APPENDIX N

Water quality impact assessment

Birriwa Solar and Battery Project Water Quality Impact Assessment

FINAL REPORT

20 June 2022

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for UPC\AC Renewables Australia under the contract titled 'CSA Alluvium Birriwa Hydrology EIS'.

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1 Introduction

ACEN Australia Pty Ltd (ACEN), formerly operating as UPC\AC Renewables Australia (UPC\AC) proposes to develop the Birriwa Solar and Battery Project; a large scale solar photovoltaic (PV) generation facility along with battery storage and associated infrastructure (the project). The solar component of the project will have an indicative capacity of around 600 megawatts (MW) and include a centralised battery energy storage system (BESS) of up to 6000 MW and2 hour duration. The BESS will enable energy from solar to be stored and then released during times of demand.

The project is in the locality of Birriwa, approximately 15 kilometres (km) south-west of the township of Dunedoo, in the Central West of New South Wales (NSW) (Figure 1.1). The project is within the Mid-Western Regional Council local government area (LGA) and is within the Central-West Orana (CWO) Renewable Energy Zone (REZ).

The project is State significant development (SSD) pursuant to Schedule 1 of the State Environmental Planning Policy (Planning Systems) 2021 (Planning Systems SEPP). Therefore, a development application for the project is required to be submitted under Part 4, Division 4.1 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). This water quality impact assessment report forms part of the Environmental Impact Statement (EIS).

This report has been presented to aid in the client addressing the Biodiversity, Conservation and Science Directorate (BCS) requirements items 6-9 as part of the SEARs. These SEARs, and the relevant sections of this report pertaining to their discussion, are provided in Table 1.

Table 1. SEARs requirements and report section reference

SEARs No.	SEARs requirements	Report section reference
6	The EIS must map the following features relevant to water and soils including: a. Acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map); b. Rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method); c. Wetlands as described in s4.2 of the Biodiversity Assessment Method; d. Groundwater; e. Groundwater dependent ecosystems; f. Proposed intake and discharge locations.	Section 2
7	The EIS must describe background conditions for any water resource likely to be affected by the project, including: a. Existing surface and groundwater; b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations; c. Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters; d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government; e. Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions	Section 3
8	The EIS must assess the impacts of the project on water quality, including: a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the project protects the Water Quality Objectives where they are currently being	Section 4 Section 5 Section 6

		achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction;	
	b.	b. Identification of proposed monitoring of water quality.	
9	The EIS must assess the impact of the project on hydrology, including:		Section 5 Section 6
	a.	Water balance including quantity, quality and source;	
	b.	Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas;	
	c.	Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems;	
	d.	Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches);	
	e.	Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water;	
	f.	Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options;	
	g.	Identification of proposed monitoring of hydrological attributes.	

2 Constraints mapping

To aid in identifying the appropriate placement of associated infrastructure, it is important to understand the relevant water and soil constraints as they exist across the study area. These constraints were reviewed as part of this assessment; the constraint and the data sources are provided in Table 2. To gain an appreciation of the extent of these constraints, a map has been presented in Figure 1, whilst the full suite of constraints reviewed are mapped and presented in Attachment 1.

Table 2. Constraint and data source

Constraint	Source
Acid sulfate soils	Acid Sulfate Soils, sourced from the NSW Planning Portal (NSW, 2022)
Rivers, streams, wetland, estuaries	Hydrography, sourced from the NSW Planning Portal (NSW, 2022) Riparian buffer zones as per Appendix E of the Biodiversity Assessment Method (DPIE, 2020)
Wetlands	As above.
Groundwater	Groundwater vulnerability, sourced from the NSW Planning Portal (NSW, 2022)
Groundwater dependant ecosystems	GDEs from the Groundwater Dependent Ecosystems Atlas (BoM, 2022)
Proposed intake and discharge locations	Provided by ACEN

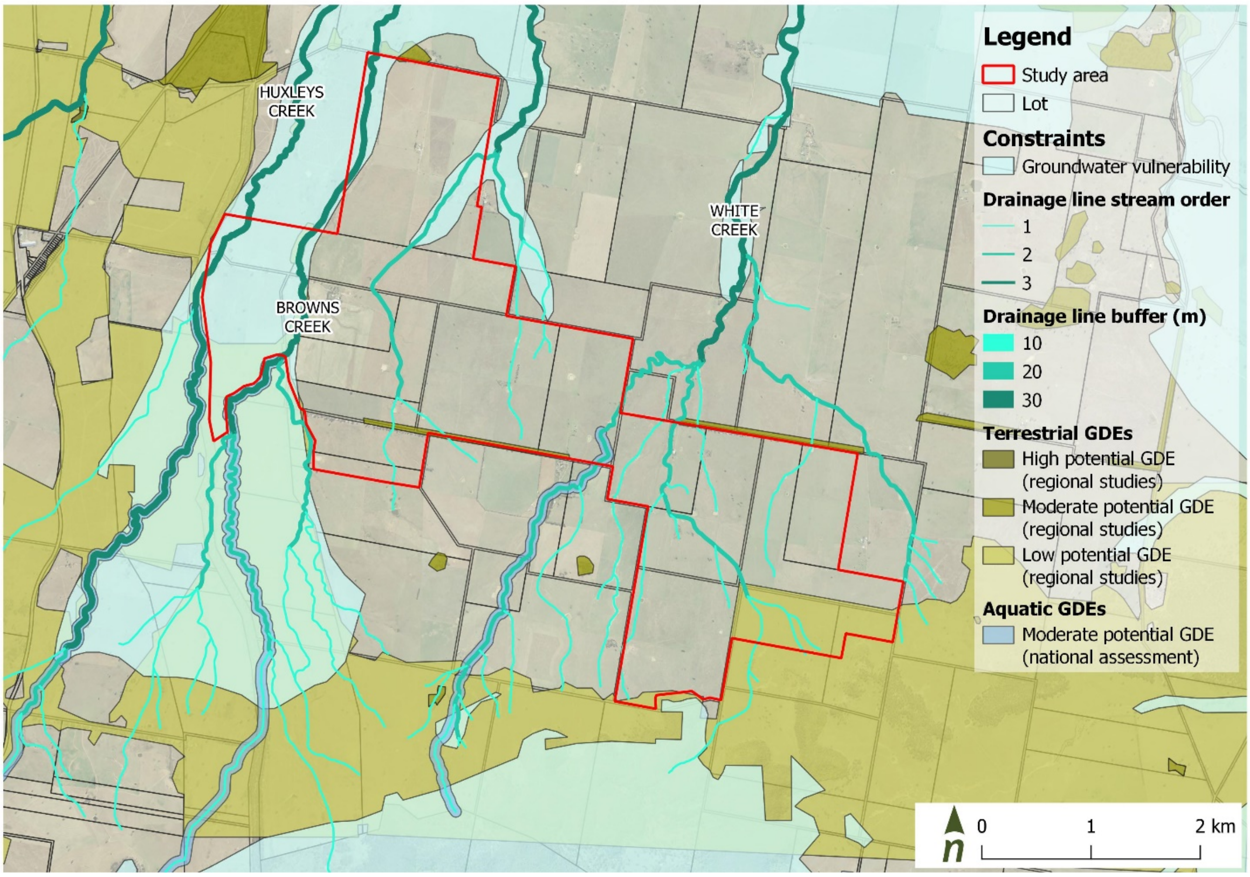

Figure 1. *Extent of constraints across the study area*

Through this assessment, several constraints across the study area have been identified. These are:

- **Acid sulfate soils**: No acid sulfate soils are mapped across the study area.
- **Drainage lines:** Three local drainage lines, Huxleys Creek, Browns Creek and White Creek, traverse the study area, flowing in a northernly direction into Talbragar River. These waterways are identified as third order streams (with first and second order tributaries). Consequently, each of these waterways require a riparian buffer of up to 30m (with a 10m and 20m buffer required for the first and second order tributaries), as per the Biodiversity Assessment Method (DPIE, 2020).
- **Wetlands**: No wetlands have been mapped across the study area.
- **Groundwater**: The study area has been identified as occurring within the Lachlan Fold Belt MBD groundwater source (NSW, 2020). Groundwater in the vicinity of the waterways through the study area have been classified as vulnerable. It is recommended that future planning over these areas consider potential contamination to this vulnerable groundwater, with additional assessment undertaken as required.
- **Groundwater dependent ecosystems (GDEs)**: A portion of the study area has identified the potential presence of terrestrial or aquatic groundwater dependent ecosystems, although these primarily occur outside and upstream of the study area. It is recommended that where these do occur on the area of the study area being developed, additional assessment be undertaken to determine the significance of the GDEs, and potential influence development may have. A more detailed assessment of GDE occurrence across the site is provided in the *Biodiversity Development Assessment Report* (EMM, 2022a).
- **Proposed intake and discharge locations**: The is no plan to engage any of the drainage lines traversing the site for water usage (with water for construction sourced from farm dams on site or trucked in as necessary), thus there are no proposed intake or discharge locations.
-

3 Water quality assessment

3.1 Locality & water sharing

The study area is located within the Macquarie-Bogan River catchment, presented in Figure 2. Runoff from the site, conveyed through Huxleys Creek, Browns Creek and White Creek, discharges into the Talbragar River, a major tributary of the Macquarie River.

The study area is governed by the *Water Sharing Plan for the Macquarie Bogan Unregulated Rivers Water Sources 2012* (NSW Government, 2020). This plan dictates water sharing, extraction, diversion, and all associated details, as set out in the *Water Management Act 2000* (NSW Government, 2022).

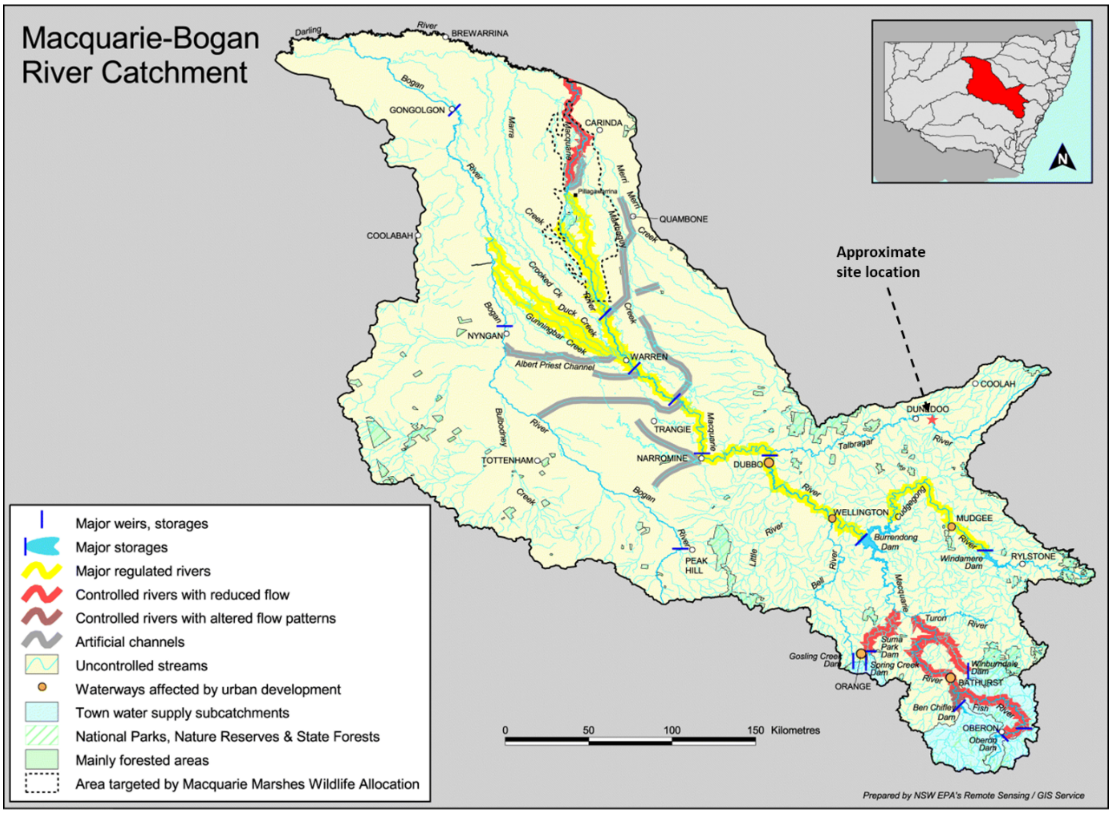

Figure 2. *Macquarie-Bogan River Catchment map (DPIE, 2006)*

3.2 Water quality objectives

Environmental values are a representation of the agreed community needs and wants for a waterway. Typically, they refer to the desired end use of the waterway, and the ecosystem services that the waterway provides. The figure below highlights all eleven specified objectives that may be applicable to a particular waterway.

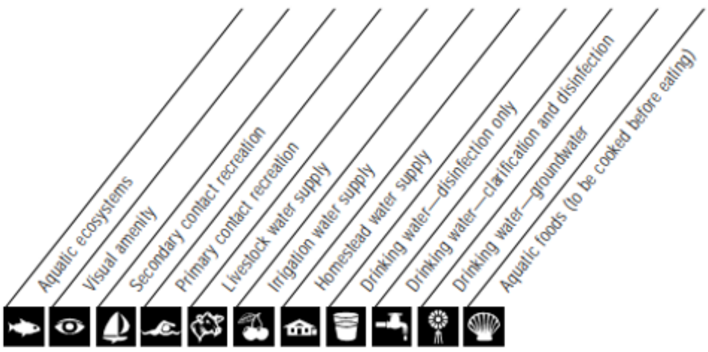

Figure 3. *Key environmental objectives (DPIE, 2006)*

The location of the proposed development falls within the Macquarie-Bogan River catchment, with all the three named tributaries flowing through the study area, and Talbragar River, being specified as uncontrolled and outside water drinking catchments. Consequently, all eleven environmental objectives are relevant.

The guidelines detailing these objectives can be obtained from the NSW Water Quality and River Flow Objectives site, hosted by NSW DPE. It is suggested for this development, the primary objective relates to the protection of aquatic ecosystems. The indicators and numerical criteria for this objective is presented in Table 3. The trigger values contained therein have been selected from the ANZECC (Australian and New Zealand Guidelines for Fresh and Marine Water Quality) 2000 guidelines.

As suggested by the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (Dela-Cruz J, Pik A & Wearne P 2017), these guidelines should be replaced by locally derived objectives, which consider current values and uses, along with the waterway's sensitivity to land use activities. Figure 4 is the framework flowchart recommended for use in developing more holistic waterway health outcomes.

Table 3. Aquatic ecosystem water quality objectives for uncontrolled streams in the Macquarie-Bogan River catchment (DPIE 2006)

Indicator	Numerical criteria (trigger values)
Total phosphorus	• Upland rivers: 20 µg/L • Lowland rivers: 25 µg/L for rivers flowing to the coast; 50 µg/L for rivers in the Murray-Darling Basin • Lakes & reservoirs: 10 µg/L • Estuaries: 30 µg/L
Total nitrogen	• Upland rivers: 250 µg/L • Lowland rivers: 350 µg/L for rivers flowing to the coast; 500 µg/L for rivers in the Murray-Darling Basin • Lakes & reservoirs: 350 µg/L • Estuaries: 300µg/L
Chlorophyll-a	• Upland rivers: not applicable • Lowland rivers: 5 µg/L • Lakes & reservoirs: 5 µg/L. • Estuaries: 4 µg/L.
Turbidity	• Upland rivers: 2–25 NTU (see supporting information) • Lowland rivers: 6–50 NTU (see supporting information) • Lakes & reservoirs: 1–20 NTU • Estuaries: 0.5–10 NTU
Salinity (electrical conductivity)	• Upland rivers: 30–350 µS/cm (see supporting information) • Lowland rivers: 125–2200 µS/cm(see supporting information)
Dissolved oxygen	• Upland rivers: 90–110% • Lowland rivers: 85–110% • Freshwater lakes & reservoirs: 90–110% • Estuaries: 80–110% Note: Dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability.
pH	• Upland rivers: 6.5–8.0 • Lowland rivers: 6.5–8.5 • Freshwater lakes & reservoirs: 6.5–8.0 • Estuaries: 7.0–8.5 Changes of more than 0.5 pH units from the natural seasonal maximum or minimum should be investigated. See supporting information
Temperature	See ANZECC 2000 Guidelines, table 3.3.1.
Chemical contaminants or toxicants	See ANZECC 2000 Guidelines, chapter 3.4 and table 3.4.1.
Biological assessment indicators	This form of assessment directly evaluates whether management goals for ecosystem protection are being achieved (e.g. maintenance of a certain level of species diversity, control of nuisance algae below a certain level, protection of key species, etc). Many potential indicators exist and these may relate to single species, multiple species or whole communities. Recognised protocols using diatoms and algae, macrophytes, macroinvertebrates, and fish populations and/or communities may be used in NSW and interstate (e.g. AusRivAS).

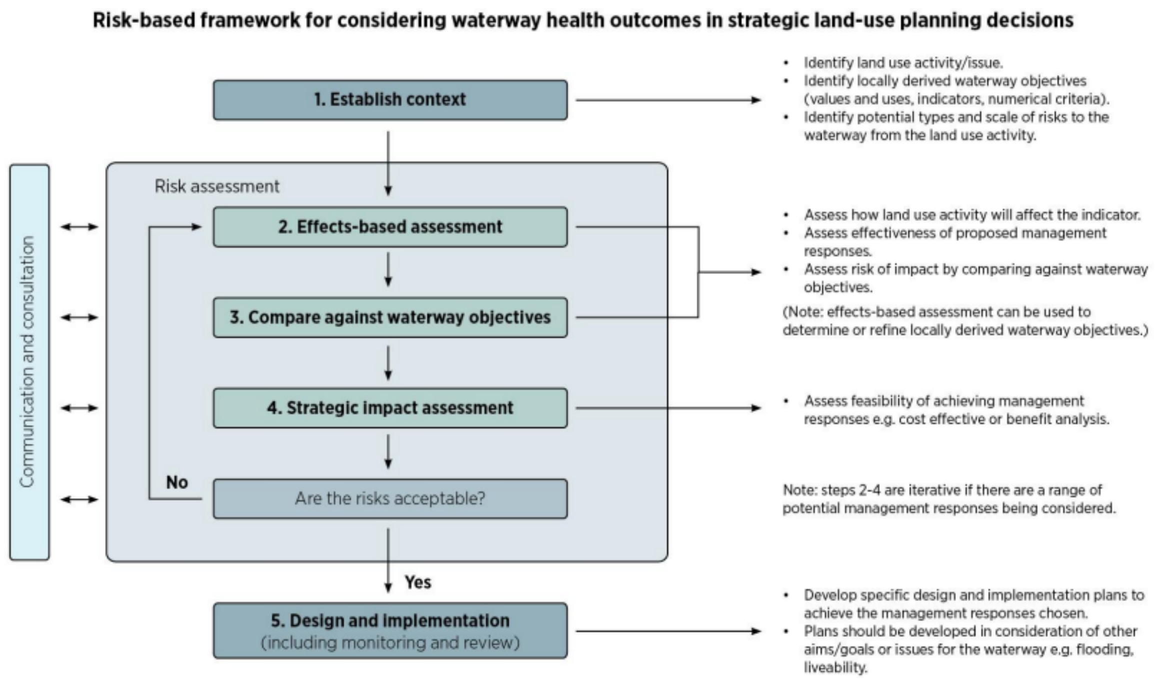

Figure 4. *Risk-based framework flowchart (Dela-Cruz J, Pik A & Wearne P 2017)*

4 Catchment modelling

To understand the nature and degree of impact on receiving waters, it was necessary to develop a model of the hydrologic network associated with runoff generation and delivery within the contributing catchment. The model was developed in the Source modelling framework which is a platform in widespread use nationally.

The Source platform is not a model on its own, but a group of models that can be configured in different combinations to suit a particular problem or answer specific modelling questions. Within Source, the user has a choice of river system or catchment configuration. In fact, these two approaches can theoretically be used interchangeably; however, in most cases, one or the other is typically applied for specific projects. For this project, the catchment configuration was applied to derive daily time series of flows and pollutants to represent current and future catchment conditions.

Source has three basic components; generation, delivery and transport (Figure 5), and each of these can be configured independently for specific catchment land uses, topographies or processes.

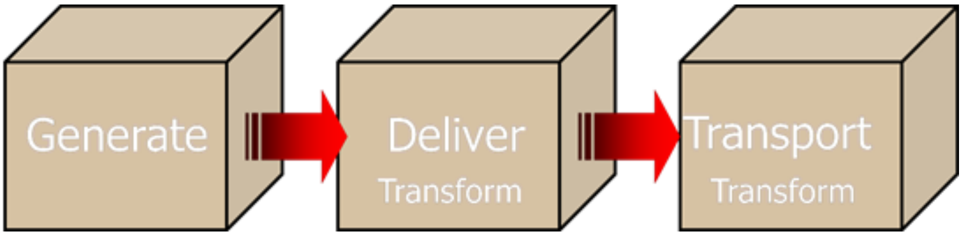

Figure 5. *Source framework concept*

Under each of the components, there are several models to choose from to allow for the best representation of the catchment processes. The primary driver of Source is rainfall-runoff, so the configuration, calibration and validation of rainfall-runoff is vital for a robust model. The generated runoff can then be used to drive a constituent generation model, which can also be a range of different model types to answer specific questions. From here, the generated flows are delivered to a system link and that delivery can be configured to account for numerous stream conditions such as stream wetting, riparian vegetation and other transformations.

4.1 Source model setup

The catchment model for the project was developed from input data for topography, land use, and climate, retrieved from several sources as outlined in Table 4. This model is built in version 5.0.3 of the Source software.

4.2 Data inputs

Given the locality and data availability, the data inputs presented in Table 4 have been used in the creation of this model.

Table 4. Data inputs

Data	Description
Topography	1 arc second, hydrologically corrected Digital Elevation Model (DEM) from Elvis Elevation and Depth (ELVIS)
Land use	Version 1.2 of the New South Wales 2017 Land use mapping, published in June 2020
Climate	Gridded rainfall and Moreton's Wet-environment potential evapotranspiration from the Queensland Government's SILO database
Pollutant loads	Consistent with MUSIC guidelines for the Sydney drinking water catchment, in lieu of site specific data.

4.3 Modelling process

The modelling process is described succinctly in a series of six steps below.

Step 1 – Catchments and streams were described using a hydro enforced 1 second DEM retrieved from ELVIS (see Figure 6).

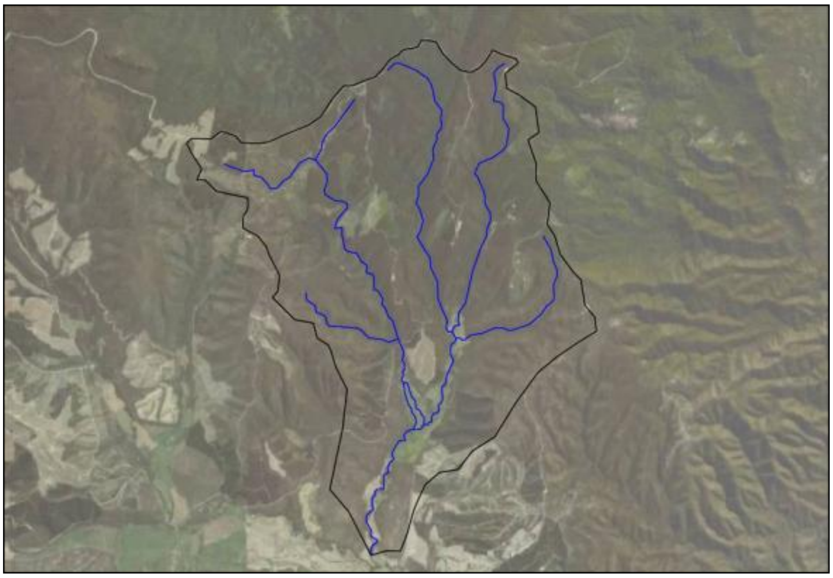

Figure 6. *A spatial description of the catchment (using an example catchment)*

Step 2 – A node-link network can be built either automatically from the DEM or manually from the data obtained in Step 1 (refer to Figure 7). In this case, nodes and links were generated automatically from the DEM and represent the hydrologic connectivity of the system.

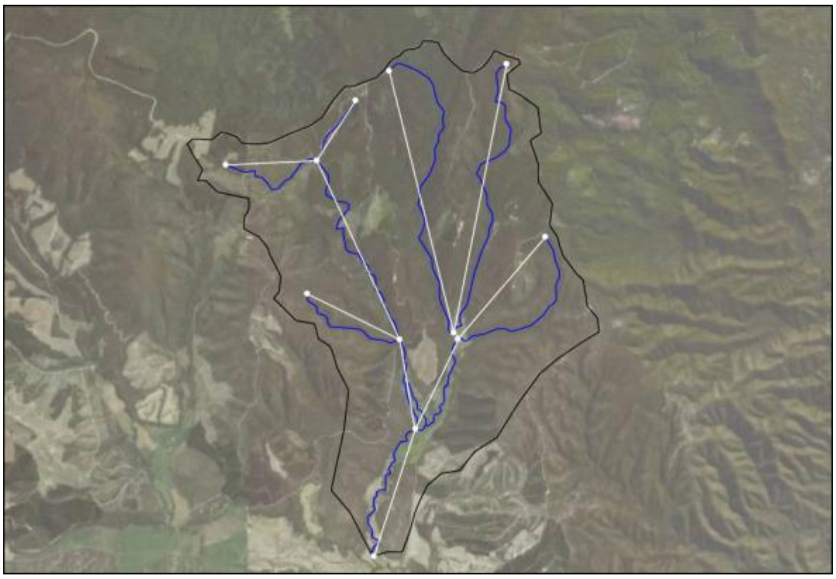

Figure 7. *Construction of a node-link network (using an example network)*

Step 3 – Information about each sub-catchment was described within this step and land use data was used to describe the "Functional Units" (FUs) within each sub-catchment where each one had a particular runoff and constituent generation characteristics. There are typically a common set of FUs for the entire catchment, though the areal extent differs within each sub-catchment (see Figure 8). In this case NSW 2017 Land use data was used to discretise the functional units and a standardised accumulation process used based on previous modelling undertaken in other parts of NSW using the same dataset.

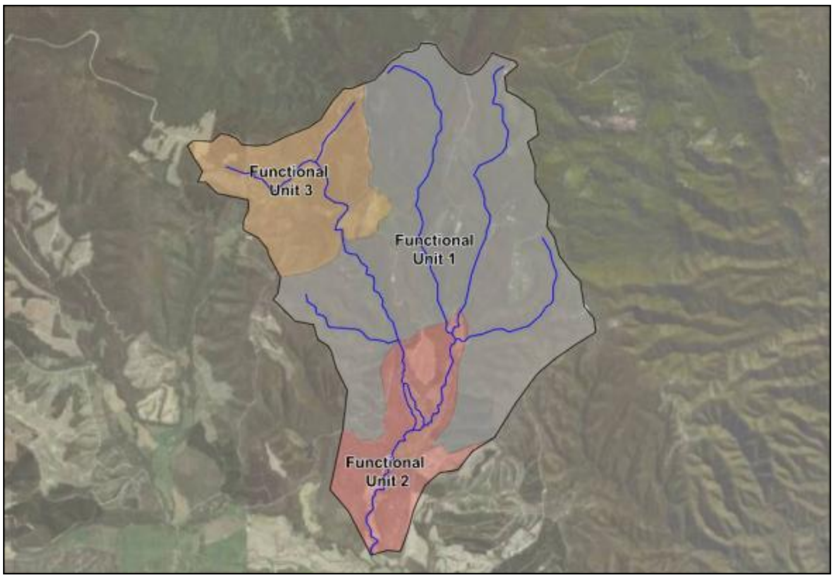

Figure 8. *Definition of functional units (using an example network)*

Step 4 – Particular models were selected which were best suited to the subcatchment/node and were then described (through different parameters) in terms of how each functional unit responds to climatic and pollutant inputs (Figure 9).

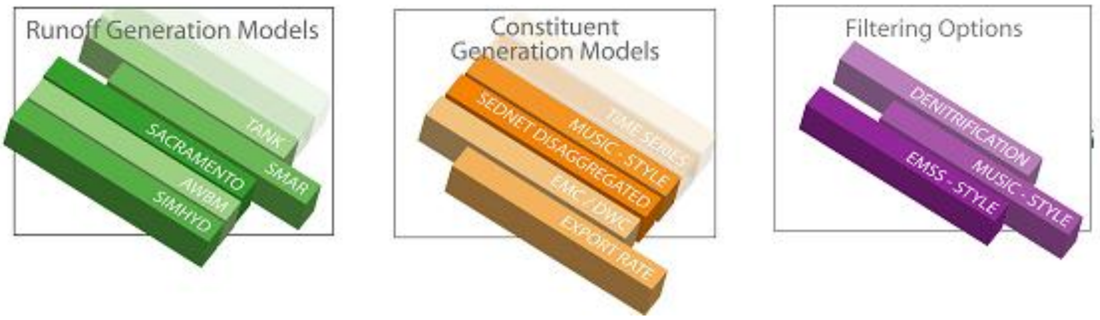

Figure 9. *Selection of node models*

Step 5 – Each link in the stream network was the defined using an appropriate model in a similar way to the subcatchments in Step 4 inputs (Figure 10).

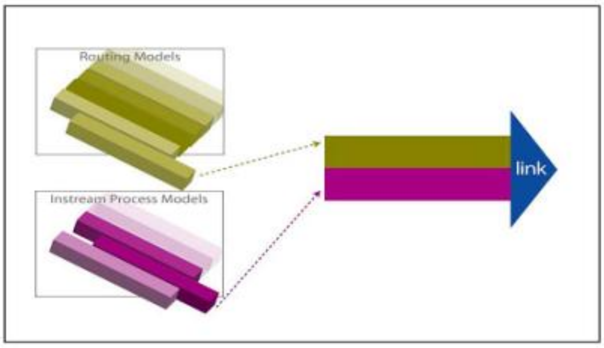

Figure 10. *Selection of link models*

Step 6 – These link models were combined with the sub-catchment/node models so that groups of models were linked together to describe the catchment as shown in Figure 11.

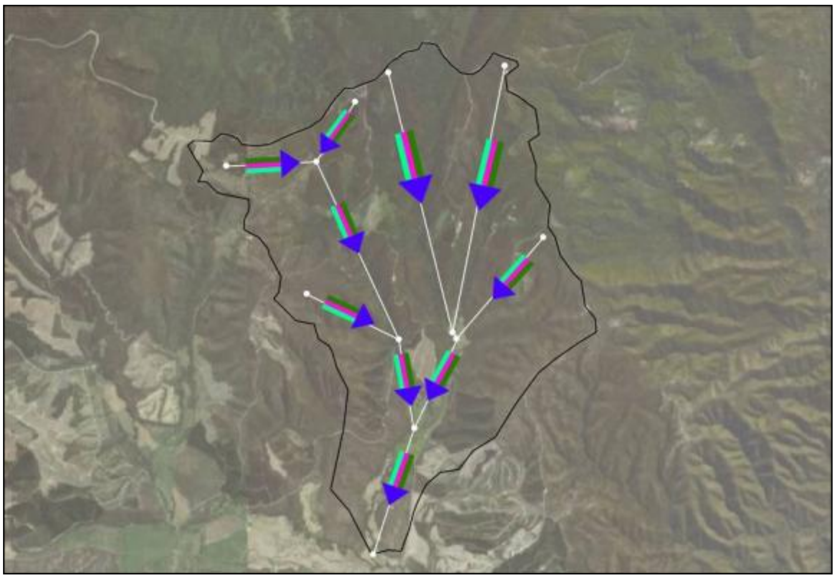

Figure 11. *Node and link models to describe the catchment (using an example network)*

4.4 Catchment delineation

The digital elevation model (DEM) was used to delineate a series of sub-catchments to ultimately be used in the catchment model. These subcatchments are defined by both the shape of the terrain and any confluences between different drainage areas but are sensitive to how the streams themselves are defined (i.e., how much area draining to a point defines a 'stream'). For this reason, the number of sub-catchments defined is somewhat arbitrary, and these can be increased or decreased to achieve a number that best aligned with different areas of management. It should be noted that there is always a trade-off between increased resolution and increased catchment complexity (and therefore computational effort). Ultimately, there are a total of 209 sub-catchments representing the area of assessment. These subcatchments are illustrated in Figure 12. Note that this model extends over a greater area than the immediate contributing catchment, as is needed to calibrate the model to the closest gauge (Talbralgar River at Dunedoo 0421904).

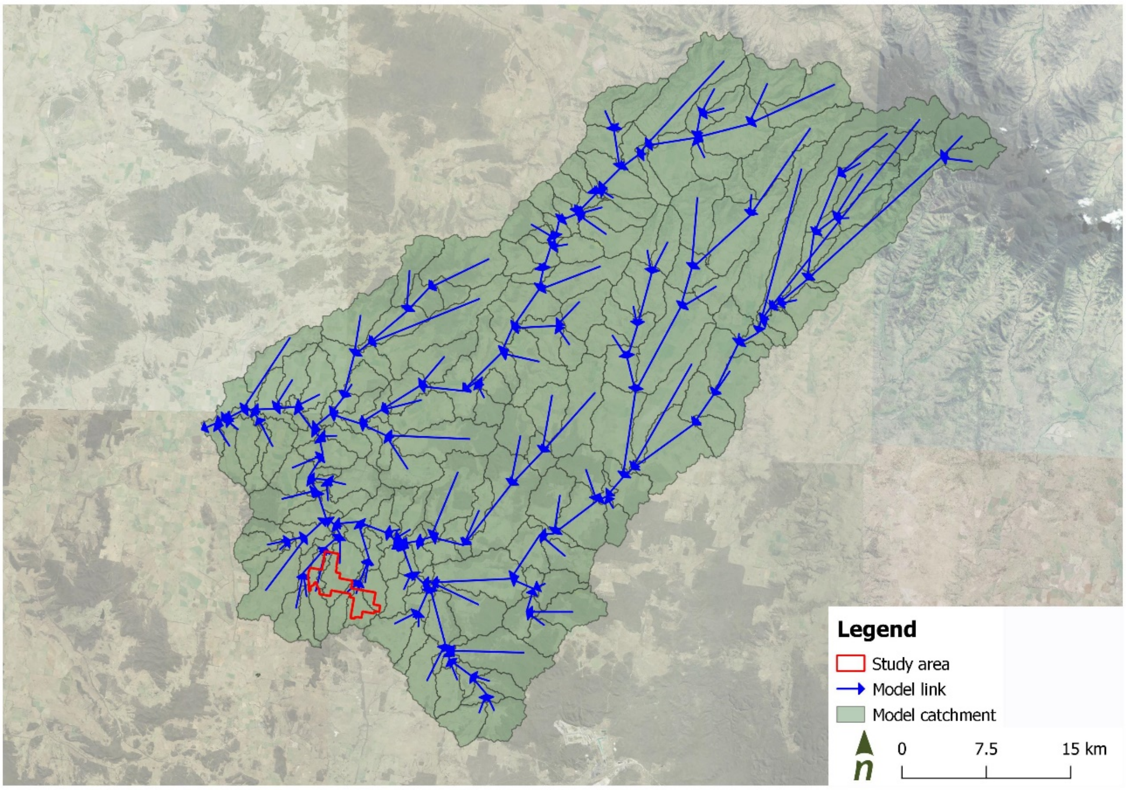

Figure 12. *Sub-catchments and links derived for the catchment model.*

4.5 Functional units

Existing scenario

Catchment land use is illustrated in Figure 13 below. Data for land use was sourced from Version 1.2 of the NSW land use mapping data, supplied by the NSW Department of Planning, Industry and Environment (DPIE, 2022). There were several land use classes available in the land use mapping for the catchment, which have been lumped into broader classes for use in the catchment model of the region. This combines land uses into categories that are likely to be similar for how they generate runoff and pollutants, but also how they may be managed differently. These categories are referred to as Functional Units.

Developed scenario

The land use of the developed scenario adopts that used within the existing case, with alteration of the development footprint with the solar arrays and operational infrastructure area including substation, operational facility and BESS. The developed scenario land use is presented in Figure 13. The following should be noted:

- Upgrade to road alignments have not been included, as a result of existing road alignment omission. Given the minimal extent of this area and negligible change to flow and quality would be expected, these have not been included.
- Only one operational infrastructure area has been modelled (with two options provided). The reporting point will be downstream of the development, meaning this change will be considered regardless of where the operational infrastructure area is placed.
- The maximum area in which solar arrays are proposed has been included. The panels are considered as ineffective impervious area (with pervious buffer between the panels and receiving waterway), thus are not anticipated to have a change in impervious area from the existing. This is consistent with the flood modelling undertaken and described in the associated flood impact assessment (Alluvium, 2022).

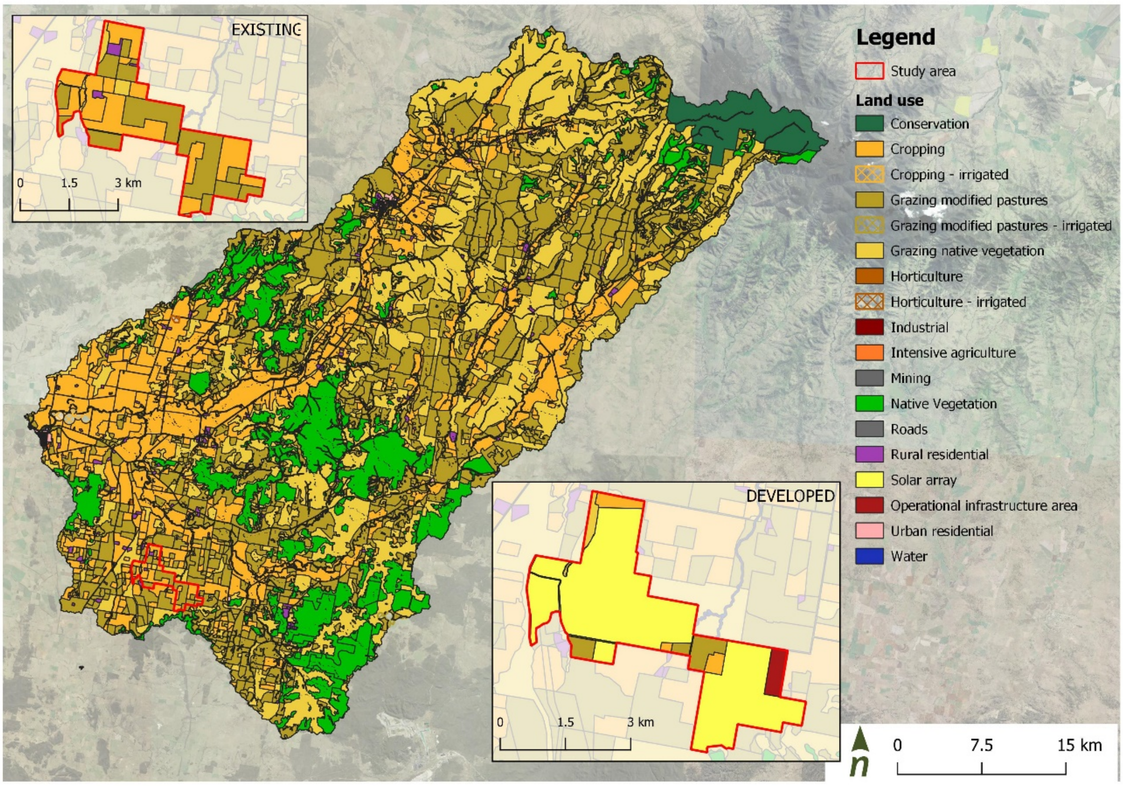

Figure 13. *Existing land use within the contributing catchment (main) with land use change excerpts of the study area for both existing case (top) and developed case (bottom)*

Table 5. Functional units and percentage of coverage adopted in the model

Functional Unit	Wider catchment		Project subcatchment	
	Existing	*Developed*	*Existing*	*Developed*
Conservation	2%	2%	-	-
Cropping	21%	20%	32%	20%
Cropping - irrigated	<1%	<1%	-	-
Grazing modified pastures	32%	32%	48%	36%
Grazing modified pastures - irrigated	<1%	<1%	-	-
Grazing native vegetation	28%	28%	15%	14%
Horticulture	<1%	<1%	-	-
Horticulture - irrigated	<1%	<1%	-	-
Industrial	<1%	<1%	-	-
Intensive agriculture	<1%	<1%	-	-
Mining	<1%	<1%	-	-
Native Vegetation	13%	13%	3%	3%
Roads	<1%	<1%	-	-
Rural residential	1%	1%	1%	1%
Urban residential	<1%	<1%	-	-
Water	2%	2%	<1%	<1%
Solar array	-	1%	-	24%
Operational infrastructure area	-	<1%	-	1%
TOTAL AREA (ha)	*200,156*		*4,501*	

4.6 Climate data

Daily rainfall and potential evapotranspiration data for the catchment was retrieved from the gridded SILO (Scientific Information for Landowners) data set available through the Long Paddock website (https://www.longpaddock.qld.gov.au/). SILO is a database of historical climate records for Australia derived from observed rainfall data and interpolated spatially to present daily rainfall surfaces for an area of interest. Climate data was obtained over the period of 1990 – 2020 (31 years) to ensure good coverage of both wet and dry years.

4.7 Pollutants

Pollutants modelled include total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS), the typical constituents modelled in these types of assessments. In lieu of site-specific data, Event Mean Concentrations (EMC) and Dry Weather Concentrations (DWC) values were taken from the *Using MUSIC in Sydney Drinking Water Catchment* guidelines (WaterNSW 2019). In this instance, EMC represents concentrations of a particular pollutant associated with quick (surface) flows from a particular functional unit, while DWC is indicative of concentrations associated with slow (base) flows. Finalised EMC and DWC values adopted in the model are presented in Table 6.

Table 6. EMC and DWC values adopted in the Source model

	TN (mg/l)		TP (mg/l)		TSS (mg/l)	
	EMC	DWC	EMC	DWC	EMC	DWC
Conservation	0.89	0.30	0.08	0.03	40	6
Cropping	3.02	1.10	0.60	0.09	141	20
Cropping - irrigated	3.02	1.10	0.60	0.09	141	20
Grazing modified pastures	3.02	1.10	0.60	0.09	141	20
Grazing modified pastures - irrigated	3.02	1.10	0.60	0.09	141	20
Grazing native vegetation	3.02	1.10	0.60	0.09	141	20
Horticulture	3.02	1.10	0.60	0.09	141	20
Horticulture - irrigated	3.02	1.10	0.60	0.09	141	20
Industrial	2.00	1.29	0.25	0.14	141	16
Intensive agriculture	3.02	1.10	0.60	0.09	141	20
Mining	2.00	1.29	0.25	0.14	141	16
Native Vegetation	0.89	0.30	0.08	0.03	40	6
Roads	2.00	1.29	0.25	0.14	141	16
Rural residential	2.00	0.89	0.22	0.06	89	14
Urban residential	2.00	1.29	0.25	0.14	141	16
Water	-	-	-	-	-	-
Solar array	2.00	0.89	0.13	0.06	20	14
Operational infrastructure area	2.00	1.29	0.25	0.14	141	16

4.8 Rainfall runoff parameters

The Australian Water Balance Model (AWBM) was adopted to model the catchments surrounding the project. The structure of this rainfall-runoff model is shown in Figure 14, and is used to describe the key rainfall-runoff and constituent/pollutant generation processes occurring within the catchment. The ultimate rainfall-runoff parameters applied are derived from adjustments to an autocalibration process. These are presented in Table 8 for the different hydrological response units (HRUs) specified in Table 7.

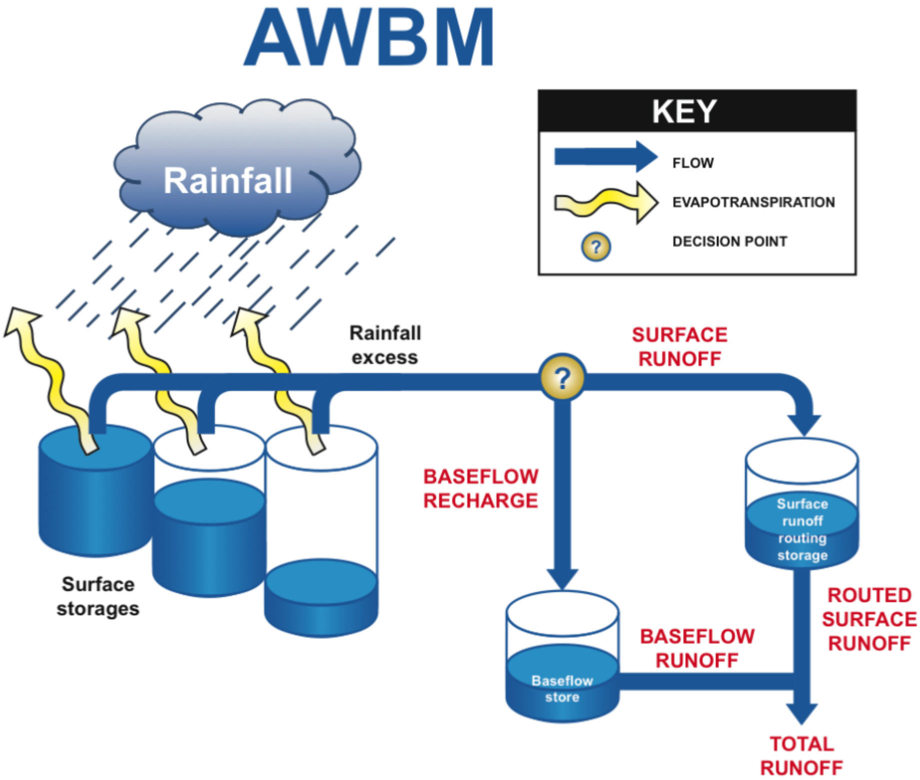

Figure 14. *Structure of the AWBM rainfall-runoff model (eWater Source, 2020)*

Table 7. Linkage between the functional units and the hydrological response units used for the rainfall-runoff model

Functional unit (FU)	HRU
Conservation	Natural
Cropping	Agriculture
Cropping - irrigated	Agriculture
Grazing modified pastures	Agriculture
Grazing modified pastures - irrigated	Agriculture
Grazing native vegetation	Agriculture
Horticulture	Agriculture
Horticulture - irrigated	Agriculture
Industrial	Urban
Intensive agriculture	Agriculture
Mining	Urban
Native Vegetation	Natural
Roads	Urban
Rural residential	Rural
Urban residential	Urban
Water	Natural
Solar array	Agriculture [1]
Operational infrastructure area	Urban

[1] *It's anticipated that rainfall runoff characteristics across the solar array will emulate that of grazing.*

Table 8. AWBM rainfall-runoff model coefficients adopted depending on the HRU

Parameter	Description	Natural	Agriculture	Rural	Urban
A1	Partial area of surface store 1 (Proportion of the catchment)	0	0.036	0.336	0.375
A2	Partial area of surface store 2 (Proportion of the catchment)	0.405	0.388	0.330	0.625
C1	Capacity surface store 1 (mm)	31.81	50.00	50.00	19.19
C2	Capacity surface store 2 (mm)	156	126	123	62
C3	Capacity surface store 3 (mm)	466	361	451	416
BFI	Base flow index (proportion of excess runoff going into the base flow store)	0.879	0.874	0.654	0.846
K_{Base}	Base flow recession constant (proportion of moisture depth remaining per time-step)	0.505	0.535	0.619	0.266
K_{Surf}	Surface flow recession constant (proportion of moisture depth remaining per time-step)	0.905	0.937	0.254	0.400

4.9 Statistical performance

The statistical performance of the hydrological parameterisation process was measured using the criteria as set out by Moriasi et. al. (2015). This sets out specific ranges for several hydrologic calibration criteria as discussed further below. As per Moriasi et. al. (2015) the model performance is determined by the poorest performing of these criteria.

Nash-Sutcliffe efficiency (NSE) coefficient

The NSE coefficient is used to assess the predictive power of hydrological models. An efficiency of 1 corresponds to a perfect match of modelled discharge to the observed data. An efficiency of 0 indicates that the model predictions are only as accurate as the mean of the observed data. An efficiency of less than 0 occurs when the observed mean is a better predictor than the model. The NSE coefficient is calculated using the following equation (from Moriasi et. al., 2015):

$$\mathrm{NSE} \qquad 1-\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2}$$

Percent bias (PBIAS)

The average tendency of modelled data to be greater or less than the corresponding observed data. PBIAS is calculated using the following equation (from Moriasi et. al., 2015):

$$\mathrm{PBIAS} \qquad \frac{\sum_{i=1}^{n}O_i-P_i}{\sum_{i=1}^{n}O_i}\times 100$$

Root Mean Squared Error (RMSE) to observed data standard deviation ratio (RSR)
Standard Regression (R^2)

A goodness-of-fit measure for the collinearity between the modelled and observed data. The closer the R^2 value is to 1, the more closely correlated the two sets of data. R^2 is calculated using the following equation (from Moriasi et. al., 2015):

$$R^2 \qquad \left[\frac{\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i-\bar{O})^2}\sqrt{\sum_{i=1}^{n}(P_i-\bar{P})^2}}\right]^2$$

Table 9. General performance ratings for model statistics for a monthly time step –stream flow (adapted from Moriasi et. al., 2015)

Performance Indicator	PBIAS (Stream flow)	NSE	R^2
Very good	PBIAS < ±5	0.80 < NSE ≤ 1	0.85 < R^2 ≤ 1
Good	±5 ≤ PBIAS < ±10	0.70 < NSE ≤ 0.80	0.75 < R^2 ≤ 0.85
Satisfactory	±10 ≤ PBIAS < ±15	0.5 < NSE ≤ 0.70	0.60 < R^2 ≤ 0.75
Unsatisfactory	PBIAS ≥ ±15	NSE ≤ 0.5	R^2 ≤ 0.60

4.10 Hydrologic calibration

The model as described above has been calibrated to the gauge at Talbragar River at Dunedoo (0421904), which is the closes gauge identified to the study area. The calibration activities have considered the general performance ratings developed by Moriasi et. al. 2015 (as per Section 4.9 above).

Over the modelled period which aligns with observed data (2018-2020) the gauge represents a "very good" calibration (with reference to the Moriasi et. al. 2015 performance ratings). Tabulated results are presented in Table 10, with a graphical representation presented in Figure 15.

Table 10. Hydrological calibration performance for the modelled period 1/1/2018 – 31/12/2020

Calibrated Gauges	PBIAS	NSE	R^2	Acceptance
Talbragar River at Dunedoo (0421904)	4.0	0.859	0.877	Very Good

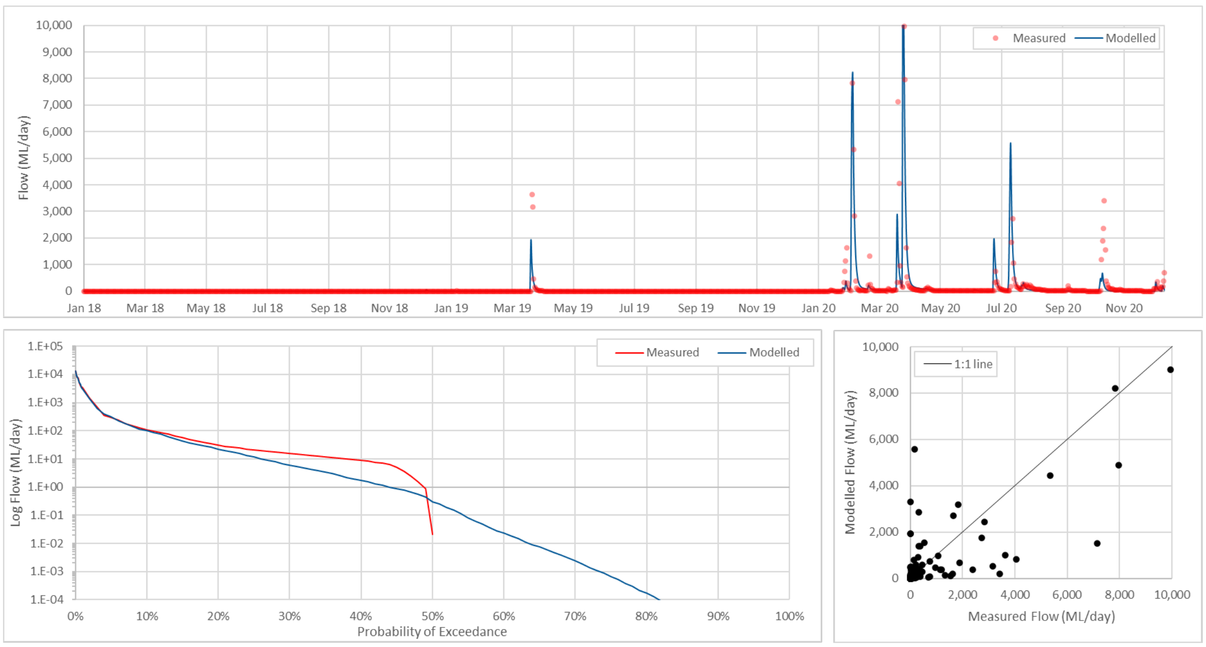

Figure 15. *Talbragar River at Dunedoo (0421904) timeseries, exceedance curve and scatter plot graph*

5 Impact Assessment

Using the calibrated catchment model as the existing base case, the fully developed scenario was configured and modelled (using the parameters described throughout Section 4), in order to describe the potential impacts of the project to flow regime and water quality. These analyses were performed at the reporting point presented in Figure 16, just prior to the discharge into Talbragar River. For the sake of this analysis, the cumulative outputs from the development on Huxleys Creek, Browns Creek and White Creek, tributaries have been reported as a single point.

The results of these are presented in the tables and graphs below.

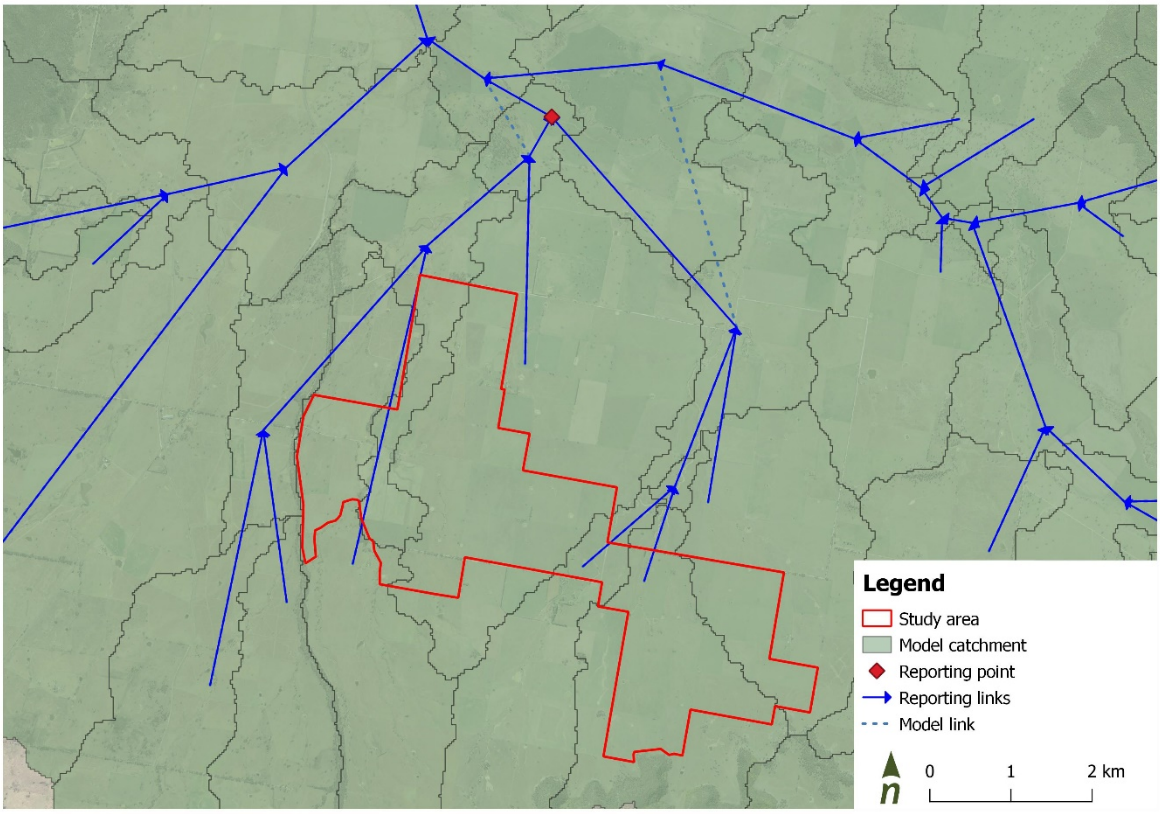

Figure 16. *Reporting point downstream of the project*

Table 11. Annual average flow & pollutant loads for the existing and developed scenarios

Parameter	Existing	Developed	% Difference
Annual Ave Flow (ML/y)	805	842	5%
Annual Ave TSS load (kg/yr)	28345	27088	-4%
Annual Ave TN load (kg/yr)	1066	1080	1%
Annual Ave TP load (kg/yr)	121	117	-4%

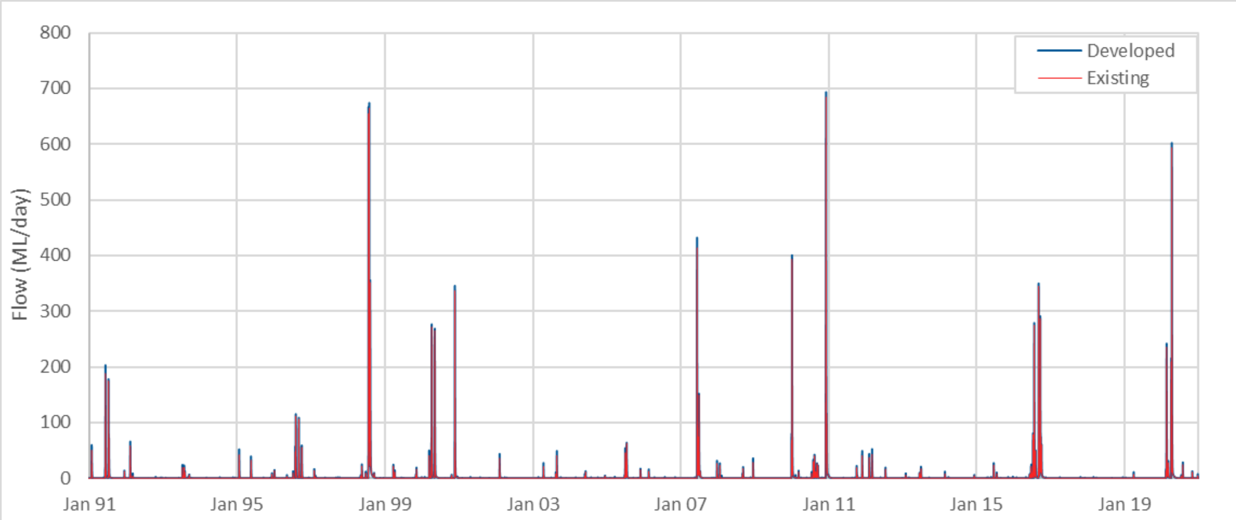

Figure 17. *Flow timeseries downstream from the study area pre and post development (1991-2020)*

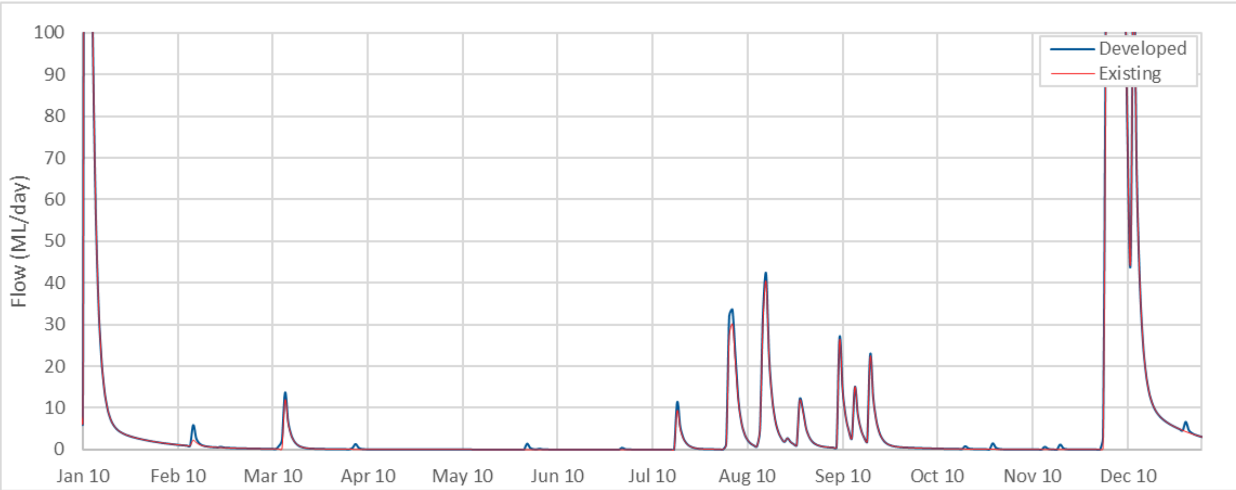

Figure 18. *Flow timeseries downstream from the study area pre and post development (2010-2011)*

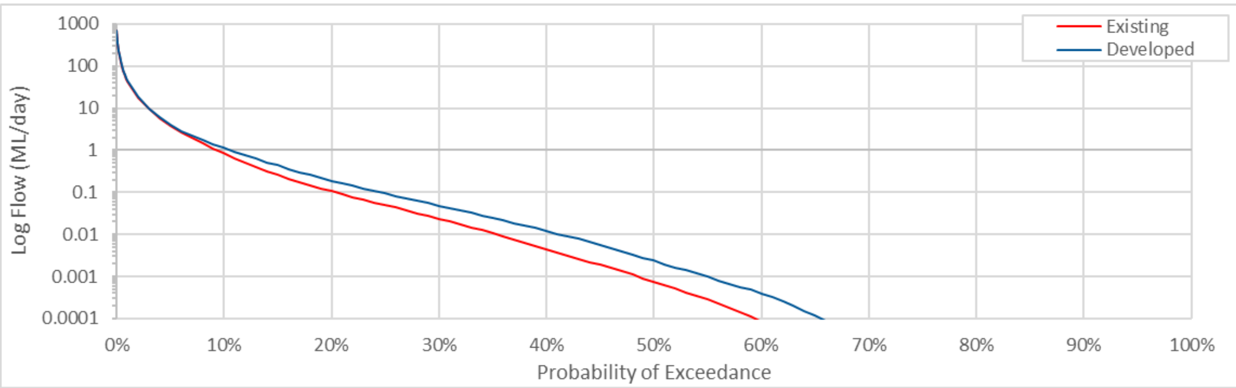

Figure 19. *Probability of exceedance curve of flows from the study area pre and post development*

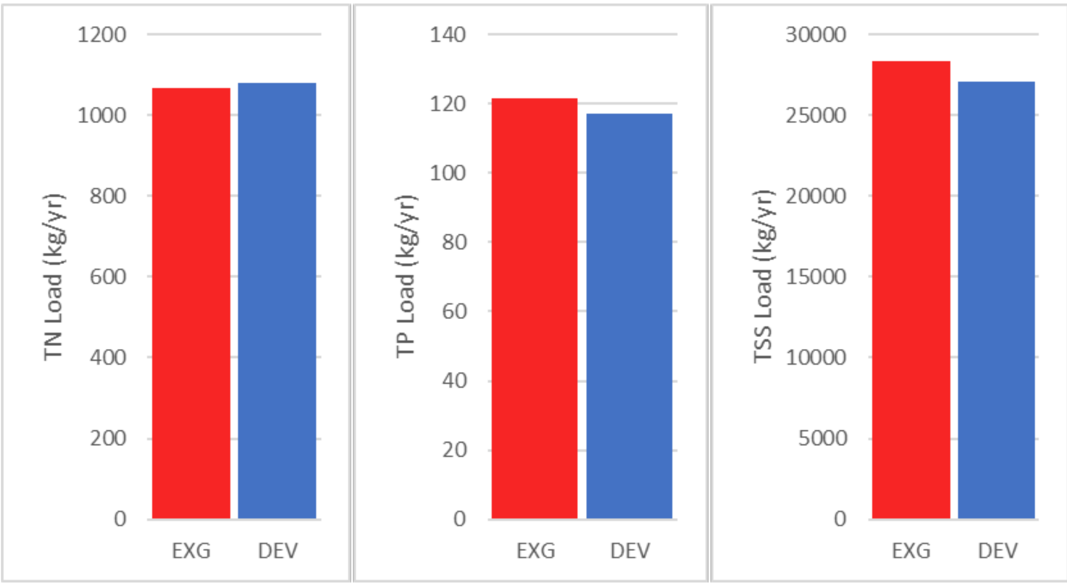

Figure 20. *Annual average pollutant load comparison for existing (EXG) and developed (DEV) conditions*

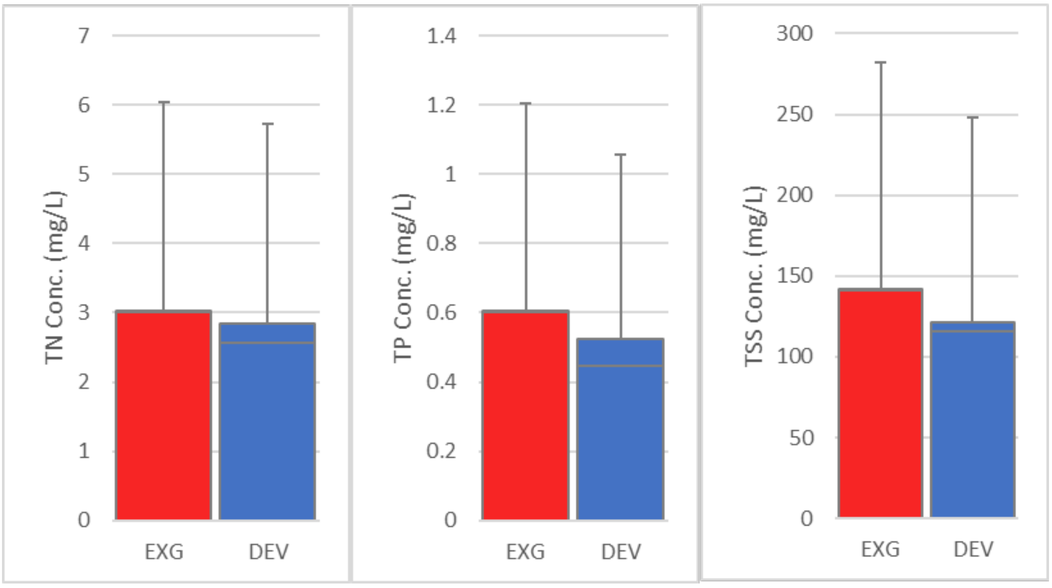

Figure 21. *Box plot of pollutant concentration for existing (EXG) and developed (DEV) conditions*

Surface water

Overall, the results indicate that the relative flow discharging from the study area is likely to increase slightly, with a reported 5% increase in annual average flow over the modelled period. The primary reason for this is the decrease in rural residential and increase in the operational infrastructure area.

Conversely to the above, there is a slight decrease in the concentrations of all the pollutants modelled from the study area. As the primary landscape is altering from cropping and grazing to a solar array, this decrease in concentration is expected. Of the loads discharged there is a marginal increase in the total nitrogen (TN) load discharged, while there is a decrease in discharge of total phosphorus (TP) and total suspended solids (TSS) loads.

Given the lack of historically observed on-site water quality, these values have been taken as best estimates from literature. Consequently, comparison of these to the water quality objectives as per the NSW Water Quality and River Flow Objectives (DIPE 2006), or any which may arise from following Risk-based Framework (Dela-Cruz J, Pik A & Wearne P 2017) is suggested as inappropriate. To remedy this, it's suggested that a baseline of water quality be determined through monitoring activities, with modelling revisited if necessary. A suggested monitoring regime is discussed in Section 6.

Groundwater

As the modelling results identify, there is anticipated to be a minor increase in the volume of surface flow being discharged from the study area. When considering a conceptual water balance approach, there is likely to be a slightly lower percentage of infiltration through the soil profile and into the groundwater reservoirs with a greater surface runoff from the study area. Given the location of the GDEs are primarily upstream of the study area (see Attachment 1), this change is likely to have a negligible impact on GDEs at the study area.

5.1 Qualitative risks & mitigation

Construction

It is expected that the construction phase will pose the highest risk to water quality in relation to increased erosion from and sediment leaving the site. Consequently, mitigation options should be explored/ implemented to minimise this risk. A qualitative assessment of potential risks and mitigation options include:

- Increased bare soil areas – an increased areas of bare soil during construction activities pose the risk of increased soil erosion, in turn increasing the sediment and particulate nutrient content of runoff. Potential mitigation options may consist of staged construction, construction outside the wet season and erosion and sediment control (ESC) measures (e.g. sediment fences, sediment ponds etc.). Solutions should be fully explored further in an Erosion and Sediment Control Plan.

- Increased heavy traffic – during construction, an increase of traffic (including heavy haul vehicles), may increase the risk of erosion along unsealed roads. Potential ESC mitigation options may include rumble pads, sediment fencing and sediment basins. Solutions should be fully explored further in an Erosion and Sediment Control Plan.

- Spillage – There is potential for chemical spillage occurring from the operational infrastructure area during the construction (and operational) phase of development. It is anticipated that a risk management and monitoring plan is undertaken to mitigate risk potential.

Further discussion regarding ESC controls is provided in the *Land Use, Soils and Erosion Assessment* (EMM, 2022b).

Operation

From these results, it is suggested that there will be negligible to no impact on the downstream receiving environment during regular operation. The primary risk during operation is anticipated to be resultant from potential spillage at the infrastructure area, which will require risk management and monitoring outlined in an operational environmental management plan (OEMP) (outside the scope of this assessment).

In the event treatment systems are required to improve the water quality of site discharge, a number of options could be explored, including:

- 'end-of-system' vegetated systems – a vegetated treatment system/s (e.g. wetland, bioretention basin) could be implemented at the downstream end of the study area, to collect and clean flow prior to discharge from the study area. Alternatively, these could be dispersed at key locations throughout the study area to provide treatment where necessary.

  In the instance where additional attenuation is required, this should be integrated with a detention basin to provide an asset with multiple benefits.

- 'in-line' vegetated systems – linear vegetated systems (e.g. vegetated swales) may be designed to collect flow from the solar panels under the drip line to clean and convey the flow prior to discharge from the study area. Consideration would have to be given to slope length and width to ensure safe conveyance through the study area with no scour.

6 Monitoring regime

As identified, no site-specific data is available to be used as a reference to existing flow regime and water quality conditions. This section provides recommendation should the applicant decide to initiate a monitoring regime at the study area to monitor for discharge quantity (flows) and quality (pollutant concentrations). To ensure that these sites are relevant both prior to and following development, reference sites should be incorporated both at the upstream and downstream extents of the study area. These should be on Huxleys Creek, Browns Creek, White Creek and the unnamed tributary of Huxleys Creek, at the approximate locations presented in Figure 22. These will aid in establishing a baseline, setting up site-specific water quality objectives, as per the Risk-based Framework (Dela-Cruz J, Pik A & Wearne P 2017), and monitoring of discharge during the construction and operation of the project.

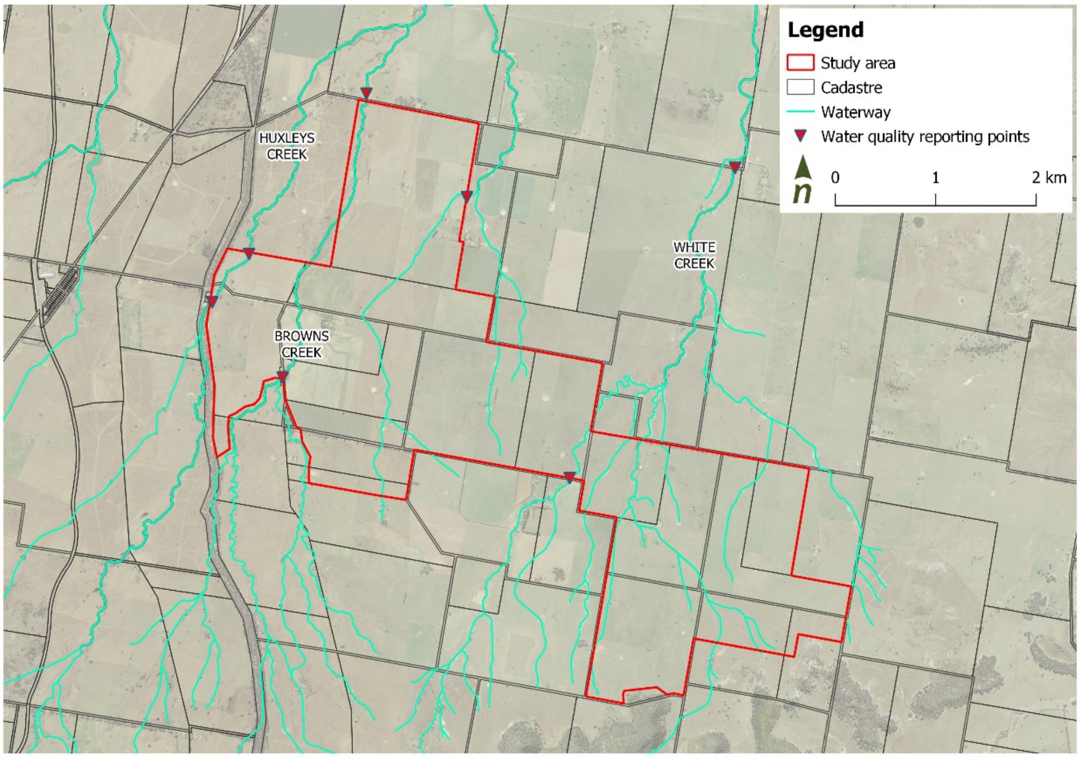

Figure 22. *Suggested locations of water quality reporting points.*

Should a monitoring regime be initiated, it is recommended that the suite of parameters monitored should be those to meet the aquatic ecosystem objectives, including:

- total phosphorus
- total nitrogen
- chlorophyll-a
- turbidity
- salinity
- dissolved oxygen
- pH
- temperature
- chemical contaminants*

* *Those typically used in the operation of a solar farm, as indicators of potential leaks/ issues.*

Specific of this development should reference the Risk-based Framework (Dela-Cruz J, Pik A & Wearne P 2017) and ANZECC guidelines (ANZECC 2000).

7 Conclusion & Recommendations

A catchment model was set up to represent current long-term water quantity and water quality characteristics of the Birriwa Solar and Battery project. The calibration of this model presented a challenge, as the closest point of truth for calibration was identified as Talbragar River at Dunedoo. This is downstream of the study area and includes a far greater contributing catchment area than that of the study area itself. Nevertheless, an acceptable calibration was achieved, with the model being deemed fit for the purposes of assessing relative change in conditions.

The modelling assessment has indicated that there is a slight increase in the long-term flows discharged from the study area, with a negligible increase in TN loads, and decrease in TP and TSS loads. Consequently, it is anticipated that there will be negligible to no impacts to the receiving environment downstream of the project. As this modelling exercise is based solely on literature and not site-based observations, this report provides recommendation on how observed data could be gathered to update/ validate these findings.

To gain a better understanding of the study area in its current conditions, and those anticipated following development, this report includes recommendations should a monitoring regime be developed. This includes monitoring upstream and downstream of the study area, collecting water quality parameters identified to meet the aquatic ecosystem objectives.

An assessment of the primary risks to water quality has been undertaken, with a heightened risk of erosion and sedimentation during construction (to be mitigated by the implementation of appropriate ESC controls) and hazardous material spills from operation (mitigated through procedures detailed in an OEMP). If required, several water quality mitigation options have been explored (either vegetated 'in-line' or 'end-of-system' measured, or a combination of both, depending on site requirements).

Given the marginal change identified through the modelled exercise, and the location of the GDEs at the study area, there is anticipated to be negligible impact to potential GDEs from this development.

8 References

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Attachment 1. Constraints Mapping

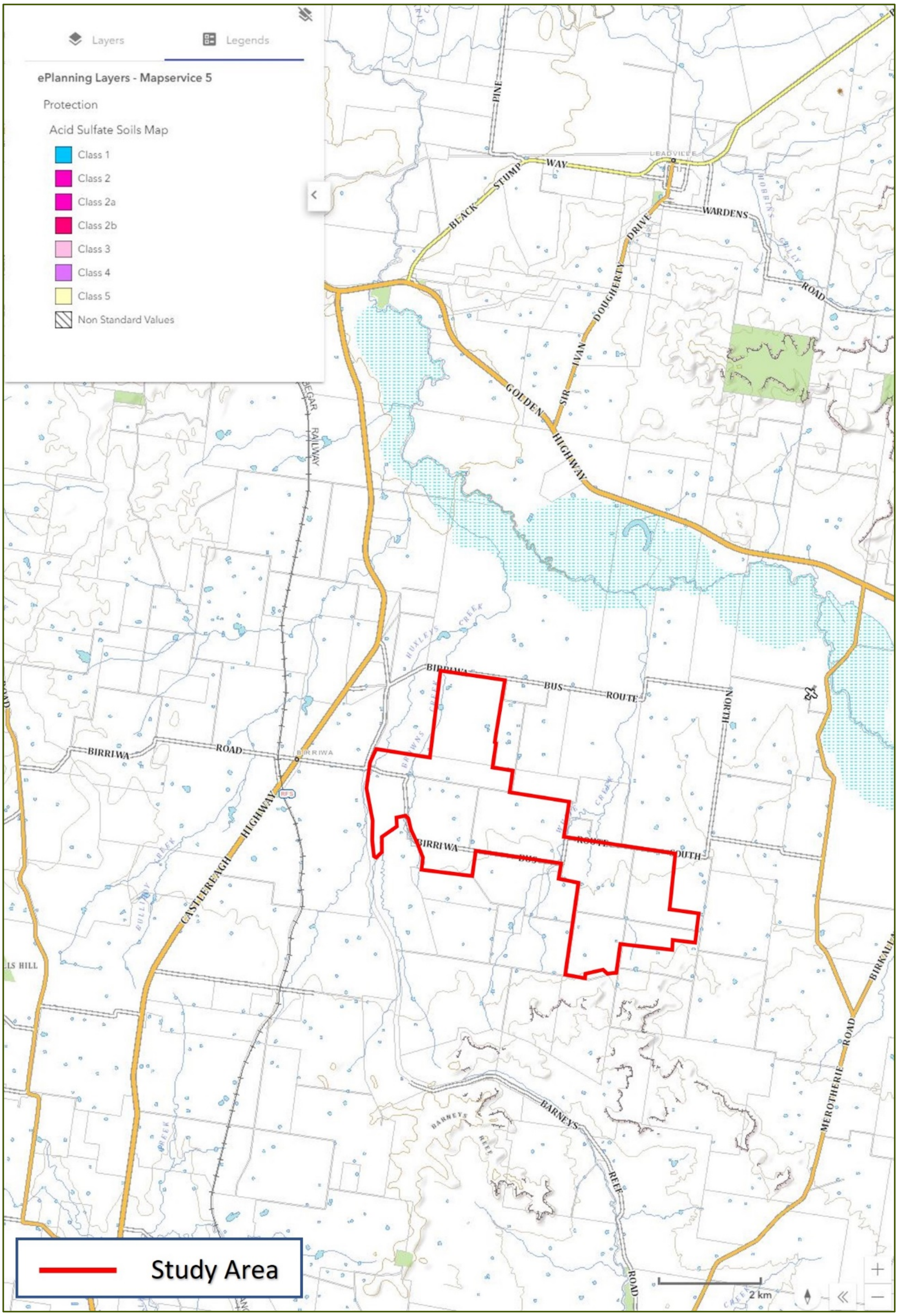

Figure A1 - Acid Sulphate Soils

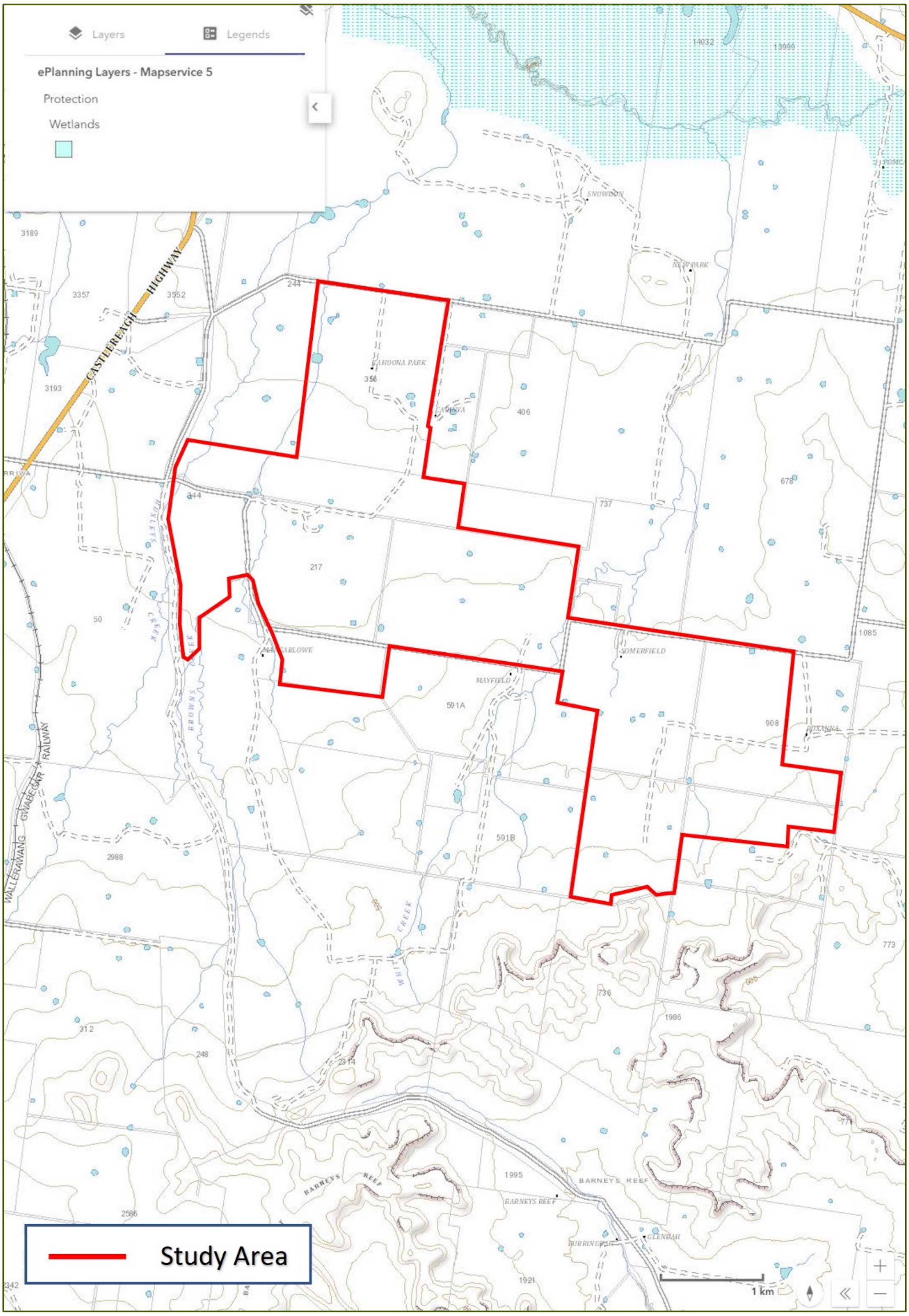

Figure A2 - Wetlands

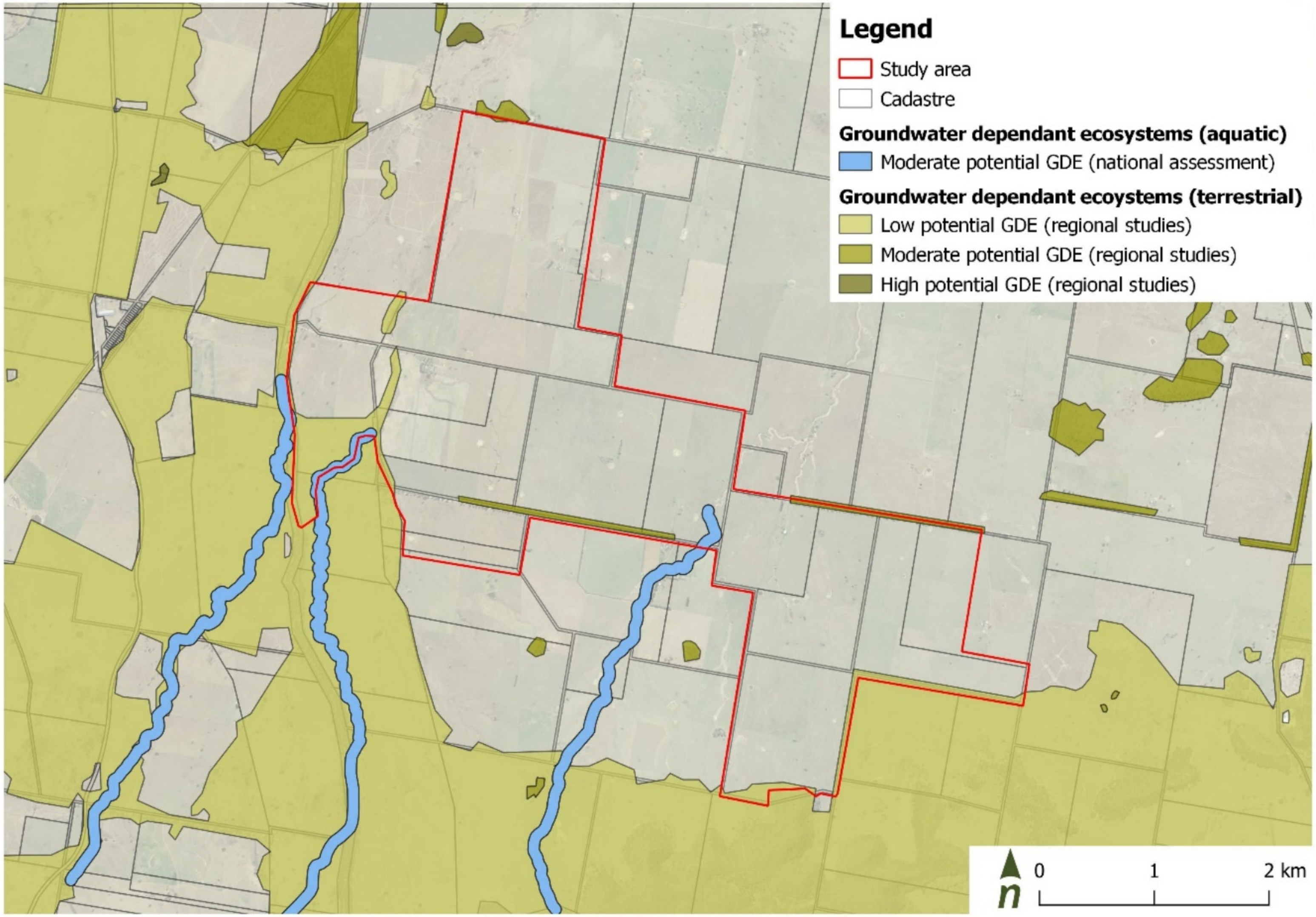

Figure A3 - Groundwater Dependant Ecosystems

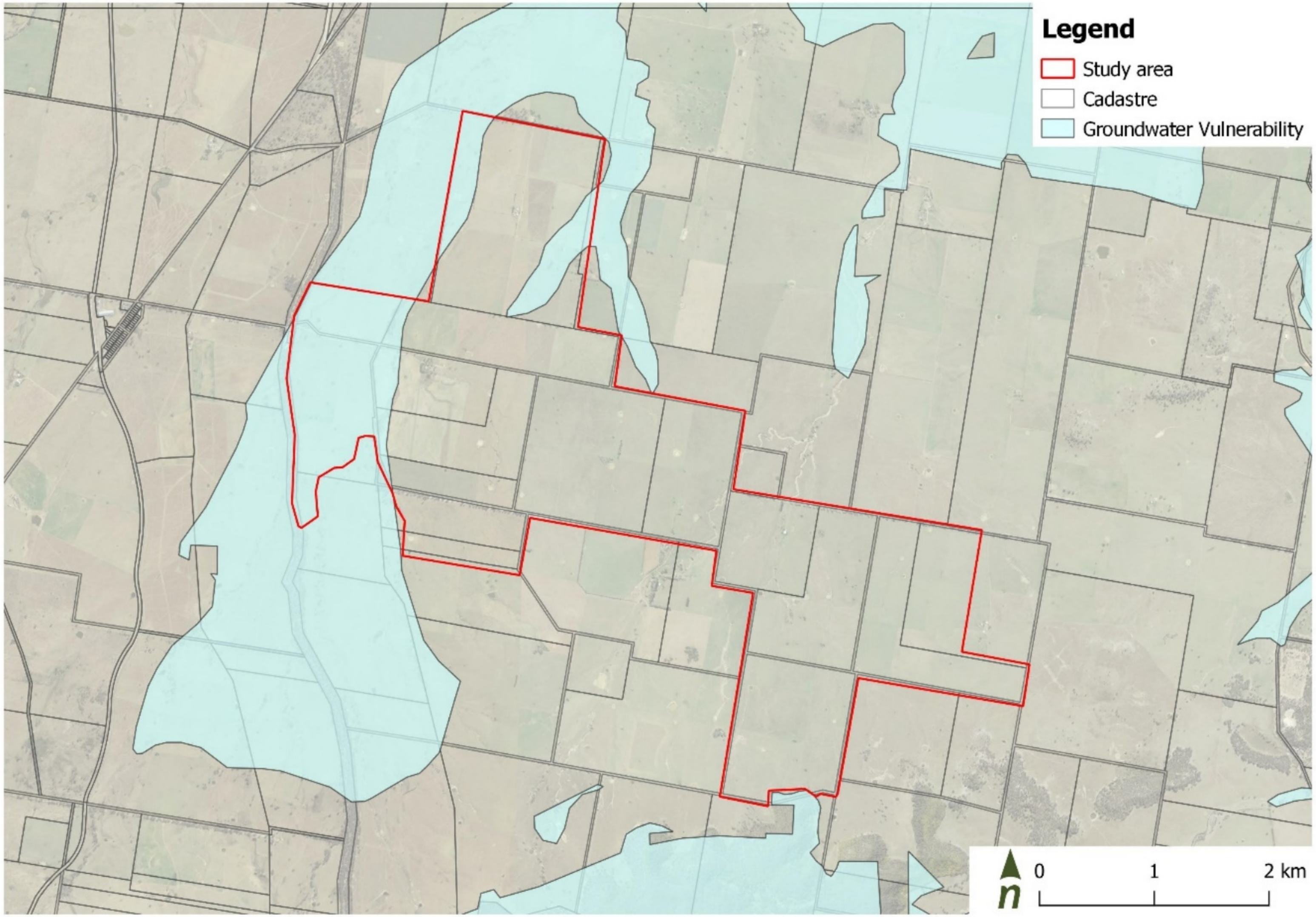

Figure A4 - Groundwater Vulnerability

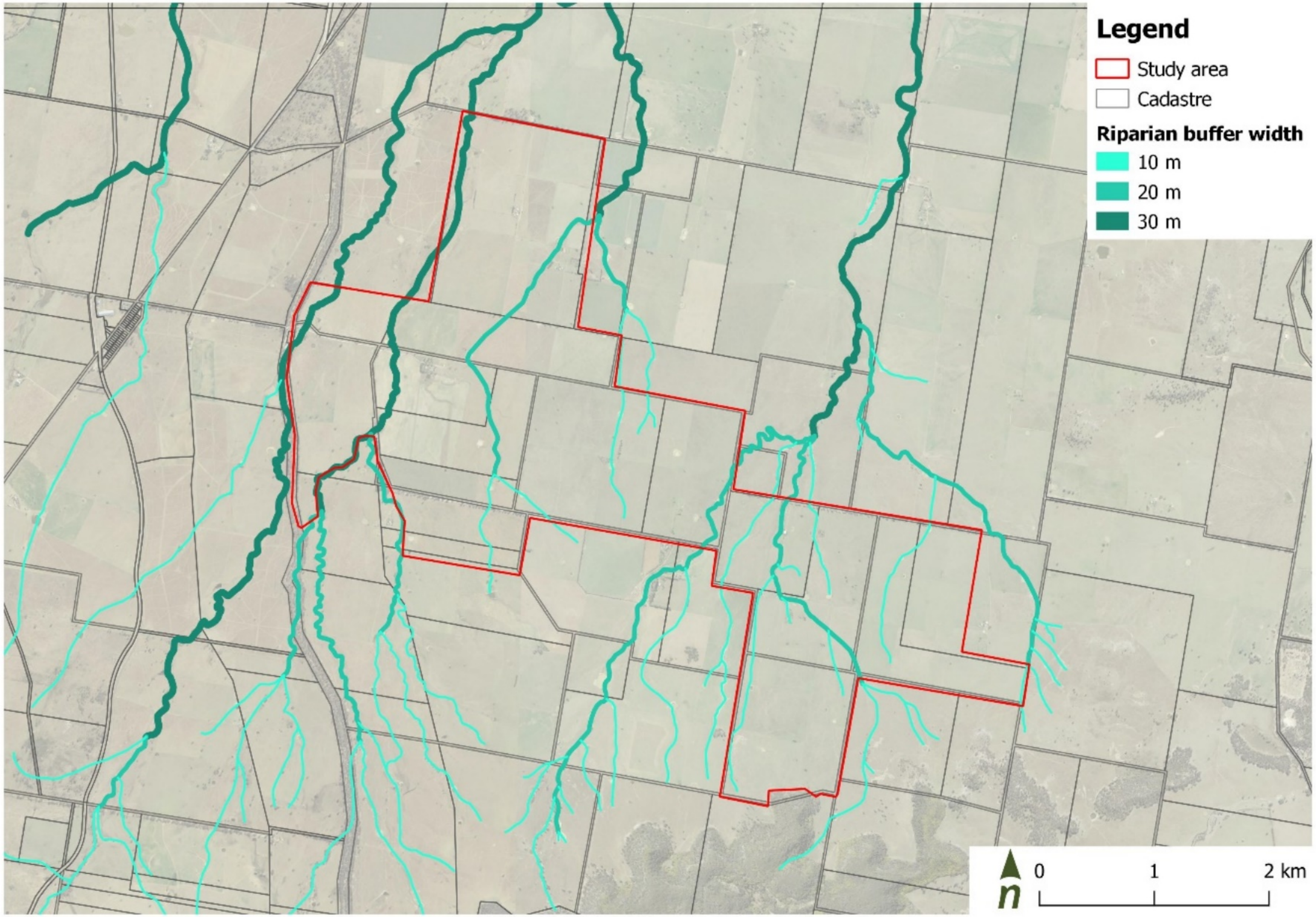

Figure A5 - Riparian Buffer Width

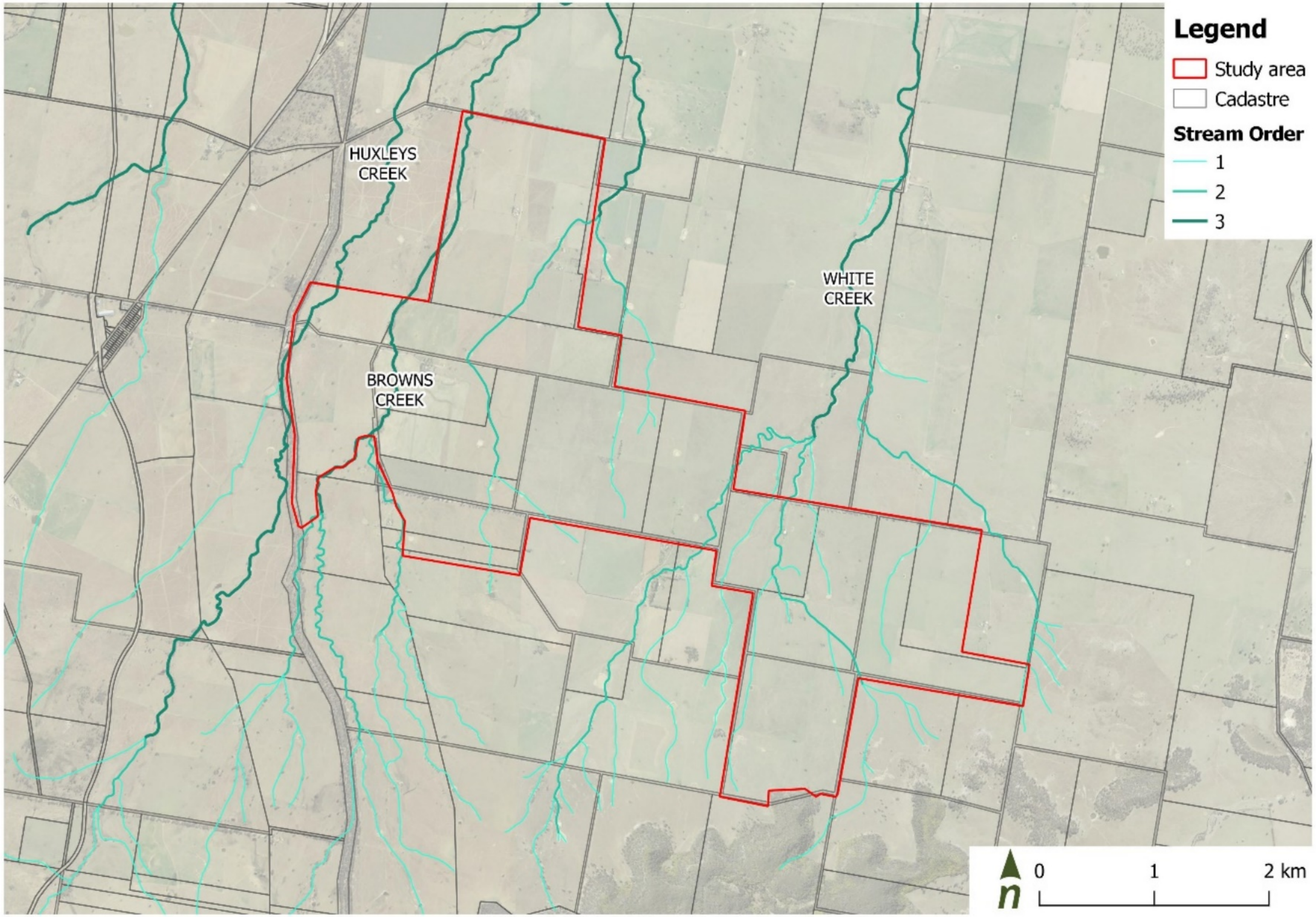

Figure A6 - Waterways Stream Order