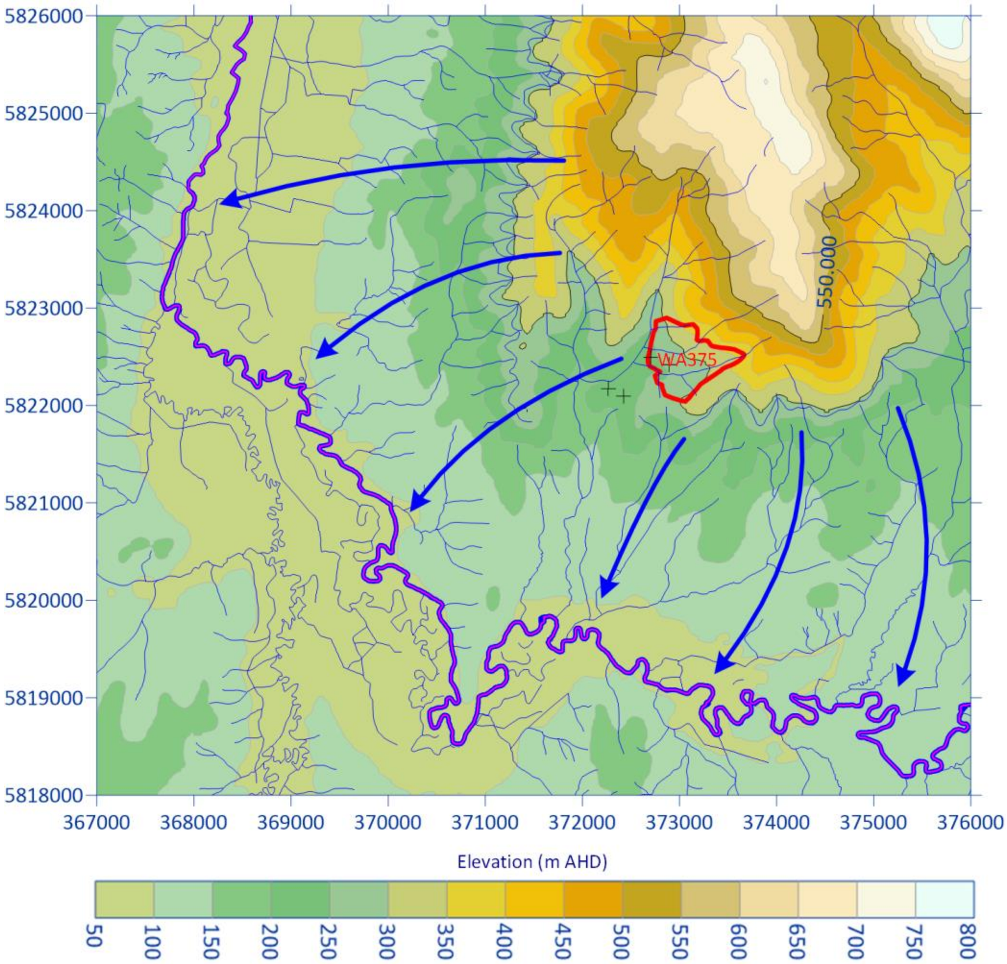


FIGURE 4.1 Generalized Groundwater Flow Directions

Three-dimensional mapping of the topography (generated from 2016 Lidar elevation data) and the groundwater elevation in the 4 bores monitored by DPQ indicates that the water table is below the bed of the "Moora Creek" (Figure 4.2).

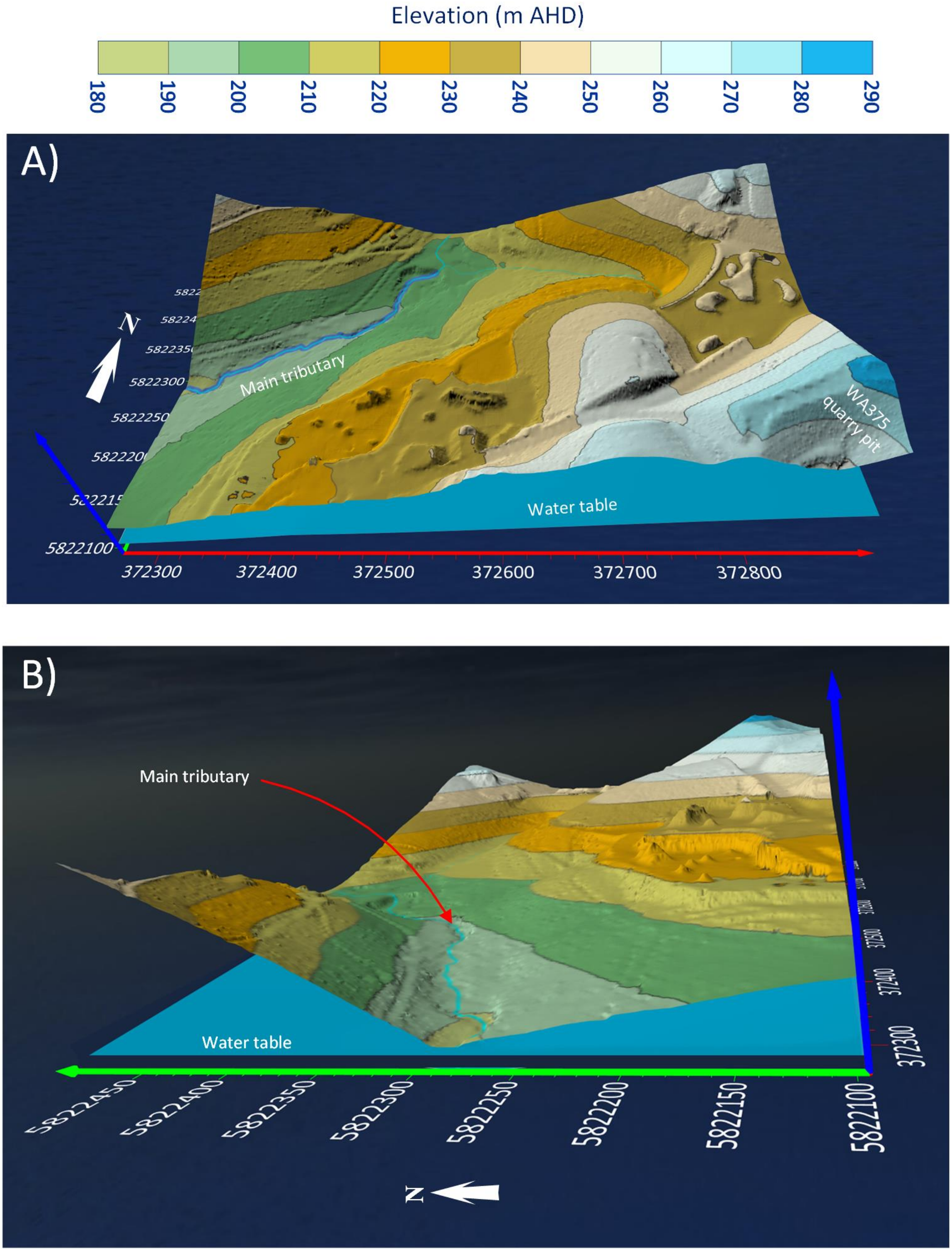


FIGURE 4.2 Water Table-Ground Surface Visualisation

4.3 GROUNDWATER RECHARGE

In hilly terrain, groundwater flow is generated only by the infiltration of surface water. The quantity of recharge that reaches the water table depends on rainfall amount, evapotranspiration, runoff and infiltration. Near-surface geologic materials, degree of weathering and the structure and permeability of the underlying bedrock and local topography control the quantity of direct infiltration and the generation of runoff, and whether basins are likely to be dominated by runoff or by infiltration and groundwater. For example, infiltration into high permeability soils reduces the amount of runoff whereas low permeability rocks allow little infiltration creating greater potential for runoff. Large-scale geologic features and properties (e.g., faults and fractures), sloping strata, matrix permeability, and degree of weathering all influence deeper movement of water through the subsurface.

4.3.1 Recharge Estimate Methodology

Groundwater recharge cannot be directly measured but can be estimated indirectly using the Chloride Mass Balance Method (CMB). Chloride is excluded from evapotranspiration; thus, assuming no change in salt storage over very long time periods, chloride fluxes provide valuable constraints for recharge rates within basins which can be used to constrain the hydraulic conductivity of aquifers and estimates of groundwater flow rates.

$$R = P\,(Cl_p / Cl_{gw})$$

where

R is the recharge.
P is precipitation across the catchment.
Cl_p is the chloride in rainfall.
Cl_{gw} is the chloride in groundwater.

Assumptions that underpin the CMB were summarized by Wood (1999), are:

- Chloride in groundwater is only sourced from rainfall (not rock weathering or interactions with streams or deeper aquifers).
- Chloride is conservative in the system (no sources or sinks).
- The chloride flux does not change over time (steady state conditions).
- There is no recycling of chloride in the system

Recharge was calculated using rainfall chlorinity derived from 1) analysis of the rainfall sample collected at WA375 in December 2022, and 2) estimated by interpolating from Cl concentrations recorded at climate stations across southeastern Australia published by CSIRO (2021).

WA375 Rainfall Chlorinity

The chloride concentration in the tested rainfall sample collected in December 2022 was less than the Limit of Reporting (LOR) (1 mg/L) for the method used by Eurofins analytical laboratory. For calculation purposes, the Cl concentration was assumed to be equal to the LOR (1 mg/L).

CSIRO Rainfall Chloride Concentration Mapping

Extensive studies have been carried out on chloride in rainfall across Australia. The chloride ion concentration in rainfall decreases with increased distance from the coast. A range of 1 to 6 mg/L chloride occurs across Eastern Victoria (Blackburn and McLeod, 1983; Crosbie *et al*., 2012; Hutton and Leslie, 1958; CSIRO, 2021). The chlorinity of precipitation derived by gridding and contouring the rainfall chlorinity data in CSIRO (2021) is shown for south-central Victorian in Figure 4.3. Interpolation of the chlorinity contours indicates that the chlorinity of precipitation in the WA375 area is about 3.9 mg/L.

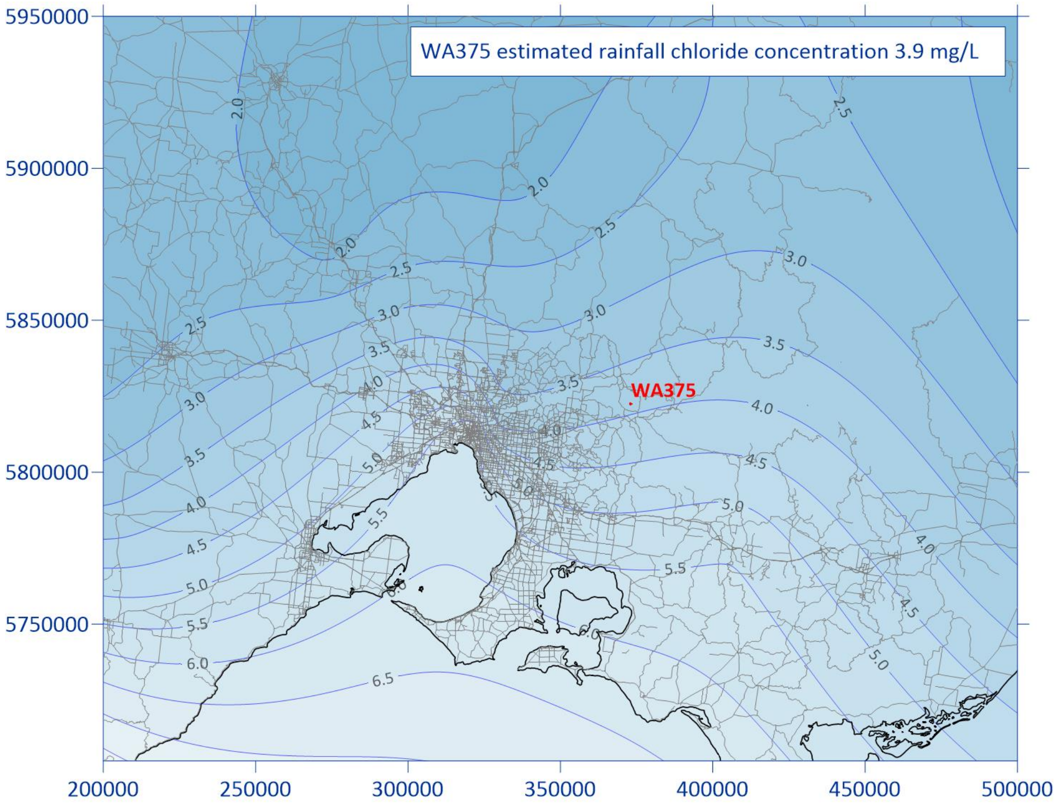


FIGURE 4.3 South-Central Victoria Rainfall Chlorinity (derived from CSIRO 2021 Data Set)

4.3.2 WA375 Area Groundwater Chlorinity

Groundwater chloride ion concentrations measured during 2022 are presented in Table 4.2.

TABLE 4.2 Groundwater Chloride Concentrations

Bore	Feb-22	Jun-22	Sep-22	Dec-22	Bore	Feb-22	Jun-22	Sep-22	Dec-22
GW1	250	230	240	230	**GW3**	310	310	320	250
GW2	300	310	340	220	**GW4**	240	200	190	170

Note: units are mg/L.

4.3.3 Estimated Recharge WA375 Area

Recharge rates were estimated for different rainfall and groundwater chlorinity data pairs, and the average rainfall measured at WA375 during the 2009 to 2022 period (Table 4.6).

TABLE 4.6 CMB Estimated Groundwater Recharge

Rainfall		Groundwater			Recharge, R			
Average Annual (mm)	**Chlorinity Cl_p (mg/L)**	**Bore ID**	**Sample Date**	**Chlorinity Cl_p (mg/L)**	**Amount (mm/yr)**	**Average (mm/yr)**	**Per cent Annual Rainfall**	**Average Per cent**
995	1	GW1	Feb-22	250	3.98		0.40	
995	1	GW1	Jun-22	230	4.33		0.43	
995	1	GW1	Sep-22	240	4.15		0.42	
995	1	GW1	Dec-22	230	4.33	4.19	0.43	0.42
995	1	GW2	Feb-22	300	3.32		0.33	
995	1	GW2	Jun-22	310	3.21		0.32	
995	1	GW2	Sep-22	340	2.93		0.29	
995	1	GW2	Dec-22	220	4.52	3.49	0.45	0.35
995	1	GW3	Feb-22	310	3.21		0.32	
995	1	GW3	Jun-22	310	3.21		0.32	
995	1	GW3	Sep-22	320	3.11		0.31	
995	1	GW3	Dec-22	250	3.98	3.38	0.40	0.34
995	1	GW4	Feb-22	240	4.15		0.42	
995	1	GW4	Jun-22	200	4.98		0.50	
995	1	GW4	Sep-22	190	5.24		0.53	
995	1	GW4	Dec-22	170	5.85	5.05	0.59	0.51
				Average	**4.03**	**4.03**	**0.40**	**0.40**
995	4	GW1	Feb-22	250	15.92		1.60	
995	4	GW1	Jun-22	230	17.30		1.74	
995	4	GW1	Sep-22	240	16.58		1.67	
995	4	GW1	Dec-22	230	17.30	16.78	1.74	1.69
995	4	GW2	Feb-22	300	13.27		1.33	
995	4	GW2	Jun-22	310	12.84		1.29	
995	4	GW2	Sep-22	340	11.71		1.18	
995	4	GW2	Dec-22	220	18.09	13.98	1.82	1.40
995	4	GW3	Feb-22	310	12.84		1.29	
995	4	GW3	Jun-22	310	12.84		1.29	
995	4	GW3	Sep-22	320	12.44		1.25	
995	4	GW3	Dec-22	250	15.92	13.51	1.60	1.36
995	4	GW4	Feb-22	240	16.58		1.67	
995	4	GW4	Jun-22	200	19.90		2.00	
995	4	GW4	Sep-22	190	20.95		2.11	
995	4	GW4	Dec-22	170	23.41	20.21	2.35	2.03
				Average	**16.12**	**16.12**	**1.62**	**1.62**

The annual groundwater recharge based on the measured chlorinity of the WA375 rainfall sample and the chlorinity in the tested 2022 groundwater samples was 0.4 per cent of the 10-year average annual rainfall recorded at WA375 or 1.6 per cent based on the rainfall chlorinity interpolated from the CSIRO dataset. The estimated low rainfall recharge is consistent with a value 1% estimated by Leonard (1992), and with the mapped high stream density in the Upper Yarra Catchment and the general dendritic stream pattern. [Dendritic drainage patterns typically form V-shaped valleys in areas of “impervious, non-porous rocks” (Lambert, 1989).]

5.1 SITE INVESTIGATIONS

5.1 ROCK RESOURCES DRILLING

BCA conducted a rock resources investigation drilling program in the area of the proposed quarry pit extension during 2008. The results of the investigation program were presented in a report titled ‘Drilling Data Summary - Woori Yallock Quarry’, dated 14 July 2010 (BCA Reference No. D10-001). drilling campaign consisted of 49 percussion drill holes and 5 diamond drill holes. Drilling details area summarised in Table 5.1. Drillhole locations are mapped on a 2010 Google Earth Satellite Image base and shown as a “true” 3D Visualisation in Figure 5.1.

TABLE 5.1 WA375 Rock Resource Investigation Drillhole Details

Drillhole	MGA E	MGA N	Depth (m)	RLGL (m AHD)	Drillhole	MGA E	MGA N	Depth (m)	RLGL (m AHD)
P08-01	372798	5822181	27.0	254.5	P08-28	372876	5822512	25.2	265.4
P08-02	372885	5822263	25.2	250.0	P08-29	373165	5822487	25.2	300.2
P08-03	372981	5822289	23.4	250.0	P08-30	373122	5822539	25.2	302.9
P08-04	372964	5822358	21.6	248.0	P08-31	373007	5822436	25.2	276.3
P08-05	373061	5822373	25.2	259.0	P08-32	372987	5822521	25.2	275.1
P08-06	373137	5822393	25.2	267.0	P08-33	372746	5822513	25.2	244.5
P08-07	373259	5822401	25.2	280.0	P08-34	372719	5822502	25.2	239.7
P08-08	372879	5822188	25.2	264.0	P08-35	372987	5822573	14.4	266.7
P08-09	372969	5822121	23.4	274.0	P08-36	372853	5822624	25.2	264.2
P08-10	373296	5822411	23.4	284.0	P08-37	372793	5822671	25.2	262.2
P08-11	373332	5822420	25.2	288.0	P08-38	372786	5822718	25.2	262.2
P08-12	373379	5822437	21.6	295.0	P08-39	372807	5822753	25.2	265.2
P08-13	373413	5822457	19.8	302.0	P08-40	372942	5822774	25.2	295.1
P08-14	373450	5822481	14.4	310.0	P08-41	372936	5822730	25.2	299.2
P08-15	373483	5822501	21.6	320.0	P08-42	373015	5822670	25.2	298.8
P08-16	373268	5822610	25.2	339.9	P08-43	372946	5822696	25.2	296.9
P08-17	373173	5822535	25.2	311.0	P08-44	373040	5822740	25.2	328.0
P08-18	373116	5822502	25.2	300.6	P08-45	373063	5822785	25.2	332.1
P08-19	373210	5822565	25.2	320.3	P08-46	373100	5822735	25.2	336.1
P08-20	373142	5822516	25.2	304.8	P08-47	373087	5822753	25.2	337.6
P08-21	373049	5822490	25.2	292.5	P08-48	372933	5822844	25.2	289.8
P08-22	373305	5822579	25.2	337.0	P08-49	372898	5822911	25.2	311.9
P08-23	373349	5822557	25.2	333.9	D08-01	372883	5822507	147.0	266.0
P08-24	373243	5822522	25.2	313.0	D08-02	373131	5822492	64.0	299.0
P08-25	373210	5822609	25.2	320.7	D08-03	372714	5822505	51.0	238.0
P08-26	372979	5822494	25.2	278.6	D08-04	372957	5822692	70.2	297.0
P08-27	372914	5822504	25.2	267.4	D08-05	372957	5822692	56.2	263.0

Notes P prefix = Percussion drillholes; D prefix = Diamond drillhole.

5.2 MONITORING BORES

Three purpose designed monitoring bores were installed during February 2022 by Matthew & Sons Drilling Services Pty Ltd (licensed driller Matthew Englebrecht) under Works Licence Number WLE082642 issued by Southern Rural Water (SRW). The bore Works/Bore IDs were WRK13016, WRK13017 and WRK13018 but designated as B, A and GB respectively on the Borehole Survey plan (Figure 5.1) by Landair (job Number 2220216

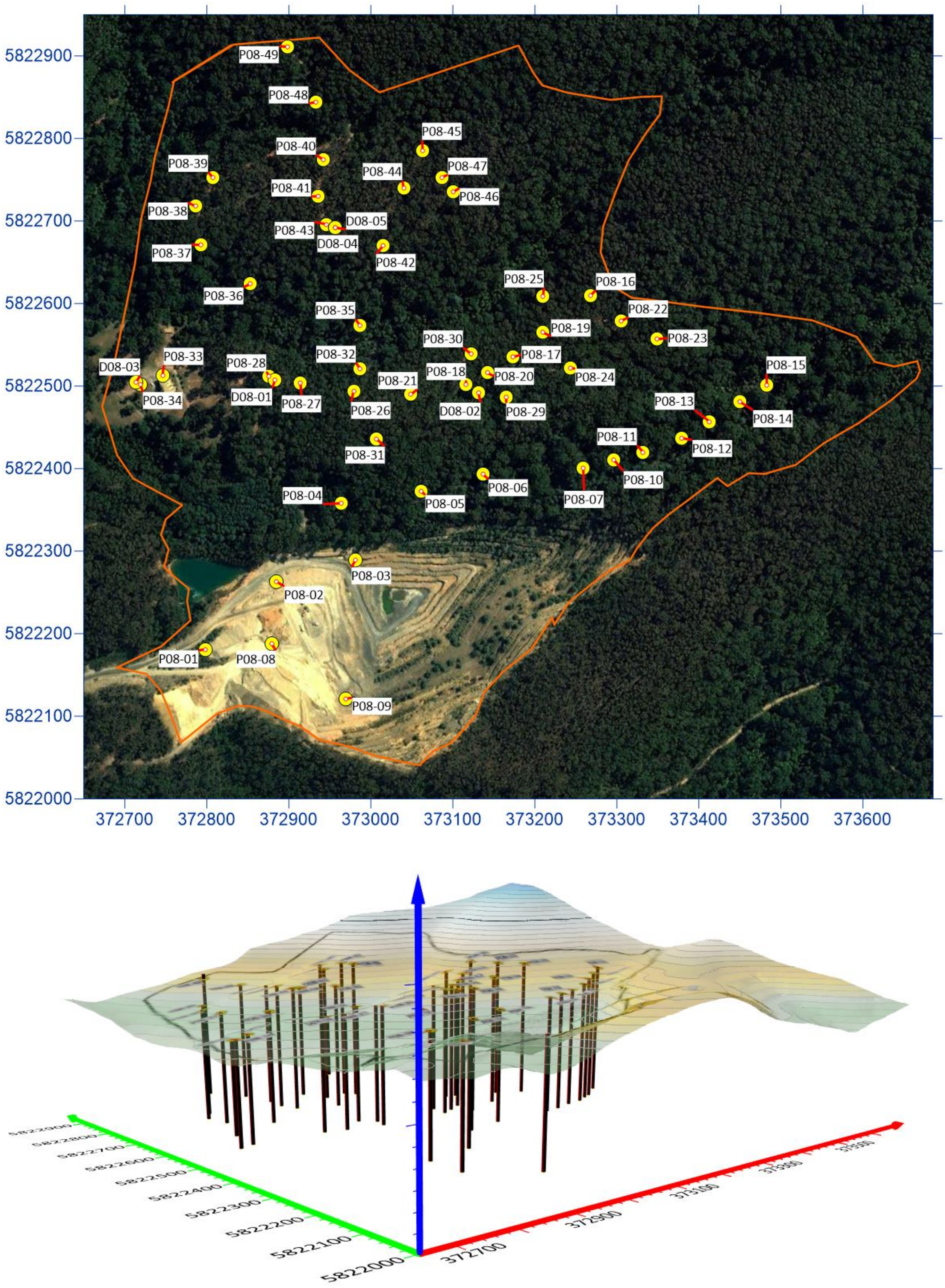
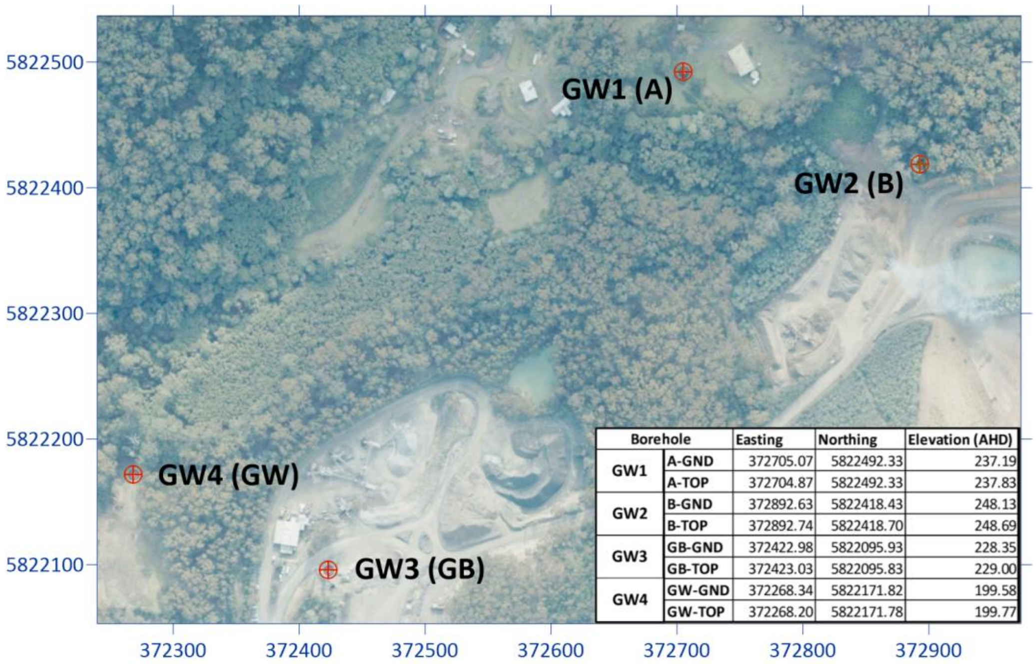


FIGURE 5.1 Rock Investigation Drillhole Locations (2010 Google Earth Base Image) and Drillhole 3D Visualisation

survey date 22/02/2022) and changed to consistent "GW" identifier prefix by BCA. (A=GW1, B=GW2, GB=GW3). The Bore Completion Reports for these 3 bores are included in Appendix A. Key bore details are summarised in Table 5.1, and lithologic logs (logged by respective drilling contractors) for the 3 bores installed during February 2022 and the existing bore on land now owned by DPQ (bore 66222) are provided in Table 5.2.



Borehole		Easting	Northing	Elevation (AHD)
GW1	A-GND	372705.07	5822492.33	237.19
	A-TOP	372704.87	5822492.33	237.83
GW2	B-GND	372892.63	5822418.43	248.13
	B-TOP	372892.74	5822418.70	248.69
GW3	GB-GND	372422.98	5822095.93	228.35
	GB-TOP	372423.03	5822095.83	229.00
GW4	GW-GND	372268.34	5822171.82	199.58
	GW-TOP	372268.20	5822171.78	199.77

FIGURE 5.2 WA375 Monitoring Bore Locations (modified Landair Borehole Survey Plan)

The bores installed by DPQ were all completed with nominal 100 mm diameter Class 12 uPVC casing and with factory slotted screen sections. A filter pack material was placed around the screen section and a bentonite plug and rubber seals were placed above the filter pack. The annulus between the hole wall and the casing above the seal was backfilled with drill cuttings. The headworks were completed with steel standpipe which was concreted into the ground.

TABLE 5.1 WA375 Monitoring Bore Details

Bore	WMIS Bore Identifier	MGA Coordinates		RLNS (m AHD)	RLTC (m AHD)	S/U (m)	Depth (m bgl)	Dia. (mm)	Screens (m bgl)	
		Easting	Northing						From	To
GW1	WRK130817	372704.87	5822492.33	237.19	237.83	0.64	42.00	100	38.00	41.00
GW2	WRK130816	372892.74	5822418.70	248.13	248.69	0.56	78.00	100	74.00	77.00
GW3	WRK130818	372423.03	5822095.83	228.35	229.00	0.65	63.00	100	59.00	62.00
GW4	66222	372268.20	5822171.78	199.58	199.77	0.19	58.4	200	30.00	58.40

Notes: 1) Bore cross reference GW1=A, GW=B and GB=C; 2) WL; Works Licence, 3) RLNS, Reduced Level Natural Surface, 4) RL TC, Reduced Level Top Casing, 5) S/U, casing Stick-Up; 6) Dia., nominal casing/screen string diameter, 7) m AHD, metres Australian Height Datum, and 8) m bgl metres below ground level.

TABLE 5.2 Lithological Logs, WA375 Monitoring Bore

Bore	SRW ID	From (m)	To (m)	Lithology
GW1	WRK130817	0.00	1.00	Fill
		1.00	3.00	Soil
		3.00	18.00	Siltstone - weathered - soft - yellow
		18.00	27.00	Siltstone - weathered - grey
		27.00	36.00	Siltstone - medium - grey
		36.00	42.00	Siltstone - medium/hard - grey
GW2	WRK130816	0.00	1.00	Soil
		1.00	14.00	Siltstone - weathered - soft -yellow
		14.00	38.00	Siltstone - medium - grey
		38.00	62.00	Siltstone - medium/hard -grey
		62.00	78.00	Siltstone - hard - grey
GW3	WRK130818	0.00	0.20	Fill
		0.20	2.00	Siltstone - weathered -soft
		2.00	24.00	Siltstone - medium weathered - yellow
		24.00	36.00	Siltstone - medium - grey
		36.00	55.00	Shale
		55.00	63.00	Siltstone - hard - grey
GW4	66222	0.00	0.30	Topsoil
		0.30	1.20	Yellow clay
		1.20	3.60	Red clay
		3.60	19.80	Yellow/orange mudstone
		19.80	33.50	Green medium hard mudstone
		33.50	54.80	Blue /grey hard mudstone with fractures

The fourth monitored bore is a private bore on land purchased by DPQ. This bore was designated as “GB” on the Landair Borehole Survey plan but was changed to “GW4” by BCA. The plotted position of GW4 was close to bore 66222 on the WMIS interactive web site (the coordinates of the private bores in the WMIS database were not surveyed and can be very inaccurate).

5.3 SURFACE WATER SAMPLING SITES

DPQ commenced monitoring surface water quality in April 2010 to provide baseline surface water chemistry data. The surface water monitoring sites were initially identified based on their physical location (e.g., Ure Creek Upstream) but the site designations were changed by simplifying the site descriptors (e.g., SW1, SW2, etc.). The 2022 sampling locations are plotted on a satellite image base in Figure 5.

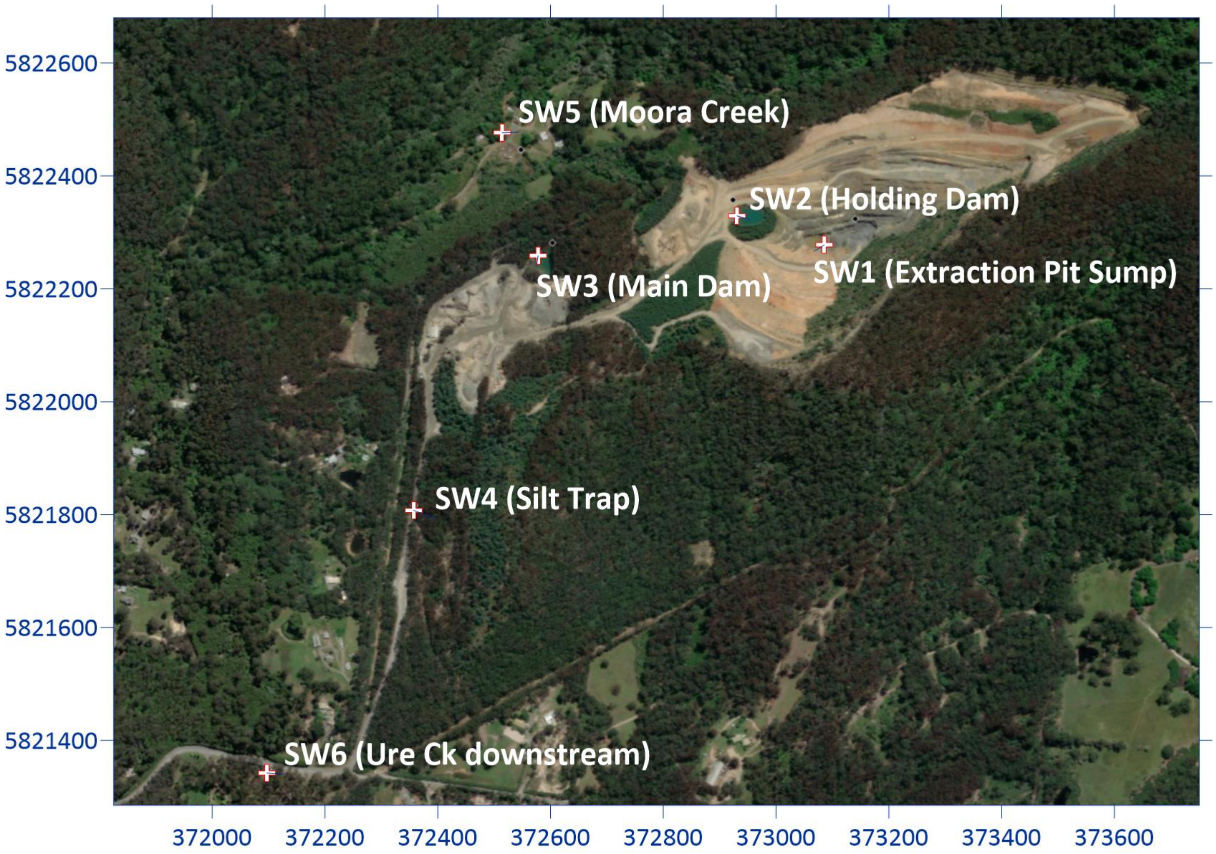


FIGURE 5.3 WA375 Surface Water Monitoring Locations

6.0 WATER MONITORING RESULTS

6.1 GROUNDWATER MONITORING

Groundwater in the 3 purpose installed monitoring bores and in a pre-existing bore (GW4) on land now owned by DPQ were monitored 4 times during 2022 (February, June, September, December. Groundwater samples collected during each monitoring event were tested in the field for acidity (pH), electrical conductivity, dissolved oxygen, redox potential (Eh) and temperature. The samples were also analysed for Total Dissolved Solids, Sodium, Potassium, Calcium, Magnesium, Chloride, Bicarbonate Alkalinity (as HCO3), Carbonate Alkalinity (as CaCO3), Sulphate (as SO4), Bicarbonate Alkalinity (as CaCO3), Hydroxide Alkalinity (as CaCO3), Total Alkalinity (as CaCO3), Conductivity (at 25°C), pH (at 25 °C), Nitrate & Nitrite (as N), Nitrate (as N), Ammonia (as N), Nitrite (as N), Organic Nitrogen (as N), Total Kjeldahl Nitrogen (as N), Total Nitrogen (as N), Phosphate total (as P), Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, and Zinc.

6.1.1 Groundwater Levels

Groundwater level monitoring results are summarised in Table 6.1. The standing water levels, measured in the WA375 monitoring bores during 2022 varied from about 12 to 30 m bgl. Comparison of the screen depths in the monitoring bores and the water levels measured during February 2022 showed that the water level was between about 19 and 50 m above the top of the screened interval (Table 6.2).

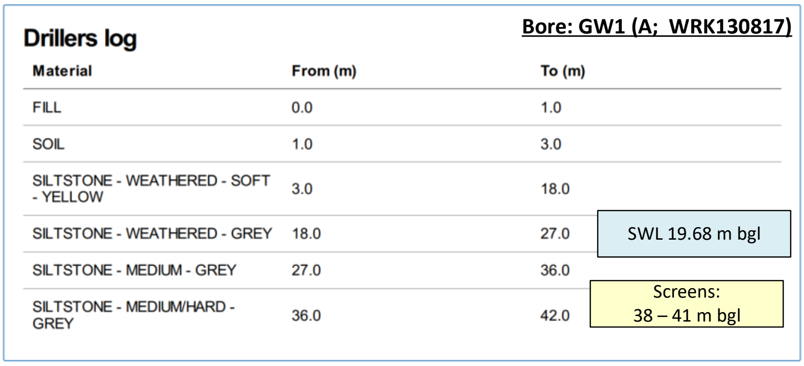
TABLE 6.1 WA375 Groundwater Level Monitoring Results

Date	Water Depth Below Ground (m)				Water Depth Below Top Casing (m)				Water Level Elevation (m AHD)			
	GW1	GW2	GW3	GW4	GW1	GW2	GW3	GW4	GW1	GW2	GW3	GW4
18-Feb-22	19.68	23.62	29.75	13.67	20.32	24.18	30.40	13.86	217.52	224.52	198.61	185.92
16-Jun-22	20.56	21.27	29.75	13.58	21.20	21.83	30.40	13.77	216.63	226.86	198.60	186.00
26-Sep-22	18.24	18.20	29.46	12.95	18.88	18.76	30.11	13.14	218.96	229.93	198.89	186.64
12-Dec-22	16.83	18.37	28.71	12.40	17.47	18.93	29.36	12.59	220.37	229.76	199.65	187.18

The water level elevation in GW1, GW2, GW3 and GW4 varied by 3.73, 5.42, 1.05 and 1.26 m, respectively. The difference in the fluctuation range reflects the different effective porosity at the different bores with lower porosity resulting in larger fluctuations (assuming that recharge is consistent across the local area).

Bore hydrographs (transient water level elevation versus time plots) for the 4 monitoring bores are shown in Figure 6.1, Daily rainfall histogram are also shown in Figure 6.1. The hydrographs exhibit increasing water elevation trends particularly post June in all bores except GW2 were the increasing trend started post February 2022 (and stabilised earlier in September) in response to the observed winter-spring-early summer wet conditions.

TABLE 6.2 WA375 Monitoring Bore Logs, Bore Screened Intervals and February 2022 SWLs



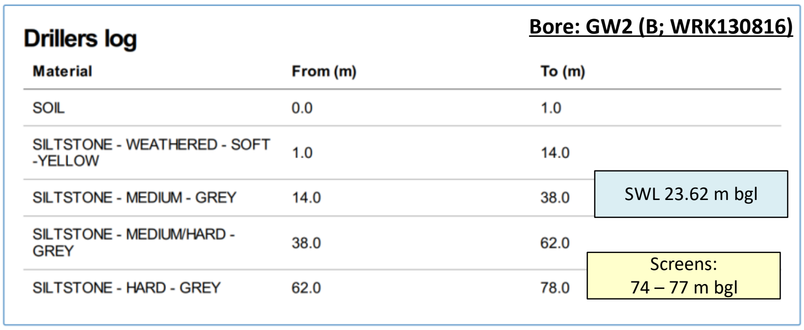
Bore: GW1 (A; WRK130817)

Drillers log

Material	From (m)	To (m)
FILL	0.0	1.0
SOIL	1.0	3.0
SILTSTONE - WEATHERED - SOFT - YELLOW	3.0	18.0
SILTSTONE - WEATHERED - GREY	18.0	27.0
SILTSTONE - MEDIUM - GREY	27.0	36.0
SILTSTONE - MEDIUM/HARD - GREY	36.0	42.0

SWL 19.68 m bgl

Screens:
38 – 41 m bgl



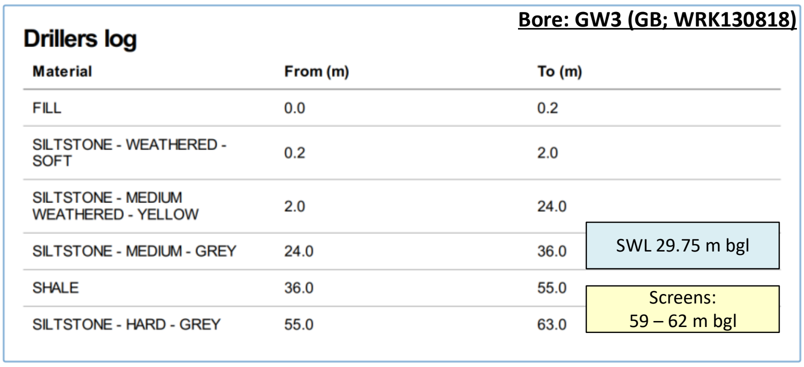
Bore: GW2 (B; WRK130816)

Drillers log

Material	From (m)	To (m)
SOIL	0.0	1.0
SILTSTONE - WEATHERED - SOFT -YELLOW	1.0	14.0
SILTSTONE - MEDIUM - GREY	14.0	38.0
SILTSTONE - MEDIUM/HARD - GREY	38.0	62.0
SILTSTONE - HARD - GREY	62.0	78.0

SWL 23.62 m bgl

Screens:
74 – 77 m bgl



Bore: GW3 (GB; WRK130818)

Drillers log

Material	From (m)	To (m)
FILL	0.0	0.2
SILTSTONE - WEATHERED - SOFT	0.2	2.0
SILTSTONE - MEDIUM WEATHERED - YELLOW	2.0	24.0
SILTSTONE - MEDIUM - GREY	24.0	36.0
SHALE	36.0	55.0
SILTSTONE - HARD - GREY	55.0	63.0

SWL 29.75 m bgl

Screens:
59 – 62 m bgl

Water table elevation contours are presented in Figure 6.2. [Note that the gridding algorithm used assumes homogeneous, isotropic aquifer conditions.] The water table mapping indicates the groundwater flow direction through WA375 was from ENE to WSW and that the hydraulic gradient varied between the 2022 monitoring rounds from 0.059 to 0.064 (Table 6.3) with a representative gradient of about 0.06 . The gradients were all very steep consistent with flow through low permeability rocks.

TABLE 6.2 Hydraulic Gradient

Month	Δh (m)	Δl (m)	Gradient, i	Month	Δh (m)	Δl (m)	Gradient, i
Feb-22	22	375	0.059	Jun-22	20	340	0.059
Sep-22	20	320	0.063	Dec-22	20	312.5	0.064

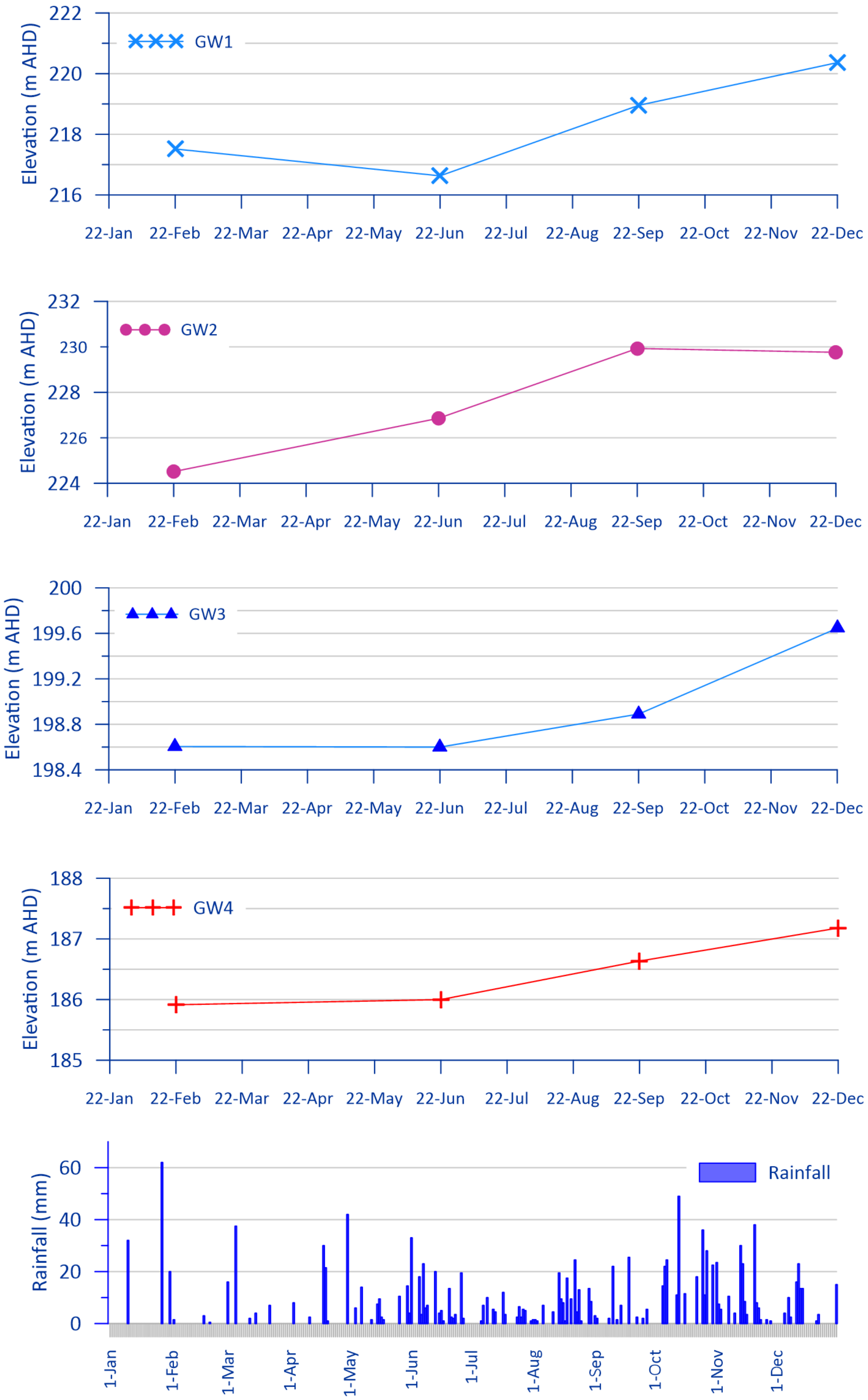


FIGURE 6.1 WA375 Monitoring Bore Hydrographs

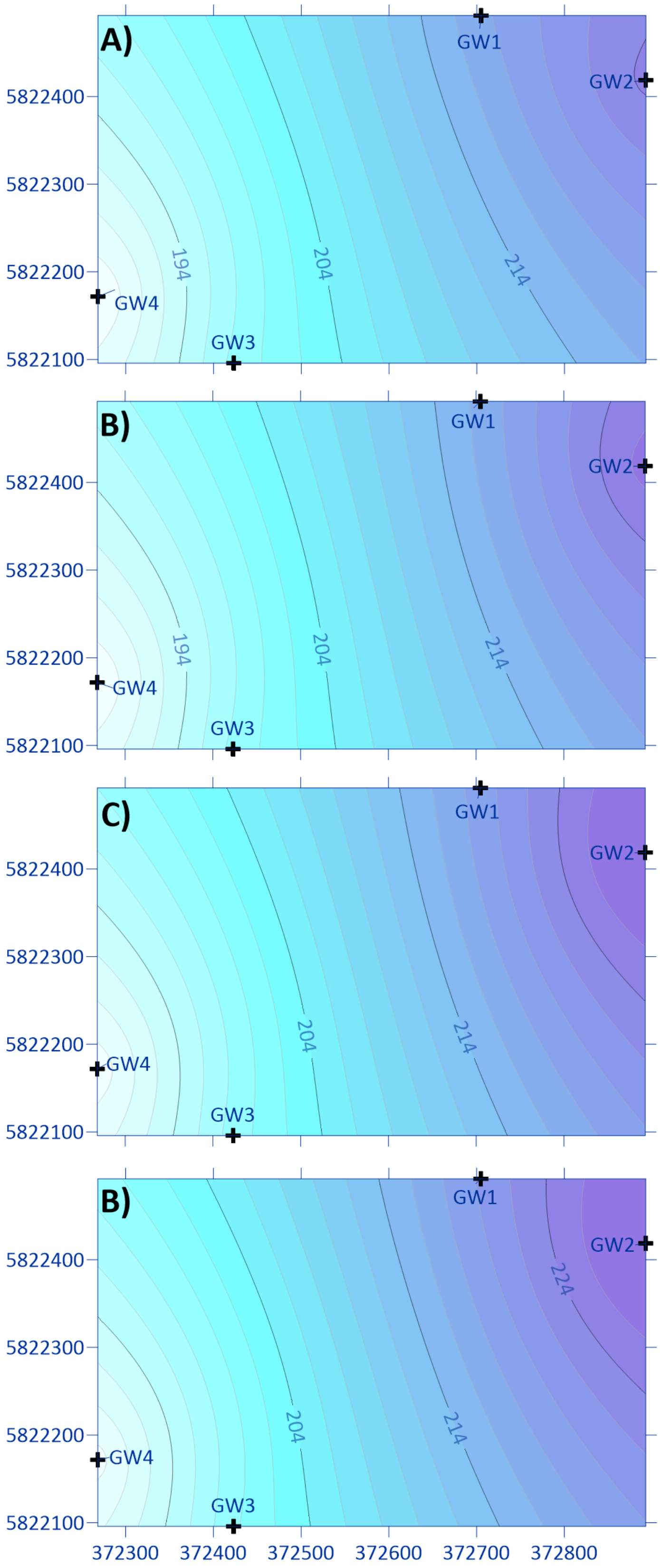


FIGURE 6.2 2022 Potentiometric Surface Contours, A) February, B) June, C) September, and D) December (Contours in m AHD)

6.1.2 Groundwater Chemistry

Groundwater laboratory analyses and measured field parameters are presented in Table 6.1 and Table 6.2. The assessed water types of each of the samples tested are also presented in Tables 6.1 and 6.2. TDS concentrations versus time trends are plotted in Figure 6.3 and isosalines (TDS concentration contours) for each of the 4 monitoring events are plotted in Figure 6.4.

TABLE 6.1 GW1 and GW2 2022 Groundwater Testing Analysis Results

Analyte	**GW1**				**GW2**			
	Feb-22	**Jun-22**	**Sep-22**	**Dec-22**	**Feb-22**	**Jun-22**	**Sep-22**	**Dec-22**
Total Dissolved Solids	680	480	540	560	1000	930	1100	980
Electrical Conductivity	1000	860	820	960	1500	1500	1900	1500
Sodium	130	140	170	100	130	140	180	88
Potassium	6.0	5.3	4.4	5.2	4.6	5.1	4.7	4.5
Calcium	22	13	7.2	18	120	130	120	96
Magnesium	22	18	16	18	34	34	32	28
Chloride	250	230	240	230	300	310	340	220
Sulphate (as SO4)	27	9.4	8.1	16	83	73	77	63
Bicarbonate Alkalinity (as HCO3)	62	52	48	37	268	342	537	488
Carbonate Alkalinity (as CaCO3)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Bicarbonate Alkalinity (as CaCO3)	51	43	39	30	220	280	440	400
Hydroxide Alkalinity (as CaCO3)	<20	<20	<20	<20	<20	<20	<20	<20
Total Alkalinity (as CaCO3)	51	43	39	30	220	280	440	400
Nitrate & Nitrite (as N)	1.3	1.5	1.7	0.95	<0.05	<0.05	0.05	0.06
Nitrate (as N)	1.3	1.5	1.7	0.95	<0.02	<0.02	0.05	0.06
Ammonia (as N)	0.04	0.03	<0.01	<0.01	0.04	0.04	<0.01	<0.01
Nitrite (as N)	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Organic Nitrogen (as N)*	0.26	0.57	0.7	<0.2	0.36	0.36	0.4	1.1
Total Kjeldahl Nitrogen (as N)	0.3	0.6	0.7	<0.2	0.4	0.4	0.4	1.1
Total Nitrogen (as N)	1.6	2.1	2.4	0.95	0.4	0.4	0.45	1.16
Phosphate total (as P)	<0.05	0.02	0.06	0.17	<0.05	0.02	0.02	<0.01
Arsenic (filtered)		< 0.001	0.001	0.002		< 0.001	< 0.001	< 0.001
Cadmium (filtered)		< 0.0002	< 0.0002	< 0.0002		< 0.0002	< 0.0002	< 0.0002
Chromium (filtered)		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Copper (filtered)		0.001	0.003	< 0.001		< 0.001	< 0.001	< 0.001
Lead (filtered)		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Mercury (filtered)		< 0.0001	< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001
Nickel (filtered)		0.076	0.031	0.012		0.014	0.010	0.008
Zinc (filtered)		0.073	0.063	0.017		0.013	0.020	0.016
pH (laboratory)	7.5	6.6	6.7	7.6	8.1	7.8	7.3	8.0
pH (field)	5.71	5.67	5.6	5.79	6.81	7.02	7.05	6.87
Temperature (field)	20.1	12.2	14.3	13.9	19.2	13.3	13.5	13.4
Electrical Conductivity (field)	1047	855	691	988	1597	1435	1238	1074
Redox Potential (field)	-67	238	145	101	63	208	161	93
Dissolved Oxygen (field)	3.76	2.08	3.96	0.47	2.16	2.11	3.08	4.42
Water Type	Na-Cl	Na-Cl	Na-Cl	Na-Cl	Ca-Cl	Ca-Cl	Na-Cl	Na-HCO3

Notes 1): Units in mg/L except for pH which pH units, 2) Bicarbonate concentration reported as HCO3 as CaCO3 converted to bicarbonate ion concentration, and 3) water type determined by JLCS using the AqQA hydrochemical software program.

TABLE 6.2 GW3 and GW4 Groundwater Testing Results

Analyte	GW3				GW4			
	Feb-22	Jun-22	Sep-22	Dec-22	Feb-22	Jun-22	Sep-22	Dec-22
Total Dissolved Solids	710	620	830	620	690	510	450	420
Electrical Conductivity	1200	910	1200	990	1000	870	700	600
Sodium	140	230	190	95	110	160	150	89
Potassium	12	13	12	11	5.2	4.5	3.5	3.3
Calcium	11	13	12	6.6	42	33	22	16
Magnesium	30	28	28	24	29	23	18	17
Chloride	310	310	320	250	240	200	190	170
Sulphate (as SO4)	33	27	28	22	26	8.6	7.8	9.9
Bicarbonate Alkalinity (as HCO3)	88	159	116	112	90	95	88	63
Carbonate Alkalinity (as CaCO3)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Bicarbonate Alkalinity (as CaCO3)	72	130	95	92	74	78	72	52
Hydroxide Alkalinity (as CaCO3)	<20	<20	<20	<20	<20	<20	<20	<20
Total Alkalinity (as CaCO3)	72	130	95	92	74	78	72	52
Nitrate & Nitrite (as N)	<0.05	<0.05	0.31	0.07	<0.05	0.08	0.39	0.29
Nitrate (as N)	<0.02	<0.02	0.31	0.07	<0.02	0.08	0.39	0.29
Ammonia (as N)	0.07	0.05	<0.01	<0.01	0.04	0.05	<0.01	<0.01
Nitrite (as N)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Organic Nitrogen (as N)*	0.83	_	0.4	<0.2	_	<0.2	0.4	0.5
Total Kjeldahl Nitrogen (as N)	0.9	<0.2	0.4	<0.2	<0.2	0.2	0.4	0.5
Total Nitrogen (as N)	0.9	<0.2	0.71	<0.2	<0.2	0.28	0.79	0.79
Phosphate total (as P)	0.24	0.10	0.03	0.04	0.11	0.07	0.02	0.01
Arsenic (filtered)		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Cadmium (filtered)		< 0.0002	< 0.0002	< 0.0002		< 0.0002	< 0.0002	< 0.0002
Chromium (filtered)		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Copper (filtered)		< 0.001	0.002	< 0.001		< 0.001	< 0.001	< 0.001
Lead (filtered)		< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001
Mercury (filtered)		< 0.0001	< 0.0001	< 0.0001		< 0.0001	< 0.0001	< 0.0001
Nickel (filtered)		0.027	0.034	0.028		0.007	0.008	0.010
Zinc (filtered)		0.077	0.079	0.037		0.051	0.11	0.049
pH (laboratory)	7.7	7.1	6.7	7.4	7.9	6.6	7.0	7.7
pH (field)	5.85	6.05	6.12	5.96	6.03	5.92	5.81	5.65
Temperature (field)	21.9	11.3	15.4	16.4	19.2	13.5	14	14.9
Electrical Conductivity (field)	1301	1095	1003	916	1114	786	577	498
Redox Potential (field)	22	239	166	116	50	159	179	121
Dissolved Oxygen (field)	2.56	4.61	6.01	1.2	0.5	1.23	1.98	0.62
Water Type	Na-Cl	Na-Cl	Na-Cl	Na-Cl	Ca-Cl	Ca-Cl	Na-Cl	Na-HCO3

Notes 1): Units in mg/L except for pH which pH units, 2) Bicarbonate concentration reported as HCO3 as CaCO3 converted to bicarbonate ion concentration, and 3) water type determined by JLCS using the AqQA hydrochemical software program.

Total Dissolved Solids (TDS) concentration (a key determinant in assessing potential impact of quarrying operations on groundwater) in the analysed groundwater samples varied from 680 to 1,000 mg/L in the February samples, 480 to 930 mg/L in the June samples, 450 to 1,100 mg/L in the September samples, and 420 to 980 mg/L in the December samples. The highest salinity was consistently in the eastern up-hydraulic gradient bores. This finding was unexpected as groundwater salinity generally increases with increasing distance along groundwater flow paths and reflects the complex hydrogeology of varyingly weathered and fractured rocks where water chemistry and hydraulic head can change significantly over short distances.

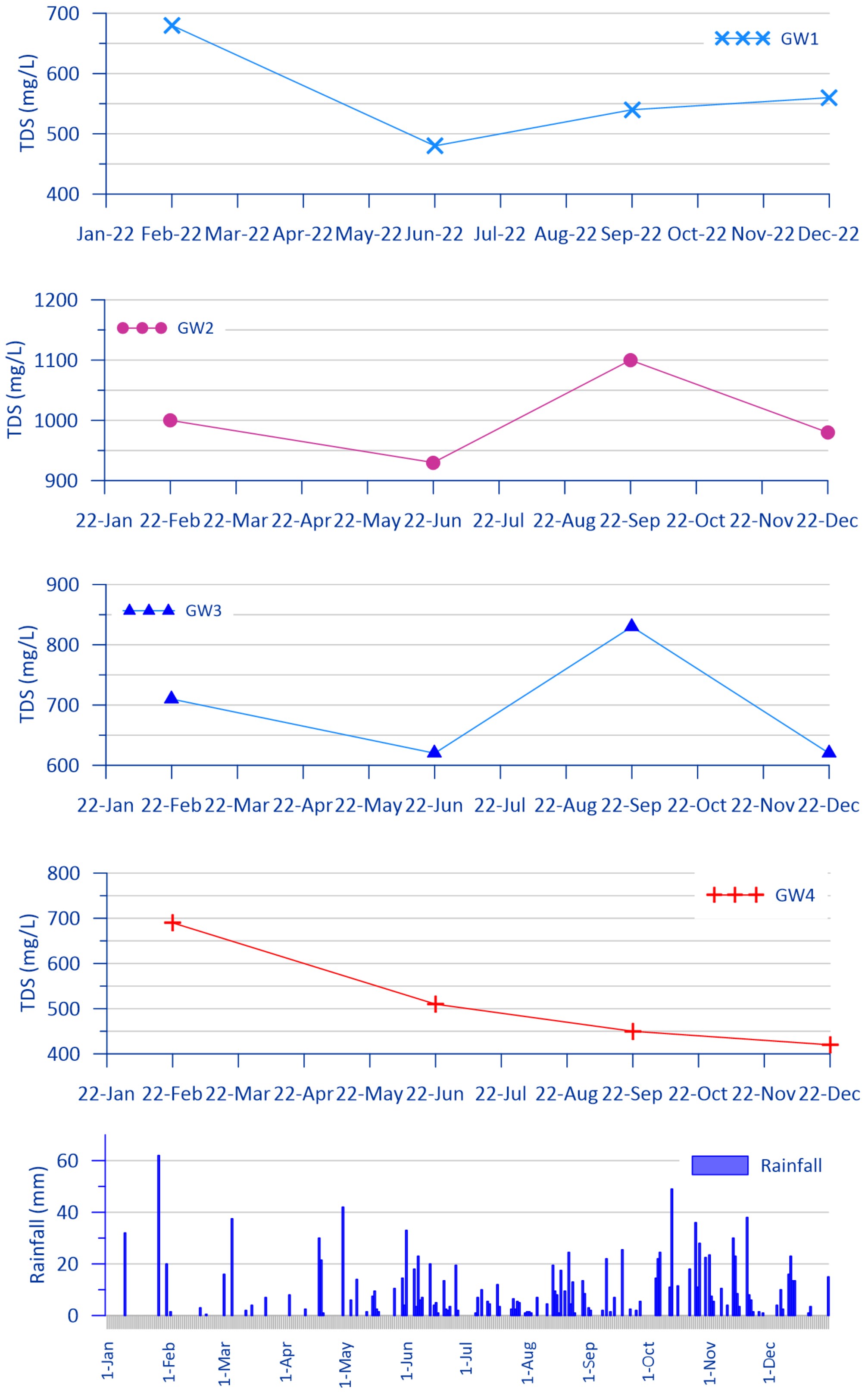


FIGURE 6.3 Groundwater Salinity Trend Plots

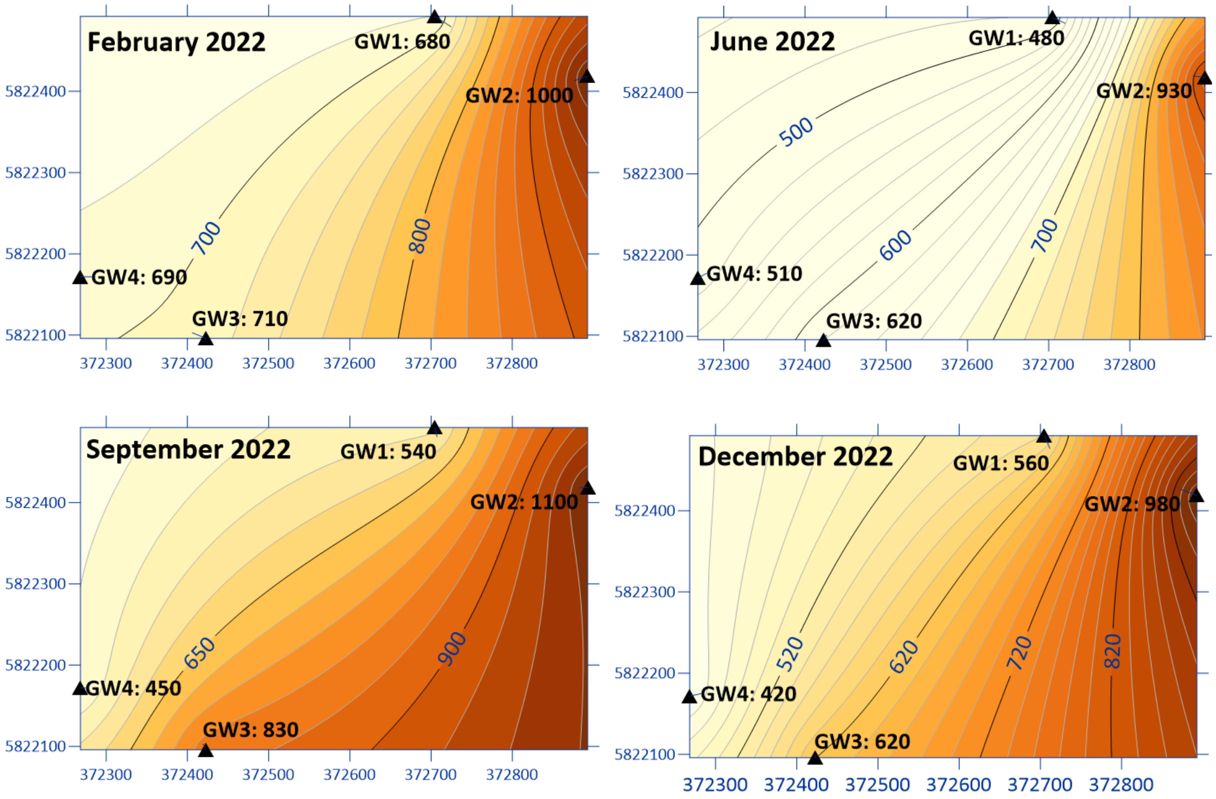


FIGURE 6.4 2022 Groundwater TDS Concentration Contours (Contours in mg/L)

The major anions and cations (expressed in units of millequivalents per litre) for GW1 and GW2, and for GW3 and GW4 are plotted on Piper diagrams in Figure 6.5 and 6.6, respectively. The tested groundwater samples were mostly sodium chloride type water[3] except for the December 2022 sample from bore GW2 which was sodium bicarbonate type water (Tables 6.1 and 6.2).

6.2 SURFACE WATER MONITORING

6.2.1 Surface Water Chemistry

Surface water laboratory analysis results are presented in Tables 6.3, 6.4, and 6.3. The assessed water types of each of the samples tested are also presented in theses Tables. TDS concentrations versus time trends are plotted in Figure 6.7.

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[3] The water type was determined by finding the predominant inorganic cation and anion based on electrical equivalents. In determining water type, AqQA accounts whenever possible for the carbonate speciation in solution, using the sum in electrical equivalents of the CO_3^{2-} and HCO_3^{-} concentrations to represent carbonate. If carbonate is the dominant anion by this criterion, AqQA states the water type in terms of whichever of the two species is present in larger equivalent concentration (e.g., Ca-HCO_3 or Na-CO_3). AqQA also calculates, where pH is given, the free ion concentrations of H^+ and OH^-, and accounts for these species when assigning a water type. An acidic solution might be typed H-SO_4, for example, or an alkaline water, Ca-OH.

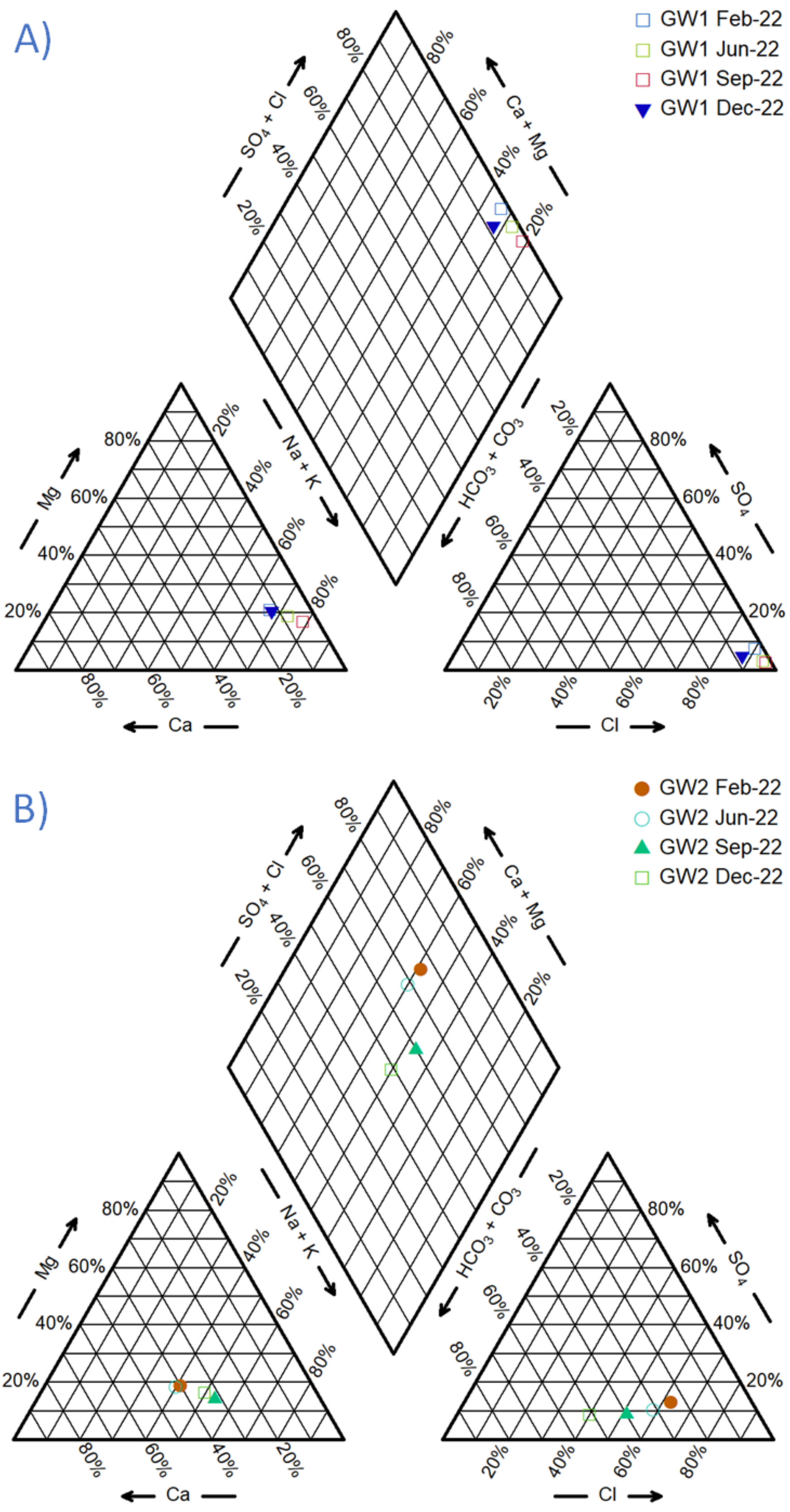


FIGURE 6.5 GW1 and GW2 Piper Diagram Plots

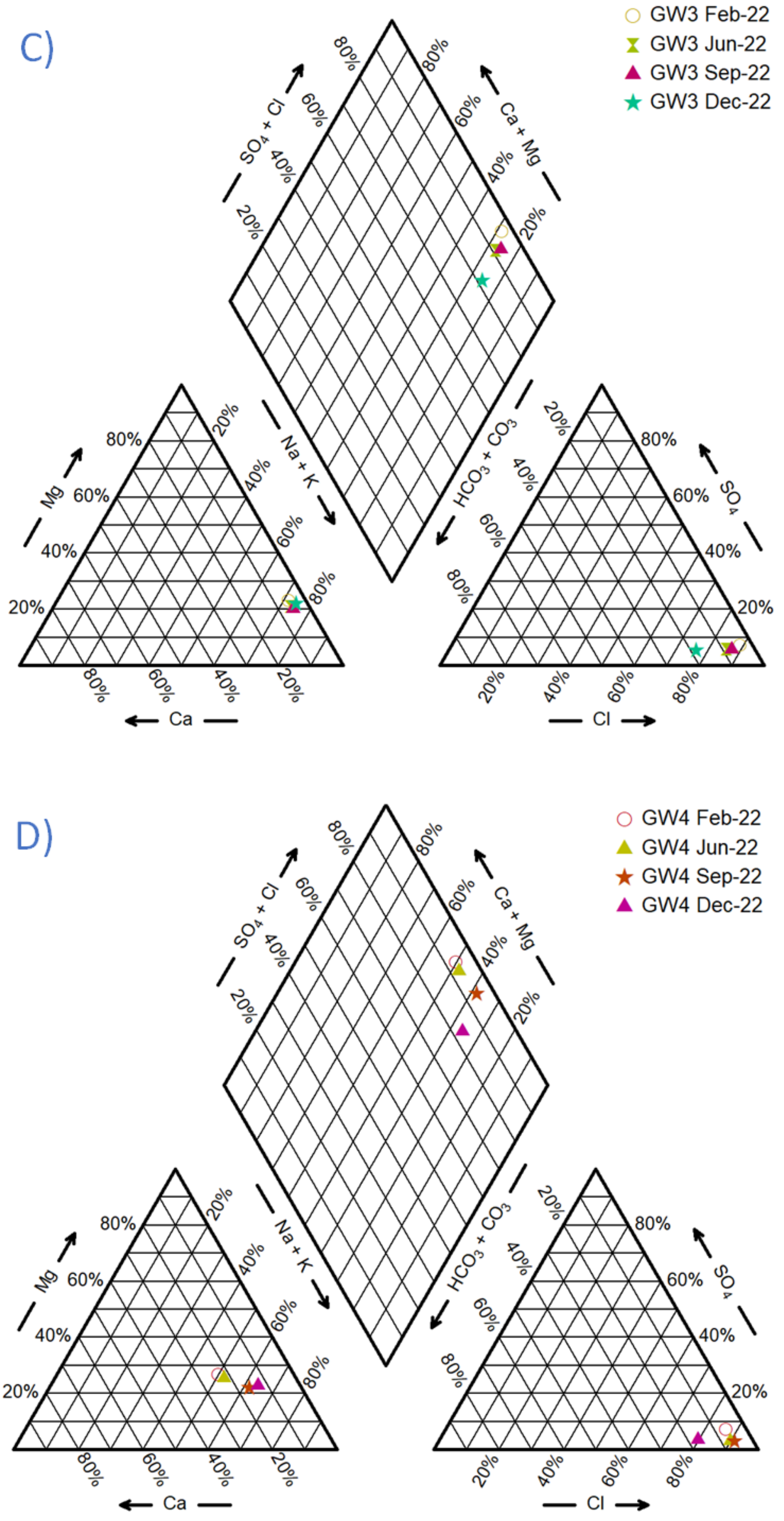


FIGURE 6.6 GW3 and GW4 Piper Diagram Plots

TABLE 6.3 SW1 and SW2 2022 Surface Water Testing Results

Analyte	SW1 (extraction pit sump)			SW2 (Holding dam)		
	Jun-22	Sep-22	Dec-22	Jun-22	Sep-22	Dec-22
Total Dissolved Solids	480	880	610	500	660	570
Electrical Conductivity	730	1500	800	710	1100	770
Sodium	42	57	34	20	23	34
Potassium	5.4	5.1	5.3	9.4	11	4.9
Calcium	48	110	57	48	54	55
Magnesium	32	51	31	41	57	29
Chloride	51	250	44	11	33	41
Sulphate (as SO4)	270	470	390	310	360	350
Bicarbonate Alkalinity (as HCO3)	26	<24	<24	<24	<24	<24
Carbonate Alkalinity (as CaCO3)	< 10	< 10	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	<20	<20	<20	<20	<20	<20
Total Alkalinity (as CaCO3)	21	<20	<20	<20	<20	<20
Nitrate & Nitrite (as N)	0.94	1.5	3.0	0.40	0.14	2.8
Nitrate (as N)	0.94	1.5	3.0	0.40	0.13	2.8
Ammonia (as N)	0.15	0.33	0.61	<0.01	<0.01	0.58
Nitrite (as N)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Organic Nitrogen (as N)*		0.27	1.59	0.3	0.4	1.72
Total Kjeldahl Nitrogen (as N)	<0.2	0.6	2.2	0.3	0.4	2.3
Total Nitrogen (as N)	0.94	2.1	5.2	0.7	0.54	5.1
Phosphate total (as P)	<0.01	0.01	<0.01	0.02	0.01	<0.01
Arsenic (filtered)	< 0.001	< 0.001	< 0.001	< 0.001	0.002	< 0.001
Cadmium (filtered)	0.0004	0.0006	0.0007	0.0009	0.0014	0.0006
Chromium (filtered)	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Copper (filtered)	0.017	0.036	0.041	0.032	0.048	0.034
Lead (filtered)	< 0.001	0.004	0.002	< 0.001	< 0.001	0.001
Mercury (filtered)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel (filtered)	0.41	0.74	0.61	1.0	1.4	0.55
Zinc (filtered)	0.56	1.3	0.88	1.1	1.6	0.80
pH (laboratory)	5.7	4.9	4.5	4.4	4.7	4.6
Water Type	Mg-SO4	Ca-SO4	Ca-SO4	Mg-SO4	Mg-SO4	Ca-SO4

Notes 1): Units in mg/L except for pH which pH units, 2) Bicarbonate concentration reported as HCO3 (as CaCO3) converted to bicarbonate ion concentration, and 3) water type determined by JLCS using the AqQA hydrochemical software program.

Salient findings from the DPQ WA375 surface water chemistry monitoring program include:

- The salinity of the water collected from the two stream sampling locations, SW5 (Moora Creek) and SW6 (Ure Creek) were mostly less than 100 mg/L TDS except for the December 2022 sample from SW6 which was 230 mg/L TDS.

- The water samples from within the 2022 pit footprint (SW1, extraction pit sump; SW2, coffer dam; and SW3, main dam) were between 480 and 880 mg/L TDS except for the salinity high of 1,200 mg/L TDS in the June sample from SW3. The range in salinity reflects the relative contributions from surface water (predominantly) and groundwater (minor) input sources and evapo-concentration effects from the larger standing water bodies.

TABLE 6.4 SW3 and SW4 2022 Surface Water Testing Results

Analyte	SW3 (Main Dam)			SW4 (Silt Trap)		
	Jun-22	Sep-22	Dec-22	Jun-22	Sep-22	Dec-22
Total Dissolved Solids	1200	790	710	610	2700	2700
Electrical Conductivity	1400	1300	870	840	3700	2800
Sodium	45	39	21	31	140	96
Potassium	5.2	4.7	9.9	26	27	30
Calcium	110	90	60	80	270	260
Magnesium	79	49	44	53	240	170
Chloride	34	55	11	11	62	72
Sulphate (as SO4)	630	410	480	370	1600	1900
Bicarbonate Alkalinity (as HCO3)	<24	24	<24	<24	113	35
Carbonate Alkalinity (as CaCO3)	< 10	< 10	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	<20	<20	<20	<20	<20	<20
Total Alkalinity (as CaCO3)	<20	20	<20	<20	93	29
Nitrate & Nitrite (as N)	3.3	1.2	0.90	2.7	0.17	7.4
Nitrate (as N)	3.3	1.2	0.90	2.7	0.17	7.3
Ammonia (as N)	0.37	0.21	<0.01	1.2	0.20	1.0
Nitrite (as N)	<0.02	<0.02	<0.02	<0.02	<0.02	0.13
Organic Nitrogen (as N)*	1.53	0.39	1	0.7	0.5	1.3
Total Kjeldahl Nitrogen (as N)	1.9	0.6	1.0	1.9	0.7	2.3
Total Nitrogen (as N)	5.2	1.8	1.9	4.6	0.87	9.7
Phosphate total (as P)	0.03	<0.01	<0.01	3.9	0.02	0.30
Arsenic (filtered)	< 0.001	< 0.001	0.002	0.11	0.002	0.012
Cadmium (filtered)	0.0015	0.0009	0.0014	0.0011	0.0004	0.0021
Chromium (filtered)	0.002	< 0.001	< 0.001	0.52	< 0.001	0.030
Copper (filtered)	0.10	0.046	0.053	0.26	0.011	0.039
Lead (filtered)	0.006	0.004	< 0.001	0.16	0.001	0.013
Mercury (filtered)	< 0.0001	< 0.0001	< 0.0001	0.0003	< 0.0001	< 0.0001
Nickel (filtered)	1.6	0.90	1.5	1.2	3.1	4.1
Zinc (filtered)	2.9	1.6	1.7	1.7	0.93	3.7
pH (laboratory)	4.0	5.4	4.6	4.7	5.6	4.6
pH (field)	1200	790	710	610	2700	2700
Temperature (field)	1400	1300	870	840	3700	2800
Electrical Conductivity (field)	45	39	21	31	140	96
Redox Potential (field)	5.2	4.7	9.9	26	27	30
Dissolved Oxygen (field)	110	90	60	80	270	260
Water Type	Mg-SO4	Ca-SO4	Mg-SO4	Mg-SO4	Mg-SO4	Mg-SO4

Notes 1): Units in mg/L except for pH which pH units, 2) Bicarbonate concentration reported as HCO3 as CaCO3 converted to bicarbonate ion concentration, and 3) water type determined by JLCS using the AqQA hydrochemical software program.

TABLE 6.5 SW5 and SW6 Surface Water Testing Results

Analyte	SW5 (Moora Creek)			SW6 (Ure Creek)		
	Jun-22	**Sep-22**	**Dec-22**	**Jun-22**	**Sep-22**	**Dec-22**
Total Dissolved Solids	78	92	73	98	100	230
Electrical Conductivity	86	140	110	170	190	320
Sodium	12	13	12	16	15	20
Potassium	1.7	1.5	1.5	2.0	1.5	2.8
Calcium	2.7	2.7	2.4	7.2	4.8	15
Magnesium	2.1	2.4	2.3	5.0	3.7	9.1
Chloride	11	67	29	23	26	36
Sulphate (as SO4)	<5	10	14	30	14	90
Bicarbonate Alkalinity (as HCO3)	<24	31	<24	<24	82	<24
Carbonate Alkalinity (as CaCO3)	< 10	< 10	< 10	< 10	< 10	< 10
Hydroxide Alkalinity (as CaCO3)	<20	<20	<20	<20	<20	<20
Total Alkalinity (as CaCO3)	<20	25	<20	<20	67	<20
Nitrate & Nitrite (as N)	1.2	1.1	1.3	0.93	0.91	1.5
Nitrate (as N)	1.2	1.1	1.3	0.92	0.91	1.5
Ammonia (as N)	<0.01	0.06	<0.01	0.11	0.07	<0.01
Nitrite (as N)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Organic Nitrogen (as N)*	<0.2	0.44	<0.2		0.63	1.3
Total Kjeldahl Nitrogen (as N)	<0.2	0.5	<0.2	<0.2	0.7	1.3
Total Nitrogen (as N)	1.2	1.6	1.3	0.93	1.61	2.8
Phosphate total (as P)	0.03	0.02	<0.01	0.02	0.02	0.02
Arsenic (filtered)	0.003	0.003	0.002	0.002	0.003	0.002
Cadmium (filtered)	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Chromium (filtered)	0.002	0.002	0.002	0.002	0.003	0.002
Copper (filtered)	0.001	< 0.001	0.002	0.002	0.001	0.005
Lead (filtered)	< 0.001	< 0.001	< 0.001	< 0.001	0.002	< 0.001
Mercury (filtered)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Nickel (filtered)	0.001	0.001	0.001	0.050	0.032	0.14
Zinc (filtered)	< 0.005	0.007	0.013	0.094	0.063	0.25
pH (laboratory)	7.2	6.9	7.2	6.4	6.7	6.5
pH (field)	78	92	73	98	100	230
Temperature (field)	86	140	110	170	190	320
Electrical Conductivity (field)	12	13	12	16	15	20
Redox Potential (field)	1.7	1.5	1.5	2.0	1.5	2.8
Dissolved Oxygen (field)	2.7	2.7	2.4	7.2	4.8	15
Water Type	Na-CL	Na-Cl	Na-Cl	Na-Cl	Na-HCO3	Na-SO4

Notes 1): Units in mg/L except for pH which pH units, 2) Bicarbonate concentration reported as HCO3 as CaCO3 converted to bicarbonate ion concentration, and 3) water type determined by JLCS using the AqQA hydrochemical software program.

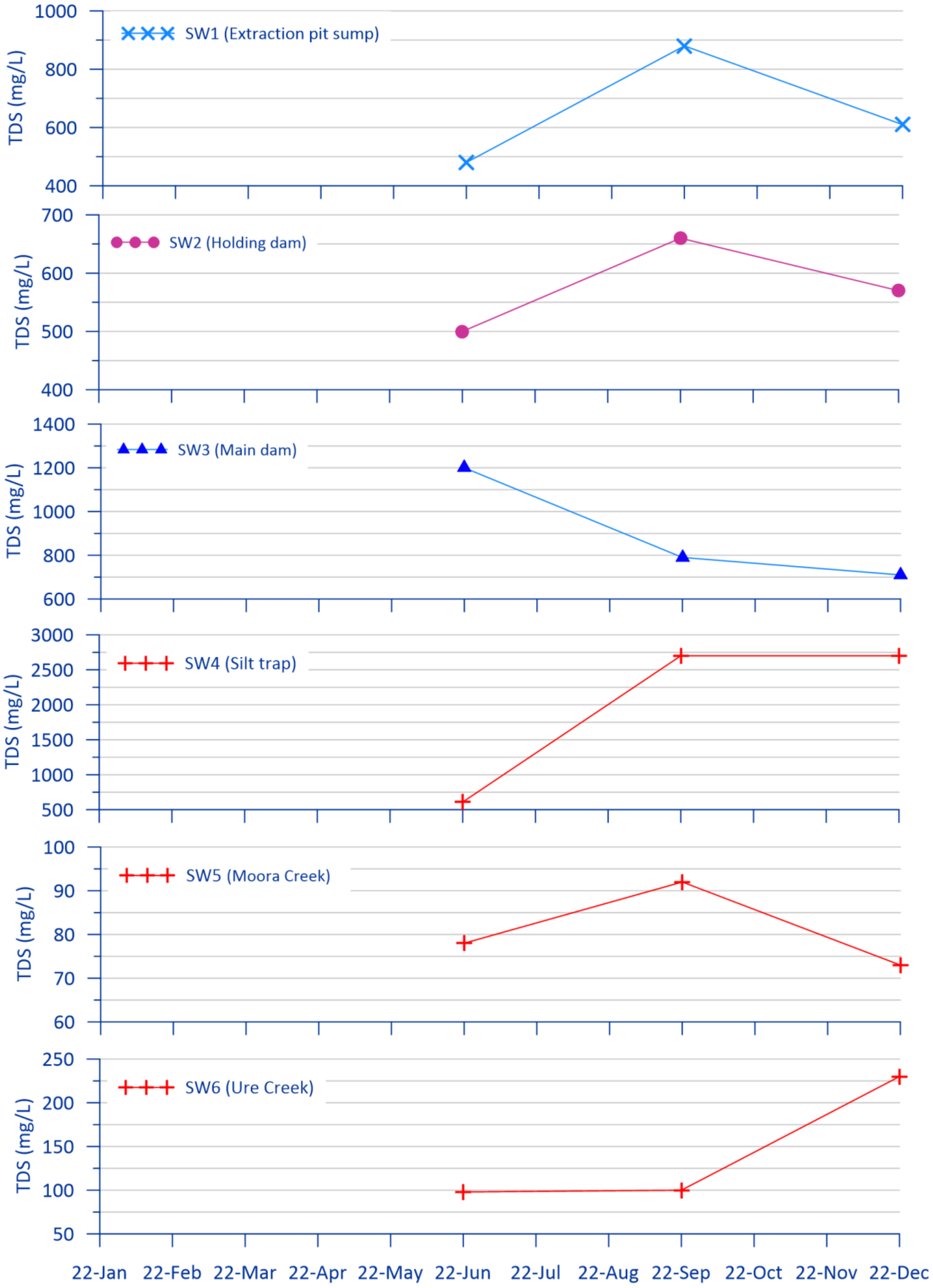


FIGURE 6.6 Surface Water Salinity Trend Plots

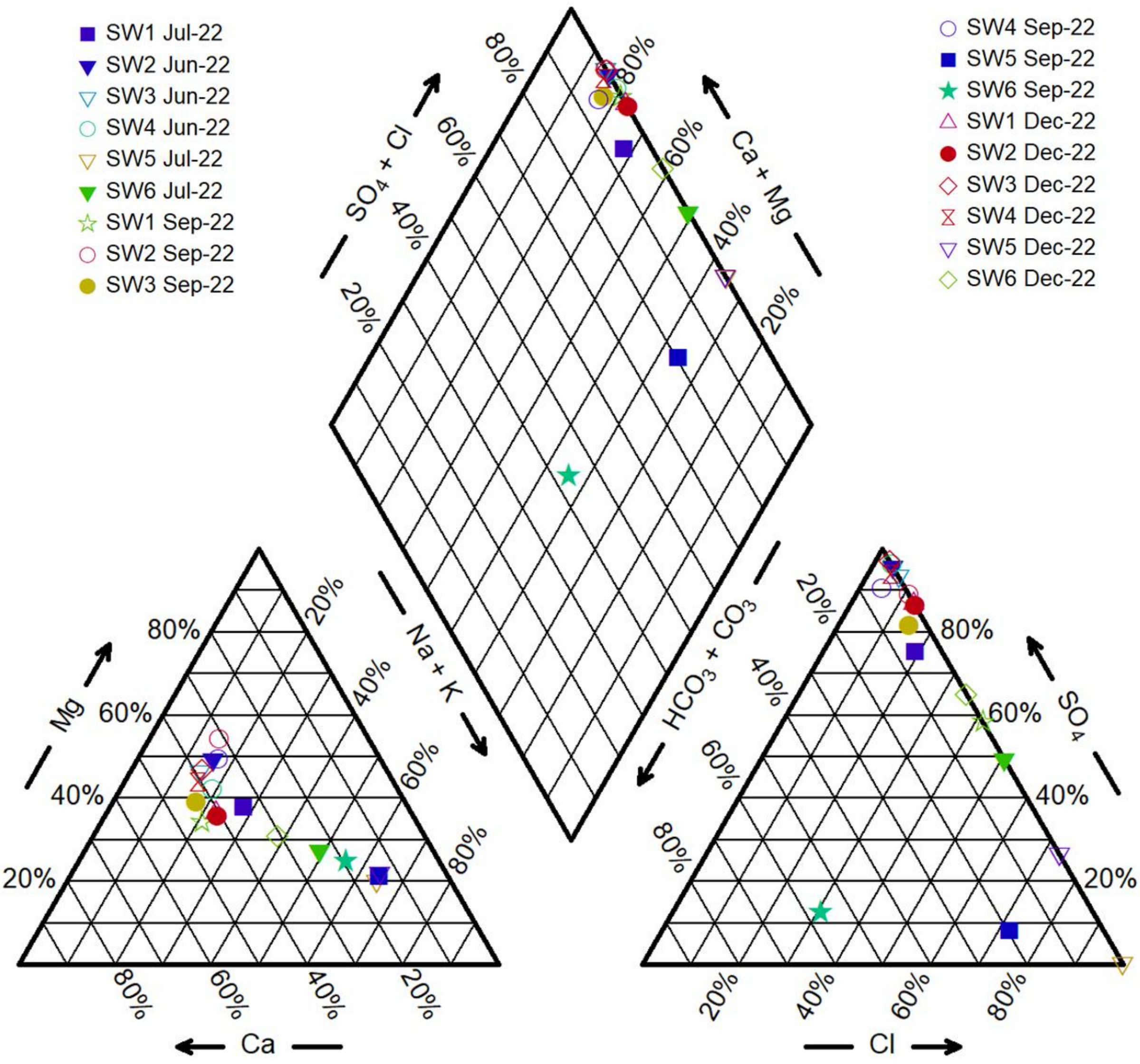
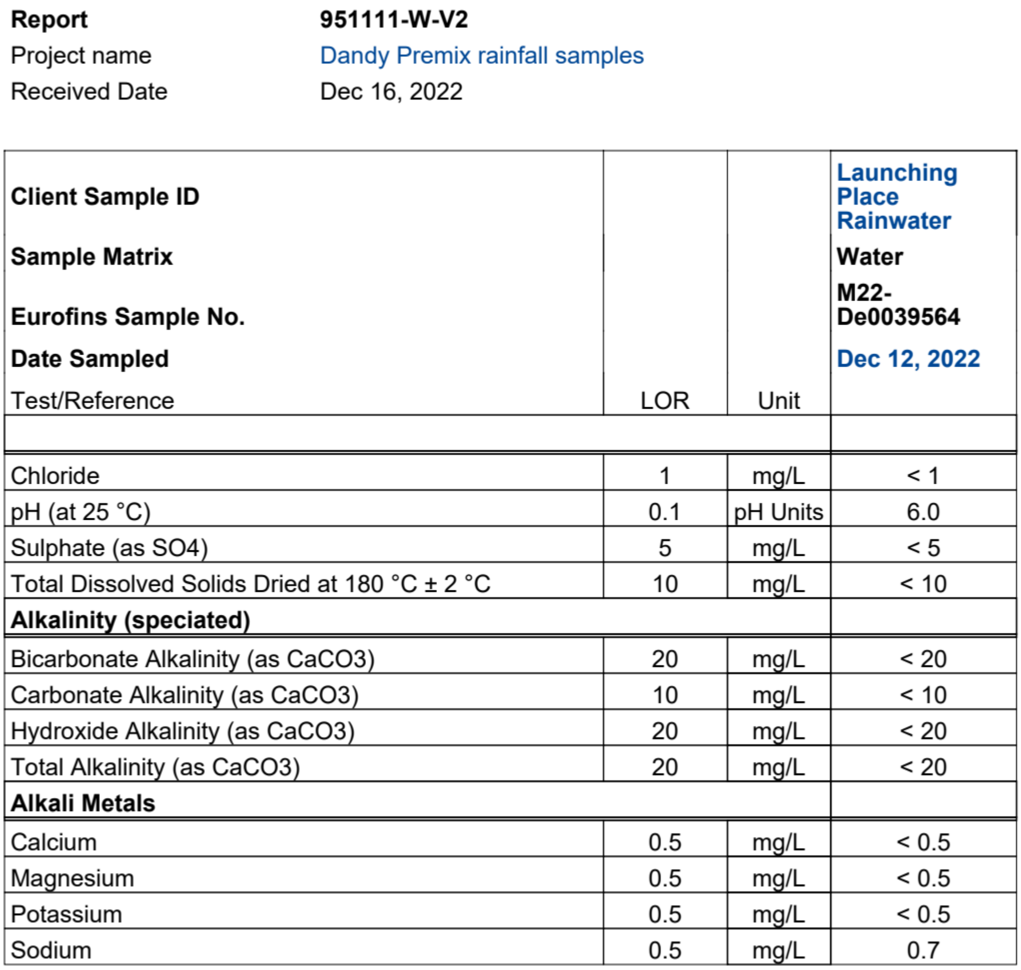


FIGURE 6.7 Surface Water Piper Diagram

6.3 RAINWATER

A sample of rainwater was collected at the WA375 quarry site during December 2022 and analysed for TDS, major ions and pH (Table 6.6). The rainwater total dissolved solids concentration and most ions were less than respective limits of reporting (LOR). The chloride concentration (required for estimating groundwater recharge; see Section XX) was <1 mg/L. The reported pH was 6.0 pH units however this result is indicative only as the testing was not undertaken within stipulated maximum sample holding time.

TABLE 5.3 WA375 Rainwater Test Results



Report	**951111-W-V2**
Project name	Dandy Premix rainfall samples
Received Date	Dec 16, 2022

Client Sample ID			**Launching Place Rainwater**
Sample Matrix			**Water**
Eurofins Sample No.			**M22-De0039564**
Date Sampled			**Dec 12, 2022**
Test/Reference	LOR	Unit	
Chloride	1	mg/L	< 1
pH (at 25 °C)	0.1	pH Units	6.0
Sulphate (as SO4)	5	mg/L	< 5
Total Dissolved Solids Dried at 180 °C ± 2 °C	10	mg/L	< 10
Alkalinity (speciated)			
Bicarbonate Alkalinity (as CaCO3)	20	mg/L	< 20
Carbonate Alkalinity (as CaCO3)	10	mg/L	< 10
Hydroxide Alkalinity (as CaCO3)	20	mg/L	< 20
Total Alkalinity (as CaCO3)	20	mg/L	< 20
Alkali Metals			
Calcium	0.5	mg/L	< 0.5
Magnesium	0.5	mg/L	< 0.5
Potassium	0.5	mg/L	< 0.5
Sodium	0.5	mg/L	0.7

Source: Eurofins Certificate of Analysis – Report 951111-W-V2

7.0 GROUNDWATER USE AND ENVIRONMENTAL VALUES

7.1 GROUNDWATER USE

Records of registered bores within a 5 km radius of the approximate centre of the proposed WA375 terminal quarry pit were extracted from the Victorian Water Measurement Information System (WMIS) online database (https//data.water.vic.gov.au; accessed November 2022). Details of the identified bores within the specified search radius are summarised in Table 7.1. The positions of the registered bores and registered uses are plotted on geological base maps in Figure 7.1A and Figure 7.1B, respectively.

TABLE 7.1 Bore Records Summary

Bore ID	MGA Z54 coordinates		Dist. (m)	Completed	RLGL (mAHD)	Depth (m)	Screens (m)	Status	Use(s)
	Easting	Northing							
66222	**372173.3**	**5822144.1**	**565**	**25/01/1991**	**201.87**	**54.80**	**30 to 54.8**	**U**	**DM ST**
WRK090333	372777	5824814	1,920	4/12/2015		65.00	60 to 63	U	DM ST
WRK981742	372165	5820275	1,960		121.17	25.00		NU	
WRK985982	374089	5820247	2,055		124.15	150.00		NU	
66221	370733.2	5820934.1	2,420	14/03/1990	113.48	48.40	27 to 45.4	U	DM ST
WRK032680	375248.3	5824124.1	2,440	1800/01/01	415.73			U	CO
WRK051495	370293	5823308	2,500	22/12/2009	146.4	141.00		U	IR
WRK989998	376168	5822605	2,515	5/05/2009	259.88	68.00		U	DM
66212	371163.2	5820234.1	2,520	12/05/1983	147.95	88.39	1.98 to 88.39	U	DM ST
109398	376363.3	5823584.1	2,890	17/02/1983	335.76	60.60	24.85 to 60.6	U	DM ST
WRK991754	375378	5819749	3,255	19/08/2009	132.27	61.00		U	DM AT
132430	369513.2	5823284.1	3,255	15/01/1998	123.83	85.50	69 to 85.5	U	DM ST
133111	369593.2	5823664.1	3,260	19/01/1998	113.32	43.00	27 to 40	U	DM ST
134226	369493.2	5823424.1	3,305	22/04/1998	125.76	61.00	37 to 61	U	DM ST
66215	369613.2	5824384.1	3,490	31/10/1983	95.32	73.50	3.2 to 73.5	U	DM ST
WRK089692	369987	5825013	3,500	28/10/2015		90.00	85 to 88	U	DM AT
66216	369763.2	5824834.1	3,585	12/04/1985	102.67	61.00	35 to 61	U	IR
66211	371687.3	5826668.1	3,950	20/12/1982	212.84	60.96	6.1 to 60.96	U	DM ST IR
WRK076180	369989	5825688	3,955	23/09/2013		80.00	75.5 to 78.5	U	DM AT
66202	369453.2	5825284.1	4,100	16/11/1978	85.99	15.50	14 to 15.5	U	DM ST
142175	369458.2	5825294.1	4,100	25/11/1999	86.31	17.00	13 to 17	U	DM ST
66201	373893.3	5827104.1	4,330	24/01/1978	393.95	29.00		U	DM
66200	371174.3	5827226.1	4,540	7/05/1973	159.21	51.81	37.49 to 51.81	U	DM ST
66218	369809.2	5826458.1	4,645	1/03/1985	91.84	97.60	22 to 97	U	DM ST

Notes: 1) Dist, Distance from edge of proposed terminal pit; fist 4 listed bores are within an approximate 2 km buffer zone area stipulated in the ERR Work Plans and Work Plan Variations Guidelines (DJPR, 2019); 2) U, Used, NU, Not Used; 3) IR, Irrigation; ST, Stock; DM, Domestic, CO, Commercial.

Twenty-five bores were identified in the 5 km radius search area (Table 7.1) as mapped for this project; but only 3 bores, 66222, WRK09033, and WRK981742 are within a 2 km buffer zone around the proposed terminal pit (buffer radius stipulated in the ERR Work Plans and Work Plan Variations Guidelines; DJPR, 2019). The closest bore, 66222 is on land owned by DPQ. Bores WRK09033 and WRK981742 are 1,920 and 1,960 m from the footprint of the proposed Stage 4 terminal quarry pit, respectively.

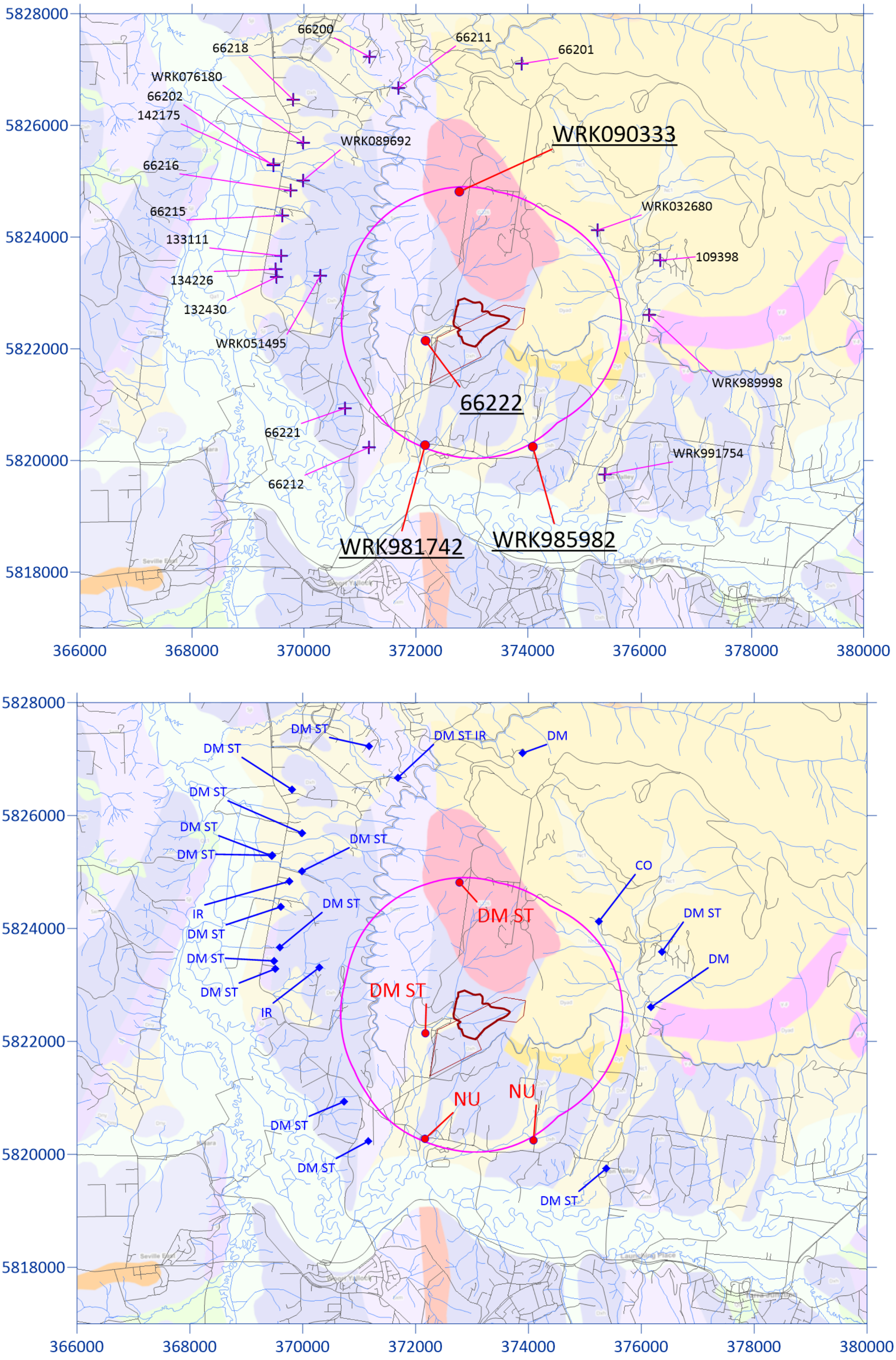


FIGURE 7.1 Registered Bore A) Locations, and B) Uses

The identified registered bores range from 15.5 to 150 m deep. The majority (18) of the bores are registered as Stock and/or Domestic (ST and/or DM). Two bores were listed for irrigation use only, and one bore for irrigation (IR) as well as for stock and domestic use. However, only one of the registered IR bores has an assigned WRK identification number suggesting that the other 2 bores do not have a groundwater "Take and Use" licence. Two bores, both within the 2 km buffer zone are not used (NU). The remaining bore is registered for commercial (CO) use.

7.2 GROUNDWATER ENVIRONMENTAL VALUES

The salinity of groundwater in the four DPQ monitoring bores tested during 2022 ranged from 420 to 1,100 mg/L TDS with average, median and standard deviation of 695, 650 and 2013, respectively. These salinities are considered to be representative of local natural, uncontaminated groundwater. The ambient, local groundwater is therefore Groundwater Environmental Segment A2 (refer Table 2.1). However, not all of the environmental values are applicable (Table 7.2).

TABLE 7.2 Applicable Groundwater Environmental Values

Environmental Value	Applicable	Comment
Water dependent ecosystems and species	**Yes**	
Potable water supply (desirable)	**No**	Background salinity too high
Potable water supply (acceptable)	**Yes**	
Potable mineral water supply	**No**	Local groundwater not defined as mineral water under the Water Act 1989; not in recognised Mineral Water area.
Agriculture – irrigation	**Yes**	Unlikely to be realised because of low bore yields.
Agriculture – stock watering	**Yes**	
Industrial and commercial	**Yes**	
Water based recreation	**Yes**	
Traditional Owner cultural values	**Yes**	
Building and structures	**Yes**	
Geothermal properties	**No**	Unsuitable groundwater temperature.

8.0 QUARRY FACILITIES AND PROPOSED DEVELOPMENT

8.1 QUARRY FACILITIES

The main quarry service facilities at WA273 are shown in Figure 8.1. The most relevant from a groundwater protection viewpoint is Fuel Bowser (located about 80 m north and 100 m east of the southwestern corner of the image in Figure 8.1) which is a potential source of groundwater contamination.

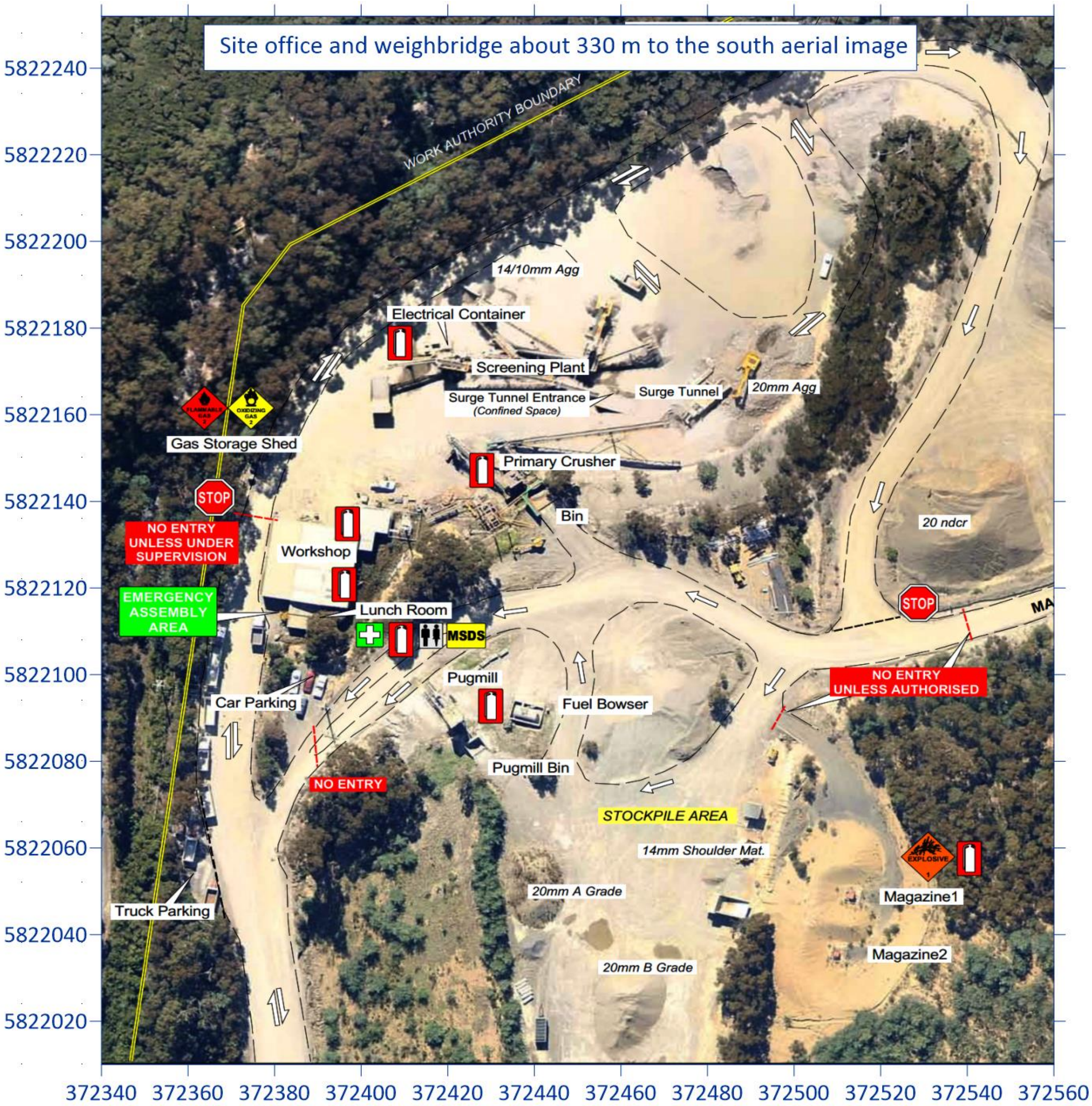


FIGURE 8.1 WA375 Main Facilities

8.2 ROCK EXTRACTION

Overburden and weathered rock at WA375 are extracted using conventional earth moving equipment (rippers, excavators and bulldozers). Harder, less weathered rock requires conventional drilling and blasting to enable extraction using the earth moving equipment. The blasting breaks the hard hornfels rock into small rock pieces suitable for crushing, and the blasted material is extracted using conventional earth-moving equipment. The extracted rock is transported by haul trucks from the quarry face to the processing plant where it is crushed, washed, and sorted by size.

Blasting at WA375 is undertaken in compliance with the Blast Management Plan prepared for Yarra Valley Quarries by Betts Blasting Pty Ltd (2018). The explosive used for blasting at WA375 is an emulsion[4] of ammonium nitrate salt (NH_4NO_3), diesel fuel, paraffinic mineral oil and vegetable oil (Table 8.1). The nitrogen is in two water-soluble forms, ammonium (NH4+) and nitrate (NO3-) ions but the thin film of oil surrounding the salt solution minimizes contact with external water sources (Forsyth, et al., undated).

TABLE 8.1 Explosives Composition Details

Chemical name	CAS No.	Weight-%
Ammonium nitrate	6484-52-2	>60%
Fuels, diesel	68334-30-5	0-<10%
Paraffinic mineral oil	-	0-<10%
Vegetable oil	-	0-<10%
Non hazardous component(s)	-	to 100%

Source Orica Safety Data sheet, 2021.

Blasting operations involve (1) setting up a drill pattern (Plate 8.1) (2) drilling blast holes (3) placing explosives in the blast holes and (4) detonating the explosives. [Blasting Terminology is illustrated in Figure 8.2.] Blasting typically occurs once per month with about 10 tonnes of explosives used each round. the blast holes are loaded and fired on the same day. If there is any water in the blast holes when they are loaded, the water is displaced by the explosive as it enters the hole (J Morse. Quarry Manager, pers. Comm., 2023).

TABLE 8.2 WA375 Blasting Summary Details

Explosives		**Blasting**			
Product Density	1.14	Burden[1] (m)	2.7	Hole Angle/Inclination (degrees)	5
Hole Length (m)	10.5	Spacing (m)	2.5	Number of Holes	152
Column rise per meter	8.1	Face Height (m)	10.0	S. G. of Rock (gr/cc)	2.7
Kg per hole	65.35	Stemming Length (m)	2.5	Powder Factor (kg/m^3)	0.97
Total Quantity (kg)	9,933	Subdrill (m)	0.5		

Note: 1) burden is the distance from the face to the blast hole at the time the hole is fired (https://academyblasting.com/burden/).

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[4] An emulsion is a mixture of two or more fluids that don't normally mix. One liquid contains a dispersion of the other liquid.

PLATE 8.1 WA375 Blasting Drillhole Layout (courtesy DPQ, 2023)

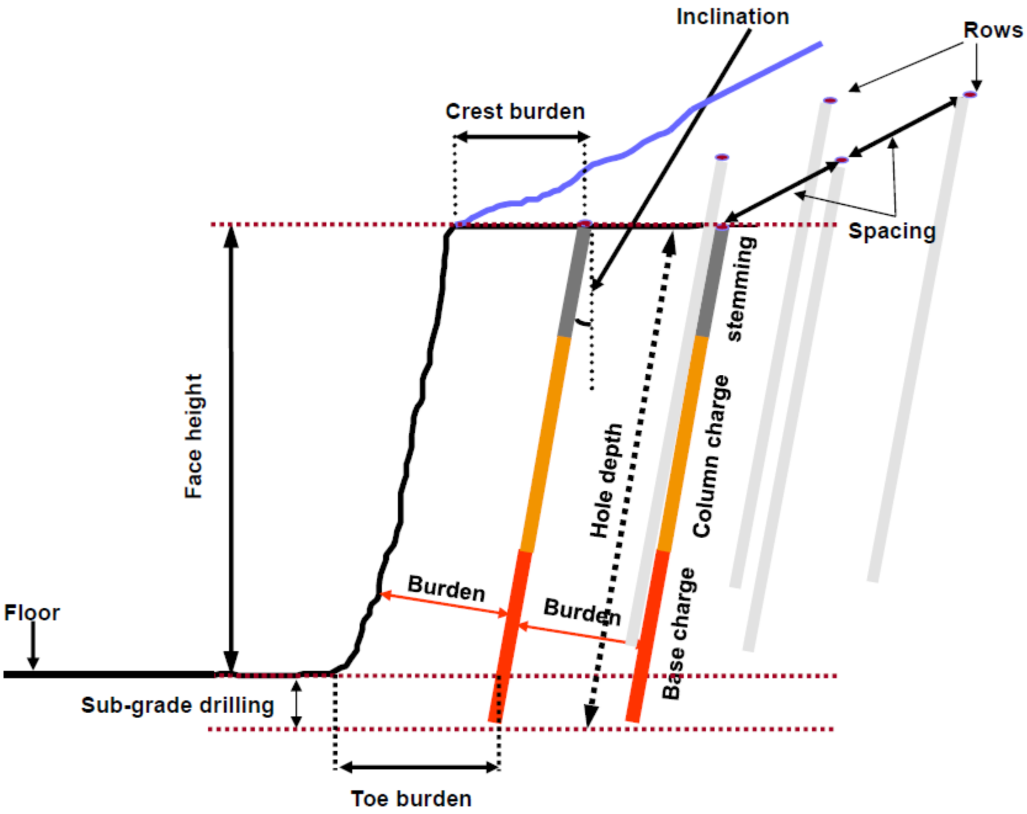


FIGURE 8.2 Quarry Blasting Terminology

8.2 WATER MANAGEMENT

The main water management infrastructure at WA375 is depicted in Figure 8.2, and the description of water management works described below is based on details provided by DPQ.

FIGURE 8.3 WA375 Water Storage Locations

Surface water run-off up slope from the quarry pit including water that flows along the drainage line intersected by the pit and groundwater seepage into the pit is captured in a sump in the quarry floor. Historical aerial images show that the sump has been located at different locations across the pit floor at various times.

Water collected in the sump is pumped to an upper level "Holding Dam" that also functions as a bio-retention and fines filter basin). Water from the Holding Dam is used for dust suppression along haul roads, on the crushing and stockpile pad traffic areas and other vehicle access roads including the sealed quarry entrance road from McMahons Road. Higher seasonal inflows that exceed the fill capacity of the Holding Dam are discharged in a southwest direction via a 300 mm internal diameter spillway pipe into Tributary 1 that discharges into Moora Creek within the adjoining DPQ land (Lot 30C).

The Main Dam receives surface water inflows from the small area of treed land to its northeast and the northern extent of the sales loading and stockpile pad area. Water from the Main Dam is plumbed to service the spray-bar dust suppression equipment installed on the primary and secondary crushing plants and product conveyors and the sales loader concrete aggregates stockpiles. Overflow water from the 'Main Dam' is discharged via a spillway pipe into Tributary 1.

8.3 PIT DEVELOPMENT STAGES

Pit stages were designed by BCA Consulting. Design drawings for Stages 1, 2, 3 and 4 prepared by BCA and 3D visualizations are presented in Figures 8.4, 8.5, 8.6 and 8.7, respectively. The sumps in stages 1, 2 and 3 pits would be at similar locations and elevations of about 180 m AHD whereas the sump in the Stage 4 pit would be 90 m deeper at an elevation of about 110 m AHD.

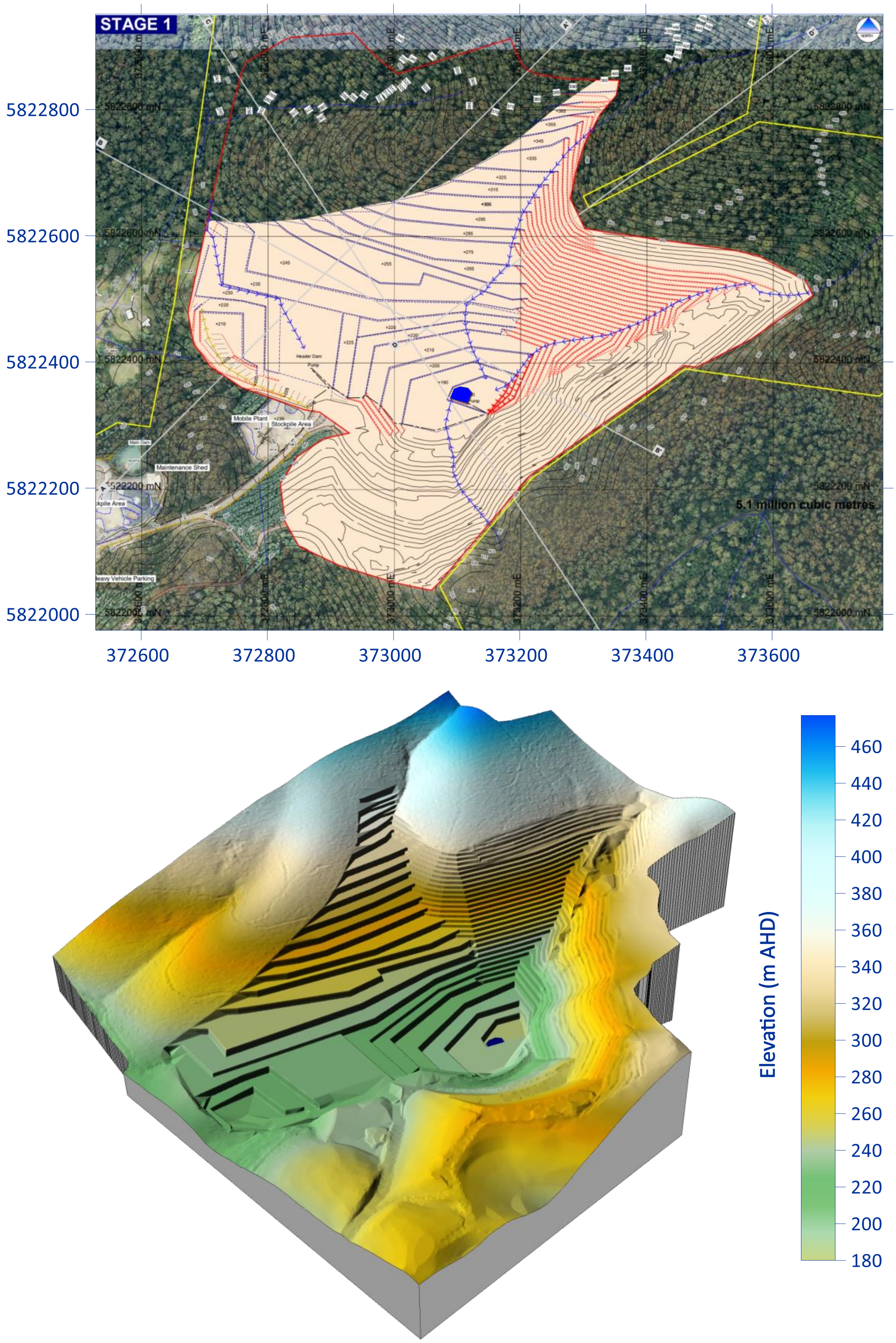


FIGURE 8.4 WA375 Stage 1 Design and 3D Visualisation

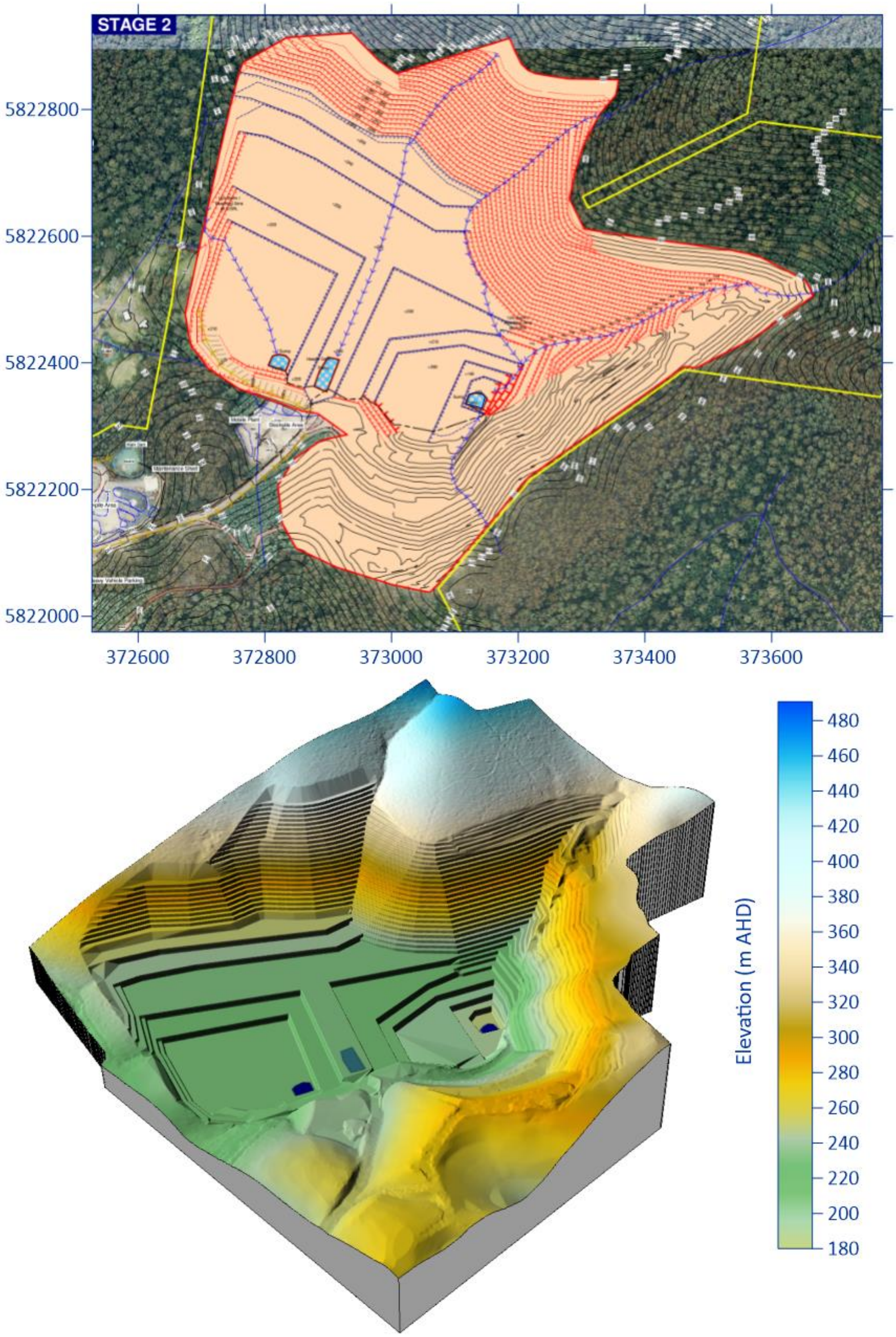


FIGURE 8.5 WA375 Stage 2 Design and 3D Visualisation

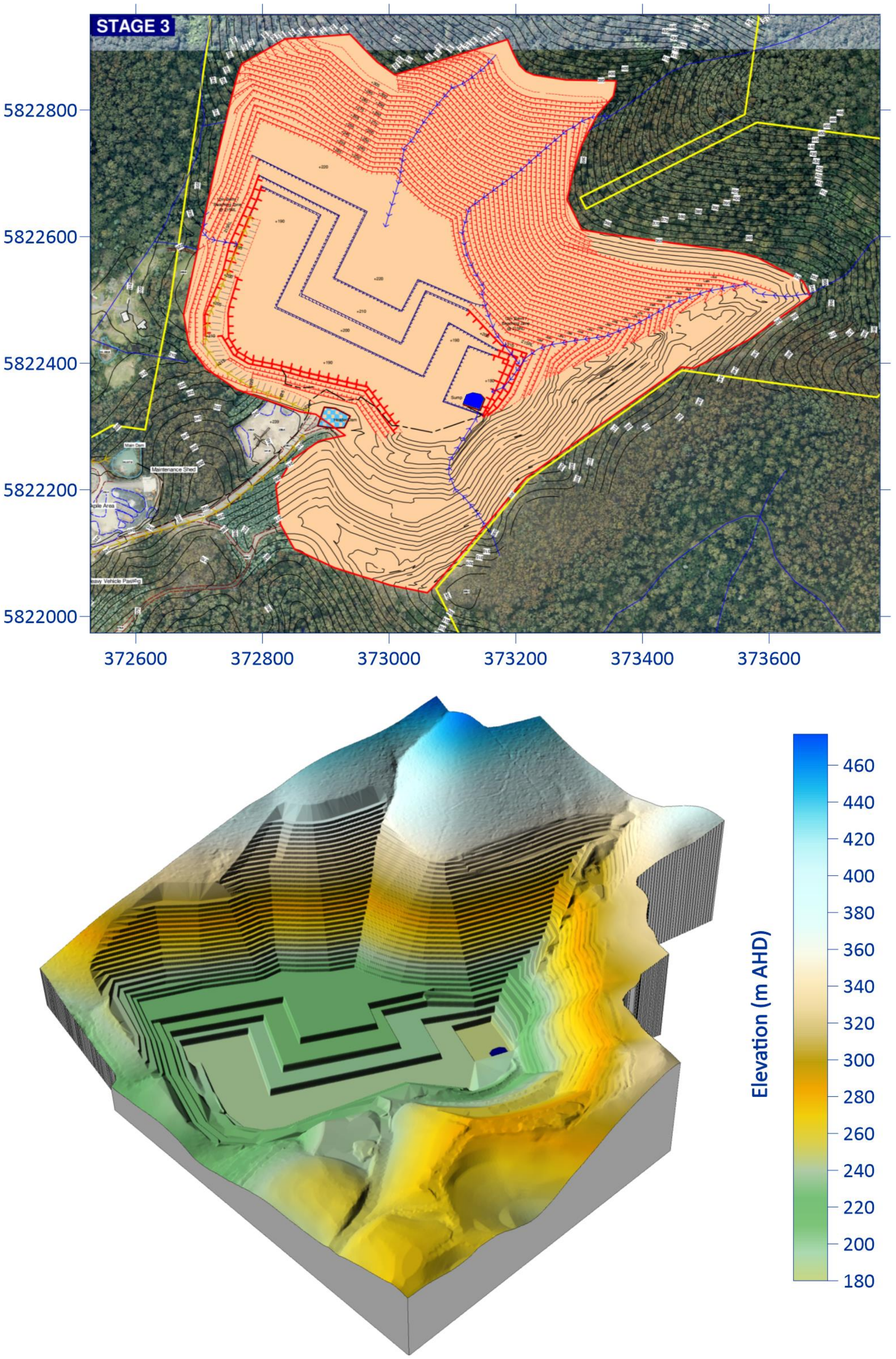


FIGURE 8.6 WA375 Stage 3 Design and 3D Visualisation

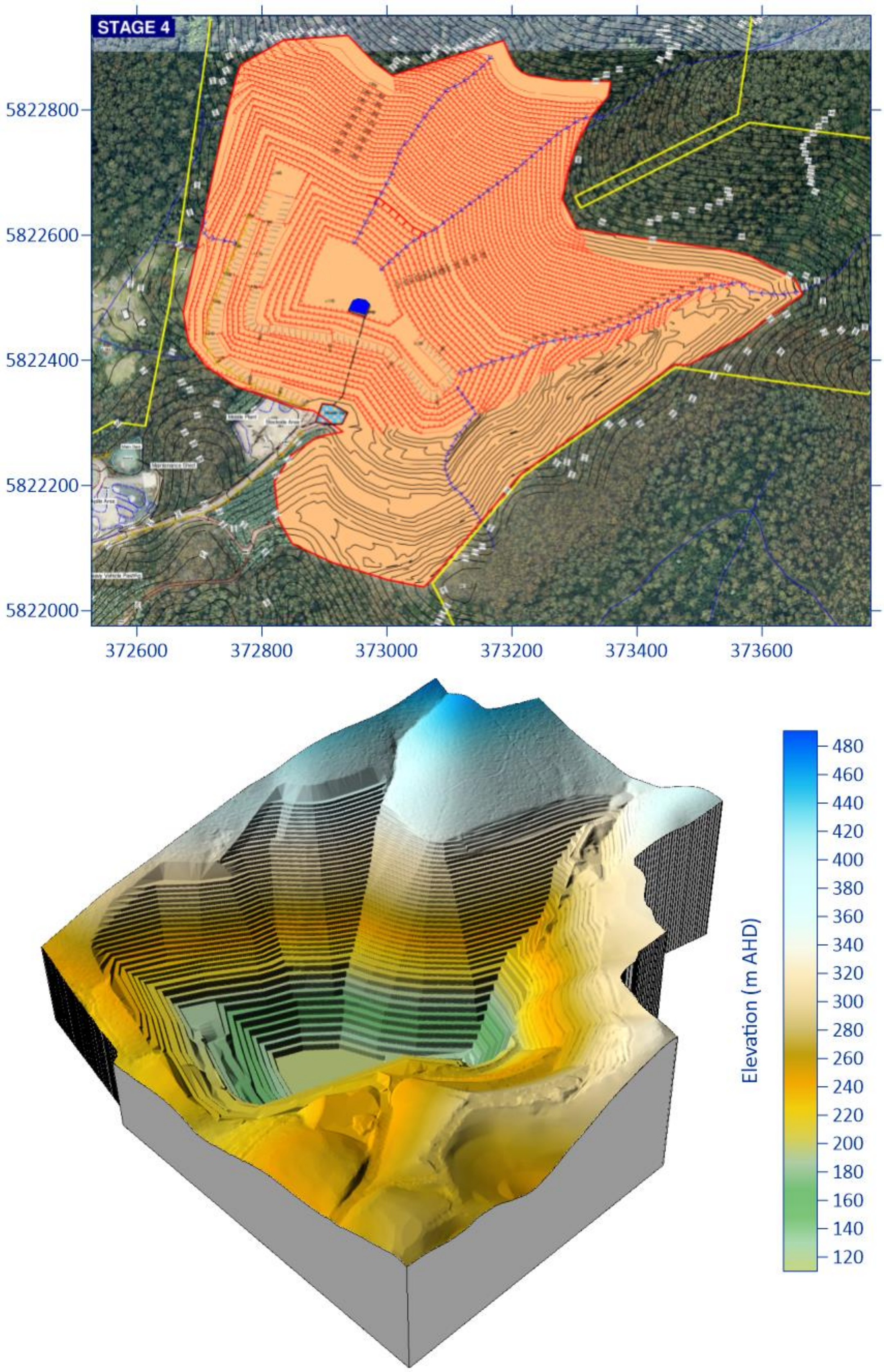


FIGURE 8.7 WA375 Stage 4 Design and 3D Visualisation

8.4 PIT REHABILITATION

Quarried-out areas at WA375 have been rehabilitated by emplacing overburden and revegetation. Future areas will also be rehabilitated by the same method (Figure 8.8) as per the site rehabilitation Plan. On cessation of quarrying the pit void will fill predominately by captured surface water forming a pit lake. Three-Dimensional terrain models of the pit lake for water level elevations of 110, 130, 150, 170, 190, 210 and 217 m AHD, and a “true” 3D visualization of the terminal pit lake in the WA375 Stage 4 quarry pit are shown in Figures 8.9 and 8.10, respectively. The final pit lake will function hydraulically as a “throughflow lake” with groundwater entering from up-hydraulic gradient to the northeast and exiting from the southwestern side of the lake (Figure 8.11).

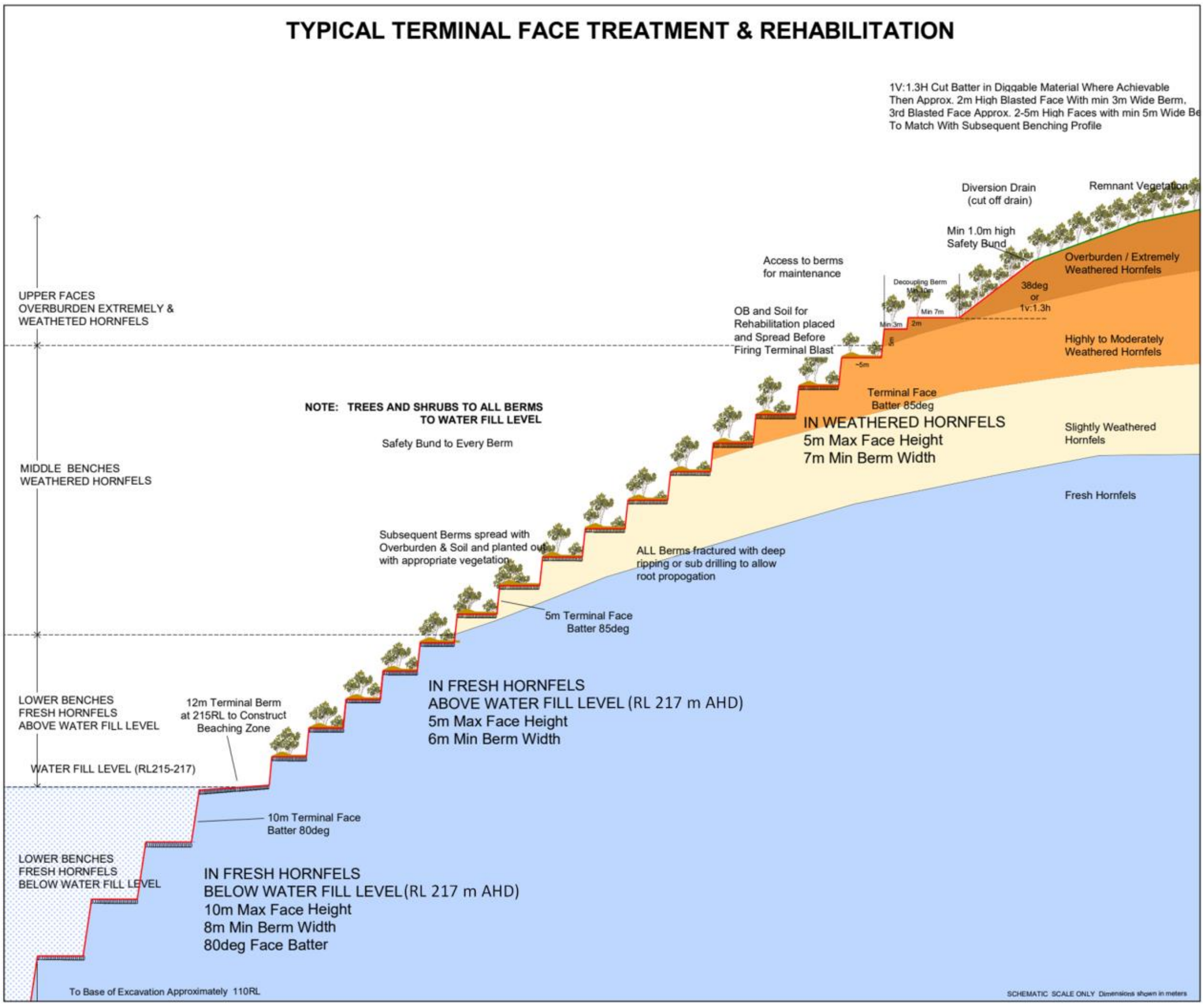


FIGURE 8.8 **Typical Terminal Face Treatment and Rehabilitation (Modified after “WA375 Yarra Valley Quarries Site Layout Plan”, BCA Consulting, 2022”)**

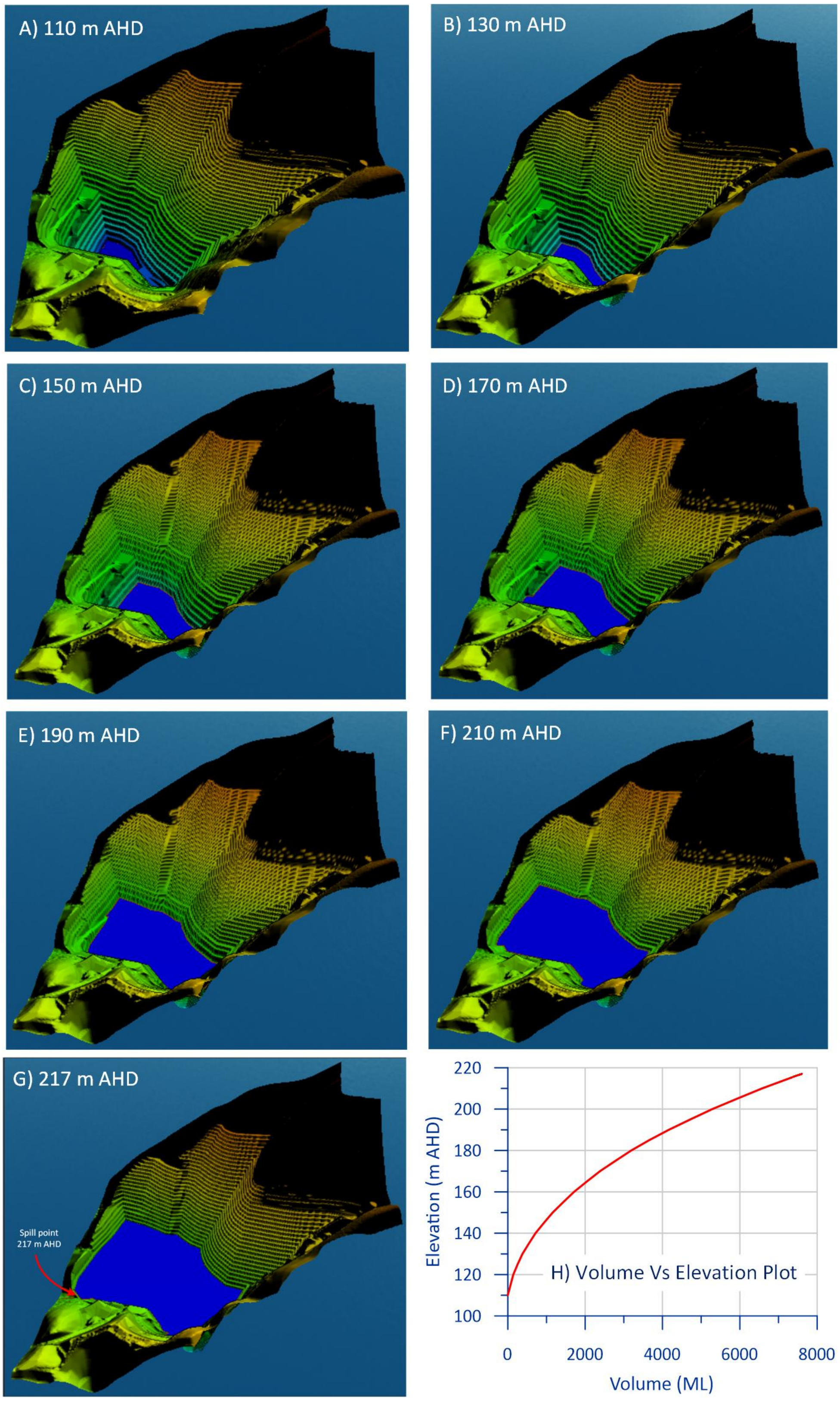


FIGURE 8.9 WA375 Stage 4 Pit Lake Fill Level DEM and Lake Volume Versus Elevation Plot

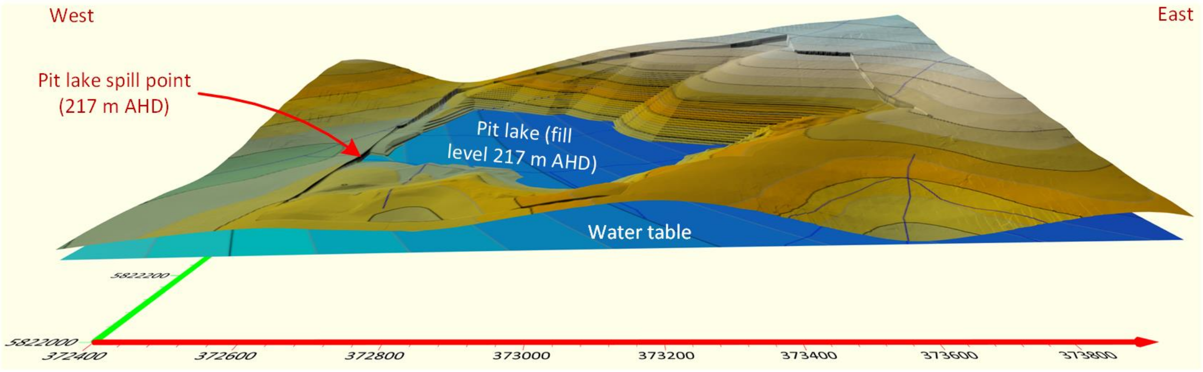


FIGURE 8.10 WA375 Terminal Pit Lake True 3D Visualization

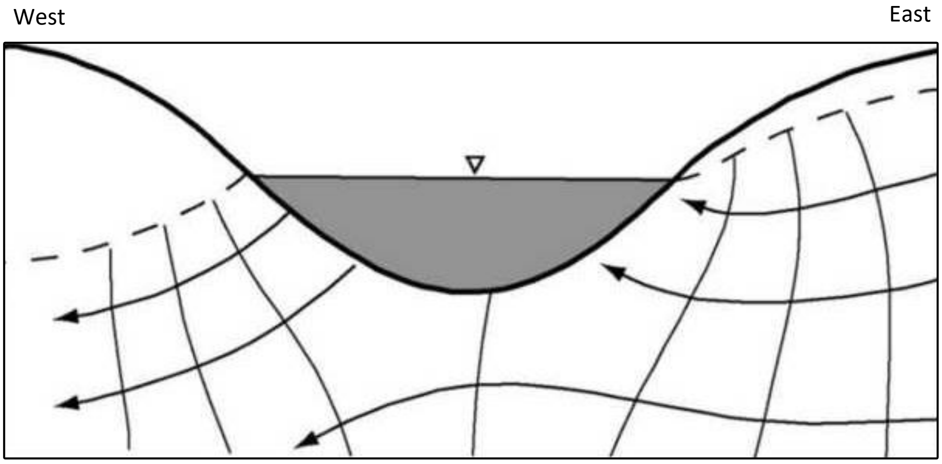


FIGURE 8.11 WA375 Throughflow Lake Schematic

9.0 QUARRY PT-WATER TABLE RELATIONSHIPS

A series of profiles were constructed through the W8375 quarry pit along flow lines for the 2022 pit, and for each of the proposed pit 4 stages to investigate the relationship between the quarry pit and the local water table. The profiles which were aligned parallel to groundwater flow lines (WbS-EbN bearing) all pass through respective pit floor sumps. The profile line locations and the profiles are shown in Figures 9.1 to 9.5.

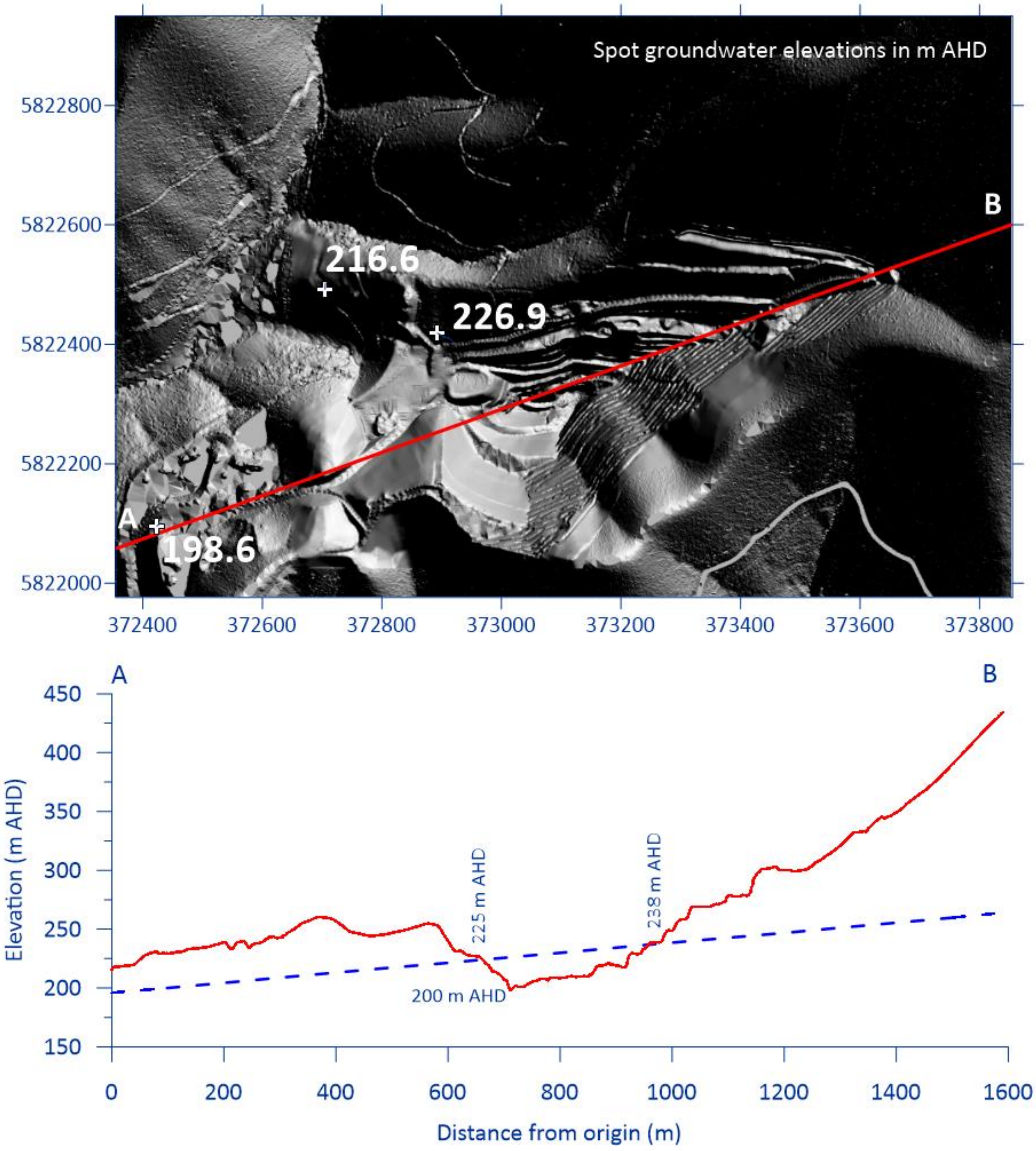


FIGURE 9.1 Approximate WbS-NbE Profile Through WA375 July 2022 Quarry Pit

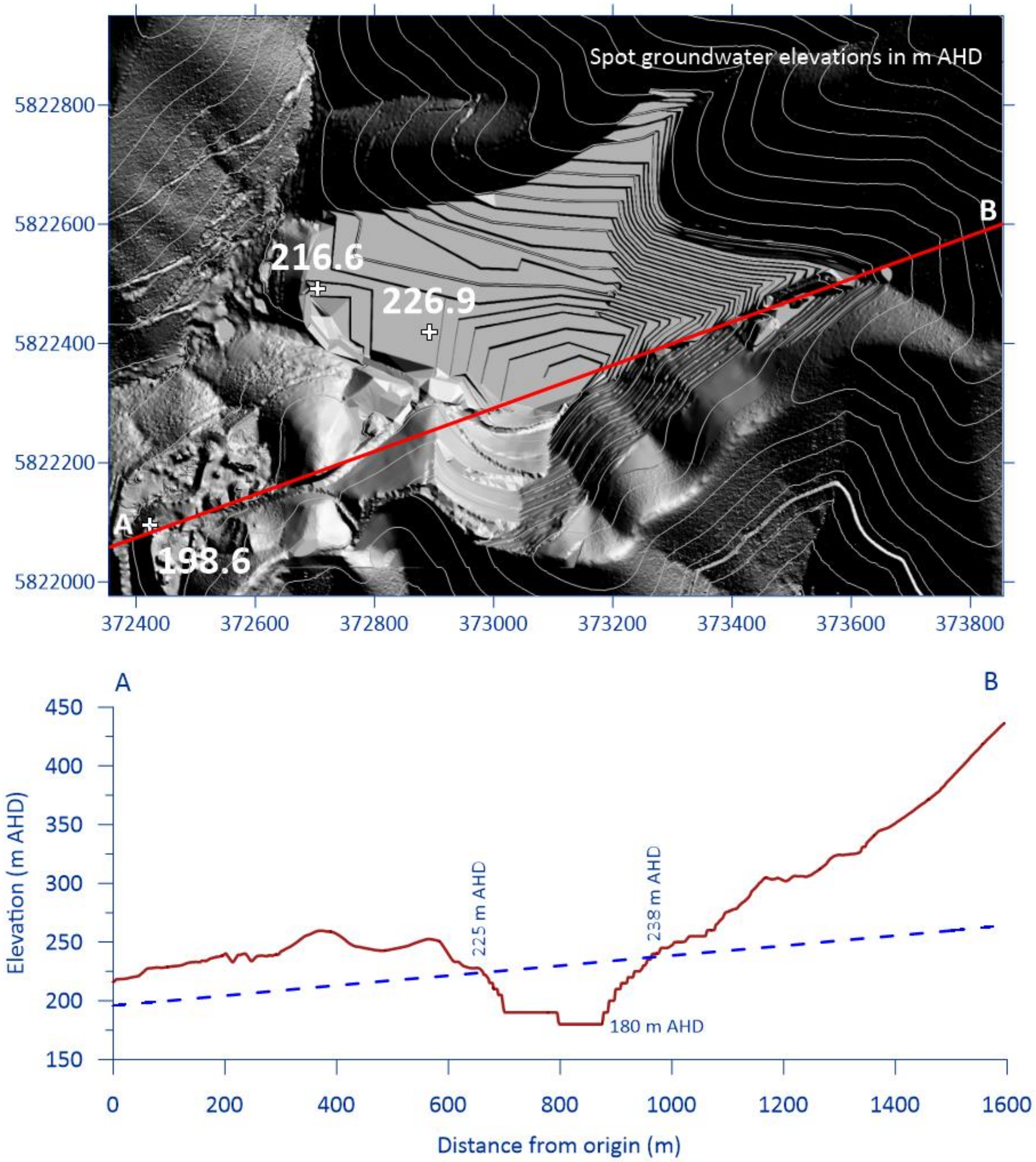


FIGURE 9.2 Approximate WbS-NbE Profile Through WA375 Stage 1 Quarry Pit

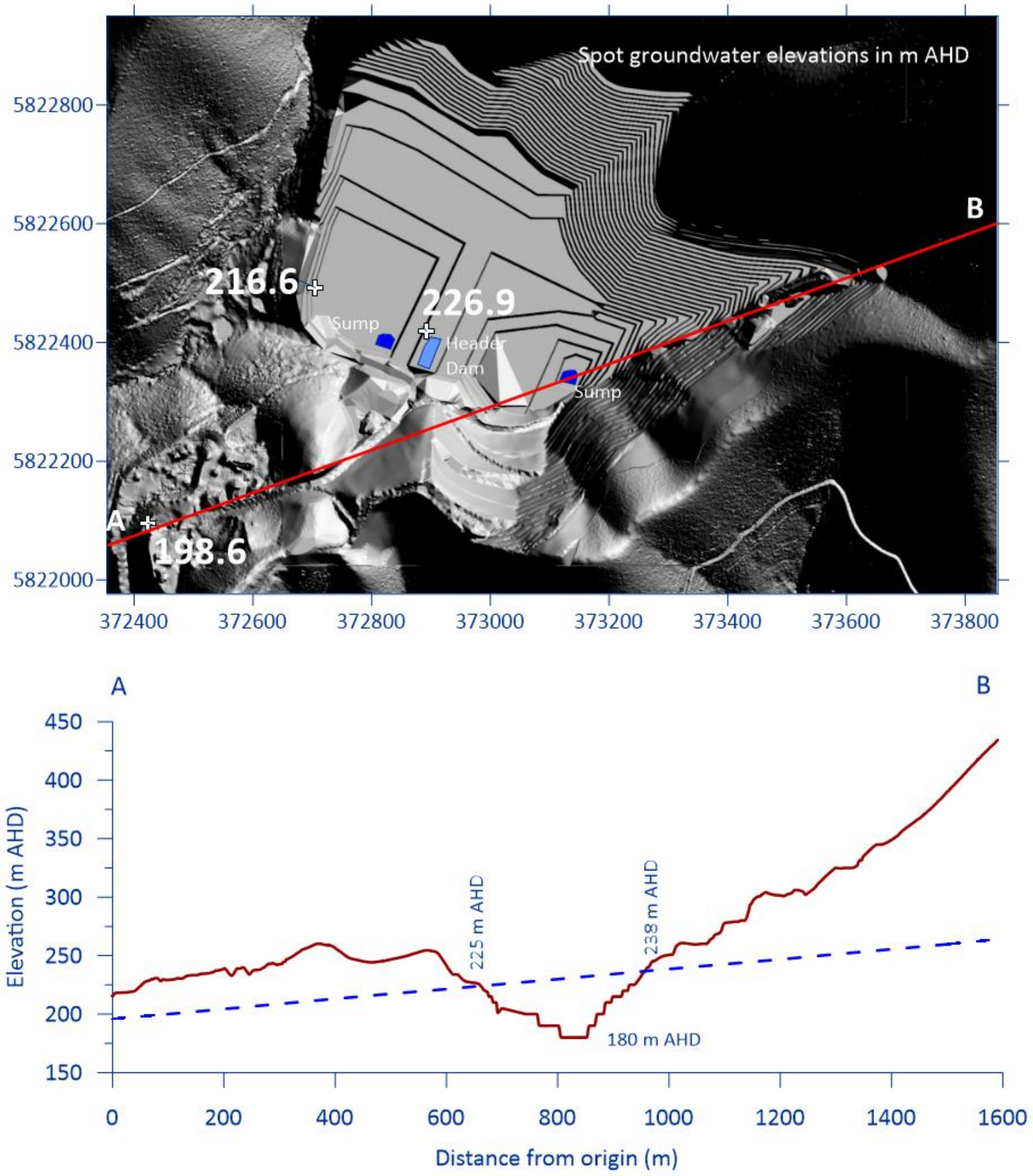


FIGURE 9.3 Approximate WbS-NbE Profile Through WA375 Stage 2 Quarry Pit

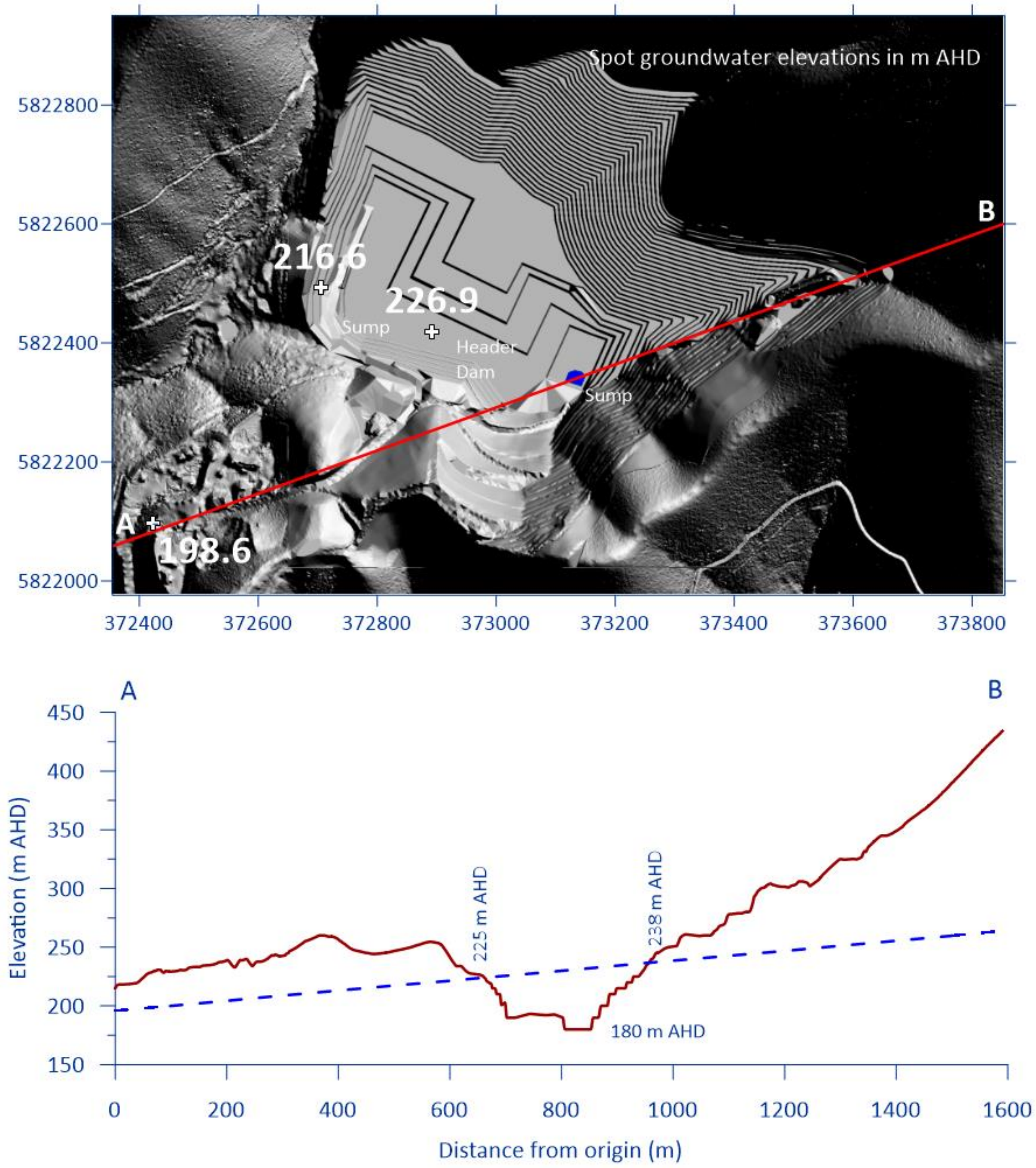


FIGURE 9.4 Approximate WbS-NbE Profile Through WA375 Stage 3 Quarry Pit

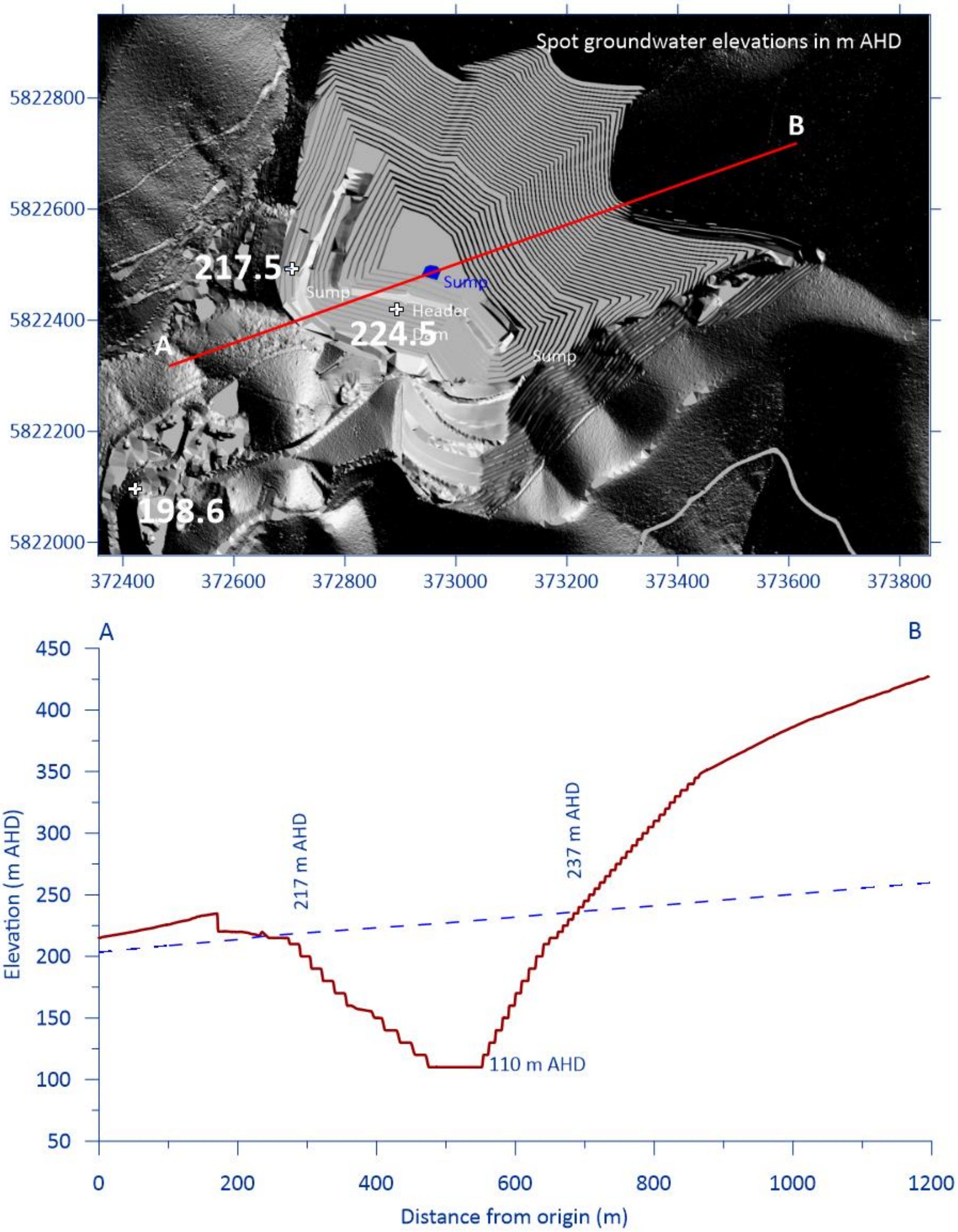


FIGURE 9.5 Approximate WbS-NbE Profile Through WA375 Stage 4 Quarry Pit

10.0 GROUNDWATER FLOW INTO QUARRY PITS

10.1 THEORETICAL CONSIDERATIONS

10.1.1 Drawdown and Cone of Depression

The proposed WA375 Stage 4 quarry floor will be more than 120 m below the water table. Groundwater will drain into the pit by gravity drainage as the local discontinuities in the Humevale Siltstone are dewatered. Groundwater flow quarry pit excavated below the water table is illustrated in Figure 10.1. This schematic shows the local steeping of the hydraulic gradient as groundwater flow lines converge towards the pit seepage faces.

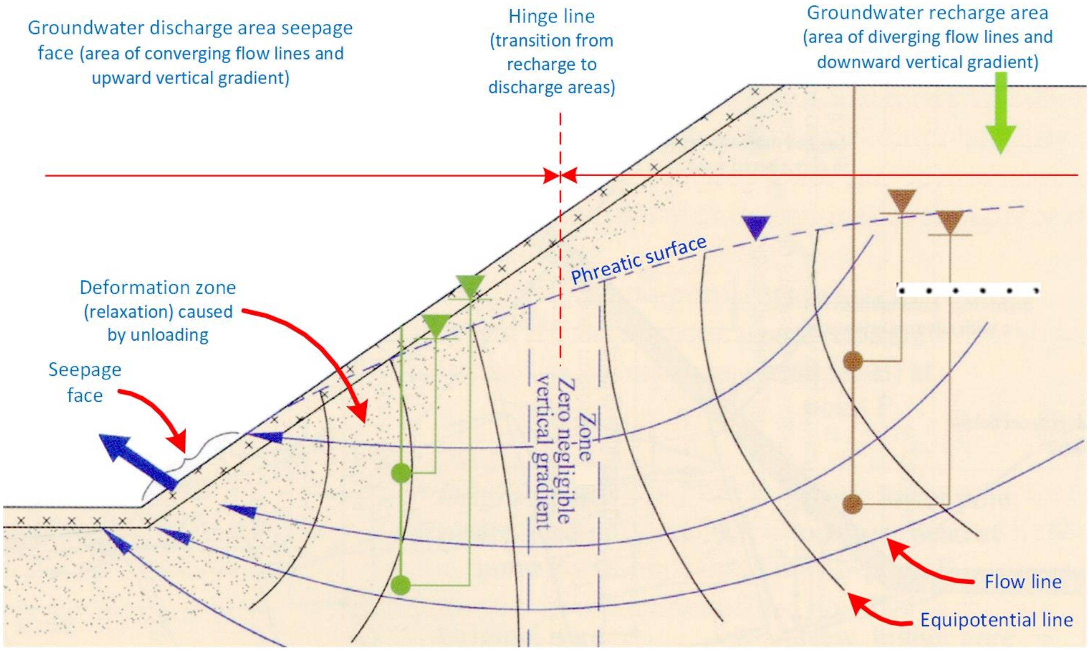


FIGURE 10.1 Idealized Groundwater Flow, Quarry Pit Area (modified after Beale *et al*, 2013)

The drawdown vortex created around quarry pits that extend below the water table is referred to as a "cone of depression" and the area affected by the gravity drainage is referred to as the "area of influence" (Figure 10.2). An example of the cone of depression in an isotropic aquifer with a flat-lying water table is shown in Figure 10.2. The shape of the circular drawdown cone can be distorted in anisotropic aquifers and/or in areas with a steeply sloping water table. The maximum distance at which drawdown can be detected with the usual measuring devices in the field (Dragoni 1998; Soni *et al*. 2015) is referred to as the "radius of Influence (R_o).

The drawdown at any point within the area of influence is directly proportional to the discharge rate and inversely proportional to aquifer transmissivity (hydraulic conductivity by saturated thickness) and aquifer storativity with transmissivity exerting a greater influence than storativity. The Humevale Siltstone bedrock has exceedingly low transmissivity (product of hydraulic conductivity by saturated aquifer thickness) and low storativity, consequentially the cone of depression around the proposed pit would be very steep and relatively localised (i.e., of high vertical magnitude and of narrow horizontal extent)and mainly restricted close to the quarry footprint. Steep, deep localised (limited aerial extent) drawdown around a pit in extensive low permeability aquifer is illustrated in Figure 10.3.

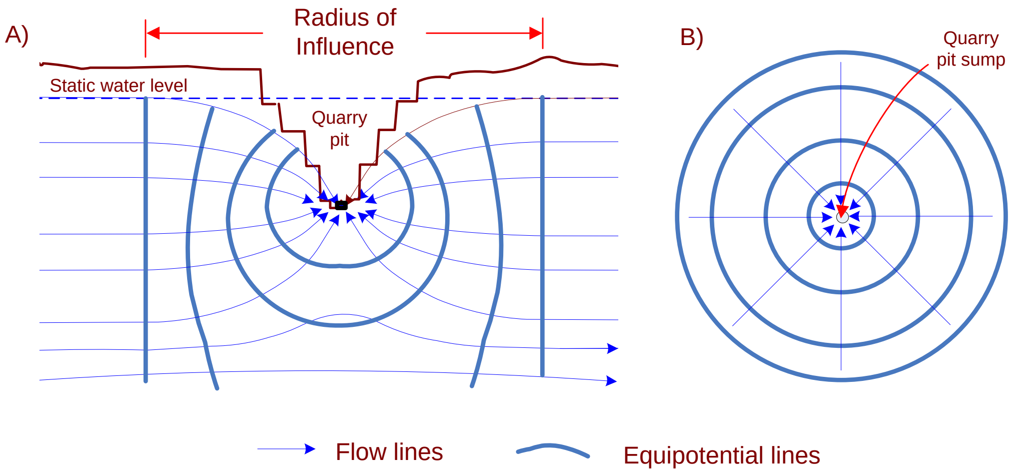


FIGURE 10.2 Drawdown Cone Around Quarry Pit in an Ideal (Isotropic) Aquifer with a Flat-Lying Water Table, A) Sectional View and B) Plan View

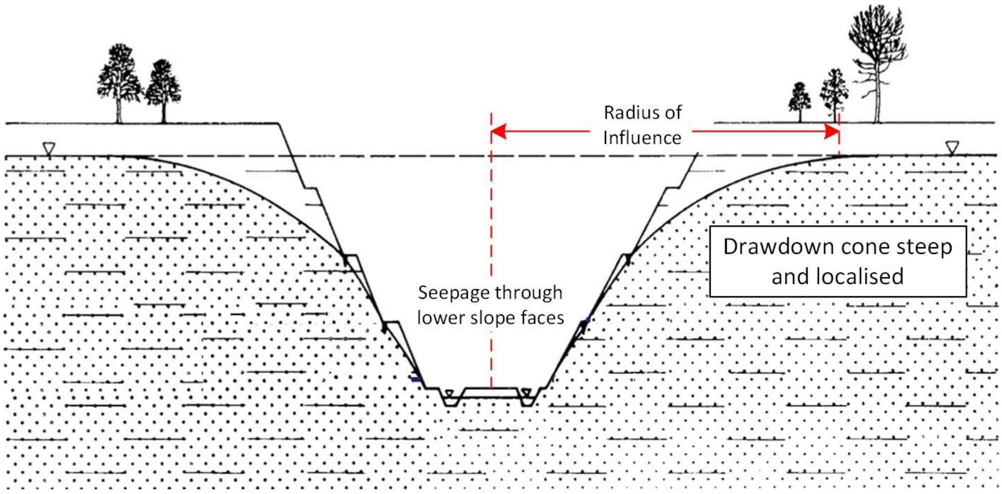


FIGURE 10.3 Drawdown Around Pit in Extensive Low Permeability Rocks (modified after Hall, 2014)

10.1.2 Radius of Influence and Pit Inflow

Both the R_o and pit inflows are dependent on aquifer hydraulic conductivity, a parameter that is difficult (and problematic) to determine in fractured rock aquifers. Consequently, both R_o and inflows were estimated for a range of hydraulic conductivities based on values in for siltstone in Morris and Johnson (21967 as reported in Halford and Kuniansky (2002), and values determined for calibrated groundwater flow models in rocks with similar hydraulic characteristics to the Humevale Siltstone including the Port Phillip CMA Groundwater Model (GHD, 2010) and models developed for major infrastructure projects in the Melbourne area (SKM, 2013). The results of the R_o and inflow calculations and correspond times to fill the WA375 quarry pit void were used to constrain the range of K values.

The WA375 site hydrogeology as with many hard rock quarries does not fully conform with the assumption for analytical modelling in that the host aquifer is fractured rock not a porous medium, the water table is not horizontal (water table rarely are horizontal; if there is no hydraulic gradient, groundwater would not flow) and the configuration of the quarry pit is not of simple cylindrical geometry. Regardless of the lack of conformity, analytical solutions of groundwater flow equations are considered to provide a reasonable estimate of the radius of influence and groundwater inflows at WA375.

10.2 WA375 RADIUS OF INFLUENCE

There are many empirical formulas that estimate R_o. when drawdown has stabilized. i.e., steady state drawdown) with the solutions developed by Sichardt (Kyrieleis and Sichardt, 1930) the most common (Cashman and Preene, 2013). The R_o of the WA375 quarry pit was estimated from the Sichardt equation (the most commonly used in dewatering studies; Cashman and Preene, 2013). and from a variant modified by Yihdego (2017). The Sichardt equation was first formulated as $R_o = 3000\ s\ \sqrt{K}$ where R_o is the radius of influence in m, s is the drawdown in m, and K is hydraulic conductivity in m/sec. Louwyck *et al*. (2022) reformulate the equation with K in m/day as $R_o = 10.206\ s\ \sqrt{K}$. The variant modified by Yihdego (2017) for analysing large equivalent bores in unconfined aquifers (reformulated with K in m/day for this report) is $R_0 = r_e + 10.206\ s\ \sqrt{K}$, where r_e is the radius of the quarry pit in m (other terms as previously defined).

Radii of influence were computed for the 1 Stage 4 terminal pit immediately on cessation of quarrying with the water depth on the quarry floor set to 0 m as this represents the worst-case drawdown and the largest area of influence scenario. Four different hydraulic conductivities (0.001, 0.01, 0.05 and 0.1 were modelled. The estimated radii of influence are summarised in Table 10.1.

The analysis indicates that the area of influence for the lower modelled K values would be mostly within the footprint of the terminal Stage 4 quarry pit, but the area associated with highest modelled K (0.1 m/day) extends beyond the Stage 4 pit perimeter to the north, northwest west and southwest by up to about 250 m (Figure 10.4).

Although the calculated radii are indicative only, they are consistent with commonly observed drawdown in low permeability fractured rock aquifers, i.e., localized steep drawdown cone of limited lateral extent. The equations used do not include recharge and therefore would over-estimate drawdown all other factors being equal.

TABLE 10.1 Stage 4 Terminal Pit Radii of Influence

Configuration	r_e (m)	S (m)	K (m/day)	R_o (m)		Comments
				Sichardt	Yihdego	
Sump at 110 m AHD	66	127	0.001	40	105	Low K
	66	127	0.01	130	195	Likely K
	66	127	0.05	225	290	Based on calibrated regional groundwater flow models
	66	127	0.1	410	475	High K

Notes: 1) R_o values have been round to nearest 5 m, 2) Regional groundwater flow models; Port Phillip CMA groundwater model (GHD, 2010), and East West Link Hydrogeological Investigations (SKM, 2013).

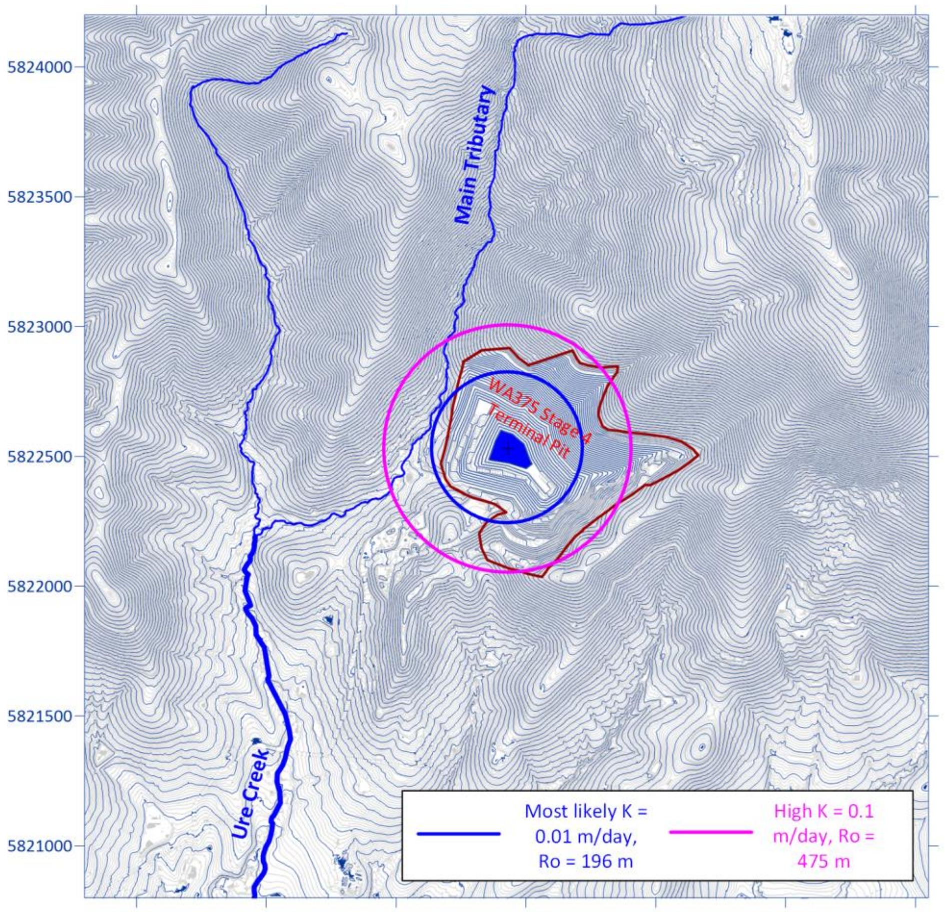


FIGURE 10.4 Stage 4 Quarry Pit Floor and Estimated Radii of Influence Prior to Groundwater Recovery

10.3 GROUNDWATER INFLOW

Groundwater flow into the WA375 Stage 4 pit at full extent is illustrated in the schematic southwest-northeast cross-section in Figure 10.5 (flow lines converge towards the pit floor).

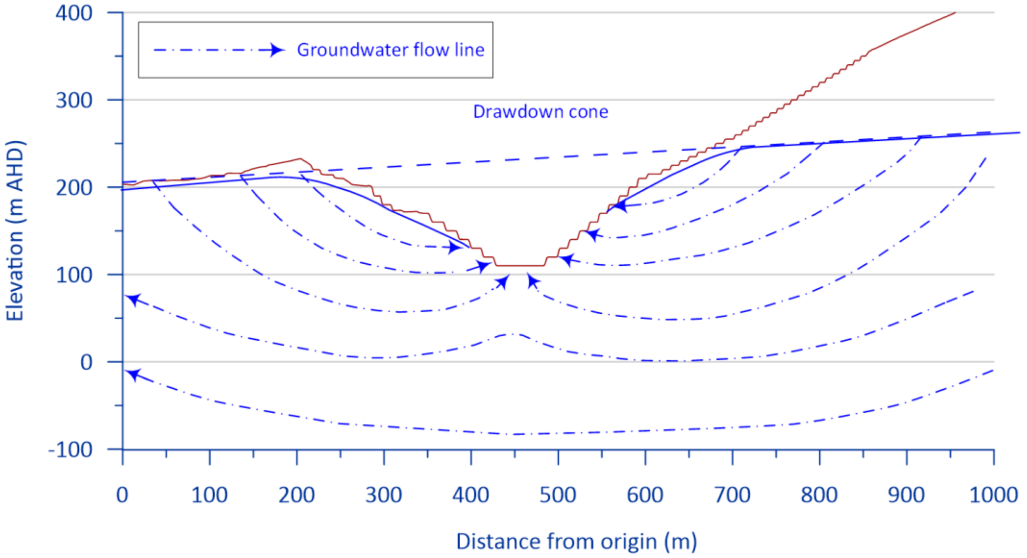


FIGURE 10.5 Stage 4 Active Quarrying Groundwater Flow Lines Slice-Section

The assessment of groundwater inflow to the WA375 quarry pit included 1) qualitative assessment based on anecdotal evidence and historic observations, and 2) analytical modelling of groundwater inflow into the Stage 4 pit after quarrying ceases.

10.3.1 WA375 Historic Pit Groundwater Inflow Observation

Comparison of water level data from the purpose-installed 2022 monitoring bores with the quarry feature survey (Landair, 2022) indicates that the floor of WA375 quarry floor was about 27 m below the water table in nearby monitoring bores during 2022. However, no significant groundwater inflow into the pit have been observed (Quarry Manager, J Morse, pers. comm., 2023), A few isolated small wet seepage areas were observed during the project team site visit in May 2022 (after recent heavy rain events). It is uncertain whether the observed wet areas were interflow water or groundwater. [Interflow refers to horizontal flow of water below the ground surface, but above the water table.] These observations are consistent with the water table mapping (Figure 6.2) that does not show any drawdown towards the sump confirming that the area of influence is small, and that the drawdown cone is steep and localised.

10.3.2 WA375 Stage 4 Pit Groundwater Inflow

Groundwater inflow into the Stage 4 pit lake was modelled using the groundwater algorithm incorporated into the Pit Lake Iterative Simulation Model (PLISM) developed by Halford Hydrology (Halford, 2023). PLISM is a water-balance model that simulates pit-lake time-dependent inflow and outflow components. Groundwater exchanges in PLISM are based on the Jacob-Lohman equation (Lohman, 1972; Fontaine et al, 2003). Four different hydraulic conductivity values (K = 0.001, 0.01, 0.05 and 0.1 m/day) were simulated. The modelled groundwater inflow fluxes versus time expressed as “years after quarrying ceased” are plotted in units of L/sec, ML/day and ML/year in Figure 10.6. The modelled groundwater inflow rate ranged from about 0.15 ML/day for K = 0.001 m/day up to 3.5 ML/day for K = 0.1 m/day.

The inflow fluxes decrease over time because the hydraulic gradient towards the pit decreases as the pit fills.

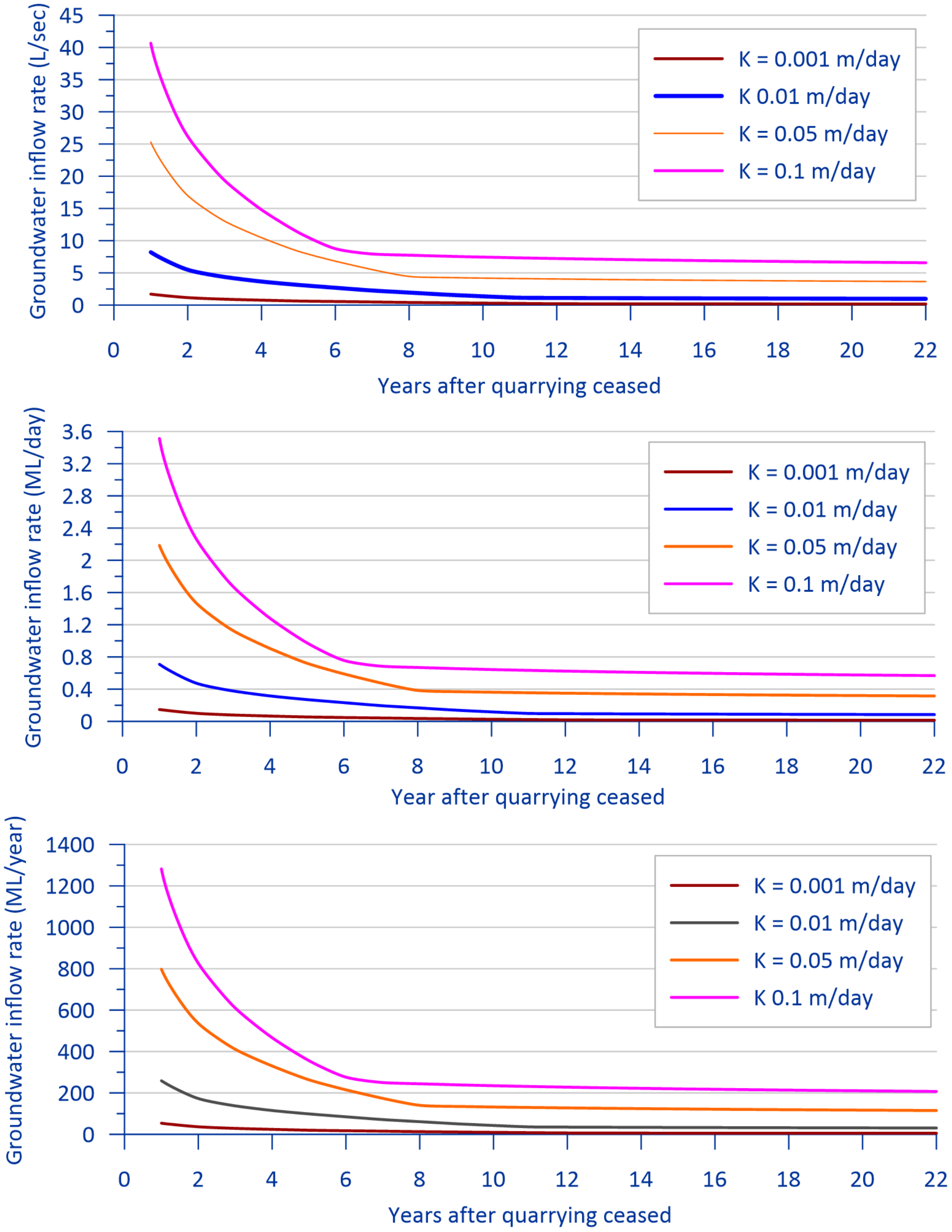
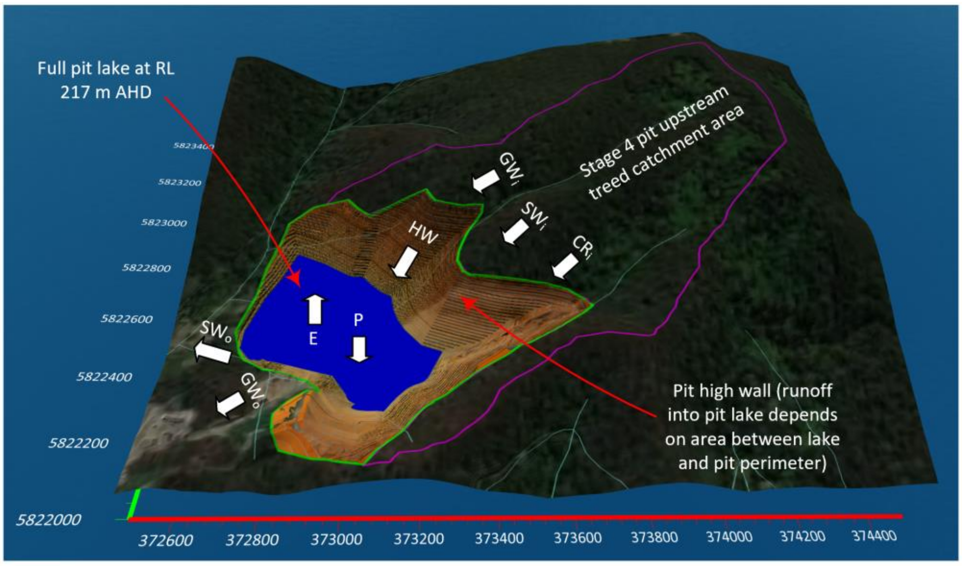


FIGURE 10.6 Stage 4 Pit Lake Filling Groundwater Inflow Flux

10.4 STAGE 4 PIT LAKE FILLING

After quarrying ceases the Stage 4 pit void will begin to fill from surface water (captured tributary flows, runoff from pit high walls, direct rainfall over lake water surface less evaporation) and groundwater inflow (Figure 10.7). The relationship between the surface area of the pit lake as it fills and the lake water storage volume as the lake fills, and the water level elevation are plotted in Figure 10.8. The Surface area and lake volumes were calculated from the Stage 4 design drawings prepared by BCA using the Surfer GIS software program (Golden Software©, Version 25). [Note that BCA did not allow for placement of overburden back into the pit void.]



Stage 4 pit footprint area 485,337.7 m^2; pit lake minimum area (110 m AHD bounding contour) 13,772.3 m^2; pit lake maximum area (217 m AHD bounding contour) 164,255.3 m^2; final pit lake highwall area 321,082.4 m^2; pit catchment area 750,750.6 m^2.

FIGURE 10.7 WA375 Stage 4 Water Balance Components

Water Technology (2023) developed a water balance model using the eWater Source program to assess the potential impact of the proposed WA375 quarry expansion on downstream waterways[5]. The eWater Source model incorporates a rainfall-runoff model (based on land use) and a streamflow model incorporating nodes and links. [Nodes are specific points along the river where water can be added, extracted, stored or recorded such as for water demand, storage and water usage. Links store or route water and constituents between nodes.]

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[5] The modelling approach used by Water Technology differs from the conventional approach used in groundwater flow modelling. Water Technology generated a "synthetic" water balance of the Ure Creek catchment based on local climatic data and gauged streamflow from nearby catchments (Don River - Launching Place, 229220; Don River - Dairy Road Don Valley, 229220B; Hoddles Creek - Launching Place, 229224A; and Yarra River - Launching Place, 229226). In contrast, groundwater flow models are typically developed by splitting the historic groundwater head data into two periods (data sets) using the first data set in developing the model which is then used to simulate the head distribution during the second data set period. The mode is then calibrated by adjusting the input parameters until the modelled heads agree (within acceptable limits) with the simulated heads. The calibrated model is then used to simulate future head distributions.

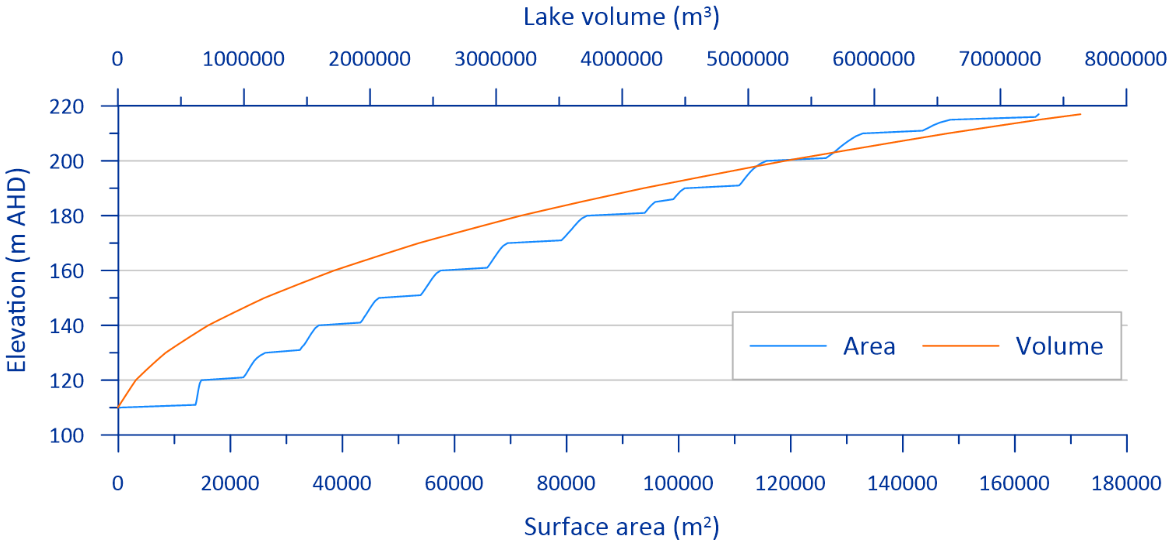

FIGURE 10.8 WA375 Stage 4 Pit Elevation Versus Pit Lake Surface area and Pit Lake Storage Volume (possible placement of overburden back into the pit void not included)

10.4.1 No Rehabilitation Vegetation or Overburden Placed into Pit Void

The eWater Source program was used to develop a water balance model for five different scenarios. This modelling utilized rainfall (1955-2020) from the BoM, verified against daily rainfall at the site since 2009 and monthly evapotranspiration data averaged toa daily scale. The Australian Water Balance Model (AWBM) was used to estimate the flow generated from each sub-catchment based on the applied climatic data (rainfall and evapotranspiration). The base model was calibrated using eWater Rainfall Runoff Library (RRL) tool kit for the nearby Hoddles Creek catchment, which had a streamflow gauging station record extending back to 2003. The parameters adopted in the calibration were then applied for the study catchment (Water Technology, 2023).

The Water Technology report presented a plot of pit lake water level versus time for three periods, for the fit lake filling from surface water only namely 1) base period commencing on 1 January 1955, 2) wet period commencing 1 January 1984, and 2) dry period commencing 1 January 2000. But, because the groundwater inflow modelling approach used by JLCS is based on inflow volumes (rather the lake stage elevation), the pit lake storage volume versus time were also plotted from data provided by Water Technology for the wet and the dry periods in Figure 10.9.

The Stage 4 pit lake filling phase was simulated using the results of the surface water balance modelling by Water Technology (2023) and groundwater inflow estimates using the analytical routine incorporated in PLISM (Halford, 2023). [Although the PLISM can model surface water components of a water balance e.g., precipitation, highwall runoff, evaporation from the pit lake etc., as well as groundwater exchanges, the surface water components were not modelled but were input from the water balance modelling by Water Technology (2023).]

Groundwater inflows volumes were modelled for hydraulic conductivity values of 0.001, 0.01, 0.05 and 0.1 m/day. The computed groundwater inflow volumes were added to the pit lake water storage volumes from derived from the water balance modelling by Water Technology (Figure 10.10). The Stage 4 pit lake fill times for the various modelled scenarios are summarised in Table 10.2.

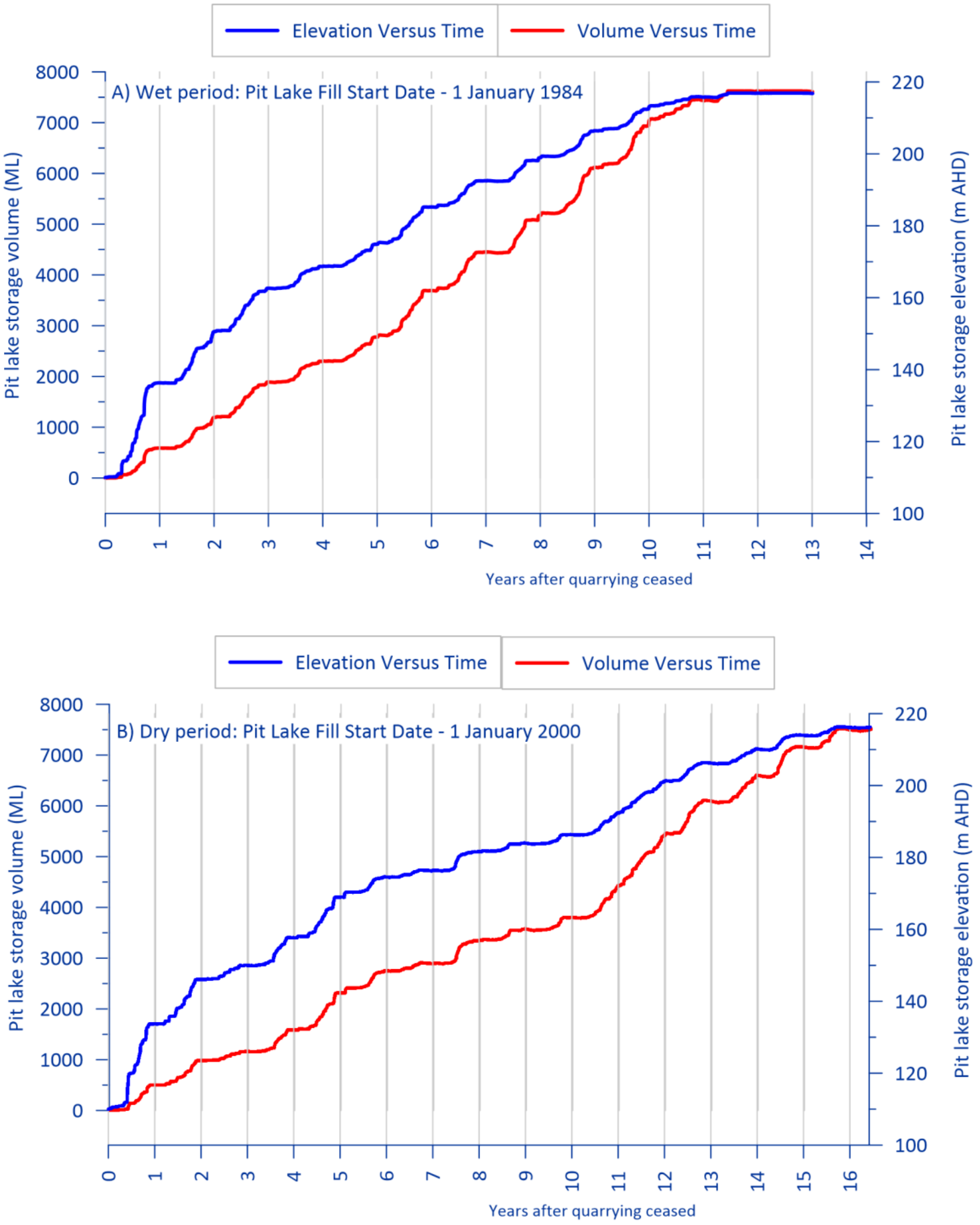

FIGURE 10.9 Stage 4 Pit Lake Filling Water Level and Storage Versus Time, A) Wet Period, and B) Dry Period

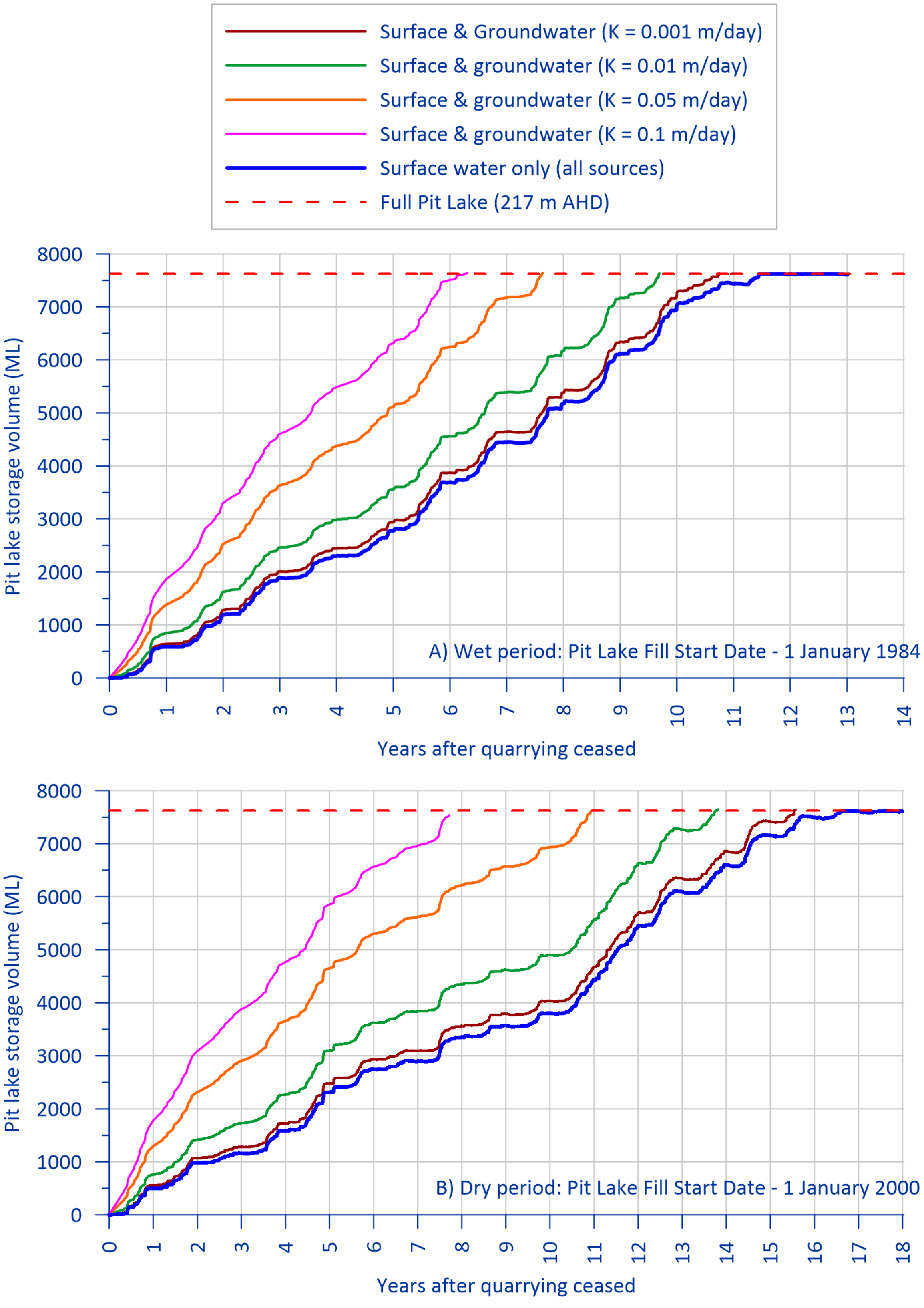

FIGURE 10.10 Stage 4 Pit Lake Filling Times , Surface Water and Groundwater Sources, A) Dry Period, and B) Wet Period

TABLE 10.2 Stage 4 Pit Lake Filling Scenarios and Fill Times

Climatic Condition	Surface Water Only (years)	Both Surface Water and Groundwater Inflows (years)			
		K = 0.001 m/day	K = 0.01 m/day	K = 0.05 m/day	K = 0.1 m/day
Wet period	11.7	10.8	9.7	7.5	6.2
Dry period	16.5	15.5	13.9	11	7.5

Modelled WA375 Stage 4 pit lake fill times with both surface water and groundwater inflows ranged from 6.2 to 10.8 years for modelled wet period, and from 7.5 to 15.5 years for modelled dry period (Table 10.2). The fill times based on the most likely K value (0.01 m/day) were 9.7 and 13.9 years for the wet period and dry period filling scenarios, respectively.

10.4.2 Established Rehabilitation Vegetation

Water Technology also modelled the quarry void fill time for the rehabilitated pit void that would change from exposed rock (quarry type) to trees (forested type) based on the Rehabilitation Plan for WA375. This modelled changed land type increased the fill time to about 20 years (Water Technology, 2023).

10.4.3 Placement of Overburden Back into Pit Void

An option for managing overburden at WA375 is to place it into the pit void. Under this option the overburden would most likely be placed on the lower levels of the pit. Consequently, the storage volume below the 217 m AHD spill elevation would be reduced by up to 25-30% which would reduce the pit lake fill time by a corresponding amount. This scenario has not been modelled.

10.4.4 Update Pit Lake Infill Assessment

Because of the inherent uncertainty in modelling groundwater inflows in fractured rock aquifers it is here recommended that the pit lake fill times is reassessed well before pit closure when more information on actual pit inflows and pit rehabilitation works is available.

10.5 WA375 POST QUARRYING PIT LAKE WATER QUALITY

A pit lake will form in the WA375 Stage 4 quarry void post quarrying. The quality of the water in pit lakes is a function of several factors, including: the quarry configuration (area, depth, storage volume), climate (rainfall and evapotranspiration), runoff into quarry pit, hydrogeology (aquifer type, hydraulic parameters), chemistry of input source water (rainfall, surface water, groundwater) and relative contributions, and lake type (terminal or throughflow), pit lake hydrodynamics and in-pit chemical processes (modified after Bowell 2002; Castendyk and Eary, 2009).

10.5.1 WA375 Pit Lake Water Quality

A mass balance approach was used to predict the quality of the water in the pit lake with both surface water and groundwater inflows (based on the observation that evaporation from the pit lake is approximately equal to precipitation that falls on the lake surface). was used rather than the sump because the sump water is a mixture of groundwater and surface water potentially subjected to evaporation that would alter the water chemistry.

For the mass balance it was assumed that surface water would account for about 85% of the water in the WA375 pit lake with groundwater inflow contributing about 15%. A final pit lake volume of 7.64×10^9 L (7,640 ML) was used in the modelling (does not allow for placing overburden back into the pit void). Evapoconcentration was not considered because 1) precipitation is similar to evaporation, 2) the pit lake will be "topped-up" by year-round inflow of good quality surface water, and 3) the lake will be a groundwater through lake, not a terminal discharge lake. Some small-scale variability in lake water chemistry is expected because of fluctuations in pit lake surface area and water storage volume due to seasonal variability in runoff from the surface water catchment and pit high wall, and in rainfall and evaporation patterns.

The concentrations of the analytes that were tested in groundwater and surface water at WA375 during 2022 in the final pit lake were determined by:

1. Calculating the mass (mg) of respective analytes in the volume of water (L) derived from surface water (captured tributary flow and runoff).
2. Calculating the mass (mg) of respective analytes (mg) in the volume of water (L) derived from groundwater inflow.
3. Calculating the total mass (mg) of respective analytes in the full lake volume (L).
4. Calculating the mass (mg) of respective analytes in one litre of lake water (L)

Example TDS Concentration Calculations

Mass of salt in surface water component: 80 (mg/L) x 6.61×10^9 (L) = 5.29×10^{11} mg.

Mass of salt in groundwater component: 1,000 (mg/L) x 1.03×10^9 (L) = 1.03×10^{12} mg.

Total mass of salt: 5.29×10^{11} (mg) + 1.03×10^{12} (mg) = 1.56×10^{12} mg.

Lake water salinity: $(1.56 \times 10^{12})/(7.64 \times 10^9)$ (mg/L) = $2.04 \times 10^2 \approx 200$ mg/L.

The likely analyte concentrations in the pit lake water that will develop in the WA375 quarry pit void after quarrying ceases are presented in Table 10.3. [pH is not included in the water mixing analysis because the pH scale is logarithmic, i.e., mixing a pH 5 water with a pH 7 water does not result in a mixture of pH 6.]

TABLE 10.3 WA375 Pit Lake Surface Water-Groundwater Mixture Chemistry

Analyte	Concentration (mg/L)			Analyte	Concentration (mg/L)		
	SW5	GW2	Mixture		SW5	GW2	Mixture
TDS	80	1003	204	NO2	0.001	0.001	0.001
Na	12.3	135	29	Org-N	0.44	0.555	0.456
K	1.6	4.7	2	TKN	0.5	0.575	0.510
Ca	2.6	117	18	∑N	1.4	0.6025	1.264
Mg	2.3	32	6	∑PO4	0.025	0.02	0.024
Cl	35.7	293	70	As	0.003	0.0005	0.002
SO4	12	74	20	Cd	0.0001	0.0001	0.000
HCO3	31	409	82	Cr	0.002	0.0005	0.002
CO3	<10	<10	<10	Cu	0.0015	0.0005	0.001
∑ Alk	25	335	67	Pb	0.0005	0.0005	0.001
NO3 + NO2	1.2	0.055	1.046	Hg	0.00005	0.00005	0.0001
NO3	1.2	0.055	1.046	Ni	0.001	0.011	0.002
NH3	0.06	0.04	0.057	Zn	0.01	0.016	0.011

10.5.2 Discussion

Salinity

Water salinity is the key parameter for identifying Environmental Values as defined in the Environmental Reference Standard (ERS) (Government Gazette, No. S 245, 2021). The average salinity of surface water measured at the Moora Creek monitoring point SW5 during 2022 was about 80 mg/L TDS. The TDS in monitoring bore GW2 located within the proposed quarry expansion area was taken as indicative of the groundwater inflow salinity. The groundwater salinity in this bore varied from 930 to 1,100 mg/L during 2022 (average about 1,000 mg/L) which is significantly higher than in the other WA375 monitoring bores e.g., the groundwater salinity in nearby GW1 varied from 480 to 680 mg/L. The salinity pit lake water for 85% and 15% surface water and groundwater mixture would be about 200 mg/L TDS (rounded value).

TABLE 10.3 WA375 Pit Lake Water Salinity

Scenario	Lake Volume	Surface water		Groundwater		TDS (mg/L)		
	(ML)	%	Volume	%	Volume	Surface water	Groundwater	Mixture
All groundwater	7,640.0	0	0.0	100	7,640.0	–	1,000	1,000
Mixture	7,640.0	85	6,608.6	15	1,031.4	80	1,000	204
All surface water	7,640.0	100	7,640.0	0	0	80	–	80

The worst-case pit lake water salinity will occur in the pit is filled with groundwater only (no surface water enters the lake). Under this scenario, the pit lake water chemistry would be the same as the local groundwater (assuming that rainfall and evaporation are approximately equal) After the lake level reaches 217 m AHD, it will overflow into Moora Creek via Tributary 1. The overflow water under the worst-case lake water salinity scenario would be captured groundwater that would have otherwise discharged naturally into local creeks and the Yarra River albeit at lower elevations, i.e., the pit lake overflow would in effect “short-circuit” the natural groundwater flow system. Consequently, the worst-case pit lake overflow water would not adversely affect the natural stream water salinity.

Acid Mine Drainage

Acid mine drainage is caused by the oxidation of pyrite and other sulphides that occurs when sulphide minerals are exposed to air and water. The site geology and geochemical environment at WA375 is not conducive to generation of acid drainage. No pyrite rich beds have been exposed or logged in rock resource drillholes at WA375 and groundwater and surface water pH is neutral to slightly alkaline with low heavy metal concentrations.

11.0 RISK ASSESSMENT

A “groundwater” risk assessment was undertaken to identify and assess all potential risks that the proposed WA1488 variation poses to the groundwater environment including groundwater users, hydraulically interconnected surface water systems (streams, wetlands, springs, ocean) and associated Groundwater Dependent Ecosystems (GDEs). The risk assessment was conducted in accordance with ERR requirements as documented in “Preparation of Work Plans and Work Plan — Variations Guidelines for Mining Projects” (DJPR, 2019)

11.1 ROCK EXTRACTION AND POTENTIAL IMPACTS

Rock extraction operations can have detrimental impacts on groundwater quantity if the water table is lowered and/or groundwater quality if extraction operations cause groundwater contamination. Lowering the water table can impact local groundwater users and/or hydraulically connected surface water systems (receiving waters) such as streams, wetland and Groundwater Dependent Ecosystems (GDEs).

Potential impacts on groundwater users, surface water, wetland and GDE assets vary according to 1) the local hydrogeological setting (aquifer type, degree of groundwater confinement, etc.), 2) aquifer hydraulic parameters, 3) position of pit floor relative to the water table, 4) groundwater extraction method (passive gravity drainage; aggressive dewater works), 5) method used to extract the rock, 6) proximity of bores to groundwater extraction location(s), and 7) proximity of streams, wetlands and GDEs to pit or groundwater extraction location(s) and degree of hydraulic interconnection.

Groundwater at quarries can be contaminated indirectly via percolation from a source down to the water table or directly if runoff from a contaminated source area flows into a sump or pit (dredge pond) excavated below the water table. The potential for groundwater at quarries to be contaminated requires 1) a contamination source(s) (e.g., leaking fuel storage tank, accidental spills or leaks of potential contaminants, application of pesticides or herbicides, etc.), 2) complete hydrogeological pathway between the contamination sources and groundwater.

11.2 RISK ASSESSMENTS

Risk analysis involved considering the likelihood of an event occurring, and the severity of an event’s consequence(s). The likelihood of an event (Table 11.1) and the consequence/severity of the event (Table 11.2) were combined to derive a risk matrix (Table 11.3). The risk matrix is then used to ascertain the risk of harm to the identified receptors. Once the risk rating has been established some risks will need to have controls in place to reduce them to an acceptable level. Higher risk levels should take priority. Guidance on whether the inherent risks are acceptable or if steps need to be taken to eliminate or reduce the risks is provided in Table 11.4.

TABLE 11.1 Likelihood Description

Likelihood	Description	Event probability
Almost Certain	The risk event is expected to occur in most circumstances.	90-100%
Likely	The risk event will probably occur in most circumstances.	70-90%
Possible	The risk event might occur at some time.	30-70%
Unlikely	The risk event could occur at some time.	5-30%
Rare	Highly unlikely, but the risk event may occur in exceptional circumstances.	0-5%

Source: DJPR, 2019.

TABLE 11.2 Consequences Description

Indicator	Human Impact	Environmental impact	Economic impact
Critical	Death, permanent health impact	Catastrophic on-site or off-site impacts	Immense financial loss
Major	Extensive injuries or illness	Substantial on-site or off-site impacts	Major financial loss
Moderate	Some health impacts	Some on-site or off-site impacts	Large financial loss
Minor	First aid treatment required	Minimal on-site or off-site impacts	Small financial loss
insignificant	No injuries or illness	No environmental impacts	Negligible financial loss

Modified after EPA Publication 1321.2, June 2011.

TABLE 11.3 Risk Matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Critical
Almost Certain	Medium	High	Very high	Very high	Very high
Likely	Medium	Medium	High	Very high	Very high
Possible	Low	Medium	Medium	High	Very high
Unlikely	Low	Low	Medium	High	High
Rare	Low	Low	Medium	Medium	High

None*	None	None	None	None	None

Notes: 1) Source: modified after DJPR, 2019, and 2) *The ERR Risk Matric does not have a category for events that have no likelihood of occurring but that may be of interest to referral agencies and/or the general community.

TABLE 11.4 Risk Rating Acceptability

Risk level	Description
Very High	Totally unacceptable level of risk. Controls must be put in place to reduce the risk to lower levels
High	Generally unacceptable level of risk. Controls must be put in place to reduce the risk to lower levels or seek specific guidance from ERR-
Medium	May be acceptable provided the risk has been minimised as far as reasonably practicable.
Low	Acceptable level of risk provided the risk cannot be eliminated

Source: DJPR, 2019.

The effect of applying the risk matrix is that a risk that is rare but would have an extreme consequence if it did occur is allocated a very high-risk rating. A risk that is almost certain and has only a moderate consequence is also allocated a very high-risk rating. This ensures that likely risks are given appropriate prominence in the impact assessment and that remote risks with major (or above) consequences are appropriately recognized and managed to ensure that they do not eventuate and cause environmental and or human health harm. It is therefore necessary to consider the impact both in terms of consequence and likelihood for the development of potential management and mitigation measures in response to significant risks. [Risk ratings should not be confused with the outcomes of the impact assessment, which consider the likely impacts and focus on current consequences.]

11.3 DRAWDOWN INTERFERENCE RISK ASSESSMENT

11.3.1 Drawdown Interference Risks

The likelihood, Consequence and Risk of harm from drawdown interference by active (gravity drainage) dewatering and aggressive dewatering (e.g., if unexpected, highly fractured aquifer zones are intersected at the proposed expanded quarry pit are summarised in Table 11.5.

TABLE 11. 5 Groundwater Dependent – Likelihood, Consequence and Risk of Harm

Risk event	Receptor(s)	Present within AoI	Likelihood of DdI	Consequence	Risk	Comments
Passive dewatering	Supply bores	No	None	Minor	No risk	Drawdown cone largely confined to within quarry footprint.
	Gaining streams	No	None[2]	Moderate	No risk	Water table below local stream beds within the area of gravity drainage influence.
	Wetlands, GDEs	No	None[2]	Moderate	No risk	None identified with 2 km buffer zone.
Aggressive dewatering	Supply bores	Yes	Unlikely	Minor	**Low**	Only one supply bores within 2 km from quarry pit (bore WRK090333 (about 1.92 km from pit) but drawdown unlikely to exceed acceptability criteria.
	Gaining streams	Possible along lower reaches of Ure Ck.	Unlikely	Moderate	**Low**	Drawdown cone could intersect local stream at lower elevations. However, associated stream deletion unlikely to be significant.
	Wetlands, GDEs	Possible along lower reaches of Ure Ck.	Unlikely	Moderate	**Low**	Drawdown cone unlikely to reach mapped sensitive groundwater dependent ecosystem and vegetation with high environmental value.

Notes: 1) AoI; Area of Influence, 2) DdI; Drawdown Interference; 3) the DJPR (2019) Risk Matrix does not have a "no likelihood" ranking; DJPR/ERR accepts that a "risk" is not present and does not need to be included in the WPV Risk Register.

No "Risk of Harm" associated with passive dewatering of the proposed expanded WA375 quarry pit has been identified. This finding was based on:

- The area of influence would not extend to the nearest groundwater supply bores.

- The streambeds of the reaches of the tributaries of Ure Creek beyond the quarry pit footprint are above the water table (the tributaries are losing streams) consequently lowering the water table further below the streambeds would not induce more streambed infiltration.
- There are no mapped wetlands or GDEs within the expected maximum Area of Influence

The qualitative Risk Assessment identified Low risks of harm to groundwater users and sensitive Environmental Values (streams, wetlands, GDEs), respectively if more aggressive dewatering works are required because of the likely expanded drawdown cone of depression.

11.3.2 Drawdown Interference Risk Mitigation

If higher hydraulic conductivity fractured rock zones are encountered, pit inflows of groundwater would be higher, and the area of influence would be larger. The risks of adversely impacting streamflow (streamflow depletion) would be greater and but the potential to cause unacceptable drawdown interference in supply bores (define as 10 percent reduction of the available drawdown in a supply bore) would not change as the three nearest supply bores are all about 2 km from the WA375 pit and beyond the modelled extent of the cone of depression for the extreme high hydraulic conductivity. Likewise, the potential to adversely impact sensitive environmental values including GDEs, which are also more than 2 km from the WA375 pit.

In addition, if higher hydraulic conductivity zones intersected, larger volumes of water would have to be pumped from the WA375 quarry pit. The additional water would be released into Tributary 1 and discharged into Moora Creek. The release of the additional water would mitigate adverse impacts associated with expanded drawdown cone and lowered water table that could potentially cause stream depletion in the lower reaches of Ure Creek.

11.4 GROUNDWATER CONTAMINATION RISK ASSESSMENT

Groundwater contamination risk assessments (GCRAs) identify the risk of harm to groundwater users and/or the environment from potential contamination sources and involve determining the likelihood of a risk occurring and the consequence if it occurs. GCRAs require identification of source (hazard), pathways and receptors and are based on Source-Pathway-Receptor-Consequence (SPRC) models (Figure 11.1). If contamination is to cause harm, it must reach a receptor. A contaminant linkage occurs when a source, pathway and receptor are all present. If no pathways are present the linkage is incomplete. Consequently, there is no risk of the source adversely affecting a receptor.

11.4.1 WA376 contamination sources

Potential contamination sources at WA375 include the storage and use of fuels and lubricants, and the use of ammonium nitrate blasting explosives. Sources and pathways for contaminants to enter the depressed water table at WA375 include:

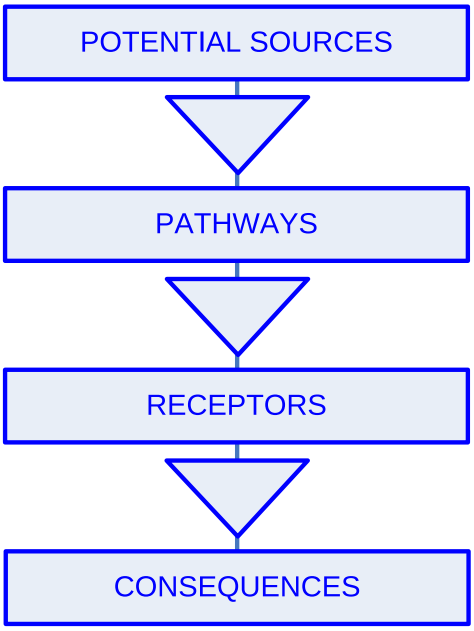

FIGURE 11.1 Groundwater Contamination S-P-R-C Model

- Diesel fuels: Diesel fuels could enter the groundwater at WA375 if the above ground storage tanks developed leaks or if accidental spills onto the ground occurred at the site. The contaminants would have to percolate vertically through the unsaturated zone created by dewatering and enter the depressed water table.

- Blasting: Fragmentation of hard rocks with Ammonium Nitrate (NH4NO3) explosives is a potential source of nitrate (NO3) contamination of groundwater (Gascoyne and Thomas, 1997; Ihlenfeld et al., 2009; Bailey et al., 2013; Degan et al., 2015). The bulk emulsions emplaced in the blasting holes at WA375 consist mainly of NH4NO3 and fuel oil (ANFO). High NO3 concentrations in groundwater affected by explosives can be caused by several different processes, including l) leaching of NO3 from unexploded NO3-bearing explosive compounds, 2) oxidation (nitrification) of reduced N components of the explosives and 3) injection of soluble NH_3 or NOx gases into the subsurface by blasting. Direct entry into groundwater is unlikely as the gravity drainage towards the sump(s) would depress the water table below the blast area.

11.4.2 Pathways - quarry operating and pit lake filling phases:

Groundwater Flow System

- ➢ Contaminated groundwater flows under inward hydraulic gradient into sump during quarrying or into pit lake post-quarrying until lake fills to spill level flows.

- ➢ No pathway for contaminated groundwater to migrate impact local groundwater users, surface water systems and/or GDEs.
- ➢ No Risk of Harm (cannot have risk without complete pathway).

Surface Water Flow System

- Water pumped from sump into Moora Creek represents complete pathway for contaminated water to enter the surface water flow system.

11.4.3 Pathways post quarrying pit lake at spill elevation

Groundwater Flow System

- Contaminated lake water migrates out of the lake in down-hydraulic gradient direction thereby impacting groundwater quality.

Surface Water Flow System

- Contaminated water in the pit lake spills into surface water system.

11.4.4 Potential receptors

Potential receptors include (in order of decreasing contamination likelihood) 1) gaining reaches of local creeks at lower elevations, 2) local groundwater users (closest about 2 km from WA375), and 3) groundwater dependent ecosystems (no wetlands or GDEs have been identified within 2 km of the proposed WA375 quarry).

11.4.5 Inherent Risks

Groundwater contamination event likelihood, event consequences and associated risk of harm are summarised in Table 11.6.

The concentration of any contaminants that enter groundwater would be dilution and attenuation during migration from the source to receptors. Concentration levels in discharged groundwater would be further reduced by dilution with surface water.

11.4.6 Risk Mitigation and Residual Risks

Measure that will be used to mitigate risks of fuels and/or chemicals storage and use causing groundwater contamination will include:

- All fuels and other chemicals will be stored in compliance with 1) Hydrocarbon storage in accordance with AS 1940 (The Storage and Handling of Flammable and Combustible Liquids) and 2) the Dangerous Goods (Storage and Handling) Act.
- Underground fuel storage tanks will not be used.
- Vehicle refuelling will only be in bunded hardstand containment areas.
- Contaminant spill kits will be kept onsite.
- All machinery and equipment will be regularly checked and maintained to minimize the potential for equipment failure.
- The use of explosives will adhere to industry Best Practice.

TABLE 11.6 Groundwater Contamination Inherent Risk Ratings

Risk Event	Phase	Pathway	Receptor(s)	Present	Likelihood	Consequence	Risk	Comments
Leaking fuel storage tank, fuel spills, or nitrate from explosives contaminating groundwater	Quarrying and lake filling	Groundwater	Groundwater users	Yes	None	Moderate	No risk	No pathway
			Gaining streams	Yes	None	Moderate	No risk	
			Wetlands, GDEs	No	None	Moderate	No risk	
		Surface water	Streams	Yes	Unlikely	Minor	**Low**	
			Wetlands, GDEs	Yes	Unlikely	Minor	**Low**	
	Full pit	Groundwater	Groundwater users	Yes	None	Minor	No risk	Contaminant concentrations greatly reduced by dilution in pit lake and water flow systems
			Gaining streams	Yes	Unlikely	Moderate	**Low**	
			Wetlands, GDEs	No	Unlikely	Moderate	**Low**	
		Surface water	Groundwater users	Yes	None	Moderate	No risk	
			Gaining streams	Yes	Unlikely	Moderate	**Low**	
			Wetlands, GDEs	No	Unlikely	Moderate	**Low**	

Notes: 1) GDEs; Groundwater Dependent Ecosystems.

If any potential groundwater contaminating events occur, DPQ should initiate works to either remove or control the potential contamination source, install investigation/monitoring bores down hydraulic gradient from the source to determine water quality impacts, up-date the risk assessment to determine whether the risk of harm has become unacceptable, instigate clean-up measures appropriate to the source characteristics to rehabilitate any contaminated groundwater to the extent practicable or until the risks are acceptable.

Implementing the risk mitigation measures as outlined including undertaking action in the event of a potential groundwater contaminating event occurring, will reduce both the “Likelihood” of an event being potentially contaminating and the “Consequences’ of any potential contaminating event to the “Rare” and “Minor” categories, respectively, and the risk ratings to “Low”.

12.0 GROUNDWATER MONITORING AND MANAGEMENT

12.1 MONITORING BORES

There are currently four permanent DPQ monitoring, three new bores (GW1, GW2 and GW3) that were installed in February 2022 and a previously installed private bore on adjoining land now owned by DPQ (GW4) at WA375. Two of the permanent monitoring bores, GW1 and GW2, and the non-constructed diamond drillhole (DDH; water level only) are within the footprint area of the Stage 1 quarry pit (Figure 12.1) and will be destroyed during the initial expansion works. These bores should be replaced by bores installed outside of the quarry pit footprint. Additional bores could be required to ensure that the network of monitoring bores is adequate to detect changes to groundwater levels and chemistry for assessing quarry impacts. The locations of all new bores need to be carefully selected to minimise disruption to native vegetation beyond the quarry limit as well as providing suitable control point for assessing the impact of the proposed expanded quarry on local groundwater. The number of monitoring bores and bore location should be agreed with government regulators including Earth Resources Regulations and Southern Rural Water.

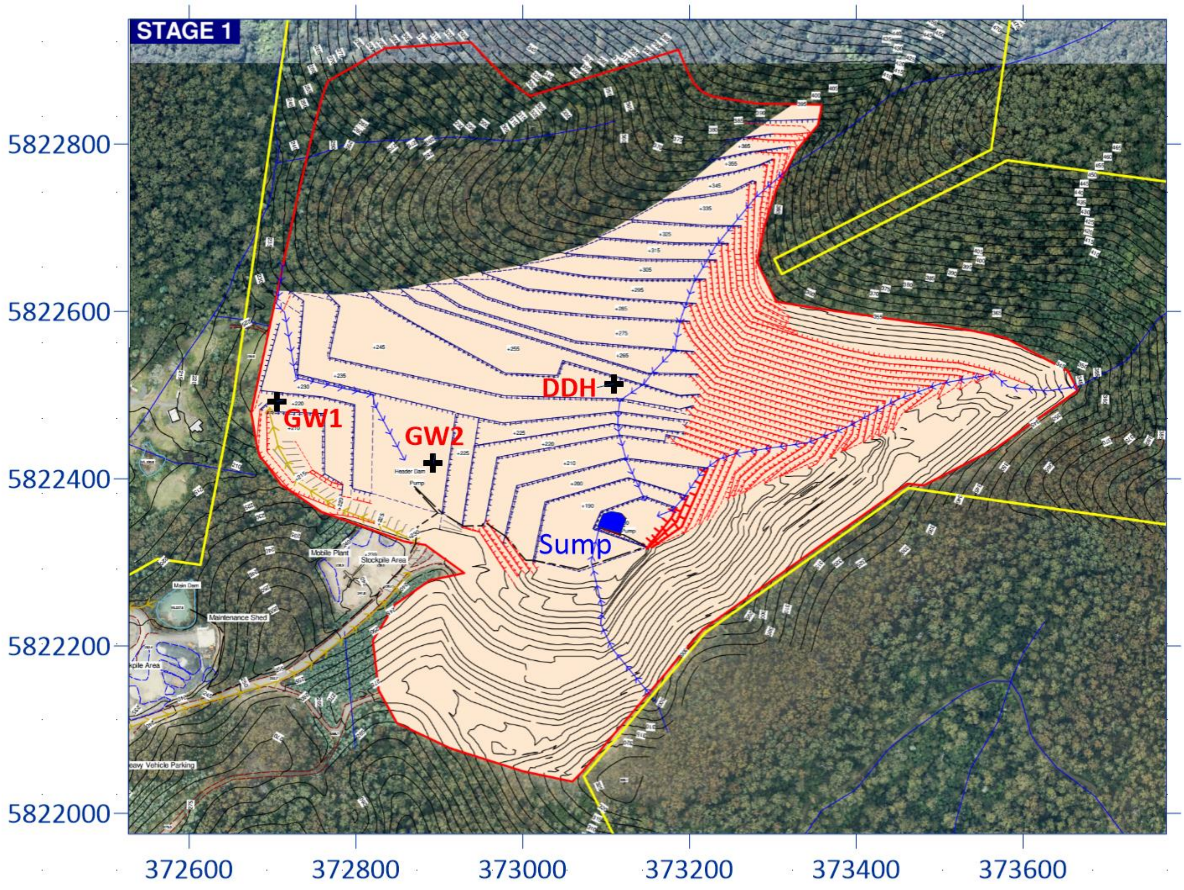

FIGURE 12.1 Stage 1 Design Footprint and Monitoring Bore GW1 and GW2 Locations

12.2 GROUNDWATER PROGRAM

Groundwater levels and chemistry should continue to be monitored quarterly for use in assessing the impact of hard rock (hornfels) extraction operations and passive (gravity) drainage dewatering (and more aggressive dewatering works, if required in the future) on local groundwater, groundwater users and the environment. Surface water quality at the nominated locations should be monitored concurrent with groundwater monitoring.

Groundwater at WA375 should continue to be monitored quarterly using suitable experience contractors and laboratories certified for the required analyses (Table 12.1). The standing water level and measured prior to sampling which undertaken in compliance with EPA Groundwater Sampling Guidelines (EP Publication 669, last updated 28 February 2022).

TABLE 12.1 WA375 Water Monitoring Analytical Monitoring Program

Type	**Parameter/analyte**	**Parameter/analyte**	**Parameter/analyte**
Field measurement	pH (field) Temperature (field) Electrical Conductivity (field) Redox Potential (field) Dissolved Oxygen (field)	Sulphate (as S04) Bicarbonate Alkalinity (as HCO3) Carbonate Alkalinity (as CaCO3) Bicarbonate Alkalinity (as CaCO3) Hydroxide Alkalinity (as CaCO3) Total Alkalinity (as CaCO3) Nitrate & Nitrite (as N) Nitrate (as N) Ammonia (as N) Nitrite (as N) Organic Nitrogen (as N)* Total Kjeldahl Nitrogen (as N)	Total Nitrogen (as N) Phosphate total (as P) Arsenic (filtered) Cadmium (filtered) Chromium (filtered) Copper (filtered) Lead (filtered) Mercury (filtered) Nickel (filtered) Zinc (filtered) pH (laboratory)
Laboratory analysis	Total Dissolved Solids Electrical Conductivity Sodium Potassium Calcium Magnesium Chloride		

12.3 GROUNDWATER CONTAMINATION EVENT MONITORING

No additional measures are recommended to manage groundwater contamination at this stage. However, if potentially groundwater contaminating events occur JLCS recommends:

- Installation of bores specifically located to monitor groundwater impacts around the potentially contaminating source such as spill and or leak areas.
- Sample the contamination bores for Chemicals-of-Concern associated with the identified source.
- Review the water chemistry analytical results to identify any groundwater quality degeneration.
- Assess the impact of the groundwater contamination,
- Update to the Groundwater Risk Assessment to determine whether the risk of harm has become unacceptable.
- If assessed impacts and/or risks are unacceptable develop and implement measure to remediate the contaminated groundwater.

12.4 GROUNDWATER SEEPS AND INFLOWS

Unexpected seeps or groundwater inflows associated with perched groundwater or from intersected hydraulically interconnected fractures below the water table could occur as quarrying advances. All significant inflow areas should be photographed and located on site plans for use in groundwater impact assessments and for designing groundwater control measures, if required. Depending on the nature of the seeps or inflow and the potential to cause batter slope instability or other safety impacts, groundwater control measures to drain working faces and lower pore pressure could be required such as 1) installation of groundwater interception system, e.g., cut-off drains; 2) installation of dewatering bores; and/or 3) installation of horizontal or sub-horizontal drainage bores. A detailed Ground Control Management Plan (GCMP) has been prepared by GHD as stand-alone, iterative management document (tool) that will be updated to reflect changed conditions as the proposed extraction areas at WA375 are developed.

12.5 GROUNDWATER MONITORING REVIEW

Transient water levels and key chemical parameters (.e.g., TDS) should be plotted annually to ascertain whether unacceptable drawdown impacts are occurring and whether groundwater quality is being adversely impacted. If either of these impacts are identified, the risks assessment should be updated and if any risks are unacceptable measures to remove or mitigate any identified risks should be agreed with the appropriate regulatory agency. A more detailed impact assessment report should be prepared by a suitably qualified and experienced hydrogeologist every 5-years.

12.5 GROUNDWATER MANAGEMENT PLAN

The objectives of the GMP are to ensure that no unacceptable changes in the condition of local groundwater due to quarrying activities occur, and that groundwater does not affect the health and/or safety of site employees, local groundwater users and other environmental values.

A specific Groundwater Management Plan (GMP) should be prepared if any groundwater, or ground stability risks are identified, or if required by any regulatory agency. Most of the information and assessment required for a GMP is included in this HA report the main excepts include descriptions of field monitoring procedures and action trigger criteria. A GMP if required would be a stand-alone, iterative management document (tool) that can be updated to reflect changed conditions as the proposed pit extension WA375 is developed.

An important requirement of the GMP would be to ensure that the network of monitoring bores is adequate to detect change to groundwater levels and chemistry. The groundwater monitoring network and monitoring program for water level and ambient groundwater chemistry should be commensurate with the risk of quarrying activities causing unacceptable risks of drawdown that adversely effects the water level in local supply bores and/or hydraulically interconnected surface water systems including ecosystems that depend on groundwater (GDEs).

13.0 KEY FINDINGS

13.1 WA375 WORK PLAN VARIATION

Dandy Premix Quarries Pty Ltd (‘Dandy Premix’) are seeking a Work Plan Variation (WPV) to expand their currently approved quarrying operations at the WA357 Launching Place quarry.

13.2 WA375 SETTING

- WA375 is located in the foothills of the Yarra Ranges. The quarry extracts Humevale Siltstone bedrock that has been metamorphosed to hornfels in the area of the WA375 quarry.

- The Humevale Siltstone (including the hornfels) is a low permeability fractured aquifer Analytical modelling with varying hydraulic conductivity (K) indicated that K values are less than 0.03 m/day which is consistent with calibrated regional groundwater flow models. The bedrock is a low productivity aquifer with bore yields mostly < 2 L/sec.

- Groundwater recharged into the bedrock aquifer is less than 5% of the mean annual rainfall. Groundwater flow is sub-radial from the more elevated hills to the northeast toward the Yarra River. Flow tubes that pass through WA375 flow in a general southwesterly direction. Groundwater discharge occurs into local creeks at lower elevation and across the Yarra River floodplain. The hydraulic gradient is steep which is consistent with hydraulic theory of groundwater flow in hilly terrain.

- The salinity of the local bedrock groundwater is in the range 620 to 1,100 mg/L TDS range. The groundwater is within environmental segment A2 as defined in the Environmental Reference Standard for Victoria. The assessed Environmental Values to be protected are 1) Water dependent ecosystems and species; 2) Potable water supply (acceptable); 3) Agriculture and irrigation (irrigation) 4) Agriculture and irrigation (stock watering); 5) Industry and commercial use; 6) Water based recreation (primary contact recreation); 7) Traditional owner cultural values, and 8) Buildings and structures.

- Groundwater Dependent Ecosystems (GDEs) have been mapped along the Yarra River floodplain. Mapped moderate potential aquatic GDE areas are all more than 2,900 m from the outer edge of the proposed Stage 4 quarry pit. High potential terrestrial GDEs have been mapped along the Yarra River flood plain along a roughly 8 km stretch more than 2,800 m south of the WA375 Stage 4 pit. Low potential terrestrial GDEs have been mapped over a relatively large area in the “valleys” of many of the Yarra River tributaries including an area about 600 m south of the Stage 4 quarry pit. The nearest registered supply bores are about 2 km from WA375.

13.2 WA375 DEVELOPMENT PROPOSAL

The proposed expanded extraction pit would be developed in four stages. The deepest areas of stages 1, 2 and 3 pits will all be at about 180 m AHD, but the terminal (Stage 4) pit floor will be about 70 m deeper at 110 m AHD.

- The proposed expansion will proceed in four stages. The final floor of the proposed Stage 4 quarry pit will be at a general elevation of about 110 m AHD and will be up to 140 m below the undisturbed water table.

- The proposed expansion will capture flow from two ephemeral tributaries. The captured surface water and any groundwater seepage will accumulate in sumps in the quarry floor. Most of the sump water will be discharged into the surface water system down gradient from the quarry.

- A pit lake will form in the quarry void after quarrying ceases. The final water level will be controlled by the elevation of the spill-point (217 m AHD) on the southwestern corner of the pit. The pit lake will be filled predominantly by surface water from the intersected tributaries and run-off from the pit highwalls, plus some groundwater inflow. The final pit lake can be classified as a “surface water dominated groundwater throughflow lake”.

- Pit lake water balance modelling indicated that it would take about 7.5 years to fill the pit during a wet period assuming a high hydraulic conductivity of 0.1 m/day and about 11.5 years during a dry period assuming a low hydraulic conductivity of 0.001 m/day. Placement of overburden back into the pit void could reduce the modelled fill time by about 30 per cent.

- Based historic observation at WA375 and observation and practices at quarries in similar fractured hard rock aquifers, it is considered that advanced (aggressive) dewatering will not be required unless currently unknown major rock discontinuity zones are intercepted.

13.3 WA375 GROUNDWATER IMPACT AND RISKS

No adverse groundwater impacts have been detected to date. However, as the proposed quarry expansion would extend an additional 100 m below the water table the potential to adversely impact local Environmental Values will increase.

The Risk Assessment of drawdown interference to groundwater users and hydraulically interconnected surface water environmental values under passive groundwater inflow conditions did not identify any unacceptable risks. The assessment of risks if more aggressive dewatering is required identified ‘Low Risks of Harm’ to groundwater users, surface water systems and GDEs. The risks to surface waters will be mitigated by the return of surface water and groundwater captured in the pit sump(s) to the surface water system.

Potential groundwater contamination sources are associated with the onsite storage of fuels and the use of ammonia-nitrate based explosives. The only pathways from source to receptors during quarrying and pit lake filling is for contaminated groundwater to discharge into the pit sump and then the sump water is pumped into the Moora Creek (i.e., there is no direct groundwater pathway). After the pit lake fills to the spill point elevation (217 m AHD), a groundwater pathway is present as well as a lake water overflow pathway. Low, acceptable risks were identified for pumping water from the sump into Moora Creek during quarrying and lake filling, and for both surface water and groundwater after the pit lake fills. The risks were assessed as low because the likelihood of contamination occurring was assessed as “rare” and the consequence as insignificant or minor because of substantial dilution of any contaminates in the pit lake (full lake storage volume of about 7,640 ML) before any outflow occurs.

14.0 RECOMMENDATIONS

- The groundwater bore network should be expanded as quarrying progresses and some of the current monitoring bores are destroyed. Changes to the monitoring network should be agreed with ERR and SRW.

- If future quarrying encounters significant groundwater inflows, the impact on local groundwater, groundwater users and interconnect surface waters should be assessed and mitigation measures implemented, if required.

- Groundwater levels and chemistry should be monitored annually in conjunction with surface water monitoring. The monitoring should include measuring the standing water level in all monitoring, bores collecting samples of groundwater in accordance with the EPA Groundwater Sampling Guidelines (EPA, 2022). The EC, pH, DO and Eh of all samples should be measured in the field and the TDS, major ions, TKN, NO3-N, NO2-N, TN, TP and heavy metal concentrations determined by a NATA accredited laboratory.

- The pit lake fill time should be reassessed well before pit closure when more information on actual pit inflows and pit rehabilitation works is available.

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16.0 LIMITATIONS OF THIS REPORT

The advice provided in this report relates only to the project described herein and must be reviewed by a competent Engineer or Scientist before being used for any other purpose. JOHN LEONARD CONSULTING SERVICES Pty Ltd accepts no responsibility for other use of the data.

Where drill hole or test pit logs, laboratory tests, geophysical tests and similar work have been performed and recorded by others the data is included and used in the form provided by others. The responsibility for the accuracy of such data remains with the issuing authority, not with JOHN LEONARD CONSULTING SERVICES Pty Ltd.

The advice tendered in this report is based on information obtained from the investigation locations, test points and sample points and is not warranted in respect to the conditions that may be encountered across the site at other than these locations. It is emphasized that the actual characteristics of the subsurface and surface materials may vary significantly between adjacent test points and sample intervals and at locations other than where observations, explorations and investigations have been made. Sub-surface conditions, including groundwater levels, chemistry and contaminant concentrations can change in a limited time. This should be borne in mind when assessing the data. However, it is our opinion that the test points chosen are representative of conditions on the site.

It should be noted that because of the inherent uncertainties in sub-surface evaluations, changed or unanticipated sub-surface conditions may occur that could affect total project cost and/or execution. JOHN LEONARD CONSULTING SERVICES Pty Ltd does not accept responsibility for the consequences of significant variances in the conditions.

An understanding of the site conditions depends on the integration of many pieces of information, some regional, some site specific, some structure-specific and some experienced-based. This report should not be altered, amended, or abbreviated, issued in part or issued incomplete in any way without prior checking and approval by JOHN LEONARD CONSULTING SERVICES Pty Ltd. JOHN LEONARD CONSULTING SERVICES Pty Ltd accepts no responsibility for any circumstances which arise from the issue of the report which has been modified in any way as outlined above.

John Leonard

February 2024
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