Hexham Wind Farm

Surface Water and Groundwater Impact Assessment

Hexham Wind Farm Pty Ltd

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27 August 2025

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Dear Rory,

Surface Water and Groundwater Impact Assessment

Please see the attached Surface Water and Groundwater Impact Assessment for the Hexham Wind Farm. This report is intended to inform the Hexham Wind Farm Environment Effects Statement.

This version of the report (V05) has been prepared in response to comments from the Technical Reference Group (TRG). The main updates include:

- **Additional cumulative impact assessment**
- **Groundwater impact assessment updated s responding to specific TRG comments**

If you have any queries, please don't hesitate to contact me.

Yours sincerely

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WATER TECHNOLOGY PTY LTD

EXECUTIVE SUMMARY

Hexham Wind Farm Pty Ltd commissioned Water Technology to conduct surface water and groundwater investigations to inform an assessment of the potential impacts to surface water and groundwater values as part of the Environment Effects Statement process for the Hexham Wind Farm, located in southwestern Victoria. The proposed wind farm consists of 106 wind turbines and supporting ancillary infrastructure including an on-site quarry, which would provide materials to support construction activities.

The proposed project area is in southwest Victoria, approximately 37 kilometres north of Warrnambool and extends across both sides of the Woolsthorpe–Hexham Road. The project area is spread across the Hopkins River catchment, within the Glenelg Hopkins Catchment Management Authority (GHCMA) management area. Much of the site is low lying, with a number of waterways of varying size intersecting the site. The Hopkins River and Mustons Creek are the largest waterways in the site, with tributaries of Mustons Creek and of the Merri River also flowing through the site. Land use within the project area and upstream catchments is a mixture of private and public land that is largely used for agriculture, predominantly sheep and cattle grazing with some cereal and fodder crops.

It is likely that surface water bodies may be gaining and losing groundwater in different reaches and that this will change according to the season. The water table at the site is located within the Upper-Tertiary/Quaternary Basalts, the Upper-Tertiary Aquifer and the Quaternary Alluvium. Variability in the location of these aquifers and their aquifer properties leads to a complex relationship between surface water and groundwater.

A baseline understanding of the existing environment was determined through a review of the existing surface and groundwater information and a site visit, including a review of the available climatic, topographic, groundwater and surface water data. This enabled a characterisation of the existing surface water and groundwater systems though detailed investigation and modelling.

Surface and groundwater investigations were undertaken and included:

- Surface water
  - Flood modelling of the Hopkins River, Mustons Creek and tributaries and all areas within the Hexham Wind Farm project area.
  - An assessment of 1% and 10% AEP flood depth at the proposed turbine locations.
  - Calculation of 1% and 10% AEP flow rates at each of the proposed waterway crossing locations.
  - Water balance modelling at the temporary on-site quarry.
- Groundwater
  - Characterisation of the site geology.
  - Preparation of a hydrogeological conceptual model and groundwater level maps.
  - Consideration of groundwater quality.
  - Estimation of inflow rates and drawdown around the temporary on-site quarry.

Characterisation of the existing site conditions enabled identification of potential impact pathways. The most relevant surface and groundwater pathways were identified as:

- Surface Water
  - Hydrological changes to surface water flows due to:
    - Project infrastructure with the introduction of impermeable surfaces – turbines and hardstands.
    - Physical disturbance - waterway crossings for tracks and cables.

- Water quality reductions (e.g., turbidity, dissolved oxygen) due to:
  - Surface water runoff (erosion) and sedimentation due to stockpiles and earthworks for infrastructure, tracks and hardstands.
  - Damage to stream beds and banks leading to surface water runoff (erosion) and sedimentation - waterway crossings for tracks and cables.
  - Disposal of poor quality water into waterways or waterbodies - collected during construction of turbines and hardstands.
  - Accidental spills of hazardous waste during construction and operation.
- Groundwater
  - Dewatering of groundwater during construction activities 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 waterways 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.

An assessment and quantification of the potential impact pathways assisted in determination of proposed mitigation measures and management controls which may be used to reduce impacts. This was followed by an assessment of residual impacts.

Construction and operation of the project has the potential to impact surface water systems and supporting environmental values through distinct impact pathways, which may result in lowering of the watercourse crossings, reduced water quality and altered flows.

Flood behaviour within the project catchments was used to inform the siting of infrastructure to avoid areas of potential flooding. Other design mitigation included designing the project with buffers around all mapped wetlands, and minimisation of watercourse crossings through siting of access tracks. Assuming detailed designs have been completed in accordance with best practice guidelines and in consultation with relevant authorities the residual effects of watercourse crossings and to a lesser extent reduced water quality from construction works were assessed to be localised and temporary.

Construction and operation of the project has the potential to impact groundwater and supporting environmental values in the water table aquifer. At the site this includes the Upper-Tertiary/Quaternary Basalts, the Upper-Tertiary Aquifer and the Quaternary Alluvium. Potential impacts are through distinct and localised impact pathways, which may result in localised lowering of the water table, altered groundwater recharge and flows, altered groundwater discharge, and reduced water quality. To minimise the potential for the project to impact local GDEs, the design has incorporated a minimum 100 m buffer from potential aquatic ecosystems and 25 m buffer from potential terrestrial systems when placing turbine foundations. The quarry site has been located away from sensitive receptors, including groundwater bores, mapped potential GDEs and DEECA wetlands.

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

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GLOSSARY AND ABBREVIATIONS

Term	Definition	Abbreviation
Action/Activity	Part of the project, such as installing infrastructure in a certain manner, that may have an impact on receptors	
Acid Sulfate Soils	Acid sulfate soils are natural sediments that contain iron sulphides. However, if the soils are drained, excavated or exposed to air by a lowering of the water table, the sulphides react with oxygen to form sulfuric acid	ASS
Assess	To consider an action and the likely effects of that action	-
Annual Exceedance Probability	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.	AEP
Australian Height Datum	The datum that sets mean sea level as zero elevation.	AHD
Average Recurrence Interval	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration.	ARI
Beneficial Uses	Specific environmental values/receptors/assets protected by legislation. These may include environmental matters such as natural resources or ecosystems. SEPP (Waters) refers to Beneficial Uses which has been updated to Environmental Values in the Environmental Reference Standard.	-
Department of Energy, Environment and Climate Action	Department of Energy, Environment and Climate Action (Formerly DELWP)	DEECA
Design Flood	A significant event to be considered in the design process; various works within the floodplain may have different design event requirements. E.g., some roads may be designed to be overtopped in the 1 in 10 year or 10% AEP flood event.	-
Depth to Water	Depth to groundwater from ground level	DTW
Digital Elevation Mode	A bare-earth elevation model of the earth's surface, with features such as vegetation, bridges and roads filtered out	DEM
Digital Terrain Model	A DTM is a mathematical representation of the ground surface. A DTM augments a DEM by including linear features of the bare-earth terrain	DTM
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.	-
Effect	The outcome of an event or a circumstance that is likely to occur. It may be caused directly or indirectly by an action. It can also be termed a consequence. The significance of the effect may vary.	-
Environment Effects Statement	Statement required under the Environment Effects Act (1978)	EES
Environmental Management Framework	The framework setting the limits and objectives for the scope of the EES prepared by HWF	EMF
Environmental Value	Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits	-

Term	Definition	Abbreviation
Environment Reference Standard	Environment Reference Standard (ERS) incorporated State Environment Protection Policy (Waters) (SEPP (Waters)) in 2021. ERS includes environmental values, indicators and objectives	ERS
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.	-
Flood Frequency Analysis	A technique to predict flow values corresponding to specific return periods or probabilities along a watercourse or flow path	FFA
Foundation	A 12.5 m radius, 3.5 m deep excavation filled with impervious material used as a foundation for a turbine tower. While groundwater may be dewatered from the excavation, these are not classed as bores.	Foundation
Glenelg Hopkins Catchment Management Authority	The Glenelg Hopkins Catchment Management Authority	GHCMA
Groundwater dependent ecosystems	Flora and fauna relying on a groundwater source to survive	GDEs
Groundwater flow systems	Local, intermediate and regional groundwater flow systems described by GHCMA and documented in Dalhaus et. al 2002	GFS
Hexham Turbine	Unique turbine identification number	WTG
Hexham Wind Farm Pty Ltd	Hexham Wind Farm Pty Ltd, the proponent	HWF
Hydrograph	A graph that shows how discharge changes with time at any particular location.	-
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs.	-
Impact	An adverse effect	-
Intensity Frequency Duration	An intensity-duration-frequency curve is a mathematical function that relates the rainfall intensity with its duration and frequency of occurrence	IFD
Light Detection and Ranging	A remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth	LiDAR
Matter of national environmental significance	Listed threatened species or ecological community	MNES
metres Australian Height Datum	Elevation of point relative to National datum	mAHD
metres below natural surface	Depth the natural ground level	mBNS
Milligram per litre, Total Dissolved Solids	The measure of the salinity of water, by the conversion of the measured electrical conductivity of the water,	mg/L (TDS)
Moyne Shire Council	Moyne Shire Council	Shire
Peak Flow	The maximum discharge occurring during a flood event.	-
Potential Acid Sulfate Soils	ASS which has not been oxidised by exposure to air	PASS
Receptors	Entities that may be impacted by a water affecting activity, such as GDEs or people. Also termed values or assets.	-

Term	Definition	Abbreviation
Reduced water level	The water level reported to a common datum; in this case m AHD	RWL
Risk	A description of the effects of an action	-
Regional Flood Frequency Estimation	Methods used to estimate design floods in ungauged and poorly gauged catchments. It is a data-based empirical procedure which attempts to compensate for the lack of temporal data at a given location by spatial data	RFFE
Rain on Grid	Method to model direct rainfall on an area using hydraulic model software and rainfall data.	RoG
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.	-
Salinity Management Overlay	Areas mapped by the CCMA as land requiring salinity management for infrastructure and farming	SMO
Significance	The relevance of an effect on the values held by a stakeholder. Significant matters are usually protected by legislation or raised by stakeholders during consultation.	-
Southern Rural Water	Southern Rural Water	SRW
Stakeholders	Entities potentially affected by the proposed activities, represented by the GHCMA, Shire, DEECA, SRW groups	Stakeholders
State Environment Protection Policy (Waters) 2018	Legislation governing principles of environment protection, and guidance on the protected values of groundwater and inland waters	SEPP (Waters)
Static/standing water level	The natural water table water level in a bore, measure as metres below natural surface	SWL
State observation bore network	Bores used to monitor groundwater data across Victoria	SOBN

1 INTRODUCTION

1.1 Purpose and scope

Hexham Wind Farm Pty Ltd (HWF, the proponent) is developing the proposed Hexham Wind Farm (the project) in Moyne Shire, south-western Victoria. The purpose of this report is to provide an assessment of likely effects to surface water and groundwater as a result of the proposed project to support the project's Environment Effects Statement (EES).

The scope of the report includes:

- Characterisation of the existing site conditions and available background data.
- Identification of potential impact pathways.
- Assessment and quantification of the potential impact pathways.
- Proposal of mitigation measures and management controls which may be used to reduce impacts.
- Assessment of residual impacts.

This report considers planned activities associated with the construction, operation and decommissioning of the development concept and is intended to be used to both inform the approval and future design process. Early stages of the assessment informed the planning and the infrastructure layout to avoid and minimise potential impacts to the environment and community.

1.2 Overview of the study area

The proposed project area is located in southwest Victoria near the township of Hexham approximately 37 kilometres north of Warrnambool and extends across both sides of the Woolsthorpe–Hexham Road. The project is spread across the Hopkins River catchment, within the Glenelg Hopkins Catchment Management Authority (GHCMA) management area. Much of the site is low lying, with a number of waterways of varying size intersecting the site. The Hopkins River and Mustons Creek are the largest waterways in the site, with tributaries of Mustons Creek and of the Merri River also flowing through the site. Land use within the project area and upstream catchments is a mixture of private and public land that is largely used for agriculture, predominantly sheep and cattle grazing with some cereal and fodder crops.

The project is located in the south of the Western Volcanic Plain. This volcanic region is part of a broad basaltic lava province active over the past six million years and referred to as the Newer Volcanic Province, a major geological unit of southern Australia.

The surface geology within the project area predominantly consists of the Newer Volcanic Group basalt flows. The depth to groundwater within the Newer Volcanic Group basalts varies both spatially and seasonally, influenced by rainfall and longer-term climatic conditions. In general, groundwater is shallow across the project area, with large areas where groundwater is expected to be within 5 metres of ground level, and smaller areas with depths of 5 to 20 metres. Localised areas of shallow groundwater (less than 3 metres below ground level) are likely to occur, particularly in topographic lows.

Detailed context on the existing environment is provided in Section 6; however, the key issues relevant to water are presented in Section 2.1. The likely processes in the study area affecting these values are the focus of this study.

2 EES SCOPING REQUIREMENTS

2.1 EES evaluation objectives

The scoping requirements for the EES determined by the Minister for Planning set out the specific environmental matters to be investigated and documented, which informs the scope of the EES technical studies. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project.

The following evaluation objective is relevant to the surface water assessment:

- *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.*

2.2 EES scoping requirements

The aspects from the scoping requirements relevant to surface water and groundwater evaluation objective/s are shown in Table 2-1, as well as the location where these items have been addressed in this report.

Table 2-1 Scoping requirements relevant to surface water and groundwater

Aspect	Scoping requirement	Section addressed
Key issues	Potential for the project to have a significant effect on hydrology and affect existing sedimentation and erosion processes leading to land and aquatic habitat degradation.	Section 7
	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.	Surface water and groundwater related receptors are outlined in Section 6.2.5 and Section 6.3.3.7 respectively Construction and operation related impacts are outlined in Section 7
	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.	Receiving wetlands are outlined in Section 6.2.4.4 Residual effects for wetlands are outlined in Section 8.1.4.4
Existing environment	Characterise the groundwater (including depth quality and availability to licence/ use) and surface water environments and drainage features in the project area.	The existing groundwater environment is described in Section 6.3 The existing surface water environment in described in Section 6.2

Aspect	Scoping requirement	Section addressed
	Characterise the wetland systems in and around the project site and the type, distribution and condition of wetlands that could be impacted by the project, having regard to terrestrial and aquatic habitat and habitat corridors or linkages.	Section 6.2.4.4
	Characterise soil types and structures in the study area and identify the potential location of acid sulfate soils, including hydrological requirements and their acceptable limits for change.	Addressed in the Hexham, Wind Farm Soil and Landform Assessment (WSP, 2025)
Assessment of likely effects	Assess the potential effects of the project on surface water and groundwater environments and beneficial uses, including on permanent and ephemeral wetland systems (both on-site and adjacent to the proposal), and surface water and groundwater flow and quality.	Section 8
	Identify and assess potential effects of the project on soil stability, erosion and the exposure and disposal of any waste or hazardous soils.	Section 8
Mitigation measures	Identify proposed measures to mitigate any potential effects, including any relevant design features or preventative techniques to be employed during construction.	Section 8.1.2 and Section 8.2.1
Performance criteria	Describe proposed measures to manage and monitor effects on catchment values and identify likely residual effects and identify if further management is required.	Section 8.1.3
	Describe contingency measures for responding to unexpected impacts on catchment values and hydrology, including resulting from disturbed acid sulfate soils.	Section 8.1.3 and the Hexham, Wind Farm Soil and Landform Assessment (WSP, 2025)

3 PROJECT DESCRIPTION

3.1 Project location

Hexham Wind Farm Pty Ltd (the proponent) is developing the proposed Hexham Wind Farm (the project) in Moyne Shire, south-western Victoria. The project extends across approximately 16,000 hectares of private and public land located approximately 15 kilometres west of Mortlake and approximately 15 kilometres north-east of Woolsthorpe. The closest townships are Hexham, Caramut and Ellerslie, located approximately 3 kilometres north-east, 4 kilometres north-west and 3 kilometres south-west, respectively.

The road network that borders and runs through the project area includes the Hamilton Highway to the north, Woolsthorpe-Hexham Road and Hexham-Ballangeich Road to the east, Warrnambool-Caramut Road to the west and Gordons Lane to the south.

The main land use within the project site is agricultural (predominantly cattle and sheep grazing, along with some cropping). Much of the area has been cleared of native vegetation with remnant vegetation largely restricted to roadside reserves and along watercourses, with small, isolated areas on private land.

3.2 Project description

The project will harness strong and reliable winds to generate renewable energy through the construction and operation of up to 106 wind turbines generators and would operate for a period of at least 25 years following a two-year construction period. The wind farm is proposed to have a capacity of around 721 MW, which would generate approximately 2,559 gigawatt hours (GWh) of renewable electricity each year. Electricity produced by the project would be fed through underground and overhead cables to a new on-site terminal station, where it would be exported to the national electricity network via the Moorabool to Heywood 500 kilovolt transmission line.

Around 151 kilometres of new access tracks, including upgrades to around 16.7 kilometres of existing access tracks within the project site, would be required to provide for construction and maintenance access from the public road network to each wind turbine and supporting infrastructure. These access tracks can also be used by emergency vehicles and by landowners for their farming operations.

Other project infrastructure would include:

- A 200 MW battery energy storage system (BESS).
- An operations and maintenance (O&M) facility, consisting of site offices and amenities.
- Up to five meteorological masts, to be in place for the life of the project.
- A main temporary construction compound, consisting of office facilities, amenities and car parking. Four additional temporary construction compounds are also planned.
- Up to 26 temporary staging areas.

A temporary on-site quarry will also be developed for the purposes of providing aggregate materials for access tracks and hardstand areas, and to minimise traffic movements on local roads during construction.

Figure 3-1 shows the proposed project layout.

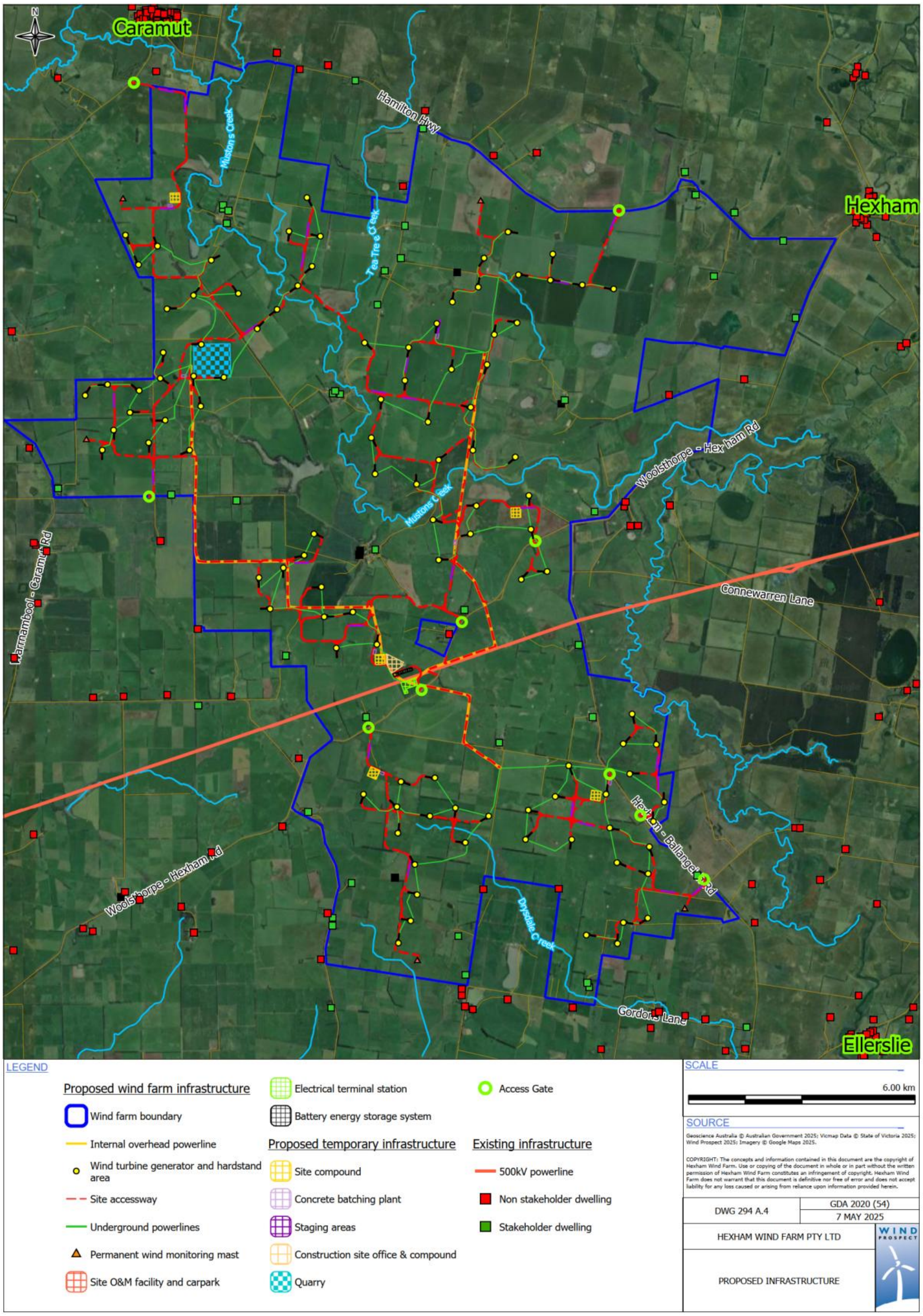

Figure 3-1 Project layout

3.3 Key construction and operation components

The project consists of the following key components:

- Wind turbines:
  - Up to 106 with a maximum tip height of 260 metres, maximum rotor diameter up to 190 metres and minimum tip height of 40 metres.
  - Maximum tower base width of between 5 and 6 metres
  - Blade length of up to 93 metres.
- Hardstands:
  - Each wind turbine would have an adjacent hardstand area of around 6,500 square metres, which equates to 70 hectares for all project wind turbines.
- Underground cables:
  - Approximately 119 kilometres of 33 kV electricity cable laid in approximately 85 kilometres of trenches about 1 metre below the ground. The work area width for the excavator to operate and for stockpiling of soil would be about 8 metres wide for all trenches.
- Terminal station:
  - On-site terminal station approximately 7.3 hectares in size.
- Operations and maintenance facility:
  - An operations and maintenance facility would be located adjacent to the on-site terminal station and provide office, storage, and maintenance facilities.
  - Nominally 90 metres by 200 metres.
- Site access tracks:
  - Approximately 134.6 kilometres of new internal access track and upgrades to approximately 16.7 kilometres of existing access track (i.e., a total of around 151.3 kilometres of access tracks). The final access tracks would be 9 metres wide (inclusive of drainage, where required) and a maximum 120 metre turning radius. The construction footprint of access tracks would be around 20 metres wide.
  - Eleven site access points are proposed from two arterial and five local council roads.
- Battery energy storage system (BESS):
  - An on-site battery energy storage facility with a is proposed to be located adjacent to the on-site terminal station.
  - The BESS would consist of a series of 20-foot containerised batteries with transformers, high voltage AC (HVAC) coolers and other electrical plant. The BESS would be sited on a hardstand area of up to 3 hectares (nominally 413 metres x 67 metres.
- Temporary components:
  - A quarry supplying aggregate material for the construction of hardstands and access tracks. The work authority area is 52.3 hectares with an approximate extraction area of 21.5 hectares, a material stockpile area of approximately 8.6 hectares and an area of approximately 0.5 hectares for amenities and light vehicle parking. The remaining area will be used for stockpiling overburden and for groundwater management infrastructure.

- A main temporary construction compound would be located within the project site and include office facilities, amenities, and car parking (8 hectares). Four additional temporary construction compounds are also planned (200 x 200m).
- Seven concrete batching plants would be established to supply concrete for the wind turbine foundations, the on-site terminal station, and the BESS (around 50m x 100m each).

3.4 Project life and decommissioning

A minimum 25-year operating life is expected, following a period of up to 3 years of pre-development and construction activities. Pre-development would include detailed design and early works, where permitted.

Within 12 months of wind turbines permanently ceasing to generate electricity, the wind farm would be decommissioned. This would include removing all above ground equipment, restoration of all areas associated with the project, unless otherwise useful to the ongoing management of the land, and post-decommissioning revegetation with pasture or crop (in consultation with and as agreed with the landowner).

The landowner at the location of the quarry has agreed to the rehabilitated land remaining as a void, with a small farm dam at the low point. All plant and infrastructure will be removed, and batters and hardstand areas ripped, soiled and returned to pasture. Rehabilitation batters will be at least 1V:4H to quarry floor level, which will be backfilled to above the recovered groundwater level. The construction and rehabilitation stages of the quarry are assessed in Section 6.4.

4 LEGISLATION, POLICY, GUIDELINES AND CRITERIA

The key legislation, regulations and guidelines that apply to the surface water impact assessment for the project are summarised in Table 4-1.

Table 4-1 Key legislation and policy

Legislation, policy, guidelines	Relevance to technical discipline
Commonwealth	
Australian and New Zealand Governments (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality	The Australian and New Zealand Guidelines for Fresh and Marine Water Quality were prepared as part of Australia's National Water Quality Management Strategy and contain guidelines for water and sediment chemical and physical parameters, and biological indicators to assess water quality. Where indicators and objectives are not prescribed in the ERS, trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems (lowland rivers) were used in the assessment of water quality.
Australian Rainfall and Runoff (2019)	The recommendations set out in ARR2019 are used as the base methodology for hydrology and hydraulics technical assessment.
Victorian State	
Catchment and Land Protection Act 1994 (Vic)	Provides a framework for the integrated management and protection of catchments. Considers adverse groundwater effects due to extraction on receptors. Guidance for works on waterways
Environmental Effects Act 1978 (Vic)	Provides a framework for investigation under a range of outcomes. Requires methods for mitigating adverse environmental effects and risks. The Minister will assess this Project against the Act.
Environment Protection Act 2017	Established the legislative framework for protecting the environment in Victoria. Regulations regarding protection of environmental values and of the environment ensuring the project demonstrates its implementing measures so far as 'reasonably practicable' to meet the general environmental duty.
EPA Victoria (2020) Publication 1834 Civil construction, building and demolition guide	Outlines controls for civil construction and earthworks to manage risks and obligations under the general environmental duty in relation to air, noise, land and water. This includes controls regarding the management of stormwater flows, stockpiles, works within waterways, and storage and handling of chemicals. Measures for the management of surface water developed in accordance with controls contained in EPA Victoria Publication 1834.
EPA Victoria (2020) Publication 1893 Erosion, sediment and dust: treatment train	Outlines measures to eliminate or reduce the risk of harm from erosion, sediment and dust using a treatment train approach. Measures to limit erosion and sedimentation of surface water considered the treatment train and an approach have been proposed.
EPA Victoria (2020) Publication 1894 Managing soil disturbance	Provides information about managing soil disturbance and how to eliminate or reduce the risk of harm from erosion, sediment and dust. Measures to reduce the risk of harm from erosion, sediment and dust from ground disturbance have been proposed.
EPA Victoria (2020) Publication 1896 Working within or adjacent to waterways	Provides information about how to eliminate or reduce the risk of harm from erosion, sediment and dust when working within or adjacent to waterways. Measures for conducting works within or adjacent to waterways have been proposed.

Legislation, policy, guidelines	Relevance to technical discipline
EPA Victoria Publication 1895: Managing stockpiles	Provides information about how to eliminate or reduce the risk of harm from stockpile sediment.
Environmental Reference Standard (ERS) 26 May 2021	The State Environment Protection Policy *(Waters) (SEPP (Waters))* operating under the *Environment Protection Act 1970* was replaced by the EP Act 2017, its regulations and the *Environment Reference Standard* (ERS), or through new guidance published by EPA. ERS includes environmental values, indicators and objectives.
Flora and Fauna Guarantee Act 1988	Protect threatened species. Examine potential effects on biodiversity and ecological values. Enforced by the Office of the Conservation Regulation, overseeing DELWPs regulatory functions in relation to timber-harvesting regulation, public land use, biodiversity and fire prevention.
Environment Protection and Biodiversity Conservation Act 1999	Significant species on site to be protected by DEECA under the bilateral agreement.
Water Act 1989	Provides the legal framework for managing Victoria's water resources. Authorises Catchment Management Authorities (CMAs) various powers for the control, management and authorisation of works and activities in or over designated waterways in the CMA's waterway management district.
Extractive Industries Development Act 1995	Requires the extractive industry to meet safe operating standards and ensures rehabilitation of quarried land to an appropriate, stable landform. Enables the Earth Resources Regulator to oversee the operation of the quarry.
Water (Irrigation Farm Dams) Act 2002	Water Act 1989 Guidelines for Quarries and Mines 2004. Regulates the management of farm dams (the decommissioned quarry pit)
Catchment Management Authorities (CMAs)	
Glenelg Hopkins Catchment Management Authority	The Glenelg Hopkins Catchment Management Authority has developed the following relevant strategies: ■ '2021-27 Glenelg Hopkins Regional Catchment Strategy'. Each CMA prepares the RCS on behalf of their region. It's the overarching strategy for all involved in managing land, water and biodiversity. Works would be undertaken in accordance with Glenelg Hopkins CMA Works on a Waterway permit licence requirements. ■ 'Glenelg Hopkins Waterway Strategy 2014-2022', which provides a single planning document for river, estuary and wetland management in the region. ■ 'Glenelg Hopkins Regional Floodplain Management Strategy 2017', which seeks to improve management and reduce flood risks across the region.

Southern Rural Water (as the delegated authority under the Water Act 1989) confirmed that an approval to Take or Use groundwater would not be required for dewatering where groundwater will not be intentionally encountered (A. Ramsay pers. comm. 10/7/19). Permits and any associated investigations will be required if groundwater is targeted as a water supply. Since the proposed quarry will intercept groundwater levels, the proponent will apply for a Take and Use Licence to dewater the quarry, should water be used external to the quarry site.

Additionally, since upstream surface water runoff will be diverted around the quarry works authority area, surface water Take and Use licensing is not required.

4.1 Surface water and groundwater assessment criteria

The guidelines and standards against which the project is being assessed are outlined in Section 4. They focus on ensuring the development does not cause a change to water quantity or quality which will adversely impact areas external to the project area. This includes ensuring the project construction, operation and or decommissioning does not:

- Cause a reduction in water quality i.e. decreased water quality in waterways and decreased groundwater quality.
- Cause a decrease in water quantity i.e. decreased water availability for native vegetation/dams and groundwater dependent ecosystems.
- Cause an increase in water quantity i.e. increased inundation depth in cropped paddocks, roads, houses, sheds etc.

The major driving guidelines and standards for this work include:

- Commonwealth Government
  - Australian Rainfall and Runoff (2019)
- Victorian State Government
  - Water Act 1989 (Vic)
  - Environment Reference Standard (2021)

4.2 Ecology

The Environment Protection and Biodiversity Conservation Act (1999) enables the Australian Government to legislate environment and heritage protection and biodiversity conservation. It refers responsibility to the states for matters that are not of national environmental significance. The project proposal was viewed as a controlled action under the EPBC Act (1999) and hence requires investigation and approval under the Act. The relevant provisions under the Act are listed threatened species and ecological communities which are Matters of National Environmental Significance (MNES). The findings from this report have informed the assessment of MNES by Nature Advisory.

4.3 Water quality

4.3.1 Overview

From 1 July 2021, the Environment Protection Act 2017 (EP Act 2017) replaced the Environment Protection Act 1970. Much of the State Environment Protection Policy (Waters) (SEPP (Waters)) operating under the Environment Protection Act 1970 was replaced by the EP Act 2017, its regulations and the Environment Reference Standard (ERS), or through new guidance published by EPA.

The ERS incorporated State Environment Protection Policy (Waters) (SEPP (Waters)) in 2021. The ERS sets a statutory framework for the protection of uses and values of Victoria's fresh and marine waters. The ERS (Water) aims to ensure that catchments, rivers and coasts are managed in an integrated manner so that actions in the catchment do not have detrimental impacts on water quality in fresh and marine environments. To achieve this, ERS identifies protected environmental values and sets out a series of environmental water quality objectives and indicators to ensure the environmental values of waters are protected. The ERS refers to environmental values, whereas SEPP (Waters) refers to beneficial uses.

4.3.2 Water quality objectives

As required by the Environment Protection Act 2017, the ERS 2021 outlines environmental values of the environment that the community wishes to protect. Environmental values are defined as a use of the environment or any element or segment 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 or of the emission of noise; or
- Is declared in State environment protection policy to be an environmental value.

Environmental quality indicators and objectives for rivers and streams (Water Quality Objectives or WQOs) have been outlined in the ERS 2021 for defined segments of landscapes/catchments to protect these environmental values (Victorian Government 2021). The regionalisation of environmental WQOs for different landscape segments accounts for natural variations due to processes related to soils, topography, meteorology and vegetation.

The surface water environments relevant to the project area fall within the Murray and Western Plains segment which falls under 'slightly to moderately modified' resource plan areas. The Murray and Western Plains segment comprises river and stream reach of lowlands (which are generally below 200 m in altitude) including the Hopkins basin. The water quality objectives for the Hopkins basin are set out in Table 4-2. Note that in the absence of specific indicators/objectives not prescribed in the ERS, default ANZECC 2000/ANZG 2018 trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed freshwater ecosystems can be used.

Table 4-2 Environmental water quality objectives for lowlands of Glenelg, Hopkins, Portland and Corangamite and Millicent Coast basins (Victorian Government Gazette 2021)

Parameter	Environmental Quality Indicator		
	25th percentile	75th percentile	Maximum
Total Phosphorus (µg/L)	-	≤55	-
Total Nitrogen (µg/L)	-	≤1000	-
Dissolved oxygen (percent saturation)	≥65	-	130
Turbidity (NTU)	-	≤20	-
Electrical Conductivity (EC) (µS/cm@ 25°C)	-	≤2000	-
Acidity/alkalinity (pH units)	≥7.0	≤8.0	

For toxicants, ERS (Water) recommends using the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) guidelines (previously ANZECC (Australian and New Zealand Environment and Conservation Council) (2000)) trigger values for 95% species protection. These are outlined in Table 4-3.

Table 4-3 Relevant toxicant trigger values for slightly to moderately disturbed waters (ANZECC 2000/ANZG 2018)

Toxicants	Trigger
Metals and non-metallic inorganics	**95% protection trigger values for freshwater**
Ammonia (mg/L)[1]	0.9

[1] Ammonia as total ammonia (NH_3-N) at pH 8

Toxicants	Trigger
Nitrate (mg/L)[2]	2.4
Aluminium (pH >6.5) (mg/L)	0.055
Aluminium (pH <6.5) (mg/L)	0.0008
Arsenic (AsIII) (mg/L)	0.024
Arsenic (AsV) (mg/L)	0.013
Boron (mg/L)	0.370
Cadmium (mg/L)	0.0002
Chromium (CrVI) (mg/L)	0.001
Copper (mg/L)	0.0014
Lead (mg/L)	0.0034
Manganese (mg/L)	1.9
Mercury (mg/L) (inorganic)	0.0006
Nickel (mg/L)	0.011
Selenium (mg/L)	0.011
Silver (mg/L)	0.00005
Zinc (mg/L)	0.008
Hydrocarbons	
EP080: BTEXN[3]	
Benzene (µg/L)	950
Toluene (µg/L)[4]	180
Ethylbenzene (µg/L)[4]	80
meta- & para-Xylene (µg/L)[4]	75 and 200 respectively
ortho-Xylene (µg/L)	350
Total Xylenes (µg/L)	-
Naphthalene (µg/L)	16

Groundwater indicators and objectives exist for the environmental values defined in ERS (2021). Where groundwater discharges to surface water, the indicators are the indicators applicable to the relevant surface water body. Other indicators and objectives are contained within the ADWG (2011) and ANZG (2018) for potable supply and agriculture, irrigation and stock watering, respectively. Groundwater environmental values are discussed further in Section 6.3.3.7.

[2] Nitrate as NO3-N, based on “Grading" guideline values published in the report "Updating nitrate toxicity effects on freshwater aquatic species".
[3] Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene
[4] Note that reliability of trigger values available for Toluene, Ethylbenzene and m- and p-Xylene are still considered unknown so they were generally not applicable under ANZECC 2000 due to being inaccurately represented.

5 METHODOLOGY

This surface water and groundwater assessment has been undertaken in several key steps. The methodology used is as follows:

- The key Environment Effects identified by the Minister in the scoping requirements were reviewed along with the key EES evaluation criteria (Section 2).
- A review of the project proposal was undertaken with respect to the EES evaluation criteria.
- All surface water and groundwater relevant policy and legislation was reviewed to ensure the technical assessment methodology would cover the required detail (Section 4).
- Key issues raised by stakeholders were reviewed to ensure the technical assessment methodology would the required detail and address areas of concern (Section 2).
- The existing surface water and groundwater environment, data availability and environmental values were identified and made a focus for the technical assessment outcomes (Section 6). This included characterisation of the existing surface water environment through the collation, analysis of data and modelling focusing on the following key areas:
  - Waterway classification.
  - Stream condition.
  - Waterways and wetland characterisation.
  - Groundwater and surface water interaction.
  - Waterway and wetland characterisation.
  - Land and water use.
  - Local catchment inundation.
  - Riverine inundation.
  - Climate change.
  - Water quality analysis.
- The scoping requirements and evaluation criteria were used to define the key technical components of the study to inform the impact assessment.

6 EXISTING CONDITIONS

The existing conditions of the assets, values and uses being considered throughout this assessment are described in the following sections.

6.1 Information sources

6.1.1 Hydrological data

6.1.1.1 Rainfall data

Rainfall data was accessed via the Bureau of Meteorology (BoM)[5] where gauged rainfall data is available on a daily and sub-daily basis. Daily rainfall gauges exist across Australia at relatively high densities; however, the number of sub-daily gauges was limited. Figure 6-1 shows the location of the following available open rainfall gauges close to the project area:

- Daily gauges
  - Woolsthorpe (090084)
    - Available from October 1884, located 14.7 km southwest of the project (proposed site substation)
  - Caramut (090136)
    - Available from June 1958, located 15.0 km northwest of the project
  - Mortlake Racecourse (090176)
    - Available from June 1994, located 17.2 km east of the project
  - Hawkesdale (Post Office) (090045)
    - Available from September 1884, located 22.7 km west of the project
  - Penshurst (The Gums) (090062)
    - Available from January 1932, located 26.1 km northwest of the project
  - Kolora (Wirwin) (090170)
    - Available from June 1981, located 33.4 km east of the project
  - Kolora (Wooiwyrite) (090085)
    - Available from February 1895, located 36.1 km east of the project
- Sub-daily gauges
  - Mortlake (090058) (closed)
    - Available from December 1973 to July 1996, located 18.5 km east of the project
  - Lake Bolac (Post Office)
    - Available from April 1968 to January 2017, located 47.2 km north of the project

The average annual rainfall within the project area is around 650 mm/yr, compared to an average annual pan evaporation of 1300 mm.

[5] Bureau of Meteorology, Climate Data Online, http://www.bom.gov.au/climate/data/

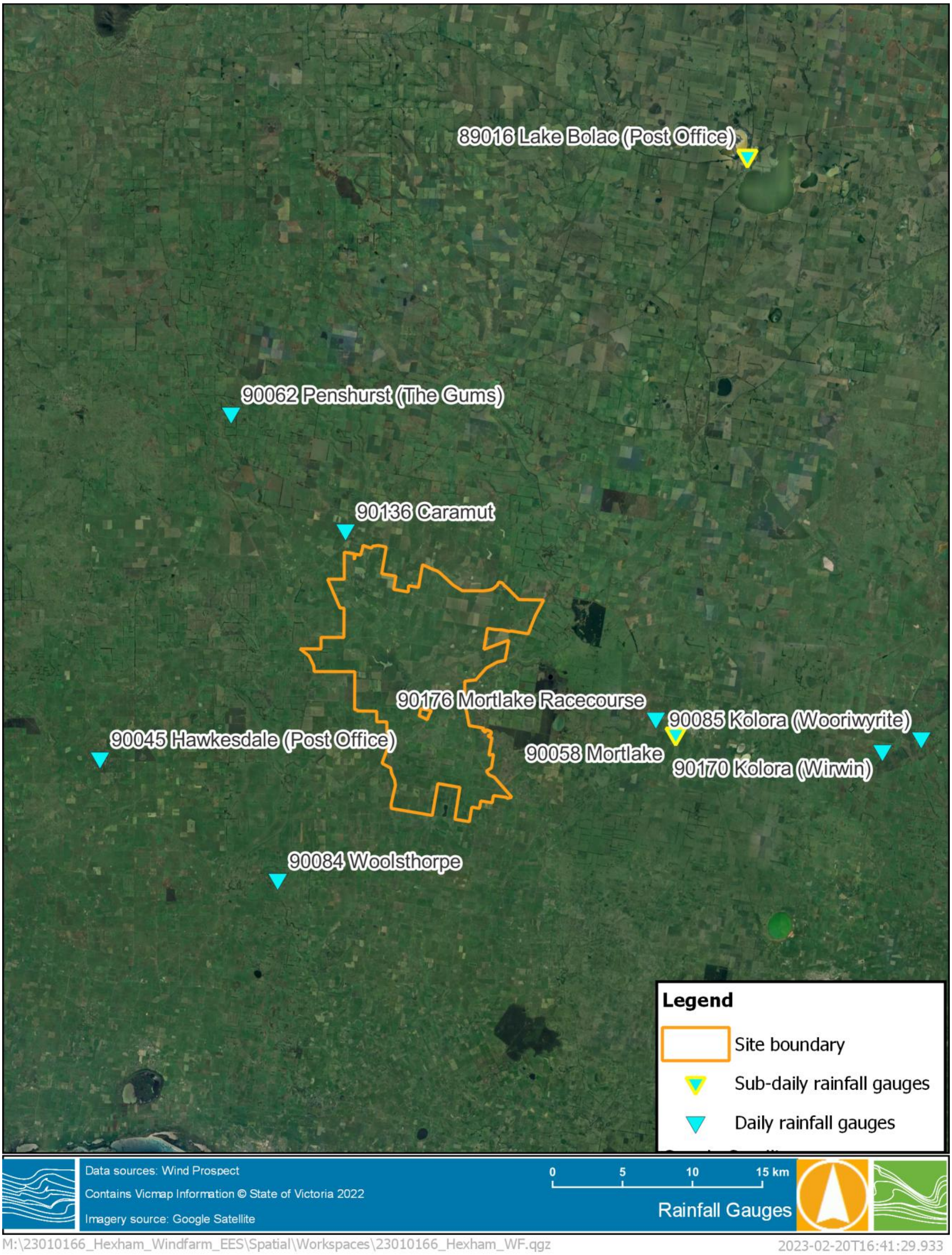

Figure 6-1 Rainfall gauges near the project area

6.1.1.2 IFD data

Intensity Frequency Duration (IFD) curves and underpinning data for the project area were downloaded from the BoM website[6]. The IFD curves are presented in Figure 6-2, showing the relationship between rainfall duration and intensity for each Annual Exceedance Probability (AEP) event. Each AEP is represented as a % probability of exceedance. For example, a 1% AEP event is an event that has a probability of 1% of occurring in any given year. It is equivalent to a 1 in 100 year event. For the general area, rainfall intensity reaches 7.98 millimetres per hour (mm/hr) for a 1% AEP, 12 hour storm event, equal to a total rainfall depth of 95.80 mm. IFD curves are used to determine the likelihood of rainfall and, therefore, inundation. They are used to define design rainfall depths for the Rain on Grid (RoG) modelling.

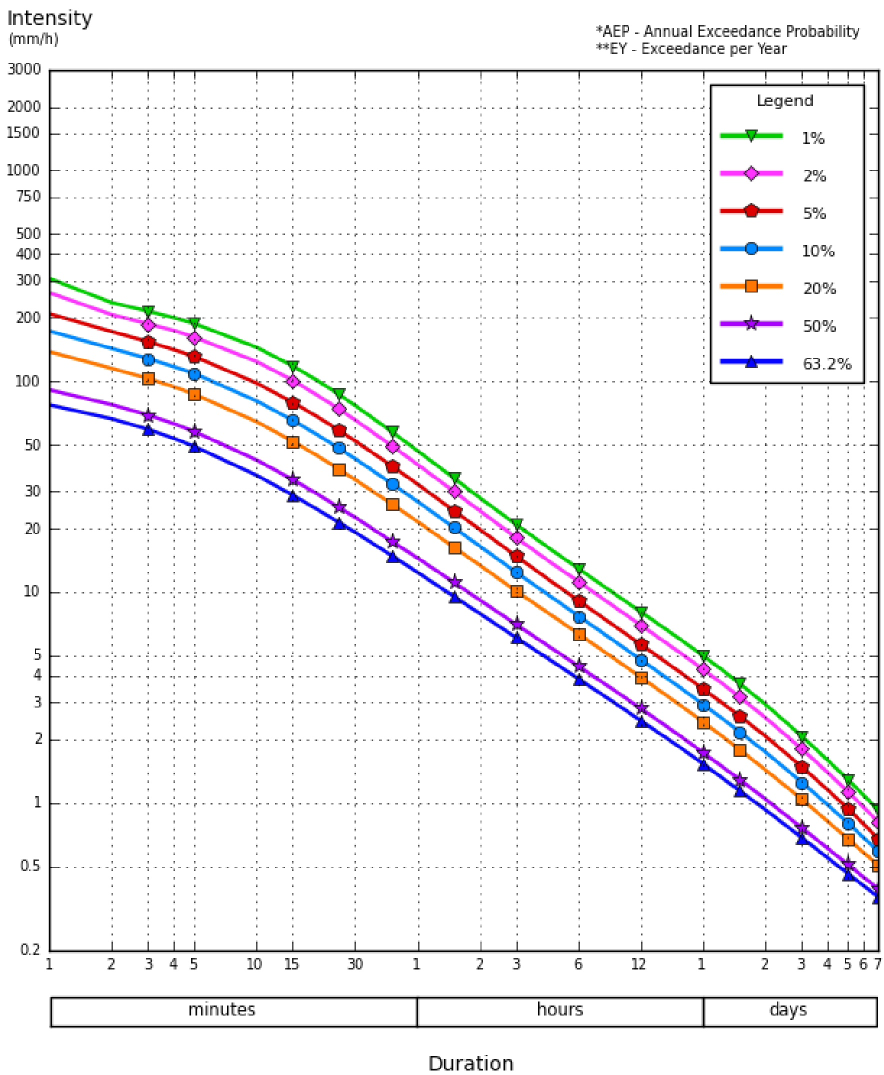

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Figure 6-2 IFD curves at the project site (38.0625°S, 142.5875°E)

[6] Bureau of Meteorology. Design Rainfall Data System (2016), http://www.bom.gov.au/water/designRainfalls/revised-ifd/

6.1.1.3 Streamflow data

Historical streamflow data is used to determine design flows as well as the existing water quality of waterways Figure 6-3 shows streamflow gauges within and nearby the project area including:

- Mustons Creek at Hexham (236214).
  - Available from 1975 to 1982, located 8.8 km northeast of the project (proposed site substation).
- Hopkins River at Wickliffe (236202).
  - Available from 1964, located 45 km north of the project.
- Hopkins River at Framlingham (236210).
  - Available from 1955, located 21 km southeast of the project.

6.1.2 Topographic data

A Light Detection and Ranging (LiDAR) dataset captured in 2020 with a 1-metre resolution topographic dataset extending across the entire Project area was provided by HWF. It provided a raster representation of the area capturing details of the topography across the catchment. Areas outside the project boundary were represented using the 2009-10 Victorian State Wide Rivers LiDAR and the VicMap 10m digital terrain model (DTM) available through the Victorian Department of Energy, Environment and Climate Action (DEECA - formerly known as DELWP). Figure 6-4 shows the extent of each topographic dataset within the study area.

Other features, such as major roads, railways, waterways, water bodies, townships and alignment details were available through other VicMap data.

The Project area is characterised by flat open agricultural space used for grazing and cropping. The Hopkins River flows along the eastern site boundary with several creeks flowing through or near the site, including Mustons, Drysdale, Tea Tree, and Lyall Creeks. A number of wetlands have also been identified. Surface water in the area generally flows towards Mustons Creek which joins the Hopkins River just east of the project area, however flow from the southern parts of the project area flows south to Drysdale and Lyall Creeks or southeast directly to the Hopkins River.

6.1.3 Site investigations

A site visit was undertaken by Water Technology on 31 January 2023 to gain a better understanding of the project area, local topography, land use and existing surface water environment. During the site visit, the local waterways were inspected and water quality sampling was undertaken at a number of locations. Photos from the site inspection are presented in Section 6.2.4.

6.1.4 Water quality data

Water quality data used to establish the existing water quality was accessed from several sources. Historic water quality observations were available through DEECA for the Hopkins River, recorded at the Hopkins River at Framlingham gauge (236210). This gauge is located 21 km downstream of the project area, see Figure 6-3. The data consisted of spot field data for five general water quality parameters at 164 occasions between 1976 and 1990 and laboratory data for six toxicants at three occasions between 1998 and 2005. Observations were also available for the Hopkins River at Wickliffe gauge (236202). This gauge is located 45 km upstream of the project area. The data consisted of spot field data for five general water quality parameters at 266 occasions between 1975 and 1998 and laboratory data for six general parameters at 99 occasions between 1990 and 1998. Due to the age of available water quality records, it was decided to conduct further sampling during the site visit, See Section 6.2.10 for further details.

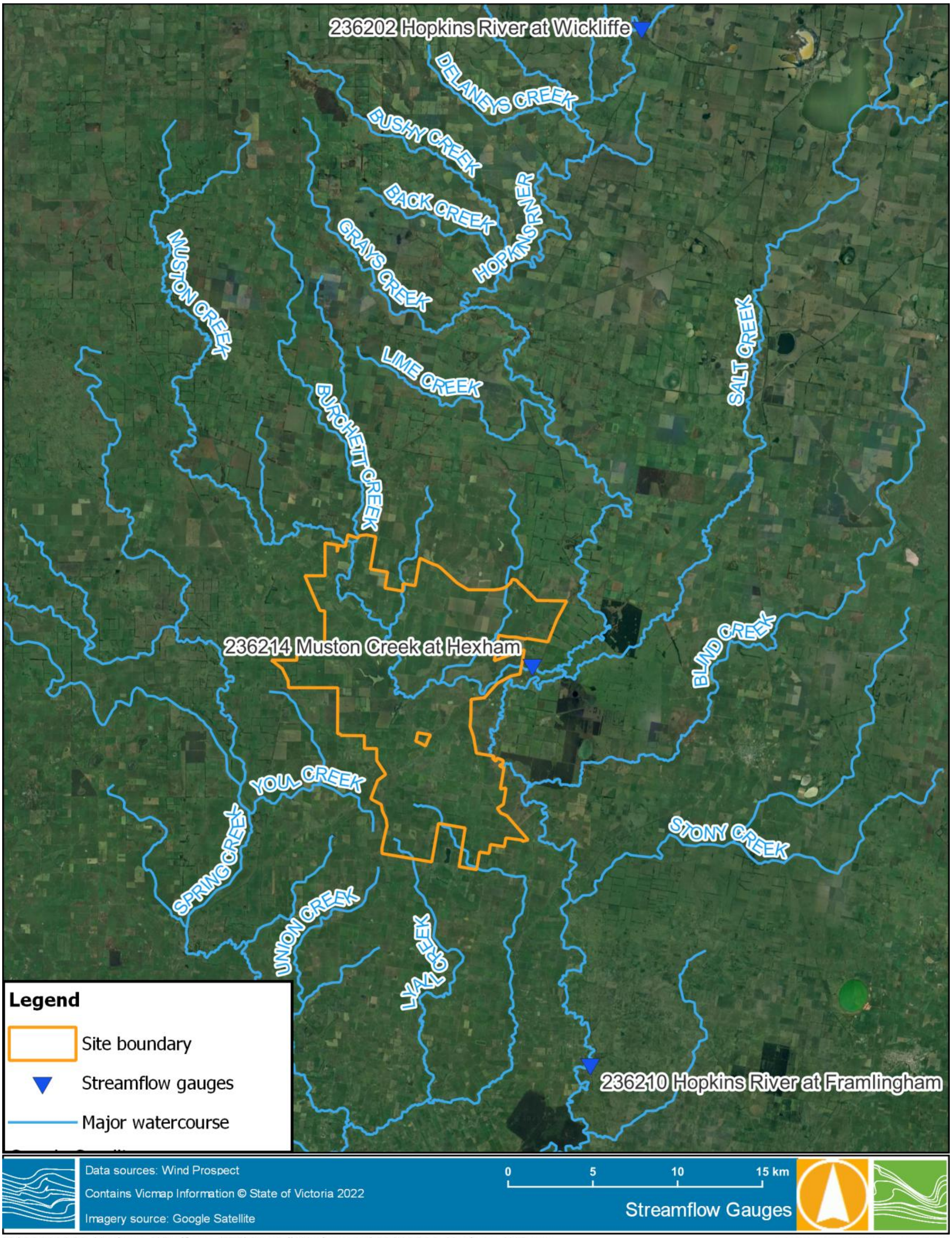

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Figure 6-3 Streamflow gauges near the project area

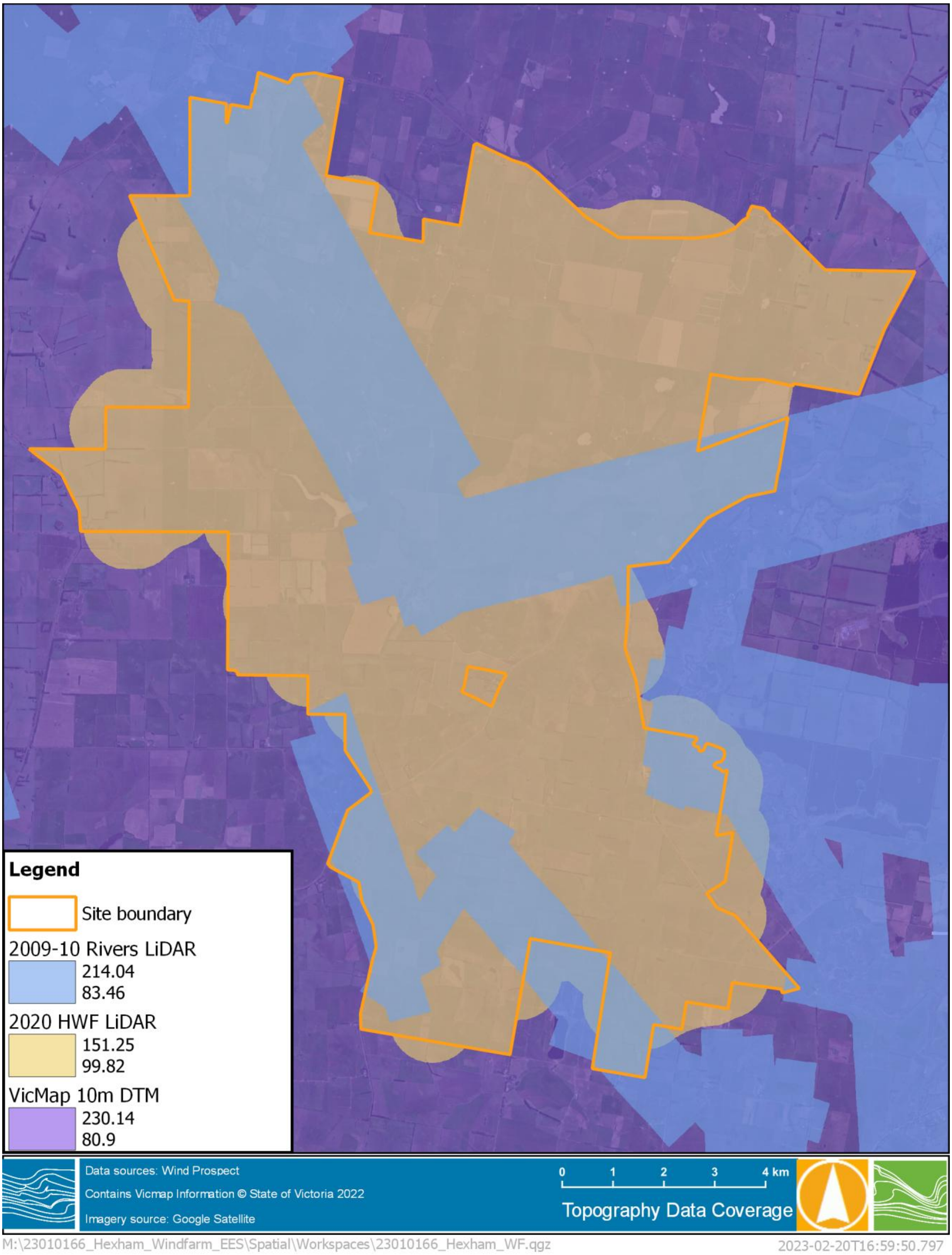

Figure 6-4 Available topography datasets

6.2 Characterisation of hydrological environment

6.2.1 Overview

Lying between the Grampians to the north and Bass Strait to the south, the project is located on the Western District Plains and is within the Hopkins River Basin, within the Glenelg Hopkins Catchment Management Authority (GHCMA) management region. The Project sits west of the Hopkins River with most of the project area outside of the Hopkins River floodplain.

There are several waterways in proximity to the project area, the dominant land use within the catchments to these waterways is sheep/cattle grazing and cereal cropping. There are also smaller vegetated areas planted for forestry or as environmental works. The major waterways interacting with the proposed development include:

- The Hopkins River (flows into Warrnambool Bay at Warrnambool) - flowing east of the project area with limited interaction with the development.
- Mustons Creek (a tributary of the Hopkins River) - flowing through the centre of the project area towards the east.
- Tea Tree Creek (Tributary of Mustons Creek) - flowing south through the north part of the project area and joining Mustons Creek just south of Caramut.
- Drysdale and Lyall Creeks (tributaries of the Merri River) - originating in the southern part of the project area and flowing south.

There is also a number of ephemeral wetlands within and surrounding the project area. The catchment generally slopes towards the southeast and the Hopkins River with some exceptions along the project boundary with the topography generally sloping away from the centre of the site.

Characterisation of the existing surface water environment was based around two key aspects; understanding the current quantity of water available and the quality of that water. This assessment included developing an understanding of the following:

- Riverine flooding.
- Direct/localised catchment inundation including local creeks.
- Regional surface water contributions to downstream environments.
- Existing water quality.
- The potential impact of climate change.

6.2.2 Waterway classification

Mapping of waterways/watercourses and wetlands can be separated into two distinct types:

- *VicMap watercourses* - VicMap watercourses are a spatial dataset which provides a visual representation of drains, channels, creeks, rivers and water storages. The layer is maintained by DEECA and is purely indicative. The layer generally includes, but is not limited to, Designated Waterways (see below) and constructed channels. VicMap waterways are generally displayed in figures and maps as "Waterways" and are included in some maps within this report. Where available the dataset also indicates named waterways. The VicMap watercourses layer gives a better representation of potential overland flow paths than Designated Waterways because it covers drainage lines and smaller flow paths which are not included in the Designated Waterway definition. Figure 6-5 shows the VicMap watercourses near the project area.

- *Designated Waterways* - The *Water Act 1989* defines a 'designated waterway' as "a natural channel in which water regularly flows, whether or not the flow is continuous". Within Victoria, each CMA has a mapping of its designated waterways. Glenelg Hopkins CMA has statutory responsibilities under the *Water Act 1989* and 'By-law No.2 Waterway Protection 2014' to monitor, manage, enforce, and administer control over all works which may impact upon designated waterways throughout the Hopkins region to ensure works undertaken do not adversely affect the health of those waterways.

  Not only natural waterways fall within the classification of a designated waterway, man-made channels can also feature in the Glenelg Hopkins CMA designated waterway mapping.

  Works and activities on or near a designated waterway require a licence from the CMA. Works and activities relevant to the project include:

  - Building a crossing – culverts, bridge or ford.
  - Connecting to a waterway by pipe or drain.
  - Cleaning out the waterway – removing weeds and silt.

  Unfortunately, there is no digital (i.e., Geographic Information Systems (GIS) layer) of designated waterways within the Glenelg Hopkins CMA management area. However, the project area is within Map 12 on their online mapping available as an image[7]. A recreation of the designated waterways within the project area is show in Figure 6-6. These designated waterways are all tributaries of the Hopkins and Merri Rivers (predominantly the Hopkins River).

[7] https://www.ghcma.vic.gov.au/wp-content/uploads/2017/06/Area12.jpg

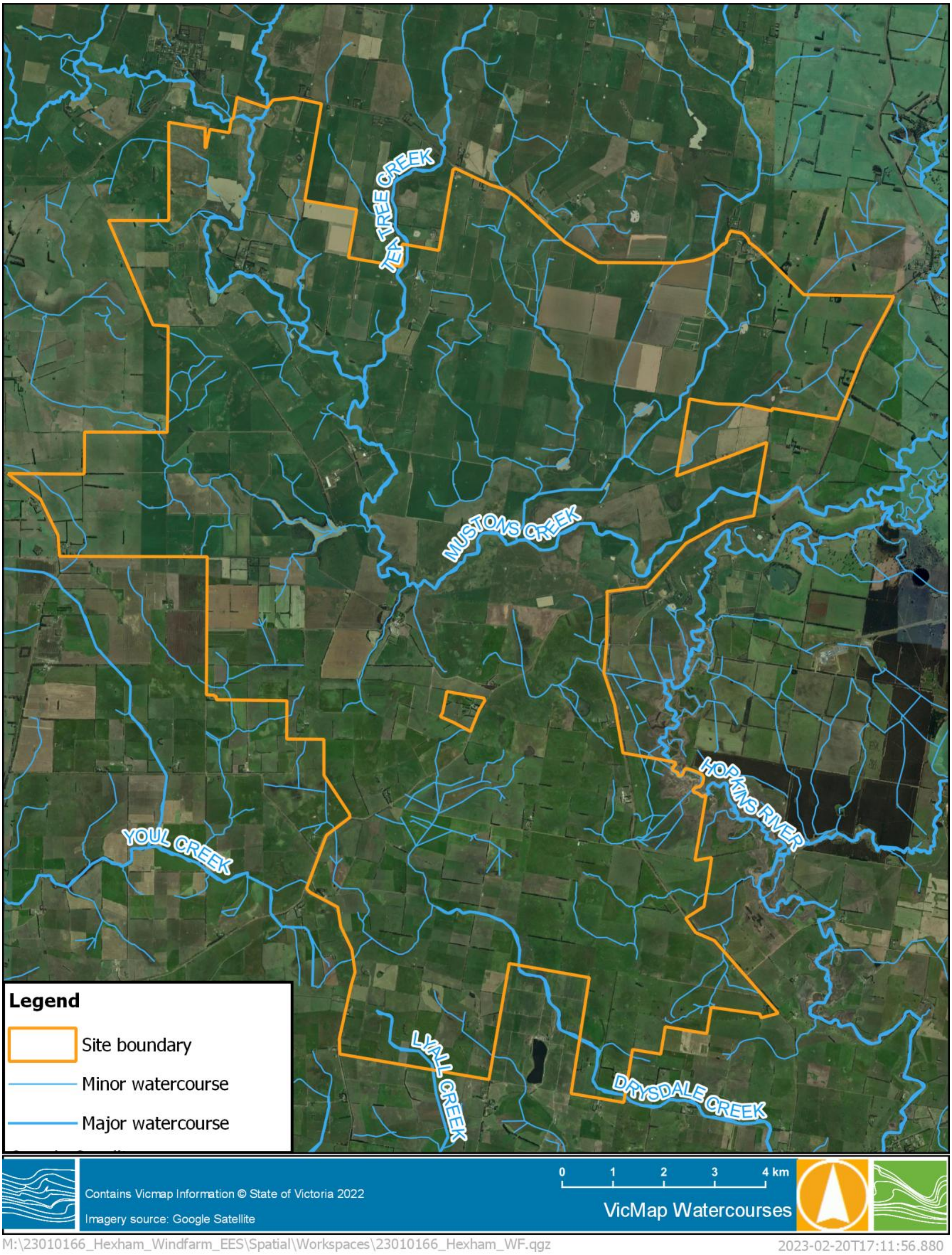

Figure 6-5 VicMap watercourses near the project area

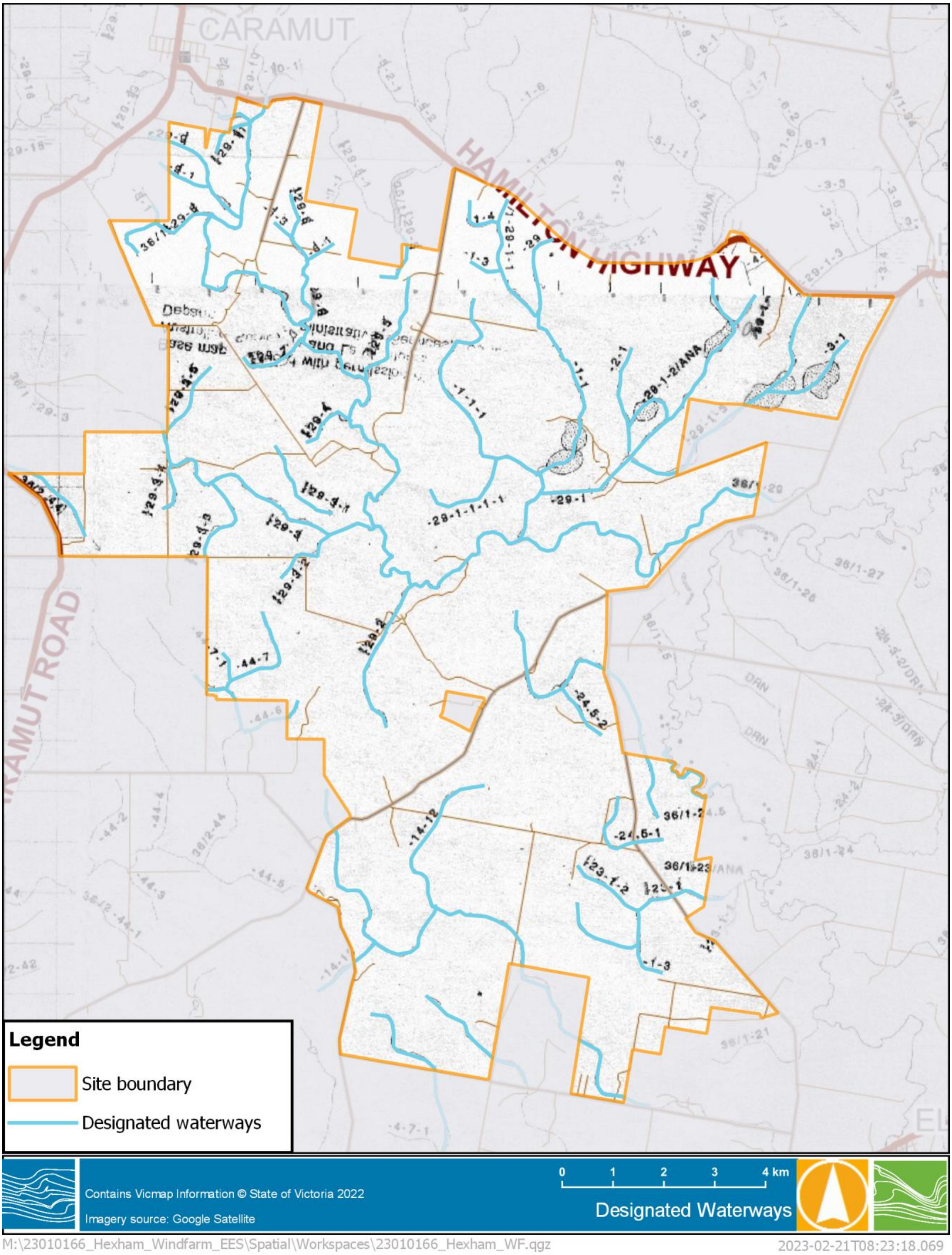

Figure 6-6 Designated waterways within the project area

6.2.3 Stream condition

The Victorian government, in conjunction with the Catchment Management Authorities (CMAs), have undertaken a state-wide benchmark of the environmental condition of Victoria's major rivers and streams. The benchmarking process provides an integrated measure of river condition – the Index of Stream Condition. The Index of Stream Conditions provides scoring on five key aspects (or sub-indices) of river condition:

- Hydrology – refers to the amount of water within the river channel at a specific location and point in time. Considers seasonality and variability of flows.
- Streamside zone – measures characteristics of woody vegetation within 40 metres of the river's edge, including fragmentation, tree cover and presence of weeds.
- Physical form – considers the condition of the riverbank and instream habitat, including presence of artificial barriers.
- Water quality – considers Total Phosphorus, turbidity, salinity (electrical conductivity) and pH levels.
- Aquatic life – based on the number and type of aquatic macroinvertebrates in the river.

Each sub-index is scored out of 10, with higher scores indicating better river condition. These scores are combined to give an overall Index of Stream Condition Score between 0 and 50, which are then categorised into five broad condition bands (i.e., excellent, good, moderate, poor or very poor) for sections of rivers in Victoria, referred to as 'reaches'.

The latest Index of Stream Condition report found that the majority of stream length in the Hopkins basin was in poor condition (38%) or very poor condition (56%) with a small portion in moderate condition (6%).

A summary of the latest Index of Stream Condition report findings for reaches within the Hopkins Basin (DEPI, 2013) is provided in Table 6-1.

Table 6-1 Summary of stream reach sub-indices assessed within the Hopkins basin (DEPI 2013)

Sub-indices	Summary
Hydrology	Natural flow regimes in the Hopkins basin were highly altered, demonstrating extended periods of low flow, zero flow and summer stress. Two-thirds of reaches in the Hopkins basin had extremely modified flow regimes. The lower reaches of the Hopkins River, Merri River and Mt. Emu Creek recorded extended periods of low flow.
Physical Form	Physical condition of reaches varied greatly with excellent (52%) conditions in the south of the basin while also containing poorest reach recorded for the entire Glenelg Hopkins region - reach 28 on Fiery Creek, which scored poorly for fish passage and very poorly for bank stability.
Streamside Zone	All reaches were in poor (70%) or moderate (30%) condition. Poor condition of streamside vegetation and a lack of large trees along most reaches.
Water Quality	The five reaches tested were found to be in poor condition with highly elevated results for phosphorus and salinity. All five reaches were located in the lower area of the basin where land is cleared of vegetation.

Sub-indices	Summary
Aquatic Life	24% of reaches were in good or excellent condition. This reflects the extent of land cleared for agriculture and urban development.

6.2.4 Waterways and wetlands

6.2.4.1 Hopkins River

The Hopkins River catchment covers a rural area of approximately 10,000 km^2 including all its tributaries. The river originates north of Ararat, being fed by various tributaries before it discharges into the ocean at Warrnambool, the largest township within the catchment. Most of the catchment area is agricultural used for a mixture of dryland sheep and cattle grazing and cereal cropping. The catchment is characterised by relatively gentle grades with a maximum elevation of approximately 340 m AHD and an average slope of 0.001. The catchment features some floodplain storage in the form of wetlands and swamps.

There have been numerous large floods on the Hopkins River, these have included: 1960, 1975, 1978, 1983, 1986, 2010, 2011 (largest on record) and 2016. The severity of each event has varied along the catchment, with catchment response dependent on the local catchment characteristics.

The north and central areas of the project area are within the Hopkins River catchment and the river makes up a small part of the eastern Project boundary, see Figure 6-5. Mustons Creek, a major tributary of the Hopkins River, flows through the project area. The Hopkins River is a larger waterway with a more defined floodplain while Mustons Creek is narrower but still has well-defined banks.

The Hopkins River is deemed a designated waterway by Glenelg Hopkins CMA, with waterway reference number Waterway 36/1. A map showing the ISC reach numbers for the Glenelg Hopkins CMA management area is presented in Figure 6-7.

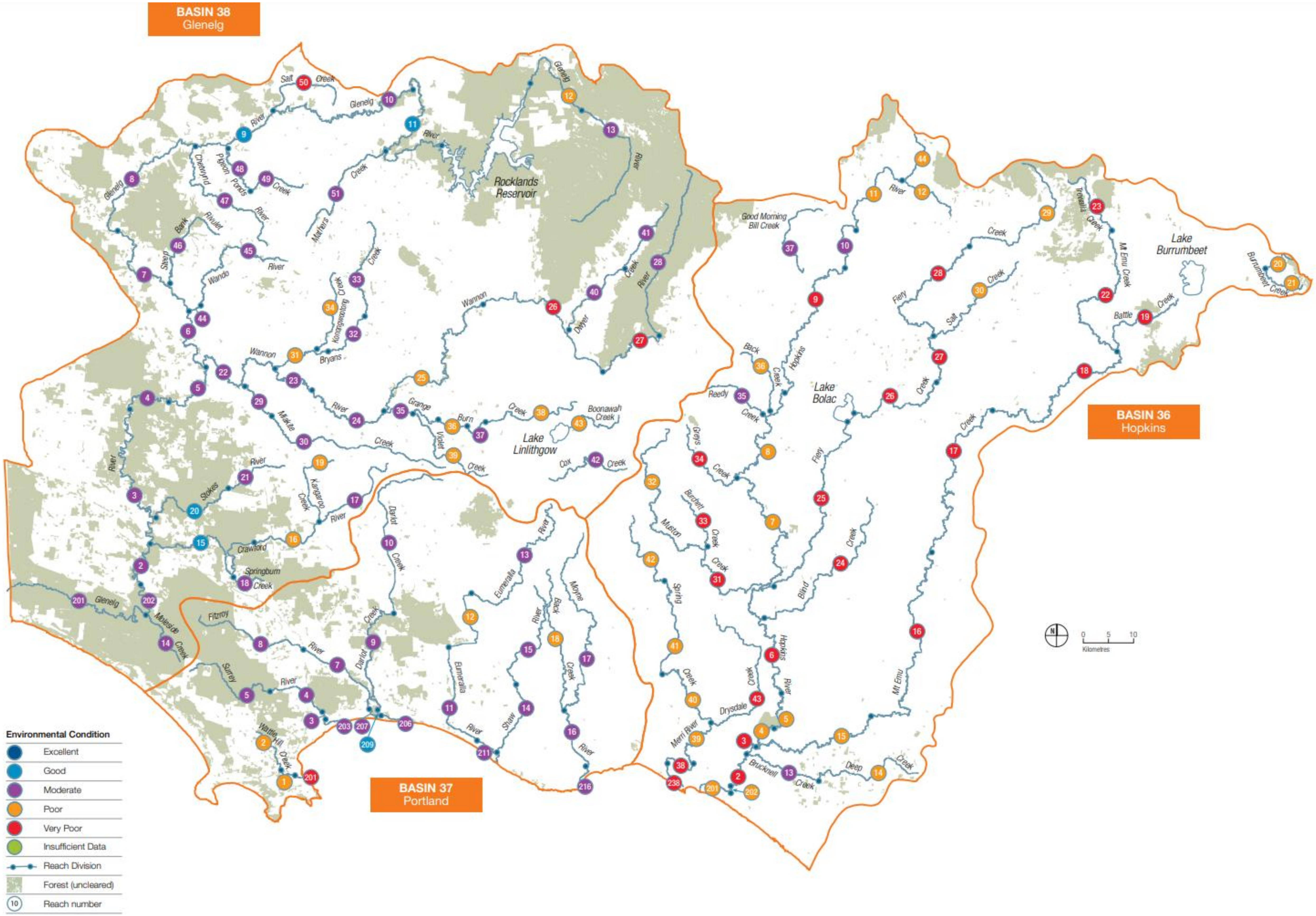

Figure 6-7 ISC reach numbers – Glenelg Hopkins CMA management area (DEPI, 2013)

14 reaches assessed in the Index of Stream Condition report are located on Hopkins River, with the Index of Stream Condition parameters for these sites shown in Table 6-2. Photographs of Hopkins River near the development site is shown in Figure 6-8 and Figure 6-9. A map showing the location of the presented photographs is shown in Figure 6-23.

Table 6-2 Hopkins River Index of Stream Conditions

River	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	Index of Stream Condition
Hopkins River reach 2	2	10	4	3	Not assessed	Very poor
Hopkins River reach 3	2	9	3	4	4	Very poor
Hopkins River reach 4	2	10	5	Not assessed	5	Poor
Hopkins River reach 5	2	9	5	Not assessed	6	Poor
Hopkins River reach 6	2	8	4	3	7	Very poor
Hopkins River reach 7	3	7	4	Not assessed	6	Poor
Hopkins River reach 8	4	7	4	Not assessed	3	Poor
Hopkins River reach 9	3	9	3	Not assessed	4	Very poor
Hopkins River reach 10	3	9	5	Not assessed	6	Moderate
Hopkins River reach 11	3	8	6	Not assessed	3	Poor
Hopkins River reach 12	3	8	4	Not assessed	Not assessed	Poor
Hopkins River reach 44	3	7	6	Not assessed	Not assessed	Poor
Hopkins River reach 201	2	9	4	Not assessed	Not assessed	Poor
Hopkins River reach 202	2	10	5	Not assessed	Not assessed	Poor

Figure 6-8 The Hopkins River at Hexham

Figure 6-9 The Hopkins River at Ellerslie

6.2.4.2 Mustons Creek

Mustons Creek is a tributary of the Hopkins River, and covers an area of approximately 510 km^2, with the lower parts of the catchment falling within the project area. The creek originates northeast of Penshurst and is fed by tributaries including Burchett Creek and Tea Tree Creek before joining the Hopkins River east of the project area. Most of the catchment is agricultural, used for a mixture of dryland sheep and cattle grazing and cereal cropping, with livestock paddocks located directly on the creek.

Mustons Creek, Burchett Creek and Tea Tree Creek are deemed designated waterways by Glenelg Hopkins CMA, with waterway reference numbers Waterway 36/1-29, Waterway 36/1-29-10 and Waterway 36/1-29-5. A small number of unnamed designated waterways also feed into Mustons Creek.

Three reaches assessed in the Index of Stream Condition report are located on Mustons and Burchett Creeks, with the Index of Stream Condition parameters for these sites shown in Table 6-3. Photographs of Tea Tree, Burchett and Mustons Creeks near or within the development site are shown in Figure 6-10 to Figure 6-15.

Table 6-3 Mustons and Burchett Creeks Index of Stream Conditions

River	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	Index of Stream Condition
Mustons Creek downstream	2	10	3	Not assessed	5	Very poor
Mustons Creek upstream	2	8	3	Not assessed	8	Poor
Burchett Creek	3	8	3	Not assessed	4	Very poor

Figure 6-10 Tea Tree Creek at Hamilton Highway, 10 km west of Hexham.

Figure 6-11 Burchett Creek at Caramut

Figure 6-12 Mustons Creek at Caramut

Figure 6-13 Mustons Creek 1.5 km south of confluence with Tea Tree Creek

Figure 6-14 Mustons Creek at Woolsthorpe-Hexham Road, upstream of confluence with the Hopkins River

Figure 6-15 Unnamed tributary of Mustons Creek

6.2.4.3 Drysdale Creek

Drysdale Creek is a tributary of the Merri River and covers an area of almost 200 km^2. The upper parts of the catchment where Drysdale Creek and its main tributary Lyall Creek both originate, fall within the project area. The creeks then flow south towards their confluence upstream of joining the Merri River. Most of the catchment area is agricultural land used for a mixture of dryland sheep and cattle grazing and cereal cropping.

Drysdale Creek and Lyall Creek are deemed designated waterways by Glenelg Hopkins CMA, with waterway reference numbers Waterway 36/2-14 and Waterway 36/2-14-4 respectively.

One reach assessed in the Index of Stream Condition report is located on Drysdale Creek, with the Index of Stream Condition parameters for this site shown in Table 6-3. Images of Drysdale and Lyall Creeks within the development site are shown in Figure 6-16 and Figure 6-17.

Table 6-4 Drysdale Creek Index of Stream Conditions

River	Hydrology	Physical Form	Streamside Zone	Water Quality	Aquatic Life	Index of Stream Condition
Drysdale Creek	2	10	4	Not assessed	4	Very poor

Figure 6-16 Lyall Creek at Gordons Lane, 9 km west of Ellerslie

Figure 6-17 Drysdale Creek at Gordons Lane, 3.5 km west of Ellerslie

6.2.4.4 Wetlands

A number of wetlands have been identified by DEECA within and surrounding the site, as shown in Figure 6-24. There are no Ramsar listed wetlands located within the project site, with the closest being the Western District Lakes Wetlands approximately 40 kilometres east of the project site.

Wetlands within the project area generally capture localised runoff from isolated catchment areas, there are some which receive creek overflows from Mustons Creek or its tributaries. The wetlands are mainly linked through natural channels, but in some cases wetlands have been connected by constructed channels or drained to increase the area of land available for agricultural production. Wetland drainage has been both to other wetlands as well as to larger drainage systems or waterways. The assessment in this report has modelled these wetlands and their catchments based on the available topographic data and has not included detail around specific wetlands, the habitat they provide or their specific hydraulic regimes, this has been assessed in other components of the EES.

Due to the nature of the topography, most of the depressions within the project site are inundated during winter and spring (during some years) but largely dry out during summer. Larger areas are known to hold water for three to four months, then dry (through both natural flow paths and manmade drains) and form modified grasslands, which are grazed by sheep and cattle. During drier years these areas do not fill and remain modified grasslands.

Modelling undertaken by Water Technology assessed the potential duration of inundation across all potential wetland areas, assessing if they were able to hold water for more than 120 consecutive days between the 2009-2019 period (Water Technology, 2021). The purpose of this modelling was to inform detailed assessment of potential brolga breeding habitat. The modelling used hydraulic modelling to identify potential wetland areas, then modelled those which had the potential to hold water for a sustained period. The wetlands which had the potential to hold water for a sustained period were then modelled using an eWater Source water balance model. The hydraulic modelling identified 745 areas that held water post a flood event, of these:

- 75 had an incorrect topographic representation within the model (i.e. roads were artificially creating pools of water).
- 497 had constructed drainage from the invert of the depression.
- 46 had very limited size, depth and catchment area. This combination of low depth, the size being close to 0.1 hectares and the small catchment mean these areas would dry quickly.
- 97 were farm dams – automatically meeting the inundation criteria.
- 24 were deemed to require further assessment of their longer term potential to hold water.
  - 4 wetlands were assessed using hydraulic model as they were potentially impacted by riverine inundation in addition to local runoff.
  - 2 wetlands were determined as suitable for brolga breeding and night roosting directly from the aerial image.
- The detailed water balance assessment determined 18 of the 24 wetlands sustained water within them for more than consecutive 120 days within the 2009-2019 period, making them hydrologically suitable for brolga breeding.

The modelling was used together with observations and site investigations to determine wetlands likely to be used for brolga breeding. Detail around this assessment can be found in the Brolga Impact Assessment report (Nature Advisory, 2025).

Figure 6-18 to Figure 6-22 show some of the wetlands visited during the surface water site investigation.

Figure 6-18 Large farm dam located close to Mustons Creek, 9.5 km southeast of Caramut.

Figure 6-19 Wetland identified in the wetlands assessment (Water Technology, 2021) located east of Mustons Creek, 10.7 km southwest of Hexham.

Figure 6-20 Wetland identified in the wetlands assessment (Water Technology, 2021) located east of Mustons Creek and Tea Tree Creek, 6.5 km southwest of Hexham.

Figure 6-21 Wetland identified in the wetlands assessment (Water Technology, 2021) located north of Mustons Creek close to confluence with unnamed tributary, 8 km southwest of Hexham.

Figure 6-22 Wetland identified in the wetlands assessment (Water Technology, 2021) located south of Mustons Creek directly west of Hexham-Woolsthorpe Road, 10.5 km southwest of Hexham.

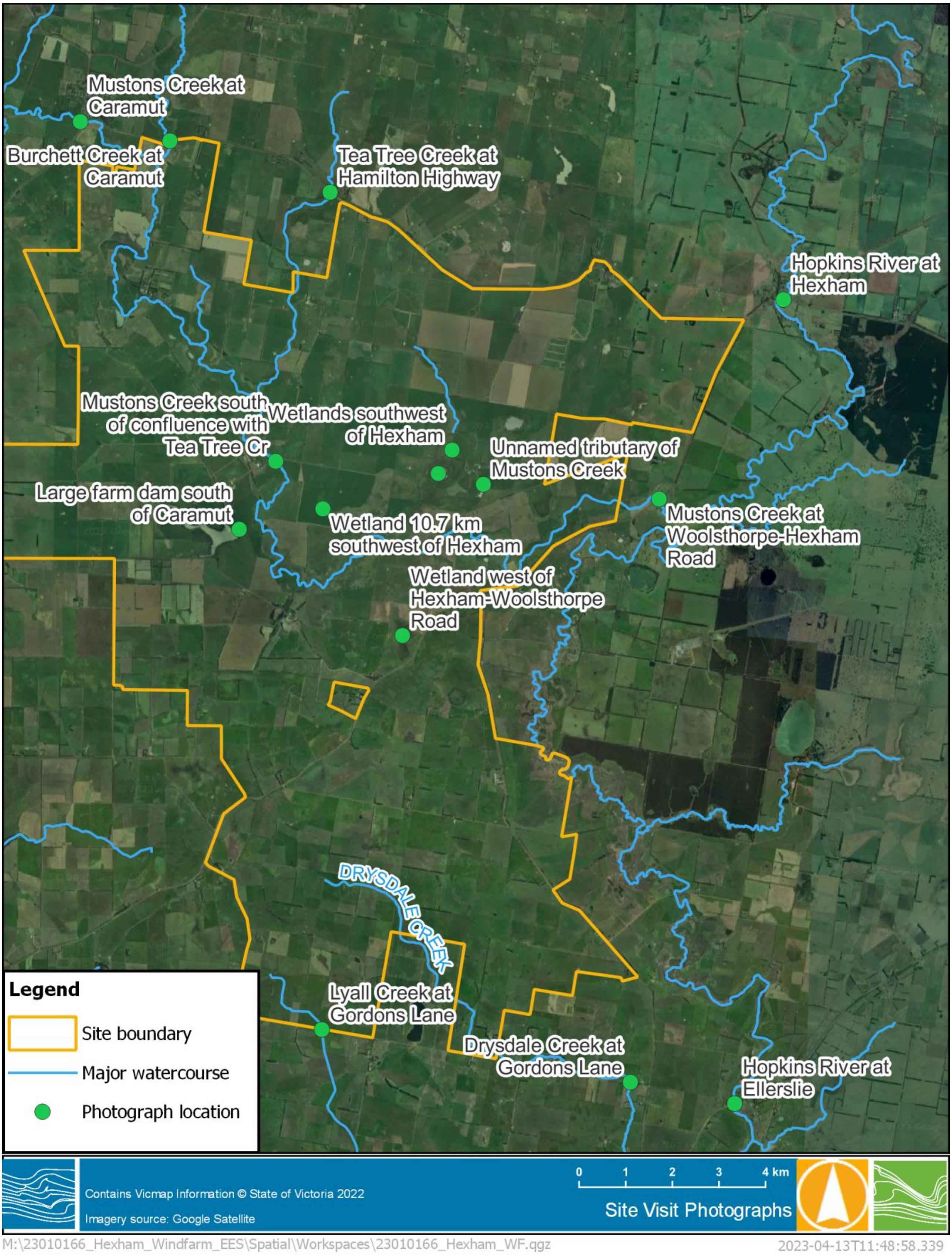

Figure 6-23 Site visit photograph locations

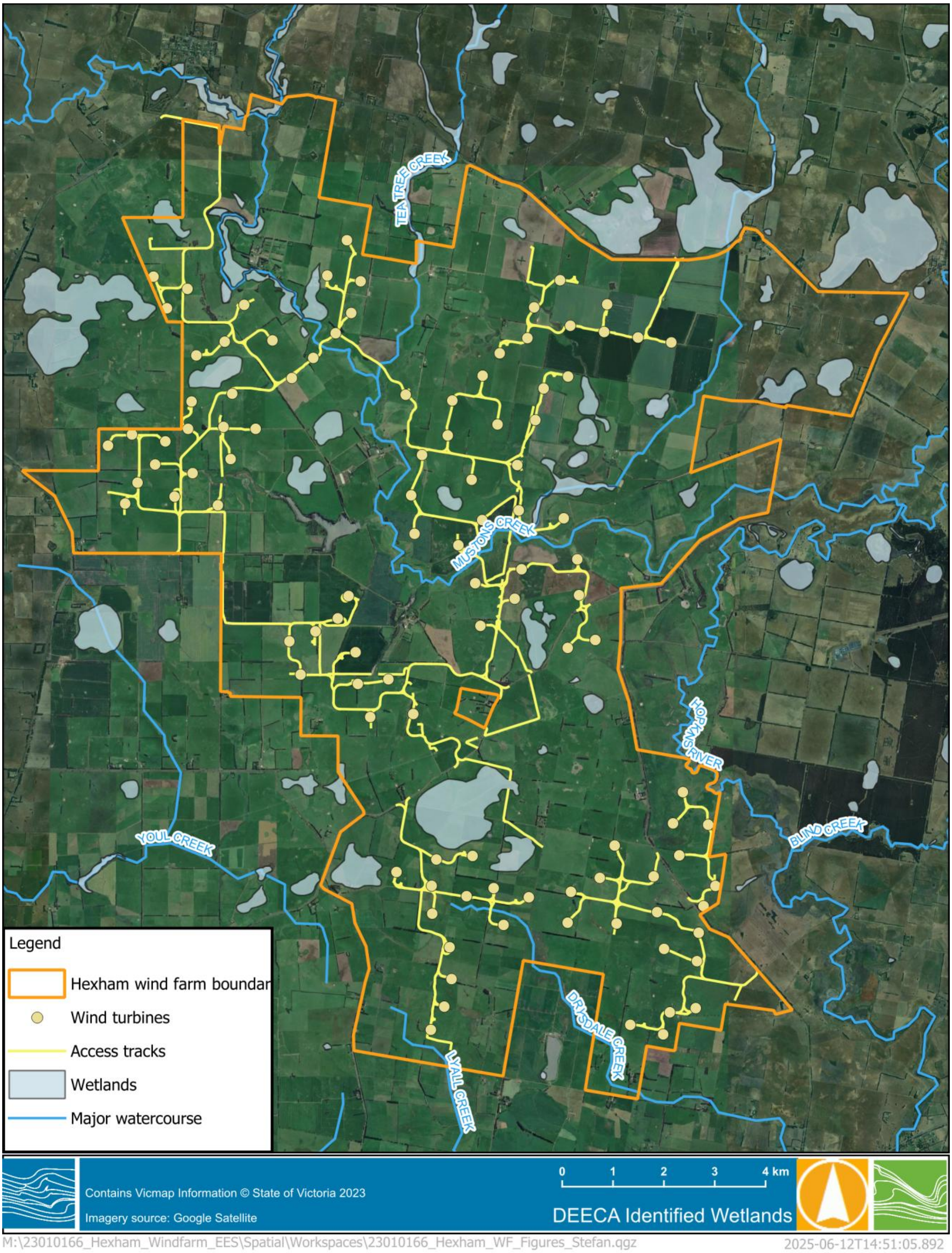

Figure 6-24 DEECA identified wetlands

6.2.5 Identification of environmental values

The EES Scoping Requirements note Key Issues in the Environmental Objectives. These reflect the environmental values under ERS.

The ERS identifies environmental values of water environments that that need to be protected and enhanced. Rainfall runoff from the project area flows toward the Hopkins River and creek tributaries, as well as local wetlands (if not contained). Environmental values and sensitive receptors of water are predominantly related to these receiving waterways. The environmental values listed in the ERS can be categorised into 10 themes, these themes and their relevance to the project are listed in Table 6-5 based on the project location within the Murray and Western Plains surface water geographic region.

The Victorian Planning and Local Planning provisions were considered to identify any matters related to water as well as the Western Region Sustainable Water Strategy (DSE, 2011). The GHCMA is within the Murray and Western Plains segment and is not included in any of the additional Schedules of Areas of High Conservation Value, or in any special water supply catchment area listed in Schedule 5 of the Catchment and Land Protection Act 1994 (neither the Hopkins River nor the local creeks are listed in Schedule 5).

Table 6-5 Environmental values and their relevance to the project area

Sensitive receptors / environmental values	Relevance to project area
Water dependent ecosystems and species that are slightly to moderately modified.	Rainfall runoff from the project area flows toward the Hopkins River, creek tributaries and wetlands (if not contained).
Human consumption after appropriate treatment.	The Project area is not within a declared Special Water Supply Catchment Area.
Agriculture and irrigation (including stock watering).	There are several farm dams in proximity of the project area and a majority of the project area and surroundings is agricultural.
Human consumption of aquatic foods (natural populations - commercial and recreational catch).	The Project area is not within the catchment of any aquatic food operations; however, consumption of recreationally caught fish from the Hopkins River is common.
Aquaculture.	The Project area is not within the catchment of any aquaculture operations.
Industrial and commercial.	The Project area does not contain any current industrial or commercial operations dependent on or impacted by surface water.
Water based recreation.	The Hopkins River is used for a significant number of water-based recreation activities; these include: ■ Fishing/boating ■ Swimming ■ Kayaking/canoeing. ■ Bird watching. ■ Camping. ■ Caravanning

Sensitive receptors / environmental values	Relevance to project area
Traditional Owner cultural and spiritual values.	The Project area is located on Eastern Maar country and the Hopkins River and its tributaries are of significant Traditional Owner cultural and spiritual value.
Protection of buildings and structures.	There are several rural residential properties and local roads in proximity to the project area.

Environmental values identified as potentially impacted by the project are highlighted in Table 6-5. Those not highlighted will still be protected by the required impact mitigation measures (as they focus on ensuring avoiding or minimising all impacts), they have not been highlighted to ensure focus on specific issues during consultation and/or assessment of the existing environment. The major waterways all have the same general environmental values (water dependent ecosystems, and species, cultural and spiritual values and agriculture and irrigation); however, the specific environmental values as determined by the Hexham Wind Farm Flora and Fauna Assessment (Nature Advisory, 2025) include:

- Flora – Purple Blown-grass, Buloke, Black Wattle, Onion-orchis and Sun Orchid
- Non-migratory bird species - Australasian Shoveler, Black Falcon, Blue-billed Duck, Brolga, Freckled Duck, Hardhead and Musk Duck
- Migratory bird species - Common Greenshank, Curlew Sandpiper, Double-banded Plover, Fork-tailed Swift, Latham's Snipe, Red-necked Stint, Sharp-tailed Sandpiper and Whitethroated Needletail
- Wetland bird species - Nankeen Night-heron, Royal Spoonbill, Whiskered Tern.
- Bat species - Grey-headed Flying-fox, Southern Bent-wing Bat and Yellow-bellied Sheath-tail Bat
- Reptile species – Striped Legless Lizard and Tussock Skink
- Frog Species – Growling Grass Frog

The assessment of impact pathways (Section 7) and effects/impacts (Section 8) aim at reducing the impact of the development to the minimum level possible regardless of the sensitivity of the environmental values of each waterway or wetland.

6.2.6 Land and water use

6.2.6.1 Comparison of landscape with other wind farms

A comparison between the project area landscape and Ryan Corner and Stockyard Hill windfarm projects is included here for reference.

The ~3,600 hectares Ryan Corner wind farm is located some 40 km southwest of the project area and has a ground elevation ~130 m lower. The site is bordered by the Shaw River to the west and is ~5 km from the coastal dunes to the south and comprises Western District Volcanic Plains. Basaltic 'stony rises' of the Pleistocene Mt Rouse-Port Fairy lava flow traverse the site with intervening depressions containing ephemeral wetlands (Moyne Shire Council, 2008).

The 15,600 ha. Stockyard Hill windfarm project is approximately 220 m higher than the project area and located close to Black Lake and Lake Goldsmith. There are more landholders associated with this project than for the Hexham Wind Farm, but these are also generally in relation to grazing and cropping. The Stockyard Hill area is also covered by undulating volcanic rocks and contains native vegetation near the Trawalla State Forest in the north of the site.

6.2.6.2 Agriculture

Grazing of sheep and cattle is the main land use within the site which is classed as 'Grazing Modified Pastures'. Farm dams are common across the site. The generally agricultural land use has a mixed impact on the surface water attributes of the project area. In some areas it has the potential to increase or decrease runoff dependent on paddock specific use. Waterway and water quality is generally degraded by agricultural use with stock and fertilisers increasing organic loads.

6.2.6.3 Ecological land use

Potential habitat zones for ecosystems (including aquatic and terrestrial GDEs) have been mapped by the Bureau of Meteorology (GDE Atlas). This database (which does not include subterranean GDEs) is the reference for this report.

In addition, based on field investigations over the last decade a range of water dependent ecosystems may support significant ecological communities and species, such as:

- Seasonal herbaceous wetlands.
- Flora species.
- Migratory and non-migratory bird species.
- Wetland bird species.
- Bat species.
- Reptile species.
- Frog Species.

These values (species protection) were considered when conducting the investigation to ensure the potential changes to groundwater and surface water regimes were considered in sufficient detail for the likely effects to be assessed in the ecology section of the EES.

6.2.7 Direct/localised catchment inundation

Inundation caused by the waterways intersecting the site as well as direct rainfall onto the site was assessed simultaneously using a TUFLOW hydraulic model with in-channel inflows from the upstream determined using hydrological modelling and direct rainfall modelled using a Rain on Grid (RoG) approach.

6.2.7.1 Hydrological modelling

6.2.7.1.1 Model extent and delineation

A 1-metre resolution LiDAR dataset was available for the area within the site boundary, enabling detailed modelling of the rainfall onto the site. The upstream catchment for the waterways through the site, as well as smaller catchments contributing runoff directly towards the site were however only covered by a coarse 10-metre DTM. There was a disparity between the course 10m DTM and the finer, more accurate LiDAR and including areas outside the site boundary in the hydraulic model would lead to the datasets not matching. By only modelling areas covered by the LiDAR dataset, this could be avoided. The hydrologic assessment of the areas outside of the site boundary used a runoff routing approach, modelled using RORB software. The model covered the Mustons Creek catchment upstream of the confluence of Mustons Creek and the Hopkins River. The RORB model was used to produce hydraulic model inflows for Mustons, Burchett and Tea Tree Creeks as well as smaller local catchments located just outside of the site boundary, but still generated runoff to the site.

The final RORB model had 70 sub-catchments encompassing a total catchment area of approximately 510 km^2, with the hydraulic study area located towards the lower end of the catchment, as shown in Figure 6-25. In channel reaches were defined as ‘excavated unlined’ with remaining reaches defined as ‘natural’. The impervious fractions were left as zero given most of the catchment is agricultural land.

6.2.7.1.2 Model inputs and parameters

Australian Rainfall and Runoff (ARR2019) recommended temporal patterns and BoM 2016 IFD parameters were adopted for the rainfall input, which consists of data based on nearby rainfall stations, see Section 6.1.1. The ARR2019 design rainfalls assume present day conditions.

The ten recommended temporal patterns for each storm duration are provided to represent the variation in rainfall distribution over time. These temporal patterns are provided by ARR and were developed based on the long-term historical data in Australian rainfall gauges. Depending on the catchment characteristics, even for events with the same total rainfall depth, the variation of temporal distribution of rainfall depth could result in variation of flood extent and level within the catchment. ARR2019 recommends running an ensemble simulation using the ten temporal patterns to determine the temporal pattern which produces the median peak flow.

The RORB parameters kc and m, hydrology model fitting parameters dependent on catchment characteristics such as channel roughness and slope, as well as initial and continuing loss were determined by comparing to values used in a number of nearby studies, as well as regional flow estimates at the model outlet. kc was calculated using the average flow distance in the reach network and a ratio of 2. Initial and continuing losses were adjusted to achieve a reasonable 1% AEP flow at the outlet when comparing to regional flow estimates and recorded flows in Mustons Creek and the Hopkins River at the gauges listed in Section 6.1.1.3. Table 6-6 shows the comparison as well as the final values adopted for the Mustons Creek RORB model.

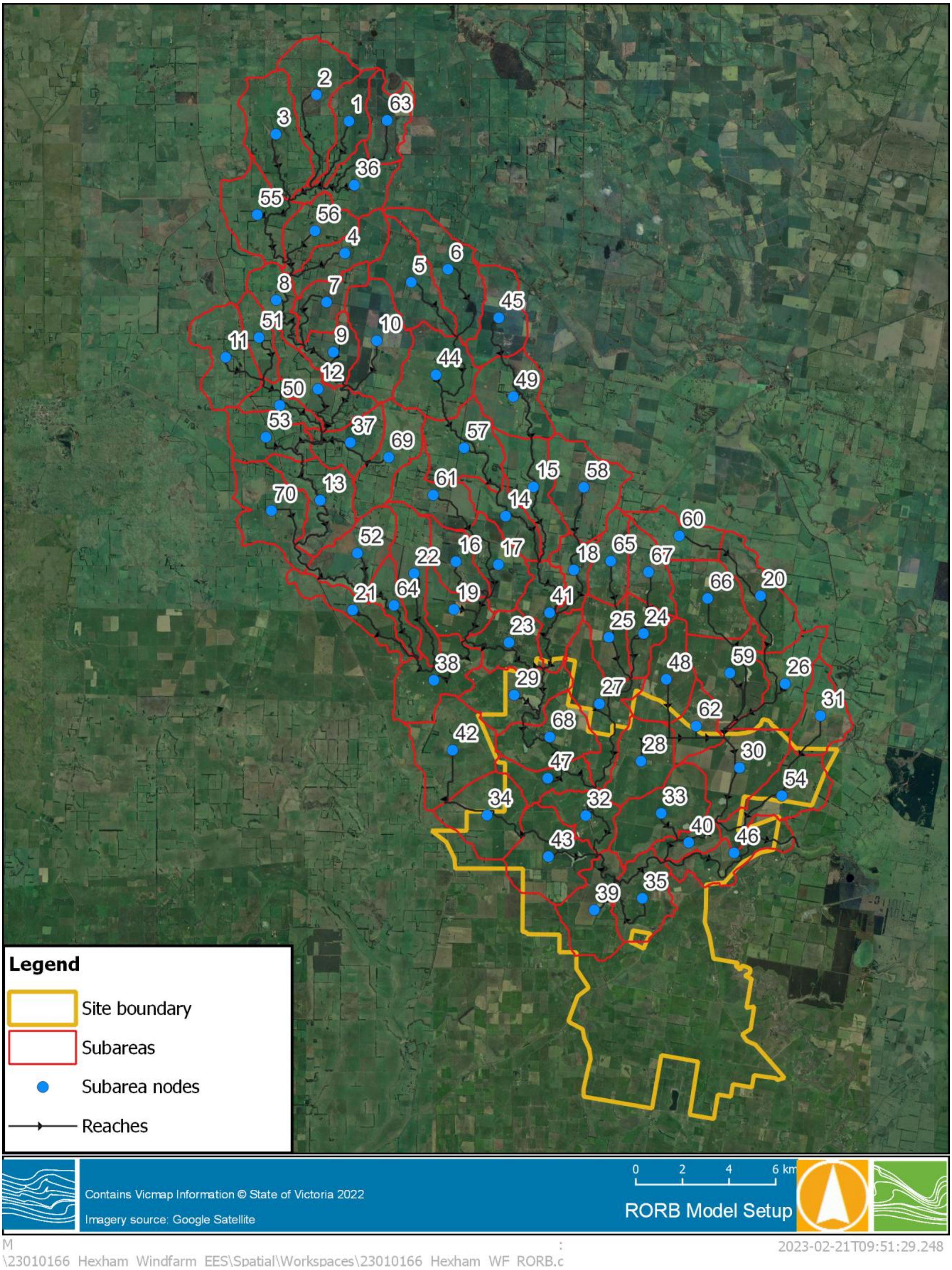

Figure 6-25 RORB model setup

Table 6-6 1% AEP RORB coefficients

	Kc	Kc/Dav	m	Initial losses	Continuing losses
Wickliffe Flood Study (Cardno, 2013)	120	2.69	0.73	29	3
Port Fairy Regional Flood Study (Water Technology, 2008)	46	1.48	0.8	15	1.3
Upper Mt. Emu Creek Flood Investigation (Water Technology, 2020)	120	2.04	0.8	16	0.5
South Warrnambool Flood Study (Water Technology, 2007)	58	0.86	0.8	20	3.9
Hexham Wind Farm Surface Water Impact Assessment	82.4	2	0.8	20	2.5

6.2.7.1.3 Results

The critical duration and temporal pattern were determined for Mustons Creek at the model outlet for each of the 1% and 10% AEP events. The 12-hour storm and TP01 produced the peak flow among the durations modelled and was adopted for the design modelling.

A long and a short duration was also selected, with median temporal pattern for the short duration determined by the smaller local catchments located at the site boundary and median temporal pattern for the long duration determined at the model outlet. The modelled durations and temporal patterns for each of the 1% and 10% AEP events are listed in Table 6-7. Output hydrographs from all three durations were used in the hydraulic model and the results were combined into maximum grids.

Table 6-7 Modelled storm duration and temporal pattern (TP) adopted

AEP Event	Short duration and TP	Critical duration and TP	Long duration and TP
1% AEP	2 hours, TP03	12 hours, TP01	48 hours, TP09
10%	2 hours, TP10	12 hours, TP09	48 hours, TP08

There are several peak flow estimation methods that can be used for broad comparison to modelled peak flows. The Rational Method is a commonly adopted method to verify the flow at catchment outlet and a more recently developed and recommended method in ARR2019 is the Regional Flood Frequency Estimation Tool (RFFE).

Table 6-8 shows the comparison of modelled and estimated flows at the Mustons Creek model outlet from the Adams and RFFE Tool. The modelled peak flow was larger than the estimated peak flows, but results in lower peak flow at the same location when using the RORB model results in the hydraulic model due to internal storage in the hydraulic model. The RORB peak flow was also compared to the gauged peak flow at the Mustons Creek at Hexham (236214) gauge. This gauge recorded a peak flow of 116 m^3/s between 1970 and 1985. Based on the relatively short period of record, this gauge is unlikely to have covered a 1% AEP event, indicating that the actual peak flow is larger than the gauged peak.

Table 6-8 Modelled flow verification

Estimation method	1% AEP flow (m^3/s)
Rational (Adams method)	140
RFFE tool (2021)	141

Estimation method	1% AEP flow (m^3/s)
RORB model	210

RORB hydrographs were extracted at four in channel inflow locations for the hydraulic model, in Mustons, Burchett and Tea Tree Creeks as well as an unnamed tributary east of Tea Tree Creek. Hydrographs were also extracted for four local catchments located outside of but generating runoff to the project area.

6.2.7.2 Hydraulic modelling

6.2.7.2.1 Overview

A hydraulic model was built using the TUFLOW HPC software modelling package. TUFLOW is an industry standard one and two-dimensional modelling package which has been used across numerous flood modelling projects across Victoria. A gridded model was developed with multiple in-channel and local catchment inflow boundaries applied to represent flows from Mustons Creek and tributaries as well as local catchments surrounding the site. Additionally, a Rain on Grid (RoG) modelling approach was adopted for modelling of local storm events across the project area.

RoG modelling directly applies rainfall to a topographic grid of the catchment area, identifying all major flow paths through modelling of surface water runoff and then mapping of resulting depth, velocity and hazard (mapped as per the ARR2019 recommendations). RoG modelling is a robust method to determine both runoff volumes, peak flow rates and areas of high flood risk in sites with complex topography. RoG models can identify major flow paths, depressions/wetlands and the complex interactions of overland flow. A traditional rainfall runoff model (RORB, URBS etc.) would not be able to resolve these within the project area due to its inability to represent the complex terrain. Rainfall runoff modelling requires separation of flow paths and has no ability to hydraulically model discontinuous flow paths or wetland interactions (aside from a simple stage storage relationships). RoG modelling enables the complex of interaction between overland flow paths and depressions to be represented across the very flat terrain.

The modelling completed focused on using infiltration losses, hydraulic roughness (modelled as Manning’s ‘n’) and design rainfall intensities to produce runoff volumes (rainfall minus infiltration losses) and discharge rates covering the site, within upstream and downstream catchment areas.

The development of the TUFLOW model for the project area consisted of the following components:

- Model extent.
- Topography.
- Material layer – representing hydraulic roughness.
- Model boundaries – representing external flows into the model as well as flows out of the model extent.
- Rainfall.

6.2.7.2.2 Model extent and topography

They hydraulic model extent was selected to match the extent of the available 1 metre LiDAR dataset. The TUFLOW Digital Elevation Model (DEM) was developed using the LiDAR. This high-resolution dataset was able to represent the topography including open drains, using a model grid resolution of 5 m to reduce model runtime. The extent and DEM used in the TUFLOW model is shown in Figure 6-26.

6.2.7.2.3 Material layer

A material layer was created based on planning and parcel layers available through VicMap and verified using aerial imagery. The hydraulic roughness coefficients (i.e. Manning’s n) and the rainfall loss values were assigned to each use type. The catchment consists primarily of rural farming land, with roads, open water surfaces and some vegetated areas. Table 6-9 gives the Manning's n-values adopted for the overland flow model based on land use type and standard industry values (e.g. VicRoads road design guidelines). Figure 6-27 shows the land use types corresponding with modelled Manning's n-values for hydraulic roughness.

Rainfall losses were adopted from ARR2019 and adapted based on land use and nearby studies.

Table 6-9 Manning's 'n' roughness values

Land Uses	Manning's 'n'	Initial Loss (mm)	Continuous Loss (mm/hr)
Urban residential	0.35	10	1.5
Open space or waterway, minimal vegetation	0.04	10	2
Open space or waterway, moderate vegetation	0.08	10	2
Open space or waterway, heavy vegetation	0.12	10	2
Open water	0.02	0	0
Waterway	0.04	0	0
Roads	0.02	2.5	0.5

6.2.7.2.4 Model boundaries

As discussed in Section 6.2.7.1.3, hydraulic model inflows were extracted from the RORB model. The upstream model inflow boundaries were located on Mustons, Burchett and Tea Tree Creeks as well as an unnamed tributary east of Tea Tree Creek. Distributed source inflow boundaries were applied directly to the centre of the waterway channels, which represented upstream tributary inflows along each waterway. Hydrographs for the four local catchments were applied as discharge-time relationships (i.e. QT type) at the model boundary. The downstream hydraulic model outflow boundaries were represented using a stage-discharge relationship (i.e. HQ type). These boundaries allowed water to leave the model domain without influencing flood levels. During simultaneous flooding in the Hopkins River and in tributaries of the study area, increased water levels in the Hopkins River may impact the ability for local inundation to leave the southeastern part of the study area. The catchment draining from the study area to the Hopkins River is approximately 17 km^2, compared to the entire upstream Hopkins River catchment, which is over 4,000 km^2. The disparity in size makes simultaneous flooding unlikely, as flooding from the Hopkins River will occur later than runoff from the study area. Should this still occur, the increase in local 1% AEP water levels would be minor and not change the outcome of the impact assessment. All model boundaries are shown in Figure 6-26.

6.2.7.2.5 Rainfall input

Direct rainfall inputs to the TUFLOW model were derived from ARR2019. They were extracted via the QGIS ARR2019 plugin tool which downloads data from the ARR Data Hub and BoM. The critical durations and temporal patterns for the 1% and 10% AEP events were adopted from the RORB model results, see Table 6-7. The same long and short durations were also adopted.

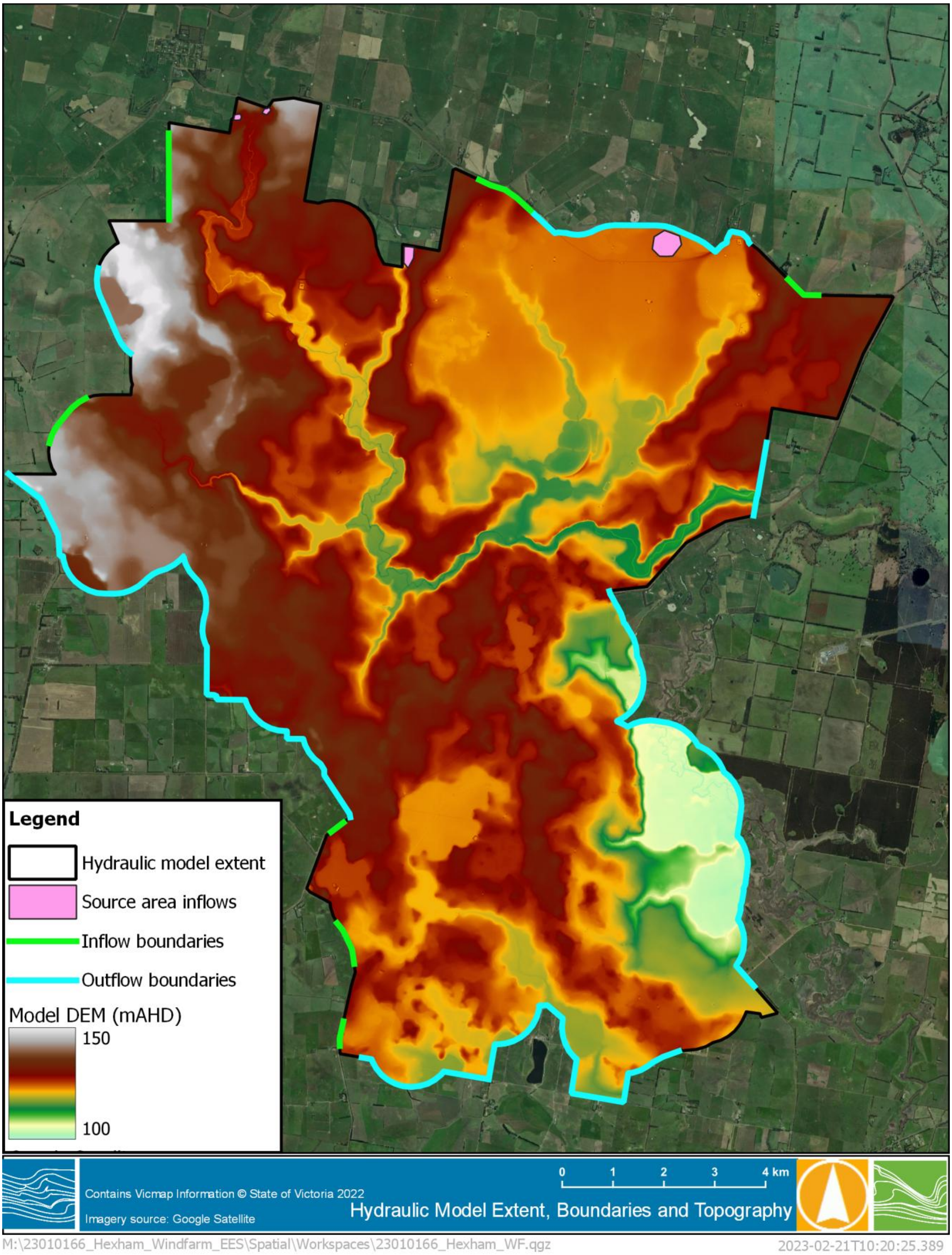

Figure 6-26 TUFLOW model extent, boundaries and topography

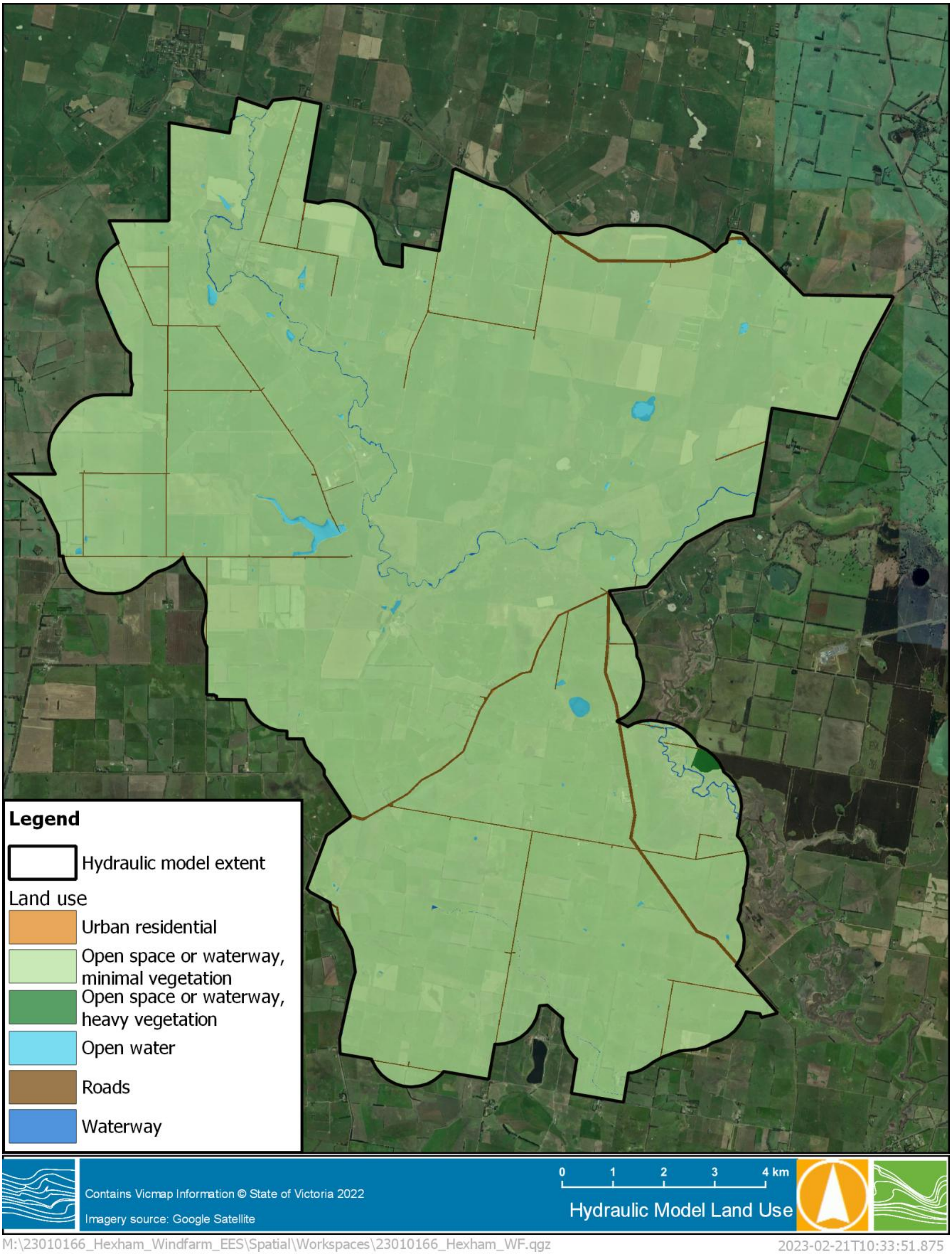

Figure 6-27 TUFLOW model land use

6.2.7.3 Model verification

The modelled 1% AEP peak flow in Mustons Creek near the hydraulic model outlet, which is in a similar location as the RORB model outlet, was 195 m^3/s for the critical duration. This was compared to the peak flow estimates presented in Table 6-8. The hydraulic model peak flow is higher than the verification flows, which is expected based on the discussion in Section 6.2.7.1.3 and indicates that the inflows used represent a conservative approach.

The hydraulic model was also run using the long and short duration model inflows and rainfalls, and the results obtained using the three durations were combined into maximum grids for each variable.

6.2.7.4 Results

The existing conditions 1% and 10% AEP hydraulic model results are outlined in Figure 6-28 to Figure 6-31. Depths below 5 cm were filtered in all presented results. The results indicated that most of the proposed development is located outside of overland flow paths and areas of ponding.

In a 1% AEP event, Mustons Creek breaks out of its banks and inundates a wider floodplain up to 400 m wide. The inundation from Tea Tree, Lyall and Drysdale Creeks is less widespread. Pooling of water in local depressions is observed at many locations, in many instances these local depressions are large and/or connected to nearby depressions. Flow velocities within waterways and major overland flow paths reach up to 2 m/s, with velocities outside of the waterways and flow paths generally less than 0.5 m/s.

While most wind turbines are located outside of the inundation extent, many proposed access tracks intersect waterways of flow paths. This is discussed further in Section 7.1.2.

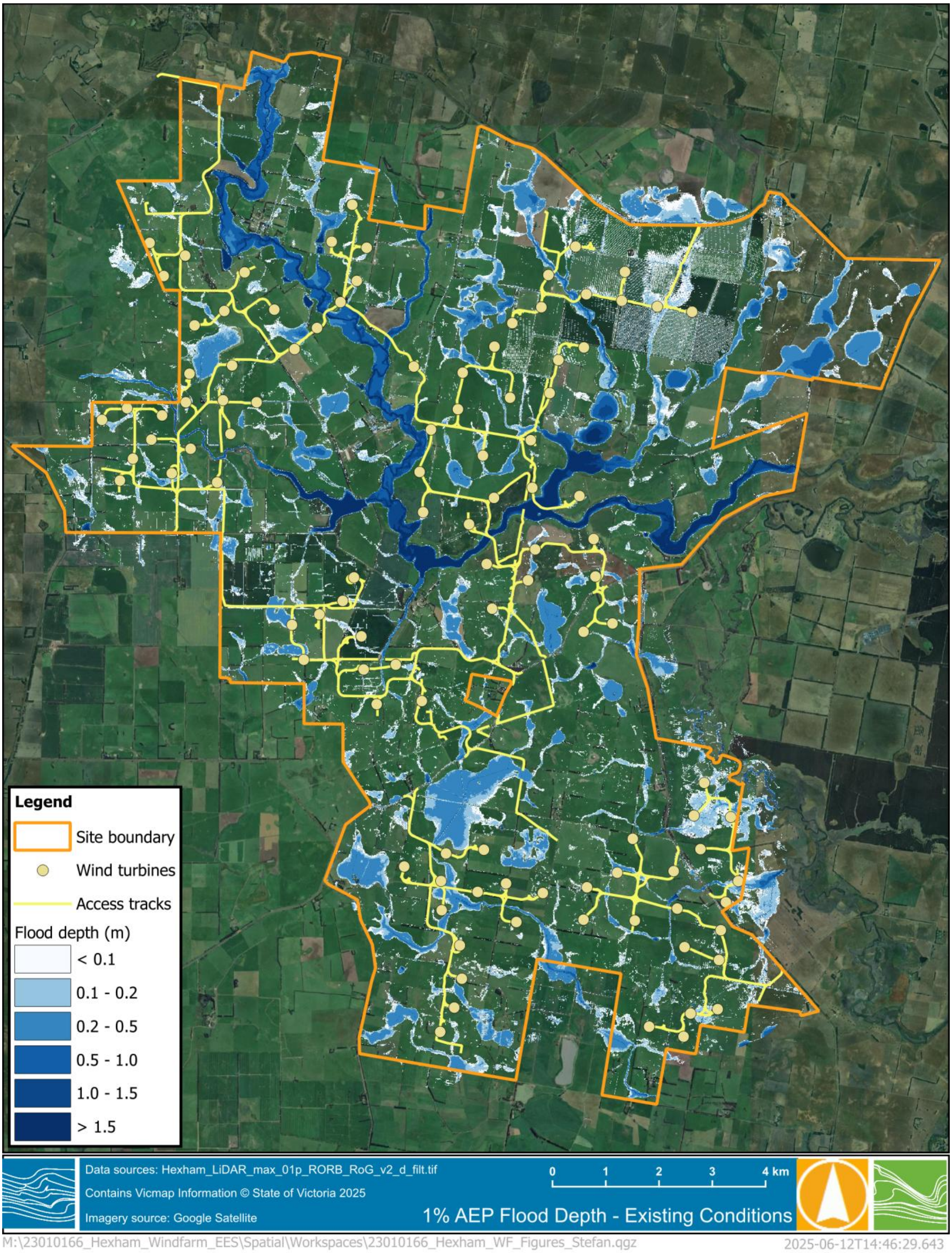

Figure 6-28 1% AEP flood depth – Existing conditions

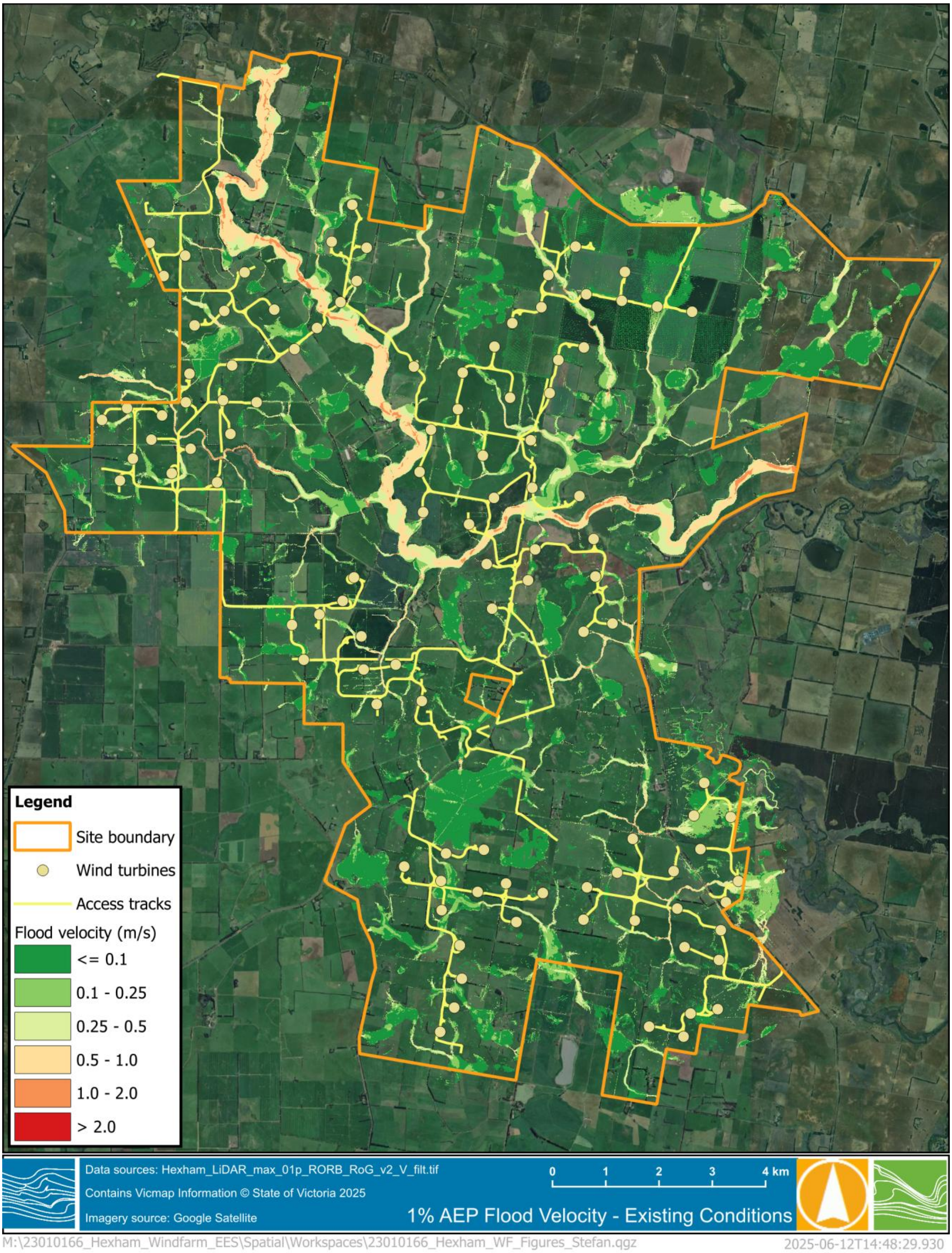

Figure 6-29 1% AEP flood velocity – Existing conditions

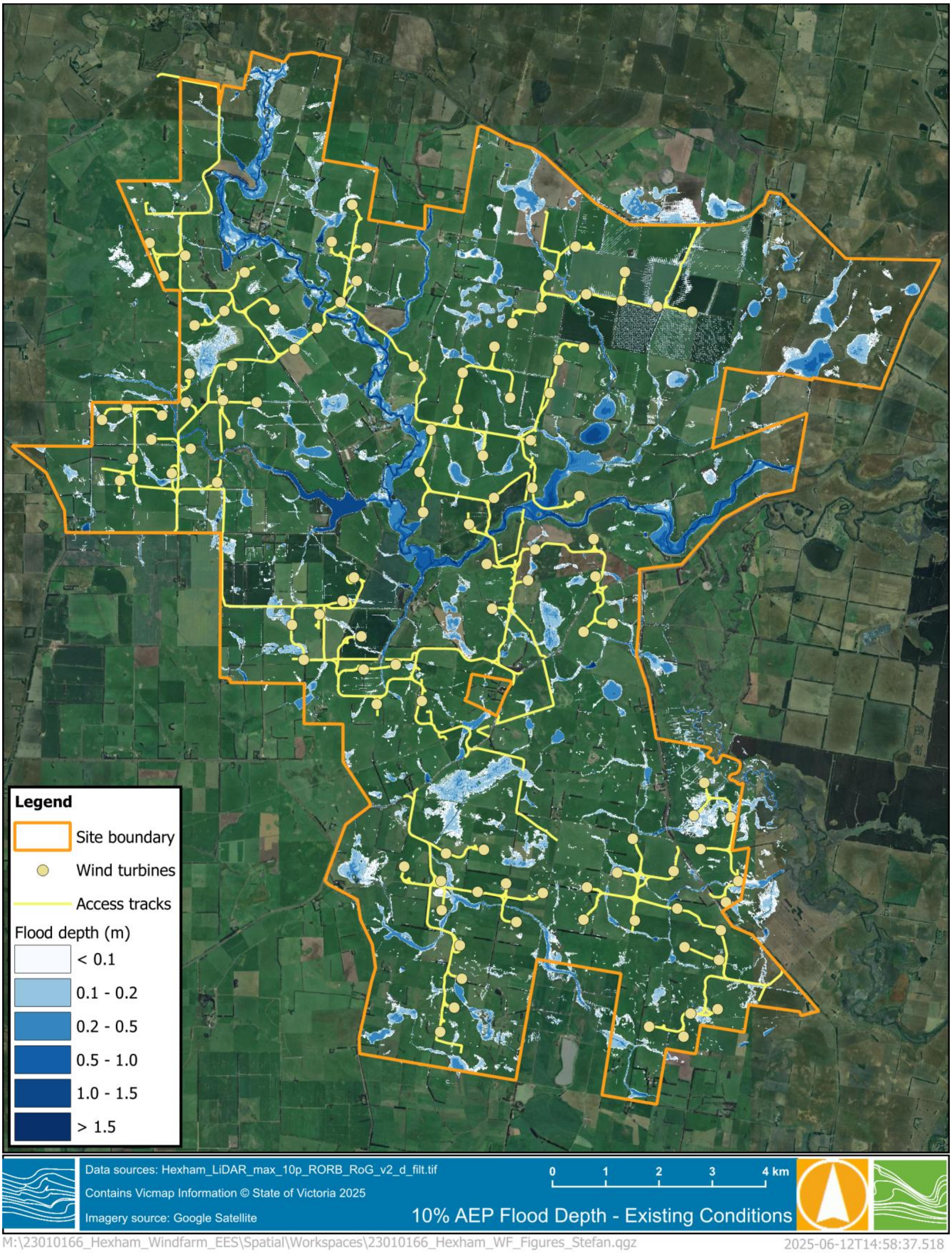

Figure 6-30 10% AEP flood depth – Existing conditions

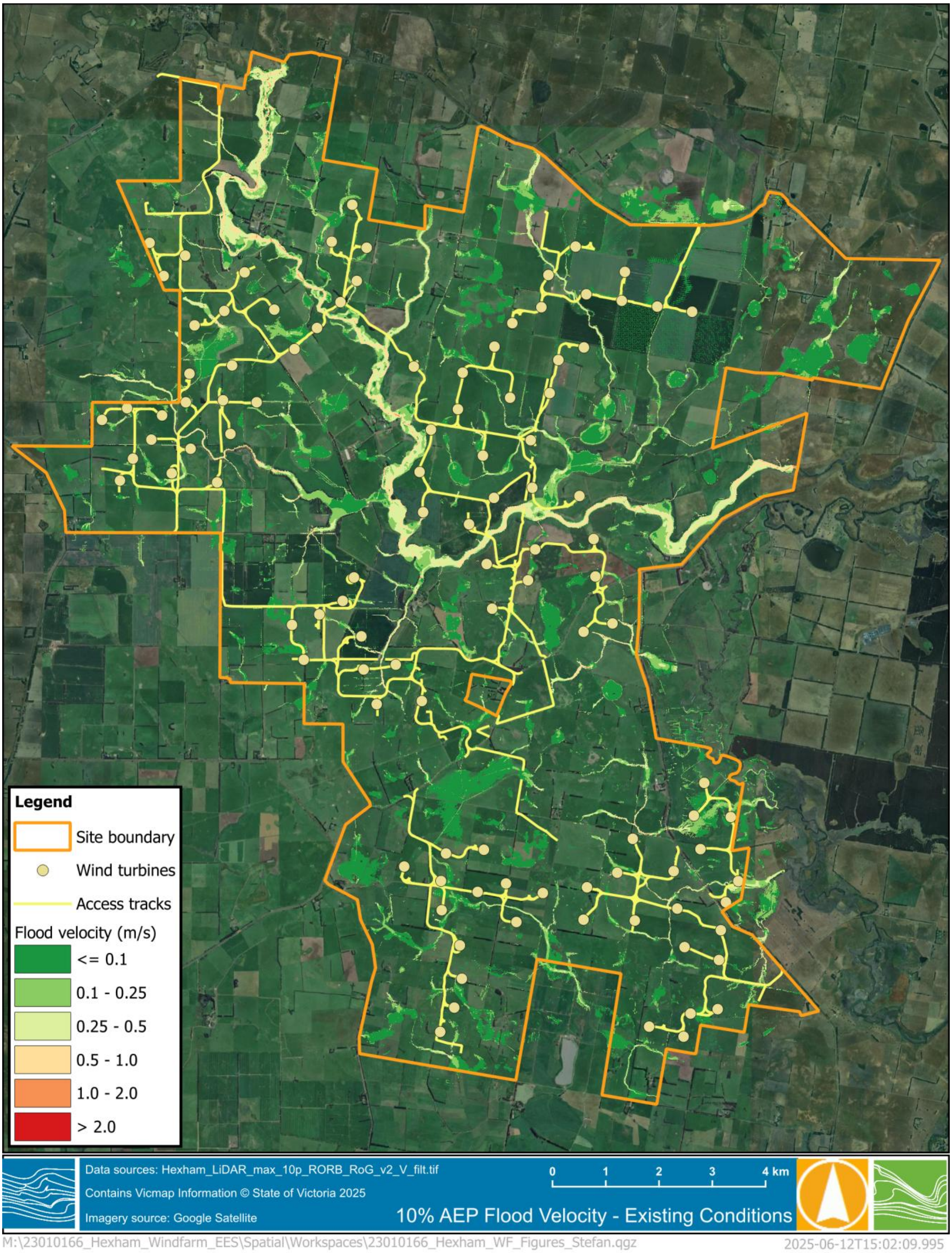

Figure 6-31 10% AEP flood velocity – Existing conditions

6.2.8 Riverine inundation

6.2.8.1 Methodology and inputs

6.2.8.1.1 Overview

A second TUFLOW hydraulic was built to model riverine inundation from the Hopkins River. A single upstream inflow boundary was represented using a hydrograph and the outlet was represented by a stage-discharge relationship. The topography was represented using a combination of the available datasets listed in Section 6.1.2, with a zshape polygon applied along the LiDAR boundary for smoothing. Figure 6-32 shows the model extent, boundaries and topography. The Hopkins River 1% AEP streamflow was determined using flood frequency analysis (FFA) of data from the Hopkins River at Framlingham gauge (236210).

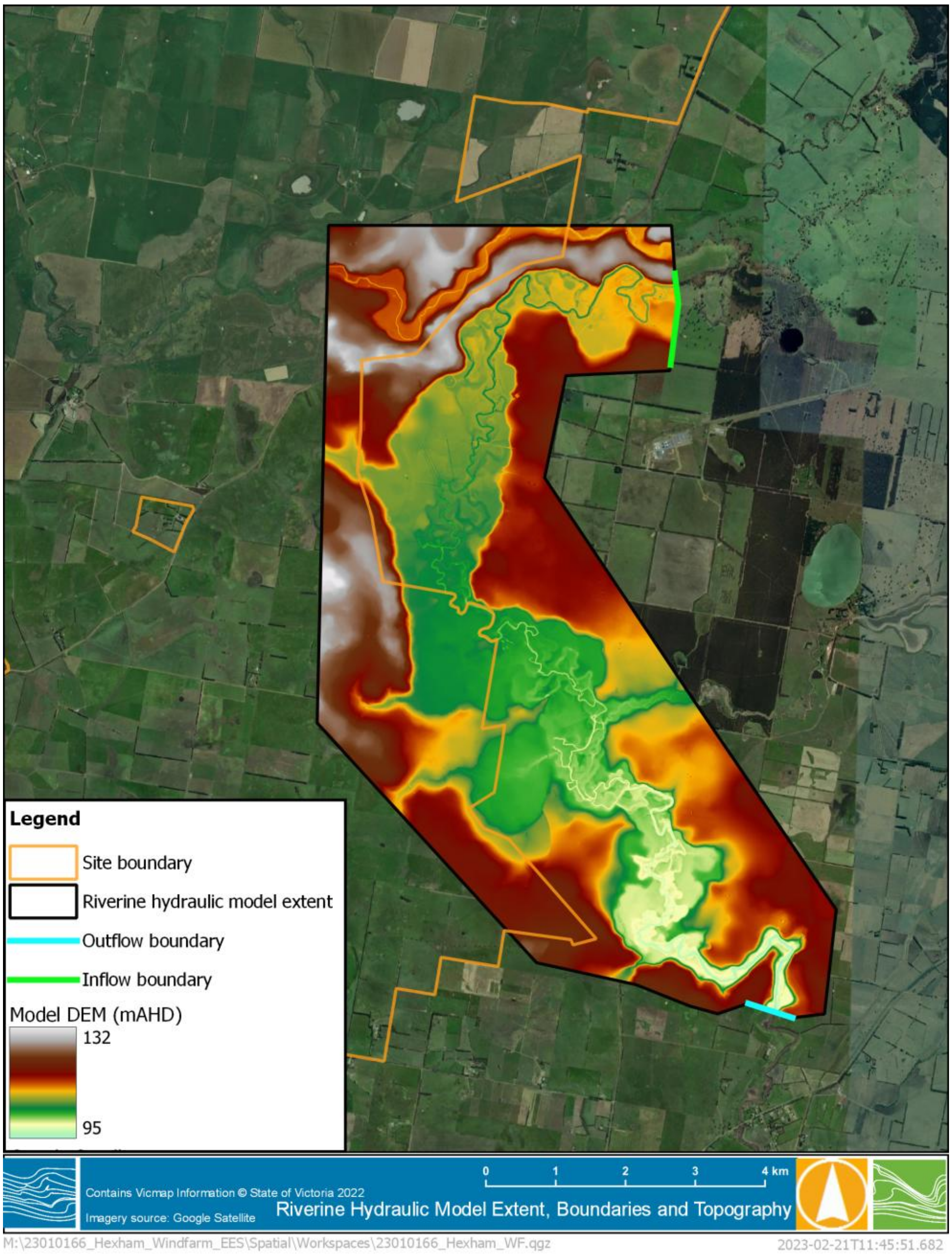

Figure 6-32 Riverine TUFLOW model extent, boundaries and topography

6.2.8.1.2 Flood frequency analysis

FFA was undertaken using streamflow records from the Hopkins River at Framlingham gauge (236210), located 21 km downstream of the project area. This gauge has a period of record from 1955 onwards, providing sufficient data for the FFA. The annual series used for the analysis consisted of the annual maximum streamflow recorded at the gauge, for the 68 years from 1955 to 2022. The largest annual maximum streamflows on record were:

- 2011: 23,092 ML/day
- 2016: 22,433 ML/day
- 2010: 22,016 ML/day
- 1983: 21,048 ML/day
- 1978: 20,733 ML/day

ARR2019 suggests testing of multiple statistical distributions when conducting a FFA for design flow estimation. FLIKE FFA software was used to estimate design flows using the Log Pearson III and Generalised Pareto distributions. The Multiple Grubbs Beck test was applied as a method of low flow censoring. The results from the FFA for the different distributions are presented in Table 6-10.

The Log Pearson III distribution with Grubbs Beck censoring applied was found to provide the best fit with the annual maximum streamflow series, see Figure 6-33. The resulting 1% AEP peak streamflow was 26,779 ML/day, equal to 310 m^3/s. A similar fit was observed for Generalised Pareto with censoring, also resulting in a similar 1% AEP peak flow.

Table 6-10 FFA design flows (ML/d)

Design flood (AEP)	50%	20%	10%	5%	2%	1%
LPIII	4,352	11,634	16,338	20,080	23,700	25,638
10% confidence limit	3,115	9,445	13,855	17,567	21,053	22,776
90% confidence limit	5,839	14,451	19,862	24,573	30,289	35,624
LPIII with GB	4,109	11,631	16,653	20,702	24,653	26,779
10% confidence limit	3,114	9,217	13,516	17,562	20,825	22,620
90% confidence limit	6,023	14,893	20,285	24,876	32,888	38,915
GP	4,579	10,977	16,118	21,534	29,139	35,250
10% confidence limit	3,365	8,560	12,671	16,551	20,800	23,313
90% confidence limit	5,819	13,463	21,188	31,708	49,664	67,372
GP with GB	10,418	16,935	20,424	23,020	25,461	26,768
10% confidence limit	8,289	13,903	17,281	19,735	21,819	22,612
90% confidence limit	12,632	19,468	23,683	28,773	36,019	41,415

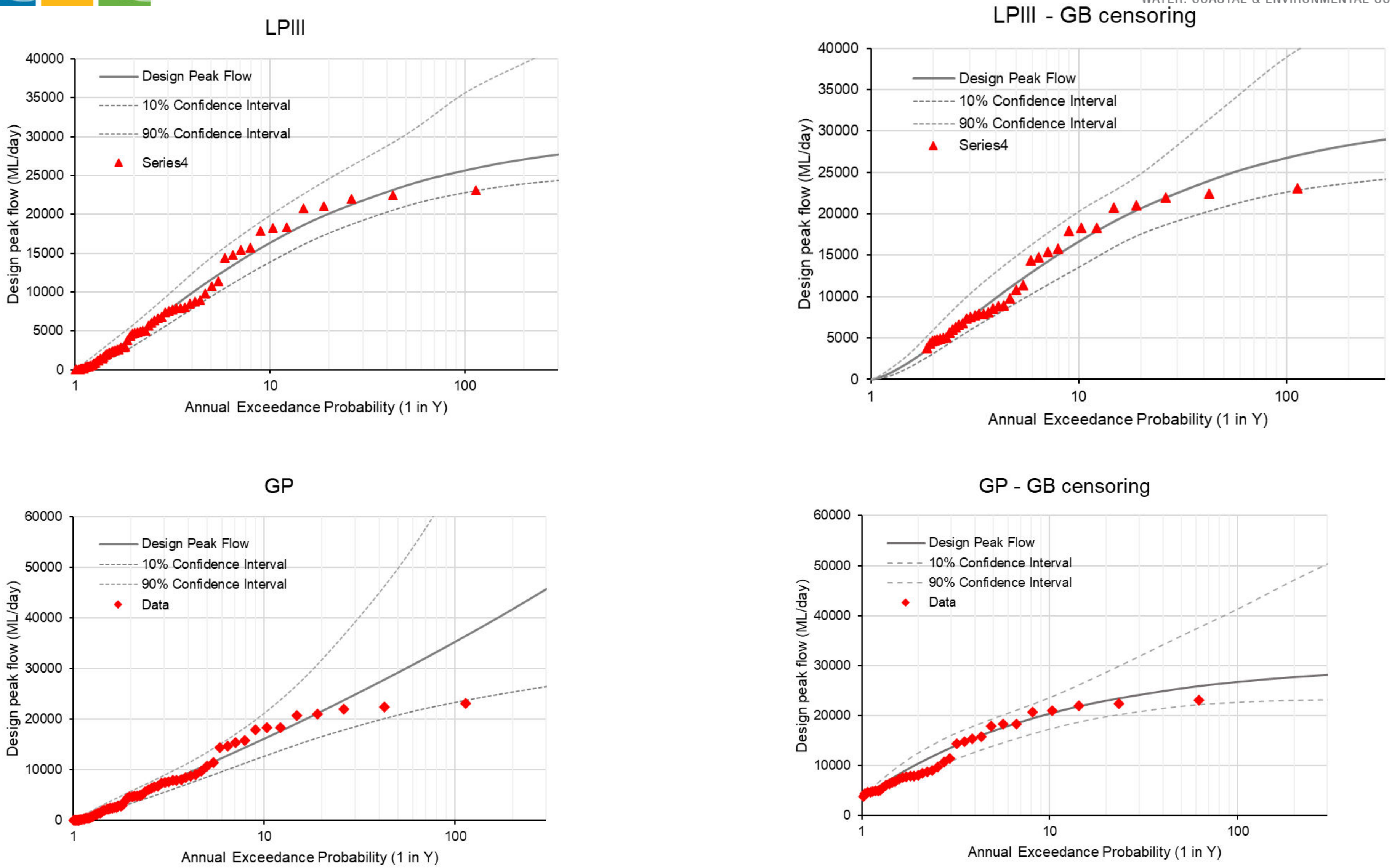

Figure 6-33 Annual maximum streamflow series and distributions – Peak flow

To create an inflow hydrograph using the 1% AEP peak streamflow, FFA was also done for the total flood event volume. Based on the longevity of flood events observed at this gauge, a 14 day volume was used to determine the annual series of peak volumes. For years where the timing of the peak 14 day volume did not agree with the timing of the peak flow, either the peak or volume were adjusted to use the annual event best representing the annual maximum flood event.

The largest annual maximum 14 day volumes on record were:

- 1983: 178,396 ML
- 2022: 150,582 ML
- 1975: 145,485 ML
- 2011: 133,787 ML
- 1984: 126,747 ML

The Log Pearson III and Generalised Pareto distributions with and without the Multiple Grubbs Beck test were used to estimate design flow volumes, see Table 6-11. The Log Pearson III distribution with Grubbs Beck censoring applied was found to provide the best fit with the annual maximum volume series, see Figure 6-34. The resulting 1% AEP peak volume was 192,465 ML.

Table 6-11 FFA design 14 day volumes (ML)

Design flood (AEP)	50%	20%	10%	5%	2%	1%
LPIII	27,724	75,790	110,315	140,651	173,584	193,418
10% confidence limit	20,532	58,557	91,519	117,526	145,622	161,272
90% confidence limit	37,524	96,166	136,131	172,389	221,186	257,977
LPIII with GB	29,541	77,894	111,891	141,466	173,350	192,465
10% confidence limit	21,284	61,534	91,869	118,350	145,028	159,796
90% confidence limit	39,031	97,282	140,491	176,697	221,748	255,134
GP	31,067	74,729	110,172	147,837	201,278	244,657
10% confidence limit	22,807	58,273	86,408	112,387	140,590	157,834
90% confidence limit	38,772	92,209	145,800	216,667	366,846	523,791
GP with GB	33,313	75,933	110,099	146,016	196,337	236,676
10% confidence limit	24,844	59,576	87,025	112,278	140,682	157,865
90% confidence limit	41,792	91,816	138,138	207,289	344,176	497,197

The 1% AEP peak flow and 14 day volume were used to construct an inflow hydrograph for the Hopkins River just upstream of the project area. Since the flow and volume were based on recorded data at Framlingham, downstream of the project area, the Hopkins River catchment upstream of Framlingham was investigated to identify any tributary catchments upstream of Framlingham, but downstream of the project area. Only the Stony Creek catchment was identified as not contributing flow to Hopkins River in the vicinity of the project area, and the hydrograph was scaled using a catchment area ratio to reduce the flow.

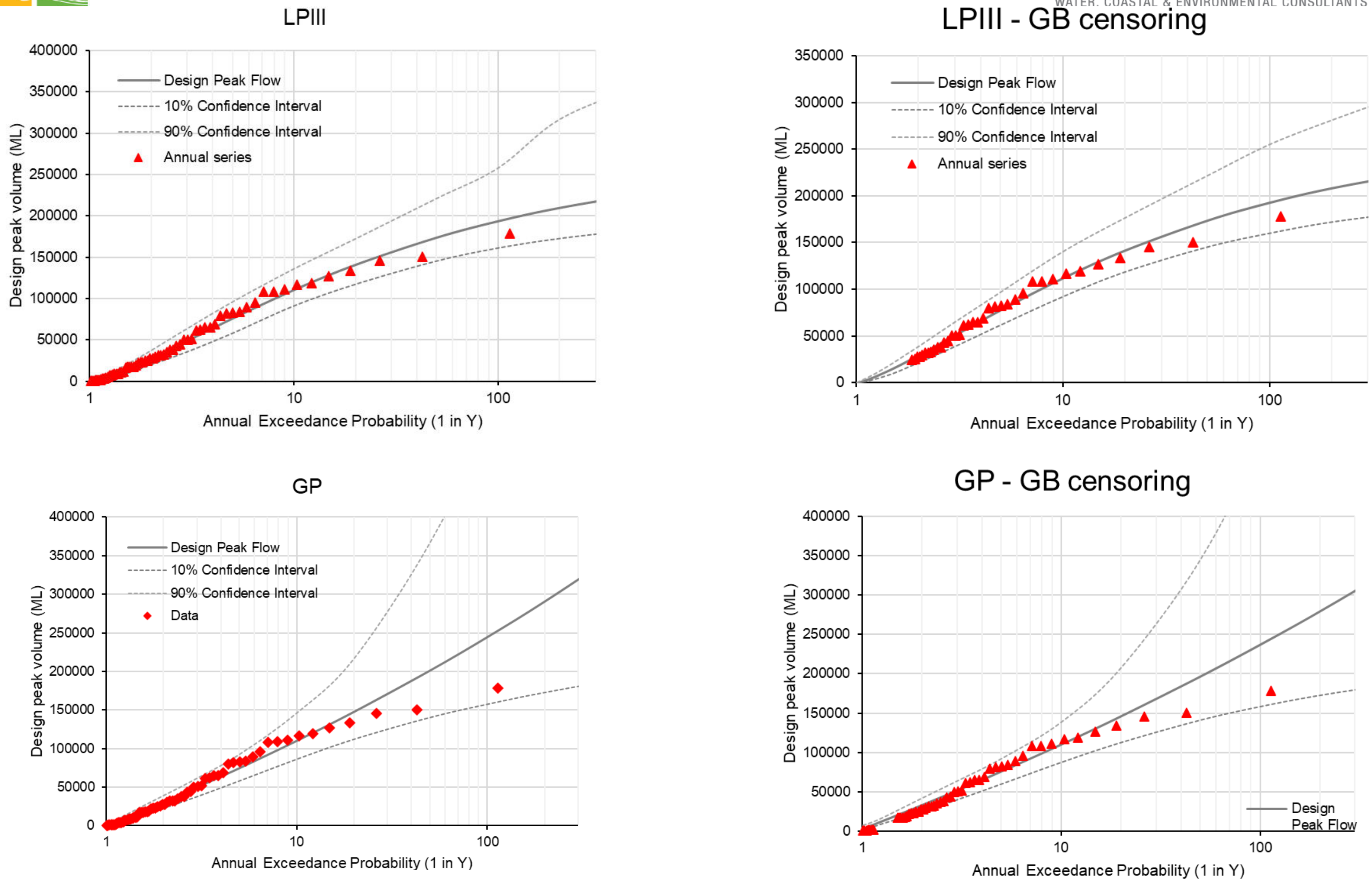

Figure 6-34 Annual maximum streamflow series and distributions – Peak volume

6.2.8.2 Results

The 1% AEP riverine hydraulic model results are shown in Figure 6-35, in an 1% AEP flood event, the Hopkins River inundates a floodplain that is wider than 1 km in some sections near the project area. While most of the project area is shown to be outside of the modelled Hopkins River flood extent, a small part of the proposed development components including a number of wind turbines, access tracks and underground cables are within the riverine inundation extent. This is discussed further in Section 7.1.2.

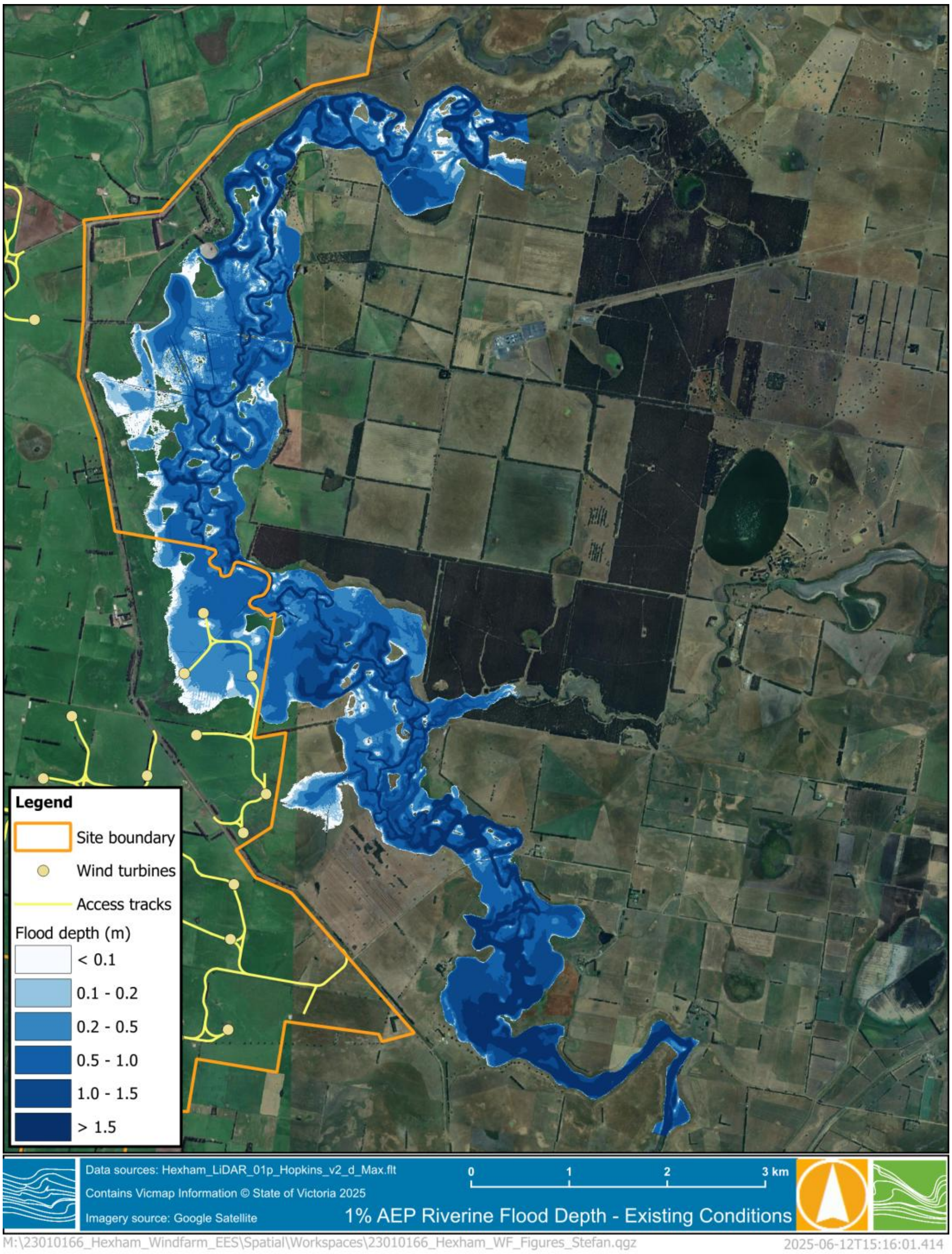

Figure 6-35 1% AEP riverine inundation

6.2.9 Climate change modelling

The Project is in the "Southern Slopes Climate Zone" according to BoM and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) classifications. There are a set of 40 global climate projection models used to assist in the analysis and representation of future temperature, evaporation, and rainfall. These models relate results to the Representative Concentration Pathway (RCP) projections and the specific locations throughout Australia. There are predictions for four RCPs, these are as follows:

- RCP8.5 - a future with little curbing of emissions, with a CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100.
- RCP6.0 – lower emissions, achieved by application of some mitigation strategies and technologies. CO_2 concentration rising less rapidly (than RCP8.5), but still reaching 660 ppm by 2100 and total radiative forcing stabilising shortly after 2100.
- RCP4.5 - CO_2 concentrations are slightly above those of RCP6.0 until after mid-century, but emissions peak earlier (around 2040), and the CO_2 concentration reaches 540 ppm by 2100.
- RCP2.6 - the most ambitious mitigation scenario, with emissions peaking early in the century (around 2020), then rapidly declining. Such a pathway would require early participation from all emitters, including developing countries, as well as the application of technologies for actively removing carbon dioxide from the atmosphere. The CO_2 concentration reaches 440 ppm by 2040 then slowly declines to 420 ppm by 2100) (Detlef P. van Vuuren et. al. (2011), The representative concentration pathways: An Overview).

The future impacts from anthropogenic greenhouse gas and aerosol emissions remains highly uncertain with many known and unknown influences and of the above scenarios none is considered more likely given these uncertainties. A graphical comparison of the pathways is represented in Figure 6-36 below.

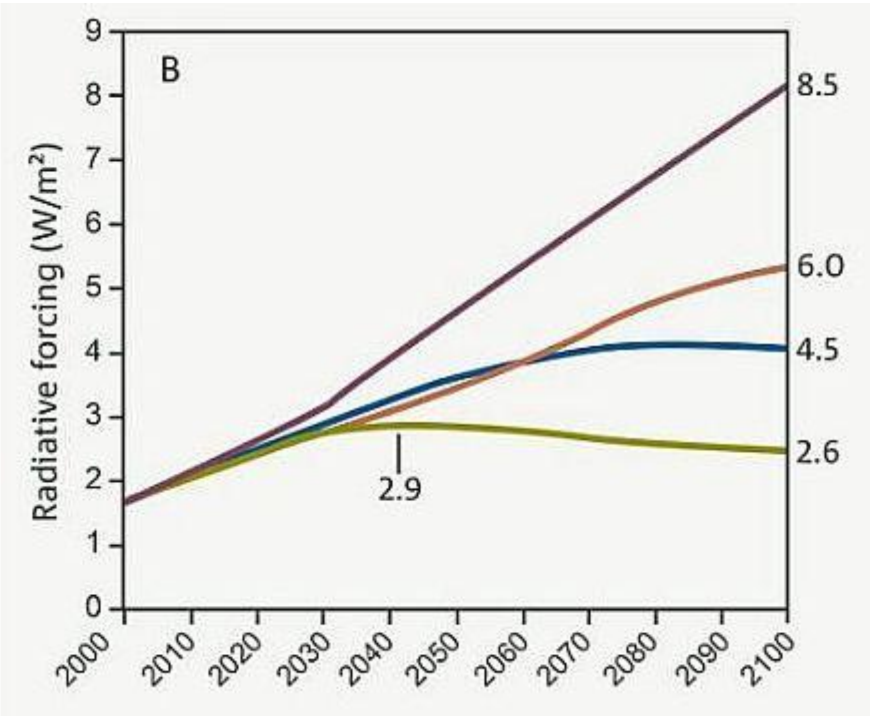

Figure 6-36 Radiative forcing for the different RCPs. The numbers on the right show the final radiative forcing at 2100 and give each scenario its name (8.5, 6.0, 4.5, and 2.6 W/m^2) (Climate change in Australia Technical Report

Given the uncertainty regarding which RCP scenario will be relevant in the future it was determined that RCP 8.5 by 2100 would be modelled in this Project giving the highest RCP scenario to achieve the most conservative assessment. Modelling all the available scenarios was not considered useful, just adding to the numerous uncertainties. Modelling of the RCP 8.5 demonstrates the worst case of the four options.

The following section details how climate change has been included in the event based hydraulic modelling.

6.2.9.1 Overview and model input

Climate change modelling was adopted for the direct/localised catchment inundation modelling described in Section 6.2.7. Predicted climate change rainfall was extracted via the ARR2019 plugin tool which downloads data directly from the ARR Data Hub and BoM, and consisted of increased rainfall intensities. Since data is only available up until the year 2090, the climate change rainfall intensities had to be extrapolated to represent 2100 values. How these depths were determined for existing climatic conditions is detailed in Section 6.2.7.2.5. The extracted data represents design rainfall under the selected climate change scenario and was used both in the hydrologic model for hydrograph extraction and in the RoG hydraulic model.

6.2.9.2 Results

The effect of climate change on flood levels for the existing topographic conditions was assessed by comparing results obtained using current climatic conditions with results obtained using the climate change scenario. The change in water levels across the site due to climate change for the 1% AEP and 10% AEP events are shown in Figure 6-37 and Figure 6-38 respectively. Increased rainfall under the climate change scenario has generally brought about greater flooding depths and a slightly greater inundation extent, but no overall change to inundation patterns or runoff pathways.

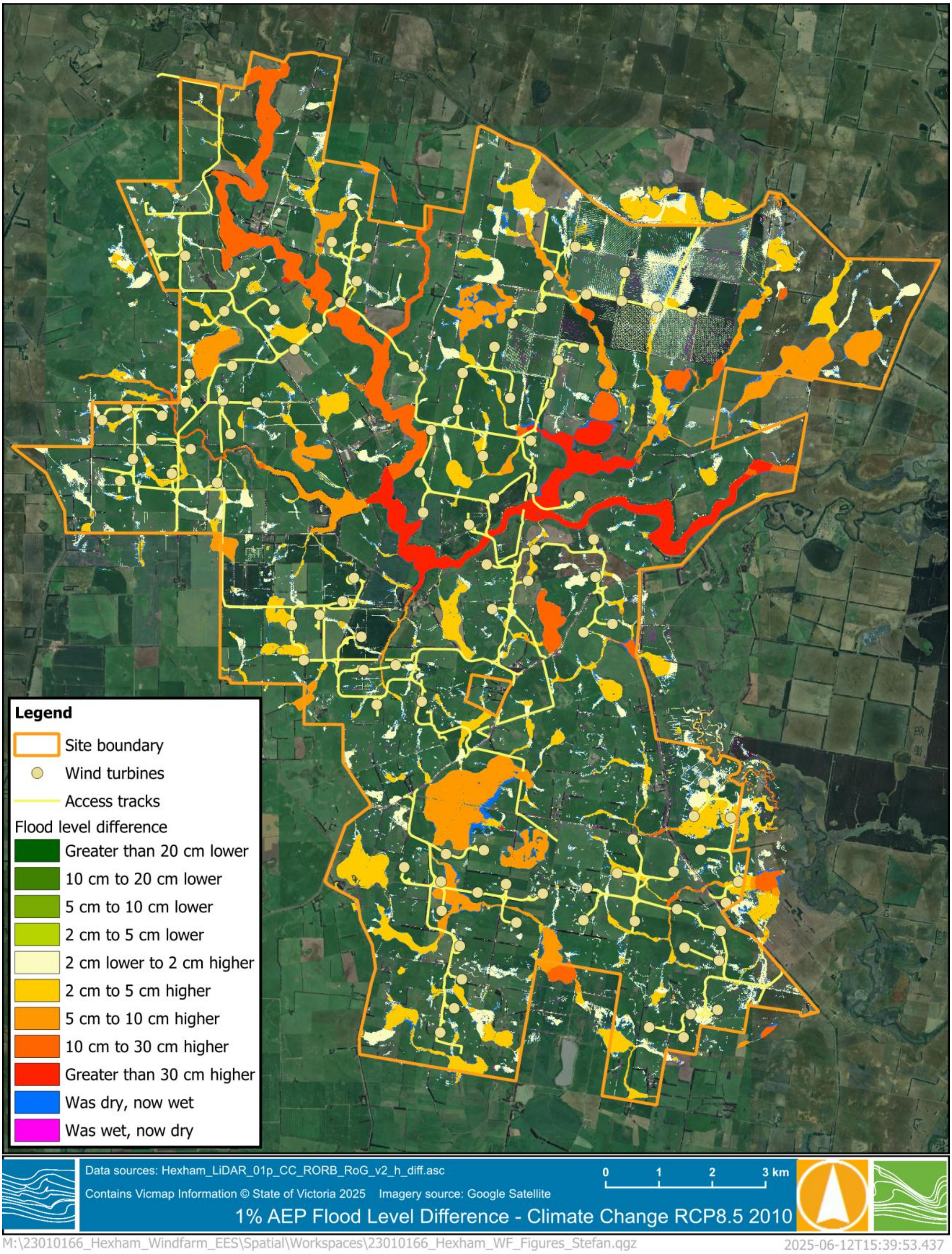

Figure 6-37 1% AEP flood level difference – RCP8.5 2100

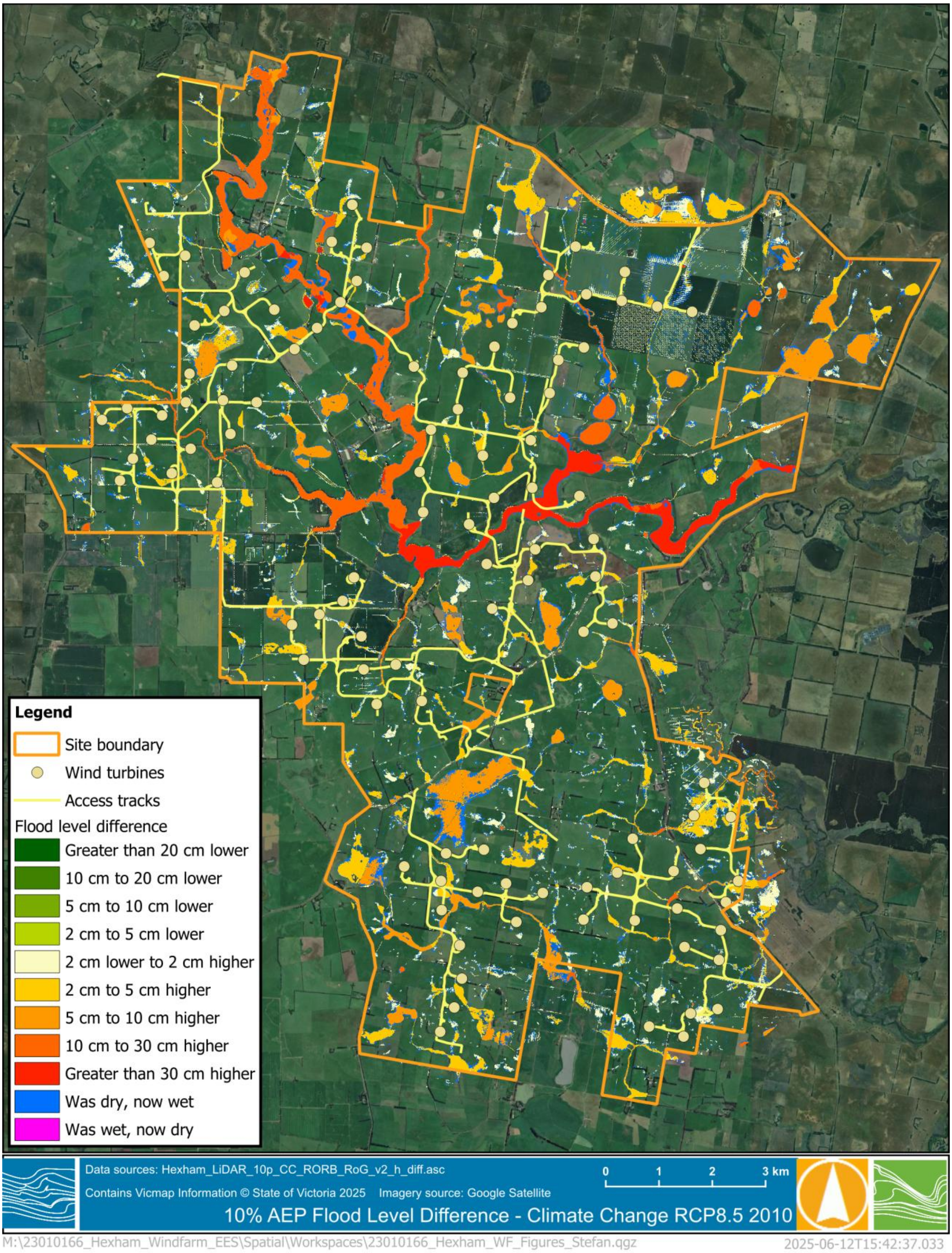

Figure 6-38 10% AEP flood level difference – RCP8.5 2100

6.2.10 Water quality

6.2.10.1 Historic water quality data

There are no known recent water quality data available for the site and its surrounds or from watercourses upstream or downstream of the site. However, historic water quality observations available through DEECA for the Hopkins River were included in this assessment for contextual purposes. Two historic gauges with relevant water quality data were identified as follows:

- Hopkins River at Wickliffe gauge (236202) located upstream of the site (data available from 1976 to 2005)
  - Historic data from the above gauge primarily consists of general water quality parameters (physical/chemical stressors such as DO, Turbidity, Conductivity, pH, Temperature, etc.) measured on an approximately monthly basis
  - Nutrient data (Nitrogen speciates, and Total Phosphorus and speciates) are available for an 8-year period (1990 to 1998), sampled monthly
  - No toxicant data was available for this location
- Hopkins River at Framlingham gauge (236210) located downstream of the site (data available from 1975 to 1998).
  - Historic data from the above gauge location primarily consists of general water quality parameters (physical/chemical stressors and nutrients such as DO, Turbidity, Conductivity, pH, Temperature, etc.) measured on an approximately monthly basis
  - Unlike the Wickliffe gauge, nutrient data (Total Nitrogen and Total Phosphorus or speciates) were not available for this location
  - Data for toxicants was available for this gauge, albeit for three sampling events only.

Table 6-12 summarises relevant water quality stressors from historic samples against ERS guidelines. Table 6-13 summarises available historic toxicant data from the Framlingham gauge against ERS/ANZECC guidelines. Values exceeding guideline trigger values are highlighted in red text. It is important to note that the values presented are for contextual purposes only and are from a period when ANZECC or ERS guidelines did not apply. Locations of the two gauges in reference to the site are presented in Figure 6-3.

Table 6-12 Environmental water quality objectives vs historic sampled data

Stressor	Sample count	Environmental Quality Indicator (value in brackets)	Measured values
Hopkins River at Wickliffe gauge (#236202)			
Total Phosphorus (µg/L)	99	75^{th} percentile ≤55	75^{th} percentile = 80
FRP (µg/L)	99	N	Median = 4
Total Nitrogen (µg/L)	-	75^{th} percentile ≤1000	75^{th} percentile = 1800[8]
Total NO2+NO3 (µg/L)	99	Not Applicable	Median = 4
Kjeldahl N (µg/L)	99	Not Applicable	Median = 1350
Dissolved oxygen (percent saturation)	-	25^{th} percentile ≥65 Maximum = 130	Not available

[8] Derived from sampled values for Total NO2 + NO3 + Kjeldahl N

Stressor	Sample count	Environmental Quality Indicator (value in brackets)	Measured values
DO (ppm)	266	Not Applicable	Median = 8.5
Turbidity (NTU)	266	75th percentile ≤20	75th percentile = 8
Electrical Conductivity (EC) (µS/cm@ 25°C)	266	75th percentile ≤2000	75th percentile = 11,050
Acidity/alkalinity (pH units)	266	25th percentile ≥7.0 75th percentile ≤8.0	25th percentile = 7.5 75th percentile = 8.1
TSS (µg/L)	99	Not Applicable	Median = 800
Hopkins River at Framlingham gauge (#236210)			
Total Phosphorus (µg/L)	-	75th percentile ≤55	Not available
FRP (µg/L)	-	Not Applicable	Not available
Total Nitrogen (µg/L)	-	75th percentile ≤1000	Not available
Total NO2+NO3 (µg/L)	-	Not Applicable	Not available
Kjeldahl N (µg/L)	-	Not Applicable	Not available
Dissolved oxygen (percent saturation)	-	25th percentile ≥65 Maximum = 130	Not available
DO (ppm)	164	Not Applicable	Median = 9.2
Turbidity (NTU)	164	75th percentile ≤20	75th percentile = 16
Electrical Conductivity (EC) (µS/cm@ 25°C)	164	75th percentile ≤2000	75th percentile = 7225
Acidity/alkalinity (pH units)	164	25th percentile ≥7.0 75th percentile ≤8.0	25th percentile = 7.48 75th percentile = 8.3
TSS (µg/L)	-	Not Applicable	Not available

Table 6-13 **Relevant toxicant trigger guideline values vs historic sampled data @ Framlingham gauge (236210) located downstream of the site**

Toxicants	Sample count	95% protection trigger values for freshwater	Measured values
Ammonia (mg/L)[9]	-	0.9	Not available
Nitrate (mg/L)[10]	-	2.4	Not available
Aluminium (pH >6.5) (mg/L)	-	0.055	Not available
Aluminium (pH <6.5) (mg/L)	-	0.008	Not available
Arsenic (AsIII) (mg/L)	-	0.024	Not available

[9] Ammonia as total ammonia (NH3-N) at pH 8

[10] Nitrate as NO3-N, based on "Grading" guideline values published in the report "Updating nitrate toxicity effects on freshwater aquatic species".

Toxicants	Sample count	95% protection trigger values for freshwater	Measured values
Arsenic (AsV) (mg/L)	-	0.013	Not available
Boron (mg/L)	-	0.37	Not available
Cadmium (mg/L)	3	0.0002	0.0002
Chromium (CrIII+CrVI) (mg/L)[11]	3	0.001	0.0019
Copper (mg/L)	3	0.0014	0.0057
Lead (mg/L)	3	0.0034	0.001
Manganese (mg/L)	-	1.9	Not available
Mercury (mg/L) (inorganic)	-	0.0006	Not available
Nickel (mg/L)	3	0.011	0.0059
Selenium (mg/L)	-	0.011	Not available
Silver (mg/L)	-	0.00005	Not available
Zinc (mg/L)	3	0.008	0.019

The following observations were made from the historic sampled data:

- Upstream: Hopkins River at Wickliffe gauge (236202)
  - Nutrient values (Total Nitrogen and Total Phosphorus) were observed to exceed the 75th percentile guideline trigger values
  - Electrical conductivity was significantly elevated when comparison with the 75th percentile guideline trigger value
  - The upper limit for pH was observed to slightly exceed guideline trigger values
- Downstream: Hopkins River at Wickliffe gauge (236202)
  - Nutrient values were not measured at the Wickliffe gauge
  - Electrical conductivity was significantly elevated when comparison with the 75th percentile guideline trigger value
  - The upper limit for pH was observed to slightly exceed guideline trigger values
  - Toxicants (Copper, Chromium and Zinc) were observed to exceed the 95th percentile guideline trigger values
- 75th percentile turbidity values were observed to be well within the guideline trigger values at both the upstream and downstream sampled locations. However, turbidity levels were observed to significantly rise during or immediately after rainfall events at both locations (see Figure 6-39 and Figure 6-40).

[11] In its aqueous form, Chromium exists as CrIII and CrVI. The trigger value is for CrVI only; however the sample represents CrIII and CrVI.

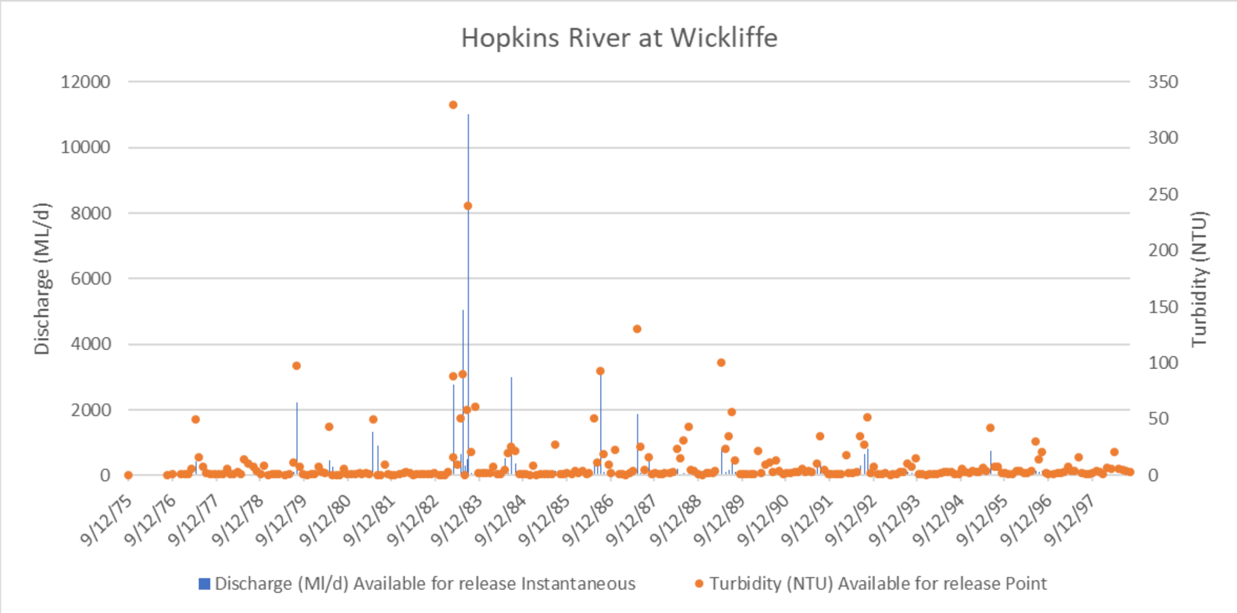

Figure 6-39 Historic Turbidity values at Wickliffe Gauge

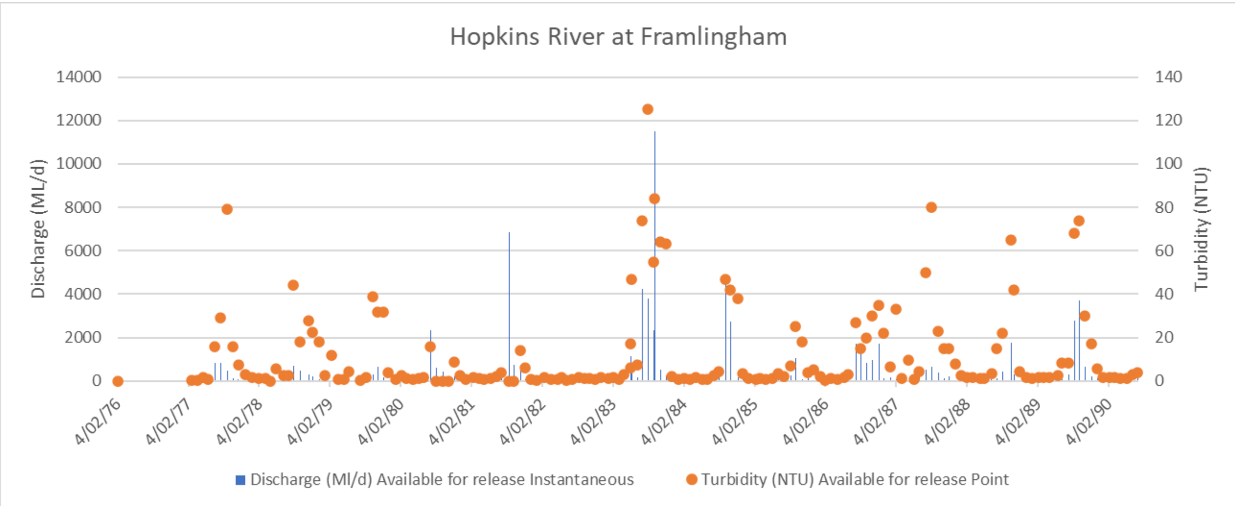

Figure 6-40 Historic Turbidity values at Framlingham Gauge

6.2.10.2 Sampled data overview

One set of baseline surface water quality samples was collected by Water Technology from six locations (five upstream and one downstream) on the 31st of January 2023, near the site. The samples were analysed for physical and chemical stressors and select toxicants. It is important to note that the sampled data cannot be used as a substitute for compliance purposes as the sample numbers are limited (only one sample was collected per site).

The Water Technology sampling locations are shown in Figure 6-41, and further details are presented in Table 6-14. Note that the location labelled "S4" was originally included in an unnamed tributary of Mustons Creek but later removed from the sampling schedule due to lack of flow.

Table 6-14 Water quality sample locations

Sample ID	Location
S1	Burchett Creek
S2	Mustons Creek US
S3	Tea Tree Creek
S5	Hopkins River US
S6	Mustons Creek DS
S7	Hopkins River DS

6.2.10.3 General water quality

Sampled water quality parameters with respect to the relevant ERS or ANZECC/ANZG water quality objectives (where present) are presented in Table 6-15.

As the samples do not provide information on the temporal variability of ambient water quality in the sampled sites, an indicative understanding of local water quality can be derived. Values highlighted in red indicate recorded values which exceeded the ERS water quality objectives. The samples were also assessed as a group. The following parameters exceeded ERS water quality objectives or ANZECC guideline values:

- pH exceeded 75th percentile trigger values in some samples (S1, S2, S3 & S5)
- Electrical Conductivity exceeded 75th percentile trigger values for all samples (S1, S2, S3, S5, S6 & S7)
- Turbidity (S3)
- Total Phosphorus (S3, S5 & S6)

It is important to note that the measured values are from single (one-off) samples at each site and therefore cannot statistically be representative of site general conditions. However, they can be indicative of site conditions. We note that observations of historic data from the DEECA gauge showed that measured background electrical conductivity and pH values upstream and downstream of the site also exceeded guideline values.

Further water quality sampling and analysis is required to establish an understanding of the baseline water quality prior to works commencing on site, this is described in Section 8.1.3 and Appendix B.

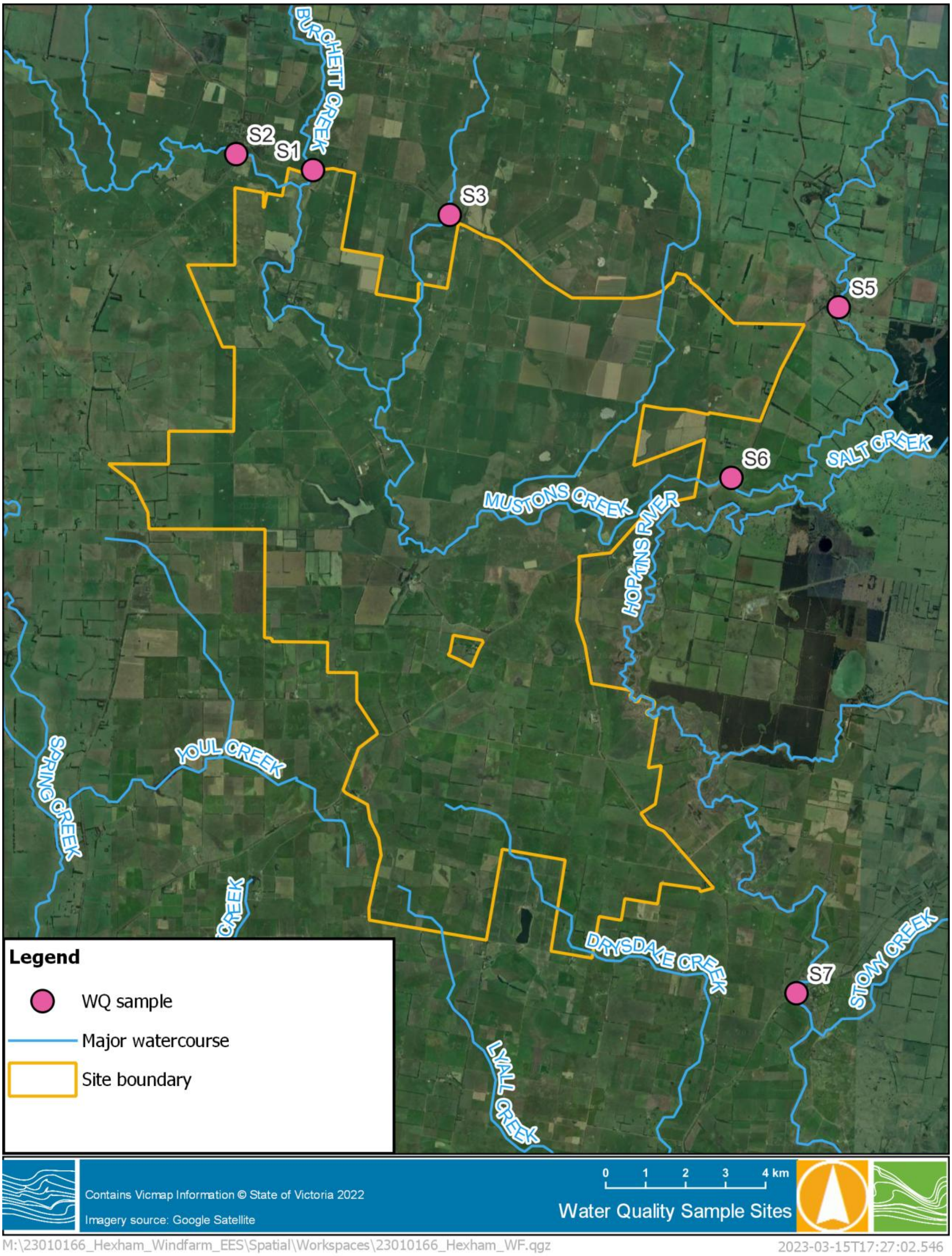

Figure 6-41 Water quality sampling locations

Table 6-15 Water quality sampling data - physical and chemical stressors

Parameter	Units	LOR	ERS / SEPP / ANZECC objective	S1	S2	S3	S5	S6	S7	Group analysis		
										25th percentile	75th percentile	Max
pH Value	pH Unit	0.01	25th percentile ≥7.0 75th percentile ≤8.0	8.3	8.3	8.2	8.2	7.8	7.9	7.9	8.2	
Electrical Conductivity @ 25°C	µS/cm	1	75th percentile ≤2000	6940	5140	1510	8280	5720	5560	5245	5640	6635
Turbidity	NTU	0.1	75th percentile ≤20	15.5	7.3	44.7	4.1	11.5	5.2	-	9.4	-
Nitrite + Nitrate as N	µg/L	0.01	Not applicable	20	10	50	40	20	100	-	-	-
Total Kjeldahl Nitrogen as N	µg/L	0.1	Not applicable	200	200	1200	600	3600	400	-	-	-
Total Nitrogen as N	µg/L	0.1	75th percentile ≤1000	200	200	1200	600	3600	500	-	550	-
Total Phosphorus as P	µg/L	0.01	75th percentile ≤55	20	10	60	80	610	10	-	40	-
Dissolved Oxygen Sat	%	n/a	25th percentile ≥65 Maximum =130	n/a	n/a	n/a	n/a	n/a	n/a	-	-	-
Dissolved Oxygen	mg/L	0.1	Not applicable	11	10.2	9.6	9.7	9.7	9.9	-	-	-

6.2.10.4 Toxicants

Samples collected by Water Technology were analysed for hydrocarbons at location S5 due to its location downstream of several waterways intersecting the site.

The sampled data is presented in Table 6-16. The samples did not exceed the ANZECC 95th percentile freshwater ecosystem guideline values. It should be noted the dataset is likely to contain numerous periods of low flow due to the impact of drought, changed climate and overextraction of catchment flow (largely captured in upper catchment dams, both farm dams and more formal storages).

Table 6-16 Relevant toxicant Trigger Values for Slightly to Moderately Disturbed Waters (ANZECC 2000/ANZG 2018)

Toxicants	LOR	Trigger	Measured values
Hydrocarbons		**95% protection trigger values for freshwater**	
EP080: BTEXN[12]			
Benzene (µg/L)	1	950	<1
Toluene (µg/L)[13]	2	180	<2
Ethylbenzene (µg/L)[13]	2	80	<2
meta- & para-Xylene (µg/L)[13]	2	75 and 200 respectively	<2
ortho-Xylene (µg/L)	2	350	<2
Total Xylenes (µg/L)	2	-	<2
Sum of BTEX (µg/L)	1	-	<1
Naphthalene (µg/L)	5	16	<5

6.2.11 Groundwater/surface water interaction

The surface water assessment carried out for the project included estimation of infiltration losses; however, these were represented as a loss from surface water and may not necessarily contribute to groundwater. A large proportion of infiltration loss is retained as subsoil moisture to be taken up by plants (evapotranspiration) in the weeks following each rainfall event.

6.3 Groundwater availability and origin

6.3.1 Geology

The Project Site is located in the south of the Western Volcanic Plain, a broad basaltic lava province active throughout the late Tertiary and Quaternary period (the past six million years). The Volcanic Plain is referred to as the Newer Volcanic Province, a major geological unit of southern Australia. The gently undulating plains are formed of lava flows up to 60 m thick and are studded with volcanic hills.

[12] Benzene, Toluene, Ethylbenzene, Xylene & Naphthalene
[13] Note that reliability of trigger values available for Toluene, Ethylbenzene and m- and p-Xylene are still considered unknown so they were generally not applicable under ANZECC 2000 due to being inaccurately represented.

Underlying the Newer Volcanic Province is the Late Jurassic to Cenozoic Otway Basin, a large northwest trending onshore and offshore basin on the southern margin of Australia. The sediments of the Otway Basin are several hundred metres thick in the south of the project Site. The Otway Basin overlies older basement crust of the Kanmantoo Fold Belt, which consists of folded Lower Palaeozoic sedimentary rocks (Torkzaban et al., 2020).

Figure 6-42 shows the mapped surface geology across the site, mainly consisting of basalt flows of the Newer Volcanic Group of Tertiary Neogene geological age. The unit is described as volcanic rock including sheet and valley flows along with intercalated gravel, sand, and clay. The Late Miocene-Pliocene age Whalers Bluff/Hanson Plain Sand outcrops in the north and to the east of the project Site. Alluvial deposits of quaternary age are scattered across the landscape, mainly in and adjacent to drainage lines.

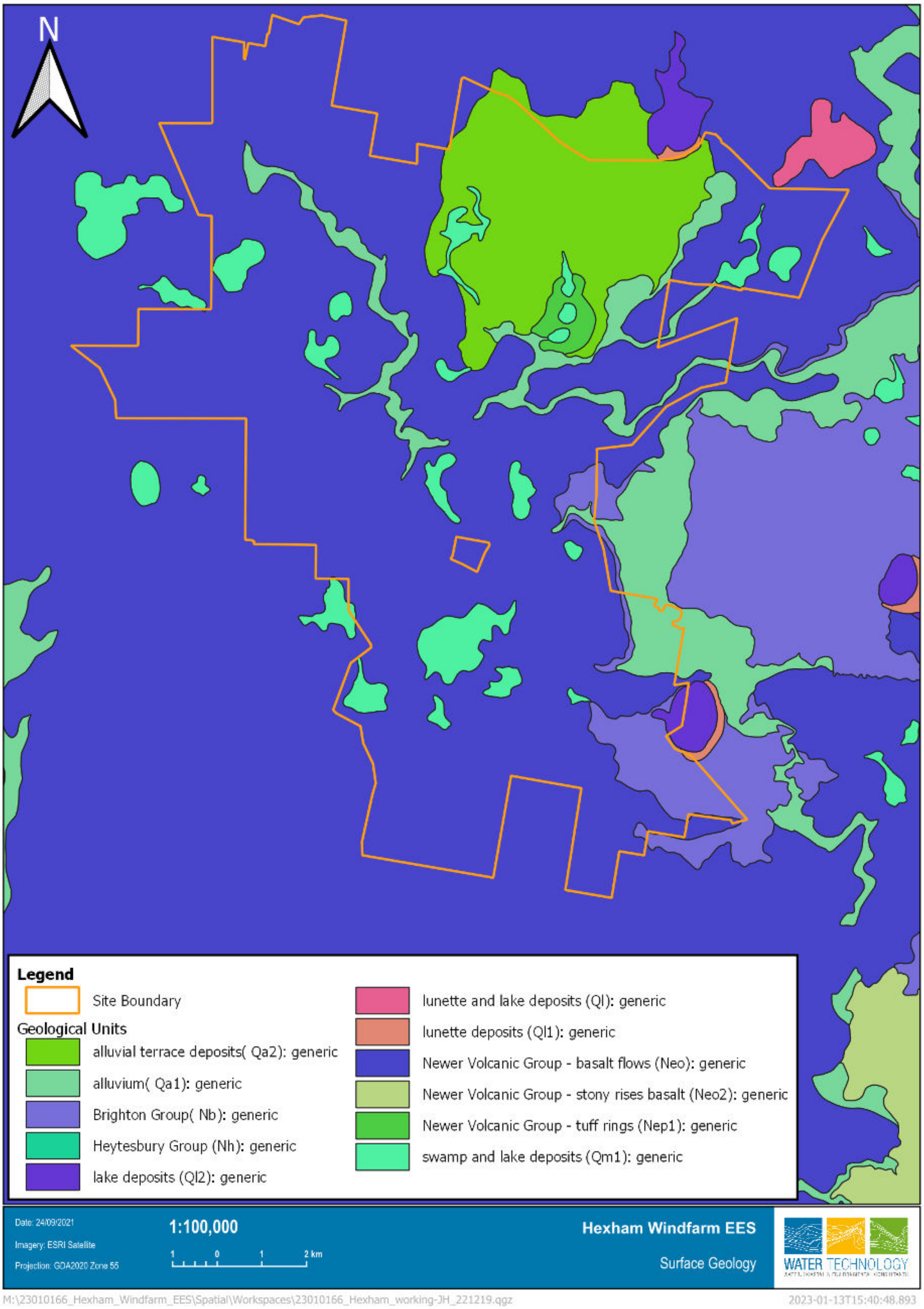

Figure 6-42 Surface Geology

6.3.2 Aquifers

6.3.2.1 Overview

The Victorian Aquifer Framework (VAF) (GHD, 2012) has been used as the framework to identify hydrostratigraphic units at the project Site. The aquifers of interest for this assessment include the Quaternary Alluvium (QA; Quaternary), Upper-Tertiary/Quaternary Basalts (UTB; Newer Volcanic Group) and the Upper-Tertiary Aquifer (UTAM; Whalers Bluff / Hanson Plain).

The Upper Mid-Tertiary Aquifer (UMTA; Port Campbell Limestone) is located in the southern third of the project area at a depth of around 50 m below ground level. A thick and extensive confining layer, the Upper Mid-Tertiary Aquitard (UMTD; Gellibrand Marl) forms a barrier between the above hydrostratigraphic units and deeper units of the Otway Basin.

Table 6-17 provides the hydrostratigraphic layers from the Victorian Aquifer Framework (VAF) and their lithological descriptions. These units are shown in cross section view in Figure 6-43 and Figure 6-44 based on the VAF layers. The cross sections illustrate the stacked succession of sedimentary aquifers beneath the site. The thickness of the Late Jurassic to Cenozoic Otway Basin sediments increases to the south towards the centre of the Otway Basin.

Table 6-17 Hydrostratigraphic Units

Unit	Name	Lithology	Extent
Quaternary Alluvium (100) QA	Molineaux Sand (Lowan Sand) Malanganee Sand Bridgewater Formation Coomandook Formation	Quartz sand Calcareous sand	Present in some drainage channels across the Site
Upper-Tertiary/Quaternary Basalts (101) UTB	Newer Volcanic Group deposits	Basalt Scoria Ash Tuff	Across the majority of site, except in the central north and the southeast corner
Upper-Tertiary Aquifer (Marine) (104) UTAM	Whalers Bluff Formation Hanson Plain Sand	Calcareous/shelly sand Quartz sand Silty sand Gravelly sand	Present across the site, though pinches out to the north, south and west
Upper Mid-Tertiary Aquifer (107) UMTA	Port Campbell Limestone (Gambier Limestone)	Calcarenite Limestone Shelly limestone	Present only in south of project area
Upper Mid-Tertiary Aquitard (108) UMTD	Gellibrand Marl	Calcareous silty clay and clayey silt	Present across the site
Lower Mid-Tertiary Aquifer (109) LMTA	Clifton Formation (Point Addis Limestone)	Calcarenite Shelly limestone with quartz sand matrix	Present only along western boundary and southern end
Lower Mid-Tertiary Aquitard (110) LMTD	Narrawaturk Marl	Calcareous mudstone Minor thin calcarenite beds	Absent at Site, present immediately to the south
Lower-Tertiary Aquifer (111) LTA	Dilwyn Formation (Dartmoor Formation)	Sands with variable silt, clay, gravel and carbonaceous content	Absent at Site, present to the south
Cretaceous and Palaeozoic Basement (114)	Grampians Group and Cambrian Basement	Sandstone Mudstone Metavolcanics Metasediments	Present at depth across the whole Site

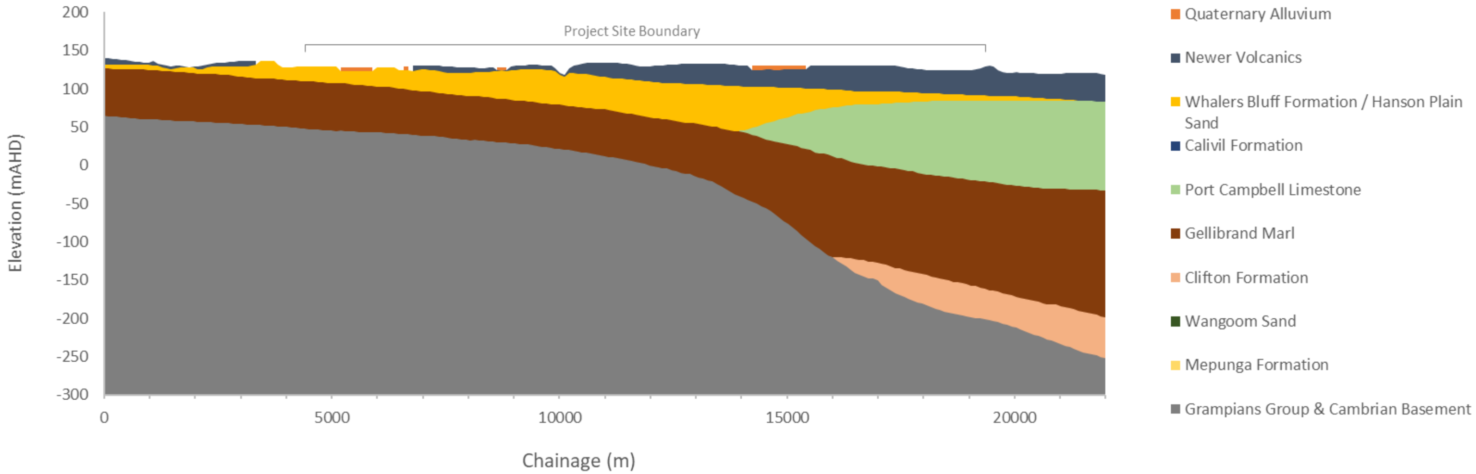

Figure 6-43 North-South Cross Section Line

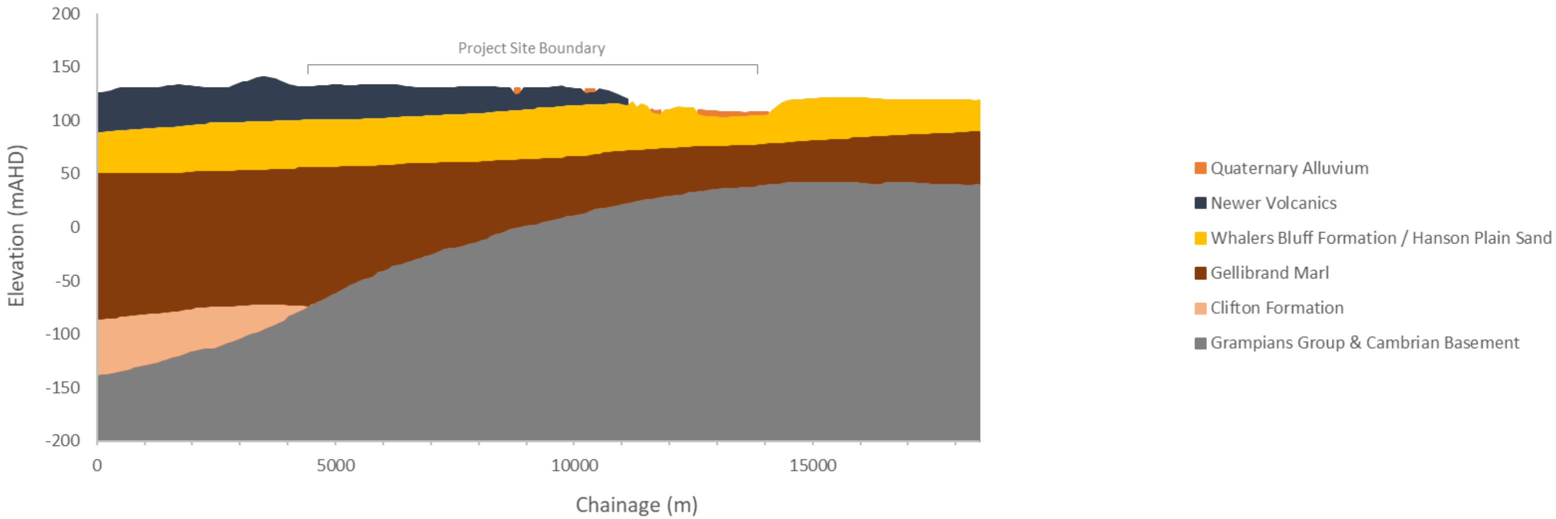

Figure 6-44 West-East Cross Section Line

6.3.2.2 Unconsolidated alluvium and colluvium deposits (Quaternary Aquifer)

The unconsolidated alluvium and colluvium deposits (or Quaternary Aquifer) are comprised of gravels, sands and silts forming a thin layer of material in low-lying areas near drainage channels and on the base of hillslopes. Where present, these deposits are located from surface to a depth of around 5 metres below ground level. Within the project Site, unconsolidated alluvium and colluvium deposits are located near Mustons Creek, Tea Tree Creek and Drysdale Creek.

6.3.2.3 Newer Volcanic Group basalts (Upper Tertiary/Quaternary Basalt)

The Newer Volcanic Group basalts (or 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, except in the north and to the east of the project Site. The Newer Volcanic Basalts outcrop over much of the project Site and occur to a depth of around 40 metres below ground level.

Stony rises occur in areas within the project Site where lava flows buried soil that was present on previous lava flows. The Stoney rises are thought to be less weathered and more fractured.

Across the project area, the Newer Volcanic Group basalt and stony rises are interpreted to behave as an unconfined fractured rock aquifer. In these aquifers, groundwater movement 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.

6.3.2.4 Whalers Bluff Formation / Hanson Plain Sand (Upper Tertiary Marine and Fluvial Aquifer)

Marginal marine and fluvial deposits of Pliocene age occur widely throughout the region, composed mostly of quartz sand, silty sand, shelly sand and basal reworked gravels, which are often strongly ferruginous (Torkzaban et al., 2020). The formations consist of the Whalers Bluff Formation and the Hanson Plain Sand which reach a combined thickness of up to 50 m at the project Site. These units occur as a continuous layer beneath the site. The distribution of the UTAMF units is shown in Figure 6-43 and Figure 6-44. These deposits are reported to have variable lithology resulting in variable well yields (Torkzaban et al., 2020).

6.3.2.5 Port Campbell Limestone (Upper mid-Tertiary Aquifer)

The Port Campbell Limestone is present in the southern third of the project Site, occurring at depths of around 50 to 200 metres below ground level. The unit is dominated by calcarenite, with well-developed intergranular porosity as well as karstic features, resulting in high yields and low-salinity groundwater. It is a major aquifer in the region. The Port Campbell Limestone aquifer is classified as ‘partially confined’ in areas where it is overlain by Newer Volcanic Group basalts.

6.3.2.6 Gellibrand Marl (Upper Mid-Tertiary Aquitard)

The Gellibrand Marl forms a regionally extensive aquitard consisting of shallow marine marl, clay and fine calcareous sediments with low permeability. Due to its low permeability, this unit is not used as a water source. The Gellibrand marl is present from around 50 to 100 m below ground level at the project Site. It forms a barrier between the above hydrostratigraphic units, and the deeper units of the Otway Basin detailed below.

6.3.2.7 Other Regional Hydrostratigraphic Units

Other hydrostratigraphic 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 that the Clifton Formation is not hydraulically connected to the Port Campbell Limestone aquifer, as it is separated by the Gellibrand Marl.
- Dilwyn Formation (Lower Tertiary Aquifer): located up to 1,000 metres below the surface in some areas, this aquifer provides the water supply for the townships of Portland, Port Fairy, Heywood and Dartmoor. Due to the depth of this aquifer, it is not extensively used.

6.3.3 Hydrogeology

6.3.3.1 Groundwater data availability

Groundwater data available online is limited across the project area, with few wells showing recorded groundwater levels. There are, however, more wells with salinity data. Figure 6-45 shows the available groundwater level and salinity data points across the Site. The available data is further discussed in the sections below.

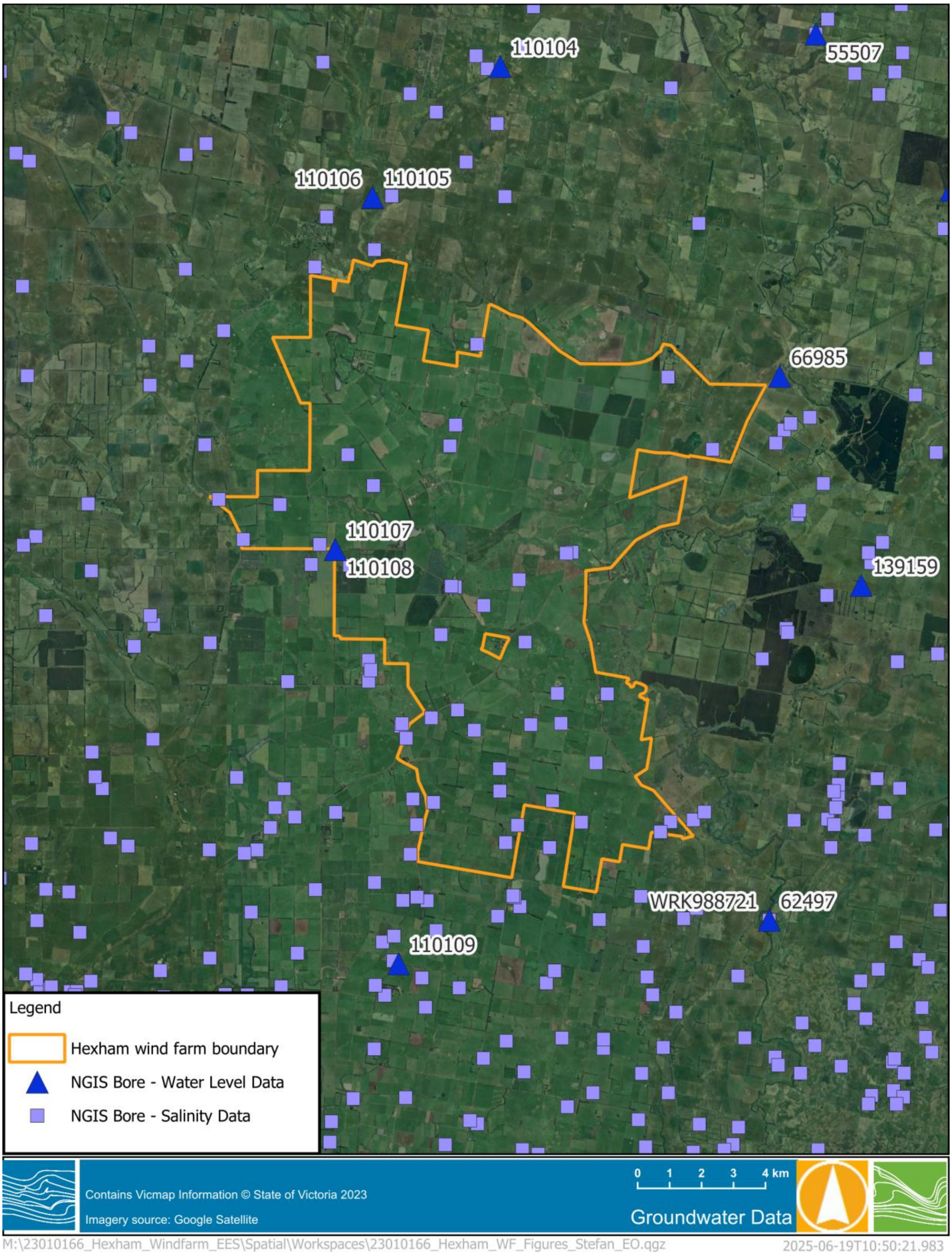

Figure 6-45 Groundwater Wells

6.3.3.2 Groundwater flow, recharge and discharge

Groundwater flow in the water table aquifer has been interpreted from the Visualising Victoria's Groundwater database (VVG) water table elevation raster grid (Figure 6-46). The range of water table elevations varies from 150 m AHD north of the project Site to below 100 m AHD at the south-eastern corner of the project Site. This follows a regional groundwater gradient from north to south, out and away from the regions of higher elevation.

Groundwater flow in the water table aquifer is influenced by recharge which occurs via infiltrating rain (during winter and spring), with recharge estimates of between 10 to 40 millimetres per annum reported by Dahlhaus et al., (2002). In areas of stony rises, groundwater recharge may be higher than within the basalt flows as they typically have a higher permeability and are more fractured. The underlying Whalers Bluff Formation / Hanson Plain Sand aquifer is recharged via direct rainfall infiltration where the aquifer is expressed at the surface.

Discharge from the Newer Volcanic Group basalt aquifer and the Whalers Bluff Formation / Hanson Plain Sand aquifer occurs through evapotranspiration and groundwater extraction from wells, as well as at the edge of formations and topographic lows where groundwater expresses at surface (e.g. springs). Local groundwater information provided by landowners indicates that most springs in the area fill during winter and dry up during summer. Groundwater may also discharge into streams (as baseflow) and into unconsolidated alluvium / colluvium deposits (Quaternary Aquifer).

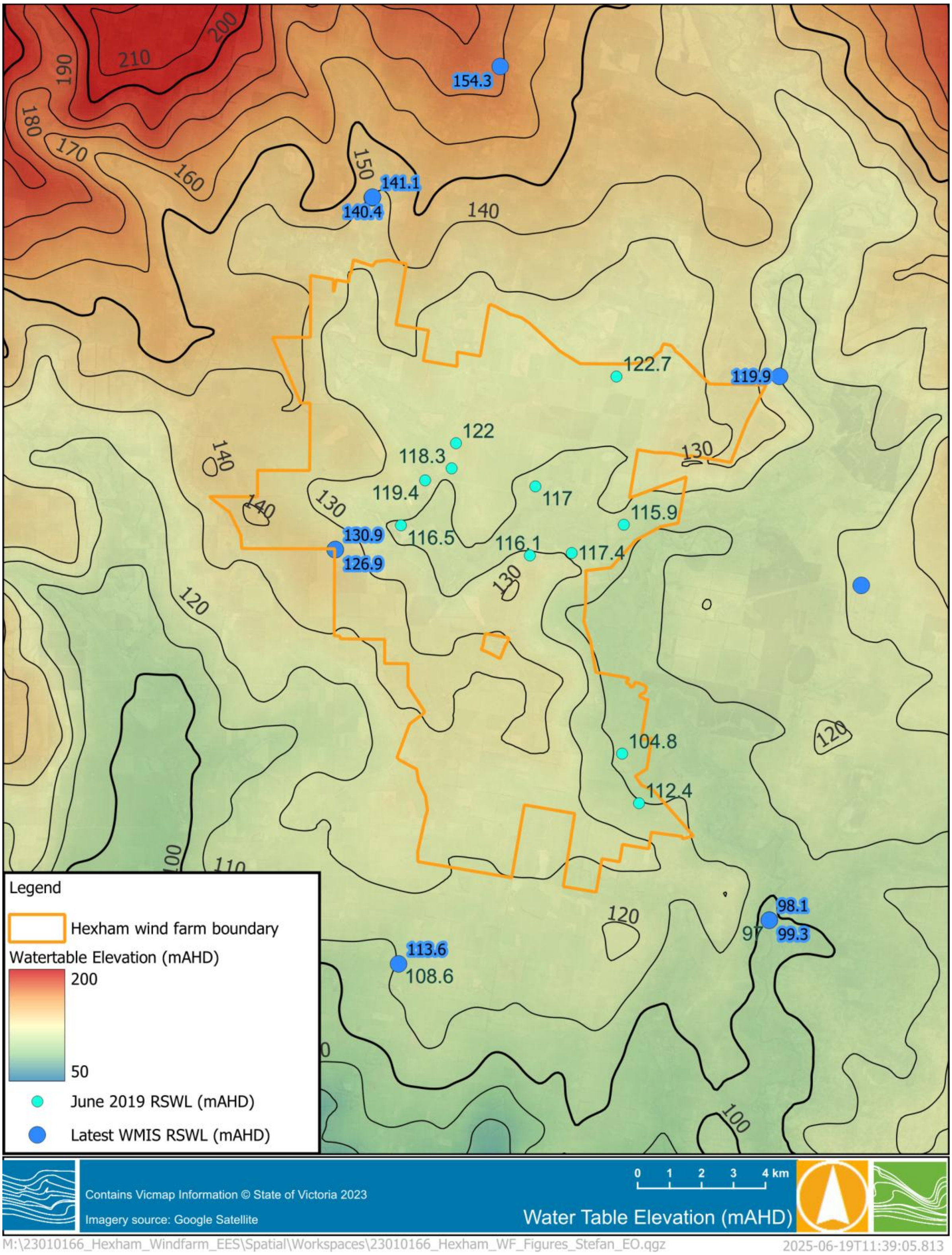

Figure 6-46 VVG Water Table Elevation Contours and Groundwater Elevation Point Data

6.3.3.3 Depth to groundwater

The Newer Volcanic Group basalts and the Whalers Bluff Formation / Hanson Plain Sand form the water table at the project site. Due to the shallow nature of the proposed works, these are the main aquifers of interest for the project.

Groundwater levels in the water table vary both spatially and seasonally, influenced by rainfall and longer-term climatic conditions. A regional interpretation of average depth to water from ground level (DTW) from Visualising Victoria's Groundwater database is shown in Figure 6-47. This figure shows that across the project Site there are areas where groundwater may be within 5 metres of ground level. These areas coincide with topographic lows and drainage lines. Away from drainage lines where the surface topography is higher, the depth to water is greater and is expected to be in the range of 5 to 20 metres as shown in Figure 6-47.

Groundwater level measurements taken from fifteen groundwater bores in June 2019 ranged from 3.25 to 13.75 metres below ground level. This data correlates reasonably well with the VVG depth to water table layer as shown in Figure 6-47. Available data from WMIS is also plotted on Figure 6-47for comparative purposes, noting that there is limited water level data available through the WMIS database.

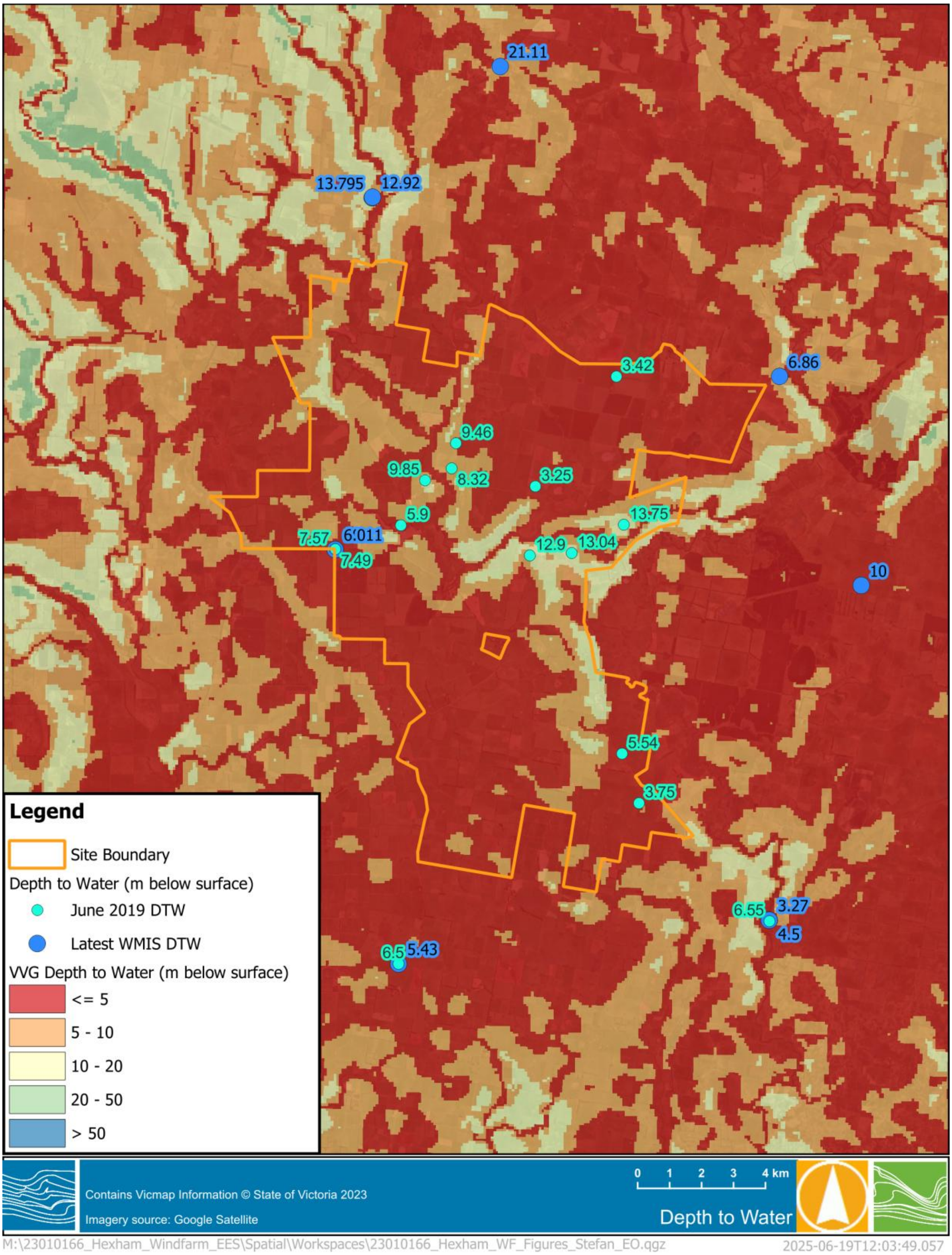

Figure 6-47 Depth to Water Table and Depth to Water Point Data

6.3.3.4 Groundwater level trends

There are relatively few wells near the project Site from which to assess groundwater level trends with time. The closest wells are 110107 and 110108 located on the western Project Site boundary which have data from 1992 through to 2022. The long-term trends show a gradual decline of around 1 m from 1992 through to around 2008, after which time groundwater levels are observed to increase by a similar magnitude through to 2022. Seasonally, groundwater levels vary by about 0.2 m with the highest levels generally observed around spring and the lowest levels around autumn. Other wells with time series data are all located outside of the project Site boundary. Similar trends are observed in these wells, though the seasonality in some wells is higher with variability of around 0.5 m. Figure 6-48 shows hydrographs of the nearby wells with available water level data.

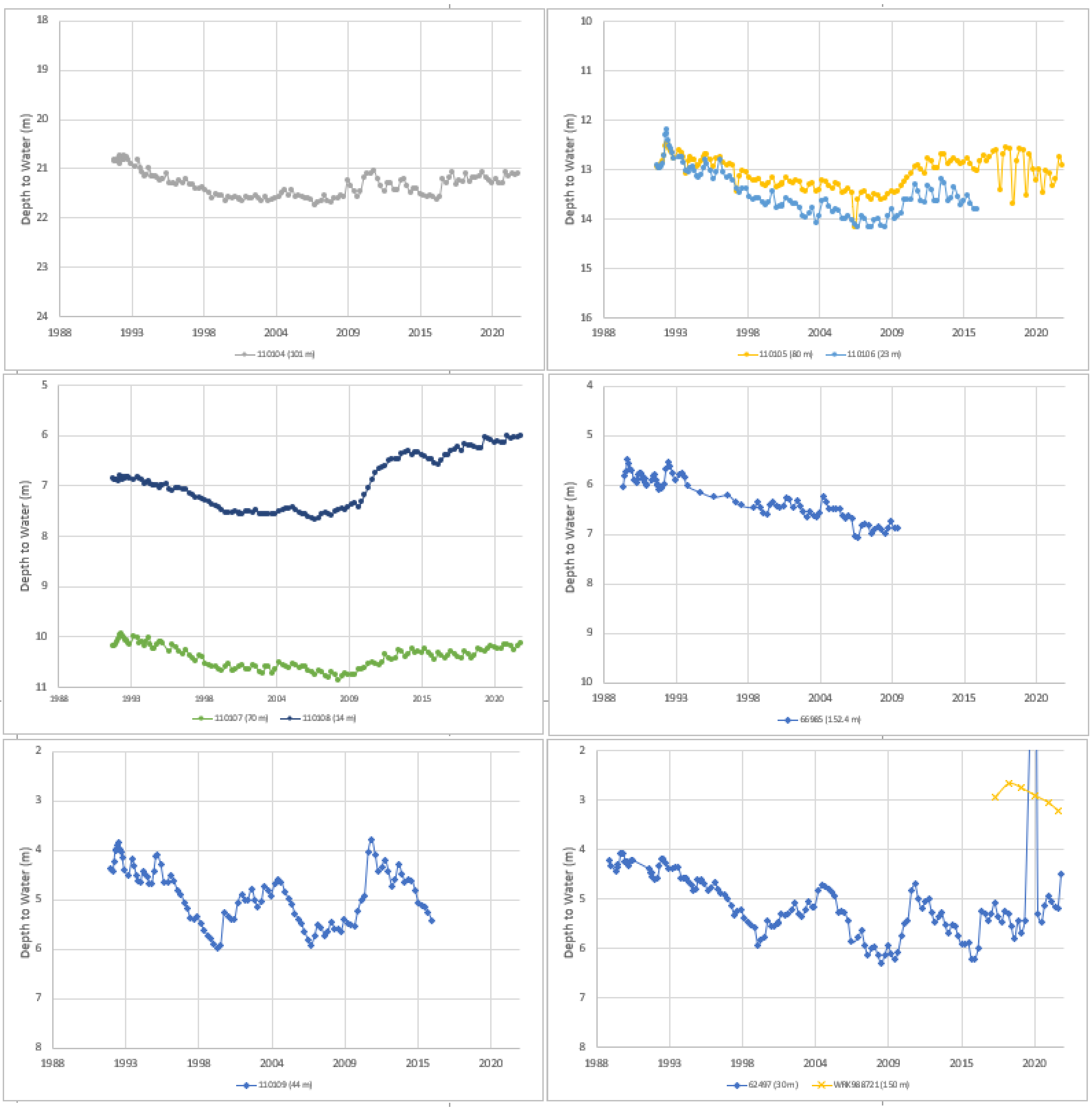

Figure 6-48 Groundwater Hydrographs within and Adjacent the Project Site

6.3.3.5 Aquifer parameters

The Newer Volcanic Group basalt is the main hydrostratigraphic unit within the project area. Groundwater flow within this aquifer is variable, due to the variability in hydraulic parameters that exist in aquifers of volcanic origin.

Estimates of hydraulic conductivity for groundwater flow systems at the project Site are summarised in Table 6-18 with corresponding aquifer zones shown spatially in Figure 6-49 (after Dahlhaus et al., 2002). Hydraulic conductivity values are reported to range from 0.001 to 100 m/d 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). Quaternary deposits exhibit a wider hydraulic conductivity range from 1 x 10^{-6} to 100 m/d while the Pliocene Sands range from 0.01 m/d to 10 m/d.

The geometric mean of the Newer Volcanic basalt hydraulic conductivity from four falling head (slug) tests located at the proposed quarry site was 0.025 m/d. This indicates that the site specific values may be towards the lower end of the ranges provided in the regional assessment described above. The falling head (slug) testing methodology and analysis is provided in Section 6.4.3.5.

Table 6-18 Groundwater Flow Systems and Hydraulic Conductivity Ranges (After DAHLHAUS ET AL., 2002)

Unit/System (Dahlhaus et al., 2002)	VVG Reference	Hydraulic Conductivity Range (m/d)
Quaternary Alluvium	Quaternary Alluvium (QA; Quaternary)	1 x 10^{-6} to 100 m/d
Volcanic Plains Basalt	Upper-Tertiary/Quaternary Basalts (UTB; Newer Volcanic Group)	0.001m/d to 100 m/d
Pliocene Sands	Upper-Tertiary Aquifer (UTAM; Whalers Bluff / Hanson Plain)	0.01 m/d to 10 m/d

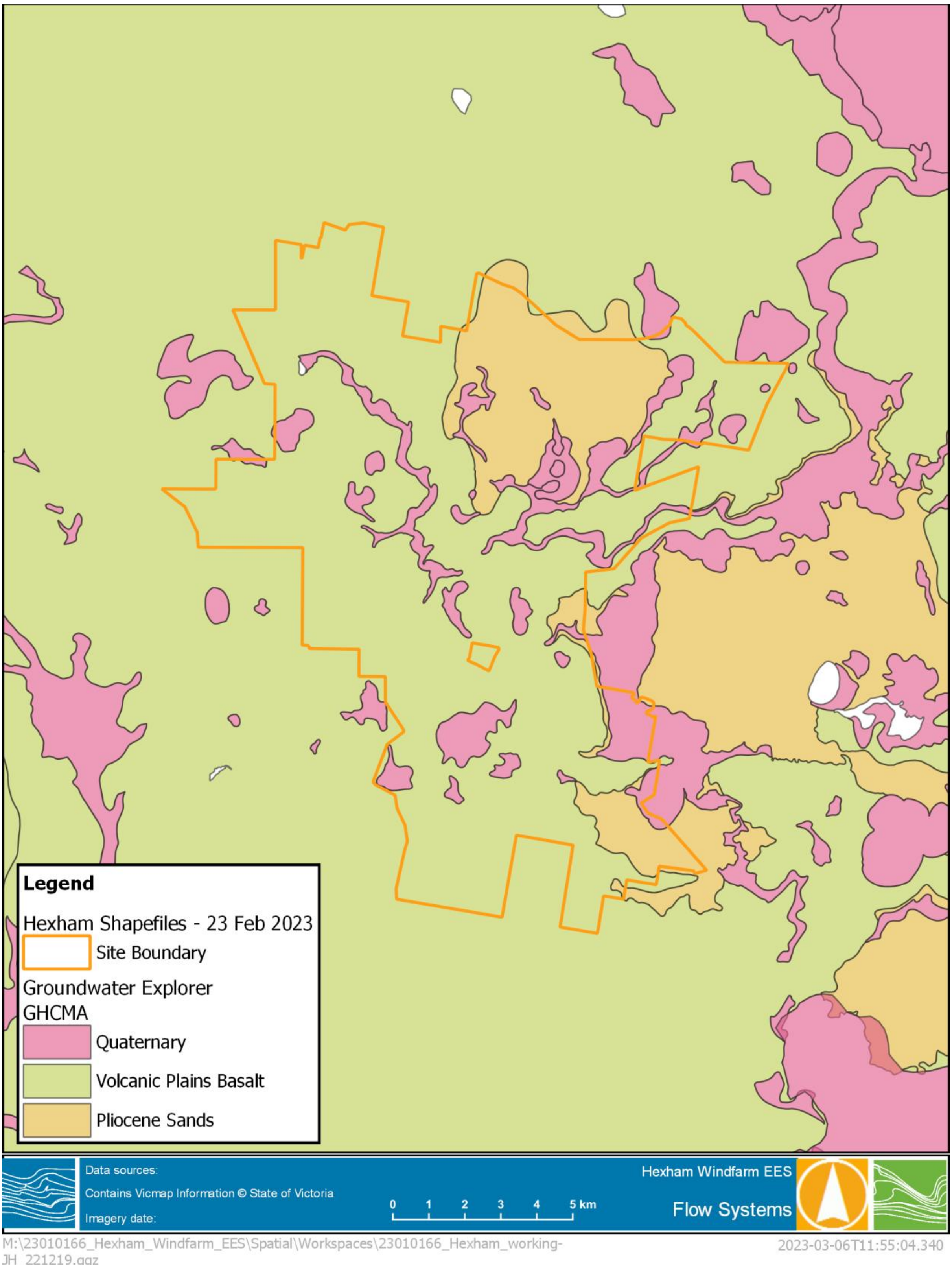

Figure 6-49 Groundwater Flow Systems and Hydraulic Conductivity Ranges (After Dahlhaus Et Al., 2002)

6.3.3.6 Groundwater quality

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

The VVG water table salinity mapping available through the Visualising Victoria's Groundwater database (Figure 6-50) indicates that groundwater salinity is in the range of 1,000 to 3,500 mg/L in the south of the project Site and 3,500 to 7,000 mg/L in the north. Available groundwater salinity data from WMIS has been plotted on Figure 6-50, with the two datasets correlating reasonably well.

Groundwater salinity measurements taken from fifteen groundwater wells in June 2019 for this project are also plotted on Figure 6-50. The data ranges from 528 to 5,874 mg/L which also correlates well with the VVG salinity classifications.

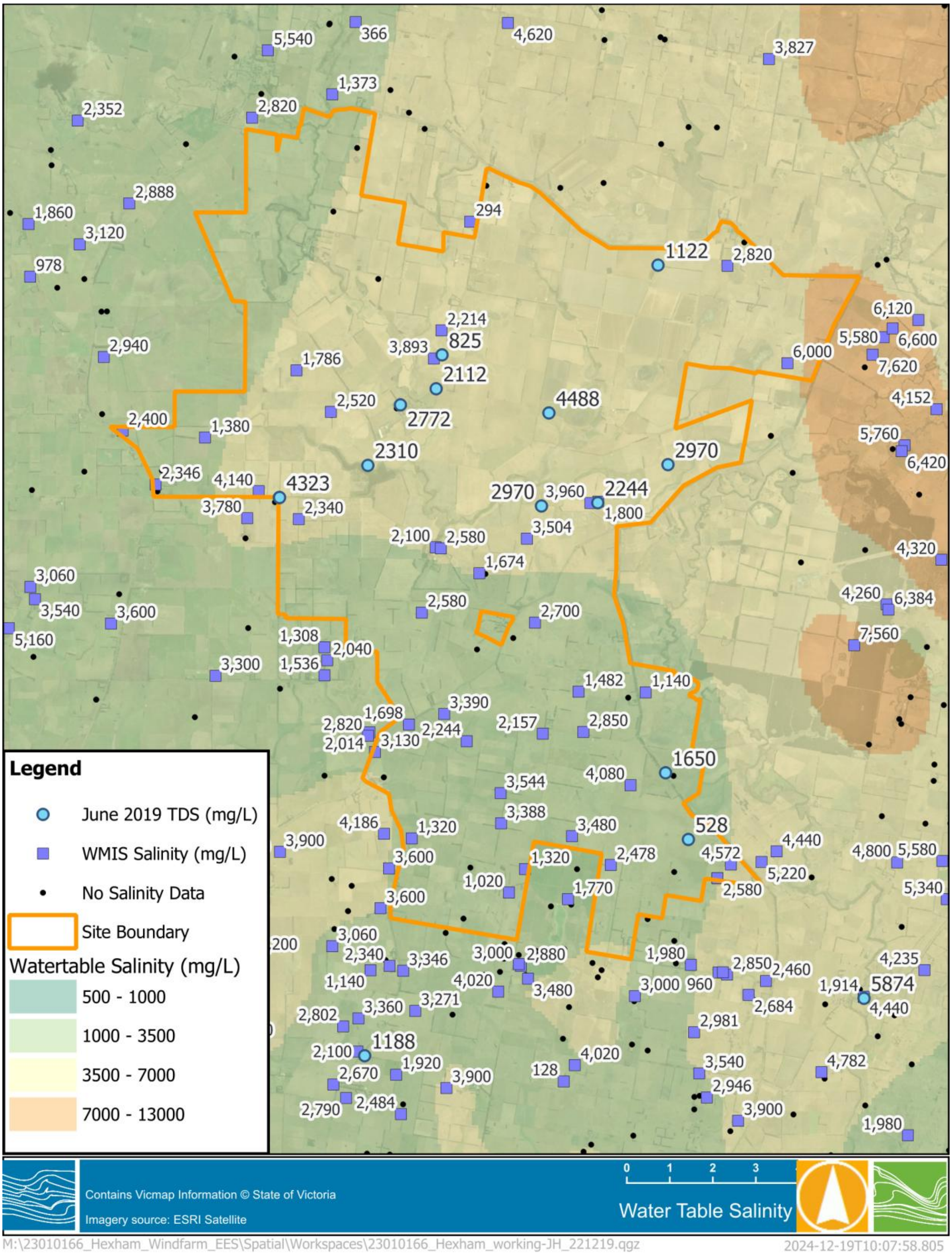

Figure 6-50 VVG Salinity Classifications and Salinity Point Data

6.3.3.7 Environmental values

Under section 93 of the Environment Protection Act (2017), the Governor in Council made an environment reference standard which sets out defined environmental values for designated salinity (TDS) ranges (Part 5, Division 2). Table 6-19 shows the groundwater segments and applicable salinity ranges and Table 6-20 shows the environmental values associated within the defined groundwater segments.

Table 6-19 Groundwater Segments

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

Table 6-20 Environmental Values that apply to the Groundwater Segments

Environmental Value	Segment (TDS mg/L)						
	A1 (0 – 600)	A2 (601 – 1,200)	B (1,201 – 3,100)	C (3,101 – 5,400)	D (5,4021– 7,100)	E (7,101 – 10,000)	F (> 10,000)
Water dependent ecosystems and species	✓	✓	✓	✓	✓	✓	✓
Potable water supply (desirable)	✓						
Potable water supply (acceptable)		✓					
Potable mineral water supply	✓	✓	✓	✓			
Agriculture and irrigation (irrigation)	✓	✓	✓				
Agriculture and irrigation (stock watering)	✓	✓	✓	✓	✓	✓	
Industrial and commercial use	✓	✓	✓	✓	✓		
Water-based recreation (primary contact)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner and cultural values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

For the purpose of defining the appropriate groundwater environmental values for this project, the salinity data from WMIS and the 2019 field survey data has been used (refer to Figure 6-50), along with the salinity data collected from the four quarry investigation wells (Table 6-27). Salinity is predominantly between 1,000 and 7,000 mg/L, however, values as low as 528 mg/L have been recorded within the site boundary and as high as 7,620 mg/L outside the eastern site boundary (Figure 6-50). Based on the observed salinity data within and surrounding the site the applicable groundwater segments are A1, A2, B, C, D and E. When defining environmental values, a conservative approach has been taken whereby the lowest salinity within the site boundary has been used, in this case 528 mg/L which correlates with segment A1. Based on this, groundwater quality needs to be maintained to protect the following environmental values:

- Water dependent ecosystems and species
- Potable water supply (desirable, acceptable and mineral water supply)

- Agriculture and irrigation (irrigation)
- Agriculture and irrigation (stock watering)
- Industrial and commercial use
- Water-based recreation (primary contact)
- Traditional Owner and cultural values
- Buildings and structures
- Geothermal properties

Table 6-21 summarises the applicable indicators and objectives for each of the environmental values identified above which apply to groundwater at the site. Where groundwater discharges to surface water, the indicators are the indicators applicable to the relevant surface water body. Guideline values for toxicants associated with the 95% protection trigger values for freshwater are provided in Table 6-22 along with guideline values for the same parameters for potable water (ADWG, 2011) and irrigation and stock watering (ANZECC 2000/ANZG 2018). It is proposed that the baseline groundwater quality sampling adopts the same sampling parameters as those defined in the surface water monitoring plan (Appendix B), a subset of which is shown below in Table 6-22. These parameters (Appendix B) provide a robust list of indicators and potential toxicants suitable for establishing baseline conditions and assessing potential changes in groundwater quality as a result of the proposed development. The final list of sampling analytes will be confirmed in the Water Management Plan in consultation with the relevant authorities.

It is noted that where the background (baseline) concentrations are lower than the published guideline values, the background (baseline) concentrations are adopted as the water quality investigation criteria, which set the benchmark for future monitoring. Where the background concentrations are greater than the published guideline values, the background concentrations may be adopted provided that sufficient information can be presented to support the adoption of concentrations above guideline values.

Table 6-21 Applicable groundwater environmental values and their objectives and indictors

Environmental values	Relevance to the Project	Indicators	Objectives
Water dependent ecosystems and species	Relevant where groundwater discharges to surface water bodies and where stygofauna are present.	For groundwater that discharges to surface water, the indicators are the indicators applicable to the relevant surface water as specified in Division 3 of Part 5 of the ERS. Indicators that are relevant to the subterranean species of stygofauna, which may include TSS, salinity, toxicants in water, toxicants in sediment and dissolved oxygen.	Where groundwater discharges to surface water, the indicators are the indicators applicable to the relevant surface water body. Refer to Section 4.3.2. and Section 6.2.5 for surface water environmental values and water quality objectives. The level that ensures the groundwater quality does not adversely affect the stygofauna that depend on the groundwater. To be determined following baseline stygofauna sampling.
Potable water supply (desirable, acceptable and mineral water supply)	Groundwater is able to be used for potable water in some areas within the project site based on the salinity (TDS). Note concentrations of other parameters in ADWG (2011) may prevent groundwater from being used as a potable supply.	Indicators specified in the ADWG (2018).	Health-related guideline value for each indicator specified in the ADWG (2018). Aesthetic guideline value for each indicator specified in the ADWG (2018).
Agriculture and irrigation (irrigation)	Groundwater is able to be used for irrigation within the project site based on the salinity (TDS). Note concentrations of other parameters in ANZECC 2000/ANZG 2018 may prevent groundwater from being used for irrigation.	Indicators specified for irrigation and water for general on-farm use in ANZG (2018).	In the absence of water quality objectives, ANZG (2018) default to the ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, investigation levels for Primary Industries (Chapter 4.2 Water quality for irrigation and general water use).

Environmental values	Relevance to the Project	Indicators	Objectives
Agriculture and irrigation (stock watering)	Groundwater is able to be used for stock watering within the project site based on the salinity (TDS). Note concentrations of other parameters in ANZECC 2000/ANZG 2018 may prevent groundwater from being used for stock watering.	Indicators specified for livestock drinking water quality in the ANZG (2018).	In the absence of water quality objectives, ANZG (2018) default to the ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, investigation levels for Primary Industries (Chapter 4.3 Livestock drinking water quality).
Industrial and commercial use	Based on the background salinity (TDS), groundwater is able to be used for industrial and commercial use.	Indicators specific to the particular industrial or commercial activity and their use of water.	Groundwater quality that is suitable for its industrial or commercial use.
Water-based recreation (primary contact)	Groundwater is not known to be directly used for water based recreation in the study area. Where groundwater discharges to surface water, refer to Section 4.3.2. and Section 6.2.5.	Section 4.3.2. and Section 6.2.5 for surface water environmental values and water quality objectives.	Section 4.3.2. and Section 6.2.5 for surface water environmental values and water quality objectives.
Traditional Owner and cultural values	The Project area is located on Eastern Maar country and the Hopkins River and its tributaries are of significant Traditional Owner cultural and spiritual value.	Traditional Owner and cultural values are assessed in the cultural heritage impact assessment and cultural values report for this project.	Objectives to be defined in the cultural heritage management plan.
Buildings and structures	There are several rural residential properties and local roads in proximity to the project area, however, buffers are maintained between these assets and the proposed works.	pH, sulphate, chloride, redox potential, salinity or any chemical substance or waste that may have a detrimental impact on the structural integrity of buildings or other structures	Groundwater that is not corrosive to or otherwise adversely affecting structures or building
Geothermal properties	Groundwater is not known to exceed 30 degrees Celcius in the project area.	Temperature between 30 and 70 degrees Celsius	Groundwater between 30 and 70 degrees Celsius not known to occur in the project area.

Table 6-22 Guideline values for potential toxicants

Toxicants	Trigger			
Metals and non-metallic inorganics	**95% protection trigger values for freshwater**	**Potable water supply ADWG (2011) (health guideline value unless stated otherwise)**	**Irrigation Water LTV (100 yrs) ANZG (2018) default to ANZECC (2000)**	**Stock Water ANZG (2018) default to ANZECC (2000)**
Ammonia (mg/L)	0.9	0.5	NA	NA
Nitrate (mg/L)	2.4	50 (<3 months age) to 100 (>3months age)	NA	400
Aluminium (pH >6.5) (mg/L)	0.055	0.2 (aesthetic)	5	5
Aluminium (pH <6.5) (mg/L)	0.0008			
Arsenic (AsIII) (mg/L)	0.024	0.01	0.1	0.5
Arsenic (AsV) (mg/L)	0.013	0.01	0.1	0.5
Boron (mg/L)	0.370	4	0.5	5
Cadmium (mg/L)	0.0002	0.002	0.01	0.01
Chromium (CrVI) (mg/L)	0.001	0.05	0.1	1
Copper (mg/L)	0.0014	2	0.2	0.4 (sheep)
Lead (mg/L)	0.0034	0.005	2	0.1
Manganese (mg/L)	1.9	0.1	0.2	NA
Mercury (mg/L) (inorganic)	0.0006	0.001	0.002	0.002
Nickel (mg/L)	0.011	0.02	0.2	1
Selenium (mg/L)	0.011	0.004	0.02	0.02
Silver (mg/L)	0.00005	0.1	NA	NA
Zinc (mg/L)	0.008	3 (aesthetic)	2	20

6.3.3.8 Groundwater regulation and existing users

The project area lies within the South West Limestone (SWL) Groundwater Management Area (GMA). Within this management area, groundwater extraction from the Gambier Limestone, Port Campbell Limestone and the Portland Limestone is regulated.

The SWL GMA water allocation plan does not regulate groundwater extraction from the:

- Quaternary and upper Tertiary aquifers [QA. UTB, UTAF, UTAM] (e.g. the Newer Volcanics Basalt).
- Isolated occurrences of upper mid-Tertiary limestone (UMTA).
- Duddo Limestone (upper mid-Tertiary) aquifer in the northern part of the Glenelg catchment.
- Underlying aquifers and aquitards (e.g. lower mid-Tertiary Clifton [LMTA] and lower Tertiary Dilwyn [LTA]).

No Water Supply Protection Areas, declared under the *Water Act 1989* occur within the project Site.

The region has a history of pastoral and cropping land uses, and groundwater is used for domestic and agricultural purposes. There are 59 records of wells within the project site based on the data available through WMIS (well details provided in Appendix C). Field investigations during 2019 suggest that the actual number of wells in use is likely to be much lower. Many of the wells are listed as being used for stock and domestic use purposes. The location of these bores is shown in Figure 6-51. Unregistered bores in operation may also be present within the project Site based on results from the field visit in June 2019, which identified several bores at locations which did not correlate with the WMIS database. There are two state observation bores located on the western Project Site boundary (110107 and 110108).

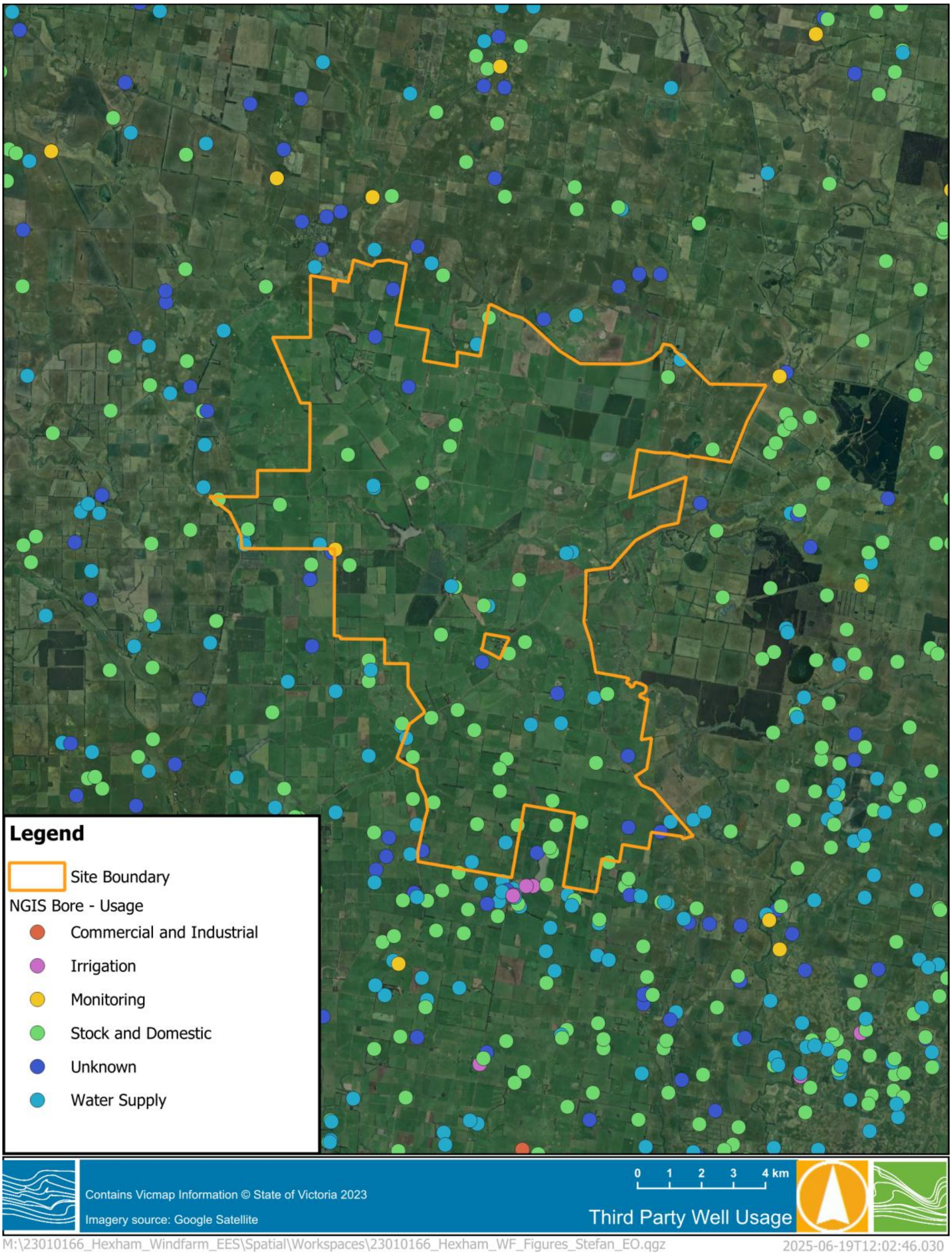

Figure 6-51 Location of Potential Groundwater Bores in Relation to the Project Site

6.3.3.9 Groundwater Dependent Ecosystems

Some ecosystems rely on groundwater to meet ecological water requirements, and as such may be sensitive to changes in the natural groundwater regime. These ecosystems are defined as Groundwater Dependent Ecosystems (GDEs). The Australian GDE Atlas published by the National Water Commission (2012) provides locations of potential GDEs based on broad scale analysis, existing data sets and remote sensing. GDEs are broadly categorised into the following types:

- Aquatic ecosystems that rely on the surface expression of groundwater; this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs.
- Terrestrial ecosystems that rely on the subsurface presence of groundwater; this includes all vegetation ecosystems.
- Subterranean ecosystems; this includes cave and aquifer ecosystems.

Inspection of the Australian GDE Atlas via the Bureau of Meteorology (BoM) web-based mapping application indicates the presence of aquatic and terrestrial groundwater dependent ecosystems (GDEs) in the project area.

Aquatic GDEs are identified predominately along creek lines such as Mustons Creek, Tea Tree Creek and Drysdale Creek (Figure 6-52). Although these systems are assigned as having a high potential of being supported by groundwater, it is important to consider several factors 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 for the project suggests that these systems are strongly influenced by surface water with inundation only occurring during winter months. During summer, these systems are dry, which indicates that groundwater does not provide a permanent water source.

Other moderate and low potential aquatic GDEs including temporary freshwater marshes and meadows occur in the project area, though these are small and isolated in nature. Some unclassified GDEs also exist within the project area, listed as Palustrine or Lacustrine Lakes.

Potential terrestrial vegetation communities are limited in size and extent, occurring as isolated patches in paddocks, along creek lines and along road verges (Figure 6-52). Vegetation communities are assigned as Creekline Grassy Woodland, Lunette Woodland, Plains Grassy Woodland, Riparian Woodland and Swampy Riparian Woodland. These communities are assigned as having a moderate to high potential of being supported by groundwater.

It is important to note that the GDE Atlas displays ecosystem polygons where groundwater interaction may occur, it does not suggest all vegetation within the polygon depends on groundwater (Doody et al. 2017) nor does it make any assessment of the ecological value of these ecosystems. Whilst no subterranean ecosystems have been mapped in the study area, this is not necessarily an indication that they do not exist.

The potential impacts of the project on GDEs are further discussed in the Hexham Wind Farm Flora and Fauna Impact Assessment (Nature Advisory, 2025).

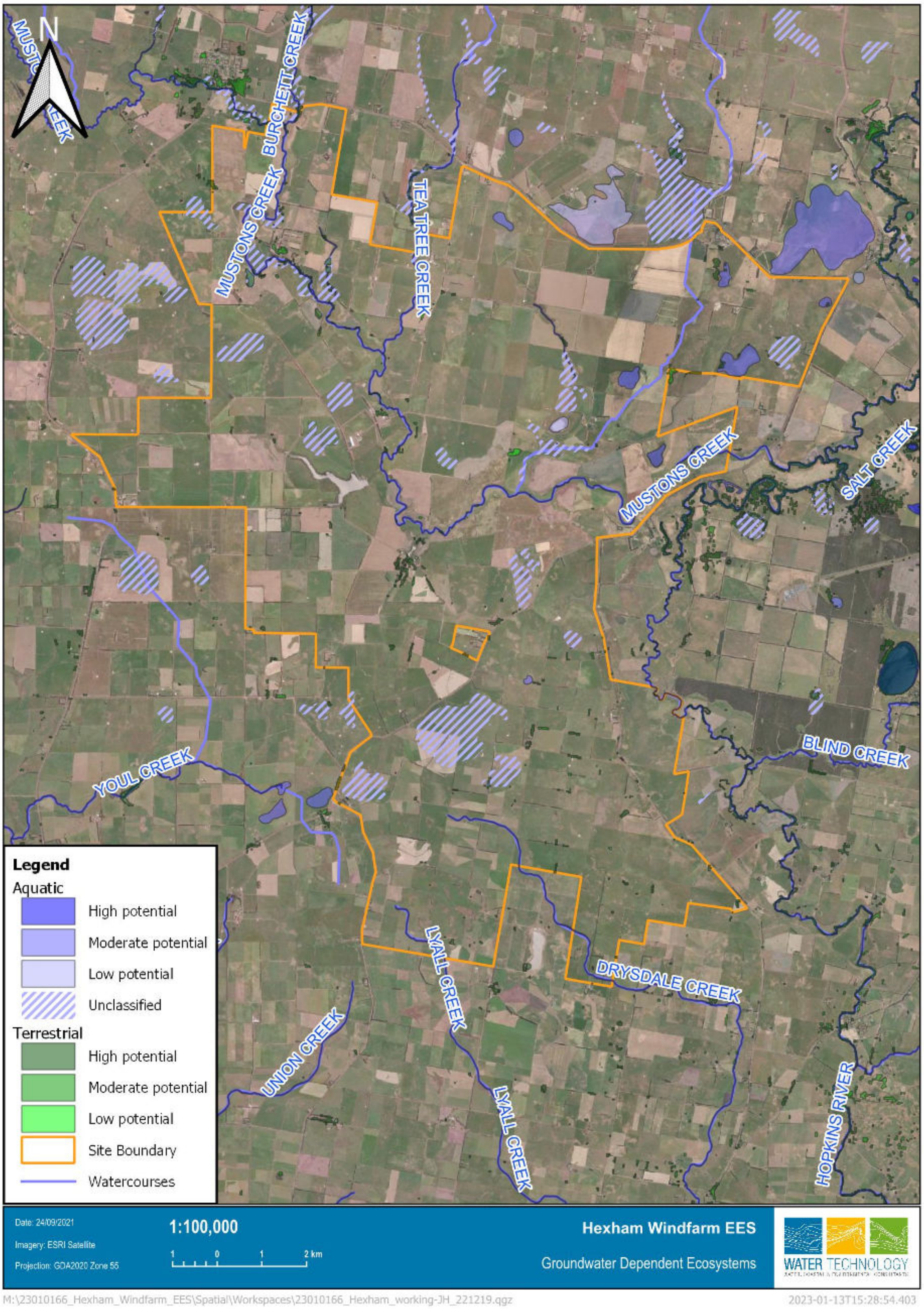

Figure 6-52 Groundwater Dependent Ecosystems

6.3.3.10 Stygofauna

Stygofauna are aquatic animals that inhabit groundwater for their entire life cycle (Bold et al., 2020). In Australia, stygofauna are reported to exist within alluvial, karstic, calcrete and certain fractured rock aquifers (Bold et al., 2020).

A regional baseline survey of stygofauna was undertaken in the Otway Basin by Bold et al. (2020). The survey identified stygofauna in 6 out of 80 sampled groundwater bores with a total of 149 individual animals from five stygofauna taxa identified. Of the 6 bores, 3 were completed in the Upper Tertiary Basalt aquifer which is the main aquifer of interest for the Hexham project. Occurrences were found in bore 110108 located on the western project site boundary around 3 km south of the proposed quarry location (Figure 6-45). The other 2 bores are located around 45 km northeast of the site. In this area there is a cluster of 8 Upper Tertiary Basalt bores, of which only 2 recorded stygofauna.

Based on the work of Bold et al. (2020) it is possible that stygofauna may be present at the Project site, however, the site and in particular the Newer Volcanic Group basalts are not considered highly conducive environments for stygofauna due to the relatively unfractured nature of the basalt and high clay content where the basalt is weathered. Clay and fine-grained sediments are also known to occur throughout the Quaternary Alluvium. This interpretation is consistent with the results of Bold et al. (2020) where only 3 out of 16 Upper Tertiary Basalt aquifer wells and 1 out of 7 Quaternary aquifer wells reported stygofauna occurrences.

Bold et al (2020) reported that the low number of bores where stygofauna were identified does not suggest the groundwater environment is of poorer ecological health. Rather, the fine-grained nature of sediments is suggested to be the likely limiting factor for the presence of stygofauna. Variability in porosity and water quality within the unconfined aquifers also suggests the possibility of genetic isolation and therefore some stygofauna taxa may exhibit short range endemism (Bold et al., 2020).

6.4 Quarry assessment

6.4.1 Overview

6.4.1.1 Description of proposed development

The proposed Works Authority Area for the quarry covers 52.3 ha, with a total extraction area of 21.5 ha, stockpile, plant, dam area of approcimately 30 ha and amenities/parking/weigh bridge area of approximately 0.5 ha. Details of the proposed quarry are summarised below:

- Extraction area of 21.5 hectares.
- Maximum excavation depth of approximately 14 m.
- Working batter profiles of approximately 1V:0.3H (75 degrees).
- Rehabilitation batter profile of at least 1V:4H (approximately 14 degrees) to quarry floor.
- Method of extraction to include digging and traditional drill and blast.
- Operational life of up to 24 months, then decommissioned to at least 1 m above the water table with a retention basin to capture surface water flow.
- A preliminary water requirement of 10 to 15 ML/yr for dust suppression.

6.4.1.2 Assessment purpose

This report provides an assessment of the surface water and groundwater considerations related to the proposed quarry development. The objectives of this assessment are summarised below:

- Assess the likely surface water contribution to the site.

- Estimate the likely range of groundwater inflows to the quarry and the extent of groundwater drawdown.
- Provide recommendations on the preferred surface water and groundwater management strategy.

Detailed engineering designs and consideration of constructability of infrastructure are outside the scope of this assessment.

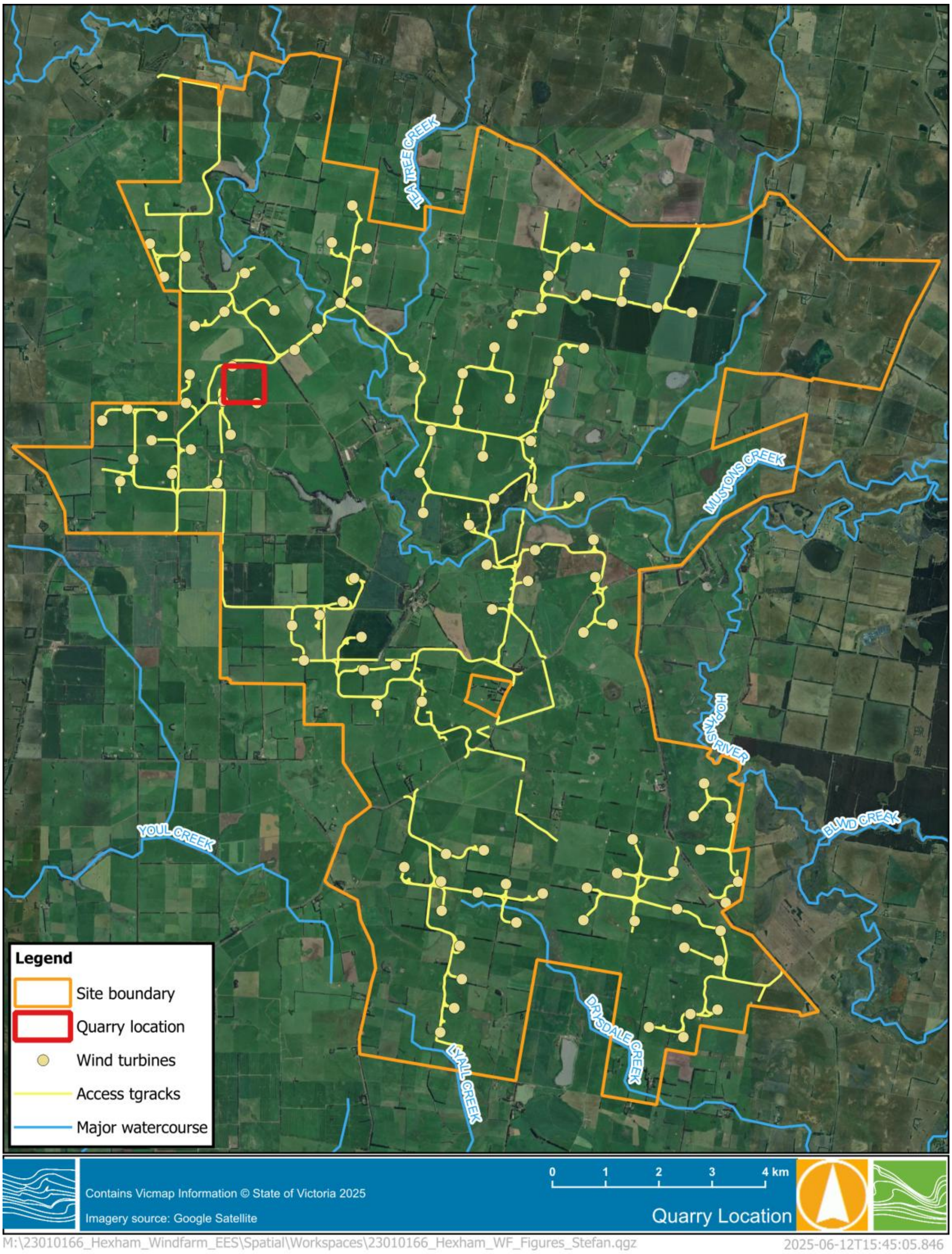

Figure 6-53 Quarry location

6.4.1.3 Topography

The topography of much of the project site is relatively flat, with a number of waterways of varying size intersecting the site. The Hopkins River and Mustons Creek are the largest waterways near the quarry site, with tributaries of Mustons Creek and of the Merri River also flowing through the site. Outside of the waterways, the landscape consists of an undulating surface with a series of small depressions with informal drainage lines, creating several small independent localised catchments. These catchments are susceptible to periods of inundation and reliant on infiltration and evaporation to disperse the water. The quarry site itself is located on a ridge and has no upstream catchment, with the site draining towards the northwestern and southeastern sides of the ridge. The quarry site has an elevation difference of around 10.7 m between the highest point close to the western boundary (142.9 m AHD) and lowest point in the southeastern corner of the site (132.2 m AHD). The topography of the site is shown in Figure 6-54 along with the proposed site infrastructure including the extraction area, stockpile area, works authority boundary and site access and parking.

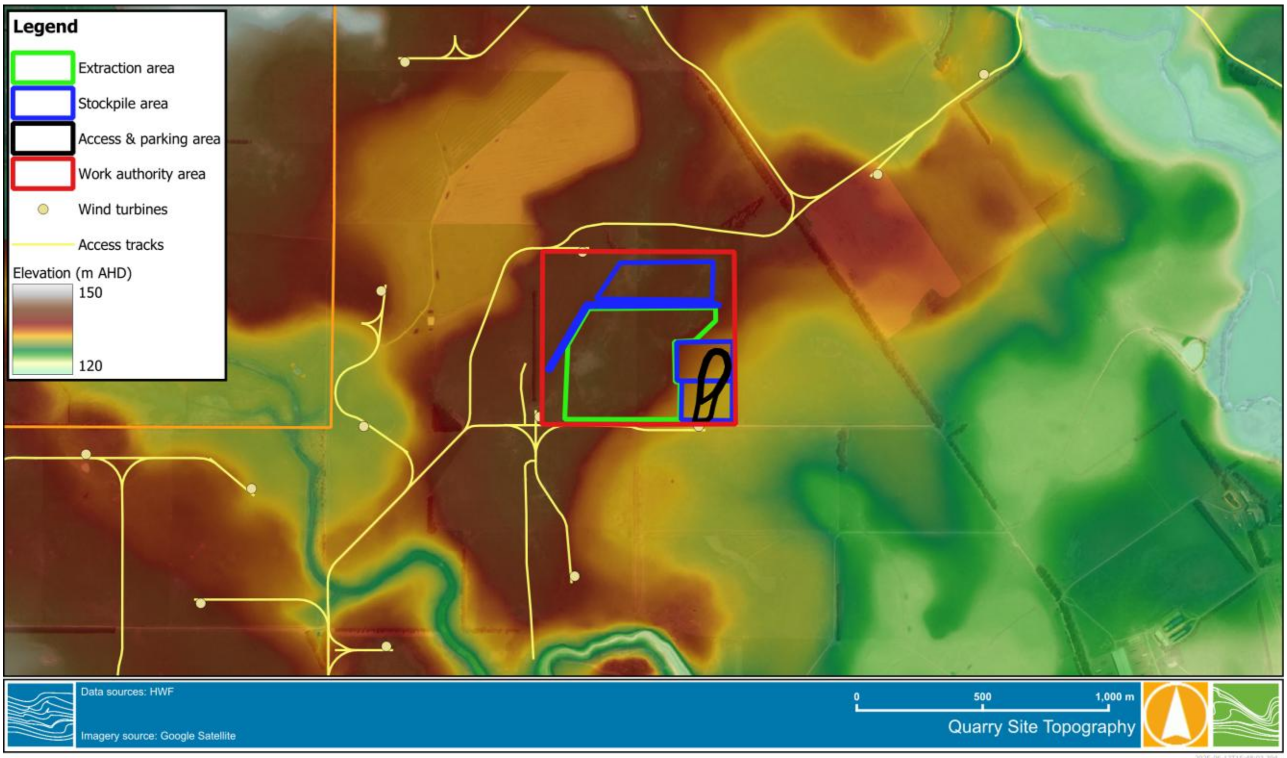

Figure 6-54 Site Topography

6.4.2 External catchment surface water impact

6.4.2.1 Surface water methodology

Water Technology previously undertook hydraulic modelling of the project area and upstream catchment using TUFLOW. TUFLOW is one of the most widely used hydraulic modelling software packages in Australia and is the preferred modelling package for the Glenelg Hopkins Catchment Management Authority (CMA), in which the project is located within. The software was considered an appropriate modelling tool for assessing surface water changes at the site. A rain-on-grid approach was used, allowing the simulation of runoff generated from local rainfall on a two-dimensional grid representative of the site topography. Results of the hydraulic modelling were used to assess the potential external catchment surface water changes to the quarry site for the 1% Annual Exceedance Probability (AEP) event.

6.4.2.2 Quarry investigation existing conditions

Hydraulic model results for the 1% AEP event under existing conditions demonstrate that the proposed quarry is not influenced by an external catchment. The site experiences inundation up to a maximum of 200 mm in localised depressions (Figure 6-55).

The proposed extraction area is mainly influenced by localised rainfall, with no external overland flow path entering the site. This means that the flood behaviour for the extraction area is localised inundation and the site is not affected by flow from the broader site extent.

The surface water within the quarry area can be managed as part of development, through drainage storage and/or diversion infrastructure. It should be noted that this investigation was based upon existing topography and surface water behaviour and is likely to change as part of the construction of the quarry. However, as the site has no external catchment the assessment outlined here demonstrates challenges and works required to inform the planning process.

Figure 6-55 1% AEP Flood Depths – Existing conditions

6.4.2.3 Quarry investigation developed conditions

The hydraulic model was updated to incorporate the proposed wind farm layout, associated infrastructure and high level representations of proposed structural mitigation measures, see Section 7.1.2.1. The model included proposed bunding around the quarry works authority area. The site experiences inundation up to a maximum 200 mm deep in localised depressions (Figure 6-56). The maximum velocity experienced across the site is 0.2 m/s (Figure 6-57). Figure 6-58 shows the 1% AEP water level difference across the quarry site under developed conditions, indicating minimal impacts caused by the quarry bunding outside of the quarry area.

Figure 6-56 1% AEP Flood Depths – Developed conditions

Figure 6-57 1% AEP Flood Velocity – Developed conditions

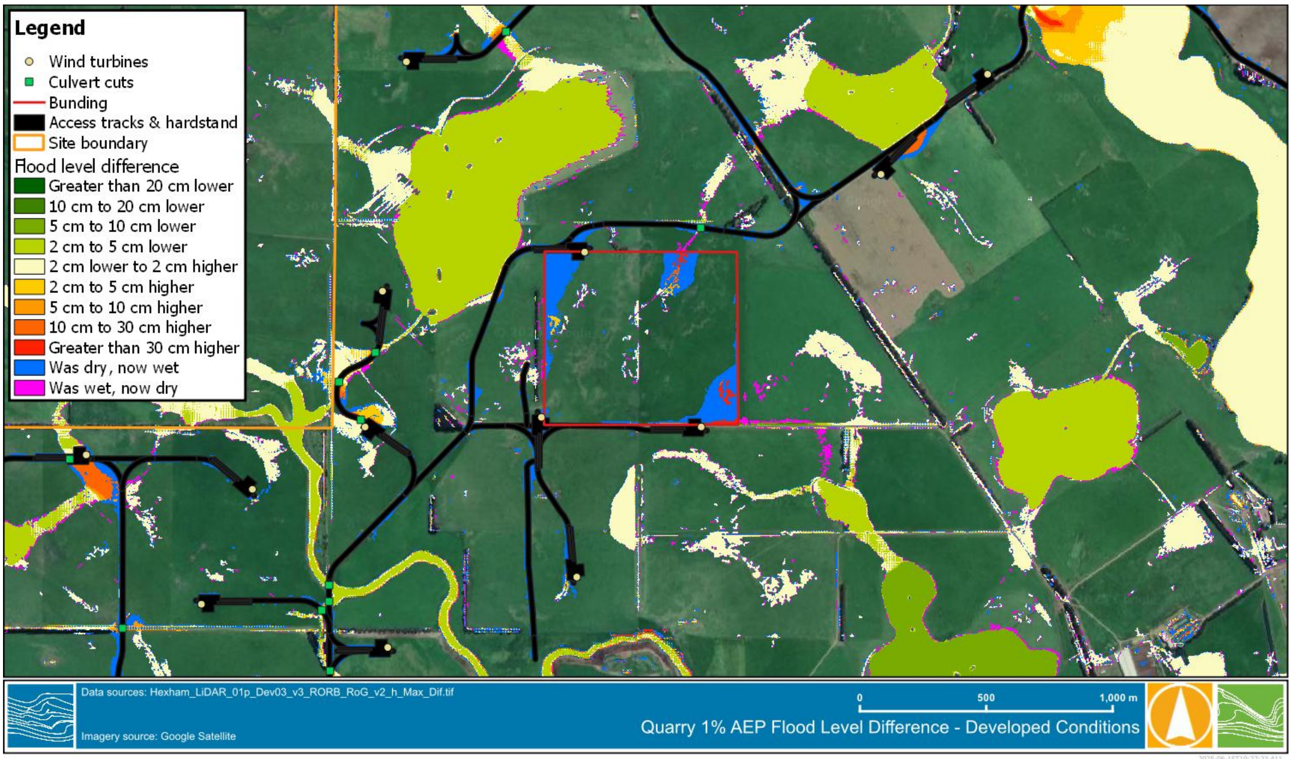

Figure 6-58 1% AEP flood level difference – at proposed quarry

6.4.3 Hydrogeology

6.4.3.1 Overview

The following sections focus on the hydrogeological conditions at the proposed quarry site. The data and information used in this assessment draws on the information presented in Sections 6.3.1 to 6.3.3 and is supported by additional site-specific data which has been collected for the purpose of assessing the proposed temporary on-site quarry.

6.4.3.2 Geology

Assessment of the geology has been informed by 25 resource investigation drillholes which were drilled to depths of up to 18 m at the proposed quarry site (Figure 6-59). This data is supported by several drill logs from existing wells which have been drilled near the quarry site as well as geological and hydrogeological spatial layers available through Visualizing Victoria's Groundwater online portal (VVG).

The surface geology of the site is dominated by the weathered plains and stony rise basalts of the Newer Volcanic Group. At the proposed quarry site, weathering of the basalt material to clay is observed in several drillholes. The weathered material occurs predominantly in the centre and south of the work authority area, with the exception of one hole in the northeast. The depth of the weathering profile extends up to 7.2 m in some locations. Below the weathering profile, the majority of the resource investigation drill holes were reported to be terminated in basalt (23 out of 25), with the exception of P23-04 and P23-013 which were terminated in clay. This suggests that the basalt is likely to extend to at least 18 m in most locations.

The nearest existing well with a geological log is well 89336 within the proposed quarry footprint (Figure 6-59). Note that this well was unable to be found at the exact coordinates provided in the WMIS database and it is assumed that it relates to one of the three holes surveyed at the quarry site (Bore 1, Bore 2 or Bore 3 in Figure 6-59). The drill log for well 89336 suggests that the basalt material extends from surface down to 24 m, with a clay layer observed below this from 24 m to 38 m and marl from 38 m to 40 m (refer to Table 6-23 for geological log).

Beyond well 89336, the closest existing wells are located around 1 km to the southeast (89340 and 89342 in Figure 6-65). 89340 which is the deeper of the two wells intersects clay/gravel to 10 m, basalt from 10 m to 14 m, clay from 14 m to 30 m, clay/gravel from 30 m to 42 m and clay from 42 m to 48 m. The uppermost 10 m of this hole is interpreted to be weathered basalt, with the material described as gravel likely to be unweathered fragments of basalt within the weathered profile. Well 89342 is11 m deep with the entire profile logged as clay.

Spatial layers available through VVG suggest that the Upper Tertiary Marine Aquifer (UTAM) which consists of the Whalers Bluff Formation and Hanson Plain Sand is present below the basalt. The VVG layers suggest the boundary between the basalt and the UTAM occurs at around 15 to 18 m below ground surface, however, the bore logs discussed above suggest that the boundary is slightly deeper. The other key observation is that the units below the basalt are generally described as clay at the quarry site. It is interpreted that these are associated with finer grained deposits of the UTAM.

Table 6-23 WMIS Drillhole Logs

Hole ID	Depth From (m)	Depth To (m)	Description
89336 (Figure 6-59)	0	0.3	Black Soil
	0.3	0.61	Black Clay
	0.61	0.91	Clays And Rock
	0.91	24.38	Decomposed Basalt
	24.38	37.79	Clays
	37.79	39.01	Marl
89340 (Figure 6-65)	0	10	Clay, Gravel
	10	14	Basalt
	14	30	Clay
	30	42	Clay, Gravel
	42	48	Clay
89342 (Figure 6-65)	0	11	Clay

6.4.3.3 Aquifers and aquitards

There are two main hydrogeological units of interest at the proposed quarry site, the Newer Volcanic basalt in which the quarry will be excavated and the deeper UTAM. At the quarry site, the basalt is interpreted to extend to a depth of 24 m below ground level based on the drill log from existing well 89336. This is approximately 6 m below the proposed base of the quarry. Below this is a clay unit from 24 m to 38 m (Table 6-23). This unit is interpreted to be finer grained deposits associated with the UTAM. The dominance of clay in this interval suggests this unit is more likely to be acting as an aquitard or a very low permeability aquifer.

Below these units is the Gellibrand Marl (Upper Mid Tertiary Aquitard) which has an estimated thickness of around 100 m at the quarry site based on the VVG layers. The top of the marl is logged from 38 m in well 89336 (Table 6-23). The Gerribrand Marl is interpreted to overlie basement rocks at the quarry site, and it is considered to be an aquitard.

6.4.3.4 Groundwater levels and flow

Four groundwater monitoring wells were established at the proposed quarry site in April 2023 (locations shown in Figure 6-59). Groundwater levels were obtained from these wells shortly after drilling and again in July 2023. The depth to groundwater from natural surface for these wells is provided below in Table 6-24 along with the observed levels in three other existing wells located near the quarry site (Bore 1, Bore 2 and Bore 3 in Figure 6-59).

Groundwater levels range from 9.38 to 13.30 metres below ground level with groundwater elevations ranging from 127.32 to 129.99 m AHD (Figure 6-60). The data suggests a groundwater flow direction from the northwest to the southeast (Figure 6-60).

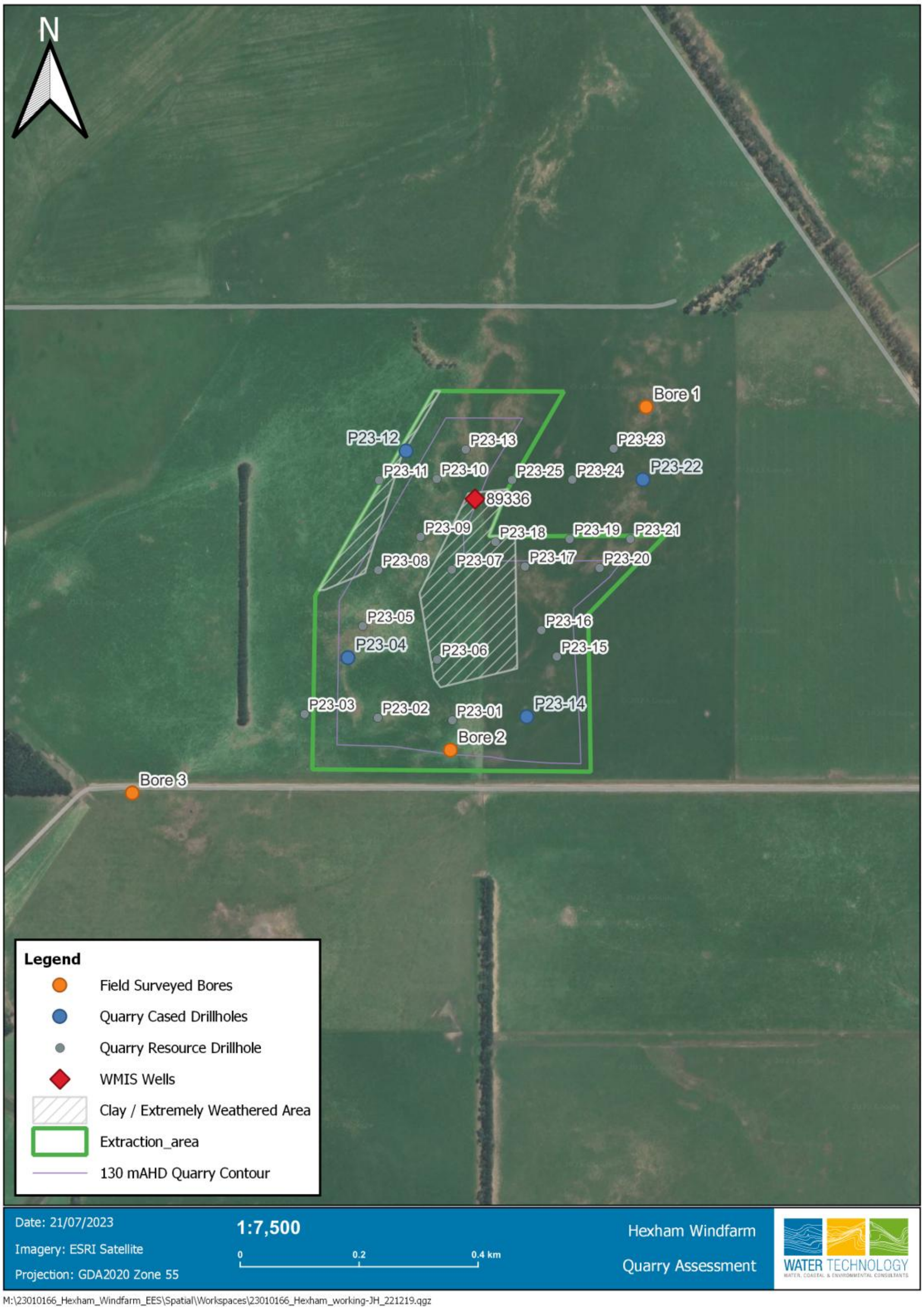

Figure 6-59 Percussion Drillholes and Proposed Quarry Extent

Table 6-24 Hexham Quarry Site Groundwater Levels (July 2023)

Hole ID	Groundwater Level (mBGL)	Surface Elevation (mAHD)	RSWL (mAHD)
Bore 1	11.47	140.83	129.36
Bore 2	10.20	139.64	129.44
Bore 3	9.38	139.25	129.87
P23-04	13.30	142.65	129.35
P23-12	9.24	139.23	129.99
P23-14	10.23	137.55	127.32
P23-22	12.27	140.61	128.34

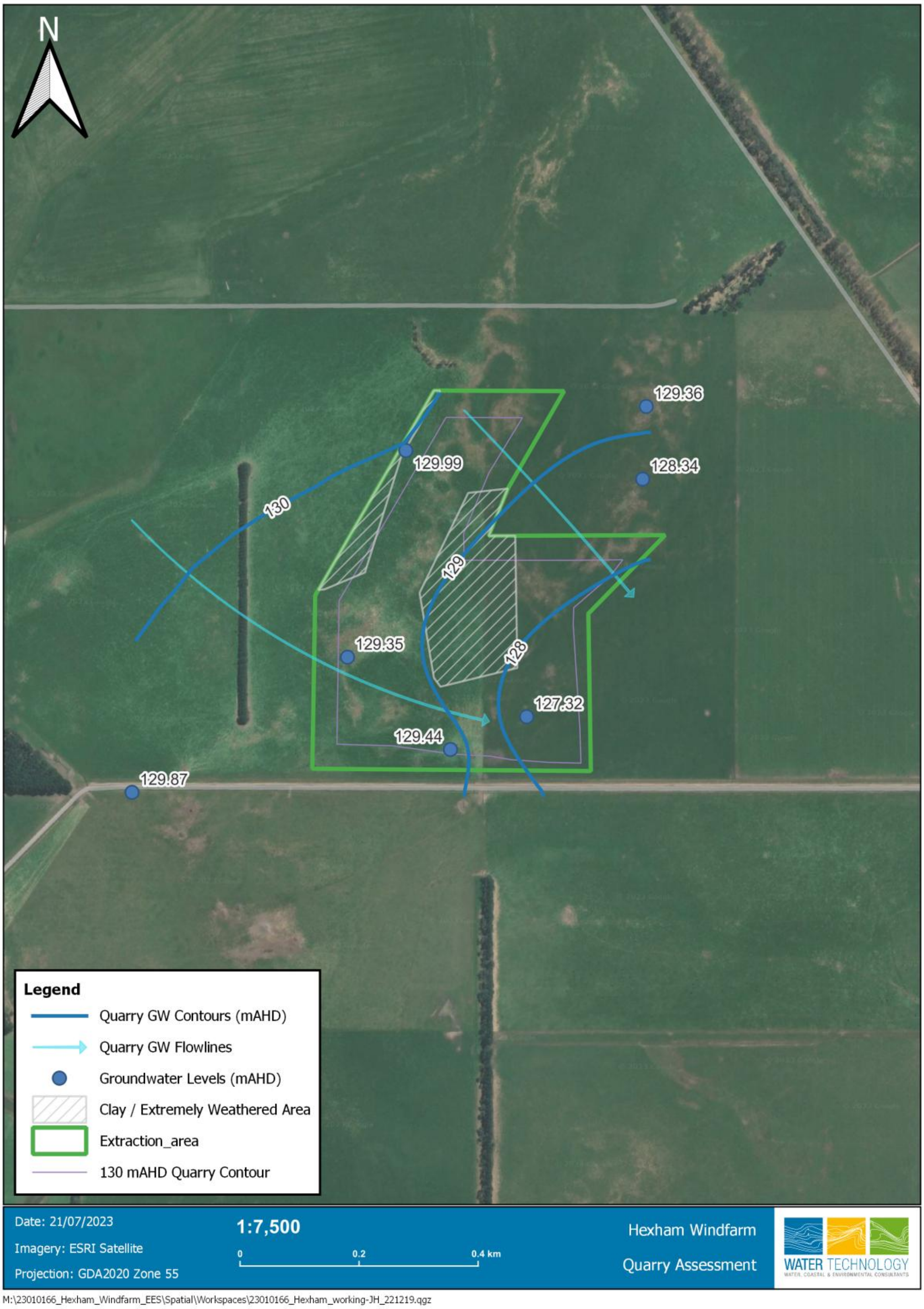

Figure 6-60 Groundwater Contours (05 July 2023)

6.4.3.5 Hydraulic conductivity

Hydraulic testing was undertaken on the four cased quarry wells in July 2023. Testing was undertaken by inserting a slug of known volume into the well which resulted in a displacement of water. The groundwater level was then monitored using both manual measurements and groundwater loggers until it was within 95% of the pre-testing level. Slug test results were analysed using the Bouwer-Rice (1976) solution within the AQTESOLV (Duffield, 2007) software package.

During the analysis, several options for aquifer anisotropy were trialled (Kv/Kh = 0.01, 0.1 and 1). The resulting hydraulic conductivity values are presented in Table 6-25. Figure 6-64 through to Figure 6-64 provide the modelled fit against observed data when Kv/Kh = 0.1 for bores P23-04, P23-12, P23-14 and P23-22, respectively. P23-22 recorded the lowest hydraulic conductivity and P23-12 the highest. The geometric mean of the hydraulic conductivity results using the 0.1 Kv/Kh ratio is 0.031 m/d. The hydraulic conductivities obtained from the slug testing are within the mid to lower range of 0.001 to 100 m/d presented by Dahlhaus et al., (2002) for the Newer Volcanic basalt.

Table 6-25 Hydraulic Conductivity Values Derived from Slug Testing

Hydraulic conductivity (K, m/day)			
Hole ID	Kv/Kh = 1	Kv/Kh = 0.1	Kv/Kh = 0.01
P23-04	0.019	0.024	0.030
P23-12	0.141	0.181	0.235
P23-14	0.032	0.040	0.053
P23-22	0.004	0.006	0.007
Min	0.004	0.006	0.007
Geometric Mean	0.025	0.032	0.040
Max	0.141	0.181	0.235

Notes: 1. Groundwater level in Bore 2 likely to be impacted by pumping.

The hydraulic conductivity of other formations at the site have not been estimated, however, the presence of clay below the basalt at the quarry site suggests that the hydraulic conductivity of these layers is likely to be low (i.e. similar or lower than the values obtained from the slug testing). Kruseman and de Ridder (1991) report hydraulic conductivity values of clay in the range of 1×10^{-8} to 1×10^{-2} m/d.

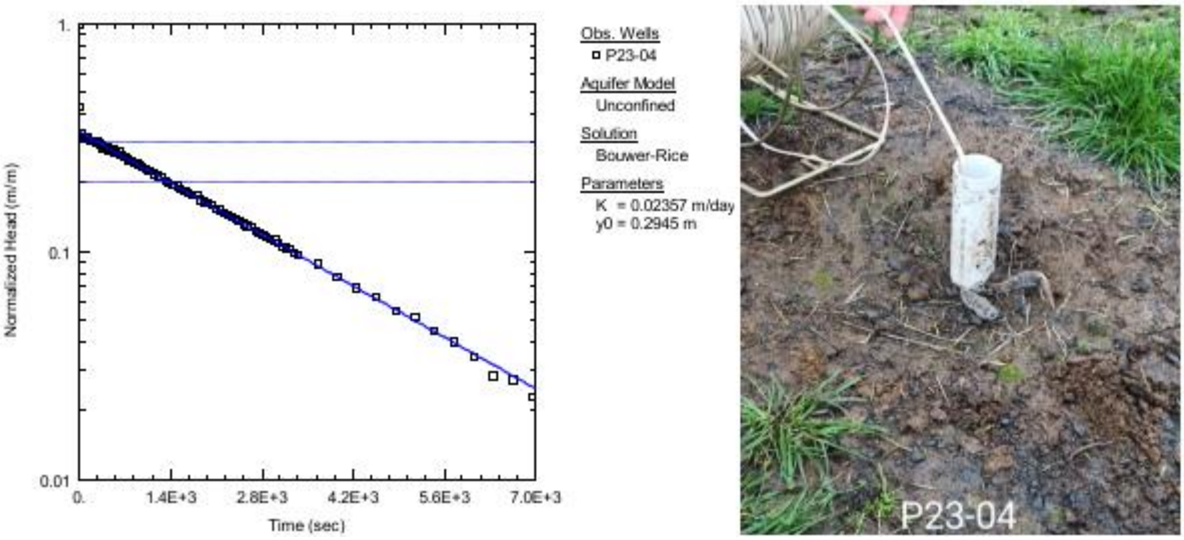

Figure 6-61 P23-04 AQTESOLV Output (Kv/Kh = 0.1)

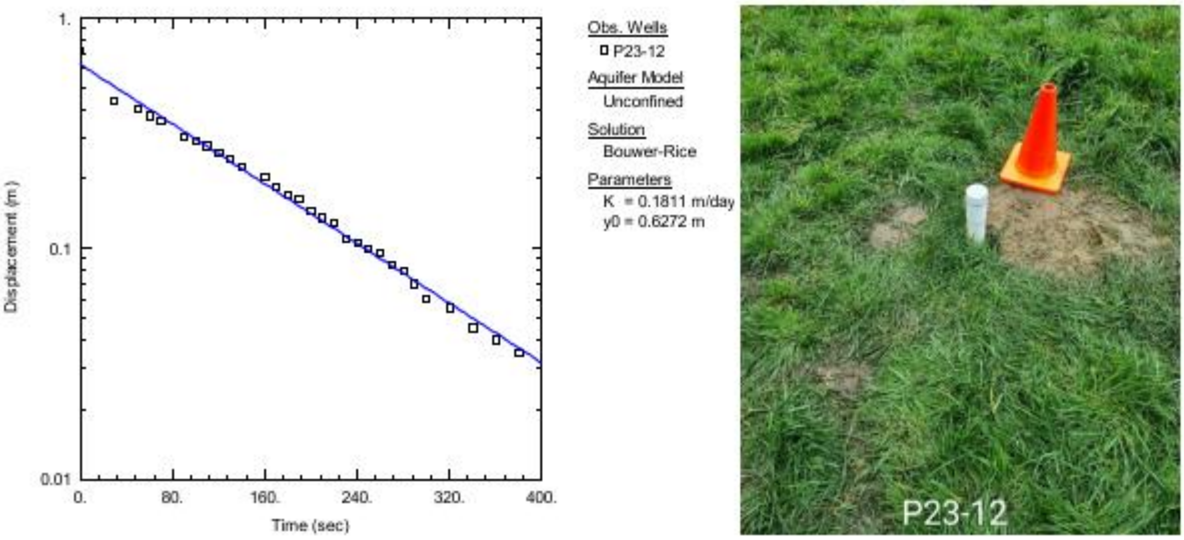

Figure 6-62 P23-12 AQTESOLV Output (Kv/Kh = 0.1)

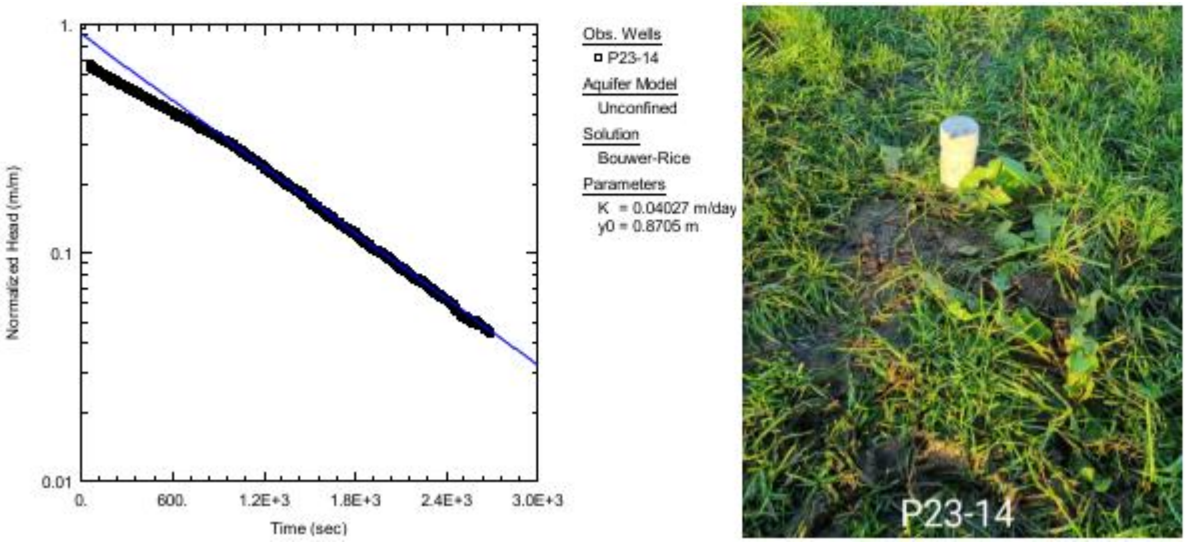

Figure 6-63 P23-14 AQTESOLV Output (Kv/Kh = 0.1)

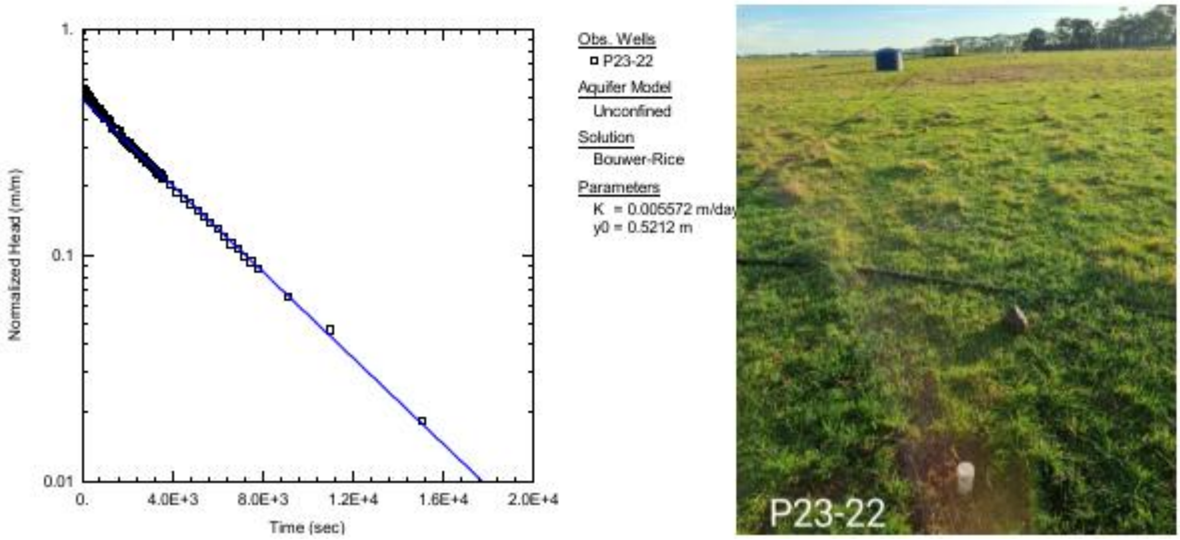

Figure 6-64 P23-22 AQTESOLV Output (Kv/Kh = 0.1)

6.4.3.6 Groundwater recharge

Groundwater recharge within the Volcanic Plains basalt is reported to be between 10 mm and 40 mm annually (Dahlhaus et al., 2002). Recharge is reported to occur largely in winter and spring, with more recharge in wetter years, when soil waterlogging can occur (Dahlhaus et al., 2002).

6.4.3.7 Groundwater quality

Groundwater samples were obtained from the four cased quarry holes for field and laboratory analysis. The bores were purged to ensure a minimum of three casing volumes were removed and physico-chemical parameters were stable, prior to water chemistry sampling. In-situ parameters were recorded during the purging process using a calibrated YSI Professional Plus; temperature (°C), specific conductivity (µS/cm) and pH (Table 4). Samples for analysis were collected in laboratory supplied containers and stored on ice and provided directly to a NATA accredited laboratory in Melbourne (ALS).

Salinity of the groundwater at the quarry site was found to range from 962 mg/L to 3,330 mg/L while pH is neutral ranging from 7.87 to 8.35. The observed salinity is less than that indicated by the VVG water table salinity layer which estimates the salinity to be between 3,500 to 7,000 mg/L at the quarry site.

Table 6-26 Groundwater Quality

Hole ID	TDS (mg/L) Lab	EC (µS/cm) Lab	pH Field
P23-04	962	1,480	7.87
P23-12	2,090	3,220	8.27
P23-14	3,330	5,130	8.35
P23-22	1,890	2,910	8.11

6.4.3.8 Existing wells

Existing wells within 2 km of the proposed quarry site are illustrated in Figure 6-65 with key information for each well tabulated in Table 6-27. The locations of the wells are based on the coordinates provided in WMIS. A field survey conducted between 04 and 05 July 2023 identified three wells near the quarry at the locations presented in Figure 6-65. It is noted that discrepancies exist between these locations and the coordinates available through WMIS. Groundwater levels were obtained from the three surveyed wells and are provided in Table 6-27. Water quality samples from the existing wells were unable to be collected due to the limited space between the casing and existing downhole infrastructure. Historical data available through WMIS indicates a salinity of 1,410 mg/L for well 89336 and 2,306 mg/L for well 89340 (Table 6-27).

Table 6-27 WMIS Groundwater Wells within 2 km of the Proposed Quarry

Well ID	Distance from Quarry (m)	Purpose	Total Depth (m)	SWL (m)	Salinity (mg/L)	Data Source
89336	0	Stock	39.01	-	1,410 (13/08/71)	WMIS
89340	778	Domestic, Stock	48	-	2,306 (13/02/83)	WMIS
89342	842	Domestic, Stock	11	-	-	WMIS
Bore 1	130	Stock	-	11.47	-	Field Survey July 23
Bore 2	0	Stock	-	10.42	-	Field Survey July 23
Bore 3	305	Stock	-	9.58	-	Field Survey July 23

Notes: 1. (-) Denotes no data available
2. SWL measured as distance below ground level

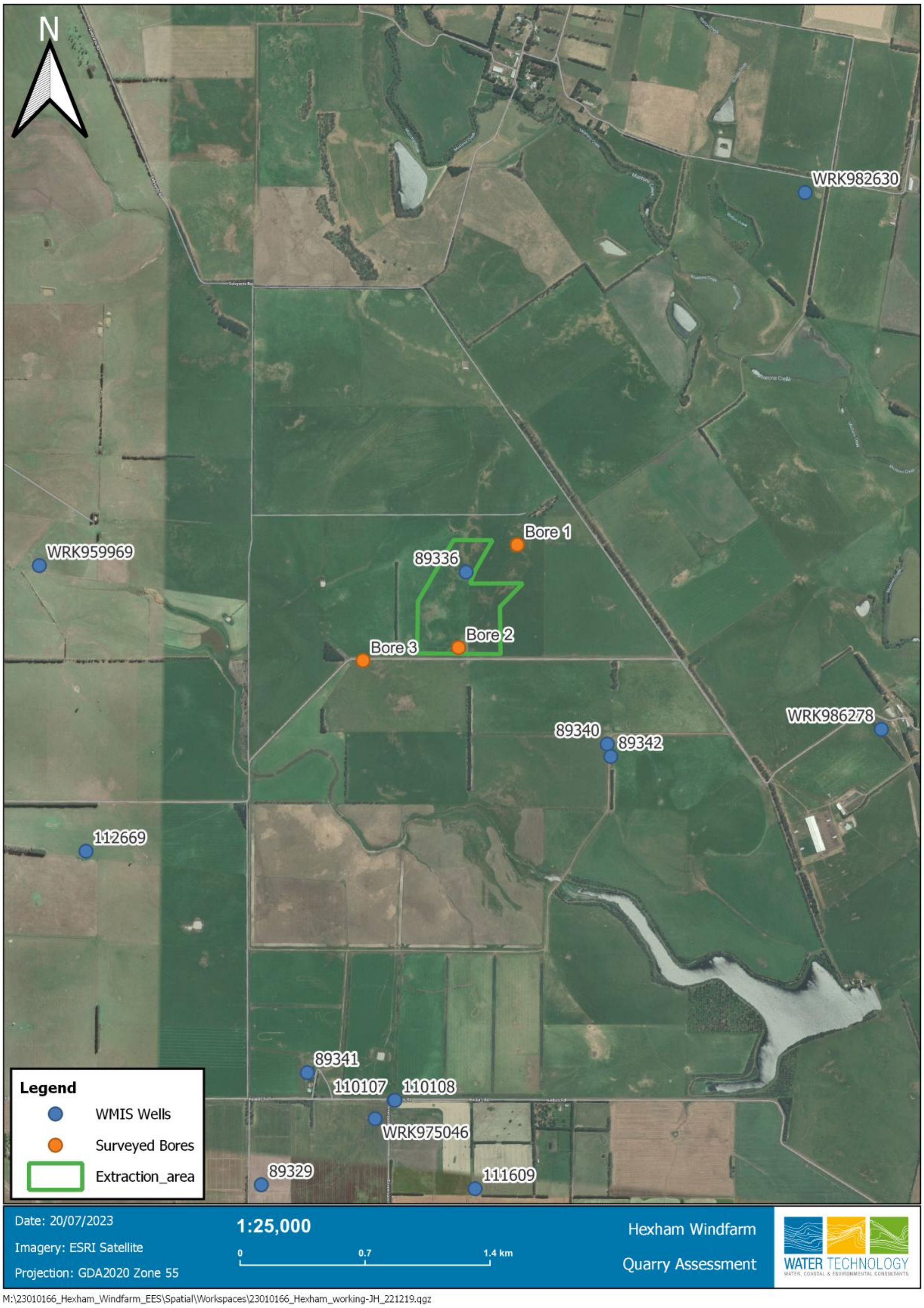

Figure 6-65 WMIS and Field Surveyed Wells

6.4.4 Groundwater inflow and drawdown analysis

6.4.4.1 Analysis method

An estimation of the steady state groundwater inflow to the proposed quarry pit and the extent of drawdown has been made using the Marinelli and Niccoli (2000) method. The analytical method assumes a simplification of the hydrogeological environment and is used to provide an estimate of inflow and drawdown. The method is based on the Dupuit – Forchheimer approximation. The flow into the pit is divided into two zones as shown below in Figure 6-66, with Zone 1 representing the inflow from the pit walls and Zone 2 inflow from the base of the pit.

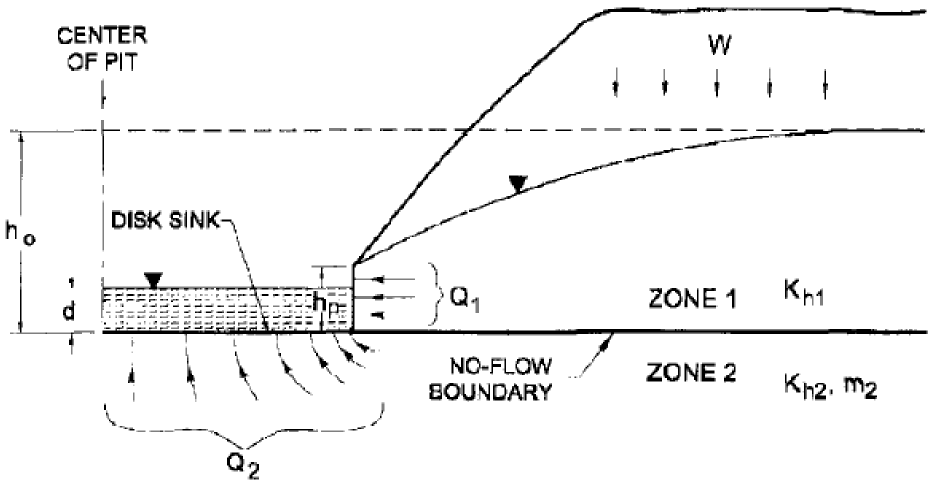

Figure 6-66 Pit Inflow Model (Marinelli and Niccoli, 2000)

The following equations are used to estimate the inflow and drawdown (Marinelli and Niccoli., 2000):

<u>Zone 1</u>

$$Q1 = W\pi(r_o^2 - r_p^2)$$

<u>Zone 2</u>

$$Q2 = 4r_p\,(K_{m_2}^{k_{h2}})(h_o - d)$$

$$h_o = \left(h_p^2 + \frac{W}{K\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right)\right) - \left(\frac{r_o^2 - r_p^2}{2}\right)]}\right)1/2$$

$$m_2 = \left(\frac{k_{h2}}{k_{v2}}\right)1/2$$

Where:

h_o = Initial pre-mining aquifer saturated thickness (metres above base of pit)

h_p = Saturated thickness at the pit wall (metres above base of pit)

W = Distributed rainfall recharge flux (metres per day)

K_{h1} = Horizontal hydraulic conductivity Zone 1 (metres per day)

K_{h2} = Horizontal hydraulic conductivity Zone 2 (metres per day)

K_{v2} = Vertical hydraulic conductivity Zone 2 (metres per day)

r_p = Effective pit radius (metres)

r_o = Radius of influence (metres)

d = Depth of the pit lake (metres)

6.4.4.2 Quarry stages

The quarry is proposed to be excavated in a staged manner which is designed to limit the groundwater and surface water inflows to the quarry pit. The quarry is divided in to approximately four areas of equal size as shown in Figure 6-67. The size of the stages range from around 3 to 5 hectares. Groundwater inflow and drawdown has been estimated for each individual stage. As the quarry progresses, the stages will be backfilled to at least 1 m above the water table.

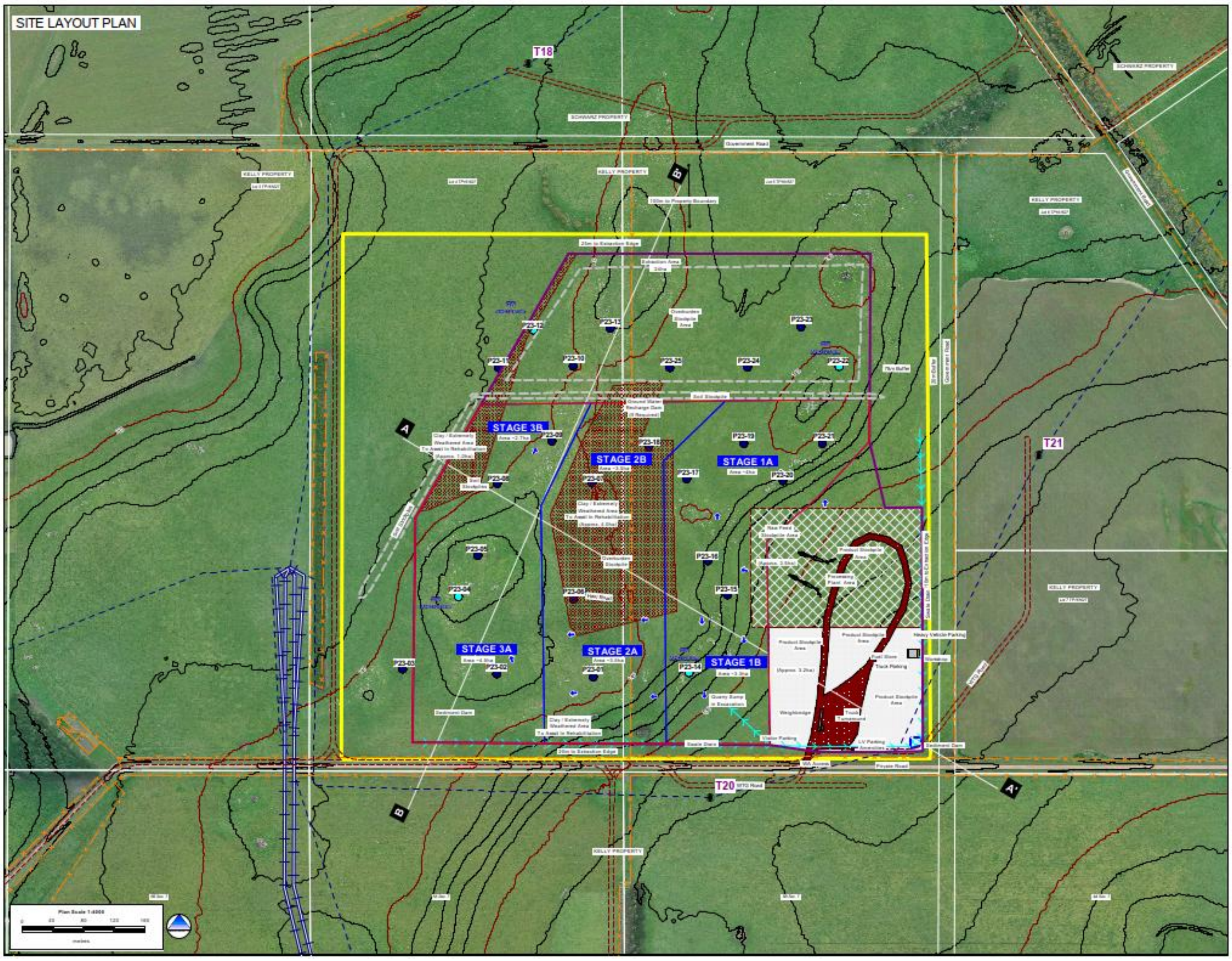

Figure 6-67 Proposed Quarry Staging (BCA Consulting, 2024)

6.4.4.3 Input parameters and scenarios

Several of the input parameters such as quarry pit depth, saturated aquifer thickness and the depth of the water in the quarry pit are able to be estimated with reasonable confidence, and a single value has therefore been used for these input parameters. Aquifer hydraulic conductivity and recharge parameters are likely to have a greater degree of variability and may vary spatially over the extent of the quarry pit. To account for the uncertainties and inherent variability in these parameters, multiple scenarios have been assessed to provide a range of possible groundwater inflows and drawdown extents.

The adopted base case hydraulic conductivity for the Newer Volcanics basalt is 0.025 m/d, which is the geometric mean of the slug testing undertaken in the four cased quarry holes using a kv/kh ratio of 1. It is recognised that both higher and lower hydraulic conductivities may exist, however, the adopted value is considered to provide a realistic representation as it is based on site specific data.

The horizontal and vertical hydraulic conductivity for Zone 2 is estimated to be the same as Zone 1 for the base case scenario, as the basalt extends up to 6 m below the base of the quarry. The input parameters and ranges used to estimate pit inflow and drawdown extent are provided in Table 6-28.

Table 6-28 Marinelli and Nicoli (2000) Input Parameters

Parameter	Description	Value/Range	Comment
h_o	Saturated thickness of basalt aquifer above the base of the pit	3 - 5 m	Estimated at the deepest point in the proposed quarry (southeast corner).
h_p	Saturated thickness above Zone 1	0 m	Quarry assumed to be dry.
W	Distributed recharge flux	10 to 40 mm/a	From Dahlhaus et al., 2002.
K_{h1}	Horizontal hydraulic conductivity in Zone 1	0.025 m/d	Geometric mean of slug tests using Kh/Kv ratio of 1.
K_{h2}	Horizontal hydraulic conductivity in Zone 2	0.025 m/d	Geometric mean of slug tests using Kh/Kv ratio of 1.
K_{v2}	Vertical hydraulic conductivity in Zone 2	0.025 m/d	Geometric mean of slug tests using Kh/Kv ratio of 1.
r_p	Radius of quarry	98 - 127 m	Assumed to be cylindrical. Equivalent to an area range of 3-5 hectares.
D	Depth of water in the pit above Zone 1	0	Quarry assumed to be dry.

The following scenarios were assessed to account for the uncertainties and inherent variability in hydraulic conductivity and recharge and to provide a range of possible groundwater inflows and drawdown extents:

- Base Case: Represents the geometric mean of the hydraulic conductivity (0.025 m/d) and the middle of the recharge range (25 mm/d).
- High K: Represents an upper estimate of the hydraulic conductivity range (0.05 m/d) and the middle of the recharge range (25 mm/d).
- Low Recharge: Represents the lower estimate of the recharge range (10 mm/d) and the geometric mean of the hydraulic conductivity (0.025 m/d).

- High Recharge: Represents the higher estimate of the recharge range (40 mm/d) and the geometric mean of the hydraulic conductivity (0.025 m/d).

The predicted groundwater inflow volumes and drawdown extents are provided in Table 6-29. Under the base case scenario, inflows are expected to be up to 19 ML/yr. Sensitivity analysis of key parameters suggests that inflows of up to 37.2 ML/yr cannot be discounted at this stage if the hydraulic conductivity is higher than assumed. The analysis shows that the predictions are most sensitive to changes in hydraulic conductivity and that changes in recharge results in relatively small changes to the predicted pit inflow volume. Groundwater inflows are proposed to be managed through in-pit sump pumping and storage on-site in retention basins.

Drawdown as a result of pit inflow is predicted to extend up to 189 m from the centre of the pits for the base case scenario and up to 226 m for the low recharge scenario (Table 6-29). For the purposes of assessing the potential impacts on existing users the low recharge drawdown contours have been used as these provide the largest predicted drawdown extent. The predicted drawdown extent for each of the four stages is shown in Figure 6-68. This distance represents the distance from the centre of each pit stage to the point at which drawdown is predicted to be zero. The predicted drawdown extent remains highly localised around the quarry pits due to the low hydraulic conductivity and the limited extent in which the quarry pits are excavated below the water table (i.e. <5 m).

One groundwater well identified during the site survey is within the predicted extent of drawdown (Bore 2 in Figure 6-68). It is possible that an alternate water source will need to be provided to replace this well.

All potential aquatic and terrestrial Groundwater Dependent Ecosystems (GDEs) are located outside of the predicted drawdown extent (Figure 6-68). Impacts to GDEs are not expected as a result of quarry pit dewatering.

6.4.4.4 Rehabilitation

As the quarry progresses, each stage will be backfilled to at least 1 m above the water table which will prevent the ongoing loss of groundwater from the quarry pit that would occur if it remained open and below the water table. A retention basin is proposed to capture any surface water inflow. Any water captured in the retention basin will be lost through evaporation and seepage.

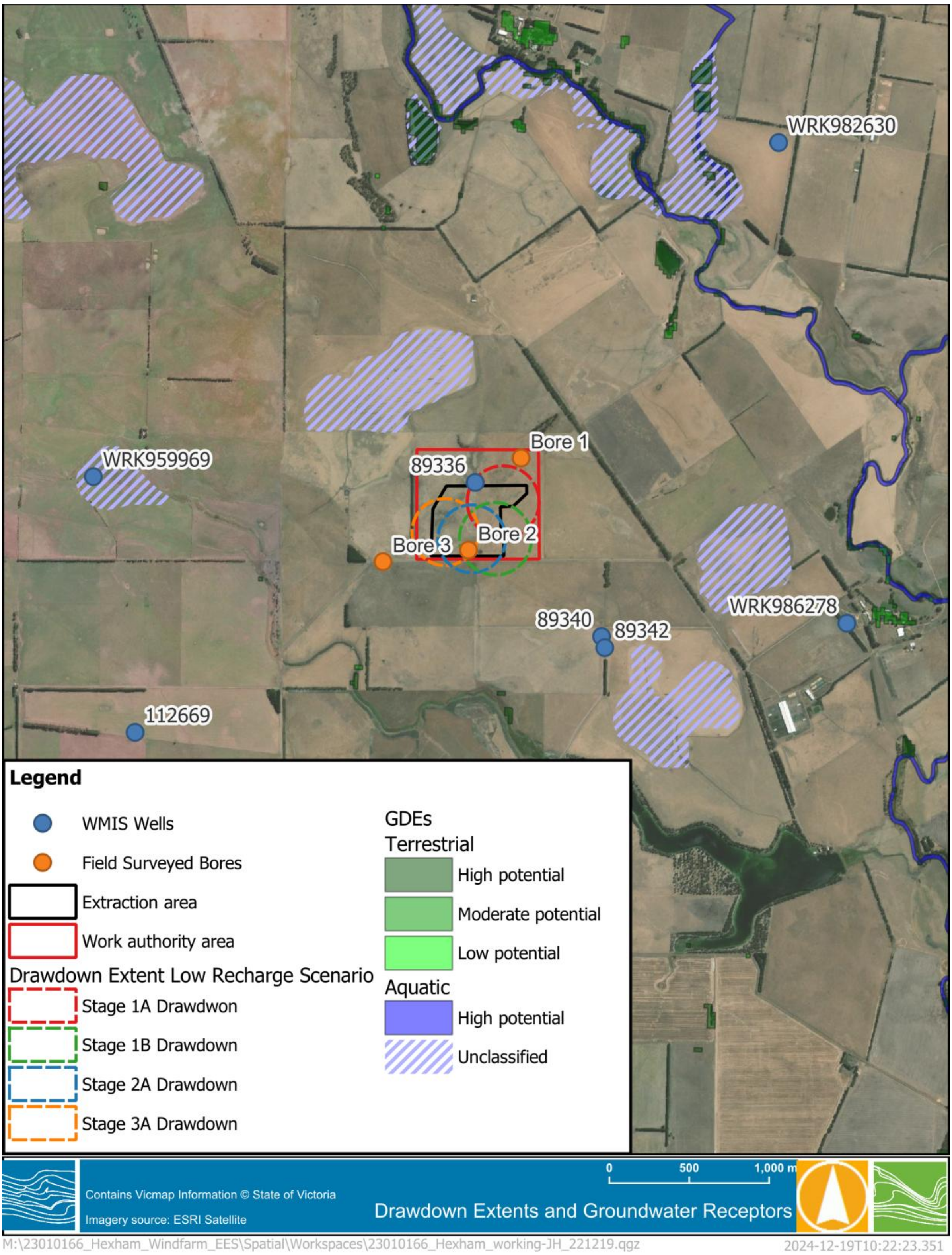

Figure 6-68 Pit Drawdown Extents and Groundwater Receptors

Table 6-29 Predicted Groundwater Inflow and Drawdown Extent

Scenario	Stage	Effective Pit Radius (m)	Saturated Thickness (m)	Recharge (mm/d)	Hydraulic Conductivity (m/d)			Radius of Influence (m)	Zone 1 Groundwater Inflow (ML/yr)	Zone 2 Groundwater Inflow (ML/yr)	Total Groundwater Inflow (ML/yr)
					K_{h1}	K_{h2}	K_{v1}				
Base Case	Stage 1A	119	4	25	0.025	0.025	0.025	189	1.7	16.7	18.4
	Stage 1B	98	5					183	1.9	17.2	19.0
	Stage 2A	106	4					175	1.5	14.9	16.4
	Stage 3A	127	3					180	1.3	13.4	14.6
High K	Stage 1A	119	4	25	0.05	0.05	0.05	215	2.5	33.4	35.9
	Stage 1B	98	5					214	2.8	34.3	37.2
	Stage 2A	106	4					201	2.3	29.7	32.0
	Stage 3A	127	3					201	1.9	26.7	28.6
Low Recharge	Stage 1A	119	4	10	0.025	0.025	0.025	225	1.1	16.7	17.8
	Stage 1B	98	5					226	1.3	17.2	18.5
	Stage 2A	106	4					212	1.1	14.9	15.9
	Stage 3A	127	3					209	0.9	13.4	14.2
High Recharge	Stage 1A	119	4	40	0.025	0.025	0.025	175	2.1	16.7	18.7
	Stage 1B	98	5					166	2.3	17.2	19.4
	Stage 2A	106	4					162	1.9	14.9	16.7
	Stage 3A	127	3					170	1.6	13.4	15.0

6.4.4.5 Model limitations and uncertainty

The groundwater inflow and drawdown extent assessment requires simplification of the hydrogeological environment. The largest degree of uncertainty relates to the hydraulic conductivity of the basalt material. To account for this uncertainty, a range of hydraulic conductivity values were used in the assessment based on testing of four site specific groundwater wells. It is possible that higher than expected groundwater inflows could occur if significant water producing structures are intersected which have higher than assumed permeability. It is also possible that groundwater inflow rates could be lower than the modelled estimates if the quarried area proves to have lower than assumed permeability. Either of these scenarios could impact the planned water management regime for the quarry. If higher than expected inflows occur, the stage areas can be reduced to manage the inflow.

6.4.5 Site water management

6.4.5.1 Overview

The site is proposed to be a *'zero discharge'* site, with all surface water and groundwater managed within the WAA using retention basins. While the basins will have 'zero discharge', stored water will be used for dust suppression and other processing activities. A water use of 10 to 15 ML/yr was determined by HWF. Water Technology has estimated the storage requirements considering surface and groundwater contributions, evaporation, seepage and site use. Key assumptions provided by HWF are outlined below:

- The storage is sized to account for all surface runoff within the site and groundwater inflow to the pit (to be pumped from the pit to the storage) over a 24-month period (January to December).
- The storage is to be located within the Works Authority Area, above and below the water table depending on the quarry stage.
- The quarry will be progressively backfilled with on-site material to at least 1 m above the water table.
- Once the proposed quarry is decommissioned it will no longer be actively managed for surface water inflow. The proposed retention dams will be rehabilitated, and the quarry pit will remain with a permanent dam located at the bottom.

The likelihood that the rehabilitated quarry pit surface will overtop from surface water inflow post decommissioning has also been assessed.

6.4.5.2 Source model set-up

A conceptual water balance model was built for the site using eWater Source. Source was used to estimate catchment run-off volume and behaviour and included the following key components:

- Sources of inflow water to the storage (detention pond) was rainfall, rainfall runoff and groundwater inflow (either directly into the pond when located below the water table or pumped from the quarry pit).
- Outflows from the catchment and storage modelled included evapotranspiration, interflow with soil layers and water demands.

The rainfall runoff model adopted in Source was SIMHYD, estimating the flow generated from the catchment based on the applied climatic data (rainfall and evapotranspiration). Climatic data was obtained from SILO Queensland Point Data obtained for the point closest to the site. The model adopted recommended SIMHYD parameter values for medium to heavy clays from the NSW MUSIC Modelling Guidelines (BMT WBM, 2015), as there was no gauge data available to calibrate the model. Catchments are represented by nodes, watercourses by links, and storage nodes for the pond. The model required daily rainfall and potential evapotranspiration data and had nine parameters as shown in Table 6-30, along with their recommended range.

Table 6-30 Model parameters

Parameter	Description	Units	Min	Max	Adopted
Baseflow Coeff.	Base flow Coefficient		0.0	1.0	0.1
Impervious Threshold	Impervious Threshold	mm	0.0	5.0	See **Table 6-31**
Infiltration Coeff.	Infiltration Coefficient		0.0	400	135
Infiltration shape	Infiltration Shape		0.0	10.0	4
Interflow Coeff.	Interflow Coefficient		0.0	1.0	0
Perv. Fraction	Pervious Fraction		0.0	1.0	See **Table 6-31**
Recharge coefficient	Recharge Coefficient		0.0	1.0	0.1
RISC	Rainfall Interception Store Capacity	mm	0.0	5.0	1.5
SMSC	Soil Moisture Store Capacity	mm	1.0	500	94

- 122 years of meteorological data (rainfall and evapotranspiration) was derived using SILO data from Bureau of Meteorology[14]. The rainfall time series has a mean annual rainfall of 650 mm/year and a mean annual evapotranspiration of 785 mm/year.
  - This data was previously used as part of the wetland analysis undertaken by Water Technology for the project.
- The catchment consisted of the quarry works area and was split into four zones based on the land use.
  - Surface Area (ha) was based upon the provided plan, assuming that only runoff generated within the bunded extraction area, stockpile areas and access/amenities area remained on site (38 ha).
  - As shown in Table 6-29, extraction stage 1B results in the highest groundwater inflow. Hence this scenario was selected for the surface water balance modelling.
  - Impervious Area was assumed as outlined in Table 6-31. Note that the assumed Total Impervious Area (TIA) was adjusted to Effective Impervious Area (EIA) based upon Table 4.2 in "Using MUSIC in Sydney Drinking Water Catchment, WaterNSW 2019"[15].
  - Soil moisture storage capacity was set as 94 mm. This is the recommended value for an upper subsoil texture of Medium to Heavy Clays as outlined in Table 4.4 of the WaterNSW report. The upper subsoil texture was determined based upon Agriculture Victoria's map (Figure 6-69)
  - The recommended Rainfall Threshold as outlined in Table 4.3 of the WaterNSW report, was adopted (Table 6-31).
- The model was run at a daily timestep.

Additional assumptions were made for each of the conceptual solutions identified and are outlined in their respective sections below.

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[14] https://www.longpaddock.qld.gov.au/silo/
[15] MUSIC Modelling Guidelines (waternsw.com.au)

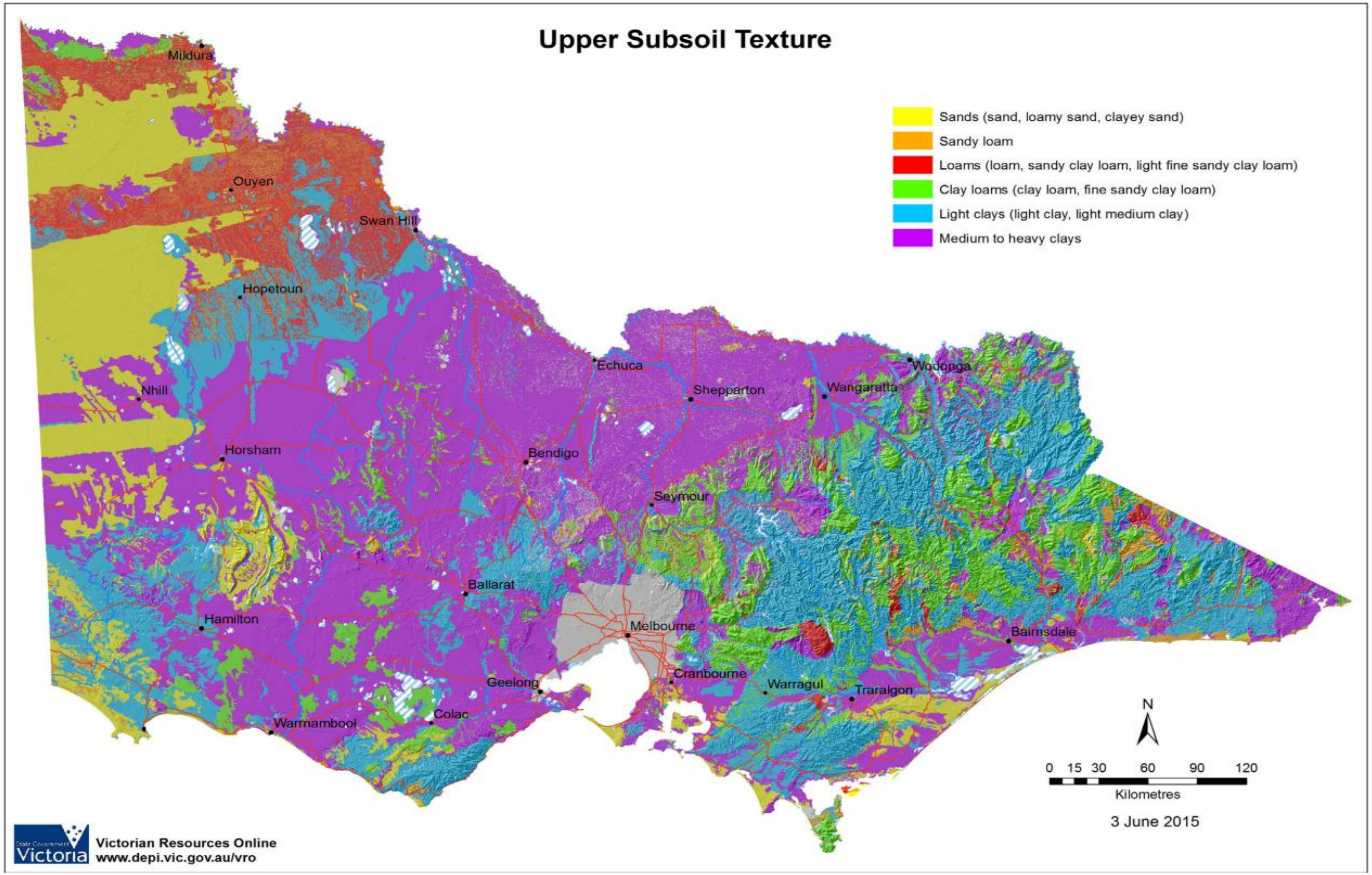

Figure 6-69 Agriculture Victoria Upper Subsoil Texture (Source: Agriculture Vic)

Table 6-31 Model Node Areas

Node	Total Area (ha)	Assumed TIA (ha)	EIA (ha)	Modelled Impervious Area (%)	Impervious Threshold (mm)
Quarry (Stage 1B)	3.3	1.65	0.83	25%	1
Stockpile	6.93	3.47	1.73	25%	1.5
Parking & Access	0.94	0.47	0.47	50%	1.5
Remaining Area	26.83	2.68	2.68	10%	1

6.4.5.3 On-site storage – During operation

To assess the required on-site storage during the proposed 24-month quarry operation, the following adaptions were made to the Source model:

- Groundwater Inflow
  - A base case scenario of 19 ML/yr was adopted, with 37.2 ML/yr used to represent a conservative sensitivity analysis. Further information on how these estimates were defined is detailed in Section 6.4.4.
- Storage
  - A storage node was used to represent the proposed storage. The exfiltration rate of the pond was set to 0 mm/hr to represent a conservative scenario assuming no seepage losses.
  - Further information on the sizing methodology is provided in Section 6.4.6.1.
  - An annual dust suppression re-use demand of 15 ML/yr was applied, with a monthly demand variation, based upon the following methodology:
    - Daily Demand for Dust Suppression = Daily Evaporation Rate – Daily Rainfall (when >0)[16].
      - The average monthly demand was determined over the entire dataset and was adopted for as the expected demand. The average monthly dust suppression demand is provided in Table 6-32.

Table 6-32 Average Dust Suppression Demand

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
mm	142.15	112.90	85.51	42.24	18.83	10.32	11.89	21.79	41.59	72.88	98.22	125.27
%	18.14	14.41	10.91	5.39	2.40	1.32	1.52	2.78	5.31	9.30	12.53	15.99

A schematic diagram of the Source model set up is presented in Figure 6-70.

[16] https://environment.des.qld.gov.au/__data/assets/pdf_file/0027/107397/app0050143-appendix-a.pdf

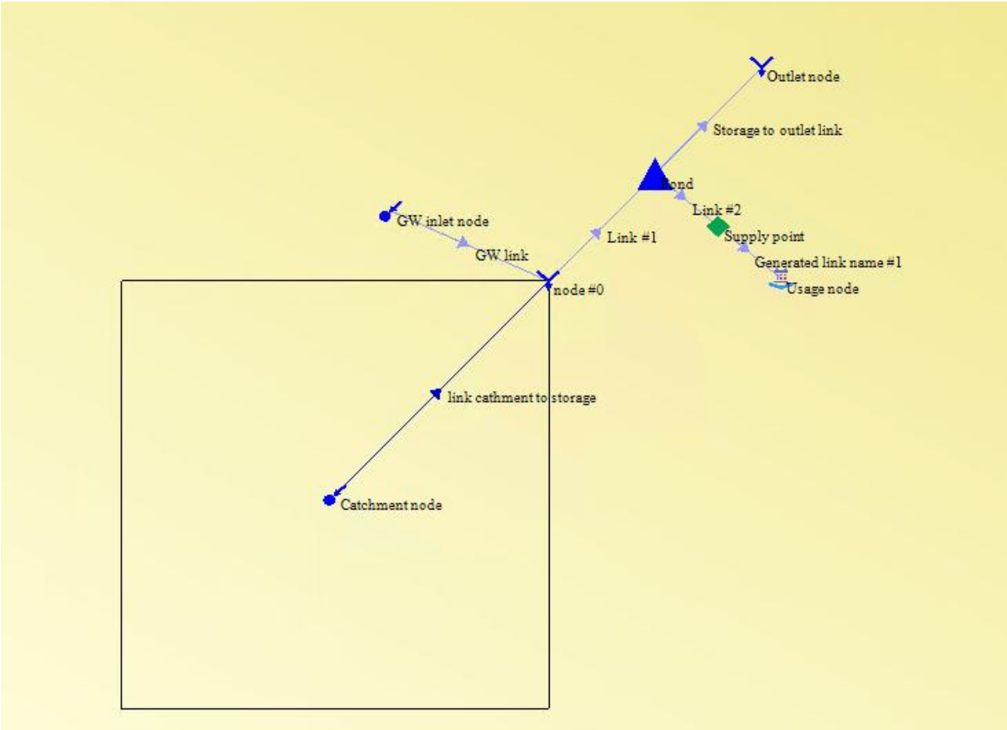

Figure 6-70 Model Schematic – During Operation

6.4.5.4 Quarry Pit Storage – Post Decommissioning

To assess the likelihood of the rehabilitated quarry pit surface overtopping after decommissioning the following adaptions were made to the Source model:

- Catchment
  - Based upon the topography of the site, it is expected that the quarry will not receive surface water runoff from other areas of the site, with diversion and catch drains designed to capture and direct elsewhere.
  - Sensitivity analysis assuming surface water contribution from the entire quarried site was also undertaken.
- Groundwater inflow
  - No groundwater inflow is expected as the rehabilitated quarry pit surface will be at least 1m above the water table.
- Storage (Quarry Pit)
  - A storage node was used to represent the proposed decommissioned quarry. As the rehabilitated quarry pit surface is above the water table, a seepage rate of 0.063 mm/hr was applied.
  - Further information on the sizing methodology is provided in Section 6.4.6.2.

A schematic diagram of the Source model set up is presented in Figure 6-71.

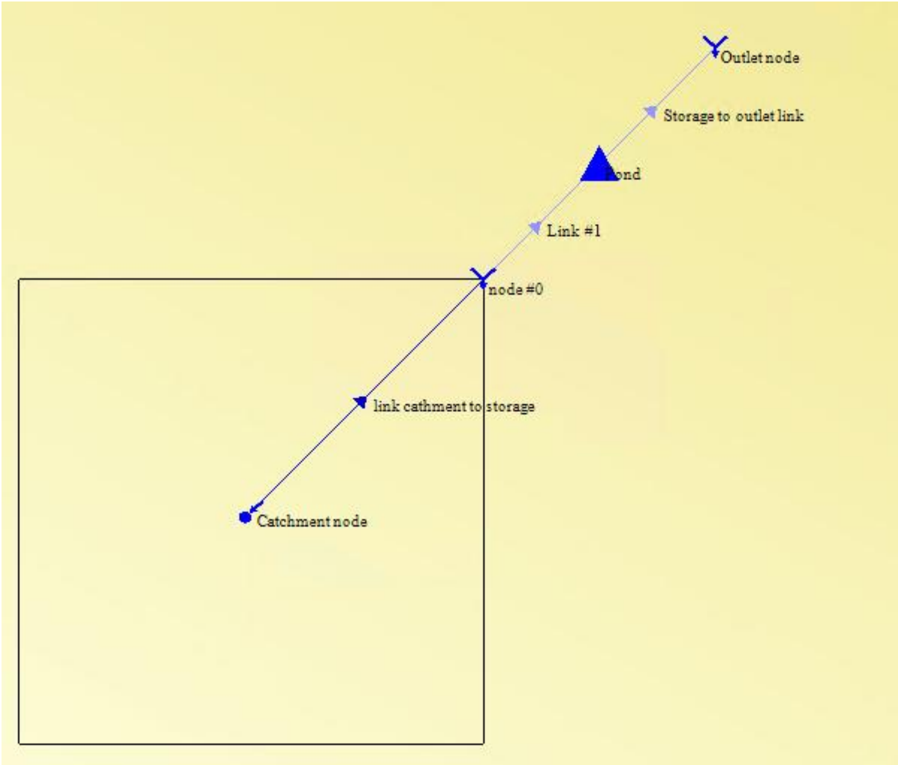

Figure 6-71 Model Schematic – After Decommissioning

6.4.6 Storage sizing and analysis

6.4.6.1 During operation

The Source model was initially run for the entire available period of rainfall data (1900-2022) to allow an assessment of annual catchment water yield. The water yield for the proposed storage across a 24-month period for several percentiles is presented in Table 6-33. Note the water yield analysis assumed the following preliminary parameters:

- Storage surface area of 1.7 hectares with an infinite depth to prevent overtopping
- Seepage rate and groundwater inflow: 0.36 mm/hr & 19 ML/yr, respectively.

These parameters were adopted to determine the information presented in **Table 6-33**, it is noted the values presented may vary slightly from the design yields due to variation in evaporation and seepage loss because of a variation in surface area and depth.

The storage was assessed to ensure no overtopping in both the 90th and 99th percentile events. The storage was sized to account for the expected conditions with a seepage rate and groundwater inflow of 0.36 mm/hr & 19 ML/yr, respectively.

To assess the uncertainty in the input parameters, the following four scenarios were run iteratively to size a storage, which did not overtop in Scenarios 1 & 2 as outlined below:

- Scenario 1 (Base Case & Design Scenario) – Used to assess the impact of the 90th percentile annual water yield.
  - 1983 – 1984 24-month period.
  - Seepage rate and groundwater inflow: 0.36 mm/hr & 19 ML/yr.

  - Dust Suppression demand of 15 ML/yr.
- Scenario 2 (Design Scenario) – Used to assess the impact of the 99th percentile annual water yield.
  - 1946 – 1947 24-month period.
  - Seepage rate and groundwater inflow: 0.36 mm/hr & 19 ML/yr.
  - Dust Suppression demand of 15 ML/yr.
- Scenario 3 – Used to assess impact of low infiltration rate.
  - 1983 – 1984 24-month period.
  - Seepage rate and groundwater inflow: 0.036 mm/hr & 19 ML/yr.
  - Dust Suppression demand of 15 ML/yr.
- Scenario 4 – Used to assess the impact of high groundwater inflow.
  - 1983 – 1984 24-month period.
  - Seepage rate and groundwater inflow: 0.36 mm/hr & 37.2 ML/yr.
  - Dust Suppression demand of 15 ML/yr.

The assessment determined that 88 ML of storage is needed to hold 24 months of surface and groundwater inflow in the design scenario (Scenario 1), equivalent to a storage with surface area of 1.7 hectares and depth of 5.4 m. It should be noted the Source model assumed a constant stage-storage relationship (i.e., a cylindrical storage) and site conditions will vary. Variation from the proposed surface area will result in a variation in losses, additional modelling should be undertaken for any proposed design – noting that increasing the area will reduce the risk and vis vera.

Results of the analysis are presented in Table 6-34, storage water levels for Scenarios 1 & 2 are presented in Figure 6-72 and Figure 6-73 respectively.

Table 6-33 shows negative numbers in the minimum and 10th percentile years because use and losses are higher than inflow (i.e., 69.3 ML is the largest deficit of inflows versus use and losses).

Table 6-33 Annual Water Yield (Based on Surface Area of ~1.7 ha)

Percentile	Water Yield (ML/yr)
Min	-69.3
10%	-34.4
50% (Median)	7.0
90%	52.8
99%	89.0
Max	110.5

Table 6-34 Storage Analysis Results

Scenario	Maximum Storage (ML)	Maximum Depth (m)
S1 (Design)	88	5.4
S2	103	6.3
S3	159	9.5

Scenario	Maximum Storage (ML)	Maximum Depth (m)
S4	115	7.0

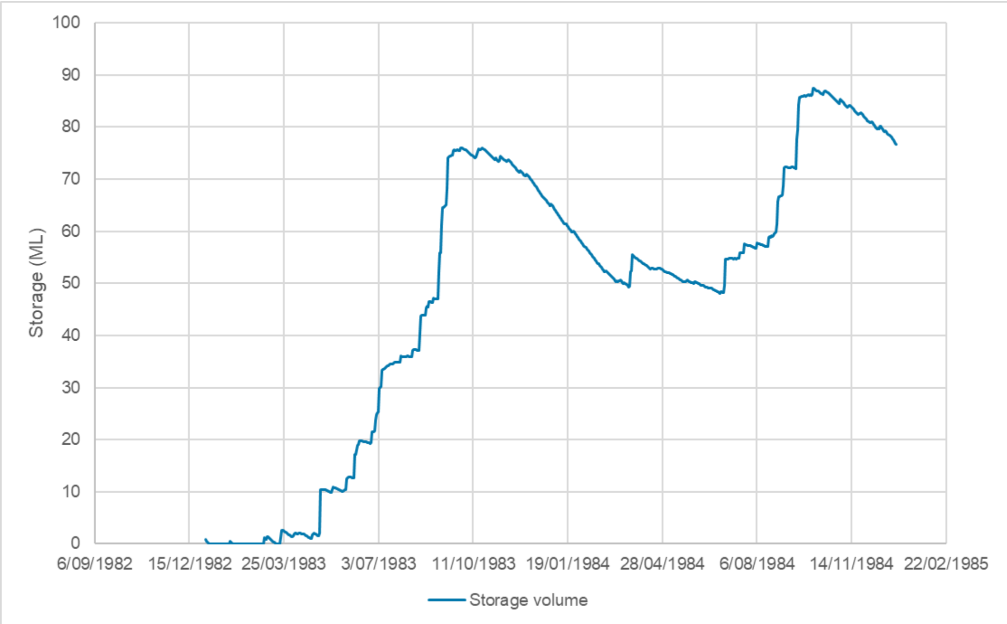

Figure 6-72 Scenario 1 – 83/84 Base Case Storage versus Time

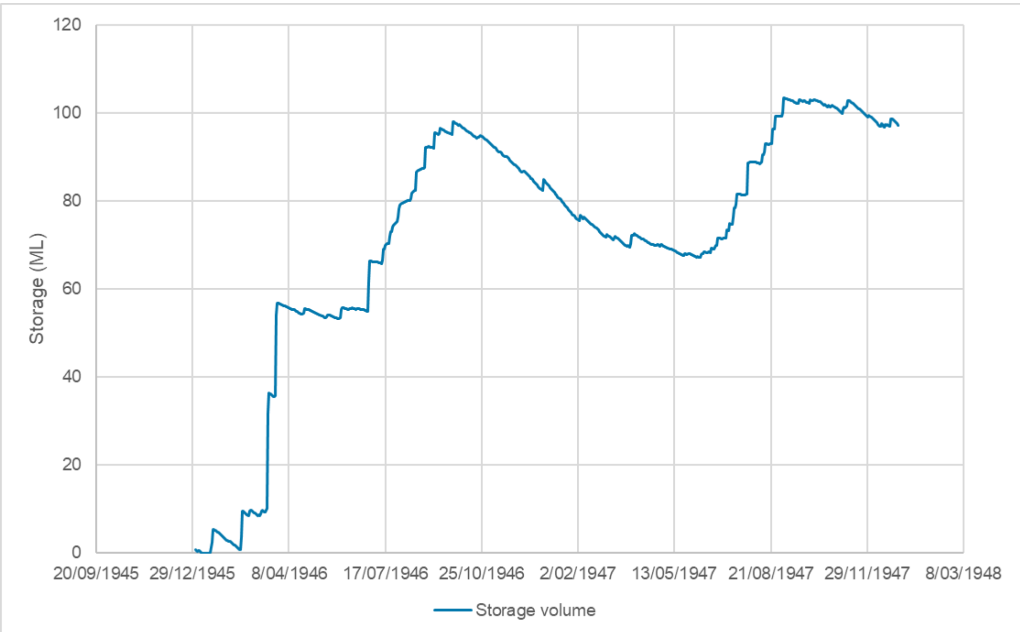

Figure 6-73 Scenario 2 – Adjusted 46/47 Storage versus Time

6.4.6.2 Post operations

Post operations, the quarry will be rehabilitated as a void, with a small farm dam at the low point. Note that with the limited catchment area contributing to this storage, it will not act as a typical dam, only capturing the rainfall runoff within the void, and will not reduce the water available in the overall catchment. All plant and infrastructure will be removed, and batters and hardstand areas ripped, soiled and returned to pasture. Rehabilitation batters will be at least 1V:4H to quarry floor level, which will be backfilled to above the recovered groundwater level.

The time for the quarry pit lake to reach equilibrium following the end of quarrying will depend on several factors including the final rehabilitated quarry pit surface, the surface water inflow rate and losses through evaporation and seepage. The surface water contribution is magnitudes larger than the evaporation losses. As the rehabilitated quarry pit surface will be backfilled to at least 1 m above the water table, there are not expected to be any groundwater inputs during the post operations stage.

To assess the risk of overtopping, the Source model was run for the entire available period of rainfall data (1900-2022) with the "Pond" effectively designed to represent the post decommissioning storage pond. As the exact design of this is unknown the analysis assumed a freeboard height of 7.5 m and a surface area of 10 ha, with a storage capacity of 762ML. The analysis showed that due to the large surface area, evaporation prevented the storage from overtopping throughout the 120-year period in the design scenario.

As a sensitivity analysis two scenarios were run for the determined storage, as outlined below:

- Scenario 1 – Base Case (Design Scenario) – 22 hectare catchment – quarried area.
- Scenario 2 – Used to assess impact of entire site contributing flows – 38 hectare catchment.

The results of the analysis are presented in Table 6-35. Note that S1 is the design scenario used to assess the capacity of the final rehabilitated quarry, with S2 illustrating a sensitivity assessment.

Table 6-35 Quarry Analysis – Post Decommissioning

Scenario	Maximum Storage Achieved (ML)	Time Period to Overtop	Average Annual Increase (ML)
S1 (Design)	171 ML	120 + years	-0.14
S2	762 ML	52	13.7 (until overtopping)

6.4.7 Summary

The site is proposed to be a *'zero discharge'* site with all surface water and groundwater managed within the WAA using retention basins. Groundwater inflows are expected to be around 19 ML/yr under the base case scenario, with lower and upper values of 37.2 ML/yr derived from sensitivity analysis of key input parameters. The onsite storage requirements to manage surface water and groundwater inflows were assessed using an eWater Source model for the operational and post operational phases of the project. Modelling demonstrated the following key points:

- During operation:
  - Assuming an operational storage area of ~1.7 hectares a 6.5 m deep storage can hold both a 90th and 99th percentile surface water inflow year and a groundwater inflow of 19 ML/yr (assuming 24 months of inflow and water usage of 15 ML/yr).
  - Surface water and groundwater inflows can be managed through in-pit sump pumping.
- Post operation:

- If the quarry pit is converted to a water storage and only the previous extraction area can contribute runoff/inflow the storage will need to hold at least 171 ML and be located above the groundwater level. Initially, the farm dam at the bottom of the rehabilitated pit will fill up, and if it exceeds capacity the quarry pit will contain the excess water. The design scenario volume of 171 ML can be contained within the former pit. This is significantly less than the remaining quarry void.
- If the quarry pit is converted to a water storage and the former disturbed area (stockpiles, office, hard stand etc.) can contribute runoff/inflow the storage of 171 ML will not be sufficient. The results show that it is desirable to limit the catchment contributing flows to the quarried area.
- The contributing catchment area will be limited to the former extraction area, with bunding preventing other areas from discharging to the storage.

6.5 BESS assessment

6.5.1 External catchment surface water impact

6.5.1.1 Surface water methodology

Water Technology previously undertook hydraulic modelling of the project area and upstream catchment using TUFLOW. TUFLOW is one of the most widely used hydraulic modelling software packages in Australia and is the preferred modelling package for the Glenelg Hopkins Catchment Management Authority (CMA), the project is located within the Glenelg Hopins CMA management region. The software was considered an appropriate modelling tool for assessing surface water changes at the site. A rain-on-grid approach was used, allowing the simulation of runoff generated from local rainfall on a two-dimensional grid representative of the site topography. Results of the hydraulic modelling were used to assess the potential external catchment surface water changes to the BESS site for the 1% Annual Exceedance Probability (AEP) event.

6.5.1.2 BESS assessment existing conditions

Hydraulic model results for the 1% AEP event under existing conditions demonstrated the proposed BESS site is not influenced by an external catchment. However, the proposed terminal station is located in an overland flow path with inundation depths up to a maximum of 500 mm (Figure 6-74). This overland flow path will require diversion around the development to prevent inundation of the terminal station and to return the flow path to its original path downstream of the terminal station.

Direct rainfall onto the terminal station and BESS area can be managed as part of development, through drainage storage and/or diversion infrastructure. It should be noted that this investigation was based upon existing topography and surface water behaviour and is likely to change as part of the construction.

6.5.1.3 BESS assessment developed conditions

The hydraulic model was updated to incorporate the proposed wind farm layout, associated infrastructure and high level representations of proposed structural mitigation measures, see Section 7.1.2.1. This included bunding around the site compound, BESS and terminal station areas. The maximum depth within the site reaches 800 mm in these mitigated condtions (Figure 6-75). The maximum velocity experienced across the site is 0.2 m/s (Figure 6-76).

Figure 6-77 shows the 1% AEP water level difference across the BESS site under developed conditions. As seen in the existing conditions modelling, the proposed terminal station intersects a deeper flow path and adding bunding around the extent of the terminal station and BESS causes ponding upstream. Open drains along the proposed terminal station are required to divert flows around the area and back to its natural flow path. The internal pooling of water indicates that water management is required within the proposed terminal station, or alternatively a location outside of existing flow paths should be adopted.

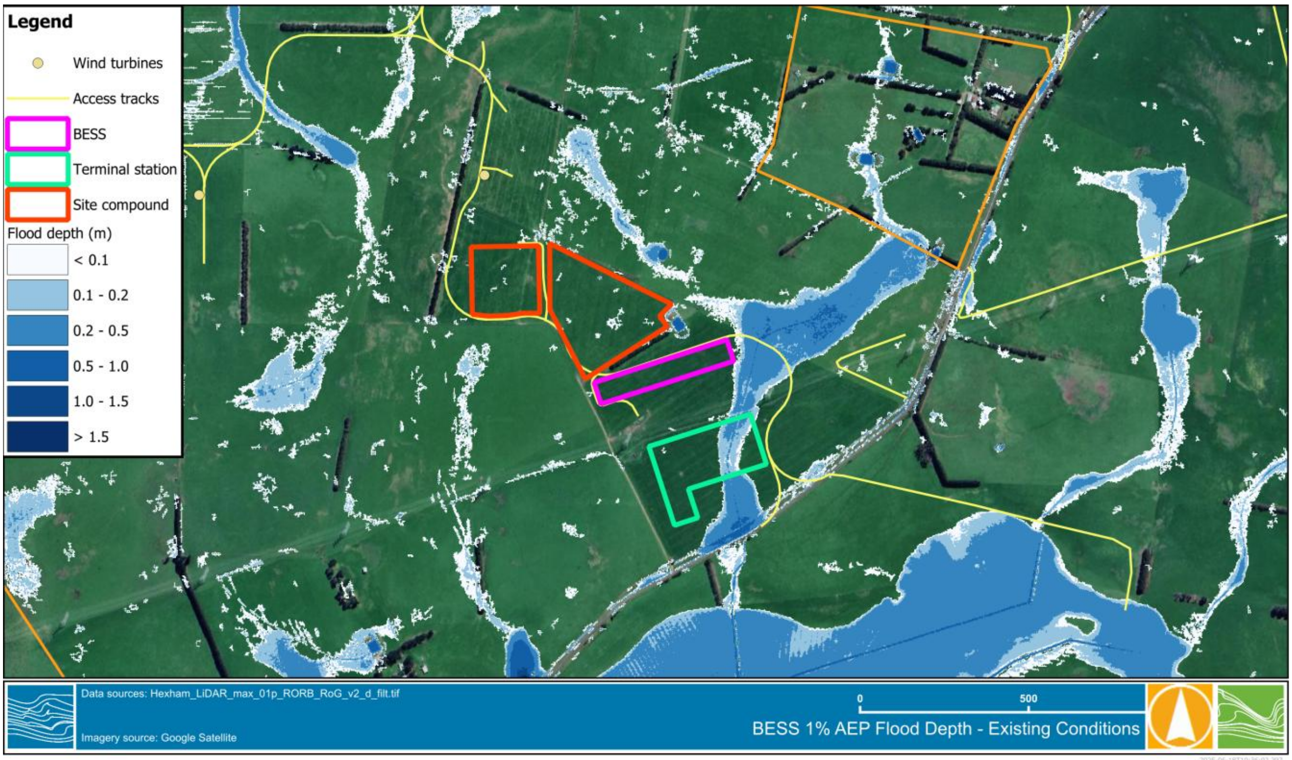

Figure 6-74 1% AEP Flood Depths at BESS– Existing conditions

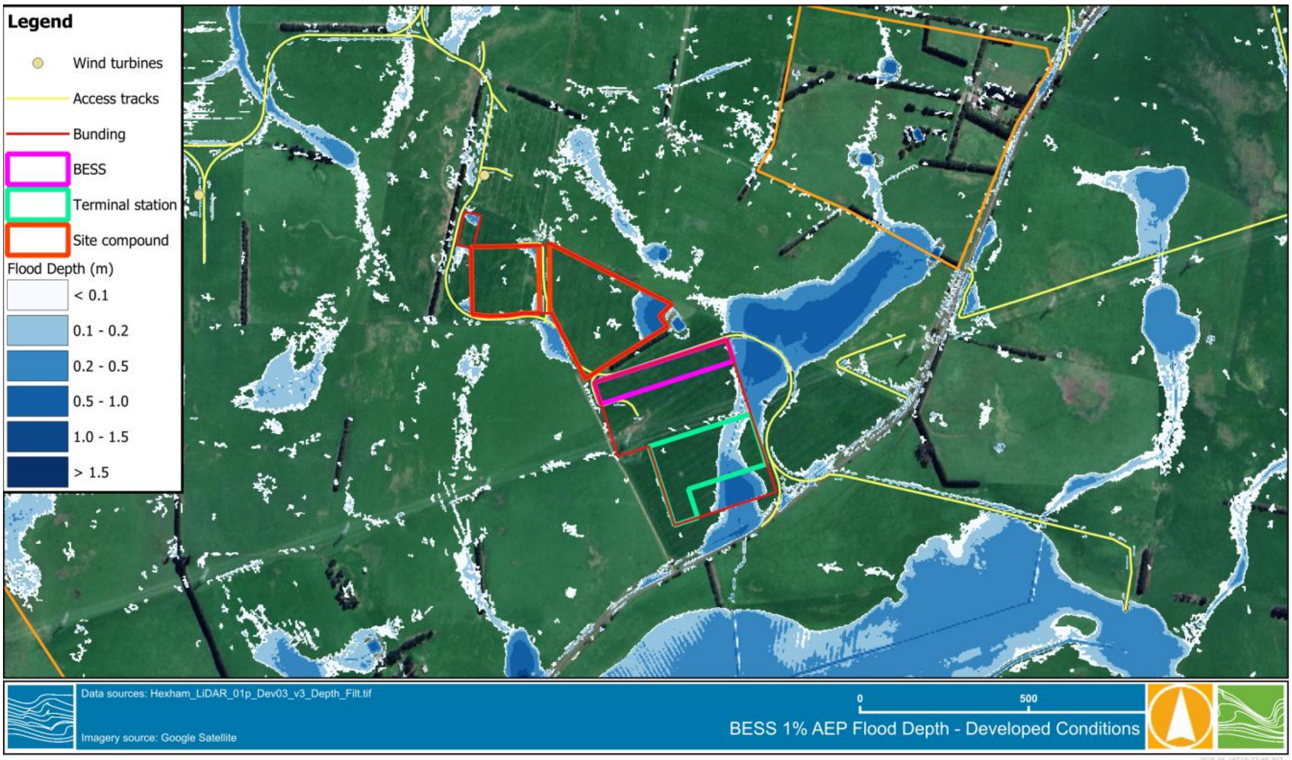

Figure 6-75 1% AEP Flood Depths at BESS– Developed conditions

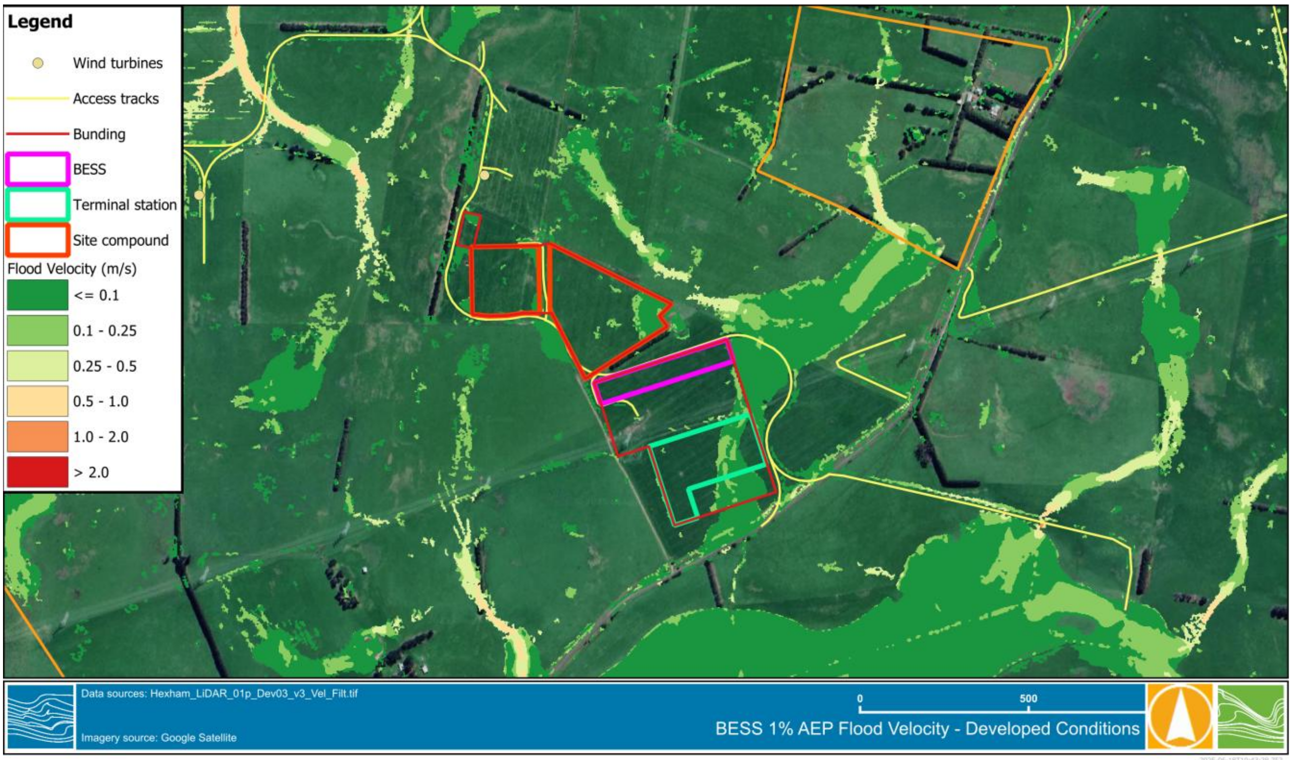

Figure 6-76 1% AEP Flood Velocity at BESS– Developed conditions

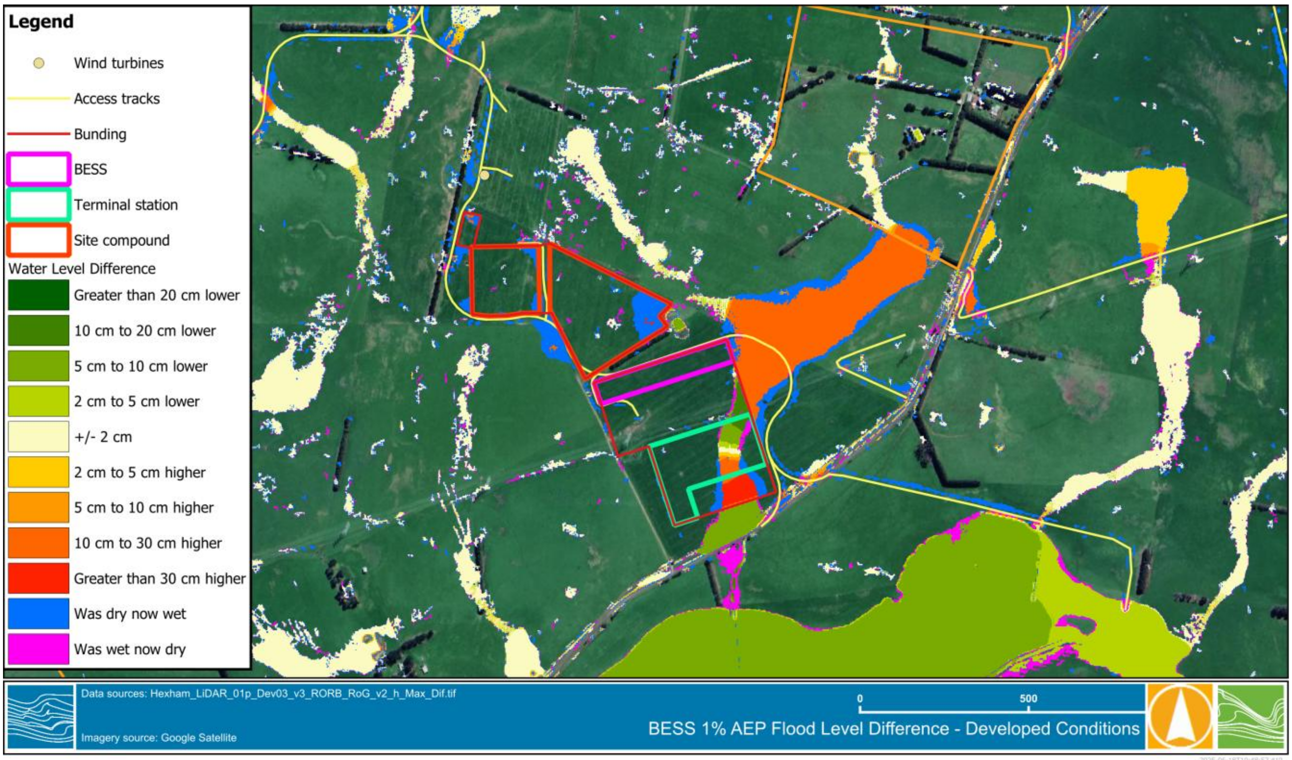

Figure 6-77 1% AEP flood level difference – at proposed BESS

7 IMPACT PATHWAYS

7.1 Surface water

7.1.1 Overview

This section investigates the likely impact pathways of the proposed activity on values related to surface water. The proposed infrastructure has the potential to impact surface water hydrology if appropriate management measures are not used, a large part of this mitigation is ensuring appropriate locations are chosen for turbines, waterway crossings and other infrastructure.

The identification of proposed infrastructure placement (turbines, quarry, BESS, tracks and waterway crossings) has been made by HWF with input from technical specialists. By overlaying the surface water modelling results on the proposed infrastructure layout an assessment of the inundation depth, velocity and flowrates can be made at each location. This provides an understanding of infrastructure requirements (i.e. culvert size, access track heights, if micro siting can remove inundation risk etc.) and the potential for construction, operation and decommissioning of the project to impact surface water environments and their capacity to support environmental values.

The impact pathways relevant to the project are changes to streamflow hydrology (flow rate and volume) and water quality. More specifically they include:

- Hydrological changes to surface water flows due to:
  - Project infrastructure with the introduction of impermeable surfaces – turbines and hardstands.
  - Physical disturbance - waterway crossings for tracks and cables, bunding to prevent inundation of project infrastructure such as the quarry, BESS and terminal station.
- Water quality reductions (e.g., turbidity, dissolved oxygen) due to:
  - Surface water runoff (erosion) and sedimentation due to stockpiles and earthworks for infrastructure, tracks and hardstands
  - Damage to stream beds and banks leading to surface water runoff (erosion) and sedimentation - waterway crossings for tracks and cables
  - Spills of poor quality into waterways or waterbodies - collected during construction of turbines and hardstands
  - Accidental spills of hazardous waste during construction and operation.
  - Impacted water spilling from the quarry to downstream waterways and wetlands.

There is also a potential level of flood risk to infrastructure that should be considered to prevent damage. Figure 7-1 displays an overview of the 1% AEP flood depth (from both direct/localised catchment inundation and riverine inundation) extent within Project area and the maximum flood depth found at each proposed turbine location.

7.1.2 Flood risk

The turbine locations are spread across the project area and are located on both rises and lower areas of topography. It is likely the construction of the turbines will require minor earth works to ensure a flat and stable base to build from, in some cases this base is within the 1% AEP flood extent.

Inundation across the project area is generally less than 0.3 m in a 1% AEP event, with depths exceeding 1 m in the major flow paths and in some localised areas due to ponding (e.g., wetlands). Proposed buildings such as the site compound, office and car park are affected by very small areas of localised inundation less than

0.3 m; however, the proposed terminal station location is within a flow path possessing floodwater up to 0.5 m in the existing scenario (see Figure 7-2). The BESS area itself is outside of the flood extent.

Inundation depths at the turbines vary across the site. As shown in Figure 7-1, two of the proposed turbine locations are inundated by a maximum inundation of more than 0.3 m in the existing scenario. These turbines are located within the Hopkins River floodplain. Most of the proposed turbines are affected by inundation less than 0.1 m. Construction of the inundated turbine locations will be particularly important to ensure no water is able to enter excavations during construction and impacted water unable to flow offsite.

A level of inundation and some flood risk is found at some proposed access track locations, including intersections with waterways as well as overland flow paths. Some sections of access track would need to be raised to allow safe access and egress during flood events and the likelihood this inundation will happen more frequently should be considered (i.e., mapping shows the maximum 1% and 10% AEP inundation but may be inundated to a lower depth much more frequently).

The modelling developed as part of this assessment has been used to guide the location and design of each proposed asset by HWF. It is anticipated that where turbines/hardstands are inundated risk can be addressed through elevation of the hardstand areas and drainage. The specifics of the design will be determined during detailed design.

7.1.2.1 Developed conditions modelling

7.1.2.1.1 Hydraulic model update

To represent the wind farm topography under developed conditions, the proposed turbine hardstands and access tracks were raised by 300 mm. Additionally, access tracks were opened at their intersection with existing flow paths and waterways, to represent culvert crossings. The sizing of these structures will be completed during detailed design based on the modelled flows. Bunding was added around the proposed quarry works area, BESS and terminal station, site compound, office and car park areas.

7.1.2.1.2 Results

The difference between developed and existing conditions flood levels and extents for the direct catchment inundation model are shown in Figure 7-3. Figure 7-4 shows the flood level difference for the Hopkins River model.

There are small areas of increased and decreased flood levels directly adjacent to raised access tracks. Larger areas of decreased flood levels are observed in large depressions and wetlands, as well as in the downstream parts of Mustons Creek. Decreases in flood level up to 100 mm are observed. This is caused by the runoff detention upstream of raised access tracks. This does not mean the water does not reach these areas but the peak flow into them is reduced. Also note that culvert crossings may not be required at all the proposed locations, depending on flood depth and hazard across the road at each location. This can be finalised as part of the detailed design.

For developed conditions, only two turbines are in areas where the flood depth is above 300 mm. Turbine T102 is affected by a depth up to 780 mm and turbine T106 is affected by a depth up to 340 mm in the Hopkins River flood scenario.

Figure 7-5 and Figure 7-6 show the flood level difference (between existing and developed conditions) at the proposed quarry location and BESS/terminal station/amenities area respectively. The quarry is located on top of a local ridge, and the bunding only results in increased ponding within the bunded area. This is assessed further in the quarry water balance assessment in Section 6.4. As seen in the existing conditions modelling, the proposed terminal station intersects a deeper flow path and adding bunding around the extent of the terminal station and BESS causes ponding upstream. Open drains along the proposed terminal station are required to divert flows around the area and back to its natural flow path. The internal pooling of water indicates that water management is required within the proposed terminal station, or alternatively a location outside of existing flow paths should be selected.

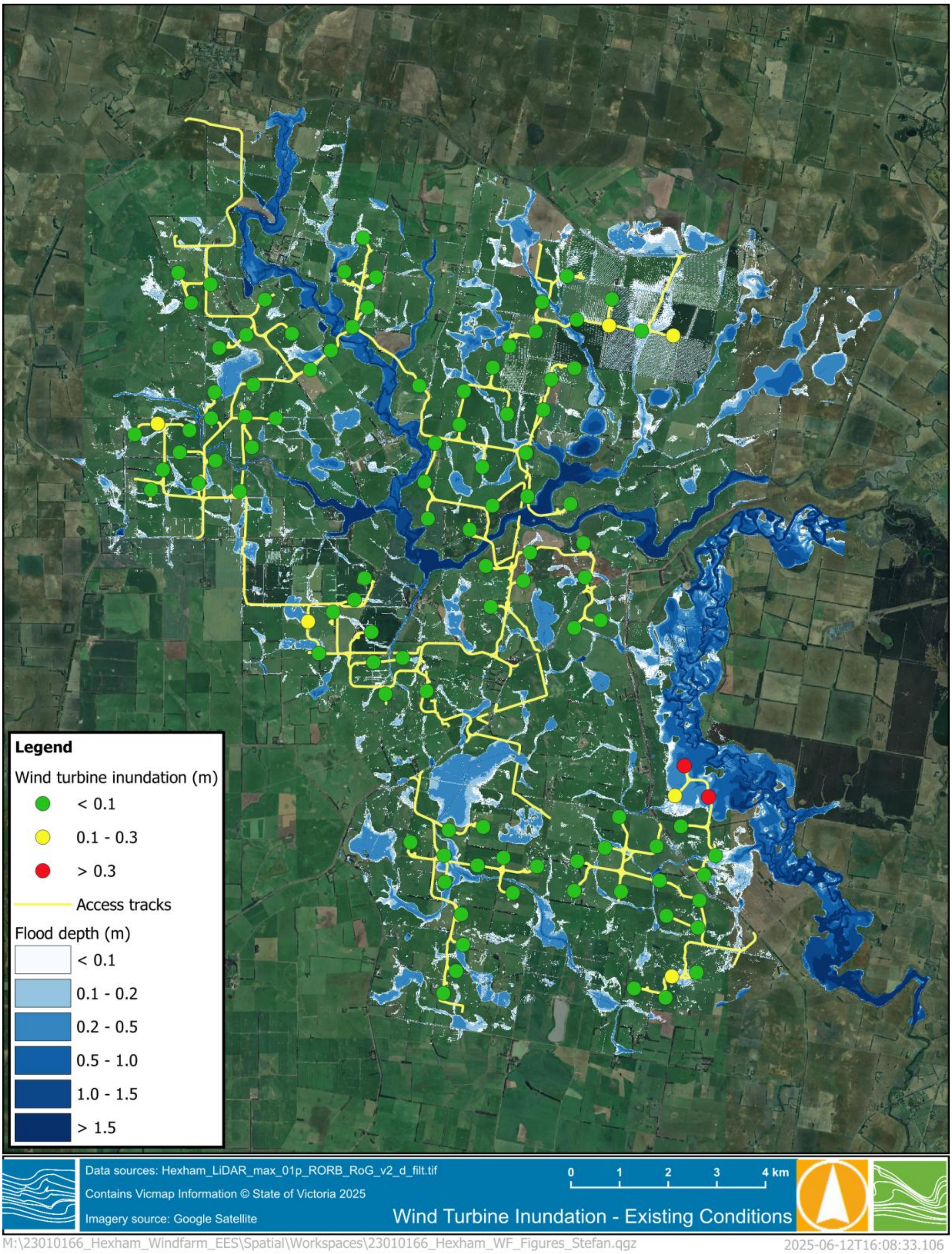

Figure 7-1 1% AEP wind turbine inundation

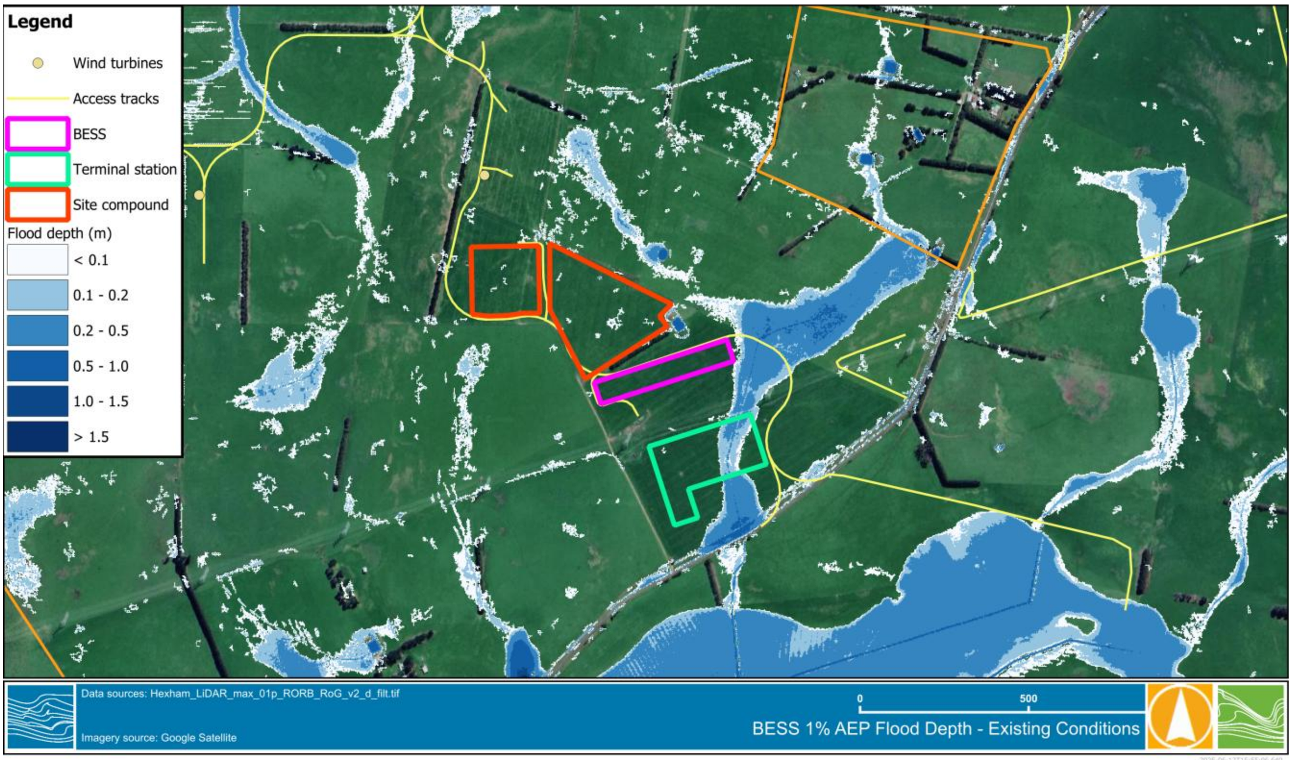

Figure 7-2 1% AEP site facilities inundation

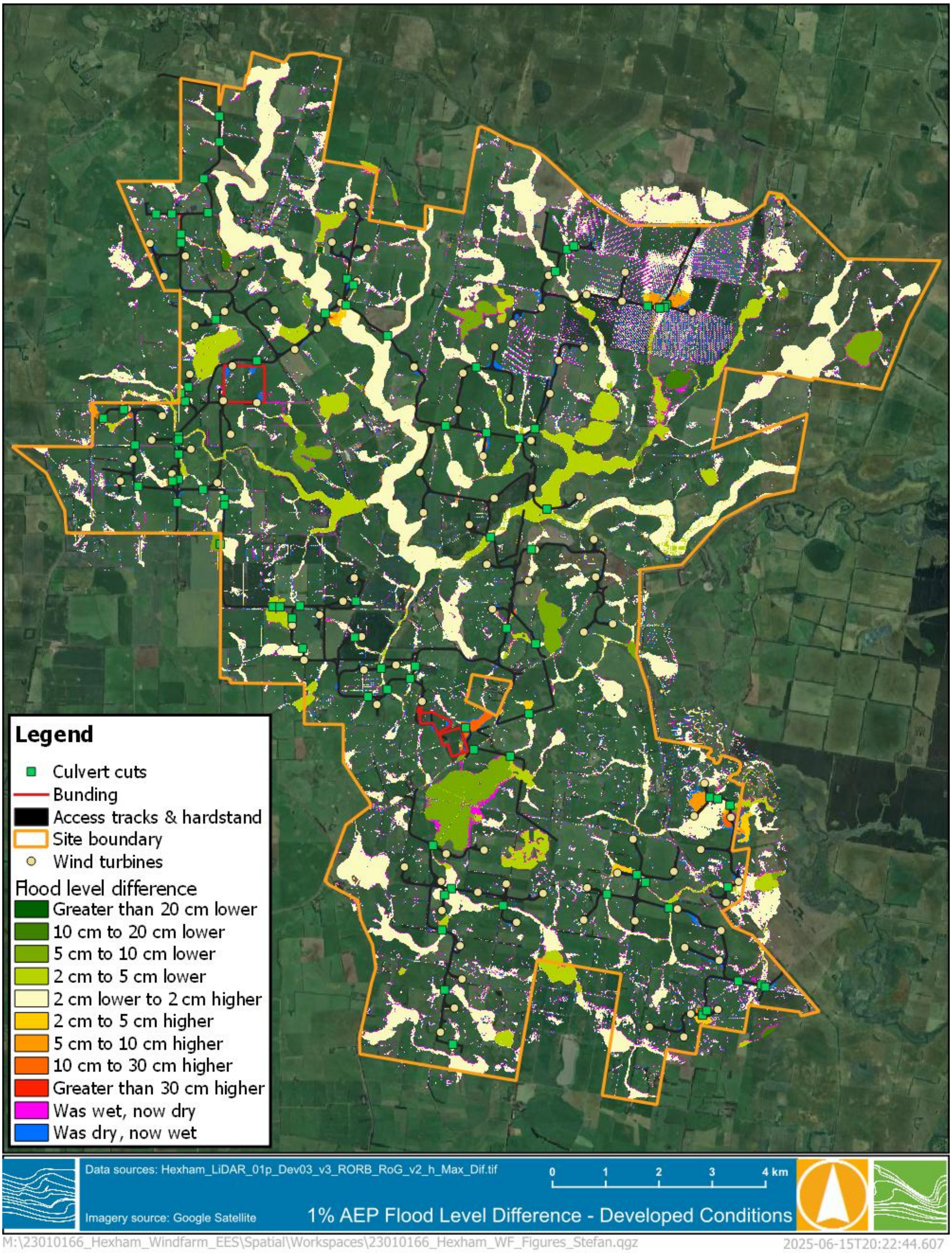

Figure 7-3 1% AEP flood level difference – developed VS existing conditions

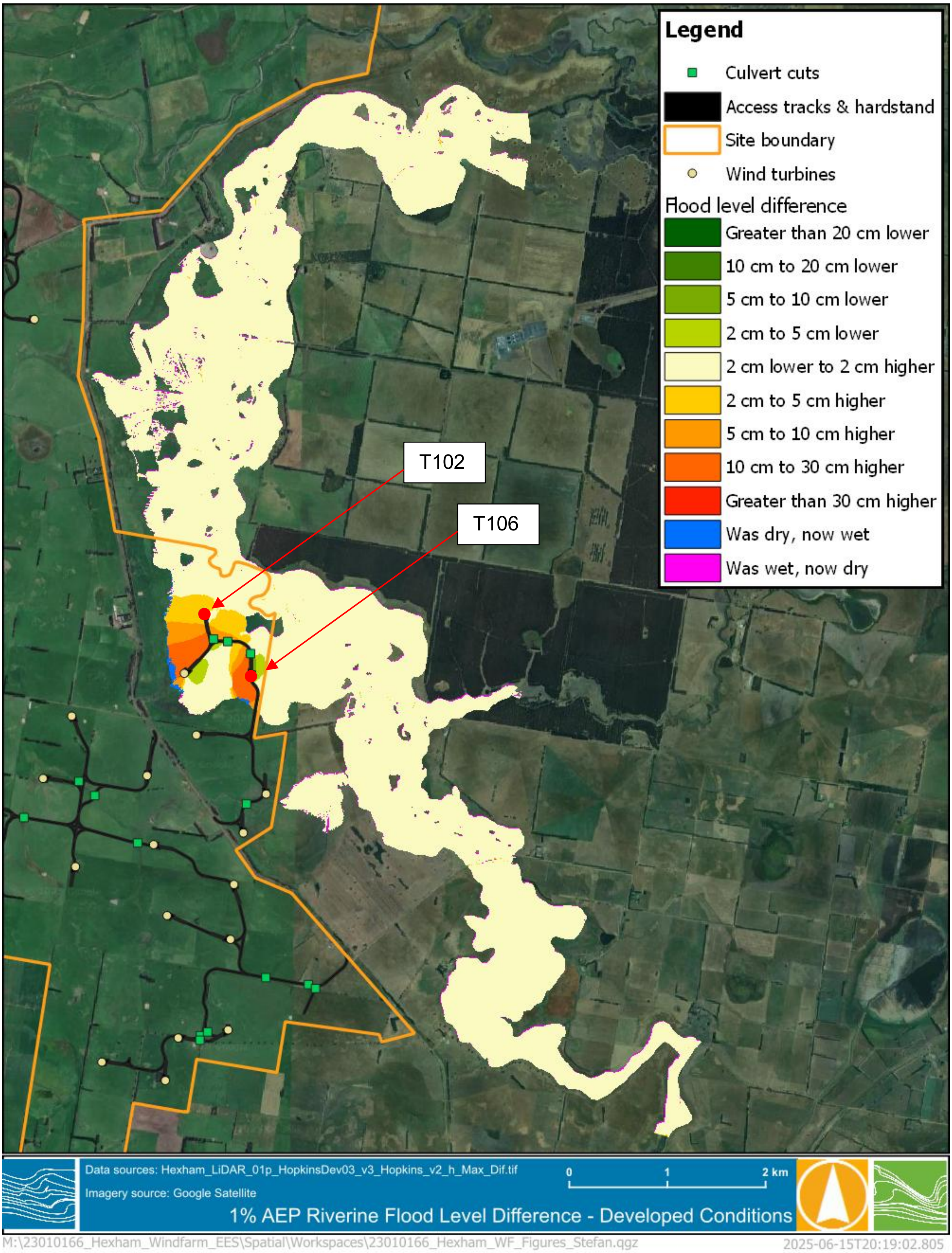

Figure 7-4 1% AEP Hopkins River flood level difference – developed VS existing

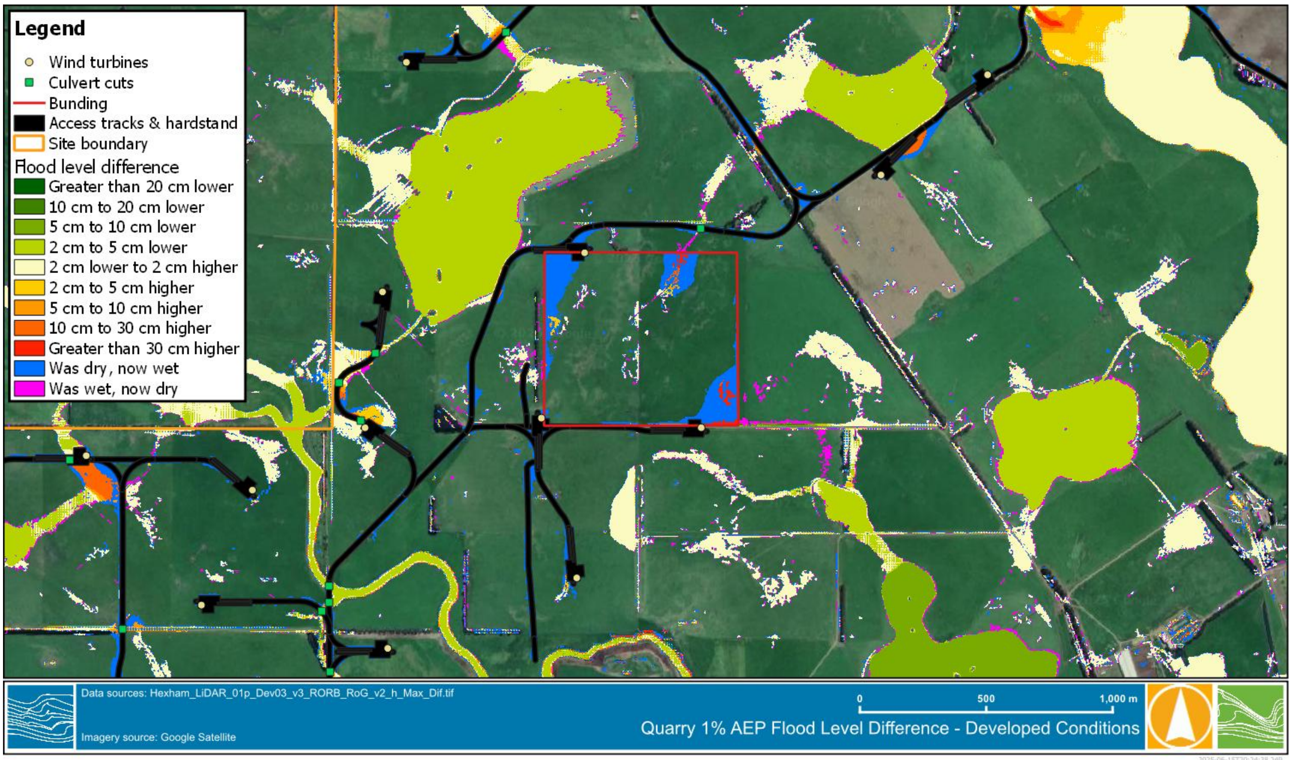

Figure 7-5 1% AEP flood level difference – at proposed quarry

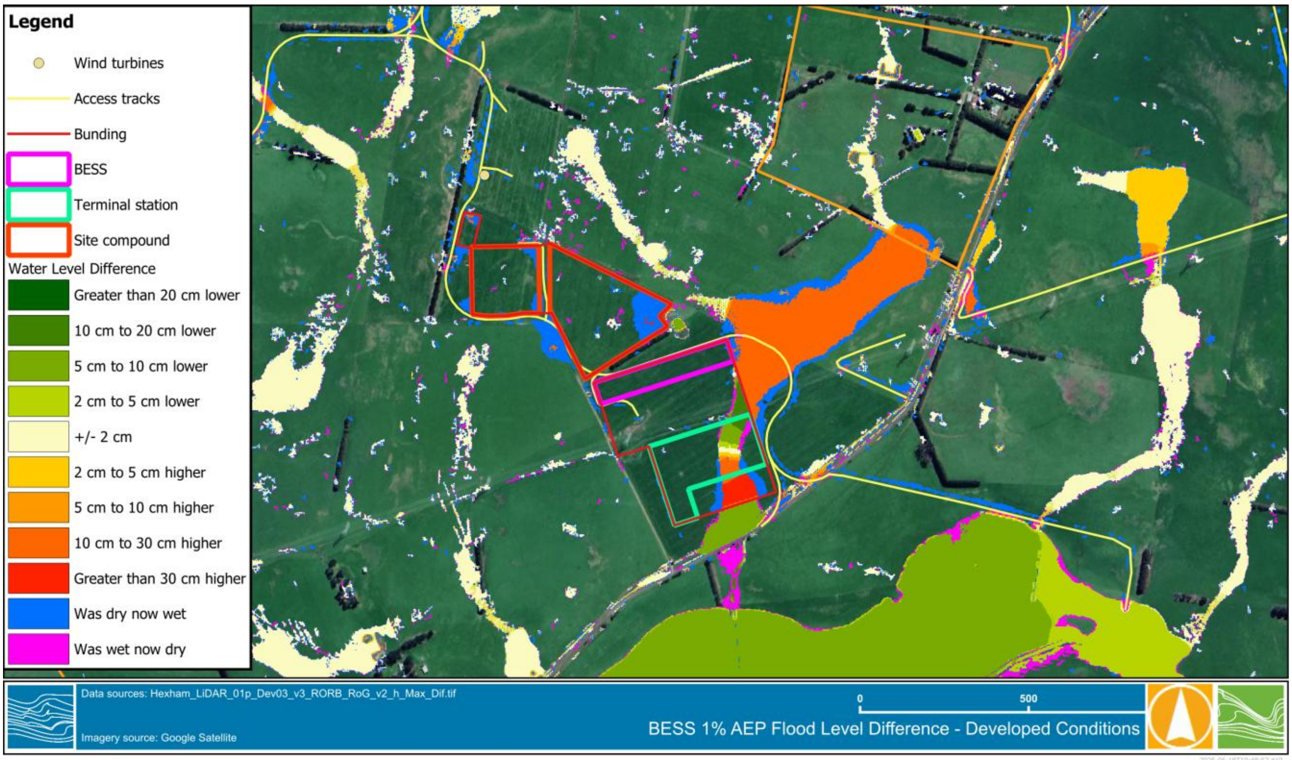

Figure 7-6 1% AEP flood level difference – at proposed terminal station and site compound

7.1.3 Hydrological changes

The construction of access tracks and larger infrastructure has the potential to alter existing drainage patterns through diversion of flow. Changes to drainage patterns, either increasing or decreasing flow to a given area can lead to ecologic changes. The developed conditions modelling presented in Section 7.1.2.1 shows changes to water levels and extents caused by the additional infrastructure.

Depending on the watercourse characteristics and construction crossing method, there may be temporary disruption to surface water flows. During construction, partial or complete diversion may be required if the watercourse is flowing at the time of construction. Construction of impervious hardstand areas and infrastructure (e.g., wind turbines) also has the potential to alter flow paths; however, most of the wind turbines are located outside of the inundation extent.

7.1.4 Water quality reductions

There are numerous access tracks and cables crossing both waterways and overland flow paths, as well as turbines located in areas of potential inundation. These works and their ongoing operation have the potential to impact water quality, if unmitigated, through the following:

- Excavation, stripping of topsoil and track construction mobilising sediment into downstream waterways/wetlands.
- Erosion/mobilisation of sediment at track and cable waterways crossings.
- Water entering excavations and then impacted water spilling to downstream waterways/wetlands.
- Spills of fuel and oil entering downstream waterways/wetlands.
- Impacted water spilling from the quarry to downstream waterways and wetlands.

These potential impacts are the same as what would be expected for typical road construction and/or excavation works, the location of these potential impacts has been highlighted by the surface water modelling and mapping enabling the design mitigation measures outlined in Section 8.1.2 to be targeted.

Additionally, there are water quality impacts related to discharge from firefighting within the BESS area.

While the background water quality in receiving waterways has been assessed as best possible, it is important to note all potential reductions in water quality should be avoided regardless of the water quality indicators assuming the presence of significant flora and fauna species.

7.2 Groundwater

7.2.1 Overview

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 (including stygofauna), because of reduced levels or supply of groundwater, reduced groundwater quality or both.

These impacts could occur through the following potential impact pathways:

- Dewatering of groundwater during construction activities and lowering the water table resulting in groundwater drawdown that affects water availability.
- Disruption of groundwater recharge and flow, such as from introduction of less permeable surfaces and physical barriers in the form of wind turbine foundations.

- Disruption of groundwater discharge to waterways 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.

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

7.2.2 Dewatering and disposal of extracted groundwater

Excavation of turbine foundations and trenches during construction will be to depths of less than 3.5 metres. Groundwater extraction will therefore be limited to locations where perched or very shallow aquifers are present. If shallow groundwater is intercepted during construction of turbine foundations and trenches, localised groundwater from the uppermost zones may seep into the excavated area. Groundwater abstraction via pumping (termed ‘dewatering’ of the excavation) may be required to create a safe and stable work area in some instances. If required, dewatering may temporarily lower the water table until the works are complete. As the construction period for turbine foundations and trenches is short (i.e., up to two weeks for turbine foundations and three hours for open trenches) , impacts are unlikely to materially affect groundwater users.

The proposed quarry excavation depth is 14 m and the depth to groundwater is estimated to range from around 9 m to 13 m based on water level measurements taken at the proposed quarry site in seven bores (Section 6.4) The quarry is therefore expected to extend below the water table, and dewatering is expected to be required for the quarry during operation as discussed in the quarry investigation (Section 6.4)

A summary of the proposed excavation depths for Project infrastructure is provided in Table 7-1.

Table 7-1 Proposed Project Excavation Depths of One Metre or More

Project Activity/Infrastructure	Proposed excavation depth	Approximate depth to groundwater
Quarry excavation	14 metres	Estimated to range from around 9 m to 13 m based on water level measurements taken at the proposed site in seven bores (Section 6.4).
Excavation for foundations	3.5 metres	Foundations may intercept shallow groundwater less than 3.5 m below the natural surface. This would be most likely to occur during winter and early spring when levels are expected to be highest.
Underground cabling	1 metre	Cable trenches may intercept very shallow groundwater less than 1 m below the natural surface during winter and early spring in isolated areas.

7.2.3 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. 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 and levels at the Site.

Vegetation removal can also influence groundwater recharge rates; however, this is not expected given the minimal vegetation removal required for this project.

7.2.4 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 waterway 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.

7.2.5 Groundwater contamination

Contamination could occur if fuels, chemicals or other substances were accidentally released from contained areas onto the ground. During construction and operation of the 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, will also be stored on site.

Groundwater contamination may also occur from exposure and oxidation of potential acid sulfate soils (PASS), which may arise during excavation of trenches in PASS zones. The release of acidic waters may adversely impact groundwater quality and downgradient receiving environments or users. Characterisation and assessment of PASS is documented in the Hexham Wind Farm Soil and Landform Assessment (WSP, 2024).

Disposal of collected groundwater and its management is a potential issue due to variable groundwater quality, including elevated salinity. The quality of collected groundwater will determine the disposal method, including discharge to surrounding land or environmental value (e.g., stock water and irrigation). A reduction in groundwater quality, due to contamination, may extend to existing users or GDEs depending on the aquifers affected.

8 IMPACT ASSESSMENT

8.1 Surface water

8.1.1 Overview

The study has shown several areas where proposed infrastructure has the potential to impact surface water environments, as discussed in Section 7.1.1. The aim of the design mitigation measures is to protect identified surface water values and meet the EES scoping requirement evaluation objectives. The detail provided in this report should be used to ensure infrastructure is designed and constructed appropriately, meeting Council, DEECA and Glenelg Hopkins CMA requirements. This section considers methods to control or mitigate likely impacts through the location of infrastructure, including any relevant design features or preventative techniques that can be employed during construction.

8.1.2 Design mitigation

8.1.2.1 General

The infrastructure throughout the site intersects with flow paths (both overland and riverine), creating a potential pathway between infrastructure and waterways and wetlands. Construction, operation and decommissioning works in these areas need to be managed to minimise land disturbance, soil erosion and the discharge of sediments and other pollutants to surface waters. To enable this, construction managers will need to implement effective management practices that are consistent with guidance from the Environment Protection Authority, including that provided in the EPA Victoria (2020) Publication 1893 Erosion, sediment and dust: treatment train. Where construction activities adjoin or cross surface waters, construction managers need to monitor affected surface waters, to assess if environmental values are being protected. The risk of adverse impacts can be managed during the design and construction phases by the design/implementation of turbines, bridges/culverts and cable crossings.

8.1.2.2 Bridges and culverts

Flow paths were identified and reviewed to allow design considerations to be understood for affected infrastructure. At the scale provided in this report it is difficult to present the detail required for design at crossing location as they are very specific, but the information contained in this report can establish impact mitigation design criteria and inform detailed design. Each crossing has a different inundation length, depth, velocity and significance to the project. This information has been provided to HWF for inclusion in the design process, with the aim of minimisation of watercourse crossings through siting of access tracks, and appropriate design of crossing infrastructure where a crossing is necessary.

All waterway crossings (tracks and cables) and culvert/bridge designs should conform to local Council and Glenelg Hopkins CMA guidelines. Council will have internal design requirements while the Glenelg Hopkins CMA Works on Waterways Licence requirements will also apply, as outlined in Appendix A.

Design guidelines vary dependent on the size of the watercourse and its potential classification as a Designated Waterway, see Section 6.2.2. Structure designs should be sized to accommodate the required design capacity and ensure they are not damaged during a flood event i.e., culverts/bridges must be designed to enable access to a recurrence HWF are comfortable with and structural/erosion control measures must be designed to prevent damage to the structure.

Dependent on the size of the flow path a bridge or culverts may be used. Bridges and culverts are required to be designed to allow flow beneath the access tracks along their natural flow paths with the required erosion control to ensure no sediment can be transported downstream. A typical culvert design capacity (still enabling vehicle access) used across other windfarms within Victoria is a 10% AEP, this will be discussed with GHCMA.

A higher level of recurrence should also be used for suitable erosion control design, preventing damage and emergency repairs. Some overtopping of the structure may be allowed to occur during high flows provided there is no erosion potential and safe access and egress can be achieved at the structure design capacity.

A series of discharge calculations have been made throughout the model (56 locations), the location and peak discharge for each of these locations has been provided to HWF for both the 1% AEP and 10% AEP events. These flow rates can be used as a basis for culvert capacity design along with the provided GIS depth and velocity information.

There are 56 designated waterway crossings (access tracks and underground cables) within the project area. Figure 8-1 shows the 31 access track crossings and Table 8-1 shows the peak flow and discharge at each of the designated waterway access track crossings along with the waterway name/number (as per the designated waterway numbering made by Glenelg Hopkins CMA).

Table 8-1 Surface Water Flows at Designated waterways

Map number	Waterway name/number	1% AEP flow (m^3/s)	10% AEP flow (m^3/s)	Likely flow conditions
1	Mustons Creek 36/1-29	166.0	43.3	Sustained flow, with lower flow in summer
2	Mustons Creek 36/1-29	191.7	48.4	
3	36/1-29-1	22.9	5.4	Intermittently flowing after rain.
4	36/1-29-1-1	14.2	4.3	
5	36/1-29-1-1	18.2	5.0	
6	36/1-29-1-2	1.9	0.5	
7	36/1-29-1-1-1	1.9	0.3	
8	36/1-29-1-1-1	9.8	2.6	
9	36/1-29-1-1-1-1	4.7	1.5	
10	36/1-29-2	3.2	2.1	
11	36/1-29-2	6.2	4.4	
12	36/1-29-3	2.7	1.2	
13	36/1-29-3	20.2	7.5	
14	36/1-29-3-3	1.6	0.4	
15	36/1-29-3-4	4.5	0.7	
16	36/1-29-3-4	3.2	1.3	
17	Tea Tree Creek 36/1-29-5	36.6	13.0	Potential for sustained flow. Low flow in summer
18	36/1-29-8	0.1	0	Intermittently flowing after rain.
19	36/1-29-8	2.50	1.2	
20	36/1-29-9	2.7	1.9	
21	36/1-29-9-1	1.6	1.2	

Map number	Waterway name/number	1% AEP flow (m^3/s)	10% AEP flow (m^3/s)	Likely flow conditions
22	36/1-23-1	6.4	2.1	
23	36/1-23-1	11.1	4.1	
24	36/1-23-1-2	2.4	0.9	
25	36/1-23-1-2	2.4	0.9	
26	36/1-23-1-3	3.8	1.0	
27	Drysdale Creek 36/2-14-12	5.8	2.0	
28	Drysdale Creek 36/2-14-12	2.7	0.7	
29	Drysdale Creek 36/2-14-12	2.8	0.8	
30	36/2-44-7	0.8	0.4	
31	36/2-44-7	0	0	

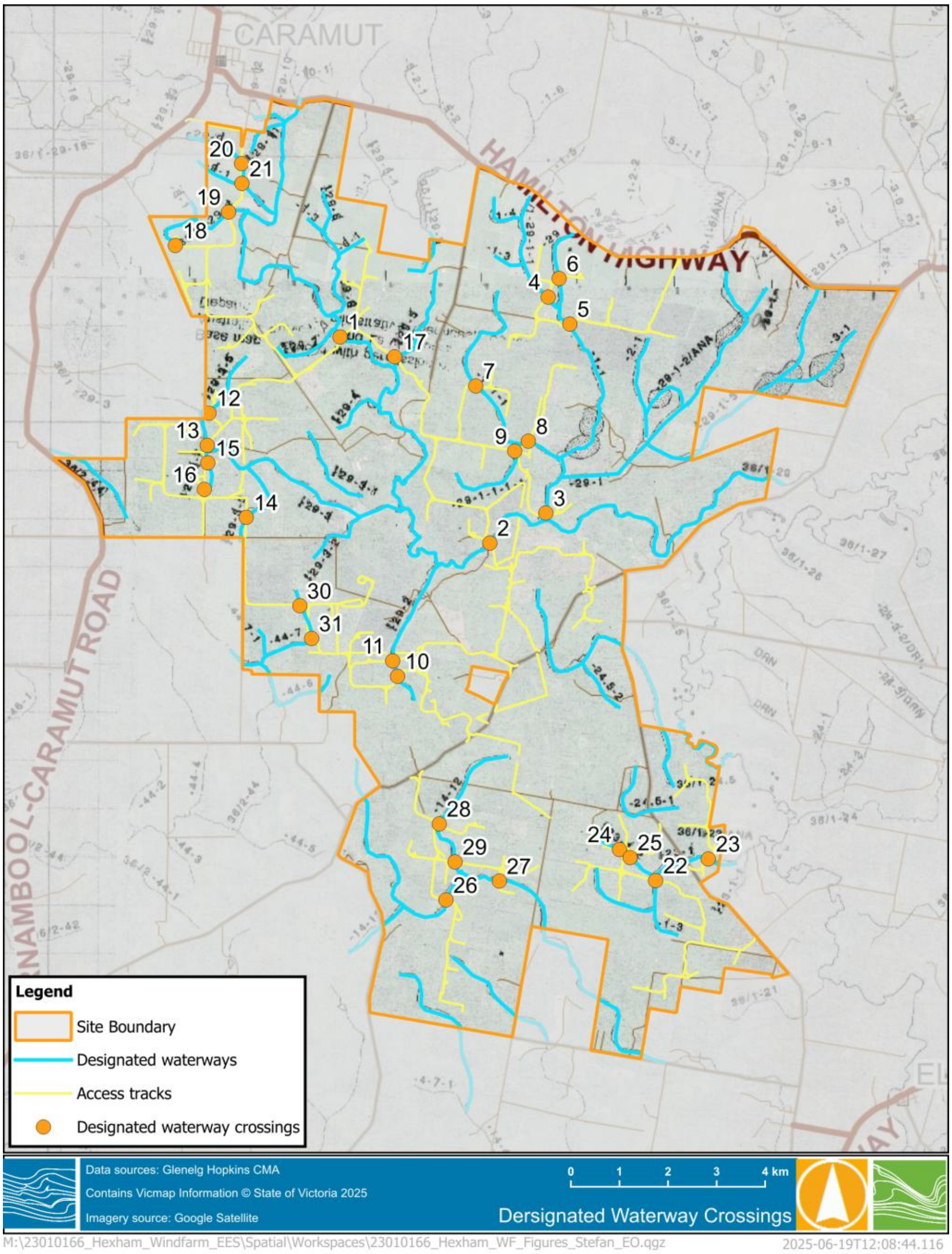

Figure 8-1 Internal access tracks interacting with designated waterways

Recommendations have been made in this report as to how the potential for impact can be minimised, but site-specific design will be required for each crossing prior to construction. It is not generally expected this level of detail will be made available through the EES, but the recommendations made in this report should be considered for each structure design. If these works are to occur on a Designated Waterway a Works on Waterways Licence will be required and the crossing design should meet the requirements set out by Glenelg Hopkins CMA, we have included a set of Glenelg Hopkins CMA design criteria as Appendix A.

The following mitigation measures to be considered during the design phase. The designer's brief should include:

- Avoid areas identified as potential habitat for threatened aquatic species, where possible (as detailed in the Hexham Wind Farm Flora and Fauna Impact Assessment - Nature Advisory 2025).
- Microsite infrastructure proposed in identified flow paths to reduce risk of erosion, sediment transfer, affected access and inundation of infrastructure.
- Design of infrastructure to consider resilient design for flooding, including mitigating measures such as culverts beneath access tracks and building threshold levels relative to anticipated water levels.
- Confirming that the underground cabling trenches are refilled with material of the same permeability will mitigate land salinisation and induced groundwater flows.
- Design criteria such as:
  - Accessibility for all access tracks to be maintained for a recommended 10% AEP, or as determined following development of maintenance and inspection requirements.
  - Gully crossings to ensure modelled design flows at any location can be passed for a recommended 10% AEP.
  - Operating parameters.
  - Accessibility and operational requirements.
  - Functional requirements (e.g. turbine operating parameters).
  - Flood protection requirements.
  - Standards, guidelines and reference documents.
- Contribution to information contained in the Construction Specifications to guide appropriate construction management requirements, such as method statements, Contractor's Environmental Management Plan and Traffic Management Plan.

8.1.2.3 Cable crossings

25 locations were identified where underground cables intersect with designated waterways, see Figure 8-2. Cable crossings are required to be designed to limit the potential for erosion. There are numerous construction methods available, and the chosen method will be site specific. These options include:

- Trenching – Trenching requires works within the drainage line or waterway, creating an open excavation through the flow path. Trenching is not generally used for ephemeral overland flow paths due to its invasive nature. It should also be avoided in areas with high velocities. The Construction Management Plan and Environmental Management Plan should highlight a construction methodology for construction of trench excavations and restoration of fill to natural surface with the required material and compaction.
- Directional drill – Directional drilling is less invasive (in appropriate ground conditions, it may not be feasible in some circumstances) than trenching and uses directional bore to drill a cable alignment underneath a road, railway or waterway. A directional drill is typically used for major waterways where flows are occurring and difficult to manage from an environmental and cost perspective. This option may not be possible due to the presence of rock at many crossings.
- Designing structures to accommodate cables – if a waterway crossing is large enough there is potential for the cables to be attached to the structure removing the need for additional crossing construction (i.e., a trench or directional bore).

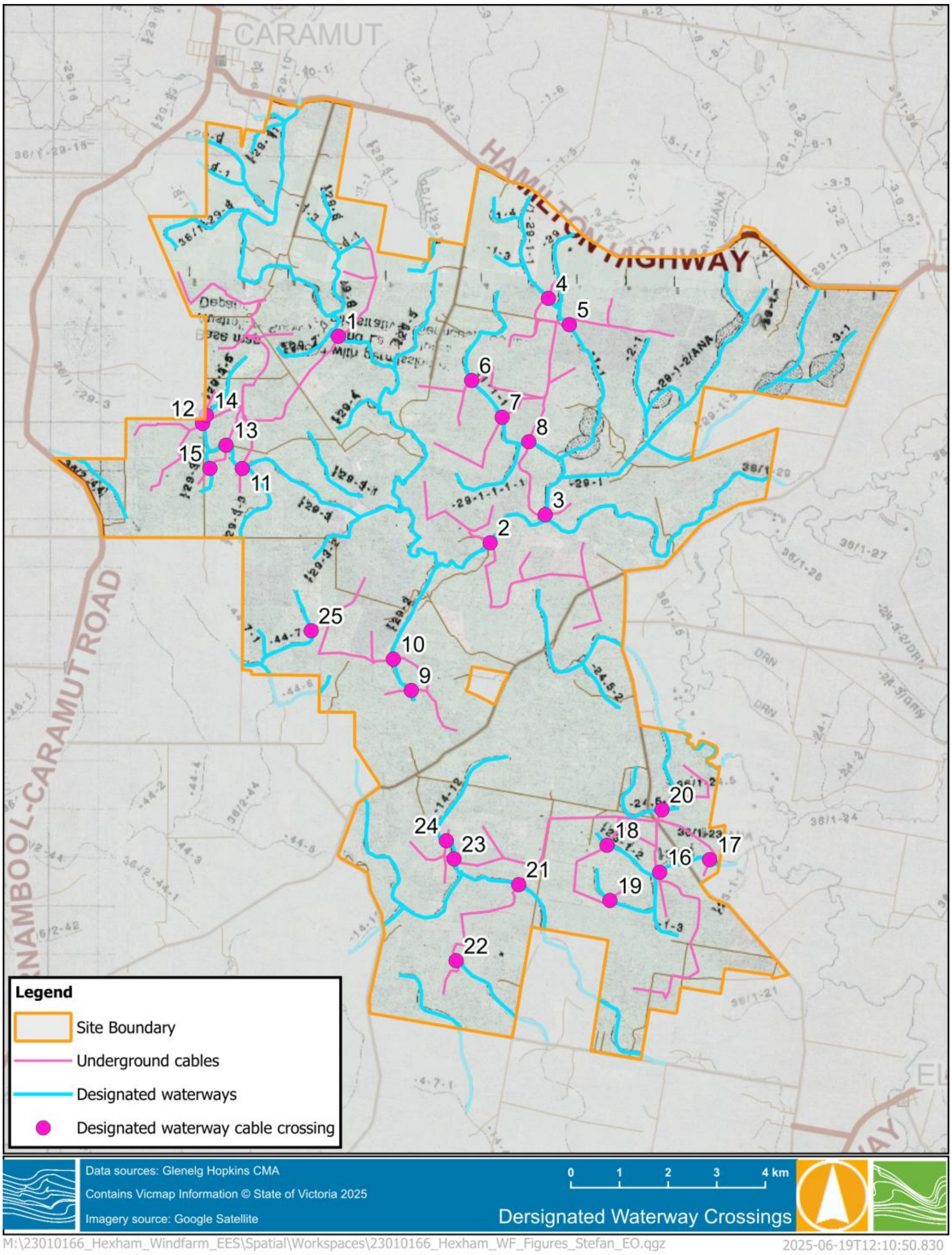

Figure 8-2 Underground cables interacting with designated waterways

8.1.2.4 Turbines

A small number of turbines are being shown as within the 1% AEP flood extent. Construction and operation of these turbine foundations will need to be completed in a way which removes the risk of inundation. These are as follows:

- Construction

  - Flood water must be prevented from interacting with excavations through levees or bunds. These structures can be earthen, constructed of clean fill with adequate clay content, constructed with sufficient compaction and have a level at least 300 mm above the 1% AEP flood level. They must also allow for free drainage of flood water post a flood event (i.e., not trap floodwater behind them). The Victorian Levee Management Guidelines (DELWP, 2015) can be used as guidance for the construction standards of earthen embankments.
  - Drains should be constructed allowing water to flow around construction works, all drains should have erosion and sediment control measures put in place.
- Operation
  - All drains should be maintained with grassed or rocked inverts and sides to limit the potential for erosion. Inspection of these assets should be undertaken as part of a regular maintenance program and enable the ability for landholders to report or provide feedback on asset condition.

8.1.2.5 Construction phase management

Mitigation measures to be considered during the construction phase have been identified. As part of the EMP, a Contractor's Environmental Management Plan (CEMP) could be prepared by the designer and included as part of the construction tender package.

Generally, the CEMP describes how activities undertaken during the construction phase will be managed to avoid or mitigate environmental or nuisance impacts, and how those environmental management requirements will be implemented.

In addition, contractor's method statements will be required for Health and Safety, constructability, environmental or nuisance protection, and to protect groundwater and surface water should include:

- Dewatering during construction, including discharge location and quality of water, pollution control and management of sediment in line with EPA approvals processes
- Construction activities and temporary works that may impact on permeability, groundwater and surface water.
- How GHCMA's Waterways Licensing requirements will be met.

8.1.2.6 Quarry

The temporary quarry is designed to be a *'zero discharge'* site with all surface water and groundwater managed within the quarry site using retention basins, either infiltrating or evaporating stored water. Onsite storage requirements to manage surface water and groundwater inflows were assessed using an eWater Source model for the construction and post operational phases of the project, as detailed further in Section 6.4.

Post operations the quarry will be rehabilitated to a void, with a small farm dam at the low point. The contributing catchment area will be limited to the former extraction area, with bunding preventing other areas from discharging to the storage. By limiting the catchment area contributing to this storage, it will not act as a typical dam and will not reduce the water available in the overall catchment as it does not occupy a significant proportion of the catchment.

To minimise the risk of contamination of surface water or a mixture of surface water and groundwater the following recommendations have been made:

- The storage be properly designed by an appropriately qualified engineer and constructed to meet the relevant construction standards.

- A weekly record of storage water levels should be kept throughout the operation of the quarry. When the storage reaches within 1.5 m of the dam spillway height, monitoring should be undertaken on a daily basis. Water management strategies such as water reuse or deep injection should be in place should monitoring indicate any change to the planned zero discharge off site is required.
- The dam's detailed design should be assessed under the relevant design guidelines. All onsite water use, within the quarry and across the windfarm should be taken from the water storage where possible (i.e., if it meets relevant water quality standards) to reduce the risk of exceeding the storage capacity.
- Metering of site water usage and internal transfers should be undertaken weekly to reconcile the estimates provided in this study.
- Development of a small starter pit (e.g., 30 x 30 m) which extends to the base of the quarry to be used to validate the groundwater inflow estimates prior to excavation of the broader quarry area could be considered.
- Wells which are outside the drawdown extent should be checked to validate their purpose and status. These may be used as water level monitoring wells (monthly during quarry operation and quarterly for 12 months afterwards) to verify the drawdown estimate.
- In the event that inflows are greater than predicted in this study, the following contingency measures could be enacted:
  - Add additional water storage retention basins within the quarry site.
  - Partition areas within the pit to provide additional storage.
  - Consider recharge to the aquifer through groundwater wells (subject to permission under the Environment Protection Regulations).
  - Increase usage of pit and retention basin water for off-site water requirements, subject to licensing approval.
- If the quarry operator detects Potential Acid Sulfate Soils (PASS) during excavation, an appropriate management plan should be prepared along with further pH testing. The Contractor's Environmental Management Plan should include management recommendations to avoid disturbing soil from any areas identified as high risk of PASS. See also the Hexham Wind Farm Soil and Landform Assessment (WSP, 2024).

8.1.2.7 BESS

Floodwater up to a depth of 300 mm pools against bunding around the combined extent of the BESS and the terminal station. The bunding obstructs an adjacent flow path (the BESS itself has not been positioned within this prevailing drainage line). An open channel draining along the outside of the bunding will be required to convey flows around the area and back to their natural flow path. Additionally, the bunding will need to be as high as the floodwater depth plus a level of freeboard in order to ensure the facilities are not inundated in an 1% AEP flood event.

No internal ponding is observed within the proposed BESS extent. Subsequently, it is not anticipated that any specific water management will be required for the proposed BESS, other than standard internal surface water management measures.

Water quality impacts related to discharge from firefighting within the BESS area can be mitigated by bunding of infrastructure areas and ensuring that such discharge is diverted to designated storage areas within the BESS and terminal station area.

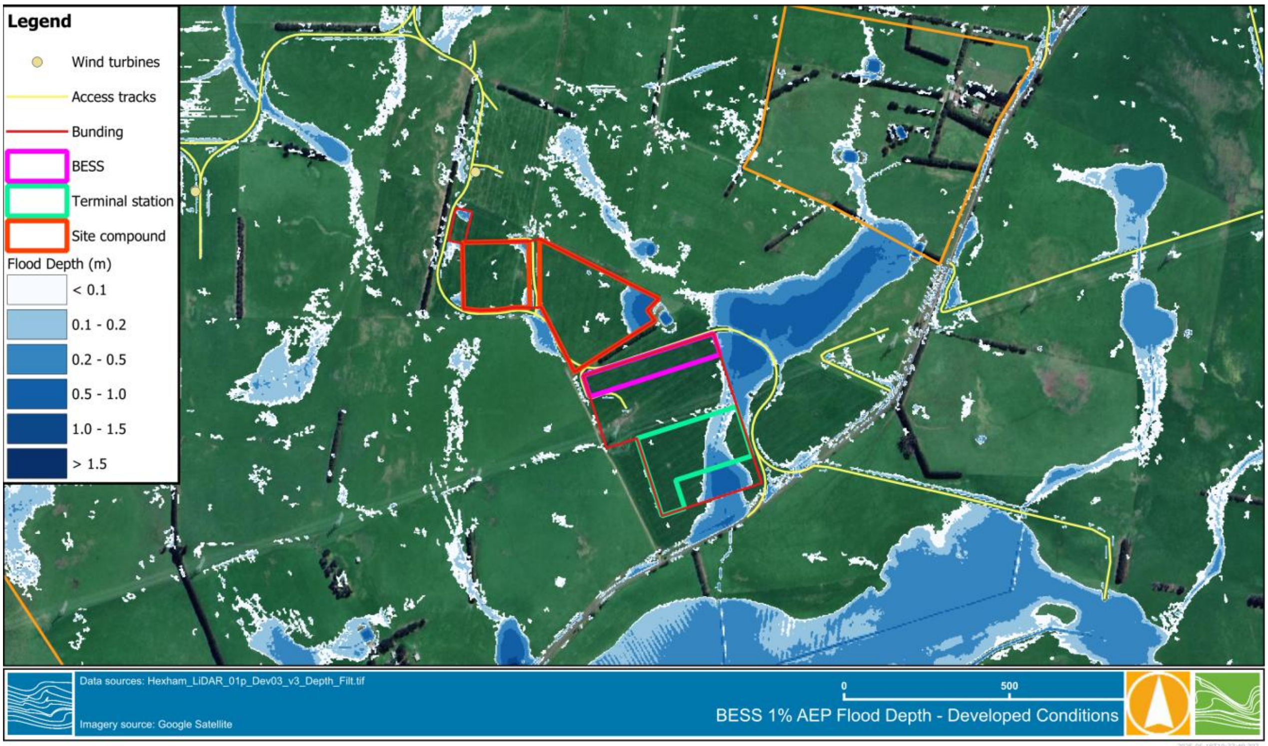

Figure 8-3 1% AEP site facilities inundation

8.1.3 Management controls

Engineering design measures are required to avoid potential surface water impacts. To further minimise potential impacts to surface water features (and their supporting values) management controls are required to be implemented during the design, construction, operation and decommissioning of the project. Recommended management measures are outlined in Table 8-2.

Table 8-2 Surface water management control measures

Surface water impact	Project phase	Management measures
Alternation of existing drainage lines and flow paths	Detailed design	Development of the detailed drainage design in consultation with the Glenelg Hopkins Catchment Management Authority, considering best practice design guidelines. Design measures is required to include, but not be limited to: • Permanent surface structures designed to maintain existing overland flow paths and not cause increased upstream flood levels. • Culverts be installed parallel to the alignment of the banks of the waterway • Use of a reduced-width construction right of way at watercourse crossings and aim to avoid any standing water • Micro-siting crossings of Mustons Creek to avoid deeper pools where practicable to prevent potential effects on the Growling Grass Frog (Nature Advisory, 2022).
	Construction	Works within a designated watercourse require a Works on a Waterway licence from Glenelg Hopkins Catchment Management Authority. Works be undertaken in accordance with the requirements of the Catchment Management Authority licence.
	Construction	Where essential wind farm infrastructure (e.g., access tracks) crosses a creek, measures for avoiding and minimising impacts are required to be documented in the Construction Environmental Management Plan, including: • Where watercourse trenching is required, preferentially schedule works during drier months of the year and lowest flow of the waterway. • Avoiding undertaking of works when high rainfall events are expected. • Maintaining adequate flow rates and water levels in waterway to be crossed (as determined in consultation with the relevant authorities) to minimise impacts on aquatic ecosystem and environmental values. • Restoration of temporarily disturbed waterways and vegetation (removing any obstructions to waterway flow) as soon as practicable following the open cut trenching works to at least its pre-construction condition. • Design measures to minimise future erosion in areas where trenching occurred (e.g., use of riprap made of stones to stabilise the waterway, geofabric to prevent erosion and scour until establishment of vegetation.

Surface water impact	Project phase	Management measures
Erosion and sedimentation (surface water runoff, destabilisation of waterway banks)	Design, Pre-construction, Construction	Development and implementation of a Sediment, Erosion and Water Quality Management Plan, in consultation with the Glenelg Hopkins Catchment Management Authority and in accordance with EPA Victoria Publications 1834 *Civil construction, building and demolition guide* and 1894 *Erosion, sediment and dust: treatment train*. Erosion and sediment control measures within the construction site are required to include, but not be limited to: • Water quality testing during detailed planning, construction and operation phases. • Phasing of ground-disturbing works to periods of lower rainfall, where possible. • Minimising clearance of vegetation, particularly along drainage lines, waterways and steep slopes. Vegetation, including within the watercourse and riparian zones, be reinstated as quickly as practicable as open cut trenching works are completed. • Design and designate an area for stockpiles before construction commences. Stockpiles to be left inactive for longer periods, establish vegetation or grass. • Ensuring that stockpiles and batters are designed with slopes no greater than 2:1 (horizontal/vertical). • Stabilising exposed soils as appropriate. • Installing sediment fencing during construction to protect riparian zones if works are to be undertaken within 30 metres of creeks. • Installing sediment treatment control measures as appropriate (including around stockpiles) to adequately capture sediment loads. • Managing vehicle movements to designated roads and access areas. • Directing stormwater within a constructed lined channel or sediment basin where applicable to reduce the velocity of run-off water. • Monitoring surface water quality upstream and downstream from the works area and confirm effectiveness of established controls and if environmental values are being protected. • Development of contingency measures for works within a waterway or floodplain, including controls to be implemented when a storm event is forecast. • Implementation of management controls for stockpiles as per EPA Guidance Sheet 2: *Managing stockpiles.*

Surface water impact	Project phase	Management measures
		• Implementation of management controls for construction works within or near waterways as per EPA Guidance Sheet 1: *Working within or adjacent to waterways*.
	Design, Construction, Operation, Decommissioning	A Quarry Work Plan is required and will be implemented, it is required to include measures to manage and monitor surface water impacts in accordance with the Work Authority. These measures would include, but are not limited to: • Dam storage be properly designed by an appropriately qualified engineer and constructed to meet the relevant construction standards. • Weekly record of storage water levels should be kept throughout the operation of the quarry. • Management of surface water inflows through in-pit sump pumping during quarry operation.
Waterway contamination (from accidental spills)	Construction, Operation, Decommissioning	Measures to manage potential pollutants from entering waterways include: • Spills risk assessment and response plan, incorporating measures for the use, storage, transfer and disposal of hydrocarbons and chemicals (in accordance with EPA Victoria Publication 1698: *Liquid storage and handling guidelines*). • Storage of liquid fuels and chemicals within containment facilities (e.g., bunded areas) more than 50 metres from waterways in designated areas within the project site. • Spill response kit, to be located at waterway crossings, at locations where machinery/plant are operating, and refuelling and fuel/chemical storage areas during construction • Incorporation of spill containment measures into the drainage design.
		Battery Energy Storage System to include retention basin to capture firefighting water to prevent uncontrolled release of water to the environment. Contaminated water captured within the retention basin to be discharged to a lawful place.
Disposal of collected water	Construction	Water collected dewatering of excavations shall be managed in accordance with the Environment Protection Regulations 2021. These measures should be incorporated into the Construction Environmental Management Plan and should include, but not be limited to: • Monitoring of water quality of captured water (e.g. pH, salinity, suspended solids). • Approval should be sought from relevant authorities to discharge water. • Disposal of water would be at a site that is lawfully able to receive it.

Surface water impact	Project phase	Management measures
		• Use sediment control devices, where required. The EPA would be consulted in the preparation of the Construction Environmental Management Plan.

8.1.4 Residual effects

Following the development of design measures and management controls, an assessment of residual effects and impacts was completed describing the changes to the surface water environment brought about by the construction, operation and eventual decommissioning of the project, and rating the significance of these effects according to Table 8-3. These residual effects assume the required migration management controls are implemented.

Table 8-3 Impact significance criteria for surface water impacts

Very low / negligible	Low	Moderate	High	Very high
Project results in negligible changes to waterway flow and/or quality. Negligible reduction in the extent of a water resource 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 (isolated) changes to waterway flow and/or quality. Minor reduction in the extent of a water resource 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 changes to waterway flow and/or quality in a local area. Reduction in the extent of a water resource 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 significant changes to waterway flow and/or quality in local and downstream areas. Significant reduction in the extent of a water resource that: • Results in a long-term reduction of the current or future use 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 extensive changes to waterway flow and/or quality in the catchment. Significant reduction in the extent of a water resource 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.

The greatest likelihood of impacts to the waterways and wetlands is from construction activities associated with watercourse crossings, and to a lesser extent, from general construction activities. These activities have the potential to result in physical streambed disturbance and also in stormwater runoff containing sediments entering waterways.

The following section assesses the likely residual effects to key surface water assets assuming design measures outlined in Section 8.1.2, and management controls outlined in Section 8.1.3, are implemented.

The EPA will be consulted on the Environmental Management Plan before construction and will be subject to their approval / endorsement.

8.1.4.1 Hopkins River

8.1.4.1.1 Runoff entering Hopkins River

Most of the project area is within the Hopkins River catchment and the river makes up a small part of the eastern Project boundary, but is otherwise not within the project area. As such, direct impacts to this watercourse in terms of physical disturbance are not predicted. However, most of the project area is located within the Hopkins River catchment and therefore any changes to downstream water quality or hydrological impacts to its tributaries located within the project site, including Mustons Creek, may indirectly impact the Hopkins River.

During construction there is the potential for a temporary increase in sedimentation (and to a lesser extent other contaminants), in waterways leading to the Hopkins River which has the potential to reduce water quality, which can cause impacts for other users of a watercourse or for aquatic and semi-aquatic flora and fauna.

Sedimentation is most likely to occur from runoff from stockpiles or cleared areas including hardstand areas, access tracks and cable trenches. This would most likely occur during periods of intense rainfall. Through the implementation of watercourse buffers, most project infrastructure are located away from tributary drainage channels, except for a number of watercourse crossings for access tracks and cables. With the implementation of sediment control measures and avoiding watercourse crossings during high flow periods the impacts to the Hopkins River via transport of poor water quality in drainage channels was assessed to be localised and unlikely to reach the Hopkins River itself, for a short duration during periods of high rainfall and of low severity/intensity. Considering the existing condition and the temporary and localised effects predicted within the project site the significance of this impact was assessed to be **low**.

8.1.4.1.2 Alteration of existing drainage patterns

The construction of access tracks and hardstand areas has the potential to alter existing drainage patterns if not accounted for during design. Hydrological effects have the potential to occur over a larger area, due to the nature of the shallow topographical relief of floodplain systems. Hydrological flood modelling was used to inform the placement of turbine locations outside of water flow paths and size culverts to ensure flow pathways are not altered. Three turbine locations within the Hopkins River floodplain but away from the river channel were identified, with two of the proposed turbine locations inundated by a maximum inundation of more than 0.3 m. The effect of these structures both during construction and operation on the river flow behaviour is considered low.

Designated waterway crossings (access tracks and cables) were identified in the Hopkins River catchment (as highlighted in Sections 8.1.2.2 and 8.1.2.3). With the implementation of recommended measures at the crossings and within the catchment the magnitude of potential impacts to altering the hydrology within the Hopkins River catchment was assessed to be of very low significance, with any impacts likely to be localised, for a short duration and of low severity. The detailed access track and culvert designs would include updated modelling to ensure hydrological connectivity is maintained and culverts are placed at appropriate locations.

8.1.4.2 Mustons, Tea Tree, Lyall, Drysdale and other Creeks/designated waterways

8.1.4.2.1 Creek crossings

The key impact pathway to the local creeks is physical disturbance to the creek beds and associated aquatic habitats at the access track and cable crossing points (as highlighted in Section 7.1.2, 8.1.2.2 and 8.1.2.3). To minimise potential environmental impacts, these waterway crossings are required to be designed and constructed to maintain appropriate flow capacity of drainage lines, minimise the extent of disturbance and vegetation removal within the waterway, and rehabilitate disturbed areas following completion of works to the satisfaction of the Glenelg Hopkins CMA. Construction works should be timed to avoid periods of high flow periods, where possible.

Crossing of creeks should be limited but is required to provide access between wind turbines. The crossings are proposed to consist of culverts with co-located cables when possible, while there are some track-only and cable-only crossings.

If a creek is flowing at the time of construction, water must be diverted through use of a temporary upstream coffer dam with piped flow around the construction works area. Excavation through a dry creek bed could occur followed by installation of the culvert or cable followed by immediate reinstatement and rehabilitation of the creek banks. Downstream sediment control measures including sediment traps, are required in accordance with best practice guidelines outlined in Appendix A. Water pollution must be minimised or avoided by reducing land disturbance and maintaining areas of vegetation. As such, a reduced working space is required at the approaches and exits of the creek crossings.

With the implementation of design and control measures, the potential impacts to the creeks via physical disturbance of waterway crossings and generation of poor water quality runoff was assessed to be localised (mainly at crossing points), for a short duration (expected to be over several weeks) and of low severity.

8.1.4.2.2 Runoff entering creeks

Several larger creeks run through the project area, as such there is also the potential for run-off from construction work areas (e.g., stockpiles or cleared areas) to reach the creeks during construction, which may reduce its water quality. This can cause impacts for other users of a watercourse or for aquatic and semi-aquatic flora and fauna. The most effective measure to limit this potential impact is the implementation of watercourse buffers from these works' areas.

Sedimentation is most likely to occur from runoff from stockpiles or cleared areas including hardstand areas, access tracks and cable trenches. This will most likely occur during periods of intense rainfall. Through the implementation of watercourse buffers, most project infrastructure are located away from tributary drainage channels, except for a number of watercourse crossings for access tracks and cables. With the implementation of sediment control measures and avoiding watercourse crossings during high flow periods the impacts to the creeks via transport of poor water quality in drainage channels was assessed to be localised and unlikely to reach the creeks themselves, for a short duration during periods of high rainfall and of low severity/intensity. Considering the degraded condition of the drainage channels within the project area, the significance of this impact was assessed to be low.

8.1.4.2.3 Alteration of existing drainage patterns

During operation of the project, impacts to the creeks would largely relate to potential hydrological modification in the catchment as a result of altered drainage patterns, if these are not accounted for during design. With the implementation of the management controls outlined in Section 8.1.3, potential impacts associated with altering the hydrology of the creeks were assessed to be localised around wind turbines and along access tracks and are unlikely to alter the overall dynamics of the catchment.

The construction and operation of the project is not predicted to impact the physical form (via hydrological modification) of any creek. With measures in place, the significance of these impacts was considered to be low during construction, reducing to very low during operations.

8.1.4.2.4 Impacts of on-site quarry

Impacts to the creeks and local catchments during construction and operation related to the on-site quarry are of the same nature as the categories above:

- Alteration of existing drainage patterns due to the quarry bunding; and
- Runoff entering creeks.

During operations, the site is proposed to be *'zero discharge'* with all surface water and groundwater managed within the WAA using retention basins. Runoff generated within the upstream catchment will be diverted around the quarry WAA.

Post operations the quarry will be rehabilitated to as a void, with the contributing catchment area limited to the former extraction area using bunding to prevent other areas from discharging to the storage. By limiting the catchment area contributing to this storage, it will not act as a typical dam and will not reduce the water available in the overall catchment as it does not occupy a significant proportion of the catchment.

8.1.4.2.5 Impacts of on-site BESS

Impacts to the creeks and local catchments during construction and operation related to the on-site BESS and terminal station are of the same nature as the categories above:

- Alteration of existing drainage patterns due to site bunding and drainage around the BESS area; and
- Runoff entering creeks.

During operations the site is proposed to be a *'zero discharge'* site with all surface water and groundwater managed within the BESS area using retention basins and internal surface water management. This includes water used for internal firefighting within the BESS. Runoff generated within the upstream catchment will be diverted around the BESS area and returned to the natural flow path.

Post operations the BESS area will be rehabilitated to existing ground conditions.

8.1.4.3 Merri River

8.1.4.3.1 Runoff entering Merri River

The Merri River is located more than 20 km south of the project area, as such direct impacts to this watercourse in terms of physical disturbance are not predicted. However, its tributaries Lyall and Drysdale Creek both originate within the project area and are affected by access track and cable crossings, therefore any changes to downstream water quality or hydrological impacts to its tributaries may indirectly impact the Merri River.

During construction there is the potential for a temporary increase in suspended sediments (and to a lesser extent other contaminants), which has the potential to reduce water quality. This is most likely to occur immediately downstream of stockpiles or cleared areas during periods of intense rainfall. The most effective measure to limit this potential impact is the implementation of watercourse buffers from these works' areas. Other key measures to limit potential impacts to this waterway include the installation of cut-off or interception drains to redirect stormwater away from cleared areas, installing erosion and sediment control measures prior to construction in accordance with best practice standards, and rehabilitating disturbed areas promptly. With these measures in place, changes to water quality in the Merri River as a result of the project are not predicted. Any downstream transport of sediments would likely settle in grassed swales within agricultural areas before reaching the main Merri River located far downstream, and impacts are assessed to be very low.

8.1.4.3.2 Alteration of existing drainage patterns

During the project design, hydrological flood modelling was used to inform the placement of turbine locations. Similarly, modelling of flood and flow velocity will be considered for the sizing of culverts to ensure flow pathways are not affected by the project. As such, permanent changes to hydrological drainage patterns within the Merri River catchment are not predicted. During construction, earthworks and stockpiles also have the potential to impede natural drainage. Measures required include avoiding the creation of continuous rows of stockpiled materials and providing gaps to allow flow, and minimising the length that stockpiles are in place to minimise this hazard.

Considering the nature and scale of works, required to construct the project, hydrological changes are not predicted to impact the Merri River, with any changes highly localised and temporary around ephemeral drainage pathways and waterways within the project site. The significance of these changes was predicted to be very low.

8.1.4.4 Ephemeral wetlands

Potential impacts to ephemeral wetlands as a result of the construction and operation of the project are:

- Disruption of hydrology and flows reaching these areas influencing the inundation of these areas.
- Runoff of poor water quality (e.g., suspended sediments) altering water quality of these ephemeral systems.

To avoid and minimise potential impacts to ephemeral wetlands a 100-metre buffer was placed around all DEECA mapped wetlands by HWF to exclude all project infrastructure as a means of avoiding physical disturbance to wetlands and their fringes and to limit the likelihood of poor-quality surface water runoff from construction works zones reaching these areas. In addition, turbine-free buffers were proposed for Brolga breeding wetlands as a combination of Brolga breeding home range plus an additional disturbance buffer of 300 metres and a turbine blade length buffer of 95 metres. Buffers and their potential impact reduction are described further in the Hexham Wind Farm Flora and Fauna Impact Assessment (Nature Advisory, 2025).

During the project design undertaken by HWF, the hydrological flood modelling presented in this report was used to inform the placement of project infrastructure, including turbine locations. Similarly, modelling of flood and flow velocity will be considered for the sizing of culverts to ensure flow pathways are not affected by the project. Providing the recommended design requirements are met no permanent changes to the hydrological regime for the Hopkins River or local creek catchments within the project site, including ephemeral wetlands, is predicted. With the implementation of control measures, the potential impacts to the wetlands from poor water quality runoff was assessed to be localised (mainly likely to be generated at crossing points away from the wetlands), for a short duration (expected to be over several weeks) and of low severity.

8.1.5 Impact assessment summary

A summary of the surface water impact assessment is shown in Table 8-4.

Table 8-4 Surface water impact assessment summary

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
Hopkins River and tributaries (other than Mustons Creek)	Reduced water quality (e.g., turbidity, dissolved oxygen) due to culvert crossings of tributary drainages, and sedimentation due to stockpiles and earthworks for infrastructure, tracks and hardstands	Construction	• Hydrological buffer for all infrastructure excluding crossings • Bridge/culvert design based on hydrological modelling • Crossing structures would conform to relevant local Council, Glenelg Hopkins Catchment Management Authority and DEECA guidelines • Placement of flow diversion banks upstream of works areas to divert overland flow • Installation of sediment control devices • If a creek is flowing at the time of construction, water must be diverted through use of a temporary upstream coffer dam with piped flow around the construction works area.	Impacts would be localised (within tens of metres), occur for a short duration (weeks), and be of low severity in the context of the existing conditions Temporary increase in sedimentation (and to a lesser extent other contaminants), from runoff from stockpiles or cleared areas. This would most likely occur during periods of intense rainfall which has the potential to reduce water quality.	**Low** Considering the moderate physical and ecological condition of this waterway within the project site and the very poor to moderate existing water quality, the significance of this impact was assessed to be low.

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
	Hydrological changes to surface water flows due to project infrastructure with the introduction of impermeable surfaces, and waterway crossings for tracks and linear infrastructure.	Construction, Operation	• Detailed design incorporating hydrological modelling • Flows will be considered for the sizing of culverts	The magnitude of impacts predicted localised (within tens of metres), occur for a short duration (weeks) and of low severity.	**Low** The magnitude of any hydrological alterations outside turbine free buffers was assessed to be of very low significance
Mustons, Tea Tree, Lyall, Drysdale and other Creeks/designated waterways	Reduced water quality (e.g., turbidity, dissolved oxygen) due to culvert crossings of tributary drainages, and sedimentation due to stockpiles and earthworks for infrastructure, tracks and hardstands	Construction	• Hydrological buffer for all infrastructure excluding crossings • Minimisation of crossing points in the design process • Crossing design based on hydrological modelling • Placement of flow diversion banks upstream of works areas to divert overland flow • Installation of sediment control devices • Minimisation of crossing construction width • If a creek is flowing at the time of construction, water must be diverted	Localised physical disturbances due to watercourse crossings and resulting sedimentation and temporary (weeks) water quality changes. Temporary increase in sedimentation (and to a lesser extent other contaminants), from runoff from stockpiles or cleared areas. This would most likely occur during periods of intense rainfall which has the potential to reduce water quality.	**Low** Sensitive due to several crossings but with manageable construction of established impact mitigation techniques.

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
			through use of a temporary upstream coffer dam with piped flow around the construction works area.		
	Hydrological changes to surface water flows due to project infrastructure with the introduction of impermeable surfaces, and waterway crossings for tracks and linear infrastructure.	Construction, Operation	• Hydrological flood modelling was used to inform the placement of turbine locations • Modelling of flood and flow velocity will be considered for the sizing of culverts	Temporary (weeks) modification of hydrological drainage (for example during watercourse crossings). No permanent impact the physical form (via hydrological modification) of these creeks predicted.	**Low** significance of these impacts was considered to be **low** during construction, reducing to very low during operations.
	Quarry development influencing downstream water quality and hydrology	Construction, operation and post closure	• 'Zero discharge' site (all surface water and groundwater managed using retention basins) • Surface water management using swale drains, bunding, sediment traps and sumps in alignment with Sediment, Erosion and Water Quality Management Plan • Water retention basins to capture water run-off	Quarry is located within the Mustons Creek catchment. Quarry is not affected by the 1% AEP flood event. With the implementation of measures into the design of the quarry, no impacts from quarry construction and operation are predicted to receiving waters within the Mustons Creek catchment.	**Very low** Impacts to surface water are not anticipated

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
	BESS development influencing downstream water quality and hydrology	Construction, operation and post closure	• 'Zero discharge' site (all surface water managed internally using retention basins) • Surface water management using swale drains, bunding, sediment traps and sumps in alignment with Sediment, Erosion and Water Quality Management Plan • Water retention basins to capture water run-off	BESS is located within the Mustons Creek catchment. BESS is affected by the 1% AEP flood event but flows can be diverted. With the implementation of measures into the design of the BESS, no impacts from BESS construction and operation are predicted to receiving waters within the Mustons Creek catchment.	**Very low** Impacts to surface water are not anticipated
	Accidental spill of firefighting contaminated water reduces water quality	Construction, operation and post closure	• Retention basin to prevent uncontrolled release of firefighting water.	Uncontrolled release of fire water at the Battery Energy Storage System has the potential to cause contamination of receiving surface water system. Uncontrolled releases are considered unlikely with the implementation of best-practice measures.	Low

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
Merri River	No direct impact Potential indirect impacts to water quality and hydrological changes during project construction and operation	Construction, Operation	• Watercourse buffers from works areas. • Placement of flow diversion banks upstream of works areas to divert overland flow • Installation of sediment control devices • If a creek is flowing at the time of construction, water must be diverted through use of a temporary upstream coffer dam with piped flow around the construction works area.	Localised (tens of metres) change to sedimentation, change to flood levels and/or change to flow regime up or downstream of the modification location.	**Very low** Any downstream transport of sediments would likely settle in grassed drainage channels within agricultural areas before reaching the main Merri River approximately 20 kilometres downstream.
			• Hydrological flood modelling was used to inform the placement of turbine locations • Avoiding the creation of continuous rows of stockpiled materials and providing gaps to allow flow.	Permanent changes to hydrological drainage patterns within the Merri River catchment are not predicted. Any changes highly localised and temporary around ephemeral drainage channels within the project site	**Very low** Any hydrological changes would be limited to tributary drainage lines.

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
Ephemeral wetlands	Disruption of hydrology and flows	Construction	• Turbine free buffer around Brolga breeding wetlands • 100-metre buffer around all mapped wetlands to exclude all project infrastructure with the exception of access tracks and cable crossings • Detailed design incorporating hydrological modelling	Permanent changes to hydrological drainage patterns are not predicted. Temporary modification of flows around project infrastructure (weeks), particularly during construction, but these would be unlikely to effect the inflows to these wetlands overall.	**Negligible** Changes to hydrological drainage patterns are not predicted
	Potential impacts to water quality and hydrological changes during project construction and operation	Construction, Operation	• Installation of sediment control devices • Placement of flow diversion banks upstream of works areas, to divert overland flow • Implementing an acid sulfate soil management plan • If a creek is flowing at the time of construction, water must be diverted through use of a temporary upstream coffer dam with piped flow	Any changes highly localised (tens of metres) and temporary (weeks) around ephemeral drainage channels within the project site.	**Negligible** Impacts to surface water are not anticipated

Watercourse	Impact pathway	Project phase	Mitigation and management	Likely impact (considering magnitude, extent and duration)	Significance rating and justification
			around the construction works area.		
All	Waterway contamination from accidental spills of hazardous waste, resulting in impacts to water quality	Construction, Operation	• Implement a spills risk assessment and response plan • Storage of liquid fuels and chemicals within containment facilities more than 50 metres from waterways • Spill response kit, to be located at waterway crossings, at locations where machinery/plant are operating, and refuelling. • Incorporation of spill containment measures into the drainage design	With control measures in place any spills are predicted to be localised and could be readily remediated.	**Low** Uncontrolled releases are unlikely using best-practice construction and operational management measures.

8.2 Groundwater

8.2.1 Design mitigation

Based on known environmental constraints, design measures are required to avoid potential groundwater impacts to local groundwater users and environmental values. The required design measures were determined in consultation with HWF and include:

- A 100-metre buffer around all mapped potential aquatic GDEs to exclude turbine foundations within the buffered area. This area is recommended as a means of avoiding physical disturbance to the potential GDEs and their fringes, and to limit surface water runoff, and entrained sediment loads reaching these potential GDEs from construction work zones.
- A 100-metre buffer around all mapped DEECA wetlands to exclude turbine foundations within the buffered area.
- A 25-metre buffer around mapped potential terrestrial GDEs to exclude turbine foundations within the buffered area. A smaller buffer area compared to the potential aquatic GDEs is required as a means of limiting potential physical disturbance and deposition of eroded sediments.
- Minimise the construction time of turbine foundations, therefore reducing the time required to manage groundwater (if intersected).

Specific design mitigation measures relating to the development of the temporary onsite quarry include:

- Quarry positioned on topographic high where the water table is deep, therefore minimising dewatering requirements.
- Quarry positioned greater than 500 m from nearest potential aquatic GDE, terrestrial GDE and DEECA wetland.
- Quarry to be developed in stages with progressive backfill to minimise dewatering requirements and operational impact.
- Quarry to be backfilled to 1 metre above the seasonally high water table level to minimise ongoing losses of groundwater and promote groundwater level recovery.

8.2.2 Management controls

HWF has included a number of engineering design measures such as establishing buffer distances between infrastructure and potential groundwater receptors and limiting the time in which excavations remain open (Section 8.2.1). With consideration of these design measures groundwater impacts in the investigation area are very low to low.

To further manage potential impacts to groundwater, the following management measures outlined in Table 8-5 are required for the project construction, operation and decommissioning.

Table 8-5 Groundwater Management Controls

Groundwater impact pathway	Project phase	Management controls
Excavation and dewatering leads to lowering of groundwater level	Pre-construction	The contractor shall obtain a Work Authority (through approval by Resources Victoria) for the quarry construction and operation and adhere to its requirements (if an on-site quarry is developed).
		The likely occurrence of groundwater in turbine foundations and trenches and potential dewatering volumes is to be assessed during the pre-construction works and documented in a Water Management Plan.
		Micrositing turbine foundation excavations and trenches to avoid any unmapped springs and watercourses identified during detailed design works.
		Consultation with relevant landowners regarding potential impacts to bores, including loss of access, should occur prior to commencement of construction.

Groundwater impact pathway	Project phase	Management controls
	Pre-construction, Construction, Operation, Decommissioning	A Water Management Plan should be developed and implemented by the contractor, and approved by the Responsible Authority, prior to the commencement of Project construction. The Water Management Plan will detail groundwater management approaches required to identify, avoid and minimise impacts to groundwater levels, flow and quality as far as reasonably practicable. The Water Management Plan will also respond to any final design details and ensure all risks are appropriately managed. The Water Management Plan should include, but not be limited to: • Baseline groundwater level and quality (pH and salinity) monitoring in the four cased quarry investigation bores and three existing bores at the proposed quarry site prior to construction (refer to Figure 6-59 for locations). Monitoring should be undertaken quarterly for up to two years. This data will be used to determine the seasonally high water table elevation which will be used to guide the quarry backfill level. • Stygofauna monitoring at the quarry. • Quarry and foundation excavation dewatering activities: – Purpose of dewatering (an explanation of why dewatering is necessary). – Description of dewatering technique to be employed. – Anticipated dewatering flow rate, duration and total volume. – Water collection and storage options. – Monitoring of water quality of captured water (e.g. pH, salinity and suspended solids). – If off-site discharge is required, detail discharge location and quality of water, pollution control and management of sediment in line with EPA approval processes. – Dewatering and disposal to be managed in accordance with Environment Protection Regulations 2021. • Operational groundwater monitoring requirements including locations, frequency and parameters and method for assessing against baseline conditions and predicted impacts. • Management of unmapped springs/seeps. • Management of changes in surface permeability and groundwater discharge from construction activities. • Water Management Plan to be reviewed annually. • Guidance provided in EPA Publication 668: Hydrogeological Assessment (Groundwater Quality) Guidelines.

Groundwater impact pathway	Project phase	Management controls
Foundation excavations intersect shallow water table and alters groundwater flow and recharge	Construction	Construction activities and temporary works that may impact on surface permeability and groundwater should be included within the contractors Water Management Plan. Measures to minimise groundwater recharge and flow related impacts relating to these activities and works should include, but not be limited to: • Revegetation of disturbed areas. • Backfilling using excavated material were possible.
Disruption of groundwater discharge	Construction	Construction activities and temporary works that may impact on groundwater discharge should be included within the contractors Water Management Plan. Measures to minimise groundwater discharge related impacts should include, but not be limited to: • Micrositing turbine foundation excavations and trenches to avoid unmapped springs and watercourses. • Backfilling using excavated material were possible.
Accidental spills of hazardous materials reduce water quality	Construction, Operation, Decommissioning	To manage potential impacts to groundwater quality, mitigation measures to be implemented (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 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 CEMP. • Rehabilitation of any areas where a spill has occurred.

Groundwater impact pathway	Project phase	Management controls
		Battery Energy Storage System to include retention basin to capture firefighting water to prevent uncontrolled release of water to the environment. Contaminated water captured within the retention basin to be discharged to a lawful place.

8.2.3 Residual effects

Following the development of design measures, an assessment of residual effects and impacts was completed describing the likely changes to the environment brought about by the construction, operation and eventual decommissioning of the project and rating the significance of these effects.

Potential groundwater impacts from the project construction, operation and decommissioning were assessed for each identified groundwater asset within the project area. The significance of groundwater impacts was assessed against the impact ratings outlined in Table 8-6.

Table 8-6 Significance 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 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 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 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 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 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.

8.2.3.1 Quaternary aquifer (QA)

Three crossings for accessways and cables are proposed for the area of Quaternary Alluvium surrounding Mustons Creek and two on the upper reaches of Drysdale Creek. Several other crossings for accessways and cables exist across minor unnamed watercourses in the Quaternary Aquifer. The key impact pathway for the Quaternary Aquifer is surface disturbance and shallow excavation for cables. Disturbance in the accessways and cable crossing areas would be minimal (in a localised area) and temporary, limited to the construction period for these crossings. If saturated, direct disturbance may require dewatering to enable construction for a short period of time (i.e., two weeks). This in turn may temporarily lower the water table for the duration of construction activities. The magnitude of impacts predicted within the Quaternary Alluvium are highly localised (tens of metres) and any impacts are predicted to be short term (weeks). These effects are unlikely to impact existing bores, potential aquatic and terrestrial GDEs, springs, wetlands or stygofauna communities.

Disturbed areas would be rehabilitated following completion of works to the satisfaction of the Glenelg Hopkins CMA. No permanent impacts to existing bores, potential aquatic and terrestrial GDEs, springs, wetlands or stygofauna communities are anticipated.

8.2.3.2 Water Table Aquifer (Newer Volcanic Group Basalts Aquifer (UTB) / Whalers Bluff Formation / Hanson Plain Sand (UTAM))

8.2.3.2.1 Dewatering and disposal of extracted groundwater

Quarry

The Newer Volcanic Group basalt aquifer will be intersected by the proposed on-site quarry. The quarry has a proposed depth of 14 m, with the water table depth estimated to range from around 9 m to 13 m below ground level. An assessment of groundwater inflow and drawdown from quarry dewatering is detailed in the quarry assessment in Section 6.4. This section contains details of the hydraulic testing, water level monitoring, groundwater quality sampling and analytical groundwater modelling undertaken to assess groundwater inflow and potential drawdown extents.

Groundwater inflows are proposed to be managed through in-pit sump pumping (i.e., in-pit dewatering). Groundwater inflows in the quarry excavation site are expected to be around 19.0 ML/yr, however, groundwater inflows could be higher if hydraulic conductivity is greater than anticipated. Sensitivity testing using higher hydraulic conductivity values indicates that inflows of up to 37.2 ML/yr may be possible.

Drawdown as a result of pit inflow is predicted to extend up to 189 m from the centre of the sub-pits for the base case scenario and up to 226 m for the low recharge scenario. For the purposes of assessing the potential impacts on existing users the low recharge drawdown extent has been used as this provides the largest predicted drawdown extent. The predicted extent of drawdown for each of the four sub-pit stages are shown in Figure 6-68. The drawdown extent represents the distance from the centre of each sub-pit stage to the point at which drawdown is predicted to be zero. The predicted drawdown extent remains highly localised around the quarry sub-pits due to the low hydraulic conductivity and the limited extent in which the quarry pits are excavated below the water table (i.e. < 5m).

As the quarry progresses, each stage will be backfilled to at least 1 metre above the water table which will prevent the ongoing loss of groundwater from the quarry pit that would occur if it remained open and below the water table. Additional monitoring of the four cased quarry investigation bores will be required to determine the seasonally high water table elevation which will be used to guide the quarry backfill level.

One groundwater bore identified during a site survey is within the quarry excavation area (Bore 2 in Figure 6-68). It is possible that an alternate water source will need to be provided to replace this bore depending on the reliance that the landowner has on this well. Two other bores (Bore 1 and 3) located close to the quarry are not predicted to be impacted (Figure 6-68), however, it is recommended that these bores are monitored during and after quarry operations to validate the outcomes of this assessment.

All potential aquatic and terrestrial Groundwater Dependent Ecosystems (GDEs) and DEECA wetlands are located outside of the predicted drawdown extent (Figure 6-68). Impacts to GDEs are not expected as a result of quarry pit dewatering. The presence of unmapped springs is unlikely at the quarry site due to the elevated topography and lack of areas which are conducive to spring flow, particularly breaks in slope where springs are more likely to occur.

It is possible that there may be some localised temporary impacts to stygofauna. Impacts are likely to be associated with excavation of the basalt material below the water table and from localised drawdown up to 226 m from the quarry excavation (Figure 6-68). It is noted that the Newer Volcanic Group basalts in which the quarry will be excavated are not considered highly conducive environments for stygofauna due to the relatively unfractured nature of the basalt and high clay content where the basalt is weathered.

Drawdown during quarrying will be controlled by the quarrying advancement rate which is slow (i.e. several months to reach maximum depth) compared to other groundwater affecting activities such as extraction from groundwater wells which can occur much more rapidly (i.e. days). The two-year quarrying timeframe is considered short term when considering climatic cycles such as the millennium drought where groundwater levels in shallow aquifers were reduced for up to a decade.

The two stygofauna species identified in bore 110108 near the site (*Copepoda Cyclopidae* and *Tubificida Enchytraeidae*) have also been found in other wells in the Otway Basin indicating that these two species are not endemic to this location. *Tubificida Enchytraeidae* was also found in the Gippsland baseline stygofauna survey.

Once the quarry is backfilled, the water table is expected to recover to its pre-quarrying level. Impacts to stygofauna are therefore expected to be temporary. Overall, potential impacts to stygofauna are considered to be low.

Turbine Foundations and Cable Excavations

During turbine foundation construction, it is important to have a clean excavated foundation base until blinding concrete (thin layer of concrete to preserve excavation founding material and create level surface for works) is poured. This is typically achieved by pumping the water out using a sump at the base of the excavation if the excavation is below the water table.

During construction of infrastructure foundations, dewatering may temporarily lower the water table before the concrete foundations are laid. If observed, drawdown would be expected to last for weeks rather than months or years. Anecdotal observations from other windfarm construction projects indicate that groundwater inflow is generally minimal in the form of minor seepage into the foundations. Some instances of active pumping (dewatering) are known to have occurred mainly in the winter months when groundwater levels are highest (pers comm., Wind Prospect).

Estimation of the potential radius of influence around excavations has been made using the Sichardt equation which has been used by the Western Australian Department of Environment Regulation (DER, 2015) to assess drawdown around shallow construction excavations. Estimates using the Sichardt equation indicate that drawdown could be between 6 m to 18 m from the edge of excavations. These estimates are based on dewatering to 3.5 m with hydraulic conductivity values of 0.025 m/d and 0.25 m/d. Hydraulic conductivities higher than this are not likely in the first 3.5 m of soil/rock. These drawdown estimates are preliminary in nature and will be updated should the detailed design works indicate that groundwater intersection is an issue.

The occurrence of groundwater in foundation excavations and potential dewatering volumes (should this be required) will be assessed in more detail during the pre-construction works which includes on-site geotechnical works and soil testing/profiling. This data is required to understand the foundation conditions at each turbine location. If active pumping is required, groundwater inflow monitoring would be required as part of the Water Management Plan. Following dewatering the water table is predicted to recover quickly over several weeks.

Groundwater drawdown near potential aquatic GDEs, DEECA wetlands and potential terrestrial GDEs is not expected to occur as a result of the buffer distances used to avoid these features. Any drawdown from foundation excavation dewatering (if required) would be expected to be highly localised (within tens of metres of foundations as discussed above). If unmapped springs and watercourses are found to exist near turbine locations, it is proposed that micrositing is used to avoid these areas.

Measurable impacts to groundwater bore water levels are considered to be very low due to the limited drawdown extent and temporary nature of the works. Potential impacts to stygofauna as a result of foundation excavations are expected to be highly localised and temporary.

Dewatering for cable excavations may be required where groundwater levels are less than 1 metre below the natural surface. Given this would be limited to isolated areas, and the excavations for the underground cables will be open for less than three hours, impacts to groundwater receptors from these works are not anticipated to occur.

8.2.3.2.2 Disruption of groundwater recharge and flow

The surface area of wind turbine foundations will be approximately 27 x 27 metres and hardstands (next to each wind turbine) will be approximately 6,500 square metres. To minimise impacts, turbine foundations are shaped to allow rainwater run-off and to re-establish natural recharge adjacent to these features. Considering the surface area for foundations and hardstands is small, the estimated reduction in groundwater recharge will be minimal and can be offset by appropriate drainage design.

Given the unconfined nature of the Newer Volcanic Group Basalts Aquifer (UTB) / Whalers Bluff Formation / Hanson Plain Sand (UTAM), and existing seasonality of groundwater recharge and flow, any impacts to groundwater flow around infrastructure foundations are anticipated to be localised and minor. With design buffers of 100 metres around potential aquatic GDEs and DEECA wetlands, any changes to groundwater flow and recharge caused by infrastructure foundations are unlikely to affect these features.

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 should be backfilled with the excavated material. As such, there will be no change to permeability and recharge rates in these areas.

8.2.3.2.3 Disruption of groundwater discharge

With design buffers of 100 metres around potential aquatic GDEs and DEECA wetlands, any changes to groundwater discharge caused by turbine foundations are unlikely to affect these features. Discharge to watercourses is also unlikely to be impacted as turbine locations have been positioned to avoid watercourses and areas which may receive overland flows. If unmapped springs and watercourses are found to exist near turbine locations, micrositing of turbine locations can be used to avoid these areas.

8.2.3.2.4 Groundwater contamination

If construction controls and spill prevention and abatement techniques are not properly implemented, accidental spills of hydrocarbons or other chemicals have the potential to result in contamination of the groundwater system, impacting surrounding groundwater users including GDEs, wetlands, stygofauna and groundwater bores. The impact of an uncontrolled release of hazardous material is predicted to be highly localised near the spill. Measures are required to be outlined in the Construction Environmental Management Plan (CEMP) to prevent, manage and contain spills. As such, impacts are predicted to be low.

There is potential for shallow groundwater to flow into foundations and open trenches, more so during winter and early spring. As such, it may be necessary to pump water (dewater) from these excavations. This water is required to be tested for turbidity, salinity, pH and, if it meets the relevant ERS / ANZECC water quality indicators, could either be pumped into a neighbouring farm dam or discharged to adjacent land. If it exceeds acceptable limits, the water should be treated or disposed of by alternative means such as to an EPA Victoria licensed facility.

The exposure of PASS can acidify water and impact groundwater quality and resources. The potential impact from acid sulfate soils is further discussed in the Hexham Wind Farm Soil and Landform Assessment (WSP, 2024)

8.2.3.3 Port Campbell Limestone aquifer

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

8.2.4 Impact assessment summary

A summary of the groundwater impact assessment is shown in Table 8-7.

Table 8-7 Groundwater Impact Assessment Summary

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
Quaternary Aquifer (QA)	Direct disturbance and dewatering leads to lowering of groundwater level	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• Waterway crossings (tracks and cables) should conform to local Council and Glenelg Hopkins CMA guidelines. • Inclusion of creek crossings in Water Management Plan. • Rehabilitate disturbed areas following completion of works.	Three crossings for accessways and cables are proposed for the area of Quaternary Alluvium surrounding Mustons Creek and two on the upper reaches of Drysdale Creek. Several other crossings for accessways and cables exist across minor unnamed watercourses in Quaternary Alluvium. Disturbance and potential impacts on groundwater levels would be minimal, highly localised (tens of metres) and temporary (weeks).	Very low
Water Table Aquifer (Newer Volcanic Group Basalts Aquifer (UTB) / Whalers Bluff Formation / Hanson	Quarry excavation and dewatering leads to lowering of groundwater level	GDEs (including potential unmapped springs)	• Quarry greater than 500 m from potential aquatic and terrestrial GDEs / DEECA wetlands. • Quarry positioned on topographic high. • Quarry to be progressively backfilled. • Post quarrying land surface rehabilitated to 1 metre above water table. • Implementation of Water Management Plan.	All potential aquatic and terrestrial GDEs and DEECA wetlands are located outside of the predicted drawdown extent (Figure 6-68). Impacts to GDEs and wetlands are not expected due to quarry pit dewatering. The presence of potential unmapped springs is considered unlikely at the quarry site due to the elevated topography and lack of areas which	Low

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
Plain Sand (UTAM))				are conducive to spring flow, particularly breaks in slope.	
		Stygofauna	• Quarry positioned on topographic high. • Quarry to be progressively backfilled. • Post quarrying land surface rehabilitated to 1 metre above water table. • Implementation of Water Management Plan.	Some localised disturbance to stygofauna is possible during the 2-year quarrying period. Disturbance is likely to be associated with excavation of the basalt material below the water table and from localised drawdown around the quarry (Figure 6-68). It is noted that the Newer Volcanic Group basalts in which the quarry will be excavated are not considered highly conducive environments for stygofauna due to the relatively unfractured nature of the basalt and high clay content where the basalt is weathered. Potential impacts to stygofauna are therefore considered to be low. The duration of disturbance is predicted to be temporary and may last for several years. Once complete, the quarry will be backfilled to 1 metre above the seasonally high water table which will prevent ongoing evaporative losses from the quarry and promote groundwater level recovery.	Low

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
		Groundwater bore users	• Quarry positioned on topographic high. • Quarry to be progressively backfilled. • Post quarrying land surface rehabilitated to 1 metre above the water table. • Implementation of Water Management Plan.	One groundwater bore identified during a site survey is within the predicted quarry area (Bore 2 in Figure 6-68). It is possible that an alternate water source will need to be provided to replace this bore depending on the reliance that the landowner has on this well. Two other bores (Bore 1 and 3 in Figure 6-68) located close to the quarry are not predicted to be impacted, however, it is recommended that these bores are routinely monitored to validate the outcomes of this impact assessment.	
	Foundation excavations leads to lowering of groundwater level	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• 100 metre buffer around potential aquatic GDEs. • 100 metre buffer around all mapped DEECA wetlands. • 25 metre buffer around potential terrestrial GDEs. • Micrositing of turbine foundations. • Where dewatering cannot be avoided, duration of dewatering to be minimised.	Due to the shallow nature of the excavations (3.5 m) and the short duration of turbine excavation (i.e., up to two weeks), any drawdown would be highly localised (tens of metres) and temporary. Buffers that has been established between foundation excavations and potential GDEs will limit drawdown at these receptors.	Very low

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
				Potential unmapped springs to be avoided by micrositing turbine locations. Some highly localised and temporary disturbance to stygofauna may occur if dewatering is required. There are not expected to be any impacts to existing bore users resulting from construction of foundation excavations.	
	Foundation excavations intersects shallow water table and alters groundwater flow and recharge	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• Turbine foundations shaped to allow rainwater run-off and re-establishment of natural recharge adjacent to these features. • Micrositing of turbine foundations to avoid unmapped springs. • Where dewatering cannot be avoided, duration of dewatering to be minimised.	Any impacts to groundwater flow around infrastructure foundations are anticipated to be localised and minor. Any reduction in groundwater recharge will be localised and will be mitigated by appropriate drainage design. Any changes to groundwater flow and recharge are unlikely to have a material effect on bores, potential GDEs, wetlands, springs and stygofauna communities.	Very low
	Foundation excavations intersects shallow water table and alters	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• 100 metre buffer around potential aquatic GDEs. • 100 metre buffer around all mapped DEECA wetlands.	Any impacts to groundwater discharge to wetlands and watercourses are anticipated to be highly localised and minor. Any changes to groundwater discharge is unlikely to have a	Very low

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
	groundwater discharge		• Micrositing of turbine foundations to avoid unmapped springs. • Placement of turbine locations to avoid low lying areas/overland flow paths.	material effect on bores, potential GDEs, wetlands, springs and stygofauna communities.	
	Accidental spills of hazardous materials reduce water quality	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• Implement a spills risk assessment and response plan. • Spill response kit, to be located at locations where machinery/plant are operating, and refuelling.	If accidentally released, fuels and chemicals stored within the project site could result in localised contamination of the groundwater system. The impact is considered to have a possible moderate magnitude and extent, and medium term (temporary) effect. Uncontrolled releases are considered unlikely with the implementation of best-practice measures.	Low
	Accidental spill of fire contaminated water reduces water quality	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	• Retention basin to prevent uncontrolled release of firefighting water.	Uncontrolled release of fire water at the Battery Energy Storage System has the potential to cause localised contamination of the groundwater system. Uncontrolled releases are considered unlikely with the implementation of best-practice measures.	Low

Aquifer	Impact pathway	Environmental value	Mitigation and management	Likely effect (magnitude, extent and duration)	Residual impact significance
Port Campbell Limestone aquifer	No linkage.	Groundwater bore users	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

8.3 Surface water and groundwater cumulative impacts

8.3.1 Overview

The surface water and groundwater environments within and surrounding the project area are inherently linked via infiltration/groundwater recharge (surface water contributing to groundwater) and plant transpiration, groundwater extraction from wells and groundwater expressing in springs and waterways (groundwater contributing to surface water). Given this connection, there is the potential for cumulative groundwater and surface water impacts. The potential impacts include:

- Reduced groundwater recharge in areas already impacted by groundwater extraction, exacerbating the potential reduction in groundwater levels.
- Contaminated surface water entering the groundwater system impacted by reduced water levels
- Reduced groundwater expression in waterways caused by groundwater extraction in areas with already reduced surface water inflows.

8.3.2 Design mitigation and management controls

Since the impact pathways described above are directly linked to already identified impact pathways for surface water or groundwater, design measures are covered in Section 8.1.2 and Section 8.2.1.

Similarly, management controls required to be implemented during the design, construction, operation and decommissioning of the project are outlined in Table 8-2 and Table 8-5.

8.3.3 Impact assessment summary

A summary of the cumulative impact assessment is shown in Table 8-8.

Table 8-8 Cumulative impact assessment summary

Receiving environment	Impact pathway	Environmental value	Surface water impact significance	Groundwater impact significance	Combined residual impact significance
Quaternary Aquifer (QA) Water Table Aquifer (Newer Volcanic Group Basalts Aquifer (UTB) / Whalers Bluff Formation / Hanson Plain Sand (UTAM))	Reduced groundwater recharge in locations impacted by alterations of existing drainage patterns through diversion of flow, caused by the project components	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	Low	Very low to low	Low
		Stygofauna	Low	Low	Low
		Groundwater bore users	Low	Very low	Low
Water Table Aquifer (Newer Volcanic Group Basalts Aquifer (UTB) / Whalers Bluff Formation / Hanson Plain Sand (UTAM))	Groundwater contamination caused by infiltration of contaminated surface water, caused during construction	GDEs (including potential unmapped springs), stygofauna and groundwater bore users	Low	Low	Low
Hopkins River and tributaries (other than Mustons Creek) Mustons, Tea Tree, Lyall, Drysdale and other Creeks/designated waterways	Reduced waterway flows caused by groundwater extraction during construction	Water dependent ecosystems and species	Low	Very low to low	Low
		Agriculture and irrigation (including stock watering)	Low	Very low to low	Low

Receiving environment	Impact pathway	Environmental value	Surface water impact significance	Groundwater impact significance	Combined residual impact significance
Ephemeral wetlands	Reduced waterway flows caused by groundwater extraction during construction	Water dependent ecosystems and species	Negligible	Very low to low	Low
Hopkins River and tributaries (other than Mustons Creek) Mustons, Tea Tree, Lyall, Drysdale and other Creeks/designated waterways	Waterway contamination caused by contaminated groundwater entering waterways through e.g. springs	Water dependent ecosystems and species	Very low to low	Low	Low
		Agriculture and irrigation (including stock watering).	Low	Low	Low
Ephemeral wetlands	Waterway contamination caused by contaminated groundwater entering waterways through springs and baseflow	Water dependent ecosystems and species	Negligible	Low	Low

9 CONCLUSIONS

9.1 Surface water

Construction and operation of the project has the potential to impact surface water systems and supporting environmental values through distinct impact pathways, which may result in lowering of the watercourse crossings, reduced water quality and altered flows.

Flood behaviour within the project catchments was used to inform the siting of infrastructure to avoid areas of potential flooding. Other design mitigation measures include designing the project with buffers around all mapped wetlands, and minimisation of watercourse crossings through siting of access tracks. Assuming detailed designs have been completed in accordance with best practice guidelines and in consultation with relevant authorities the residual effects of watercourse crossings and to a lesser extent reduced water quality from construction works were assessed to be localised and temporary

9.2 Groundwater

Construction and operation of the project has the potential to impact groundwater and supporting environmental values in the water table aquifer. At the site this includes the Upper-Tertiary/Quaternary Basalts , the Upper-Tertiary Aquifer and the Quaternary Alluvium. Potential impacts are through distinct and localised impact pathways, which may result in localised lowering of the water table, altered groundwater recharge and flows, altered groundwater discharge and reduced water quality.

To minimise the potential for the project to impact local aquatic GDEs and wetlands, the design has incorporated a minimum 100 m buffer from these features and 25 m buffer from potential terrestrial GDEs when placing turbine foundations.

Micrositing of turbine locations is proposed to avoid any unmapped springs which may be found to occur outside of the available GDE and wetland coverages. The occurrence of groundwater in foundation excavations and potential dewatering volumes (should this be required) will be further assessed during the pre-construction works which includes on-site geotechnical works and soil testing/profiling. Any drawdown from foundation excavation dewatering and excavation of trenches (if required) would be expected to be highly localised and temporary.

Some drawdown is expected around the temporary on-site quarry as quarrying progresses below the water table. One groundwater bore identified during a site survey is within the predicted quarry area. It is possible that an alternate water source will need to be provided to replace this bore depending on the reliance that the landowner has on this bore. All potential aquatic and terrestrial GDEs and wetlands are located outside of the predicted quarry drawdown extent. Some localised disturbance to stygofauna communities are possible during the 2-year quarrying period. It is noted that the Newer Volcanic Group basalts in which the quarry will be excavated are not considered highly conducive environments for stygofauna due to the relatively unfractured nature of the basalt and high clay content where the basalt is weathered.

The duration of disturbance is predicted to be temporary and may last for several years. Once complete, the quarry will be backfilled to 1-metre above the seasonally high water table which will prevent ongoing evaporative losses from the quarry and promote groundwater level recovery.

Management measures have been proposed for the construction, operational and decommissioning phases of the project to further manage potential groundwater impacts. Any proposed dewatering activities are to be captured in a Water Management Plan. With the implementation of these measures, the impacts to groundwater users and groundwater quality are considered to be very low to low.

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APPENDIX A
TYPICAL GLENELG HOPKINS CMA WORKS ON WATERWAYS LICENCE REQUIREMENTS

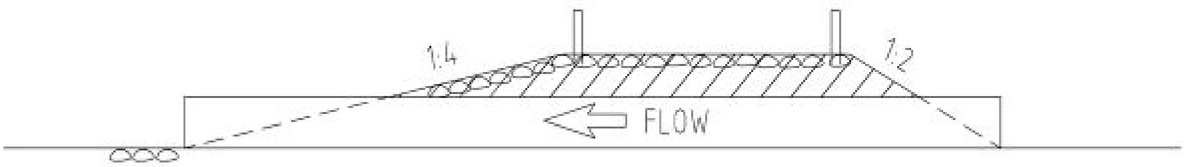
The General Works and Activities on Waterways Licence conditions are as follows:

1. The works shall be constructed in accordance with any plans approved by Glenelg Hopkins CMA. Any proposed amendments to the works including (but not limited to) changes to design, method of works or materials used must in writing be submitted to, and approved by, Glenelg Hopkins CMA.
2. The waterway shall not be deviated in any manner for construction purposes without the approval of the Glenelg Hopkins CMA.
3. Works should be undertaken during dry conditions and when water flow is minimal. All operations should cease if wet conditions prevail.
4. Construction machinery shall be washed down before arriving on-site, and upon completion of the works, to remove all soil, mud, seeds and other vegetative matter. Upon completion of the works, washing down of machinery shall be performed at least 25 metres from a waterway, or at least 5 metres from any drainage system connected to a waterway.
5. Machinery with defective and/or leaking fuel, lubrication or hydraulic systems must not be used to perform the works.
6. Disturbance of the bed and banks of the waterway and the use of construction plant and equipment is to be kept to a minimum.
7. Mitigation measures shall be implemented to prevent vegetation, silt, sediment, chemicals and spillage from construction activities either entering the waterway or moving downstream during or after the works. Sediment control measures to minimise any increase in water turbidity are of particular importance and may include provision of silt traps (*Australia Geotextile Silt Fence 2000 or approved equivalent*) and detention basins.
8. Works must comply with the following relevant EPA Guidelines where applicable:
9. "*Construction Techniques for Sediment Pollution Control*", Publication 275, May 1991.
10. *"Civil construction, building and demolition guide",* Publication 1834, November 2020.
11. "*Doing it Right on Subdivisions*", Publication 960, September 2004
12. Discharge of water polluting substances i.e., wastewater into the waterway is not permitted, unless specifically authorised by Glenelg Hopkins CMA.
13. The construction site and construction methods must comply with relevant OHS legislation and Work Safe Victoria industry standards.
14. Works shall cease immediately upon the discovery of any suspected human remains. The police or State Coroner's Office must be informed of the discovery without delay. If there are reasonable grounds to suspect that the remains are aboriginal, the discovery must also be reported to Aboriginal Affairs Victoria.
15. Works shall cease immediately upon the discovery of any aboriginal cultural material or if the site is suspected to be of aboriginal or archaeological cultural significance. Upon any such discovery 'First Peoples State Relations shall be notified immediately and works suspended until advice from Aboriginal Affairs Victoria is received.
16. It is the responsibility of the License holder to ensure that any person(s) conducting works be made aware of and comply with the requirements and conditions of this License. A copy of any Licenses and conditions shall be kept on site and be easily accessible for the duration of works.
17. The landowner or land manager shall always maintain the works in good order. Regular monitoring and maintenance of the site shall be undertaken to ensure the ongoing health of the waterway. Any concerns shall be reported to the Glenelg Hopkins CMA.

18. On completion of the works Glenelg Hopkins CMA must be contacted on planning@ghcma.civc.gov.au so that an inspection can be arranged.

The culvert Works and Activities on Waterways Licence conditions are as follows, these permit conditions relate to the construction of a culvert crossing, and are to be read in conjunction with the General Permit Conditions for Works on a Waterway listed above:

1. Culverts shall be installed parallel to the alignment of the banks of the waterway.
2. The culverts shall be placed with their inverts at or slightly below the invert of the waterway.
3. Rock protection is required on the bed and banks to at least the height of the crossing level, extending at least 4 times the culvert height downstream of the culvert.
4. Low level crossings shall have additional rock protection extending from top of bank to crossing surface.
5. The rock used for lining of bed and banks shall be dense, tough and durable. Rock size shall include a variety of diameters varying from fines to larger rock sizes and have an average diameter of 200 mm diameter. The lining thickness shall be a minimum of 400 mm with the surface of the rockfill finished flush with the bed of the waterway.
6. The embankment or trafficable surface and or access ramps over the culvert(s) shall comprise of the following:
    a. the crossing shall be surfaced with compacted rockfill or gravel;
    b. the slope of the embankment on the downstream side shall be graded and be no steeper than 4 horizontal to 1 vertical;
    c. the slope of the embankment on the upstream side shall be no steeper than 1 vertical to 2 horizontal and, where practicable, this upstream face shall be top soiled and planted with approved grasses.



7. Bank batters or embankment fill shall not encroach into the flow path of the culvert. Batters shall be constructed at a grade no steeper than 1 vertical to 2 horizontal.
8. Side batters of the access track excavated into the stream bank shall be on a slope of 1 vertical to 2 horizontal or flatter to facilitate the establishment of a vegetative cover and planted with appropriate native grasses (contact DSE at www.dse.vic.gov.au for further information about appropriate vegetation)
9. Surface runoff from the access track including dairy crossings shall be managed to minimise the transport of sediment and nutrients into the waterway. Where possible, runoff shall be diverted away from the site or into the grassed filter zone adjacent to the waterway.
10. Waterway to be fenced out 30 meters either side of each culvert crossing, and 5 metres either side of the waterway if stock exclusion is required. The fenced out area is to be revegetated using indigenous species grown from seed of local provenance.

The bridge Works and Activities on Waterways Licence conditions are as follows, these permit conditions relate to the construction of a culvert crossing, and are to be read in conjunction with the General Permit Conditions for Works on a Waterway listed above:

1. All works including temporary works shall be constructed in accordance with any plans approved by Glenelg Hopkins CMA.
2. It is the responsibility of the permit holder to ensure that works are in accordance with all relevant Australian Standards or Bridge Design Codes.
3. Where the deck level of the bridge is below the estimated water surface level of a flood with an average recurrence interval of 100 years then:
    a) the bridge beams shall be securely anchored to piers and abutments by bolting or other approved means
    b) the bridge decking shall be securely pinned to the bridge beams
    c) the bridge shall be designed and constructed to withstand the combined forces of:
        i. hydraulic loading, including additional loading due to build-up of debris; and
        ii. impact loading of floating debris such as logs (based on the maximum weight of a log likely to be generated from the catchment).
4. Any side rails attached to the bridge crossing shall be designed to minimise the build-up of flood debris.
5. The bridge decking shall be constructed of concrete, timber or other non-erodible material.
6. The side slopes of any cut excavated into the bank of the waterway to obtain access to the crossing shall be no steeper than 2 horizontal to 1 vertical. At the completion of works all side slopes shall be top soiled and planted with approved grasses and shrubs.
7. To prevent erosion and transport of sedimentation and nutrients into the waterway, surface runoff from tracks leading to the bridge shall not be allowed to flow directly into the waterway. All such runoff shall be diverted away from the site or, into a grassed filter zone adjacent to the waterway.
8. In the case of access ramps cut into the bank, where runoff from the ramp will flow directly into the waterway, the access ramp shall be surfaced with compacted gravel to prevent scour of the track. Side drains shall be protected from scour with rockfill evenly graded from fines to 150 mm diameter.
9. Any temporary works must be removed as soon as is practicable on completion of bridge works.
10. If necessary, flows shall be pumped around the construction site or construction undertaken in stages with flow confined to one portion of the waterway.
11. That the areas of the existing bridge and adjoining road that are to be decommissioned are remediated through weed control and revegetation using indigenous species of local provenance.

APPENDIX B
SURFACE WATER QUALITY MONITORING SCOPE OF WORKS

B-1 Memorandum

To Hexham Wind Farm
From Water Technology
Date 19 July 2023
Subject Hexham Wind Farm Surface Water Quality Monitoring
Our ref 23010166_Hexam_Baseline_WQ_M01V02.docx

B-1-1 Overview

This memorandum has been prepared to address comments raised by EPA and DEECA during the TRG review process for the Hexham Wind Farm EES Surface Water Impact Assessment (SWIA) prepared by Water Technology. During the preparation of the SWIA a lack of baseline water quality data for the proposed site was identified. Additional sampling was done across a number of sites during a site visit in March 2023, to provide a snapshot of the surface water quality for the impact assessment. The work presented in the SWIA report is considered sufficient for characterising the existing surface water environment for the purpose of meeting the EES Scoping Requirements. However, further work is required to establish the baseline water quality conditions, to be able to detect any exceedances/deviations during works in the construction, operation and rehabilitation stages of the project.

An additional scope of water quality monitoring works to establish baseline water quality conditions is proposed in this memorandum. It has been developed in consultation with the EPA, DEECA, and a senior water quality engineer and a director from Water Technology.

The scope would include the following actions. Please note that we have designed this monitoring program with the underlying assumption that most, if not all, of the waterway sites associated with this project are ephemeral rather than perennial in nature. As such, the concept of 'baseline' water quality monitoring needs to be much more 'event based' rather than 'regular' (e.g., monthly) in nature.

B-1-2 Proposed Scope of Works

In summary, the following scope is proposed:

- Three control (i.e., upstream) sites, four impact (i.e., downstream) sites and four wetland sites as per Figure 10-1.
- At each of these sites, an appropriate stage height water sampling installation should be put in place (see Figure 10-2) to automatically collect water samples when there is sufficient run-off occurring within the waterways. The stage height water sampling equipment is more financially viable than automatic sampling systems and manual sampling based on the site location and timing of sampling. Surface water modelling conducted as part of the SWIA will be used to estimate the likely regular depths of flow at each site and hence the appropriate size of device.
- Several samples should be collected and analysed from each site for at least three run-off events of reasonable magnitude (of the order of '0.25 year ARI') prior to any works commencing in regard to this project. These samples should be analysed at a suitable laboratory for the following parameters:
  - Total Phosphorus
  - Total Nitrogen
  - TSS
  - Electrical Conductivity
  - Ammonia
  - Nitrate
  - Aluminium
  - Arsenic (AsIII) and (AsV)

- Boron
- Cadmium
- Chromium (CrVI)
- Copper
- Lead
- Manganese
- Mercury (inorganic)
- Nickel
- Selenium
- Silver
- Zinc
- pH

- This initial broad spectrum approach may be adjusted after the three initial events to focus on parameters and/or locations indication exceedances.
- Once the results of the above analyses are available, statistical evaluations should be conducted of the results collected in order to develop appropriate estimates of the median and range of variability of each parameter. Evaluations should be conducted of how these data compare against relevant State and Federal water quality objectives and appropriate threshold values derived for future impact monitoring.
- Once site works commence, ongoing event-based monitoring should be conducted at all sites. To reduce cost, when a run-off event does occur, the various individual water samples collected at each site should be composited so that an Event Mean Concentration (EMC) result is obtained. These composited water samples should be sent to a suitable laboratory for analysis of the parameters listed above. Once these data are received, the following regular interpretations should be conducted:
  - Has there been any significant change in water quality levels between the upstream/control and downstream/impact sites; and
  - Have there been any significant exceedances of relevant water quality thresholds identified at any or all of the sites.
- Should there be any changes based on the above performance metrics, relative causative mechanism assessments and corrective action works should be undertaken.

The above scope will be implemented in the surface water management plan and/or the sediment and erosion management plan.

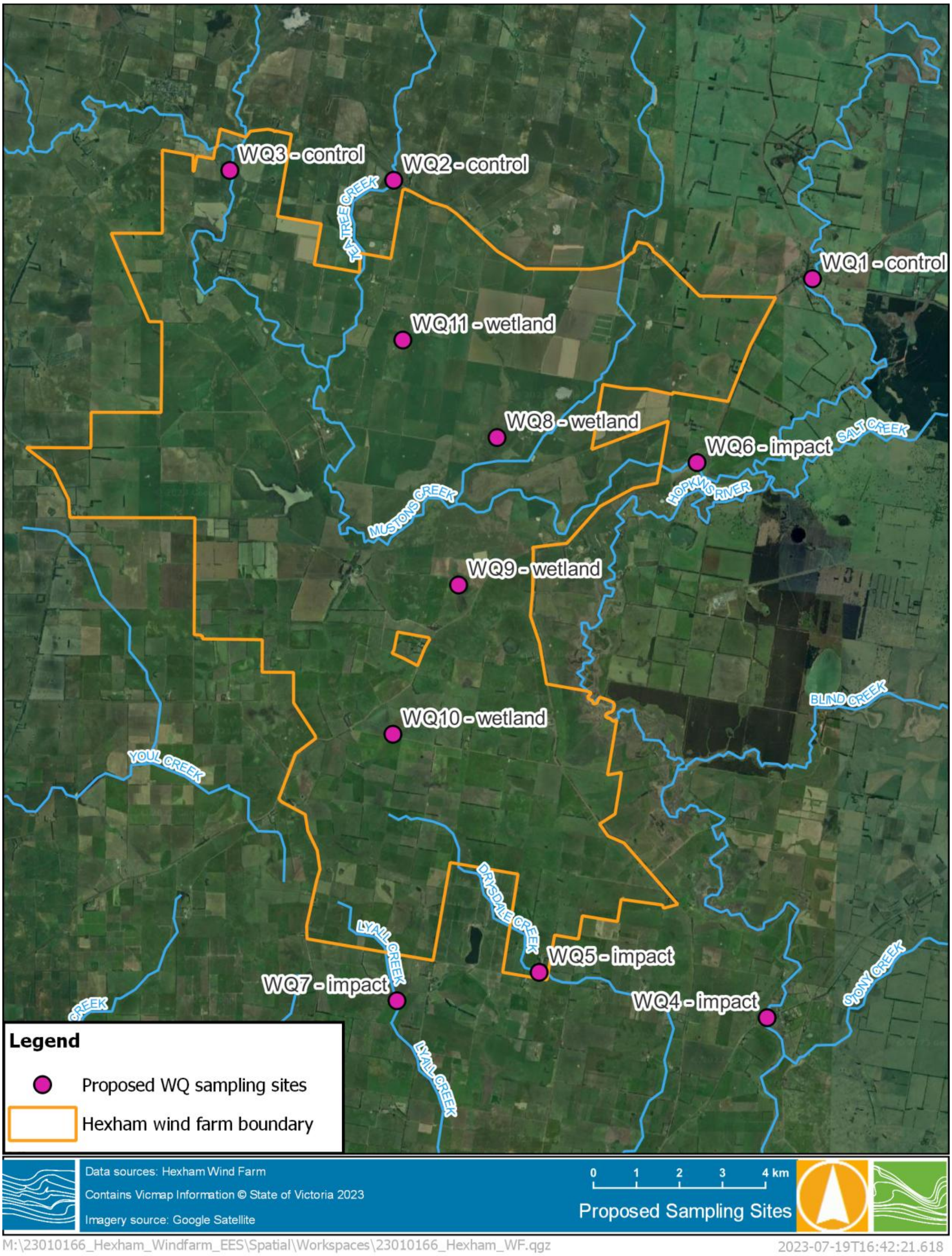


Figure 10-1 Proposed sampling sites

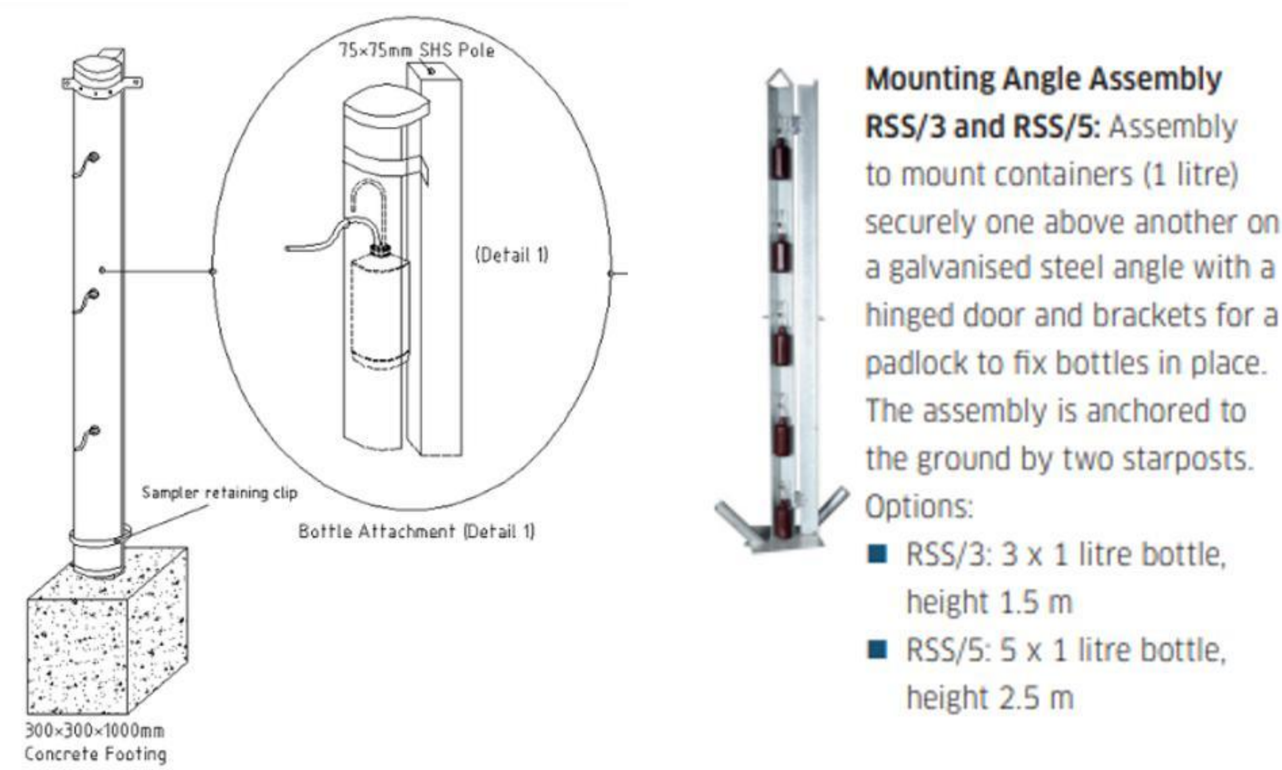


Figure 10-2 Stage Height Sampler Examples

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APPENDIX C
WMIS BORE LIST

Bore ID	Easting	Northing	Use	Date Commenced	Total Depth (m)	Screen Top (m)	Screen Bottom (m)
89332	637421	5785077	STOCK	18/03/1982	33.48	7.01	33.48
54491	635362	5794400	NOT KNOWN	31/12/1957	0	0	0
54488	635912	5795879	NOT KNOWN	31/12/1962	21.33	0	0
109265	644604	5779232	DOMESTIC,STOCK	12/03/1976	73.15	15.24	73.15
111609	634561	5787257	STOCK	14/11/1991	48	45	48
109288	637741	5786597	DOMESTIC,STOCK	18/12/1988	56.38	24.38	56.38
109287	637861	5786577	STOCK	19/05/1987	25.9	19.8	25.9
WRK977053	638701	5784227			50	0	0
109269	638759	5786002	STOCK	3/02/1977	22.49	0	0
139904	638901	5785977	STOCK,DOMESTIC	11/01/1999	79.25	57.97	76.2
109270	639867	5786803	STOCK	14/02/1977	5.79	2.43	3.65
89325	636330	5781853	STOCK,DOMESTIC	21/03/1973	21.64	14.63	21.64
141714	636536	5781257	STOCK	3/04/2000	9.4	5.44	9.4
109256	636832	5778328	NOT KNOWN	31/12/1959	0	0	0
89330	637121	5782477	STOCK	22/12/1981	24.38	6.1	24.38
109275	637189	5779841	STOCK	13/01/1981	28.95	0	0
109260	637936	5782726	STOCK	16/12/1972	12.98	4.57	12.8
109299	638386	5777983	DOMESTIC,STOCK	1/01/1988	25	0	0
109276	638461	5782098	STOCK	15/01/1981	15.24	6.1	15.24
109298	638545	5779157	STOCK	1/01/1988	25	0	0
109259	639252	5780895	STOCK	10/05/1972	27.74	25.9	26.82
109261	639260	5780190	STOCK	19/03/1973	30.48	28.95	29.56
109273	639441	5778577	DOMESTIC,STOCK	27/04/1989	83.81	10.62	83.81
122935	639471	5781197	STOCK	17/11/1993	76.2	21.33	24.38
109285	639821	5779127	STOCK	9/10/1986	30.48	4.52	30.48
109266	640233	5782266	STOCK,DOMESTIC	5/02/1976	38.1	9.14	33.52
WRK982630	636410	5792835		30/08/2007	150	0	0
141738	638921	5794997	STOCK	4/03/1999	44.19	39.58	44.19
89338	631228	5788063	DOMESTIC,STOCK	10/03/1982	16.76	12	16.76
142303	631271	5787897	DOMESTIC,STOCK	5/02/2000	35	23	35

Bore ID	Easting	Northing	Use	Date Commenced	Total Depth (m)	Screen Top (m)	Screen Bottom (m)
135473	631371	5788387	STOCK	4/03/1998	60	55	60
112669	632381	5789147	STOCK	16/12/1991	30	24	30
89341	633621	5787907	DOMESTIC,STOCK	5/01/1989	24	12	24
89336	634510	5790710	STOCK	26/07/1971	39.01	18.29	22.86
89340	635301	5789747	DOMESTIC,STOCK	13/02/1989	48	30	48
89342	635321	5789677	DOMESTIC,STOCK	12/01/1985	11	7	11
WRK986278	636837	5789829	STOCK	20/02/2009	30	0	0
89337	637697	5790995	STOCK	22/04/1973	32.3	24.99	32.3
54511	637881	5791637	STOCK	16/10/1973	18.28	12.19	18.28
66997	641341	5787627	STOCK,DOMESTIC	27/01/1989	21.3	19.2	21.3
109289	641521	5787657	DOMESTIC,STOCK	26/01/1989	24.4	22.8	24.4
109267	639546	5784488	STOCK	9/03/1976	35.35	9.14	27.42
109268	640054	5784852	STOCK	20/01/1977	27.43	3.05	24.38
109283	640910	5779892	STOCK	23/01/1986	42.67	18.28	24.38
109286	642272	5781077	STOCK	13/05/1987	63.96	46.02	63.96
109281	642622	5783227	STOCK	12/07/1982	24.38	6	24.38
109257	643276	5781286	NOT KNOWN	4/02/1960	28.04	0	0
66995	645922	5790877	STOCK	27/01/1986	21.33	18.28	21.33
109263	641813	5779220	STOCK	6/06/1974	76.06	6.1	18.29
WRK977162	643292	5779059			100	0	0
109279	644297	5778917	NOT KNOWN	31/12/1981	70.06	6.1	11.53
109280	644297	5778917	NOT KNOWN	7/01/1982	19.8	6.71	15.24
66998	644522	5793137	STOCK	6/02/1991	38.1	27.43	38.1
141867	644922	5793677	DOMESTIC,STOCK	29/12/1998	18	10	15
109274	641176	5782311	STOCK,DOMESTIC	26/06/1980	24.38	6.71	24.38
109258	641068	5783255	NOT KNOWN	31/12/1967	12.8	0	0
142232	642222	5783107	STOCK,DOMESTIC	31/03/2000	60.96	59.13	60.96
110107	634106	5787752	OBSERVATION, SOBN	6/11/1991	70	58	70
110108	634112	5787751	OBSERVATION, SOBN	13/11/1991	14	0	0

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