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Dear James

Our ref: 23030039_L01v02_Blue Hills Quarry_230203

Blue Hills Quarry Groundwater Assessment

The following assessment outlines groundwater conditions at the proposed Blue Hills Quarry site, near Maldon, Victoria (herein referred to as the Site). The findings of this assessment are summarised below:

- The quarry site is situated on outcropping metasedimentary bedrock of the Castlemaine Group, metasedimentary hornfels of Early Ordovician Age. Igneous rocks of the Baringhup Granodiorite make up outcropping basement to the east and south. The fluvial Upper Tertiary Shepparton Formation Aquifer is present 3 km west of the Site. Colluvium is present along watercourses with some quartz veins and dykes also mapped in the area. Primary porosity of the bedrock is expected to be low, with any groundwater likely to be found in fractures and faults in the rock matrix.
- There are no groundwater wells within 2 km of the Site, with wells in the region mainly existing for investigation, monitoring, dryland salinity, or stock and domestic use. The nearest recorded operating well is 2 km to the WSW, listed as an observation well, with other observation, investigation, and dryland salinity wells 2.5 km to the northeast.
- The Site does not intersect any high potential Groundwater Dependent Ecosystems (GDEs) as defined by the Bureau of Meteorology's groundwater atlas. The nearest high potential terrestrial GDEs are located around 3 km to the northeast of the Site. This area coincides with a high potential aquatic GDE at Bradford Creek. The moderate potential GDEs within the Site boundaries are classified as Box Ironbark Forrest within moderately high plateaus and strike ridges.
- There are few groundwater wells with recorded depth to groundwater data, and these wells are situated away from the elevated land upon which the quarry is located.
- The topography in the region positions the Site at higher elevations than the surrounding ground. The current quarry pit outline has a minimum elevation of 256 mAHD in the west, and a maximum elevation of 333 mAHD in the east. The quarry sits on a ridge between two gullies, with a proposed pit floor depth of 170 mAHD. The depth of the quarry is around 140 m from surface level at its deepest point.
- Groundwater resource drilling has been undertaken at 17 sites within the proposed quarry extent, with 9 of these sites intersecting groundwater and the remaining 8 being recorded as dry.
- A groundwater elevation spatial layer is available through the Visualising Victoria's Groundwater database (VVG). Comparison of the resource drilling groundwater levels with this layer suggests that the VVG layer is likely to be overpredicting groundwater elevations.
- Drillhole data provided by Groundwork Plus details groundwater intersection elevation above the planned pit floor, by up to 103 m at one location in the middle of the pit. It is noted that other nearby drillholes show the rock to be dry at similar or lower elevations. These observations suggest that the aquifer is compartmentalised, with groundwater occurring in discrete fractures and faults.

1 INTRODUCTION

This assessment has been conducted to support the application for quarrying at the Blue Hills site, near Maldon, Victoria (herein referred to as the Site). The Site is located around 9 km to the northwest of the town of Maldon in the Shire of Mount Alexander (Figure 1). The quarry target is the metasedimentary rocks of the Castlemaine Group, consisting of hornfels and calc-silicate rocks of Lancefieldian Age (482 To 475 Ma).

2 HYDROGEOLOGICAL SETTING

2.1 Climate and Rainfall

The Site is located around 30 km to the southwest of Bendigo. The region has a Mediterranean style climate, with warm and dry summers, and cold and cloudy winters. The temperature generally varies from 4 to 29 °C, and is rarely below 1 °C or above 37 °C. The warm season lasts from December until early March, with the hottest month in January. The cold season lasts from late May until September, with the coldest month in July.

Rainfall is most likely through the winter months, with 25% of days in August having precipitation observed and the monthly average for August of 41 mm. The month with the least rainfall is February with an average of around 24 mm. Average annual pan evaporation at the Site is between 1,200 to 1,400 mm. Annual average rainfall at nearby Bureau of Meteorology BoM weather stations is 495.9 mm at Cairn Curran Reservoir (BoM Station 88009), and 565.7 mm at Maldon (BoM Station 88161).

2.2 Topography and Drainage

The Site is located on the north-western side of a small range, 6 km to the northwest of the higher Mount Tarrangower (564 mAHD), on the edge of the town of Maldon. The hills at the Site peak at a maximum elevation of 366 mAHD based on the 10 m Digital Elevation Model (DEM) available from the Victorian government. More accurate LIDAR elevation data, with 50 cm resolution, over the Site itself was acquired by Groundwork Plus. The currently defined Site extraction outline ranges in elevation from 256 to 333 mAHD, sloping up to the eastern end, and is bounded to the north and south by two smaller, unnamed watercourses. The flatter land to the west away from the hills has a lower elevation around 160 mAHD. The defined watercourses across the region drain to the northwest towards Blind Creek, Bradford Creek, and the Loddon River. Watercourses are shown along with the Site elevation in Figure 2.

2.3 Geology

The region around the Site consists predominantly of outcropping basement rocks. The quarry Site is situated on metasedimentary rocks of the Castlemaine Group, with igneous rocks of the Baringhup Granodiorite to the east and south. Colluvium is present along watercourses with some quartz veins and dykes mapped in the area. The Seamless Geology data layer available from Earth Resources (GeoScience Victoria 2014) is shown in Figure 3.

The fluvial Upper Tertiary Shepparton Formation Aquifer is present 3 km to the west of the Site. This aquifer extends to the north and south, abutting the outcropping basement on which the Site is situated. The thickness of this aquifer ranges from 0 to 64 m, thinning to zero thickness 3.1 km to the east of the proposed quarry extractive boundary.

2.4 Groundwater Data

To assess groundwater conditions, well data was downloaded from the Visualising Victoria's Groundwater online data application. Data layers were also obtained from the Victorian Aquifer Framework, including groundwater salinity and groundwater elevation grids. A summary of the data review is presented below, including water level, quality, users, and potential groundwater dependent ecosystems.

Additional drillhole data was provided to Water Technology by Groundwork Plus, this consisted groundwater intersection depths from resource drillholes across the Site, including several within the pit outline itself. Of the data provided, nine drillholes reported water intersection depths, and eight were recorded as being dry to total depth.

2.5 Groundwater Elevation

The aquifer of relevance at the Site is the water table aquifer, hosted within the metasedimentary basement rocks of the Castlemaine Group that outcrop at the Site. There is scarce water level data from nearby wells, limited to some wells around 2.5 km to the northeast in the water table aquifer, and some wells 4 km to the west in the Upper Tertiary Aquifer of the Shepparton Formation.

Figure 4 displays the interpreted state-wide groundwater elevation data for the Site. Regional groundwater flow is generally from south to north as reported in the Central Victorian Mineral Springs Groundwater Management Area (GMA) Local Management Plan, which is located 3.7 km south of the Site. At the proposed quarry Site, there is a local topographic high, which is interpreted to generate radial flow away from this feature.

There is anecdotal evidence suggesting the presence of springs in the area (pers comm Groundwork Plus 2022), though these are not recorded on any published maps. Springs occur when the groundwater table is intersected by the ground surface. The possible presence of springs near to the Site could suggest a water table that is relatively close to the surface or the development of local perched aquifers which discharge following rainfall events near to those locations.

2.6 Drillhole Data

Drillhole data shows a distribution across the pit of varying elevations of groundwater intersection from nine drillholes, along with eight drillholes recorded as dry to their base, despite the VVG groundwater layer suggesting that groundwater should have been intersected. Groundwater observations were not recorded for the remaining drillholes across the Site. Figure 5 shows these holes along with their groundwater intersection elevation or their base of hole elevation at which they were recorded as dry.

Drillholes towards the centre of the pit show groundwater intersection elevations above the planned pit floor (highlighted in Figure 5). However, other drillholes across the pit indicate no groundwater intersection to below the planned pit floor at that location. There is variability in the groundwater intersection elevation, though the general trend is lower to higher elevation following topography from west to east. The difference between the VVG water table elevation and the drillhole groundwater intersection elevation also varies across the Site. Generally, the VVG water table elevation is higher than the intersected drillhole groundwater elevation, though there is not conclusive proof the water table is at the intersection points.

Variation in the groundwater intersection elevation and elevation of dry wells suggests there is compartmentalisation of the aquifer. The implications of compartmentalisation above the elevation of the planned pit floor is that there is the potential for water ingress in some parts of the pit, while other areas may have no to very little ingress.

Cross-sections are presented in Figure 6, showing the VVG water table elevation across the Site along with the surface elevation, the resource drilling observations, and the proposed quarry pit outline. The planned pit floor elevation of 170 mAHD is likely to be below the water table, though there is some uncertainty in the accuracy of the water table elevation layer and its continuity across the site.

2.7 Groundwater Salinity

A water table salinity layer, available from the Victorian Aquifer Framework package, indicates fresher water to the southwest of the quarry site. Site salinity is interpreted to be in the range of 1,000 to 3,500 mg/L and this then increases away to the west, with another fresher portion interpreted to the north which spans across Leichardt and Bendigo for around 30 km. There is no well salinity data available near to the Site. Figure 7 shows the interpreted groundwater salinity for the Site.

2.8 Environmental Value

Under section 93 of the Environment Protection Act (2017), the Governor in Council made an environment reference standard which sets out defined environmental values for designated salinity ranges (Part 5, Division 2). The salinity range at the Site is interpreted to be 1,000 to 3,500 mg/L which has an environmental value suitable for: water dependent ecosystems and species, potable mineral water supply, agriculture and irrigation (irrigation and stock watering), industrial and commercial use, water-based recreation, traditional owner cultural values, buildings and structures, and geothermal properties. The water does not fit the environmental value for desirable potable water supply, and it bridges the range for acceptable potable water supply of 601 to 1,200 mg/L.

Whilst these are the defined environmental values for the groundwater at the Site, the lack of any water wells other than for observation or investigation within 3.7 km of the Site suggests the groundwater is not currently being used for these purposes.

2.9 Existing Groundwater Users

Figure 8 shows the groundwater wells in the region classified by their use. There are no groundwater wells within 2 km of the Site. Wells in the area are classed as investigation, monitoring, dryland salinity, or stock and domestic use. The nearest recorded operating well is 2.0 km to the WSW, listed as an observation well, with other observation, investigation, and dryland salinity wells 2.5 km to the northeast. Wells recorded as stock or domestic use are not located within 3.5 km of the Site boundary. The closest of these is recorded as domestic and stock, within the Upper Tertiary aquifer.

No groundwater wells exist at the Site. The closest wells drilled were for gold exploration to depths of around 15 metres, though records for these make no mention of intersecting groundwater.

2.10 Groundwater Dependent Ecosystems

The Site does not intersect any high potential Groundwater Dependent Ecosystems (GDEs) as defined by the Bureau of Meteorology's groundwater atlas. The nearest high potential terrestrial GDEs are located to the northeast coinciding with a high potential aquatic ecosystem at Bradford Creek, shown in Figure 9. The moderate potential GDEs within the Site boundaries are classified as Box Ironbark Forrest within moderately high plateaus and strike ridges.

3 GROUNDWATER MANAGEMENT

3.1 Regulatory Context

The Site is located within the North Central Catchment Management Authority (CMA) area. The Central Victorian Mineral Springs Groundwater Management Area (GMA) is located 3.7 km south of the site while the Mid Loddon GMA is located 30 m west of the Site (Figure 1). The site itself is not located within a Groundwater Management Area, Groundwater Restricted Quality Usage Zone, or a Water Supply Protection area.

3.2 Recommendation for Minimum Pit Floor Elevation

Based upon the data available and subsequently detailed in Section 2.5 and Section 2.6, it is difficult to determine with any certainty a reasonable pit floor elevation that groundwater will not be intersected. Drillhole data provided across the Site shows reason to suspect compartmentalisation with water intersected in several holes though not in others despite being drilled to greater depths.

4 SUMMARY AND RECOMMENDATIONS

- To remain above the water table, the quarry would need to be limited to a depth of between 22 and 47 m from surface, based on the current observations from the resource drillholes. Given the uncertainty, monitoring for signs of seepage should be undertaken on a monthly basis. In the case that monitoring indicates seepage, a risk assessment and management plan should be developed.
- To extend the pit floor below the interpreted water table elevation, additional investigation drillholes are recommended within the footprint of the quarry to assess the groundwater elevation and permeability of the rock.
- A staged approach to quarry development may be appropriate to manage the current uncertainties regarding the water table elevation. Groundwater monitoring wells should be established to monitor potential drawdown effects.

5 CLOSING

Thank you for the opportunity to undertake this assessment. Please contact the undersigned if you have any questions or queries.

Yours sincerely

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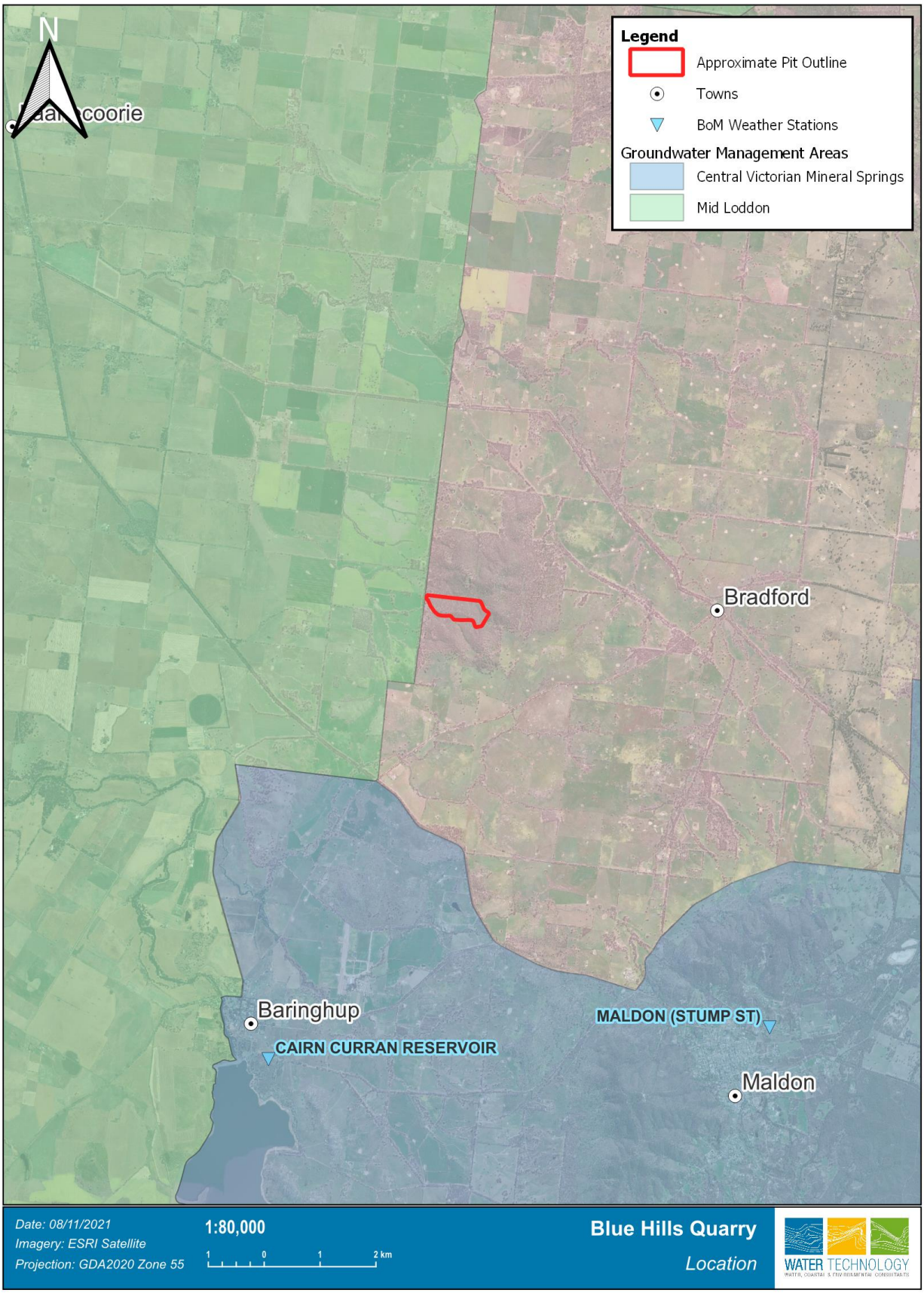

Figure 1 Location Map

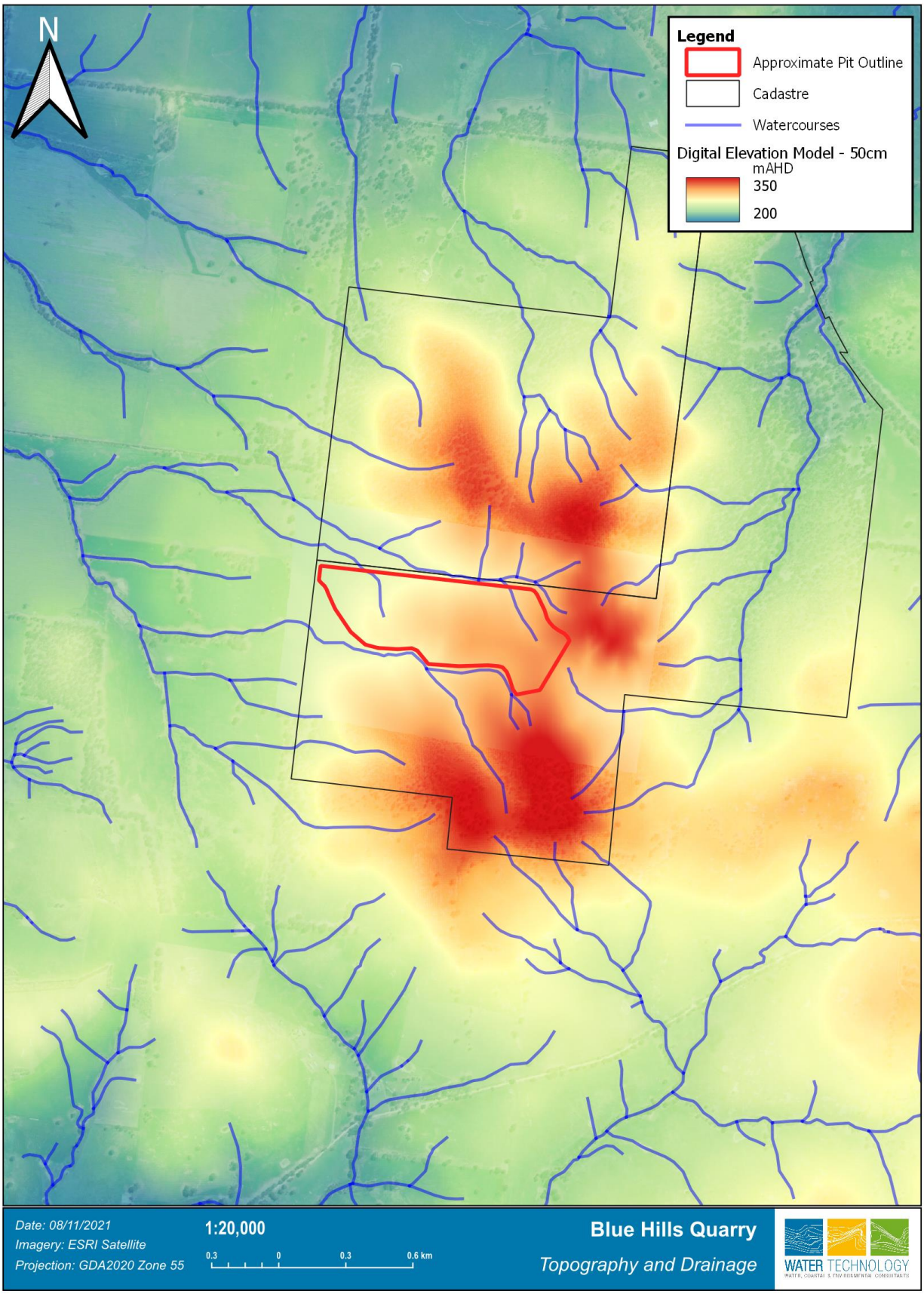

Figure 2 Site Topography and Drainage

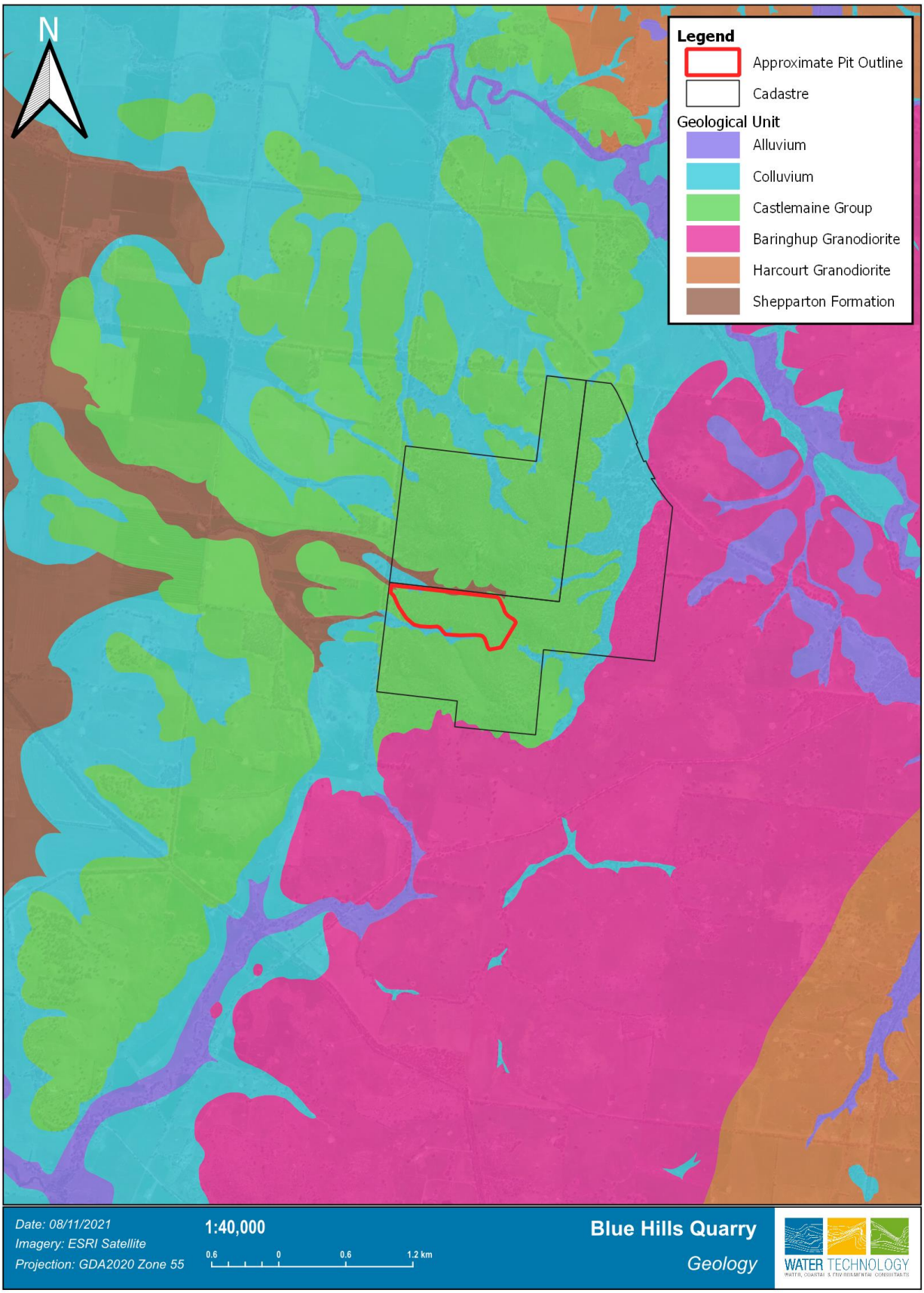

Figure 3 Surface Geology Map

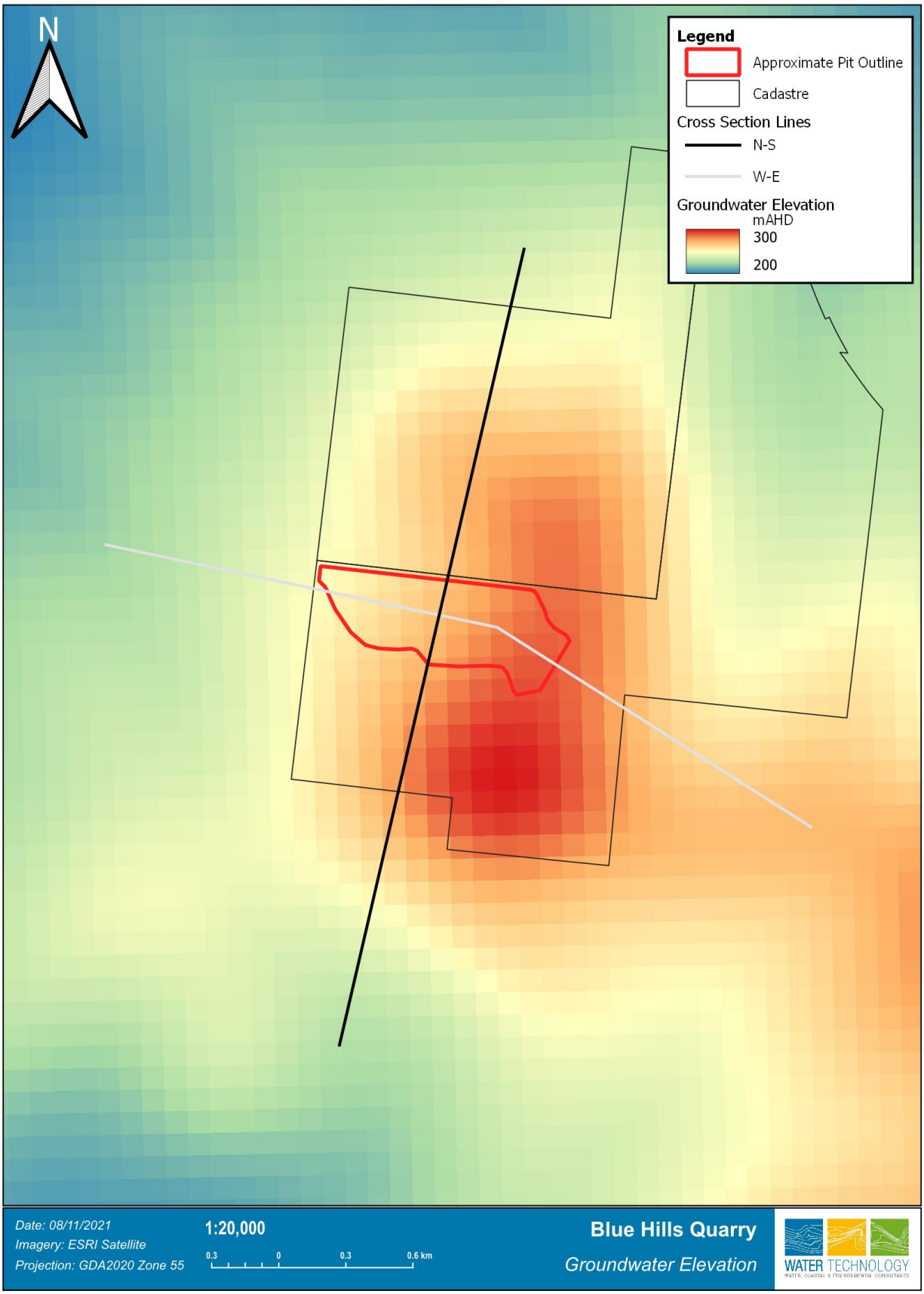

Figure 4 **Groundwater Elevation and Cross Section Location**

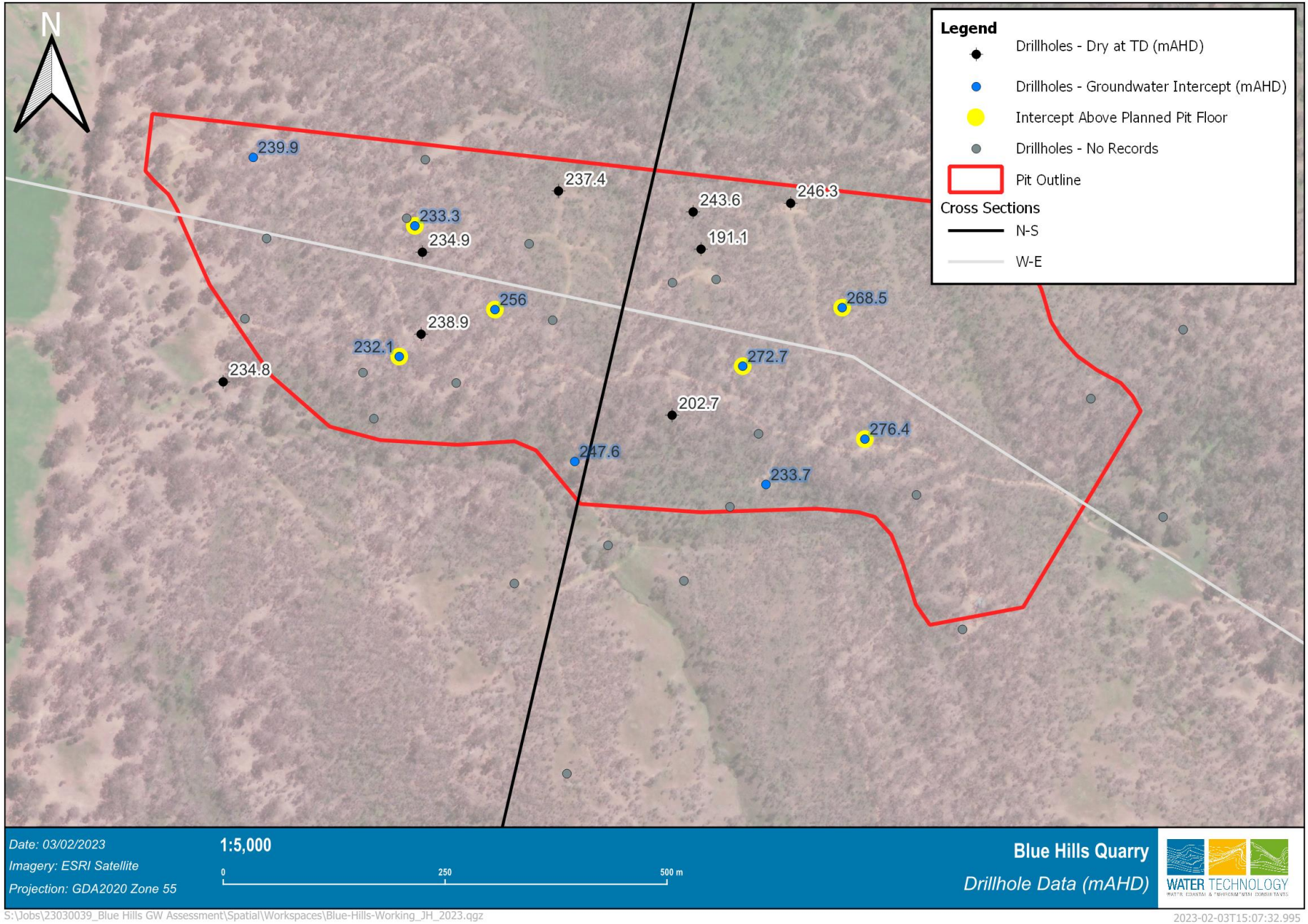

Figure 5 Drillhole Data (Groundwork Plus 2022)

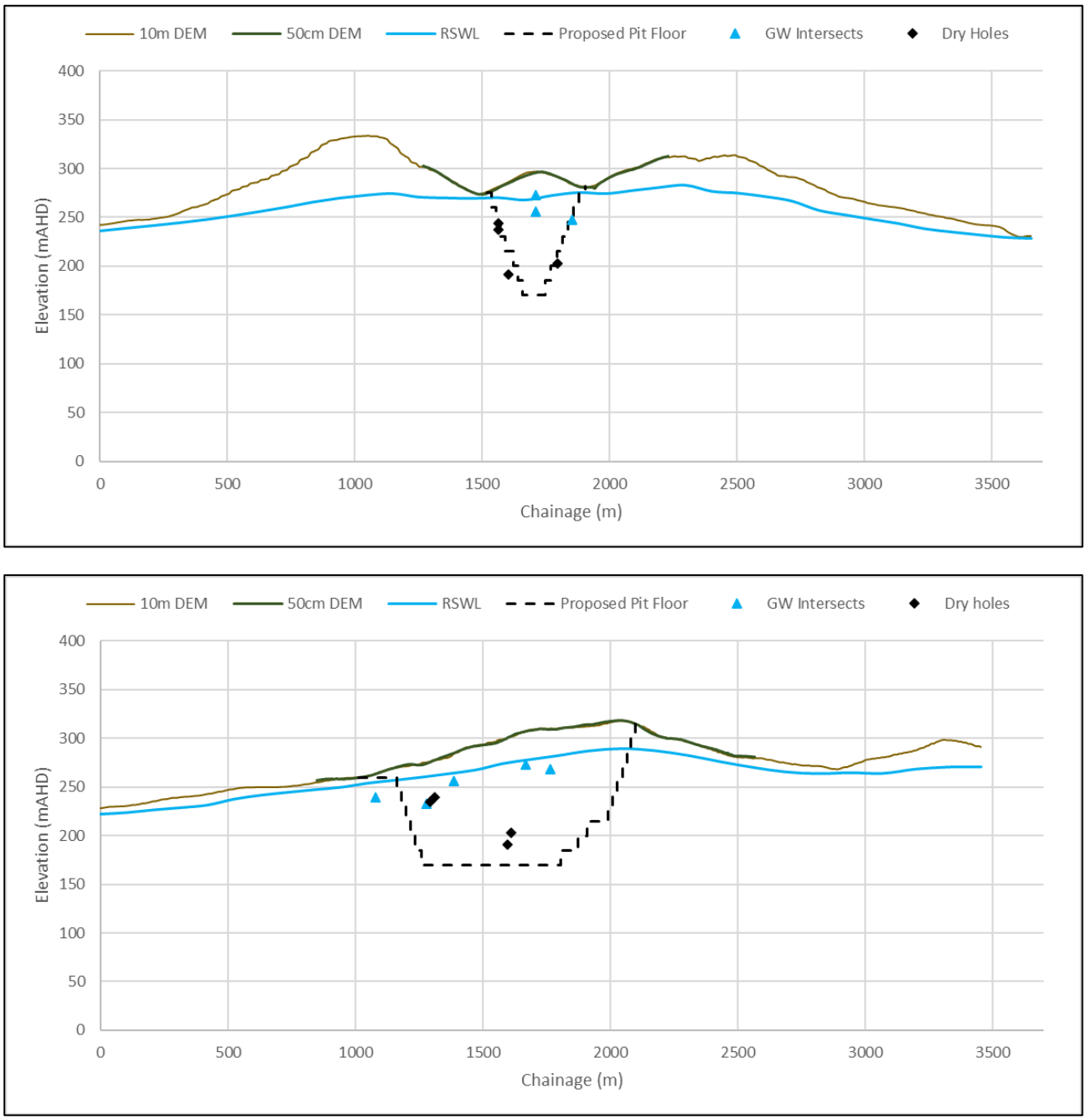

Figure 6 Groundwater and Surface Elevation Cross Section (N-S above, W-E below)

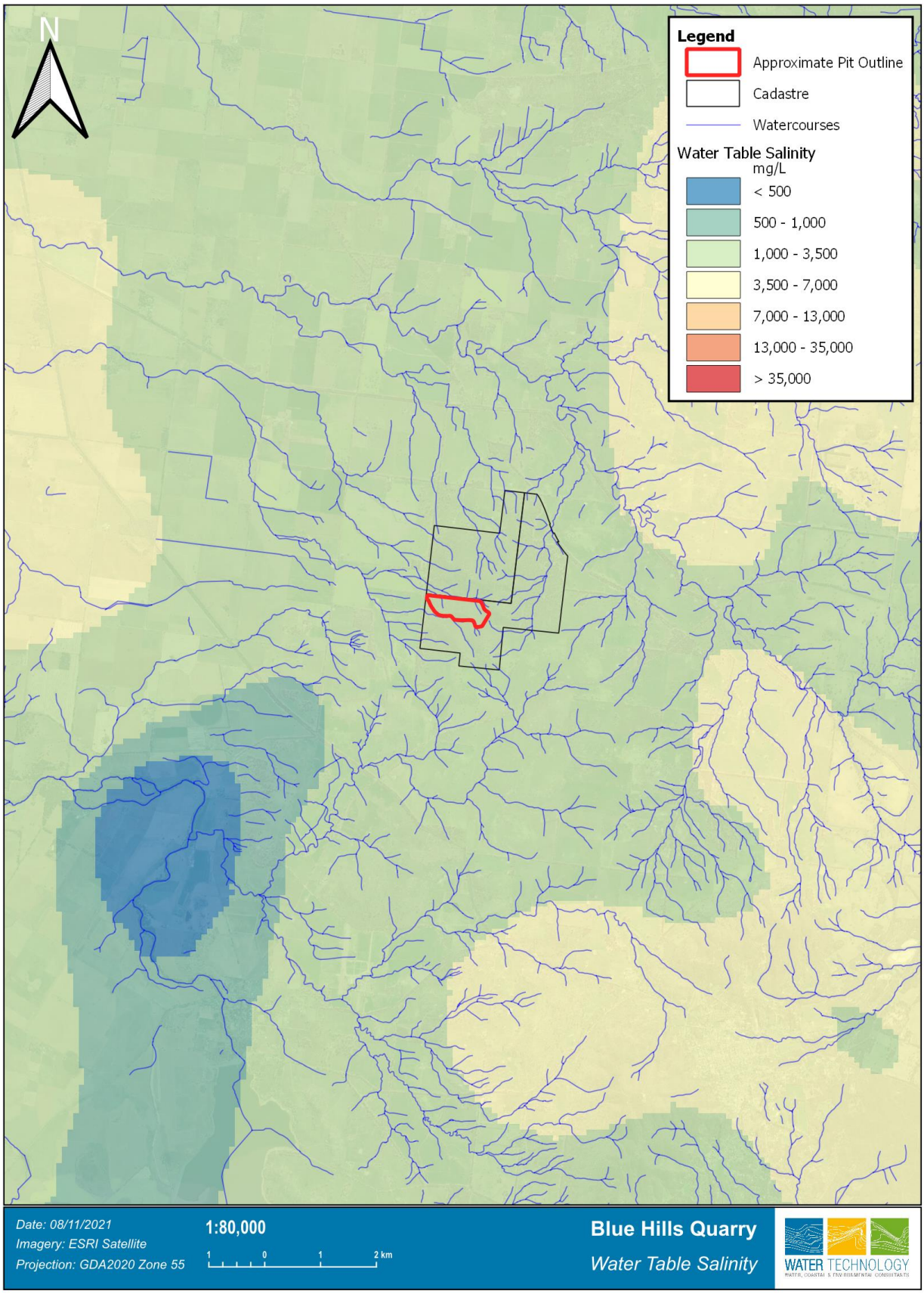

Figure 7 **Groundwater Salinity (mg/L)**

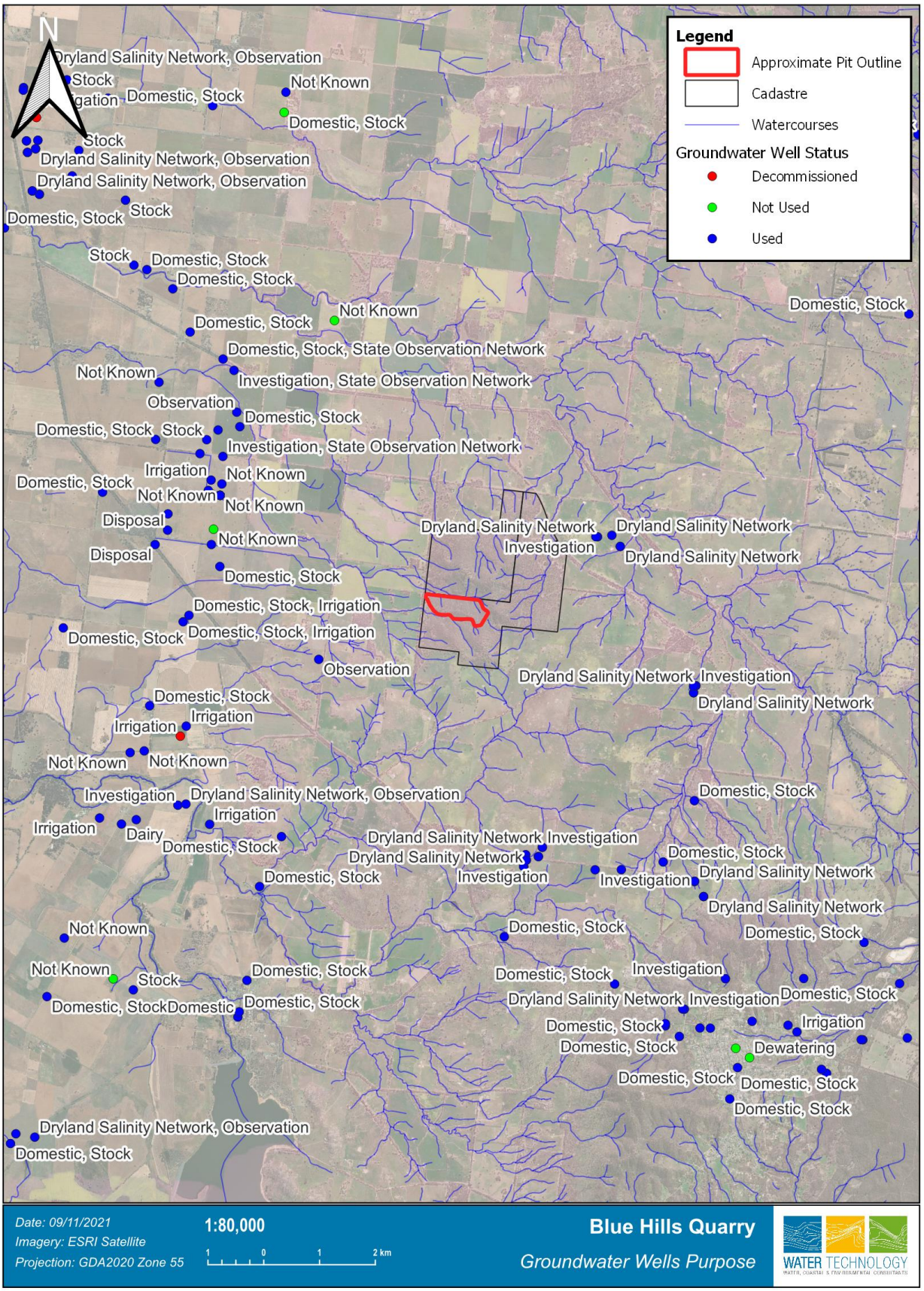

Figure 8 Groundwater Wells – Purpose

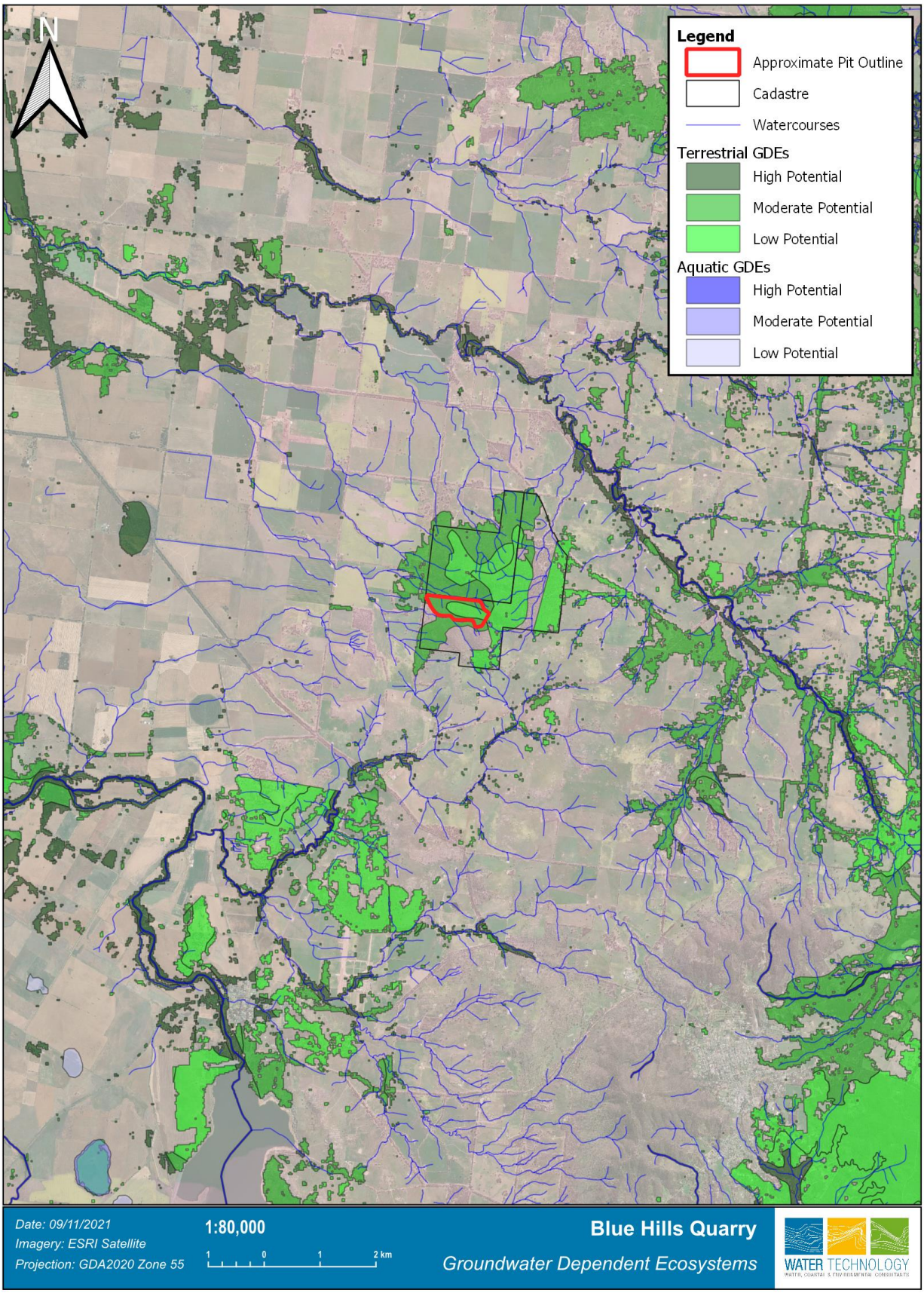

Figure 9 **Groundwater Dependent Ecosystems**