VicRoads

Western Highway Project – Section 3: Ararat to Stawell

Groundwater Impact Assessment Report

November 2012

This Groundwater Assessment Report ("Report"):

1. *Has been prepared by GHD Pty Ltd ("GHD") for VicRoads;*
2. *May only be used for the purpose of informing the Environment Effects Statement and Planning Scheme Amendment for the Western Highway Project (and must not be used for any other purpose); and*
3. *May be provided to the Department of Planning and Community Development for the purpose of public exhibition as part of the Environment Effects Statement and Planning Scheme Amendment for the Western Highway Project.*

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in Section '4. Methodology' of this Report.

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing the Report ("Assumptions"), as specified in Section '4. Methodology' and throughout this Report.

GHD excludes liability for errors in, or omissions from, this Report arising from or in connection with any of the assumptions being incorrect.

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Executive Summary

VicRoads is progressively upgrading the Western Highway to a four-lane divided highway between Ballarat and Stawell (Western Highway Project). The Western Highway Project consists of three sections, to be constructed in stages. Section 3 (Ararat to Stawell) of the Western Highway Project (the Project) is the subject of this report.

On 27 October 2010, the Victorian Minister for Planning advised that an Environment Effects Statement (EES) would be required to identify the anticipated environmental effects of the Project. GHD has been commissioned by VicRoads to undertake a groundwater impact assessment for the Project as part of the EES.

Following a multi-criteria assessment of numerous potential alignment options, VicRoads selected a final proposed alignment for the Project which was subject to the risk and impact assessment presented in this report.

This report, together with other technical reports prepared by GHD and other consultants as part of the EES, will inform VicRoads' selection of the preferred alignment for the Project. VicRoads' preferred alignment for the Project will be documented in the EES.

The EES scoping requirements for the groundwater impacts assessment of the Project are detailed in section 2 of this report. In summary, they require a characterisation of the groundwater in the Project Area, an identification and assessment of the potential effects of road construction and operation activities on groundwater, an identification and assessment of the potential effects of groundwater on road construction and integrity, and an identification of any measures to avoid, mitigate and manage any potential adverse effects.

The groundwater impact assessment undertaken by GHD involved a review of available information to assess the existing groundwater conditions within the Project Area and an assessment of the proposed alignment against the existing conditions to determine the potential positive and negative impacts of the Project on groundwater both during construction and operation.

In summary, the assessment identified the following potential impacts and risks:

- Changes to groundwater availability from:
  - Dewatering created by cuttings;
  - Groundwater use (construction water supply);
  - Changes to aquifer character (compaction from aquifer depressurisation or surcharge loading);
  - Severance to access to groundwater supplies
- Changes to groundwater quality from:
  - Groundwater contamination (materials storage and handling, spills, waste management);
  - Activation of acid sulphate soil conditions; and
  - Changes in groundwater flow (e.g. cuttings).

All of the identified risks are considered to be negligible or low provided that the identified mitigation measures (specified in Section 7 of this report) are implemented.

Over much of the Project Area the existing groundwater quality is saline and the existing level of groundwater development is low, generally being limited to stock and non-potable domestic use. However, in some areas where shallow water tables, springs or perched water table aquifers are disrupted (where groundwater flow is severed, aquifer materials drained or flow dislocated), and the groundwater quality in these areas is such that it could support sensitive ecosystems, then the impact may be more significant. Geotechnical investigations would be undertaken to inform the design of the road (and cuttings) and likelihood of intersecting groundwater in these areas. More detailed information from the geotechnical investigations, coupled with the available measures to mitigate groundwater inflows, would suggest that the overall impact of the Project on the groundwater environment could be considered to be minor.

1. Introduction

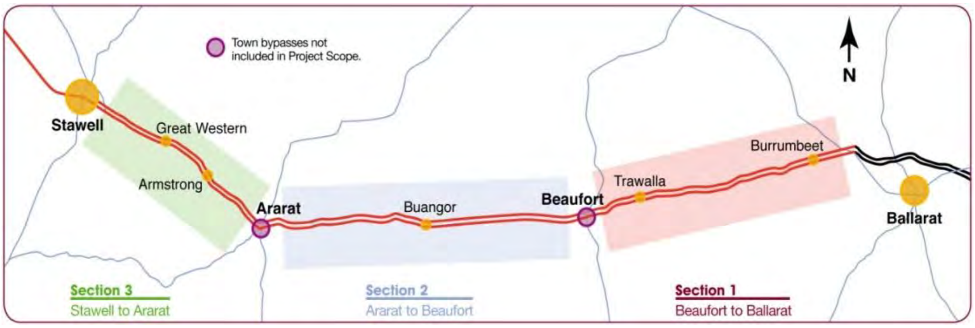
1.1 Background and Project Description

The Western Highway (A8) is being progressively upgraded to a four-lane divided highway for approximately 110 km between Ballarat and Stawell. As the principal road link between Melbourne and Adelaide, the Western Highway serves interstate trade between Victoria and South Australia and is the key corridor through Victoria's west, supporting farming, grain production, tourism and a range of manufacturing and service activities. Currently, more than 5,500 vehicles travel on the highway west of Ballarat each day, including 1,500 trucks.

The Western Highway Project consists of three stages, illustrated in Figure 1:

- Section 1: Ballarat to Beaufort
- Section 2: Beaufort to Ararat
- Section 3: Ararat to Stawell

Figure 1 The Western Highway Project



Works on an initial 8 km section between Ballarat and Burrumbeet (Section 1A) commenced in April 2010 and will be completed in 2012. Construction for Section 1B (Burrumbeet to Beaufort-Carngham Road) commenced in early 2012 and is expected to be completed by June 2014. The last 3 km section from Beaufort-Carngham Road to Smiths Lane in Beaufort (Section 1C) commenced in late 2011 and will finish in 2012.

Separate Environment Effects Statements (EESs) and Planning Scheme Amendments (PSAs) must be prepared for both Sections 2 and 3. It is expected that Sections 2 and 3 will be completed and opened in stages through to 2016 subject to future funding.

Section 2 of the Project commences immediately west of the railway crossing (near Old Shirley Road) to the west of the Beaufort township and extends for a distance of approximately 38 km to Heath Street, Ararat.

Section 3 of the Project commences at Pollard Lane, Ararat and extends for approximately 24 km to Gilchrist Road, Stawell.

The EES will focus on assessment of the proposed ultimate upgrade of the Western Highway between Beaufort and Stawell to a duplicated highway standard complying with the road category 1 (freeway) of VicRoads Access Management Policy (AMP1). The project includes a duplicated road to allow for two lanes in each direction separated by a central median.

The EES has also considered a proposed interim upgrade of the Western Highway to a highway standard complying with the VicRoads Access Management Policy AMP3. When required, the final stage of the project is proposed to be an upgrade to freeway standard complying with AMP1.

The proposed interim stage of the Project (AMP3) would provide upgraded dual carriageways with wide median treatments at key intersections. Ultimately, the Western Highway is proposed to be a freeway (AMP1) where key intersections would be grade separated, service roads constructed and there would be no direct access to the highway.

To date $505 million has been committed for the Western Highway Project by the Victorian Government and the Australian Government as part of the Nation Building Program.

Highway improvements for the three sections between Ballarat and Stawell would involve:

- Constructing two new traffic lanes adjacent to the existing highway, separated by a central median.
- Converting the existing highway carriageway to carry two traffic lanes in each direction.
- Constructing sections of new four-lane divided highway on a new alignment.

In addition to separating the traffic lanes, highway safety would be improved with sealed road shoulders, safety barriers, protected turning lanes, intersection improvements, and service lanes for local access at some locations.

Town bypasses of Beaufort and Ararat are not included in the current proposals. Beyond Stawell to the Victorian border, ongoing Western Highway improvements would continue with shoulder sealing works, new passing lanes and road surface improvements.

The aims/objectives of this Project are to:

- Provide safer conditions for all road users by:
  - Reducing the incidence of head-on and run-off-road crashes;
  - Improving safety at intersections; and
  - Improving safety of access to adjoining properties.
- Improve efficiency of freight by designing for High Productivity Freight Vehicles.
- Provide adequate and improved rest areas.
- Locate the alignment to allow for possible future bypasses of Beaufort and Ararat.

1.2 Project and Study Area

1.2.1 Project Area

The Project Area was defined for the purposes of characterising the existing conditions for the Project, and to consider alignment alternatives. The Project Area encompasses a corridor extending generally up to 1500 m either side (east and west) of the edge of the road reserve, except around Great Western where the Project Area extends up to 1800 m (encompassing the extent of new alignment possibilities).

1.2.2 Study Area

The Study Area for this Groundwater assessment is the same as the Project Area described above.

1.2.3 Proposed Alignment

A multi-criteria assessment of alignment options was conducted based on information from the existing conditions assessments. The outcome was the selection of a proposed alignment for further consideration in the EES for the Project. The proposed alignment and associated construction area are the subject of the risk and impact assessment presented in this report and are described in more detail in Section 4.2. The assessment of alignment options and selection of the proposed alignment is documented in Chapter 5 of the EES, and in the Options Assessment Paper (Technical Appendix to the EES).

2. EES Scoping Requirements

2.1 EES Objectives

For the Groundwater aspects of the Western Highway Project, the relevant objective outlined in the EES scoping requirements is:

'To protect catchment values, surface water and groundwater quality, stream flows and floodway capacity, as well as to avoid impacts on protected beneficial uses.'

2.2 EES Requirements

The EES Scoping Requirements for Groundwater aspects are as follows:

'The EES should assess the potential effects of the project on groundwater, in the context of the State Environment Protection Policy (Groundwaters of Victoria).' Specifically, it should:

- *Characterise the groundwater in the Project Area in terms of location, behaviour, and quality, including its protected beneficial uses under the State Environment Protection Policy (Groundwaters of Victoria);*
- *Identify potential effects of road construction and operation activities on groundwater and any potential effects of groundwater quality on road construction and integrity (e.g. salinity);*
- *Identify measures to avoid, mitigate and manage any potential effects including any relevant design features of the road or techniques for construction; and,*
- *Describe likely residual effects of road construction and operation activities on groundwater in the Project Area.'*

Interrelated objectives exist between the groundwater and biodiversity and habitat, surface water and geology aspects of the EES. These relate to the protection of catchment values and the maintenance of ecological habitats of both fauna and flora i.e. habitats that may directly or indirectly rely upon groundwater.

3. Legislation, Guidelines and Policies

3.1 State

This section provides an overview of the key legislation and policy documents which form the regulatory framework for groundwater in Victoria.

Groundwater in Victoria is managed primarily through the following legislation:

- *Water Act* (1989); and
- *Environment Protection Act* (1970).

These two Acts provide the principal framework for the management of groundwater. In the context of groundwater, the *Water Act* (1989) primarily deals with the sustainable and equitable management and allocation of the resource. It also provides a means for the protection (and enhancement) of all elements of the terrestrial phase of the water cycle.

The *Environment Protection Act* (1970) empowers the Environment Protection Authority (EPA) to implement regulations and protect the State's environment.. The Act regulates the discharge or emission of waste to water, land or air by a system of works approvals and licences. It has the objective of preventing and managing pollution and environmental damage, and for the setting of environmental quality goals and programs.

A number of sub-ordinate legislation and guidelines exist which further expand upon the general tenets of the *Water Act* and *Environment Protection Act*. State Environment Protection Policies (SEPPs) set out policies of the Government to control and reduce environmental pollution and have been formulated for discharges to atmosphere, water, land and noise emissions. They 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).

In terms of groundwater impacts, an objective of the EES Scoping Requirements is the requirement to protect groundwater quality. Under the *Environment Protection Act* (1970), and upon the recommendation of the EPA, the State of Victoria enacted a State Environment Protection Policy *Groundwaters of Victoria* (1997) which has the objective to maintain and where possible, improve groundwater quality sufficient to protect existing and potential beneficial uses.

The policy forms the primary guide to determining existing impacts and risk of impacts to groundwater quality. It provides that groundwater is categorised into segments based on the groundwater salinity, with each segment having particular identified beneficial uses. The segments and their beneficial uses are summarised in Table 1.

Table 1 Protected Uses of the Segments

Beneficial Use	Segment (mg/L TDS)				
	A1	A2	B	C	D
	0 – 500	501 – 1,000	1,001 – 3,501	3,501 – 13,000	>13,000
Maintenance of Ecosystems	✓	✓	✓	✓	✓
Potable Water					
Desirable	✓				
Acceptable		✓			
Potable Mineral Water Supply	✓	✓	✓		
Agriculture, parks and gardens	✓	✓	✓		
Stock Watering	✓	✓	✓	✓	
Industrial water use	✓	✓	✓	✓	✓
Primary contact recreation (eg. swimming / bathing)	✓	✓	✓	✓	
Buildings and structures	✓	✓	✓	✓	✓

Note: TDS – Total Dissolved Solids (mg/L)

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

- There is insufficient yield;
- The background level of a water quality indicator other than TDS precludes a beneficial use;
- The soil characteristics preclude a beneficial use; or
- A groundwater quality restricted use zone has been declared.

The SEPP (*Groundwaters of Victoria*) also requires that occupational health and safety (OH&S) and odour and amenity be considered, due to the fact that vapours sourced from impacted groundwater may present a potential risk to workers, and that odours or discolouration may result in the degradation of the overall beneficial use.

Brief summaries of other relevant key SEPPs are provided below.

- State Environment Protection Policy (*Waters of Victoria*) (1988):
  - This has the objective of providing a co-ordinated approach to the protection, and where necessary, rehabilitation of the health of Victoria's waterways.
  - There have been subsequent amendments and variations, which are also appropriate to this project.

- The SEPP (*Groundwaters of Victoria*) refers to the SEPP (*Waters of Victoria)* when assessing the impact of groundwater discharging to surface water environments.
- State Environment Protection Policy (Prevention and Management of Contamination of Land) (2002):
  - In relation to groundwater, this policy sets out procedures to clean-up contaminated groundwater.
- National Environment Protection (Assessment of Site Contamination) Measure, 1999, [NEPM]:
  - Schedule A identifies the recommended process for the Assessment of Site Contamination and Schedule B of the NEPM identifies 10 general guidelines for the assessment of site contamination.

This report evaluates and presents information within the framework of the above legislation and policies. The Victorian EPA has also issued a number of guidelines which also deal with various aspects of groundwater. These guidelines and their relevance are noted below:

- EPA (Vic) Publication 668: Hydrogeological Assessment (Groundwater Quality) Guidelines:
  - Aims to promote a more consistent approach to data collection, reporting and interpretation.
- EPA (Vic) Publication 840: The Clean-up and Management of Polluted Groundwater:
  - Provides a formalised approach to the clean-up of polluted groundwater.
- EPA (Vic) Publication 669: Groundwater Sampling Guidelines:
  - Provides a standardised approach to the sampling of groundwater.
- EPA (Vic) Publication 441: A guide to the sampling and analysis of waters, wastewaters, soils and waters:
  - Provides a standardised approach to the sampling and analysis of groundwater.

In addition, there are EPA guidelines which inform (directly or indirectly) protection of groundwater during construction activities:

- EPA (Vic) Publication 480: Environmental Guidelines for Major Construction Sites:
  - These guidelines provide general information on how to avoid and minimise environmental impacts from construction activities.
- EPA (Vic) Publication 275: Construction Techniques for Sediment Pollution Control:
  - The guidelines provide recommendations on structures and strategies that reduce sediment export from construction sites.
- EPA (Vic) Publication 347: Bunding Guidelines:
  - These guidelines specifically apply to above ground storage and transfer areas used for refuelling during construction.

In the assessment of impacts to groundwater quality the following guidelines are relevant:

- ANZECC, 1992. Australian Water Quality Guidelines for Fresh and Marine Waters.
- ANZECC and ARMCANZ, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

The SEPP (*Groundwaters of Victoria*) specifies groundwater investigation objectives for various beneficial uses. For the majority of the beneficial uses, these objectives are those contained within the

ANZECC (1992). For the protection of aquatic ecosystems, reference is made to the SEPP (*Waters of Victoria*). The SEPP (*Waters of Victoria*) has been updated and refers to the ANZECC (2000) guidelines.

3.2 Federal

From a Federal perspective, the *Water* Act (2007) establishes the Murray Darling Basin Authority (MDBA) and requires the MDBA to prepare a strategic plan (Basin Plan) for the integrated and sustainable management of water resources in the Murray-Darling Basin.

Amongst a range of objectives, the Basin Plan places limits on groundwater that can be taken from the overall water resource, and implements strategies to manage (ground)water quality and salinity.

The Projects falls within the southern extent of the Murray-Darling Basin.

3.3 Groundwater Approvals

3.3.1 Approvals Requirements

The EES requires an assessment of the groundwater availability and its quality (maintenance / protection). Changes to groundwater level (availability) may:

- influence its access by existing groundwater users;
- determine interaction with construction and construction inflows,
- alter the movement of contaminated groundwater,
- result in subsidence (or heave);
- affect interactions with waterways;
- alter the water supply to dependent ecosystems; and
- lead to the generation of acid sulphate soils.

Changes to groundwater quality may influence its existing use, the health of receiving environments (for example, waterways, ecosystems) and construction methods/materials (for example, groundwater aggressivity to materials used in the construction of the Project).

Approvals may be required under the *Water Act* (1989) for the extraction, use or disposal of groundwater as part of the Project construction and its operation. Whilst approval is not required under the *Water Act* (1989) for the disposal of groundwater to surface water or the sea, such disposal must meet the water quality criteria of the SEPP (*Waters of Victoria*), prepared under the *Environment Protection Act* (1970).

In addition, it must be determined whether the Project has the potential for a significant impact on a Matter of National Environmental Significance (MNES), protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act* (1999), to occur. For example, Ramsar wetlands or a waterway containing a habitat for an endangered species.

Other approvals may be required for dewatering activities (for example, infrastructure running across public land) which may need the land manager’s consent.

3.3.2 Responsible Authority

Grampians Wimmera Mallee Water is the Rural Water Authority delegated by the Department of Sustainability and Environment in the Project Area responsible for the issuing of licenses to take and use groundwater, and for providing approval for the disposal of matter underground, under the *Water Act* (1989).

The approval process involves licensing of bores (extraction/injection) and volumes (take and use/dispose). Grampians Wimmera Mallee Water may refer applications to other agencies (for example, EPA Victoria, Catchment Management Authorities) where there are sensitive issues surrounding the proposal, and may undertake advertisement, public consultation or request technical assessment of the application. There are two Catchment Management Authorities (CMAs) which are relevant to Section 3, Glenelg-Hopkins, and Wimmera CMAs.

Whilst approval is not required for the discharge of groundwater into surface water under either the *Water Act* (1989) or *Environmental Protection Act* (1970), the latter Act requires that the discharge or emission into the waters of Victoria is at all times in accordance with the relevant SEPP, and its specified acceptable conditions (water quality objectives).

4. Methodology

4.1 Existing Conditions

4.1.1 Description

The method applied in describing the existing conditions was based on a desktop review of available literature relating to groundwater and hydrogeology of the Project Area. To complete this existing conditions description, a number of tasks were completed which are described below. The existing conditions assessment informed the ultimate selection of the proposed alignment, and the risk and impact assessment, which is described in Section 6.

To describe the existing conditions, a review of existing information was undertaken which included the following tasks:

- Review published and unpublished hydrogeological reports pertaining to the area in the immediate proximity of the Western Highway;
- Provide a description of the geology and relationships between aquifers at the local and regional scale, including the degree of confinement of the systems, the protection offered to the aquifers by the soil profile, unsaturated zone or aquitards or the potential for downward seepage through to the aquifers via fissures, permeable soils etc;
- Describe the groundwater flow systems through the distribution of groundwater potentials, water table depth and morphology, directions and rate of groundwater flow and seasonal fluctuations;
- Describe interpreted/inferred processes for recharge, discharge and interactions between surface water and groundwater;
- Describe the groundwater chemistry/quality in relation to the interpreted geology and the flow systems;
- Identify the groundwater segment and list the protected beneficial uses of the groundwater in relation to the SEPP (*Groundwaters of Victoria*);
- Identify the location of users/receptors of the groundwater systems such as bore owners, streams and wetlands; and
- Provide a concise summary of the conceptual hydrogeological model for the Western Highway Study Area.

The identification of impacts has been based upon review of the project description and experience with other linear infrastructure projects. Whilst impacts have been qualitatively assessed, in most cases a paucity of data has resulted in limited quantitative analysis of impacts. Where some data is available, a quantitative assessment of impacts has been made, and assumptions and limitations of the quantitative analysis provided within the report.

In addition, a site inspection of Section 3 was also undertaken. No subsurface intrusive investigations were completed as part of the groundwater assessment.

4.1.2 Hydrogeology Data Sources

The hydrogeological investigations have relied upon the following data sources:

- Published geological and hydrogeological mapping;
- State Groundwater Management System (Victorian Data Warehouse); and
- Existing technical reports prepared by the Victoria Geological Survey, Department of Primary Industries and Department of Sustainability and Environment.

4.1.3 Note Regarding Use of Borehole Information

This report has relied upon existing, publicly available groundwater data (State Groundwater Management System) and limitations of this data have been noted within the document.

Where borehole construction details, groundwater laboratory analysis, geophysical or pumping tests and similar work have been performed and recorded by others, the data is included and used in the form provided by others. GHD accepts responsibility for satisfying itself that the data is representative of conditions on the site but does not warrant the accuracy of the information.

Based on the review of the available groundwater information, the information quantity (and quality) is relatively poor given the low bore densities along the alignment, and in many cases groundwater information is absent e.g. bore yield, groundwater quality, depth to groundwater. In many cases, regional scale mapping, i.e. based on sparse bore data, has been adopted.

4.2 Impact and Risk Assessment

4.2.1 Process

The following impact assessment methodology was used to determine the Groundwater impact pathways and risk ratings for the Project:

1. Determine the ‘impact pathway’ (how the Project impacts on a given Groundwater value or issue).
2. Describe the ‘consequences’ of the impact pathway.
3. Determine the maximum credible ‘consequence level’ associated with the impact. Table 2 provides guidance criteria for assigning the level of consequence. The method for defining these criteria is described in this section.
4. Determine the ‘likelihood’ of the consequence occurring to the level assigned in step 3. Likelihood descriptors are provided in Table 3; and
5. Use the Consequence Level and Likelihood Level in the Risk Matrix in Table 4 to determine the risk rating.

Table 2 Groundwater Impacts Consequence Table

Project Phase	Insignificant	Minor	Moderate	Major	Catastrophic
Road Construction	Negligible change to groundwater regime, quality and availability	Temporary or slight changes to groundwater regime, quality and availability but no significant implication.	Changes to groundwater regime, quality and availability with minor implications for a localised area	Groundwater regime, quality or availability significantly compromised	Widespread groundwater resource depletion, contamination or subsidence
Road Operation	Negligible change to groundwater regime, quality and availability	Changes to groundwater regime, quality and availability but no significant implication	Changes to groundwater regime, quality and availability with minor implications for a localised area	Groundwater regime, quality or availability significantly compromised	Widespread groundwater resource depletion, contamination or subsidence

Table 3 Likelihood Guide

Descriptor	Explanation
Almost Certain	The event is expected to occur in most circumstances
Likely	The event will probably occur in most circumstances
Possible	The event could occur
Unlikely	The event could occur but not expected
Rare	The event may occur only in exceptional circumstances

Table 4 Risk Matrix

Likelihood	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Negligible	Low	Medium	High	High
Unlikely	Negligible	Low	Medium	Medium	High
Rare	Negligible	Negligible	Low	Medium	Medium

4.2.2 Consequence Criteria

Consequence criteria range on a scale of magnitude from “insignificant” to “catastrophic”. Magnitude was considered a function of the size of the impact, the spatial area affected and the expected recovery time of the environmental system. Consequence criteria descriptions indicating a minimal impact over a local area, and with a recovery time potential within the range of normal variability were considered to be at the insignificant end of the scale. Conversely, catastrophic consequence criteria describe scenarios involving a very high magnitude event, affecting a State-wide area, or requiring over a decade to reach functional recovery.

With the groundwater assessment, impacts can be generally simplified into two categories, those that effect groundwater quality, and those that effect groundwater level. Falls or rises in groundwater level effect hydraulic gradients and groundwater movement. The effect on movement of groundwater flow translates to a change in groundwater availability, be it available for environmental reserves or resource users. Similarly, changes in groundwater quality would affect those either wholly or partly reliant upon groundwater, be it for the environment or abstractive use.

The groundwater environment will change over time, particularly groundwater levels and therefore slight changes in water level, and quality can be naturally restored within an aquifer over time, e.g. water levels can recover with rainfall, which can also provide a fresh source of recharge to the groundwater system.

The groundwater consequences increase in severity with:

- Increasing area of impact;
- Increasing time to recover / return to natural or baseline conditions;
- Economics, complexity and ability to restore a groundwater to baseline conditions; and
- Whether the groundwater environment can be restored.

5. Existing Conditions

5.1 Study Area Definition

For the purposes of the EES, the groundwater Study Area encompasses a corridor extending approximately 1,500 metres in to the northeast and southwest of the edge of the existing Western Highway, except around Great Western where it extends up to 1,800 m to incorporate alignment options. In some areas this corridor has been widened to incorporate alignment options. The Study Area is shown in Figure 2.

As groundwater needs to be considered both on a local and regional scale, this report, whilst concentrating on this defined Study Area, has in some cases extended beyond the corridor.

5.2 Geology

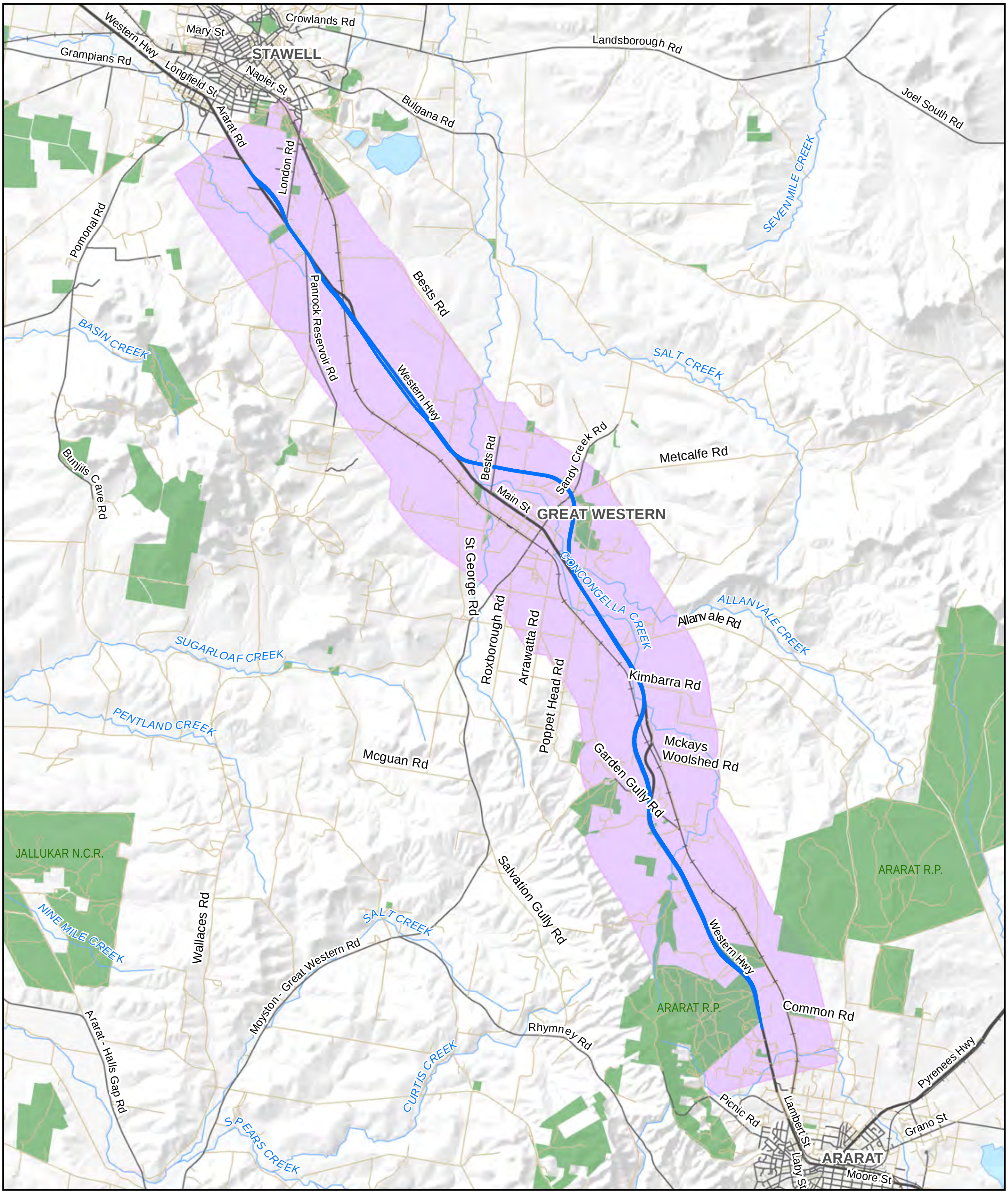
5.2.1 Regional Setting

Although somewhat structurally complex, the stratigraphy is relatively simple with only a limited number of formations occurring within the Study Area. The Study Area lies within areas previously mapped by the Victorian Geological Survey (e.g. 1:250,000 scale Ballarat and St Arnaud map sheets, and 1:100,000 scale Ararat Deep Leads map sheet).

A summary of the regional stratigraphy has been provided as Table 5 and the surface geology shown in Figure 3.

The oldest rocks in the region are the Cambro-Ordovician age indurated marine sediments of the Pyrenees Formation (part of the St Arnaud Group). These comprise monotonous sequences of thinly bedded shales, slates and sandstone. These rocks have been extensively folded and faulted, are several kilometres in thickness and have been subdivided based on biostratigraphic evidence (e.g. graptolites).

They outcrop, or appear at surface, over much of the study between Ararat and Great Western, and on the south-eastern outskirts of Stawell (refer Figure 3). Elsewhere, the basement rocks are unconformably overlain by Tertiary and Quaternary age sediments.



LEGEND

- Proposed Alignment
- Highway
- Study Area
- Sealed road (arterial & local)
- Unsealed road
- Parks

Paper Size A4

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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vicroads

VicRoads
Western Highway Project

Ararat to Stawell
Study Area

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Figure 2

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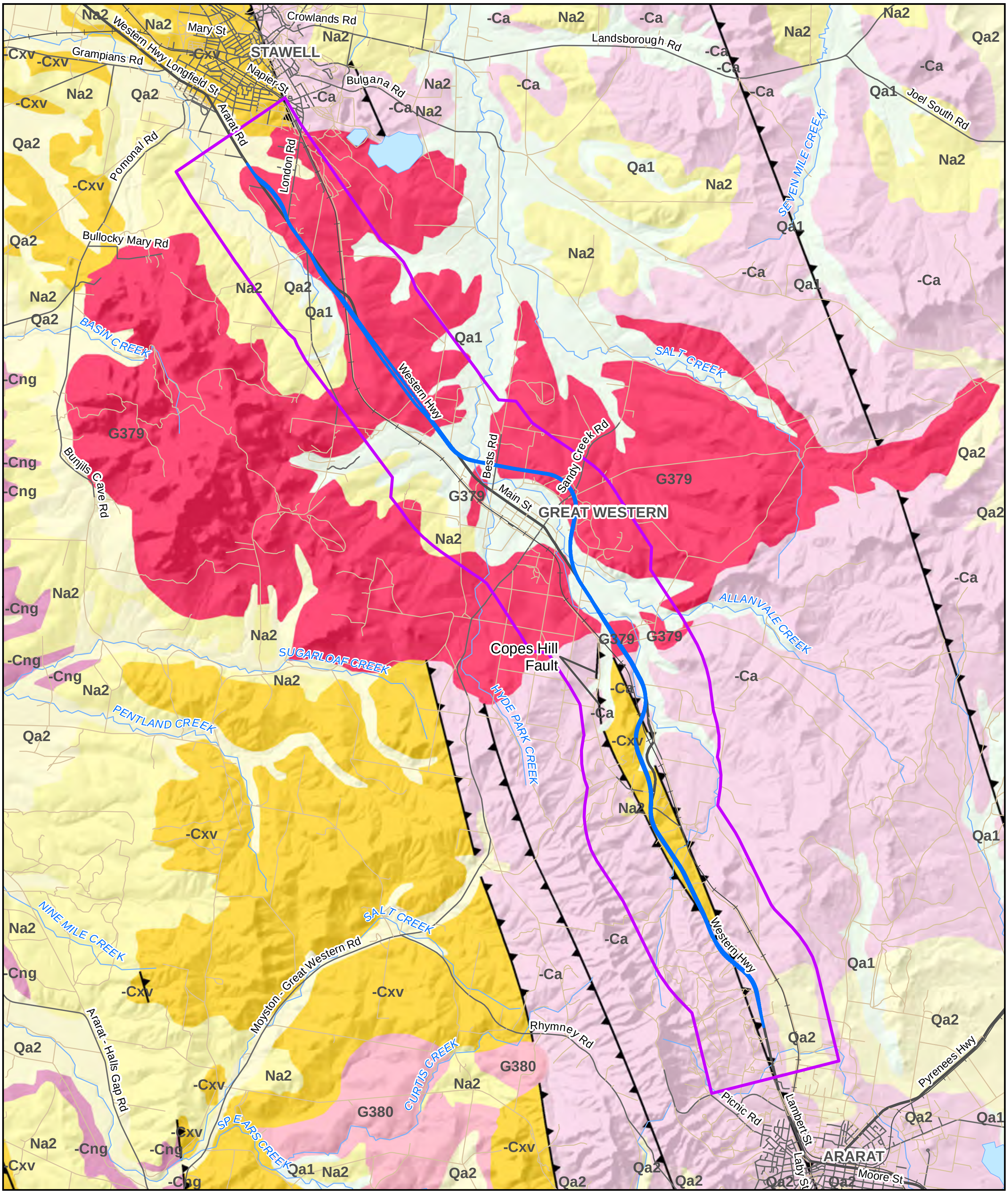
Data source: DSE, VicMap, 2012; VicRoads, 2011; GHD, Design, 2012. Created by:splaird



LEGEND

- Proposed Alignment
- Study Area
- Quaternary (Holocene) (Unnamed alluvium) Qa1
- Quaternary (Pleistocene) (Unnamed alluvium) Qa2
- Neogene (Pliocene) (Unnamed) Na2
- Devonian (Middle Devonian) (Ararat Granodiorite) G380
- Devonian (Early Devonian) (Stawell Granite) G379
- Cambro-Ordovician (Palaeozoic) (St Arnaud Group) -Ca
- Cambrian (Palaeozoic) (Magdala Volcanics & Deenicull Schists) -Cxv
- Cambrian (Palaeozoic) (Glenthompson Sandstone) -Cng
- Anticline fine
- Fault
- Syncline fine
- Highway
- Sealed road (arterial & local)
- Unsealed road

Geology Data: DPI 250K Seamless Geology

Paper Size A4

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Ararat to Stawell Regional Geology

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Figure 3

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Data source: DSE, VicMap, 2011; VicRoads, 2011; DPI, 2011. Created by:splaird

Table 5 Simplified Regional Stratigraphy

Period	Formation	Lithological Description	Comment
Quaternary	Undifferentiated alluvials, colluvials (Shepparton Formation equivalents)	Fluvial, alluvium, gravel sand silt	Generally restricted to existing creeks and drainage lines
Quaternary / Tertiary	Newer Volcanics	Olivine and iddingsite basalt, limburgite, scoria, minor tuff	East of Ararat, else generally absent in the Section 3 Study Area.
Tertiary	Moorabool Viaduct Formation	Sand, ferruginous, calcareous, gravel	Stratigraphic differentiation of these two Formations problematic in this area.
	Calivil Formation ('Deep Leads')	Unconsolidated sands, gravels and clays	
Unconformity			
Devonian	Stawell Granite (Ararat Suite)	Granite, biotite granite, associated aplite, pegmatite	Great Western to Stawell region.
Unconformity			
Cambro-Ordovician	Pyrenees Formation (St Arnaud Group)	Indurated marine sandstones, siltstones and shales	Geological basement

The indurated sedimentary basement rocks have in places been intruded by Devonian age granite. A large granite intrusion has been mapped within the corridor of the existing Western Highway between the southern outskirts of Great Western and extending through to the southern outskirts of Stawell (refer Figure 3). Black Range and Sisters Rocks form part of the Stawell Granite intrusion.

There was a period of no deposition between the Cambro-Ordovician and the Tertiary. During this period, deformation (several phases) occurred in the Devonian (with the emplacement of granite intrusives) and uplift in the late Cretaceous (Caley and McDonald, 1995).

During the early Tertiary the uplift resulted in deep dissection of the weathered Palaeozoic rocks, forming drainage systems in the pre-existing Palaeozoic valleys, and basement depressions. These valleys and depressions were infilled with fluvial sediments, and sediments eroded from the basement rocks.

The Lower to Mid Tertiary age, unconsolidated sediments, unconformably overlie the basement rocks and granites. The sediments are equivalents to the Moorabool Viaduct Formation, and in some areas are further differentiated e.g. Calivil Formation ('Deep Lead' deposits). The Tertiary sediments consist of variable mixtures of sand, gravel and minor clay. They generally do not form a laterally continuous sheet across the region, but tend to be restricted in extent, being deposited along channels typically incised into the Palaeozoic bedrock surface.

In some areas, the Tertiary sediments contained gold, derived from the erosion of the basement rocks, and in these instances they are referred to as ‘Deep Leads’. The leads consist of a few tens of metres of sand and clay ‘drift’ overlying several metres of gravel material. The ‘Deep Leads’ were often subjected to historic mining activities, notably at:

- Great Western – Armstrong area (Glover or Wet Lead); and
- Ararat (Langi Logan / Main Hopkins Lead).

Within the Study Area, the Tertiary sediments outcrop (south of Stawell and northwest of Great Western), however elsewhere they are covered by undifferentiated Quaternary age sediments.

During the upper Tertiary – early Quaternary (refer Table 5), basalt flows of the Newer Volcanics poured out from numerous eruption centres. Outcropping flows of the Newer Volcanics have not been mapped within the Section 3 area, however they have been mapped on the south-eastern outskirts of Ararat (refer Figure 3).

The Quaternary sediments predominantly comprise of alluvial and colluvial deposits. These sediments are essentially Shepparton Formation equivalents, in the region north of Great Western.

The alluvial sequences have been mapped along the alignment and floodplains of the existing waterways (e.g. Allanvale and Hyde Park Creeks). The colluvial outwash fans from drainage lines in the steeper basement and granitic topography have been mapped along the existing Western Highway between Armstrong and Great Western, and extend northwards along drainage lines from Great Western.

5.3 Aquifer Types

5.3.1 Identified Aquifers

Groundwater occurs throughout the stratigraphic sequence with all formations constituting aquifers to varying degrees. The Cambro-Ordovician basement rocks, and the Devonian granites represent fractured rock aquifers where groundwater is stored and transmitted via fractures, joints and other discontinuities within the rock mass.

The Quaternary sediments (colluvium and alluvium), and the Tertiary sediments function as porous media aquifers where groundwater flow occurs through the interstices of the sedimentary particles forming the soil matrix.

In the area of outcropping granite or basement rocks, there is predominantly one aquifer system only, that of the watertable, however in other areas, multiple aquifers may be present within the vertical profile, e.g. where the Quaternary and Tertiary sediments overlie the Palaeozoic rocks.

5.3.2 Nature of Confinement

Without localised information on groundwater potentiometry, it is difficult to confirm the nature of confinement in the aquifers with the Study Area, however inferences can be made based on the geological setting.

The Cambro-Ordovician basement and Devonian granites are typically unconfined, or the water table, aquifers where they are mapped in outcrop. They may become semi confined to confined where:

- They are overlain by thick sequences of fine grained, low permeability material (e.g. Tertiary and Quaternary sediments);
- Where thick saprolitic or weathered profiles are present within the shallower parts of the rock mass that act to impart confinement on deeper, fresher rock; or,
- Where locally, deeper fracture sets are developed that are hydraulically disconnected (or have restricted connection) with shallow fracturing (watertable).

The Tertiary sediments may be confined to some degree where they are covered by younger sedimentary deposits, however where exposed in outcrop, they typically function as the unconfined watertable.

5.4 Groundwater Use

5.4.1 Groundwater Management

An understanding of groundwater use, or the likelihood of use, can be determined from existing bore information but also the level of groundwater regulation in the area.

The Victorian Department of Sustainability and Environment (DSE) has recognised areas of intensive groundwater use throughout Victoria. The principle management unit for groundwater resources in Victoria is the Groundwater Management Unit or GMU. A GMU may be a Groundwater Management Area (GMA), a Water Supply Protection Area (WSPA) or an Unincorporated Area. These are declared under the *Water Act* (1989) to ultimately provide sustained management of the groundwater resources.

Under the *Water Act* (1989), the Minister may declare the total volume of groundwater (and/or surface water) which may be taken in an area. This is termed the Permissible Consumptive Volume (PCV).

A WSPA is essentially a GMA with a management plan. Within WSPAs, caps or moratoriums on the issue of additional extraction licenses are often present. An unincorporated area is a region falling outside of a GMA or WSPA. The total volume of water allocated under the PCV is a trigger for declaration of a GMA.

There are no groundwater management units within 5 km of the Study Area and it is thus considered the Study Area is located in an unincorporated area. The lack of groundwater development in this area is circumstantial evidence of the groundwater within these aquifers being considered of low value.

5.4.2 Groundwater Use

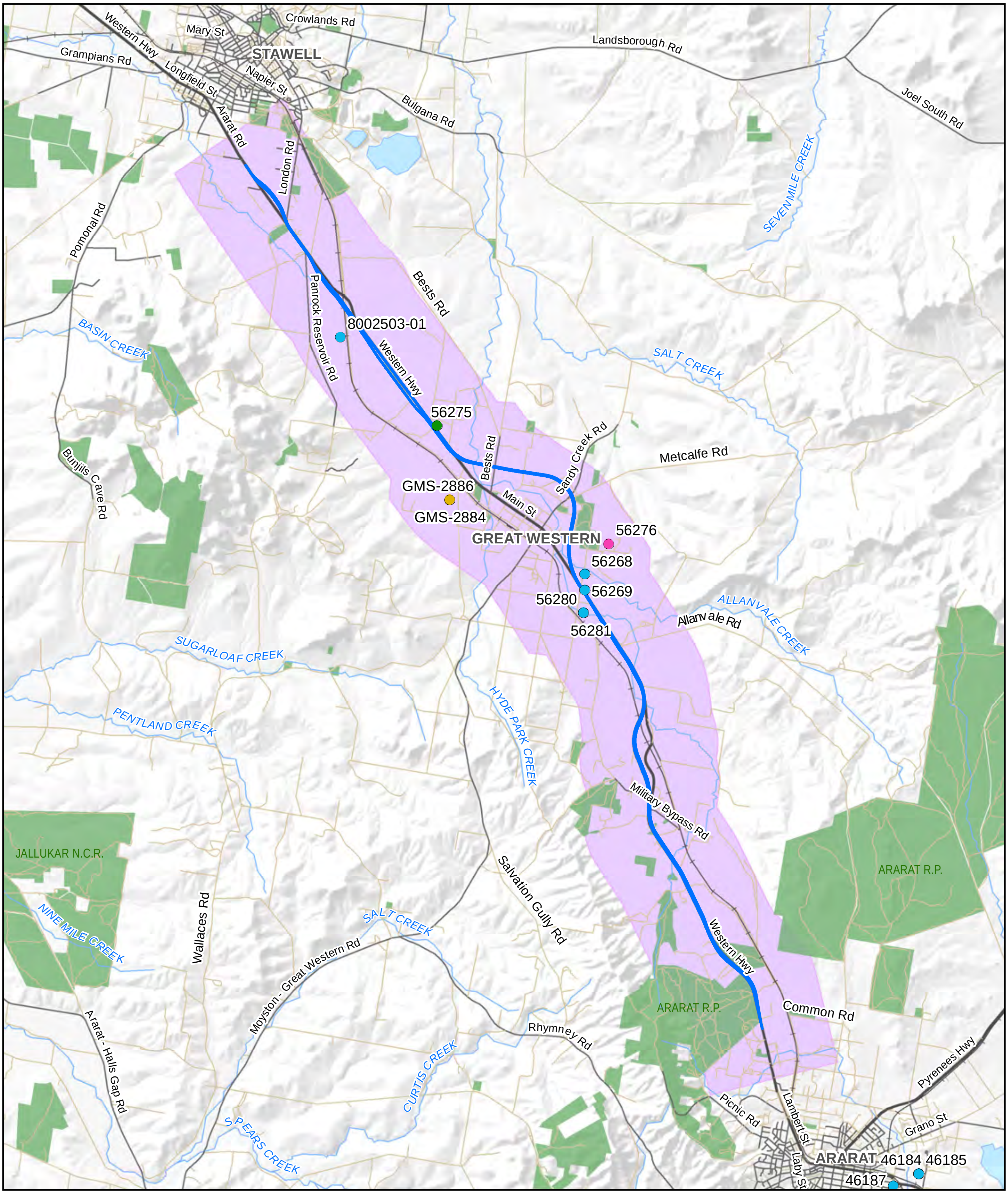
A search of the State Groundwater Management System (GMS) was undertaken to identify and characterise groundwater use in the region. A filter was applied to identify all bores within 1 km of the alignment options. The following comments are made regarding the GMS data:

- Bores installed prior to the proclamation of the original *Water Act* (1969) may not be registered as there was no mandatory requirement to licence bores prior to this date;
- The GMS does not provide information regarding the operational status of groundwater bores;
- The GMS does not provide information regarding the casing condition status of groundwater bores;

- Bores installed without a bore construction licence, are unlikely to be registered on the GMS (unless detected by later audits by drilling inspectors / diversions officers);
- Many bores have not been surveyed for location. Bore locations as registered were often those initially proposed on the bore construction licence application. In many instances drilling contractors could not gain access to these sites and final locations often have a positional accuracy greater than ± 250 m;
- The information registered on the GMS is subject to the accuracy of bore completion reports submitted by drilling contractors;
- Information registered on the GMS is subject to change since the completion of the bore e.g. water level information, pump setting depth, groundwater quality; and
- Some information is not available on the GMS, e.g. pump setting depth, bore ownership.

The GMS does not provide information regarding the currency of bores with licensable extractive use i.e. a bore indicated as being an irrigation bore may not have any allocation attached to it. That is, the intended use may have altered due to low yield potential recorded or poor quality groundwater intercepted. These use changes are not reflected in the GMS.

A total of nine (9) drilling records were identified within the search area and summary bore details for the identified bores have been attached in Appendix A. The groundwater bores identified within the Study Area are shown in Figure 4. A breakdown of the bore use is provided in Table 6.



LEGEND

- Proposed Alignment
- Study Area

GMS Bores (Use)

- DOMESTIC
- NOT KNOWN
- OBSERVATION
- STOCK
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Parks

Paper Size A4

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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vicroads

VicRoads
Western Highway Project

Ararat to Stawell
Study Area Groundwater Bores

Job Number	31-27558
Revision	B
Date	07 Nov 2012

Figure 4

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

G:\31\27558\GIS\Maps\Deliverables\Stage 3\RISK AND IMPACT ASSESSMENT\01_HYDROGEOLOGY\3127558_S3_003_Groundwater_Bores_A4P.mxd

Data source: DSE, VicMap, 2012; VicRoads, 2011; GHD, Design, 2012; DPI, GMS, 2011. Created by:splaird

Table 6 Study Area Groundwater Use

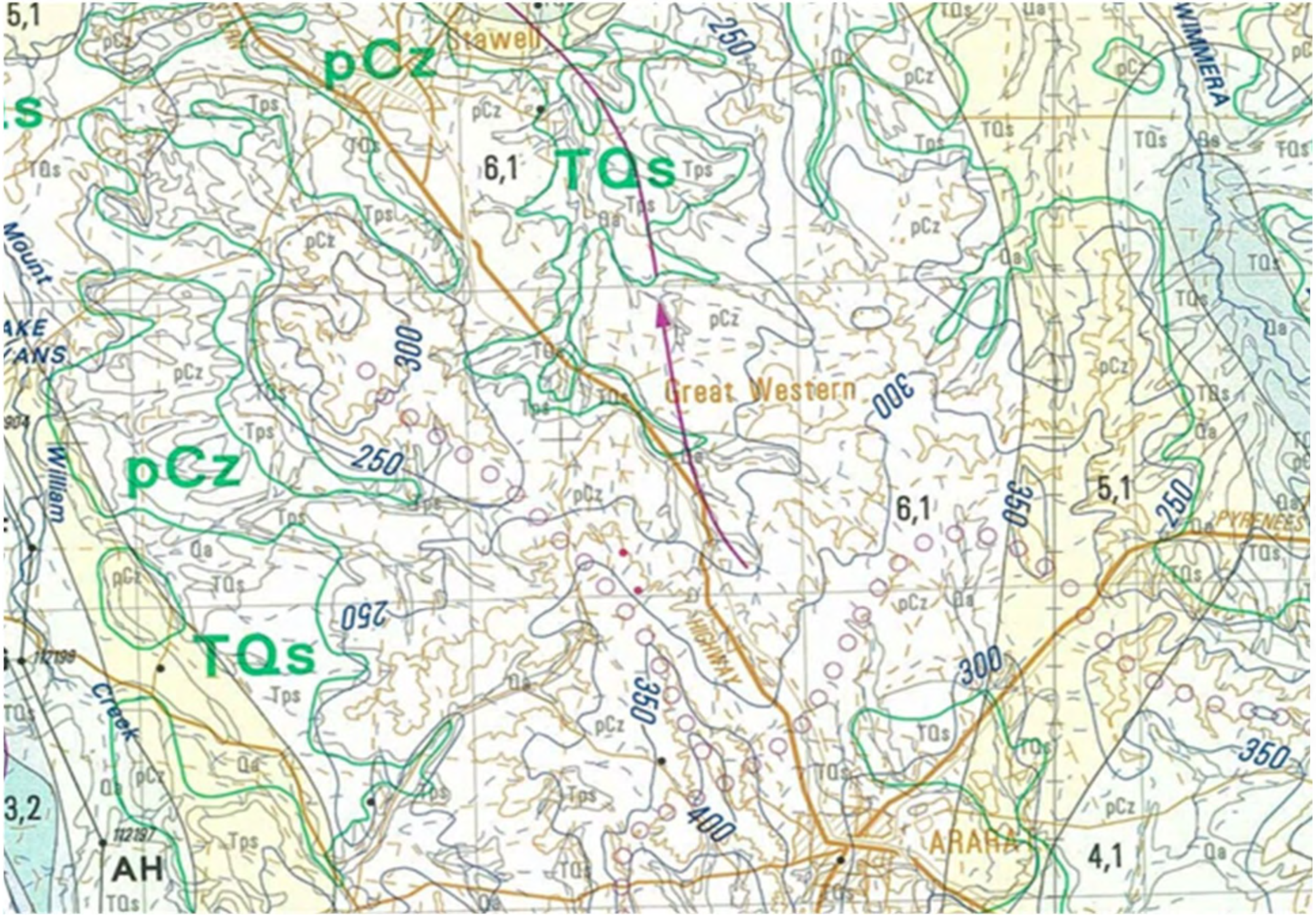
Description (GMS Code)	Number of Bores	Comment
Non-groundwater (SEC or NG)	0	
Not Known (NKN)	6	Largely mineral (extractive or coal) exploration bores.
Investigation, Observation (IV OB)	2	Monitoring bores Salinity monitoring bores
Dewatering (DW)	0	
Stock and Domestic (DM, ST)	1	
Irrigation (IR)	0	
Dairy (DY)	0	
State Observation	0	
Not used	0	
Miscellaneous Use (MI)	0	
Commercial (CO)	0	

5.5 Groundwater Quality

5.5.1 Regional Mapping

Hydrogeological mapping completed by Bradley *et al* (1994) indicates that the water table aquifer has a salinity of over 7,000 mg/L TDS in the Project Area. At such salinities the groundwater falls within Segment C or higher (refer Table 1) and has limited extracted beneficial uses apart from stock watering and industrial use. A reproduction of the regional mapping has been shown in Figure 5. The broad salinity range reflects the varying groundwater flow processes within the Study Area.

On the southern outskirts of Stawell, the groundwater salinity is marginally fresher, mapped in the range of 1,500 mg/L to 3,000 mg/L TDS. In this area the groundwater falls within Segment B (refer Table 1). Whilst groundwater of this salinity falls within the range for irrigation, salinities generally below 1,500 mg/L to 2,000 mg/L TDS are required to minimise plant stress due to salt.



SALINITY (mg/L TDS)	BORE YIELD L/s <0.5	0.5–5	5–50	>50
<500	1,1	1,2	1,3	1,4
500–1000	2,1	2,2	2,3	2,4
1000–1500	3,1	3,2	3,3	3,4
1500–3000	4,1	4,2	4,3	4,4
3000–7000	5,1	5,2	5,3	5,4
7000–14000	6,1	6,2	6,3	6,4
14000–35000	7,1	7,2	7,3	7,4
35000–100000	8,1	8,2	8,3	8,4
>100000	9,1	9,2	9,3	9,4

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VicRoads
Western Highway Project Section 3 Ararat - Stawell
Groundwater Quality (Bradley *et al, 1994)*

job no. 31 / 2755809
report no. 213394
Rev no. B

scale: as shown
date: 31 October 2012

Figure 5

Level 8, 180 Lonsdale Street, Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

5.5.2 Local Bore Information

Of the nine bores identified within 1 km of the alignment, there was no information registered on the groundwater database regarding groundwater salinity, i.e. none of the nine bores had groundwater chemistry, specifically mg/L TDS or EC (electrical conductivity) information.

5.5.3 Potentially Contaminating Land Uses

Land uses can influence groundwater quality and provide circumstantial evidence of potential groundwater quality impacts. Some of the broader land use activities in the Study Area include:

- Broad acre cropping and livestock grazing;
- Plantation forestry;
- Township / urbanisation e.g. Great Western
- Regional Parks / Flora and Fauna Reserves
- Industrial Park (Stawell);
- Former municipal landfill, e.g. Great Western
- Quarrying, e.g. Great Western; and
- Railway.

Land use activities may result in localised, or diffuse impacts to groundwater quality. Some potential contaminating land uses have been summarised in Table 7. There is no site specific information available which could inform the existing condition study regarding the groundwater quality in the areas of these particular land uses.

Table 7 Potentially Contaminating Land Use Activities

Distribution in Study Area	Sources
Localised / Point Source	Storage, handling, spillage of hazardous materials, e.g. Underground Storage Tanks at Service Stations, garages and workshops.
	Septic systems (residential housing clusters e.g. Great Western)
	Leachate from landfills, e.g Great Western
Diffuse	Application of pasture improvement chemicals, fertilisers, herbicides, pesticides (broad acre cropping, forestry, vineyards).
	Grazing of animals.

Apart from the former Great Western landfill and nearby quarries, there is no site specific information available which could inform the existing condition study regarding the groundwater quality in these specific areas.

Golder (2011) completed investigations of the Great Western Landfill, including the excavation of ten testpits. Golder (2011) noted that the geology principally comprised of Quaternary age fluvial sediments, and that groundwater was not encountered in test pits excavated to 4 m in depth.

VicRoads (2010) undertook a preliminary assessment of sand and gravel pits in the Great Western area. The inspections did not include intrusive subsurface sampling and did not document any information regarding groundwater conditions.

5.6 Bore Yield

5.6.1 Regional Mapping

Bore yield can be used as a guide to the hydraulic character of aquifers. It should be noted that bore yield is dependent upon bore construction and aquifer penetration / intersection, and that many stock and domestic bores may not necessarily have been constructed as high yielding bores.

Hydrogeological mapping completed by Bradley *et al* (1994) indicates that bore yields are generally less than 1 L/s. Exceptions to this would include:

- Localised zones of extensive fracturing in the basement and granitic rocks; and
- Tertiary / Quaternary systems.

Localised areas of coarse grained sediments (e.g. Deep Lead system) may be capable of higher bore flow rates.

5.6.2 Local Bore Information

There was limited information available regarding bore yields, however two bores are registered with yields of 1 L/s and 1.2 L/s (refer Appendix A). This is consistent with the regional mapping.

5.7 Groundwater Potentiometry

5.7.1 Standing Water Levels

The available information for the small number of bores within the Study Area indicates water levels ranging from less than 3 m to 4 m below the ground surface. Groundwater levels are expected to be deeper in the higher topographies, and shallower in the flatter topographies.

The regional water table mapping completed by Bradley *et al* (1994) (refer Figure 5) indicated a water table elevation of between 350 m AHD (southern end of the Study Area) and 250 m AHD (northern end of Study Area). It is noted that this would have been compiled from sparse bore data, and given a high likelihood of localised (strongly topographically driven) groundwater flow systems, is considered to be of low confidence.

There is no understanding of the seasonal groundwater response. It could be reasonably expected that groundwater levels would respond to seasonal rainfall, given that rainfall recharge is the principal recharge mechanism for the water table aquifers in the Study Area. Under these conditions, groundwater levels would be at seasonal highs in late spring / early summer, and at their nadir in late autumn.

5.7.2 State Observation Bores

A search of the GMS was undertaken to identify the presence of any active State Observation Network (SON) bore. The SON bores can provide valuable information for a region as they provide a water level monitoring record, and at some sites, water quality monitoring data. Most SON bores are monitored at a quarterly frequency, however monthly monitoring frequencies are adopted in some WSPAs.

No SON bores were identified within the Study Area, however two such bores were identified within a broader search area on the northern outskirts of Stawell. Details of these bores have been summarised in Table 8.

Whilst the monitoring bores are located a significant distance from the Study Area, they provide an insight of the seasonal groundwater response. The monitoring bore hydrographs have been attached as Appendix B and a discussion of their response has been included in Table 8.

5.7.3 Other Bores

Bores GMS-2884 and GMS-2886 were identified on the southern outskirts of Great Western which had some time-series groundwater level information. It is suspected that these are salinity monitoring bores. The bores are shown in Figure 4, their hydrographs have been attached as Appendix B and a discussion of their response has been included in Table 8.

Table 8 State Observation Bore Summary

Bore Id	Location Description	AMG Co-ordinates		Total Depth (m)	Screen			Monitoring Record	Hydrograph Response
		Easting	Northing		From	To	Lithology		
67749	Between Lake Lonsdale and Stawell	6,506,02.1	5,900,464.9	48	19	25	Tertiary / Quaternary sediments	1991 to present	Stable, but exhibiting a strong seasonal response.
67750	Between Lake Lonsdale and Stawell	651,763.8	5,900,185.4	21	9	15	Tertiary / Quaternary sediments (clayey gravels)	1991 to present	Stable, but exhibiting a strong seasonal response.
GMS-2884	Great Western Bushland Reserve, southwest of Great Western	662,706	5,887,230	14	-	-	Tertiary / Quaternary sediments (clayey gravels)	1995 to 2005	Both bores have the same water level response. Strong seasonal response with highest water levels noted during the spring and lowest water levels in late summer to autumn. Water levels over the monitoring period were generally less than 1.5 m, and during some periods, within 0.5 m of the top of casing. Although water quality information was not available from the site, the shallow water levels suggest a high risk of salinisation and/or water logging.
GMS-2886		662,706	5,887,230	14.5	-	-		1995 to 2005	

Source: Victorian Water Data Warehouse.

5.8 Groundwater Flow Systems

5.8.1 Local Groundwater Flow

In general, the direction of the regional groundwater flow is expected to be a subtle reflection of topography, from the higher topographies to the low lying areas. Groundwater flow in the water table aquifer is expected to be influenced by:

- Localised groundwater flow systems;
- Connected waterways; and
- Groundwater extraction.

Groundwater extraction is limited in the region and therefore it is considered to have a limited, localised influence only.

Further information is required (i.e. standpipes installed), to characterise the exact depth to water and thus the groundwater flow directions within the Study Area. Hydrogeological mapping completed by Bradley *et al* (1994) interprets a number of groundwater divides formed by the Black Range and Great Dividing Range. Bradley *et al* (1994) also interprets northwards groundwater flow in the north trending sedimentary systems extending from Great Western towards Stawell.

5.8.2 Conceptualisation

All of the identified aquifers are primarily recharged by infiltrating rainfall. The amount of recharge will depend upon topographic slope, surface soils (permeability and infiltration capacity), land use and vegetation cover (e.g. evapotranspiration).

Other components of recharge may be sourced from:

- Surface water flow (during flood events); and
- Through flow / leakage from adjoining / overlying aquifers e.g. between the Quaternary sediments.

Recharge to the ‘Deep Leads’ is poorly understood and whilst rainfall recharge is perhaps the principle source of recharge, recharge may occur in intake zones (e.g. areas of outcrop or shallow subcrop) which may be some distance from the confined parts of the aquifer.

Groundwater discharge depends upon the type of groundwater flow systems that can be identified within the geological and hydrogeological settings. A component of groundwater may form components to baseflow in the waterways and drainage systems of the Study Area.

Where there are significant changes in topography flow systems can be local with groundwater discharge manifested as spring discharge. These areas are most commonly associated with the bedrock terrains of the Devonian Granite, or Cambro-Ordovician indurated sediments. The more recent geology, e.g Quaternary and Tertiary, tends to result in flatter terrains.

5.8.3 Flow System Mapping

The southern parts of the Study Area fall within the Glenelg Hopkins Catchment. As part of salinity investigations in the Glenelg Hopkins Catchment, groundwater flow system mapping has been undertaken by Dahlhaus *et al* (2002). There are three groundwater flow systems relevant to the project Study Area and these are:

- GFS 1 – Local Flow Systems in Quaternary Alluvium (and Coastal Deposits);
- GFS 13 – Intermediate and Regional Flow Systems; and
- GFS 15 – Regional and Intermediate Flow Systems in the subsurface Deep Leads.

Descriptions of these flow systems are summarised in Table 9. Dahlhaus *et al* (2002) has defined a number of other flow systems e.g. GFS 3 (Local Flow Systems in Fractured Granitic Rocks) and GFS 14 (Regional and Intermediate Flow Systems in the Volcanic Plains Basalt) which are also potentially relevant. GFS 3 occurs within granite terrains and such have been identified beyond the Glenelg Hopkins Catchment mapping area within the Wimmera CMA area. GFS 14, whilst not strictly occurring within the Study Area, falls to the east of Ararat Township.

Table 9 Summary of Study Area Groundwater Flow Systems

Groundwater Flow System	Title	Hydrogeology	Aquifer Type (porosity and conditions)	Aquifer Hydraulic Conductivity & Transmissivity	Aquifer Storativity	Hydraulic Gradient	Flow Length	Recharge Estimate	Aquifer Use
GFS 1	Local Flow Systems in Quaternary Alluvium (and Coastal Deposits)	Quaternary deposits of stream alluvium, hillside colluvium.	Unconsolidated gravel, sand, silt and clay. Unconfined	Extremely variable. Possible range of 10^{-6} to 10^{2} m/day Variable, T<20 m^2/day.	Extremely variable. Estimated to be from 0.001 to 0.05.	Varies with landscape.	Generally short, ranging from a few metres to 1 km to 2 km .	Unknown.	Minor stock and domestic use from shallow bores
GFS 3	Local Flow Systems in Fractured Granitic Rocks	Devonian (Lower and Upper) granite	Fractured rock and saprolite (primary porosity), soil and grus[1] (secondary porosity). Unconfined and semi-confined.	Highly variable. Saprolite: 10^{-6} to 10^{-1} m/day Grus: 10^{-3} to 10^{-1} m/day Fractured rock: <0.01 m/day T:<50 m^2/day	Variable. Estimated to be less than <0.05 (saprolite, grus) and <0.01 (fractured rock)	Estimated to be moderate to steep	Generally <5 km	Unknown. May be 25 mm to 200 mm annually.	Minor stock and domestic use from shallow bores
GFS 13	Intermediate and Regional Flow Systems in fractured Palaeozoic rocks	Indurated Ordovician sediments	Fractured rock and saprolite (secondary porosity). Unconfined and semi-confined.	Highly variable. Saprolite: 10^{-5} to 10^{-1} m/day. Fractured rock: 10^{-5} to 2 m/day T:<50 m^2/day	Variable. Estimated to be <0.03 (saprolite) and 0.02 to 0.05 for fractured rock.	Estimated to be moderate in intermediate systems, and locally steep in local systems.	Generally <25 km for intermediate systems and <5 km for local systems	Approximately 40 mm to 50 mm	Minor stock and domestic use from shallow bores
GFS 14	Regional and Intermediate Flow Systems in the Volcanic Plains Basalt	Newer Volcanic Basalt	Fractured rock (secondary porosity) and soil (primary porosity) Unconfined and semi-confined.	Extremely variable. 10^{-3} to 10^{2} (Fractured rock) 10^{-6} to 10^{-2} (soil) T: <50 m^2/day to 200 m^2/day.	Variable. Estimated to be less than <0.03 to >0.05 (fractured rock)	Estimated to be very low (0.0001) for regional systems, and low (0.001) in intermediate systems.	Generally <50 km for regional systems, <10 km for intermediate systems.	Variable. Generally 10 mm to 40 mm	Significant use for stock and domestic purposes
GFS 15	Regional and Intermediate Flow Systems in the subsurface Deep Leads	Calivil Formation equivalents	Gravel, sand, silt and clay (primary porosity) Confined	Largely unknown. Estimated 10^{-2} to 10^{2} m/day. T<1000 m^2/day	Estimated range from 0.05 to 0.2	Generally low to very low.	Estimated up to 30 km	Unknown	Irrigation, stock and domestic use

Note: Adapted from Dahlhaus *et al* (2002). T = Transmissivity.

[1] Grus – Weathered granite.

5.9 Groundwater Dependent Ecosystems

5.9.1 Definition

Whilst not directly noted in the EES Scoping Requirements (DPDC, 2011), there is some crossover in requirements between those of the Biodiversity and Habitat, and Groundwater studies. These specifically relate to the protection of ecological habitats and remnant vegetation that may be dependent upon groundwater, that is, biological assets that use groundwater.

A groundwater dependent ecosystem (GDE) is an ecosystem which has its species composition and natural ecological processes determined by groundwater (ARMCANZ & ANZECC, 1996). That is, they are natural ecosystems that require access to groundwater to meet all, or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (SKM, 2007). In some cases groundwater use can be opportunistic, in that groundwater is used when other water may or may not be readily available. If the availability of groundwater to GDEs is reduced, or if the quality is allowed to deteriorate, these ecosystems would be impacted (Hatton and Evans, 1998).

Whilst groundwater quality and quantity are the key aspects to maintaining healthy ecosystems, superimposed over this are fluctuations through time that allow periods of wetting and drying, or periodical changes in water quality, e.g. fluxes of fresher water or nutrient or oxygen rich water.

It is widely acknowledged that a poor understanding exists in recognising GDEs, or understanding the hydrogeological processes affecting GDEs, or their environmental water requirements. The recent Draft Western Sustainable Water Strategy (DSE, 2010) broadly groups GDEs into three categories:

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

5.9.2 GDEs in the Study Area

There are a number of potential GDEs in the Study Area that potentially use groundwater to some degree, although they may not necessarily be dependent upon it. These have been summarised in Table 10. The following discussion regarding potential GDEs in the Study Area has been based on actual tests of groundwater dependence, or even groundwater use in these ecosystems. It is noted that there is very little data currently available to assess whether these ecosystems are dependent upon groundwater. The discussion on the ecological communities within the Study Area is supported by the conceptual understanding of the hydrogeology and groundwater dependence in other similar environments.

Table 10 Potential GDEs in Study Area

Potential GDE	Description
Hyporheic zones and river baseflow of waterways	The hyporheic zone is an area of active mixing between groundwater and surface water and is likely to be present in the beds of the rivers (e.g. Concongella Creek, Donald Creek, Robinsons Creek and Hyde Park Creek), tributaries and ephemeral creeks and unnamed drainage lines throughout the Study Area. The mixing occurring within this zone may drive a number of biogeochemical processes. The flux of water between the hyporheic zone is moderated by stream bed conductivities, vertical hydraulic gradients and river bed gradients. The coarser grained Quaternary alluvial sediments potentially have significant groundwater storage capacity, particularly in the ephemeral waterways. The groundwater flow may contribute to the flow in some of these waterways (i.e. baseflow) during periods of declining surface water levels, and can prolong the period of surface water flow in ephemeral creeks. The rewetting created by shallow groundwater tables can allow more prompt return to flow conditions, and provide access to nutrients to facilitate the re-starting of seasonal aquatic processes.
Deep rooted terrestrial vegetation	Deep rooted vegetation can use groundwater, however it is noted that over much of the Study Area the groundwater quality is over 5,000 mg/L TDS and therefore may become marginal to support healthy growth. In the granitic terrain (largely north of the existing highway alignment) near the Black Range (State Forest) west of Great Western, and the Ararat Hills (Regional Park), vegetation is potentially dependent upon groundwater, particularly where localised flow systems and fresher groundwater may exist.
Riparian vegetation	Riparian vegetation may use groundwater intercepted by tree roots prior to it discharging and entering into waterways. In ephemeral streams, tree roots would use groundwater when surface water flow is absent. The riparian zone may act as an important corridor for fauna movement.
Springs and seepage zones	Spring flow may form the origins of waterways, or form a water supply for flora and fauna. Spring flow is most likely expected in the granite terrain, however it may not necessarily be confined to this terrain only.

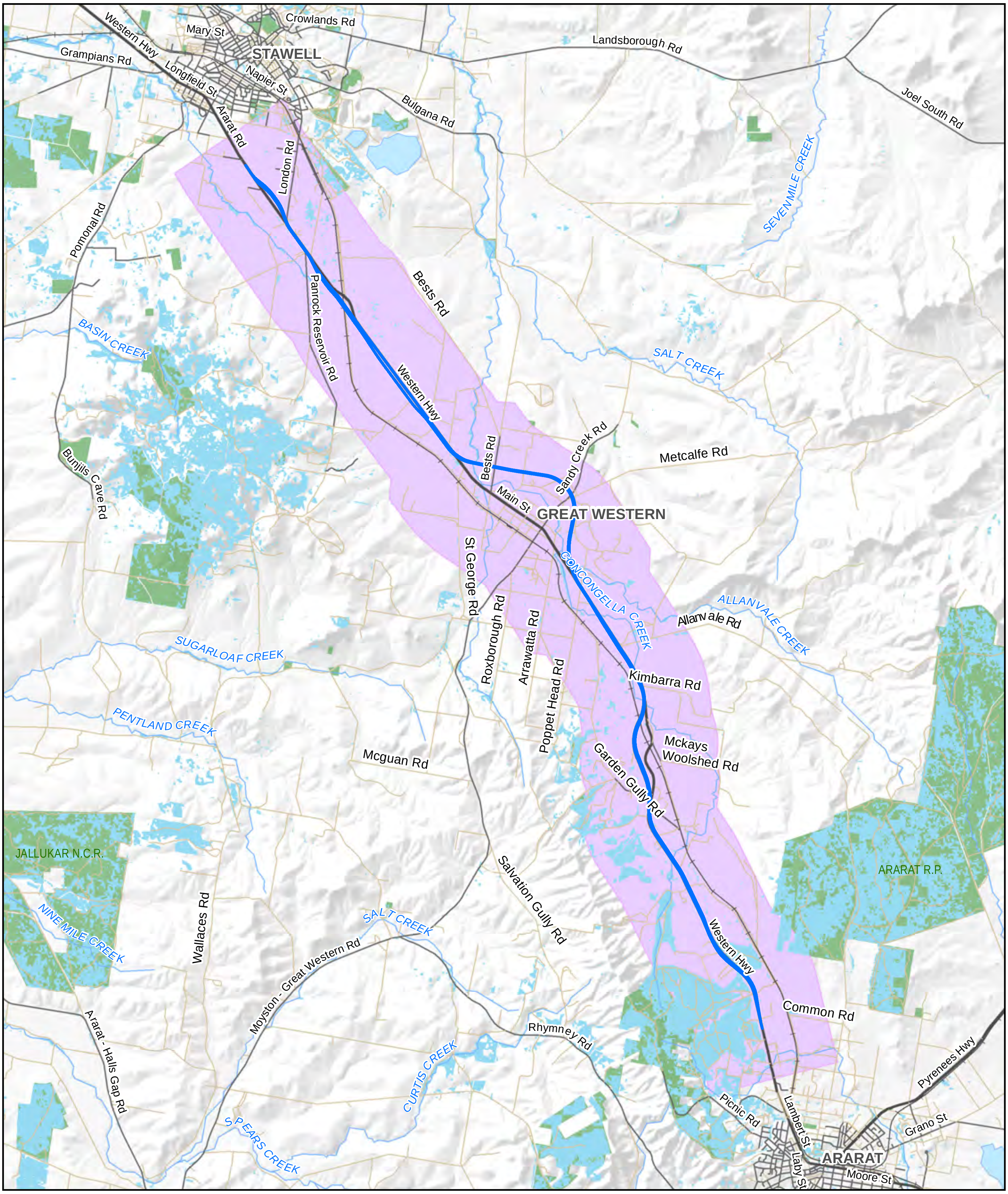
The Department of Primary Industries (DPI) has undertaken mapping of potential GDEs and the data has been reproduced in Figure 6. Broad scale mapping of GDEs in Victoria by DSE/DPI also suggests that within the Study Area there are potential terrestrial GDEs. These are mostly terrestrial vegetation systems potentially relying on access to groundwater by tree roots.

The degree of dependency of vegetation on groundwater is unknown and can be difficult to establish, considering for example, that a species may use groundwater once every decade to survive or once each year.

The potential GDEs (refer Figure 6) are interpreted to be largely associated with the granitic geology near the Black Ranges, which is outside the study area.

There is potential for spring activity to be present in Section 3 of the Project. However, potential spring activity has not been identified at this stage. Investigations for spring activity would be undertaken as part of the detailed design process.

Spring flow is considered most likely in areas of steeper or undulating topography. In such areas, shallow groundwater systems may form an important water source for ecological habitats, particularly where flow paths are shorter and localised, and where potentially fresher groundwater may be present.



LEGEND

Proposed Alignment	Highway
Study Area	Sealed road (arterial & local)
Groundwater Dependant Ecosystems	Unsealed road
	Parks

Paper Size A4

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

GHD

CLIENTS | PEOPLE | PERFORMANCE

vicroads

VicRoads
Western Highway Project
Ararat to Stawell
Potential Groundwater
Dependent Ecosystem

Job Number	31-27558
Revision	B
Date	08 Nov 2012

Figure 6

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

G:\31\27558\GIS\Maps\Deliverables\Stage 3\RISK AND IMPACT ASSESSMENT\01_HYDROGEOLOGY\3127558_S3_006_GDE_A4P.mxd

Data source: DSE, VicMap, 2012; VicRoads, 2011; DPI, GDE, 2012; GHD, Design, 2012. Created by:splaird

5.10 Potential for Groundwater/Surface Water Interaction

Where there is the occurrence of a shallow water table, there is a greater likelihood for interaction between groundwater and waterways. The identified waterway crossings are summarised in Table 11. The crossings have been divided into major waterways (designated river or stream) and minor waterways (unnamed tributary stream or drainage line). The likelihood of interaction of these waterways with groundwater is not known.

Table 11 Identification of Waterway Crossings

Description	Number of Crossings	Waterway
Significant Waterways	10	Concongella Creek (x 7) Allanvale Creek Donald Creek Robinsons Creek
Minor Waterways	28	Tributary to Hopkins (x 2) Tributary to Concongella Creek (x 23) Pleasant Creek (No designated tributary crossing, however need for accommodation of local catchment flows).

5.11 Overall Summary

The Section 3 Study Area traverses a region having multiple hydrogeological terrains, including the Cambro-Ordovician age basement aquifer, the Devonian age granites, and the Tertiary and Quaternary sediments. Groundwater salinity is variable, but generally brackish and over 7,000 mg/L TDS over much of the Study Area. The poor groundwater quality, and tendency for low bore yields, has acted to restrict intensive development of the groundwater resource. Groundwater is most commonly used for stock and domestic (non-potable) purposes.

The low bore density has resulted in a lack of understanding of the groundwater potentiometries throughout the Study Area. Shallow groundwater has been identified southwest of Great Western, however over most of the alignment it is poorly characterised.

6. Risk and Impact Assessment

6.1 Overview

The detailed impact assessment documented in this report addresses the potential impacts that may arise from the construction and operation of the proposed alignment of Section 3 of the Project. The alignment being assessed in this report was determined through the progressive refinement of the design and consideration of potential impacts of the Project. The process for assessment and rationale for selection of the proposed alignment assessed in the EES is described in the 'Western Highway Project Section 3 Alignment Options Assessment Report' (February 2012) (Technical Appendix B of the EES).

The Existing Conditions outlined in Section 5 of this report cover a broad geographical area encompassing the long list of alignment options considered for the Project. Potential impacts of each option in the long list of alignments were considered in Phase 1 of the options assessment process, and were used to reduce the initial long list to a short list of alignment options.

The potential impacts of each option in the short list of alignment options were considered in more detail in Phase 2 of the option assessment process. A single proposed alignment was subsequently selected for further detailed assessment in the EES. The impacts of the proposed alignment, together with potential mitigation measures, were considered in detail through the environmental risk assessment process. The outcomes of the risk assessment process were used to finalise the proposed alignment assessed in the EES. The environmental risk assessment methodology and complete risk register for all specialist disciplines is presented in 'Western Highway Project Section 3 EES Environmental Risk Assessment' (November 2012) report.

The proposed alignment assessed in this impact assessment report is the outcome of progressive refinement through each phase of the options assessment process. The proposed alignment was also refined following the initial consideration of the environmental risk assessment.

Extracts from the environmental risk register prepared for the EES are provided in this report and the identified impacts of the proposed alignment are considered in detail in the following sections.

6.2 Project Description

The Project provides for two lanes in each direction, and associated intersection upgrades to improve road safety and facilitate the efficient movement of traffic. It commences at Pollard Lane, Ararat, and extends northwest for approximately 24 km to Gilchrist Road, Stawell. The upgrade assessed in this impact assessment is a combination of freeway standard (AMP1) and duplicated highway standard (AMP3). The first length is proposed to be upgraded duplicated highway standard (AMP3) from Pollard Lane to the Majors Road. Then the upgrade is proposed to be freeway standard (AMP1) from Pollard Lane until London Road on the outskirts of Stawell.

From Ararat the existing carriageway is to be duplicated to the northwest, crossing the railway via a new bridge adjacent to the existing Armstrong Deviation bridge. A new dual carriageway highway provides for a north-eastern bypass of Great Western, commencing north-west of Delahoy Road and passing through part of the former Great Western landfill and a quarry, meeting the existing highway alignment again near Briggs Lane. The existing carriageway is then duplicated to the northwest until Harvey Lane. Oddfellows Bridge at Harvey Lane would be upgraded to accommodate one carriageway crossing of the railway, and a second bridge would be constructed for the other carriageway further westwards.

Overall, the proposed alignment involves two crossings of the Melbourne to Adelaide railway, eight crossings of major waterways and 26 minor waterways (tributaries, drainage lines and irrigation channels), and bypasses of both Armstrong and Great Western townships.

The topography is undulating, and the surrounding land use predominately agricultural (grazing, cropping, viticulture), apart from the forested Ararat Regional Park and other smaller remnants.

Apart from the Melbourne to Adelaide railway line, which carries both freight and passenger services, no State significant infrastructure, such as major pipelines or powerlines, is located within the Study Area.

6.3 Key Issues

Overall, the construction of Section 3 of the Project would provide no benefit to the groundwater environment. The proposed alignment would be predominantly above grade, with limited cuts below the existing grade. Under these circumstances there would be limited or no opportunity for the road to directly interact with the groundwater environment. Potential indirect effects have been identified and these have been addressed in the impact assessment.

6.4 Impact Pathways

As indicated in Section 4.2, impacts to the groundwater environment can be simplified to those relating to groundwater level (and therefore flow and its availability for or access to beneficial uses), and those concerning groundwater quality. In some cases there is overlap between categories e.g. construction dewatering can not only alter groundwater levels, but can also trigger the oxidation of acid sulphate soils and thus changes to groundwater quality. Groundwater flow is determined by groundwater levels (and hydraulic gradients) which can also be affected by groundwater recharge.

Potential impacts to groundwater have been identified and summarised in Table 12. These have been based upon a number of source – pathway – impact receptor situations. The source is the aspect of the highway construction and operation, the pathway is the mechanism at which that aspect would translate into an impact, and the impact is that which is ultimately affected.

The impacts also need to be considered in a temporal sense, in that groundwater impacts can occur:

- As part of construction activities which are likely to be short term, e.g. the use of groundwater as a construction water supply; and,
- Long term or permanent impacts. These can arise either as a result of construction activities, or on-going road operation.

Some of the long term or permanent impacts may potentially influence the road alignment and/or its design. These are expected to occur in those areas where excavation cuts intersect the water table (refer Section 6.6).

Table 12 Summary of Groundwater Impact Pathways

Category	Event	Development activity	Pathway/mechanism		Receptor / Impact
Groundwater availability	Changes to groundwater levels through use	Construction dewatering (for deep excavations below the water table). Development of groundwater supplies to service construction water requirements.	Reduction in groundwater level as a result of groundwater pumping or through modified drainage (for example, site drainage, buried service/earthworks).		Reduced groundwater availability, i.e. impact to existing users – bore operation, access. Temporary change to groundwater availability for flora and fauna habitats.
	Changes in groundwater recharge	Aquifer exposure by earthworks (removal of vegetation, removal of confining beds or overburden).	Changes to surface infiltration. Changes to evaporation or evapotranspiration.	Increased recharge, water table rise and possible land salinisation/mobilisation of salt/water logging. OR Decreased recharge, loss of supply of low salinity water.	Changes to groundwater availability, i.e. impact to existing users, changes in flow (saturated and unsaturated) to receptors such as flora and fauna habitats, baseflow to waterways. Changes in groundwater quality.
		Ponding of water due to inadequate drainage, construction of barriers/embankments across wetlands/surface water damming.	Roadside embankment drainage. Embankments damming surface water flow.		
		Placement of fill materials, paving and changed surface conditions.	Decreased surface infiltration.		
		Onsite drainage, earthworks intersecting the water table.	Increased surface infiltration.		
	Changes to groundwater aquifer character (compaction)	Depressurisation of compressible soils .	While this is not strictly an impact to groundwater, it is a side effect of groundwater removal in unconsolidated, compressible sediments. Construction dewatering, aquifer drainage. Loading through embankment construction.		Differential settlement – damage to buildings, roads, buried pipes. Changed groundwater migration rates.
		Surcharge loading of aquifer materials.			
	Changes to groundwater flow	Construction of diaphragm walls/linear structures buried beneath the water table.	Diversion of flow around buried structures		Changes to groundwater availability, i.e. impact to existing users, changes in flow (saturated and unsaturated) to receptors such as flora and fauna habitats, baseflow to waterways.
		Alteration of conditions at waterway crossings (for example, removal of confining beds). Earthworks providing barriers to surface water flow	Altered interaction between surface water and groundwater		Changes to the natural flow regimes occurring between surface and groundwater systems.
	Severance of access to groundwater	Road alignment	Results in destruction or severance of access to spring fed dam or groundwater abstraction bore		Loss in water supply or access to supply to groundwater user.

Category	Event	Development activity	Pathway/mechanism	Receptor / Impact
Groundwater quality	Groundwater contamination	Handling and storage of hazardous materials, construction practice	Leakage of contaminants into aquifer via surface infiltration	Degradation of groundwater quality for the existing users. Changes to groundwater quality may impact health of receptors that may use groundwater such as flora and fauna habitats.
		Disposal/management of groundwater derived from construction dewatering	Leakage into other aquifers via surface infiltration from storages, storage of water in the aquifer	
		Spills, runoff of storm water, leakage from lagoons, run-off from stockpiles, work areas	Leakage into aquifer via surface infiltration	
	Activation of acid sulphate conditions	Existing potential or actual acid sulphate soils are exposed through excavation or construction dewatering or alteration of recharge	Lowered water level, exposure (or re-exposure) of acid generating materials to oxidation. Release of acid, and mobilisation of heavy metals	
	Changes to groundwater quality through use	Construction dewatering (for deep excavations below the water table). Development of groundwater supplies to service construction water requirements.	Changes in quality through interception, mixing or dislocation of saline (or contaminated) waters.	

6.5 Groundwater Risk Register

The risk register has been included as Table 13. The register is a compilation of the groundwater risks for the Project that have been identified. The register describes the risk pathways, and where relevant, specific information as to where the risk could be reasonably expected with the Project Area. Risks have been initially ranked, and a residual risk also determined following consideration of controls available to mitigate these risks. The consequence and likelihood criteria have been defined in section 4.2. A description of the potential impact, mitigation measures and risk has been presented in the section 6.6.

VicRoads has a standard set of environmental protection measures which are typically incorporated into its construction contracts for road works and bridge works. These are described in *VicRoads Contract Shell DC1: Design & Construct, April 2012*, hereafter referred to as the "VicRoads standard environmental protection measures". These measures have been used as the starting point for the impact assessment. Those that are relevant to groundwater are included in the "planned controls" column of the risk assessment (Table 13) and outlined in more detail in Section 7 (Mitigation Measures).

As a result of the initial risk assessment, in some cases additional Project specific controls have been proposed to reduce risks. These are outlined in the "additional controls" column of the risk assessment in Table 13, and are described in more detail in Section 7.

Both VicRoads standard environmental protection measures and the additional Project specific controls have been included in the Environmental Management Framework for the Project.

Of most importance to the groundwater environment is that part of the alignment which would have the greatest likelihood of interacting with it. This is most likely in those areas where the highway would be below the existing grade. Excavations below the existing ground can cause direct interaction with groundwater, or increase the likelihood of interaction should groundwater levels fluctuate in the future. Groundwater can also be affected by other project processes (road construction or operation) that occur remote from areas of cut, and anywhere along the proposed alignment, and this has also be included in the discussion.

Table 13 Groundwater Risk Register

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW1	Cuts below water table along alignment, requiring dewatering.	Construction dewatering results in unacceptable impact to other groundwater users, e.g. existing irrigators, stock and domestic users. (construction and/or operation). Ch. 4,850 – 5,000 m, 5,400 – 5,550 m, 13,100 – 14,000 m and 14,150 – 14,550 m are areas where this risk may be relevant.		1200.05	Implementation of a Groundwater Management Plan and Monitoring Program. Implementation of sediment control measures, and water disposal options.	Insignificant	Rare	Negligible		Insignificant	Rare	Negligible
GW2	Cuts below water table along alignment, requiring dewatering.	Management of the recovered groundwater - erosion or water quality degrades receiving surface waterways (construction and/or operation). Ch. 4,850 – 5,000 m, 5,400 – 5,550 m, 13,100 – 14,000 m and 14,150 – 14,550 m are areas where this risk may be relevant.		1200.05 1200.08	Implementation of a Groundwater Management Plan and Monitoring Program. Implementation of sediment control measures, and water disposal options.	Insignificant	Rare	Negligible		Insignificant	Rare	Negligible

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW3	Cuts below water table along alignment, requiring dewatering.	Dewatering / depressurisation consolidates compressible materials causing settlement and land instability. (construction and/or operation). Few built structures are in those areas that are below the grade. Ch. 4,850 – 5,000 m, 5,400 – 5,550 m, 13,100 – 14,000 m and 14,150 – 14,550 m are areas where this risk may be relevant.	Geology and Soils		Implementation of a Groundwater Management Plan and Monitoring Program.	Minor	Unlikely	Low		Minor	Unlikely	Low
GW4	Cuts below water table along alignment, requiring dewatering.	Temporary construction dewatering adversely affects groundwater flow to Groundwater Dependent Ecosystems (GDEs). Cuts below grade that permanently result in change in groundwater flow regime. (construction and/or operation). Ch. 4,850 – 5,000 m, 5,400 – 5,550 m, 13,100 – 14,000 m and 14,150 – 14,550 m are areas where this risk may be relevant.	Surface water, Flora and Fauna	1200.05	Implementation of a Groundwater Management Plan and Monitoring Program.	Minor	Rare	Negligible		Minor	Rare	Negligible

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW5	Cuts below water table along alignment, requiring dewatering.	Dewatering alters hydraulic gradients resulting in existing groundwater contamination plumes potentially being dislocated / moved. Interruption of existing groundwater remediation efforts. Ch. 4,850 – 5,000 m, 5,400 – 5,550 m, 13,100 – 14,000 m and 14,150 – 14,550 m (specifically the former Great Western landfill 13,200 – 13,400 m) are areas where this risk may be relevant.	Soils and Geology	1200.05 1200.09	A Groundwater Management Plan and Monitoring Program would be implemented. Management of Contaminated Soils and Materials: 1) The discovery of contaminated material on the site during works shall be managed in accordance with VicRoads and EPA Guidelines. 2) Where putrescible waste material is encountered the Superintendent and EPA shall be notified. 3) The Contractor shall undertake a visual assessment of the Site for contaminated soils and materials.	Minor	Rare	Negligible		Minor	Rare	Negligible
GW6	Cuts below water table along alignment, requiring dewatering.	Potential generation of acid plumes / mobilisation of heavy metals / aggressive groundwater, leading to attack on submerged steel / concrete structures (piles, services).	Soils and Geology Planning and Land Use	1200.08	Management of construction dewatering (as per above). DSE Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulphate Soils.	Moderate	Rare	Low		Moderate	Rare	Low

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW7	Contamination of groundwater from construction activities, e.g. spillage, use of 'contaminated' fill material, construction waste management, hazardous materials handling.	Impact to groundwater quality/ breach of SEPP (Groundwater of Victoria). Potential to breach SEPP (Waters of Victoria). Impact to worker safety during construction. This could occur anywhere along with the Project area.	Soils and Geology Surface Water	1200.09 1200.11	Contaminated Soils and Materials 1) The discovery of contaminated material on the site during works shall be managed in accordance with VicRoads and EPA Guidelines 2) Where putrescible waste material is encountered the Superintendent and EPA shall be notified. 3) The Contractor shall undertake a visual assessment of the Site for contaminated soils and materials. Fuels and Chemicals 1) EMP to include specific procedures to minimise leakage or spillage of any fuels or chemicals, mitigate the effect. 2) Fuel and chemical storages and equipment fill areas shall be monitored at intervals of not more than 7 days.	Minor	Rare	Negligible		Minor	Rare	Negligible
GW8	Contamination of groundwater from operational activities (road runoff, traffic accidents, stormwater, spillage).	Impact to groundwater quality/ breach of SEPP (Groundwater of Victoria). This could occur anywhere along with the Project Area.	Soils and Geology Surface Water	1200.05	Standard procedures for State Emergency Response, Country Fire Authority and Environment Protection Authority.	Minor	Rare	Negligible		Minor	Rare	Negligible

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW9	Ponding and retention of water associated with highway drainage (operation).	New or increased groundwater accessions, altered groundwater flow patterns, new or exacerbated waterlogging and salinity impacts. This could occur anywhere along with the Project Area.	Soils and Geology Surface Water Economic		Water Sensitive Road Design measures would be evaluated for inclusion in the detailed design phase, as described in VicRoads Integrated Water Management Guidelines (August 2011).	Moderate	Rare	Low		Moderate	Rare	Low
GW10	Construction earthworks removing impervious layers (across site, floodplains, river crossings and embankments).	Site recharge enhanced increasing groundwater levels (water logging, groundwater displacement) and or introducing contaminants. This could occur anywhere along with the Project Area.		1200.05	Implementation of a groundwater management plan. River crossings duplicated consistent with CMA requirements.	Minor	Rare	Negligible	Earthwork surface finish / rehabilitation specifications to mitigate enhanced accessions.	Minor	Rare	Negligible
GW11	Construction works create impervious ground surface layers.	Reduced recharge to groundwater system. This could occur anywhere along with the Project Area.		1200.05	A Groundwater Management Plan and Monitoring Program would be implemented.	Minor	Possible	Low		Minor	Possible	Low

Risk No.	Impact Pathway	Description of Consequences	Linkages	VicRoads Standard Specifications	Planned Controls to Manage Risk (as per Project Description, and VicRoads Standard Specification (April 2012)).	Initial Risks			Additional Controls Recommended to Reduce Risk	Residual Risks		
						Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
GW12	Project pipelines or service conduits constructed in saturated materials alter groundwater flow.	Buried services within the alignment located below the water table may create preferential groundwater seepage paths, and alter seepage migration routes. In shallow groundwater environments the resulting impact can be significant. Furthermore groundwaters (e.g. saline groundwater) may be aggressive to buried services.		1200.05	A Groundwater Management Plan and Monitoring Program would be implemented.	Insignificant	Possible	Negligible	Apply standard pipeline construction measures (trench cut offs- or breakers) that mitigate risk process.	Insignificant	Possible	Negligible
GW13	Alignment of road passes through existing groundwater bore location (or farm dam) or severs access for stock or irrigation infrastructure.	Requirement to compensate groundwater user, install replacement bore (observation, stock, irrigation etc.) or replacement dam. Temporary loss of production.	Economic Social		Negotiation with asset owner.	Insignificant	Rare	Negligible	Confirmation of bore locations (and operational status) within construction corridor / landholder consultation.	Insignificant	Rare	Negligible
GW14	Use of groundwater for construction water supply.	Adverse impact to existing groundwater users, environment.			Grampians Wimmera Mallee Water extraction licensing process.	Insignificant	Rare	Negligible		Insignificant	Rare	Negligible
GW15	Shallow groundwater or rising water tables.	Rising water and/or precipitation of salts can damage road pavements.	Road Design		Adequate road (under) drainage. Understanding of conditions of existing road i.e. correlations from existing behaviour.	Insignificant	Rare	Negligible		Insignificant	Rare	Negligible

Ch.Contraction of chainage

6.6 Discussion and Assessment of Impacts

The preceding sections 6.4 and 6.5 discuss the various risk pathways and summarise the project risks to the groundwater environment. This section discusses the risks for each of the identified risk pathways, and assesses the potential consequences of the impacts.

6.6.1 Assessment of Construction Dewatering

Definition

The extraction of groundwater, from either a bore or through the dewatering of an excavation within saturated conditions, results in a decline in groundwater levels surrounding the bore. The decline in water level is referred to as the 'drawdown cone' or 'cone of depression' around the pumping bore, or drawdown zone around an excavation. Excessive groundwater inflows can be an impediment to subsurface construction, and pose issues in terms of depletion of a resource, management of the volume recovered and the effects of drawdown.

The extent of drawdown depends primarily on the nature of the aquifer, the pumping rate and pumping duration. If the aquifer system consists of fractured rock, or is of odd shape, the shape and extent of drawdown may vary in certain preferential directions. If the drawdown extends such a distance from the extraction centre such that it intersects other bores or in the case of unconfined aquifers, environmental features, e.g. creeks, rivers, dependent ecosystems, it is said to have interfered with these features. The altering of the hydraulic gradient may result in changes to the groundwater movement from (or to) these features, thus affecting water availability. Features like lakes and rivers may stabilise the cone of depression (recharge boundaries), whereas aquifer thinning or permeability changes may result in increased drawdown as the cone expands to meet the dewatering rate (discharge boundaries).

The proposed alignment involves a number of areas of cut, which may or may not be below the water table. Cuts that do not intersect the water table do not pose a risk as they do not interact with the groundwater environment. Cuts that intersect the water table and result in the interception of groundwater at these locations would have ramifications in terms of the volumes of groundwater that may need to be controlled (and ultimately disposed). Dewatering may also influence the generation of acid from acid sulphate soils and induce subsidence and these are both discussed individually as separate risks.

The risk pathways are schematically shown in Figure 7, which shows a vertically exaggerated alignment intersecting the water table. It shows a change in the water table and perched water table caused by earthworks. The same effect of the cut could be achieved if groundwater is proposed to be sourced for construction water supply.

A cut has the potential to cause the following impacts (as shown in Figure 7):

- Reduction in available drawdown in neighbouring bores, e.g. stock, domestic, irrigation, through the lowering of the water table. This is relevant where bores develop the same aquifer as the one being subject to the cut;
- Dewatering / depressurisation of perched groundwater aquifers;
- Loss of water supply to flora and fauna habitats;
- Consolidation, and settlement to overlying structures;

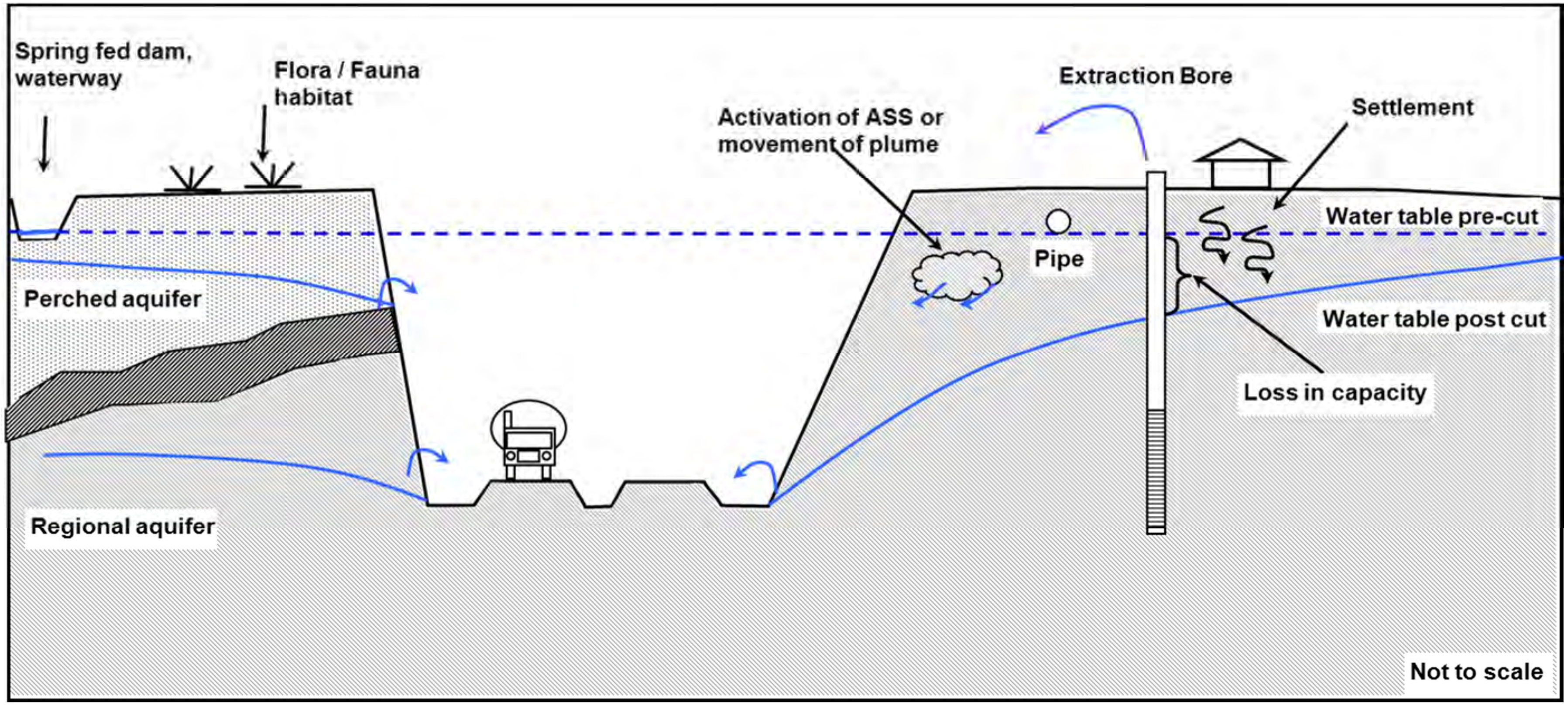
- Activation of acid sulphate soils / or mobilisation of contaminated groundwater plumes; and
- Reduction in water availability to groundwater dependent ecosystems.

Owing to these impacts, the excavation and placement of cuttings as part of the Project potentially poses the greatest disturbance to the groundwater environment. The effect of drawdown could be short term, related to the construction period, or long term /permanent, related to the permanent presence of the cuts and its continued interaction with the groundwater environment.

Excessive inflows can also lead to excavation instability, however it is a reasonable expectation that geotechnical investigations would be undertaken prior to road construction and cut construction to assess and inform the engineering design.

It should be further noted that shallow water tables can be detrimental to the long term stability and integrity of road pavements, and therefore it is in the best interests of road designers to avoid grade lines that fall below the regional water table, or require on-going water management.

Figure 7 Schematic of Potential Dewatering Effects



Assessment of the Likelihood of Drawdown and its Limitations

In order to assess the risk of potential impacts to groundwater as a result of dewatering, an understanding of the location and magnitude of drawdown required, is necessary. This is problematic when the definition of the water table throughout the proposed alignment is poorly characterised.

To provide an insight into potential areas that may require some form of dewatering, cuts below grade that are greater than 3 m below the ground surface have been summarised in Table 14. The 3 m criterion has been nominally selected as a guide as:

- Where groundwater levels are within 2 m of the ground surface, evaporative effects can lead to salinization and water logging issues. Obvious evidence has not been identified within the various option alignments of Section 3 and where such conditions prevail, road designers are likely to use embankments (grade lines in fill) to ensure the stability and integrity of road pavements.
- Cuts less than 3 m may still encounter perched water, but are considered less likely to intersect the regional water table, and inflows are likely to be minimal and controllable with a minimum of intervention, e.g. roadside drainage.

Table 14 Areas Below Grade (Section 3)

Chainage (m)	Approximate Length (m)	Maximum Depth of Cut (m)	Comment
4,850 – 5,000	<100	3	
5,400 – 5,550	<100	4.36	
13,100 – 14,000	850	9.63	Approximately 300 m over 8 m depth
14,150 – 14,550	350	6.91	Approximately 250 m over 5 m depth

Note:

1. Based on the east bound carriageway. The west-bound carriageway alignment is expected to have a similar magnitude of cut given its proximity to the eastern alignment. This is considered a reasonable assumption given that the grade line resolution is 50 m, and may change through engineering design and micro alignment changes.

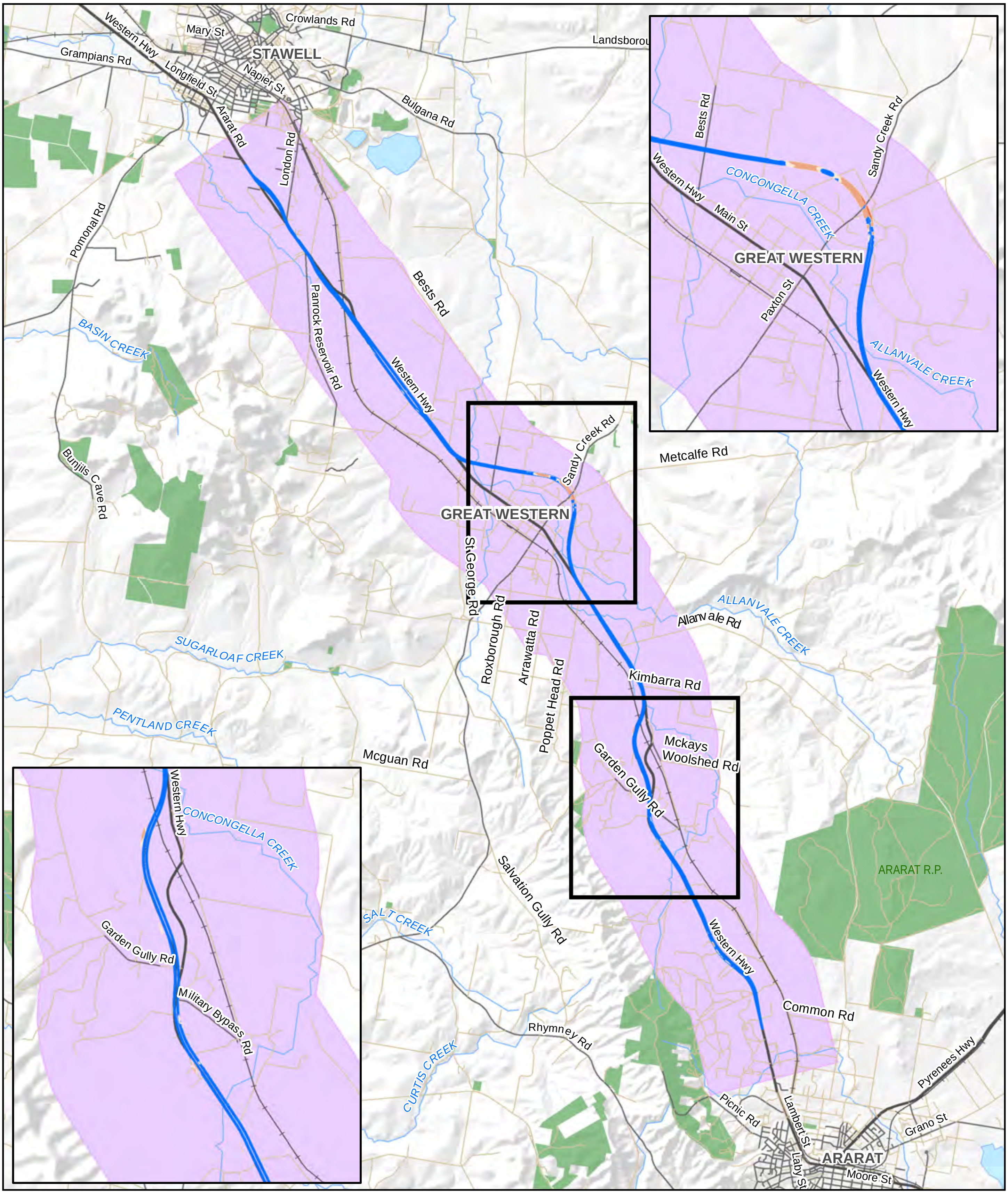
Table 14 indicates that along the 24 km alignment, less than 1.5 km has an elevated risk of intersecting groundwater. The deepest cuts occur within steeper topographies, e.g.north-east of Great Western, where water levels are also expected to be deeper. The location of these areas is shown in Figure 8.

In the Great Western area the proposed alignment would pass through part of an existing quarry and landfill. The landfill is located between Ch. 13,100 m and 13,400 m, whereas two areas of quarrying activity are noted between Ch. 13,100 m and 14,000 m on either side of the existing Great Western – Bulgana (Metcalfe) Road. Available information suggests that the existing base of the quarry is close to the proposed gradeline of the highway. The quarry is not currently subject to active dewatering activities, i.e. dry. VicRoads (2010) document that the quarry extracts gravels, which are stratigraphically referred to as White Hills Gravels, an early Tertiary sedimentary sequenced derived from weathering of the Palaeozoic bedrock.

There are two lines of evidence to suggest that groundwater occurrence is deep, and that a reduced likelihood of groundwater intersection exists in this area:

- VicRoads (2010) describe the sampling of quarry product from two testpits excavated 4 m to 6 m below the existing quarry surface (Newton Quarry) and neither encountered groundwater.
- Golder (2011) describe the excavation of ten (10) test pits at the former Great Western Landfill to depths of approximately 4 m below the existing surface. No evidence of groundwater being encountered was noted by Golder (2011). Interpretative cross sections documented by Golder (2011) noted the depth of landfilling to be generally less than 3 m below the surface.

Noting that the deepest areas of cut are proposed in the above chainages, overall, there would be a low likelihood of encountering groundwater elsewhere on the alignment. However it cannot be discounted that groundwater may be unexpectedly encountered at localised areas along the proposed alignment. Accordingly, some semi-quantitative analysis has been undertaken to determine the impact of encountering unexpected groundwater and this is described below.



LEGEND

- Proposed Alignment
- Study Area
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Parks

Areas of large construction Excavation (m Depth)

- 3 - 5
- 5.1 - 10
- 10.1 - 15
- 15.1 - 26

Paper Size A4

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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vicroads

VicRoads
Western Highway Project

Job Number 31-27558
Revision B
Date 08 Nov 2012

Ararat to Stawell
Areas of Large Excavation

Figure 8

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

G:\31\27558\GIS\Maps\Deliverables\Stage 3\RISK AND IMPACT ASSESSMENT\01_HYDROGEOLOGY\3127558_S3_004_Areas_Large_Cut_A4P.mxd

Data source: DSE, VicMap, 2012; VicRoads, 2011; GHD, Design, 2012. Created by:splaird

Note that Table 14 (and Figure 8) do not provide an indication of water level depth, nor the requirement to, or magnitude of dewatering that may be required. Most of the cuts to be undertaken are required to maintain carriageways at grades of no greater than 6%. Review of cut areas for each option within the Study Area, indicates the cuts to be located in the steeper topographies, i.e. approaching and upon the crests of hills. This is an important factor when considering the potential influence of dewatering, and potential flows into cuttings. A schematic showing two conceptualised inflow scenarios has been provided as Figure 9.

The first scenario (Case 1) could occur in the flatter topographies and plains of the Study Area. Any cut below the regional water table would result in on-going inflows into the excavation (and completed cutting) as the cut would always act a sink or depression feature in the regional watertable. However, there is limited to no likelihood of this occurring as there is no requirement to maintain shallow grades for traffic on planar or horizontal terrain.

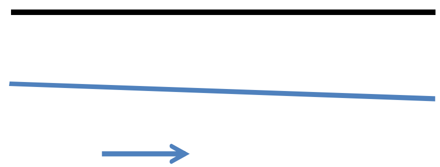
The second scenario (Case 2) is expected to occur in the undulating and steeper topography of the alignment (e.g. Cambro-Ordovician basement terrain). As noted earlier (refer Section 5.8), in such terrain local groundwater flow systems could be present. Rainfall recharge to each hill would radially flow away towards the depressions and lower topographies. With the construction of a cutting, to achieve smoother and gentler (<6%) grades for traffic, any recharge occurring would have two flow components. There would be a component towards the cutting, and a component flowing radially away towards the lower topographies.

The volume of water that would need to be controlled during excavation of the cutting would be that in storage in the aquifer between the original (pre-construction) watertable and design gradeline. Owing to the rate of progress of earthworks, this drainage is usually concurrent with earthwork stripping rates and often does not require intervention (i.e. active dewatering) to remove.

The cuttings identified in Table 14 fall into the second scenario (Case 2). When the watertable reaches its new equilibrium post construction, most seepage into the cutting would be controlled by lateral roadside drainage, and evaporation effects. The mounding of the watertable on either side of the excavation may eventually disappear. An increase in seepage into the cutting may be identified after rainfall periods, when rainfall recharge re-creates the watertable mounding.

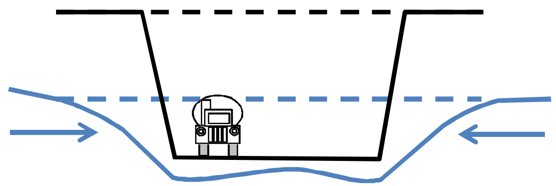
Case 1
On-going groundwater management

Pre-Construction Conditions



Aquifer is recharged, and flow according to regional hydraulic gradients.

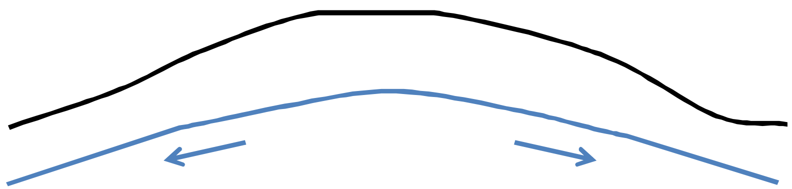
Post-Construction Conditions



Continued supply of groundwater into cutting as radius of influence is 'infinitely extensive' or significant. On-going water management or tanking structure required.

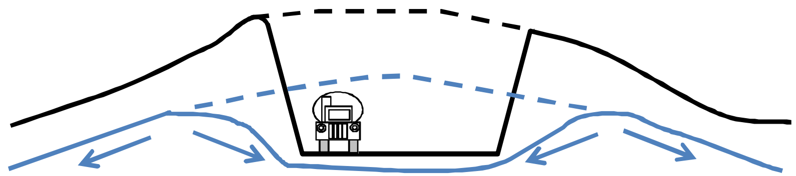
Case 2
Short-term groundwater management

Pre-Construction Conditions



It undulating topography, local groundwater systems develop

Post-Construction Conditions



Construction inflow until new water table equilibrium established. Periodical seepage as reacharge occurs to the aqufier, which can be managed by drainage (or evaporation).

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VicRoads
Western Highway Section 3 - Ararat - Stawell
Schematic Conceptualisation of Cutting Inflow

job no.	31 / 2755809
report no.	213394
Rev no.	A

scale: Not to scale | date: 23 July 2012

Figure 9

Level 8, 180 Lonsdale Street, Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au

Estimated Influence of Dewatering

In evaluating the effect of potential groundwater drawdown resulting from cut construction, it is important to understand the term drawdown (i.e. change in waterlevel) and the limitations in predicting drawdown. The extent of influence is time-dependent, and therefore dependent upon construction progress (or excavation and ground support) rates / time periods considered.

The extent and magnitude of drawdown is not only dependent upon the aquifer hydraulic parameters (principally transmissivity, storativity and homogeneity), but also factors such as leakage between adjoining aquifers and aquitards and interactions with hydraulically connected waterways / discharge features. Where hydrogeological systems become more complex, the accuracy of the drawdown predictions becomes increasingly problematic.

An approach to estimating the drawdown influence is to use an empirical relationship that allows a steady state approximation of the distance from the excavation at which a particular drawdown condition occurs. This has been shown in Table 15 for drawdowns of 1 m, 2 m, and 12 m with a range of hydraulic conductivities representing geological materials that may be expected along the proposed alignment.

Table 15 Steady State empirical estimate of Pumping Radius of Influence

Method	Condition	Hydraulic Conductivity (m/day)					
		0.1 (Clay)	0.5	1	2	5	10 (Gravel)
Sichardt	Drawdown of 1 m	3.2	7.2	10.2	14.4	22.8	32.3
	Drawdown of 2 m	6.5	14.4	20.4	28.9	45.6	64.5
	Drawdown of 12 m	38.7	86.6	122.5	173.2	273.9	387.3
Kussakin	Drawdown of 1 m	3.1	6.9	9.8	13.8	21.9	30.9
	Drawdown of 2 m	6.2	13.8	19.6	27.7	43.7	61.9
	Drawdown of 12 m	37.1	83.0	117.4	166.0	262.5	371.2

Note: Based on a 25 m aquifer saturated thickness

In reality it is unusual to get a drawdowns extent of less than 50 m (Cashman, 2001) and the radius of influence shown in Table 15 should be viewed with low confidence, particularly without pumping and geotechnical testing. The empirical estimates of radius of influence, however, indicate that the steady state or long term radius of influence is expected to be less than 400 m.

The extent of drawdown would have implications on settlement, the activation of potential acid sulphate soils, and potential impacts to groundwater resource uses and these are discussed in subsequent sections. The drawdown is obviously greater at the face of the excavation, and decreases with increasing distance from the excavation face. This means that a feature (e.g. abstraction bore, area of acid sulphate soils, potential groundwater dependent ecosystem) may not necessarily be adversely impacted, by being within the radius of influence. Effects are more likely nearest the seepage / cutting face, or within 30% of the radius of influence as this is where more than 50% of the total drawdown is likely to be observed (based on analytical modelling).

Considering potential groundwater dependent ecosystems within the Study Area:

- Riparian habitats are not going to be present in areas of cut. To maintain waterway and floodplain function, bridging structures would be used;
- Terrestrial vegetation may need to be removed. Offsets would be determined by ecological assessment (refer GHD, 2012c). Landscaping and rehabilitation would also be consistent with VicRoads (2011); and
- Springs and seeps are more likely to be identified at the break of slope and those parts where cut depths are likely to be shallower. Whilst springs have not been identified, should they be located in areas of cut they may be removed (or destroyed).

A better understanding and definition of the water table would be obtained following the completion of geotechnical investigations that are required to inform the engineering design of road and waterway crossing design. Given the uncertainties of intersecting groundwater and imposing drawdown, a groundwater investigation and monitoring program prior to construction would be required to calibrate models and confirm predictions. This is required by VicRoads Standard Specifications (Clause 1200.05).

Estimate of Potential Inflows

Using steady state flow approximations based on the Dupuit-Forcheimer equation, and considering the excavations as a series of pumping bores with an equivalent area, analytical estimates of construction inflows are available for Case 1 cutting conceptualizations (refer Figure 9). However, it was noted that there is limited likelihood of such cuttings being present within the Study Area and therefore this has not been undertaken.

The inflow estimate into Case 2 cuttings is more problematic given the lack of understanding of the form of the watertable at each cut. Analytical flow approximations are likely to grossly over-estimate the inflow volumes as the aquifer system would not be infinitely extensive. As noted earlier, the volume of water that would be removed from the system would be equivalent to that contained within the aquifer materials to be removed by the excavation (ignoring recharge that could occur during the construction period).

Assuming a specific yield (drainable porosity) of 0.01 for the Cambro-Ordovician basement materials (rock and saprolite), for each metre excavated below the water table, a dual carriageway cutting of assumed 100 m width, would yield 0.1 ML per 100 m length of cut.

It is possible, particularly in the Cambro-Ordovician basement rocks, that geological structures could influence groundwater inflows. Geological faults have been identified along the alignment (e.g. Copes Hill Fault between Ararat and Armstrong / Garden Gully, faulting on the southern outskirts of Stawell) and these may pose geotechnical issues to the design of road cuttings. Depending upon the nature of the faulting and shearing, faults may locally increase the fracturing and (groundwater storage) of a local rock mass. Such areas may have a higher likelihood of increased inflow of groundwater should a cutting excavation expose such a structure. Geotechnical drilling to inform the design of road cuttings would be used to identify and characterise the nature of any geological structures and their impact on groundwater inflows.

Assessment of Impact

The above discussions assess the risk of impact. The lack of information regarding the groundwater level along the proposed alignment makes quantification of potential impacts to the groundwater environment, problematic.

Areas of deepest cut are proposed in the Great Western area (Ch. 13,100 m to 14,600 m). Excavation of testpits completed by VicRoads (2010) and Golder (2011) in two quarries and the former Great Western landfill, to depths between 4 m and 6 m below the surface at these locations did not intersect groundwater. Furthermore, the proposed highway alignment gradeline is near co-incident with the existing quarry elevations. These are multiple lines of evidence to support the absence of shallow groundwater and low likelihood for cuttings to directly interact with the groundwater environment. If groundwater is unexpectedly encountered the imposed drawdowns and resultant impacts are therefore likely to be minor.

In most cases, it is suspected that a reduction in groundwater level (or flow) would have a minor to negligible impact on the groundwater environment, where the regional water table is influenced, and where the groundwater in the regional water table aquifer is poor (saline). This is based on the likely long term inflows into a cutting (designed to minimise water table intersection for engineering construction and stability), and a limited reliance upon saline groundwater by vegetation.

Where shallow water tables, springs or perched water table aquifers are disrupted (where groundwater flow is severed, aquifer materials drained or flow dislocated), and the groundwater quality in these areas is such that it could support sensitive ecosystems, then the impact may be more significant.

As noted above, geotechnical investigations undertaken to inform the detailed design of these cuttings (and likelihood of intersecting groundwater), and the available measures to mitigate groundwater inflows, would suggest that the overall impact of the Project on the groundwater environment could be considered to be low.

6.6.2 Changed Groundwater Levels – Use of Groundwater Resources

Definition

Changes to groundwater levels near excavations and road cuttings may also influence the water levels and operation of neighbouring groundwater users.

Groundwater bores may be installed by a construction contractor for water supply (e.g. road making, dust suppression). The drawdown created by the operation of such a bore and the potential impacts of pumping is the same as for construction dewatering (refer Section 6.6).

Assessment of Impact

The likelihood of a construction water supply bore causing potential impacts to neighbouring groundwater users is negligible. Any groundwater bores installed for construction water supply or permanent water supply would need to be licensed by a rural water authority (Southern Rural Water) in accordance with the *Water Act* (1989), and thus be subject to their licensing determinations. This would include an assessment of impact to existing users, surface water flows and water availability. A groundwater supply would not be licensed by Southern Rural Water unless the risks of extraction to groundwater (other users, the environment) are acceptable.

Few bores were identified close to the proposed alignment, and this is largely an artefact of the poor groundwater quality (elevated salinity). Of the bores identified, most were registered as stock and domestic bores, and although nearby bores may be subject to loss of available water due to construction drawdown / changes to groundwater levels near to road cuttings, the operational capacity of a stock bore may not be impacted.

Previous discussions (refer Section 6.6) provide estimates of the potential radius of influence (refer Table 15) in areas of cut. This indicates that a bore would have to be close to the construction works to be influenced. If a bore is identified within the potential radius of influence of groundwater drawdown from a cutting, and determined to have greater than 10% loss of available drawdown, there are a number of mitigating measures available to reduce potential impacts, e.g. lowering pumps, provision of alternate supplies, or shifting the point of extraction. Reinstatement of the supply could be negotiated between VicRoads and the impacted party.

Considering the limited existing development of groundwater, and processes in place under the *Water Act* (1989) to access groundwater, impact to the groundwater environment for the proposed alignment, is considered negligible.

6.6.3 Changes to Aquifer Character – Compaction / Subsidence

Definition

Settlement is a result of changed stress conditions on compressible geological materials. It may result from loadings (embankment construction), aquifer depressurisation (discussed in this report), heave from underlying aquifer pressures, or creep (secondary settlement).

Land subsidence induced by aquifer depressurisation is a gradual settling of ground surface due to reduction in water pressure and a corresponding increase in effective stresses in the ground. If drawdown occurs under built up areas, under some soil conditions, (differential) ground movements could be a concern to the integrity of structures, e.g. residential housing), other roads and underground services. This type of subsidence is commonly caused by the compression of soils and rock in and around areas of large scale groundwater pumping.

Depressurisation of aquifers may occur through cuttings within saturated materials. The depressurisation of unconsolidated or poorly consolidated sediments such as the Quaternary and Tertiary sediments, can lead to the drainage of clay and silt aquitards. Aquitard drainage leads to compaction and land subsidence. Therefore, if drawdown occurs under built up areas, under some soil conditions, (differential) ground movement could be a concern to the integrity of structures, e.g. buildings, roads and underground services.

Initially, the weight of overburden (soil and water) above an aquifer is in equilibrium, being carried by support forces consisting of water pressure and grain-to-grain stress. As water is removed from the aquifer, the fluid pressure decreases and because the weight above the aquifer does not change with time, this weight must continue to be carried by the aquifer system. The portion of overburden weight that was initially supported by the water decreases and an increasing portion is carried by the soil structure. The skeletal structure of the soil becomes more densely packed to achieve a new equilibrium resistance to the overburden load. The result is compression within the aquifer system and corresponding subsidence of the land surface.

In addition, the slow draining, low permeability clay members of an aquifer system are often found to be more compressible than sands. This results in a time lapse between changes in water pressure and cumulative compression of the entire system. Although settlement of sand units is relatively fast and occurs quickly, volume changes within the clay soils are of greater magnitude and are delayed and occur over a long period of time. The settlement behaviour of clay soils is usually dependant on their stress history (normally and over-consolidated).

Assessment

GHD (2012b) has documented controls to identify compressible soils and assess subsidence risks. There are a number of factors which indicated that there is a very limited likelihood of settlement occurring.

For subsidence to be an impact, compressible soils, if such soils are identified, have to be located in an area close to where groundwater levels are to be influenced, i.e. where construction dewatering is to occur. Furthermore, any settlements induced have to translate into an unacceptable deformation to an overlying structure (building, pavement, buried service).

The geological terrains most likely to have compressible materials are the Tertiary and Quaternary age sediments. These sediments are generally restricted to the present day waterways where the proposed carriageways are likely to cross above grade with bridging structures and therefore obviate the cutting and interaction with the groundwater environment.

Overall, the impact to the groundwater environment, e.g. compression of aquifers, for any of the alignment options, is considered to be negligible owing to:

- Most areas requiring (deeper) cuts are located on the Cambro-Ordovician basement. The Cambro-Ordovician basement is an indurated (rock) material and is not considered to be compressible material.
- The estimated extent of the drawdown from cuts has been summarised in Table 15 (based on empirical lithological – drawdown relationships). Drawdowns, in fine grained materials, would generally extend less than 100 m from an alignment.
- Controls are available and those noted previously to mitigate the effects of construction dewatering (Section 6.6) are relevant.

6.6.4 Changes to Groundwater Recharge

Definition

One of the principle mechanisms of recharge to unconfined aquifers such as the Cainozoic sediments and Palaeozoic bedrock along the proposed alignment is through infiltrating rainfall. The infiltration and subsequent groundwater accessions can be influenced by:

- Topography and gradients;
- Site drainage;
- Vegetation; and
- Surface conditions and run-off character.

Earthworks including excavations may also remove low permeability soil cover materials and expose the permeable zones within the aquifer. This may result in greater recharge. In other parts of the site the construction of a road may replace an aquifer recharge area, e.g. outcropping permeable aquifer material, with an impervious cover, e.g. bitumen sealed road.

The form of river crossings may result in changed floodplain conditions and increased flooding may result in greater likelihood of groundwater accessions, water table rise, water logging and land salinization.

Assessment

The alteration of groundwater recharge has conflicting risk pathways depending upon the spatial and hydrogeological context within the Project Study Area. For factors which may reduce groundwater recharge:

- the construction of the road and adjoining impervious surfaces, the changes to the ground surface conditions would almost certainly reduce recharge to the aquifer;
- the land uses / surface conditions would not significantly change within the footprint and therefore the recharge behaviour to the aquifer is not considered to change; and
- Road drainage would divert surface water to furrows and lagoons.

For factors which may increase groundwater recharge:

- Alteration of floodplain conditions can lead to the retarding of surface water flows, and thus a greater likelihood of infiltration and groundwater accession; and
- Ponding and creation of large depressions for retarding run-off may occur as part of landscaping activities and stormwater run-off and treatment works adopted for the Project.

The changes to recharge conditions, whether they result in increased or decreased accessions to groundwater, are considered to have negligible impact to the groundwater environment. This is based upon:

- What falls on the road ultimately drains away and ends upon unpaved surfaces. The net change would be minimal. Seepage of road run-off would be diverted to the adjoining landscape where it is either evaporated, taken up by vegetation, contributes to waterways, or forms seepage and accessions to the groundwater system;
- As the footprint of the Project is considered to be very small relative to the overall intake area for the regional water table aquifer, the consequences of the highway being constructed and associated landscaping (improvements) are considered insignificant;
- An objective of the EES relating to surface water is to maintain the functions and values of floodplains, and the design of waterway bridging structures would be designed to achieve this objective (refer GHD, 2012b). Therefore, changes (potential increased recharge) to the groundwater environment are highly unlikely; and
- The application of water sensitive roadside design (VicRoads, 2011). Landscaping (revegetation) may actually increase evapotranspiration and groundwater losses, however the landscaping (vegetation) improvements may achieve a positive outcome for fauna.

Areas of localised earthworks, e.g. the existing quarries and former landfill at Great Western, may have locally removed vegetation (reducing evapotranspiration effects), exposed underlying permeable soils and therefore potentially provided enhanced access for infiltrating rainfall to become groundwater accessions. The influence of these anthropogenic features on recharge, relative to overall recharge to the water table aquifer is considered to be minor. There are various lines of evidence from investigations (Golder, 2012b, VicRoads, 2011) which indicate deep water levels in this part of Great Western.

Improper management of highway run-off, such as the diversion of road run-off to areas of existing shallow groundwater, may lead to an increased risk of water logging and land salinization in localised areas. The likelihood of increased recharge leading to groundwater level rise and salinity impacts is considered to be low to negligible given the marginal increase in drainage relative to the existing highway footprint, but also the application of water sensitive roadside design (VicRoads, 2011).

6.6.5 Changes to Groundwater Flow

Definition

There may be buried underground services near the alignment. If these services are buried below the watertable, or store and re-direct intercepted perched water, groundwater impacts may arise as a result of relocating these services through changes to the existing level of hydraulic connection as a result of the service trench construction.

Assessment

It is acknowledged that such services are existing in parts of the current alignment, however it is not known whether they are interacting with groundwater. There are a number of factors that suggest a limited likelihood for potential impact to groundwater:

- The services would have to be deeply buried (i.e. several metres) to interact with groundwater. It is not cost effective construction to bury services below the water table if it can be avoided; and,
- The shift in location of these services is likely to be within 100 m of their existing position.

There are measures which would be implemented to mitigate construction and on-going pipeline operation impacts to groundwater. Trench cut-offs (or breakers) are one identified mitigation measure that can be implemented to achieve this in terms of preventing lateral migration of groundwater (or hydraulically connected surface water) along permeable pipeline backfill materials. This would be the responsibility of pipeline constructors.

6.6.6 Changes to Groundwater Availability – Severance of Access to Groundwater

Definition

The alignment may pass close to existing groundwater bores or spring fed dams, which may require these water supplies to be lost. In other cases, the alignment may sever access to such a supply, depending upon landowner’s property and stock management practices.

__Assessment__

Few groundwater bores were identified within the alignment (refer section 5.4 and Figure 4). Spring fed dams are defined as being sufficiently deep in construction as to intersect the watertable, or are located immediately down-gradient of a spring or seepage zone emanating from the earth (usually occurring at or close to a break of slope).

Whilst there was no obvious evidence that spring fed dams are present in Section 3, and within other parts of the Study Area, this does not discount their presence or absence (particularly given the lack of understanding of groundwater levels). Potential spring activity would be investigated as part of the detailed design phase.

A recommended control is that prior to construction, an audit of water supply infrastructure on landholders properties is recommended to identify bores which may not have been registered, or the presence of potential spring fed dams.

Bores that are within the footprint of the construction works, and which are threatened with destruction, could be relocated outside of the footprint. There are limited restrictions (location, size, depth) regarding the replacement of stock and domestic bores, however bores with an attached licensed use, e.g. irrigation bores (although no such sites have been identified in this Section), would be required to undergo a more rigorous process when being replaced i.e. assessment of impact of extraction at the new location.

Similarly, it is also possible to replace dams either through re-location (subject to Rural Water Authority determination processes) or with a bore water supply (subject to confirmation of water quality). The relocation of dams could be a process considered by the proponent to the dams identified on the above properties.

6.6.7 Changes to Groundwater Quality – Groundwater Contamination

__Definition__

As required by the *Environment Protection Act* (1970), and the SEPP (*Groundwaters of Victoria*), groundwater has defined beneficial uses dependent on its salinity. The groundwater quality must be protected to preserve the identified beneficial uses. Potential groundwater quality changes may arise from:

- Spillage, improper handling, storage and application of hazardous materials;
- Disposal of fluids or waste to groundwater;
- Aquifer re-injection to mitigate drawdown and related impacts (e.g. settlement);
- Exposure of Acid Sulphate Soil);
- Incompatibilities with construction materials, e.g. leaching from imported backfill;
- Intersection and/or dislocation of leachate / contaminated groundwater;
- Establishing hydraulic connection between two aquifers of differing water quality which were previously hydraulically isolated; and/or
- Spillage, road run-off during operation of the Project.

These impacts could arise both during the construction and operation of the highway.

Assessment

The background groundwater quality of the water table aquifer is variable, but generally in most areas of the proposed alignment, fall within Segment C (refer Section 5.5).

It is possible that construction activities may result in localised groundwater quality impacts as a result of spillage or improper application of hazardous materials, e.g., the storage, refuelling and maintenance of plant and equipment. Controls in the VicRoads Standard Specifications address these.

Roadside run-off from the operating Western Highway is likely to generate water that may contain oils, greases, heavy metals and other potential contaminants. It would take an exceptional circumstance for this to result in an adverse impact to groundwater owing to the pathways involved:

- Most of this run-off would be harvested by conventional roadside drainage. Significant quantities of impacted run-off would have to pond and then vertically infiltrate into the groundwater table, before it is either evaporated or taken up (transpired) by roadside vegetation;
- Water Sensitive Road Design (WSRD) principles applied to the stormwater management regime and landscaping of the Project would result in features such as grass swales being incorporated into its design that naturally treat run-water; and
- Soils within the proposed alignment, particularly in the Cambro-Ordovician basement terrain, may have appreciable fine fractions, e.g. clays, silts, or carbonaceous material. The low permeability of these soils would retard the vertical migration of contaminated waters, but also naturally attenuate some contaminants, e.g. heavy metals, through adsorption.

Release of contaminants from traffic accidents may result in major impacts to groundwater quality, however, again the pathway of the groundwater contamination process is restricted. These accidents are generally localised and emergency services response is likely to be rapid, thereby reducing the potential for migration to the groundwater system.

Incompatibilities between construction materials may result in leaching of constituents into the groundwater system. This is considered unlikely given that most construction materials:

- Would be relatively inert, or be designed / engineered for the anticipated conditions if aggressive conditions are expected;
- Would be of similar make-up, i.e, clean backfill, earthen materials derived from the same (or similar) geologies, e.g. cut and fill balances would be aimed at minimising the need to obtain and import additional foreign fill;
- Would be subject to a reasonable expectation for performance standards (soil quality) to be applied to any fill imported on to the site; and
- Require significant contact with groundwater, or significant fluid to leach and migrate to groundwater, i.e. in areas of fill the material is above the water table.

Under these circumstances, it is unlikely that construction materials would have a deleterious impact upon groundwater quality.

Whilst the risks of impact to the groundwater environment is low, the significance of impact, for any of the alignment options, is dependent upon the local groundwater quality. Overall, the regional groundwater quality is poor (saline) ranging from 1,500 mg/L to over 7,000 mg/L TDS and the existing level of groundwater development is consequently low. The groundwater quality falls within Segment B or higher and the more saline groundwater has limited beneficial uses. Where the groundwater salinity is at the upper end of the range, the impact to the groundwater environment is likely to be negligible. Where groundwater is at the lower end of salinity range, the impact could be significant if the contamination adversely effects existing beneficial uses, e.g. down-gradient receiving environments and sensitive receptors, e.g. stock and/or domestic bores.

6.6.8 Changes to Groundwater Quality – Activation of PASS (by Construction Dewatering)

Definition

The occurrence of Acid Sulphate Soils (ASS) can be present in the form of:

- Potential Acid Sulphate Soils (PASS): Soil that contains unoxidised iron sulfides. When exposed to oxygen through drainage or disturbance, these soils produce sulfuric acid; and
- Actual Acid Sulphate Soil (AASS): Potential ASS that has been exposed to oxygen and water, and has generated acidity.

These soils are rich in organics and were formed in low oxygen or anaerobic depositional environments. They are rich in sulphides and when oxygen is introduced, the sulphides oxidise to sulphate, with resultant soils having low pH and potentially high concentrations of the heavy metals. When water levels rise, pH and heavy metals are subsequently mobilised into the environment and can potentially impact deep rooted vegetation, aquatic flora and fauna, and be aggressive to reactive materials (for example, concrete, steel) of foundations, underground structures (piles, pipes, basements) or buried services in contact with groundwater.

In some locations, some of the rocks that make up the Saint Arnaud Group are expected to be pyritic. Therefore, there is a potential for oxidation of the pyrite and the resultant production of acid in locations where rocks from the Saint Arnaud Group outcrop within the Study Area (between Ararat and Great Western). These rocks have been exposed in cuttings in the existing highway, however it is considered prudent to assess and confirm the rocks are not pyritic.

There are two main pathways for the activation of ASS to form groundwater impacts:

- Excavation of PASS soils above the water table and their management, for example, acid run-off from stockpiles and treatment areas; and
- Dewatering required as part of the construction of features below the water table, for example, excavation of road cuttings.

The impacts of the ASS management of soils have been assessed through a separate study (GHD 2012b). This assessment focuses on the potential impacts caused by alteration of the groundwater environment, i.e. groundwater level reduction, which could occur in short time frames through construction dewatering, or over longer timeframes through reductions in recharge.

Assessment

There is a limited likelihood of potential groundwater impacts occurring. Regional scale mapping of PASS soils have been documented by GHD (2012b) which indicated a low probability of the presence of PASS. It cannot be discounted, however, that they may be identified unexpectedly during construction and GHD (2012b) has documented controls to address this.

For PASS soils to be activated through dewatering, if it is identified unexpectedly, it has to be located in an area close to where groundwater levels are to be influenced. The estimated extent of the drawdown from cuts has been summarised in Table 15 (based on empirical lithological – drawdown relationships). Drawdown extents in fine grained materials, are generally less than 100 m from the proposed alignment. Controls noted previously (Section 6.6) are also relevant.

Based on these conditions, the risk of impact is considered low. The overall impact to the groundwater environment, for any of the alignment options, is also expected to be low given that the groundwater beneficial uses are mostly limited along much of the alignment (to non-potable domestic and stock use), and that the existing level of groundwater development is limited.

6.6.9 Changed Groundwater Quality – Interception or Displacement of Contaminated Groundwater

Definition

High volumes of polluted groundwater may pose a threat to construction (and maintenance) worker safety, as well as posing a disposal issue where it is recovered in areas of dewatering (e.g. excavation of cuttings). Saline groundwater inflows (which may not necessarily be contaminated) captured during construction may also pose a disposal issue.

The change in hydraulic gradients due to construction may alter the migration rates (and directions) of contaminated groundwater plumes. The changes in water level may also result in increased oxidation of contaminants, smearing and may alter attenuating mechanisms within an aquifer.

Assessment

The Soils and Geology Assessment GHD (2012b) documents the effort to identify potential soil and groundwater contamination risks based on a review of aerial photographs and landuse, the locations of registered EPAV Priority Sites, and sites which have Certificates or Statements of Environmental Audit.

Whilst it is difficult to identify and characterise contaminated (or saline) groundwater in terms of is constituents and spatial distribution, the following is noted:

- The land uses within the alignment do not support the presence of widespread, contaminated groundwater. Point source areas of potential pollution have been identified (refer section 5.5.3, GHD, 2012b), notably the former landfill at Great Western;
- Construction dewatering would act as a drain or sink, drawing contamination to it. The minimisation of inflow would reduce the dewatering radius of influence and the magnitude of drawdown at distance from the alignment. At distances greater than 800 m the drawdown effects are estimated to be low (refer Table 15), limiting the likelihood of plume capture;
- Contaminated groundwater that is captured may require treatment prior to disposal. It is noted, however, that the capturing may further dilute concentrations as non-contaminated parts of a plume are captured;

- Construction dewatering is temporary. When construction dewatering ceases, recovery of water levels is a reasonable assumption and thus, plume stability would return following re-equilibration of water levels;
- The distance, type of contaminant, and hydrogeological conditions (for example, prevalence of natural attenuation mechanisms) are all factors affecting the potential for impact; and
- Sufficient contingency must be incorporated into water treatment plans, monitoring programs (environmental, safety) to cope with the ingress, management, treatment and disposal of contaminated groundwater that may be unexpectedly encountered.

The proposal alignment passes through the former Great Western landfill, which is located on the eastern side of the junction of Sandy Road and the Great Western – Bulgana Road. Golder (2011) suggests that the landfilling may have originated in a former gravel quarry, and may not have been constructed with an engineered lining system. As noted in Section 6.6.1, geotechnical test pit investigations by Golder (2011) to 4m depth did not encounter groundwater. Golder (2011) document that a rehabilitation plan has been prepared for the landfill, however the plan required no groundwater or leachate monitoring. Golder (2011) proposed a number of options to manage the construction of a highway through the landfill, including bridging structures and the excavation and re-deposition of waste material elsewhere onsite (under controlled conditions and subject to EPA endorsement).

The groundwater quality at the former Great Western landfill is not known. Contaminated groundwater resulting from landfilling activities can represent a significant risk to human health and the environment. A cutting in this area that intersects groundwater may dislocate an underlying plume or contaminated groundwater, and result in the need to manage contaminated groundwater seepage.

The test pitting (Golder 2011) suggests that wastes (generally less than 3 m in thickness) have been deposited above the groundwater table. The geology of the landfill comprises coarse grained sediments, and therefore, on the assumption that an engineered lining system is not present, any leachate generated would have continued to vertically infiltrate towards the underlying groundwater, and opportunities for retardation or dispersion of contamination to be limited locally. The likelihood of intercepting contaminated groundwater is considered low because:

- Landfilling activities ceased in 2000, and given the inferred permeable nature of the underlying geology, any leachate plumes may have migrated some distance from the site;
- The waste exhumed by Golder (2011) was dry and showed minimal signs of decomposition, suggesting that the soil cover capping could be providing a reasonable barrier to limiting rainfall infiltration
- Testing pitting investigations (Golder 2011) suggest that groundwater occurrence is deep and that a cut located in this area is unlikely to intersect saturated ground conditions.

The Golder (2011) report did document any management of groundwater. As this landfilling area represents that part of the proposed alignment with the deepest cuts (Ch. 13,000 m to 14,500 m) it is considered that further geotechnical investigations would be undertaken to inform the engineering design of the cutting, and therefore the characterisation of groundwater occurrence and quality. If landfill materials are excavated and relocated (either locally or remote from the alignment), controls would be required to manage run-off from stockpiling activities, and protection of the groundwater environment.

It is further noted that the VicRoads Standard Specifications and GHD (2012b) have controls for the encountering of unexpected groundwater and management of contamination.

The risk of interception or displacement of contaminated (or saline) groundwater is considered to be low elsewhere in the alignment owing to the proposed gradelines relative to the anticipated groundwater table depth. The overall impact of such to the groundwater environment, is also considered to be low given the expectation of poor background quality (salinity) of the regional groundwater.

As noted in Section 5.5, regionally the groundwater can be saline and therefore groundwater flow recovered from excavations may require careful management. Discharge to land (irrigation) or waterways may require treatment including:

- Settling, to remove solids and improve turbidity; or
- Shandying, to reduce salinity.

Approvals to dispose of recovered groundwater may be required from either the EPA or local catchment management authority (Glenelg Hopkins CMA). Characterisation of inflow water quality and disposal monitoring may form components of the VicRoads Standard Specifications.

6.7 Benefits and Opportunities

In terms of the groundwater environment, the project is considered to have negligible benefit. It is noted, however, that any geotechnical and groundwater investigations undertaken to inform the engineering design, and associated monitoring, e.g. groundwater level, and groundwater quality, may add to the local geological and hydrogeological understanding of this part of the State. Furthermore, improved drainage and waterway crossings along the alignment may result in more effective management of issues relating to containment of uncontrolled spills.

7. Mitigation Measures

7.1 Construction

VicRoads would require the construction contractor to develop and implement a Construction Environmental Management Plan (CEMP) for the Project. VicRoads standard environmental protection measures and some additional Project specific controls identified below have been incorporated into the Environmental Management Framework for the Project which is documented in the Project Environment Protection Strategy (PEPS). The PEPS is a VicRoads Document that details the environmental management arrangements for the design, construction and operation of the Project. VicRoads would require the construction contractor to incorporate all of these measures into the CEMP. Refer to Chapter 21 of the EES for further explanation of the environmental management framework and documentation proposed for the project.

VicRoads standard environmental protection measures for groundwater that would be adopted for this Project are summarised in Table 16.

Table 16 Extraction of VicRoads Contract Shell DC1, Section 1200 Environment Protection

Section	Description
1200.05	Groundwater
(a)	General
	The beneficial uses of groundwater shall not be adversely affected.
	An assessment of the potential impact of the work under the Contract shall be undertaken to ascertain the beneficial uses to be protected as provided for in SEPP (Groundwaters of Victoria) and SEPP (Waters of Victoria) when groundwater is: • expected to be encountered during works under the Contract – as part of the development of Environmental Management Plans; • unexpectedly encountered during works under the Contract – immediately after identification of the presence of groundwater. The Contractor shall consider the beneficial uses, quality and quantity of groundwater when determining the ongoing management of groundwater (i.e. reuse, discharge, aquifer recharge). Such consideration shall be completed prior to the completion of related design and prior to commencement / continuation of related construction activities.
	Where groundwater is unexpectedly encountered, a management plan shall be developed and implemented to manage the groundwater and protect beneficial uses in accordance with the requirements of the EPA and/or relevant authority. The contractor shall undertake monitoring in accordance with the requirements of the relevant authority and/or EPA and identified in the management plan.
	Groundwater encountered on-site shall be assessed for the opportunity for reuse as a non-potable water source for the duration of the Contract.
(b)	Monitoring
	(i) Locations
	Groundwater monitoring shall be undertaken at:
	##specify any existing stand pipe/bore locations that should be utilised for ground water monitoring:
	Where stand pipe/bores are disturbed by work under the Contract, replacement monitoring locations shall be provided. Replacement and/or new stand pipes/bores shall be located outside of the limits of ground disturbing activities and where the impact of ground movement is likely to have the greatest effect.

Section	Description
	Details of monitoring locations for groundwater shall be maintained on a site plan.
	(ii) Timing
	The timing and frequency of groundwater monitoring shall be in accordance with Table 1200.051.

Table 1200.051

Timing and Frequency	Location	Parameter	##:Issue Specific Requirements
##:immediately prior to work commencing	##:All monitoring locations specified	Groundwater level & flow Salinity as total dissolved solids (TDS mg/L) Electrical conductivity (µS/cm) ##:other parameters as agreed with VicRoads Environmental Services and/or EPA and/or relevant authority	##:as determined from planning/ pre-construction studies
Monthly	##:All monitoring locations specified	As above	As above

Note:

1. The following sections have been omitted for brevity:

Section 1200.08 documents Erosion and Sediment Control Procedures.

Section 1200.09 documents Contaminated Soils and Materials

Section 1200.10 documents Waste and Resource Use

Section 1200.11 documents Fuels and Chemical Management

7.2 Operation

If shallow groundwater is intersected either during field investigations undertaken to inform the engineering design, or unexpectedly during the construction, there may be a requirement to implement a monitoring plan as per the VicRoads Standard Specifications (Clause 1200.05).

7.3 Summary

Table 17 presents a summary of the mitigation measures that have been identified to avoid, reduce or minimise impact risk. The measures are considered in addition to the VicRoads Standard Specifications (Clause 1200.05). The aim is to achieve the relevant EES Objectives described in Section 2.3.

Table 17 Summary of Mitigation Measures

Risk	Description	Mitigation Measures
Water Availability	Construction dewatering / intersection of groundwater	• Effort to minimise dewatering required by micro-review of gradelines; • Preconstruction investigations of groundwater (occurrence and quality), particularly in proposed areas of cut, and establishment of baseline conditions; • Detailed design of cuts and ground support. Alteration of the construction technique to reduce the need for dewatering. A variety of engineering options are available, e.g. use of sheet piles / contiguous piles; • Careful design of the dewatering methodology, e.g. multiple closely spaced bores may create a localized cone of depression; • Increased construction effort, e.g. reducing the duration over which dewatering

Risk	Description	Mitigation Measures
		may be required; • Careful timing of the works to periods where water levels may be at their lowest; • Re-injection of the pumped groundwater between the excavation site and impacted part to impart hydraulic control (aquifer recharge); • Non-continuous pumping that may allow water level recovery during pumping quiescence. • Supplying any affected parties with an alternate water supply, e.g. carting water, deepening the pump intake setting depth; • Replacement of existing bores that are adversely impacted by construction; • Implementing a groundwater monitoring program; • Sufficient contingency must be incorporated into water treatment plans, monitoring programs (environmental, safety) to cope with the ingress, management, treatment and disposal of contaminated groundwater water that may be unexpectedly encountered.
	Impact to Groundwater users	• Refer to those measures to mitigate construction dewatering; • Construction groundwater supplies would have to be from licensed bores and subject to the Grampians Wimmera Mallee Water approvals process and/or groundwater trading rules / local management rules; • Audit of landholders to identified water supplies that may be impacted, e.g. dams or bores.
	Impact to Groundwater Dependent Ecosystems	• Refer to those measures to mitigate construction dewatering; • In some instances, an alternate water supply may have to be established to maintain environmental water requirements, e.g. treated stormwater / road drainage could be redirected as a replenishing or alternate water supply.
	Relocation of underground services.	• Trench breakers / cut-offs.
	Changed recharge conditions	• Rehabilitation of vegetation / grasses; • Grading for erosion control; • Allowances for subsidence with backfilled excavations; • Removal of temporary access tracks and rehabilitation of ground conditions.
	Inducement of subsidence	• Site specific investigation during detailed design to identify likelihood; • Refer to those measures to mitigate construction dewatering.
Water Quality	Interception of saline (or contaminated) groundwater.	• Refer to those measures to mitigate construction dewatering; • Refuelling procedures, hazardous materials storage and handling; • Waste management; • Use of clean fill; • Disposal (recharge) of material to groundwater to be licensed / approved by regulatory agency; • Management of construction groundwater inflow; • Spill procedures; • Water sensitive road side design.
	Activation of PASS	• Minimisation of the dewatering influence near PASS materials (refer to those measures to mitigate construction dewatering); • Soil sampling and laboratory analysis as part of the detailed design phase

Risk	Description	Mitigation Measures
		confirm the presence of ASS; • Development of an Environmental Management Plan (EMP) to establish a consistent and sustainable approach to managing PASS, e.g., DSE (2010); • Monitoring of groundwater levels and quality (in all aquifers adjoining PASS materials); and • Establishment of performance standards and action triggers: - implementing remedial actions. Impacted or at risk areas / assets remediation can be undertaken through pH adjustment, e.g. lime dosing. - consider need for artificial recharge. Those documented by GHD (2011b).

8. Conclusions

This report forms part of the Western Highway Project Section 3 EES. The purpose of the report is to provide an overview of existing groundwater conditions within the Project Area of the proposed Western Highway Project between Ararat and Stawell (Section 3).

Existing Conditions

The Project Area encompasses generally poor quality (saline) groundwater found within unconsolidated Cainozoic age sediments and Palaeozoic bedrock. Owing to its poor salinity, groundwater development is limited to mainly stock and non-potable domestic purposes. Owing to a lack of groundwater development, the understanding of groundwater occurrence, specifically the depth to water along the alignment, is poorly understood. There is also limited understanding regarding the dependence of ecosystems within the Project Area, upon groundwater.

Risk Assessment

Potential impacts to groundwater were identified based upon a number of source – pathway – impact receptor situations. With the groundwater assessment, impacts can be generally simplified into two categories, those that affect groundwater quality, and those that affect groundwater level. Falls or rises in groundwater level effect hydraulic gradients and groundwater movement. The effect on movement of groundwater flow translates to a change in groundwater availability, be it available for environmental reserves or resource users. Similarly, changes in groundwater quality would affect those either wholly or partly reliant upon groundwater, be it for the environment or abstractive use.

A multi-criteria assessment was undertaken to assess potential alignment options, and an impact assessment undertaken on the proposed alignment within Section 3. In summary, the assessment identified the following potential impacts and risks:

- Changes to groundwater availability from
  - Dewatering created by cuttings;
  - Groundwater use (construction water supply);
  - Changes to aquifer character (compaction from aquifer depressurisation or surcharge loading);
  - Severance to access to groundwater supplies;
- Changes to groundwater quality from
  - Groundwater contamination (materials storage and handling, spills, waste management);
  - Activation of acid sulphate soil conditions; and
  - Arising from changes in groundwater flow (e.g. cuttings).

Impact Assessment

Potential impacts were assessed, considering both the construction or short term nature of impacts, and the long term potential with on-going Highway operation.

The value or sensitivity of the groundwater resource in the locality is low as bore yields tend to be low and the groundwater is generally saline, with abstractive beneficial uses only for stock and non-potable domestic purposes. Whilst potential groundwater dependent ecosystems have been identified in the locality in regional-scale mapping, the high salinity of the groundwater in the locality is not considered to be conducive to healthy plant growth. However, fresher groundwater may be found in areas where groundwater recharge is more rapid, or where shorter flow paths exist.

The consequence of the construction of the Project intercepting groundwater is also low as less than 1.5 km (6%) of the alignment length is of a depth that could encounter groundwater (greater than 3 m depth) and most of the deep cuts are near the crest of hills where the likelihood of encountering groundwater is further reduced.

The risk is low and the consequence of any depressurisation, drainage of aquifers, or severance or dislocation of flow from dewatering of an aquifer around a cut is also low due to absence of productive bores and few built structures being located in areas where deep cut is required. The poor groundwater within much of the Project Area limits its beneficial uses and is therefore of low sensitivity.

Where shallow water tables, springs or perched water table aquifers are disrupted (where groundwater flow is severed, aquifer materials drained or flow dislocated), and the groundwater quality in these areas is such that it could support sensitive ecosystems, then the impact may be more significant.

Groundwater inflows into any excavation is deleterious during construction, as it results in both unstable and unsafe working conditions, delayed construction rates and greater water management issues, all of which ultimately impact the Project cost. Therefore exclusion of groundwater and thus maintaining existing hydraulic relationships between the groundwater environment and existing users is a desired construction outcome.

Areas of Uncertainty

Depth to groundwater along the alignment, specifically at areas where the gradeline is in cut is not known, and groundwater quality is characterised at a regional scale only. As a consequence, uncertainty exists in defining the likelihood, and consequences of risk events to the groundwater environment. Therefore conclusive identification of areas of impact, and quantitative assessment of impacts can not be made.

Geotechnical investigations to be carried out during the detailed design phase of the Project would confirm groundwater depth and if groundwater is encountered. There are well developed management measures to avoid detriment to the groundwater, surface water or other assets. These investigations would also aid the selection of appropriate mitigation measures. The deepest cuts are proposed to the north of Great Western, and near existing quarries and a former landfill. There is a risk of potentially encountering leachate and therefore this could be assessed as part of these geotechnical investigations.

For the above reasons, the overall impact of the Project on the groundwater environment is considered to be low.

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10. Glossary of Hydrogeological Terms

Annulus	The space between the rising main and the casing, or between the casing and the wall of the well.
Anisotropic	Having some physical property that varies with direction.
Aquifer	A geologic formation, a group of formations or part of a formation that is water bearing. A geological formation or structure that stores and transmits water to wells, springs and seeps.
Aquifer, perched	Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.
Aquifer System	A body of permeable or relatively permeable materials that functions regionally as a water yielding unit. It comprises two or more permeable units separated by at least locally by confining units that impede groundwater movement.
Aquifer Test	A test undertaken to determine the hydraulic properties of an aquifer. It involves the withdrawal of measured quantities of water from or the addition of water to a well and the measurement of resulting changes in aquifer pressure.
Aquitard	A saturated by poorly permeable bed that impeded groundwater water movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers.
Artesian Well	A well deriving uts water from a confined aquifer in which the water level stands above the ground surface.; synonymous with flowing artesian wells.
ASR	Aquifer Storage and Recovery is the re-injection of water (typically potable or semi-potable) back into an aquifer for later recovery and use
ASS	Acid Sulphate Soil (refer to PASS)
AASS	Actual Acid Sulphate Soil
Available Drawdown	The difference between the standing water level and the pump intake (i.e. the amount of water above a pump prior to pumping).
Baseflow	Also called drought flow, groundwater recession flow, low flow, and sustained or fair-weather runoff), is the portion of streamflow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow"
Beneficial Use	A use of the environment or any element of the environment which is conducive to public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from the effects of waste discharges, emissions or deposits
Boundary	A lateral discontinuity or change in the aquifer resulting in a significant change in hydraulic conductivity, storativity, or recharge.
Capillary fringe	The zone at the bottom of a vadose zone where groundwater is drawn upward by capillary force.
Cavitation	A phenomena of cavity formation or formation and collapse, especially in regard to pumps, when the absolute pressure within the water reaches the vapour pressure causing the formation of vapour pockets.

Confined Aquifer	A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations. Confined groundwater is generally subject to pressure greater than atmosphere.
Development	The act of repairing damage to the formation caused by drilling procedures and increasing the porosity and permeability of the materials surrounding the intake portion of a well.
Delayed Yield	Gravity drainage of water from interstices in the unsaturated zone, which may occur more slowly than the lowering of the watertable in an unconfined or semi-confined aquifer. The effect becomes negligible as the pumping period increases.
Discharge	The volume of water pumped or flowing from a well per unit of time, expressed in litres per second.
Drawdown	The distance between the static water level and the surface of the cone of depression
Effluent	A waste liquid discharged from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment.
Evaporation	In groundwater terms, evaporation is the loss of water from the water table to the atmosphere.
Evapotranspiration	Loss of water from a land area through transpiration of plants and evaporation from the soil
Flowing well, overflowing well, free-flowing well	A well from which groundwater is discharged at the ground surface without the aid of pumping.
Fouling	The process in which undesirable foreign matter accumulates in a bed, screen, bore, pump or rising main infrastructure clogging pores and coating surfaces and thus inhibiting or retarding proper operation of the bore.
Freshwater / saline interface	The contact between two groundwaters of varying salinity, typically occurring near coastal regions, but can occur in terrestrial environments. The flow is governed by density flow processes, and the contact described as a mixing zone. Saline intrusion is when the movement of salt water occurs into a body of fresh water. It can occur in either surface water or groundwater basins.
GDE	Groundwater Dependent Ecosystem – Ecosystems that require a supply of groundwater (either directly or indirectly) to maintain their current structure (special composition) and function (for example, rates of carbon fixation).
Geothermal	Of or relating to the natural heat generated by the earth. In the context of groundwater: 1. Groundwater that can be of naturally elevated temperature which can be used for heating and power generation purposes. 2. Groundwater heat pumps that use a circulating fluid (often water) to pump heat to or from the ground for heating / cooling purposes.
GIS	Graphical Information System
GMA	Groundwater Management Area
Grouting	The operation by which grout is placed between the casing and sides of a well bore (annulus) to a predetermined height above the bottom of the well. This secures the casing in place and excludes water and other fluids from the well bore.
Groundwater Flow System	Groundwater flow is defined as the "…part of streamflow that has infiltrated the ground, has entered the phreatic zone, and has been discharged into a stream channel as spring or seepage water". Flow is driven by hydraulic gradients,

Head	Energy contained in a water mass, produced by elevation, pressure or velocity
Head Loss	That part of head energy which is lost because of friction as water flows
Heterogeneous	Non uniform in structure or composition throughout.
Homogeneous	Uniform in structure or composition throughout
Hydraulic Conductivity	The rate at which water at the prevailing kinematic viscosity will move under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow, expressed in metres per day. NOTE: This definition assumes medium in which the pores are completely filled with water.
Hydraulic Gradient	The rate of change in total head per unit of distance of flow in a given direction.
Hydrogeologic	Those factors that deal with subsurface waters and related geologic aspects of surface waters.
Interference	The condition occurring when the area of influence of a water well comes into contact with or overlaps that of a neighbouring well, as when two wells are pumping from the same aquifer or are located near each other.
Isotropic	Said of a medium whose properties are the same in all directions.
Leachate	The liquid that has percolated through solid waste and dissolved soluble components.
Lost Circulation	The result of drilling fluid escaping from a borehole into the formation by way of crevices or porous media.
MAR	Managed Aquifer Recharge
Monitoring Bore	Refer Observation bore
Numerical Model	A groundwater model is a (computer) program for the calculation of groundwater flow and level. Some groundwater models include (chemical) quality aspects of the groundwater. Groundwater models may be used to predict the effects of hydrological changes (like groundwater abstraction or irrigation developments) on the behaviour of the aquifer and are often named groundwater simulation models. As the computations in mathematical groundwater models are based on groundwater flow equations, which are differential equations that can often be solved only by approximate methods using a numerical analysis, these models are also called mathematical, numerical, or computational groundwater models.
Observation Bore	A well drilled in a selected location for the purpose of observing parameters such as water levels and pressure changes.
Partial Penetration	The condition of the intake portion of the well being less than the full thickness of the aquifer.
PASS	Potential Acid Sulphate Soil (and ASS). Acid Sulphate soils are naturally occurring soils, sediments or organic substrates (e.g. peat) that are formed under waterlogged conditions. These soils contain iron Sulphide minerals (predominantly as the mineral pyrite) or their oxidation products. When oxidised they can generate acidic (aggressive) groundwater
Permeability	The property of capacity of a porous rock, sediment or soil for transmitting a fluid, it is a measure of the relative ease of fluid flow under unequal pressure.
Piezometer	A pipe in which the elevation of the water level or potentiometric surface can be determined. The pipe is sealed along its length and open to water flow at the bottom.

Potentiometric surface	A surface that represents the standing or total hydraulic head. NOTES: 1. In an aquifer system, it represents the levels to which water will rise in tightly cased wells. 2. The watertable is the potentiometric surface of an unconfined aquifer.
Pump column	That part of the rising main from a pump within the well.
Recovery	The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.
Recycled Water	Reclaimed water, sometimes called recycled water, is former wastewater (sewage) that has been treated to remove solids and certain impurities, and then used for other purposes such as irrigation or to recharge groundwater aquifers. This is done for sustainability and water conservation, rather than discharging the treated wastewater to surface waters such as rivers and oceans.
Residual drawdown	The difference between the observed water level during the recovery period following pumping and the pre-pumping water level.
Rising main	The pipe carrying water from within a well to a point of discharge.
Semi-confined (or leaky) aquifer	An aquifer confined by a layer of moderate permeability (aquitard) that allows vertical leakage of water into or out of the aquifer.
Sieve Analysis	Determination of the particle size distribution of a soil, sediment or rock by measuring the percentage of the particles that will pass through standard sieves of various sizes.
Specific Capacity	The rate of discharge of a water well per unit of drawdown. IT varies with duration of discharge.
Specific Yield	The ration of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass.
Spring	A spring — also known as a rising or resurgence — is a component of the hydrosphere. Specifically, it is any natural situation where water flows to the surface of the earth from underground. Thus, a spring is a site where the aquifer surface meets the ground surface.
Static Water Level or Standing Water Level	The level of water in a well that is not being affected by withdrawal of groundwater.
Static head	The height, relative to an arbitrary reference level, of a column of water that can be supported by the static pressure of the aquifer at a given point.
Steady State conditions	A numerical (or analytical) model in which model stresses do not vary over time. A steady state model is run until the modelled region is in equilibrium and no more changes in potentiometric head are calculated. Steady state conditions can often be modelled under long term transient conditions.
Storage Coefficient / Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. Note: 1. In an unconfined aquifer, it is normally referred to as specific yield. 2. In confined aquifers, it may be referred to as storage coefficient.

Stormwater	Stormwater is a term used to describe water that originates during precipitation events and that is collected by urban infrastructure (e.g. drains, some rivers).
Stream Depletion	A decrease in river gains or an increase in river losses resulting from a change in the water table. The depletion of streamflow caused by the operation of producing wells completed in the same aquifer intersected (or connected) with the stream or river.
Stratigraphy	The study of rock / soil strata, especially of their distribution, deposition and age.
Submersible Pump	A water pump with the motor and pump assembly located below ground at the bottom of the well column. A pump which is designed to operate under water. Usually these are electrical centrifugal pumps and have the electrical motor enclosed in a waterproof casing.
Sustained yield	The predicted long-term pumping yield of a well or well field under natural or established artificial conditions. NOTE: The values are normally calculated from pumping tests, allowance being made for hydrogeological and climatic conditions at the site.
Throughflow	Throughflow is the 'horizontal' flow of groundwater through a saturated aquifer.
Transmissivity	The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient.
Transient conditions	Typically applied in the context of a numerical model in which the model stresses (inflows and outflows) and aquifer head vary over time.
Transpiration	The process by which water is absorbed by plants, usually through the roots, is evaporated in to the atmosphere from the plant surface.
Unconfined Aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.
Vadose Zone	The zone containing water under pressure less than that of the atmosphere including soil water, intermediate vadose water and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is the water table.
Water table	The water table is the level at which the groundwater pressure is equal to atmospheric pressure. It may be conveniently visualized as the 'surface' of the subsurface materials that are saturated with groundwater in a given vicinity. However, saturated conditions may extend above the water table as surface tension holds water in some pores below atmospheric pressure
Well Point or Spear Point	A screening device, generally less than 10 m that is meant to be driven into the ground to extract water.
Well Yield	The volume of water discharged from a well. Usually measured in litres per second or ML/day.

Appendix A

Summary of Groundwater Bore Information

Table 18 Summary of Bore Information (within 1 km of alignment)

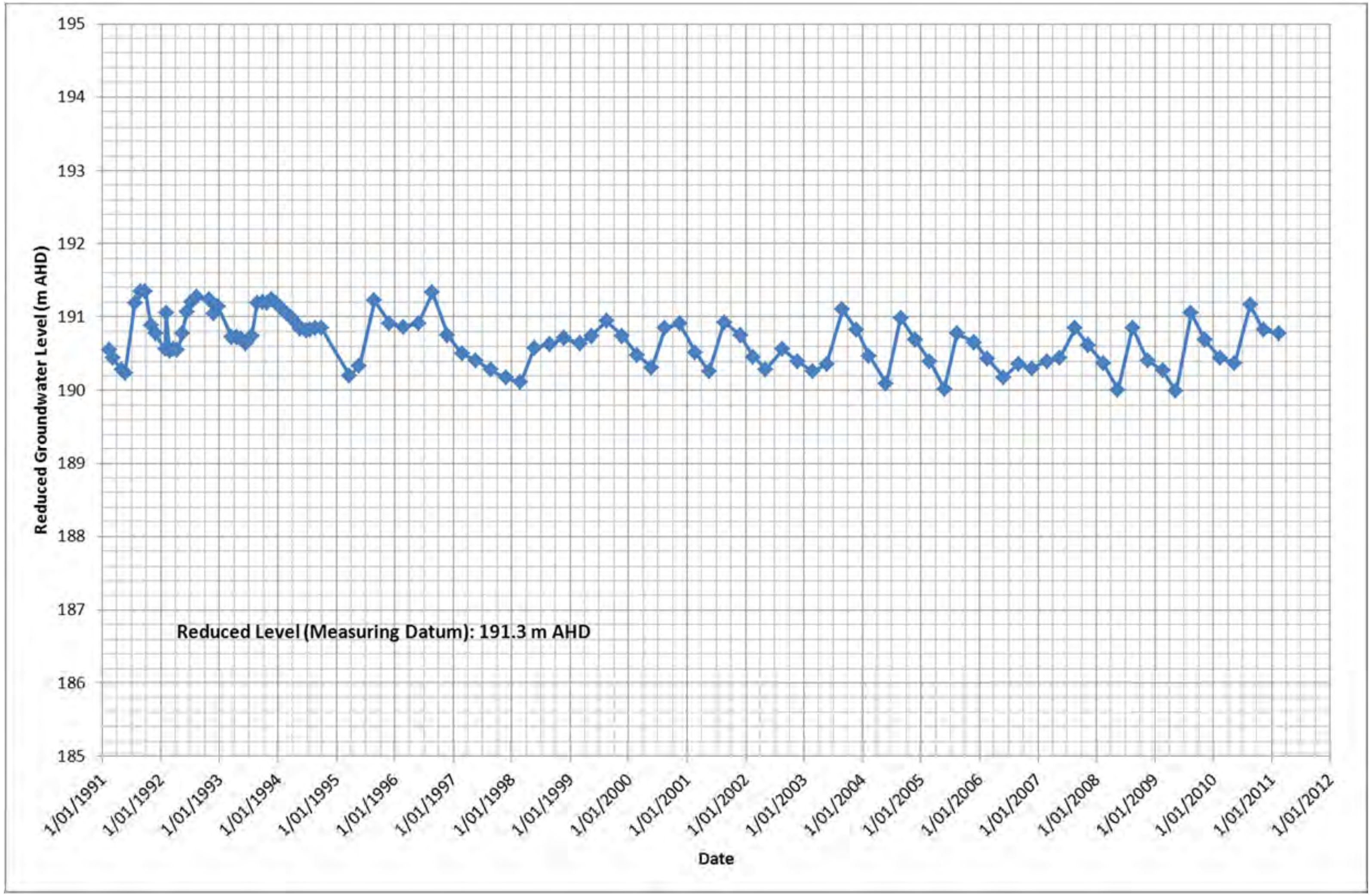
Bore ID	Zone 54 Co-ordinates		Date Completed (m)	Total Depth (m)	Bore Use	Aquifer		Salinity		Lithology	SWL (m)	Bore Yield (L/s)
	Easting	Northing				From	To	TSS	EC			
8002503-01	-	-	-	-	NOT KNOWN	-	-	-	-	-	-	-
56275	662418.447	5888917.82	25/09/1972	6.09	DOMESTIC	-	-	-	-	-	-	-
GMS-2884	662706	5887230	14/04/1995	14	OBSERVATION	-	-	-	-	-	-	-
GMS-2886	662706	5887230	14/04/1995	14.5	OBSERVATION	-	-	-	-	-	-	-
56268	665791.458	5885536.813	3/11/1967	17.37	NOT KNOWN	5.8	14	-	-	CLAY	2.7	1.2
56280	665765.458	5884647.811	1/01/1970	18.29	NOT KNOWN	-	-	-	-	-	-	-
56281	665765.458	5884647.811		9.14	NOT KNOWN	-	-	-	-	-	-	-
56269	665791.458	5885167.812	9/11/1967	15.24	NOT KNOWN	4.57	6.71	-	-	CLAY	3.66	1.01
56276	666338.459	5886221.815		30.48	STOCK	-	-	-	-	-	-	-

Notes: TDS – Salinity as Total Dissolved Solids (mg/L), EC – Salinity and Electrical Conductivity (µS/cm)

Appendix B

State Observation Bore Hydrograph Responses

Bore 67749



195
194
193
192
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190
189
188
187
186
185
Reduced Groundwater Level (m AHD)
Reduced Level (Measuring Datum): 191.3 m AHD
1/01/1991
1/01/1992
1/01/1993
1/01/1994
1/01/1995
1/01/1996
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
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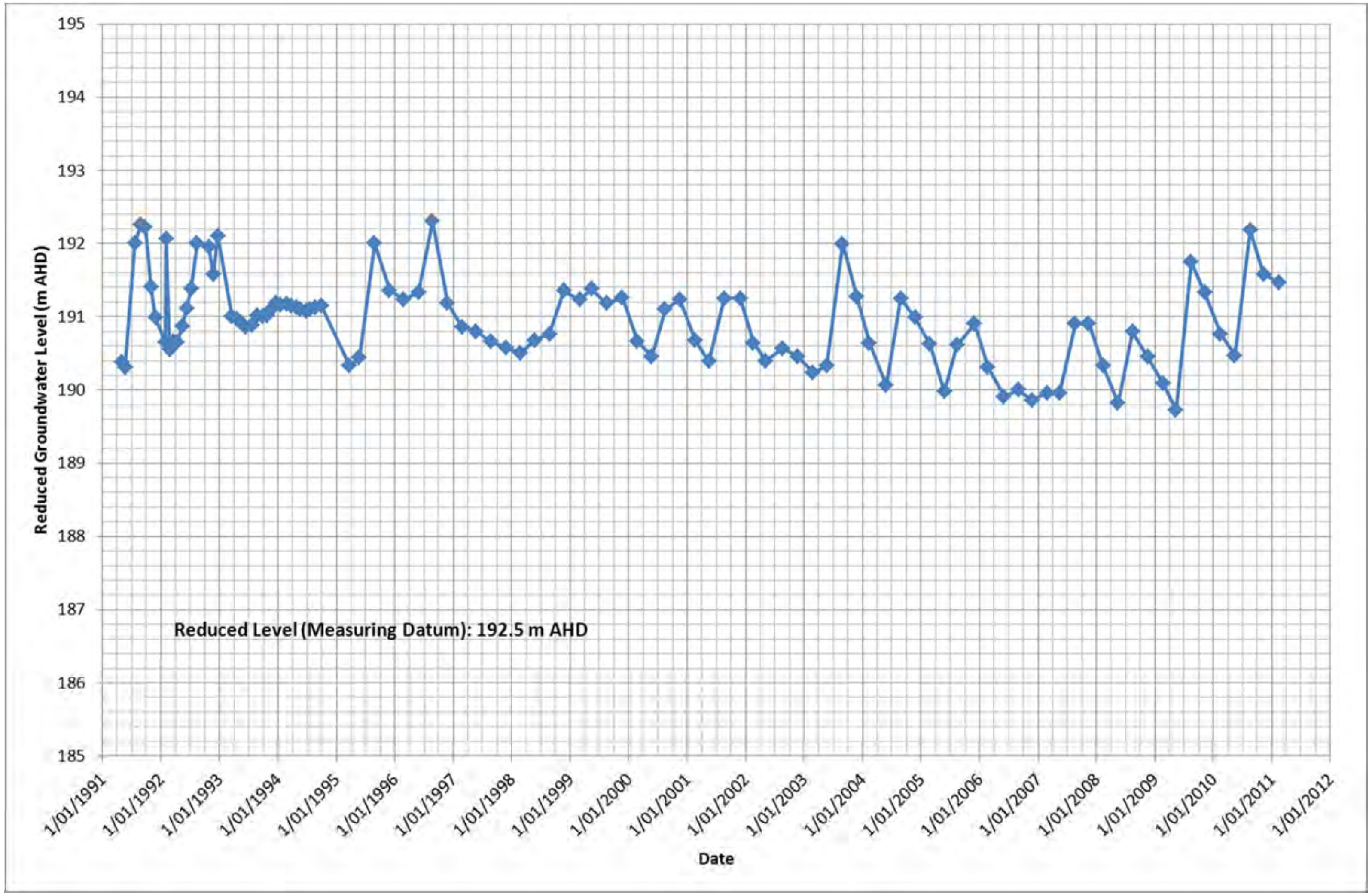
1/01/2009
1/01/2010
1/01/2011
1/01/2012
Date

Bore 67750



195
194
193
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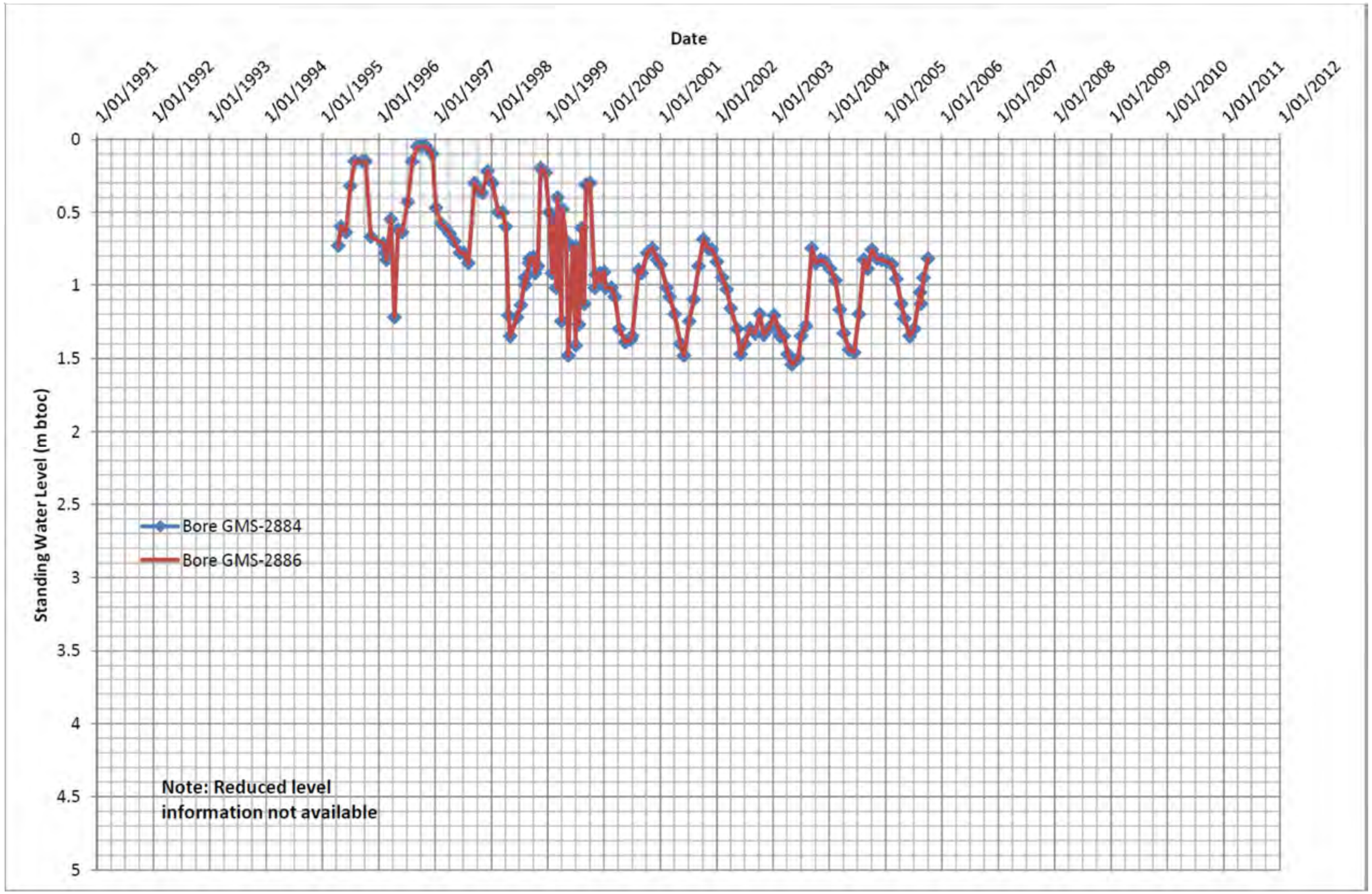
185
Reduced Groundwater Level (m AHD)
Reduced Level (Measuring Datum): 192.5 m AHD
1/01/1991
1/01/1992
1/01/1993
1/01/1994
1/01/1995
1/01/1996
1/01/1997
1/01/1998
1/01/1999
1/01/2000
1/01/2001
1/01/2002
1/01/2003
1/01/2004
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011
1/01/2012
Date

Nested site: Bores GMS-2884 and GMS-2886



GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

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		Name	Signature	Name	Signature	Date
0	T R Anderson	D Stanley		D Stanley		24/08/2012
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