REGIONAL ROADS VICTORIA

MAY 2021

BEAUFORT BYPASS ENVIRONMENT EFFECTS STATEMENT

GROUNDWATER IMPACT ASSESSMENT

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Beaufort Bypass Environment Effects Statement
Groundwater Impact Assessment

Regional Roads Victoria

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00	11/05/2021	Final

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GLOSSARY

Alluvial/Alluvium	General term for unconsolidated deposits of inorganic materials (clay, silt, sand, gravel, boulders) deposited by flowing water.
Alluvium aquifer	An aquifer formed within alluvium. See *Alluvium.*
Aquifer	Rock or sediment in a formation, group of formations or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Aquitard	Saturated geological unit with a relatively low permeability that can store large volumes of water but does not readily transmit or yield significant quantities of water to bores or springs. An aquitard can sometimes, if completely impermeable, be called an aquiclude.
Australian Height Datum (AHD)	A level datum, uniform throughout Australia, that generally approximates mean sea level.
Baseflow	The component of river or stream flow that is derived from groundwater discharge to the river or stream.
Baseline	A basic standard or level, usually regarded as a reference point for comparison.
Bore	Artificially constructed or improved groundwater cavity used for the purpose of accessing or recharging water from an aquifer. Interchangeable with borehole and piezometer.
Borehole	Includes a well, excavation, or other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. Interchangeable with bores, wells and piezometers.
Clay	Deposit of particles with a diameter less than 0.002 mm, typically contain variable amounts of water within the mineral structure and exhibit high plasticity.
Confined aquifer	An aquifer bounded above and below by impervious (confining) layers. In a confined aquifer, the water is under sufficient pressure so that when wells are drilled into the aquifer, measured water levels rise above the top of the aquifer.
Cumulative impact	The combined impact to one or more environmental values delivered by multiple projects being undertaken simultaneously within the same sphere of physical influence.
Drawdown	The change in groundwater level in a bore, or the change in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.
Fault	Zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.
Formation	General term used to describe a sequence of rock layers.

Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.
Groundwater flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone.
Groundwater resource	Groundwater available for beneficial use, including human usage, aquatic ecosystems and the greater environment.
Hydraulic conductivity	Measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (metres per day).
Hydraulic gradient	Change in the hydraulic head over a certain distance.
(Hydraulic) head	Elevation to which water will rise in a borehole connected to a point in an aquifer.
Hydrogeology	The study of the interrelationships of geological materials and processes with water, especially groundwater.
Hydrograph	Graph that shows groundwater or surface water properties as a function of time.
Impact	An event that disrupts ecosystem, community, or population structure and alters the physical environment, directly or indirectly.
Infiltration	The downward movement of water from the atmosphere into the ground; not to be confused with percolation.
Lithology	The physical character of rocks.
Modelling	The creation of a computerised model that simulates the natural environment and allows simulations to project future outcomes.
Monitoring bore	A bore used to monitor groundwater levels or quality.
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (metres per day).
Recharge	Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.
Runoff	All surface and subsurface flow from a catchment, but in practice refers to the flow into a river i.e. excludes groundwater not discharged into a river.
Semi-confined aquifer	An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur, also referred to as a leaky aquifer.
Stratigraphy	Branch of geology dealing with the classification, nomenclature, correlation and interpretation of stratified rocks.
Terrestrial	Relating to, consisting of, or representing the Earth; relating to the land as distinct from the water.

Water table	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric; it can be measured by installing shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.
Watercourse	A river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events: — in a natural channel, whether artificially modified or not — in an artificial channel that has changed the course of the stream. It also includes weirs, lakes and dams.
Wetland	In Victoria, wetlands are defined as areas whether natural, modified or artificial, subject to permanent or temporary inundation, that hold static or very slow-moving water and develop, or have the potential to develop, biota adapted to inundation and the aquatic environment. Wetlands may be formed by natural processes or human activities. Wetlands include freshwater and saline lakes, swamps and shallow waters in Victoria's estuaries, bays and inlets. The international treaty on wetlands, the Ramsar Convention on Wetlands, uses a broader definition of wetlands which also includes rivers and other shallow marine waters. Wetlands provide many values to the community: — Traditional Owners and Aboriginal people have used wetlands over many tens of thousands of years and they are an important part of Aboriginal cultural heritage. — Wetlands act as sediment traps and filter nutrients from catchments. This helps protect the water quality of rivers, estuaries and marine areas. — Wetlands reduce the impacts of flooding by holding and slowing floodwater. — Wetlands provide habitat for native plants such as river red gum (*Eucalyptus camaldulensis*), mangroves, saltmarshes and for native animals such as water birds, frogs and fish. — Wetlands provide a range of recreational opportunities such as boating, camping, bird watching, fishing and duck hunting which help to support tourism and local economies. Many wetlands in Victoria are recognised for their environmental significance.
Yield	The quantity of water removed from a water resource e.g. yield of a borehole.

ABBREVIATIONS

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
mBGL	Meters below ground level
BoM	Bureau of Meteorology
BSE	Basement
CDFM	Cumulative deviation from mean
CGM	Conceptual groundwater model
DELWP	Department of Environment, Land, Water and Planning
DSE	Department of Sustainability and Environment
EC	Electrical conductivity
EES	Environment Effects Statement
EMF	Environmental Management Framework
EMP	Environmental management plan
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
GDE	Groundwater dependent ecosystem
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
HSUs	Hydrostratigraphic Units
km	kilometre
L/s	Litre per second
m	metre
mAHD	metres Australian Height Datum
mg/L	milligrams per litre
m/day	metres per day
MNES	Matters of National Environmental Significance
NHMRC	National Health and Medical Research Council
PCV	Permissible Consumptive Volumes
QA	Quaternary Aquifer

RRV	Regional Roads Victoria (formerly VicRoads)
SEPP	State Environment Protection Policy
SPT	Standard penetration test
SRWC	Southern Rural Water Corporation
TDS	Total dissolved solids
UA	Unincorporated area
VAF	Victorian Aquifer Framework
WMIS	Water Measurement Information System
WSPA	Water Supply Protection Area

EXECUTIVE SUMMARY

GROUNDWATER CONTEXT

The purpose of this groundwater impact assessment is to characterise the existing environment and provide an impact assessment in line with the *Scoping Requirements for the Beaufort Bypass Project under the Environment Effects Act 1978* (Scoping Requirements). This report consists of a desktop assessment of the existing conditions within the groundwater investigation area and incorporates observations and data from recent geotechnical and hydrogeological drilling that was undertaken for the project.

This report assesses the potential impacts to the groundwater regime from the project, including but not limited to, the excavation of road cuttings and the construction embankment structures. Road cuttings have the potential to intersect groundwater, causing groundwater to drain into the excavation lowering groundwater levels with the potential to impact on sensitive receptors and groundwater users. The embankment structures have the potential to reduce permeability through loading of soft unconsolidated sediments. The reduction in permeability has the potential to alter the local groundwater flow and impact down gradient users of groundwater.

This report provides a conceptual understanding of regional and local hydrogeological environment and assesses the potential impact of the project. The impact assessment helps inform the development of management and mitigation measures such as Water Management Plans.

METHOD

The groundwater impact assessment is built upon previous preliminary, desktop and intrusive hydrogeological investigations. The method utilised in this assessment included the following:

- desktop review
- site investigations that included:
  - hydrogeological and geotechnical drilling program
  - groundwater and surface water sampling
  - groundwater level monitoring
  - hydraulic testing
- update of conceptual hydrogeological model to include data obtained in the site investigation, water quality data and geochemical analysis
- risk identification and assessment
- impact assessment, resulting from the progressive refinement of the design and assessment of the potential impacts to beneficial users.

The impact assessment consisted of an initial assessment to screen the initial risks rating and where required, identify additional mitigation measures to avoid and minimise potential impacts resulting in a residual impact ratings.

EXISTING CONDITIONS

The project investigation area is located within Pyrenees Shire Council and extends for approximately 9 km from the eastern end to the western end of the Beaufort township. The proposed bypass corridor options occur across a patchwork of landscapes including rural and agricultural freehold land, privately owned land, state forests and bushland reserves, private mine tenements and roadsides.

The majority of the investigation area consists of the outcropping Beaufort and Pyrenees formations that make up the rolling hills surrounding the town of Beaufort, and localised Quaternary alluvial and colluvial material situated in drainage lines associated with the ephemeral Yam Holes Creek and its tributaries. There are two primary hydrostratigraphic units within the investigation area being:

- Quaternary Aquifer (QA), spatially limited to drainage lines and consists of a shallow, unconfined aquifer with a thickness of approximately 2–5 m.
- Basement (BSE), this regional extensive aquitard is associated with the Beaufort and Pyrenees formations. The BSE is considered low yielding with water levels >50 m below ground surface.

The desktop investigation and preliminary risk assessment identified that the potential risks to groundwater are associated with the excavation cuttings through the north of the town, and the compression of alluvial material from the loading of the embankment structures, both of which could potentially impact groundwater flow and reduce availability to groundwater users. Groundwater users within the investigation area are the registered groundwater bores and groundwater dependent ecosystems.

The investigation area is also within the Beaufort Salinity Province. Salinity impacted areas are mostly confined to drainage lines or are associated with previous gold mining activity. Impacted areas have been mapped by Agriculture Victoria who have noted little change in the last decade.

Sixteen geotechnical boreholes were drilled across the four alignments options. These boreholes targeted locations where deep cuttings or embankment structures would be required as the construction of these have the greatest potential to interact with groundwater. Three geotechnical boreholes were converted to groundwater monitoring bores during the drilling program. Originally, six groundwater monitoring bores were planned, however, as groundwater was not encountered in any of the Pyrenees or Beaufort formations, the total number of bores installed was reduced.

The absence of groundwater located within the outcropping Beaufort and Pyrenees formations reflects the regional aquitard classification of the formations. The fine-grained sediments of these formations are dry with sufficiently low permeability that prevents the movement of groundwater.

Drilling through the Quaternary alluvial sediments indicated the heterogenous nature of the alluvial material, with only three of the seven geotechnical boreholes intersecting groundwater during drilling. The alluvial material is observed to be upward fining and consists of low permeable fine-grained silts and clays overlying a silty sand of medium to coarse grained material with the entire layer varying from 2 to 5 metres in thickness.

Drilling has indicated that the QA consists of low permeable silts and clays that are variable and unsaturated in parts. While the QA is mapped as an aquifer in the Victorian Aquifer Framework, the QA predominantly consists of an upward fining low permeable silts and clay underlain by basal coarse-grained sediments. Where groundwater was encountered during drilling, it was associated with the basal coarse-grained lenses. Water quality sampling within the QA indicated brackish groundwater with total dissolved solids ranging between 3,300 to 3,600 mg/L, which falls within the protected beneficial uses of Segment C classification of the State Environmental Planning Policy (Waters). The absence of registered bores and records of low yields within the alluvial material indicates the QA is not a significant water resource within the investigation area.

Groundwater flow within the QA is expected to be topographically driven and follow the drainage line of Yam Holes Creek and its tributaries. Groundwater levels within the QA are expected to fluctuate seasonally with observed water levels ranging between surface and 1 m below ground level. Groundwater levels are typically closer to surface during the wetter winter months and lower during the summer months that are typically drier and experience greater losses to evapotranspiration.

RISK AND IMPACT ASSESSMENT

A risk assessment was undertaken in accordance with AS/NZS ISO 31000:2009 Risk Management Process.

For all the main project activity categories (e.g. design, clearing, earthworks, operation, maintenance) impact pathways were created by identifying the project activity/aspect and the primary environmental impact in the risk register. The identification of impact pathways relies on an understanding of the existing environment as defined by the specialist studies, and an understanding of the project activities as dictated by the engineering design. The following risks were assessed for the construction and operation phases of the project:

- interference to groundwater availability (groundwater levels/flow)
- impacts to groundwater quality
- impact to the beneficial use of groundwater.

The impact assessment has assessed potential impacts to groundwater within the study area and identified several mitigations to ensure residual impacts to groundwater availability, groundwater quality and beneficial uses remain low.

Mitigations will include:

- incorporation of a combination of culverts/bridge structures across unconsolidated sediments of the QA to avoid compaction impacts across the QA
- construction controls to manage potential contamination impacts through spills
- a groundwater management plan to manage potential impacts on groundwater from potentially contaminated and saline soils.

KEY FINDINGS

Within the study area, groundwater is only associated within the QA, which is spatially limited to along drainage lines and flood plains. The Beaufort and Pyrenees formations that outcrops across most of the study area is a regional basement aquitard and no groundwater was encountered at proposed excavation depths for the project.

The absence of groundwater throughout the regional aquitard of the Beaufort and Pyrenees formations indicates that excavations for road cuttings would have negligible impact as groundwater was not expected to be intersected through construction or operation.

Changes made to the functional design included embankment structures being replaced with culverts/bridges across unconsolidated sediments of the QA. This design change further reduces the potential impacts to groundwater flow by reducing the potential compaction impact of the embankments across the QA.

For the impact assessment, each of the four alignment options were assessed as having the same potential risks and impacts from a groundwater perspective. All alignment options include large cuts through the Beaufort and Pyrenees formations, and all involve embankment structures at both the eastern and western ends over Main Lead Road, Beaufort-Lexton Road, Racecourse Road and the Melbourne-Ararat rail line.

On this basis, the groundwater impact assessment for all alignment options demonstrates that the overall impacts to groundwater for the project are low to negligible. No additional mitigation measures outside the design recommendations across the QA and RRV standard environmental controls are required, as all alignment options are considered to have the same impact rating.

1 INTRODUCTION

Regional Roads Victoria (RRV), formerly VicRoads, proposes to construct a new freeway section of the Western Highway to bypass the town of Beaufort (the project), linking completed sections of the Western Highway duplication to the east and west of Beaufort.

On 22 July 2015, the Minister for Planning determined an Environment Effects Statement (EES) would be required under the *Environment Effects Act 1978* (EE Act) to assess the potential environmental effects of the project. The EES includes consideration of four alternative alignments and selection of a preferred bypass alignment which identifies the land to be reserved for the future construction. The EES process provides for identification and analysis of the potential environment effects of the project and the means of avoiding, minimising and managing adverse effects. It includes public involvement and allows stakeholders to understand the likely environmental effects of the project and how they will be managed.

1.1 PROJECT BACKGROUND

The Western Highway is the primary road link between Melbourne and Adelaide. It serves interstate trade between Victoria and South Australia and is a key transport corridor through Victoria's west. Over 6,500 vehicles utilise the Western Highway, west of Ballarat each day. Of these 6,500 vehicles, 1,500 are classed as commercial heavy vehicles. These traffic volumes are expected to increase to approximately 7,500 by 2025 and 9,500 by 2040.

RRV have identified the need to upgrade the Western Highway from Ballarat to Stawell to:

- improve road safety at intersections
- improve safety of access to adjoining properties
- enhance road freight efficiency
- reduce travel time
- provide better access to local facilities
- improve roadside facilities.

As part of planning studies commissioned by the Commonwealth and State Governments, bypass route options around the town of Beaufort have been considered to meet the objectives identified by RRV and the National Land Transport Network's Nation Building Program.

The project would include construction of a dual carriageway, connections to major intersecting roads, interchanges to connect Beaufort to the Western Highway at the eastern and western tie-in points, several waterway crossings, an overpass of the Melbourne-Ararat rail line, and intersection upgrades at local roads and provision for service roads as required.

1.2 PROJECT OBJECTIVES

The objectives of the project are to:

- improve road safety and maintain the functionality of Beaufort's road network
- improve freight movement and efficiency across the road network
- improve Beaufort's amenity by removing heavy vehicles
- improve access to markets and the competitiveness of local industries.

2 PROJECT DESCRIPTION

The project would comprise of an 11 km freeway standard bypass to the north of the township of Beaufort, connecting the two recently duplicated sections of the Western Highway to the east and west of Beaufort. The project would be constructed under a Design and Construct or Construct only contract administered by a superintendent at RRV/Major Road Projects Victoria (MRPV), following a competitive tender process. Department of Transport would manage and maintain the asset.

2.1 FREEWAY STANDARD BYPASS

The project would connect the duplicated sections of the Western Highway to the east and west of Beaufort via the Option C2 bypass to the north of Beaufort that avoids Snowgums Bushland Reserve and cuts through Camp Hill. The bypass would include the following key components:

- designed as a freeway standard bypass
- approximately 11 km long
- designed to 120 km/hr and sign posted to 110 km/hr for its entirety
- two tie-in interchanges
- one road over rail bridge
- waterway crossings
- diamond interchange to connect with the local road network
- four overpass bridge structures over the local road network.

2.2 INTERCHANGES

The project would have interchanges at the following locations:

- tie-in points to existing Western Highway at the eastern and western ends of the bypass
- diamond interchange at existing local road network connection (Beaufort-Lexton Road).

2.3 BRIDGES AND CULVERTS

The route option would have bridge structures at the following locations:

- road over rail bridge structure for the Melbourne-Ararat rail line
- several waterway bridge structures over Yam Holes Creek
- overpass bridge structures for the existing local road network:
  - Main Lead Road
  - Beaufort-Lexton Road (diamond interchange)
  - Racecourse Road
  - Back Raglan Road.

2.4 ALIGNMENT DESCRIPTIONS

Four alignment options, referred to as Options A0, A1, C0 and C2, were assessed in order to identify a preferred bypass (see Figure 2.1). Following extensive community consultation and technical assessments, Option C2 was selected as the preferred route.

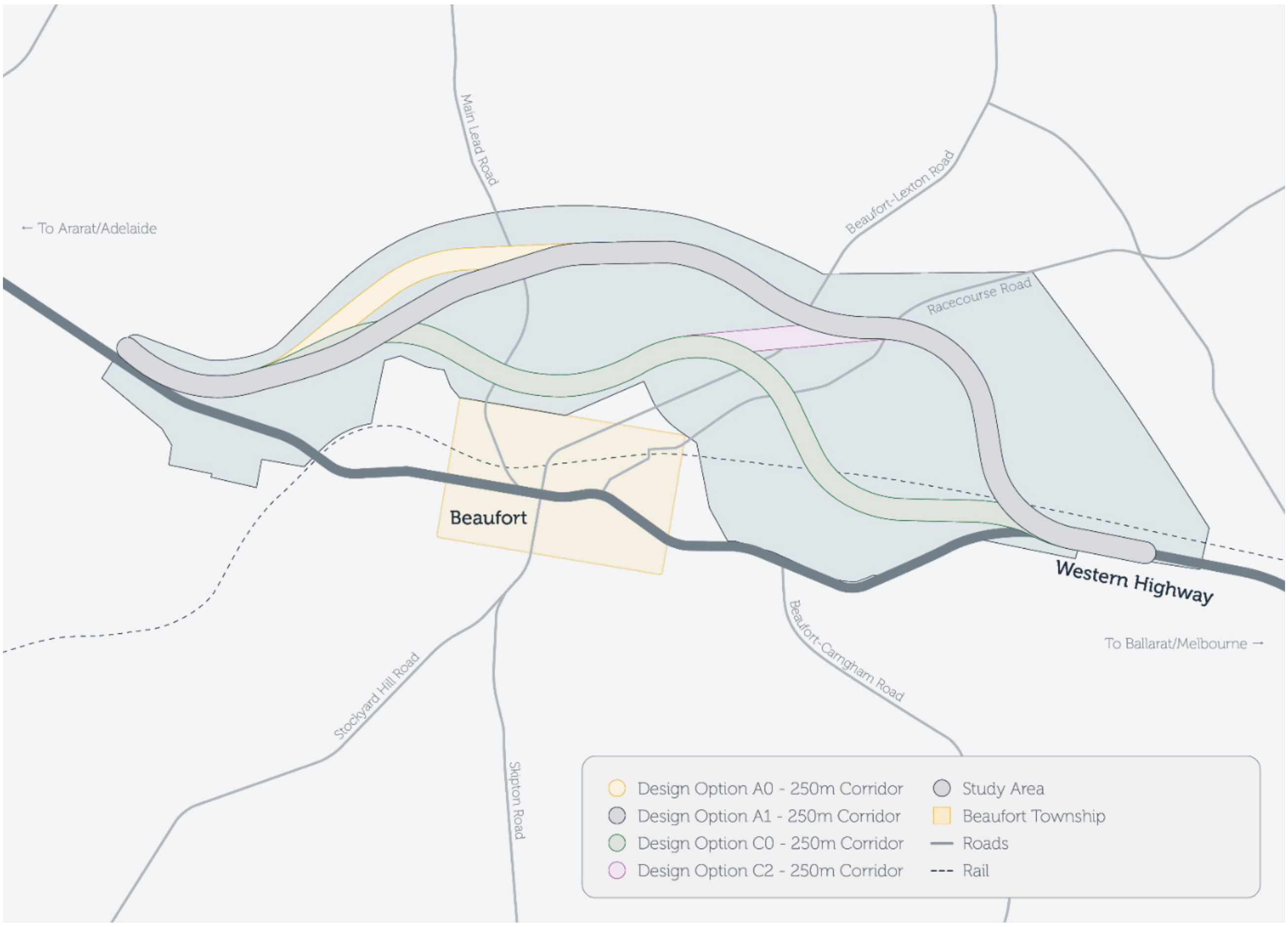


Figure 2.1 Beaufort Bypass alignment options and study area

2.4.1 *OPTIONS ASSESSED*

2.4.1.1 OPTION A0

The A0 bypass alignment is 11.2 km in length and is the northern most bypass option (see Figure 2.2). From the western tie-in point, approximately 3 km from the Beaufort township, this alignment curves north – north-east, where there will be a west-facing, half diamond interchange to maintain access to private properties and the township via the existing Western Highway. The alignment passes over Main Lead Road then climbs through the State Forest north of Camp Hill. From here it descends to a full diamond interchange at Beaufort-Lexton Road, which will provide access to the north and south of the township, before re-joining the Western Highway at its eastern extent, approximately 4.5 km from Beaufort. An outbound exit ramp at the eastern interchange will allow for eastern access to Beaufort via the existing Western Highway. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations with a large cut section north of Camp Hill.

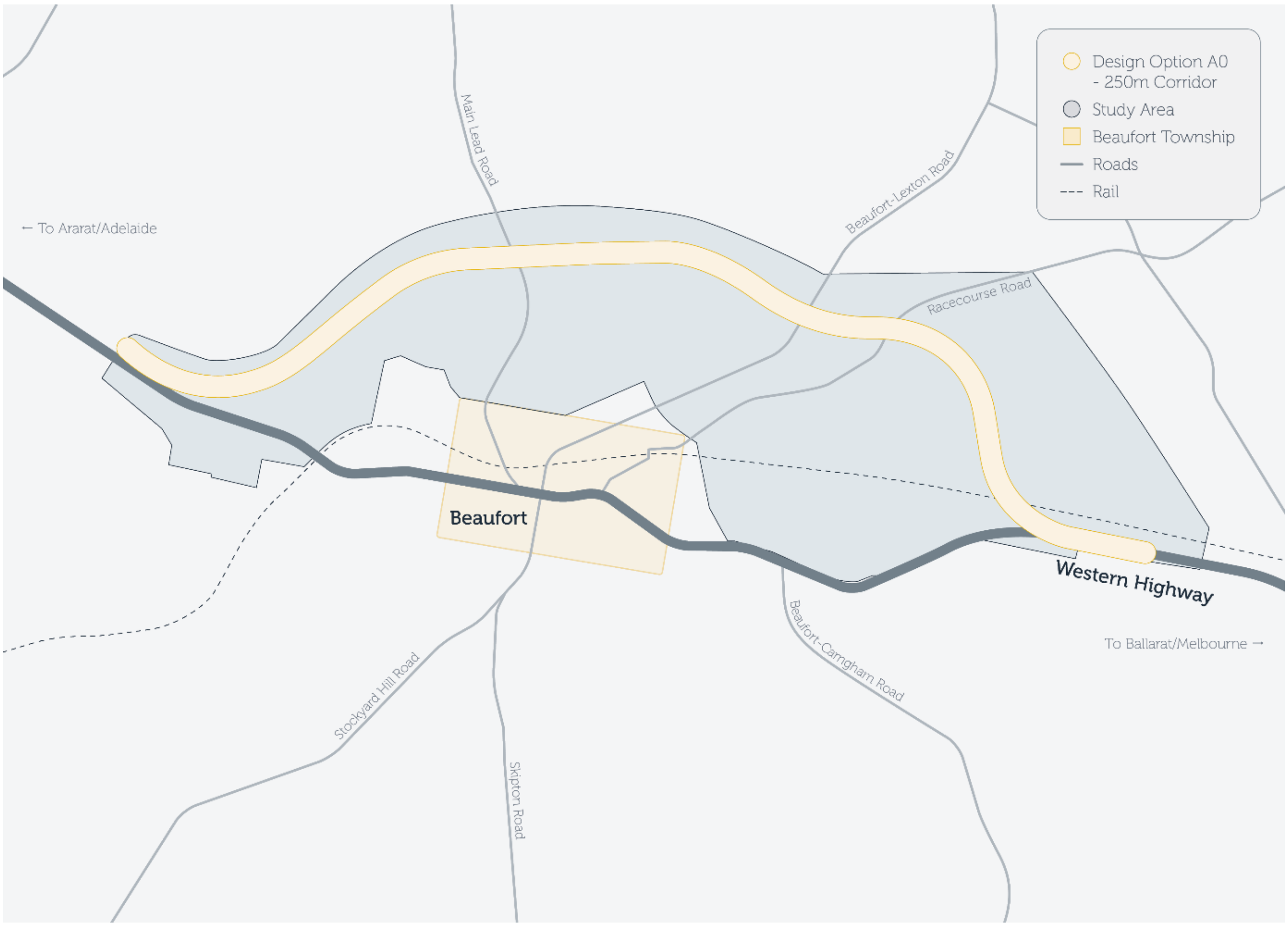


Figure 2.2 Beaufort Bypass A0 alignment option

2.4.1.2 OPTION A1

The A1 bypass alignment option is 11.1 km in length (see Figure 2.3). Approximately 3 km from the Beaufort township, this alignment deviates north-east from the Western Highway, staying slightly south of option A0 until a point east of Main Lead Road, where it re-joins the A0 alignment. There will be a west-facing, half diamond interchange at the western tie-in to maintain access to private properties and the township of Beaufort via the existing Western Highway, and a full diamond interchange at Beaufort-Lexton Road to maintain north-south access. The A1 alignment will re-join the Western Highway approximately 4.5 km to the east of the township. An outbound exit ramp at the eastern interchange will allow for eastern access to Beaufort via the existing Western Highway. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with cuts north-east of Back Raglan Road, and north of Camp Hill.

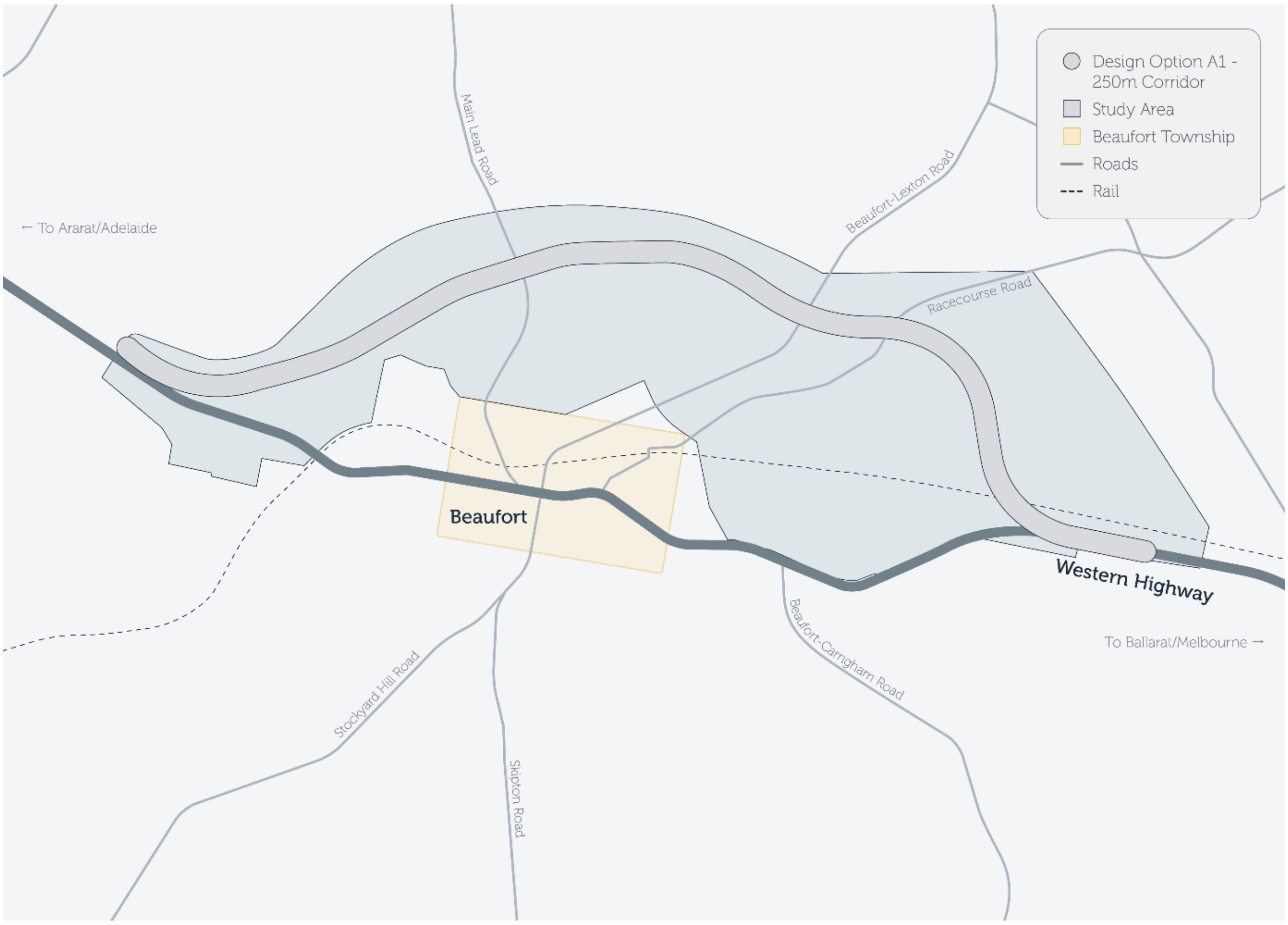


Figure 2.3 Beaufort Bypass A1 alignment option

2.4.1.3 OPTION C0

The southernmost option, C0, is approximately 10.6 km in length from the west to east tie-in points of the Western Highway (see Figure 2.4). Access to the Beaufort township via the existing Western Highway will be maintained by a west-facing, half diamond interchange in the west. The C0 option follows the A0 option from the western tie-in point, approximately 3 km from the Beaufort township, before deviating at Back Raglan Road in a more easterly direction almost parallel to the existing Western Highway. This option passes close to the north of Camp Hill, with some cut and fill required in this section, before curving south-east to a full diamond interchange at Beaufort-Lexton Road, providing north-south access. The C0 alignment will re-join the Western Highway approximately 4.5 km to the east of the township. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with the largest cut and fill areas north and north-east of Camp Hill.

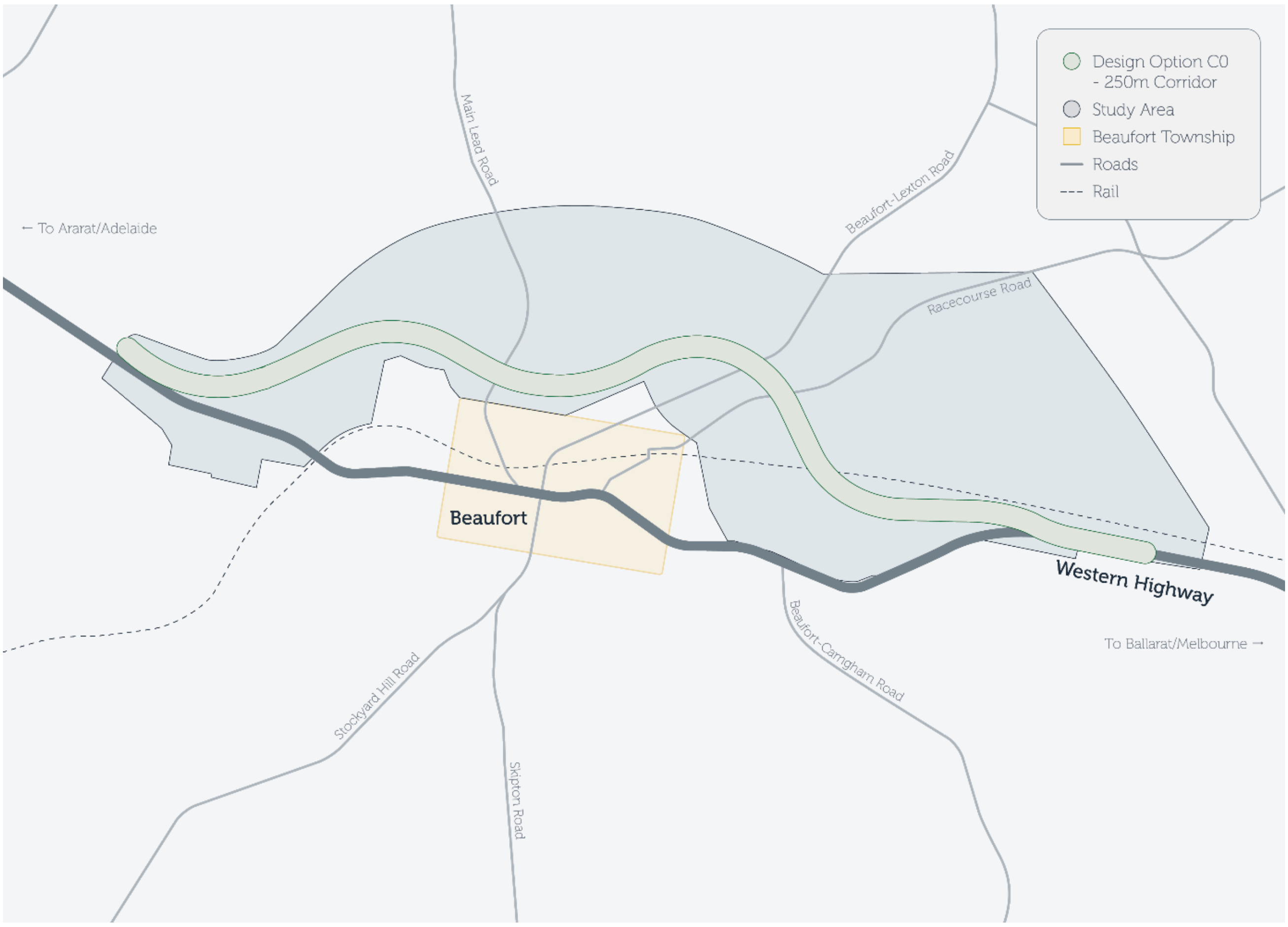


Figure 2.4 Beaufort Bypass C0 alignment option

2.4.2 *PREFERRED ALIGNMENT*

2.4.2.1 OPTION C2

Option C2 is 11 km in length and is a hybrid between the A0 and the C0 options (see Figure 2.5). It follows the C0 option from the western tie-in point (approximately 3 km from the Beaufort township) until Beaufort-Lexton Road, where it continues in an easterly direction and joins the A0 alignment near Racecourse Road. The C2 alignment will re-join the existing Western Highway at the eastern tie-it point, approximately 4.5 km from the township. At the western extent, access to Beaufort via the existing Western Highway will be maintained by a half diamond interchange, and there will be a full diamond interchange over Beaufort-Lexton Road. Access to Beaufort via the existing Western Highway at the eastern approach will be maintained by an outbound exit ramp at the eastern interchange. Bridges will pass over Main Lead and Racecourse Roads, as well as over the Melbourne-Ararat rail line. The main areas of fill occur at bridge and interchange locations, with the largest cut and fill areas north and north-east of Camp Hill.

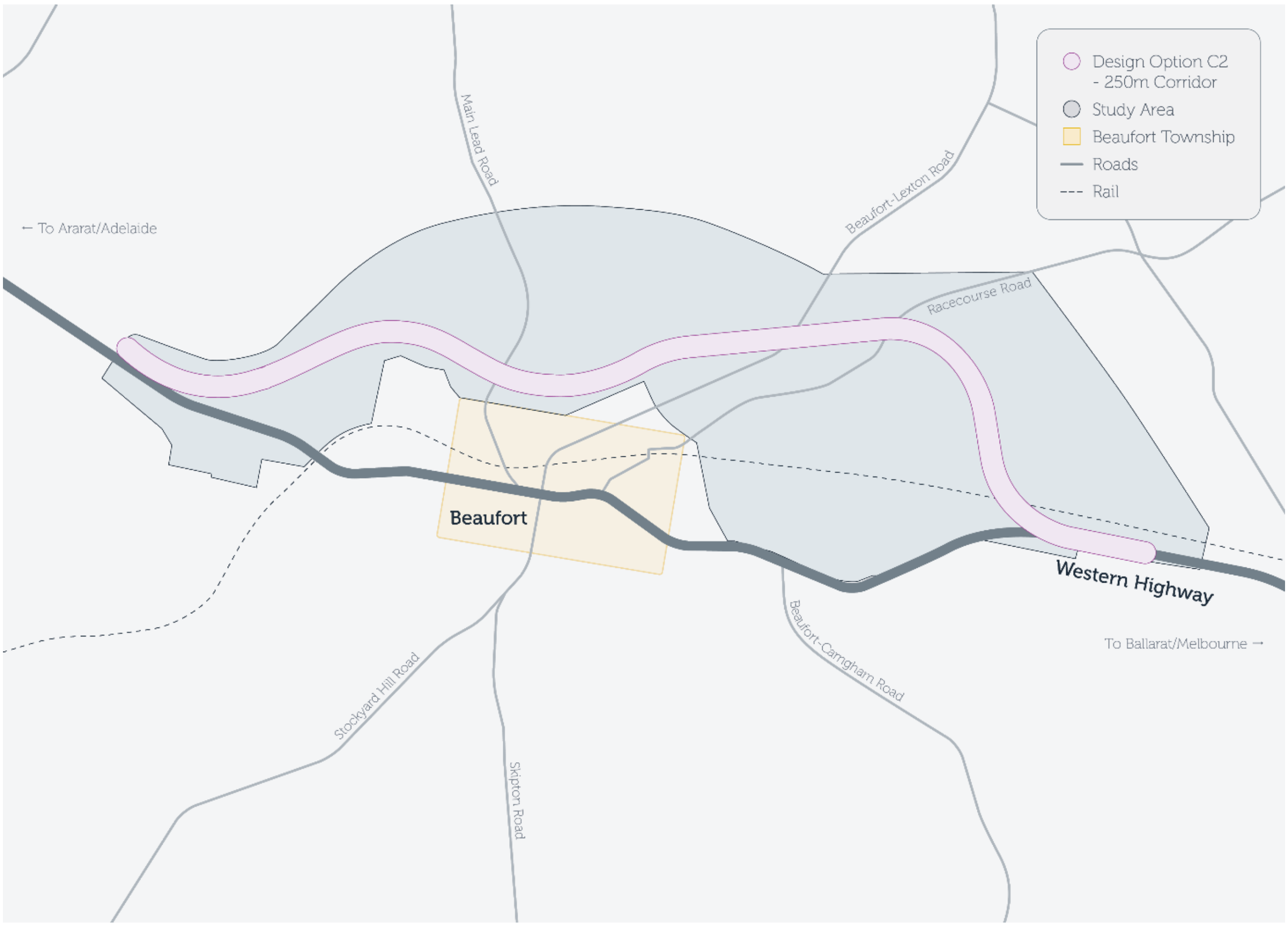


Figure 2.5 Beaufort Bypass C2 alignment option

2.5 PROJECT CONSTRUCTION

The following construction sub-section describe the construction activities for the project. Construction of the bypass is expected to take two years and commence once construction funding and approvals are obtained.

2.5.1 CONSTRUCTION ACTIVITIES

Construction activities would include:

- preconstruction site delineation and compound setup, which may include (but not be limited to) tree clearance and vegetation lopping/removal, and establishment of construction site(s) and access tracks
- establishment of environmental and traffic controls
- route clearance and relocation and/or protection of utilities
- channel realignments to maintain existing flow paths
- construction drainage and sediment and erosion control mitigation
- general earthworks:
  - excavation of a cut including stripping of topsoil and placement of fill
  - import, export and stockpiling of fill
  - treatment of contaminated soil or removal of hazardous material, if required
- development of structures, interchanges, batters, drainage and pavement
- development of ancillary infrastructure:
  - noise barriers
  - lighting
  - safety barriers
  - line marking
- landscaping and site reinstatement.

2.6 OPERATIONS AND MAINTENANCE

Operations and maintenance of the project would be consistent with current practices and standards, including the VicRoads' *Roadside Management Strategy* (2011). Key objectives include:

- asset management of:
  - landscaped areas
  - stormwater drains
  - bridges and culverts
  - road pavement
  - signage
  - barriers
  - line marking
- enhancement of transport safety, efficiency and access
- protection of environmental and cultural heritage values
- management of fire risk
- preservation and enhancement of roadside amenity
- routine and life cycle maintenance activities throughout operations
- monitoring and management of areas of environmental sensitivity such as water bodies and wildlife corridors.

3 EES SCOPING REQUIREMENTS

The *Scoping Requirements for Beaufort Bypass Project Environment Effects Statement* (Department of Environment, Land, Water and Planning (DELWP) 2016) (Scoping Requirements) have been prepared by DELWP on behalf of the Minister for Planning. The Scoping Requirements set out the specific environmental matters to be investigated and documented in the EES, which informs the scope of the EES technical studies.

The following matters of the Scoping Requirements are relevant to the groundwater impact assessment:

EES EVALUATION OBJECTIVE

Catchment values and hydrology: To protect catchment values, surface water and groundwater quality, stream flows and floodway capacity, and avoid impacts on protected beneficial uses.

Table 3.1 EES scoping requirements – groundwater

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
Key issues	Potential changes to the extent and severity of floodwaters in the area, that could have an effect on Beaufort or other significant locations.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
	Potential adverse effects on the functions and values of existing waterways during construction and operation.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
	Potential for unsuitable soil conditions to support the proposed bypass, including the potential for unearthing acid sulphate and contaminated soils.	Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
	Potential for effects on surface water quality, stream flows and ground water, in particular on protected beneficial uses.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
		Groundwater impact assessment	✓
	Potential for increased salinity, and related impacts on vegetation, soil and habitat values.	Groundwater impact assessment	✓
		Flora and fauna impact assessment	EES Chapter 9: *Biodiversity and habitat*
		Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
Priorities for characterising the existing environment	Undertake a hydrology assessment of the study area for the proposed project consistent with outcomes of the Glenelg Hopkins Catchment Management Authority (GHCMA) catchment and modelling study of Beaufort.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
	Identify and characterise surface water environments, ground water, salinity and floodplain environments that could be affected by relevant alternatives, including an analysis of drainage features and flood behaviour.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
		Groundwater impact assessment	✓
	Undertake a geotechnical assessment to identify soil types and structures in the study area and to identify the potential for unsuitable soil conditions to support the bypass, and potential location of acid sulphate, contaminated soils and fill.	Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
Design and mitigation measures	Undertake assessment (modelling) of the hydrology of the study area to inform concept design(s) to minimise the impacts of the proposed project.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
	Identify potential and proposed design alternatives and mitigation measures which could avoid or minimise effects on catchment functions and values, in particular for creeks and other surface water environments.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
	Identify the potential risks at waterway crossings, and the potential for soil erosion, soil stability, aquifers, acid sulphate, cut and fill and storage of topsoil in flood plains.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
		Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
		Groundwater impact assessment	✓
	Identify potential and proposed design alternatives and mitigation measures which have the least environmental, social and economic impact.	Groundwater impact assessment	✓
		Regional economy impact assessment	EES Chapter 13: *Land use and economics*
		Social impact assessment	EES Chapter 12: *Social effects*

SCOPING REQUIREMENTS SUB-SECTION	MATTER TO BE ADDRESSED	RELEVANT ASSESSMENT	ADDRESSED IN THIS ASSESSMENT
Assessment of likely effects	Identify potential effects of alternatives on surface water environments especially in relation to run-off impacts on water quality and flood flows.	Surface water impact assessment	EES Chapter 11*: Catchment values and hydrology*
	Assess the potential for effects of alignment alternatives on groundwater and for effects of groundwater on the proposed project, as a result of intersection works with the groundwater.	Groundwater impact assessment	✓
	Assess the potential for effects associated with the exposure and disposal of any waste including acid sulphate and contaminated soils.	Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
	Identify the potential risks of saline discharges and discharge impacts to soil, vegetation and habitat.	Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
		Flora and fauna impact assessment	EES Chapter 9: *Biodiversity and habitat*
		Groundwater impact assessment	✓
	Confirm which alignment alternatives have the greatest risk from a geotechnical perspective and the relative cost implications of each alignment alternative.	Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
Approach to manage performance	Identify proposed principles or approach for managing surface run-off, preventing sedimentation of waterways, flood risks and risks associated with excavation spoil, areas of contaminated land and other waste management.	Surface water impact assessment	EES Chapter 11: *Catchment values and hydrology*
		Soils and geology impact assessment	EES Chapter 16: *Soils, geology and contaminated land*
	Identify an approach to manage risk and impacts associated with construction and operation.	Groundwater impact assessment	✓
	Include identified measures in the Environmental Management Framework (EMF).	Groundwater impact assessment	✓

4 METHODOLOGY

4.1 STUDY AREA

The terminology utilised throughout the current technical assessment relating to the study area and alignment options is defined below.

Study area: The study area for the Beaufort Bypass EES project includes approximately 1,800 ha of land north of the Beaufort township, which contains the four bypass options assessed in this report. During the development stages of the alignment options, the study area was assessed to determine potential environmental impacts and constraints to individual alignment options.

Alignment options: Alignment options (A0, A1, C0 and C2) refer to the four selected bypass options assessed within the study area. Each alignment option consists of a 250 m corridor in which the specific bypass option has been designed. Each alignment option, unless otherwise stipulated, is the area assessed for direct and indirect impacts resulting from the construction, operation and maintenance of the project.

Groundwater investigation area: An additional 2 km buffer was applied to the study area to capture potential impacts at sensitive receptors such as groundwater dependent ecosystems (GDEs) and registered groundwater bores. This area is referred to as the groundwater 'investigation area' and was used for preliminary characterisation of the existing hydrogeological environment and assessment of the potential impacts of the project.

4.2 METHODOLOGY OVERVIEW

As described in Section 2, the EES report, this report focusses on satisfying the State Government requirements under the *Water Act 1989,* the *Environment Protection Act 1970*, and State Environment Protection Policy (Waters) (SEPP (Waters)) instruments described in Section 5.2.

4.2.1 AIMS AND OBJECTIVES

The overall aim of this EES is to describe the existing groundwater conditions and potential for impact of the project on the local and regional groundwater systems, and, associated existing and potential beneficial uses of groundwater.

This report has the following objectives:

- create a conceptual hydrogeological model (CHM) representative of the groundwater regime in the investigation area
- characterisation of the existing investigation area groundwater environment that could be affected by the four proposed alignments
- recommend mitigation measures, if required, which may minimise or avoid impacts to the groundwater regime, where such impacts are considered meaningful when considered against the existing conditions
- provide recommendations for additional assessment work as required.

4.2.2 SCOPE OF WORK

To achieve the aims and objectives described above, the following key activities, commensurate with the anticipated degree of impact, were undertaken:

- a desktop review of publicly available information on the known regional groundwater environment
- preparation of groundwater risk register to identify potential impacts and initial mitigation measures
- a limited field investigation to establish site-specific conditions, that might have a bearing on the local and regional conditions that are identified in the desktop review. These intrusive investigations were designed to install a groundwater monitoring network and gather water level data from the key aquifers of the aquifer units
- finalise impact assessment outcomes and provide conclusions and recommendations on the impact rating to sensitive receptors based on inferred groundwater disruptions and precautionary design measures to be included in the project design process.

Aspects pertaining to soil and groundwater contamination, and acid sulfate soils are discussed in EES Appendix K: *Soils and geology impact assessment* (WSP 2021a).

4.3 EXISTING CONDITIONS ASSESSMENT

4.3.1 REGIONAL GROUNDWATER CONCEPTUALISATION AND DESKTOP INVESTIGATION

To develop a conceptual understanding of groundwater conditions within the investigation area, a desktop review of available geological and hydrogeological information for the investigation area was completed. This included the following:

- review of geological mapping at the local and regional scale
- review of publicly available data and reports from previous and current studies within and adjacent to the investigation area including the Beaufort to Ararat Groundwater Impact Assessment (GHD 2012)
- search of the Bureau of Meteorology (BoM) groundwater dependent ecosystems atlas
- search of the Water Measurement Information System (WMIS) bore database (DELWP)
- review of the Visualising Victoria's Groundwater database.

The desktop review assisted in the characterisation of the hydrogeological environment and development of a conceptual groundwater model (CGM) for the investigation area including the following:

- hydrostratigraphy
- description of groundwater flow systems
- groundwater quality and beneficial use, including identification of the groundwater segment and protected beneficial uses of groundwater as per the SEPP (Waters)
- sensitive receptors including groundwater users and GDEs.

4.3.2 SITE INVESTIGATION

To refine the CGM for the investigation area, a targeted drilling program was conducted to install groundwater monitoring bores at locations of significant cuts and loading along each of the alignment options. This was combined with a site investigation by WSP hydrogeologists to obtain groundwater level data and gain an appreciation of ground conditions. Details of the site investigation are provided below.

4.3.3 DRILLING PROGRAM

An initial geotechnical drilling program was undertaken for the project involving the drilling of 16 boreholes along the four proposed bypass alignment options. The program was supervised by a geotechnical engineer from WSP who sighted the borehole locations, nominated geological sampling and testing and prepared engineering logs.

The geotechnical boreholes targeted proposed cuttings through the Beaufort and Pyrenees formations and proposed areas of fill loading for embankments over mapped alluvial sediments. These areas were targeted because the excavation of road cuttings have the potential to intersect groundwater and impact on groundwater levels. Similarly, the introduction of fill associated with road construction can result in compression of the unconsolidated alluvial sediments, subsequently impacting the groundwater levels within the alluvial aquifer by reducing permeability and altering the groundwater flow path. Changes to groundwater flow paths can increase/decrease groundwater levels up and down gradient of surcharging resulting in reduction in availability down gradient.

Sonic drilling was used to bore to depths between 5 m and 20 m below the existing surface level using a track mounted Borat Longyear LS250 drilling rig. Standard Penetration Tests, thin-walled tube and disturbed samples were recovered from the boreholes for visual classification, logging purposes and select laboratory testing. A summary of drilled geotechnical and groundwater monitoring boreholes are provided in Table 4.1 and detailed geotechnical logs presented in EES Appendix K: *Soils and geology impact assessment* (WSP 2021a). The location of geotechnical and groundwater monitoring bores is also presented in Figure 4.1.

The initial drilling plan proposed installation of six groundwater monitoring bores: five at the location of proposed cuttings, and one in an area of proposed fill over alluvium. However, groundwater was not intersected at most locations within relevant depth levels (e.g. base of cut depth, 15–20 m depth) during the geotechnical drilling program, and therefore the number of groundwater monitoring bores installed was reduced to three.

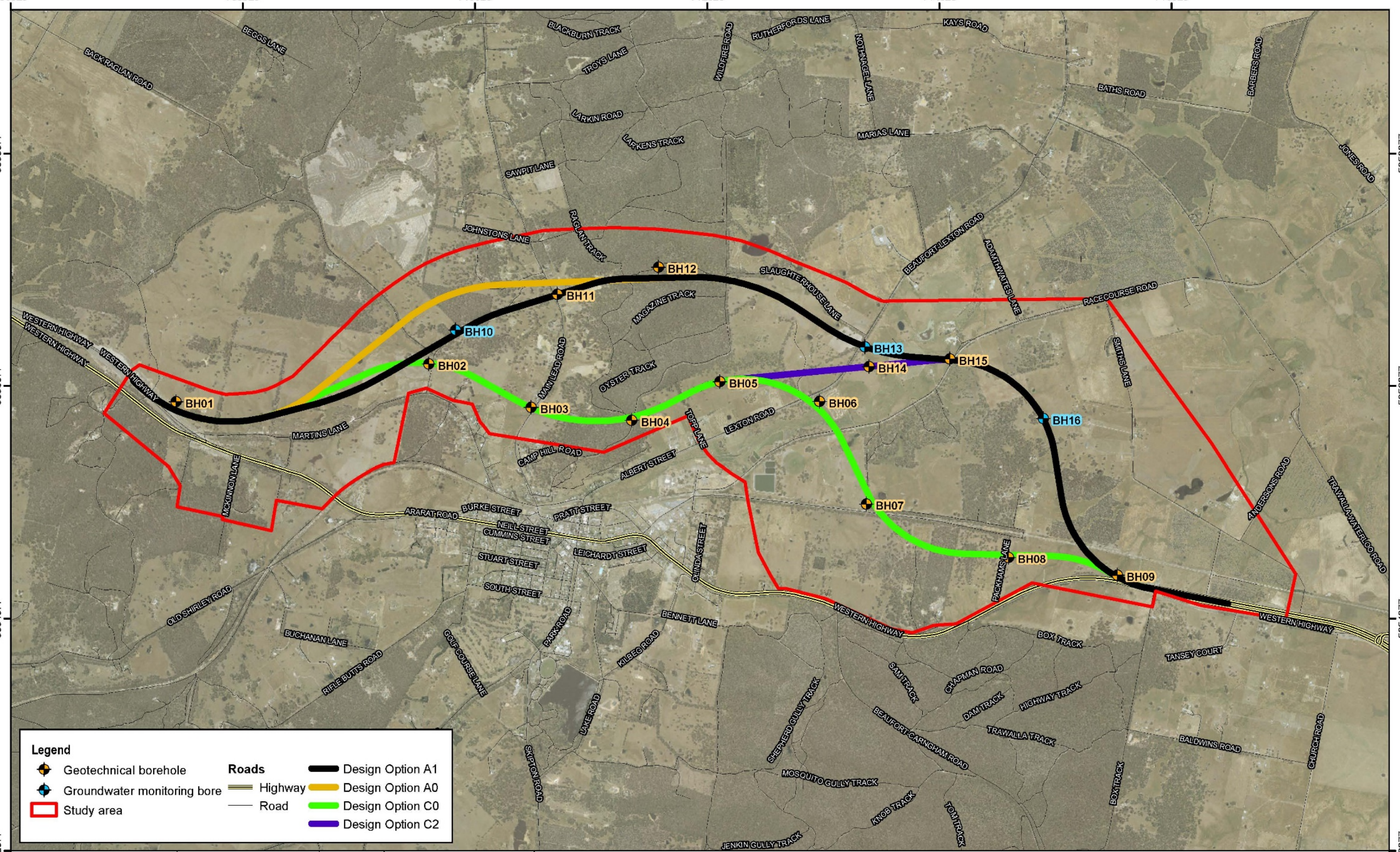
Of the three dedicated groundwater monitoring bores, two screened in the Beaufort Formation (BH10, BH16) and one monitoring bore within the alluvial sediments (BH13). The absence of groundwater intersected during drilling of the drilling program reduced the number of monitoring bores installed as these locations were not considered water bearing.

The remaining boreholes were backfilled with spoil and made flush with the surrounding ground surface. Each borehole location and groundwater monitoring bore were surveyed for position and elevation by Geomatic Services Pty Ltd. The groundwater monitoring bores were installed under supervision of WSP qualified personal and constructed to *Minimum Construction Requirements for Water Bores in Australian 3rd edition* (National Uniform Drillers Licensing Committee 2012). The three monitoring bores were licenced under the authority of Southern Rural Water.

Table 4.1 Geotechnical and groundwater monitoring bore construction summary

BORE ID	EASTING	NORTHING	BORE DEPTH (m)	MONITORING BORE INSTALLED	SCREEN (mBGL)	NATURAL SURFACE (mAHD)
BH01	707447.53	5855940.31	14	–	–	441.82
BH02	709624.58	5856265.92	5.45	–	–	393.4
BH03	710507.66	5855892.89	5.45	–	–	389.38
BH04	711374.61	5855781.03	20	–	–	429.7
BH05	712130.11	5856113.11	17	–	–	411.26
BH06	712988.98	5855943.35	5.45	–	–	379.19
BH07	713393.79	5855064.51	5	–	–	385.67
BH08	714616.49	5854604.16	10	–	–	396.43
BH09	715555.74	5854452.39	5.17	–	–	377.93

BORE ID	EASTING	NORTHING	BORE DEPTH (m)	MONITORING BORE INSTALLED	SCREEN (mBGL)	NATURAL SURFACE (mAHD)
BH10	709855.99	5856558.92	17	Yes	8–17	416.32
BH11	710734.2	5856866.09	5.45	–	–	393.97
BH12	711603.76	5857099.79	16	–	–	415.39
BH13	713379.78	5856413.13	5	Yes	2–5	377.6
BH14	713415.83	5856243.74	5.3	–	–	378.19
BH15	714112.25	5856309.48	5.45	–	–	377.01
BH16	714917.41	5855796.46	17	Yes	8–17	411



Map: 2270290A_GIS_106_A3 | Author: MB
Date: 17/10/2019 | Approved by: -
Data source: VicRoads, Trimble

regional roads victoria
wsp

Beaufort Bypass Environment Effects Statement
Figure 4.1
Borehole locations

\\Apmelfil01\proj\V\VicRoads\2270290A_BEAUFORT_BYPASS_EES\10_GIS\Projects\Maps\2270290A_GIS_106_A3.mxd
VicRoads
www.wsp.com

4.3.4 GROUNDWATER LEVEL LOGGING

Initial groundwater levels were measured during the geotechnical drilling program using manual groundwater level tape. Following installation of the groundwater monitoring bores, three rounds of manual groundwater level recordings have occurred. The first monitoring occurred approximately three weeks after the drilling program in February 2018.

In August 2019, the monitoring bores were revisited and an automated groundwater level monitoring logger was installed in BH13 for a period of two weeks to assess groundwater level responses to rainfall. The logger was set to record water levels at hour intervals. A barometric logger was also installed to allow data to be compensated for atmospheric influences. These loggers were recovered two weeks after installation and a third manual water level was obtained from BH06.

Dates of manual groundwater level measurements are presented in Table 4.2. No loggers were installed in BH10 or BH16 as these bores were recorded as dry during all manual water logging events.

Table 4.2 Groundwater level monitoring events

DATE	TASK	SEASON
12 February 2018	Manual groundwater level measurement	Summer
14 August 2019	Manual groundwater level measurement, installation of automated groundwater logger	Winter
30 August 2019	Manual groundwater level measurement, retrieval of automated groundwater logger	Winter

4.3.5 GROUNDWATER AND SURFACE WATER QUALITY MONITORING

To obtain water quality data, groundwater and surface water samples were obtained in August 2019. Two separate water quality samplings occurred. The first was collected from BH06 and the adjacent Yam Holes Creek. As part of the first collection, an additional surface water sample was obtained from Yam Holes Creek at the King Street bridge up gradient from the town. The second groundwater sampling event occurred when the data logger was recovered from BH06.

Water quality samples from BH06 were collected using a disposable bailer after stagnant water was purged from the bore and filter pack. Surface water samples were collected as grab samples using an extended sampling pole from the edge embankment of Yam Holes Creek.

Field parameters (including dissolved oxygen (DO), temperature, pH, redox, electrical conductivity (EC)) were recorded periodically during purging and water samples were obtained following stabilisation of parameters to within 10% (or 0.2°C for temperature), in accordance with EPA Victoria publication 669.

Groundwater and surface water samples were collected in laboratory supplied bottles with appropriate preservation where required. Samples collected for dissolved metal analysis were field filtered through a 0.45 µm filter.

Water samples were transported under appropriate chain-of-custody protocols in an ice-filled esky to ALS (NATA accredited) within holding times and were analysed for major ions, dissolved metals and nutrients.

To characterise water quality conditions within groundwater, major ions and metals were selected for analysis. Surface water samples were collected for comparison in water types. As such, the water quality samples were analysed for the following:

- physico-chemical parameters (pH, electrical conductivity (EC), Total dissolved solids (TDS))
- major ions (calcium (Ca), chlorine (Cl), bicarbonate (HCO_3), magnesium (Mg), potassium (K), sodium (Na), nitrate (NO_3), sulfate (SO_4), fluorine (F), sodium absorption ratio (SAR))
- dissolved metals (arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), mercury (Hg), lead (Pb), manganese (Mn), nickel (Ni), selenium (Se), vanadium (V), zinc (Zn))
- nutrients (nitrogen dioxide (NO_2), nitrate (NO_3), ammonia (NH_3), total nitrogen (TN), total Kjeldahl nitrogen (TKN), phosphorous (P)).

The analysis of these samples is discussed in Section 6.6.7.

4.4 RISK ASSESSMENT

An environmental risk assessment (ERA) has been utilised in the Beaufort Bypass EES to identify environmental impacts associated with the construction and operation phases of the project. The risk assessment process is consistent with the guidance provided in Sections 3.1 and 4 of the *Scoping Requirements for the Beaufort Bypass Project EES* (DELWP 2016) and the *Ministerial guidelines for assessment of the environmental effects under the Environment Effects Act 1978* (Department of Sustainability and Environment (DSE) 2006).

The purpose of the ERA was to provide a systematic approach to the identification and further assessment of potential impacts resulting from the project, whether they be environmental, social or economic. The ERA articulates the probability of an incident with environmental, social and economic effects occurring and the consequence of that impact to the environment. Identified impacts with a medium or higher initial risk are subject to impact assessment and mitigation treatments, detailed within each discipline impact assessment.

The project defines risk and impact as:

- "Environmental risk reflects the potential for negative change, injury or loss with respect to environmental assets" (DSE 2006). This approach is consistent with ISO 31000: 2018, which defines risk as "the effect of uncertainty of [environmental] objectives". Both definitions reflect the fact that risk is typically expressed in terms of the likelihood of a change occurring and the consequence of that change.
- Environmental impact is described as any change to the environment as a result of project activities.

The risk assessment is a critical part of the EES process as it guides the level and range of impact assessment for the EES and facilitates a consistent approach to risk assessment across the various disciplines.

4.4.1 RISK ASSESSMENT PROCESS

The ERA has guided the environmental impact assessment for the project. The objectives of the ERA are to:

- identify primary environmental risks that relate to the construction and operation of the project
- guide the level and extent of investigation and data gathering necessary for accurately characterising the existing environment and assessing the project's environmental impact
- help identify mitigation measures to avoid, minimise and mitigate environmental risks
- inform assessment of likely residual effects that are expected to be experienced after standard controls and proposed mitigations have been implemented.

The risk assessment process for the EES adopts a risk management framework as detailed in the VicRoads Environmental Sustainability toolkit. The process includes:

- an approach to environmental management which is aligned with ISO 31000: 2018
- systems used to manage environmental risk and protect the environment, and how these are implemented at different stages of road construction, operation and maintenance
- tools and reporting requirements which provide guidance in managing environmental issues throughout the project.

The ERA identifies impact events for each relevant element of the environment, details the primary risks and has informed the level and range of technical reporting required to address predicted impacts. The ERA utilises a risk matrix approach where the likelihood and consequence of an event occurring are considered (Table 4.3, Table 4.4 and Table 4.5). All risks are reassessed at regular intervals during all phases of the project, from the development of the EES to operation and maintenance, to ensure they are still applicable, that controls are appropriate and effective, and that they reflect most recent outcomes of specialist technical studies.

Table 4.3 Risk assessment matrix

	Risk categories		LIKELIHOOD Rare (A)	Unlikely (B)	Possible (C)	Likely (D)	Almost Certain (E)
CONSEQUENCE	Catastrophic	5	Medium	High	High	Extreme	Extreme
	Major	4	Medium	Medium	High	High	Extreme
	Moderate	3	Low	Medium	Medium	High	High
	Minor	2	Negligible	Low	Low	Medium	Medium
	Insignificant	1	Negligible	Negligible	Negligible	Low	Low

Based on the project objectives and context, a set of project-specific and appropriate assessment, likelihood and consequence criteria were developed.

The likelihood categories and consequence descriptions are used as a guide for evaluating risk and are shown in Table 4.4 and Table 4.5.

Table 4.4 Likelihood categories

RARE (A)	UNLIKELY (B)	POSSIBLE (C)	LIKELY (D)	ALMOST CERTAIN (E)
Less than once in 12 months OR 5% chance of recurrence during course of the contract	About once in 6 months OR 10% chance of recurrence during course of the contract	About once in 4 months OR 30% chance of recurrence during course of the contract	About once in 2 months OR 50% chance of recurrence during course of the contract	About once in a month OR 100% chance of recurrence during course of the contract
The event may occur only in exceptional circumstances	The event could occur but is not expected	The event could occur	The event will probably occur in most circumstances	The event is expected to occur in most circumstances
It has not happened in Victoria but has occurred on other road projects in Australia.	It has not happened regionally but has occurred on other road projects in Victoria	It has happened in the Beaufort region	It has happened on an adjoining section of the Western Highway	It has happened on more than one of the adjoining Western Highway projects OR It has happened multiple times on an adjoining Western Highway project.

Consequence criteria have been developed for the project in consultation with technical specialists. The result is a discipline and aspect-specific set of consequence descriptors used to define what would be considered an Insignificant, Minor, Moderate, Major and Catastrophic consequence associated with a risk event.

Table 4.5 Groundwater environmental risk assessment consequences descriptors

ASPECT	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC
Construction affects groundwater	Negligible change to groundwater regime, quality and availability	Temporary changes to groundwater regime, quality and availability within the range of natural variability	Temporary and reversible changes to groundwater regime, quality and availability resulting in loss of one or more beneficial uses of the groundwater	Groundwater regime, quality or availability significantly compromised with permanent loss of one or more beneficial uses locally	Widespread groundwater resource depletion, contamination or subsidence resulting in permanent loss of one or more beneficial uses on a regional scale
Operation phase affects groundwater	Negligible change to groundwater regime, quality and availability	Temporary changes to groundwater regime, quality and availability within the range of natural variability	Temporary and reversible changes to groundwater regime, quality and availability resulting in loss of one or more beneficial uses of the groundwater	Groundwater regime, quality or availability significantly compromised with permanent loss of one or more beneficial uses locally	Widespread groundwater resource depletion, contamination or subsidence resulting in permanent loss of one or more beneficial uses on a regional scale
Construction impacts on protected beneficial uses	Negligible change to groundwater quality and groundwater levels affecting existing users (registered bore owners, GDEs and surface water)	Temporary minor change to groundwater quality and groundwater levels affecting existing users (registered bore owners, GDEs and surface water)	Permanent minor change to groundwater quality and groundwater levels affecting existing users (registered bore owners, GDEs and surface water)	Localised significant change to groundwater quality and groundwater levels affecting existing users (registered bore owners, GDEs and surface water). "Make good" measures required	Widespread significant change to groundwater quality and groundwater levels affecting existing users (registered bore owners, GDEs and surface water). "Make good" measures required
Construction encounters land contamination	Negligible change to groundwater regime, quality and availability	Temporary changes to groundwater regime, quality and availability within the range of natural variability	Temporary and reversible changes to groundwater regime, quality and availability resulting in loss of one or more beneficial uses of the groundwater	Groundwater regime, quality or availability significantly compromised with permanent loss of one or more beneficial uses locally	Widespread groundwater resource depletion, contamination or subsidence resulting in permanent loss of one or more beneficial uses on a regional scale

The risk assessment was undertaken for each discrete alignment option as each option had a distinct profile, type and extent of environmental impacts. The assessment of these impacts is detailed within Sections 8 and 9 of this report.

See Appendix A for outcomes of the ERA process.

4.5 IMPACT ASSESSMENT

The impact assessment for the project has utilised the ERA to inform the areas for further investigation. Impacts assessed within this assessment have typically been identified as having a medium or higher initial risk within the risk assessment when standard controls were applied. Impact assessments were prepared in two stages, initially to inform the options assessment and following the selection of the preferred alignment, impact assessments were revised to report impacts and mitigations specifically on the preferred alignment. The project describes and assesses impacts in terms of the following:

- description of impact
- identification of whether impacts are direct or indirect
- prediction of the magnitude, extent and duration of impact
- overall rating of impact (without mitigation)
- residual rating of impact (with mitigation).

Impacts to groundwater resources can be simplified into two categories: impacts to *groundwater quality* and impacts to groundwater levels (*groundwater quantity*). Impacts to groundwater resources have the potential to impact on existing groundwater users and GDE.

Potential impacts to groundwater quality associated with the project include chemical spills and cross-connection of aquifers through activities such as drilling, excavation and fill placement. Potential impacts to groundwater levels associated with the project include drawdown where cuts intersect the water table (saturated aquifer/s) and alteration of flow paths due to compaction arising from embankment loading.

RRV and industry best practice and standard mitigation controls intrinsic to the project were identified, these included requirements under the VicRoads Standard Specification Sections:

- Section 177 – Environmental Management (Major), which sets out the minimum environmental management obligations for RRV major projects and Standards and Policies relevant to hydrogeology (refer Section 10).

4.6 MITIGATION

Mitigation measures for identified impacts were developed by discipline specialists in consultation with RRV. All identified mitigations developed for the project have been informed by specialist experience with proven feasible control measures for major civil infrastructure projects, industry best practice measures and regulatory measures defined by State, Commonwealth and International Standards and agreements.

Mitigation measures for the project were developed throughout the impact assessment process to inform the identification of residual impacts of the preferred alignment, which are detailed in Section 11.

4.7 OPTIONS ASSESSMENT

The alignment refinement for the Beaufort Bypass has been undertaken in three distinct phases since project inception. These are discussed in EES Attachment IV: *Options assessment* as:

- Phase 1 – Concept alignment development
- Phase 2 – Option development and assessment
- Phase 3 – Identification of preferred alignment.

This options assessment method section considers the Phase 3 assessment and details the process for selection of the preferred alignment.

The Phase 3 assessment considered four alignment options to select the preferred alignment, utilising a customised comparative options assessment to rank each option against the following areas:

- biodiversity
- catchment values and hydrology
- cultural heritage (Aboriginal and historic)
- social and community
- amenity
- landscape and visual.

Multiple scoring scenarios and sensitivity testings were undertaken against each option to ensure the environmental, social, heritage and economic assessment criteria aligned with the EES evaluation objectives. The scoring framework developed sought to ensure a wholistic decision-making process was undertaken, and that no single scoring or sensitivity scenario would be the primary determining factor in the identification and selection of the preferred alignment.

Weightings for the assessment included the application of six scenarios and sensitivity tests to eliminate bias of specific environmental constraints. These scenarios included:

- Scenario 1: Apply a score of 1 to 4 from least to highest impact
- Scenario 2: Alignment with highest number of least impact scores
- Scenario 3: Apply a score of 1 to the highest impact and the subtract the percentage difference between alignments
- Scenario 4: Apply a score of 1 to least impact and then add the percentage difference between remaining alignments
- Scenario 5: As per Scenario 3, but minus criteria that can be mitigated
- Scenario 6: As per Scenario 4, but minus criteria that can be mitigated.

The sensitivity tests included:

- Scoring sensitivity scenario 1:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–20% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 20% or greater than the lowest impact option are apportioned a score of minus one and a red light.
- Scoring sensitivity scenario 2:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–25% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 25% or greater than the lowest impact option are apportioned a score of minus one and a red light.
- Scoring sensitivity scenario 3:
  - Options with the lowest impact and other options within 5% of the lowest impact are apportioned a score of one point and a green light.
  - Options within 5–15% of the lowest impact option are apportioned a score of zero points and an amber light.
  - Options with an impact of 15% or greater than the lowest impact option are apportioned a score of minus one and a red light.

The assessment process included an iterative process with RRV, the Technical Reference Group (TRG), legal and discipline specialists to refine the assessment environmental risk workshops and develop a customised assessment matrix. The assessment criteria are detailed within EES Attachment IV: *Options assessment* (RRV 2019).

4.8 LINKAGE TO OTHER TECHNICAL REPORTS

This report is supported by several previous technical assessments that have assisted in the identification of potential risks and the development of the conceptual groundwater understanding of the investigation area. These technical assessments are:

- desktop and targeted contaminated land investigations including landfill assessment in the northern portion of the alignment and acid sulfate soil investigation undertaken by WSP (EES Appendix K: *Soils and geology impact assessment*, WSP 2021a)
- surface water impact assessment undertaken by WSP (EES Appendix L: *Surface water impact assessment*, WSP 2021b)
- description of GDEs in EES Appendix C: *Flora and fauna impact assessment* (WSP 2021c)
- Environmental Risk Assessment undertaken by WSP, EES Attachment II.

5 LEGISLATION

This section assesses the project against the Commonwealth and State legislation, policies and guidelines relevant to the groundwater impact assessment.

5.1 COMMONWEALTH LEGISLATION

5.1.1 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) prescribes the Commonwealth's role in environmental assessment, biodiversity conservation and the management of protected areas and species, population and communities and heritage items. Approval from the Commonwealth Minister for the Environment is required for:

- an action which has, would have, or is likely to have a significant impact on 'Matters of National Environmental Significance' (MNES). The current MNES include:
  - World Heritage properties
  - National Heritage places
  - wetlands of international importance
  - listed threatened species and ecological communities
  - migratory species protected under international agreements
  - Commonwealth marine areas
  - the Great Barrier Reef Marine Park
  - nuclear actions (including uranium mines)
  - a water resource, in relation to coal seam gas development and large coal mining development
- an action by the Commonwealth or a Commonwealth agency which has, would have, or is likely to have a significant impact on the environment
- an action on Commonwealth land which has, would have, or is likely to have a significant impact on the environment
- an action which has, would have, or is likely to have a significant impact on the environment of Commonwealth land, no matter where it is to be carried out.

Impacts on MNES were assessed through a referral process to the Commonwealth Minister for the Environment. The Minister determined the project is likely to have a significant impact on a MNES for potential significant impacts to the Golden Sun Moth, and has controlled the action, requiring approval by the Commonwealth Minister for the Environment before construction works can commence.

5.2 STATE LEGISLATION, REGULATION AND POLICY

5.2.1 ENVIRONMENT EFFECTS ACT 1978

Assessment of the potential environmental, cultural and social impacts of proposed public works in Victoria may be required before works can proceed. This assessment process is done through the preparation of an EES guided by the *Environment Effects Act 1978*. The process aims to identify negative impacts and develop mitigation measures to suit the local environment.

An EES may be required when the Minister for Planning determines that a proposed development might:

- require more thorough assessment than is currently provided in existing statutory processes
- have regionally or state significant adverse impacts on the environment; or
- require an integrated assessment of potential environmental, social and economic impacts.

On 22 July 2015 the Minister for Planning determined that an EES was required for the project due to the potential for significant effects.

5.2.2 WATER ACT 1989 AND ENVIRONMENT PROTECTION ACT 1970

The framework for the management of groundwater in Victoria is established primarily through the:

- *Water Act 1989* – This Act deals with the sustainable, efficient and equitable management and allocation of groundwater resources.
- *Environment Protection Act 1970* – This Act empowers the Environment Protection Authority Victoria (EPA Victoria) to implement regulations, maintain SEPPs, manage waste and protect the environment from pollution. The Act also regulates the discharge or emission of waste to water, land or air by a system of Works Approvals and licences.

Several subordinate legislation and guidelines exist which support the *Water Act 1989* and the *Environment Protection Act 1970*.

5.2.2.1 STATE ENVIRONMENT PROTECTION POLICIES

SEPPs set out State Government policies that control and reduce environmental pollution and have been formulated for discharges to land, water, atmosphere and noise emissions. These policies protect the environment and human activities (beneficial uses) from pollution caused by waste discharges and noise and are subordinate documents to the *Environment Protection Act 1970*.

The SEPP (Waters) was formally adopted on 19 October 2018, replacing both SEPP (Waters of Victoria) and SEPP (Groundwaters of Victoria). Combining the previous two SEPPs, the SEPP (Waters) aims to maintain and, where necessary, improve groundwater quality to a standard that protects existing and potential beneficial uses of groundwater. It sets a consistent approach to, and provides quality objectives for, groundwater protection throughout Victoria. This policy overrides all existing groundwater protection provisions in other SEPPs.

The policy provides that groundwater is categorised into segments, with each segment having identified uses. Groundwater with higher concentrations of salinity (measured as mg/L TDS) is deemed to have higher TDS concentrations and fewer beneficial uses. The segments and their beneficial uses are summarised in Table 5.1 and Table 5.2.

Table 5.1 Groundwater segments (Government of Victoria 2018)

SEGMENT	A1	A2	B	C	D	E	F
TDS range (mg/L)	0–600	601–1,200	1,201–3,100	3,101–5,400	5,401–7,100	7,101–10,000	>10,001

Table 5.2 Beneficial uses for groundwater (Government of Victoria 2018)

BENEFICIAL USES	SEGMENTS (mg/L TDS)						
	A1	A2	B	C	D	E	F
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 water use	✓	✓	✓	✓	✓		
Primary contact recreation	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

EPA Victoria may determine these beneficial uses do not apply to groundwater where:

- there is insufficient aquifer yield to sustain the beneficial use
- the application of groundwater, such as for irrigation, may be a risk to beneficial use 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 troglofaunal; and
- the background level of an environmental quality indicator would not provide for the protection of the beneficial use.

SEPP (Waters) specifies groundwater investigation objectives for various beneficial uses. For the majority of beneficial uses, these objectives are those contained within the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Environment Conservation Council (ANZECC)/Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000) and Australian Drinking Water Guidelines (National Health and Medical Research Council (NHMRC) 2011).

SEPP (Waters) also requires that occupational health and safety, odour and amenity be considered, since vapours sourced from impacted groundwater may present a potential risk to human health, and that odours or discolouration may result in degradation of overall beneficial use.

5.2.3 ENVIRONMENT PROTECTION AMENDMENT ACT 2018

The *Environment Protection Amendment Act 2018* will take effect in 2021 and provides the foundation for the transformation of Victoria's environment protection laws and the EPA. This Act focuses on preventing waste and pollution impacts rather than managing those impacts after they have occurred. New guidelines are under development by EPA and will be released following implementation of the *Environment Protection Amendment Act 2018*. Central to the Environment Protection Amendment Act is the general environmental duty (GED). Under the GED, businesses must understand the risk from their activities and how to address them. The extent of measures undertaken depends on how much risk the business' activities pose to human health and the environment.

5.2.4 GROUNDWATER LICENCING REQUIREMENTS

In Victoria, groundwater resource units are identified in Groundwater Management Areas (GMAs), Water Supply Protection Areas (WSPAs) or Unincorporated Areas (UAs). There are 40 GMAs in which groundwater has been extensively developed or has the potential to be developed. They are geographically defined as such for the purposes of ongoing management of the aquifer and are carefully monitored via DELWP State Observation Bore Network.

WSPAs are areas declared by the Minister for Water under the Act to protect stressed groundwater or surface water resources through the implementation of a statutory Groundwater Management Plan for the area. There are currently 16 WSPAs declared in Victoria. Collectively, these WSPAs and GMAs are referred to as Groundwater Management Units (GMUs). There is no declared groundwater WSPA over the investigation area.

UAs are areas where no significant development of the groundwater resource has occurred. This is usually because the resource is low yielding, or its quality has traditionally severely limited its use. They exist outside of GMU boundaries, although they will be defined within a GMU in the next few years.

Groundwater extraction is managed through licensing and is allocated under the *Water Act 1989*:

- to drill a bore, a Bore Construction License is required under Section 67 of the Act for all persons
- to extract groundwater for commercial purposes (not including domestic and stock users), a Take and Use Licence is required under Section 51 of the Act.

Rural Water corporations are responsible for assessing licence applications, deciding whether to issue licences and the terms and conditions on which the licence is issued. The licence will specify the exact location and depth from which groundwater can be extracted, the annual volume of water that can be pumped and the rate at which the pumping can occur (Southern Rural Water 2017).

Permissible Consumptive Volumes (PCVs) have been set by the Minister for Water, which detail the maximum volume of water that can be allocated in an area. Many areas have been allocated to their PCV limit, meaning no new licences can be issued in these areas. The only way to acquire new groundwater in these areas is to trade with an existing groundwater licence holder. PCVs are imposed to protect the resource and prevent depletion. PCVs do not apply to UAs. The investigation area is not within a groundwater management unit area and is therefore located in an unincorporated area.

Where excavations penetrate the water table and dewatering is required, a licence to take groundwater must be sought from Southern Rural Water. An analysis will need to be carried out to estimate the required dewatering rate and volume (Southern Rural Water 2017).

The discharge of dewatered groundwater to the environment or to drainage infrastructure will need to be licensed by the relevant authority; water disposal to a licensed facility will not require a licence. An assessment of volume and water chemistry will need to be carried out to assess the most appropriate discharge method and obtain the relevant approvals.

5.3 GUIDELINES

Guidelines relevant to the management of groundwater include:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC / ARMCANZ 2000). These guidelines provide for the sustainable use of Australia’s water resources by protecting and enhancing quality, while maintaining economic and social development. These guidelines are used as groundwater quality criteria for assessing beneficial uses outlined in the SEPP (Waters).
- *Australian Drinking Water Guidelines* (NHMRC 2011). These guidelines provide guidance to the Australian community and the water supply industry on what constitutes good quality drinking water. These guidelines are used as groundwater quality criteria for assessing beneficial uses outlined in the SEPP (Waters).

6 EXISTING CONDITIONS

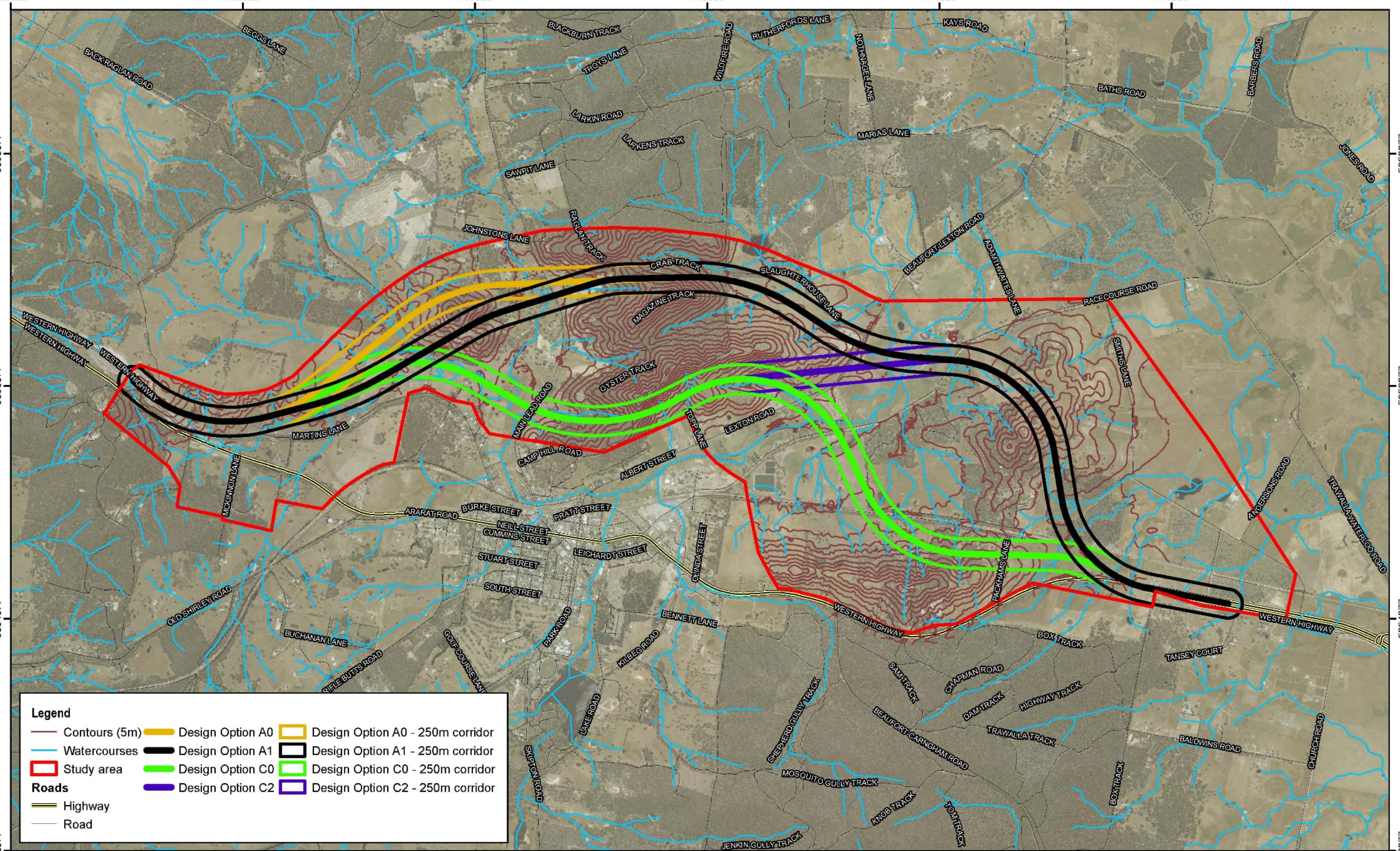
6.1 EXISTING CONDITIONS OVERVIEW

The desktop and site investigations have been used to develop a description of the existing conditions and to inform a conceptual understanding of the investigation area, including climatic, hydrological, hydrogeological and ecological aspects. This is a requirement of the EES scoping requirements (Section 3). The following sections describe each of these aspects.

6.2 TOPOGRAPHY AND DRAINAGE

The township of Beaufort is situated within a circle of hills, at the confluence of the ephemeral Ding Dong, Cemetery, Cumberland and Yam Holes Creeks. Yam Holes Creek is the main waterway through the town and a major tributary of Mount Emu Creek. Yam Holes Creek flows south then east, at the confluence of Ding Dong Creek, to join Mount Emu Creek at Trawalla. The confluence of Yam Holes Creek with Mount Emu Creek is approximately 10 km downstream of the Beaufort township. Mount Emu Creek is a major tributary of the Hopkins River which flows into the Southern Ocean just east of Warrnambool.

The hills surrounding Beaufort are gently to moderately inclined and range from 420 m to 440 mAHD in elevation. The low-lying areas were observed to be flat to gently undulating with an elevation of approximately 320 mAHD. Topography and drainage features described above are presented in Figure 6.1 which shows each of the four proposed alignments intersecting the hills to north and east of Beaufort and crossing Yam Holes Creek drainage to the east and a an unnamed drainage line adjacent Main Lead Road to the north.



Map: 2270290A_GIS_134_A1

Author: MB

Date: 11/09/2019

Approved by: -

Data source: VicRoads, Trimble

Coordinate system: GDA 1994 MGA Zone 54
Scale ratio correct when printed at A3

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Beaufort Bypass Environment Effects Statement
Figure 6.1
Drainage and elevation contours

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6.3 CLIMATE

6.3.1 LONG TERM RAINFALL TREND

Rainfall data obtained from Beaufort Station (No. 89005), the closest BoM weather station to the investigation area. Figure 6.2 depicts the average monthly rainfall for Beaufort from 1883 to 2018. Most rainfall occurs from May to November whilst February has the lowest long-term monthly average. Historical data shows that Beaufort receives on average approximately 680 mm per year based on rainfall data from 1883 to 2018 (BoM 2018).

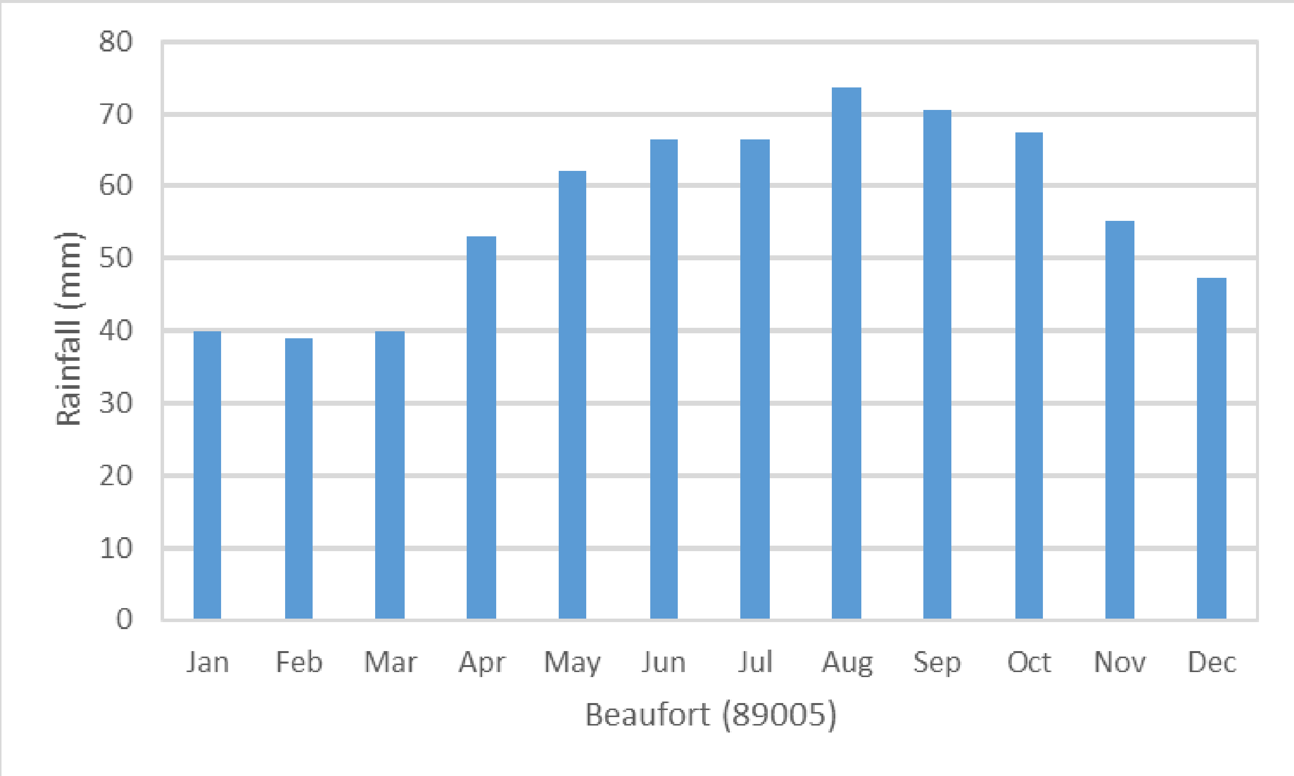


Figure 6.2 Average monthly rainfall (1882 to 2018 period for Beaufort)

The long-term, annual cumulative deviation from mean rainfall for the 1883 to 2018 period at the Beaufort station is shown in Figure 6.3. The long-term cumulative rainfall residual plots provide an indication of the broad scale trends in rainfall pattern behaviour and are formulated by subtracting the average annual rainfall for the recorded period from the actual annual rainfall and then accumulating these residuals over the assessment period. Periods of below average rainfall are represented as downward trending slopes while periods of above average rainfall are represented as upward trending slopes.

The cumulative deviation plot shows a general upward sloping cumulative deviation trend from 1914 to 1964, followed by a downward sloping trend until 2009, largely reflecting the end of the Millennium drought. The rainfall trend following the Millennium drought shows both upward and downward sloping records, indicating a variability in rainfall within the region with the general trend decreasing from in the last five years to present day indicating below average rainfall for this period.

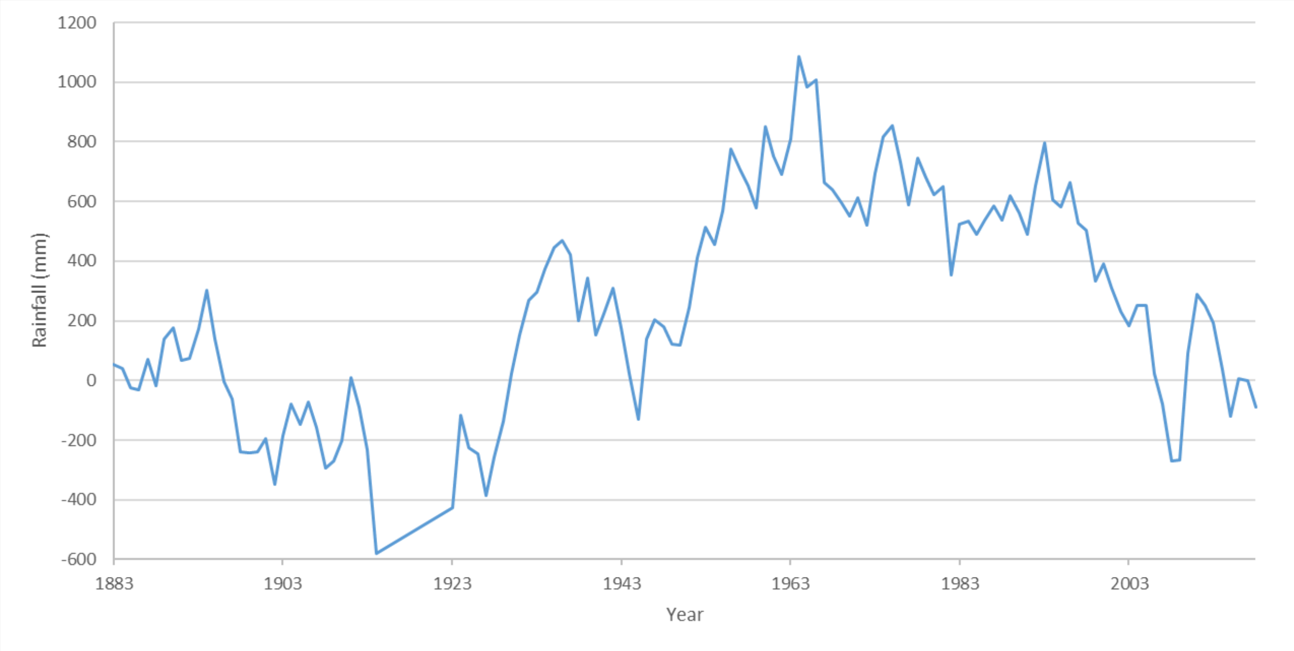


Figure 6.3 Cumulative annual rainfall departure (1882 to 2017 period for Beaufort)

6.3.2 EVAPORATION

The mean daily evaporation data available from the BoM weather station at Creswick (No. 88019) is for the 1973 to 1985 period (Figure 6.4). This weather station is located approximately 40 km east of Beaufort and is the closest station with records for daily evaporation.

Mean daily evaporation at the Creswick weather station ranged from 0.9 mm in June to 6.7 mm in January (Figure 6.4). Average annual evaporation for the 12-year monitoring period was 1,204 mm per year, which is almost two times the long-term rainfall average (BoM 2018).

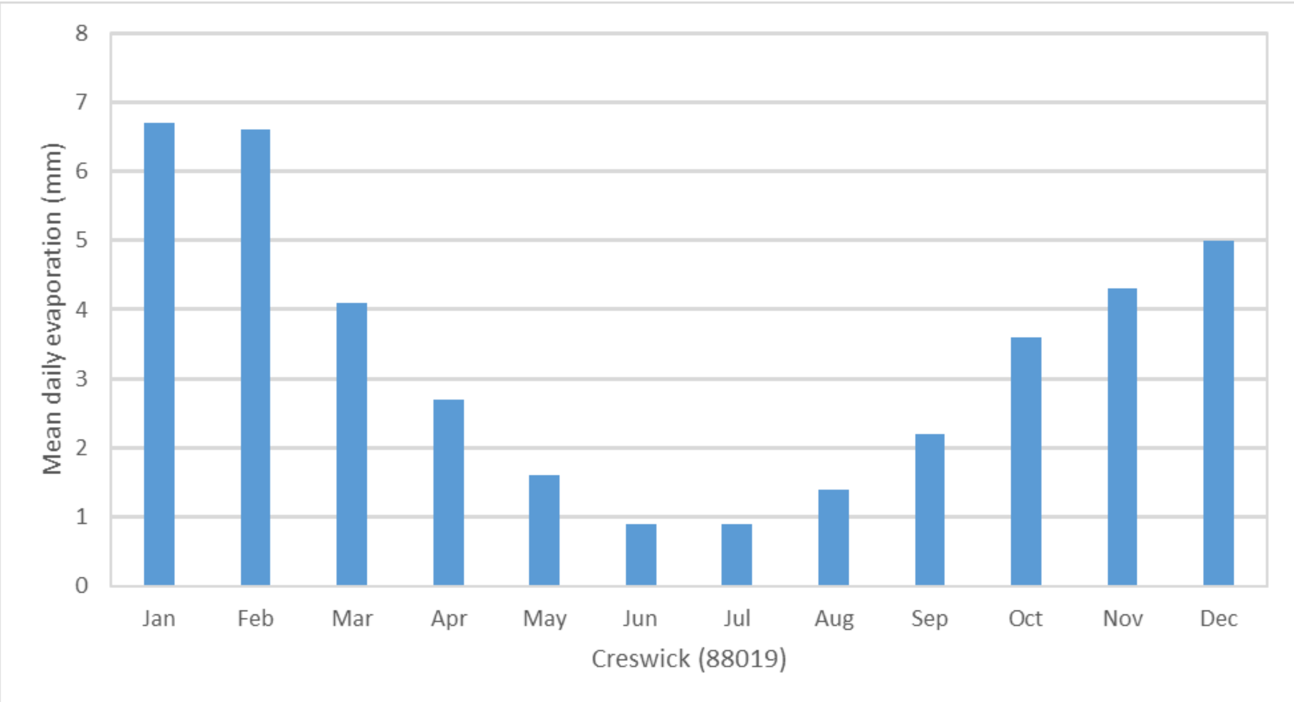


Figure 6.4 Daily mean evaporation at Creswick (mm)

6.4 GEOLOGY

The surface geology of the investigation area is shown on the Department of Economic Development, Jobs, Transport and Resources (newly titled Department of Jobs, Precincts and Regions) (2010) Ballarat 1:250,0000 geology map and reproduced in Figure 6.5. The stratigraphy of the investigation area is summarised in Table 6.1.

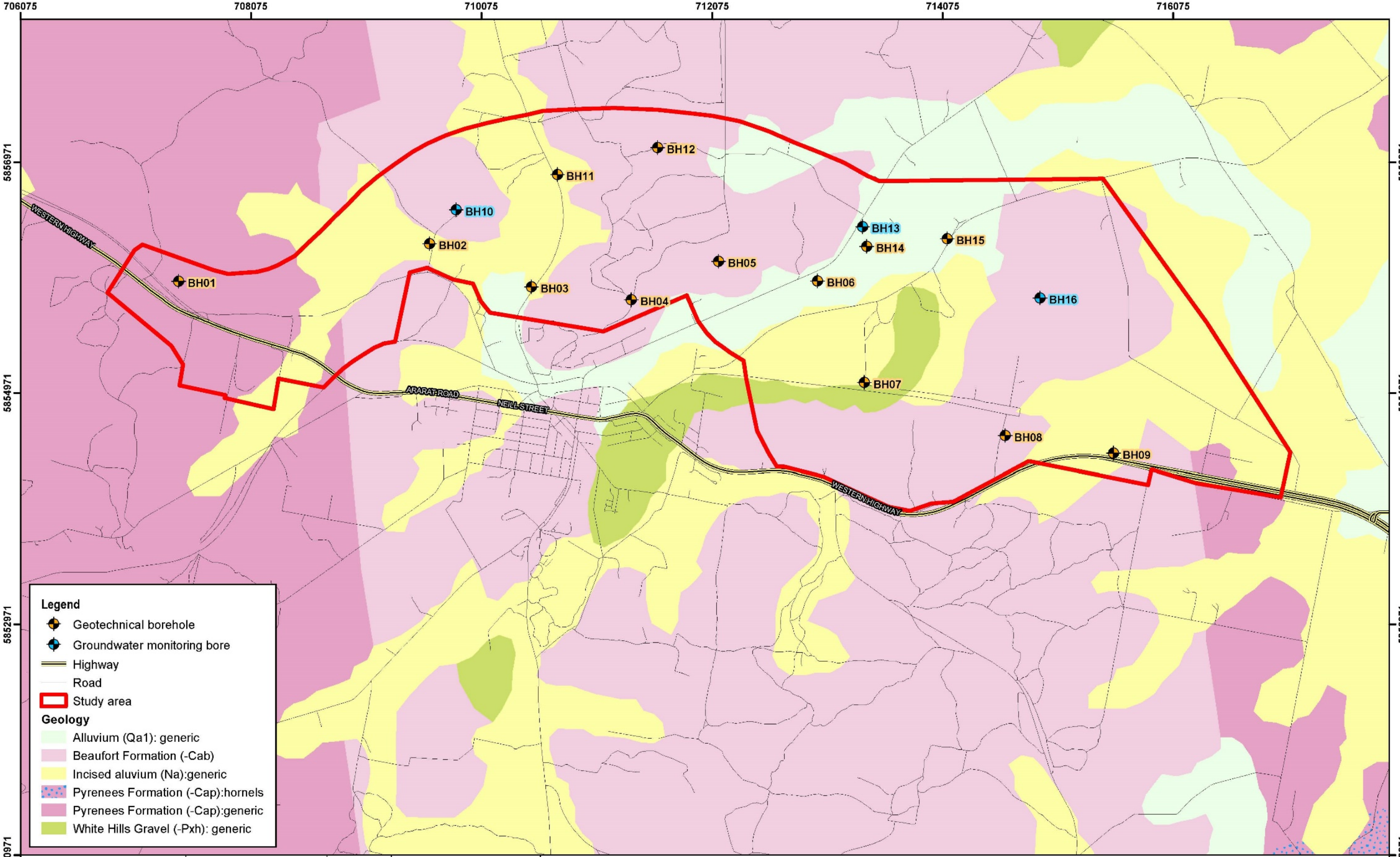
The study area is largely underlain by the Cambrian-Ordovician aged marine sediments of the Beaufort Formation and Pyrenees Formation. Both units are part of the Saint Arnaud Group and are comprised of interbedded siltstone and mudstones with minor sandstones lenses. The Beaufort and Pyrenees formations are the geological basement within the study area.

These units underlie most of the study area and outcrop as the hills surrounding Beaufort. Minor Tertiary gravels and Quaternary alluvial sediments unconformably overlie the Saint Arnaud Group and are located within drainage lines and floodplains. Geotechnical bore holes that intersect the Quaternary alluvial indicate the material tends to fine upwards with dense clay and silts as the predominant material layer and coarser grained material present at the basal contact of the underlying basement formations.

Whilst outside the study area, the Newer Volcanics Group is located within the investigation area at the eastern extent of the project. This unit consists of fracture basalts and overlies the Beaufort Formation. The Newer Volcanics forms the Eastern boundary of the Yams Hole and Mount Emu creeks with the alluvial material channelled south along the geological contact.

Table 6.1 Surface geology of the Beaufort Bypass study area

AGE	FORMATION	LITHOLOGICAL DESCRIPTION
Quaternary	Alluvium (Qa1): generic	Gravel, sand, silt: variably sorted and rounded; generally unconsolidated; includes deposits of low terraces; alluvial floodplain deposits, however field observations indicated upwards fining to dense clays and silts with basal coarse-grained layer.
	Incised alluvium (Na): generic	Gravel, sand, silt, minor ferricrete; variably incised. However, field observations indicated upwards fining to dense clays and silts with basal coarse-grained layer.
Tertiary	White Hills Gravel (Pxh): generic	Vein quartz conglomerate, sand, silt, clay in fluvial braid plain, outwash fan and colluvial deposits; typically compositionally mature, with ubiquitous well-rounded pebbles and cobbles of reef quartz, lesser more angular vein quartz and bedrock clasts; moderately to well sorted, massive to crudely stratified, cross-bedded and channelled; richly auriferous in places; variably ferruginised, silicified or kaolinized.
Ordovican	Pyrenees Formation (-Cap): generic	Sandstone and mudstone: dominantly sand-rich turbidite facies; moderately to well sorted, variably rounded quartz with minor feldspar and lithic grains in quartz silt or clay matrix; medium to thick bedded; unfossiliferous; weathered to partly kaolinised; deep marine deposits. Mostly nonmagnetic, but some parts are weakly to moderately magnetic.
Cambrian	Beaufort Formation (-Cab): generic	Sandstone, mudstone and black shale: sand-poor turbidite facies tectonically modified to phyllite, quartz-mica or graphitic schist; weathered to partly kaolinised; deep marine deposits.



Map: 2270290A_GIS_027_A3	Author: MB	
Date: 17/10/2019	Approved by: -	

Data source: VicRoads, Trimble

1:30,000

Coordinate system: GDA 1994 MGA Zone 54
Scale ratio correct when printed at A3

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Beaufort Bypass Environment Effects Statement and Planning Scheme Amendment
Figure 6.5
Surface geology of the study area

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6.5 SOIL

6.5.1 SOIL PROFILE

Subsurface conditions encountered in the boreholes were consistent with geological mapping, however, the White Hills Gravel was not encountered during the drilling program. Soil conditions experienced in drilling indicated that the soil profile was dry with dominant silt/clay material resulting in a sufficiently low permeability that recharge and infiltration of rainfall is negligible. Table 6.2 and Table 6.3 summarise the subsurface profile encountered in the hills comprised of the Beaufort and Pyrenees formations and low lying – alluvial materials, respectively.

Table 6.2 Subsurface profile of Pyrenees and Beaufort formations

MATERIAL	ENCOUNTERED SUBSURFACE CONDITIONS	TYPICAL THICKNESS OF UNIT (m)
Disturbed soil	SILT: low plasticity, dark brown, brown, pale brown, trace to with roots/rootlets, dry, disturbed by cultural heritage sieving.	0.2 – 0.4
Residual soil	SILT / CLAY: low to high plasticity, brown, orange-brown, grey, red, dry, hard, typically friable.	0.25 – 4.6
Extremely weathered material	SILT: low plasticity, (pale) orange-brown, (pale) grey, (pale) red-brown, (pale) brown, dry, hard, friable.	>4.6

Table 6.3 Subsurface profile of low lying – alluvial areas

MATERIAL	ENCOUNTERED SUBSURFACE CONDITIONS	TYPICAL THICKNESS OF UNIT (m)
Disturbed soil	SILT: low plasticity, dark brown, brown, pale brown dry, disturbed by cultural heritage sieving.	0.3 – 0.9
Alluvium	GRAVEL / SAND / SILT / CLAY: low to high plasticity clay/silt, fine to coarse grained sand/gravel, brown, orange-brown, grey, red, dark brown, dark red, dry to moist, stiff to hard, medium dense to dense, friable in places. Typically becoming coarser grained with depth.	0.25 – 4.4
Residual Soil	SILTY SAND / SILT / CLAY: fine grained sand, low plasticity silt/clay, (pale) grey, orange-brown.	0 – > total depth of borehole
Extremely weathered material	SILT: low plasticity, orange, (pale) grey, red, pale red-brown, dry to moist, stiff to hard, friable.	> total depth of borehole

6.5.2 SALINITY

The study area is within the Beaufort Salinity Province where scattered patches of salinity have been mapped. These patches are largely confined to drainage lines and are possibly attributed to previous gold mining activity or other anthropogenic ground disturbance and land use.

Mapped salinity areas within the study area are limited to small patches off Martins Lane and down gradient of the water treatment plant within Yam Holes Creek floodplain. In some areas, salt tolerant grasses and vegetation have been planted to prevent erosion and mobilisation of salts. Monitoring of salt affected areas by Agriculture Victoria has recorded little change in the last decade (Agriculture Victoria 2017).

6.6 HYDROGEOLOGY

6.6.1 HYDROGEOLOGY UNITS

The *Victorian Aquifer Framework* (VAF), developed by DELWP (2017), is a three-dimensional model of Hydrostratigraphic Units (HSUs) within Victoria. HSUs are comprised of geological materials of similar hydrogeological properties and include aquifers and aquitards. HSU are generally aligned with stratigraphic units.

The HSUs identified in this groundwater impact assessment are consistent with the VAF and are summarised below in Table 6.4. Within the investigation area, the HSUs align with the geological stratigraphy outlined in Section 6.4, with the QA consisting of alluvial sediments, and the Basement sedimentary aquitard (BSE) consisting of the Pyrenees and Beaufort formations. Characteristics are defined as per groundwater resource reports obtained through DELWP's online mapping tool.

Table 6.4 Groundwater resource units present at Beaufort Bypass investigation area (DELWP 2017a)

HYDROSTRATIGRAPHIC UNIT (GEOLOGY UNIT)	ESTIMATED DEPTH BELOW SURFACE (m)	GROUNDWATER SALINITY (mg/L)	CHARACTERISTICS
Quaternary Aquifer (**QA**) – sand, gravels, clay, silt	0–9	1,001–3,500 (Beneficial use Segment B, Government of Victoria, 2002)	Unconfined water bearing zones.
Mesozoic and Palaeozoic Bedrock (**BSE**) – basement sedimentary (fractured rock): sandstone, siltstone, mudstone, shale, igneous (fractured rock), includes volcanics, granites, granodiorites Beaufort and Pyrenees formations	9–209	1,001–3,500	Widespread subsurface aquitard, generally with low yields and occasional poor water quality.

6.6.2 RELEVANT AQUIFER

6.6.2.1 QUATERNARY AQUIFER

The QA is associated with unconsolidated alluvial sediments located in drainage features and intersects both the eastern and western portions of the investigation area, roughly following Main Lead Road in the west, and the Beaufort-Lexton and Racecourse Roads floodplain to the east (see Conceptual Cross Section (West – East) in Figure 6.5. The QA consists of alluvial materials including clays, silts sands and gravels.

The QA consists of an unconfined aquifer forming the water table aquifer where present. Drilling within the investigation area has indicated that the QA is generally less than 4 m thick although a greater thickness was at BH14 with the borehole terminated at 5.3 m within alluvial material.

The Tertiary White Hills Gravel sediments is also classified as the QA based. The White Hills Gravel consists of quartz vein conglomerate with sand, silts clay and gravels and is located along the southern extent of Yam Holes Creek flood plain. The White Hills Gravel was not intersected during the geotechnical drilling program.

Hydraulic properties and water quality of the QA are described in Sections 6.6.5, 6.6.6 and 6.6.7, respectively.

6.6.3 RECHARGE AND DISCHARGE OF THE RELEVANT AQUIFER

The primary recharge mechanism to the QA is direct rainfall infiltration and large flooding events. The proportion of net rainfall recharging the groundwater systems depends largely on the characteristics of the surface geology, soils, the land use and depth to the water table. Recharge is expected to be lower in areas where the surface is covered by clayey soils with a low hydraulic conductivity and specific yield.

Recharge to the clayey soils is a predominantly recharge-in/evapotranspiration (ET)-out process, associated with rainfall infiltration, which typically characterise the behaviour of shallow water systems and limited vertical infiltration from the perched, shallow system down to the deeper regional BSE aquifer.

Recharge also occurs via leakage from surface water features in areas where the groundwater table is below watercourses and landholder dams. Recharge rates will largely depend on the river stage and hydraulic characteristics of the riverbed material and underlying geology.

Groundwater can discharge from the shallow QA into creeks as baseflow or drains via seepage depending on the hydraulic gradient of the geological units in the aquifer. Groundwater in lower aquifers moves by subsurface flow discharging into wetlands and surface streams providing baseflow to streams or eventually discharging offshore.

Extraction of groundwater using existing bores in the investigation area is also considered a mechanism of discharge from the groundwater systems. ET from the water table is another mechanism of groundwater discharge. The ET rate depends on land use and depth to groundwater. In areas where the water table is shallow and within the rooting depth of vegetation, ET can be a significant component of the water. The vegetation extent within the study area is discussed within EES Appendix C: *Flora and fauna impact assessment* (WSP 2021c).

6.6.4 GROUNDWATER MANAGEMENT ARRANGEMENTS

Previously described in Section 5.2.4, groundwater resource units are identified in GMAs, WSPAs or UAs. Of the three administrative boundaries, only the WSPAs are declared by the Minister for Water under the Act to provide sustainable management of groundwater resources.).

The investigation area is not located within a groundwater management unit area and is therefore located in an UA. Groundwater licencing is administered by Southern Rural Water Corporation (SRWC).

6.6.5 GROUNDWATER LEVELS MEASUREMENT

Groundwater levels were recorded in the investigation area using manual measurements of the standing water level and automated groundwater loggers within the groundwater monitoring bores and geotechnical boreholes as described in Section 4.3.4.

6.6.5.1 WATER LEVELS – QUATERNARY AQUIFER

During the January 2018 geotechnical drilling program, seven boreholes (BH02, BH03, BH06, BH07 BH09, BH11, BH13, BH14) intersected alluvial material. Groundwater was encountered in only three of the seven geotechnical boreholes (BH03, BH13, BH14), indicating the alluvial material in the investigation area is variably saturated at the time of drilling. Only borehole BH13 was converted into a groundwater monitoring bore. The groundwater level recorded at monitoring bore BH13 in February 2018, approximately three weeks after installation, was 0.9 m below ground level. BH13 was revisited in August 2019 after a period of heavy rain to obtain manual groundwater levels and install a data logger, these levels are presented in Table 6.5.

During the 14 August 2019 gauging event, monitoring bore BH13 was waterlogged with the surrounding ground inundated and the bore flush gatic cover was submerged under pooled water. It was noted that the bore cap had become dislodged and ingress from surface water into BH13 had occurred with water levels static at surface level. This created an artificial recharge pathway where surface water saturated the bore.

The water column in BH13 was purged dry with a total volume of 12L removed from the bore casing and filter pack. Once the bore was purged dry it was noted that the bore recharged at a very low rate. A groundwater data logger and barometric pressure logger was then installed to monitor recovery and standing water level.

BH13 was revisited two weeks later to recover the data loggers. Again, it was observed that the bore gatic cover had been inundated after a period of rain and surface water ingress has occurred into the bore. A review of recorded water levels indicates water levels stabilising close to surface after approximately 24 hours. Several concurrent rainfall events occurred between the 17 and 20 of August where it appears surface water ingress has again occurred into the bore maintaining water levels artificially at surface.

Based on the initial observation during drier summer months, and the follow up gauging events during wetter periods it is expected that groundwater levels within the QA will fluctuate seasonally, with water levels declining during drier periods and recovering during wetter periods.

6.6.5.2 WATER LEVELS – BEAUFORT / PYRENEES FORMATIONS

Eight geotechnical boreholes were drilled in the Beaufort Formation and a single bore was drilled in the Pyrenees Formation as described in Table 4.1. None of the nine geotechnical boreholes intersected groundwater. The two groundwater monitoring bores that were installed within the Beaufort Formation are BH10 and BH16.

Both BH10 and BH16 were revisited in February 2018 after installation and again in August 2019 and they were dry on both occasions as displayed in (Table 6.5). The fine-grained sediments of the Beaufort and Pyrenees formations are regarded as a regional aquitard and not water bearing at the intersected drilled depth, as described in Section 4.3.3.

A search of government database WMIS (DELWP 2017b) identified 13 registered bores within the investigation area, however no groundwater level data were available for these bores.

Table 6.5 Groundwater monitoring bores in the investigation area

BORE ID	GROUND SURFACE (mAHD)	BORE DEPTH (m)	SCREEN DEPTH (m)	TARGET FORMATION	GROUNDWATER LEVEL (mBGL) 12 FEBRUARY 2018	GROUNDWATER LEVEL (mBGL) 14 AUGUST 2019	GROUNDWATER LEVEL (mBGL) 30 AUGUST 2019
BH10	416.3	17	8-17	Beaufort formations	Dry	Dry	Dry
BH13	377.6	5	2-5	Alluvium	0.9	0.0[1]	0.0[1]
BH16	411	17	8-17	Beaufort formations	Dry	Dry	Dry

(1) Water level compromised from surface water ingress into BH13

6.6.6 HYDRAULIC TESTING AND YIELD

6.6.6.1 HYDRAULIC TESTING

In-situ rising and falling head (slug) testing was completed on BH13 to provide estimates of hydraulic conductivity of the QA. Hydraulic conductivity (K) is rate of flow through a porous medium in a unit of time under a unit hydraulic gradient through a cross sectional area commonly measured at a rate of metres per day (m/day).

Conditions were unfavourable to allow aquifer testing using conventional ‘slug’ methods and therefore it was not possible to obtain an estimate of K. A recovery test was undertaken in BH13 post sampling after the bore had been purged dry. The data logger was installed within BH13 and recorded water levels as they recovered over a 15-hour period.

The recovery tests were analysed in AQTESOLV using the Bower and Rice (1976) solution was adopted for the analysis as the QA is unconfined. Hydraulic conductivity results from the recovery tests are estimates of close conditions of limited radius. Testing can be compromised due to poor bore design or development. It is common for aquifer testing results to over-estimate and the accuracy of these test should be treated as 'indicative' level (+ /- one order of magnitude).

Recovery data was compensated for barometric pressures and K values were determined using AQTESOLV© software. The single recovery test at BH13 indicated a K of 0.003 m/day, which is representative for unconsolidated silts/clays.

6.6.6.2 YIELD

Data for two registered bores within the investigation area, 48445 and 51493, indicate low yields of 0.38 L/s and 0.64 L/s respectively. Bore construction details and surface geology suggest these bores target the alluvium sediments. The low yields recorded in these two bores suggest the alluvial aquifer is a poor resource for abstraction.

Borehole BH13 was purged dry for sampling on two occasions in August 2019. On both occasions the volume of water removed from the bore was the calculated volume of the water column and filter pack storage. After the bore was purged, recovery rates were observed as being very low at approximately 0.05 L/min (0.001 L/sec) also indicating that the alluvial sediments at this location are low yielding.

There was no yield data available for the Beaufort and Pyrenees formations within the investigation area.

6.6.7 WATER QUALITY

Water quality data for the project has been obtained through groundwater sampling of the QA from monitoring bore BH13, and through WMIS (DELWP 2017b) with four registered bores containing water quality data (48445, 51493, 51496, 75818). Construction details for the registered bores suggest these bores target alluvial sediments or basalts associated with the Newer Volcanics. No water quality samples were collected from BH10 and BH16 within the BSE aquitard as these monitoring bores were dry.

Two groundwater samples were collected from BH13 on the 14th and 30th of August 2019. Two surface water samples were also collected for comparison during the initial sampling event from Yam Holes Creek as detailed in Section 4.3.5. Samples were submitted and analysed by NATA accredited laboratory. Full water quality results and laboratory reports are presented in Appendix B. To allow for comparison of water types, surface water samples locations were situated both close to the groundwater monitoring point, and up gradient of the King Street bridge.

Major ion chemistry for both the QA (BH13 and 48445), and surface water samples is plotted with rainwater (Melbourne) on the piper diagram in Figure 6.6. A piper diagram is a graphical representation of the relative concentrations of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-} and SO_4^{2-}), and is used to distinguish the chemical profile of major water types. In the QA, groundwater is a Na-Cl type and similar to relative proportions to the surface water samples, although at elevated concentrations.

Water quality from both surface water samples were comparatively similar. A slightly lower salinity concentration (measured as EC) at the down gradient sample location adjacent to BH13 compared to the up-gradient King Street Bridge sample location indicating minor dilution from runoff through Beaufort. Measured concentrations from all other analysis were relatively consistent between both the up-gradient King Street Bridge and down gradient Yam Holes Creek sample location with the exception of manganese, which was slightly elevated at the down gradient sample location at 0.117 mg/L compared to 0.024 mg/L up gradient.

Water quality for groundwater from BH13 and surface water samples from Yam Holes Creek is summarised in Table 6.6.

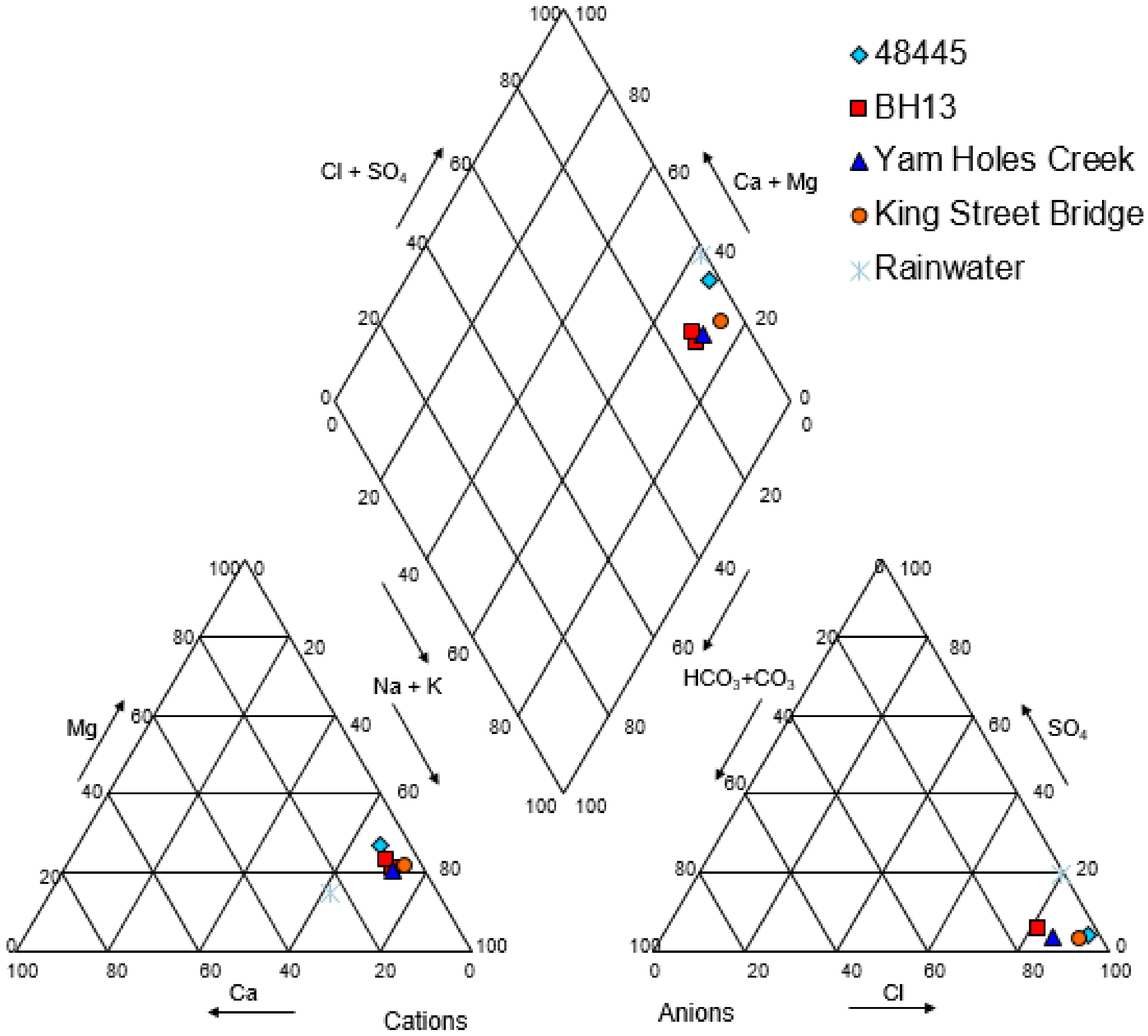


Figure 6.6 Piper diagram for groundwater samples collected from the QA and Yam Holes Creek

Table 6.6 Summary of groundwater quality

PARAMETER	QUATERNARY AQUIFER (BH13) WATER QUALITY	YAM HOLES CREEK
Field electrical conductivity (EC)	Brackish to saline BH13 (14/08/19): 4,480 BH13 (30/08/19): 6,442	Fresh Yam Holes Creek (BH13): 355 Yam Holes Creek (King Street Bridge): 438
Field pH	Field values for pH are neutral BH13 (14/08/19): 7.23 BH13 (30/08/19):7.29	pH is near-neutral to weakly alkaline Yam Holes Creek (BH13): 7.6 Yam Holes Creek (King Street Bridge): 8.6
Major ions	Na-Cl; type (high salinity)	Na-Cl; type

PARAMETER	QUATERNARY AQUIFER (BH13) WATER QUALITY	YAM HOLES CREEK
Dissolved metals	Below LoR: Be, Cd, Cr, Cu, Hg, Pb, Se and V. ANZECC 2000 FW 95% guidelines surpassed for metals Mn (2.52 mg/L) and Ni (0.072 mg/L)	Below LoR: B, Be, Cd, Hg, Pb, Se, and V. ANZECC 2000 FW 95% guidelines surpassed for metals Cr, Cu, Pb and Zn
Nutrients	No concentrations surpassing ANZECC 2000 FW 95% guideline). Typically, low nitrate and nitrite concentrations (as N), with higher total nitrogen	No concentrations surpassing ANZECC 2000 FW 95% guideline). Typically, low nitrate and nitrite concentrations (as N), with higher total nitrogen

Groundwater quality data from BH13 and the four registered bores indicated that the pH of groundwater is slightly acidic to slightly alkaline neutral, ranging from 6.7 to 8.5 for groundwater within the alluvial and basalt. Groundwater salinity data was available for the same registered bores and EC values were converted to TDS and compared against the Beneficial Uses outlined in the SEPP (Waters) as described in Section 5.2. TDS concentrations indicate that groundwater within the alluvial ranges from Segment A1 to C falling within all listed beneficial uses. The single TDS concentration within the Basalt falls within Segment B for protected beneficial uses. The water quality of the four registered bores is summarised in Table 6.7.

No water chemistry data was available for the BSE aquitard from registered bores within the investigation area. Groundwater Resource Reports for the investigation area (DELWP) indicates that the bedrock aquitard has a salinity range of 1,001 mg/L to 3,5000 mg/L TDS. At such salinities the groundwater falls within Segment A2, B and C with all protected beneficial uses included.

The major ion characteristics of a registered groundwater bore (48445) obtained through the State groundwater database, is also shown on the piper diagram in Figure 6.6. Groundwater quality is dominated by sodium and chloride. It should be noted that this water quality data from bore 48445 is located within a separate branch of the alluvial aquifer and may not be representative of water quality within the investigation area.

Table 6.7 Groundwater quality at bores within the groundwater investigation area

BORE ID	PH	EC (µS/cm)	TDS (mg/L)	BENEFICIAL USE SEGMENT	FORMATION
BH13	6.8	4,480	3,382	C	Alluvial
BH13	7.3	6,442	3,670	C	Alluvial
48445	6.82	6,200	4,030[1]	C	Alluvial
51493	8.5	n/a	3,370	C	Alluvial
51496	6.7	n/a	450	A1	Alluvial
75818	7.0	n/a	2,670	B	Basalts

*(1) TDS = EC*0.65 (Australian Water Resources Council, 1988)*

n/a no data

6.7 SENSITIVE RECEPTORS

6.7.1 GROUNDWATER USERS

Registered groundwater bores located within the groundwater investigation area was identified using data sourced from WMIS (DELWP 2017b). A total of 13 registered bores with a 'used' status are located within the investigation area.

Of these 13 bores:

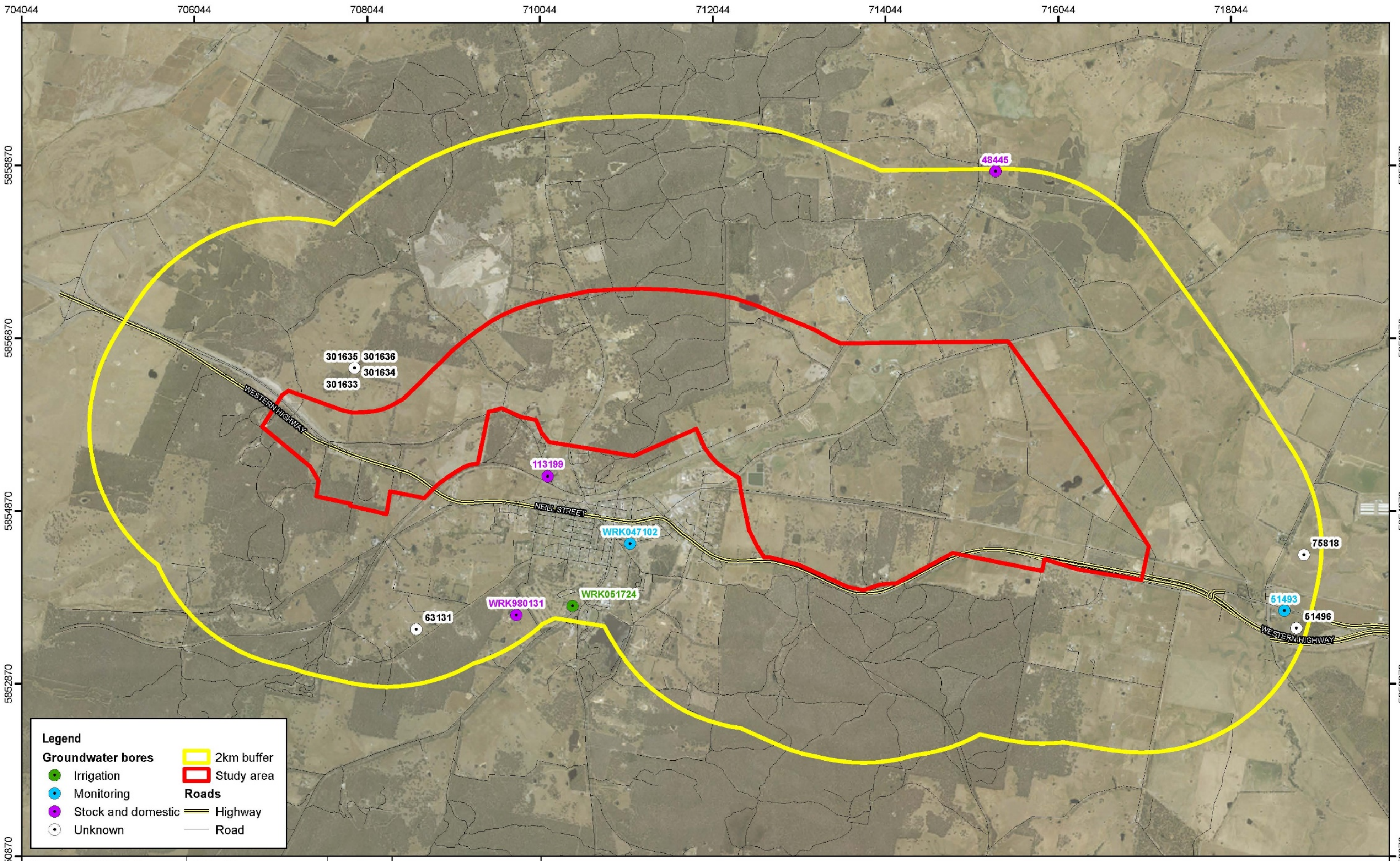
- three are used for stock and domestic purposes
- one is used for irrigation
- seven have no information available about use
- two are groundwater monitoring bores.

The locations of the groundwater bores are shown on Figure 6.7. The relatively low density of registered groundwater bores within the region reflects the poor quality and low yielding properties of the Beaufort and Pyrenees formations and variable saturation of the alluvium. To the eastern extent of the investigation area, two bores (51496, 75818) are screened within the Newer Volcanic Group which is classified as one of Victoria's aquifers as the Upper Tertiary/Quaternary Basalt (fractured rock).

Details of the registered bores with beneficial uses, or with no information available, are provided in Table 6.8.

Table 6.8 Details of registered bores in the investigation area

BORE ID	BENEFICIAL USE	DEPTH (m)	GEOLOGY	DATE INSTALLED	DISTANCE FROM STUDY AREA (m)
113199	Stock and domestic	29.0	Gravel	13/11/1991	389
301633	No information available	2.0	Pyrenees Formation	4/03/1965	509
301634	No information available	2.3	Pyrenees Formation	4/03/1965	509
301635	No information available	2.5	Pyrenees Formation	4/03/1965	509
301636	No information available	2.3	Pyrenees Formation	4/03/1965	509
63131	No information available	39.6	Pyrenees Formation	31/12/1961	1,373
WRK980131	Stock and domestic, drought relief	73.0	Beaufort Formation	17/03/2007	1,720
75818	No information available	87.2	Newer Volcanic	31/12/1960	1,798
WRK047102	Monitoring	66	Beaufort Formation	27/10/2008	1,078
WRK051724	Irrigation	90.0	Beaufort Formation	19/10/2004	1,824
51496	No information available	Unknown	Newer Volcanic	31/12/1960	1,877
51493	Monitoring	58.8	Pyrenees Formation	31/12/1960	1,695
48445	Stock	6.7	Alluvial	2/08/1976	1,974



Map: 2270290A_GIS_026_A3	Author: MB
Date: 11/09/2019	Approved by: -

Data source: VicRoads, Trimble, ESRI, DigitalGlobe, GeoEye.

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Coordinate system: GDA 1994 MGA Zone 54
Scale ratio correct when printed at A3

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Beaufort Bypass Environment Effects Statement and Planning Scheme Amendment
Figure 6.7
Registered groundwater users within 2 km of the study area

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6.7.2 GROUNDWATER DEPENDENT ECOSYSTEMS

GDEs are communities of plants, animals and other organisms that depend on groundwater for survival (former Department of Land and Water Conservation 2002). A GDE may be either entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans 1998).

GDEs include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems. The GDE Atlas (BoM 2017) categorises GDEs into three classes:

- aquatic ecosystems that rely on the surface expression of groundwater – this includes all the 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 – this includes all vegetation ecosystems
- subterranean ecosystems – this includes cave and aquifer ecosystems.

Groundwater discharge can be important in maintaining baseflow in rivers and streams, and ecosystems associated with these discharge areas may have a high dependency on groundwater for their water requirements. However, some of these ecosystems rely on perched aquifer systems that are shallow, surficial and are largely not connected to the deep regional groundwater system. The ecosystems that rely on perched aquifer systems are sustained by rainfall infiltration.

6.7.2.1 POTENTIAL GDES IN THE INVESTIGATION AREA

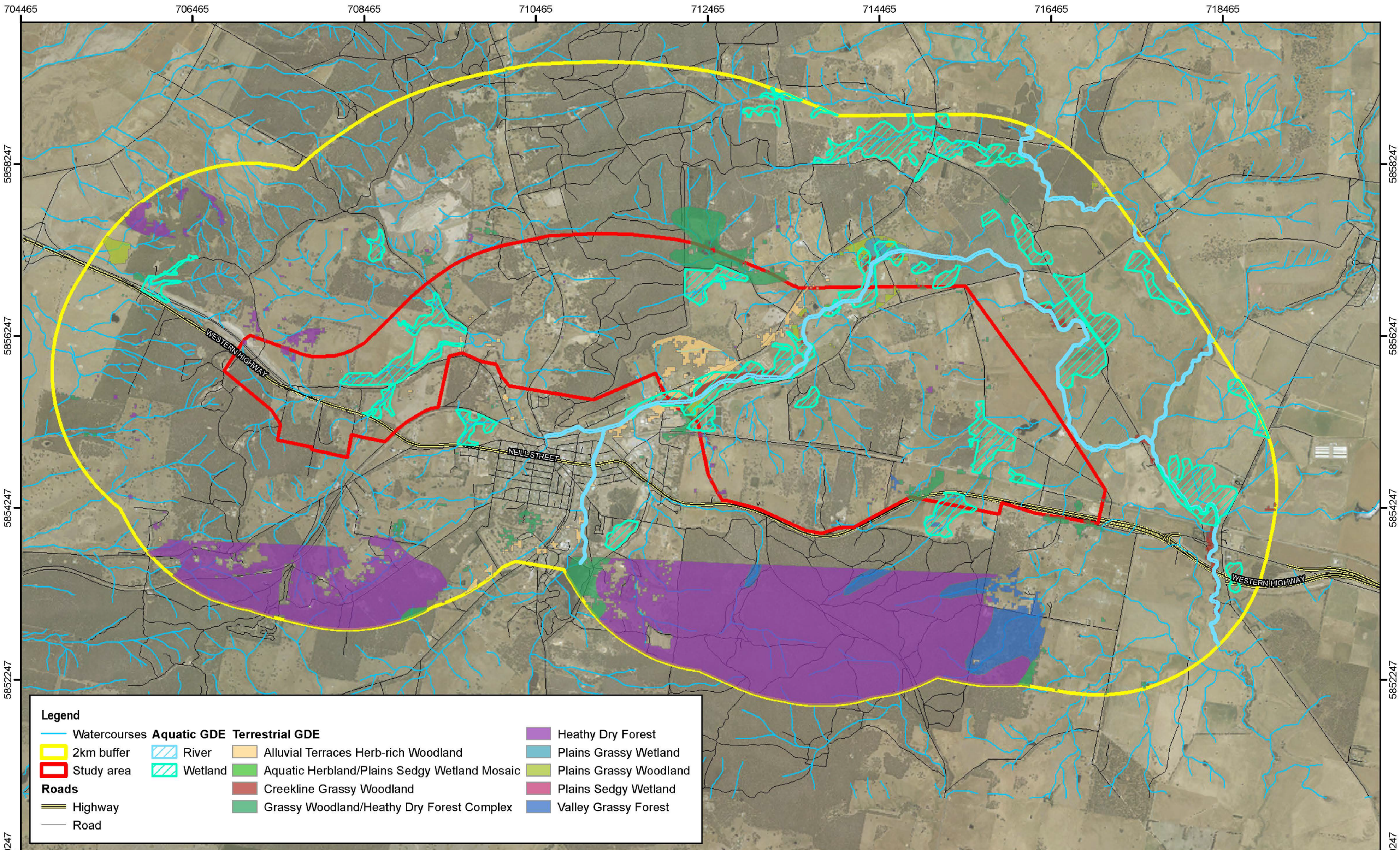
Whilst the characterisation of GDEs is not included within the scoping requirements for the Beaufort Bypass, a desktop review has been included as part of the conceptualisation. A search of the BoM GDE Atlas was undertaken to identify potential GDEs within the investigation area. It is important to note that the GDE Atlas mapping is an indicative regional scale mapping layer based on remote mapping and regional scale data sets and because desktop methods are based on regional scale data, they generally tend to overestimate the extent of GDEs (Richardson et al. 2011).

During a site walkover of the investigation area, which was completed to gauge installed groundwater wells, installed by the Geotechnical team, WSP hydrogeologists noted discrepancies between the BoM GDE Atlas mapping and the local scale, some wetlands that were mapped in the GDE Atlas did not exist. This reflects the indicative nature of the GDE Atlas, which is further described in EES Appendix C: *Flora and fauna impact assessment* (WSP 2021c).

The GDEs mapped within the investigation area are listed in Table 6.9 shown on Figure 6.8.

Table 6.9 Details of GDEs within the investigation area

GDE TYPE	ECOSYSTEM TYPE
Aquatic	Yams Holes Creek, Garibaldi Creek, Mount Emu Creek, Trawalla Creek
Aquatic	Unnamed wetlands
Terrestrial	Alluvial Terraces Herb-rich Woodland
Terrestrial	Aquatic Herbland/Plains Sedgy Wetland Mosaic
Terrestrial	Creekline Grassy Woodland
Terrestrial	Grassy Woodland/Heathy Dry Forest Complex
Terrestrial	Heath Dry Forest
Terrestrial	Plains Grassy Wetland
Terrestrial	Plains Grassy Woodland
Terrestrial	Plains Sedgy Wetland
Terrestrial	Valley Grassy Forest



Map: 2270290A_GIS_028_A4	Author: MB
Date: 7/11/2019	Approved by: -

Data source: VicRoads, Trimble, ESRI, DigitalGlobe, GeoEye,

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Coordinate system: GDA 1994 MGA Zone 54
Scale ratio correct when printed at A3

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Beaufort Bypass Environment Effects Statement
Figure 6.8
Groundwater dependent ecosystems in the study area

6.8 CONCEPTUAL HYDROGEOLOGICAL MODEL

Information obtained to inform the existing conditions description of this report has been integrated to develop a CHM of the investigation area. Conceptual models are a useful tool that captures the existing environmental condition primarily hydrological and hydrogeological aspects and illustrating the interaction and functions between the two. The following section summarises the conceptual aspects of groundwater within the investigation area and its interactions with both natural and anthropogenic elements while a graphical representation is presented in Figure 6.9.

6.8.1 TOPOGRAPHY AND DRAINAGE

The investigation area is within a circle of hills at the confluence of the ephemeral Ding Dong, Cemetery, Cumberland and Yam Holes Creeks. Yam Holes Creek is the main waterway through the town and a major tributary of Mount Emu Creek. Yam Holes Creek flows south then east, at the confluence of Ding Dong Creek, to join Mount Emu Creek at Trawalla. The confluence of Yam Holes Creek with Mount Emu Creek is approximately 10 km downstream of the Beaufort township.

The hills surrounding Beaufort are gently to moderately inclined and range from 420 m to 440 mAHD in elevation. The low-lying areas were observed to be flat to gently undulating with an elevation of approximately 320 mAHD. A floodplain associated with Yam Holes Creek is located to the east of Beaufort between Beaufort-Lexton and Racecourse Roads.

6.8.2 HYDROGEOLOGY

The primary HSU within the investigation area is the unconfined QA. The QA is associated with unconsolidated alluvial sediments deposited within drainage lines of the investigation area (Figure 6.5). The QA is limited in thickness with bore logs indicating thickness ranging from 1 m to 5.3 m. The QA within the investigation area is spatially limited within a branch arm of the larger QA associated with Mount Emu Creek.

Drilling in the study area has shown the QA is variably saturated and dry in some areas. Where groundwater occurs the water table is relatively shallow (less than 2 m below the ground surface) with flow inferred to follow drainage lines. Recharge of the alluvium is expected to be primarily via rainfall infiltration and discharge is expected to be primarily via evapotranspiration. The ephemeral nature of Yams Holes Creek indicates groundwater does not provide permanent baseflow to the creek. However, during wetter periods, groundwater is expected to discharge to the creek and drainage lines when groundwater levels are elevated.

The outcropping Beaufort and Pyrenees formations is considered geological basement and an aquitard and underlies the entire study area.

The outcropping Beaufort and Pyrenees formations are a low yielding regional aquitard where limited groundwater flow is largely confined to secondary defect structures (fractures, faults and joints). Drilling in the study area has shown the Beaufort and Pyrenees formations are dry in the hills of the study area where cuts are proposed for the project. Localised fractures may be recharged through vertical leakage from overlying Quaternary sediments, however this was not observed during site investigations.

6.8.3 GROUNDWATER QUALITY

Water quality of the QA characterised through sampling of BH13, and from data of registered bores indicate that groundwater is saline within the Yam Holes Creek drainage lines with TDS concentrations falling within Segment C classification for groundwater (SEPP (Waters)). Outside of the study area, TDS concentrations of registered bores 48445, 51493, 51496, and 75818 varied between Segment A1 to C. These bores are located within either alluvium associated within Mount Emu Creek or a basalts HSU aquifer that does not fall within the study area. The pH of groundwater is slightly alkaline to slightly acidic, ranging from 6.7 to 8.5. TDS and pH concentrations are summarised in Table 6.7.

In addition to the registered bores, Groundwater Resource Reports for the study area (DELWP) indicates that the QA aquifer and the bedrock aquitard have salinity range of 1,001 mg/L to 3,500 mg/L total dissolved solids (TDS). The range of TDS values observed within the investigation area covers beneficial use segments A2, B, C and D. Therefore, the groundwater has the potential to be used for all beneficial uses detailed in Table 6.7.

6.8.4 SENSITIVE RECEPTORS

The low density of registered groundwater bores within the investigation area indicate that groundwater resources in the investigation area are not widely exploited or are of unsuitable quality/quantity for agriculture. A search of the WMIS database identified a total of 13 registered bores, with most bores being screened within the QA.

The potential for groundwater-surface water interaction within the investigation area is likely during wetter periods where groundwater levels within the QA are above the base of Yam Holes Creek and other drainage features contributing baseflow. Water quality collected from Yams Holes Creek indicates similarities with groundwater samples collected from the QA. The ephemeral nature of these waterways indicates that groundwater is not in permanent connection with surface water.

A search of the BoM GDE Atlas identified potential aquatic and terrestrial GDEs within the investigation area as described in Section 6.7.2. High potential aquatic GDEs based on national assessment include portions of Yam Holes, Garibaldi, Mount Emu and Trawalla Creeks. High potential terrestrial GDEs included Grassy Woodland/Health Dry forest, Creekline Grassy Woodland, and Plains Grassy Wetland. These are further described EES Appendix E: *Flora and fauna impact assessment* (WSP 2019c).

6.8.5 CONCEPTUAL CROSS SECTION

The conceptual understanding of hydrogeological conditions within the existing environment as described in Section 6.8.2 above are presented in Figure 6.9. The Figure displays the west-east cross section that roughly follows alignment C2 and displays both geotechnical and groundwater monitoring bores, recharge and runoff mechanisms and geological units.

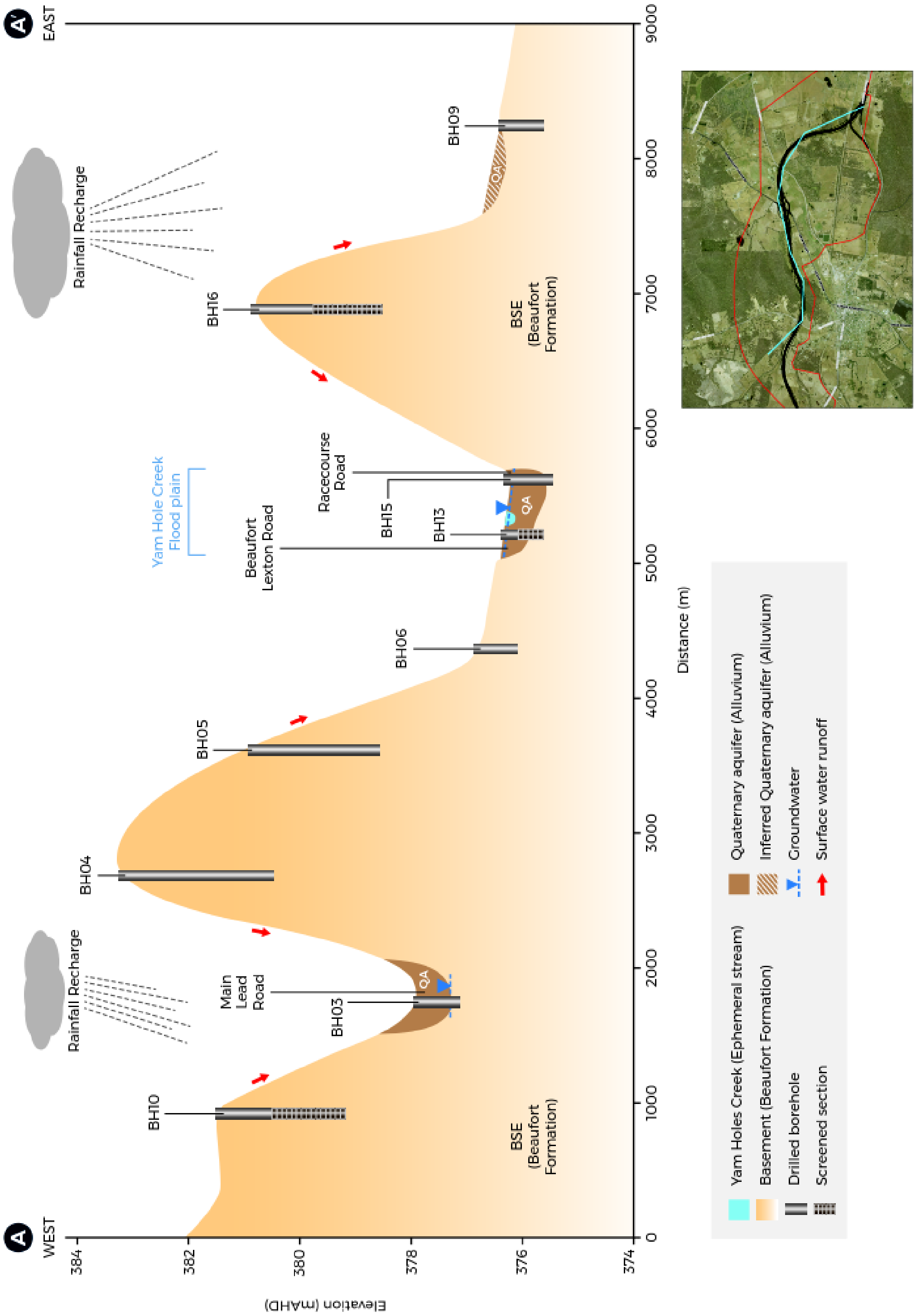

Figure 6.9 Conceptual cross section (West – East)

7 IMPACT ASSESSMENT – FOUR ALIGNMENT OPTIONS

7.1 ALIGNMENT CONSIDERATION

The four alignment options involve the same potential risks and impacts. All alignment options include excavated road cuttings through the Beaufort and Pyrenees formations and all involve embankment structures at both the eastern and western ends over Main Lead Road, Beaufort-Lexton Road, Racecourse Road and the Melbourne-Ararat rail line. Therefore, each option is assessed as a single alignment.

7.2 IDENTIFIED POTENTIAL IMPACTS

Through the processes described in Sections 4.4 and 4.5, the potential impacts to groundwater can be simplified into two groupings, impacts on groundwater quality and impacts to groundwater levels (quantity). Both the construction and operation phases of the project have the potential to impact on groundwater levels (quantity) and groundwater quality.

7.2.1 CHANGES TO GROUNDWATER LEVELS

7.2.1.1 QUATERNARY ALLUVIAL AQUIFER

Initially, the embankment structures along the proposed route alignments were identified as potentially sufficient to load and compress the shallow and unconsolidated aquifers (Quaternary alluvium). In turn these effects may give rise to measurable reductions in subsurface hydraulic conductivity in the shallow alluvium and hence could disrupt groundwater flow where the flow is not parallel with the route alignment.

Changes made during the iterative development of the functional designs throughout the EES process have reduced the potential impacts caused by the embankment structures by incorporating spans of culverts across the Yam Holes Creek floodplain and reducing the loading effect of the embankment.

Field investigations indicate that groundwater levels within the alluvium material can be within 1 m of natural surface. While fine-grained sediments can become saturated, the low hydraulic conductivity of theses sediments limits any meaningful groundwater flux through the upper layers of the alluvium. The basal coarse-grained layer is expected to have a higher hydraulic conductivity with much of groundwater flux occurring in this layer. The coarse-grained layer is also more resilient to the compression effect caused by the construction of embankments.

Any compression of the fine-grained silts and clay would not be expected to impact groundwater levels either up or down gradient of the embankment as the low permeability limits any meaningful groundwater flux. As coarse-grained sediments do not experience magnitude reductions in hydraulic conductivity due to loading and compression, impacts to groundwater flux will be negligible.

Overall impacts to groundwater levels, and therefore receptors both up and down gradient of the project, such as registered bores or GDEs during construction and operation will be negligible and no substantial impact to the ecological values is anticipated as a result of the project.

7.2.1.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

No groundwater was encountered during the geotechnical drilling within the bedrock formations of the Beaufort and Pyrenees formations. Impacts attributing to a reduction in groundwater levels through cutting excavation are low. Similarly, the aquitard properties of the Beaufort and Pyrenees formations make it unsuitable source for construction water and therefore groundwater levels would not be impacted from extraction or dewatering activities.

Impacts to groundwater levels within the Beaufort and Pyrenees formations during construction and operation is considered negligible as groundwater is not expected to be intersected through construction or operation.

7.2.2 CHANGES TO GROUNDWATER QUALITY

7.2.2.1 QUATERNARY ALLUVIAL AQUIFER

The QA is susceptible to disturbance to saline soils, accidental spills and leaks through infiltration during the construction and ongoing phases of the project. RRV standard environmental management procedures and Water Sensitive Road Design measures included in the detailed design (EES Appendix N: *Surface water impact assessment*) will be implemented as part of the contractual requirements to mitigate impacts from construction and operational phases. These standard controls are described below in Section 10 and are considered sufficient in managing and mitigating potential impacts. Impacts to groundwater quality during construction and operation with standard controls in the QA are assessed as low.

7.2.2.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

As groundwater was not encountered, it is not likely that the project would impact the groundwater quality of the Beaufort and Pyrenees formations aquitard. Impacts to groundwater quality in the Pyrenees formation aquitard during construction and operation are assessed as low.

8 OPTIONS ASSESSMENT AND PREFERRED ALIGNMENT SELECTION

As the four alignment options involved the same potential impacts to groundwater, the options assessment has not relied on the outcomes of this impact assessment. The information within this section is provided as context for the process utilised to select the preferred alignment.

The options assessment completed for the project assessed alignment options A0, A1, C0 and C2 against the customised set of criteria summarised in Section 4.6. The results of the options assessment and sensitivity testing are detailed in Table 8.1. As well as the score for each alignment under each scenario, a colour coding has been applied to rank the performance of the options under each scenario as follows:

- best performing alignment option: Green
- second performing alignment option: Yellow
- third performing alignment option: Orange
- worst performing alignment option: Red.

Table 8.1 Combined alignment option scenario scoring

SCENARIO	ALIGNMENT A0	ALIGNMENT A1	ALIGNMENT C0	ALIGNMENT C2
Scenario 1	128	123	126	111
Scenario 2	18	22	20	27
Scenario 3	45.85	44.89	50.01	43.95
Scenario 4	81.03	77.59	93.98	74.12
Scenario 5	24.16	22.70	27.03	19.44
Scenario 6	47.74	42.69	56.16	35.49
Sensitivity Scenario 1	-6	-3	-5	9
Sensitivity Scenario 2	-3	2	-4	11
Sensitivity Scenario 3	-11	-6	-9	5

The alignment scoring scenarios outlined in Table 8.1 show that the best performing option is the C2 Alignment, while the worst performing options are the A0 and C0 Alignments. The primary drivers for this outcome were due to the C2 alignment having:

- the lowest amount of total native vegetation clearance
- the least impact on threatened vegetation communities identified under the EPBC Act and *Flora and Fauna Guarantee Act 1988*
- the least impact on wildlife corridors, particularly the core habitat areas
- the lowest amount of native vegetation with high conditions to be removed by Ecological Vegetation Class Conservation Status
- the lowest potential impacts on known or registered sites of Aboriginal and historic heritage significance
- the smallest number of dwellings within 100 m, 200 m and 300 m of the alignment corridor.

Further detail on the options assessment process is provided in the EES Attachment IV: *Options assessment*.

9 IMPACT ASSESSMENT – PREFERRED ALIGNMENT

9.1 HYDROGEOLOGICAL CONSIDERATION ON THE PREFERRED ALIGNMENT

As discussed in Section 7.1 all four alignments involve the same potential risks and impacts with no distinguishable difference between the four alignments. Sections 9, 10 and 11 detail the impacts and proposed mitigation measures for the preferred C2 alignment.

9.1.1 CHANGES TO GROUNDWATER LEVELS

9.1.1.1 QUATERNARY ALLUVIAL AQUIFER

The preferred C2 alignment crosses the QA at Main Lead Road and again over Yam Holes Creek and the associated floodplain. The embankments associated with the C2 alignment do not result in a material impact to groundwater levels during construction or operational phases. The impact to the groundwater levels in the QA is low.

9.1.1.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

The proposed excavations for road cuttings on the preferred C2 alignment through the Beaufort and Pyrenees formations are not expected to intersect groundwater. The impact to groundwater during construction and operation is negligible.

9.1.2 CHANGES TO GROUNDWATER QUALITY

9.1.2.1 QUATERNARY ALLUVIAL AQUIFER

The potential impacts to quality described in Sections 7.2.1 and 7.2.2 were consistent across all options and equally apply to the preferred C2 alignment. The QA is susceptible to disturbance to saline soils, accidental spills and leaks through infiltration during the construction and ongoing phases of the project. RRV standard environmental management procedures and will be implemented as part of the contractual requirements to mitigate impacts from construction and operational phases. These standard controls are described below in Section 10 and are considered sufficient in managing and mitigating potential impacts. Impacts to groundwater quality during the construction and operation with standard controls in the QA are assessed as low.

9.1.2.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

As groundwater was not encountered, it is not likely that the project would impact the groundwater quality of the Beaufort and Pyrenees formations aquitard. Impact to groundwater quality during construction and operation in the Beaufort and Pyrenees formation aquitard are assessed as low.

10 MITIGATION

10.1 ENVIRONMENTAL MANAGEMENT FRAMEWORK

The development of an EMF would provide a transparent framework with clear accountabilities for managing environmental effects and hazards associated with construction and operation phases of the project in order to achieve acceptable environmental outcomes.

Environmental management plans (EMPs) form part of the EMF and are considered standard requirements for civil construction sites (EPA Victoria 2020). An EMP, such as a groundwater or water management plan, to monitor the impacts to surface and groundwater is required to be developed by the principal contractor after the EES process and prior to construction. It is to include proposed objectives, monitoring requirements and include management responses to impacts in the event that the proposed objectives have been exceeded.

The principal contractor will be responsible for developing a suitable groundwater monitoring plan for the period of construction.

10.2 DESIGN REQUIREMENTS

Incorporation of spans of culverts and bridges over earth embankment options across the Yam Holes Creek has been included in the functional design and should be carried through in the detailed design to reduce the loading effect on the fine grain silts and clay in the QA.

Any compression of the fine-grained silts and clay from culvert and bridge structures would not be expected to impact groundwater levels either up or down gradient of the embankment as the low permeability limits any meaningful groundwater flux.

10.3 STANDARD CONTROLS

Based on the existing groundwater conditions and assessment of groundwater risks associated with the project, non-standard water management or mitigation measures are not considered necessary. Standard RRV environmental and engineering management procedures should be applied to the project design, construction and operational phases of the project.

Mitigation measures for the potential impacts associated with the project are provided in Table 10.1.

Table 10.1 Summary of potential impacts and proposed mitigation measures

POTENTIAL IMPACTS	PROPOSED MITIGATION MEASURES	MITIGATION FOR INCORPORATION INTO EMF	PROJECT PHASE
Road design	Incorporation of culvert and bridge structures across the Yam Holes Creek floodplain.	Detailed design to include culvert and bridge structures across the Yam Holes Creek floodplain.	Design
Accidental spills	Mitigation measures shall comply with VicRoads environmental management procedures (VicRoads 2014) which include: — nominated fuel and chemical storage areas — nominated points for the refuelling and fluid top up of vehicles and plant — spill kits for cleaning up chemical, oil and fuel spillages — personnel purpose trained.	Development of a Construction EMP with consideration to groundwater impacts.	Construction
Disturbance of saline soils or existing contamination during in construction resulting in mobilisation of contaminants into groundwater	Management of potential impacts on groundwater in accordance with S177, B2, Groundwater: — develop a groundwater management plan — contaminated soils identified in reports of other environmental assessments are to be considered — soil excavated in known and suspected to be saline or contaminated areas to be routinely tested prior to and during earthworks.	Development of a groundwater management plan to manage potential contamination and saline soil impacts to groundwater.	Construction

11 RESIDUAL IMPACTS

As all initial impacts to groundwater were assessed as low to negligible, no additional controls from those described in Section 10 are recommended. The residual impacts for groundwater remain as initially assessed, ranging from negligible to low.

11.1 CHANGES TO GROUNDWATER LEVELS

11.1.1 QUATERNARY ALLUVIAL AQUIFER

The preferred C2 alignment crosses the QA at Main Lead Road and again over Yam Holes Creek and the associated floodplain. The embankments associated with the C2 alignment do not result in a material impact to groundwater levels during construction or operational phases. The residual impact to groundwater levels in the QA is low.

11.1.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

The proposed excavations for road cuttings on the preferred C2 alignment through the Beaufort and Pyrenees formations are not expected to intersect groundwater. The residual impact to groundwater from excavations during construction and through operational phases in the Beaufort and Pyrenees formations is negligible.

11.2 CHANGES TO GROUNDWATER QUALITY

11.2.1 QUATERNARY ALLUVIAL AQUIFER

The QA is susceptible to accidental spills and leaks through infiltration during the construction and ongoing phases of the project. RRV standard environmental management procedures and will be implemented as part of the contractual requirements to mitigate impacts from construction and operational phases. These standard controls are described in Section 10 will managing and mitigating potential impacts related to groundwater quality. Residual impacts to groundwater quality during construction and operation, with standard controls in the QA are assessed as low.

11.2.2 BEAUFORT AND PYRENEES FORMATIONS AQUITARD

As groundwater was not encountered in the Beaufort and Pyrenees formations, residual impacts to groundwater quality during construction and operations are assessed as low.

12 CONCLUSION

This groundwater impact assessment report forms part of the Beaufort Bypass EES and provides an overview of existing hydrogeological conditions, and associated groundwater impact assessment within the investigation area.

In relation to the impact assessment each of the four alignment options involve the same potential impacts. All alignment options include large cuts through the Beaufort and Pyrenees formations and all involve the potential for embankment structures over Main Lead Road at the western end and at the eastern end; Beaufort-Lexton Road, Racecourse Road and the Melbourne-Ararat rail line. Therefore, each option was assessed as having the same potential impacts.

12.1 EXISTING CONDITIONS

The existing hydrogeological conditions within the investigation area can be characterised as a localised QA largely limited to drainage lines and low-lying areas surrounding Beaufort. This material is heterogenous in nature with drilling results indicating that the material is unsaturated in certain areas and saturated in others.

Water quality within the QA is saline with TDS concentrations falling within Segment C as defined in the SEPP (Waters) (EPA 2018) for groundwater with all protected beneficial uses listed (Table 5.2). The QA is observed to be low yielding and largely consists of silts and clays with low hydraulic conductivity.

The underlying geological basement of the Beaufort and Pyrenees formations form a regional low yielding aquitard. Geotechnical drilling along the route alignment failed to intersect groundwater at depths greater than the base of the deepest proposed cut. Both hydrogeological units are poorly utilised with few registered groundwater users within the investigation area. Mapped GDEs are largely associated with the alluvial terraces of the ephemeral creeks.

12.2 RISK ASSESSMENT

The potential impacts to the existing groundwater environment were identified based on source – pathway – receptor approach. Potential impacts were categorised as impacts on groundwater level and impact on groundwater quality. Impacts that alter the groundwater level effects the hydraulic gradient and groundwater movement. Therefore, alteration of water levels impacts the availability of groundwater for both environmental and anthropogenic groundwater users. Changes to groundwater quality have the potential to impact those who partially or fully rely on groundwater, this includes both environmental users and for abstractive use.

A multi-criteria risk assessment was completed assessing the potential risks on each alignment. All alignments include large cutting through the Beaufort and Pyrenees formations and loading of alluvial material to the east and west of the study area. Therefore, each of the proposed alignment routes were assessed as having the same impact and risk rating with no preferred option identified. The risk assessment identified the following potential impacts and risks to groundwater:

- identified risks that have the potential to change to groundwater levels include:
  - dewatering of aquifer caused by cuttings and excavations
  - changes to aquifer properties caused by surging for embankment structures
  - groundwater extraction – construction water supply.
- identified risks that have the potential to change groundwater quality includes:
  - groundwater contamination (spills, material handling, waste management during construction and operation)
  - groundwater extraction (construction water supply)
  - aquifer interaction arising from excavation, trenching.

12.3 IMPACT ASSESSMENT

The potential impacts were assessed considering the project phases of construction and ongoing operation, and short or long-term nature of the impact.

The conceptual understanding of hydrogeological conditions derived from desktop and site investigations has indicated the absence of groundwater within the regional aquitard of the outcropping Pyrenees and Beaufort formations. The potential impacts to groundwater from excavation and cutting is minimal. The low yielding aquitard properties of these formations also make it an unsuitable resource for supplying construction water requirements. Potential impacts to Beaufort and Pyrenees formations arising from the construction and operation are negligible.

Similarly, the QA is variably and unsaturated in some areas. Where saturated it is observed as low yielding with the primary water bearing zones associated to coarse grained basal lens rather than within the overlying fine-grained clays and silts. The potential impacts arising from the construction of embankment structures over the alluvial material would be realised within the fine-grained clays and silts which already have a low hydraulic conductivity with no meaningful groundwater flux. The basal coarse-grained material do not experience magnitude reductions in hydraulic conductivity due to loading and compression and therefore impacts to groundwater flux and levels through this layer are considered negligible.

Additionally, the changes made during the iterative development of the functional design during this assessment have also had a mitigating effect to the potential impacts to groundwater. The inclusion of box culverts and bridge spans reduces the potential loading effect across the alluvial aquifer.

Potential impacts to groundwater quality arising from contamination from construction and operation can be suitably mitigated and managed through standard controls and the environmental management framework. Potential impacts to groundwater quality are considered negligible.

12.4 CONCLUSION

The identified impacts to groundwater as a result of the project has been assessed within this groundwater impact assessment. The outcome of this assessment has identified that groundwater is limited to the localised QA and thin deposits of alluvial material located within drainage lines. Groundwater is absent within the depths of the cuts throughout the basement Beaufort and Pyrenes formations.

As such, residual impacts to groundwater beneficial uses, the mobilisation of contaminants, or the degradation of GDEs, when standard controls are implemented is considered low to negligible.

The development of an EMF is required for large construction projects and would include consideration to surface and groundwater management to monitor prior, during and after construction. The standard controls described in Section 10 are expected to be suitable to monitor and manage any potential impacts to groundwater.

13 LIMITATIONS

This Report is provided by WSP Australia Pty Limited (*WSP*) for Regional Roads Victoria (*Client*) in response to specific instructions from the Client and in accordance with WSP's proposal dated 2 September 2020 and agreement with the Client dated 10 September 2020 (*Agreement*).

13.1 PERMITTED PURPOSE

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (*Permitted Purpose*).

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The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions and limitations set out in the Report or otherwise communicated to the Client.

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REFERENCES

- ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Volumes 3 and 4*. Australian and New Zealand Environment Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.
- Agriculture Victoria (2017) *Salinity Province 8, Beaufort*, accessed 19/02/18, http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/salinity-province-8-beaufort.
- Bureau of Meteorology (BoM) (2018) *Climate data online*, accessed 20/03/18, http://www.bom.gov.au/climate/data/.
- Bureau of Meteorology (BoM) (2017) *Groundwater dependent ecosystems atlas*, accessed 15/07/17, http://www.bom.gov.au/water/groundwater/gde/index.shtml.
- Crosbie, R., Morrow, D., Cresswell, R., Leaney, F., Lamontagne, S., & Lefournour, M. (2012) *New insights to the chemical and isotopic composition of rainfall across Australia.* CSIRO Water for a Healthy Country Flagship, Australia.
- Department of Environment, Land Water and Planning (DELWP) (2017a) *Groundwater resource reports*, accessed 12/7/17, http://www.depi.vic.gov.au/water/groundwater/groundwater-resource-reports.
- Department of Environment, Land Water and Planning (DELWP) (2017b) *Groundwater bore information online*, accessed 13/7/17 http://data.water.vic.gov.au/monitoring.htm.
- Department of Environment, Land Water and Planning (DELWP) (2016) Scoping Requirements Beaufort Bypass Project Environment Effects Statement.
- Department of Economic Development, Jobs, Transport and Resources (2010) *Victoria GIS Data Geological units 250k*.
- EPA Victoria (2020) Civil Construction, building and demolition guide, Publication 1834.
- EPA Victoria (2003) State Environment Protection Policy (SEPP) (Waters of Victoria), Publication 905.
- EPA Victoria (2009) *Industrial Waste Resource Guidelines (IWRG)*, Publication IWRG621.
- EPA Victoria (2018) State Environment Protection Policy (SEPP) (Waters), Publication S499.
- GHD Pty Ltd (2012) VicRoads Report for Western Highway Project Section 2 (Beaufort to Ararat), Groundwater Impact Assessment Report.
- Government of Victoria (2001) *Environment Protection Act 1970*.
- Government of Victoria (2002) State Environment Protection Policy (SEPP) (Groundwaters of Victoria), Government of Victoria.
- Hatton and Evans (1998) *Dependence of ecosystems on groundwater and its significance to Australia*. Land and Water Resources Research and Development Corporation, Canberra ACT.
- National Water Quality Management Strategy (NHMRC) (2011) *Australian Drinking Water Guidelines 6, Version 3.3* updated November 2016.
- National Uniform Drillers Licensing Committee (2011) Minimum construction requirements for water bores in Australia 3rd edition.
- Regional Roads Victoria (2019) Beaufort Bypass Options Assessment Report.
- Richardson, S., Irvine, E., Barber, S., & Bonneville, B. (2011) *Australian groundwater-dependent ecosystems toolbox part 1: assessment framework*. Canberra: Waterlines report, National Water Commission.

- Southern Rural Water (2017) Groundwater licencing information. accessed 13/7/17 http://www.srw.com.au/customers/forms/.
- VicRoads (2014) *Section 177 Environmental Management (Major), Part G*. Available at http://epbcnotices.environment.gov.au/_entity/annotation/52074b35-0c87-e711-994c-005056ba00a8/a71d58ad-4cba-48b6-8dab-f3091fc31cd5?t=1503619200353.
- WSP (2018) Beaufort Bypass Environmental Effects Statement, Geotechnical Investigation.
- WSP (2021a) Beaufort Bypass EES – Soil and Geology Impact Assessment.
- WSP (2021b) Beaufort Bypass EES – Surface Water Impact Assessment
- WSP (2021c) Beaufort Bypass EES – Flora and Fauna Impact Assessment.

APPENDIX A

RISK REGISTER

Project	Beaufort Bypass	**Lead**	WSP
Description	EES Environmental Risk Register	**Last Updated**	Dec-20

				Impact Pathway					Initial Risk				Residual Risk		
Risk No.	**Alignment Option**	**Discipline**	**Project Phase**	**Project Activity / Aspect**	**Primary Environmental Impact**	**Secondary Environmental Impact (if applicable) (further details provided in column V)**	**Description of risk and impact**	**Standard Controls (i.e. VicRoads Contract Specification e.g. Section 177, Section 720, Section 750; EPA Environmental Guidelines for Major Construction Sites and other relevant industry standards) (please detail)**	**Consequence**	**Likelihood**	**Risk Rating**	**Additional Controls (recommended to further reduce risk)**	**Consequence**	**Likelihood**	**Risk Rating**
GW1d	C2	Groundwater	Initial	Design	Changes in Hydrogeology	Impacts to Biodiversity	Reduction in groundwater levels affecting existing users/sensitive receptors - such as registered and unregistered groundwater bores (water users), GDEs and surface waters systems.	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater, - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan The Contractor shall consider the beneficial uses, quality and quantity of groundwater when determining the ongoing management of groundwater	Minor	Possible	Low	Risk is already considered acceptable. The groundwater management plan developed (GMP) by the Principal contractor should include sufficient provisions to capture any changes to the potential risk throughout the detailed design and construction phases. If additional geotechnical investigations, or design changes result in an unacceptable change to the risk ranking, then the GMP must incorporate suitable flexibility to incorporate additional controls if required.	Minor	Rare	Negligible
GW2d	C2	Groundwater	Development	Earthworks	Impacts groundwater quality	Impacts to Biodiversity	Disturbance of existing soils with elevated levels of contamination, including salinity, during construction resulting in mobilisation of contaminants into groundwater	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater - Contract Specification Section 177.G1 Fuels and Chemicals - Contract Specification Section 177.E Contaminated Soils and Material - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan Groundwater encountered on site shall be assessed for the opportunity for reuse as a non-potable water source Comply with - Environment Protection Act 1970. - Environment Protection Amendment Act 2018 - Occupational Health and Safety Act 2004	Minor	Possible	Low	Contaminated soils, included soils with elevated salinity identified in reports of other environmental assessments are to be considered - soil excavated in known and suspected salinity affected areas to be routinely tested prior to and during earthworks	Minor	Rare	Negligible
GW3d	C2	Groundwater	Development	Earthworks	Changes in Hydrogeology	Impacts to Biodiversity	Excavation of cuttings resulting in groundwater inflows during construction (and operation), leading to groundwater drawdown and changes to groundwater flow paths	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater, - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan Groundwater encountered on site shall be assessed for the opportunity for reuse as a non-potable water source	Minor	Possible	Low	Risk is already considered acceptable. The groundwater management plan developed (GMP) by the Principal contractor should include sufficient provisions to capture any changes to the potential risk throughout the detailed design and construction phases. If additional geotechnical investigations, or design changes result in an unacceptable change to the risk ranking, then the GMP must incorporate suitable flexibility to incorporate additional controls if required.	Minor	Rare	Negligible
GW4d	C2	Groundwater	Development	Earthworks	Impacts groundwater quality		Inflow of contaminated groundwater presenting OH&S and ongoing environmental compliance issues	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater, - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan Groundwater encountered on site shall be assessed for the opportunity for reuse as a non-potable water source	Minor	Possible	Low	- If groundwater is encountered during 'Design Stage' works and the risk of groundwater inflow is established, then provisions for the installation of groundwater observation bores to test water quality should be incorporated into the GMP. Groundwater is to be tested and compare against water quality guidelines for ANZECC 2000 Primary contact (recreational use) - Elimination to the extent practical the source/s of contamination so as to minimise potential OH&S and impact/s to environmental values - adopt appropriate precautionary Personal Protective Equipment (PPE) when handling residual contaminated groundwater - apply applicable treatment measures to meet disposal guidance criteria prior to returning water to local waterways, or off-site disposal (as contaminant levels dictate).	Minor	Unlikely	Low

				Impact Pathway					Initial Risk				Residual Risk		
Risk No.	Alignment Option	Discipline	Project Phase	Project Activity / Aspect	Primary Environmental Impact	Secondary Environmental Impact (if applicable) (further details provided in column V)	Description of risk and impact	Standard Controls (i.e. VicRoads Contract Specification e.g. Section 177, Section 720, Section 750; EPA Environmental Guidelines for Major Construction Sites and other relevant industry standards) (please detail)	Consequence	Likelihood	Risk Rating	Additional Controls (recommended to further reduce risk)	Consequence	Likelihood	Risk Rating
GW5d	C2	Groundwater	Development	Construction	Impacts groundwater quality	Impacts to Biodiversity	Construction works impacting water quality in watercourses, GDE environments, and wetlands (as applicable) (sedimentation and salinity)	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater, - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan The Contractor shall consider the beneficial uses, quality and quantity of groundwater when determining the ongoing management of groundwater	Minor	Possible	Low	Risk is already acceptable, development of the GMP combined with other controls within the EMF is sufficient for control and mitigation of risk.	Minor	Unlikely	Low
GW6d	C2	Groundwater	Operation/Maintenance	Operation	Impacts groundwater quality	Impacts to Biodiversity	Water quality impacts during operation of road	Management of potential impacts on groundwater in accordance with: - Contract Specification Section 177, B2, Groundwater, - Environmental guidelines for Civil construction, building and demolotion guide (EPA Publication 1834) - Construction Techniques for Sediment Pollution Control (EPA Publication 275) Develop a groundwater management plan The Contractor shall consider the beneficial uses, quality and quantity of groundwater when determining the ongoing management of groundwater	Minor	Possible	Low	Risk is already acceptable using standard controls this includes design measures to mitigate and manage ongoing (post construction stage) road run-off and associated operations pollution, as per VicRoads/RRV guidance standards	Minor	Unlikely	Low

APPENDIX B

WATER QUALITY

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EM1913184**	Page	: 1 of 4
Client	: **WSP Australia Pty Ltd**	Laboratory	: Environmental Division Melbourne
Contact	: ALISTAIR STEWART	Contact	: Graeme Jablonskas
Address	: Level 15, 28 Freshwater Place SOUTHBANK VIC, AUSTRALIA 3006	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: ----	Telephone	: +6138549 9609
Project	: PS102347-117	Date Samples Received	: 15-Aug-2019 10:55
Order number	:	Date Analysis Commenced	: 15-Aug-2019
C-O-C number	: 90363	Issue Date	: 19-Aug-2019 16:03
Sampler	: JEANNE DROUET		
Site	: Beaufort		
Quote number	: EN/008/18 B		
No. of samples received	: 3		
No. of samples analysed	: 3		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EA010-P: Electrical Conductivity @ 25°C was analysed by manual method (EA010).
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	BH13	BH13 YHC	Black Raglan Bridge	----	----
			Client sampling date / time	14-Aug-2019 11:45	14-Aug-2019 12:30	14-Aug-2019 13:30	----	----
				EM1913184-001	EM1913184-002	EM1913184-003	--------	--------
				Result	Result	Result	----	----
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	**7.31**	**6.88**	**6.50**	----	----
EA006: Sodium Adsorption Ratio (SAR)								
^ Sodium Adsorption Ratio	----	0.01	-	**14.1**	**4.15**	**4.81**	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	**5400**	**518**	**589**	----	----
EA016: Calculated TDS (from Electrical Conductivity)								
Total Dissolved Solids (Calc.)	----	1	mg/L	**3510**	**337**	**383**	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	**755**	**67**	**68**	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**394**	**28**	**14**	----	----
Total Alkalinity as CaCO3	----	1	mg/L	**394**	**28**	**14**	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	**160**	**9**	**9**	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	**1760**	**156**	**193**	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**73**	**7**	**4**	----	----
Magnesium	7439-95-4	1	mg/L	**139**	**12**	**14**	----	----
Sodium	7440-23-5	1	mg/L	**889**	**78**	**91**	----	----
Potassium	7440-09-7	1	mg/L	**19**	**3**	**2**	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	**0.004**	**0.002**	**0.001**	----	----
Boron	7440-42-8	0.05	mg/L	<0.05	<0.05	<0.05	----	----
Barium	7440-39-3	0.001	mg/L	**0.096**	**0.028**	**0.030**	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.012**	**0.003**	**0.001**	----	----
Chromium	7440-47-3	0.001	mg/L	**0.002**	**0.004**	**0.004**	----	----
Copper	7440-50-8	0.001	mg/L	**0.002**	**0.005**	**0.003**	----	----
Manganese	7439-96-5	0.001	mg/L	**2.52**	**0.117**	**0.024**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.052**	**0.009**	**0.005**	----	----

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	BH13	BH13 YHC	Black Raglan Bridge	----	----
Client sampling date / time				14-Aug-2019 11:45	14-Aug-2019 12:30	14-Aug-2019 13:30	----	----
				EM1913184-001	**EM1913184-002**	**EM1913184-003**	--------	--------
				Result	Result	Result	----	----
EG020F: Dissolved Metals by ICP-MS - Continued								
Lead	7439-92-1	0.001	mg/L	<0.001	**0.004**	<0.001	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Zinc	7440-66-6	0.005	mg/L	**0.015**	**0.040**	**0.010**	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**0.4**	<0.1	<0.1	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.16**	**0.06**	**0.04**	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	<0.01	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	<0.01	**0.07**	**0.05**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	**0.07**	**0.05**	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**2.6**	**1.6**	**1.6**	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**2.6**	**1.7**	**1.6**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**2.32**	**0.18**	**0.07**	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	**0.06**	**0.09**	**0.02**	----	----
EN055: Ionic Balance								
ø Total Anions	----	0.01	meq/L	**60.8**	**5.15**	**5.91**	----	----
ø Total Cations	----	0.01	meq/L	**54.2**	**4.81**	**5.36**	----	----
ø Ionic Balance	----	0.01	%	**5.74**	**3.42**	**4.88**	----	----

ABOUT US

WSP is one of the world's leading engineering professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services. With 43,600 talented people in more than 550 offices across 40 countries, we engineer projects that will help societies grow for lifetimes to come.