Appendix H
Flood impact assessment

Sub Appendix E - Wanganella Hydraulic Modelling Report

SDLAM Program

RfS_063

Yanco Creek Modernisation: Hydraulic Modelling Technical Report – Piccaninny Weir to Wanganella Weir Study Area

Revision 0

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1. About This Report

1.1 Purpose

The 3Rivers Joint Vent (3Rivers) has been engaged to provide certain Engineering 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 sole purpose of this report and the associated services performed by 3Rivers is to summarise the technical background, assumptions and setup of the hydraulic modelling undertaking for the assessment of proposed Yanco Modernisation Infrastructure (namely Wanganella Regulator, Upper Clarkes Creeks Regulator, MacCrabbs Regulator, Eight Mile Creek Regulators, Forest Anabranch Offtake structures) to enable smarter use of water and environmental restoration in the Yanco Creek System – including Yanco, Billabong, Forest Creek and Eight Mile Creek. The works contained in the Work Package 20 (WP20) model as part of the Reconnecting River Country (RRC) project. This work was carried out in accordance with the scope of services set out in the Agreement and the following approved RFS forms:

- RFS63 - Yanco Creek Modernisation Project - Strategic Assessment and Concept Design Phase
- RFS76 – Yanco Creek Modernisation Detailed Design Enabling Works
- RFS77 - Yanco Creek Modernisation Detailed Design

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1.2 Scope and Limitations

This report documents the background, assumptions, and setup of the "existing" and "proposed" hydraulic models used to inform the design of proposed works and/or assess the impact of these works to inform the relevant Review of Environmental Factors (REF) or Environmental Effects Statement (EIS).

3Rivers has prepared this report to the usual standard of care and skill to be expected of the consulting profession. The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. No other warranty or guarantee, whether expressed or implied, is made to the extent permitted by law.

In preparing this report, 3Rivers has relied on information provided by DCCEEW (including but not limited to RFS documentation, existing modelling, and assumptions regarding status, condition, or characteristics of structures) and others (including but not limited to filed survey information, operational and gauge data, bathymetry and LiDAR terrain information). 3Rivers has not independently verified or checked the information provided beyond the agreed scope of work. 3Rivers does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.3 Assumptions

The opinions, conclusions and any recommendations in this report are based on the assumptions made by 3Rivers described in this report. The assumptions have been made using the usual standard of care and skill to be expected of the consulting profession. 3Rivers disclaims liability arising from any of the assumptions being incorrect.

2. Introduction

2.1 Background

This technical Hydraulic Modelling Report has been developed by 3Rivers to summarise the hydraulic modelling activities undertaken to inform the design or assess impact of the proposed works for the Sustainable Diversion Limit Adjustment Mechanism (SDLAM) Yanco Creek Modernisation project.

Hydraulic modelling is being undertaken to provide understanding, information and/or assess impacts for a number of flow scenarios, which range from operational flows (or environmental baseflows) to flood flows (50% AEP up to PMF). The Work Package 20 (WP20) model created as part of the Reconnecting River Country (RRC) programme was used as the basis of this model, with some changes based on the flow scenarios required and/or new information (such as additional survey). The location and extent of the model used for the study are shown on Figure 1, which shows that the model covers the following key areas:

- Billabong Creek from upstream of Boonoke Road to the downstream of the junction of Wanganella Creek.
- Forest Creek from upstream of Conargo Road to downstream of the junction of Billabong Creek.
- Eight Mile Creek from where it splits away from the Forest Creek to downstream of the junction of Forest Creek.
- Sheepwash Creek from where it splits away from the Billabong Creek to downstream of the junction of Billabong Creek.
- Browns Creek from the reach junction of Box Creek to downstream of the junction of Sheepwash Creek.

The model results are valid for the following area (referred to from here on in as the 'Study Area', which is also shown on Figure 1 relative to the hydraulic model boundaries):

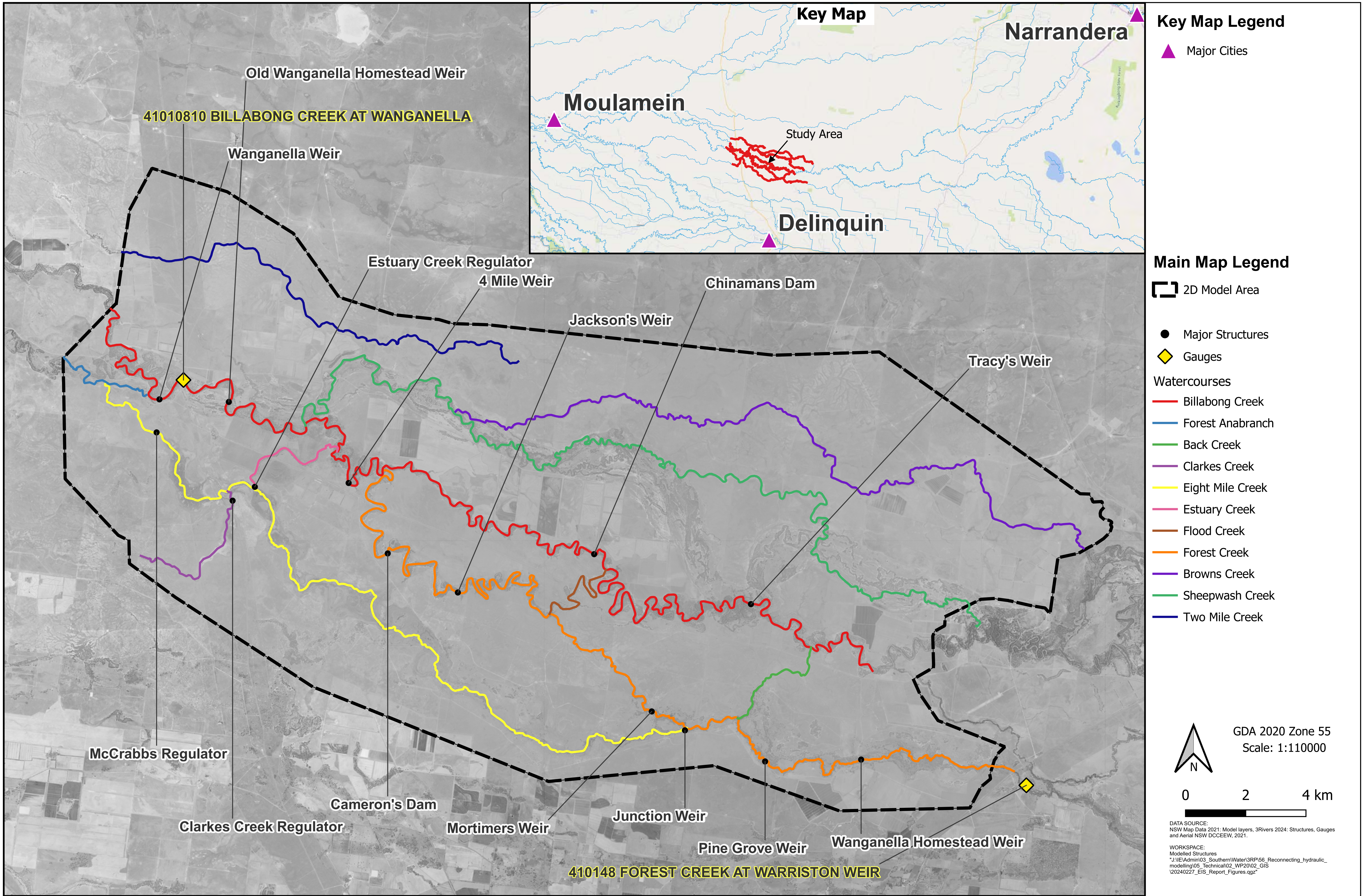
- Billabong Creek from downstream of Piccaniny Weir to an approximate distance of 5 kilometres downstream of Wanganella Weir.
- Forest Creek and Eight Mile Creek from the downstream vicinity of Warriston Weir to approximately 5 kilometres downstream of McCrabbs Regulator.

2.2 Study Objectives

The objectives of this study include and are not limited to:

- Inundation mapping of the study area for a number of flow scenarios and producing the datasets of hydraulic properties such as water level, depth, and velocity for the current ("existing") conditions.
- Providing information to assisting in the development of proposed designs for upgraded assets.
- Inundation mapping of the study area for a number of flow scenarios and producing the datasets of hydraulic properties such as water level, depth, and velocity for the "proposed" conditions with the proposed Yanco Modernisation Project works, both individually and cumulatively.
- Processing of results to understand impacts of the proposed works to inform the design of the works and the relevant REF or EIS process.

These objectives have been achieved through the development of a fit-for-purpose 2D TUFLOW HPC hydraulic model for Billabong Creek, Forest Creek and Eight Mile Creek developed according to current best practice and guidance and the Hydraulic Modelling Standard Specification V1.0 (DCCEEW, 2021).



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

Figure 1: WP20 Study Area Overview

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2.3 Report Structure

This report has been structured to summarise the relevant hydraulic modelling work undertaken to develop the model and final setup used for impact assessment and includes relevant information based on work carried out as part of this Study as well that undertaken as part of the WP20 RRC study. The report is structured with the following sections to highlight the development of the model for its current purpose:

- Data (see Section 3)
    - An overview of the review and identification of relevant information for the hydraulic model setup
- Existing Model Setup (see Section 4)
    - An outline of how the model was schematised and then ultimately setup to represent “existing” conditions.
- Model Sensitivity and Calibration (see Section 5)
    - A summary of the sensitivity and calibration activities undertaken on the “existing” model.
- Proposed Model Setup (see Section 6)
    - An overview of changes made to the model to represent “proposed” conditions, which include the final Yanco Creek Modernisation works. The section also summarises testing work to represent the proposed structures.
- Results (see Section 7)
    - A brief summary of results, highlighting the “existing” and “proposed” flood behaviour or characteristics and the associated change in flow, water surface level and/or velocity within the Study Area.
- Limitations, assumptions and uncertainty (see Section 7.2.2.2)
    - An outline of some of the key possible limitations, assumption and/or uncertainty around the modelling outcomes.

3. Data

3.1 Data Review

Sections 3.1.1 to 3.1.8 briefly summarise the existing datasets available in the study area that have been used to inform the development of the hydraulic model.

3.1.1 Elevation Data

The following LIDAR (Light Detection and Ranging) datasets were available within the study area:

- Conargo, Jerilderie, Wanganella DEM:
    - Provided by DCCEEW
    - 1 m resolution
    - Collected between 13/09/2021 and 24/09/2021 by NSW Spatial Services.
- Yanco_WFR_LIDAR_1m_2007:
    - Provided by DCCEEW
    - 1m resolution
    - Collected in 2007 by Water For Rivers (WFR)
- Wanganella LiDAR DEM:
    - ELVIS (https://elevation.fsdf.org.au/).
    - 2m resolution
    - Collected March 2017 by NSW Spatial Services.
- Conargo LiDAR DEM:
    - Available online on ELVIS (https://elevation.fsdf.org.au/).
    - 5m resolution.
    - Collected December 2011 by NSW Spatial Services.

3.1.2 Channel and Topographic Survey

There was some historical cross-section data of some of the key watercourses within the study area. These areas included:

- Survey of 3 cross sections along Billabong Creek collected by Michael McBurnie Irrigation Designs in September 2009 and provided by DCCEEW. This data was used directly or indirectly to inform the study.
- Topographic data in and around Wanganella Weir pool and survey of Wanganella Weir as detailed under Bathymetric survey item.
- Topographic survey of temporary benchmarks used in the Bathymetric survey of Billabong Creek (SKM, 2007). This data was used indirectly to inform the study.

- Topographic survey of McCrabb's Regulator, culverts under Cobb Highway, culverts under Zara Homestead Road and McCrabb's Bridge was collected on 15th May 2015 by Advance Survey Design Pty Ltd. This data was used directly or indirectly to inform the study.

- Topographic survey of Estuary Creek Regulator, McCrabb's Spillway and a number of structures (including culverts and bridges) at Wanganella Swamp was collected in April 2021 by Price Merrett Consulting. This data was used directly or indirectly to inform the study.

- Survey of 6 cross sections upstream and downstream of Wanganella Weir collected by Price Merrett Consulting on 10th February 2022.

- DCCEEW provided additional survey data of 47 river cross-section collected in April 2022 that have been requested by 3Rivers as part of the data review process.

3.1.3 Structures

There are a substantial number of operational structures in the system with the key structures listed below:

- Wanganella Weir
- Old Wanganella Homestead Weir
- 4 Mile Weir
- Chinamans Dam
- Tracys Weir
- Camerons Dam
- Camerons Dam Block Bank
- Jacksons Weir
- Mortimers Weir
- Pine Grove Weir
- Homestead Wanganella Weir
- McCrabbs Regulator
- Estuary Creek Regulator
- Clarkes Creek Regulator
- Piccaninny Weir

Other structures included in the model were:

- Bridge at upstream of Wanganella Weir
- Bridge at downstream of Homestead Wanganella Weir
- Bridge at downstream McCrabbs Regulator
- Bridge at downstream of Junction Weir
- 2 block banks within Forest Creek at downstream junction of Eight Mile Creek and Forest Creek

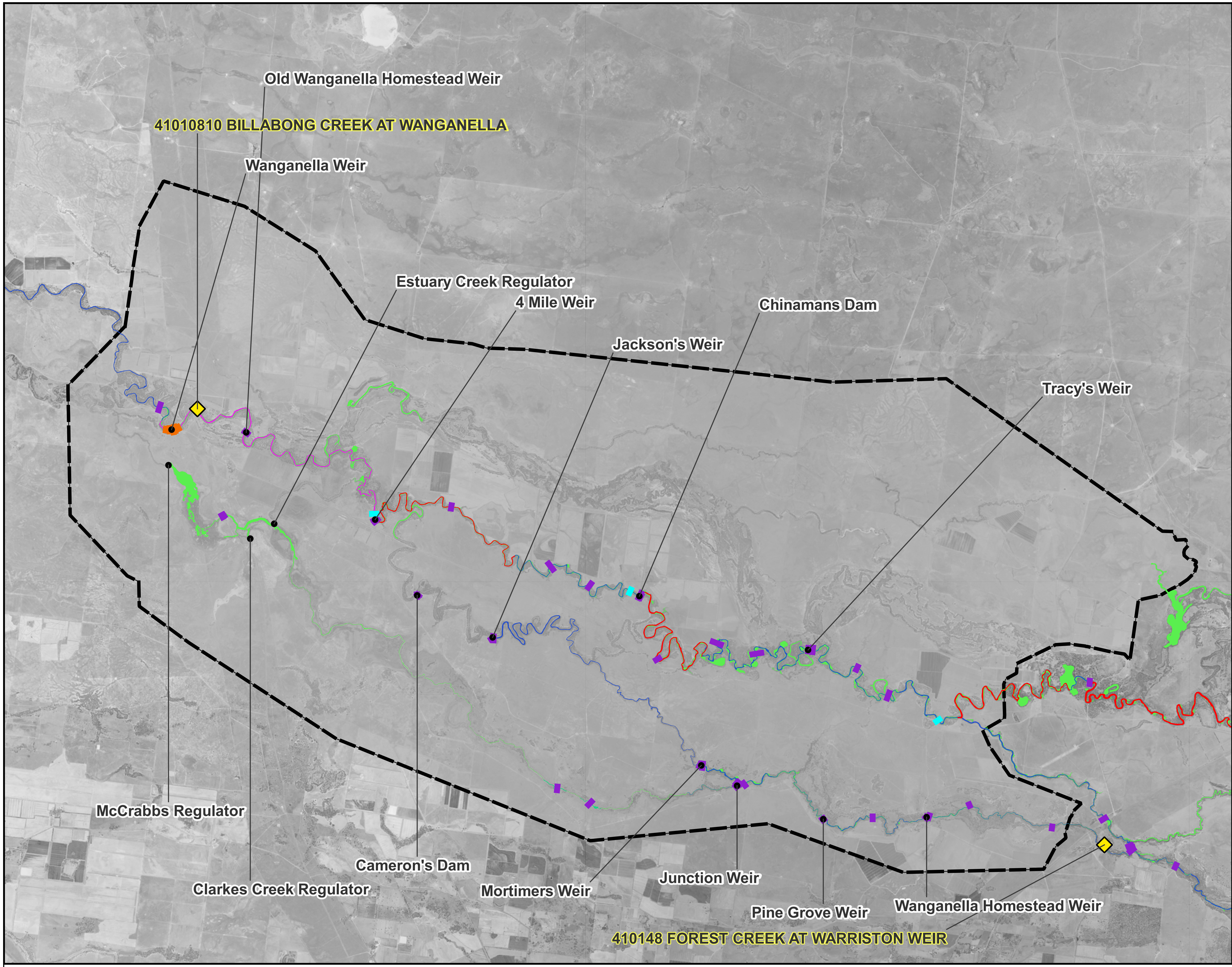
- 31 culverts within the Study Area are presented in Table 11.

3.1.4 Bathymetric Survey

There were several sets of bathymetric data that covered some of the major watercourses in the study area, the location of which is shown in Figure 2. This data includes:

- Billabong Creek Bathymetric Survey (SKM, 2007) – "Yanco_All" (SKM, 2007). This data source provided bathymetric details of the upstream pools of:
    - Chinamans Dam
    - 4 Mile Weir
- Billabong Creek near Wanganella Weir Bathymetric Survey (Hydrographic and Cadastre Survey, 2021) – "HCS381_Wang_1m_210628". This data source provided bathymetric survey of the area of Wanganella Weir.

The creation of additional bathymetric profiles along key waterways was informed by a range of historical and recently obtained cross-sections as discussed above, the location of which are shown on Figure 2.



Main Map Legend

- 2D Model Area
- Major Structures
- Gauges
- 2022 DP Survey Cross Sections
- 2022 Wanganella Cross Sections
- Historic Cross Sections

Available Bathymetry Data Sources

- 12d created bathymetry
- 2007 Lidar within 2021 Lidar area
- 2021 Bathymetry
- SKM Bathymetry

N

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_Southern\Water\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: WP20 Bathymetry Data Sources

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3.1.5 Gauge Data/Inflows

Key gauges in the study area include (Figure 1):

- 41010810 - Billabong Creek at Wanganella:
    - Zone 55; -35.2123 Latitude 144.8165 Longitude.
    - Data available from 16/11/1999 to present.
    - Suitable source of flow and water level for calibration within the WP20 Study Area.
- 410017 Billabong Creek at Conargo (Puckawidgee) was used in the Hartwood model only.
- 410148 Forest Creek at Warriston Weir was used in the Hartwood model only.

3.1.6 Existing Hydraulic Models

There are a few existing models that cover parts of the Study Area, which are detailed below.

Yanco Creek System Environmental Flows Study (May 2013)

This study aimed "to derive scientifically based recommendations to identify the benefits for the use of environmental water in the Yanco Creek system from the available sources in the regulated Murrumbidgee or NSW Murray River systems". The "Final Report describes the environmental values and threats in the Yanco Creek system, environmental objectives for flow dependent environmental values, reach by reach environmental flow requirements to meet the objectives, and an assessment of the performance and risk associated with the current water management regime". It describes the use of hydraulic modelling using HEC-RAS for some reaches in the Study Area and some terrain analysis for areas dominated by weir pools. Some cross-sections of channels within the current Study Area were collected by Michael McBurnie and as part of this Study and have been used for checking and/or preparing the current bathymetry.

Conargo Floodplain Risk Management Study and Plan (2010)

There is an existing flood study of Conargo within the study area developed as part of the Conargo Floodplain Risk Management Study and Plan (2010). The HEC-RAS model was developed for the purposes of assessing 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.

Yanco Creek System Water Recovery Scoping Study (2010)

This study aimed to produce a series of calibrated SOBEK models of various reaches of the Yanco Creek system, based on earlier scoping work. The work includes setting up a model, referred to as "Reach 5 - Yanco Bridge & Hartwood Gauge to Conargo", which is within the Hartwood model Study Area. This model data was not readily available and has therefore not been used to obtain and/or check structure details and/or channel bathymetry.

Billabong Creek Floodplain Management Plan (2002)

This study aimed to achieve the following for the broader Billabong Creek system [with a focus upstream of Jerilderie]:

- "review works undertaken to date within the study area;
- identify areas of environmental significance that may be reliant of flood flows;
- develop an understanding of flood behaviour; and
- establish a computer model capable of assessing various floodplain management options."

This study set up a MIKE-11 model for Billabong Creek upstream of Jerilderie, which is upstream of Hartwood Study Area. This model data was provided but did not provide useful data to check or infer details of bathymetry in parts of the current study. The Flood Frequency Analysis (FFA) was however indirectly used to inform parts of this Study.

3.1.7 Landuse Layers

Landuse layers have been provided to inform hydraulic roughness within the 2D floodplain extent. These are:

- Water dependent vegetation and wetland areas. Provided by DCCEEW.
- 'NSW Landuse 2017 V1.2' has been provided by DCCEEW and reflects land use characteristics within the WP20 Study Area such as food production, nature conservation and urban development.
- Drone imagery collected and provided by DCCEEW, covering Wanganella Swamp (15/02/2021), Wanganella Weir (09/10/2021), Chinamans Dam and Traceys Weir (11/03/2022).

3.1.8 Aerial Imagery Capture

There are a number of aerial imagery products available including:

- Murrumbidgee Site B36a aerial imagery provided by DCCEEW and captured on 23/12/2021 by Photomapping Services during a flow event, partially covering the Study Area. This was not used during the calibration process.
- Aerial imagery from NSW Spatial Information eXchange (SIX) Maps.
- High-resolution aerial imagery was captured in September 2021 in conjunction with Jerilderie to Wanganella LiDAR data collection, provided by DCCEEW. The imagery has been reviewed and used as part of the model calibration process for the September 2021 calibration event.
- Drone imagery collected and provided by DCCEEW, as detailed under Land Use Layer Item.
- Suitable inundation imagery for the model calibration and validation process have been reviewed by extracting Landsat and Sentinel imagery via the Sentinel Playground (refer to Section 3.3).

3.2 Data Collection Programme

Table 1 provides details of data collected as part of the hydraulic modelling commission.

Table 1: Data collected as part of Study

Item	Comments
Elevation data	LiDAR data was captured from Jerilderie to Wanganella in October 2021 and has been used in this study.
Channel survey	Additional channel surveys within the WP20 model boundary as requested by 3Rivers has been provided by DCCEEW as part of this study. This survey was collected in February and April 2022 (Phase 2 and Phase 3 surveys respectively). The survey extent was as detailed below: • Forest Creek: F30.61 downstream to F74.16. • Billabong Creek: B193.04 downstream to B244.88. • Eight Mile Creek: E0.17 to E23.98. • Clarkes Creek: upstream of Clarkes Creek Regulator. • Piccaninny West Creek: downstream of Instream Dam. Survey of 6 cross sections upstream and downstream of Wanganella Weir collected by Price Merrett Consulting for 3 Rivers on 10/02/2022 (file number S1099).
Topographic survey	No additional topographic survey has been undertaken as part of this study.

Bathymetric survey	Apart from additional channel survey in the form of cross-sections described above, no additional bathymetric survey was obtained.
Hydraulic structures	Available information on Hydraulic Structures was reviewed as part of the model build. As listed below: • Wanganella Weir Survey collected by Price Merrett Consulting Pty Ltd on 10/02/2022 (file number S1099). • Cross section survey collected by DCCEEW in February 2022 (Phase 2 survey) • Cross section survey collected by DCCEEW in April 2022 (Phase 3 survey). Any gaps in required data were identified and included as part of the survey request, although not all sites could be visited due to the size of the area and adverse weather conditions. Some structural information was also collected during a site visit that was conducted in March 2022. Remaining gaps were filled with engineering judgement.

3.3 Inundation Imagery

To assist in the calibration/validation process the inundation imagery summarised in Table 2 was sourced for the project. The average daily flow rate at Billabong Creek at Conargo (Gauge 410017) and Billabong Creek at Wanganella (41010810) has been used to represent the corresponding flow rate at the time of the given inundation image. The timing of the imagery below against the flow rate at the nominated gauges is also presented graphically in Figure 3 and Figure 4.

Table 2: Summary of Satellite Imagery Suitable for Model Calibration (Calibration events highted in blue)

Imagery date	Source	Reference gauge	Approx. flow (ML/day)	Trend	Suitability
24/08/2017	Sentinel	41010810	288	Rising	Potential for low range calibration. No cloud cover.
30/08/2020	Sentinel	410017	275	Falling	Potential for low range calibration. No cloud cover.
18/08/2021	Sentinel	41010810	2261	Peak	Potential for high -range calibration. No cloud cover.
23/09/2021	Aerial Imagery in conjunction with LiDAR	41010810	1792	Rising	Potential for high -range calibration. No cloud cover.
22/10/2021	Sentinel	41010810	1927	Peak	Potential for validation. No cloud cover.

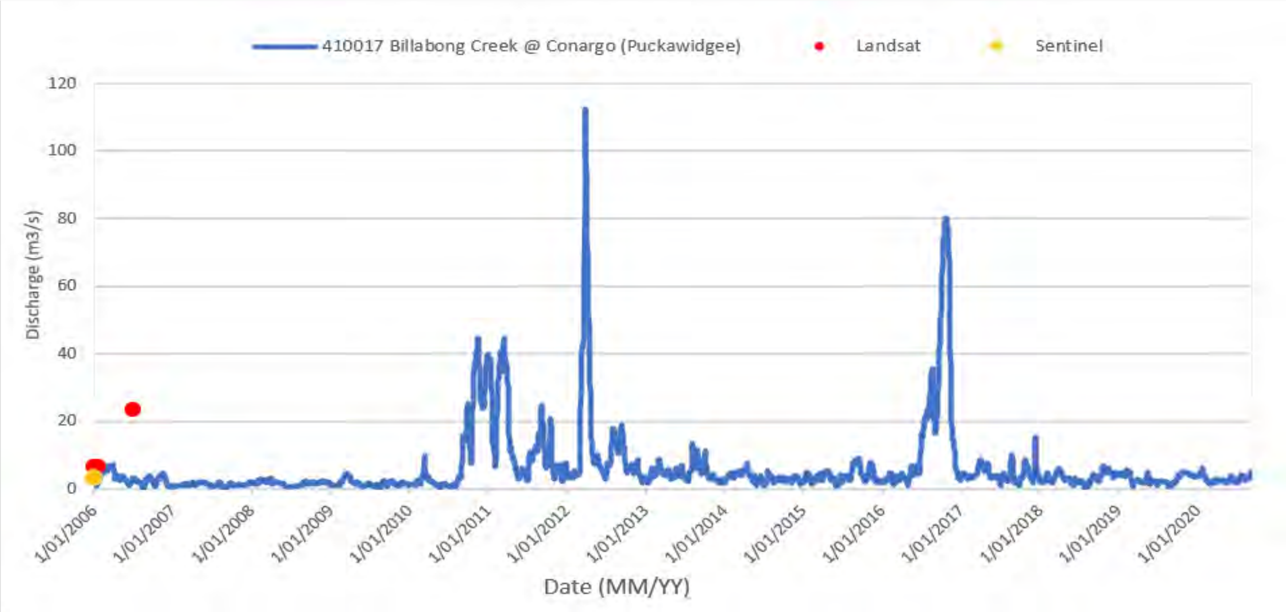


Figure 3: Inundation imagery in the study area against flow hydrograph at Billabong Creek @ Conargo (410017)

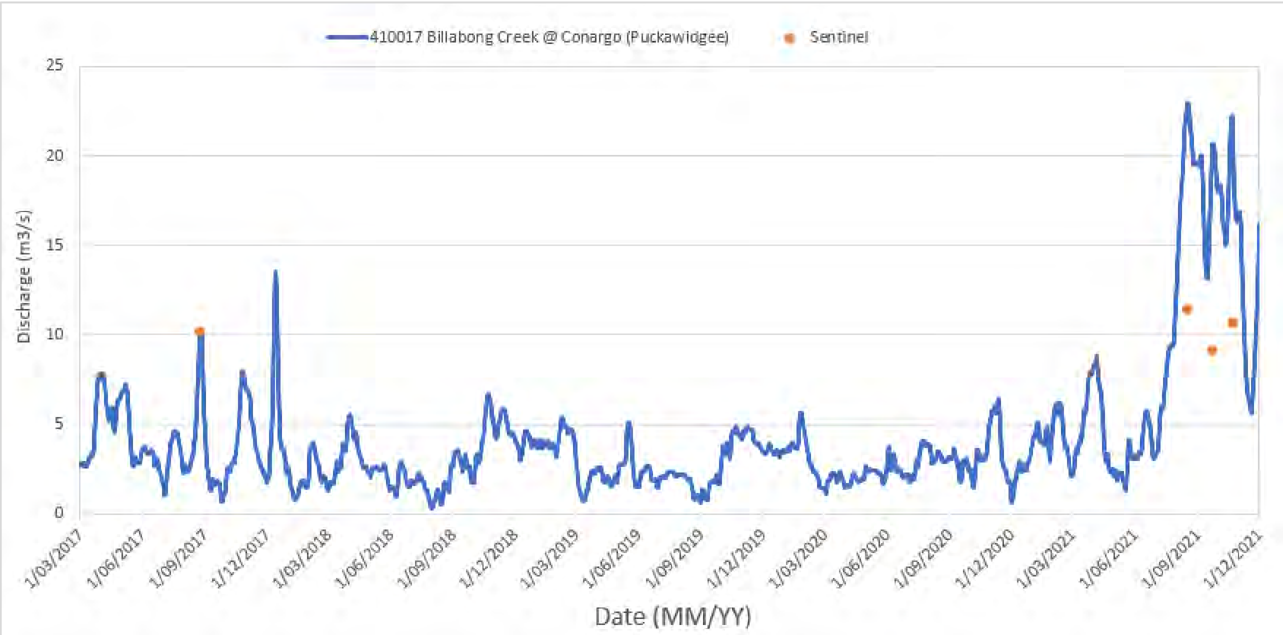


Figure 4: Inundation imagery in the study area against flow hydrograph at Billabong Creek @ Wanganella (41010810)

4. Existing Modelling Approach and Setup

4.1 General Schematisation

4.1.1 Modelling Approach

Both the floodplain and channels will predominately be 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.

1-Dimensional (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 key watercourses in the Study Area have the following characteristics:

- Billabong Creek is typically 40-50m wide although the width varies from around 20m to more than 70m in places with a typical cross-section show in Figure 5.
- Forest Creek is smaller than Billabong Creek with a typical width of between 30-40m. A typical cross section is shown in Figure 6.
- Eight Mile Creek is an ephemeral watercourse with a typical width of around 15-25m and branches off Forest Creek at approximately 150 m upstream of Junction Weir. A typical cross section is shown in Figure 7.

4.1.2 Software and Reason for Choice

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 is was considered that 2D solution would better represent that 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 TUFOW 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 waters 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 the 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 section, historical creek cross-sections and local survey of structures.

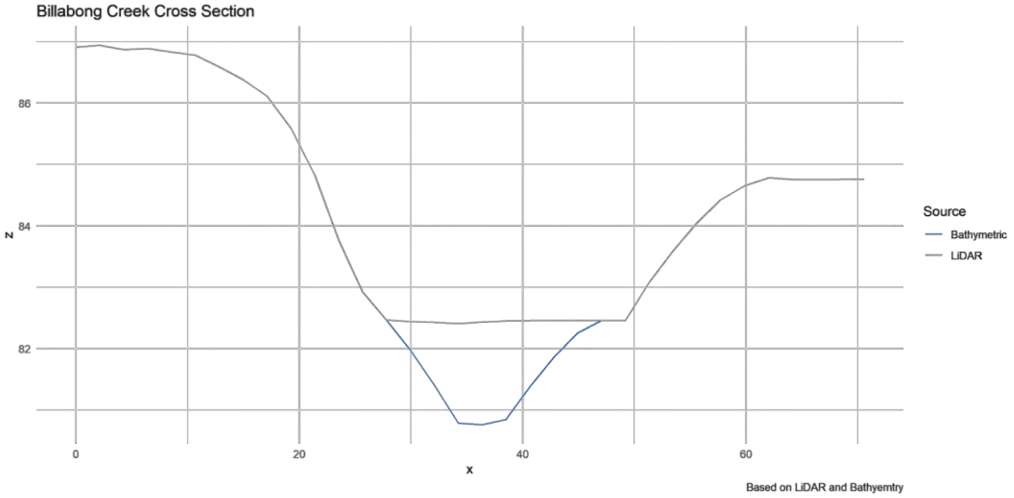


Figure 5: Typical Billabong Creek Cross Section

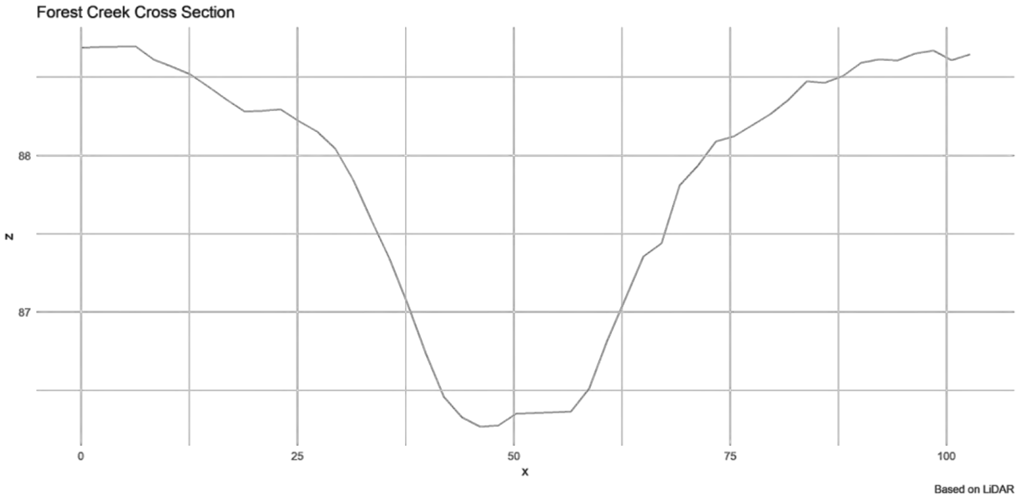


Figure 6: Typical Forest Creek Cross Section

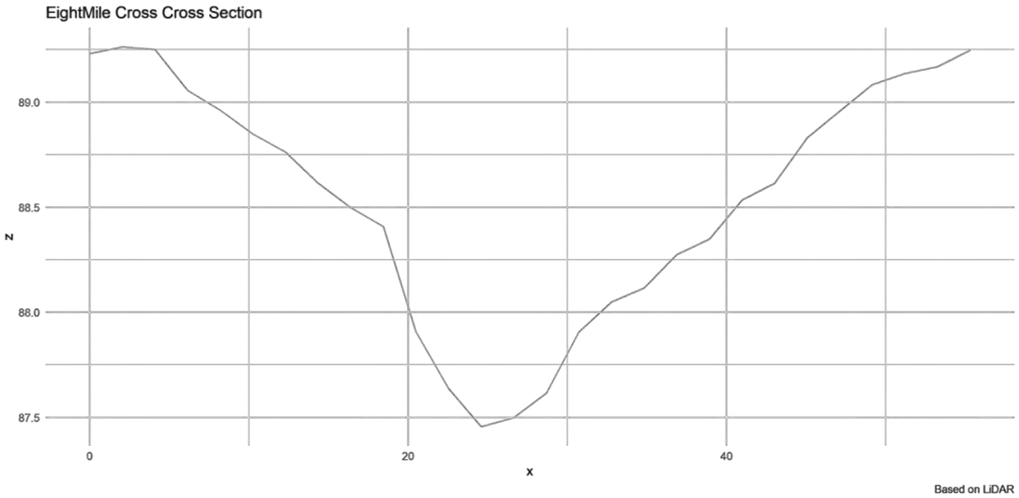


Figure 7: Typical Eight Mile Creek Cross Section

4.2 Model Topography

4.2.1 Digital Elevation Model (DEM)

Due to the 2D nature of the model, considerable effort has been put into creating a Digital Elevation Model (DEM) for this study, especially along the channel beds of the main creeks.

The final DEM is presented in as Figure 8 and was assembled from the following data sources (the spatial distribution of which is presented in Figure 2.

- 1m LiDAR captured in September 2021 by NSW Spatial Services.
- 2m LiDAR captured in 2017 by NSW Spatial Services (small section on Eight Mile Creek between chainages E5.38 to E6.2).
- 1m LiDAR captured in 2007 by Water For Rivers (WFR).
- Bathymetry data from the combination of sources described in Section 4.2.2 below.

The 1m LiDAR flown in September 2021 covered most of the Study Area apart from a small section at the downstream end of the model (this section covers 5.8km downstream of Clarkes Creek Regulator).

When the LiDAR was flown in September 2021, the water level in the creeks were high and the water level, rather than bed level, was captured. This was considered unsuitable for representing the channel topography.

A new DEM called "Combined DEM" was created in ArcGIS Pro which amalgamated a number of datasets following the data preference sequence below when creating the channel topography:

- Adopt the 2021 LiDAR for all out of bank areas.
- Adopt all bathymetric data where available.
- Adopt the 2007 DEM where:
    - The 2021 LiDAR was not suitable due to high water levels within the Eight Mile Creek (including Wanganella Swamp) starting at chainage E2.02.
    - Channels appear to be dry in this LiDAR dataset.
    - The 2021 LiDAR was missing.
- Adopt a digitally created channel bed where there was neither bathymetric data, nor suitable 2007 LiDAR. The channel was created for the main creeks (Billabong Creek and Forest Creek) using surveyed cross sections in the 12d software.
- Adopt the 2017 LiDAR for Eight Mile Creek between chainages E5.38 to E6.2 and E6.65 to E7.55, where the 2007 LiDAR was not available.

Additionally, a number of modifications have been incorporated into the model using z-shape features.

The 2021 dataset was also used during the model calibration process of the September 2021 flood event.

A summary of validation of the DEM against known data sources is provided in Appendix A. This comparison shows that the DEM reliably represents known elevation points and is suitable as the basis for hydraulic modelling.

4.2.2 Model Bathymetry

Bathymetric survey of Billabong Creek was collected by Hydrographic and Cadastral Survey Pty Ltd and SKM in 2021 and 2007 respectively (refer to previous Section 3.1).

The bathymetric survey came in the form of point elevations dotted along the channel. The points were processed into cross-sections by assuming a channel width (based on water surface level from the LiDAR and aerial imagery). The bed level was then extrapolated back up to the bank lines captured by either the 2007 LiDAR, or 2021 LiDAR, whichever captured a lower water level (and hence captured more bank). (Refer to Figure 2)

4.2.3 Domain Orientation

The 2D model domain was orientated to be in line with the westerly flow direction of the Billabong Creek and parallel to Wanganella Weir (main structure within this model). Refer to Figure 1 for the model domain. It is noted that SGS reduces the effect of grid orientation on results.

4.2.4 Domain Dimensions and Grid Cell Size

The model domain has dimensions of 31.3km by 21.9km. A grid cell size of 16m was selected for the following reasons:

- Since 2020, TUFLOW allows the application of Sub-Grid Sampling. Sub-Grid Sampling (SGS) stores and uses curves representing the sub-2D-cell terrain data of the Digital Elevation Model, TINs and Z shapes, instead of each 2D cell and each 2D face having one elevation. Benchmarking has shown the benefits to be substantial for certain types of applications, for example:
    - Catchment scale models flow much more effectively with water not being “trapped” by a coarse cell resolution, and, importantly, improved cell size convergence (i.e. demonstration that by reducing the cell size(s) the model results do not demonstrably change) at much coarser cell sizes.
    - Disturbed flow fields that can be apparent along “saw-tooth” regular mesh wet-dry boundaries can be significantly reduced, with no spurious additional head losses generated, and the results consistent with a well-designed flexible mesh result. This has major benefits in that open channels can now be accurately modelled using TUFLOW HPC using coarse cell sizes at any orientation to the channel, removing the need to utilise 1D open channels carved through the 2D domain.

A SGS sampling frequency of 17 has been applied to all 16m grid cells which is equivalent to a sampling distance of 1m.

The adoption of a 16 m grid cell size with SGS was considered a reasonable compromise between model run time and the impact on model results.

4.2.5 Terrain Modifications

To improve the representation of the Study Area a number of terrain modifications have been incorporated into the models. The modifications include the following and the location of these model changes are highlighted in Figure 8**.**

- Ridge lines defining the crest or flow control elevation of linear floodplain features, such as road embankments and levees (represented as thin z-shape features that raise the cell side only).
- Shaping to block off the 2D domain where weirs are represented as 1D elements (represented by nulling the 2D cells representing the weir).
- Removing bridge overpasses and weir crests that have been picked up in the LiDAR data.

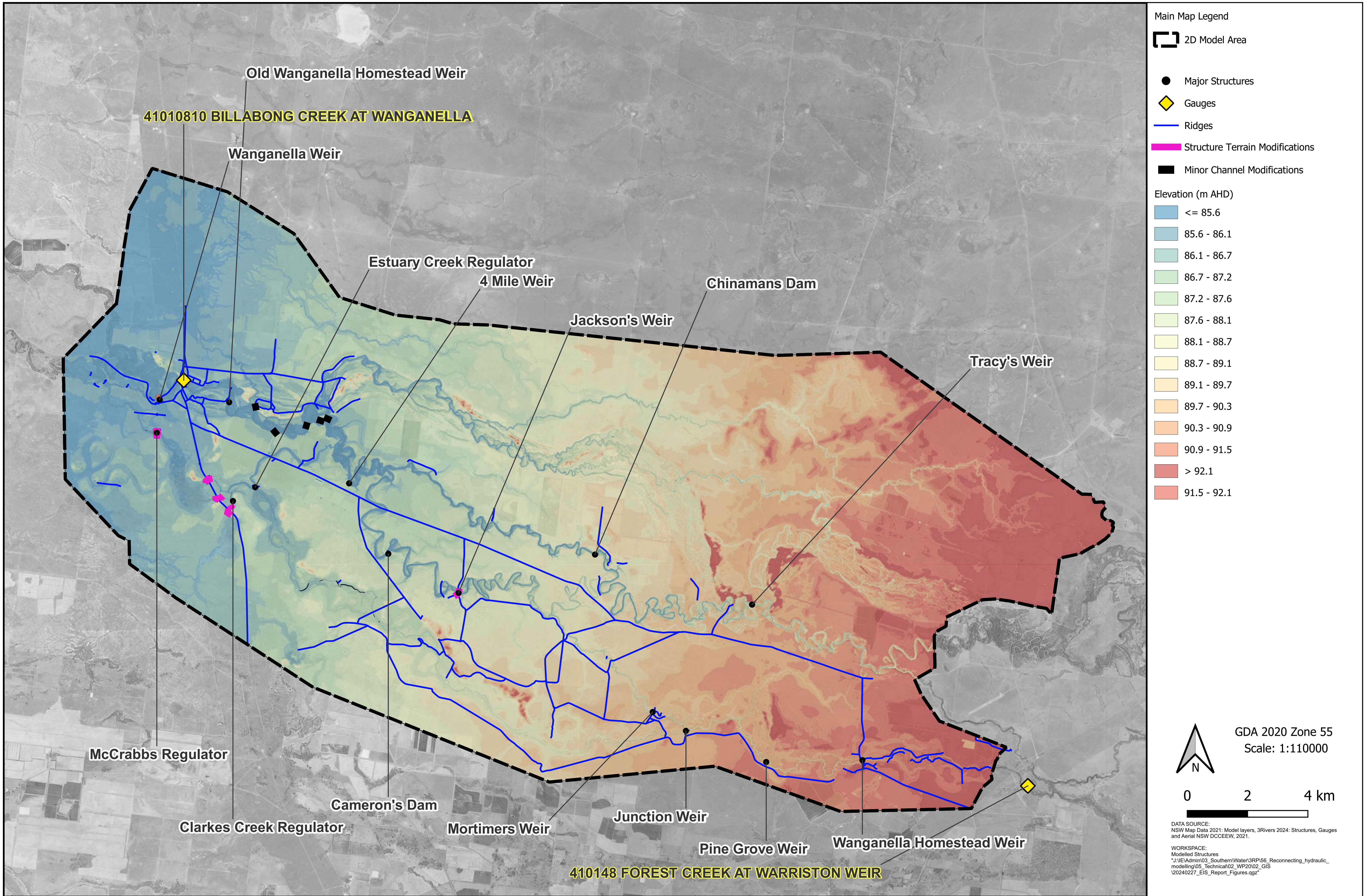
- A coarse representation of minor floodplain structures with limited data (modelled as one cell gaps in the obstruction with inverts based on upstream and downstream terrain and a cell width reduction factor limiting the width of the cell to 3 m).

- Minor smoothing at interface between some sources of bathymetry (modelled as a shaping region to connect invert from one data source to that from another).

- Lowering of terrain at structures based on surveyed invert levels of structures differing to terrain (these were represented as regions and/or with a ‘Z’ flag in the “SX” connection to allow “SX” connections to operate).

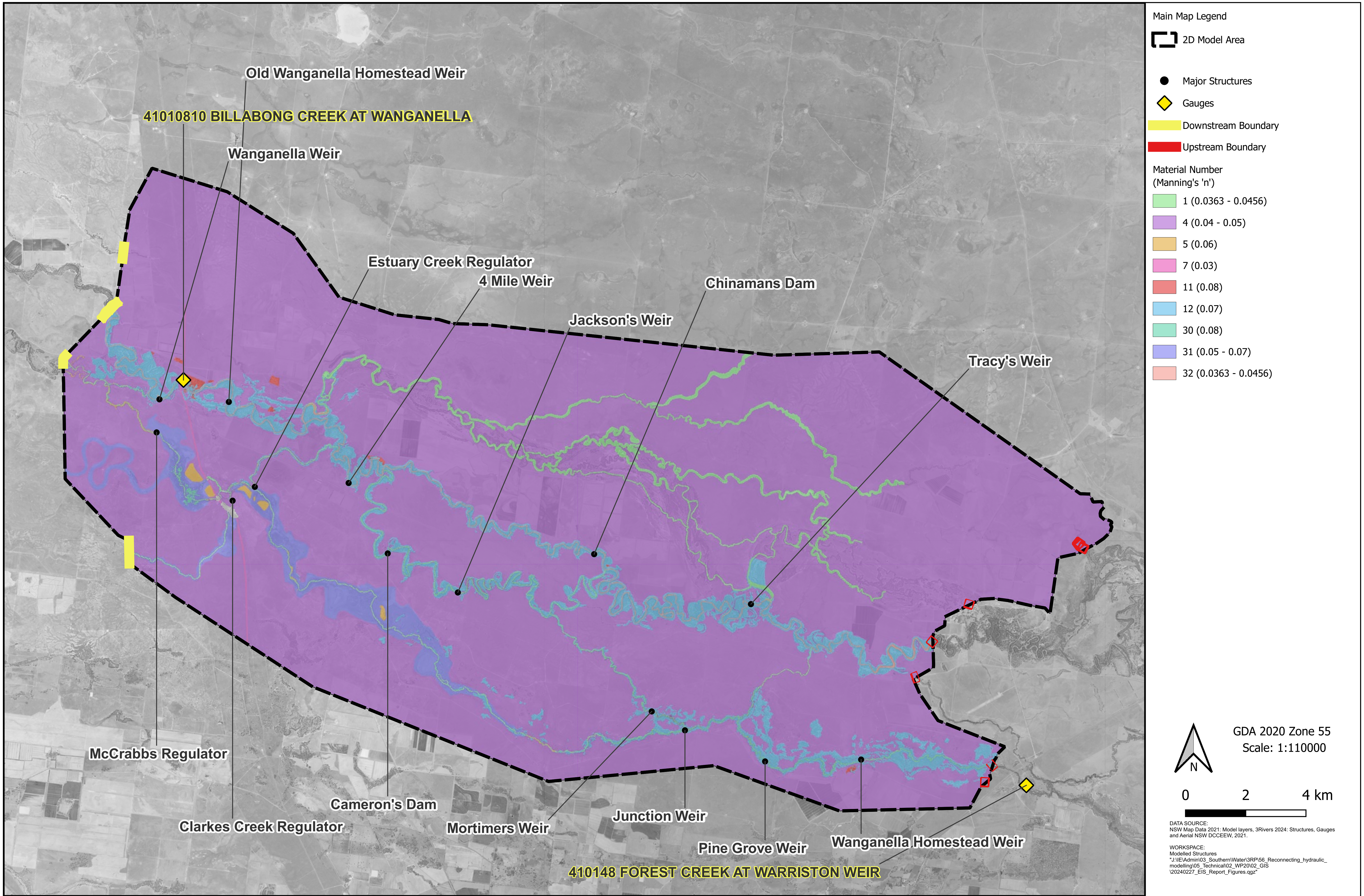
4.3 Boundary Conditions

The model has two sets of boundary conditions, one representing inflows to the model at the upstream end and one representing tailwater conditions to remove water from the model at the downstream end. The locations of the adopted upstream and downstream boundary conditions are shown in Figure 9 and the nature of these boundaries is summarised in Table 3 and Table 4 respectively. No internal flow boundaries were included in the model as inflows into the system through Piccaninny Weir to Wanganella Weir along in the Yanco Creek system. Wanganella inflow hydrographs input adopted upstream Hartwood hydraulic results which results has demonstrated that the Yano Creek system in the vicinity of Wanganella is a losing system. that is, water is lost to infiltration rather than gained from local inflow. For the unregulated Billabong Creek, downstream of Jerilderie, analysis of high flows during the 2022 event demonstrated that watercourse was gaining based on upstream Hartwood model results.



Yanco Creek Modernisation: Hydraulic Modelling - Piccaninny Weir to Wanganella Weir Work Package 20 Study Area
Figure 8: WP20 Adopted DEM

3Rivers



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

Figure 9: WP20 Material Roughness

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Table 3: Summary of upstream inflow boundary conditions (Current model)

Inflow Boundaries	Description
Billabong Creek (BC/ BROWNSC/ BROWNSC_FP/ PC/SWC)	This is a fluvial inflow representing inflows from Billabong Creek at the upstream extent of the model approximately 7 km downstream of Billabong Creek at Conargo (Puckawidgee) Gauge Station 410017 (Zone 55: 337154E, 6093783N). The study area has been adopted the inflow data from the output hydrographs of the Hartwood model (WP19), represented as flow versus time relationship ("QT" boundary) applied to the model via "SA" polygons covering upstream section of Billabong Creek and surrounding floodplain.
Forest Creek (FC/FCFP)	This is a fluvial inflow representing inflows from Forest Creek at the upstream extent of the model approximately 1.5 km downstream of Forest Creek at Warriston Weir Gauge Station 410148 (Zone 55: 329202E, 6087786N). The study area has been adopted the inflow data from the output hydrographs of the Hartwood model (WP19), represented as flow versus time relationship ("QT" boundary) applied to the model via "SA" polygons covering upstream section of Forest Creek and surrounding floodplain.

Table 4: Summary of downstream tailwater boundary conditions (Current model)

Outflow Boundaries (location)	Description
Billabong Creek (Zone 55: 298809E, 6103587N)	This is a downstream boundary representing outflows from Billabong Creek via the main channel at the downstream extent of the model approximately 7.0 km downstream of Wanganella Weir. Due to the lack of grade leading to the boundary, instabilities were observed when using a 2D boundary, particularly during high flow events. Modelling refinements were unable to resolve the instabilities. This is a robust approach often used in situations where model boundaries are either very shallow or very steep. As such, a 1D weir boundary with a rating curve from the downstream Caroonboon model (which connects to the Wanganella model) was adopted. This resolved the boundary instabilities. Analysis of results shows that stabilising the boundary did not affect levels at Wanganella Weir.
Forest Creek Anabranch (Zone 55: 297224E, 6101804N)	A downstream boundary representing outflow from Forest Anabranch at the eastern via the main waterway at the downstream extent of the model approximately 1.3 km downstream of the existing Block Bank structure. This was represented as head versus discharge (“HQ” boundary) snapped to the model boundary with a slope (or “b” attribute) of 0.0002.
Two Mile Creek (Zone 55: 299222E, 6105468N).	A downstream boundary representing outflow from upstream Willurah Road catchment the overland flow to the downstream Two Mile Creek that is located approximately 1.9km in south-west of intersection of Wanganella-Moulamein Road to Cobb Highway. This was represented as head versus discharge (“HQ” boundary) snapped to the model boundary with a slope (or “b” attribute) of 0.0002.
Clarkes Creek (Zone 55: 330452E, 6096451N)	A downstream boundary representing outflow from upper north Clarkes Creek via the main waterway at approximately 5.8km downstream extent of the model. This was represented as head versus discharge (“HQ” boundary) snapped to the model boundary with a slope (or “b” attribute) of 0.0005.

4.4 Model Roughness

Model roughness for both the 1D and 2D models was defined using Manning's (n) coefficients based on a combination of readily available spatial data (including land use, wetlands, and water dependent vegetation spatial datasets) and aerial imagery or photos collected via site visit, surveyors and/or as part of broader LiDAR capture. The adopted values are presented in Table 5 and Table 6 for the 2D and 1D domains of the Study respectively. These values have been tested and refined throughout the model build and proving activities, some of which is discussed in the “Sensitivity” section of this report. The adopted distribution of the roughness is also presented spatially in Figure 9.

Table 5: 2D Roughness Categories

Feature Code/ Material No.	Description	Example Photo	Manning’s *n* coefficient
1	River – generally clear waterway		0.035
4	Floodplain/open pervious area		0.04
5	Thick Vegetation		0.09
7	Road		0.03
11	Urban Residential		0.08
12	Medium vegetation (trees)		0.07
30	Cumbungi		0.08
31	Wetland		0.05
32	Billabong Creek (Varies depth= D)		D<=1m, n =0.035 D>=2.4m, n= 0.046

Table 6: 1D Roughness Categories

Description	Manning’s *n* coefficient
Concrete pipes and culverts	0.015
Pipe size <=dia.0.45m	0.012

4.5 Hydraulic Structures

The section outlines the hydraulic structures included within the model domain, which have been separated into the following categories within each waterway:

- Key Structures – which includes a summary of the purpose and modelling approach used to represent these more significant structures modelled in either the 1D or 2D domain along that watercourse.

- Other Structures – a section that tabulates the remain structures modelled in 1D or 2D domain along that watercourse with actual or assumed details.

The modelled structures are shown in Figure 10, which also includes some “nominal floodplain structures” that were added to the model to allow for continuity of flow paths in certain areas based on initial and/or calibration/validation modelling.

4.5.1 Key Structures

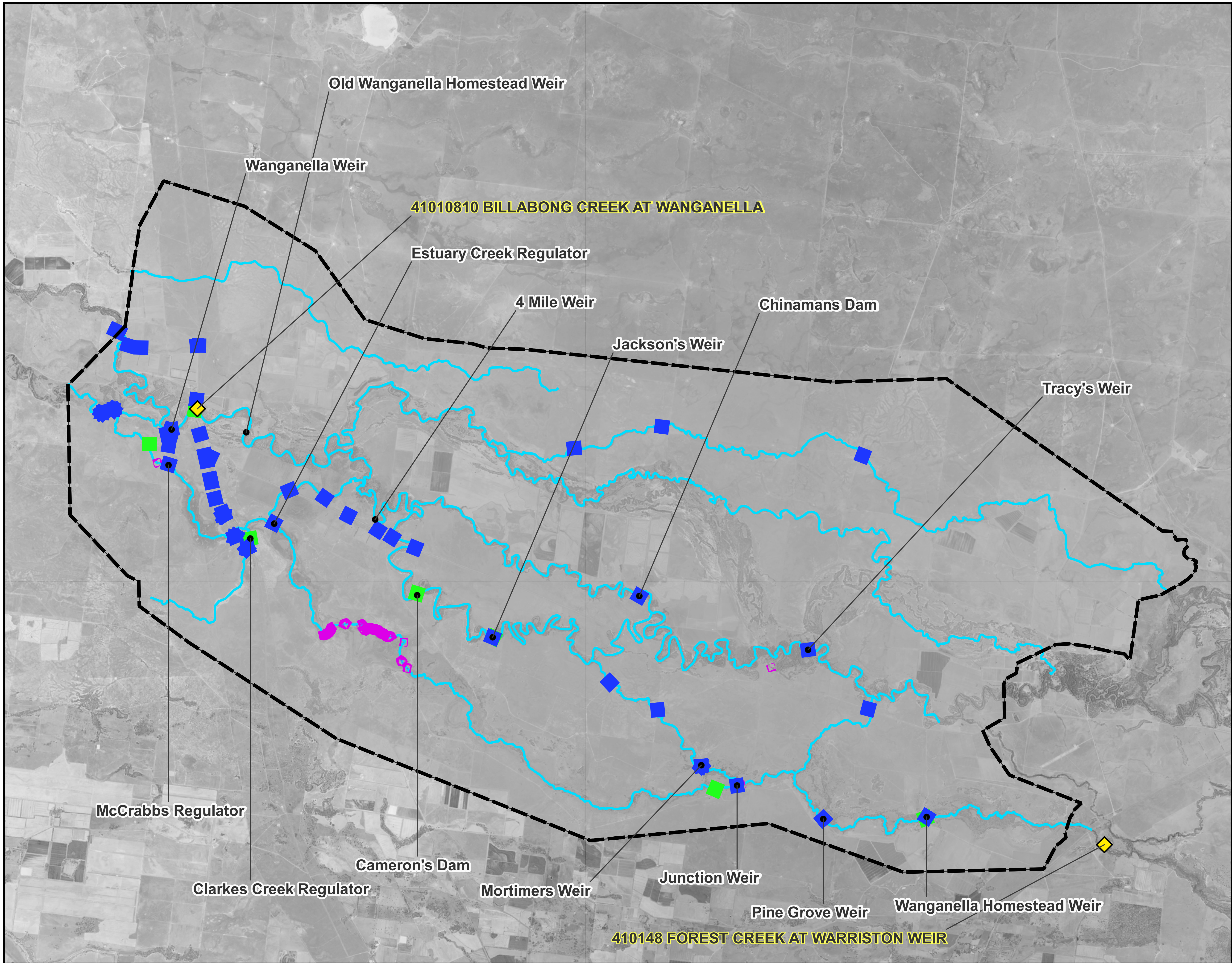
Within the Study Area, there are series of key structures along four (4) waterways within the study area:

- Billabong Creek.
- Forest Creek.
- Eight Mile Creek.
- Clarkes Creek.

A description and the adopted details of these structures for the modelling are explored in the proceeding section.

4.5.1.1 Billabong Creek

A series of existing flood mitigation and water quantity control measures along Billabong Creek within Study area has been checked against the available survey detailed in section 3. The information of operational conditions and some structural measurements unknown, the adopted modelling assumptions for existing operation structures within Billabong Creek are summarised in Table 7.



Main Map Legend

2D Model Area

Major Structures

Gauges

Key Watercourses

Other Modelled Structures (1D Domain)

Modelled Bridges (2d_lfcsh)

Nominal Floodplain (2d_zsh)

GDA 2020 Zone 55
Scale: 1:110000

N

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_Southern\Water\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 10: WP20 Modelled Structures

3Rivers

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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 "Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Piccaninny Weir to Wanganella Weir Study Area" 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.

Table 7: Modelling assumptions for operational structures along Billabong Creek

Structure Name	**Wanganella Weir**
Location	MGA2020 Zone 55: 300420E, 6100594N
Included in model	Yes
Model label	B253.5_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir
Function	Creates weir pool in Billabong Creek
Information Source	Survey collected in April 2021 by Hydrographic and Cadastral Survey Pty Ltd provided by DCCEEW. Survey collected on 19/10/2021 by Price Merrett Consulting provided by DCCEEW. Site visit photos taken in March 2022 by 3Rivers and in March 2021 by DCCEEW.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section. The 2D flow has been blocked with a 2d_code inactive feature. Width of 31m, sill level at 80.75 m AHD, crest level at 81.30 m AHD to 81.51 m AHD, abutment levels at 81.51 m AHD to 82.09 m AHD. Overtopping represented in the 1D cross section.
Head loss over structure for largest flow scenario modelled	0.042 m
Photo of upstream face 	Photo of downstream face 

Structure Name	**Bridge Upstream of Wanganella Weir**
Location	MGA2020 Zone 55: 301144E, 6101228N
Included in model	Yes
Model label	B242.5_B
Type of structure	Bridge
Information Source	2021 LiDAR
How has the structure been modelled	Modelled as 2D layered flow construction: Layer 1 (ground to bridge obvert): invert level between 78.91 m AHD and 80.07 m AHD, lowest obvert at 86.46 m AHD, FLC of 0.1 and 5% blockage to represent piers. Layer 2 (bridge deck): 100% blocked, 1 m deep and FLC of 1.6. Layer 3: not represented.
Head loss through structure for largest flow scenario modelled	0.005 m
No site photos available.	

Structure Name	**Old Wanganella Homestead Weir**
Location	MGA2020 Zone 55: 302724E, 6100508N
Included in model	Yes
Model label	B239.7_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir
Function	Not applicable as weir abutments have failed
Information Source	Site visit photos taken in March 2022 by 3Rivers. 2021 bathymetric survey. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW.
How has the structure been modelled	Modelled as 2d_zsh with: A 2d_cwf (Cell Width Factor) to adjust the 2D cell flow width which allows to more accurately represent the weir length given the cell size used in the model. Width of 11 m (assumed from aerial imagery), sill level at 80.20 m AHD (from April 2022 survey). Weir abutments were not represented as they were observed to be destroyed on site. Overtopping represented in the 2D.
Head loss over structure for largest flow scenario modelled	0.005 m
Photo of upstream face 	Photo of downstream face 

Structure Name	**4 Mile Weir**
Location	MGA2020 Zone 55: 306702E, 6097817N
Included in model	Yes
Model label	B230.1_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir
Function	Creates weir pool in Billabong Creek
Information Source	Yanco Creek System Bathymetric Survey (SKM, 2007) provided by DCCEEW. Site visit photos taken in March 2022 by 3Rivers and in March 2021 by DCCEEW. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section with an allowance for the defunct right hand bank wingwall. The 2D flow has been blocked with a 2d_code inactive feature. Width of 35 m, sill level at 82.45 m AHD, crest level at 83.88 m AHD. Overtopping represented in the 1D cross section.
Photo of upstream face 	Photo of downstream face 

Structure Name	**Chinamans Dam**
Location	MGA2020 Zone 55: 314854E, 6095456N
Included in model	Yes
Model label	B214.1_W
Type of structure	Fixed Crest Weir
Function	Creates weir pool in Billabong Creek
Information Source	Yanco Creek System Bathymetric Survey (SKM, 2007) provided by DCCEEW. Report by NSW Department of Primary Industries (2006). Reducing the Impact of Weirs on Aquatic Habitat - New South Wales Detailed Weir Review. Murray CMA region. Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW. Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section. The 2D flow has been blocked with a 2d_code inactive feature. Width of 27m, sill level at 85.79 m AHD to 85.85 m AHD, abutment levels at 86.37 m AHD and 86.48 m AHD. Overtopping represented in the 1D cross section.
Photo of upstream face 	Photo of downstream face 

Structure Name	**Tracys Weir**
Location	MGA2020 Zone 55: 314854E, 6095456N
Included in model	Yes
Model label	B198.2_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir
Function	Creates weir pool in Billabong Creek
Information Source	Yanco Creek System Bathymetric Survey (SKM, 2007) provided by DCCEEW. Report by NSW Department of Primary Industries (2006). Reducing the Impact of Weirs on Aquatic Habitat - New South Wales Detailed Weir Review. Murray CMA region. Report to the New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW. Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section. 0.6 m high dropboards have been assumed to be in place to achieve a match with the September 2021 calibration event. The 2D flow has been blocked through a 2d_code feature. Width of 29m, sill level at 87.50 m AHD and 0.6 m dropboards, crest level at 88.19 m AHD and 88.22 m AHD, abutment levels at 90.01 m AHD to 90.03 m AHD. Overtopping represented in the 1D cross section.
Head loss over structure for largest flow scenario modelled	0.170 m
Photo of upstream face 	Photo of downstream face 

4.5.1.2 Forest Creek

A series of existing flood mitigation and water quantity control measures located along Forest Creek within Study area has been checked against the available survey detailed in section 3. The information of operational conditions and some structural measurements unknown, the adopted modelling assumptions for existing operation structures within Forest Creek are summarised in Table 8.

Table 8: Modelling assumptions for operational structures along Forest Creek

Structure Name	**Camerons Dam**
Location	MGA2020 Zone 55: 307999E, 6095480N
Included in model	Yes
Model label	F69.8_W
Type of structure	Adjustable crest (dropboards)
Function	Unregulated blockage of Forest Creek.
Information Source	Site visit photos taken in March 2022 by 3Rivers. 2021 LiDAR and aerial imagery.
How has the structure been modelled	Modelled as 2d_lfcsh (Layered Flow Constriction Layer) with 50% blockage to represent the dropboards. The following levels were assumed: Layer 1 (ground to top of dropboard): invert level at 85.75 m AHD to 85.96 m AHD. Obvert (representing top of dropboards) at 87.05 m AHD to 87.16 m AHD. Layer 2: not represented. Layer 3: not represented.
Head loss over structure for largest flow scenario modelled	Not inundated
Photo of upstream face 	

Structure Name	**Camerons Dam Block Bank**
Location	MGA2020 Zone 55: 307999E, 6095480N
Included in model	Yes
Model label	Part of “WP20_Banks”
Type of structure	Block bank
Function	Blocks flow along Forest Creek
Information Source	Site visit photos taken in March 2022 by 3Rivers. 2021 LiDAR and aerial imagery. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW.
How has the structure been modelled	Modelled as a 2d_zsh representing the block bank with levels from 86.41 m AHD to 87.36 m AHD.
Head loss over structure for largest flow scenario modelled	Not inundated

Photo standing on block bank, looking towards Forest Creek

<table>
<tr><th>Structure Name</th><th colspan="2">Jacksons Weir</th></tr>
<tr><td>Location</td><td colspan="2">MGA2020 Zone 55: 310356E, 6094169N</td></tr>
<tr><td>Included in model</td><td colspan="2">Yes</td></tr>
<tr><td>Model label</td><td colspan="2">F64.15_W</td></tr>
<tr><td>Type of structure</td><td colspan="2">Adjustable crest (dropboards)</td></tr>
<tr><td>Function</td><td colspan="2">Concrete weir structure with dilapidated wooden plank bridge on top. Unregulated blockage of Forest Creek.</td></tr>
<tr><td>Information Source</td><td colspan="2">Site visit photos taken in March 2022 by 3Rivers.
2021 LiDAR and aerial imagery.</td></tr>
<tr><td>How has the structure been modelled</td><td colspan="2">Modelled as 2d_lfcsh (Layered Flow Constriction Layer) with the following assumptions:
Layer 1 (ground to obvert of wooden bridge): invert level at 85.19 m AHD, FLC of 0.12 and 30% blockage to represent concrete weir structure and fallen bridge planks.
Layer 2 (bridge deck): Obvert at 85.78 m AHD, 100% blocked, 1.6 m deep.
Layer 3: not represented.</td></tr>
<tr><td>Head loss over structure for largest flow scenario modelled</td><td colspan="2">Not inundated</td></tr>
<tr><td colspan="2">Photo of upstream face
</td><td>Photo of downstream face
</td></tr>
</table>

Structure Name	**Jackson's Weir Block Bank (with culvert)**
Location	MGA2020 Zone 55: 310361E, 6094169N
Included in model	Yes
Model label	Jackson_Track
Type of structure	Block bank with culvert
Function	Blocks flow along Forest Creek
Information Source	Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW. 2021 LiDAR and aerial imagery.
How has the structure been modelled	Modelled as: A 2d_zsh representing the block bank with levels from 87.83 m AHD to 88.03 m AHD. 1d_nwk representing a circular culvert crossing under the block bank. Size was 0.9 m (measured on site) with 50% blockage.
Head loss over structure for largest flow scenario modelled	Not inundated
Photo of block bank 	Photo of culvert 

Structure Name	**Mortimers Weir**
Location	MGA2020 Zone 55: 316766E, 6090236N
Included in model	Yes
Model label	F48.8_W
Type of structure	Block bank and pipe with manually adjustable gates
Function	Creates weir pool in Forest Creek
Information Source	Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW. 2021 LiDAR and aerial imagery.
How has the structure been modelled	Modelled as: 1d_nwk including two 1050 circular culverts with operational sluice gate (SGO). Gates were assumed to be closed. Downstream observed to be dry in March 2022 site visit. 2d_zsh (thick) representing the block bank with crest at 90.56 m AHD.
Head loss over structure for largest flow scenario modelled	Not inundated downstream
Photo of upstream face 	Photo of downstream face 

Structure Name	**Pine Grove Weir**
Location	MGA2020 Zone 55: 320530E, 6088577N
Included in model	Yes
Model label	F42.63_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir.
Function	Creates weir pool in Forest Creek
Information Source	Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW. 2021 LiDAR and aerial imagery.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section. The 2D flow has been blocked with a 2d_code inactive feature: Width of 29m, sill level at 89.84 m AHD, abutment levels at 90.72 m AHD to 90.74 m AHD, seven slots (counted during site visit). Overtopping represented in the 1D cross section.
Head loss over structure for largest flow scenario modelled	0.302 m
Photo of upstream face 	Photo of downstream face 

Structure Name	**Bridge Downstream of Homestead Wanganella Weir**
Location	MGA2020 Zone 55: 323681E, 6088601N
Included in model	Yes
Model label	F37.8_B
Type of structure	Bridge
Information Source	2021 LiDAR. Site visit photos taken in March 2022 by 3Rivers.
How has the structure been modelled	Modelled as 2D layered flow constriction (2d_lfcsh): Layer 1 (ground to bridge obvert): invert level at 85.78 m AHD, obvert at 88.13 m AHD, FLC of 0.12 and 5% blockage to represent piers. Layer 2 (bridge deck): 100% blocked, 0.94 m deep and FLC of 1.6. Layer 3: not represented.

Photo of downstream face

Structure Name	**Homestead Wanganella Weir**
Location	MGA2020 Zone 55: 323719E, 6088639N
Included in model	Yes
Model label	F37.75_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir.
Function	Creates weir pool in Forest Creek
Information Source	Site visit photos taken in March 2022 by 3Rivers. 2021 LiDAR and aerial imagery.
How has the structure been modelled	Modelled as 1d_nwk (WW Type) including 1d_xs cross section: The 2D flow has been blocked with a 2d_code inactive feature. Width of 19m, sill level at 91.05 m AHD, crest levels at 91.71 m AHD to 91.75 m AHD, abutment levels at 92.06 m AHD, 9 slots (counted on site). Overtopping represented in the 1D cross section.
Photo of upstream face 	Photo of downstream face 

4.5.1.3 Eight Mile Creek

A series of existing flood mitigation and water quantity control measures along Eight Mile Creek within Study area has been checked against the available survey detailed in section 3. The information of operational conditions and some structural measurements unknown, the adopted modelling assumptions for existing operation structures within Eight Mile Creek are summarised in Table 9.

Table 9: Modelling assumptions for operational structures along Eight Mile Creek

Structure Name	**Access Bridge Downstream of McCrabbs Regulator**
Location	MGA2020 Zone 55: 299737E, 6100151N
Included in model	Yes
Model label	E29.0_B
Type of structure	Bridge
Information Source	2021 LiDAR. Site visit photos taken in March 2022 by 3Rivers.
How has the structure been modelled	Modelled as 2D layered flow constriction (2d_lfcsh): Layer 1 (ground to bridge obvert): invert level at 83.41 m AHD, obvert at 85.26 m AHD, FLC of 0.12 and 5% blockage to represent piers. Layer 2 (bridge deck): 100% blocked, 0.94 m deep and FLC of 1.6. Layer 3: not represented.

Photo of downstream face

Structure Name	**McCrabbs Regulator**
Location	MGA2020 Zone 55: 300325 E, 6099496N
Included in model	Yes
Model label	E28.0_W
Type of structure	Rock spillway, block bank and penstock weir/pipe
Function	Control water levels at Wanganella Swamp
Information Source	Survey collected on 05/07/2021 by 3Rivers. Survey collected on 15/05/2015 by Advanced Survey Design provided by DCCEEW. Site visit photos taken in March 2022 by 3Rivers.
How has the structure been modelled	Modelled as: 2d_zsh (thick line) representing the spillway. 1d_nwk including a circular culvert and a rectangular pit located to represent the penstock weir. The weir was assumed to be always open. Dimensions: Spillway levels extracted from the 2021 3Rivers survey 3D surface. Levels vary between 85.51 m AHD and 86.00 m AHD. 600 RCP with upstream invert level at 84.12 m AHD, downstream invert level at 84.36 m AHD and length of 7.4 m. Rectangular pit (0.92 m x 0.93 m) with upstream invert level at 85.05m AHD and downstream invert level at 84.12.
Photo of upstream face 	Photo of downstream face 

Structure Name	**Estuary Creek Regulator**
Location	MGA2020 Zone 55: 303586E, 303586N
Included in model	Yes
Model label	E22.8_W
Type of structure	Block bank and Penstock weir/pipe with manually adjustable gates
Function	Located in the junction between Eight Mile Creek and Estuary Creek. Controls flow between the two creeks.
Information Source	Survey collected on 05/07/2021 by 3Rivers. Survey collected on 19/10/2021 by Price Merrett Consulting provided by DCCEEW. Site visit photos taken in March 2022 by 3Rivers and in 2015 by Jacobs provided by DCCEEW.
How has the structure been modelled	Modelled as: 1d_nwk including a circular culvert and an operational sluice gate (SGO) connected upstream. The gates were assumed to be always closed. 2d_zsh representing the embankment. Dimensions: 900 RCP with upstream invert level at 84.82 m AHD, downstream invert level at 84.64 m AHD and length of 7.3 m. Embankment level ranging from 84.49 m AHD to 86.95 m AHD which was extracted from the 2021 3Rivers survey 3D surface.
Head loss over structure for largest flow scenario modelled	No flow downstream
Photo of upstream face 	Photo of downstream face 

Photo of pipe	Photo of embankment (upstream on RHS)
	

<table>
<tr><td>Structure Name</td><td colspan="2">Bridge Downstream of Junction Weir</td></tr>
<tr><td>Location</td><td colspan="2">MGA2020 Zone 55: 317196E, 6089490N</td></tr>
<tr><td>Included in model</td><td colspan="2">Yes</td></tr>
<tr><td>Model label</td><td colspan="2">E0.95_B</td></tr>
<tr><td>Type of structure</td><td colspan="2">Bridge</td></tr>
<tr><td>Information Source</td><td colspan="2">2021 LiDAR
Site visit photos taken in March 2022 by 3Rivers</td></tr>
<tr><td>How has the structure been modelled</td><td colspan="2">Modelled as 2D layered flow constriction (2d_lfcsh):
Layer 1 (ground to bridge obvert): invert level at 88.57 m AHD, obvert at 90.3 m AHD, FLC of 0.12 and 5% blockage to represent piers.
Layer 2 (bridge deck): 100% blocked, 1 m deep and FLC of 1.6.
Layer 3: not represented.</td></tr>
<tr><td colspan="2">Photo of bridge surface
</td><td>Photo of downstream face
</td></tr>
</table>

Structure Name	**Junction Weir**
Location	MGA2020 Zone 55: 317869E, 6089610N
Included in model	Yes
Model label	E0.2_W
Type of structure	Adjustable crest (dropboards). However, currently non-operational therefore modelled as a fixed crest weir.
Function	Creates weir pool in Forest Creek.
Information Source	Site visit photos taken in March 2022 by 3Rivers. Cross section survey collected in April 2022 by Northern Land Solutions and provided by DCCEEW. 2021 LiDAR and aerial imagery
How has the structure been modelled	Modelled as: 1d_nwk (WW Type) including 1d_xs cross section. The 2D flow has been blocked with a 2d_code inactive feature. Weir dimensions: Width of 13m. Sill level at 89.53 m AHD (2 left slots), 89.56 m AHD (2 middle slots) and 89.47 m AHD (2 right slots). Abutment levels at 90.21 m AHD and 90.34 m AHD. Overtopping represented in the 1D cross section.
Head loss over structure for largest flow scenario modelled	0.678 m

Photo of upstream face	Photo of downstream face
	

4.5.1.4 Clarkes Creek

A series of existing flood mitigation and water quantity control measures along Clarkes Creek within Study area has been checked against the available survey detailed in section 3. The information of operational conditions and some structural measurements unknown, the adopted modelling assumptions for existing operation structures within Clarkes Creek are summarised in Table 10.

Table 10: Modelling assumptions for operational structures along Clarkes Creek

Structure Name	**Clarkes Creek Regulator**
Location	MGA2020 Zone 55: 302849E, 6097231N
Included in model	Yes
Model label	E23.8
Type of structure	Adjustable crest (dropboards)
Function	Not applicable as structure appears non-operational and is acting as blockage only
Information Source	Survey collected on 05/07/2021 by 3Rivers. Site visit photos taken in March 2022 by 3Rivers provided by DCCEEW.
How has the structure been modelled	Modelled as: A 2d_zsh (thin line) blockage. One grid cell (16 m) was raised. Whilst this is a coarse representation, it was considered appropriately conservative given the heavy overgrowth and lack of maintenance.
Head loss over structure for largest flow scenario modelled	N/A
Photo of existing regulator	

4.5.2 Other Structures

Table 11 list the assumptions and approximate location of other structures modelled explicitly in 1D or 2D domain in the hydraulic model.

Table 11: Modelling assumptions for other structures within the WP20 Study Area

3Rivers Structure Code	Type	Manning's n	U/S Invert Level (m AHD)	D/S Invert Level (m AHD)	Blockage (%)	Width (m)	Height (m)	Number of Cells	Easting (GDA2020 / MGA Zone 55)	Northing (GDA2020 / MGA Zone 55)	Comments
Z21_010	Circular	0.015	83.13	83.11	0	0.525	0	1	298621	6101210	From 2021 3Rivers survey
Z21_010	Circular	0.015	82.82	82.80	0	0.75	0	1	298624	6101214	From 2021 3Rivers survey
Z21_011	Circular	0.015	83.29	82.56	0	0.75	0	1	298270	6101100	From 2021 3Rivers survey
Z21_011	Circular	0.012	83.70	83.64	0	0.45	0	1	298269	6101105	From 2021 3Rivers survey
Z21_011	Circular	0.015	82.88	82.90	0	0.6	0	1	298267	6101107	From 2021 3Rivers survey
3R20_071	Circular	0.015	90.10	90.05	0	0.9	0	1	298267	6101107	Assumed
Z20_077	Circular	0.015	85.88	85.83	0	0.75	0	6	321918	6091972	From EES, assumed commercial diameter and ILs From 2007 LiDAR
Z20_080	Circular	0.015	86.30	85.78	0	0.6	0	1	302739	6096913	From 2021 3Rivers survey
Z20_081	Circular	0.015	85.49	85.62	0	0.6	0	1	301759	6098467	From RMS shp, assumed length
Z20_082	Circular	0.015	85.63	85.54	0	0.5	0	1	301643	6098971	From RMS shp, assumed length
Z20_083	Circular	0.015	85.51	85.45	0	0.5	0	1	301620	6099069	From RMS shp, assumed length
Z20_084	Circular	0.015	85.68	85.49	0	0.5	0	1	301494	6099621	From RMS shp, assumed length
Z20_085	Circular	0.015	85.38	85.41	0	0.5	0	1	301452	6099806	From RMS shp, assumed length
COBBHY_07*	Circular	0.015	85.44	85.50	0	0.455	0	1	301298	6100446	From RMS shp, assumed length
COBBHY_08*	Circular	0.015	84.76	84.67	0	0.61	0	1	301187	6101518	From RMS shp, assumed length
Z20_078	Rectangular	0.015	85.14	84.86	0	2.3	2.45	2	301265	6103184	From 2021 3Rivers survey

3Rivers Structure Code	Type	Manning's n	U/S Invert Level (m AHD)	D/S Invert Level (m AHD)	Blockage (%)	Width (m)	Height (m)	Number of Cells	Easting (GDA2020 / MGA Zone 55)	Northing (GDA2020 / MGA Zone 55)	Comments
Z20_079	Rectangular	0.015	85.05	84.18	0	1.63	3.05	4	302367	6097290	From 2021 3Rivers survey
3R20_017	Circular	0.015	85.94	85.84	99.99	0.375	0	1	302008	6097936	From 2021 3Rivers survey, blocked as per DCCEEW request
Z20_071	Circular	0.015	84.16	83.77	0	1.05	0	1	302002	6098028	DCCEEW fish passage, assumed dimensions
Z20_069	Circular	0.015	84.48	84.45	0	1.05	0	1	305141	6098487	From EES, assumed commercial diameter and ILs From 2007 LiDAR
3R20_051	Circular	0.015	85.97	85.63	0	0.5	0	1	304056	6098715	From EES, assumed commercial diameter and ILs From 2007 LiDAR
Z20_065	Circular	0.015	86.30	86.18	0	0.5	0	1	307226	6097263	From EES, assumed commercial diameter and ILs From 2007 LiDAR
3R20_052	Circular	0.015	83.40	82.50	0	1.05	0	1	306787	6097485	From EES, assumed commercial diameter and ILs From 2007 LiDAR
Z20_047	Circular	0.015	87.85	86.39	0	1.2	0	1	307933	6096940	Stage 2 Survey
3R20_055	Circular	0.015	86.01	85.99	0	0.95	0	1	315418	6091945	Stage 2 Survey
3R20_001	Circular	0.015	84.57	84.57	0	0.6	0	1	313938	6092790	From 2021 3Rivers survey
3R20_005	Circular	0.015	86.97	87.25	0	0.75	0	1	300333	6100100	From Yanco_Potential_Third_Party_Impact_Sites_24Sept2021

3Rivers Structure Code	Type	Manning's n	U/S Invert Level (m AHD)	D/S Invert Level (m AHD)	Blockage (%)	Width (m)	Height (m)	Number of Cells	Easting (GDA2020 / MGA Zone 55)	Northing (GDA2020 / MGA Zone 55)	Comments
Z20_057	Circular	0.015	85.11	85.06	50	0.9	0	1	305873	6097940	From site visit. Pipe under track ds Jacksons Weir. Blocked as per site observations
Z21_001	Circular	0.015	82.82	82.90	0	0.875	0	1	310323	6094178	From 2021 3Rivers survey
Z21_001	Rectangular	0.015	84.90	84.83	0	0.7	0.4	1	300277	6100456	From 2021 3Rivers survey
Z21_001	Rectangular	0.015	84.84	84.77	0	0.75	0.4	1	300349	6100472	From 2021 3Rivers survey

4.6 Model Losses

The model has two sets of losses applied, one representing volumetric losses and one representing hydraulic losses. These losses are applicable for all model scenarios/events and the means of application is summarised in Section 4.6.1 and Section 4.6.2, respectively. The evaporation losses have been applied in the model, with the infiltration losses applied via the three zones below (and shown spatially in Figure 11):

- "Billabong Creek @ Piccaninny Weir to Billabong Creek @ DS Wanganella Weir", which includes Billablong Creek upstream of Traceys Weir and 4 Mile Weir.
- "Forest Creek @ Mortimers Weir to downstream Forest Creek @ the reach junction of Estuary Creek and Eight Mile Creek", which includes Jackson's Weir and Cameron's Dam.
- "Eight Mile Creek @ Warriston Weir to downstream the reach junction of Forest Creek @ Wanganella", which includes Forest Creek downstream weirs in Wanganella Swamp.

Analysis of the calibrated Source model results demonstrated that infiltration losses varied between reach (typically defined by river gauging stations) with higher losses in the Billabong Creek and lower losses on Forest Creek and Eight Mile Creek.

4.6.1 Summary of Volumetric Losses

4.6.1.1 Evaporation

This has been represented as a negative rainfall depth based on available data for time period of the modelled flow. The calibration events had these losses applied as a timeseries which are presented in Figure 12 and Figure 13 for the 'Aug2021' and 'Aug2017' events respectively.

For validation scenario model, the 'Aug2022' event adopted the loss value from upstream the Hartwood model and this assessed in current study.

For the impact assessment simulations, no evaporation losses have been modelled as these losses were deemed insignificant given the nature and/or mechanism generating the flow scenarios been assessed.

4.6.1.2 Infiltration

This has been represented via a soils layer and/or negative rainfall. A soils layer was used for lower flows as it was found that for low flows the losses were relatively constant whereas for higher flows losses were found to vary with flow. For lower calibration flows an average loss was calculated from the Source model results which was converted to a loss in mm per hour by taking into account the water surface area for a steady state flow of the average of the scenarios.

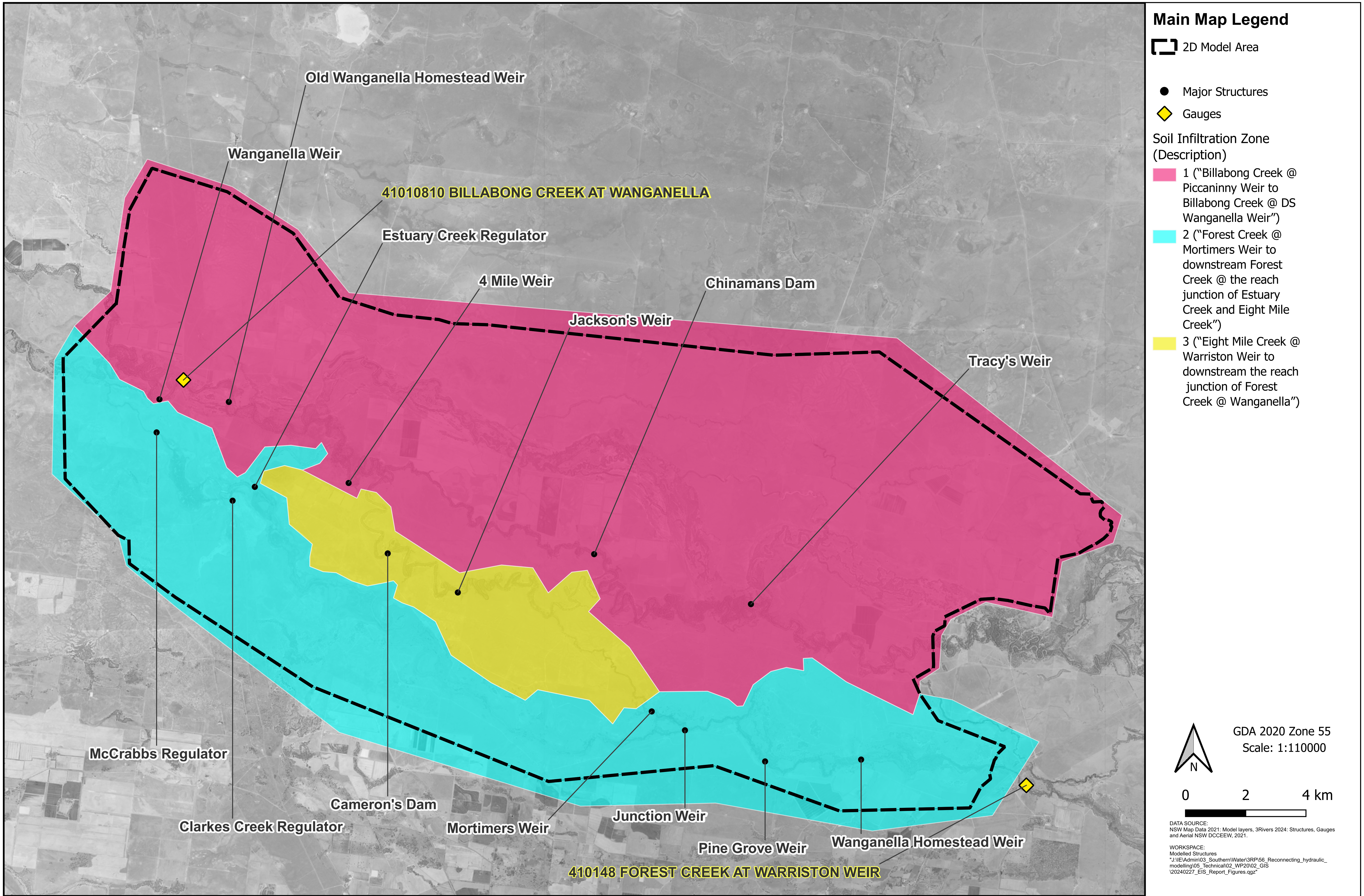
For the 2021 calibration event the loss between relevant gauges (as the Source model results were not available post 2020) was calculated and converted to a mm per hour rate as described above and applied as a negative rainfall boundary.

The loss rate applied to the zones of the model via the soils layer for each of the nominated events is summarised in Table 12 and those applied via a negative rainfall timeseries are presented in Figure 12 for the 'Aug2021' high flow event.

For the impact assessment simulations, infiltration losses have been modelled in current study.

Table 12: Overview of Infiltration Losses

Event	**Infiltration Loss (mm/hr)**		
	Billabong Creek	Eight Mile Creek	Forest Creek
All flow scenario events. runs for ‘B010413’ model (Including sensitivity run) ‘B020120’ model ‘S030161’ model	(0, 1)	(0, 0.25)	(0, 0.25)
‘Aug2017’	(0, 0.195)	(0, 0.195)	(0, 0.195)
‘Aug2021’	(0, 0)	(0, 0.195)	(0, 0.195)



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

Figure 11: WP20 Infiltration Loss Zones

3Rivers

Figure 12: Evaporation and infiltration loss timeseries applied for 'Aug 2021' event

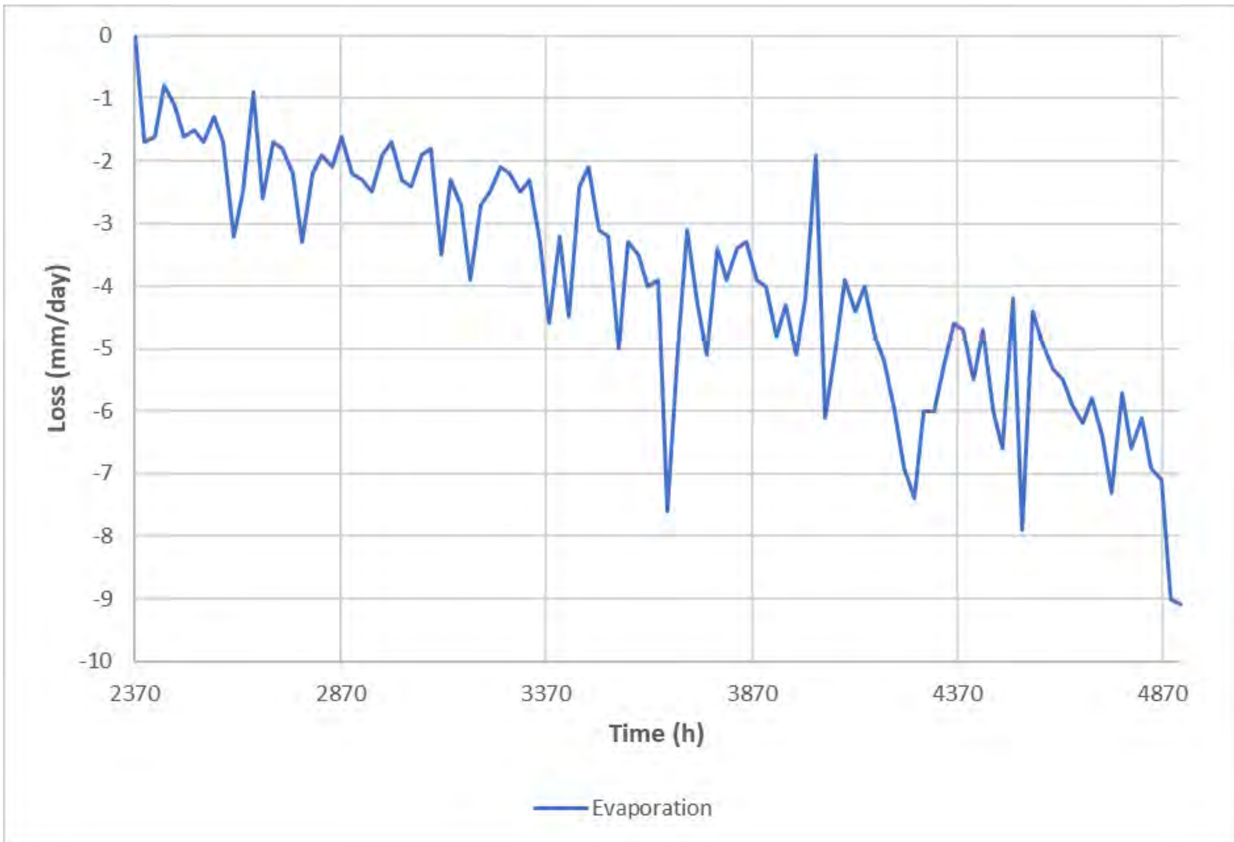


Figure 13: Evaporation loss timeseries applied for 'Aug2017' event

4.6.2 Summary of Structure Losses

4.6.2.1 Culverts

Standard entrance (0.5) and exit losses (1) have been applied, with default height and width contraction coefficients.

4.6.2.2 Bridges

Bridges have been represented as 2D layered flow constrictions using the newly introduced "Method C" to determine losses based on assigned FLC values, which calculated as follows:

- Level 1 – based on Bradley, 1980 considering blockage and pier types;
- Level 2 – form the loss associated with the bridge deck, FLC target of 1.6;
- Level 3 – assumed no FLC at this stage.

The adopted losses for each bridge are summarised in Appendix B and were considered appropriate given the nature of the structures and flow scenarios being considered.

4.6.2.3 Weirs

No additional losses other than default weir coefficients have been applied. The following weir types have been used in the modelling, unless otherwise stated:

- Lay-flat gates – modelled as sharp-crested weirs or "WR" type channels with default parameters as per TUFLOW Version 2020-10-AB.
- Block banks and fixed crest weirs – modelled as broad-crested weirs using either "WB" or "WW" type channels when have a flat level with a known width or cross-section applied respectively. These have also adopted default parameters as per TUFLOW Version 2020-10-AB.

4.6.2.4 Sluice Gates

No additional losses other than default gate coefficients for "SGO" channels (e.g., the Mortimers Weir and Estuary Creek Regulator) have been applied.

4.7 Flow Scenarios

Based on the information required by the design team and as part of the Environmental Impact Statement (EIS) process for Wanganella Weir, there were numerous flow scenarios to be assessed for works individually and in combination across the WP20 model. The required flow scenarios are detailed in Table 3, which breaks the flow into the following two categories and scenarios:

1. Operational Flows– which are steady-state runs with flows based on the following –

    - Minimum Operation Flow(“30MLD”) - flows were based on minimum operating flow for Wanganella Regulator based on Water NSW advice (SAYM-REQ-003) and the minimum environmental baseflow provisions for “Billabong Creek @ downstream Wanganella Regulator” based on the Yanco Creek System Operations Plan (DCCEEW, 2023).

    - Maximum Operation Flow (“400MLD”) - flows were based on maximum operating flow for Wanganella Regulator based on Water NSW advice (SAYM-REQ-003) and the maximum environmental baseflow provisions for “Billabong Creek @ downstream Wanganella Regulator” based on the Yanco Creek System Operations Plan (DCCEEW, 2023).

2. Flood Flows (“Flood”) – which are unsteady flow simulations of design flood flows (i.e. event hydrographs) with peak flows based on the Flood Frequency Analysis (FFA) on the “Yanco Creek @ Morundah (410015)” and “Billabong Creek @ Jerilderie (410016)” gauges (3Rivers, 2023b) the detail of generate inflow hydrograph at upstream of Hartwood site refer to the separate Hartwood Flood Model Report (3Rivers, 2024b). All design scenarios inflow hydrographs within the WP20 study area, extracted from upstream Hartwood model (WP19)[1].

Note[1]: Hartwood Hydraulic model outflows provide in July 2023, except inflow hydrology for Aug2022 event data provided in January 2024.

Table 13: Flow Scenarios

Flow Category	Flow Scenario	Peak Inflow (ML/day)[1]
		Billabong Creek
Operational Flows ("OpFlows")	Maximum Operating Flow ("MaxOF")	400
	Minimum Operating Flow ("MinOF")	30
Flood Flows ("Flood") Current Study	50% or 1 in 2 AEP ("50AEP")	2,986
	20% or 1 in 5 AEP ("20AEP")	4,933
	10% (1 in 10) AEP ("10AEP")	8,020
	5% (1 in 20) AEP ("5AEP")	9,618
	2% (1 in 50) AEP[2] ("2AEP")	13,150
	1% (1 in 100) AEP[2] ("1AEP")	17,324
	0.5% (1 in 300) AEP ("0.3AEP")	23,206
	0.3% (1 in 300) AEP ("0.3AEP")	28,473
	0.2% (1 in 300) AEP ("0.3AEP")	34,802
	PMF	98,588
	Validation Event from 08/2022 – 12/2022 ("Aug2022")	15,154
RRC Programme Modelled Flow Scenarios	Minimum Flow ("MinQ")	30
	Max Flow ("MaxQ")	300
	Calibration Event from 08/2017 – 09/2017 ("Aug2017")	881
	Calibration Event from 07/2021– 10/2021 ("Aug2021")	August – 1,989 September – 1,792 October – 1,927

Note [1]: Flows presented in this table are inflows into Wanganella model.
Note [2]: For assessment on the potential flooding impact at the downstream Cobb Highway, an extra inflow 7m^3/s at downstream Junction Weir within the Eight Mile Creek was added for 1% AEP flood event, and 6m^3/s inflow for 2% AEP flood event. The extra inflow was added to account for breakout flows into the forest creek systems.

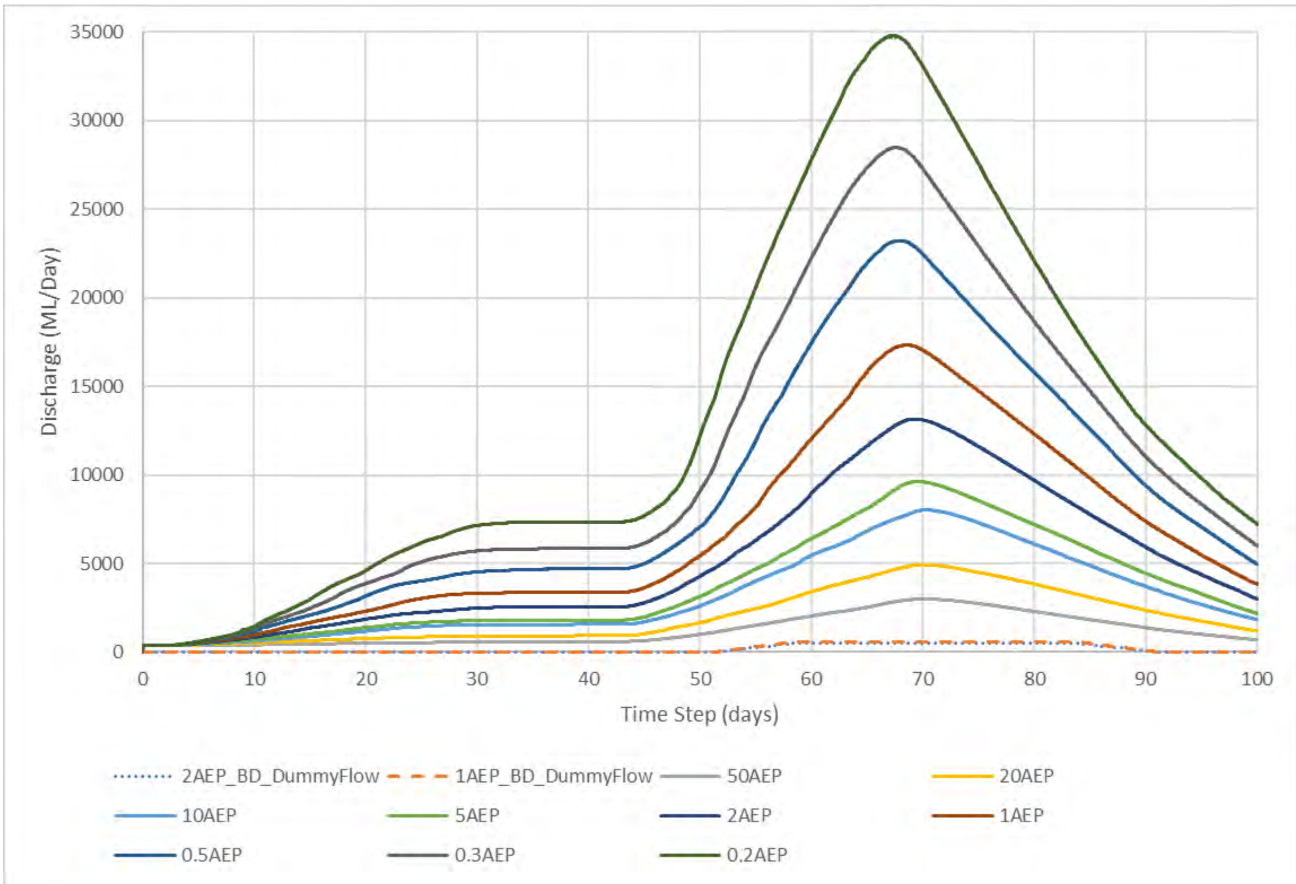


Figure 14: Flood Hydrographs for Flood Flows (Current Study- 50%AEP to 0.2%AEP)

4.8 Model Naming Convention

Models for this study have been named in accordance with the Hydraulic Modelling Standard Specification (DCCEEW, 2021) as summarised below and detailed in Table 14. Some of the results are based on RRC modelling, for details on model scenarios from this package refer to RRC Model User Report (3Rivers, 2023a).

<Region>_<Package>_<Model-Version>_~e1~_~s1~.tcf

Table 14: Summary of naming convention

Variable	Description
Region	YNC (Yanco Creek)
Package	WP20 (Wanganella model)
Model-Version	As per the naming convention, we have adopted the following version names for this Study: • V0201003 – the model used for validating the 2022 storm event. • B020120 – adopted "existing" condition model for this Study. • S030161 – adopted "proposed" condition model for this Study.
Events ~e1~	The validation model (V0201003) model were run for the following events: • "Aug2022" – the August 2022 flood event. Both "existing" and "proposed" condition models (B020120 and S030161) were run for the following events: • "30MLD" – a steady state model with minimum operational flows (30ML/Day) based on Water NSW advice (SAYM-REQ-003), see discussion in Section 4.7. • "400MLD" – a steady state model with maximum operational flows (400ML/Day) based on Water NSW advice (SAYM-REQ-003), see discussion in Section 4.7. • "50AEP_BD" - a 50% AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "20AEP_BD" - a 20% AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "10AEP_BD" - a 10% AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "5AEP_BD" - a 5% AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "2AEP_BD" - a 2% AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "1AEP_BD" - a 1 AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "0.3AEP_BD" - a 0.3 AEP equivalent unsteady flow event for Study Area where Billabong Creek is dominant. • "PMF_BD" - a Probable Maximum Flood (PMF) for Study Area where Billabong Creek is dominant.
Scenario ~s1~	The "existing" condition model (B020120) was run for the following scenario: • "OpFlows" – Operational flow scenario. • "Flood" – Flood scenario. The "proposed" condition model (S030161) was run for the following scenario: • "MinOL"– Minimum Operational Level at upstream weir pool, see discussion in Section 6.2.1. • "MaxOL" – Maximum (Normal) Operational Level, 0.24m above the MinOL level at upstream weir pool, see discussion in Section 6.2.1. *Note: this scenario was labelled as "NormOL" in Wanganella model files, but is referred as "MaxOL" in this report to*

Variable	Description
	be consistent with the Hartwood Flood Model Report (3Rivers, 2024a) and the EIS report (3Rivers, 2024b). • "FSL" – Full Supply Level based on Water NSW advice (SAYM-REQ-003), see discussion in Section 6.2.1. *Note: this scenario was labelled as "MaxOL" in Wanganella model files, but is referred as "FSL" in this report to be consistent with the Hartwood Flood Model Report (3Rivers, 2024a) and the EIS report (3Rivers, 2024b).* • "Flood" – Flood scenario. s1 was not used for validation model (V0201003).

5. Existing Model Sensitivity and Calibration

5.1 Introduction

This section provides a concise overview of the sensitivity testing, calibration, and validation conducted during the RRC study phase – the results of which are still relevant given the current model is largely an extension and/or minor update of this model. Additionally, it includes a validation case for the "Aug 2022" historical storm event in the current study.

5.2 Sensitivity Analysis

5.2.1 Overview

Sensitivity analysis of model parameters is a required step in the development of a hydraulic model to understand the model's dependence upon model assumptions. The results of the sensitivity testing can be used to gain an understanding of the likely "level of confidence" that can be associated with the model results.

All sensitivity testing has been undertaken for a steady state flow scenario with the following flow based on the nominated RRC flow scenarios:

- Billabong Creek – 3,024 ML/day or 35.0 m³/s

  (The average peak of the 10 Strategic Business Case flow scenarios as described in Table 14).

- Forest Creek – 357 ML/day or 4.1 m³/s

  (The average peak of the 10 Strategic Business Case flow scenarios as described in Table 14).

As part of the RRC study, the following Five (5) sensitivity scenarios were completed to understand the performance and potential variability in model results:

1. Impact of change in hydraulic roughness in the channel and in the floodplain (Manning's 'n' ± 20%).
2. Impact of volumetric losses (Evaporation and infiltration set to reasonable upper and lower values).
3. Impact of structural losses at bridges (Level 1 Form Loss Coefficient ± 20%)
4. Impact of blocking culvert structures by 50%.
5. Impact of the TUFLOW control numbers on results and model stability (default vs factor of 0.5).

Results for these sensitivity runs were compared in terms of flow and WSL at key locations, as well as the change in WSL via a long-section plot along the thalweg of Billabong Creek, Forest Creek and Eight Mile Creek. Afflux maps for all sensitivity analysis are presented in Appendix C.

5.2.2 Catchment Roughness

The impact of the adopted catchment roughness was tested by factoring the Manning's 'n' values specified in the Tuflow Material File (or *.tmf) using the following multipliers:

- 1.2 – this increases the Manning's 'n' value in *.tmf by 20% (i.e., 0.35 x 1.2 = 0.42).
- 0.8 – this decreases the Manning's 'n' value in *.tmf by 20% (i.e., 0.35 x 0.8 = 0.28).

This change did not require any other modifications to model inputs and resulted in the impact presented in Table 15 and (an afflux map is also presented in Appendix C this impact assessment was conducted in the RRC Study Phase).

These results show that catchment roughness has the following impact on results:

- Minor change in flow with a peak change of:
  - Less than 11 ML/day at all locations when catchment roughness reduced by 20%.
  - Less than -14 ML/day at all locations when catchment roughness increased by 20%.
- Noticeable changes in WSL along the thalweg of Billabong Creek with:
  - An average difference of -218 mm (with a range of 0 mm to -300 mm) when catchment roughness reduced by 20%.
  - An average difference of +185 mm (with a range of 0 mm to 250 mm) when catchment roughness increased by 20%.
  - Noticeable impact in Eight Mile Creek from Junction Weir to upstream of the Cobb Highway. Differences ranged mostly from +/- 100 mm with some locations exceeding this.
- Afflux plot shows similar results to the long-section, with noticeable changes to the WSL along all creeks within the Study Area when the catchment roughness is adjusted by ±20 %.

Table 15: Flow and water level changes at key locations due to catchment roughness (RRC Study)

Location	**Flow (ML/day)**				
	Baseline – 20%	Baseline	Baseline + 20%	-20% – Baseline Difference	+20% – Baseline Difference
Wanganella Weir (Billabong Creek)	2944	2936	2922	7	-14
Billabong Creek @ Wanganella gauge	2945	2933	2923	11	-10
Forest / Eight Mile Creek Junction	334	334	333	1	-1
Location	**Water Level (m AHD)**		**Water Level Difference (m)**		
	Baseline – 20%	Baseline	Baseline + 20%	-20% – Baseline Difference	+20% – Baseline Difference
Wanganella Weir (Billabong Creek)	82.38	82.67	82.79	-0.29	0.12
Billabong Creek @ Wanganella gauge	82.44	82.75	82.87	-0.30	0.13
Downstream of Junction Weir (Eight Mile Creek)	89.30	89.39	89.48	-0.09	0.09

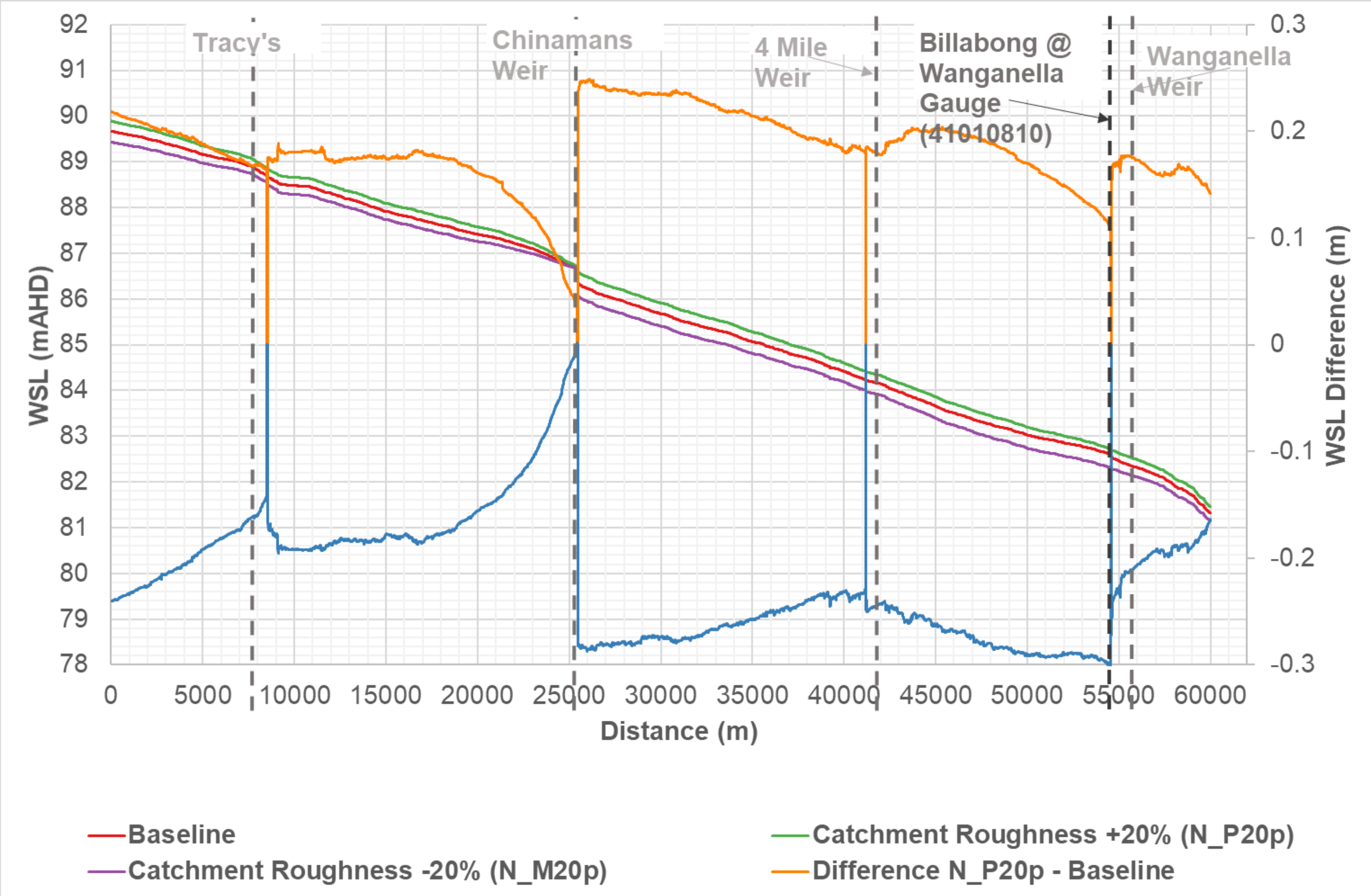


Figure 15: Catchment roughness WSL comparison along Billabong Creek (RRC Study)

5.2.3 Volumetric Losses

The impact of the adopted volumetric losses was tested by factoring the continuing loss (representing infiltration) set in the soils file (.tsoilf). The models have adopted the loss rates described in Table 16. The baseline volumetric loss was derived from the average loss for the 2021 calibration event extracted from the Source model.

Given the small hourly evaporation rates (0.1 mm/hr), this variable was not included as testing of the volumetric losses was adequately tested through the infiltration sensitivity.

Impacts of varying the volumetric loss are presented in Table 17 and Figure 16 (an afflux map is also presented in Appendix C). These results show that volumetric losses have the following impact on results:

- Minor change in flow with a peak change of:
  - Less than +45 ML/day at all locations when volumetric losses were reduced.
  - Less than -87 ML/day at all locations when volumetric losses were increased.
- Minor changes in WSL along the thalweg of Billabong Creek with:
  - An average difference of +12 mm (with a range of 0 mm to 35 mm) when volumetric losses were reduced.
  - An average difference of -30 mm (with a range of -4 mm to -107 mm) when volumetric losses were increased.
- Afflux plot shows similar results to the long section, with some noticeable changes to WSL along Forest Creek and Eight Mile Creek.

Table 16: Adopted volumetric losses (RRC Study)

Volumetric Loss	Lower Sensitivity	Baseline	Upper Sensitivity
Evaporation (mm/hr)	0	0	0
Infiltration for "Billabong Creek @ Conargo to Billabong Creek @ Wanganella" zone (mm/hr)	0.5	1	2

Table 17: Flow and water level changes at key locations due to volumetric losses (RRC Study)

Location	**Flow (ML/day)**				
	Baseline +100%	Baseline	Baseline -50%	+100% – Baseline Difference	-50% – Baseline Difference
Wanganella Weir (Billabong Creek)	2849	2936	2982	-88	45
Billabong Creek @ Wanganella gauge	2847	2934	2978	-87	45
Forest / Eight Mile Creek Junction	311.3	333.5	345.0	-22	12
Location	**Water Level (m AHD)**			**Water Level Difference (m)**	
	Baseline +100%	Baseline	Baseline -50%	+100% – Baseline Difference	-50% – Baseline Difference
Wanganella Weir (Billabong Creek)	82.57	82.67	82.69	-0.10	0.02
Billabong Creek @ Wanganella gauge	82.64	82.75	82.77	-0.11	0.02
Forest / Eight Mile Creek Junction	89.83	89.85	89.86	-0.02	0.01

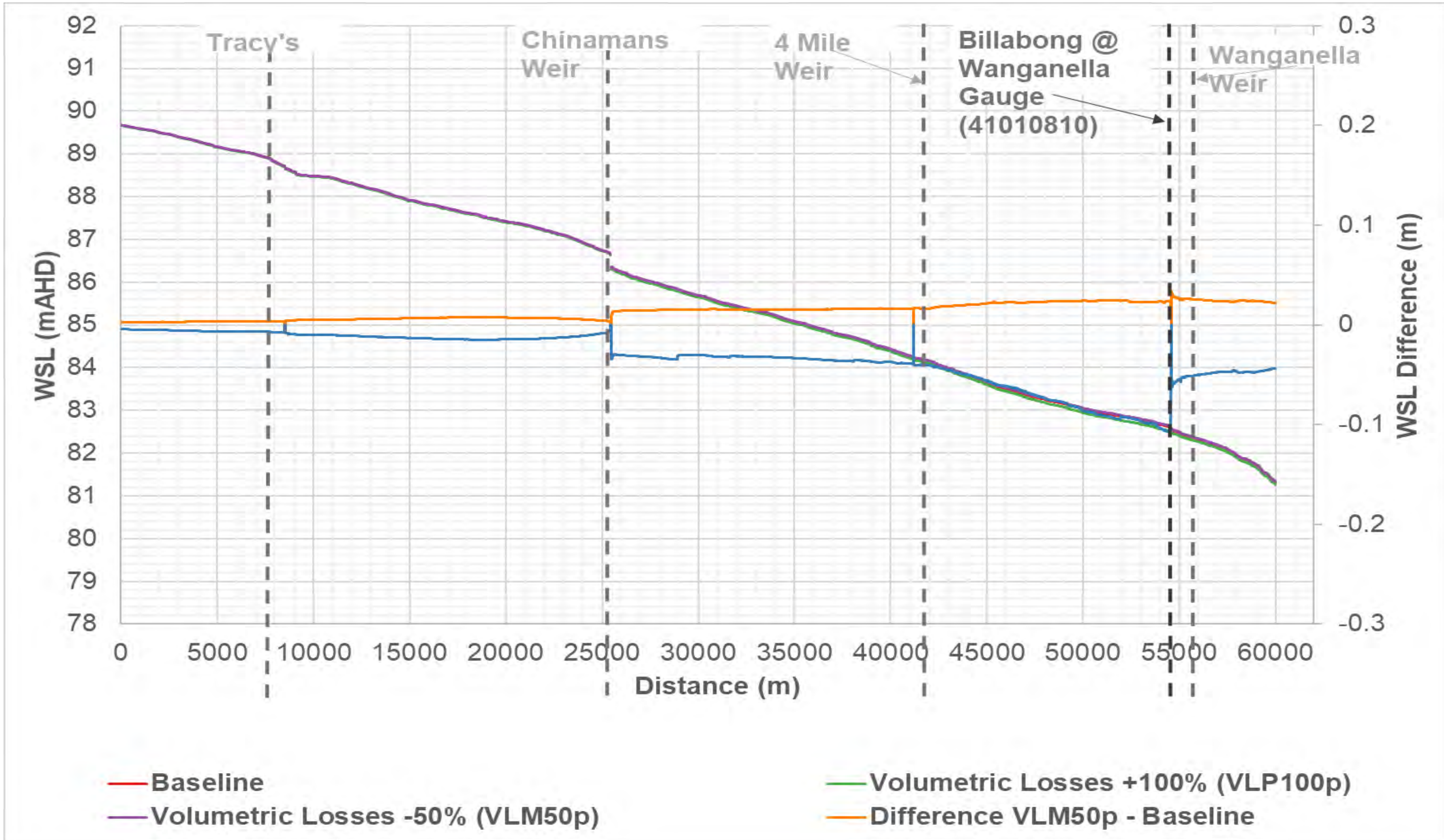


Figure 16: Volumetric losses WSL comparison along Billabong Creek (RRC Study)

5.2.4 Structure Losses at Bridge

The impact of the adopted structure losses was tested by factoring the Layer 1 FLC values on all bridges modelled as layered flow constrictions (2d_lfcsh) up and down by 20%. The location of the bridges affected by this change are presented spatially in Figure 10 and described in the Section 4.5.

It was found that varying the bridge losses had no discernible impact on flow or water level anywhere in the system. Marginal differences in water level (in the order of 0.1 mm) were observed upstream of the bridge structures, where the losses were applied. The lack of sensitivity can be attributed to the low velocity at the structures. This change of flow and water surface level impact results presented in Table 18.

The afflux maps from this sensitivity run are presented in Appendix C.

Table 18: Flow and water level change at key locations due to structure losses at bridges (RRC Study)

Location	**Flow (ML/day)**					**Water Level (m AHD)**				
	Baseline – 20%	Baseline	Baseline + 20%	-20% – Baseline Difference	+20% – Baseline Difference	Baseline – 20%	Baseline	Baseline + 20%	-20% – Baseline Difference	+20% – Baseline Difference
Wanganella Weir (Billabong Creek)	2936.4	2936.4	2936.6	0.0	0.1	82.67	82.67	82.67	0.00	0.00
Billabong Creek @ Wanganella gauge	2933.5	2933.5	2933.5	0.0	0.0	82.75	82.75	82.75	0.00	0.00
Forest / Eight Mile Creek Junction	333.5	333.5	333.5	0.0	0.0	89.85	89.85	89.85	0.00	0.00

5.2.5 Blockage

The impact of blockage was tested by applying 50% blockage (via 'pBlockage' attribute) to all pipe and box culverts in the Study Area. The location of the structures affected by this change is shown spatially in Figure 10. This sensitivity run resulted in the impact presented in Table 19 (an afflux map is also presented in Appendix C). These results show that blockage has the following impact on results:

- No change in flow or WSL in Billabong Creek, as there are no culvert structures crossing this system.
- No change in flow or WSL in Forest Creek. Only minor culverts cross this system.
- Minimal change in flow and WSL in Eight Mile Creek. The changes were observed to be centred around the culverts under the Cobb Highway. Up to 50 mm increase in WSL could be observed for a short distance upstream of the culvert.

Table 19: Flow and water level change at key locations due to blockage (RRC Study)

Location	Flow (ML/day)			Water Level (m AHD)		
	Baseline	Baseline + 50%	+50% – Baseline Difference	Baseline	Baseline + 50%	+50% – Baseline Difference
Wanganella Weir (Billabong Creek)	2936.4	2936.4	0.0	82.67	82.67	0.00
Billabong Creek @ Wanganella gauge	2933.5	2933.5	0.0	82.75	82.74	0.00
Forest / Eight Mile Creek Junction	333.5	333.5	0.0	89.85	89.85	0.00
Eight Mile / Clarkes Creek Junction	260.7	260.6	-0.1	86.191	86.19	0.05

5.2.6 TUFLOW HPC Control Number Factor

The impact of TUFLOW's HPC Control Numbers was tested by adding the following command to the Tuflow Control File (or *.tcf) to reduce the three control numbers by a factor of 0.5:

"Control Number Factor == 0.5"

This resulted in the control numbers being reduced as follows:

- Nu = Courant Number = 1.0 x 0.5 = 0.50
- Nc = Wave Celerity = 1.0 x 0.5 = 0.50
- Nd = Diffusion = 0.3 x 0.5 = 0.15

It was found that using a control number factor of 0.5 had no discernible impact on flow or water level anywhere in the system the comparison results shown in Table 20. The lack of sensitivity indicates that the default control number factor of 1 is appropriate.

The afflux map from this sensitivity run is presented in Appendix C.

Table 20: Flow change at key locations due to TUFLOW Control Numbers (RRC Study)

Location	Flow (ML/day)			Water Level (m AHD)		
	Baseline	CNF=0.5	Difference (CNF=0.5 – Baseline)	Baseline	CNF=0.5	Difference (CNF=0.5 – Baseline)
Wanganella Weir (Billabong Creek)	2936.4	2936.1	-0.3	82.67	82.67	0.00
Billabong Creek @ Wanganella gauge	2933.6	2933.5	-0.1	82.75	82.75	0.00
Forest / Eight Mile Creek Junction	333.5	333.5	0.0	89.85	89.85	0.00

5.2.7 Conclusion

The above analysis has tested the model's sensitivity to a number of model parameters and found that the results are generally within +/- 300mm with the direction of change in all tests being as expected. The results show that the most sensitive parameters are as follows in order of impact:

- Catchment roughness (or Manning's 'n'), and
- Followed by volumetric losses.

This testing demonstrates that the model is preforming as expected with no unusual changes in results to reasonable parameter alterations. The adopted parameters are considered reasonable based on the results of the calibration and validation exercise outlined in Section 5.3. The analysis also highlights that catchment roughness is the appropriate calibration parameter.

5.3 Calibration and Validation

5.3.1 Overview

The purpose of model calibration is to demonstrate that the model can reproduce recorded events and to refine model parameterisation and topography. Calibration is achieved by comparing the outputs from the model against known water levels and flood extents for historic events. Calibration helps to improve the accuracy of model results. Whereas the purpose of model validation is to test the performance of the calibrated hydraulic model against historic flow events and provide a level of confidence in the performance of the model. Ideally, more recent events will be tested as these will best reflect current instream and floodplain conditions.

With regards to model calibration and/or validation, ideally both gauge and imagery data should be considered. The gauge data will assist in the calibration of instream parameters, whilst the observation data will assist in the calibration/validation of model floodplain roughness parameterisation and topographical edits.

The following criteria are generally used to determine the suitability of historical events to use for calibration or validation:

- The availability, completeness and quality of rainfall, river flow and flood level event data.
- The amount of reliable historical flood information data available.

- The variability of events – preferably events would cover the range of flow rates of interest.

For this study, recorded streamflow data and aerial imagery of the selected calibration events were available to use for calibration and/or validation purposes. Furthermore, the availability of recent 1 m LiDAR survey flown during the September 2021 calibration event allowed for a detailed calibration of the model.

As discussed in the Sections 3 and 4 of the report, the following events have been chosen to perform model calibration and/or validation for the stated purposes:

- August 2017 (01/08/17 to 10/09/17) – low flow event to check model performance for in-bank flows.
- August 2021 (01/07/21 to 10/09/21) – initial high flow calibration event before November 2022 storm event occurs during RRC hydraulic modelling program.
- September 2021 (11/09/21 to 09/10/21) – initial second high flow calibration event with some out-of-bank flows, but due to uncertainty around presence of drop boards at Hartwood Weir and the actual minimum crest elevation of Forest Creek this ultimately formed a verification run.
- October 2021 (10/10/21 to 10/11/2021) –low flow validation event.
- Rating Curve (RC) – a scenario where a ramped hydrograph was run to compare model performance to the s at a key gauge within the study area and to other know levels based on flood information.
- August 2022 (01/08/2022 to 01/10/2023) – high flow validation event.

Low flow gauge data was used to assist in the calibration of instream parameters, whilst high flow gauge data was used to assist in the calibration of instream and floodplain roughness parameterisation.

There are two gauges in or nearby WP20 study area:

- 410148 Forest Creek at Warriston Weir.
- 401010810 Billabong Creek at Wanganella.

The Forest Creek gauge at Warriston Weir is at the boundary of the Hartwood and WP20 and therefore does not represent suitable calibration gauge for the model. Further this gauge has been used in the Hartwood model development. Inflows into Forest Creek have been applied downstream of the Warriston Weir. There are no further gauges available for calibration on Forest Creek or Eight Mile Creek downstream of Warriston Weir. Flow calibration was only able to be performed for Billabong Creek, using the Billabong Creek @ Wanganella gauge.

The peak flow and stages for the events chosen are described in Table 21.

Table 21: Calibration and validation gauge data

Event	41010810 Billabong Ck @ Wanganella		
	Peak Flow (ML/d)	Peak Stage (m AHD)	Date of Peak Flow
Aug 2017 (low flow calibration)	881	81.31	25/08/2017
Aug 2021 (high flow calibration)	1,989	82.22	18/08/2021
Sep 2021 (high flow calibration)	1,792	82.07	24/09/2021
Oct 2021 (validation)	1,927	82.18	22/10/2021
Aug 2022 (validation)	11,649*	85.45	28/11/2022

** The peak of the gauged hydrograph of the Aug 2022 event was flat (i.e., missing) due to the lack of recorded information; therefore, the gauged peak discharge is not fit for validation purpose. See details in Section 5.3.7.*

Inflow hydrographs for the calibration and validation event were adopted from the outflows of the Hartwood model for the same event. The Aug, Sep and Oct 2021 flows were the gauged flows from the Conargo gauge routed through the Hartwood mode rather than the calibration flows. This was done to remove to reduce errors accumulating through the models.

The Aug 2017 flows were adopted from the calibrated flows from the Hartwood flood model – refer to the Hartwood Flood Model Report (3Rivers, 2024a) for more information on the Hartwood flood model calibration). This approach was chosen as it provided the most accurate representation of flows entering the WP20 model, in the absence of gauges at the WP20 model boundary.

The Hartwood flows and model performance have been calibrated to the gauges listed below. A good calibration was achieved which provides confidence for adopting its outflows as inflows into the WP20 model for the Aug 2017 event:

- 410168 Billabong Creek DS Hartwood Weir
- 410017 Billabong Creek at Conargo (Puckawidgee)
- 41010309 Forest Creek at Offtake
- 410148 Forest Creek at Warriston Weir

5.3.2 August 2017 Event

The August 2017 calibration event was modelled using the calibration flows extracted from upstream of the Hartwood model presented in Figure 17. This calibration event is a low flow event with a peak of 881 ML/day occurring on the 25/08/2017 at the Wanganella gauge (41010810).

shows the comparison of gauged and modelled flow hydrographs. Similarly, Figure 19 presents a comparison of gauged and modelled water level hydrographs. Table 22 provides a summary of the model performance against gauged values.

Table 22: August 2017 Event Model Performance

Event	41010810 Billabong Ck @ Wanganella		
	Difference in Peak Flow (ML/d)	Difference in Peak Stage (m)	Difference in Timing of Peak Stage (h)
Aug 2017	-1.9 (-0.2%)	0.094	-14.25

Modelled peak flows achieved a good match with a difference of 1.9 ML/d (0.2%). Modelled water levels at Wanganella gauge was approximately 94 mm higher than the observed peak water level which is considered adequate. The timing of peak flow achieved a good match with a difference of 14.25 hours.

The results presented in Table 23 represent a good a calibration in terms of flow and a good calibration in terms of area under the level-time plot; however, the peak water level are poor with respect to the NSE statistic, systematically underestimating water levels by a mean of 113mm. Regardless, this still matches the peak water level within a tolerance of 100mm.

The performance of the model was also assessed spatially by comparing the flood extent generated by the model to the Sentinel satellite imagery captured on the 24/08/2017. The results of this comparison are presented in Figure 20 which show that the model generally matches the areas captured as wet in the satellite imagery well. This provides additional confidence that the model is performing well.

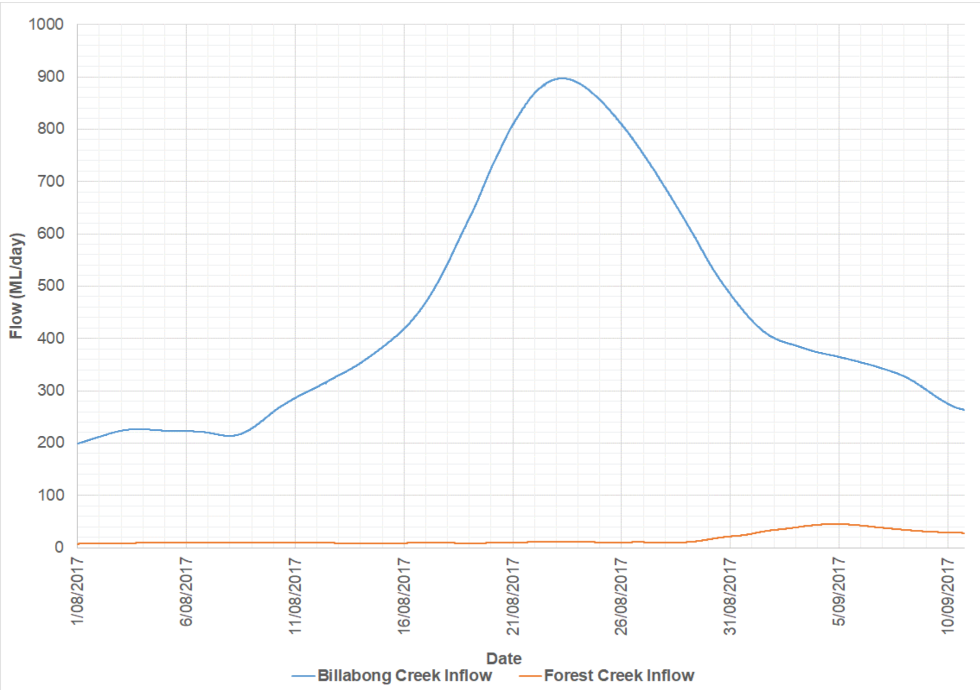


Figure 17: Inflow hydrographs for August 2017 Calibration Event (01/08/2017 to 10/09/2017)

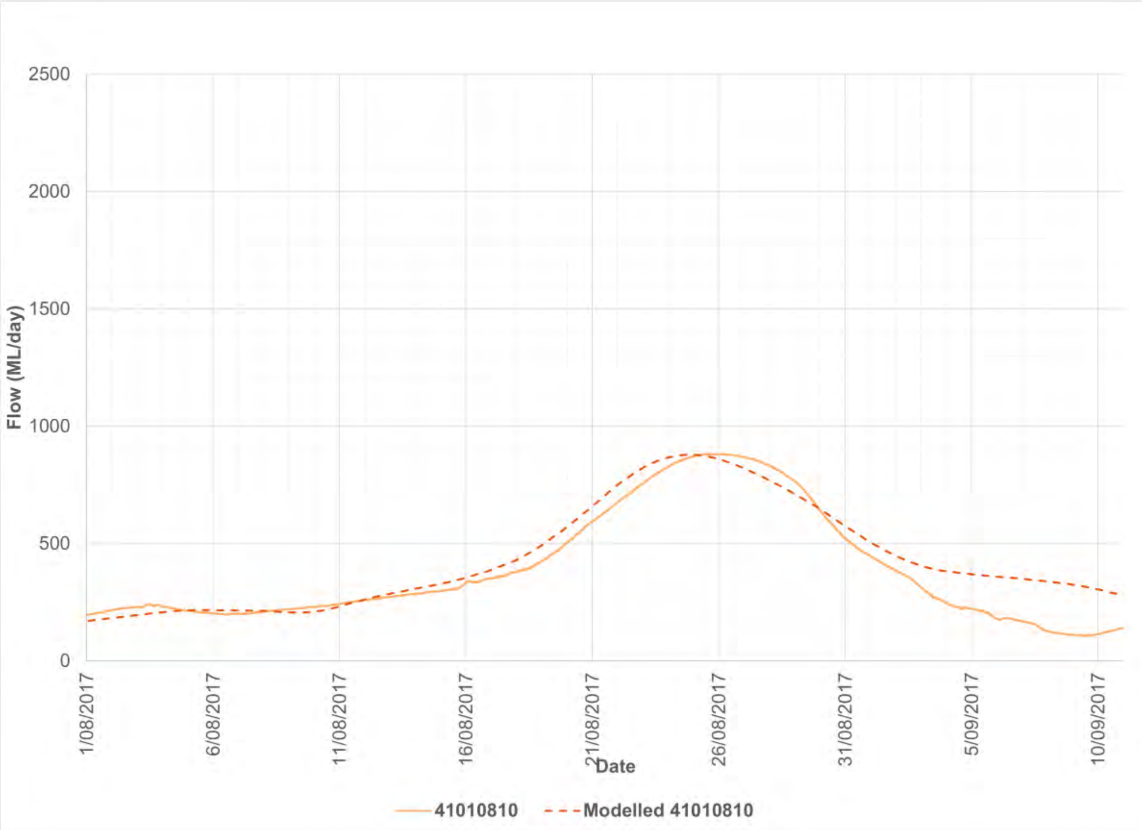


Figure 18: Gauge data flow comparison for August 2017 calibration event

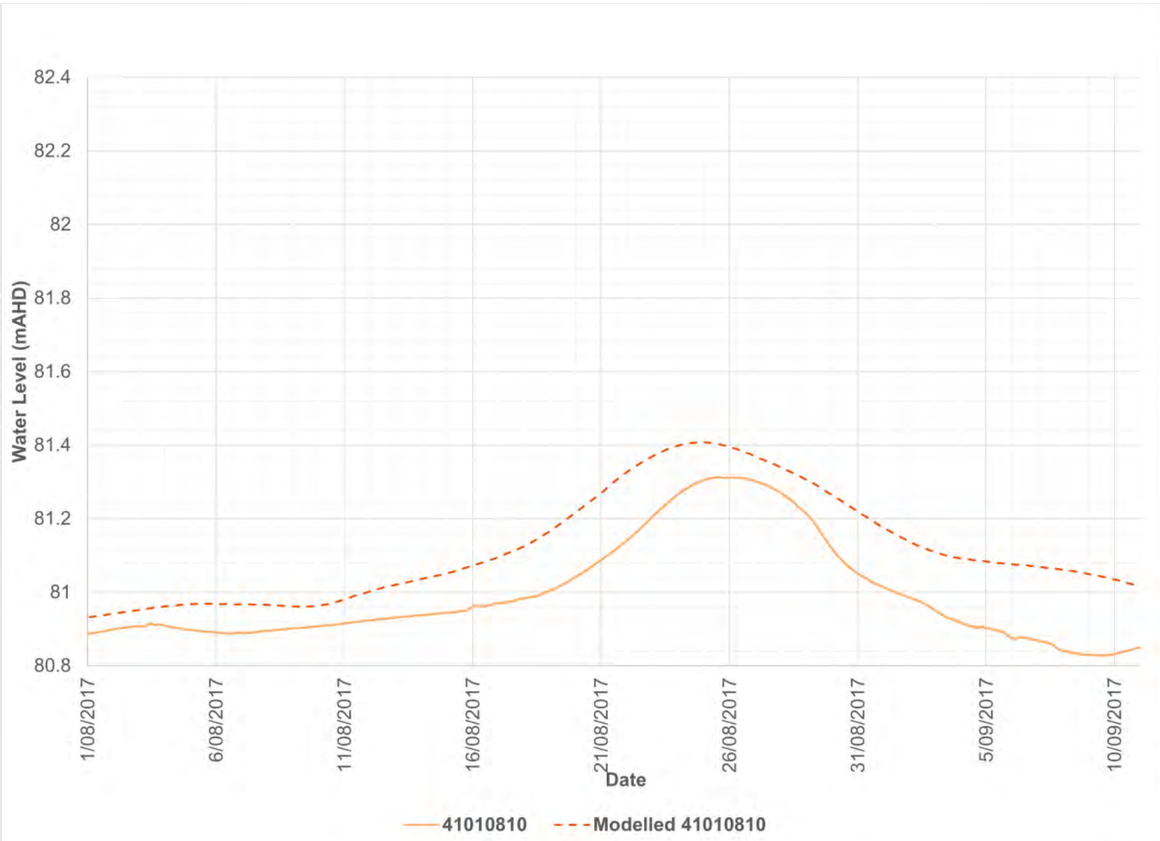


Figure 19: Gauge data water level comparison for August 2017 calibration event

Table 23 provides statistical analysis on the correlation between the modelled and gauged flow and water levels. Performance ratings of results have been defined by the criteria outlined in (Moriasi, 2007).

Table 23: August 2017 Flow and Water Level Statistics

Statistic	**41010810 Billabong Ck @ Wanganella**	
	Flow	Water Level
PBIAS %	11.7	0.1
NSE	0.87	0.23
r	0.95	0.94
R^2	0.91	0.87
KGE	0.85	0.94
VE	0.84	1

The results presented in Table 23 represent a good a calibration in terms of flow and a good calibration in terms of area under the level-time plot; however, the peak water level are poor with respect to the NSE statistic, systematically underestimating water levels by a mean of 113mm. Regardless, this still matches the peak water level within a tolerance of 100mm.

Note on Statistics

The statistics presented in calibration statistics tables are:

- PBIAS – Percent Bias is the percentage difference in the area under the curve or mass.
- NSE – Nash-Sutcliffe Efficiency (-Inf <= NSE <= 1). This metric is particularly affected by timing errors. ‘1’ indicates a perfect fit and ‘0’ the average of the observed series and ‘< 0’ is worse than the average.
- r – Pearson Correlation coefficient (-1 <= r <= 1). This statistic is a measure of linear correlation between the modelled and observed series. ‘1’ indicates a perfect correlation and ‘0’ indicates no correlation between the modelled and observed series.
- R^2 – Coefficient of Determination ($0 <= R^2 <= 1$) – Gives the proportion of the variance of one variable that is predictable from the other variable. ‘1’ indicates a perfect fit and value of ‘0’ indicates a poor relationship between modelled and observed series.
- KGE Kling-Gupta efficiency between modelled and observed (0 <= KGE <= 1). The KGE is a decomposition of the NSE that is considered to be more balanced, has been widely used for calibration and evaluation hydrological models in recent years. The interpretation of the value is similar to the NSE.
- VE Volumetric efficiency between modelled and observed (-Inf <= VE <= 1). ‘1’ indicates a perfect fit and ‘0’ the average of the observed series. Volumetric efficiency was proposed in order to circumvent some problems associated to the NSE. It represents the fraction of water delivered at the proper time; its compliment represents the fractional volumetric mismatch (Criss and Winston, 2008).

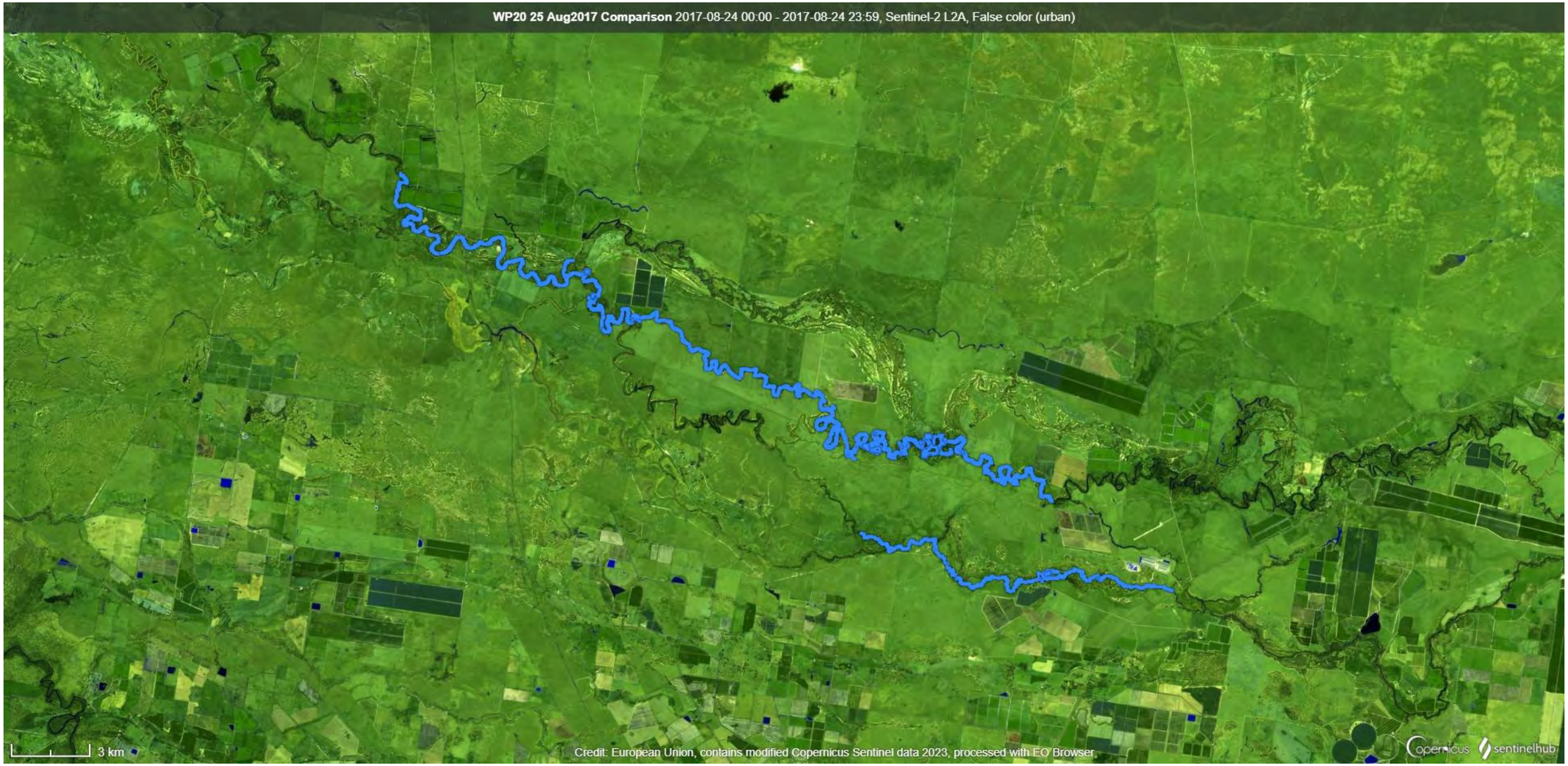


Figure 20: Comparison of model flood extent to Sentinel satellite imagery on 24/08/2017 with False Colour (urban) filter across entire WP20 model area

5.3.3 August 2021 Event

The August 2021 calibration event was modelled using the Conargo gauge flows routed through the Hartwood model present in Figure 21. This calibration event is a high flow event with a peak of 1,989 ML/day occurring on the 18/08/2021 at the Wanganella gauge (41010810).

Figure 22 shows the comparison of gauged and modelled flow hydrographs. Similarly, Figure 23 presents a comparison of gauged and modelled water level hydrographs. Table 24 provides a summary of the model performance against gauged values.

Table 24: August 2021 Event Model Performance

Event	**41010810 Billabong Ck @ Wanganella**		
	Difference in Peak Flow (ML/d)	Difference in Peak Stage (m)	Difference in Timing of Peak Stage (h)
Aug 2021	103 (5.2%)	-0.105	-31

For the adopted calibration run, the gauged flows from the Billabong Creek @ Conargo gauge were routed through the Hartwood model and applied in WP20. This resulted in a close match between observed and modelled values. Further, the inclusion of volumetric losses and evaporation improved calibration results, reducing the overestimation of peak flows. Modelled peak flows were 103 ML/d higher than the observed peak flows.

Modelled water levels at Wanganella gauge provided an adequate match to the peak observed gauge data, as seen in Figure 23. The modelled peak water level result was approximately 105 mm lower than observed. The timing was approximately 31 hours earlier than the observed gauge peak.

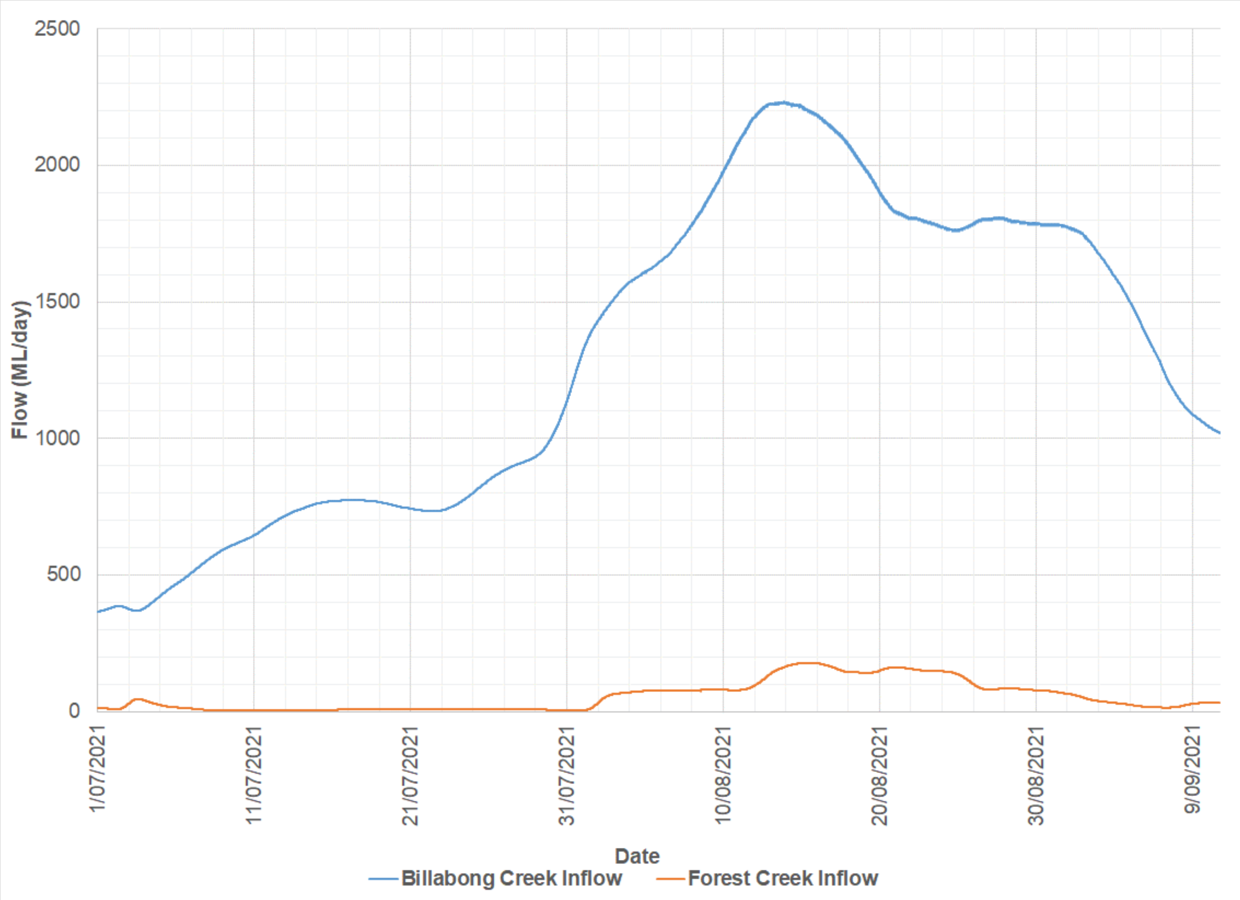


Figure 21: Inflow hydrographs for August 2021 Calibration Event (01/07/2021 to 09/09/2021)

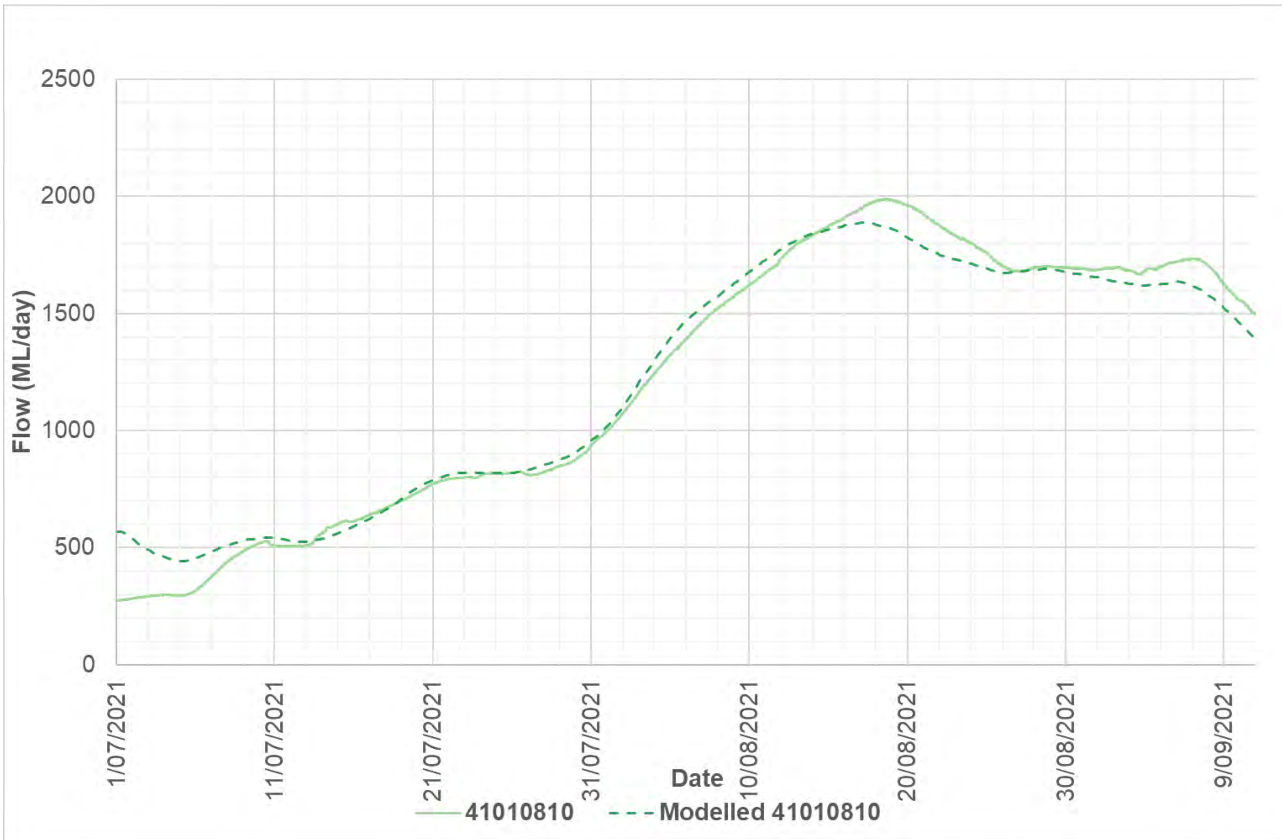


Figure 22: Gauge data flow comparison for August 2021 calibration event

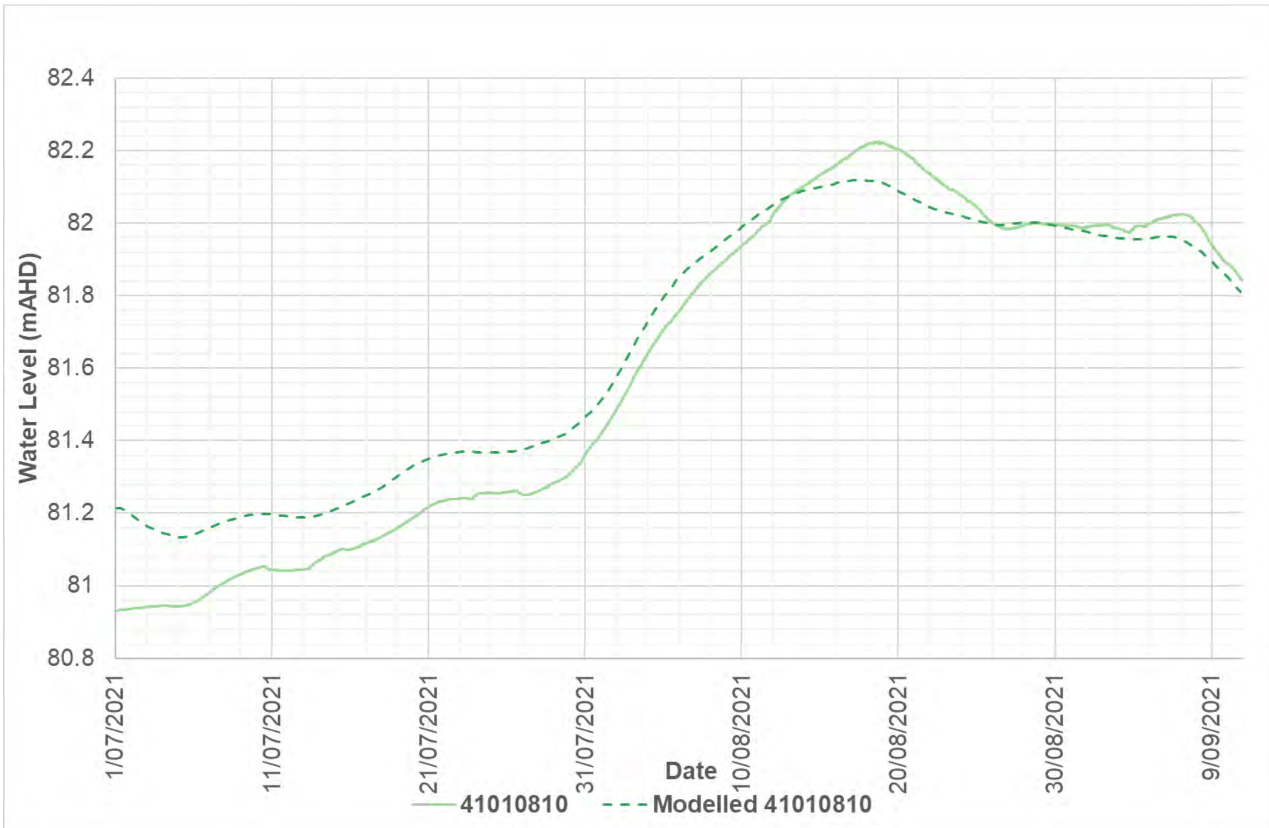


Figure 23: Gauge data water level comparison for August 2021 calibration event

Table 25 provides statistical analysis on the correlation between the modelled and gauged flow and water levels. Performance ratings of results have been defined by the criteria outlined in (Moriasi, 2007). The results in presented in Table 25 demonstrate the August 2021 has an excellent fit to the data in terms of peaks, volume and timing.

Table 25: August 2021 Flow and Water Level Statistics

Statistic	**41010810 Billabong Ck @ Wanganella**	
	Flow	Water Level
PBIAS %	0.2	0.1
NSE	0.98	0.94
r	0.99	1
R2	0.99	0.99
KGE	0.91	0.8
VE	0.95	1

The performance of the model was also assessed spatially by comparing the flood extent generated by the model to the Sentinel satellite imagery captured on the 18/08/2021. The results of this comparison are presented in Figure 24 which show that the model generally matches the areas captured as wet in the satellite imagery well. This provides confidence that the model is performing well.

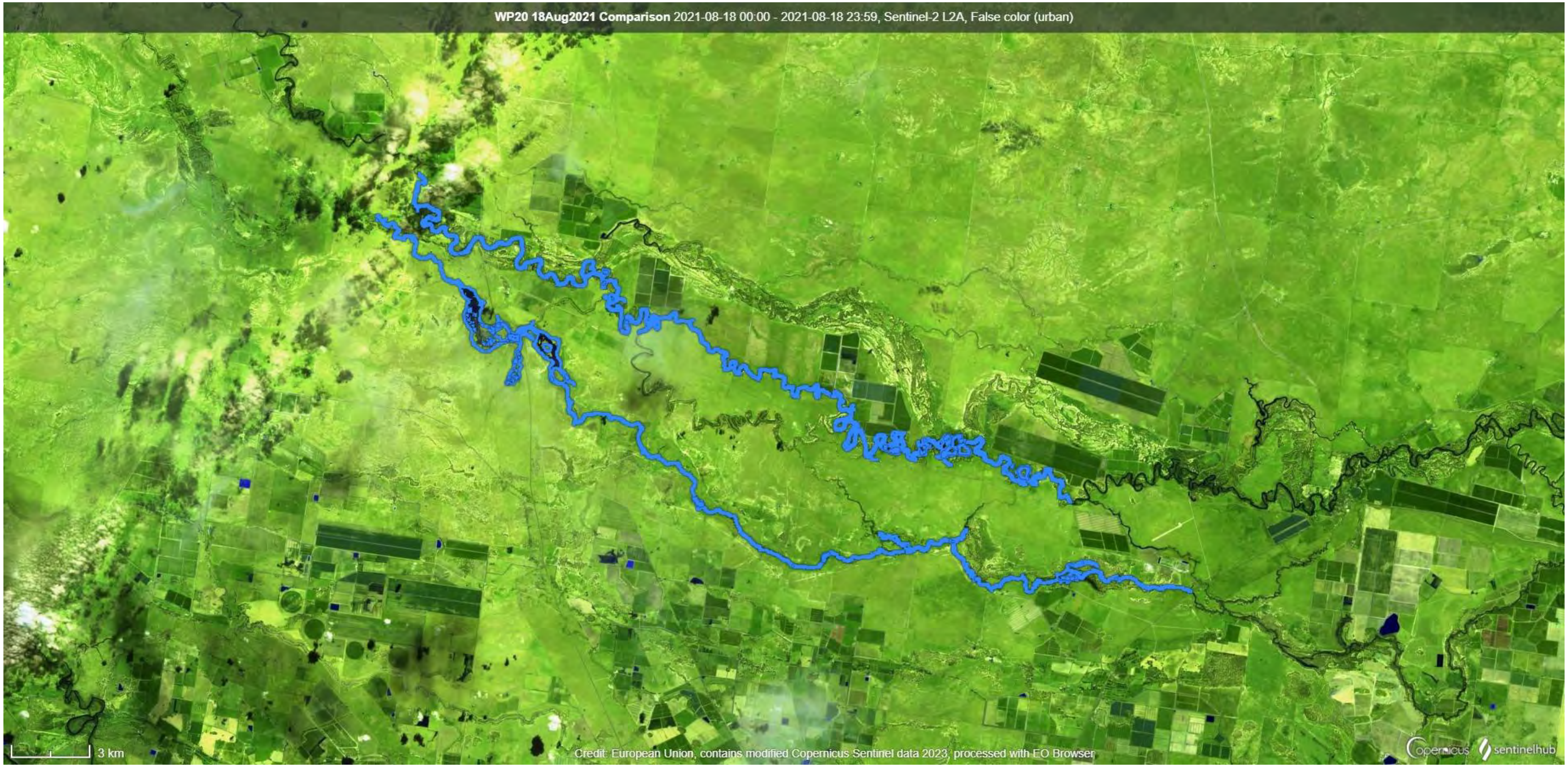


Figure 24: Comparison of model flood extent to Sentinel satellite imagery on 18/08/2021 with False Colour (urban) filter across entire WP20 model area

5.3.4 September 2021 Event

The September 2021 calibration event was modelled using the Conargo gauge flows routed through the Hartwood model presented in Figure 25. This calibration event is a high flow event with a peak of 1,792 ML/day occurring on the 24/09/2021 at the Wanganella gauge.

Figure 26 shows the comparison of gauged and modelled flow hydrographs. Similarly, Figure 27 presents a comparison of gauged and modelled water level hydrographs. Table 26 provides a summary of the model performance against gauged values.

Table 26: September 2021 Event Model Performance

Event	**41010810 Billabong Ck @ Wanganella**		
	Difference in Peak Flow (ML/d)	Difference in Peak Stage (m)	Difference in Timing of Peak Stage (h)
September 2021	34 (1.9%)	0.014	-6.25

Modelled flows and water levels at the Wanganella gauge achieved a good calibration with the observed gauge peaks. The difference in peak water level results was approximately 14 mm. The timing was also a good match with a difference of approximately six (6) hours. The rising and falling limbs in the model were also consistent with those observed at the gauge.

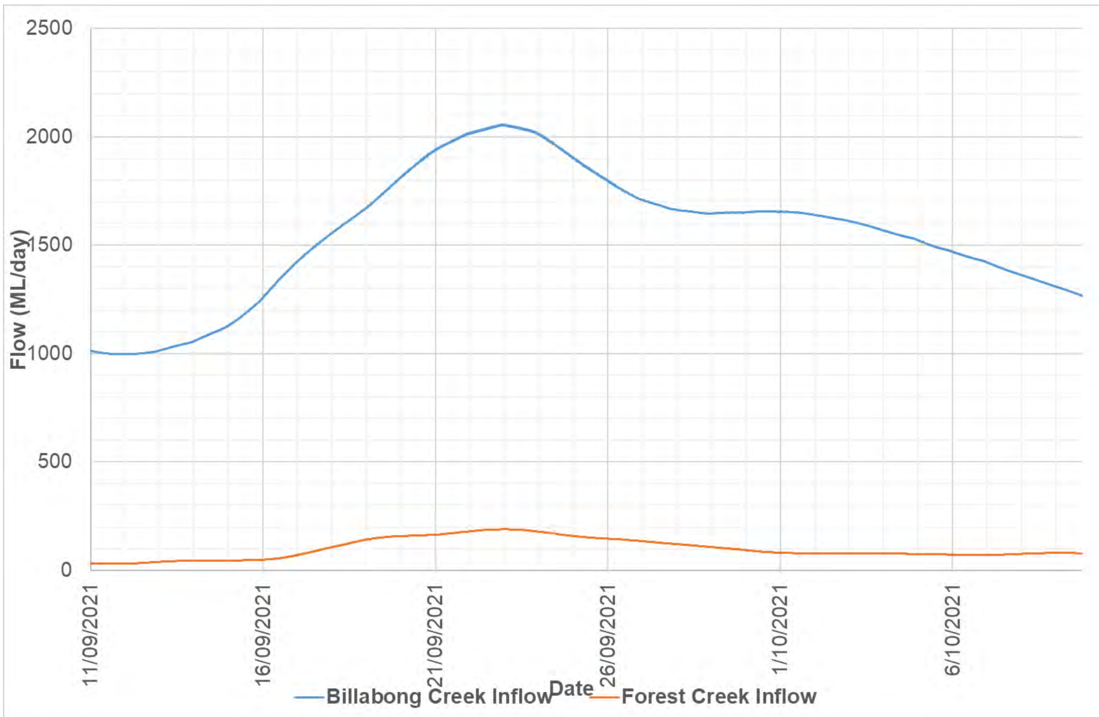


Figure 25: Inflow hydrographs for September 2021 Calibration Event (11/09/2021 to 06/10/2021)

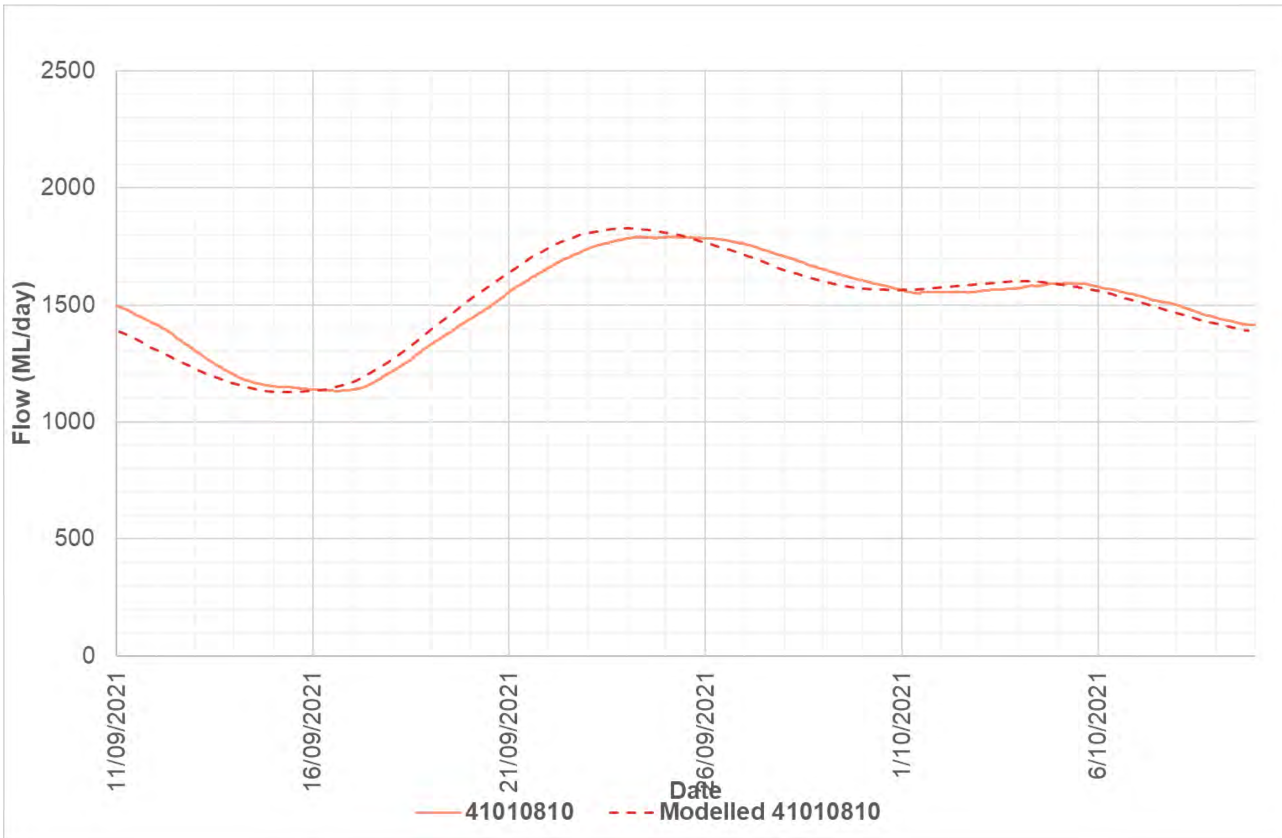


Figure 26: Gauge data flow comparison for September 2021 calibration event

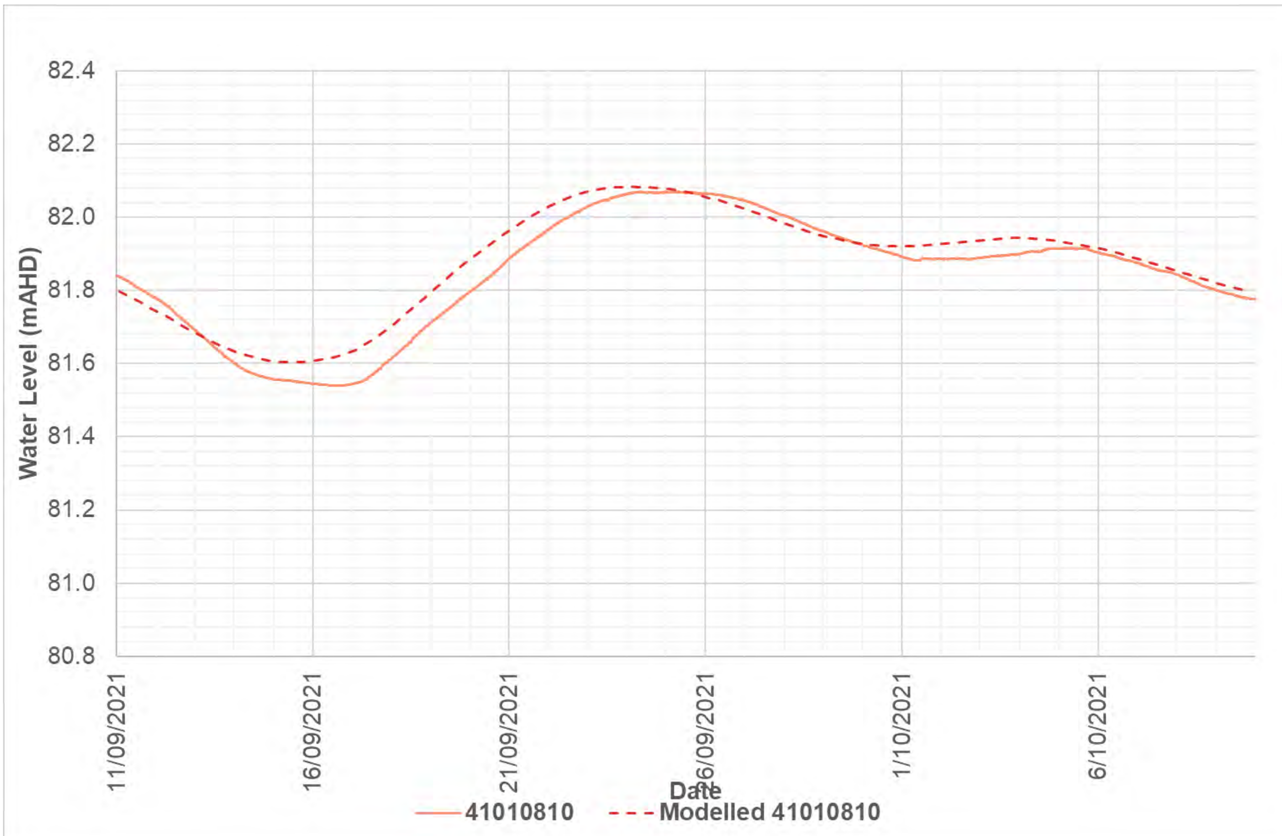


Figure 27: Gauge data water level comparison for September 2021 calibration event

Table 27 provides statistical analysis on the correlation between the modelled and gauged flow and water levels. Performance ratings of results have been defined by the criteria outlined in (Moriasi, 2007).

Table 27: September 2021 Flow and Water Level Statistics

Statistic	**41010810 Billabong Ck @ Wanganella**	
	Flow	Water Level
PBIAS %	0	0
NSE	0.93	0.92
r	0.97	0.98
R2	0.94	0.95
KGE	0.94	0.91
VE	0.97	1

The results in presented in Table 27 present an excellent calibration in terms of peaks, volume and timing.

5.3.4.1 September 2021 Event Comparison against LiDAR

The 2021 LiDAR data 1m and high-resolution aerial imagery was flown for most of the Study Area during September 2021. The availability of this data has allowed for a detailed assessment of model performance for the September 2021 event. The flight dates range from 16th – 23rd September 2021. The exact flight time, however, is unknown.

Modelled flood extents for this date have been compared against the corresponding imagery and LiDAR levels, which captured the surface water level at the time of flight. As the exact time of flight was unknown, the extracted model results may be offset by up to 8 hours.

The comparisons show the following:

- Billabong Creek – a satisfactory match was achieved between modelled and LiDAR levels along the thalweg.
- Forest Creek - a satisfactory match was achieved between modelled and LiDAR levels along the thalweg.
- Eight Mile Creek – a satisfactory match was achieved at the upper and lower (near McCrabbs Regulator) sections of the creek. There appears to be an overestimation of up to 400 mm in water level for a 7km section upstream of Clarkes Creek Regulator. The 2021 LiDAR shows a step level change of approximately +400 mm at Chainage 22000 in Figure 31. This step change in LiDAR seems unusual and could not be replicated in the hydraulic model. For this reason, this discrepancy was not considered to be significant.

A comparison of captured LiDAR water levels to modelled WSL on a range of flight days are presented in the form of long-sections and cross-sections from Figure 29 to Figure 34.

The performance of the model was also assessed spatially by comparing the flood extent generated by the model to the Sentinel satellite imagery captured on the 23/09/2021. The results of this comparison are presented in Figure 28 which show that the model generally matches the areas captured as wet in the satellite imagery well. This provides additional confidence that the model is performing well.

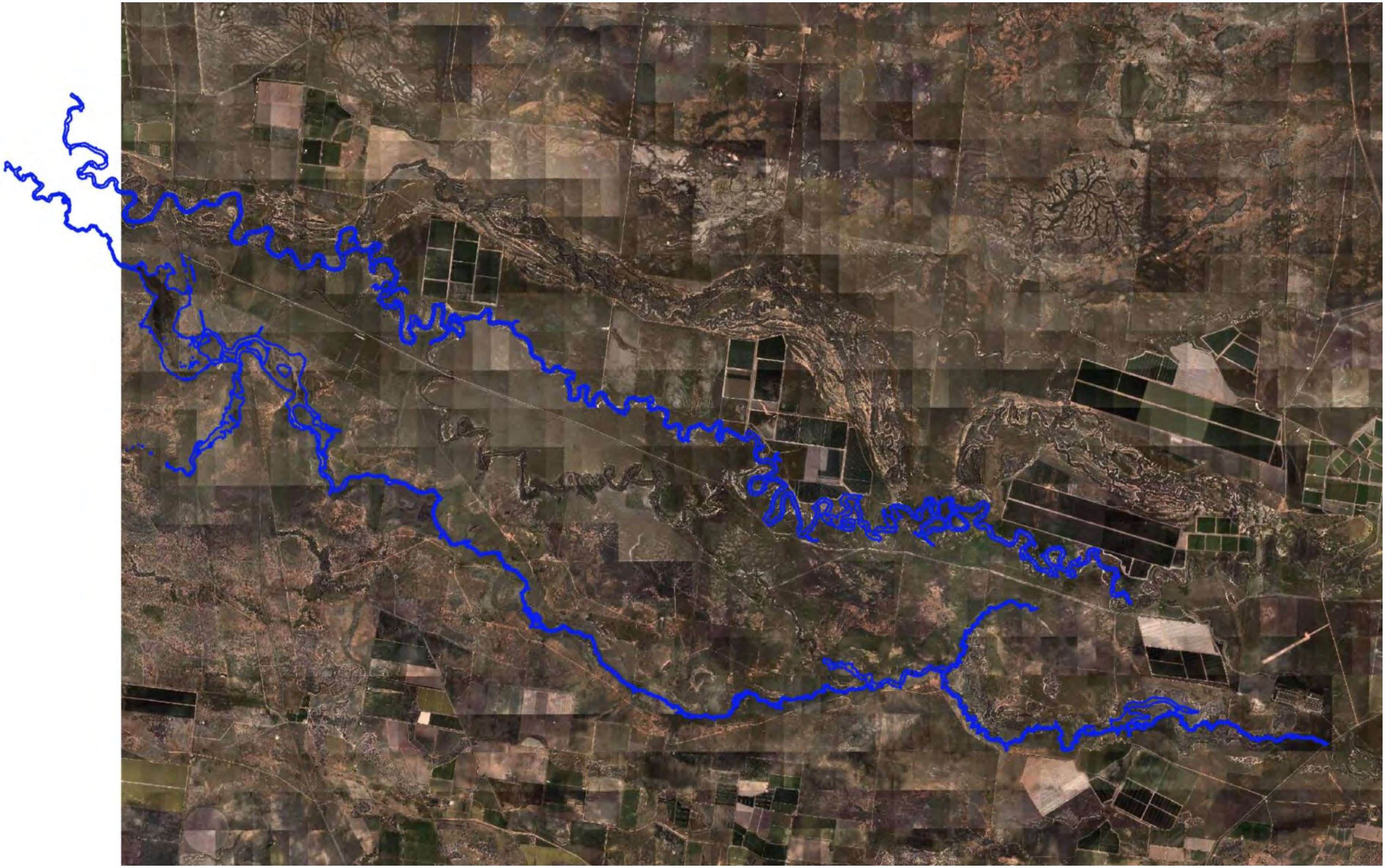


Figure 28: Comparison of model flood extent to Sentinel satellite imagery on 23/09/2021 with LiDAR flown imagery

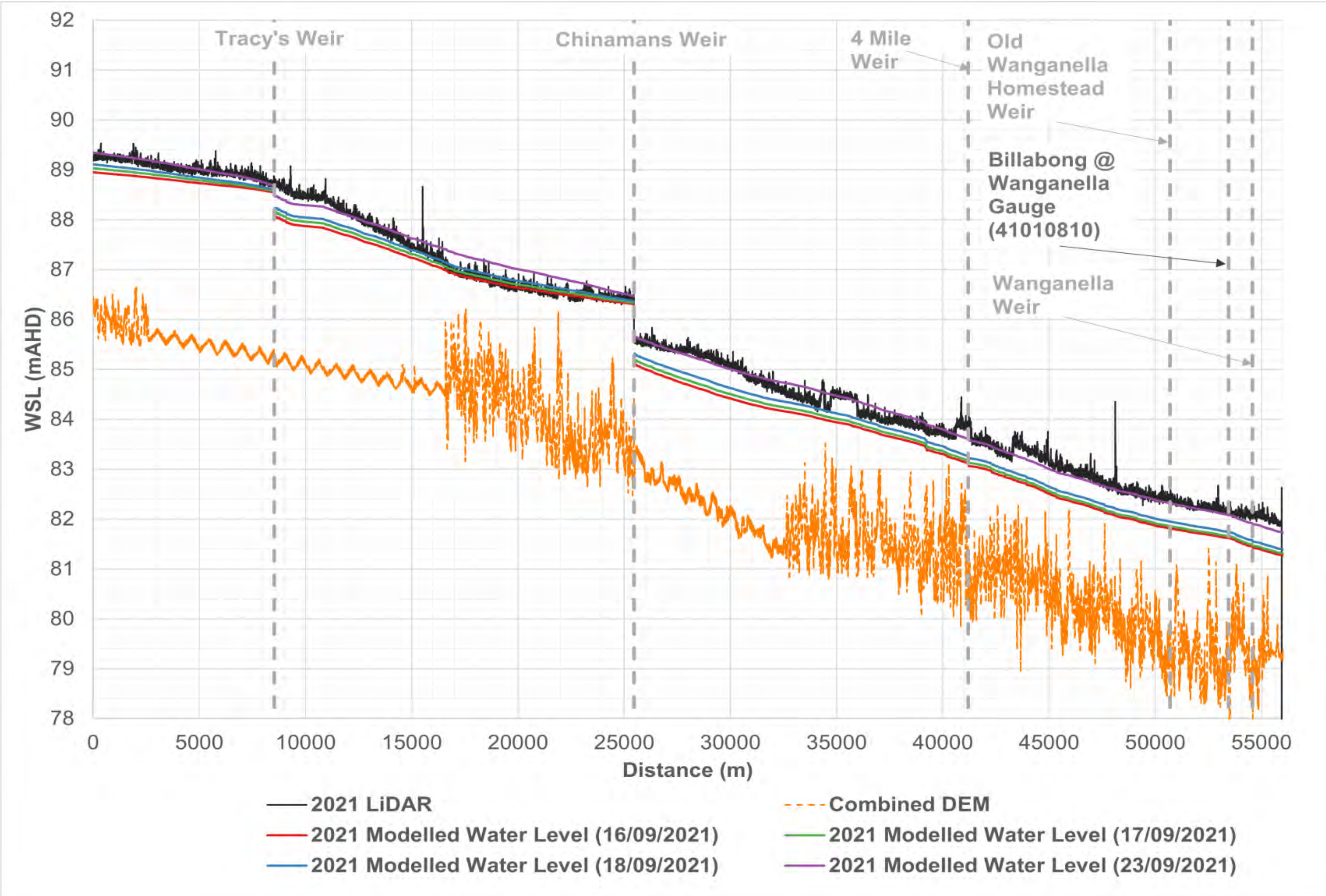


Figure 29: Longitudinal-section profile of Billabong Creek - 16th, 17th, 18th, 23rd Sep 2021

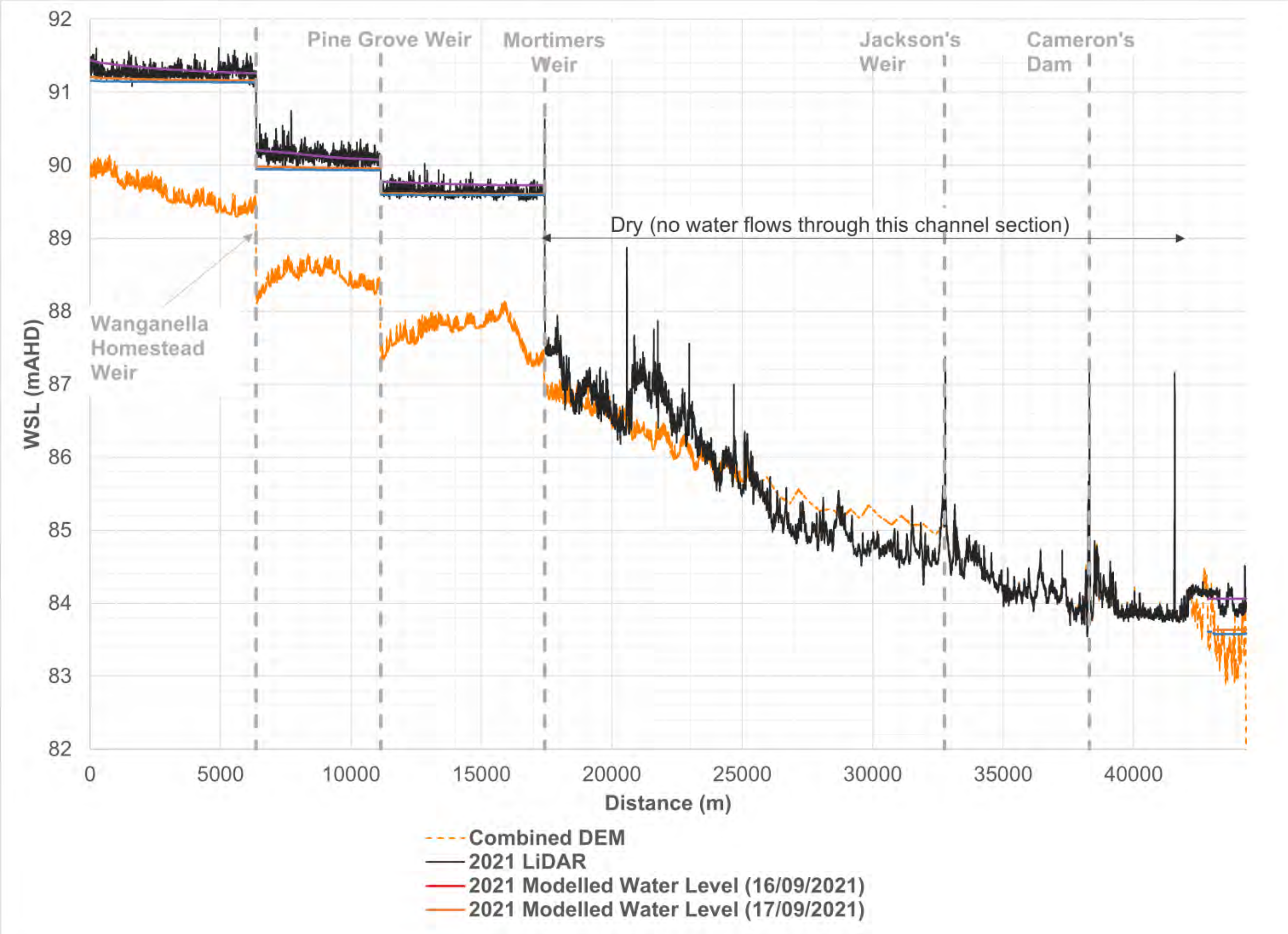


Figure 30: Longitudinal-section profile of Forest Creek - 16th, 17th, 18th, 23rd Sep 2021

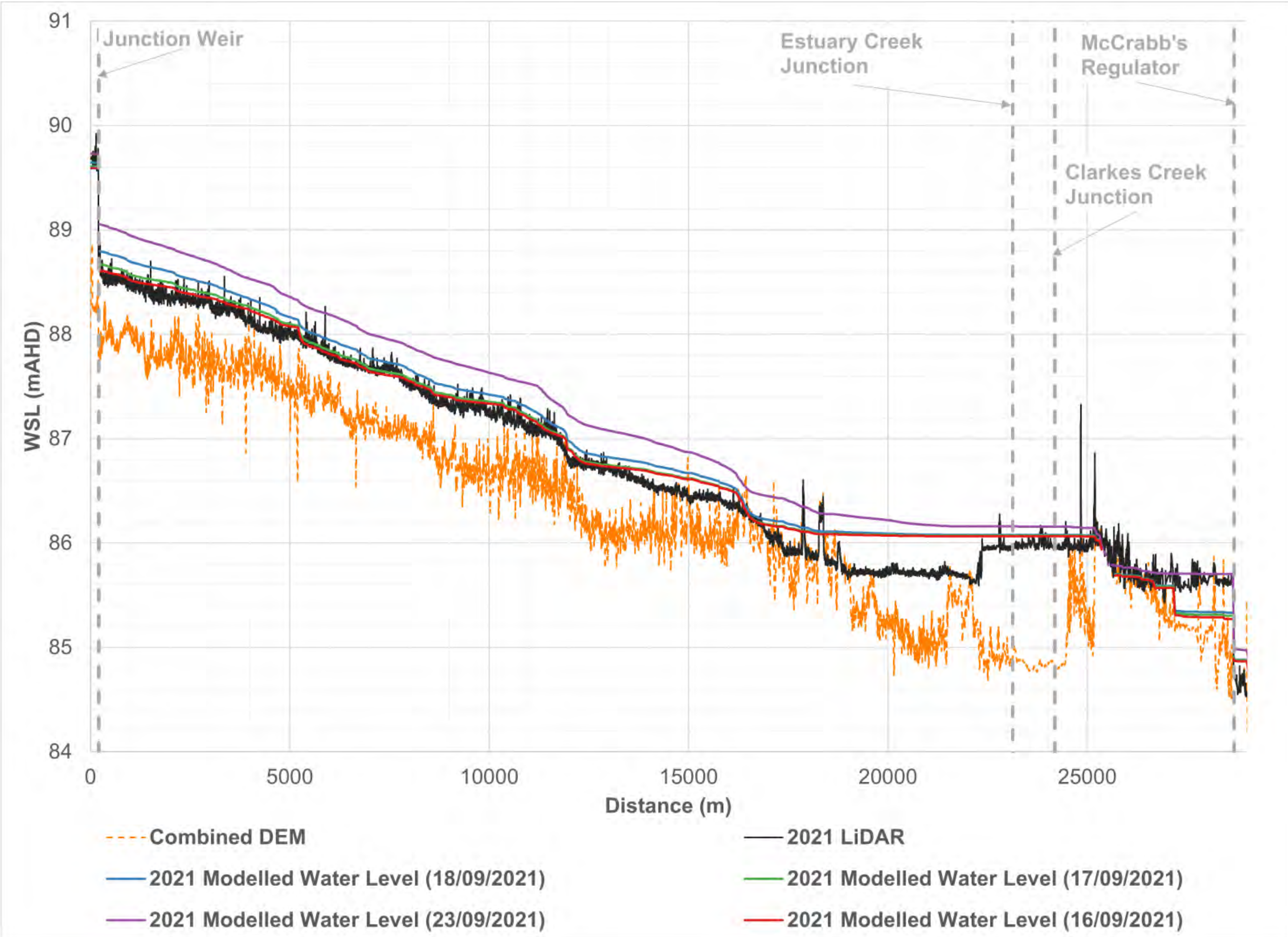


Figure 31: Longitudinal-section profile of Eight Mile Creek - 16th, 17th, 18th, 23rd Sep 2021

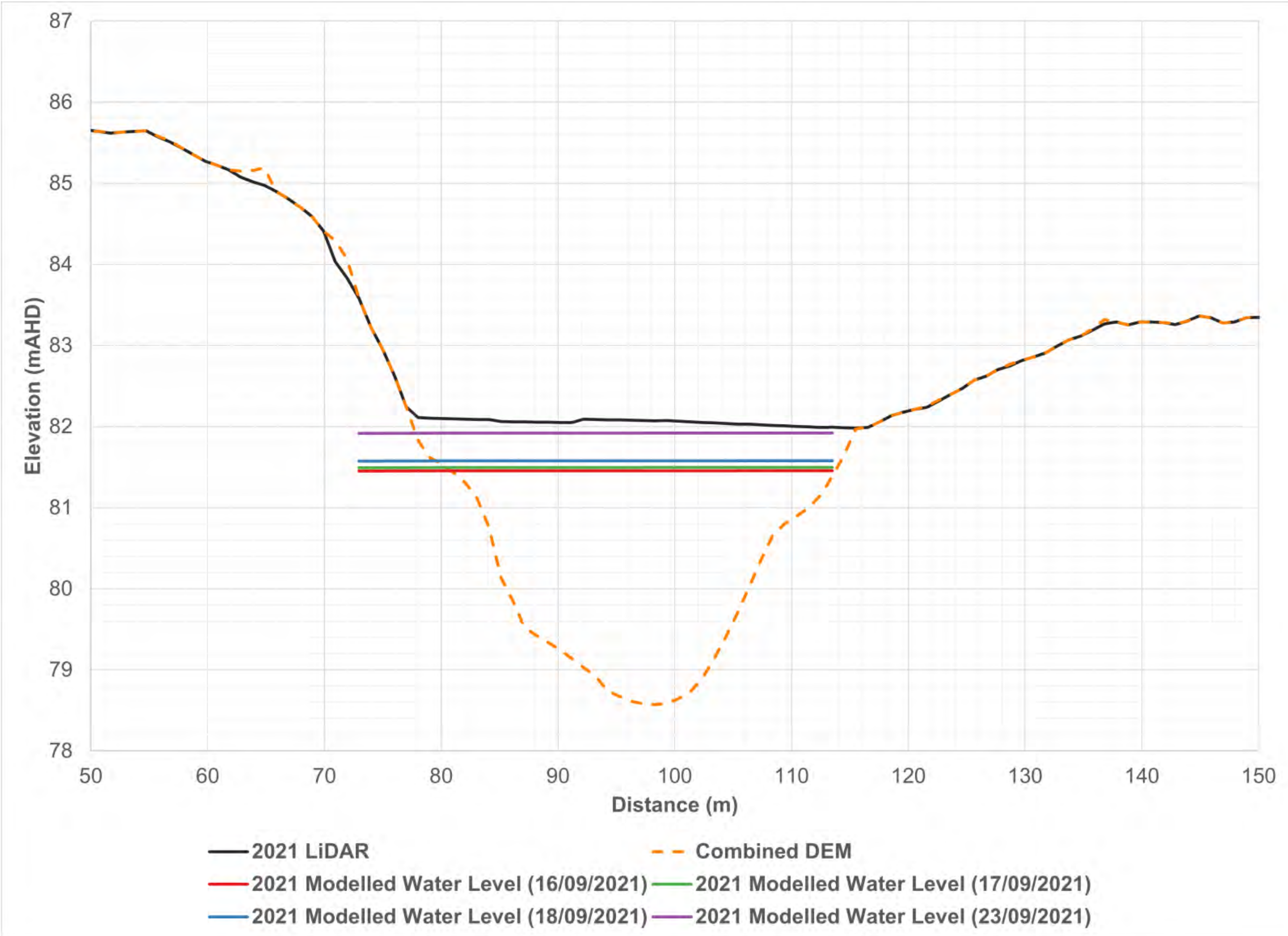


Figure 32: Upstream of Wanganella Weir cross section comparing 2021 LiDAR and modelled water levels

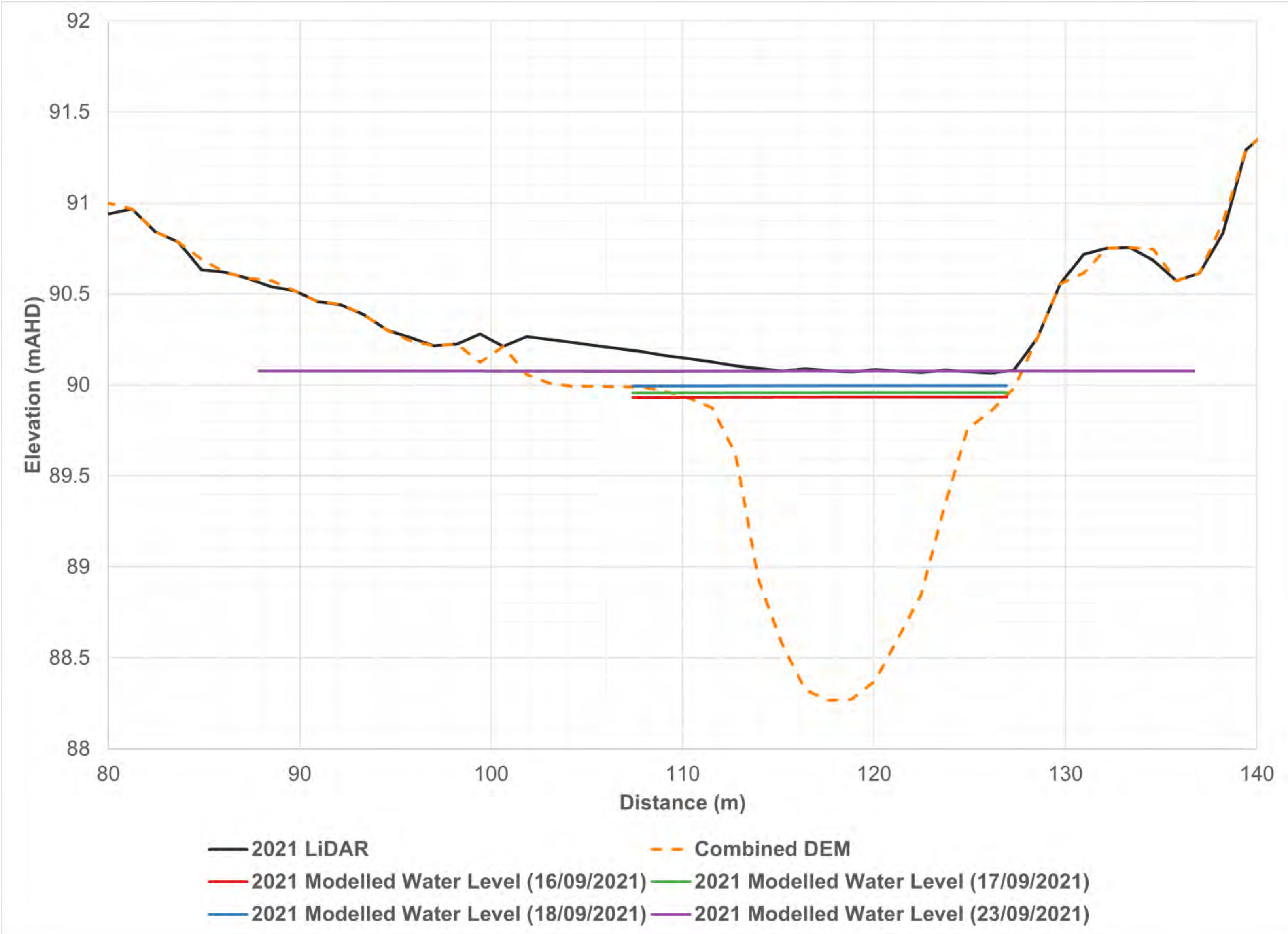


Figure 33: Upstream of Pine Grove Weir cross section comparing 2021 LiDAR and modelled water levels

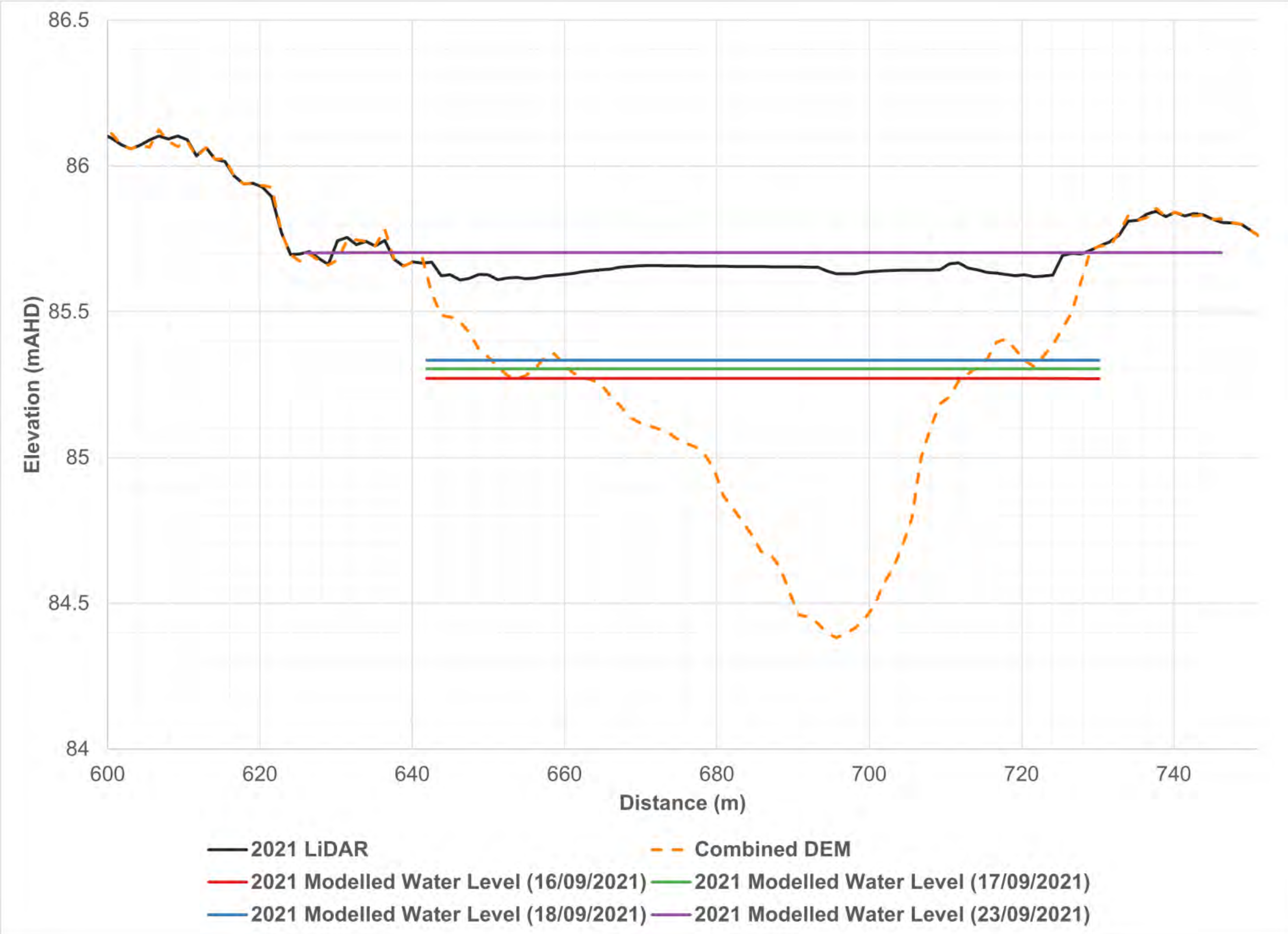


Figure 34: Upstream of McCrabbs Regulator cross section comparing 2021 LiDAR and modelled water levels

5.3.5 Validation October 2021 Event

The purpose of model validation is to test the performance of the calibrated hydraulic model against historic flow events and provide a level of confidence in the performance of the model. Ideally, more recent events will be tested as these will best reflect current instream and floodplain conditions. The October 2021 high flow event was chosen as the validation event as it provided a recent representation of instream and floodplain behaviour.

The October 2021 validation event was modelled using the Conargo gauge flows routed through the Hartwood model presented in Figure 35. This calibration event is a high flow event with a peak of 1,927 ML/day occurring on the 22/10/2021 at the Wanganella gauge. Figure 36 shows the comparison of gauged and modelled flow hydrographs. Similarly, Figure 37 presents a comparison of gauged and modelled water level hydrographs. Table 28 provides a summary of the model performance against gauged values.

Table 28: October 2021 Event Model Performance

Event	**41010810 Billabong Ck @ Wanganella**		
	Difference in Peak Flow (ML/d)	Difference in Peak Stage (m)	Difference in Timing of Peak Stage (h)
Aug 2021	3.7 (0.2%)	-0.023	-34

Modelled water levels at Wanganella gauge matched the peak observed gauge data well. The difference in peak water level results was approximately 23 mm. As with the August 2021 and September 2021 calibration events, the timing of the peak was early, in this case 34 hours early. The timing difference has propagated through to this event as August – October 2021 has been simulated as one long series.

The performance of the model was also assessed spatially by comparing the flood extent generated by the model to the Sentinel satellite imagery captured on the 22/10/2021. The results of this comparison are presented in Figure 38 which show that the model generally matches the areas captured as wet in the satellite imagery well. This provides additional confidence that the model is performing well.

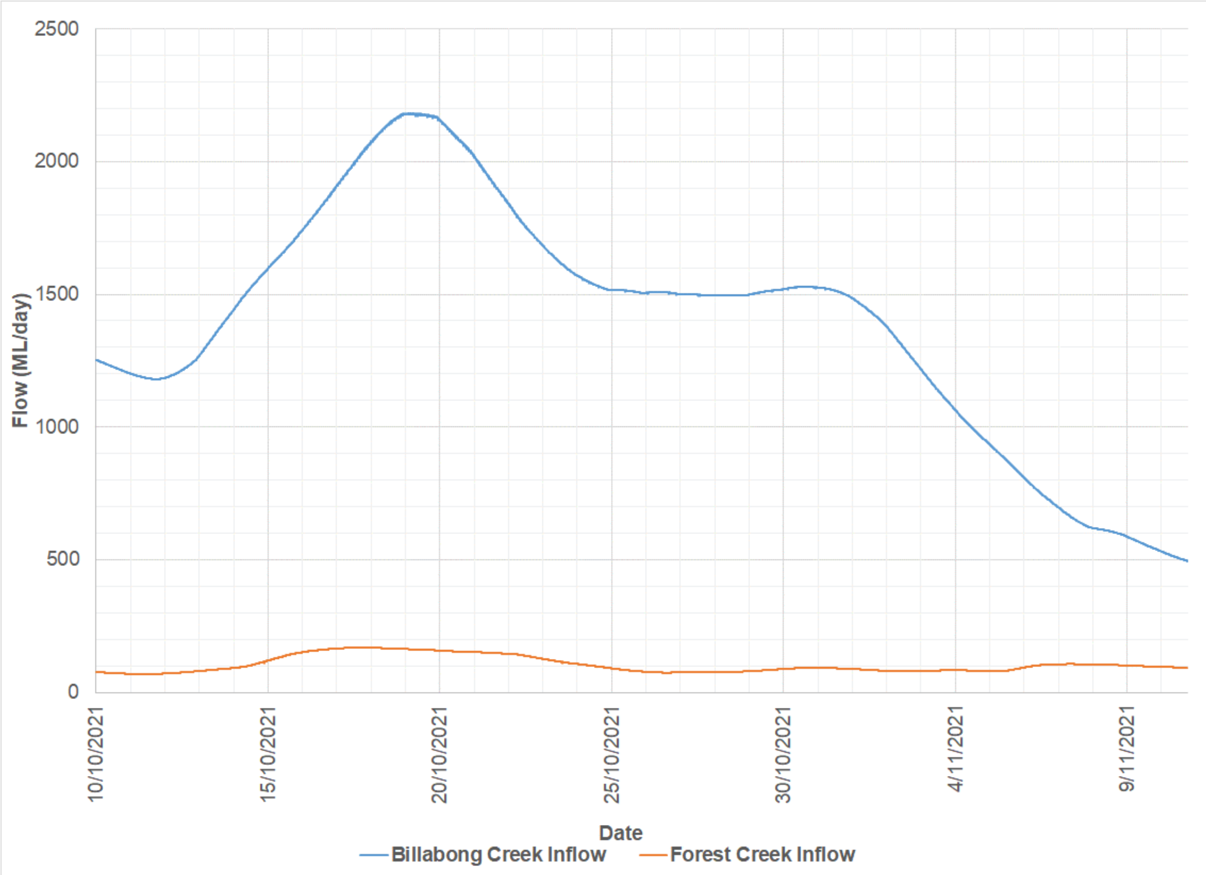


Figure 35: Inflow hydrographs for October 2021 Validation Event (10/10/2021 to 09/11/2021)

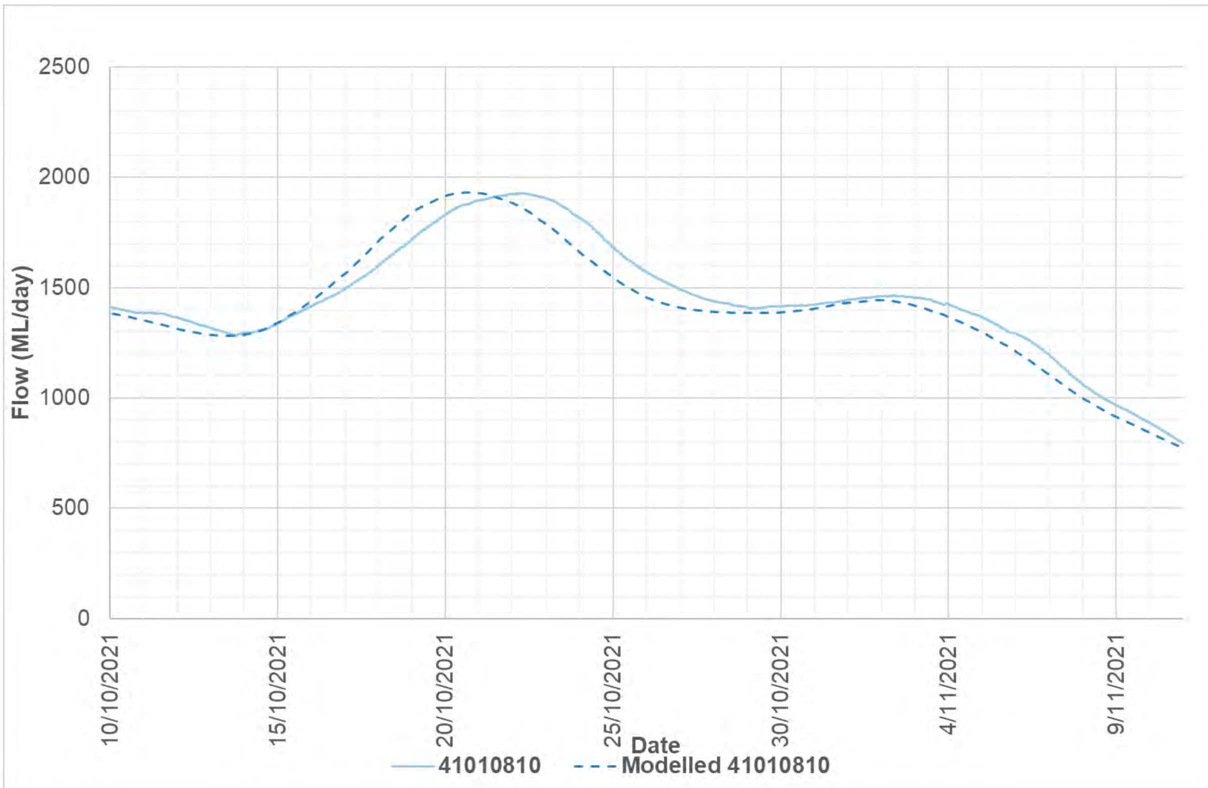


Figure 36: Gauge data flow comparison for October 2021 validation event

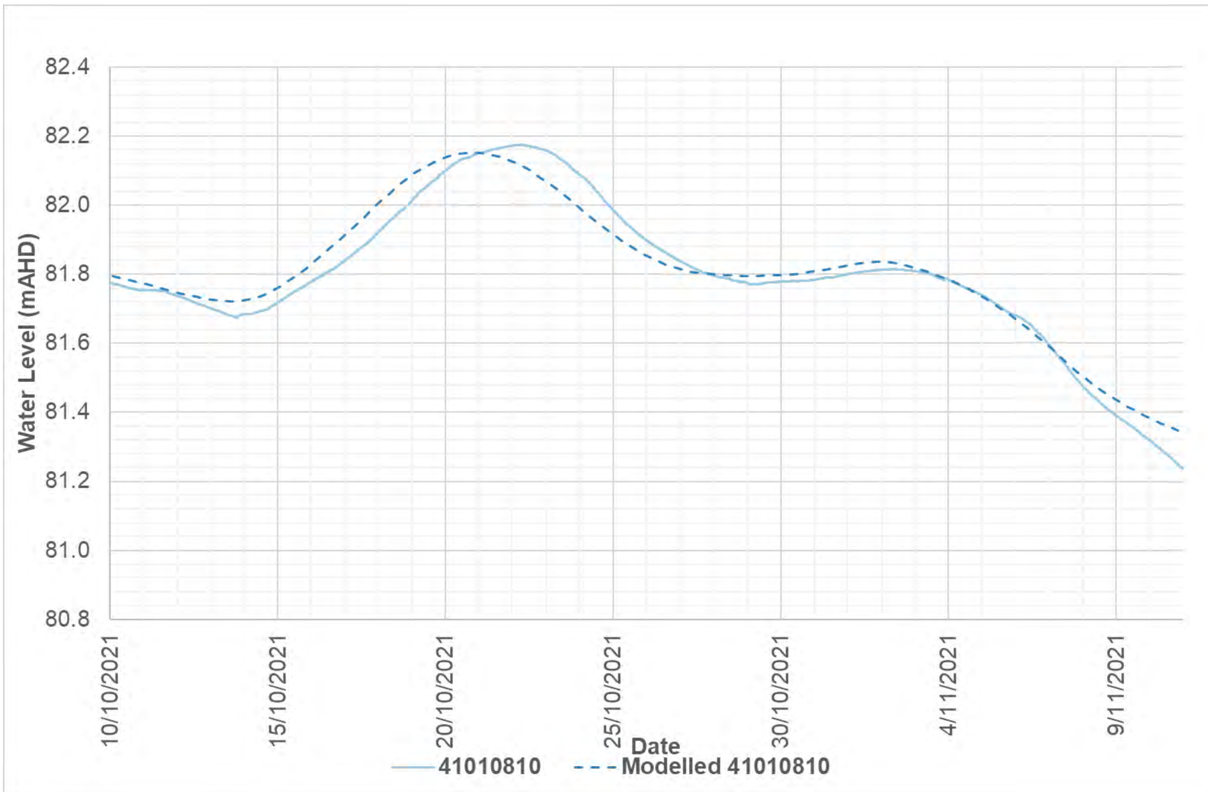


Figure 37: Gauge data water level comparison for October 2021 validation event

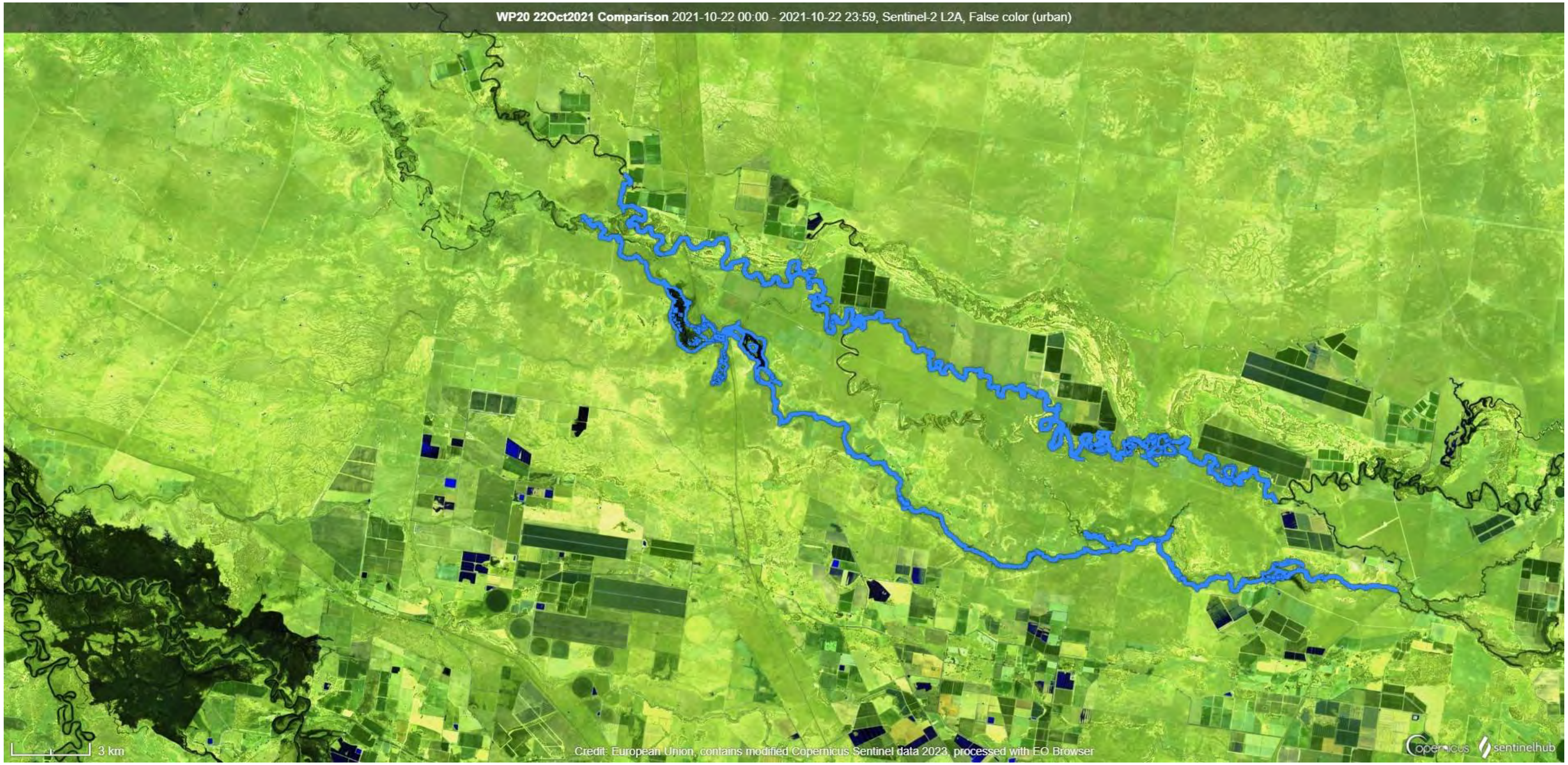


Figure 38: Comparison of model flood extent to Sentinel satellite imagery on 22/10/2021 with False Colour (urban) filter across entire WP20 model area

Table 29 provides statistical analysis on the correlation between the modelled and gauged flow and water levels. Performance ratings of results have been defined by the criteria outlined in (Moriasi, 2007).

Table 29: October 2021 Flow and Water Level Statistics

Statistic	**41010810 Billabong Ck @ Wanganella**	
	Flow	Water Level
PBIAS %	-2.1	0
NSE	0.92	0.95
r	0.97	0.98
R2	0.95	0.96
KGE	0.93	0.91
VE	0.96	1

The results presented in Table 29 represent an excellent fit to peaks, volume and timing.

5.3.6 Rating Curve

Figure 39 presents the rating curve derived from modelling results plotted against the current rating curve listed for the Billabong Creek at Wanganella (41010810) gauge. The plot shows the following key results:

- Within the approximate scenario design flow range of 1,000 ML/day to 2,100 ML/day on Billabong Creek, the model represents the rating curve to within ± 80 mm.
- For the same flow of approximately 1,000 ML/day and 2,100 ML/day, the model matches the recorded gauging's to ± 10 mm, which is a closer match than to the rating curve.
- For flows larger than 2,100 ML/day, the model consistently produces lower water surface levels. At 5,000 ML/day, the model predicts a water surface level that is -250 mm compared to the rating curve.

The following key observation can be made:

- No gauging has been recorded for flows larger than 2,100 ML/day; the highest gauged flow was 2,070 ML/day on the 15/09/2000.

Given that the highest gauged flow was 2,070 ML/day on the 15/09/2000, discharges greater than this are extrapolated. It is well known that extrapolated rating curves contain significant uncertainty (see Herschy, 2009) and therefore it is common to find differences between modelled discharge at higher stages. It is noted that the rating table at Wanganella has been recently extended (during the November 2022 flood event) using a theoretical rating.

To investigate this modelling iterations varying the Manning's n roughness value were simulated but were unable to match the rating curve at higher flows. Even with a Manning's n value that would be considered too high to reasonably adopt, the water surface level was consistently around 200 mm lower than the rating curve. Given that the model explicitly accounts for changes in floodplain topography and accounts for the hydraulic effect of the Cobb Highway Bridge the modelled levels are preferred for higher/larger discharges.

Considering this, the model is considered representative of the gauge up to the gauged flow of 2100 ML/day. The model is considered reasonable to use for higher flow events, until high flow gaugings are undertaken and certainty around the current rating curve can be provided.

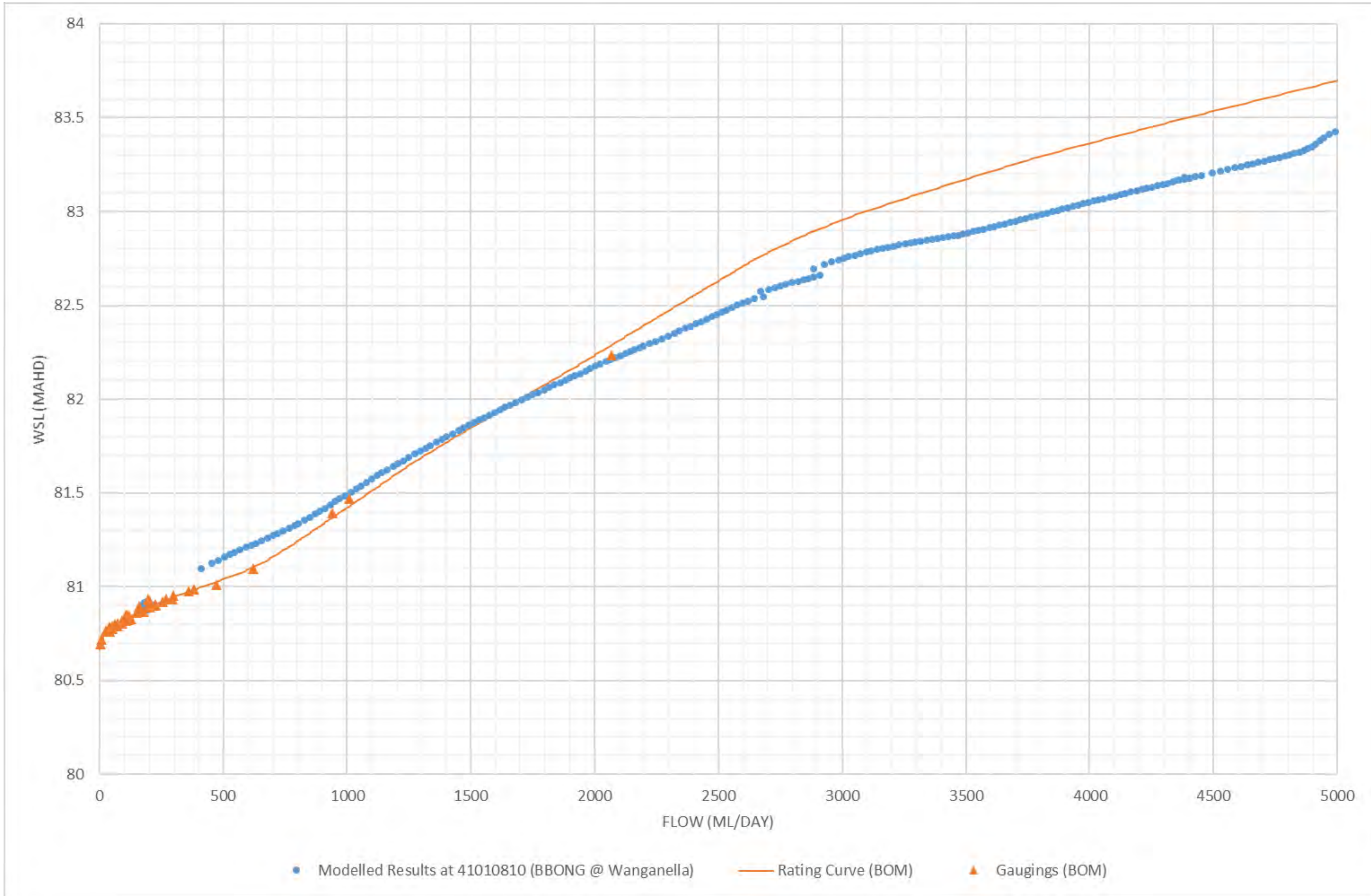


Figure 39: Billabong @ Wanganella Gauge Rating Curve Validation

5.3.7 Validation August 2022 Event (Current Study)

The August 2022 flow event was modelled as an additional validation event based on having a greater understanding of details this high flow event (equivalent to approximately a 2% AEP) on study area for Current Study. The modelling had the following design input:

- The inflow data to this model was based on the Conargo gauge flows routed through the Hartwood model. .
- Modelling the historical storm event between 18/08/2022 8:00am to 30/12/2022 8:00am on the Billabong Creek.
- Boundary condition and Rating Curve applied at the downstream Billabong Creek details see Section 4.3 and Section 5.3.6.

5.3.7.1 Inflow Hydrographs

The inflow hydrographs shown on Figure 40 were adopted for this model. This figure shows that the event is ongoing with an initial peak in August followed by a larger peak, particularly on Billabong Creek during at last four-months of the event. The entire event has a peak flow of 175m^3/s (or 15,000ML/day) in Billabong Creek and 13.7m^3/s (or 1,180ML/day) on Forest Creek. Table 30 summarises the upstream tributary flows into the Wanganella model through Billabong Creek and Forest Creek.

Table 30: Flows toward Billabong Creek and Forest Creek

Reach /Tributary	Billabong Creek		Reach /Tributary	Forest Creek	
	Peak Flow (m^3/s)	Flow @ end of the event (m^3/s)		Peak Flow (m^3/s)	Flow @ end of the event (m^3/s)
Billabong Creek	93.98	20.11	Forest Creek	12.83	3.12
Piccaninny Creek	21.59	0.60	Forest Creek FP	0.82	0.00
Sheepwash Creek	16.02	0.00	-	-	-
Browns Creek	41.59	0.71	-	-	-
Browns Creek FP	2.29	0.00	-	-	-
Total flow (m^3/s)	175.39	21.42	Total flow (m^3/s)	13.65	3.12

5.3.7.2 Results Validation

Figure 41 and Figure 42 below show a comparison of gauged and model results for flow and water level respectively. The results presented in Figure 41 show that modelled peak flows match the timing of the gauged peak flows reasonably well, with Table 31 showing an overestimation of around 3,415 ML/day (or around 29%) of the peak flow in Billabong Creek. However, as shown in Figure 41, the gauged did not capture the peak. Therefore, the comparison/difference between modelled and gauged peak flows are not reliable. Nevertheless, the model appears to reproduce the rising and falling of the hydrograph well in general.

The modelled water level results, presented in Figure 42, provide a good fit to the observed data during the peaks of the flow event with Table 31 showing an underestimation of around 0.38 m at the peak level. This is opposite to the finding in peak flow, indicating the uncertainty is largely caused by the missing rating on large flow rates. The modelled and gauged water level timeseries (shape) in Billabong Creek downstream of Wanganella (41010810) exhibit a reasonable match considering the uncertainties high flows rating.

Table 31: August 2022 Event Model Performance

Event	**41010810 Billabong Ck @ Wanganella**		
	Difference in Peak Flow (ML/d)	Difference in Peak Stage (m)	Difference in Timing of Peak Stage (h)
Aug 2022	3,415(29%)	-0.38	-72

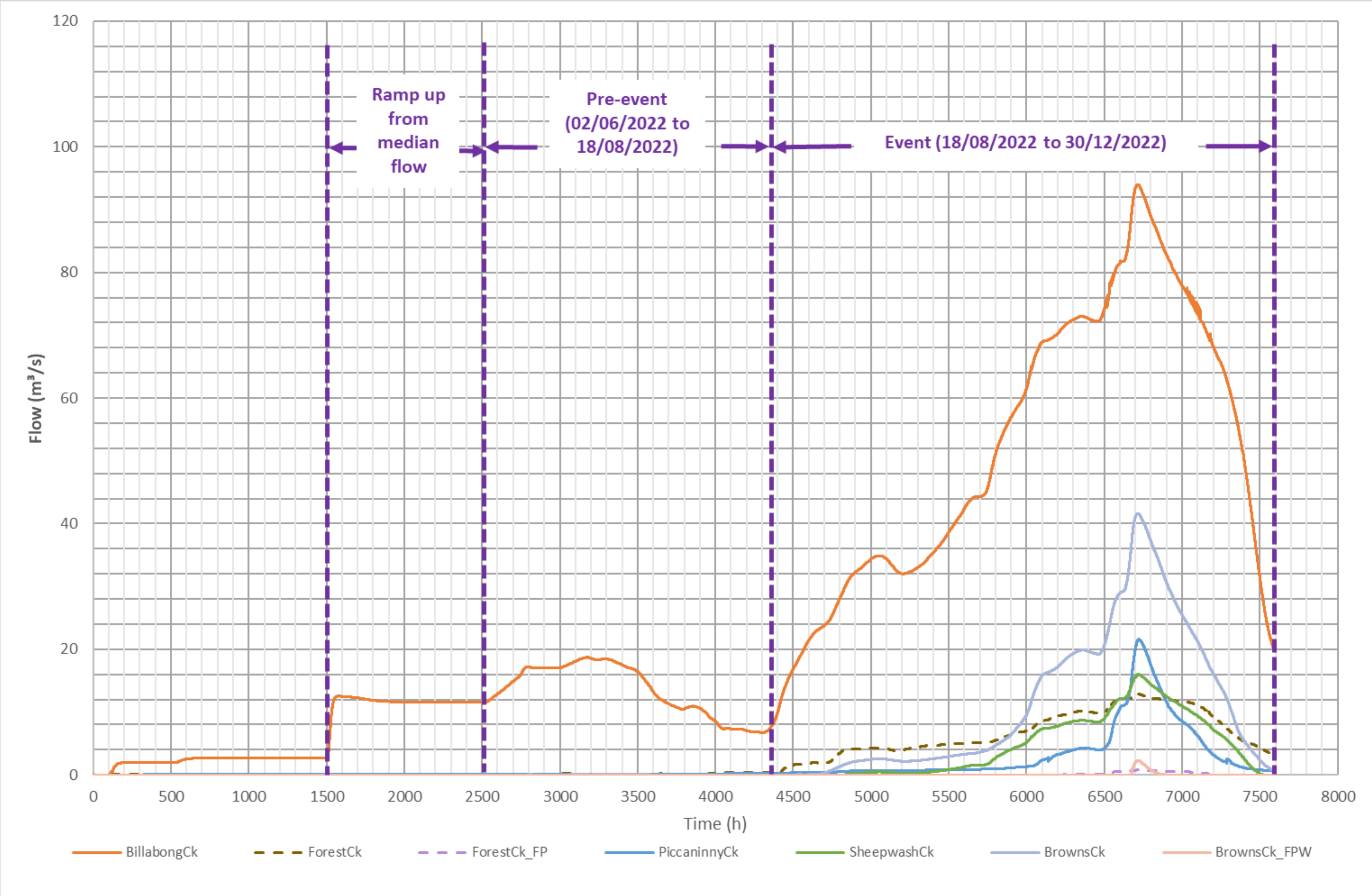


Figure 40: Inflow hydrographs for August 2022 Event (18/08/2022 to 30/12/2022) for Current Study

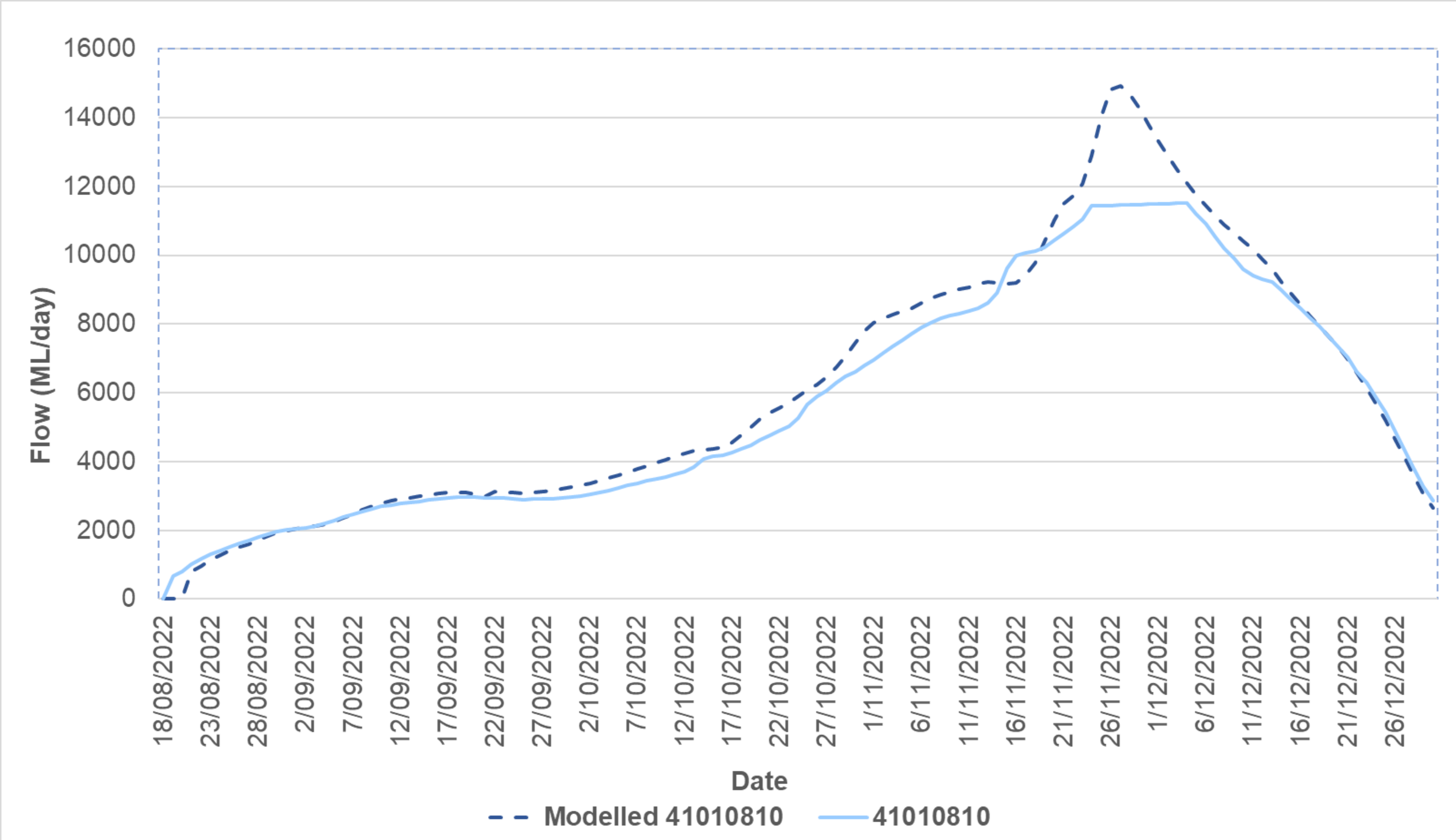


Figure 41: Gauge data flow comparison for August 2022 validation event for Current Study

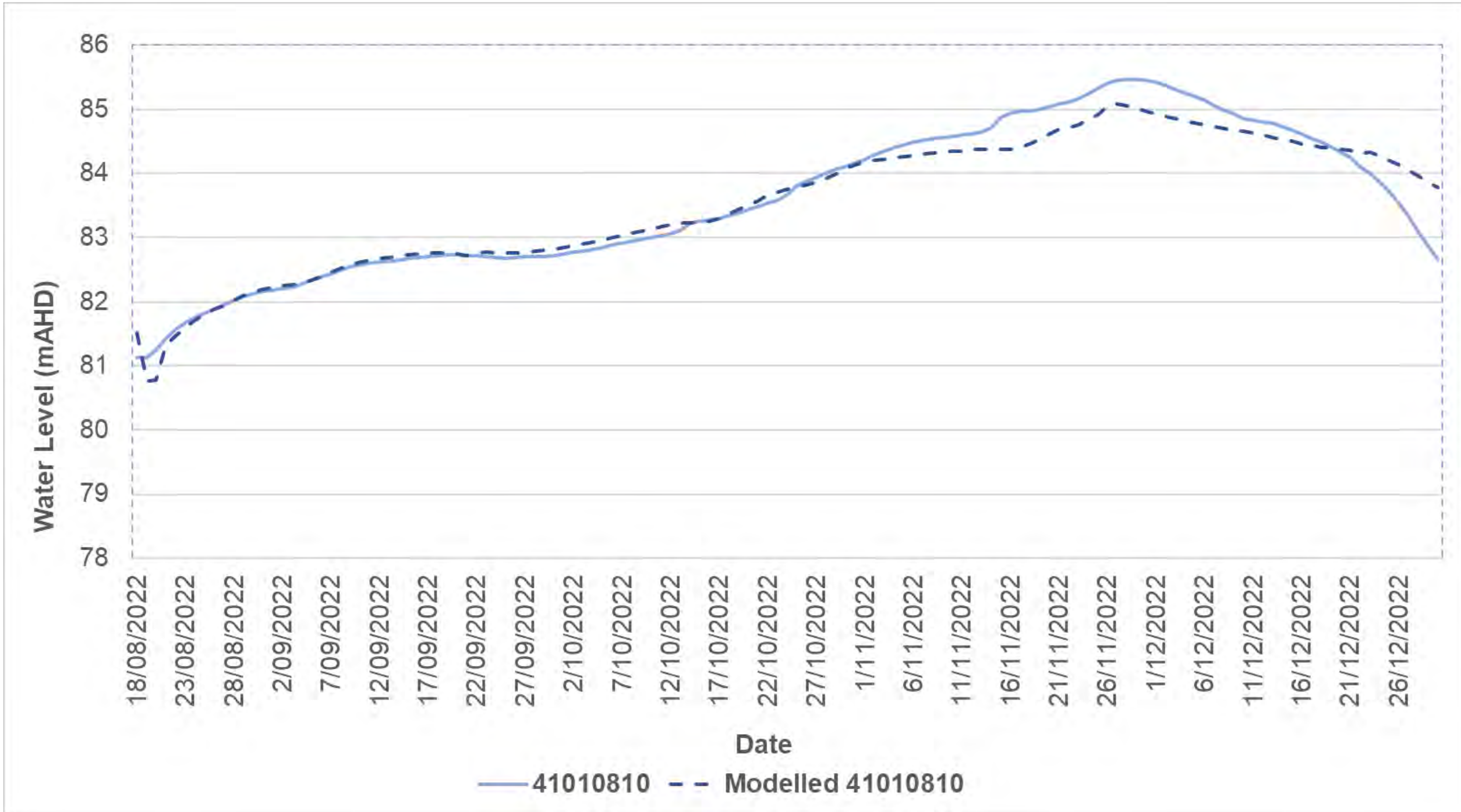


Figure 42: Gauge data water level comparison for August 2022 validation event for Current Study.

Table 32 provides statistical analysis on the correlation between the modelled and gauged flow and water levels. Performance ratings of results have been defined by the criteria outlined in (Moriasi, 2007). The results presented in Table 31 represent a reasonable fit to peaks, volume and timing.

Table 32: August 2022 Flow and Water Level Statistics

Statistic	**41010810 Billabong Ck @ Wanganella**	
	Flow	Water Level
PBIAS %	+7.2	-0.1
NSE	0.94	0.94
r	0.99	0.97
R2	0.94	0.94
KGE	0.84	0.89
VE	0.91	1.00

5.3.8 Calibration and Validation Conclusion

The WP20 model has been rigorously tested through calibration and validation with the following modelling runs:

- August 2017 low flow event calibration.
- August 2021 Initial high flow event calibration.
- September 2021 Initial second high flow event calibration.
- October 2021 validation event.
- Rating Curve verification.
- August 2022 high flow validation event (Current Study)

All of the calibration and validation runs were able to reproduce peak flow within 10% of gauged values and peak water levels within 105 mm, except for the August 2022 event. Statistical analysis of the results indicated that there were some timing errors which particularly effected the September 2021 and October 2021 results; however, the WP20 model was able to reproduce the same of the events and the volumes. Given this model can be considered well calibrated.

The WP20 model was also able to reproduce the established rating table in the peak flow range between 1,000 to 2,000 ML/day. Below this range the model tended to overestimate water level. Above the 2,000 ML/day the model results are preferred for the reasons outlined above.

The relatively lower accuracy in the August 2022 event validation is not only caused by the reliability of the model but also the significant uncertainty in the observed water level and rating curve during the high flow / peak period. This issue is not considered to be significant for the following reasons:

- The assessment presented here is effectively a comparative assessment and it is the differences that are of interest more so than the absolute values.
- It has been comprehensively demonstrated in, Section 7.2, that there are no flood impacts from larger events, with reductions in flood levels near sensitive receptors. Hence if the actual water levels for the 1% AEP event are higher there will be no impact.

The results presented in this section have shown that the model performs reasonably well under a range of flow scenarios and is therefore considered appropriate for use in the current Study to assess the impact of the proposed Wangenella Regulator independently, as well as cumulatively with other SDLAM works within the Study Area.

6. Proposed Model Setup

6.1 Overview of Changes

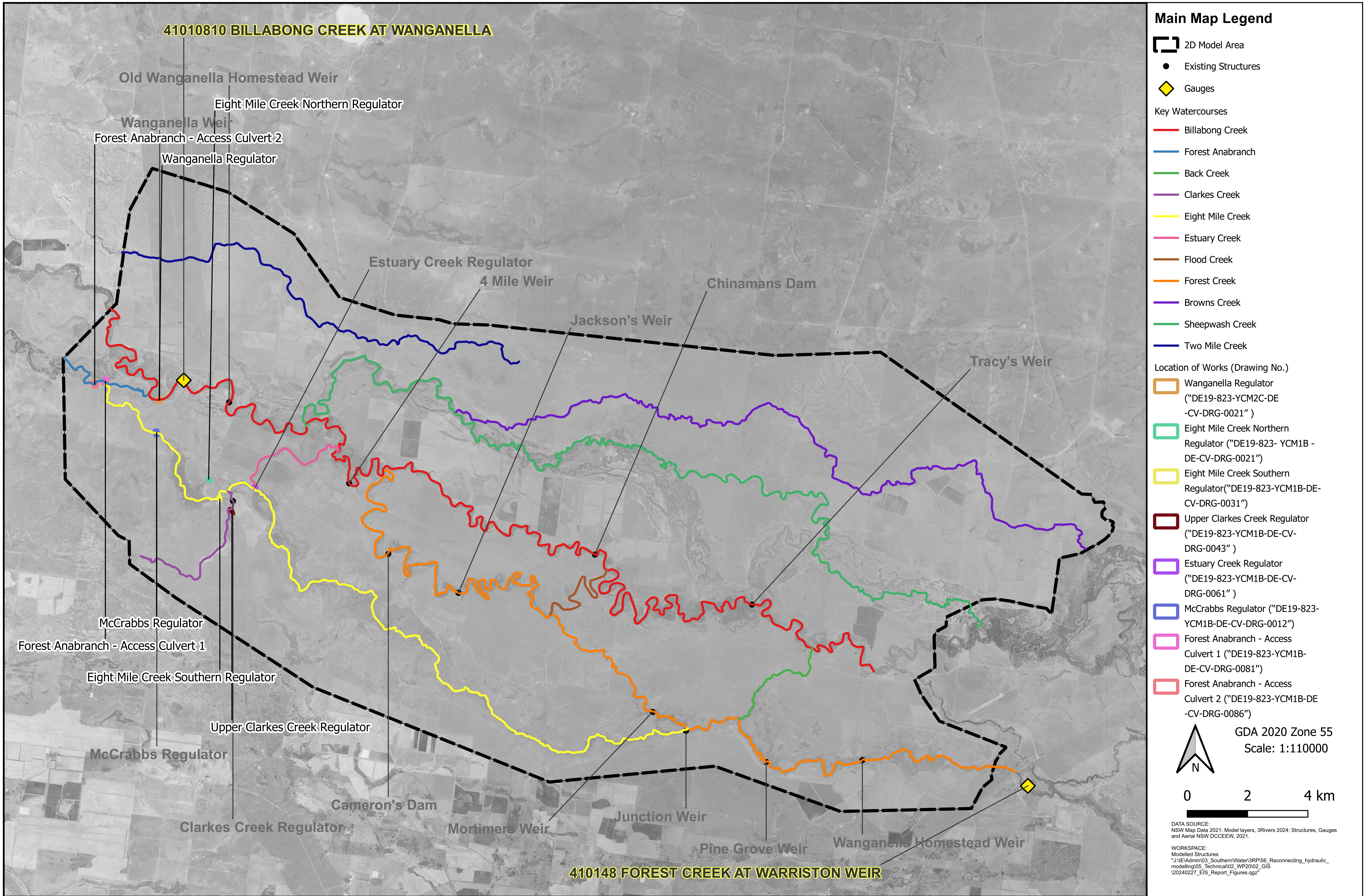
The proposed model has had the following new proposed structures added or updated for the design case:

- Wanganella Regulator.
- Eight Mile Creek Northern Regulator*.
- Eight Mile Creek Southern Regulator*.
- Upper Clarke's Creek Regulator*.
- Estuary Creek Regulator.
- McCrabbs Regulator*.
- Forest Anabranch Access Culvert 1 & 2

* *These structures are currently Work-In-Progress and it is expected that the design of these structures will change in the future.*

Details of how these structures have been added to the model are summarised in the proceeding sections and are based on the design as of mid-October 2023 and the following design drawings relevant at that time:

- Wanganella Regulator – marked up version B of the "DE19-823-YCM2C-DE-CV-DRG-0021" drawing set from 19/06/2023.
- Eight Mile Creek Northern Regulator – a copy of version C of the "DE19-823- YCM1B -DE-CV-DRG-0021" drawing set from 17/08/2023.
- Eight Mile Creek Southern Regulator – a copy of version A of the "DE19-823-YCM1B-DE-CV-DRG-0031" drawing set from 17/08/2023.
- Upper Clarkes Creek Regulator – a copy of version A of the "DE19-823-YCM1B-DE-CV-DRG-0043" drawing set from 17/08/2023.
- Estuary Creek Regulator – marked up version B of the "DE19-823-YCM1B-DE-CV-DRG-0061" drawing set from 17/08/2023.
- McCrabbs Regulator – marked up version C of the "DE19-823-YCM1B-DE-CV-DRG-0012" drawing set from 17/08/2023.
- Forest Anabranch -Access Culvert 1 – a copy of version A of the "DE19-823-YCM1B-DE-CV-DRG-0081" drawing set from 17/08/2023.
- Forest Anabranch -Access Culvert 2 – a copy of version A of the "DE19-823-YCM1B-DE-CV-DRG-0086" drawing set from 17/08/2023.



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

Figure 43: WP20 Proposed Locations of works

3Rivers

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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 "Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Piccaninny Weir to Wanganella Weir Study Area" 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.

6.2 Wanganella Weir Regulator Design

The proceeding sections outline the model changes that have been included in one or more of the proposed scenario model simulations associated with the works at Wanganella Weir, the location of which is presented in Figure 43.

6.2.1 Proposed Regulator Structure

As per the Concept Design the proposed Wanganella Weir has been shifted approximately 55 m downstream of the existing structure and has now been designed to include the following elements to control the passing flow and level of the weir pool:

- A fishway section to allow fish passage on the western bank– which is being modelled in detail in CFD, but has been included in the hydraulic model as an arbitrary link (an operational pump in TUFLOW) that will pass a constant flow of approximately 20 ML/day.
- A gated section of weir that can be controlled to pass operational and/or environmental flows, whilst maintaining a weir pool level – this section consists of four (4) by 2.02 m wide lay flat gates with a sill level of 80.75 m AHD (modelled as a sharp crested weir or “WR” channel in TUFLOW with a 4× multiplier to represent the multiple gates with invert level of 80.20 m AHD).
- A fixed crest section of weir that will block off the remainder of the channel to maintain the weir pool – this section consists of a rectangular shape broad crested weir with a crest level of 82.20 m AHD and a width of 20.5 m (modelled as a broad crested weir or “WW” channel with a user-defined cross-section in TUFLOW).
- The proposed structure will also include the following works around Wanganella Weir will also include the following:
    - A maintenance gantry over the fishway and gated/fixed crest portions of the proposed weir – this has not currently been modelled to allow gates and fixed crest weir to be represented as weirs within TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 85.40 m AHD (the impact will particularly be minor for the operational flows and more frequent events).
    - Basin at upstream and downstream of the weir (modelled as a 1D channel or “S” type channel in TUFLOW) and transition back to natural downstream channel to facilitate fish passage, which also has a trafficable deck over it to allow for maintenance of the structure this structure has not been modelled, however the fish way with flow rate 20MLD (modelled as a pumping function with Type ‘P’ in TUFLOW).

The general cross-section of the obstruction of the proposed weir is presented in Figure 44, which shows the sill level of the structure at three locations through the proposed structure – upstream cross-section (representing fishway, gates and fixed crest weir), mid cross-section (representing the stilling basin downstream of gates and weir) and downstream cross-section (representing the transition back to existing terrain under the trafficable deck).

The gated section of the upstream cross-section has been modelled as follows under the various flow scenarios:

- Minimum Operational Flow or “MinOF” (30 ML/day) – target flow is passed through fishway (20 ML/day) and one of the four gates (10 ML/day), which were set to be open as follows (the remaining three gates were fully closed and set to a level of 82.20 m AHD to match the fixed crest weir height) -
    - Minimum Operating Level or “MinOL” (a weir pool level of 80.75 m AHD) – the open gate has been set to have a crest level of 80.71 m AHD based on a weir calculation for opening, target flow rate and target upstream level.

  - Maximum (Normal) Operating Level or "MaxOL" (a weir pool level of 80.99m AHD) – the open gate has been set to have a crest level of 80.95 m AHD based on a weir calculation for opening, target flow rate and target upstream level.
  - Full Supply Level or "FSL" (a weir pool level of 82.10 m AHD, when the pool is in full supply, i.e., "FSL") – the open gate has been set to a crest level of 82.06 m AHD based on a weir calculation for opening, target flow rate and target upstream level.
- Maximum Operational Flow or "MaxOF" (400 ML/day) – target flows are passed through fishway (20 ML/day) and three of the four gates flow (380 ML/day), which were set to be open as follows (the remaining one gates were fully closed and set to a level of 82.20 m AHD to match the fixed crest weir height) -
  - Minimum Operating Level or "MinOL" (a weir pool level of 80.75 m AHD) – the open gates have been set to have a crest level of 80.20 m AHD based on a weir calculation for opening, target flow rate and target upstream level.
  - Maximum (Normal) Operating Level or "MaxOL" (a weir pool level of 80.99 m AHD) – the open gates have been set to have a crest level of 80.54 m AHD based on a weir calculation for opening, target flow rate and target upstream level.
  - Full Supply Level or "FSL" (a weir pool level of 82.10 m AHD) – the open gates have been set to have a crest level of 81.65 m AHD based on a weir calculation for opening, target flow rate and target upstream level.
- Flood flows (50% AEP to PMF) – all four gates are fully opened in advance of event based on proposed operating rules and understanding of likely flows based upstream gauges. As per the design, the fully open state of the gates has been assumed to match the sill of 80.75 m AHD for modelling purposes.

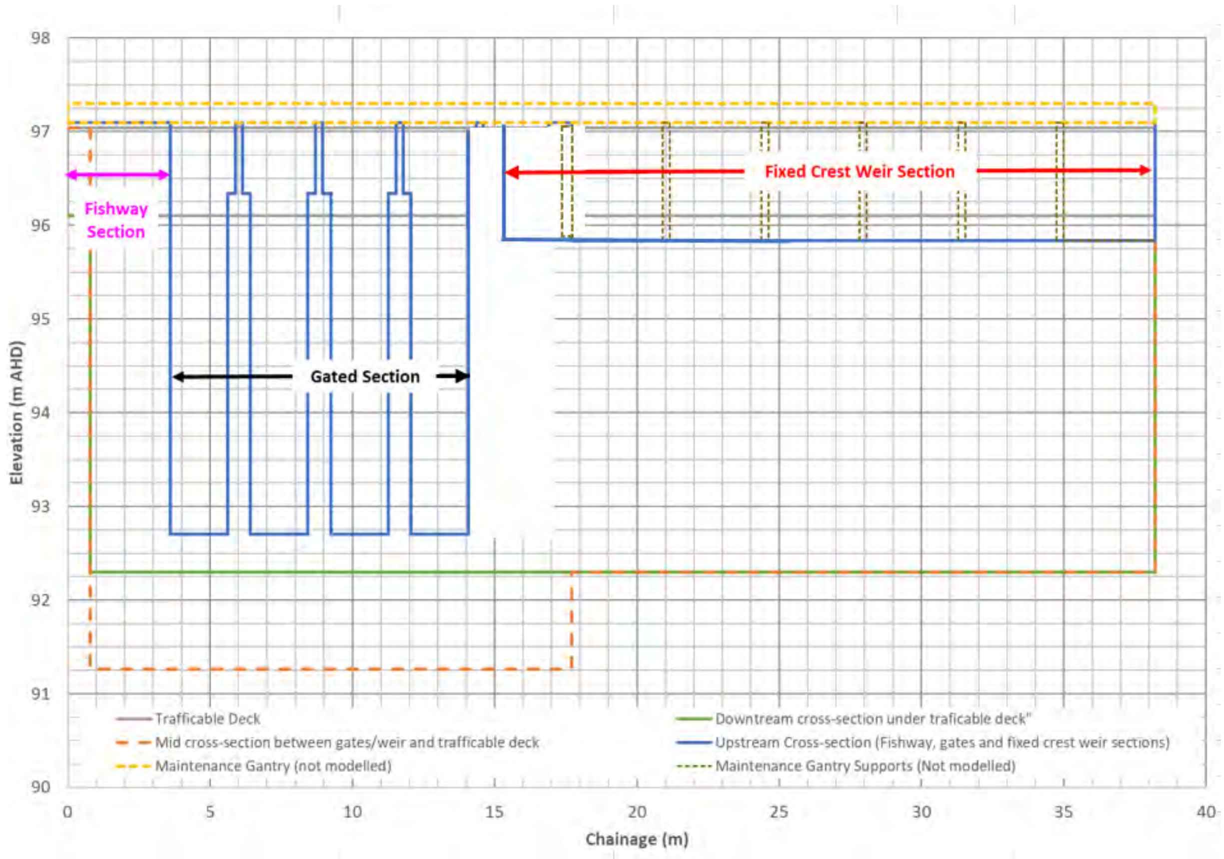


Figure 44: Proposed Wanganella Weir Cross-section

6.2.2 Existing Regulator Structure

To allow the proposed structure to control the weir pool most effectively, in consultation with the design team it was agreed that the existing Wanganella Weir piers will be removed. Given that the extent of this removal was not fully known, it was conservatively assumed that all the piers would be removed between the abutments within the channel – the adopted cross-section for proposed conditions is presented in Figure 45.

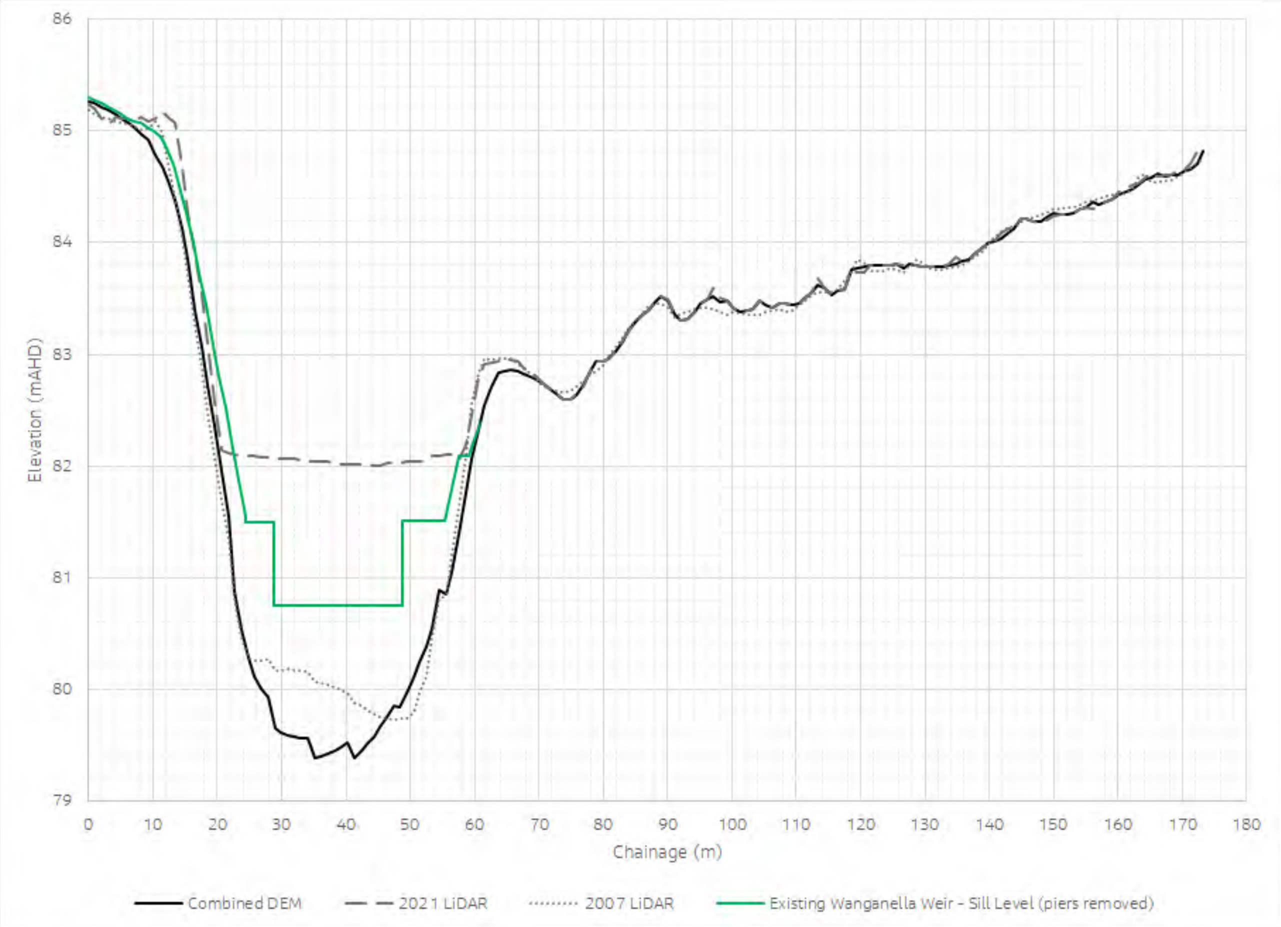


***Figure 45:** Modelled changes to existing Hartwood Weir in "proposed" modelling conditions*

6.3 Eight Mile Creek Northern Regulator Design

As per the Concept Design the proposed Wanganella Swamp Northern Regulator, the structure works including Rock embankment dam structure with water quantity control regulator and a board crested shape water spillway on the existing Eight Mile Creek located approximately 17m of upstream of the existing four (4) by 3.05m (W) x1.63m (H) RCBC box culverts under the Cobb Highway, it has been modelled with the following components:

- The Gated Weir section, initially designed for one gate, during the design progress phase, the model results shown a significant increase in flood levels (over 200mm) on Cobb Highway during a 1% AEP flood event. Following discussions with DCCEEW and 3Rivers, alternative design assumptions were adopted. The revised design involves ten gates by 1.20m wide and using lay flat technology, with an invert level of 84.70m AHD. These gates are modelled collectively as a shape crested weir or "WR" channel in TUFLOW, using a 10x multiplier to represent the multiple gates and enhance floodway capacity.

- A fixed spillway section of weir that will block off the reminder of the channel to maintain the weir pool with a board crested shape weir with a crest level of 86.40 m AHD and a width of 35.0 m (modelled as a broad crested weir or "WB" channel with a user -defined cross-section in TUFLOW)

- The proposed structure will also include the following works around North Weir will also include the following:

    - A maintenance gantry over the gated/fixed crest portions of the proposed weir – this has been modelled to allow gates and fixed crest weir to be represented as weirs within TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 86.51 m AHD this was not in the model as the impact will particularly be minor for the operational flows and more frequent events, for major and rare flood events, the flow over rock embank structure was modelled as a broad crested weir or "WW" channel in the TUFLOW.

    - A stilling basin downstream of the weir (modelled as a 1D channel or "S" type channel in TUFLOW with a user-defined cross-section) and connect to existing 4 x1.630m(H) x 3.05m (W) box culverts with an overflow weir level of 86.51 m AHD and a maximum flow pathway 48m on the Cobb Highway and then transition back to downstream natural creek, (this was modelled as a broad-crested weir or "WB" in TUFLOW).

- Gate operated in accordance with following operating principles -

    - Operational flows 150MLD, for delivery environmental flow into downstream Eight Mile Creek, minimise spills over Eight Mile Creek Northern Weir target 150 ML/day.

        1 Weir flow > 150 ML/day = regulator gate to be fully opened (assumed to match invert level of 84.70 m AHD for modelling purposes).

    - Flood flows – Flume gate fully open during "natural" flood events.

        1. The embankment each side of the Flume gate is designed to overtop and "drown out" during moderate to large unregulated flow events downstream of Forest Creek @ Warriston Weir (410148).

An extract from the design drawings showing the change to the block bank is presented in Figure 46.

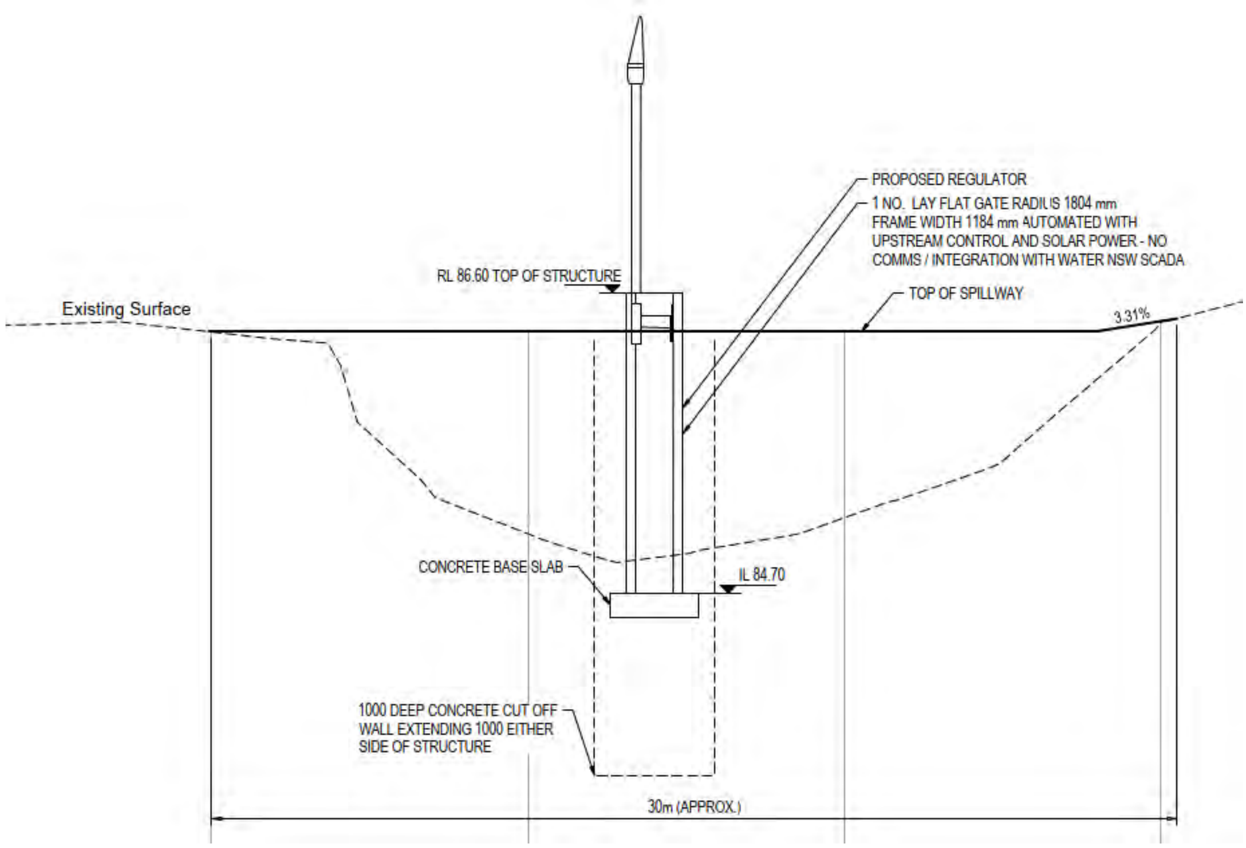


Figure 46: Eight Mile Creek Northern Regulator Cross-section (extracted from "DE19-823-YCM1B-DE-CV-DRG-0012" drawing dated 17/08/2022]

6.4 Eight Mile Creek Southern Regulator Design

As per the Concept Design the proposed Eight Mile Creek Southern Regulator , the structure works including Rock embankment dam structure with water quantity control regulator and a broad crest shape water spillway within the existing Eight Mile Creek located approximately 17m of upstream of the existing 2 x 2.30m (W) x 2.45m (H) box culverts under the Cobb Highway, it has been modelled with the following components:

- The Gated Weir section, initially designed for one gate, during the design progress phase, the model results shown a significant increase in flood levels (over 200mm) on Cobb Highway during a 1% AEP flood event. Following discussions with DCCEEW and 3Rivers, alternative design assumptions were adopted. The revised design involves four gates by 1.20m wide and using lay flat technology, with an invert level of 84.70m AHD. These gates are modelled collectively as a sharp crested weir or "WR" channel in TUFLOW, with a 4x multiplier to represent the multiple gates and enhance floodway capacity.

- A fixed spillway section of weir that will block off the reminder of the channel to maintain the weir pool with a rectangular shape broad weir with a crest level of 86.35 m AHD and a width of 68.0 m (modelled as a broad crested weir or "WB" channel with a user -defined cross-section in TUFLOW)

- The proposed structure will also include the following works around North Weir will also include the following:

    - o A maintenance gantry over the gated/fixed crest portions of the proposed weir – this has not been modelled to allow gates and fixed crest weir to be represented as weirs within TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 86.51 m AHD this was not in the model as the impact will particularly be minor for the operational flows and more frequent events, for major and rare flood events, the flow over rock embank structure was also modelled as a broad crested weir or "WW" channel in the TUFLOW)

- A stilling basin downstream of the weir (modelled as a 1D channel or "S" type channel in TUFLOW with a user-defined cross-section) and connect to existing 2 x 2.30m (W) x 2.45m (H) box culverts with an overflow weir level of 87.40 m AHD and a maximum flow pathway 50m on the Cobb Highway and then transition back to downstream natural creek, (this was modelled as a broad-crested weir or "WB" in TUFLOW).

- Gate operated in accordance with following operating principles -
  - Operational flows 150MLD, for delivery environmental flow into downstream Eight Mile Creek, minimise spills over Eight Mile Creek Northern Weir target 150 ML/day.
    1. Weir flow > 150 ML/day = regulator gate to be fully opened (assumed to match invert level of 84.70 m AHD for modelling purposes).
  - Flood flows – Flume gate fully open during "natural" flood events.
    1. The embankment each side of the Flume gate is designed to overtop and "drown out" during moderate to large unregulated flow events downstream of Forest Creek @ Warriston Weir (410148).

An extract from the design drawings showing the change to the block bank is presented in Figure 47.

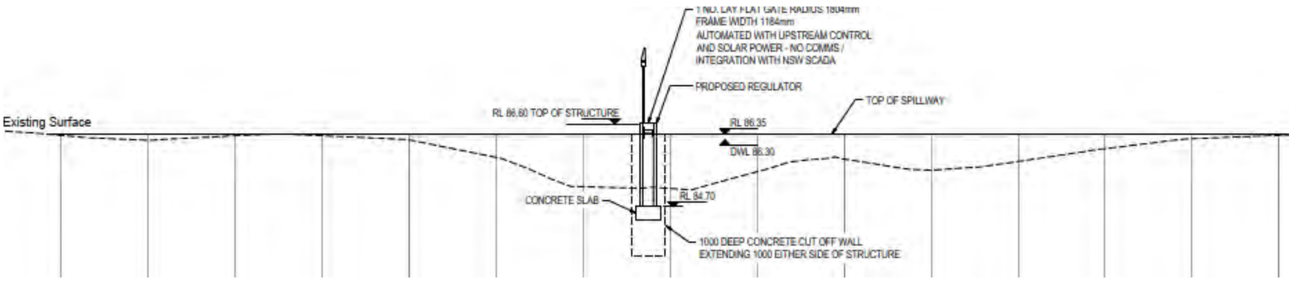


Figure 47: Eight Mile Creek Southern Regulator Cross-section (extracted from "DE19-823-YCM1B-DE-CV-DRG-0031" drawing dated 17/08/2023)

6.5 Upper Clarkes Creek Regulator Design

As per the Concept Design the proposed Wanganella Swamp Upper Clarkes Creek Regulator, the structure works including Rock embankment dam structure with water quantity control regulator and a broad-crested shape water spillway within the existing Upper Clarkes Creek located approximately 13m of upstream of the existing 6 x Ø 0.75m Culverts under the Cobb Highway, it has been modelled with the following components:

- A gated section of weir that can be controlled to pass operational and environment flows, with one (1) by 1.20 m wide lay flat gate, with an invert level of 85.70 m AHD (modelled as a sharp crested weir or "WR" channel in TUFLOW with a 1 x multiplier to represent the multiple gate).

- A fixed spillway section of weir that will block off the reminder of the channel to maintain the weir pool with a rectangular shape broad weir with a crest level of 86.40 m AHD and a width of 70.0 m (modelled as a broad crested weir or "WB" channel with a user -defined cross-section in TUFLOW)

- The proposed structure will also include the following works around North Weir will also include the following:
  - A maintenance gantry over the gated/fixed crest portions of the proposed weir – this has not been modelled to allow gates and fixed crest weir to be represented as weirs within TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 86.35 m AHD this was not in the model as the impact will particularly be minor for the operational flows and more frequent events, for major and rare

flood events, the over flow over this rock embankment structure was modelled as a broad crested weir or "WW" channel in the TUFLOW)

  - A stilling basin downstream of the weir (modelled as a 1D channel or "S" type channel in TUFLOW with a user-defined cross-section) and connect to existing 6 x Ø 0.75m culverts with an overflow weir level of 87.148 m AHD and a maximum flow pathway 50m on the Cobb Highway and then transition back to downstream natural creek, (this was modelled as a broad-crested weir or "WB" in TUFLOW).

- Gate operated in accordance with following operating principles -

  - Operational flows 50MLD, for delivery environmental flow into Clarkes Creek, minimise spills over Clarkes Creek Weir target 50 ML/day.

    1 Weir flow > 50 ML/day = regulator gate to be fully opened (assumed to match invert level of 85.70 m AHD for modelling purposes).

  - Flood flows – Flume gate fully open during "natural" flood events.

    2. The embankment each side of the Flume gate is designed to overtop and "drown out" during moderate to large unregulated flow events downstream of Forest Creek @ Warriston Weir (410148).

    3. The Flume gate does not need to be fully open during small to moderate natural flow events if there is support form environment water managers and other key stakeholders (e.g. landholders) to do so.

An extract from the design drawings showing the change to the block bank is presented in Figure 48.

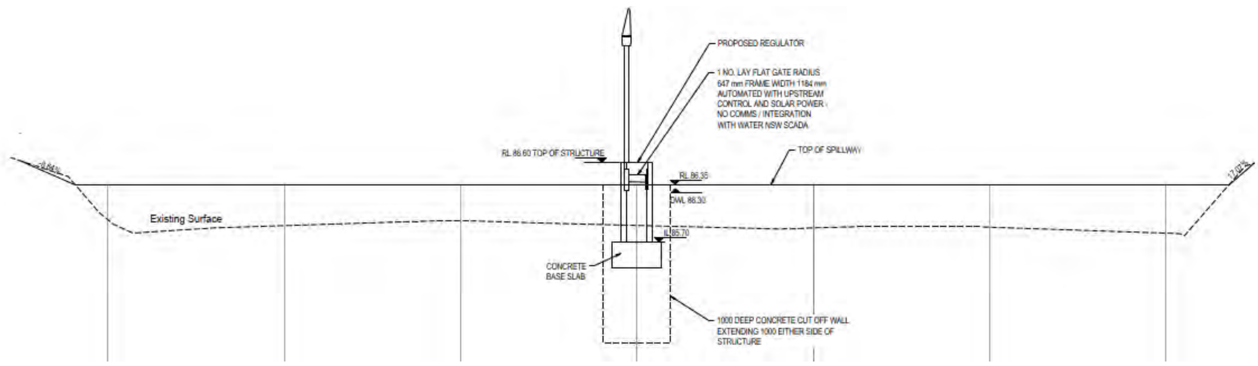


Figure 48: Upper Clarkes Creek Regulator Cross-section (extracted from "DE19-823-YCM1B-DE-CV-DRG-0043" drawing dated 17/08/2023)

6.6 Estuary Creek Regulator Design

The proceeding sections outline the model changes that have been included in one or more of the proposed scenario model simulations associated with the works at Estuary Weir, the location of which is presented in Figure 43.

6.6.1 Proposed Regulator Structure

As per the Concept Design the proposed Wanganella Swamp Estuary Creek Regulator, the structural elements comprise 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. Additionally, a board crest-shaped water spillway is envisaged within the Estuary Creek, situated at the existing block bank's junction, where Eight Mile Creek converges with the downstream Estuary Creek, it has been modelled with the following components: A full set of assumptions for the proposed conditions (and existing conditions) for the current modelling is provided in a comparison table in Appendix C.

- A gated section of weir that can be controlled to pass operational and environment flows, with one (1) by 1.8 m wide lay flat gates with a invert level of 84.90 m AHD (modelled as a sharp crested weir or "WR" channel in TUFLOW with a 1 x multiplier to represent the multiple gate)

- A fixed spillway section of weir that will block off the reminder of the channel to maintain the weir pool with a crest level of 86.60 m AHD and a weir length of 17.5 m (modelled as a 2d_zsh in TUFLOW)

- The proposed structure will also include the following works around Estuary Creek Weir will also include the following:

    - A maintenance gantry over the gated/fixed crest portions of the proposed weir – this has not been modelled to allow gates and fixed crest weir to be represented as weirs within TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 86.50 m AHD (the impact will particularly be minor for the operational flows and more frequent events)

    - A proposed 1.80m (W) x 1.50m (H) box culvert at downstream connect to regulator (modelled as a 1D pipe or "R" type in TUFLOW).

- Gate operated in accordance with following operating principles -

    - Operational flows 150 MLD, for delivery environmental flow into Estuary Creek, minimise spills over Estuary Creek Weir target 150 ML/day.

        1. Weir flow > 150 ML/day = regulator gate to be fully opened (assumed to match invert level of 84.90 m AHD for modelling purposes).

    - Flood flows – Flume gate fully open during "natural" flood events. The Flume Gate does not be fully open during small to moderate natural flow events if there is support from environmental water managers and other key stakeholders (e.g. landholders) to do so.

An extract from the design drawings showing the change to the block bank is presented in Figure 49.

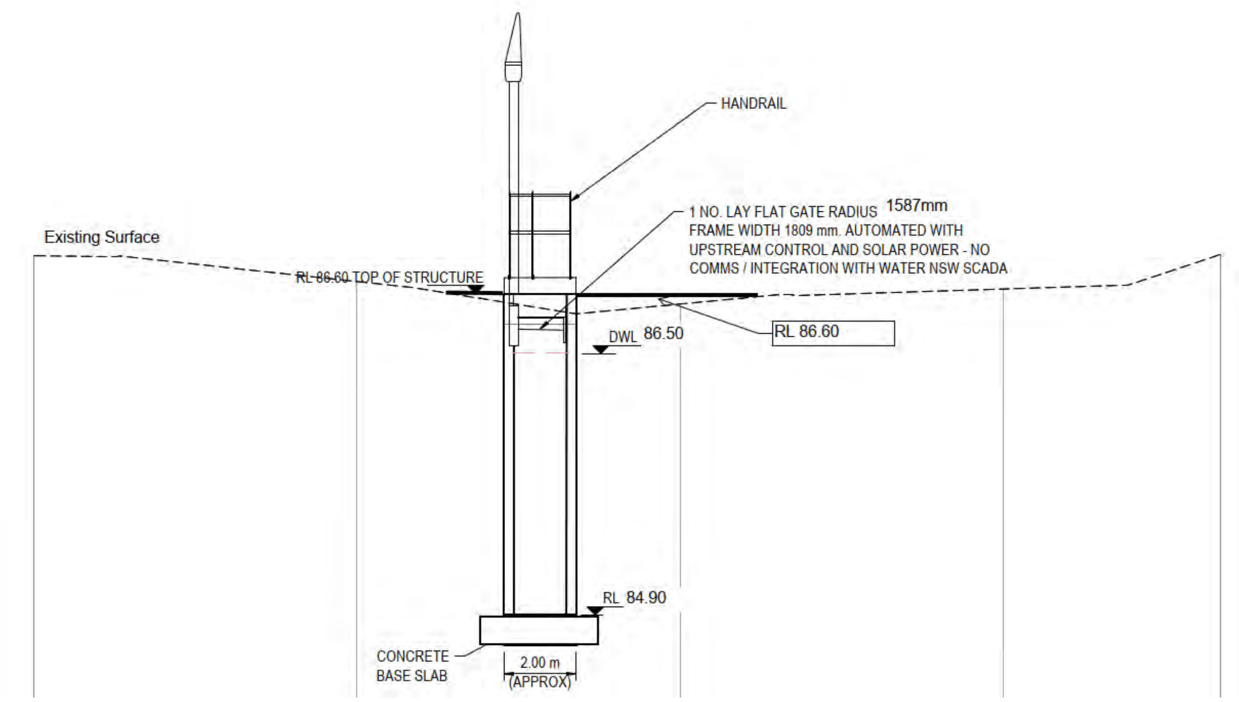


Figure 49: Estuary Creek Regulator Cross-section (extracted from "DE19-823-YCM1B-DE-CV-DRG-0061" drawing dated 17/08/2023)

6.6.2 Existing Structure

To allow the proposed structure to control the weir pool most effectively, replace 1.80(W)x 1.50 (H) Reinforcement Box Culvert to the existing diameter 0.9m cross drain connect to the upstream of regulator.

6.7 McCrabbs Regulator Design

The proceeding sections outline the model changes that have been included in one or more of the proposed scenario model simulations associated with the works at McCrabbs Weir, the location of which is presented in Figure 43.

6.7.1 Proposed Regulator Structure

As per the Concept Design the proposed Wanganella Swamp McCrabbs Creek Regulator, the structural elements comprise 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. Additionally, a board crest-shaped water spillway is envisaged within the Estuary Creek, situated at the existing block bank's junction, where Eight Mile Creek converges with the downstream Estuary Creek, it has been modelled with the following components:

- A gated section of weir that can be controlled to pass operational and environment flows, with one (1) by 1.8 m wide lay flat gates with an invert level of 84.00 m AHD (modelled as a sharp crested weir or "WR" channel in TUFLOW with a 1 x multiplier to represent the multiple gate)

- A fixed spillway section of weir that will block off the reminder of the channel to maintain the weir pool with a crest level of 85.70 m AHD and a weir length of 25.0 m (modelled as a 2d_zsh in TUFLOW)

- The proposed structure will also include the following works around McCrabbs Weir will also include the following:

    - A maintenance gantry over the gated/fixed crest portions of the proposed weir – this has not been modelled to allow gates and fixed crest weir to be represented as weirs within

TUFLOW and was considered acceptable as it is unlikely to substantially affect results due to its nominated soffit level of 85.81 m AHD this was not in the model as the impact will particularly be minor for the operational flows and more frequent events.

  - A proposed 1.80m (W) x 1.80m (H) box culvert at downstream connect to the upstream regulator has not been modelled in TUFLOW.

- Gate operated in accordance with following operating principles -

  - Operational flows 150MLD, for delivery environmental flow into downstream Eight Mile Creek, minimise spills over McCrabbs Weir target 150 ML/day.

    1. Weir flow > 150 ML/day = regulator gate to be fully opened (assumed to match invert level of 84.00 m AHD for modelling purposes).

  - Flood flows – Flume gate fully open during "natural" flood events. The structure is designed so water starts to flow over the spillway during moderate to large natural flow events.

An extract from the design drawings showing the change to the block bank is presented in Figure 50.

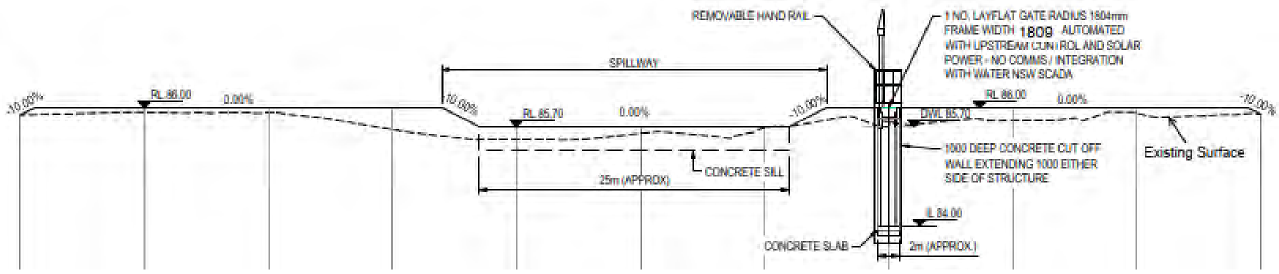


Figure 50: McCrabbs Creek Regulator Cross-section (extracted from "DE19-823-YCM1B-DE-CV-DRG-0012" drawing dated 17/08/2023)

6.8 Forest Anabranch Two Access Culverts Design

In the course of the Wanganella Swamp downstream improvements, two access culverts have been introduced 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. Meanwhile, Access Culvert 2 is situated approximately 400 meters downstream from Access Culvert 1, contributing to the enhancement of drainage efficiency within the designated area (this is modelled as "1d_nwk" in TUFLOW).

These access culverts have been incorporated into the overall design to address the specific hydraulic and hydrological requirements of the downstream Wanganella Swamp region. The strategic placement of Access Culvert 1 at the junction of Forest Creek and Eight Mile Creek ensures optimal water conveyance, while Access Culvert 2, located downstream, further complements the waterway network to facilitate the seamless flow of water within the specified area.

The introduction of these access culverts not only replaces the existing cross drain but also contributes to the overall improvement of hydraulic infrastructure, aligning with the project's objectives for enhanced water management in the downstream Forest Creek vicinity. The locations of the culverts are shown in Figure 43. Both culverts are proposed to be 2 x 1.20m (W) x 1.20m (H) box culverts.

6.9 Flood Relief Channel

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 as part of the Wanganella Regulator works which offsets the increase 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 model simulations and results presented in this report include the flood relief channel.

7. Results

The assessment of impacts has been separated into the “Operational Flow” and “Flood Flow” scenarios, with results compared in terms of the following to address the Secretary’s Environmental Assessment Requirements (SEARS):

- Flow.
- Afflux (or change in Water Surface Level, WSL).
- Flood hazard.
- Velocity.
- Bed Shear Stress.

The above variables have been compared at the locations presented in Figure 51, which labels the modelled Print Out (PO) lines and points used to assess the impact of the proposed works across the Study Area.

In the “Operational Flow” scenario, the term “operation” specifically refers to the operation of the Wanganella Regulator, not the regulators in the Wanganella Swamp. Therefore, only flows in Billabong Creek was modelled and the impact of the Wanganella Regulator was assessed.

In the “Flood Flow” scenario, the flood impacts were assessed from two aspects:

- The impact caused by the Wanganella Regulator only; and
- The cumulative impact caused by all proposed works, including the Wanganella Regulator and other construction works in the Wanganella Swamp.

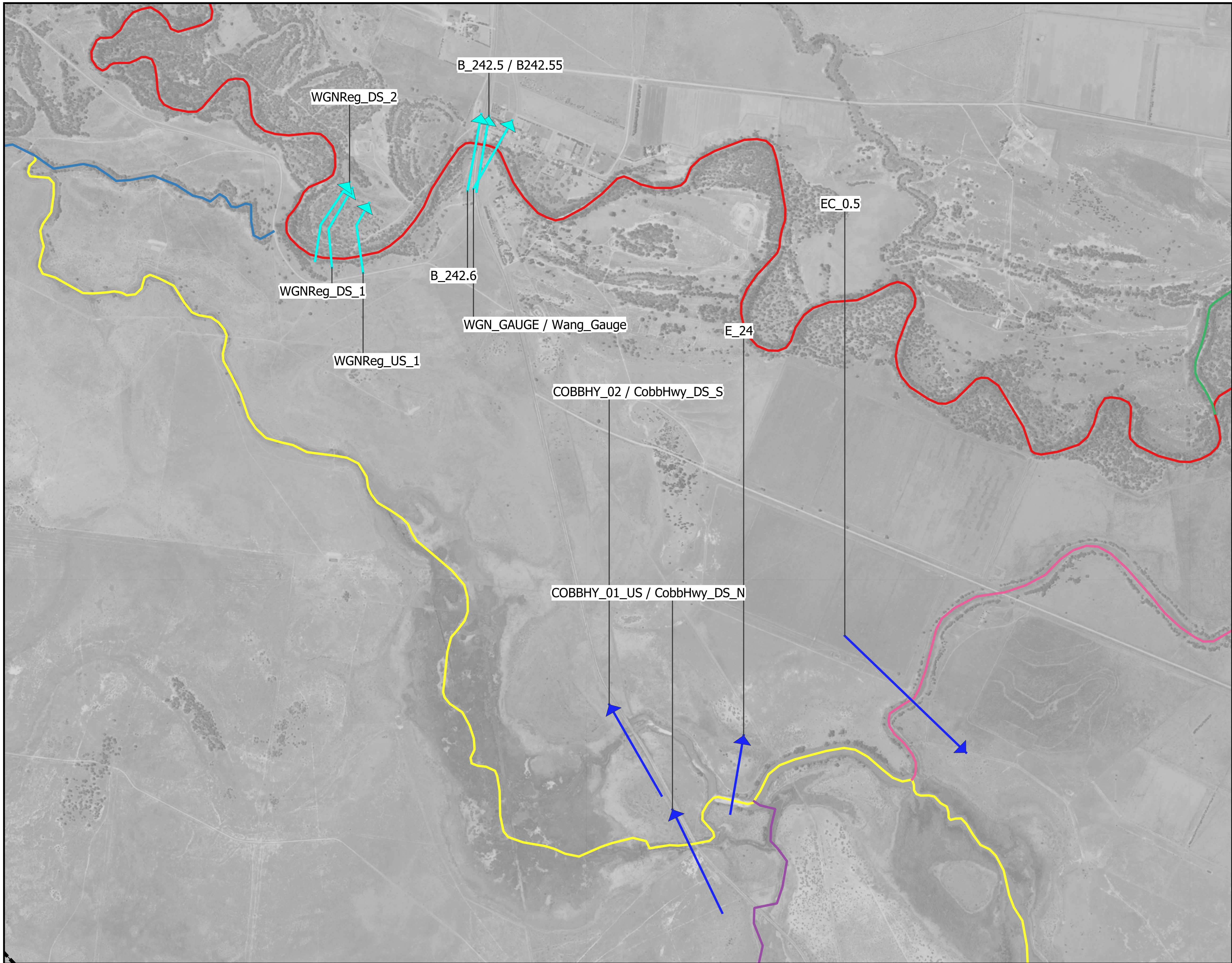
7.1 Operational Flow Scenarios

7.1.1 Flow

A summary of flows for “Existing” and “Proposed” under the modelled operational flow regimes are presented in Table 33. The results indicate:

- Under the MaxOF (400 ML/day) scenario –
    - The proposed work (i.e., the Wanganella Regulator) does not cause notable change to the flows within the Billabong Creek upstream and downstream of the work when control is set to MinOL or MaxOL.
    - There is a 2 – 4 ML/day decrease of flows within the Billabong Creek upstream and downstream of the work when control is set to FSL.
- Under the MinOF (30 ML/day) scenario –
    - The proposed work does not cause notable change to the flows within the Billabong Creek upstream and downstream of the work when control is set to MinOL or MaxOL.
    - There is a 5 – 6 ML/day decrease of flows within the Billabong Creek upstream and downstream of the work when control is set to FSL.

The volumetric reduction in flow when control is set to FSL under both MaxOF (400 ML/day) and MinOF (30 ML/day) scenarios was likely to be caused by attenuation of flow or the increased infiltration loss as a result of increase of inundation area. Regardless, these changes in flow are small and are not a concern as the flow in the fishway is at 20 ML/day under both scenarios, providing environmental flow and a path for fish. Additionally, the change in flow rate does not cause an inundation impact, as discussed in the sections below.



Main Map Legend

- 2D Model Area

PO LInes

- Only Flood Scenarios
- Both Operational and Flood Scenarios

Key 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: 1:20000

N

0 0.4 0.8 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_Southern\Water\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 51: WP20 PO Lines

3Rivers

Table 33: Flow Comparison for Operational Flow Scenarios.

Location	PO ID	Flow (ML/day) at comparison locations [Flow difference relative to "Existing" conditions (ML/day)]							
		Maximum Operating Flow (MaxOF) – 400 ML/day passing Wanganella Weir or Wanganella Environmental Water Regulator				Minimum Operating Flow (MinOF) – 30 ML/day passing Wanganella Weir or Wanganella Environmental Water Regulator			
		Existing	Proposed with Wanganella Pool at Full Supply Level (FSL)	Proposed with Wanganella Pool at Maximum Operating Level (MaxOL)	Proposed with Wanganella Pool at Minimum Operating Level (MinOL)	Existing	Proposed with Wanganella Pool at Full Supply Level (FSL)	Proposed with Wanganella Pool at Maximum Operating Level (MaxOL)	Proposed with Wanganella Pool at Minimum Operating Level (MinOL)
Billabong Creek @ Wanganella Gauge	**WGN_GAUGE**	390	388 [-2]	390 [0]	390 [0]	31	26 [-5]	30 [-1]	31 [0]
Billabong Creek approx. 15m downstream of the Cobb HWY	**B_242.6**	390	388 [-2]	390 [0]	390 [0]	31	26 [-5]	30 [-1]	31 [0]
Billabong Creek approx. 55m upstream of the existing Wanganella Weir	**WGNReg_US_1**	390	387 [-3]	390 [0]	390 [0]	30	25 [-5]	30 [0]	30 [0]
Billabong Creek between existing and proposed Wanganella Weirs (modelled as 1d channel)	**B253.5_B_W_US**	390	387 [-3]	390 [0]	390 [0]	30	24 [-6]	30 [0]	30 [0]
Billabong Creek approx. 0.1km downstream of the existing Wanganella Weir	**WGNREG_DS_1**	390	386 [-4]	390 [0]	390 [0]	30	24 [-6]	29 [-1]	30 [0]

7.1.2 Water Level Changes

A summary of the WSL impacts between "Existing" and "Proposed" are presented spatially in Appendix D, which presents two sets of water level difference or afflux maps, one across the downstream part of the Study Area (covering the entire Wanganella Pool) with a modelling tolerance of ±50 mm (no impact) and the other focused on the Wanganella Township Area with a modelling tolerance of ±10 mm (no impact). 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. Figure 52 and Figure 53, which presents a long section plot along Billabong Creek from "Billabong Creek @ Wanganella (41010810)" gauge (upstream Wanganella Weir) to just downstream of the confluence of Wanganella Creek and Billabong Creek. The actual WSL in both "Existing" and "Proposed" scenarios, as well as the afflux or differences at some key locations are also presented numerically in Table 34. These results collectively show the following key outcomes:

- Under the MaxOF (400 ML/day) scenario –
  - As anticipated, the WSL upstream of the Wanganella Weir reached the FSL (82.1 m AHD) when the control level was set to FSL, which however indicates an afflux of 1.05 m and a slight increase of flood extent upstream of the Wanganella Weir. Nevertheless, the afflux was fully contained within the creek channel and there was no impact extended outside of the watercourse. There was no notable change of the WSL (less than ±10 mm) downstream of the Wanganella Weir.
  - There was no notable change of the WSL (less than ±10 mm) either upstream or downstream of the Wanganella Weir when control was set to MaxOL or MinOL.
- Under the MinOF (30 ML/day) scenario –
  - As anticipated, the WSL upstream of the Wanganella Weir reached the FSL (82.1 m AHD) when the control level was set to FSL, which however indicated an afflux of 1.28 m upstream of the Wanganella Weir. Nevertheless, the afflux was fully contained within the creek channel and there was no impact extended outside of the watercourse. The WLS had a decrease up to around 60 mm downstream of the Wanganella Weir.
  - The WSL has increased by up to 190 mm upstream of the Wanganella Weir when control is set to MaxOL. The WLS has decreased up to 130 mm only immediately downstream of the Wanganella Weir, but there was no notable difference in WSL further downstream.
  - There was no notable change of the WSL upstream of the Wanganella Weir when control was set to MinOL. The WLS had a decrease up to 130 mm only immediately downstream of the Wanganella Weir, but there was no notable difference in WSL further downstream.
- The WSL had certain increase between the existing and proposed structures (modelled in 1d), i.e., up to 1.46 m under MaxOF scenario and up to 2.12 m under MinOF scenario. This was a consequence of relocating the structure, i.e., moving the weir pool control downstream in proposed scenarios.
- No notable changes in WSL elsewhere within the Study Area.

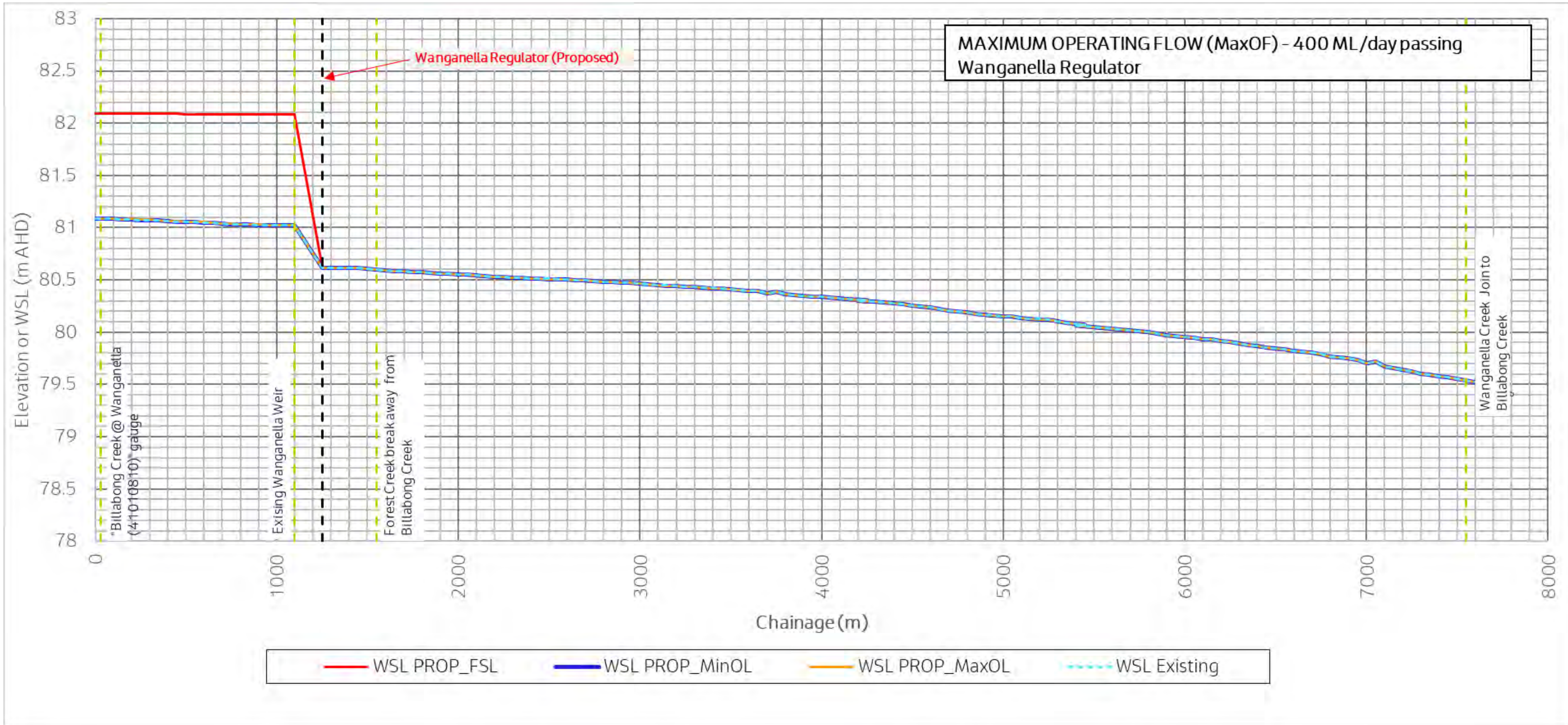


Figure 52: "Proposed" and "Existing" WSL comparison along Billabong Creek for Maximum Operating Flow (MaxOF) of 400 ML/day at Wanganella Regulator

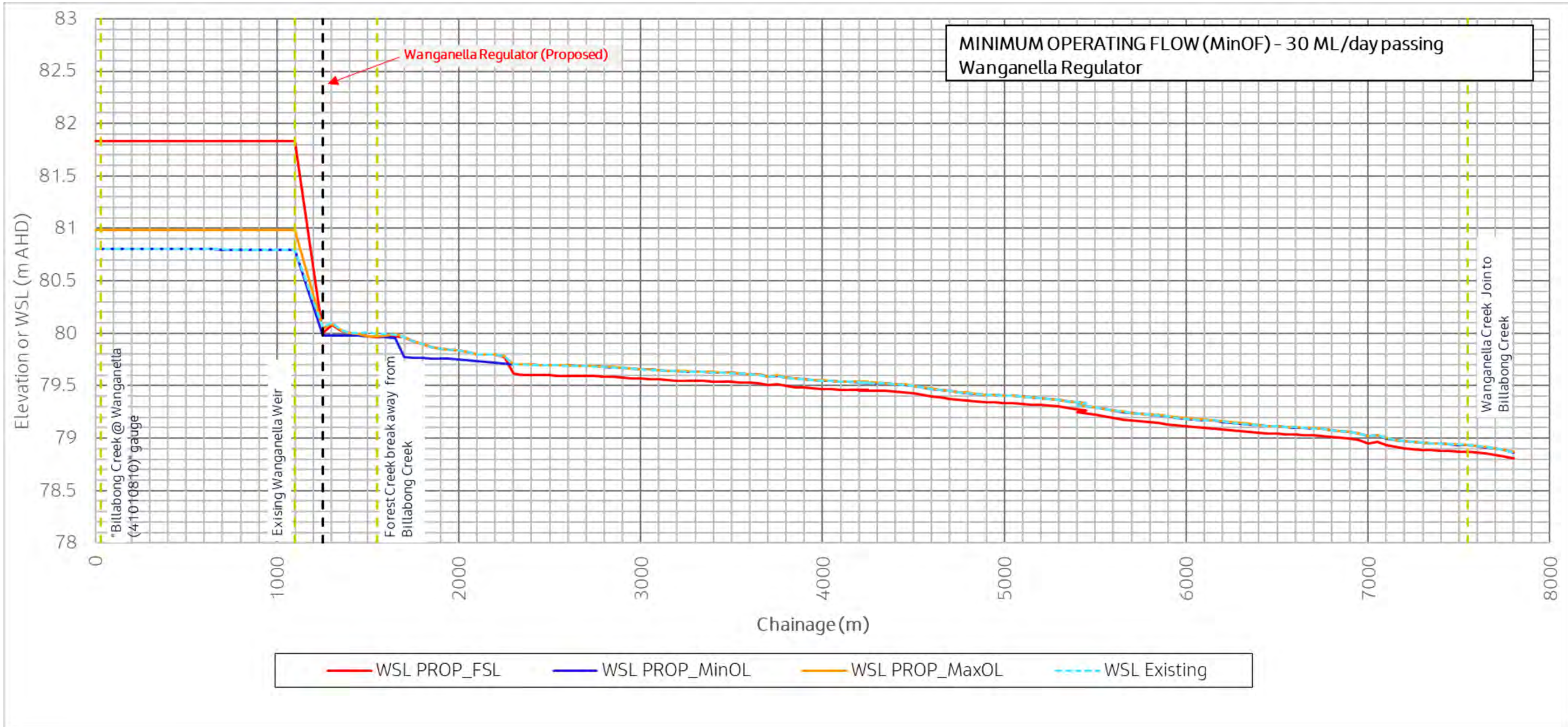


Figure 53: "Proposed" and "Existing" WSL comparison along Billabong Creek for Minimum Operating Flow (MinOF) of 30 ML/day at Wanganella Regulator

Table 34: WSL Comparison for Operational Flow Scenarios

Location	PO ID	WSL (m AHD) at comparison location [Afflux or "Proposed" WSL minus "Existing" WSL (mm)]							
		Maximum Operating Flow (MaxOF) – 400 ML/day passing Wanganella Weir or Wanganella Environmental Water Regulator				**Minimum Operating Flow (MinOF) – 30 ML/day passing Wanganella Weir or Wanganella Environmental Water Regulator**			
		Existing	Proposed with Wanganella Pool at Full Supply Level (FSL)	Proposed with Wanganella Pool at Maximum Operating Level (MaxOL)	Proposed with Wanganella Pool at Minimum Operating Level (MinOL)	Existing	Proposed with Wanganella Pool at Full Supply Level (FSL)	Proposed with Wanganella Pool at Maximum Operating Level (MaxOL)	Proposed with Wanganella Pool at Minimum Operating Level (MinOL)
Billabong Creek @ Wanganella Gauge [1]	**WGN_GAUGE**	81.08	82.09 **[1009]**	81.08 **[2]**	81.08 **[0]**	80.80	82.08 **[1281]**	80.99 **[188]**	80.80 **[0]**
Billabong Creek approx. 15m downstream of the Cobb HWY [1]	**B_242.6**	81.08	82.09 **[1009]**	81.08 **[2]**	81.08 **[0]**	80.80	82.08 **[1281]**	80.99 **[188]**	80.80 **[0]**
Billabong Creek approx. 55m upstream of the existing Wanganella Weir [1]	**WGNReg_US_1**	81.02	82.08 **[1064]**	81.02 **[3]**	81.02 **[0]**	80.80	82.08 **[1282]**	80.99 **[188]**	80.80 **[0]**
Billabong Creek between existing and proposed Wanganella Weirs (modelled as 1d channel) [2]	**B253.5_B_W_US**	80.62	82.08 **[1464]**	80.98 **[360]**	80.76 **[137]**	79.97	82.08 **[2115]**	80.99 **[1019]**	80.75 **[780]**
Billabong Creek approx. 0.1km downstream of the proposed Wanganella Weir	**WGNREG_DS_1**	80.62	80.61 **[-5]**	80.62 **[0]**	80.62 **[0]**	79.97	79.95 **[-22]**	79.97 **[-2]**	79.97 **[-129]**

Note:
1 – As detailed in Section 6.2.2, only the piers of the existing weir were removed, i.e., the sill of the existing weir was not emoved. Therefore, in the MinOL scenarios, the water level in the weir pool is restricted by the existing weir sill level, rather than by the operation of the proposed regulator. It is understood that the design is still in progress and It is expected that the existing weir sill should also be removed to allow the proposed regulator to control the water level in the weir pool.
2 – The Billabong Creek between the existing and proposed weirs were modelled in 1d domain; therefore, the the water level in the modelled 1d channel was presented here, indicating the proposed regulator and operation can achieve the target water levels, i.e., 80.75 m AHD (MinOL), 80.99 m AHD (MaxOL), and 82.1 m AHD (FSL).

7.1.3 Flood Hazard

A summary of the flood hazard characteristics in the “Existing” and “Proposed” scenarios are presented spatially in Appendix D, which presents maps across the downstream part of the Study Area (covering the entire Wanganella Pool) based on NSW’s “Flood Hazard: Flood Risk Management Guideline FB03” document and Australian Rainfall and Runoff 2019 (ARR2019) – which are defined in Figure 54. A comparison of the distribution of the categories within the Wanganella Weir Pool Area are presented in Figure 55 and Figure 56 for the MaxOF and MinOF flow scenarios respectively. These results collectively show the following key outcomes:

- As per the afflux trends, there has been the following changes within Wanganella Weir Pool:
  - Under the MaxOF scenario, the inundation area within the Pool has increased by around 54% and 7% when weir pool control was set to FSL and MaxOL, respectively, which is anticipated as the proposed regulator stores more water within the Pool. No change of inundation extent has been identified when weir pool control is set to MinOL.
  - Under the MinOF scenario, the inundation area within the Pool has increased by around 27% when weir pool control was set to FSL, which is anticipated as the proposed regulator stores more water within the Pool. No change of inundation extent has been identified when weir pool control was set to MaxOL or MinOL.
- There has only been some level change and redistribution of hazard categories, specifically:
  - Under the MaxOF scenario –
    - When the weir pool control was set to FSL, the significant increase of WSL and depth within the Wanganella Weir Pool has resulted in a decrease of H1 (-2%), H2 (-13%), and H3 (-10%) and an increase of H4 (+21%) and H5 (+4%).
    - No notable change of hazard categories (less than ±1%) has been identified when weir pool control is set to MaxOL or MinOL.
  - Under the MinOF scenario –
    - When the weir pool control was set to FSL, the significant increase of WSL and depth within the Wanganella Weir Pool has resulted in a decrease of H1 (-6%) and H2 (-24%), and an increase of H3 (+2%), H4 (+23%), and H5 (+4%).
    - When the weir pool control was set to MaxOL, there is minor redistribution of the hazard categories, i.e., a decrease of H2 (-4%), and an increase of H3 (+3%) and H4 (+1%).
    - No notable change of hazard categories (less than ±1%) has been identified when weir pool control is set to MinOL.

7.1.4 Velocity

A summary of the velocity characteristics in the “Existing” and “Proposed” scenarios are presented spatially in Appendix D, which presents maps across the downstream Study Area of the velocity distribution based on the fish habitat categorisation in Table 35. A comparison of the distribution of the categories within the Wanganella Weir Pool Area are presented in Figure 57 and Figure 58 for the MaxOF and MinOF flow scenarios respectively. These results collectively shows there has been minor redistribution of velocity categories, with the following trends centred around changes in extent and the shifting of the weir pool control downstream (see Figure 59 and Figure 60 for a long-section comparison of velocity along Billabong Creek):

- Under the MaxOF scenario, the velocity in the Pool exhibited a small decrease in general when weir pool control was set to FSL, with a decrease of up to 4% for “backwater”, “weir pool”, "slow flowing" and "moderate flowing" velocity categories and an increase of up to 3.7% for "fast flowing" and "very fast" velocity categories. No notable change of velocity categories has been identified when weir pool control is set to MaxOL or MinOL.

- Under the MinOF scenario, the velocity in the Pool exhibited a small decrease in general when weir pool control was set to FSL, with a decrease of up to 4.5% for "backwater", "weir pool", and "slow flowing" velocity categories and an increase of up to 3.7% for "moderate flowing", "fast flowing", and "very fast" velocity categories. No notable change of velocity categories has been identified when weir pool control is set to MaxOL or MinOL.

Table 35: Velocity Categorisation based on fish habitat

Fish Habitat	Water Velocity (m/s)
Backwaters	0.00 to 0.03
Weir pools	0.03 to 0.10
Slow flowing	0.10 to 0.17
Moderate flowing	0.17 to 0.30
Fast flowing	0.30 to 0.50
Very fast	>0.50

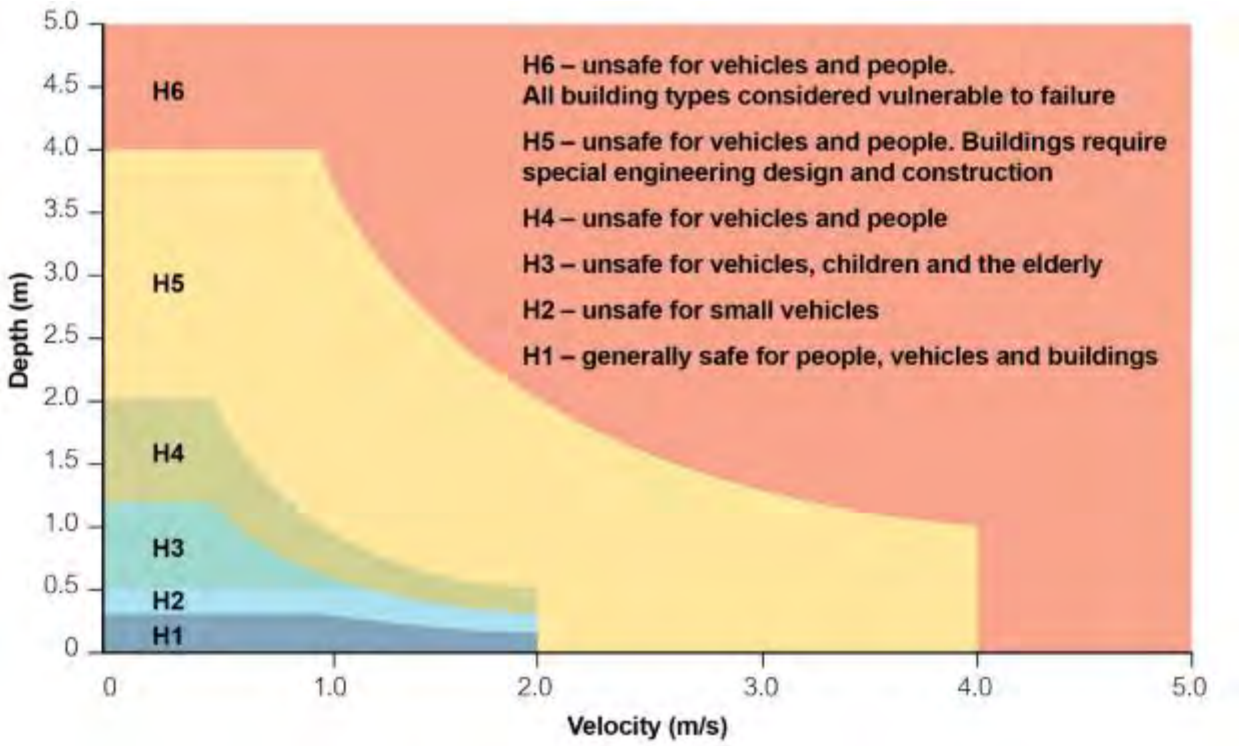


Figure 54: General flood hazard vulnerability curve (copy of Figure 1 from "Flood Hazard: Flood Risk Management Guideline FB03" – NSW DCCEEW, 2023)

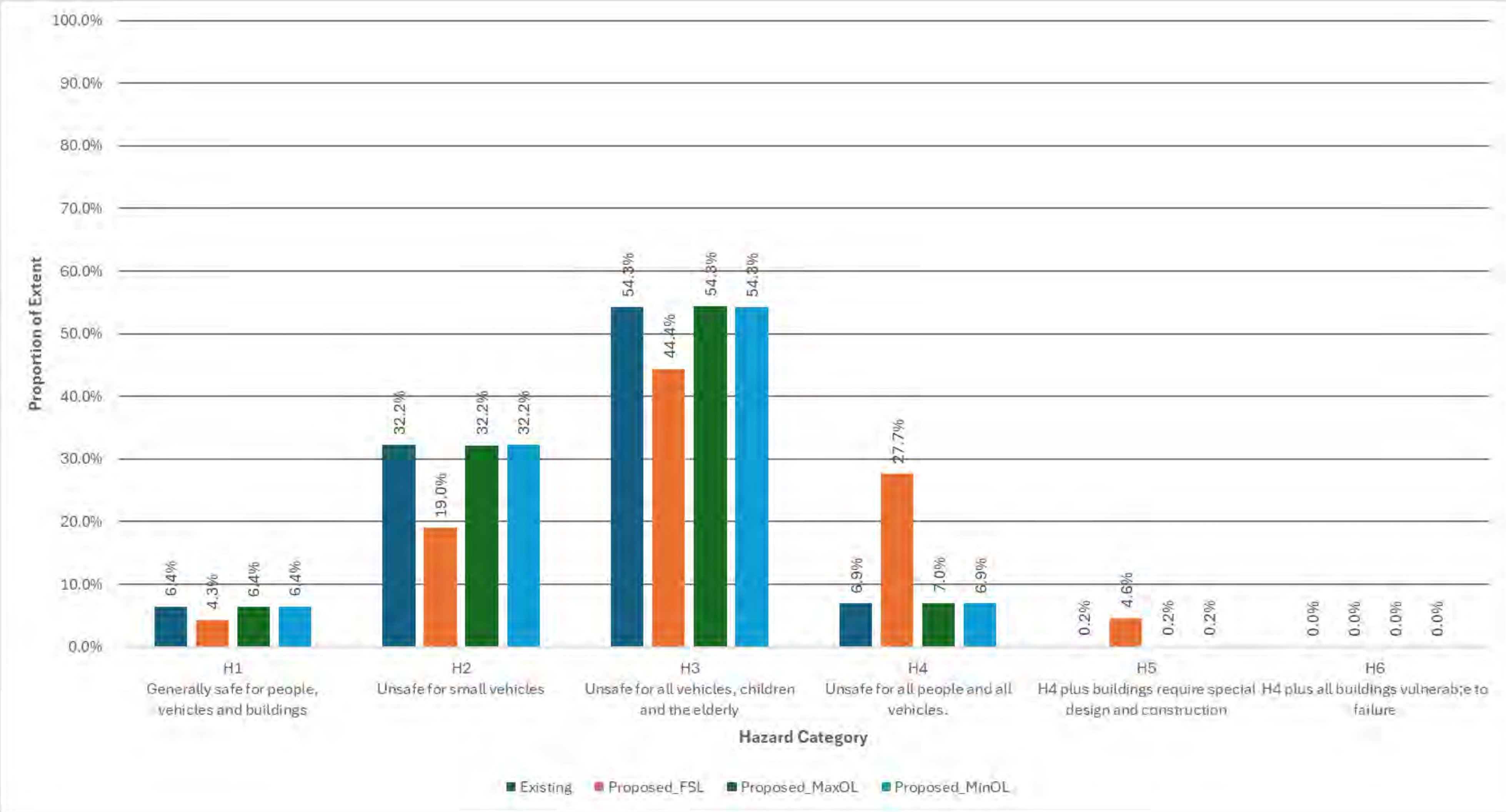


Figure 55: Hazard category distribution comparison for "Proposed" and "Existing" scenarios with MaxOF of 400 ML/day within the Wanganella Weir Pool (Four Mile Creek Weir to Wanganella Weir)

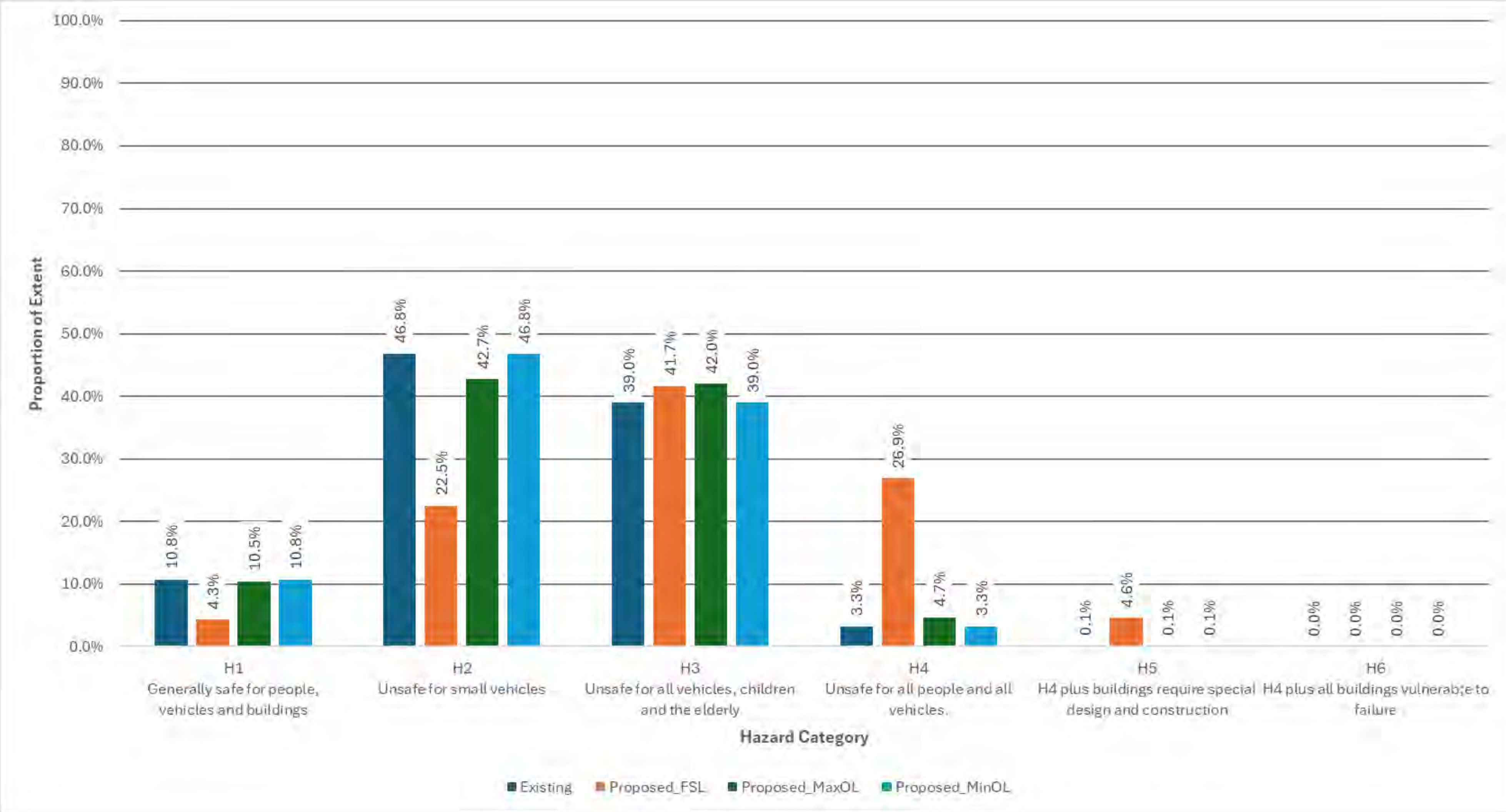


Figure 56: Hazard category distribution comparison for "Proposed" and "Existing" scenarios with MinOF of 30 ML/day within the Wanganella Weir Pool (Four Mile Creek Weir to Wanganella Weir)

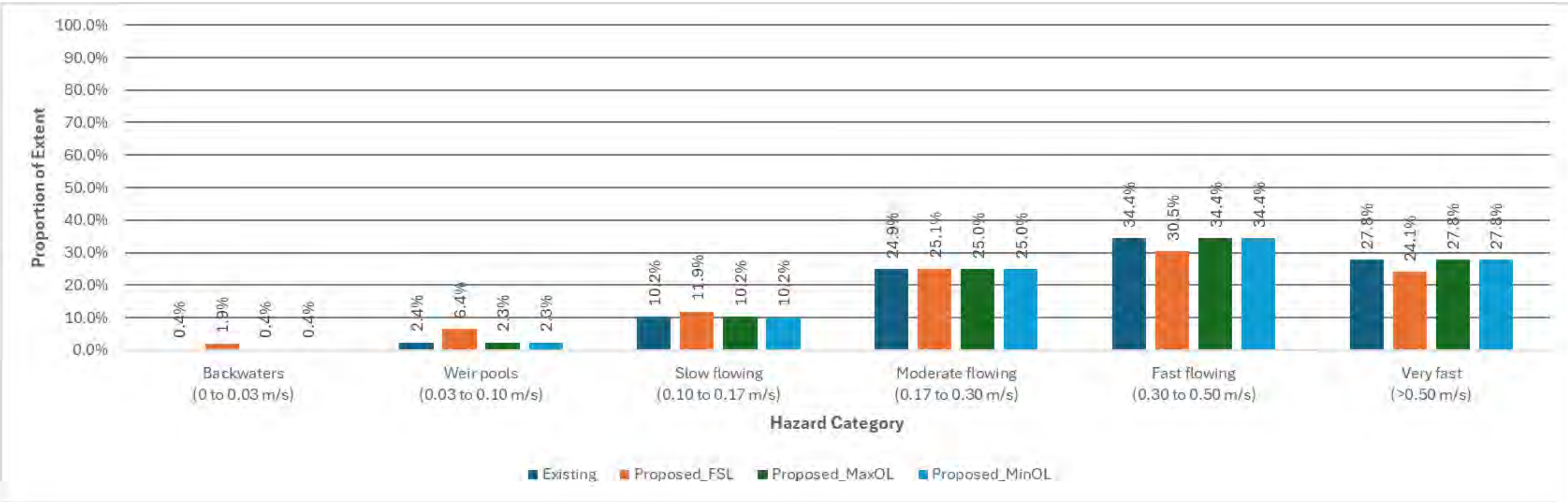


Figure 57: Velocity category distribution comparison for "Proposed" and "Existing" scenarios with MaxOF of 400 ML/day within the Wanganella Weir Pool (Four Mile Creek Weir to Wanganella Weir)

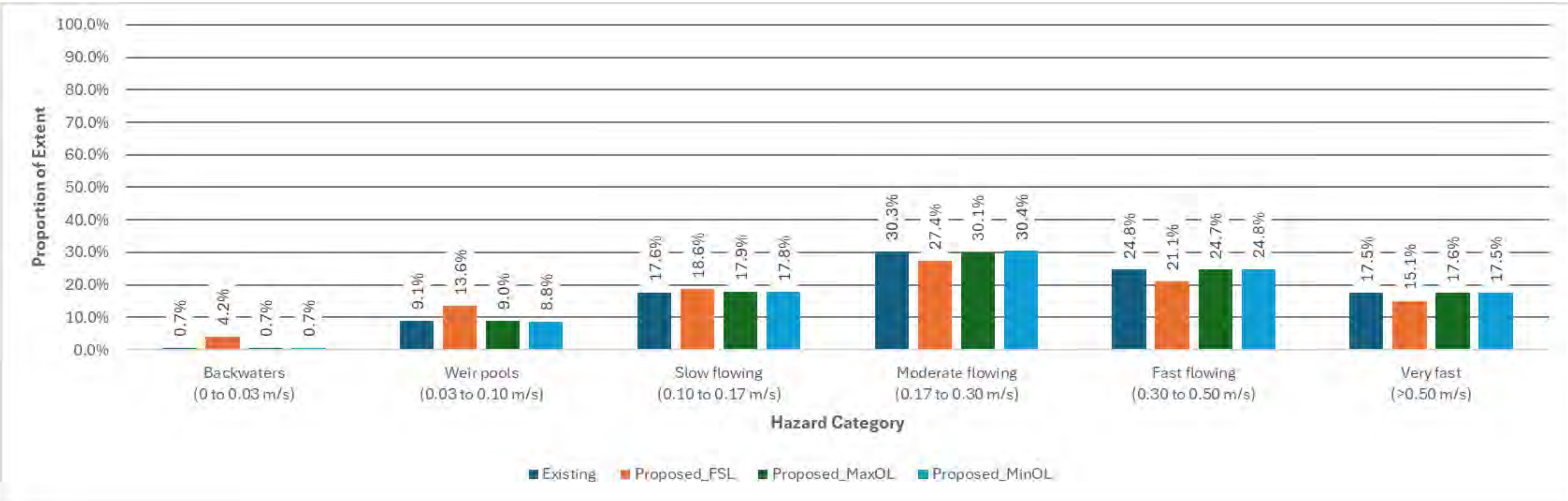


Figure 58: Velocity category distribution comparison for "Proposed" and "Existing" scenarios with MinOF of 30 ML/day within the Wanganella Weir Pool (Four Mile Creek Weir to Wanganella Weir)

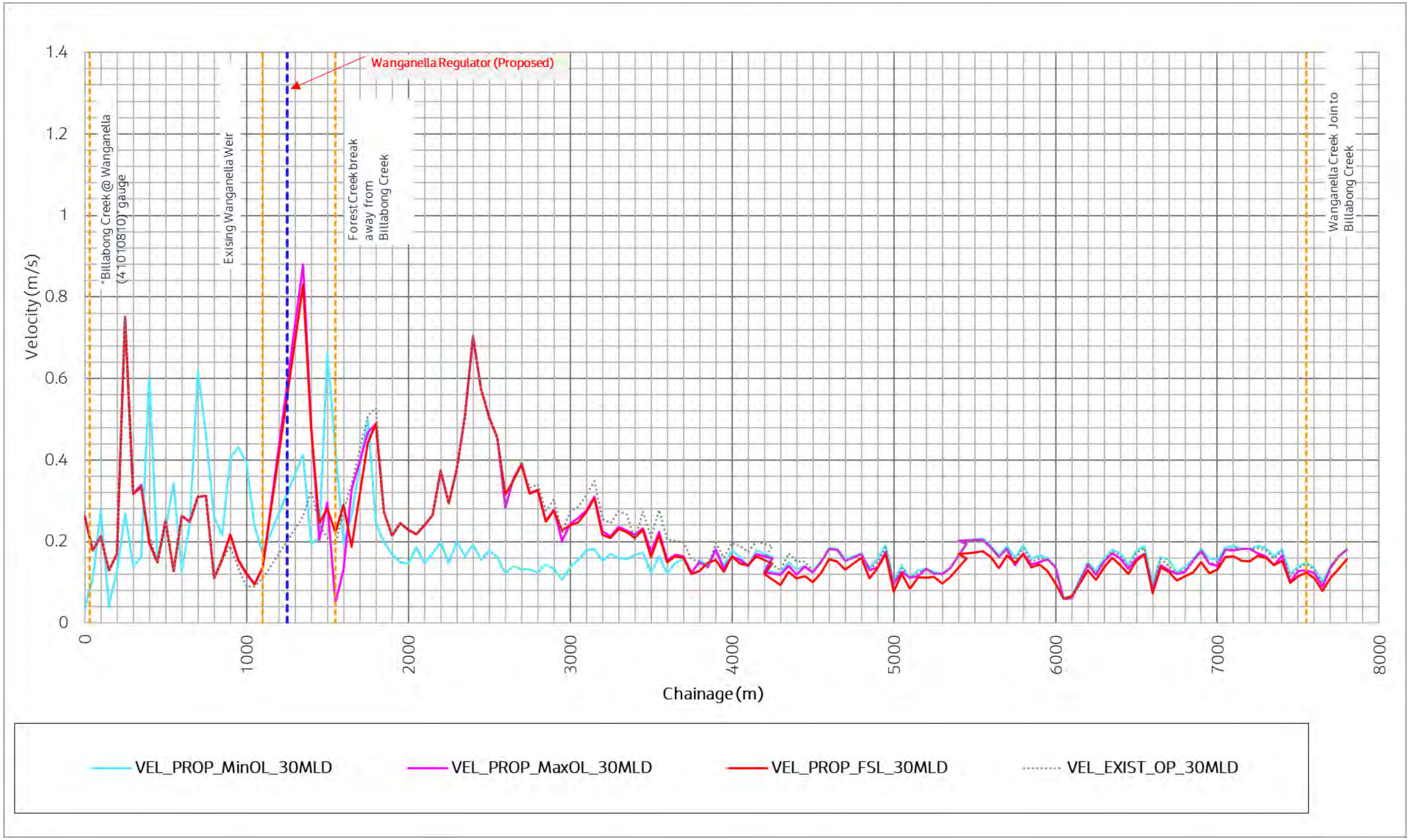


Figure 59: "Proposed" and "Existing" Velocity comparison along Billabong Creek for Minimum Operating Flow (MinOF) of 30 ML/day at Wanganella Regulator

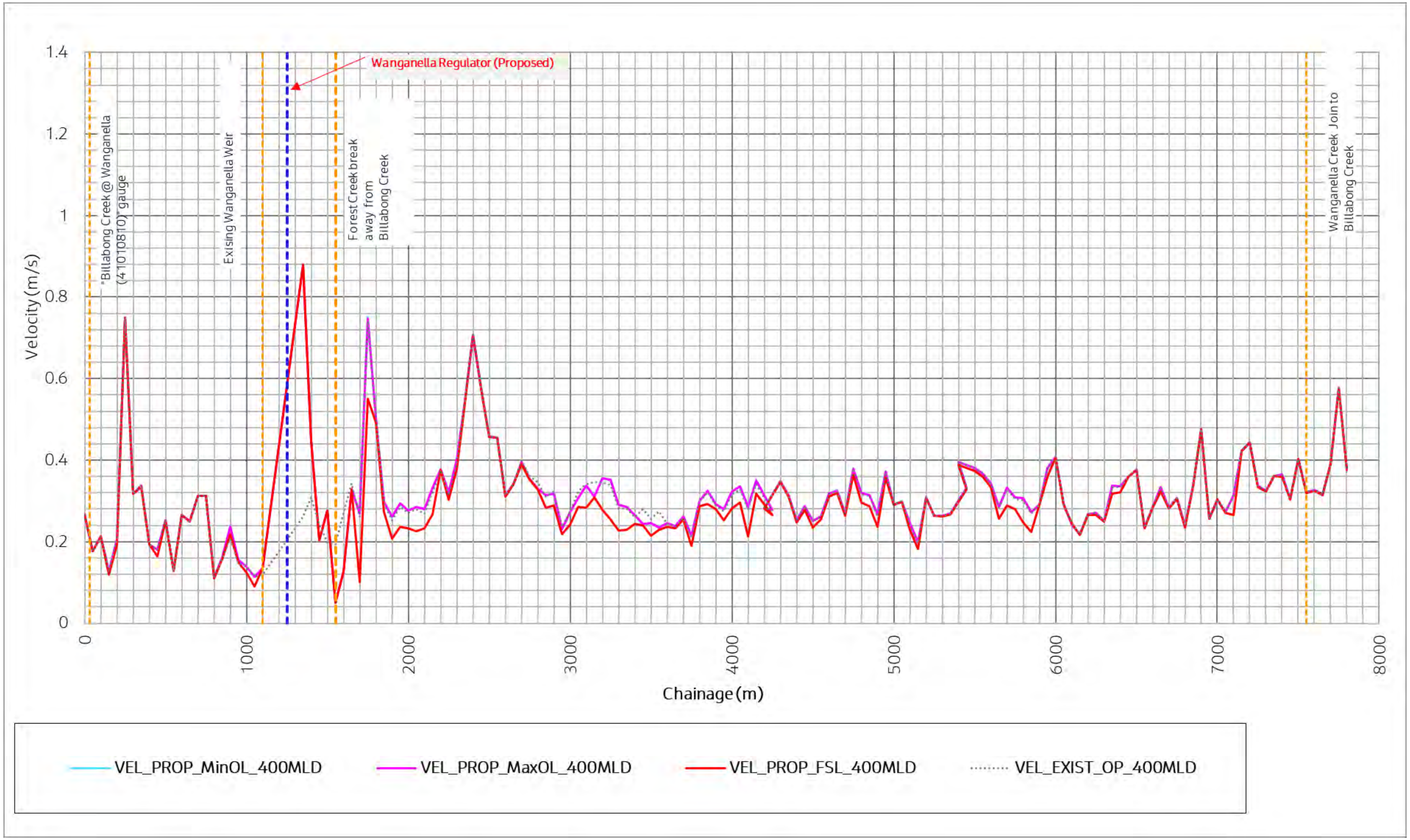


Figure 60: "Proposed" and "Existing" Velocity comparison along Billabong Creek for Maximum Operating Flow (MaxOF) of 400 ML/day at Wanganella Regulator

7.2 Flood Flow Scenarios

As noted above, the impacts in the "Flood Flow" scenario were assessed from two aspects:

- The impact caused by the Wanganella Regulator only; and
- The cumulative impact caused by all proposed works, including the Wanganella Regulator and other construction works in the Wanganella Swamp.

Preliminary assessments suggested that the Wanganella Regulator works will not affect the southern area while the southern works (i.e., Wanganella Swamp works) can impact the northern area at certain location (i.e., through Estuary Creek). This was anticipated as the southern waterways (i.e., Estuary Creek, Eight Mile Creek, and Forest Anabranch) are generally higher than the northern waterway (i.e., Billabong Creek). Therefore, the "all proposed works" scenario (cumulative impact) is more conservative (i.e., the worst-case) scenario, as the proposed works in Wanganella Swamp are either independent or likely to amply the impact caused by the Wanganella Regulator.

With the consideration of above findings, the flood impact in the Wanganella Regulator only scenario was assessed for 20%, 5%, and 1% AEPs only, whilst the cumulative impact in the "all proposed works" scenario was assessed for a wider range of storm probabilities, including 20%, 5%, 1%, 0.5%, 0.2% AEPs and PMF, among which the 0.5% and 0.2% AEPs were modelled as proxies for climate change scenarios – refer to EIS report (3Rivers, 2024b) for detailed explanation. Only the cumulative case was modelled for the 0.5% and 0.2% AEP climate change sensitivity events and the PMF as:

- This represented the worst-case scenario in terms of flood impacts
- Initial modelling indicated that there was no impacts in the rarer events
- Hence if there were no impacts in the worst-case scenario (cumulative case) there would be no impacts in the regulator only case

7.2.1 Impact by Wanganella Regulator

7.2.1.1 Flows

A summary of flows for "Existing" and "Proposed" under the modelled flood flow scenarios are presented in Table 36 for the 20%, 5%, and 1% AEP flood scenarios where Billabong Creek is dominant, which shows the following general trends based on the comparison locations:

- 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 1% AEP events, 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) on Billabong Creek flows. 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) on Billabong Creek flows, 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).

7.2.1.2 Afflux

A summary of the WSL impacts between "Existing" and "Proposed" are presented spatially in Appendix E, which presents two sets of afflux maps, one across the downstream part of the Study Area (covering the entire Wanganella Pool) with a modelling tolerance of ±50 mm (no impact) and the other zoomed into the Wanganella Township Area with a modelling tolerance of ±10 mm (no impact). 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. Figure 61 presents a long section plot along Billabong Creek from "Billabong Creek @ Wanganella (41010810)" gauge (upstream Wanganella Weir) to just downstream of the confluence of Wanganella Creek and Billabong Creek for the 20%, 5%, and 1% AEP flood scenarios where Billabong Creek is dominant.

The results 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. The results collectively show the following:

- 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 immediately upstream of the regulator. 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 1% AEP events, the upstream and immediately downstream of Wanganella Weir experience minor decreases in WSL, with changes of up to approximately -25 mm. The reduction in these larger events is the result of the engagement of the proposed flood relief channel to the north in these events, which is designed to activate in these 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.

The area between Billabong Creek and Lang Street in Wanganella township, including several private properties (i.e., backyards), experienced moderate increase in flood levels (up to +68 mm) during 20% AEP event, and minor flood level increases (up to +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 with the flood relief channel in place. Nevertheless, the change in flood characteristics in this area do not result in an increase of flood risk, because of the following reasons:

- 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).

- The evacuation (emergency) route through Lang Street is not affected.

- 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.

7.2.1.3 Flood Hazard

The results show that there has been minimal change in hazard category distribution with noted changes across all scenarios of around +/-0.02% within the study area (refer to Figure 62). These minor 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.

7.2.1.4 Wanganella Regulator Impacts Discussion

The modelling and assessment of results has demonstrated there are no significant impacts from the Wanganella Regulator and associated works including the Flood Relief Channel to the Study Area. There is a small area of impact to residential properties, but not buildings, along the Billabong Creek. It has been found that the riparian zone between the Billabong Creek and Lang Street experienced moderate afflux (approximately 68 mm) in the 20% AEP event which reduces to no impact 1% AEP event. The reduction of impact in the 1% event is due to a) the flood relief channel and b) the structure is effectively drained out in larger events. Nevertheless, the change in flood characteristics in the riparian zone will unlikely result in real increase of flood risk, because:

1. The vast majority of the areas impacted are inundated in the existing case1)

2. The impact has not extended to the existing dwellings, i.e., no +10 mm afflux to the residential dwellings;

3. 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;

4. The impacted area would be classified as floodway or flood storage in 1% AEP, and thus there are no increases in the extent at the plaining level and there should be no future development in the affected area.

Climate change sensitivity assessment A climate change sensitivity assessment was undertaken by modelling the 0.5% (1 in 200) AEP and 0.2% (1 in 500) AEP events. These events were modelled for only the cumulative case as model results have demonstrated that the Wanganella regulator impacts are independent to the impacts from the Wanganella Swamp results for larger events. The results from these events (presented in Section 7.2.2) demonstrate there are no impacts in Billabong Creek (with some impacts in and around Wanganella Swamp as discussed in Section 7.2.2.2). This removal of impacts is due to the flood relief channel.

Probable Maximum Flood

The PMF was modelled for only the cumulative case, which is presented in Section 7.2.2 demonstrated that there are no impacts in this event in the Billabong Creek or Wanganella Township.

Table 36: Flow Comparison for Flood Flow Scenarios – Wanganella Regulator Only vs Existing

Flow Description	Model Condition & Variable	Location [PO ID]			
		Billabong Creek @ Wanganella Gauge [WNG_GAUGE]	Billabong Creek approx. 15m downstream of the Cobb HWY [B_242.6]	Billabong Creek approx. 55m upstream of the existing Wanganella Weir [WGNReg_US_1]	Billabong Creek approx. 0.1km downstream of the existing Wanganella Weir [WGNREG_DS_1]
20% (1 in 5) AEP Billabong Dominant	EXIST Flow (ML/day)	3,752	3,752	3,750	3,750
	PROP Flow (ML/day)	3,751	3,751	3,749	3,748
	Change in Flow (ML/day) [PROP - EXIST]	**-1**	**-1**	**-1**	**-2**
5% (1 in 20) AEP Billabong Dominant	EXIST Flow (ML/day)	8,113	8,113	8,107	8,105
	PROP Flow (ML/day)	8,114	8,114	8,107	8,104
	Change in Flow (ML/day) [PROP - EXIST]	**1**	**1**	**0**	**-1**
1% (1 in 100) AEP Billabong Dominant	EXIST Flow (ML/day)	14,552	14,492	14,552	14,550
	PROP Flow (ML/day)	14,555	14,502	13,591	13,586
	Change in Flow (ML/day) [PROP - EXIST]	**3**	**10**	**-961**	**-964**

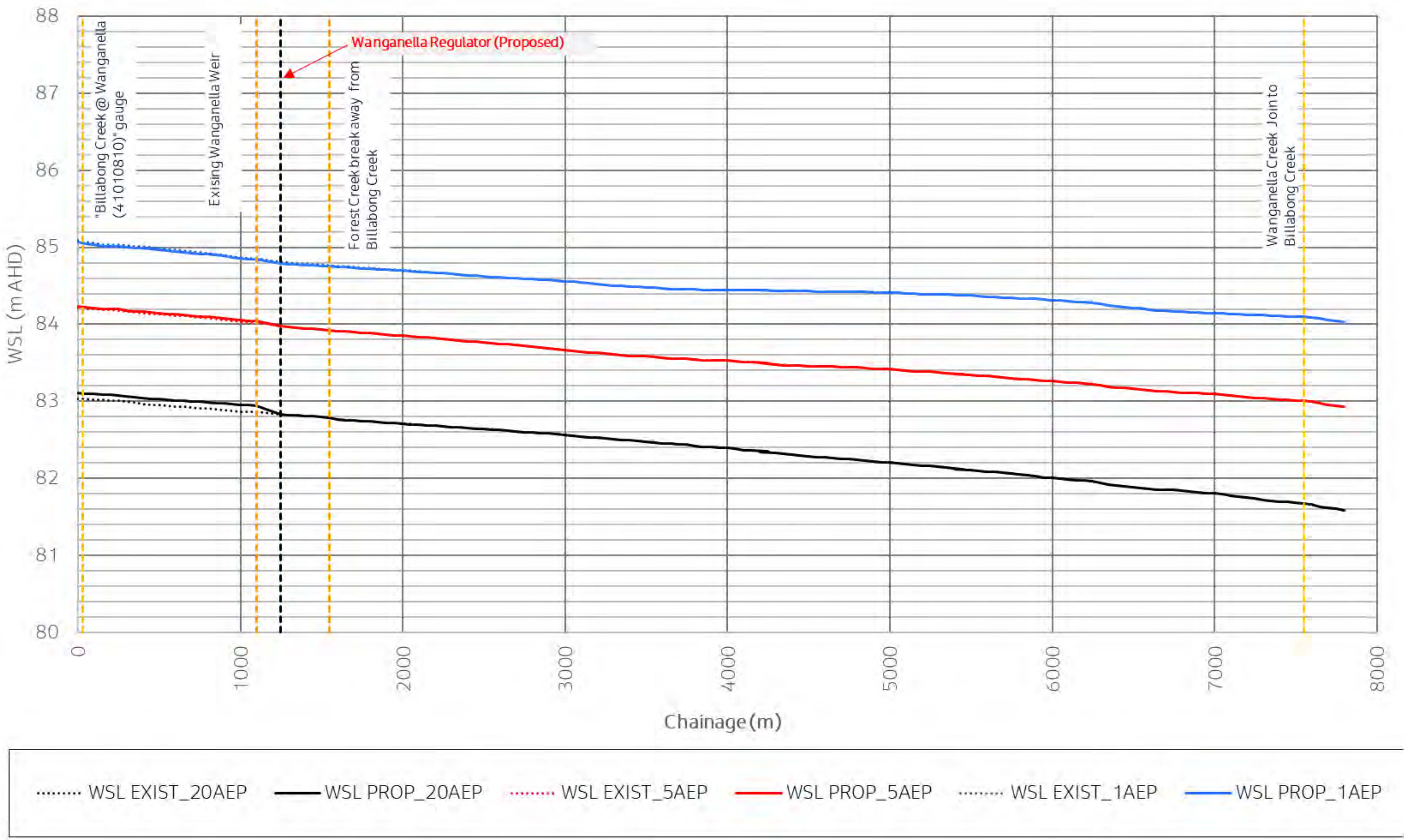


Figure 61: WSL comparison along Billabong Creek for flood scenarios – Wanganella Regulator Only vs Existing

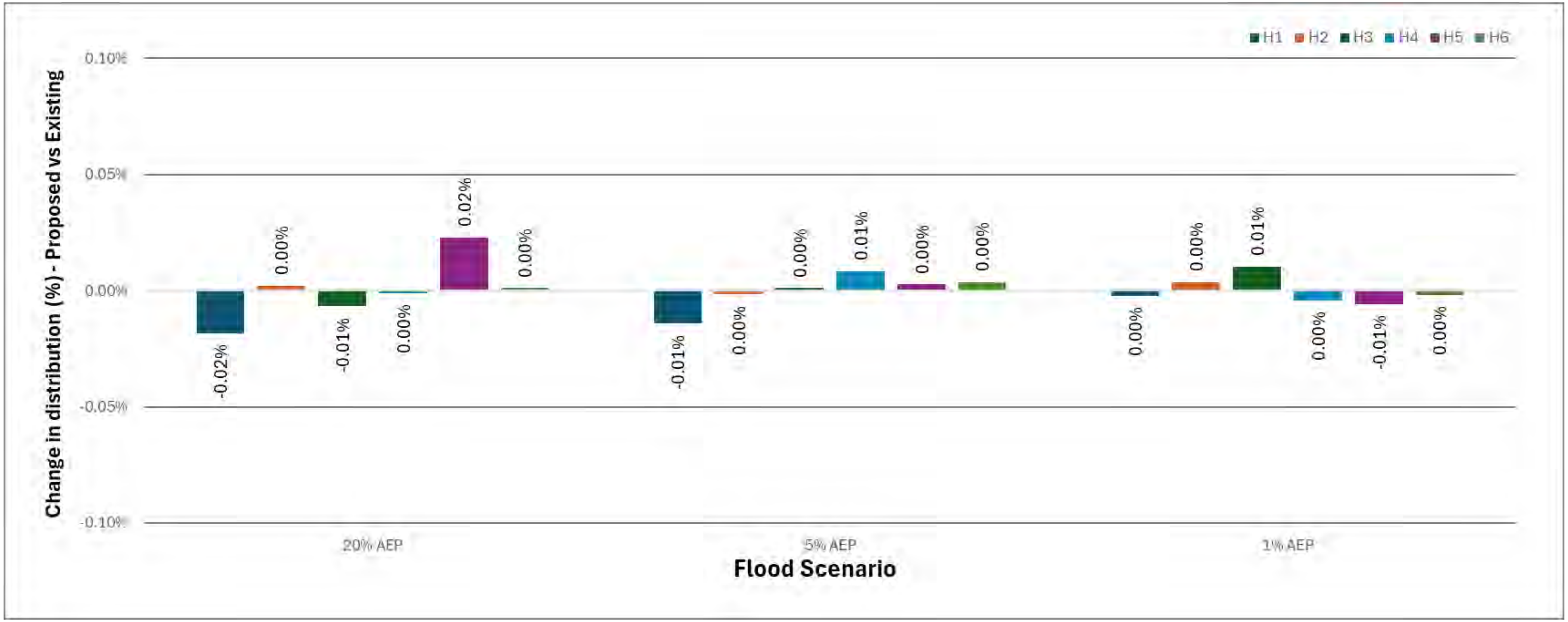


Figure 62: Hazard category distribution change flood scenarios – Wanganella Regulator Only vs Existing

7.2.2 Cumulative Impact by All Works

As discussed above, the at the time of the design freeze the Wanganella Swamp works were not finalised. Given the level of uncertainty in the design of these elements worst case design were used in the cumulative assessment. It is noted that the designs have progressed, and the flood impacts have been reduced.

7.2.2.1 Flows

A summary of flows for “Existing” and “Proposed” under the modelled flood flow scenarios are presented in Table 37 for the 20% AEP to PMF flood scenarios where Billabong Creek is dominant, which shows the following general trends based on the comparison locations:

- 20% (1 in 5) AEP – a general increase of peak flow rates in Billabong Creek downstream of 4 Mile Weir and Estuary Creek, and a decrease in the Eight Mile Creek downstream of Estuary Creek Regulator. The increase of flow rates in Billabong Creek is around 130 ML/Day (~ 3.5% of existing condition flow rates). The flow redistribution between the northern and southern watercourses is expected due to the following factors:
    - The existing Estuary Creek Regulator is mainly controlled by a 900 RCP culvert with operational sluice gate (SGO) which was found to be significantly blocked (i.e., SGO unfunctional) and thus modelled as fully blocked.
    - The proposed Estuary Creek Regulator with 1.80(W)x 1.50 (H) RBC and a flume gate fully open during flood events is a significant improvement compared to the existing regulator which diverts more flow from Eight Mile Creek into Estuary Creek, which is the intention of the design.
    - It is understood that the intent is to operate the existing regulator during flood events; however, for this assessment the regulator was modelled as closed based on site observations and to ensure the assessment was conservative.
- 5% (1 in 20) AEP – same trend as 20% AEP, but with a further altered magnitude of change. The increase of flow rates in Billabong Creek is around 100 ML/Day (~ 1.2% of existing condition flow rates). The decrease of flow rates in Eight Mile Creek varies from upstream to downstream, i.e., 5% to 33% of existing condition flow rates.
- 1% (1 in 100) to 0.2% (1 in 500) AEPs – there are no notable increase of flow rates (less than +0.5%) upstream of the Wanganella Regulator, but a decrease downstream of the Wanganella Regulator, i.e., -6.4% (-930 ML/Day), -12.3% (2,294 ML/Day), and -15.0% (-3,460 ML/Day) respectively in 1%, 0.5%, and 0.2% AEPs, due to the engagement of ,the new flood relief channel to the north.
- PMF – up to +440 ML/Day (+1.1%) upstream of the Wanganella Regulator while -2,780 ML/Day (-9.2%) downstream due to the engagement of the new flood relief channel to the north.

Table 37: Flow Comparison for Flood Flow Scenarios – All Proposed Works vs Existing

Flood Scenario	Model Condition & Variable	Location [PO ID]				
		Billabong Creek @ Wanganella Gauge [WNG_GAUGE]	Billabong Creek approx. 15m downstream of the Cobb Hwy [B_242.6]	Billabong Creek, approx. 0.2km downstream of Wanganella Weir [WGNReg_DS_2]	Estuary Creek, approx. 0.5Km downstream of Estuary Creek Regulator [EC_0.5]	Eight Mile Creek immediately upstream of Southern Regulator [COBBHY_01_US]
20% (1 in 5) AEP Billabong Dominant	EXIST Flow (ML/day)	3,752	3,752	3,749	86	253
	PROP Flow (ML/day)	3,884	3,884	3,880	173	182
	Change in Flow (ML/day) [PROP - EXIST]	**132**	**132**	**131**	**86**	**-71**
5% (1 in 20) AEP Billabong Dominant	EXIST Flow (ML/day)	8,113	8,113	8,105	86	352
	PROP Flow (ML/day)	8,214	8,214	8,203	173	289
	Change in Flow (ML/day) [PROP - EXIST]	**101**	**101**	**99**	**86**	**-63**
1% (1 in 100) AEP Billabong Dominant	EXIST Flow (ML/day)	14,552	14,492	14,549	86	694
	PROP Flow (ML/day)	14,602	14,548	13,618	173	646
	Change in Flow (ML/day) [PROP - EXIST]	**50**	**56**	**-932**	**86**	**-48**
0.5% (1 in 2000) AEP Billabong Dominant	EXIST Flow (ML/day)	18,616	18,397	18,614	78	694
	PROP Flow (ML/day)	18,670	18,474	16,319	186	630
	Change in Flow (ML/day) [PROP - EXIST]	**53**	**77**	**-2,294**	**108**	**-64**
0.2% (1 in 500) AEP Billabong Dominant	EXIST Flow (ML/day)	24,724	24,359	23,075	78	1,202
	PROP Flow (ML/day)	24,860	24,513	19,614	177	1,183

Flood Scenario	Model Condition & Variable	Location [PO ID]				
		Billabong Creek @ Wanganella Gauge [WNG_GAUGE]	**Billabong Creek approx. 15m downstream of the Cobb Hwy [B_242.6]**	**Billabong Creek, approx. 0.2km downstream of Wanganella Weir [WGNReg_DS_2]**	**Estuary Creek, approx. 0.5Km downstream of Estuary Creek Regulator [EC_0.5]**	**Eight Mile Creek immediately upstream of Southern Regulator [COBBHY_01_US]**
	Change in Flow (ML/day) [PROP - EXIST]	**136**	**153**	**-3,460**	**99**	**-19**
PMF	EXIST Flow (ML/day)	39,706	39,435	30,284	53	2,603
	PROP Flow (ML/day)	40,139	39,873	27,505	183	2,606
	Change in Flow (ML/day) [PROP - EXIST]	**433**	**437**	**-2,779**	**130**	**3**

7.2.2.2 Afflux

A summary of the WSL impacts between “Existing” and “Proposed” are presented spatially in Appendix F, which presents water level change maps across the downstream Study Area, and Figure 63 and Figure 64, which presents long sections along Billabong Creek from “Billabong Creek @ Wanganella (41010810)” gauge (upstream Wanganella Weir) to just downstream of the confluence of Wanganella Creek and Billabong Creek where Billabong Creek is dominant. The actual WSL in both scenarios, as well as the afflux or differences at some key locations are also presented numerically in Table 38 and Table 39. These results collectively show the following key outcomes:

- 20% (1 in 5) AEP – Due to the cumulative effect of the Wanganella Regulator and the Wanganella Swamp regulators, there is a general increase of peak flood level in the Billabong Creek downstream of 4 Mile Weir and Estuary Creek. Specifically:
    - The WSL has increased by up to 130 mm in the Wanganella Weir Pool, due to the proposed Wanganella Regulator. This is an increase of 44 mm from the regulator only case and this additional increase is due to additional flow along Estuary Creek.
    - As discussed in Section 7.2.2.1, the additional flow along Estuary Creek (as well as increased WSL) is due to the assumption made to the existing Estuary Creek Regulator, i.e., fully blocked, which is conservative for this assessment.
    - In general, the WSL impact (over 50 mm afflux) in Billabong Creek is constrained within the water course, i.e., weir pool area, except for the Wanganella township area between the Billabong Creek and Lang Street, which is discussed in detail below.
- 5% (1 in 20) AEP – In general, there is no over 50 mm afflux in Billabong Creek. The minor impact in Billabong Creek is up to 43 mm, which is an increase of 23 mm from the regulator only case and this additional increase is due to additional flow along Estuary Creek. This afflux has extended to Wanganella township area between the Billabong Creek and Lang Street, which is discussed in detail below.
- 1% (1 in 100) AEP to PMF – In general, there is no notable flood impact in Billabong Creek. The only minor increase of WSL (< 50 mm afflux) is identified immediately downstream of the Flood Relief Channel, which is restricted in the reserve area, i.e., not affecting private properties.

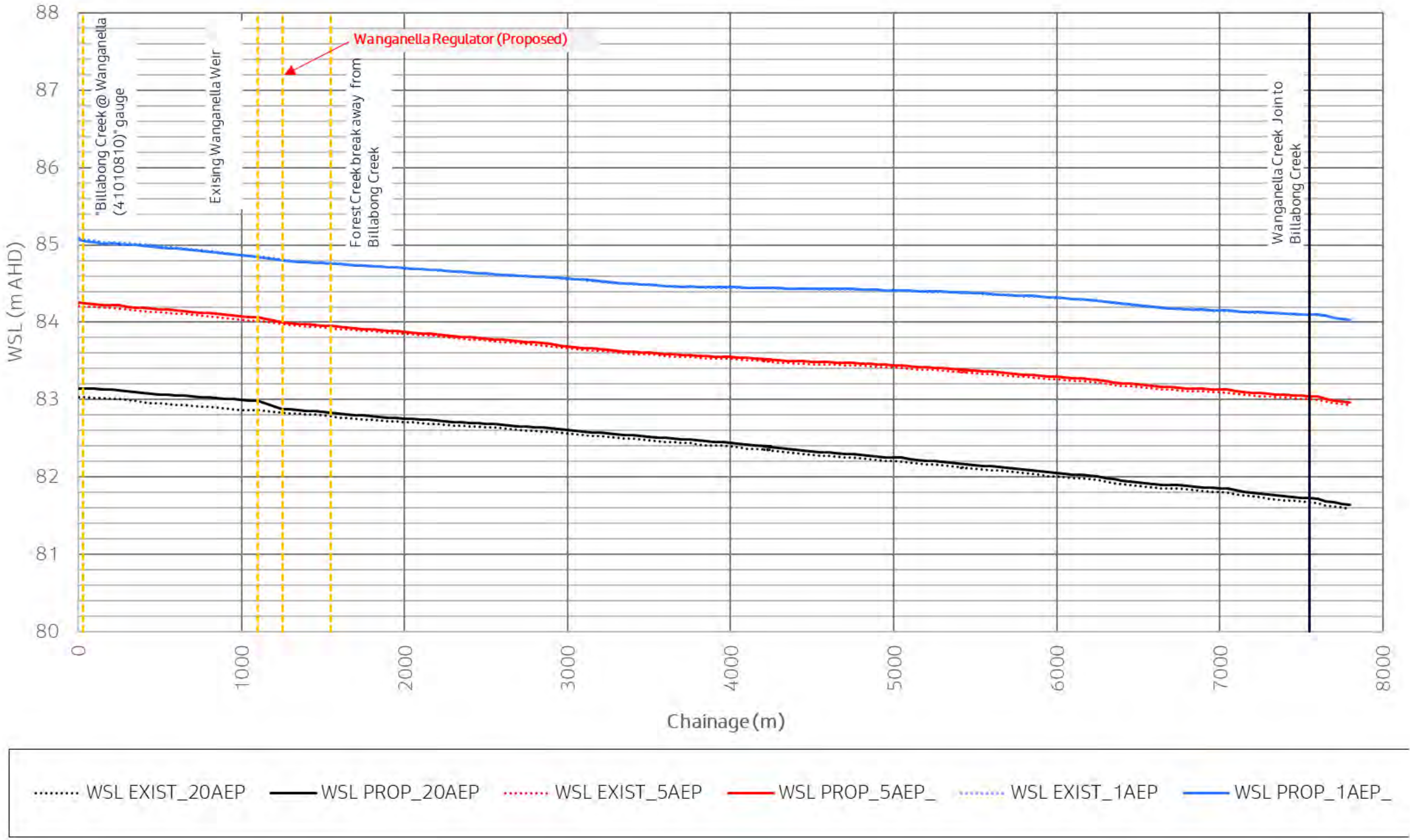


Figure 63: WSL comparison along Billabong Creek for 20% AEP to 1% AEP flood scenarios – All Proposed Works vs Existing

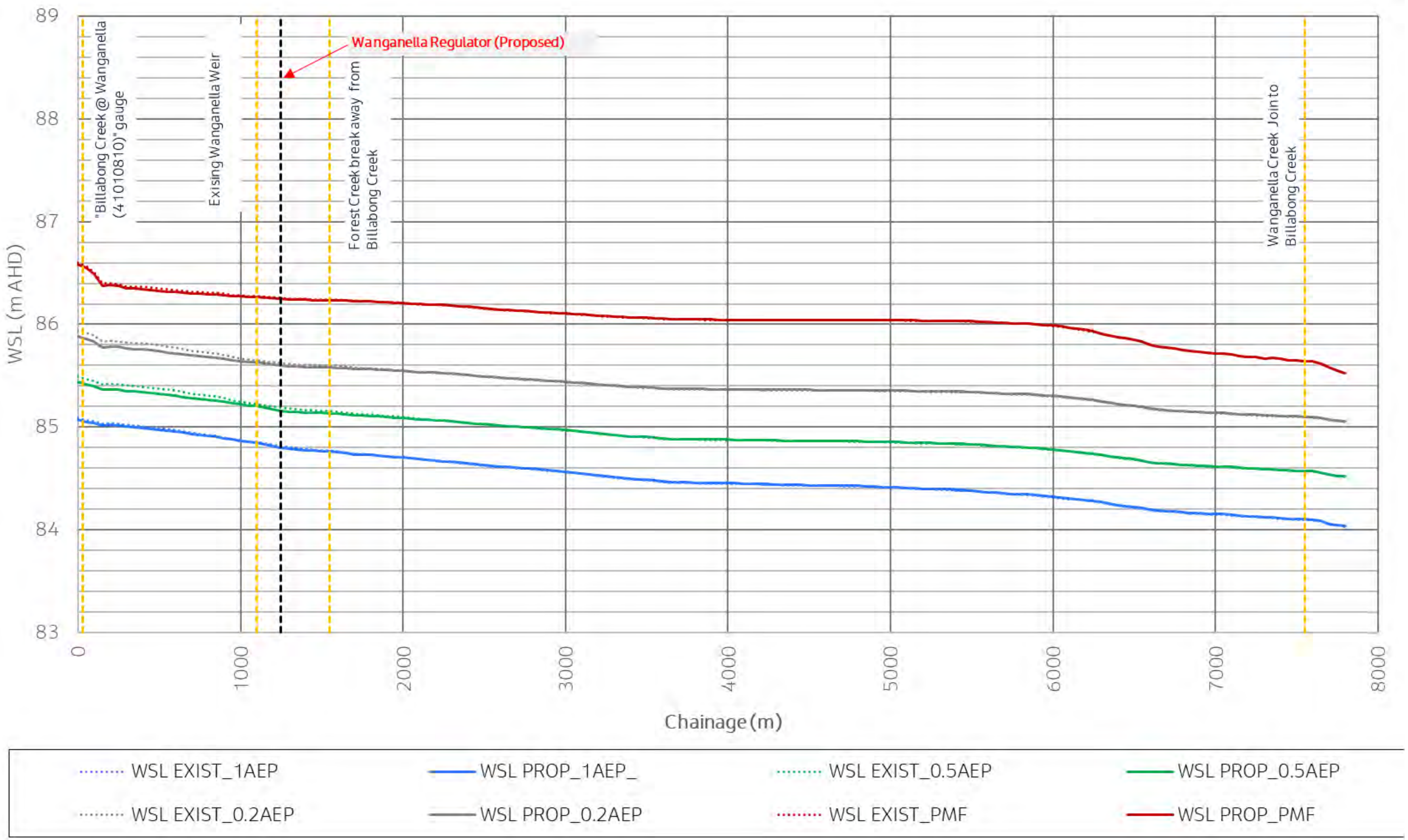


Figure 64: WSL comparison along Billabong Creek for 1% AEP to PMF flood scenarios – All Proposed Works vs Existing

Table 38: WSL Comparison for 50% AEP to 1% AEP flood flow scenarios – All Proposed Works vs Existing

Location Description	PO_ID	20% (1 in 5) AEP			5% (1 in 20) AEP			1% (1 in 100) AEP		
		Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)	Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)	Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)
Billabong Creek @ Wanganella Gauge	Wang_Gauge	83.03	83.14	**113**	84.20	84.24	**38**	85.07	85.05	**-17**
Billabong Creek approx. 15m downstream of the Cobb Hwy	B_242.55	83.02	83.13	**114**	84.19	84.22	**38**	85.03	85.02	**-18**
Billabong Creek approx. 55m upstream of the existing Wanganella Weir	WGN_REG_US1	82.86	82.99	**128**	84.02	84.06	**44**	84.85	84.85	**-3**
Billabong Creek, approx. 0.11km downstream of Wanganella Weir	WGN_REG_DS2	82.83	82.88	**47**	83.97	83.99	**25**	84.81	84.79	**-14**
Estuary Creek approx. 0.35km downstream of Estuary Creek Regulator	EC_1	85.15	86.08	**928**	85.48	86.23	**751**	86.35	86.50	**152**
Eight Mile Creek approx. 1.2km downstream of Estuary Creek Regulator	E_24	86.30	86.27	**-32**	86.35	86.34	**-13**	86.49	86.51	**16**
Eight Mile Creek approx. 70m downstream of Southern Regulator	CobbHwy_DS_S	86.25	86.22	**-27**	86.28	86.26	**-19**	86.36	86.35	**-9**
Eight Mile Creek approx. 70m downstream of Eight North Regulator	CobbHwy_DS_N	86.29	86.26	**-29**	86.33	86.32	**-13**	86.42	86.43	**5**

Table 39: WSL Comparison for 0.5% AEP to PMF flood flow scenarios – All Proposed Works vs Existing

Location Description	PO_ID	0.5% (1 in 200) AEP			0.2% (1 in 500) AEP			PMF		
		Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)	Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)	Existing WSL (m AHD)	Proposed WSL (m AHD)	Change in WSL (mm)
Billabong Creek @ Wanganella Gauge	Wang_Gauge	85.47	85.42	**-50**	85.92	85.86	**-54**	85.74	85.68	**-55**
Billabong Creek approx. 15m downstream of the Cobb Hwy	B_242.55	85.42	85.36	**-51**	85.83	85.78	**-57**	85.67	85.61	**-57**
Billabong Creek approx. 55m upstream of the existing Wanganella Weir	WGN_REG_US1	85.23	85.20	**-23**	85.65	85.63	**-23**	85.48	85.46	**-25**
Billabong Creek, approx. 0.11km downstream of Wanganella Weir	WGN_REG_DS2	85.18	85.16	**-27**	85.62	85.59	**-23**	85.45	85.42	**-26**
Estuary Creek approx. 0.35km downstream of Estuary Creek Regulator	EC_1	86.53	86.54	**2**	86.82	86.80	**-19**	86.69	86.66	**-28**
Eight Mile Creek approx. 1.2km downstream of Estuary Creek Regulator	E_24	86.49	86.50	**11**	86.69	86.69	**2**	86.58	86.59	**6**
Eight Mile Creek approx. 70m downstream of Eastern Swamp Southern Regulator	CobbHwy_DS_S	86.36	86.34	**-12**	86.43	86.43	**-3**	86.40	86.39	**-5**
Eight Mile Creek approx. 70m downstream of Eight Mile Creek North Regulator	CobbHwy_DS_N	86.42	86.42	**2**	86.54	86.53	**-7**	86.48	86.48	**-3**

7.2.2.3 Flood Hazard

A summary of the flood hazard characteristics in the "Existing" and "Proposed" scenarios are presented spatially in Appendix F, which presents maps across the downstream Study Area based on hazard categories defined in NSW's "Flood Hazard: Flood Risk Management Guideline FB03" document and Australian Rainfall and Runoff 2019 (ARR2019) – which are defined in Figure 54 in Section 7.1.3. A comparison of the distribution of the categories of the entire Study Area is presented in Figure 65 for the 20% to 1% AEP flood scenarios.

These results collectively show the distribution of hazard categories have changed slightly as expected with changes across all AEPs ranging from between around -1.5% to +0.6%.

A more notable change occurs during more frequent events, e.g., 20% AEP flood scenario, with a decrease in H1 and increase of the other hazard categories. However, this is not concerned as the increase of hazard level is mostly restricted within the water courses, i.e., not causing external hazard impact. The hazard change in the rest rarer AEPs is relatively minor.

7.2.2.4 Velocity

A summary of the velocity characteristics in the "Existing" and "Proposed" scenarios are presented spatially in Appendix F, which presents maps across the downstream Study Area based on the fish habitat categorisation in Table 35 in Section 7.1.4. A comparison of the distribution of the categories of the entire Study Area are presented in Figure 66 for the 20% to 1% AEP flood scenarios.

These results collectively show the distribution of velocity categories have changed slightly as expected with changes across all AEPs ranging from between around -0.5% to +0.5%. 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, which is partially demonstrated by the comparison of velocity along a long-section on Billabong Creek presented in Figure 67.

7.2.2.5 Cumulative Impact Discussion

A cumulative impact assessment has been undertaken that incorporates the details of the Wanganella Swamp proposals. Other parts of the Yanco Creek modernisation project are remote to the location of Wanganella Swamp and cumulative impact assessment for the Hartwood Regulator has shown that these proposals have no impact and are independent from Hartwood. As Hartwood is upstream of Wanganella with the existing Piccaninny weir between it was concluded that these other works were also independent form Wanganella.

Design details for the proposed Wanganella Swamp structures were not finalised at the time this assessment was undertaken, therefore, designs that created the worst-case flooding conditions were adopted for this assessment. So, this assessment can be considered conservative with respect to cumulative flood impacts i.e. the flood impacts in Billabong Creek are the most that would be expected.

The modelling and assessment of results has demonstrated there are no significant cumulative impacts to the Study Area with the potential exception of the riparian zone between the Billabong Creek and Lang Street. Inundation in this area is increased compared to the regulator only assessment in smaller (more frequent) AEP events. As outlined above this the increased impact in smaller flood events is primarily due to the opposing assumptions regarding the operation of Estuary Creek in the existing and proposed case modelling. If the same assumption was used in both cases the impacts in the cumulative case would be reduced. The modelled impact in the riparian zone was approximately 112 mm in the 20% AEP event which reduces to no impact in the 1% AEP event. The reason for no impact in the 1% AEP event was because of the flood relief channel. While there in an increase impact in the 20% AEP event compared to the Wanganella only case, this is not considered to significant as this is a worst-case impact and for the reasons outlined in Section 7.2.1.4.

Climate change sensitivity assessment

As noted above in Section 7.2.1.4 and Section 7.2.2.1 to 7.2.2.4, there are no impacts in the climate change sensitivity runs in Billabong Creek nor Wanganella Township.

Probable Maximum Flood

As noted above in Section 7.2.1.4 and Section 7.2.2.1 to 7.2.2.4, there are no impacts in the PMF runs in Billabong Creek or Wanganella Township.

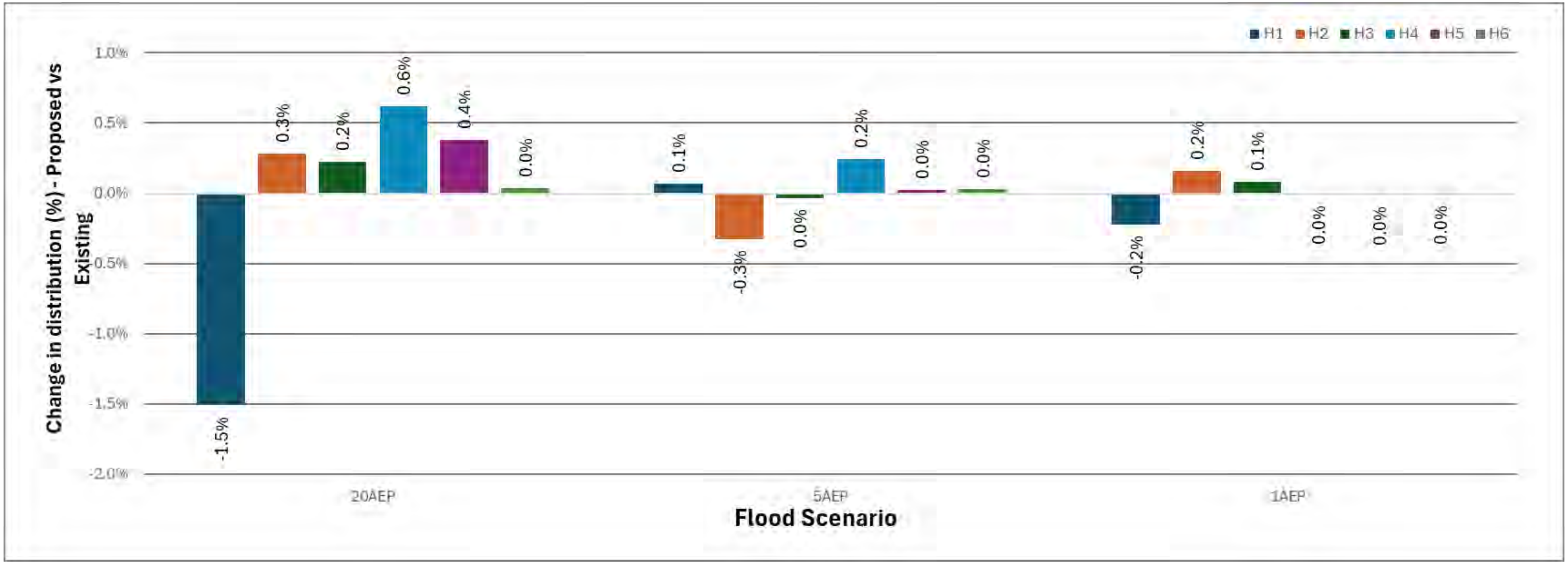


Figure 65: Hazard category distribution change for 20% AEP to 1% AEP flood scenarios where Billabong Creek is dominant – All Proposed Works vs Existing

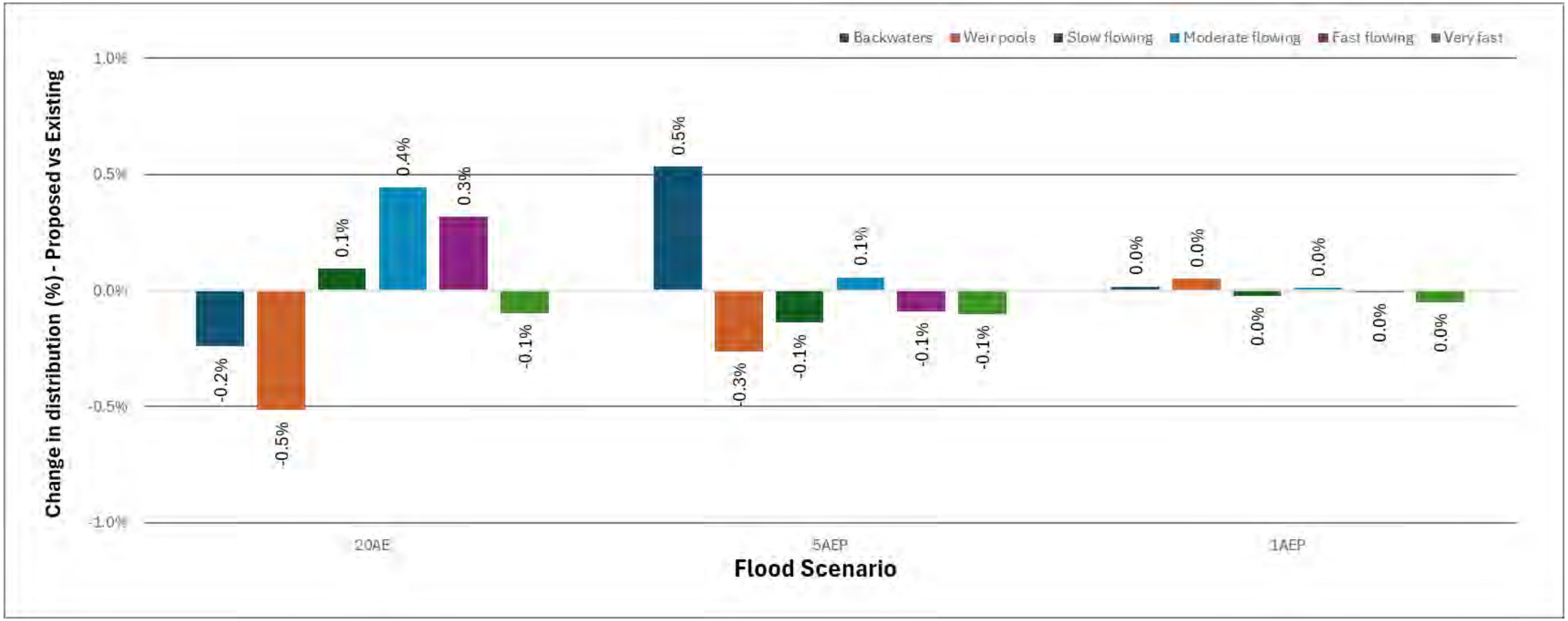


Figure 66: Velocity category distribution change for 20% AEP to 1% AEP flood scenarios where Billabong Creek is dominant – All Proposed Works vs Existing

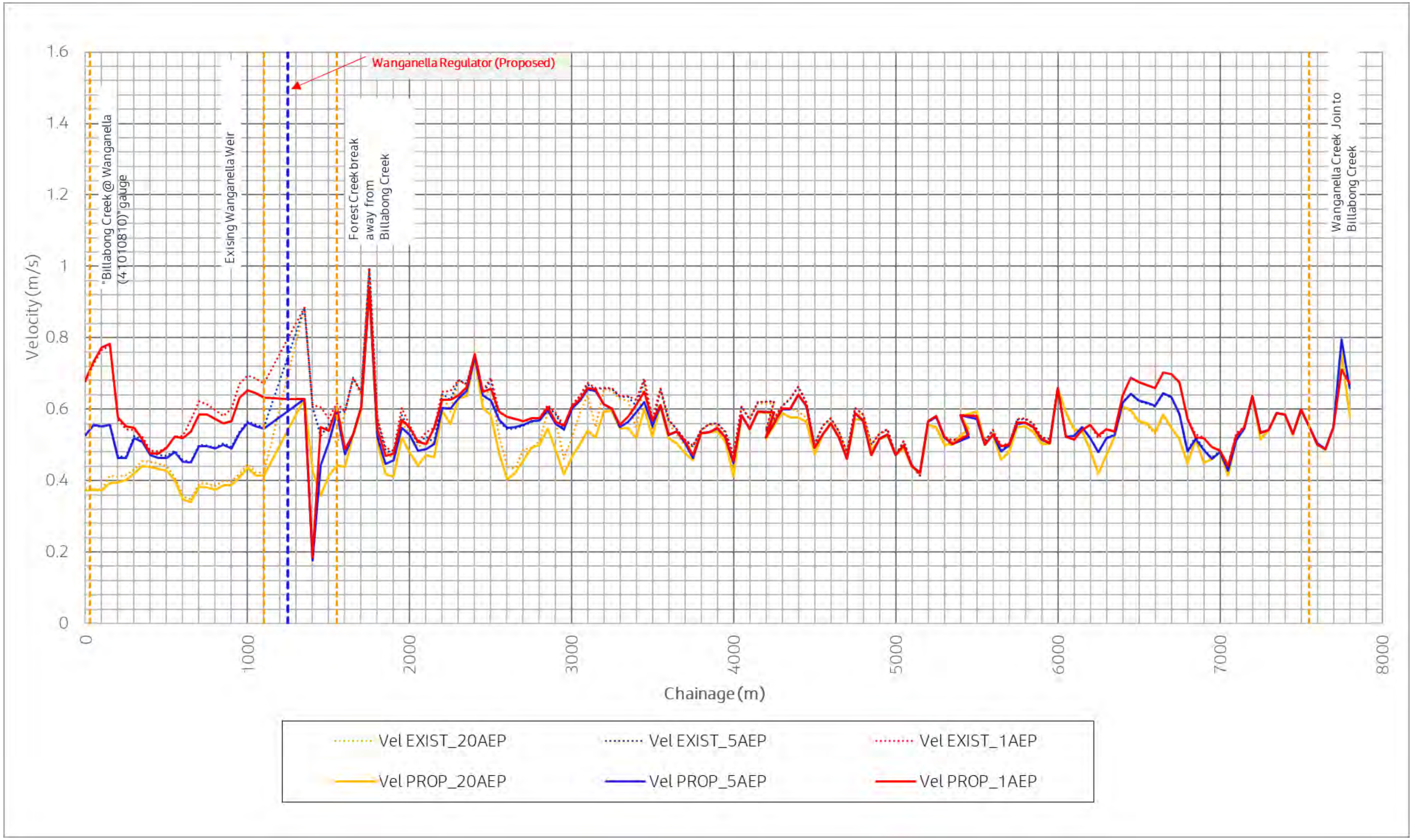


Figure 67: Velocity comparison along Billabong Creek for for 20% AEP to 1% AEP flood scenarios where Billabong Creek is dominant – All Proposed Works vs Existing

7.3 Impact Conclusion

Based on the results presented the proposed works at Wanganella Creek Regulator and the Swamp regulators do not have a significant impact on the flood characteristics of the Study Area.

It has been found that the riparian zone between the Billabong Creek and Lang Street in Wanganella township, covering a portion of several private properties (i.e., backyards), experienced moderate afflux during 20% AEP event (i.e., 68 mm afflux under regulator only scenario and 112 mm afflux under all works scenario), and minor afflux (< 50 mm) during 5% AEP events. The impact was not found during 1% AEP event or above due to the proposed construction of the flood relief channel. Nevertheless, the change in flood characteristics in the riparian zone will unlikely result in real increase of flood risk, because:

1. The vast majority of the areas impacted are inundated in the existing case
2. The impact has not extended to the existing dwellings, i.e., no +10 mm afflux to the residential dwellings;
3. 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;
4. The impacted area would be classified as floodway or flood storage in 1% AEP, and thus there are no increases in the extent at the plaining level and there should be no future development in the affected area.

Finally, it should be noted that the cumulative impacts are a worst-case assessment as discussed above. there are some optimisations of the designs and/or operation plans that may occur as part of the detailed designs, but this is only likely to reduce the assessed impacts.

8. Limitations, Assumptions and Uncertainty

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.

Although data collection prior to this model build has been extensive, there are still areas of uncertainty which may cause limitations to the accuracy of the model. The following elements have been identified as uncertainties, assumptions or limitations related to the development of this model:

- Many but not all floodplain structures were visited during the 3Rivers site visits and therefore assumptions were made to the size, elevation, and type of those structures. Localised flooding during the data collection phase also prevented measurements or survey being completed. Assumptions were made based on nearby structure information and LiDAR products. Most floodplain structures invert levels were also assumed based on LiDAR products and/or the measured height to crest.

- The high-resolution LIDAR products available in the area were collected when there was ponded water in the floodplain and assumptions have been made to ensure the flow paths are more representative of the dry channel. LiDAR products collected previously did not cover all areas of ponding.

- Soil losses were estimated based on typical infiltration rates and assumed minimal initial losses given the length of the modelled events and scenarios. Infiltration data for soils is very limited and can vary greatly depending on antecedent conditions, soil type and compaction for example. Without field sampling of the soil, infiltration rates will be an estimate.

- General modelling assumptions relate to the selection of various parameters within the model, for example, the roughness values used within the model. A programme of model proving was undertaken to understand any uncertainties associated with the choice of parameters and their impact upon model results. The full details of the model proving can be found within this report. In summary, the model was shown to be reasonably sensitive to changes in in-channel roughness, but generally insensitive to other parameters. Changes in in-channel roughness were found to have a substantial influence on the areas of inundation within the study area.

- As is typically the case with hydraulic model outputs, areas close to the upstream and downstream extents of a hydraulic model should be treated with caution and this is particularly important for areas where the models will not have had the spatial coverage to adequately develop to realistic inundation and flow mechanisms.

- The RRC model was calibrated the 2022 event that was ongoing during the project as such live data, that is data that had not yet been fully quality controlled, was used. This data will change in the future and could affected the model outcomes and information presented in this report in Section 5.3.7 and has actually been revisited as part of the current study modelling and is discussed in Section 5.3.8.

- In preparing this report, the authors have relied on information provided by other and publicly available information. Except where explicitly noted these data have not been independently verified or checked. This unverified information may contain errors and omissions which have caused by errors or omissions in this report.

- The proposed works included in the “proposed” scenarios were based on designs at a specific point of time (see discussion in Section 5.3.8) and have progressed since this time. The changes are noted at the end of the discussion on the “Proposed Model Setup”, but are not considered to be significant or likely to alter the general findings of this Study. The changes are in fact more likely to reduce the impact discussed 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).

9. Conclusion

The modelling described in this report is suitable for describing the current flood characteristics within the Study Area and for assessing the change or impact assessment as a result of the proposed Wanganella Regulator works. The model was shown to calibrate/validate reasonably well across the range of flow scenarios being assessed and is considered appropriate for undertaking the required impact assessment for the proposed Wanganella Regulator and other works in the Wanganella Swamp.

The impact assessment found that the proposed works at the Wanganella Regulator and do not have a significant impact on the flood characteristics of the Study Area. It has been found that the riparian zone between the Billabong Creek and Lang Street in Wanganella township, covering a portion of several private properties (i.e., backyards), experienced moderate afflux during 20% AEP event and minor afflux during 5% AEP event. The impact was not found during 1% AEP event or above due to the proposed flood relief channel. However, the change in flood characteristics in the riparian zone is unlikely to increase flood risk.

In addition, a cumulative assessment was undertaken using a conservative design of the proposed Wanganella Swamp proposals. The cumulative assessment found there was moderate to minor in small flood events and no impact in larger flood events. The minor event impacts are exacerbated due to the different operational assumptions between the existing case and proposed case modelling and these impacts do not result in a significant impact. In the larger events, impacts in the Wanganella Swamp are demonstrably from the Wanganella Swamp structures and do not impact the proposed regulator of Wanganella Township. The Wanganella Swamp impacts will be assessed are part of the different project.

10. References

3Rivers (2023a). Sustainable Diversion limits Adjustment Mechanism (SDLAM) – Work Package 20 – Piccaninny Weir to Wanganella Model User Report. January 2023.

3Rivers (2023b). Yanco Creek Modernisation Flood Frequency Analysis (DE19-823-YCM-DE-HY-MEM-0004)

3Rivers (2024a). Yanco Creek Modernisation: Hydraulic Modelling Technical Report - Hartwood Weir to Piccaninny Weir Study Area (Document No.: DE19-823-YCM2A-DE-HY-RPT-0001).

3Rivers (2024b). Billabong Creek Regulators Flood Impact Assessment. August 2024.

DCCEEW (2021). Hydraulic Modelling Standard Specification V1.2, NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW)

DCCEEW (2023). Yanco Creek System Operations Plan – Yanco Creek Modernisation Project (Sep 2023), NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW)

Appendix A. DEM Verification

Verification of the combined DEM for the bathymetric portion was undertaken by comparing combined DEM levels to known points:

- Channel cross sections
  - Northern Land Solutions (Phase 3 DCCEEW Survey), April 2022
  - Price Merrett Consulting Pty Ltd Wanganella Weir Survey, 10/02/2022
  - Michael McBurnie Survey Irrigation Designs, September 2009

The results show that the Combined DEM generally represents the waterway well (see examples in Figure A- 1 and Figure A- 3). However, the Combined DEM is not entirely accurate as shown in Figure A- 2 and Figure A- 4 due to the automated nature of the DEM production process and to localised natural or artificial changes in the channel.

Some of the issues encountered are listed below.

  - Incorrect location of channel top of bank due to automated process used to determine the boundary between the 2021 LiDAR and the 2007 DEM. This issue was addressed through a further refinement of the Combined DEM by using a buffer to match the surveyed cross-sections or bathymetric data where available.
  - Inconsistent channel bed level and longitudinal slope when transitioning between 12d created bathymetry and surveyed bathymetric datasets. This issue was resolved by re-processing the 12d created bathymetry by increasing or decreasing the channel longitudinal slope to tie in with the bathymetry.

- Out of channel points
  - Price Merrett Consulting Pty Ltd Wanganella Weir Survey, 10/02/2022
  - Price Merrett Consulting Pty Ltd Estuary Ck Regulator & McCrabbs Survey, 21/07/2021
- Advance Survey Design Pty Ltd, 15/05/2015
- In-channel points
  - 3Rivers Bathymetric Survey, 28/06/2021
  - SKM Bathymetric Survey, November 2007
  - Price Merrett Consulting Pty Ltd Wanganella Weir Survey, 10/02/2022

The bathymetry comparison was made through a histogram by, firstly, subtracting the vertical elevation at each point between the Combined DEM and the corresponding dataset. The graphs in Figure A- 5 and Figure A- 6 compare the Combined DEM to the two bathymetric datasets above. As expected, there is close agreement given the datasets were inputs to the Combined DEM process; however, these results demonstrate the Combined DEM accurately represents the input datasets.

Figure A- 6**,** Figure A- 8 and Figure A- 9 show a general agreement between the Combined DEM and the topographic datasets listed above with the expected scatter of random errors. However, analysis of the differences shows that the Combined DEM is slightly higher than the topographic datasets as list in the table below. These results show that the Combined DEM was around 50mm higher than the topographic survey. It should be noted that the larger differences listed as the maximum and minimum values are typical in this sort of analysis and usually correspond to data points around bridges or other topographic discontinuities which are poorly represented in the LiDAR data. Given the relatively small typical difference the Combined DEM is considered to be representative of the topographic levels.

Dataset	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Wanganella Weir Survey	-0.219	0.00	0.032	0.042	0.067	0.477
Estuary Ck Regulator & McCrabbs	-5.815	-0.041	0.042	0.028	0.122	1.427
Advance Survey Design	-0.726	0.033	0.077	0.075	0.124	0.987

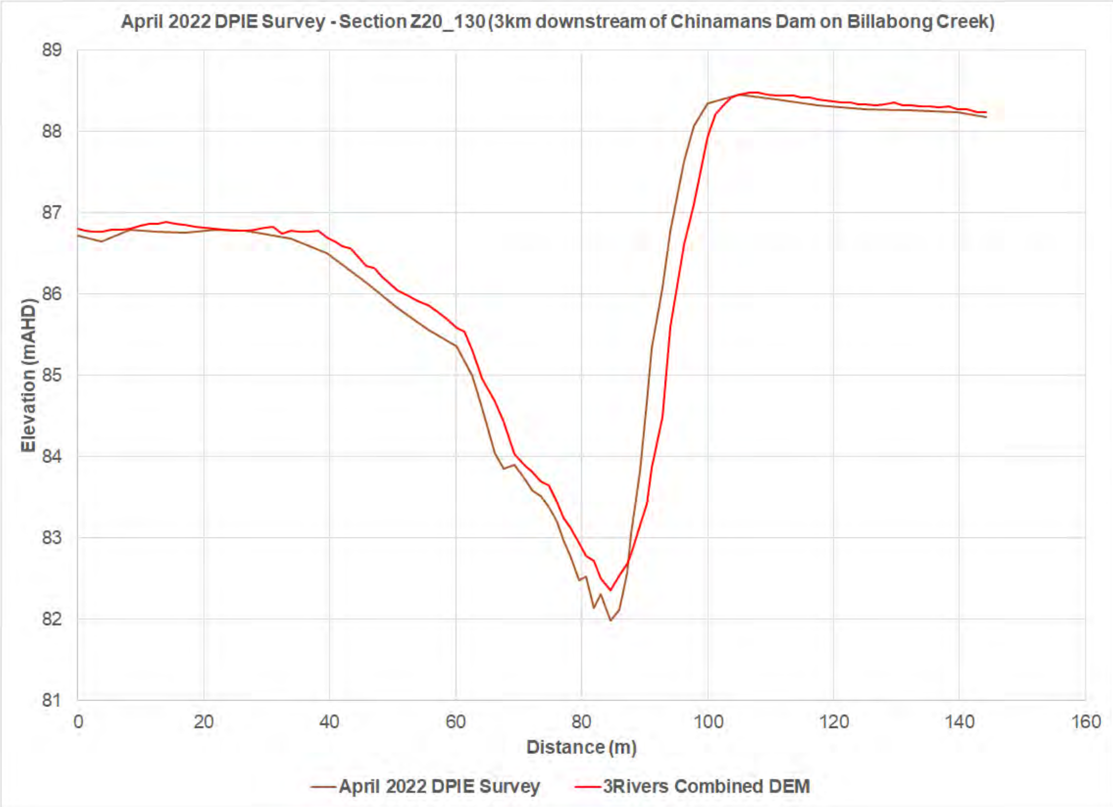


Figure A- 1: Combined DEM Validation - April 2022 DCCEEW Survey - Section Z20_130 (Billabong Creek) Example

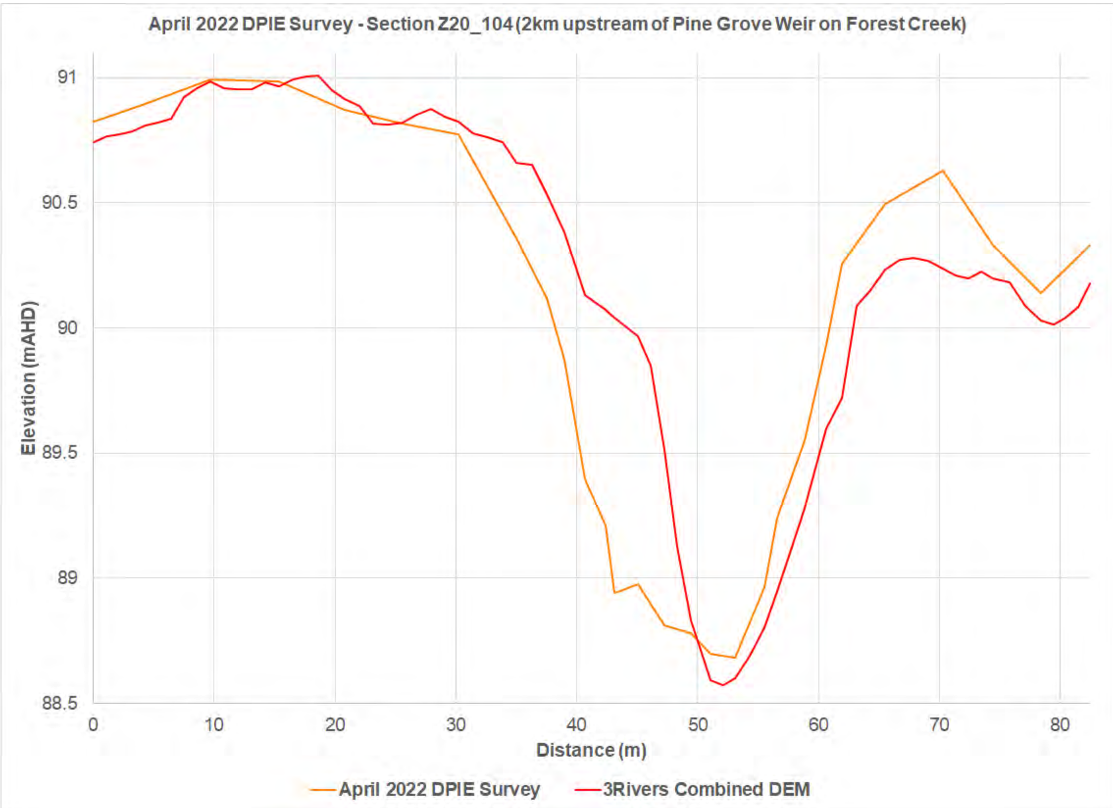


Figure A- 2: Combined DEM Validation - April 2022 DCCEEW Survey - Section Z20_104 (Forest Creek) Example:

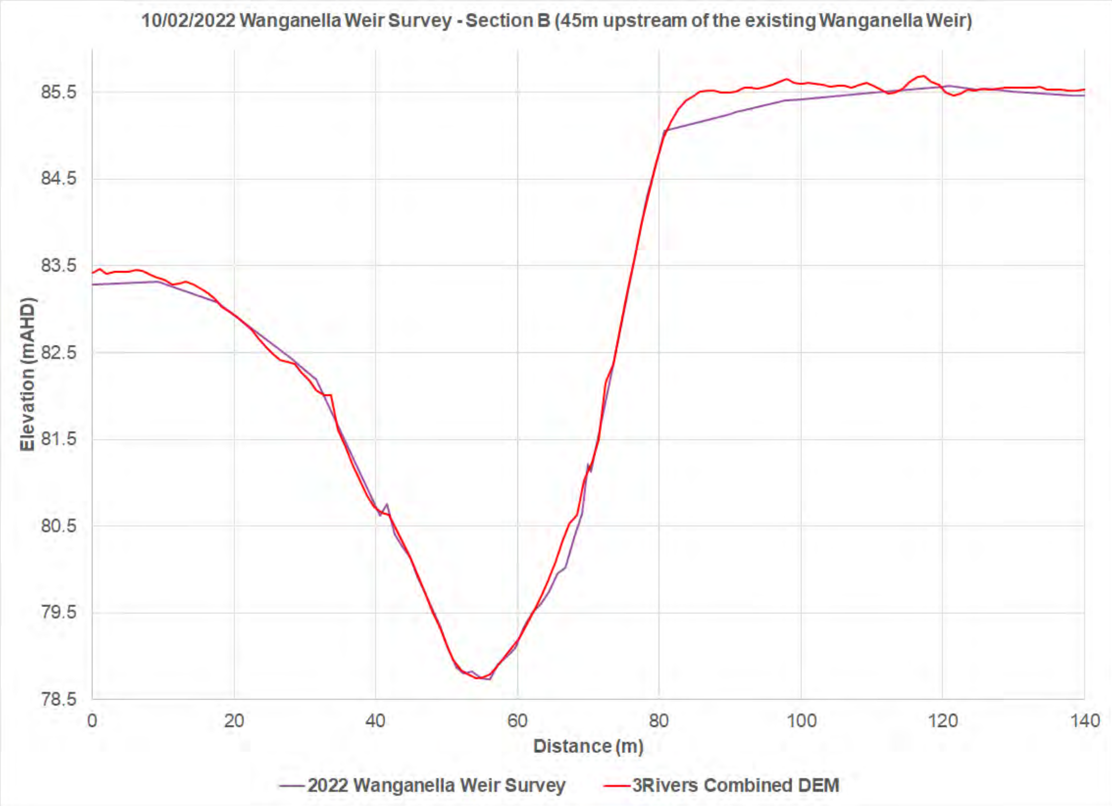


Figure A- 3: Combined DEM Validation – 10/02/2022 Wanganella Weir Survey - Section B Example

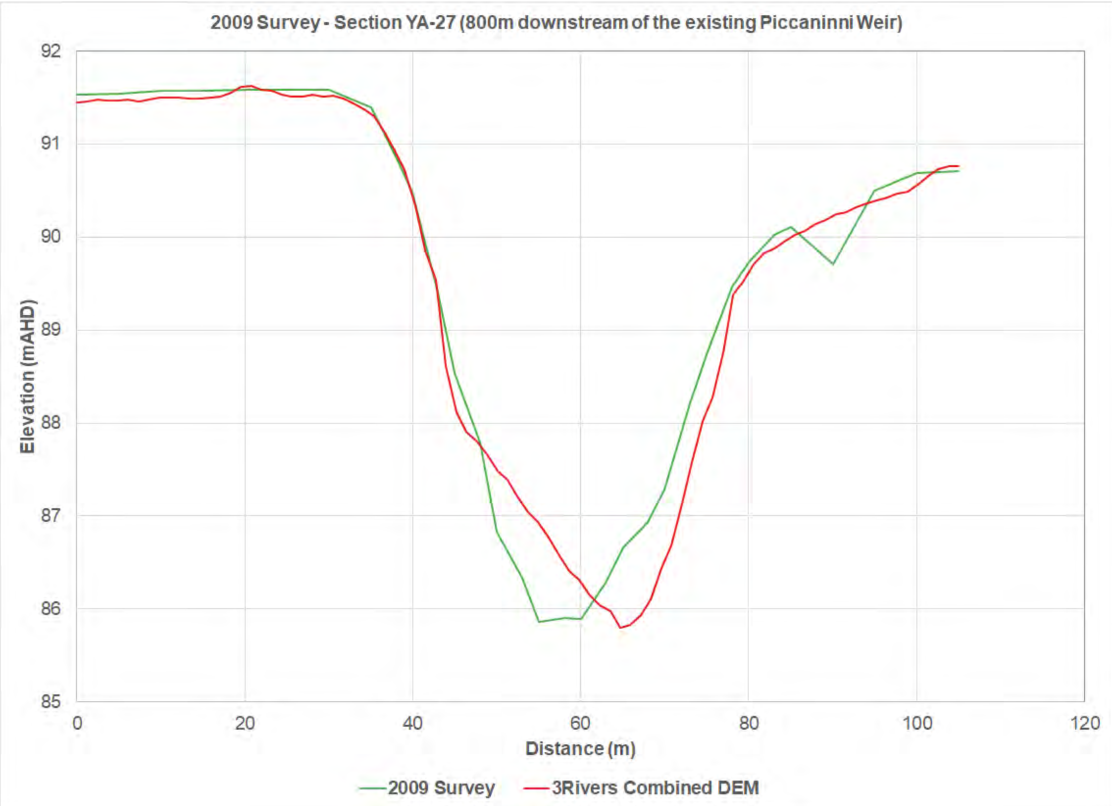


Figure A- 4: Combined DEM Validation -2009 Survey - Section YA-27 Example

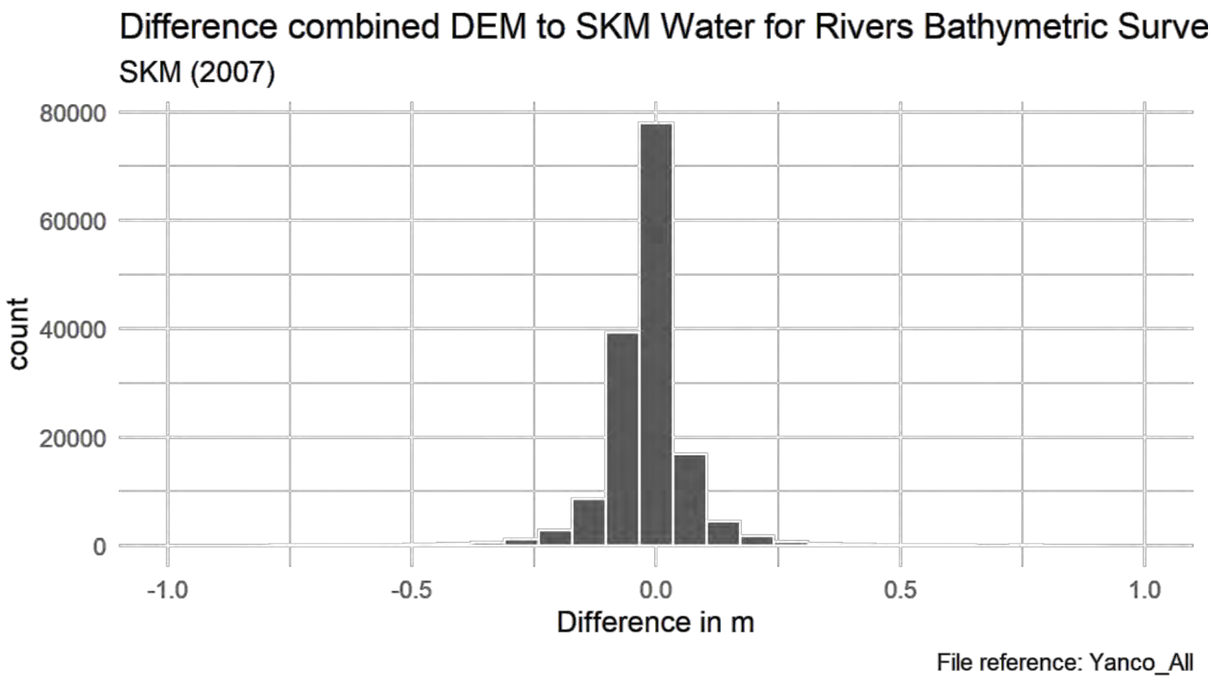


Figure A- 5: 3Rivers Combined DEM Validation - In-channel 2007 SKM Bathymetric Survey Histogram

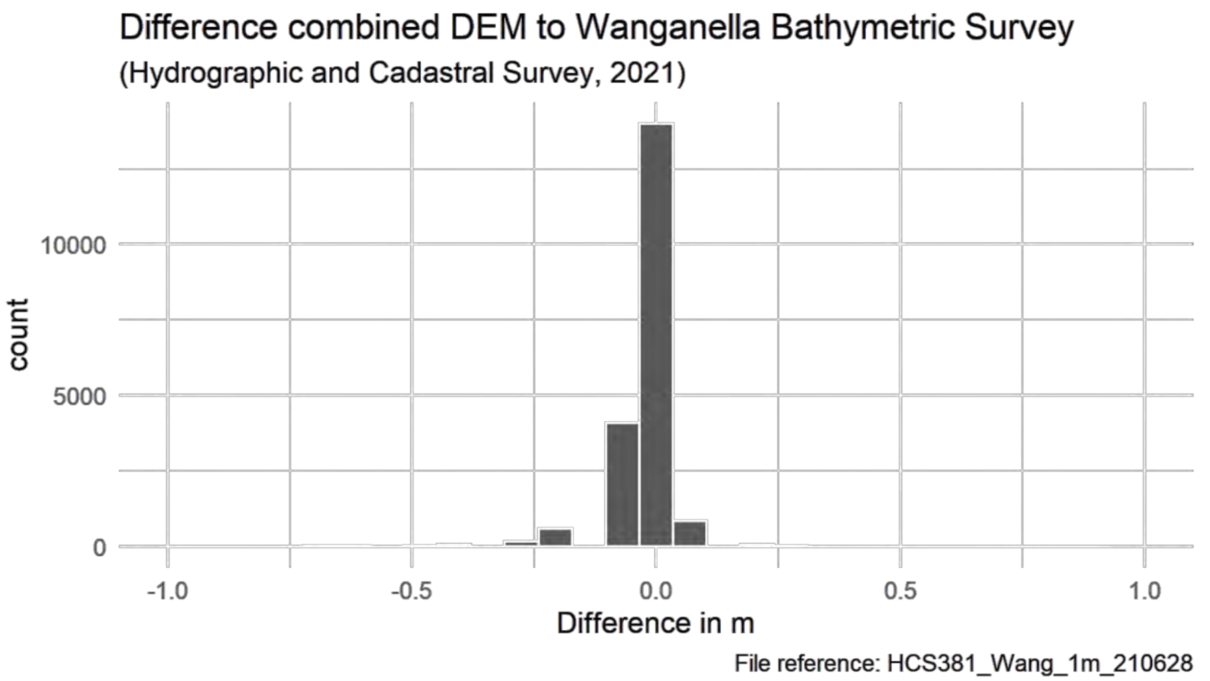


Figure A- 6: 3Rivers Combined DEM Validation - In-channel 2021 Survey Histogram

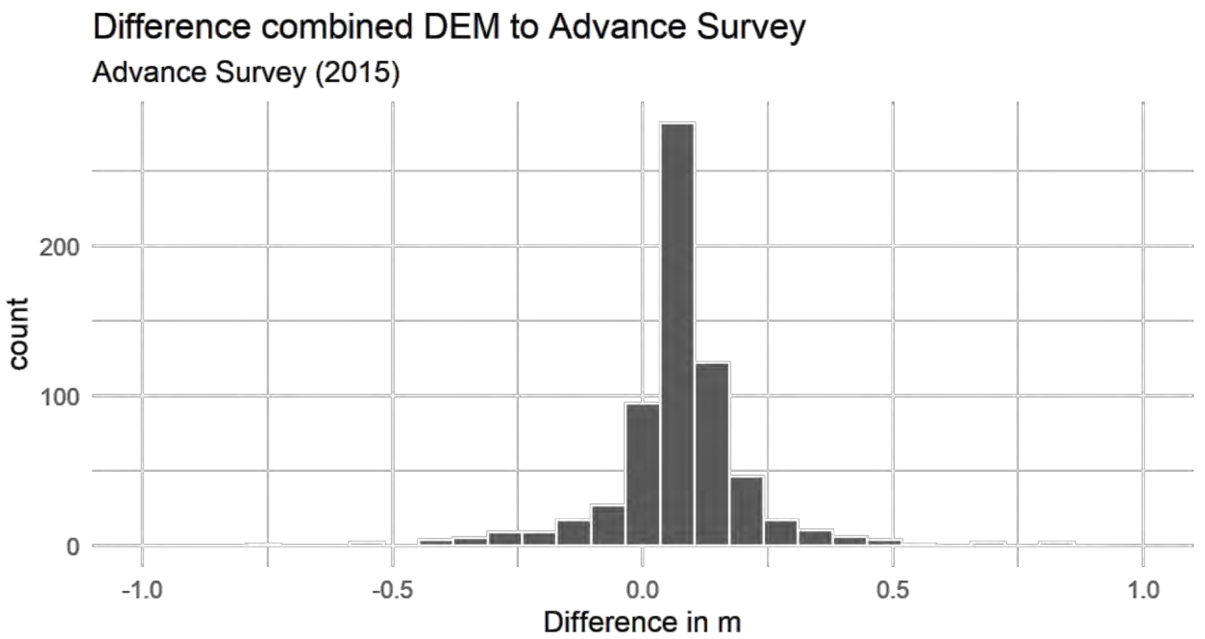


Figure A- 7: 3Rivers Combined DEM Validation - Out of Channel 2021 Survey Histogram

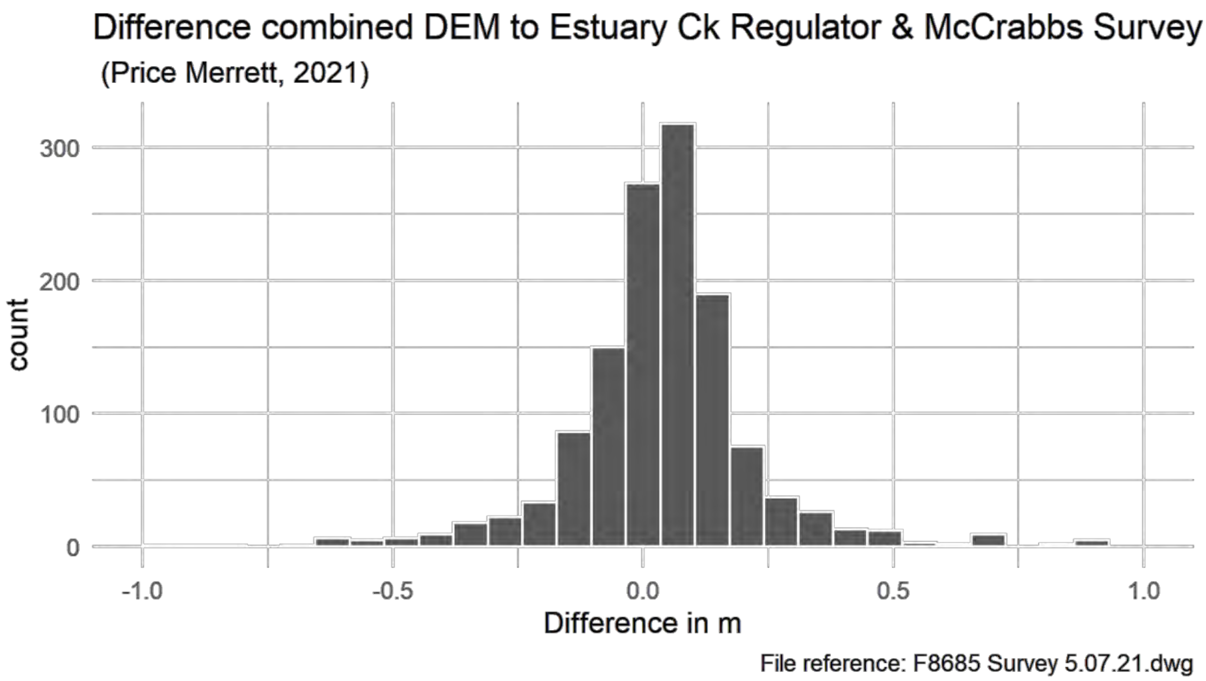


Figure A- 8: 3Rivers Combined DEM Validation – Estuary Creek and McCrabbs Spillway Survey Histogram

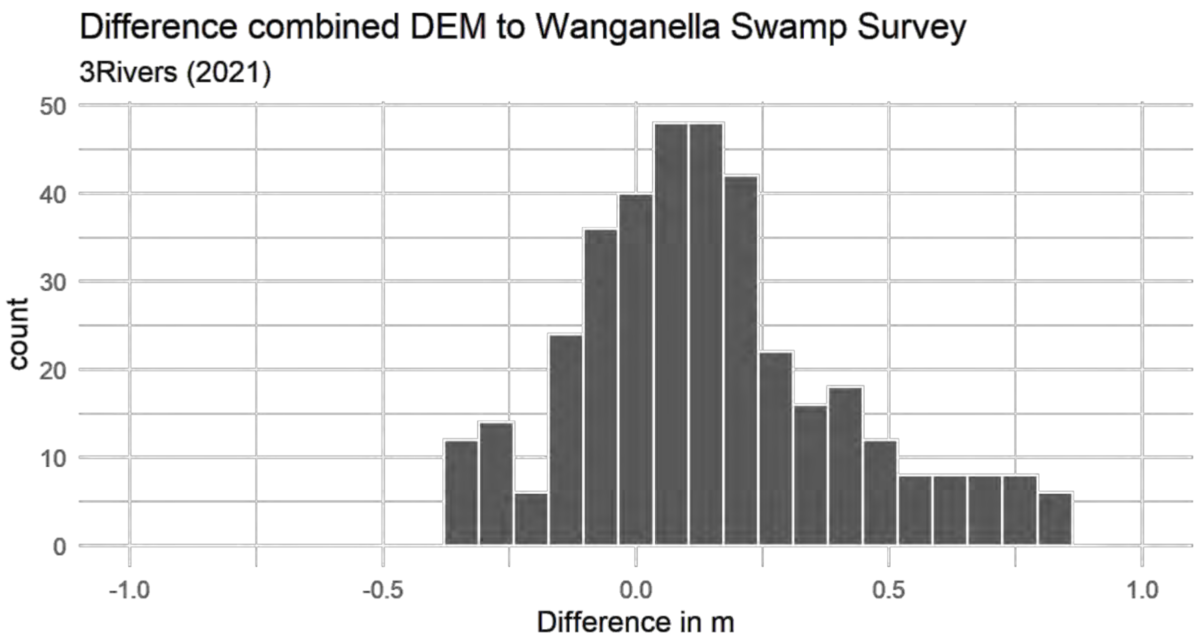


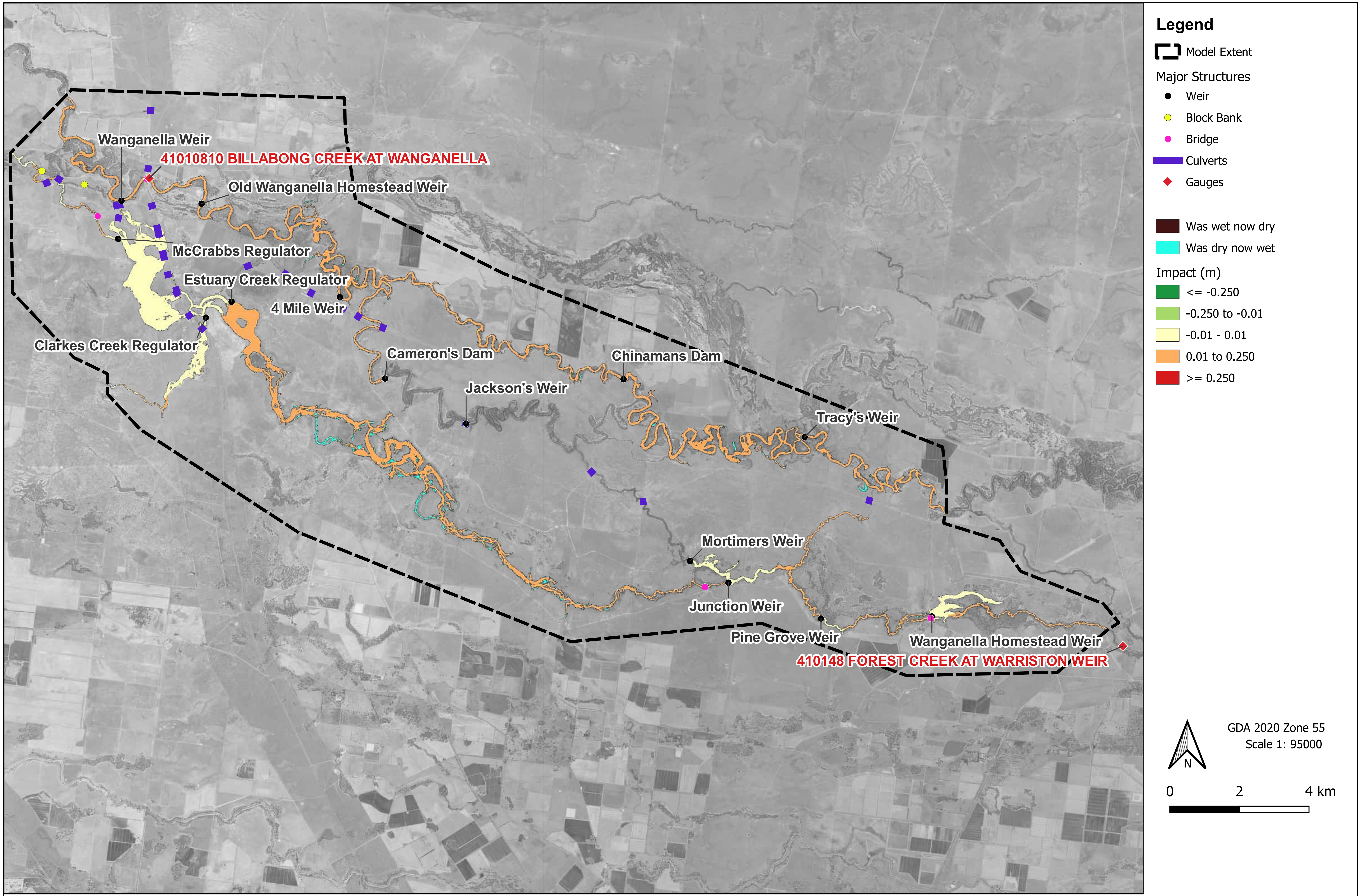
Figure A- 9: 3Rivers Combined DEM Validation – Wanganella Swamp Survey 2021 Survey Histogram

Appendix B. Adopted Bridge Loss

Adopted Bridge Loss

Name	Invert	dZ	Shape_Width	Shape_Option	L1_Obvert	L1_pBlockage	L1_FLC	L2_Depth	L2_pBlockage	L2_FLC	L3_Depth	L3_pBlockage	L3_FLC
4 Mile Weir	82.45				83.88	35.5	0.1	0	0	0	0	0	0
Bridge Upstream of Wanganella Weir	-99999				86.34 to 86.62	5	0.1	1	100	1.6	0	0	0
Bridge Downstream of Junction Weir	-99999				90.3	5	0.12	1	100	1.6	0	0	0
Clarkes Creek Regulator	85.88				86.57	0	0	0.75	100	1.6	0	0	0
Access Bridge Downstream of McCrabbs Regulator	83.41				85.26	5	0.12	0.94	100	1.6	0	0	0
Bridge Downstream of Homestead Wanganella Weir	88.13				91.66	5	0.12	0.94	100	1.6	0	0	0
Jackson's Weir	85.191				85.781	30	0.12	0.45	100	1.6	0	0	0
Cameron's Dam	85.75 to 85.96				86.95 to 87.16	50	0	0	0	0	0	0	0

Appendix C. Sensitivity Afflux Maps



Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Roughness 20% Increase (N_P20p)

3Rivers

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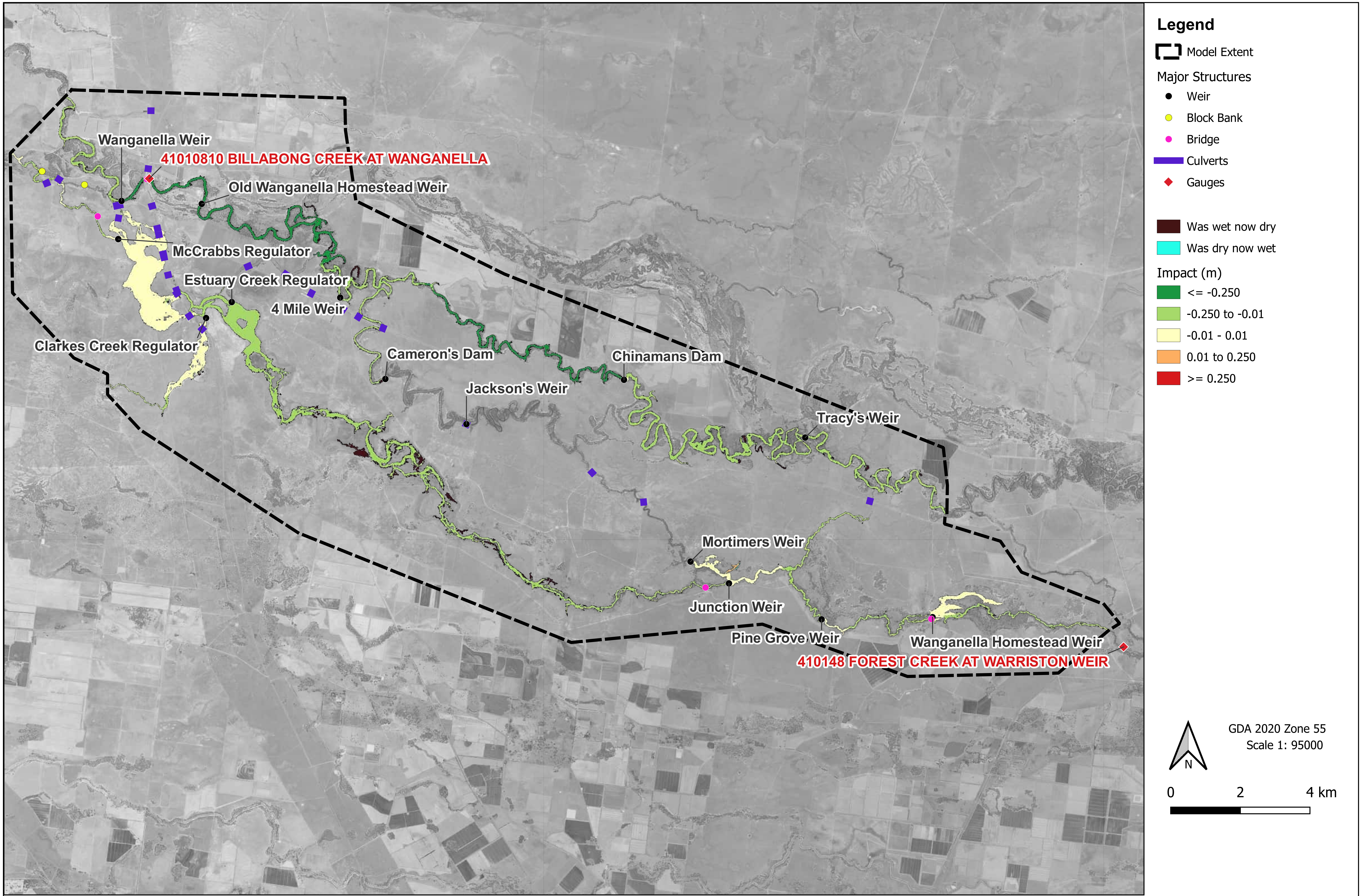

Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Roughness 20% Decrease (N_M20p)

3Rivers

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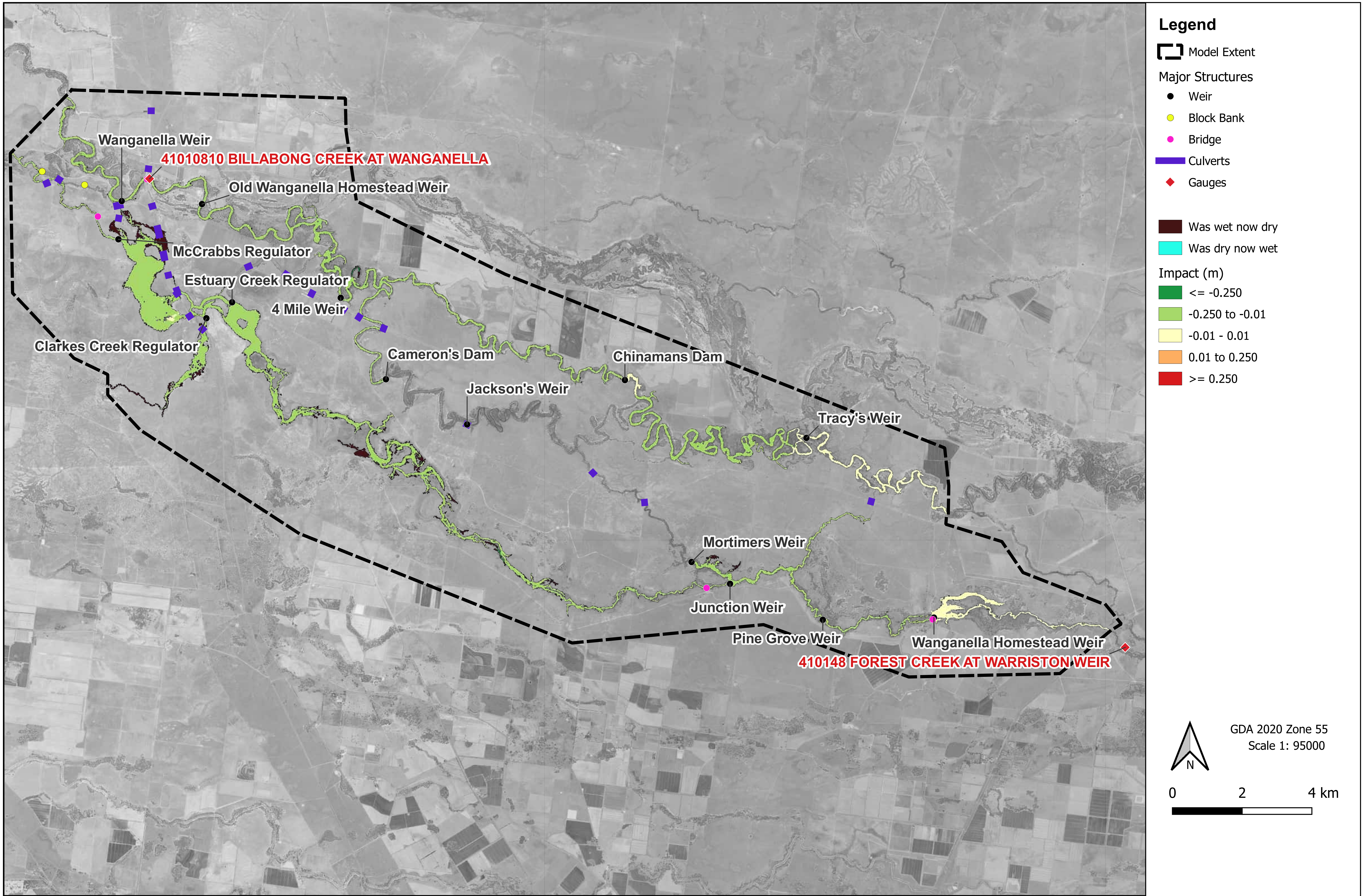
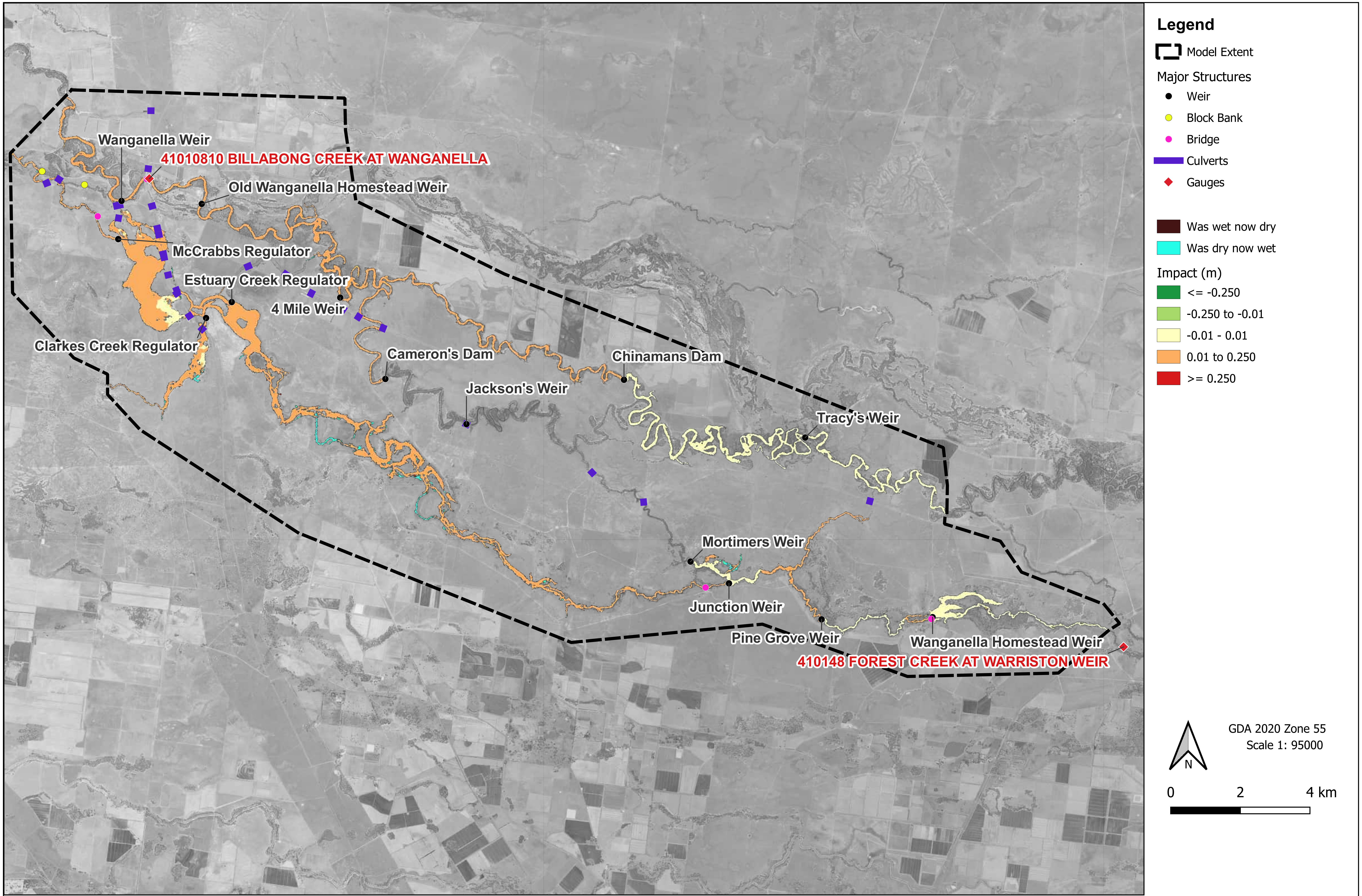


Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Volumetric Loss +100% (VLP100p)

3Rivers



Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Volumetric Loss -50% (VLM50p)

3Rivers

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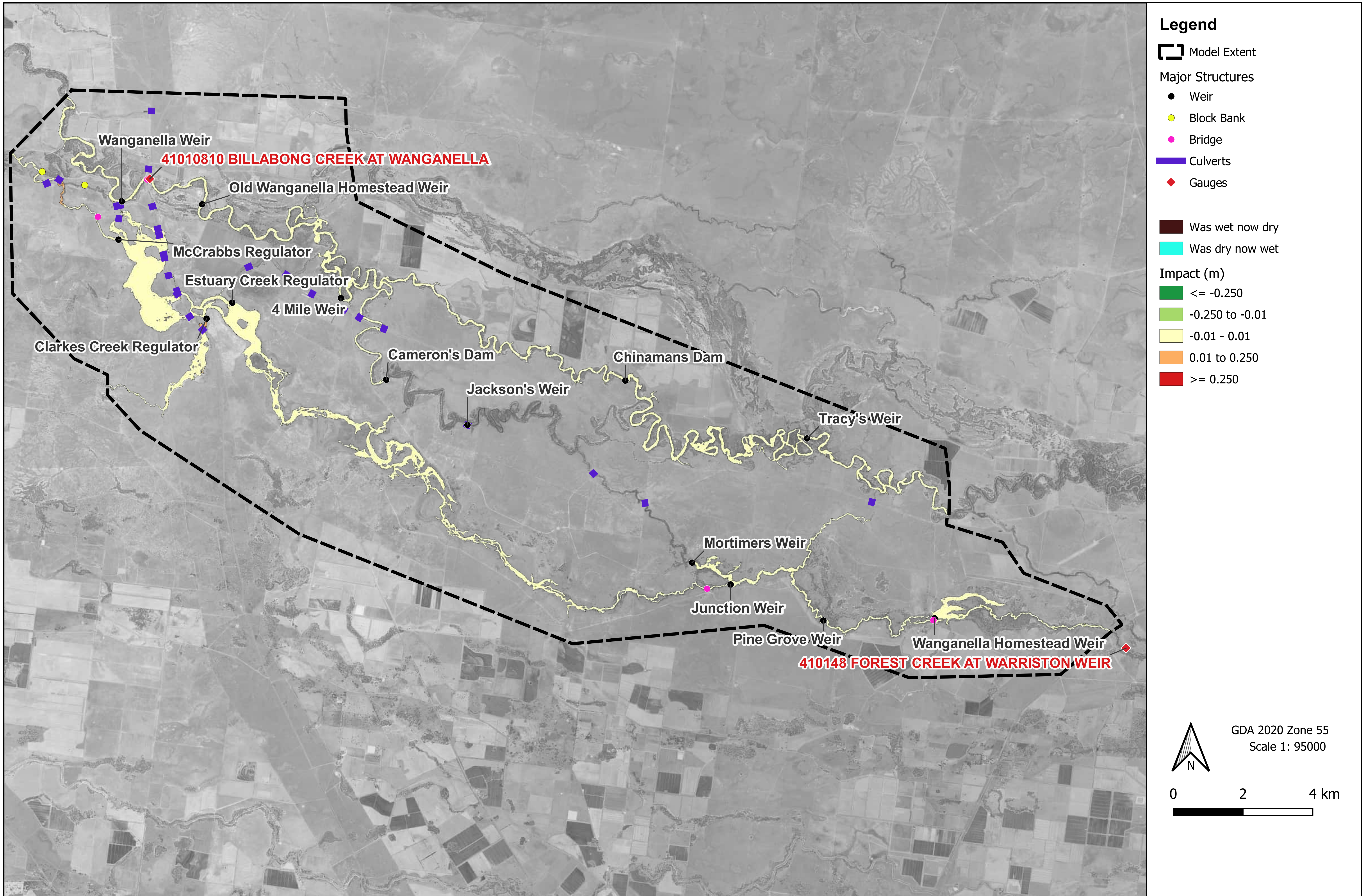

Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Culvert Blockage +50% (C_Blk)

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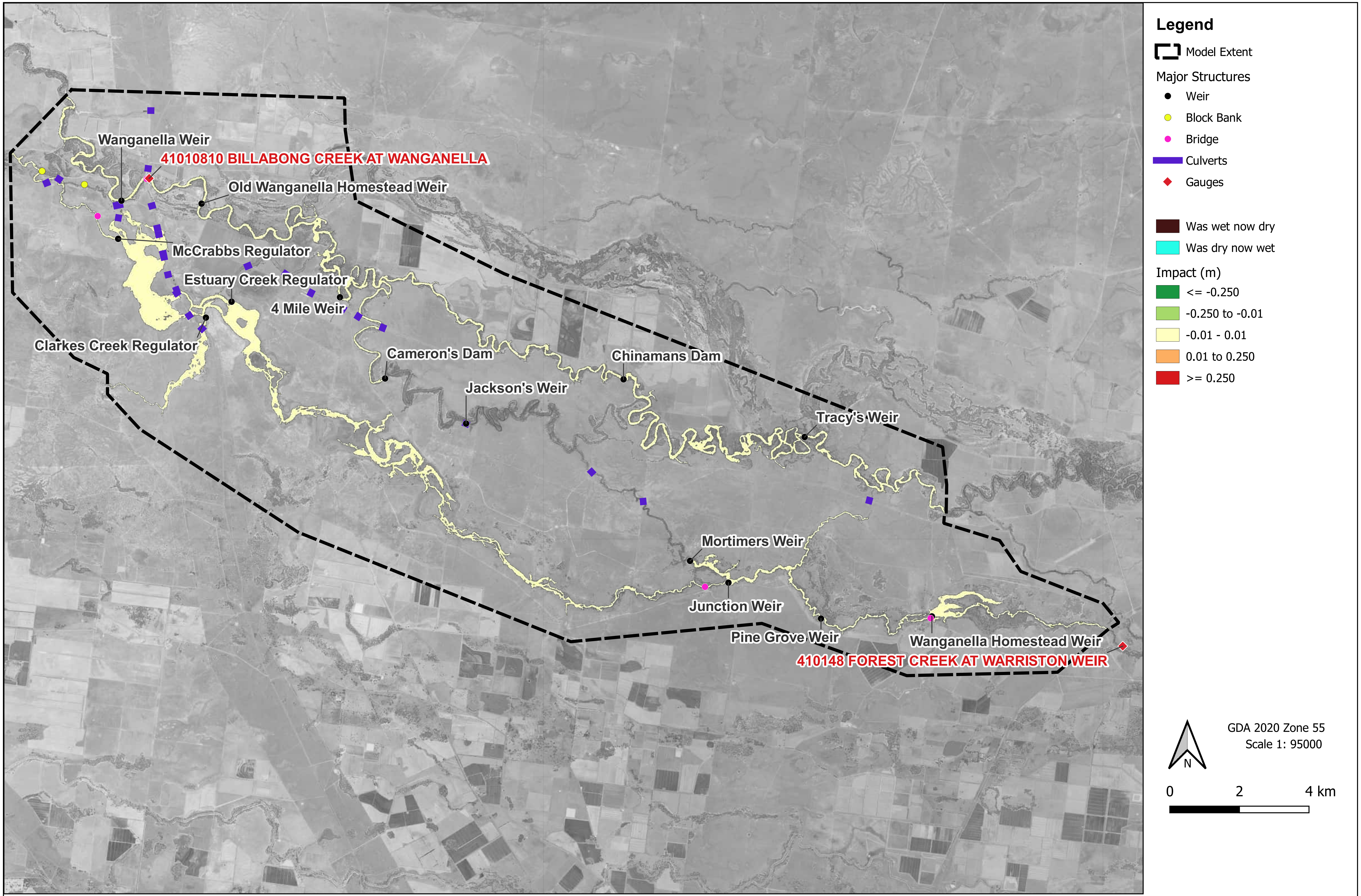

Murrumbidge Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Structure Loss at Bridges +20% (L_P20)

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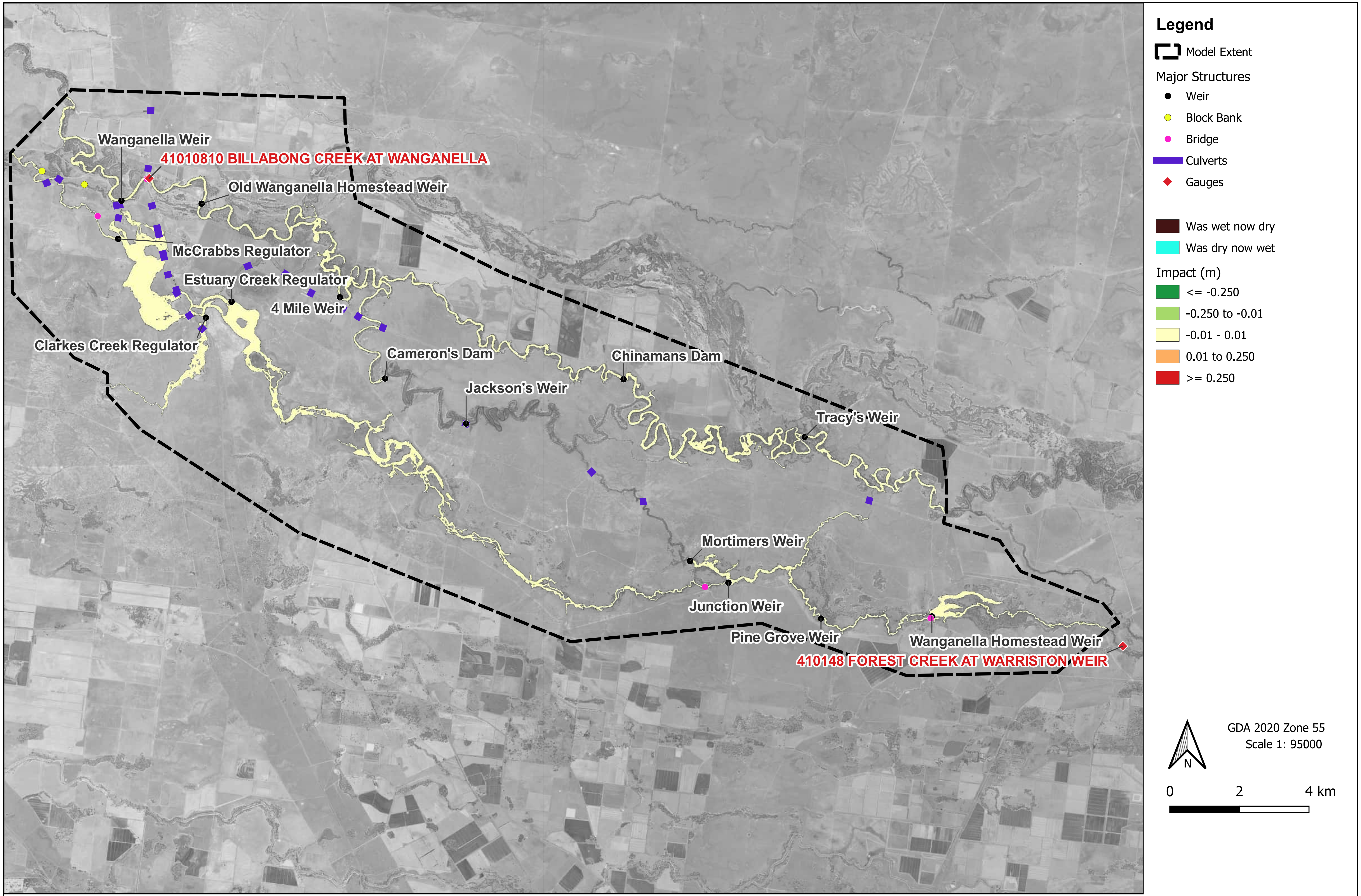

Murrumbidgee Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Structure Loss at Bridges -20% (L_M20)

3Rivers

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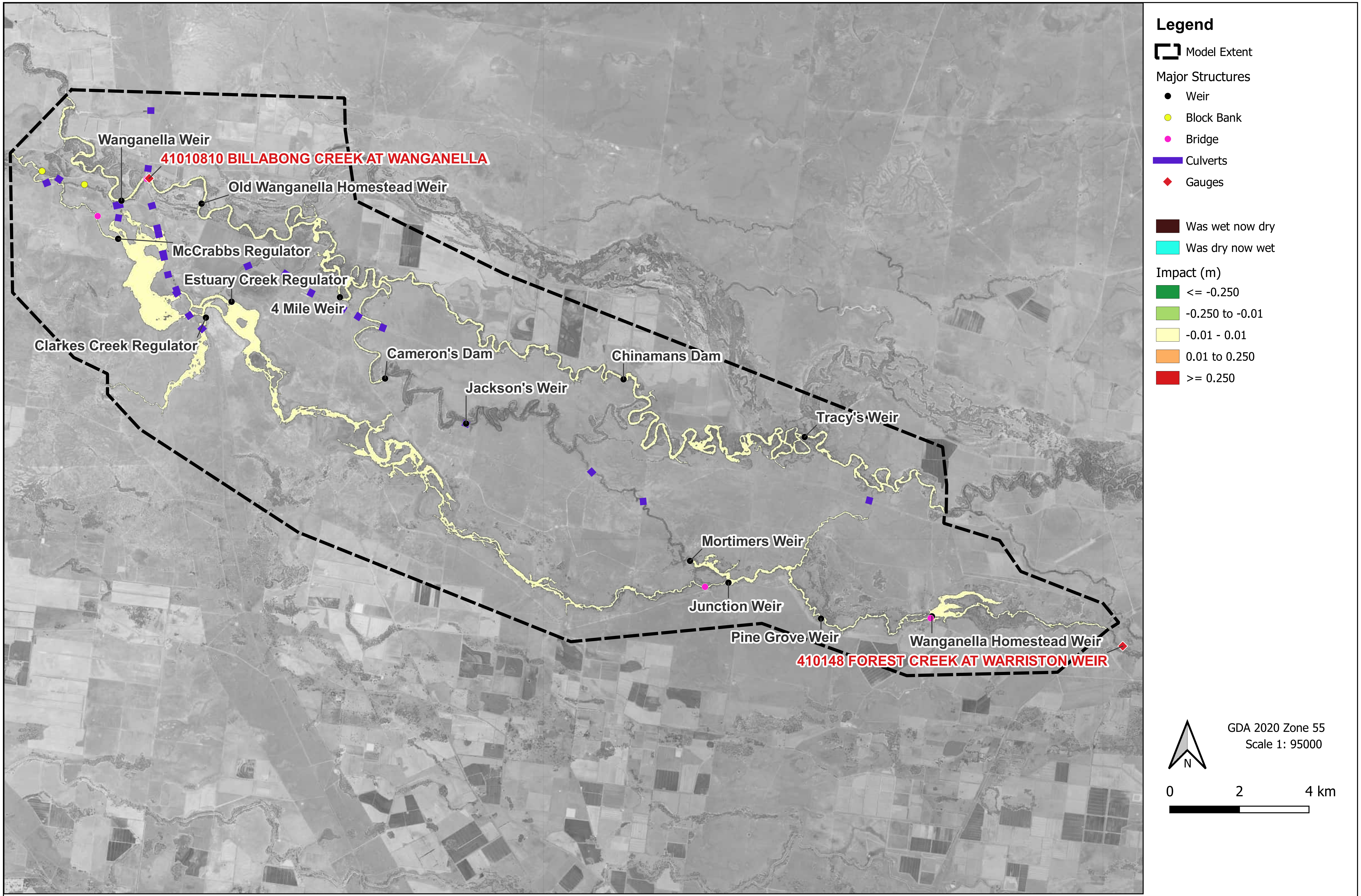
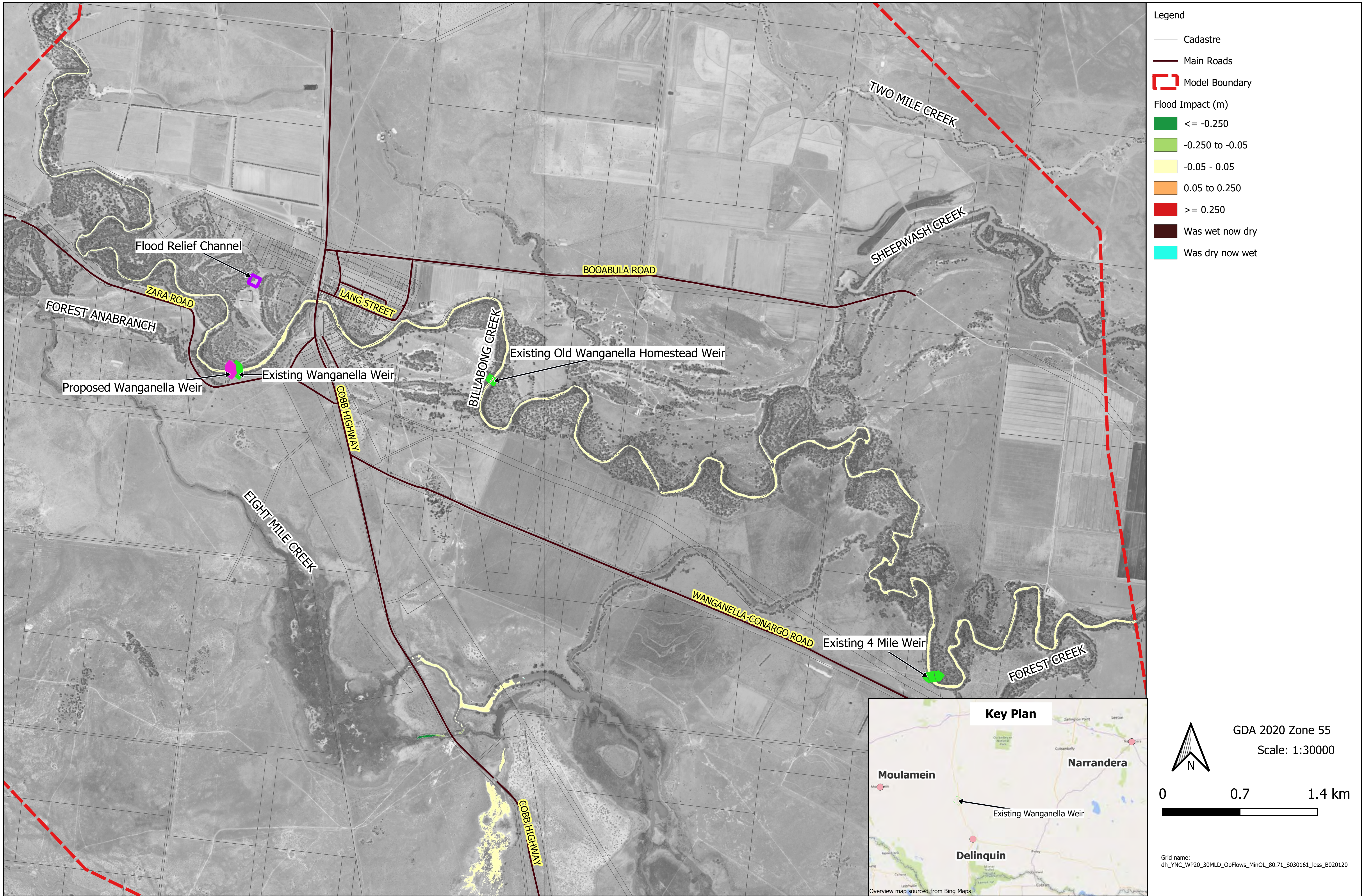


Murrumbidgee Hydraulic Modelling Work Package 20
Sensitivity Testing: Design Flow 3,024ML/d, Control Number Factor 0.5 (CF0p5)

3Rivers

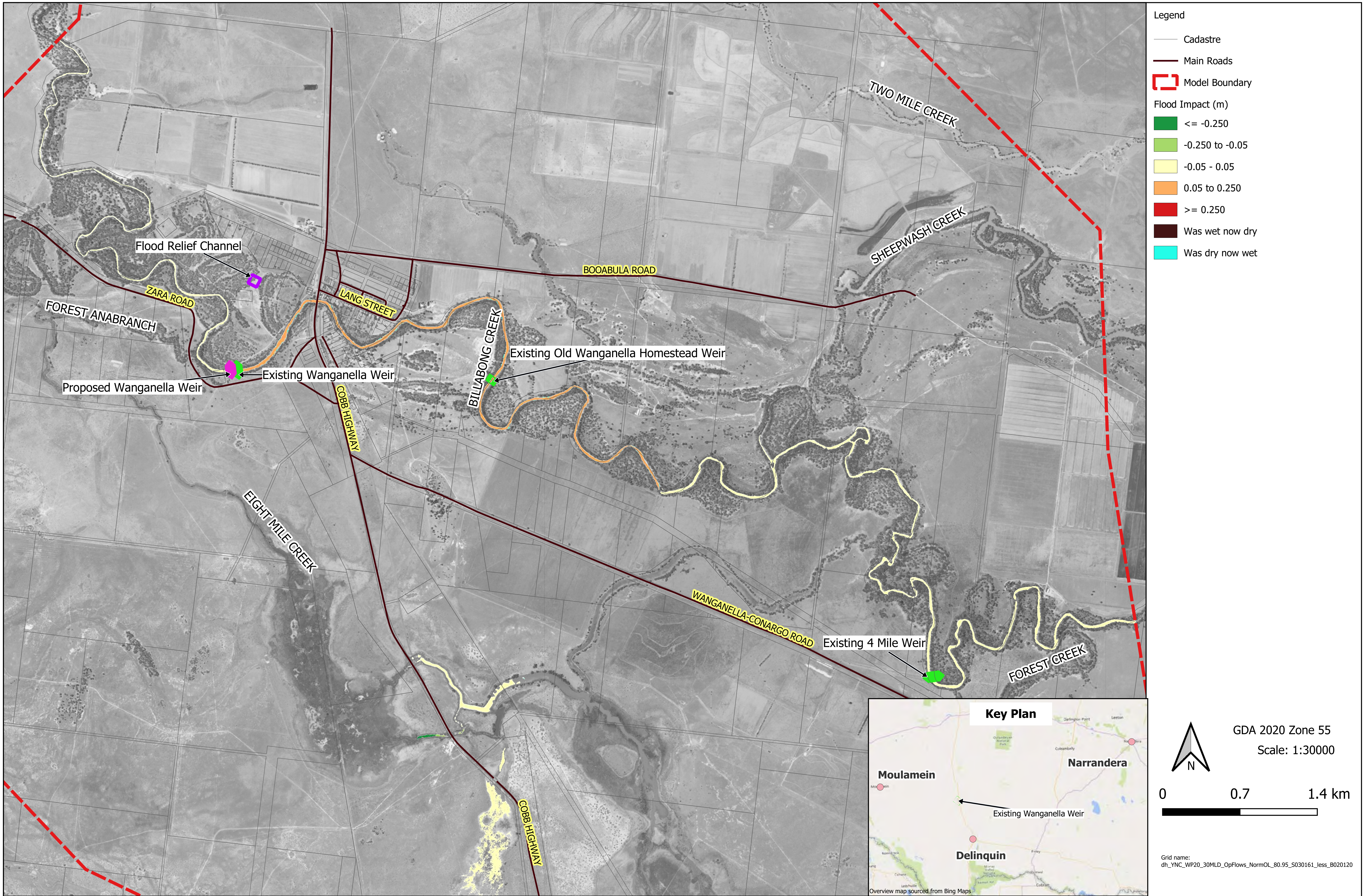
Appendix D. Impact Assessment – Operational Flow Scenarios

D1 Flood Impact Plots



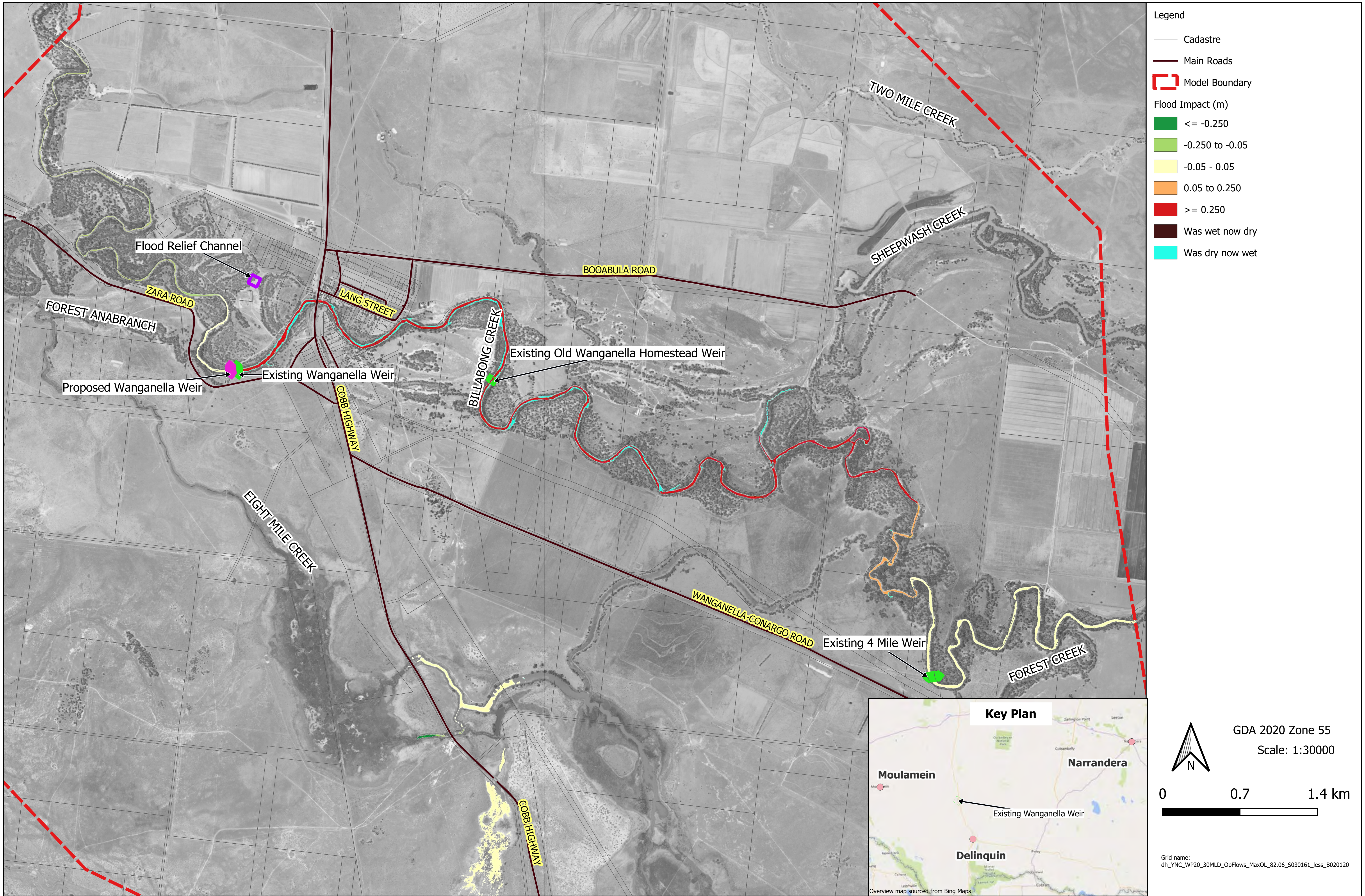
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.1 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Minimum Operational Level 80.71m vs Existing"

3Rivers



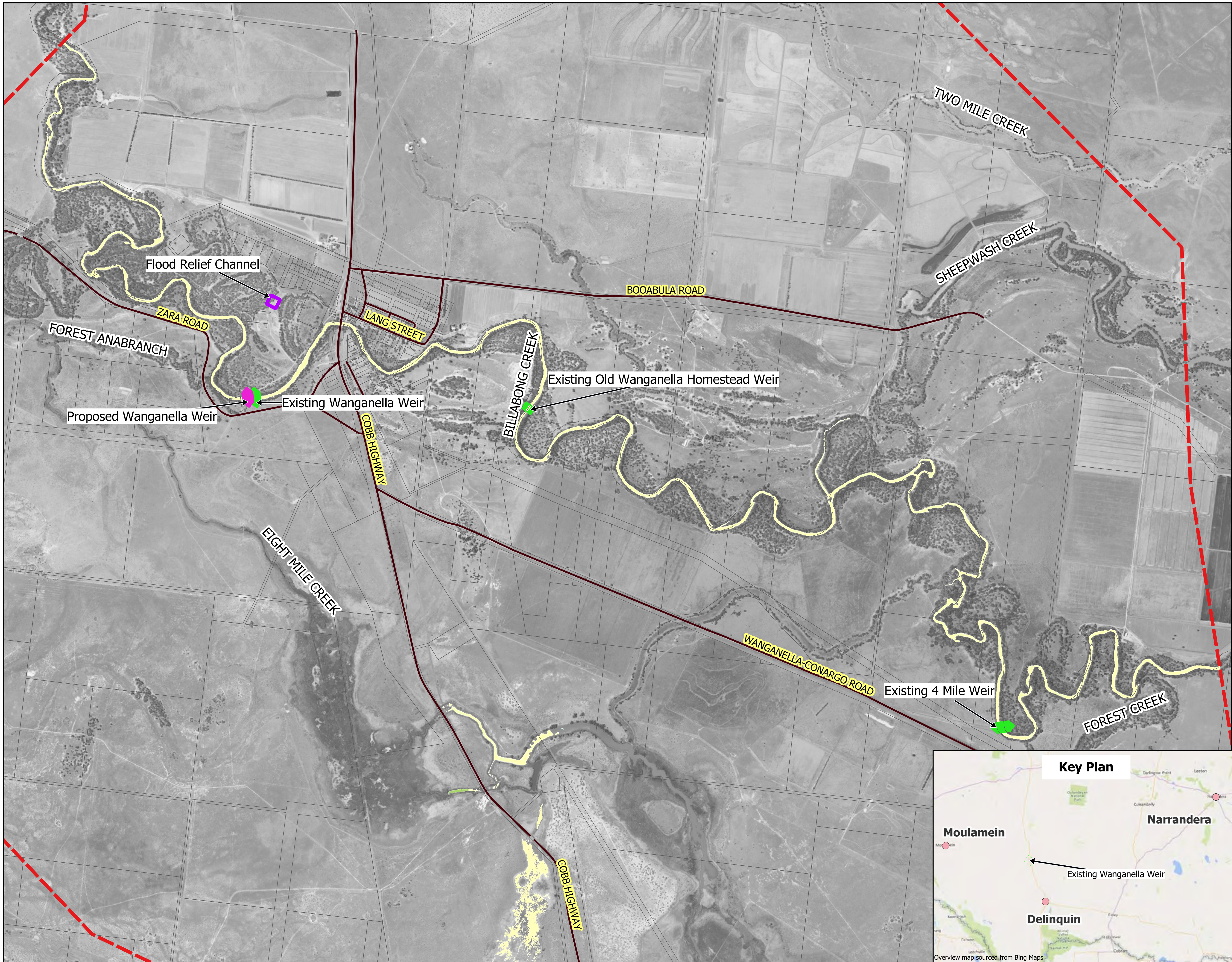
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.2 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Maximum Operational Level 80.95m vs Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.3 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level 82.06m vs Existing"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

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

N

GDA 2020 Zone 55

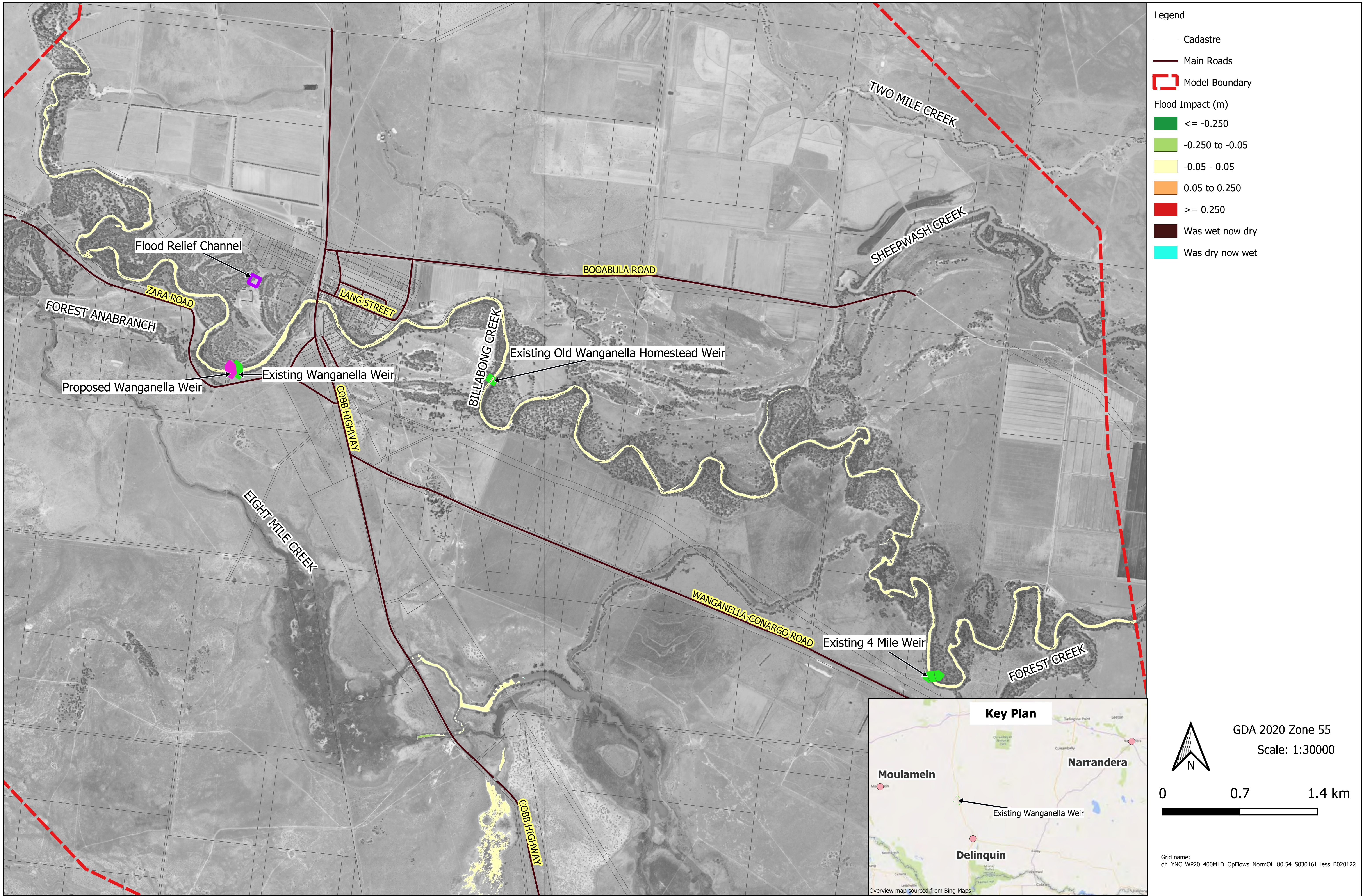
Scale: 1:30000

0 0.7 1.4 km

Grid name:
dh_YNC_WP20_400MLD_OpFlows_MinOL_80.20_S030161_less_B020122

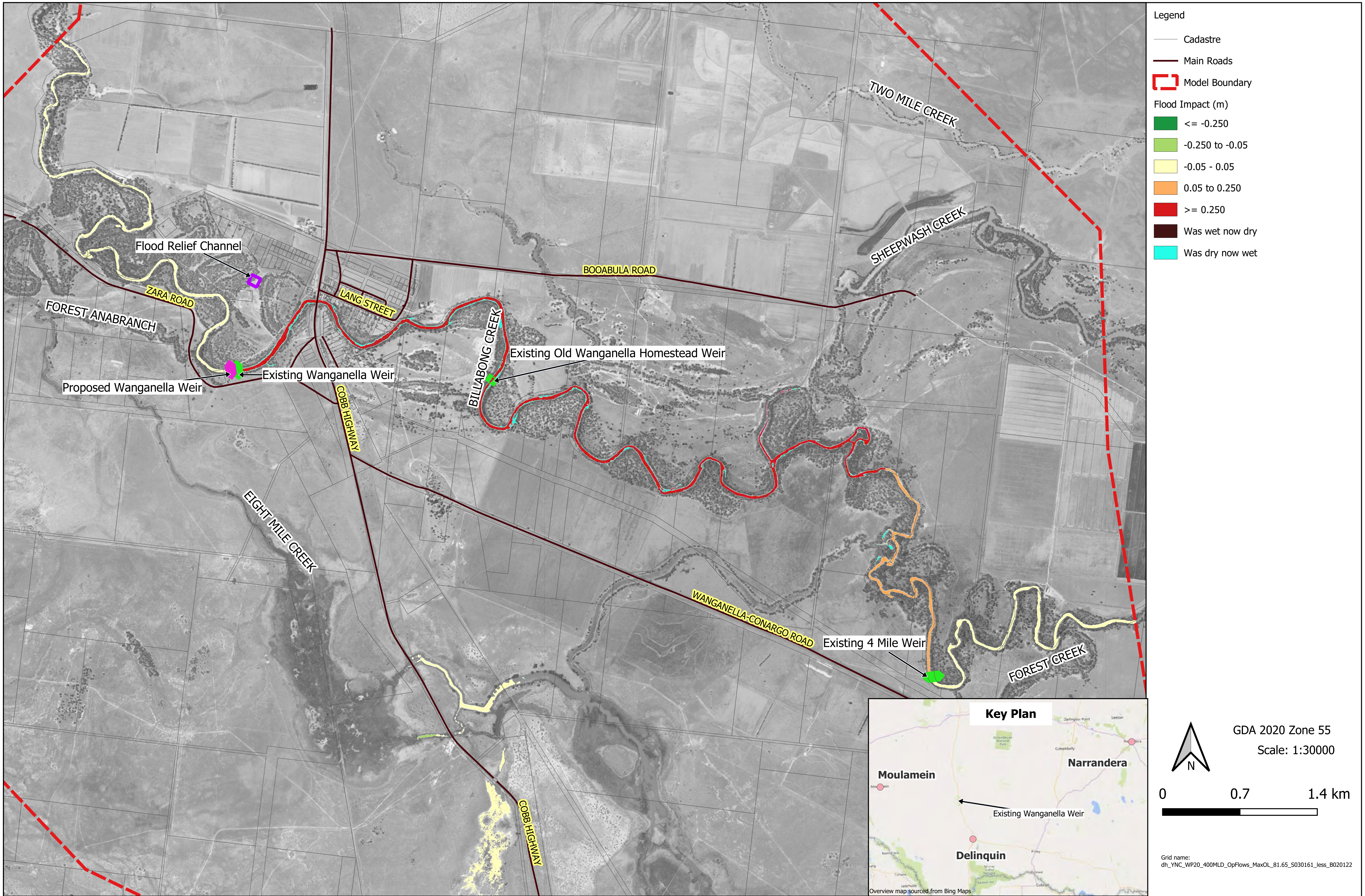
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.4 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Minimum Operational Level 80.20m vs Existing"

3Rivers



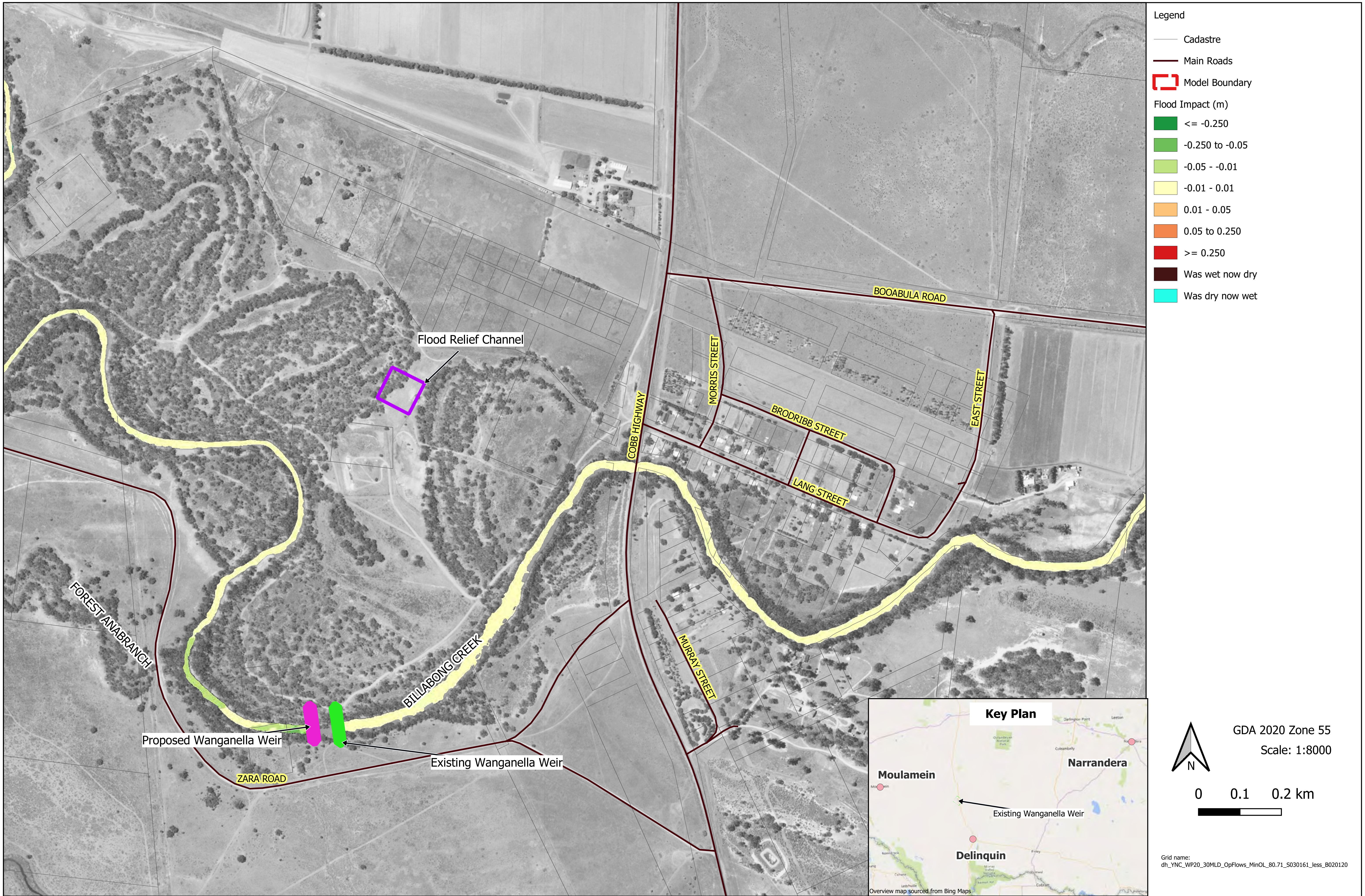
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.5 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Maximum Operational Level 80.54m vs Existing"

3Rivers



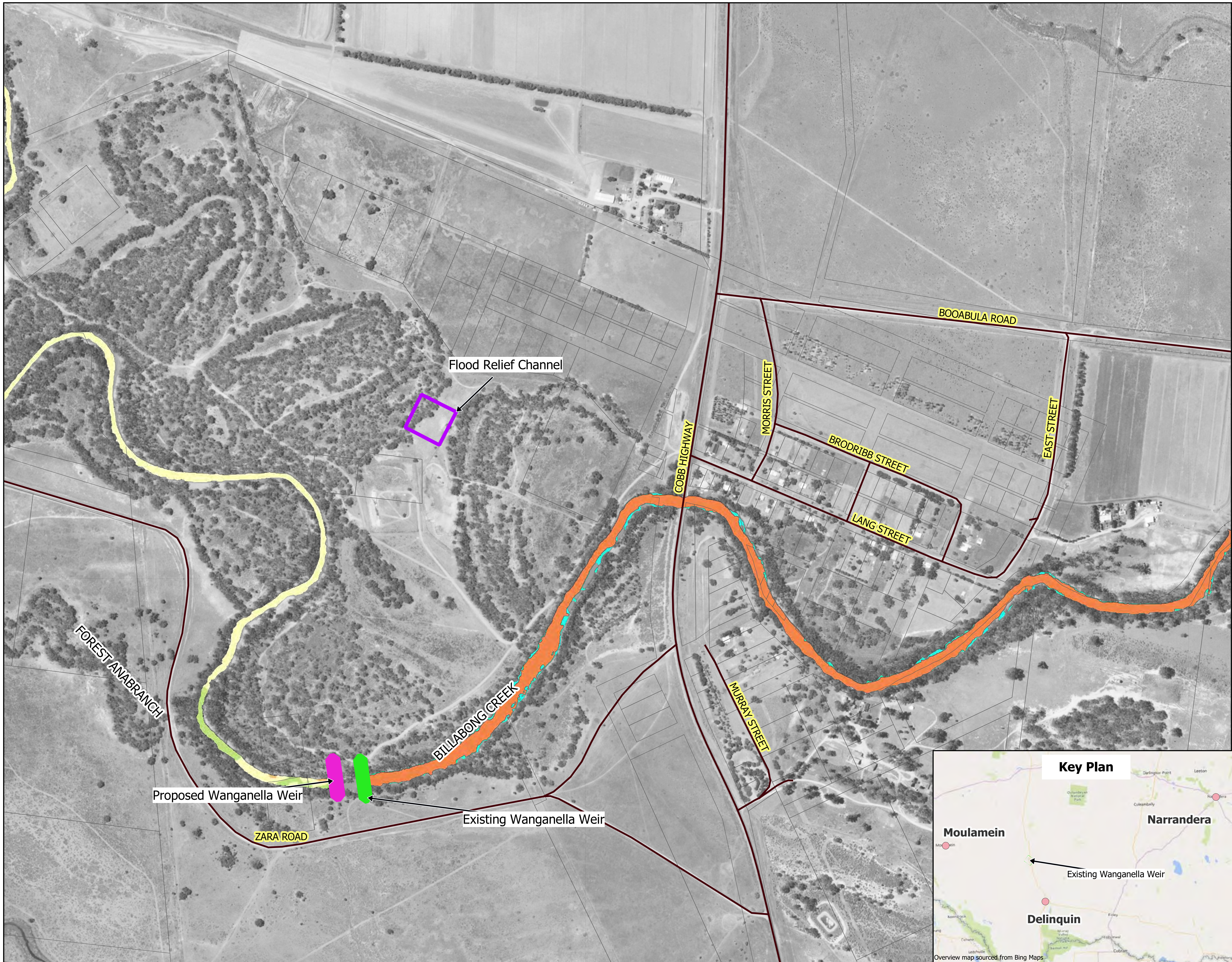
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.6 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level 81.65m vs Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.7 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Minimum Operational Level 80.71m vs Existing"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

GDA 2020 Zone 55

Scale: 1:8000

0 0.1 0.2 km

Grid name:
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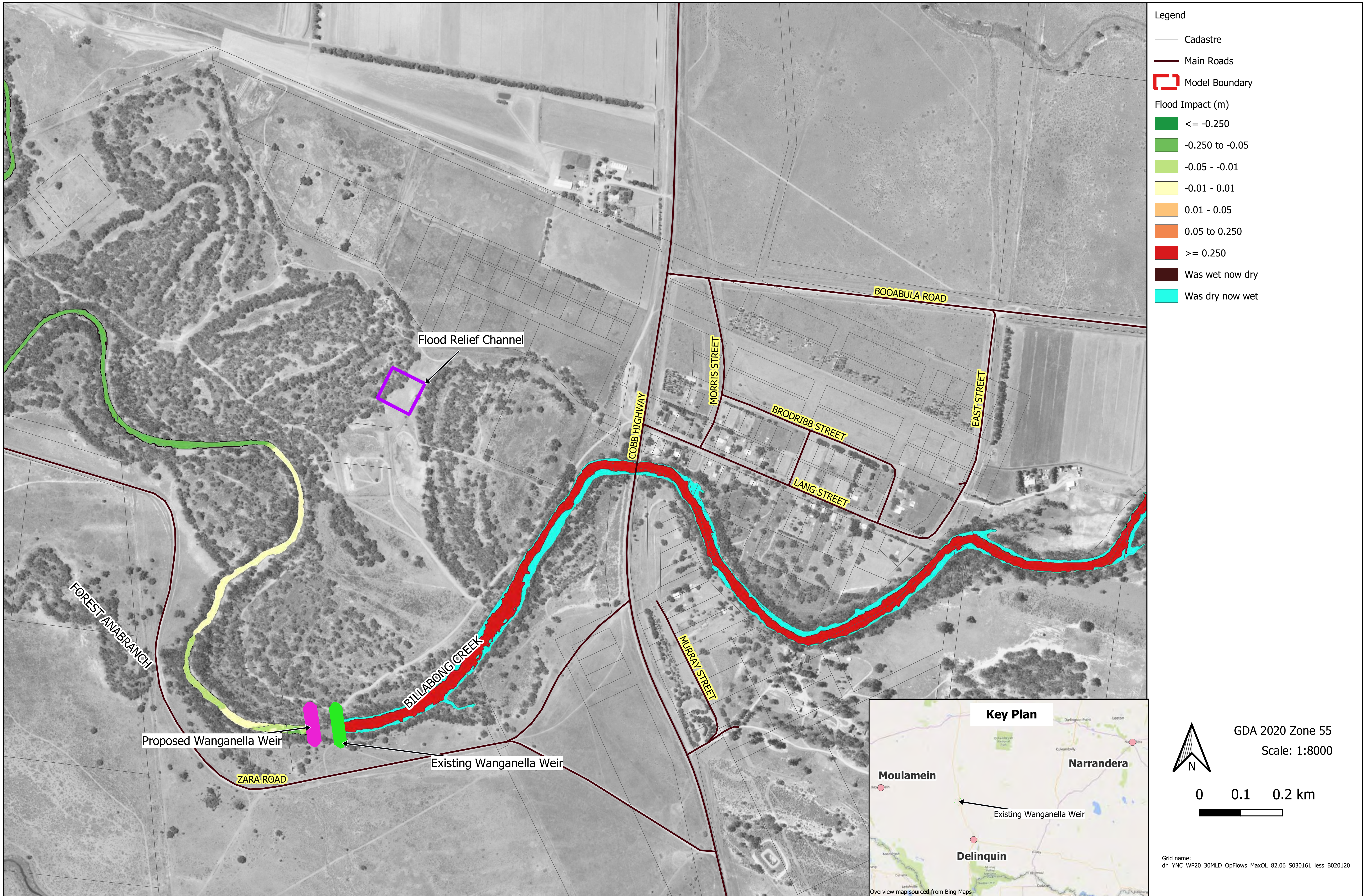
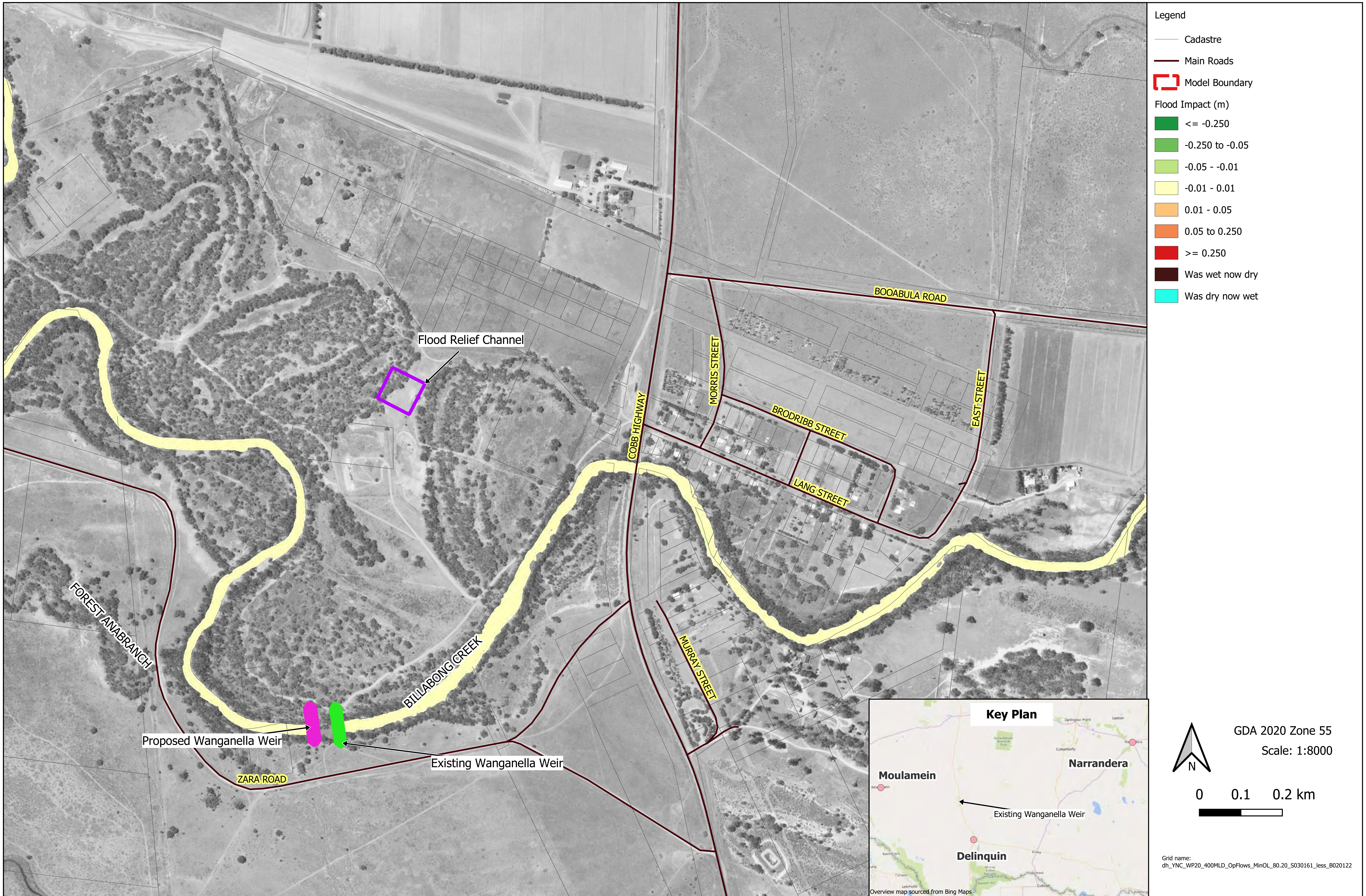
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.8 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Maximum Operational Level 80.95m vs Existing"

3Rivers

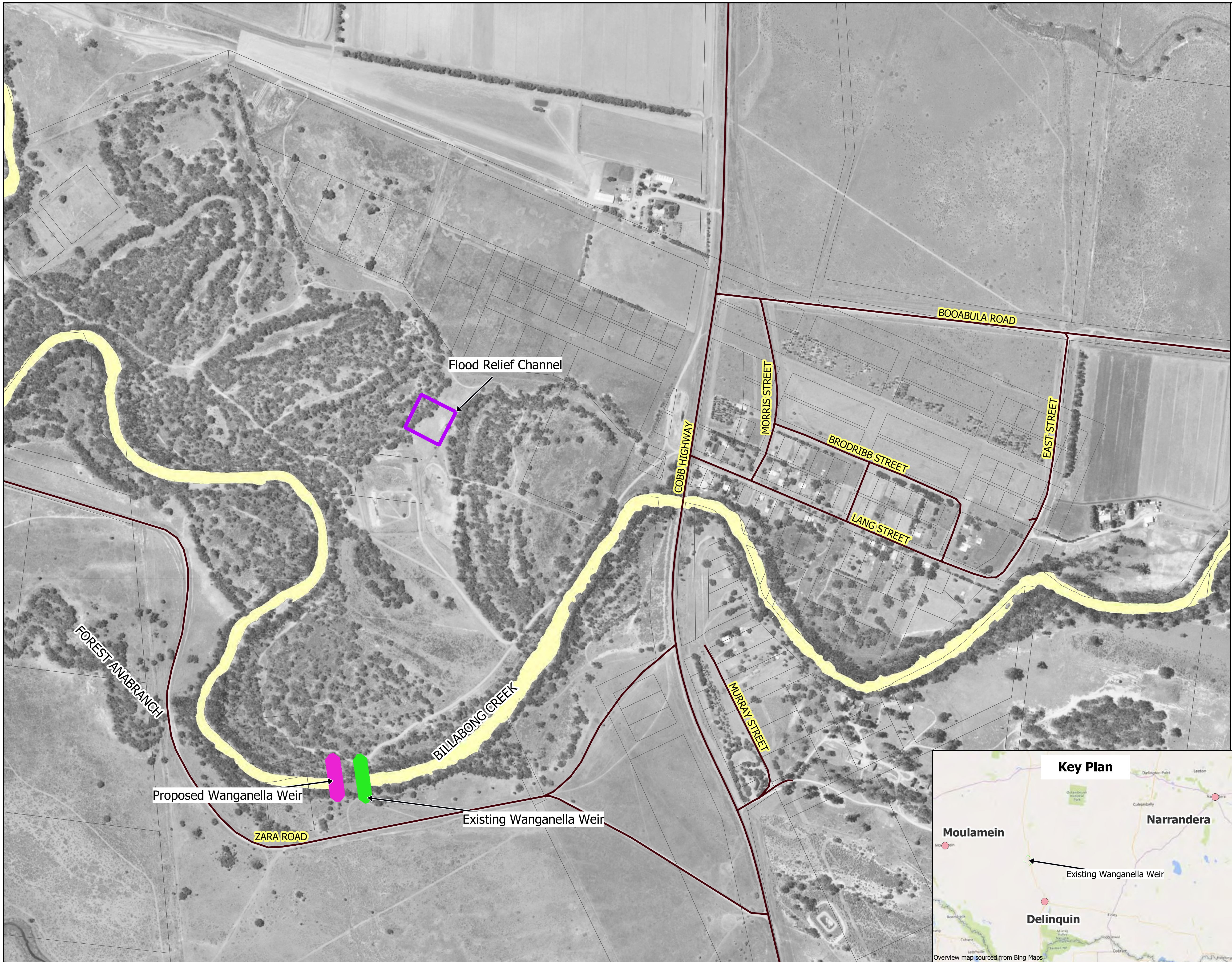


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.9 - Minimum Operating Flow (30 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level 82.06m vs Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.10 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Minimum Operational Level 80.20m vs Existing"



Legend

- Cadastre
- Main Roads
- Model Boundary

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

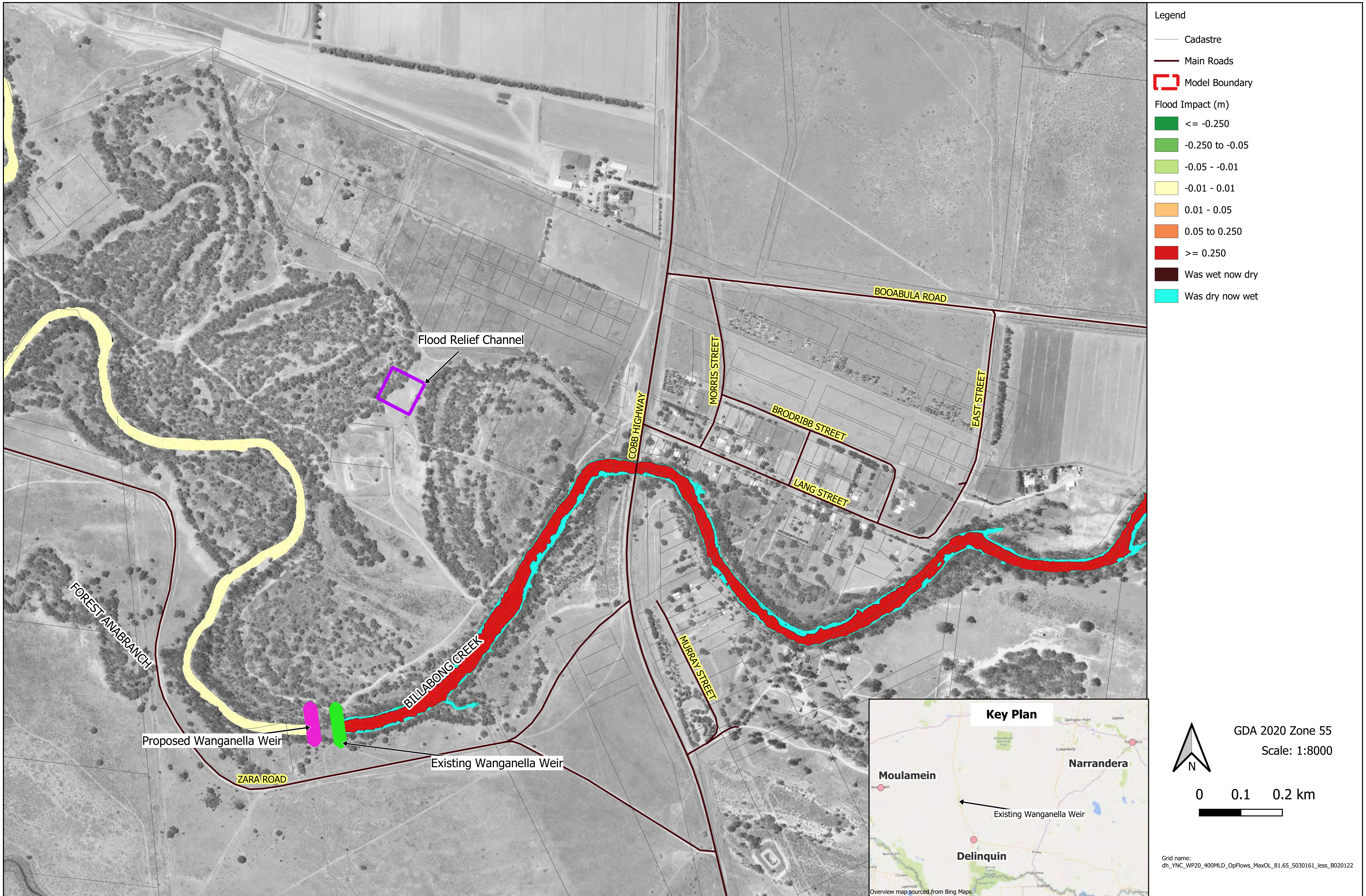
GDA 2020 Zone 55

Scale: 1:8000

0 0.1 0.2 km

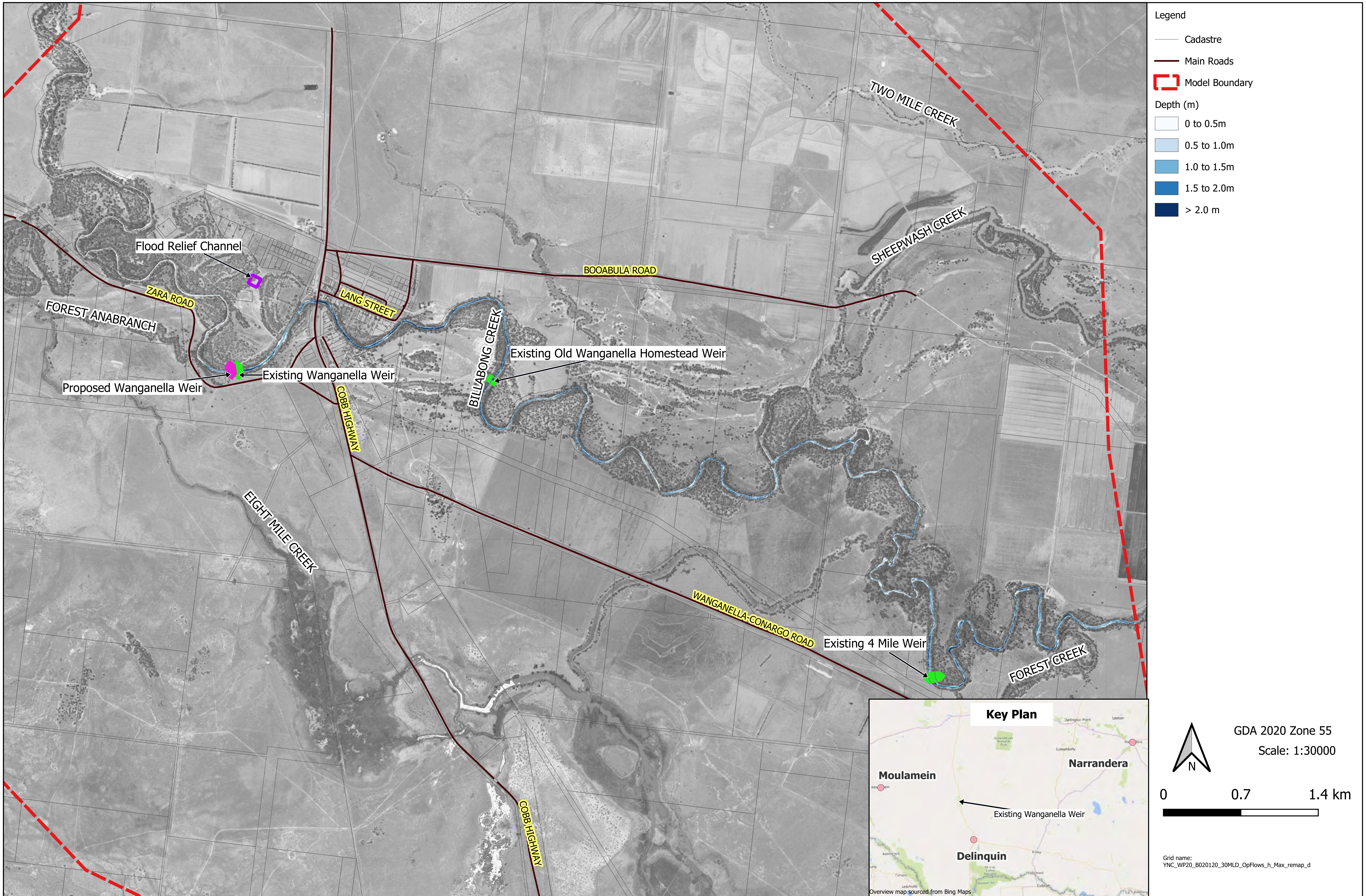
Grid name:
dh_YNC_WP20_400MLD_OpFlows_NormOL_80.54_S030161_less_B020122

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.11 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Maximum Operational Level 80.54m vs Existing"



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D1.12 - Maximum Operating Flow (400 ML/day) Flood Level Impact
"Proposed Full Supply Operational Level 81.65m vs Existing"

D2 Depth Plots



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.1 - Minimum Operating Flow (30 ML/day) Flood Depth
"Existing"

3Rivers

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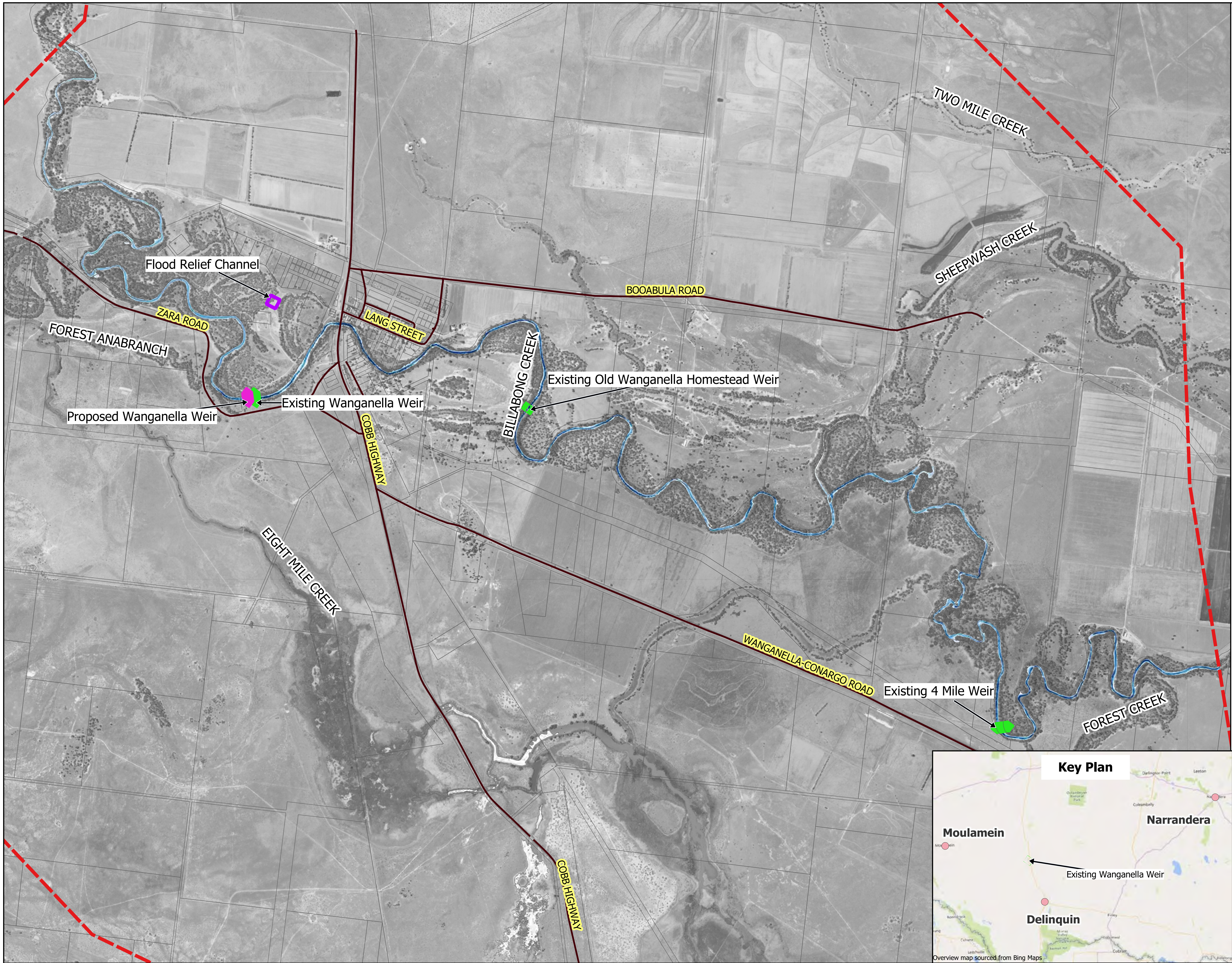


Legend

- 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

N

GDA 2020 Zone 55

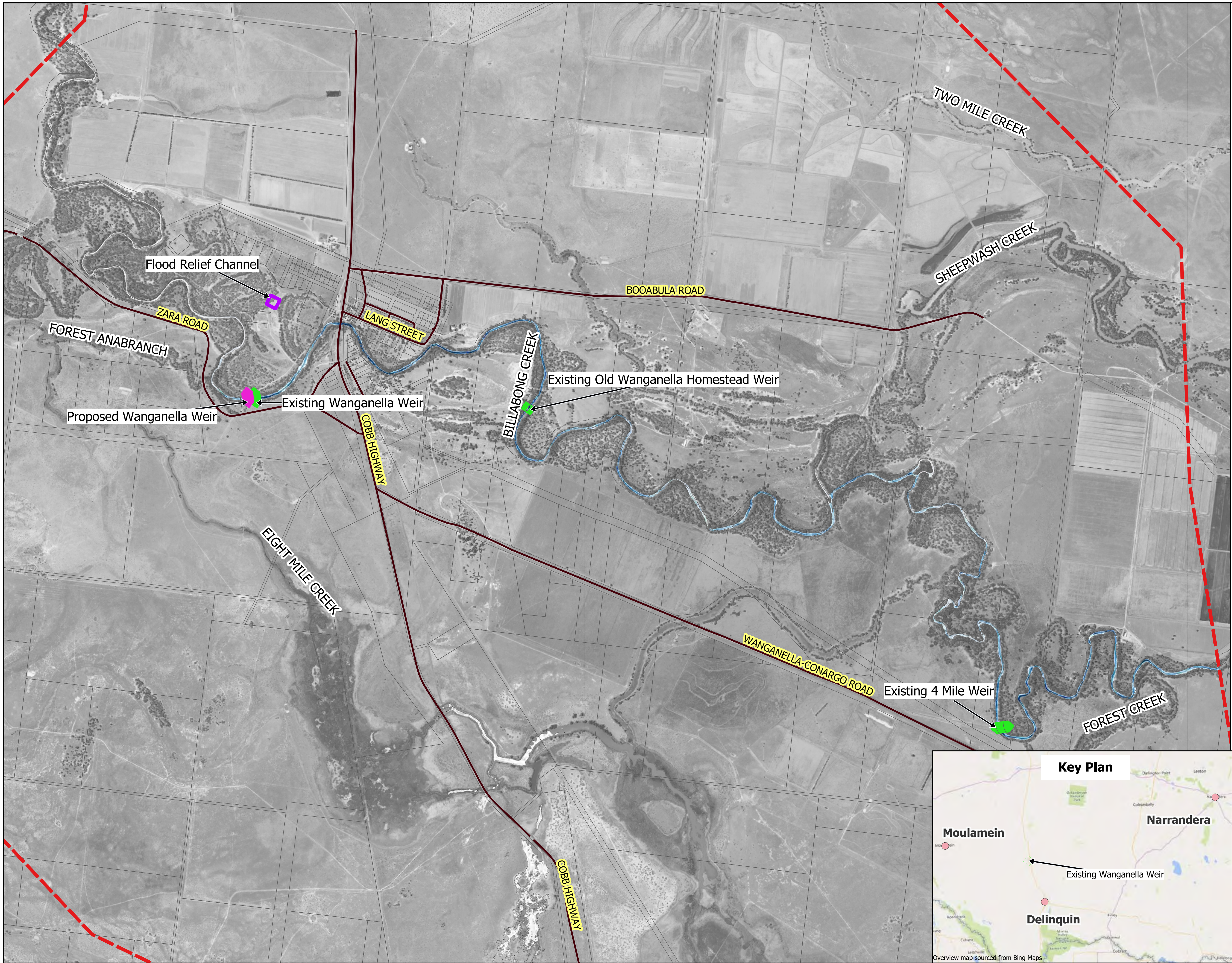
Scale: 1:30000

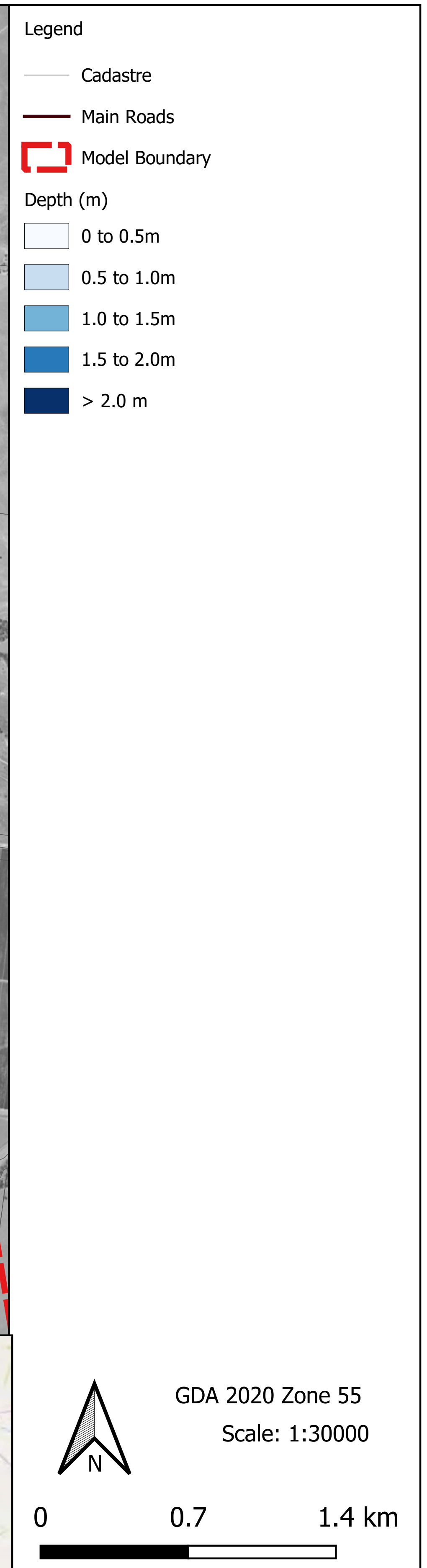
0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_400MLD_OpFlows_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.2 - Maximum Operating Flow (400 ML/day) Flood Depth
"Existing"

3Rivers

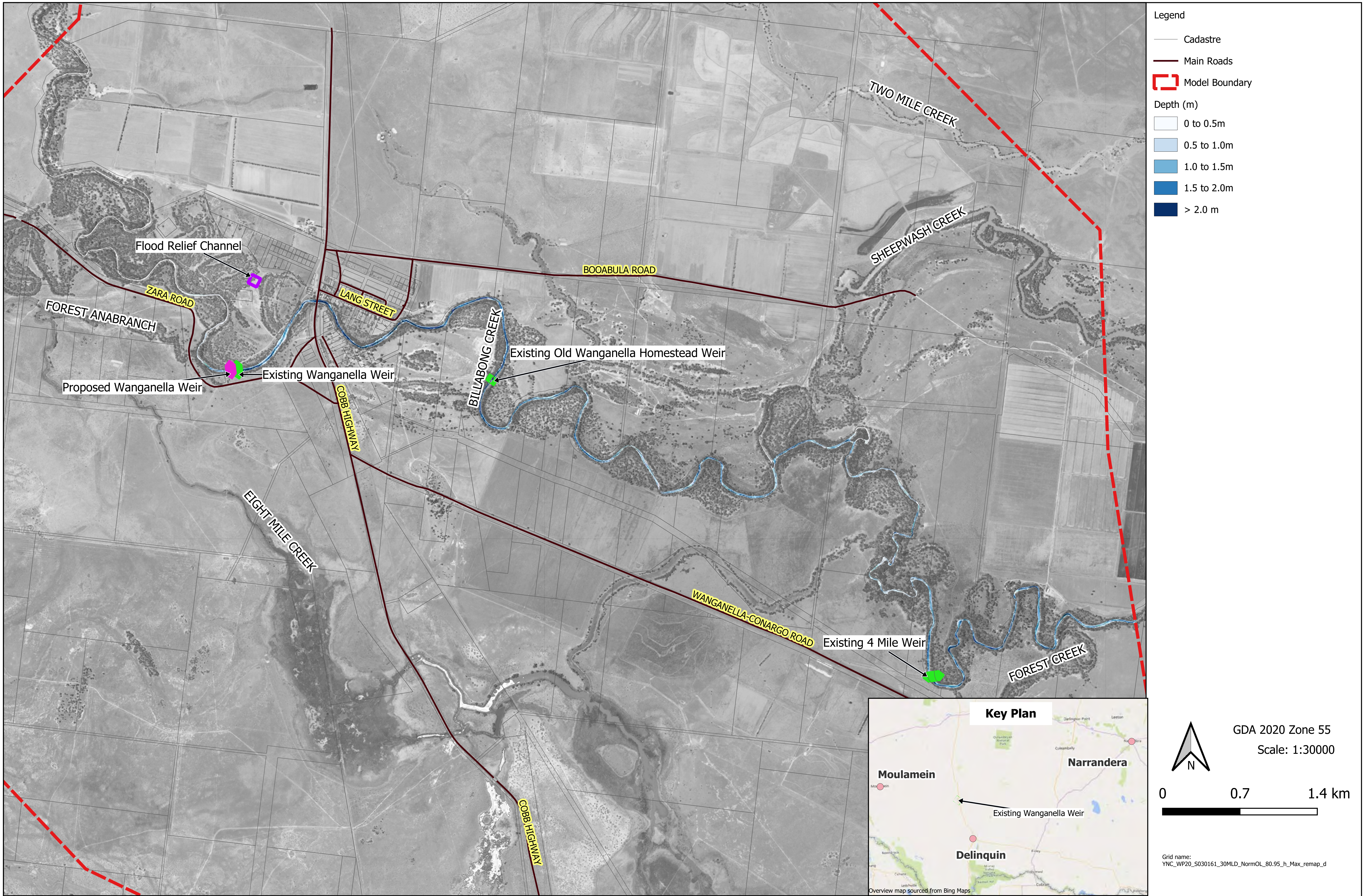




Grid name:
YNC_WP20_S030161_30MLD_MinOL_80.71_h_Max_remap_d

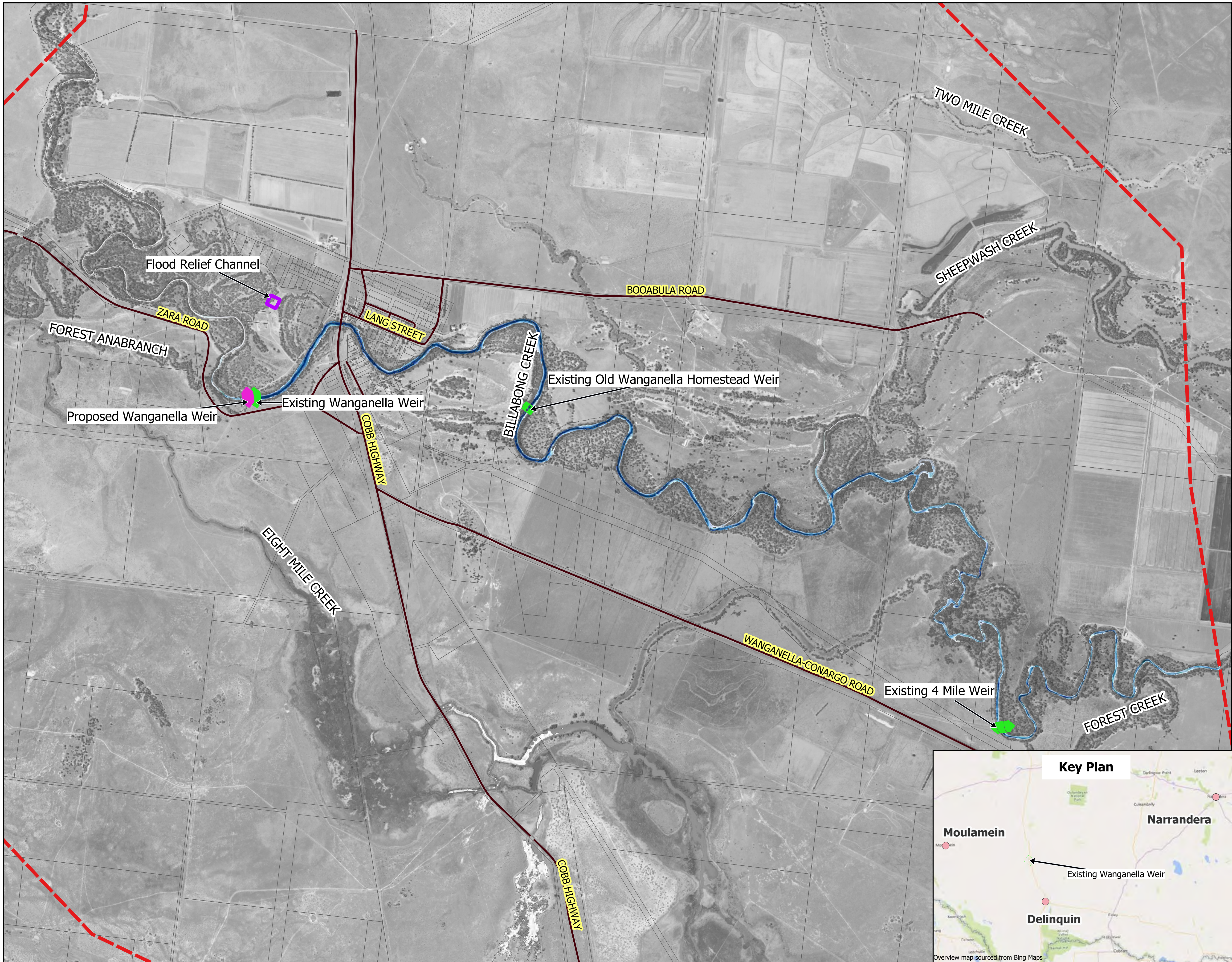
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.3 - Minimum Operating Flow (30 ML/day) Flood Depth
"Proposed Minimum Operational Level 80.71m"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.4 - Minimum Operating Flow (30 ML/day) Flood Depth
"Proposed Maximum Operational Level 80.95m"

3Rivers



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

N

GDA 2020 Zone 55

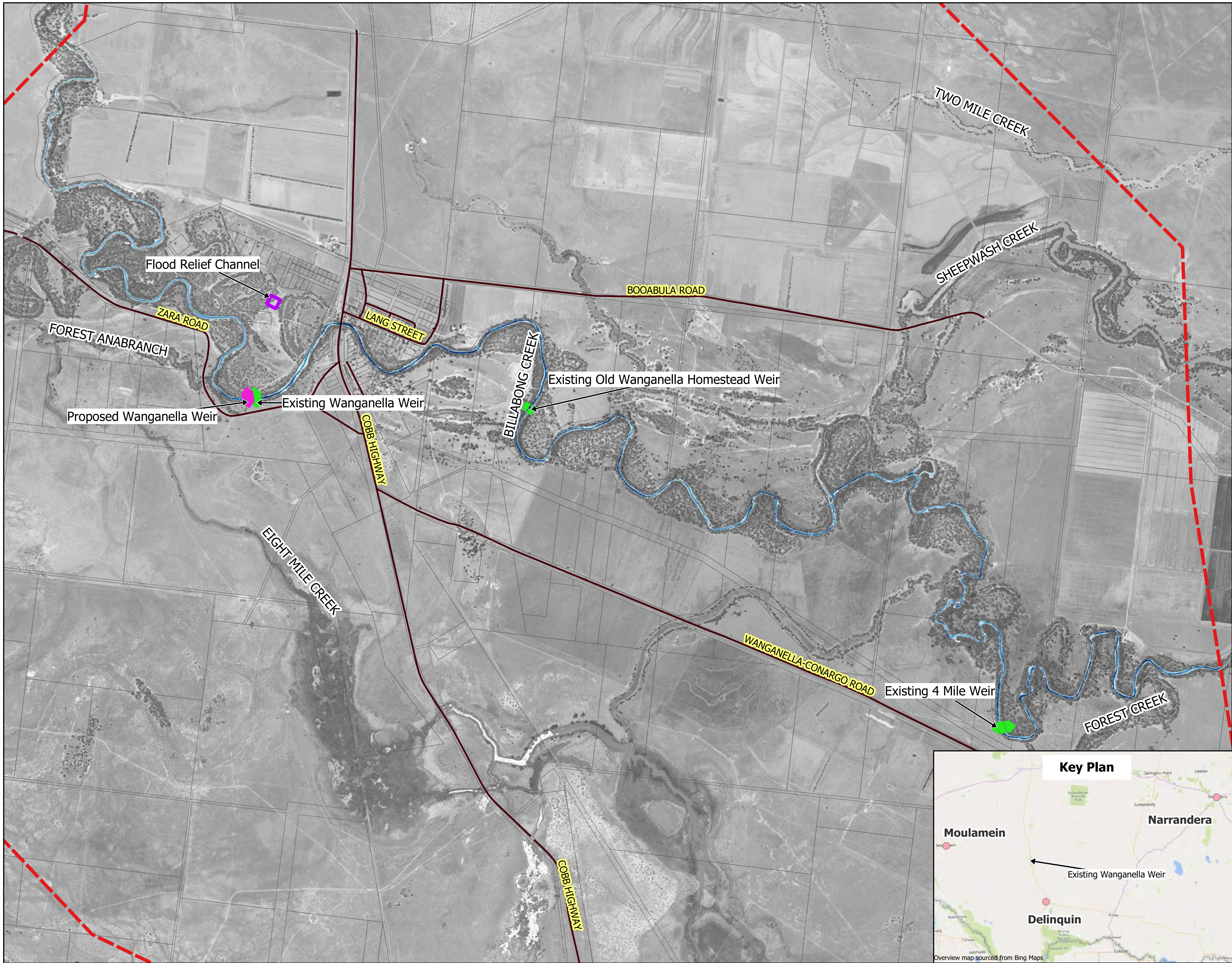
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_30MLD_MaxOL_82.06_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.5 - Minimum Operating Flow (30 ML/day) Flood Depth
"Proposed Full Supply Operational Level 82.06m"

3Rivers



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

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_400MLD_MinOL_80.20_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.6 - Maximum Operating Flow (400 ML/day) Flood Depth
"Proposed Minimum Operational Level 80.20m"

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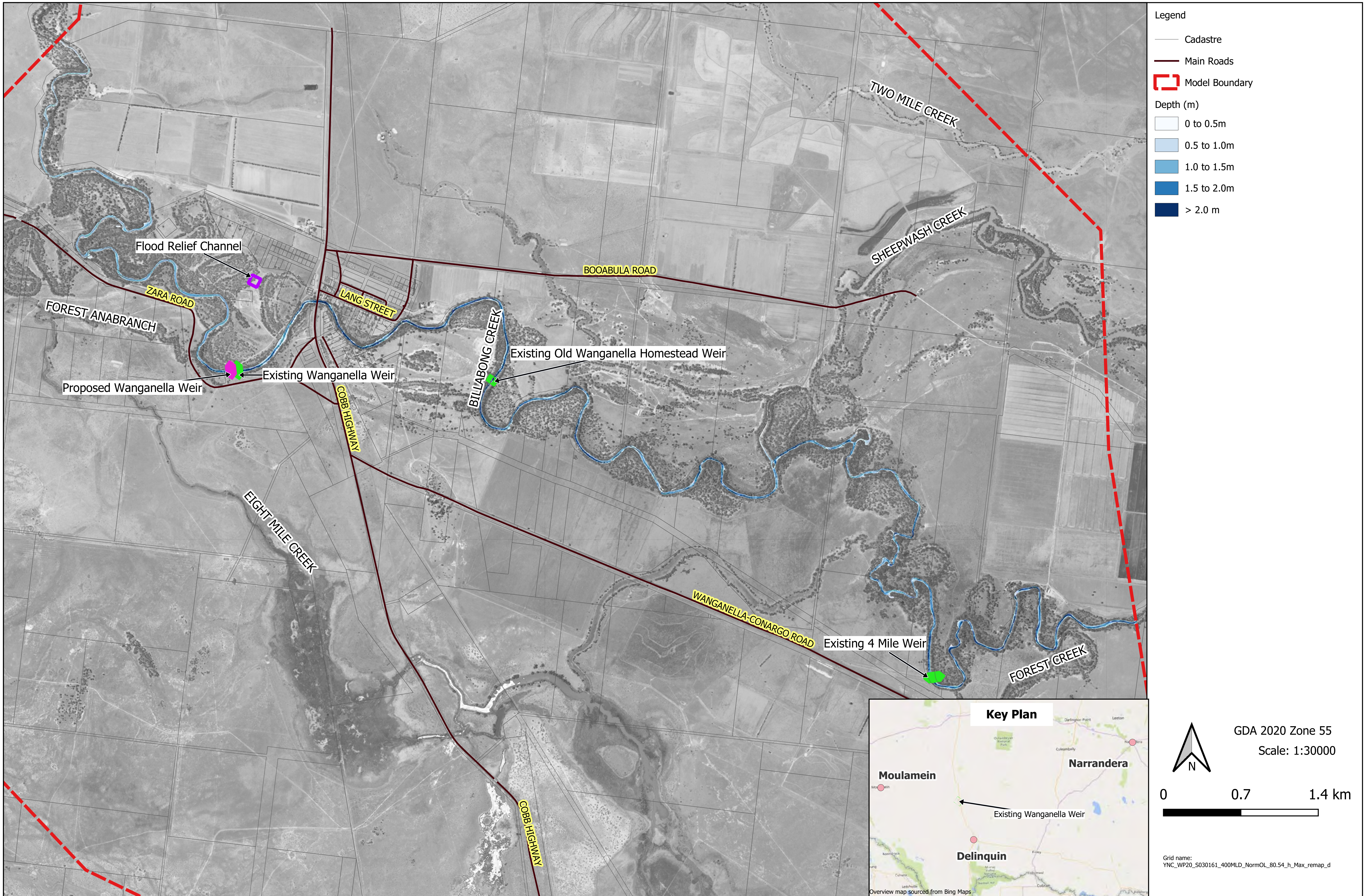

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.7 - Maximum Operating Flow (400 ML/day) Flood Depth
"Proposed Maximum Operational Level 80.54m"

3Rivers

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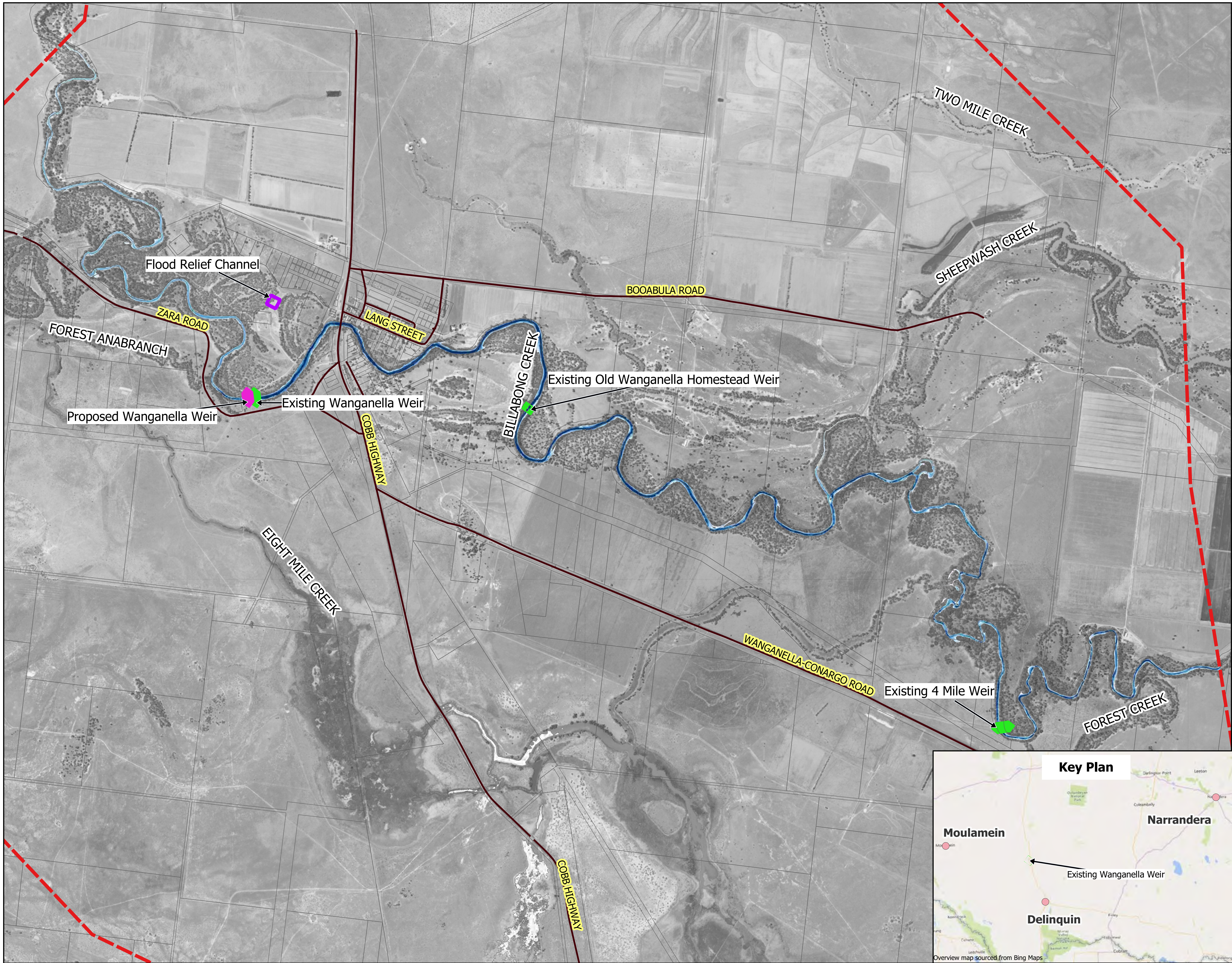

Legend

- 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

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_400MLD_MaxOL_81.65_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D2.8 - Maximum Operating Flow (400 ML/day) Flood Depth
"Proposed Full Supply Operational Level 81.65m"

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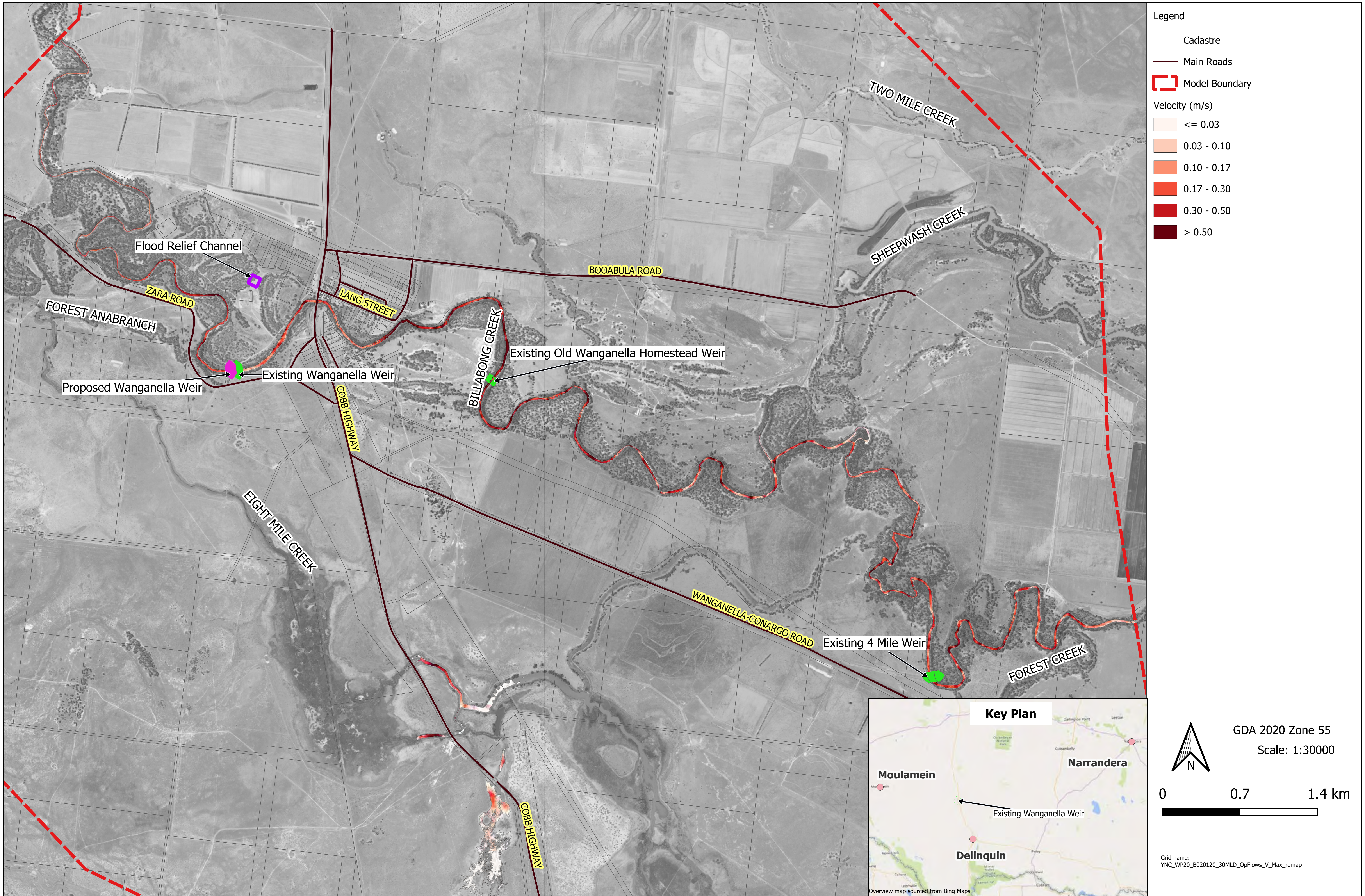
D3 Velocity Plots



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.1 - Minimum Operating Flow (30 ML/day) Flood Velocity
"Existing"

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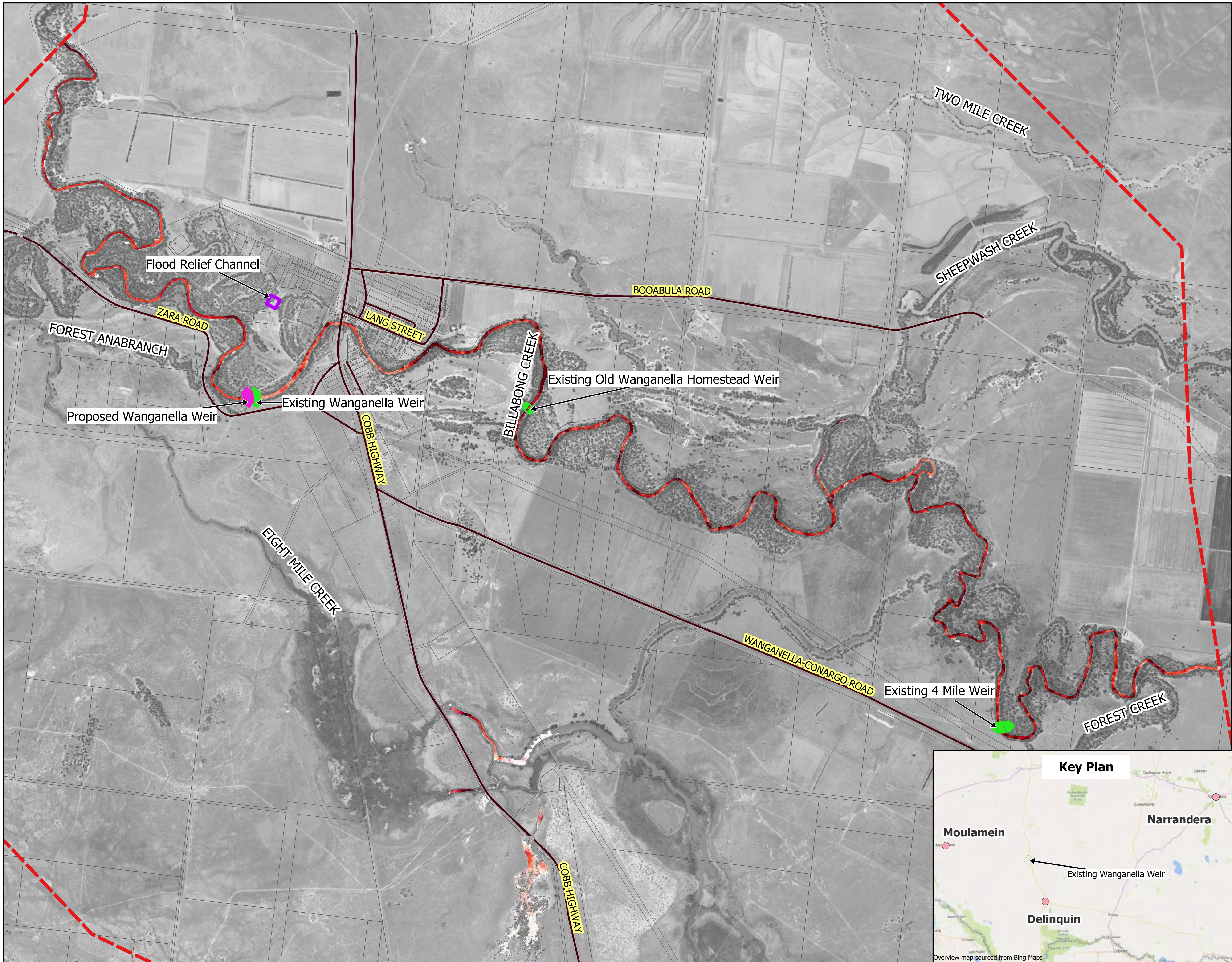


Legend
- Cadastre
- Main Roads
- Model Boundary

Velocity (m/s)
- <= 0.03
- 0.03 - 0.10
- 0.10 - 0.17
- 0.17 - 0.30
- 0.30 - 0.50
- > 0.50

N

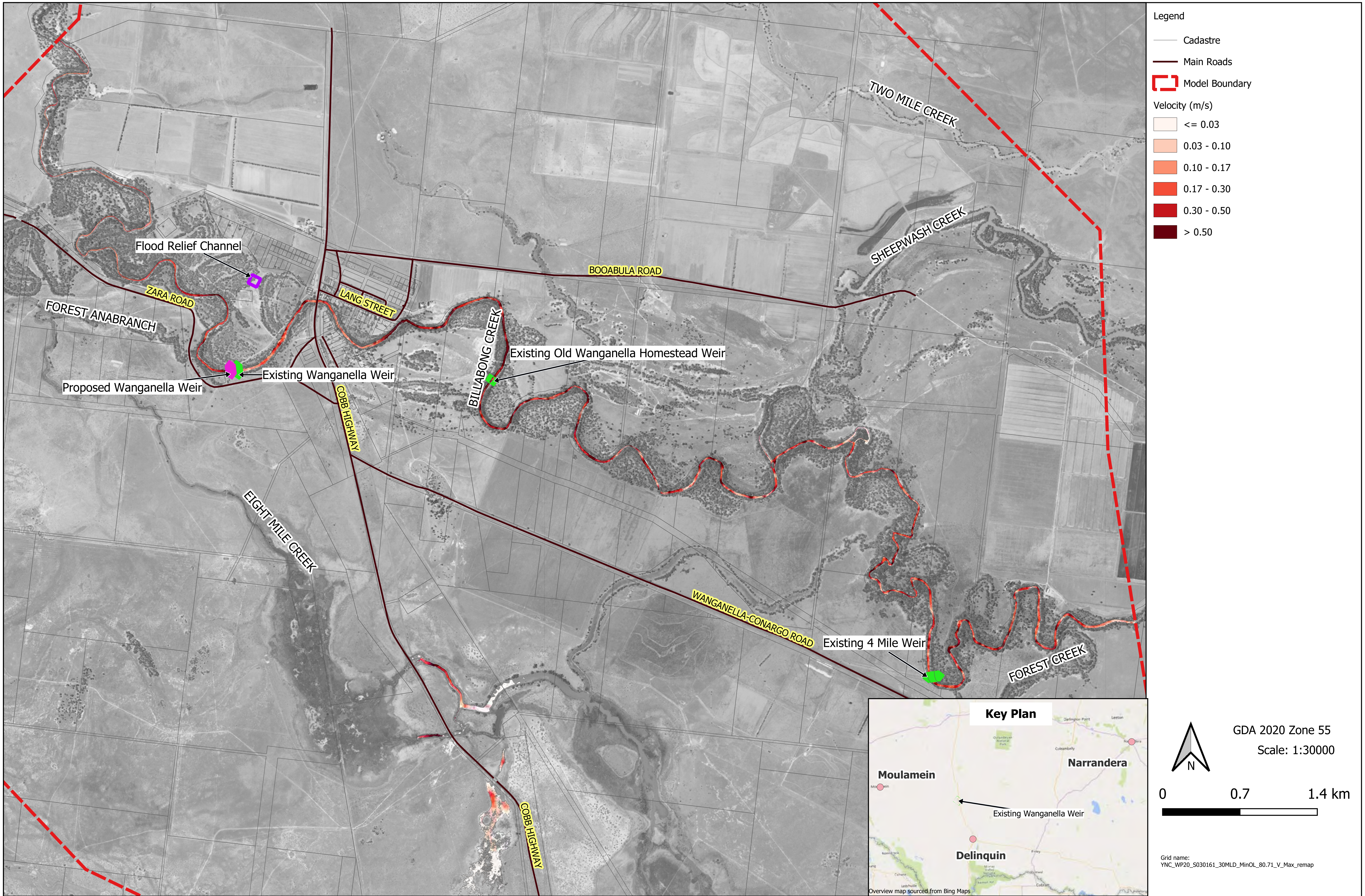
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_400MLD_OpFlows_V_Max_remap

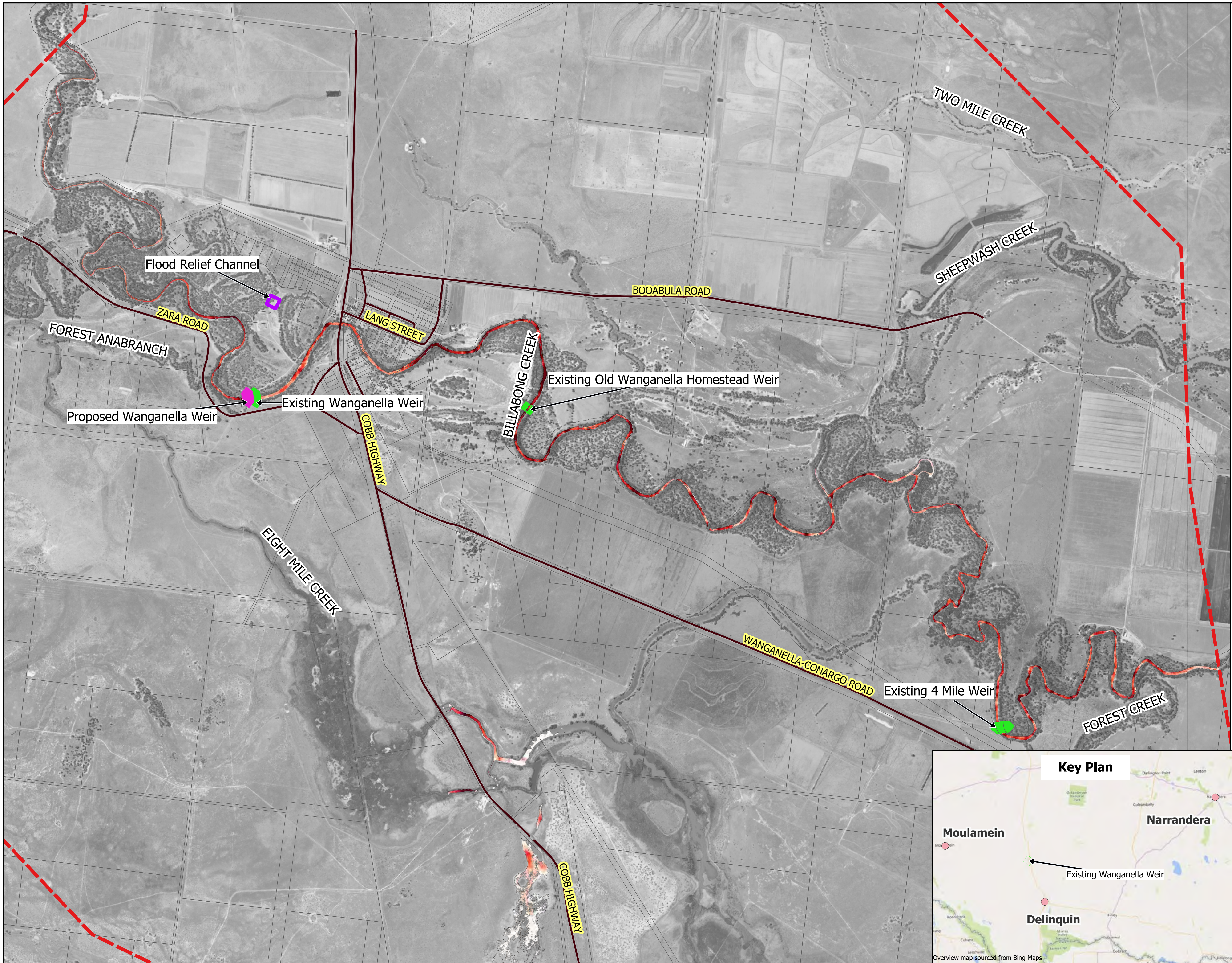
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.2 - Maximum Operating Flow (400 ML/day) Flood Velocity
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.3 - Minimum Operating Flow (30 ML/day) Flood Velocity
"Proposed Minimum Operational Level 80.71m"

3Rivers



Legend
Cadastre
Main Roads
Model Boundary
Velocity (m/s)
<= 0.03
0.03 - 0.10
0.10 - 0.17
0.17 - 0.30
0.30 - 0.50
> 0.50

N

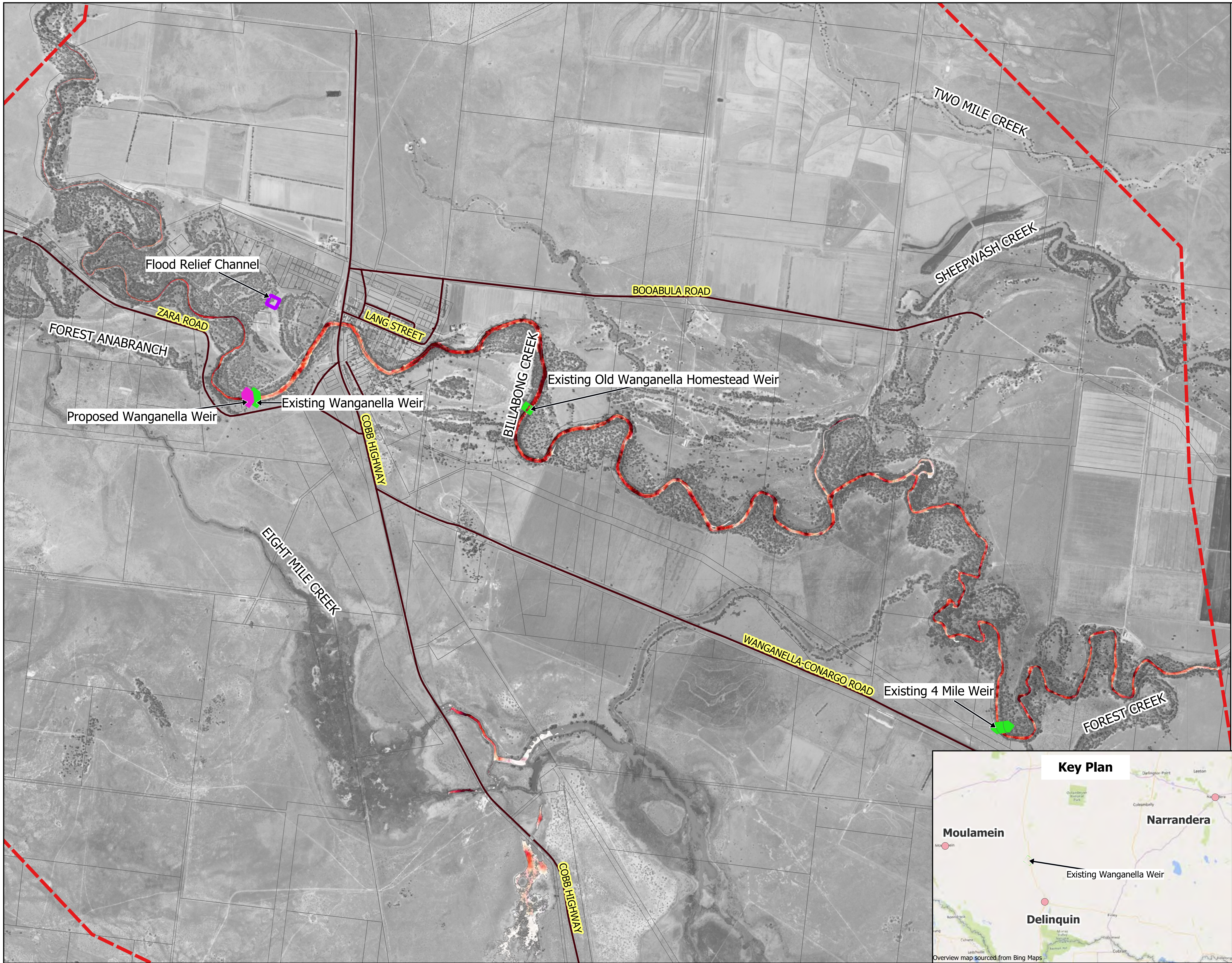
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_30MLD_NormOL_80.95_V_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.4 - Minimum Operating Flow (30 ML/day) Flood Velocity
"Proposed Maximum Operational Level 80.95m"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Velocity (m/s)

- <= 0.03
- 0.03 - 0.10
- 0.10 - 0.17
- 0.17 - 0.30
- 0.30 - 0.50
- > 0.50

N

GDA 2020 Zone 55

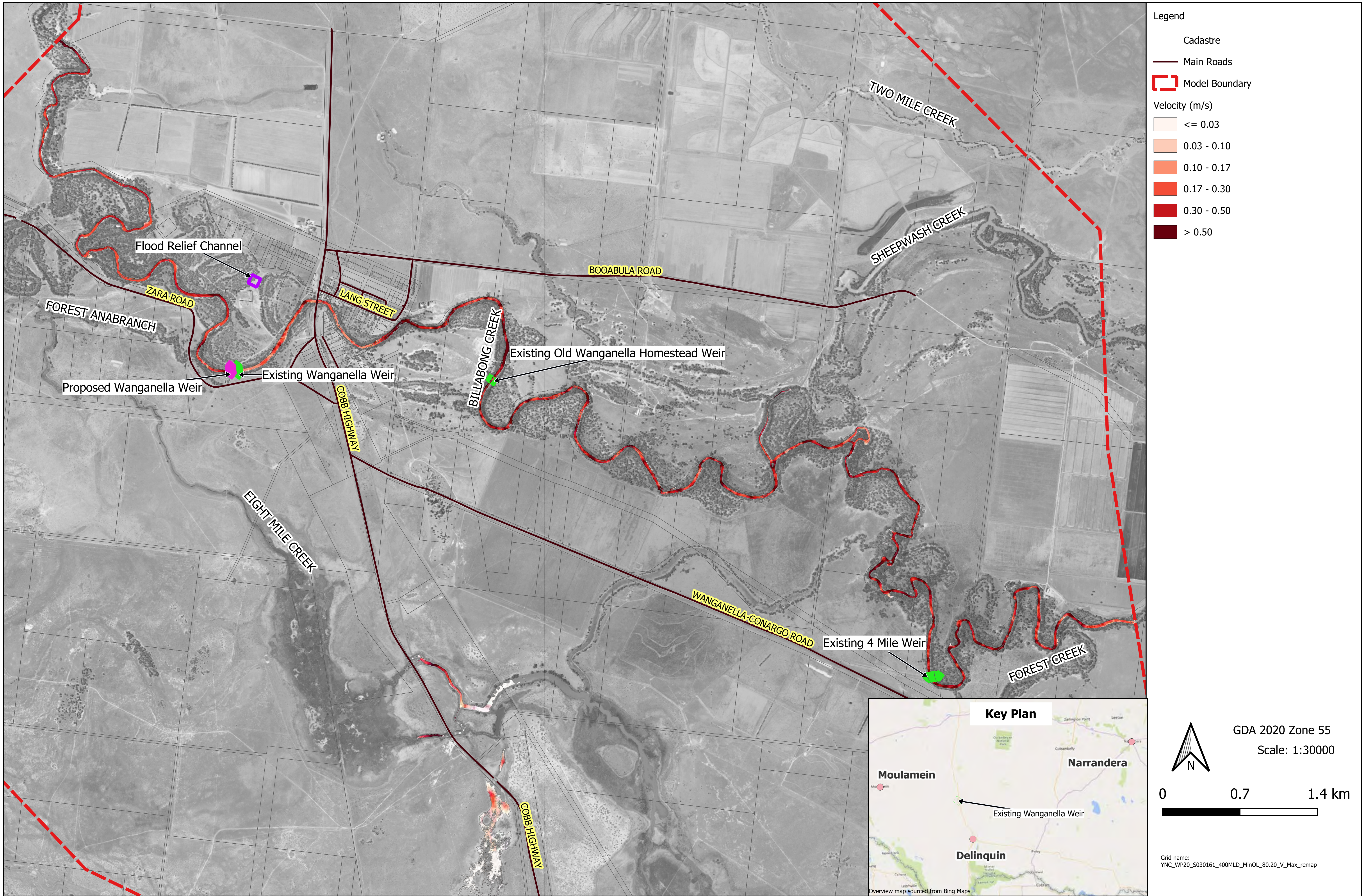
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_30MLD_MaxOL_82.06_V_Max_remap

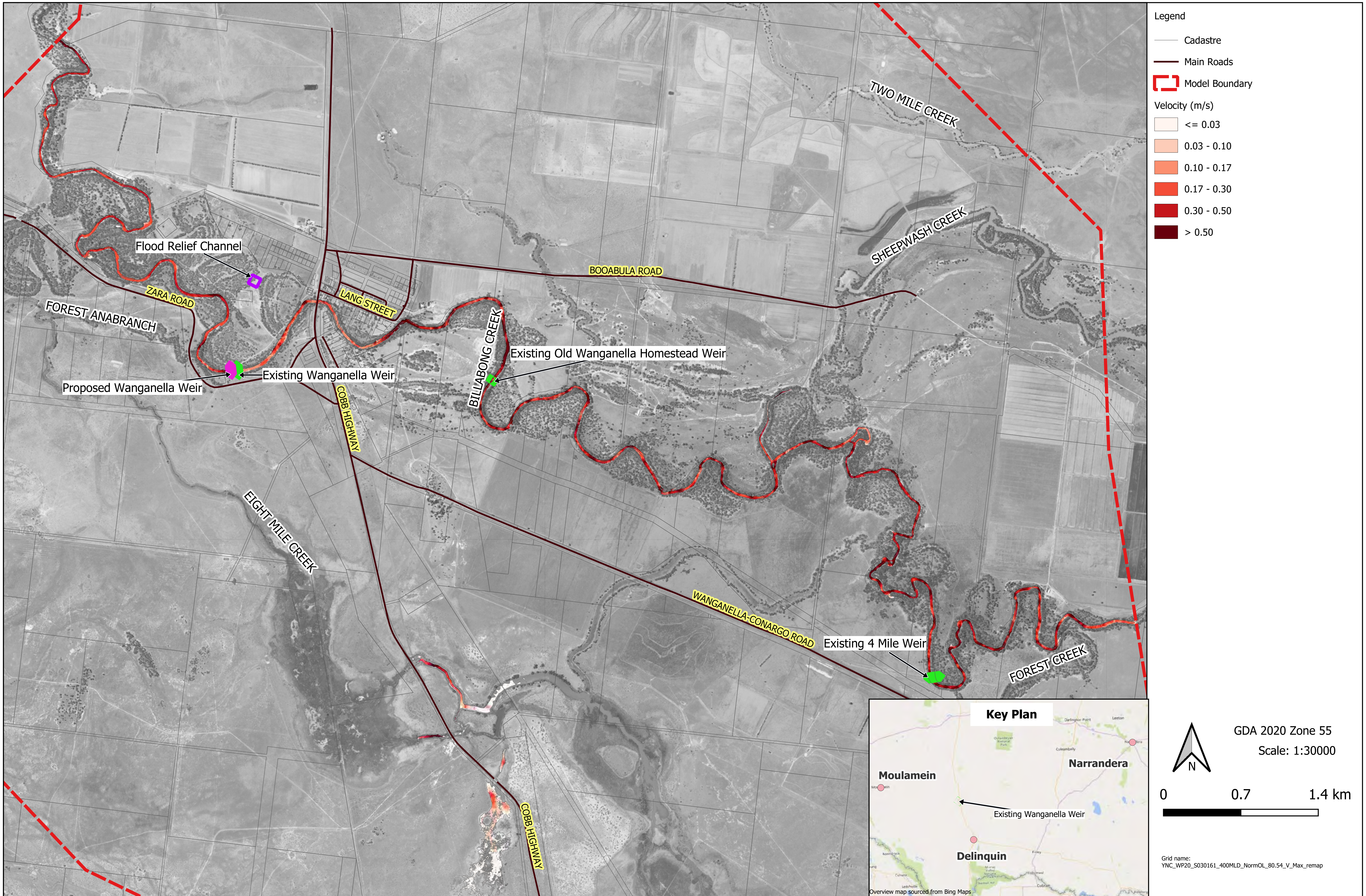
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.5 - Minimum Operating Flow (30 ML/day) Flood Velocity
"Proposed Full Supply Operational Level 82.06m"

3Rivers

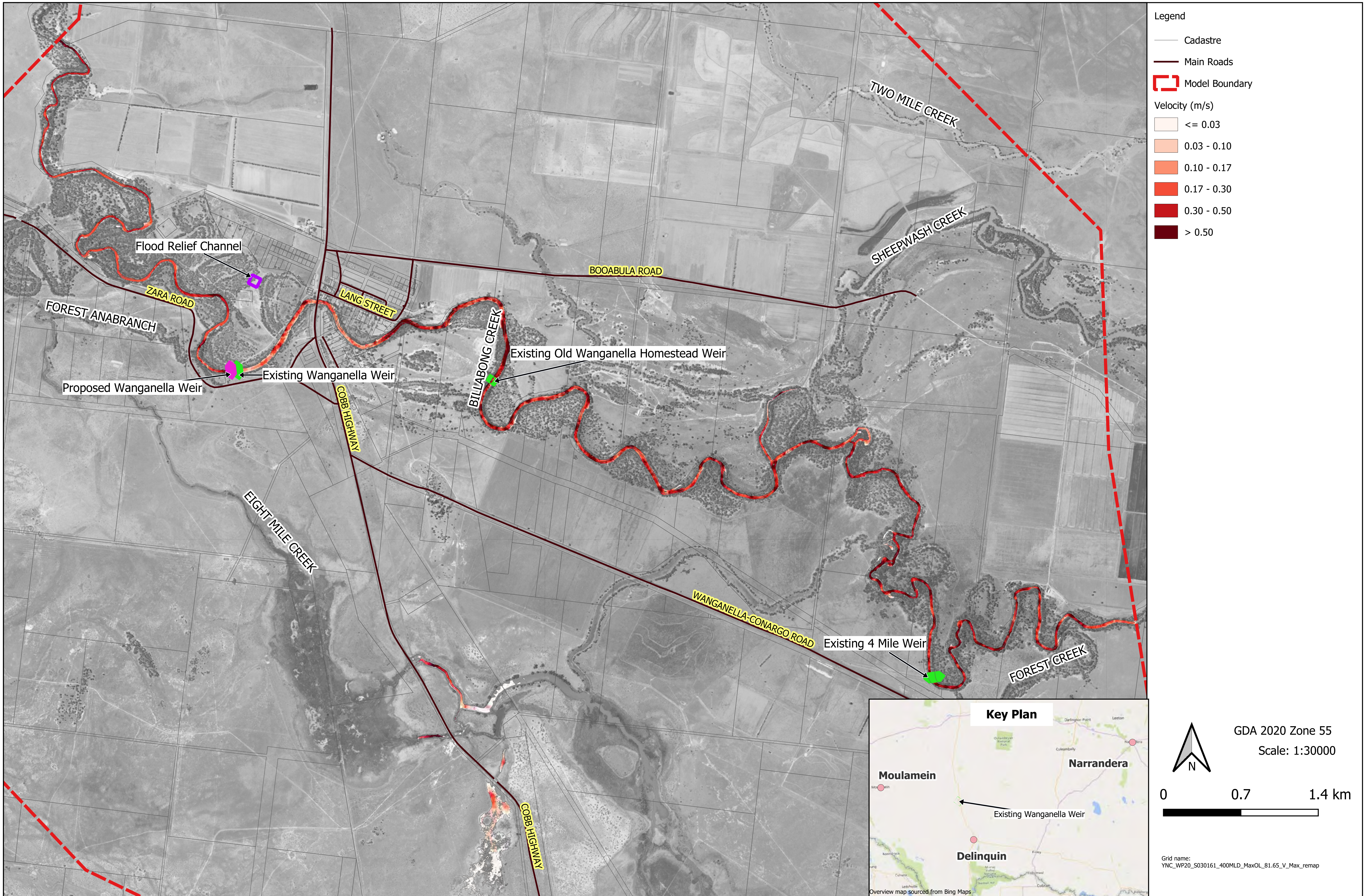


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.6 - Maximum Operating Flow (400 ML/day) Flood Velocity
"Proposed Minimum Operational Level 80.20m"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.7 - Maximum Operating Flow (400 ML/day) Flood Velocity
"Proposed Maximum Operational Level 80.54m"



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D3.8 - Maximum Operating Flow (400 ML/day) Flood Velocity
"Proposed Full Supply Operational Level 81.65m"

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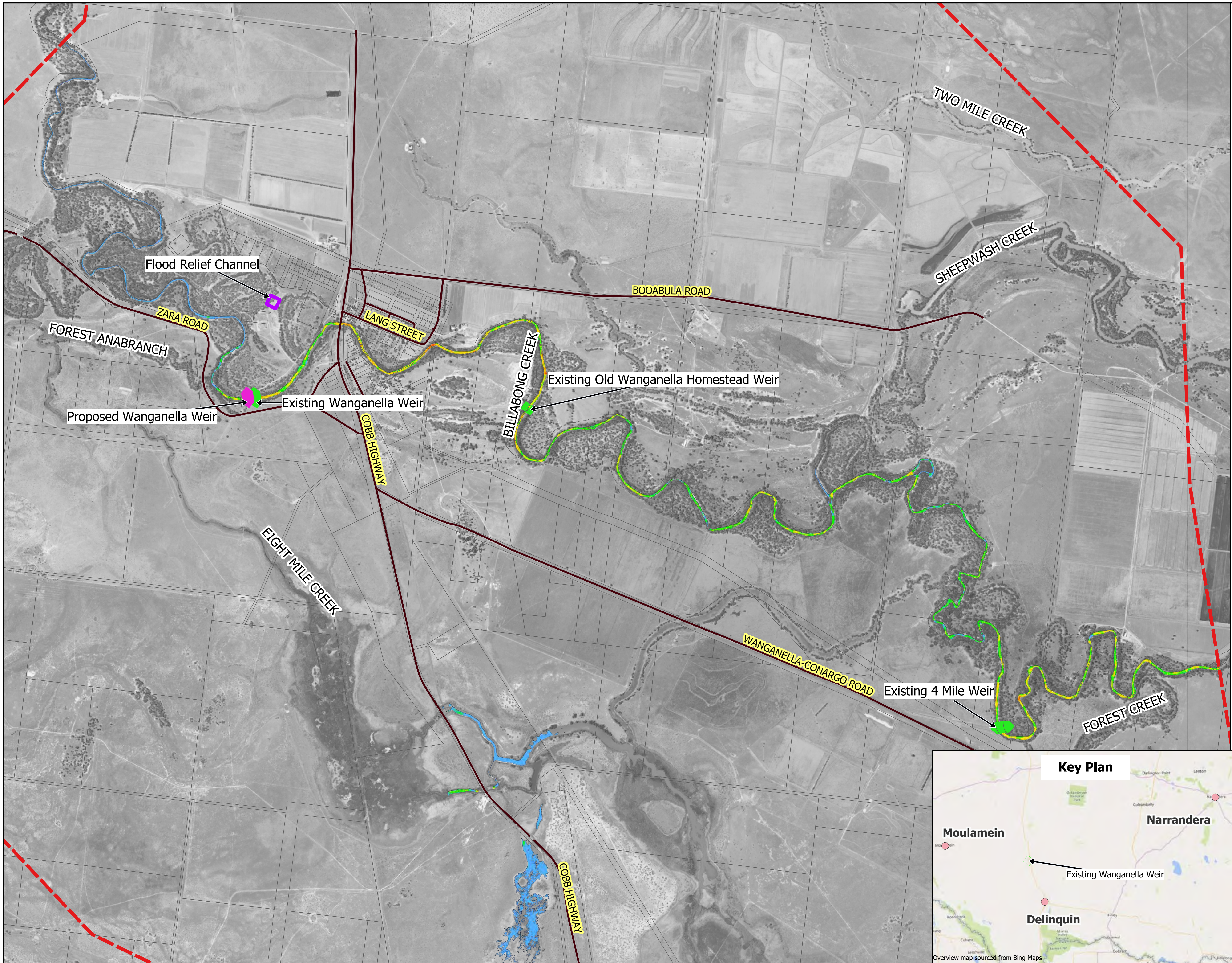
D4 Hazard Category Plots



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

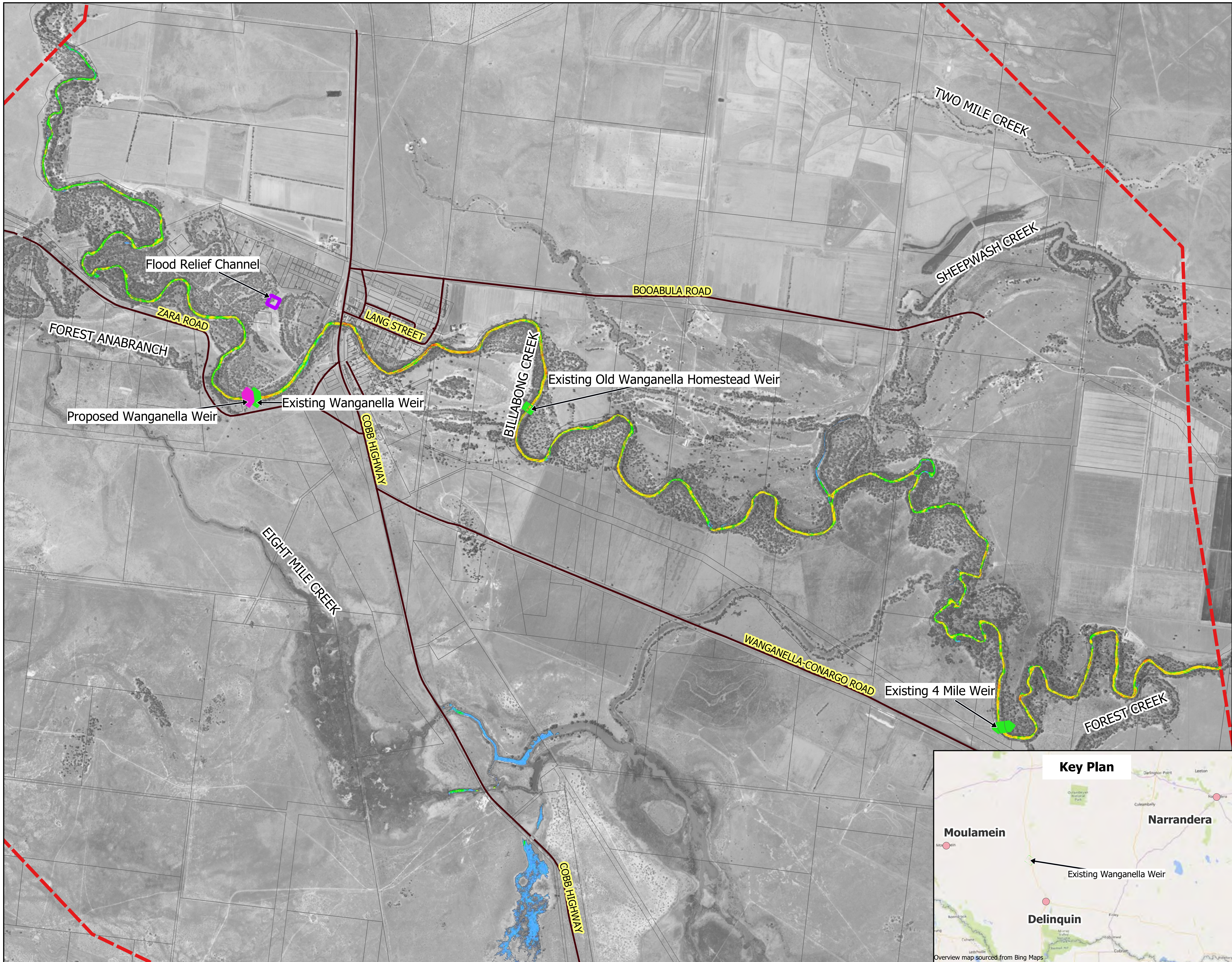
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_30MLD_OpFlows_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.1 - Minimum Operating Flow (30 ML/day) Flood Hazard
"Existing at Maximum Operating Level"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

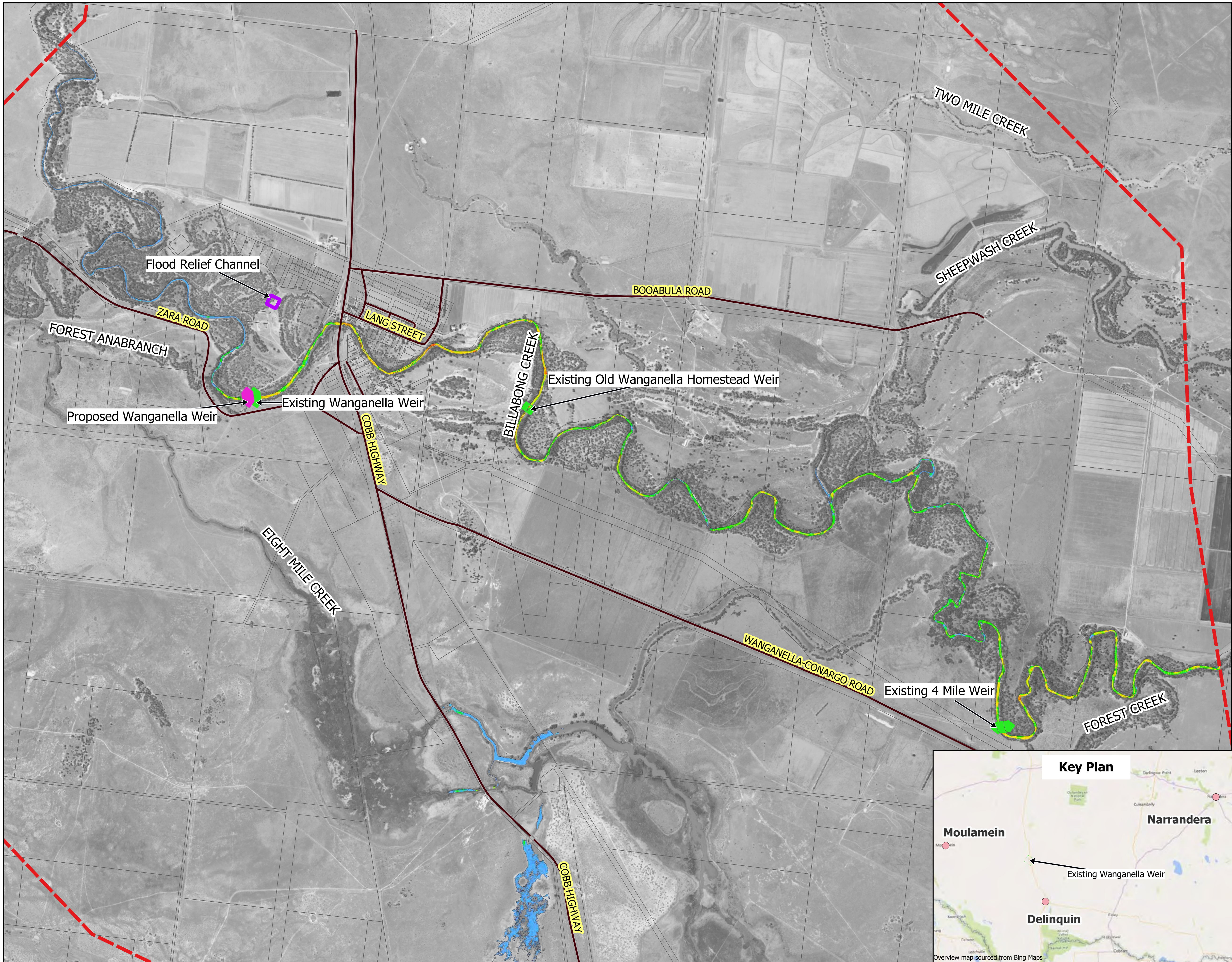
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_400MLD_OpFlows_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.2 - Maximum Operating Flow (400 ML/day) Flood Hazard
"Existing at Maximum Operating Level"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

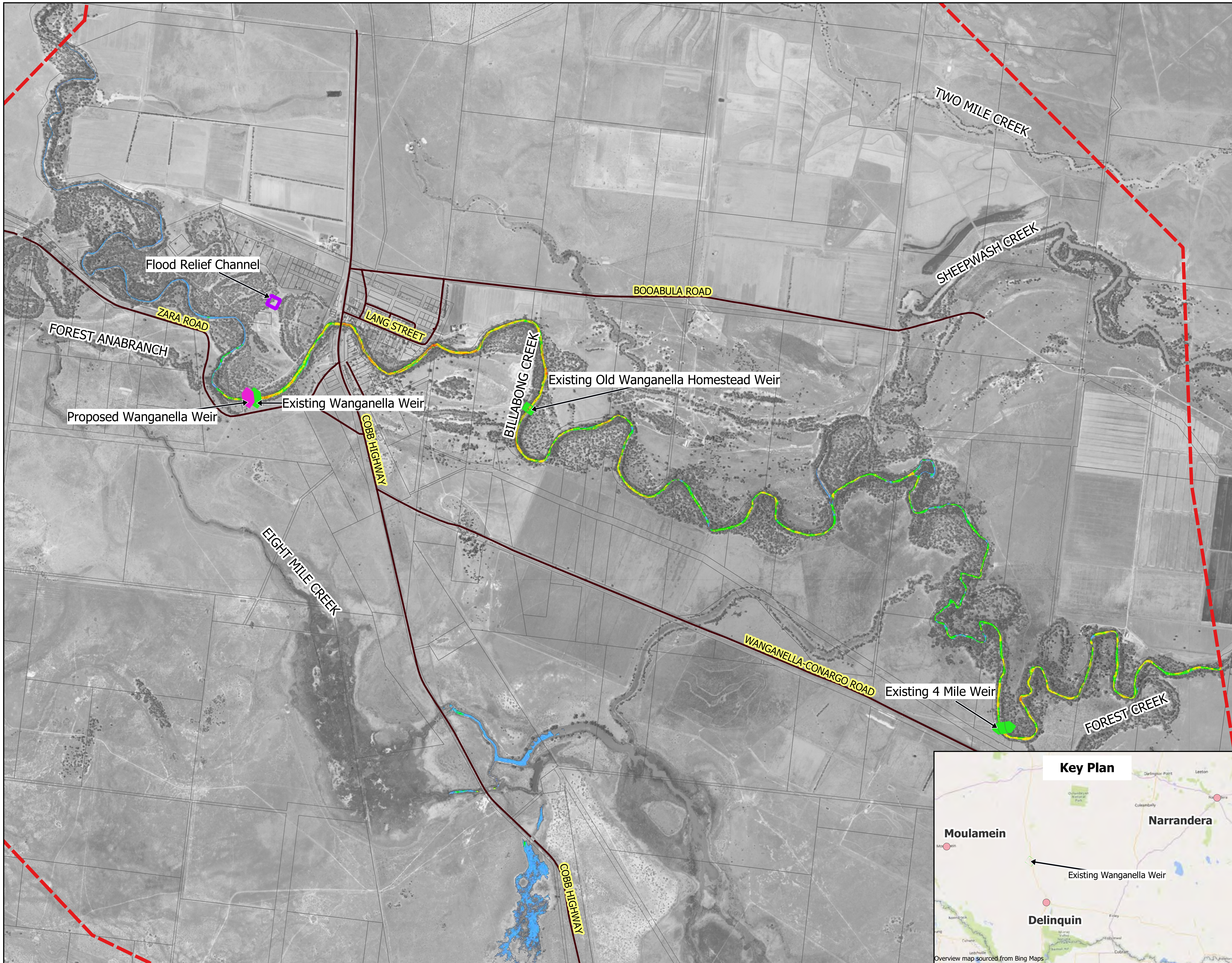
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_30MLD_MinOL_80.71_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.3 - Minimum Operating Flow (30 ML/day) Flood Hazard
"Proposed Minimum Operational Level 80.71m"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles, plus buildings require special design and construction
- H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

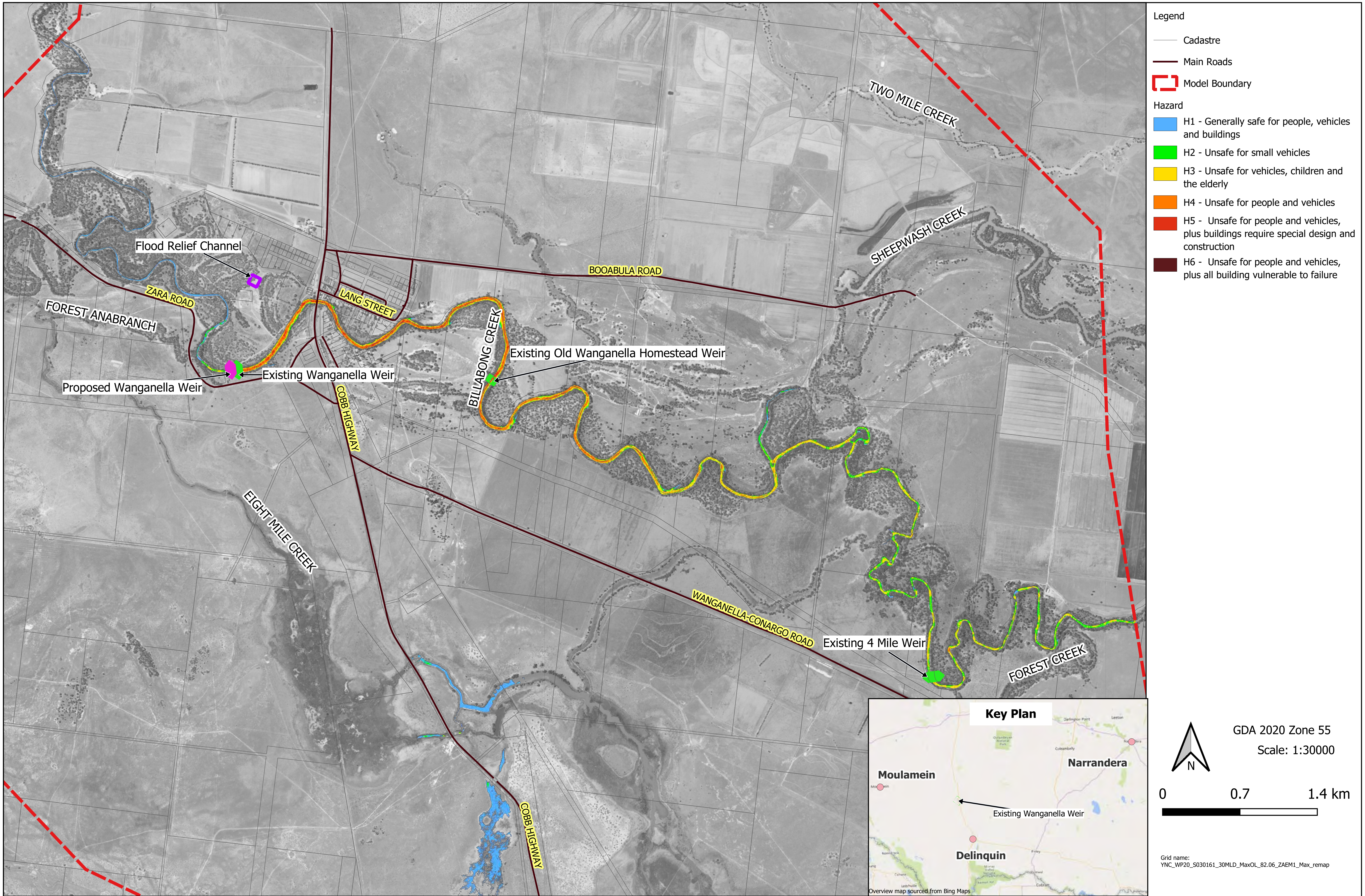
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_30MLD_NormOL_80.95_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.4 - Minimum Operating Flow (30 ML/day) Flood Hazard
"Proposed Maximum Operational Level 80.95m"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.5 - Minimum Operating Flow (30 ML/day) Flood Hazard
"Proposed Full Supply Operational Level 82.06m"

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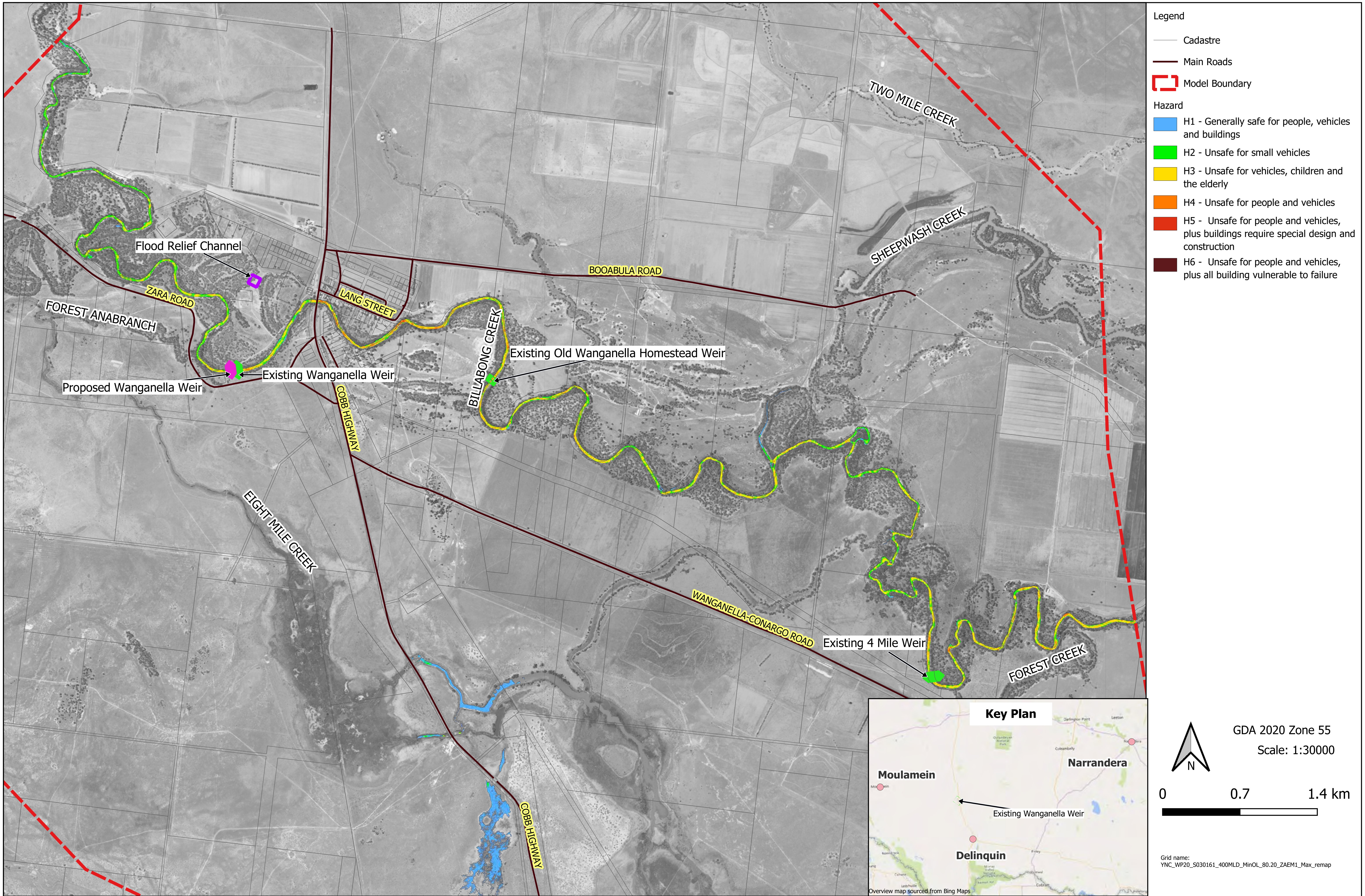
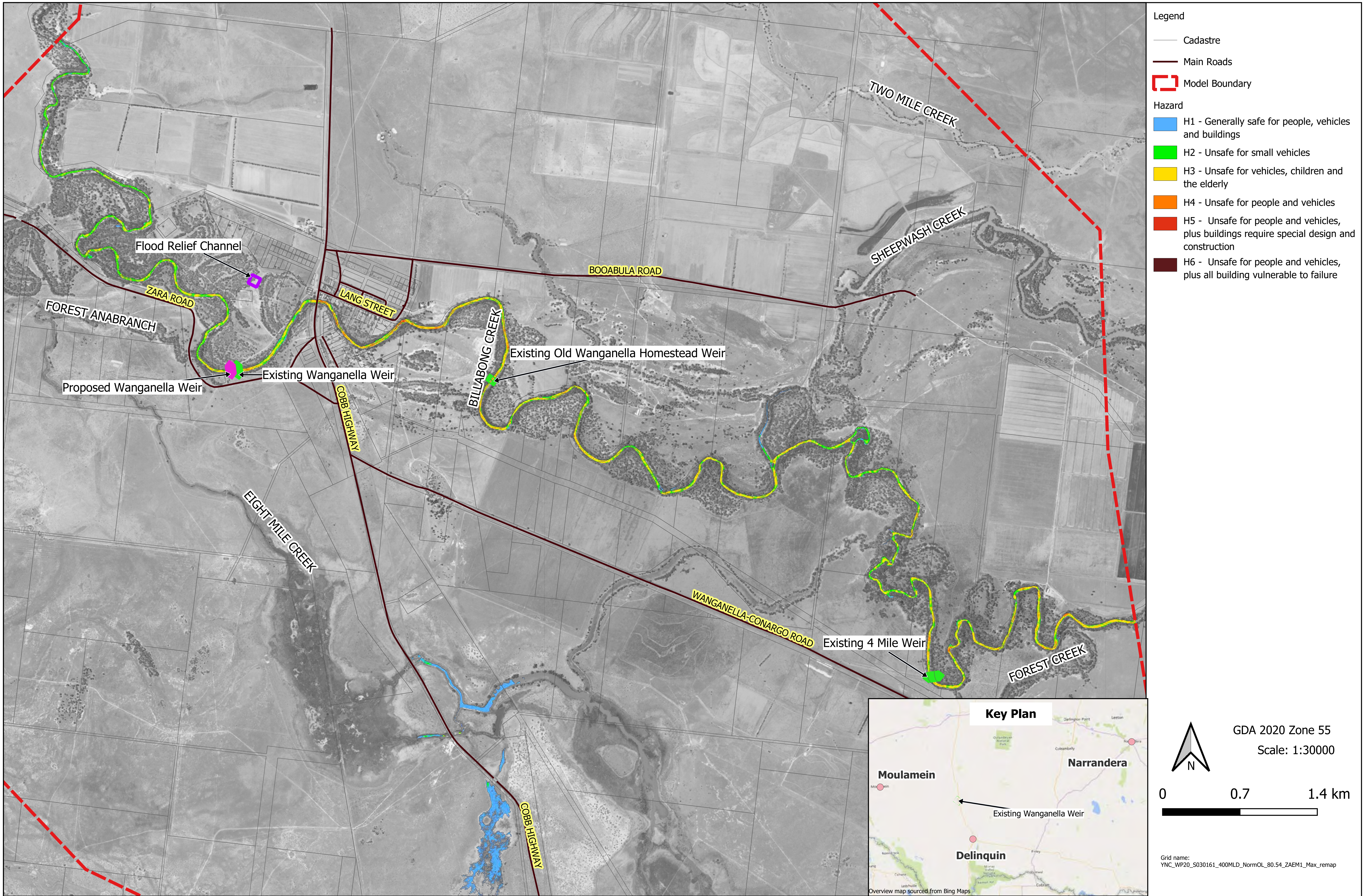


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.6 - Maximum Operating Flow (400 ML/day) Flood Hazard
"Proposed Minimum Operational Level 80.20m"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.7 - Maximum Operating Flow (400 ML/day) Flood Hazard
"Proposed Maximum Operational Level 80.54m"

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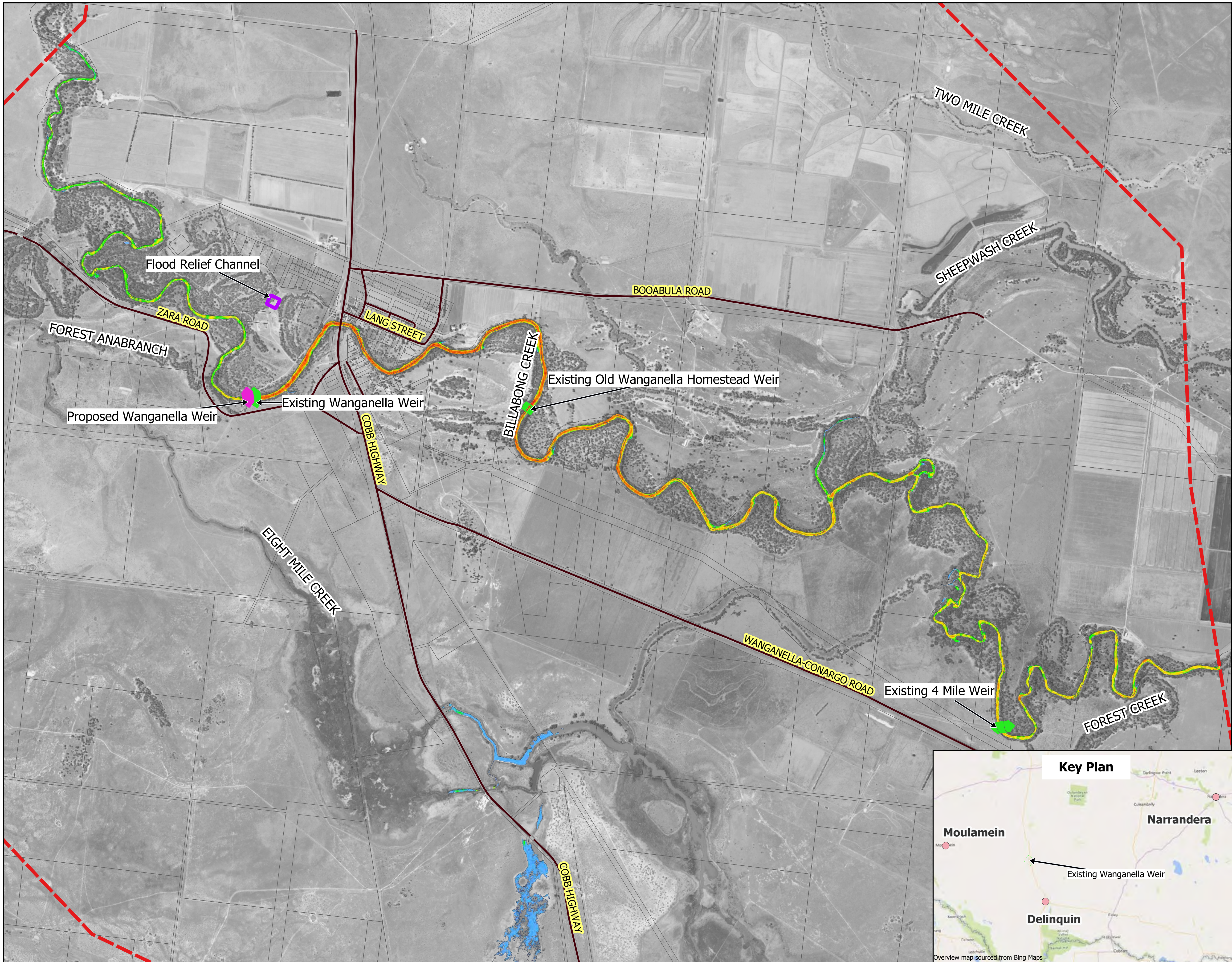

Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_400MLD_MaxOL_81.65_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure D4.8 - Maximum Operating Flow (400 ML/day) Flood Hazard
"Proposed Full Supply Operational Level 81.65m"

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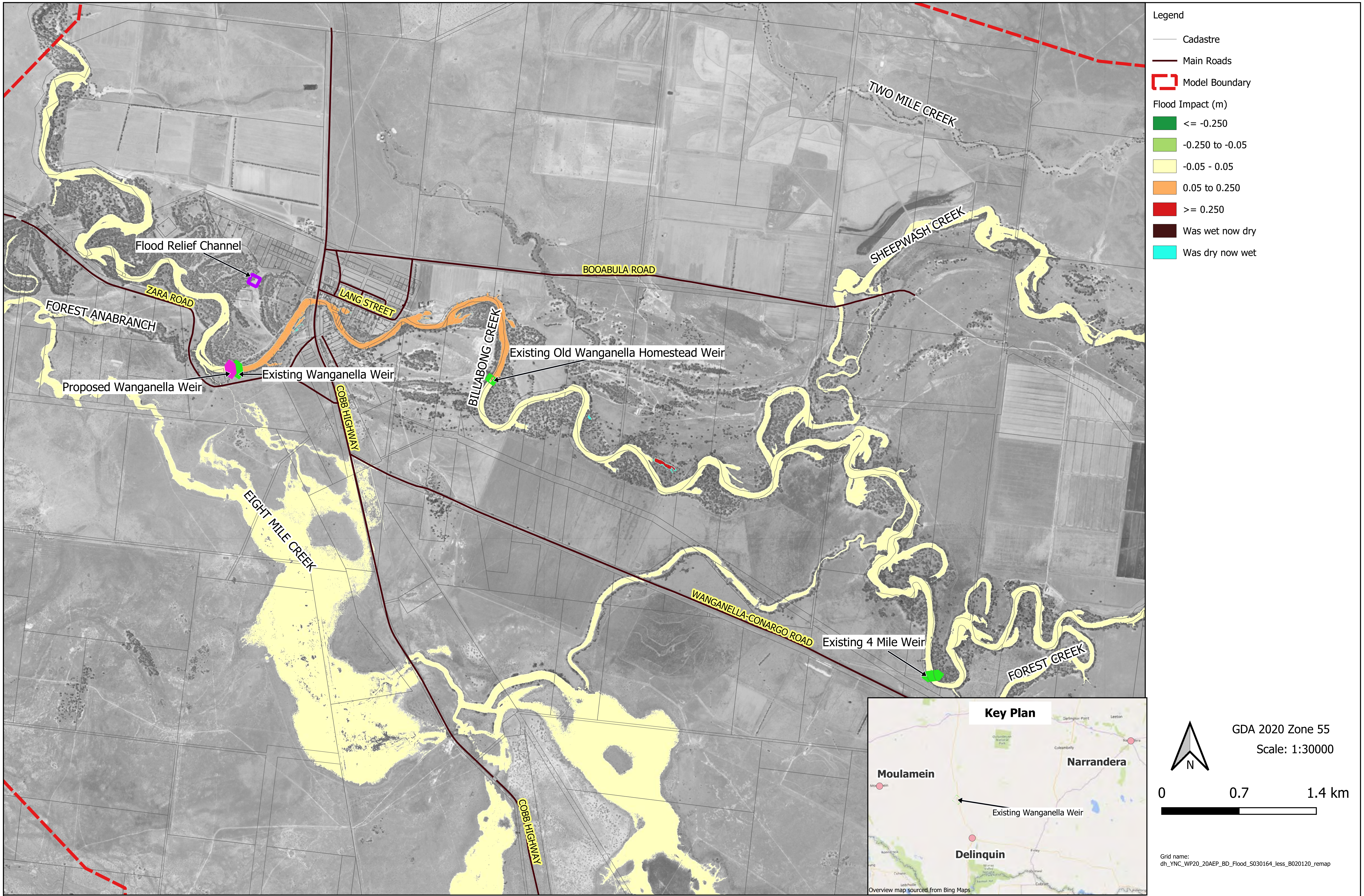
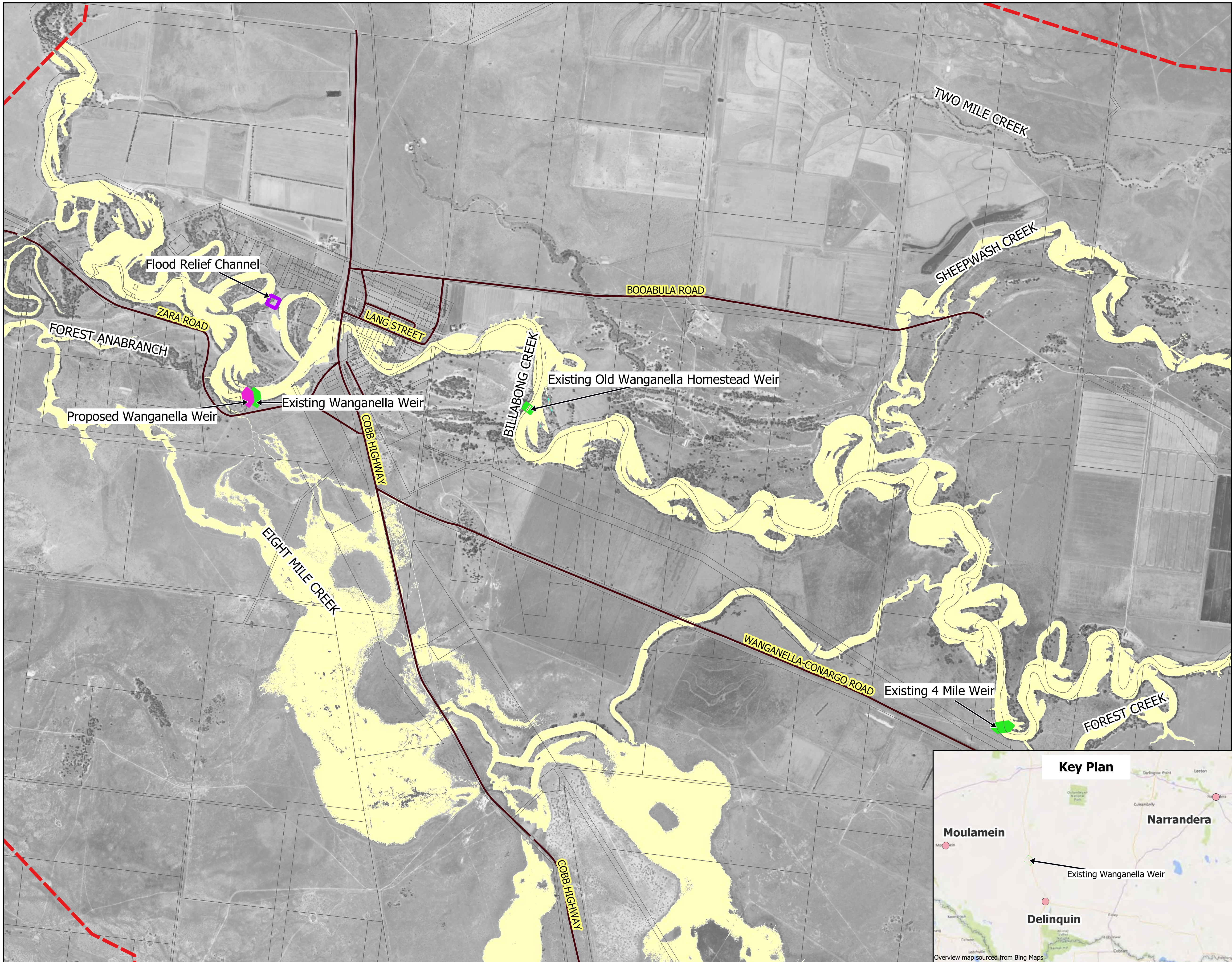
Appendix E. Impact Assessment – Flood Flow Scenarios Wanganella Regulator Only

E1 Flood Impact Plots



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E1.1 - 20% AEP Flood Level Impact
"Proposed vs Existing"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

GDA 2020 Zone 55

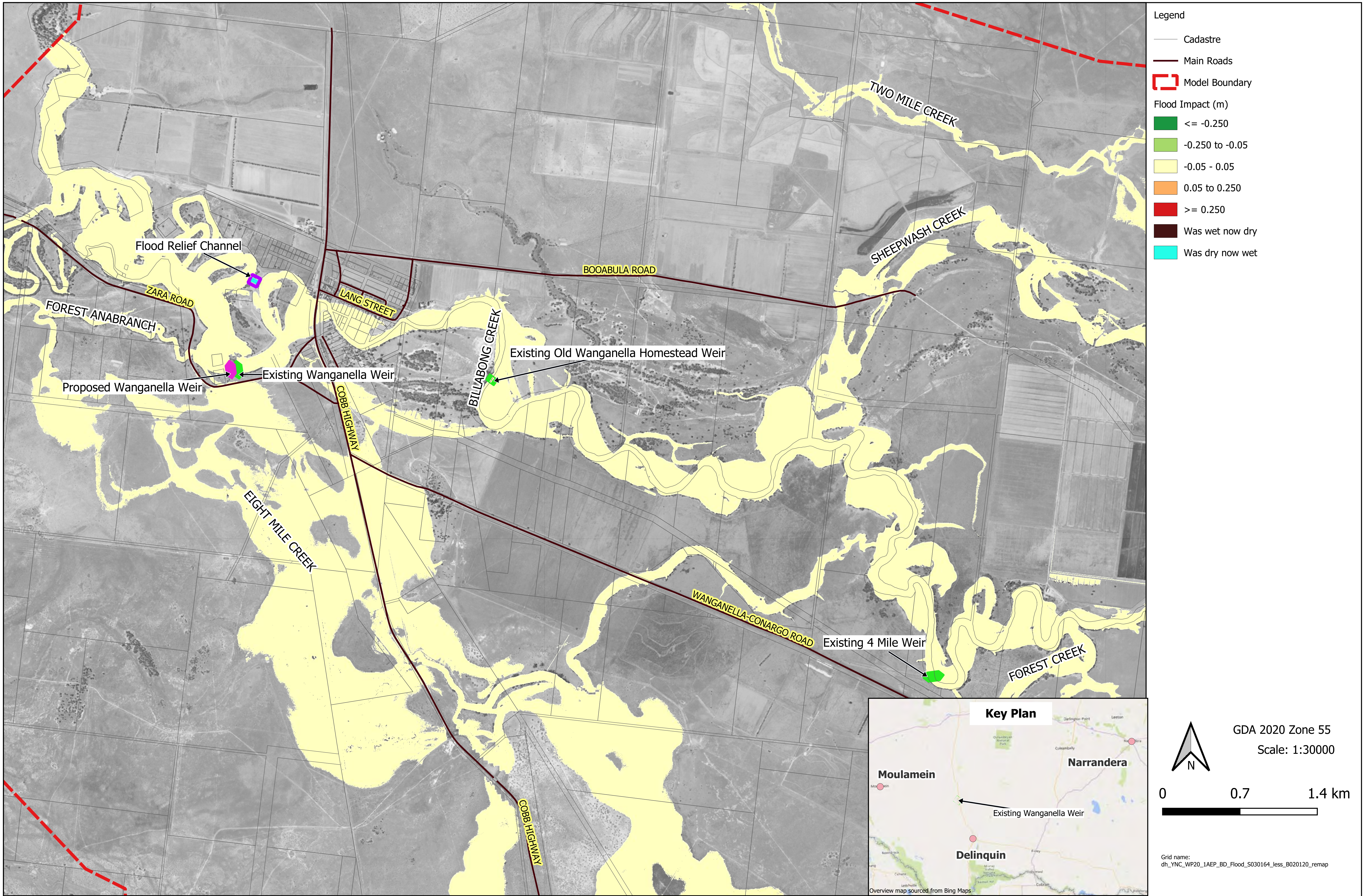
Scale: 1:30000

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 E1.2 - 5% AEP Flood Level Impact
"Proposed vs Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E1.3 - 1% AEP Flood Level Impact
"Proposed vs Existing"

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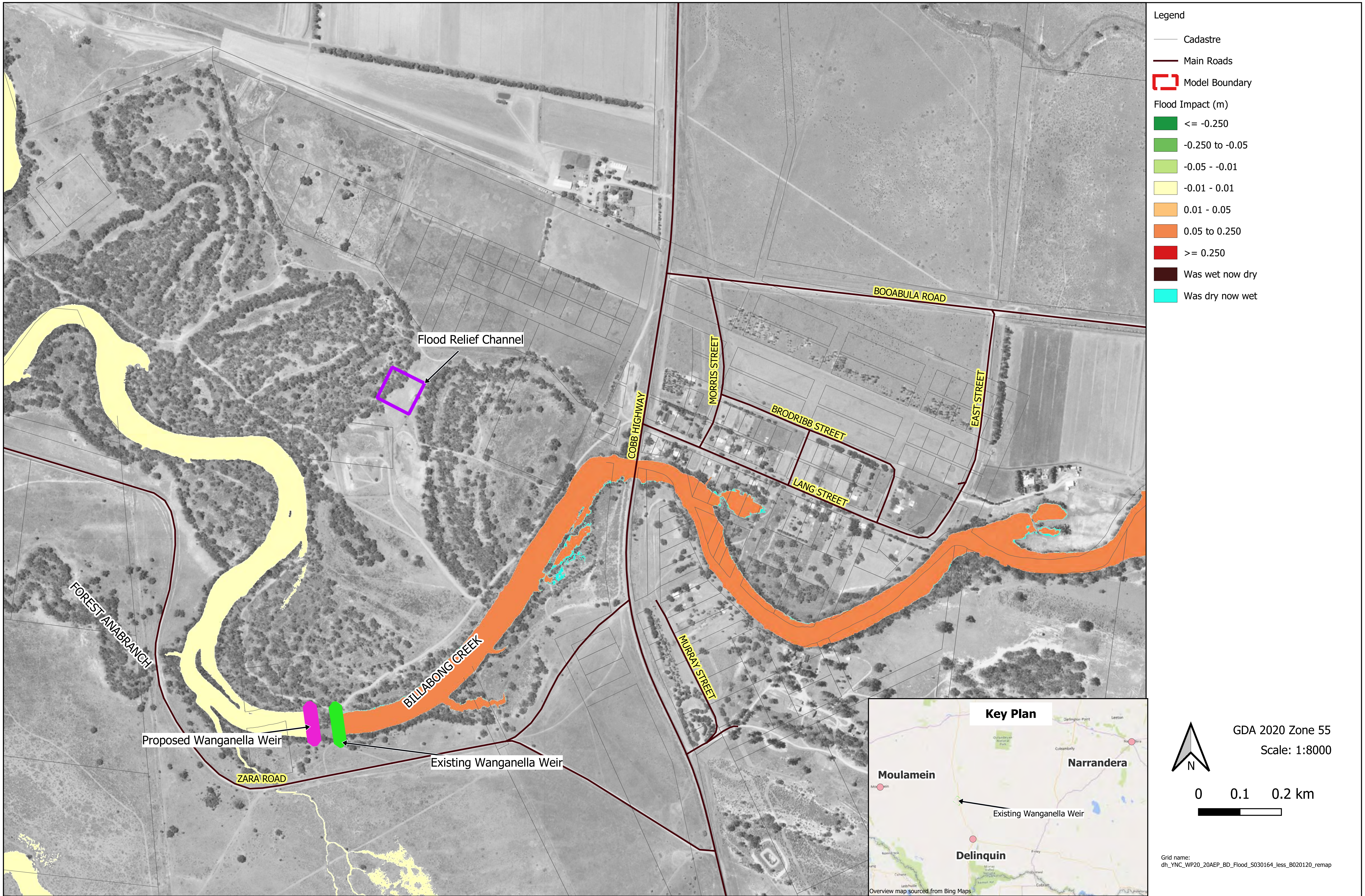
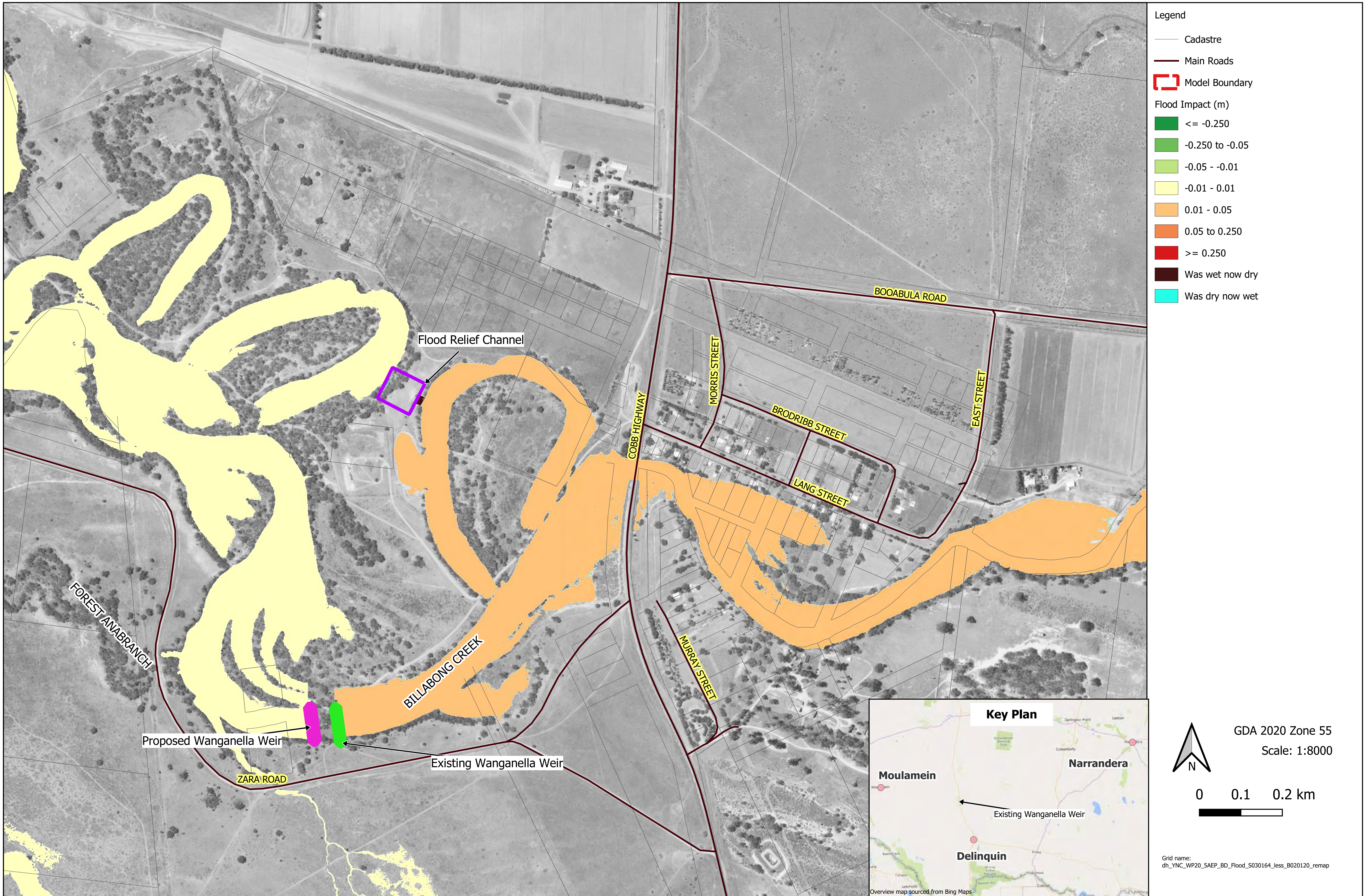


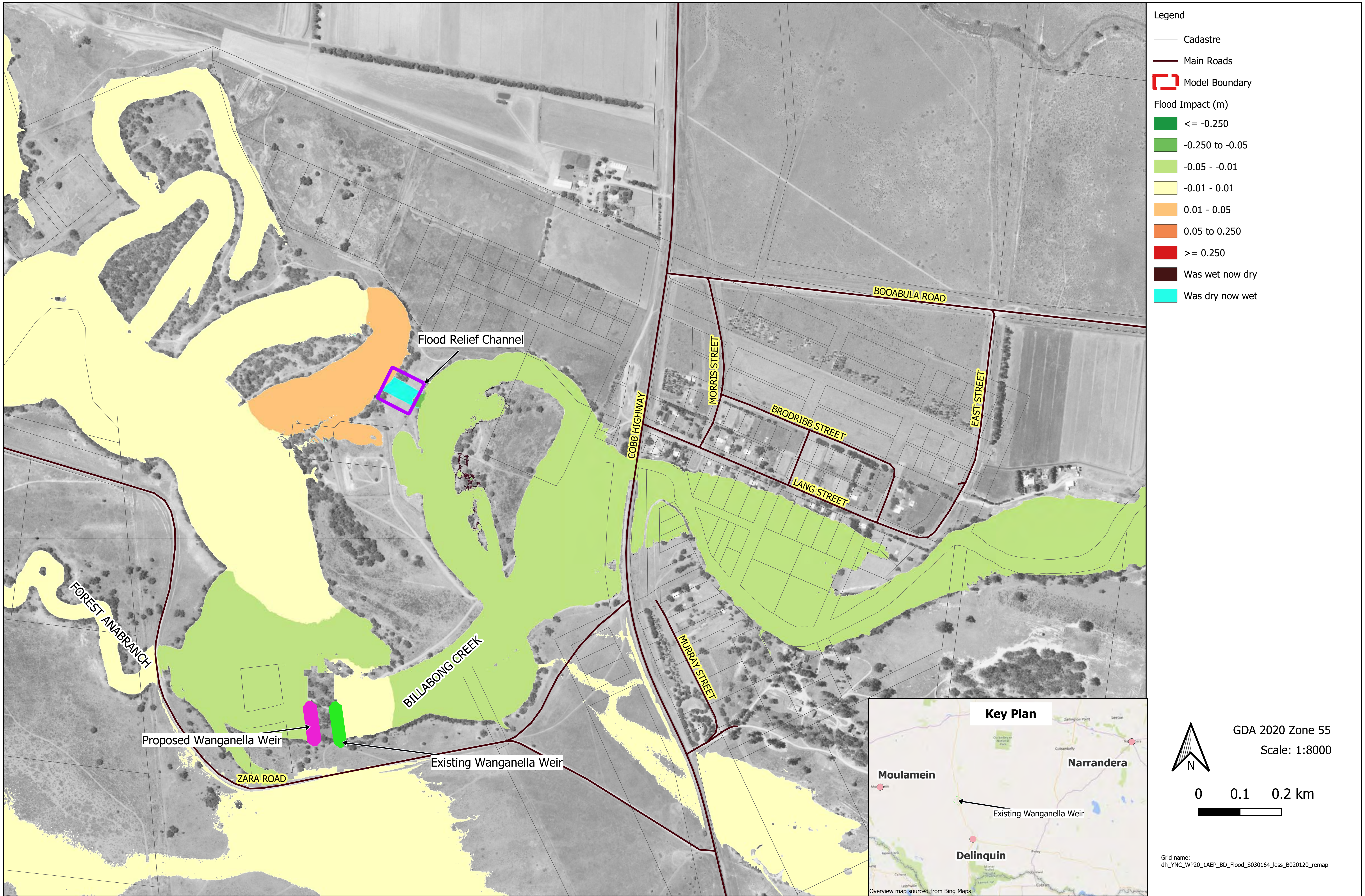
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E1.4 - 20% AEP Flood Level Impact
"Proposed vs Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E1.5 - 5% AEP Flood Level Impact
"Proposed vs Existing"

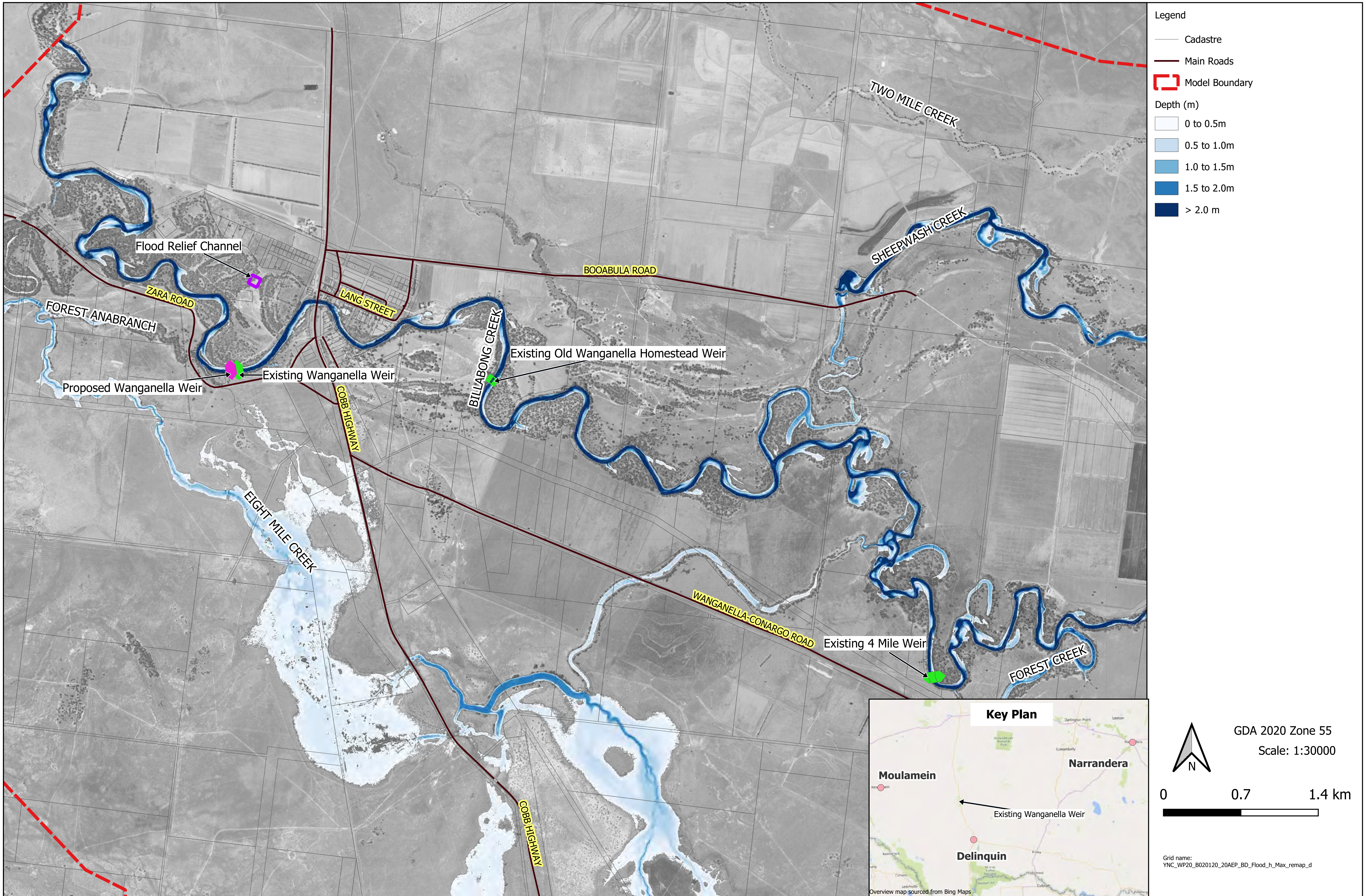
3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E1.6 - 1% AEP Flood Level Impact
"Proposed vs Existing"

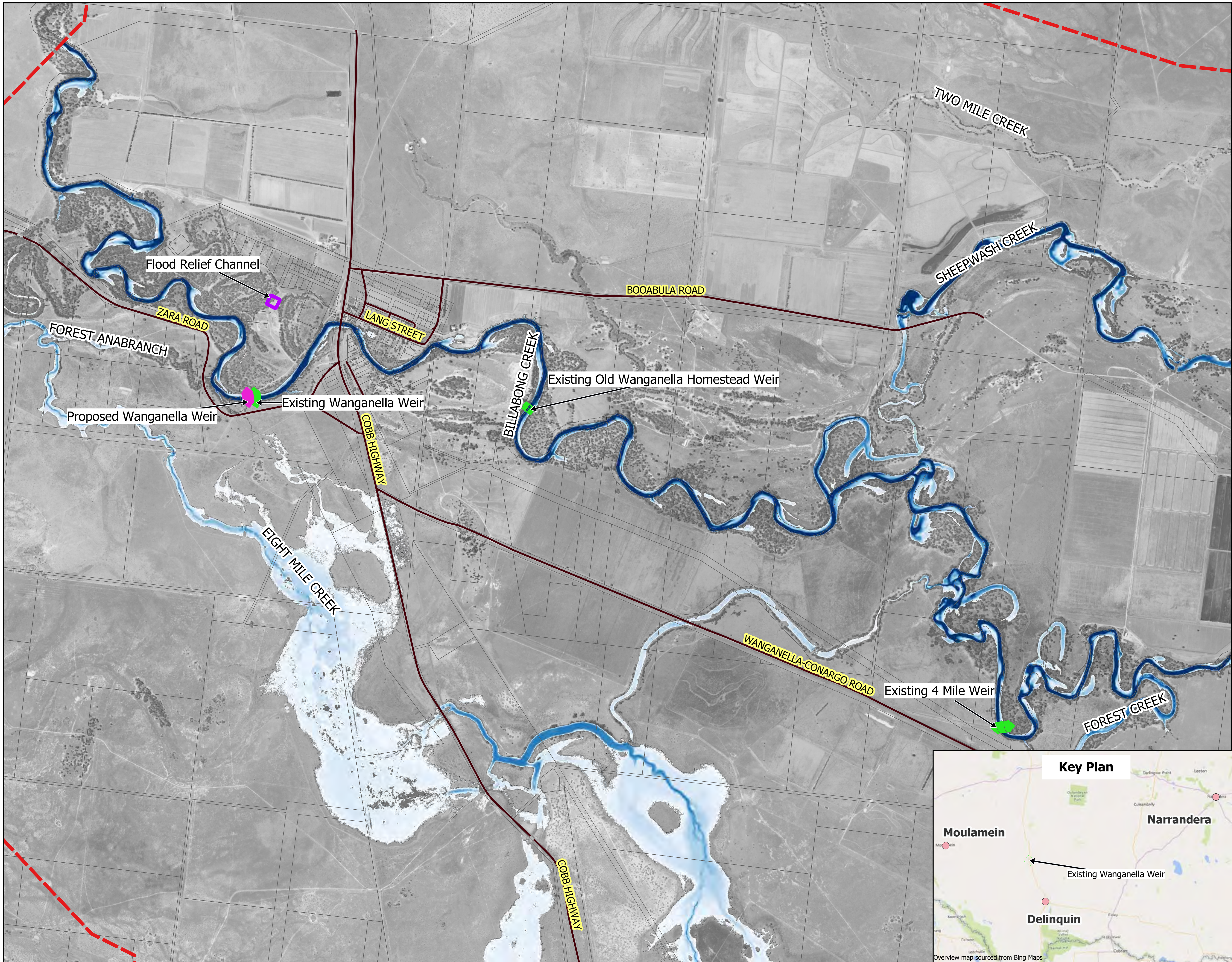
3Rivers

E2 Depth Plots



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.1- 20% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



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

N

GDA 2020 Zone 55

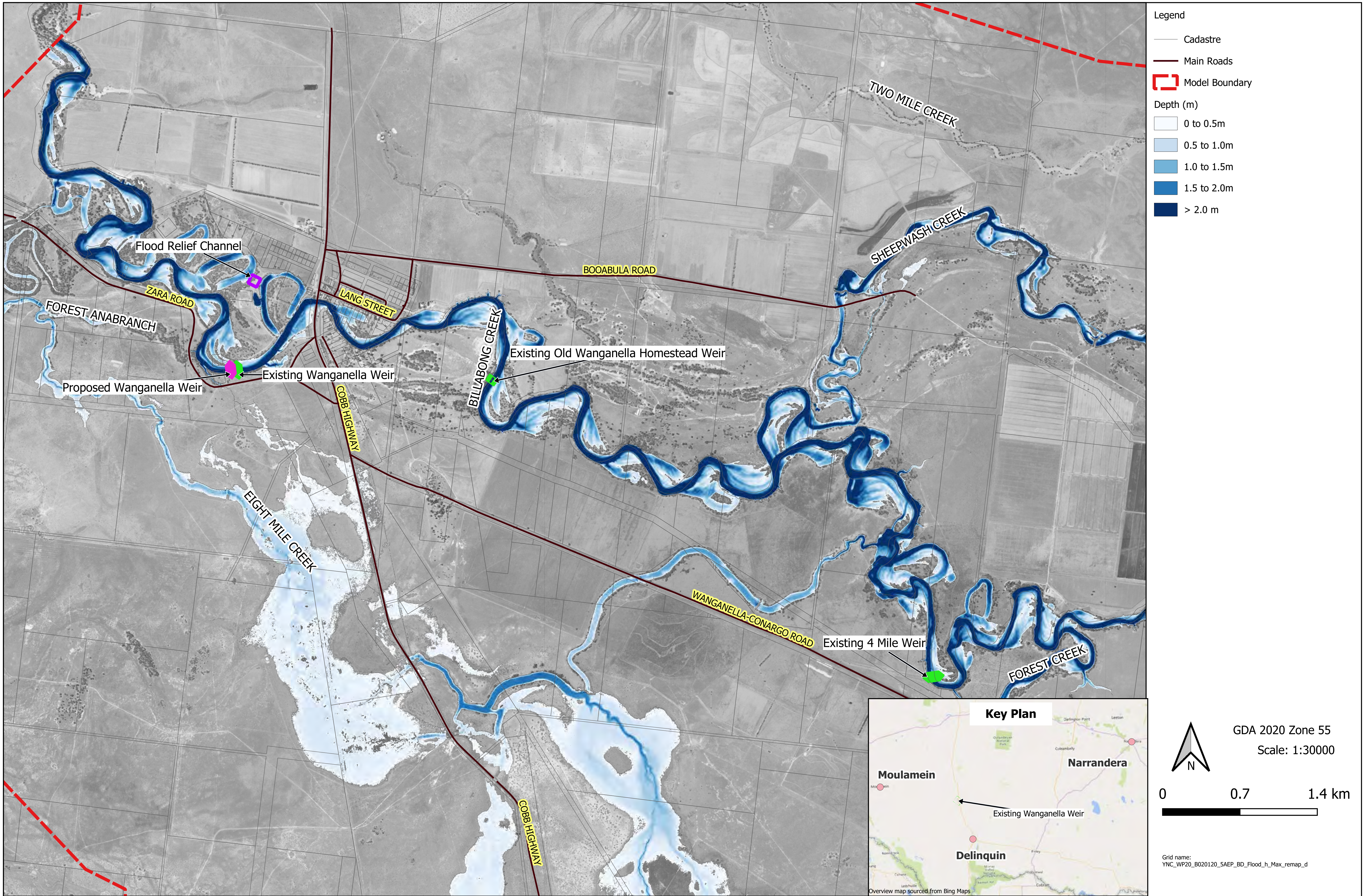
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_20AEP_BD_Flood_h_Max_remap_d

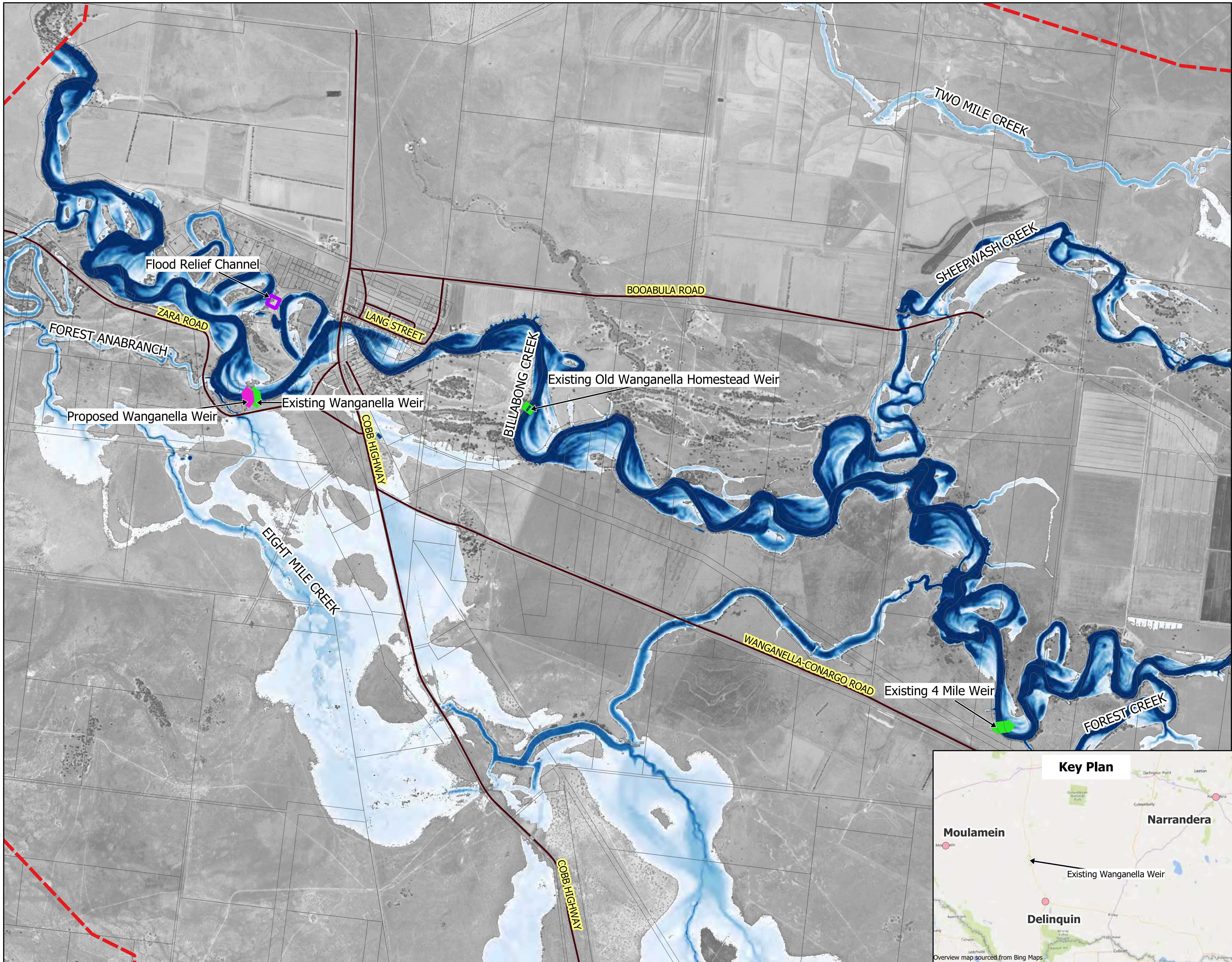
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.1- 20% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.2- 5% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



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

N

GDA 2020 Zone 55

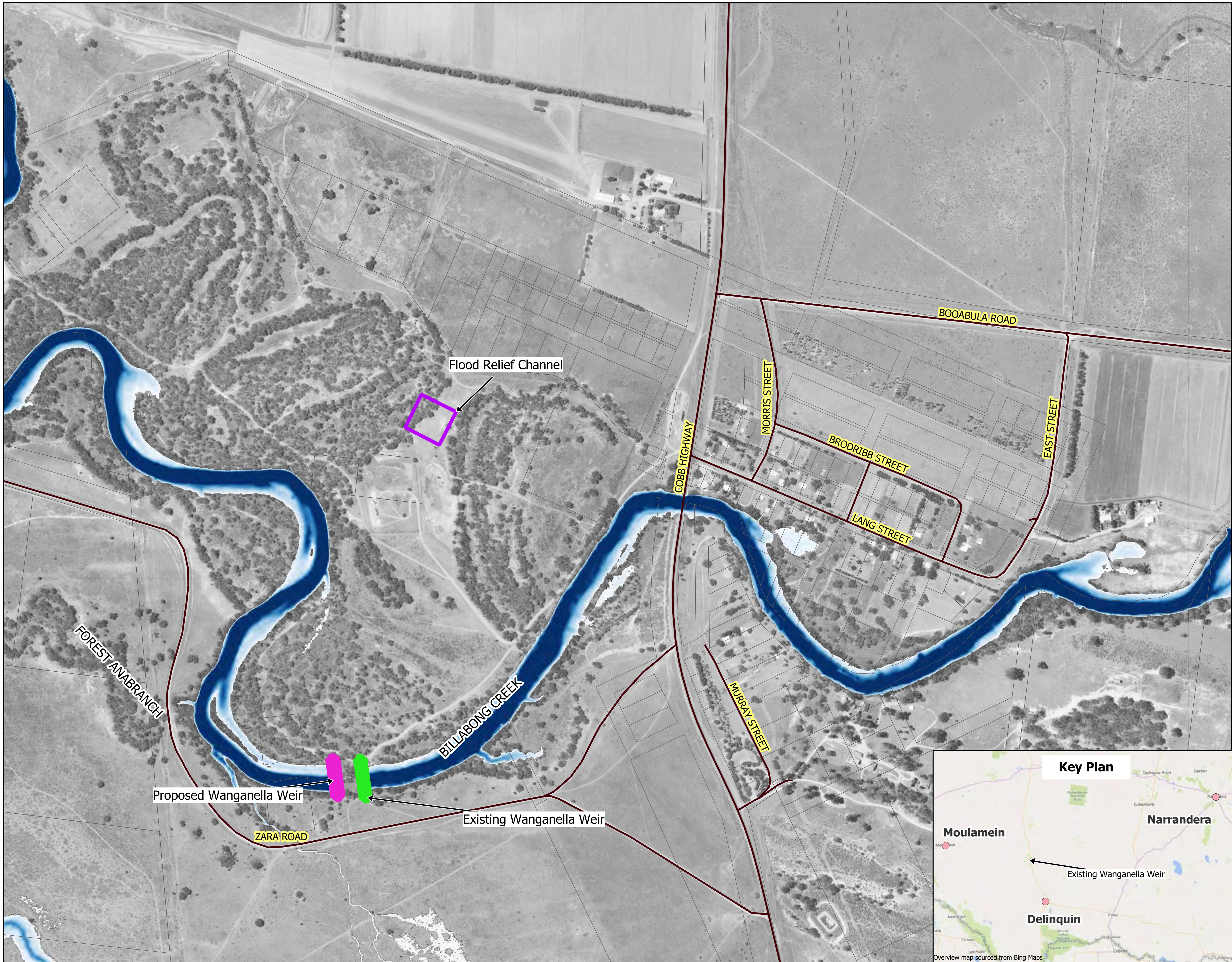
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_1AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.3- 1% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



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

N

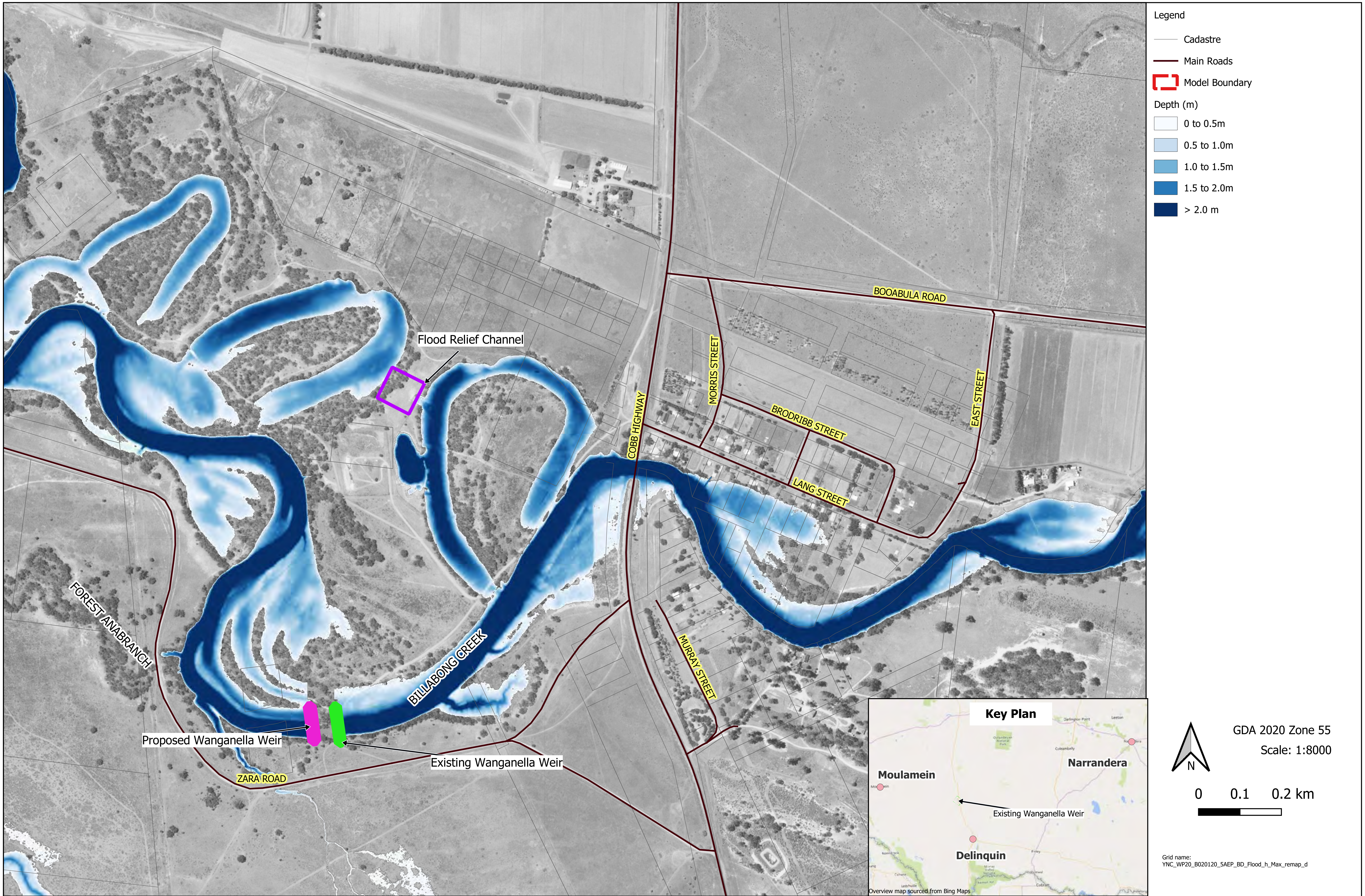
GDA 2020 Zone 55
Scale: 1:8000

0 0.1 0.2 km

Grid name:
YNC_WP20_B020120_20AEP_BD_Flood_h_Max_remap_d

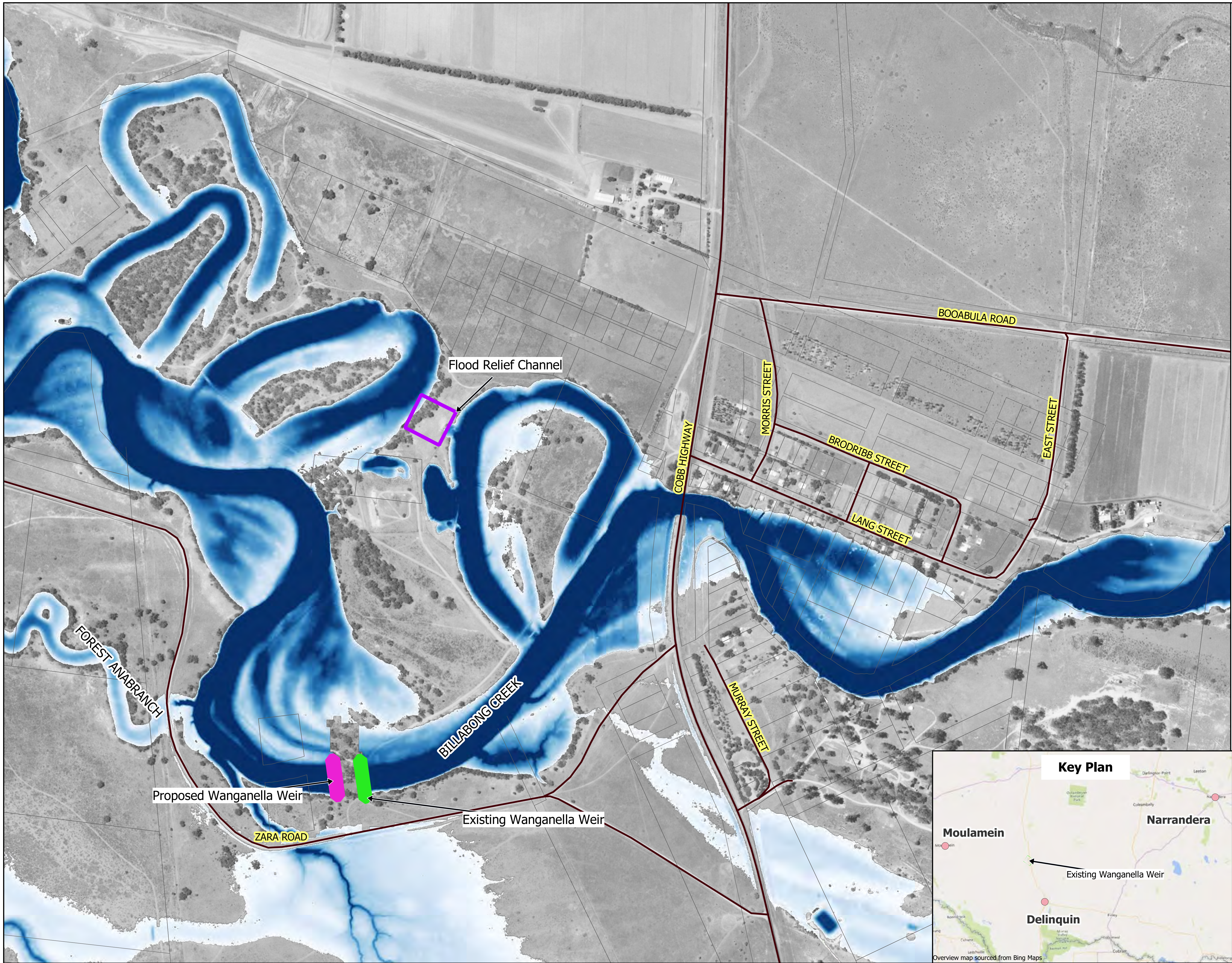
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.4 - 20% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.5 - 5% AEP Maximum Peak Flood Depth
"Existing"

3Rivers



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

N

GDA 2020 Zone 55

Scale: 1:8000

0 0.1 0.2 km

Grid name: YNC_WP20_B020120_1AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure E2.6 - 1% AEP Maximum Peak Flood Depth
"Existing"

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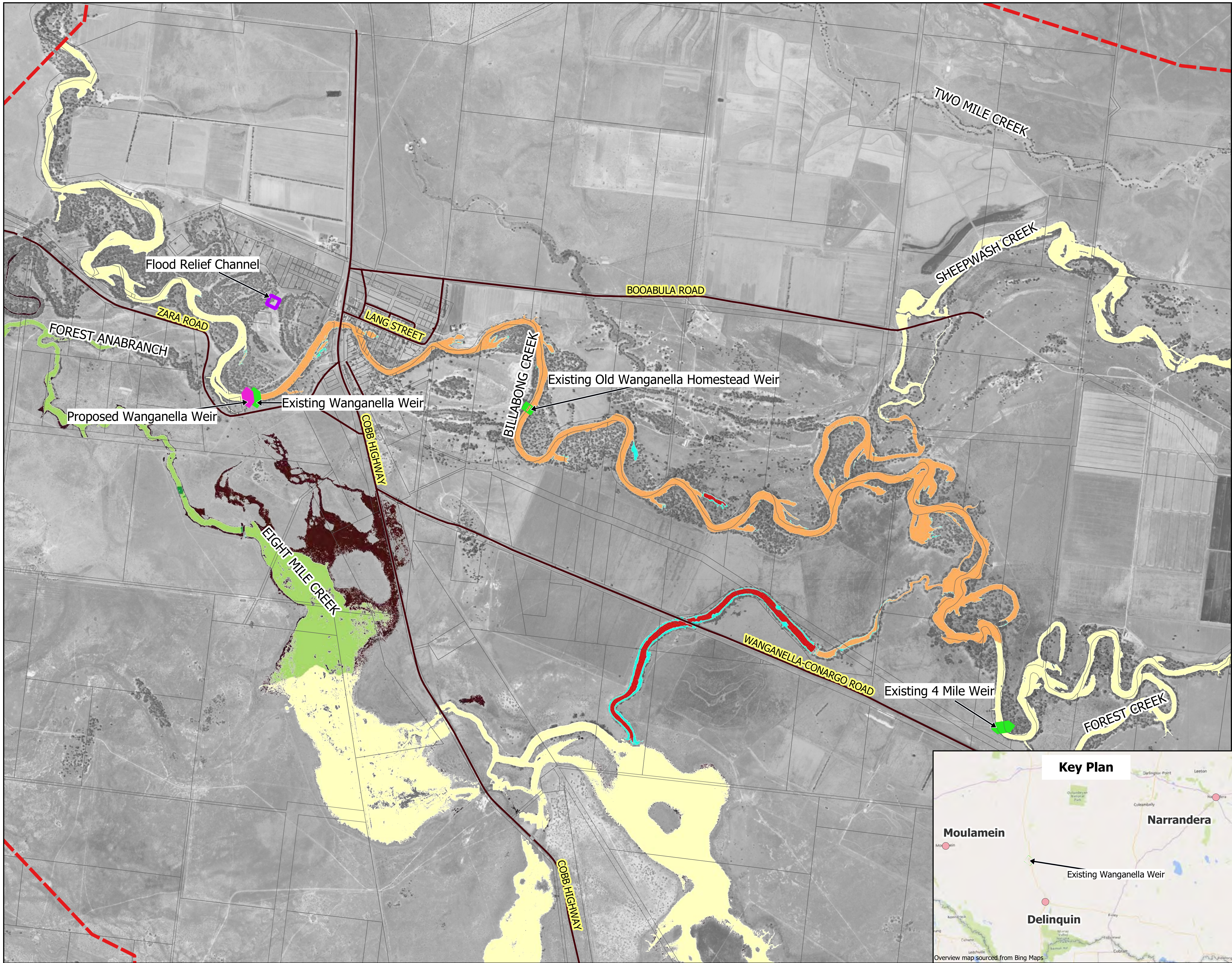
Appendix F. Impact Assessment – Flood Flow Scenarios All Proposed Works

F1 Flood Impact Plots



Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

GDA 2020 Zone 55

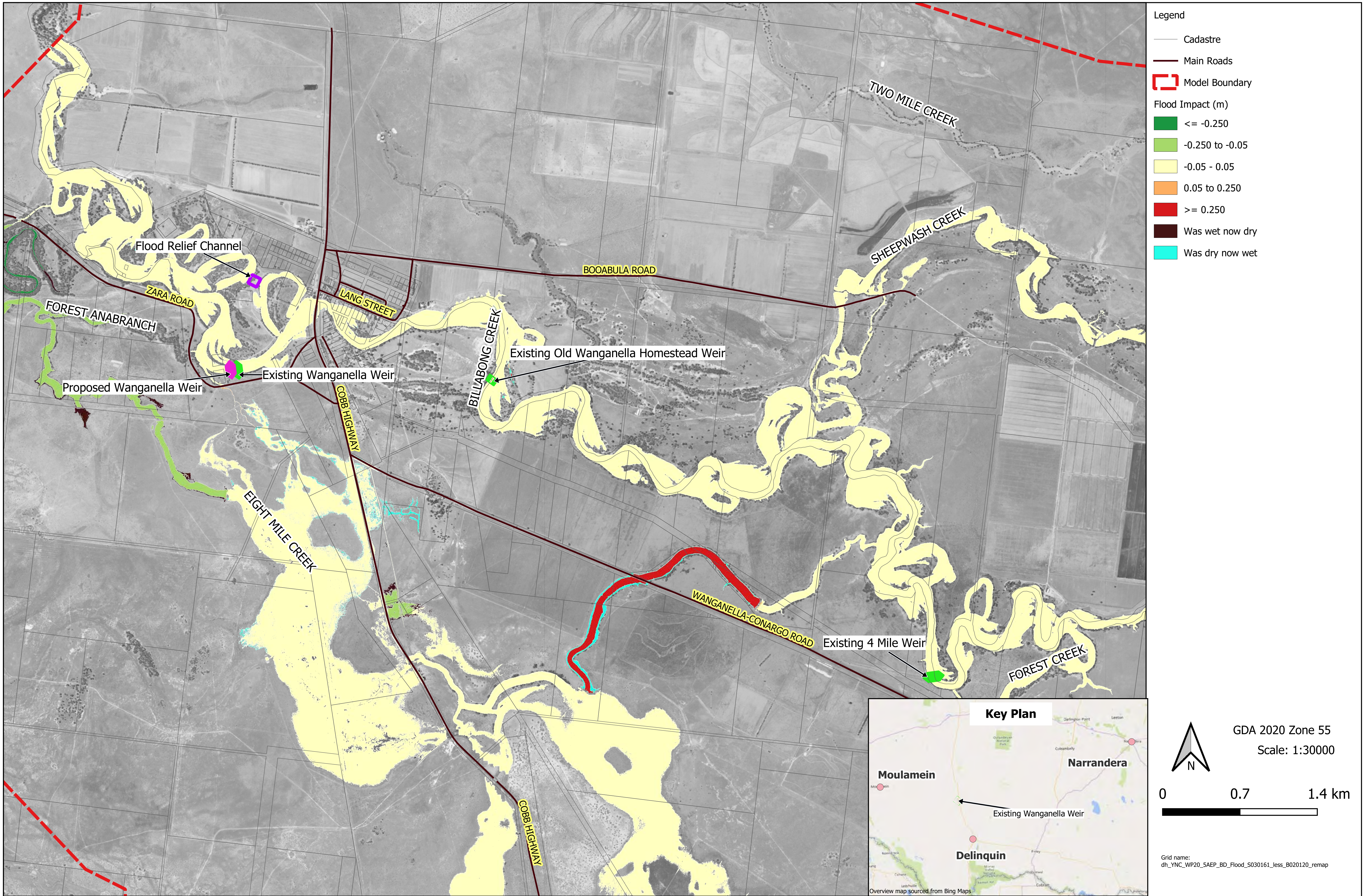
Scale: 1:30000

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 F1.1 - Flood Level (20% AEP) Afflux Plot
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.2 - Flood Level (5% AEP) Afflux Plot
"Proposed"

3Rivers

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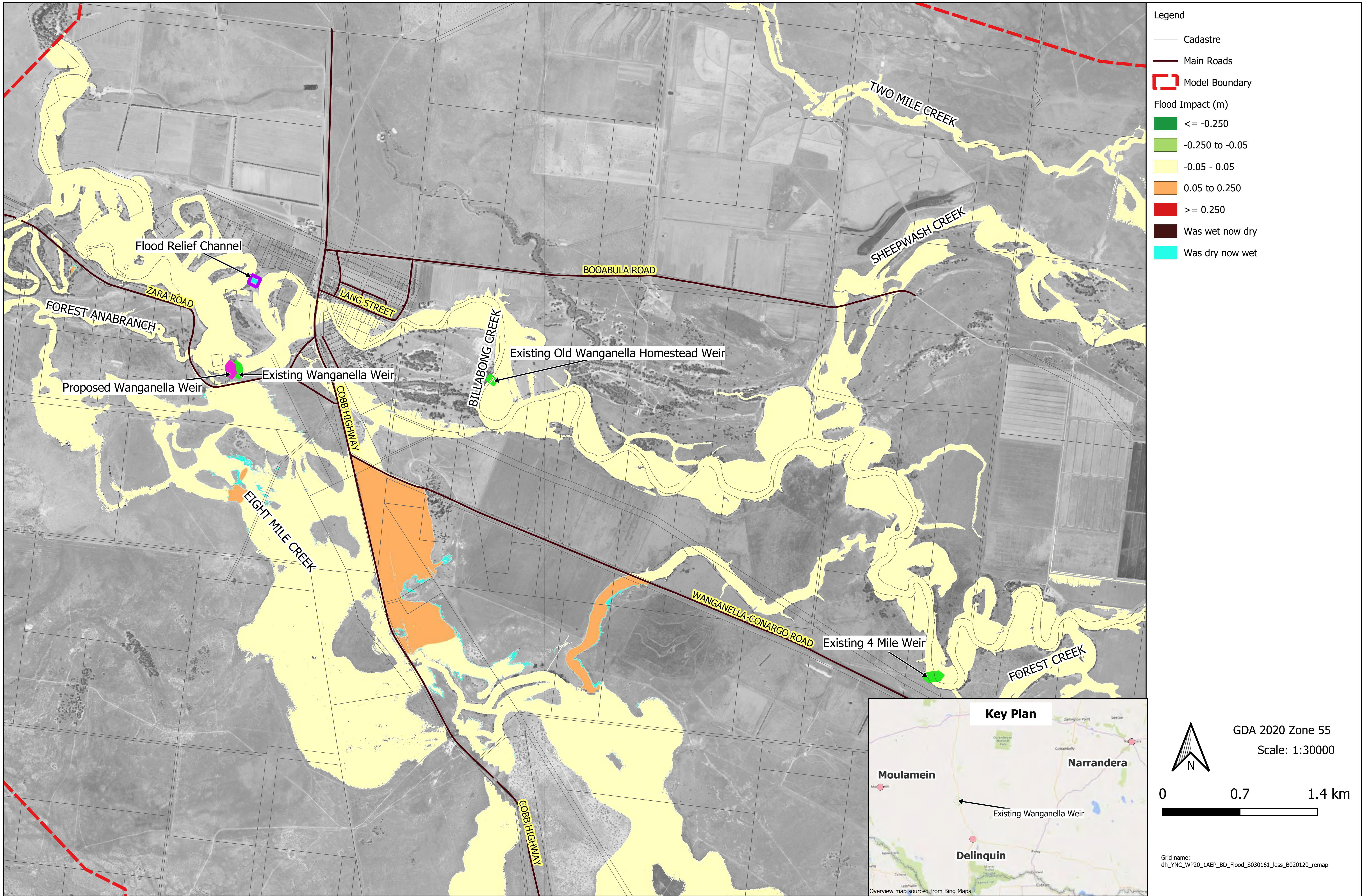
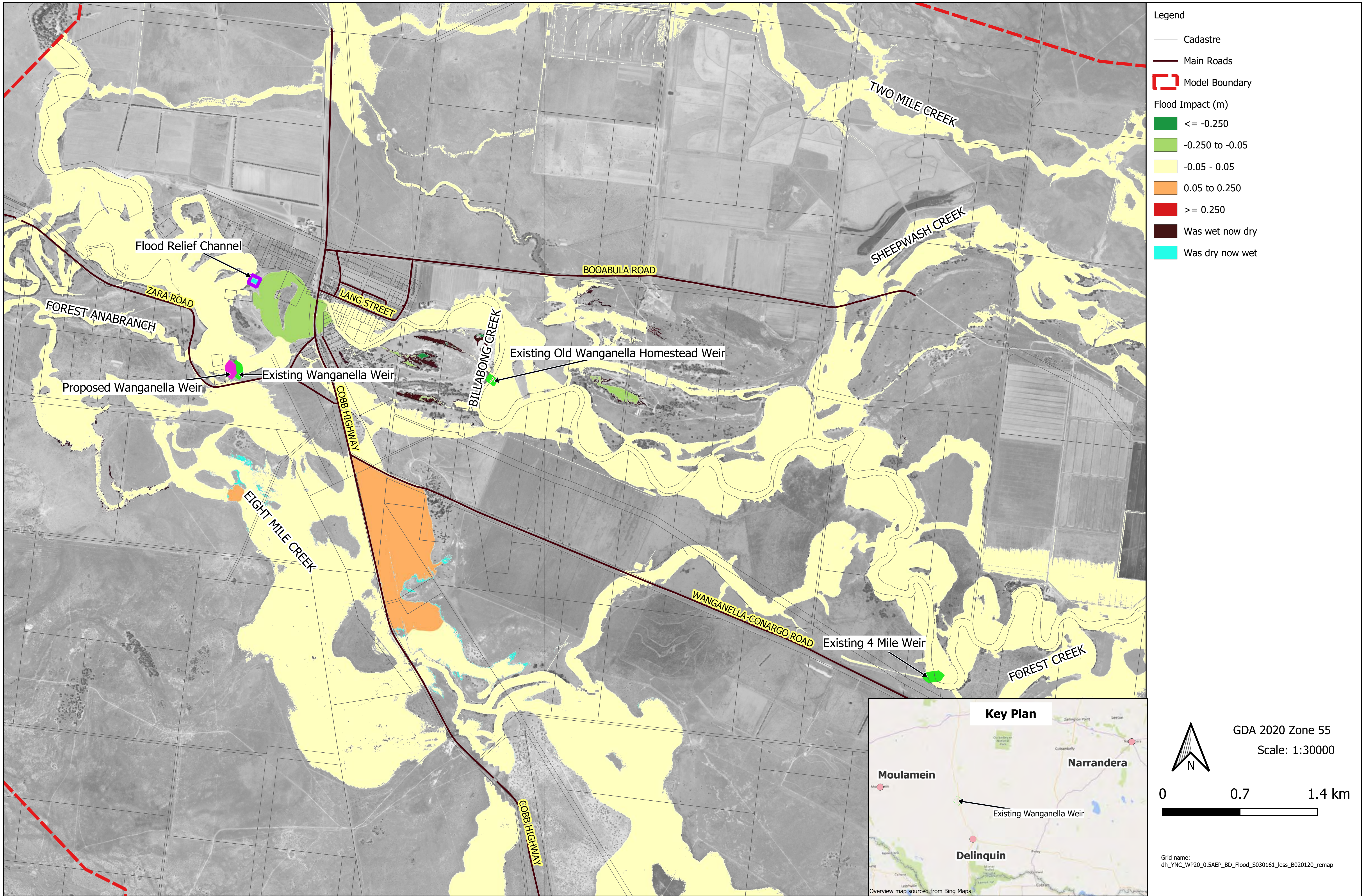


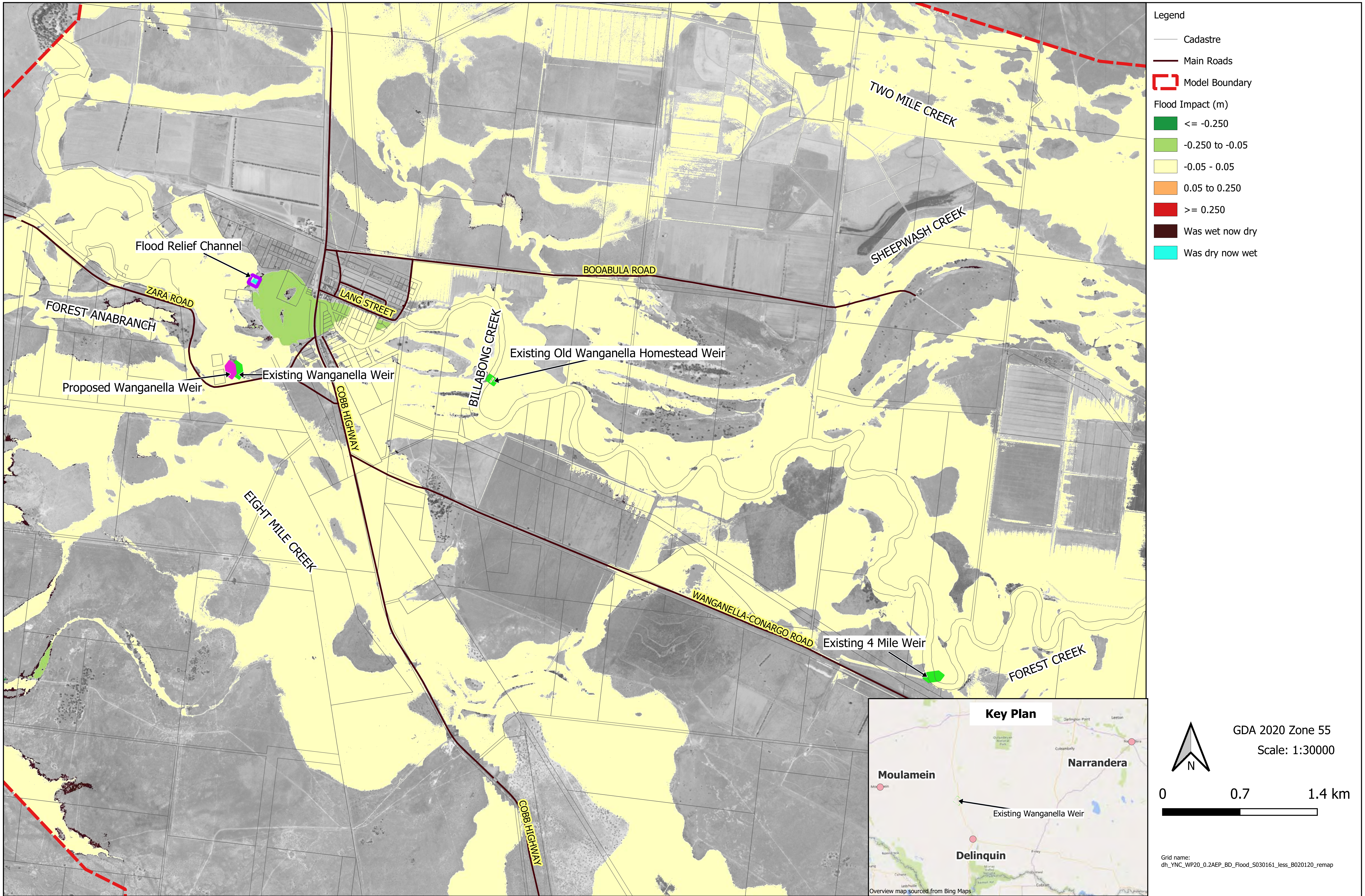
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.3 - Flood Level (1% AEP) Afflux Plot
"Proposed"

3Rivers



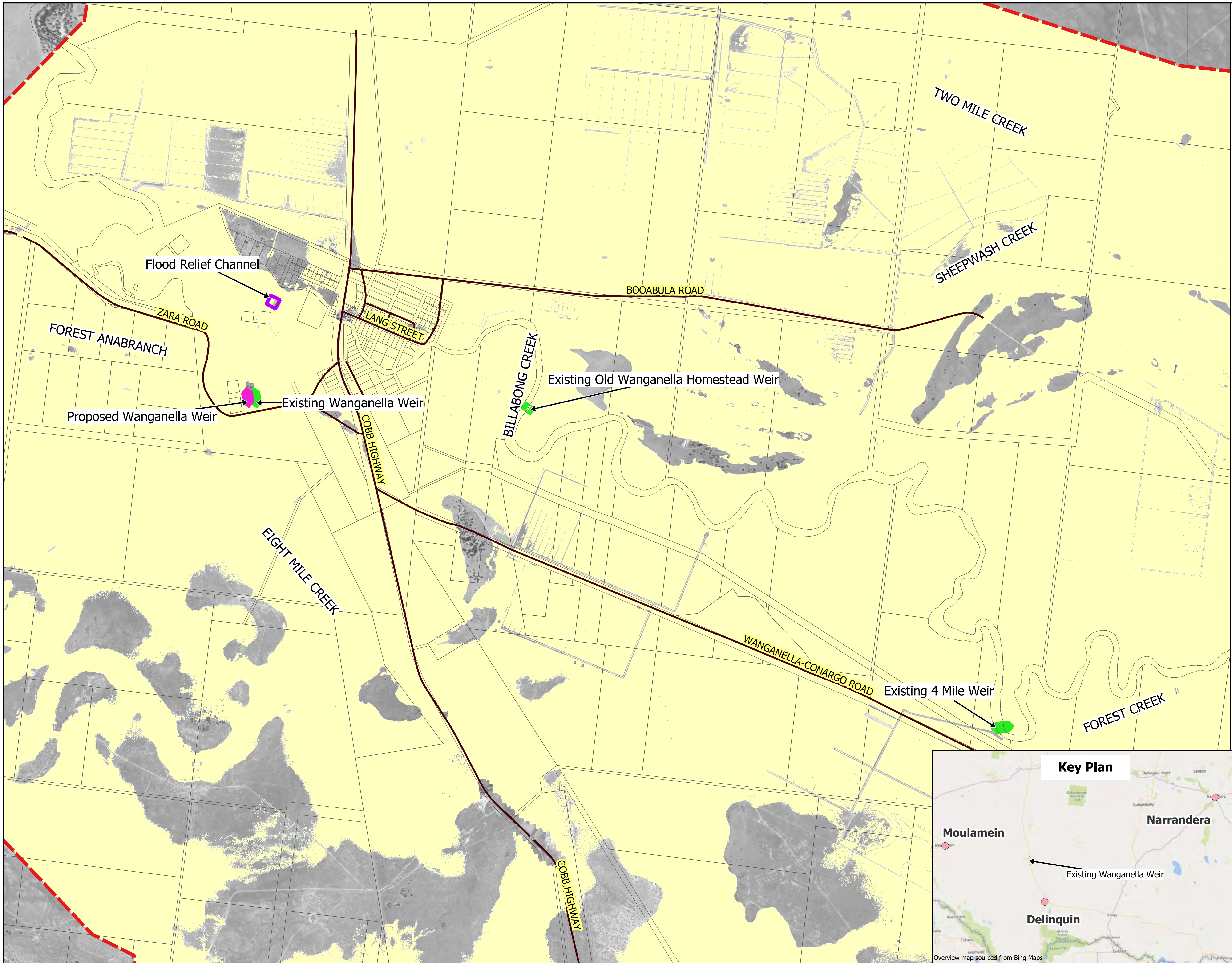
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.4 - Flood Level (0.5% AEP) Afflux Plot
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.5 - Flood Level (0.2% AEP) Afflux Plot
"Proposed"

3Rivers



Legend
- Cadastre
- Main Roads
- Model Boundary

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

N

GDA 2020 Zone 55

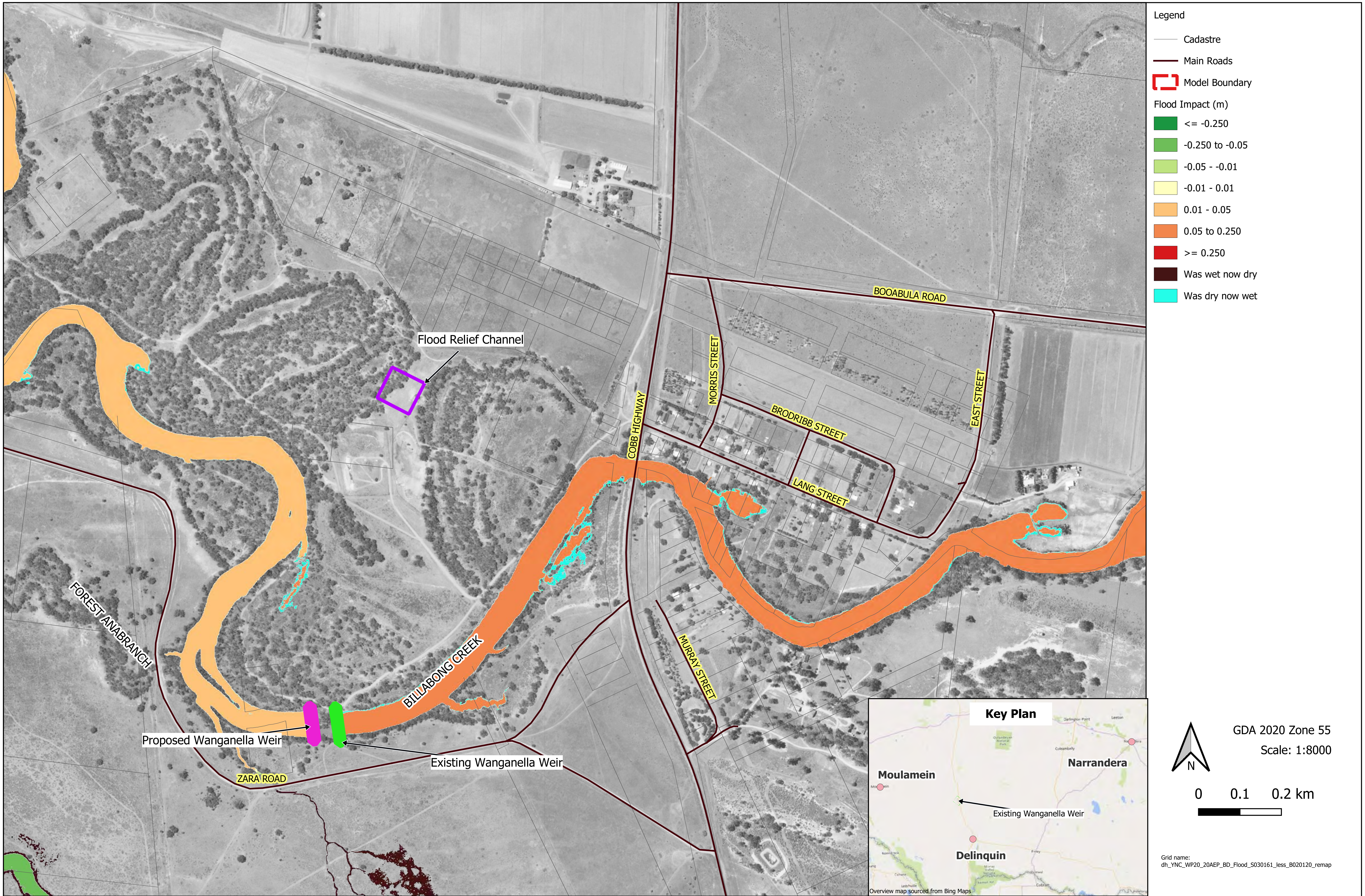
Scale: 1:30000

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 F1.6 - Flood Level (PMF) Afflux Plot
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.7 - Flood Level (20% AEP) Afflux Plot
"Proposed"

3Rivers

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.8 - Flood Level (5% AEP) Afflux Plot
"Proposed"

3Rivers

Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

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 F1.9 - Flood Level (1% AEP) Afflux Plot
"Proposed"

3Rivers

Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

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 F1.10 - Flood Level (0.5% AEP) Afflux Plot
"Proposed"

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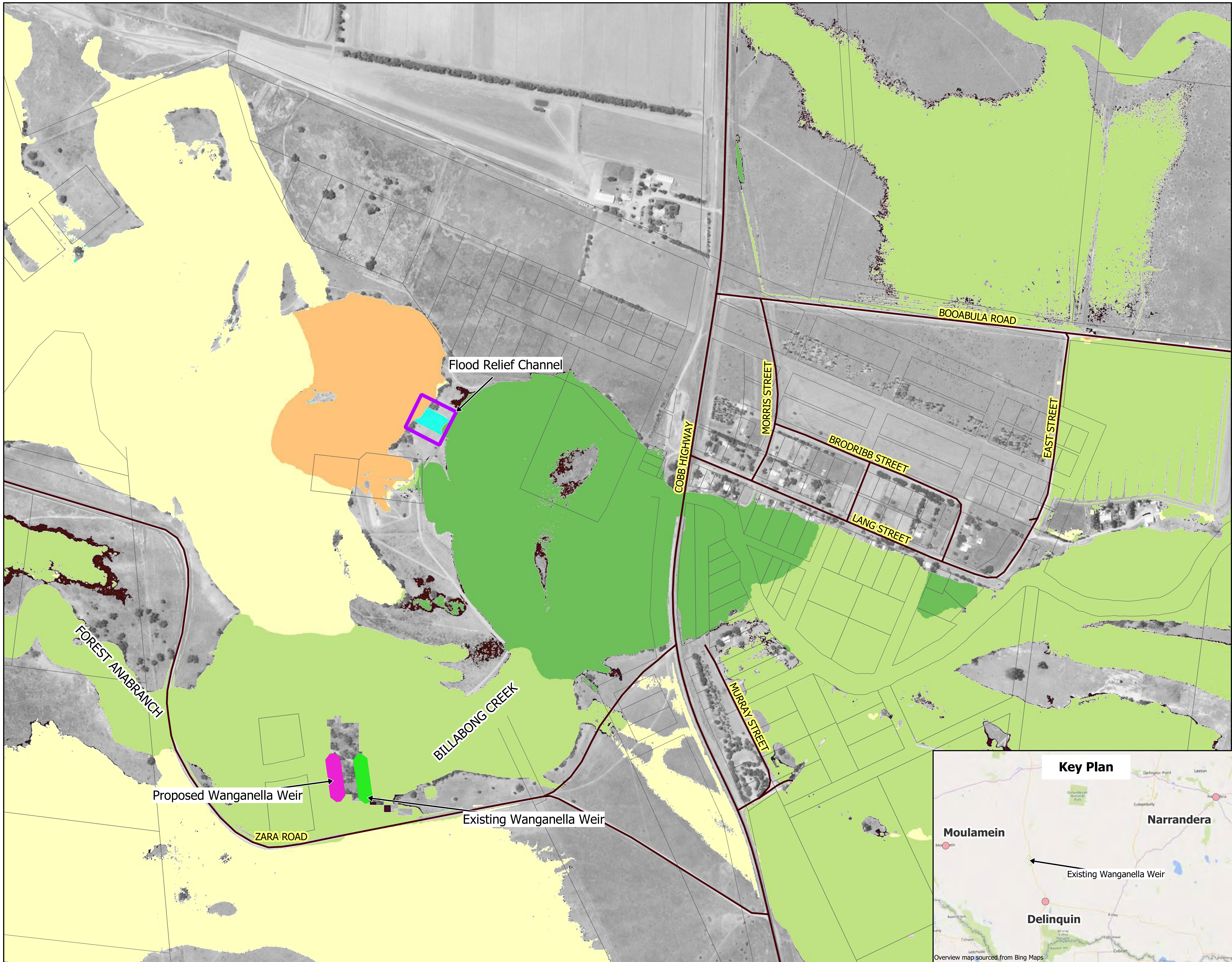


Legend

- Cadastre
- Main Roads
- Model Boundary

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

N

GDA 2020 Zone 55

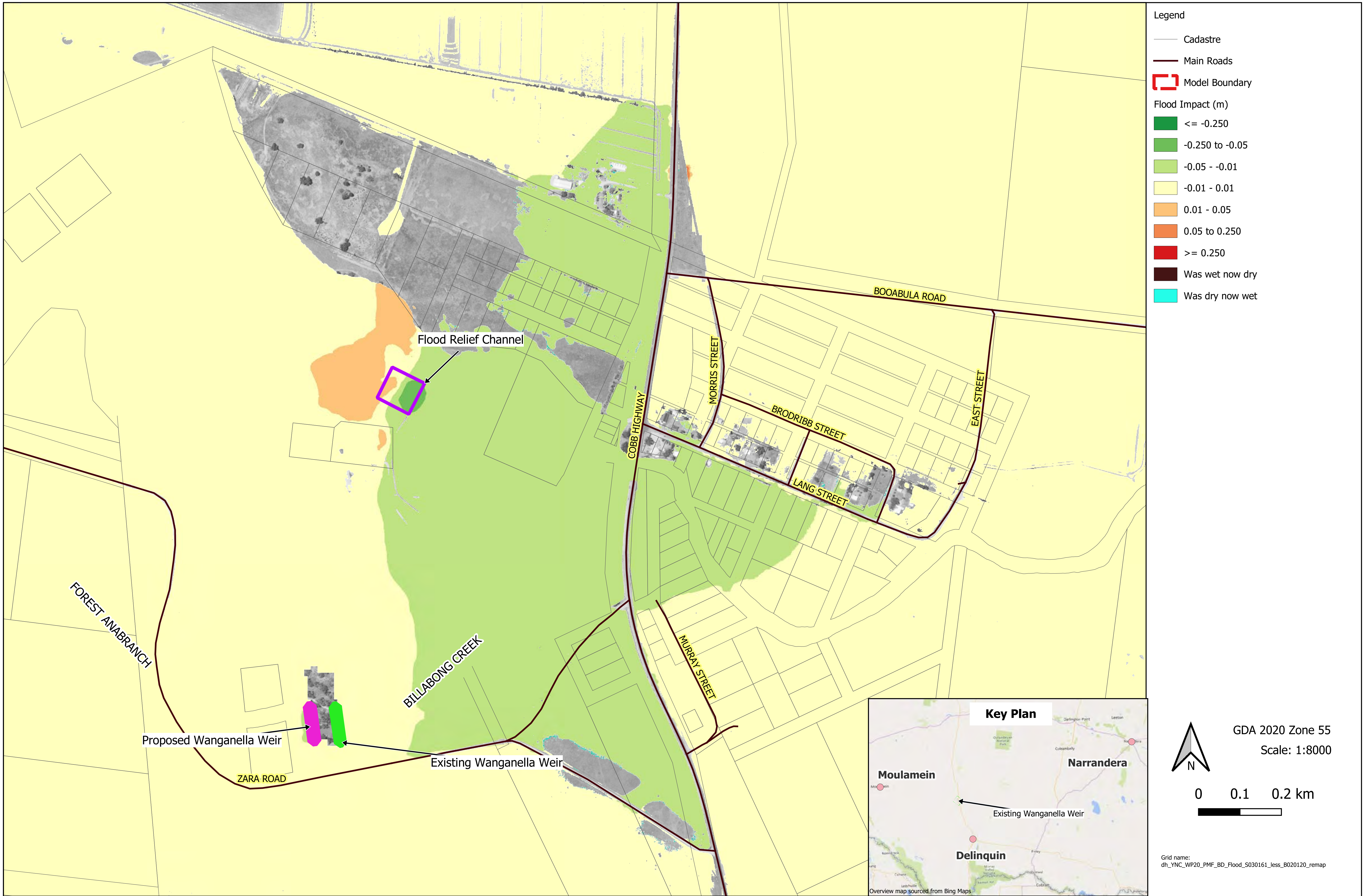
Scale: 1:8000

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 F1.11 - Flood Level (0.2% AEP) Afflux Plot
"Proposed"

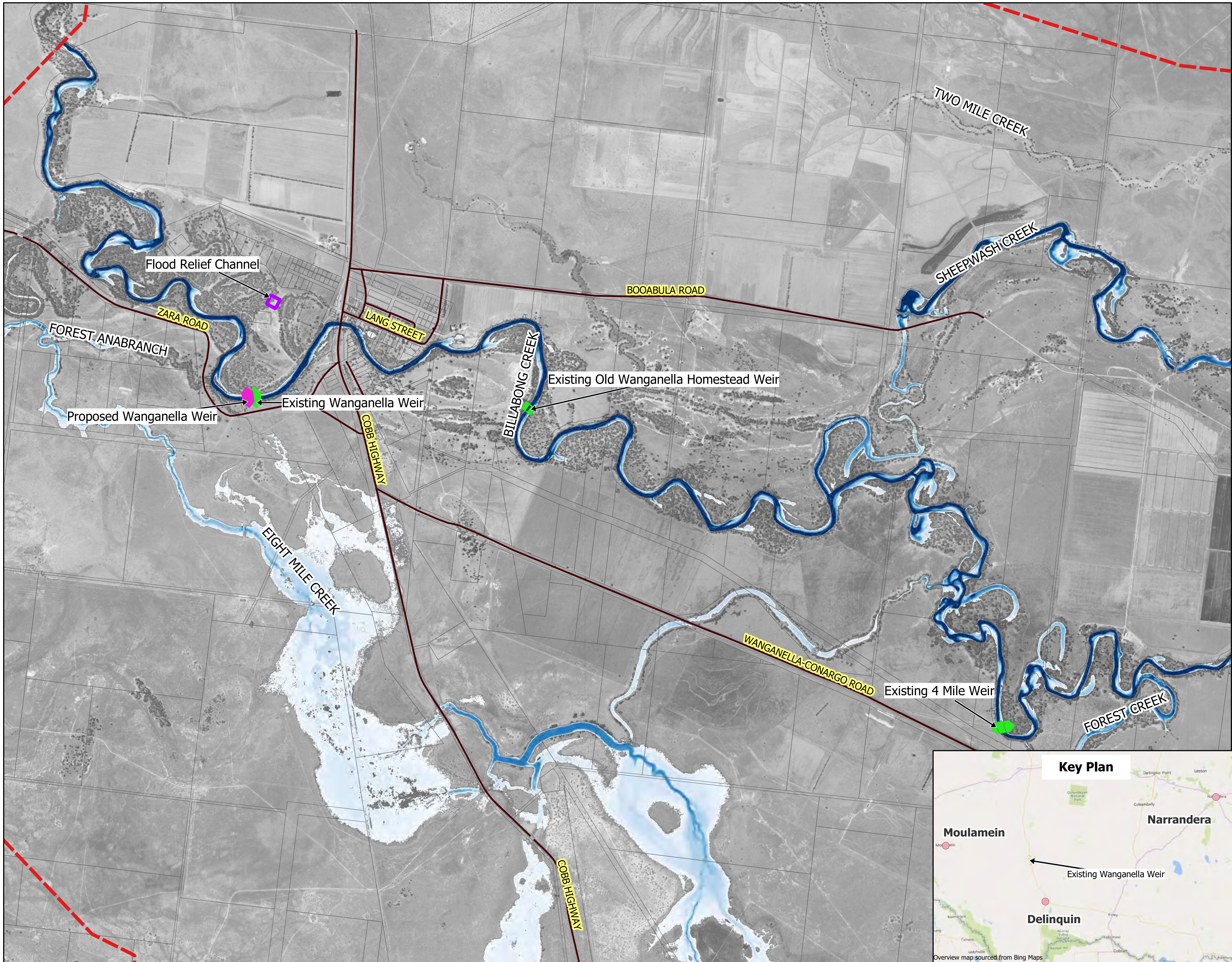
3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F1.12 - Flood Level (PMF) Afflux Plot
"Proposed"

3Rivers

F2 Depth Plots



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

N

GDA 2020 Zone 55

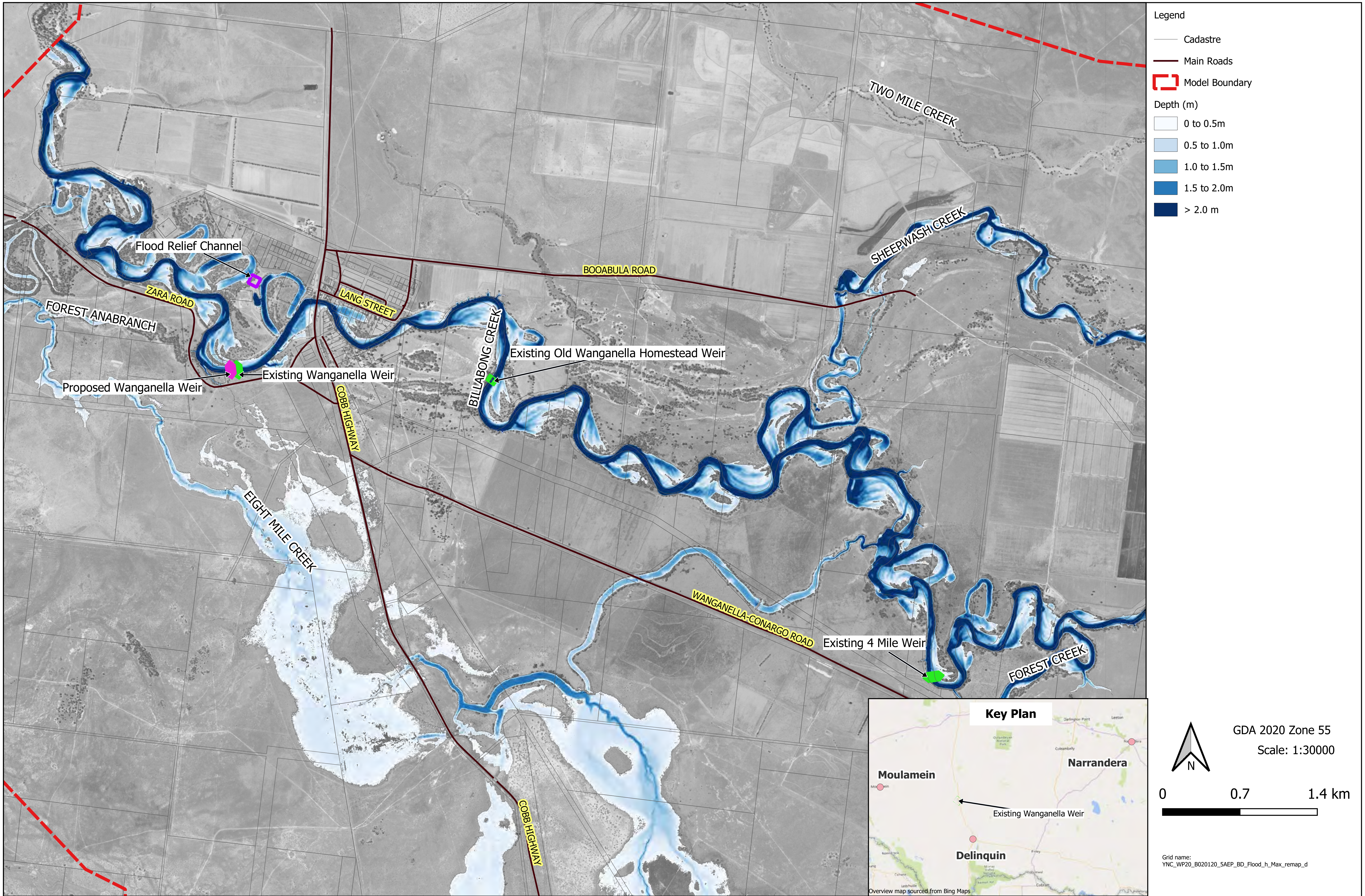
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_20AEP_BD_Flood_h_Max_remap_d

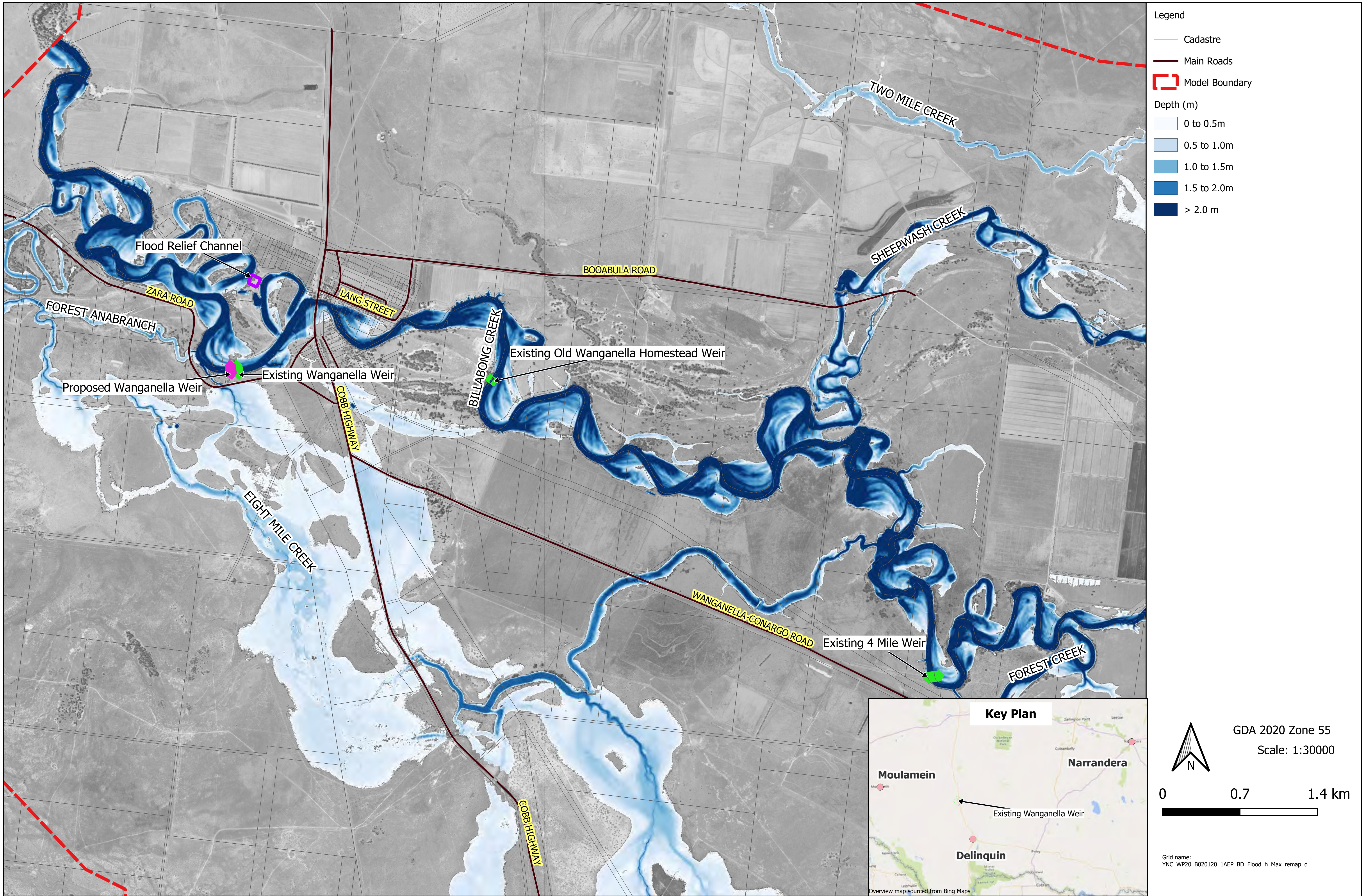
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.1 - Maximum Depth Plot (20% AEP)
"Existing"

3Rivers



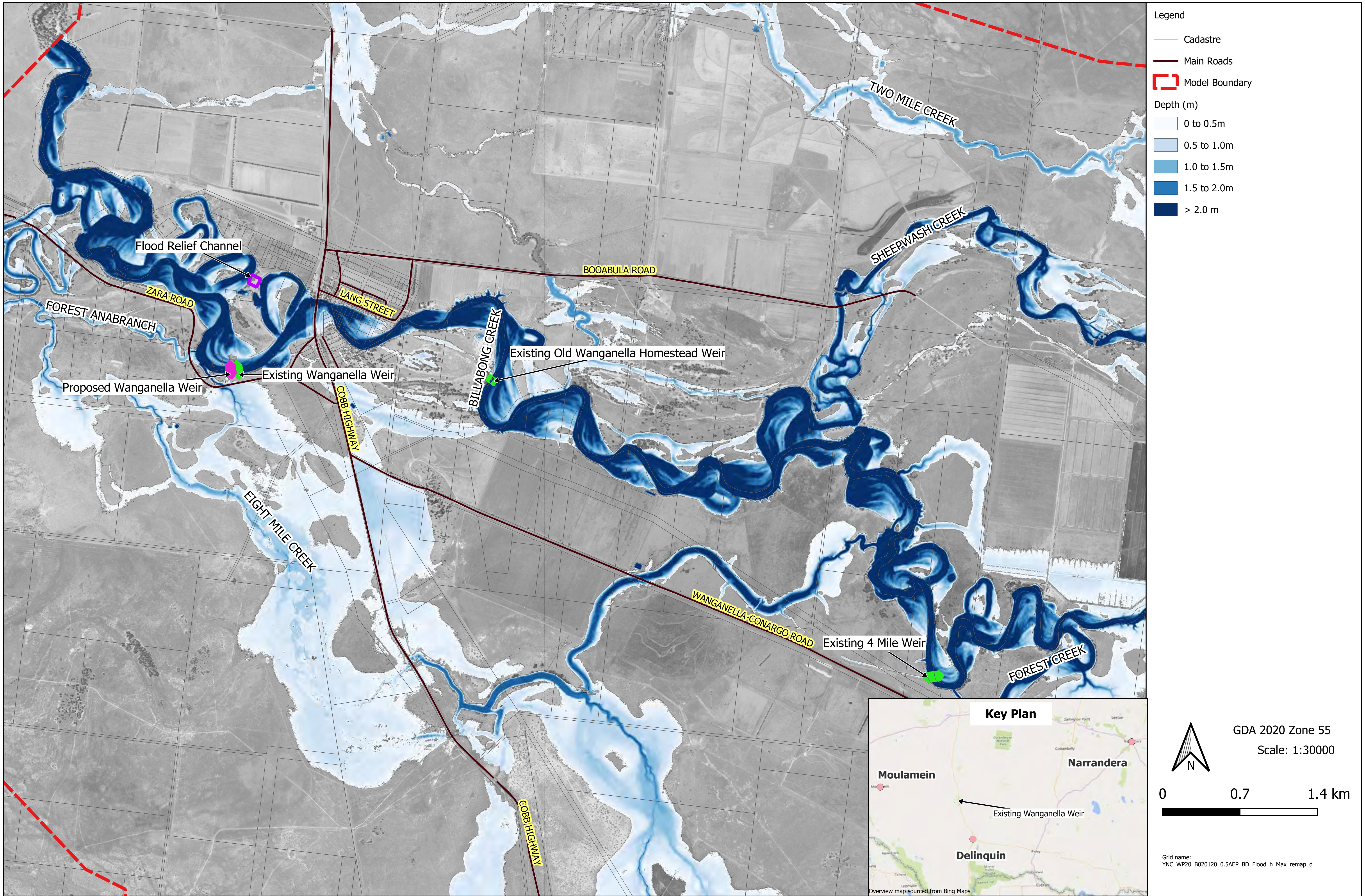
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.2 - Maximum Depth Plot (5% AEP)
"Existing"

3Rivers



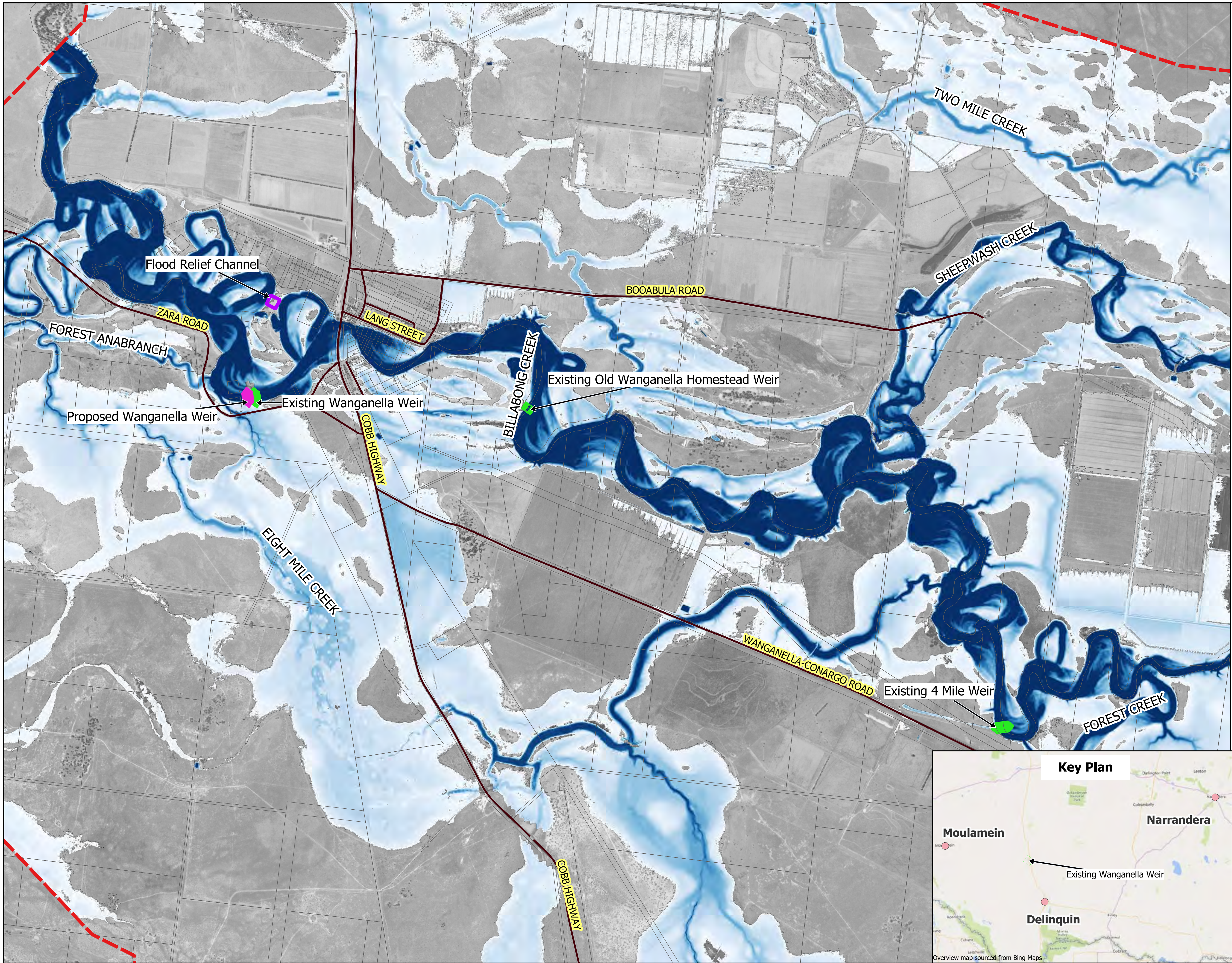
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.3 - Maximum Depth Plot (1% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.4 - Maximum Depth Plot (0.5% AEP)
"Existing"

3Rivers



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

N

GDA 2020 Zone 55

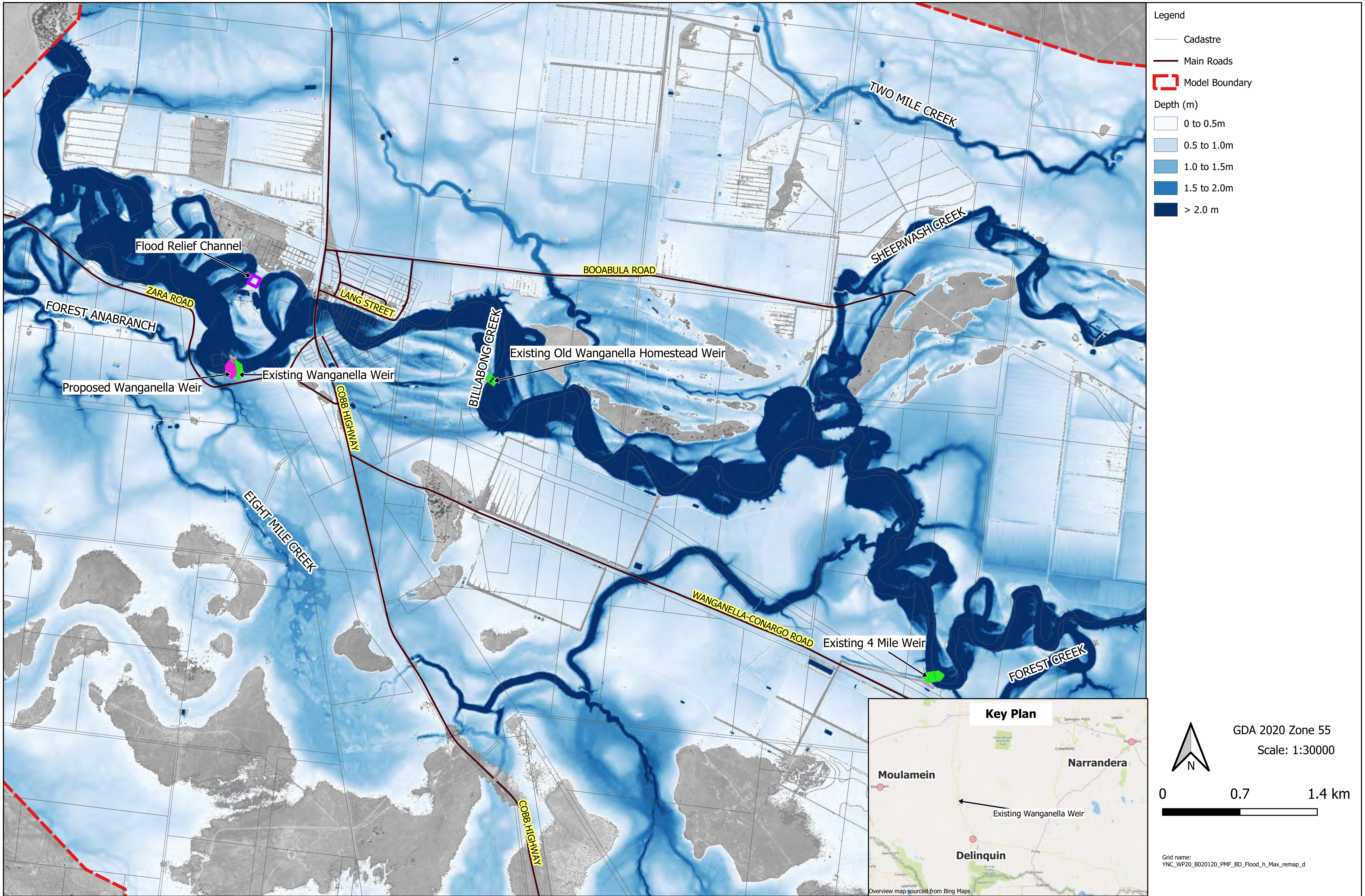
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_0.2AEP_BD_Flood_h_Max_remap_d

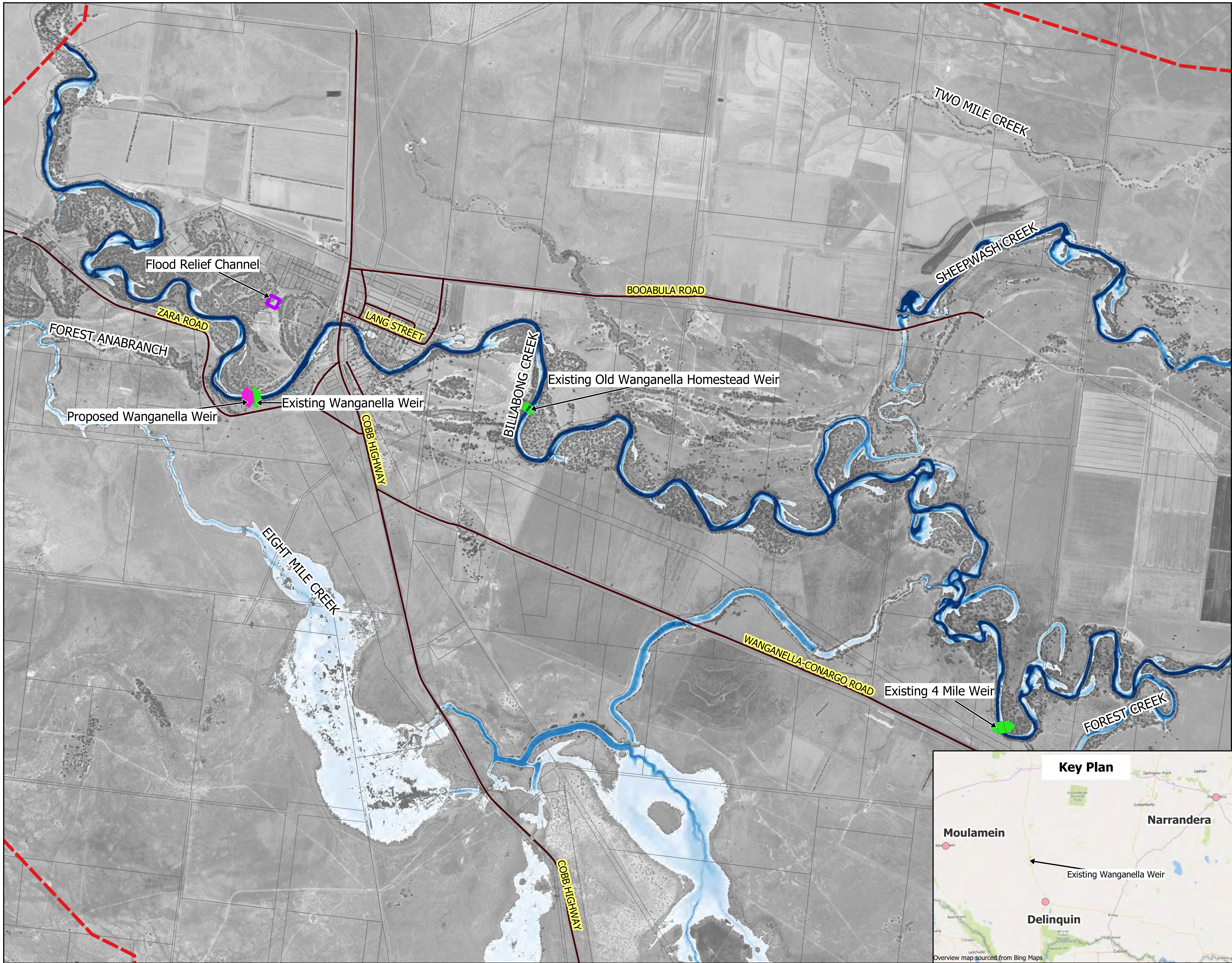
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.5 - Maximum Depth Plot (0.2% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.6 - Maximum Depth Plot (PMF)
"Existing"

3Rivers



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

N

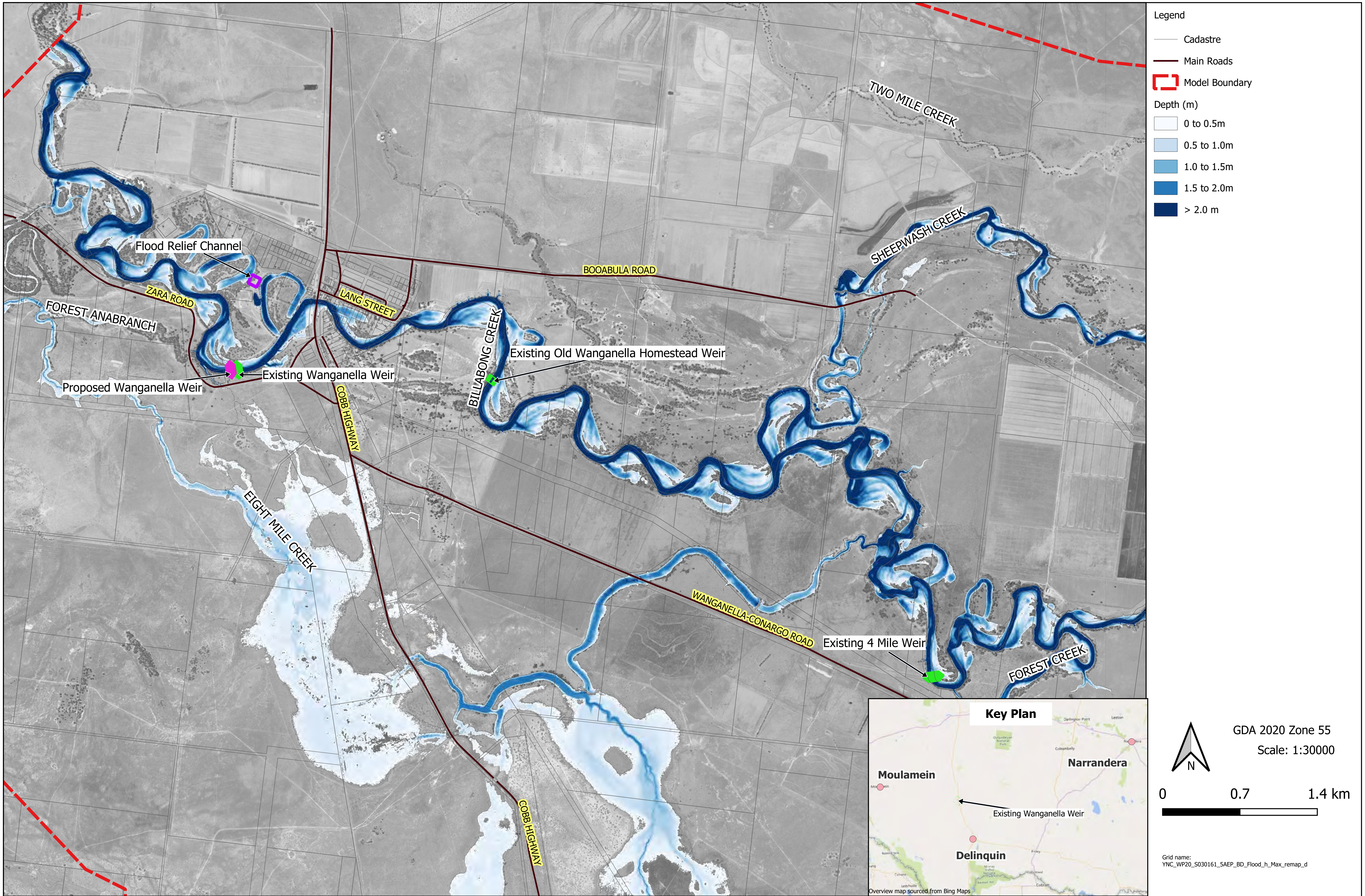
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_20AEP_BD_Flood_h_Max_remap_d

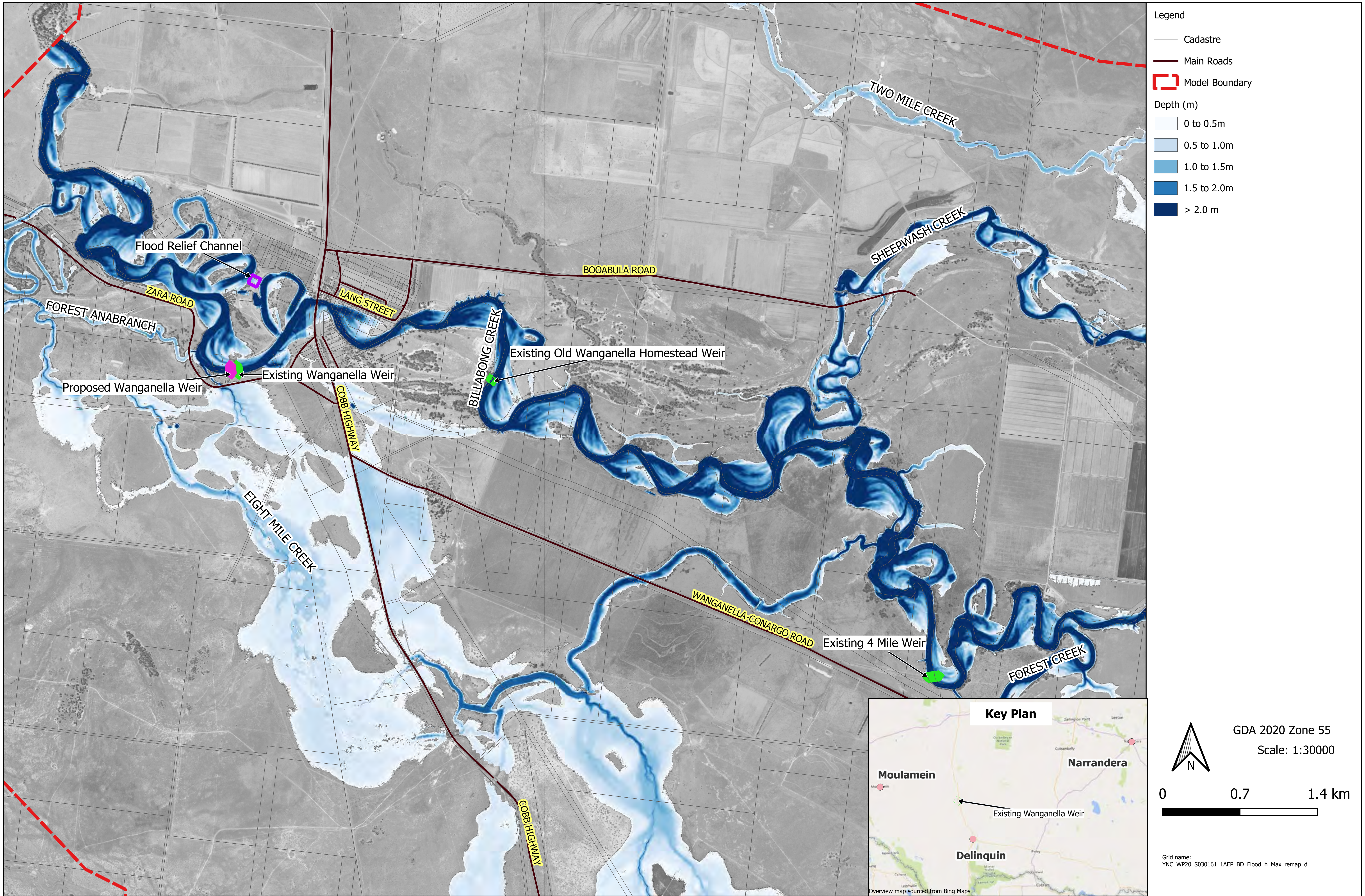
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.7 - Maximum Depth Plot (20% AEP)
"Proposed"

3Rivers



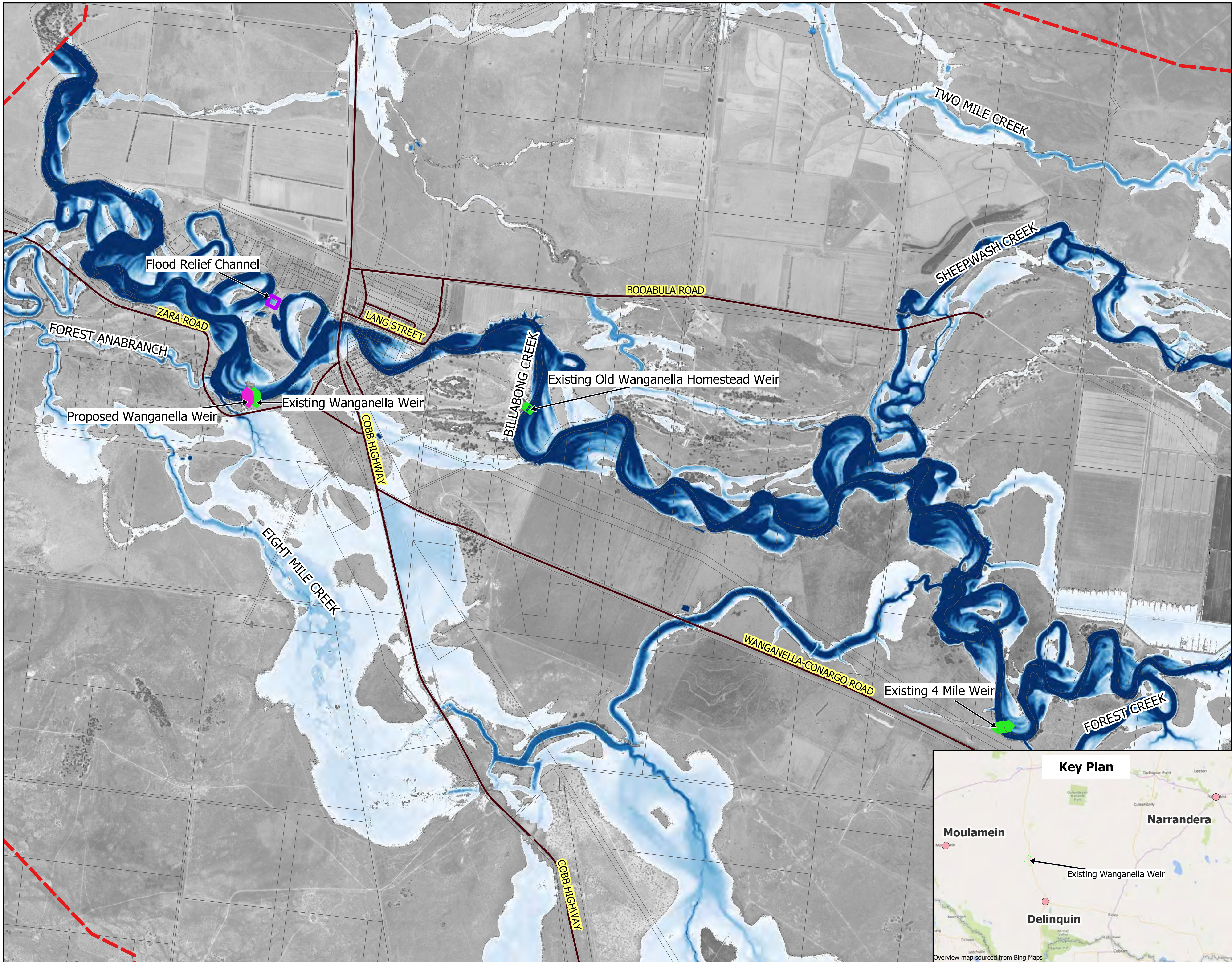
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.8 - Maximum Depth Plot (5% AEP)
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.9 - Maximum Depth Plot (1% AEP)
"Proposed"

3Rivers



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

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

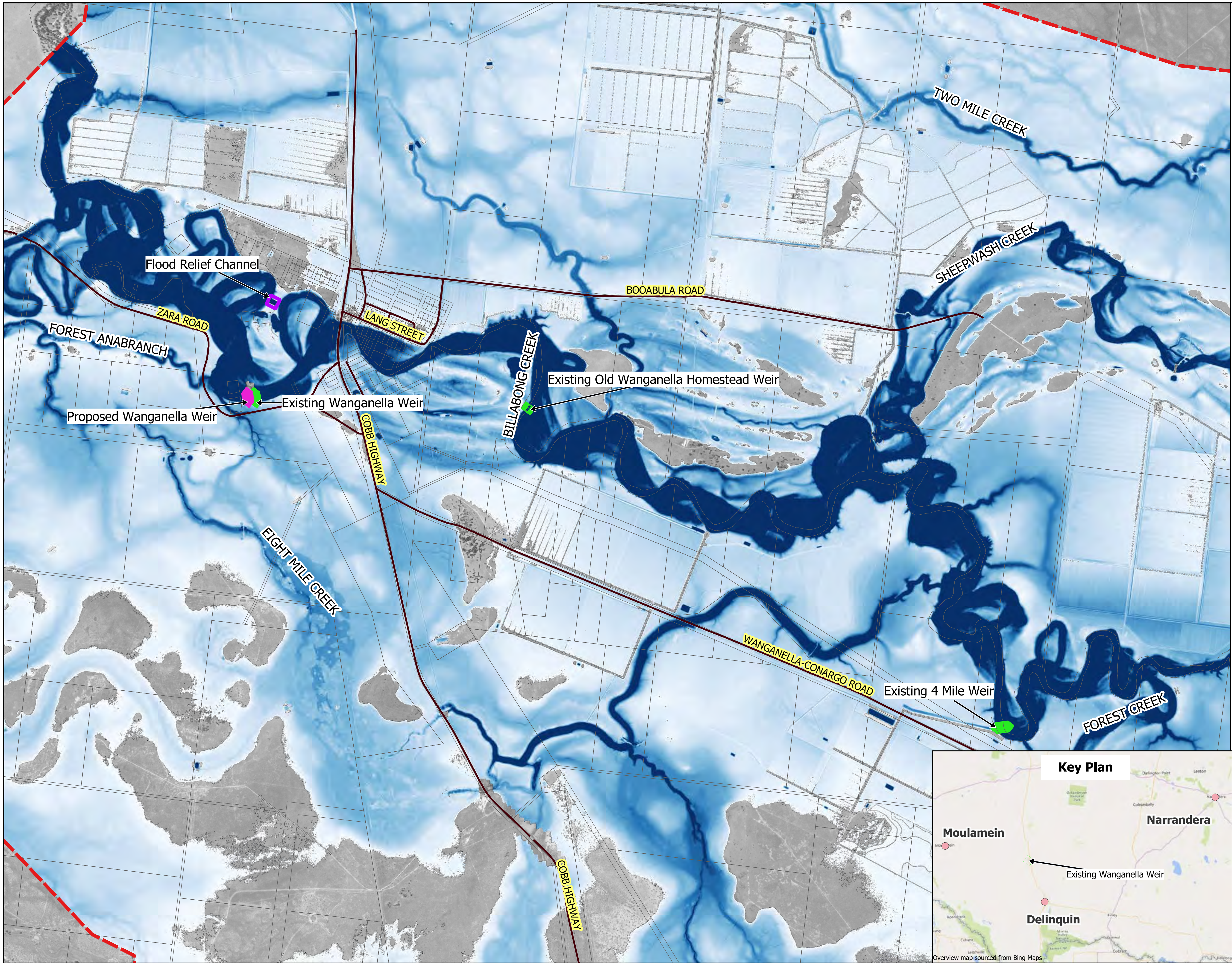
Grid name:
YNC_WP20_S030161_0.5AEP_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.10 - Maximum Depth Plot (0.5% AEP)
"Proposed"

3Rivers

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.11 - Maximum Depth Plot (0.2% AEP)
"Proposed"

3Rivers



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

N

GDA 2020 Zone 55

Scale: 1:30000

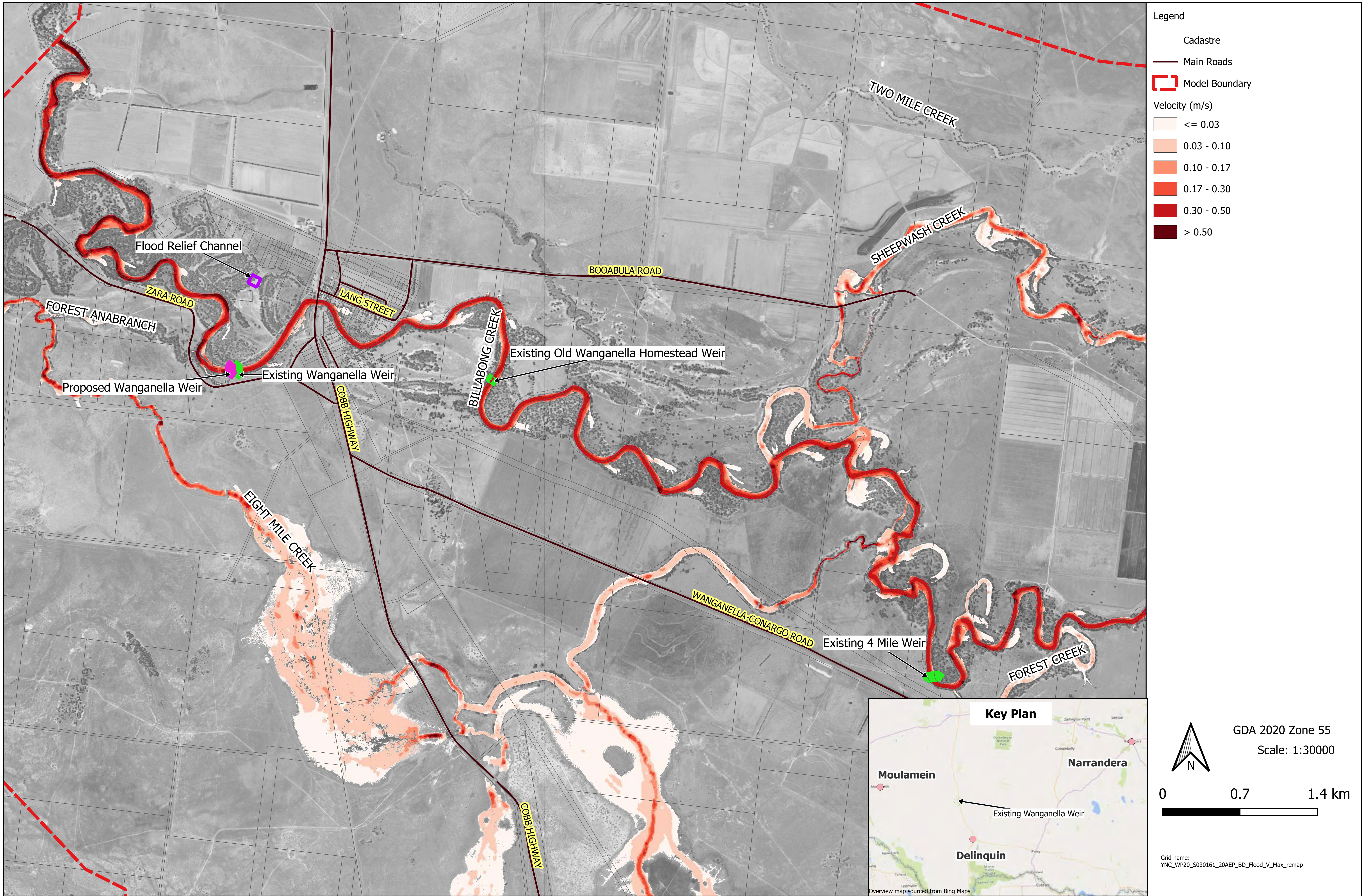
0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_PMF_BD_Flood_h_Max_remap_d

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F2.12 - Maximum Depth Plot (PMF)
"Proposed"

3Rivers

F3 Velocity Plots



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.7 - Maximum Velocity Plot (20% AEP)
"Proposed"

3Rivers

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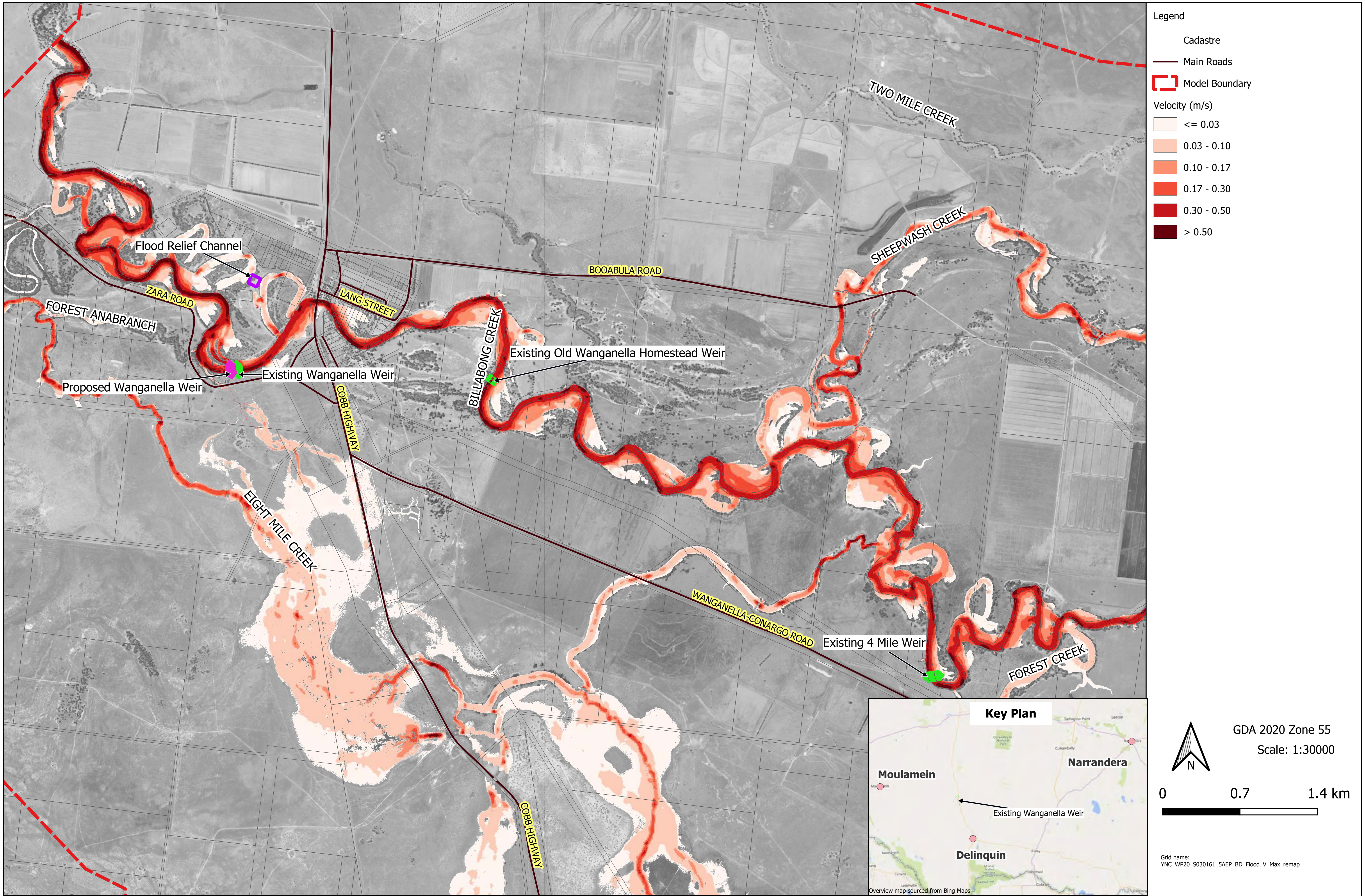


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.8 - Maximum Velocity Plot (5% AEP)
"Proposed"

3Rivers

Legend
Cadastre
Main Roads
Model Boundary
Velocity (m/s)
<= 0.03
0.03 - 0.10
0.10 - 0.17
0.17 - 0.30
0.30 - 0.50
> 0.50

N

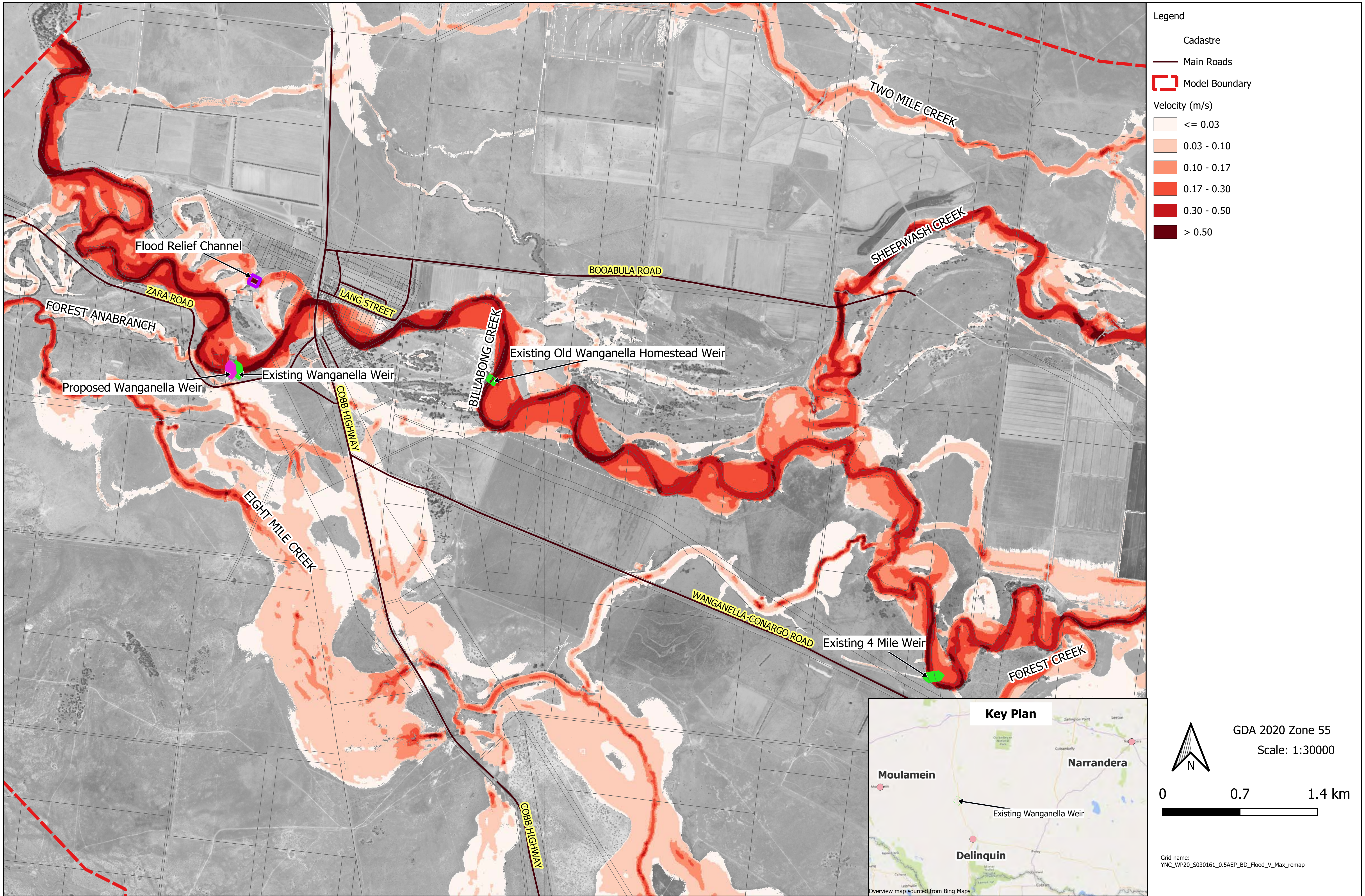
GDA 2020 Zone 55
Scale: 1:30000

0 0.7 1.4 km

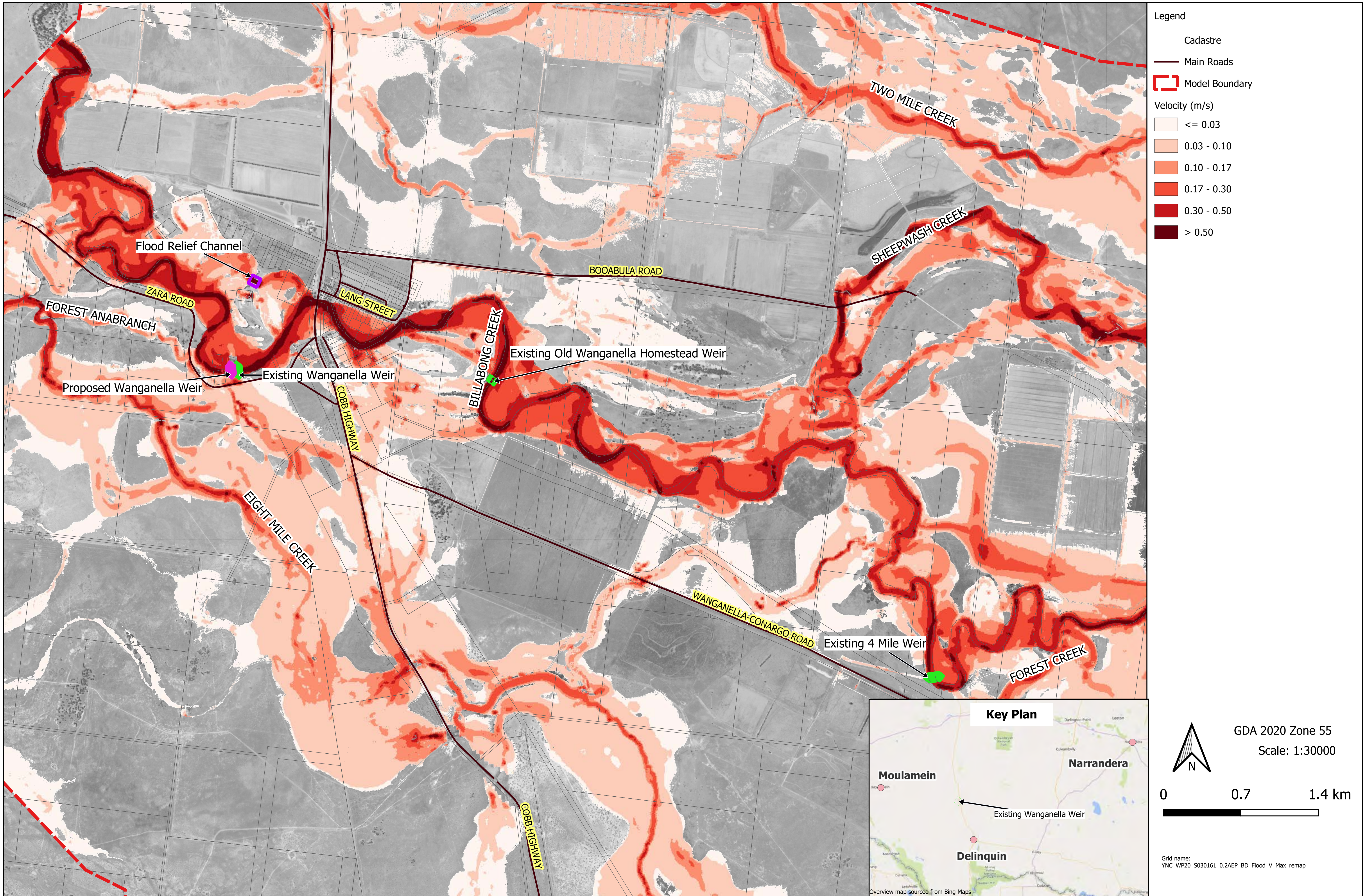
Grid name:
YNC_WP20_S030161_1AEP_BD_Flood_V_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.9 - Maximum Velocity Plot (1% AEP)
"Proposed"

3Rivers

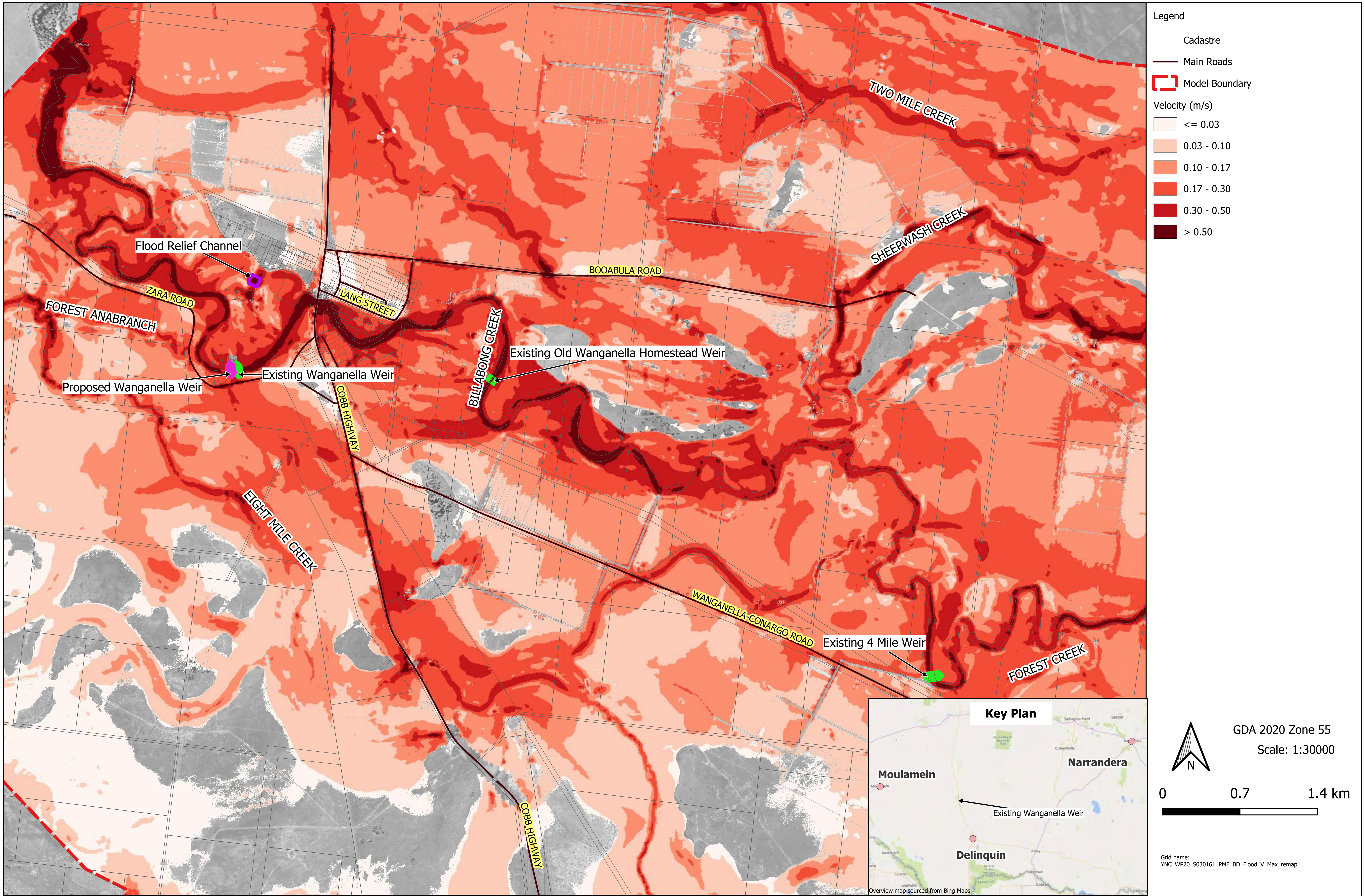


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.10 - Maximum Velocity Plot (0.5% AEP)
"Proposed"



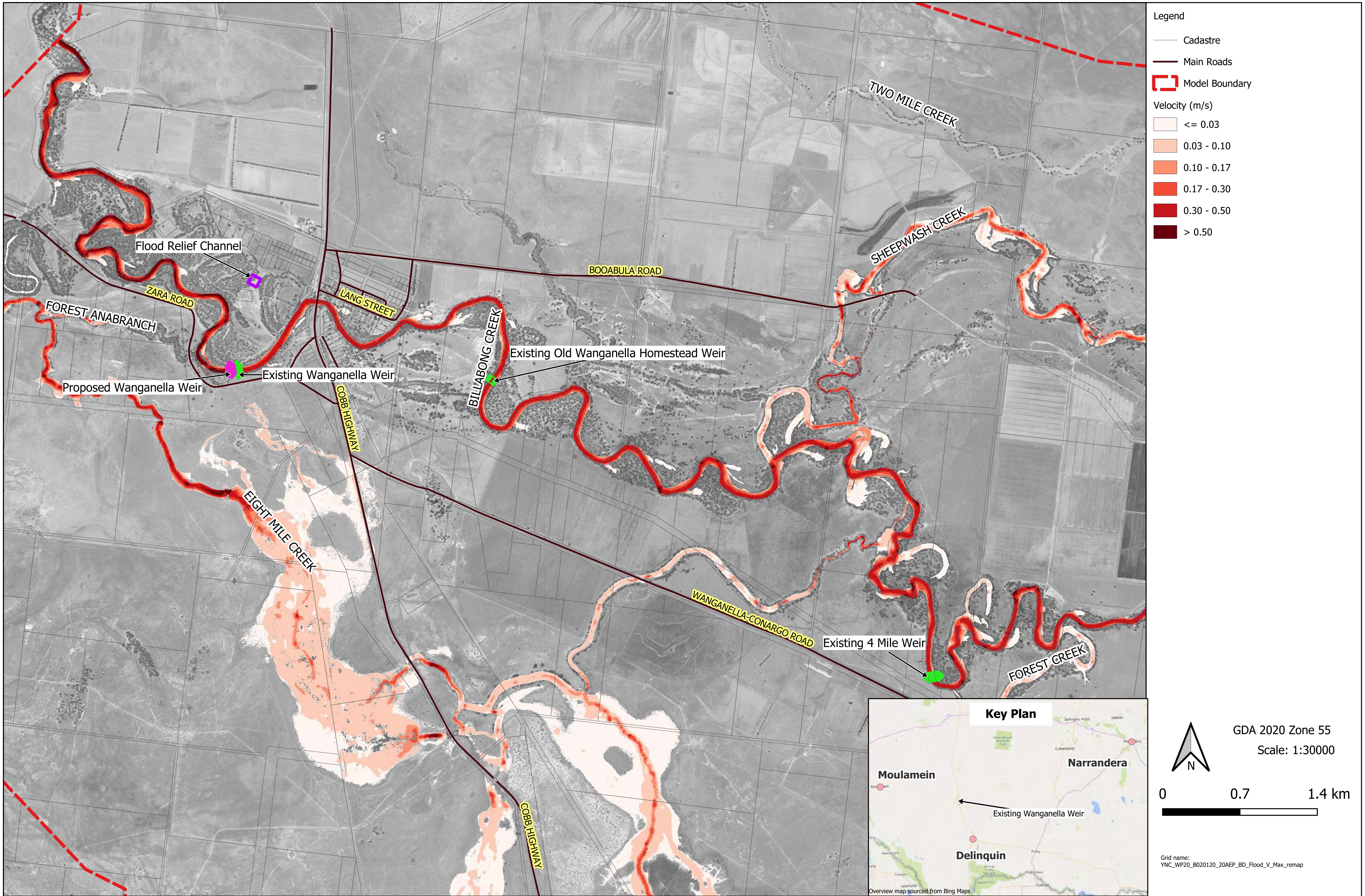
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.11 - Maximum Velocity Plot (0.2% AEP)
"Proposed"

3Rivers



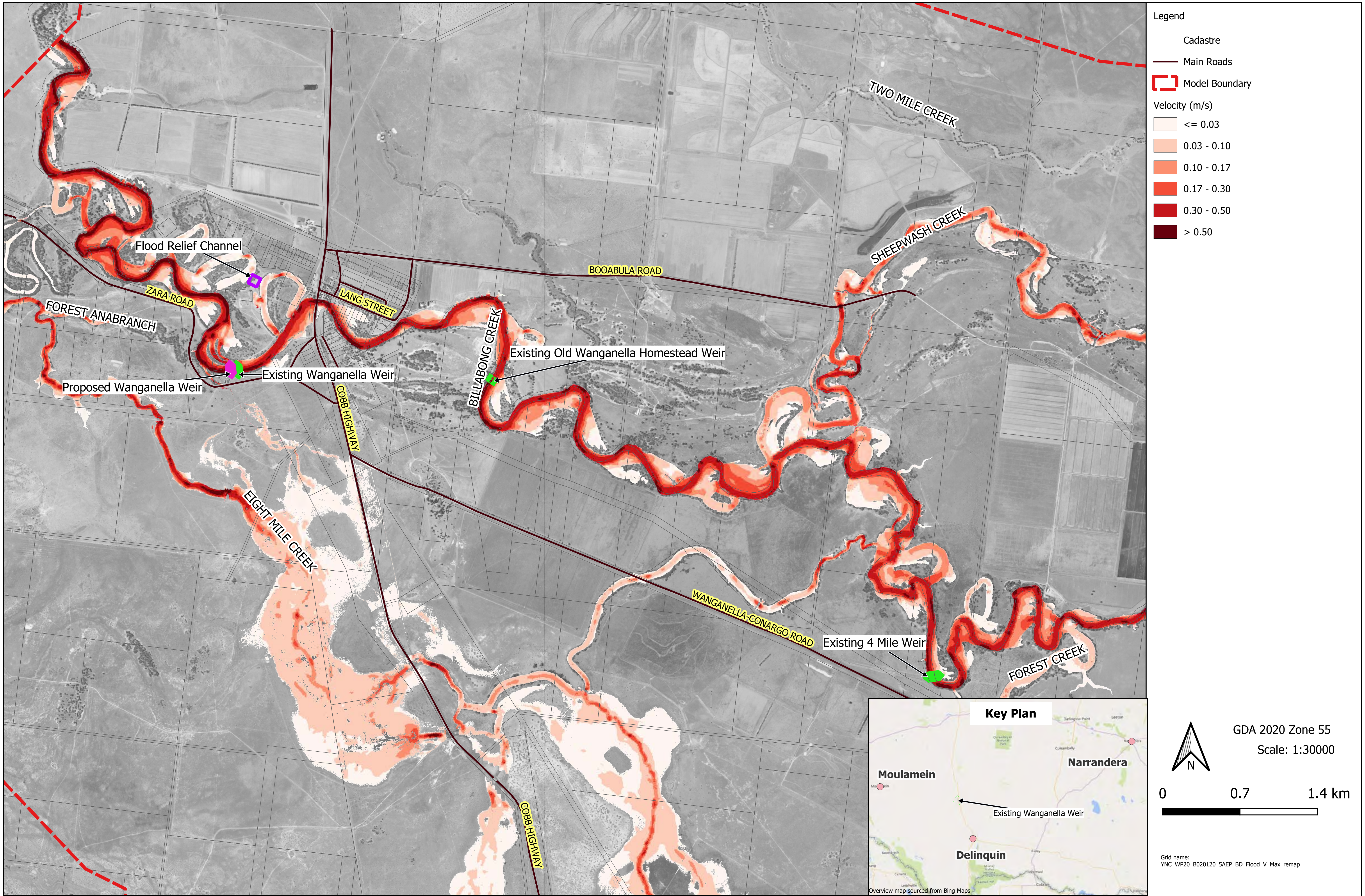
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.12 - Maximum Velocity Plot (PMF)
"Proposed"

3Rivers

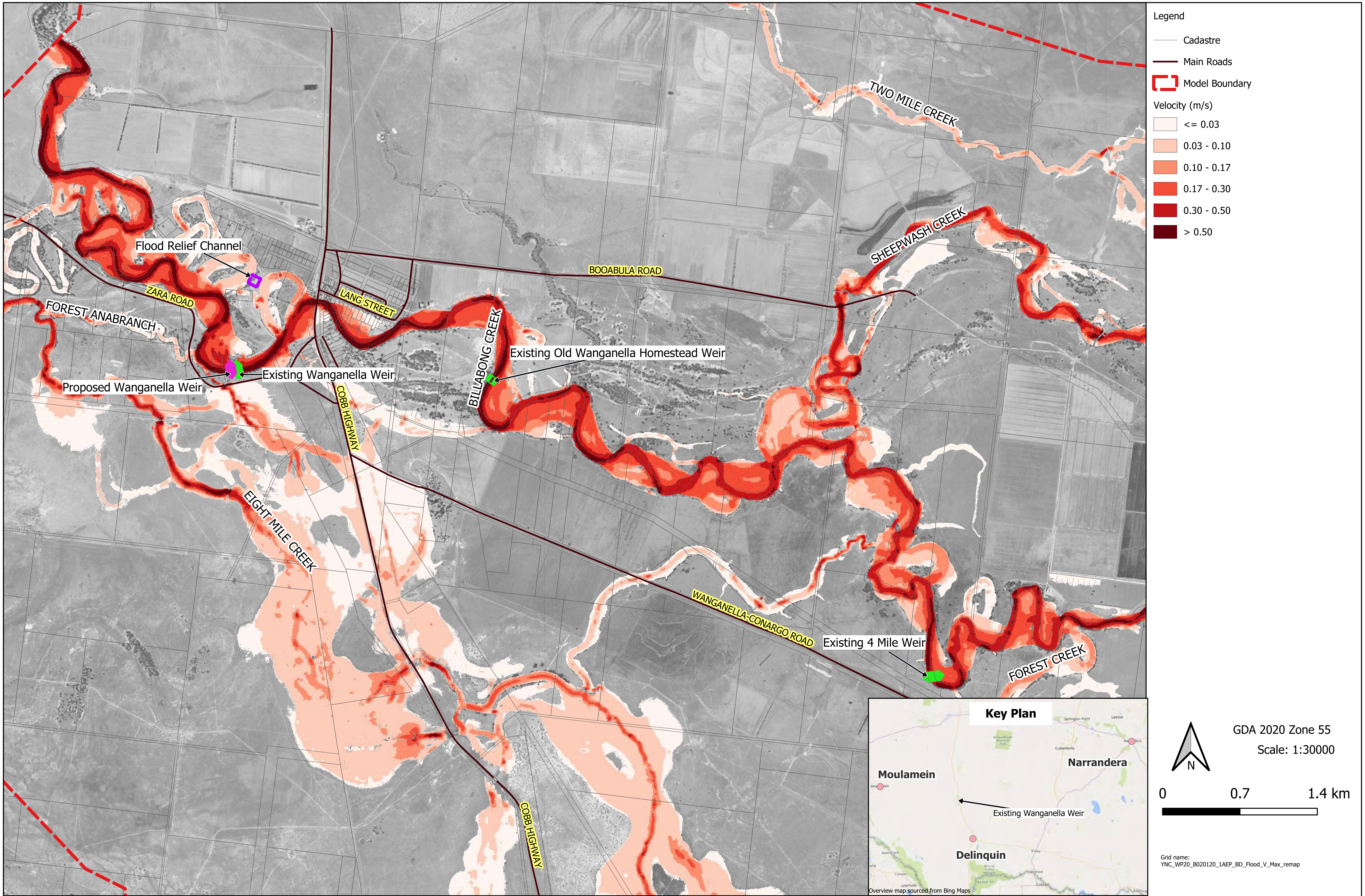


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.1 - Maximum Velocity Plot (20% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.2 - Maximum Velocity Plot (5% AEP)
"Existing"

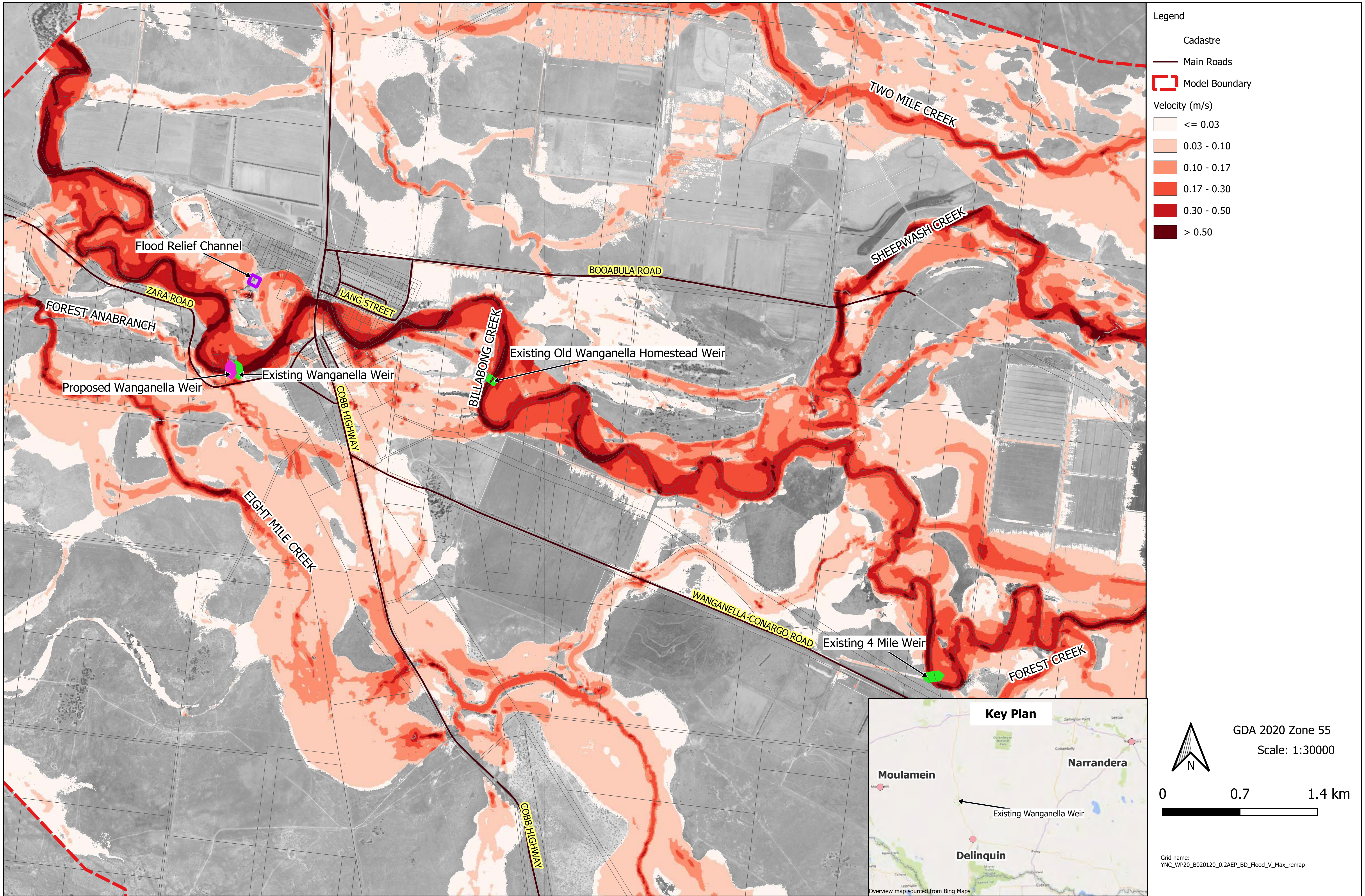


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.3 - Maximum Velocity Plot (1% AEP)
"Existing"

3Rivers

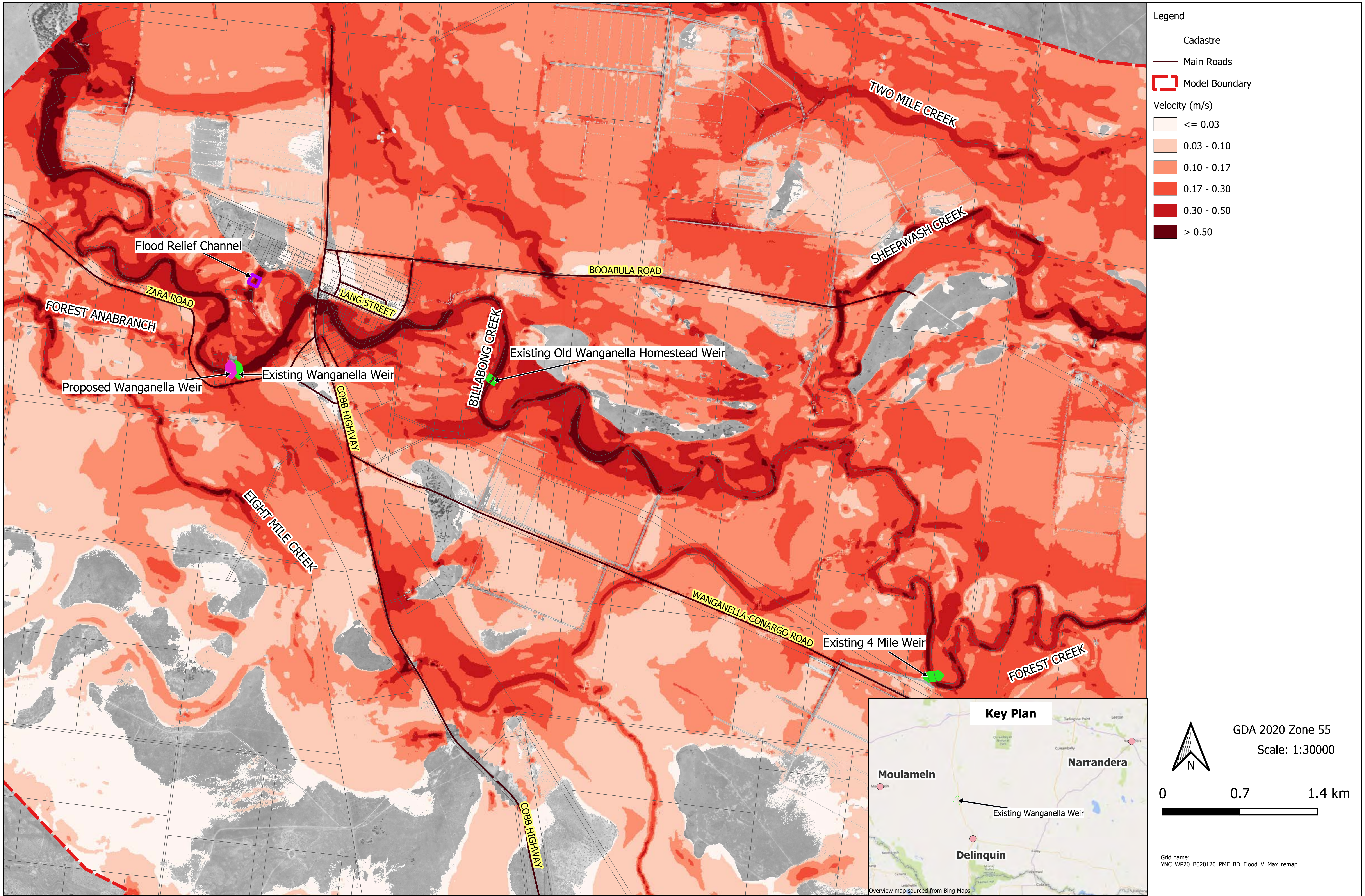
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.4 - Maximum Velocity Plot (0.5% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.5 - Maximum Velocity Plot (0.2% AEP)
"Existing"

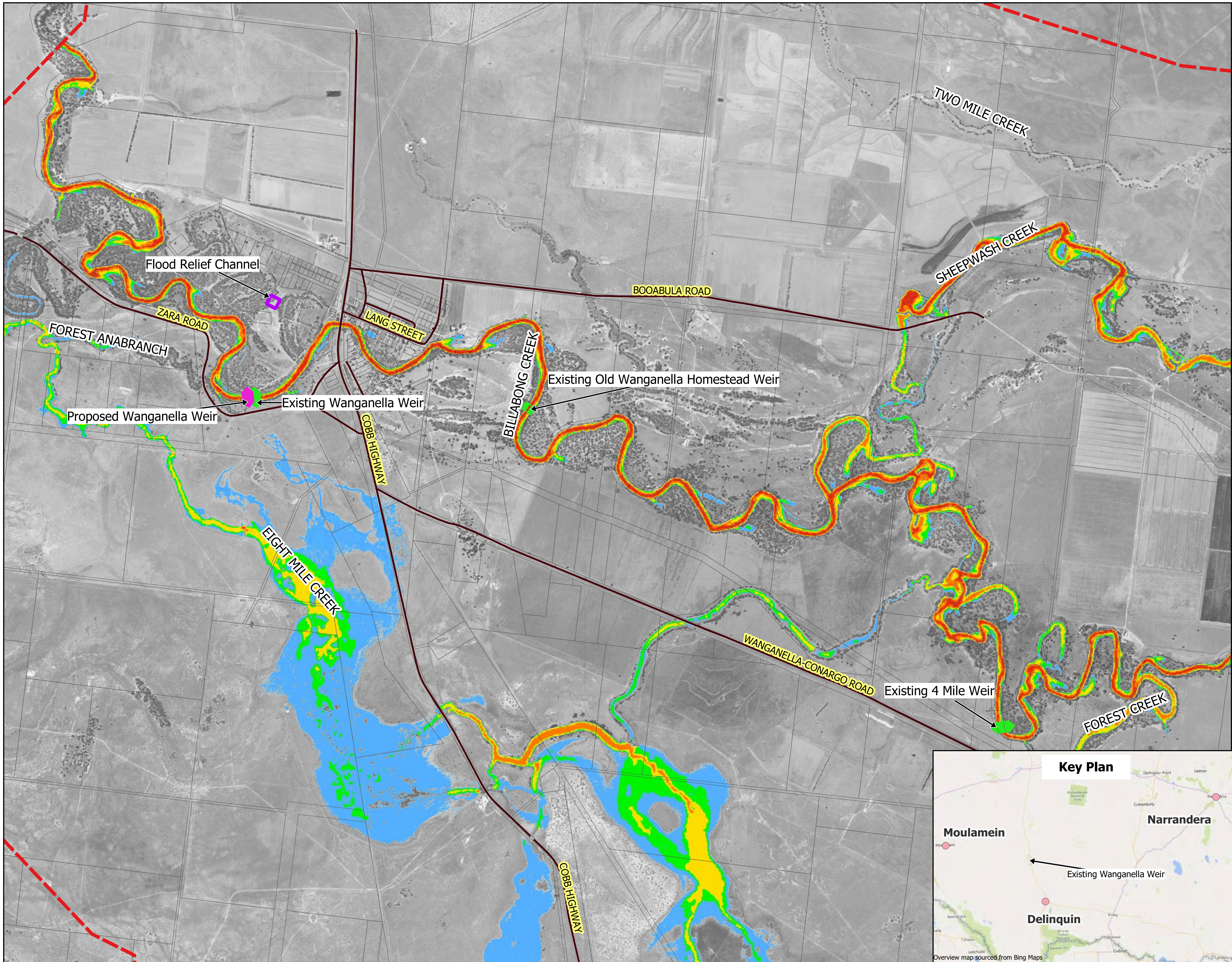
3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F3.6 - Maximum Velocity Plot (PMF)
"Existing"

3Rivers

F4 Hazard Category Plots



Legend

- Cadastre
- Main Roads
- Model Boundary

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles, plus buildings require special design and construction
- H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

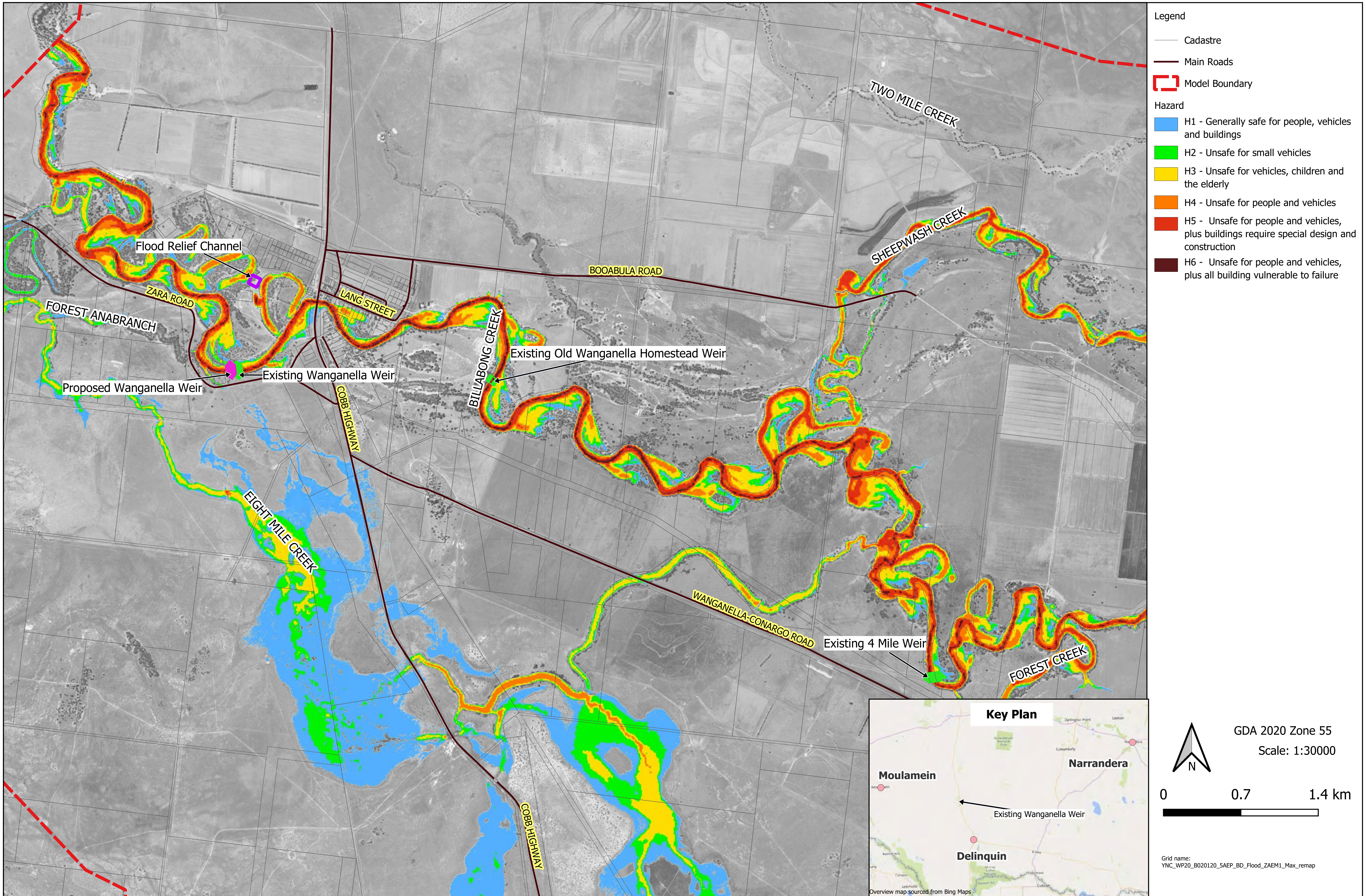
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_20AEP_BD_Flood_ZAEM1_Max_remap

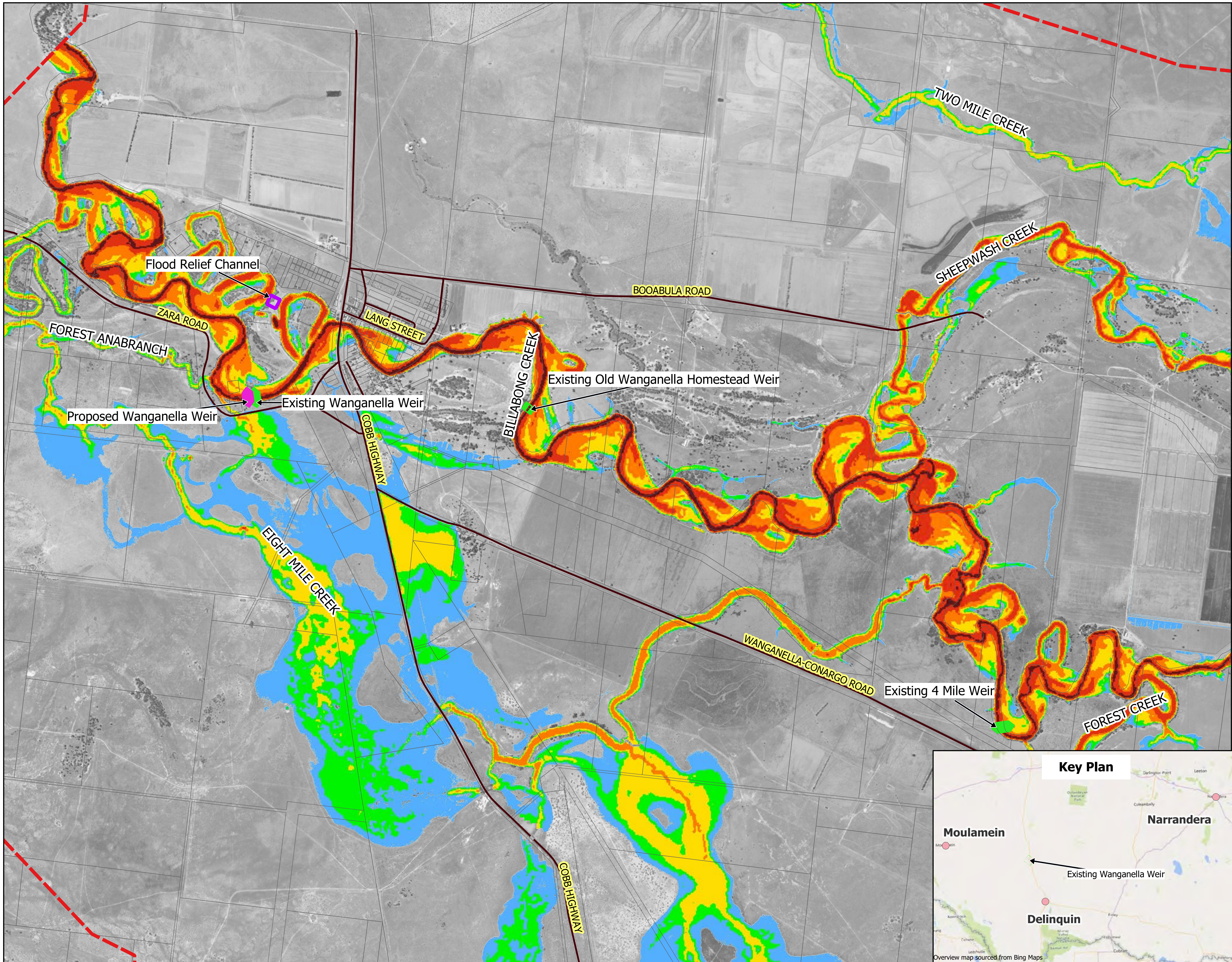
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.1 - Maximum Hazard Plot (20% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.2 - Maximum Hazard Plot (5% AEP)
"Existing"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_1AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.3 - Maximum Hazard Plot (1% AEP)
"Existing"

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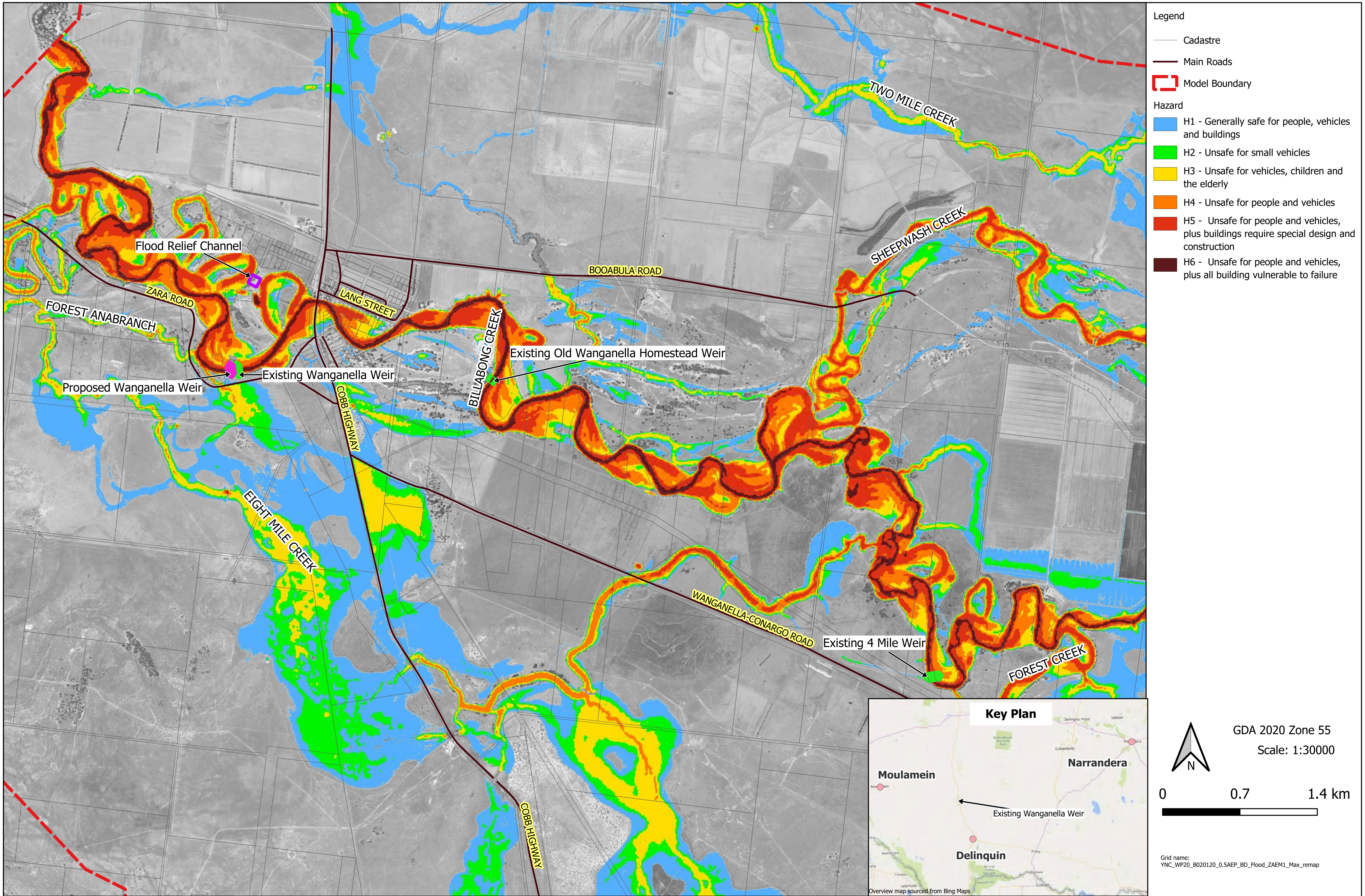
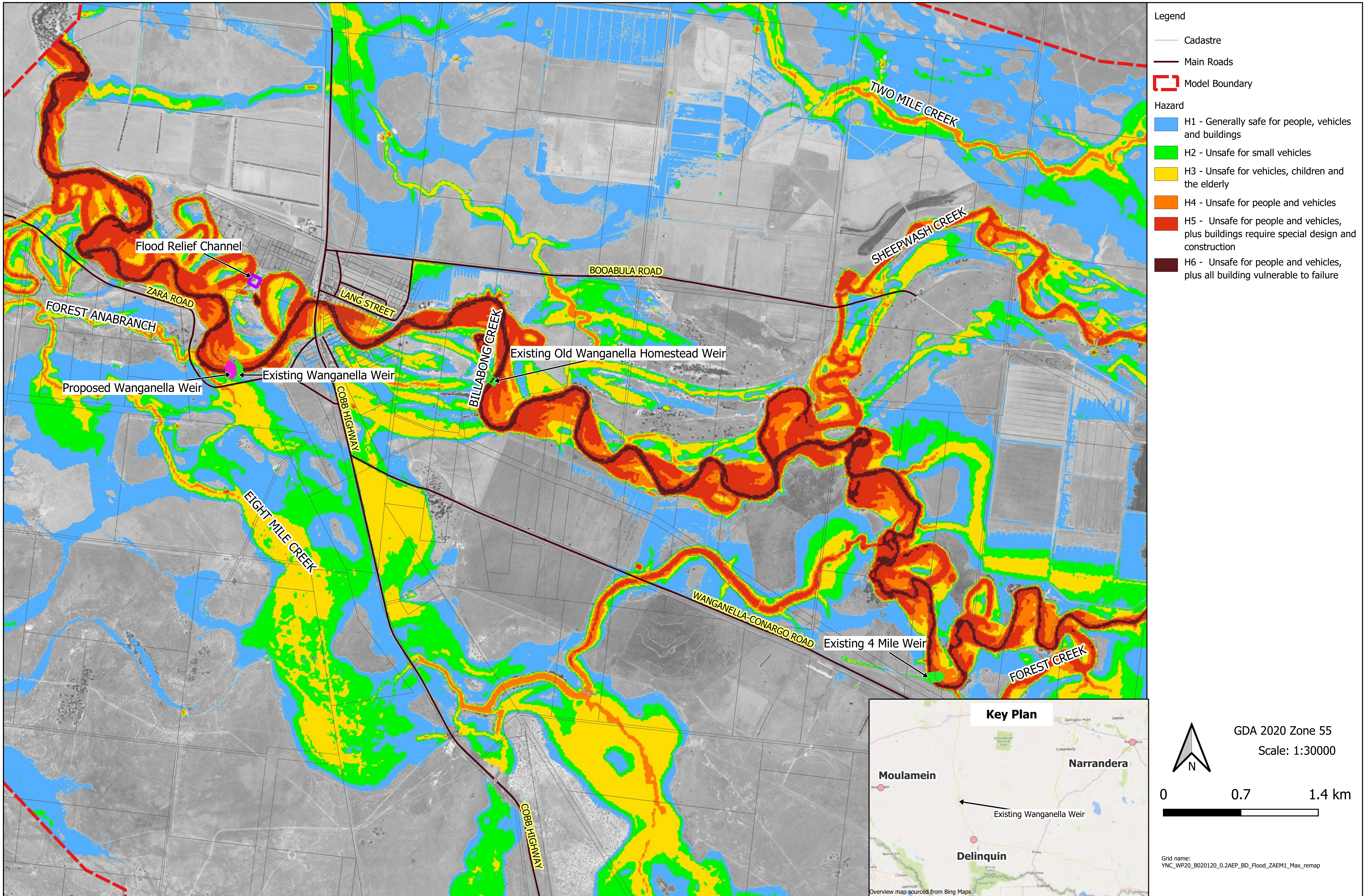


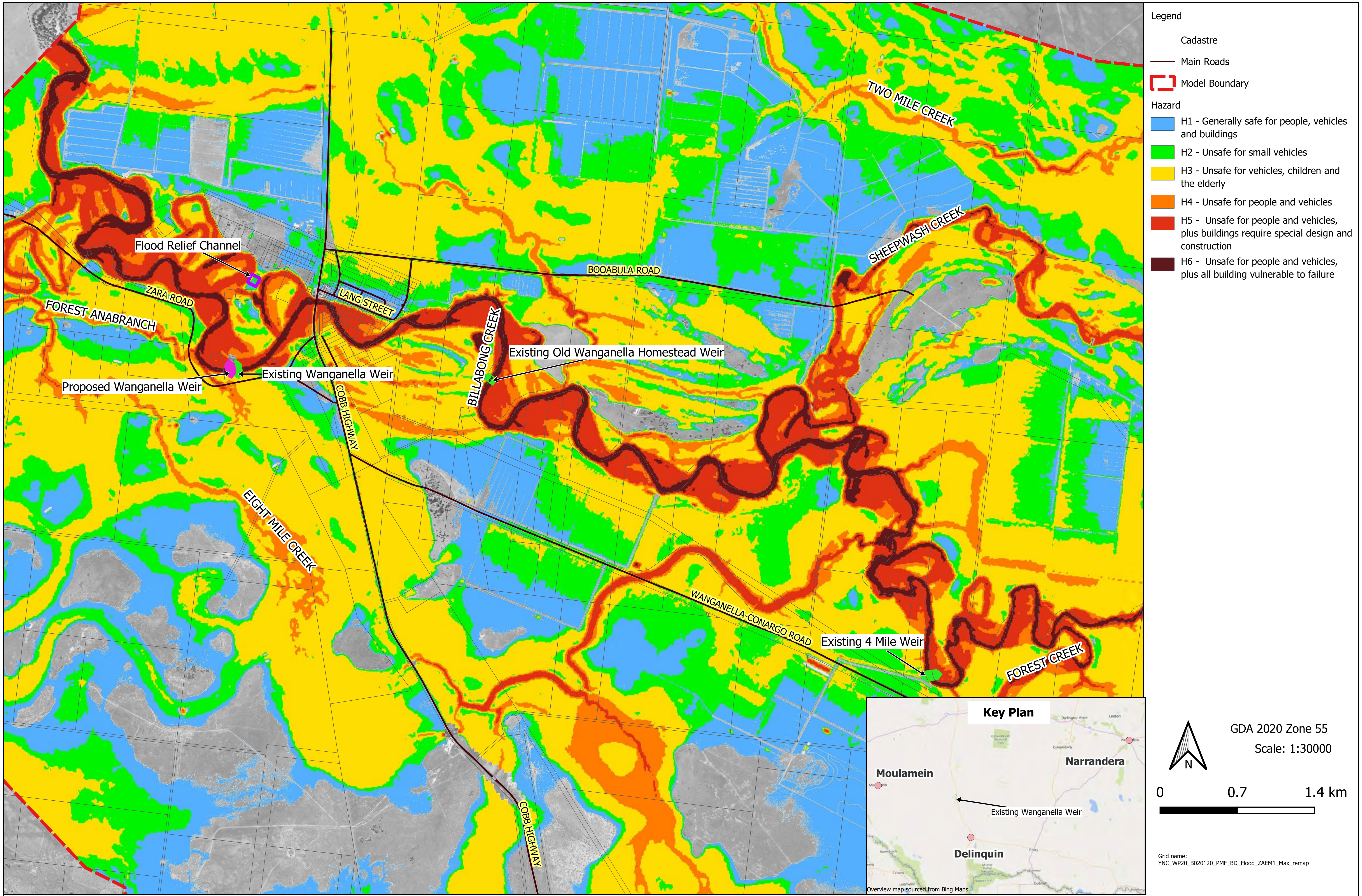
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.4 - Maximum Hazard Plot (0.5% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.5 - Maximum Hazard Plot (0.2% AEP)
"Existing"

3Rivers

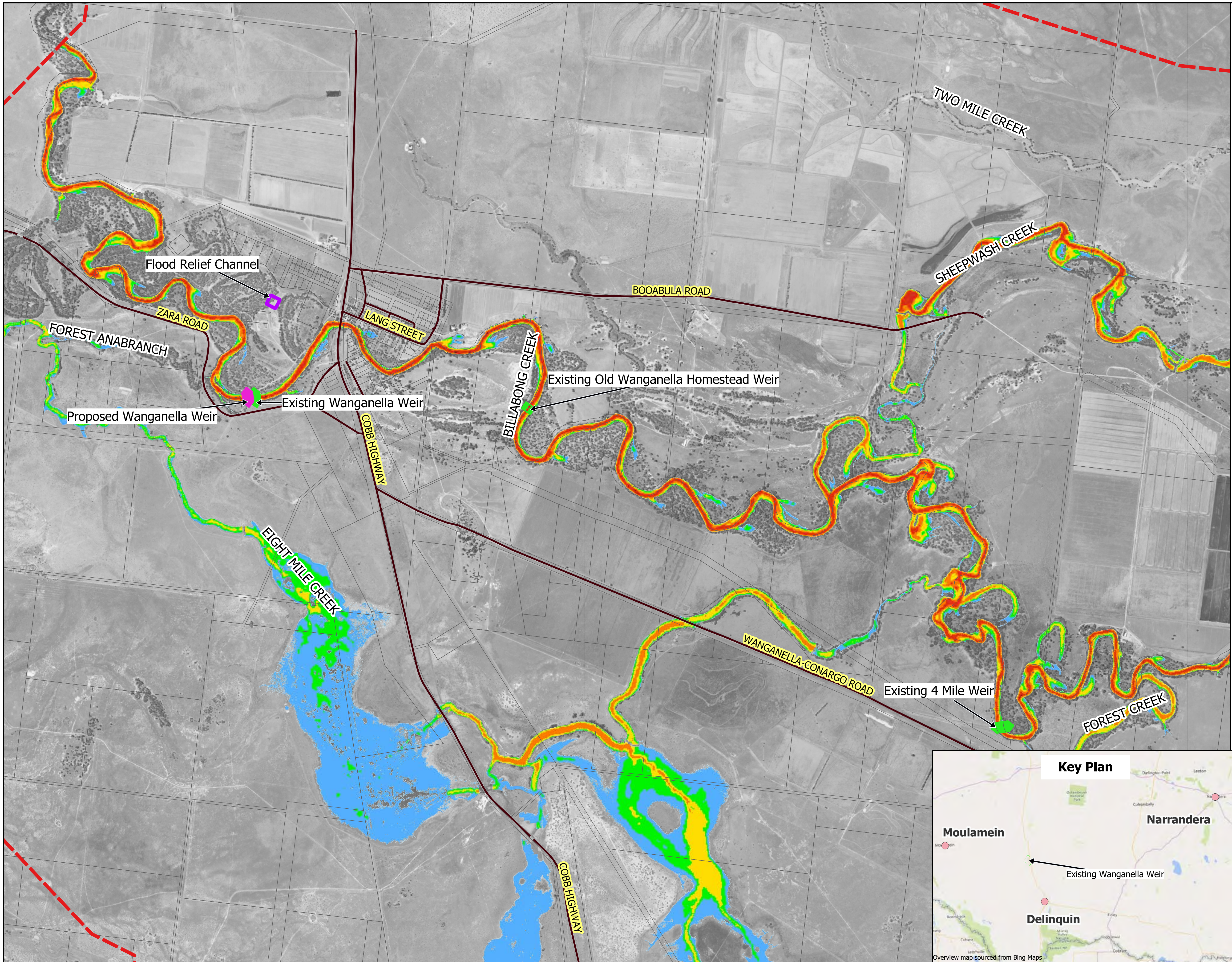


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator

Figure F4.6 - Maximum Hazard Plot (PMF)

"Existing"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

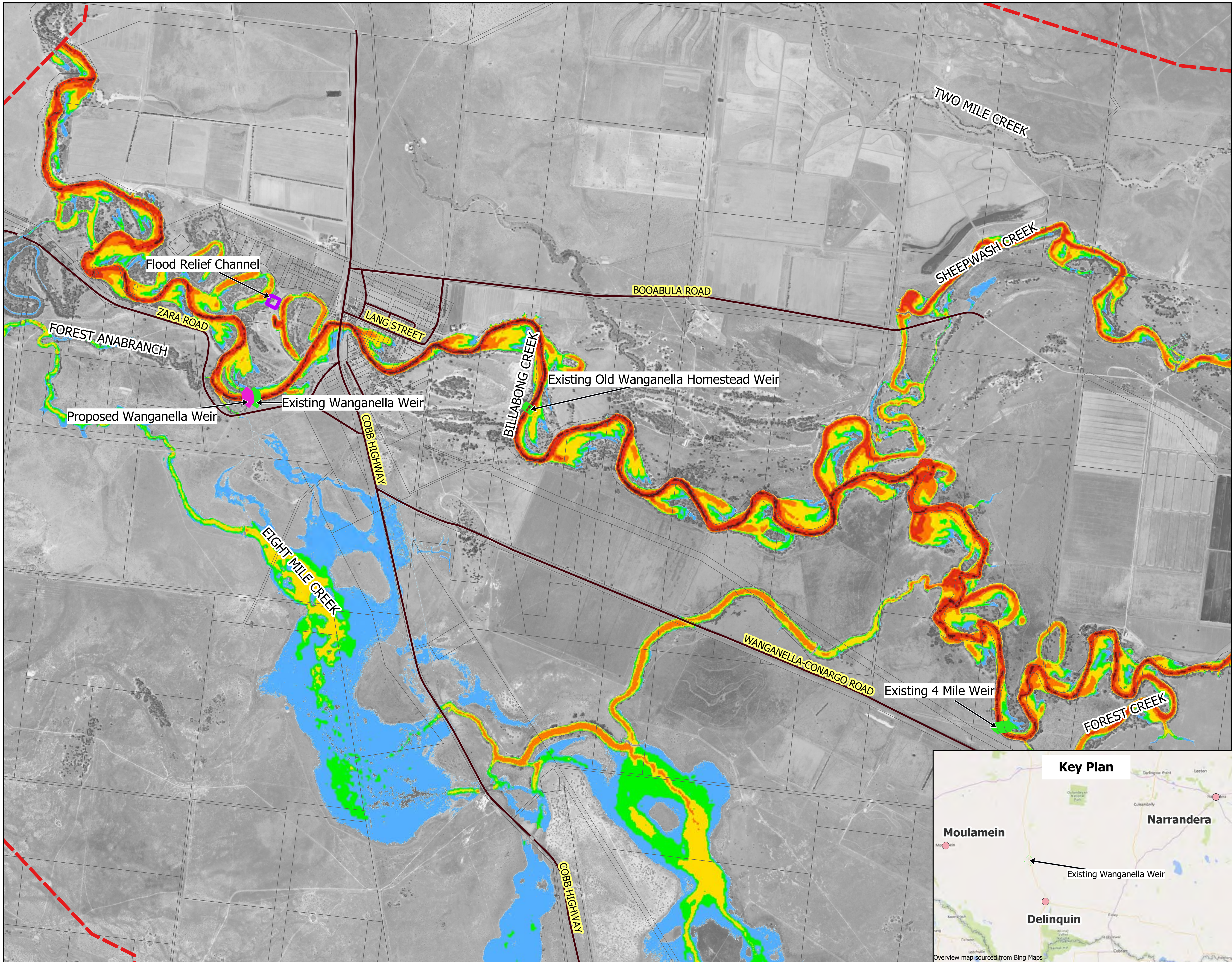
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_20AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.7 - Maximum Hazard Plot (20% AEP)
"Proposed"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles, plus buildings require special design and construction
- H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

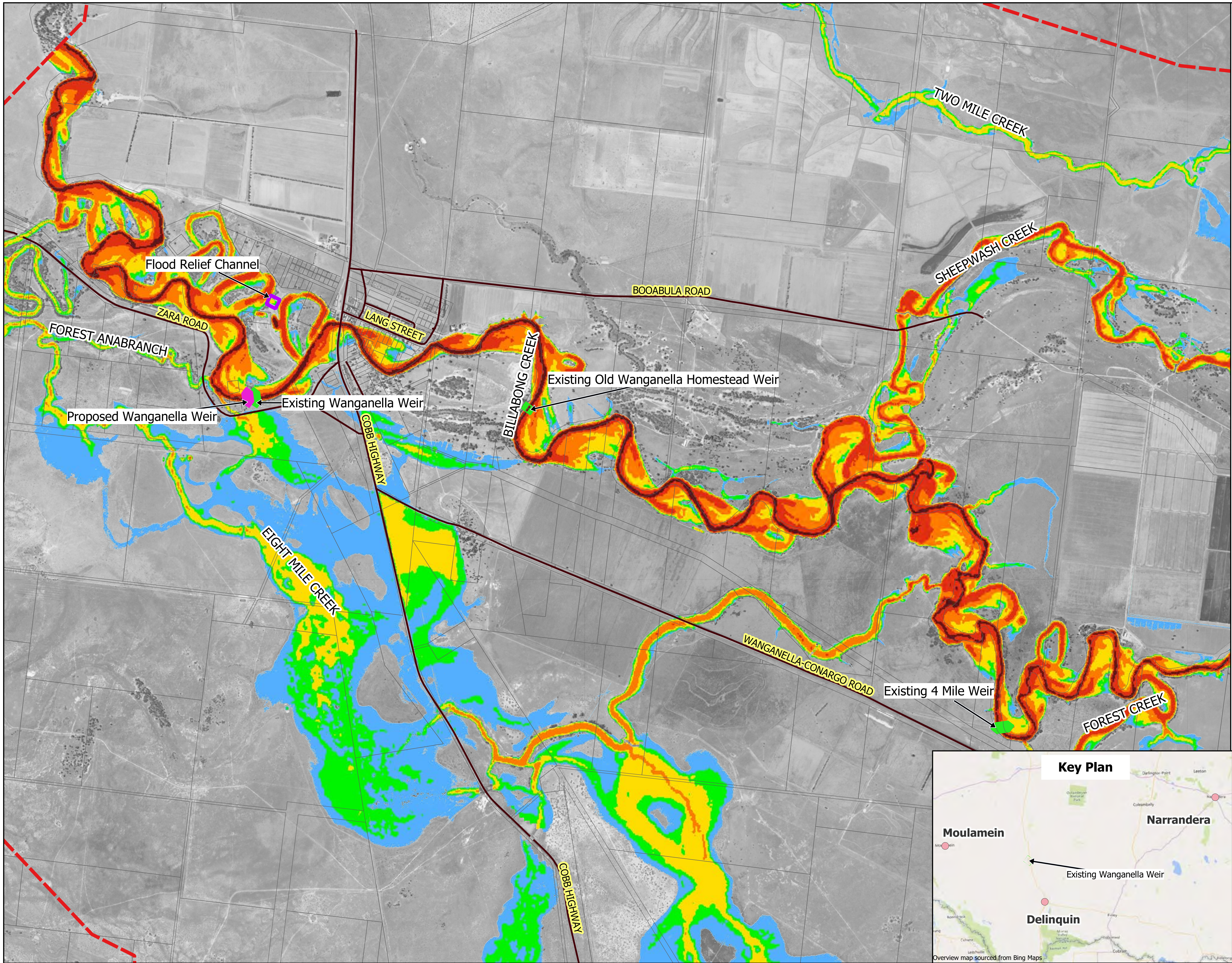
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_5AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.8 - Maximum Hazard Plot (5% AEP)
"Proposed"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

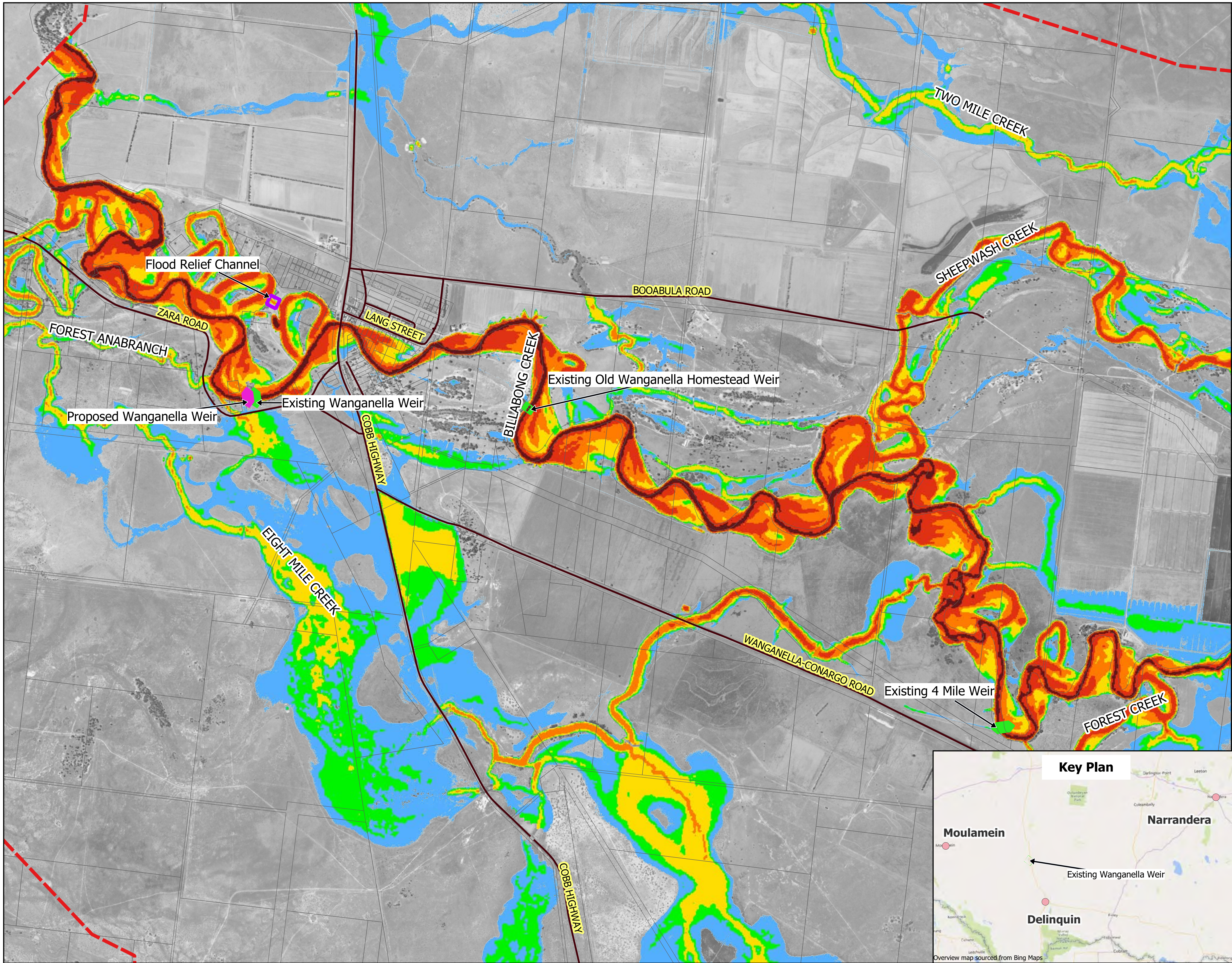
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_1AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.9 - Maximum Hazard Plot (1% AEP)
"Proposed"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Hazard

H1 - Generally safe for people, vehicles and buildings

H2 - Unsafe for small vehicles

H3 - Unsafe for vehicles, children and the elderly

H4 - Unsafe for people and vehicles

H5 - Unsafe for people and vehicles, plus buildings require special design and construction

H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_0.5AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.10 - Maximum Hazard Plot (0.5% AEP)
"Proposed"

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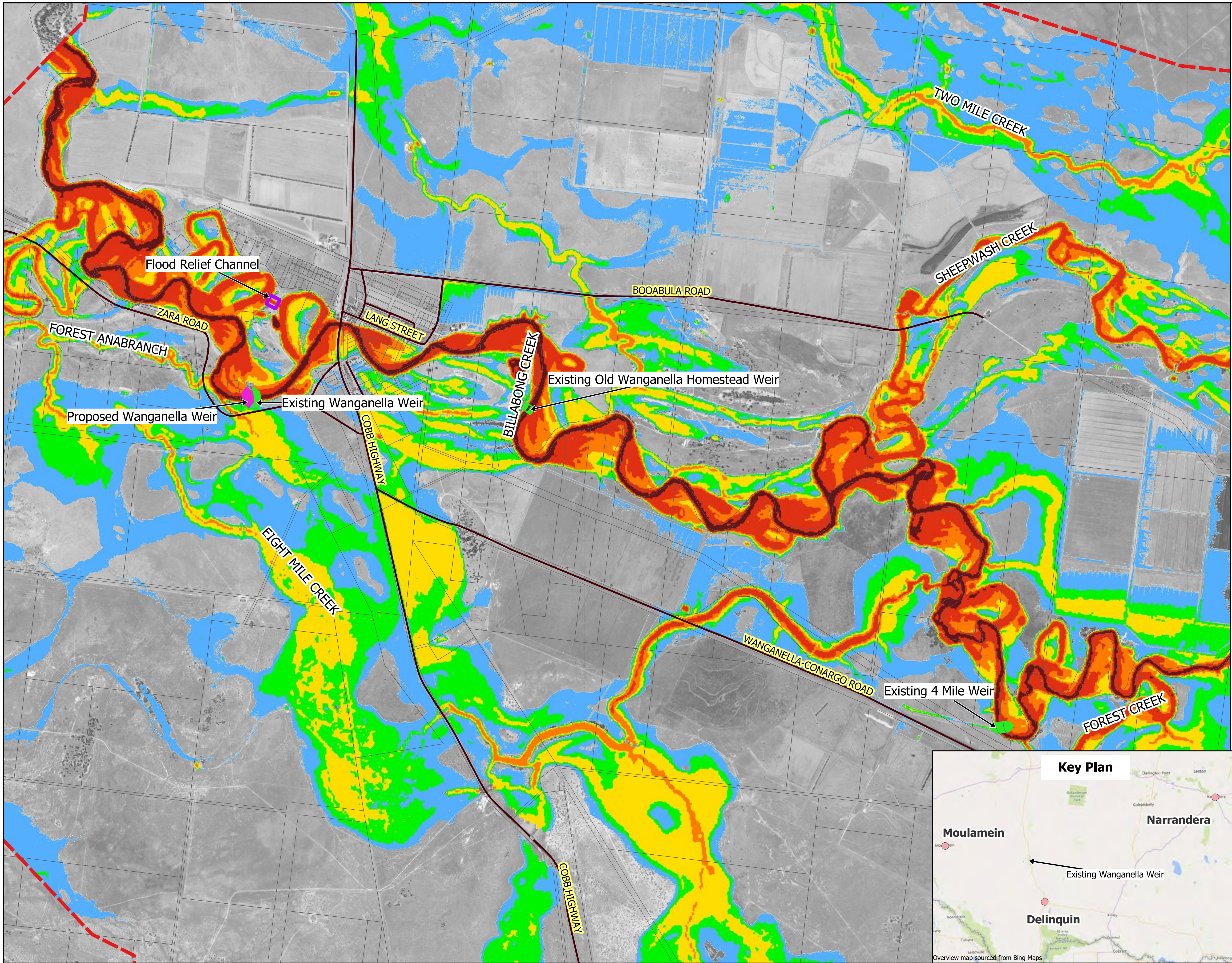


Legend

- Cadastre
- Main Roads
- Model Boundary

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles, plus buildings require special design and construction
- H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

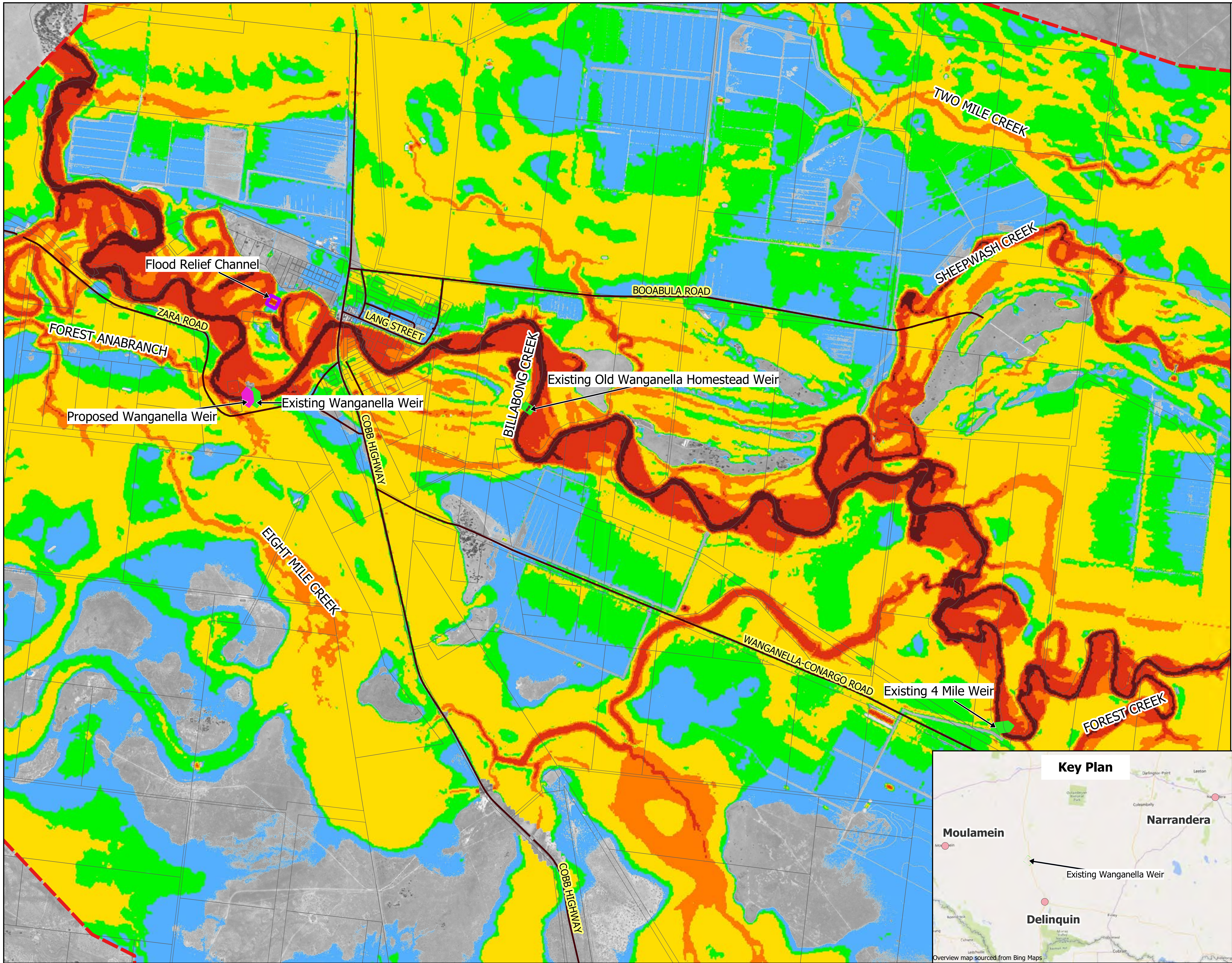
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_0.2AEP_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.11 - Maximum Hazard Plot (0.2% AEP)
"Proposed"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles, plus buildings require special design and construction
- H6 - Unsafe for people and vehicles, plus all building vulnerable to failure

N

GDA 2020 Zone 55

Scale: 1:30000

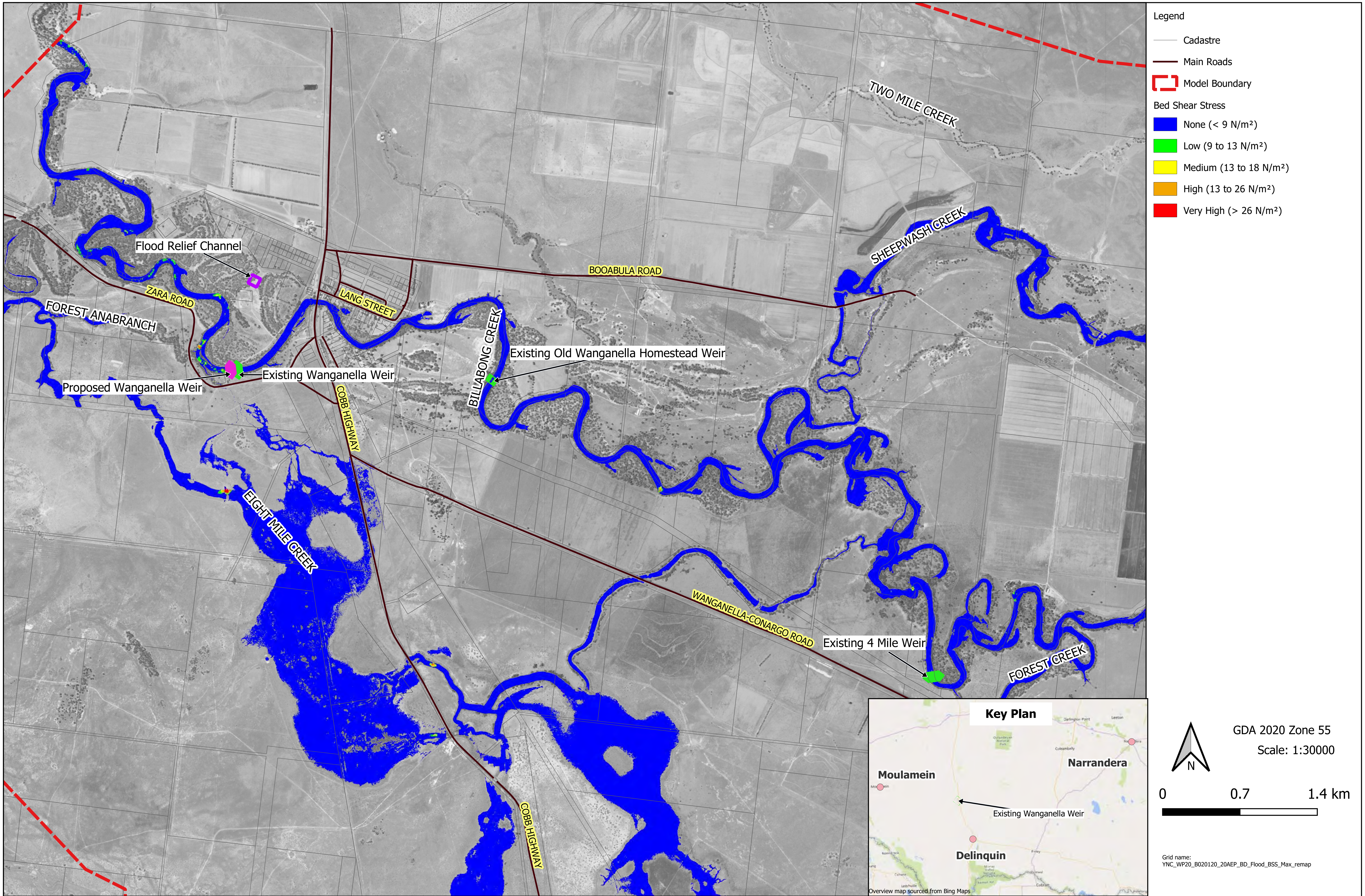
0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_PMF_BD_Flood_ZAEM1_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F4.12 - Maximum Hazard Plot (PMF)
"Proposed"

3Rivers

F5 Bed Shear Stress Maps

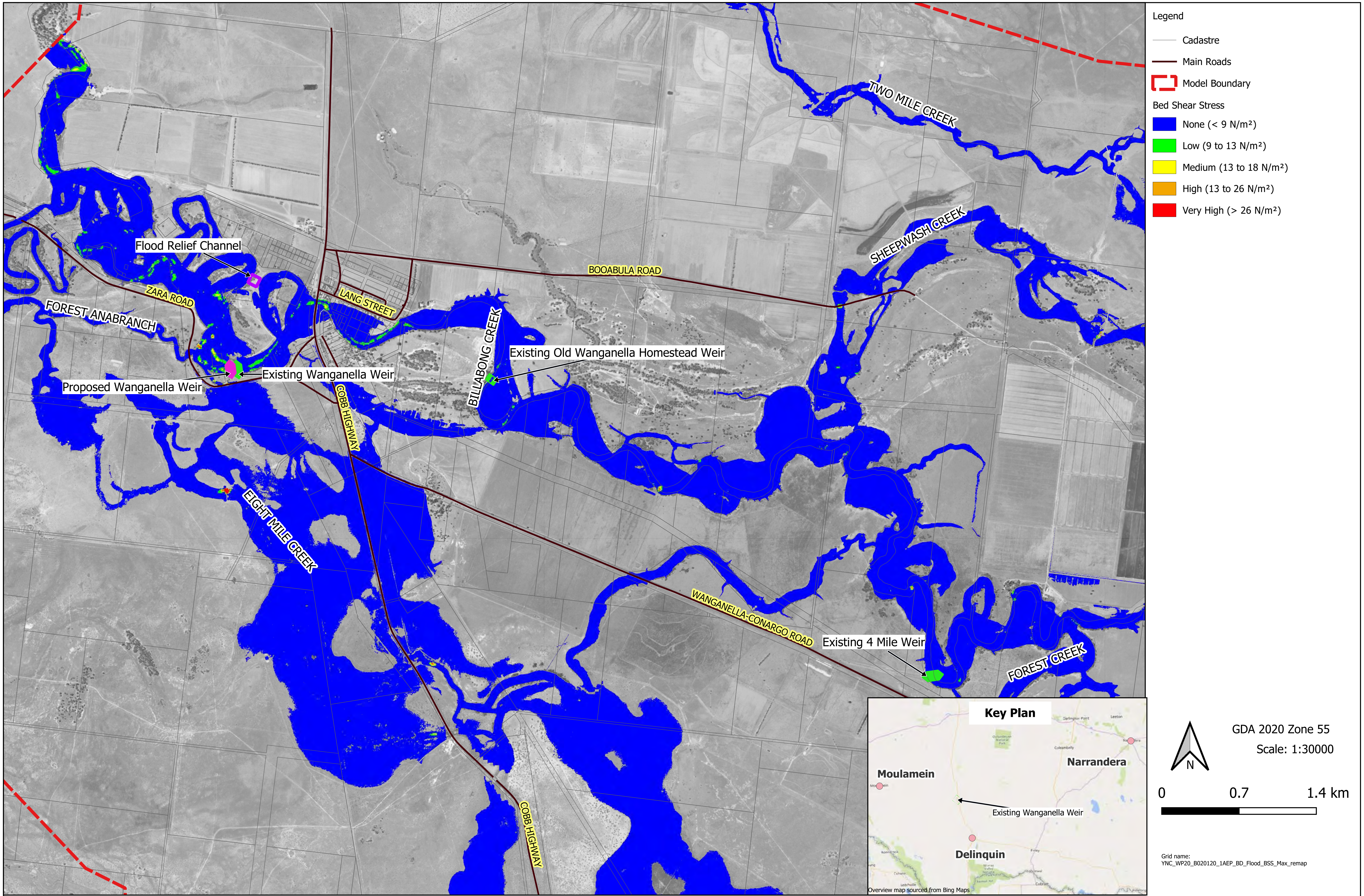


Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.1 - Maximum BSS Plot (20% AEP)
"Existing"

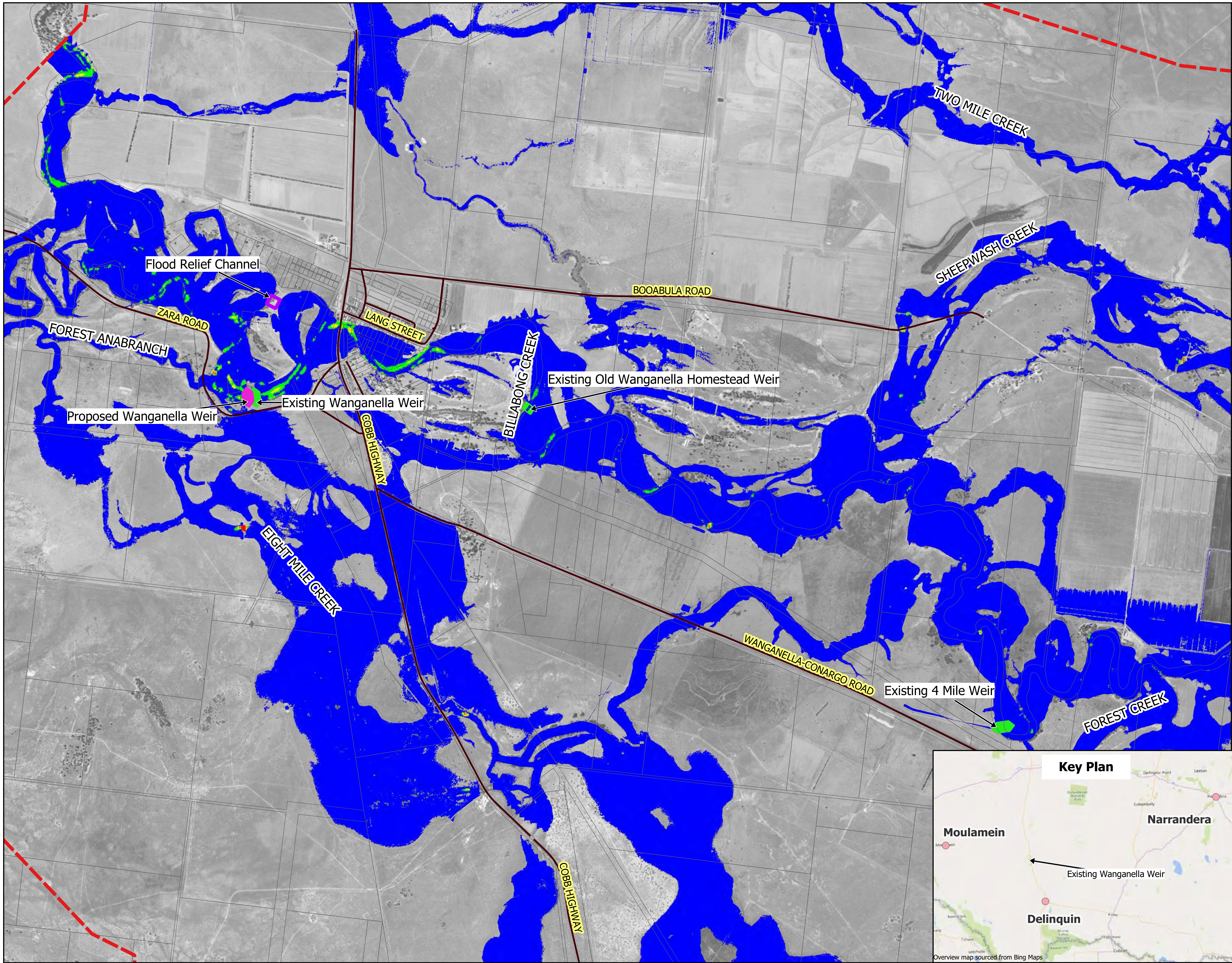
3Rivers

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.2 - Maximum BSS Plot (5% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.3 - Maximum BSS Plot (1% AEP)
"Existing"



Legend

- Cadastre
- Main Roads
- Model Boundary

Bed Shear Stress

- None (< 9 N/m²)
- Low (9 to 13 N/m²)
- Medium (13 to 18 N/m²)
- High (13 to 26 N/m²)
- Very High (> 26 N/m²)

N

GDA 2020 Zone 55

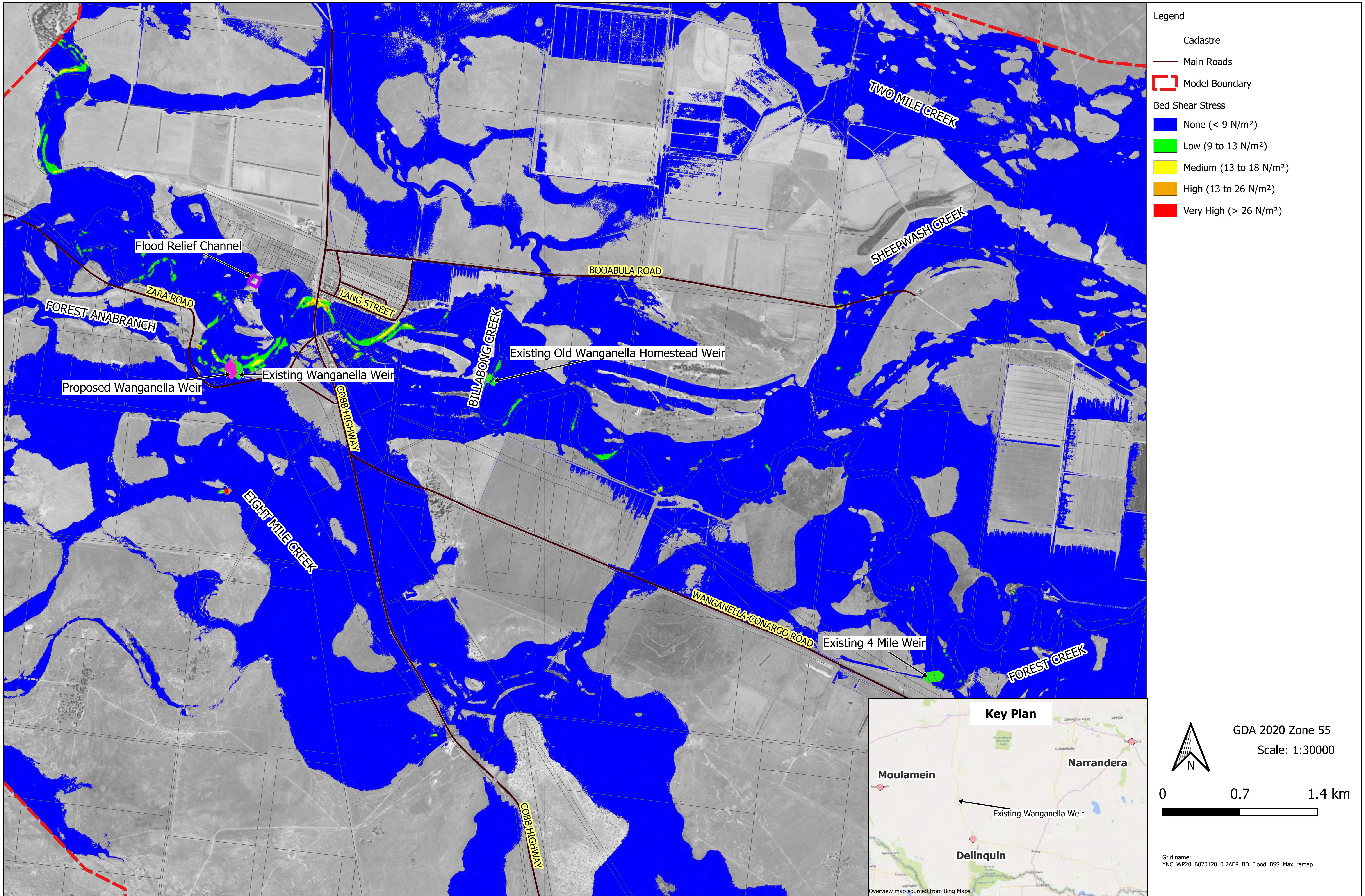
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_0.5AEP_BD_Flood_BSS_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.4 - Maximum BSS Plot (0.5% AEP)
"Existing"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.5 - Maximum BSS Plot (0.2% AEP)
"Existing"

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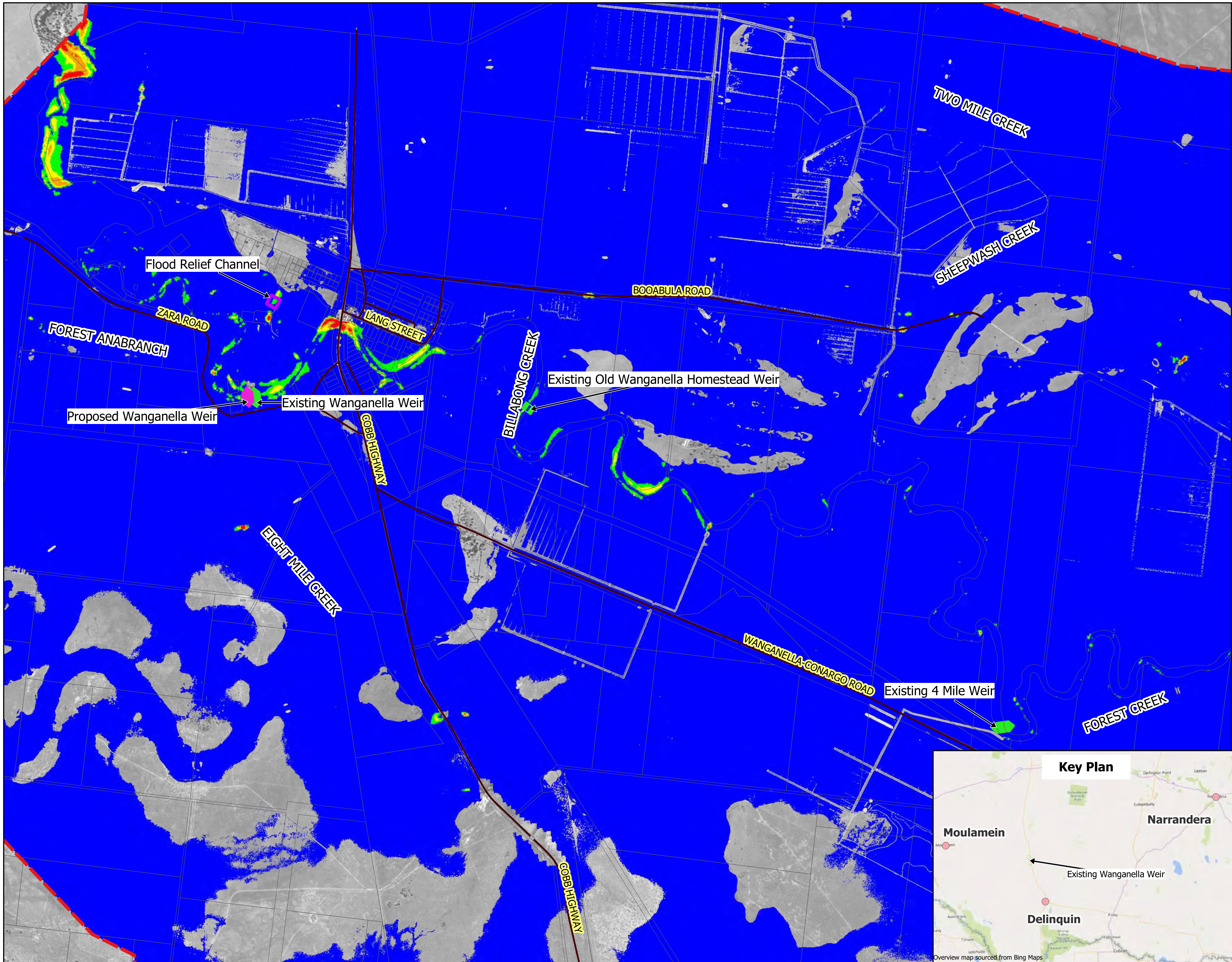


Legend

- Cadastre
- Main Roads
- Model Boundary

Bed Shear Stress

- None (< 9 N/m²)
- Low (9 to 13 N/m²)
- Medium (13 to 18 N/m²)
- High (13 to 26 N/m²)
- Very High (> 26 N/m²)

N

GDA 2020 Zone 55

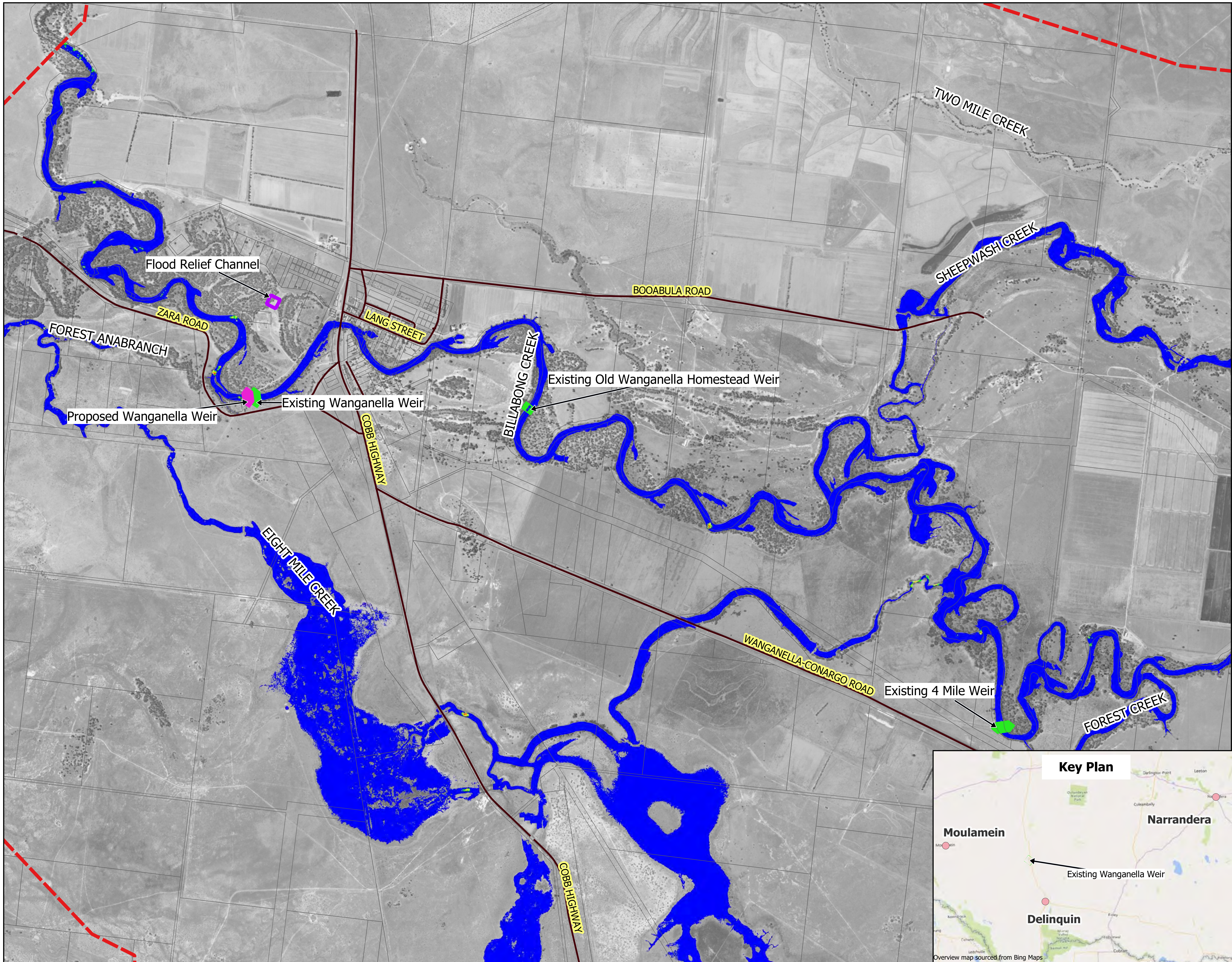
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_B020120_PMF_BD_Flood_BSS_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.6 - Maximum BSS Plot (PMF)
"Existing"

3Rivers



Legend

Cadastre

Main Roads

Model Boundary

Bed Shear Stress

None (< 9 N/m²)

Low (9 to 13 N/m²)

Medium (13 to 18 N/m²)

High (13 to 26 N/m²)

Very High (> 26 N/m²)

N

GDA 2020 Zone 55

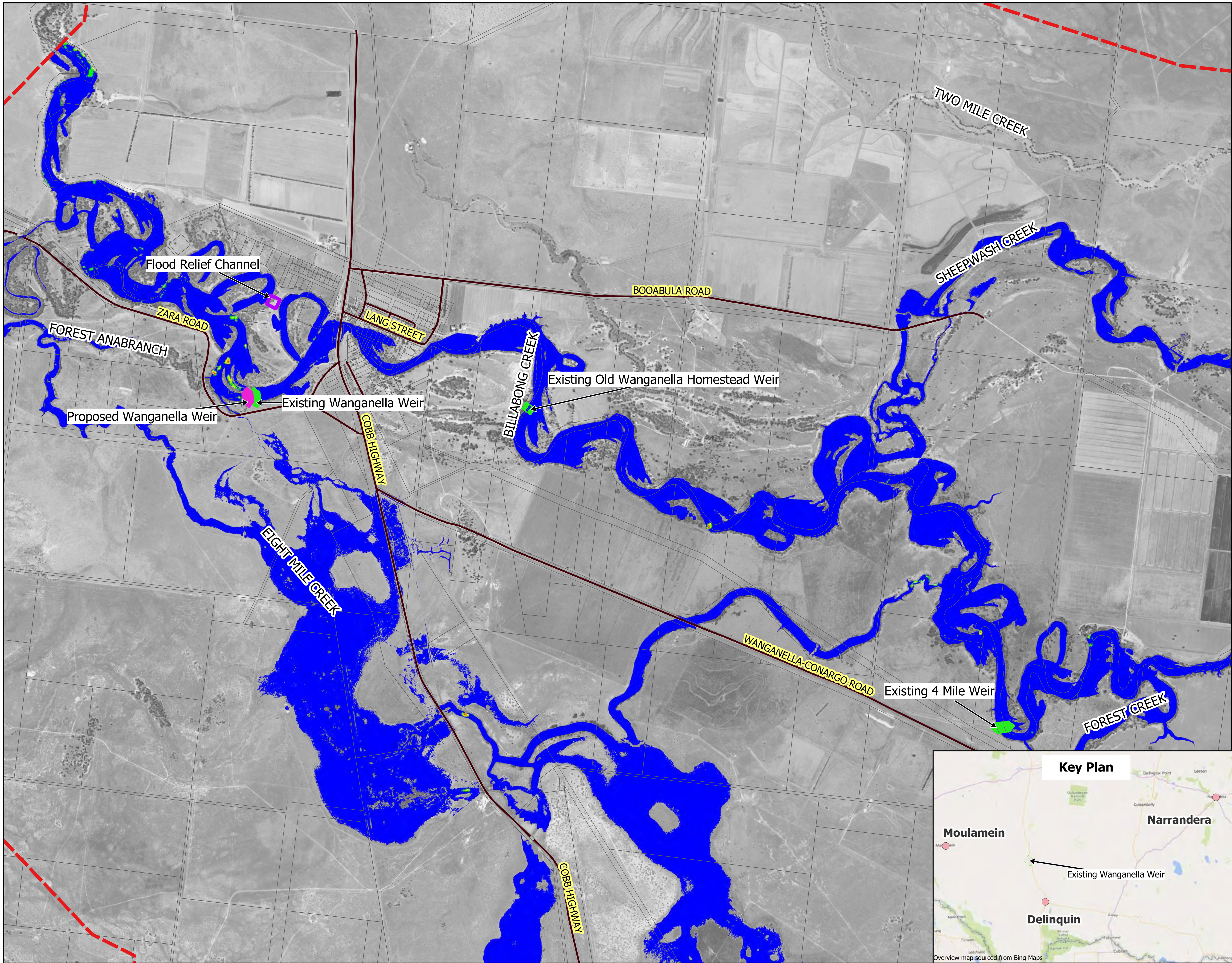
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_20AEP_BD_Flood_BSS_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.7 - Maximum BSS Plot (20% AEP)
"Proposed"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Bed Shear Stress

- None (< 9 N/m²)
- Low (9 to 13 N/m²)
- Medium (13 to 18 N/m²)
- High (13 to 26 N/m²)
- Very High (> 26 N/m²)

N

GDA 2020 Zone 55

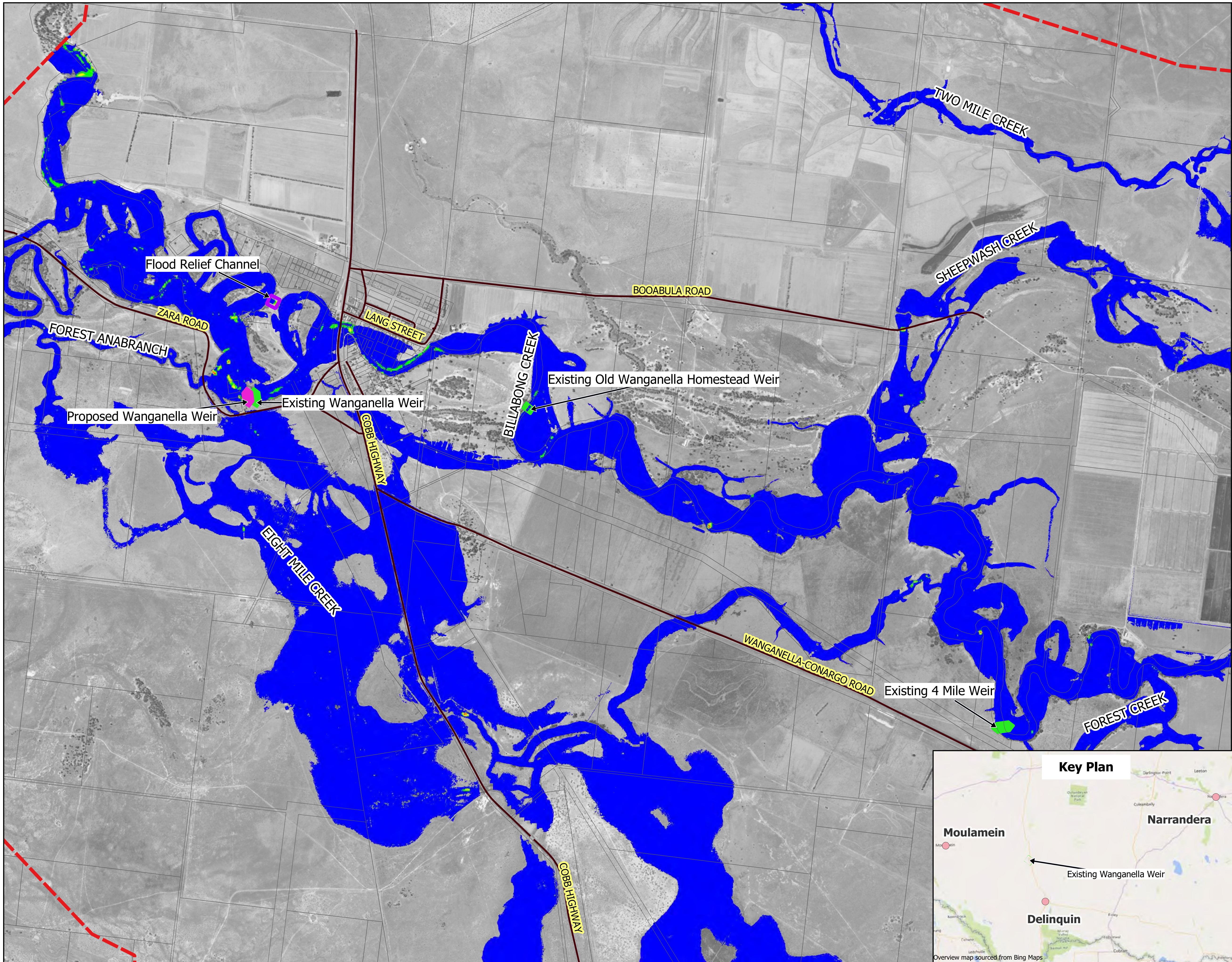
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_5AEP_BD_Flood_BSS_Max_remap

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.8 - Maximum BSS Plot (5% AEP)
"Proposed"

3Rivers



Legend

- Cadastre
- Main Roads
- Model Boundary

Bed Shear Stress

- None (< 9 N/m²)
- Low (9 to 13 N/m²)
- Medium (13 to 18 N/m²)
- High (13 to 26 N/m²)
- Very High (> 26 N/m²)

N

GDA 2020 Zone 55

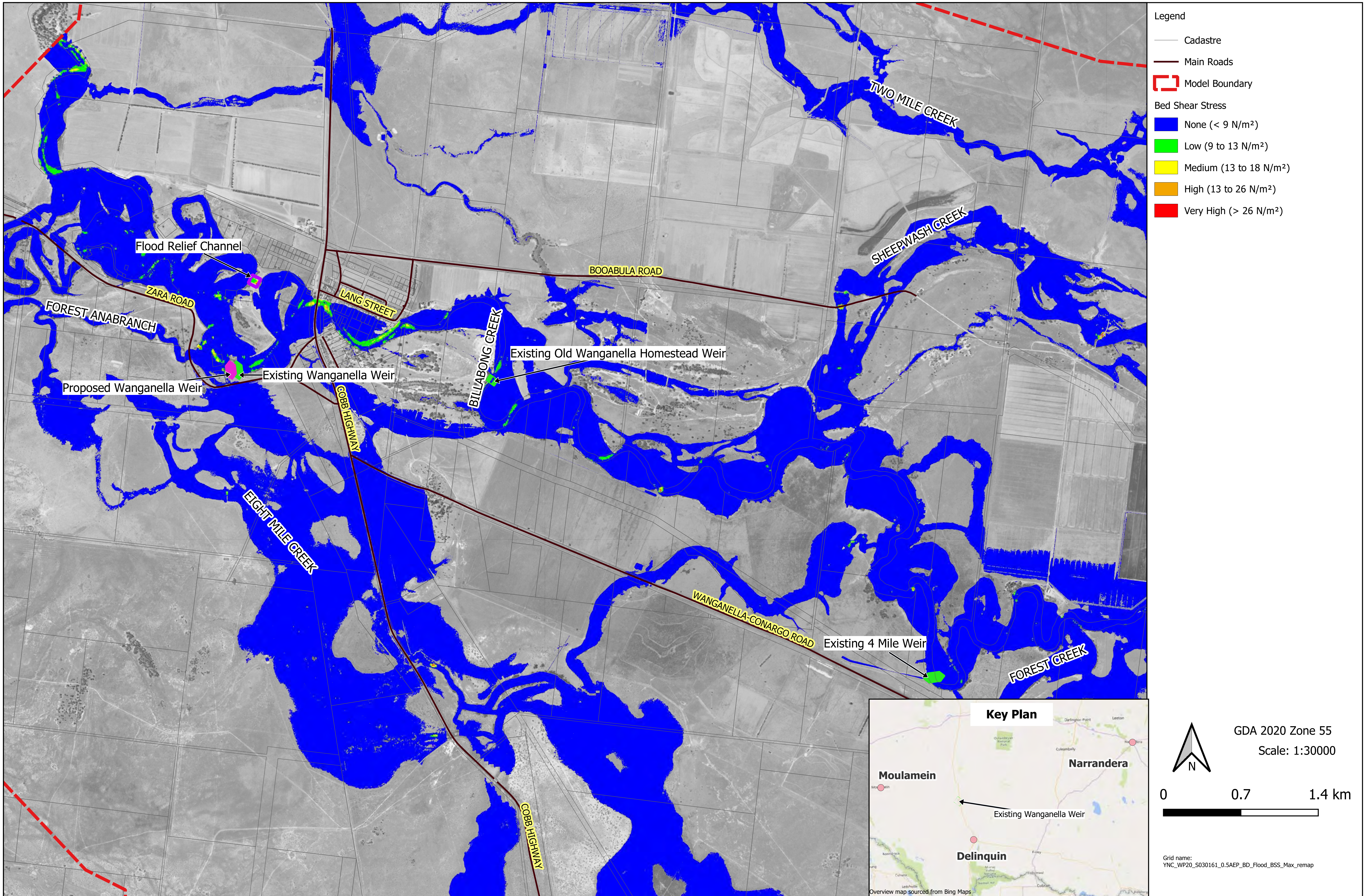
Scale: 1:30000

0 0.7 1.4 km

Grid name:
YNC_WP20_S030161_1AEP_BD_Flood_BSS_Max_remap

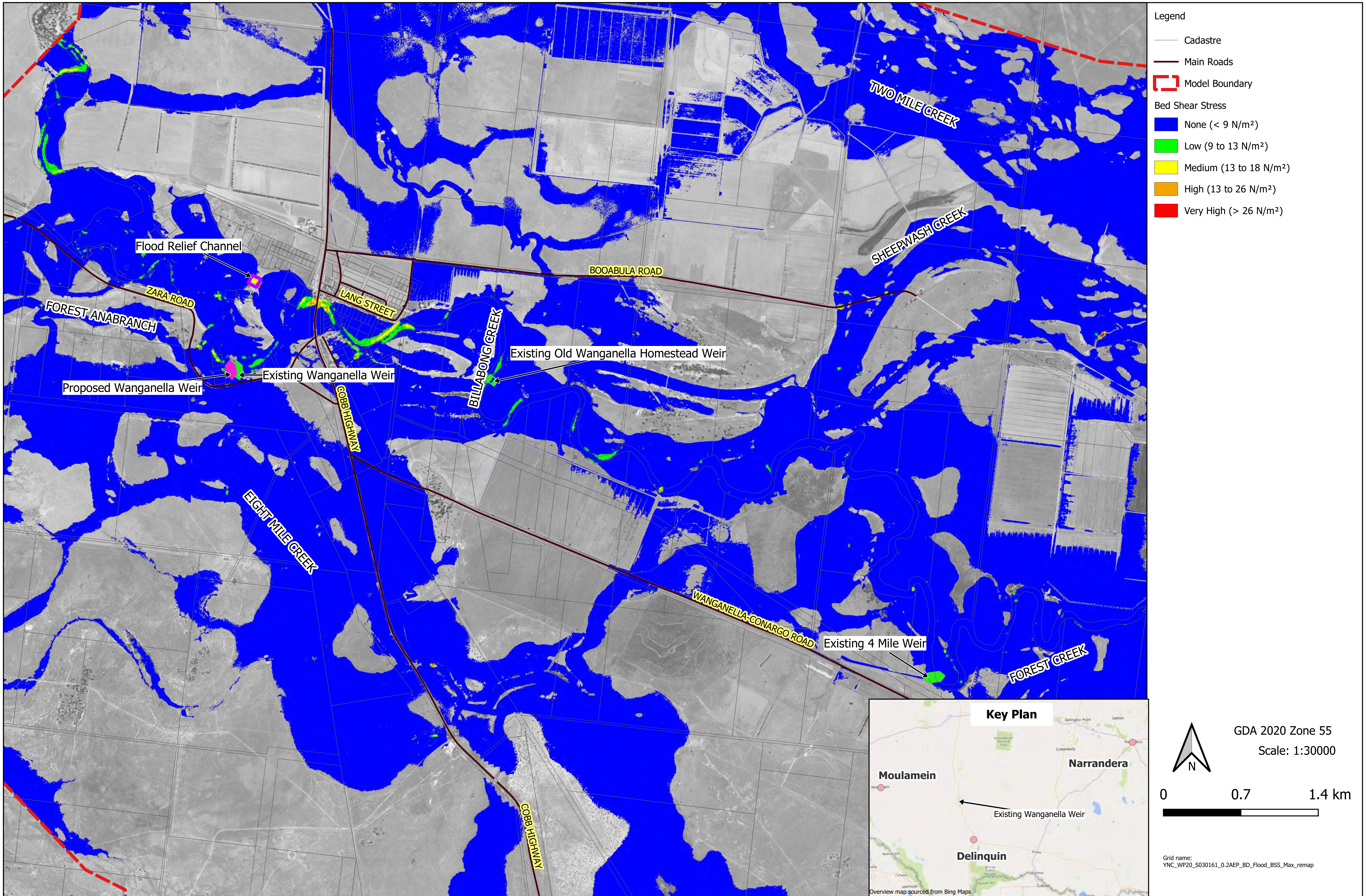
Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.9 - Maximum BSS Plot (1% AEP)
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.10 - Maximum BSS Plot (0.5% AEP)
"Proposed"

3Rivers



Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.11 - Maximum BSS Plot (0.2% AEP)
"Proposed"

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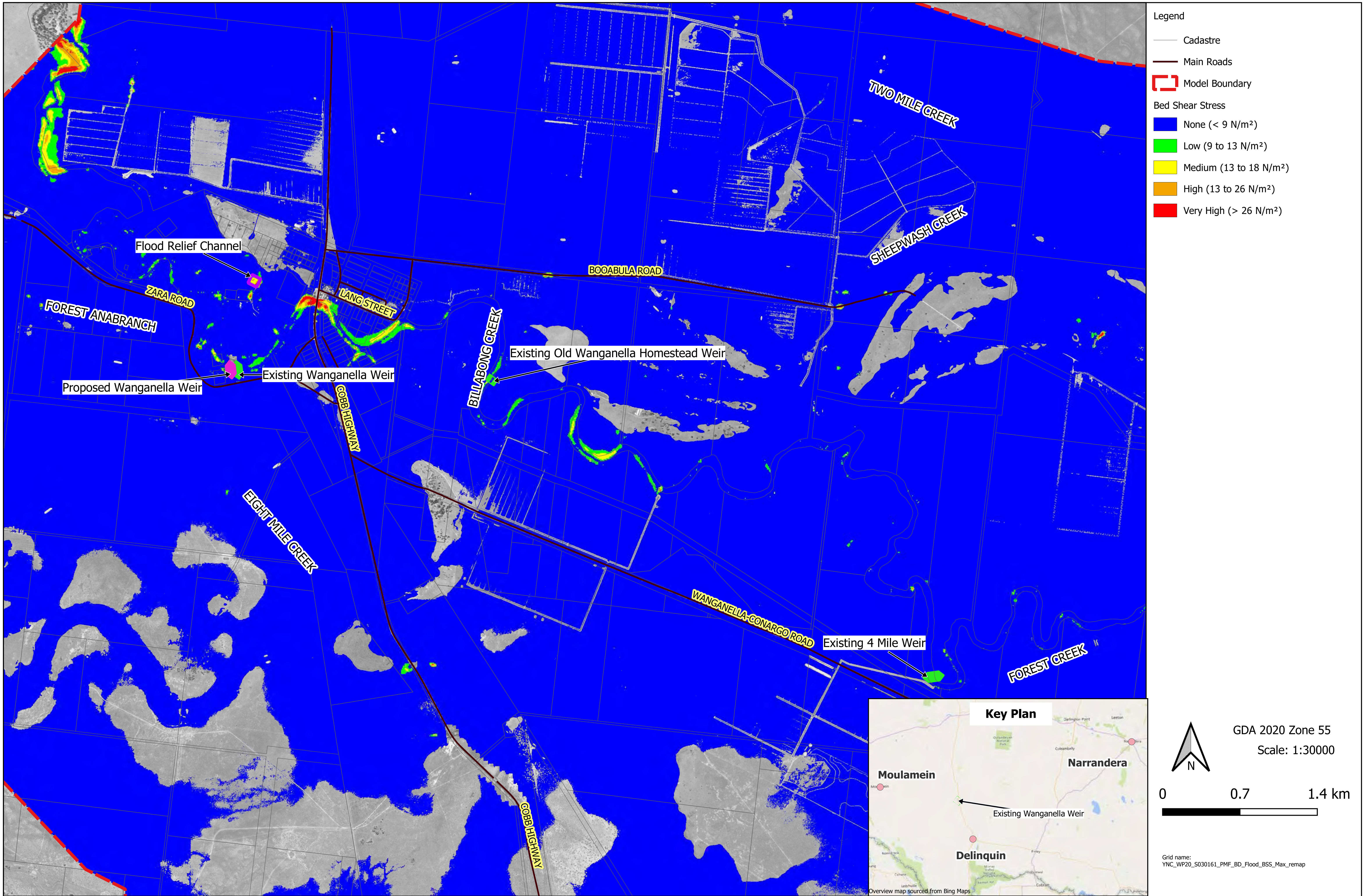

Yanco Creek Modernisation Program - Part 2 Wanganella Regulator
Figure F5.12 - Maximum BSS Plot (PMF)
"Proposed"

3Rivers