Moorabool Shire Council

Wallace Flood Study

Report

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0	29/10/2021	Wallace Flood Study Report	Alexander Nee	Jack Haywood	Jack Haywood	Glenn Ottrey
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Signatures						

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Contents

List of Tables

List of Figures

1 INTRODUCTION

1.1 STUDY OVERVIEW AND OBJECTIVES

Moorabool Shire Council (Council) engaged Engeny Water Management (Engeny) to undertake flood modelling for the town of Wallace and the surrounding area. Engeny understands that flooding has been reported in the town however the extent and susceptibility of the town to flooding is not well understood. The objective of the Wallace Flood Study is to improve Council's understanding of regional flood patterns to inform structure planning processes.

1.2 STUDY AREA DESCCRIPTION

As part of the study, Engeny has modelled a catchment area of approximately 16.7 square kilometres (km^2), rising from an elevation of 544 metres (m) Australian Height Datum (AHD) at Moorabool River West Branch to 630 m AHD at the north-western perimeter of the catchment along Springbank Road. Figure 1.1 shows the study area catchment and existing topography.

The catchment is predominately rural and farm zoned properties with some general residential and commercial properties along Bungaree-Wallace and Westcotts Road. The catchment includes parcels of land north and south of the Western Freeway (M8) which is a major Roads Corporation of Victoria (VicRoads) asset and runs perpendicular to Moorabool River West Branch.

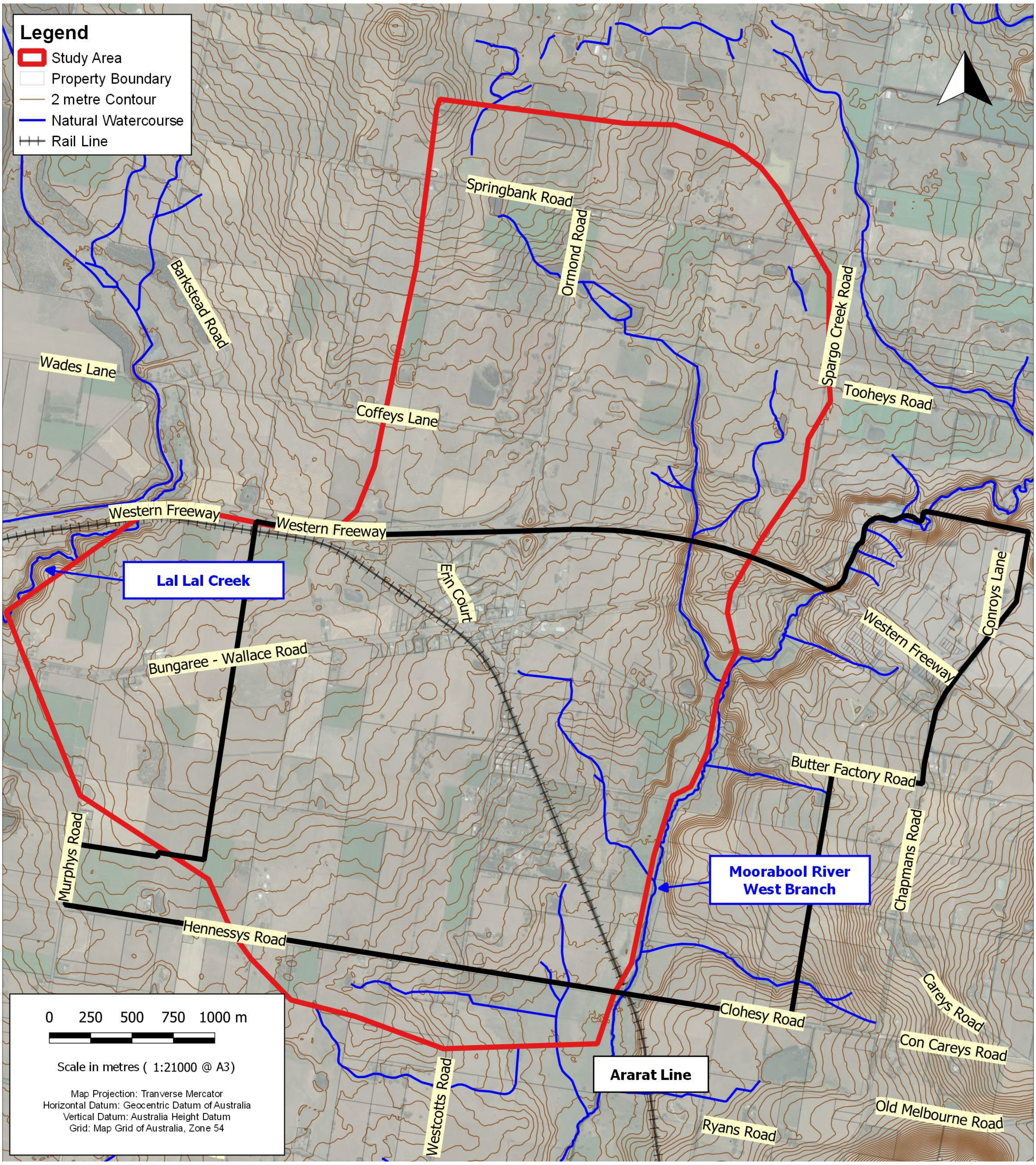
Although the study area includes sections of the Moorabool River West Branch, no modelling has been undertaken for the river itself. The Moorabool River West Branch does not run through the existing town of Wallace and is not expected to influence flooding within the township and therefore acts as a downstream boundary for the flood modelling undertaken which allows local catchment flows from the study area to discharge freely (discussed further in Section 3).

1.3 SCOPE

As per our discussions with Council, the following tasks were undertaken to address the key requirements of this study.

- Collation and analysis of Council and VicRoads existing drainage networks.
- Development of a rainfall-runoff hydrological (RORB) model using methods outlined in Australian Rainfall and Runoff 2019 (ARR 2019).
- Validation of the hydrological modelling rainfall losses to Rainfall Flood Frequency Estimation (RFFE) quantile estimates.
- Development of a hydraulic model using the industry standard TUFLOW flood modelling software.
- Hydraulic modelling of the 1 % AEP base case and climate change events.
- Preparation of flood maps showing the 1 % AEP base case flood depth and extent.
- Produce a plan identifying key overland flow paths within the catchments.

Figure 1.1: Catchment Study Area and Topography



2 DATA COLLATION AND REVIEW

Engeny obtained data and information to assist with the flood modelling from a variety of sources, including but not limited to Moorabool Shire Council, the Department of Environment, Land, Water, and Planning (DELWP), and the Data VIC website. Table 2.1 summarises the data used for this study, its purpose, and its source.

Due to the COVID19 restrictions, Engeny was not able to undertake a site visit. Council undertook a site visit on Engeny's behalf. The information provided by Council was used to fill missing gaps in the drainage data and informed waterway crossing measurements at several identified locations throughout the catchment. These locations and a description of the data provided by Council are summarised in **Appendix A.**

Table 2.1: Summary of Data Used

Data	Purpose	Source
NearMap Aerial Imagery (2021)	Used to identify land use within the catchment and verify the adopted losses and manning roughness values (an input to the hydraulic model)	NearMap
Light Detection and Ranging (LiDAR) Data (2011)	Used to verify the catchment study area and construct the Digital Elevation Model (DEM) (an input to the hydraulic model)	DELWP - Data accessed and provided by Moorabool Shire Council
10 – metre Elvis Elevation and Depth Foundation Spatial Data (Open Source)	Utilised to define hydrological sub-catchment delineation of hydrology model (outside of provided LiDAR extents)	Geoscience Australia
Mapbase Information (Including parcels, road easements, and planning zones)	Used to identify land use within the catchment and verify the adopted losses and manning roughness values (an input to the hydraulic model)	Data VIC
Commercial and Residential Building Footprints	Used to identify building footprints and inform catchment fraction impervious values	Microsoft derived from Bing satellite imagery
Council drainage pit and pipe data (GIS)	Used to construct one dimensional (1D) pit and pipe layers to accurately convey stormwater in the hydraulic model	Moorabool Shire Council
Council drainage pipe, culvert and bridge crossing survey data / photos	Used to fill in gaps in information in council provided 1D drainage pit, pipe, and culver t1D data and to inform two dimensional (2D) bridge and rail crossings	Moorabool Shire Council
VicRoads drainage pit and pipe (Layout plans and longitudinal sections)	Used to construct 1D pit and pipe layers to accurately convey stormwater in the hydraulic model along Western Freeway	Department of Transport (DoT)

3 FLOOD MODELING

3.1 OVERVIEW

Hydrological Modelling

A rainfall-runoff hydrological model was constructed using the software RORB to produce rainfall excess (rainfall minus losses) hydrographs for sub-catchments covering the study area. The RFFE model developed by Engineers Australia and the University of Western Sydney to estimate peak flows in ungauged catchments was utilised to validate the rainfall losses for 1 % AEP peak flows produced by the RORB model.

Hydraulic Modelling

A combined one-dimensional (1D) and two-dimensional (2D) dynamic hydraulic model of the study area was created and simulated using TUFLOW version 2020-10-AA to undertake flow routing and estimate flood water levels, extents, hydraulic variables for the 1 % AEP base case and climate change scenarios. The model has been run using TUFLOW's HPC solution schemes and adopted a 3-metre grid cell size.

3.2 HYDROLOGY

3.2.1 Model Development

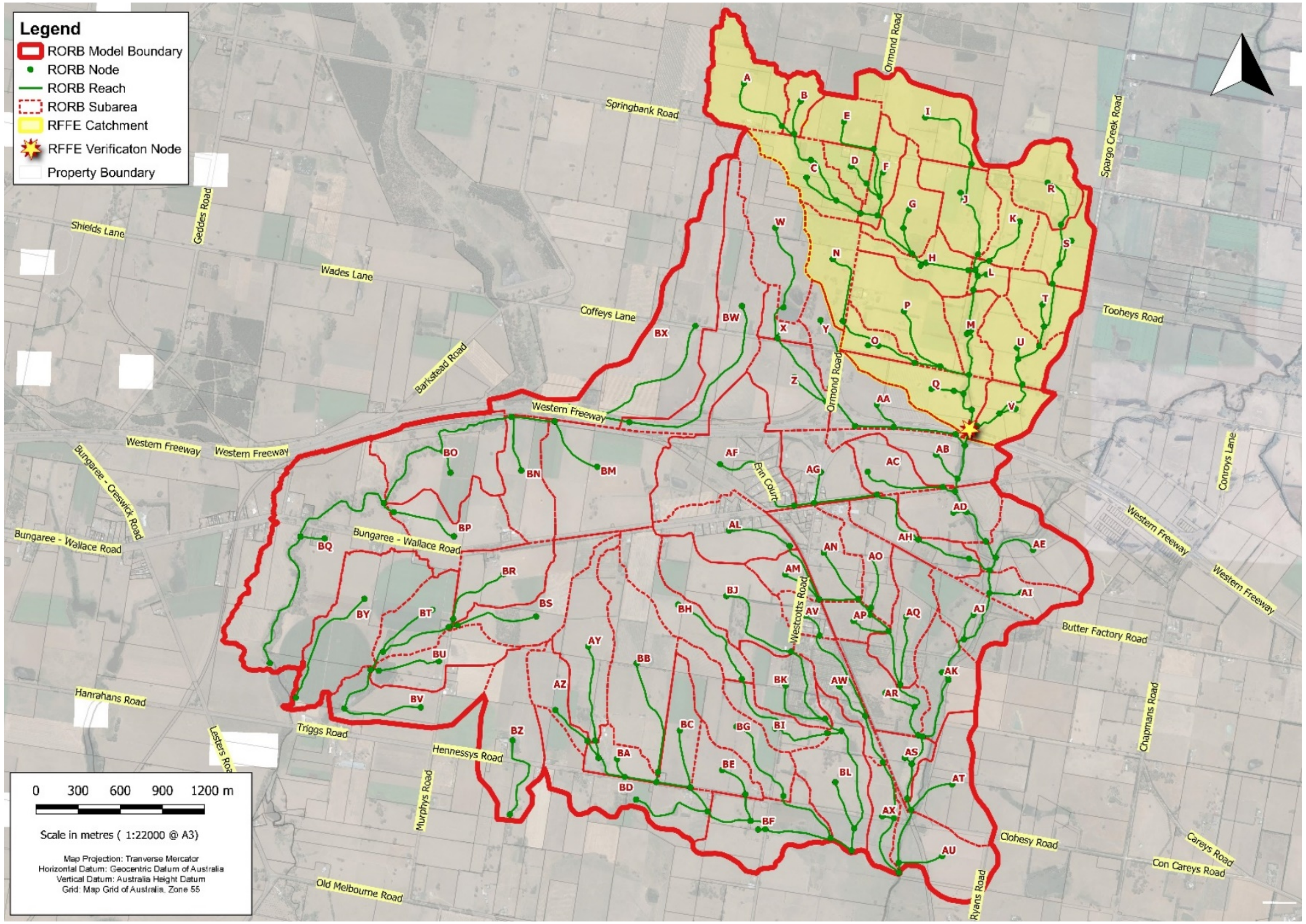
Catchment and Sub-Catchment Delineation

The sub-catchments for the RORB model were delineated considering the following information:

- 1 metre LiDAR (2011) provided Council.
- 10 metre elevation data and contours from ELVIS.
- Council and VicRoads drainage data.
- Land use identified in the Victorian Planning Scheme.
- Property boundaries.
- Aerial photography.

Figure 3.1 presents the RORB model setup and highlights the sub-catchment upstream of the Western Freeway which was used for determining RFFE quantiles and model verification.

Figure 3.1: RORB Model Layout



Fraction Impervious

Each sub-catchment within the RORB model was assigned an area weighted average fraction impervious value. These were based on individual fraction impervious values assigned to parcel areas of different land uses. Table 3.1 provides a summary of the typical FI values adopted for various land use types within the catchment.

Table 3.1: Typical Fraction Impervious Values for Land Uses

Land Use Type	Fraction Impervious (FI)
Farming Zones	0 – 5 %
Roads (unpaved)	20 – 30 %
Local roads and car parks (paved)	40 – 60 %
Major roads (paved	60 – 70 %
Low Density Residential Zones (Informed by lot sizes and aerial photography)	10 – 20 %
General Residential / Township Zones (Informed by lot sizes and aerial photography)	30 – 50 %
Rail Lines	40 %
Farm Dams / Ponds	70 %

3.2.2 Design Rainfall

Burst Depth

ARR2019 IFD data for the catchment was sourced from the Bureau of Meteorology (BoM) using the online Rainfall IFD request system. Data was requested for the catchment centroid. **Appendix B** presents the design rainfall depths for each duration and AEP for the catchment.

Climate Change Factors

The ARR Data Hub interim climate changes factors were requested for the catchment centroid and used to calculate increased rainfall scenarios. These values are presented in **Appendix B** and have been extrapolated to determine the 2100 climate conditions, resulting in a temperature increase of 3.5°C which correlates to an increase in rainfall of **18.4 %** within the Representative Concentration Pathway (RPC) 8.5 scenario. The RCP8.5 scenario is the ‘business as usual’ climate change scenario wherein minimal curbing of emissions is undertaken. This increase was applied via the burst depth within the hydrological model for the climate change scenario.

Spatial Variation

Uniform spatial patterns were adopted for this study given catchment area was less than 20 square kilometres.

Temporal Patterns

ARR2019 temporal patterns, downloaded from the ARR Data Hub, were adopted for the model. Point temporal patterns were used in this assessment, as per ARR2019 guidelines.

Areal Reduction Factors (ARF)

Engeny has considered the purpose of the study, which is to flood map the entire Wallace Township and surrounding area. Whilst the total hydrological study area is approximately 17 km^2, the study is a collection of individual sub-catchments, which drain to the Moorabool River West Branch, many of which are less than 1 km^2 and should be modelled as such. Therefore, it is appropriate to use an ARF of 1 for this study.

Rainfall Losses

The following rainfall loss values were extracted from the ARR Data Hub.

- IL = 25 mm
- CL = 4.3 mm / hr

These losses were verified by checking RORB modelled peak flow estimates to RFFE quantiles, rural prediction equations, and routed flow produced by the hydraulic (TUFLOW) model upstream of the Western Freeway. This is discussed in Section 3.5.

Pre-burst Depth

While the design rainfall values (IFDs) from the Bureau of Meteorology are for bursts, the initial loss values from the ARR Data Hub are for complete storms, not bursts. To calculate the initial loss for the design rainfalls (IL_B), the initial loss value for the complete storms (IL_S) was reduced by the pre-burst rainfall depth.

Initial burst losses were applied in RORB as duration factors, which were calculated as ratios between a burst initial loss (IL_B) for each duration and AEP and storm initial loss (IL_S). The pre-burst rainfall depth and adopted duration factors are summarised in **Appendix B.**

The recent Benchmarking ARR2019 for Victoria study undertaken by HARC (2020) found that the 75th percentile pre-burst rainfall magnitudes provided by ARR Data Hub provided a better fit across catchments in loss region 3 when compared to the median pre-burst rainfall magnitudes. The RORB model catchment falls within loss region 3, and as such the 75th pre-burst rainfall depths have been adopted for this study. As pre-burst depths are not provided for storm durations of less than 60 minutes, the pre-burst rainfall is assumed to be the same for durations 60 minutes and less.

3.2.3 Routing Parameters

The RORB model developed has been used to produce rainfall excess hydrographs only, rainfall – runoff flow routing has been undertaken in the hydraulic (TUFLOW) model. As such the RORB model routing parameters (k_c and m) do not have any influence on the flood mapping results presented in this study. Routing parameters were adopted to provide a sanity check of the Data Hub provided losses and RORB modelled peak flows upstream of the Western Freeway, discussed further in discussed in Section Model Verification3.5.

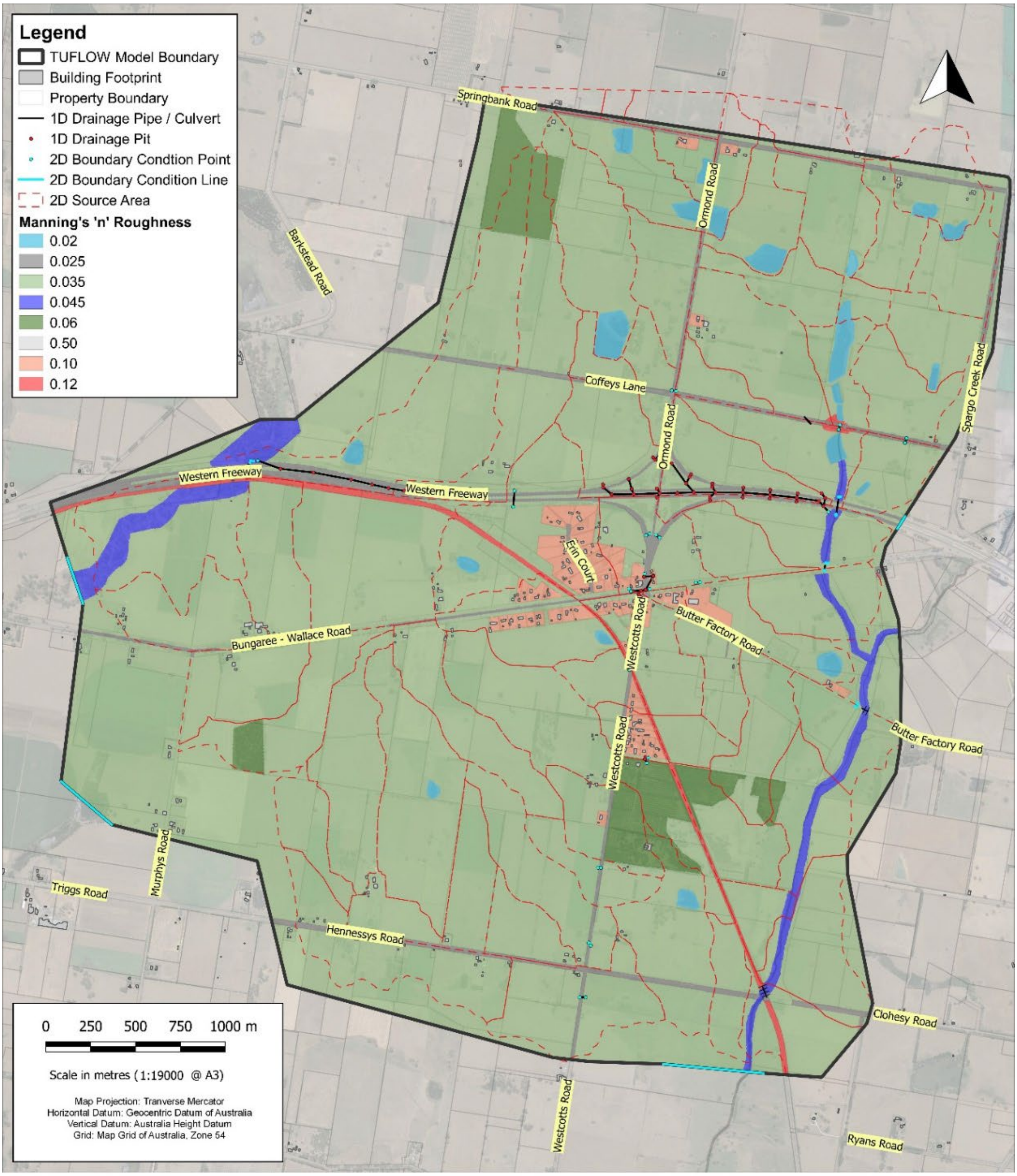
3.3 HYDRAULICS

3.3.1 Model Development

Model Extent

The extent of the hydraulic model matches that of the 1 metre LiDAR data provided by Council. Except for a few subareas north of Springbank Road, the hydraulic model extent matches the hydrological (RORB) model extent, which allows for the routing of flows for the study area in TUFLOW. The hydraulic model extent is sufficient to ensure that runoff through the township and surrounds is accurately modelled. Figure 3.2 shows the extent of the hydraulic model and depicts some of the key inputs to the model which are described further in the following sections of this report.

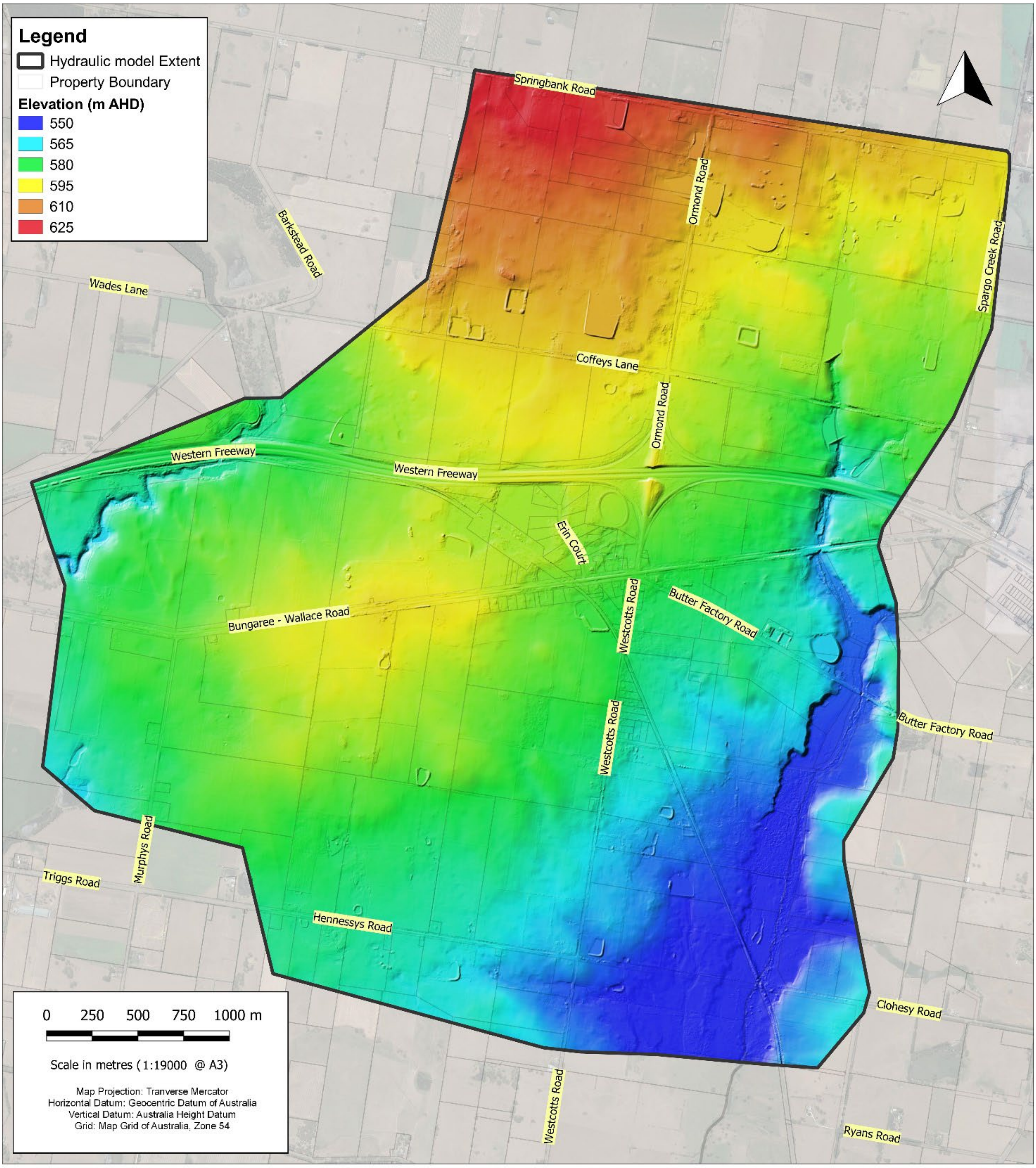
Figure 3.2: Hydraulic Model Layout



Digital Elevation Model

An underlying topographic Digital Elevation Model (DEM) was generated from the 2011 LiDAR data provided by Council with a 1-metre resolution. Engeny has adopted a grid (cell) size of 3-metres for the TUFLOW model. This grid size allows for an appropriate definition of the catchment terrain and reasonable simulation times to run the model. Figure 3.3 presents the generated DEM for the hydraulic model extent, the red areas indicate areas of higher elevation, and the blue areas designate the areas of lower elevation.

Figure 3.3: Hydraulic Model DEM



Surface Roughness

Within TUFLOW, a materials layer is utilised to define surface roughness information in the model. The GIS property layer available from the Department of Environment, Land Water and Planning (DELWP) was used as a base for setting up the materials layer. The materials layer was created by assigning a Manning's roughness value to land parcels according to the land use based initially on planning zone type. The roughness values were refined further based on the land use shown in the aerial imagery such as open pervious areas originally categorised as paved roads along the Western Freeway. These roughness values are listed in Table 3.2.

Table 3.2: Hydraulic Model Roughness

Land Use	Manning's 'n' Roughness
Open pervious area, minimal vegetation	0.035
Open pervious area, moderate vegetation	0.06
Open pervious area, dense vegetation	0.12
Paved roads / carparks / driveways	0.025
Commercial and residential building footprint	0.50
Remainder of parcel (general residential)	0.10
Railway Line	0.12
Waterways / open channels, moderate vegetation	0.045
Farm Dams / ponds (assumed to be full)	0.02

Boundary Conditions

The TUFLOW model includes a series of 1D and 2D boundary conditions to control points where the overland flow enters or leaves the drainage networks. 2D boundary conditions have been assigned to each 1D drainage network included in the model to allow discharge of water from the pipe network to the 2D surface and also allow runoff to enter the 1D network if the pipe capacity allows it.

HQ (head versus flow) lines were drawn at the catchment boundaries to allow overland flow to leave the model at the catchment outlets. The relationship is based on the downstream terrain slope as an input. These were positioned in the following locations:

- Downstream of the study area where the West Moorabool River Branch discharges south.
- West of the study area where Lal Lal Creek and its tributaries exit the model.
- Along the Western Freeway where it intersects the eastern model extent.

Source Areas

As most of the sub-catchments used to define the hydrological model do not have any underground drain inlet pits, 2D source areas (2d_sa) polygons matching the hydrological RORB sub-catchment have been used to apply rainfall-excess inflow evenly to each cell within the 2D domain.

Initial Water Levels

Polygons were digitised and assigned an initial water level for all significant dams along the major tributaries within the model. This was also done for other farm dams that displayed significant storage capacity. As LiDAR generally defines the water level in the dam at the time of the LiDAR capture, the initial water level shapes have been used to fill the dams to just below the spilling point so that the dams do not provide flood storage in the modelled storm events. This is a conservative approach.

3.3.2 Council and VicRoads Drainage Data

Geographic Information System (GIS) tables of Council's drainage assets were provided for the study area. The majority of these drains were 375 mm in diameter or smaller.

All major culvert and bridge crossings along VicRoads and Council owned roads have been included in the model with the culverts modelled as pipes in the 1D domain and bridges modelled as layered flow constrictions in the 2D domain. During the data collection phase, emphasis was taken to ensure data gaps for the major culvert and bridge crossings along the Western

Freeway and major overland flow paths were resolved. The accuracy of representing the correct dimensions of drainage structures in these locations was considered particularly important, as they represented important hydraulic constrictions to overland flow paths within the study area. The data was sourced from:

- Council which included information from internal data records as well as onsite measurements / observations **(Appendix A).**
- VicRoads which included as constructed/ design drawing plans culverts.

Table 3.3 and Table 3.4 provides a summary of the major culvert and bridge crossings included within the TUFLOW. Utilising the referenced IDs, the locations of these are displayed within Figure 3.4.

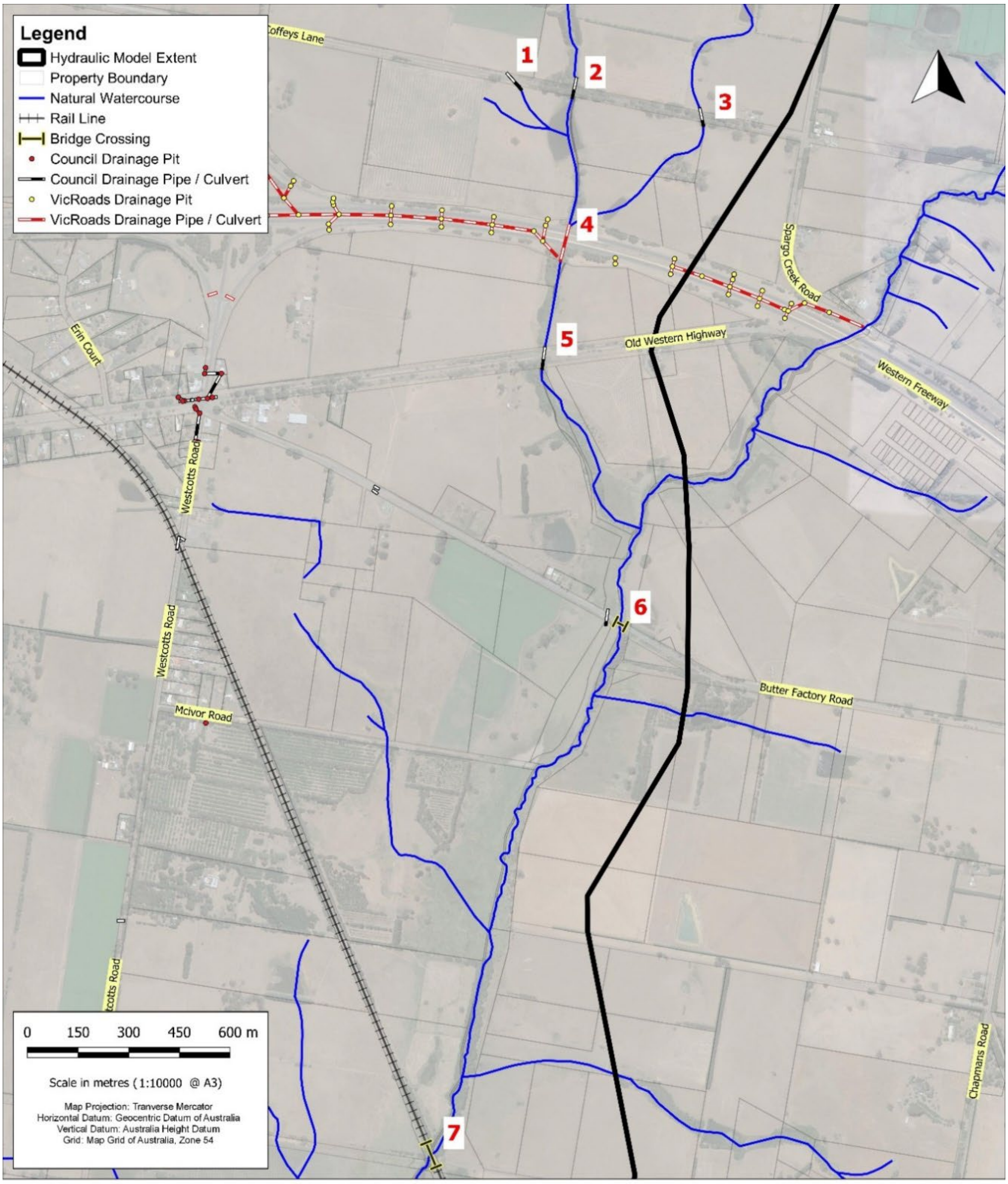
Table 3.3: Summary of Existing Culvert Structures

Location (Figure 3.4)	Description	Dimensions	Comments
1	Circular culvert	2 x 380 mm	-
2	Assumed circular culvert	2 x 380 mm	Council could not locate culvert during site visit but confirmed asset in their database. Assumed same dimensions as Location 1
3	Circular culvert	1 x 380 mm	
4	Circular culverts	3 x 1980 mm	From VicRoads Drainage plans
5	Box culvert	1 x 1800 mm (width) x 2400 mm (height)	Modelled as 50 % blocked according to Council onsite photos and comments
6	Box culverts	4 x 1220 mm (width) x 750 mm (height)	Modelled as 25 % blocked according to Council onsite photos and comments

Table 3.4: Summary of Existing Bridge Structures

Location (Figure 3.4)	Pier Blockage	Deck Height (m)	Bridge Deck Width (m)	Railing Height (m)	Railing Blockage	Comments
6	0 %	1.9	0.7	1.15	30 %	Bridge ID plate 006092
7	16 %	1.7	1.2	0	0 %	Rail track has been pulled up

Figure 3.4: Location of Bridge and Culvert Structures Along Key Overland Flow Paths



3.4 SCENARIOS AND DURATIONS MODELLED

For each AEP, Engeny have run a single, middle loaded temporal pattern design storm through the hydraulic model. This was completed to determine the critical durations throughout the catchment. Five critical durations (10 minute through to 2 hour) were selected based on the above approach, for which then all ten temporal patterns were run through the hydraulic model for each of those critical durations and AEP events.

For each grid cell, the flood height derived from the median temporal pattern was taken for each duration. The maximum for all durations was then taken to provide the design flood depth for each AEP. This was repeated for the other gridded outputs as part of this study.

3.5 MODEL VERIFICATION

There are no flow gauges located on any of the waterways within the study catchment. The lack of gauge data means that the hydrological (RORB) model was not calibrated, and in turn, the routing and loss parameters were not calibrated to known events.

Verification of the Data Hub rainfall losses was undertaken by checking TUFLOW modelled peak flow estimates to RFFE quantiles, rural prediction equations, and routed flow estimates produced by the hydrological (RORB) model for the approximately 4.4 km^2 of contributing catchment upstream of the Western Freeway (refer to Figure 3.1). The routing parameter, *m*, in RORB was set at 0.8 area as per the recommendations in the RORB manual and ARR 2019. The routing parameter, k_c , value was derived from the regional prediction equations provided in ARR 2019 (Book 7, Chapter 6, ARR 2016).

Table 3.5 provides a comparison between the TUFLOW 1 % AEP modelled peak flows to RFFE quantiles, rural prediction equations, and RORB estimates using the various regional k_c prediction equations. Based on Engeny's experience in hydrologic and hydraulic modelling the flows from the RFFE tool seem unrealistically low given the size of the catchment. The Nikoloau / vont Steen prediction equation[1] and hydraulic modelling results suggest flows well above the upper confidence of the RFFE. Therefore, it is assumed that the RFFE is underpredicting flows for the catchment area and as such the results from the RFFE tool have been disregarded for flow validation.

The k_c as a function of the average flow distance (d_{av}) equations provided by Pearse (2002), Dyer (1993), and Yu (1989), provide reasonable peak flow estimates, ranging between 20.9 and 26.5 m^3/s, for the catchment area. The routed flows in the hydraulic (TUFLOW) model provide a larger peak flow estimate of 28.4 m^3/s. This is expected due to the significant number of dams that have been modelled as full in the hydraulic model which reduces the routing time and storage within the catchment, increasing the peak flow rates.

Since the focus of this study is to identify key flood patterns within the study area and determine flood risk for development, the adopted loss values which provide conservative flow estimates in the hydraulic model (i.e., above the upper confidence limit of RFFE estimate and rural prediction equation) were considered appropriate.

Table 3.5: Comparison of RORB Model Peak Flows RFFE quantiles, rural prediction equations, and TUFLOW estimates (1 % AEP event)

Source	k_c value	RORB Modelled Peak Flow (m^3/s)	RORB Modelled Critical Duration	RFFE Expected Flow (m^3/s) (Confidence Limit)	Nikoloau / vont Steen Approximate Peak Flow for Rural Catchments (m^3/s)	TUFLOW peak flow (m^3/s) (Critical Duration)
Victoria (Mean Annual Rainfall > 800 mm) k_c = 2.57 x *Area* $^{0.45}$	4.98	9.0	2 hour	3.9 (1.2 – 12.6)	15.5	28.4 (2 hour)
Victoria Wide Data (Pearse et al, 2002) k_c = 1.25 x d_{av}	2.4	20.9	2 hour			
Australia Wide Dyer (1994) data (Pearse et al, 2002) k_c = 1.14 x d_{av}	2.19	22.8	2 hour			
Australia Wide Yu (1989) data (Pearse et al, 2002) k_c = 0.96 x d_{av}	1.84	26.5	2 hour			

[1] Melbourne Water's Flood Mapping and Technical Specifications (September 2020) recommend that the following Nikoloau / vont Steen equation for urban catchments be used as a sanity check for modelled flow rates: $Q_{100} = 4.67 \times Area^{0.763}$

4 FLOOD MODELLING RESULTS AND MAPPING

4.1 FLOOD DEPTH RESULTS

The 1 % AEP base case and climate change flood depth layout plans have been included in **Appendix D** and **Appendix E** respectively**.** These results have been filtered to display depths greater than 50 mm only.

4.2 FLOOD EXTENTS

The following 1 % AEP flood extent polygons have been provided to Council in GIS (ESRI Shapefile) format.

1. **Raw flood extent –** A 50 mm filter was applied to the raw 1 % AEP flood depth grid.
2. **Filtered flood extent** – The following approach has been adopted to ensure a more smooth and continuous extent:
    a) 50 mm filter was applied to the raw 1 % AEP flood depth grid.
    b) The filtered extent was smoothed using the Feature Manipulation Engine (FME).
    c) Small elevated dry island "holes" were filled within the extent.
    d) All isolated areas of flooding not within the main overland flow paths for areas less than 500 m^2 were removed as these do not represent active flow paths.
    e) Flow paths have been joined particularly where flows overtop roads to capture very shallow sheet flows which were originally interpolated out through results processing functions.

The 1 % AEP filtered flood extent plan has been included in **Appendix E.** These are the areas in which Council should focus on controlling future development. Depending on the depth of flooding and the velocity of flow, development may be permissible, but it should be subject to conditions that ensure that dwellings are not subject to flooding and that people are not placed at risk from flood waters.

It is recommended that the filtered flood extent be used to improve Council's understanding of regional flood patterns and could be used as a basis to inform structure planning processes, however further refinement of the extent is recommended if it is to be adopted into the planning scheme as an SBO.

4.3 KEY FLOOD PRONE AREAS

Utilising the flood mapping results produced, several key areas subject to inundation were identified. The following provides a summary of these locations.

- Key overland flow paths along the West Moorabool River Branch and other minor watercourses (identified within the DELWP GIS watercourses layer and shown in **Appendix E** plans).
- Minor overland flow paths originating from the upstream catchment causing ponding at low points along Coffeys Land and the Western Freeway – Ormond Road off Ramp.
- Several parcels north of Bungaree – Wallace Road showing ponding of more than 300 millimetres.
- Minor overland flow paths originating south of Butter Factor Road and West of Westcotts Road and extending to the Moorabool River West branch upstream of the Ararat train line.
- Minor overland flow path originating north of Hennessys road and west of Westcotts Road discharging into the Moorabool River West Branch just downstream of the hydraulic model extent.

5 CONCLUSIONS AND RECOMMENDATIONS

From the flood modelling undertaken, Engeny provides the following summary of outcomes.

- Major overland flow paths though the study area coincide with the existing watercourse, Moorabool River West Branch.
- Minor overland flow paths are present through the broader Wallace township area.
- Numerous localised trapped low points exist within the study area. Some of these areas pond to significant depths (greater than 300 mm) within the township.
- Development of this area will significantly increase the fraction imperviousness of the land and will increase future runoff volumes.

Considering the findings of this study, Engeny recommends:

- Appropriate waterway setbacks are included in any development plan which would prevent development in areas subject to flooding in a 1 % AEP adjacent to waterways. The final discretion for waterway setbacks rests with the Corangamite Catchment Management Authority (CCMA), who should be consulted on this matter.
- Finished floor levels of future developments are set to a nominated freeboard height above the developed conditions flood levels. The amount of freeboard should be confirmed with CCMA (if the flooding is associated with a designated waterway) but would typically be 300 or 600 mm.
- The numerous trapped low points which are shown as flooding should not be developed unless the topography is regarded so that they are free draining. This could be achieved by filling these areas or boxing out roads so that they drain towards existing open channel drains which drain into the Moorabool River West Branch waterways. Relying on underground drains alone in these areas would present a significant risk of flooding in the future should a storm occur which exceeds the underground drainage capacity of the system. This should be set as a condition of developing these areas of land.
- Upgrades will be required to the existing drainage infrastructure within the town zone as it is currently sized to provide a level of service suitable in a small urban town with low levels of development and would be undersized if development densities are increased.
- Any future development within this area should adopt the drainage requirements outlined in the Infrastructure Design Manual (IDM) in addition to what is listed above.
- Mitigation measures should be included in any development plan to protect downstream properties and the receiving waterways from an increase in peak flow discharges from the developed areas. While outside the scope of this report, frequent flows and stormwater quality should also be addressed prior to discharge into the waterways.

6 REFERENCES

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Appendix A:
Culvert and Water Crossing Survey Data and Notes Provided

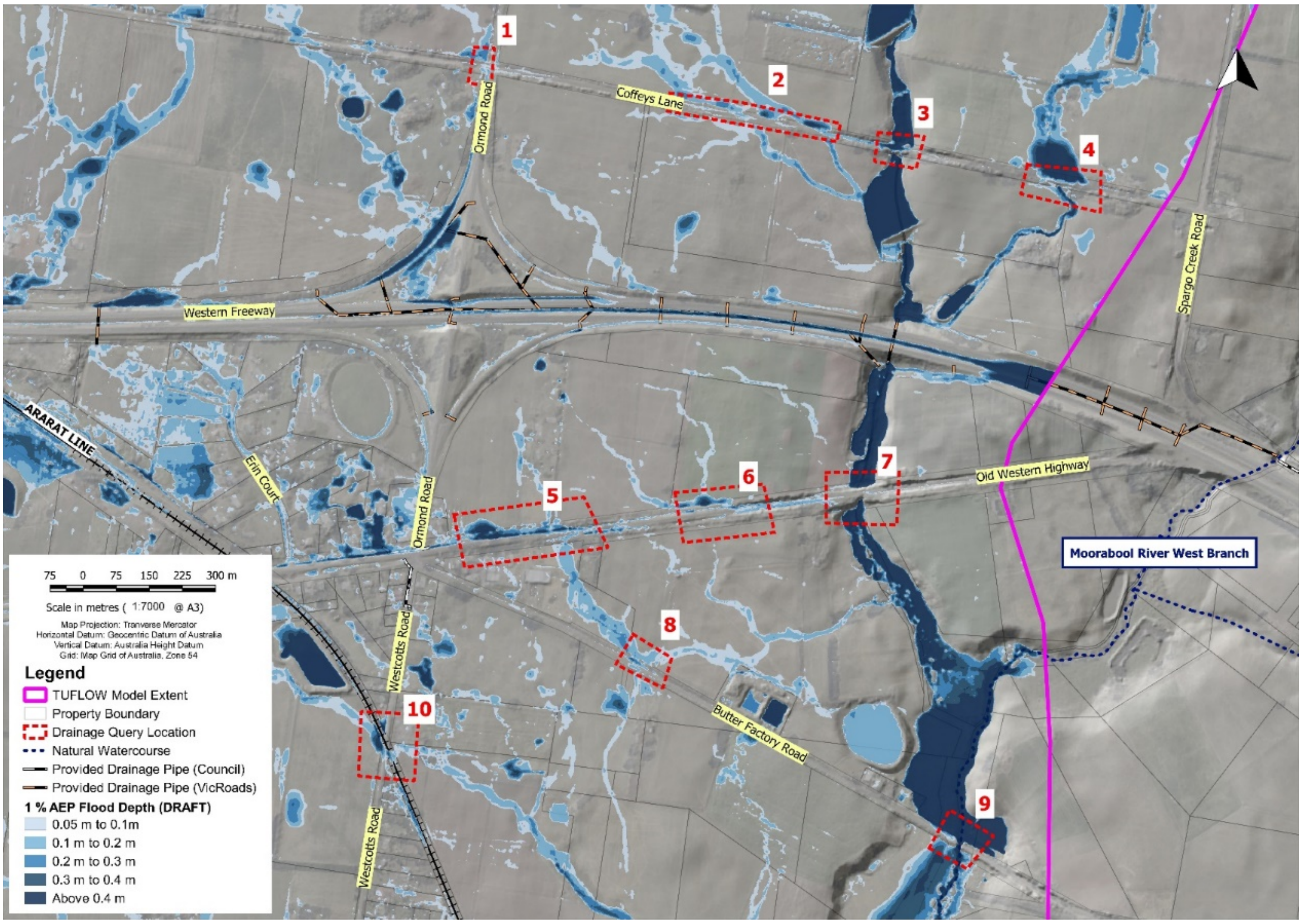
Appendix Table A- 1 provides a summary of the drainage and waterway survey measurement and comments at each of the locations presented in Appendix Figure A- 1 and Appendix Figure A- 2.

Appendix Table A- 1: Summary of Engeny Drainage and Waterway Crossing Queries and Council Provided Measurements and Comments

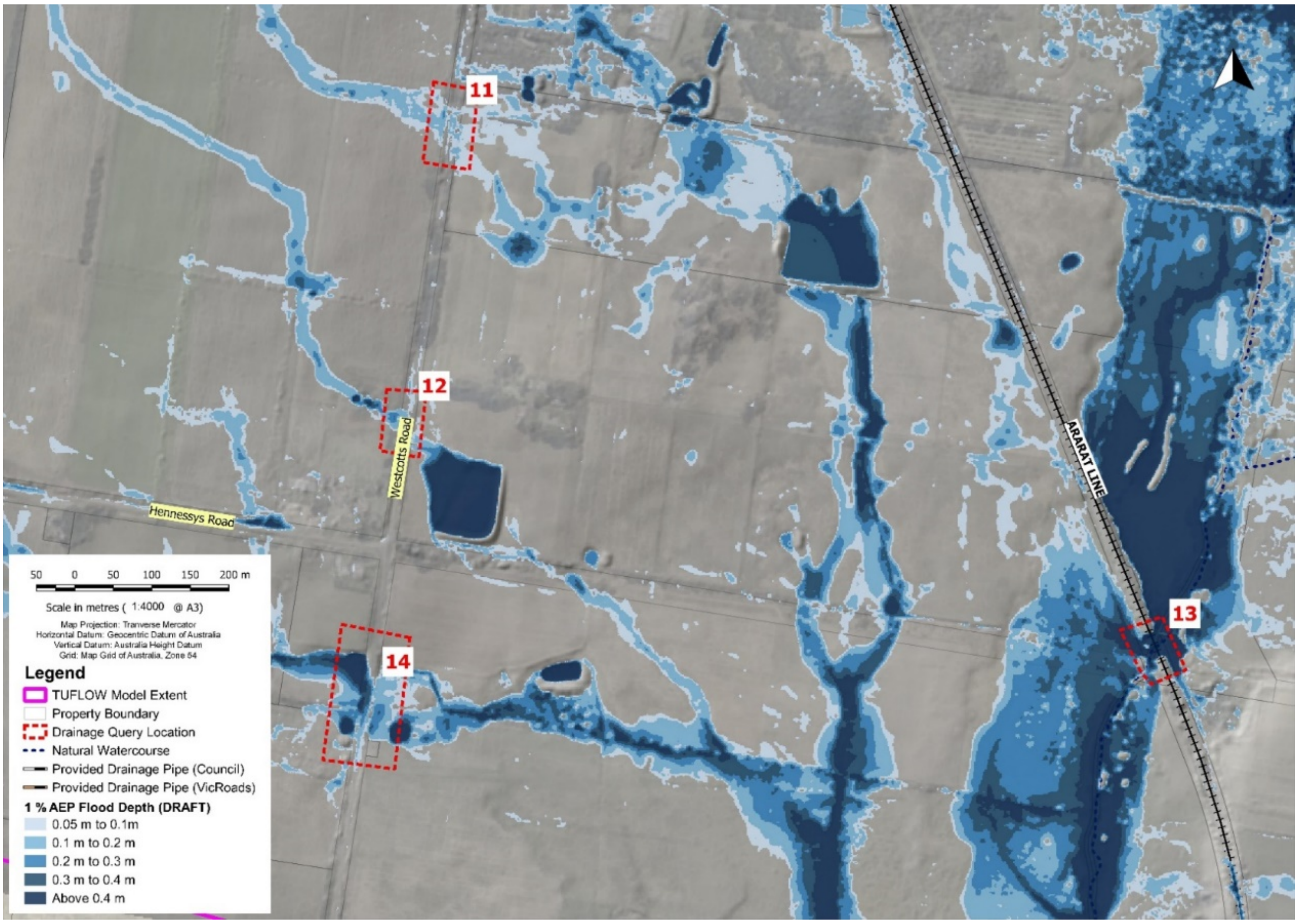
Location	Engeny Description	Engeny Request	Council Provided Measurements and Comments
1	Water ponding along the northwest intersection of Ormond Road and Coffeys Lane	Confirm if any culverts are located at the intersection.	350 mm round pipe running north side of Coffey's Lane under Ormond Road
2	Water ponding along the northern side of Coffeys Lane ~500 metres east of Ormond Road.	Confirm if any culverts are located at the intersection.	Two 380 mm round pipes running under Coffeys Lane, (see screenshot and photo datatag for location)
3	Water ponding along the northern side of Coffeys Lane between Ormond Road and Spargo Creek Road. Aerial imagery suggest culvert crossing upstream farm dam.	Confirm any culverts across Coffeys Lane at this location.	Assets database says there is a culvert in this location. Unable to see it on site. The northern waterway is dammed, with a dry open channel on the north side of the road, filled with blackberries and impossible to access. The southern side of the road is more accessible, falling away steeply to a waterway/dam which reaches the base of the raised road, again this verge is heavily covered with blackberries and unable to determine any exit points of pipes
4	Water ponding along the northern side of Coffeys Lane just ~300 metres west of Spargo Creek Road	Confirm any culverts across Coffeys Lane at this location.	380 mm round pipe
5	Water ponding along the northern side of Old Western Highway just east of Ormond Road. Council provided GIS, LiDAR, and Google Street view confirm open channel drain along northern roadside reserve	Confirm any culverts across th Old Western Highway at this location.	No culvert located. round pipes beneath driveway crossings along sides of road, e.g images of number 90 driveway
6	Water ponding along the northern side of Old Western Highway ~650 east of Bungaree-Wallace Road and Ormond Road Intersection.	Confirm any culverts across the Old Western Highway at this location or if any culverts / open channel drains discharge into natural watercourse to the east (tributary of Moorabool River West Branch).	Yes, open channel on the northern side of road appears to naturally fall to waterway, southern side has shallower open channel. No connections under road between them where visible
7	Flood modelling results suggest waterway crossing / culvert at natural watercourse draining into Moorabool River West Branch. Council provided GIS, LiDAR elevation data, and Google Street view suggest culvert(s)	Confirm any culvert(s) and / or bridge crossings along natural watercourse at this location.	Road is very high above bridge, low metal railings and heavy surrounding vegetation – trees and blackberries. Bridge opening constructed of stone and is 2.4 m high X 1.8 m wide, with a water depth of approx. 25 cms. Internal blockages from fallen timber props.
8	Water ponding and overtopping Butter Factory Road.	Confirm any culverts crossing Butter Factory Road at this location.	360 mm round pipes beneath driveway crossings along sides of road
9	Flood modelling results, LiDAR elevation data, and Google Street view suggest waterway crossing along Moorabool River West Branch at Butter Factory Road.	Confirm any culverts and / or waterway crossings at this location.	Bridge ID plate 006092. Two water crossings, the western on is 5.7 metres long, with four box culverts approx. 1220 mm wide X 750 mm high. The eastern is 11.6 metres wide, water 300 mm deep, 1.9 m between bottom of bridge to water, bridge deck is 700 mm thick, bridge rail is 1150 mm high

Location	Engeny Description	Engeny Request	Council Provided Measurements and Comments
10	Water ponding along the northwest and western intersections of Westcotts Road and the Ararat railway line.	Confirm if any culverts are located at the intersection.	Culvert under western leg of rail line is 610 mm round pipe but south end partially obscured by blue metal gravel. Culvert on north side of rail line running approx. E-W is 450 mm round pipe
11	Overland flow sheeting cross Westcotts Road from the west ~550 metres north of Hennessys Road	Confirm any culverts across Westcotts Road at this location.	380 mm round pipe, see photos for damage – eastern end cracked in roadside and shifted and unsure where real exit of pipe is
12	Water ponding west of Westcotts Road ~ 150 metres north of Hennessys Road	Confirm any culverts across Westcotts Road at this location.	480 mm wide x 160 mm high, arch shape, dry/ or blocked
13	Flood modelling results and LiDAR elevation data suggest waterway crossing along Moorabool River West Branch at the Ararat railway line.	Confirm any culverts and / or waterway crossings along Moorabool River West Branch at this location.	Disused rail bridge (track has been pulled up), no railing. End span distance 3.4 m, columns are 0.8 m, distance between columns are 3.9 m. Assuming these measurements are consistent for the whole bridge it would span 31.1 m.
14	Water ponding west of Westcotts Road ~ 200 metres south of Hennessys Road	Confirm any culverts across Westcotts Road at this location.	1.7 m measured between water and bottom of bridge deck

Appendix Figure A- 1: Overview of Drainage Pits, Pipes, and Waterway Crossings for Survey (Northern Section)



Appendix Figure A- 2: Overview of Drainage Pits, Pipes, and Waterway Crossings for Survey (Southern Section)



Appendix B:
Hydrological Model Data

B.1 IFD DATA

The resultant IFDs for the catchment are shown in Appendix Table B- 1 and Appendix Table B-2 for the base case and climate change scenarios respectively.

Appendix Table B- 1: Design Rainfall Burst Depths in Millimetres (mm) for the Base Case Scenario (-37.56 °S, 145.05 °E)

	Annual Exceedance Probability (AEP)					
Duration	**50 %**	**20 %**	**10 %**	**5 %**	**2 %**	**1 %**
10 minutes	7.9	11.9	14.9	18.0	22.4	26.1
15 minutes	9.7	14.5	18.2	22.0	27.5	32.1
30 minutes	12.7	19.0	23.6	28.5	35.5	41.4
1 hour	15.9	23.2	28.6	34.2	42.3	48.9
2 hours	19.7	27.9	33.9	40.2	49.0	56.3
3 hours	22.5	31.3	37.8	44.5	53.9	61.7
6 hours	29.0	39.3	46.9	54.7	65.9	75.0
12 hours	38.3	51.3	60.9	70.7	84.8	96.2
24 hours	50.7	68.2	80.9	93.9	113.0	127.0
Table 24 hours	60.0	80.8	95.8	111.2	133.8	150.4

B.2 CLIMATE CHANGE FACTORS DATA

The ARR Data Hub provides interim climate changes factors for calculation of increased rainfall scenarios. These values are summarised for the catchment centroid in Appendix Table B-2.

Appendix Table B-2: Interim Climate Change Factors from ARR Data Hub (-37.56 °S, 145.05 °E)

Year	**RCP 4.5**		**RCP6**		**RCP8.5**	
	Temperature Increase (°C)	**Increase in Rainfall Intensity**	**Temperature Increase (°C)**	**Increase in Rainfall Intensity**	**Temperature Increase (°C)**	**Increase in Rainfall Intensity**
2030	0.6	3.2 %	0.7	3.4 %	0.8	4.0 %
2040	0.9	4.4 %	0.8	4.1 %	1.1	5.4 %
2050	1.1	5.4 %	1.0	5.1 %	1.4	7.3 %
2060	1.3	6.3 %	1.2	6.2 %	1.9	9.5 %
2070	1.4	7.0 %	1.5	7.4 %	2.3	11.9 %
2080	1.5	7.4 %	1.7	8.6 %	2.7	14.2 %
2090	1.5	7.6 %	1.9	9.7 %	3.1	16.3 %
2100 [1]	1.5	7.8 %	2.1	10.8 %	3.5	18.4 %

Notes: 1. *The values for the year 2100 scenario are extrapolated from the available ARR Data Hub data for the years between 2030 - 2090*

B.3 PRE-BURST RAINFALL DEPTH AND DURATION FACTORS

The adopted pre-burst rainfall depth and duration factors are presented in Appendix Table B- 3. In order to calculate the initial loss for the design rainfalls (IL_B), the initial loss value for the complete storms (IL_S) was reduced by the pre-burst rainfall depth:

$$IL_B = IL_S - Preburst\ rainfall\ depth\ (mm)$$

Initial burst losses were applied in RORB as duration factors, which were calculated as ratios between a burst initial loss (IL_B) for each duration and AEP and storm initial loss (IL_S). For example, the duration factor for the 1 % AEP storm of 60 minutes duration was determined as follows:

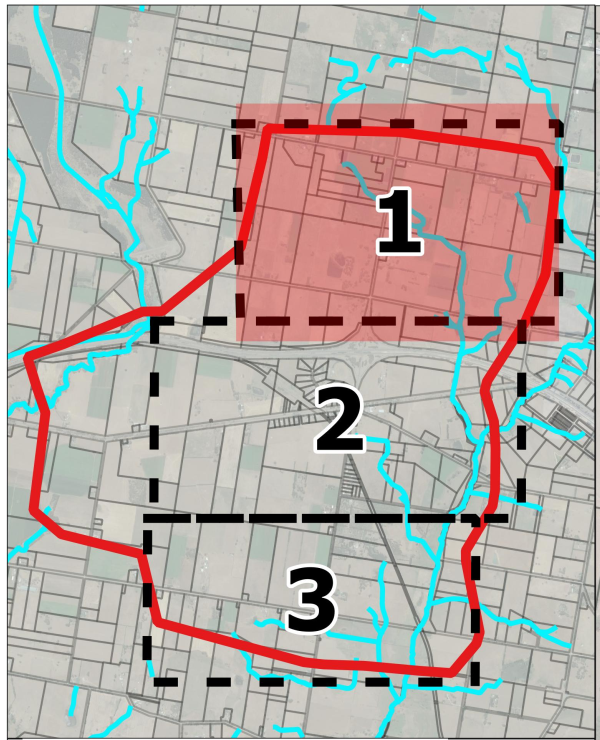
$$Duration\ Factor\ (1\ \%\ AEP, 60\ minute) = \frac{IL_S - Preburst\ rainfall\ depth}{IL_S} = \frac{25\ mm - 1.1\ mm}{1.1\ mm} = 0.96$$

Appendix Table B- 3: Summary of Adopted Pre-burst Rainfall and Duration Factors (1 % AEP Event)

Duration	Pre-Burst Rainfall Depth (mm)	Duration Factor
10 minutes	10.5	0.58
15 minutes	10.5	0.58
30 minutes	10.5	0.58
1 hour	10.5	0.58
2 hours	21.8	0.13
3 hours	20	0.20
6 hours	14.9	0.40
12 hours	22.7	0.09
18 hours	11.3	0.55
24 hours	10.5	0.58

Appendix C:

1 % AEP Base Case Scenario Flood Depth Layout Plan

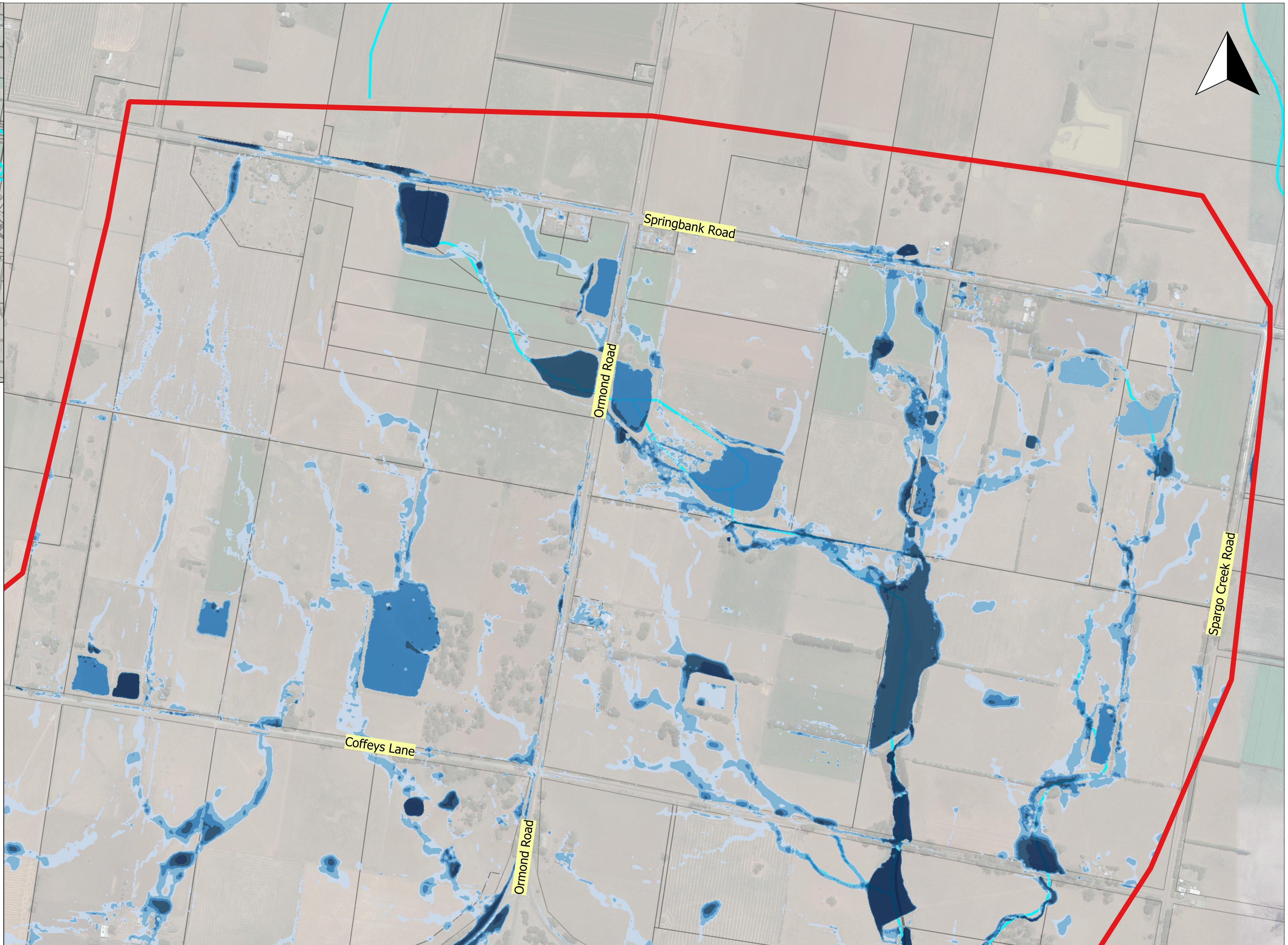


Legend

- Hydraulic Model Extent
- Natural Watercourse
- Property Boundary

Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.5 m
- Above 0.5 m



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ENGENY WATER MANAGEMENT

MOORABOOL SHIRE COUNCIL

100 0 100 200 300 400 m

Scale in metres (1:10000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Base Case Scenario
Flood Depth
Map Location 1

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022

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MOORABOOL SHIRE COUNCIL

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Scale in metres (1:10000 @ A3)

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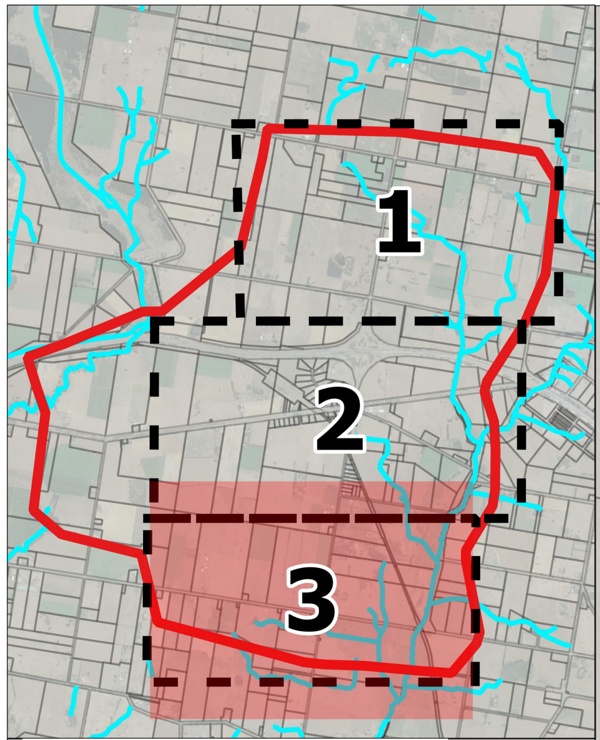
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Base Case Scenario
Flood Depth
Map Location 2

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022

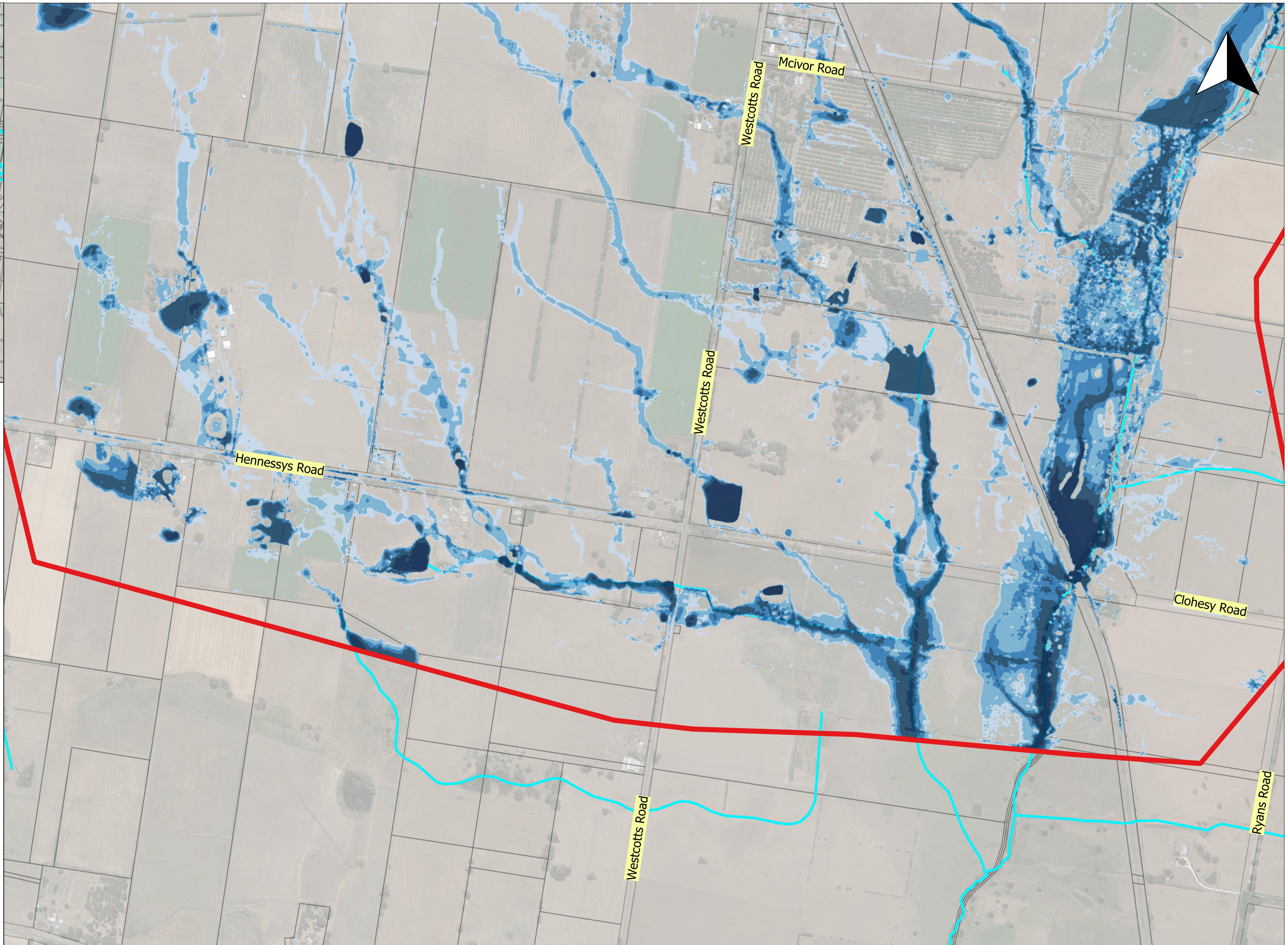


Legend

- Hydraulic Model Extent
- Natural Watercourse
- Property Boundary

Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.5 m
- Above 0.5 m



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MOORABOOL SHIRE COUNCIL

100 0 100 200 300 400 m

Scale in metres (1:10000 @ A3)

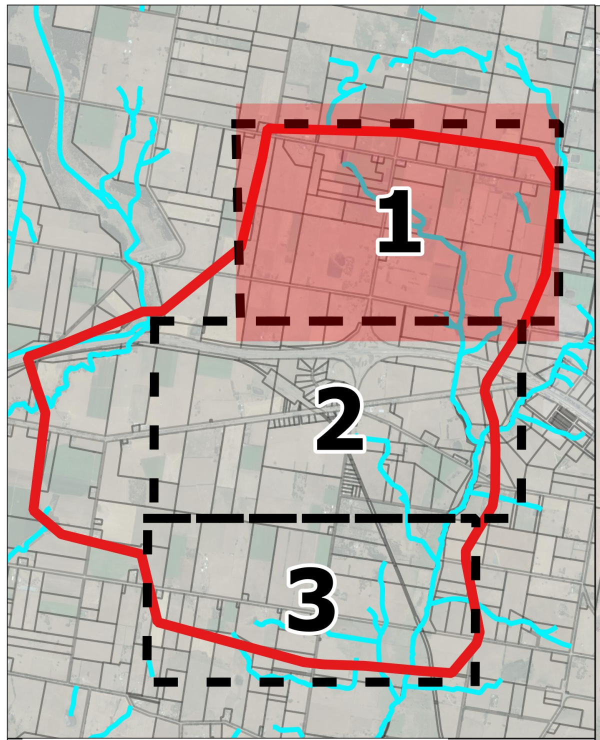
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Base Case Scenario
Flood Depth
Map Location 3

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022

Appendix D:
1 % AEP Climate Change Scenario Flood Depth Layout Plan

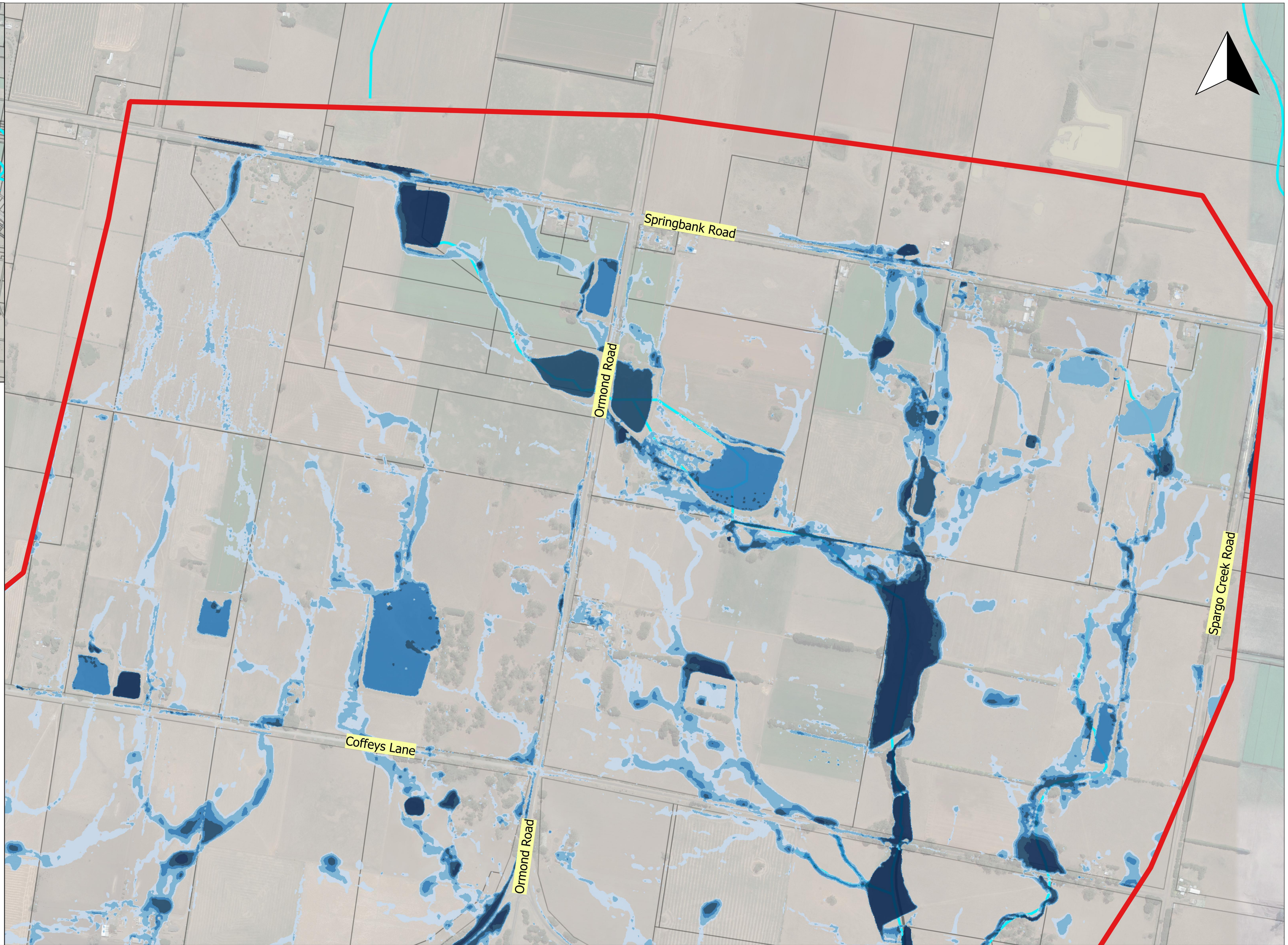


Legend

- Hydraulic Model Extent
- Natural Watercourse
- Property Boundary

Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.5 m
- Above 0.5 m



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MOORABOOL SHIRE COUNCIL

100 0 100 200 300 400 m

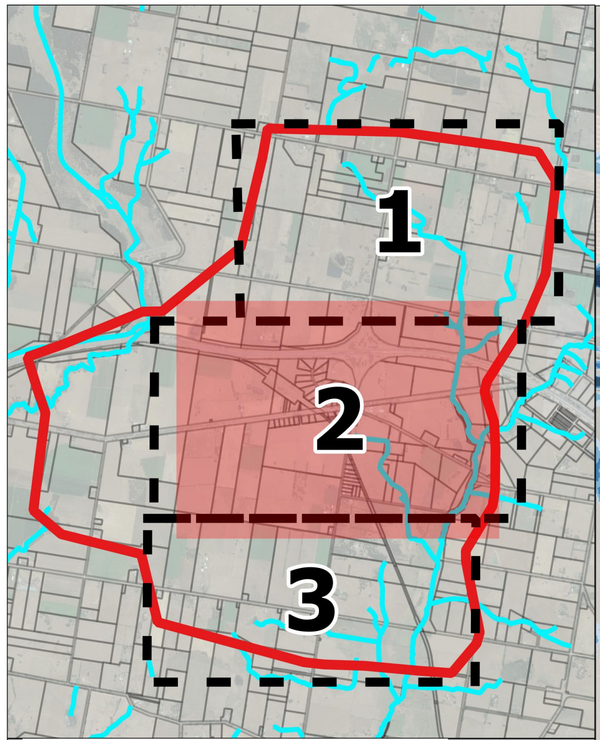
Scale in metres (1:10000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Climate Change Scenario
Flood Depth
Map Location 1

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022



Legend

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- Natural Watercourse
- Property Boundary

Flood Depth

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SHIRE COUNCIL

100 0 100 200 300 400 m

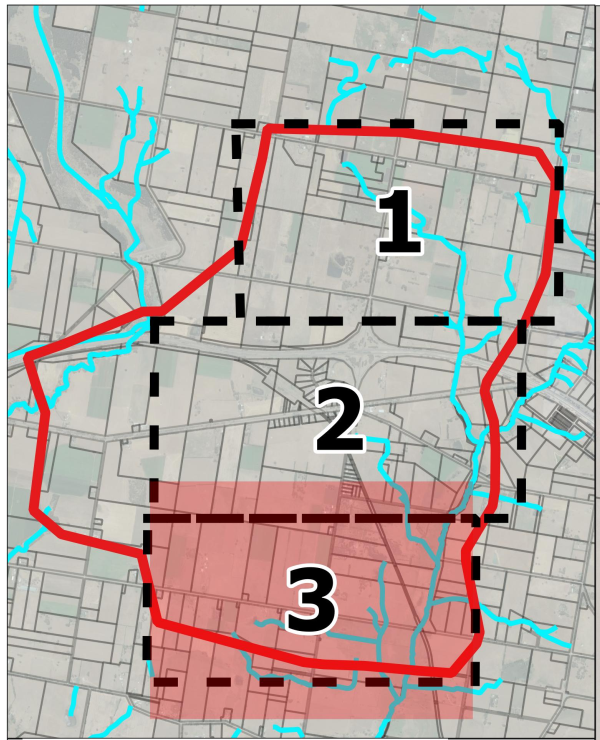
Scale in metres (1:10000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Climate Change Scenario
Flood Depth
Map Location 2

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022



Legend

- Hydraulic Model Extent
- Natural Watercourse
- Property Boundary

Flood Depth

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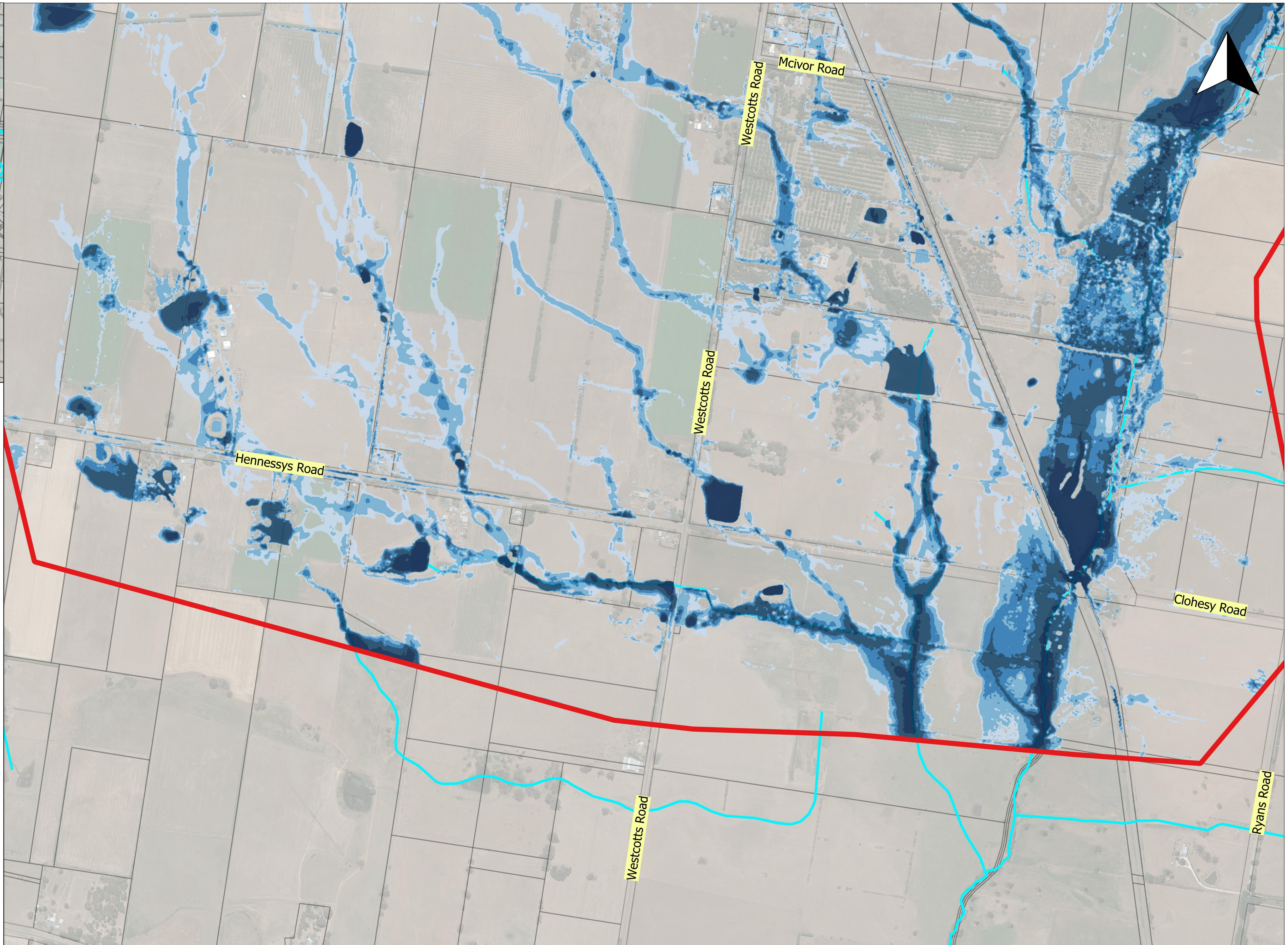

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Wallace Flood Study

1 % AEP Climate Change Scenario
Flood Depth
Map Location 3

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022

Appendix E:
1 % AEP Filtered Flood Extents

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MOORABOOL SHIRE COUNCIL

100 0 100 200 300 400 m

Scale in metres (1:10000 @ A3)

Map Projection: Tranverse Mercator
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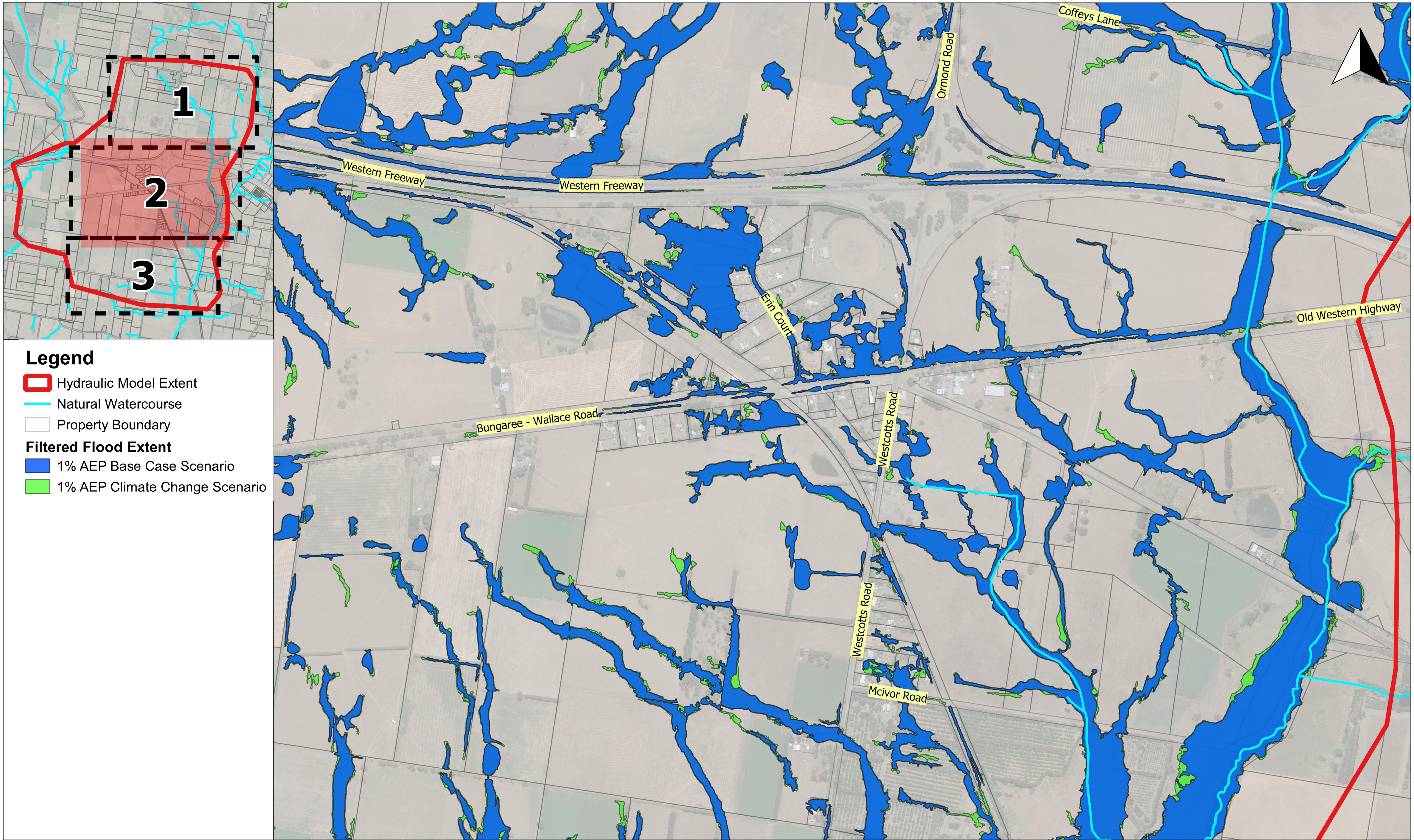
Wallace Flood Study

1 % AEP Filtered Flood Extents
Map Location 1

Job Number: V2027_011
Revision: 0
Drawn: AN
Checked: JH
Date: 4/1/2022



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MOORABOOL SHIRE COUNCIL

100 0 100 200 300 400 m

Scale in metres (1:10000 @ A3)

Map Projection: Tranverse Mercator
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Grid: Map Grid of Australia, Zone 54

Wallace Flood Study

1 % AEP Filtered Flood Extents
Map Location 2

Job Number: V2027_011
Revision: 0
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Checked: JH
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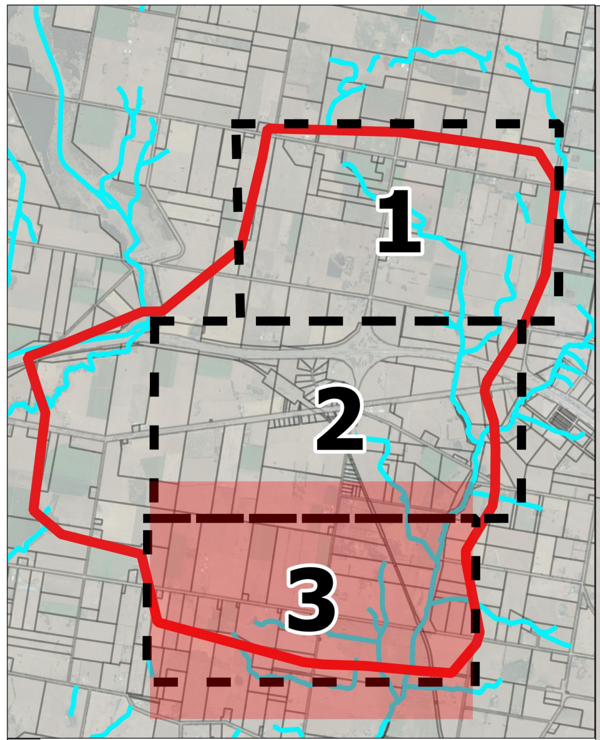
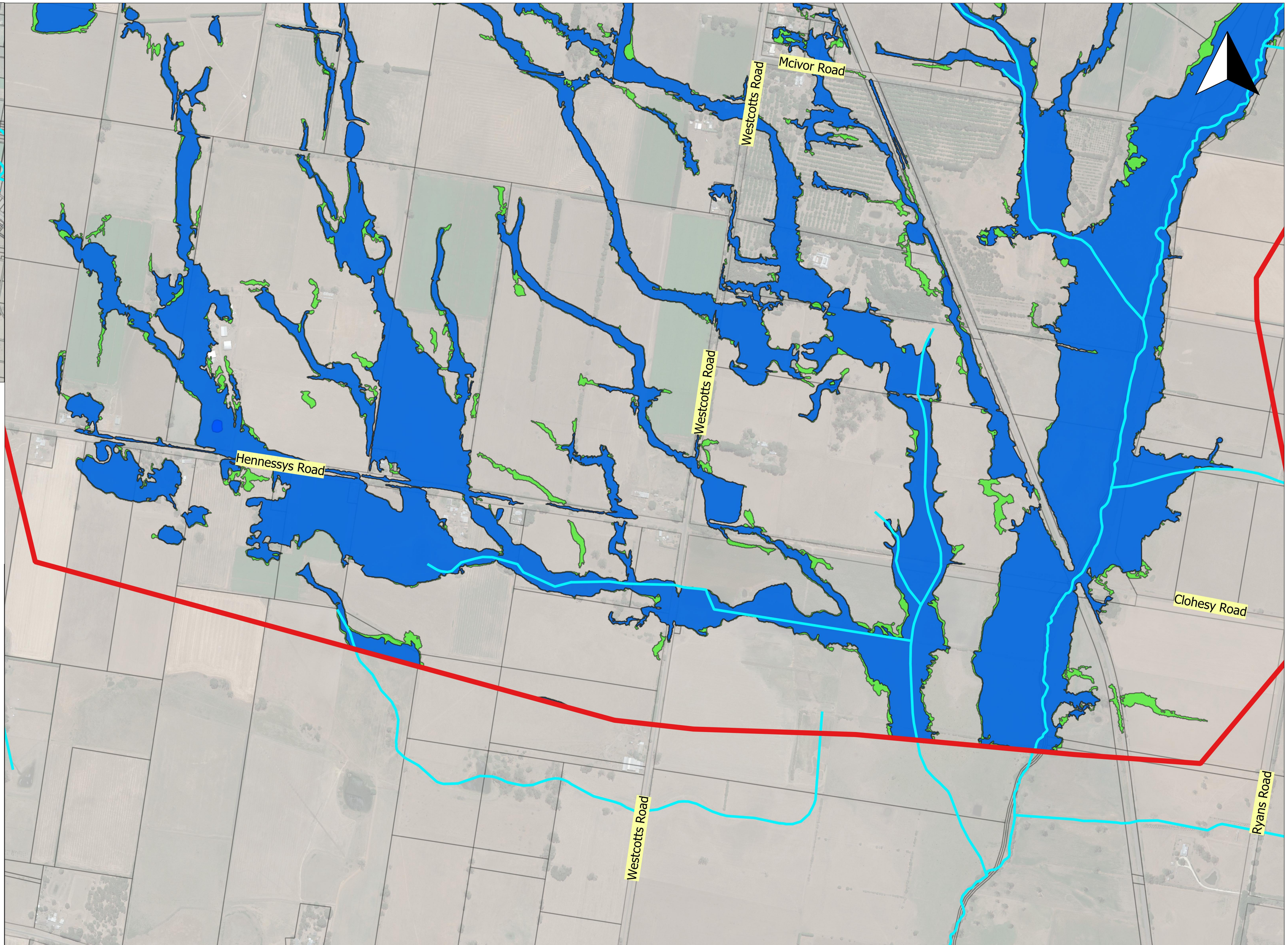


Legend

- Hydraulic Model Extent
- Natural Watercourse
- Property Boundary

Filtered Flood Extent

- 1% AEP Base Case Scenario
- 1% AEP Climate Change Scenario



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Wallace Flood Study

1 % AEP Filtered Flood Extents
Map Location 3

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