Chapter 9

Groundwater

9.1 Overview

This chapter describes the groundwater within and surrounding the project site and defines key values associated with it. It describes potential project impacts on these values, and measures to be taken to avoid and minimise these impacts. This chapter is based on the findings of the hydrogeological and hydrological impact assessment (Appendix B), prepared by Water Technology Pty Ltd. Aspects relating to Groundwater Dependent Ecosystems (GDEs) also considered the biodiversity impact assessment by Nature Advisory Pty Ltd (Appendix D).

Groundwater refers to a water resource beneath the surface of the earth that forms when water seeps into the ground and is collected within aquifers (permeable rock).

Groundwater makes up around 17% of Australia's accessible water resources.

Source: Geoscience Australia

The geology across most of the project site consists of basalt flows and stony rises. There are also isolated occurrences of alluvium and colluvium restricted to lower lying areas near drainage channels and floodplains and at the base of hillslopes. The main aquifer within the project site occurs in the Newer Volcanic Group basalt. Depth to groundwater is typically between 1 and 12 metres below ground level, depending on the season. The highest groundwater levels occur in late spring after recharge by winter rainfall, and the lowest levels occur in late summer.

Groundwater depletes through evapotranspiration as well as through discharge via extraction from wells and at the edge of geological formations and topographic lows where surface expressions of groundwater occur (e.g., springs and freshwater meadows). In general, groundwater in the project site is too brackish and hard for potable domestic use, but of sufficient quality to be used for stock or irrigation. There are registered groundwater bores within the project site used for farming. There are also potential aquatic and terrestrial groundwater dependent ecosystems (GDEs) that occur within the site.

Construction and operation of the project has the potential to impact groundwater in near-surface Newer Volcanic Group basalts and supporting environmental values. Possible impact pathways include localised lowering of the water table from groundwater dewatering during quarry operation and, to a lesser extent, during wind turbine foundation excavation. Other impact pathways may include altered groundwater recharge and flows from infrastructure foundations and hardstands (creating barriers to water movement), and reduced water quality from accidental spills of hazardous chemicals.

The on-site quarry is proposed in an area with few bores or potential GDEs, therefore minimising potential impacts to people and the environment.

Groundwater inflows in the quarry pit were predicted by Water Technology to be around 77 cubic metres per day during operation. This is predicted to result in groundwater drawdown, reducing groundwater levels out to about 500 metres from the proposed quarry. This is not predicted to impact the closest registered groundwater bore about 1,000 metres west, or significantly impact potential terrestrial and aquatic GDEs about 450 metres north-east of the quarry. Further groundwater investigations are proposed prior to construction to improve confidence in groundwater drawdown predictions. Ongoing monitoring during quarry operation is also proposed. The monitoring plan and groundwater level triggers for further management measures, if needed, would be included in a construction phase Water Management Plan.

Management measures have been proposed for the construction, operation and decommissioning phases of the project to further manage potential groundwater impacts. With these measures in place, the impacts to groundwater users and groundwater quality were assessed to be very low to low.

9.2 EES objectives and key issues

The EES scoping requirements specify the following draft evaluation objective and key issues, outlined in Table 9.1, relevant to groundwater that have guided this assessment.

Table 9.1 EES draft evaluation objective and key issues

Draft evaluation objective	
Catchment values and hydrology: *To maintain the functions and values of aquatic environments, surface water and groundwater quality and stream flows and avoid adverse effects on protected beneficial uses*	
Key issues	• Potential for the project to have a significant effect on surface water and/or groundwater and its beneficial uses, including through the temporary on-site quarry. • Potential for the project to have significant impact on wetland systems, including, but not limited to, Seasonal Herbaceous Wetlands (EPBC Act listed community), and the ability for wetland systems to support habitat for flora species listed under the FFG Act and EPBC Act.

9.3 Legislation, policy and guidelines

Key legislation, policies and guidelines relevant to the groundwater impact assessment are summarised in Table 9.2.

Table 9.2 Relevant legislation, policies and guidelines

Legislation and guidelines	Description	Relevance to project
State		
Environment Protection Act 2017	The *Environment Protection Act 2017* establishes the legislative framework for protecting the environment in Victoria. The *Environment Protection Amendment Act 2018* amended the *Environment Protection Act 2017* and introduced the general environmental duty in relation to risks of harm to human health and the environment from pollution or waste.	The project is being developed under the provisions of the *Environment Protection Act 2017* that relate to the project's general environmental duty and is required to demonstrate it is implementing measures so far as 'reasonably practicable' to meet the general environmental duty.
	Environment Reference Standard	The Environment Reference Standard (ERS), made under the *Environment Protection Act 2017*, identifies environmental values to be achieved and maintained, and how these values are to be assessed. The ERS is comprised of many 'reference standards', including water (surface water and groundwater). The ERS (Part 5 – Water) includes standards contained within the former State Environment Protection Policy (Waters). With minor changes, the ERS adopts the environmental values, segments, indicators and objectives of the former State Environment Protection Policy (Waters). The project design and construction would need to consider and apply the ERS relevant to the project.

Legislation and guidelines	Description	Relevance to project
Planning and Environment Act 1987	The Moyne Planning Scheme contains clauses within the Planning Policy Framework and Particular Provisions relevant to groundwater.	The following Clauses of the Planning Policy Framework are relevant to the groundwater assessment for the project: • 14.02-1S Catchment planning and management: objective is *"to assist the protection and restoration of catchments, water bodies, groundwater, and the marine environment"* • 14.02-2S Water quality: objective is *"to protect water quality"*, with a key strategy *"to identify the beneficial uses of groundwater resources and have regard to potential impacts on these resources from proposed land use or development".*
Water Act 1989	Victoria's *Water Act 1989* promotes the orderly, equitable and efficient use of water resources to make sure that water resources are conserved and properly managed for sustainable use for the benefit of present and future Victorians. The *Water Act 1989* regulates the impacts on and use of surface water and groundwater.	Southern Rural Water is the delegated authority under the *Water Act 1989*. An approval to Take or Use groundwater is not required from Southern Rural Water for dewatering where groundwater will not be intentionally encountered (e.g., in foundations). However, the project would apply for a Take and Use Licence to dewater the quarry, which is anticipated to intersect groundwater. Permits and any associated investigations will be required if groundwater is targeted as a water supply.
EPA Victoria Publication 668: *Hydrogeological assessment (groundwater quality) guidelines*	The EPA Victoria Publication 668 outlines the requirements for assessments of groundwater, including desktop and field investigations, and groundwater data collection and sampling.	The groundwater impact assessment completed for the project has been undertaken in accordance with these guidelines.
EPA Victoria Publication 669: *Groundwater sampling guidelines*	The key objective of EPA Victoria Publication 669 is to enable "consistent determination of chemical and biological indicators of groundwater" to ensure "groundwater samples are representative of groundwater in the aquifer".	These guidelines inform the process for collecting groundwater samples for chemical analysis. Groundwater monitoring during project construction would be undertaken in accordance with these guidelines.
Local		
Western Region Sustainable Water Strategy (Department of Sustainability and Environment, 2011)	The *Western Region Sustainable Water Strategy* (Department of Sustainability and Environment, 2011) identifies actions to ensure sustainable water supply and management during the next 50 years for the Western Region of Victoria. A key action of the strategy is to improve groundwater management, including: • "Using a risk-based approach to consider the needs of groundwater dependent ecosystems in management decisions. • Protecting the health of groundwater resources with long-term, viable and cost-effective groundwater monitoring."	The project is within the Portland Coast region river basin and the 'South-west Coast' sub-region identified in the Western Region Sustainable Water Strategy. The approach to considering the needs of GDEs and protecting the health of groundwater resources is contained in Section 9.7 of this chapter.

Legislation and guidelines	Description	Relevance to project
South West Limestone Local Management Plan (Southern Rural Water, 2016)	The *South West Limestone Local Management Plan* (Southern Rural Water, 2016) seeks to ensure the groundwater resources in the south-west Victorian upper mid-Tertiary limestone aquifer (referred to as the South West Limestone Groundwater Management Area) are sustainably managed. This management area replaces former management units for the region.	The project site lies within the Portland Coast River Region in the South West Limestone Groundwater Management Area. This Groundwater Management Area includes the Port Campbell Limestone.

9.3.1 Environment Reference Standard

The ERS (see Table 9.2) specifies potential beneficial uses based on the background water quality of groundwater, specifically the concentration of total dissolved solids (TDS). Seven 'segments' of groundwater are defined depending on the concentration of TDS in groundwater, with Segment A1 having a TDS concentration of 0–600 mg/L and Segment F having a TDS concentration of more than 10,001 mg/L.

Groundwater within the project site is classified as falling within Segments B to C, with a TDS range of 1,201–5,400 mg/L. Environmental values (formerly called 'beneficial uses' under the State Environment Protection Policy (Waters)) applicable to these segments are:

- water dependent ecosystems and species
- potable mineral water supply
- agriculture and irrigation (irrigation)
- agriculture and irrigation (stock watering)
- industrial and commercial use
- water-based recreation (primary contact recreation)
- cultural values
- buildings and structures
- geothermal properties.

Beneficial uses/environmental values

Before the introduction of the new *Environment Protection Act 2017*, State Environment Protection Policies were established under the *Environment Protection Act 1970* to protect environmental values and human activities, referred to as '**beneficial uses**'. State Environment Protection Policy (Waters) sought to protect and manage surface water and groundwater in Victoria and their beneficial uses through the establishment of environmental quality objectives.

The new *Environment Protection Act 2017* and subordinate legalisation came into force on 1 July 2021, which includes the Environment Reference Standard (ERS). With minor changes, the ERS adopts the environmental values, segments, indicators and objectives of the former State Environment Protection Policy (Waters). A key change is the previous term 'beneficial uses', defined in State Environment Protection Policy (Waters), are now referred to as '**environmental values**' in the ERS.

Of these environmental values, 'water dependent ecosystems and species' and 'agriculture and irrigation (stock watering)' are relevant to the project. Environmental quality indicators and objectives for these environmental values are outlined in the ERS and include reference to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2018).

9.4 Method

9.4.1 Existing conditions

A combination of desktop information and field-based survey techniques were used to characterise groundwater within the project site.

The groundwater existing conditions desktop assessment included:

- review of legislation and policies relevant to the assessment of groundwater impacts
- review of existing land and water use, including the identification of:
  - registered groundwater bores via the Visualising Victoria's Groundwater website
  - GDEs as shown in the Bureau of Meteorology GDE Atlas
- characterisation of the surface and underlying geology, based on review of the Geoscience Australia database and relevant literature applicable to the project site
- development of a hydrogeological conceptual model to determine potential 'impact pathways', and the effect of project activities on groundwater resources and users that incorporated:
  - local geological information
  - groundwater flow systems of the Glenelg Hopkins Catchment Management Authority region
  - LiDAR ground elevation data
  - hydraulic conductivity (K) of shallow geological units based on previous groundwater studies carried out in the regional area
  - bore data for the presence of perched aquifers (i.e., seasonally high-water table due to winter rainfall, rather than from groundwater rising from below).

A **hydrogeological conceptual model** represents the hydrogeological (groundwater) setting, including:

- movement of groundwater
- groundwater-surface water interactions
- groundwater receptors (users and receiving environments).

Twenty-three exploration boreholes were drilled within the proposed quarry area at depths ranging from 6.9 to 21.3 metres below natural surface level. The geological logs from these boreholes were analysed to determine the characteristics of the underlying basalt material. Water level gauging was also done on 5 February 2021 at five boreholes within the proposed quarry extraction area (i.e., quarry pit).

Native vegetation communities recorded during field surveys by Nature Advisory (see Appendix D – *Biodiversity*) were assessed against a range of criteria to determine the likelihood of GDEs being present within the investigation area.

9.4.2 Impact assessment

Given the main factor in groundwater flow within the project site is rainfall recharge, an estimation of the groundwater inflow to the proposed on-site quarry pit and the extent of drawdown was made by simplifying the hydrogeological environment. The inputs for this assessment included proposed quarry depth and pit radius, aquifer thickness and the depth of the groundwater in the pit, as well as aquifer hydraulic conductivity and recharge. Multiple scenarios were assessed to provide a range of possible groundwater inflows and drawdown extents. Anecdotal evidence from the Tarrone basalt quarry, 10 kilometres to the south-east of the proposed on-site quarry and of similar physical and hydrological characteristics, was also used to constrain the project quarry inflow and drawdown assessment.

For the wind turbine foundation and cable trench excavation sites, which are short-term excavations (i.e., up to two weeks), qualitative assessment of impacts has been undertaken and adjustments made to site infrastructure in locations where excavations were within prescribed buffer distances from defined groundwater receptors, including groundwater bores and mapped potential GDEs.

9.5 Investigation area

The groundwater impact assessment investigation area focuses on the project site and immediate surrounding areas that may have hydrogeological connectivity with site activities. A broader area was considered to provide geological context and to identify potential groundwater users.

9.6 Existing conditions

9.6.1 Geology

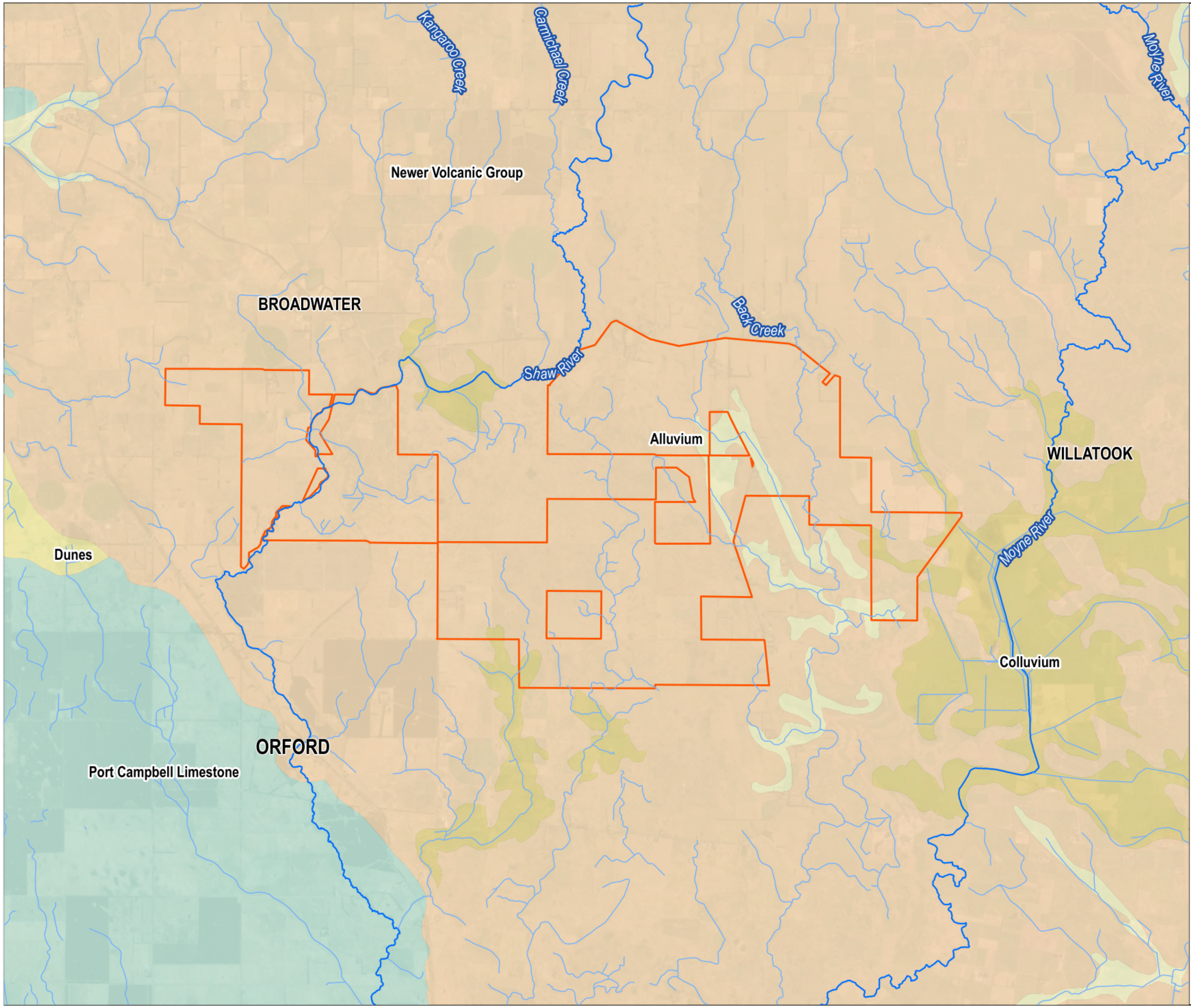
The project is on the southern margin of the Western Volcanic Plain, north of Port Fairy. This volcanic region is part of a broad basaltic lava province active during the past six million years and referred to as the Newer Volcanic Province, a major geological unit of southern Australia. Further discussion of the local geology and volcanic history relevant to the region is contained within Chapter 8 – *Geoheritage*.

The surface geology within the project site consists of the Newer Volcanic Group basalt flows (Qbn) with isolated occurrences of Alluvium (Qa) and Colluvium (Qrc) restricted to lower lying areas. Alluvium refers to material (e.g., clay, silt, sand) deposited by running water, while colluvium refers to loose material deposited at the base of a steep slope. Other surface geological layers mapped within the region, but outside the project site and immediate surrounds, are the Molineaux Sand (Qd) and Port Campbell Limestone (Czipc). The spatial distribution of these formations is illustrated in Figure 9.1.

Within the Newer Volcanic Province, several subsurface geological units form aquifers that have a range of depths and quality. The primary aquifer units that occur in the project site are associated with the following geological layers:

- unconsolidated alluvium and colluvium deposits (Quaternary Aquifer)
- Newer Volcanic Group basalts (Upper Tertiary/Quaternary Basalt)
- Port Campbell Limestone (Upper mid-Tertiary Aquifer, part of the Upper Middle/Limestone Aquifer).

A cross-section of the aquifer layers shown in Figure 9.2.



LEGEND

- Major watercourse
- Minor watercourse
- Willatook Wind Farm boundary

Surface geology

- Alluvium
- Newer Volcanic Group
- Dunes
- Port Campbell Limestone
- Colluvium

SOURCE:
Willatook Wind Farm boundary from Wind Prospect.
Watercourses from Vicmap.
Surface geology from Geoscience Australia.
Imagery from ArcGIS Online (various capture dates).

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WIND PROSPECT
WILLATOOK WIND FARM

FIGURE 9.1

Surface geology

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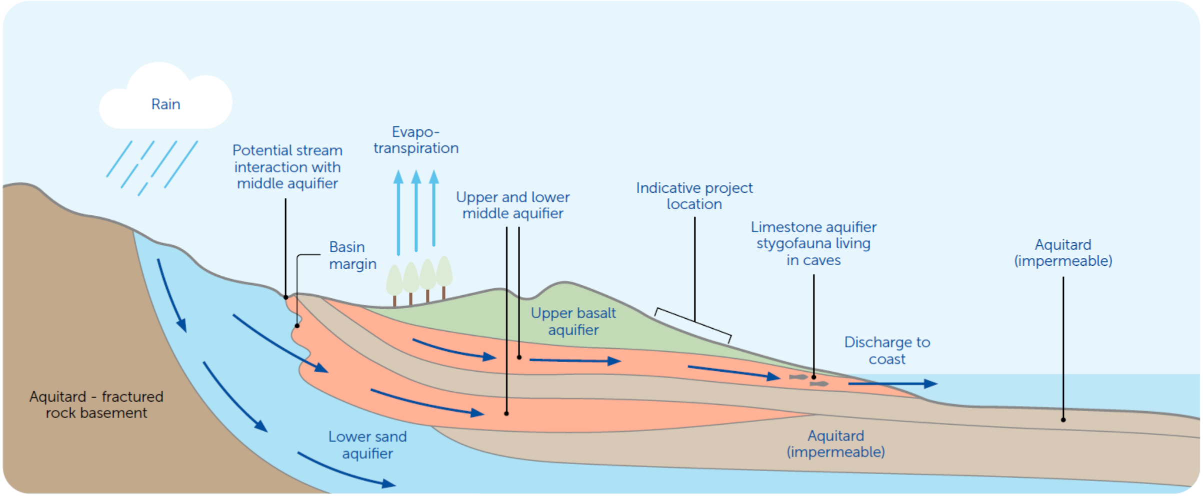


Figure 9.2 **Regional conceptual model with indication of project location highlighted (*Source: South West Victoria Groundwater Atlas SRW, 2017*)**

Unconsolidated alluvium/colluvium deposits (Quaternary Aquifer)

The local Quaternary Aquifer is comprised of gravels, sands and silts forming a thin layer of alluvial material in low-lying areas near drainage channels and floodplains, or residual deposits, consisting of sheetwash, talus, and scree (see text box). Where present, these deposits occur between the natural surface to a depth of around 5 metres.

Within the project site, unconsolidated alluvium and colluvium surface deposits are found near Tarrone North Road, associated with a drainage line that feeds into Back Creek, and swamp/lake deposits south of Woolsthorpe-Heywood Road associated with Shaw River and Cockatoo Swamp (Figure 9.1). The unconsolidated alluvium and colluvium surface deposits overlie the Newer Volcanic Group basalts.

> **Sheetwash:** process of erosion where a sheet of water flows downslope as a thin film, transporting loose surface material
>
> **Talus:** heaped rock fragments accumulated at the base of a cliff or rocky slope, forming an angled slope.
>
> **Scree:** loose small rocks at the base of a steep slope or cliff.

Newer Volcanic Group basalts (Upper Tertiary/Quaternary Basalt)

The local Upper Tertiary/Quaternary Basalt comprises the Newer Volcanic Group basalt flows, overlain locally by stony rises and scoria. These basalt flows and stony rises comprise the majority of the project site surface geology (Figure 9.1). The Newer Volcanic Basalts occur between the natural surface to a depth of around 50 metres.

Stony rises occur in areas within the project site where lava flows buried soil that was present on previous lava flows. The stony rises are reported to be less weathered and more fractured, allowing for higher volumes of groundwater recharge and storage. For a detailed description on the formation and spatial occurrence of the Newer Volcanic Basalts in the region see Chapter 8 – *Geoheritage*.

Across the project site the Newer Volcanic Group basalt and stony rises behave as an unconfined fractured rock aquifer. In these aquifers, groundwater flow is controlled by fracture zones through which groundwater infiltrates and flows, as well as the rock type, level of rock deformation and undulations of the land surface. While both basalt flow and stony rise aquifers are important for groundwater supply, the aquifer potential in stony rises is reported to be higher.

Port Campbell Limestone (Upper mid-Tertiary Aquifer)

Beneath the Newer Volcanic Group basalts is the Port Campbell Limestone, comprised of marine silts and clays from depths of around 20 to 200 metres below the natural surface. This Upper mid-Tertiary Aquifer is typically around 100–200 metres thick across the South-west Coast sub-region and is a major aquifer in the region. Outcropping of Port Campbell Limestone occurs in some areas and overlain by Newer Volcanic Group basalts in others. Small outcrops occur between Yambuk and Orford. The Port Campbell Limestone aquifer is classified as 'partially (or semi) confined' in areas where it is overlain by Newer Volcanic Group basalts. No outcrop areas of Port Campbell Limestone are mapped within the project site.

Other regional geological units

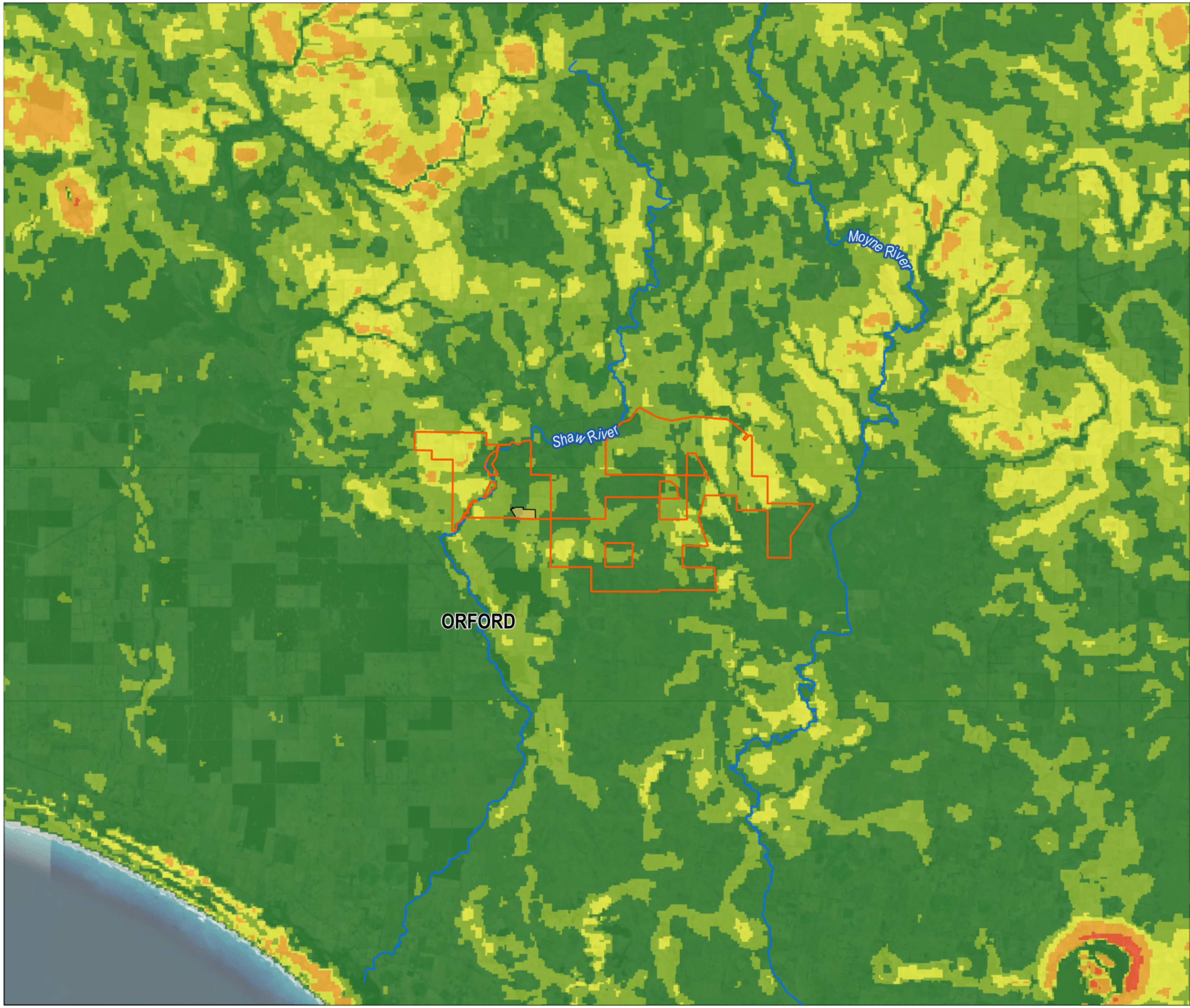
Other aquifer units that occur in the vicinity of the project site include:

- Clifton Formation (Lower mid-Tertiary Aquifer): a confined limestone aquifer, typically 15 to 25 metres thick, located throughout most of the Otway Basin. It is considered the Clifton Formation is not hydraulically connected to the Port Campbell Limestone aquifer.
- Dilwyn formation (Lower Tertiary Aquifer): up to 1,000 metres below the surface in some areas, this aquifer is used to supply the townships of Portland, Port Fairy, Heywood and Dartmoor. Due to the depth of this aquifer, it is not extensively used (unlike the limestone and basalt aquifers).

9.6.2 Depth to groundwater

Depth to groundwater varies across the region. It also varies at different times of the year, influenced by seasonal rainfall and longer-term climatic changes. In general, groundwater is shallow across the project site, estimated to be between 1 and 12 metres below natural surface level. Localised areas of shallow groundwater (less than 3 metres below natural surface level) are likely to occur, particularly in topographic lows.

A regional interpretation of average depth to groundwater is shown in Figure 9.3. This figure shows that across the project site there are large areas of shallow groundwater (less than 5 metres in depth), interspersed with areas where groundwater depth is between 5 metres and 20 metres, with small, isolated areas where groundwater is up to 50 metres deep. Areas of deeper groundwater are predominately in the north-eastern, eastern and western parts of the project site. Based on observations of the site, shallow aquifers that intercept the surface may also be present as small, saturated wetland areas or springs.



LEGEND

- Watercourse
- Willatook Wind Farm boundary
- Quarry area

Depth to water table (mAHD)

- <5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 -100

SOURCE:
Willatook Wind Farm boundary from Wind Prospect.
Depth to water table from Visualing Victoria's Groundwater.
Watercourses from Vicmap.
Imagery from ArcGIS Online (various capture dates).

0 5 km

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PROJECTION: **GDA 1994 MGA Zone 54**

WIND PROSPECT

WILLATOOK WIND FARM

FIGURE 9.3

Regional predicted depth to water table

Groundwater level measurements taken during May 2016 for the project at six registered groundwater bores ranged from 1.0 to 11.7 metres below ground level. Additional measurements taken 5 February 2021 from five boreholes within the proposed quarry extraction site ranged from 2.1 to 5.2 metres below ground level. The data is consistent with that presented in Figure 9.3.

Groundwater levels in this region are known to vary markedly between seasons, with the highest levels occurring in late spring after recharge by winter rainfall and the lowest levels occurring in late summer. Figure 9.4 below shows the seasonal variability recorded at the six registered groundwater bores. This shows there is typically an annual fluctuation in groundwater depth of between 0.5 and 3.5 metres, depending on the location, between the beginning of spring when groundwater levels are highest and the end of summer when groundwater levels are at their lowest.

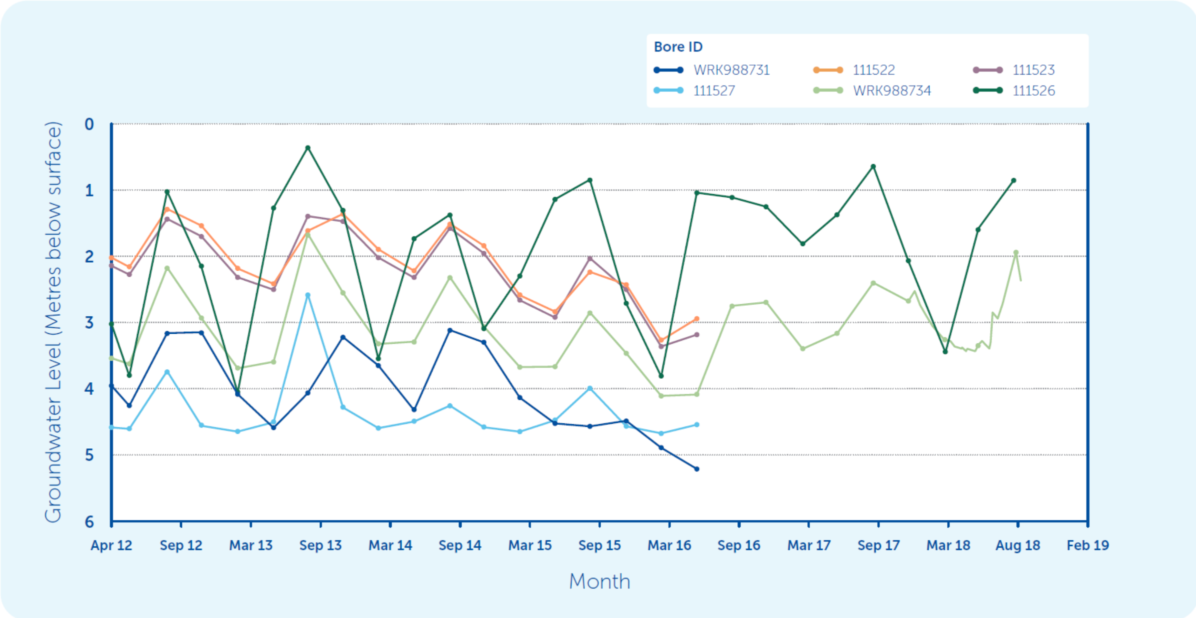
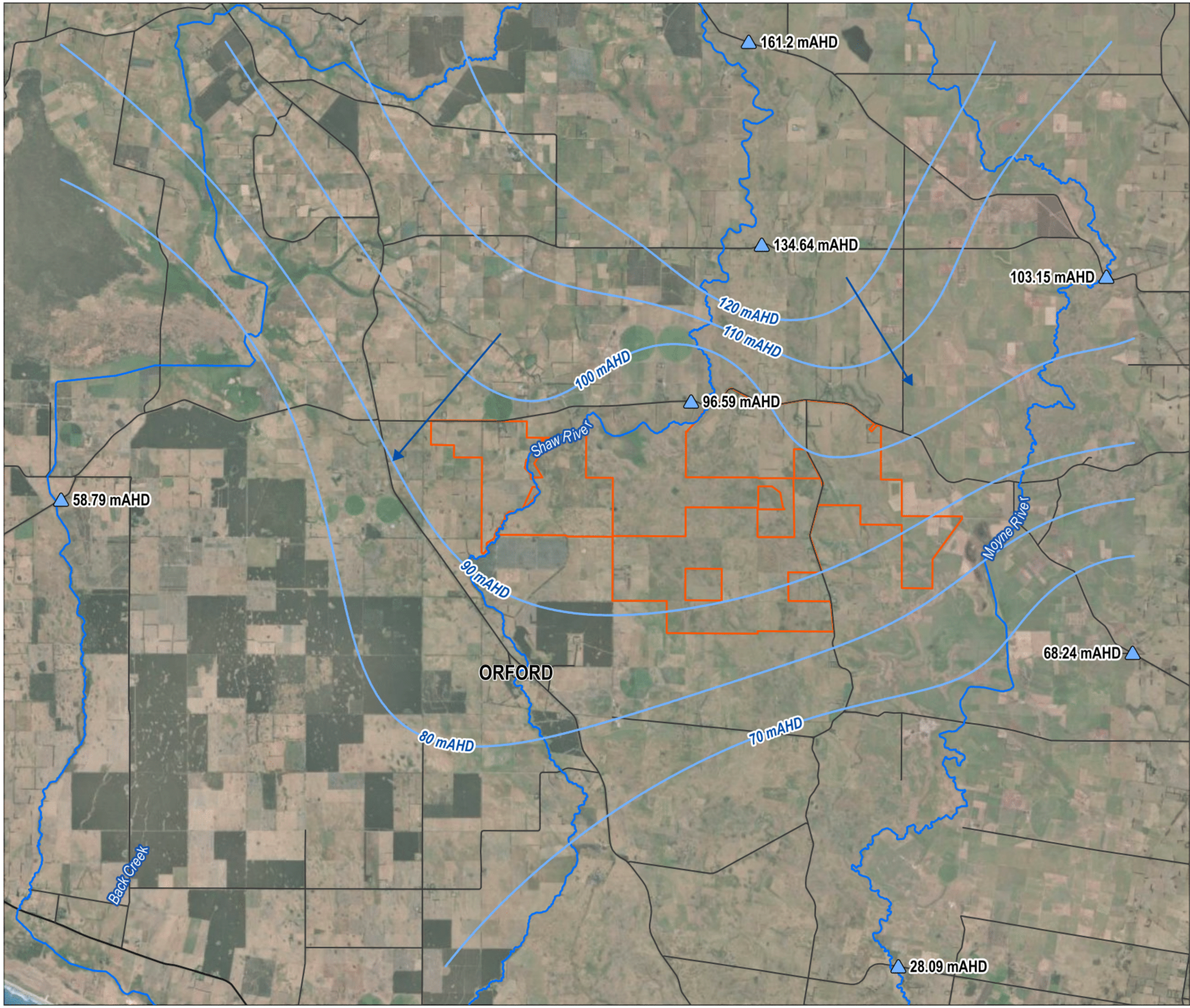


Figure 9.4 **Seasonal water level change for the six groundwater bores**

9.6.3 Groundwater flow, recharge and discharge

On a regional scale, groundwater flow in the Newer Volcanic Group basalts (Upper Tertiary/Quaternary Basalt) is southwards towards the coast (see Figure 9.5). Groundwater flow is driven by recharge which predominantly occurs via infiltrating rain (during winter and spring), with estimates of between 10 to 40 millimetres per annum reported by Dahlhaus et al. (2002). The underlying Port Campbell Limestone aquifer is recharged via indirect rainfall infiltration where it is overlain by basalt aquifers, and via direct rainfall infiltration where the aquifer is expressed at the surface.

Discharge from the Newer Volcanic Group basalt aquifer occurs through groundwater extraction from wells and at the edge of formations and topographic lows where surface expressions of groundwater (e.g., springs and freshwater meadows) are common. Depletion also occurs through evapotranspiration. Local groundwater information provided by landowners indicates that most springs in the area fill during winter and dry up during summer. When full, springs along Shaw River discharge into the watercourse and Cockatoo Swamp. Groundwater may also discharge into streams (as baseflow) and into unconsolidated alluvium/colluvium deposits (Quaternary Aquifer).



LEGEND

- Groundwater elevation SOBN bores
- Groundwater contours
- Major watercourse
- Groundwater flow direction
- Highway
- Major road
- Willatook Wind Farm boundary

SOURCE:
Willatook Wind Farm boundary, groundwater contours and groundwater wells from Wind Prospect.
Roads and watercourses from Vicmap.
Imagery from ArcGIS Online (various capture dates).

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PROJECTION: **GDA 1994 MGA Zone 54**

WIND PROSPECT
WILLATOOK WIND FARM
FIGURE 9.5
Inferred groundwater flow

DATE: 24.01.22 PROJECT: 754-MELEN287657 FILE: 287657_02_F037_GIS DOC REFERENCE: 287657_02_FIGS_D APRX_V01

DISCLAIMER: THIS FIGURE HAS BEEN PRODUCED FOR INTERNAL REVIEW ONLY AND MAY CONTAIN INCONSISTENCIES OR OMISSIONS. IT IS NOT INTENDED FOR PUBLICATION.

The Newer Volcanic Group basalt is the main aquifer within the project site. Groundwater flow within this aquifer is variable due to the inherent variability in hydraulic parameters that exist in aquifers of volcanic origin. The parameter of interest is hydraulic conductivity. Hydraulic conductivity values are reported to range from 0.001 to 100 m/d (metres per day) for the Newer Volcanic basalt, with the lower estimate described as tight fractures and the upper estimate described as open fractures and lava tubes. The hydraulic conductivity range is consistent with the description that groundwater moves through the fractured rocks at highly variable rates (Dahlhaus et al., 2002). The stony rises are generally more permeable with a range of 0.1 to 100 m/d, while the quaternary deposits exhibit a wider hydraulic conductivity range from 1 x 10^{-6} to 100 m/d.

Hydraulic conductivity represents the ease in which water can move through the pore spaces and fractures in the rock.

9.6.4 Groundwater quality

The geology, water-rock interactions and local groundwater flow systems can influence groundwater quality and recharge. Groundwater salinity (measured as electrical conductivity or as TDS) is generally used as a measure of quality due to its implications for groundwater use and land management.

Using the Visualising Victoria's Groundwater database, groundwater salinity is expected to range from 1,001 to 3,500 mg/L in the water table aquifer across much of the project site. Isolated occurrences of lower salinity groundwater in the range of 501 to 1,000 mg/L are possible in the north and south of the project site. Groundwater in the underlying limestone aquifer is generally lower salinity, typically around 1,500 mg/L. The salinity ranges correspond to Segments A2 to C in the updated Environment Reference Standard.

In general, groundwater in the project site is too brackish and hard for potable domestic use but of sufficient quality to be used for irrigation, stock and some industrial processes.

9.6.5 Groundwater users

The project site lies within the Portland Coast River Region in the South West Limestone Groundwater Management Area, which includes the Port Campbell Limestone in the Western Region of Victoria. The Portland Groundwater Management Area underlies the South West Limestone Groundwater Management Area from a depth of 200 metres. Within the Western Region, the project is within the South-west Coast sub-region, which extends from the Otway Coast to South Australia. There are no Water Supply Protection Areas, declared under the *Water Act 1989*, within the project site.

Groundwater Management Areas in Victoria are established where groundwater has been intensively developed or has the potential to be developed.

The region has a history of pastoral and cropping land uses, and groundwater is used for domestic and farming purposes. Groundwater in the underlying limestone is predominately used for irrigation, as well as supplementing the local urban water supply. Regionally, groundwater in deeper formations is used extensively for municipal supply. For example, supplies for Koroit and Warrnambool are sourced from the Port Campbell Limestone, and supply for Port Fairy and Portland is sourced from the Dilwyn Aquifer.

There are 9 bores within the project site interpreted to be completed in the Newer Volcanic Group basalts within the project site that are registered by Southern Rural Water as unmetered bores for stock and domestic use (Figure 9.6). These bores are less than 40 metres deep. The depths of the six registered bores monitored for the project ranged from 8 to 38 metres below the surface. There are also several other bores in proximity to the project site (Figure 9.6).

Unregistered bores in operation may also be present within the project site. Two state observation bores are located beyond the project site immediately to the north and there are a further four state observation bores within 5 kilometres.

No cropping irrigation within the project site has been identified.

9.6.6 Groundwater dependent ecosystems

The Bureau of Meteorology's GDE Atlas indicates the presence of aquatic and terrestrial GDEs in the project site. These ecosystems are rated as having moderate to high likelihood of receiving groundwater inflows.

Mapped aquatic potential GDEs within the atlas include:

- temporary freshwater marshes and meadows associated with the Cockatoo Swamp wetland complex and an area of the Shaw River, which were assigned a high probability that are likely to receive groundwater inflows in addition to rainfall
- smaller isolated temporary freshwater marshes and meadows assigned moderate probability to receive groundwater inflows in addition to rainfall
- areas of ephemeral wetlands highly likely to receive groundwater inflows in addition to rainfall.

Bureau of Meteorology mapped potential aquatic and terrestrial GDEs within the project site are shown in Figure 9.6.

Groundwater Dependent Ecosystems (GDEs) refer to ecosystems that rely on groundwater (either permanently or intermittently) to meet some or all of their water requirements to maintain the flora and fauna, ecological processes and ecosystem services they support.

The '*Australian groundwater-dependent ecosystems toolbox part 1: Assessment framework*' (Richardson et al. 2011) identifies three classes of GDEs:

- **Aquifer and cave ecosystems (Type 1):** includes karst aquifer systems, fractured rock and saturated sedimentary environments, providing habitats for organisms such as stygofauna and troglofauna.
- **Ecosystems dependent on the surface expression of groundwater (Type 2):** a visible expression of groundwater as it extends above the earth surface. This includes wetlands, lakes, springs, marine ecosystems, etc.
- **Ecosystems dependent on subsurface presence of groundwater (Type 3):** groundwater is not visible on the surface in these ecosystems, and includes terrestrial vegetation where the root zones is within the water table (either permanently or episodically).

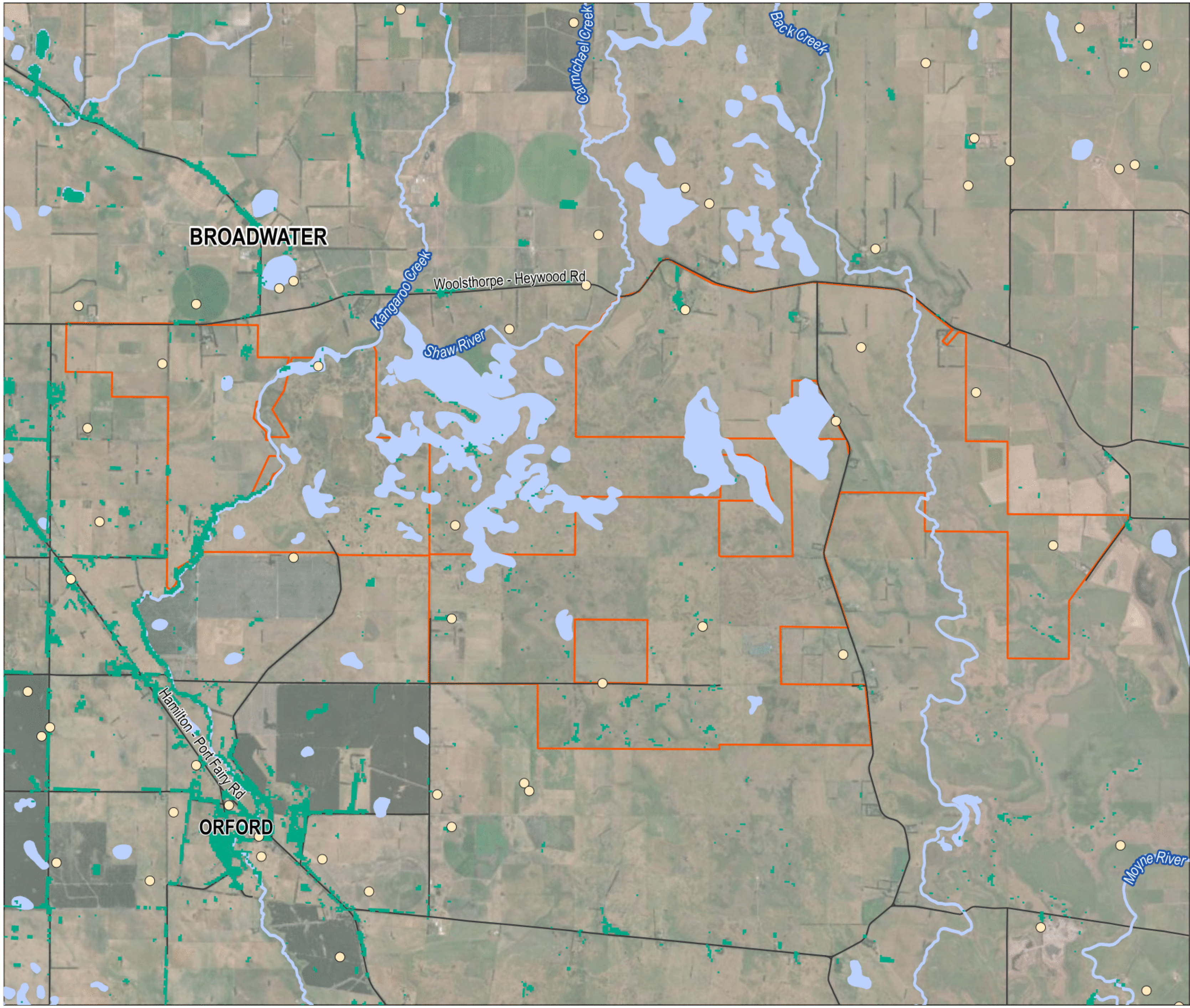
Source: 'Australian groundwater-dependent ecosystems toolbox part 1: Assessment framework' (Richardson et al. 2011)

Terrestrial GDEs in the atlas within and near the project site include six terrestrial vegetation wetland, woodland and shrubland communities typically in isolated fragments or along major watercourses. These areas were based on broad-scale habitat modelling, refined by field investigations of native vegetation present within and near the project site (see Appendix D – *Biodiversity*).

A key aspect of the GDE Atlas modelling of potential terrestrial GDEs is depth to groundwater. Groundwater less than 10 metres below surface is often conducive to tree root penetration if the soil conditions are suitable. It is important to note the GDE Atlas displays ecosystem polygons where groundwater interaction may occur, but it does not suggest that vegetation within the polygon is dependent on groundwater (Doody et al., 2017).

Field surveys identified four vegetation types (Ecological Vegetation Classes (EVCs)) within the project site that could potentially to be Type 2 terrestrial GDEs (see definition box). These are:

- Plains Grassy Wetland (EVC 125)
- Tall Marsh (EVC 821)
- Aquatic Herbland (EVC 653)
- Swamp Scrub (EVC 53).



LEGEND

- Groundwater bore
- Road
- Potential terrestrial GDE
- Potential aquatic GDE
- Willatook Wind Farm boundary

SOURCE:
Willatook Wind Farm boundary, GDEs and boreholes from Wind Prospect.
Roads and watercourses from Vicmap.
Imagery from ArcGIS Online (various capture dates).

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SCALE 1:75,000
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PROJECTION: **GDA 1994 MGA Zone 54**

WIND PROSPECT

WILLATOOK WIND FARM

FIGURE 9.6

Potential groundwater environmental values

WIND PROSPECT

DATE: 01.12.21 PROJECT: 754-MELEN287657 FILE: 287657_02_F027_GIS DOC REFERENCE: 287657_02_FIGS_C.APRX_V01

Aquatic Herbland and most Plains Grassy Wetland within and near the project site occurs in wet depressions away from watercourses. These have been found to be ephemeral, with water level fluctuating seasonally according to rainfall. This suggests that although these vegetation types may interact with groundwater, it is not their primary water source.

Tall Marsh, Swamp Scrub and a small area of Plains Grassy Wetland within and near the project site occur next to watercourses. Some of these watercourses are permanent, while others are ephemeral. The water level of all watercourses fluctuates seasonally according to rainfall. This suggests that although these vegetation types may interact with groundwater, it is not the primary water source for these vegetation types, and they are supported by seasonal high flows from watercourses and local catchment runoff.

Field surveys identified four vegetation types within the project site that could be Type 3 terrestrial GDEs. These are:

- Stony Knoll Shrubland (EVC 649)
- Higher-rainfall Plains Grassy Woodland (EVC 55_63)
- Basalt Shrubby Woodland (EVC 642)
- Heavier-soils Plains Grassland (EVC 132_61).

Given the relatively high annual rainfall of the project site, it is considered likely the primary source of water for terrestrial vegetation types is rainfall (Appendix D – *Biodiversity*). The low stature and generally shallow root systems of the plants that make up most of the terrestrial EVCs make it unlikely that this vegetation is dependent on groundwater for its survival or good health. Terrestrial vegetation could benefit from access to groundwater during summer or drought periods, however, during this time groundwater levels would be significantly lower (see Section 9.6.2) making this less likely.

The local groundwater environment was assessed not to be conducive for subterranean GDEs (i.e., below natural ground surface level) (Appendix D – *Biodiversity*).

9.7 Impact assessment

9.7.1 Impact pathways

The potential for groundwater-related issues associated with the construction and operation of the project relate to the potential for adverse impacts to existing users of groundwater and to GDEs because of reduced groundwater levels and associated impacts to the supply of groundwater. Impacts may also occur due to reduced groundwater quality.

These impacts could occur through the following potential impact pathways:

- dewatering of groundwater during construction and lowering the water table resulting in groundwater drawdown that affects water availability
- disruption of groundwater recharge and flow, such as from introduction of impermeable surfaces and physical barriers in the form of wind turbine foundations
- disruption of groundwater discharge to watercourses or waterbodies by intersecting groundwater discharge water features (e.g., natural springs) or from a reduction in groundwater availability (e.g., due to dewatering)
- groundwater contamination, including from accidental spills or formation of acid sulfate soils.

The degree of impact would depend on the reliance that existing users and GDEs have on groundwater and the extent, timing and duration of impacts resulting from project activities.

Dewatering and disposal of extracted groundwater (drawdown)

Groundwater extraction would be limited to locations where a perched or very shallow aquifer is encountered during the construction. Excavation during construction would typically be to depths of less than 3.5 metres, except at the quarry site. If shallow groundwater is intercepted during construction, localised groundwater from the uppermost zones may seep into the excavated area. Under this scenario, groundwater abstraction via pumping (termed ‘dewatering’ of the excavation) may be required to create a safe work area. Dewatering may temporarily lower the water table until the concrete foundations are laid, however, as the construction period for turbine foundations is short (i.e., up to two weeks), impacts are unlikely to materially affect groundwater users.

As the proposed quarry excavation depth extends below the water table level, dewatering is expected to be needed for this site during operation. This would be managed under a Take and Use Licence, to be approved by Southern Rural Water as the delegated authority under the *Water Act 1989*.

A summary of the proposed excavation depths for project infrastructure and the approximate depth to groundwater at these locations is provided in Table 9.3.

Table 9.3 Proposed project excavation depths of one metre or more, and approximate depth to groundwater at these locations

Project activity/ infrastructure	Proposed excavation depth	Approximate depth to groundwater
Quarry excavation	14 metres maximum within a 10.4-hectare extraction area	Assumed to be 3 metres below the natural surface.
Excavation for foundations	3.5 metres	Foundations may intercept shallow groundwater less than 3 metres below the natural surface, particularly during winter and early spring.
Underground cabling	1 metre	Cable trenches may intercept very shallow groundwater less than 1 metre below the natural surface during winter and early spring in isolated areas.

Disruption of groundwater recharge and flow

Infrastructure foundations have the potential to decrease the permeability of the ground surface, resulting in altered rates of infiltration and groundwater recharge. Vegetation removal can also influence groundwater recharge rates.

After foundations are in place, these structures may influence the lateral flow of groundwater, however, this would be highly localised (in the order of tens of metres) and is unlikely to materially affect groundwater availability at the project site.

Disruption of groundwater discharge

Direct impacts to groundwater discharge may occur if the placement of project infrastructure intersects groundwater discharge features, such as springs. Earthworks or watercourse crossings have the potential to intersect the groundwater table, which may result in indirect impacts to these groundwater discharge features due to changes in groundwater availability and baseflow.

Groundwater contamination

Contamination could occur if significant quantities of fuels, chemicals or other substances were accidentally released from contained areas onto the ground. During construction and operation of project, the use of fuels and chemicals can pose a threat to groundwater quality if not managed appropriately. Bulk liquid chemicals, including fuels and lubricants, would also be stored on site.

Groundwater contamination may also occur from exposure and oxidation of potential acid sulfate soils, which may arise during excavation of trenches in potential acid sulfate soils zones (see Chapter 10 – *Surface water*). The release of acidic waters may adversely impact groundwater quality and downgradient receiving environments or users.

Disposal of abstracted groundwater and its management is a potential issue due to variable groundwater quality, including elevated salinity. The quality of abstracted groundwater would determine the required management method. A reduction in groundwater quality, due to contamination, may extend to existing users or GDEs depending on the aquifers affected.

9.7.2 Design mitigation

Design measures were put in place, based on known environmental constraints, to avoid potential groundwater impacts to local groundwater users and environmental values. These included:

- locating the quarry away from environmental values like groundwater bores and areas of potential GDEs [GWD01]. This is a key design mitigation measure aimed at avoiding, or at least substantially limiting, potential impacts to local groundwater users and environmental values
- applying a 100-metre buffer around all mapped aquatic GDEs to exclude all project infrastructure within the buffered area [GWD02]. This area was selected as a means of avoiding physical disturbance to the GDEs and their fringes, and to avoid surface water runoff and entrained sediment loads reaching these GDEs from construction work zones
- applying a single, large buffer around a series of wetlands that form the Cockatoo Swamp in response to Brolga impact mitigation. This area contains most of the potential aquatic and terrestrial GDEs mapped within the site. A detailed justification for this buffer is described in Chapter 11 – *Brolga*
- avoiding areas of mapped native vegetation (which have the potential to be GDEs) where possible based on site surveys that have progressively refined the understanding of the presence and distribution of native vegetation. This has included re-routing access tracks and underground cabling, and moving proposed wind turbines and other infrastructure. These measures are described in further detail in Chapter 12 – *Biodiversity and habitat*.

Because aquatic GDEs have a high likelihood of being inflow systems (i.e., they receive local surface water inflows), hydrological modelling of the site was considered during the project design to ensure natural flow paths (hydrological connectivity) are not interrupted by the project [GWD03] (see Chapter 10 – *Surface water*).

The proposed construction footprint consists of 222.3 hectares of expected ground disturbance. As the construction footprint has been derived in accordance with the 'avoid' and 'minimise' principles, most of the native vegetation has been avoided and would be retained, including areas mapped as potential terrestrial GDE by the Bureau of Meteorology (see Chapter 12 – *Biodiversity and habitat*).

9.7.3 Management controls

Where possible, engineering design measures have been included to avoid potential groundwater impacts. To further manage potential impacts to groundwater, the management measures outlined in Table 9.4 have been proposed for project construction, operation and decommissioning.

Management and disposal of water extracted from excavations during project construction (including dewatering) is discussed in Chapter 10 – *Surface water*.

Table 9.4 Groundwater management measures

Groundwater impact pathway	Project phase	Management measures	Number
Quarry excavation and dewatering leads to lowering of groundwater level	Pre-construction	Obtain a Work Authority (through approval by Earth Resources Regulation, Department of Jobs, Precincts and Regions) for the quarry construction and operation and adhere to its requirements.	GW01
	Pre-construction	Consult with relevant landowners about potential impacts to bores would occur prior to commencement of construction.	GW02
	Pre-construction	Conduct further groundwater monitoring within and around the quarry excavation to refine estimates of hydraulic conductivity.	GW03
	Pre-construction	If any assumptions underpinning predictions of groundwater drawdown from the quarry change, update drawdown predictions and complete a site-specific risk analysis for neighbouring environmental values.	GW04

Groundwater impact pathway	Project phase	Management measures	Number
	Pre-construction, construction	A Water Management Plan would be developed and its requirements carried out by the contractor, and approved by the Responsible Authority, prior to the commencement of project construction. The Water Management Plan would respond to any final design details and ensure all risks are appropriately managed. The Water Management Plan would include, but not be limited to: • dewatering procedures (including discharge location and quality of water, pollution control and management of sediment) in line with EPA Victoria approval processes • procedures for groundwater inflow monitoring in accordance with EPA Victoria Publication 669: *Groundwater sampling guidelines* • groundwater level triggers for further management measures, if needed.	GW05
	Pre-construction, construction	The use of quarry water would be in accordance with a Take and Use licence under Section 51 of the *Water Act 1989* and in accordance with Environment Protection Regulations 2021	GW06
Foundation excavations intersect shallow water table and alters groundwater flow and recharge	Pre-construction, construction	Conduct further groundwater monitoring and mapping using exiting bores prior to and during construction to establish local groundwater levels and groundwater quality.	GW07
	Pre-construction, construction	Construction activities and temporary works that may impact on surface permeability and groundwater would be included within the contractor's Construction Environmental Management Plan. Measures to minimise groundwater recharge and flow related impacts relating to these activities and works would include, but not be limited to: • revegetation of disturbed areas • backfilling using excavated material were possible.	GW08
	Construction	Water collected dewatering of excavations would be managed in accordance with the Environment Protection Regulations 2021. These measures would include, but not be limited to: • monitoring of water quality of captured water (e.g., pH, salinity, suspended solids) • approval would be sought from relevant authorities to discharge water • disposal of water at a site that is lawfully able to receive it.	GW09

Groundwater impact pathway	Project phase	Management measures	Number
Infrastructure (tracks and hardstands) and accidental spills of hazardous materials that reduce water quality	Construction	In areas of predicted elevated salinity, groundwater would be tested to determine the appropriate disposal method.	GW10
	Construction, operation, decommissioning	To manage potential impacts to groundwater quality, management measures to be carried out (in accordance with relevant guidelines and procedures) would include, but not be limited to: • a site-specific risk analysis for any hazardous chemicals (batteries, explosives etc.) under relevant guidelines including EPA Victoria 1698: *Liquid storage and handling guidelines* • storage of fuels and chemicals within containment facilities (e.g., self-bunded, above ground in a suitable covered area), outside floodplains or watercourse areas, in accordance with relevant legislative requirements • spill kits for fuel, chemical and oil spills to be maintained on site • chemical handling training for construction personnel • spill response procedure, to be contained within the Construction Environmental Management Plan • rehabilitation of any areas where a spill has occurred.	GW11

9.7.4 Residual effects

An assessment of residual effects and impacts was completed after the development of design measures. The assessment included rating the significance of these effects.

Potential groundwater impacts from the project construction, operation and decommissioning were assessed for each identified groundwater aquifer within the investigation area, based on the findings of the hydrogeological assessment. These are the Quaternary Aquifer, Newer Volcanic Group basalts aquifer and Port Campbell Limestone aquifer, as described in Section 9.6.1. The significance of groundwater impacts was assessed against the impact ratings outlined in Table 9.5.

Table 9.5 **Significant rating criteria for groundwater impacts**

Very low/ negligible	Low	Moderate	High	Very high
Project results in negligible groundwater drawdown. Negligible reduction in the extent of the groundwater resource and/or quality that: • has a negligible impact on the current or future utility of the water resource for third-party users; and/or • results in negligible or temporary adverse effect on aquatic ecosystems.	Project results in minor (highly localised) groundwater drawdown. Minor reduction in the extent of the groundwater resource and/or that: • results in a short-term (temporary) reduction of the current or future utility of the water resource for third-party users; and/or • results in short-term adverse effect on aquatic ecosystems.	Project results in groundwater drawdown in a local area. Reduction in the extent of the groundwater resource and/or that: • results in a medium-term (temporary) reduction of the current or future utility of the water resource for a number of third-party users; and/or • results in medium-term adverse effect on aquatic ecosystems.	Project results in groundwater drawdown that extends into the regional area. Significant reduction in the extent of the groundwater resource and/or that: • results in a long-term reduction of the current or future utility of the water resource for a number of third-party users; and/or • results in long-term adverse effect on aquatic ecosystems.	Project results in groundwater drawdown on a regional scale. Significant reduction in the extent of the groundwater resource and/or that: • results in a permanent reduction of the current or future utility of the water resource for a number of third-party users; and/or • results in permanent adverse effect on aquatic ecosystems.

Quaternary aquifer

Four crossing for access tracks and underground cables would intersect with the mapped Quaternary Alluvium near Back Creek. Additionally, two wind turbines are within mapped Quaternary Alluvium. The key impact pathway for the Quaternary Aquifer would be surface disturbance. Disturbance in the access tracks and cable crossing areas would be minimal and temporary, limited to the localised area and the short construction timeframe for these crossings. If saturated, direct disturbance may need dewatering to enable construction. This in turn may temporarily lower the water table for the duration of construction activities. Effects are unlikely to impact agricultural bores or aquatic GDEs.

Disturbed areas would be rehabilitated after completion of works to the satisfaction of the Glenelg Hopkins Catchment Management Authority. No permanent impacts are anticipated.

Newer Volcanic Group basalts aquifer

Quarry dewatering and disposal of extracted groundwater (drawdown)

The Newer Volcanic Group basalts aquifer would be intersected by the proposed on-site quarry. Groundwater inflow, as well as surface water runoff and rainfall, are proposed to be managed through in-pit sump pumping (i.e., dewatering). Groundwater inflows in the quarry excavation site are expected to be around 77 cubic metres per day during operation, however, groundwater inflows could be higher if hydraulic conductivity is greater than anticipated. The key mitigation measure to avoid impacts of groundwater dewatering was the selection of the quarry location in an area that has few nearby environmental values such as groundwater bores or potential GDEs.

Likely drawdown from the quarry pit dewatering is predicted to extend out to 518 metres from the quarry. This distance represents the point at which the drawdown is predicted to be zero. If hydraulic conductivity is greater than predicted (i.e., high) the drawdown could extend out to 1,080 metres, as a worst-case scenario (Figure 9.7). The closest registered groundwater bore (ID 69405) to the quarry site is about 1,000 metres west of the proposed quarry (Figure 9.7). At this location, negligible drawdown from quarry operations is predicted for the likely or worst case scenario.

Several factors were considered in the assessment of potential impacts to potential aquatic GDEs, including the surface water contribution to the GDEs, seasonal groundwater level variations and other historic landscape changes that have influenced these systems. Surface water modelling suggests that these systems are predominately surface water driven with inundation occurring during winter and spring months (Appendix B – *Hydrology and hydrogeological*). During summer, these systems are dry, which confirms that groundwater does not provide a permanent water source. This conceptualisation is consistent with groundwater level variations at the site which show seasonal highs in winter and groundwater levels which are around 1.5 meters lower in summer. These systems have also been heavily modified since European settlement, and groundwater levels are reported to be higher than pre-European times due to increased recharge as a result of land clearance (Dahlhaus et al., 2002).

The predicted residual effects on aquatic and terrestrial GDEs from quarry pit dewatering are summarised in Table 9.6.

Table 9.6 Residual effects on aquatic and terrestrial GDEs from quarry pit dewatering

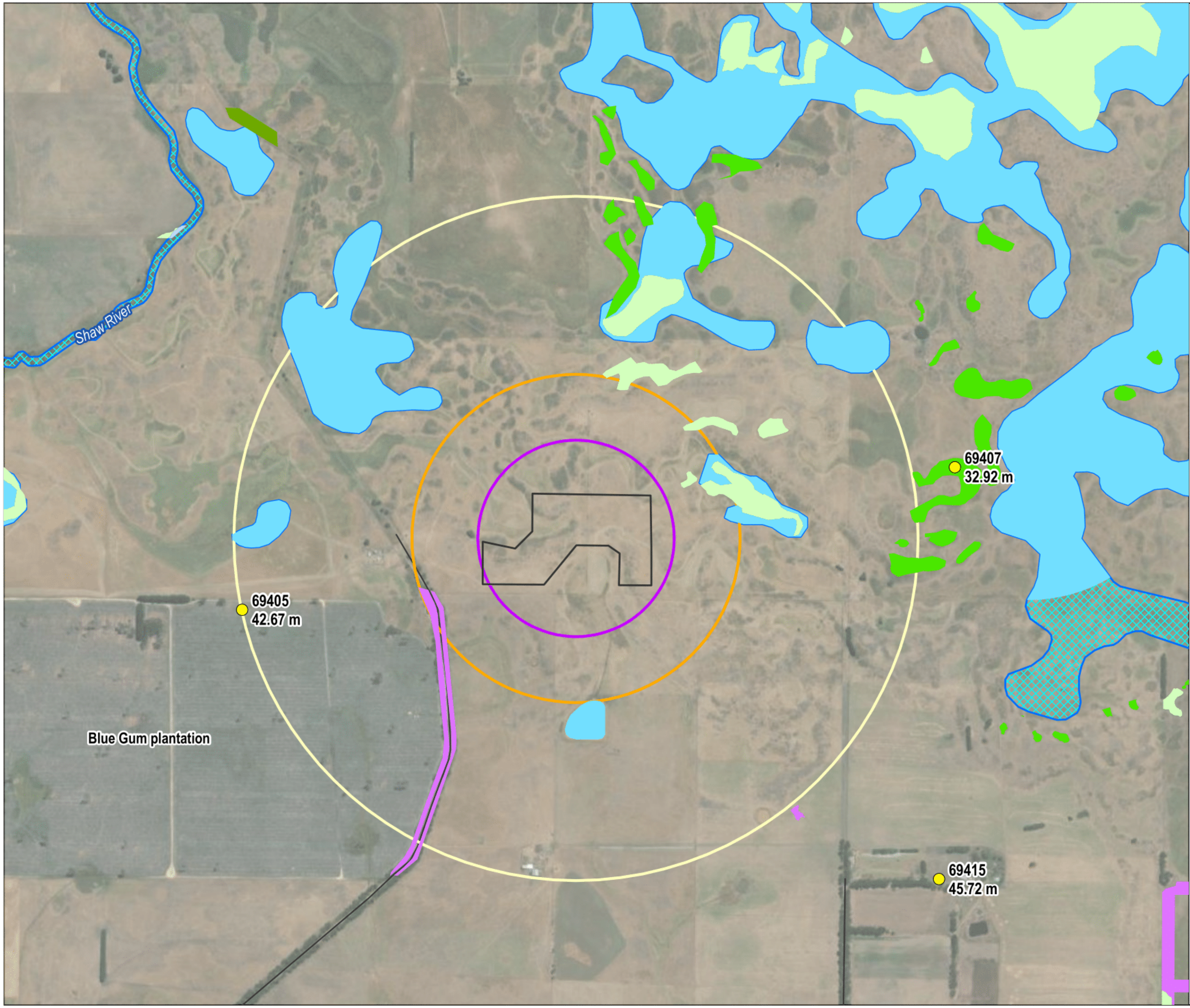
	GDE type	
	Aquatic GDEs	**Terrestrial GDEs**
GDE description	Temporary freshwater marshes and meadows that are predicted to receive some groundwater inflows during winter and spring, although surface water was predicted to be the primary water source.	Potential terrestrial GDEs in proximity to the quarry include the Plains Grassy Wetland vegetation community. An assessment of their dependence (or lack thereof) is provided in Appendix D – *Biodiversity*.
Base case scenario	A small area of one potential aquatic GDE is located on the edge of the 0-metre drawdown contour for the likely groundwater drawdown scenario (Figure 9.7). This area of potential GDE represents approximately 2% of the potential mapped GDEs within the site. The maximum drawdown at this GDE is predicted to be around 2 metres. The recovery of groundwater levels may take up to several decades. Locating the proposed water storage ponds between the quarry and these GDEs would assist mitigating this effect.	The nearest patch occurs about 450 metres northeast from the quarry pit, the edge of the likely groundwater drawdown extent (Figure 9.7). Some reduction of groundwater levels beneath this patch of potential GDE could occur, particularly during winter/spring when groundwater levels are highest.
High hydraulic conductivity scenario	There are five patches of mapped areas of aquatic GDE within the worst-case drawdown extent. Under this worst-case scenario, drawdown may be up to 6 metres at the closest wetland. Some reduction in groundwater inflow (particularly during winter and spring) to these fragments could occur during the operation of the quarry if high hydraulic conductivity is significantly greater than expected. Recovery of groundwater in these areas is predicted to occur over several years. However, as noted above, surface water modelling suggests that these systems are predominately surface water driven with inundation occurring following rainfall events in winter and spring.	Groundwater drawdown is predicted to intersect with six patches of the Plains Grassy Wetland vegetation community and three patches of Stony Knoll Shrubland under this scenario and therefore could indirectly reduce groundwater availability to these communities. Surface water modelling suggests that these systems are predominately surface water driven with inundation occurring following rainfall events in winter and spring. An assessment of their dependence (or lack thereof) is provided in Appendix D – *Biodiversity*.

	GDE type	
	Aquatic GDEs	**Terrestrial GDEs**
Important note	The mapped aquatic GDEs are temporary/ephemeral ecosystems that are known to fill seasonally after periods of rainfall in winter and spring (see Chapter 10 – *Surface water*). This indicates that, although groundwater may form a component of these ephemeral systems, their primary water source is rainfall-fed surface runoff. As such, even under a worst-case scenario, reduced groundwater levels are not predicted to potential GDEs around the proposed quarry site.	Plains Grassy Wetland within the project site typically occurs in depressions away from watercourses that fill seasonally with rainfall. This suggests that although this community may interact with groundwater expressions, it is not their primary water source. Similarly, it is unlikely that Stony Knoll Shrubland depends on groundwater considering the shallow root systems of the plants that make up the community and the likely groundwater levels (and annual fluctuations) around the quarry. The Bureau of Meteorology GDE Atlas includes potential native vegetation as potential terrestrial GDEs. The distribution of native vegetation (some of which may access groundwater) has been refined based on field surveys.

Noting the uncertainties surrounding the hydraulic conductivity, groundwater levels would be monitored at the closest registered groundwater bore (ID 69405) and other nearby bores prior to construction to validate the drawdown predictions (mitigation GW03). If any assumptions underpinning predictions of groundwater drawdown from the quarry change following the additional monitoring, drawdown predictions would be updated and a complete a site-specific risk analysis for neighbouring environmental values would be carried out. The risk analysis would contribute to the Water Management Plan, which would include groundwater level triggers for further management measures, if needed (mitigation GW05). The choice of any subsequent management response would be commensurate with the extent, magnitude and duration of the impact. If groundwater dependence has been confirmed and warrants management intervention, measures that would be considered include:

- partitioning areas within the quarry to reduce the area needing dewatering
- altering the timing and duration of dewatering to maintain groundwater levels (e.g., dewater during wetter months when GDEs are supported by rainfall and surface water and groundwater levels are seasonally higher)
- environmental watering of priority GDEs (subject to assessment of source and receiving water quality)
- re-injection of groundwater to maintain groundwater levels near priority GDEs.

The need for and type of management intervention would rely on monitoring groundwater levels, surface water flow/inundation and ecosystem health, the details of which would be documented in the Water Management Plan. Post-operation, the quarry pit would be converted to a water storage. During this time, the rate of inflow would be controlled by losses from evaporation, water usage and the permeability of the Newer Volcanic Group basalt aquifer. Water quality within the quarry and the onsite storages would be a combination of groundwater and surface water, both of which are anticipated to have similar water quality characteristics (including TDS). Near the quarry, groundwater salinity is expected to be in the order of 1,000 to 3,500 mg/L based on regional salinity mapping available through Visualising Victoria’s Groundwater platform. Wells located closer to the quarry suggest that salinities may be at the lower end of this salinity range (around 1,000 mg/L). When mixed with surface water, lower salinities can be expected. As such, it is likely that groundwater and surface water are well connected within the project site, and mixing of these water sources is unlikely to result in undesired impacts.



LEGEND

- Groundwater wells
- Road
- Aquatic GDE

Ecological vegetation class (EVC)

- Plains Grassland
- Tall Marsh
- Current Wetlands
- Basalt Shrubby Woodland
- Plains Grassy Wetland
- Stony Knoll Shrubland
- Extraction area

Scenario (distance)

- Low K (310m)
- Base case (518m)
- High K (1080m)

SOURCE:
Willatook Wind Farm boundary, quarry buffers, GDEs and boreholes from Wind Prospect.
Roads and watercourses from Vicmap.
Imagery from ArcGIS Online (various capture dates).

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0 0.5 km

SCALE 1:17,000
PAGE SIZE: **A4**
PROJECTION: **GDA 1994 MGA Zone 54**

WIND PROSPECT

WILLATOOK WIND FARM

FIGURE 9.7

Quarry pit drawdown extent and groundwater receptors

WIND PROSPECT

DATE: 11.02.22 PROJECT: 754-MELEN287657 FILE: 287657_02_F035_GIS DOC REFERENCE: 287657_02_FIGS_D.APRX_V01

Other dewatering and disposal of extracted groundwater (drawdown)

During turbine foundation construction, it is important to have a clean excavated foundation base until blinding concrete is poured. This involves a thin layer of concrete to preserve excavation founding material and create a level surface for works. This is typically achieved by pumping water (if present) out using a sump at the base of the excavation. During construction of wind turbine foundations, dewatering (if needed) may temporarily lower the water table before the concrete foundations are laid.

Given the limited extent and duration (i.e., up to two weeks) of dewatering for foundation excavations, measurable impacts to groundwater bore water levels were assessed to be very low. If active pumping is needed, groundwater inflow monitoring would be required as part of the Water Management Plan. After dewatering, the water table is predicted to recover in several weeks or months.

Some temporary reduction in groundwater inflows or groundwater availability to GDEs may occur where turbine foundations are near these GDEs. Any impacts would be highly localised and temporary and are most likely to occur when groundwater levels are higher (closer to the surface) during wetter months, when water is not limited due to the pattern of winter and spring rains.

Dewatering for cable excavations in isolated areas may be needed where groundwater levels are less than 1 metre below the natural surface during winter and early spring. Given this would be limited to isolated areas, and the excavations for the underground cables would normally be open for less than a day or two, impacts to groundwater levels from these works are not anticipated to occur.

Disruption of groundwater recharge and flow

The surface area of wind turbine foundations would be about 27 x 27 metres and hardstands (next to each wind turbine) would be about 50 x 60 metres. To minimise impacts, turbine foundations are shaped to allow rainwater runoff to occur and to re-establish natural recharge to the aquifer next to these built features. Considering the surface area for foundations and hardstands is small, the estimated reduction in groundwater recharge would be highly localised and can be offset by appropriate drainage design.

Given the unconfined nature of the Newer Volcanic Group basalt aquifer, and existing seasonality of groundwater recharge and flow, any impacts to groundwater flow around infrastructure foundations are anticipated to be localised and minor and would only occur when groundwater levels are high. With design buffers of 100 metres around wetlands, and much larger buffers around the Cockatoo Swamp wetland complex, any changes to groundwater flow and recharge caused by infrastructure foundations are unlikely to affect ephemeral wetlands and springs. These buffers would also likely significantly reduce the likelihood of impacts associated with groundwater discharge to watercourses and wetlands.

If cable trench backfill material has a higher hydraulic conductivity than the surrounding undisturbed soils, there is a potential to create a preferential flow path (where groundwater flows faster through the backfill material than in surrounding material). To mitigate this risk, the trench would be backfilled with the excavated material. As such, there would be no change to surface permeability and recharge rates in these areas.

Groundwater contamination from spills

If construction controls and spill prevention and abatement techniques are not properly carried out, accidental spills of hydrocarbons or other chemicals have the potential to result in contamination of the groundwater system, impacting surrounding groundwater users including GDEs and groundwater bores. The impact of an uncontrolled release of hazardous material is predicted to be highly localised near the spill. Measures would be outlined in the Environmental Management Plan to prevent, manage and contain spills. As such, impacts are predicted to be low. Uncontrolled releases are considered unlikely with best-practice construction and operational management approaches in place (outlined in Section 9.7.3).

Disposal of groundwater

There is potential for shallow groundwater to flow into foundations and open trenches, particularly during winter and early spring. Water collected dewatering of excavations would be managed in accordance with the Environment Protection Regulations 2021. These measures would include, but not be limited to monitoring of water quality (e.g., pH, salinity, suspended solids) and seeking the necessary approval to discharge water at a suitable site.

The exposure of potential acid sulfate soils can acidify water and impact groundwater quality and resources. The impact from acid sulfate soils is further discussed in Chapter 10 – *Surface water*.

Port Campbell Limestone aquifer

It is assumed that uniform clay layers identified during exploration drilling at the proposed quarry site would prevent hydrogeological interaction with the Port Campbell Limestone aquifer. Additionally, the base of the quarry pit, proposed at 14 metres, would be well above the Port Campbell Limestone formation. As such, impacts to this aquifer from the quarry site are not anticipated.

Impacts of the project on groundwater drawdown, flows, recharge and contamination are not predicted for this aquifer due to the anticipated lack of connectivity with the Newer Volcanic Group basalt aquifer and the depth to the Port Campbell Limestone aquifer.

9.7.5 Impact assessment summary

A summary of the groundwater impact assessment is provided in Table 9.7, with the full assessment presented in Appendix B – *Hydrology and hydrogeological*.

Table 9.7 **Groundwater impact assessment summary**

Aquifer	Environmental value	Impact pathway	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
Quaternary aquifer	GDEs	Direct disturbance and dewatering leads to lowering of groundwater level.	• Applying construction-free buffers around mapped potential GDEs for all infrastructure excluding crossings [GWD02].	Aquifer is restricted to areas surrounding a drainage line that flows into Back Creek. Four crossings for access tracks and underground cables, and two wind turbines intersect with areas of Quaternary Alluvium. Disturbance and potential impacts on groundwater levels would be highly localised and temporary.	**Very low**
Newer Volcanic Group basalt aquifer	Groundwater bore users GDEs	Quarry excavation and dewatering leads to lowering of groundwater level.	• Consult with relevant landowners about potential impacts to bores would occur prior to commencement of construction (GW02). • Selection of quarry site in an area with few nearby environmental values (i.e., groundwater bores and GDEs) [GWD01]. • Conduct further groundwater monitoring within and around the quarry excavation to refine hydraulic conductivity and groundwater drawdown extent (GW03). • Conduct a site-specific risk analysis for the quarry where excavation dewatering rates exceed 77 cubic metres per day (GW04). • Detail and carry out dewatering procedures (including discharge location and quality of water, pollution control and management of sediment) (GW05). • Conduct groundwater inflow monitoring (GW05).	Dewatering is likely to be sporadic and largely restricted to the wetter winter months. The nearest groundwater bore to the quarry is about 1,000 metres away (this aligns with the 0-metre drawdown contour for the high hydraulic conductivity scenario). As such, impacts to water levels in groundwater bores from quarry dewatering and drawdown are not anticipated to occur. The nearest potential GDE (ephemeral wetlands and Plains Grassy Wetland vegetation community) are about 450 metres from the quarry site. This is close to the outer extent of predicted groundwater drawdown. No material impact is predicted to these GDEs based on a negligible reduction in groundwater levels predicted.	**Low**

Aquifer	Environmental value	Impact pathway	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
	Groundwater bore users GDEs	Foundation excavations leads to lowering of groundwater level.	• Conduct further groundwater monitoring and mapping using exiting bores to establish local groundwater levels and groundwater quality (GW07). • Detail and carry out dewatering procedures (including discharge location and quality of water, pollution control and management of sediment) (GW05).	Water levels in existing bores may be impacted if dewatering of excavations is required, mainly during times of high groundwater levels in winter and spring. This impact is considered to be temporary given the short duration of turbine excavation (i.e., up to two weeks). Measurable impacts to groundwater bore water levels are not anticipated. After foundation excavations are filled groundwater levels are expected to recover. As such, any impacts to wetlands would be temporary.	**Very low**
	Groundwater bore users GDEs	Foundation excavations intersects shallow water table and alters groundwater flow and recharge.	• Turbine foundations would be shaped to allow rainwater runoff and to re-establish natural recharge [GWD03].	Any impacts to groundwater flow around infrastructure foundations are anticipated to be localised and minor, and during times when groundwater levels are high (winter and spring). Any reduction in groundwater recharge would be localised and would be mitigated by appropriate drainage design. Any changes to groundwater flow and recharge are unlikely to affect bores or ephemeral wetlands and springs.	**Very low**
	Groundwater bore users GDEs	Accidental spills of hazardous materials reduce water quality.	• Store fuels and chemicals within containment facilities (e.g., self-bunded, above ground in a suitable covered area) (GW11). • Maintain spill kits for fuel, chemical and oil spills on site (GW11). • Train construction personnel in appropriate chemical handling (GW11). • Include a spill response procedure outlined within the Construction Environmental Management Plan (GW11). • Rehabilitation of any areas where a spill has occurred (GW11).	If accidentally released, fuels and chemicals stored within the project site could result in localised contamination of the groundwater system.	**Low**

Aquifer	Environmental value	Impact pathway	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
Port Campbell Limestone aquifer	Groundwater bore users	No linkage.	N/A	Due to the shallow nature of the proposed works, the limited connectivity with the Newer Volcanic Group basalt aquifer and the depth to the Port Campbell Limestone aquifer, no impact is anticipated.	N/A

9.8 Conclusions

Construction and operation of the project has the potential to impact groundwater in near-surface Newer Volcanic Group basalts and supporting environmental values through distinct and localised impact pathways, which could result in localised lowering of the water table, altered groundwater recharge and flows, and reduced water quality.

Possible impact pathways include localised lowering of the water table from groundwater dewatering for the operation of the on-site quarry and, to a lesser extent, wind turbine foundations. They also include altered groundwater recharge and flows from infrastructure foundations and hardstands, and reduced water quality from accidental spills of hazardous chemicals.

To minimise potential impacts to groundwater the on-site quarry is proposed in an area with few agricultural bores and GDEs. Groundwater inflows into the quarry pit were predicted to result in groundwater drawdown, reducing groundwater levels out to about 500 metres from the quarry. This is not predicted to impact the closest registered groundwater bore (located about 1,000 metres to the west), or potential terrestrial and aquatic GDEs about 450 metres north-east of the proposed quarry. Further groundwater investigations prior to construction are proposed to improve confidence of groundwater drawdown predictions, with quarry operation monitoring also proposed to ensure groundwater drawdown does not affect surrounding environmental values. The monitoring plan and groundwater level triggers for further management measures, if needed, would be included in a construction phase Water Management Plan.

Management measures have been proposed for the construction, operational and decommissioning phases of the project to further manage potential groundwater impacts. With these measures in place, the impacts to groundwater users and groundwater quality are considered to be very low to low.