Technical Report - Flooding and hydrology

Virya Energy

Yanco Delta Wind Farm
26 July 2022

Executive summary

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure. The generating capacity of the wind farm is approximately 1,500 megawatts (MW).

This flooding and hydrology assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) relating to flooding and hydrology impacts and will assist the Minister for Planning to make a determination on whether or not to approve the Project. This assessment provides an assessment of potential impacts of the Project on flooding and hydrology and outlines proposed management measures.

Assessment methodology

This assessment assesses any flooding and hydrology impacts from the construction and operation of the Project on flooding behaviour and sensitive receivers, such as nearby dwellings and roads. The assessment also investigates the existing flood risk to the proposed Project infrastructure, including WTGs and substations.

Both the 1% Annual Exceedance Probability (AEP) event and the probable maximum flood (PMF) were modelled for the existing case flooding. Given the generally low flood risk to the Project area, a qualitative flood impact assessment was conducted.

Potential impacts were also assessed on the natural hydrology of the local environment. The hydrological factors considered include:

- Protecting natural low flows and natural rises in water levels
- Maintaining wetland and flood plain inundation
- Maintaining natural drying and flow variability
- Maintaining natural rates of change in water levels
- Minimising the effect of weirs and hydraulic structures.

Existing environment

The topography of the Project area is relatively flat with gentle undulations, sloping gently down gradient. There are three creeks in the Project area:

- Delta Creek – An ephemeral waterway that flows through the northern section of the Project area from east to west.
- Yanco Creek – A permanent waterway that flows from east to west and divides the northern and southern extent of the Project area
- Turn Back Jimmy Creek – An ephemeral waterway that flows from the south-east through the southern section of the Project area and joins with Yanco Creek downstream of the Project area.

There are also numerous ephemeral drainage depressions within the Project area.

Flooding within the Project area, in both the 1% AEP event and the PMF, is generally characterised by flow velocities of less than 0.5 metres per second and depths of one to three metres along the three major creeks and around one metre on the adjacent floodplains.

Overview of flooding impacts

The assessment identified the following key findings:

- The Project is not anticipated to have significant potential impacts on flooding and hydrology within the Project area or surrounding areas. Impacts around WTGs, filled hardstand areas and watercourse crossings are expected to be minor and localised and would not affect nearby dwellings
- During Project construction, the potential for increased risk of flood impact due to stockpiling of materials and construction of access roads would be managed by environmental management measures such as siting these outside the 1% AEP flood extent
- There would be negligible impacts on any hydrological factors, as the increase in impervious areas on a catchment scale would be negligible. The Project would be designed so as not to impede flows paths or impact on surface flow regimes
- There would be a minor risk of localised erosion and scouring of ground surfaces at drainage discharge areas and at the toe of hardstand fill areas during flood events.

Cumulative potential flooding impacts of relevant nearby developments have also been assessed. Any cumulative impacts are likely to be negligible as identified proposals would not impact on any hydraulically significant flow paths connected to Project area.

Management measures

Various environmental management measures have been identified to mitigate potential flooding and hydrology impacts. Management measures include:

- Design of the Project for the construction and operational phases to minimise flooding impacts, hydrology, surface flow regimes and erosion/scour risks
- Raising substation sites to provide adequate flood immunity
- Potential relocation of seven WTGs and several access tracks and cabling routes in consultation with landowners, in order to reduce exposure to flood flows, reduce potential flood impacts and avoid clash with farm dams and dam inflows.
- Monitoring of impacts such as scouring and implementation of appropriate remedial works if necessary.

Conclusion

Overall, with the implementation of the proposed controls and management measures, the Project would have minimal potential impacts on flooding and hydrology. Further, there would be negligible impacts on any hydrological factors and only minor risk of localised erosion and scouring of ground surfaces.

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Glossary and terms

Term	Definition
ARR	Australian Rainfall and Runoff. Guidelines prepared by the Institute of Engineers Australia for the estimation of design floods. Reference is made to the 1987 or the 2019 versions of ARR, as specified.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger 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.
Catchment	The land area draining through the mainstream, as well as tributary streams, to a particular Project area. It always relates to an area above a specific location.
EIS	Environmental Impact Statement
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.
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.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this technical paper the hazard is flooding which has the potential to cause damage to the community.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
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.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Overland flow path	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.
Probable maximum flood (PMF)	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.
Probable maximum precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over 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 (World Meteorological Organisation, 1986). It is the primary input to probable maximum flood estimation.

Term	Definition
Runoff	The amount of rainfall which ends up as a streamflow, also known as rainfall excess.
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation (hydraulics). 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.

1. Introduction

1.1 Background

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure. The generating capacity of the wind farm is approximately 1,500 megawatts (MW). The Project would be located within the South-West Renewable Energy Zone (REZ), 10 kilometres north-west of the town of Jerilderie, within the Murrumbidgee Council and Edward River Council Local Government Areas (LGAs) (refer to **Figure 1-1**).

The Project area is defined as the property boundaries of Project landowners (i.e. landowners that have entered into agreements with Virya Energy to have WTGs or associated infrastructure on their properties).

1.2 Project description

The Project would include the following key features:

- Up to 208 WTGs to a maximum tip height of 270 metres
- Generating capacity of approximately 1500 MW
- BESS, approximately 800 MW/800 megawatt hours (MWh) (type yet to be determined)
- Permanent ancillary infrastructure, including operation and maintenance facility, internal roads, hardstands, underground and overhead cabling, wind monitoring masts, central primary substation and up to eight collector substations
- Temporary facilities, including site compounds, laydown areas, stockpiles, gravel borrow pit(s) and concrete batch plants.

An indicative Project layout is provided in **Figure 1-2**.

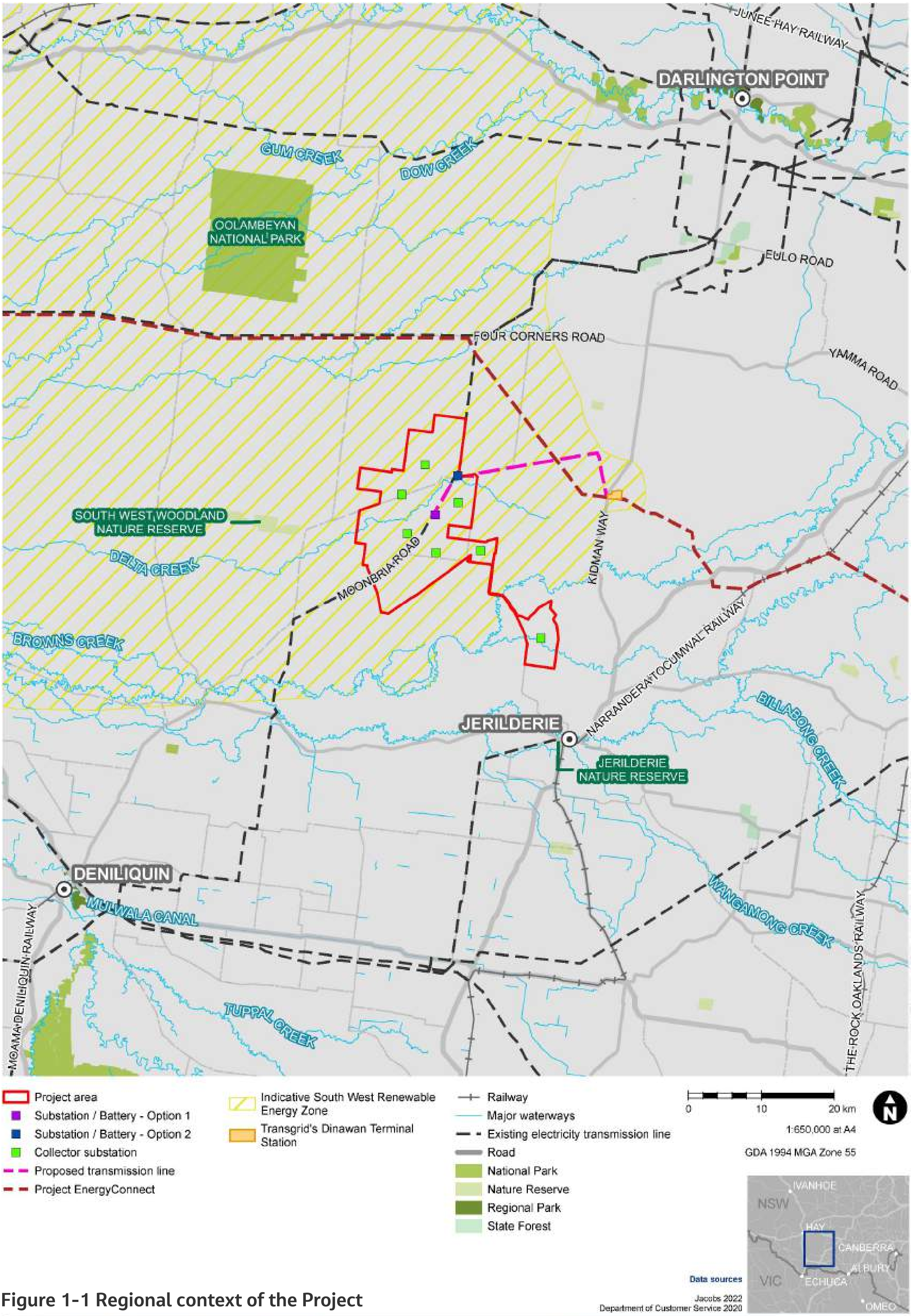

Figure 1-1 Regional context of the Project

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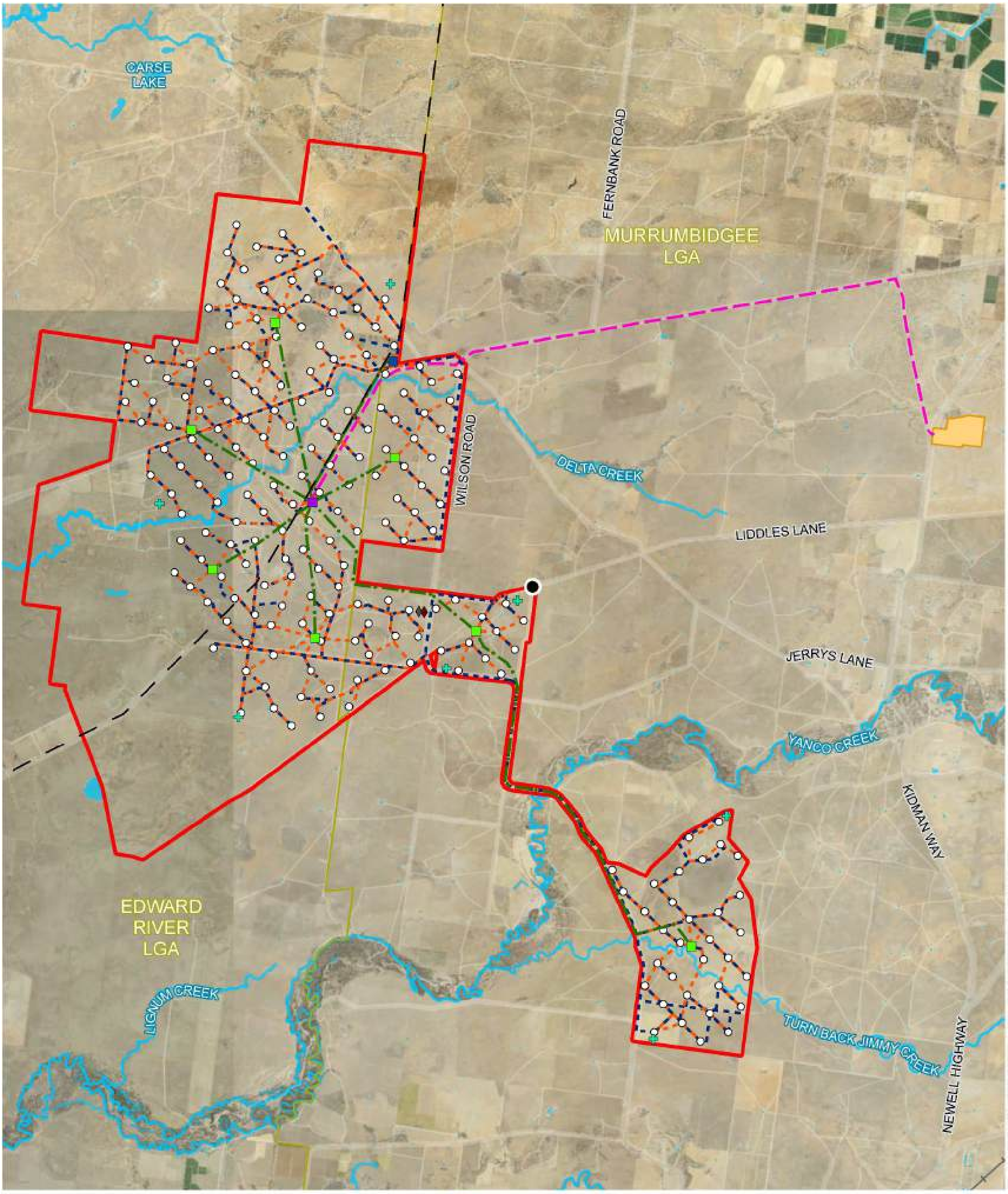
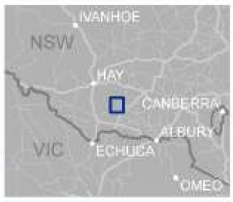


Indicative Project
Project area
Turbine locations
Substation / Battery - Option 1
Substation / Battery - Option 2
Collector substation
Access tracks
Internal cabling
Overhead powerline
Proposed transmission line

Permanent MET mast
Site facilities
O&M facility
Site compound

Transgrid's Dinawan Terminal Station
Local Government Area
Site access
Railway
Waterways
Existing 132kV transmission line
Road

0 2 4 km
1:200,000 at A4
GDA 1994 MGA Zone 55



Data sources
Jacobs 2022

Figure 1-2 Indicative Project layout

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1.3 Secretary's Environmental Assessment Requirements

This assessment forms part of the environmental impact statement (EIS) for the Project. The EIS has been prepared under Division 4.7 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSD-41743746) relating to flooding and hydrology impacts and will assist the Minister for Planning to make a determination on whether or not to approve the Project.

Table 1-1 outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to flooding and hydrology impacts

Secretary's requirement	Where addressed in this report
Water and Soils – the EIS must:	
• An assessment of the likely impacts of the development (including flooding) on surface water and groundwater resources traversing the Project area and surrounding watercourses (including their Strahler Stream Order), drainage channels, wetlands, riparian land, farm dams, groundwater dependent ecosystems and acid sulfate soils, related infrastructure, adjacent licensed water users and basic landholder rights, and measures proposed to monitor, reduce and mitigate these impacts;	Potential flooding impacts during construction and operation of the Project are discussed in **Chapter 5** and **Chapter 6** respectively. Refer to the Surface water quality and groundwater technical report (Jacobs, 2022a) for potential impacts to watercourses (including Strahler Stream Order), groundwater resources and groundwater dependent ecosystems. Refer to the Biodiversity Development Assessment Report (Jacobs, 2022b) for impacts to wetlands and riparian lands.

1.4 Structure of this report

The structure and content of this report are outlined in **Table 1-2**.

Table 1-2 Structure and content

Chapter	Description
Chapter 1 Introduction	Outlines key elements of the Project, SEARs and the structure of this report (this Chapter)
Chapter 2 Legislative and policy context	Provides an outline of the statutory context, including applicable legislation and planning policies
Chapter 3 Assessment methodology	Provides a description of the assessment methodology for this assessment
Chapter 4 Existing environment	Provides a preliminary description of the existing environment
Chapter 5 Potential construction impacts	Presents the outcomes of the construction impact assessment
Chapter 6 Potential operational impacts	Presents the outcomes of the operational impact assessment
Chapter 7 Potential decommissioning impacts	Provides assessment of the flooding and hydrology impacts from decommissioning of the Project.

Chapter	Description
Chapter 8 Cumulative impacts	Presents the qualitative assessment of potential cumulative construction and operational flooding and hydrology impacts with other projects near the Project
Chapter 9 Environmental management measures	Presents the flooding and hydrology management measures applicable for the Project
Chapter 10 Conclusion	Summarises the findings of this report
References	Provides details of external resources used
Appendix A Flood modelling development and assessment	Description of the flood model development
Appendix B Flood mapping for the existing condition	Figures showing the flood depths, velocities, and hazard levels in the Project area for both the 1% AEP event and the Probable Maximum Flood (PMF)

2. Legislative and policy context

2.1 State legislation

2.1.1 Environmental Planning and Assessment Act 1979

The EP&A Act and Environmental Planning and Assessment Regulation 2021 establish the framework for development assessment in NSW. The EP&A Act and the Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction.

Part 4 of the EP&A Act establishes the framework for assessing development that is permissible with consent. The Project is State Significant Development (SSD) under Section 2.6(1) in conjunction with Section 20 of Schedule 1 of the State Environmental Planning Policy (Planning Systems) 2021.

The Project is defined as electricity generating work and has a capital investment value (CIV) estimated to exceed one billion Australian dollars. Therefore, the Project is proceeding with an application for planning approval as an SSD. Under Section 4.12(8) of the EP&A Act, the application is to be accompanied by an EIS prepared by or on behalf of the applicant in the form prescribed by the Regulations.

This assessment forms part of the EIS in order to comply with the SEARs and assess flooding impacts of the Project in accordance with any relevant Government legislation, plans, policies and guidelines.

2.1.2 Water Management Act 2000

Development on floodplains is managed under the *Water Management Act 2000,* including the provisions of floodplain management plans and 'flood works' i.e. works that affect, or are likely to affect, flooding and/or floodplain functions. Given the nature of the Project and the proximity of elements of the Project to natural watercourses including Yanco Creek, Delta Creek and Turn Back Jimmy Creek, the provisions under the *Water Management Act 2000* have been considered. There are no current floodplain management plans applicable to the Project area (refer to **Section 2.2.6**).

A controlled activity approval under section 91 of the *Water Management Act 2000* is required for certain types of developments and activities that are carried out in or near waterfront land. However, under the EP&A Act, a controlled activity approval is not required for SSD, such as this Project, and so the NSW Office of Water's guidelines for controlled activities on waterfront land have not been considered further.

2.2 Regulatory policies/relevant guidelines

2.2.1 Australian Rainfall and Runoff 2019

Australian Rainfall and Runoff 2019 (ARR 2019) (Ball et al, 2019) provides industry guidance on technical analysis and specifies design rainfall parameters for flooding and hydrologic studies in Australia. The approaches presented in ARR are essential for policy decisions and projects involving:

- Infrastructure such as roads, rail, bridges, dams and stormwater systems
- Floodplain risk management plans for urban and rural communities
- Flood warnings and flood emergency management
- Estimation of extreme flood levels.

Reference was made to ARR 2019 (Ball et al, 2019) in developing the methodological framework for the assessment, including modeling to define existing flooding conditions and for assessing potential impacts of the Project on hydrology and flooding.

2.2.2 Floodplain Development Manual and Flood Prone Land Policy

The assessment of potential flooding impacts of the proposal on existing flood regimes has been conducted in accordance with the requirements of the Floodplain Development Manual (NSW Government, 2005), which incorporates the NSW Government's Flood Prone Land Policy. The key objectives of this policy are to identify potential hazards and risks, reduce the impact of flooding and flood liability on owners and occupiers of flood prone property, and to reduce public and private losses resulting from floods. This policy also recognises the benefits of the use, occupation, and development of flood prone land.

This assessment has been undertaken with consideration of these objectives and provisions outlined above.

2.2.3 2007 Flood Planning Guideline

The Flood Planning Guideline 2007 provides an amendment to the Floodplain Development Manual (2005). The Guideline confirms that unless there are "exceptional circumstances", Councils are to adopt the 1% AEP plus freeboard as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Guideline does provide those controls on residential development above the 1% AEP plus freeboard may be subject to an "exceptional circumstance" justification being agreed to by the Department of Planning, Industry and Environment and the Department of Planning Industry and Environment prior to the exhibition of a Draft Local Environment Plan (LEP) or Draft Development Control Plan (DCP).

The "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual" defines Standards for Flood Controls for Residential Development. Whilst the flood used to define the residential FPL is a decision of Council, FDM highlights that FPLs for typical residential development would be based around the 1% AEP plus an appropriate freeboard (typically 0.5 metres).

For the Project, it is considered appropriate to adopt the standard residential FPL for the operation and maintenance buildings and facilities.

2.2.4 2020 Updated Flood Prone Land Package

Significant flood events, like those in Brisbane in 2011 and those more recently in NSW show the importance of managing flood risk up to and beyond the 1% AEP event and considering flood risks up to the probable maximum flood level. This will build resilience in communities located on floodplains and reduce the extent of property damage and potential loss of life from severe to extreme flooding throughout NSW.

The NSW Department of Planning Industry and Environment made updates to the Flood Prone Land Package (including the 2007 flood planning guideline – refer to **Section 2.2.3**) which provides advice to Councils on considering flooding in land use planning and consists of:

- An amendment to schedule 4, section 7A of the Environmental Planning and Assessment Regulation 2000
- A revised planning circular
- A revised local planning direction regarding flooding issued under section 9.1 of the EP&A Act
- Revised Local Environmental Plan flood clauses
  - Clause 5.21 – The "flood planning clause" (mandatory)
  - Clause 5.22 – The "Special flood considerations" clause (optional)
- A new guideline: Considering Flooding in Land Use Planning (2021)
- Revoking the Guideline on Development Controls on Low Flood Risk Areas (2007)
- A SEPP amendment to replace councils existing flood planning clause with the new mandatory standard instrument clause.

The updates promote the effective consideration of flood risk in land use planning, which involves developing an understanding of the full range of flood behaviour up to the Probable Maximum Flood (PMF) and considering this in management of flood risk. Hence, this flooding and hydrology assessment has analysed the flooding conditions and potential flood impacts in the PMF event.

2.2.5 Council planning instruments

The following council planning instruments are relevant to the Project area:

- Murrumbidgee Council – Jerilderie Local Environment Plan (LEP) 2012 and Jerilderie Development Control Plan (DCP) 2012
- Edward River Council – Conargo LEP 2013. There is currently no DCP applicable to the Edward River Council portion of the Project area.

Flood planning areas are defined for some parts of the area covered by the LEPs, but this excludes the Project area. In general, the FPL (minimum floor level) for standard residential development would be the 1% AEP flood event plus a freeboard (typically 0.5 metres) with minimum fill levels at the 1% AEP flood level. This FPL would be appropriate for the Project's operation and maintenance facility.

Consideration should be given to using the PMF as the FPL when siting and developing critical infrastructure (NSW Government, 2005). This should include substations and battery system related to the Project.

2.2.6 Council floodplain management plans

Floodplain risk management plans are generally prepared to address the existing, continuing and future flood risk in accordance with NSW Government's Flood Prone Land Policy (refer **Section 2.2.2**). Floodplain management plans also often define the flood planning level and flood planning areas, in addition to hydraulic categorisation of the floodplain (that is, floodway and flood storage areas) which are then incorporated into relevant development controls.

There are no floodplain management plans relevant to the Project area, hence flood planning levels and areas and hydraulic categorisation of the floodplain is not defined for the Project area.

2.2.7 NSW River Flow Objectives

The NSW River Flow Objectives (DECCW, 2006) are the environmental values and long-term goals for NSW surface waters. Project impacts to NSW river flow objectives nominated for waterways within the study area have been described and addressed in this report.

The NSW River flow objectives are the agreed high-level goals for surface water flow management which have been developed by the NSW Government (DECCW, 2006). They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses. Each objective aims to improve river health by recognising the importance of natural river flow patterns.

The key surface water management zone identified for the Murrumbidgee River, and which is relevant to the Project study area are for "Controlled rivers with altered flows (regulated creeks)". Yanco Creek receives controlled flows from the Murrumbidgee River. It has been declared a regulated stream. Provision of a continuous flow for irrigation and other purposes results in moderately high flows in summer and autumn when flows would naturally be brief or low. In other seasons flows may sometimes be less or more than would naturally occur. The variability of flows has been altered.

In total, there are eleven inland River Flow Objectives, each dealing with a critical element of hydrologic and river processes. Eight of these are relevant and are used in the impact assessment, refer to **Section 6.3**.

3. Assessment methodology

3.1 Study area

For the purposes of this assessment, the flooding study area in which impacts have been assessed is as shown in **Figure 3-1**.

3.2 Overall assessment approach

The objective of this hydrology and flooding assessment is to identify the existing flooding behaviour within and surrounding the Project area and assess the potential flooding impacts associated with the Project. The assessment methodology is summarised below:

- Desktop review of available flood study reports (refer to **Section 3.3**)
- As there is no adequate existing flood mapping in the vicinity of the Project area, flood modelling has been undertaken to determine flooding conditions for the existing case. Description of the model development and validation is provided in **Appendix A**
- Review of council planning and policy documents to identify flood-related development controls including mitigation requirements
- Assessment of potential impacts to flooding and hydrology associated with the Project during construction and operation. A review of existing flooding conditions indicated that impacts on flooding and impacts to sensitive receivers would be minor. As such a qualitative impact assessment has been undertaken
- Identification of appropriate measures to mitigate and manage potential flooding and hydrology impacts associated with the Project.

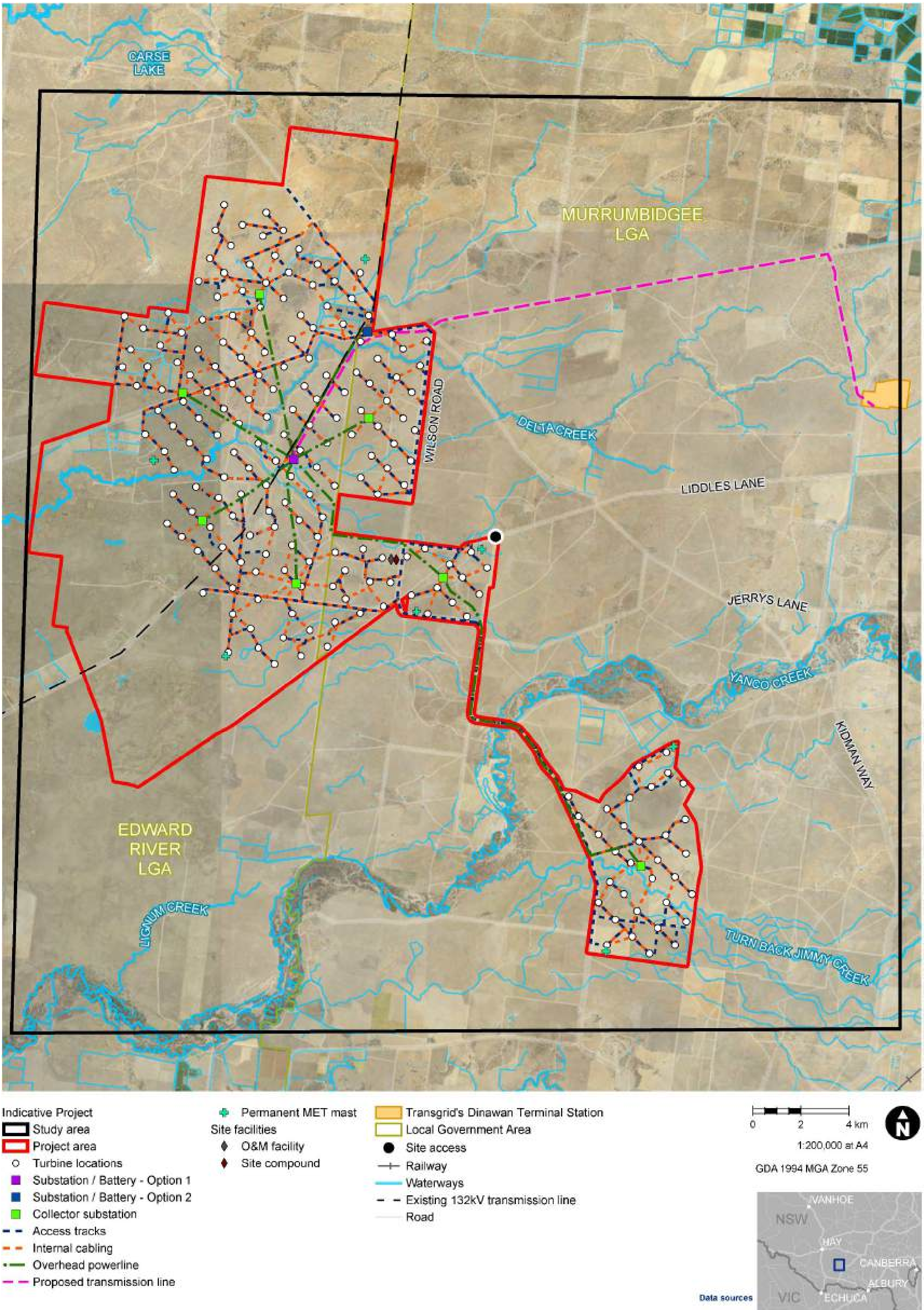
3.3 Review of existing studies

Existing flooding studies relevant to this assessment include:

- Flood Study Report for Morundah (Jacobs 2017a)
- Flood Study Report for Rand (Jacobs 2017b)
- Narrandera Floodplain Risk Management Study (Lyall and Associates 2019)
- Murrumbidgee River at Darlington Point and Environs Flood Study (BMT 2018).

These reports were reviewed and data inputs from the flood modelling associated with the studies were extracted, including historic and design flood event inflows and details of selected hydraulic structures.

Murrumbidgee Valley Flood Plain Atlas – Yanco, Colombo & Billabong Creeks (Sinclair Knight and Partners, 1987) maps the extent of the historic 1974 flood event in Yanco Creek, which was used to validate the flood modelling results for existing conditions.



Data sources
Jacobs 2022
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Figure 3-1 Study area

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3.4 Key assumptions

Based on the description of construction activities the worst-case stage for the construction phase would be upon completion of required civil works for the substations and WTGs. This would be when earthworks are being undertaken, in addition to the installation of impervious paved and roof surfaces. As such, would have the maximum potential impact on flood flow obstruction and increased Project area runoff rates. Temporary stockpiles and cabling trench works would also be included in the worst-case.

While there are no requirements in the Edward River or Murrumbidgee Council development on flood immunity or flood protection levels specifically relevant to the WTGs, this assessment uses the following assumptions:

- WTGs are resistant to flooding at the tower base to several metres depth and may be located within the floodplain
- Hardstand areas for the WTGs would be regraded with minimal cut and fill to provide a level surface for construction and maintenance cranes
- BESS and substations are considered sensitive and critical infrastructure and would be at a minimum flood protection level of the PMF flood level. This would be achieved by filling of selected substations
- The operation and maintenance facility would be at a minimum flood protection level of 0.5 metres above the 1% AEP flood level which is consistent with typical planning controls for minimum fill levels for residential developments. Filling of the operation and maintenance facility site would be required to raise the finished ground levels where these are below the relevant flood level
- Drainage swales would be provided to convey overland flows around WTGs, hardstand areas and other Project infrastructure to prevent redirection of flows
- Access tracks that would cross ephemeral watercourses would be raised above the watercourse bed to provide a low-level crossing. Culverts or bridges may need to be provided at the crossings to convey flows through the crossing. Appropriate scour protection and design considerations will be provided at crossings and hydraulic structures to minimise the likelihood of erosion and scouring
- Meteorological masts would be guyed lattice tower structures up to 180 metres tall and about one metre wide. Up to eight masts would be installed across the Project area. All masts will be designed to withstand flood-flow forces
- Wilson Road would be used as a construction traffic route. The Traffic and transport technical report (Jacobs, 2022c) states that Wilson Road is not an OSOM approved route. The existing bridge crossing of Yanco Creek would be assessed at a later stage to determine suitability for equipment and load to be transported along this route. Any upgrade of the bridge is not considered as a part of the Project. It is assumed Wilson Road would not be raised to provide improved flood immunity as a part of the Project.

4. Existing environment

4.1 Catchment overview

The Project would be located within the lower Murrumbidgee River Catchment in southern NSW. The Murrumbidgee River Catchment flows in a south-westerly direction from its headwaters in Kosciuszko National Park to the alluvial floodplains at the western end of the valley where the Project would be situated.

4.1.1 Topography

The Project area is largely flat with altitudes varying between 100 metres and 114 metres Australian Height Datum (AHD).

4.1.2 Watercourses and terrain

The Project area is mostly situated on an alluvial floodplain between two watercourses, Yanco Creek which bisects the northern and southern portions of the Project area, and Delta Creek in the northern portion of the Project area. Yanco Creek is a major perennial watercourse which flows south-west toward the Murray River. Delta Creek is a minor, ephemeral watercourse which also drains in a south-westerly direction during significant rainfall, although does not connect to any downstream major channel unless the area is flooded. A third minor watercourse, Turn Back Jimmy Creek, intersects the southern portion of the Project area. Refer to **Figure 4-1**, **Figure 4-2** and **Figure 4-3** for photos of the three watercourses.

Aside from the three watercourses described above, there are some minor drainage depressions that hold water during rainfall and flooding, and drain in a south-westerly direction. A slope dips toward Delta Creek in the northern portion of the Project. Several minor topographic depressions on the floodplain hold water for longer, creating scattered swamp environments within the Project area.

Figure 4-1 Delta Creek

Figure 4-2 Yanco Creek

Figure 4-3 Turn Back Jimmy Creek

4.1.3 Regional drainage patterns

The Murrumbidgee River flow from east to west 60 kilometres to the north of the Project area. At the town of Narrandera, the Murrumbidgee River has a catchment area of 84,000 square kilometres, with elevations ranging from 2,200 metres AHD in the east to less than 50 metres AHD in the west.

Yanco Creek is a major breakout channel from the Murrumbidgee River, diverging from the Murrumbidgee River 14 kilometres downstream of Narrandera in the vicinity of the Yanco regulator and offtake structures. From that location, Yanco Creek flows south and then south-west, intersecting the Project area 31 kilometres downstream of the town of Bundure. Downstream of the Project area, Yanco Creek continues to flow in a westerly direction.

Coleambally Canal is a major irrigation canal which offtakes water from the Murrumbidgee River about 40 kilometres west of Narrandera. It flows southward and distributes irrigation water to the Coleambally Irrigation Area between the Murrumbidgee River and the Project area (about 15 kilometres to the east and north-east of the Project area) via a network of smaller canals.

Billabong Creek is located 15 kilometres south of the Project area and flows in a general eat to west direction. The Creek has a catchment area of 2,620 square kilometres. Yanco Creek joins Billabong Creek upstream of Conargo, about 35 kilometres south-west of the Project area.

Regionally, the land to the south of the Murrumbidgee River generally grades in a west to south-westerly direction. During major to extreme flood events, there is potential for floodwaters to break out from the watercourses described above, with the breakouts in some areas having the potential to contribute to flooding in the Project area. Floodwaters would drain according to the fall of the land and via the watercourses, eventually draining to the Murray River 150 to 200 kilometres to the west of the Project area or becoming trapped in low points of the floodplain and eventually being lost from the floodplain via infiltration or evaporation.

4.1.4 Land use

The Project area is zoned as RU1 – Primary Production under the Conargo Local Environment Plan (LEP) and Jerilderie LEP, for agricultural activity. The Project area is located across eight properties, which are currently used for sheep and cattle grazing, irrigated cropping and groundwater extraction. Native vegetation also exists within parts of the Project area.

4.1.5 Climate

4.1.5.1 Rainfall and temperature

Review of data available through the Bureau of Meteorology BOM) – Monthly Statistics: Climate Data Online BOM, 2022) indicates that the nearest BOM weather station for rainfall and temperature data is the Yanco Agricultural Institute Weather Station (#74037) located approximately 80 kilometres northeast of the Project area at its nearest point.

Utilising the BOM climate database, the average total rainfall for each calendar month from 1996 to 2021 (25 years) was calculated and is summarised in **Table 4-1**. The average total annual rainfall is 407.1 millimetres.

Table 4-1 shows there is only a moderate level of seasonality to rainfall within the study area, and that rainfall is typically low in most months. Lowest average rainfall is recorded in April (23.7mm) and May (27.4 millimetres), followed by January. Highest monthly rainfall is recorded in March (44.6mm) followed by June and November. Between July and October there is very little variation between monthly rainfalls.

Long term temperature data from Yanco Agricultural Institute Weather Station (BOM, 2022) was reviewed and is presented in **Table 4-1**. **Table 4-1**indicates that monthly average maximum and minimum temperature ranges from 2000 to 2021. The analysis of available temperature data indicates that the Project is positioned within a temperate climatic region characterised by warm summers and cool winters. Average minimum and maximum temperature range from approximately 15 to 34°C (December to March) and 5 to16°C (June to August) seasonally, with predominately mild to moderate autumn and spring months.

Climate change predictions in the Murrumbidgee catchments is expected to occur and result in a decrease in spring rainfall but an increase in autumn rainfall. Summer rainfall is also expected to increase (DPIE 2020). Mean temperatures are also expected to increase across the region with the greatest increase during summer.

Table 4-1 Summary of climate recorded at Yanco Agricultural Institute Weather Station (#74037)

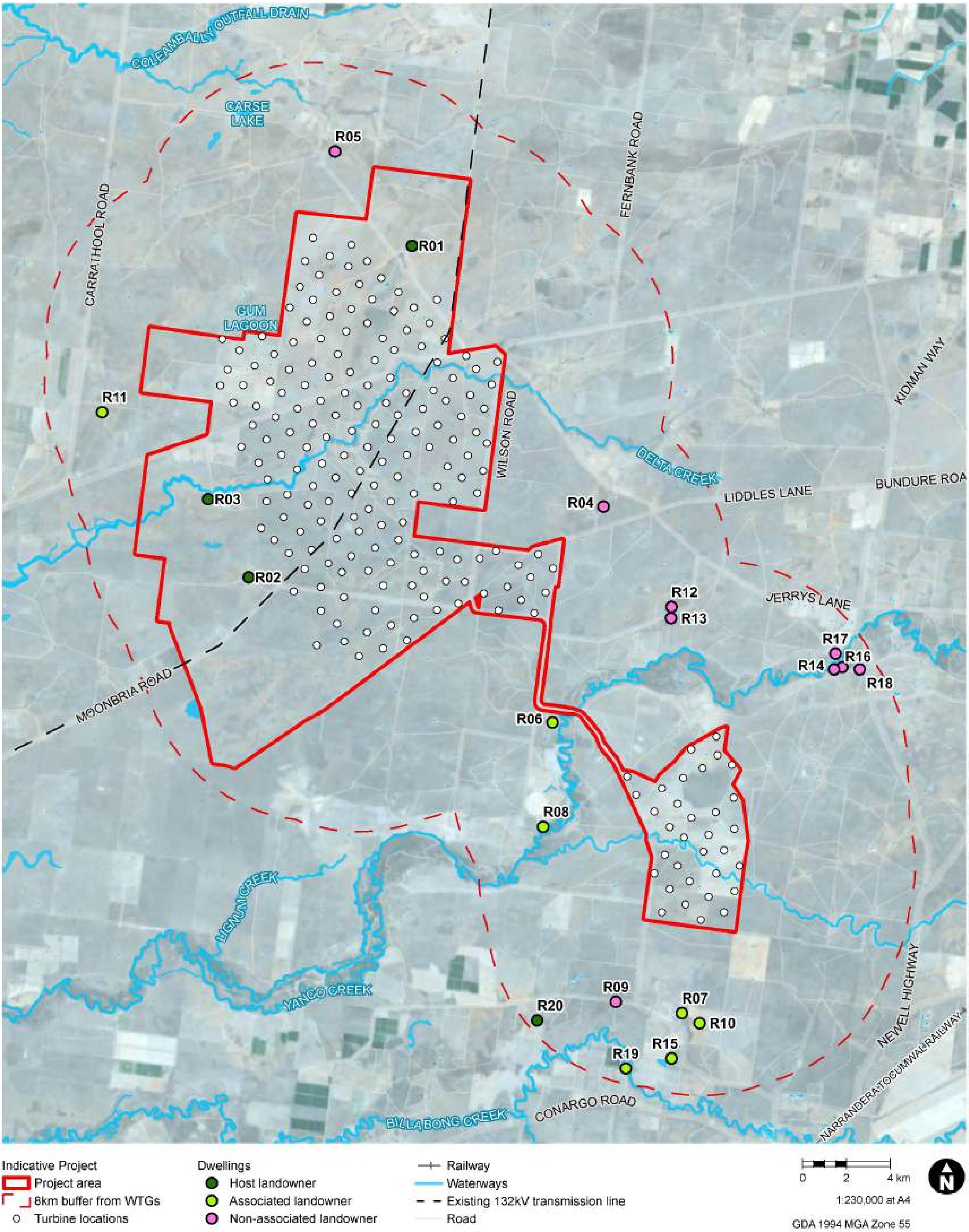
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Average Total Rainfall (mm)	27.2	37.7	44.6	23.7	27.4	40.7	34.5	35.7	34.0	31.2	40.5	29.9
Minimum temperature (°C)	19.0	18.3	15.4	11.7	7.7	5.7	4.9	5.1	7.6	10.6	14.4	16.2
Maximum temperature (°C)	34.2	32.4	28.9	24.3	19.0	15.2	14.5	16.3	20.5	24.9	28.9	30.8

4.2 Sensitive receivers

Dwellings and roads are the main sensitive receivers. There are three dwellings within the Project area, all owned by Host landowners and all landowners' dwellings are at a minimum of two kilometres from any proposed WTGs. No turbines are placed within 3.7 kilometres of any habitable dwellings on Non-associated properties neighbouring the Project area.

Figure 4-4 shows that there are 20 dwellings within eight kilometres from Project infrastructure (i.e. WTGs). The closest town, Jerilderie, is 10 kilometres from the Project area and is outside the flooding study area.

There are numerous public and private access roads within the Project area connecting dwellings to main roads as well as across agricultural land. Some of these roads cross Delta and Turn Back Jimmy Creek as well as the Wilson Road bridge crossing Yanco Creek.



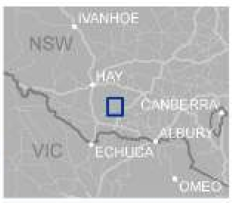


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Figure 4-4 Dwellings

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4.3 Existing flood behaviour

Flooding across the Project area is caused by a combination of flood flows in Delta Creek, Yanco Creek and Turn Back Jimmy Creek in addition to local catchment runoff in flow paths. Delta Creek generates most of the higher velocity and depth levels in this area. Yanco Creek generates flooding in the lower extent of the northern section as well as the southern portion of the Project area, however the Project area avoids its channel. Turn Back Jimmy Creek generates high flows in its channel and contributes to overland flows on the floodplain in the southern portion of the Project area.

4.3.1 Flood depths

Mapping of flood depths is presented in **Figure 4-5** and **Figure 4-6** for the 1% AEP and PMF events, respectively. Zoomed in mapping is provided in **Figure B-1** and **Figure B-2** in **Appendix B** for the 1% AEP and PMF events, respectively.

4.3.1.1 1% AEP Event

In the 1% AEP event Delta Creek has a peak depth of 2.5 metres at the north-western extent of the Project area. Typically values along the channel range between 1 to 2 metres. There are also farm dams and waterholes along the channel creating localised high depth areas, the highest of which reaches 3.2 metres. Away from the main Delta Creek channel throughout the north section of the Project area there is consistent patchy flooding with depths up to 1 metre with typical values around 0.5 metres.

In the 1% AEP along Turn Back Jimmy Creek in the southern section of the Project area typical values range from 2 to 2.2 metres with localised high depth areas from farm dams and waterholes reaching a maximum of 2.9 metres. The remainder of the southern section has areas of flooding with depths generally ranging from 0.2 to 0.6 metres with a significant vegetated area ranging from 0.6 to 1.1 metres in depth.

Both the access road and the bridge experience high flood depths with the 1% AEP event resulting in a depth of 3.7 metres at the bridge and a significant area of the road submerged with higher depths seen on the north-west side of the bridge. Along the road on the north-west side of the bridge typical values range between 0.5 and 1 metre with areas in the close vicinity of the road reaching up to 2.2 metres. The access road the south-east of the bridges has depths ranging between 0.2 to 0.3 metres and some areas free from major inundation, there are localised wetland or farm dam areas which have depths up to 2 metres in the vicinity of the road.

Within the northern extent of the Project area access roads crossing Delta Creek experience high flood depths up to 1.7 metres. Throughout the remainder of the northern section most access roads experience some degree of flooding with many having depths over 0.5 metres. In the southern extent of the Project area the access road crossing Turn Back Jimmy Creek experiences flood depths up to 2.2 metres whilst the remaining access roads only experience moderate flooding with depths generally below 0.5 metres.

Several dwellings upstream of Wilson Road which connects the northern and southern sections of the Project area are very close to flooded areas in the 1% AEP Event but no dwellings experience a significant level of flooding and the dwellings along Yanco Creek are outside the 1% AEP modelled flood extent (refer to **Figure 4-5**). There could be potential impacts as they are very close to the flood extent and small increases in modelled flood depths may lead to inundation of these dwellings. Dwellings away from the creek do not appear to be in significant flood paths.

4.3.1.2 PMF Event

The northern section of the Project area experiences significant flood depths in the PMF event along Delta Creek. In the PMF event flood depths of up to 2.2 metres occur as Delta Creek enters the north-eastern extent of the Project area. High depths continue along Delta Creek at typical values of 2 metres and peak at 3.2 metres on the north-western extent of the Project area. There are also several waterholes and farm dams along Delta Creek creating localised high depth levels, the highest of which reaches 3.7 metres. In the PMF there is also significant levels of water breaking out from the main channels across the floodplain in the northern portion of the Project area, depths on the floodplain reach 1.2 metres near Delta Creek and up to 1.1 metres to the north of Yanco Creek however typical values range from 0.2 to 0.7 metres.

In the PMF event the southern section of the Project area experiences high flood depths along Turn Back Jimmy Creek, within the channel the depth is typically 2.5 metres with farm dams or waterholes generating depths of up to 3.2 metres. The entire southern section is somewhat uniformly inundated with typical levels of 0.5 metres with some localised low depths at the southern extent and a large, vegetated wetland area in the north with typical depths of 1.4 metres.

Wilson Road, which connects the southern and northern sections of the Project area has a bridge crossing Yanco Creek. In the PMF event, flood depths in the creek channel at the bridge are at least 4.8 metres, and Wilson Road to the north-west of the bridge experiences typical depths of between 1 to 2 metres. To the south-east of the bridge Wilson Road flood depths generally range from 0.5 to 0.7 metres with some localised high depth areas in wetlands and farm dams reaching up to 2.3 metres. Wilson Road bridge is overtopped in the PMF event.

Most dwellings only experiencing minor flooding, however in the PMF dwellings along Yanco Creek experience a high degree of flooding. The location of dwellings is shown in **Figure 4-6**. Dwelling R13 (upstream of bridge) has a flood depth of 1.1 metres, R4 (downstream) at 1.9 metres and dwelling R14 (downstream) has a flood depth of between 1 to 3 metres.

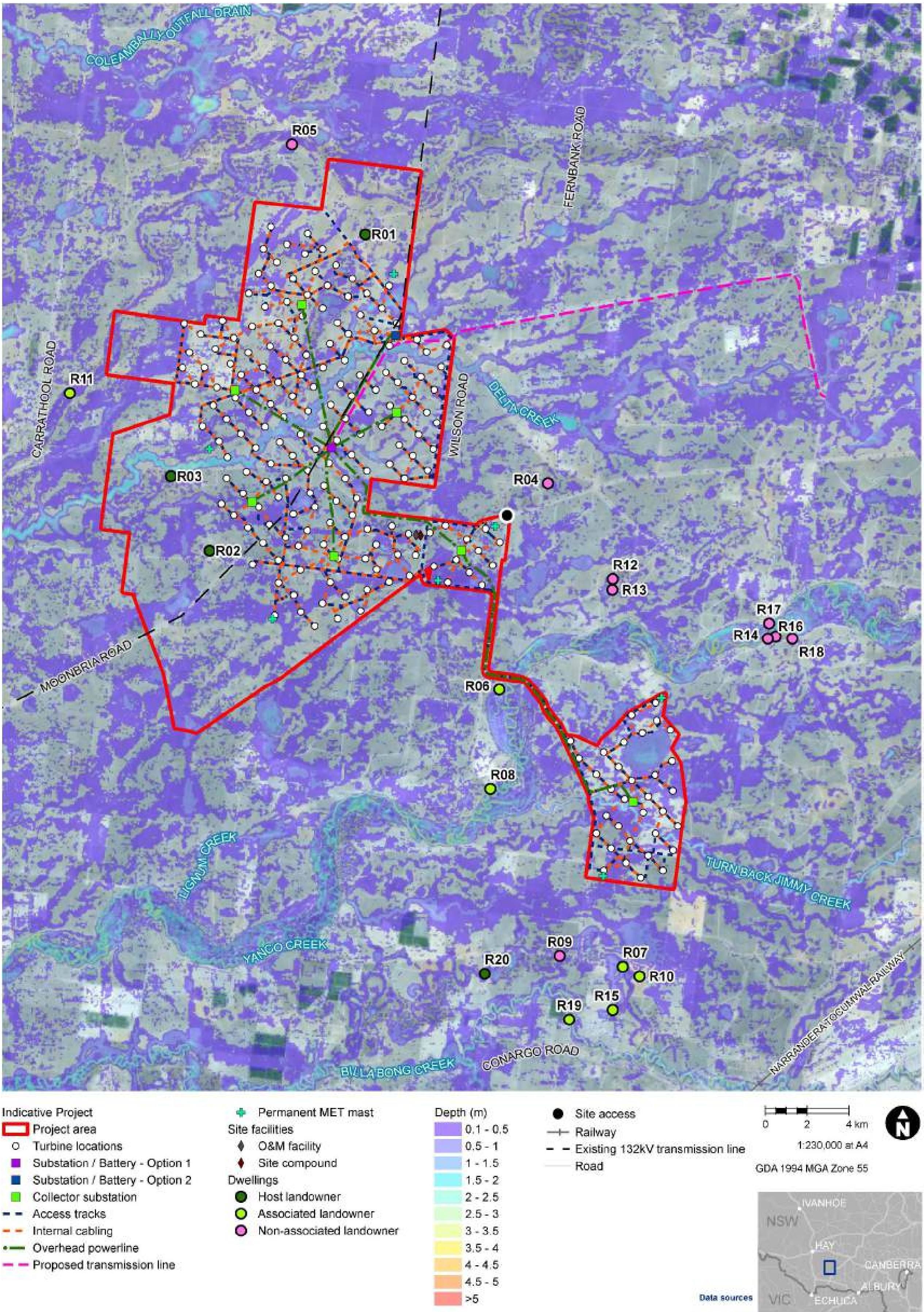

Figure 4-5 Existing flood depth - 1% AEP event

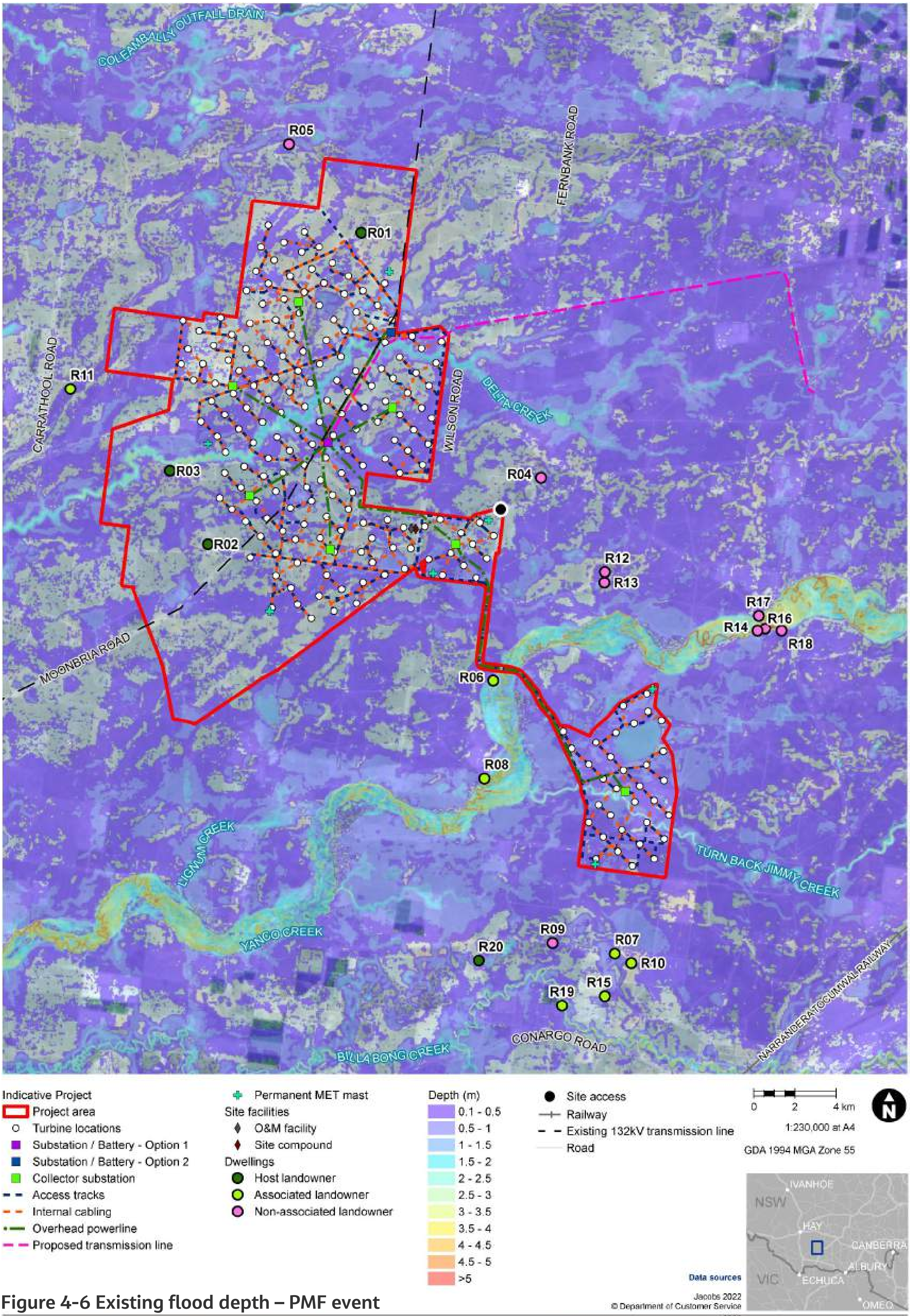

Figure 4-6 Existing flood depth – PMF event

4.3.2 Flood hazard

Recent research has been undertaken into the hazard that flooding poses and the vulnerability of the public and assets when interacting with floodwaters. A combined flood hazard classification based on this research is presented in *Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017a) and *Guideline 7-3 Flood Hazard* (AIDR, 2017b), and is illustrated in **Figure 4-7**. This recent flood hazard method has been adopted in *Book 6: Flood Hydraulics of the Australian Rainfall and Runoff 2019* guidelines. The flood hazard categories according to the AIDR definition are:

- H1 – Generally safe for people, vehicles and buildings;
- H2 – Unsafe for small vehicles;
- H3 - Unsafe for vehicles, children and the elderly;
- H4 - Unsafe for people and vehicles;
- H5 - Unsafe for people and vehicles. Buildings require special engineering design and construction; and
- H6 – Unsafe for people or vehicles. All building types considered vulnerable to failure.

Mapping of flood hazard is presented in **Figure 4-8** and **Figure 4-9** for the 1% AEP and PMF events, respectively. Zoomed in mapping is provided in **Figure B-3** and **Figure B-4** in **Appendix B** for the 1% AEP and PMF events, respectively.

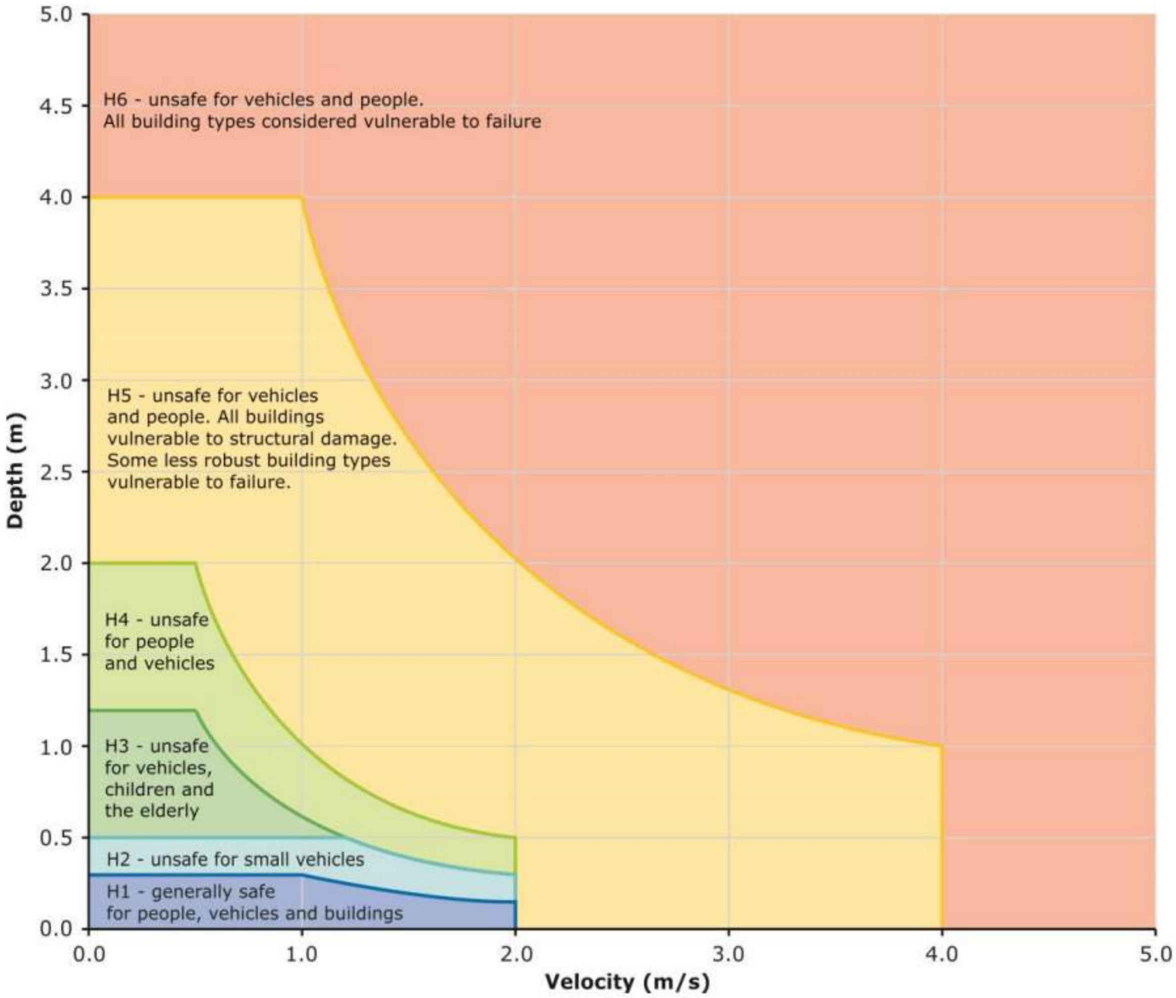

Figure 4-7 General flood hazard vulnerability curves, Australian Institute for Disaster Resilience (AIDR) definition.

Reproduced from Figure 6 in Guideline 7-3: Flood Hazard (AIDR, 2017b)

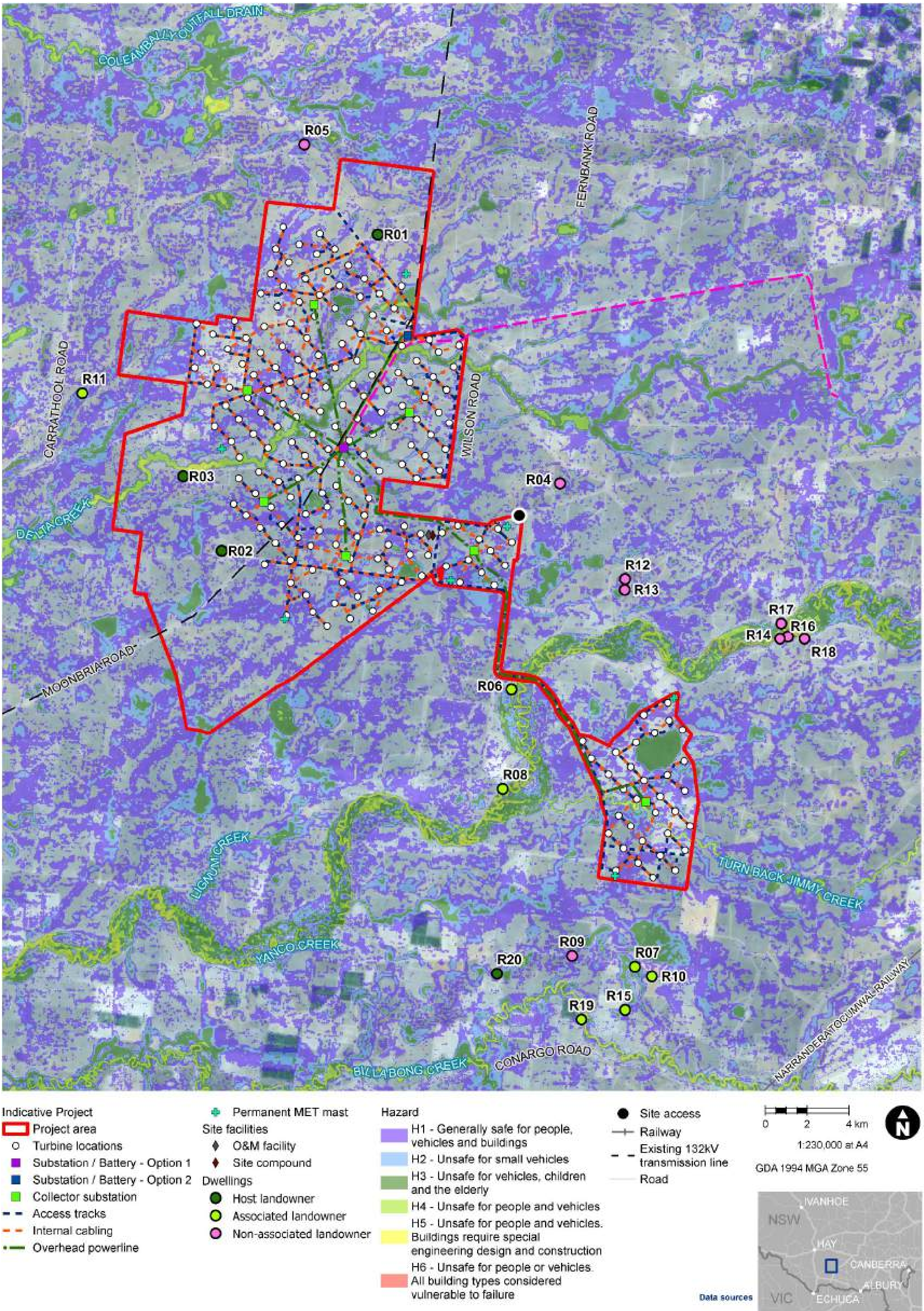

Figure 4-8 Existing flood hazard in the 1% AEP event

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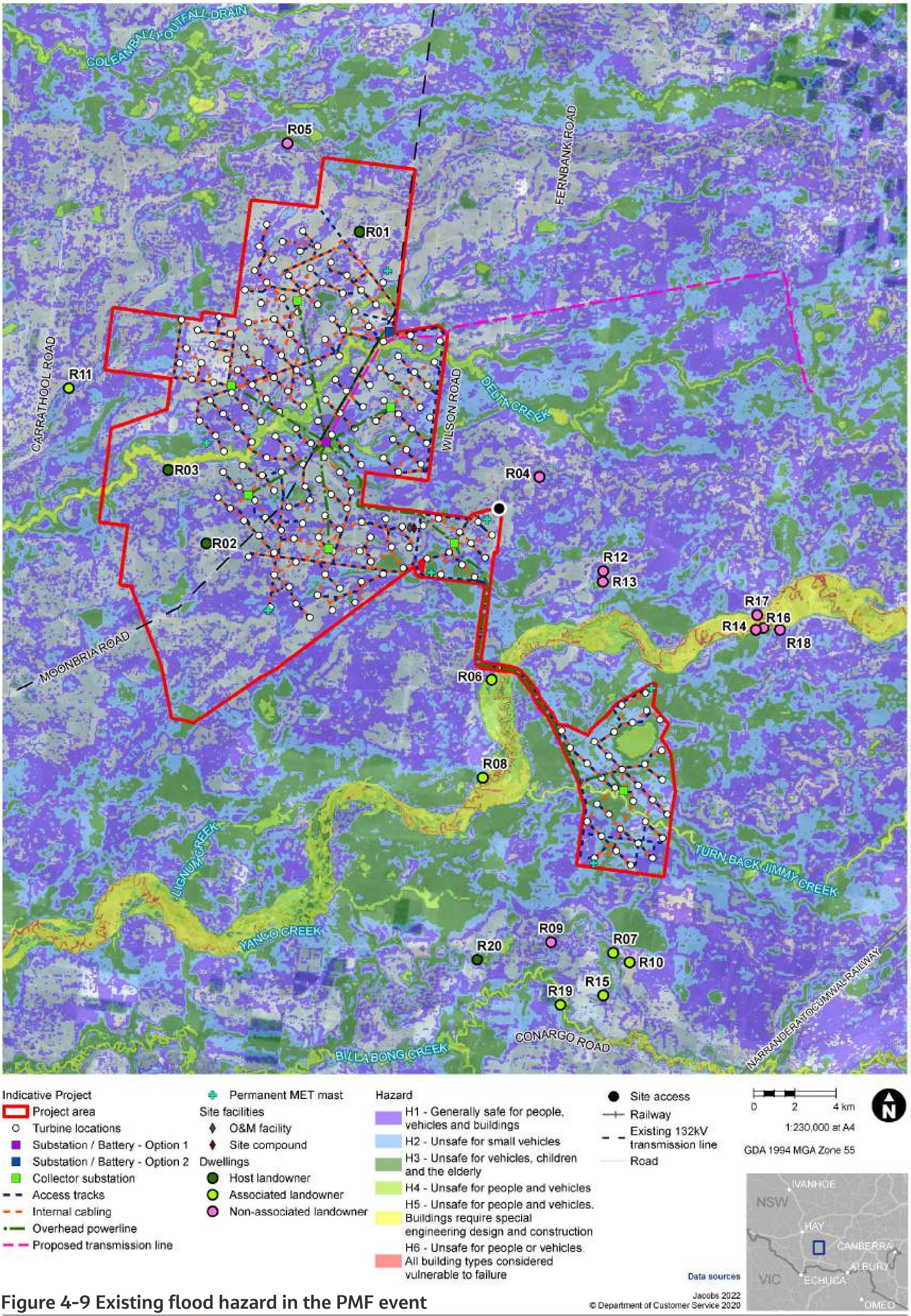

Figure 4-9 Existing flood hazard in the PMF event

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4.3.2.1 1% AEP Event

In the 1% AEP event the northern section experiences flood hazard categories ranging from H1 to H5. The H5 areas are only experienced in isolated areas of the western end of Delta Creek. The centre of the Delta Creek channel primarily has a hazard category of H4 with some areas of H3 and H5. Away from Delta Creek the remainder of the northern section has significant areas of H1 with some isolated regions of H2 and H3.

At the Wilson Road bridge crossing of Yanco Creek there are some limited areas of H6 upstream of the bridge whilst most of the centre Yanco Creek has a hazard category of H5. The remainder of the Yanco Creek channel has a hazard category generally between H2 and H4. The roads on either side approaching Yanco Creek have areas of H1 with a smaller amount of H2.

The southern extent of the Project area has a H5 hazard category along the large majority of the centre of the Turn Back Jimmy Creek channel. The outer extents of the channel have hazard category levels ranging from H1 to H4. There are also significant areas of H1 and H2 in other areas with a large area of H3 in the wetland in the north-eastern extent of the section.

The dwellings with high hazard levels in the 1% AEP event correspond to those with high flood depths as outlined in **Section 4.3.1**.

4.3.2.2 PMF Event

In the PMF event the northern section of the Project area experiences a range of flood hazard categories from H1 to H5. Along the Delta Creek channel, the hazard categories range between H4 and H5. Further from the centre of the channel the hazard level drops gradually and across the floodplain there are a significant number of areas between H1 and H3.

The PMF event generates the maximum hazard category H6 at the bridge at Yanco Creek connecting the southern and northern sections of the Project area. Wilson Road immediately to the north-west of the bridge has hazard categories ranging between H4 and H5. To the south-east of the bridge, Wilson Road has hazard categories ranging from H1 to H3 with areas of H4 in the near vicinity of the bridge.

In the southern section of the Project area the PMF event generates a consistent H5 hazard category along Turn Back Jimmy Creek. Areas in the vicinity of Turn Back Jimmy Creek have hazard categories ranging from H2 to H4 and the broader area ranges between H1 and H3. There is also a significant area of H4 in the north-eastern extent of the section which corresponds to a vegetated wetland area.

The dwellings with high hazard levels in the PMF event correspond to those with high flood depths as outlined in **Section 4.3.1**.

4.3.3 Velocities

Mapping of flow velocities is presented in **Figure 4-10** and **Figure 4-11** for the 1% AEP and PMF events, respectively. Zoomed in mapping is provided in **Figure B-5** and **Figure B-6** in **Appendix B** for the 1% AEP and PMF events, respectively.

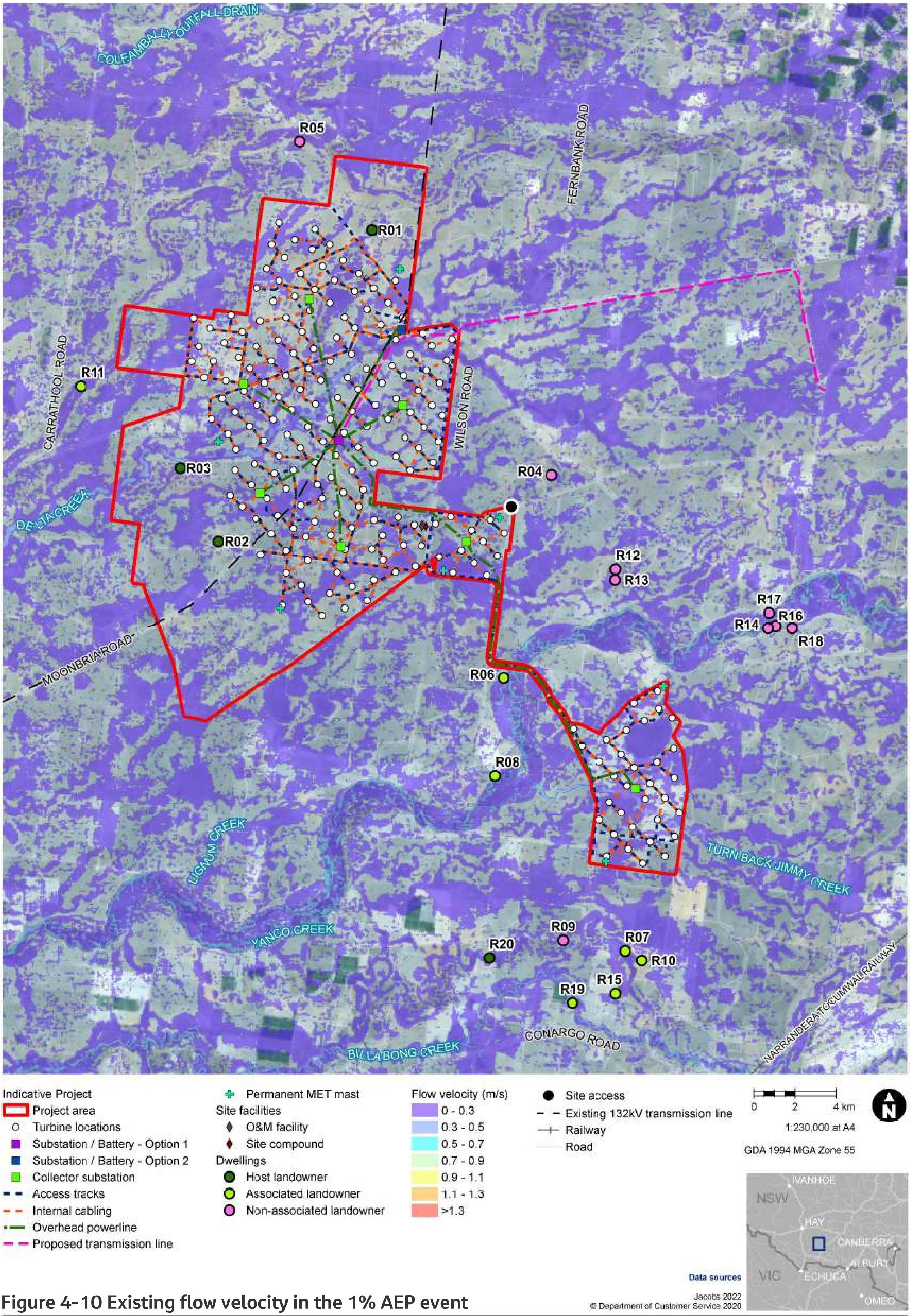

Figure 4-10 Existing flow velocity in the 1% AEP event

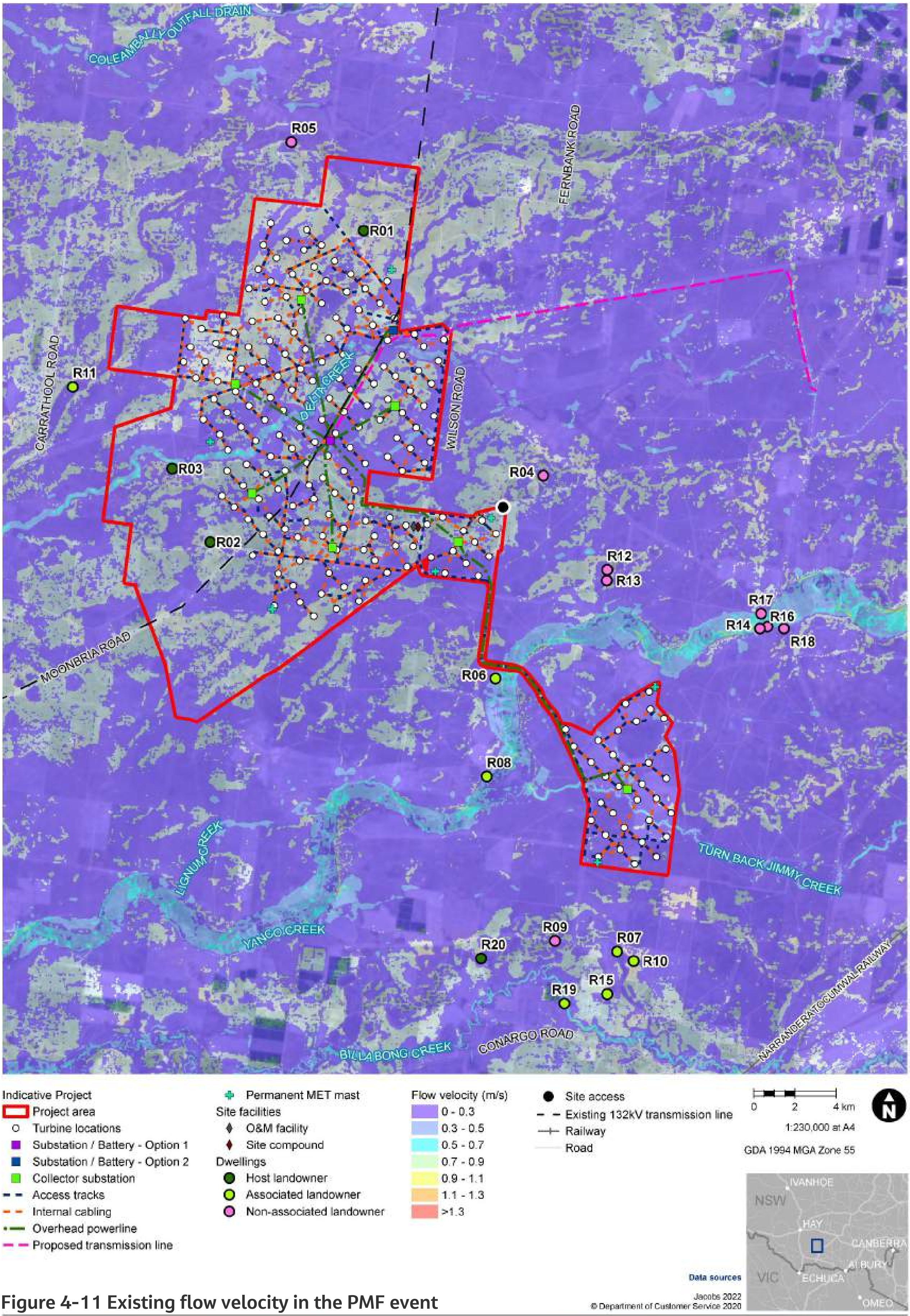

Figure 4-11 Existing flow velocity in the PMF event

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4.3.3.1 1% AEP Event

In the 1% AEP event the northern section of the Project area has velocities up to 0.8 metres per second in some isolated sections along Delta Creek with typical values along the creek between 0.2 to 0.4 metres per second. Most of the northern section does not experience significant velocities, away from Delta Creek there are some isolated flow paths with velocities up to 0.2 metres per second.

The bridge across Yanco Creek has a maximum velocity of 0.9 metres per second while the access road to the north has velocities typically between 0.1 metres per second and 0.3 metres per second with an isolated area of 0.6 metres per second.

The southern section of the Project area has some isolated areas with velocities of 0.8 metres per second along Turn Back Jimmy Creek. Typical velocities along the creek range from 0.2 to 0.5 metres per second whilst the remainder of the southern section generally does not experience significant velocities with some flow paths reaching 0.2 metres per second.

The sensitive receivers with high velocities in the 1% AEP event correspond to those with high flood depths as outlined in **Section 4.3.1**.

4.3.3.2 PMF

In the PMF event the northern section of the Project area experiences very high velocities along Delta Creek which has typical maximum velocities of 0.5 to 0.6 metres per second and some isolated areas experiencing up to 1 metre per second. High velocities are largely confined to Delta Creek with most of the section having maximums below 0.1 metres per second with some flow paths reaching velocities up to 0.2 metres per second.

Along Yanco Creek at the bridge connecting the southern and northern sections of the Project area there are velocities up to 1.2 metres per second with high velocities also present along the access road to the north with typical velocities between 0.6 metres per second and 0.8 metres per second.

In the southern section of the Project area high velocities are present along Turn Back Jimmy Creek with typical velocities of 0.4 to 0.6 metres per second as well as some isolated areas experiencing velocities up to 1 metre per second. The remainder of the southern section has velocities typically ranging from 0.1 to 0.3 metres per second.

The sensitive receivers with high velocities in the PMF event correspond to those with high flood depths as outlined in **Section 4.3.1**.

5. Potential construction impacts

The construction elements would involve a range of activities, including vegetation clearing and subsequent mulching, earthworks, trenching, concrete work materials stockpiling, trenching of cable routes and backfilling, and the establishment of a construction compound. Gravel for concrete production would be sourced from nearby gravel pits, with locations to be determined.

These construction activities present a potential risk to flooding and hydrology if appropriate management measures are not implemented, monitored, and maintained throughout construction. **Table 5-1** lists the waterways that may be impacted by the construction of the Project.

Table 5-1 Waterways and crossings by the Project infrastructure

Waterway	Intersected by
Delta Creek (Ephemeral)	Existing access tracks that would be widened
Unnamed drainage line to Delta Creek (south-east) (Ephemeral)	Underground cabling and access tracks at 8 locations
Unnamed drainage line to Delta Creek (north) (Ephemeral)	Underground cabling and access tracks at 12 locations
Yanco Creek (Perennial)	Wilson Road (existing road that would be utilised as access road)
Turn Back Jimmy Creek (Ephemeral)	Underground cabling at 3 locations
Unnamed drainage line to Turn Back Jimmy Creek (south) (Ephemeral)	Underground cabling at 5 locations and access track at 2 locations
Unnamed drainage line to Turn Back Jimmy Creek (north) (Ephemeral)	Underground cabling and access tracks at 6 locations
Other unnamed drainage lines (Ephemeral)	Several other unnamed drainage lines within the Project area would be intersected by access roads and underground cabling

Potential impacts of flooding and hydrology on the Project and potential Project impacts to flooding and hydrology during construction, and the risk of their occurrence are described in the sections below.

5.1 Potential impacts of flooding on the Project

5.1.1 Wind Turbine Generators

Table 5-2 reports on the 1% AEP and PMF depths at WTGs which would have a 1% AEP depth of 0.3 metres or more. There would be a number of other WTGs with shallow flood depths less than 0.3 metres which are not summarised in the table. There would be 16 WTGs that would experience flood depths of more than 0.3 metres in the 1% AEP flood event. The highest depth would be at W-031 at about one metre depth in the 1% AEP event. These WTGs are shown in **Figure 5-1** to **Figure 5-3**. Flow velocities at these WTG locations would be relatively low, less than 0.5 metres per second in the PMF event.

Given that the WTGs would be resistant to flooding at the base of the WTG towers and depths of flooding less than two metres in up to and including the PMF event, they do not require relocating or raising to provide flood-proofing. A minimal amount of filling and regrading would be undertaken to provide a level hardstand area for construction and maintenance of the WTGs. Filling within the flood extent area may partially obstruct flows and potentially result in minor flood impacts.

Table 5-2 Flood Depths at Proposed WTG Locations

WTG *	1% AEP Flood Depth (metres)	PMF depth (metres)
W-031	0.90	0.93
W-079	0.89	1.45
W-065	0.83	1.48
W-064	0.68	1.37
W-193	0.62	1.00
W-109	0.61	0.65
W-195	0.57	0.93
W-129	0.50	1.07
W-073	0.40	0.41
W-171	0.39	0.46
W-093	0.34	0.76
W-155	0.34	0.55
W-008	0.33	0.33
W-107	0.32	0.52
W-208	0.30	0.63
W-157	0.30	0.51

* WTGs with depths of 0.3 metres or more in the 1% AEP event only are indicated.

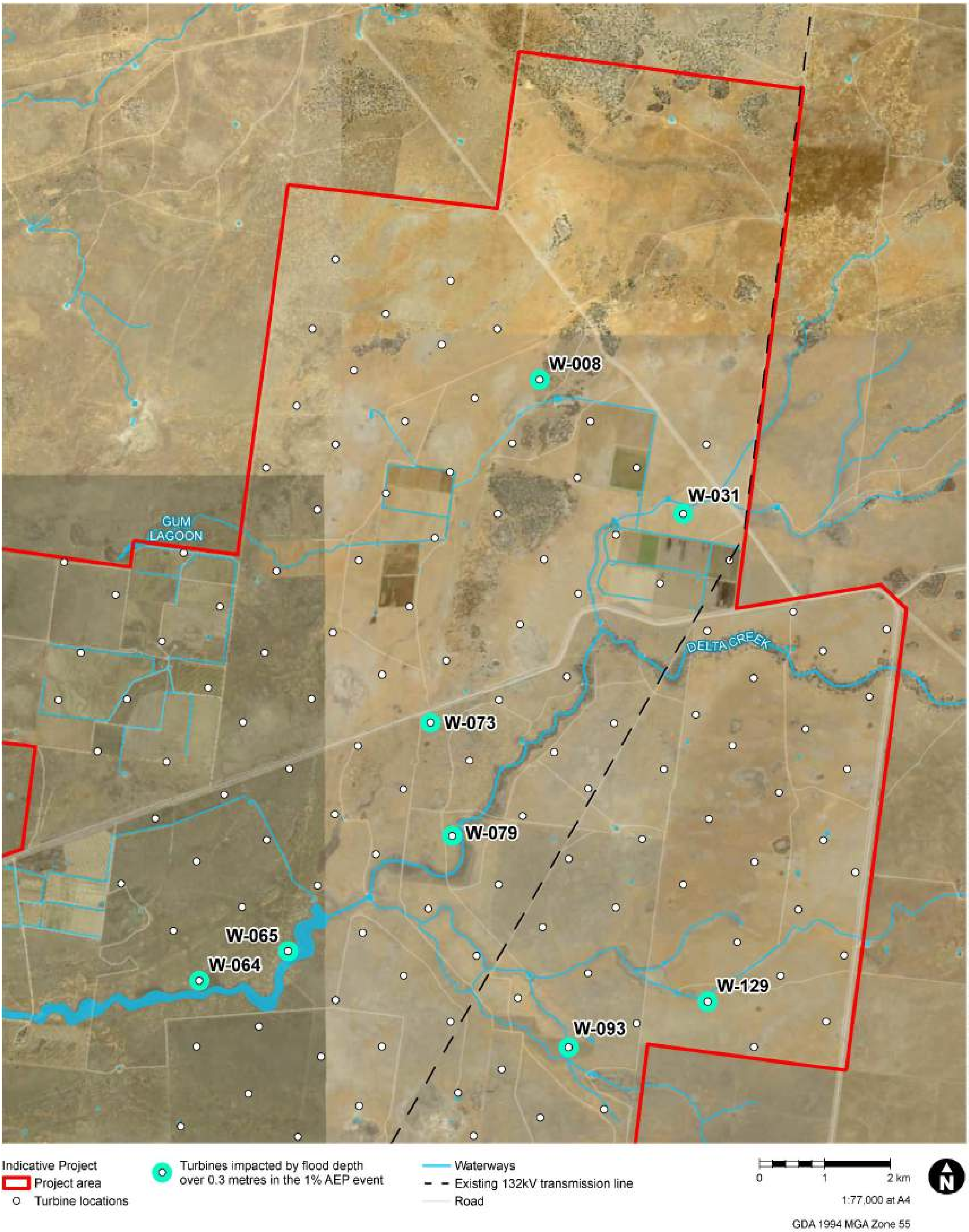
5.1.2 Substations

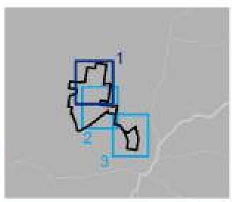
There are two proposed options for the central primary substation/BESS configuration. The central primary substation/BESS configuration for Option 1 is mostly flood-free affected in the 1% AEP event, with maximum flood depths of less than 0.3 metres. During the PMF it is affected by 0.3 to 0.8 metres depth. The central primary substation/BESS configuration for Option 2 is mostly flood-free affected in both the 1% AEP and PMF events. Maximum flood depths in the 1% AEP event are around 0.2 metres. During the PMF the maximum flood depths are 0.3 metres. Hence, filling would be required to raise the central primary substation/BESS configuration above the PMF for both Option 1 and Option 2.

Based on the option selected for the central primary substation, the other option would be utilised as a collector station. There are up to eight collector substations in the Project with depths in the PMF of 0.2 metres and 0.7 metres. Filling would be required to ensure these are above the PMF level.

5.1.3 Construction compound

A flood protection level of the 1% AEP flood level plus 0.5 metre freeboard is assumed for the construction compound. This site is above the PMF and hence filling of this site is not required during construction.





Data sources

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Figure 5-1 Turbines impacted in the 1% AEP event (sheet 1)

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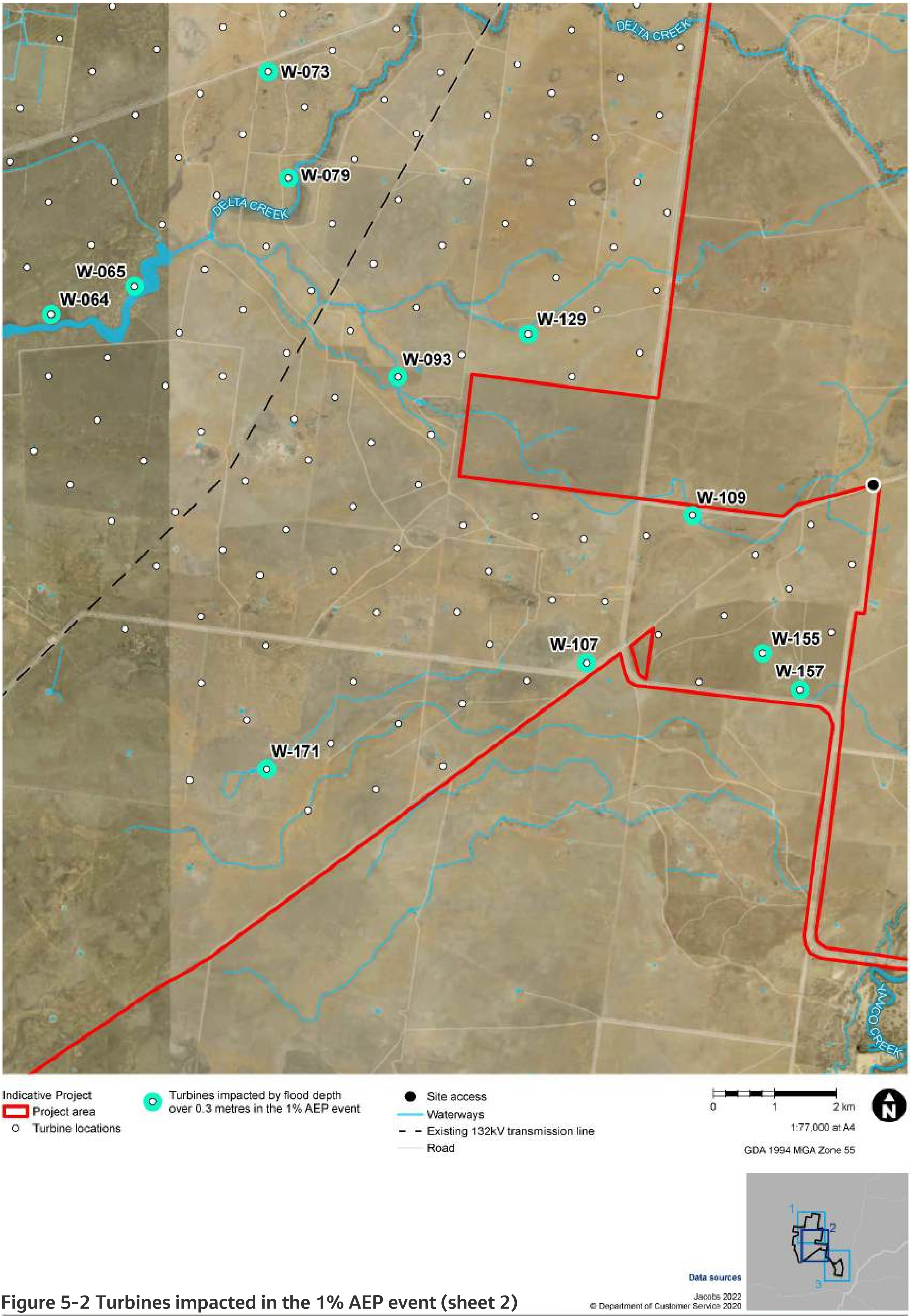

Figure 5-2 Turbines impacted in the 1% AEP event (sheet 2)

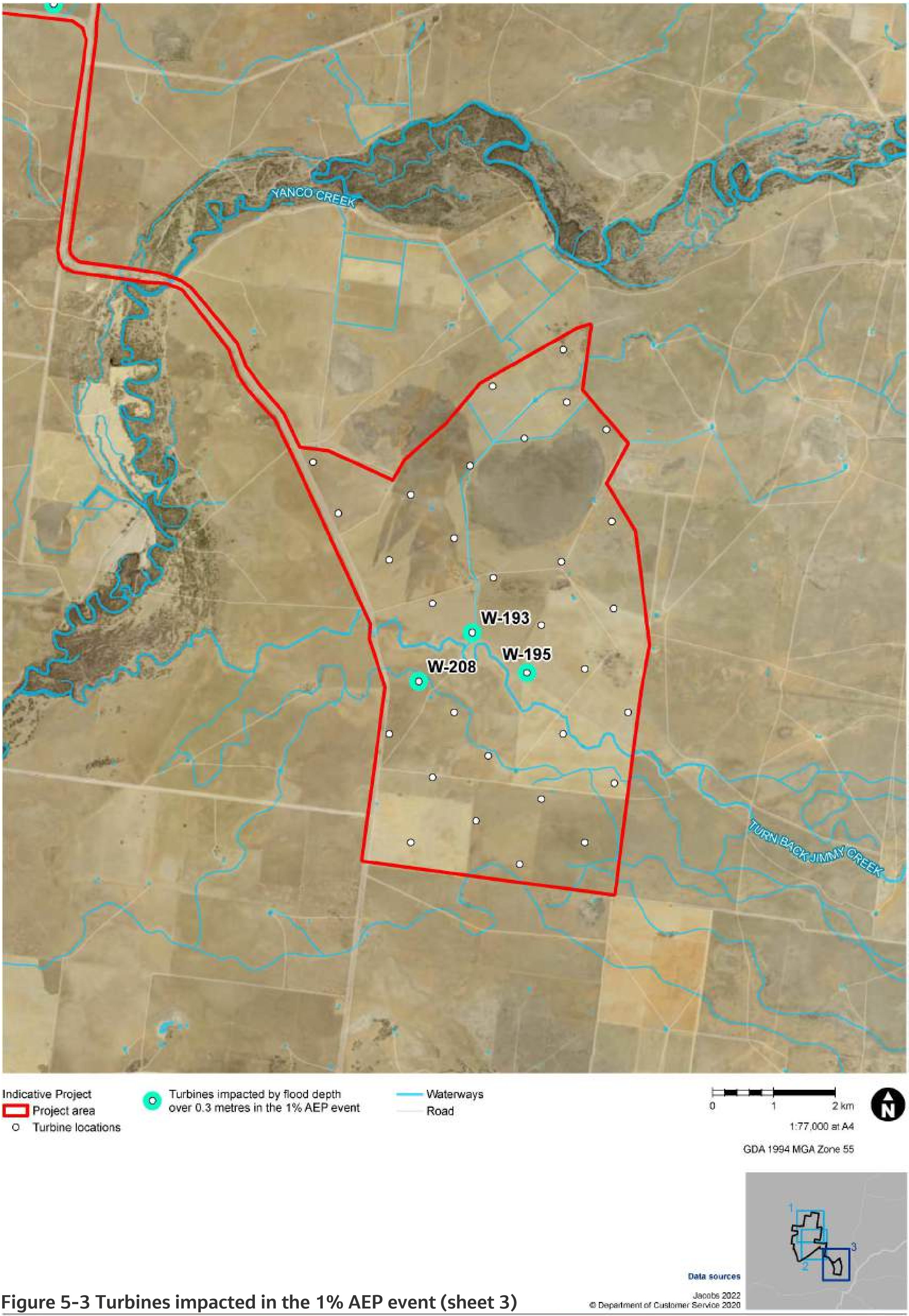

Figure 5-3 Turbines impacted in the 1% AEP event (sheet 3)

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5.2 Potential impacts of the Project on flooding

5.2.1 Impacts on mainstream flooding hydraulics and flood levels

The Project area is located on the fringes of the flooding extents and not in the main flow conveyance zones of Delta Creek, Turn Back Jimmy Creek and adjoining tributaries. There are ten WTGs that would be located within mainstream flooding extents of these watercourses in the 1% AEP event, and 22 WTGs in the PMF event. Their location along the main watercourses and flow paths means they have a higher potential for flooding impacts compared to others in minor flow paths and ponding areas. Depths at these WTGs would be generally between 0.3 to 0.7 metres in the 1% AEP event, with two WTGs with depths up to one metre (W-39 and W-74). Minor increases in flood levels at these locations may result due to minor filling/regrading of hardstand areas potentially resulting in partial obstruction of flows and loss of floodplain storage.

Flow velocities at the WTGs would be relatively low, less than 0.5 metres per second, in up to and including the PMF event. The flow widths of Delta Creek and Turn Back Jimmy Creek would be greater than 400 metres in the 1% AEP event, which would be significantly wider than the partial obstruction which would potentially be posed by the filled hardstand areas (40 metres by 50 metres), noting that the amount of filling is expected to be minor. Additionally, depths and the surface area of filling are relatively small compared to the large areas of flood storage and hence loss of floodplain storage is minor. Hence, increases in flood levels and depths are expected to be minor and localised.

There are no WTGs proposed along Yanco Creek. Trenching for cable construction at ephemeral watercourse crossings may impact on flooding during construction when earthworks are present and may obstruct flows. Trench construction itself at the crossings would not obstruct flows.

New Project access roads would be constructed, and existing access roads upgraded during construction. Access road crossings of ephemeral watercourses may be raised above existing road levels and above the watercourse bed. This could result in increases in flood levels upstream of the crossings.

The cable crossing of Yanco Creek would be via overhead wiring or utilise the Wilson Road bridge crossing and construction, therefore, would not impact on flood behaviour.

In general, the substations/BESS and collector stations would be located away from three main streams and as such they would not impact on the mainstream flooding and hydraulics. One collector station in the southern portion of the Project area would be located on the floodplain of Turn Back Jimmy Creek and there may be minor flooding impacts in the 1% AEP event resulting from construction of this collector station. Depths of flooding at this location are about 0.3 to 0.5 metres in the 1% AEP event.

Temporary construction facilities and material stockpile areas during construction will be placed away from drainage lines and waterways (outside of the 1% AEP flood extent) and are unlikely to result in impacts to flooding.

There is the potential for impacts to flow behaviour if gravel borrow pits are situated in flow paths, including ephemeral creeks, as they may capture or redirect flows if appropriate management measures are not in place.

5.2.2 Impacts on overland flooding and drainage

In both the 1% AEP and PMF events, Project infrastructure, in particular WTGs, would experience some degree of overland flooding. Several WTGs are in minor overland flow paths and may result in localised impacts such as increased flood depths and velocities. The impacts are expected to be minor due to low flow velocities.

The location for the central primary substation/BESS Option 1 is located adjacent to an overland flow path. During construction it is expected to have negligible impact on flooding in up to and including the 1% AEP event due to interaction with shallow, low velocity flows. In the PMF event there are expected to be minor impacts to flooding due to loss of floodplain storage. The footprint of Option 1 does not block active flow paths.

The location of the central primary substation/BESS Option 2 is mostly flood-free in up to the PMF event with the maximum depths of flooding less than 0.3 metres and with low flow velocities. It is expected to result in negligible impacts to overland flooding.

The proposed transmission line to the Dinawan Terminal Station would be constructed with overhead line support towers at approximately 400 metre intervals. The transmission line would cross several overland flow paths. There is minor risk of localised impacts to overland flows if the transmission line support towers are constructed within the overland flow paths, although impacts are expected to be minor due to relatively shallow flows (up to 1 metre depth) and low flow velocities.

Temporary construction facilities and material stockpile areas during construction will be placed away from overland flow paths (outside of the 1% AEP flood extent) and are unlikely to result in impacts to overland flooding.

There is the potential for impacts to flow behaviour if gravel borrow pits are situated in overland flow paths, as they may capture or redirect flows if appropriate management measures are not in place.

5.2.3 Impacts on dwellings and roads

In both the PMF and 1% AEP event there are some dwellings and access roads that experience flooding as outlined in **Section 4.3**. However, given the large distances from dwellings, roads and the Project infrastructure and generally minor impacts on flood behaviour, there is not expected to be any significant impacts on sensitive receivers.

Most dwellings which are flood-affected in the existing case are located along Yanco Creek about 15 kilometres upstream of the Wilson Road bridge crossing, as shown on the flood depth mapping on **Figure 4-5** and **Figure 4-6** for the 1% AEP event and PMF event, respectively. There would not be any flood impacts to these dwellings as no construction works are proposed on the Yanco Creek floodplain as a part of the Project.

Other dwellings in and around the Project area are not flood-affected or are affected by minor overland flooding but are located downstream of Project infrastructure. Hence, these dwellings would not be affected by flooding impacts resulting from the construction of the Project.

5.2.4 Surface water resources

The Project is located downstream of the Coleambally Irrigation Area (about 15 kilometres to the east and north-east of the Project area) and construction would not affect water availability to this scheme.

Construction activities would not dam an or redirect any ephemeral watercourses or flow paths which may deliver surface water to properties downstream of the Project. Flows would be conveyed around Project infrastructure and construction sites for WTGs and substations/BESS. Project construction would not dam, redirect, or extract flows of Yanco Creek. As such, it would not impact on the availability of water to licensed water users along Yanco Creek.

The majority of water required to meet Project water demands would be imported and would most likely be sourced through a commercial arrangement with Murrumbidgee Council, with raw water utilised for construction and potable supplies sourced for Project offices and amenities. Refer to the Surface water quality and groundwater technical report (Jacobs, 2022a) for further details.

6. Potential operational impacts

6.1 Potential impacts of flooding on the Project

As discussed in **Section 3.4** the design and componentry of the WTG towers means that the base of the towers are resilient to flooding and water damage. If flooding exceeds the hardstand areas, there is not expected to be damage to the WTGs.

As discussed in **Section 5.1.2**, there are two proposed options for the central primary substation/BESS configurations. Option 1 requires filling to a height of 0.3 to 0.8 metres above natural ground level, and Option 2 requires filling to a height of up to 0.3 metres above natural ground level to raise the substation/BESS above the PMF. There are up to eight collector substations in the Project with depths in the PMF of 0.2 metres and 0.7 metres. Filling would be required to ensure these are above the PMF level.

A flood protection level of the 1% AEP flood level plus 0.5 metre freeboard is assumed for the operation and maintenance facility. This site is also above the PMF and hence filling of these sites is not required during construction. Hence, workers associated with the Project would have a flood-free Project area to refuge in the event of a flood. Maximum flooding on Delta Creek and Turn Back Jimmy Creek would occur during short period PMF storm events where there would be minimal warning time. However, road access to evacuation centres and towns off-Project area are likely to be cut by flooding and hence the construction compound and operation and maintenance facility would be isolated during flood events.

The permanent meteorological masts are generally sited in locations of shallow (less than 0.4 metres depth), lower velocity flows in up to the PMF. One mast would be installed on Wilson Road near Moonbria Road at the south-eastern corner of the northern portion of the Project area would be subject to flood depths of 0.8 metres in the PMF event. All masts will be designed to withstand flood-flow forces.

6.2 Potential impacts of the Project on flooding

The potential hydrologic and flooding impacts of the Project operation is expected to be similar to the potential construction phase impacts associated with civil works. In summary:

- There are expected to be minor and localised impacts on flooding due to partial obstruction of flows and loss of floodplain storage caused by filled hardstand areas for WTGs and substations
- Access road crossings of ephemeral watercourses may be raised above existing road levels and above the watercourse bed and result in increases in flood levels upstream of the crossings
- There is minor risk of localised impacts to overland flows if the transmission line support towers are constructed within the overland flow paths.

Refer to **Section 5.2** for discussion.

The WTGs themselves would consist of towers with a 5 metre diameter at their base which may be flood-affected in rare flood events greater than the 1% AEP event. Due to their relatively small diameter only minor and localised impacts on flooding would be expected due to the WTGs impeding flood flows.

Meteorological masts would be guyed lattice tower structures up to 180 metres tall and one metre wide. Up to eight masts would be installed across the Project area. Due to their relatively small diameter only minor and localised impacts on flooding would be expected due to the masts impeding flood flows.

6.3 Potential hydrological impacts

6.3.1 Impacts on creek geomorphology and erosion

There would be negligible increases in runoff peak rates, volumes and durations of flow in Delta Creek and Turn Back Jimmy Creek resulting from increased impervious areas associated with hardstand areas for WTGs and substations. This is based on 208 WTGs with a hardstand area of 40 by 50 metres each, eight collector substations about 1 hectare each and a central primary substation/BESS area of up to 15 hectares, translating to a proportional increase in impervious area of less than 0.2 per cent over the entire Project area. Additionally, with catchment areas of over 300 square kilometres and 200 square kilometres upstream of the Project area for Delta Creek and Turn Back Jimmy Creek, respectively, the increase in impervious area in these watercourse catchments would be negligible. Subsequently, negligible geomorphic changes in the creek channel are expected.

There would be a minor risk of localised erosion and scouring of ground surfaces at drainage discharge areas from WTG and substation hardstand areas, without appropriate management measures. Appropriate scour protection at flow discharge areas, monitoring for erosion and implementation of remedial works such as stabilising eroded surfaces will be undertaken to minimise impacts.

There may be localised velocity increases at the toe of hardstand fill areas during flood events, although the risk of increased scour is expected to be low due to the existing low flow velocities.

6.3.2 River flow objectives

To assess the hydrological impacts of the Project it is necessary to assess impacts to river flow objectives as outlined in the NSW River Flow Objectives (DECCW, 2006) which details key river flow objectives for different types of rivers and catchments.

Yanco Creek receives controlled flows from the Murrumbidgee River through the operation of a weir downstream of Narrandera. As such, it is declared as a regulated stream. It has the following river flow objectives as outlined in **Table 6-1**. The potential impacts of the Project and measures to achieve the objectives are outlined.

Table 6-1 River Flow Objectives for Controlled Rivers with Altered Flows

Controlled River with Altered Flows (Regulated Creeks)		
River Flow Objective	**Potential Impacts of Project**	**Measures To Achieve Objective**
Protect natural low flows	Minimal – The Project will not create new irrigation or infrastructure to withdraw water from Yanco Creek.	Ensure in low flow periods that water is not diverted from Yanco Creek
Protect important rises in water levels	Minimal/Nil – The Project will not reduce the frequency or magnitude of rises in water levels important for riparian and floodplain inundation	Allow natural inundation to occur across the floodplain in large flood events, especially in areas of environmental importance as well as minimising changes and activity in natural waterways

Controlled River with Altered Flows (Regulated Creeks)		
River Flow Objective	**Potential Impacts of Project**	**Measures To Achieve Objective**
Maintain wetland and floodplain inundation	Minimal – The Project is not expected to have any significant impact or interactions with any wetlands. There may be minor effects on floodplain inundation in localised areas by new impervious areas from the development of WTGs and substations.	Do not drain or interfere with wetlands and minimise increase in impervious areas to allow continued inundation of the floodplain
Mimic natural drying in temporary waterways	Minimal/Nil – The Project is not expected to generate any significant unnatural flows which could impact drying as new hardstand and impervious areas are minor compared to overall catchment areas.	Minimise impervious areas
Maintain natural flow variability	Minimal – Access roads across creeks may have a minor impact on flow variability. New hardstand and impervious areas are minor compared to overall catchment areas.	Minimise changes to run off and natural flow regime by minimising infrastructure in flow paths and any erosion or changes to access roads across creeks Provide culverts/bridges at crossings to maintain conveyance of low flows.
Maintain natural rates of change in water levels	Minimal – Increases in impervious surfaces from substation, access roads or turbines may have a minor impact on overall rates of change in water levels across the Project area. New hardstand and impervious areas are minor compared to overall catchment areas.	Minimise increases to impervious surfaces or infrastructure in flow paths or close to creeks Provide culverts/bridges at crossings to maintain conveyance of low flows
Manage groundwater for ecosystems	Refer to Surface water quality and groundwater technical report (Jacobs, 2022a)	Refer to Surface water quality and groundwater technical report (Jacobs, 2022a)
Minimise effects of weirs and other structures	Minimal – No weirs will be built as a part of the Project, any changes to access roads across creeks may have a minor impact. Allow for flow conveyance around WTGs where these are located in minor overland flow paths.	Where possible avoid constructing weirs and other structures that may interfere with flow regimes. Provide culverts/bridges at crossings to maintain conveyance of low flows.

6.3.3 Farm dams

There are numerous farm dams in the study area and are mapped with the project infrastructure on **Figure 6-1** to **Figure 6-3**.

Most of the farm dams are not located close to any Project infrastructure and are unlikely to be impacted. **Table 6-2** identifies the seven WTGs within 100 metres of existing farm dams which should be considered for relocation in consultation with landowners due to potential clash with the dams. Drainage swales will be provided around the WTG and other hardstand areas which will maintain inflows to farm dams. The substations and operation and maintenance facility are not in the vicinity of existing farm dams.

Table 6-2 WTGs within 100 metres of existing farm dams

Turbine	Distance and direction to nearest farm dam (metres)
W-140	60 m to north
W-070	70 m to south
W-124	40 m to north-east
W-030	40 m to north
W-016	40 m to south-east
W-109	90 m to south-east
W-106	90 m to south

There are several proposed access tracks and internal cabling routes in close proximity to existing farm dams which would need to be relocated. New tracks will be constructed in such a manner so that inflows to existing farm dams are not diverted away from the dams.

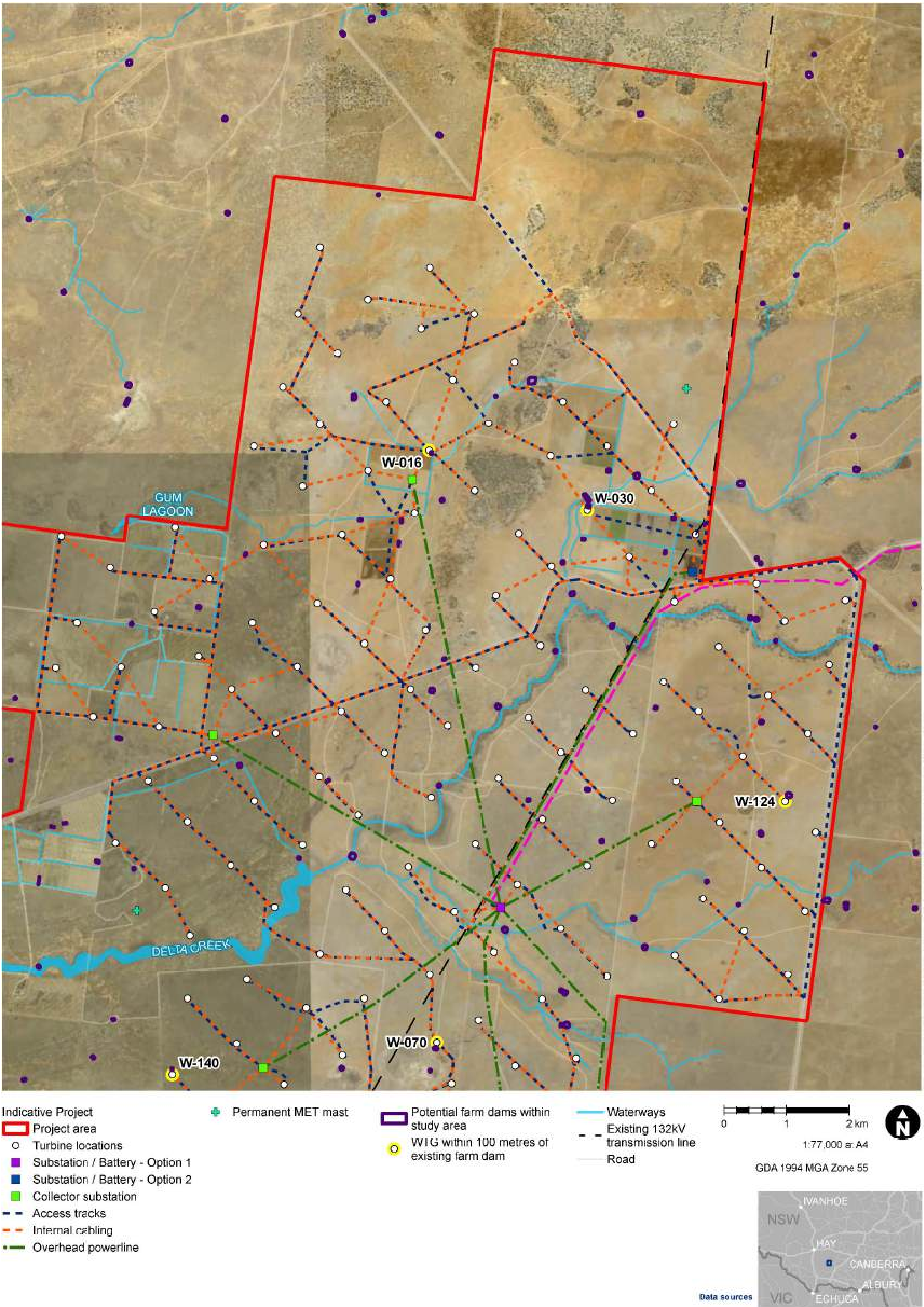

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Figure 6-1 Farm dams close to Project infrastructure (sheet 1)

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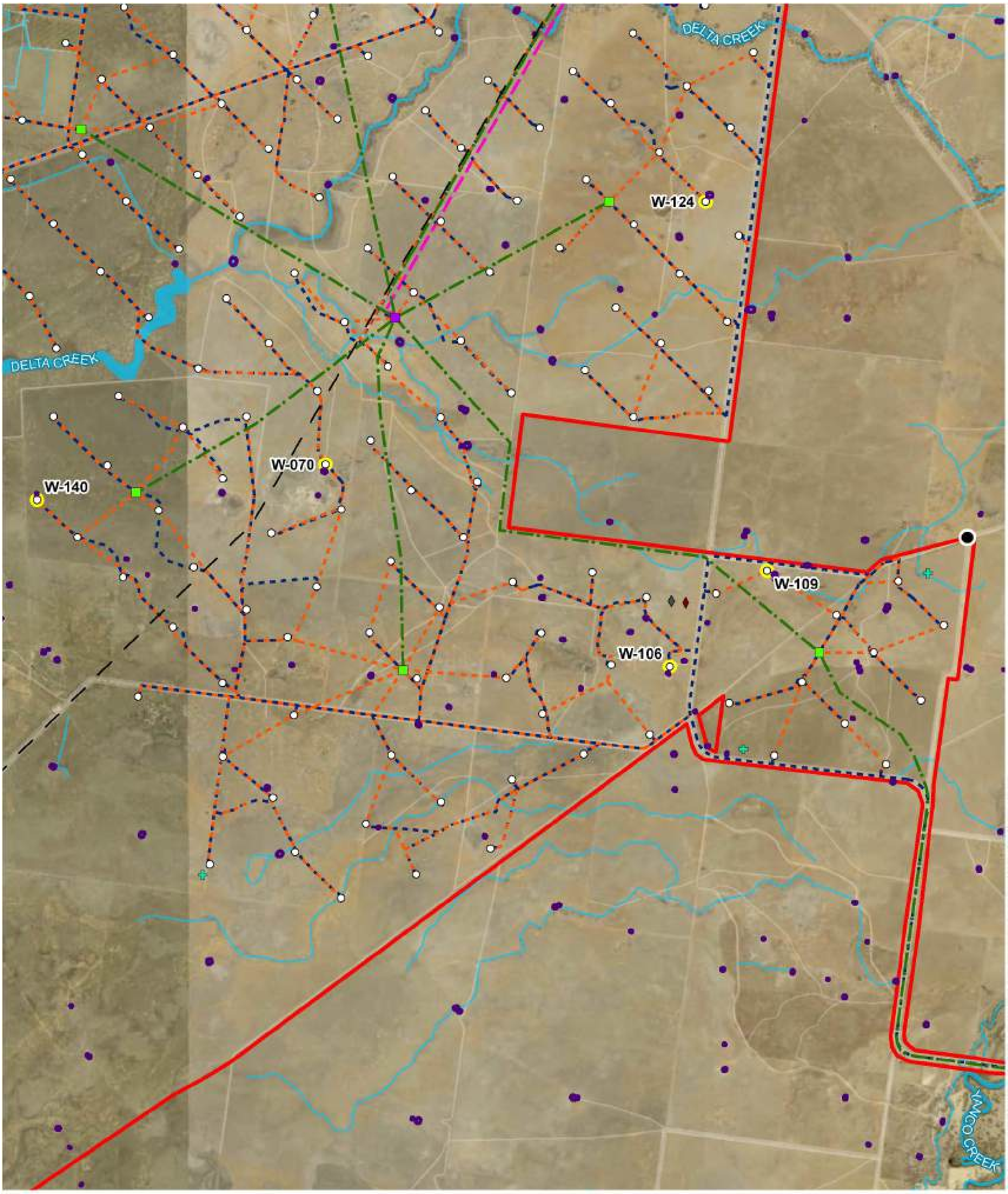

Indicative Project
Project area
Turbine locations
Substation / Battery - Option 1
Collector substation
Access tracks
Internal cabling
Overhead powerline

Permanent MET mast
Site facilities
O&M facility
Site compound

Potential farm dams within study area
WTG within 100 metres of existing farm dam

Site access
Waterways
Existing 132kV transmission line
Road

0 1 2 km
1:77,000 at A4
GDA 1994 MGA Zone 55

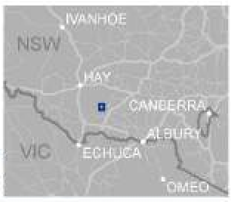

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Figure 6-2 Farm dams close to Project infrastructure (sheet 2)

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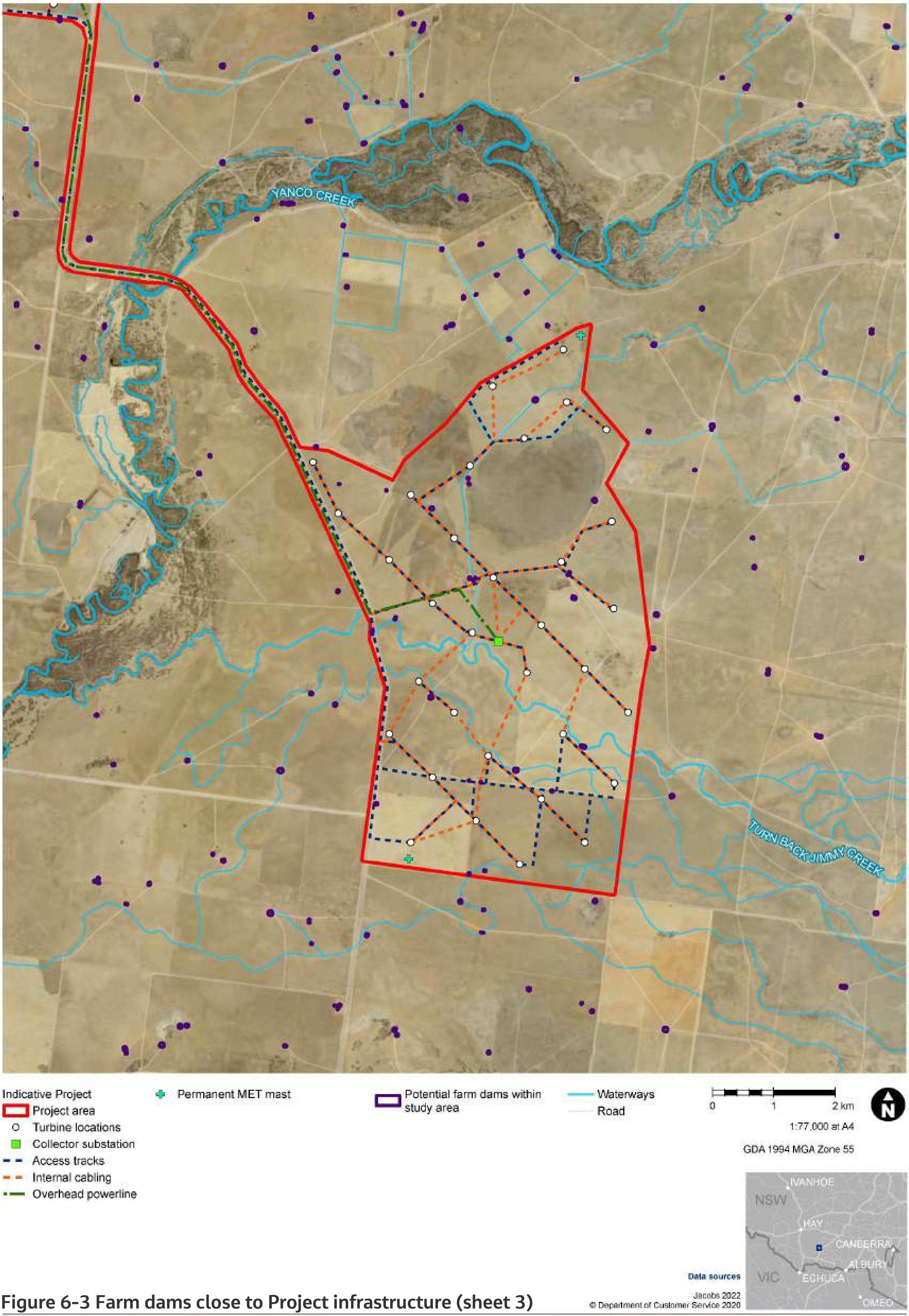

Figure 6-3 Farm dams close to Project infrastructure (sheet 3)

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6.3.4 Surface water resources

The Project would be located downstream of the Coleambally Irrigation Area (about 15 kilometres to the east and north-east of the Project area) and operation would not affect water availability to this scheme.

The Project would not dam any or redirect any ephemeral watercourses or flow paths which may deliver surface water to properties downstream of the Project. Flows would be conveyed around Project infrastructure.

The Project would not dam, redirect, or extract flows in Yanco Creek and hence would not impact on availability of water to licensed water users along Yanco Creek.

7. Potential decommissioning impacts

The decommissioning process for the Project would generally involve the removal of above ground infrastructure, including WTGs, electrical infrastructure and maintenance buildings unless required for the future land use of the Project area. If a future use is identified for any above ground infrastructure associated with the Project, that infrastructure may be retained in agreement with the interested stakeholders. Otherwise, all above ground electrical infrastructure would be removed during the decommissioning phase.

Filled areas and hardstand surfaces would remain in place. Drainage swales around the filled areas will be retained.

Underground infrastructure such as underground cables and footings, would generally remain in situ to avoid further disturbance. Some infrastructure, such as access tracks and laydown areas, may be of benefit to the landowners and may be retained in situ following an agreement with the landowners.

During decommissioning, existing access tracks would generally be used for equipment access and removal of materials from the Project area.

Disturbed areas would be rehabilitated to meet the intended final land use and be comparable with pre-construction conditions in consultation with landowners.

Based on the above, there would be no additional impacts to the operational flooding and hydrology impacts.

8. Cumulative impacts

Cumulative impacts are a result of incremental, sustained and combined effects of human action and natural variations over time and can be both positive and negative. They can be compounded when the potential impacts of a project are combined with past, current, planned, or reasonably anticipated future impacts (DPIE, 2021a). Cumulative impacts can result in a greater extent, magnitude or duration of impacts and may also arise where multiple or consecutive construction for development impact the same receivers.

Cumulative flooding and hydrology impacts could result if there are substantial concurrent impacts predicted for the Project and for other nominated projects and if they are hydraulically linked. That is, the impacts from one project could combined with those of the other due to flood behaviour and runoff patterns and close distance between the projects. If they are at far distances from each other or they affect different flow paths, then cumulative impacts may not be expected. Cumulative impacts could result due to redirection of flows or increased runoff rates and volumes caused by both projects.

The identified projects in **Table 8-1** are in varying stages of delivery and planning. This chapter provides a qualitative assessment of cumulative flooding impacts based on the most current publicly available information on the nominated projects.

Table 8-1 Projects considered in the cumulative impact assessment

Project (approval status)	Brief project description	Potential cumulative impacts on flooding
Micro Solar Farm (Approved)	Construction and operation of a 5MW micro solar farm and associated infrastructure, located within the Coleambally Irrigation Area.	Minimal/Nil cumulative impacts due to minimal hydraulic interaction with the Project. The proposal will potentially result in some localised flood depth and velocity impacts to flow paths surrounding the Coleambally irrigation channels however these flows ultimately remain to the north of the site. Connections with flow paths that connect with Delta Creek and the northern section of the Project area are minor in PMF event.
Woodland BESS (Planning)	Construction and operation of a 200MW / 800MWh BESS located about 10 kilometres south of Darlington Point. This project is located next to the Darlington Point Solar Farm.	Minimal/Nil cumulative impacts. The site is situated just south of the Murrumbidgee River and will have some localised impact on overland flows from the Murrumbidgee River and the Coleambally Canal in both the 1% AEP event and the PMF. However, the overland flows head to the west and are not hydraulically connected to the Project area.
Riverina and Darlington Point BESS (Approved)	Modification to increase the capacity and construct a 200MW / 400 MWh BESS, including ancillary infrastructure, to connect to the existing Transgrid Darlington Point substation.	Minimal/Nil cumulative impacts. The site is situated just south of the Murrumbidgee River and will have some localised impact on overland flows from the Murrumbidgee River and the Coleambally Canal in both the 1% AEP event and the PMF. However, the overland flows head to the west and are not hydraulically connected to the Project area.
Baldon Wind Farm (Planning)	Construction, operation and maintenance of a wind farm with up to 162 WTGs, BESS and associated infrastructure.	Nil cumulative impacts. This proposal is located 120 kilometres to the west of the Project area and on watercourses which are not hydraulically connected to the Project area.
Keri Keri Solar Farm (Planning)	Solar farm with a maximum installed capacity of 500MWp (MW-peak) and an alternating current capacity of up to 400 MWn (MW-nominal). The project will also include ancillary infrastructure.	Nil cumulative impacts. This proposal is located 130 kilometres to the west of the Project area and on watercourses which are not hydraulically connected to the Project area.

Project (approval status)	Brief project description	Potential cumulative impacts on flooding
Keri Keri Wind Farm (Planning)	Construction, operation and maintenance of a wind farm with up to 176 WTGs, BESS (up to 200 MW/800 MWh) and associated infrastructure.	Nil cumulative impacts. This proposal is located 130 kilometres to the west of the Project area and on watercourses which are not hydraulically connected to the Project area.
Project EnergyConnect (Eastern) (Approved)	Construction and operation of a high voltage interconnector between NSW and SA. The transmission project's eastern section includes new transmission lines between Wagga Wagga and Buronga, with a new Dinawan Terminal Station to be located next to Kidman Way about 55 kilometres south of Darlington Point.	The operational features would consist of transmission line towers in the floodplain and the supported transmission line. The towers would be spaced on average around every 450 to 600 metres with a footing area of up to 64 by 64 metres. The footings would not significantly reduce floodplain storage or impede flow and hence there would be insignificant or localised impacts to flood behaviour. Permanent access tracks and optical repeater structures will have minimal impact to overland flow paths as they will be designed to mimic the undulating nature of the existing surface The Dinawan 330kV substation is not located within flood prone land and are therefore no impacts to or from flooding are anticipated. The site drainage at the proposed Dinawan 330kV substation would be designed to match on site overland flow conditions. The flooding and hydrologic impacts from the development would be negligible, and hence when combined with the negligible to minor impacts from the Project, the cumulative impacts are expected to be negligible to minor.
Coleambally BESS (Planning)	Construction and operation of a 100MW / 200-400 MWh BESS including ancillary infrastructure in Coleambally, NSW. The BESS footprint would be about four hectares and is located near Kidman Way with proposed transmission connection to the Transgrid Coleambally substation.	Minimal/Nil – In both the 1% AEP event and the PMF the irrigation channels around Coleambally have moderate flows and there could be potentially some localised changes in flood depths and velocities due to the BESS however these flows head west and remain to the north of the Project area and as such would be unlikely to contribute to any cumulative Impact.
Bullawah Wind Farm (Announced)	Construction, operation and maintenance of a wind farm with up to 170 WTGs (up to 300m tip height), BESS and associated infrastructure. The project will have a capacity of 1000MW.	Nil cumulative impacts. This proposal is located 17 kilometres to the north-west of the Project area and on watercourses which are not hydraulically connected to the Project area

Project (approval status)	Brief project description	Potential cumulative impacts on flooding
Dinawan Energy Hub (Announced)	Construction and operation of a hybrid wind, solar and battery storage project, with capacity up to 2.5GW, to be located between Coleambally and Jerilderie, west of the Kidman Way. The energy hub would connect to Project EnergyConnect.	The Dinawan Energy Hub proposal is located in the vicinity of the Project. As such, there is the possibility of common receivers in relation to flooding and hydrology. However, as the details of the proposal have not yet been finalised, the level of impact to flooding and hydrology resulting from this proposal is currently unknown. Consequently, cumulative impacts associated with the construction or operation of the project is unknown.
Victoria to NSW Interconnector West (VNI West) (Announced)	A new interconnector between Victoria and NSW including a series of high voltage transmission lines and terminal stations that links the regions of Murray River, Western Victoria, South West NSW. The WNI West transmission route is indicated to link the Dinawan Terminal Station to Kerang, Bendigo and Ballarat, where the Western Victoria Transmission Network Project would be constructed. The transmission route is not yet finalised.	The transmission route for the Victoria to NSW Interconnector West is located in the vicinity of the Project. As such, there is the possibility of common downstream receivers. However, as the transmission route has not yet been finalised, the level of impact to flooding and hydrology resulting from this proposal is currently unknown. Consequently, cumulative impacts associated with the construction or operation of the project is unknown.

9. Environmental management measures

The following management measures detailed in **Table 9-1** have been developed to specifically manage potential flooding and hydrology impacts which have been predicted during construction, operation and decommissioning of the Project.

Table 9-1 Flooding and hydrology environmental management measures

Impact	Reference	Environmental management measure	Timing
Impacts on mainstream and overland flooding	F1	During detailed design, the Project will be further refined with the following considerations to minimise impacts to flooding where possible, including: • Minimising filling of WTGs, BESS and substations sites • Minimising encroachment of Project infrastructure into the 1% AEP flood extent • Design to manage flood impacts and flow conveyance at watercourse crossings • Power poles for the proposed transmission line will be located away from flow paths where possible.	Detailed design
	F2	If upgrade of Wilson Road bridge crossing of Yanco Creek is required, design considerations to minimise hydraulic impacts including increases in flood levels will be made during detailed design.	Detailed design
Geomorphic impacts and scouring during flood and storm events	F3	During detailed design, the Project will be further refined with considerations to minimise erosion, scouring and geomorphic impacts where possible, including: • Permanent operational infrastructure and landforms will be designed and implemented/formed to minimise any potential scour and erosion risks associated with surface water runoff • Appropriate scour protection will be provided at flow discharge areas, hydraulic structures and other identified at-risk locations.	Detailed design
Impacts on the Project area resulting from flooding	F4	The Project design will provide filling for any necessary infrastructure to above the PMF level for the central primary substation/BESS and collector substations.	Detailed design
Farm dams and surface water resources	F5	During detailed design, the Project will be further refined with the following considerations to minimise impacts to surface water resources where possible: • Minimising changes to runoff and natural flow regime by minimising infrastructure in flow paths. • Constructing Project facilities, hardstand areas and access tracks in such a manner to reduction of inflows to farm dams and surface water resources • Provision of culverts/bridges at road crossings to maintain conveyance of low flows.	Detailed design
	F6	Potential impacts to flow paths associated with Project infrastructure in proximity to existing farm dams will be	Detailed design

Impact	Reference	Environmental management measure	Timing
		discussed and management measures (such as diversions) will be confirmed in consultation with landowners to avoid impacts to farm dams inflows. During detailed design, the Project will be further refined to relocate several access tracks and cabling routes where possible to avoid clashes with existing farm dams.	
Flood and surface water quantity impacts from temporary construction work and facilities	F7	Material stockpiles and construction facilities will be located outside the 1% AEP flood extent.	Construction
	F8	Temporary access tracks will be constructed in such a manner to maintain existing drainage conditions and flow paths.	Construction
	F9	Drainage swales and channels will be installed to convey runoff and flows around construction areas and gravel pits.	Construction

10. Conclusion

This assessment has been conducted to assess any potential flooding impact from Project. The assessment has considered the available flooding studies, policies, and guidelines and flood modelling has been developed to define existing case flooding conditions for the 1% AEP event and the PMF.

Review of existing flood conditions in and around the Project area indicated that the Project area is partially inundated in both the 1% AEP event and PMF event. There are areas with higher flood depths, velocities and hazard levels in the areas surrounding Delta Creek and Turn Back Jimmy Creek in the northern and southern sections of the Project area respectively. Ponding and minor overland flow paths are also seen throughout other areas of the Project area.

An assessment of impacts of the Project on flooding was undertaken based on qualitative assessment. Construction, operational and decommissioning impacts have been considered. Potential impacts include minor and localised impacts on flood depths, levels and velocities around certain WTGs and substations due partial obstruction of flow and loss of floodplain storage. There are generally not expected to be any significant impacts on the flood behaviour as obstruction of flood flows and loss of storage would generally be minor. Access road crossings of ephemeral watercourses may be raised above existing road levels and above the watercourse bed which could result in increases in flood levels upstream of the crossings.

Impacts to hydrology and surface flow regimes in main watercourses would be negligible as increases in impervious areas would be negligible compared to watercourse catchment areas. There is no significant expected flood impact on nearby dwellings as most are not flood-affected or are unlikely to be affected by the localised minor increases in flooding resulting from the Project.

There would be a minor risk of localised erosion and scouring of ground surfaces at drainage discharge areas and at the toe of hardstand fill areas during flood events.

Temporary construction facilities and material stockpile areas during construction will be placed away from drainage lines and waterways (outside of the 1% AEP flood extent) and are unlikely to result in impacts to flooding. There is the potential for impacts to flow behaviour if gravel borrow pits are situated in flow paths, including ephemeral creeks, as they may capture or redirect flows if appropriate management measures are not in place.

Relocation of seven WTGs and several access tracks and cabling routes are proposed for consideration in consultation with landowners, in order to reduce exposure to flood flows, reduce potential flood impacts and avoid clash with farm dams and dam inflows.

Cumulative impacts of selected nearby developments were also considered. While there may be some minor localised impacts of overland flow paths upstream of the Project area there is not expected to be any cumulative impacts on the Project due to the large scale of the area and the minor hydraulic significance of the flow paths impacted.

A range of mitigation and management measures have been identified to manage the potential impacts to flooding and hydrology from the Project. Management measures include design considerations to minimise flooding impacts, hydrology, surface flow regimes and erosion/scour risks, raising substation sites to provide adequate flood immunity, potential relocation of selected elements of the Project, monitoring of impacts such as scouring and implementation of appropriate remedial works if necessary.

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Appendix A. Flood modelling development and assessment

A.1 Hydraulic Modelling

This assessment involves numerical modelling of hydraulics using hydrological inputs from existing flood modelling, the details and methods will be provided in this appendix. This modelling defined the existing case flood behaviour in both the 1% AEP event and the PMF as well as examining the floods depths, velocities, and hazards.

A.1.1 Model Configuration

The model was developed with a two-dimensional set up in TUFLOW. One-dimensional features were also included to represent hydraulic structures such as weirs and culverts.

The Murrumbidgee River, 50 kilometres to the north of the Project area, is the main waterway in the region and as such has the potential to overflow during major flood events, potentially contributing to floodplain flows at the Project area. The Murrumbidgee River also includes river offtakes and contributes to flows into Yanco Creek which crosses the Project area from the east. Offtake flows also contribute to flows in Coleambally Canal, which may contribute to floodplain flows at the Project area.

Billabong creek approaches the Project area from the South-East and may contribute to overland flows into the Project area in large flood events.

Given the potential contributions and influences on flood flows at the Project area, these watercourses were represented in the TUFLOW model.

A.1.2 Extent and Terrain

The model covers a large area as shown in **Figure A-1**. An area of 16,302 square kilometres was modelled due to the flatness of the terrain and the associated interconnectivity of the floodplain in large flood events. This is relevant in overland flow paths connecting the Murrumbidgee River and the Project area.

A five-metre digital elevation model (DEM) was used for the terrain data, the DEM was constructed using the triangular irregular network method of averaging ground heights. The terrain data was sourced from the *Intergovernmental Committee on Surveying and Mapping* where it was provided by the *NSW Government – Spatial Services*.

A grid size of 100 square metres was taken for the modelled area however a quadtree mesh of 25 square metres was used along waterways, in the Project area and in areas of hydraulic importance. The quadtree mesh can be seen in **Figure A-1.** Insets for the model are shown in **Figure A-2** to **Figure A-5**.

Site contours for the Project area are shown in **Figure A-6** to **Figure A-9**.

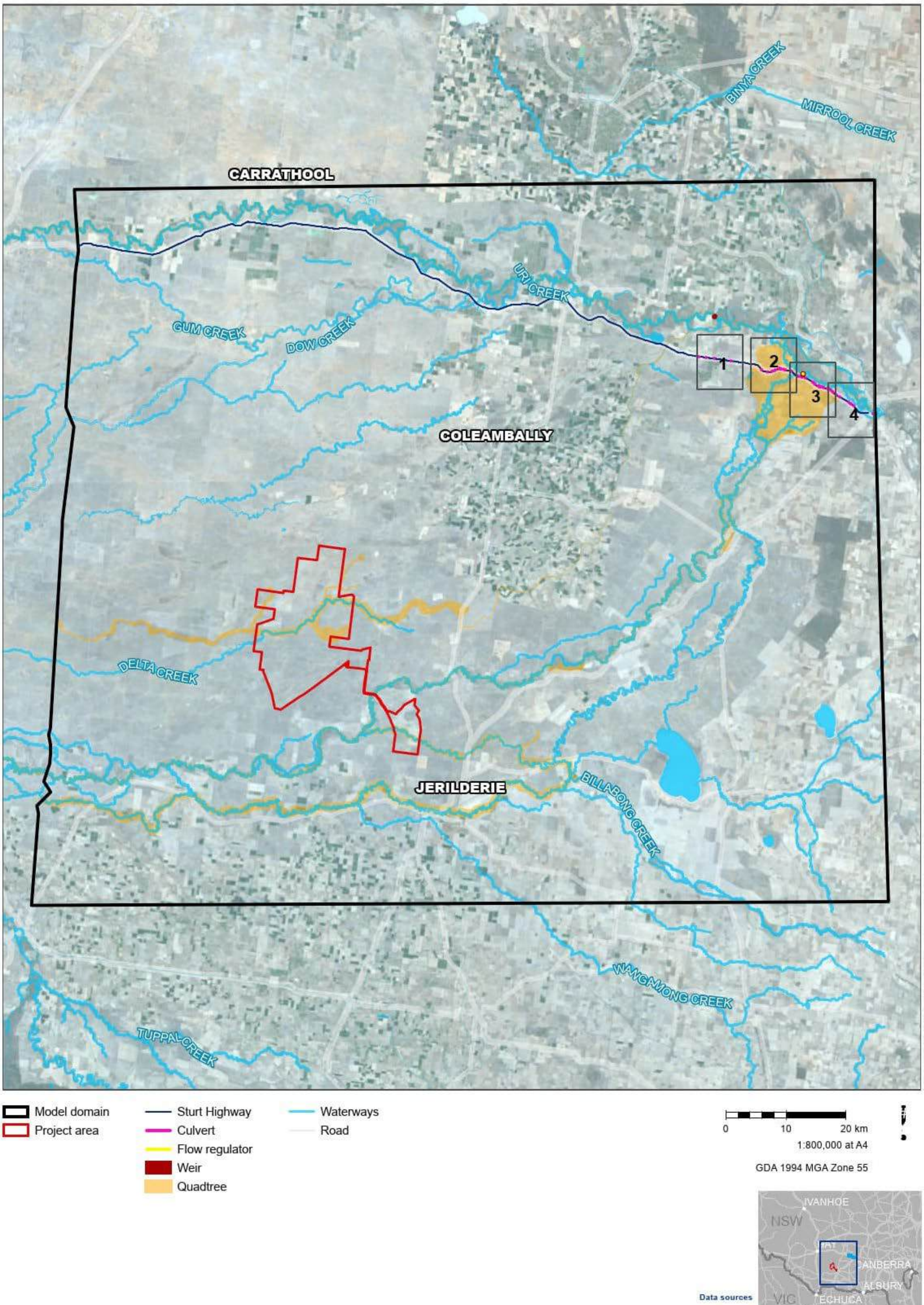


Figure A-1 Model layout overview

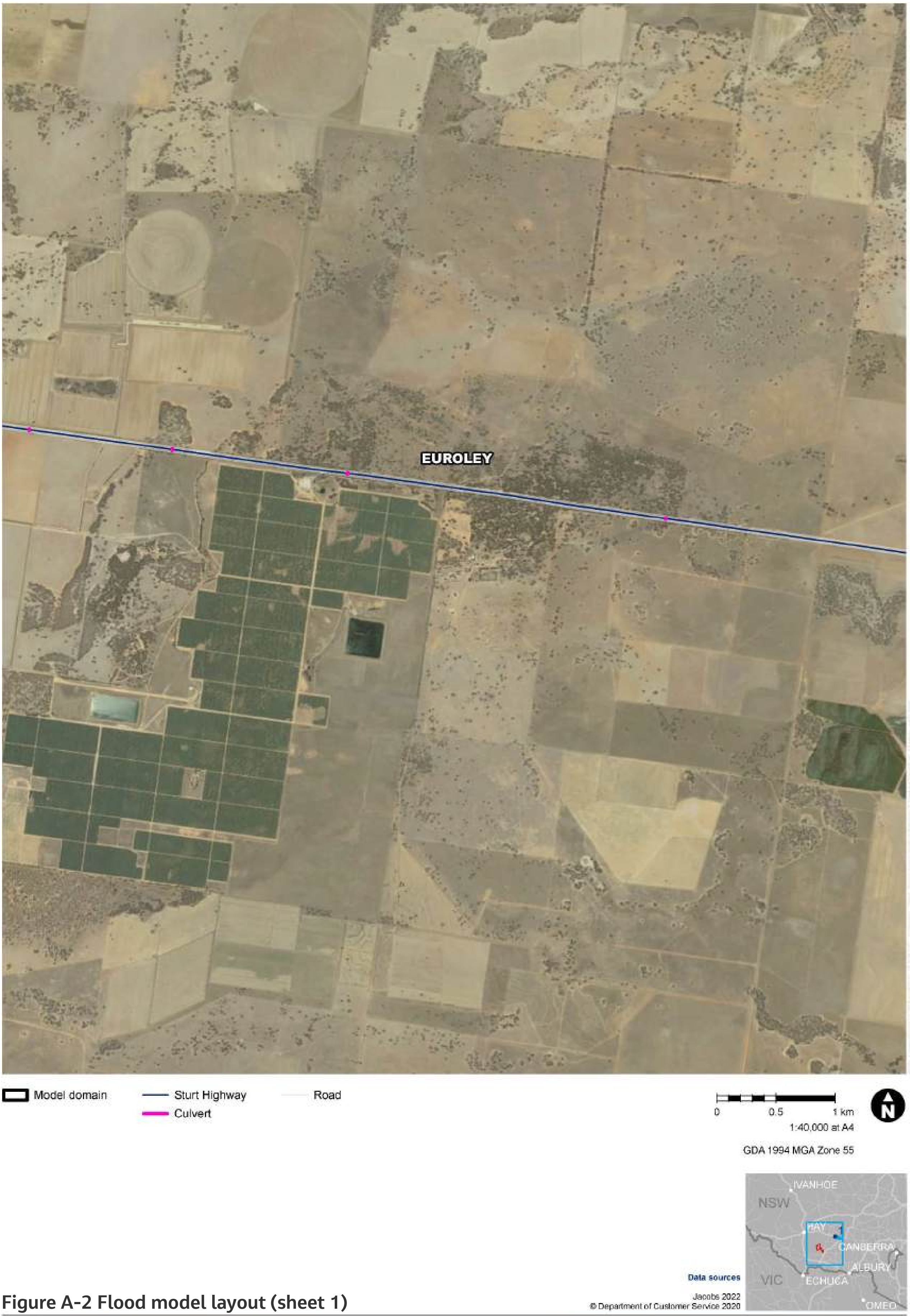
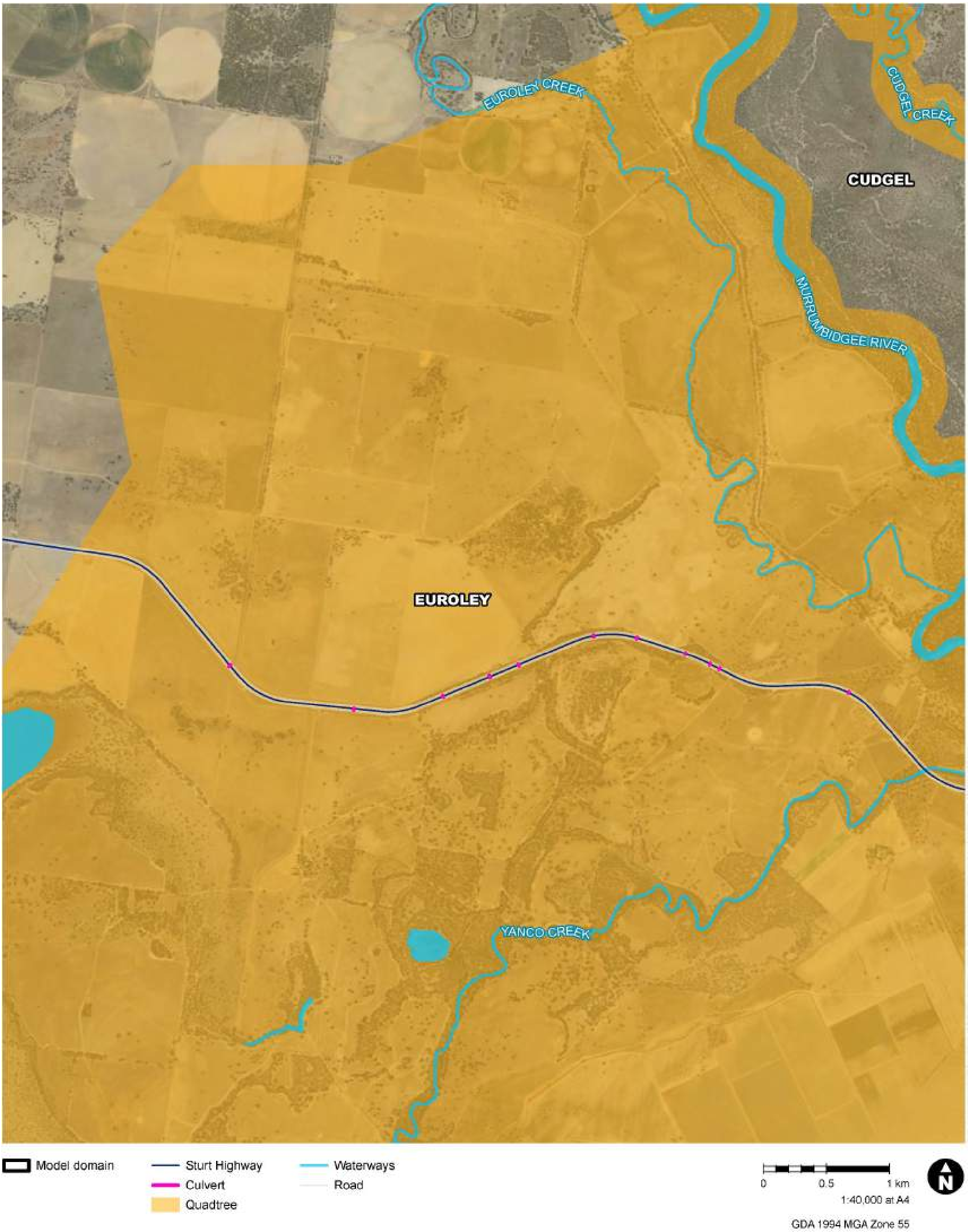
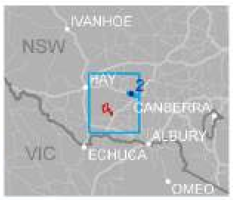


Figure A-2 Flood model layout (sheet 1)





Data sources

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Figure A-3 Flood model layout (sheet 2)

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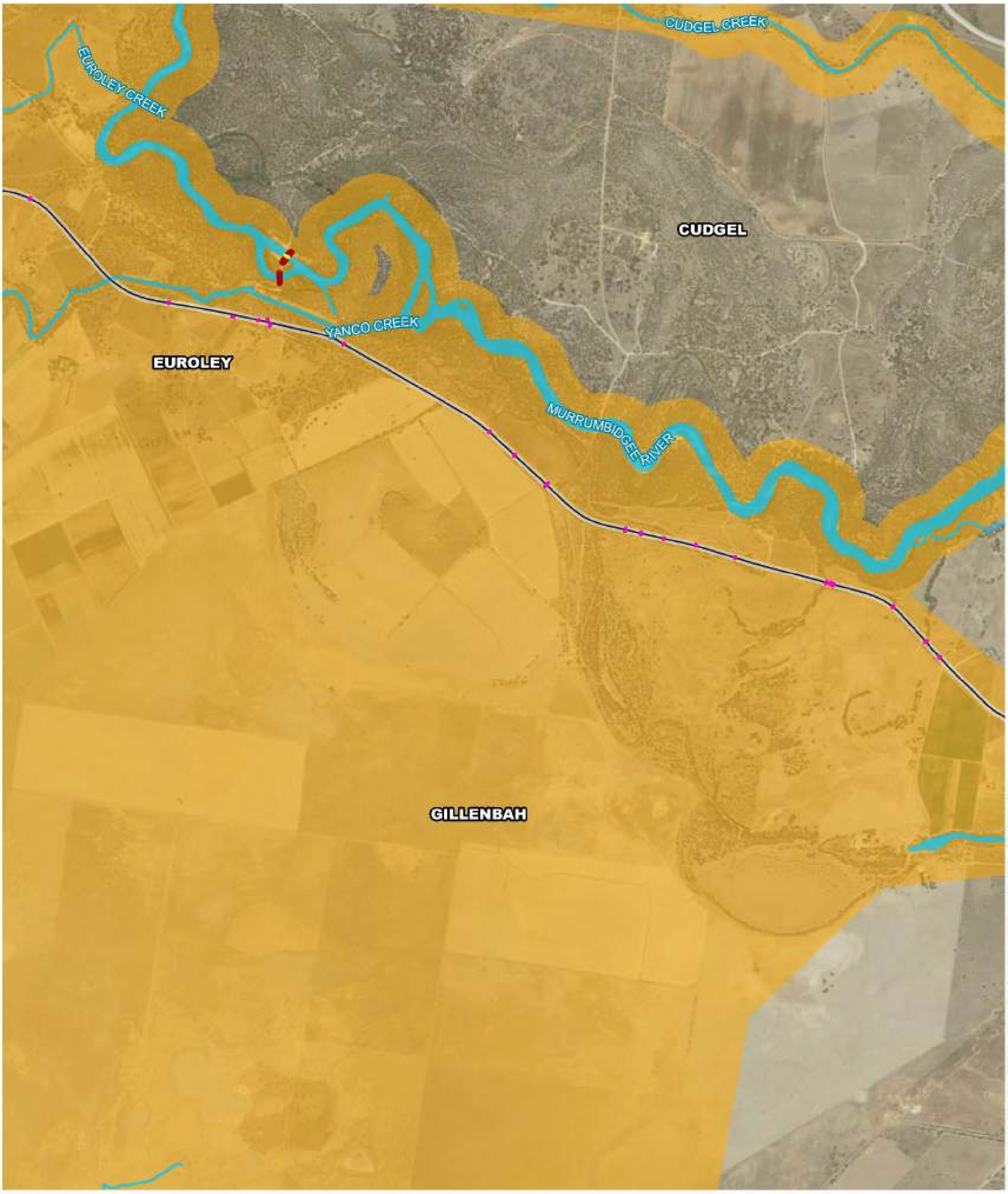
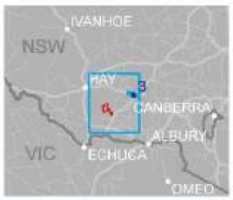


Model domain
Sturt Highway
Culvert
Flow regulator
Weir
Quadtree
Waterways
Road

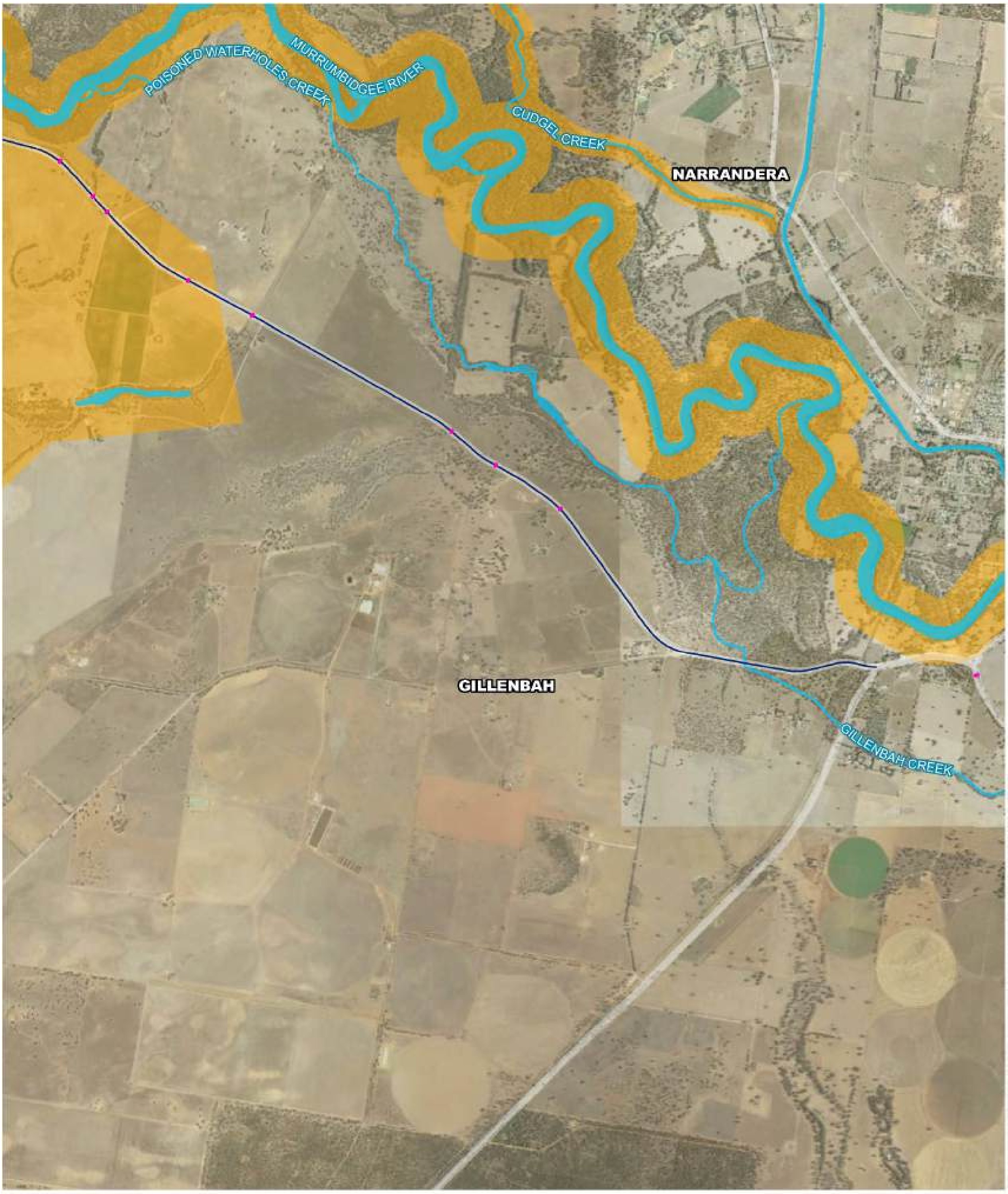
0 0.5 1 km
1:40,000 at A4
GDA 1994 MGA Zone 55



Data sources
Jacobs 2022
© Department of Customer Service 2020

Figure A-4 Flood model layout (sheet 3)

Jacobs NSW Spatial | Buildings & Infrastructure | Eastern Asia Pacific | www.jacobs.com



Model domain
Sturt Highway
Culvert
Quadtree
Waterways
Road

0 0.5 1 km
1:40,000 at A4
GDA 1994 MGA Zone 55

IVANHOE
NSW
HAY
CANBERRA
ALBURY
VIC
ECHUCA
OMEO

Data sources
Jacobs 2022
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Figure A-5 Flood model layout (sheet 4)

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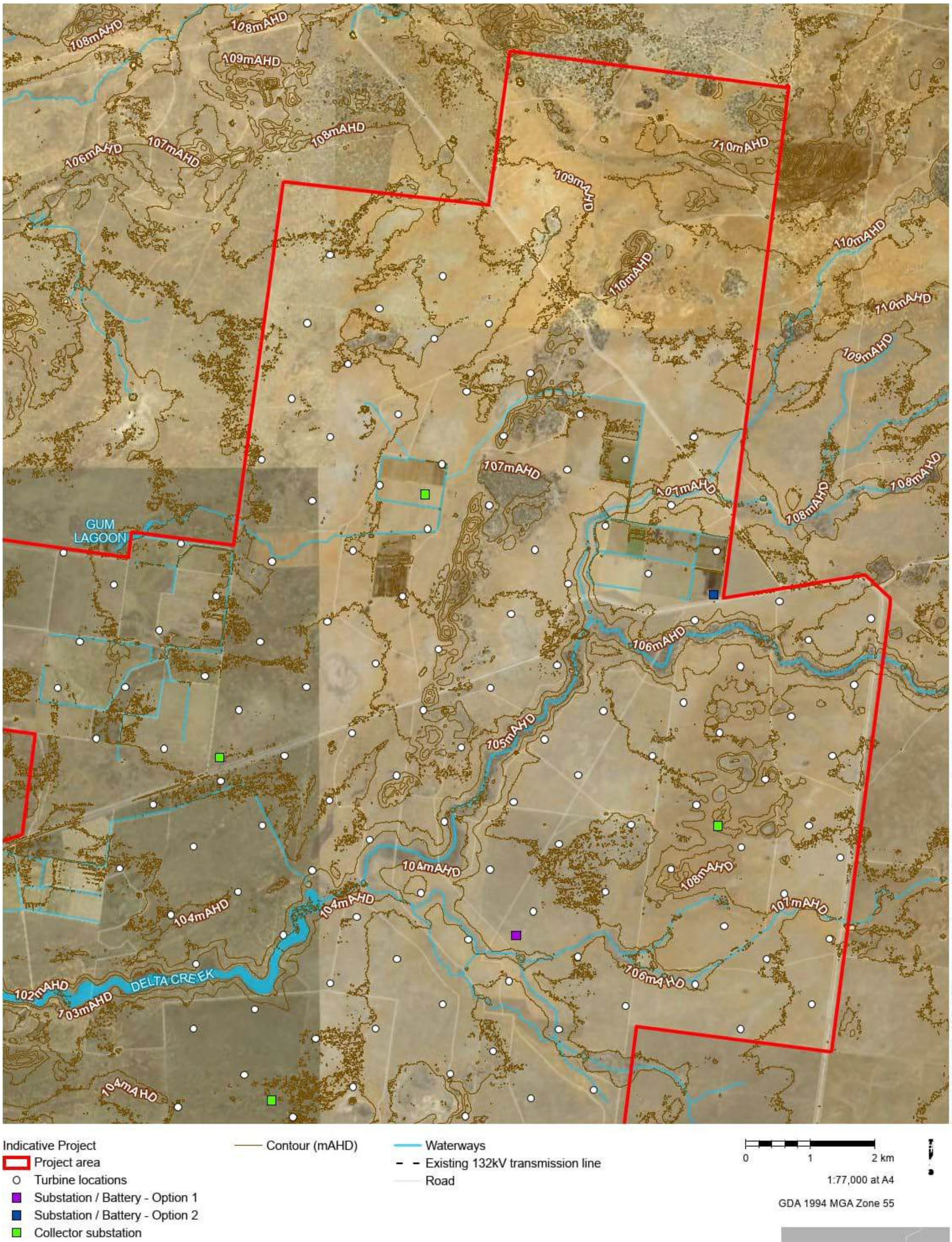

Figure A-6 Site contours (sheet 1)

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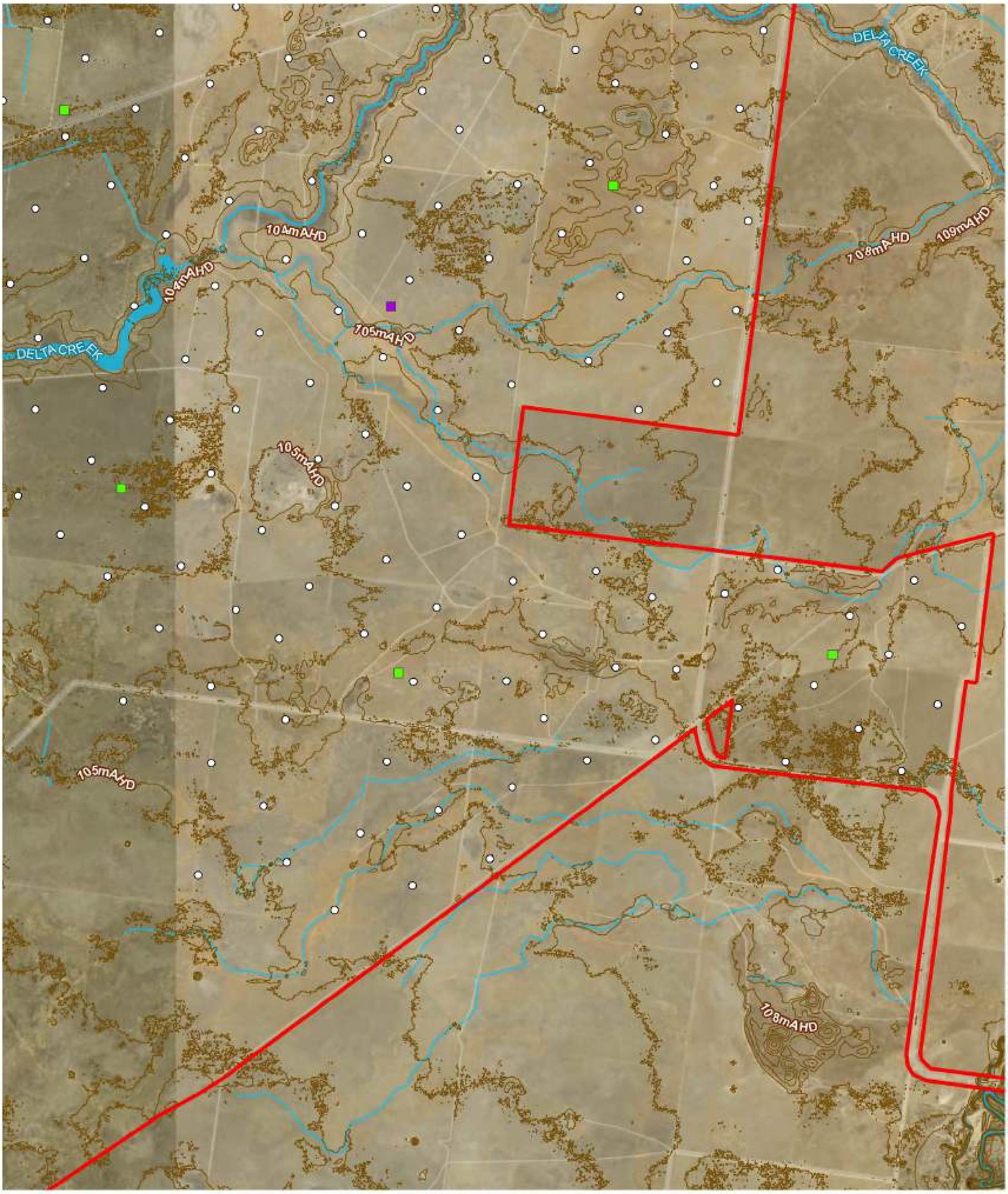
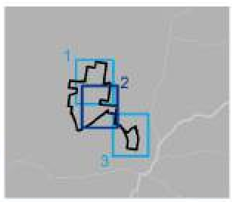


Indicative Project
Project area
Turbine locations
Substation / Battery - Option 1
Collector substation

Contour (mAHD)

Waterways
Existing 132kV transmission line
Road

0 1 2 km
1:74,000 at A4
GDA 1994 MGA Zone 55



Data sources
Jacobs 2022

Figure A-7 Site contours (sheet 2)

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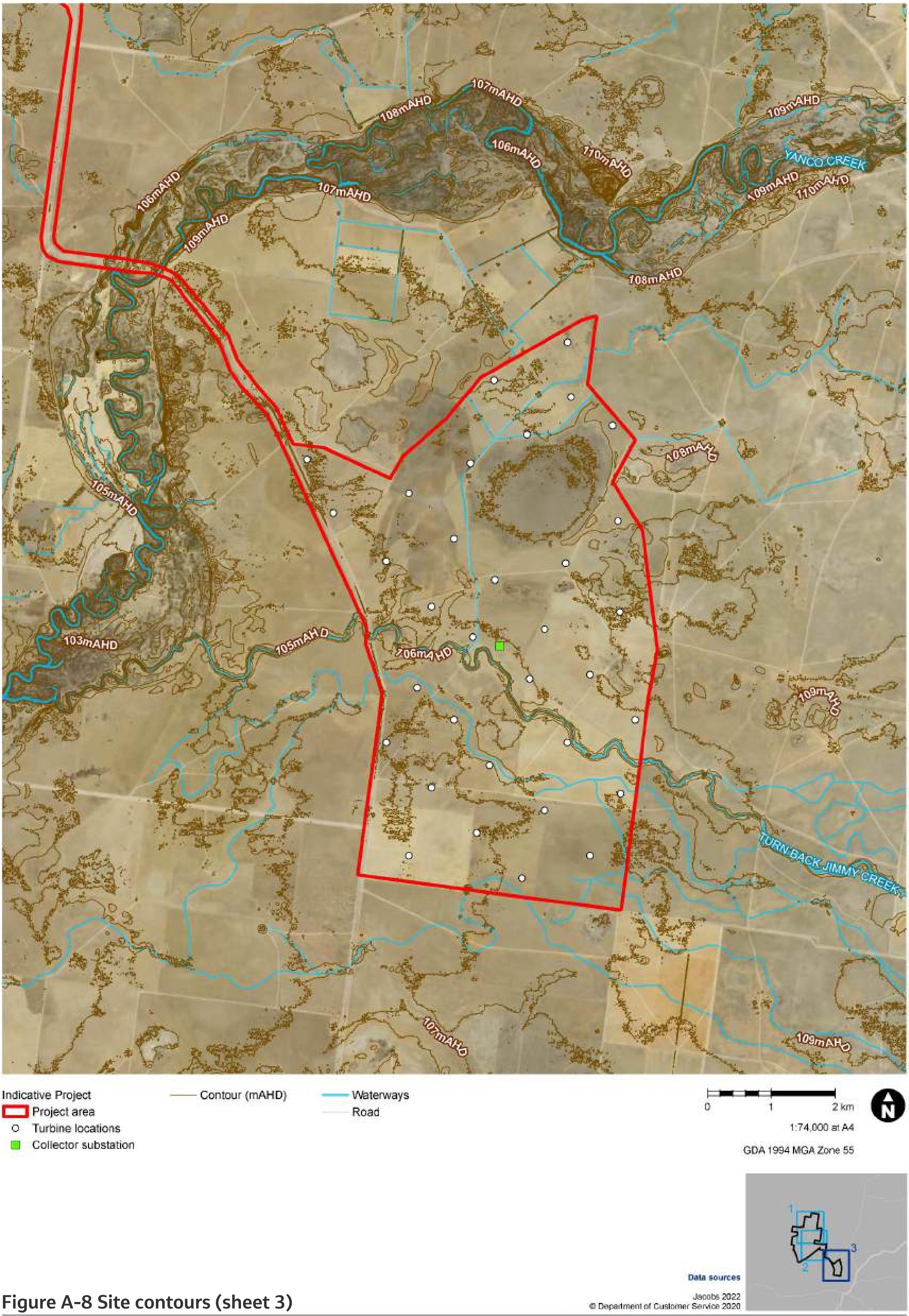

Figure A-8 Site contours (sheet 3)

A.1.3 River inflow boundaries

Inflows were input for the Murrumbidgee River at Narrandera as well as at Billabong Creek upstream of Jerilderie. Inflow data was sourced from TUFLOW modelling from the following studies:

- Murrumbidgee River inflow at Narrandera: *Review of the Narrandera Floodplain Risk Management Study and Plan* (Lyall and Associates, 2019)
- Billabong Creek upstream of Jerilderie: *Flood Study Report for Rand* (Jacobs, 2017b).

Table A-1 summarises the peak inflows for the 5%, 1% AEP and PMF events for the Murrumbidgee River and Billabong Creek model inflow boundaries.

Table A-1 Peak flows for inflow boundaries

	Peak Flows (m^3/s)		
Inflow Boundary	**PMF**	**1% AEP**	**5% AEP**
Murrumbidgee River	10342.1	3106.6	1552.8
Billabong Creek	265.2	135.6	134.1

A.1.4 Downstream Boundaries

Downstream boundaries were defined on the Murrumbidgee River, Delta Creek, Coleambally Creek, Forest Creek, Billabong Creek, Sheepwash Creek and Browns Creek as a normal slope boundary with the slope based on the terrain slope.

A.1.5 Local Catchment Inflows

Inflows from rainfall-runoff on the local catchment areas within the model domain were defined based on a rain-on-grid boundary across the entire model domain. This approach was adopted given the flat terrain and poorly defined drainage catchment boundaries, which make it difficult to develop a conventional node-link hydrologic model.

Design rainfall used for the rainfall boundaries for the 1% AEP event was downloaded from The Bureau of Meteorology Design Rainfall for Coleambally (Bureau of Meteorology 2016), which is roughly in the middle of the model domain and 33 kilometres north-east of the Project area. Probable maximum precipitation depths were derived based on *The Estimation of Probable Precipitation in Australia: Generalised Short-Duration Method (BoM, 2003)* and *Guide to the Estimation of Probable Maximum Precipitation: Generalised South-East Australian Method (GSAM)* (BOM, 2006).

The TUFLOW model was run for the 1% AEP event for a range of design storm durations from five days up to seven days to identify the critical storm duration for local catchment flooding at the Project area. The six-day duration event was adopted as the critical storm duration for the design flood event simulation.

Rainfall losses were referenced from the Australian Rainfall and Runoff Data Hub (Ball et al 2019). These are summarised in **Table A-2**.

Table A-2 Rainfall losses

	Up to 1% AEP event	PMF
Initial loss (mm)	19	0
Continuing loss (mm/hr)	0	0

A.1.6 Hydraulic Roughness

Different parameters were adopted to define the hydraulic roughness of different land types present in the model domain. These values can be seen in **Table A-3** and are consistent with guidelines in ARR 2019. The hydraulic roughness areas are mapped on **Figure A-9.**

Detailed categorisation of material roughness was prioritised along the various waterways due to their hydraulic importance as well as their greater diversity of landscapes. The remainder of the model domain not categorised in and was by default set as grass/farmland.

Table A-3 Adopted Manning's n values

Land Use Type	Manning’s n value
Water	0.05
Thin Trees	0.06
Thick Trees	0.08
Dense Wetland	0.08
Urban Areas	0.06
Grass/Farmland	0.05

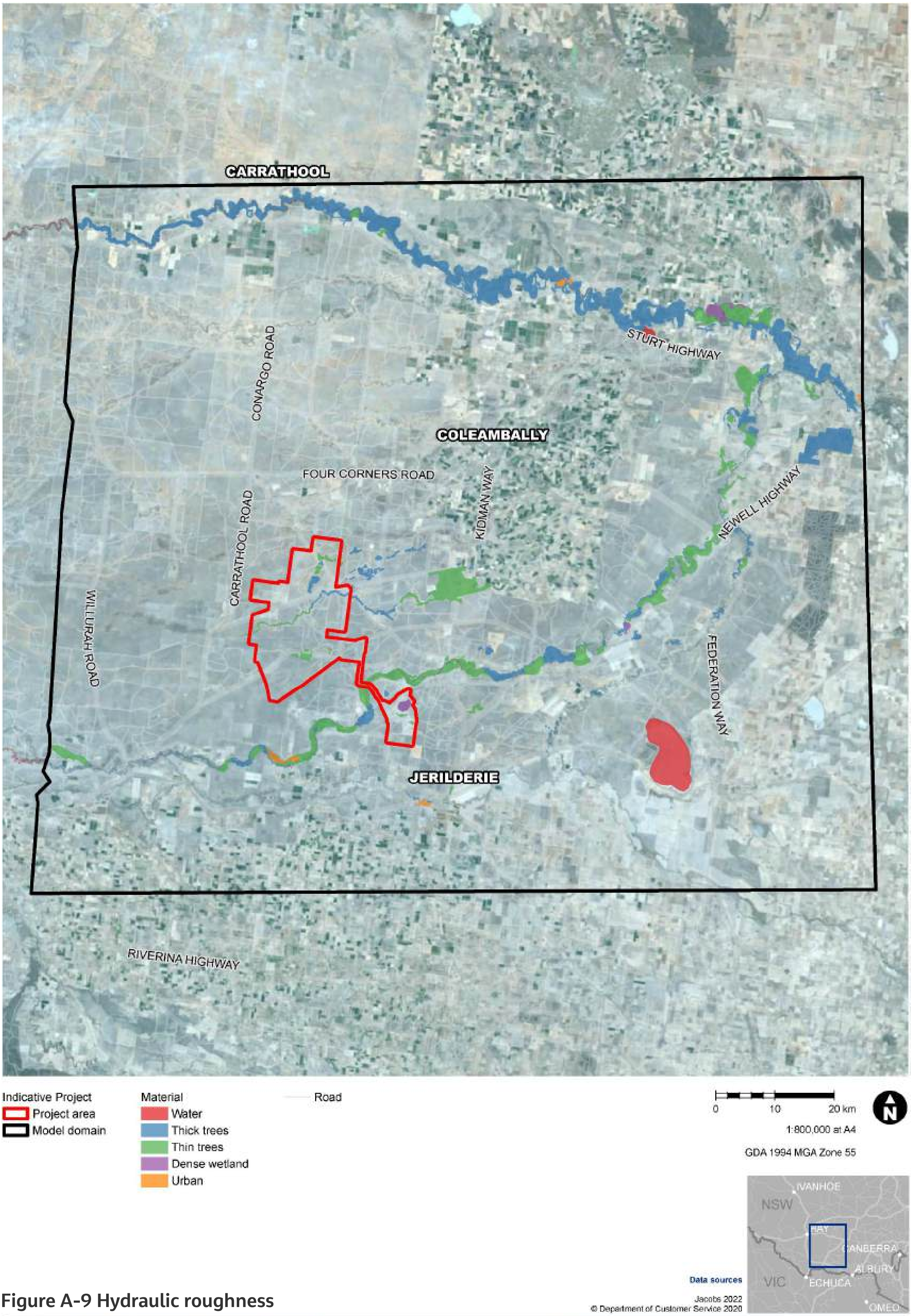

Figure A-9 Hydraulic roughness

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A.1.7 Hydraulic Structures

The Yanco Regulator is a major hydraulic structure located on the Murrumbidgee River which controls offtake flows in the Yanco Creek. Details of sill elevations, structure dimensions etc were sourced from *Improved Flow Management Works at the Murrumbidgee Rivers - Yanco Creek Offtake* (Department of Primary Industries, 2015). Yanco south weir on the Murrumbidgee River was defined as a 2D breakline based on LiDAR elevation.

The Stuart Highway runs east-west to the south of the Murrumbidgee River. It is constructed on a raised embankment and acts as control on overflows from the Murrumbidgee River. The road embankment was modelled as a 2d breakline based on LiDAR elevations and transverse culverts crossing the highway were obtained from the TUFLOW model for the *Review of the Narrandera Floodplain Risk Management Study and Plan* (Lyall and Associates, 2019).

The hydraulic structures are shown on **Figure A-1** to **Figure A-5.**

A.2 Model Validation

A.2.1 Main Watercourse Flooding

The TUFLOW model was run for the historic September 1974 flood event, which was approximately equivalent to the design 1% AEP flood event on the Murrumbidgee River at Narrandera (Lyall and Associates, 2019) in terms of peak flows. Model inflows for this event were defined based on recorded streamflow data at the Murrumbidgee Narrandera gauge (410005) and the Billabong Walbundrie gauge (410091).

There are no suitable streamflow gauge data on Yanco Creek to validate the TUFLOW model for the 1974 event. Hence, the modelled flood behaviour was compared to flood extent mapping for the 1974 event contained in *Murrumbidgee Valley Flood Plain Atlas – Yanco, Colombo & Billabong Creeks* (Sinclair Knight and Partners, 1987). The TUFLOW model flood behaviour and extents agreed with the mapped flood extents for the main watercourses in the floodplain atlas.

A.2.2 Local Catchment Flooding

The modelled flows derived from the rain-on-grid boundary were compared to the ARR2019 Regional Flood Frequency Estimate (Ball et al 2019) for Delta Creek at the upstream (eastern) boundary of the Project area. The assessment is summarised in **Table A-4** below.

Table A-4 Local catchment runoff validation to RFFE

Parameter	Value
Delta Creek catchment area	320 km^2
RFFE 1% AEP flow estimate	148 m^3/s
RFFE 5% confidence limit	44.2 m^3/s
RFFE 95% confidence limit	507 m^3/s
TUFLOW 1% AEP estimate	66 m^3/s

The results show that the TUFLOW model results for peak flows in Delta Creek are within the confidence limits of the RFFE, albeit at the lower range of the confidence limits. This is attributed to the flat terrain and low degree of flow continuity in Delta Creek, with a poorly defined channel in many sections of this ephemeral watercourse. The RFFE is based on streamflow gauging data on watercourses which are typically well-defined and hydraulically more efficient, resulting in the flow estimates being higher than that estimated in TUFLOW for Delta Creek. Overall, the validation to RFFE was considered satisfactory.

A.3 Design Flood Simulation

A.3.1 Flood Events Analysed

Flooding in the model domain may be caused by a combination of flooding originating from the Murrumbidgee River catchment, Billabong Creek catchment and from local catchment flooding. The coinciding flood scenarios in each waterway simulated for the 1% AEP and the PMF events are summarised in **Table A-5**. The large extent of each of these catchments means that during flood events it is unlikely that a similar magnitude flood would occur at the same time in each waterway. Hence, for example, the probable maximum flood in one waterway was coincided with the 1% AEP event in the other waterway, and vice versa.

Each flood combination scenario was run separately, and a maximum flood envelope derived for each AEP from the modelling results of the simulations.

Table A-5 Adopted combinations of coincident flood events

Design Flood Envelope AEP	Dominant Flood	Flood Event AEP Flows			
		Murrumbidgee River	Billabong Creek	Delta Creek	Turn Back Jimmy Creek
1%	Murrumbidgee River	1%	5%	Nil	Nil
	Billabong Creek	5%	1%	Nil	Nil
	Delta Creek	Nil	Nil	1% AEP Global Rainfall	1% AEP Global Rainfall
	Turn Back Jimmy Creek	Nil	Nil	1% AEP Global Rainfall	1% AEP Global Rainfall
Probable Maximum Flood	Murrumbidgee River	PMF	1%	1%	1%
	Billabong Creek	1%	PMF	1%	1%
	Delta Creek	1%	1%	PMP 2hr and 6hr	1% AEP Global Rainfall
	Turn Back Jimmy Creek	1%	1%	1% AEP Global Rainfall	PMP 2hr and 6hr

A.4 Description of Existing Flood Behaviour

A.4.1 1% AEP Event

A significant portion of the 1% AEP flood flow in the Murrumbidgee River is diverted down Yanco Creek at the junction which continues down to the access road and bridge separating the northern and southern extents of the Project area. Whilst there is significant flooding on the floodplain directly adjacent to Yanco Creek it largely doesn't extend into the northern or southern sections of the Project area. There Is also a significant diversion of flow at the Coleambally Canal and subsequent overland flows to the south some of which continue south and merge with Yanco Creek or turn west and feed into Delta Creek. The overland flows into Delta Creek directly impact and flow through the northern extent of the Project area. Like the PMF event the Stuart highway forms a natural breakline in the flooding extent along the Murrumbidgee River, the most significant overflow of the highway is at the Coleambally Canal, overall, there are less flows over the highway in the 1% AEP event in comparison to the PMF event.

There are minimal flows from Billabong Creek impacting the Project area in the 1% AEP event, the majority of the flow merges into Colombo Creek after its junction with Turn Back Jimmy Creek and heads west without any significant subsequent overland flows. Despite this Turn Back Jimmy Creek still conveys significant flow into the southern section of the Project area. It is primarily sourced from Colombo Creek which diverts from Yanco Creek downstream of the Murrumbidgee River junction as well as its local catchment.

Local catchment flooding plays a significant role in flooding at the Project area in the 1% AEP event however due to rainfall being less extreme and less concentrated on the direct catchments for both Turn Back Jimmy Creek and Delta Creek overall it has a relatively reduced impact compared to the PMF event. As such in the 1% AEP the primary source of flooding at the Project area comes from the Murrumbidgee inflows which indirectly source both Delta Creek and Turn Back Jimmy Creek which in turn generate the largest flood depths and velocities in both sections of the Project area.

A.4.2 Probable Maximum Flood (PMF)

The PMF event has very large inflows at the Narrandera Bridge inflow boundary of over 10,000 cubic metres per second. At the junction between the Murrumbidgee River and Yanco Creek there is a significant division of flow as high flows divert down Yanco Creek towards the Project area, in these extreme events the Yanco Weir is generally kept open. There are high flood depths and velocities along Yanco Creek at the bridge and access which separates the northern and southern sections of the Project area, these high flows can be primarily attributed to the flows diverted from the Murrumbidgee River at the junction with Yanco Creek. Approximately 26 kilometres along the Murrumbidgee from the Yanco Creek junction the Coleambally Canal diverts flow to the south which provides a small amount of flow into Delta Creek which crosses the northern extent of the Project area. A significant proportion of the flow from the Coleambally Canal split diverts to the west after before joining Delta Creek and ultimately has little impact on the Project area. There are also several smaller diversions from the Murrumbidgee River which generate overland flood paths primarily heading to the west and not impacting the Project area. The Stuart Highway approximately parallel to the Murummbidgee River and acts as a natural flood breakline downstream of the Yanco Creek junction, there is a significant spillage in the vicinity of the Coleambally canal and minor spillages else but in many places along the Murrumbidgee there are breaks in the flood extent due to the Stuart Highway.

Billabong Creek provides flows towards the Project area from the south. These inflows also flow north along Nowranie Creek which flows alongside Billabong Creek before merging as they turn to the West. Billabong Creek generates overland flows which merge with Colombo Creek. Colombo Creek and overland flows from Billabong Creek flow into Turn Back Jimmy Creek which flows directly through the southern section of the Project area before merging with Yanco Creek. Colombo Creek originates from Yanco Creek approximately 30 kilometres to the south of the Murrumbidgee River junction and as such its flow is primarily sourced from the Murrumbidgee River.

In the PMF event the local catchment over Delta Creek experiences an extreme storm and the localised flooding generates significant flows into the northern extent of the Project area. This localised flooding generates larger flows and poses a higher risk to the northern extent of the Project area in comparison to the overland flows generated from the Murrumbidgee River and Yanco Creek.

The PMF event also has an extreme localised storm over the Turn Back Jimmy Creek catchment which generates high flood depths and velocities along Turn Back Jimmy Creek and directly through the southern extent of the Project area, as such it poses a large risk to the Project area and has considerable influence on the level of flooding.