APPENDIX 11

Water Resources Impact Assessment

WATTLE CREEK BATTERY ENERGY STORAGE SYSTEM PROJECT

Water Resources Impact Assessment

SSD-63345458

Spark Renewables Pty Ltd

17 March 2025

2066-02-E2

DETAILS

Report Title	WATTLE CREEK BATTERY ENERGY STORAGE SYSTEM PROJECT, Water Resources Impact Assessment
	Wattle Creek Battery Energy Storage System - SSD-63345458
Client	Spark Renewables Pty Ltd

THIS REVISION

Report Number	2066-02-E2
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NOTE ON FLOOD FREQUENCY TERMINOLOGY

A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An Annual Exceedance Probability (AEP) is attributed to the estimate. The frequency of flood events is expressed as an AEP, for example, a flood magnitude having 10% AEP, there is a 10% probability (or 1 in 10 chance) that there would be floods of that magnitude or greater each year. While a related concept Annual Recurrence Interval (ARI) is now outmoded due to the confusion it generates. A flood with a 10 year ARI, refers to floods that equal or of greater magnitude once in ten years on average. For very frequent events, the concept is referred to as Exceedances per Year (EY). The approximate correspondence between terminology, in particular the relationship between AEP and ARI applies to this study (ARR, 2019). The frequency of flood events can be grouped into five broad descriptive categories, as shown below.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

Source: Australian Rainfall and Runoff Guidelines (Ball et al, 2019)

In this report, the frequency of flood events is referred to in terms of AEP for floods categorised as very rare, for example 1%, 0.2% or 0.5% AEP. These floods were calculated using the historical climate records. Over recent years, the climate record is showing the influence of non-stationarity. Evidence now exists that the magnitude of floods, i.e. those based on the historical record, are becoming more frequent. It is considered that this will continue as a warming climate will lead to more moisture being held in the atmosphere. For planning purposes, it is prudent to consider a 0.5% AEP based on the historical record as a proxy of the 1% AEP flood event based on future climate depths.

The 1 in 2000 (0.05%) AEP event is considered the limit of credible extrapolation of the historical record. These floods are categorised as extreme with the limit being the concept of the Probable Maximum Flood (PMF). The PMF occurs as a result of the Probable Maximum Precipitation (PMP) and The PMP is the result of the maximum atmospheric carrying capacity of moisture and the efficiency of the storm mechanism to produce rainfall in a region. A PMF flood is not shown above as it is extreme and beyond the statistical limit. A PMF flood cannot have an AEP assigned to its magnitude as it applies the most conservative assumptions related to temporal patterns, losses and so on. Note also, that the PMF is not the same as the PMP Flood.

Very rare design events floods are useful for the purposes of planning as there is a remote chance that it may occur. Extreme floods are considered so far beyond the credible limit of record and contain so much inherent uncertainty that they exist only to provide a theoretical limit.

The approach to estimating an actual (or historic) flood from a particular rainfall event is quite different in concept and is of a deterministic nature. All causes and effects are directly related to the specific event under consideration. The actual antecedent conditions prevailing at the time of occurrence of the rain are directly reflected in the resulting flood and must be allowed for in its estimation. No real information on the probability of the historic flood can be gained from consideration of a single actual flood event.

ABBREVIATIONS AND DEFINITIONS

Term/ Abbreviation	Definition
ABS	Australian Bureau of Statistics
AEP (Annual Exceedance Probability)	Annual Exceedance Probability. The change of a flood of a given or large size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding.
ADWG	Australian Drinking Water Guidelines.
AHD (mAHD)	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARR	Australian Rainfall and Runoff. Guidelines prepared by Engineers Australia for the estimation of design floods. The latest being ARR2019 (Ball et al, 2019)
ASC	Australian Soil Classification (Isbell, R. F.,2021)
BESS	Battery Energy Storage System
BFEMOP	Bush Fire Emergency Management and Operations Plan.
BGL (mBGL)	Below Ground Level. A relative datum used in bore holes to measure depth to groundwater.
BSAL	Biophysical Strategic Agricultural Land
CEMP	Construction Environment Management Plan
CSWMP	Construction Soil and Water Management Plan
DEM	Digital Elevation Model
Development Footprint	This is the disturbance area required for the Project. Quantification of the Project impacts are to be based on the disturbance footprint as a realistic estimate of the disturbance required to construct the Project.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
EIS	Environmental Impact Statement
EP&A Act	*NSW Environmental Planning and Assessment Act* 1979
ESCP	Erosion Sediment Control Plan
EV	Environmental Value
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 local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Term/ Abbreviation	Definition
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below: Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
GDE	Groundwater Dependent Ecosystem.
GHG	Greenhouse Gas
GW	Gigawatts
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
kL	Kilolitre, one thousand litres.
km	Kilometres.
kV	Kilovolt.
LEP	Local Environmental Plan
LGA	Local Government Area
LSC	Land and Soil Capability.
mAHD	Metres Australian Height Datum (AHD).
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or “cumecs”. A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
ML	Megalitre, one million litres.
MNES	Matters of Nationale Environmental Significance.
MW	Megawatt.

Term/ Abbreviation	Definition
PMF (Probable maximum flood)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The probable maximum flood defines the extent of flood prone land, that is, the floodplain.
PMP (Probable maximum precipitation)	The greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Project Area	The Project Area encompasses all land within and including the Project Boundary.
Project Boundary	The outer boundary of the Project Area. The Project Boundary is the maximum spatial extent of the potential land access defined by the boundaries of the host landholder properties (i.e. all agreed lots owned by host landholders)
REZ	Renewable Energy Zone. The equivalent of modern-day power stations, combing new renewable energy infrastructure, including generators (such as solar and wind farms), storage (such as batteries and pumped hydro) and then high-voltage transmission infrastructure
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual, it is the likelihood of consequences arising from the interaction of floods, communities, and the environment.
Runoff	The amount of rainfall which ends up as a streamflow, also known as rainfall excess.
RUSLE	Revised Universal Soil Loss Equation.
Scour	Erosion by mechanical action of water, typically of soil.
SEARs	Secretary's Environmental Assessment Requirements
SSD	State Significant Development
SSP (Shared Socioeconomic Pathways)	SSPs are climate change scenarios of projected socioeconomic global changes up to 2100 as defined in the IPCC Sixth Assessment Report on climate change in 2021. In terms of quantitative elements, they provide data accompanying the scenarios on national population, urbanization and GDP (per capita). The five scenarios are: SSP1: Sustainability ("Taking the Green Road") SSP2: "Middle of the Road" SSP3: Regional Rivalry ("A Rocky Road") SSP4: Inequality ("A Road Divided") SSP5: Fossil-fuelled Development ("Taking the Highway").
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
Umwelt	Umwelt (Australia) Pty Ltd
WM Act	*NSW Water Management Act* 2000
WRIA	Water Resources Impact Assessment
WSP	Water Sharing Plan

1 INTRODUCTION

1.1 OVERVIEW

Spark Renewables Australia Pty Ltd proposes to develop the Wattle Creek Battery Energy Storage System (BESS) Project (The Project) on the Arthursleigh Farm (Lot 3 of DP 1120270). The Project Area is located in the Southern Highlands Region of New South Wales, approximately 80 kilometres (km) west of Wollongong and 15 km northwest of Marulan. The Project includes a standalone BESS with 350 MW capacity (AC or DC coupled) and project-related infrastructure.

1.2 PROJECT CONTEXT

WRM Water & Environment Pty Ltd (WRM) was engaged to prepare this WRIA to support the Environmental Impact Statement (EIS) for the Project.

The Project is a State Significant Development (SSD) as defined under State Environmental Planning Policy (Planning Systems) 2021 (Planning Systems SEPP) and will require development consent under Part 4 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). The Project's conceptual layout is provided in Figure 1-2.

The Project Area is approximately 6,350 hectares (ha) located within the Upper Lachlan Shire and Goulburn Mulwaree Local Government Areas (LGAs). The Project Area is located 35 km to the northeast of Goulburn at 34.59S, 150.04E on the northern side of the Wollondilly River. The address of the Project Area is 1001 Canyonleigh Road, Brayton, 15 km north-west of Marulan, refer to Figure 1-1.

The Project comprises the installation, operation, maintenance and decommissioning of a large-scale BESS, supported by associated infrastructure. The Project will have a capacity of up to approximately 350 MW (AC or DC coupled) and will have provision for up to four (4) hours of storage (1600 MWh), with the aim of providing both storage as well as firming capacity to the NEM and assisting in grid stability by providing frequency control ancillary services. The design of the BESS will allow for the storage and exportation of renewable energy within the network so that it can be used during times of peak demand.

The conceptual project layout represents a development footprint of approximately 75 ha, including associated ancillary infrastructure (i.e. substations, the operations and maintenance facility, test bed and both transmission line corridors for optionality). The conceptual project layout is shown on Figure 1-2 with the indicative project components outlined in Table 1.1.

The key components of the Project include:

- Batteries – most likely a lithium-ion technology.
- Inverters – bi-directional inverters to convert DC current to AC current (when exporting electricity) and vice versa (when importing electricity).
- Transformers – skid-mounted transformers will be installed adjacent to each inverter to step up the voltage to the internal reticulation voltage of the plant.
- On-site collector substation to connect to the electricity transmission network via Marulan Substation. An 80m communication mast is also included at the substation location.
- An overhead transmission line options are being investigated to connect the Project to the transmission network, to allow for optionality during the assessment process and greater flexibility in the connection design.
- Internal electrical reticulation network, i.e., a combination of underground cables and overhead powerlines.

- Operation and maintenance (O&M) facility – including a site office, O&M buildings, amenities, equipment sheds, storage, and parking areas.
- Other associated permanent infrastructure including hardstands, new access tracks, upgrades to existing access tracks, minor upgrade to the existing access point from Canyonleigh Road, operation and maintenance buildings, static water tanks.
- A research Test-Bed Facility – comprising of a 1.4 ha hard standing area, demountable buildings, security fencing, parking, 200kVa power supply and 100kVA dummy load (simulated electrical load for testing purposes).
- Temporary construction facilities including:
  - Construction compound/s with site office building(s).
  - On-site concrete batching plants for use during the construction phase.
  - Potential construction material areas such as borrow pits, quarry and rock crushing facilities.
  - Laydown areas used for installation and storage of Project components.

Table 1.1 Indicative BESS Components and Approximate Dimensions/Capacity (SSD-63345458)

Project component(s) / infrastructure	Approximate dimensions and/or capacity	Quantity
BESS Modules		
Maximum height	3 m	-
Minimum height	1.5 m	
Containers	Approximately 3.85 MWh per container (subject to final BESS provider selection)	415
Ancillary Infrastructure		
Collector (on-site) substation	6 ha	1
High voltage Transformers	300 megavolt amperes (MVA) high voltage transformers within substation (subject to detailed design)	3
Inverters and medium voltage transformers	4200 kVA inverters, with one medium voltage per transformer (subject to final inverter selection)	248
Overhead transmission lines (high to low voltage)	Internal overhead cables i.e. high voltage transmission lines from the BESS to the grid connection point.	n/a
Underground cables (medium to low voltage)	2 km	n/a
Internal access tracks	Approximately 5 km of internal roads	n/a
Primary site access point(s)	Canyonleigh Road is subject to detailed design.	2
Operations and maintenance facility	100 m x 80 m	1
Temporary Construction Facilities		
Construction compound, including: • construction laydown areas for equipment and supplies, • stockpile and material storage areas • concrete batching plants, as required • construction compounds, site office, etc.	~ 2 ha	Up to 3

1.3 KEY PROJECT FEATURES

The Project Area is much larger than the anticipated development footprint ~75 ha and involves the construction, operation, maintenance and decommissioning of:

- Construction of a Battery Energy Storage System that will have an estimated capacity of 350 MW / 1400 MWh,
- Ancillary infrastructure relating to frequency control and grid stability
- Connection to existing transmission infrastructure.

The project is expected to operate for up to 40 years. After its operational life, it would either be decommissioned (by removing all infrastructure and returning the site to its existing land capability) or repurposed with new equipment, subject to technical feasibility and planning consents.

The conceptual layout for the Project has been designed to avoid impacts on areas of high biodiversity value and minimise impacts to proximal landholders regarding noise and visibility, surface water resources (including flooding) and cultural heritage constraints.

1.3.1 Development Footprint

Within the Project Area, a development footprint has been determined which includes all Project elements and temporary disturbance areas. The development footprint within the Project Area has been established in consideration of environmental, social and engineering constraints in the immediate vicinity of the Project Area.

The Project Area is situated in a region with low population density and a limited number of nearby rural residences. The Project Area and surrounds was historically cleared for agricultural use and is generally homogenous agricultural land. The development footprint is primarily used for grazing livestock on native pastures, with supplementary cropping. Extensive clearing for agriculture has significantly modified the original vegetation. Currently, sheep, cattle, and some horses graze the development footprint, with limited crop cultivation. The Project is compatible with existing pastoral land uses, with minimal impact to current agricultural activities.

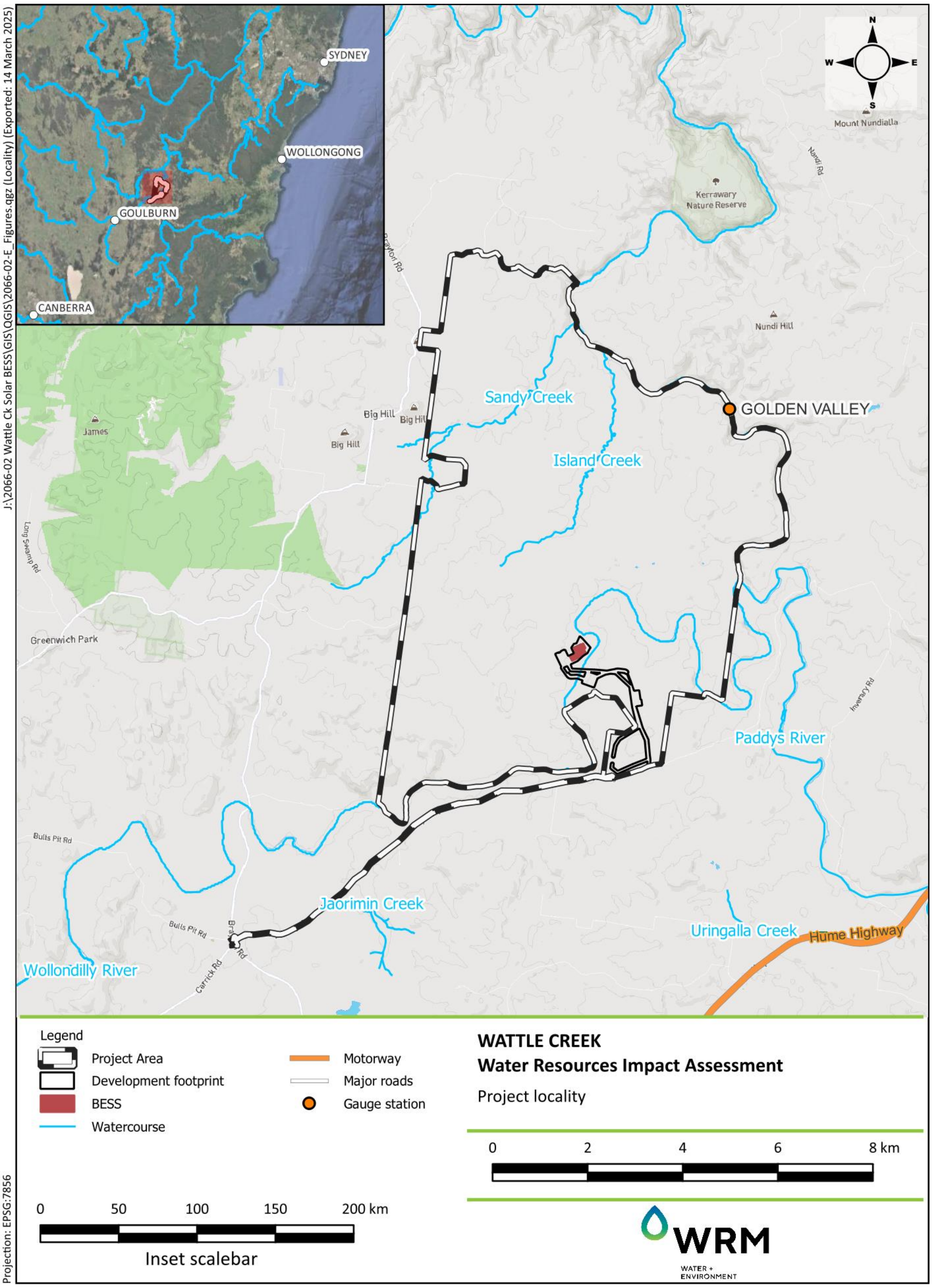

Figure 1-1 Locality of Project Area

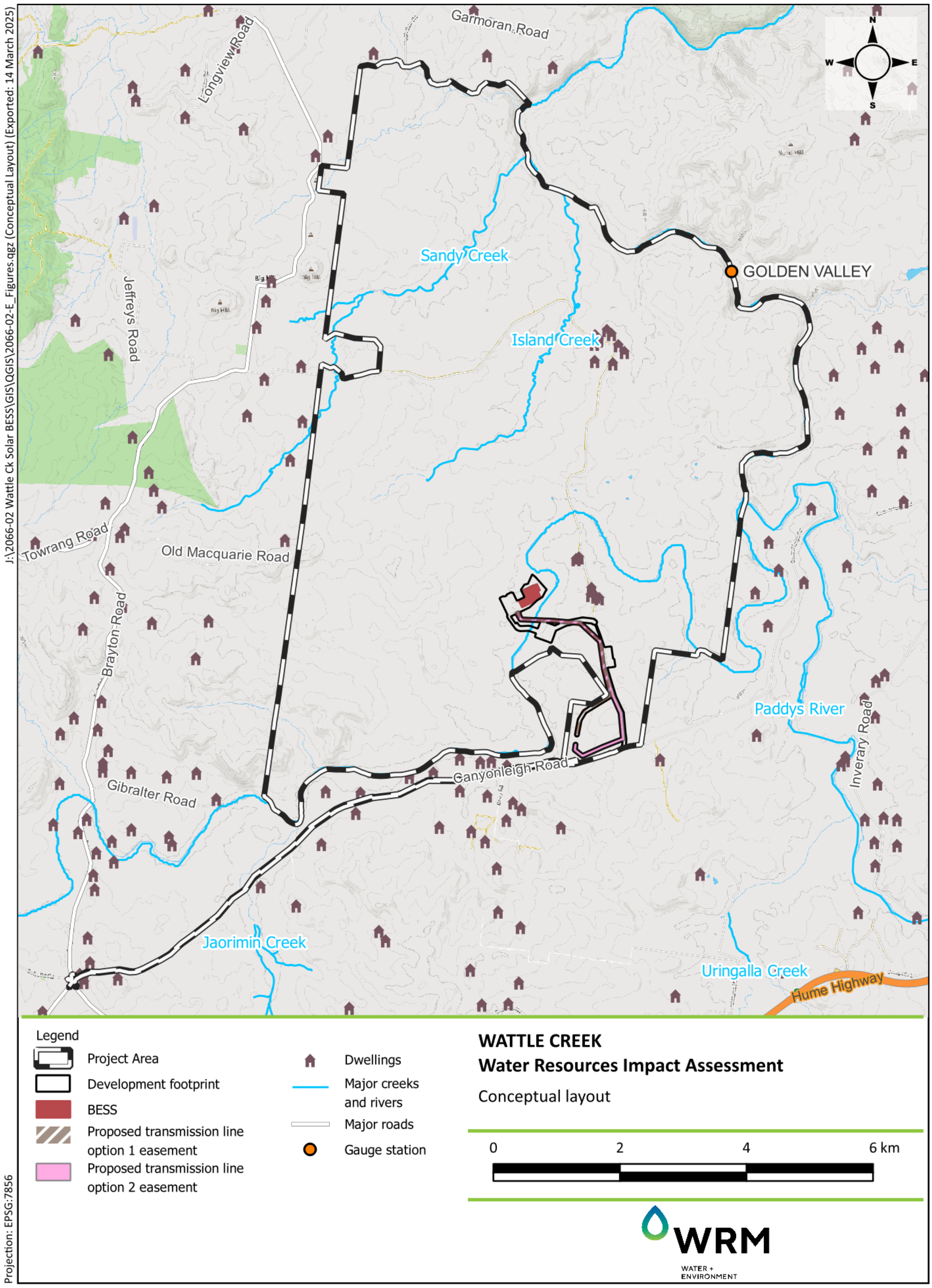

Figure 1-2 Conceptual Layout

1.4 PURPOSE AND SCOPE

This WRIA was prepared by WRM Water & Environment Pty Ltd (WRM) in accordance with the Secretary's Environmental Assessment Requirements (SEARs) (Application Number SSD-63345458, issued on 22 December 2023). The requirements of the SEARs, as they relate to water resources, are presented in Table 1.2.

The WRIA provides an assessment of the potential impacts of the Project on the water resources in the vicinity of the Project Area. The assessment considers surface water, groundwater, water quality and hydrology impacts associated with the construction, operation and decommissioning of the Project and includes the following scope:

- Assessment of the potential impacts on:
  - flooding for the 10%, 1%, 0.5%, 0.2% Annual Exceedance Probability (AEP) events and the Probable Maximum Flood (PMF) for the current climate;
  - future 1% AEP flood risk under a changing climate projected over 30 years depending on the actual emissions trajectory is likely to be between the bookends of:
    - 0.5% AEP current climate as a proxy for SSP1: very-low emissions
    - 0.2% AEP current climate as a proxy for SSP5: high emissions
  - Probable Maximum Flood (PMF), which was modelled using the Probable Maximum Precipitation (PMP) depths to determine the extreme flood event;
  - erosion and sedimentation;
  - surface water and groundwater quality; and
  - water users and supply;
- Confirming the environmental values and water quality objectives associated with surface water resources;
- Describing appropriate mitigation measures to manage the potential impacts.

The SEARs for the Project identify key issues and reference guidelines that must be addressed in the EIS. Table 1.2 outlines where the specific SEARs requirements for water resources are addressed in this report. Appendix A summarises Agency Advice appended to the SEARs and outlines where this advice has been addressed in this Report.

A meeting was held on 11 September 2024 with WaterNSW, Spark, Umwelt and WRM to discuss preliminary findings of the Water Quality assessment. Further MUSIC modelling in line with the WaterNSW's NorBE requirements was undertaken.

Table 1.2 SEARs issued for Wattle Creek BESS (SSD-63345458)

Planning Secretary's Environmental Assessment Requirements Key Issues - Water:	Location
A detailed and consolidated site water balance and an assessment of the likely impacts of the development (including flooding) on surrounding watercourses (including their Strahler Stream Order) and groundwater resources and measures proposed to monitor, reduce and mitigate these impacts including water management issues.	Section 4
Details of water requirements and supply arrangements for construction and operation.	Sections 4 to 6
A description of the erosion and sediment control measures that would be implemented to mitigate any impacts in accordance with *Managing Urban Stormwater: Soils & Construction* (Landcom 2004).	Sections 4 and 7
Assessing the impacts of the development, including any changes to flood risk and overland flows on-site or off-site, and detail design solutions and operational procedures to mitigate flood risk where required.	Sections 6 to 7
Where the project involves works within 40 metres of any river, lake or wetlands (collectively waterfront land), identify likely impacts to the waterfront land, and how the activities are to be designed and implemented in accordance with the DPI Guidelines for Controlled Activities on Waterfront Land (2018) and (if necessary) Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (DPI 2003), and Policy & Guidelines for Fish Habitat Conservation & Management (DPE, 2013).	Sections 5 to 7
An assessment of the potential impacts of the development on the Sydney drinking water catchment, including consideration of Water NSW's current recommended practices and standards, a Water Cycle Management Study, stormwater quality modelling (MUSIC), and whether the development can be constructed and operated to have a neutral or beneficial effect on water quality consistent with the provisions of State Environmental Planning Policy (Biodiversity and Conservation) 2021.	Section 5 and 7

1.5 REPORT STRUCTURE

This report is structured as follows:

- Section 2 provides details of the regulatory framework
- Section 3 provides details of the existing surface water and groundwater environment
- Section 4 describes water management and demand for the Project
- Section 5 describes the MUSIC modelling methodology and results
- Section 6 describes the methodology and results of the flood assessment
- Section 7 presents an assessment of the potential impacts of the Project
- Section 8 outlines the proposed management and mitigation measures
- Section 9 presents the conclusions of the assessment
- Section 10 is a list of references
- Appendix A outlines and addresses Agency Advice on the Project SEARs
- Appendix B contains A3 flood mapping
- Appendix C provides soil data for the Project Area.

2 REGULATORY FRAMEWORK

2.1 OVERVIEW

This section describes the regulatory framework (legislations, policies and standards) at Commonwealth and State level that would apply to surface water management at this Project[1]:

- *Water Management Act* 2000 (WM Act) (NSW Government, 2000).
- *Water Act* 1912 (Water Act) (NSW Government, 1912).
- Flooding:
  - Australian Rainfall and Runoff Guidelines 2019 (Commonwealth of Australia (Geoscience Australia), 2019)
  - Floodplain Risk Management Manual and Guideline LU01[2] (NSW Government 2023)
- Surface Water:
  - NSW Government Water Quality and River Flow Objectives at http://www.environment.nsw.gov.au/ieo/
  - Australian Guidelines for Fresh and Marine Water Quality (Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia, 2018) (ANZG, 2018)
  - Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004) and Volume 2 (Department of Environment and Climate Change, 2008)
  - Storing and Handling Liquids: Environmental Protection – Participants Handbook (Department of Environment and Climate Change, 2007)
- Policy & Guidelines for Fish Habitat Conservation & Management (Department of Primary Industries, 2013).
- Guidelines for Controlled Activities on Waterfront Land:
  - Guidelines for riparian corridors on waterfront land (Department of Planning and Environment (DPE) Water, 2018)
  - Guidelines for instream works on waterfront land (DPE Water, 2022)
  - Guidelines for vegetation management plans on waterfront land (DPE Water, 2022)
  - Guidelines for watercourse crossings on waterfront land (DPE Water, 2022)
  - Controlled Activities on Waterfront Land: Controlled activity exemptions on waterfront land (DPE Water, 2022)
  - ARRB Unsealed Roads Best Practice Guide Edition 2 (ARRB, 2020)
  - Water Sensitive Design Guide for Rural Residential Subdivisions (WaterNSW, Feb 2023)

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[1] https://www.planning.nsw.gov.au/Policy-and-Legislation/Planningreforms/Rapid-Assessment-Framework/Improving-assessment-guidance

https://www.planningportal.nsw.gov.au/major-projects/assessment/policiesand-guidelines

http://www.environment.gov.au/epbc/publications#assessments

[2] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Water/Floodplains/flood-risk-management-impact-risk-assessment-230234.pdf

- Using MUSIC in the Sydney Drinking Water Catchment (WaterNSW, 2023)

- Groundwater:
  - NSW State Groundwater Policy Framework Document and component policies (Department of Planning, Industry and Environment)
  - *NSW Aquifer Interference Policy* 2012 (Department of Primary Industries Office of Water)
  - National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC).

2.2 *Environment Protection and Biodiversity Conservation Act* 1999

The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) outlines the requirements relating to the management and protection of matters of national environmental significance (MNES).

'Controlled actions' are those actions that the Minister decides have, will have or are likely to have a significant impact on one or more protected matters and therefore require assessment and approval under the Act. The protected matters upon which the action may have a significant impact are called the 'controlling provisions' or 'triggers' for assessment and approval under the Act, for that controlled action.

2.3 *Water Management Act* 2000

The *Water Management Act 2000* (WM Act) is the primary legislation for the management of water in the Project Area. The WM Act contains provisions for the licensing of water access and use. Groundwater quality protection is also achieved through consideration of both the objects and principles of the WM Act.

In general, the WM Act governs the issue of water access licences (WALs) and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where Water Sharing Plans (WSPs) exist. Additional groundwater sources and WSPs underly the upper-most groundwater source and WSP. However, these deeper groundwater sources and WSPs are not applicable as Project works are not proposed at depths of greater than a few metres below ground level and are unlikely to influence these deeper groundwater systems.

3 EXISTING ENVIRONMENT (SURFACE WATER AND GROUNDWATER)

3.1 CATCHMENT CHARACTERISTICS

Located in the NSW Southern Tablelands region, the Project Area is located in the headwaters of the Hawkesbury-Nepean catchment. The topography of the Project Area is undulating with elevations ranging from the riverbank elevation of 605 up to 720 metres Australian Height Datum (mAHD) see Figure 3-1. On a local scale, the Project Area covers an area of 63 km^2 with several mapped creeks traversing through the Project Area which ultimately drain to the Wollondilly River. The Wollondilly River's catchment to the Project Area is 2106 km^2. The Wollondilly River ultimately drains into Lake Burragorang (Warragamba Dam), which is part of the Sydney drinking water catchment.

3.1.1 Topography and drainage

The local topography of the Project Area based on LiDAR survey is shown in Figure 3-1. Topographic data at a two metre and five metre grid resolution was obtained from ELVIS database. The extent of the topographic data is shown in Figure 3-2. The development footprint's landform is considered stable and free draining landform. The majority of surface cover was highly disturbed in the past by land clearing for agriculture. Stands of native trees exist in the development footprint but they are sporadic located. Minor drainage features are present throughout with small farm dams and water troughs present for livestock.

The drainage network in the vicinity of the Project Area is shown in Figure 3-12. The majority of the Project Area drains in an easterly direction. Sandy and Island Creeks flow through the Project Area from the south-west to the north-east and into the Wollondilly River. Several other unnamed perennial creeks and drainage lines traverse the Project Area

The regional watercourses that drain to the Project Area are shown in Figure 6-1. The Project Area is adjacent to the confluence of the Wollondilly River with four catchments flowing from the east. The largest tributary is Paddys River, immediately to the east of the Project Area. Long Swamp and Uringalla Creeks join with Paddys River slightly upstream of the confluence with Wollondilly River. Jaorimin Creek flows from the south into the Wollondilly River near the model domain.

3.1.2 Regional flood history

Flooding at Goulburn due to the Wollondilly and Mulwaree Rivers has been documented since European settlement. Flooding is infrequent and no long-term gauge is available in the region on either river. However, historic newspaper articles indicate that major flood events, known to have caused flooding of properties at Goulburn, occurred in April 1870, July 1900, June 1925, June 1950, October 1959, November 1961 and August 1974. More recently, significant flooding in Goulburn has occurred in August 1990, December 2010, March 2012 and June 2012. Flooding within the Project Area is not recorded and no anecdotal information, such as debris marks, were available for this study.

Flood studies have been undertaken for the Goulburn Local Government Area (LGA) in Wollondilly and Mulwaree Rivers (WMA 2016, GRC 2022). However, the extent of the existing flood mapping for these studies only extends to a location about eight kilometres upstream of the Project Area. Table 3.1 summarises the flood studies nearby to the Project Area. Existing flood mapping for the Goulburn Mulwaree Local Government Area LGA does not extend to the Project Area.

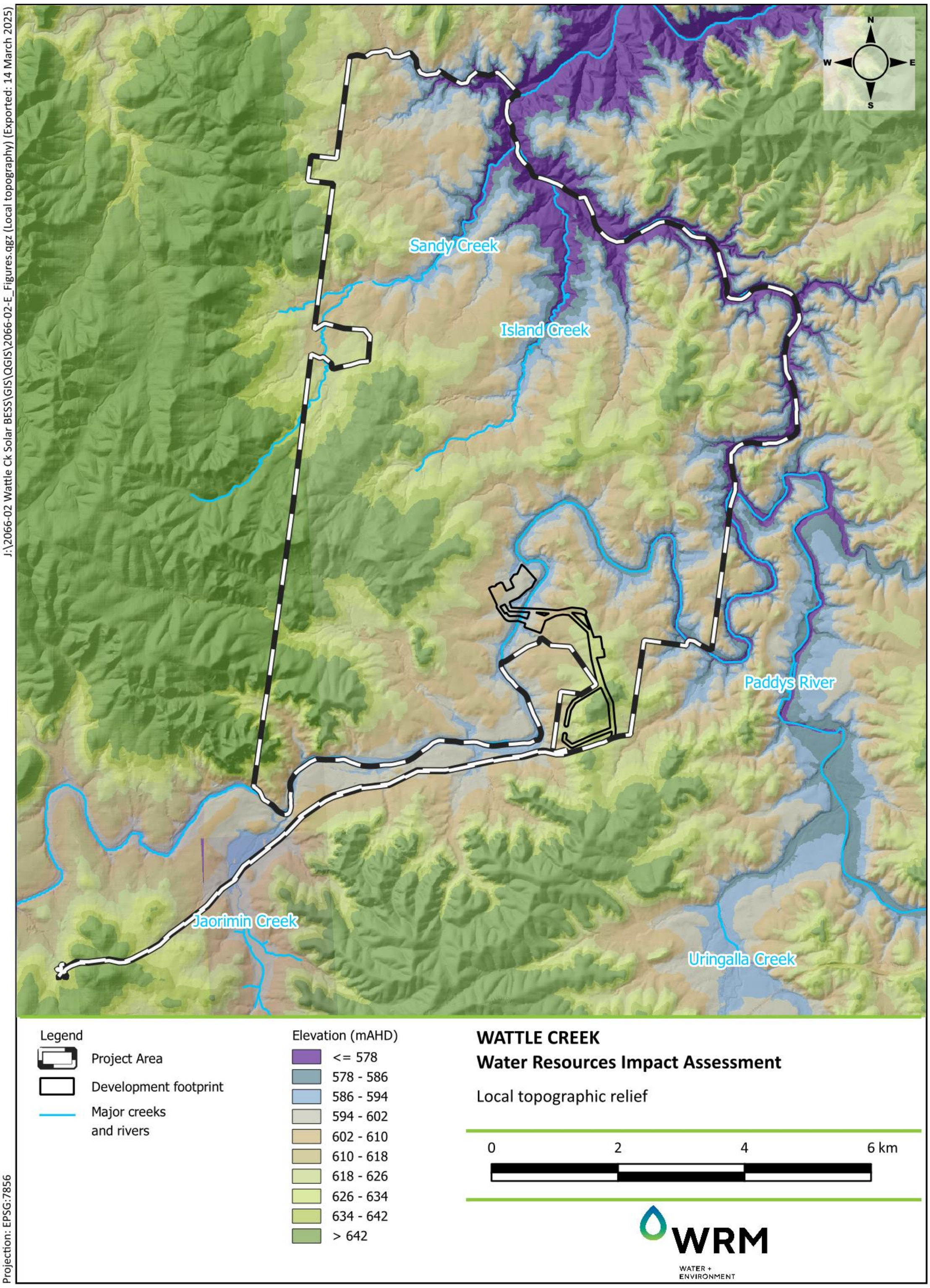

Figure 3-1 Local topography and drainage features

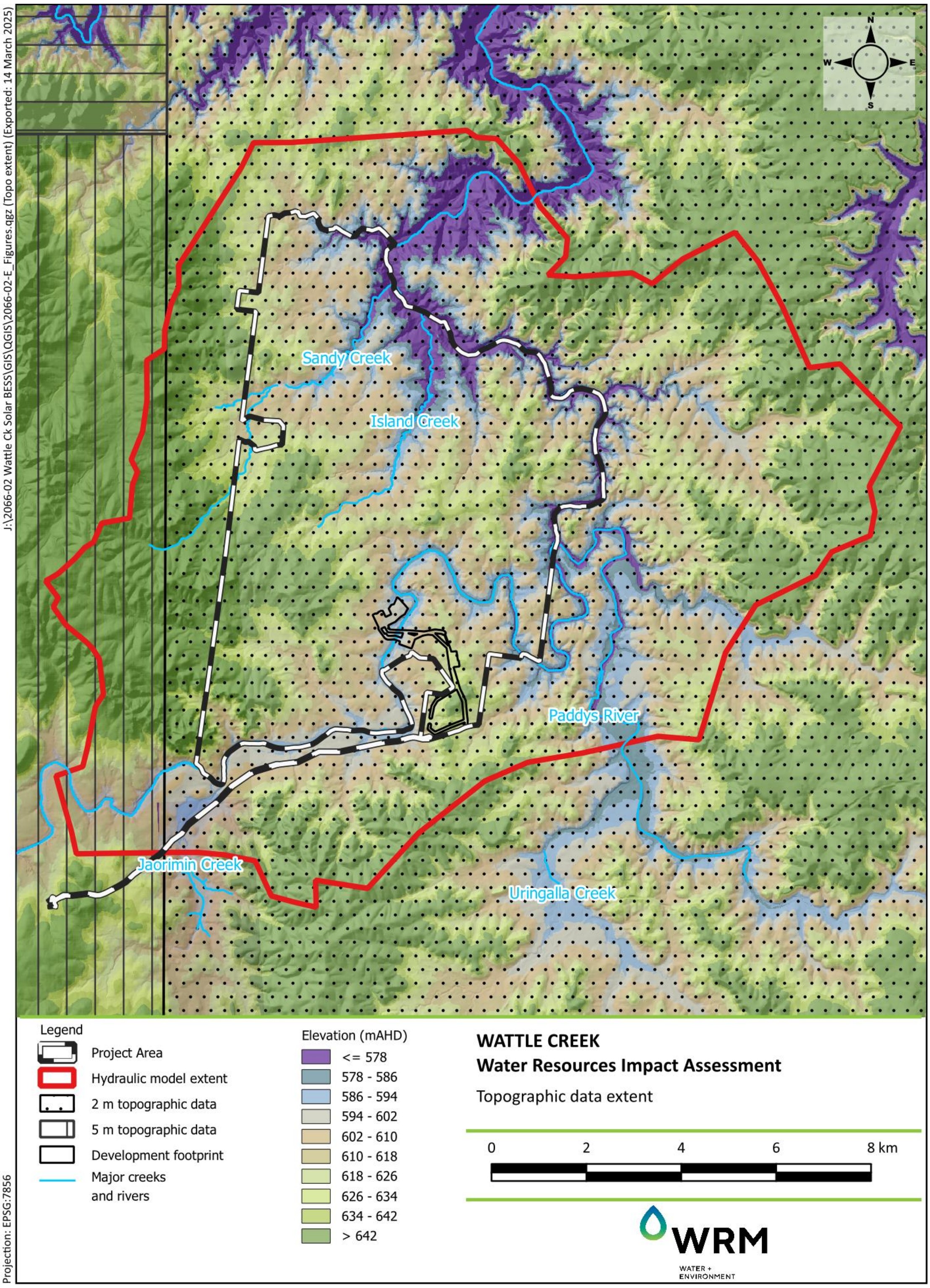

Figure 3-2 Available topographic datasets

Table 3.1 Available nearby flood studies

Author	Report Title
WRM, 2024 Flood Study	Wattle Creek Preliminary
GRC Hydro, 2022 Management Study and Plan	Goulburn Floodplain Risk
WMAwater, 2016 Rivers Flood Study Final Report	Wollondilly and Mulwaree

3.1.3 Regional landform

The Project Area is situated west of the Great Dividing Range within the Southeastern Highlands Bioregion, a region characterised by high elevations and cleared grazing land. This region is also part of the Lachlan Fold Belt. Lachlan Fold Belt is characterised by widespread sandstones and shales.

The region's underlying geology is diverse as shown in Figure 3-3 and Figure 3-4 . Ordovician slates dominate the region, while the Project Area specifically is underlain by Devonian granites and Ordovician slates. Igneous rocks, including volcanic rock, granite, and diorite, are also present. The ancient Shoalhaven River system has deposited fluvial sands and gravels in the Braidwood area. Common rock types in the region include siltstones, quartzites, rhyolites, tuffs, and alluvium.

A basalt outcrop in the southwestern part of the Project Area suggests potential prehistoric human activity, as this rock type is often used for toolmaking. Permian sandstone, siltstone, and mudstone are also found in this area. The Bindook Porphyry rock unit, composed of porphyritic rocks containing quartz and feldspar, is another geological feature within the Project Area.

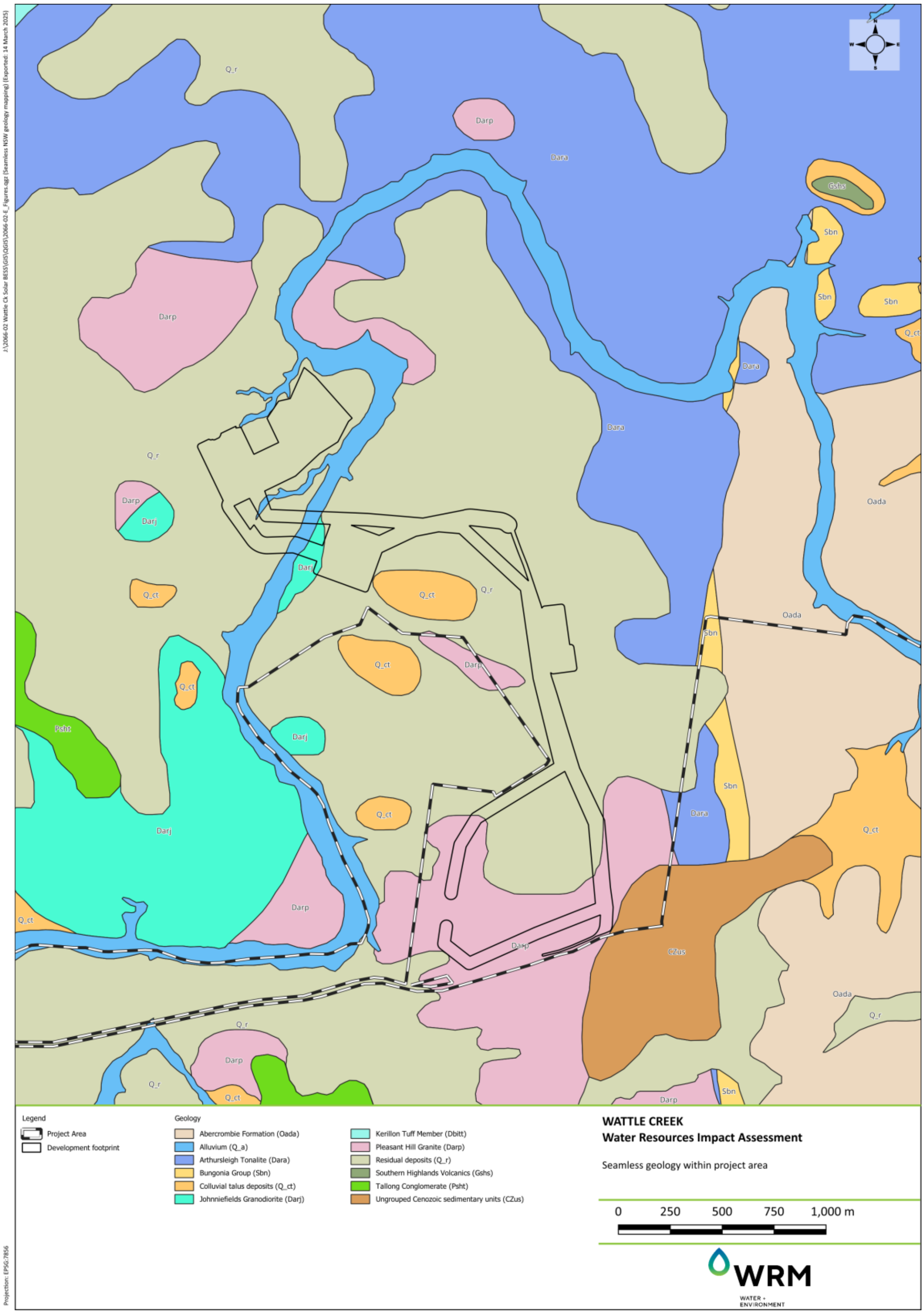

Figure 3-3 Seamless NSW geology mapping

Source: NSW 2024a

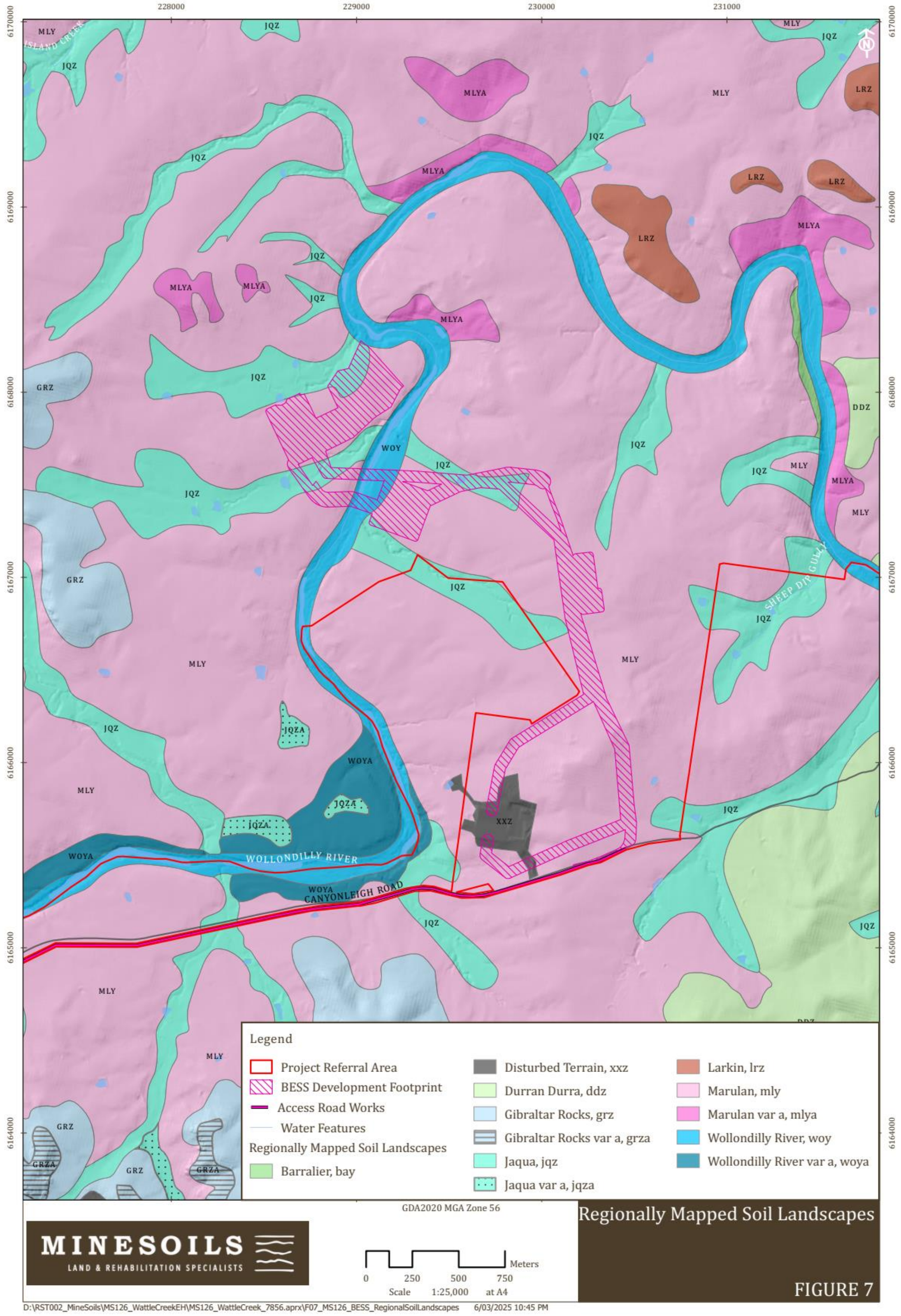

Figure 3-4 Soil Landscapes

3.1.4 Land use

The Project Area is zoned as RU2 Rural Landscape within the Upper Lachlan Local Environment Plan (LEP) 2010. The majority of the land that surrounds the Project Area is zoned as RU1 Primary Production and RU2 Rural Landscape. The Project Area is currently used for various agricultural activities including grazing and agricultural research by the university of Sydney. The Project Area falls within both Category 1 (exempt land) and Category 2 (regulated land) under the NSW DPE Land Management Framework. Category 1 land is historically cleared and has minimal ecological value, allowing for greater flexibility in development.

A review of the NSW Landuse 2017 v1.5, published 2023 mapping from the DPIE SEED Portal identified a range of land uses at and surrounding the Project Area. Land uses within the Project Area are listed as:

- Grazing modified pastures
- Grazing native vegetation
- Residential and farm infrastructure
- Plantation forests
- Managed resource protection
- Utilities
- Transport and communication
- Reservoir/dam

Figure 3-5 Landform of Project Area grazing and farm dams

Photograph credit: Minesoils, 2024

Figure 3-6 Landform of Project Area broadacre cropping

Photograph credit: Minesoils, 2024

Figure 3-7 Landform of Project Area showing gully erosion

Photograph credit: Minesoils, 2024

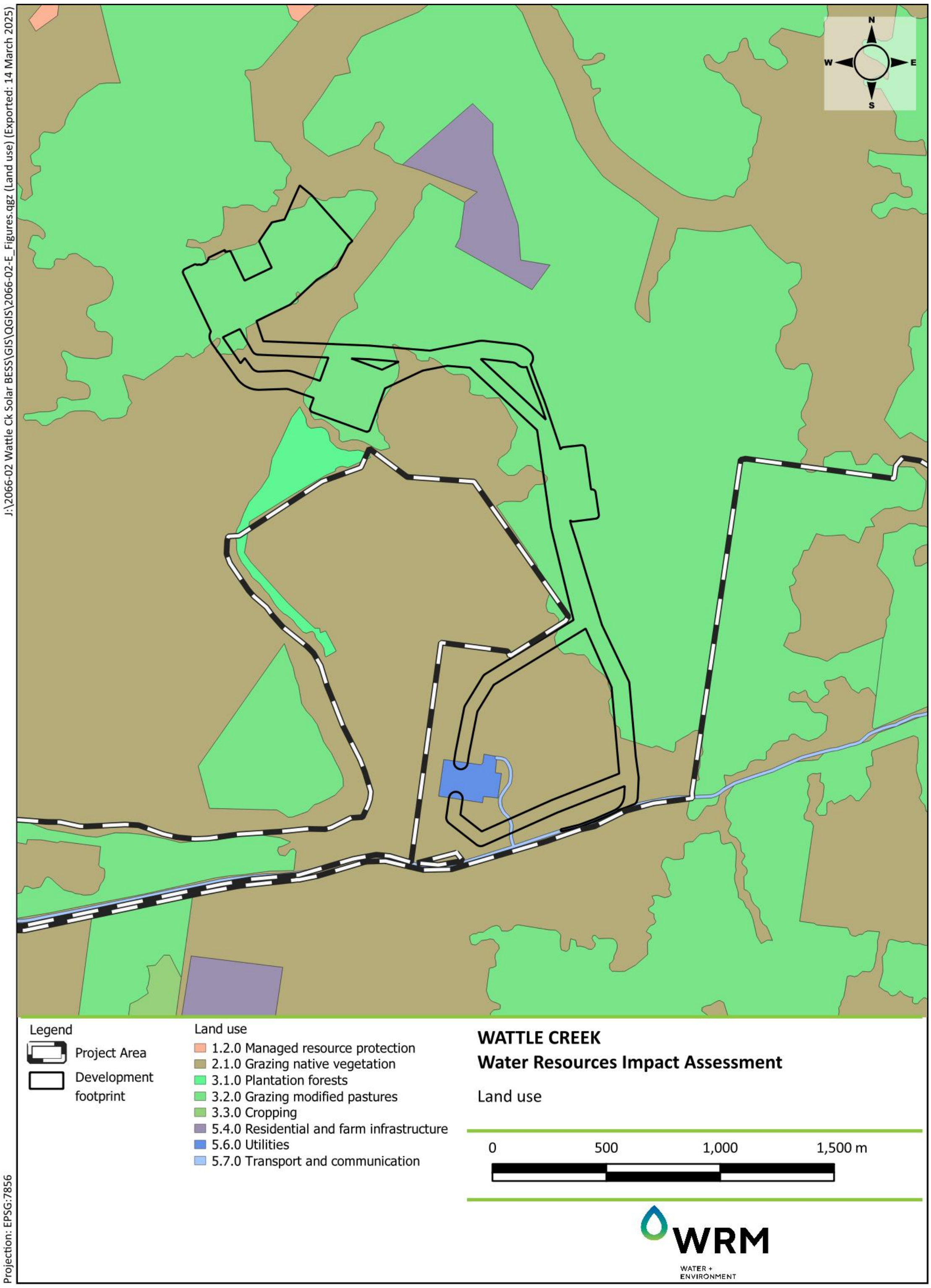

Figure 3-8 **Land use**

3.2 CLIMATE

The nearest open Bureau of Meteorology (BOM) daily rainfall gauge to the Project Area is at Marulan (George St gauge 070063[3]), 20 km south of the Project Area. Given the proximity of the gauge to the Project Area, the recorded data is considered representative of the local region rainfall patterns. The period of record for the observation covers 112 years from 1894 to 1923 and then 1941 until 2024.

Climate data was also obtained from the SILO database of historical climate records for Australia hosted by the Queensland Government's Department of Environment and Science (DES). This service interpolates raw rainfall and evaporation records obtained from the Bureau of Meteorology (BOM) to provide a spatially and temporally complete climate dataset. Climate data was obtained for SILO grid point -34.56 Latitude and 150.05 Longitude which is the grid point closest to the Project Area between 01/01/1889 to 31/01/2024.

Table 3.2 and Figure 3-9 present the annual rainfall and evaporation statistics based on the Project Area climate data sourced for SILO grid point. Table 3.3 and Figure 3-10 present the monthly rainfall and evaporation statistics based on data for the SILO grid point. The median annual rainfall is 675 millimetres and median evaporation is 1327 mm.

Utilising the climate database, the average total rainfall for each calendar month from 1889 to 2024 was calculated and is summarised in Table 3.3. Figure 3-10 shows there is only a moderate level of seasonality to rainfall within the Project Area, and that rainfall is typically low in most months. Lowest average rainfall is recorded in 258.7 mm Highest monthly rainfall is recorded in XXX.

Table 3.2 Annual Rainfall and Evaporation (mm) for Project Area, (source: SILO, 2024)

Statistic	Rainfall [a]	Evaporation (Class A Pan) [a]
10th percentile	472	1196
50th percentile	675	1327
90th percentile	986	1363

[a] Data source: https://www.longpaddock.qld.gov.au/silo/

[3]Marulan Daily Rainfall
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=070063

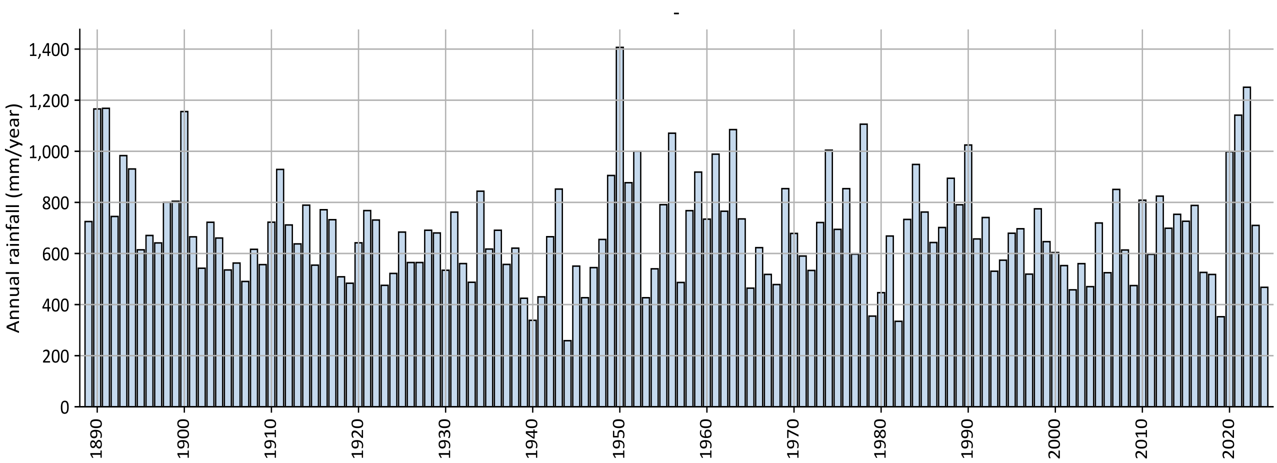

Figure 3-9 Annual rainfall totals at Project Area

Source: SILO, 2024

Table 3.3 Monthly climate statistics (mm), 1890 to 2024

Month	Evaporation (Class A Pan)	Rainfall
October	130.9	54.0
November	151.6	62.3
December	185.7	62.7
January	186.1	70.4
February	144.3	74.2
March	124.2	72.1
April	83.1	52.9
May	55.5	49.6
June	39.7	59.6
July	46.5	45.6
August	69	47.5
September	98.2	43.8

Source: SILO, 2024

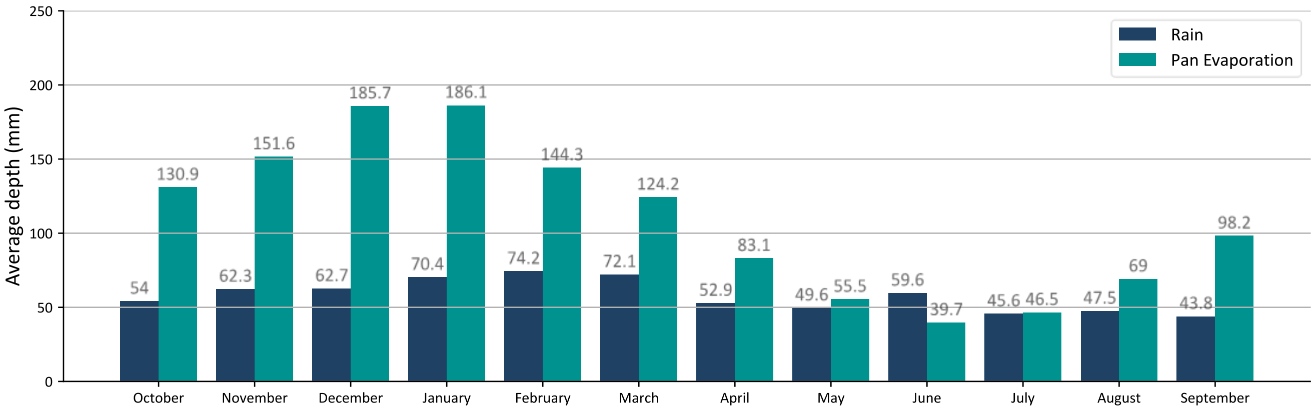

Figure 3-10 Monthly rainfall and evaporation

Source: SILO, 2024

Figure 3-11 presents a timeseries of daily rainfall accumulation starting on 1 October each year to represent the water year. There is minimal variance between the 25th to 75th percentile annual rainfall total. It is possible for annual rainfall sequences to generate three times the median rainfall as occurred in the 1949/50 water year.

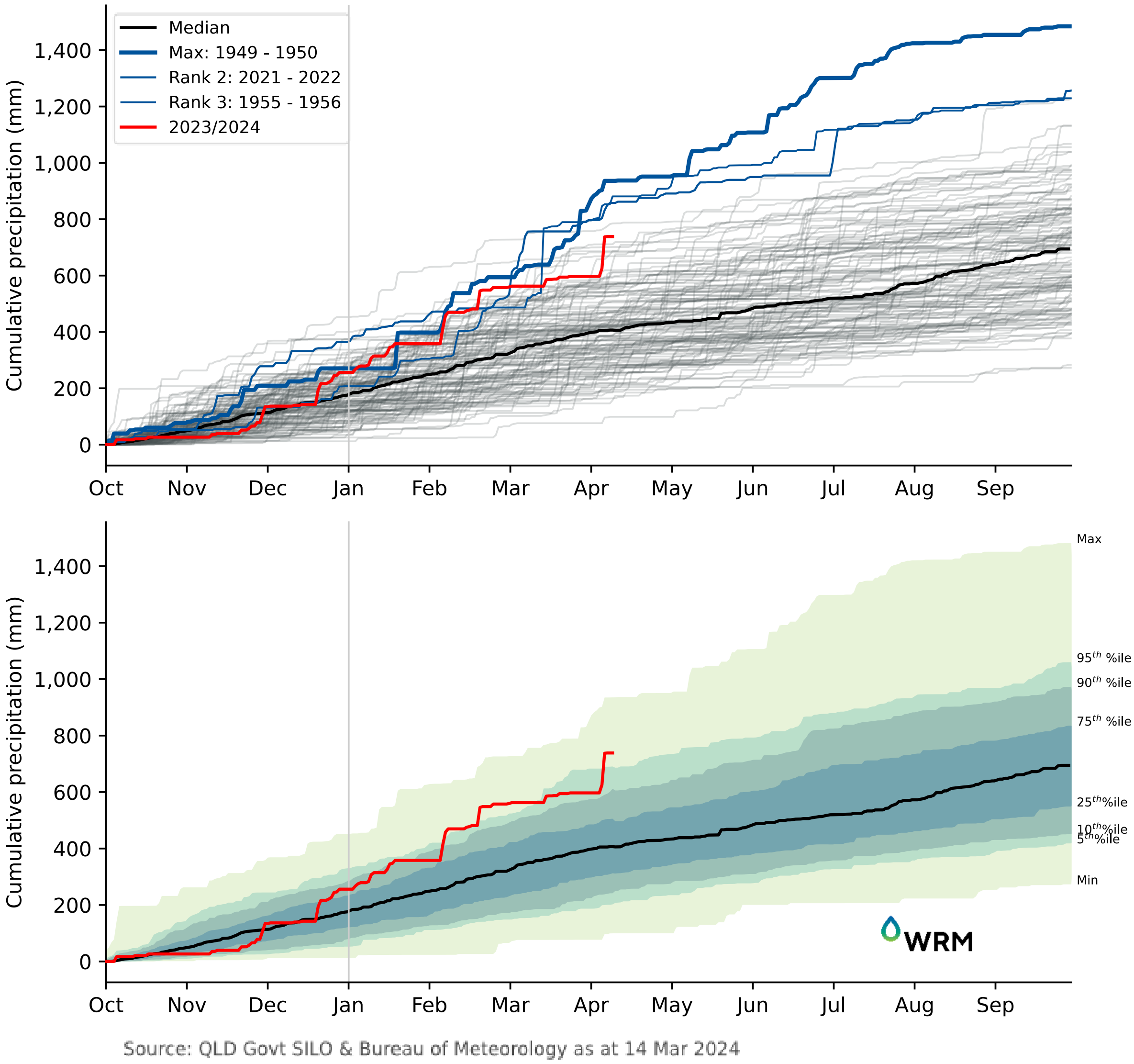

Figure 3-11 Rainfall variability at Project Area

Source: SILO, 2024

3.3 WATERCOURSES

The watercourse network traversing the Project Area is shown in Figure 3-12, including numerous minor watercourses of 1st and 2nd Strahler order based on NSW hydroline spatial data. The Project Area is drained by several ephemeral watercourses, the higher stream orders being Sandy Creek and Island Creek.

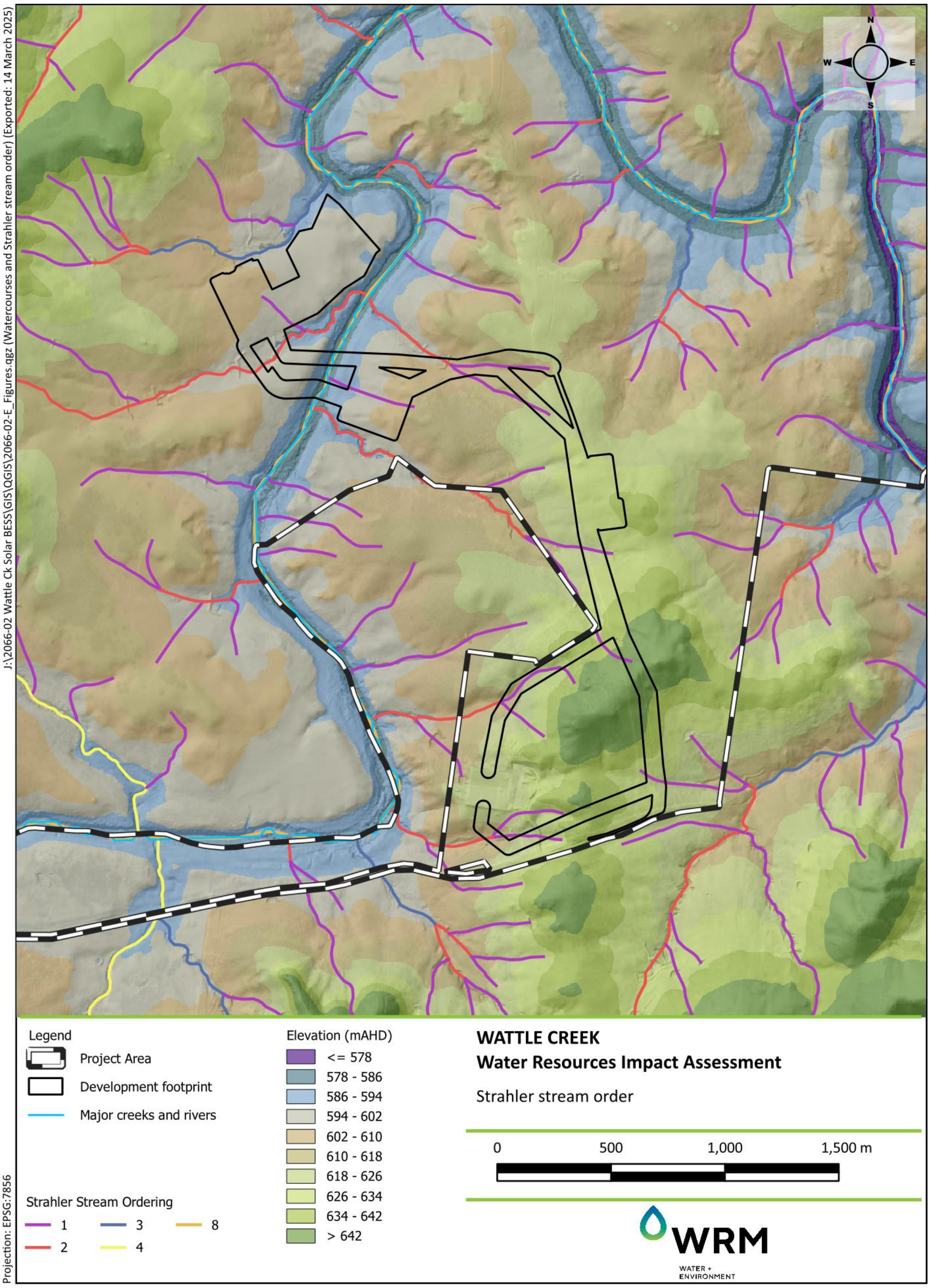

Figure 3-12 Watercourses and Strahler stream order

3.4 SOIL LANDSCAPES

The following section presents the NSW state government regional mapping data for soil types, inherent soil fertility and Land and Soil Capability (LSC) as applied to the Project Area (NSW and Department of Planning, Industry and Environment, 2022). Minesoils Pty Ltd (Minesoils) was engaged by Umwelt to conduct a Soil, Land and Agricultural Impact Assessment of the Project. The baseline soil and agriculture resources are detailed within the Soil and Agricultural Impact Assessment report (Minesoils, 2024).

Based on aerial imagery, there is evidence gully erosion along watercourses within the Project Area. This observation was made in the context of assessing land and soil capability, where much of the Project Area is classified as Class 5 (severe limitations). However, due to the nature of the landform, the risk of erosion and sedimentation impacts as a result of the Project remains low.

3.4.1 Soil Types

A soil survey undertaken by Minesoils (2024) found the Project Area to contain three dominant soil mapping units. The NSW regional soil mapping indicates the dominant soil types within the development footprint are Sodosols and Natric Kurosols as per Australian Soil Classification (ASC). Figure 3-13 demonstrates the four dominant soil mapping units within the Project Area. In summary, the soil type areas are as follows:

- Soil Unit: Sodosols

  Sodosols are soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is sodic and not strongly acid.

- Soil Unit: Natric Kurosols

  Kurosols are soils other than Hydrosols with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) is strongly acid. If the upper 0.2 m of the B2 horizon (or the major part of the entire B2 horizon if it is less than 0.2 m thick) of the Kurosol is sodic, it is classed as a Natric Kurosol.

3.4.2 Inherent Soil Fertility

NSW regional mapping estimates the inherent fertility of soils in NSW. The mapping describes soil fertility as: *Low*, *Moderately Low*, *Moderate*, *Moderately High*, and *High*. Soils with '*Low'* fertility, due to their poor physical and/or chemical status, only support limited plant growth. Soils with '*Moderately Low'* fertility can generally only support plants suited to grazing; large inputs of fertiliser are required to make the soil suitable for arable purposes. (MineSoils, 2024). The Project Area is dominated by soils with *Moderately Low* fertility.

3.4.3 Land and Soil Capability

The Land Capability as outlined in the LSC scheme, refers to a land's natural potential to support various uses and management methods over an extended period without harming soil, air, or water. Improper land management can cause both on-site and off-site environmental damage, reducing the value of natural ecosystems, agricultural output, and infrastructure.

The Project Area LSC mapping is shown in Figure 3-14. In accordance with the LSC scheme, the development footprint was found to contain LSC class 5 severe limitations.

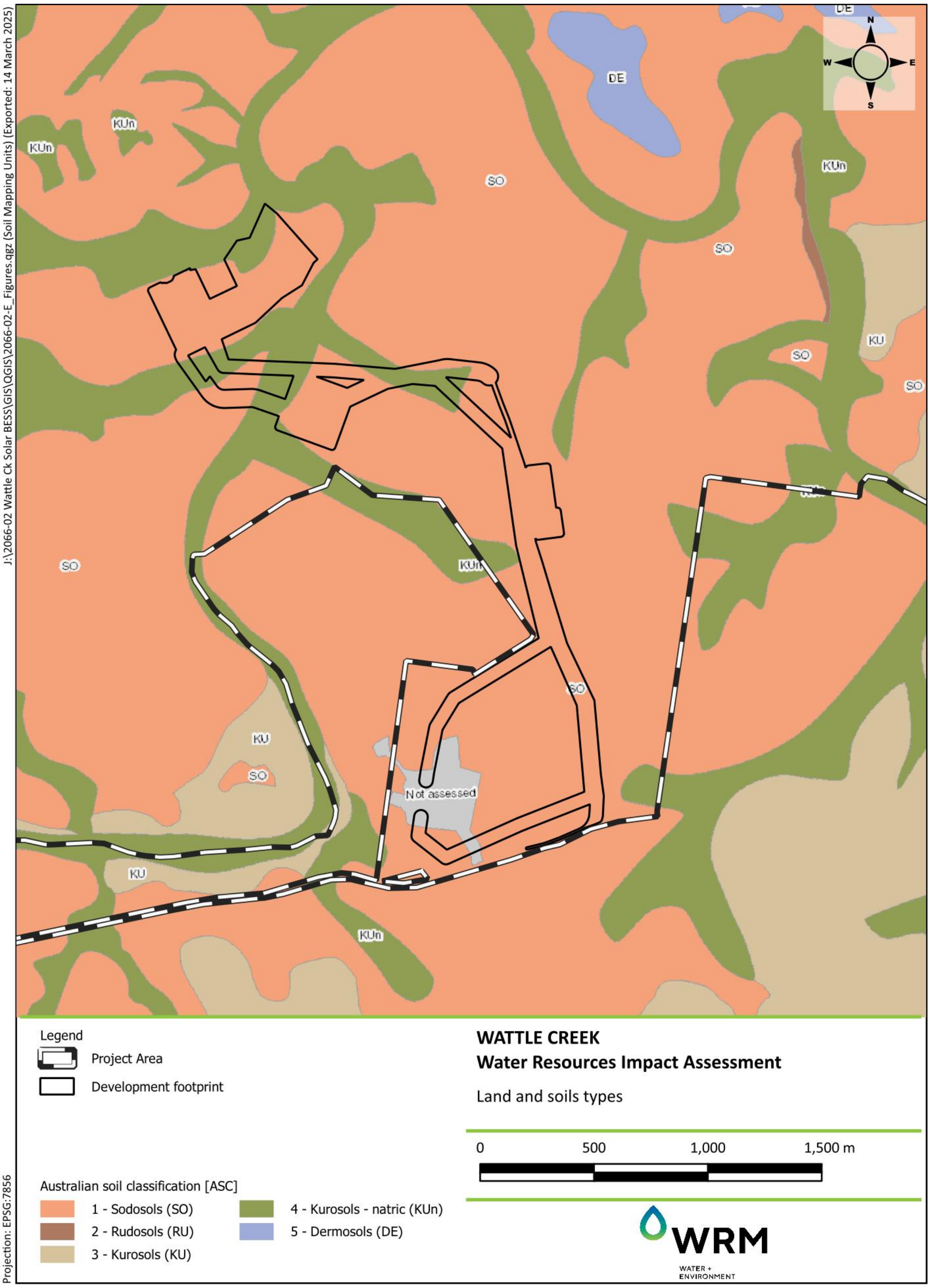

Figure 3-13 Regional Soil Mapping Units

Figure 3-14 Regional Land and soil capability

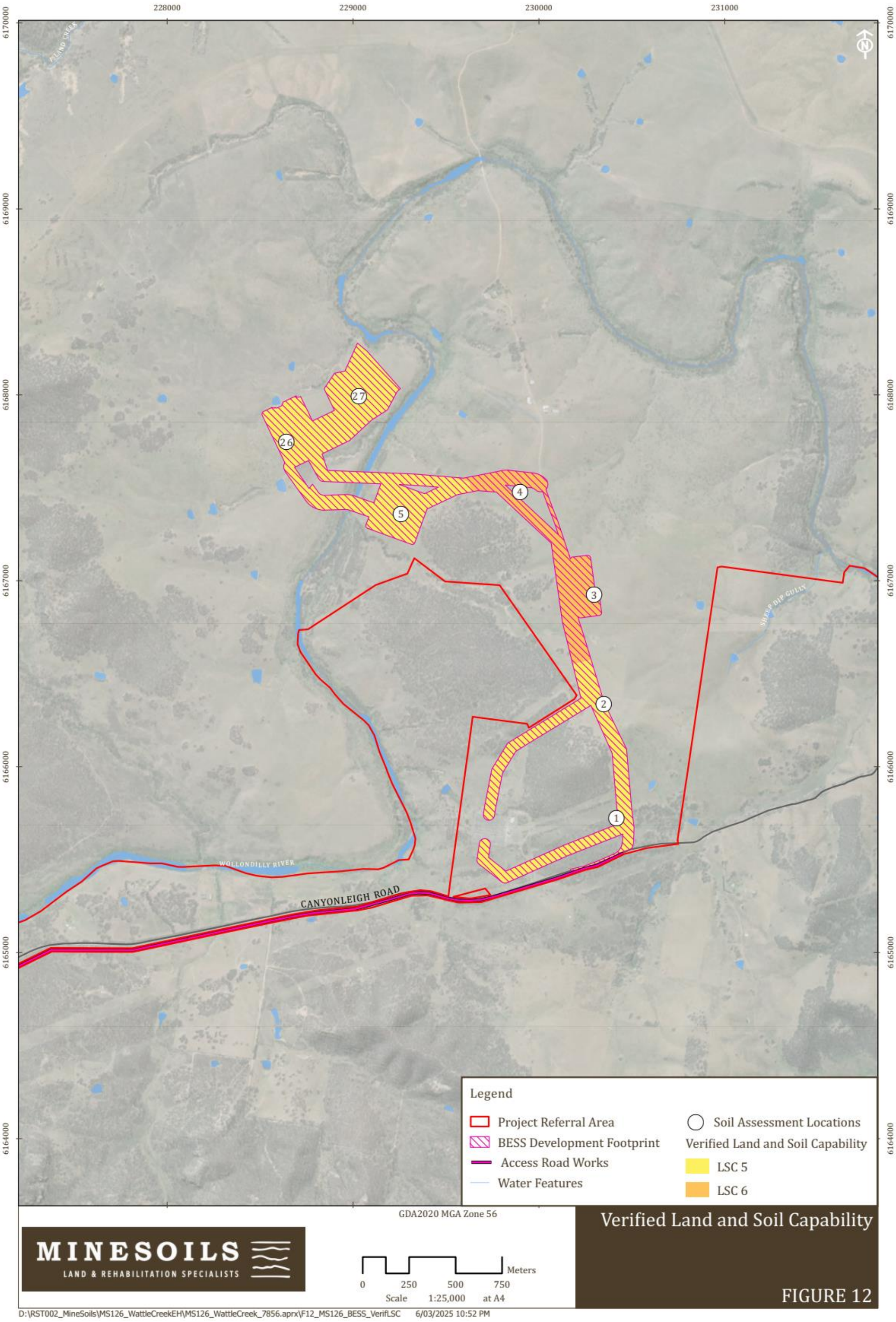

Figure 3-15 Verified Land and Soil Capability

3.4.4 Biophysical Strategic Agricultural Land

There is no Biophysical Strategic Agricultural Land (BSAL) present within the Project Area. The nearest BSAL is located 10 km to the west of Project Area. Additionally, there is no land mapped Class 1-3 land, defined as capable of a wide variety of land uses under the Land and Soil Capability Assessment Scheme (LSC) present within the Project Area. All land within the Project Area is mapped as at least severely limited or worse, Class 5 to Class 8 Existing agricultural activities within the host properties will continue and co-exist with the Project.

The Project Area is considered low risk for Acid Sulfate Soil and there are no high-risk areas mapped on NSW Acid Sulfate Soils within the Project Area.

Table 3.4 presents the soil properties for the Project Area, sourced from the Minesoils Report (2024). The Site ID corresponds with the numbering shown on Figure 3-16 and sample site specific detail is provided within Appendix C.

Table 3.4 Erosion risk and Soil Profile

Erosion Risk	Site #	Soil Mapping Units	Soil Profile - Australian Soil Classification
Moderate – High	1	Chromosols	Bleached Eutrophic Brown Chromosol
Moderate – High	2	Chromosols	Mottled Mesotrophic Brown Kurosol
Moderate – High	3	Chromosols	Red Chromosol
Very High	4	Sodosols	Yellow Sodosol
Very High	5	Sodosols	Eutrophic Mesonatric Brown Sodosol
Very High	26	Sodosols	Brown Sodosol
Very High	27	Sodosols	Mesotrophic Subnatric Brown Sodosol

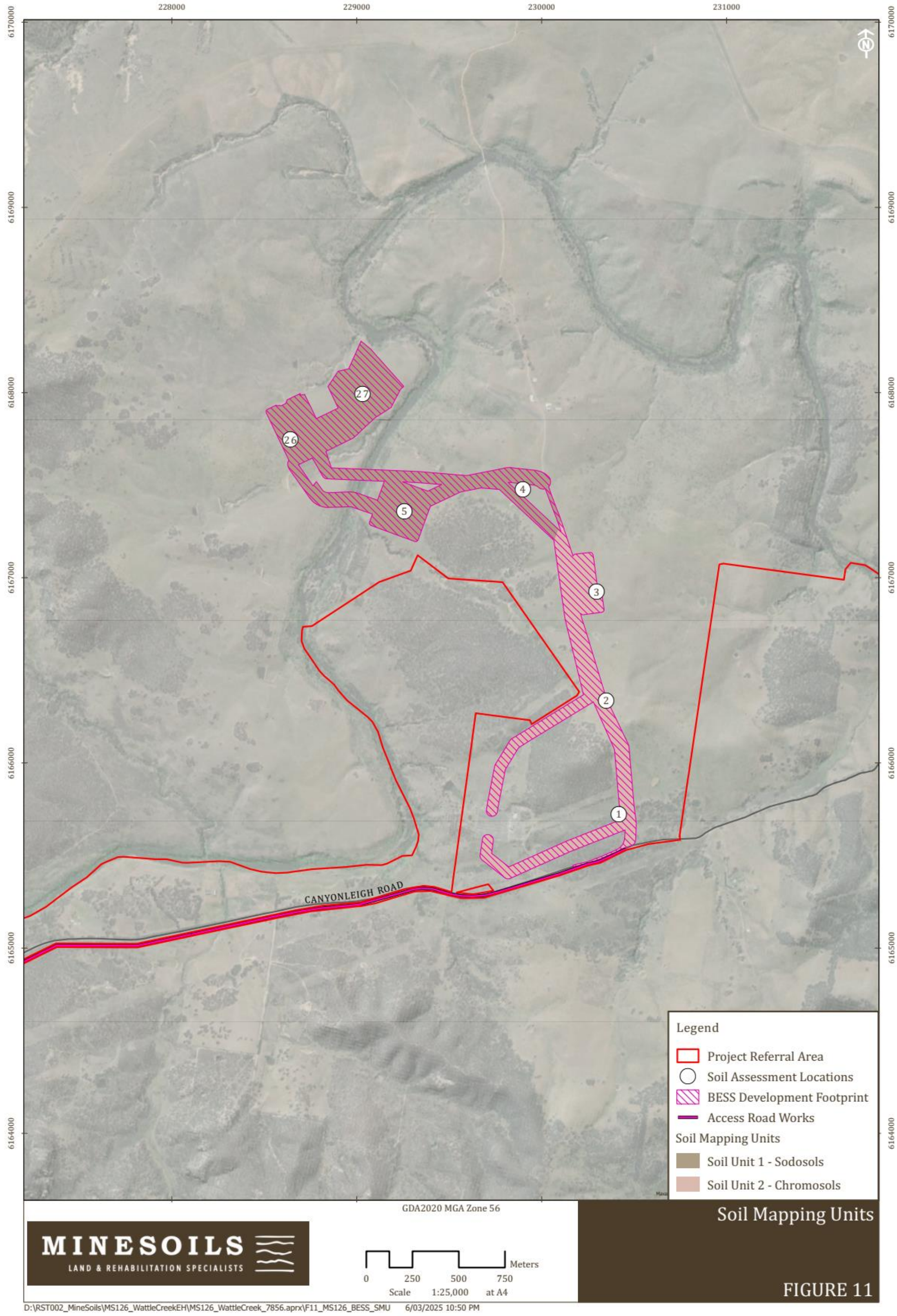

Figure 3-16 Verified Soil Mapping Units

3.5 WATER QUALITY

The NSW Water Quality Objectives (WQOs) have been developed to guide plans and actions to achieve healthy watercourses. The WQOs are based on measurable environmental values (EVs) for protecting aquatic ecosystems, recreation, primary industries, drinking water and industrial water. At the time the environmental values were approved the Hawkesbury-Nepean Rivers was being assessed separately as part of the Healthy Rivers Commission.

Chapter 8 (Sydney Drinking Water Catchment) of the State Environmental Planning Policy (Biodiversity and Conservation) 2021 (BC SEPP) applies to the site as it is located within the Sydney Drinking Water Catchment. Section 8.8 of Chapter 8 (Sydney Drinking Water Catchment) of the BC SEPP states:

> *(1) A consent authority must not grant consent to the carrying out of development under Part 4 of the Act on land in the Sydney drinking water catchment unless it is satisfied that the carrying out of the proposed development would have a neutral or beneficial effect on water quality.*
>
> *(2) For the purposes of determining whether the carrying out of the proposed development on land in the Sydney drinking water catchment would have a neutral or beneficial effect on water quality, the consent authority must, if the proposed development is one to which the NorBE Tool applies, undertake an assessment using that Tool.*

As the Project is a development under Part 4 of the EP&A Act and it is located within the Sydney Drinking Water Catchment, the consent authority must be satisfied that the development would have a neutral or beneficial effect (NorBE) on water quality.

The following is a summary of the work undertaken, and in accordance with the *Neutral or Beneficial Effect on Water Quality assessment Guidelines* (WaterNSW, 2021) (the 'NorBE Guidelines'), to determine whether the development would have a neutral or beneficial effect on water quality.

3.5.1 Neutral or beneficial effect

A neutral or beneficial effect on water quality is satisfied if the development:

(a) has no identifiable potential impact on water quality, or

(b) will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or

(c) will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

The NSW Water Quality Objectives (WQOs) have been developed to guide plans and actions to achieve healthy waterways. The WQOs are based on measurable environmental values (EVs) for protecting aquatic ecosystems, recreation, primary industries, drinking water and industrial water. There are no specific WQOs for the Hawkesbury-Nepean catchment. In the absence of regionally defined objectives, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC & ARMCANZ, 2000) was assessed to provide a guide for the WQOs for the Project Area. The WQOs have been developed to achieve suitable water quality for the protection of:

- aquatic ecosystems
- visual amenity
- primary and secondary contact recreation
- livestock water supply
- irrigation water supply

- homestead water supply
- drinking water
- aquatic foods.

Based on the likely construction activities and operations for the Project and the environmental values listed above, the water quality objectives presented in Table 3.5 are considered relevant to the Project.

Table 3.5 Project Relevant Water Quality Objectives

Parameter	Units	Value/Range
pH	-	6.5 to 8.0
Salinity (Electrical conductivity)	µS/cm	30 to 350
Turbidity	NTU	2 to 25
Total Phosphorus	µg/L	20
Total Nitrogen	µg/L	250
Visual clarity and colour	-	Natural visual clarity should not be reduced by more than 20 %. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50 %.
Surface films and debris	-	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.

3.5.2 Neutral or Beneficial Effect on Water Quality

As the Project is located within the Sydney drinking water catchment and as such must have a Neutral or Beneficial Effects (NorBE) on water quality. Neutral or Beneficial Effect on Water Quality Assessment Guideline (WaterNSW, 2022) indicates that a development is considered to have a NorBE on water quality if the development:

E1.1 has no identifiable potential impact on water quality, or

E1.2 will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or

E1.3 will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

An assessment of the potential impact on water quality is presented in Section 5.5 and considers the estimated pre- and post-development (operational phase of the Project, not construction) pollutant concentrations and loads in stormwater discharging from the Project Area based on water quality modelling (refer to Section 5).

3.6 WATER EXTRACTION AND USERS

Water Sharing Plans (WSPs) have been developed under the WM Act to protect the environmental health of water sources, whilst securing sustainable access to water for all users. The WSP encompassing the Project Area is the Greater Metropolitan Region Groundwater Sources 2023. The

WSPs specify maximum water extractions and allocations and provide licensed and unlicensed water users with a clear picture of when and how water will be available for extraction. A check was undertaken for the Lot Plan numbers within the Project Area. Table 3.7 summarises the nearby WALs to the Project Area.

Table 3.6 Wollondilly River Water Source Water Access Licences

Access Licence Category	No. of WAL(s)	Total Share Component	Share Component Unit	Water made Available (ML)	Usage 2024 (ML)
UNREGULATED RIVER	78	5111	ML per share	5111	0.9

Table 3.7 Water Sharing Plan and Water Access Licences near Project Area

WAL No.	Licence Category	Share components	Water Source
25592	Unregulated River	543	Lower Wollondilly River Water Source
27408	Unregulated River	543	Lower Wollondilly River Water Source
35649	Unregulated River	439	Lower Wollondilly River Water Source
25723	Unregulated River	372	Lower Wollondilly River Water Source
37259	Unregulated River	166	Lower Wollondilly River Water Source
25470	Unregulated River	138	Lower Wollondilly River Water Source
25620	Unregulated River	133	Lower Wollondilly River Water Source
25575	Unregulated River	130	Lower Wollondilly River Water Source
25525	Unregulated River	130	Lower Wollondilly River Water Source
25697	Unregulated River	130	Lower Wollondilly River Water Source
25772	Unregulated River	123	Lower Wollondilly River Water Source
25638	Unregulated River	123	Lower Wollondilly River Water Source
25719	Unregulated River	111	Lower Wollondilly River Water Source
25644	Unregulated River	90	Lower Wollondilly River Water Source
25497	Unregulated River	86	Lower Wollondilly River Water Source
25475	Unregulated River	84	Lower Wollondilly River Water Source
25666	Unregulated River	82	Lower Wollondilly River Water Source
25611	Unregulated River	81	Lower Wollondilly River Water Source

3.7 GROUNDWATER

In total there are no registered groundwater bores located within the Project Area (BoM, 2023), as shown in Figure 3-17. The drilled depth of water supply and stock and domestic bores is reported at the adjacent ranges between 36 m and 120 m.

The regional water table is relatively deep located at least 20 metres below ground level (BGL). Localised perched groundwater systems are still possible. No salinity data was provided from the registered bores, so groundwater quality in the Project Area is unknown. (BOM Groundwater Explorer – Bore log)[4]

3.7.1 Groundwater Dependent Ecosystem

A Groundwater Dependent Ecosystem (GDE) is an ecosystem which is dependent on the availability of groundwater to maintain structure and function. Terrestrial (including riparian vegetation) GDEs are dependent on the subsurface presence of groundwater to a depth of 10 m BGL. Aquatic GDEs are dependent on surface water's interaction with groundwater. Ecosystems are classified as:

- High potential ecosystems which have a high (strong possibility) of groundwater interaction
- Moderate potential ecosystems which have a moderate potential for groundwater interaction.
- Low potential ecosystems which have a low (unlikely) potential for groundwater interaction.

According to the Groundwater Dependent Ecosystem (GDE) Atlas (BOM, 2017), the Project Area is mapped as containing GDEs, see Figure 3-17. GDEs are shown within Wollondilly River, which flows through the Project Area. The GDEs present are aquatic GDEs, recorded as high potential from a national assessment (DPE, 2012).

3.7.2 Groundwater Vulnerability

Groundwater vulnerability is described by the NSW Government (2023) as the vulnerability or risk of aquifers to contamination, relating to physical characteristics of the location, such as the depth to the water table and soil type. Mapping provided by the NSW Government was reviewed for groundwater vulnerability within and surrounding the Project Area. There are no groundwater vulnerability areas mapped for the Project Area (DPE, 2014). The geologic units are shown in Figure 3-3.

[4] bom.gov.au/water/groundwater/explorer

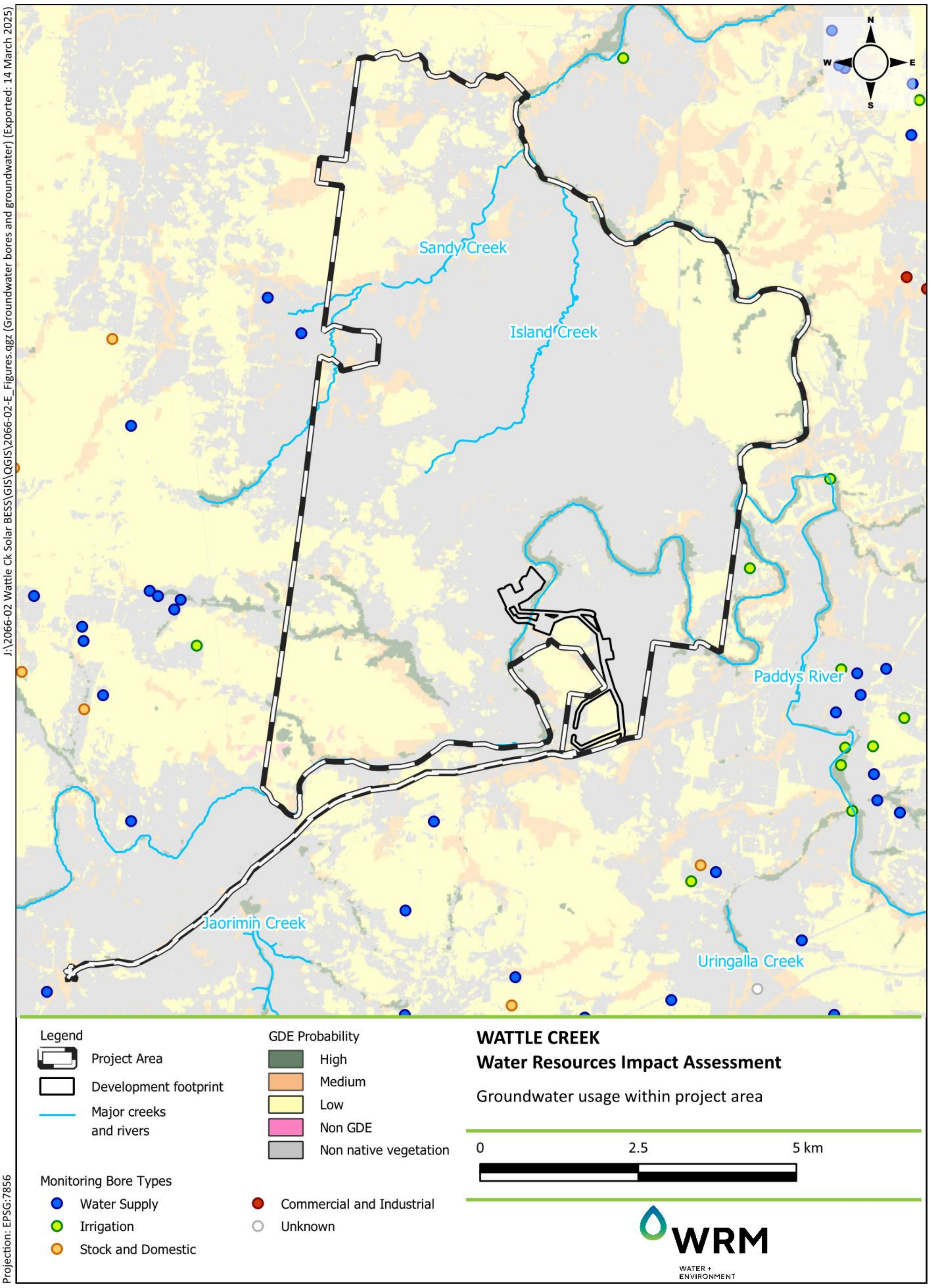

Figure 3-17 Groundwater bores and groundwater dependent ecosystems

Source: BOM, 2024a

4 WATER MANAGEMENT

4.1 OVERVIEW

The Project will require a water supply during the construction, operation and decommissioning phases. During construction, water will primarily be used for revegetation, dust suppression and potable use. The associated water demand during the construction phase is estimated to be approximately 12 ML for the duration of the construction phase. The majority of water consumption relates to the access tracks related to the Projects. The majority of water demand is for stabilisation when constructing access tracks and dust suppression on access tracks. Both of these requirements are dependent on underlying geology and the weather experienced during construction.

Water demands for the infrastructure relating to the construction of the Project will be modest, comprising water necessary for concrete pads and concrete washdown. The water demand during operations and decommissioning is expected to be significantly lower in the range of 1 to 3 ML per annum.

4.2 WATER DEMAND

4.2.1 Construction Water Demand

The greatest water demand would be during the construction phase of the Project. Key Project water demands include:

- Soil stabilisation and fill conditioning (dependent on ground conditions)
- Dust suppression (dependent on weather)
- Concrete production
- Concrete washout
- Vehicle and equipment wash down, and
- Amenities.

Table 4.1 provides a preliminary assessment of the construction phase water demands. A preliminary assessment of water demands has been made based on the current design and a number of assumptions outlined in Table 4.2. Water demand during construction phase would increase gradually, peak and then decline gradually as the Project reaches practical completion. Construction is expected to take 18 months. Maximum water demand is expected towards the end of the first six months of construction. This coincides with the main period of construction of access tracks, foundations and hardstand areas. Over the first half of the construction phase, the average monthly demand is approximately twice the consumption expected in the final half. Water demand during the initial operational phase would be lower again comprising mainly of the solar array cleaning.

Table 4.1 Construction Phase Total Water Demand

Water Demand	Total Water Usage (kL)
Dust suppression (nett. evaporation)	600
Construction – stabilised road /hardstands	354
Construction – concrete	20
Washdown – Vehicle	110
Potable	250
Total demand	**~ 2 ML**

Table 4.2 Construction Phase Water Assumptions

Water Demand	Water Usage Assumptions
Dust suppression	Active work areas only - assume at 25% of total tracks at any one time Assume balanced with pan evaporation, refer Section 3.2
Construction – road	5m wide by 3 km. Rip to 500mm and re-compact - add 8% water content to condition. 300mm road base - add 12% water content to condition pro-rata over period of road construction
Washdown – concrete	Approx. 125 L per 1 cubic metre (m^3) of concrete poured
Washdown – vehicle	Allowance 5 kL/day typical (dry days), 10 kL/day (wet days), refer Section 3.2
Construction – Concrete	120 m^3 to cover footings, BESS, substations
Potable	Construction workforce: Median 30 personnel, Peaking at 65 personnel Allowance 40 litres per person per day - 6 day week
Operational allowance	Allowance 1 litre per square metre of solar array area for every wash (washed every 3 months)

The assumed average and maximum daily breakdown of water requirements for the construction period:

- Peak daily demand of 50 kilolitres per day (kL/day) raw with 40 kL/day potable water; and
- Average daily demand of 30 kL/day raw with 20 kL/day of potable water.

These values are indicative only for the purposes of impact assessment. Detailed assessment of water demands would be undertaken during detailed design of the Project.

4.2.2 Operational Water Demand

During operations, water would be required for ongoing maintenance activities such as amenities and potable purposes by operational staff and for washing down equipment if required. Washing would not require any detergent or cleaning agents. A static water supply, with the capacity to be determined during the detailed design phase, would also be established and maintained for fire protection.

4.3 WATER SUPPLY SOURCES

The majority of water required to meet Project water demands would be imported and would most likely be sourced through a commercial arrangement with local suppliers. Raw water would be utilised for construction and potable supplies sourced for site offices and amenities. Water for construction and operational phase non-potable water demands will be supplied from one or a combination of the following sources:

- Commercial suppliers in the nearby region (via water truck);
- Harvested runoff from farm dams under agreement with host or local landholders;
- Groundwater from licenced bores under agreement with host or local landholders;
- Harvested runoff from disturbed areas captured in excavations or sediment basins/traps constructed to prevent sediment transport off-site; and,
- Recycling and reusing water.

Based on the total Project Area of 63 km^2, the Maximum Harvestable Right Dam Capacity (MHRDC), from which water can be used for any purpose, is 504 ML. This value was calculated using WaterNSW's MHR calculator[5].

The largest water demands, such as for dust suppression, soil conditioning, and concrete batching, are all nonrecoverable water uses. Where possible, water uses. such as for concrete facility and vehicle washdown, would be recycled and reused as far as practical.

During construction, there may also be opportunities to utilise water collected in sediment retention ponds, or locally sourced from farm dams or private bores. Local water supply from private dams and bores would need to be with harvestable water rights and water access licencing conditions.

Any water supplied to the Project from existing groundwater bore or farm dams would be sourced under agreement with relevant landholders while ensuring any WALs, works approvals and water use approvals required under the *WM Act* (2000) are obtained.

Water sources would be determined prior to the commencement of construction in consultation with suppliers and landholders. Town water supplies would generally be avoided for use in construction but may be used where appropriate and available.

4.3.1 Potable Water Supply

Potable water demands for the Project would be supplied via water tanker and stored in on-site water tanks. Potable water storages would be routinely tested to ensure water quality meets the requirements of the Australian Drinking Water Guidelines (ADWG) (National Health and Medical Research Council, 2011) and an appropriate maintenance regime would be implemented to ensure water quality ADWG water quality standards are maintained.

4.3.2 Amenities Wastewater

Treatment of wastewater from amenities during all phases of the Project will be provided by an on-site collection and treatment system. The proposed treatment system will be a contained system and is anticipated to include mechanical screening, biological and chemical treatment, filtration and disinfection. The waste solids produced by the treatment system will be emptied by a licensed contractor and disposed of at a nearby council operated wastewater treatment plant or other appropriately licensed facility.

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[5] https://www.waternsw.com.au/customer-services/water-licensing/maximum-harvestable-rights-calculator

Treated effluent suitable for reuse for construction purposes, which are anticipated to include dust suppression and earthworks conditioning, will be stored in sealed tanks or lined basins to avoid potential interaction with groundwater.

4.4 SITE WATER BALANCE

The Project would require water to be supplied from a variety of sources and qualities. The water demands were quantified in Section 4.2 and the possible supply sources were outlined in Section 4.3. An indicative summary detailed site water balance is shown in Table 4.3.

All on-site storages required as part of the water supply were assumed to be constructed during the construction phase, i.e., prior to the commencement of operations. The purpose of each reservoir is determined by the water usage and quality. If there is insufficient on-site storage, an external water source would be required to meet site water demand during dry periods.

Table 4.3 Detailed site water balance

		Construction Phase (kL)	Operation (annual) (kL)
Water Demands			
	Dust suppression (nett. Evaporation)	600	Neg.
	Construction – stabilised road /hardstands	354	n/a
	Construction – concrete BESS	20	n/a
	Potable	250	100
Water Supply			
	Rainfall	Max Harvestable Right	
	External potable water	250 (Purchased)	100 (Purchased)
	Harvested project water	974 (max.)	negligble

4.5 EROSION AND SEDIMENT CONTROL

Throughout the construction phase of the Project, erosion and sediment controls would be established in general accordance with *Managing Urban Stormwater – Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2C: Unsealed Roads* (DECC, 2008) (i.e. the 'Blue Book'). The following sections outline the Project erosion and sediment control design standards and anticipated erosions and sediment controls to be implemented at the Project. Should the Project be approved and constructed, soil and water management measures would be prepared to facilitate the implementation of best practice ESCs during all phases of the Project.

4.5.1 Construction on Waterfront Land

Approved SSD projects are exempt from the requirement to acquire Controlled Activity Approvals (CAAs) for works on waterfront land (works within 40 m of the top of bank of a waterway) under s.4.41(1)(g) of the *Environmental Planning and Assessment Act* 1979. While an exemption from CAAs, all works on waterfront land for the Project would be undertaken in accordance with DPEs *Guidelines for Controlled Activities on Waterfront Land*.

4.5.2 Erosion hazard assessment

An erosion hazard assessment has been undertaken in accordance with Chapter 4.4.1 of Volume 1 of the 'Blue Book'. The Australia Natural Resource Atlas provides gridded factor values within the Project Area. The Project Area slope was estimated based on the geospatial analysis to determine the average site slope of the existing landform. These gridded values were averaged and are presented in Table 4.4 and were used to assess erosion hazard for the entire Project Area.

The annual soil loss for the Project Area was estimated from the Revised Universal Soil Loss Equation (RUSLE). The annual soil loss rate is classified as a high or low erosion hazard. The erosion hazard assessment for the Project Area predicts that it can be classified as low erosion hazard. As such, standard erosion control measures will be applied during construction.

Table 4.4 Annual soil loss calculation

	Description	Value	Range
R	Annual average rainfall erosivity factor	1005	997-1009
k	Soil erodibility factor	0.045	0.018-0.061
LS	Slope length gradient factor based on Table A1 of *Managing Urban Stormwater Volume 1* (Landcom, 2004)	1.3	0.03-17.04
C	Ground cover factor sourced from Figure A5 of *Managing Urban Stormwater Volume 1* (Landcom, 2004)	0.0065	0.0034-0.0193
P	Erosion control practise factor sourced from Table A2 of *Managing Urban Stormwater Volume 1* (Landcom, 2004).	1.3	Compacted and smooth
A	Calculated annual soil loss rate (RUSLE) tonnes/ha/year	4.97	

The calculated annual soil loss rate for the Project Area corresponds to a very low erosion hazard, (soil loss class 1). Classification of soil loss is provided in Volume 1 of the Blue Book (Landcom, 2004) at Table 4.2. The Blue Book's Figure 4.9 indicates that the Project Area is located in rainfall distribution zone 12. Consulting *Lands where special erosion control measures apply* in the Blue Book's Table 4.3 indicates that for zone 12 and soil loss class 1, there are no time of year restrictions applicable to the Project Area.

The Blue Book instructs that all land within 40 m of the bank of a defined watercourse is to be considered as a very high erosion hazard (soil loss class 6). As such, timing restrictions apply to any works on these lands between October and April. *Table 4.3* of the 'Blue Book'. indicates that for zone 12 and soil loss class 1, there are no time of year restrictions applicable to the Project Area.

Where scheduling of works during periods where the three-day forecast indicates that rain is likely, erosion control measures should aim to protect disturbed lands with 60% ground cover. Where non-forecast rainfall arrives, site management techniques should endeavour to minimise and mitigate site erosion within 24 hours.

4.6 GENERAL EROSION AND SEDIMENT CONTROL STRATEGY

The detailed design phase will finalise drainage sizing and alignments. Once this information is known, and prior to construction, a detailed Erosion and Sediment Control plan will be developed and included in a Construction Environmental Management Plan (CEMP). This will specify the locations of all necessary Erosion and Sediment Controls (ESCs) to achieve the principles outlined below. The ESCs are to be installed, managed and maintained in general accordance with the Blue Book Volume 1 (Landcom, 2004) and Volume 2C (DECC, 2008). This will be achieved using the following principles and strategies.

4.6.1 Principles of Site Management

- Clean water flows will be diverted and prevented from entering the site. Flows generated from runoff within the site will have their water velocity minimised and any sediments captured before discharge from site.
- Stockpiles of erodible material that have the potential to cause environmental harm if displaced would be located away from concentrated surface flow and excessive up-slope stormwater surface flows.
- Sediment removed from any trapping device is to be disposed of in locations where further erosion and consequent pollution to downslope lands and watercourses will not occur.
- Temporary soil and water management structures are to be removed only after the Project Area is stabilised appropriately.
- Refuelling of plant and equipment is to be undertaken in an impervious bunded area located a minimum of 50 m from drainage lines or watercourses.
- Emergency spill kits are to be kept on site at all times. All workers are to be made aware of the location of the spill kits and trained in their use.
- All fuels, chemicals and liquids will be stored in an impervious bunded area, a minimum of 50 m away from drainage lines or watercourses.
- Any concrete washout undertaken on site (during construction phase) will be in a bunded area that is not on waterfront land and at least 10 m from drains.

4.6.2 Erosion Sediment Controls strategy

The following ESC management strategies will be implemented within the Project Area.

- To minimise ground disturbance, construction and operational activities including vehicle and machinery movements, stockpiling, temporary vehicle parking and material laydown will be restricted to designated work areas. The development footprint is to be clearly delineated with construction fencing or barrier tape.
- Where possible, topsoil will be stripped and handled only when it is moist (not wet or dry) to avoid decline of soil structure.
- Topsoil stockpiles will be stabilised with vegetation (seeded) if they are to be inactive for long periods.
- Sediment traps should be located as close to the source of the sediment as practicable.
- Sediment control devices must be de-silted and made fully operational as soon as reasonable and practicable after a sediment-producing event. Sediment traps should be maintained to ensure that no more than 30% of their design capacity is lost to accumulated sediment.

The use of sediment basins will depend on the practicality of draining flat, disconnected and disturbed areas to a single sediment basin. The Blue Book suggests a contiguous disturbance area threshold of around 2 ha. Other more effective sediment controls are possible, and they would protect receiving waters from sediment generated within the Project Area.

4.6.3 Drainage Controls

- All temporary drainage controls are to be designed to have non-erosive hydraulic capacity to convey runoff from a 10% AEP critical duration storm event.
- Wherever reasonable and practicable, “clean” surface waters must be diverted away from sediment control devices and any untreated, sediment-laden waters.

* All runoff from the works is to be passed through sediment controls.

4.6.4 Monitoring and Maintenance

* Monitoring will be undertaken by a construction supervisor or a designated representative of the contractor during all work to ensure that the proposed ESC measures are functioning as intended.
* Any erosion and sediment control failures or excess sediment build up identified during the site inspections is to be rectified as soon as practicable following identification. Any sediment removed from devices should be disposed of in a lawful manner that does not cause ongoing soil erosion or environmental harm.

5 WATER QUALITY MODELLING

5.1 OVERVIEW

The water quality assessment for the Project was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). MUSIC estimates the pollutant loads and concentrations in stormwater runoff discharged from a representative catchment area. As the Project Area is within the Sydney Drinking Water Catchment, MUSIC was required to demonstrate that the Project will have a Neutral or Beneficial Effect (“NorBE”) on receiving environment water quality.

5.1.1 NorBE Criteria

MUSIC models the predicted changes in the total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP). Given the uncertainty in MUSIC modelling outcomes, WaterNSW requests a 10% improvement in post-development pollutant loads when compared with the pre-development pollutants (WaterNSW, 2023). A further criterion for pollutant loads requires that TSS, TN and TP concentrations must be equal to, or better, compared to the pre-development case pollutant concentrations for the 50th to 98th percentile cumulative frequency over the five-year modelling period.

5.2 MODEL CONFIGURATION

MUSIC modelling was undertaken for pre- and post-development conditions to estimate the pollutant loads discharged from the development footprint. The development footprint consists of the Project, which covers a total area of 74 ha and defines the catchment boundaries for modelling purposes. The development footprint has been broken into two (2) catchments as described in Table 5.1. Figure 5-1 illustrates the catchment locations for the development footprint.

It is noted that existing dams, gullies and some ridges are located outside the bounds of the development footprint. It is proposed that exclusion zones around these features be provided to ensure no disturbance to these areas. As the existing dams and ridges are to remain unchanged under post-development conditions, they have not been included within the catchment areas and have, therefore, been excluded from the MUSIC modelling. Additionally, the proposed treatment measures are to be offline and above or outside of the 2% AEP flood-affected areas as noted in Section 3.5.2 of “*Using MUSIC in the Sydney Drinking Water Catchment*” (WaterNSW, 2023). As the existing dams are generally located within the 2% AEP flood extent, exclusion from the modelling is further justified.

Table 5.2 outlines the amended water quality catchment areas which are to be included in the MUSIC modelling. Figure 5-2 illustrates the modelled catchment locations.

Table 5.1 Development Footprint Catchment Description

Catchment	Total Area (ha)	Description
2	25.10	Catchment 2 is the development footprint located to the west of the Wollondilly River and drains to the Wollondilly River. Under pre-development conditions this catchment consists of agricultural land (cropping and grazing). Under post-development conditions this catchment consist of, one (1) Construction Compound, a Substation, an Operation and Maintenance Facility (O&M Facility), BESS area, Electrical Cabling and Access Tracks.
3	25.41	Catchment 3 is the development footprint located to the east of the Wollondilly River and drains to the Wollondilly River. Under pre-development conditions this catchment consists of agricultural land (cropping and grazing) and an existing unsealed Access Track. Under post-development conditions this catchment consist of two (2) Laydown Areas, a Construction Compound, a Test Bed and an Access Tracks from the southern project boundary. The majority of the Access Track is an unsealed road.

Table 5.2 Modelled Water Quality Catchment Description

Catchment	Total Area (ha)	Description
2	25.10	Catchment 2 is located to the west of the Wollondilly River and drains to the Wollondilly River. Under pre-development conditions this catchment consists of agricultural land. Under post-development conditions this modelled catchment consist of one (1) Construction Compound, a Substation, an Operation and Maintenance Facility (O&M Facility), BESS area and new Access Tracks.
3	25.41	Catchment 3 is located to the east of the Wollondilly River and drains to the Wollondilly River. Under pre-development conditions this catchment consists of agricultural land and an existing unsealed Access Track. Under post-development conditions this catchment consist of two (2) Laydown Areas, a Construction Compound, a Test Bed and an unsealed Access Tracks from the southern project boundary. The majority of the Access Track is an existing unsealed road.

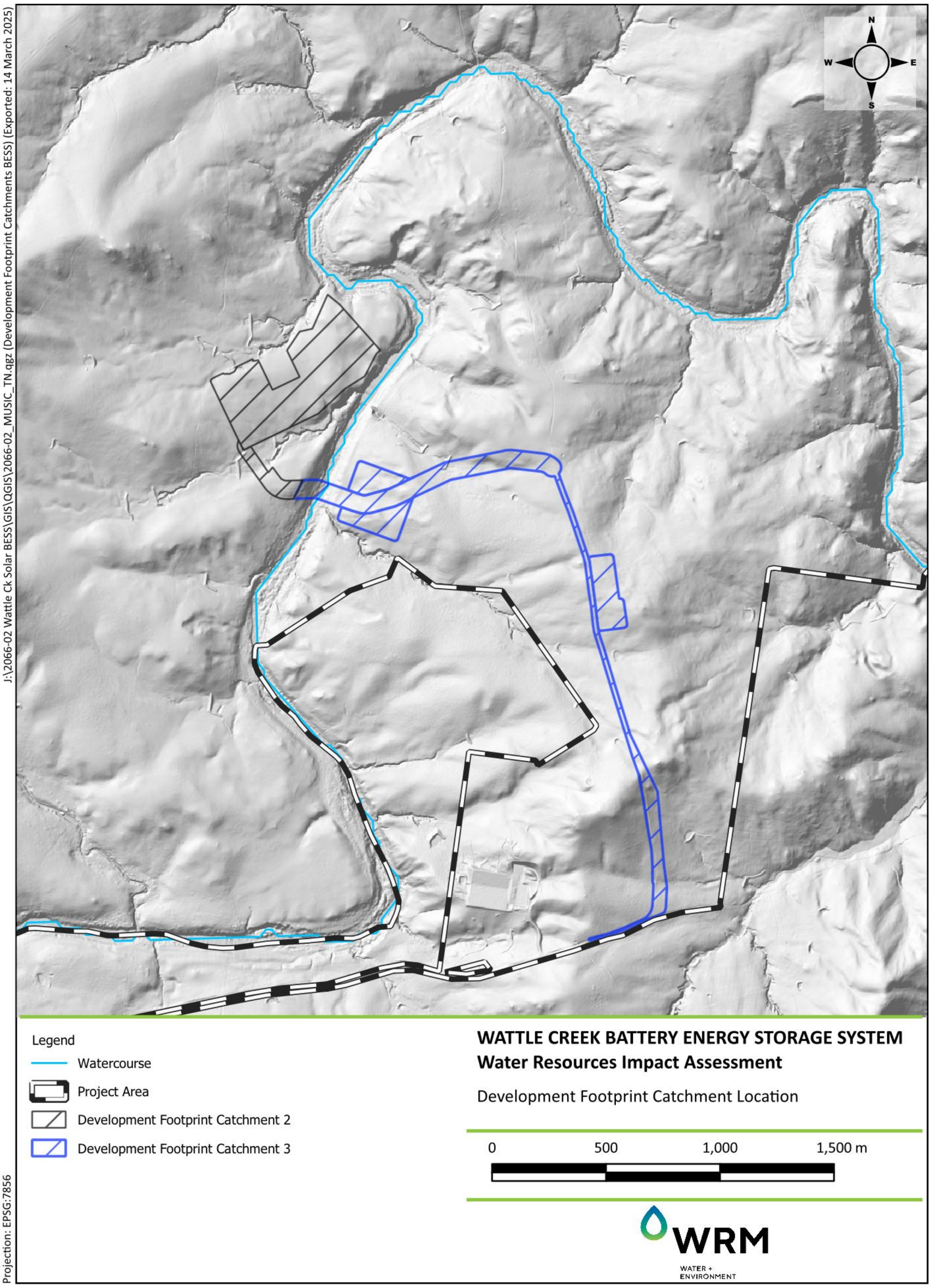

Figure 5-1 Development Footprint Catchment Locations

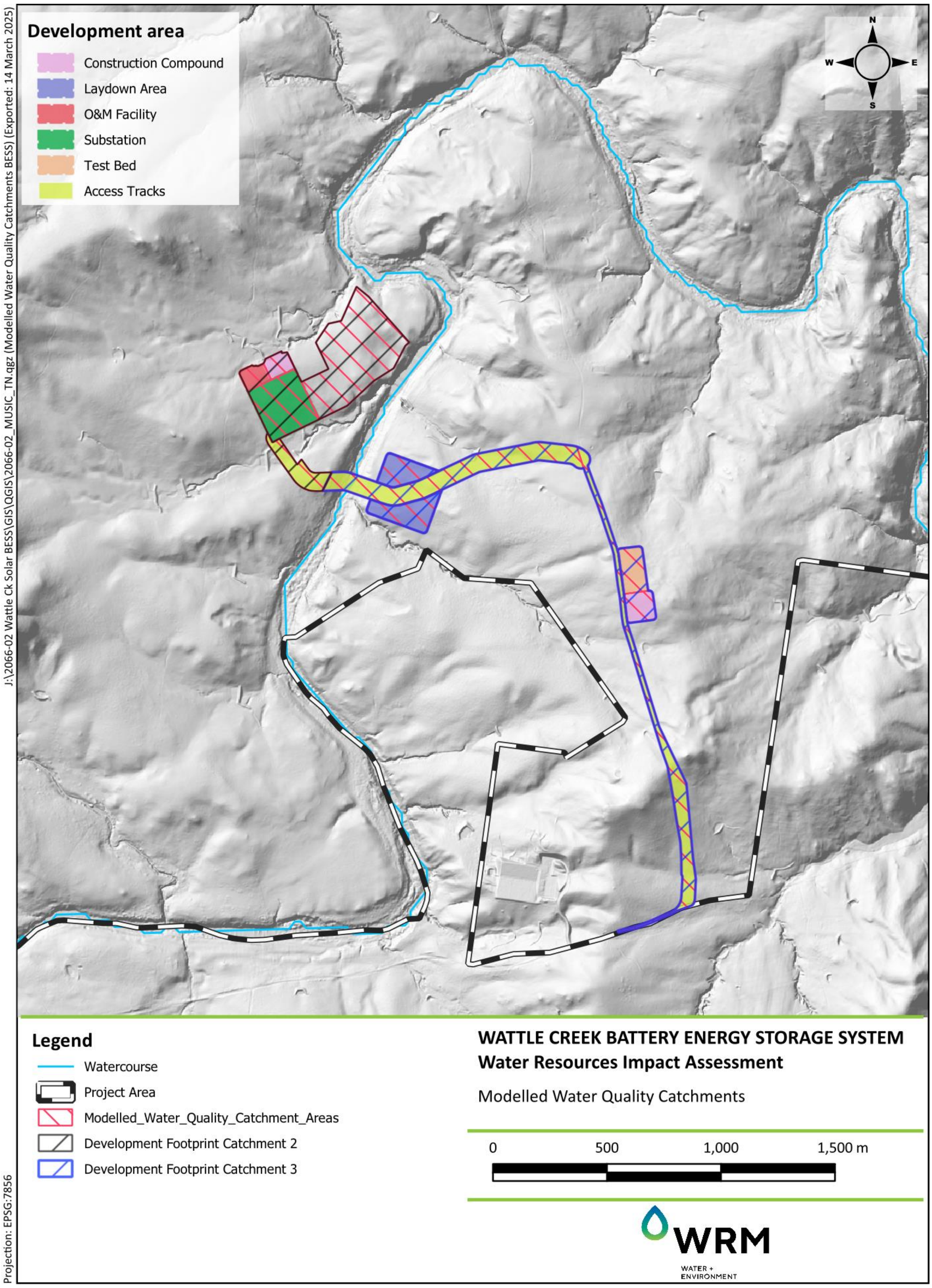

Figure 5-2 Modelled Water Quality Catchment Area for pre- and post-developed conditions

5.2.1 Meteorological Data

The Project Area is within the Wollondilly River catchment and is in Climate Zone 1 in Figure 3.1 of the *Using MUSIC in the Sydney Drinking Water Catchment* (WaterNSW, 2023). The meteorological MUSIC input data file data for Zone 1 was sourced from the WaterNSW website[6]. The provided data included average areal evapotranspiration estimates and six-minute rainfall depths. The supplied period covered 1 January 1995 to 31 December 1999. The provided data was loaded into MUSIC, as shown in Figure 5-3 and Figure 5-4

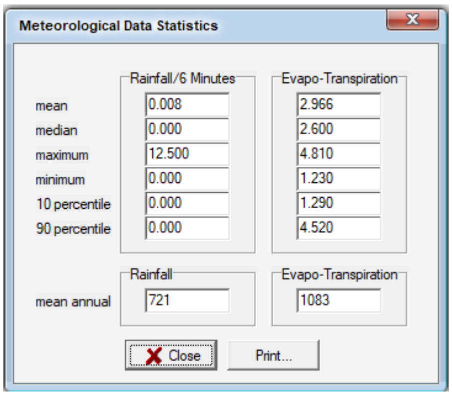

Figure 5-3 MUSIC Summary statistics of Meteorologic data

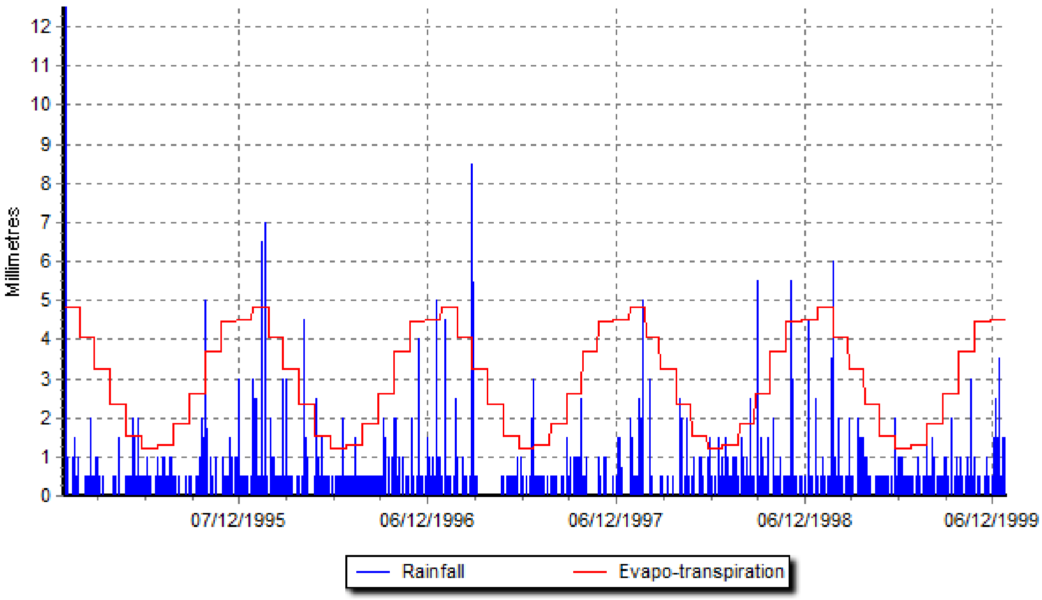

Figure 5-4 MUSIC Meteorologic time-series data
Source: WaterNSW

5.2.2 Model Configuration

The MUSIC model of the pre- and post-development was configured as shown in Figure 5-5 to enable the same stochastic seed to be utilised in both scenarios.

6 https://www.waternsw.com.au/water-services/catchment-protection/councils-and-developers

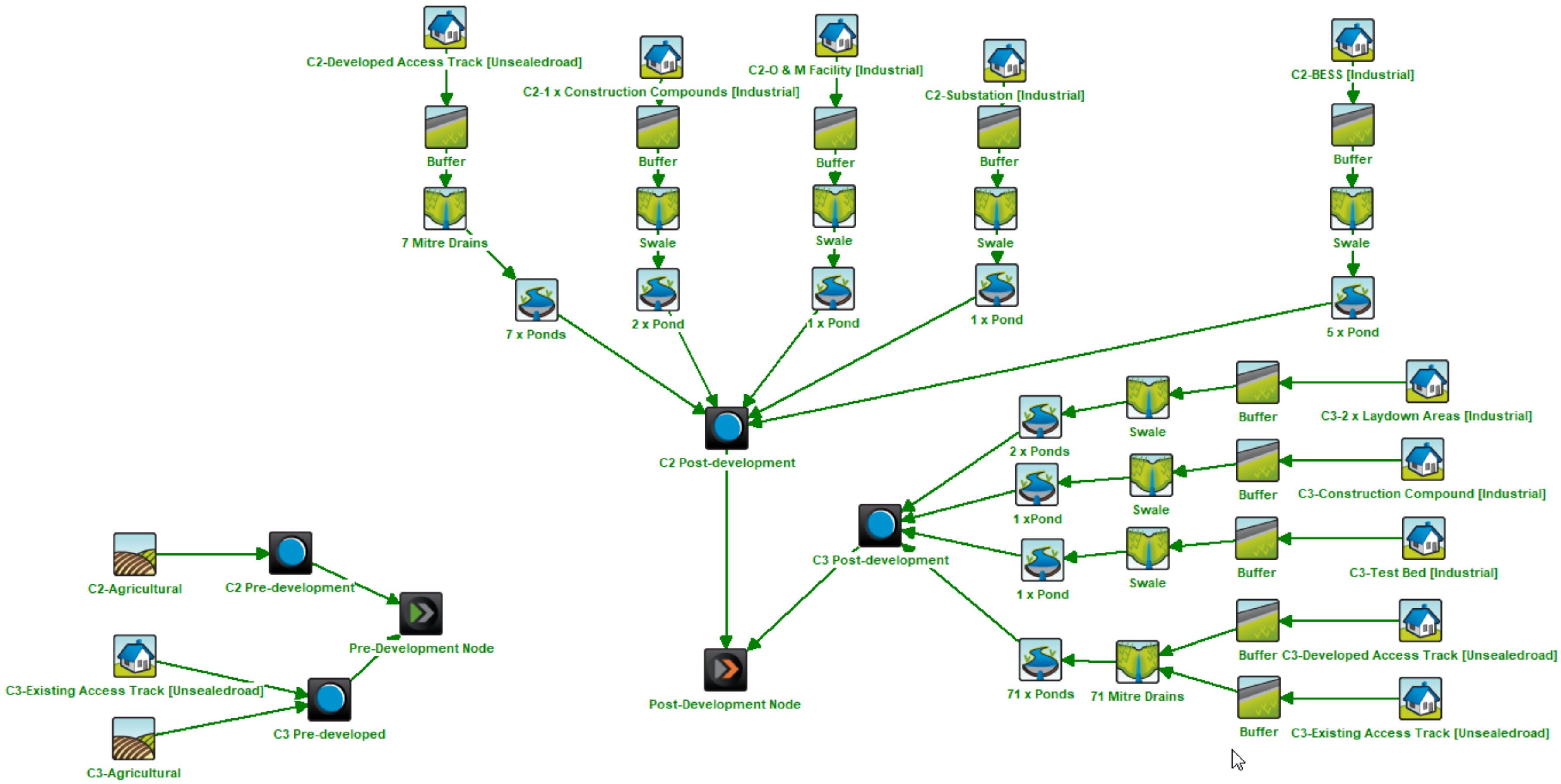

Figure 5-5 **MUSIC Model Configuration**

5.2.3 Source node parameters, areas and imperviousness

The modelled area is considered to be an agricultural land use, which is the source node in the water quality model. There are two soil types in the modelled area: Sodosols and Chromosols, which are based on the soil characteristic investigation by MineSoils. The soil types were identified in reference to the Australian Soil Classification (ASC) Scheme. The soil characteristics of the relevant sample location to the modelled area are presented in Table 5.3. Based on the survey results, the dominant soil types of the modelled area are sand, loamy sandy and clay.

Table 5.3 Soil type characteristics

Sample location	17	26	28	29	30
ASC Name	*Brown Sodosol*	*Brown Sodosol*	*Brown Chromosol*	*Brown Sodosol*	*Yellow Sodosol*
Permeability	Moderate	Moderate	Moderate	Moderate	Moderate
0.00 – 0.20	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand
0.20 – 0.40	Loamy Sand	Medium Clay (0.20 – 0.55)	Sand (0.20 – 0.40)	Sand (0.20 – 0.30)	Loamy Sand (0.20 – 0.30)
0.40 – 0.65	Heavy Clay	Decomposing parent material 0.55+	Light Clay (0.40 – 0.70)	Heavy Clay 0.3+	Medium Clay (0.30 – 0.65)

Tables 4.4 and 4.5 in the WaterNSW 2023 document show soil and groundwater parameters, including soil storage capacity, field capacity, and runoff. Table 5.4 below shows the adopted parameter for this study according to the investigated soil data. It is noted that as there are three main soil types within a 0.5m root depth zone in the modelled area, Per WaterNSW 2023 Section 4.1.3.2, sand has been adopted for the Pervious area parameters as it will result in a lower estimate of flow volume for the pre-development condition.

Table 5.4 Soil and groundwater parameters

Rainfall-Runoff Parameters	Values
Pervious area properties	
Soil Storage Capacity (mm)	175
Initial Storage (% of Capacity)	25 (default)
Field Capacity (mm)	74
Infiltration Capacity Coefficient - a	360
Infiltration Capacity Coefficient - b	0.5
Groundwater properties	
Initial Depth (mm)	10 (default)
Daily Recharge Rate (%)	100
Daily Baseflow Rate (%)	50
Daily Deep Seepage Rate (%)	0

Source: WaterNSW, 2023

Table 4.6 and Table 4.7 in the WaterNSW (2023) document provide the defaults mean base flow and storm flow pollutant concentration and standard deviation for the source nodes in the MUSIC model. The default pollutant generation parameters presented in Table 5.5 were applied in this study.

Table 5.5 Adopted MUSIC pollutant concentration parameters

Land use type	Parameter	Total suspended solids (Log_{10} mg/L)		Total phosphorus (Log_{10} mg/L)		Total nitrogen (Log_{10} mg/L)	
		Base flow	Storm flow	Base flow	Storm flow	Base flow	Storm flow
Agriculture	Mean	1.30	2.15	-1.05	-0.22	0.04	0.48
	Std Deviation	0.13	0.31	0.13	0.30	0.13	0.26
Unsealed road	Mean	1.20	3.00	-0.85	-0.30	0.11	0.34
	Std Deviation	0.17	0.32	0.19	0.25	0.12	0.19
Industrial	Mean	1.20	2.15	-0.85	-0.60	0.11	0.30
	Std Deviation	0.17	0.32	0.19	0.25	0.12	0.19

Source: WaterNSW, 2023

5.3 PRE-DEVELOPMENT MODEL CONFIGURATION

MUSIC modelling of the pre-development scenario was undertaken to estimate the discharged pollutant loads and stormwater discharge concentrations from each pre-development MUSIC node. Table 5.6 presents the MUSIC source nodes corresponding to pre-development land features. It also presents the surface types, and associated parameters applied to the pre-development features.

Table 5.6 MUSIC source node parameter for pre-development

Catchment/MUSIC Node	Existing Feature	Source Node	MUSIC Surface Type	Area (ha)	Effective Impervious Area	Rainfall Threshold (mm)
C2- Agricultural Land	Agricultural Land	Agricultural	-	25.10	0%	1.0
C3- Existing Access Track	Existing Access Track	Urban	Unsealed road	7.16	50%	1.5
C3- Agricultural Land	Agricultural Land	Agricultural	-	18.25	0%	1.0

5.4 POST-DEVELOPMENT MODEL CONFIGURATION

MUSIC modelling of the post-development scenario was undertaken to estimate the discharged pollutant loads and stormwater discharge concentrations that would be produced from each MUSIC node, with the proposed Project infrastructure included.

Stormwater treatment measures were included in the modelled post-development scenario. Table 5.7 presents the MUSIC source nodes corresponding to each Project Design Feature under post-developed conditions. It also presents the surface types, and associated parameters applied to the post-development infrastructure surfaces.

Figure 5-2 illustrates the modelled water quality boundaries and land use mapping for the post-development scenario. Figure 5-5 shows the MUSIC model configuration for post-development conditions.

Table 5.7 MUSIC source node parameter for post-development

Catchment/MUSIC Node	Project Design Feature	Source Node	MUSIC Surface Type	Area (ha)	Effective Impervious Area	Rainfall Threshold (mm)
C2- Construction Compound	1 x Construction Compounds	Urban	Industrial	1.05	25%	1.5
C2-O&M Facility	O&M Facility	Urban	Industrial	1.02	25%	1.5
C2-Substation	Substation	Urban	Industrial	5.70	40%	1.5
C2-BESS	BESS	Urban	Industrial	15.14	40%	1.5
C2- New Access track	New Access Track	Urban	Unsealed road	2.19	35%	1.5
C3-Existing Access Track	Existing Access Track	Urban	Unsealed road	7.16	50%	1.5
C3-New Access track	New Access Track	Urban	Unsealed road	9.30	35%	1.5
C3-Laydown Areas	2 x Laydown Areas	Urban	Industrial	5.19	25%	1.5
C3-Construction Compound	1 x Construction Compound	Urban	Industrial	1.63	25%	1.5
C3-Test Bed	Test Bed	Urban	Industrial	2.13	25%	1.5

5.4.1 Stormwater Treatment

The following stormwater treatment train is proposed for the development footprint under post-development conditions:

Existing and Proposed Access Tracks

- Vegetated buffer strips are proposed along the sides of the existing and proposed access tracks. Sheet flow runoff from the road will flow across the vegetated roadside strips removing coarse pollutants.
- Mitre drains are proposed at regular intervals along the proposed access tracks. Mitre drains will intercept concentrated flow from access track table drains and spread it out to level vegetated areas as sheet flow. This low velocity of sheet flow causes sediment to drop out. Mitre drains also provide a small amount of phosphorous reduction. A conservative estimate of a mitre drain every 50 m along existing and new access tracks is proposed. Each mitre drain is proposed to be 20m long with a base width of 0.5m, a top width of 1.5m, a depth of 0.3m and a vegetation height of 0.1m. The mitre drains have been modelled as a single treatment node with a total length calculated by multiplying the number of mitre drains by the proposed length of the mitre drain (No. of x 20m). Mitre drain spacing has been conservatively estimated based on Table 3-2 in Section 3.4.2 of the Water Sensitive Design Guide for Rural Residential Subdivision (WaterNSW, Feb 2023). Additionally, Access tracks should also be design in general accordance with *ARRB Unsealed Roads Best Practice Guide Edition 2* (ARRB, 2020).

- Small ponds are to be located at the end of each mitre drain. The ponds will promote settling of medium to coarse grained particles. The retention time within the pond ensures treatment of nutrients. Each pond is proposed to have a 2 m^2 surface area, a 3 m^3 pool volume, estimated 1 m^3 initial volume, and average depth of 1 m and a notional detention time of greater than 48 hours. If more than 1 pond is proposed the above parameters are multiplied by the number of proposed ponds.
- Table 5.8 outlines further details of this treatment train for the corresponding modelled nodes.

Construction Compounds, O & M Facility, Laydown Areas, Substation, BESS and Test Bed

- Vegetated buffer strips are proposed along the perimeter of the development footprint. Sheet flow runoff will flow across the vegetated strips removing coarse pollutants.
- Vegetated swale drains are to be located adjacent to buffer strips along the downstream side of the development footprint. The vegetated swales will convey and filter stormwater runoff through vegetation to remove coarse sediment and total suspended solids. Each vegetated swale drain is proposed to have a base width of 1 m, a top width of 5 m, a depth of 0.35 m and a vegetation height of 0.25 m. The length of each vegetated swale drain will vary. Refer to Figure 5-6 for typical swale layout.
- Ponds are to be located at low points at the end of the proposed vegetated swales. The ponds will promote settling of medium to coarse grained particles. The retention time within the pond ensures treatment of nutrients. Each pond is proposed to have a 78.5 m^2 surface area, a 170 m^3 pool volume, estimated 85 m^3 initial volume, and average depth of 1.5 m and a notional detention time of greater than 48 hours. If more than 1 pond is proposed the above parameters are multiplied by the number of proposed ponds. Refer to Figure 5-6 and Figure 5.7 for typical pond layout.
- Table 5.8 outlines further details of this treatment train for the corresponding modelled nodes.

Table 5.8 Stormwater Quality Treatment Measures for Post-development Conditions

Catchment/MUSIC Node	Treatment Train	Description/Parameters
C2 – One (1) x Construction Compound	Buffer → Swale → Pond	Swale drain with: ○ Total length of 412 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m <u>2 Ponds with:</u> ○ Total surface area of 157 m^2 ○ Each pond has an extended detention depth of 2m ○ Total Permanent Pool Volume of 340 m^3 ○ Initial Volume of 170 m^3

Catchment/MUSIC Node	Treatment Train	Description/Parameters
C2 – O & M Facility	Buffer → Swale → Pond	Swale drain with: ○ Total length of 108 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 1 Pond with: ○ Total surface area of 78.5 m^2 ○ Extended detention depth of 2m ○ Total Permanent Pool Volume of 170 m^3 ○ Initial Volume of 85 m^3
C2 - Substation	Buffer → Swale → Pond	Swale drain with: ○ Total length of 320 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 1 Pond with: ○ Total surface area of 78.5 m^2 ○ Extended detention depth of 2m ○ Total Permanent Pool Volume of 170 m^3 ○ Initial Volume of 85 m^3
C2 - BESS	Buffer → Swale → Pond	Swale drain with: ○ Total length of 1243 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 5 Ponds with: ○ Total surface area of 392.5 m^2 ○ Each pond has an extended detention depth of 2m ○ Total Permanent Pool Volume of 850 m^3 ○ Initial Volume of 425 m^3
C2 - New Access track	Buffer → Mitre Drains → Pond	7 Mitre Drains with: ○ Total length of 140 m ○ Equates to 1 Mitre Drain every 50 m ○ Base with 0.5 m; Top width 1.5 m; Depth of 0.3 m; Vegetation height of 0.1 m 7 Ponds with: ○ Total surface area of 14 m^2 ○ Each pond has an extended detention depth of 2m ○ Total Permanent Pool Volume of 21 m^3 ○ Initial Volume of 7 m^3

Catchment/MUSIC Node	Treatment Train	Description/Parameters
C3 - Existing Access Track & C3 - New Access track	Buffer → Mitre Drains → Pond	71 Mitre Drains with: ○ Total Drain length of 1,420 m ○ Equates to 1 Mitre Drain every 50 m ○ Base with 0.5 m; Top width 1.5 m; Depth of 0.3 m; Vegetation height of 0.1 m 71 Ponds with: ○ Total surface area of 142 m^2 ○ Each pond has an extended detention depth of 2m ○ Total Permanent Pool Volume of 213 m^3 ○ Initial Volume of 71 m^3
C3 – Two (2) x Laydown Areas	Buffer → Swale → Pond	Swale drain with: ○ Total length of 863 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 2 Ponds with: ○ Total surface area of 157 m^2 ○ Each pond has an extended detention depth of 2m ○ Total Permanent Pool Volume of 340 m^3 ○ Initial Volume of 170 m^3
C3 - Construction Compound	Buffer → Swale → Pond	Swale drain with: ○ Total length of 357 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 1 Pond with: ○ Total surface area of 78.5 m^2 ○ Extended detention depth of 2m ○ Total Permanent Pool Volume of 170 m^3 ○ Initial Volume of 85 m^3
C3 - Test Bed	Buffer → Swale → Pond	Swale drain with: ○ Total length of 317 m ○ Base with 1 m; Top width 5 m; Depth of 0.5 m; Vegetation height of 0.25 m 1 Pond with: ○ Total surface area of 78.5 m^2 ○ Extended detention depth of 2m ○ Total Permanent Pool Volume of 170 m^3 ○ Initial Volume of 85 m^3

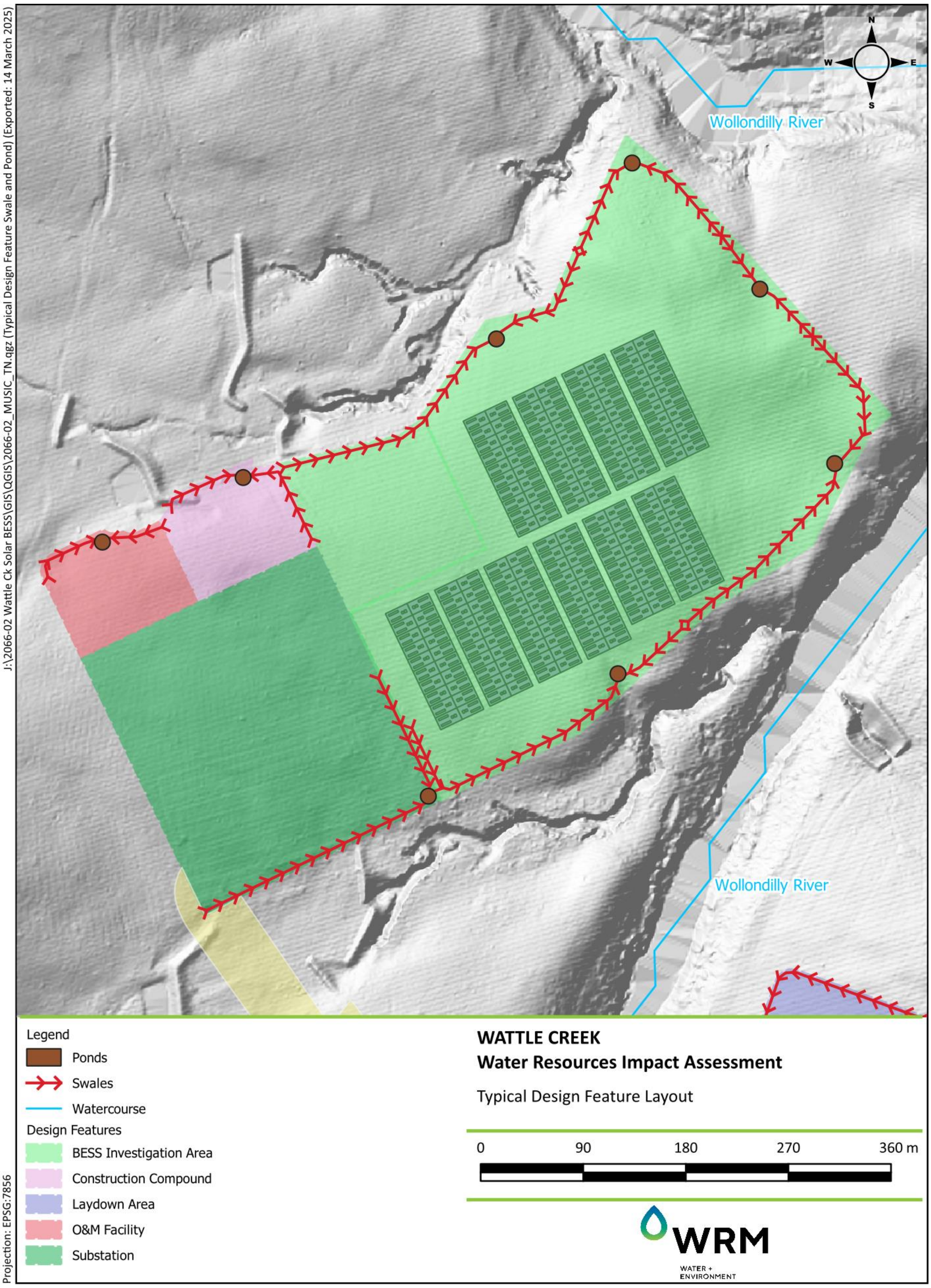

Figure 5-6 Typical Design Feature Swale and Pond layout 1

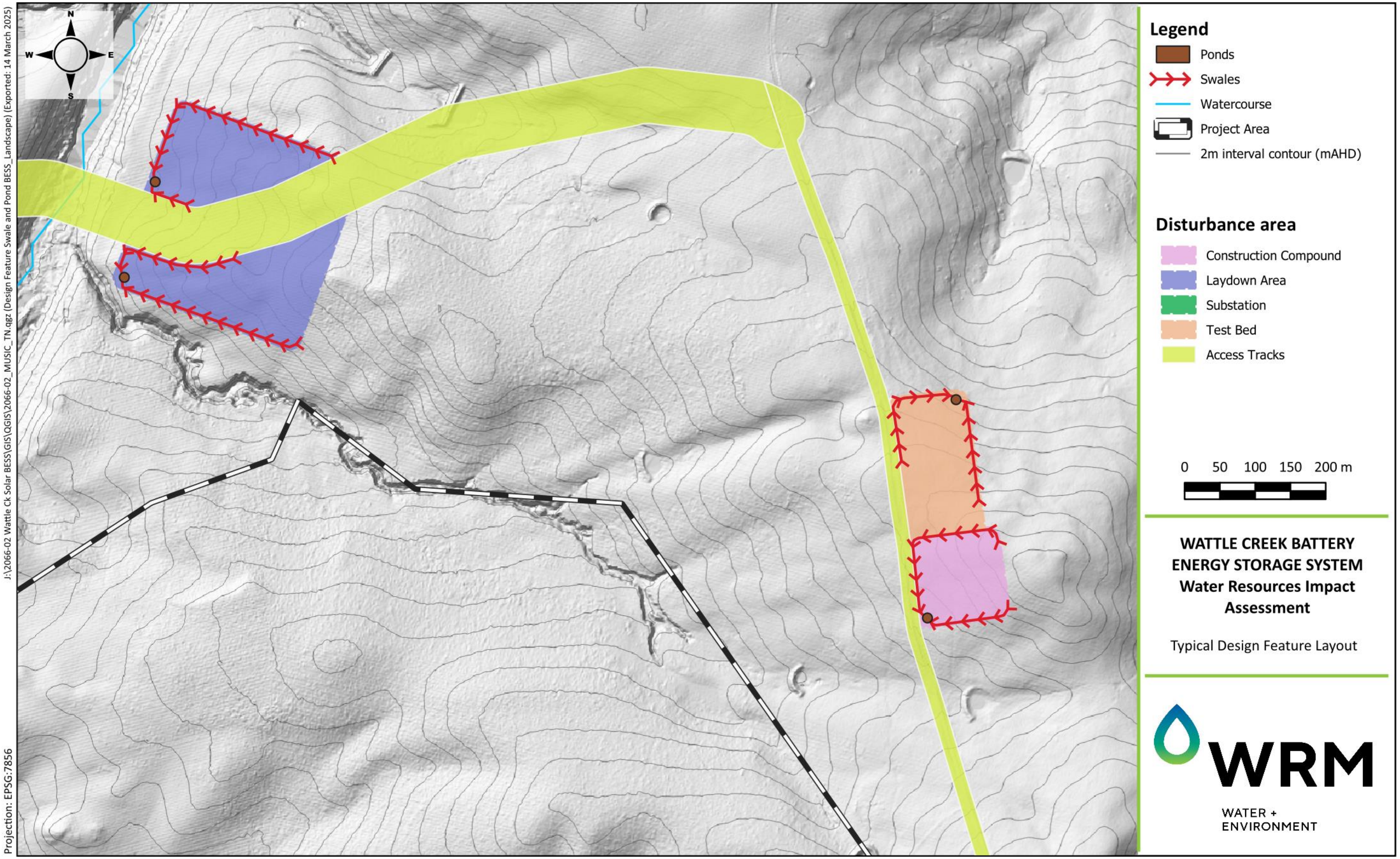

Figure 5.7 Typical Design Feature Swale and Pond layout 2

5.5 WATER QUALITY MODELLING RESULTS

5.5.1 Pollutant Loads

Table 5.9 presents a comparison of the modelled mean annual pollutant loads for the pre- and post-development (with treatment) scenarios, including the estimated percentage reduction in pollutant loads. Modelling predicts reductions in annual pollutants loads for TSS and Gross Pollutants. These reductions surpass the NorBE requirement for a 10% beneficial impact and are therefore NorBE compliant.

While a reduction in TP is predicted the reduction does not meet the NorBE requirements. The MUSIC modelling of the post-development scenario also expects there would be an increase in annual pollutant loads for TN. A reduction in TN and TP could be achieved through the construction of tertiary treatment measures - such as bio-retention basins or constructed wetlands. Table 5.1 within WaterNSW (2023) specifies the suitability of treatment measures. Bio-retention basin are indicated to be unsuitable due to the scale of this Project. For the scale of this Project constructed wetlands are suitable, however the use of such measures is not feasible given the Project Area not possessing large and level expanses for its construction. Additionally, Section 3.5.2 (WaterNSW, 2023) requires a constructed wetland to be located outside of the 2% AEP flood envelope.

At present, the land usage of the Project Area comprises cropping and grazing. Both activities would involve application of fertilizers and the biological fixation of nitrogen. Within the post-development scenario, sources of nitrogen would remain unchanged, or would be lower due to the construction of infrastructure. Therefore, TN predicted by the MUSIC model's parameter set appears to be demonstrating an overly low pre-development quantity, and possibly an over-estimated TN load for post-development conditions. This anomaly should be investigated further prior to implementation of tertiary treatment trains.

Should further treatment train measures be required to satisfy NorBE criteria for TN and TP, it is recommended that Project stormwater treatment measures be considered during the detailed design phase with a refined MUSIC model that reflects the detailed Project design.

Table 5.9 WQ Study Area Comparison: Mean Annual Pollutant Loads

Pollutant	Pre-development (kg/year)	Post-development (kg/year)	Difference	Load Reduction	Neutral or beneficial effect
TSS	27,300	2,810	-24,490	90%	True
TP	17.1	16.5	-0.60	4%	False
TN	109	196	87	-	False
Gross Pollutants	847	0	-847	100%	True

5.5.2 Pollutant Concentrations

Figure 5-8, Figure 5-9 and Figure 5-10 present comparisons of the predicted TSS, TP and TN concentrations, respectively, for the pre- and post-development (with treatment) scenarios and indicate:

- TSS concentrations are equal or better for the post-development scenario between the 5th and 98th percentile. Post-development TSS concentrations achieve the NorBE criteria.

- Post-development TP concentrations do not achieve the NorBE criteria of being better than the pre-development scenario between the 50th and 98th percentiles. TP concentrations are better for the post-development scenario above the 60th percentile result.
- Post-development TN concentrations do not achieve the NorBE criteria of being better than the pre-development scenario between the 50th and 98th percentiles. TN concentrations are better for the post-development scenario above the 80th percentile result.

As such, additional treatment train measures may be required to satisfy NorBE criteria for TN. Additional Project stormwater treatment train measures should be considered during the Project's detailed design phase with a refined MUSIC model that reflects the detailed Project design.

Figure 5-8 Pre-development and Post-development Comparison: Predicted TSS Concentrations

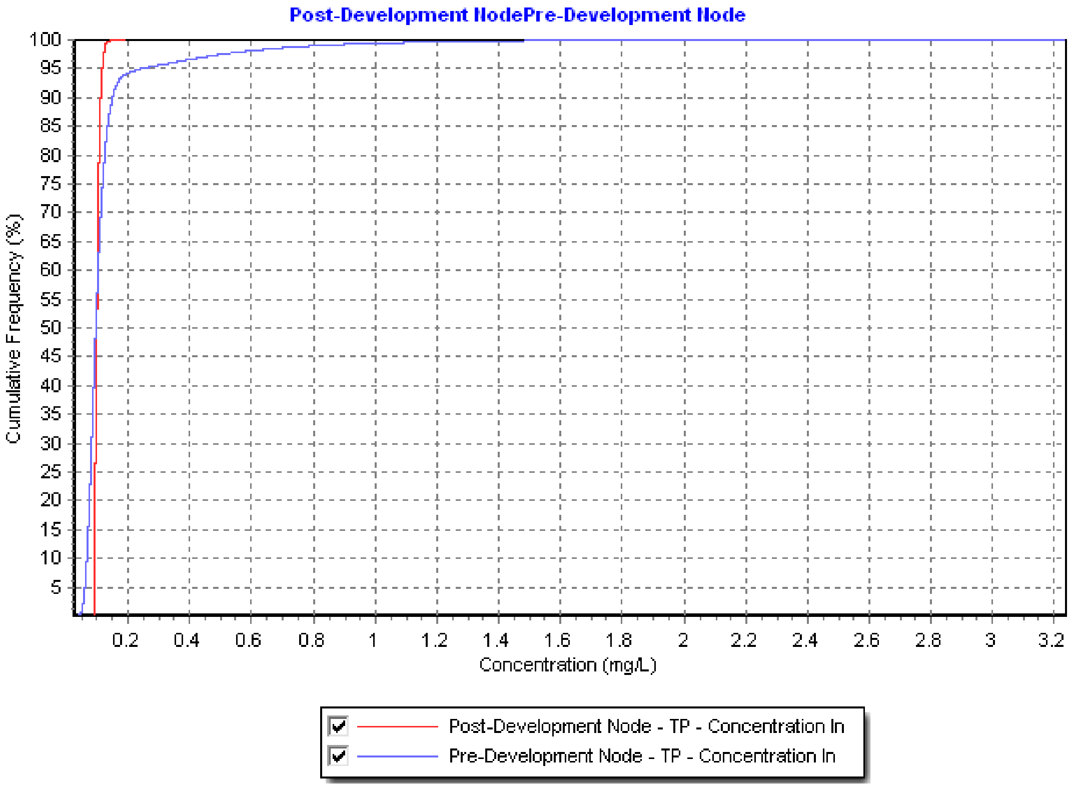

Figure 5-9 Pre-development and Post-development Comparison: Predicted TP Concentrations

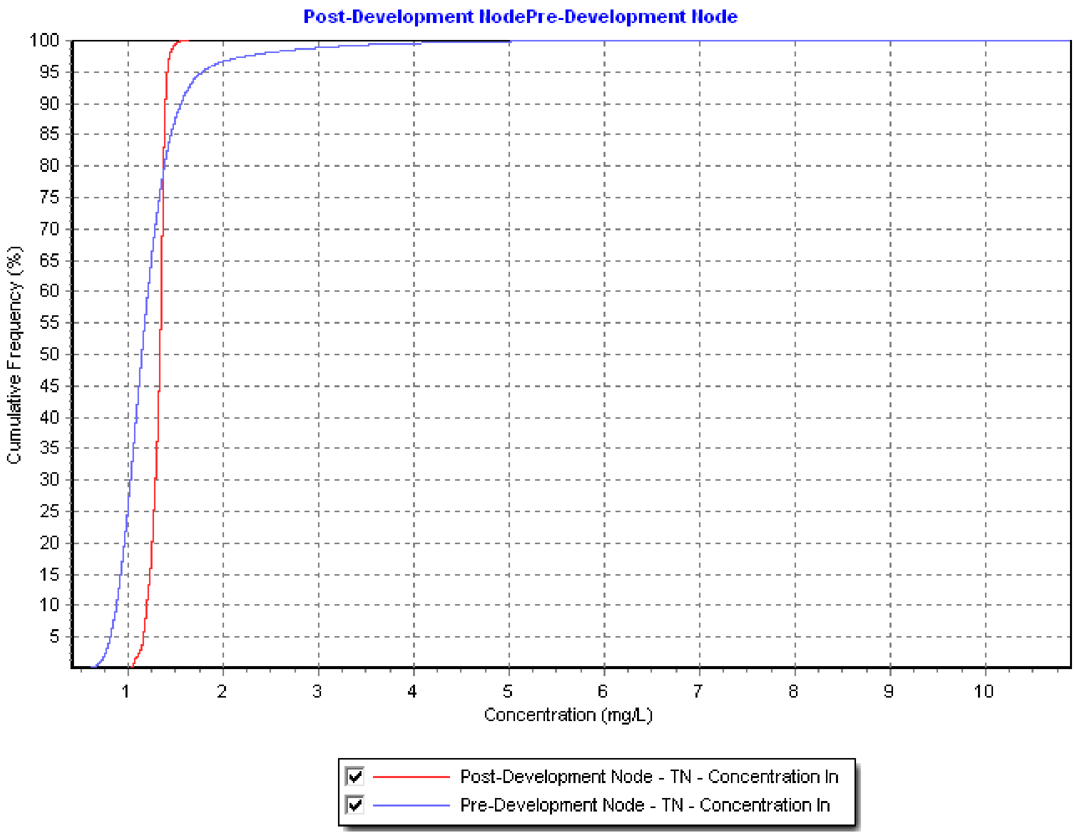

Figure 5-10 Pre-development and Post-development Comparison: Predicted TN Concentrations

6 EXISTING FLOOD BEHAVIOUR

6.1 MODELLING APPROACH

The flood modelling aimed to assess the current climate flood behaviour within the Project Area to inform siting of flood vulnerable infrastructure and assessment of Project impacts. The 2023-03-AC version of the two-dimensional TUFLOW hydrodynamic model (BMT, 2018a) was used to simulate the flow behaviour in the vicinity of the Project Area for the 10%, 1%, 0.5% (1 in 200) and 0.2% (1 in 500) AEP and the Probable Maximum Flood (PMF) for the current climate.

It is noted that the 0.5% and 0.2% AEPs are modelled as proxies for sensitivity to an increase in rainfall intensity of flood-producing rainfall events due to climate change, in accordance with the recommended SEARs from NSW BCD.

There is no recorded water level data or anecdotal information within the Project Area, so model calibration was not possible.

Model topography was based on a 2-metre Digital Elevation Model (DEM) supplemented by a 5-metre DEM, both available from the ELVIS (Elevation Information System) portal. The model grid size was 15 m. Combined with TUFLOW's sub-grid sampling (SGS) functionality, the 15 m model grid size provided adequate resolution to capture key drainage features and overland flow paths, while maintaining reasonable simulation times.

Inundation within the Project Area could occur exclusively or as a combination of three mechanisms:

- Site runoff: Short duration (< 30 minutes) intense rain falling directly on the Project Area;
- Local catchment flooding: Medium duration (1 hour – 6 hours) rain falling on land draining to the Project Area;
- Regional flooding: Long duration (> 6 hours) from rainfall falling on the Wollondilly River, Jaorimin Creek, Paddys River, and Long Swamp Creek catchments, all upstream of the Project Area.

Site runoff and local catchment flooding were modelled using a direct rainfall model to determine the extent of the surrounding sub-catchments draining to the Project Area. The hydraulic model domain was defined by the extent of rainfall assessed as likely to reach the Project Area. This ensured that model run times and file sizes provided optimal local catchment flood behaviour coverage.

The modelled flood events are indicative of conditions as outlined below:

- 10% AEP event – representative of a frequent-rare flood event.
- 1% AEP event – representative of the principal flood planning event.
- 0.5% and 0.2% AEP events represent a future climate's 1% AEP flood risk.
- PMF – representative of the extreme flood event. This is based on the probable maximum precipitation (PMP) estimate and has no design event probability.

Regional catchment flooding was modelled using external inflow boundaries. Due to the size of the Wollondilly River catchment (2106 km^2) reaching the Project Area and the preliminary nature of this study, a hydrological model of the Wollondilly River catchment was not developed. Instead, representative Wollondilly River flows were informed by the nearby regional Goulburn Mulwaree flood study report (GRC Hydro, 2022), which provided flood frequency analysis of Wollondilly River flows at Murrays Flat (1606 km^2). The following approach to these three sources of flooding within the Project Area was conservatively estimated using the following approach:

- The regional Wollondilly River flow estimate was based on the 1% AEP peak flow estimated at the Murrays Flat in the GRC Hydro 2022 flood frequency assessment);

- Catchment flows downstream of the Murrays Flat gauge (Jaorimin Creek, Paddys River, Long Swamp Creek) were input based on the Regional Flood Frequency estimation method, which determined 1% AEP flows based on their area.

6.2 REGIONAL WOLLONDILLY RIVER FLOWS

Design flows in the Wollondilly River at the upstream inflow boundary were estimated by applying the 1% flood frequency analysis derived and provided by GRC Hydro (2022) for the Murrays Flat gauge, as shown in Table 6.1. The flow rate of 1550 m^3/s estimated for the Wollondilly River was applied as a constant inflow boundary. Other estimates for Wollondilly River flood flows at Goulburn are shown in Table 6.1.

Table 6.1 Historical Flood Frequency Estimate for Wollondilly River

AEP (%)	Wollondilly River at Murrays Flat[7] (1606 km^2)	Wollondilly River at Golden Valley (2106 km^2)	Wollondilly River at Goulburn[8] (741 km^2)	Wollondilly River at Goulburn[10] (741 km^2)
	GRC Hydro 2022 (m^3/s)	RFFE[9&] (m^3/s)	WMA 2016 Study (m^3/s)	SMEC 2003 study (m^3/s)
10%	680	489	312	428
5%	920	706	487	648
2%	1280	1070	935	1026
1%	**1550^**	1430	1114	1415
0.5%	1800	-	1298	1868
0.2%	2180	-	-	-
PMF	17,151	-	11,032	-

^ This value was used as the flow in the Project Area at the Wollondilly River

[7] Source: Table C-5 Wollondilly Design Flows (GRC Hydro, 2022)

[8] Source: (WMA Water, 2016) Does not include flows in Mulwaree River

[9] Source: RFFE-2021.wmawater.com.au Shown for comparative purposes with GRC Hydro 2022. RFFE is used for estimating smaller catchment inflows to the east of Project Area

6.3 TRIBUTARY CATCHMENT FLOWS

Catchment flows for tributaries downstream of the Murrays Flat gauge (Jaorimin Creek, Paddys River, Long Swamp Creek) were input based on the Regional Flood Frequency Estimation[10] (RFFE) method. The RFFE method determines the 1% AEP flows based on the catchment's area, centroid and outlet location and the rainfall estimates for the 50% and 2% AEPs. The remaining catchment areas arriving at the Project Area's model domain and RFFE tributary flows are shown in Table 6.2. The locations of these catchments are shown in Figure 6-1.

Table 6.2 Catchment areas below Murrays Flat reaching Project Area model domain

Catchment	Catchment Area	URBS 10%	1%	0.5%	0.2%
Long Swamp Creek	40 km^2	180	216	231	258
Jaorimin Creek	53 km^2	205	247	264	319
Paddys River	179 km^2	508	615	659	739
Wollondilly River at Jaorimin Creek	1827 km^2	936	3017	3543	5878

[10] rffe-2021.wmawater.com.au

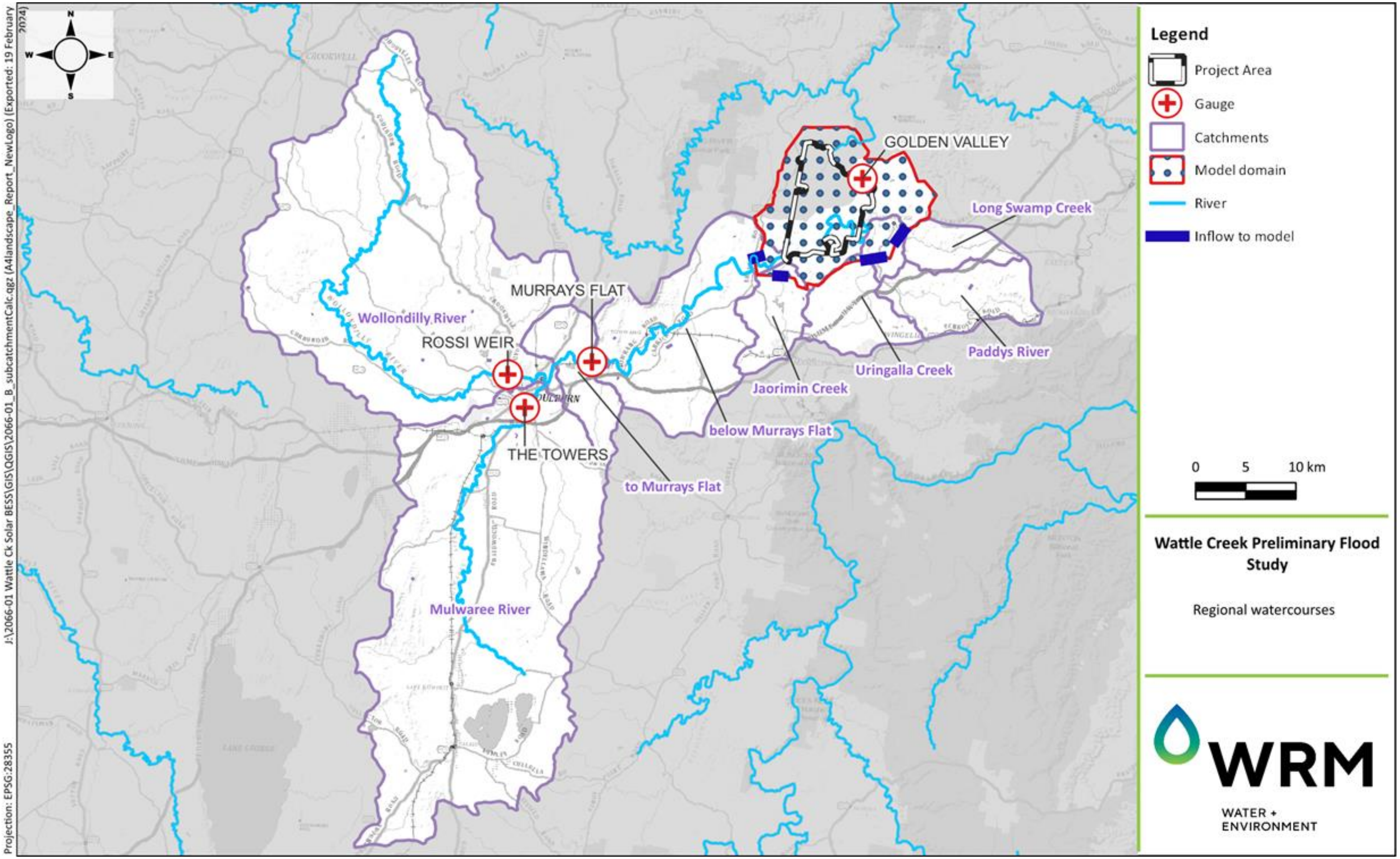

Figure 6-1 Regional catchment flows to Project Area

6.4 LOCAL CATCHMENT DESIGN EVENTS

Design rainfall depth data, design losses, and storm pre-burst details were obtained from the Australian Rainfall and Runoff (ARR) datahub in accordance with the current ARR guidelines. Preliminary TUFLOW hydraulic model runs for a range of durations and temporal patterns were used to identify the critical storm duration for the Project Area and relevant design storm temporal patterns. Design flows were estimated by applying design rainfall directly to the TUFLOW model grid. Details of the process and inputs are provided in the following sections.

Design event modelling results were post-processed to derive design flood parameters (e.g. peak flood depths and extents) for each AEP and design scenario.

6.4.1 Design Rainfall and Losses

Design rainfall depths were obtained from Design Rainfall Data System[11] based on a single point location at the centroid of the Project Area. These depths are summarised in Table 6.3, no areal reduction factors were applied to the design rainfalls for the local catchment investigation. This approach is considered conservative for the purpose of this study.

Estimation of initial and continuing loss rates is provided in ARR 2019 as accessed through the online datahub. The suggested probability-neutral losses for initial losses were adopted. The adopted initial and continuing losses are provided in Table 5.4 and Table 5.5. These losses are relevant to the pervious catchment areas noting that there is no significant proportion of impervious area within the modelled catchments.

Table 6.3 Design Rainfall Depths (mm) for Various Event Durations and AEPs

Duration (hrs)	Design rainfall depths (mm)				
	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
0.5	18.2	20.7	24.1	26.6	28.6
1	24.3	27.4	31.5	34.6	37.1
2	31.3	34.9	39.7	43.2	46.1
3	36.8	40.9	46.3	50.3	53.3
6	52	58.7	67.4	74	79
9	64.9	74	85.8	95	101.6
12	75.9	86.9	101.1	112.2	119.6
18	95.5	111.1	130.2	144.6	156.2
24	113.1	131.3	156	175	189.2

Source: BOM.gov.au

[11] http://www.bom.gov.au/water/designRainfalls/revised-ifd/

Table 6.4 PMP Design Rainfall Depths (mm) for Various Event Durations

Duration (min)	PMP Depth	Derivation Method
60	260	GSDM
120	380	GSDM
180	460	GSDM
270	550	GSDM
360	610	GSDM
540	640	-*
720	690	-*
1080	720	-*
1440	790	GSAM
2160	880	GSAM
2880	930	GSAM
4320	980	GSAM
5760	1010	GSAM

*Line of best fit to distribution curve of GSDM and GSAM rainfalls.

6.4.2 ARR datahub

Recommended design rainfall parameters were based on current ARR guidelines (referred to as ARR 2019) (Ball et al., 2019), available from the ARR Data Hub portal[12]. Key design rainfall parameters include:

- Initial and continuous loss rates;
- Design storm pre-burst depths;
- Areal reduction factors; and,
- Design storm temporal patterns.

6.4.3 Design rainfall losses and pre-burst rainfall

The storm initial loss (IL) and continuing loss (CL) methods of accounting for rainfall losses were adopted based on ARR Data Hub recommendations. The initial loss (IL) and continuing loss (CL) were adopted with median pre-burst depths obtained from the data hub to adjust the initial loss with 1% AEP.

IL and CL losses were derived by interpolating between rainfall losses adopted for infrequent events (up to 1% AEP), noting that:

- Initial Losses (ILs) for infrequent events were derived based on the Probability Neutral Burst ILs provided by ARR datahub. This approach results in a unique Initial Loss for each duration,

[12] https://data.arr-software.org/

- Continuing losses (CLs) for infrequent events were derived based on the suggested data hub and regional flood study CLs.

Table 6.5 provides the initial and continuing losses for the 1% AEP event rainfall losses. Table 6.6 provides the Probability Neutral Burst Initial Loss values referred to by Table 6.5.

Table 6.5 Losses Used in the Hydraulic Model

Losses	Infrequent (to 1% AEP)	Rare (>1% AEP)	PMF
Initial loss (mm)	Probability Neutral Burst Initial Loss	Probability Neutral Burst Initial Loss	0
Continuing loss (mm/h)	1.4	1.4	1

Source: BOM.gov.au

Table 6.6 Probability Neutral Burst Initial Loss

Storm duration (hrs)	Probability Neutral Burst Initial Loss (mm)
	1% AEP
0.5	8.9
1	7.2
2	5.6
3	5.9
6	3.7
9	3.5
12	3.4
18	3.3
24	5.1

Source: ARR2019 datahub

6.4.4 Temporal Patterns

Temporal patterns are the distribution of the total rainfall in different periods within a given duration. The suite of ten (10) temporal patterns appropriate to the Project Area were downloaded from ARR2019 datahub and used to simulate the temporal distribution of rainfall depths during each storm duration modelled. The suite of temporal patterns has been applied to estimate the critical design event for flood estimation in accordance with ARR 2019 procedures.

6.4.5 Critical Storm Durations

A range of storm durations and temporal patterns were simulated using the TUFLOW model (ARR 2019 inputs) to identify the critical storm duration and temporal pattern results that provide the design peak discharges at the Project Area. Critical durations varied across the model domain depending on the size of the upstream catchment. The critical duration and temporal pattern for the 1% AEP storm flowing from the Project Area into the Wollondilly River is 12 hour duration and temporal pattern 8.

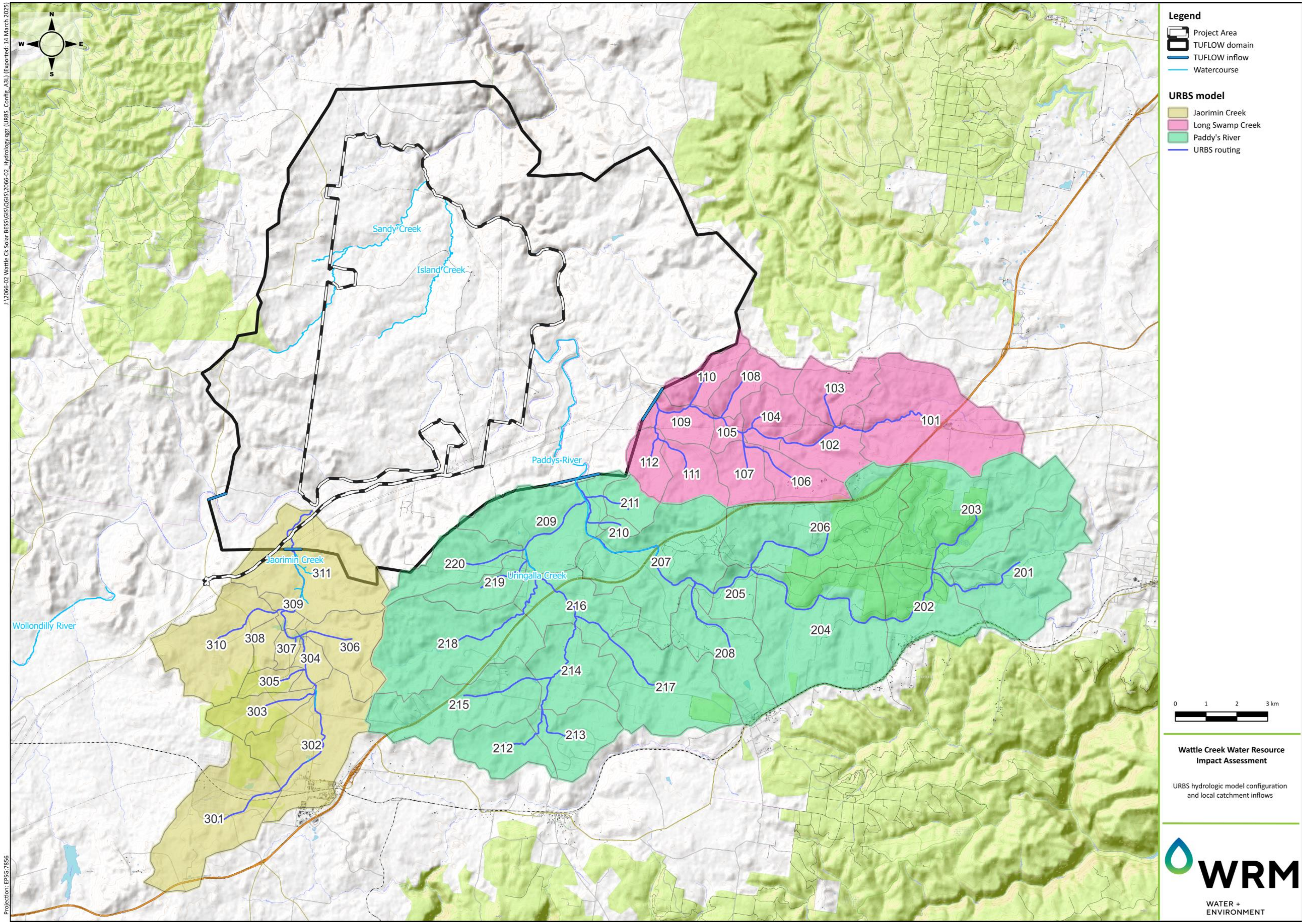

Figure 6-2 Local Catchment Inflows

6.5 HYDRAULIC MODELLING

6.5.1 Topography and grid cell size

The 2 m and 5 m topographic data obtained from the Elvis database were adopted as the base model topography. For hydraulic modelling, a 15 m grid size resolution was adopted. In combination with TUFLOW's sub-grid sampling (SGS) functionality, the 15 m cell size provides adequate resolution to capture key drainage features and overland flow paths while maintaining reasonable simulation times.

6.5.2 Boundary conditions

Figure 6-3 shows the locations of inflow and outflow boundaries in the local catchment TUFLOW model. The model includes:

- A direct rainfall boundary covering the entire hydraulic model extent;
- Four (4) total inflow boundaries representing the regional inflows from the Wollondilly River Jaorimin Creek, Paddys River, and Long Swamp Creek;
- One (1) downstream outflow boundary.

Normal flow (HQ) type boundary conditions were implemented for the downstream model boundaries. A normal depth rating curve controls the flow through the downstream boundaries. The downstream boundaries of the models were set well downstream of the Project Area to minimise the influence on flood behaviour predicted near the Project Area. The downstream boundary conditions assumed a normal depth slope of 0.008 m/m, calculated from the river water surface slope. This normal depth slope is typical of the water surface slopes.

6.5.3 Hydraulic resistance

The TUFLOW model represents hydraulic resistance using Manning's 'n' values. Analysis of available aerial imagery showed five (5) general land use classifications of relevance in the vicinity of the Project Area. Adopted Manning's 'n' values for each land use classification are listed in Table 6.7. The spatial discretisation of roughness values in the Study Area is shown in Figure 6-4.

Depth varying Manning's 'n' values were adopted as recommended by the TUFLOW manual for the direct rainfall (rain on grid) approach. For flood depths up to 100 mm, hydraulic roughness values are linearly interpolated by the TUFLOW software. The spatial discretisation of roughness values in the Study Area is shown in Figure 5.2. Light vegetation was used as the default roughness for areas not covered by a material layer in Figure 5.2.

Table 6.7 Depth-Varying Manning's Roughness used in the Hydraulic Model

Land Use	Manning's 'n'	
	Depth < 100 mm	Depth > 100 mm
Active channel with light vegetation	0.080	0.035
Light vegetation/grass	0.080	0.045
Medium vegetation/rural res	0.080	0.060
Dense vegetation/residential	0.080	0.080
Waterbody/dam/paved surface	0.080	0.020

6.5.4 Hydraulic structures

No hydraulic structures were included in the model.

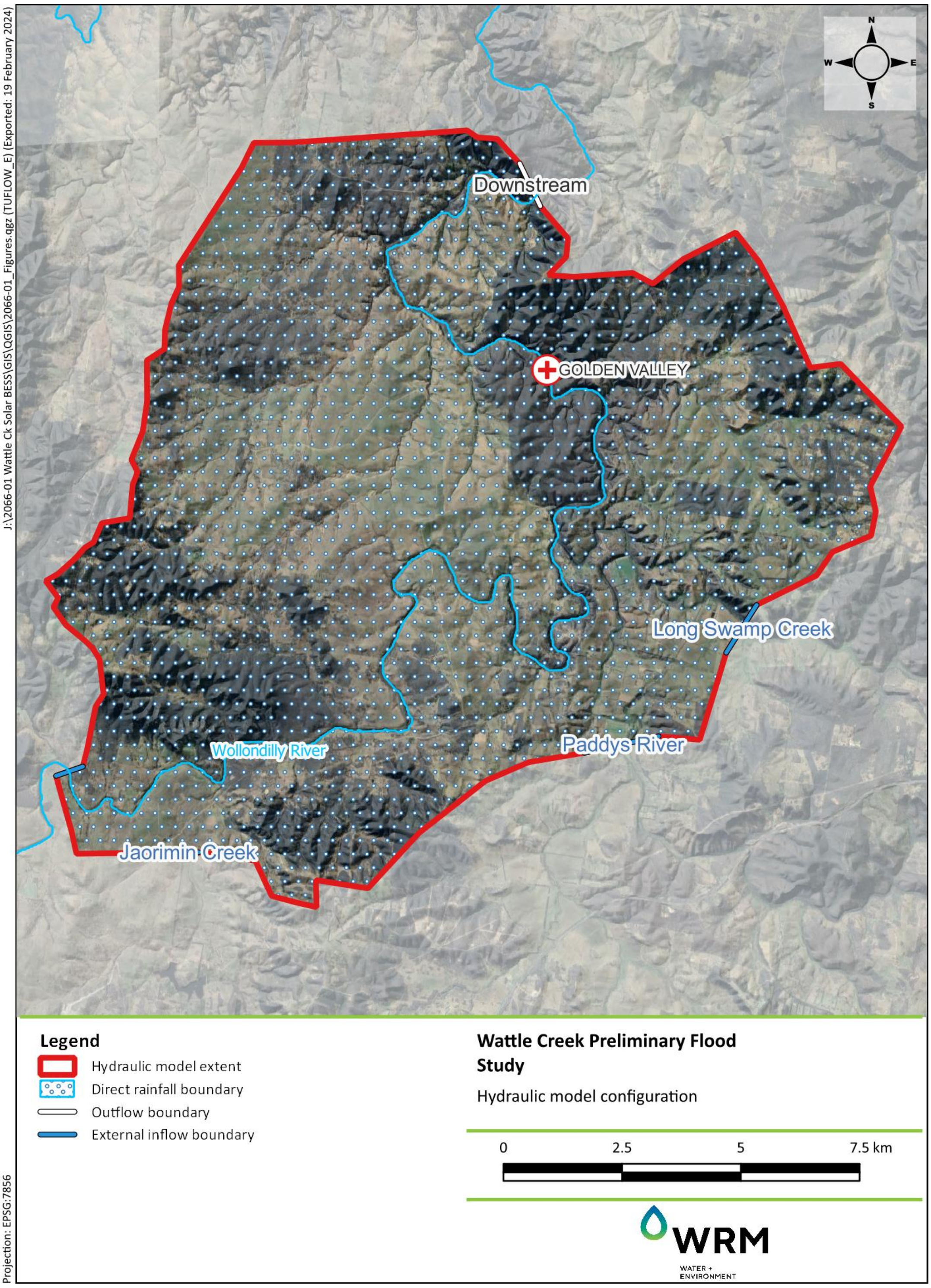

Figure 6-3 TUFLOW hydraulic model configuration

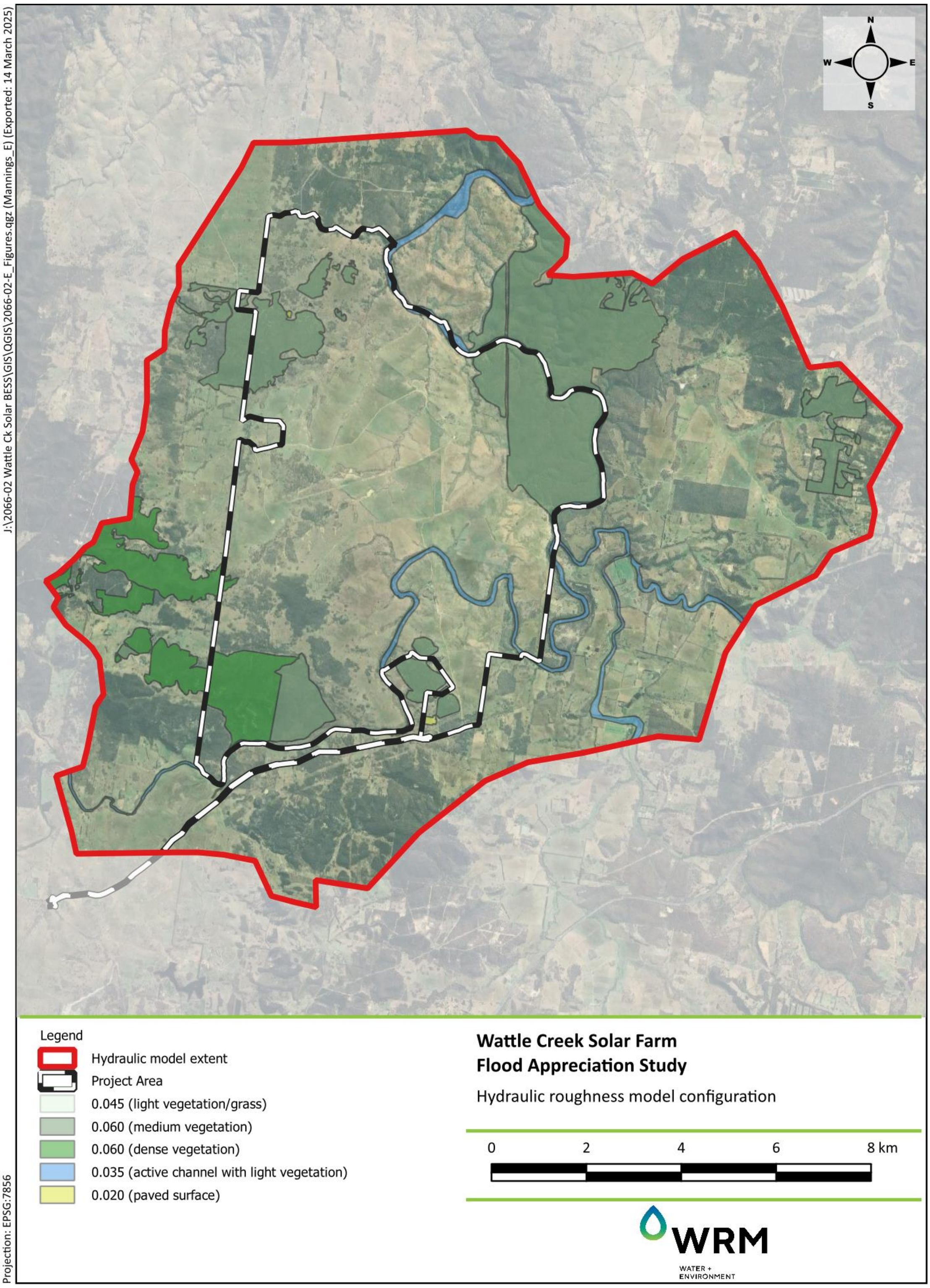

Figure 6-4 TUFLOW hydraulic model roughness configuration

6.6 EXISTING FLOOD BEHAVIOUR

6.6.1 Overview

The flood model results show peak flood levels, depths, velocities and hazards across the Project Area for each modelled design magnitude flood event. Due to the nature of the direct rainfall model results, areas where the modelled flood depths are less than 50 mm have been filtered from the results. Note that this does not affect the hydraulic computations.

The suite of detailed flood mapping of the simulated depth, velocity and flood hazard distributions for all modelled events is provided in Appendix B. The figures show that the peak flood extent is primarily confined to the watercourse alignments, with some moderate inundation beyond the channel corridors.

The modelled flood events are indicative of conditions as outlined below:

- 10 % AEP event – representative of an infrequent flood event;
- 1 % AEP event – representative of a rare event and forming the principal flood planning event;
- 0.5 % and 0.2 % AEP events – representative of extreme events and indicative of the 1% AEP event including climate change; and
- PMF – representative of the probable maximum flood event.

6.6.2 Flood Hazard

The flood hazard in the Project Area was assessed in accordance with ARR 2019. Flood hazard (or hydraulic hazard) defines the nature of a flood for a specific event, for example, depth, depth x velocity and velocity. ARR 2019 adopted the combined flood hazard classification based on research presented in the *Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017). The flood hazard categories, according to the AIDR definition, are summarised in the Table 6.8 and flood hazard colour-coded curves are shown in Figure 6-5. The flood hazard mapping is provided in Appendix B**.**

Table 6.8 Hazard Classification (AIDR, 2017)

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)	Description
H1	D*V ≤ 0.3	0.3	2.0	Generally safe for vehicles, people and buildings.
H2	D*V ≤ 0.6	0.5	2.0	Unsafe for small vehicles.
H3	D*V ≤ 0.6	1.2	2.0	Unsafe for vehicles, children, and older people.
H4	D*V ≤ 1.0	2.0	2.0	Unsafe for vehicles and people.
H5	D*V ≤ 4.0	4.0	4.0	Unsafe for vehicles and people. All buildings are vulnerable to structural damage. Some less robust buildings are subject to failure.
H6	D*V ≥ 4.0	-	-	Unsafe for vehicles and people. All building types are considered vulnerable to failure.

Source: AIDR, 2017

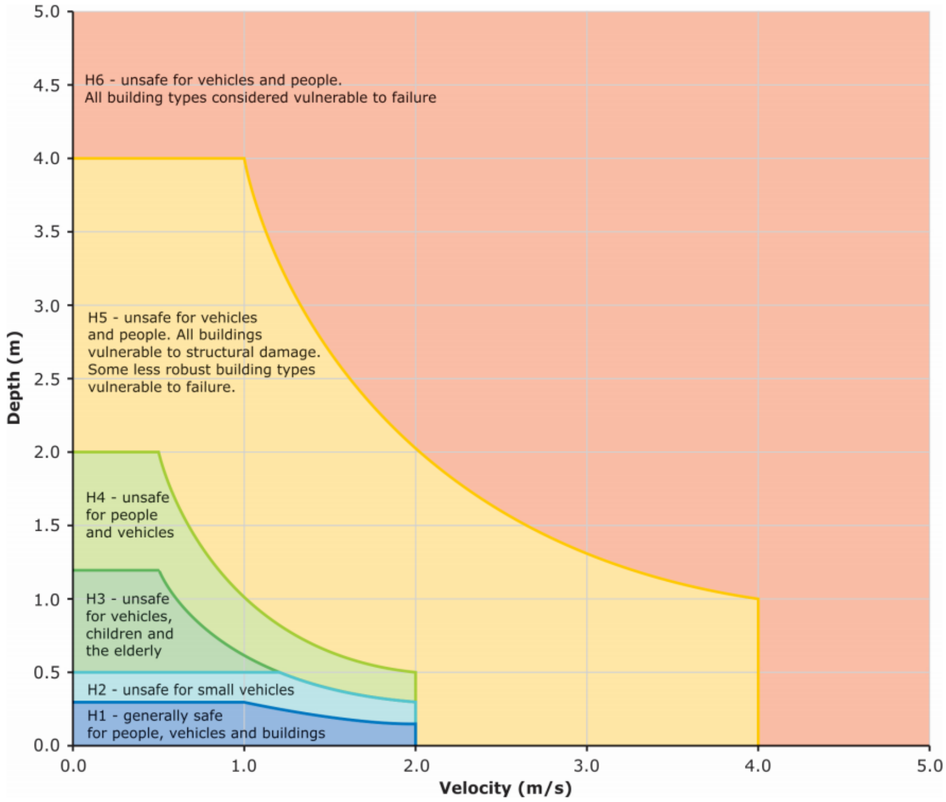

Figure 6-5 Combined Flood Hazard Curves

Source: Smith et al. 2014

6.6.3 Design Flood Events

The modelled flood behaviour within the hydraulic model's domain is shown in Figure 6-3. The flood modelling results are discussed below, and the mapped results are available in Appendix B. These flood maps show overland flow paths. For clarity, minor shallow depths (< 50mm) were removed from the maps. This depth would normally be managed via stormwater infrastructure. The purpose was a preliminary investigation to appraise flood risk that can inform the layout of site infrastructure.

The flood mapping indicates the presence of numerous watercourses, including Island Creek, which are considered areas of higher flood hazard. The installation of infrastructure should occur in areas mapped with tolerable depths and/or velocities. As such, the avoidance of flood impacts could be best be achieved by a waterway corridor buffer. The resulting output grids are statistically analysed to generate maximum water surface (depth) and velocity values from the median from the ensemble of temporal patterns from each set of storm durations. Summary observations about flood behaviour are as follows:

- 10% AEP: Results show the water is confined to the watercourses throughout the Project Area. The active flow paths through the Project Area are shallow and confined within the watercourses and local depressions. General overland flood flow depths outside the primary waterway alignments are typically shallow at less than 0.1 m. The greatest depths within the watercourses within the Project Area are up to 1.2 m. Depths within the Wollondilly River are greater than 2.5 m. No bathymetric survey for the reach of Wollondilly River through the Project Area was available, and so these may be deeper still.

- 1% AEP: Within the Project Area the flood inundation extents have increased from the 10% AEP event. The depths, velocities and hazards have increased associated with the higher flows. The flooding of the Wollondilly River has increased at the river bank, but it has remained confined with no breakout flow paths being created. The development footprint has minimal to low flood hazard predicted. Flood depths have increased and are reaching around one metre in depth near to natural depressions and existing farm dams. Flood hazard remains low throughout the Project Area.
- 0.5% AEP and 0.2% AEP: The flood depths have become much more significant within the Wollondilly River. Flows are encroaching and breaking out of the river banks, particularly in the vicinity of the BESS. Substantial flood hazards exist around areas adjacent to the Wollondilly River. The watercourses throughout the Project Area are beginning to fill and pose a flood hazard. Where flows are generated from rainfall occurring within the Project Area, flood hazards remain confined to watercourses. This indicates that the inundation impact due to climate change is not anticipated to be a significant issue for Project Area that is away from the banks of the Wollondilly River.
- PMF: Assessing the Probable Maximum Flood of any site adjacent to a catchment as large as the Wollondilly River is difficult. The PMF is the largest flood that could conceivably occur at a particular location. While the PMF defines the extent of flood-prone land, that is, the floodplain. It is understood to be '*generally, it is not physically or economically possible to provide complete protection against this event*'. As the PMF is the worst flood possible, and there are numerous dams on the Mulwaree and Wollondilly Rivers upstream of the Project Area, their releases, survival and arrival at the Project Area is difficult to determine. PMF flood estimates at Goulburn are documented in Table 6.1. Estimated flood flows at Goulburn are an order of magnitude higher than the 1 in 500 AEP. Flooding can be expected to be extensive and devastating.

The location of energy infrastructure should avoid any land subject to flooding hazard and should not contribute to an increase in risk of the flooding hazard.

A number of small farm dams exist on the southern side of the proposed BESS location, shown in aerial imagery and as areas of deeper floodwater. The removal or lowering of these dams may be considered as part of a flood risk reduction measure for the BESS. Failure or overtopping of these dams and flooding on the BESS area could present an unacceptable risk.

6.7 LIMITATIONS

The modelling accuracy is subject to sources of uncertainty and limitations. Some potential sources of inaccuracy leading to uncertainty in the hydraulic model are as follows:

- Inaccurate topographic information – The hydraulic model relies upon the representation of the ground topography to model the movement of water across the land. The DEM used to inform the model topography was captured at different times and with differing resolutions. This also implies a variance in vertical and horizontal accuracy for the survey. .
- No calibration to historical events—It is best practice to calibrate a hydraulic model to an historical event. However, calibration data for historical events is not available, making model calibration impossible. While the model parameters have been chosen in line with ARR 2019 recommendations and within industry-accepted bounds, the ability of the model to reproduce actual flood behaviour is untested.
- Critical duration—A representative critical duration and temporal pattern have been selected to represent the flood behaviour across the project area. Given the broadscale nature of this impact assessment, this is an appropriate simplification. However, future detailed design (e.g., of waterway crossings) may need to model additional durations to determine whether the critical duration at the location of interest should be updated.

7 ASSESSMENT OF POTENTIAL IMPACTS

The Projects have the potential to impact receiving surface water and groundwater quality, flood regimes, soil resources, available water supply to existing users and aquatic habitat and GDEs. However, the potential impacts listed below would be contained to a small area, and there are numerous measures proposed to mitigate that risk. In the absence of appropriate controls and assuming the worst possible case, the potential impacts to surface water resources associated with the Project may include:

- degradation of downstream surface water quality (primarily during construction and decommissioning but also potentially during operation) due to:
  - elevated concentrations of sediment and nutrients bound to sediment in any runoff;
  - elevated pH and fine sediment concentrations in runoff from mobile concrete batching plant areas;
  - chemical spills/leaks entering streams (e.g. diesel fuel or hydraulic oils from mobile plant);
- increased erosion within watercourses due to:
  - damage to stream bed and bank from construction activities adjacent to and in-stream (e.g. stream crossings);
  - damage to riparian vegetation from construction activities on waterfront land;
  - runoff being concentrated by impervious areas associated with the Project;
- potential for alteration of flood flows and levels due to infrastructure located in close proximity to streams and watercourse networks;
- loss of catchment yield during construction due to capture of water in sediment dams;
- depressurisation of groundwater aquifers and a reduction in bore yields to existing groundwater source users due to project water use (if groundwater is used to supply Project demands);
- degradation of groundwater quality due to chemical spills/leaks during construction;
- loss of catchment yield associated with sourcing water (licensed harvesting on-site or via an agreement with the host or local landholders) to meet construction water demands.

This WRIA has considered and assessed each of these potential impacts and, where there is the potential for impacts to occur, has identified appropriate management measures to mitigate these risks.

Section 7.1 through Section 7.5 outline the potential impacts and mitigation measures relating to water resources aspects.

7.1 SOIL AND WATER QUALITY IMPACTS

Potential impacts relating to soil and water quality are proportional to land disturbance. Minimising total land disturbed significantly reduces the risk of the associated impacts. The impacts listed here are intended to provide an exhaustive summary only. Inclusion within this list is not intended to indicate actual or likely outcomes as a result of this Project.

The Project Area was assessed through soil surveys and desktop studies, which has ensured a comprehensive understanding of the soil resources. Appendix C contains summary information from extensive evaluation of the current soils resources and their tolerance to the Project. Additionally, the Project has a solid commitment to minimal surface disturbance and a clear strategy to restore the land to its pre-disturbance agricultural capability and usage after the Project's completion.

7.1.1 Construction and Decommissioning

During the construction and decommissioning of both components of the Project, soils would be subject to disturbance during the removal of vegetation, excavation works and stockpiling of materials, potentially leading to sediments and/or pollutants being entrained in rainfall runoff and entering local waterways. Discharge of polluted rainfall runoff from the Project has the potential to result in the deterioration of EVs and WQOs, for example:

- Pollutants such as sediments, pH, oils/grease and other nutrients bound to sediment or dissolved form. The Project would aim, as far as practicable, to protect the Wollondilly River WQOs and aquatic ecosystems.
- Works within or near watercourse networks are a risk to downstream water quality due to the disturbance of the streambed and the mobilisation of sediments and pollutants. Work occurring outside of watercourse networks may also indirectly mobilise sediment and pollutants via the action of wind then rainfall. Construction of the Project would not require controlled discharges to watercourses.
- Mobilised high concentration nutrients (fertilisers) may trigger algal blooms that result in anoxic conditions within any fish habitat. Mobilised heavy metals and contaminant concentration could result in aquatic habitats, irrigation and drinking water degradation.
- Soils within the Project Area may contain residual herbicides/pesticides from historical or present-day farming practices.
- Loss of topsoil resources on the land and ongoing erosion reducing the area of usable land and/or damage to private property for involved landholders.
- Water quality in farm dams is impacted and not suitable for stock watering, health or aquatic fauna and flora, as well as increased turbidity and decrease in water quality to downstream watercourses.

With the implementation of erosion and sediment control measures as well as appropriate measures to manage hazardous materials such as oils, fuels, and other chemicals, potential construction-related stormwater pollution impacts can be appropriately managed and are expected to be negligible.

During the construction phase, there will be a requirement to construct watercourse crossings to enable access across the broader Project Area, on review of the Strahler Stream Order mapping and the flood mapping in Appendix B. The locations represent internal access tracks crossing existing waterways/inundated areas where the depth of flow is greater than 300mm during the 1% AEP event. This 300mm depth has been selected as at this depth it begins to become unsafe for vehicles per the combined flood hazard classification in AIDR, 2017.

Waterway crossings will warrant consideration of the flood conditions in these waterways and streams with the appropriate design of cross drainage to achieve flood immunity requirements for the access roads and internal access tracks. Requirements include:

- Adequately sized pipe drainage and/or floodways are to be provided to allow for the conveyance of overland flow under and/or across the road.
- Adequate erosion protection across and downstream of the road crossing should be provided.
- An energy dissipator should be included at the pipe outlet or downstream of the floodway to prevent potential erosion undermining the pipe/culvert and batters.
- Planned works is to be scheduled for forecasted dry weather periods.

Provided the watercourse crossings are designed and constructed in accordance with relevant guidelines and in consultation with DPI Fisheries, the Project waterway crossings are not expected to result in any measurable impacts to stream health including water quality and fish passage.

Implementing the measures outlined in Section 7 would adequately manage the potential water quality impacts during the Project's construction and decommissioning phases.

7.1.2 Operation

During the operational phase, the potential impacts on water quality relate to the establishment of additional infrastructure, hardstands, and internal access tracks. Due to the distribution of infrastructure throughout the Project Area, the impacts of increased impervious areas are likely to have minimal noticeable impact. An additional measure that will be considered as part of the Project's detailed design is to identify existing eroding gullies within the Project Area and rehabilitate them as part of the Project, which will improve post-development stormwater quality.

Other potential water quality impacts during the operational phase associated with the day-to-day activities during this phase would be limited to:

- Stormwater runoff from impervious surfaces resulting in localised erosion.
- Accidental spills or discharge through the use and storage of chemicals such as fuel.

The potential for ongoing erosion post-construction of the Project is considered to be low, provided appropriate rehabilitation of disturbed areas is undertaken and any areas identified as exhibiting signs of erosion above expected background levels are addressed.

All hazardous materials and chemicals would be stored in accordance with relevant Australian standards and other state and local guidelines including the NSW EPA's *Storing and Handling Liquids: Environmental Protection – Participants Handbook*.

7.1.3 Water Quality Impacts

Water quality modelling was undertaken to estimate pre- and post-development stormwater discharge concentrations and loads (refer to Section 5.0) for the purpose of determining whether the Project will have a NorBE on water quality. The modelling results indicated that:

- post-development mean annual TSS, TP and Gross Pollutant loads discharged in stormwater would be lower than the pre-development loads. The predicted reductions are greater than 10% and are therefore NorBE compliant (refer to Sections 5.4.1 and 5.5.1);
- post-development mean annual for TN loads discharge in stormwater are predicted to increase. This does not achieve WaterNSW NorBE criteria (refer to Sections 5.4.1 and 5.5.1);
- TSS and TP concentrations achieve the NorBE criteria as concentrations are equal or better for the post-development scenario between the between the 50th and 98th percentiles. It is noted that TSS is better between the 5th and 98th percentiles;

- Post-development TN concentrations do not achieve the NorBE criteria of being better than the pre-development scenario between the 50th and 98th percentiles. TN concentrations are better for the post-development scenario above the 75th percentile result.

While the water quality modelling indicates that WaterNSW NorBE criteria is achieved for all water quality characteristics, with the exception of mean annual TN concentrations. The impacts to receiving water quality downstream of the Project are expected to be negligible provided effective rehabilitation of development footprint is undertaken post-construction. However, refinement of the MUSIC water quality model will be undertaken during the detailed design phase of the Project to ensure the model reflects the detailed design and to optimise the operational Project stormwater treatment train. Based on the above, and with the implementation of management measures outlined in Section 7.0, water quality impacts during the operational phase for the Project are expected to be negligible.

7.2 FLOODING IMPACTS

7.2.1 Operation, Construction and Decommissioning

The 10 %, 1 %, 0.5 %, and 0.2 % AEP and PMF events were assessed to quantify flood depth, velocity, and hazard levels. Modelling has shown that the Project Area generally has a low flood hazard with minimal risk of changes in internal or external waterway flows.

The access into the Project Area from the east is predicted to be low flood risk. Design of any watercourse crossings for access points and access track crossings within the Project Area will be undertaken at the detailed design phase. Watercourse crossings are to be designed in consideration of requirements of *Guidelines for Controlled Activities on Waterfront Land*, to reduce construction impacts to any riparian corridors within the Project Area. The existing farm access track that crosses the Wollondilly River, shown in Figure 7-1 and Figure 7-2, will be enhanced to ensure site safety. This may involve the installation of water depth markers, access track markers with warning signs and gravel on approaches for any light traffic loads. Where required consultation will be undertaken with agencies to determine the optimal watercourse crossings requirements of all pertinent considerations relating to watercourse crossing safety.

Figure 7-1 Looking at Wollondilly River crossing to enter Project Area

Source: Umwelt photograph taken 10 September 2024

Figure 7-2 Looking along existing access at Wollondilly River crossing into Project Area

Source: Umwelt photograph taken 10 September 2024

The results of the 1% AEP flood hazard assessment have identified that the Project Area is classified as Generally safe (H1). Isolated pockets of H2 and H3 hazard exist where water accumulates. Peak stormwater discharges from the Project Area for impervious areas may increase slightly through the creation of compacted gravel roads and some small operational buildings. However, potential impacts to drainage features and downstream watercourses are considered likely to be minimal due to the relative size of the Project Area in relation to the size of the receiving catchments, and the distributed nature of minor impacts. The total new impervious area for the Project is estimated to be minimal within the overall Project Area, comprising:

- Footings for transmission lines, substations and switchyards,
- Roof areas relating to operation and maintenance buildings, and,
- Access and hardstand area.

The existing and post development peak flows for the catchment were assessed using the Rational Method. While the site is rural, the urban method was used as it allows for an assessment of the increase in runoff due to an increase in impervious areas. The rainfall intensities were extracted from the 2016 Intensity Frequency Duration (IFD) tool as provided by the Bureau of Meteorology and discussed in Section 6.2.

This total impervious area represents less than 1% of the total Project Area. Drainage from these impervious areas will not be directly connected, providing opportunities for stormwater distribution and infiltration between the impervious area and receiving watercourse. Consequently, the hydrologic impacts of the Project at the catchment scale are likely to be undetectable.

Minimal changes to the land topography, impervious fraction and therefore runoff and groundwater infiltration are expected due to the nature and extent of the proposed infrastructure for the Project. Subject to the management and mitigation measures outlined in Section 7.0 being implemented, the

Project is unlikely to have any residual impacts on surface water. This will require the development of various Management Plans developed prior to construction of the Project.

7.3 IMPACTS ON STREAM STABILITY, RIPARIAN HEALTH AND FISH PASSAGE

7.3.1 Construction, Operation and Decommissioning

As an SSD (SSD-63345458), if approved, will be exempt from the requirement to acquire Controlled Activity Approvals (CAAs) for works on waterfront land (works within 40 m of the top of bank of a waterway) under s.4.41(1)(g) of the *Environmental Planning and Assessment Act 1979*. Notwithstanding the exemption from requiring CAAs, if any works are required on waterfront land, they will be undertaken in accordance with DPE's *Guidelines for Controlled Activities on Waterfront Land.*

Ephemeral flow paths and local depressions are located within the Project Area. While the Project design has aimed to avoid works close to or within waterways, waterway crossings will be required for site access. Project waterway crossings will be designed to minimise impacts on stream stability and fish passage and will be designed with reference to the following documents in addition to DPE's *Guidelines for Controlled Activities on Waterfront Land*:

- *Why Do Fish Cross the Road? Fish Passage Requirements for Waterway Crossings* (NSW Department of Primary Industries (DPI) Fisheries, 2003).
- *Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management* (NSW DPI, 2013).

For works on waterfront land, the following measures will be incorporated into the design of the works and controls included in the Construction Soil and Water Management Plan (CSWMP):

- a site-specific erosion and sediment control plan will be prepared for all works on waterfront land;
- where practicable, infrastructure will be maintained outside of the vegetated riparian zone;
- utilise stream crossings for co-location of services to avoid the need to trench through stream beds wherever practicable;
- rehabilitate disturbed areas and provide scour protection to bed and banks as required to mitigate any areas with increased potential for erosion due to changes in flow regimes associated with Project infrastructure;
- where practicable, undertake works on waterfront land during periods of low rainfall erosivity from April to September when construction timing restrictions are recommended (refer to Table 3.2).

During detailed design, consultation will be undertaken with DPI Fisheries to determine if any of the proposed watercourse crossings require consideration of fish passage. The enabling works for the Project may involve the enhancement of the existing crossing of the Wollondilly River. For any crossings requiring fish passage consideration, the relevant DPI Fisheries guidelines will be considered during the detailed design process.

7.4 IMPACTS ON WATER SUPPLY

7.4.1 Construction, Operation and Decommissioning

Water required for the Project will be sourced from:

- Farm dams within the Project Area (all phases).
- Commercial suppliers (potable water) (all phases).

The maximum water demand will be during construction (refer Section 4.2). Reduced volumes are likely to be required during the decommissioning phase.

As water will be obtained from existing mains and trucked to the site, no impacts to surface water or groundwater availability in the vicinity of the Project are anticipated. Similarly, impacts on surface water availability to downstream water users are expected to be negligible.

7.5 GROUNDWATER QUALITY

7.5.1 Construction and Decommissioning

Generally, impacts to groundwater resources are not expected given the groundwater table is unlikely to be intercepted during Project construction. Further, the anticipated depth to groundwater (i.e. at least 20 m BGL) within the Project Area means that any hydrocarbon/chemical spills are unlikely to infiltrate to the groundwater table, noting that appropriate storage and spill management measures will be implemented during all phases of the Project.

Should the final Project design identify that construction activities will result in the interception of the groundwater table, further assessment will be undertaken in accordance with the NSW Aquifer Interference Policy (NSW Government, 2012), and appropriate management measures will be developed to mitigate any potential impacts.

7.5.2 Operation

There is limited scope and no conceivable mechanism for the Project to alter groundwater behaviour. Project operation and maintenance are not anticipated to intersect the regional water table. Footing excavations are also unlikely to have a lasting impact on groundwater level drawdown. Should interception of localised perched groundwater occur during construction, groundwater is expected to recover by the time the Project reaches its operational phase. As such, no impacts to groundwater resources and registered bores are expected during the operational phase of the Project.

7.6 CUMULATIVE IMPACTS

7.6.1 Overview

Related development, as outlined in the NSW Government State Significant Development Guidelines, refers to any existing or approved development that would be incorporated into, or operated in conjunction with the Project. Related development can also include development by a Proponent that is required for a Project; but is subject to a separate development approval process. At this stage, there are no existing or approved developments that would need to be incorporated into the assessment of the Project.

NSW Government – EnergyCo seeks to maximise opportunities created by the transformation of the NSW electricity system by coordinating investment in REZs across NSW. A REZ is the equivalent of modern-day power stations, combining new renewable energy infrastructure, including generators (such as solar and wind farms), storage (such as batteries and pumped hydro) and then high-voltage transmission infrastructure. Five dedicated REZs have already been identified in NSW

Based on information available within the public domain, specifically the NSW Government -Major Projects website, the following developments were identified within the 80 km of the Project:

- Wattle Creek Solar Farm Project — Co-located in Project Area
- Marulan Gas Fired Power Station — Adjacent < 1 km South
- Gunlake Quarry — Approx. 5 km Southwest
- Green Valley Quarry — Approx. 6 km Southeast
- Berrima Coal Mine — Approx. 12 km Northeast

- Marulan South Limestone Mine — Approx. 16 km South
- Peppertree Quarry — Approx. 16 km South
- Marulan Solar Farm — Approx. 18 km Southwest
- Gundary Solar Farm — Approx. 28 km Northwest
- Merino Solar Farm — Approx. 28 km Southeast
- Tarlaga Wind Farm — Approx. 30 km Northwest
- Crookwell Wind Farm — Approx. 32 km West
- Crookwell 2 Wind Farm — Approx. 32 km West
- Gullen Range Wind Farm — Approx. 50 km South
- Gullen Solar Farm — Approx. 50 km South
- Parkesbourne Solar Farm — Approx 50. km Southwest
- Woodlawn Wind Farm — Approx 69 km Southwest
- Capital Wind Farm — Approx. 81 km Southeast
- Blind Creek Solar Farm — Approx. 82 km Southeast

It is noted that because of the development activity, the above list may not address all potential sites being privately developed and not yet in the public domain. Information pertaining to any developments not yet in the public domain is therefore unavailable and excluded from this study.

7.6.2 Cumulative Impact Assessment

In the context of water, impacts may include changes to land used for agriculture to energy production. This will be a result of agricultural land use being inhibited by landform modification and the provision of infrastructure related to the Project. However, this region already has large and established agricultural industries. The interface with proposed renewable energy projects with these existing grazing and broadacre cropping are unlikely to interact with respect to water resources.

As such, the cumulative impacts are considered highly unlikely to occur. Specifically:

Water Management (erosion and sedimentation): given the Project will incorporate appropriate erosion and sediment control mitigation measures during construction and decommissioning phases, and assuming other projects in the region do the same, cumulative impacts on receiving water quality are expected to be negligible.

Water Quality (NoRBE): The Project will incorporate appropriate stormwater treatment measures as far as practicable to achieve a NorBE on water quality. All other developments proposed within the Sydney Drinking Water Catchment are also required to achieve a NorBE on water quality, and cumulative impacts to receiving water quality are expected to be neutral to beneficial.

Flooding and surface water: while other projects exist within the Wollondilly River catchment, none are connected to the Project's watercourses. Where projects are on interconnected watercourses to those of the Project Area (i.e. projects adjacent to the Wollondilly River), implementing appropriate mitigation measures into the Project Area (refer Section 8) and incorporating similar measures at the abovementioned projects in the region, will ensure that cumulative impacts on flood behaviour are negligible.

Water Management (demand, supply and balance): Project water demands will be limited to relatively short periods with respect to the overall Project lifespan during both the construction and decommissioning phases. Additionally, it is noted that most, if not all, non-potable water demand can be met by supply from, and with the agreement of, the LGA or on-site groundwater resources under existing licences (with agreement from the landholders). Water demands during the operational phase will be relatively small. Therefore, with the successful implementation of mitigation measures within the Project Area (refer to Section 8) and similar measures incorporated at the above-mentioned projects in the region, cumulative impacts on surface water or groundwater availability are not anticipated.

8 MANAGEMENT AND MITIGATION MEASURES

Table 8.1 lists the principal management measures required to manage the potential surface water impacts that are considered likely for the Project. These management measures are applicable to the components of the Project. The primary objective is ensuring downstream waterways are protected during the construction and operation of the Project. As part of the broader management measures and strategies, the proposed erosion and sediment controls are necessary to achieve this objective.

Measures for each component of the Project are to be captured in a Construction Environment Management Plan (CEMP) for the construction phase. This would include preparing sub-plans relating to the Construction Soil Water Management Plan (CSWMP).

For the operational phase of the Project, the measures outlined are to be documented in an Operations Environmental Management Plan (OEMP) for each component of the Project. This will be developed for the Project's operational phase. The OEMP will address potentially adverse impacts on the receiving environment surface water quality and flooding during the operational phase. The Emergency Response Plan will outline the flood hazards, evacuation and warning procedures to ensure the safety of all onsite.

Construction works, such as removal facilities and reinstatement works, will again be required during the project's decommissioning phase. The CSWMP and ESCP should be amended and incorporated into a Decommissioning Environmental Management Plan.

Table 8.1 Management and Mitigation Measures relating to Water Resources

Potential Risk	Proposed Management and Mitigation Measure	Owner
6.1 Soil and water quality	Maintaining the natural state of the drainage flow paths whenever possible. Internal access roads, where crossing watercourses or streams, will be designed for 10% AEP design flow and may include compacted rock causeways to provide low maintenance access with limited impact on the waterway or culvert structures	Detailed design & Construction
6.1 Soil and water quality	The design and construction of waterway tracks and cable crossings and all internal tracks crossing watercourses within the proposed development footprint should be generally in accordance with the *Guidelines for controlled activities on waterfront land – riparian corridors*, *Guidelines for watercourse crossings on waterfront land* and *Guidelines for laying pipes and cables in watercourses on waterfront land*	Detailed design & Construction
6.1 Soil and water quality	A CSWMP will be prepared to outline measures to manage soil and water impacts associated with the construction and decommissioning works.	Prior to construction
6.1 Soil and water quality	Creation of catch/diversion drains and sediment fences at the downstream boundary of construction activities where practicable to support containment of sediment-laden runoff.	Prior to construction
6.1 Soil and water quality	Erosion and sediment control measures will be implemented and maintained at all work sites in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1* and *Volume 2D* of Blue Book.	Prior to construction
6.1 Soil and water quality	Measures to minimise/manage erosion and sediment transport both within the construction footprint and offsite including requirements for the preparation of (ESCP) for all progressive stages of construction.	Prior to construction

Potential Risk	Proposed Management and Mitigation Measure	Owner
6.1 Soil and water quality	The best practice principles for stormwater and sediment control outlined in the *Managing Urban Stormwater* Blue Book guidelines will be incorporated into the design, construction and operation phases as part of a SWMP and ESCP.	Construction & Operation
6.1 Soil and water quality	BESS components will be located on hardstand areas and will be aligned with local overland flow paths to prevent flows being redirected which could lead to localised increased in flood level and higher risk of scour and erosion.	Operation
6.1 Soil and water quality	Inspection and monitoring requirements including receiving water quality monitoring.	Operation
6.1 Soil and water quality	Maintenance of stormwater infrastructure including any stormwater treatment devices (e.g. bioretention basins and culverts (e.g. clearing debris).	Operation
6.1 Soil and water quality	Maintenance of suitable ground cover and grassed table drains near access tracks to minimise the potential for erosion and export of sediment.	Operation
6.2 Flooding	During construction design flood risk will be considered and include, as a minimum, a review of temporary infrastructure layouts and arrangements to a) avoid and/or minimise obstruction of overland flow paths, b) limit the extent of flow diversion, c) include stormwater management controls to avoid/minimise the impact of flooding, and d) consider measures to mitigate alterations to local runoff conditions due to on-site works and activities.	Construction
6.2 Flooding	During construction, design stockpiles would be located outside areas anticipated to flood and experience velocities above 0.5 m/s. Where reasonable/feasible located outside the mapped 10% AEP flood extents.	Construction
6.2 Flooding	Temporary construction compounds, laydown areas, concrete batching plans and workforce accommodation (if required) would be maintained away (or above) areas anticipated to flood to depths deeper than 250 mm during a 1% AEP flood event. Based on the Project design utilised for this assessment, this mitigation is achieved and will persist if any future design revisions occur.	Construction
6.2 Flooding	Flood emergency management measures for the construction phase would be prepared and included in applicable environmental and safety management documentation i.e. the CEMP, CSWMP and ESCP noted above, as relevant. As a minimum this would include identification of flood related risks and their management, and processes to monitor and communicate weather warnings. In this regard, construction staff will have access to the following facilities for early severe weather warnings: The Bureau of Meteorology's "MetEye" and The Bureau of Meteorology's "RSS feeds". Radio and Bureau of Meteorology information will be reviewed frequently for potential storm events and to ensure on-site personnel and visitors are aware of potential flooding events and road closures.	Construction
6.2 Flooding	Flood emergency management measures for the operational phase would be prepared and included in applicable environmental and safety management documentation i.e. the BFEMOP and OEMP	Operation

Potential Risk	Proposed Management and Mitigation Measure	Owner
	noted above, as relevant. In this regard, operations staff will have access to the following facilities for early severe weather warnings: The Bureau of Meteorology's "MetEye" and The Bureau of Meteorology's "RSS feeds". Radio and Bureau of Meteorology information will be reviewed frequently for potential major storm events and to ensure on-site personnel and visitors are aware of potential flooding events and road closures	
6.2 Flooding	Evacuation routes will be designed during the detailed design phase and will consider zones of flood hazard. These routes would be and included in applicable environmental and safety management documentation i.e. the Emergency Response Plan and OEMP noted above, as relevant.	Detailed design
6.2 Flooding	Flood behaviour as a result of the Project would be confirmed during detailed design, including climate change. In this regard, foundations for the BESS and transmission lines will be located away from areas that exceed flood depths of 0.3 m and flow velocities greater than 1.5 m/s. The detailed design of the Project will consider the 1% AEP scenario.	Detailed design
6.3 Stream stability, riparian health and fish passage	Infrastructure with the potential to cause pollution to waterways in the event of flooding, such as inverters and battery storage, will be located with a minimum 300 mm freeboard above the maximum 1% AEP flood level. Given the shallow depths across the Project Area, raising these small fill pads is highly unlikely to result in any adverse impacts offsite.	Detailed design
6.3 Stream stability, riparian health and fish passage	No sensitive infrastructure (e.g., substation, BESS) will be placed within 20 m of any Strahler 3 or above order streams. Sensitive infrastructure will be placed outside the 0.2% AEP flood extent with a minimum 500mm freeboard to the 1% AEP flood level.	Detailed design
6.3 Stream stability, riparian health	Controls for receiving waterways which may include designation of 'no go' zones for construction plant and equipment.	Prior to construction
6.4 Water supply	A water sourcing and monitoring strategy to manage potential availability impacts on downstream water users and ensure compliance with legislation relating to water extraction.	Prior to construction

9 CONCLUSION

This Water Resources Impact Assessment has considered the potential impacts and appropriate measures to mitigate any potential impacts on water resources associated with the Wattle Creek BESS Project (SSD-63345458).

The Project will have minimal impact on water resources as it involves limited ground disturbance, does not store or handle large volumes of pollutants, and, once constructed, does not consume significant quantities of water.

For these reasons, the key potential risks to surface water are only associated with the Project's construction. These risks can be adequately managed through the application of well-established construction environmental management practices and appropriate design.

Key issues relevant to the water resources impacts of the Project are summarised below:

- Impacts to surface water resources occur during the construction. These potential impacts can be mitigated to represent negligible risk, as detailed in Section 7.
- The operational phase of the Project presents minimal risk provided that by the conclusion of the construction phase, appropriate ground cover and drainage are established.
- The Project will not interact with the groundwater table and therefore, no impacts to groundwater resources or GDEs are expected.
- The Project Area does not contain areas of major flood hazard.
- The large extent of the Project Area and distributed nature of minor impacts (if any) does not pose a risk to drainage features, downstream watercourses or receiving waters.

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APPENDIX A SEARS AGENCY ADVICE TABLE

Table A.1 SEARs Agency Advice Table

DPE - Biodiversity and Conservation Division (BCD) and the NSW National Parks and Wildlife Service (NPWS)		
7	The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a. Flood prone land. b. Flood planning area, the area below the flood planning level. c. Hydraulic categorisation (floodways and flood storage areas). d. Flood hazard.	Refer to Sections 5 and Section 7.2.
8	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% Annual Exceedance Probability (AEP), 1% AEP flood levels and the probable maximum flood, or an equivalent extreme event.	Refer to Sections 5 and Section 7.2 and Appendix A and B
9	The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios: a. Current flood behaviour for a range of design events as identified in 7 above. This includes the 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Refer to Sections 5 and Section 7.2 and Appendix A and B
10	Modelling in the EIS must consider and document: a. Existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies. b. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. c. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. d. Relevant provisions of the NSW Floodplain Development Manual 2005	Refer to Sections 5 and Section 7.2 and Appendix A and B

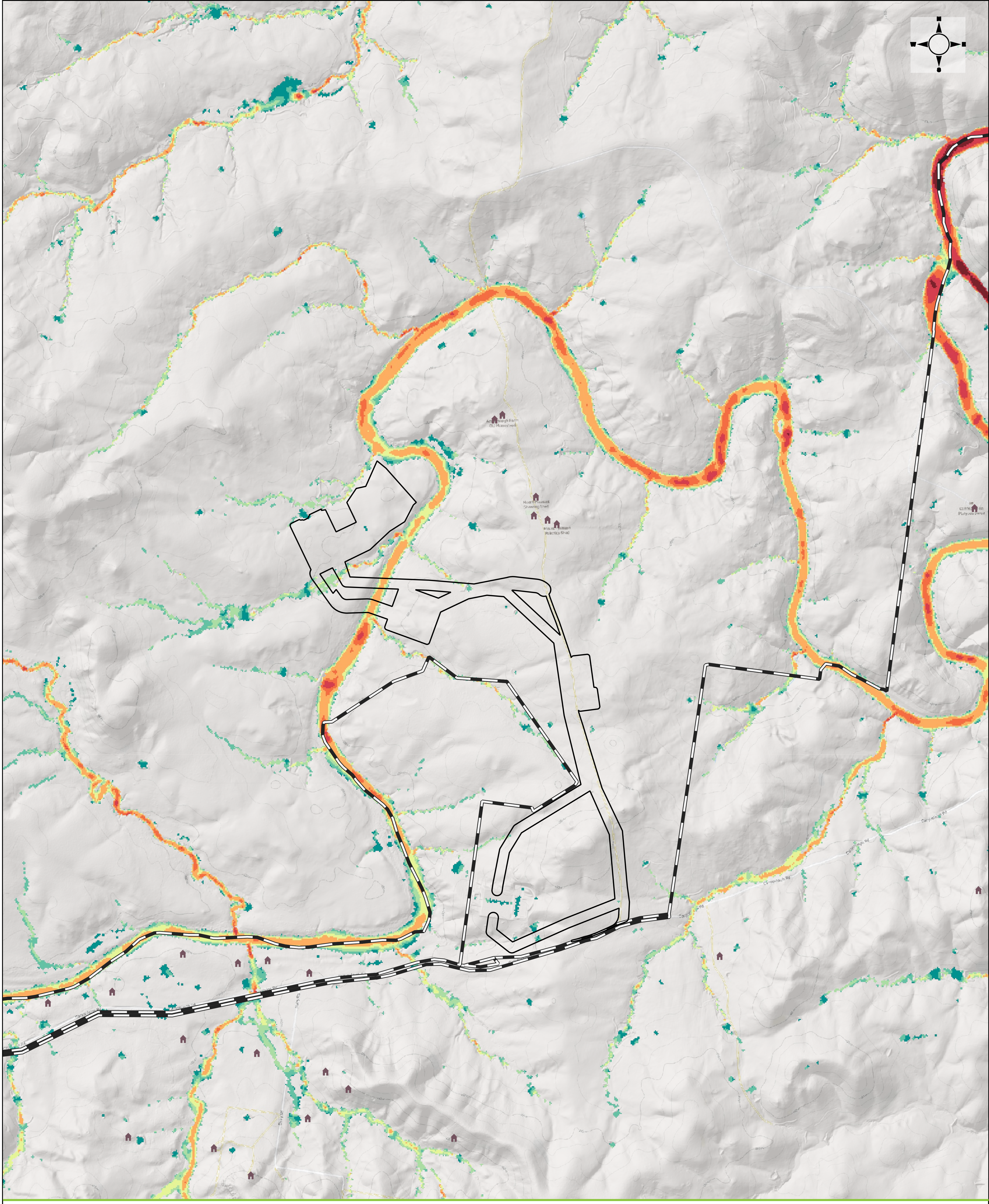
DPE - Biodiversity and Conservation Division (BCD) and the NSW National Parks and Wildlife Service (NPWS)		
11	The EIS must assess the impacts on the proposed development on flood behaviour, including: a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure. b. Consistency with Council Floodplain Risk Management Plans. c. Consistency with any Rural Floodplain Management Plans. d. Compatibility with the flood hazard of the land. e. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. f. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site. g. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. h. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council. i. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council. j. Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES. k. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	For all refer to Sections 5 and Section 7.2 and Appendix A and B For 11G. refer to Sections 0 and Section 6.0.

DPE - Water		
1	A detailed and consolidated site water balance	Refer to Sections 4.2, 4.3 and 4.4
2	Description of all works/activities that may intercept, extract, use, divert or receive surface water and/or groundwater. This includes the description of any development, activities or structures that will intercept, interfere with or remove groundwater, both temporary and permanent.	Refer to Section 4
3	Details of all water take for the life of the project and post closure where applicable. This is to include water taken directly and indirectly, and the relevant water source where water entitlements are required to account for the water take. If the water is to be taken from an alternative source confirmation should be provided by the supplier that the appropriate volumes can be obtained.	Refer to Section 4.3

DPE - Water		
4	Details of Water Access Licences (WALs) held to account for any take of water where required, or demonstration that WALs can be obtained prior to take of water occurring. This should include an assessment of the current market depth where water entitlement is required to be purchased. Any exemptions or exclusions to requiring approvals or licenses under the Water Management Act 2000 should be detailed by the proponent	Refer to Section 4, 5 and 7
5	A description of groundwater conditions that provides an understanding of groundwater level across the site under a range of wet and dry conditions.	Refer to Section 4, 5 and 7
6	Assessment of impacts on surface and ground water sources (both quality and quantity) including flooding, related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, groundwater dependent ecosystems, and ground water levels; including measures proposed to reduce and mitigate these impacts	Refer to Section 4, 5 and 7
7	Proposed surface and groundwater monitoring activities and methodologies.	Refer to Section 4, 5 and 7
8	A description of the watercourses located within the vicinity of the development, including Strahler Stream Order as mapped by Spatial Services NSW, and appropriate riparian setbacks. Impact assessment of all works/activities located on waterfront land as defined by the Water Management Act 2000, including an assessment against the Guidelines for Controlled Activities.	Refer to Section 4, 5 and 7
9	A description of erosion and sediment control measures to mitigate any impacts	Refer to Section 4, 5 and 7
10	Identification and impact assessment of all works/activities located on waterfront land including an assessment against Guidelines for Guidelines for Controlled Activities on Waterfront Land (NOW 2012) Controlled Activities on Waterfront Land (NRAR 2018).	Refer to Section 4, 5 and 7
11	Assessment of the project against relevant policies and guidelines	Refer to Section 4, 5 and 7

DPI - Fisheries		
Waterway crossings	The construction of waterway crossings should be in accordance with DPI Fisheries Policy & Guideline document: Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013). Any temporary waterway crossings must be removed immediately upon completion of the various stages of construction	Refer to Section 4, 5 and 7
Riparian buffer zones	The “degradation of native riparian vegetation” has been listed as a Key Threatening Process under the provisions of the Fisheries Management Act 1994. DPI Fisheries policy advocates the use of terrestrial buffer zones as per the Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013) in order to maintain the riparian buffer zone and limit disturbance and susceptibility to bed or bank erosion	Refer to Section 4, 5 and 7

APPENDIX B FLOOD MAPS



Legend

- Project Area
- Dwellings
- Development Footprint

Velocity (m/s)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- > 3

Wattle Creek Water Resource Impact Assessment

Modelled Peak velocity
10% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\QGIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

Projection: EPSG:7856

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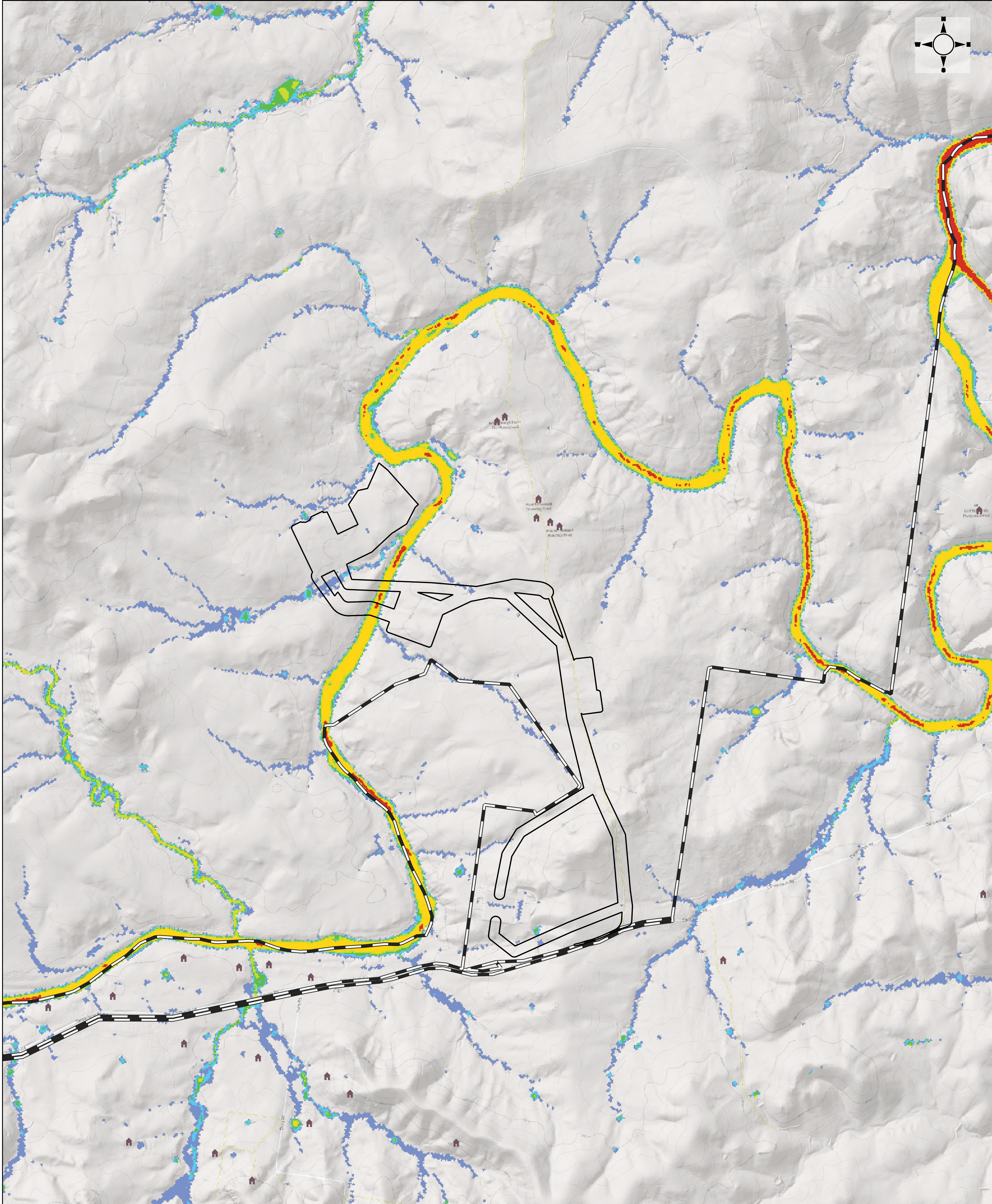

Legend

Project Area

Dwellings

Development Footprint

Australian Emergency Management Institute Hazard Category

H1 - no restrictions

H2 - unsafe for small vehicles

H3 - unsafe for vehicles, children and the elderly

H4 - unsafe for people and vehicles

H5 - unsafe for people or vehicles. Buildings require special engineering design and construction

H6 - not suitable for people, vehicles or buildings

Wattle Creek Water Resource Impact Assessment

Modelled Australian Emergency Management Institute category 10% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

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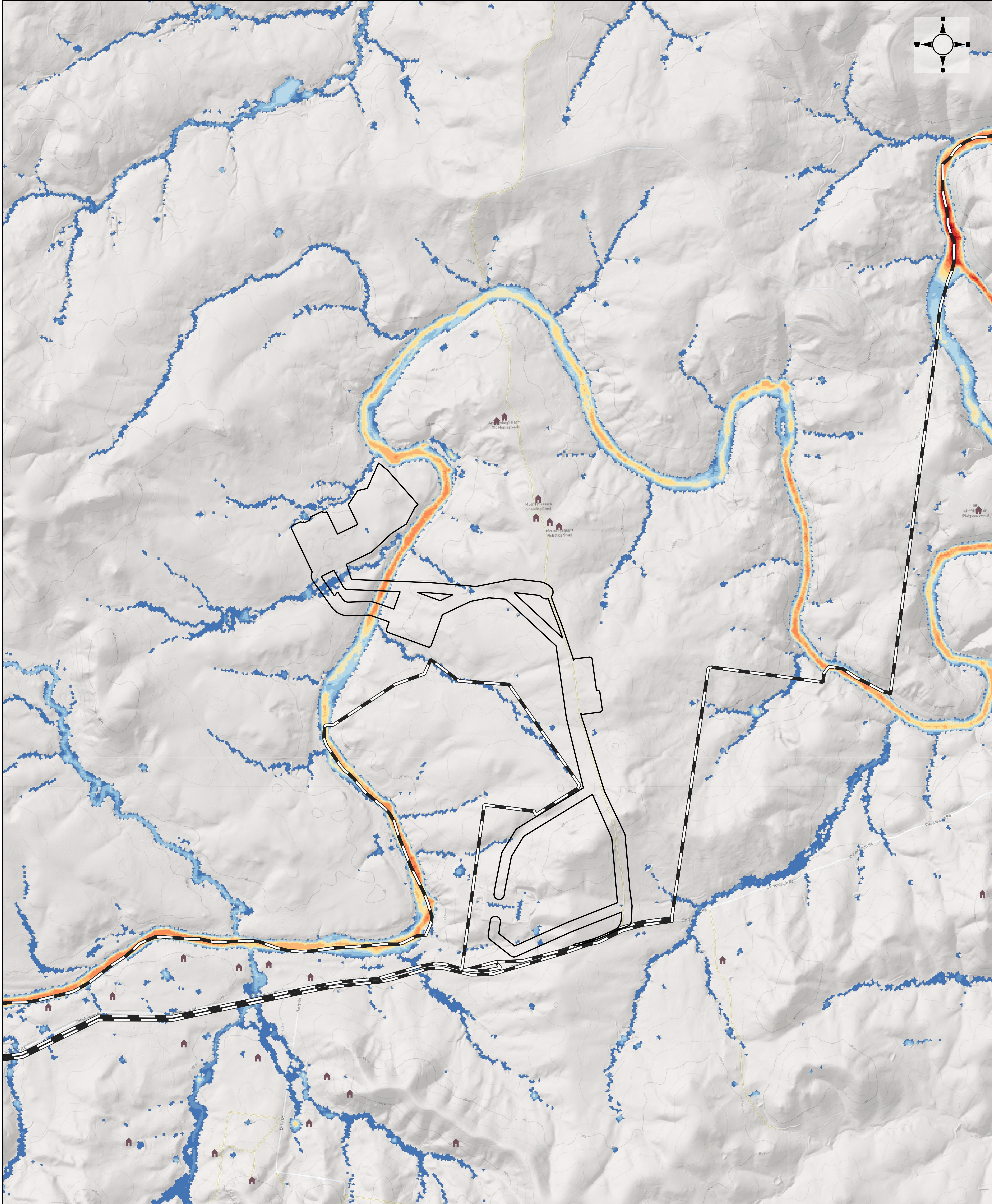

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Legend

- Project Area
- Dwellings
- Development Footprint

Depth (m)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- > 4.5

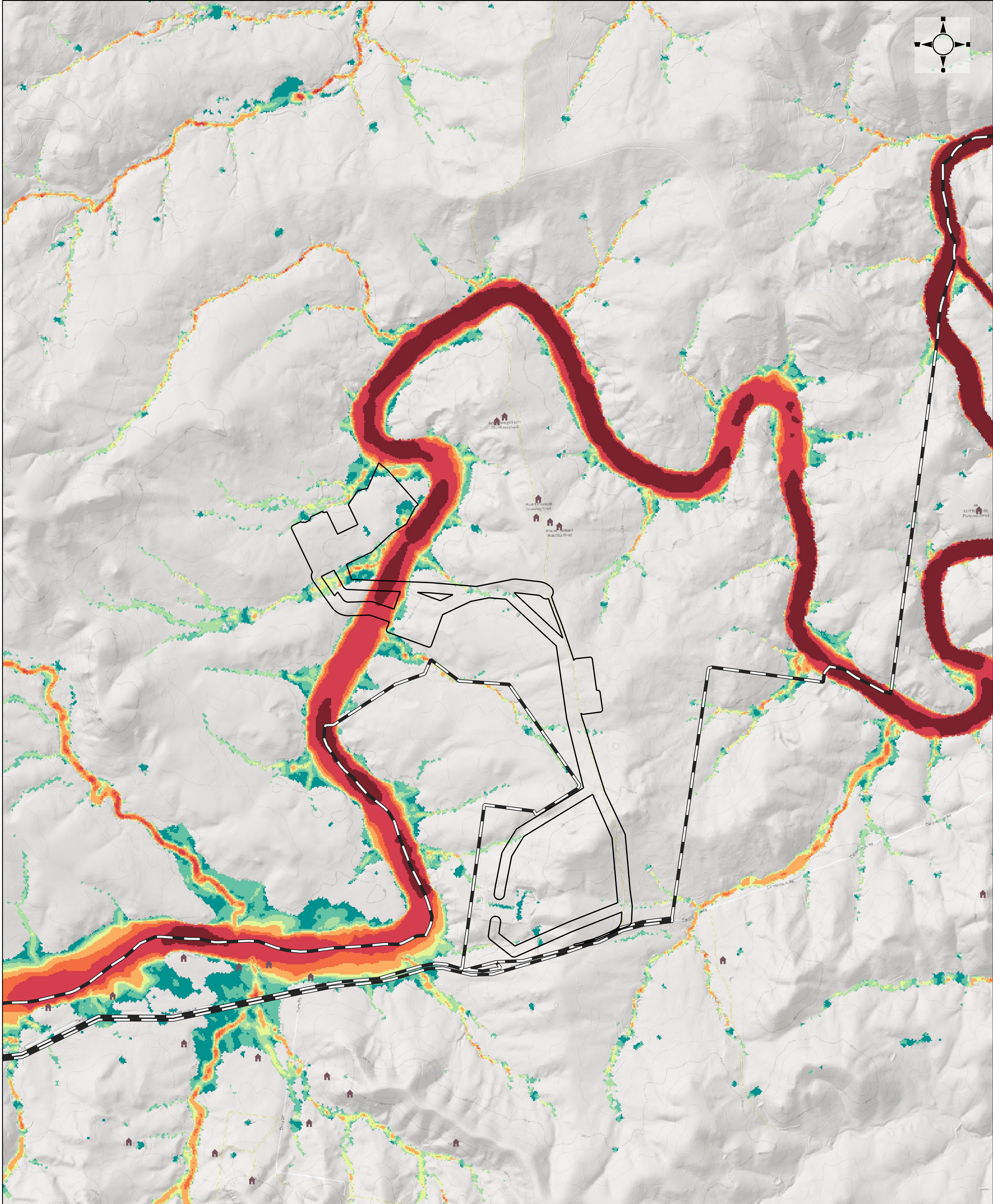
Wattle Creek Water Resource Impact Assessment

Modelled Peak depth
10% AEP Flood Event

0 300 600 m

WRM
WATER + ENVIRONMENT

Projection: EPSG:7856



Legend

- Project Area
- Dwellings
- Development Footprint

Velocity (m/s)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- > 3

Wattle Creek Water Resource Impact Assessment

Modelled Peak velocity
0.5% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\GIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

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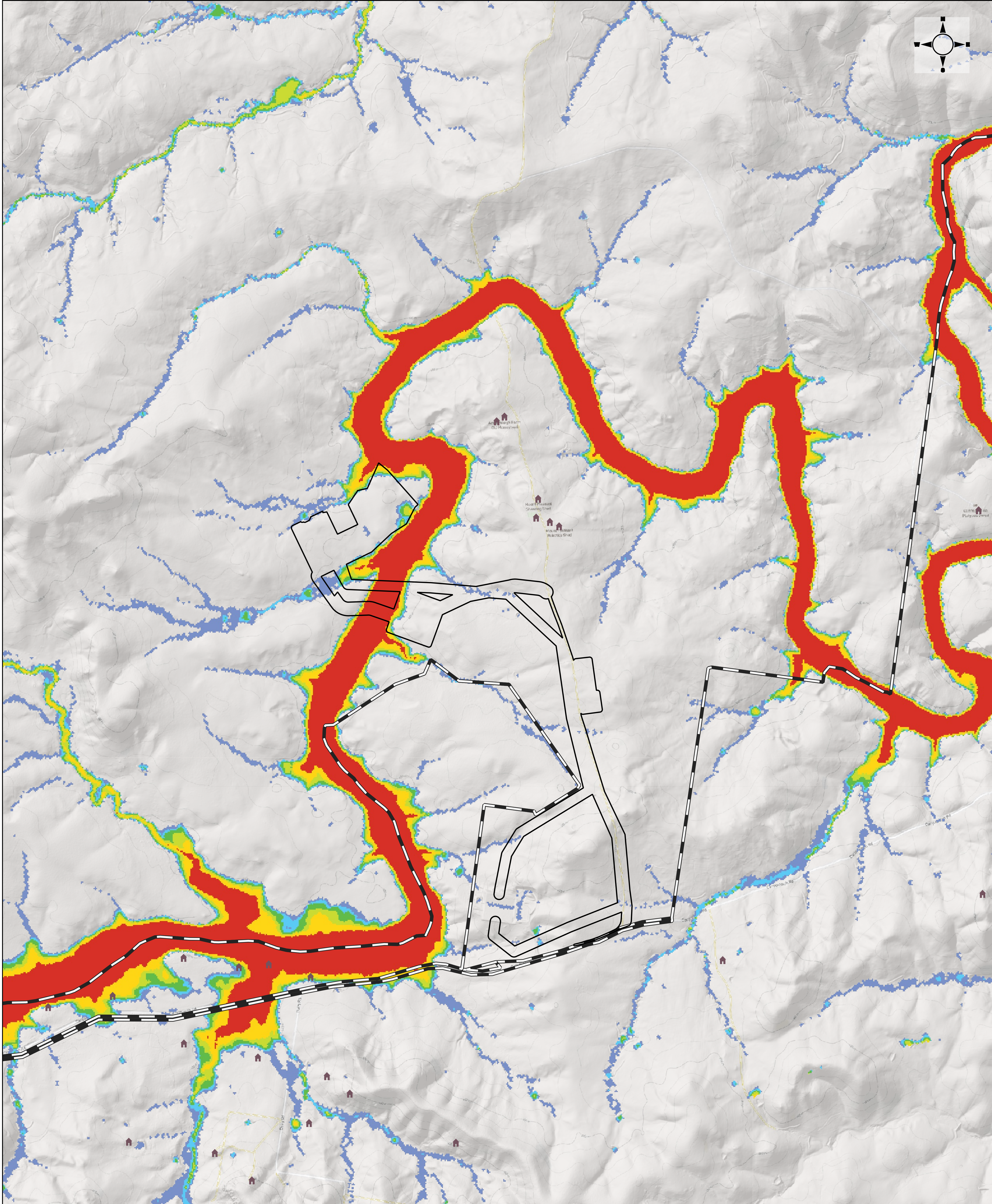


Legend

- Project Area
- Dwellings
- Development Footprint

Australian Emergency Management Institute Hazard Category

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings

Wattle Creek Water Resource Impact Assessment

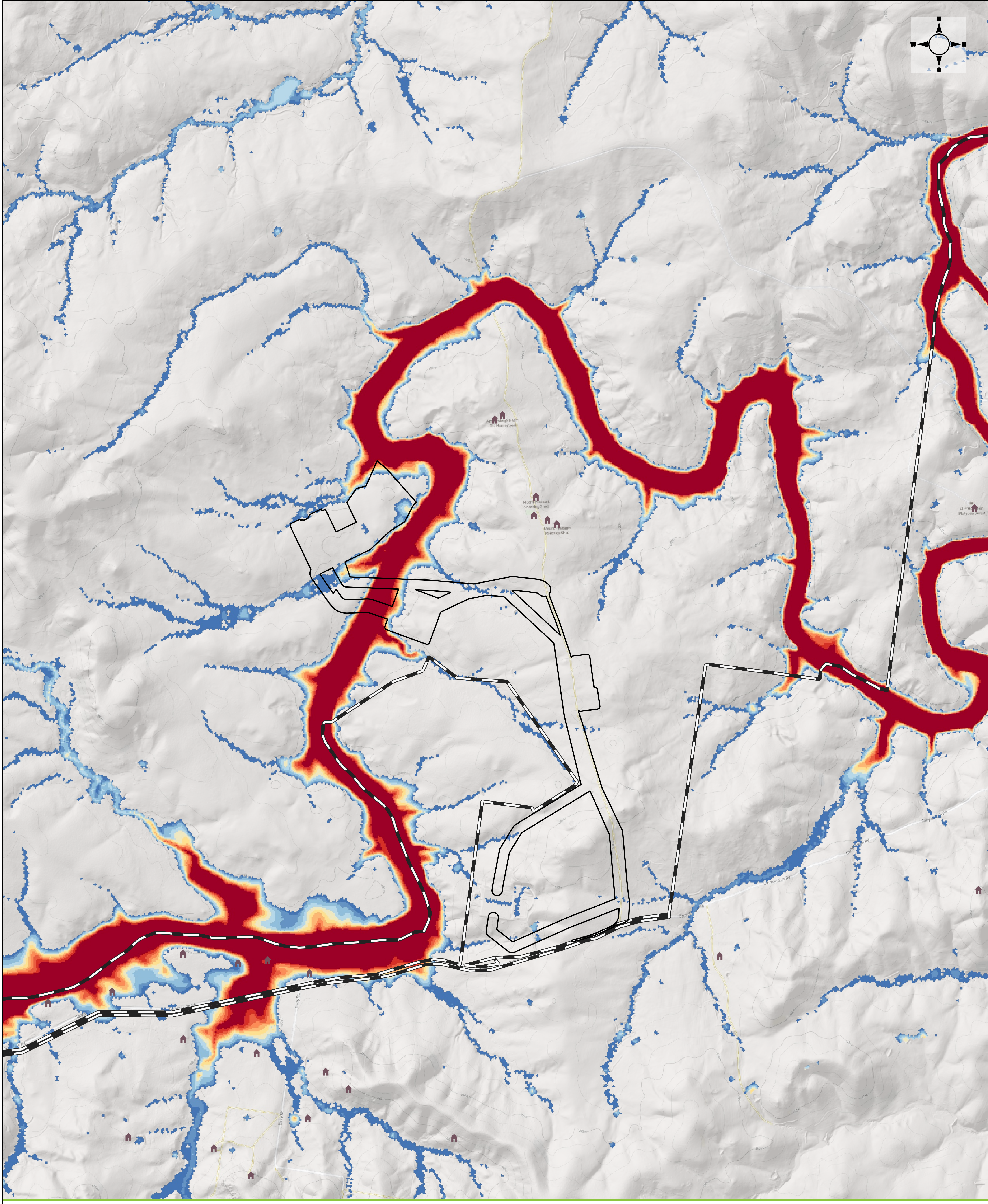
Modelled Australian Emergency Management Institute category 0.5% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\QGIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

Projection: EPSG:7856



Legend

- Project Area
- Dwellings
- Development Footprint

Depth (m)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- > 4.5

Wattle Creek Water Resource Impact Assessment

Modelled Peak depth
0.5% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\QGIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

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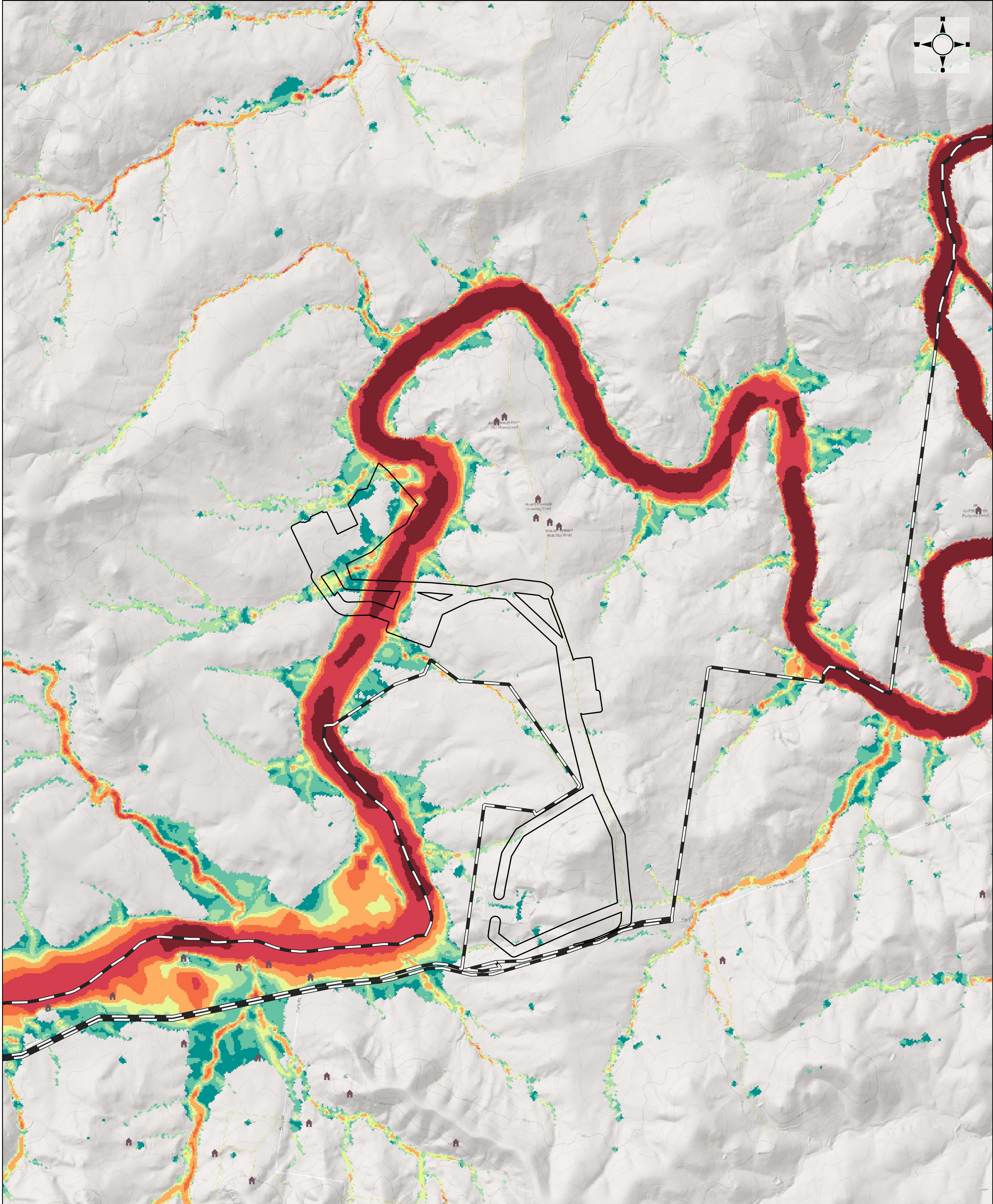


Legend

- Project Area
- Dwellings
- Development Footprint

Velocity (m/s)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- > 3

Wattle Creek Water Resource Impact Assessment

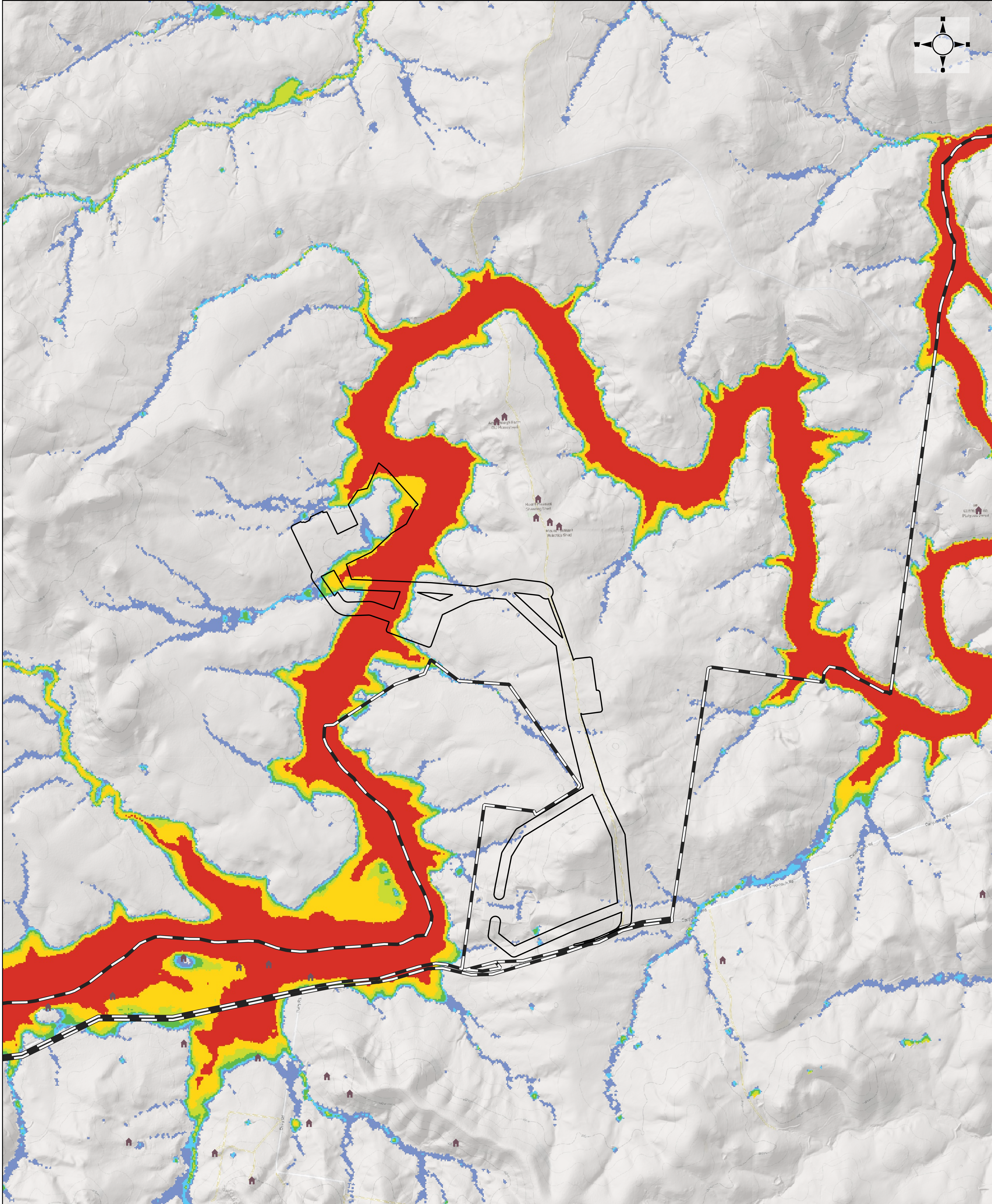
Modelled Peak velocity
0.2% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\QGIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

Projection: EPSG:7856



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Legend

- Project Area
- Dwellings
- Development Footprint

Australian Emergency Management Institute Hazard Category

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings

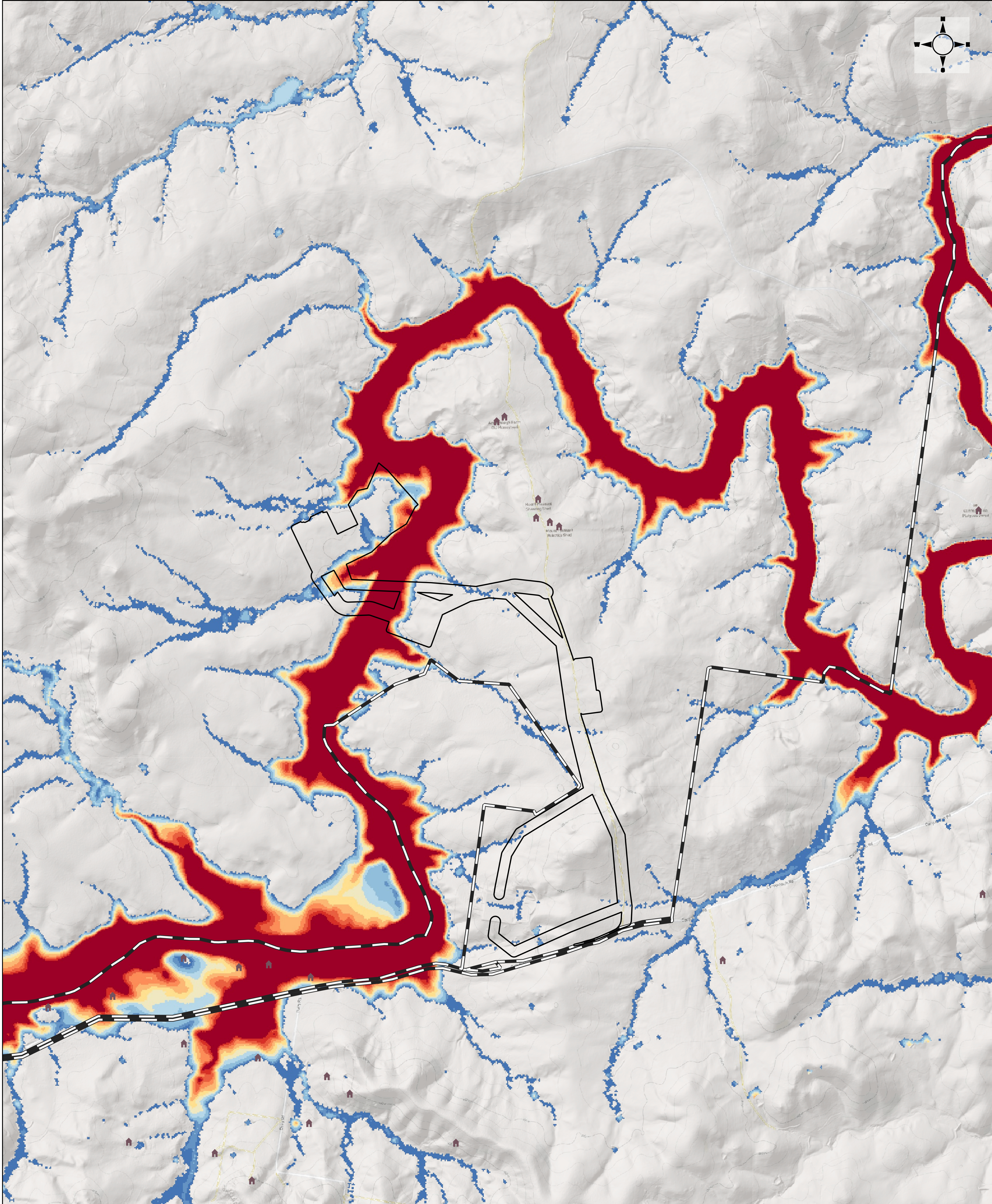
Wattle Creek Water Resource Impact Assessment

Modelled Australian Emergency Management Institute category 0.2% AEP Flood Event

0 300 600 m

WRM
WATER + ENVIRONMENT

Projection: EPSG:7856



Legend

- Project Area
- Dwellings
- Development Footprint

Depth (m)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- > 4.5

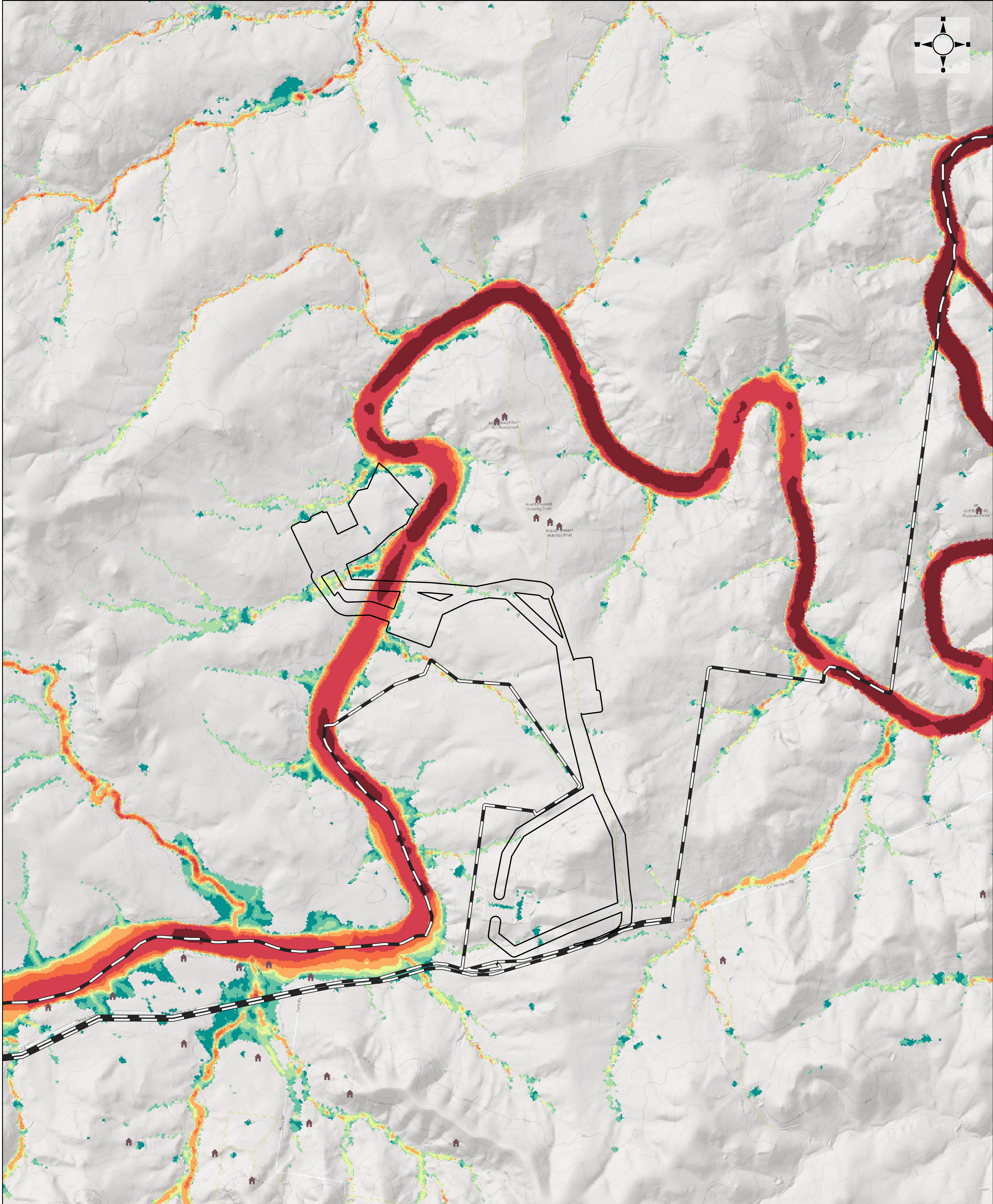
Wattle Creek Water Resource Impact Assessment

Modelled Peak depth
0.2% AEP Flood Event

0 300 600 m

WRM
WATER + ENVIRONMENT

Projection: EPSG:7856



Legend

- Project Area
- Dwellings
- Development Footprint

Velocity (m/s)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- > 3

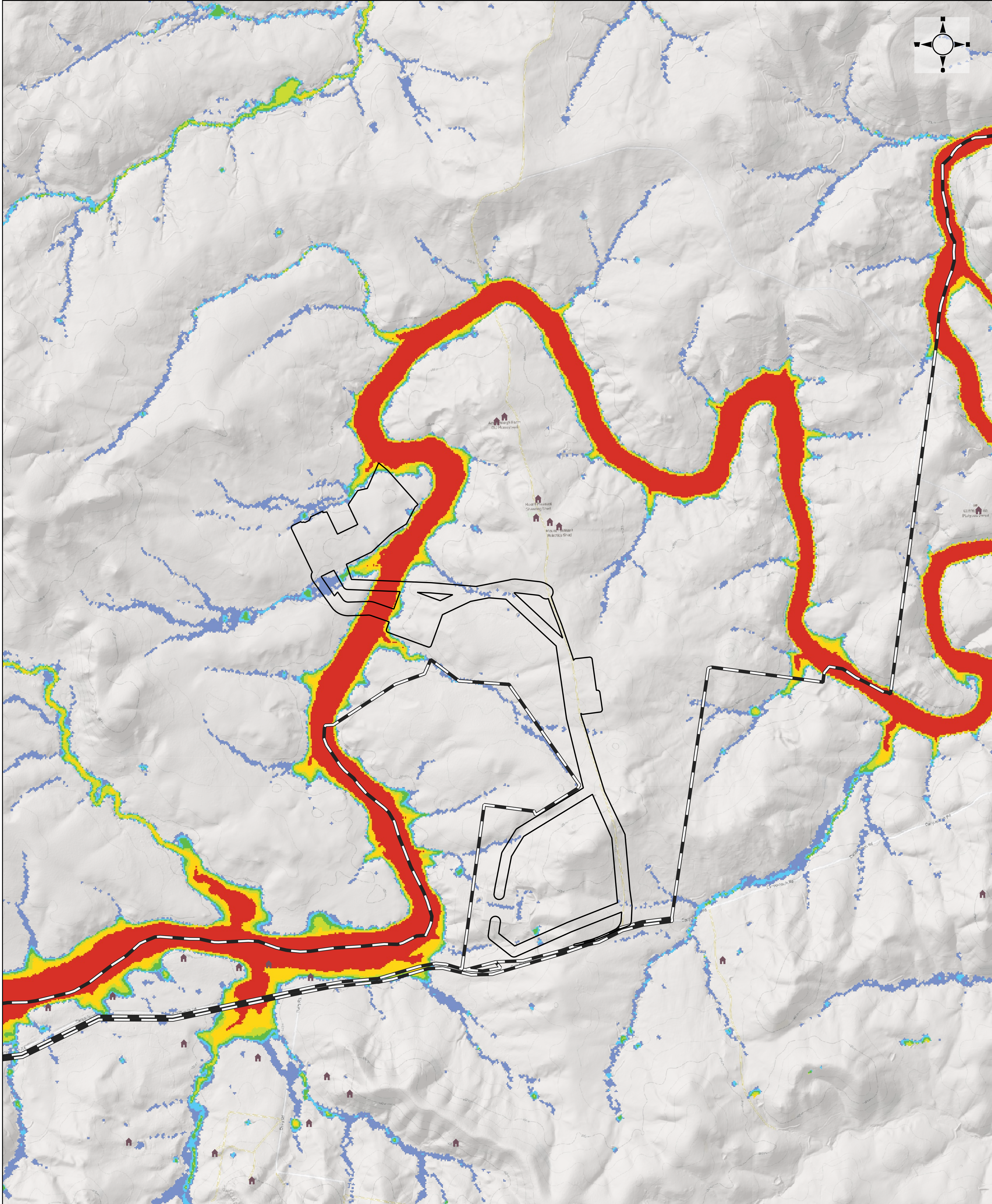
Wattle Creek Water Resource Impact Assessment

Modelled Peak velocity
1% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

Projection: EPSG:7856



Legend

- Project Area
- Dwellings
- Development Footprint

Australian Emergency Management Institute Hazard Category

- H1 - no restrictions
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and the elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - not suitable for people, vehicles or buildings

Wattle Creek Water Resource Impact Assessment

Modelled Australian Emergency Management Institute category

1% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

J:\2066-02 Wattle Ck Solar BESS\GIS\QGIS\2066-02_E_Flood_Figures.qgz (2066-02-B_AppendixB) (Exported: 14 March 2025)

Projection: EPSG:7856

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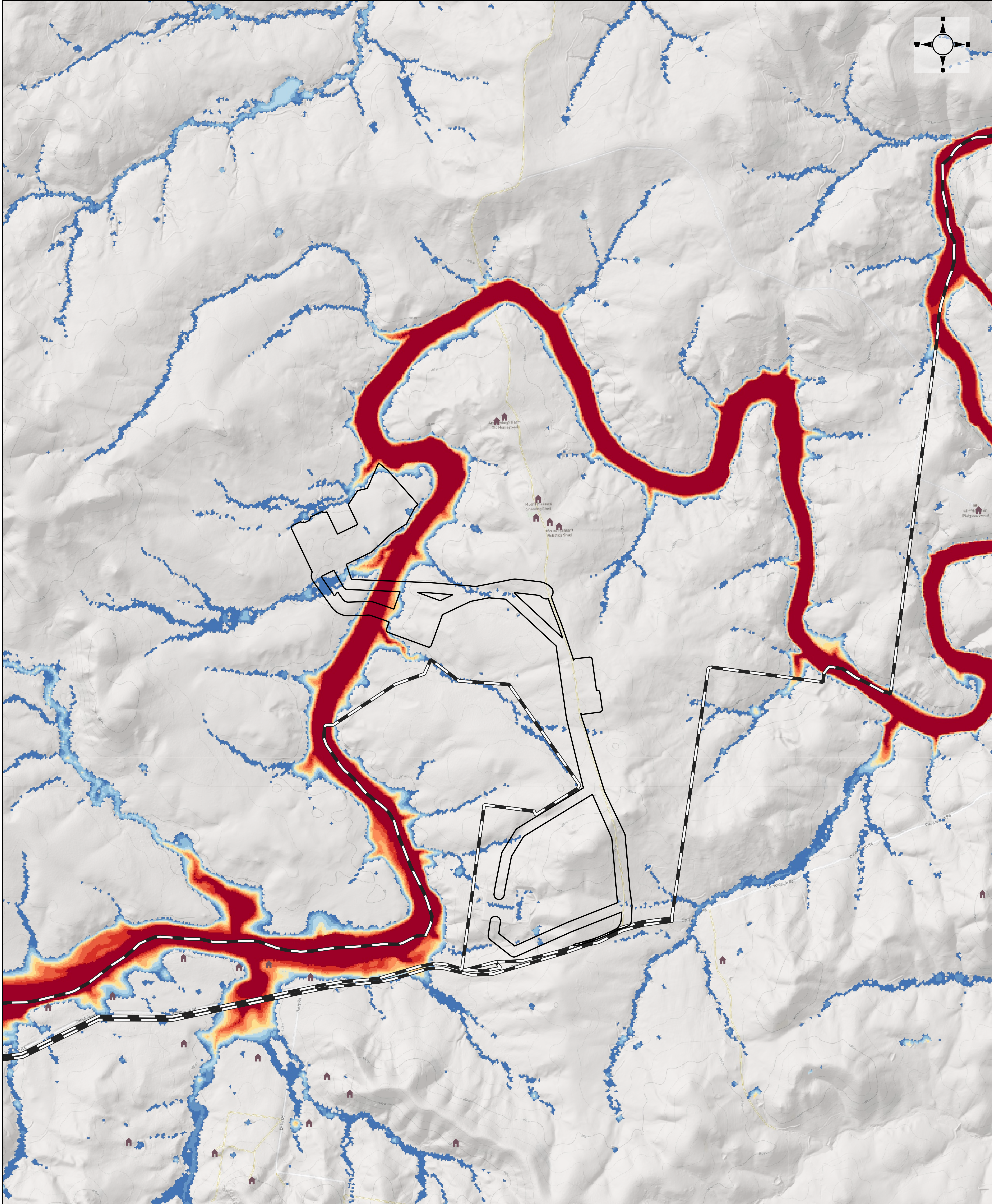

Legend

- Project Area
- Dwellings
- Development Footprint

Depth (m)

- 0 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- > 4.5

Wattle Creek Water Resource Impact Assessment

Modelled Peak depth
1% AEP Flood Event

0 300 600 m

WRM WATER + ENVIRONMENT

Projection: EPSG:7856

APPENDIX C SOIL DATA

Source- Minesoils

Site Description – Site 1					
Site Reference	1	**ASC Name**	Bleached Eutrophic Brown Chromosol (BFKOWNR)		
Average Slope	3%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55	
Landform Element	Lower Slope	**Drainage**	Imperfect	X: 780570	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6165396	

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and sodic. 5% coarse fragments 5mm. Many roots and well drained. Clear boundary.
A2	0.20 – 0.50	Bleached Grey (Munsell 10YR 6/1) apedal Loamy Sand with sandy fabric. Slightly acidic pH, non-saline and sodic. No coarse fragments. Many roots and well drained. Abrupt boundary.
B2	0.50 +	Yellowish brown (Munsell 10YR 5/6) Medium Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Trace roots and imperfectly drained. 20% grey mottling.

Sample Depth	ECe	$pH_{(1\text{-}5water)}$	ESP

	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.6	Non-saline	5.6	Moderately Acidic	11.3	Sodic
0.30 – 0.40	0.4	Non-saline	6.4	Slightly Acidic	7.2	Marginally Sodic
0.60 – 0.70	0.2	Non-saline	5.7	Moderately Acidic	5.2	Non sodic

Site Description – Site 2				
Site Reference	2	**ASC Name**	Mottled Mesotrophic Brown Kurosol (BGLOWNR)	
Average Slope	11%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderate	MGA 55
Landform Element	Upper Slope	**Drainage**	Imperfect	X: 780538
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166012

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.25**	Very dark brown (Munsell 7.5YR 2.5/3) Sandy Loam with weak pedality, earthy fabric and weak consistence. Neutral pH, non-saline and non-sodic. 15% coarse fragments 5 – 20mm. Many roots and well drained. Abrupt boundary.
B2	**0.25 +**	Yellowish brown to light yellowish brown (Munsell 10YR 5/6 to 2.5Y 6/3) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Strongly to moderately acidic pH, non-saline and non-sodic. 10% coarse fragments 5 – 20mm in upper profile. Very few roots and imperfectly drained. 30% red mottling.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.9	Non-saline	6.6	Neutral	1.5	Non sodic

0.30 – 0.40	0.2	Non-saline	5.3	Strongly Acidic	3.4	Non sodic
0.60 – 0.70	0.3	Non-saline	5.9	Moderately Acidic	2.5	Non sodic

Site Description – Site 3				
Site Reference	3	**ASC Name**	Red Chromosol	
Average Slope	4%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderate	MGA 55
Landform Element	Upper Slope	**Drainage**	Imperfect	X: 780522
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166601

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark brown (Munsell 7.5YR 3/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
B21	**0.20 – 0.45**	Dark reddish brown (Munsell 2.5YR 2.5/4) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. 10% grey mottling. Gradual boundary.
B22	**0.45 +**	Brown(Munsell 7.5YR 5/4) Light Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 10% grey mottling.

Site Description – Site 4				
Site Reference	4	**ASC Name**	Yellow Sodosol	
Average Slope	3%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 780156
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167178

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.15	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. 5% coarse fragments 5 - 10mm. Many roots and well drained. Clear boundary.
A2	0.15 – 0.35	Bleached light brownish grey (Munsell 10YR 5/2) Sand with weak pedality, earthy fabric and weak consistence. 30% coarse fragments 5 - 10mm. Few roots and imperfectly drained. Abrupt boundary.
B22	0.35 – 0.5	Brownish yellow (Munsell 10YR 6/6) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 10% grey mottling.
C	50+	Decomposing parent material.

Site Description – Site 5				
Site Reference	5	**ASC Name**	Eutrophic Mesonatric Brown Sodosol (BFKOWNR)	
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 779509
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167098

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark yellowish brown (Munsell 10YR 4/4) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. 5% coarse fragments 5mm. Many roots and well drained. Clear boundary.
A2	**0.20 – 0.35**	Brown (Munsell 10YR 4/3) apedal Loamy Sand with sandy fabric. Slightly acidic pH, non-saline and sodic. No coarse fragments. Common roots and imperfectly drained. Abrupt boundary.
B2	**0.35 – 0.65**	Dark yellowish brown (Munsell 10YR 4/4) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Slightly acidic pH, non-saline and sodic. No coarse fragments. Trace roots and imperfectly drained.
BC	**0.65+**	Transition horizon to decomposing parent material.

Sample Depth	ECe		pH$_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.5	Non-saline	5.8	Moderately Acidic	4.5	Non sodic

0.25 – 0.35	0.4	Non-saline	6.4	Slightly Acidic	7.7	Marginally Sodic
0.45 – 0.55	0.6	Non-saline	6.4	Slightly Acidic	17.9	Strongly Sodic

Site Description – Site 6					
Site Reference	6	**ASC Name**	Brown Sodosol		
Average Slope	5%	**Land Use**	Livestock Grazing		**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low		MGA 55
Landform Element	Upper Slope	**Drainage**	Imperfect		X: 779339
Surface Condition	Soft	**Permeability**	Moderate		Y: 6169558

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark brown (Munsell 10YR 3/3) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.40	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Abrupt boundary.
B2	0.40 +	Yellowish brown (Munsell 10YR 5/4) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 20% grey mottling. (Soil corer plugged by wet soil. One core only.)

Site Description – Site 7					
Site Reference	7	**ASC Name**	Mottled Eutrophic Red Chromosol (BELOWNR)		
Average Slope	4%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55	
Landform Element	Midslope	**Drainage**	Moderately Well	X: 779588	
Surface Condition	Soft	**Permeability**	High	Y: 6169020	

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Very dark brown (Munsell 7.5YR 2.5/2) Loam with moderate pedality, rough fabric and weak consistence. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
B21	**0.20 – 0.35**	Dark reddish brown (Munsell 2.5YR 2.5/4) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Neutral pH, non-saline and non-sodic. No coarse fragments. Few roots and imperfectly drained. Clear boundary.
B22	**0.35 – 0.60**	Dark yellowish brown (Munsell 10YR 4/4) Light Medium Clay with weak pedality, rough fabric and moderate consistence. Moderately alkaline pH, non-saline and non-sodic. No coarse fragments. Very few roots and imperfectly drained. 20% grey mottling.
C	**0.60+**	Decomposing parent material.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.4	Non-saline	6.1	Slightly Acidic	1.7	Non sodic

0.20 – 0.30	0.2	Non-saline	6.9	Neutral	1.1	Non sodic
0.50 – 0.60	0.3	Non-saline	7.9	Moderately Alkaline	1.7	Non sodic

Site Description – Site 8				
Site Reference	8	**ASC Name**	Haplic Eutrophic Red Chromosol (BELOWNR)	
Average Slope	6%	**Land Use**	Cropping	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55
Landform Element	Midslope	**Drainage**	Moderately well	X: 779196
Surface Condition	Soft	**Permeability**	High	Y: 6170039

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.25	Very dark brown (Munsell 10YR 2/2) Loam with moderate pedality, rough fabric and moderate consistence. Strongly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
B21	0.25 – 0.55	Dark reddish brown (Munsell 2.5YR 3/4) Heavy Clay to Medium Clay with moderate pedality, rough fabric and moderate consistence. Neutral pH, non-saline and non-sodic. No coarse fragments. Common roots and imperfectly drained. Clear boundary.
C	0.55 +	Decomposing parent material.

Sample Depth	ECe		$pH_{(1-5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	1.0	Non-saline	5.5	Strongly Acidic	1.7	Non sodic

0.20 – 0.30	0.2	Non-saline	7.0	Neutral	1.2	Non sodic
0.45 – 0.55	0.2	Non-saline	7.2	Neutral	1.3	Non sodic

Site Description – Site 9					
Site Reference	9	**ASC Name**	Yellow Sodosol		
Average Slope	8%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55	
Landform Element	Lower Slope	**Drainage**	Imperfect	X: 778652	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6170010	

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	**0.20 – 0.55**	Dark greyish brown (Munsell 10YR 4/2) apedal Medium Clay with sandy fabric. No coarse fragments. Common roots and imperfectly drained. Abrupt boundary.
B2	**0.55 +**	Yellowish brown (Munsell 10YR 5/4) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Very few roots and imperfectly drained. 20% grey mottling.

Site Description – Site 10				
Site Reference	10	**ASC Name**	Eutrophic Subnatric Brown Sodosol (BEKOWNR)	
Average Slope	4%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Upper Slope	**Drainage**	Imperfect	X: 778833
Surface Condition	Soft	**Permeability**	Moderate	Y: 6169564

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark brown (Munsell 7.5YR 3/4) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
B2	**0.20 – 0.55**	Strong brown (Munsell 7.5YR 5/8) Medium Clay with moderate pedality, rough fabric and strong consistence. Neutral pH, non-saline and sodic. No coarse fragments. Very few roots and imperfectly drained. Gradual boundary. 10% red mottling, 10% grey mottling.
C	**0.90 +**	Decomposing parent material.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.6	Non-saline	5.8	Moderately Acidic	2.2	Non sodic

0.30 – 0.40	0.5	Non-saline	6.7	Neutral	9.9	Marginally Sodic
0.60 – 0.70	1.3	Non-saline	7.2	Neutral	13.8	Sodic

Site Description – Site 11				
Site Reference	11	**ASC Name**	Brown Sodosol	
Average Slope	2%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Upper Slope	**Drainage**	Moderately Well	X: 778321
Surface Condition	Soft	**Permeability**	High	Y: 6169334

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A	0.00 – 0.20	Black (Munsell 10YR 2/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. 20% coarse fragments 5mm. Many roots and well drained. Clear boundary.
B	0.20 – 0.55	Dark brown (Munsell 10YR 3/3) Medium Clay with weak pedality, rough fabric and moderate consistence. 10% coarse fragments 5 – 10mm. Common roots and moderately well drained. Clear boundary.
C	0.50+	Decomposing parent material.

Site Description – Site 12

Site Reference	12	ASC Name	Eutrophic Subnatric Brown Sodosol (BELOVNR)	
Average Slope	2%	Land Use	Livestock Grazing	Coordinates
Landform Pattern	Hillslope	Soil Fertility	Moderately Low	MGA 55
Landform Element	Upper Slope	Drainage	Imperfect	X: 777933
Surface Condition	Soft	Permeability	Moderate	Y: 6169008

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A	0.00 – 0.20	Dark brown (Munsell 7.5YR 3/3) Sandy Loam with weak pedality, earthy fabric and weak consistence. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Abrupt boundary.
B	0.20 – 0.50	Brown (Munsell 10YR 5/3) Sandy Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Common roots and imperfectly drained. 20% grey mottling. Gradual boundary.
C	0.50 +	Decomposing parent material.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.4	Non-saline	6.2	Slightly Acidic	5.6	Non sodic
0.20 – 0.30	0.5	Non-saline	5.9	Moderately Acidic	8.5	Marginally Sodic

0.40 – 0.50	0.9	Non-saline	5.8	Moderately Acidic	10.8	Sodic

Site Description – Site 13				
Site Reference	13	**ASC Name**	Yellow Sodosol	
Average Slope	4%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Low	MGA 55
Landform Element	Lower Slope	**Drainage**	Moderately Well	X: 777646
Surface Condition	Soft	**Permeability**	Moderate	Y: 6168458

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark grey (Munsell 10YR 4/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.55	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
BC	0.55 +	Olive yellow (Munsell 2.5Y 6/6) Medium Clay with weak pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and moderately well drained.
C	0.45	Decomposing parent material.

Site Description – Site 14				
Site Reference	14	**ASC Name**	Red Sodosol	
Average Slope	5%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 777646
Surface Condition	Soft	**Permeability**	Moderate	Y: 6168458

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.15**	Very dark brown (Munsell 10YR 2/2) Sandy Loam with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
B	**0.15 – 0.55**	Dark reddish brown (Munsell 2.5YR 2.5/4)Heavy Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. 15% grey mottling. Gradual boundary.
BC	**0.55 – 0.70**	Reddish yellow (Munsell 7.5YR 6/6) Medium Clay with weak pedality, rough fabric and weak consistence. No coarse fragments. 10% grey mottling. Trace roots and imperfectly drained.
C	**0.70**	Decomposing parent material.

Site Description – Site 15				
Site Reference	15	**ASC Name**	Bleached Mesotrophic Brown Chromosols (BGKOWNR)	
Average Slope	6%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55
Landform Element	Midslope	**Drainage**	Poor	X: 778288
Surface Condition	Soft	**Permeability**	Moderate	Y: 6168672

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.10	Very dusky red (Munsell 2.5YR 2.5/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. 10% coarse fragments 5 - 10mm. Many roots and well drained. Clear boundary.
A1	0.10 – 0.20	Bleached very pale brown (Munsell 10YR 7/4) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. 20% coarse fragments 5 - 10mm. Many roots and well drained. Abrupt boundary.
B21	0.20 – 0.55	Yellowish brown (Munsell 10YR 5/6) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Common roots and poorly drained. 10% red mottling. 20% grey mottling. Gradual boundary.
B22	0.55 +	Light grey (Munsell 10YR 7/2) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. No roots and poorly drained. 30% red mottling.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.9	Non-saline	5.9	Moderately Acidic	1.8	Non sodic
0.10 – 0.20	0.4	Non-saline	6.0	Moderately Acidic	3.1	Non sodic

0.30 – 0.40	0.2	Non-saline	5.6	Moderately Acidic	3.4	Non sodic
0.60 – 0.70	0.2	Non-saline	5.5	Moderately Acidic	5.4	Non sodic

Site Description – Site 16				
Site Reference	16	**ASC Name**	Yellow Sodosol	
Average Slope	10%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 777990
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167896

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Very dark grey (Munsell 10YR 3/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.30	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Abrupt boundary.
B2	0.30 – 0.75	Brownish yellow (Munsell 10YR 6/6) Heavy Clay with weak pedality, rough fabric and moderate consistence. No coarse fragments. No roots and imperfectly drained. 20% grey mottling, increasing to 40% at depth.
C	0.75	Decomposing parent material.

Site Description – Site 17					
Site Reference	17	**ASC Name**	Eutrophic Mesonatric Brown Sodosol (BEKOWNR)		
Average Slope	11%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55	
Landform Element	Lower Slope	**Drainage**	Imperfect	X: 778510	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167645	

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark yellowish brown (Munsell 10YR 4/4) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.40	Yellowish brown (Munsell 10YR 5/4) apedal Loamy Sand with sandy fabric. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Common roots and imperfectly drained. Gradual boundary.
B2	0.40 – 0.65	Light olive brown (Munsell 2.5Y 5/4) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Trace roots and imperfectly drained. 30% red mottling toward base of horizon. Clear boundary.
BC	0.65 +	Red (Munsell 2.5YR 4/6) Sandy Clay with weak pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. No roots and moderately well drained.

Sample Depth	ECe		$pH_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.5	Non-saline	6.0	Moderately Acidic	4.5	Non sodic
0.20 – 0.30	0.3	Non-saline	6.5	Slightly Acidic	5.0	Non sodic

0.50 – 0.60	0.8	Non-saline	7.9	Moderately Alkaline	16.9	Strongly Sodic
0.70 – 0.80	1.1	Non-saline	8.3	Moderately Alkaline	19.5	Strongly Sodic

Site Description – Site 18				
Site Reference	18	**ASC Name**	Brown Sodosol	
Average Slope	10%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778193
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167404

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark grey (Munsell 10YR 4/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and rapidly drained. Clear boundary.
A2	**0.20 – 0.40**	Grey (Munsell 10YR 6/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Very few roots and well drained. Abrupt boundary.
B	**0.40 +**	Yellowish brown (Munsell 10YR 5/4) Heavy Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. No roots and imperfectly drained. 30% orange mottling, 30% grey mottling.

Site Description – Site 19

Site Reference	19	**ASC Name**	Eutrophic Subnatric Yellow Sodosol (BEKOWNR)	
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778025
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166988

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.15	Brown (Munsell 10YR 4/3) Loamy Sand with weak pedality, earthy fabric and weak consistence. Slightly acidic pH, non-saline and sodic. No coarse fragments. Many roots and well drained. Clear boundary.
A1	0.15 – 0.35	Dark yellowish brown (Munsell 10YR 4/4) apedal Loamy Sand with sandy fabric. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Abrupt boundary.
B21	0.35 – 0.70	Yellowish brown (Munsell 10YR 5/6) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Slightly acidic pH, non-saline and sodic. No coarse fragments. Common roots and imperfectly drained. 30% grey mottling. 5% red mottling. Clear boundary.
B22	0.70 +	Yellowish brown (Munsell 10YR 5/6) Heavy Clay with weak pedality, rough fabric and strong consistence. Slightly acidic pH, non-saline and sodic. No coarse fragments. No roots and imperfectly drained. 10% red mottling. 20% grey mottling.

Sample Depth	ECe		pH$_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.4	Non-saline	6.2	Slightly Acidic	7.7	Marginally Sodic
0.20 – 0.30	0.3	Non-saline	6.3	Slightly Acidic	4.8	Non sodic
0.50 – 0.60	1.1	Non-saline	6.0	Slightly Acidic	14.0	Strongly Sodic

0.70 – 0.80	0.2	Non-saline	6.1	Slightly Acidic	11.9	Sodic

Site Description – Site 20					
Site Reference	20	**ASC Name**	Yellow Sodosol		
Average Slope	2%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55	
Landform Element	Crest	**Drainage**	Moderately Well	X: 778560	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166669	

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.15**	Dark grey (Munsell 10YR 4/1) Loamy Sand with weak pedality, sandy fabric and weak consistence. 30% coarse fragments 10 – 50mm. Many roots and well drained. Clear boundary.
A2	**0.15 – 0.25**	Grey (Munsell 10YR 6/1) apedal Loamy Sand with sandy fabric. 50% coarse fragments 10 – 50mm. Many roots and well drained. Clear boundary.
B	**0.25 – 0.50**	Brownish yellow (Munsell 10YR 6/8) Clay Loam with moderate pedality, rough fabric and moderate consistence. 40% coarse fragments 10 – 50mm. Few roots and moderately well drained.
R	**0.50**	Unweathered parent material. Corer refusal.

Site Description – Site 21				
Site Reference	21	**ASC Name**	Lithic Leptic Tenosol	
Average Slope	3%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Low	MGA 55
Landform Element	Crest	**Drainage**	Moderately Well	X: 778192
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166012

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark grey (Munsell 10YR 4/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. 30% coarse fragments 10 – 50mm. Many roots and well drained. Clear boundary.
B2	0.20 – 0.55	Yellow (Munsell 10YR 7/6) Sandy Loam with weak pedality, rough fabric and weak consistence. 70% coarse fragments 10 – 50mm. Common roots and moderately well drained. Gradual boundary.
R	0.45 +	Very partially weathered parent material. Corer refusal.

Site Description – Site 22				
Site Reference	22	**ASC Name**	Basic Paralithic Leptic Tenosol (BEKKVNR)	
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Well	X: 778596
Surface Condition	Soft	**Permeability**	Moderate	Y: 6165666

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark grey (Munsell 10YR 4/1) Loamy Sand with moderate pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
A2	**0.20 – 0.30**	Dark reddish brown (Munsell 5YR 3/4) Loamy Sand with weak pedality, sandy fabric and weak consistence. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
C	**0.30 – 0.55**	90% coarse fragments 10 – 30mm

R	0.55 +	Loose, hard parent material

Sample Depth	ECe		pH(1-5water)		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.5	Non-saline	5.6	Moderately Acidic	5.2	Non sodic
0.20 – 0.30	0.2	Non-saline	6.0	Slightly Acidic	2.6	Non sodic

Site Description – Site 23				
Site Reference	23	**ASC Name**	Eutrophic Mesonatric Brown Sodosol (BEKOWNR)	
Average Slope	5%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 779078
Surface Condition	Soft	**Permeability**	Moderate	Y: 6165493

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.10	Dark brown (Munsell 10YR 3/3) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.55	Yellowish brown (Munsell 10YR 5/4) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Many roots and well drained. Clear boundary.

B22	0.55 +	Dark yellowish brown to light brownish grey (Munsell 10YR 4/6 to 10YR 6/2) Heavy Clay with moderate pedality, rough fabric and moderate consistence. Slightly acidic pH, non-saline and sodic. No coarse fragments. Trace roots and imperfectly drained. 40% grey mottling at base of horizon.

Sample Depth	ECe		pH(1-5water)		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.8	Non-saline	5.7	Moderately Acidic	7.7	Marginally Sodic
0.10 – 0.20	0.4	Non-saline	5.9	Moderately Acidic	9.2	Marginally Sodic
0.40 – 0.50	0.4	Non-saline	6.0	Slightly Acidic	15.2	Strongly Sodic
0.70 – 0.80	0.8	Non-saline	6.1	Slightly Acidic	19.2	Strongly Sodic

Site Description – Site 24				
Site Reference	24	**ASC Name**	Paralithic Leptic Tenosol	
Average Slope	5%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Low	MGA 55
Landform Element	Midslope	**Drainage**	Moderately Well	X: 778736
Surface Condition	Soft	**Permeability**	Moderate	Y: 6166090

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description

A	**0.00 – 0.20**	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with moderate pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
BC	**0.20 – 0.50**	Reddish yellow (Munsell 7.5YR 6/6) Sandy Loam with weak pedality, rough fabric and moderate consistence. 60% coarse fragments 10 – 30mm. Common roots and moderately drained. Gradual boundary.
R	**0.55 +**	Hard parent material.

Site Description – Site 25				
Site Reference	25	**ASC Name**	Paralithic Leptic Tenosol	
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Low	MGA 55
Landform Element	Midslope	**Drainage**	Moderately Well	X: 778894
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167073

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Very dark grey (Munsell 7.5YR 3/1) Loamy Sand with moderate pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Gradual boundary.
BC	**0.20 – 0.55**	Reddish yellow (Munsell 7.5YR 6/8) Sandy Clay Loam with weak pedality, earthy fabric and moderate consistence. 50% coarse fragments 10 – 30mm. Common roots and moderately drained. Gradual boundary.
R	**0.55 +**	Hard parent material.

Site Description – Site 26				
Site Reference	26	**ASC Name**	Brown Sodosol	
Average Slope	4%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778917
Surface Condition	Soft	**Permeability**	Moderate	Y: 6167521

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
B21	0.20 – 0.55	Light olive brown (Munsell 2.5Y 5/4) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. Gradual boundary.
C	0.55 +	Decomposing parent material.

Site Description – Site 27				
Site Reference	27	**ASC Name**	Mesotrophic Subnatric Brown Sodosol (BEKOWNR)	
Average Slope	8%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 779321

Surface Condition	Soft	Permeability	Moderate	Y: 6167743

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark brown (Munsell 10YR 3/3) Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Many roots and well drained. Clear boundary.
B21	**0.20 – 0.55**	Dark yellowish brown (Munsell 10YR 4/6) Light Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and sodic. No coarse fragments. Common roots and imperfectly drained. Gradual boundary.
B22	**0.55 +**	Strong brown (Munsell 7.5YR 5/8) Light Medium Clay with moderate pedality, rough fabric and moderate consistence. Moderately acidic pH, non-saline and sodic. No roots and imperfectly drained.

Sample Depth	ECe		pH$_{(1\text{-}5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.3	Non-saline	5.9	Moderately Acidic	8.4	Marginally Sodic
0.30 – 0.40	0.3	Non-saline	5.8	Moderately Acidic	10.8	Sodic
0.60 – 0.70	0.3	Non-saline	5.9	Moderately Acidic	11.5	Sodic

Site Description – Site 28				
Site Reference	28	**ASC Name**	Haplic Eutrophic Brown Chromosol (BEKOVNR)	
Average Slope	14%	**Land Use**	Livestock Grazing	**Coordinates**

Landform Pattern	Hillslope	Soil Fertility	Moderately High	MGA 55
Landform Element	Midslope	Drainage	Imperfect	X: 778947
Surface Condition	Soft	Permeability	Moderate	Y: 6168180

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark brown (Munsell 10YR 3/3) Loamy Sand with weak pedality, earthy fabric and weak consistence. Moderately acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.40	Dark yellowish brown (Munsell 10YR 4/4) Sand with weak pedality, rough fabric and moderate consistence. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Common roots and imperfectly drained. Gradual boundary.
B22	0.40 – 0.70	Yellowish brown (Munsell 10YR 5/6) Light Clay with moderate pedality, rough fabric and moderate consistence. Neutral pH, non-saline and non-sodic. No coarse fragments. Trace roots and imperfectly drained.
C	0.70	Decomposing parent material.

Sample Depth	ECe		pH$_{(1-5water)}$		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	0.4	Non-saline	5.9	Moderately Acidic	3.7	Non sodic
0.25 – 0.35	0.3	Non-saline	6.0	Slightly Acidic	1.1	Non sodic
0.55 – 0.65	0.2	Non-saline	6.8	Neutral	2.4	Non sodic

Site Description – Site 29

Site Reference	29	**ASC Name**	Brown Sodosol		
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55	
Landform Element	Midslope	**Drainage**	Imperfect	X: 778888	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6168669	

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Very dark grey (Munsell 2.5Y 3/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	**0.20 – 0.30**	Grey (Munsell 10YR 5/1) Sand with weak pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. Gradual boundary.
B22	**0.30+**	Light olive brown (Munsell 2.5Y 5/4) Heavy Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 20% grey mottling.

Site Description – Site 30				
Site Reference	30	**ASC Name**	Yellow Sodosol	
Average Slope	12%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778492
Surface Condition	Soft	**Permeability**	Moderate	Y: 6168155

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Very dark grey (Munsell 10YR 3/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	0.20 – 0.30	Grey (Munsell 10YR 6/1) Loamy Sand with weak pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. Clear boundary.
B22	0.30 – 0.65	Olive yellow (Munsell 2.5Y 6/6) Medium Clay with weak pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 20% grey mottling.
C	0.65	Decomposing parent material.

Site Description – Site 31				
Site Reference	31	**ASC Name**	Yellow Sodosol	
Average Slope	5%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately Low	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778213
Surface Condition	Soft	**Permeability**	Moderate	Y: 6170198

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	0.00 – 0.20	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
B21	0.20 – 0.60	Brownish yellow (Munsell 10YR 6/6) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Common roots and imperfectly drained. 10% grey mottling.
C	0.60 +	Decomposing parent material.

Site Description – Site 32					
Site Reference	32	**ASC Name**	Haplic Eutrophic Red Chromosol (BEKOWNR)		
Average Slope	3%	**Land Use**	Livestock Grazing	**Coordinates**	
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55	
Landform Element	Midslope	**Drainage**	Moderately Well	X: 776487	
Surface Condition	Soft	**Permeability**	Moderate	Y: 6171300	

Plate 1 – Soil Profile

Plate 2 – Landscape

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark brown (Munsell 7.5YR 3/4) Sandy Loam with weak pedality, earthy fabric and weak consistence. Slightly acidic pH, non-saline and non-sodic. No coarse fragments. Many roots and well drained. Clear boundary.
B2	**0.20 – 0.40**	Dark reddish brown (Munsell 2.5YR 2.5/4) Clay Loam with moderate pedality, rough fabric and moderate consistence. Neutral pH, non-saline and non-sodic. No coarse fragments. Common roots and moderately drained. Clear boundary.
BC	**0.40 +**	Dark reddish brown (Munsell 2.5YR 2.5/4) Sandy Loam with moderate pedality, rough fabric and moderate consistence. Neutral pH, non-saline and non-sodic. No coarse fragments. Trace roots and well drained.

Sample Depth	ECe		pH(1-5water)		ESP	
	dS/m	Rating	Value	Rating	Value	Rating
0.00 – 0.10	1.1	Non-saline	6.4	Slightly Acidic	0.7	Non sodic
0.25 – 0.35	0.4	Non-saline	6.7	Neutral	0.7	Non sodic
0.55 – 0.65	0.8	Non-saline	7.2	Neutral	1.7	Non sodic

Site Description – Site 33				
Site Reference	33	**ASC Name**	Brown Chromosol	
Average Slope	9%	**Land Use**	Livestock Grazing	**Coordinates**
Landform Pattern	Hillslope	**Soil Fertility**	Moderately High	MGA 55
Landform Element	Midslope	**Drainage**	Imperfect	X: 778175
Surface Condition	Soft	**Permeability**	Moderate	Y: 6171202

Plate 2 – Landscape

Plate 1 – Soil Profile

Plate 3 – Surface

Horizon	Depth (m)	Description
A1	**0.00 – 0.20**	Dark greyish brown (Munsell 10YR 4/2) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.
A2	**0.20 – 0.30**	Grey (Munsell 10YR 6/1) Loamy Sand with weak pedality, earthy fabric and weak consistence. No coarse fragments. Many roots and well drained. Clear boundary.

B21	**0.30 – 0.55**	Dark yellowish brown (Munsell 10YR 5/4) Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained.
B22	**0.55+**	Yellowish brown (Munsell 10YR 5/4) Light Medium Clay with moderate pedality, rough fabric and moderate consistence. No coarse fragments. Trace roots and imperfectly drained. 10% grey mottling.

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