Yarra Ranges Shire Council

Warburton Mountain Bike Destination Project

Desktop Hydrogeological Assessment

December 2019

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1. Introduction

1.1 Background

The Warburton Mountain Bike Destination Project (the Project), is situated near Warburton in the Yarra Ranges, approximately 70 kilometres north-east of Melbourne. The project will involve the creation of world-class mountain bike trails, new accommodation and a visitor's hub, to stimulate economic growth in the region through tourism and recreation. The project location is shown in Figure 1.

The trail network would be eligible for International Mountain Bike Association Gold Trail status, attracting national and international visitors.

The main trail head would be situated near the golf course, with direct access to the trails from the accommodation facilities. There would be a total of 44 trails comprising of formalised existing trails as well as new trails, providing both downhill and cross-country style experiences.

1.2 Purpose of this report

GHD Pty Ltd (GHD) has been engaged by the Yarra Ranges Shire Council (Council) to undertake a desktop Hydrogeological Assessment (HA) for the project.

The purpose of this desktop HA is to inform the development of Referrals to government under the Environment Effects Act 1978 and Environment Protection and Biodiversity Conservation Act 1999, to guide the selection of appropriate planning approval pathways for the project.

This report provides an interpretation of the existing groundwater conditions for the project based on publically available information.

1.3 Scope of work

Council engaged GHD to complete a HA for the project location, herein referred to as the site, (this report) which included:

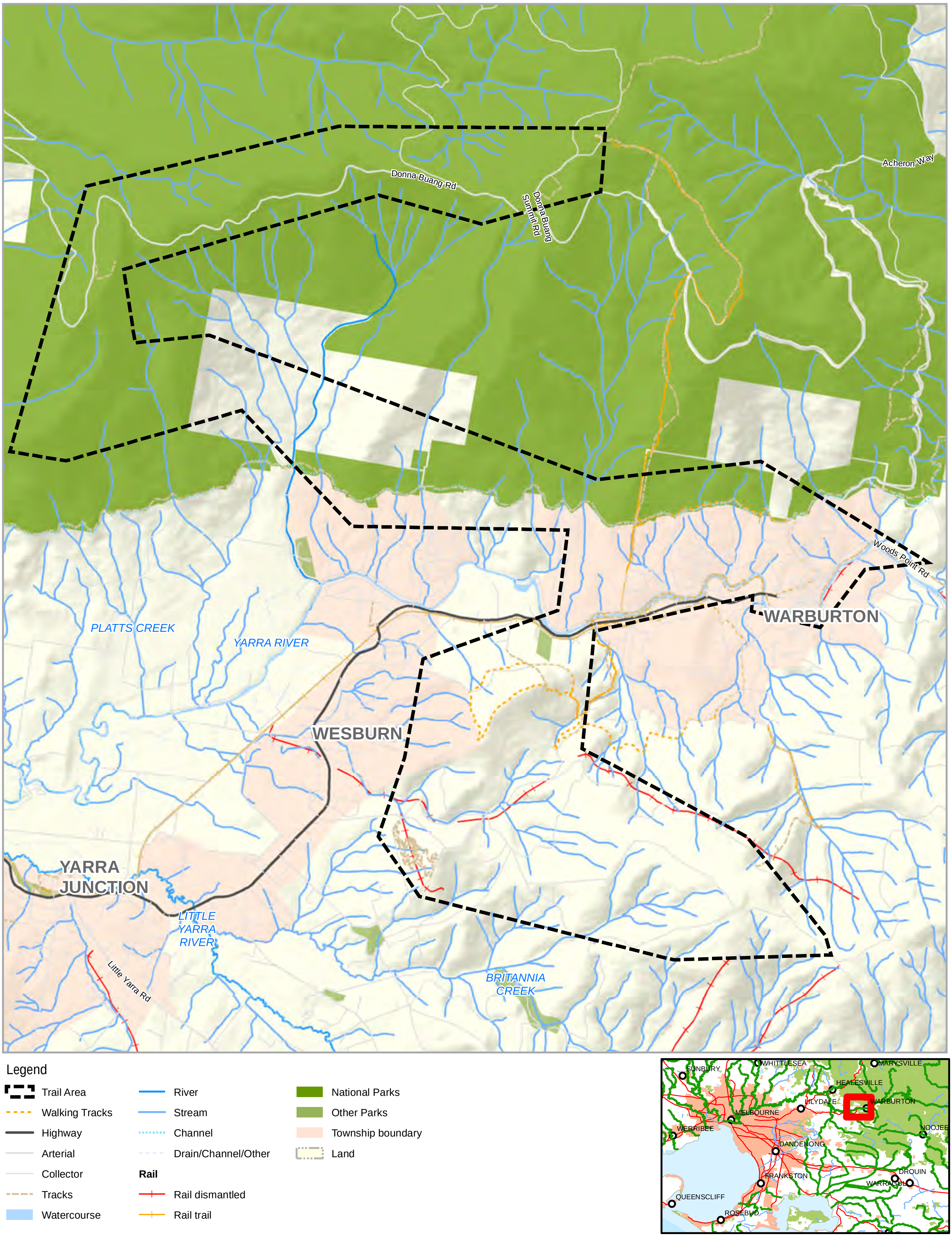
- Hydrogeological characterisation of the site.
- Identification of any potential risks to groundwater posed by the project.
- A HA report (this report) documenting the above.

1.4 Data sources

This investigation has relied on a number of data sources which have assumed to be accurate and up to date:

- Published geological and hydrogeological mapping
- Water Measurement Information System - Department of Environment, Land, Water and Planning
- Government produced literature including reports, zones, overlays, meteorological and topographical data.

These data sources have been referenced, where relevant, throughout the report and a complete list of references is provided in Section 6.



Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

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GHD

Yarra Ranges Council
Warburton Mountain Bike Destination

Site location

Project No. 31-37322
Revision No. A
Date 13/09/2019

Figure 1

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Print date: 13 Sep 2019 - 14:20

Data source: DELWP, VicMap, 2019; GHD, 2019 Created by: bsmyth

2. Project background

2.1 The project

For the purposes of this assessment, the project includes the following key components:

2.1.1 Mountain bike trails

Approximately 44 new mountain bike trails totalling approximately 186 km are proposed as part of this project. The alignment is based on the Warburton Mountain Bike Hub Master Plan (Cox Architecture), with further trail refinements based on draft recommendations within the Product Review, Warburton Mountain Bike Trail Destination by World Trail (World Trail, May 2019, Draft and further refinement in August 2019. (World Trail August 2019).

The trails are proposed to be approximately 1.2 m wide with a head clearance of approximately 2.5 m. No tree removal is proposed as part of the trail construction, however, some groundcover and understorey vegetation will be removed.

2.1.2 Visitor's Hub

The main trail head and associated facilities is proposed to be at the Warburton Golf Course. Discussions are ongoing in relation to the securing of potential additional land for the main trailhead.

The actual trailhead and associated facilities would be located at the southern end of the golf course adjacent to Dammans Road.

Facilities will include car parking for approximately 250 cars, a shuttle shelter, and four or five wash down bays. The existing golf course building is proposed to be retained and upgraded.

2.1.3 Bridges

Three longer bridges are proposed, including the Frenchman's Creek bridge, Old Warburton Road bridge, and the Yarra River bridge.

The Old Warburton Road bridge is proposed to be a truss style shared use bridge spanning approximately 23 m across the Old Warburton Road. The Yarra River bridge is proposed to be a combined suspension and truss bridge spanning approximately 121 m across the Warburton Highway, Yarra River and Dammans Road adjacent to the existing Mayer bridge.

Locations and details of these bridges are currently in concept and preliminary design stages.

2.1.4 Mt Tugwell trail head

A satellite trail head is proposed to be located close to the top of Mt Tugwell (Mt Bride Road). This will include 8 carparks, a shuttle bus and trailer turnaround and loading/unloading bay, toilet, and picnic area.

2.1.5 Mt Donna Buang trail head

A trail head is proposed to be located on the top of Mt Donna Buang, including an upgrade to the existing car parking and summit facilities such as toilets and picnic area. No new structures are planned at this location.

2.2 Construction methods

Limited construction details are provided for ancillary infrastructure such as bridges, trail head and visitor hub facilities with only general details provided on these infrastructure components.

Based on a preliminary construction methodology provided by World Trail (World Trail 2019, dated 23 July and 9 August 2019) it is understood that the trails are proposed to be constructed as follows:

- The trails are situated within a combination of disturbed and undisturbed areas. Across the approximately 186 km trail network, the core summary and segments of the trail network include 44 trails:
- Some are loop trails, some are point-to-point trails;
- Roughly 67% are cross-country trails and 33% are gravity trails. Some trails fall into both categories;
- Breakdown of trail difficulty ratings (as per MTBA's *Australian Mountain Bike Trail Guidelines*) is:
  - Easy – 28.7%
  - Easy / Intermediate – 11.7%
  - Intermediate – 44.6%
  - Intermediate / Difficult – 3.9%
  - Difficult – 11.0%
- Breakdown of trail composition is:
  - Proposed new MTB trails - 159.6 km (88.4%)
  - Existing MTB trails to be incorporated into network – 14.9 km (8.2%)
  - Existing vehicle track to be incorporated into network – 6.0 km (3.4%)
- 35.3% of the trails are located on the north side of the valley; 64.7% of the trails are located on the south side of the valley
- Construction of new trails in undisturbed areas will generally be constructed with an initial bench width of 1.2 m, but this reduces over time to a ride line of 0.3-0.6 m wide. Tree branches will be lopped to 2.5 metres high (with construction corridor restricted to a total of 2 m - refer to Section 2.2.1).

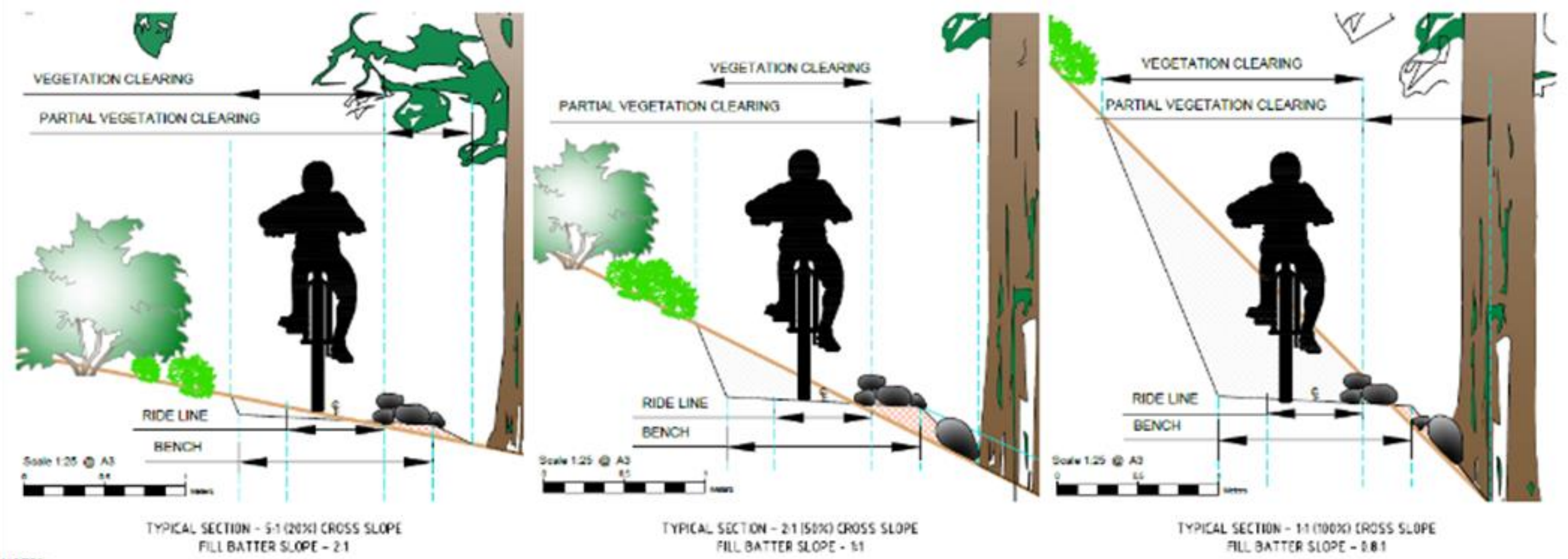
- There will be four (4) types of basic trail construction, which are further detailed in Section 2.2.1:
  - Standard Benching (Machine) – this type of construction is used when the trail traverses a cross slope and where the removal of native vegetation is involved. It is the standard technique for constructing new trails in reasonably undisturbed landscapes.
  - Standard Benching (Hand) – this is very similar to 'Standard Benching – Machine' except that it is used in situations where it may not be possible or desirable to use a mini-excavator.
  - Rock Armouring – is used to harden the trail surface, generally on steep gradients, where the soil would likely be displaced by water or trail users, leading to erosion. No rock armouring is proposed on waterway crossings.
  - Elevated Structures – the construction of bridges/elevated structures to enable a trail to cross over a waterway or area of soft or boggy ground. The structures will vary in height above the ground, with heights typically less than 1 m above the ground other than the major crossing locations. Based on the proposed waterway crossing construction methodology, all water course crossings are constructed as dry wheel crossings utilising elevated structures or bridges

2.2.1 Detailed Construction Method

Based on the methodology provided by World Trail, it is understood that further ground-truthing of the network is proposed and during construction the following specific methodology and staging would be undertaken:

- Review the ground-truthed corridor up to 100 m to 200 m ahead of an excavator. The ground-truthed corridor is generally defined to include 10 m either side of the flagged alignment (i.e. the centre line). This may vary depending on environmental values.
- Determine the exact alignment to be taken within the ground-truthed corridor. In areas of high environmental values, this is often undertaken with botanists/zoologists/ecologists to minimise impacts on local environmental values.
- Clear the construction corridor of vegetation. The construction corridor is defined as the horizontal corridor from the top or crown of the upslope batter, to the toe of the downslope batter and the vertical corridor to about 2.5 m high (sufficient to allow passage of the excavator). At this stage, all vegetation is removed except for ground covers, herbs and grasses (which are left in place for later removal by the excavator).
- Cut the bench using a balanced cut and fill technique. The topsoil and earth removed from the inner side of the bench are used to build up the outer edge of the bench. The excavator works forwards, cutting the bench ahead of it and then moving forward onto the bench. Using a rubber-tracked mini-excavator with a minimum track width of about 900 mm, the bench is generally constructed at 2.5 m width. On steeper slopes, the outer edge of the bench may need to be retained.
- At the completion of works the contractor will clean up the trail tread, removing loose rocks and roots, compacting the tread, back sloping the batter and managing drainage.

Examples of the typical trail final construction are provided in Figure 2 and Figure 3.



NOTES:

MTBA TRAIL SUSTAINABILITY GUIDELINES

THE HALF RULE

- A trail's grade shouldn't exceed half the grade of the hill slope or sideslope that the trail traverses.
- Grades exceeding the half rule may cause water to flow along the trail causing erosion.

THE TEN PERCENT AVERAGE GUIDELINE

- The overall grade of a trail should be 10% or less.
- Some sections may be steeper than 10% and some less steep.
- The ten percent average guideline may need to be adjusted to suit different soil types.

MAXIMUM SUSTAINABLE GRADE

- The maximum sustainable grade is typically 15% to 20% but is dependent on a wide range of factors.
- These factors include soil type, annual rainfall, vegetation and topography constraints and the level of difficulty for users.

GRADE REVERSALS

- Grade reversals are points at which the trail gradient changes from down to up (or up to down), creating a low point where water is pushed off the trail.
- The more frequent the grade reversals, the smaller the amount of water that needs to cross at each point thereby reducing the potential erosion and the need for drainage infrastructure.

OUTSLOPE

- Outslope is the grading of the trail to a cross slope of 5% following the general slope direction of the local terrain.
- Outsloping enables stormwater to flow across the trail as a sheet rather than as concentrated flow.
- Outslopes will not be appropriate near berms or banked turns or in some loose soil types.

CONSTRUCTION ZONES VERSUS TERRAIN SIDE SLOPE

TERRAIN CROSS SLOPE	RIDE LINE	BENCH WIDTH	VEG. CLEARING WIDTH	PARTIAL VEG. CLEARING WIDTH	TOTAL IMPACT WIDTH
5:1 (20%)	300 - 600mm	1.2 m	0.95 m	0.54 m	1.48 m
2:1 (50%)	300 - 600mm	1.2 m	1.09 m	0.66 m	1.75 m
1:1 (100%)	300 - 600mm	1.2 m	1.62 m	0.78 m	2.40 m

NOTES:

GENERAL:

- Trail excavation is to be cut and fill.
- Naturally occurring rock is to be used to protect the uphill cut and the downhill toe where available and appropriate.
- Dimensions in millimetres unless otherwise notated.
- Cut batters are at 67.5°. Fill batters are as defined.
- Rocks can be used in the toe of the fill batter to provide additional stabilisation at steeper slopes.
- Rocks and/or plants can be placed (or remain) in the bench area between the Ride Line and the Fill Batter to guide riders into the Ride Line.
- Cut material will need to be transported along the trail from steeper trail cross slope areas.
- All site clearing is is to be restricted to the trail alignment and nominal clearances for cut and fill works.
- Trail will generally be a modified surface with some hardened surfaces.
- Trail layout is to be undertaken using the "Sustainability Guidelines" as defined by the MTBA and as summarised below. More detailed information should be obtained through the MTBA.

LEGEND:
AREA OF CUT
AREA OF FILL
NATURAL GROUND SURFACE

FOR INFORMATION

WORLD TRAIL

Yarra Ranges Council

WARBURTON TRAIL DETAILED DESIGN

MOUNTAIN BIKE TRAIL SECTIONS
TYPICAL VEGETATION IMPACT ZONES
WORLD TRAIL - STANDARD DRAWING

WT2019-107

1:25 A3

WTMSTD-033-YV A

Figure 2 Indicative cross sections for standard benched trails Source: Word Trail

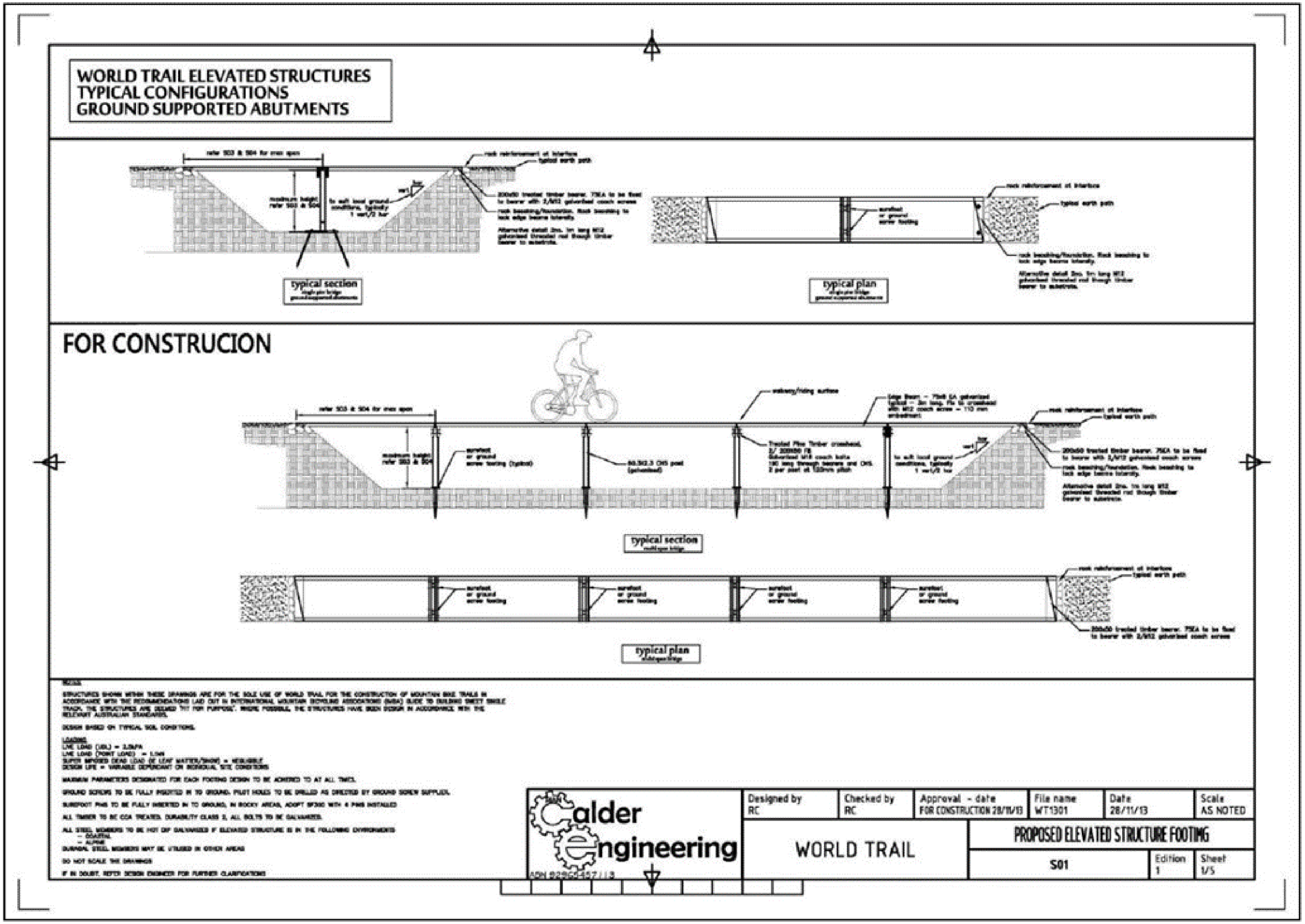


Figure 3 Typical configuration for ground supported structure Source: Word Trail

3. Hydrogeological characterisation

3.1 Introduction

This section presents a hydrogeological characterisation of the site based on a desktop review of publically available information (refer Section 1.4). It is noted that site based hydrogeological investigations, e.g. site inspections, drilling, bore installation and monitoring, etc., have not been undertaken as part of this assessment.

3.2 Climate

3.2.1 Rainfall & Temperature

It is noted the project site covers a large area with varying elevation (from 150 m to 1250 m AHD) and associated terrain, which are likely to experience different climatic conditions, particularly in respect to rainfall and temperature. This change in elevation across the project area is likely to experience extremes and variations in heavy rainfall, snowfalls and frosts particularly during the winter months.

To briefly summarise the climate conditions, data was obtained from two stations near Warburton:

- Rainfall at Warburton (O'Shannassy Reservoir station 86090 from BOM website on 14 June 2019)
- Temperature at Coldstream (station 086383 from BOM website on 14 June 2019)

The data is summarised in Table 1 which is based on the period 1915 to 2019 for rainfall and 1995 to 2019 for temperature records.

The long-term mean rainfall at the site is 1,380 mm. It is expected that most precipitation occurs as rainfall with winter (May to August) the wettest season.

Temperatures are lowest during June and July, with the long-term minimum temperatures ranging from 3.9 ºC in July to 12 ºC in January and February. Temperatures are warmest in January with the maximum temperatures ranging from 13.4ºC in July to 28.1ºC in January.

Table 1 Summary of climate data

Month	Temperature ºC		Rainfall (mm)
	Maximum	Minimum	Average
Jan	28.1	12	67.7
Feb	27.8	12	63.9
Mar	25.4	9.9	73.3
Apr	20.7	6.9	100.5
May	16.7	5.7	125.6
Jun	14	3.9	131.6
Jul	13.4	3.9	149.5
Aug	14.7	4.3	170.8
Sep	17.2	5.5	147.0

Month	Temperature °C		Rainfall (mm)
	Maximum	Minimum	Average
Oct	19.8	6.6	138.6
Nov	22.8	8.8	111.9
Dec	25.3	9.9	96.2
Annual	20.5	7.5	1380.4
Note: Site elevation 240 m at Warburton and 80 m at Coldstream. Record length: rainfall, temperature, evaporation: 1889 to May 2019.			

3.3 Relevant surface water features

The site is located in the upper catchment of the Yarra River. The Yarra River is the major waterway in the area with numerous tributary creeks flowing into the river either near or generally west of the site.

A summary of the major waterways in the area is included in Table 2. The location of these waterways are shown in Figure 1.

Table 2 Summary of surface water features

Waterway	Summary description
Yarra River	Located towards the south of the project area. The project area encompasses the river both east and west of Warburton. The Yarra River flows approximately south west towards Melbourne
Britannia Creek	Located in the south of the project area. Britannia Creek flows west out of the project area and into the Little Yarra River near Yarra Junction
Coranderrk Creek	This creek rises west of Mt Donna Buang, to the north of the project area, and flows west to join the Yarra River near Healesville.
Various	A Number of small creeks, e.g. Dee River, Walkers Creek, Frenchmans Creek (and others) rise on the southern slopes of Mt Donna Buang and flow into the Yarra River near, and downstream of Warburton

3.4 Geological setting

The geological setting for the region described below has been determined based on the 1:250,000 Geological Survey of Victoria map of Warburton (1997) and the Coffey Report (ref: M2964/1-CF).

The summary geological setting for the site is presented in Table 3 and listed from oldest to youngest. The surface geology is shown in Figure 4. In simple terms the oldest rocks are indurated marine turbidities which were deposited during the Silurian to Devonian periods. These sedimentary rocks were subsequently intruded by granites during the upper Devonian, with a large batholith present south of Warburton township. The intrusion of the granites resulted in contact metamorphism of the Silurian sediments. A geological record from the late Devonian period through to the Cainonozoic does not exist. During this period weathering of the granites resulted in the deposition of Quaternary colluvium and alluvium in the lower lying elevations.

Table 3 Summary geological setting

Geological unit	Description
Silurian to Devonian Humevale Siltstone, Melbourne Formation	This unit is found underlying the south west portion of the site and comprises siltstone that has undergone contact metamorphism to produce hornfels as a result of baking from the adjacent igneous intrusion. Note that the Melbourne Formation has not been mapped inside the project study area.
Late Devonian Warburton Granodiorite	An igneous intrusion covering a large part of the southern section of the site and forming the hills in this area.
Late Devonian Donna Buang Rhyodacite	A thick extrusive volcanic deposit which has formed the mountainous area north of Warburton. The bulk of the study area north of Warburton is located upon this geology.
Silurian to Carboniferous Felsic Dykes	A series of linear feeder dykes occurring in parts of the Donna Buang Rhyodacite which are very similar in composition.
Quaternary Colluvium and high level Alluvium	The deposits make up some of the lower slopes, larger scale landslips and high level river terraces adjacent to slopes.
Alluvium	This unit makes up the floodplains and lower terraces of the Yarra River and its tributaries.

3.5 Hydrogeological setting

3.5.1 Aquifer Systems

All the geological formations mentioned above constitute aquifers to varying degrees where they are saturated. From a high level hydrogeological perspective it is possible to simplify the various formations into two basic aquifer systems which are described below.

The water table aquifers in the study area have been shown in Figure 5.

Fractured rock aquifers (bedrock or Palaeozoic aquifers)

Within these aquifers, groundwater is (mostly) transmitted by secondary porosity flow mechanisms in these rocks such as fractures, joints and other discontinuities within the rock mass. Primary porosity flow (that is, movement between grains) is mostly negligible in these materials except where the original matrix has been altered by weathering.

The fractured rock aquifers include:

- Silurian – Devonian indurated sediments such as the Humevale Formation and Melbourne Formation
- Devonian granites (Warburton Granodiorite) and acid volcanics (Donna Buang Rhyodacite)

From a regional perspective, grouping these formations into a single aquifer system is considered a reasonable approach based on the following rationale:

- The various formations differentiated in the Palaeozoic bedrock are expected to have similar hydrogeological flow properties
- The Victorian Aquifer Framework (VAF) has collectively grouped all the Palaeozoic aquifers into a single ‘basement’ system

Under these conditions, in a regional context, these rocks have hydrogeological similarities. On a local scale, the hydraulic character of the aquifers may vary because of:

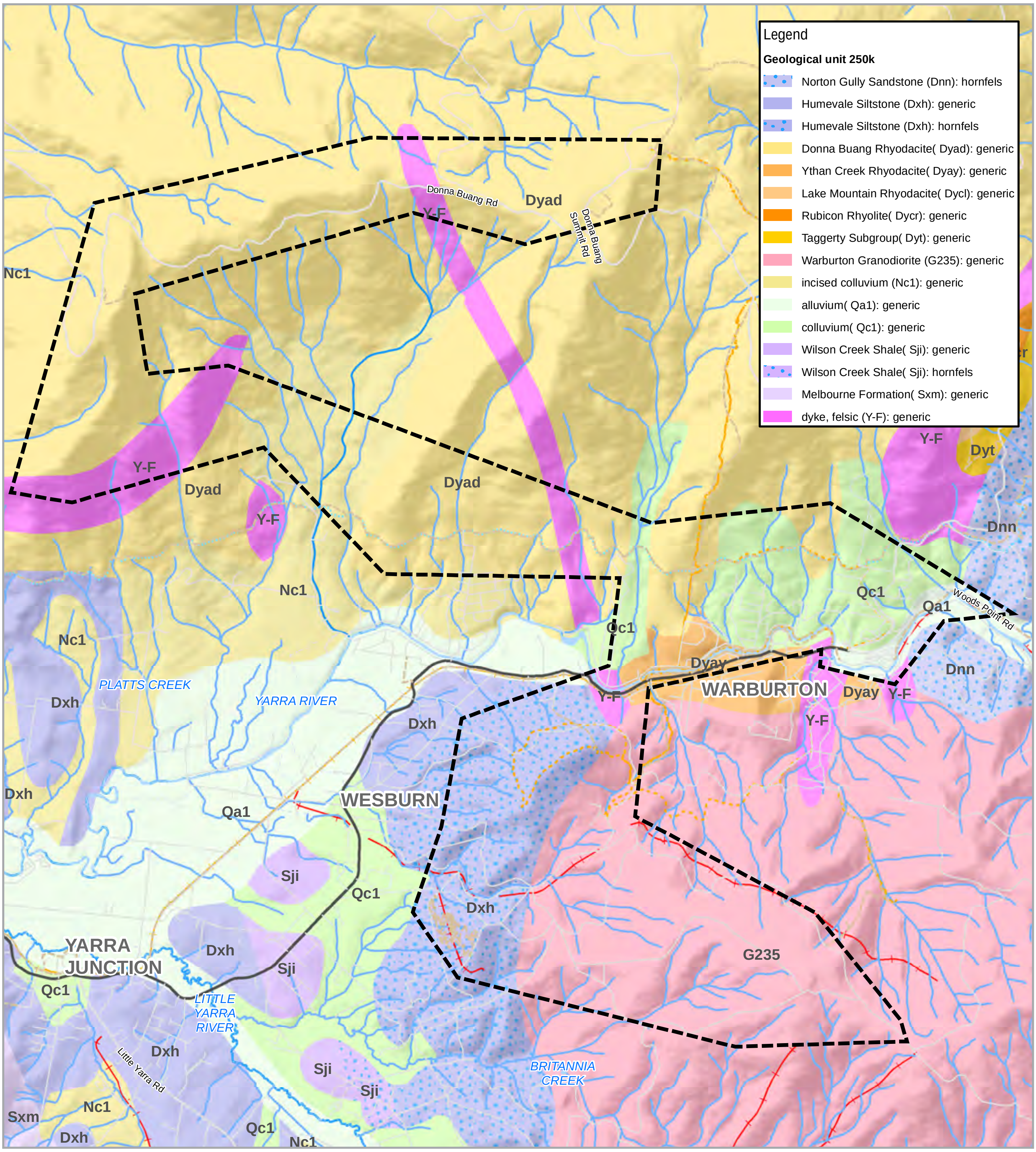
- Weathering
- Nature of fracturing (size, density, persistence, infilling)
- Nature of their formation, such as dykes, and contact metamorphism
- Tectonic history
- Local variations in lithology.

In this report, these fractured rock aquifers are referred to as the Palaeozoic or basement aquifer.

Porous media aquifers

Within porous media aquifers groundwater stored and transmitted by primary porosity flow (flow between the interstices and pore spaces of the sedimentary grains). The porous media formations in the study area include the Quaternary alluvial and colluvial sediments, which comprise variable mixtures of the sands, gravels, clays and silts.

The alluvials are laterally restricted to the present day drainage lines and waterways, and in some cases can have high degree of interaction with waterways. Under these conditions, disturbance of groundwater in these sediments has potential environmental implications. The thickness of these aquifers is variable, but tends to be generally less than 10 m.



Legend

- Trail Area
- Walking Tracks
- Highway
- Arterial
- Collector
- Tracks
- Watercourse
- River
- Stream
- Channel
- Drain/Channel/Other

Rail

- Rail dismantled
- Rail trail

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

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Surface Geology

Figure 4

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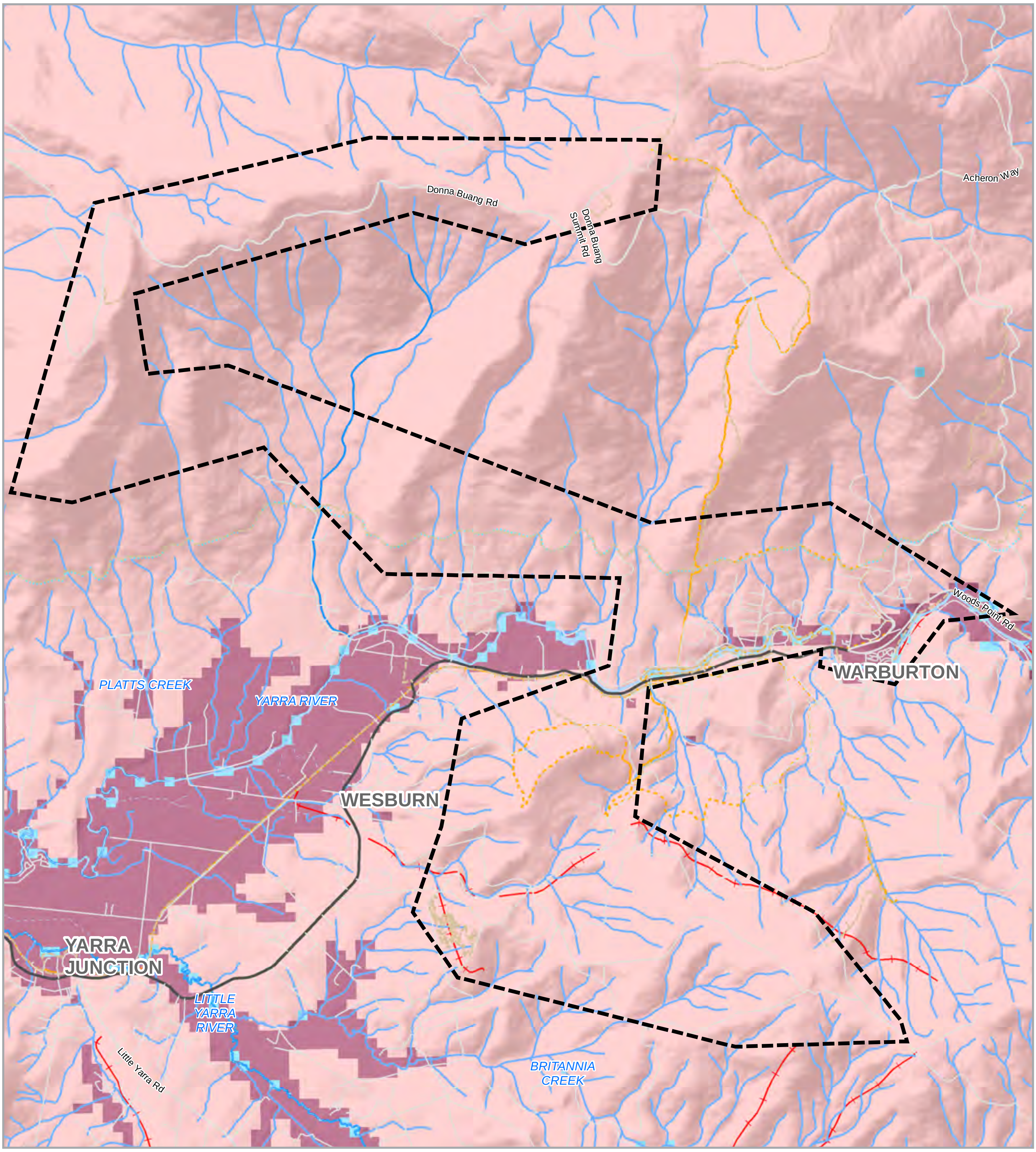
Data source: DELWP, VicMap, 2019; GHD, 2019; DPI, Seamless Geology 250k, 2011 Created by: bsmyth



Legend

Trail Area	River	**Aquifer intersected by watertable**
Walking Tracks	Stream	Water
Highway	Channel	Quaternary Aquifer (QA)
Arterial	Drain/Channel/Other	Basement (BSE)
Collector	**Rail**	
Tracks	Rail dismantled	
Watercourse	Rail trail	

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

N

Yarra Ranges Council
Warburton Mountain Bike Destination

Aquifers intersected by watertable
watertable

Project No. 31-37322
Revision No. A
Date 13/09/2019

Figure 5

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Data source: DELWP, VicMap, 2019; GHD, 2019; DELWP, SAFE data, 2012 Created by: bsmyth

3.6 Potentiometry

3.6.1 Depth to water table

The DELWP groundwater resource report indicates that in most locations within the project area, the water table depth is in excess of 50 m. Groundwater may be less than 10 m deep in the drainage lines and floodplains of waterways such as the Yarra River and Little Yarra River.

A depth to groundwater map has been interpreted from regional information and has been shown in Figure 6.

3.6.2 Groundwater flow direction

In general, the groundwater flow direction is expected to be a subtle or subdued reflection of the local topography. As such, the groundwater flow direction is expected to be from the topographic highs towards local drainage lines and ultimately the Yarra River. As noted, the aquifer fracture orientations and permeability will also have an influence on local flow directions. Groundwater is expected to form a significant component to the overall flow in waterways within the study area.

3.6.3 State Groundwater Observation Network water level trends

A search of the WMIS was also undertaken to identify the presence of active State Groundwater Observation Network bores (SON). The SON bores are usually the only bores with publically available time series water level monitoring data, and at some sites, water quality monitoring data.

There are no SON bores within the project study area.

3.7 Groundwater salinity

The DELWP groundwater resource report indicates that groundwater salinity in the Basement aquifer ranges from 501 mg/L to 1,000 mg/L Total Dissolved Solids (TDS). The salinity of the Quaternary aquifer is unknown, but suspected as being fresh and within a similar range.

The groundwater salinity, as interpreted from regional information has been shown in Figure 7 which indicates that groundwater in the study area is generally fresh.

3.7.1 Classification of groundwater

Under the *Environment Protection Act 1970*, and upon the recommendation of the EPA, the State of Victoria enacted the State Environment Protection Policy (SEPP) *Waters 2018* under Victorian Government Gazette No. S 499, which has the objective to protect and improve the quality of Victoria's waters having regard to the principles of environment protection set out in the *Environment Protection Act 1970*.

The policy forms the primary guide to determining existing impacts and risk of impacts to groundwater quality. It provides that groundwater is categorised into segments based on the groundwater salinity, with each segment having particular identified beneficial uses. The segments and their beneficial uses are summarised in Table 4.

Table 4 Beneficial uses for groundwater

Use	Segment (mg/L TDS)						
	A1	A2	B	C	D	E	F
	0 – 600	601 – 1,200	1,201 – 3,100	3,101 – 5,400	5,400 – 7,100	7,100 – 10,000	>10,001
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	✓	✓	✓	✓	✓		
Water-based recreation (primary contact recreation)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

The EPA may determine that a beneficial use does not apply to groundwater where:

- There is insufficient yield to sustain the beneficial use
- The application of groundwater, such as for irrigation, may be a risk to beneficial uses of land or the broader environment due to the soil properties
- The beneficial use specified in the definition of water dependent ecosystems and species relates to stygofauna and troglofauna
- The background level of an environmental quality indicator would not provide for the protection of the beneficial use

Based on regional interpretations of groundwater salinity in the water table aquifer, groundwater within the study area is likely to fall within Segment A, i.e. it is considered a valuable resource that can service a range of beneficial uses.

3.8 Study area groundwater use

A search of DELWPs Water Measurement Information System (WMIS) was undertaken to identify bores within the study area. The following comments are made regarding the WMIS data:

- Bores installed prior to the proclamation of the original Water Act (1969) may not be registered as there was no mandatory requirement to licence bores prior to this date
- The WMIS does not provide information regarding the operational status of groundwater bores
- Bores installed without a bore construction licence are unlikely to be registered on the WMIS (unless detected by later audits)
- Many bores have not been surveyed for location. Bore locations as registered were often those initially proposed on the bore construction licence application. In many instances drilling contractors could not gain access to these sites and final locations often have a positional accuracy greater than ± 250 m.
- The information registered on the WMIS is subject to the accuracy of bore completion reports submitted by drilling contractors
- Information registered on the WMIS is subject to change since the completion of the bore e.g. water level information, pump setting depth, groundwater quality
- Some information is not available on the WMIS e.g. pump setting depth, bore ownership

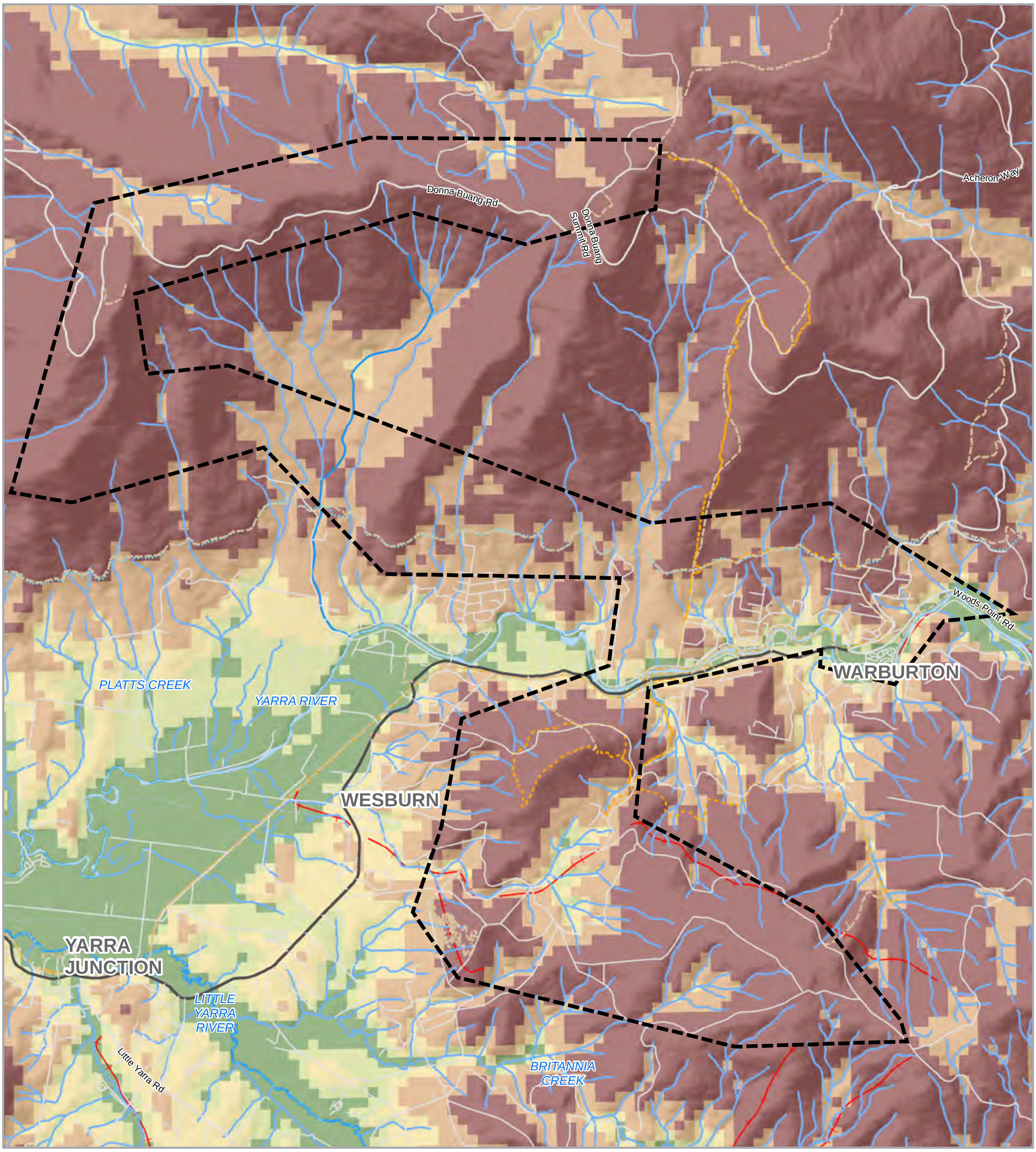
One stock and domestic bore was identified within the project boundary, towards the south of the site (refer Figure 8).

The remaining bores identified are to the west of the site and have been installed for a variety of uses including:

- Stock and/ or Domestic
- Groundwater investigation or observation
- Irrigation

3.9 Groundwater yields

Of the bores shown on Figure 8 only a few of these had yield information. Yields ranged from 0.25 L/s to 5 L/s.



Legend

Trail Area	River	**Water table depth (m)**
Walking Tracks	Stream	<5
Highway	Channel	5 - 10
Arterial	Drain/Channel/Other	10 - 20
Collector	**Rail**	20 - 50
Tracks	Rail dismantled	50 - 100
Watercourse	Rail trail	

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

N

Yarra Ranges Council
Warburton Mountain Bike Destination

Depth to watertable

Project No. 31-37322
Revision No. A
Date 13/09/2019

Figure 6

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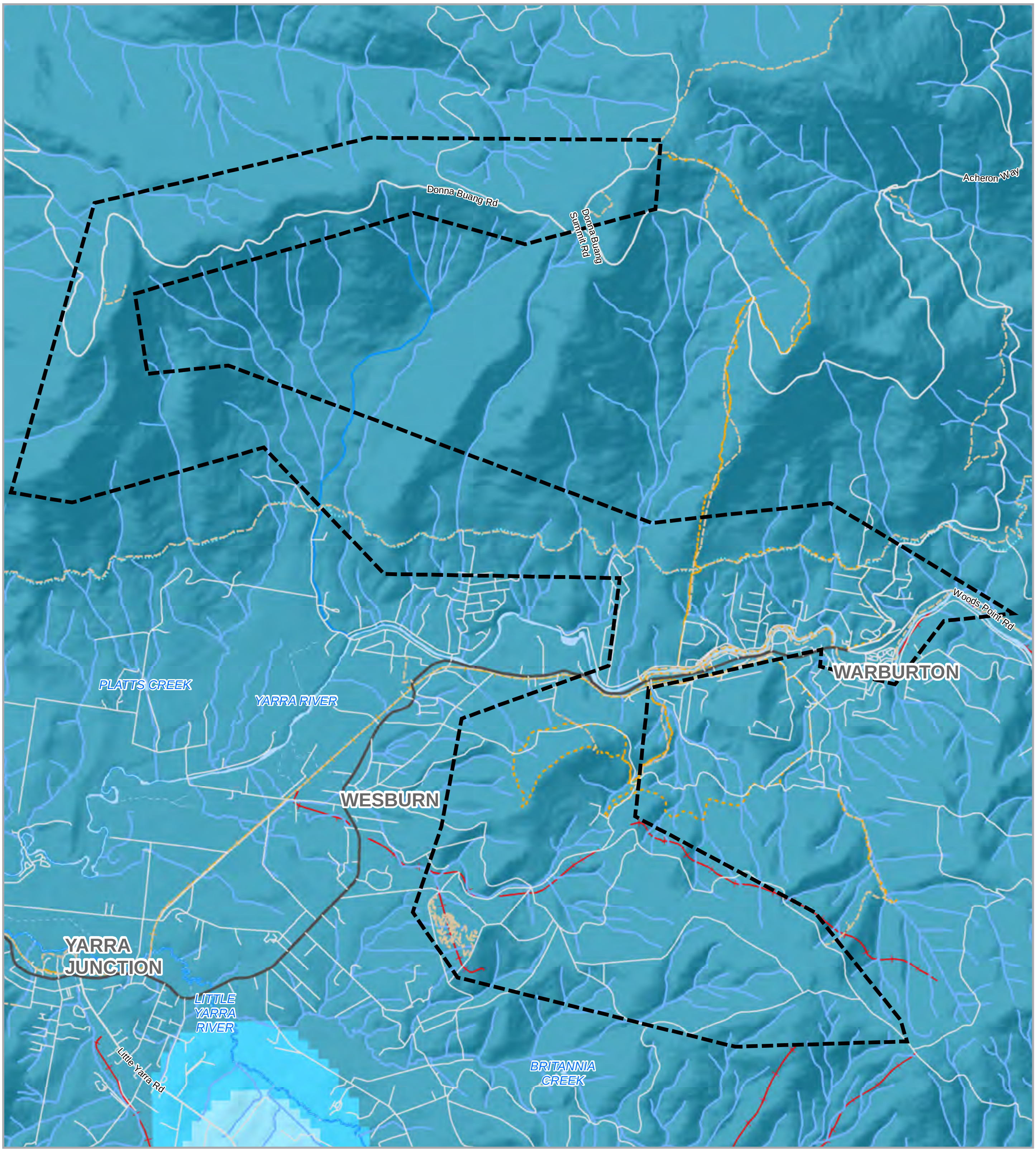
Print date: 13 Sep 2019 - 16:10

Data source: DELWP, VicMap, 2019; GHD, 2019; DELWP, SAFE data, 2012 Created by: bsmyth



Legend

- Trail Area
- Walking Tracks
- Highway
- Arterial
- Collector
- Tracks
- Watercourse
- River
- Stream
- Channel
- Drain/Channel/Other

Rail

- Rail dismantled
- Rail trail

Water table - salinity (mg/L)

- 0 - 500
- 500 - 1000
- 1000 - 3500

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

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GHD

Yarra Ranges Council
Warburton Mountain Bike Destination

Watertable salinity

Project No. 31-37322
Revision No. A
Date 13/09/2019

Figure 7

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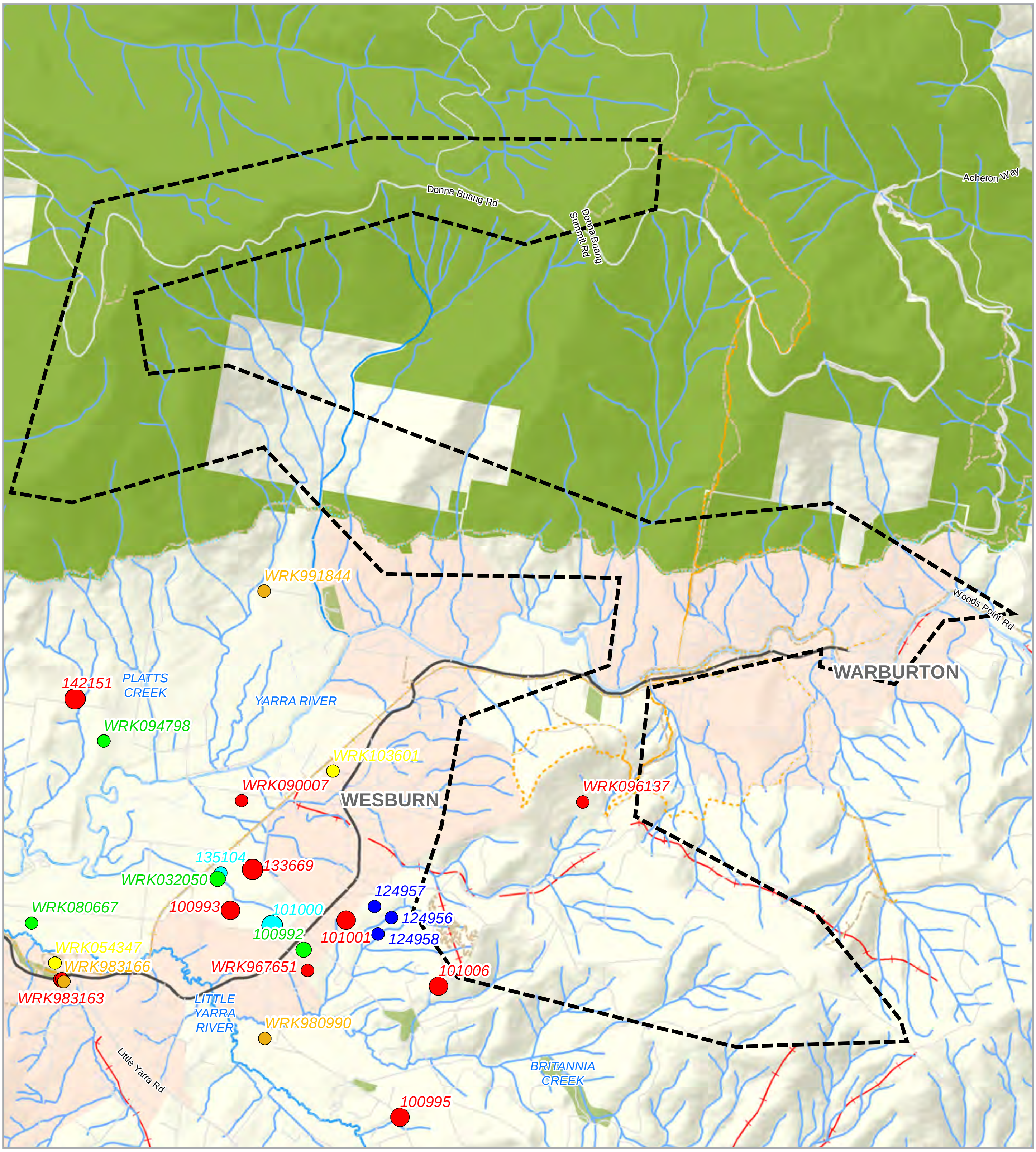
Print date: 13 Sep 2019 - 16:11

Data source: DELWP, VicMap, 2019; GHD, 2019; DELWP, SAFE data, 2012 Created by: bsmyth



Legend

Bore use

- COMMERCIAL
- DOMESTIC
- GROUNDWATER INVESTIGATION
- IRRIGATION
- NOT KNOWN
- OBSERVATION
- STOCK AND OR DOMESTIC

Yield (L/s)

- Unknown
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 15

- Trail Area
- Walking Tracks
- Highway
- Arterial
- Collector
- Tracks
- Watercourse
- River
- Stream
- Channel
- Drain/Channel/Other

Rail

- Rail dismantled
- Rail trail
- National Parks
- Other Parks
- Township boundary
- Land

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

N

GHD

Yarra Ranges Council
Warburton Mountain Bike Destination

Neighbouring groundwater users and groundwater yield

Project No. 31-37322
Revision No. B
Date 01/10/2019

Figure 8

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Print date: 01 Oct 2019 - 10:25

Data source: DELWP, VicMap, 2019; GHD, 2019 Created by: bsmyth

3.10 Groundwater management arrangements

The DELWP groundwater resource report indicates that the site is not within a Groundwater Management Area. That is, the site falls within an Unincorporated Area and is not subject to groundwater use caps.

3.11 Potential for Groundwater Dependant Ecosystems

3.11.1 Definition

A groundwater dependent ecosystem (GDE) is an ecosystem which has its species composition and natural ecological processes determined by groundwater (ARMCANZ & ANZECC, 1996). That is, they are natural ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. If the availability of groundwater to GDEs is reduced, or if the quality is allowed to deteriorate, these ecosystems are impacted.

The GDEs can be broadly grouped into three categories:

- Ecosystems that depend on the surface expression of groundwater:
  - Swamps and wetlands can be sites of groundwater discharge and may represent GDEs. These sites may be permanent or ephemeral systems that receive seasonal or continuous groundwater contribution to water ponding or shallow water tables. Tidal flats and inshore waters may also be sites of groundwater discharge. Wetlands can include ecosystems on potential acid sulfate soils and, in these cases, maintenance of high water levels may be required to prevent waters from becoming acidic.
  - Permanent or ephemeral stream systems may receive seasonal or continuous groundwater contribution to flow as baseflow. Interaction would depend on the nature of stream bed and underlying aquifer material and the relative water level heads in the aquifer and the stream.
- Ecosystems that depend on the subsurface presence of groundwater. Terrestrial vegetation such as trees and woodlands may be supported seasonally or permanently by groundwater. These may comprise shallow or deep-rooted communities that use groundwater to meet some or all of their water requirements. Animals may depend on this vegetation and therefore indirectly depend on groundwater. Groundwater quality generally needs to be high to sustain vegetation growth.
- Ecosystems that reside within a groundwater resource. These are referred to as hypogean ecosystems. Micro-organisms in groundwater systems can exert a direct influence on water quality. For example, stygofauna are typically found in karstic, fractured rock or alluvial aquifers.

It is widely acknowledged there is poor understanding of how to recognise GDEs. There is also poor understanding of the hydrogeological processes affecting GDEs, or their environmental water requirements.

3.11.2 Identification within the study area

The Bureau of Metrology's (BoMs) Groundwater Dependant Ecosystem (GDE) Atlas was interrogated to identify GDEs based on regional mapping. However, no GDEs were identified within the site (refer Figure 9).

The Yarra River, Little Yarra River and several of their tributaries were identified as high potential aquatic GDEs. Three low to moderate potential terrestrial GDEs were identified in the north, and north west of the study area. High potential terrestrial GDEs were also identified west of the site, north of Yarra Junction.

3.12 Spring occurrence

3.12.1 Mineral springs

Available information from the Victorian Mineral Water Committee (VMWC) indicates that the area does not fall within a recognised minerals springs area.

3.12.2 Groundwater seepage / (Still) water springs

There is insufficient information to determine the specific location of any still water springs in the project area as springs are not individually mapped. It is noted, however, that a spring has been anecdotally reported from near the 10 Mile picnic area near Mt Donna Buang.

Owing to the mountainous topography of the study areas (refer hydrogeological conceptualisation in section 3.14), it is a reasonable expectation that groundwater may emanate as springs or seepage within the study area, where there are abrupt changes in topography. Springs can be identified through aerial photography, or ground truthing and can sometimes be identified through vegetation growth in topographic depressions and upstream of drainage lines.

3.13 Potential for Acid Sulfate Soils

3.13.1 Definition

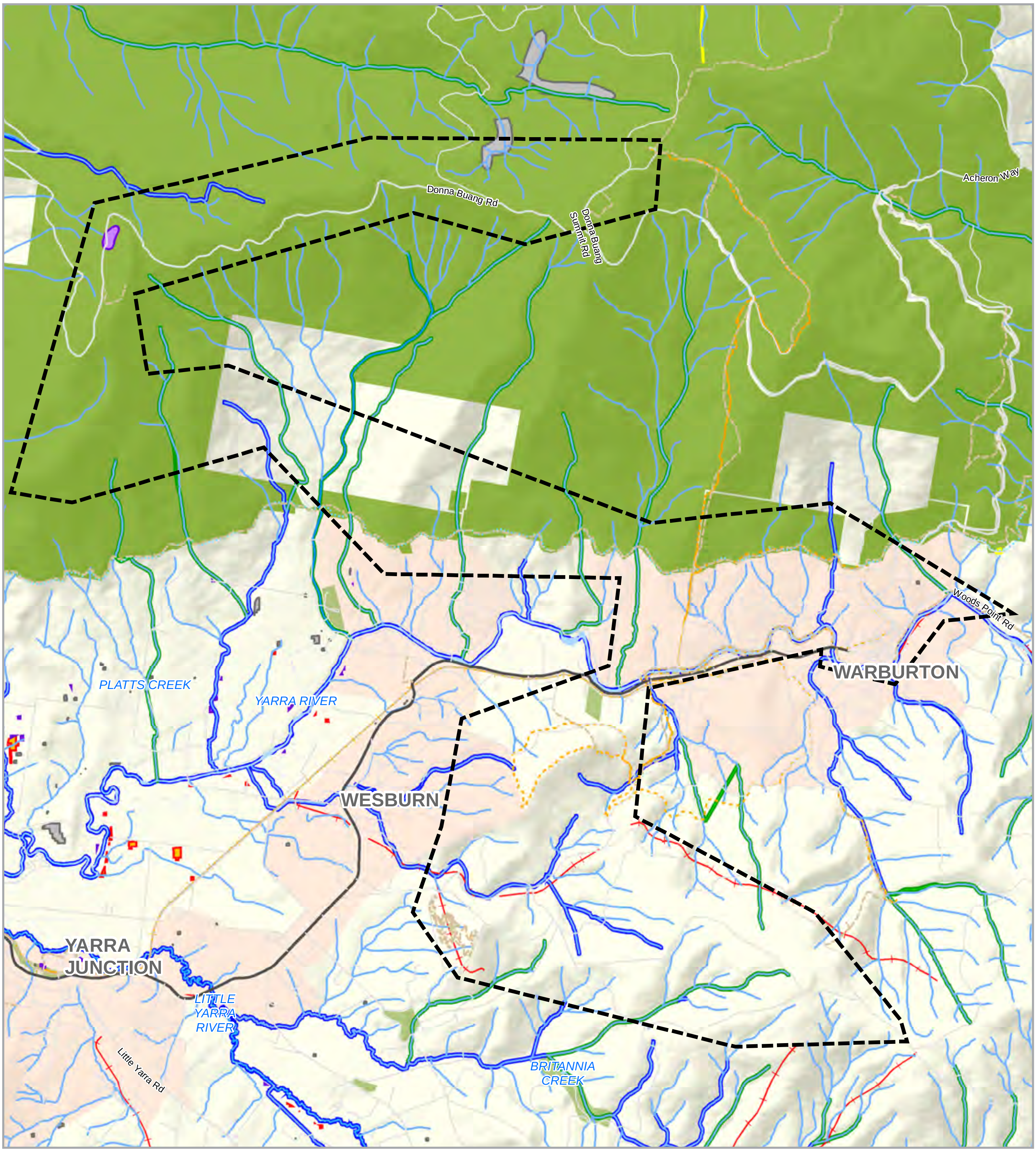
Acid sulphate soils are soils, sediments, unconsolidated geological material or disturbed consolidated rock mass that contain elevated concentrations of the metal sulfide. It occurs principally in the form of pyrite (iron sulphide). These soils can be rich in organics and were formed in low oxygen or anaerobic depositional environments.

The soils are stable when undisturbed or located below the water table. However, when oxygen is introduced, the sulphides oxidise to sulphate, with resultant soils having low pH and potentially high concentrations of the heavy metals.

Groundwater levels may rise as a result of recovery from construction dewatering activities, or leaching of infiltrating rainfall through the sulphate rich zones. This can result in oxidisation of materials and the mobilisation of pH and heavy metals into the environment where they can potentially impact deep-rooted vegetation, aquatic flora and fauna, and can be aggressive to reactive materials (such as concrete, steel) of foundations, underground structures (such as piles, pipes, basements) or buried services in contact with groundwater. It can also result in the discharge of acid groundwater to receiving surface water systems.

3.13.2 Identification within the study area

CSIROs National Acid Sulphate Soil (ASS) Atlas indicates that there is an extremely low to low probability of ASS occurring at the site. Regional ASS mapping is presented in Figure 10.



Legend

Trail Area	River	National Parks	Unclassified potential GDE
Walking Tracks	Stream	Other Parks	**Terrestrial GDEs**
Highway	Channel	Township boundary	High potential GDE
Arterial	Drain/Channel/Other	Land	Moderate potential GDE
Collector	**Rail**	**Aquatic GDEs**	Low potential GDE
Tracks	Rail dismantled	High potential GDE	
Watercourse	Rail trail	Moderate potential GDE	

Paper Size ISO A4

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

N

GHD

Yarra Ranges Council
Warburton Mountain Bike Destination

Groundwater Dependant Ecosystems (GDEs)

Project No. 31-37322
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Date 13/09/2019

Figure 9

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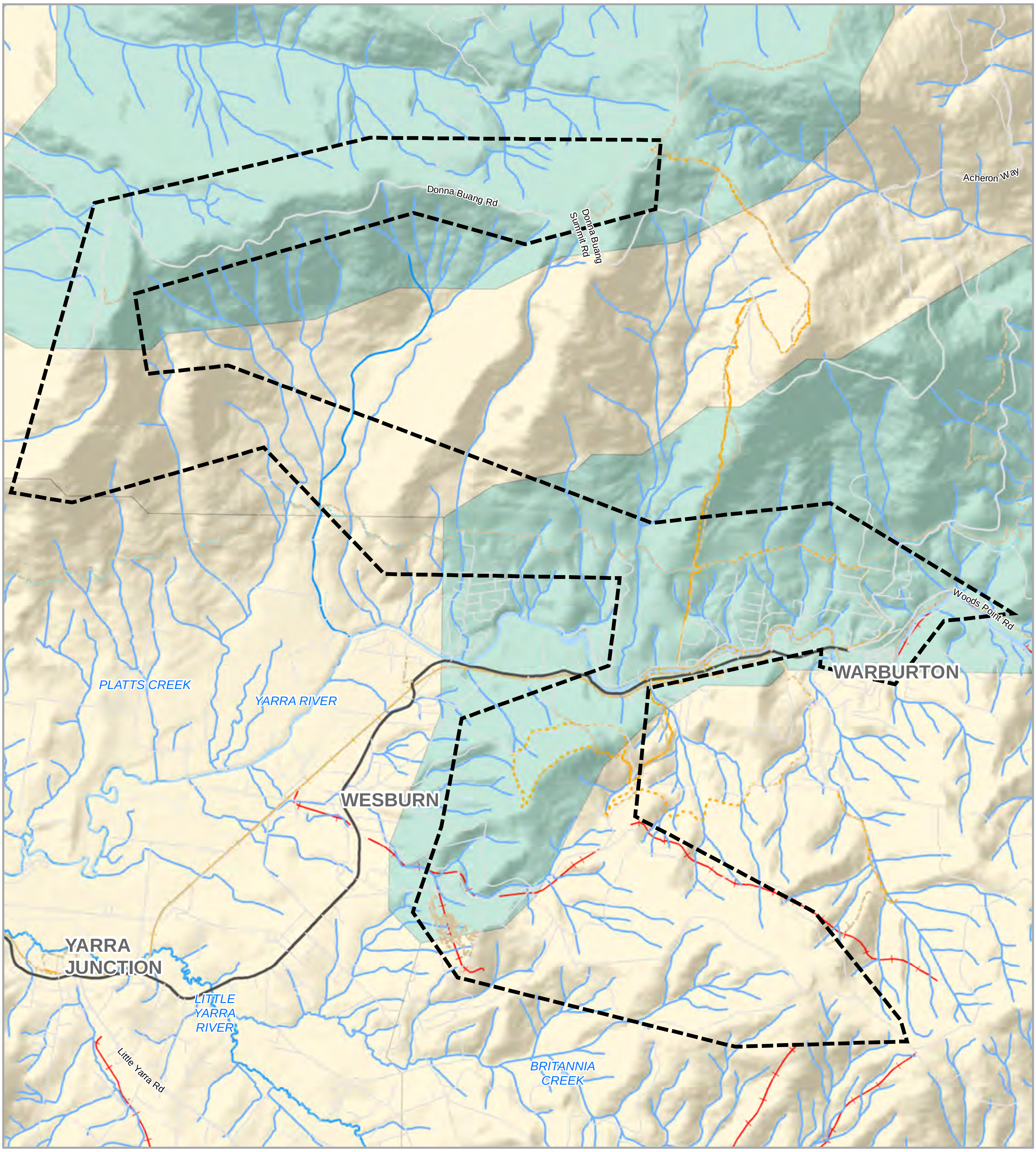
Print date: 13 Sep 2019 - 15:09

Data source: DELWP, VicMap, 2019; GHD, 2019; BoM, GDEs, 2019 Created by: bsmyth



Paper Size ISO A4
0 0.4 0.8 1.2 1.6
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA94 MGA zone 55

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Yarra Ranges Council
Warburton Mountain Bike Destination

Project No. 31-37322
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Date 13/09/2019

Potential Acid Sulphate Soils

Figure 10

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Print date: 13 Sep 2019 - 15:10

Data source: DELWP, VicMap, 2019; GHD, 2019 Created by: bsmyth

3.14 Conceptual Hydrogeological Model

The information gathered during this assessment has been synthesised to generate a conceptual hydrogeological model (CHM) of the project study area. Each aspect of this model is described below, and depicted diagrammatically in Figure 11.

The schematic is a cross-section, orientated approximately north – south through the project study area. It is a simplified representation of the geology and hydrogeology of the site. It is noted that the CHM has been developed based on available regional hydrogeological information rather than any site specific intrusive investigations.

The schematic shows a simplified two aquifer system:

- The Palaeozoic basement rocks
  These include sediments of the Humevale Siltstone, and granitic intrusions including the Warburton Granodiorite and Donna Buang Rhyodacite, and associated metamorphics.
- Quaternary (Cainozoic) unconsolidated sediments
  These are mapped within the Yarra River floodplain and form a thin sequence overlying the bedrock aquifer.

All aquifers are water table (unconfined) aquifers. Regional groundwater level information indicate a depth to groundwater of in excess of 50 m in the topographically elevated areas, e.g. Mount Donna Buang, but water levels shallow in the floodplains and lower elevations.

Overall groundwater flow is towards the lower lying area, i.e. towards the drainage systems etched into the basement topography, with water levels being a subtle reflection of the topography. Where the water table shallows, or there are abrupt changes in topography, groundwater may daylight as spring flow.

Multiple flow systems (local, intermediate and regional) may develop in these basement rocks (and are relevant to all Palaeozoic aquifers). The local flow systems are expected to predominate with flow occurring through the saprolitic (weathered profile) of the bedrock aquifers, and overlying, saturated residual zones where permeability (and storage) is high. The weathered horizons in the Palaeozoic aquifers has not been indicated in the schematic. Local flow paths are likely to be influenced aquifer fracture orientation and the degree of weathering. Intermediate and regional flows systems have also been indicated on the schematic. These may also discharge into the Yarra River floodplain, mix with shallower systems or pass beneath the floodplain.

Groundwater discharge to the waterways within the study is expected, with groundwater (baseflow) components to waterways in this area being a relatively large proportion of the overall flow in waterways.

Recharge to the basement aquifer is predominately by rainfall across the outcrop area. Groundwater discharge is towards drainage lines and to the Yarra River. The regional geological mapping does not indicate the presence of faults in the area, however, local fracturing and/or faulting in the basement rocks may result in localised spring discharge.

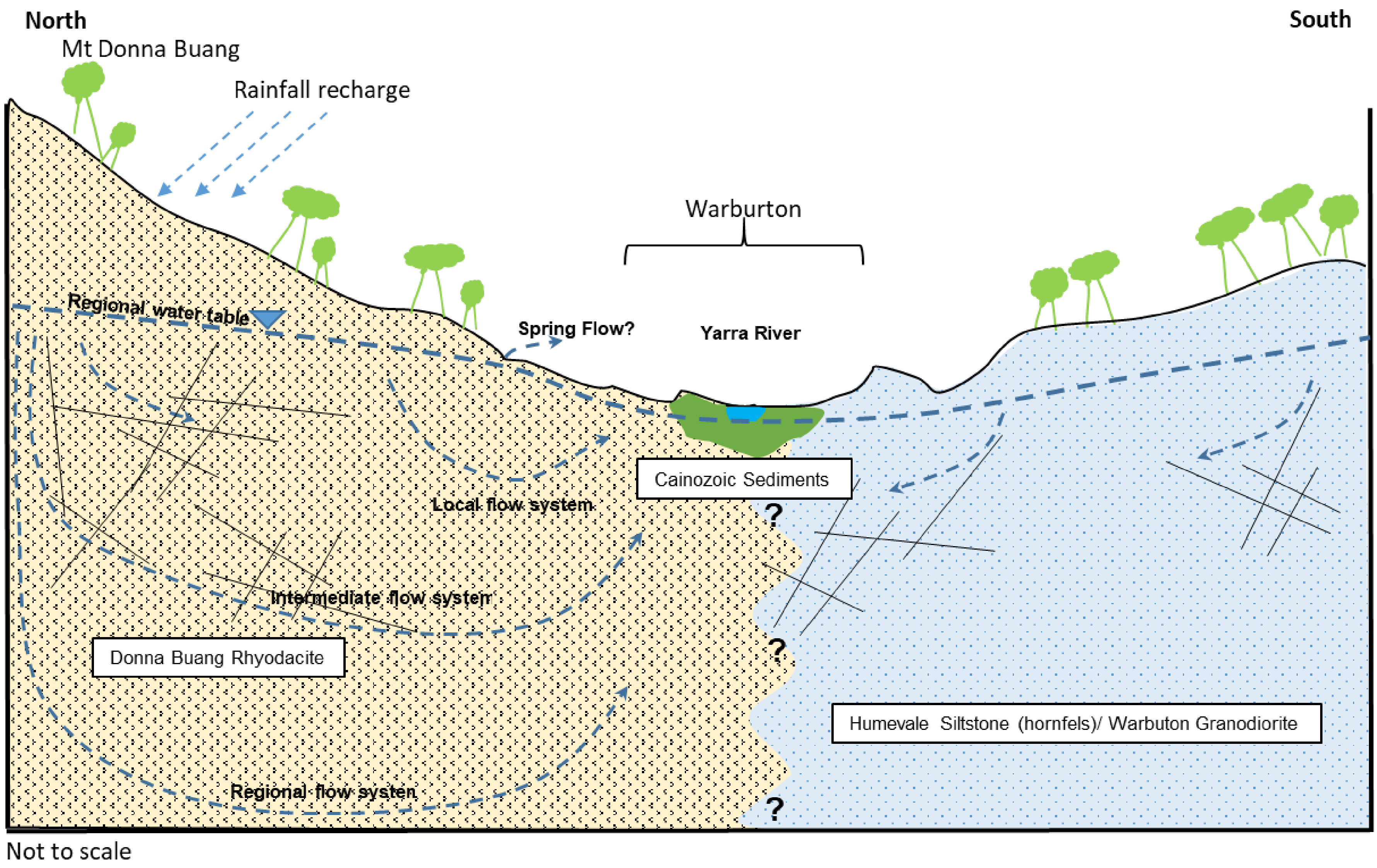

Figure 11 Conceptual hydrogeological model

4. Qualitative risk assessment

4.1 Qualitative risk assessment

To determine the potential impacts to groundwater from the proposed development, it is necessary to understand the risks. The risk assessment has been carried out in general accordance with EPA (2016) and Victorian EPA (2006). The following methodology was used to determine the groundwater impact pathways and define risk ratings for the project:

1. Determine the ‘impact pathway’ – how the site impacts on a given groundwater value or receptor
2. Describe the ‘consequences’ of the impact pathway to define levels of consequence (Table 5).
3. Determine the ‘likelihood’ of the consequence occurring to the level assigned in step 2. Likelihood descriptors are provided in Table 6.
4. Determine the maximum credible ‘consequence level’ associated with the impact as defined in Table 5.
5. Form the consequence and likelihood levels assigned to the impact pathway. Use the risk matrix to determine the risk rating (Table 7).

4.2 Consequence criteria

Consequence criteria (Table 5) range on a scale of magnitude from ‘negligible’ to ‘severe’. Magnitude was considered a function of the size of the impact (the spatial area affected and expected recovery time of the environmental system).

Consequence criteria descriptions indicating a minimal size impact over a local area, and with a recovery time potential within the range of normal variability were considered to be at the negligible end of the scale. Conversely, severe consequence criteria describe scenarios involving a very high magnitude event, affecting a catchment area, or requiring several years to reach functional recovery.

With the groundwater assessment, impacts are generally simplified into those that affect groundwater quality and/or groundwater level. Falls or rises in groundwater level affect hydraulic gradients and groundwater movement. The effect on movement or groundwater flow translates to a change in groundwater availability, be it available for environmental reserves (e.g. GDEs) or resource users.

Table 5 Consequence criteria

Criteria	Negligible	Minor	Moderate	Significant	Severe
Direct impacts to the groundwater environment	Negligible change to groundwater regime, quality and availability.	Temporary or highly localised changes to groundwater regime, quality and availability but no significant implication for groundwater users or the environment.	Changes to groundwater regime, quality and availability with minor implications (localised) (reduction in available volume or quality but existing users still viable or negligible impact to receiving environments).	Groundwater regime, quality or availability significantly compromised (existing uses of groundwater no longer viable, and/or impact on waterway flows/receiving environment).	Widespread groundwater resource depletion, groundwater quality degradation or contamination.

Table 6 Likelihood categories

Descriptor	Explanation
Almost Certain	The event is expected to occur almost all the time
Likely	The event will occur most of the time
Probable	Might occur
Unlikely	Might occur but not expected
Rare	Only expected to occur under exceptional circumstances

Table 7 Risk rating matrix

Consequence	Likelihood				
	Almost certain	Likely	Probable	Unlikely	Rare
Severe	V	V	V	H	H
Significant	V	H	H	H	M
Moderate	V	H	M	M	M
Minor	H	M	M	M	L
Negligible	H	M	L	L	L

Note: V – Very high risk; H – High risk; M – Medium risk; L – Low risk

A number of potential risks that the construction of the mountain bike trails may pose to the groundwater system have been identified.

A risk register has been summarised in Table 8.

Table 8 Summary of key potential impacts and risks

Source / Activity	Pathway(s) of risk	Receptor(s) Identified	Risk Analysis			Comment
			Likelihood	Consequence	Risk	
Disruption of potential spring flow	Groundwater is (unexpectedly) intercepted in a cutting / bench or excavation, resulting in seepage and spring flows	Excavation of soil/rock and track construction and compaction/rock armouring has the potential to dam or dislocate any identified spring flow. This may lead to excessive boggy ground or changes to local spring ecosystems, e.g. GDEs.	Rare	Minor	Medium	The publically available information is insufficient to determine the presence of any springs in the project area that would be directly impacted. It is expected that many of the existing trails will not require significant earthworks and therefore the likelihood of intersecting shallow groundwater is low. If springs are intersected they are likely to be highly localised in extent. Measures available to mitigate impact: • Micro siting of trails / paths to avoid springs or areas identified as being water logged. • Diversion of spring seepage around the trail / path via culverts / armouring / drainage design.
Disruption or dislocation to groundwater flow	Installation of supports (e.g. piles) required for bridges and elevated structures (impedance to groundwater flow). Such piles present a barrier to groundwater flow. Filling areas may retard drainage of existing springs.	Down-gradient groundwater users (few identified in region) Down-gradient groundwater dependent ecosystems and receiving environments.	Rare	Negligible	Low	Available regional information suggests the depth to groundwater in the majority of the project area is deep (>10 m). It is suspected that these depths are greater than any pile depths required for the proposed bridges/ elevated structures. Such structures tend to be small and therefore the impact to groundwater (if any) would be highly localised. Use of culverts, bridges or armouring to provide drainage of water logged areas and therefore not create impedance to spring discharge should such areas be encountered.

Source / Activity	Pathway(s) of risk	Receptor(s) Identified	Risk Analysis			Comment
			Likelihood	Consequence	Risk	
Groundwater contamination	Fuel/ oil spills from excavator (where used during track construction). Oil/ grease from new car parking bays / stormwater run-off. Construction washdown areas, maintenance areas and wastewater management.	Down-gradient groundwater users (few identified in region) Down-gradient groundwater dependent ecosystems and receiving environments (waterways)	Unlikely	Minor	Medium	Construction environmental management plan should be developed to have procedures to avoid or minimise adverse risk to the groundwater (or other) environments. Such a plan should address: • Vehicle inspections and maintenance • Refuelling, hazardous materials storage and handling. • Construction plant washdown and water treatment Water sensitive urban design around car parking and new structures and trail heads.

5. Conclusions and recommendations

5.1 Conclusions

GHD was engaged by Council undertake a desktop HA for their mountain bike destination project near Warburton. The HA has been undertaken in order to provide an interpretation of the local hydrogeological setting of the site, and to potentially guide planning approvals for the project.

Based on the investigations completed and documented in this report the following conclusions are made:

Study area groundwater characterisation

- The geology of the region principally comprises Palaeozoic indurated sediments and granites (and associated metamorphics and intrusives). Quaternary colluvial and alluvial sediments have been mapped in the lower lying areas, principally associated with drainage lines and floodplains of existing waterways.
- The aquifers in the study area can be broadly divided into two systems:
  - Palaeozoic bedrock aquifer – fractured rock aquifer system with a tendency for highly localised flow paths. This covers the bulk of the study area.
  - Quaternary sediments – a porous media type aquifer typically restricted to present day waterways and drainage lines.
- The groundwater quality within the study area is poorly characterised with an absence of site specific quantitative data, however, based upon regional mapping, the groundwater quality is expected to be high, i.e. fresh and likely to be less than 1,000 mg/L TDS.
- Groundwater use in study area is limited.
- The depth to groundwater is expected to be highly variable owing to the mountainous terrain of the region. Groundwater flow is from topographic highs towards the lower lying areas where it emerges as springs and seepage to waterways. Groundwater is expected to supply, either continuously or seasonally, a contribution to the overall flow in waterways.
- The identification of springs is problematic at the desktop phase of the hydrogeological investigation, however, localised spring activity in the region is likely.

Risks to groundwater

- Mountain bike construction will require the limited removal of vegetation in some areas, installation of elevated structures (e.g. bridges) and limited drainage works in boggy areas. As the project is mostly at grade, or within areas of shallow cut, there is limited likelihood of direct interaction between the project and the groundwater environment.
- Excavations required for bridge abutments, foundations, or shallow cuts within slopes to form the bike routes may, however, intersect shallow groundwater. Such areas are likely to be highly localised, and depending upon the depth of cut, may only seasonally expose groundwater. These risks are considered to be low and mitigation measures are available.
- Boggy areas may be manifestations of spring activity and surficial discharge of groundwater. The excavation and design of structures (e.g. armouring, bridges, culverts), may disrupt spring activity which could effect downstream ecosystems. These risks are low and mitigation measures are available to address such a risk.

- Groundwater could be contaminated during construction through the storage and handling of hazardous materials. This is considered to be a low risk which could be managed through environmental management controls.

5.2 Recommendations

The following recommendations should be considered as part of future design and construction associated with the project to manage the current identified risks (refer Table 9):

Table 9 Summary of recommendations

Recommendation	Rationale
Maintain 'like for like' conditions along trails.	Where existing water logged ground conditions are present, armouring or elevated structures should be designed to not impede drainage of the area. Micro-siting of new trails to avoid springs. Springs would be identified through study area / trail walkover. Where groundwater is intersected in benched trails, drainage design (culverts, armouring, elevated structure) is such that seepage water is diverted and not allowed to pond or accumulate. WSUD should be implemented to manage both stormwater run-off and spring flow to minimise erosion, trail damage, and sediment loads to down-slope areas and downstream waterways.
Confirm depths of piles/footings for bridges and elevated structures	To assess if groundwater will be intersected during construction
Construction environmental management plan.	Inspection and maintenance of earthwork machinery for fuel/oil leaks (potential groundwater contamination). Consider bunding washdown pads (groundwater contamination).
Implement water sensitive urban design (WSUD) at trail heads.	To plan and manage run-off generated from car parking and other features within the study area so that stormwater run-off (contaminant and sediment loads) does not result in adverse impacts to groundwater.

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Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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