
Appendix H

Flood impact assessment



Billabong Creek Regulators

Flood Impact Assessment

NSW Department of Climate Change, Energy, the
Environment and Water

September 2024



The 3Rivers Joint Venture (3Rivers), a joint venture between Jacobs Group (Australia) Pty Limited and GHD Pty Ltd has been engaged to provide certain Engineering and Approvals Services for the NSW Sustainable Diversion Limit Adjustment Mechanism (SDLAM) program in accordance with the Agreement between 3Rivers and the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) (the client).

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Document history and status

Revision	Date	Status	Description	Author	Reviewed	Approved
0	12/09/2024	Final	Appendix to EIS Impact Assessment Report	P Woodman E Karlson Y Li	P Pedruco	D Chubb

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Executive Summary

The proposed Hartwood Regulator and Wanganella Regulator are located in the Billabong Creek system. There is potential for the proposed replacement regulators' temporary or permanent construction works to impact flooding characteristics of this system. This has been assessed in this Flood Impact Assessment report, which has been prepared as part of the EIS for the proposed Hartwood Regulator and Wanganella Regulator and addresses the Secretary's Environmental Assessment Requirements (the SEARs), issued on 17 October 2024.

The existing flooding in the vicinity of the proposals has been established through flood modelling. These flood models were developed to cover the proposed regulator locations and surrounding area, which include other parts of the Yanco Creek Modernisation Project. The flood model was comprised of a hydrological assessment to understand the discharge characteristics in the Billabong Creek system and a primarily 2-Dimensional hydraulic model. Two separate hydraulic models were developed to cover each regulator and each model incorporated other parts of the Yanco Creek Modernisation Project within their bounds to allow for the cumulative assessment of different parts. The results of these models were used to define the existing flood risk within the area of interest, assess potential impacts from the proposals and test mitigation measures as required. The results from the hydraulic model have produced maps for operational flows and flood flows, specifically the 20% Annual Exceedance Probability (AEP), 5% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF events as requested by the SEARs. The 0.5% and 0.2% AEP events were used as proxies to consider the potential impacts of climate change. The prepared results included water depth, water level and flood hazard together with other hydraulic variables.

An impact assessment was completed by comparing existing case conditions to proposed conditions. Proposed conditions are the results when the proposals (i.e. demolition of the existing regulators and construction of the replacement regulators a short distance downstream) were incorporated into the hydraulic model. This assessment identified areas of changed flood risk predominately through the change in flood level and where necessary investigated physical mitigation measures to manage this risk. This assessment mapped the influence of any flood impacts both up and downstream for each of the modelled AEP events.

The impact assessment found there were only minor areas of increased flood levels outside of the ± 50 millimetres (mm) modelling tolerance due to the Hartwood proposal in larger flood events. Further, these areas of increase only occurred in agricultural areas. In smaller or more frequent events, there were increases in water levels downstream of the regulator and decreases in water levels upstream of the regulator compared to the existing conditions. This impact can readily be managed through the operation of the regulator gates. The impact assessment also found there were no significant changes to flood levels in the vicinity of the Conargo Township. The cumulative assessment of other parts of the Yanco Creek Modernisation Project with the proposals demonstrated that the other parts were hydraulically independent and there were no impacts.

At the Wanganella Regulator site, the impact assessment used two sets of modelling tolerance to determine if there were flood impacts: ± 10 mm for sensitive land uses such as residential homes in the Wanganella Township and ± 50 mm for waterways, cropping and natural bushland. Initial results indicated that there were flood level increases near residential properties in Wanganella Township and to mitigate this impact a flood bypass channel was included in the proposal. The flood bypass channel was designed to reduce flood levels in Wanganella Township for the 2% AEP event and rarer. This channel did increase levels immediately downstream, however, this was on undeveloped crown land. The cumulative assessment for the Wanganella Regulator proposal demonstrated that there were potential impacts from the Wanganella Swamp project; however, these were demonstrated to be due to the operation of the Estuary Creek regulator and can be readily managed through operational changes.

Overall, the impact assessment has demonstrated that there will be no significant detrimental increases to properties, assets, and infrastructure. As there is fundamentally no change in the flood characteristics due to the proposals, it can be concluded that the flood hazard and hydraulic functions of flow conveyance in floodways and flood storage characteristics remain consistent with current conditions and the Conargo Local Environment Plan. Further, as there is no fundamental change to the flooding conditions the existing emergency management, evacuation and access, and contingency measures remain current and relevant

where they exist and no new community emergency management arrangements for flooding are required. Similarly, as there are no changes to the existing flooding there are no impacts to social and economic costs to the community as a consequence of the proposals.

The impacts of climate change at 2100 from the proposals on the 1% AEP event, which is considered critical from a planning perspective, was assessed by comparing the existing conditions results to the proposed condition results for the 0.5% and 0.2% AEP flood events. For both regulator sites, the impact assessment demonstrated there were no significant impacts, with a minor improvement at the Wanganella Regulator due to the introduction of a flood bypass channel. The reason for the small impacts is that, in these larger flood events the proposed structures are effectively overwhelmed or drowned out. Given there were no significant impacts in the existing case and the climate change at 2100 case, it was concluded that there would be no significant impacts at 20-year intervals throughout the design life of the proposals.

The above overview is subject to, and must be read in conjunction with, the limitations set out in section 1.6 of this report and the assumptions and qualifications contained throughout this report.

Glossary

Term	Description
Anabranch	A section of a river or stream that diverts from the main channel of the watercourse and rejoins downstream.
Clearing area	This is the area required to construct the proposed infrastructure. Within this area it is assumed that all vegetation would be removed, including trees and ground cover vegetation. Borrow pits also include a clearing area. However, this is a conservative assumption, and contractors would be encouraged to avoid removal where they can (through proposed mitigation measures).
Commonwealth Environmental Water Holder	The Commonwealth Environmental Water Holder is a statutory position established under the <i>Water Act 2007</i> (Cth) responsible for managing the Commonwealth's environmental water holdings. These water holdings are used to protect or restore environmental assets of the Murray-Darling Basin.
Construction activity zone	The area surrounding and including the 'clearing area' that would be used for construction purposes e.g., laydown, site sheds, parking. It is assumed topsoil will need to be removed / cleared, with some re-grading to create level areas with grubbing and clearing of small shrubs/grasses. Trimming of trees may be required. Tree removal would not occur in portions of the CAZ outside of a clearing area.
Cumulative impacts	The combined impacts of the proposal on a matter with other relevant future projects
Disturbance area	The disturbance area includes all locations where the proposal directly impacts the land surface or water body. This includes clearing areas, construction activity zones, access tracks and power supply routes.
Efficiency measure	Provide more water for the environment by making water delivery systems for irrigation more efficient. This can include replacing or upgrading on-farm irrigation, or lining channels to reduce water losses within an irrigation network
Entitlement	The volume of water authorised to be taken and used by an irrigator or water authority; includes bulk entitlements, environmental entitlements, water rights, sales water and surface-water and groundwater licenses.
Environmental flow	Any river flow pattern provided with the intention of maintaining or improving river health.
Fish passage	The ability of fish or other aquatic species to move through an aquatic system.
Fishway	Structures placed on or around constructed barriers (such as dams or weirs) to give fish the opportunity to move past the barrier.
The proposal	The construction and operation of the two regulators and supporting infrastructure and the demolition of two existing weirs.
The proposal site	The footprint that would be directly affected by construction and the location of operational infrastructure.
Regulator	A gated structure used to actively manage or control the amount of water that flows from one location to another.
Regulated	A water system in which water is stored or flow levels are controlled through the use of structures such as dams and weirs.
Sustainable diversion limit adjustment mechanism	A mechanism under the Murray-Darling Basin Plan that allows the sustainable diversion limit (the volume of water that can be abstracted from the basin) to be adjusted under certain circumstances.

Study area	The area investigated for this assessment which includes the proposal site and surrounding area, with the potential to be directly or indirectly affected by the proposal.
Weir	A low barrier or dam that is built across a watercourse and is designed to store water, control, or alter the flow of water in a creek

Abbreviations

Abbreviations	Definitions
AEP	Annual Exceedance Probability. The probability that an event of a given size will be equalled or exceeded in a given year.
ARI	Average Recurrence Interval. The average interval between an event of a given size over a long period of time. For larger flood events, this is the inverse of the AEP expressed as a return period. For instance, the 1% AEP is equivalent to the 100-year ARI event.
AHD	Australian height datum
CEWO	Commonwealth Environment Water Office
DCCEEW	NSW Department of Climate Change, Energy, the Environment and Water
EIS	Environmental Impact Statement
EP&A Act	<i>Environmental Planning and Assessment Act 1979</i> (NSW)
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth)
FM Act	<i>Fisheries Management Act 1994</i> (NSW)
FSL	Full Supply Level. The normal maximum operating level of a storage when not affected by flooding.
GL	Gigalitre. Unit of measurement of water volume which is equivalent to 1,000,000 Litres
km ²	Square kilometres. Unit of measurement of area.
HEC-RAS	A one-dimensional steady and unsteady flow hydraulic computer modelling software.
LEP	Local Environmental Plan
LGA	Local Government Area
m	Metres. Unit of measurement of distance or length.
MaxOF	Maximum Operating Flow as issued by WaterNSW (SAYM-REQ-003, December 2021)
MinOF	Minimum Operating Flow as issued by WaterNSW (SAYM-REQ-003, December 2021)
MaxOL	Maximum Operating Level of weir pool, which is set by the operation of the proposed gates at the regulators to achieve the required level as set by draft Operations Plan (NSW DCCEEW, 2023).
MinOL	Minimum Operating Level of weir pool, which is set by the operation of the proposed gates at the regulators to achieve the required level as set by draft Operations Plan (NSW DCCEEW, 2023).
ML	Megalitre. Unit of measurement of water volume which is equivalent to 1,000 Litres

ML/d	Megalitre per day. Unit of measurement of flow rate in terms of mega litres per day
NSW	New South Wales
PMF	Probable Maximum Flood (PMF), which is the largest flood that could conceivably be expected to occur at a particular location
RRC	NSW SDLAM Reconnecting River Country Program
SDLAM	Sustainable Diversion Limit Adjustment Mechanism
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.
WNSW	Water NSW
WSL	Water Surface Level. The height of the water surface in metres AHD.

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1. Introduction

The Yanco Creek Modernisation Project involves the replacement of two existing weirs along Billabong Creek with new regulators. These regulators will interface with the Billabong Creek system which is subject to flood events of varying frequency and severity and there is potential for the regulators' temporary or permanent construction works to impact flooding characteristics in this system. These potential flood impacts and measures to mitigate any impacts have been assessed in this report.

1.1 Overview

The NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW) is proposing to replace two existing weirs along Billabong Creek with new regulators (the proposal). The two existing weirs to be demolished are Hartwood Weir and Wanganella Weir. These structures are situated on Billabong Creek within the Yanco Creek system in south-west NSW (refer to Figure 1.1).

These weirs were built in the early 20th century and have been used to regulate flows through Billabong Creek, create weirs pools for irrigation and, in the case of Wanganella Weir, provide town water supply. The weirs are currently in states of declining condition and functionality and are barriers to the movement of fish through the creek. Their condition limits their ability to regulate flows through the Yanco Creek system and leads to inefficiencies in how water is delivered to the environment and irrigators.

The new regulators would be fully automated and remotely operated meaning that operators could control the delivery of water more efficiently. The proposal is needed to improve the operator's ability to deliver the right amount of water to the right place at the right time. The new regulators would also feature fishways to support fish movement past the new structures. WaterNSW would own and operate the new regulators, once constructed.

The proposal is subject to environmental and planning approvals in accordance with the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The proposal is State Significant Infrastructure (SSI), and the Minister for Planning is the approval authority. An Environmental Impact Statement (EIS) is required to accompany the application for approval of the proposal.

1.2 Purpose and scope of this report

This report has been prepared by 3Rivers, a joint venture between GHD and Jacobs Group (Australia) as part of the EIS for the proposal. The EIS has been prepared to accompany the application for approval of the proposal and addresses the Secretary's Environmental Assessment Requirements (the SEARs), issued on 17 October 2024.

The purpose of this report is to assess potential flood impacts and issues from the construction and operation of the proposal, and where required, identify feasible and reasonable mitigation and management measures. This report:

- provides context and background regarding existing conditions and the proposed works
- outlines and addresses the Secretary's Environmental Assessment Requirements (SEARs) (SSI-50831979) relating to the flood impact assessment
- provides an overview of the hydraulic modelling and results used to conduct the flood impact assessment
- identifies and addresses flood impacts associated with the construction and operation of the proposed regulators
- identifies and addresses mitigation and management measures associated with flood impacts during the construction and operation of the proposed regulators.

1.3 Structure of this report

The report is structured as follows:

- Section 1 – introduces the proposal and the assessment.
- Section 2 – describes the methodology for the assessment.
- Section 3 – describes the existing flooding conditions.
- Section 4 – assesses the impacts of the construction and operation of the proposal.
- Section 5 – provides mitigation measures for the impacts identified.
- Section 6 – provides a conclusion for the assessment.

1.4 Summary of the proposal

1.4.1 Location

The proposal is located on Billabong Creek, which is part of the Yanco Creek system in south-west New South Wales (NSW). The Yanco Creek system forms a part of the Murray-Darling Basin. An overview of the location of the proposal is shown in Figure 1.1 and is located within the local government area (LGA) of Edward River.



-  Regulator
-  Town
-  Major Watercourse
-  Main Road
-  Water Bodies



GDA2020 MGA Zone 55
A4 Scale: 1:1,140,000

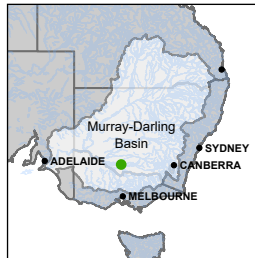
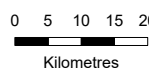


Figure 1.1 - Location of the proposal



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1.4.2 Key features of the proposal

As discussed in section 1.1, the proposal involves replacing two existing weirs along Billabong Creek with new regulators including fishways.

The core structure of the two regulators is similar and based on design progress to November 2023 would include:

- concrete piers with maintenance bulkhead slots
- automated layflat gates across the crest of the structure to assist with flow management and downstream fish passage
- a low turbulence 'keyhole' type vertical slot fishway with allowances for variable headwater to provide upstream fish passage
- automated sidewinder gates within the vertical slot fishway to allow for variable headwater conditions
- fixed concrete crests on the opposite side of the gates to the vertical slot fishway
- concrete apron downstream of the structure
- concrete wingwalls upstream and downstream of the structure
- access from a trafficable deck for maintenance (Hartwood Regulator only)
- pedestrian walkway access part way across Wanganella Regulator structure to facilitate housing of gate actuators and for maintenance
- walkway grating over gates to facilitate operations and maintenance
- crushed rock maintenance pads, access, and turnaround areas adjacent to the structure
- rip rap and rock beaching upstream and downstream of the structure for erosion protection
- control house
- sheet pile cut-off walls beneath the structure
- fencing of the structures to prevent public access
- SCADA control system.

An indicative layout of a regulator is shown in Figure 1.2. This example shows a regulator with five gates and a trafficable deck for maintenance access.



Figure 1.2 Indicative layout of a regulator

The proposal would also involve the following elements:

- Power supply to the regulators would be provided by a mix of underground and overhead electricity cables connecting the structures to the grid.
- Access to the regulators would require permanent tracks for maintenance and some additional tracks to support construction only. The access track for Hartwood Regulator will also involve a culvert at an existing irrigation channel.
- The existing Forest Creek block bank, associated with the Hartwood Regulator, would be replaced with a similar earthen structure to the existing, including two concrete sills to define the upstream and downstream top of the bank and armoured with rock beaching and crushed rock for erosion protection.
- A flood bypass channel would be constructed to reduce potential upstream flooding impacts from the Wanganella Regulator. The channel would enable flood waters to drain between the billabongs in the Wanganella Reserve during flood events. It would be 85 metres long, around 40.0 metres wide and 1.7 metres deep and located north of the Wanganella landfill. Once completed, the channel sides and base would be natural and vegetated with appropriate local native species.
- An existing borrow pit on private land at lot 56 / DP756322 near Hartwood Weir would be extended to provide material for the construction of the Hartwood Regulator and Forest Creek block bank.

The location of the existing weirs, proposed infrastructure, and the indicative proposal footprints are shown on Figure 1.3 and Figure 1.4.

It is of note that the design is under development and the assessment was completed on a design that was frozen at the end of 2023, that is, there has been design development since this assessment was completed.

1.4.3 Timing

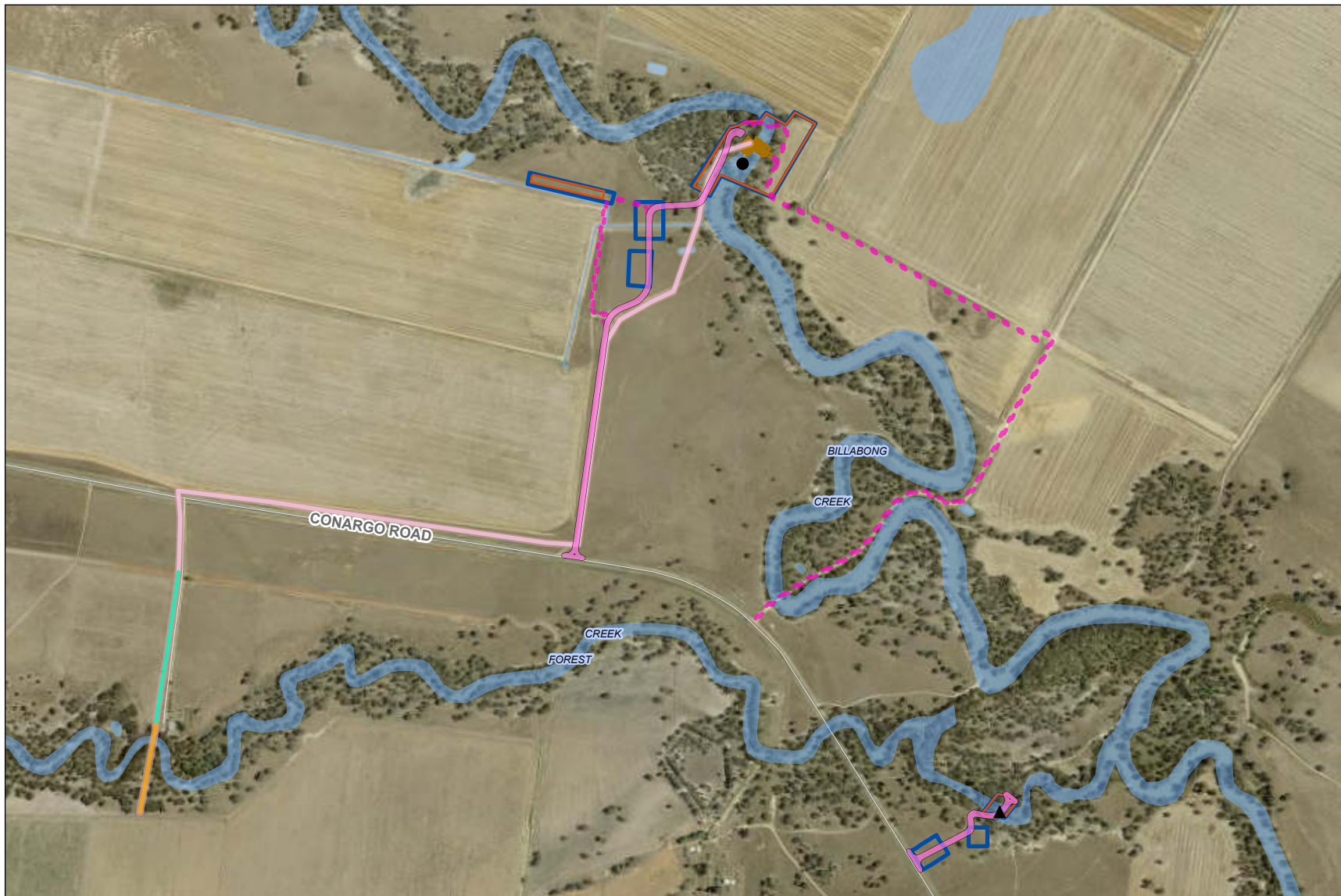
Construction of the proposal is anticipated to start in 2025 and be completed by 2026. The construction period is anticipated to be around 18 months. Construction would pause during periods of high flow. Standard construction hours would be adopted in accordance with the *Interim Construction Noise Guideline* (ICNG) (DECC, 2009) as shown in Table 1.1. Most construction activities would be undertaken during this time.

Table 1.1 Standard construction hours

Day	Start time	Finish time
Monday to Friday	7.00 am	6.00 pm
Saturday	8.00 am	1.00 pm
Sundays and public holidays	No regular work	

Notwithstanding this, the *Interim Construction Noise Guideline* (DECC, 2009) acknowledges that the following activities may need to be undertaken outside the recommended construction hours:

- emergency work
- delivery of oversized plant or structures
- works for which it can be demonstrated that there is a need to operate outside the recommended standard hours.



Proposal

- Proposed Hartwood Regulator
- Construction Activity Zone
- Clearing Area

Power Supply

- Power Supply
- Power Supply (Existing aboveground)
- Power Supply (to run underground)
- Power Supply Buffer

Access tracks

- Construction Only
- Construction plus O&M

Existing features

- Existing Weir
- ▲ Existing Block Bank
- Main Road
- Water Bodies

N



GDA2020 MGA Zone 55

A4 Scale: 1:16,000

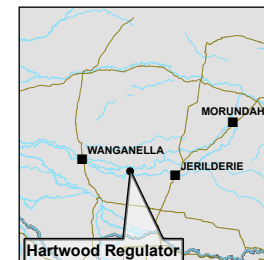
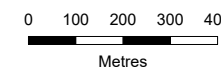


Figure 1.3 Location of Hartwood Regulator and Proposed Works



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1.4.4 Operation

The proposal would be operated in accordance with the operating requirements established with the new asset owner and developed in consultation with key stakeholders. These operating requirements are known as the Yanco Creek System Operations Plan. The plan would take into account the regulation requirements at each regulator, as well as constraints such as limits to rates of rise and fall to accommodate fish breeding requirements.

The proposed regulators would provide greater control of water levels which would be operated to meet environmental and water supply objectives under a range of scenarios. WaterNSW would own and operate the new regulators.

1.5 Secretary's Environmental Assessment Requirements

This flood impact assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs). Table 1.2 outlines the requirements relevant to this assessment and where these are addressed in the report. The assessment also considers requirements raised by NSW DCCEE and the Department of Primary Industries (Fisheries).

Table 1.2 Relevant SEARs

Requirements	Where addressed in this report
Flooding	
9. Identify flood risk (detailing the most recent flood studies for the project area) and consideration of any relevant provisions of the Flood Risk Management Manual 2023, including the potential effects of climate change and an increase in rainfall intensity. If there is a material flood risk, include design solutions for mitigation.	Section 2.1, section 4 and section 5
10. Map features relevant to flooding as described in the Flood Risk Management Manual 2023, including: a. Flood prone land. b. Flood planning area, the area below the flood planning level. c. Hydraulic categorisation (floodways and flood storage areas). d. Flood hazard.	Maps are included in Appendix B and Appendix C. These are also described and referenced in Section 4.
11. The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, to the extent of project influence up and down stream, including a minimum of the 20% Annual Exceedance Probability (AEP), 5% AEP, 1% AEP flood levels and the probable maximum flood, or an equivalent extreme event.	Section 2.2 and Section 3
12. The EIS must model the effect of the proposed development (including fill) on the flood behaviour, to the extent of project influence up and down stream, under the following scenarios: a. Current flood behaviour for a range of design events as identified in 11 above. b. The 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 4, as well as maps in Appendix B and Appendix C.

Requirements	Where addressed in this report
13. Modelling in the EIS must consider and document: a. Existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies. b. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. c. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. d. Relevant provisions of the Flood Risk Management Manual 2023	a. Section 3 b. Section 4 c. Section 4 d. Section 2.1 and section 4 - e.
14. The EIS must assess the impacts on the proposed development on flood behaviour, to the extent of project influence up and down stream, including: a. Whether there will be detrimental increases in the potential flood impacts to other properties, assets, and infrastructure. b. Consistency with Council floodplain risk management plans. c. Consistency with any Rural Floodplain Management Plans. d. Compatibility with the flood hazard of the land. e. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. f. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to, upstream or downstream of the site. g. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses. h. Any impacts the development may have upon existing community emergency management arrangements for flooding. i. Whether the proposal incorporates specific measures to manage risk to life from flood. j. Emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event). k. Any impacts the development may have on the social and economic costs to the community as consequence of flooding. l. Evidence of consultation with Council and SES, including evidence of their support, on all issues of flood emergency management.	a. Section 4 b. Section 4 c. Section 4.3 d. Section 4 e. Section 4 f. Addressed in EIS Appendix K (Surface water and aquatic ecology) and EIS Appendix L Biodiversity development assessment report. g. Addressed in EIS Appendix J (Geomorphology assessment) h. Section 4 i. Section 5 j. Section 4 k. Section 4 l. Addressed in EIS chapter 5 (Stakeholder Engagement) and EIS Appendix E (Consultation report)

1.6 Assumptions

Developing a hydraulic model requires the application of simplifications and generalisations. As such a number of assumptions are made when building the model. This can lead to model uncertainties and subsequent limitations of the results of the hydraulic modelling undertaken to determine existing flood characteristics around the proposed regulator sites and to support the impact assessment of the proposed scenario for the EIS process.

The limitations, assumptions and associated uncertainty of the model results are discussed in detail in Section 8 of both “Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Hartwood Weir to Piccaninny Weir Study Area (DE19-823-YCM2A-DE-HY-RPT-0001)” and “Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area (Area (DE19-823-YCM2B-DE-HY-RPT-DE19-823-YCM2B-DE-HY-RPT-0001)).0001)”. However, an overview of the key ones is outlined below:

- In preparing this report and models, the authors have relied on information provided by other and publicly available information. Except where explicitly noted this data has not been independently verified or checked. This unverified information may contain errors and omissions, which have caused errors or omissions in this report.
- Due to the size of the Study Area, a relatively coarse grid with additional sampling for storage and conveyance characteristics via TUFLOW “sub-grid sampling” utility was adopted and considered appropriate. This means that variables such as velocity, hazard and bed shear stress are likely to be only generally representative and may over or underestimate actual values in localised locations (such as river bends and in and around structures represented in 1D).
- Although data collection prior to this model build has been extensive, not all areas or structures have been visited during the 3Rivers site visits and/or been able to be surveyed due to local conditions and therefore assumptions were required for:
 - the size, invert elevation, losses and/or type of some structures, which were generally based on nearby structures and/or other information, such as LiDAR or anecdotal evidence
 - defining the bathymetry in some areas as the high-resolution LIDAR products available in the area were collected when there was ponded water in the floodplain
 - soil losses as infiltration data for soils is very limited and can vary greatly depending on antecedent conditions, soil type and compaction for example
 - various modelling parameters, such as roughness values used within the model.
- A programme of model proving was undertaken to understand uncertainties associated with the choice of a number of parameters and their impact upon model results. Based on this work and calibration/validation activities the adopted values and assumptions were considered appropriate for this Study.
- The developed case modelling has been completed using the design drawings available in November 2023. Further investigation and design development has occurred since this date, although these are not expected to materially alter the assessed impacts presented in this report.

2. Assessment approach and methodology

2.1 Legislative and policy context to the assessment

This section summarises the legislation, guidelines and/or policies driving the approach to the assessment. These provisions have been considered when completing the hydraulic modelling for this Study. The SEARs requirements relevant to flooding and where these have been addressed in this report, are discussed in section 1.5.

2.1.1 Flood Risk Management Manual (2023)

The Flood Risk Management Manual (DPE, 2023) has been considered in relation to the flood impact assessment. This manual replaces the 2005 Floodplain Development Manual. The manual guides the strategic management of floodplains and guides councils' management of flood risk and technical flood studies. The manual does not outline the requirements for development on flood-prone land, but the principles of the manual and its advice have been considered for the proposal. The following principles are relevant to the flood studies carried out for the purpose of this proposal:

Understand flood behaviour and constraints for a full range of flood events.

Important constraints to consider relate to flood hazard and flood range.

Flood behaviour includes understanding sensitive areas within floodways and floodplains to assess the potential impacts of proposed works.

- understand and provide information about flood flows, velocities, levels, flood extents and inundation time and extent
- understand flood risk and how it may change under development and varying environmental conditions
- consider the potential impacts of climate change, including changes in weather patterns and increased intensity and frequency of events
- consider and include the impact of variability and uncertainty on flood behaviour and modelling results.

The Manual also outlines that flood studies should include examination of catchment hydrology (storms and flow events), floodplain hydraulics (behaviour of flood flows) and post-processing of model results.

2.1.2 Billabong Creek Floodplain Management Plan 2006

The sites are downstream of the area covered by the Billabong Creek Floodplain Management Plan.

2.1.3 Edward and Wakool Rivers Stage 1 Floodplain Management

The sites are upstream of the area covered by the Edward and Wakool Rivers Stage 1 Floodplain Management Plan.

2.1.4 Conargo Local Environmental Plan 2013

The Conargo Local Environmental Plan (NSW Government, 2013) Part 5.21 provides flood planning objectives and considerations for consent authorities to follow before granting development consent. Key objectives include minimising flood risk to life and property, avoiding adverse and cumulative impacts on flood behaviour, and ensuring compatibility with the existing flood function and behaviour in the area, as well as flood behaviour under climate change conditions. These are considered in this assessment against similar provisions of the SEARs.

2.1.5 Conargo Floodplain Risk Management Study and Plan (2010)

The Conargo Floodplain Risk Management Study and Plan (DECCW, 2010) outlines the extent of flooding and severity of damage during a 1% AEP flood event on Billabong Creek within the vicinity of Conargo Township.

The study indicates that predicted flood damages from the 1% AEP event at the time would result in two residential properties being affected by inundation and no commercial or public properties being affected.

The Floodplain Risk Management Study and Plan provides recommendations surrounding the Flood Planning Level (FPL) for various categories of development. The FPL is to be considered and implemented by Local Council. Appendix B – Conargo Flood Study of the Floodplain Risk Management Study and Plan, outlines the objectives and approach to modelling Billabong Creek and the surrounding floodplain area in Conargo. Flood behaviour was modelled for flood frequencies between 5% AEP and 0.5% AEP events, as well as an extreme flood event. A HEC-RAS model was developed to assess flood risk for large and extreme events on a limited section of Billabong Creek and Piccaninny Creek around Conargo.

This study does contain flood frequency analysis, which has been indirectly used in the study. Some of the cross-section data from the HEC-RAS were located in the gap between bathymetry sources, but upon review against other sources appeared to be estimates only and subsequently were not used in checking and/or preparing the adopted bathymetry for this Study.

2.1.6 Billabong Creek Floodplain Management Plan 2006

The sites are downstream of the area covered by the Billabong Creek Floodplain Management Plan (DNR, 2006).

2.1.7 Edward and Wakool Rivers Stage 1 Floodplain Management Plan

The sites are upstream of the area covered by the Edward and Wakool Rivers Stage 1 Floodplain Management Plan (DECCW, 2011).

2.2 Methodology

2.2.1 Study area

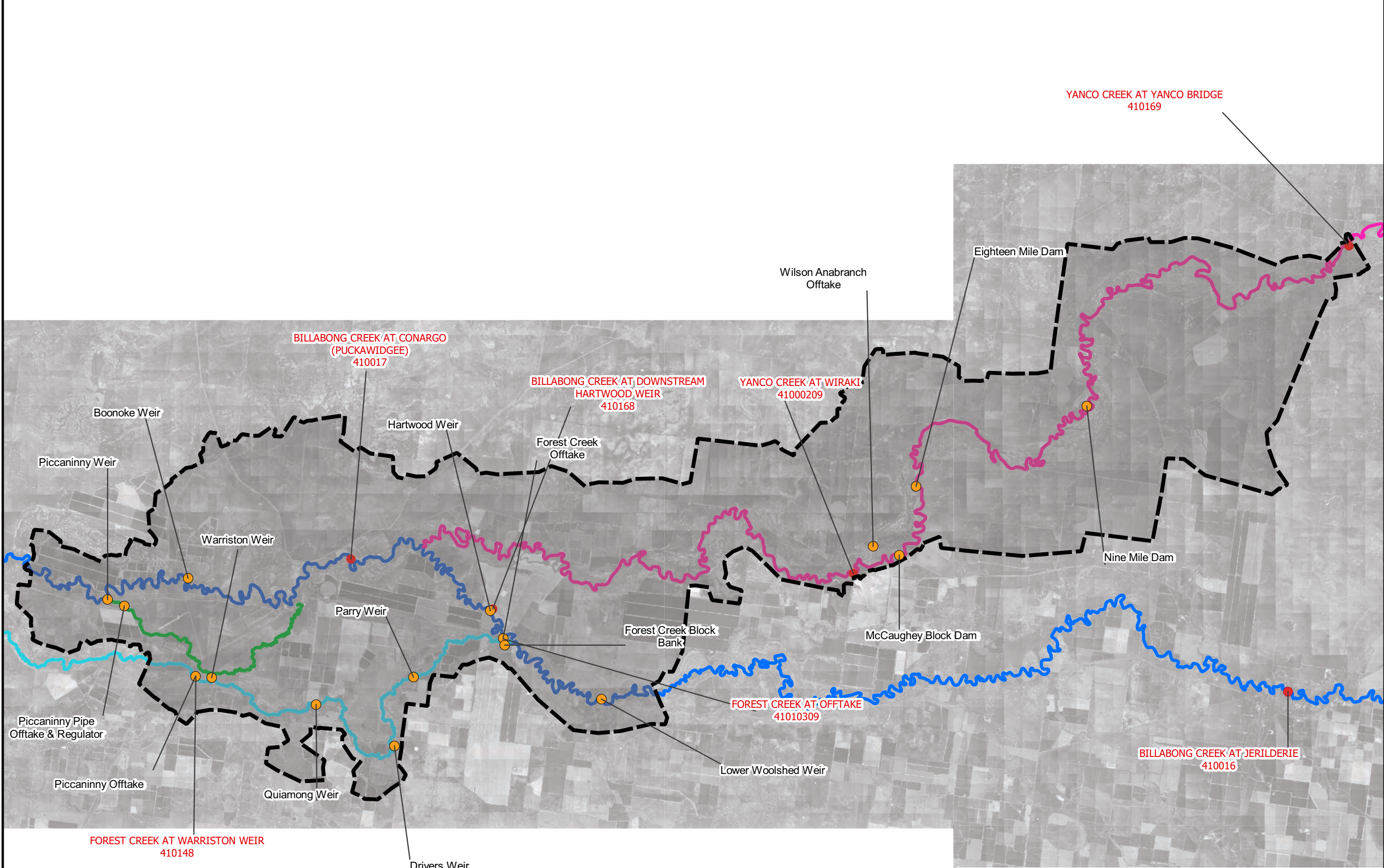
For the purposes of the assessment the construction footprint, operation footprint, and study area have been defined as follows:

- Proposal footprint – the area that would be directly disturbed by construction and the location of operational infrastructure. The disturbance area would include clearing areas, construction activity zones, access tracks, and power supply corridors.
- Study area – the area investigated which includes the footprint of the proposal and surrounding area, with the potential to be directly or indirectly affected by the proposal. The areas of investigation covered by this flood study comprised floodplains and surrounding land that may potentially be affected by flooding surrounding the proposed works of each respective regulator, as shown in Figure 2.1 and Figure 2.2. The main areas of focus within each study area are the weir pool upstream of each regulator, as flood impact is largely controlled by the respective upstream and downstream weirs and/or other controls.

2.2.2 Catchment description

The proposed sites are located on the Yanco Creek system which is an effluent or distributary of the Murrumbidgee River as well as the unregulated Billabong Creek as shown in Figure 2.3. The Murrumbidgee discharges to Yanco Creek through the Yanco Offtake, with the creek continuing to the west to its confluence with Billabong Creek. The Murrumbidgee River catchment to Yanco Offtake is approximately 34,000 km² and includes a large portion of the upper Murrumbidgee River, which includes main storages such as Blowering and Burrinjuck Reservoirs. Downstream of the Yanco Offtake, Yanco Creek bifurcates with the Colombo Creek, which also discharges to Billabong Creek.

Billabong Creek upstream of Jerilderie is essentially unregulated or natural with the exception of a small regulated inflow from Colombo Creek and its catchment area at Jerilderie is approximately 5,200 km², which is comprised of mainly of rural land. Given the size of the catchment and the number of major storages, as well as the number of interconnected tributaries catchments to the Yanco and Billabong Creeks, this area can be considered hydrologically complex.



Legend

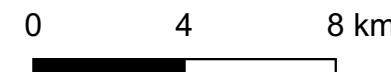
- Hydraulic Model Boundary
- Modelled significant structures
- Gauge Locations

Key Watercourses

- Billabong Creek
- Forest Creek
- Piccaninny Creek
- Yanco Creek



GDA 2020 Zone 55
Scale: 1:200,000



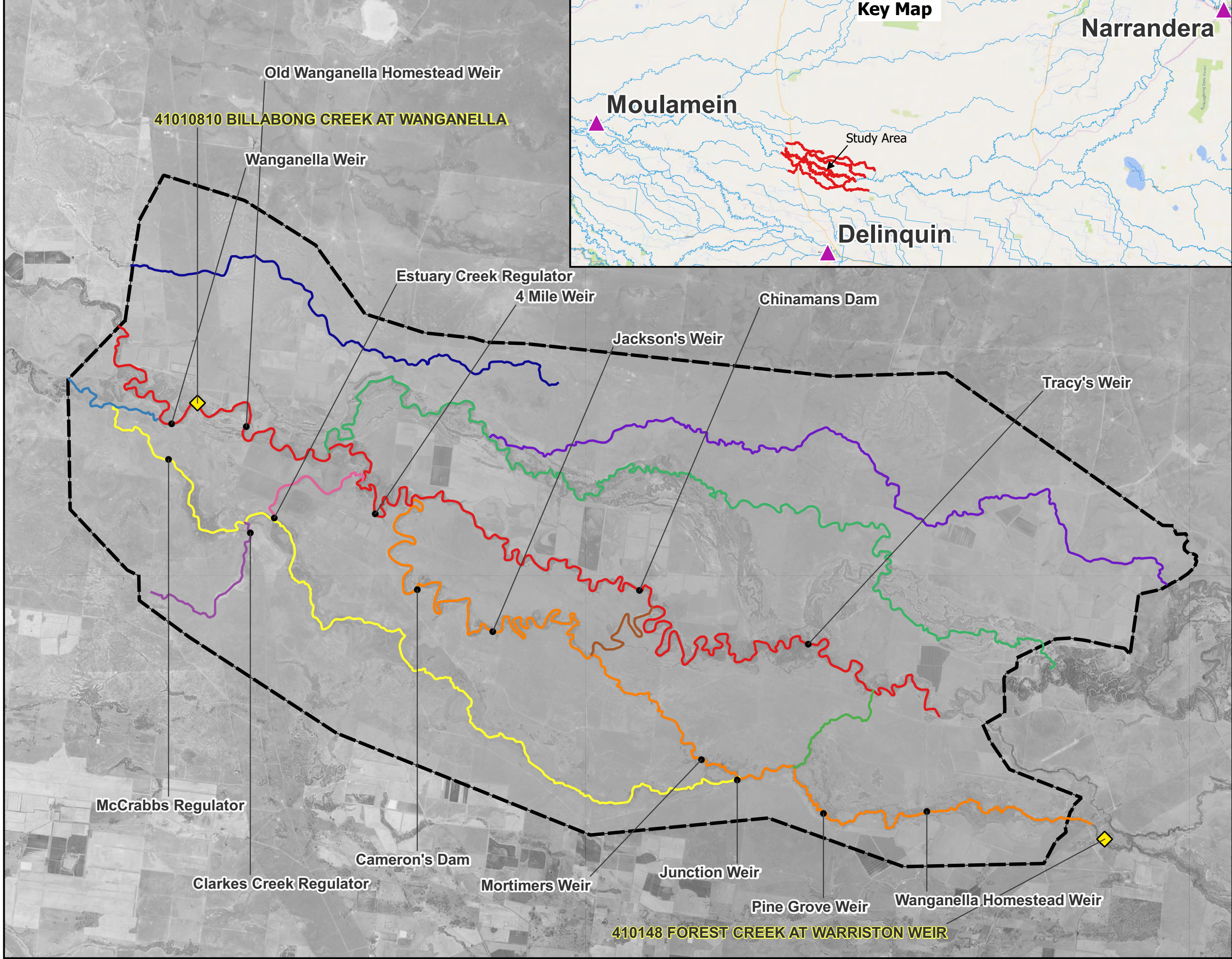
DATA SOURCE:
NSW Map Data, 2021; Model layers, 3Rives, 2023;
Structures, Gauges and Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Study Area Overview EIS Chapter
"G:\21\12537654\GIS\Maps\Working\
Yanco_Modernisation_H2P_Report_Figures_GDA2020.qgz"

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
Figure 2.1: Study Area Overview



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Key Map Legend

- Major Cities

Main Map Legend

- 2D Model Area
- Major Structures
- Gauges
- Watercourses
 - Billabong Creek
 - Forest Anabranch
 - Back Creek
 - Clarkes Creek
 - Eight Mile Creek
 - Estuary Creek
 - Flood Creek
 - Forest Creek
 - Browns Creek
 - Sheepwash Creek
 - Two Mile Creek

GDA 2020 Zone 55
Scale: 1:110000

0 2 4 km

DATA SOURCE:
NSW Map Data 2021; Model layers, 3Rivers 2024; Structures, Gauges and Aerial NSW DCCEEW, 2021.

WORKSPACE:
Modelled Structures
"J:\IE\Admin\03_SouthernWater\3RP\56_Reconnecting_hydraulic_modelling\05_Technical\02_WP20\02_GIS\20240227_EIS_Report_Figures.qgz"

Yanco Creek Modernisation: Hydraulic Modelling - Piccaninny Weir to Wanganella Weir Work Package 20 Study Area
Figure 2.2: WP20 Study Area Overview

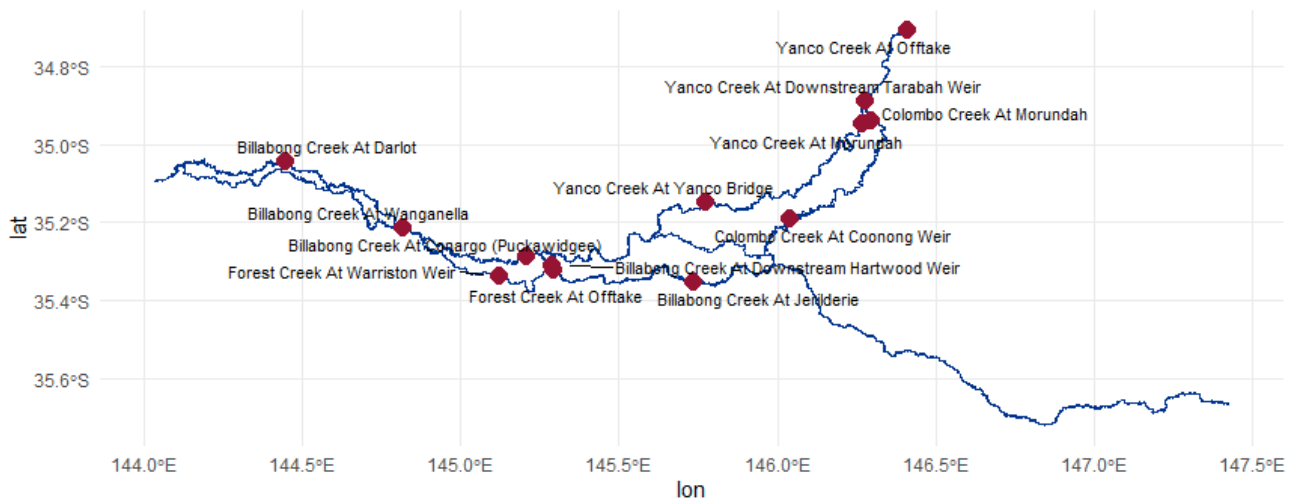


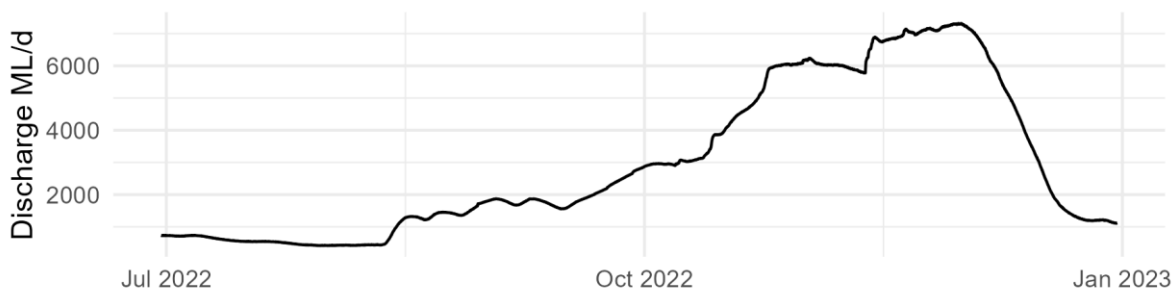
Figure 2.3 Site locality map showing key hydrological features

In essence, there were three main sources of inundation in the Yanco Creek system:

- flow originating from the Murrumbidgee River through the Yanco Offtake into Yanco Creek, as well as any breakout flows
- unregulated flows in the Billabong Creek system
- the combination of flows from the Yanco Creek and Billabong Creek.

Runoff from the local catchment was considered insignificant compared to the flows from the Murrumbidgee River or Billabong Creek. This was confirmed by observations from the 2022 flood event where a regional rainfall event in mid-November 2022 led to a peak in mid-December 2022 as illustrated in the Figure 2.4.

Discharge: Billabong Creek at Jerilderie



Rainfall gauges in Upper Billabong Creek: Holbrook (Croft St) & Woomargama Post Office

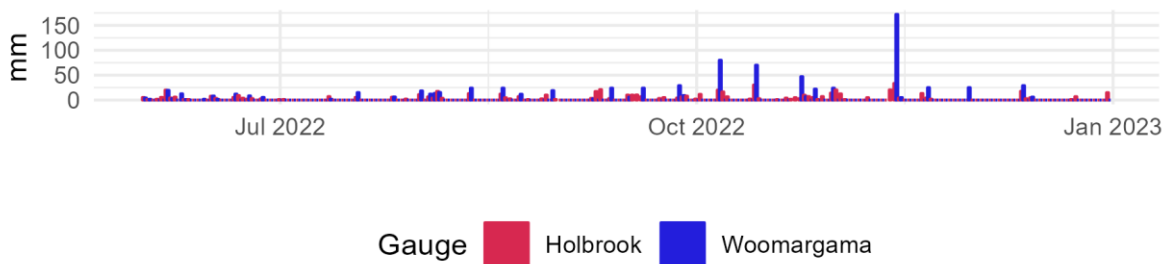


Figure 2.4 Example of flood causing rainfall and Billabong Creek's discharge demonstrating peak flood response is driven by upper catchment rainfall not local runoff.

2.2.3 Inundation modelling methodology

Inundation modelling was completed to assess the impacts of the proposed structures which was a combination of a hydrological assessment and hydraulic modelling. A summary of the approach for each of these is provided below.

2.2.3.1 Hydrology

Hydrology or watercourse discharge for application to the hydraulic model was required. Essentially, an assessment of operational flows and flood flows were required. The operational flows were provided by WaterNSW (WNSW) (SAYM-REQ-003) and are listed in Table 2.1.

Table 2.1 Operational flows at Hartwood and Wanganella from WNSW (SAYM-REQ-003)

Weir	Minimum operational flow (ML/d)	Maximum operational flow (ML/d)
Hartwood	20	500
Wanganella	30	400

A hydrology assessment for application to the hydraulic model was completed. The purpose of this assessment was to determine design flow rates (peak flows for a given probability of occurrence) to be applied to the hydraulic models. To determine these flow rates, flood frequency analysis was undertaken at key gauges. Development of an event-based rainfall-runoff model was considered, however, given the complexity of the Billabong Creek system, this was not considered feasible. It is noted that floodwater moves slowly through the system with floods taking a month or more to travel from the Yanco Offtake to Wanganella hence peak flows, rather than volumes, generally produce peak water levels.

To determine the flow rates to be applied to the Hartwood and Wanganella hydraulic models a Flood Frequency Analysis (FFA) was undertaken in accordance with the procedure outlined in Australian Rainfall and Runoff, Book 8 (Kuczera & Franks, 2019). A comprehensive assessment was completed for three gauges in the Yanco / Billabong Creek system that characterised each source of flooding and the combination of these downstream of the confluence of Yanco Creek and Billabong Creek. These gauges are listed below, with each gauge having more than 100 years of record:

- Yanco Creek at Morundah (410015)
- Billabong Creek at Jerilderie (410016)
- Billabong Creek at Conargo (Puckawidgee) (410017).

Additional gauges were also assessed to “infill” data in a number of instances, these gauges were:

- Colombo Creek at Morundah (410014)
- Colombo Creek at Coonong Weir (41000210)
- Yanco Creek at Yanco Bridge (410169).

The resulting flood quantiles (flows for a given probability) for the site comprehensively assessed are listed in Table 2.2 with further details provided in Appendix A (3Rivers, 2023a).

Table 2.2 Peak flood discharges at key gauges

Annual Exceedance Probability (AEP)	Yanco Creek at Morundah Discharge (ML/d)	Billabong Creek at Jerilderie Discharge (ML/d)	Billabong Creek at Conargo Discharge (ML/d)
50%	1,400	2,200	2,200
20%	3,400	4,000	4,600
10%	5,500	5,500	6,900
5%	8,300	6,900	9,900
2%	13,100	8,600	14,900
1%	17,900	9,900	19,800
0.5%	23,800	11,100	26,000
0.2%	33,700	12,500	36,300

2.2.3.2 Hydraulics

Hydraulic modelling at Hartwood and Wanganella has included the assessment of several flow conditions and flood events ranging from operational flow (minimum environmental base flow requirements as stipulated by NSW DCCEEW and/or Water Infrastructure NSW) to flood flows (ranging from 50% AEP up to the Probable Maximum Flood or PMF) for both existing and proposed conditions

See Section 4 and Section 6 of the following documents for a detailed summary of flow and design scenarios derived and applied to the hydraulic modelling for Hartwood and Wanganella Regulators respectively:

- Hartwood Regulator – “Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Hartwood Weir to Piccaninny Weir Study Area (Document No.: DE19-823-YCM2A-DE-HY-RPT-0001)”, hereby referred to as “Hartwood Hydraulic Modelling Report” (refer to Appendix D) (3Rivers, 2024a).
- Wanganella Regulator – “Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Piccaninny Weir to Wanganella Weir Study Area (Document No.: DE19-823-YCM2B-DE-HY-RPT-0001)”, hereby referred to as “Wanganella Hydraulic Modelling Report” (refer to Appendix E) (3Rivers, 2024b).

Results from hydraulic modelling include:

- flood extents (provided in the form of inundation maps and GIS layers)
- flood characteristic grids (water level, depth, velocity, hazard, and bed shear stress)
- difference grids (showing afflux or change in water level between proposed and existing scenarios) and long-section plots
- processed results to assist in understanding of impacts associated with the proposed works to inform the EIS process.

Hartwood

Hydraulic modelling and flood assessment for the proposed Hartwood Regulator has been carried out through the development of a targeted hydraulic model for Yanco Creek, Billabong Creek, Piccaninny Creek, and Forest Creek developed in accordance with good modelling practice and the Hydraulic Modelling Standard Specification V1.2 (NSW DCCEEW, 2021). The hydraulic model (TUFLOW HPC on GPU) was primarily 2D with some key structures modelled in 1D for some or all of the flow scenarios.

The Hartwood hydraulic model was developed to understand, provide information and/or assess the inundation impacts for several flow scenarios, which range from operational flows to flood flows (20% AEP up to PMF). The Hartwood hydraulic model was based on a hydraulic model developed for the Reconnecting

River Country (RRC) programme (3Rivers, 2023b), with some changes based on the flow scenarios required and/or new information (such as additional survey). The location and extent of the Hartwood hydraulic model is shown on Figure 2.5 which shows that the model covers the following key areas:

- Yanco Creek from upstream of Kidman Way to the confluence with Billabong Creek
- Billabong Creek from upstream of Lower Woolshed Weir to downstream of Piccaninny Weir
- Forest Creek from where it breaks away from between Billabong Creek to just downstream of Warriston Weir and Conargo Road
- Piccaninny Creek.

The model results are valid for the following area (referred to from here on in as the 'Hartwood study area', which is also shown on Figure 2.5 relative to the hydraulic model boundaries):

- Yanco Creek downstream of Kidman Way
- Billabong Creek between Lower Woolshed Weir and Wanganella model boundary approximately 2.2 km downstream of Piccaninny Weir
- Forest Creek from its breakaway from Billabong Creek to the model boundary approximately 0.9 km downstream of Conargo Road.

The general model setup adopted for the hydraulic modelling is presented in Figure 2.5. The hydraulic model developed was a 2-Dimensional model with embedded 1-Dimensional elements. The upstream extents on both Yanco Creek and Billabong Creek had inflows applied to them based on the hydrology discussed in section 2.2.3.1. Flow was removed from the downstream extents on Billabong Creek and Forest Creek as indicated on Figure 2.5. The 2D domain was based on a variety of LiDAR products which were synthesised into a Digital Elevation Model (DEM).

A 2D TUFLOW HPC hydraulic model using the Graphical Processing Unit (GPU) and double precision (version 2023-01-AA-iDP) was used to allow the model to better represent small flows. Both the floodplain and channels were predominately modelled in 2-Dimensions (2D) at a grid resolution of 16 m with the sub-grid sampling (SGS) feature enabled at a spacing of 1 m. The use of quadtree functionality to alter the grid size was tested where the major waterways of interest are narrower (i.e. Piccaninny Creek) but testing found that this did not alter the modelling outcome. 1-Dimensional (1D) structures representing sub-grid scale features and operational structures were added as appropriate to represent key features within watercourses and/or on the floodplain.

This approach was considered appropriate due to the following factors or characteristics of the Study Area:

Given the braided nature of the watercourses and floodplain in the area, it was considered that 2D solution would better represent the movement of water across the landscape as opposed to a 1D solution. A 2D solution requires fewer assumptions regarding the connectivity and movement of water and allows this to be dynamically calculated through the simulation based on the topography and hydraulics. This is of particular benefit when the direction of flow changes throughout a simulation as occurs in the study area.

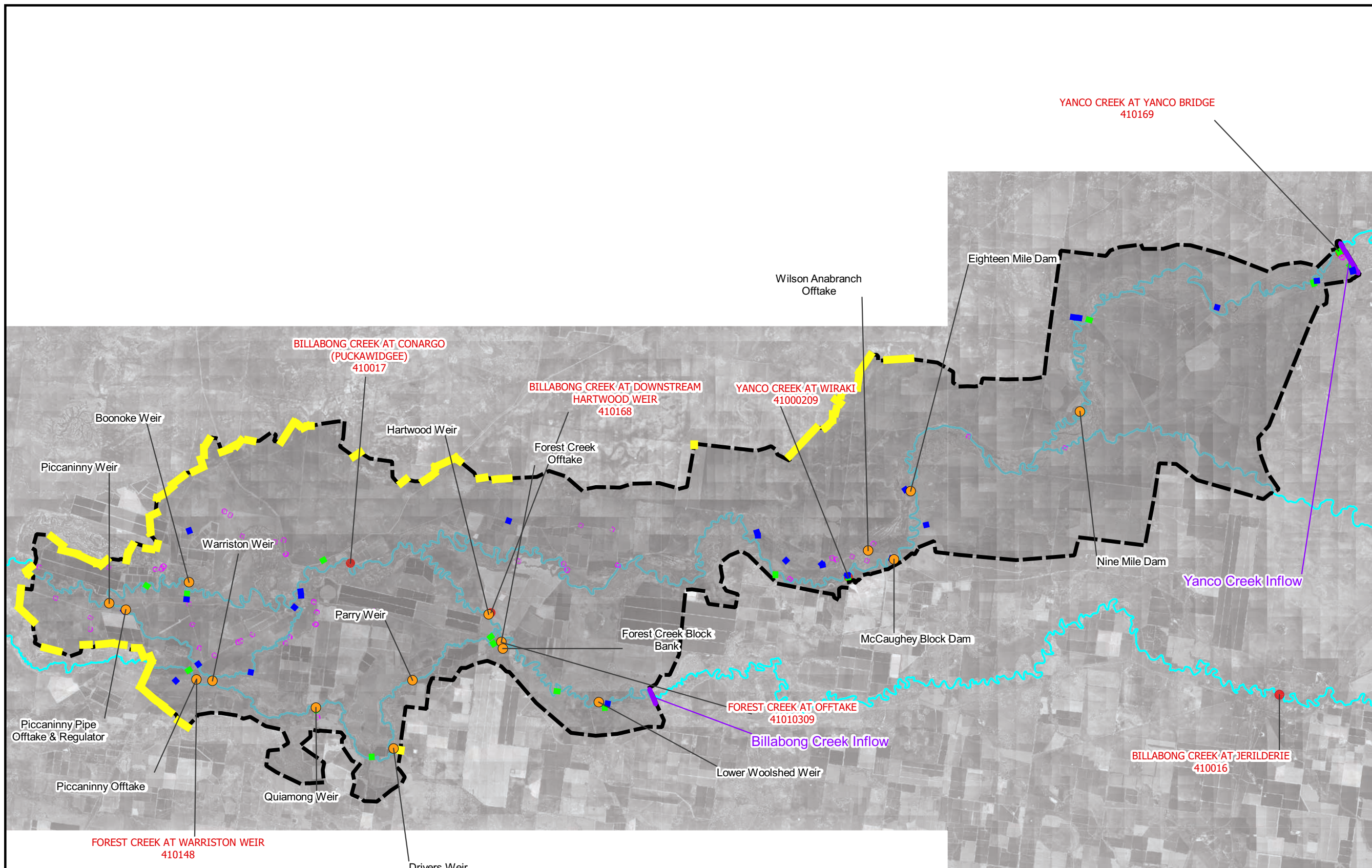
The Sub Grid Scale (SGS) sampling feature in TUFLOW incorporates topographic detail from within each grid cell and effectively creates a stage-storage relationship for each cell and cross-section at each grid face. This allows water to move through the model more realistically as sub-grid scale flowpaths are represented in the model. This means that coarser grids can run and produce accurate water levels but increases the importance of defining ridge lines appropriately.

The width of the channels was generally in the range of 3-5 grid cells recommended to accurately model channels in 2D and capture macro-losses. Further, given the low velocities it is not expected that hydraulic losses will be significant.

Except the major watercourses (Yanco Creek, Billabong Creek, Forest Creek, and Piccaninny Creek) most watercourses are ephemeral and have been captured in the LiDAR.

A significant portion of Billabong Creek was covered by bathymetric survey which allowed for the development of an accurate bathymetric surface for this watercourse.

Further details, including details on data, model build, calibration, and results for both existing and proposed conditions, are available in Appendix D, which contains the detailed modelling report: Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Hartwood Weir to Piccaninny Weir Study Area (DE19-823-YCM2A-DE-HY-RPT-0001).



Legend

- Hydraulic Model Boundary
- Upstream Inflows (2d_SA)
- Downstream Boundaries (2d_bc "HQ")
- Modelled significant structures
- Other Modelled Structures (1D Domain)
- Modelled Bridges (2d_lfcsh)
- Nominal Floodplain Structures (2d_zsh)
- Gauge Locations
- Key watercourses

GDA 2020 Zone 55
Scale: 1:200,000

0 4 8 km

DATA SOURCE:
NSW Map Data, 2021; Model layers, 3Rivers, 2023;
Bathymetry, Structures, Gauges and Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Model Schemetisation EIS
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Yanco_Modernisation_H2P_Report_Figures_GDA2020.qgz"

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
Figure 2.5: Hydraulic Model Schemetisation



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Wanganella

The Wanganella hydraulic model was developed to understand, provide information and/or assess the inundation impacts for a number of flow scenarios, which range from operational flows to flood flows (20% AEP up to PMF). The modelled 2D domain encompasses an area of about 257 km² across Billabong Creek, Forest Creek, Estuary Creek, and Eight Mile Creek developed in accordance with good modelling practice and the Hydraulic Modelling Standard Specification V1.2 (NSW DCCEEW, 2021). The model includes approximately 60 km length of Billabong Creek and was primarily 2D with some key structures modelled in 1D for some or all of the flow scenarios.

The Wanganella hydraulic model was based on a hydraulic model developed for the Reconnecting River Country (RRC) programme (3Rivers, 2023c), with some changes based on the flow scenarios required and/or new information (such as additional survey). The location and extent of the Hartwood hydraulic model is shown on Figure 2.6, which shows that the model covers the following key watercourses:

- Billabong Creek is typically 40-50 m wide although the width varies from around 20 m to more than 70 m in places.
- Forest Creek is smaller than Billabong Creek with a typical width of between 30-40 m.
- Eight Mile Creek is an ephemeral watercourse with a typical width of around 15-25 m and branches off Forest Creek at approximately 150 m upstream of Junction Weir.

The general model setup adopted for the hydraulic modelling is presented in Figure 2.6. Both the floodplain and channels were predominately modelled in 2D at a grid resolution of 16 m with the SGS feature enabled at a spacing of 1 m. 1D structures representing sub-grid scale features and operational structures will be added as appropriate to represent key features within watercourses and/or on the floodplain. The upstream extents on both Billabong Creek and Forest Creek had inflows applied to them based on the hydrology discussed in Section 2.2.3.1. Flow was removed from the downstream extents of Billabong Creek and Forest Anabran Creek as indicated on Figure 2.6. The 2D domain was based on a variety of LiDAR products which were synthesised into a Digital Elevation Model (DEM).

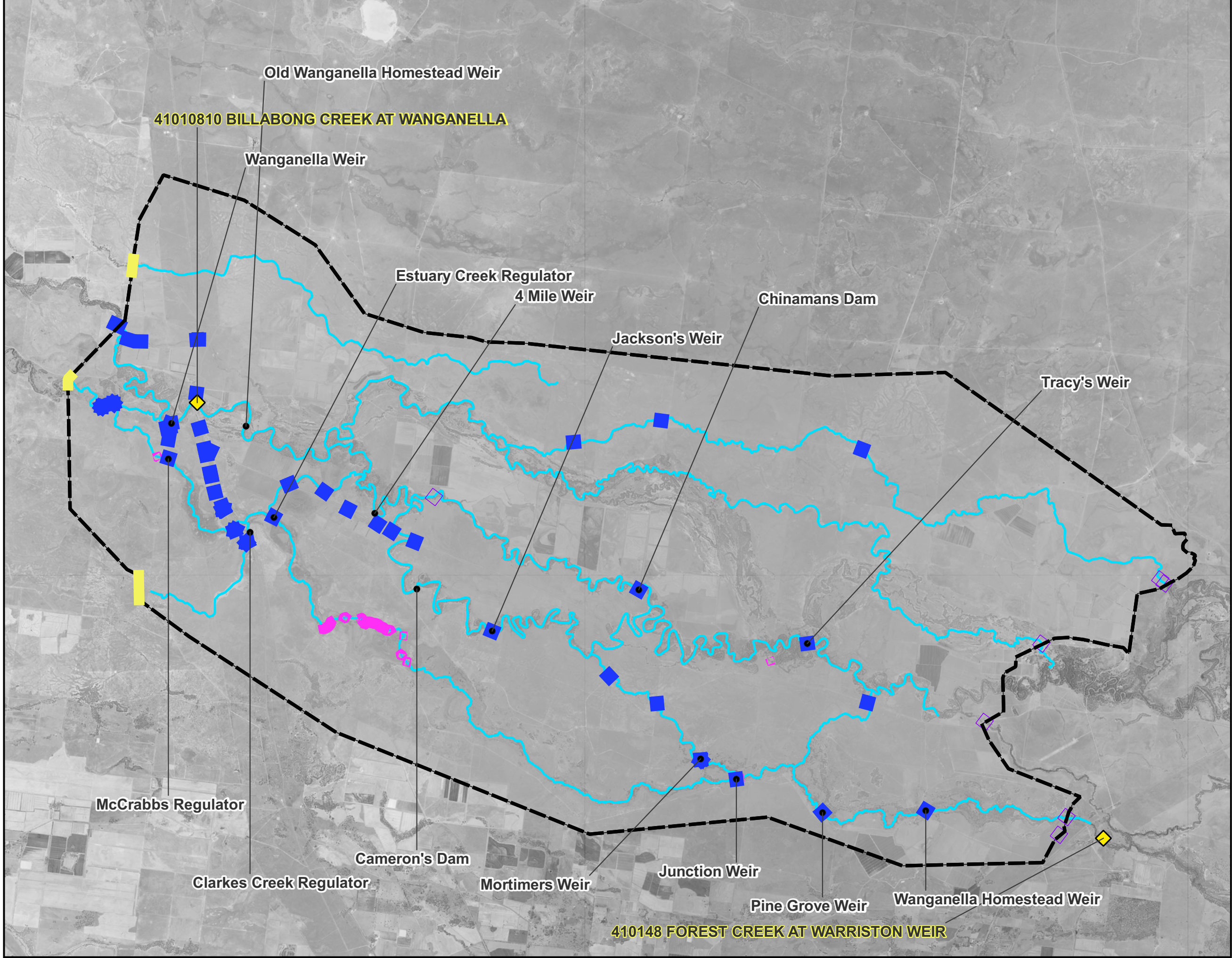
A 2D -TUFLOW HPC hydraulic model using the Graphical Processing Unit (GPU) and double precision (version 2020-10-AB) was used to allow the model to better represent small flows. All watercourses were represented in 2D based on the available LiDAR, bathymetric survey, and the infilled bathymetric data.

This approach was considered appropriate as:

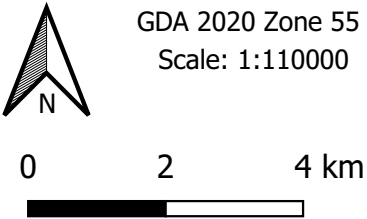
- Given the braided nature of the watercourses and floodplain in the area, it was considered that 2D solution would better represent the movement of water across the landscape as opposed to a 1D solution. A 2D solution requires fewer assumptions regarding the connectivity and movement of water and allows this to be dynamically calculated through the simulation based on the topography and hydraulics. This is of particular benefit when direction of flow changes throughout a simulation as occurs in the study area.
- The Sub Grid Scale (SGS) sampling feature in TUFLOW incorporates topographic detail from within each grid cell and effectively creates a stage-storage relationship for each cell and cross-section at each grid face. This allows water to move through the model more realistically as sub-grid scale flowpaths are represented in the model. This means that coarser grids can run and produce accurate water levels but increases the importance of defining ridge lines appropriately.
- The width of the channels was generally in the range of 3-5 grid cells recommended to accurately model channels in 2D and capture macro-losses. Further, given the low velocities, it is not expected that hydraulic losses will be significant.
- With the exception of the major watercourses (Billabong Creek, Forest Creek, and Eight Mile Creek) most watercourses are ephemeral and have been captured in the LiDAR.
- A significant portion of Billabong Creek was covered by bathymetric survey which allowed for the development of an accurate bathymetric surface for this watercourse.

- Other bathymetry can be infilled using Billabong Creek bathymetry together with surveyed cross sections, historical creek cross-sections, and local survey of structures.

Further details, including details on data, model build, calibration, and results for both existing and proposed conditions, are available in Appendix E which contains the detailed modelling report: Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area (DE19-823-YCM2B-DE-HY-RPT-0001).



- Main Map Legend
- 2D Model Area
 - Upstream Inflows (2d_SA)
 - Downstream Boundaries (2d_bc "HQ")
 - Modelled Significant Structures
 - Other Modelled Structures (1D Domain)
 - Modelled Bridges (2d_lfcsh)
 - Nominal Floodplain Structures (2d_zsh)
 - Key Watercourses
 - Gauges



GDA 2020 Zone 55
Scale: 1:110000

DATA SOURCE:
NSW Map Data 2021; Model layers, 3Rivers 2024; Structures, Gauges and Aerial NSW DCCEEW, 2021.

WORKSPACE:
Modelled Structures
"J:\IE\Admin\03_SouthernWater\3RP\56_Reconnecting_hydraulic_modelling\05_Technical\02_WP20\02_GIS\20240227_EIS_Report_Figures.ggz"

Yanco Creek Modernisation: Hydraulic Modelling - Piccaninny Weir to Wanganella Weir Work Package 20 Study Area
Figure 2.6: WP20 Model Schematisation



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3. Existing Flood Characteristics

3.1 Hartwood

There is minimal existing flood risk at Hartwood Weir and in the surrounding areas, with the faster and deeper flooding generally being contained to the creeks and defined flow paths and/or their associated floodplain corridor and other areas only engaged by ponding and/or flood fringe flows. Given the nature of Billabong Creek and the large surrounding catchments, high flow events are typically slow rising with surrounding floodplains and agricultural land gradually becoming inundated during flood events for extended periods. The existing Hartwood Weir operates as a fixed crest weir with manual drop boards that are typically removed during high-flow conditions. The existing weir creates a weir pool for water supply purposes (namely irrigation), which also regulates flow between Billabong Creek and Forest Creek via a diversion channel at Forest Creek Offtake and in higher flow events when flow overtops Forest Creek Block Bank. The upstream extent of the weir pool varies with flow scenario but can stretch up to around 16.5 km where it is restricted by Lower Woolshed Weir, and to Parry's Weir on Forest Creek if Forest Creek Offtake is open.

The most recent flood study for the area, the Conargo Floodplain Risk Management Study and Plan (2010), conducted modelling (HEC-RAS) for sections of Billabong Creek and Piccaninny Creek around the township of Conargo. Modelling of the 1% AEP (19,500 ML/d) indicated that only two residential properties in Conargo would be affected by shallow flood levels from Billabong Creek. Flooding mainly occurs around the banks of Billabong Creek and along or adjacent to local access roads that cross the floodplain in these areas.

The Yanco Creek System Environmental Flows Study (Alluvium, May 2013) provided findings and recommendations for the use of environmental water throughout the Yanco Creek system. The study included HEC-RAS modelling for some reaches in the study area and selected cross sections used for this study have been considered throughout the development of current hydraulic models. No council flood studies exist for the Hartwood area.

See Section 3.1.6 of "Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Hartwood Weir to Piccaninny Weir Study Area (DE19-823-YCM2A-DE-HY-RPT-0001)" for information and reference to the existing hydraulic models and previous flood studies that were considered during this flood study.

Modelling of existing inundation for the current Study is presented in Appendix B (refer to Figure B1 – B8), which shows that in the:

- 20% (1 in 5) AEP flood event (refer to Figure B3) - flow is largely confined to the watercourse channels of Billabong Creek, Yanco Creek, Forest Creek, Piccaninny Creek, Wilsons Anabranh, Box Creek, Browns Creek and Sheepwash Creek with some breakout flowpaths around Lower Woolshed Weir and in a few places along Forest Creek.
- 5% (1 in 20) AEP flood event (refer to Figure B4) - inundates a wider corridor along the same watercourses, engages Back Creek and has larger breakout areas, including new ones between Yanco Creek and Billabong Creek, Forest Creek and Piccaninny Creek, and Piccaninny Creek upstream of Forest Creek return flows to itself downstream.
- 1% (1 in 100) AEP flood event (refer to Figure B5) - inundates a wider corridor along the same watercourses and breakout areas, with Wilsons Anabranh being engaged from further upstream on Yanco Creek.
- Probable Maximum Flood (PMF) flood event (refer to Figure B8) - inundation covers the majority of the area with only minor areas between waterways being outside of the extents due to having naturally high terrain or protection from an embankment or levee.

3.2 Wanganella

There are two major waterway systems flowing eastwards near the downstream part of the Wanganella study area (i.e., focus area), including the Billabong Creek on the north and the Forest Creek / Eight Mile Creek system on the South. The existing Wanganella Weir is located on Billabong Creek approximately 1 km downstream of the Cobb Highway and the Wanganella township area. In a similar manner to Billabong

Creek at Hartwood Weir, the large surrounding catchment at Wanganella Regulator, high-flow events are typically slow rising. The surrounding floodplains, such as Wanganella Swamp, and agricultural land gradually becoming inundated during flood events for extended periods.

Estuary Creek, Forest Creek, Eight Mile Creek, and the Wanganella Swamp area are generally higher than Billabong Creek. Forest Creek / Eight Mile Creek is linked with Billabong Creek through Estuary Creek, however the exiting regulator at Estuary Creek is mostly blocked/unfunctional. The Forest Creek / Eight Mile Creek system also slightly interacts with Billabong Creek around the existing Wanganella Weir through breakout flows from Forest Anabranh in large flood events.

The existing weir operates with an adjustable crest level (dropboards) to create a weir pool upstream in Billabong Creek. However, the weir is currently non-operational and has been modelled as a fixed crest weir.

Some cross-sections of channels provided in the Yanco Creek System Environmental Flows Study (Alluvium, May 2013) have been considered throughout the development of hydraulic models for the existing Wanganella Weir. Other studies that were used to inform the existing condition for the existing Hartwood Weir, have not been used to inform the existing conditions or model development for Wanganella Weir as the available information does not cover the appropriate areas of Billabong Creek and the surrounding floodplains.

Modelling of existing inundation for the current Study is presented in Appendix C (refer to Figures C2 – C17), which shows that in the:

- 20% (1 in 5) AEP flood event flow (refer to Figures C4 and C12) is largely confined to the watercourse channels of Billabong Creek, Eight Mile Creek, Forest Creek, Estuary Creek, and Sheepwash Creek with some breakout flowpaths around the Wanganella Swamp area along Eight Mile Creek. Wanganella township between Billabong Creek and Lang Street is subject to minor inundation.
- 5% (1 in 20) AEP flood event (refer to Figures C5 and C13) inundates a wider corridor along the same watercourses, with larger breakout areas, including new ones along Billabong Creek downstream of Cobb Highway, which return flows to itself downstream. The inundation in Wanganella township between Billabong Creek and Lang Street also increases to some extent.
- 1% (1 in 100) AEP flood event (refer to Figures C6 and C14) inundates a wider corridor along the same watercourses and breakout areas, with Forest Anabranh being engaged between Billabong Creek and Eight Mile Creek. The flood water along Eight Mile Creek is also detained upstream of Cobb Highway to some extent. The area north of Billabong Creek and south of Lang Street is mostly under water although residential properties are above these flood levels, with inundation generally confined to public open space and backyards.
- Probable Maximum Flood (PMF) flood event inundation (refer to Figures C9 and C17) covers the majority of the area with only minor areas between waterways being outside of the extents due to having naturally high terrain or protection from an embankment or levee.

4. Impact assessment

An overview of the flood impacts, considered to be the difference between the “existing” and “proposed (developed)” case is provided in the proceeding sections for Hartwood and Wanganella Regulators respectively. For a more detailed presentation and analysis of these results please refer to Section 7 of the following documents:

- Hartwood Regulator – “Hartwood Hydraulic Modelling Report” (refer to Appendix D) (3Rivers, 2024a)
- Wanganella Regulator – “Wanganella Hydraulic Modelling Report” (refer to Appendix E) (3Rivers, 2024b).

Impact results are presented for both the construction phase and operational phase, as well as cumulatively considering the impact of other SDLAM works found within the assessed Study Areas.

To assess the flood impact of proposed structures, flood impact maps were prepared (Refer to Appendix B and Appendix C). These are maps that compare the existing case flood levels to the proposed case flood level (i.e. the difference between two flood levels). They have been calculated such that:

- increases in flood levels from existing to proposed are positive
- decreases in flood levels from existing to proposed are negative.

As there are a number of uncertainties in flood models it is necessary to select a modelling tolerance and for sensitive areas this has been selected to be ± 10 mm. This is based on the outcomes of the research project that informed the development of the National Guidelines for undertaking flood modelling: Australian Rainfall and Runoff (Ball et al., 2019). This research project (Revision Project 15, (Babister et al., 2012)) states “Typically, results are not reported to the nearest millimetre, and impacts less than 0.01 m are not reported, as they are considered to be within the precision of the numerical model and data.”

The criteria for flood impacts for this assessment are:

- ± 10 mm for sensitive land uses such as residential homes
- ± 50 mm for waterways, cropping and natural bushland.

Also considered are whether or not the area was previously inundated. For example, if a shed was not inundated in the existing case but was in the proposed case to a depth of 20 mm, then measures to manage this impact would be considered.

The flood impact maps are presented with a standard colour palette as follows:

- dark green greater than 250 mm reduction in flood level
- light green between 10 mm (or 50 mm) and 250 mm reduction in flood level
- pale yellow no impact ± 10 mm (or ± 50 mm)
- orange between 10 mm (or 50 mm) and 250 mm increase in flood level
- red greater than 250 mm increase in flood level.

4.1 Hartwood

4.1.1 Construction impacts

Decommissioning and construction involve the following elements:

- Decommissioning of the existing Hartwood Weir, likely in two parts with a coffer dam providing a dry work area for the portion of the weir and abutments being removed, while flow is allowed to pass through on the other side.
- Construction of the new proposed regulator downstream of the existing weir, likely in two parts with a coffer dam providing a dry work area for the portion being constructed, while flow is allowed to pass through on the other side.

The effects of the construction on flooding would be short-term for the period of construction, and the following risk assessment was completed for the proposed Hartwood regulators. These physical changes are smaller compared to the operational and permanent changes from the proposed regulators, which indicate potential impacts.

The chance of a flood event of a given magnitude or larger occurring during the construction period can be determined by considering the magnitude or Average Recurrence Interval¹ (ARI) of an event and the length of the construction period. These chances or probabilities have been calculated using the Risk Equation (see Shaw, 1994 or Laurenson 1987), and the results are listed in Table 4.1 for the construction periods together with different standard timeframes for context. The information in Table 4.1 shows the timeframe or period in the column headed Construction Period, which is the number of years over which the chance or probability is calculated. The columns to the right of this lists various ARIs and the chance of that ARI event being equalled or exceeded over the length of time in the first column. For example, there is a 63% chance that the 100-year ARI flood level would occur at least once in 100 years.

Over a construction period of 2-years (which is longer than the construction period for the regulators), there is about a 89% chance a flow rate of 2,900 ML/day at the “Billabong Creek @ Jerilderie (410016)” gauge will be equalled or exceeded. For context, this is equivalent to the chance that a typical drainage system would be overwhelmed over a 10-year period (on the basis of a level of service of the 5-year ARI). Assuming a level of service of the 5-year ARI for the coffer dams and the provision of adequate diversions to maintain normal flows, it is unlikely that there will be significant adverse impacts as flows are generally contained in channel up to the 5-year ARI (or 20% AEP) and hence there are no significant consequences.

Table 4.1 Chance of a flood event being equalled or exceeded for a given period.

Construction Period	Flood Event (ARI)									
	1.5-year	2-year	2.5-year ¹	3-year	4-year	5-year	10-year ²	20-year	50-year	100-year
2-year period	89%	75%	64%	56%	44%	36%	19%	10%	4%	2%
5-year period	100%	97%	92%	87%	76%	67%	41%	23%	10%	5%
10-year period	100%	100%	99%	98%	94%	89%	65%	40%	18%	10%
30-year period	100%	100%	100%	100%	100%	100%	96%	79%	45%	26%
50-year period	100%	100%	100%	100%	100%	100%	99%	92%	64%	39%
100-year period	100%	100%	100%	100%	100%	100%	100%	99%	87%	63%
Notes: 1. indicates that this is equivalent to the 2,900 ML/d event at the “Billabong Creek @ Jerilderie (410016)” gauge over the long term. 2. indicates that this is equivalent to the 5,500 ML/d event at the “Billabong Creek @ Jerilderie (410016)” gauge over the long term										

¹ ARI has been used for this element of the assessment as opposed to AEP as ARI in this context considers probabilities at a partial year scale – see <http://www.bom.gov.au/water/designRainfalls/#sec1g5> for details.

4.1.2 Operational impacts

A full outline of the flood impacts of the proposed works during their operation phase are presented in Section 7 of the Hartwood Hydraulic Modelling Report. In that section, results are presented for flow, afflux (or change in water surface level), and flood hazard represented by the flood vulnerability categories on Figure 4.1 for both the operational and flood flow scenarios. Results for the relevant events are presented in Appendix B, which shows the following general impacts:

- Operational flow scenarios
 - No change in flows (see Figure B9 and Table B1 in Appendix B for location and values of flows), which is expected given structures are operated to achieve a fixed flow split between Billabong Creek and Forest Creek from the weir pool in both existing and proposed scenarios.
 - No change in Water Surface Level (WSL) downstream of the proposed works or outside of Billabong Creek for all flow and proposed operating level scenarios (see Figure B10 – B15 and Figure B22 & B23 in Appendix B). Within Billabong Creek there was a significant increase in WSL between the proposed and existing regulators due to the shifting of the regulator downstream and creating an additional weir pool for all flow and operating level scenarios. The water levels within Hartwood weir pool increased and decreased as expected with the change in the height of gate operations, that is, if the gate were operated to achieve a higher water level the weir pool was consequently higher and vice versa. Upstream of the existing regulator water levels responded as follows, which resulted in the same directional change in the size of the overall flood extent within the weir pool:
 - For the proposed scenario where the weir pool was set to Minimum Operating Level (MinOL) there were decreased levels of up to around 40 mm for the MinOF (refer to Figure B10 and/or Figure B22) and 300 mm for the MaxOF (refer to Figure B11 and/or Figure B22) flow scenarios. In these scenarios, there was a 2.5% and 10% decrease in overall flood extent for MinOF and MaxOF flow scenarios respectively over existing conditions. Overall, these changes in flood levels and extents were contained within the watercourse and bounded by Lower Woolshed Weir on Billabong Creek and the Forest Creek Offtake (and associated infrastructure such as the Forest Creek Block Bank) on Forest Creek.
 - For the proposed scenario where the weir pool was set to Maximum Operating Level (MaxOL) there were increased levels of around 100 mm for the MinOF flow scenario (refer to Figure B13 and/or Figure B23) and decreased levels of up to 150 mm for the MaxOF flow scenario (refer to Figure B14 and/or Figure B23). In these scenarios, there was a 3% decrease and 10% increase in overall inundation extent for MaxOF and MinOF flow scenarios respectively over existing conditions. Overall, these changes in flood levels and extents were contained within the watercourse and bounded by Lower Woolshed Weir on Billabong Creek and the Forest Creek Offtake (and associated infrastructure such as the Forest Creek Block Bank) on Forest Creek.
 - For the proposed scenario where the weir pool was set to Full Supply Level (FSL) there were increased levels of up to 200 mm for the Maximum Operating Flow (MaxOF) (refer to Figure B15 and/or Figure B23) and around 400 mm for the Minimum Operating Flow (MinOF) flow scenarios (refer to Figure B12 and/or Figure B22). In these scenarios, there was a 5% and 31% increase in overall inundation extent for MaxOF and MinOF flow scenarios respectively over existing conditions. Overall, these changes in flood levels and extents were contained within the watercourse and bounded by Lower Woolshed Weir on Billabong Creek and the Forest Creek Offtake (and associated infrastructure such as the Forest Creek Block Bank) on Forest Creek.
- Flood flow scenarios:
 - There are only minor changes and redistribution of flows from the Hartwood weir pool as a result of the proposed Hartwood Regulator for events less (more frequent) than 1% (1 in 100) AEP event with flows increasing on Billabong Creek and decreasing on Forest Creek. The magnitude of these changes reduces peak flows by up to 5% (1 in 20) AEP event. These changes show the following:
 - 20% to 5% AEP – the proposed scenario has up to +1% on Billabong Creek flows and -2% on Forest Creek flows or a change of up to ± 22 ML/day relative to existing.
 - Flood flows greater than or equal to the 2% AEP event generally show very minor redistribution with decreasing flows on Billabong Creek and increasing flow on Forest Creek. The magnitude

of these changes increases from 1% (1 in 100) AEP to PMF event, which shows the following changes:

- 1% AEP to PMF - proposed scenario has up to -1.4% on Billabong Creek flows and +1.6% on Forest Creek flows or change of up to -400 to +245 ML/day relative to existing.
- There have also been some changes of up to +2% of flow on Yanco Creek due to altered tailwater levels on Billabong Creek.

The locations of comparison points and flows are presented in Figure B9 and Table B1 in Appendix B respectively.

- Hydraulic modelling results also present minor changes in water surface level (WSL) as a result of proposed Hartwood Regulator works (see Figure B16 – B21 and Figure B24 in Appendix B). Changes in WSL between existing and proposed conditions are reflective of the altered operation and control levels at the Hartwood Regulator and were as follows:
 - o For flood flows more frequent than the 5% (1 in 20) AEP event (refer to Figure B16 and/or Figure B24), the WSL in the Hartwood weir pool decrease, and the WSL downstream of the proposed regulator increase. The most significant changes in WSL are seen directly downstream and upstream of the Hartwood Regulator as expected. There are also minor changes to WSL along the lower parts of Yanco Creek for these smaller flood flow events, generally in the order of ± 10 mm and less than ± 50 mm as shown in the flood impact maps.
 - o For flood flows greater than or equal to the 5% (1 in 20) AEP event (refer to Figure B17, Figure B18 and/or Figure B24), there is minimal impact on WSL along Billabong and Yanco Creek downstream of Hartwood Regulator (generally less than ± 10 mm). There are minor upstream impacts of increasing levels and extents on Billabong Creek within the area between the existing weir and proposed regulator, Conargo Road, and the first access track across Billabong Creek (with changes ranging from just over +10 mm in 5% AEP to up to around +20 mm in 1% AEP and greater) as a result of Hartwood Regulator works.
 - o In events greater than 1% AEP and less than PMF (refer to Figure B19 – Figure B21 and/or Figure B24) there are some minor impacts to the west of the regulator due to a levee/irrigation channel just being overtopped, but these are changes of less than +25 mm. It is understood that the purpose of this levee/irrigation channel is for irrigation purposes and not flood protection. These changes in WSL have meant there is minimal to no change in flood extent within the study area, as a result of the Hartwood Regulator across the range of flood flow events that were modelled.
- The flood flow scenario results show that there has been minimal change in hazard category distribution, with noted changes across all scenarios of around +0.6% to -1.7% within the area of interest within and a short distance downstream of the proposed Hartwood Regulator weir pool (see Figure B25 in Appendix B).

The township of Conargo is the closest populated area. There is little to no change in flow and WSL across all operational and flood flow events, including the PMF event, within and around the township. In terms of flood flows, it was found that in all events changes were generally all minor (less than ± 50 mm). As a result of this, it can be concluded that the current flood risk in Conargo is not impacted by the operation of the proposed Hartwood Regulator and hence the existing community flood management is likely to be sufficient for proposed conditions.

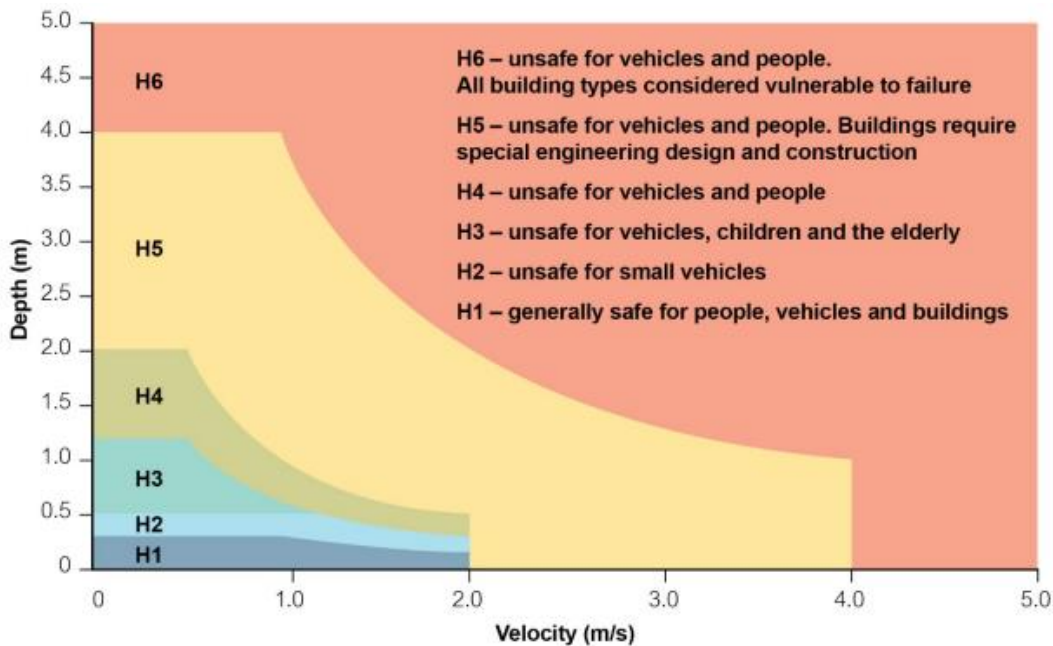


Figure 4.1 General flood hazard vulnerability curve categories (copy of Figure 1 from “Flood Hazard: Flood Risk Management Guideline FB03” – NSW DCCEEW, 2023)

The NSW Flood Risk Management Manual states there are a number of techniques to define the flood function or hydraulic categorisation of the waterway and given the minimal impact of proposed works on other variables, particularly hazard categories, and the in-stream nature of the structure it was concluded that this will not have changed between scenarios and a detailed assessment was not undertaken.

It should be noted that the results presented above are reflective of modelling that has included all proposed upgrades within the study area and should be considered in the context of the assumptions and limitations noted in this report (or the more detailed Hartwood Hydraulic Modelling Report in Appendix D). The results summarised above are focused on impacts in and around the proposed Hartwood Regulator and do not discuss changes that can be attributed to either Forest Creek Return Regulator or Wilsons Anabranh Offtake, which were shown to be independent of any impacts of Hartwood Regulator (see discussion in section 4.1.3).

Considering all of the above, the changes and impacts that have been identified through hydraulic modelling as a direct result of the Hartwood Regulator do not have a significant impact on the flood characteristics and floodplain behaviour of the study area, with changes experienced being as expected due to altering the location and level of the weir pool control. Directly upstream and downstream of the Hartwood Regulator experience the largest changes as expected, however, the overall flood risk in this area is not significantly altered as a result of the proposed works.

It is important to note that some impacts are also the result of proposed operational rules, particularly in more frequent flood events when the gates are assumed fully opened as this allows the flow to pass through at lower levels than previously. In larger (less frequent) flood events, where some flow bypasses the new regulator, the impact of the final design will be reduced with the inclusion of a ford crossing to the proposed access track on the western bank where an existing flood runner exists.

4.1.3 Cumulative impacts

The detailed hydraulic modelling has demonstrated that the proposed infrastructure for the other parts of the Yanco Creek Modernisation Project within the study area, comprising of proposed regulators on Forest Creek and Wilsons Anabranh, are hydraulically independent. Therefore, there are no cumulative flood impacts of these works when combined with the proposal. This conclusion is supported by the afflux maps presented in Appendix B (refer to Figure B26 – B28), which show that there is a slight improvement or no change (± 50 mm) in level when comparing results for models with all SDLAM works to that with just those at Hartwood Regulator.

4.1.4 Climate Change considerations

Climate change will lead to increased rainfall intensity and larger flood events. For this assessment, the increase in flood events has been represented by factoring the peak flows determined at gauges through the Flood Frequency Analysis (see section 2.2.3.1). Additionally, the 0.5% and 0.2% AEP events have also been considered as indicated in the SEARs (see Table 1.2) to assess the sensitivity of the factoring method.

The use of the factoring of flows approach was considered appropriate given the regional nature of flows in the Billabong Creek system, together with the complex floodplain characteristics. This approach was developed in consultation with NSW DCCEE. Further, the traditional means of altering hydrologic inputs to ascertain altered flows as a result of climate change cannot be used for this study. To that end, 3Rivers have considered climate change as follows:

- The impact of climate change with respect to flooding will result in increased peak flows for a given AEP event (typically the 1% AEP event is considered for planning purposes) and the percentage increase in these peak flows will increase with time. Hence, the largest increase in peak flows will occur at the end of the design life, which in the case of the regulators will be 100 years. So, considering the flood impacts under the current conditions and under climate change conditions at 2100, will effectively “bookend” the potential flood impacts. By modelling these two scenarios and undertaking impact assessments it will be possible to understand the potential impact of climate change throughout the design life of the regulators. Given that there is only a minor impact in the current conditions and at 2100, there will only be a minor impact between current conditions and 2100 as outlined below.
- Using the 1% AEP flows for the study area have been factored using ARR Data Hub values and/or interim climate change guidelines (DCCEE, 2023) together with the methodology in Ladson & Pedruco, 2022. The outcomes of this are summarised in Table 4.2. This table also includes the 0.5% (1 in 200) and 0.2% (1 in 500) flow estimates, which shows that the estimated 1% AEP with climate change flow at 2090 and 2100 falls between the 0.5% and 0.2% AEP events. These events were noted as proxies for climate change scenarios in the SEARs and were found to be 103.5 % and 99.1% of the current flow estimate for the factored 1% flow in the 2090 and 2100 scenarios respectively.
- The potential flood impacts for the 1%, 0.2%, and 0.5% AEP are all minor as illustrated by the maps in Appendix B (refer to Figure B18 – B21). In these maps, there are no changes to flood levels within a tolerance of ± 50 mm except for small areas. In these maps, potential impacts decrease with the increasing rarity (and flow) of the events i.e. there are smaller areas of impact in the 1% AEP event compared to the 0.5% AEP event. Hence under climate change conditions, potential impacts will decrease in the future although these will still be minor.

Table 4.2 *Modelled flow rates and climate change estimate for Billabong Creek Inflow – just upstream of Hartwood Regulator*

AEP	Current peak discharge in ML/d	Factored peak discharge in ML/d at 2090 (ARR Data Hub losses and ARR Data Hub rainfall factors based on ‘RCP 8.5’ scenario)	Factored peak discharge in ML/d at 2100 (ARR Data Hub losses and interim climate change guidance on rainfall factors based on ‘SSP5-8.5’ scenario for storms > 24h)
1% (1 in 100)	10,900	13,600	16,400
0.50% (1 in 200)	13,100	-	-
0.20% (1 in 500)	16,500	-	-

4.2 Wanganella

4.2.1 Construction impacts

Decommissioning and construction involve the following elements:

- Decommissioning of the existing Wanganella Weir, likely in two parts with a coffer dam providing a dry work area for the portion of the weir and abutments being removed, while the flow is allowed to pass through on the other side.
- Construction of the new proposed regulator downstream of the existing weir, likely in two parts with a coffer dam providing a dry work area for the portion being constructed, while the flow is allowed to pass through on the other side.
- Construction of a flood bypass channel on the floodplain within Wanganella Reserve.

The effects of the construction on flooding have not been modelled. Any such effects will be short-term for the period of construction. Section 4.2.2 provides details of the impact assessment for the proposed Hartwood regulators (operational impacts) including modelled results. These physical changes during construction are smaller compared to the operational and permanent changes and consideration of the operational impacts provide an indication of potential impacts.

As outlined in section 4.1.1 an appropriate level of service for the assessment of construction impacts would be the the 5-year ARI (or 20% AEP) event assuming a construction period of 2 years which equates to a ~3,750 ML/d at the Billabong Creek at Wanganella gauge. The inundation modelling for operational impacts has demonstrated that the 20% AEP event impacts are contained in-banks with some small breakouts into the floodplain including the low-lying areas to the rear of Lang Street in existing conditions. Hence there are no significant construction phase flood impacts or consequences.

4.2.2 Operational impacts

An outline of the flood impacts of the proposed works during the operation phase are summarised in this section, with maps, tables, and figures presented in Appendix C. Results are presented for flow, afflux (or change in water surface level), flood hazard represented by the flood vulnerability categories (in section 4.1.2) for both operational and flood flow scenarios.

Initial hydraulic modelling of the development proposal showed increased flood levels in the vicinity of building on Lang Street. To mitigate this impact the flood relief channel was incorporated into the design which offset increases in flood levels from the proposals in the 2% AEP event and larger (or rarer) events. The invert of this channel can be lowered to alleviate more frequent events if required. All results presented in this Section and the Cumulative impacts Section include the flood relief channel.

Results for the relevant events are presented in Appendix C, which shows the following general impacts:

- Operational flow scenarios:
 - As summarised in Table C1 in Appendix C (see Figure C1 for the location of flows), no change in flows under all flow scenarios when control was set to either Minimum Operational Level (MinOL) or Maximum Operational Level (MaxOL). However, when control is set to Full Supply Level (FSL), there is a reduction in flow of 5 – 6 ML/day (Table C1), most likely due to attenuation as a result of the increase in the inundation area. This is not considered a significant change as the flow in the fishway is at 20 ML/day under all scenarios, and the change of flow rate does not cause an inundation impact.
 - As illustrated in Figures C18 – C23, C30 – C35, C42, and C43 in Appendix C), note there is no change or a reduction in WSL downstream of Wanganella Weir or outside of Billabong Creek for all operational flows and proposed operating level scenarios. Within Billabong Creek there were increases in WSL between the proposed and existing regulators due to shifting the proposed regulator downstream for all flow and operating levels. There was also a similar level of increase in WSL upstream of the proposed regulator (i.e. the Weir Pool area) as summarised below:
 - When the control level was set to FSL, the WSL upstream of the Wanganella Weir (i.e., within the pool area) reached 82.1 m AHD. This means an increase in WSL of 1,280 mm upstream of

the Wanganella Regulator under Minimum Operational Flow (MinOF) scenario (refer to Figures C20, C32, C42) and an increase in WSL of 1,050 mm under Maximum Operational Flow (MaxOF) scenario (refer to Figures C23, C35, C43), respectively.

- When control was set to MaxOL, the WSL increased by up to 190 mm upstream of the Wanganella Weir under MinOF scenario (refer to Figures C19, C31, C42) while no change of WSL (less than ± 10 mm) was identified under MaxOF scenario (refer to Figures C22, C34, C43).
- When control was set to MinOL, no change of WSL upstream of the Wanganella Weir was identified under all flow scenarios (less than ± 10 mm). See Figures C18, C21, C30, C33, C42 and C43.
- The increase in water level and slight increase of inundation extent in scenarios mentioned above were fully contained within the Billabong Creek channel and no impact extends outside of the watercourse.

■ Flood flow scenarios:

- As summarised in Table C1 in Appendix C (see Figure C1 for location of flows), flows in Billabong Creek exhibit minor to moderate variations during different flood events, which are detailed below:
 - For 20% AEP and 5% AEP events, the change in flows in Billabong Creek both upstream and downstream of Wanganella Weir are very minor (i.e., change up to 0.03% or 2 ML/Day).
 - For events greater than or equal to the 1% AEP, relatively minor increase in flows in Billabong Creek have been identified upstream and immediately downstream of Billabong Creek at Wanganella Gauge (Gauge No 41010810) Weir, i.e., approximately up to +0.1% (+10 ML/Day), +0.4% (+76 ML/day), +0.6% (+152 ML/Day), and +1.1% (+438 ML/Day) on Billabong Creek flows during 1%, 0.5%, 0.2%, AEPs, and PMF, respectively. However, decrease in flows in Billabong Creek has been identified immediately upstream and downstream of Wanganella Weir, i.e., approximately up to -6.4% (-964 ML/Day), -12.3% (-2,295 ML/day), -15.3% (-3,571 ML/Day), and -11.9% (-3,225 ML/Day) on Billabong Creek flows during 1%, 0.5%, 0.2%, AEPs, and PMF, respectively, due to some flow bypassing part of Billabong Creek channel due to the engagement of the new flood relief channel to the north (i.e., between Wanganella Gauge and Wanganella Weir).
- Hydraulic modelling results also present minor to moderate changes in water surface level (WSL) as a result of the proposed Wanganella Regulator works. Changes in WSL between existing and proposed conditions are reflective of the effect of the proposed Wanganella Regulator. Two sets of flood impact maps were prepared; broad-scale maps that highlight any potential widespread impacts within a modelling tolerance of ± 50 mm and maps prepared to highlight impacts to Wanganella Township with a modelling tolerance of ± 10 mm. The Wanganella Township maps were prepared to highlight any potential impacts to private residences using a smaller tolerance than for other land uses such as public open space and agriculture.
 - For 20% and 5% AEP events, there are minor to moderate increases in WSL upstream of Wanganella Weir due to the proposed regulator, with changes of up to approximately +86 mm and +21 mm during 20% and 5% AEP events respectively (refer to Figures C24, C25, C36, C37, and C44). The increases of the WSL (afflux) are mostly restricted within the Wanganella Weir Pool upstream of the Wanganella Weir, i.e., not causing impact in the neighbouring sites in the floodplain, except for a small riparian zone area in Wanganella township on the north bank of Billabong Creek and rear of Lang Street, which is discussed further below.
 - Conversely, for events greater than or equal to 1% AEP events, the upstream and immediately downstream of Wanganella Weir experience minor decreases in WSL, with changes of up to approximately -25 mm, -52 mm, -58 mm, and -22 mm in 1%, 0.5%, 0.2%, AEPs and PMF events, respectively (refer to Figures C26-C29, C38-C41, and C44.). The reduction in these larger events is the result of the engagement of the new flood relief channel to the north in these events, which is designed to activate in those rare events. There is a localised minor impact (i.e., up to +18 mm afflux) immediately downstream of the flood relief channel, which is restricted within the natural reserve (riparian zone), i.e., not affecting private land. There are

flood level increases to the south of Billabong Creek in the Forest Creek / Eight Mile system shown on the mapping, but these are due to the proposed Wanganella Swamp infrastructure which is further discussed below in Section 4.2.3.

- The flood flow scenario results show that there has been minimal change in hazard category distribution with noted changes across all scenarios of around -0.12% to +0.07% within the study area (refer to Figure C45). These changes largely relate to the altered position of the control and the operating rules that allow more flow through the structure in smaller events and/or due to the activation of the flood relief channel in larger, less frequent floods.

The mapped flood impact (afflux) results in Figures C36 and C37 in Appendix C show that the area between Billabong Creek and Lang Street in Wanganella township, including several private properties (i.e. backyards), experienced moderate increase in flood levels (approximately +68 mm) during 20% AEP event, and minor flood level increases (approximately +16 mm) during 5% AEP events. These increases do not affect buildings due to the steep slope from Billabong Creek to Lang Street. The impact was not found during 1% AEP event or above with the flood relief channel in place. Nevertheless, the change in flood characteristics in this area are unlikely to result in an increase of flood risk, because of the following reasons:

1. There are no flood level increases to the existing dwelling (i.e. there is no change in flood level within +/-10 mm tolerance to the residential dwellings).
2. The evacuation (emergency) route through Lang Street is not affected (i.e. not inundated during 0.2% AEP or below and no afflux in PMF event).
3. The impacted area would be classified as floodway or flood storage in 1% AEP, and thus there are no increases in these extents at the planning level and there should be no future development in the affected area.

Based on the results presented, the proposed works at Wanganella Regulator do not have a significant impact on the flood characteristics of the Study Area. As discussed in Section 4.1.2, it also be concluded that the flood function or hydraulic categorisation will not have changed between scenarios as a result of the proposed works.

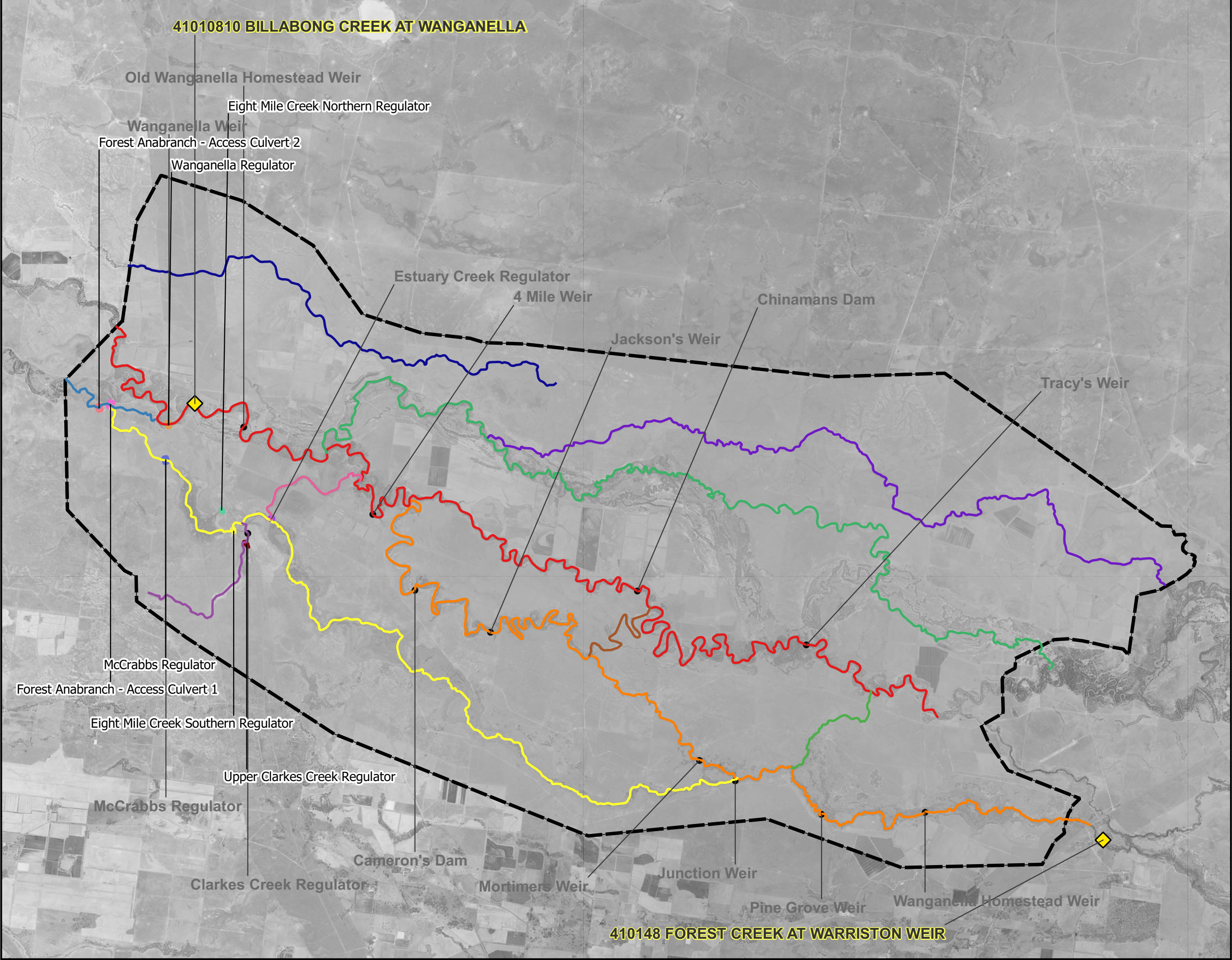
4.2.3 Cumulative Impact Assessment

4.2.3.1 Other works in Wanganella Swamp

There are several proposed structures in the Wanganella Swamp area as part of the Yanco Creek Modernisation Project which are not directly related to the Wanganella Regulator. The locations of those works are shown in Figure 4.2.

The key features of the proposed structures in the Wanganella Swamp area are summarised below. For a detailed description of the proposed structures and the representation in hydraulic modelling, refer to the Wanganella Hydraulic Modelling Report (enclosed in Appendix E). It is of note that these structures are currently under development and of the options considered those that locally have the largest flood impact have been modelled. The result of this is that the cumulative assessment can be considered conservative.

- Eight Mile Creek Northern Regulator – including rock embankment dam structure with water quantity control regulator and a board crested shape water spillway on the existing Eight Mile Creek located upstream of the existing 4 x 3.05 m (W) x 1.63 m (H) box culverts under the Cobb Highway. The gated weir includes ten (10) gates by 1.20 m wide using lay flat technology, with an invert level of 84.70 m AHD.
- Eight Mile Creek Southern Regulator – including rock embankment dam structure with water quantity control regulator and a board crested shape water spillway on the existing Eight Mile Creek located upstream of the existing 2 x 2.30 m (W) x 2.45 m (H) box culverts under the Cobb Highway. The gated weir includes four (4) gates by 1.20 m wide using lay flat technology, with an invert level of 84.70 m AHD.



Main Map Legend

- 2D Model Area
- Existing Structures
- Gauges

Key Watercourses

- Billabong Creek
- Forest Anabbranch
- Back Creek
- Clarkes Creek
- Eight Mile Creek
- Estuary Creek
- Flood Creek
- Forest Creek
- Browns Creek
- Sheepwash Creek
- Two Mile Creek

Location of Works (Drawing No.)

- Wanganella Regulator ("DE19-823-YCM2C-DE-CV-DRG-0021")
- Eight Mile Creek Northern Regulator ("DE19-823- YCM1B - DE-CV-DRG-0021")
- Eight Mile Creek Southern Regulator("DE19-823-YCM1B-DE-CV-DRG-0031")
- Upper Clarkes Creek Regulator ("DE19-823-YCM1B-DE-CV-DRG-0043")
- Estuary Creek Regulator ("DE19-823-YCM1B-DE-CV-DRG-0061")
- McCrabbs Regulator ("DE19-823-YCM1B-DE-CV-DRG-0012")
- Forest Anabbranch - Access Culvert 1 ("DE19-823-YCM1B-DE-CV-DRG-0081")
- Forest Anabbranch - Access Culvert 2 ("DE19-823-YCM1B-DE-CV-DRG-0086")

GDA 2020 Zone 55
Scale: 1:110000

0 2 4 km

DATA SOURCE:
NSW Map Data 2021; Model layers, 3Rivers 2024; Structures, Gauges and Aerial NSW DCCEEW, 2021.

WORKSPACE:
Modelled Structures
"J:\IE\Admin\03_SouthernWater\3RP\56_Reconnecting_hydraulic_modelling\05_Technical\02_WP20\02_GIS\20240227_EIS_Report_Figures.qgz"

Yanco Creek Modernisation: Hydraulic Modelling - Piccaninny Weir to Wanganella Weir Work Package 20 Study Area
Figure 4.2: WP20 Proposed Locations of works (Wanganella Regulator and other works)



DISCLAIMER:
Produced by 3RP for the Yanco Creek Modernisation Program - Part 2 Wanganella Regulator within the Reconnecting River Country Work Package 20 (RRC WP20) area, which are both SOLAM projects.
3Rivers does not warrant that this document is definitive nor free of errors and does not accept liability for any loss caused or arising from reliance upon information provided herein.
This data should be read in conjunction with the latest revision of the Report entitled "Billabong Creek Regulators Flood Impact Assessment" and is subject to the assumptions and qualifications contained therein. If the report is yet to be released, these assumptions and qualifications must be confirmed by reference to 3Rivers.

- Upper Clarke's Creek Regulator – including rock embankment structure with water quantity control regulator and a broad-crested shape water spillway within the existing Upper Clarkes Creek located approximately 13 m upstream of the existing 6 x Ø 0.75 m Culverts under the Cobb Highway. The gated weir includes one (1) by 1.20 m wide lay flat gate, with an invert level of 85.70 m AHD. This may be removed from the Wanganella Swamp project but has been retained in the modelling to demonstrate the worst case scenario.
- Estuary Creek Regulator – including a block bank weir pool structure that seamlessly integrates with the existing block bank. This integration includes the incorporation of a water quantity control regulator positioned at the front of the proposed 1.80m (W) x 1.50m (H) box culvert. The gated weir includes one (1) by 1.8 m wide lay flat gates with an invert level of 84.90 m AHD. This structure was modelled as open in the proposed case modelling whereas in the existing case modelling the structure is understood to have been closed during the 2022 flood event and was modelled as 100% blocked. This is considered a conservative assumption with respect to flood impacts as discussed below.
- McCrabbs Regulator – including a block bank weir pool structure that seamlessly integrates with the existing block bank. This integration includes the incorporation of a water quantity control regulator positioned at the front of the proposed 1.80 m (W) x 1.50 m (H) box culvert. The gated weir includes one (1) by 1.8 m wide lay flat gates with an invert level of 84.00 m AHD.
- Forest Anabranh Access Culverts 1 & 2 – two access culverts to supplant the pre-existing cross drain infrastructure. Access Culvert 1 is strategically positioned at the confluence of Forest Creek and Eight Mile Creek, serving as a pivotal point for effective water flow management. Access Culvert 2 is situated approximately 400 m downstream from Access Culvert 1, contributing to the enhancement of drainage efficiency within the designated area. Both culverts are proposed to be 2 x 1.20 m (W) x 1.20 m (H) box culverts.

4.2.3.2 Cumulative Impacts

The cumulative impacts were analysed through the modelling of a proposed scenario with all the proposed works, including Wanganella Regulator and Wanganella Swamp Regulators, for 20%, 5%, and 1% AEP events. The flood impact maps (all proposed works vs existing) are presented in Figures C46 – C51 of Appendix C.

The “all works” scenario (cumulative) flood impact maps (Figures C46 – C51), together with the Wanganella Regulator only scenario flood impact maps (Figures C24 – C26, C36 – C38), collectively show that:

- The impact from the proposed Wanganella Regulator (Wanganella Regulator only vs Existing) is restricted within the Billabong Creek area and does not extend to the Wanganella Swamp area, as shown in Figures C24 – C26.
- The introduction of other works in the Wanganella Swamp area could potentially cause increase of water levels in Estuary Creek up to +93 mm, +75 mm, and +150 mm during 20%, 5%, and 1% AEP events, respectively (refer to Figures C46 – C48), and impact in the area upstream of Cobb Highway up to +74 mm during 1% AEP event (refer to Figure C48). However, as these impacts are only in the cumulative case model results, they are caused by Wanganella Swamp works, not by the proposed Wanganella Regulator.
- Comparison of the Wanganella Regulator only works to the cumulative works results shows that there are larger impacts in the Billabong Creek resulting in the cumulative works results in Billabong Creek. Specifically, the afflux upstream of the Wanganella Regulator is up to approximately +86 mm (20% AEP) and +21 mm (5% AEP) under Wanganella Regulator only scenario (refer to Figures C24, C25, C36, and C37), which is increased to up to approximately +128 mm (20% AEP) and +43 mm (5% AEP) under “all works” scenario (refer to Figures C46, C47, C49, and C50). As the only connectivity between the Forest Creek / Eight Mile Creek system is Estuary Creek in the 20% and 5% events it can be concluded that this is the source of the flood level increase. It is of note that the Estuary Creek Regulator was modelled as closed in the existing case and open in the cumulative proposed case and it is the difference in the operation of this regulator that causes the increases in flood levels in Billabong Creek between the regulator only case and the cumulative case.

The above results show that the Wanganella Regulator will not affect the Wanganella Swamp area while the Wanganella Swamp works can impact the Billabong Creek area in certain locations (i.e., through the Estuary Creek regulator). This is anticipated for the following reasons:

- The southern waterways (i.e., Estuary Creek, Eight Mile Creek, and Forest Anabranh) are generally higher than the northern waterway (i.e., Billabong Creek).
- The proposed Estuary Creek Regulator was modelled as open which releases more water into Estuary Creek compared with the existing Estuary Creek Regulator which was modelled closed, resulting in afflux in Estuary Creek and part of Billabong Creek.

As noted above, the design of the Wanganella Swamp works is a work-in-progress, and the worst case was used in this cumulative impact assessment. It is anticipated that a reduction of the impacts can be achieved through further design refinements and modelling iterations. Moreover, it is understood that the Estuary Creek regulator was closed during the 2022 flood event and was modelled as closed (100% blocked) in the existing conditions inundation modelling. In the proposed case has the regulator fully open with the downstream existing culvert upsized to 1.8 m (W) x 1.5 m (H). This represents the worst case with respect to potential flood impacts.

The inundation results, shown in Appendix C, demonstrates the cumulative impacts are greater in more frequent events and there are no significant impacts for larger (rarer) events within the model tolerance.

In more frequent events (those smaller than the 20% AEP event) the modelling shows that impacts in terms increase in water level are generally confined to the watercourse and billabongs. There were some increases to water levels in the low-lying areas of the properties along Lang Street, noting that the buildings were not impacted in these events i.e. the buildings are outside of the flood extents.

While there is some uncertainty in the current operations of the regulator, in practice operational decisions are taken during a flood event that balance potential impacts. These decisions take into account minor impacts to private property (but no buildings) verses potential impacts to roads such as closing the Cobb Highway. In effect, this is an ongoing flood management response that is taken on a case-by-case basis under the existing management plans including the operator (WaterNSW) and Council.

Given the conservative nature of the assessment and the small flood level impacts form the Estuary Creek regulator, these potential flood level impacts are considered minor.

4.2.4 Climate Change considerations

The same approach adopted for the Hartwood Regulator (see section 4.1.4) was applied to the Wanganella Regulator. Specifically, the modelled outflows from the Hartwood hydraulic model were extracted and applied as inflows to the Wanganella hydraulic model for 0.5% and 0.2% AEP flow scenarios, which were noted as proxies for climate change scenarios in the SEARs. Table 4.3 confirms that the 0.5% and 0.2% AEP are good approximates for climate change as they are 99.1% and 95.1% of the current flow estimate for the factored 1% flow in the 2090 and 2100 scenarios respectively.

The existing condition flood depth maps for the 0.5% and 0.2% AEP events (i.e. climate change proxies) are illustrated in Figures C7, C8, C15, and C16 in Appendix C. The potential flood impact maps are shown in Figures C27, C28, C39, and C40 in Appendix C. The impact maps for the 0.5% and 0.2% AEP events exhibit similar patterns as those for the 1% AEP event. Specifically, a general decrease of water levels is achieved in the area upstream and immediately downstream of the Wanganella Regulator due to the implementation of the flood relief channel, while a localised impact (i.e., up to +20 mm afflux) immediately downstream of the flood relief channel is observed during 0.5% and 0.2% AEP events, respectively, which are all contained within the natural reserve (riparian zone) and not affecting any private land.

Based on the results presented, the proposed works at Wanganella Regulator would not have a significant impact on the flood characteristics of the study area under climate change scenarios.

Table 4.3 *Modelled flow rates and climate change estimate for flows at “Billabong Creek @ Wanganella (41010810)” gauge.*

AEP	Current peak discharge in ML/d	Factored peak discharge in ML/d at 2090 (ARR Data Hub losses and ARR Data Hub rainfall factors based on ‘RCP 8.5’ scenario)	Factored peak discharge in ML/d at 2100 (ARR Data Hub losses and interim climate change guidance on rainfall factors based on ‘SSP5-8.5’ scenario for storms > 24h)
1% (1 in 100)	15,552	19,674	23,653
0.50% (1 in 200)	19,852	-	-
0.20% (1 in 500)	24,867	-	-

4.3 Consistency with any Rural Floodplain Management Plans

The sites are not within an area subject of a rural floodplain management plan. The sites are downstream of the area covered by the Billabong Creek Floodplain Management Plan and upstream of the area covered by the Edward and Wakool Rivers Stage 1 Floodplain Management Plan. The sites are also outside the areas proposed to be covered by replacement floodplain management plans for the Murrumbidgee River Valley and the Murray River Valley.

Additionally, as there is fundamentally no change in the flood characteristics due to the proposals, it can be concluded that the flood hazard and hydraulic functions of flow conveyance in floodways and flood storage characteristics remain consistent with current conditions.

5. Mitigation and management of impacts

The inundation modelling discussed in section 4 demonstrates that there are no significant flood impacts. The proposal has addressed potential impacts near Wanganella Township through the inclusion of a flood bypass channel. As the flood bypass channel has been incorporated into the proposal it has not been discussed in this section.

6. Conclusions

The impact assessment for the proposed Hartwood Regulator and Wanganella Regulator described in this report has demonstrated that there will be no significant detrimental increases to properties, assets, and infrastructure. As there is fundamentally no change in the flood characteristics due to the proposals, it can be concluded that the flood hazard and hydraulic functions of flow conveyance in floodways and flood storage characteristics remain consistent with current conditions and the Conargo Local Environment Plan. Further, as there is no fundamental change to the flooding conditions the existing emergency management, evacuation and access, and contingency measures remain current and relevant where they exist and no new community emergency management arrangements for flooding are required. Similarly, as there are no changes to the existing flooding there are no impacts to social and economic costs to the community as a consequence of the proposals.

The impacts of climate change at 2100 from the proposals on the 1% AEP event, which is considered critical from a planning perspective, was assessed by comparing the existing conditions results to the proposed condition results for the 0.5% and 0.2% AEP flood events. For both regulator sites, the impact assessment demonstrated there were no significant impacts, with a minor improvement at the Wanganella Regulator due to the introduction of a flood bypass channel. The reason for the small impacts is that, in these larger flood events the proposed structures are effectively overwhelmed or drowned out. Given there were no significant impacts in the existing case and the climate change at 2100 case, it was concluded that there would be no significant impacts at 20-year intervals throughout the design life of the proposals.

7. References

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- NSW Government (2013), Conargo Local Environmental Plan 2013.
- WaterNSW (SAYM-REQ-003, December 2021)

Appendix A. Details of Flood Frequency Analysis and Joint Probability Assessment

Flood Frequency Analysis

This section presents the details of the at-site flood frequency analysis (FFA) with further background information in Yanco Creek Modernisation Flood Frequency Analysis (3Rivers, 2023).

The purpose of at-site FFA is to determine flood quantiles of design flood peaks. Comprehensive at-site flood frequency analysis (FFA) was undertaken at the relevant gauges including:

- Yanco Creek at Morundah.
- Billabong Creek at Jerilderie.
- Billabong Creek at Conargo.

At-site FFA was also completed at additional sites; Colombo Creek at Morundah, Colombo Creek at Coonong Weir and Yanco Creek at Yanco Bridge. This analysis did not include historical flows.

At-site FFA was completed in accordance with guidance outlined in Book 3 Chapter 2 of Australian Rainfall and Runoff (Kuczera and Franks, 2019) using the Bayesian Framework incorporated into the Flike software package.

At this stage of the analysis this exercise involved:

- Extracting the Annual Maximum series for the calendar Year (January to December).
- Fitting a statistical distribution in Flike (Log Pearson Type 3).
- Censoring Low flows.
- Incorporating historical floods.
- Producing flood quantiles (peak flows verses probability).

Note given the size of the catchment to the gauge locations (around 8,000 km²) obtaining prior parameter information from the RFFE was not considered appropriate as the catchment used in the RFFE analysis had catchment areas significantly smaller (generally 1,000 km² or less). For these reasons, assessing the influence of historical data and inputting prior parameters information from the RFFE were not carried out.

The results, of this analysis are presented for each gauge below together with notes on the analysis and discussion points. The annual maximum series for each gauge is provided in Appendix C.

Yanco Creek at Morundah

Flood quantile have previously been calculated for Yanco Creek at Morundah (410015) by Jacobs (2017). These results are listed in Table 7.2.

Flood frequency analysis was undertaken on the Yanco Creek at Morundah gauge using the following data:

- The annual maximum series from 1913 to 2022 as shown in Figure 7.1.
- No historic data.
- Bayesian fitting technique.
- Fitted to the Log Pearson Type 3 (LP3) distribution with parameters shown in Table 7.1.
- Low flows can influence higher quantiles when undertaking an FFA. Two plausible flows (i.e. 700 and 1200 ML/day) were excluded as part of a sensitivity analysis. Results indicated that when flows below 1200 ML/day were censored – 49 flood peaks in total – a better fit to rarer quantities was found.

The resulting flood quantiles are shown in Table 7.2 and displayed in Figure 7.2. The resulting fit of the LP3 distribution to the flood data in Figure 7.2 is considered acceptable.

Table 7.1 LP3 Parameters

Parameter	Mean
Mean (loge flow)	7.23
Loge (Std dev (loge flow))	0.073
Skew (Loge flow)	0.074

Table 7.2 FFA results Yanco Creek at Morundah

AEP	Discharge (ML/d)	Discharge (m ³ /s)	5% (Lower) Confidence ML/d	95% (Upper) Confidence ML/d	Jacobs 2017
50%	1,400	16	1,100	1,700	
20%	3,400	39	2,800	4,200	3,456
10%	5,500	64	4,400	7,100	5,530
5%	8,300	96	6,300	11,300	8,200
2%	13,100	152	9,100	20,400	12,900
1%	17,900	207	11,600	31,500	17,500
0.5%	23,800	275	14,100	48,600	
0.33% ¹	27,900	323	--	-	-
0.2%	33,700	390	17,500	85,100	

Note: 1. The 0.33% (1 in 300) AEP event was back calculated using the calculated LP3 parameters from the FFA hence no credibility limits were available.

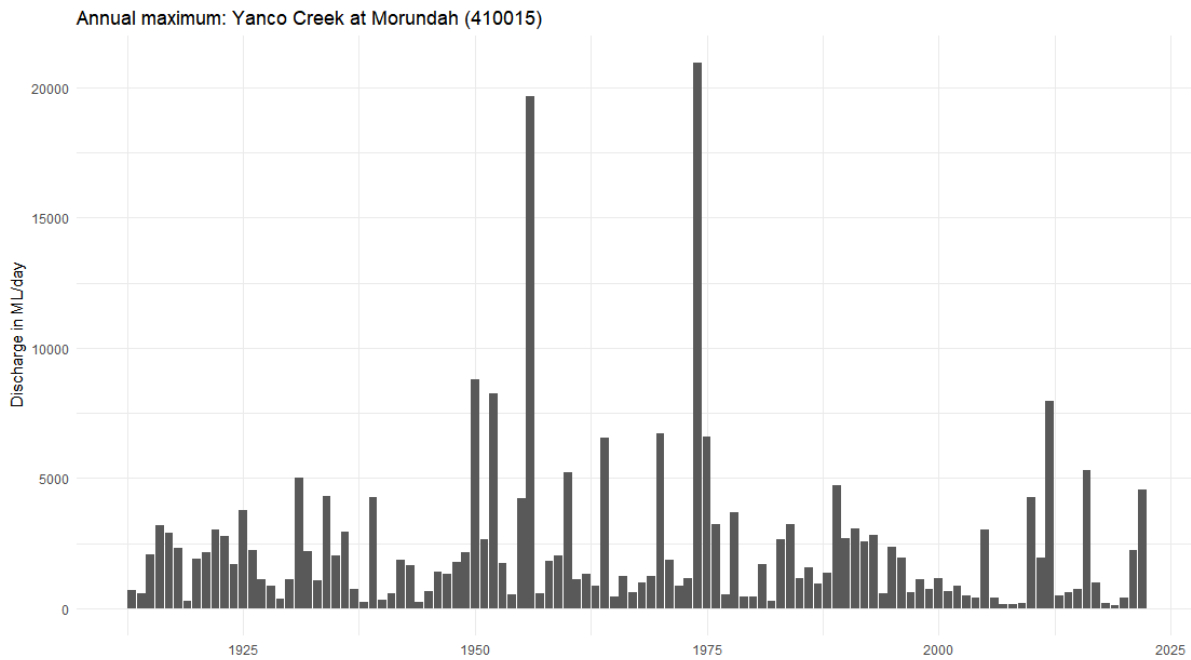


Figure 7.1 Annual maximum series Yanco Creek at Morundah

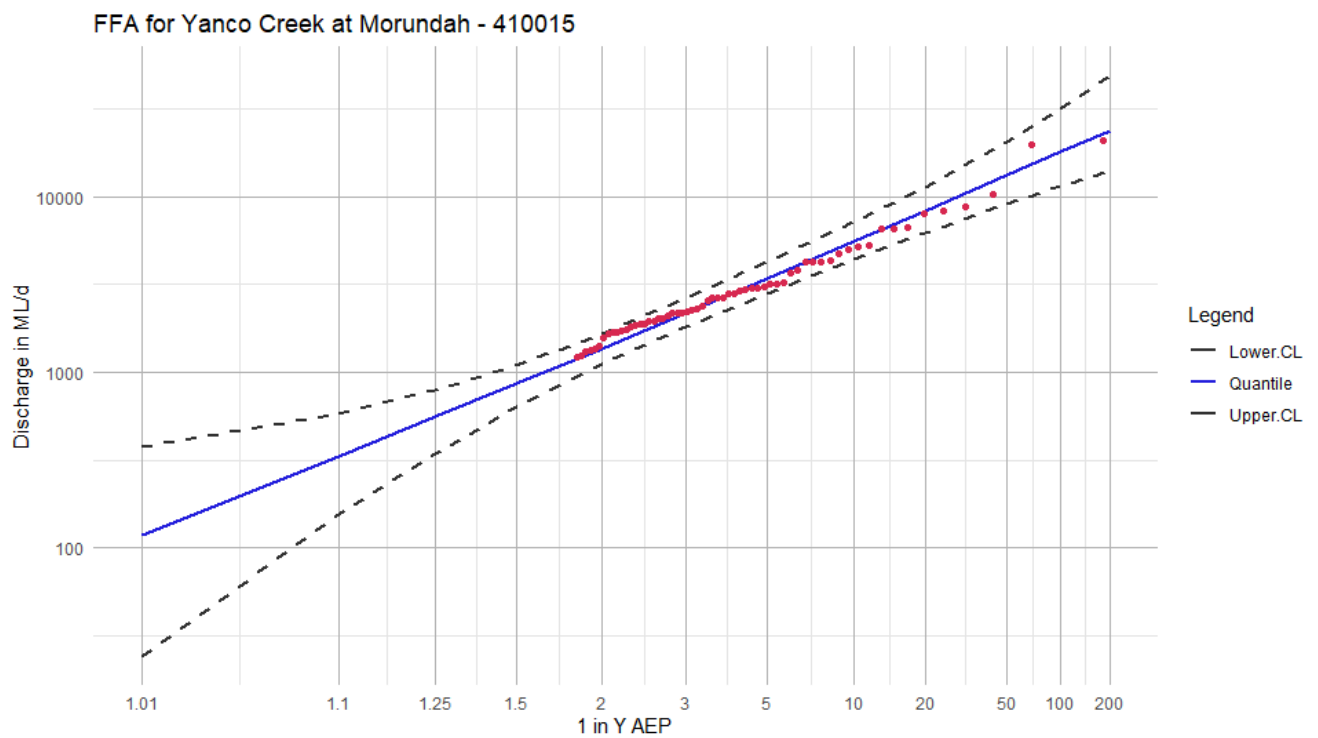


Figure 7.2 Flood frequency curve for the Yanco Creek at Morundah

Billabong Creek at Jerilderie

The Billabong Creek Floodplain Management Plan (Bewsher Consulting Pty Ltd, 2002) produced flood quantile estimates which are listed in Table 7.4.

Flood frequency analysis was undertaken on the Billabong Creek at Jerilderie gauge using the following data:

- The annual maximum series from 1913 to 2022 as shown in Figure 7.3.
- No historic events.
- Bayesian fitting technique.
- Fitted to the LP3 distribution with parameters shown in Table 7.3.
- A low flow censoring threshold of 2,031 ML/d which resulted in 56 flood peaks being censored.

The resulting flood quantiles are shown in Table 7.4 and displayed in Figure 7.4. The resulting fit of the LP3 distribution to the flood data in Figure 7.4 is considered acceptable.

Table 7.3 LP3 Parameters

Parameter	Mean
Mean (loge flow)	7.49
Loge (Std dev (loge flow))	-0.062
Skew (Loge flow)	-0.69

Table 7.4 FFA results Billabong Creek at Jerilderie

AEP	Discharge (ML/d)	Discharge (m ³ /s)	5% (Lower) Confidence ML/d	95% (Upper) Confidence ML/d	Jacobs 2017
50%	2,000	23	1,700	2,400	
20%	4,000	46	3,500	4,700	4,100
10%	5,500	64	4,800	6,400	5,800
5%	6,900	80	6,000	8,200	7,800
2%	8,600	100	7,300	10,500	10,500
1%	9,900	115	8,300	12,700	12,700
0.5%	11,100	128	9,000	15,000	
0.33% ¹	11,700	136	-	-	-
0.2%	12,500	145	9,800	18,500	

Note: 1. The 0.33% (1 in 300) AEP event was back calculated using the calculated LP3 parameters from the FFA hence no credibility limits were available.

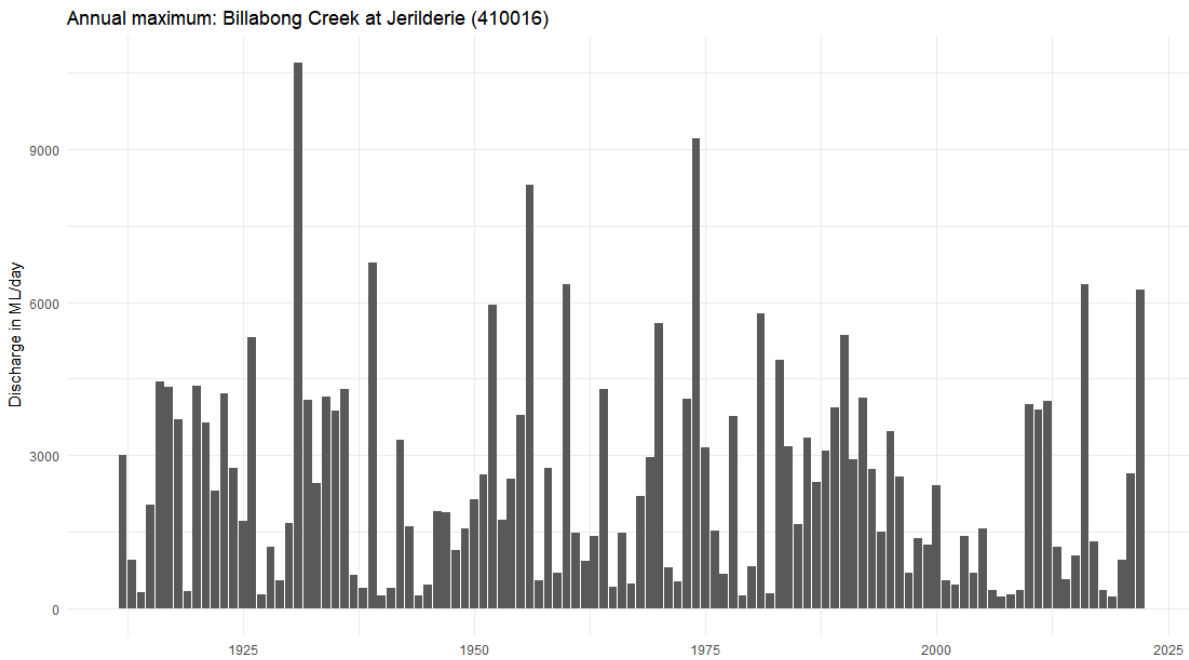


Figure 7.3 Annual maximum series Billabong Creek at Jerilderie

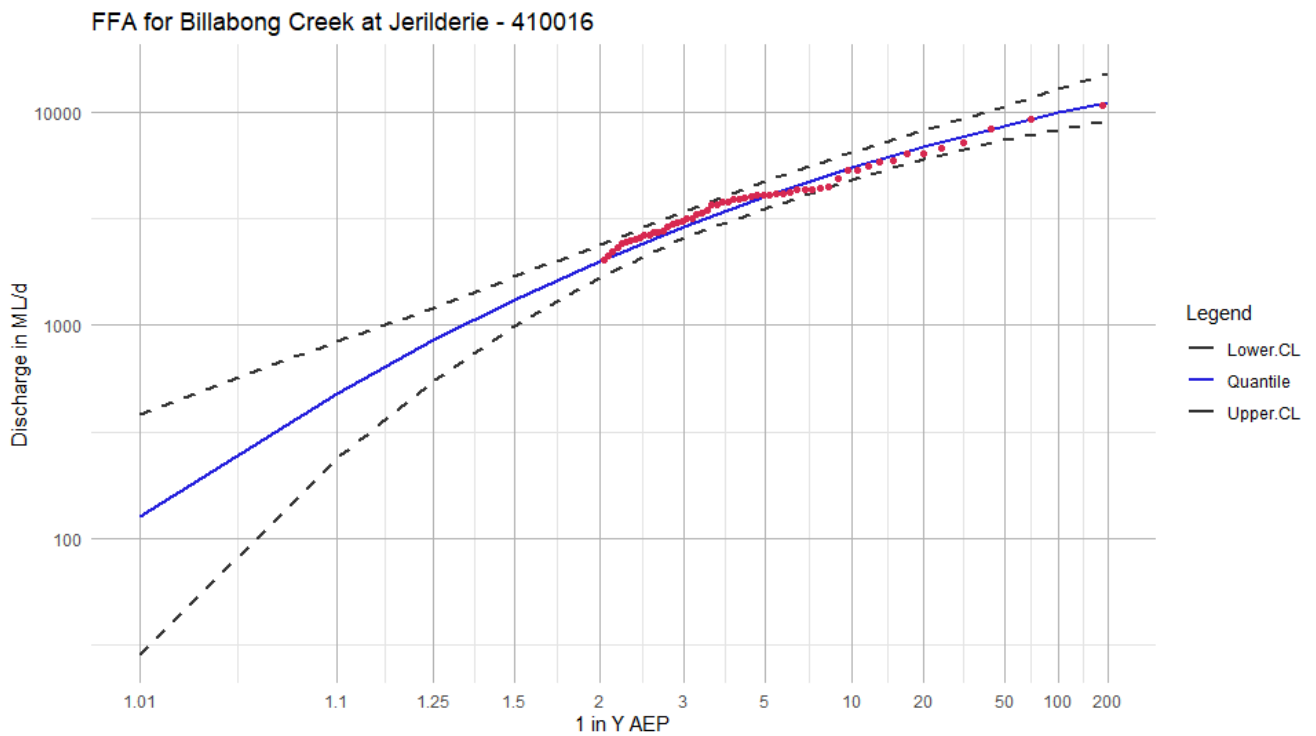


Figure 7.4 Flood frequency curve for the Billabong Creek at Jerilderie

Billabong Creek at Conargo (Puckawidgee)

The Conargo Floodplain Risk Management Study and Plan (Lyall & Associates, 2008) produced flood quantile estimates which are listed in Table 7.6.

Flood frequency analysis was undertaken on the Billabong Creek at Conargo (Puckawidgee) gauge using the following data:

- The annual maximum series from 1913 to 2022 as shown in Figure 7.5.
- No historic events.
- Bayesian fitting technique.
- Fitted to the LP3 distribution with parameters shown in Table 7.5.
- Low flows can influence higher quantiles when undertaking an FFA. Two plausible flows (i.e. 1,000 and 2,100 ML/day) were excluded as part of a sensitivity analysis. Results indicated that when flows below 2,100 ML/day were censored – 51 flood peaks in total – a better fit to rarer quantities was found.

The resulting flood quantiles are shown in Table 7.6 and displayed in Figure 7.6. The resulting fit of the LP3 distribution to the flood data in Figure 7.6 is considered acceptable. The peak flow at the Billabong Creek at Conargo gauge estimated by 3 Rivers hydraulic modelling (2022) is also shown in Table 7.6. These estimates are comparable to the FFA particularly when the Yanco system is dominant.

Table 7.5 LP3 Parameters

Parameter	Mean
Mean (loge flow)	7.76
Loge (Std dev (loge flow))	-0.19
Skew (Loge flow)	0.37

Table 7.6 FFA results Billabong Creek at Conargo (Puckawidgee)

AEP	Discharge (ML/d)	Discharge (m ³ /s)	5% (Lower) Confidence ML/d	95% (Upper) Confidence ML/d	Jacobs 2017
50%	2,000	23	1,700	2,400	
20%	4,000	46	3,500	4,700	4,100
10%	5,500	64	4,800	6,400	5,800
5%	6,900	80	6,000	8,200	7,800
2%	8,600	100	7,300	10,500	10,500
1%	9,900	115	8,300	12,700	12,700
0.5%	11,100	128	9,000	15,000	
0.33% ¹	11,700	136	-	-	-
0.2%	12,500	145	9,800	18,500	

Note: 1. The 0.33% (1 in 300) AEP event was back calculated using the calculated LP3 parameters from the FFA hence no credibility limits were available.

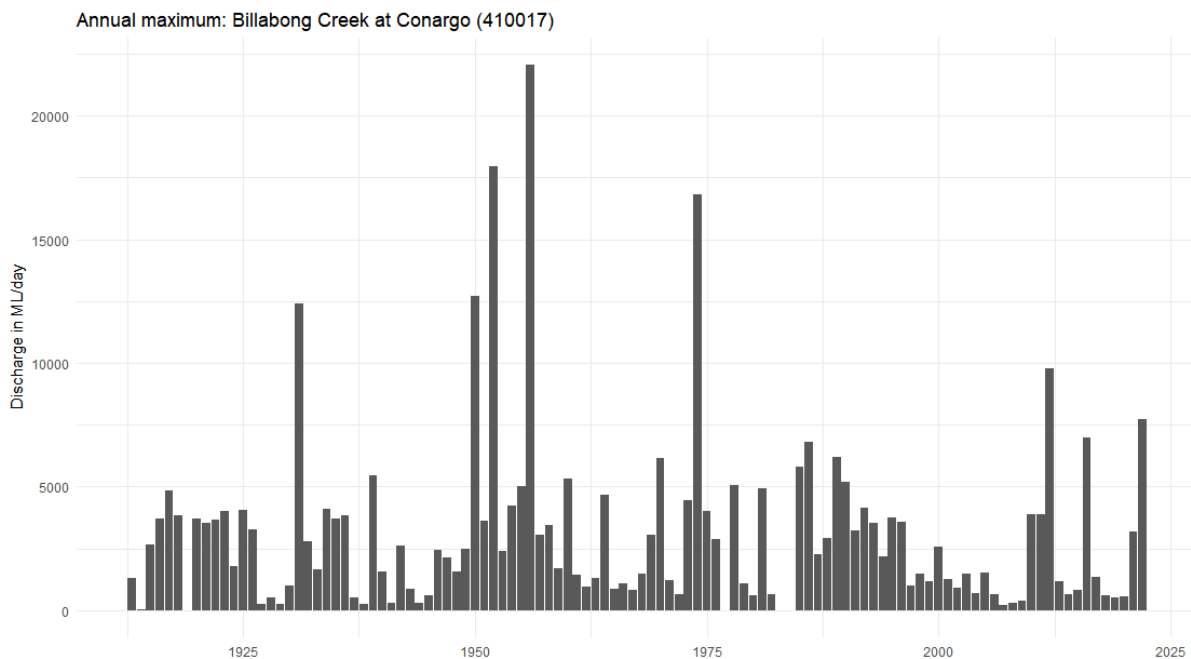


Figure 7.5 Annual maximum series Billabong Creek at Conargo (Puckawidgee)

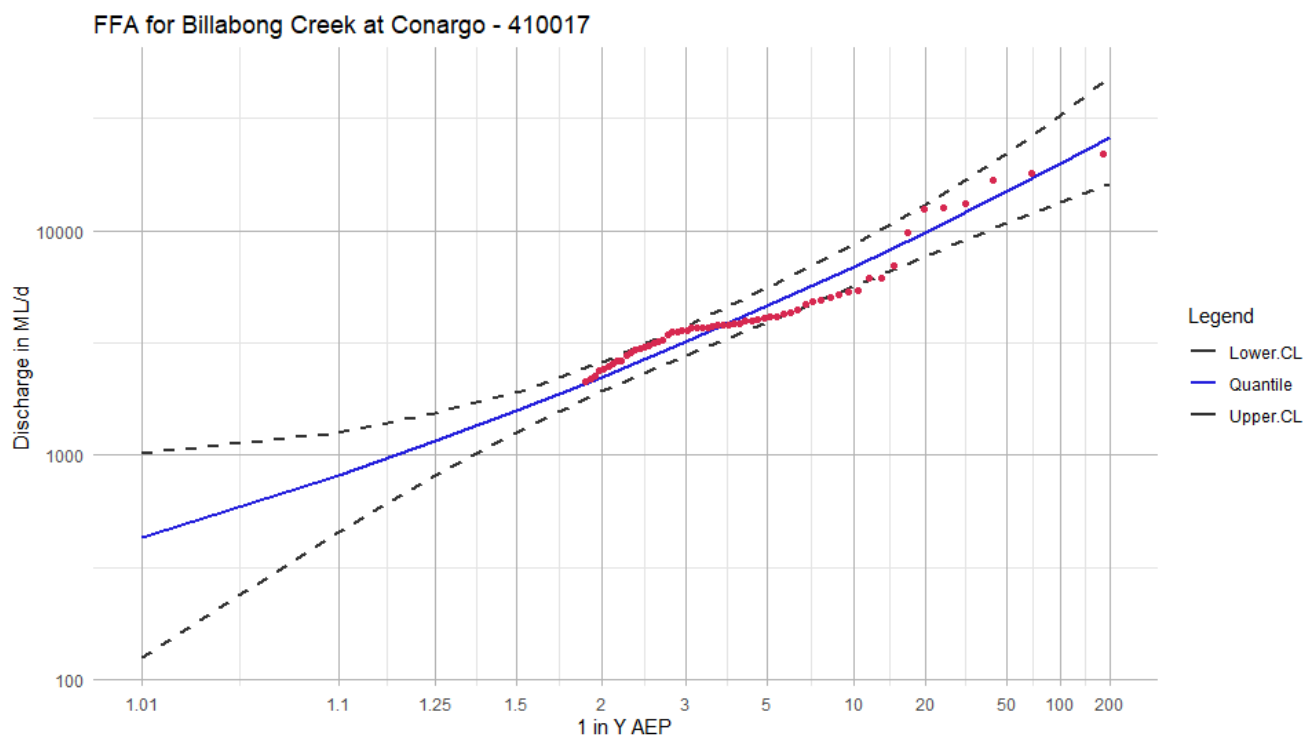


Figure 7.6 Flood frequency curve for the Billabong Creek at Conargo (Puckawidgee)

Joint probability analysis

The Yanco / Billabong Creek system has two sources of potential flood risk: discharge from the Murrumbidgee to the Yanco Creek and discharge along the Billabong Creek system. This means that discharge downstream of the confluence of Yanco Creek and Billabong Creek is combination of these two sources. Given that there are two semi-independent sources of floodwaters contributing to the streamflow observations at this location a joint probability analysis is required to reconcile the flood quantiles. This can avoid overly conservative assumptions such as assuming the same probability event on the Yanco Creek and Billabong Creek yields the same probability downstream of the confluence.

The Yanco Creek system was characterised by the Yanco Creek at Morundah gauge, Billabong Creek by Billabong Creek at Jerilderie, and the combined flows by Billabong Creek at Conargo (see Figure 2.3).

To assess the joint probability of the Yanco / Billabong Creek system the following procedure was applied:

1. Undertake FFA on each gauge listed above to calculate flood quantiles and distribution (Log Pearson Type 3 (LP3)) parameters. This was completed as outlined above.
2. Extract the concurrent series at Morundah and Jerilderie that yield largest flow at Conargo.
3. Calculate AEP of concurrent events for each of the three gauges using fitted LP3 parameters; transforming flow at each gauge into unit probability domain.
4. Calculate correlation between flows and probabilities.
5. Construct multinormal distribution using the correlation between Morundah and Jerilderie to calculate of concurrent probabilities i.e. given event M1 at Morundah and J1 at Jerilderie what is the joint probability.
6. Generate a large random sample from the multinormal distribution and numerical determine the combination of probability at Morundah and Jerilderie that yield the standard probability event at Conargo.
7. Tabulate combination of AEP events for application to the hydraulic model.

Concurrent series

The overlapping continuous series for the three gauges (Morundah, Jerilderie, and Conargo) were generated which commenced in 1978. The annual maximum for the Conargo gauge was calculated and the concurrent event peak at Morundah and Jerilderie was extracted using the following window:

- For Morundah the peak in the proceeding 30 days from the date of the peak at Conargo.
- For Jerilderie the peak in the proceeding 15 days from the date of the peak at Conargo.
- Years with missing data were removed and the resulting concurrent series is listed in Table 7.7 and illustrated in Figure 7.7.

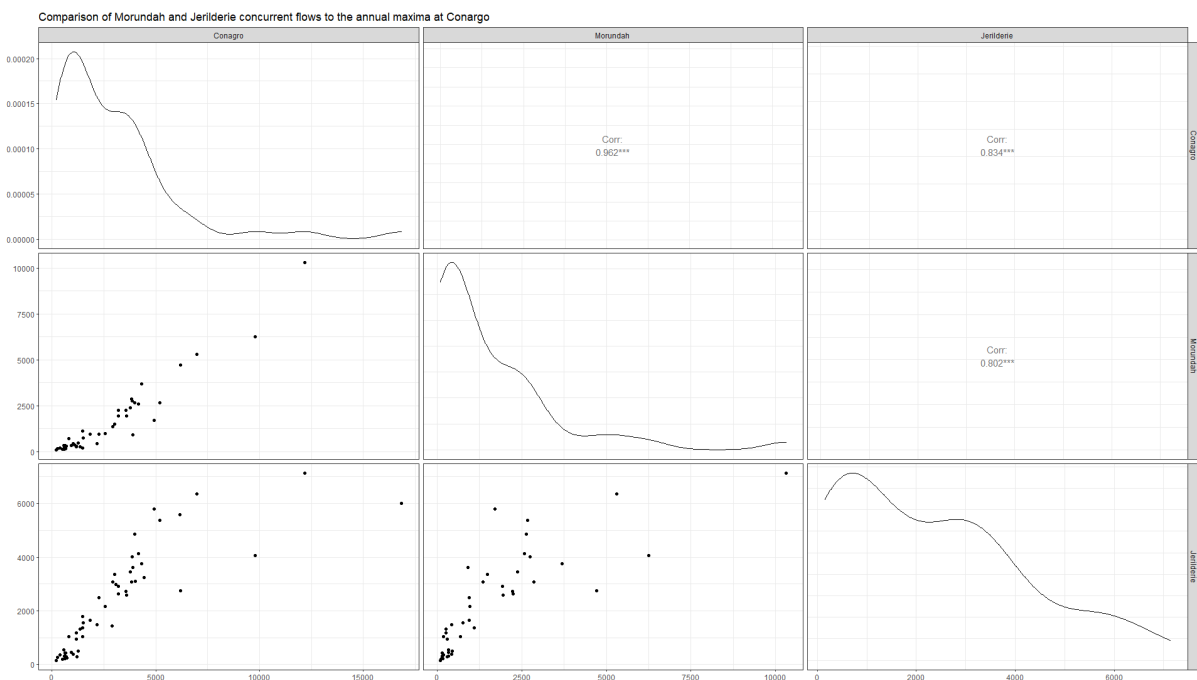


Figure 7.7 Comparison of Morundah and Jerilderie concurrent flows to the annual maximum at Conargo

Table 7.7 Concurrent peaks at Morundah and Jerilderie for the annual maximum peak at Conargo

Year	Conargo Date	Conargo	Conargo Probability	Morundah Date	Morundah	Morundah Probability	Jerilderie Date	Jerilderie	Jerilderie Probability
1978	10/10/1978	4320	0.219	24/09/1978	3680	0.181	4/10/1978	3760	0.224
1981	18/08/1981	4910	0.179	5/08/1981	1700	0.423	10/08/1981	5790	0.085
1982	2/04/1982	630	0.955	4/03/1982	160	0.978	27/03/1982	220	0.977
1983	22/09/1983	3980	0.248	9/09/1983	2640	0.273	14/09/1983	4860	0.133
1984	28/09/1984	3820	0.262	3/09/1984	2870	0.249	24/09/1984	3070	0.308
1985	15/09/1985	1830	0.596	6/09/1985	960	0.637	11/09/1985	1660	0.581
1986	10/10/1986	3000	0.361	28/09/1986	1480	0.476	2/10/1986	3350	0.272
1987	21/08/1987	2240	0.497	9/08/1987	960	0.637	16/08/1987	2480	0.403
1988	13/08/1988	2930	0.372	8/08/1988	1350	0.509	6/08/1988	3080	0.307
1989	11/05/1989	6190	0.121	24/04/1989	4720	0.127	6/05/1989	2740	0.360
1990	7/09/1990	5190	0.164	2/09/1990	2670	0.270	3/09/1990	5360	0.104
1991	1/10/1991	3210	0.333	30/09/1991	1940	0.377	27/09/1991	2910	0.332
1992	8/11/1992	4150	0.233	3/11/1992	2580	0.280	4/11/1992	4120	0.189
1993	6/10/1993	3540	0.292	27/09/1993	2230	0.328	30/09/1993	2730	0.360
1994	17/03/1994	2170	0.513	19/02/1994	430	0.864	13/03/1994	1490	0.623
1995	14/08/1995	3770	0.268	30/07/1995	2370	0.308	2/08/1995	3460	0.258
1996	28/08/1996	3590	0.287	18/08/1996	1940	0.376	22/08/1996	2580	0.386
1997	16/02/1997	1010	0.849	14/02/1997	430	0.863	2/02/1997	380	0.940
1998	11/10/1998	1470	0.702	1/10/1998	1100	0.585	7/10/1998	1370	0.654
1999	30/08/1999	1150	0.801	17/08/1999	310	0.922	24/08/1999	950	0.774
2000	8/09/2000	2550	0.437	26/08/2000	980	0.629	30/08/2000	2160	0.467
2001	7/02/2001	1250	0.771	27/01/2001	450	0.854	1/02/2001	510	0.905
2002	6/04/2002	920	0.877	1/04/2002	340	0.908	5/04/2002	460	0.918
2003	30/08/2003	1480	0.699	22/08/2003	190	0.970	27/08/2003	1030	0.751

Year	Conargo Date	Conargo	Conargo Probability	Morundah Date	Morundah	Morundah Probability	Jerilderie Date	Jerilderie	Jerilderie Probability
2004	13/12/2004	680	0.943	19/11/2004	300	0.925	11/12/2004	280	0.964
2005	16/10/2005	1500	0.691	19/09/2005	760	0.714	13/10/2005	1560	0.605
2006	29/03/2006	620	0.957	21/03/2006	340	0.909	20/03/2006	320	0.955
2007	22/05/2007	200	1.000	30/04/2007	100	0.993	8/05/2007	150	0.987
2008	2/04/2008	270	0.999	28/03/2008	160	0.981	29/03/2008	260	0.968
2009	14/03/2009	390	0.993	1/03/2009	200	0.968	13/03/2009	350	0.948
2010	16/11/2010	3860	0.259	31/10/2010	2750	0.261	4/11/2010	4010	0.200
2011	15/03/2011	3870	0.258	14/02/2011	910	0.652	1/03/2011	3610	0.240
2012	26/03/2012	9770	0.049	19/03/2012	6250	0.080	20/03/2012	4070	0.194
2013	5/08/2013	1170	0.798	28/07/2013	260	0.945	31/07/2013	1190	0.707
2014	15/04/2014	660	0.948	27/03/2014	150	0.981	3/04/2014	440	0.924
2015	17/09/2015	800	0.912	2/09/2015	690	0.743	15/09/2015	1040	0.748
2016	22/10/2016	6960	0.097	15/10/2016	5300	0.106	15/10/2016	6350	0.064
2017	12/12/2017	1340	0.741	10/12/2017	270	0.939	6/12/2017	1320	0.670
2018	22/10/2018	600	0.962	10/10/2018	140	0.984	17/10/2018	310	0.956
2019	7/02/2019	500	0.981	17/01/2019	110	0.991	6/02/2019	180	0.982
2020	11/11/2020	560	0.971	8/11/2020	330	0.911	6/11/2020	540	0.895
2021	17/12/2021	3180	0.336	9/12/2021	2240	0.326	12/12/2021	2640	0.376
2022	21/11/2022	12180	0.030	12/11/2022	10300	0.031	20/11/2022	7130	0.043

Calculate AEP of concurrent events

The AEP for each event in Table 7.7 was calculated using the fitted LP3 distribution outlined in Sections 7.1, 7.2 and 7.3 and are listed in Table 7.7. These probabilities demonstrate that the rarest event is the 2022 (current) flood event.

Correlation

The correlations between concurrent flow series and the probabilities were undertaken and are listed in Table 7.8. The information in Table 7.8 demonstrates that there is strong correlation between both flows and probabilities in the Yanco / Billabong Creek system. Further that the correlation improves probabilities with the exception of Conargo / Morundah.

Table 7.8 Pearson correlation coefficient for concurrent flows and probabilities

Concurrent flows				Probabilities		
	Conargo	Morundah		Conargo	Morundah	
Conargo	1		Conargo	1		Conargo
Morundah	0.961	1	Morundah	0.961	1	Morundah
Jerilderie	0.878	0.802	Jerilderie	0.878	0.802	Jerilderie

Multinormal distribution

A multinormal distribution was constructed based on the probabilities and their correlation. This allowed the calculation of probability of two concurrent events i.e. the joint probability.

The distribution function of the multivariate normal distribution was calculated using the mvtnorm package (v1.1-3; Genz, Bretz, Miwa and Mi, 2022) with a correlation matrix based on the correlation of Morundah and Jerilderie probabilities in Table 7.8.

The resulting bivariate probability surface has been contoured in Figure 7.8 and plotted with the concurrent peaks from Morundah and Jerilderie with the contours representing the probability at Conargo. These figures illustrate the strong dependence between the two flow series with data plotting around the 1 to 1 line. It also highlights that an event of a given probability at Conargo can be caused by different combination of flows from Morundah and Jerilderie. For instance, the 10% (0.1) AEP event at Conargo could be a result of a 2,000 ML/d event at Morundah and a 5,500 ML/d event at Jerilderie or 5,200 ML/d event at Morundah and a 3,700 ML/d event at Jerilderie.

To further illustrate the joint dependence, the point that plots to the furthest right in Figure 7.8, is the 2022 event (Morundah – 10,300ML/d and Jerilderie – 7,130 see Figure 7.7). This event plots between the 5% and 2% AEP contour which matches the calculated probability in Figure 7.7 of 3% AEP.

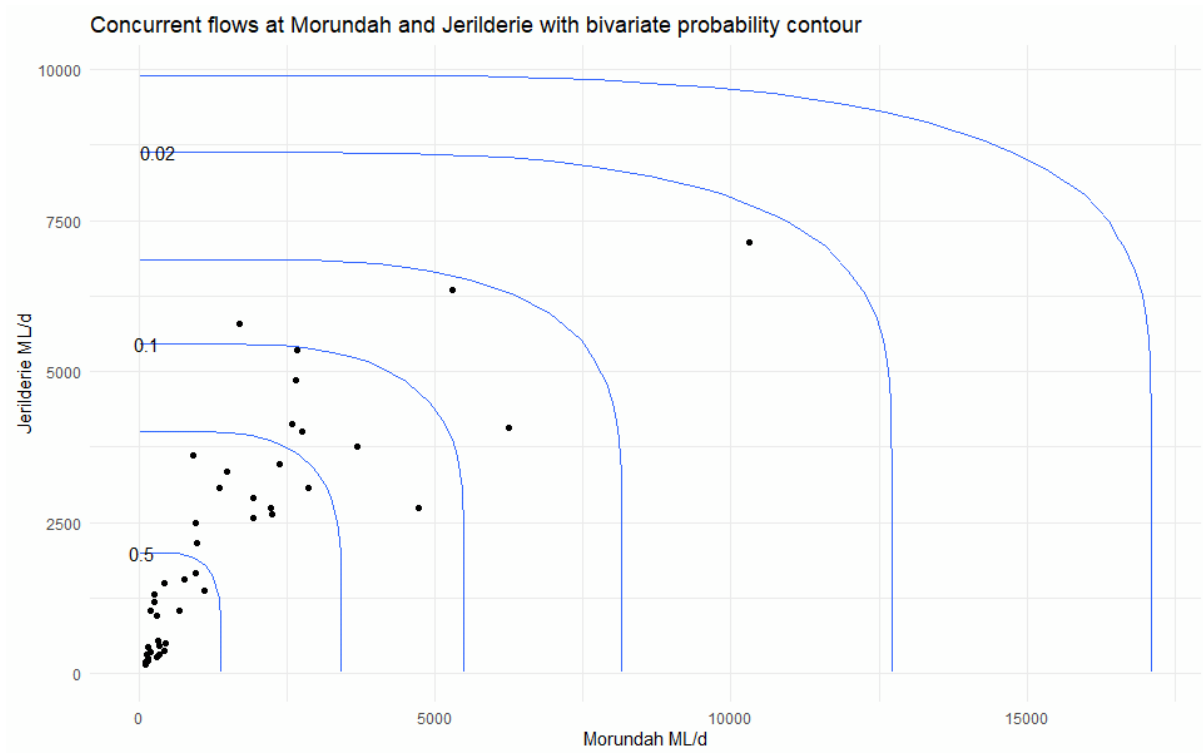


Figure 7.8 Concurrent flows at Morundah and Jerilderie with bivariate contours

Correlated random sample

A large (10,000) paired random sample from the multinormal distribution which reproduced the correlation structure was generated which is illustrated in Figure 7.9. This sample was used to numerically determine the combination of probability at Morundah and Jerilderie that yield the standard probability event at Conargo.

The large sample allowed the numeric determination of which combination of events at Morundah and Jerilderie resulted in the desired probability at Conargo.

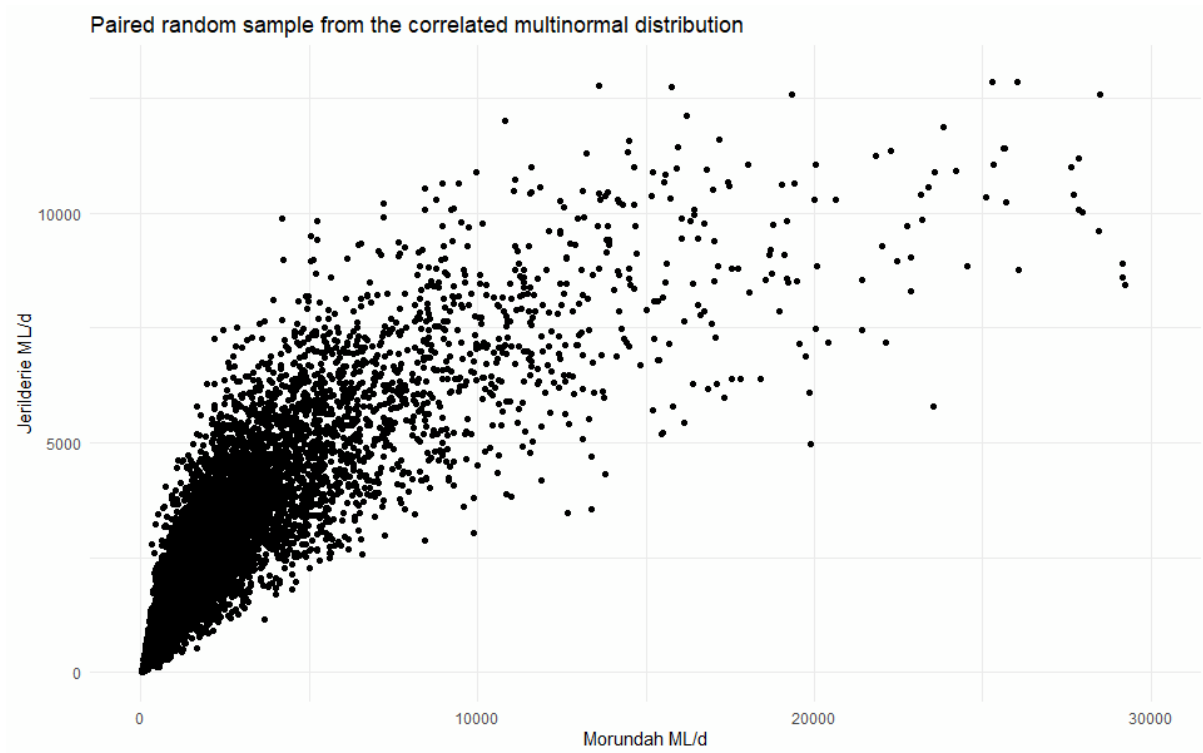


Figure 7.9 Paired random sample from the correlated multinormal distribution, $\rho = 0.919$

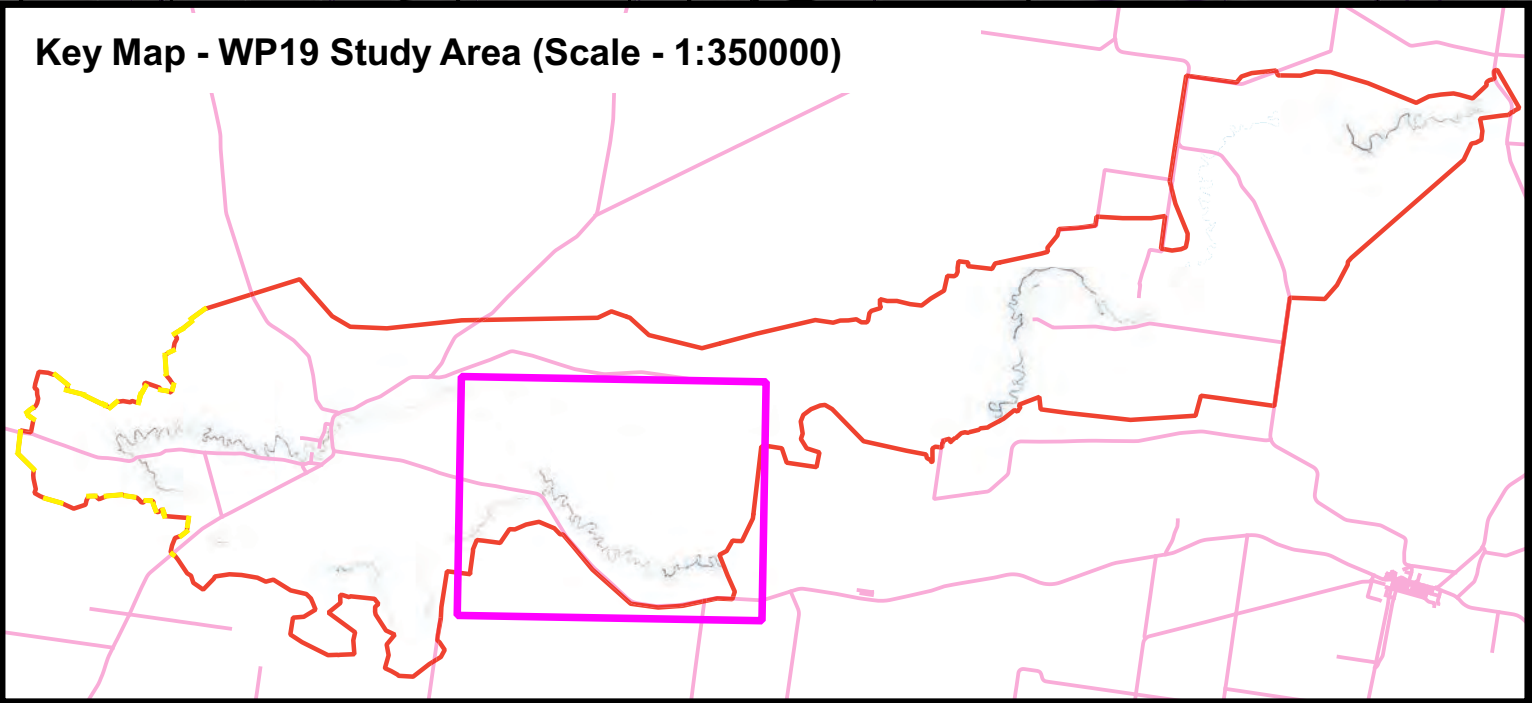
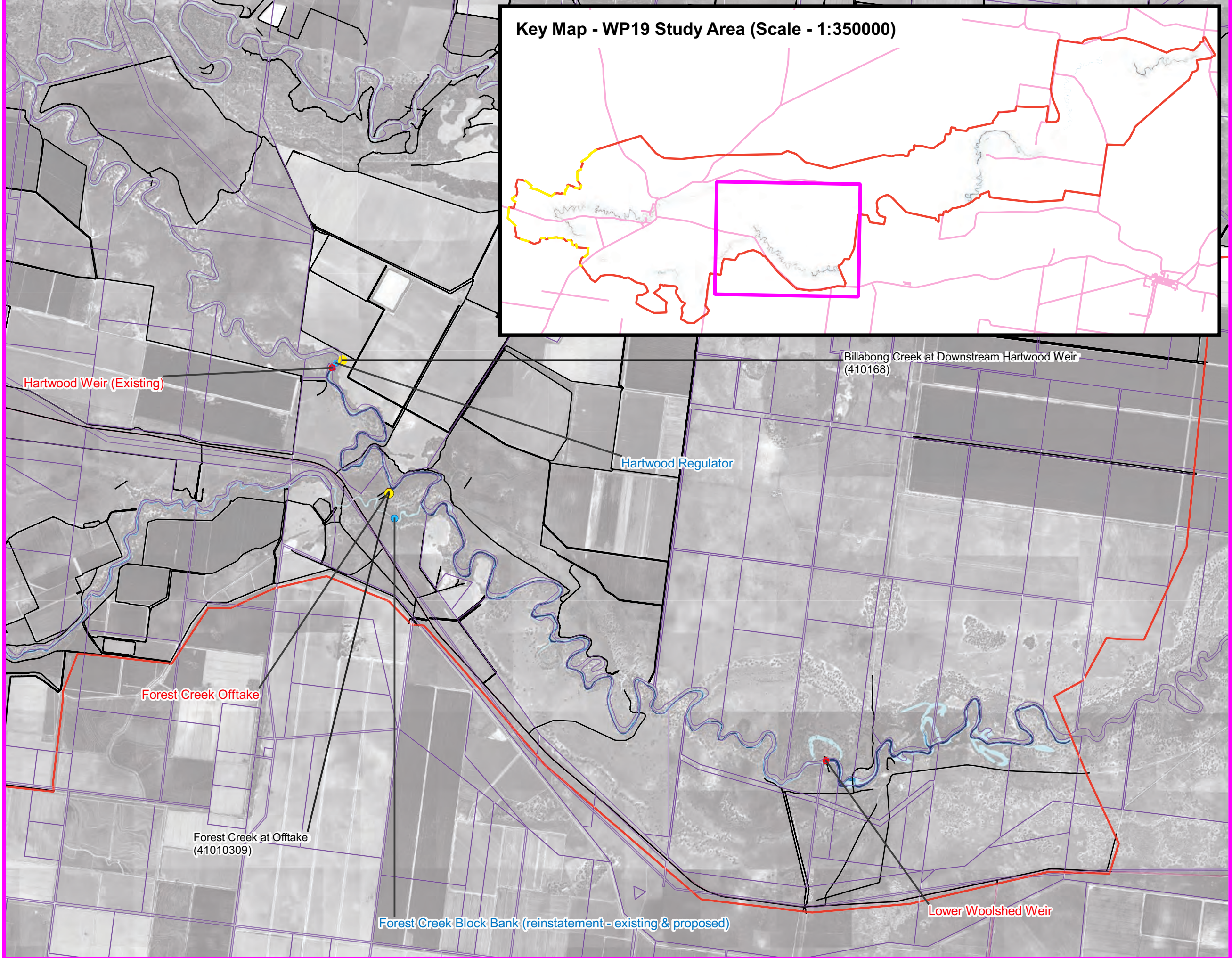
Joint probabilities

The resulting joint probabilities are listed in Table 7.9 for Yanco dominant and Billabong dominant flow events respectively. The AEP events listed in Table 7.9 have in general been rounded to the nearest standard AEP event, for instance the calculated Morundah and Jerilderie AEPs that resulted in the 1% AEP event at Conargo were 1.1% and 2.9% which were rounded to 1% and 2% AEP in Table 7.9.

Table 7.9 The adopted AEP events on Yanco Creek at Morundah and Billabong Creek at Jerilderie that result in the standard AEP event at Conargo

Yanco dominant			Billabong dominant		
Conargo	Morundah	Jerilderie	Conargo	Morundah	Jerilderie
1%	1%	2%	1%	5%	1%
2%	2%	5%	2%	10%	2%
5%	5%	10%	5%	20%	5%
10%	10%	20%	10%	20%	10%
20%	20%	20%	20%	50%	20%
50%	50%	50%	50%	50%	50%

Appendix B. Hartwood Regulator Flood Inundation and Impact Maps



- Legend**
- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Ridge Lines
 - Downstream Boundary Conditions
 - Property Boundaries
 - Hydraulic Model Boundary
 - Roads
- Depth (m)**
- ≤ 0.50
 - 0.50 - 1.00
 - 1.00 - 1.50
 - > 1.50



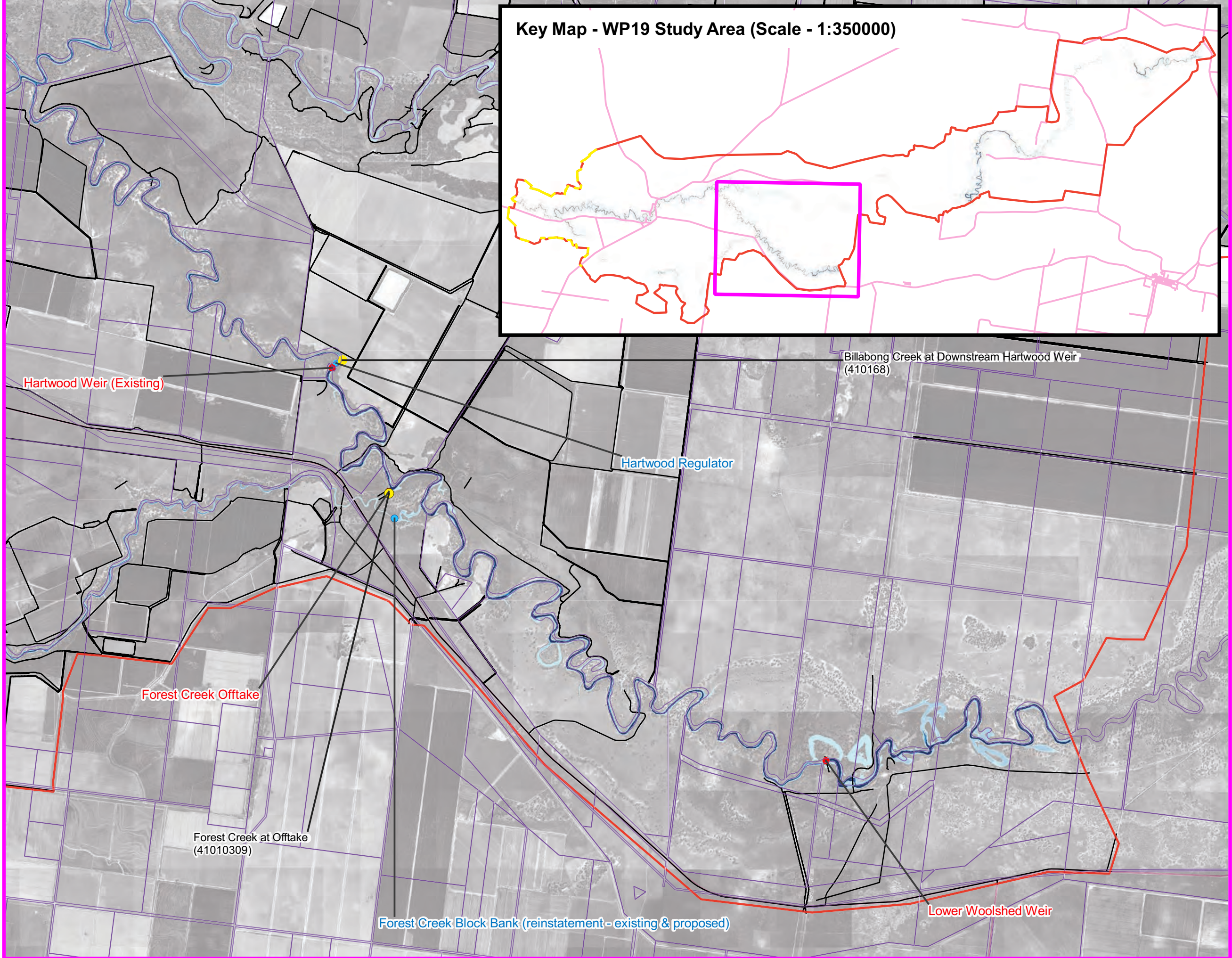
DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
EIS Chapter Depth Plot - AppB
G:\21\12537654\GIS\Maps\Working\EIS_Mapping_Results\
Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B1 - Minimum Operating Flow (25 ML/day) Depth Plot
"Existing"



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Legend

- Key Modelled Structures
- Proposed Structures
- Yanco Gauge Locations
- Ridge Lines
- Downstream Boundary Conditions
- Property Boundaries
- Hydraulic Model Boundary
- Roads

Depth (m)

- ≤ 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

North Arrow

GDA 2020 Zone 55
1:41000

0 1 2 km

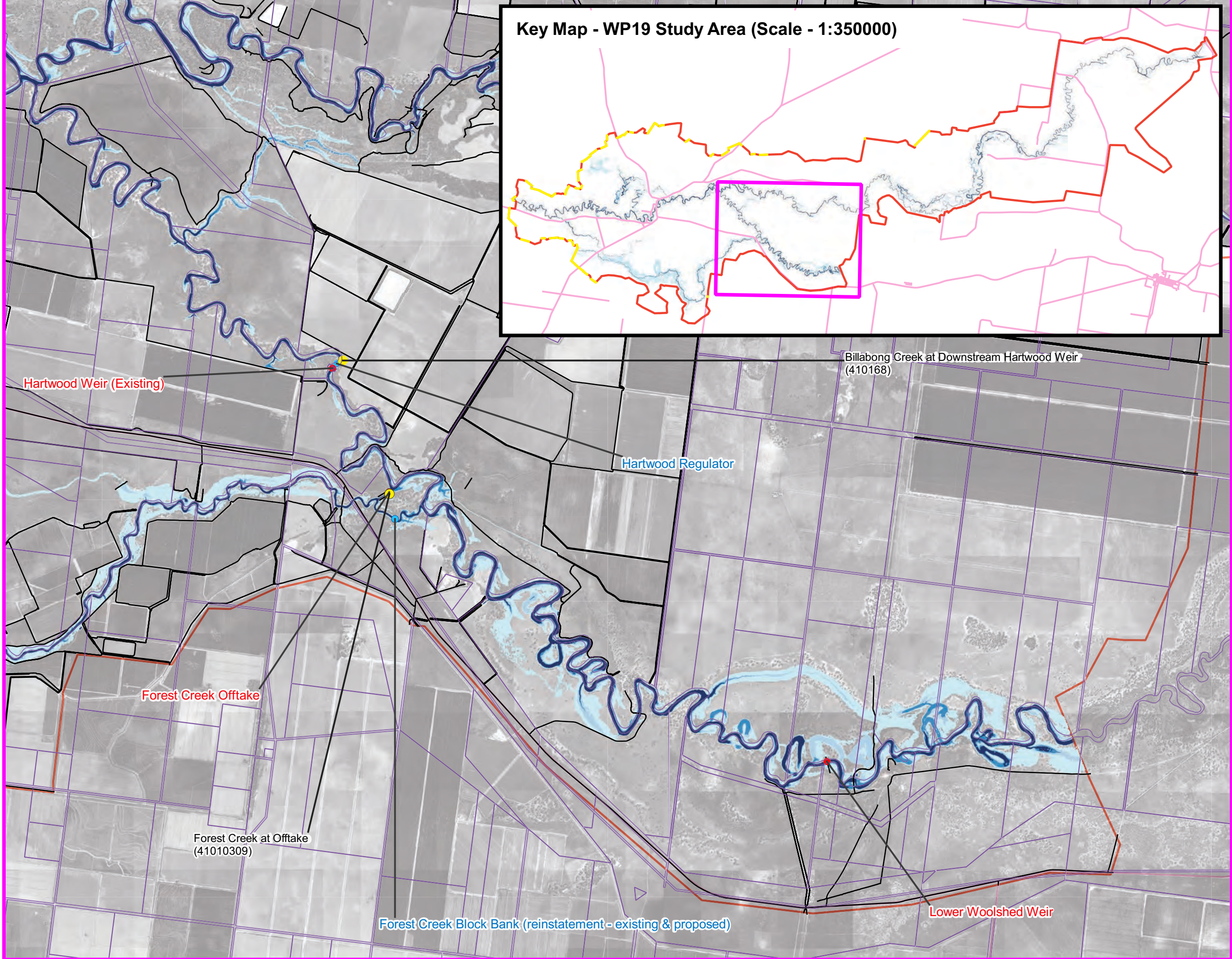
DATA SOURCE:
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WORKSPACE:
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B2 - Maximum Operating Flow (500 ML/day) Depth Plot
"Existing"



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Legend

- Key Modelled Structures
- Proposed Structures
- Yanco Gauge Locations
- Ridge Lines
- Downstream Boundary Conditions
- Property Boundaries
- Hydraulic Model Boundary

Depth (m)

- ≤ 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

— Roads

North Arrow

GDA 2020 Zone 55
1:41000

0 1 2 km

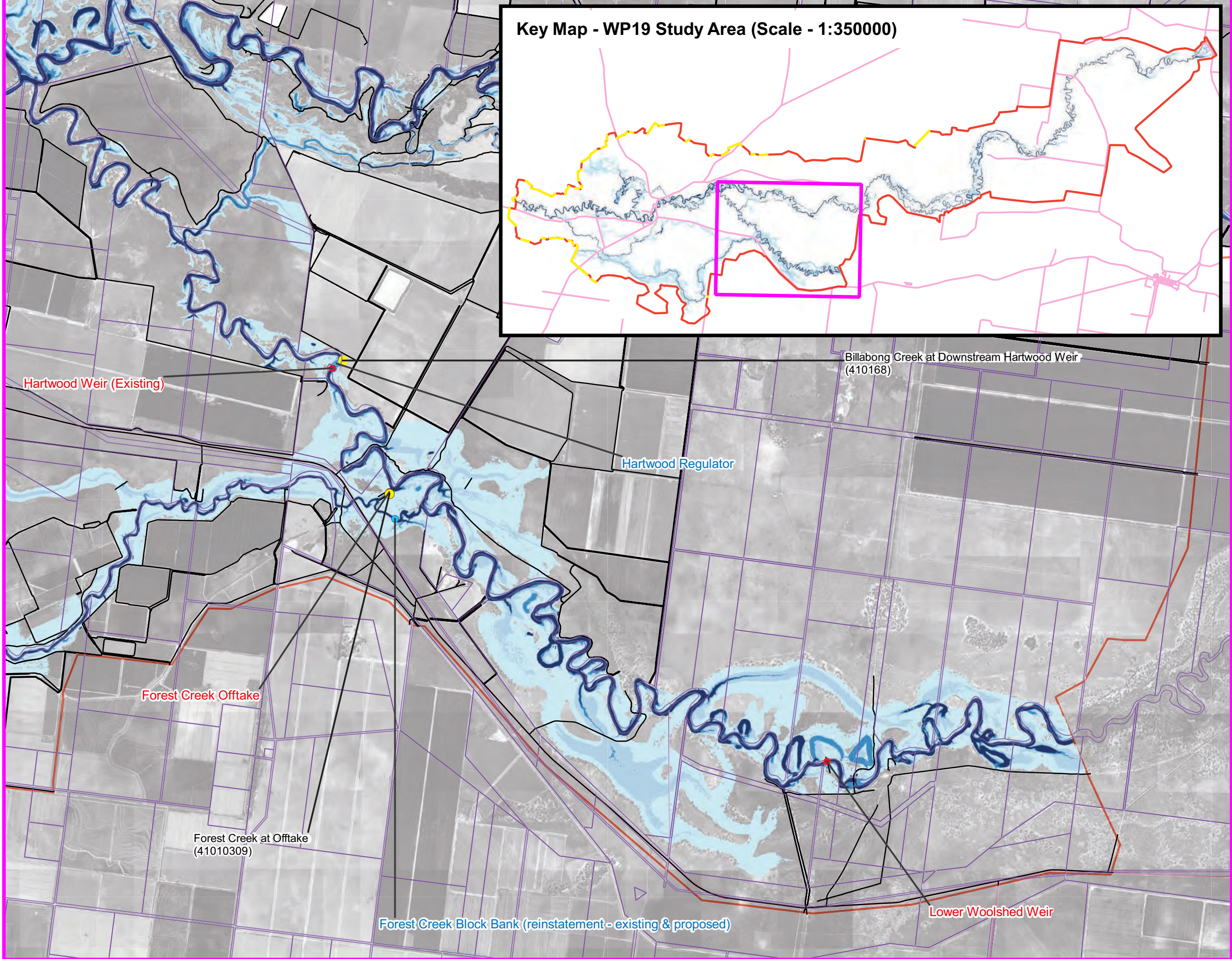
DATA SOURCE:
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WORKSPACE:
EIS Chapter Depth Plot - AppB
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B3 - 20% AEP Billabong Dominant Depth Plot
"Existing"



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Legend

- Key Modelled Structures
- Proposed Structures
- Yanco Gauge Locations
- Ridge Lines
- Downstream Boundary Conditions
- Property Boundaries
- Hydraulic Model Boundary

Depth (m)

- ≤ 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- > 1.50

— Roads

North Arrow

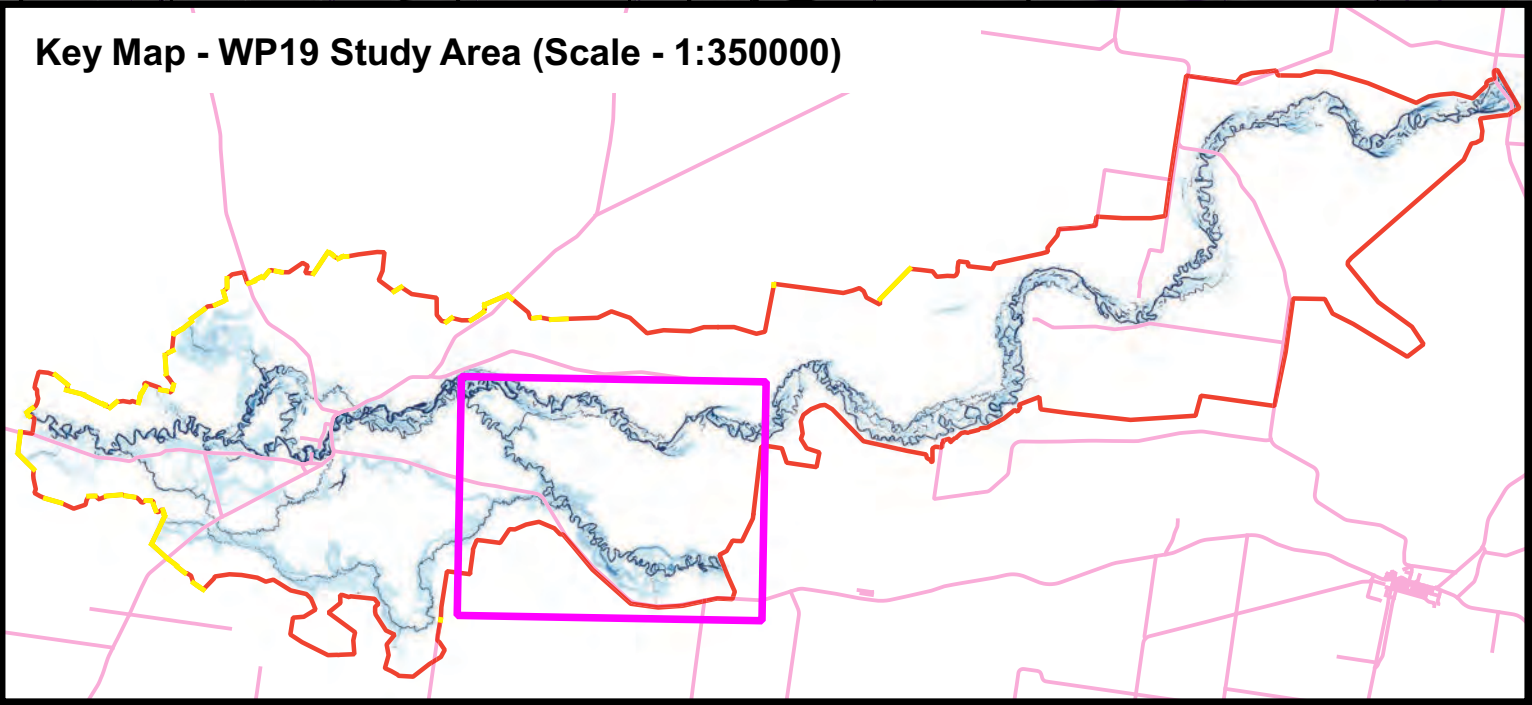
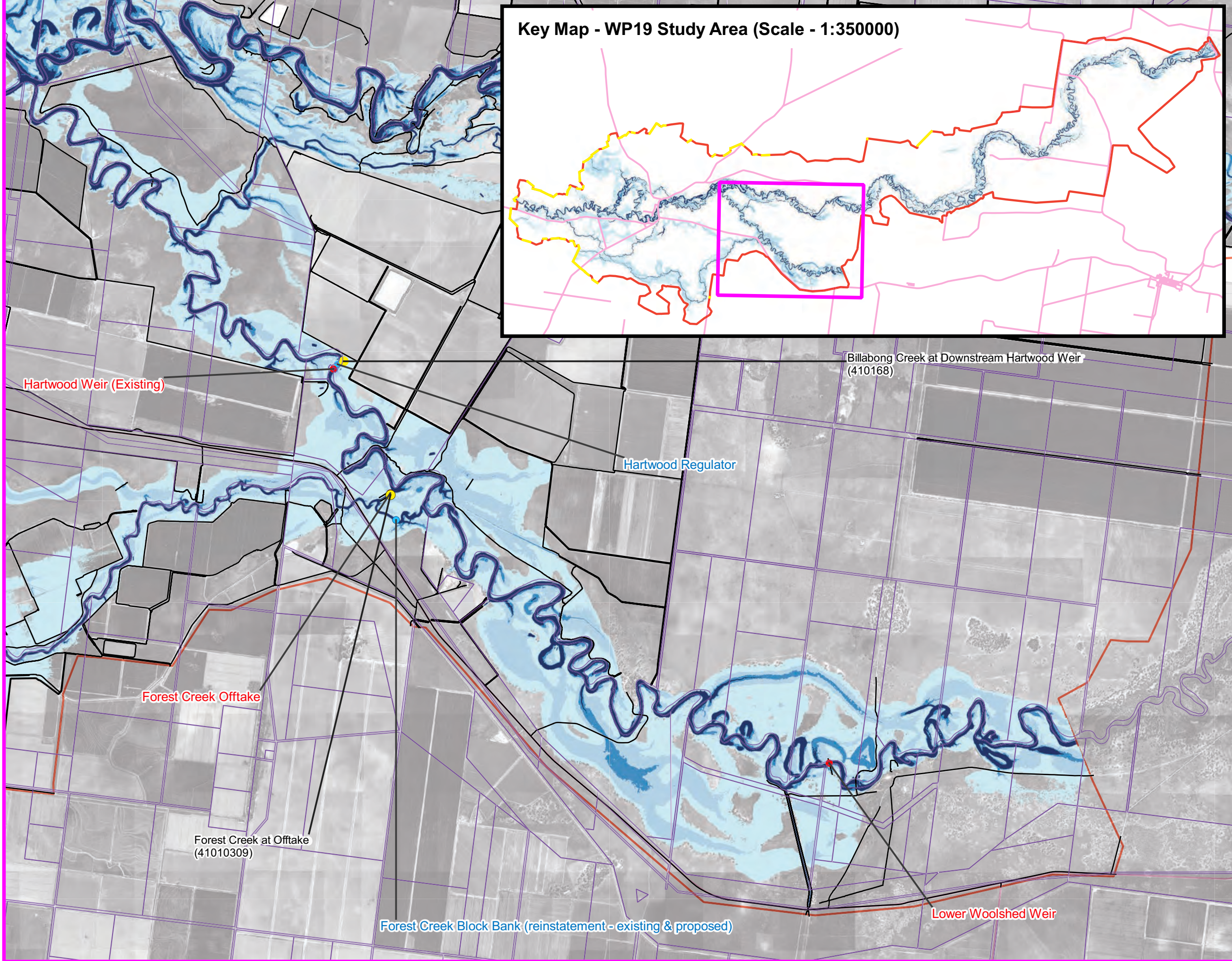
GDA 2020 Zone 55
1:41000

0 1 2 km

DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B4 - 5% AEP Billabong Dominant Depth Plot
"Existing"



- Legend**
- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Ridge Lines
 - Downstream Boundary Conditions
 - Property Boundaries
 - Hydraulic Model Boundary
- Depth (m)**
- ≤ 0.50
 - 0.50 - 1.00
 - 1.00 - 1.50
 - > 1.50
- Roads



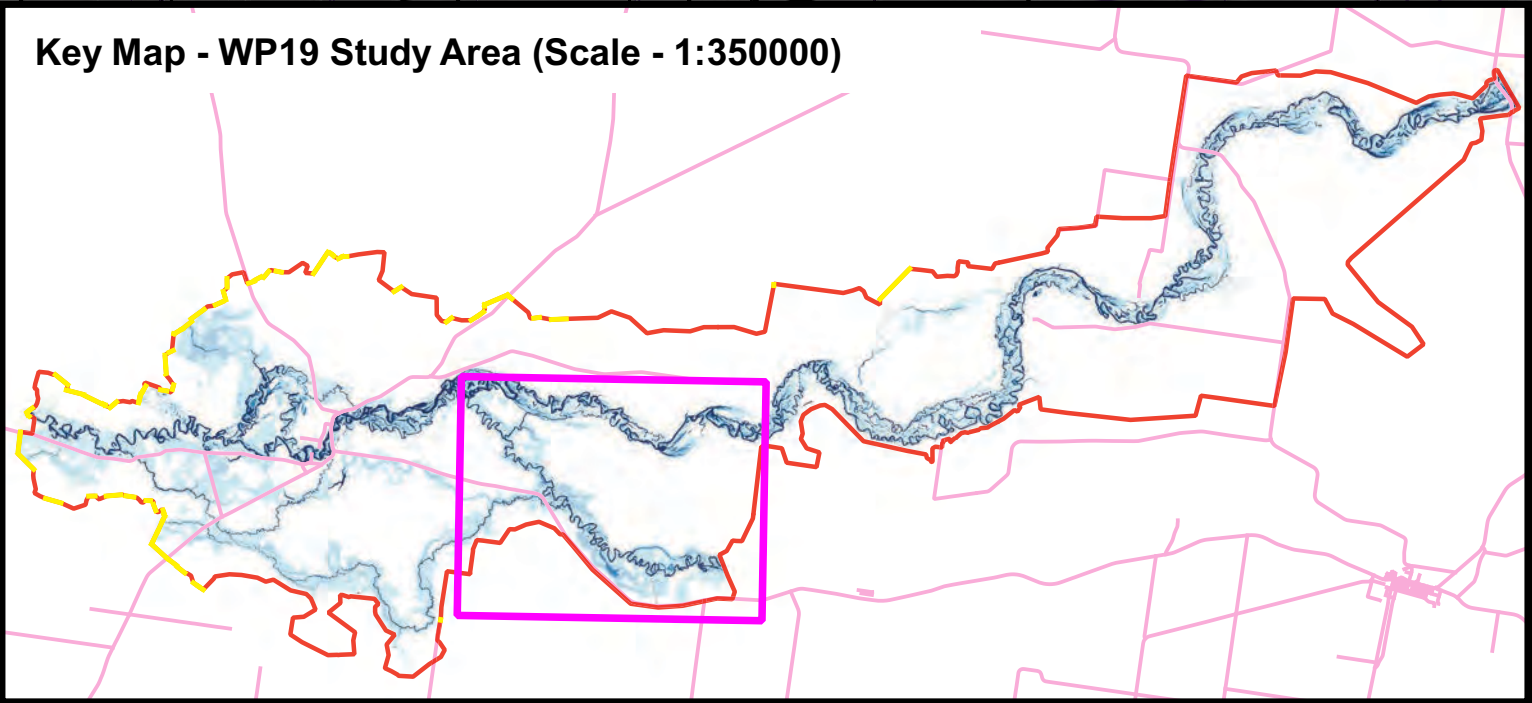
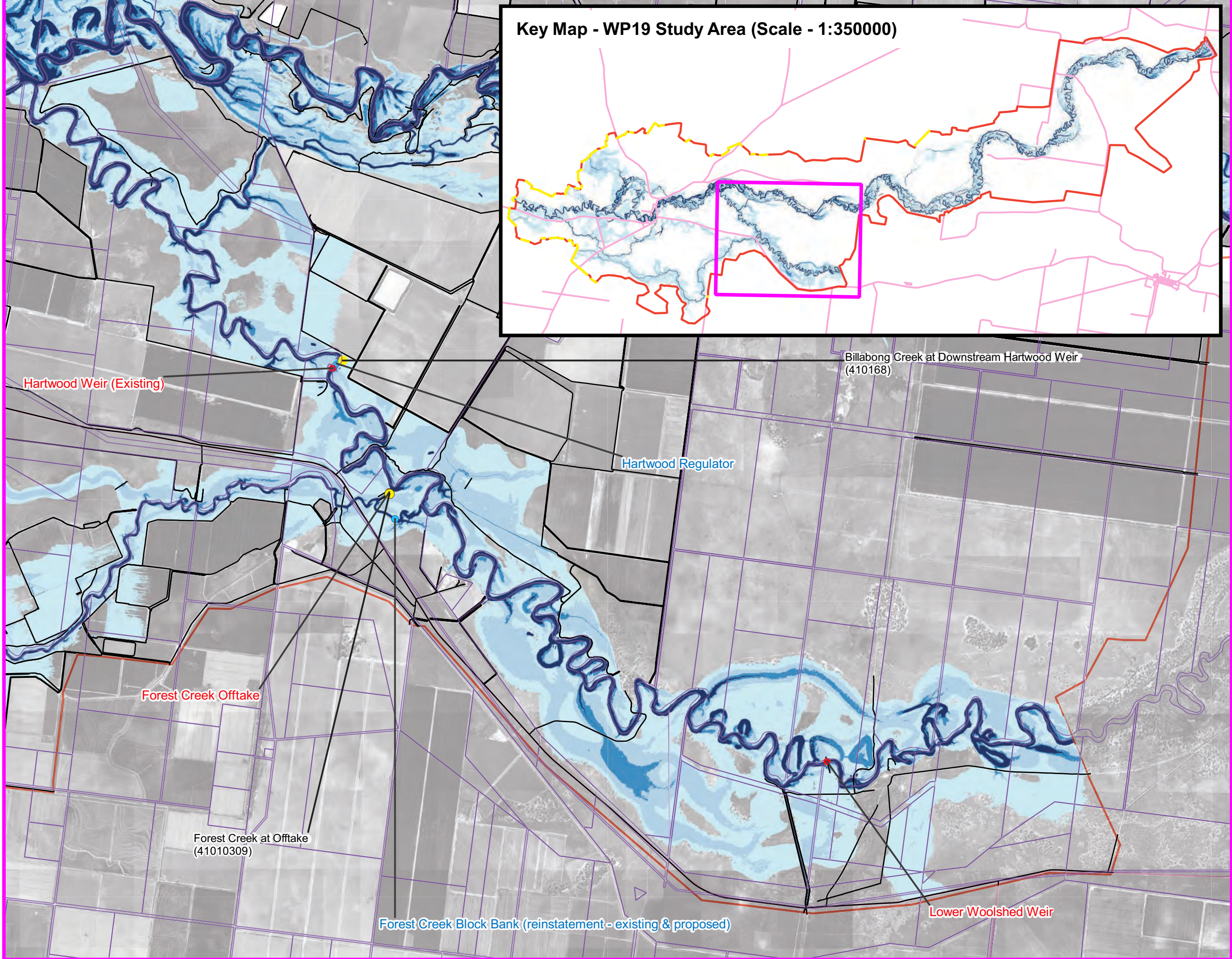
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WORKSPACE:
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B5 - 1% AEP Billabong Dominant Depth Plot
"Existing"



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- Legend**
- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Ridge Lines
 - Downstream Boundary Conditions
 - Property Boundaries
 - Hydraulic Model Boundary
- Depth (m)**
- ≤ 0.50
 - 0.50 - 1.00
 - 1.00 - 1.50
 - > 1.50
- Roads



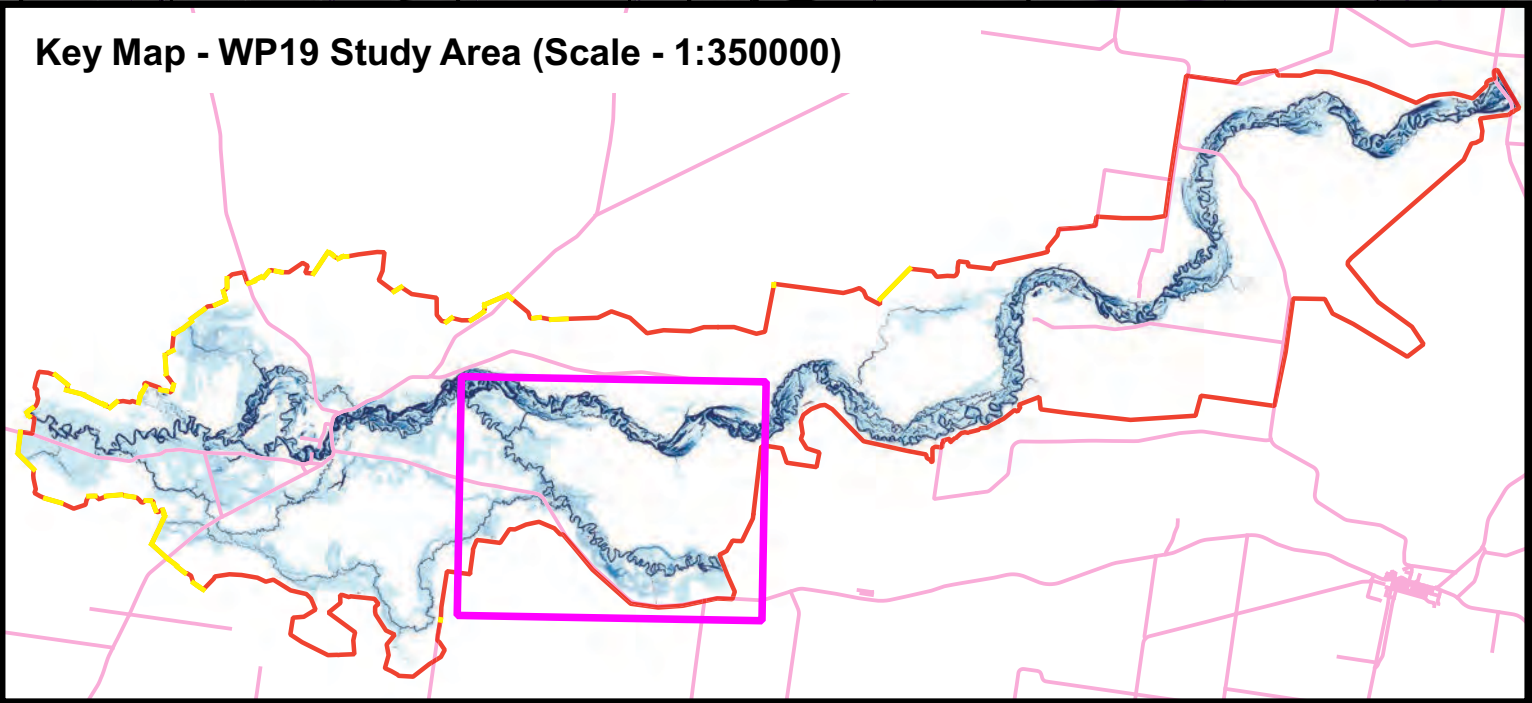
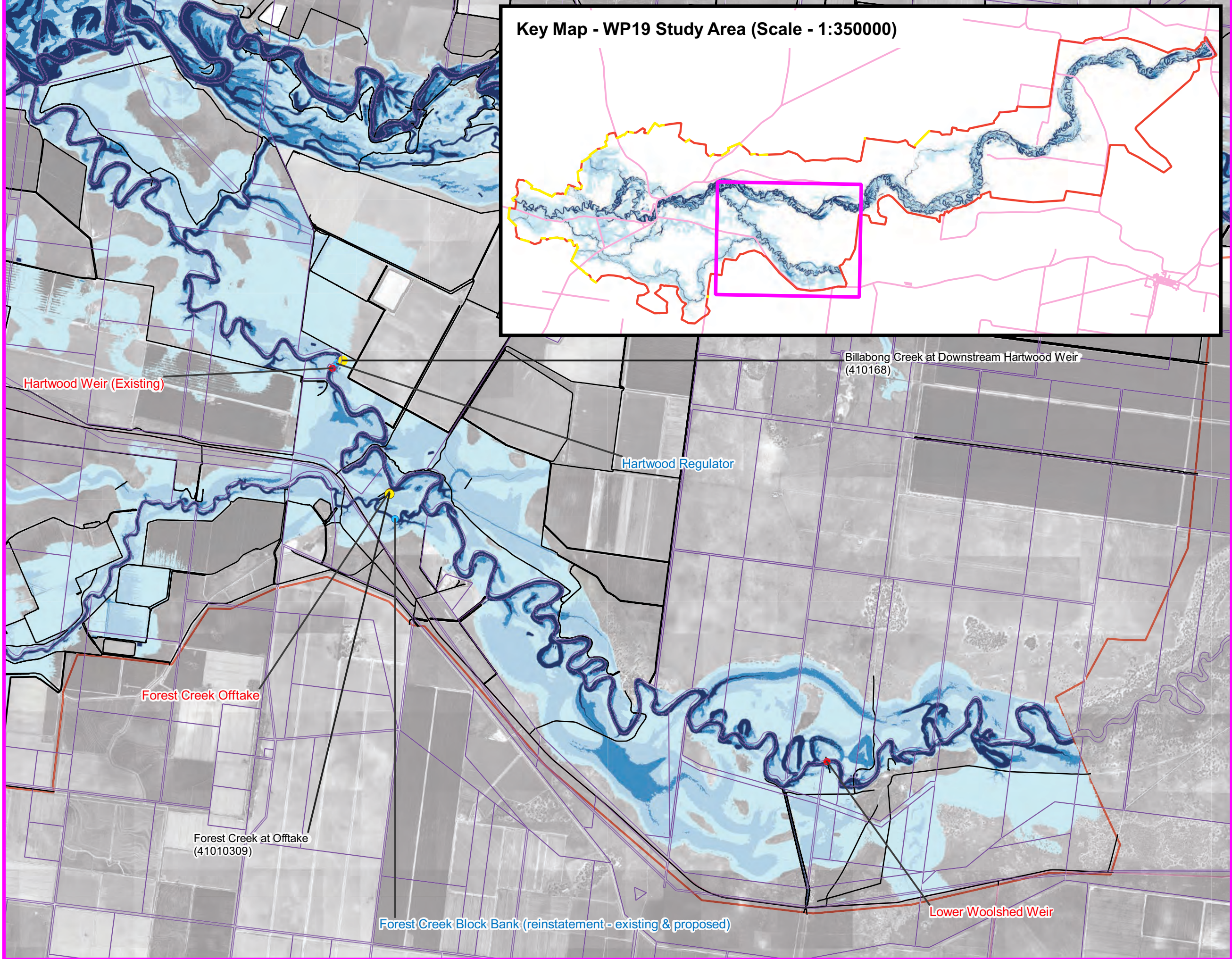
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WORKSPACE:
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B6 - 0.5% AEP Billabong Dominant Depth Plot
"Existing"



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- Legend**
- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Ridge Lines
 - Downstream Boundary Conditions
 - Property Boundaries
 - Hydraulic Model Boundary
- Depth (m)**
- ≤ 0.50
 - 0.50 - 1.00
 - 1.00 - 1.50
 - > 1.50
- Roads



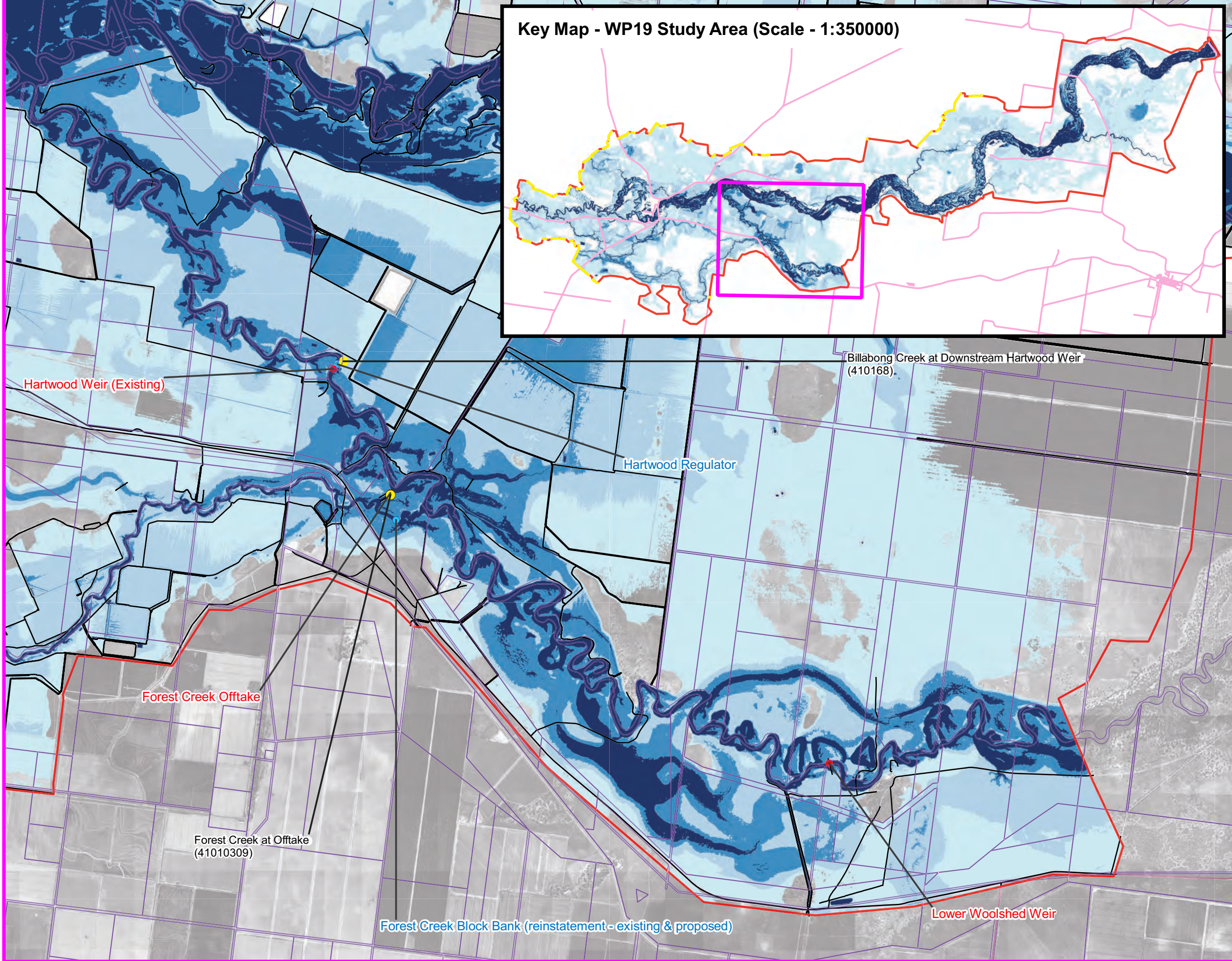
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WORKSPACE:
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Appendix_EIS_Depth_Plots_v01.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B7 - 0.2% AEP Billabong Dominant Depth Plot
"Existing"



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- Legend**
- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Ridge Lines
 - Downstream Boundary Conditions
 - Property Boundaries
 - Hydraulic Model Boundary
 - Hydraulic Model Boundary
- Depth (m)**
- ≤ 0.50
 - 0.50 - 1.00
 - 1.00 - 1.50
 - > 1.50
- Roads



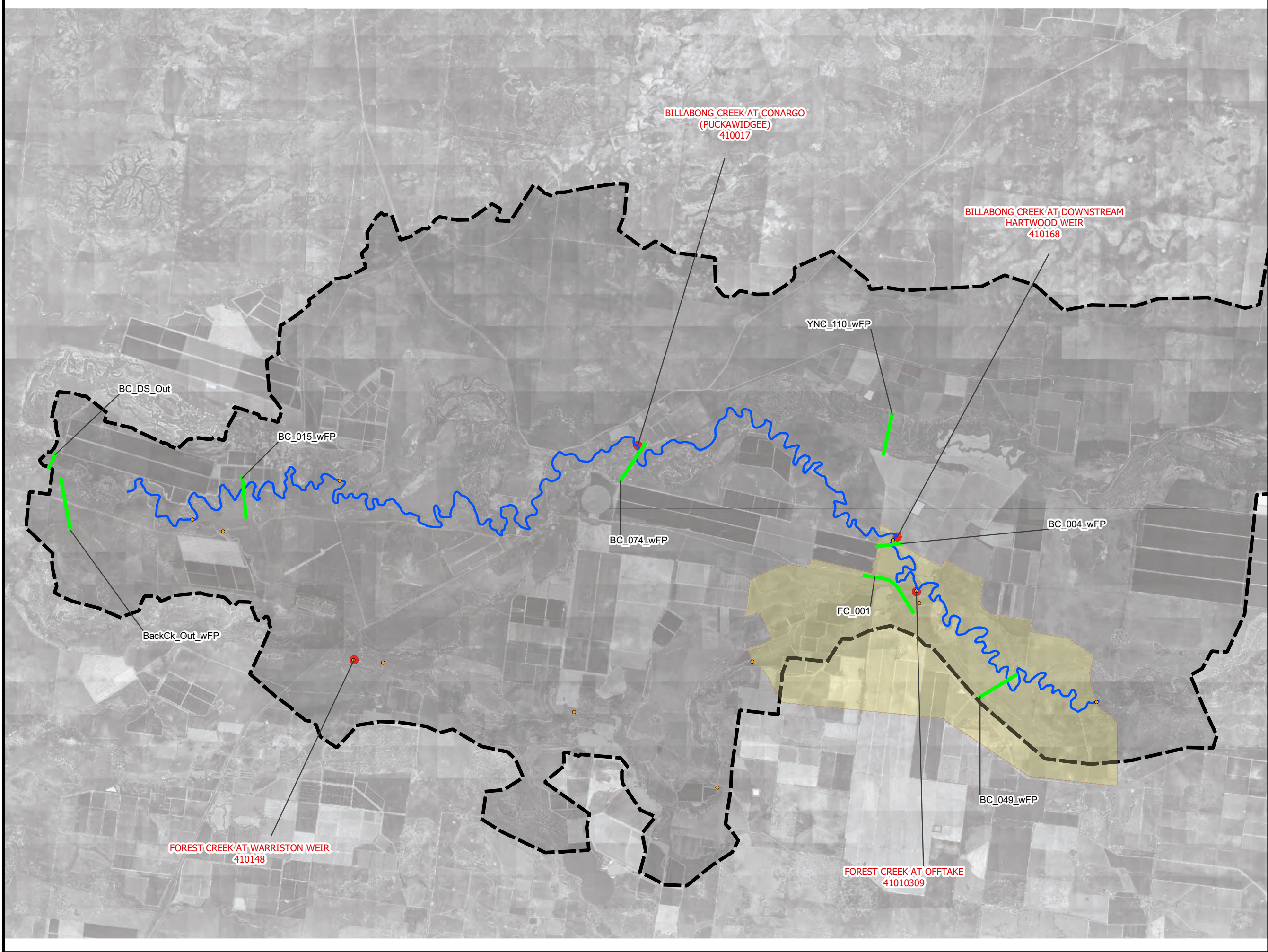
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WORKSPACE:
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Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B8 - PMF Depth Plot
"Existing"



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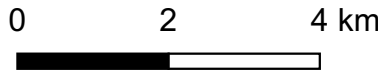


Legend

- Hydraulic Model Boundary
- Modelled significant structures
- Gauge Locations
- Billabong Creek thalweg for comparisn
- Print out locations (2d_po) for flow comparison
- Velocity and hazard categorisation comparison area



GDA 2020 Zone 55
Scale: 1:100,000



DATA SOURCE:
NSW Map Data, 2021; Model layers, 3Rivers, 2023;
Structures, Gauges and Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Modernisation Comparison Locations
"G:\21\12537654\GIS\Maps\Working\
Yanco_Modernisation_H2P_Report_Figures_GDA2020_v02.qgz"

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
Figure B9: Current Study Comparison Locations

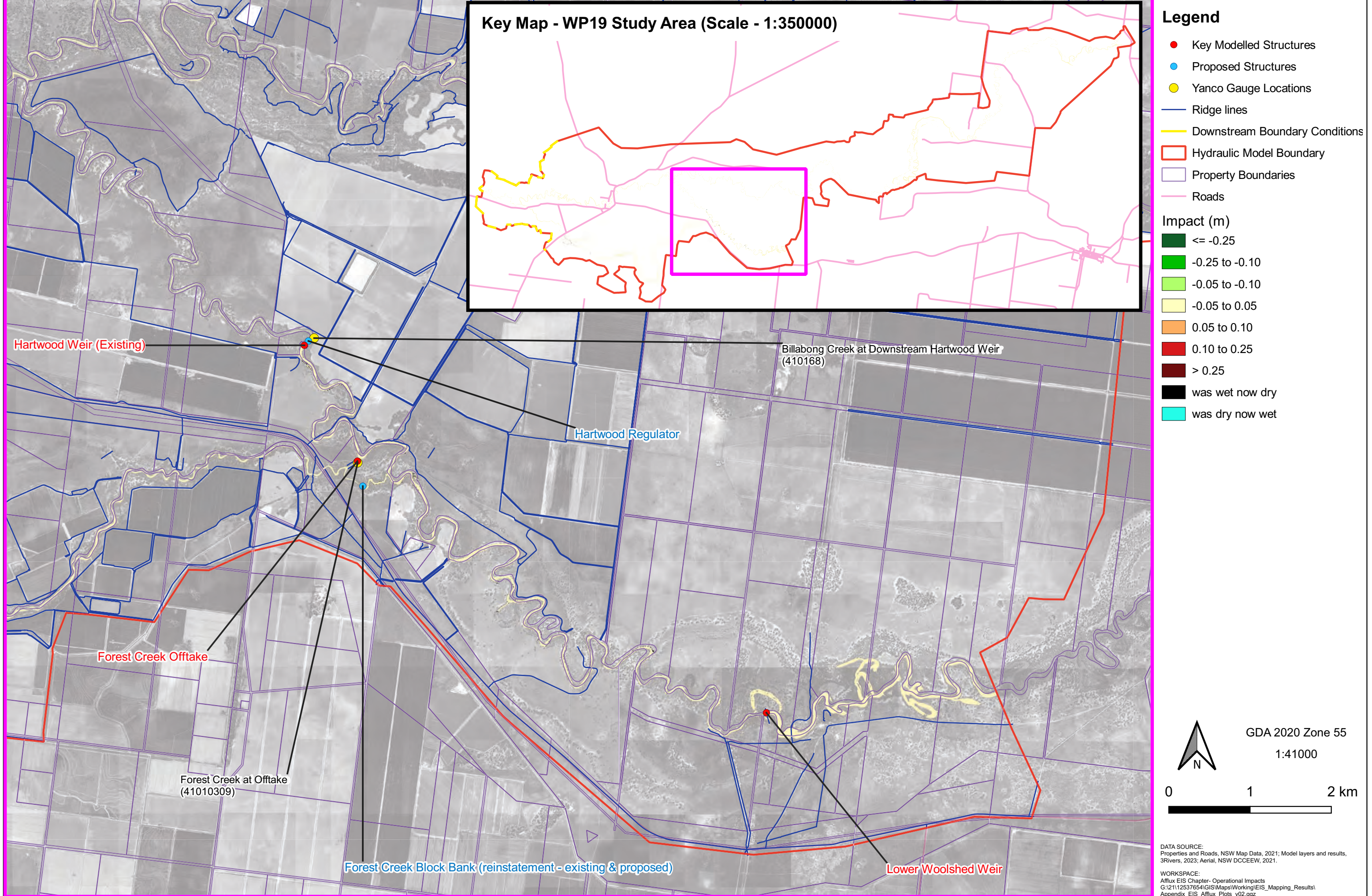


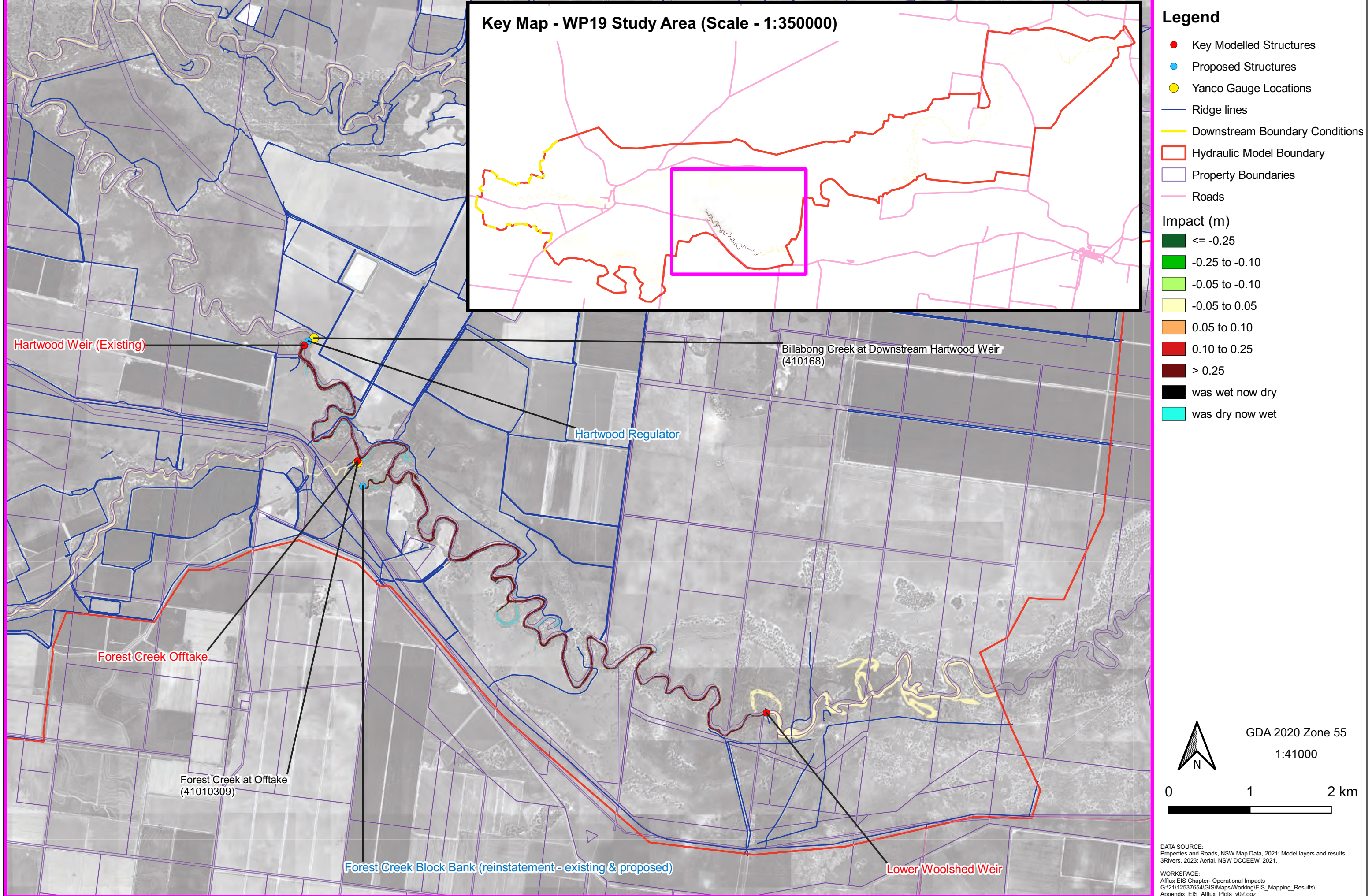
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Table B1 Flow Comparison for Hartwood Regulator

Scenario Description	Flow Description	Model Condition & Variable	Location [PO ID]							
			Yanco Creek approx. 8.3 km upstream of confluence with Billabong Creek [YNC_110_wFP]	Billabong Creek approx. 6.35 km upstream of where Forest Creek breaks away from Billabong Creek [BC_049_wFP]	Billabong Creek at around Hartwood Weir (includes channel and full floodplain flow) [BC_004_wFP]	Billabong Creek at around "Billabong Creek @ Conargo" gauge (includes channel and floodplain flow) [BC_074_wFP]	Billabong Creek approx. 3.45 km upstream of confluence with Piccaninny Creek [BC_015_wFP]	Billabong Creek approx. 7.65 km downstream of confluence with Piccaninny Creek (includes mostly channel flow only) [BC_DS_Out]	Back Creek and floodplain flow south-east of above (some floodplain flow may bypass) [BackCk_Out_wFP]	Forest Creek at Conargo Road just downstream of where Forest Creek Offtake channel joins [FC_001]
Operational Flows	Minimum Operating Flow (MinOF) with a Minimum Operating Level (MinOL) of 95.28 m AHD in weir pool	EXIST Flow (ML/day)	25	35	25	50	50	60	0	10
		PROP Flow (ML/day)	25	35	25	50	50	60	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Minimum Operating Flow (MinOF) with a Maximum Operating Level (MaxOL) of 95.44 m AHD in weir pool	EXIST Flow (ML/day)	25	35	25	50	50	60	0	10
		PROP Flow (ML/day)	25	35	25	50	50	60	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Minimum Operating Flow (MinOF) with a Full Supply Level (FSL) of 95.74 m AHD in weir pool	EXIST Flow (ML/day)	25	35	25	50	50	60	0	10
		PROP Flow (ML/day)	25	35	25	50	50	60	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Maximum Operating Flow (MaxOF) with a Minimum Operating Level (MinOL) of 95.28 m AHD in weir pool	EXIST Flow (ML/day)	99	510	500	599	599	608	0	10
		PROP Flow (ML/day)	99	510	500	599	599	608	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Maximum Operating Flow (MaxOF) with a Maximum Operating Level (MaxOL) of 95.44 m AHD in weir pool	EXIST Flow (ML/day)	99	510	500	599	599	608	0	10
		PROP Flow (ML/day)	99	510	500	599	599	608	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Maximum Operating Flow (MaxOF) with a Full Supply Level (FSL) of 95.74 m AHD in weir pool	EXIST Flow (ML/day)	99	510	500	599	599	608	0	10
		PROP Flow (ML/day)	99	510	500	599	599	608	0	10
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0	0	0	0	0
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Flood Flows	20% (1 in 5) AEP Billabong Dominant	EXIST Flow (ML/day)	1079	3991	2802	3844	3414	3631	0	1183
		PROP Flow (ML/day)	1079	3990	2823	3868	3432	3804	0	1161
		Change in Flow (ML/day) [PROP - EXIST]	0	-1	21	24	18	173	0	-22
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.7%	100.6%	100.5%	104.8%	100.0%	98.1%
	5% (1 in 20) AEP Billabong Dominant	EXIST Flow (ML/day)	2644	7089	4427	7032	5415	6153	222	2655
		PROP Flow (ML/day)	2643	7089	4428	7033	5415	6170	224	2654
		Change in Flow (ML/day) [PROP - EXIST]	-1	0	1	1	0	17	2	-1
		Change in Flow [PROP / EXIST]	100.0%	100.0%	100.0%	100.0%	100.0%	100.3%	100.9%	100.0%
	1% (1 in 100) AEP Billabong Dominant	EXIST Flow (ML/day)	6533	10888	7010	13519	7842	9056	1084	3863
		PROP Flow (ML/day)	6533	10887	6984	13492	7835	9058	1085	3888
		Change in Flow (ML/day) [PROP - EXIST]	0	-1	-26	-27	-7	2	1	25
		Change in Flow [PROP / EXIST]	100.0%	100.0%	99.6%	99.8%	99.9%	100.0%	100.1%	100.6%

Scenario Description	Flow Description	Model Condition & Variable	Location [PO ID]							
			Yanco Creek approx. 8.3 km upstream of confluence with Billabong Creek [YNC_110_wFP]	Billabong Creek approx. 6.35 km upstream of where Forest Creek breaks away from Billabong Creek [BC_049_wFP]	Billabong Creek at around Hartwood Weir (includes channel and full floodplain flow) [BC_004_wFP]	Billabong Creek at around "Billabong Creek @ Conargo" gauge (includes channel and floodplain flow) [BC_074_wFP]	Billabong Creek approx. 3.45 km upstream of confluence with Piccaninny Creek [BC_015_wFP]	Billabong Creek approx. 7.65 km downstream of confluence with Piccaninny Creek (includes mostly channel flow only) [BC_DS_Out]	Back Creek and floodplain flow south-east of above (some floodplain flow may bypass) [BackCk_Out_wFP]	Forest Creek at Conargo Road just downstream of where Forest Creek Offtake channel joins [FC_001]
Flood Flows	0.5% (1 in 200) AEP Billabong Dominant	EXIST Flow (ML/day)	10396	13048	8647	18914	9592	10403	2874	4400
		PROP Flow (ML/day)	10395	13049	8609	18876	9584	10403	2873	4438
		Change in Flow (ML/day) [PROP - EXIST]	-1	1	-38	-38	-8	0	-1	38
		Change in Flow [PROP / EXIST]	100.0%	100.0%	99.6%	99.8%	99.9%	100.0%	100.0%	100.9%
	0.2% (1 in 500) AEP Billabong Dominant	EXIST Flow (ML/day)	18835	16488	11223	29666	12714	12324	6609	5251
		PROP Flow (ML/day)	18840	16489	11162	29605	12708	12321	6605	5311
		Change in Flow (ML/day) [PROP - EXIST]	5	1	-61	-61	-6	-3	-4	60
		Change in Flow [PROP / EXIST]	100.0%	100.0%	99.5%	99.8%	100.0%	100.0%	99.9%	101.1%
	PMF	EXIST Flow (ML/day)	46923	50086	29730	60181	20633	18500	15934	15686
		PROP Flow (ML/day)	47830	50062	29327	60182	20656	18518	15958	15931
		Change in Flow (ML/day) [PROP - EXIST]	907	-24	-403	1	23	18	24	245
		Change in Flow [PROP / EXIST]	101.9%	100.0%	98.6%	100.0%	100.1%	100.1%	100.2%	101.6%

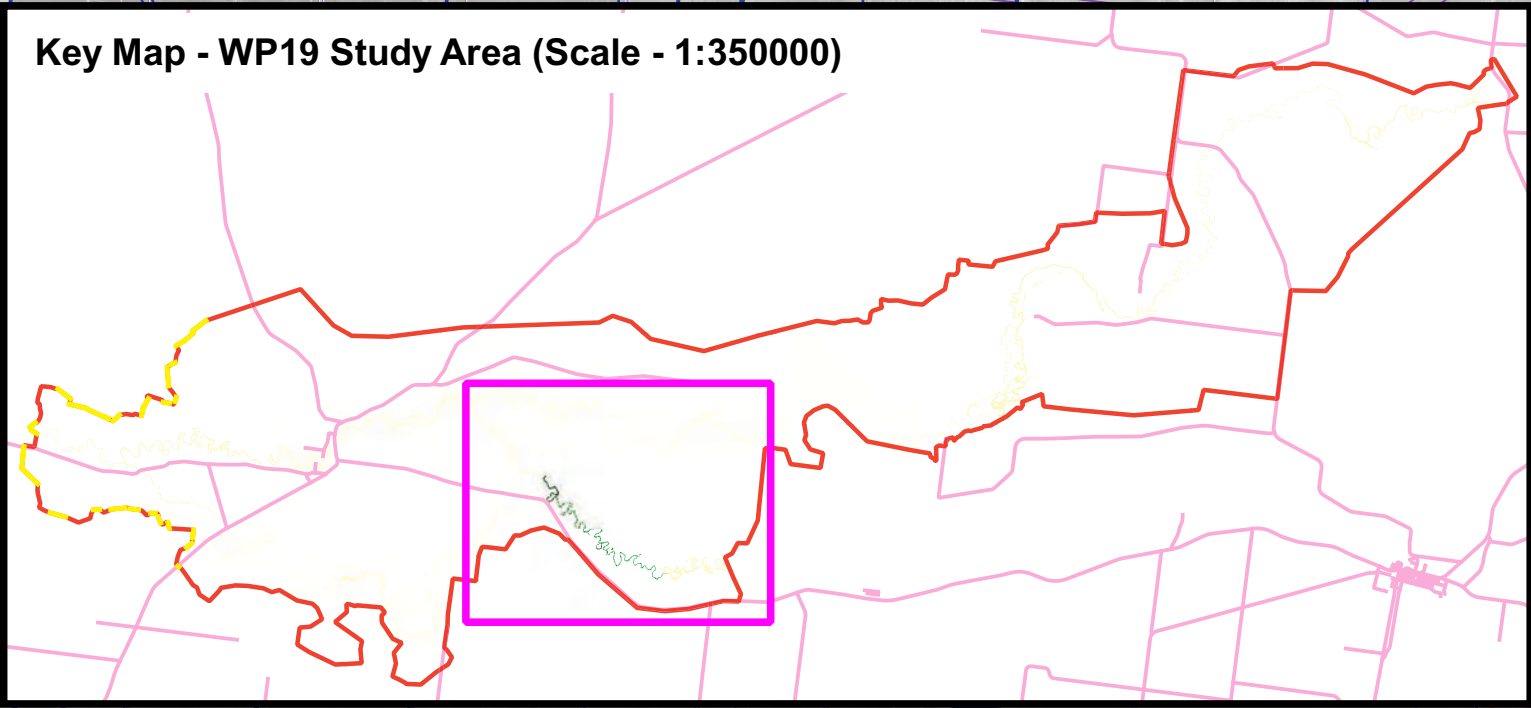
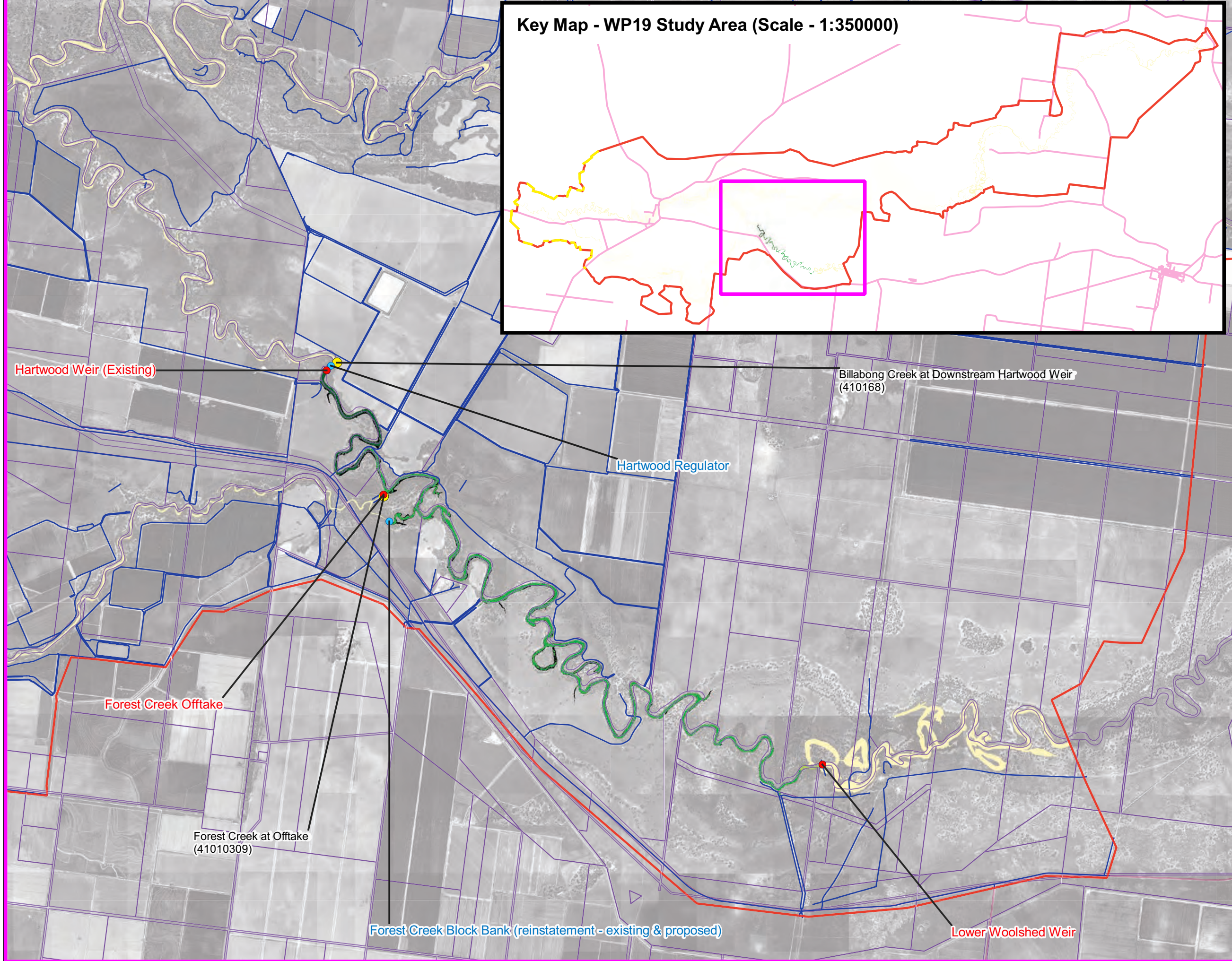




Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B12 - Minimum Operating Flow (25 ML/day) Flood Impact Plot
"Proposed at Full Supply Level" WSL - "Exisitng" WSL



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Legend

- Key Modelled Structures
- Proposed Structures
- Yanco Gauge Locations
- Ridge lines
- Downstream Boundary Conditions
- Hydraulic Model Boundary
- Property Boundaries
- Roads

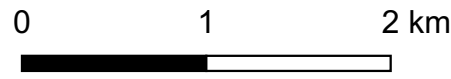
Impact (m)

- ≤ -0.25
- -0.25 to -0.10
- -0.05 to -0.10
- -0.05 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- > 0.25
- was wet now dry
- was dry now wet



GDA 2020 Zone 55

1:41000



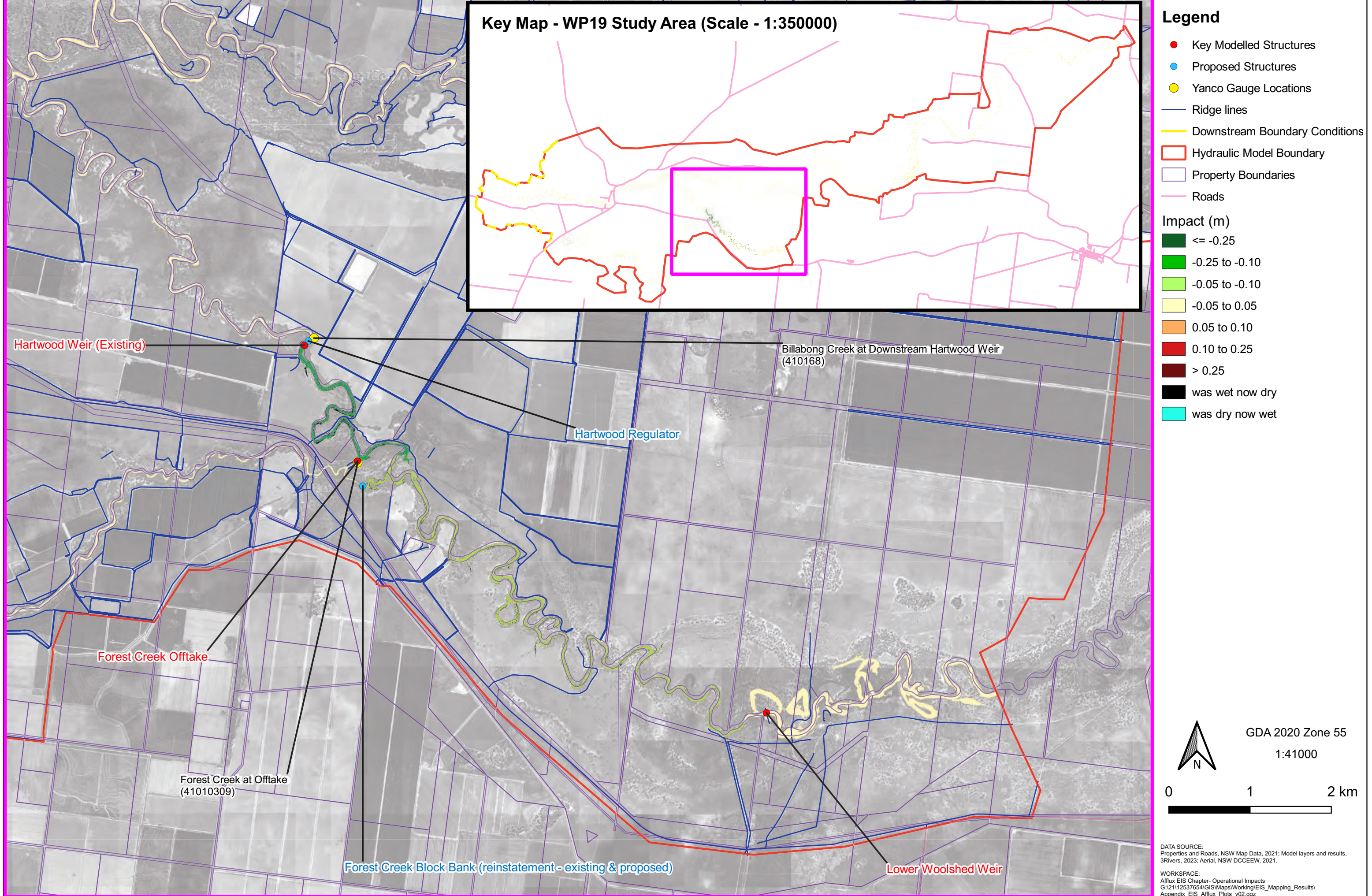
DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Afflux EIS Chapter- Operational Impacts
G:\21\12537654\GIS\Maps\Working\EIS_Mapping_Results\
Appendix_EIS_Afflux_Plots_v02.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B13 - Maximum Operating Flow (500 ML/day) Flood Impact Plot
"Proposed at Minimum Operating Level" WSL - "Exisitng" WSL



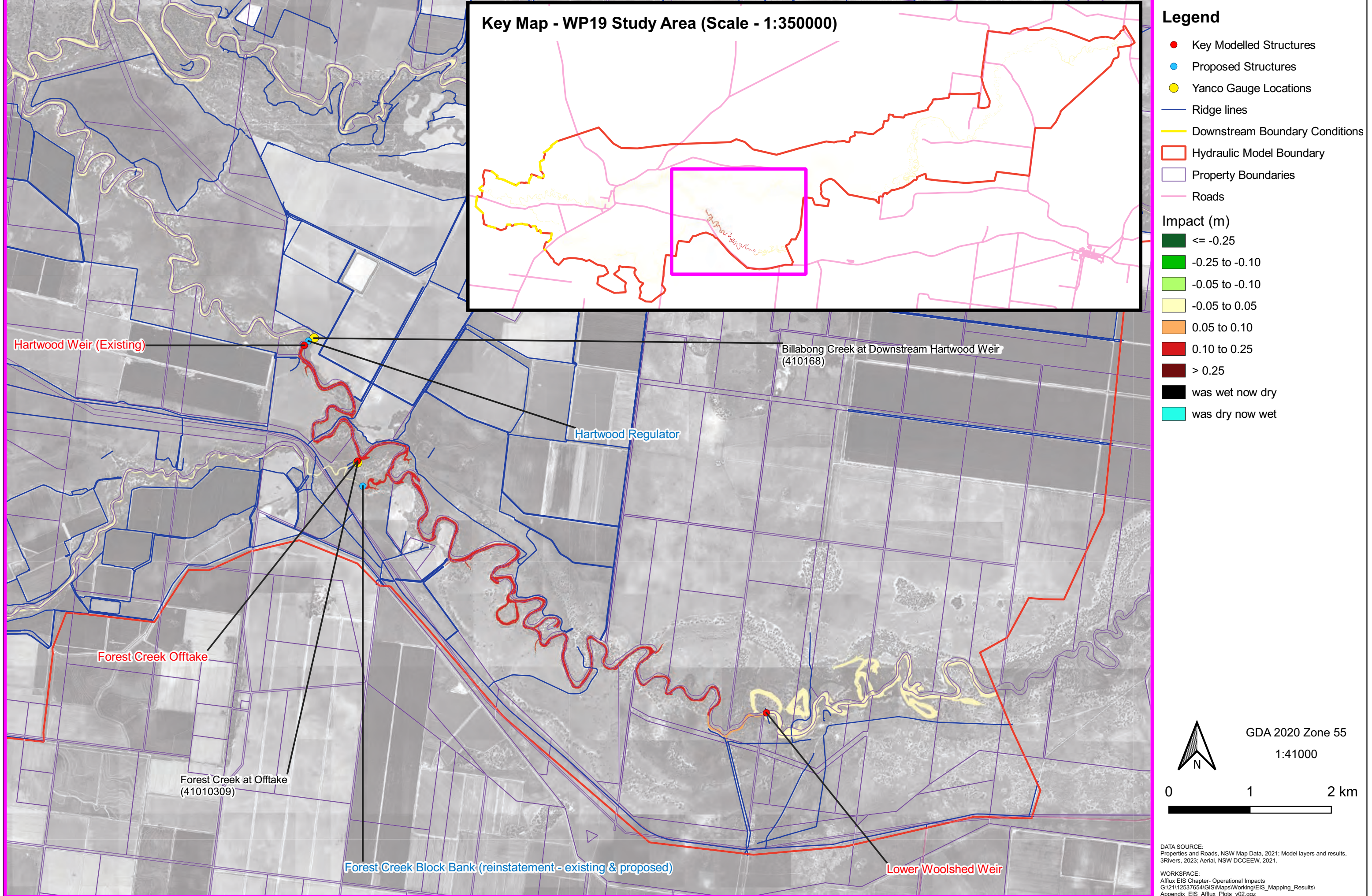
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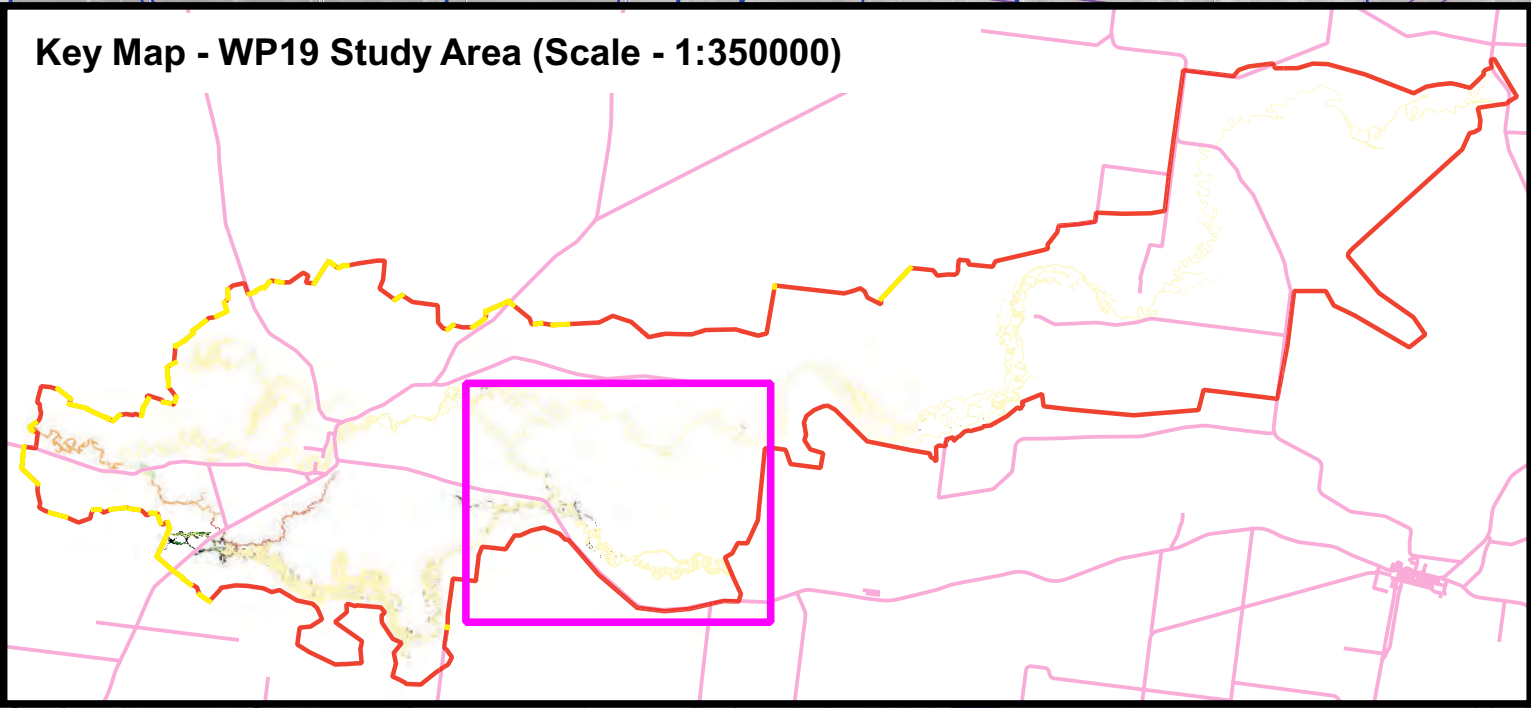
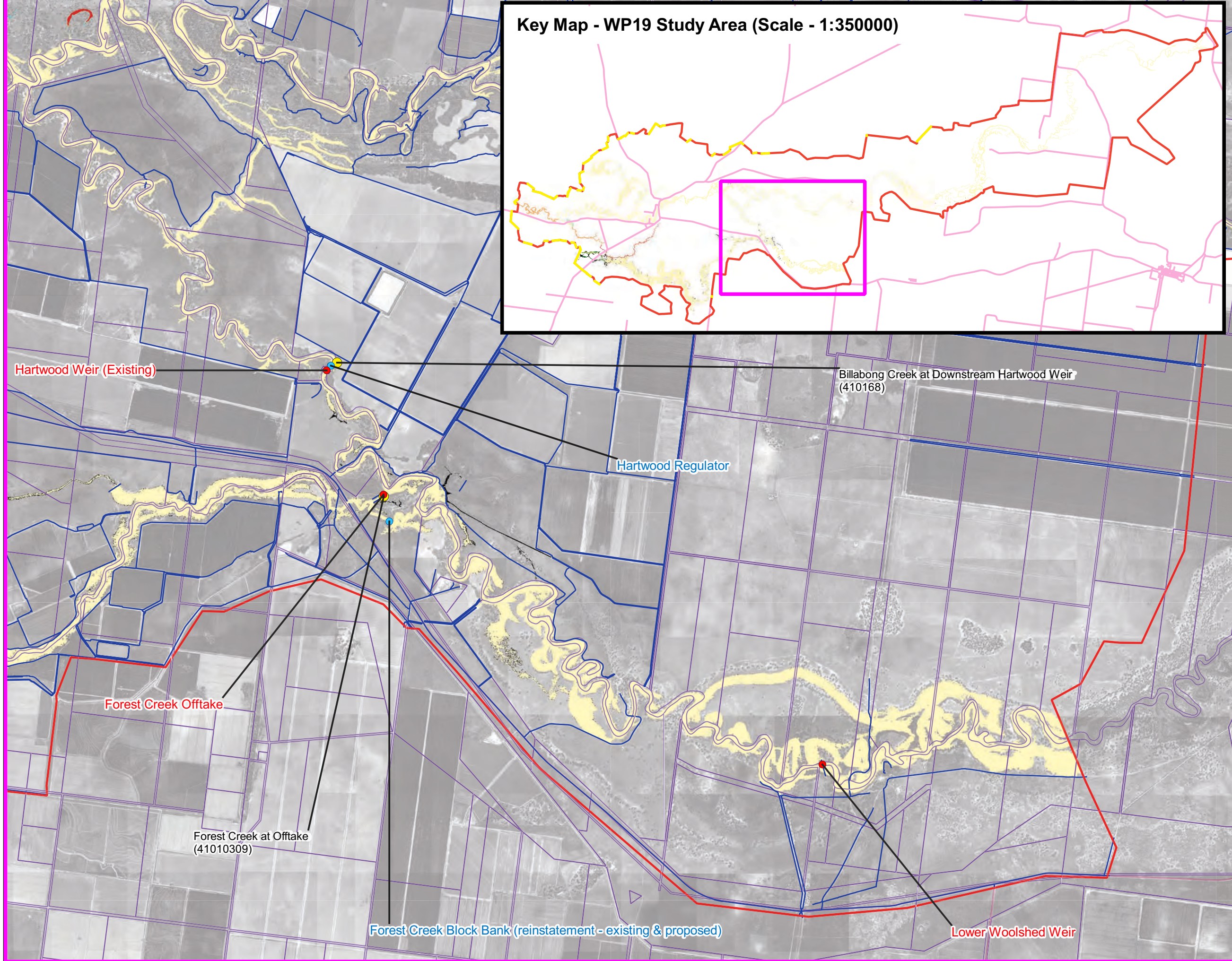


Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B14 - Maximum Operating Flow (500 ML/day) Flood Impact Plot
"Proposed at Maximum Operating Level" WSL - "Exisitng" WSL



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Legend

- Key Modelled Structures
- Proposed Structures
- Yanco Gauge Locations
- Downstream Boundary Conditions
- Hydraulic Model Boundary
- Property Boundaries
- Roads

Impact (m)

- ≤ -0.25
- 0.25 to -0.10
- 0.05 to -0.10
- 0.05 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- > 0.25
- was wet now dry
- was dry now wet

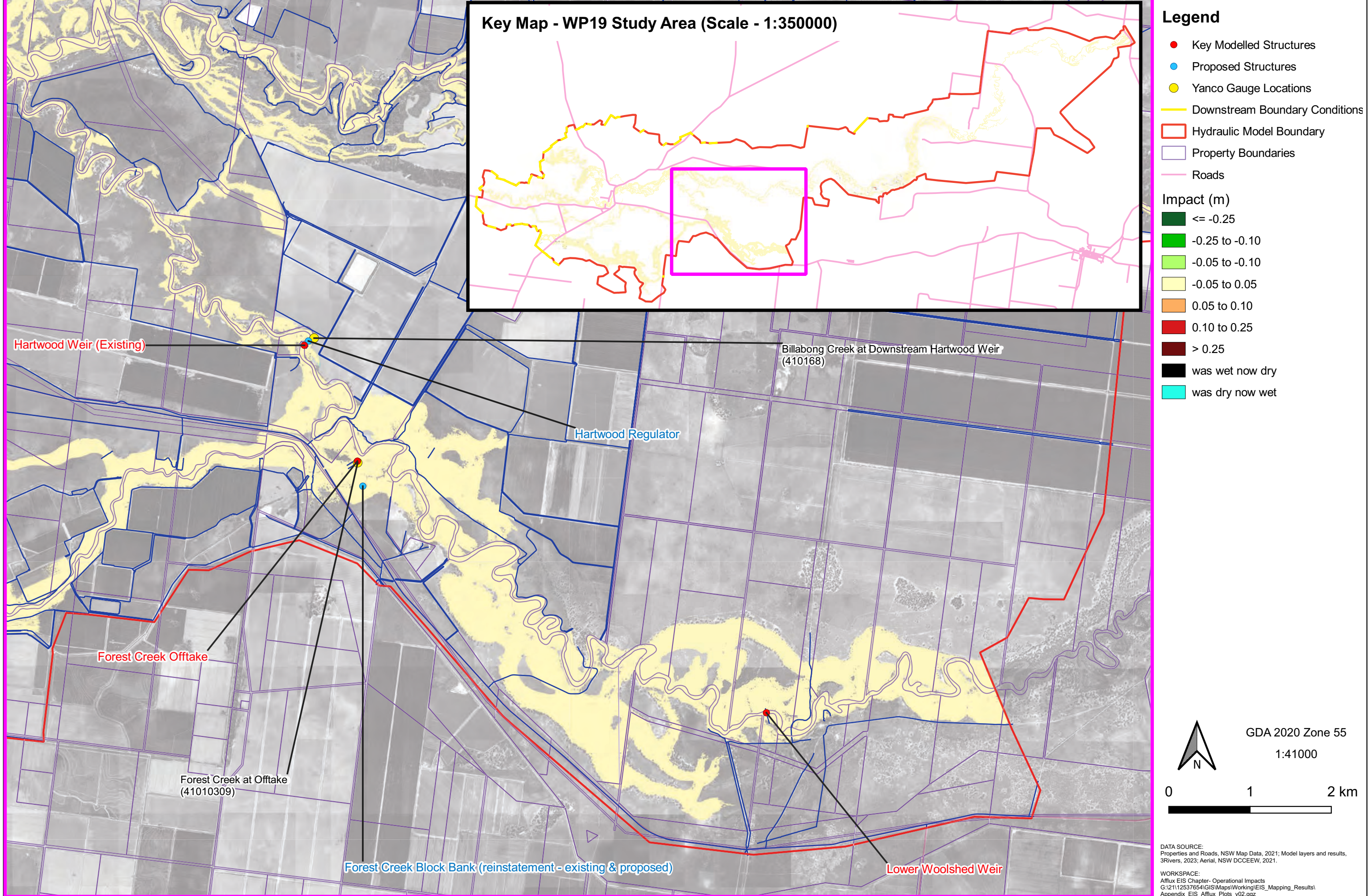
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GDA 2020 Zone 55
1:41000

DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Afflux EIS Chapter- Operational Impacts
G:\21\12537654\GIS\Maps\Working\EIS_Mapping_Results\
Appendix_EIS_Afflux_Plots_v02.qgz

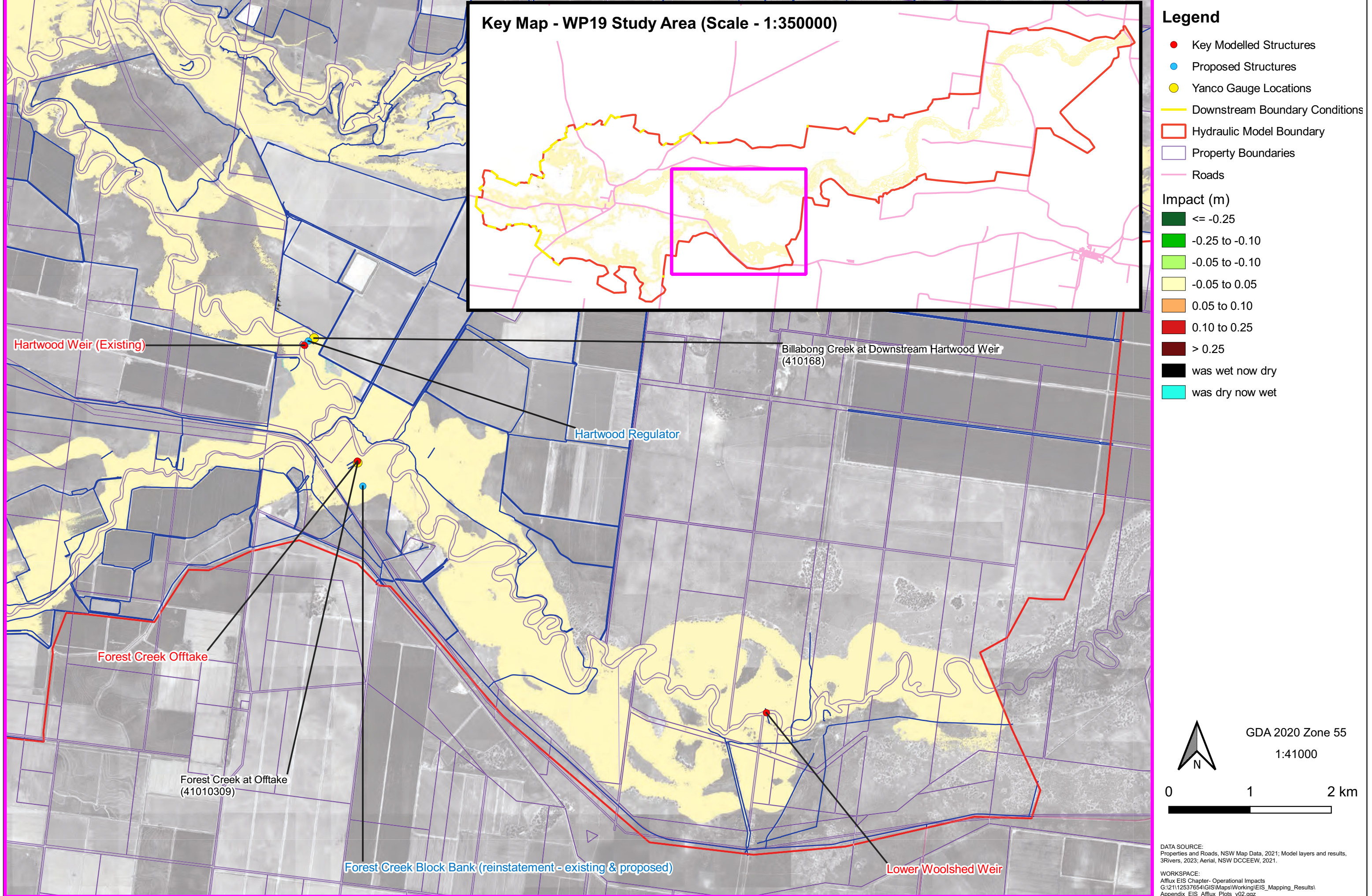
Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B16 - 20% AEP Billabong Dominant Flood Impact Plot
"Proposed" WSL - "Existing" WSL

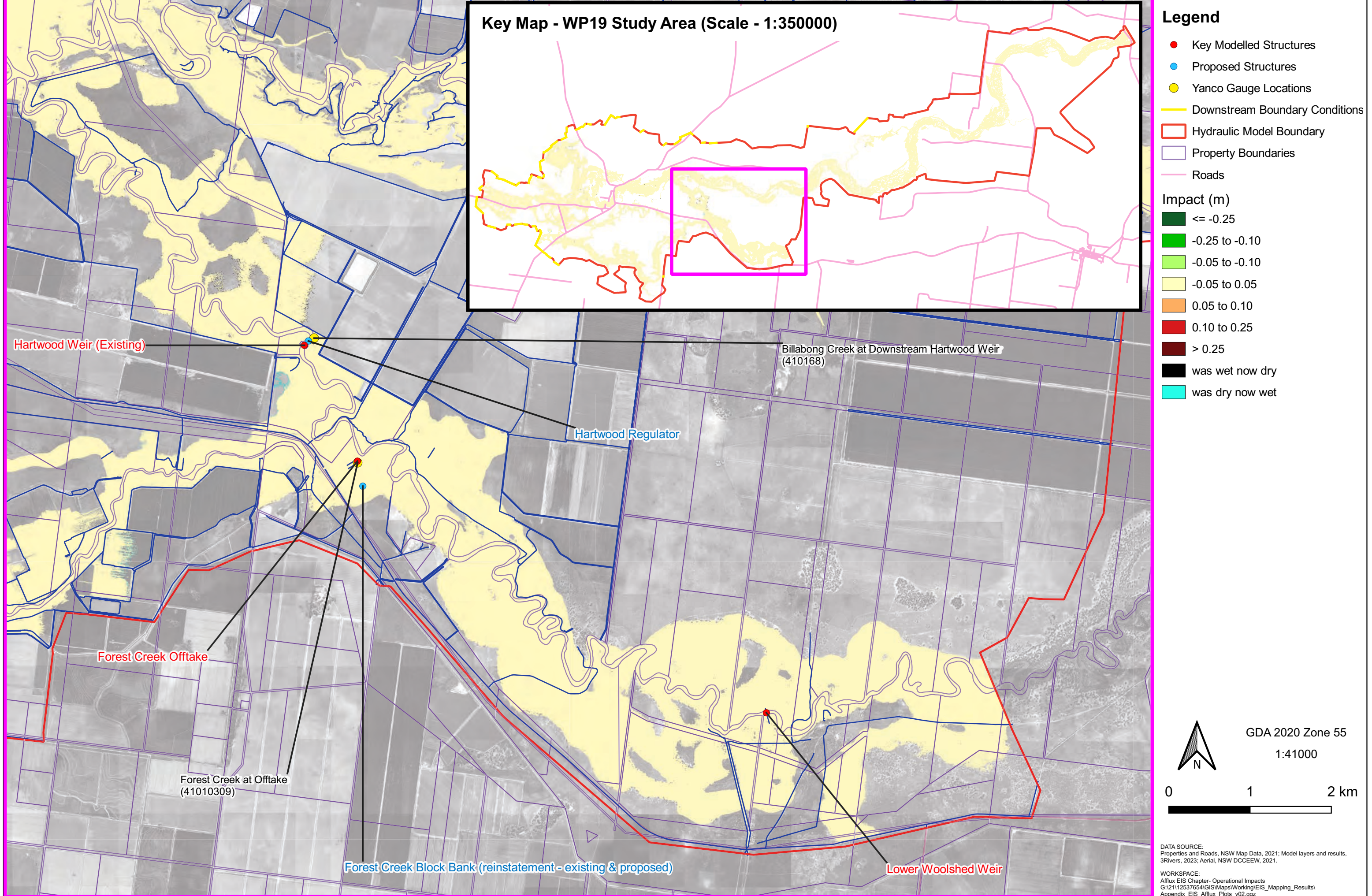


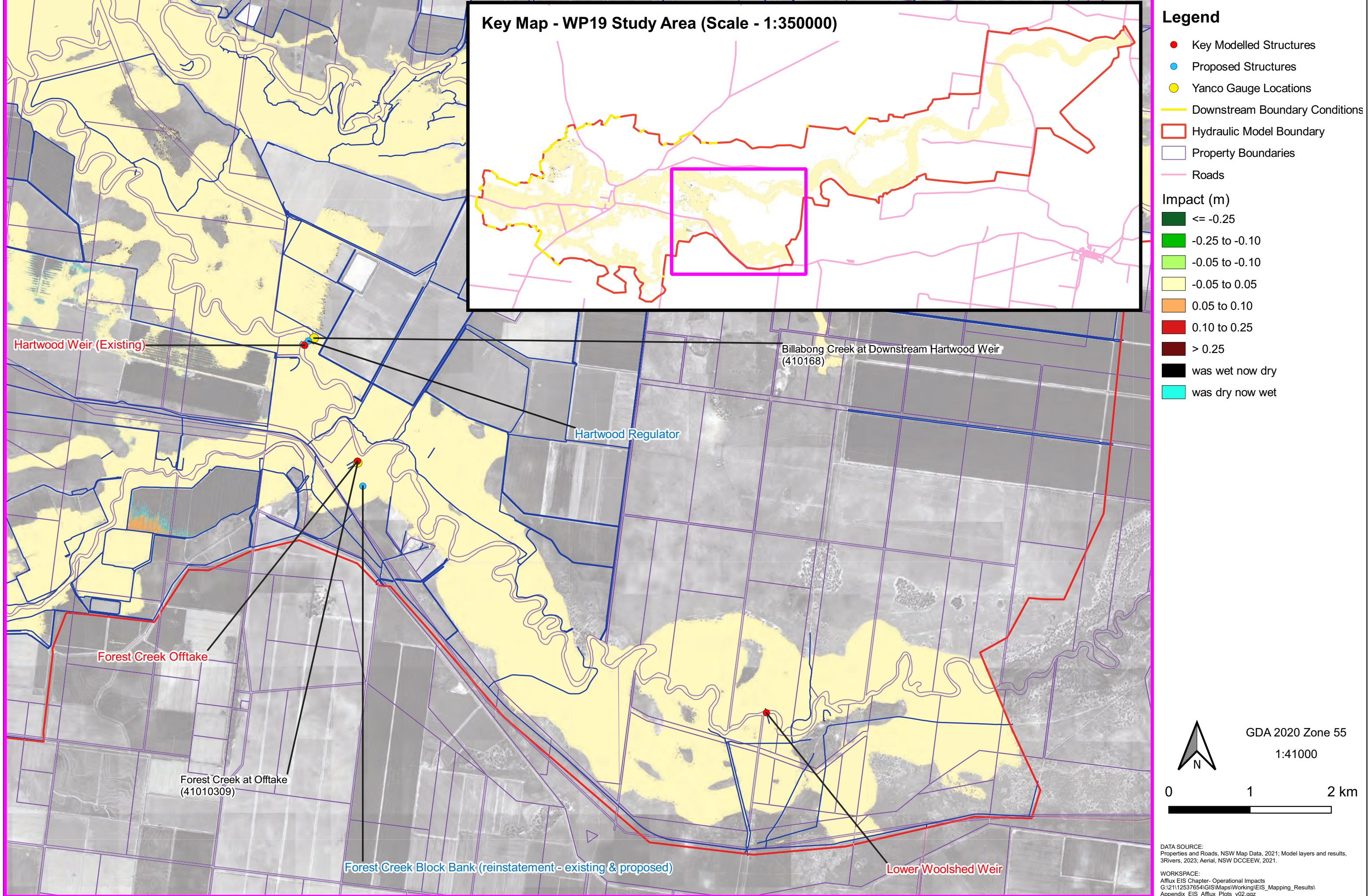
Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B17 - 5% AEP Billabong Dominant Flood Impact Plot
"Proposed" WSL - "Existing" WSL



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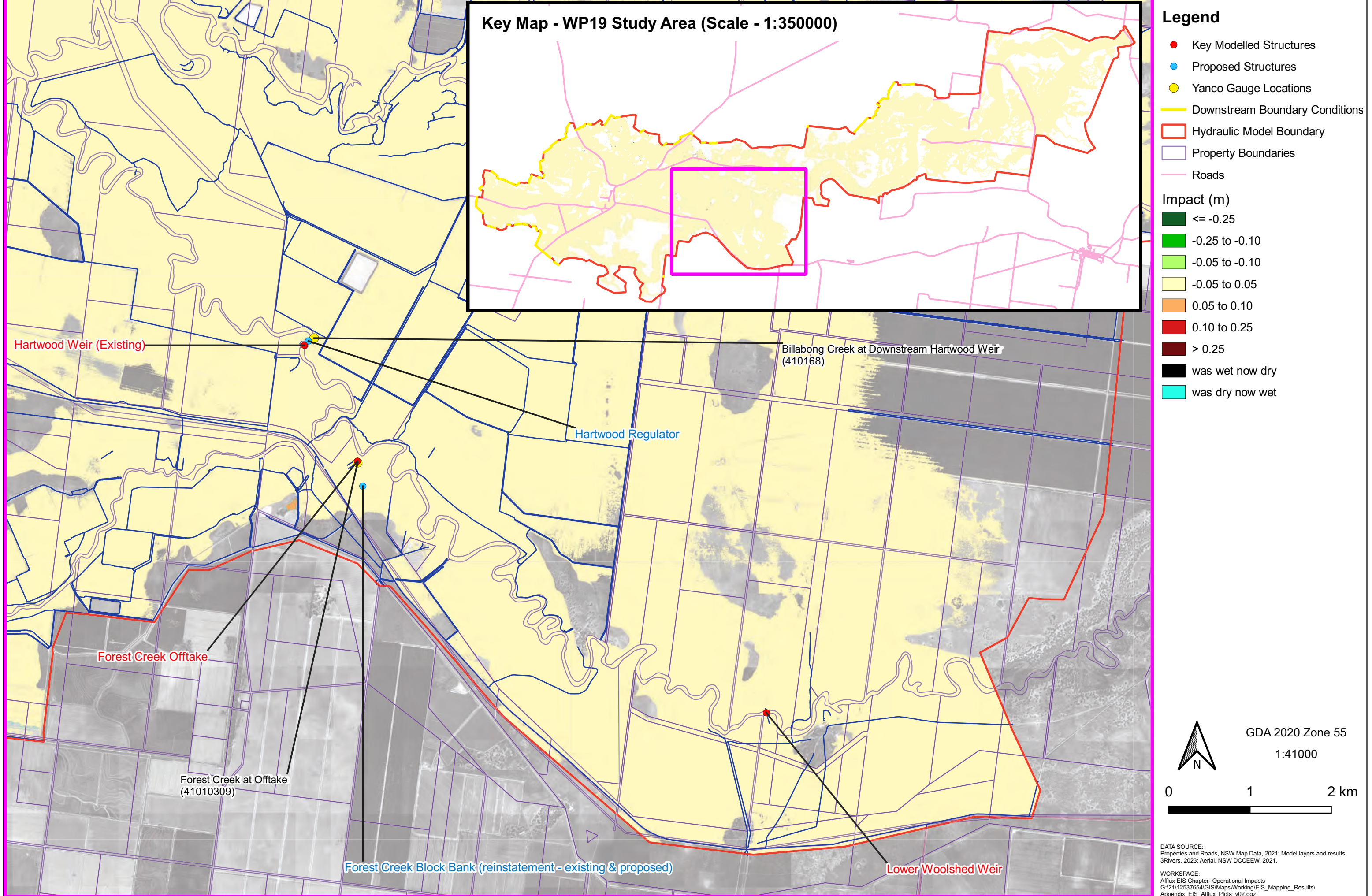




Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B20 - 0.2% AEP Billabong Dominant Flood Impact Plot
"Proposed" WSL - "Existing" WSL



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Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B21 - PMF Flood Impact Plot
"Proposed" WSL - "Existing" WSL



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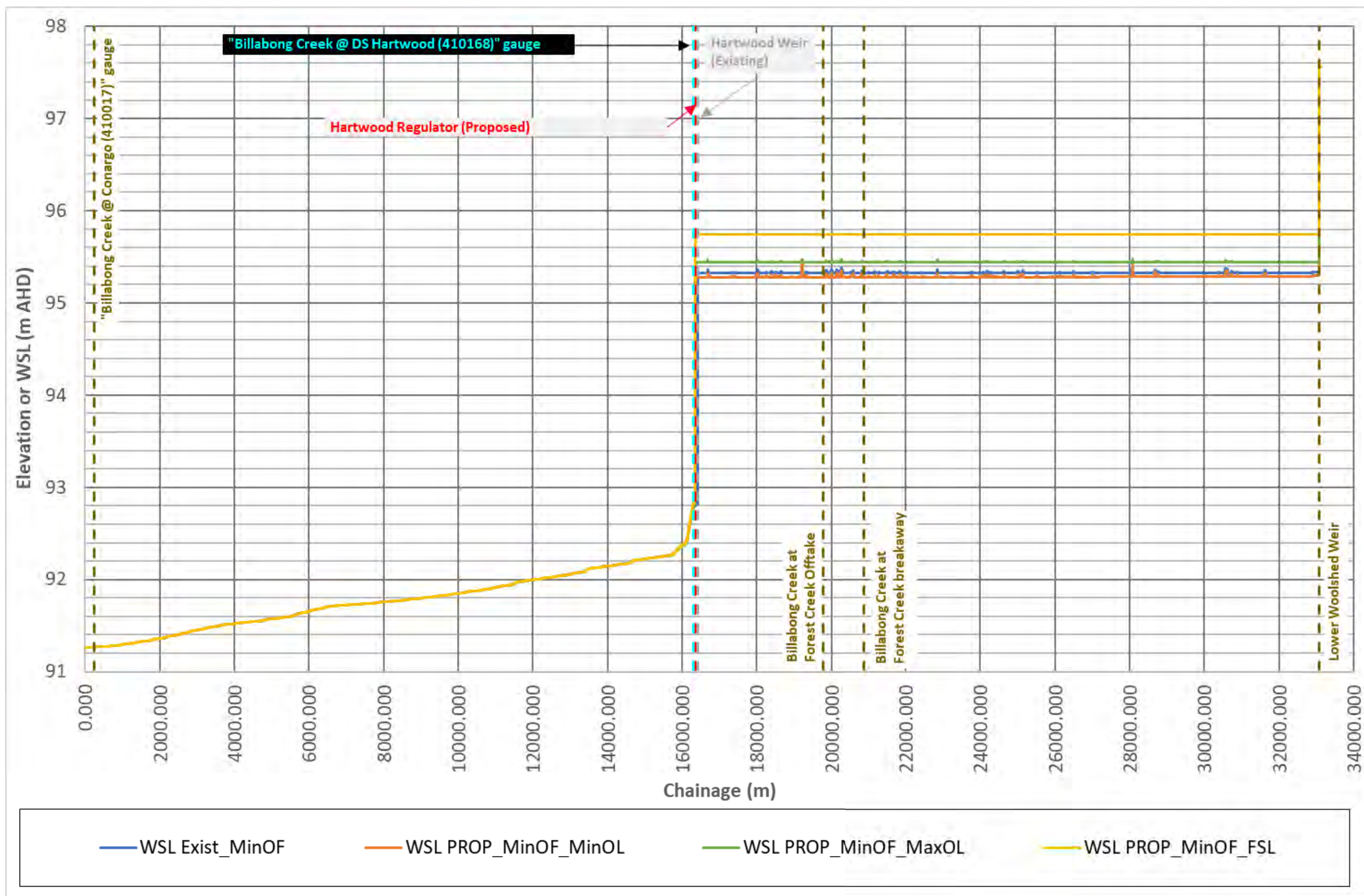


Figure B22 "Proposed" and "Existing" WSL comparison along Billabong Creek for Minimum Operating Flow (MinOF) of 25 ML/day at Hartwood Regulator

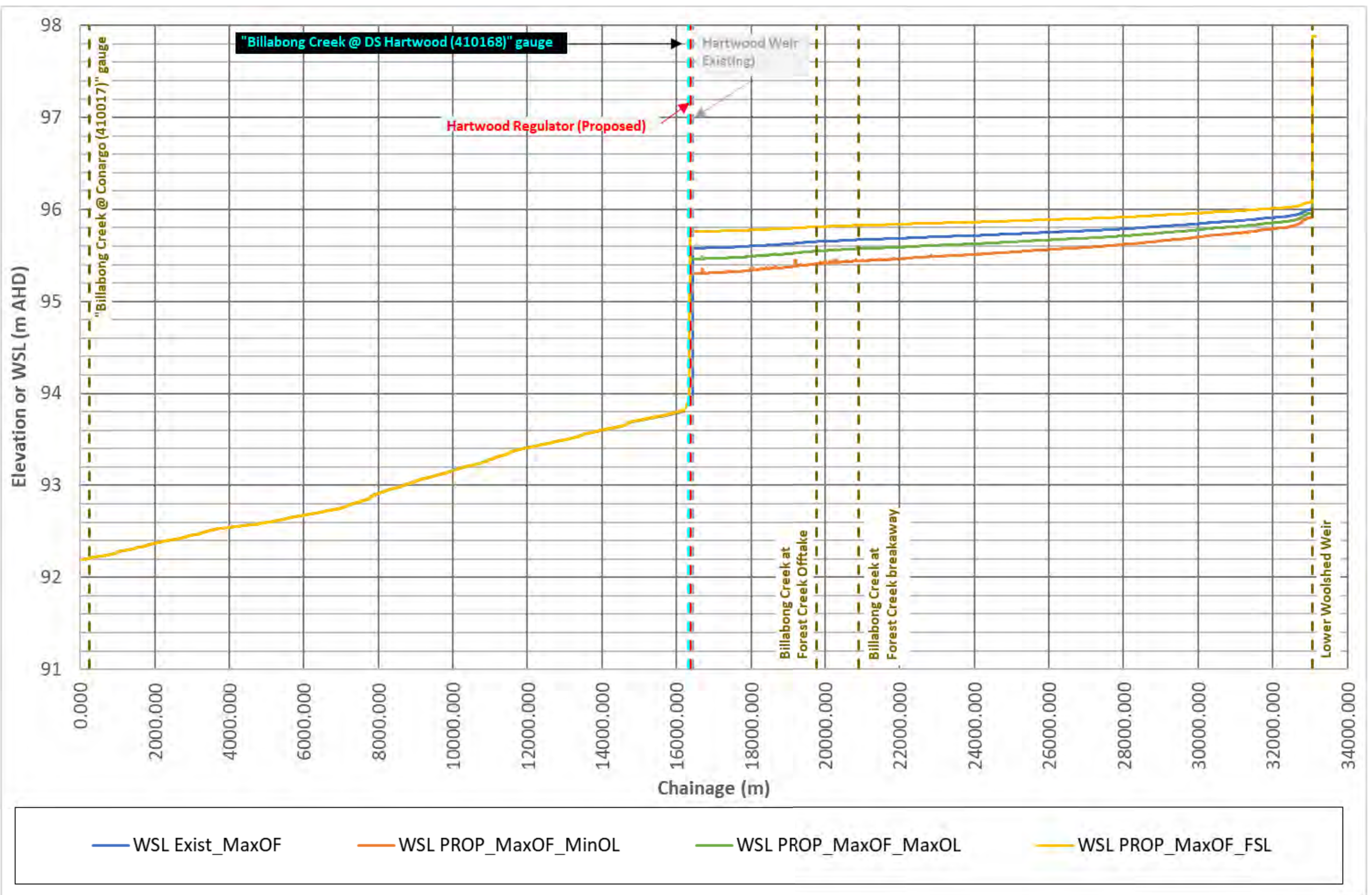


Figure B23 "Proposed" and "Existing" WSL comparison along Billabong Creek for Maximum Operating Flow (MaxOF) of 500 ML/day at Hartwood Regulator

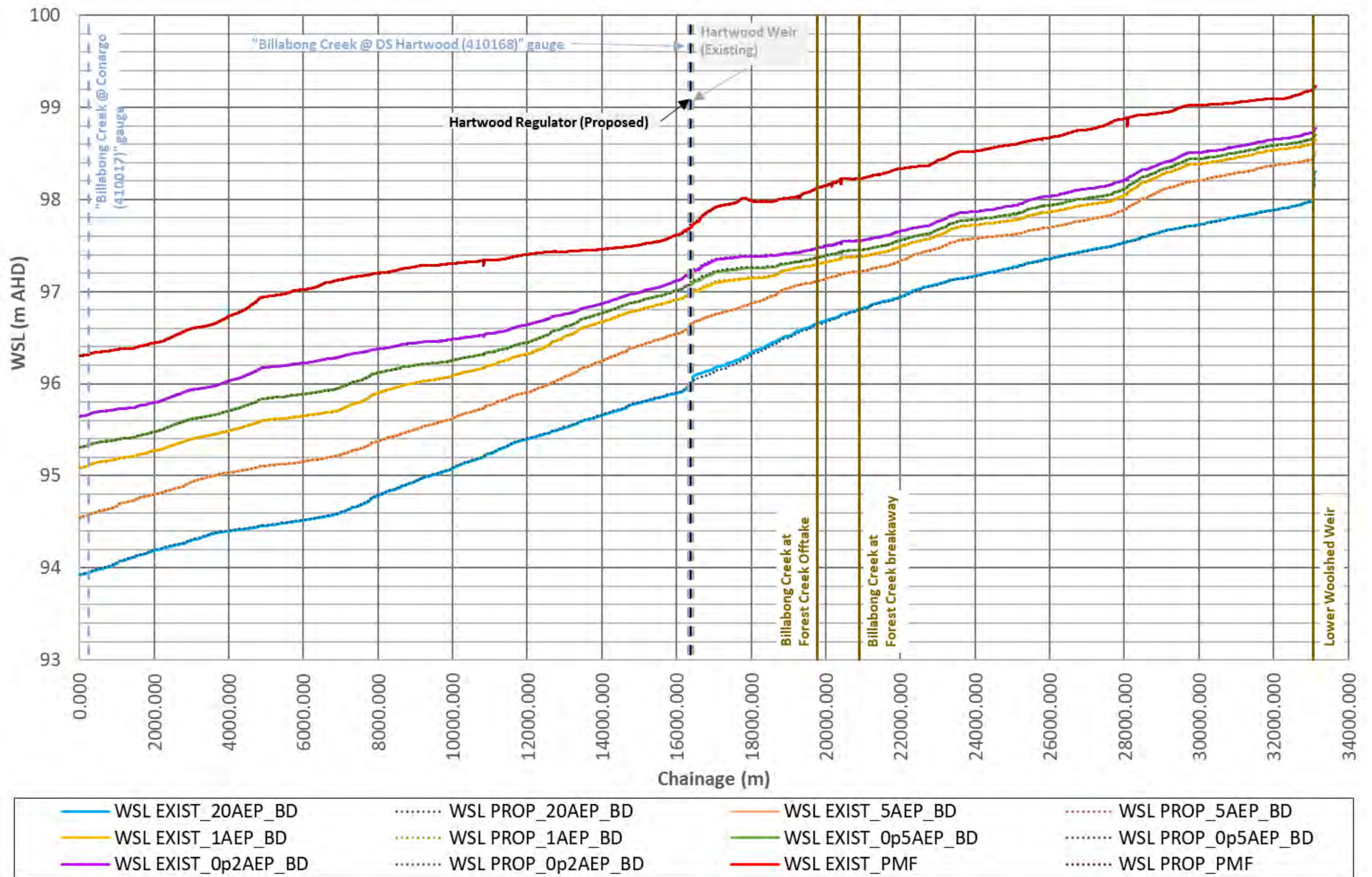


Figure B24 "Proposed" and "Existing" WSL comparison along Billabong Creek for 50% AEP to 1% AEP flood scenarios

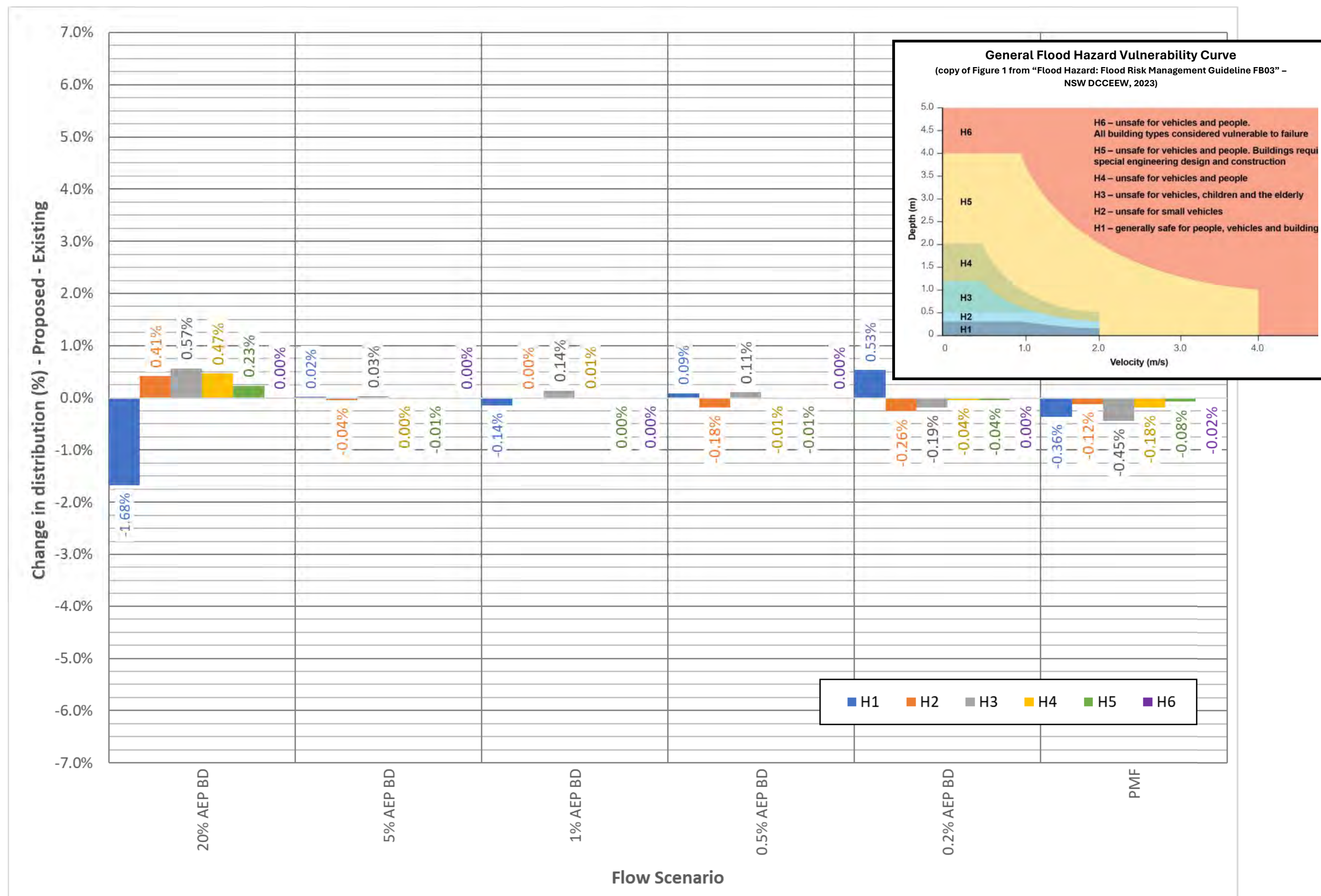
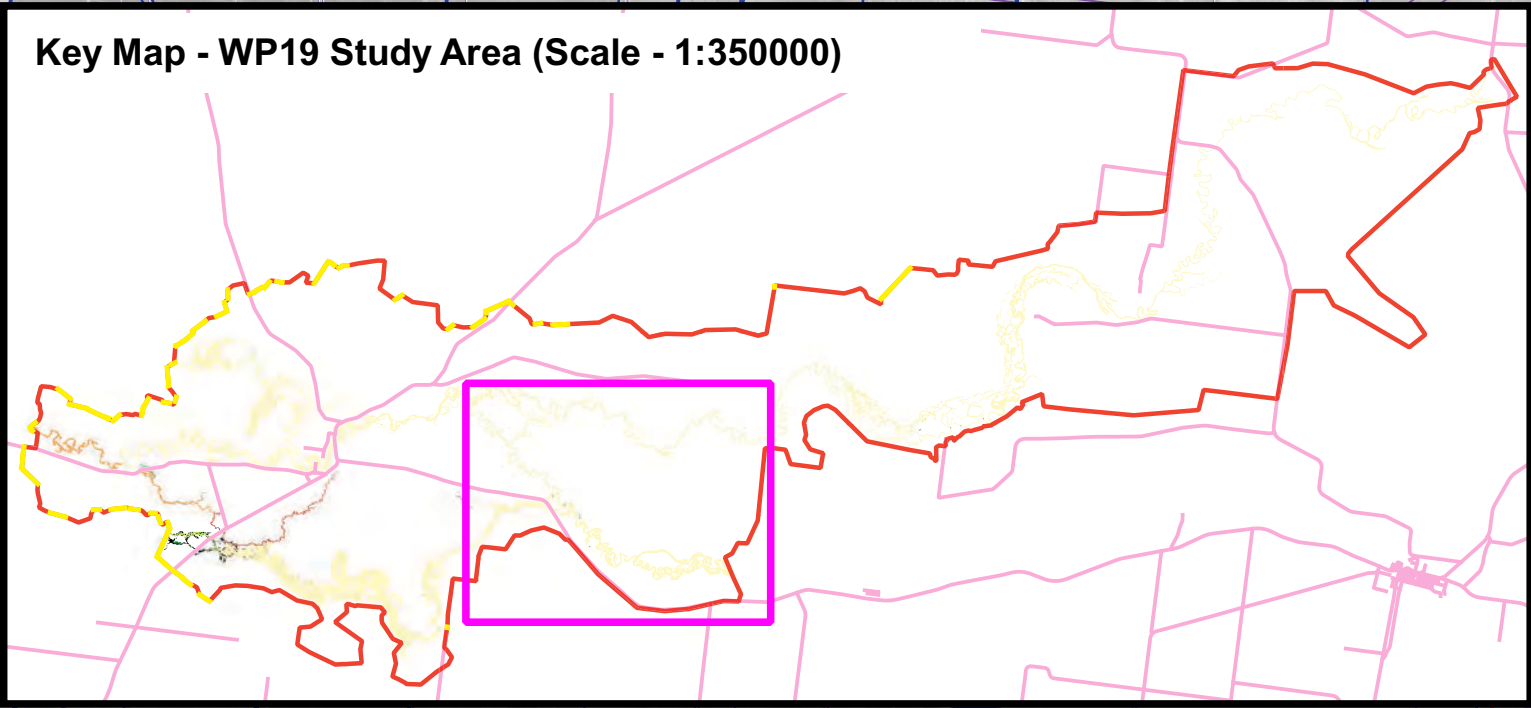
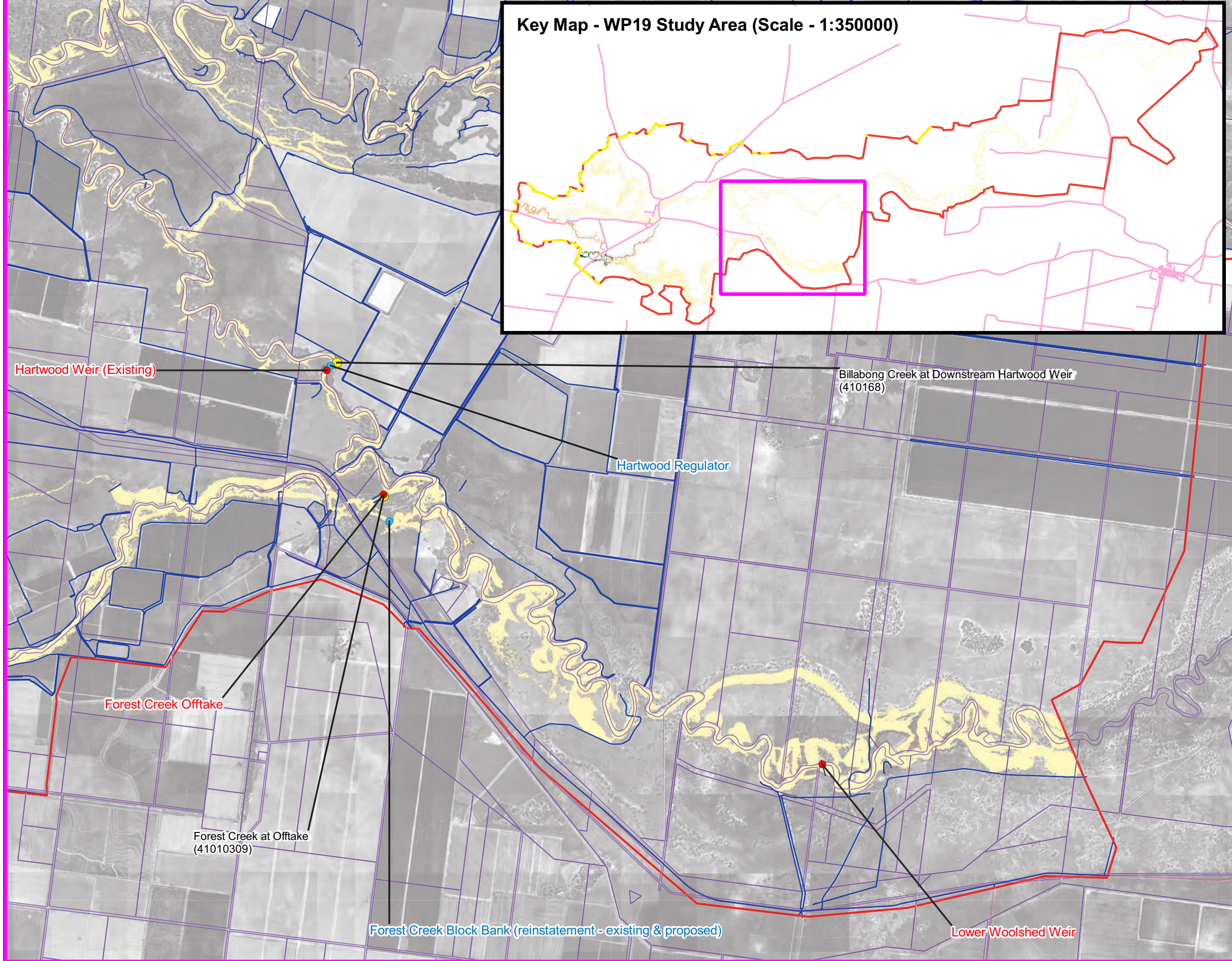


Figure B25 Change in hazard categories within proposed Hartwood Regulator weir pool



Legend

- Key Modelled Structures
 - Proposed Structures
 - Yanco Gauge Locations
 - Downstream Boundary Conditions
 - ▭ Hydraulic Model Boundary
 - ▭ Property Boundaries
 - Roads
- Impact (m)**
- █ ≤ -0.25
 - █ -0.25 to -0.10
 - █ -0.05 to -0.10
 - █ -0.05 to 0.05
 - █ 0.05 to 0.10
 - █ 0.10 to 0.25
 - █ > 0.25
 - █ was wet now dry
 - █ was dry now wet



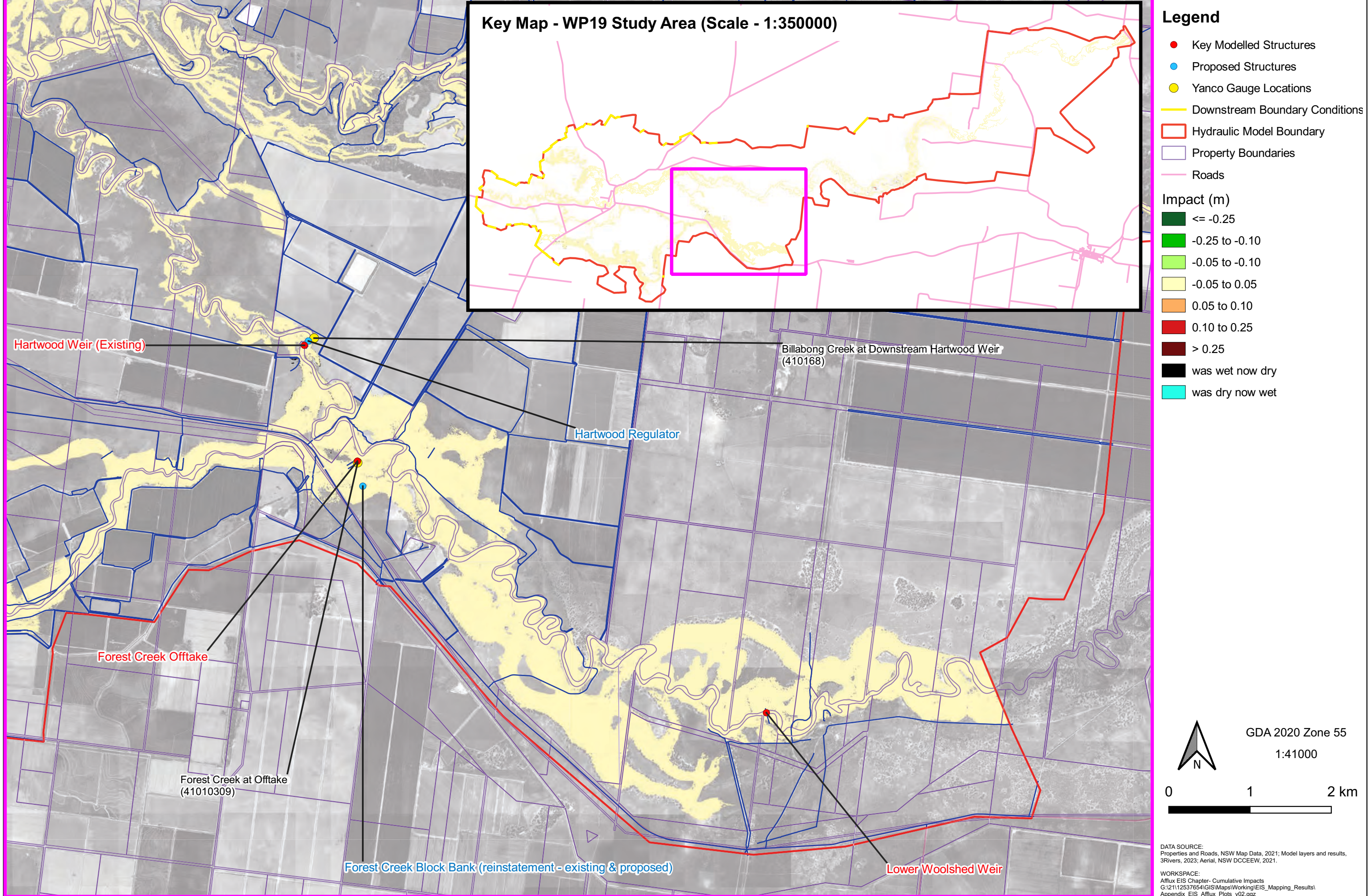
DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Afflux EIS Chapter- Cumulative Impacts
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Appendix_EIS_Afflux_Plots_v02.qgz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B26 - 20% AEP Billabong Dominant Flood Impact Plot
"Proposed (Cumulative Works)" WSL - "Proposed (Hartwood Works Only)" WSL



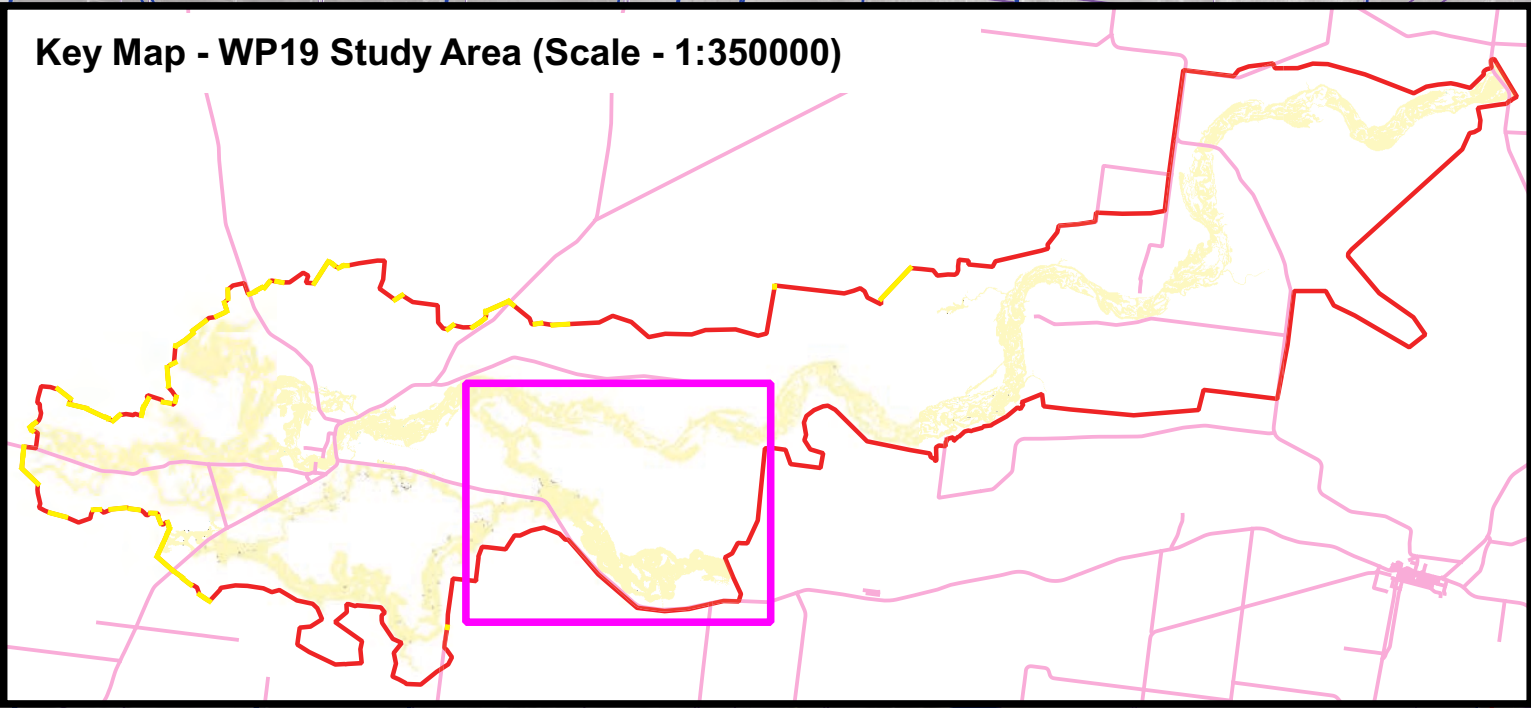
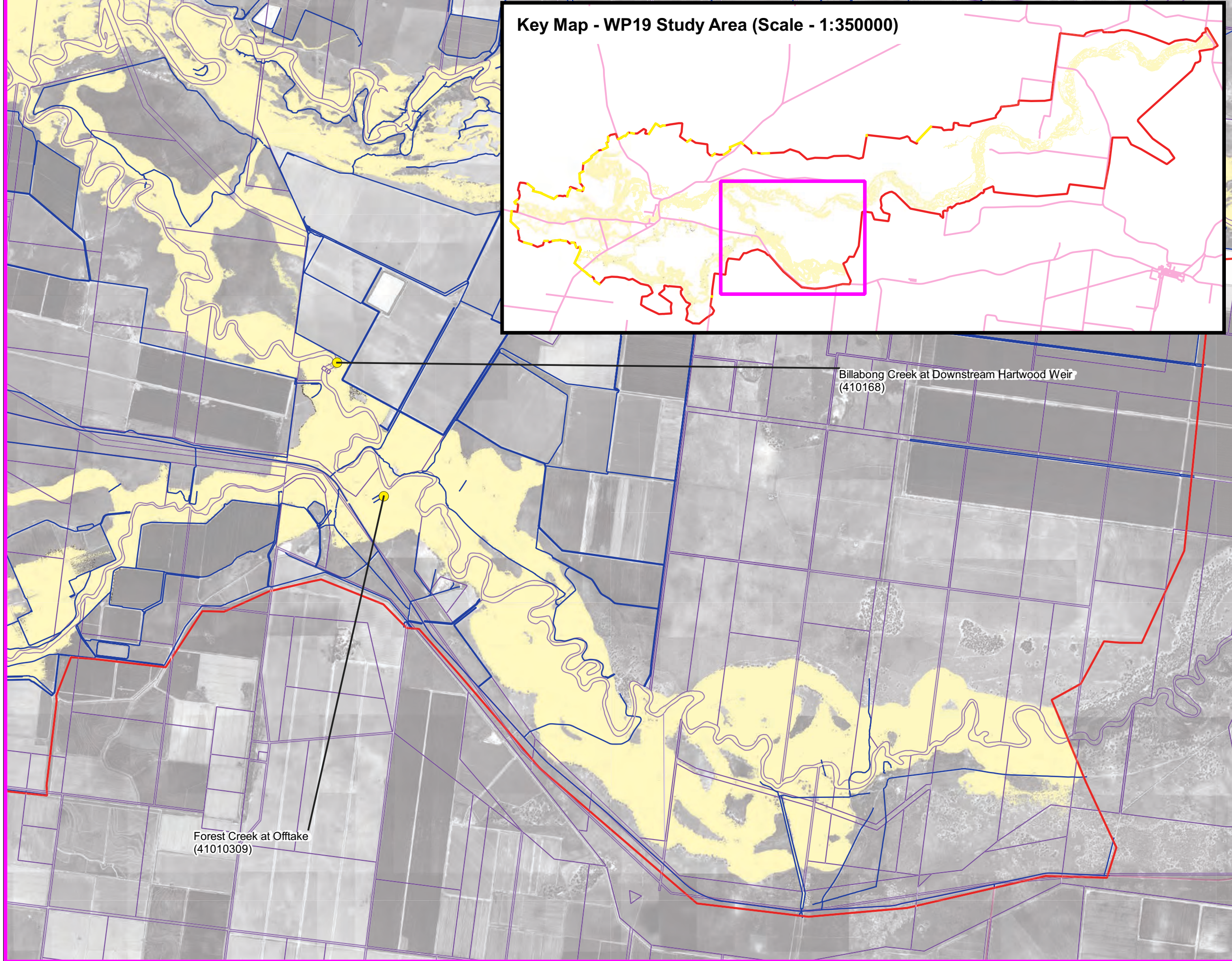
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Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B27 - 5% AEP Billabong Dominant Flood Impact Plot
"Proposed (Cumulative Works)" WSL - "Proposed (Hartwood Works Only)" WSL



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Legend

- Yanco Gauge Locations
- Downstream Boundary Conditions
- ▭ Hydraulic Model Boundary
- ▭ Property Boundaries
- Roads

Impact (m)

Band 1

- █ ≤ -0.25
- █ -0.25 to -0.10
- █ -0.05 to -0.10
- █ -0.05 to 0.05
- █ 0.05 to 0.10
- █ 0.10 to 0.25
- █ > 0.25

Band 1

- █ was wet now dry
- █ was dry now wet

0 1 2 km

GDA 2020 Zone 55
1:41000

DATA SOURCE:
Properties and Roads, NSW Map Data, 2021; Model layers and results, 3Rivers, 2023; Aerial, NSW DCCEEW, 2021.

WORKSPACE:
Afflux EIS Chapter- Cumulative Impacts
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Appendix_EIS_Afflux_Plots_v02.gqz

Yanco Creek Modernisation: Hydraulic Modelling – Hartwood Weir to Piccaninny Weir Study Area
FIGURE B28 - 1% AEP Billabong Dominant Flood Impact Plot
"Proposed (Cumulative Works)" WSL - "Proposed (Hartwood Works Only)" WSL



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Appendix C. Wanganella Regulator Flood Inundation and Impact Maps



- Legend
- Cadastre
 - Main Roads
 - Model Boundary
 - Flow Plot Output Lines



Layer name:
Zd_po_YNC_WP20_L.shp

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C1 - Flow Plot Output Locations
"Model Schematisation"

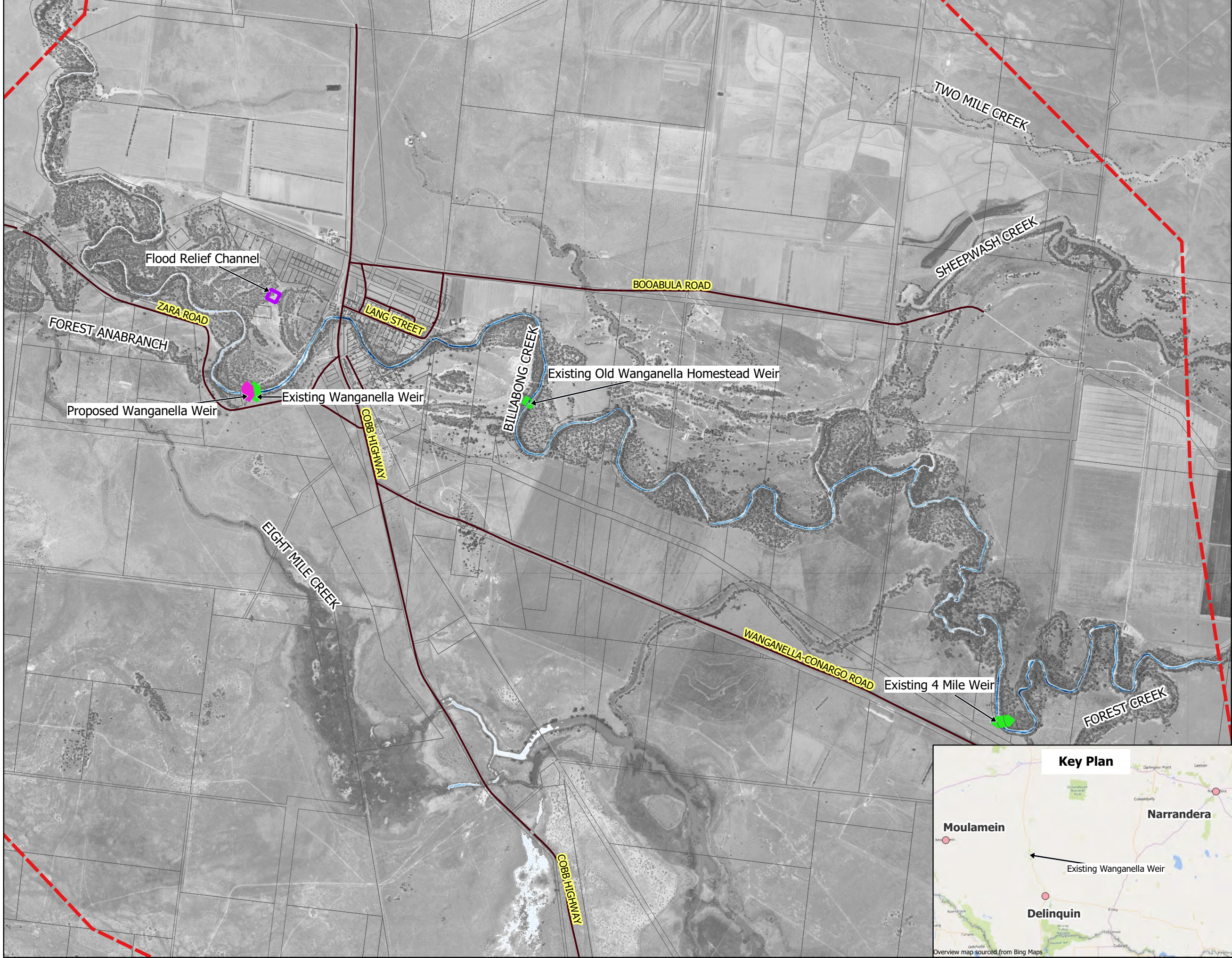


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Table C1 Flow Comparison for Wanganella Regulator

Scenario Description	Flow Description	Model Condition & Variable	Location [PO ID]			
			"Billabong Creek @ Wanganella" " (41010810) Gauge, approx. 1.1 km upstream of Wanganella Weir [WNG_GAUGE]	Billabong Creek, approx. 1.0 km upstream of Wanganella Weir, downstream of Cobb HWY [B_242.6]	Billabong Creek approx. 55 m upstream of the existing Wanganella Weir [WGNReg_US_1]	Billabong Creek approx. 0.10 km downstream of the existing Wanganella Weir [WGNREG_DS_1]
Operational Flows	Minimum Operating Flow (MinOF) with a Minimum Operating Level (MinOL) of 95.28 m AHD in weir pool	EXIST Flow (ML/day)	31	31	30	30
		PROP Flow (ML/day)	31	31	30	30
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0
		Change in Flow [PROP / EXIST]	100.00%	100.00%	100.00%	100.00%
	Minimum Operating Flow (MinOF) with a Maximum Operating Level (MaxOL) of 95.44 m AHD in weir pool	EXIST Flow (ML/day)	31	31	30	30
		PROP Flow (ML/day)	30	30	30	29
		Change in Flow (ML/day) [PROP - EXIST]	-1	-1	0	-1
		Change in Flow [PROP / EXIST]	96.77%	96.77%	100.00%	96.67%
	Minimum Operating Flow (MinOF) with a Full Supply Level (FSL) of 95.74 m AHD in weir pool	EXIST Flow (ML/day)	31	31	30	30
		PROP Flow (ML/day)	26	26	25	24
		Change in Flow (ML/day) [PROP - EXIST]	-5	-5	-5	-6
		Change in Flow [PROP / EXIST]	83.87%	83.87%	83.33%	80.00%
	Maximum Operating Flow (MaxOF) with a Minimum Operating Level (MinOL) of 95.28 m AHD in weir pool	EXIST Flow (ML/day)	390	390	390	390
		PROP Flow (ML/day)	390	390	390	390
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0
		Change in Flow [PROP / EXIST]	100.00%	100.00%	100.00%	100.00%
	Maximum Operating Flow (MaxOF) with a Maximum Operating Level (MaxOL) of 95.44 m AHD in weir pool	EXIST Flow (ML/day)	390	390	390	390
		PROP Flow (ML/day)	390	390	390	390
		Change in Flow (ML/day) [PROP - EXIST]	0	0	0	0
		Change in Flow [PROP / EXIST]	100.00%	100.00%	100.00%	100.00%
	Maximum Operating Flow (MaxOF) with a Full Supply Level (FSL) of 95.74 m AHD in weir pool	EXIST Flow (ML/day)	390	390	390	390
		PROP Flow (ML/day)	388	388	387	386
		Change in Flow (ML/day) [PROP - EXIST]	-2	-2	-3	-4
		Change in Flow [PROP / EXIST]	99.49%	99.49%	99.23%	98.97%
Flood Flows	20% (1 in 5) AEP Billabong Dominant	EXIST Flow (ML/day)	3752	3752	3750	3750
		PROP Flow (ML/day)	3751	3751	3749	3748
		Change in Flow (ML/day) [PROP - EXIST]	-1	-1	-1	-2
		Change in Flow [PROP / EXIST]	99.97%	99.97%	99.97%	99.95%
	5% (1 in 20) AEP Billabong Dominant	EXIST Flow (ML/day)	8113	8113	8107	8105
		PROP Flow (ML/day)	8114	8114	8107	8104
		Change in Flow (ML/day) [PROP - EXIST]	1	1	0	-1
		Change in Flow [PROP / EXIST]	100.01%	100.01%	100.00%	99.99%
	1% (1 in 100) AEP Billabong Dominant	EXIST Flow (ML/day)	14552	14492	14552	14550
		PROP Flow (ML/day)	14555	14502	13591	13586
		Change in Flow (ML/day) [PROP - EXIST]	3	10	-961	-964
		Change in Flow [PROP / EXIST]	100.02%	100.07%	93.40%	93.37%

Scenario Description	Flow Description	Model Condition & Variable	Location [PO ID]			
			“Billabong Creek @ Wanganella ” (41010810) Gauge, approx. 1.1 km upstream of Wanganella Weir [WNG_GAUGE]	Billabong Creek, approx. 1.0 km upstream of Wanganella Weir, downstream of Cobb HWY [B_242.6]	Billabong Creek approx. 55 m upstream of the existing Wanganella Weir [WGNReg_US_1]	Billabong Creek approx. 0.10 km downstream of the existing Wanganella Weir [WGNREG_DS_1]
Flood Flows	0.5% (1 in 200) AEP Billabong Dominant	EXIST Flow (ML/day)	18616	18397	18619	18615
		PROP Flow (ML/day)	18669	18473	16326	16320
		Change in Flow (ML/day) [PROP - EXIST]	53	76	-2293	-2295
		Change in Flow [PROP / EXIST]	100.28%	100.41%	87.68%	87.67%
	0.2% (1 in 500) AEP Billabong Dominant	EXIST Flow (ML/day)	24759	24360	23309	23305
		PROP Flow (ML/day)	24860	24512	19738	19777
		Change in Flow (ML/day) [PROP - EXIST]	101	152	-3571	-3528
		Change in Flow [PROP / EXIST]	100.41%	100.62%	84.68%	84.86%
	PMF	EXIST Flow (ML/day)	39706	39435	27086	28785
		PROP Flow (ML/day)	40139	39873	23861	25989
		Change in Flow (ML/day) [PROP - EXIST]	433	438	-3225	-2796
		Change in Flow [PROP / EXIST]	101.09%	101.11%	88.09%	90.29%



Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55

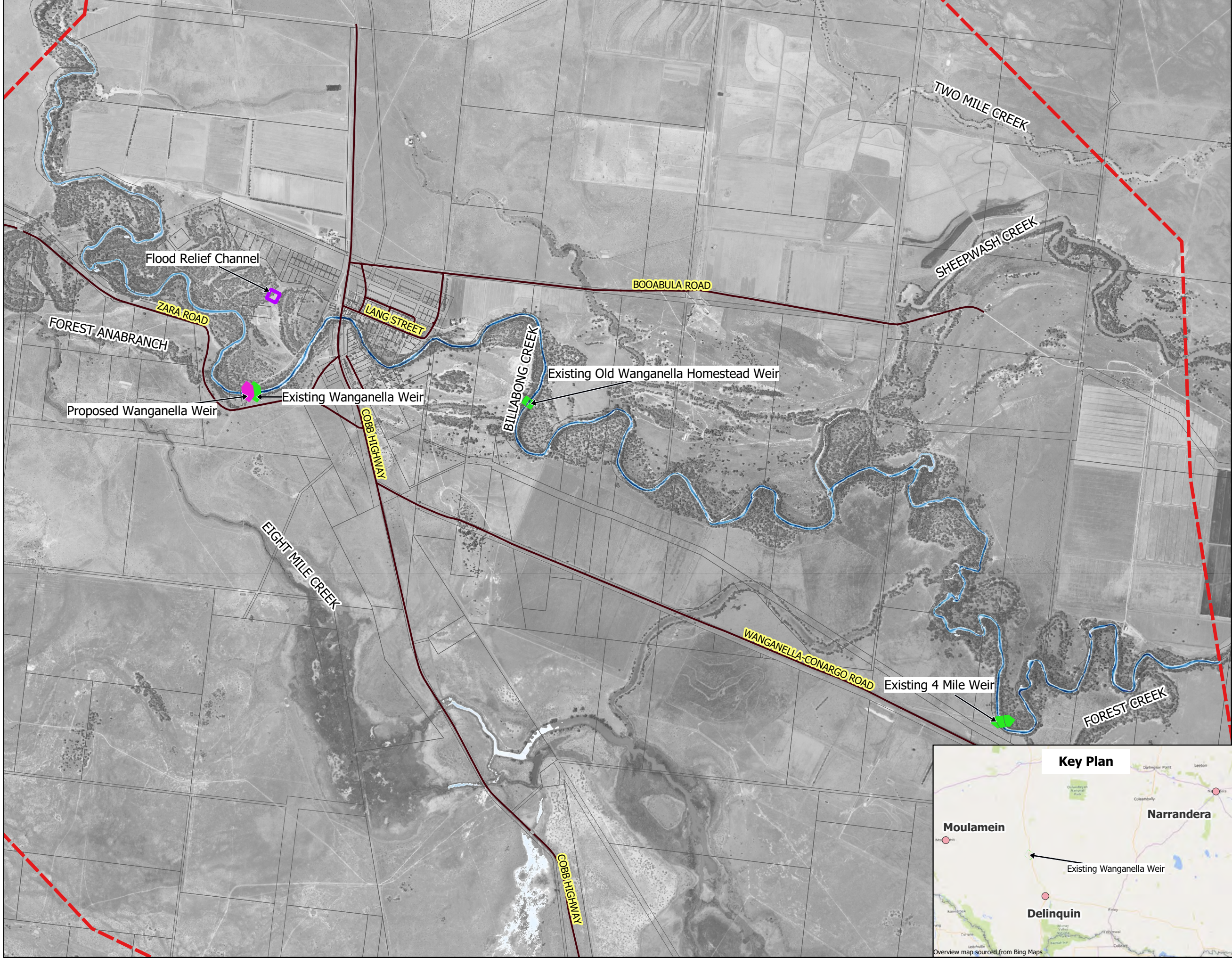
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0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_30MLD_OpFlows_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C2 - Minimum Operating Flow (30 ML/day) Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:30000

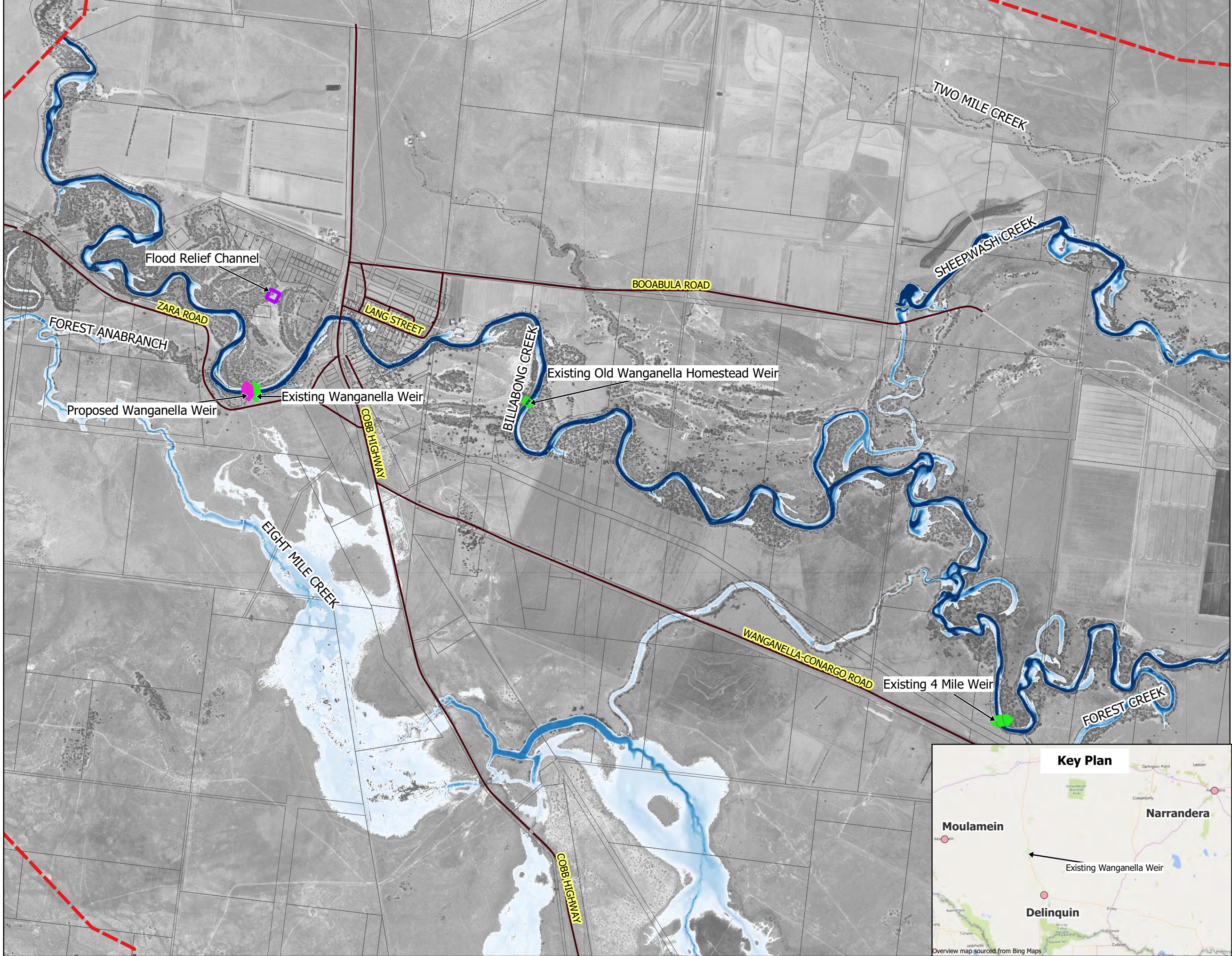
0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_400MLD_OpFlows_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C3 - Maximum Operating Flow (400 ML/day) Peak Flood Depth
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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_20AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C4 - 20% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:30000

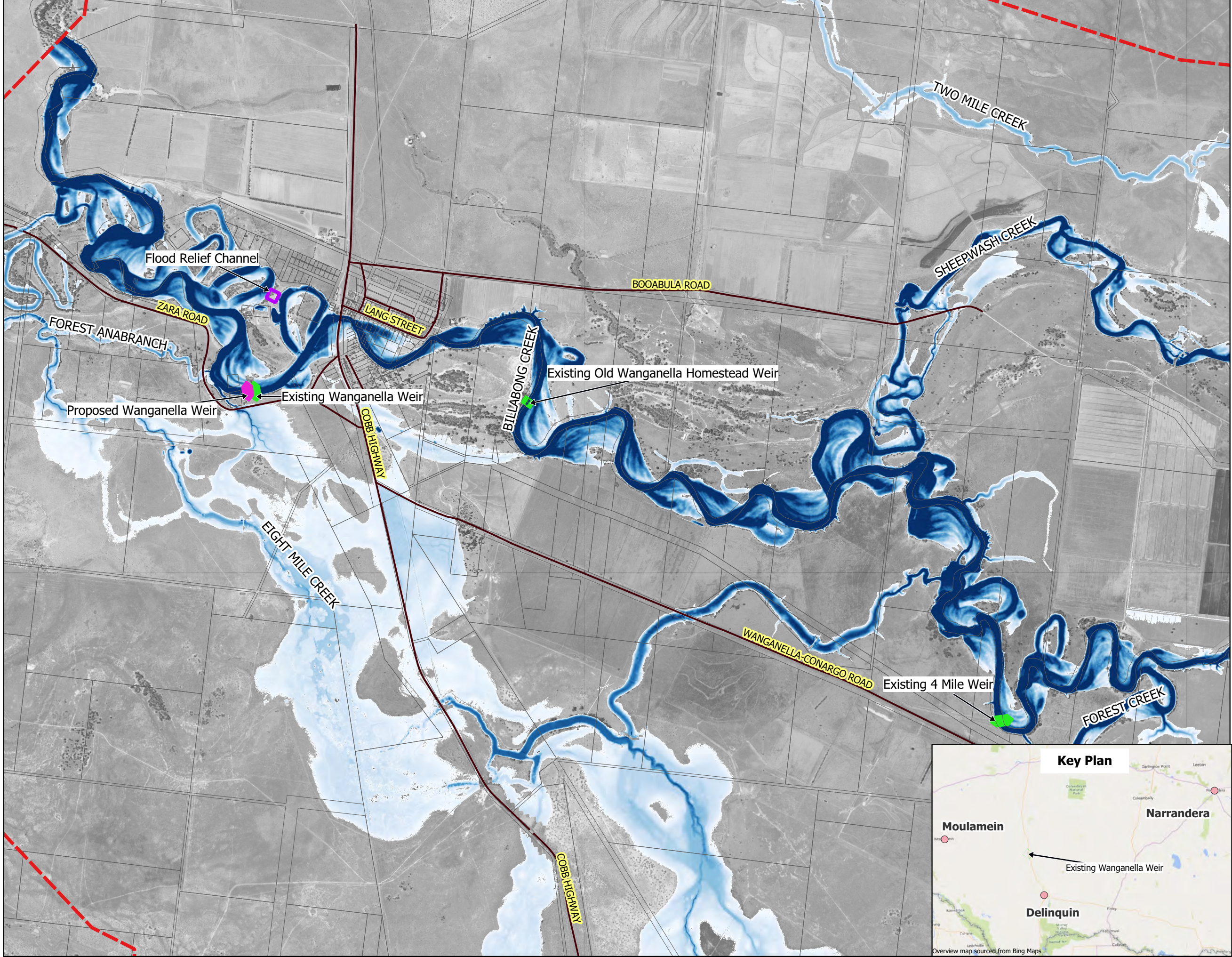
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C5 - 5% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:30000

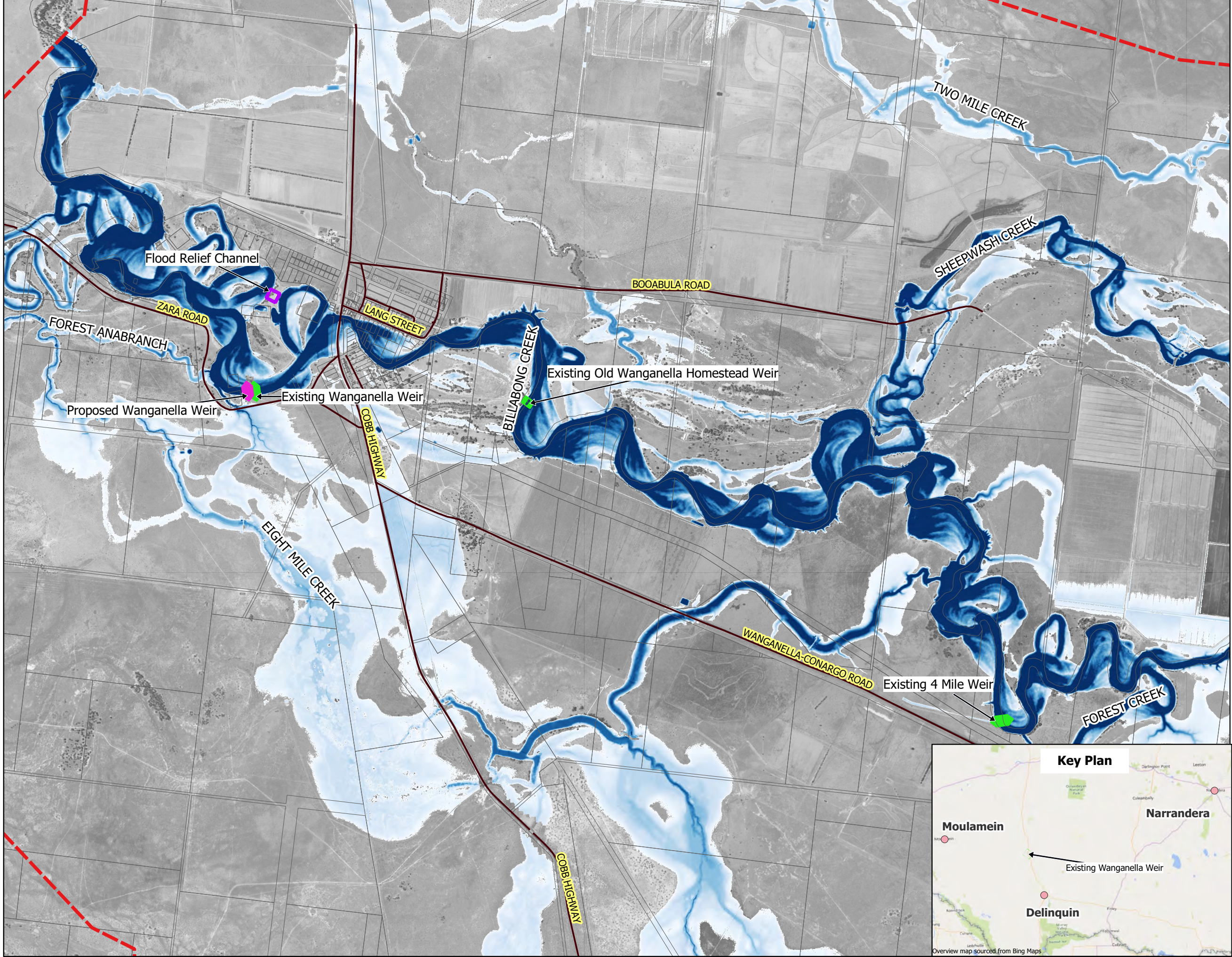
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C6 - 1% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:30000

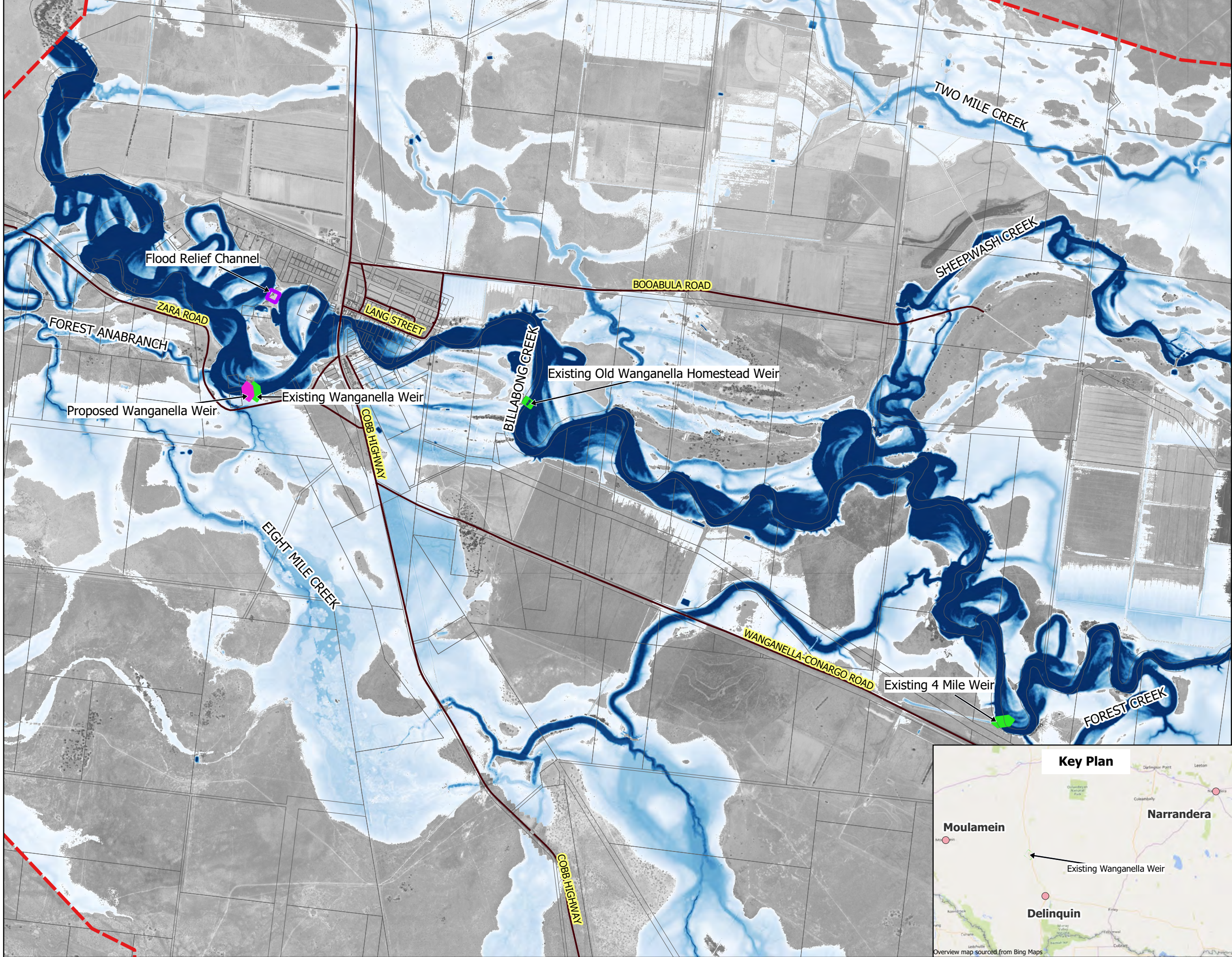
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C7 - 0.5% AEP Maximum Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:30000

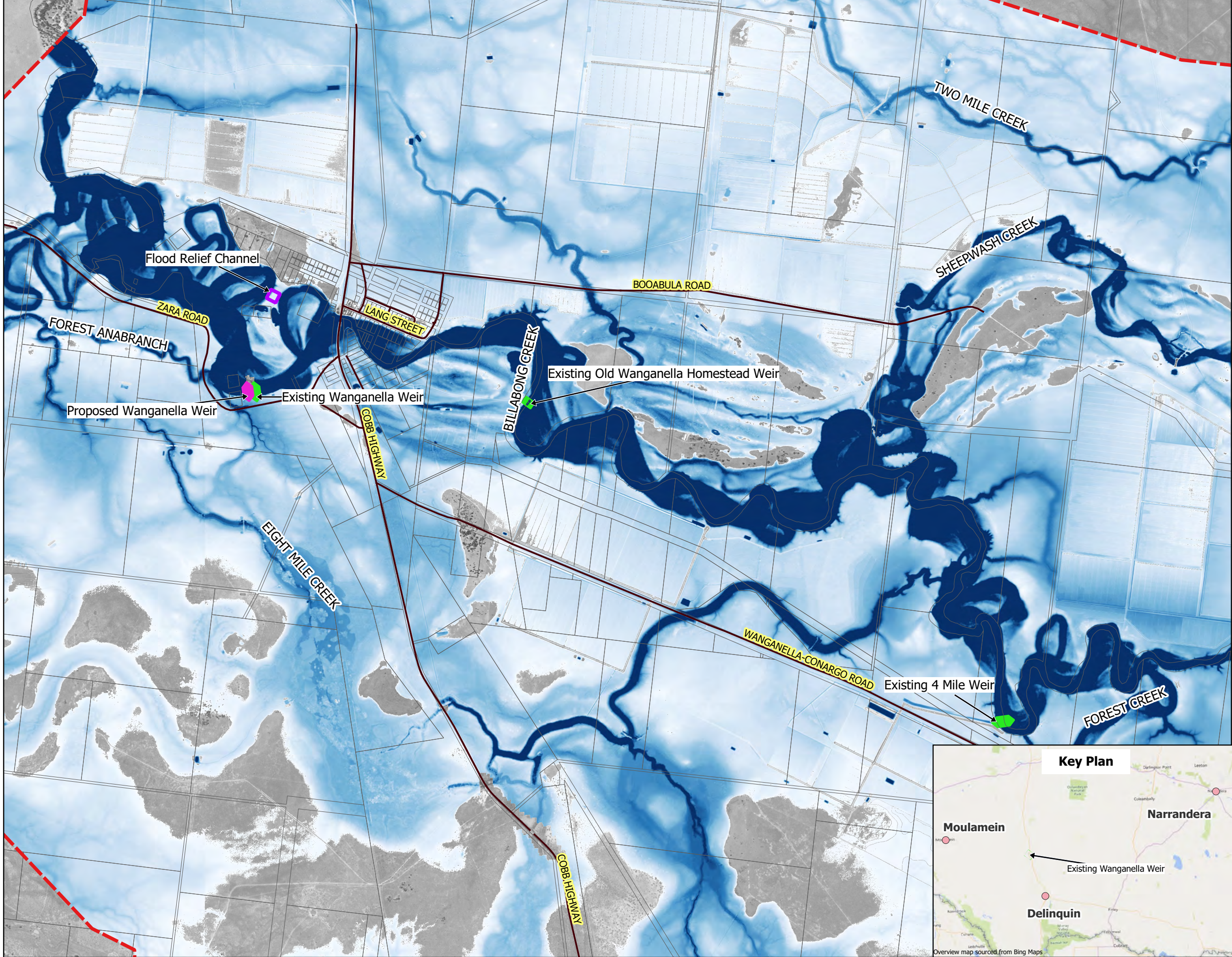
0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_0.2AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C8 - 0.2% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:30000

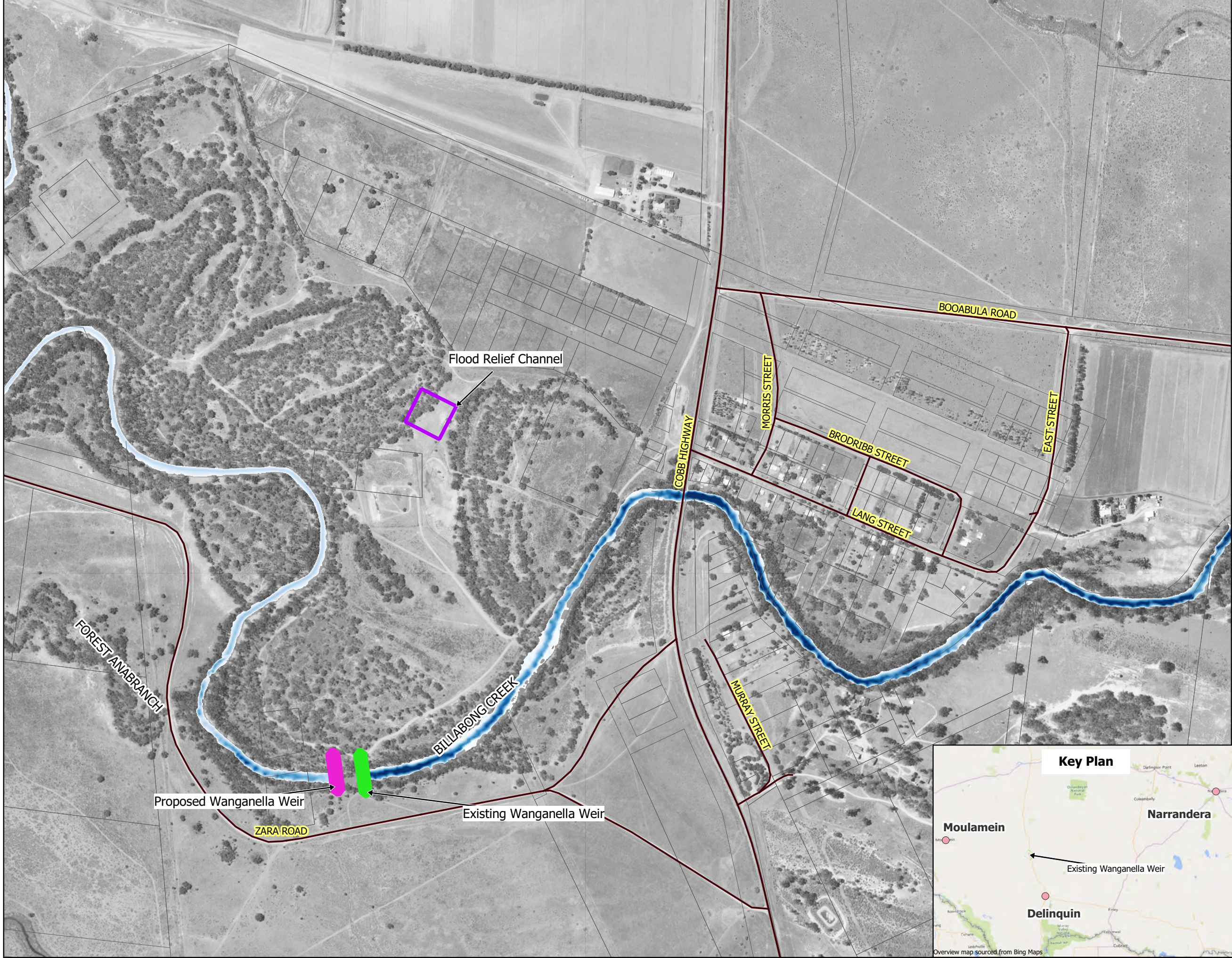
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Grid name:
YNC_WP20_B020120_PMF_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C9 - PMF Maximum Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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Scale: 1:8000

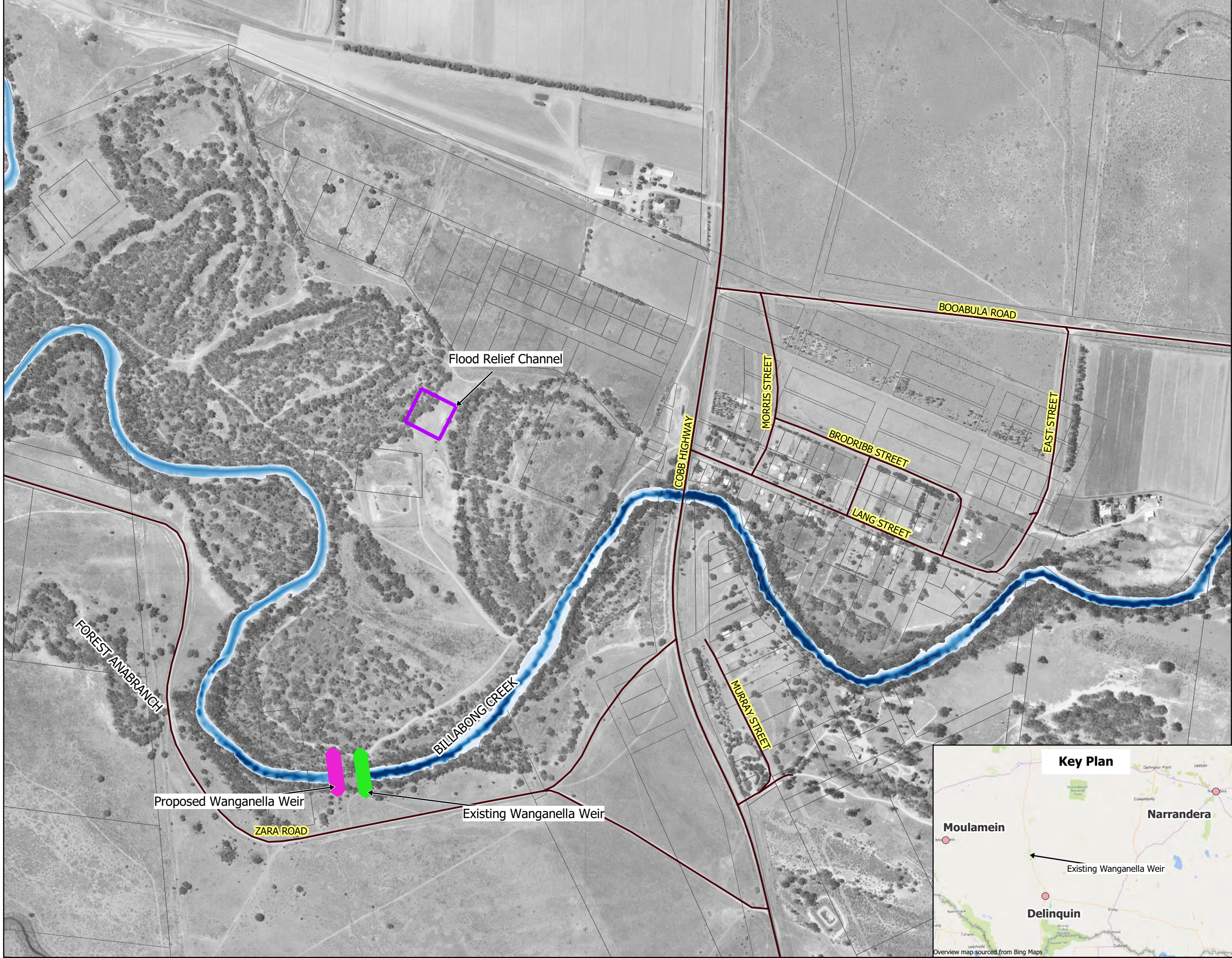
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Grid name:
YNC_WP20_B020120_30MLD_OpFlows_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C10 - Minimum Operating Flow (30 ML/day) Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55

Scale: 1:8000

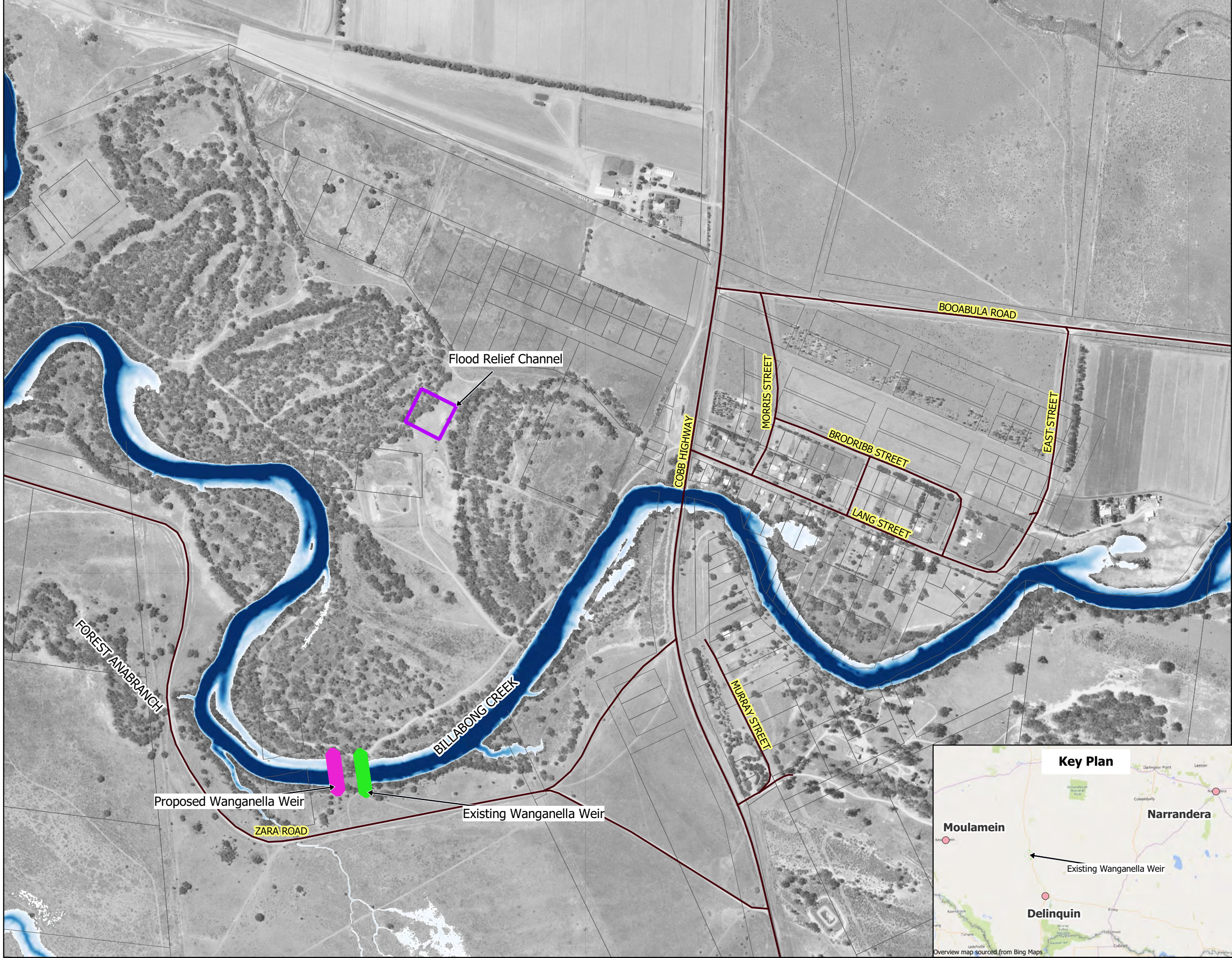
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C11 - Maximum Operating Flow (400 ML/day) Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



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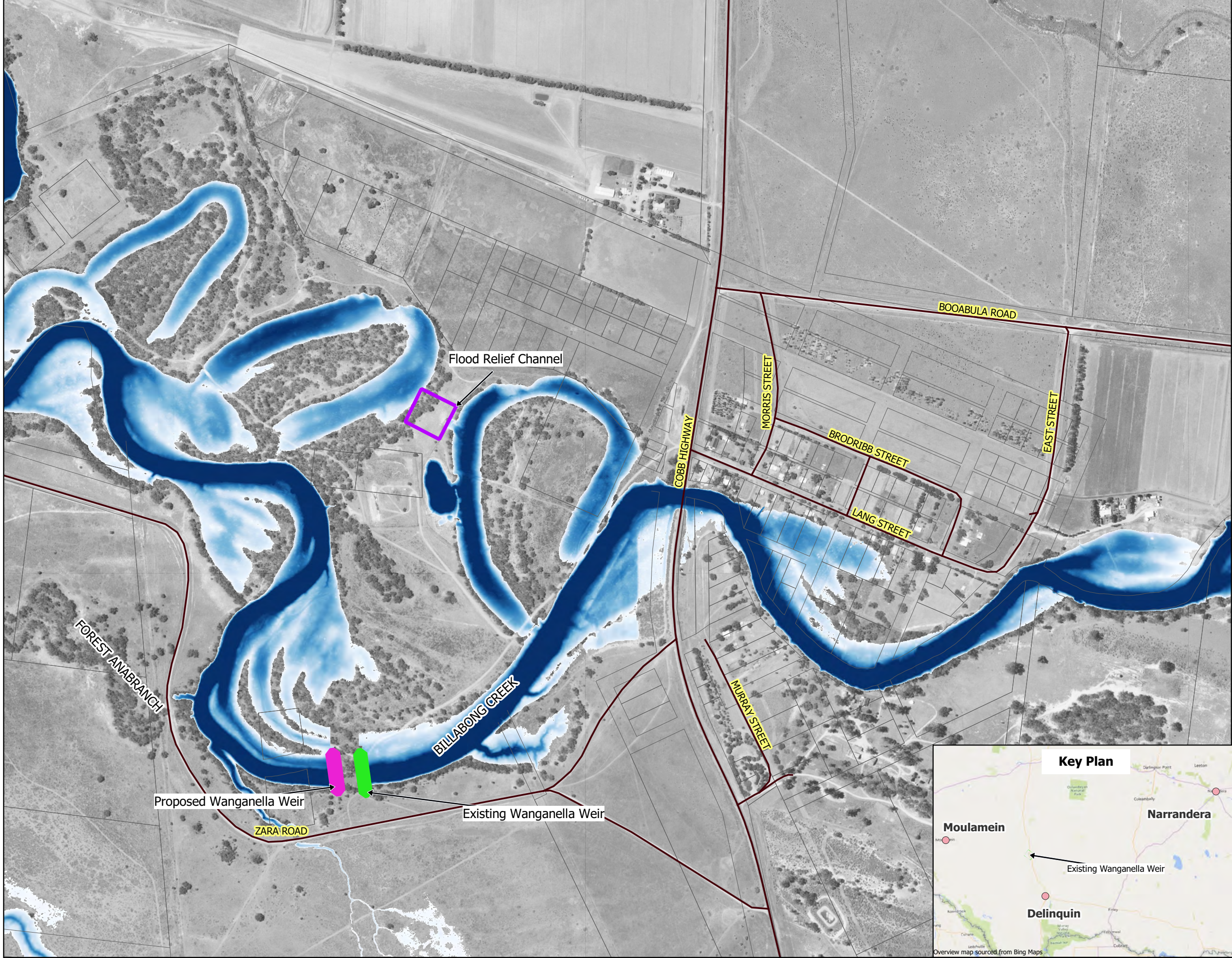
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C12 - 20% AEP Maximum Peak Flood Depth
"Existing"

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Legend

— Cadastre

— Main Roads

Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55

Scale: 1:8000

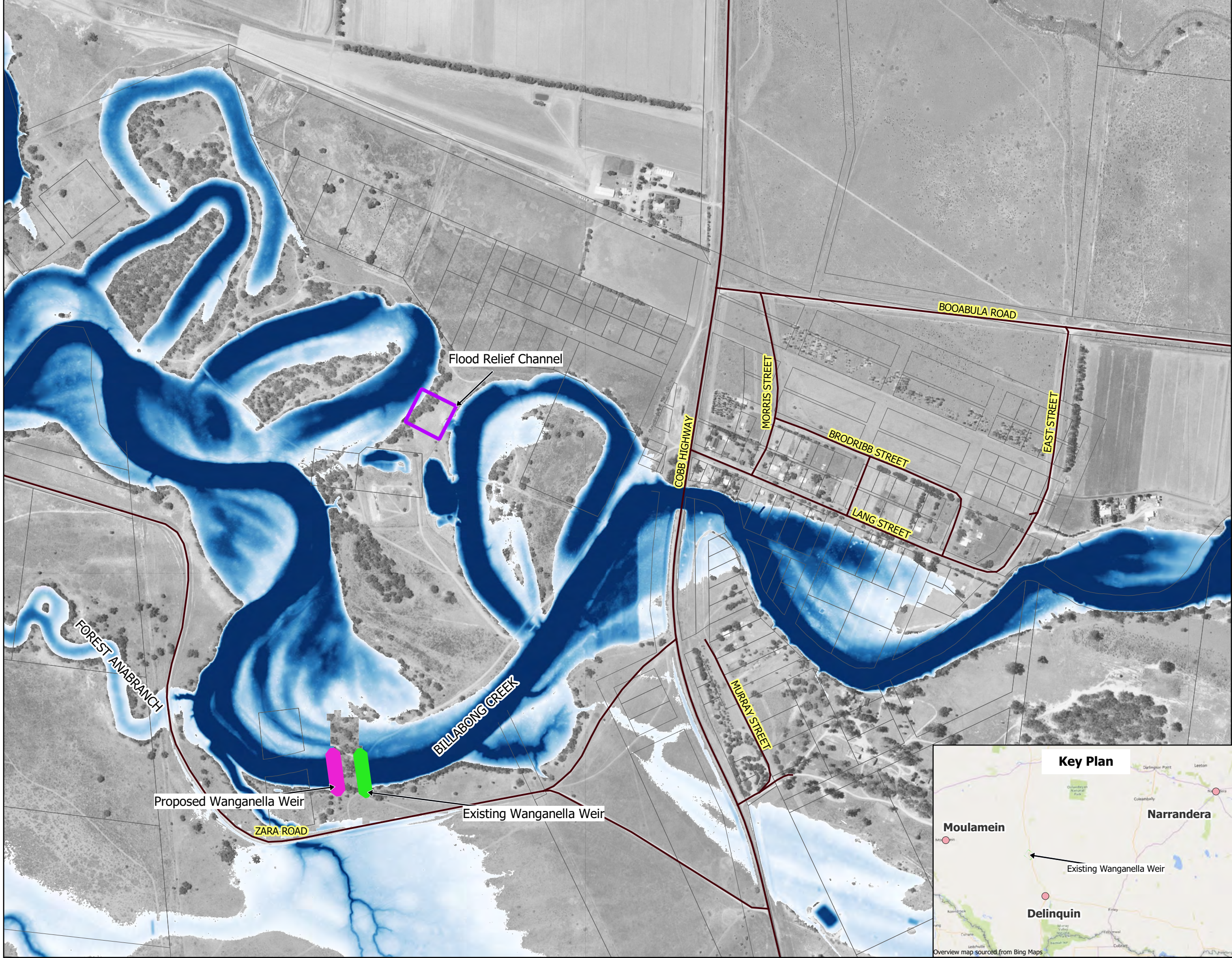
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Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C13 - 5% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:8000

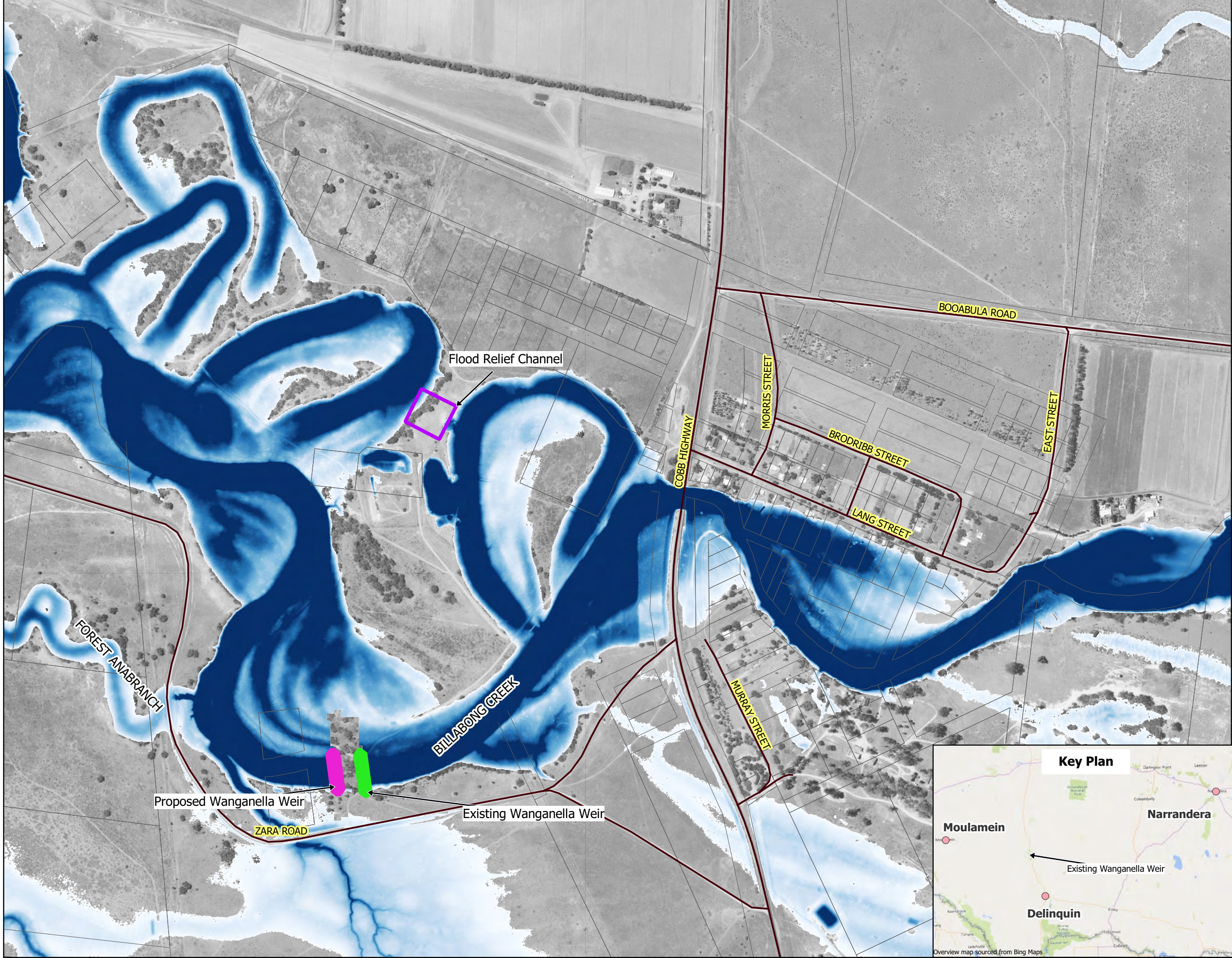
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Grid name:
YNC_WP20_B020120_1AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C14 - 1% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:8000

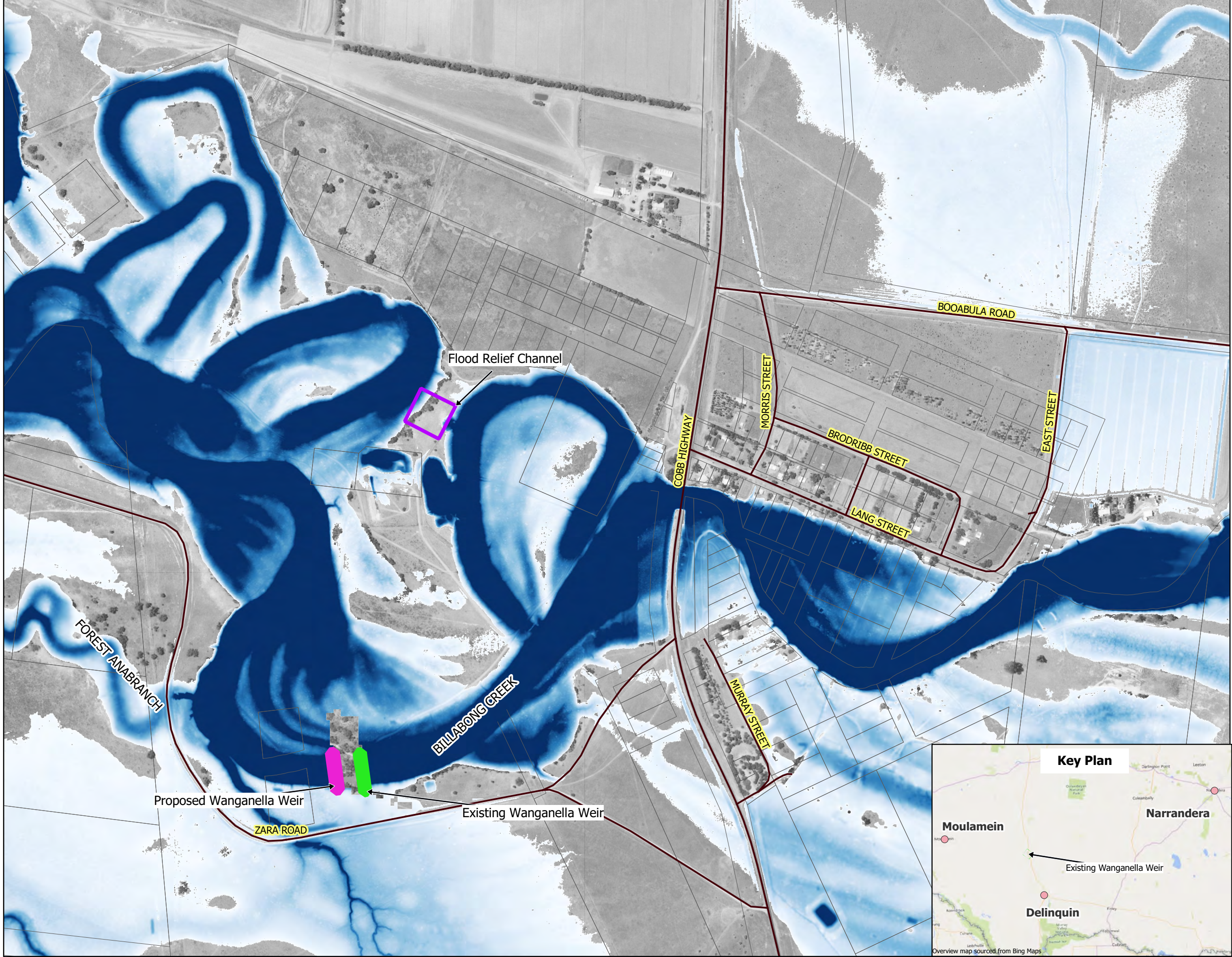
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Grid name:
YNC_WP20_B020120_0.5AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C15 - 0.5% AEP Maximum Peak Flood Depth
"Existing"



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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
YNC_WP20_B020120_0.2AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C16 - 0.2% AEP Maximum Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary

Depth (m)

- 0 to 0.5m
- 0.5 to 1.0m
- 1.0 to 1.5m
- 1.5 to 2.0m
- > 2.0 m



GDA 2020 Zone 55
Scale: 1:8000

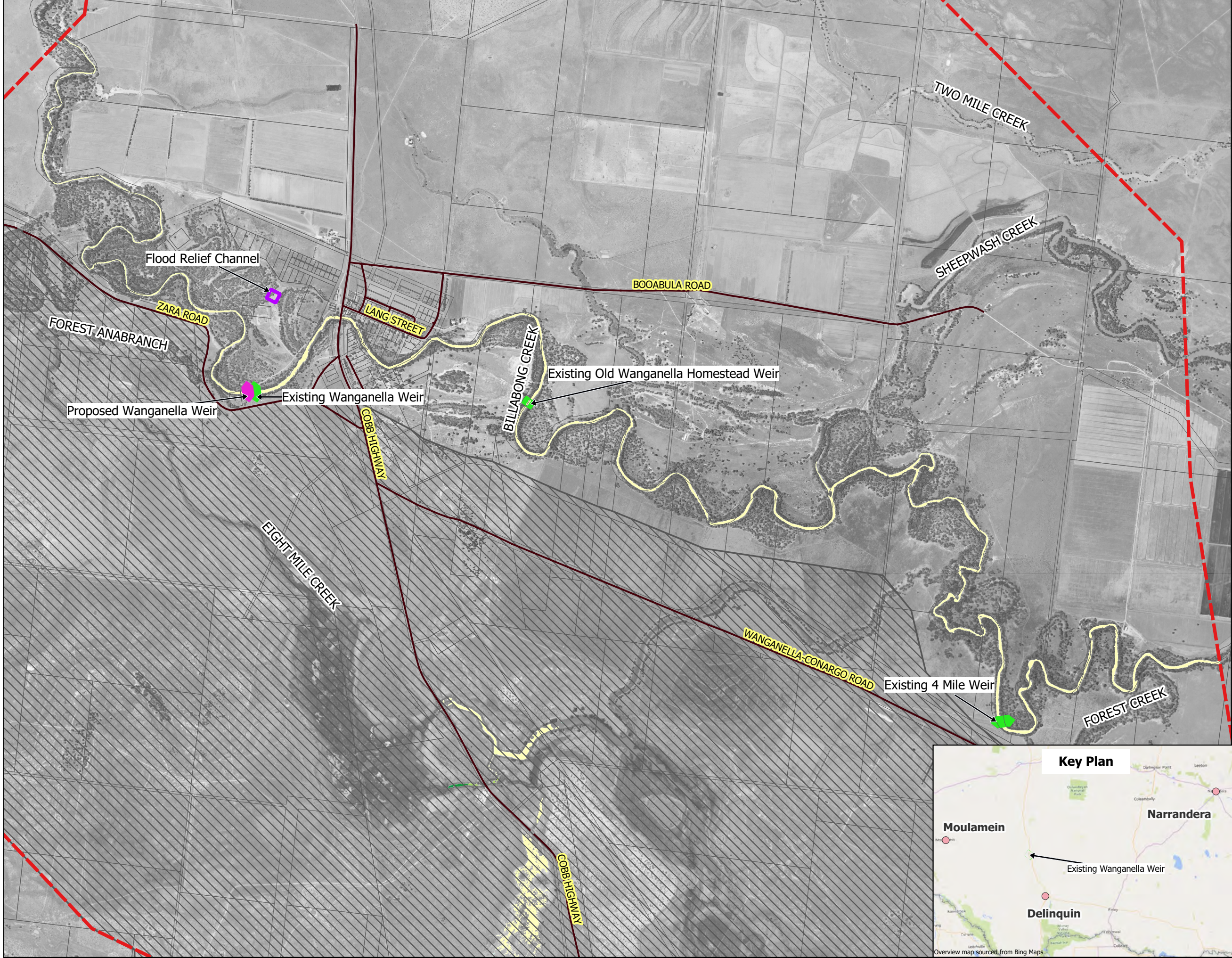
0 0.1 0.2 km

Grid name:
YNC_WP20_B020120_PMF_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C17 - PMF Peak Flood Depth
"Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



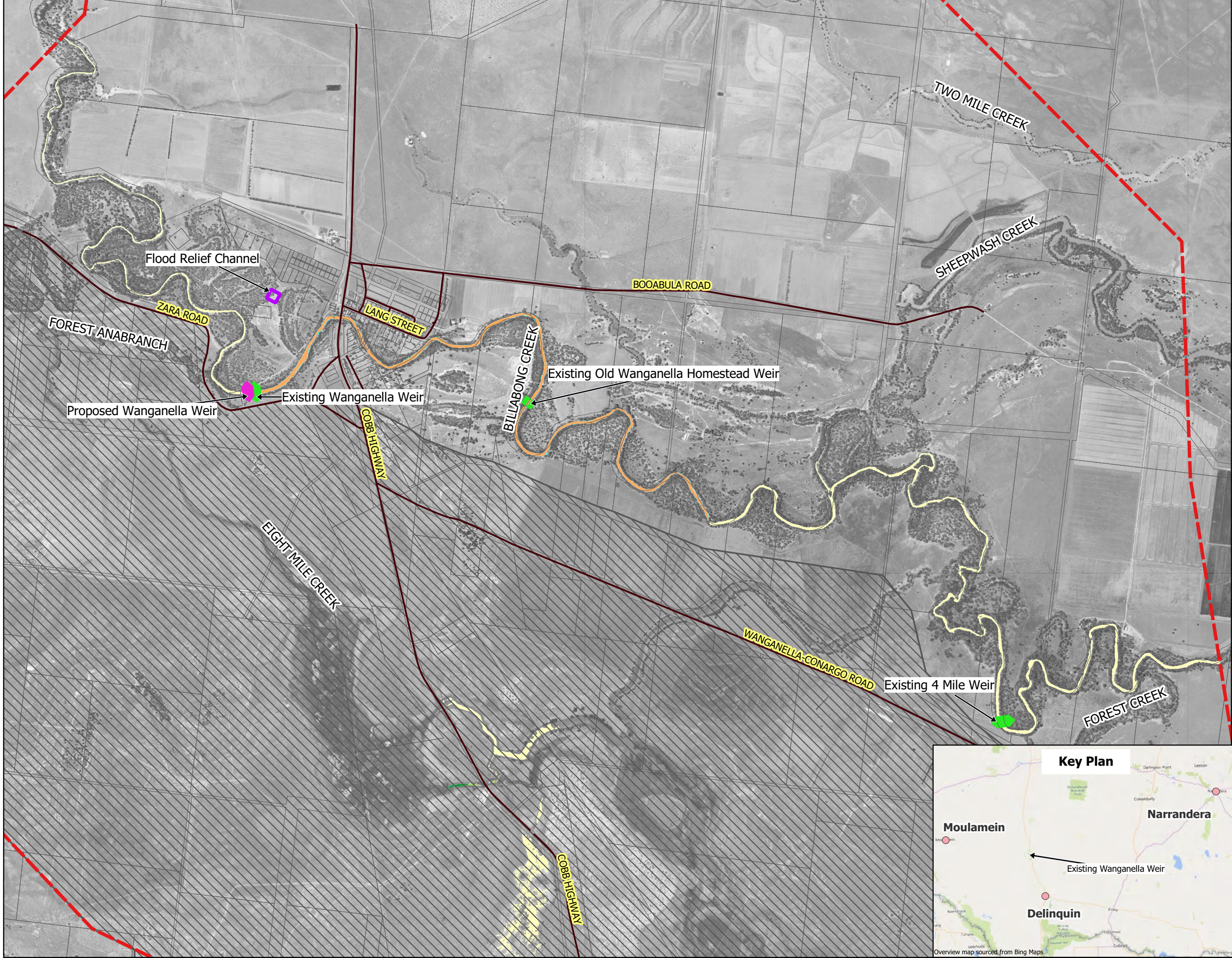
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_30MLD_OpFlows_MinOL_80.71_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C18 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Minimum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



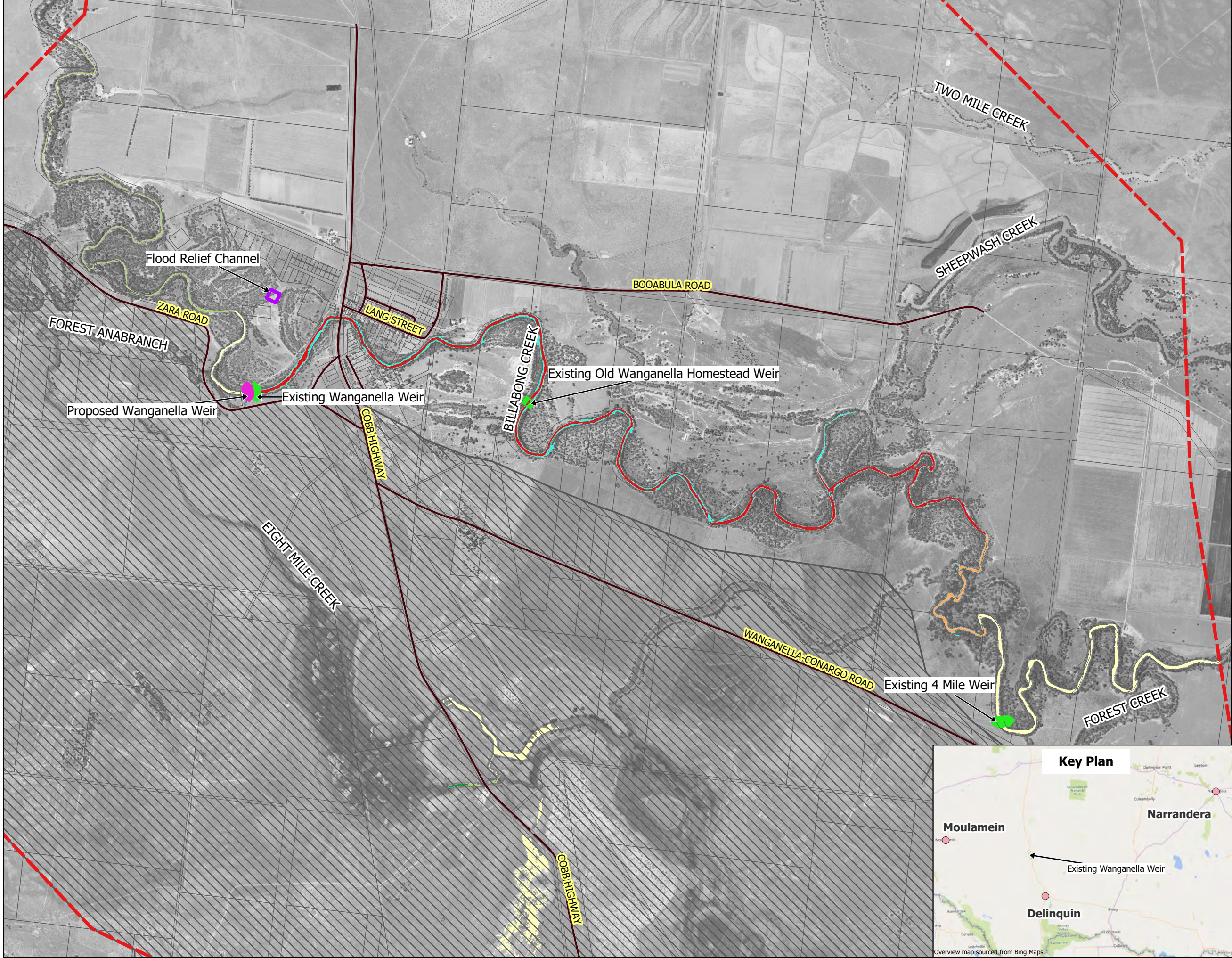
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_30MLD_OpFlows_NormOL_80.95_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C19 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Maximum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:30000

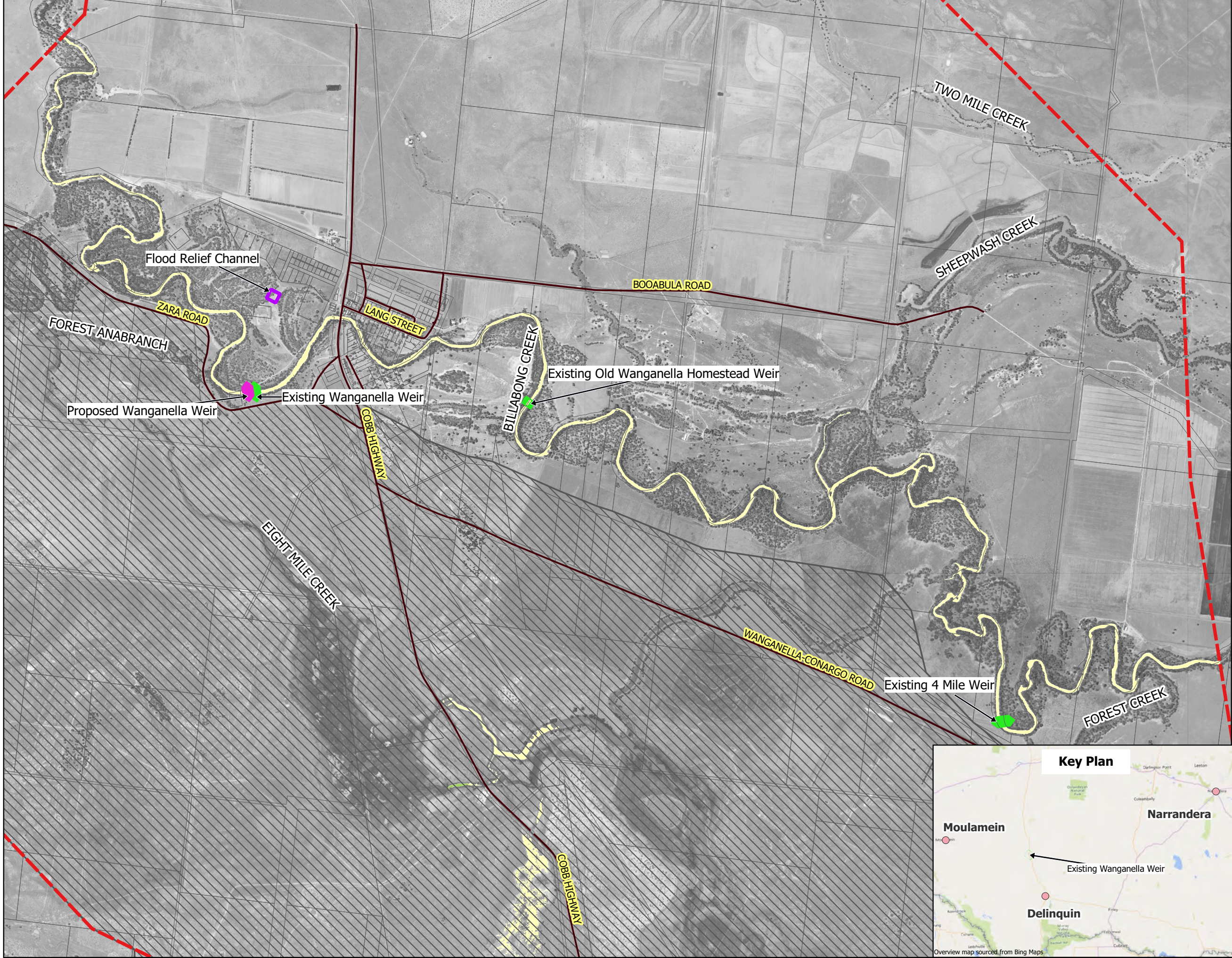
0 0.7 1.4 km

Grid name:
dh_YNC_WP20_30MLD_OpFlows_MaxOL_82.06_S030161_ Jess_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C20 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



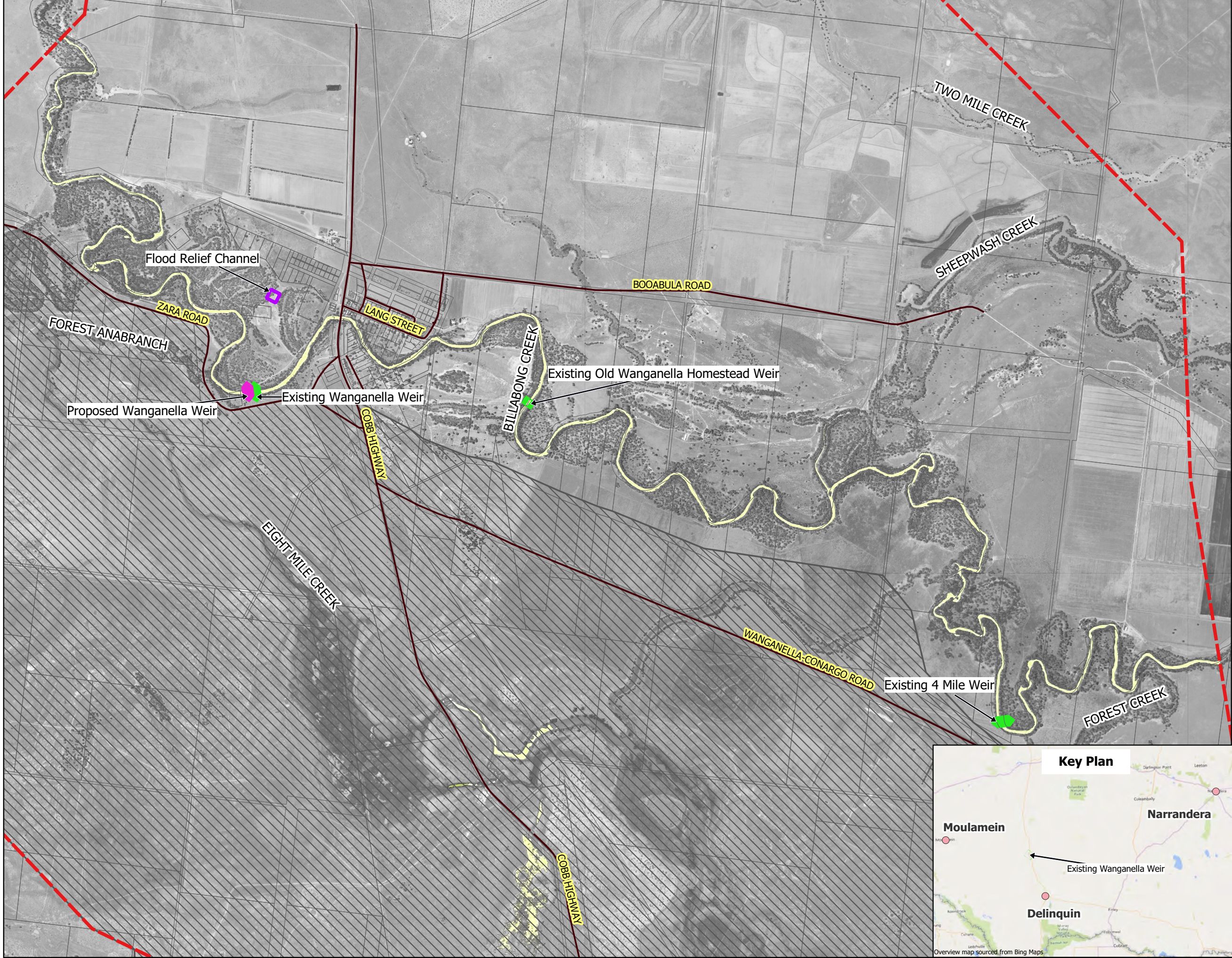
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_MinOL_80.20_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C21 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Minimum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



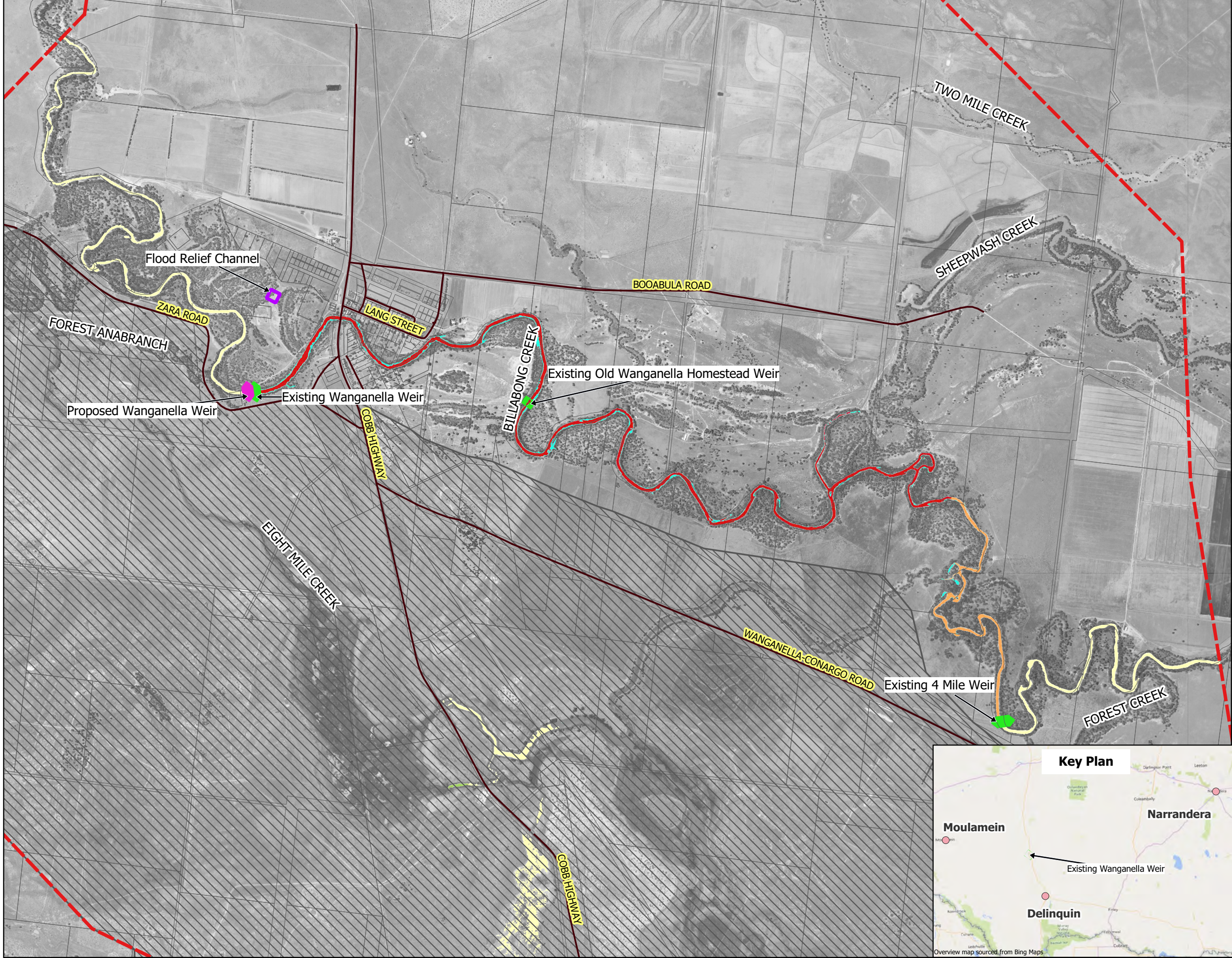
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_NormOL_80.54_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C22 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Maximum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250

Wet/Dry Status

- Was wet now dry
- Was dry now wet



North Arrow

Scale

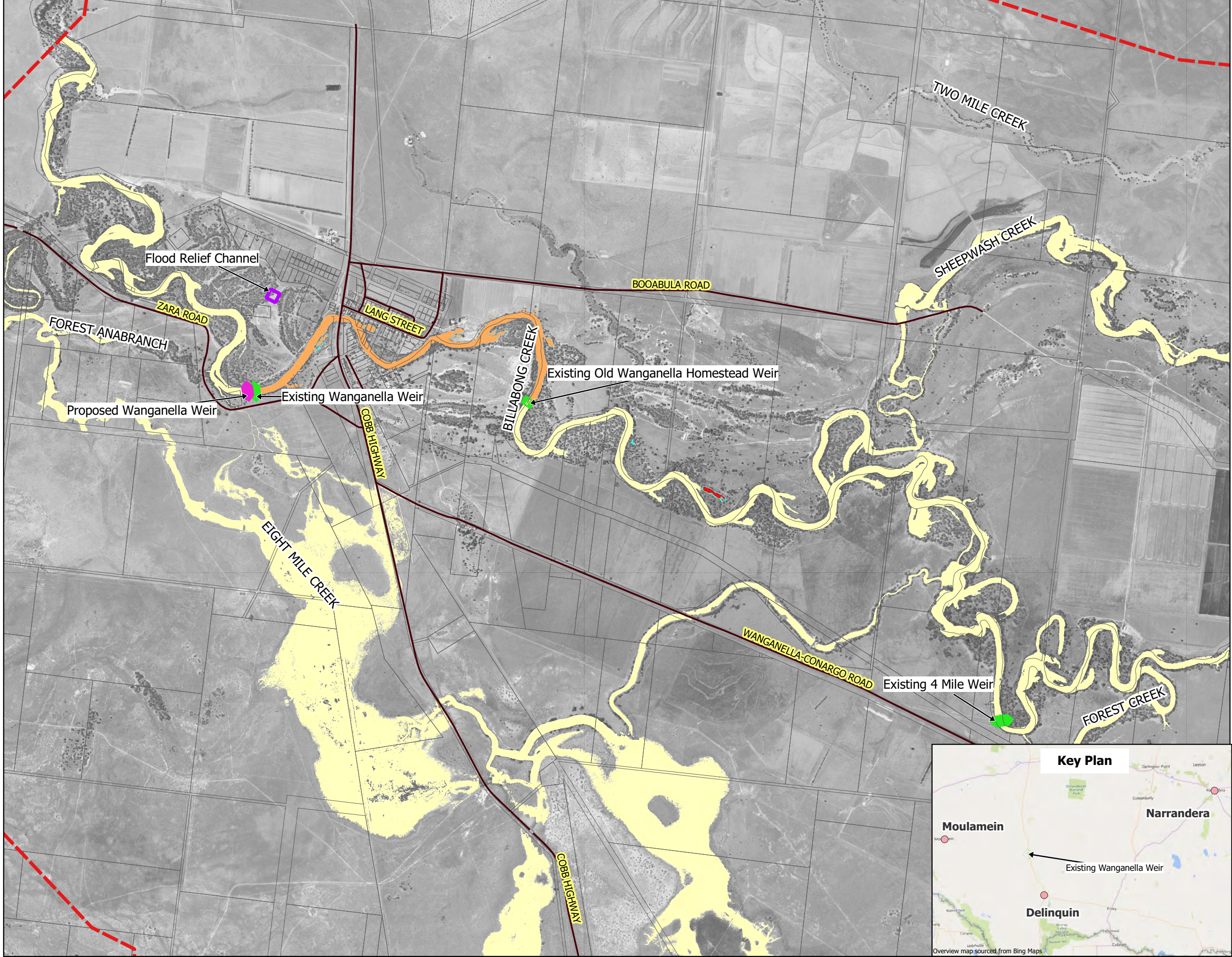
0 0.7 1.4 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_MaxOL_81.65_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C23 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- ≤ -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- ≥ 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:30000

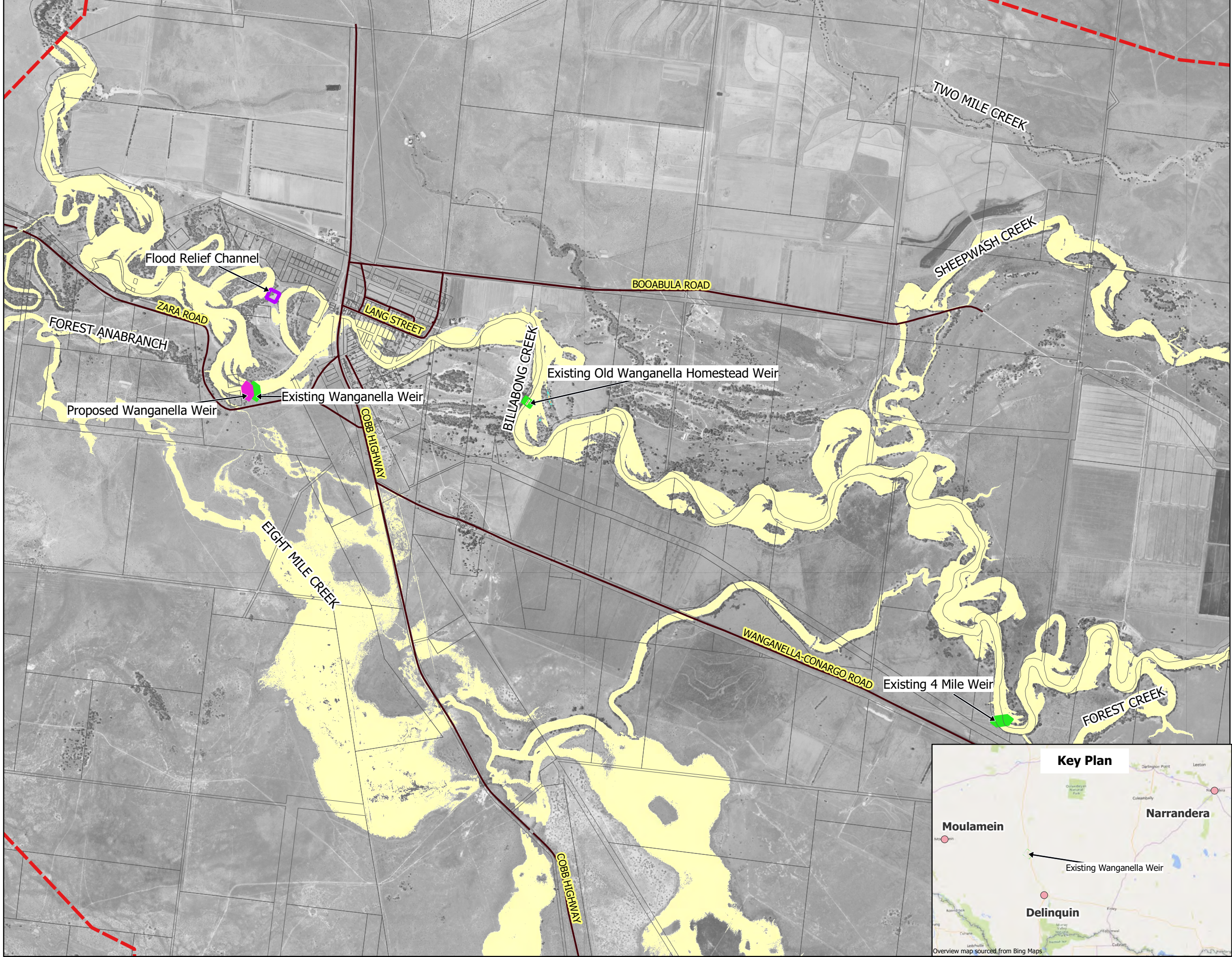
0 0.7 1.4 km

Grid name:
dh_YNC_WP20_20AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C24 - 20% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250

Wet/Dry Status

- Was wet now dry
- Was dry now wet



North Arrow

Scale: 1:30000

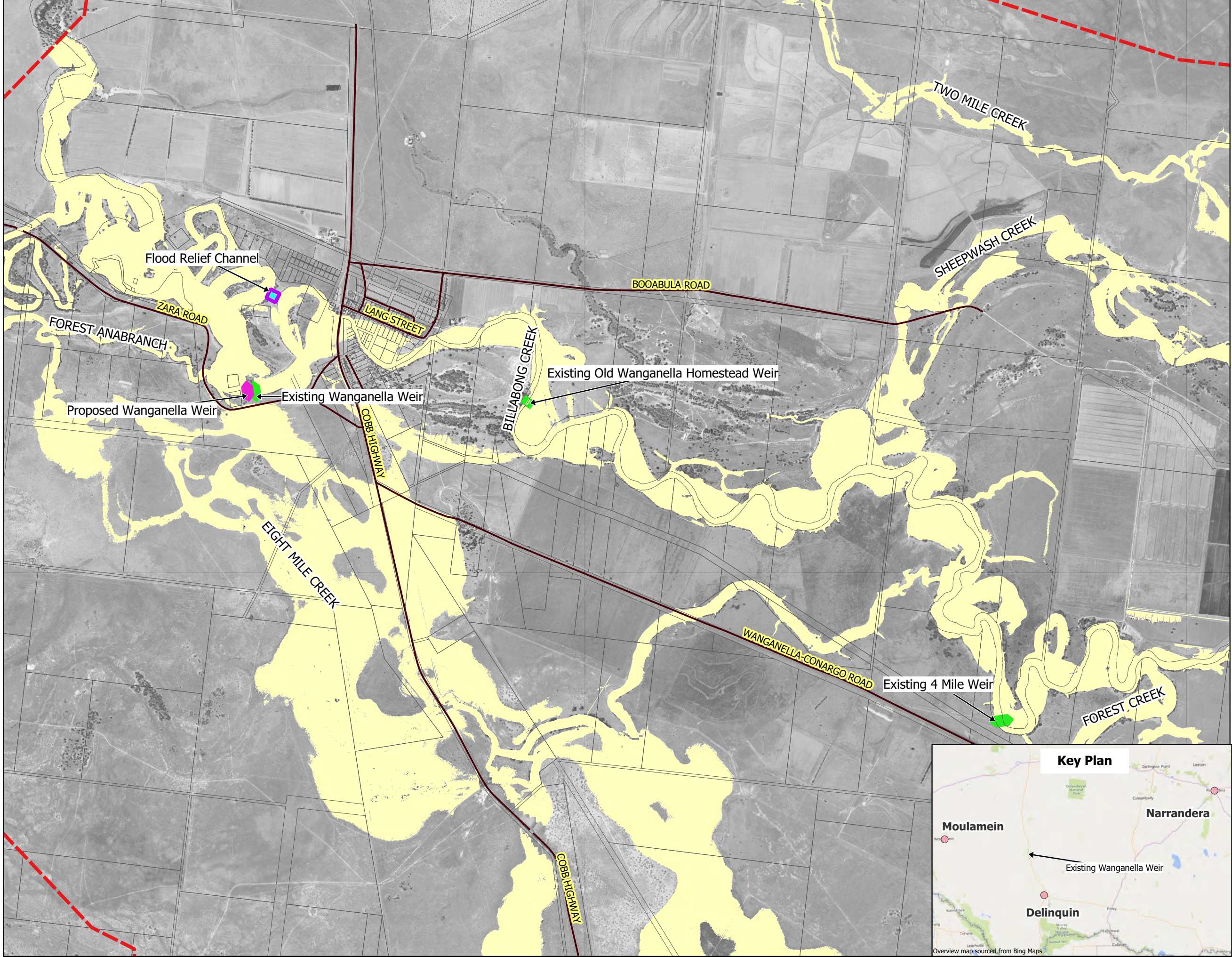
0 0.7 1.4 km

Grid name:
dh_YNC_WP20_5AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C25 - 5% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



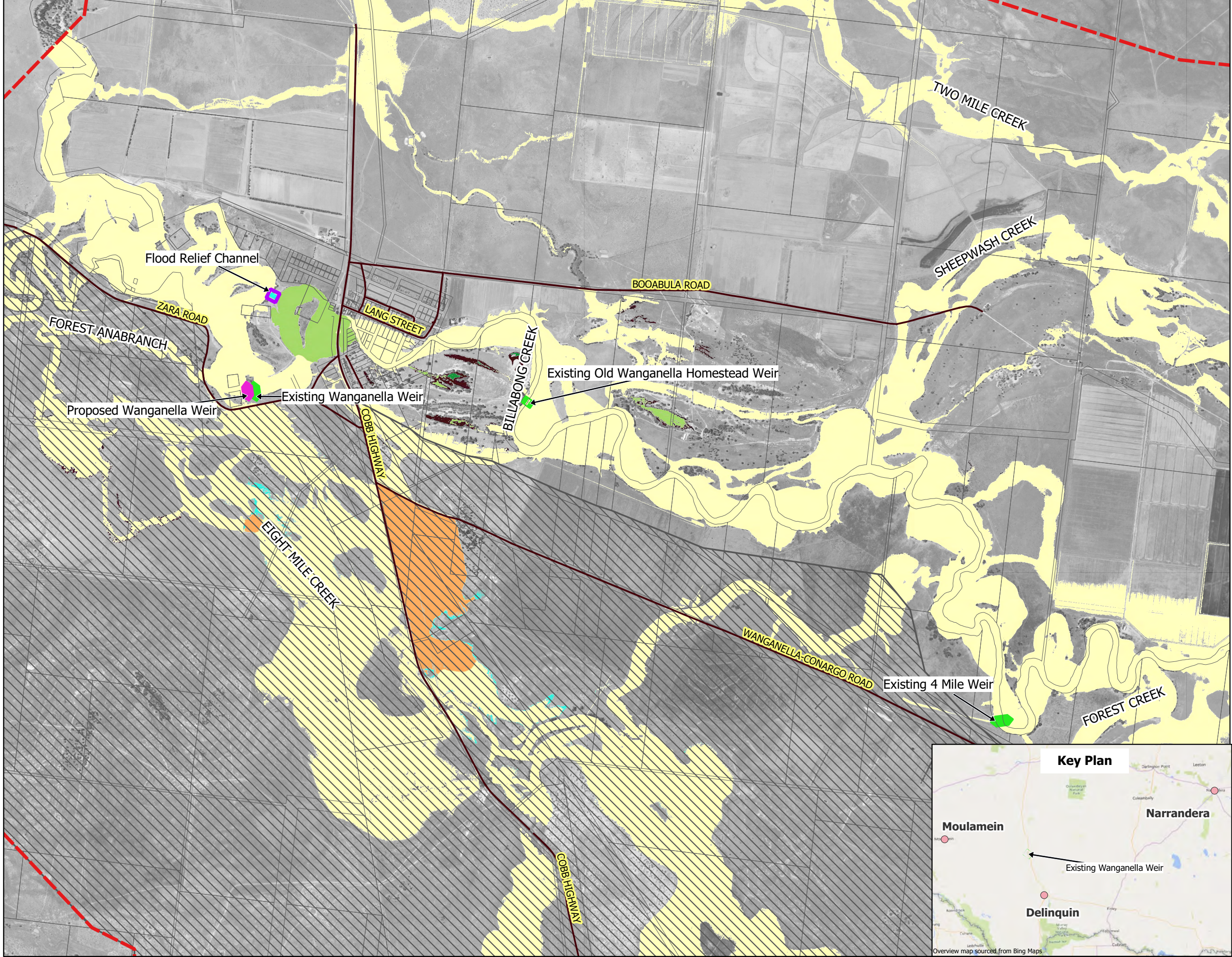
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_1AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C26 - 1% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



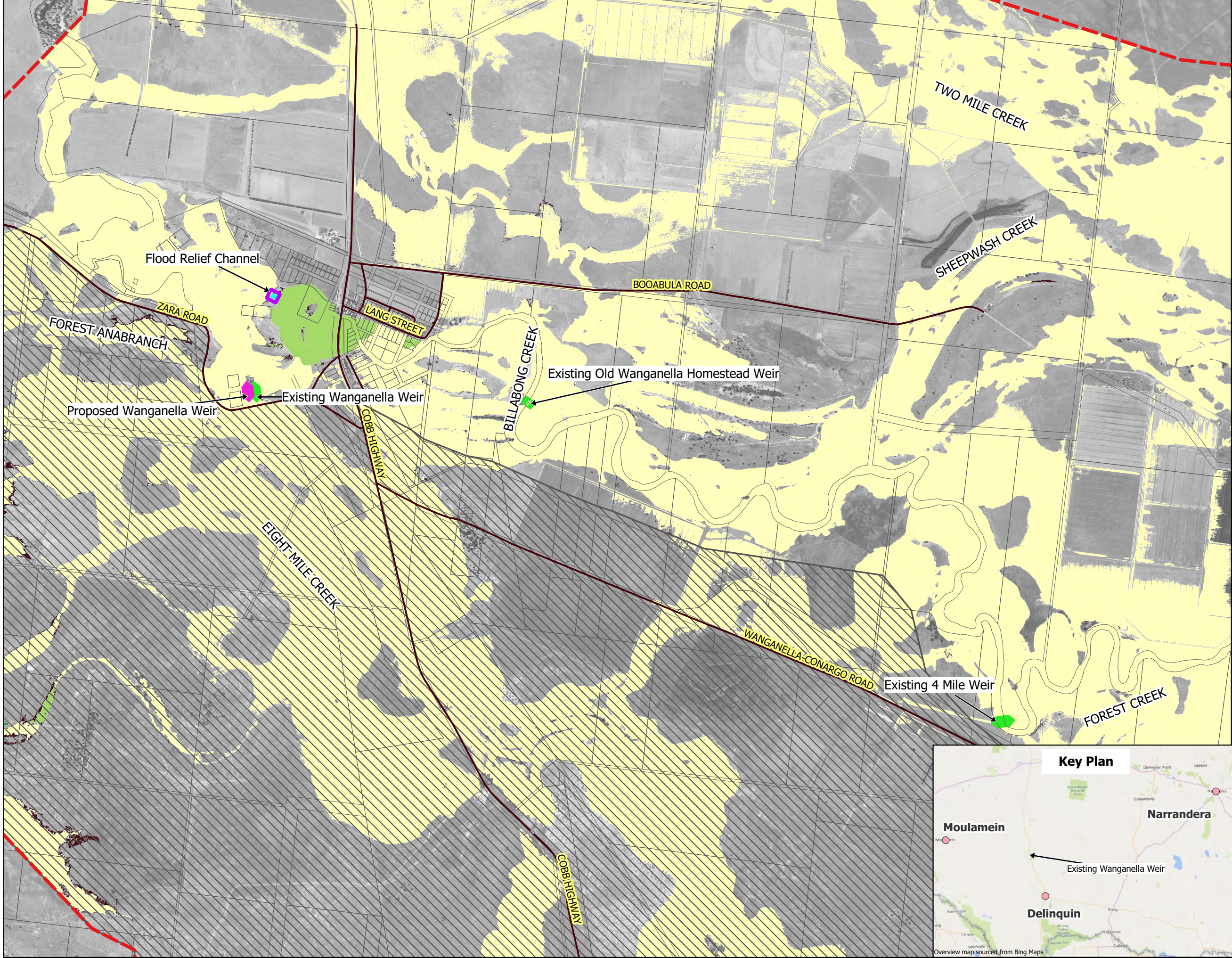
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_0.5AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C27 - 0.5% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



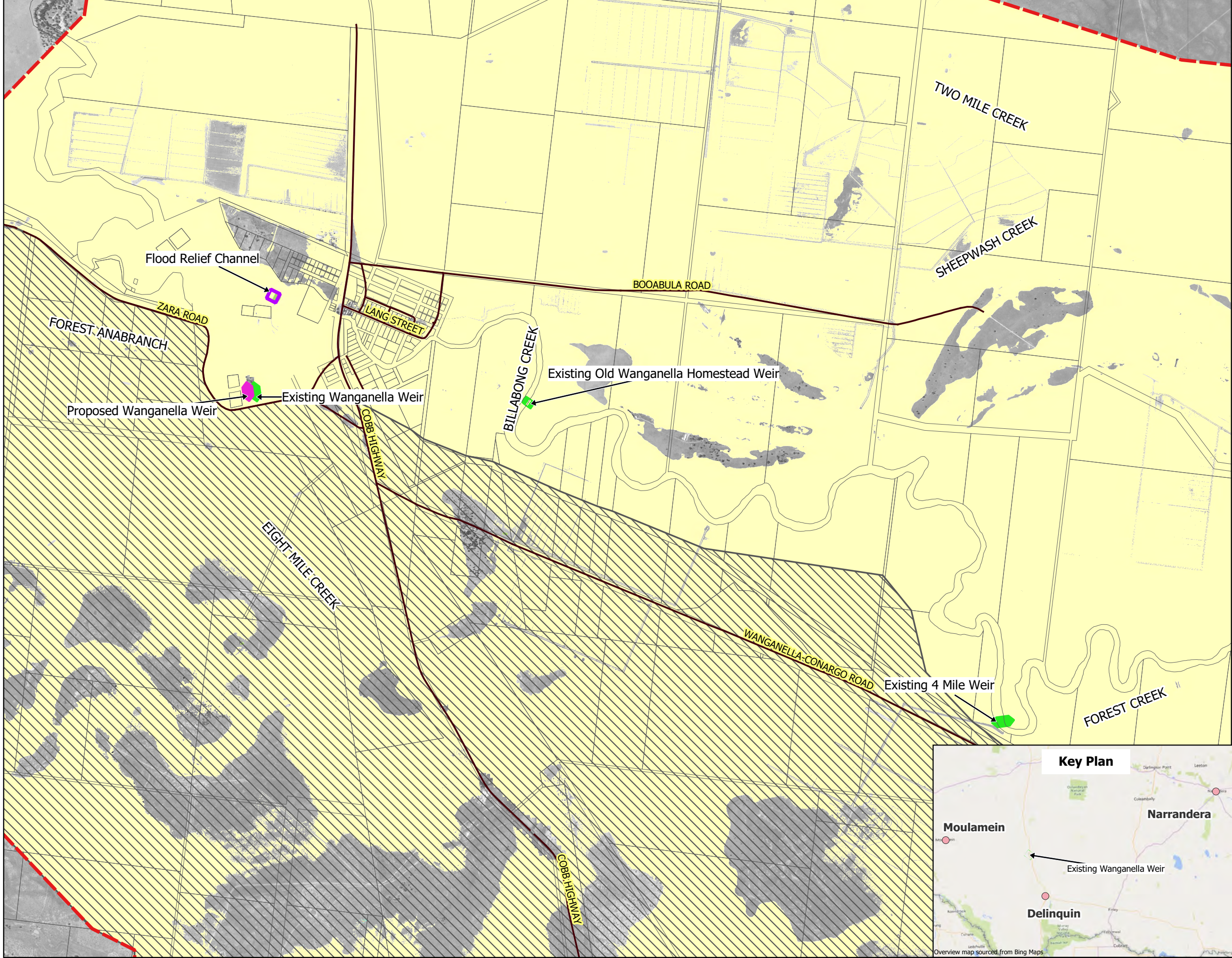
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_0.2AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C28 - 0.2% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



Key Plan

GDA 2020 Zone 55
Scale: 1:30000

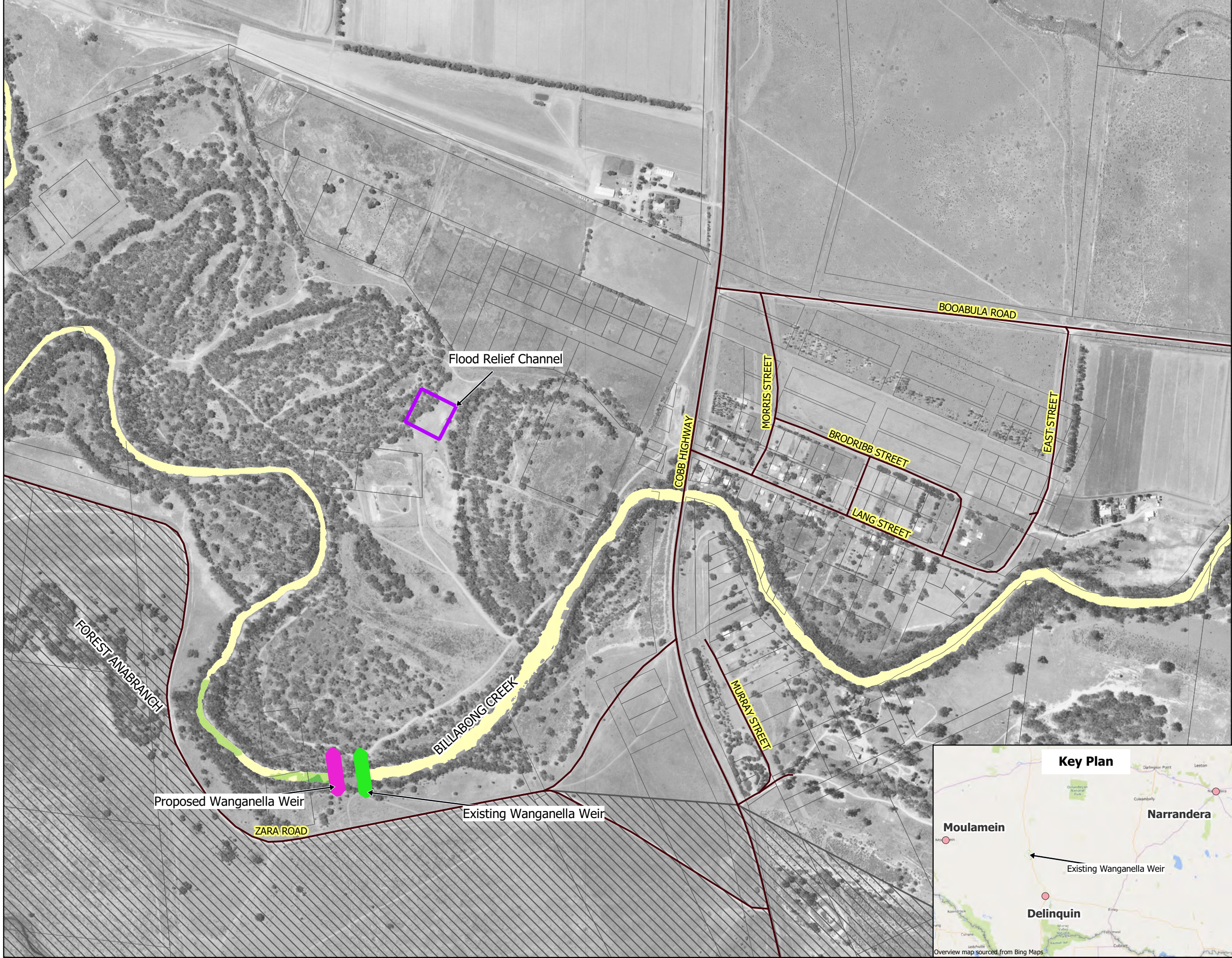
0 0.7 1.4 km

Grid name:
dh_YNC_WP20_PMF_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C29 - PMF Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- ≤ -0.250
- -0.250 to -0.05
- -0.05 - -0.01
- -0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- ≥ 0.250
- Was wet now dry
- Was dry now wet

GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_30MLD_OpFlows_MinOL_80.71_S030161_less_B020120

Key Plan

Moulamein

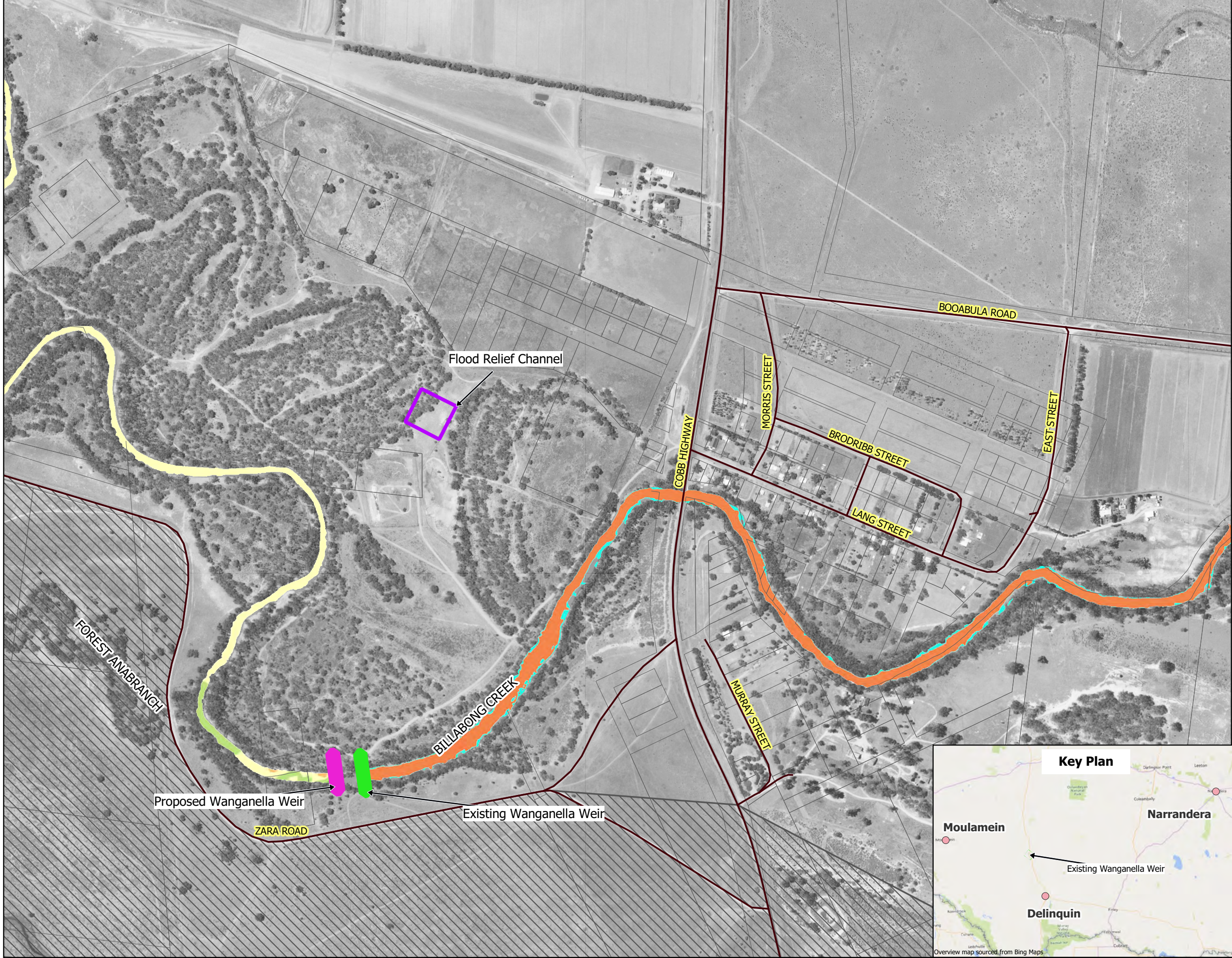
Narrandera

Delinquin

Existing Wanganella Weir

Overview map sourced from Bing Maps

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C30 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Minimum Operational Level vs Existing"



Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

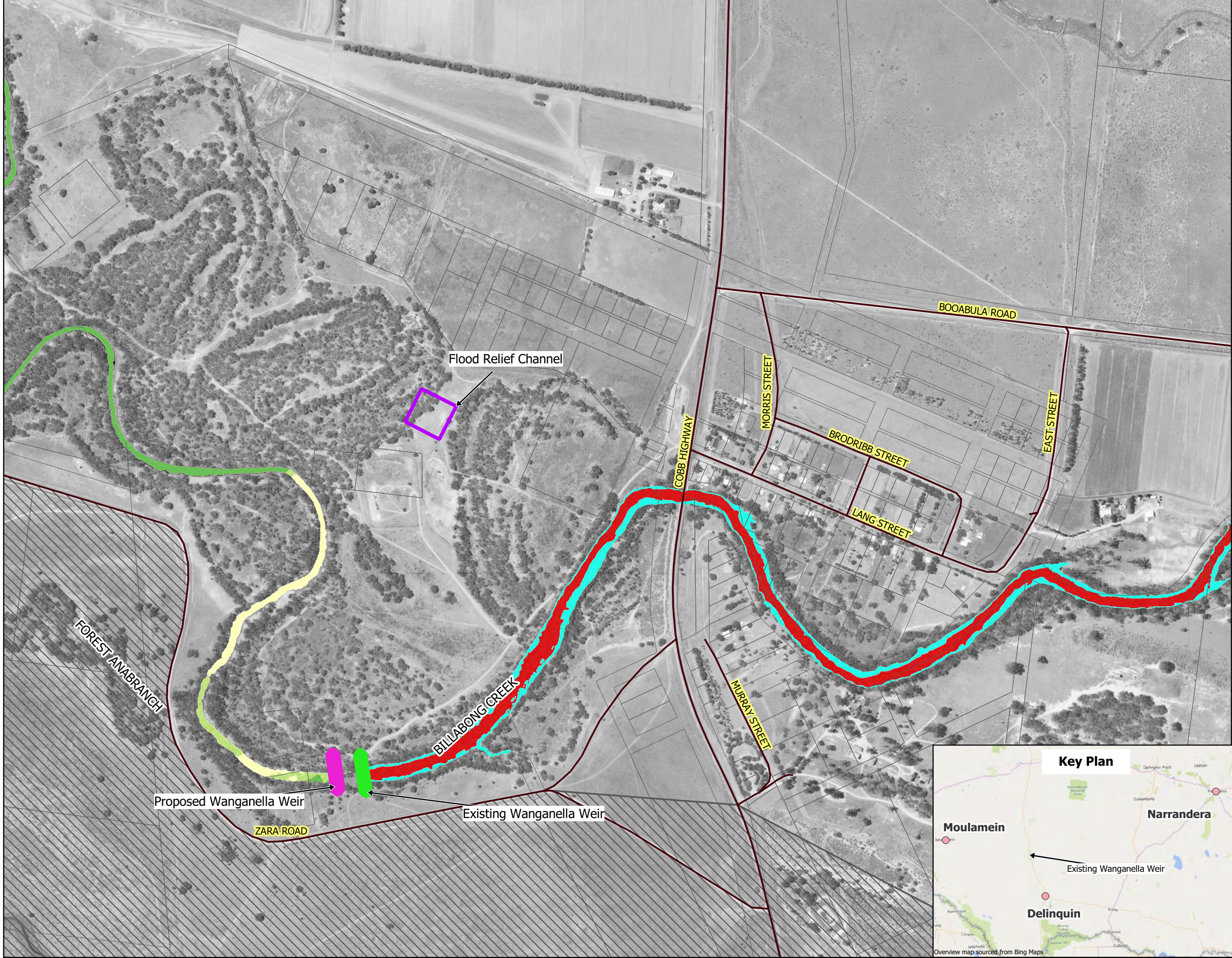
0 0.1 0.2 km

Grid name:
dh_YNC_WP20_30MLD_OpFlows_NormOL_80.95_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C31 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Maximum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



Key Plan

GDA 2020 Zone 55
Scale: 1:8000

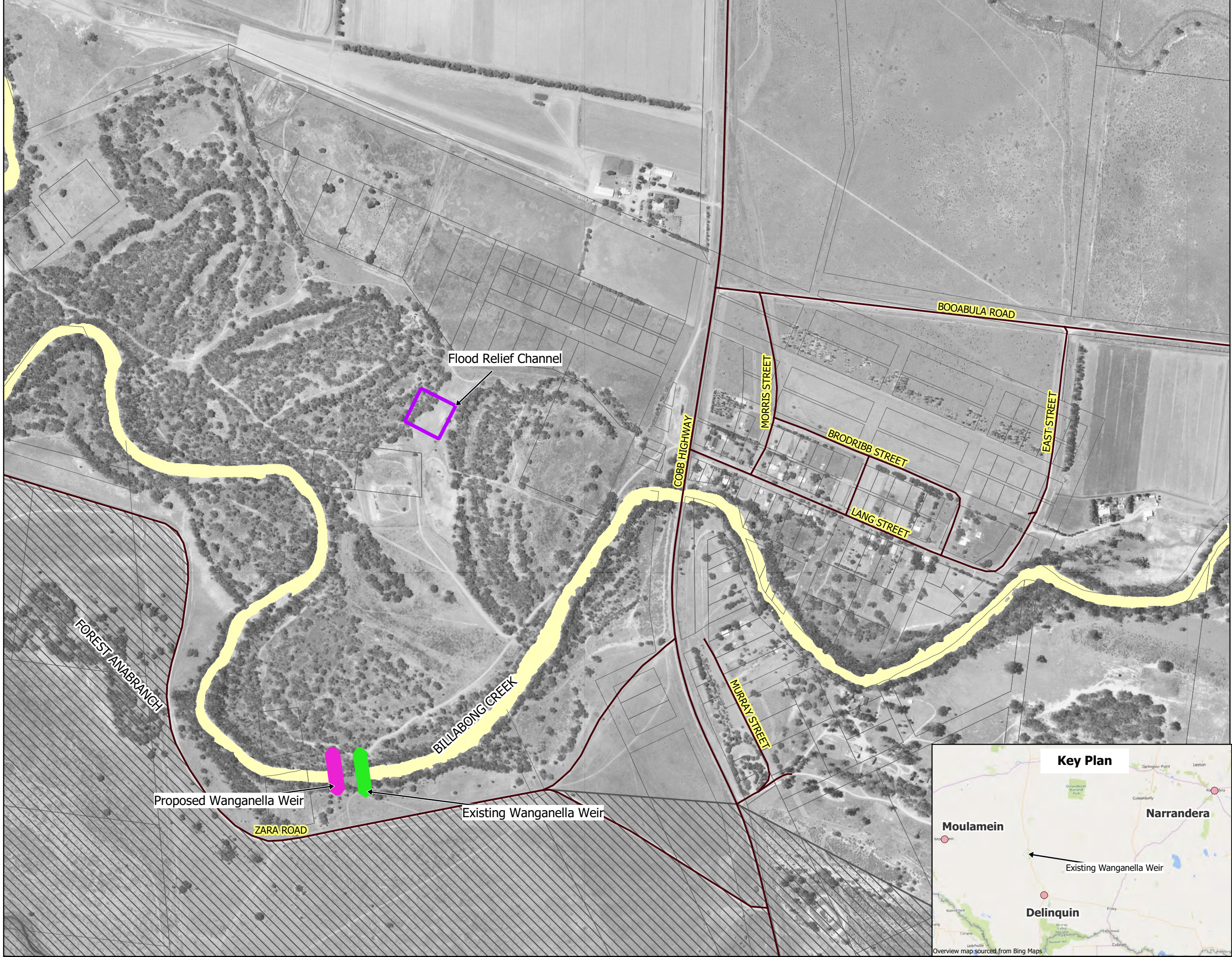
0 0.1 0.2 km

Grid name:
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Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C32 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- ▭ Model Boundary
- ▨ Impact by other works

Flood Impact (m)

- ≤ -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- ≥ 0.250
- Was wet now dry
- Was dry now wet



Key Plan

GDA 2020 Zone 55
Scale: 1:8000

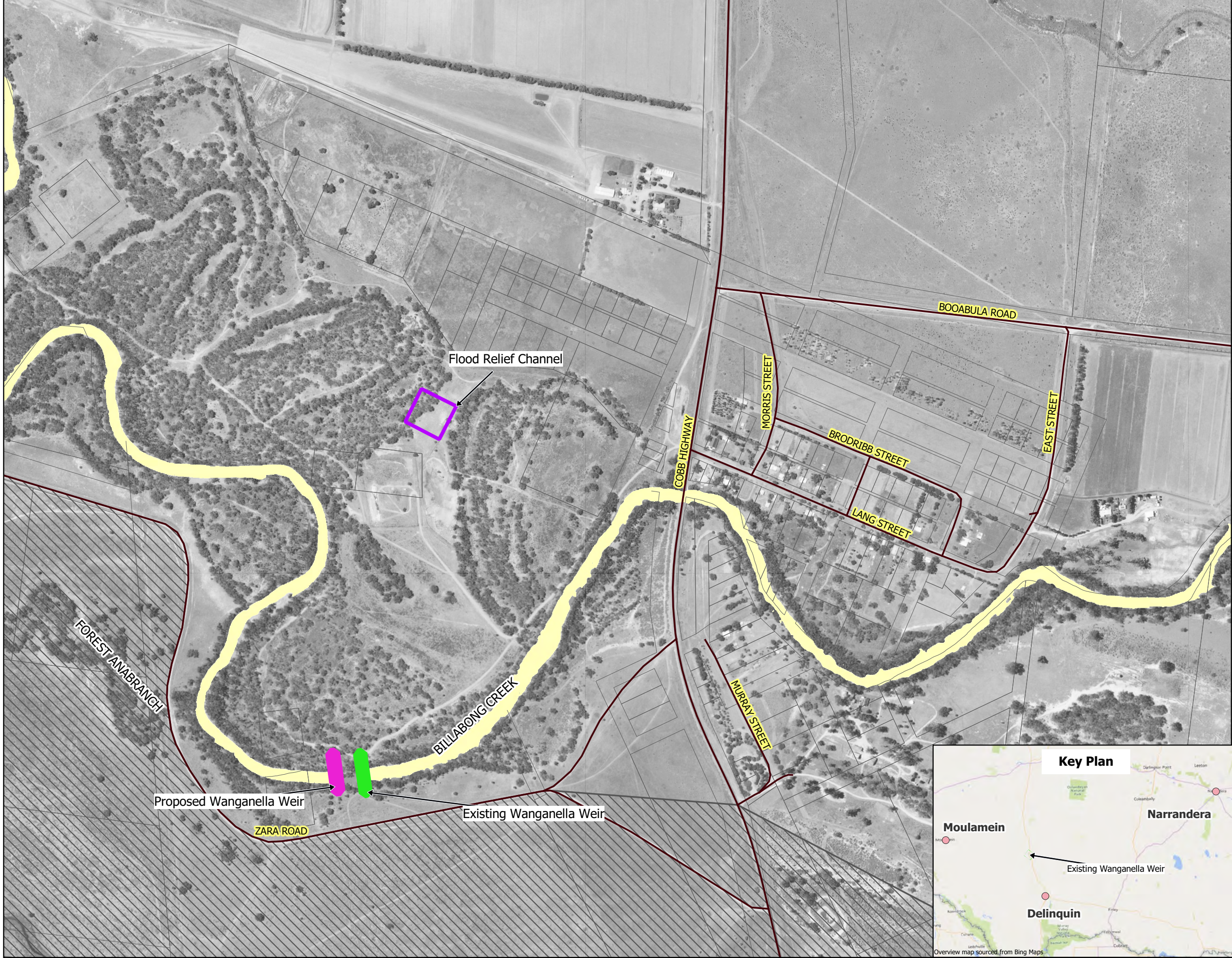
0 0.1 0.2 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_MinOL_80.20_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C33 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Minimum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

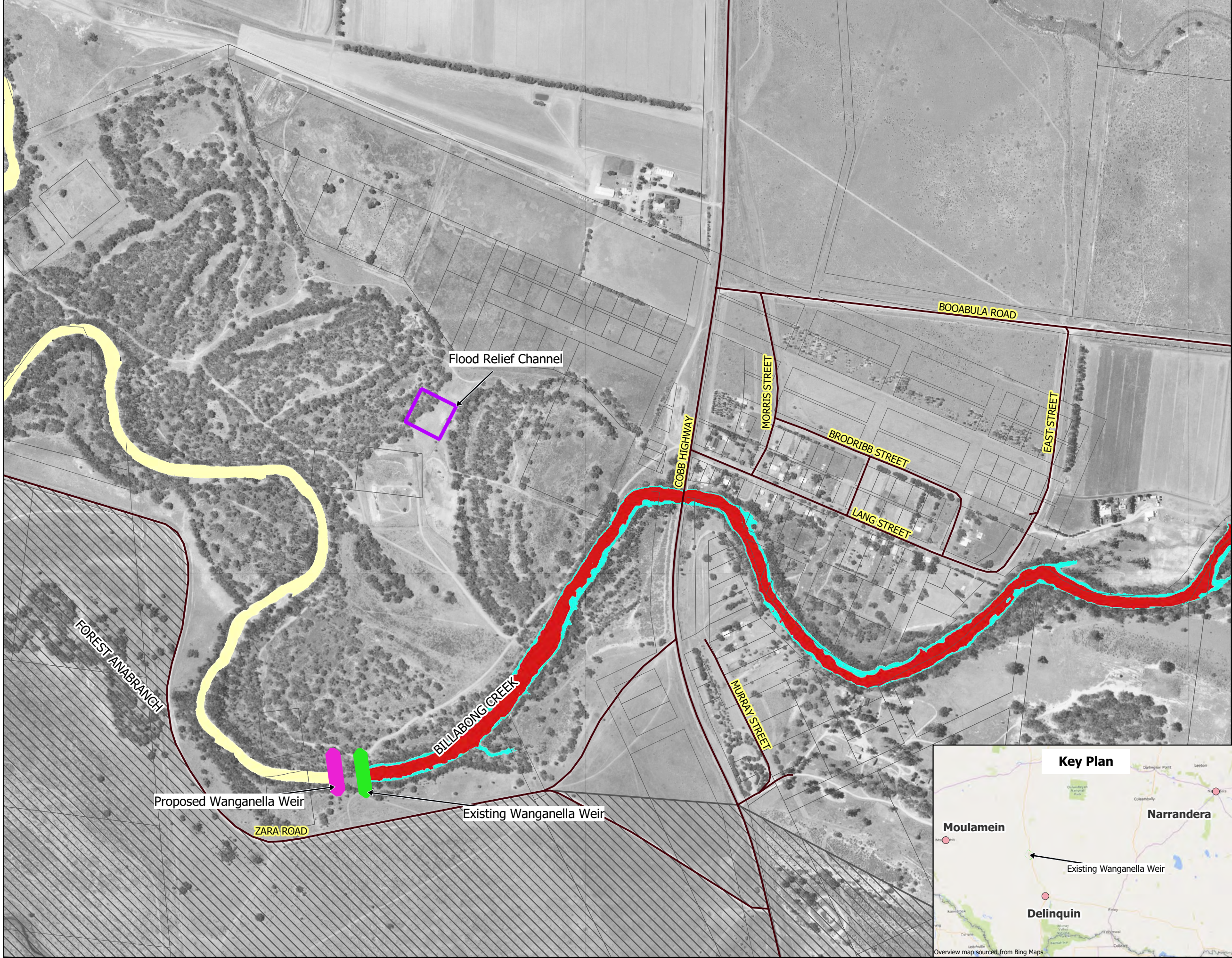
0 0.1 0.2 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_NormOL_80.54_S030161_less_B020120

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C34 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Maximum Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



Key Plan

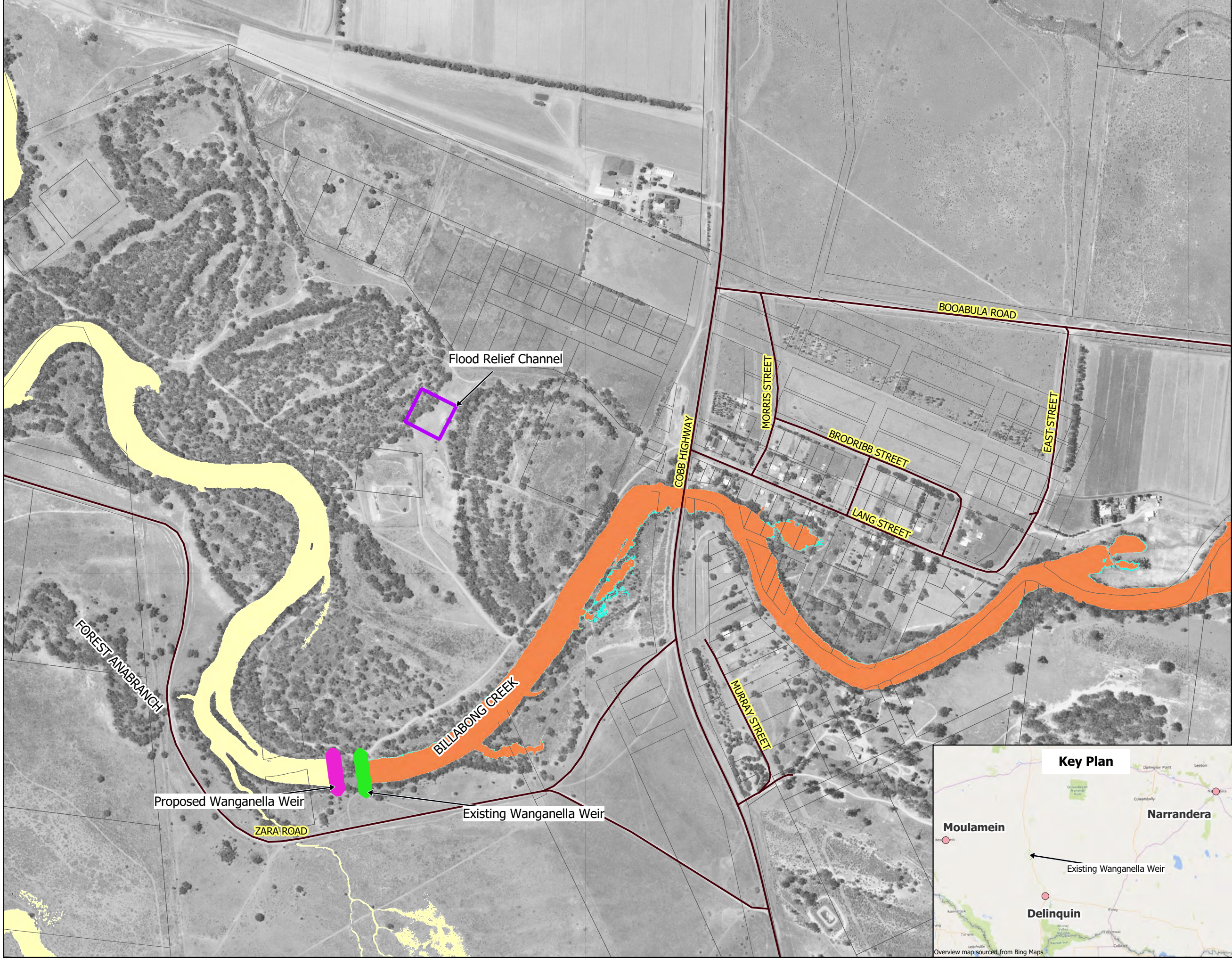
GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C35 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250

Was wet now dry

Was dry now wet



Key Plan

GDA 2020 Zone 55

Scale: 1:8000

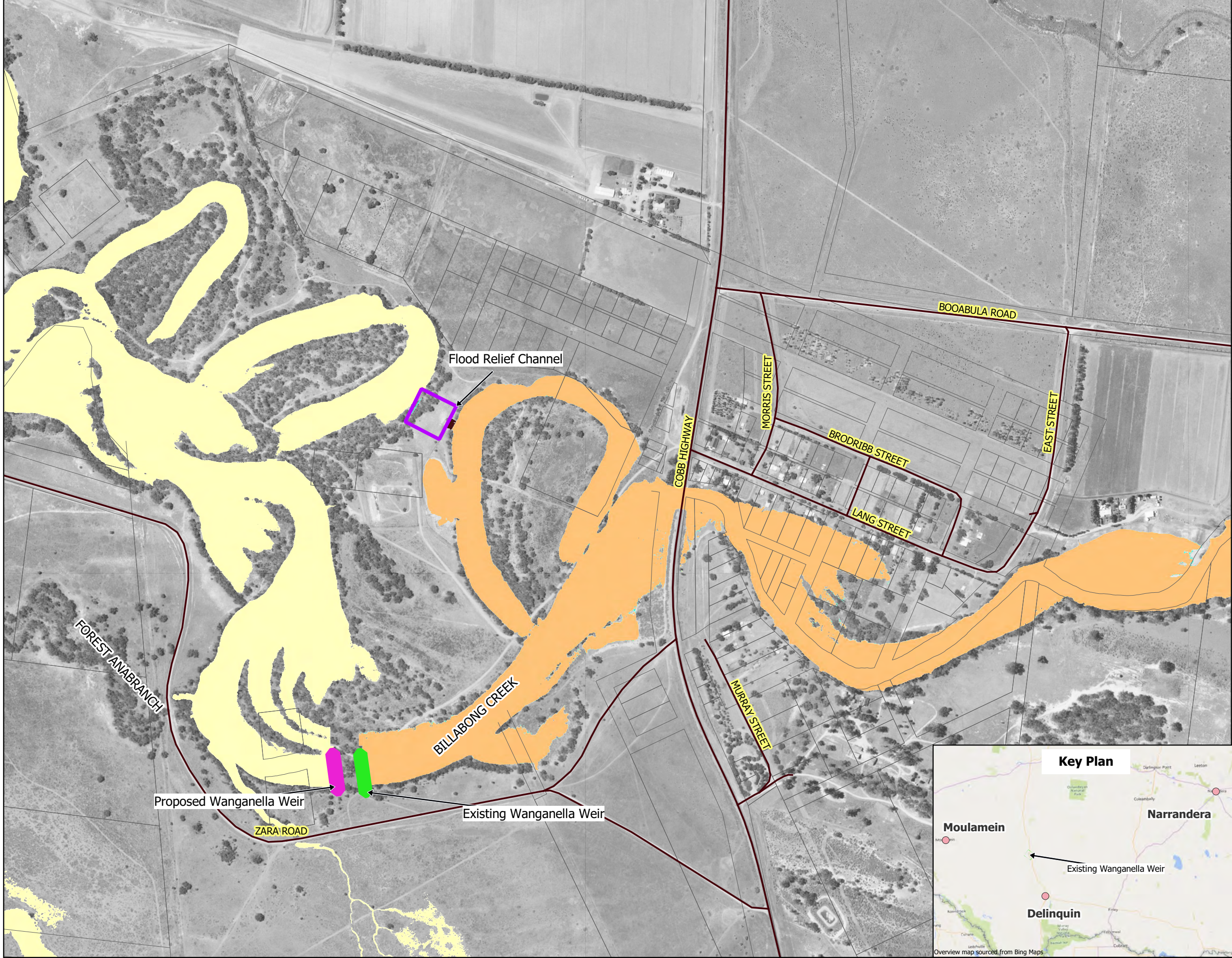
0 0.1 0.2 km

Grid name:
dh_YNC_WP20_20AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C36 - 20% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



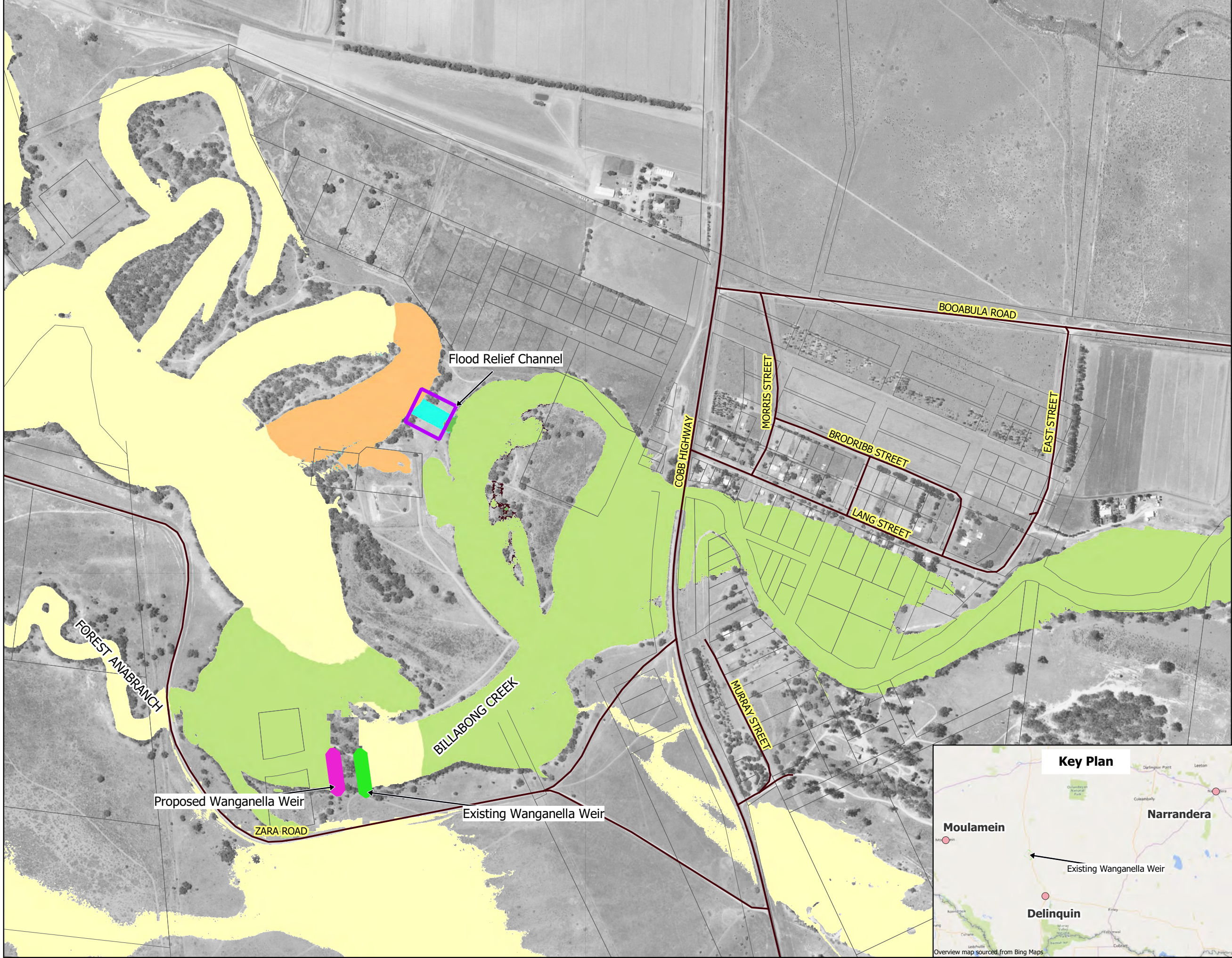
GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_5AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C37 - 5% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_1AEP_BD_Flood_S030164_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C38 - 1% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



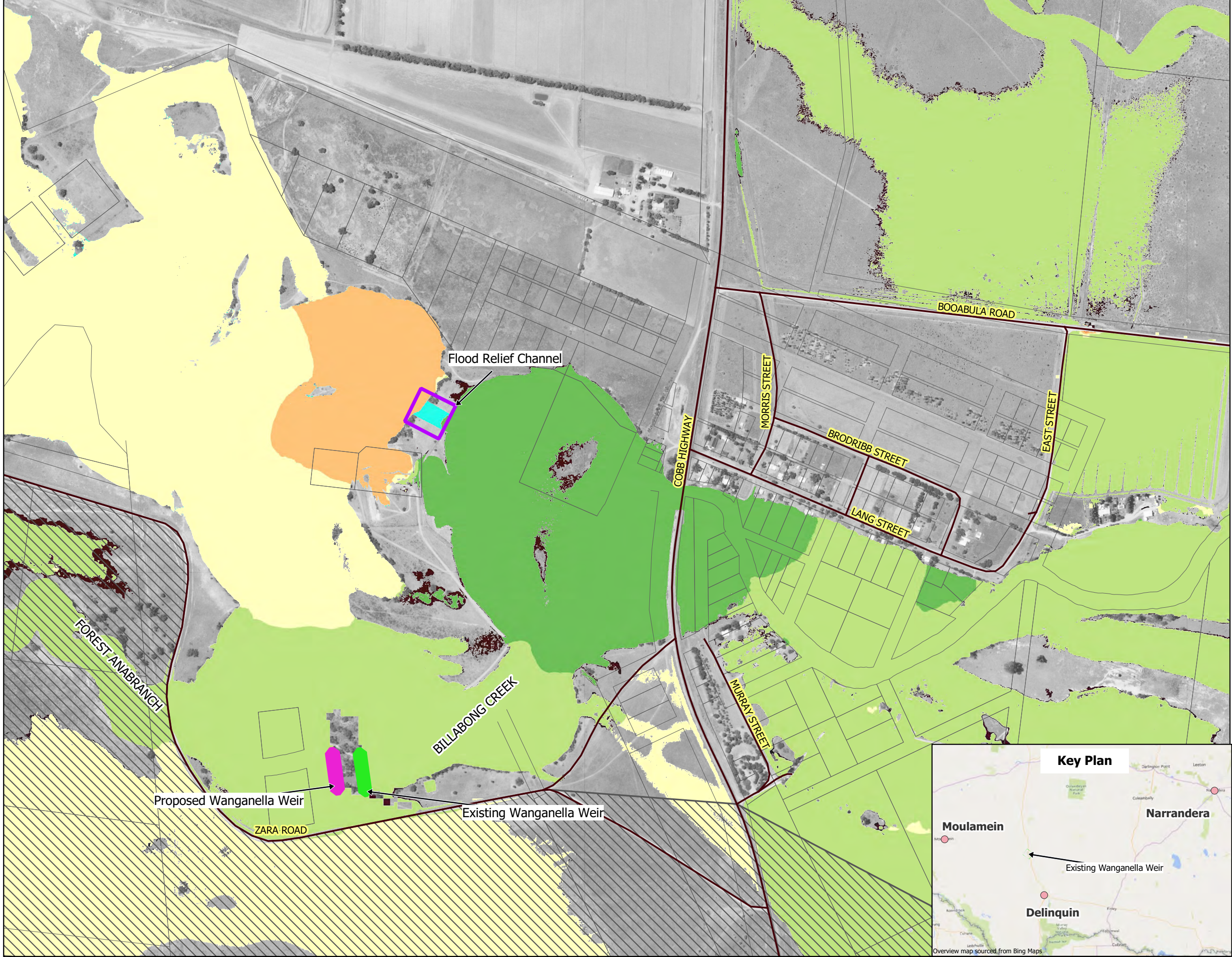
GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_0.5AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C39 - 0.5% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



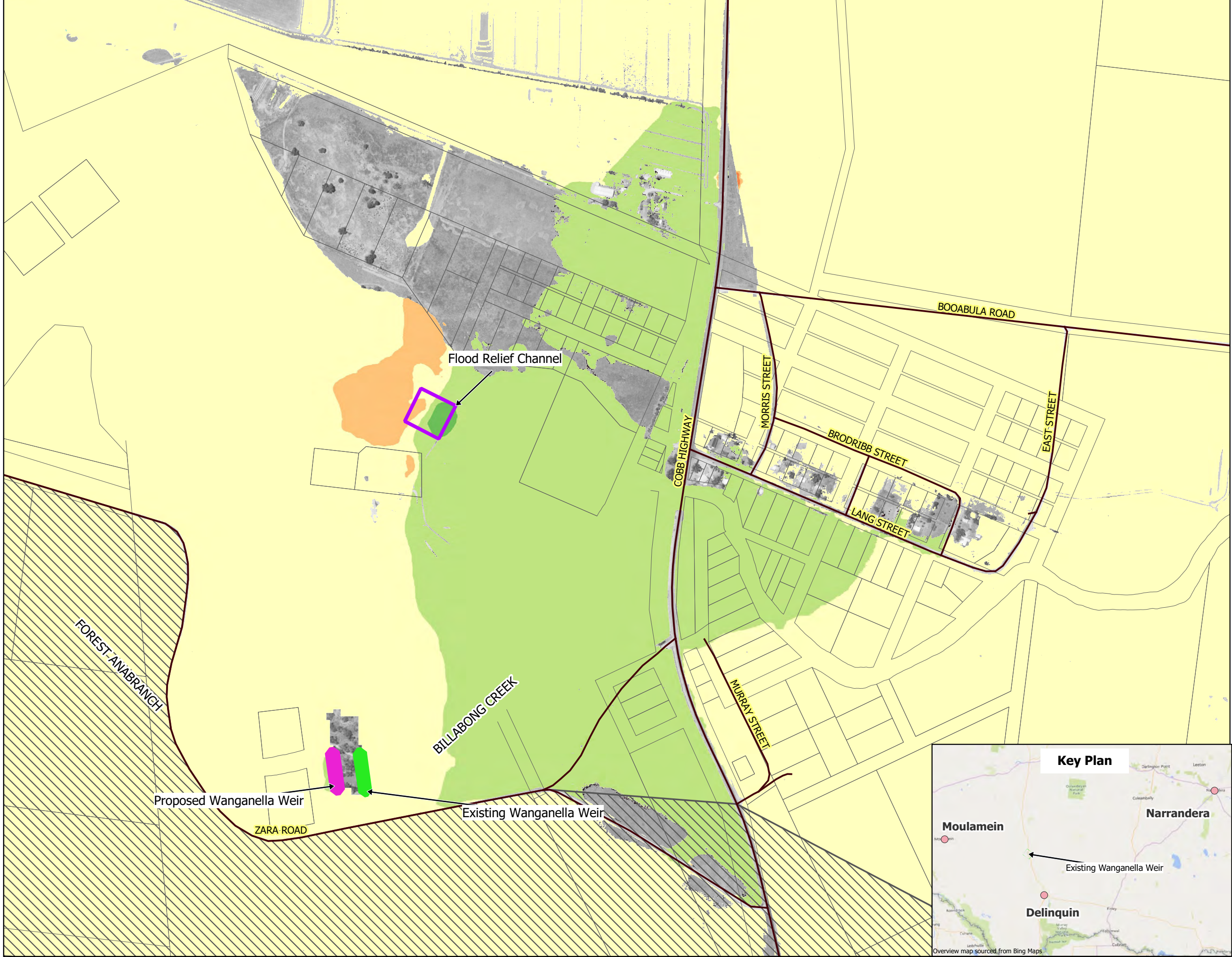
GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_0.2AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C40 - 0.2% AEP Flood Level Impact
"Proposed vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_PMF_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C41 - PMF Flood Level Impact
"Proposed vs Existing"

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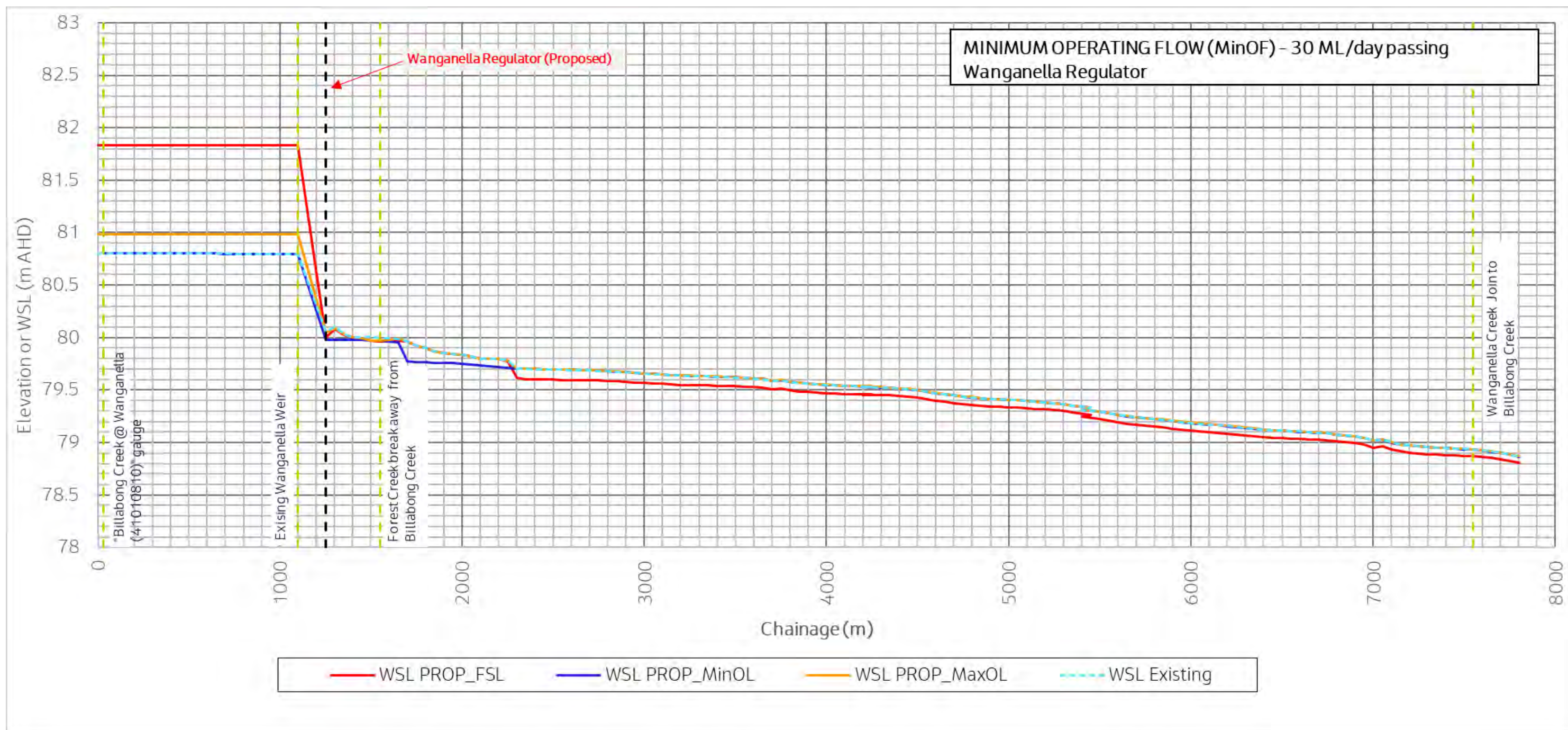


Figure C42 “Proposed” and “Existing” WSL comparison along Billabong Creek for Minimum Operating Flow (MinOF) of 30 ML/day at Wanganella Regulator

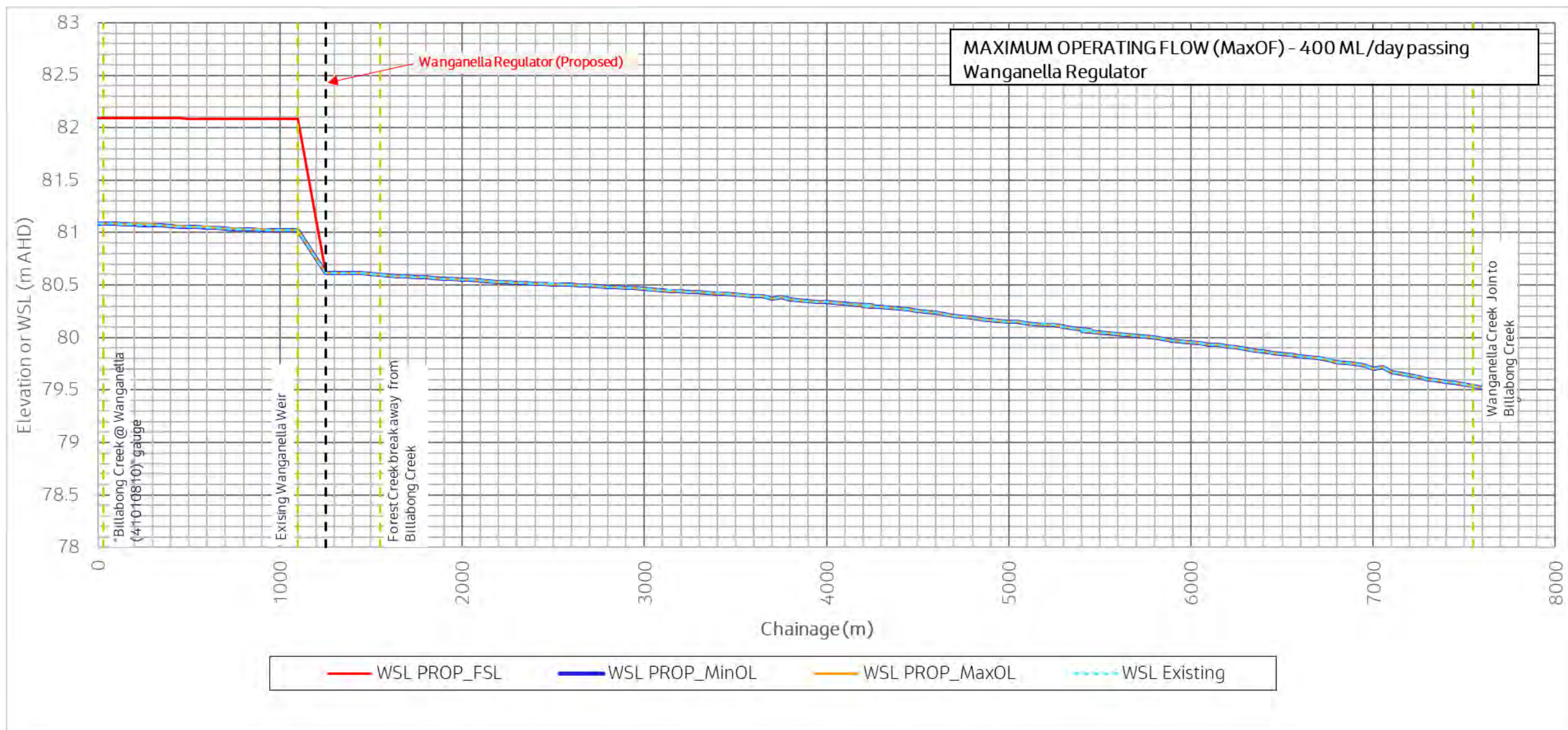


Figure C43 "Proposed" and "Existing" WSL comparison along Billabong Creek for Maximum Operating Flow (MaxOF) of 400 ML/day at Wanganella Regulator

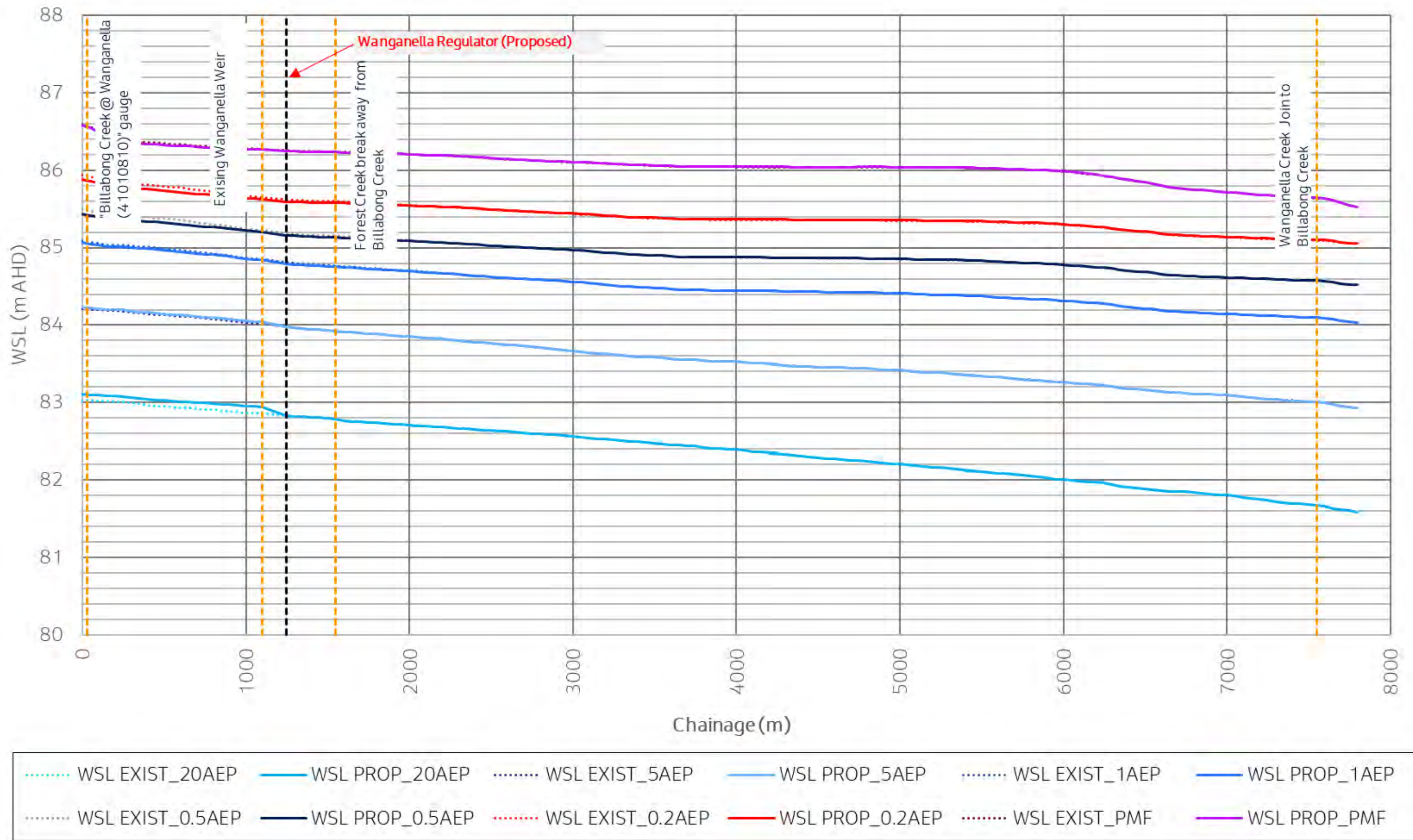


Figure C44 "Proposed" and "Existing" WSL comparison along Billabong Creek for flood scenarios at Wanganella Regulator

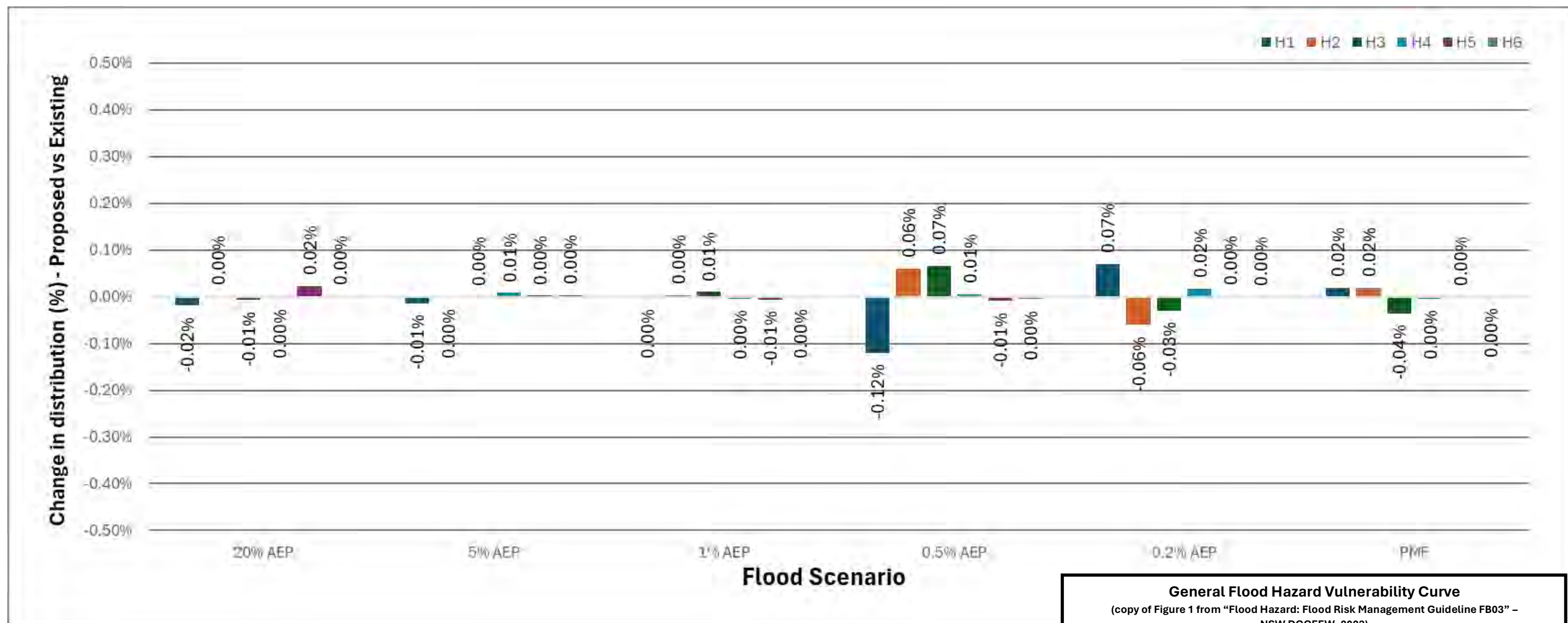
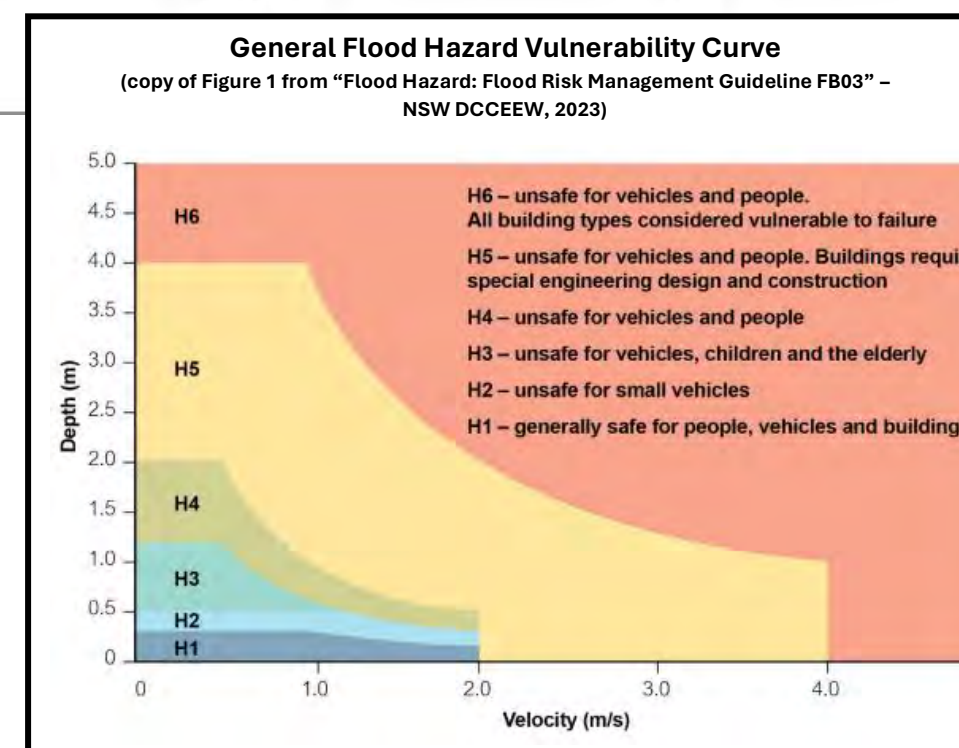
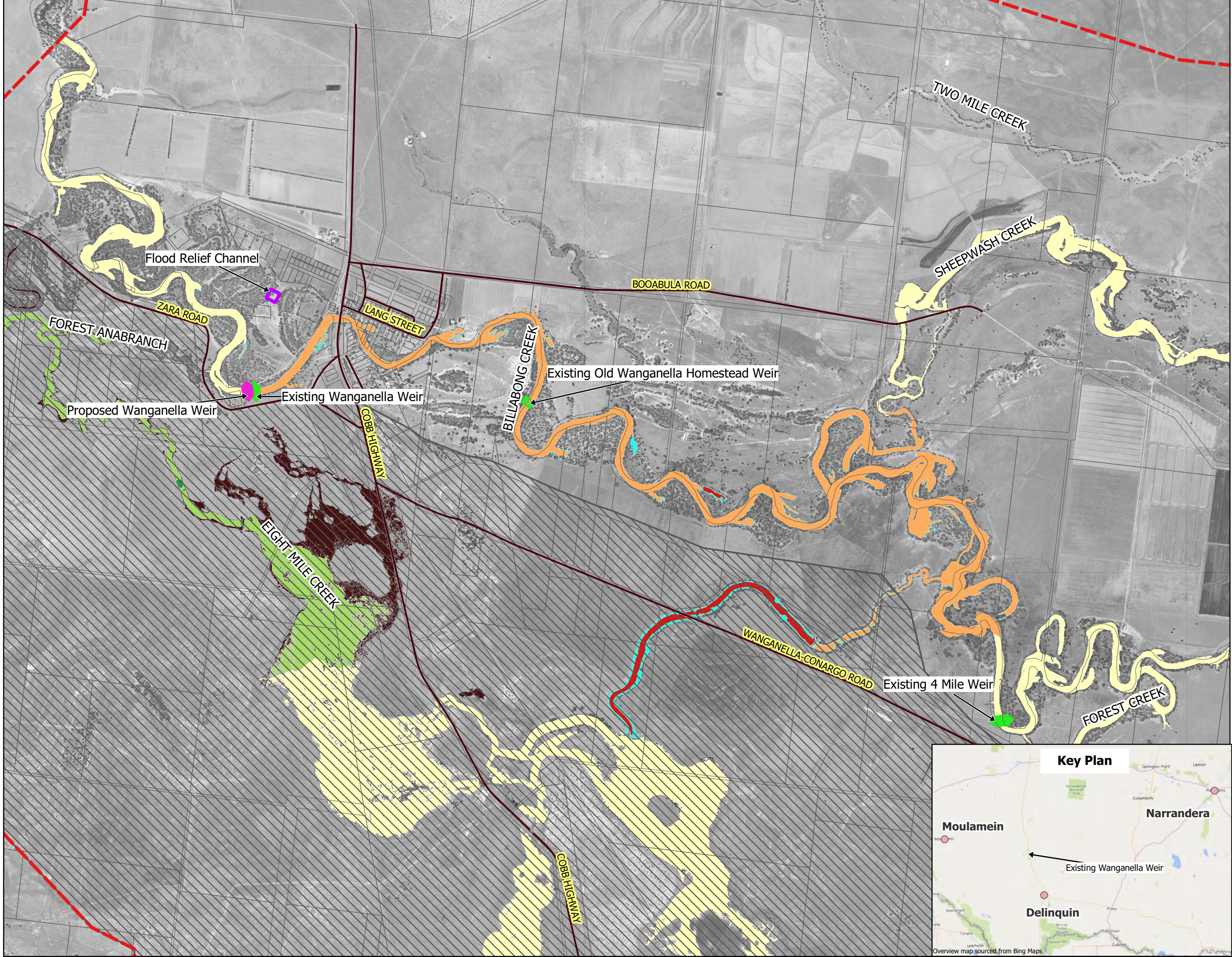


Figure C45 Change in hazard categories within the Modelling Extent





Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



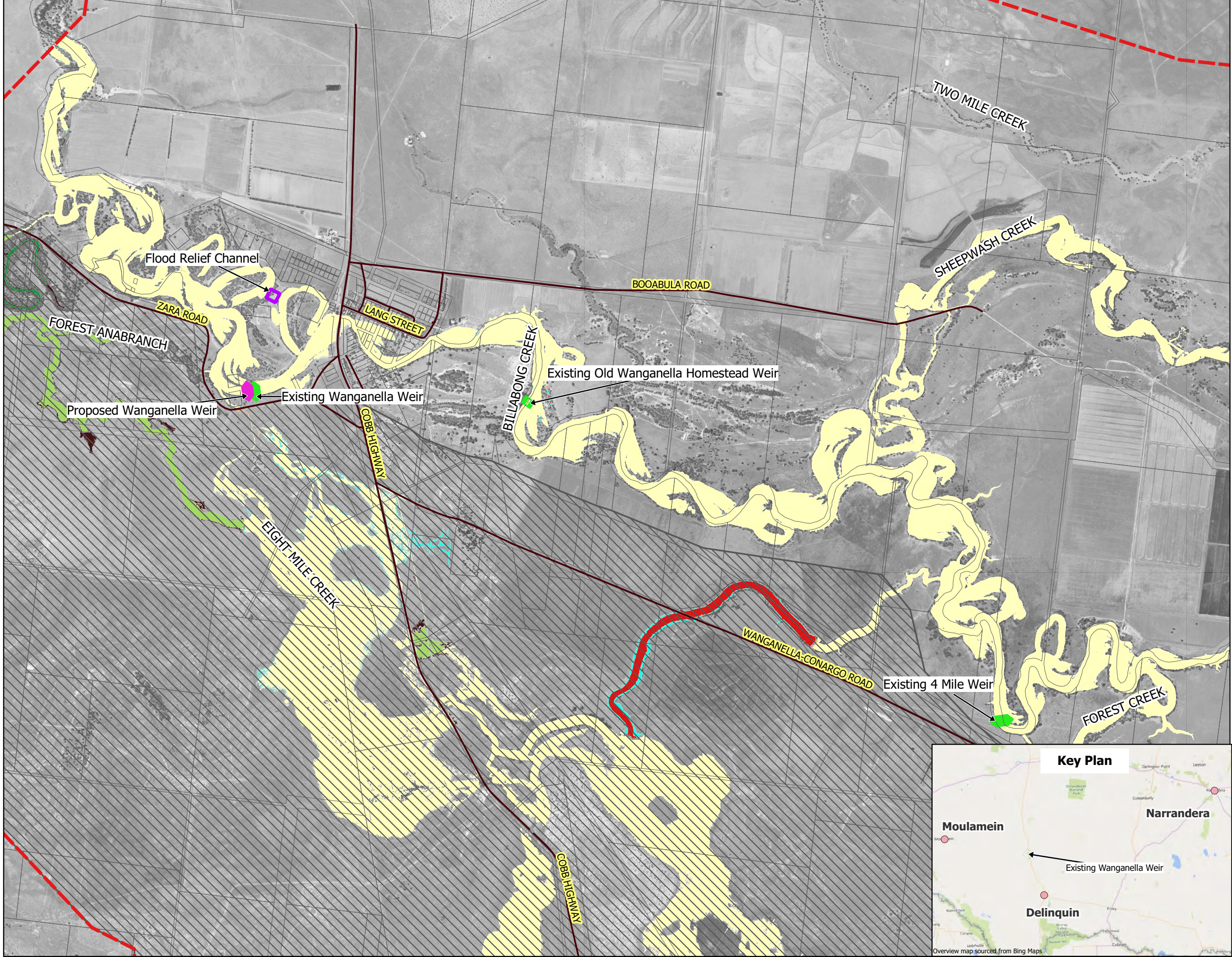
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_20AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C46 - 20% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250

Wet/Dry Status

- Was wet now dry
- Was dry now wet



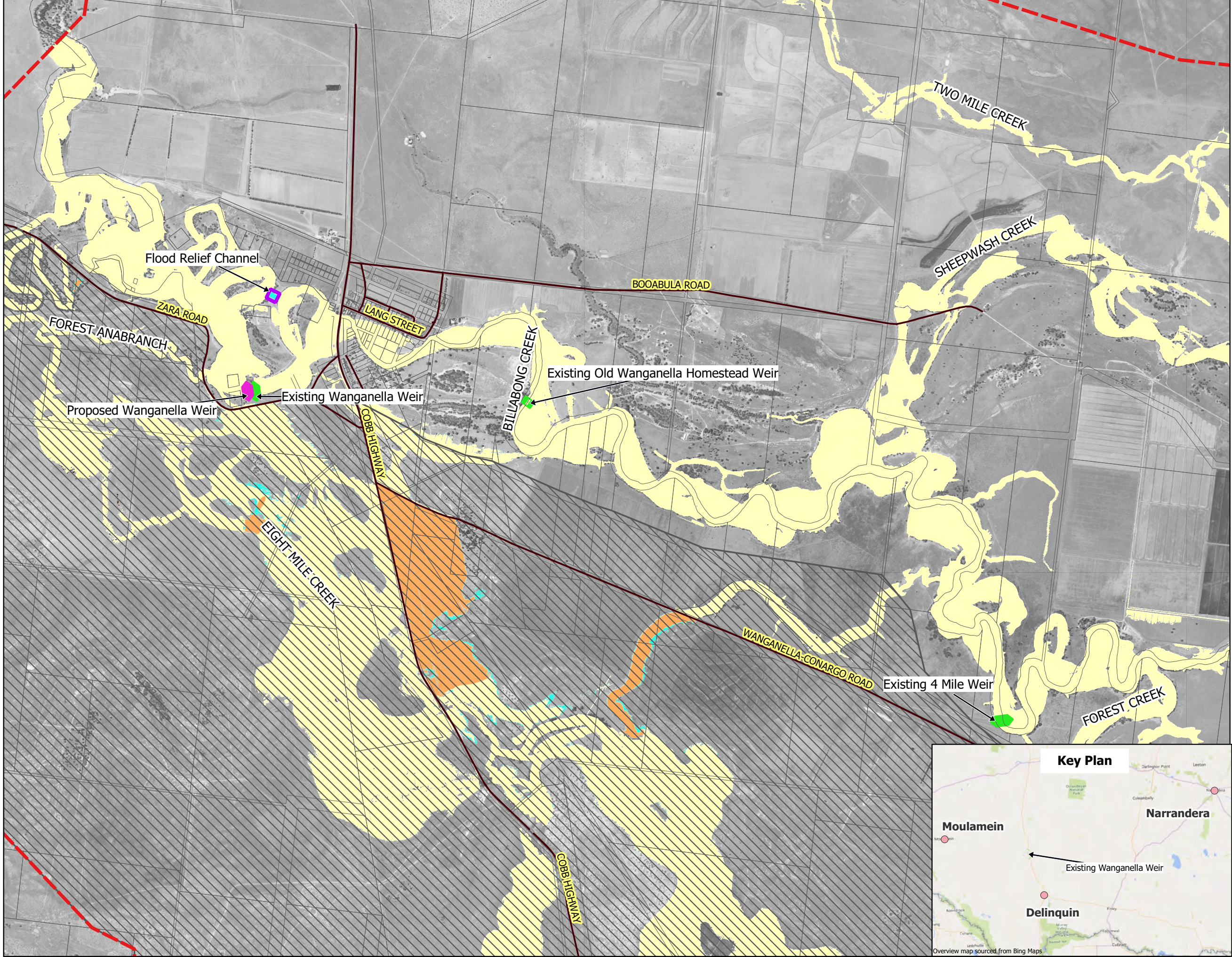
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_5AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C47 - 5% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



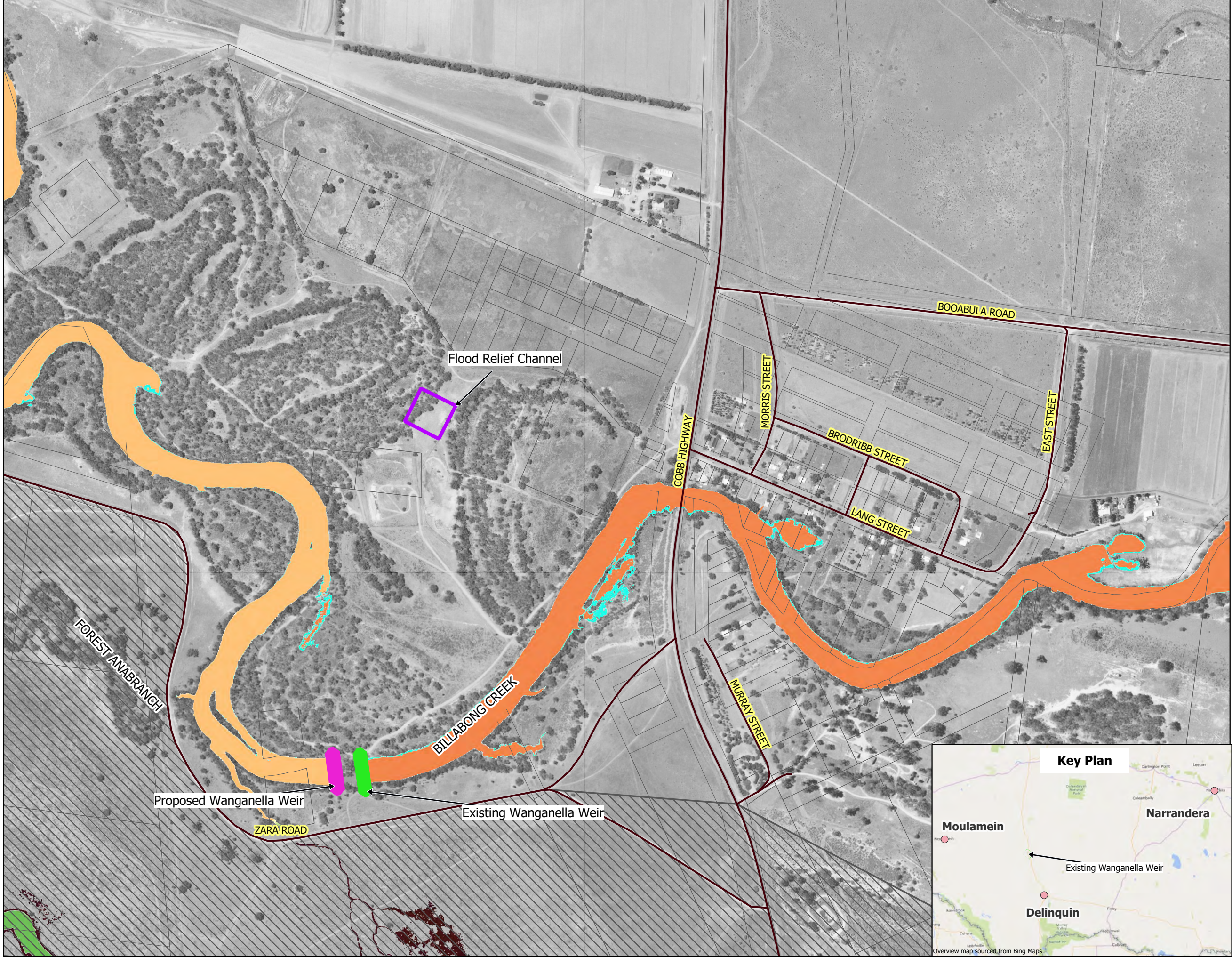
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_1AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C48 - 1% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_20AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C49 - 20% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_5AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C50 - 5% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Legend

- Cadastre
- Main Roads
- Model Boundary
- Impact by other works

Flood Impact (m)

- <= -0.250
- 0.250 to -0.05
- 0.05 - -0.01
- 0.01 - 0.01
- 0.01 - 0.05
- 0.05 to 0.250
- >= 0.250
- Was wet now dry
- Was dry now wet



GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
dh_YNC_WP20_1AEP_BD_Flood_S030161_less_B020120_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure C51 - 1% AEP Cumulative Flood Level Impact
"Proposed (all works) vs Existing"

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Appendix D. Hartwood Hydraulic Modelling Report

PROVIDED AS SEPARATE APPENDIX

Appendix E. Wanganella Hydraulic Modelling Report

PROVIDED AS SEPARATE APPENDIX