WOLLONDILLY SHIRE COUNCIL

Yanderra Drainage Master Plan

Final Report

Rev B

February 2025

rp311015-00067iw_wh250224_Yanderra DMP Final

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PROJECT 311015-00067: Yanderra Drainage Master Plan - Final Report

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date
Rev A	Draft Report	IW I Wibowo	WH W Honour	WH W Honour	30-01-2025
Rev B	Final Report	IW I Wibowo	WH W Honour	WH W Honour	24-02-2025

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1. Introduction

The village of Yanderra has experienced significant drainage issues during recent rainfall events. One such event occurred in March 2022, during which properties were impacted as the existing stormwater drainage systems (or lack thereof) were unable to adequately capture the high rates of runoff. The history of flooding in Yanderra is not formally documented, and there is limited measured hydrologic data available for the area.

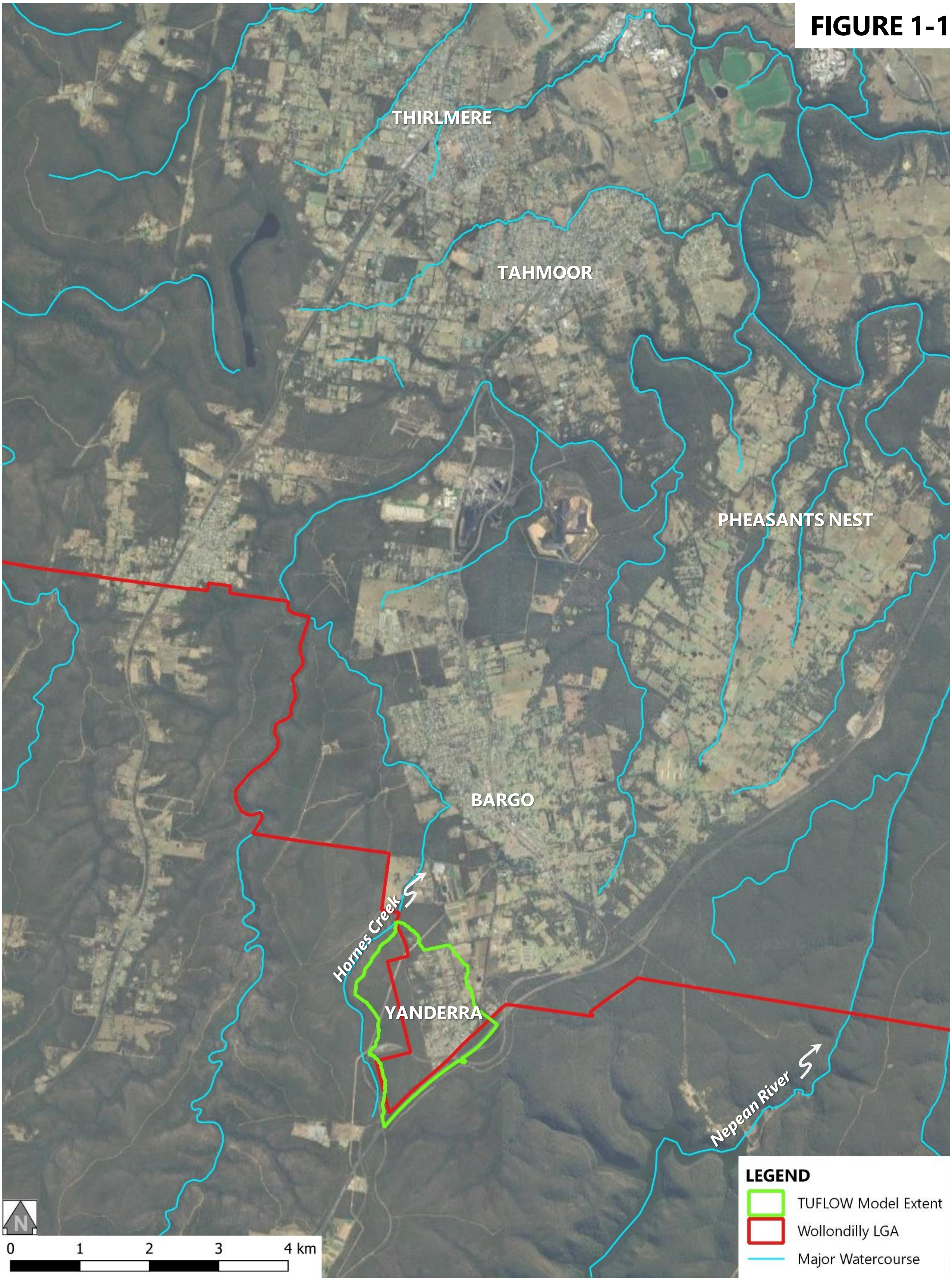
The location of Yanderra village is shown in **Figure 1-1**.

Council has previously engaged Worley Consulting to complete the *Wollondilly Shire Flood Study; Broad Scale Assessment* (in draft, 2023). This study involved the development of WBNM hydrologic and TUFLOW hydraulic models to assess flood behaviour on a shire-wide level, including the local catchment draining to the Yanderra area. Worley Consulting is also in the process of developing a more detailed Flood Study for Bargo and Yanderra. This modelling has been used as a base for further investigations.

The Yanderra Drainage Master Plan is a focused investigation that aims to address drainage issues in Yanderra by analysing stormwater runoff patterns and developing options to upgrade the stormwater drainage system.

The Yanderra Drainage Master Plan seeks to develop a comprehensive strategy to address the village's drainage issues. The scope of this study is to:

- Develop a refined drainage/flood model for Yanderra, calibrated/validated to the March 2022 rainfall event, to better understand stormwater flooding behaviour in the area.
- Assess the performance of the existing drainage infrastructure (or lack thereof) under three design rainfall events.
- Develop and assess options to upgrade or extend the current stormwater drainage system to mitigate drainage issues.
- Conduct a flood damages assessment and a benefit-cost analysis for the proposed options to evaluate their effectiveness and feasibility.
- Recommend a set of works for implementation as part of the Yanderra Drainage Master Plan.



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LOCATION OF YANDERRA

2. Background

The village of Yanderra is located east of an unnamed creek that flows to Hornes Creek (refer **Figure 2-1**), which drains into the larger Bargo River catchment. Yanderra has an urban area of approximately 70 hectares and a population of 702 people, according to the 2021 Census from the Australian Bureau of Statistics.

Yanderra has reportedly experienced multiple cases of nuisance stormwater flooding, with several reports of properties affected by runoff during major rainfall events.

2.1 Catchment Description

The Yanderra catchment shown as the TUFLOW model extent in **Figure 2-1** has an area of about 3.0 km^2 which drains in a northerly direction towards Hornes Creek. The catchment is largely made up of dense vegetation, rural properties and low-density residential housing.

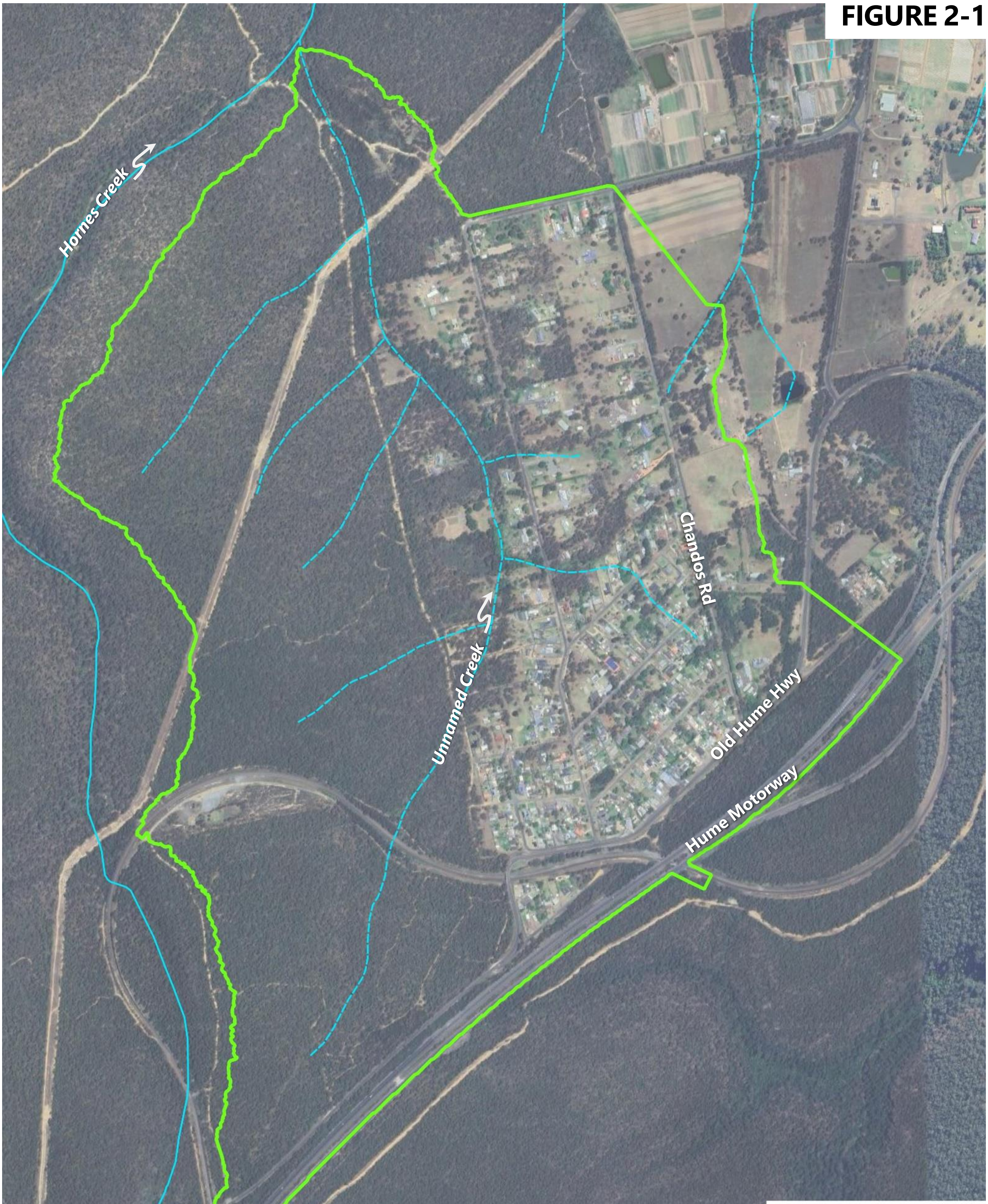
2.2 Previous Flood Investigations

Worley Consulting (formerly Advisian) prepared the *Wollondilly Shire Flood Study* (Broad Scale Assessment) (in draft) for Council. The study involved the development of WBNM hydrologic models and TUFLOW hydraulic models using the latest topographic data and techniques outlined in Australian Rainfall & Runoff 2019 (ARR 2019). A model grid size of 6m x 6m was adopted for the TUFLOW modelling.

As part of the ongoing efforts to refine flood risk understanding, the Bargo and Yanderra Flood Study is currently underway. This study adopts a higher resolution 2m x 2m grid size for the TUFLOW modelling, enabling more detailed flood behaviour assessment compared to the broad-scale study.

The assessment undertaken for this Yanderra Drainage Master Plan builds upon the Bargo and Yanderra Flood Study by incorporating an even finer level of detail, to specifically analyse local stormwater runoff behaviour and drainage infrastructure performance.

FIGURE 2-1



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YANDERRA STUDY AREA

3. Data Collection and Review

3.1 LiDAR Topographic Data

LiDAR topographic data was sourced from the online ELVIS system by Geosciences Australia. The Digital Terrain Model (DTM) data available for the entire study area was developed by the NSW Spatial Services and comprises a 1-metre LiDAR DEM for Wollongong surveyed in two separate dates (2014 and 2019). The topography of the study area is shown in **Figure 3-1**.

3.2 Council GIS Layers

3.2.1 Stormwater Asset Data

Stormwater asset data was provided by Wollondilly Shire Council in the form of two relevant GIS layers.

- StormwaterPipes2000.shp
- StormwaterPits2000.shp

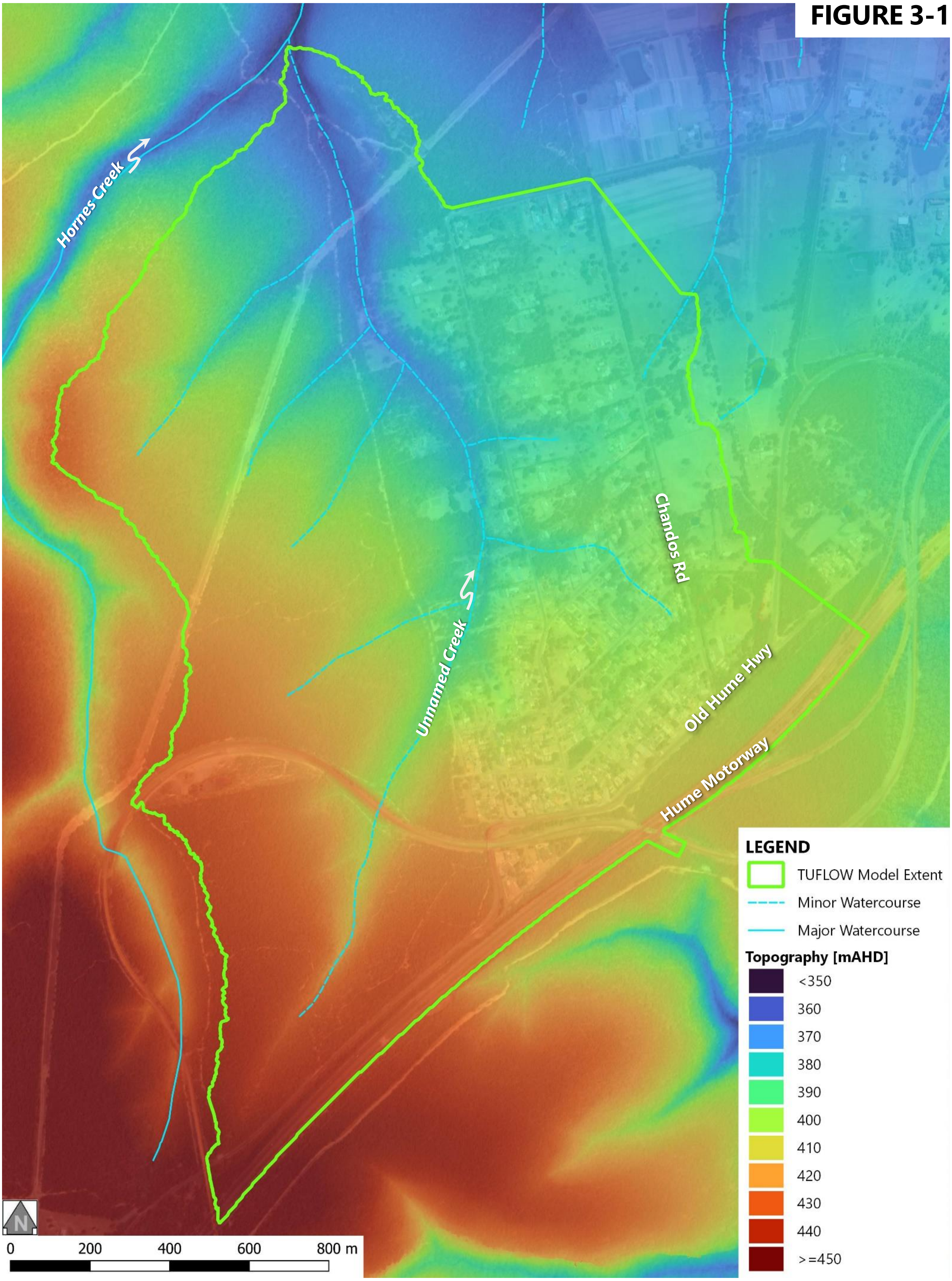
These layers were used as the basis for inclusion of the pit and pipe drainage system in hydraulic modelling. Available data typically included the pipe type (rectangular or circular), number of barrels and dimensions, and the pit type, depth, and dimensions. For some assets, such as culverts under the railway, the required data was not available, and logical assumptions were necessary to supplement the data set and include the drainage system in the hydraulic model.

3.2.2 Council Land Use Zoning Maps and Aerial Photography

The land use zone mapping from the *Wollondilly Shire Flood Study* served as the initial base layer. To ensure the data reflected any recent changes in land use, Wollondilly Shire Council provided updated future planning zones, which were incorporated to complement the existing base layer.

Additionally, the latest aerial imagery from NearMaps (March 2023) was used to verify any land use changes and recent developments in the area. The high-resolution imagery provided a detailed view of land use and infrastructure, ensuring that any changes not captured in the zoning maps were incorporated into the analysis.

FIGURE 3-1



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YANDERRA DIGITAL TERRAIN MODEL

3.3 Hydrometric and Historic Flood Data

A thorough search of available databases was undertaken to identify hydrometric data stations within or near the village of Yanderra. The search focused on rainfall pluviometers (*gauges that record continuous sub-daily rainfall*) and stations that were operating during the March 2022 large rainfall event that would be appropriate for use in pseudo-calibration of the flood model.

There were no nearby stream level / flow records in the relevant catchments surrounding Yanderra.

3.3.1 Rainfall Data

Rainfall data was sought from stations within and surrounding the Unnamed Creek catchment that runs west from Yanderra. None were identified in the immediate area and therefore, the record from the three closest stations shown in **Figure 3-2** were used to derive the rainfall data used for flood model calibration/validation in Yanderra. A particular focus was placed on obtaining data from pluviometers (gauges that record continuous sub-daily rainfall) in order to be able to properly simulate the temporal pattern of the rainfall across the catchment during the March 2022 flood event.

Rainfall stations from which data was used in the study are shown in **Section 5.1**.

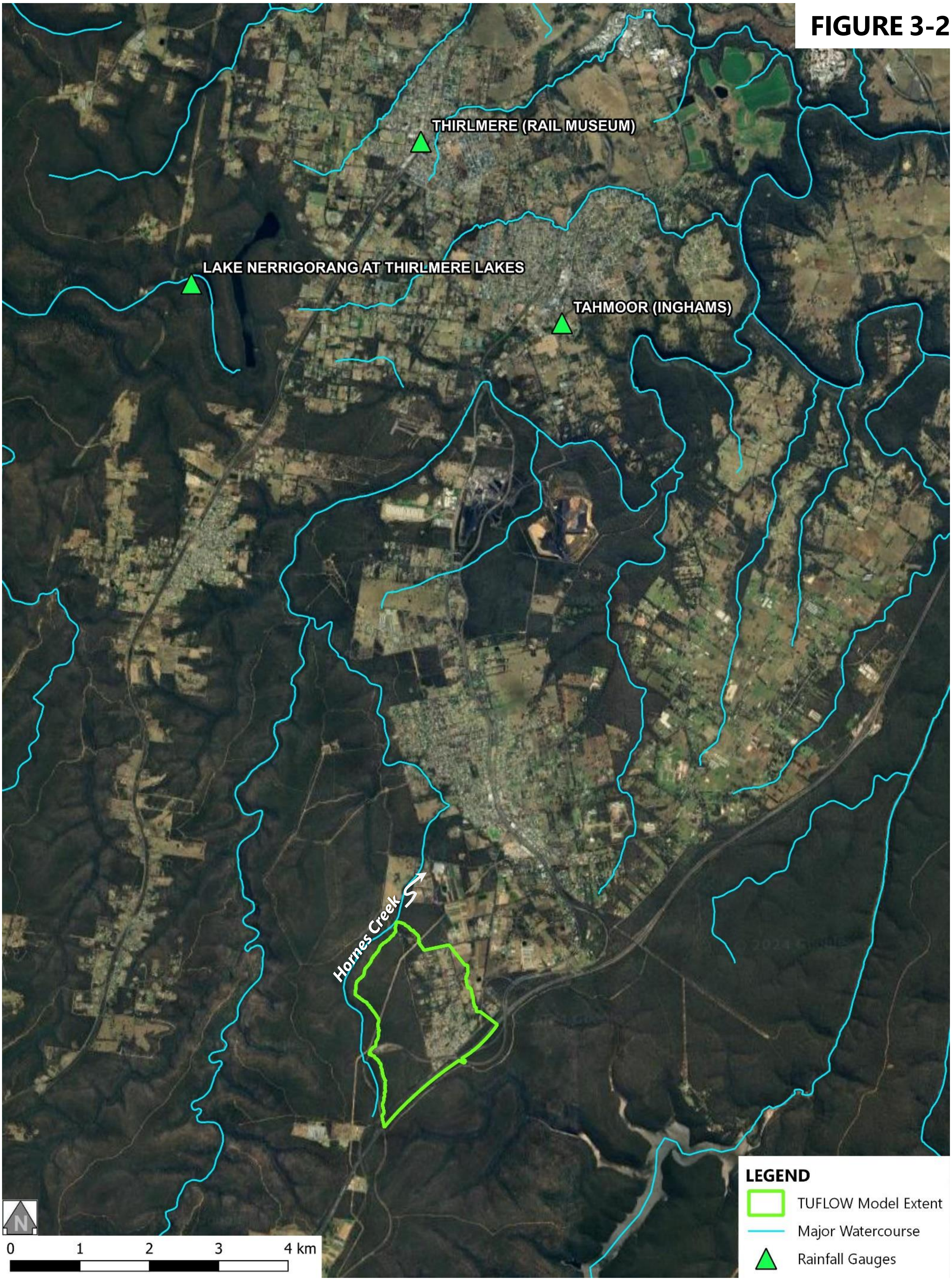
3.3.2 Drainage Complaints

Council provided a list of drainage complaints received from Yanderra residents, many of which were linked to major rainfall events, including the March 2022 storm. Some complaints were more general, reflecting recurring drainage issues, while other complaints were specifically related to recent rainfall events. The issues reported included flooding in properties, and damage to or blockages in the existing stormwater drainage systems.

The complaints covered a range of drainage issues, including excessive stormwater ponding, and runoff flowing into and through properties. In many cases, residents reported water from nearby streets flooding their properties. Others highlighted that the existing drainage systems, such as culverts and pipes, were unable to manage the volume of runoff, leading to flooding in driveways, garages, and front yards.

Additional concerns included blocked and damaged drains that required replacement or were frequently obstructed, resulting in road damage. In some areas, the lack of properly defined table drains allowed uncontrolled runoff to flow onto properties.

FIGURE 3-2



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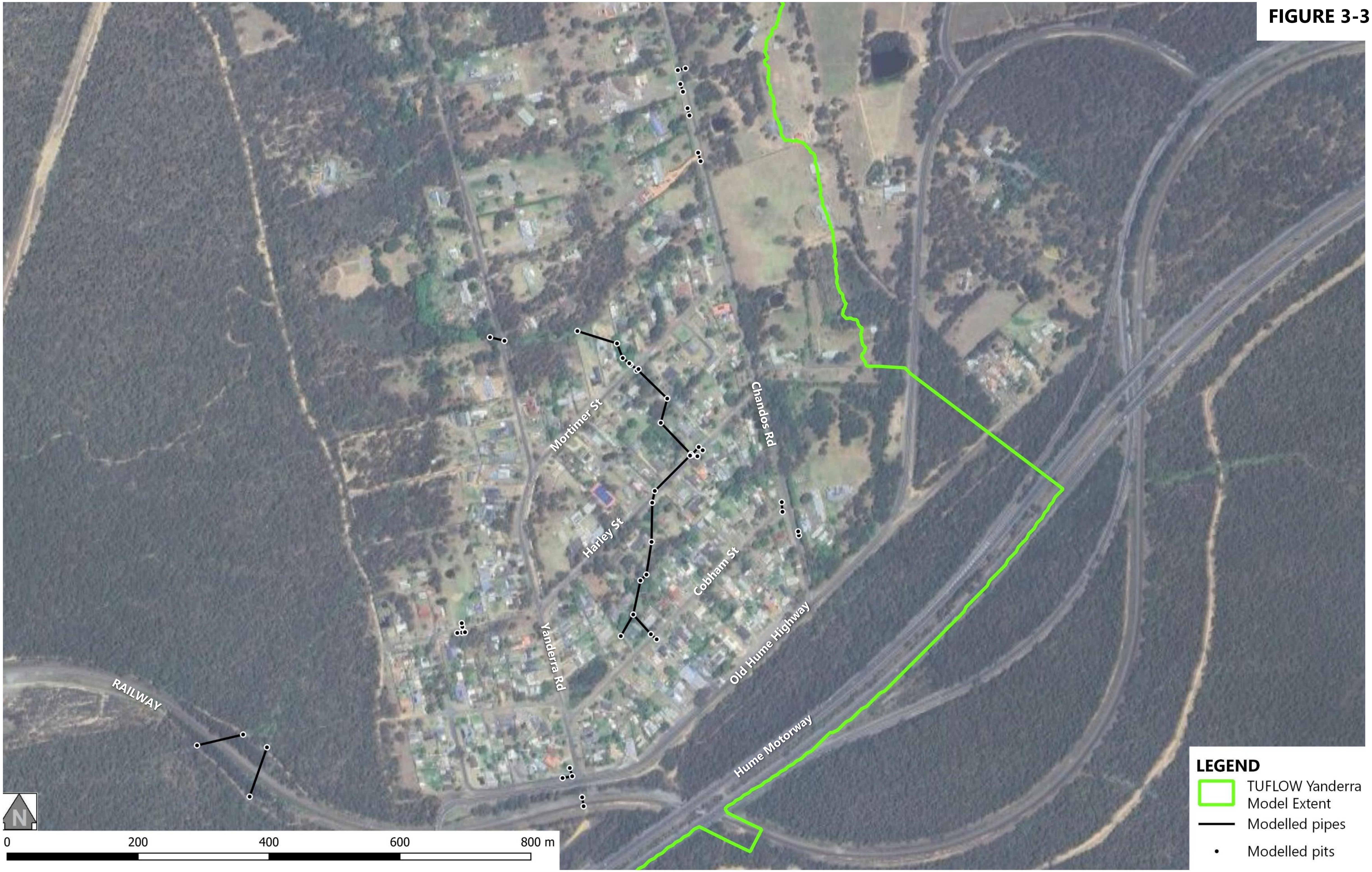
LOCATION OF RAINFALL PLUVIOMETERS

3.4 Additional Stormwater Infrastructure

The stormwater network data provided by Council, including as GIS files and PDF plans, needed to be supplemented and adjusted to ensure compatibility with the TUFLOW model. This was completed to capture all relevant stormwater infrastructure, including larger pipes and culverts, and also better represent existing overland flow paths. The original data primarily covered stormwater pits and pipes within road gutters, which discharge into nearby outlets leading to creeks or rivers. However, some important elements were missing, such as larger culverts beneath roads and railways that allow water to pass and prevent build-up against the embankments.

Accordingly, additional stormwater infrastructure was incorporated into the model by digitising the missing culverts, headwalls, and larger trunk pipes (those with diameters greater than 375mm) from the provided PDF plans. These additions ensured a more reliable representation of the stormwater system, improving the ability to simulate flow dynamics and potential flooding risks. The updated stormwater network, reflecting these amendments, is shown in **Figure 3-3** and was used in the base case existing conditions modelling.



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EXISTING STORMWATER PITS AND PIPES AT YANDERRA

4. Drainage Model Development

Numerical computer models have been adopted as the primary means of investigating the flood and drainage behaviour at Yanderra.

For this study, the WBNM hydrologic and TUFLOW 2D/1D hydraulic modelling software packages were selected to simulate the March 2022 event for pseudo-calibration and three design storms; the 50%, 10% and 1% Annual Exceedance Probability (AEP) events. The hydrologic model (WBNM) simulates the catchment rainfall-runoff processes, with resulting flow hydrographs input to the hydraulic model. The hydraulic model (TUFLOW) simulates the physical behaviour of the flow as it passes through the catchment, producing information on flood levels, flood extents and flow velocities.

The WBNM and TUFLOW software were determined to be suitable tools for replicating the complex 2D nature of flooding in the study catchment based on consideration of the following.

- WBNM hydrologic modelling software:
  - WBNM is very robust and has been validated against numerous catchments in NSW including in the Wollondilly Shire Local Government Area.
- TUFLOW hydraulic modelling software:
  - Allows accurate representation of catchment topography and bathymetry to be developed in 2D from various sources (e.g., a combination of LiDAR and detailed survey).
  - Allows integrated investigation and interaction of overland and mainstream driven components of flooding.
  - Solves the full 2D surface water equations.
  - Produces high quality, GIS compatible flood mapping outputs.

4.1 Hydrologic Model Development

4.1.1 Subcatchment Delineation

Subcatchment delineation was completed using the LiDAR data and GIS software, namely QGIS and CatchmentSIM. The raw LiDAR data sourced from ELVIS had a resolution high enough to identify large drainage features not previously known by the modelling team, such as the location of large culverts under the railway embankment, which would impact the distribution of runoff across the catchment. Therefore, after the stormwater network GIS was updated, a Digital Terrain Model (DTM) was carved with those features to properly capture the flow pathways in the terrain and allow an automated process of catchment delineation.

CatchmentSIM is an industry standard software to appropriately delineate subcatchments in urban locations. This software is capable of accurately capturing the inferred flow paths from the DTM and delineating subcatchments based on them. The final subcatchment delineation for the Yanderra catchment is presented in **Figure 4-1**.

FIGURE 4-1

YANDERRA WBNM MODEL LAYOUT AND TUFLOW OUTFLOW BOUNDARIES

4.1.2 Runoff Lag and Stream Routing Parameters

The primary parameters required by the WBNM model are a runoff lag factor 'C', and a stream routing lag factor 'F'.

The runoff lag factor 'C' controls the timing of locally generated runoff from each model sub-catchment. A low C value represents a rapid runoff response, while a high value represents a slow runoff response. WBNM documentation recommends runoff lag parameter values of between 1.3 and 1.8, with a value of close to 1.6 generally appropriate. A separate lag factor is applied to impervious areas with a value of 0.1 recommended.

The stream routing lag factor 'F' determines the time it takes for flows to travel along streams. WBNM documentation recommends a default stream lag factor of 1.0 to represent natural streams. Lower values can be adopted if the stream has undergone modifications such as clearing, straightening, or concrete lining.

Calibration to recorded events could not be done due to the lack of streamflow data, hence the recommended values were used. The final values are presented in **Table 4-1**.

Table 4-1 Adopted WBNM runoff lag and stream routing parameters

WBNM Model Parameter	Parameter Value
Runoff lag factor 'C'	1.56
Impervious runoff lag factor 'C'	0.1
Stream routing factor 'F'	1.0

4.1.3 Catchment Imperviousness

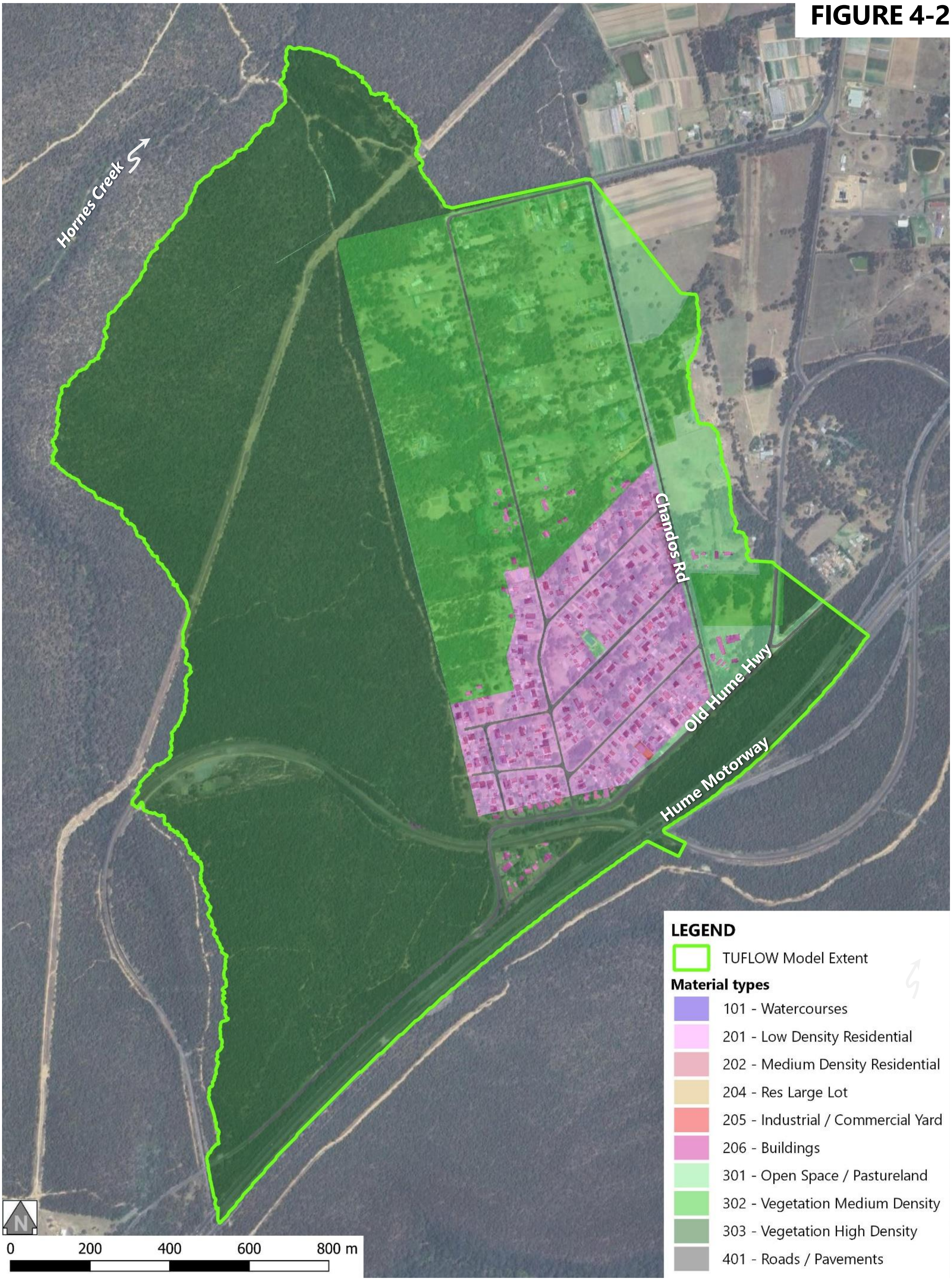
The degree of imperviousness of a catchment influence both the quantity and timing of runoff generated by a rainfall event.

The effective impervious percentage of each sub-catchment of the WBNM model was determined through analysis of the detailed surface material delineation developed for use in the TUFLOW hydraulic model (*refer* **Figure 4-2**). The effective percentage impervious assigned to each surface material type is presented in **Table 4-2**, which is based on the values in Table D5.1 of Council's *Subdivision and Engineering Standard* (D5 – Stormwater Drainage Design). Greater imperviousness reduces the surface's ability to absorb stormwater, preventing infiltration. As a result, runoff moves more quickly, altering the timing of water flow.

Table 4-2 Effective percentage impervious by land surface type

Material Type	Effective Percentage Impervious
Watercourses	100%
Low Density Residential	60%
Medium Density Residential	70%
Large Residential Lot	40%
High Density Residential (not used)	80%
Industrial/Commercial Yard	90%
Open Space / Pastureland	10%
Vegetation – Medium Density	5%
Vegetation – High Density (Forest)	2%
Road Corridor, including roadway and verge	70%
Rail Corridor	50%

FIGURE 4-2



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YANDERRA TUFLOW MODEL MATERIAL TYPES

4.2

4.2 Hydraulic Model Development

4.2.1 2D Model Domain and Terrain

The study area comprises an approximate total area of 3km^2 and includes the town of Yanderra and surrounding areas (refer **Figure 4-1**).

The 2D TUFLOW model terrain was compiled from two LiDAR data sources (refer **Section 3**) to achieve an appropriate representation of the current condition of the village and watercourses in the study area.

A model grid size of 1m x 1m was adopted to adequately resolve the drainage and flood characteristics in detail. Each square grid cell contains information on ground surface elevation, hydraulic roughness, and other parameters as necessary (*e.g., cell blockage and energy losses to represent the hydraulic effects of drainage network assets*). The ground surface elevation is sampled at the centre, mid-sides, and corners of each cell from a specified Digital Elevation Model (DEM). For a 1-metre grid this results in DEM elevations being sampled at 0.5m centres.

4.2.2 Hydraulic Structures

As discussed in **Section 3.2.1**, the stormwater network used in the model was based on both data supplied by Council and estimated alignments and sizes of culverts for which data was not available. The estimation of alignments and sizes was completed through the analysis of LiDAR data and aerial photographs, which has a resolution high enough to be able to pick-up the elevations at large culvert headwalls

The layout of the modelled drainage system for existing conditions is shown in **Figure 3-3**.

4.2.3 Hydraulic Roughness

Hydraulic roughness coefficients (*Manning's 'n'*) are used to represent the resistance to flow of different surface materials. Hydraulic roughness has a major influence on flow behaviour and is one of the primary parameters that may be altered to achieve calibration of hydraulic models.

Spatial variation in hydraulic roughness is represented in TUFLOW by delineating the floodplain into zones of similar hydraulic properties. The hydraulic roughness zones adopted in this study have been delineated based on consideration of aerial photography, land use zoning, and site observations. Manning's 'n' values assigned to each zone were determined based previous experience, with reference to values recommended in the literature (*e.g., Chow 1959*). As resistance to flow due to surface and form roughness varies with depth (*e.g., Chow 1959, ARR 1987*), variable depth-dependent hydraulic roughness values have been adopted.

Manning's 'n' roughness coefficients applied in the TUFLOW model are listed in **Table 4-3**, with the delineation of hydraulic roughness zones (Material Types) shown in **Figure 4-2**. Below 'Depth 1' the first Manning's 'n' value is applied, while above 'Depth 2' the second Manning's 'n' value is applied. At depths between 'Depth 1' and 'Depth 2' Manning's values are determined by linear interpolation.

This approach attempts to account for relatively rough conditions close to the ground surface (e.g., small retaining walls, garden beds, rockeries in residential areas) compared to a lower roughness applied to the remainder of the water column.

Table 4-3 Adopted Manning's 'n' hydraulic roughness coefficients

Material Type	Depth 1 (m)	Manning's 'n' Value 1	Depth 2 (m)	Manning's 'n' Value 2
Watercourses	0.5	0.1	1.0	0.04
Concrete Open Channels	0.05	0.04	0.1	0.02
Low Density Residential	0.1	0.12	0.2	0.06
Medium Density Residential	0.15	0.2	0.3	0.1
Large Residential Lot	0.1	0.1	0.2	0.05
Industrial/Commercial Yard	0.15	0.2	0.3	0.1
Open Space	0.1	0.06	0.2	0.04
Vegetation – Medium Density	0.15	0.16	0.3	0.08
Vegetation – High Density	0.2	0.24	0.4	0.12
Road Corridor	0.05	0.06	0.10	0.03
Rail Corridor	0.1	0.16	0.2	0.08

4.2.4 Simulation of Buildings

Building footprint data for the Yanderra study area was sourced from the ELVIS system - Point Clouds dataset, by Geosciences Australia. The point cloud data was last updated in 2014.

The building footprints derived from this dataset were manually refined using aerial imagery. For each building, the DTM was sampled to identify the highest point within the building footprint. An additional 150 mm was added to this ground elevation to approximate the floor level of the building, based on the assumption that residential structures are typically elevated slightly above ground level. The resulting adjusted elevation was applied uniformly across each building footprint.

By simulating buildings in this way, the hydraulic model captures realistic flow paths and flood behaviour in and around residential structures within Yanderra. This methodology allows for water to flow around buildings until flood depths exceed 150 mm, at which point the buildings begin to be inundated above floor level.

4.2.5 Boundary Conditions

The study area comprises the top of the catchment draining to the Bargo River and therefore, there are no inflows from upstream rivers or creeks to the study area.

The TUFLOW hydraulic model boundary conditions for the model with WBNM inputs consist of the following.

- 'Surface area' application of 'local' flow hydrographs from each hydrologic model sub-catchment within the TUFLOW model domain.
- Downstream 'normal depth' boundary applied at the location where the local streamlines flow out of the TUFLOW model.

The locations of the boundaries for the TUFLOW with WBNM inputs are shown in **Figure 4-1**.

5. Flood Model Pseudo-Calibration

Calibration is the process of adjusting model parameters to ensure that the simulated outputs closely match observed data, hence improving the reliability of the model in representing real-world conditions. It is an important step in hydrologic and hydraulic modelling, as it helps verify that the model can accurately replicate flood behaviour and simulate design events with confidence.

In the case of Yanderra, the study area lacks any stream gauges, meaning no direct flow data is available for calibration. This means that the standard approach of calibrating to a recorded stream gauge is not possible. To address this limitation, a pseudo-calibration was undertaken using qualitative data derived from the drainage complaints provided by Council.

The pseudo-calibration was performed for the rainfall event that happened between 1st and 3rd March 2022, given it was identified as the main source of nuisance stormwater flooding complaints received by Council. This event brought significant rainfall to the Yanderra area, overwhelming drainage systems and leading to reports excessive runoff, property flooding and blocked culverts. By using the information from these complaints, the model was refined to better represent the flow pathways and behaviour during this major rainfall event.

5.1 Rainfall Data

The available rainfall record from nearby gauges indicates that the majority of the rainfall occurred between 6:00 am and 6:00 pm on 2nd March 2022. Continuous rainfall data was available in 15-minute intervals.

Recorded rainfall data is applied in the WBNM software according to the coordinates of the gauges, which are considered in relation to the location of the catchment to appropriately distribute the rainfall depths and temporal patterns to each subcatchment in the model. In this way, a rainfall gauge located within or close to the catchment will have a greater influence on the rainfall applied to the model.

Rainfall data from the following three gauges was used in the calibration of the flood models for Yanderra:

- 568531 Tahmoor (Inghams) located approximately 10km north of Yanderra,
- 212063 Lake Nerrigorang at Thirlmere Lakes located approximately 11km north-west of Yanderra,
- 568352 Thirlmere (Rail Museum) located approximately 12.5km north of Yanderra.

The locations of these gauges are shown in **Figure 3-2**.

The cumulative rainfall data at the three selected gauges is shown in **Figure 5-1**, which according to nearby temporal patterns, indicates that the majority of the recorded rainfall occurred between 6:00 am and 6:00 pm on 2nd March 2022. This intense period of rainfall is represented by the steep gradient in the rainfall plot.

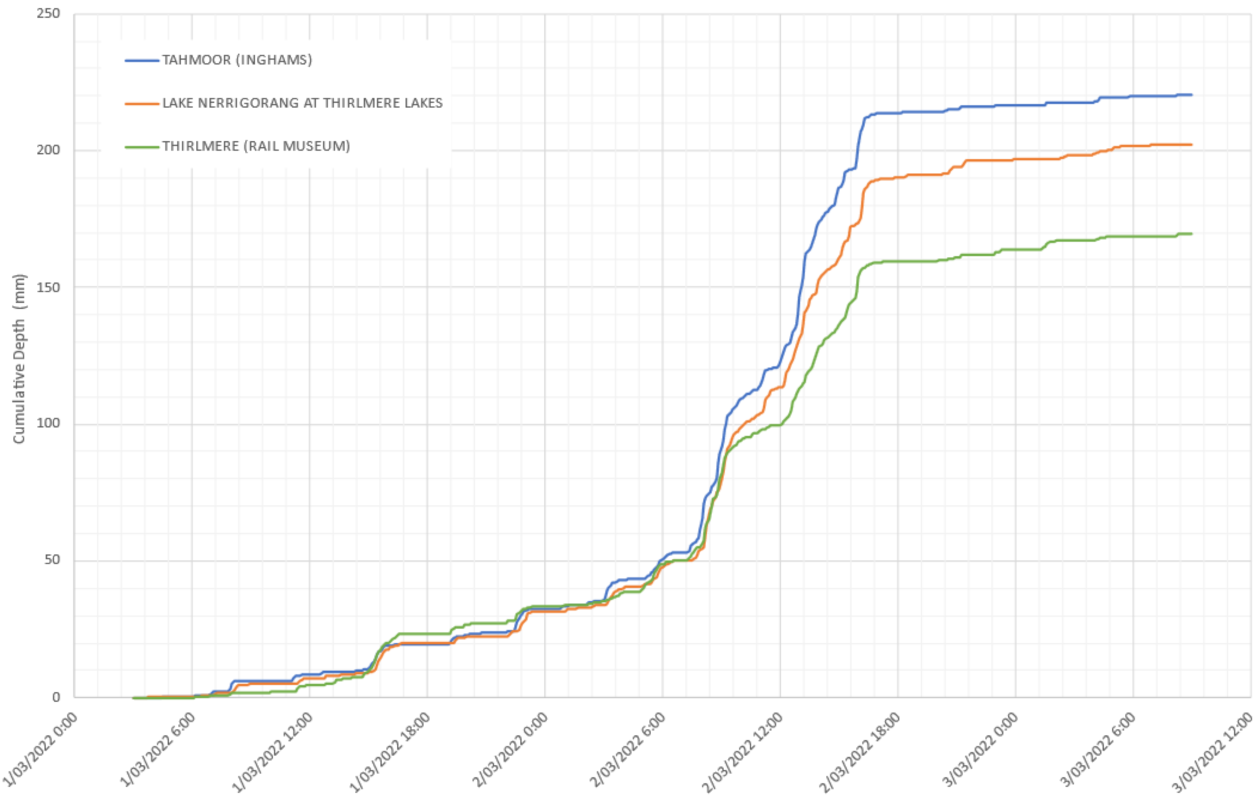


Figure 5-1 Cumulative Rainfall for the March 2022 Storm

5.2 Rainfall Loss Rates

The term 'rainfall losses' refers to precipitation that does not contribute to surface runoff. During a storm such losses occur primarily due to the processes of interception by vegetation, and infiltration into the soil. The initial loss-continuing loss (IL-CL) approach is typically used in Australia to account for losses in the rainfall-runoff process and has been adopted in this study.

Two sets of IL-CL rates were used in this study to better simulate the recorded event (March 2022) and the nominated design storm events.

For the 2022 event an initial loss of 5 mm was adopted, combined with a continuing loss rate of 1 mm/hour. This recognises that there were wet conditions over the 48 hours prior to the most intense rainfall during the March 2022 event.

5.3 Comparison to 2016 Rainfall IFD Data

The rainfall Intensity-Frequency-Duration (IFD) data is taken from the single point locations of the three gauges listed in **Section 5.1**.

The following figures compare the recorded rainfall to the IFD curves provided by the Bureau of Meteorology (refer **Figure 5-2**, **Figure 5-3**, and **Figure 5-4**). Based on the IFD charts, the March 2022 rainfall event at Yanderra is estimated to have been between a 10% and 2% AEP event. However, this estimation is subject to significant uncertainty because the nearest rainfall gauges are located at least 10 km away. Additionally, all available gauges are positioned to the north of Yanderra, resulting in an uneven distribution of data points.

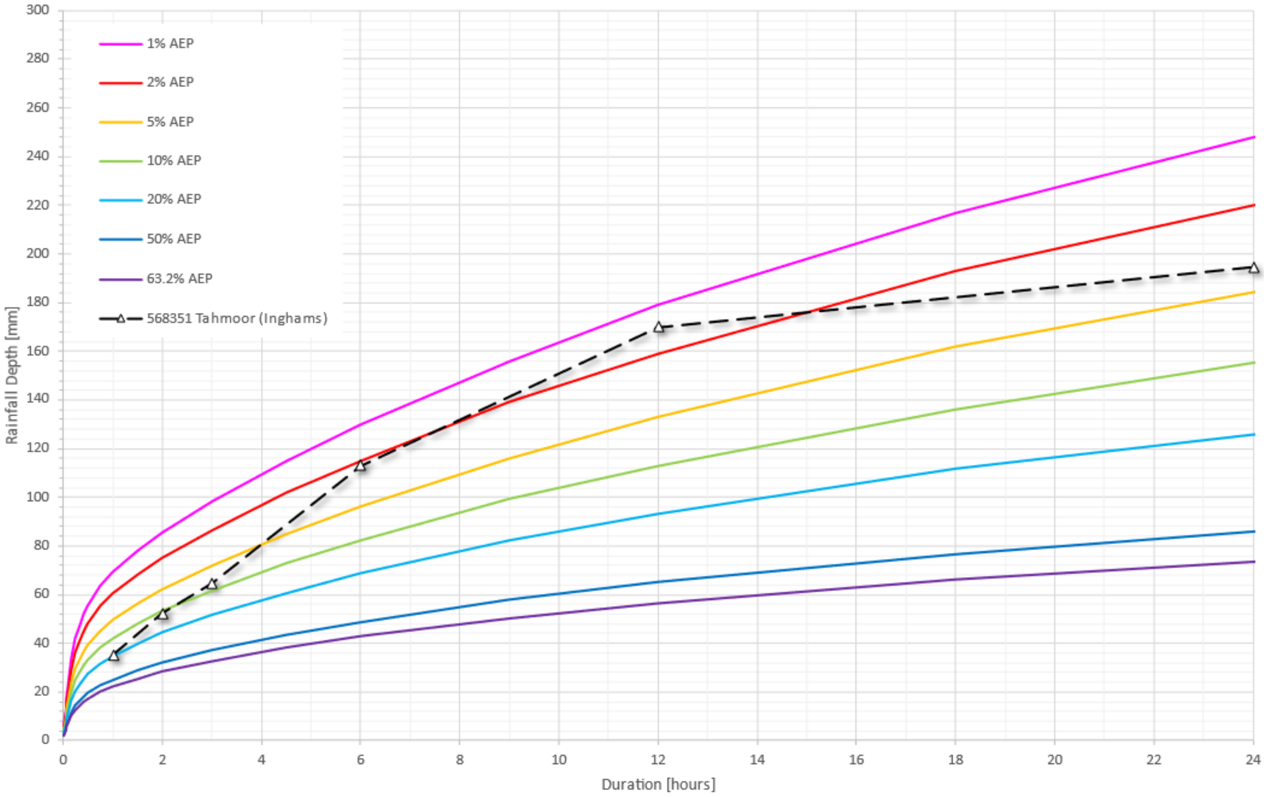


Figure 5-2 Comparison of March 2022 Recorded Rainfall to 2016 IFD at 568531 Tahmoor (Inghams)

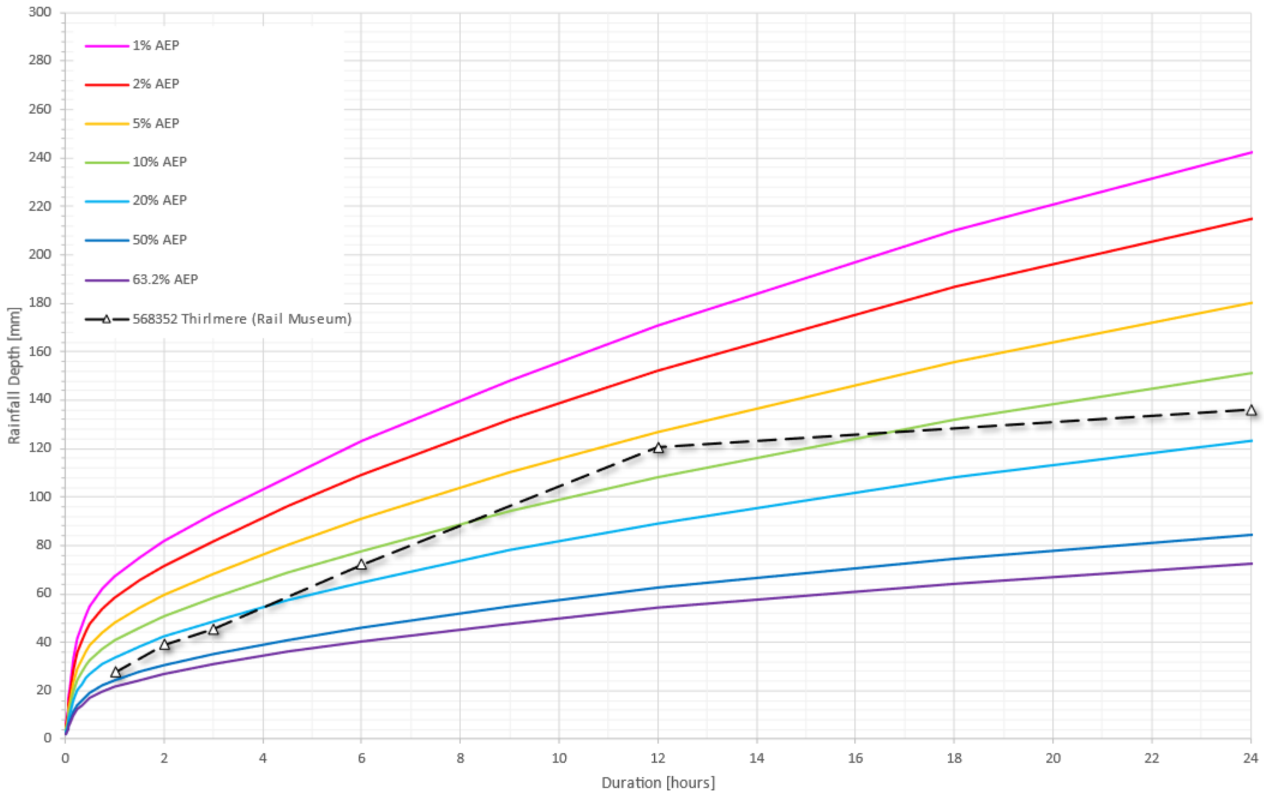


Figure 5-3 Comparison of March 2022 Recorded Rainfall to 2016 IFD at 568352 Thirlmere

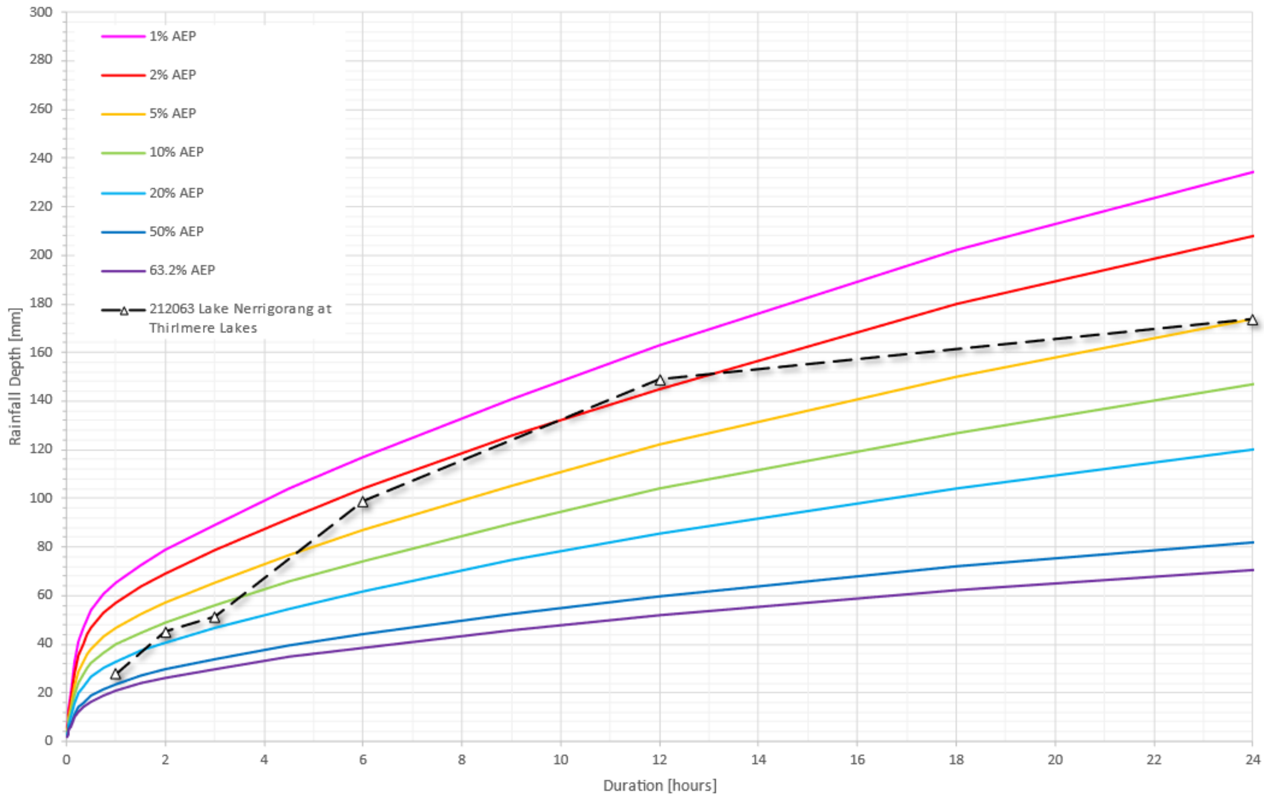


Figure 5-4 Comparison of March 2022 Recorded Rainfall to 2016 IFD at 212063 Lake Nerrigorang

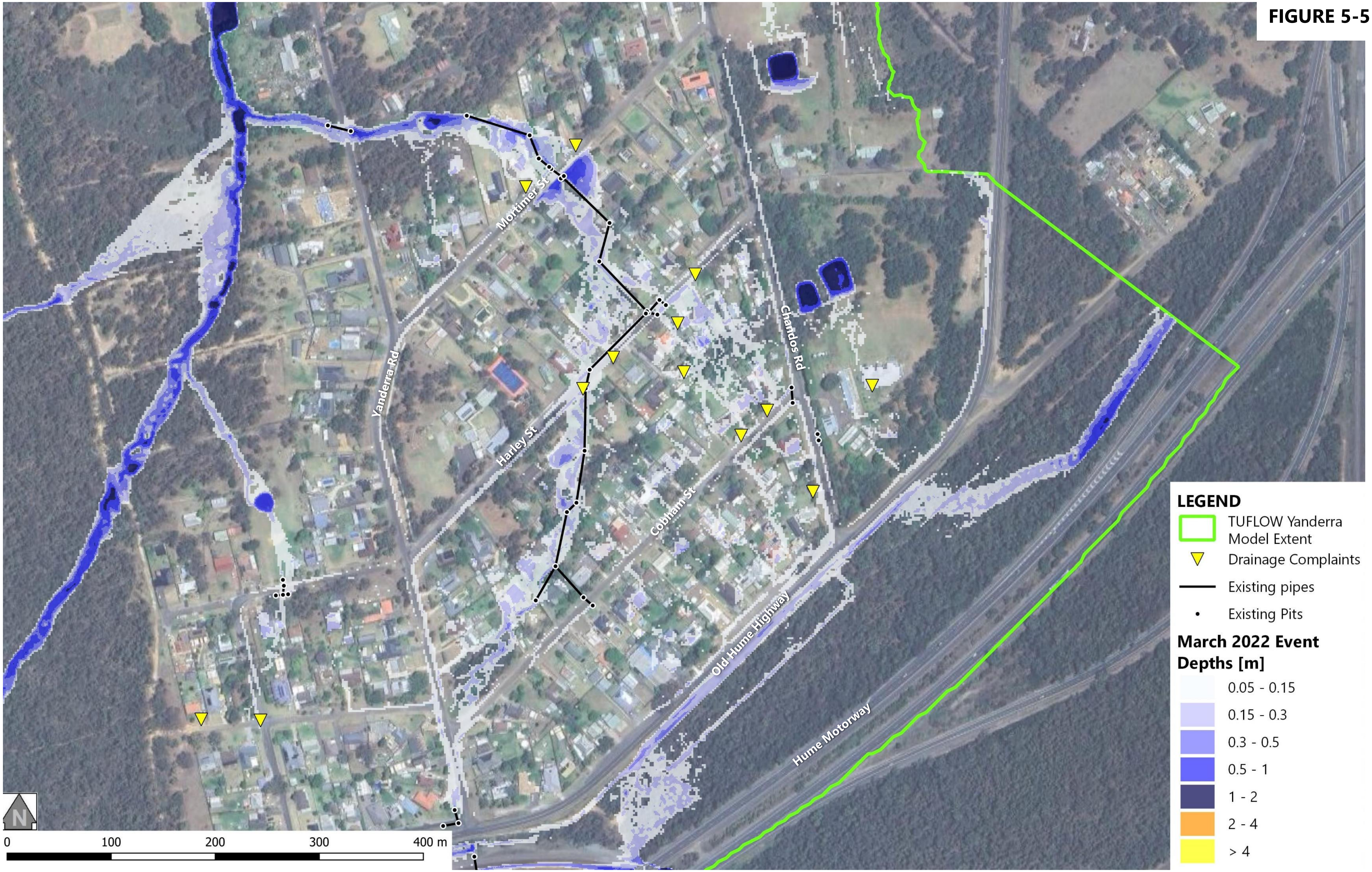
5.4 Simulation of the March 2022 Event

The WBNM model for catchments at Yanderra was used to simulate the March 2022 event using the rainfall data outlined above. Given the lack of streamflow data available for hydrologic model calibration, default WBNM parameters were adopted with a runoff lag factor 'C' of 1.56 and a stream routing lag factor 'F' of 1.0.

Local subcatchment flow hydrographs extracted from the WBNM model results were fed into the TUFLOW model to simulate drainage conditions and produce mapping of inundation extents and depths.

The inundation maps were compared to the anecdotal reports of flooding during the event.

The complaints had a street address attributed to them, which allowed them to mapped and serve as the "ground-truth" for the pseudo-calibration as shown in **Figure 5-5**.



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SIMULATION OF MARCH 2022 EVENT AND YANDERRA DRAINAGE COMPLAINTS

5.5 Summary of Pseudo-Calibration

It was found that the TUFLOW model reliably reproduced anecdotal reports of inundation provided by residents during the March 2022 event. This significant rainfall event led to overland flow and nuisance flooding in the Yanderra area, with modelled extents generally aligning with the reported property impacts as shown in **Figure 5-5**.

Simulated flows originating from the Old Hume Highway and Chandos Road were captured, consistent with residents' descriptions of runoff entering their properties. The simulated flows then flowed through Cobham Street, Harley Street, and Mortimer Street, generally in a south-to-north direction, affecting the properties situated between these streets. Reports from Berkeley Street described shallow water flowing through front yards and garages before continuing north, which the model reflected reliably.

Flood depths were generally between 50 mm and 150 mm, with some areas pooling up to 200 mm, as reported by residents. Around Mortimer Street, the ponding is expected to worsen, reaching depths of up to 800 mm due to water backing-up behind the road. Reports of flooded driveways and garages were also consistent with the inundation mapping.

The generally strong agreement between modelled flood behaviour and anecdotal observations provides confidence in the ability of the drainage model to simulate runoff conditions across the Yanderra catchment.

6. Existing Drainage Conditions

Design flood and drainage conditions are estimated from hypothetical design rainfall events that have a particular statistical probability of occurrence. Guidance and data for the estimation of design flood conditions in Australia as provided in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (ARR 2019) have been adopted in this study.

The probability of a design storm event occurring can be expressed in terms of percentage Annual Exceedance Probability (AEP) and provides a measure of the relative frequency and magnitude of the flood event. Flood conditions during the 50%, 10%, and 1% AEP design events have been investigated in this study.

6.1 Design Rainfall

6.1.1 Design Rainfall Spatial Pattern

Intensity-Frequency-Duration (IFD) data was obtained from the Bureau of Meteorology (BoM) online IFD data tool for three (3) locations across the study area to account for the spatial variation in design rainfall depths during the 50%, 10%, and 1% AEP design storms.

6.1.2 Design Rainfall Temporal Patterns

To estimate a design flood hydrograph a temporal pattern must be applied to the design rainfall depths to describe how rain falls over time.

The ARR 2019 guidelines recommend that 'ensembles' of 10 temporal rainfall patterns that have been derived to represent variability in observed patterns be analysed for each design storm magnitude and duration.

ARR 2019 states that the 10 patterns within an ensemble provide a range of plausible answers, with testing demonstrating that peak flows for a number of the patterns tend to cluster around the mean for most catchments. For the purposes of selecting a single representative design rainfall pattern, the average of the 10 resulting peak flows is taken to be the actual peak design flood flow at a given location, and the temporal pattern resulting in a peak flow nearest to (but not more than 5% less than) this average would typically be adopted to determine the design flood hydrograph.

6.1.3 Assessment of Critical Storm Duration and Temporal Pattern

Critical storm duration refers to the duration of design storm that will result in the highest peak flood flows or levels at a particular location. The critical duration is influenced by various factors including upstream catchment area and may vary between locations of interest throughout a catchment or study area. With the introduction of ARR 2019 a representative temporal pattern must also be identified which produces a peak flow closest to but not less than the design peak flow (that being the average of peak flows from an ensemble set of 10 temporal patterns).

The flood mapping represents peak flood conditions produced by a process of 'flood enveloping'. For each design AEP, this process combines maximum flood level results from two storm durations and scenarios (i.e., local stormwater catchment vs creek flooding) to produce a 'design flood envelope'.

The WBNM model was used to determine critical storm durations, associated temporal patterns and average peak design flows. The scenarios used to produce the peak design inundation envelopes are summarised in **Table 6-1**.

Table 6-1 Summary of scenarios to produce peak design inundation envelopes

Design Event	Critical Duration (min)	Pattern Set	'Average' Pattern ID
50% AEP	45 min	East Coast (South) – frequent	4552
	360 min	East Coast (South) – frequent	4737
10% AEP	45 min	East Coast (South) – intermediate	4542
	180 min	East Coast (South) - intermediate	4662
1% AEP	25 min	East Coast (South) – rare	4461
	60 min	East Coast (South) – rare	4463

6.1.4 Rainfall Losses

Initial loss rates for pervious surfaces adopted in this study are based on the 'Probability Neutral Burst Initial Loss' values available from the ARR Data Hub. Continuing loss rates for pervious surfaces are based on ARR Data Hub values with a multiplication factor of 0.4 applied per NSW specific advice provided by DPE.

Adopted initial loss (IL) and continuing loss (CL) values for design storm modelling are presented in **Table 6-2**.

Table 6-2 Adopted design rainfall loss values

Design Event	Storm Duration	Pervious Surfaces		Impervious Surfaces	
		IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
50% AEP	45 min	26.70	1.80	1.0	0.0
	360 min	26.70	1.80	1.0	0.0
10% AEP	45 min	14.60	1.80	1.0	0.0
	180 min	14.60	1.80	1.0	0.0
1% AEP	25 min	13.60	1.80	1.0	0.0
	60 min	13.60	1.80	1.0	0.0

6.2 Blockage of Hydraulic Structures

Blockage of drainage pits and pipes can impact on the drainage system and nuisance stormwater flooding. According to the complaints received by Council, the Yanderra drainage system appears to suffer blockage issues, which potentially contribute to local flooding and damage to assets, roads, and properties.

Blockage factors were derived from the guidance provided in the ARR 2019 guidelines (refer **Table 6-3**), which were applied to the 50%, 10%, and 1% AEP events.

Table 6-3 Drainage system blockage factors

Type of Inlet/Culvert	Blockage Factor (%)
RCP/culverts with a diameter < 1.5 m	25%
RCP/culverts with a diameter >= 1.5 m	0%
RCBC with a width < 2m	25%
RCBC with a width >= 2m	0%
Normal street inlet pits (lintel and grate)	20%
Grate-only Inlet Pits, behind houses, in reserves/parkland	50%

6.3 Description of Existing Flood Conditions

The WBNM and TUFLOW models were used to simulate the 50%, 10% and 1% AEP storms. Flood depth mapping for existing conditions is provided in **Appendix A**.

Flood mapping for the 10% and 1% AEP events has been filtered according to same method used in the *Wollondilly Shire Flood Study; Broad Scale Assessment* (in draft, 2023), which aims to remove depths less than 150 mm except in areas with significant flow conveyance.

For the 50% AEP event, no additional filtering was applied beyond the standard filtering to remove minor depths less than 50 mm. Given the smaller scale of this event, similar to a 1 in 2 year storm event, the resulting depths are relatively shallow. Applying the same filtering criteria as the larger events would be overly aggressive, potentially obscuring the shallow depths and any observable nuisance flooding during the 50% AEP event.

The flood model results indicate that a significant overland flow path forms to the east of Yanderra Road, running through multiple properties between Cobham Street, Harley Street, and Mortimer Street. This flow path is expected to cross Yanderra Road before discharging into the unnamed tributary leading to Hornes Creek.

South of the Old Hume Highway, floodwaters drain along an existing swale (open channel) to the north-east before turning south and flowing beneath the Hume Motorway (M31) and into Washhouse Gully.

During the 1% AEP storm, minor overtopping of the Old Hume Highway is observed at localised low points, which leads to some inundation of properties fronting the old highway and into Chandos Road (refer **Figure A3**).

To the north of the main Yanderra urban area, flows travelling north along Chandos Road eventually drain under the road and then north-east into Hornes Creek via an unnamed tributary. This overland flow path predominantly affects rural and undeveloped areas, with flood extents and depths largely avoiding any structures.

7. Flood Damages Assessment

The assessment of flood damages provides a standardised methodology to quantify the monetary impact of flooding on structures and properties. It offers an economic perspective on the adverse effects experienced by private and public property owners due to inundation.

The assessment serves multiple purposes, including establishing the base case of existing damages and evaluating the potential reductions in damages resulting from flood mitigation or drainage upgrade measures. This information is vital for conducting a benefit-cost assessment of proposed options and determining their economic viability.

Flood damages assessments are typically conducted on a larger floodplain scale, following the methodology outlined in the *Flood Damages Tool* spreadsheet published relatively recently by Department of Climate Change, Energy, the Environment and Water (DCCEEW) in 2023. The process involves determining the depth of inundation at individual properties and applying depth-damage curves, which specify the expected dollar damages at various depths. These curves are derived from established guidelines and allow for the estimation of damages to residential and non-residential properties, as well as public infrastructure. The results form the basis for calculating annual average damages (AAD) and the net present value (NPV) of flood damages.

For this study, the DCCEEW method has been adapted to suit the localised stormwater runoff and drainage issues at Yanderra.

7.1 Assessment Methodology

Flood damages were assessed using GIS tools to ensure consistency across the nominated design storm events and assessment of drainage system upgrade options. The analysis focused on the impacts to main houses (primary buildings), secondary structures such as sheds and garages, external property flooding, and underground septic systems.

To evaluate flood depths affecting each structure, a 2-meter buffer was applied around each modelled building footprint. This buffer captured the surrounding flood depth, given the buildings are modelled as slightly elevated above ground level in the model, including potential distortions caused by water pooling at building edges due to terrain or GIS raster limitations. The mean flood depth within the buffer was calculated using QGIS's zonal statistics tool. By taking the mean value, this approach ensured that irregularly high depths were not disproportionately represented, providing a more accurate assessment of flood impacts on each structure.

For primary buildings, this flood depth was compared against the Finished Floor Level (FFL), which was estimated using Streetview where required. For secondary structures, flood depth was assessed relative to Ground Level (GL).

Buildings were classified as "affected" based on a threshold for the number of wet cells within the buffer. Primary buildings required a minimum of 200 wet cells to be flagged as impacted, while secondary structures used a threshold of 100 wet cells. External property flooding was identified if a lot contained at least 500 wet cells. Septic systems were deemed impacted if any external flooding was present on the lot, as these systems were assumed to be located at the lowest point on the property.

Cells within a defined watercourse were excluded from the analysis, as changes due to the assessed options were not expected to significantly affect watercourses. This methodology was consistently applied to existing conditions for the 50%, 10%, and 1% AEP events.

The above method was developed according to several iterations of the analysis, testing buffer distances and wet cell thresholds, to provide reasonable estimates of damages.

7.2 Adopted Flood Damage Curves

Damages were calculated using damage curves and depth thresholds tailored to each property category. These damages would be applied to any "affected" building, item or property, as discussed in Section 7.1.

For Yanderra, these damage curves were adapted from a separate flood damages assessment being completed by Worley Consulting for Stonequarry Creek flooding at Picton, which involved updating the previous Picton assessment to the new DCCEEW tool.

The damage curves were adjusted to better reflect the characteristics and structures of buildings in Yanderra (refer **Table 7-1**).

Table 7-1 Flood damage curves adopted for Yanderra

Category	Depth	Damage
External Property Damage	Any	$9,000
Main House (FFL)	Below FFL	$7,000
	0.05m+	$65,000
	0.1m+	$120,000
	0.25m+	$160,000
Shed/Garage (GL)	0.05m+	$10,000
	0.1m+	$15,000
	0.25m+	$20,000
Intangible Impacts	Any	$2,000/structure
Septic Systems Damage	Any	$2,000

7.3 Existing Flood Damages

Base case damages were calculated for the 50%, 10%, and 1% AEP events. These damages represent the monetary impact on various property categories, including external property flooding, houses, sheds, intangible damages, and septic systems.

Damages during 1% AEP storm are expected to total about $2,687,000 (refer **Table 7-2**), with the main house damages contributing the most.

The Average Annual Damage (AAD) represents the expected average monetary losses due to flooding per year. AAD was calculated by integrating damage estimates across multiple flood events weighted by their exceedance probabilities (refer **Table 7-3**).

Table 7-2 Flood damages breakdown for the 1% AEP event

Category	Total Damage
External Property	$810,000
Main House	$1,091,000
Shed/Garage	$510,000
Intangible Impacts	$96,000
Septic Systems	$180,000
Total	**$2,687,000**

Table 7-3 Design storm event contribution to Average Annual Damages

Design Storm	Damage	Contribution to AAD
50% AEP	$791,000	$197,750
10% AEP	$1,525,000	$463,200
1% AEP	$2,687,000	$189,540
	Total AAD	**$850,490**

The AAD for existing conditions is expected to be about **$850,500**. Notably, the 10% AEP event contributes $463,200, making-up more than half of the AAD total.

This highlights the importance of targeting runoff management to events of this scale, as addressing flooding at the 10% AEP level is likely to reduce long-term flood related damages and yield the greatest benefit-to-cost ratio.

8. Assessment of Drainage System Upgrade Options

Drainage upgrade options were developed to address flooding issues in the Yanderra village by targeting the reported drainage problems and reducing overland stormwater runoff.

Option 1 focuses on local street drainage system improvements to capture flows into a piped network and reduce overland flows impacting properties between Cobham Street, Chandos Road, and Harley Street. These works aim to address flooding issues within the urban area by improving localised drainage capacity.

Option 1 was split into two parts:

- **Option 1A**: Addressing immediate drainage concerns along Chandos Road and Harley Street. This phase is designed to be implemented in conjunction with the West Invest Project, which provides pedestrian links between Yanderra Public School and Bargo. The works in Option 1A are also planned to accommodate flows from the proposed works as part of Option 1B.
- **Option 1B**: Upgrading the local drainage system to include additional pits and pipes, and drainage swale widening to manage runoff from Cobham Street, Berkeley Street, and the Old Hume Highway. This phase aims to address overland flows through the majority of the affected residential properties in Yanderra.

Option 2 would involve upgrades to the trunk drainage system in the lower part of the urban area. This option aims to alleviate flooding in particular properties at the downstream end of the central flow path through the town by increasing the capacity of the pipe system and inlets to accommodate larger flow rates.

8.1 Options Assessment Overview

The options assessment process involved the following steps:

- **Proposed Works and Modelling**: The proposed drainage upgrade works were incorporated into modified versions of the TUFLOW model, including drainage improvements such as modifications to pits, pipes, and drainage swales. The post-works models were used to simulate the three design storms.
- **Results Comparison**: Model results were extracted and compared against the existing conditions modelling to produce flood level difference maps that highlight changes in runoff behaviour (refer **Appendix B**).
- **Flood Damages Reduction Assessment**: The reduction in flood damages associated with each option was assessed and compared with the existing flood damages determined in Section 7.3.
- **Cost Estimation**: A detailed cost estimate was prepared for each option based on unit rates from the Rawlinsons Construction Handbook and industry pricing where available.

The flood damages reduction and cost estimates were then used to complete a benefit-cost analysis for the options (refer **Section 9**).

8.2 Option 1A – Chandos Rd North of Harley St

8.2.1 Proposed Works

Option 1A would involve the following drainage system improvements (refer **Figure 8-1** and **Figure 8-2**):

- Installation of a new pit and pipe system along Chandos Road to the north of Harley Street, including approximately six inlet pits and 450mm diameter pipe, to convey runoff to the north.
- Local deepening and widening of the existing table drain along Chandos Road to a 2-metre base width, to accommodate the headwall and flows from the new pipe system.
- Installation of two inlet pits along the trunk drainage line on Harley Street, near Yanderra Public School, as part of the footpath upgrades included in the West Invest project.

These works are proposed to address existing drainage problems and better capture runoff in these areas. Option 1A forms part of the broader Option 1 street drainage system, but is separated for implementation alongside the West Invest project, which involves footpath upgrades (and kerb and gutter in Harley Street) to establish a pedestrian link between Yanderra Public School and Bargo.

8.2.2 TUFLOW Modelling

The proposed works were included in the TUFLOW model. The post-works model was used to simulate the 50%, 10% and 1% AEP storms. Blockage factors were applied to the proposed culverts consistent with the approach adopted for existing conditions modelling (refer **Table 6-3**).

The proposed kerb and gutter along Chandos Road was modelled as a "gully line" in TUFLOW to enforce a small depression along the edge of the road, such that guides runoff into the proposed inlet pits.

The proposed works for Option 1 were modelled as a combination of both Option 1A and Option 1B works.

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OPTION 1A – STREET DRAINAGE UPGRADES
CHANDOS ROAD WORKS NORTH OF HARLEY ST

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OPTION 1A – STREET DRAINAGE UPGRADES
HARLEY STREET WORKS

8.2.3 Post-Works Flood Mapping

Refer to **Appendix B** for flood depth and flood level difference mapping to show the impact of the Option 1A works for each design event.

Flood mapping for the 10% and 1% AEP events has been filtered according to same method used in the *Wollondilly Shire Flood Study; Broad Scale Assessment* (in draft, 2023), which aims to remove depths less than 150 mm except in areas with significant flow conveyance. For the 50% AEP event, no additional filtering was applied to the flood depths and flood level difference mapping beyond the standard clipping to remove depths less than 50 mm.

Shades of yellow to red in the flood level difference mapping represent areas with flood level increases and shades of the blue are areas where flood levels are expected to be reduced. The green represents areas that are flooded under existing conditions but are no longer expected to be inundated. The magenta represents areas that would be newly inundated in the post-works scenario.

Flood level difference mapping for Option 1A indicates minor increases in flood depths (orange and red) to along the western edge of Chandos Road to the north of Mortimer Street. However, these impacts are localised along the roadside, largely confined to the verge and the very front of driveways to large lot residential properties. No structures are expected to be inundated.

Some minor increases in flood levels are expected to the east of Chandos Road, after the runoff passes through the existing box culvert beneath Chandos Road. However, the increases are no greater than 25mm and are not expected to translate to a significant increase in the flood extent as the stormwater passes along a shallow gully through private property.

The two additional pits along Harley Street are expected to provide the greatest benefit in reducing the extent of overland runoff in the 10% AEP storm.

8.2.4 Flood Damages Reduction

Option 1A is not expected to significantly reduce flood damages in its own right. The works along Chandos Road are primarily designed to accommodate and transfer stormwater flows from Option 1B to the north.

The flood damages assessment tool calculates impacts based on flood-affected areas within property boundaries and against structures, which are not significantly impacted by the Option 1A works. Despite the reduction in 10% AEP flood extent on the north side of Harley St due to the additional inlet pits, the change in affectation at houses and structures was not significant, and not sufficient to translate to a reduction in damages.

Accordingly, a damages reduction analysis was not completed for Option 1A.

8.2.5 Cost of the Works

A cost estimate was prepared for the works based on unit rates from Rawlinsons Construction Handbook and industry prices where available (refer **Appendix C**).

The works are estimated to cost about **$538,000**, which includes allowance for further design and approvals, and a construction contingency of 20%.

8.3 Option 1B – Street Drainage Upgrades South of Harley St

8.3.1 Proposed Works

Option 1B would involve the following works (refer **Figure 8-3**).

- Installation of up to 17 stormwater inlet pits and 450mm diameter pipes along Cobham Street and Chandos Road to capture overland runoff and direct flows north along Chandos Road to the Option 1A works.
- Installation of up to 6 stormwater inlet pits and 450mm diameter pipes along Berkeley Street to capture overland runoff and direct it to an outlet on the north side of Harley Street.
- Widening of the existing drainage swale along the south side of the Old Hume Highway, expanding the base width to approximately 3 meters (doubling the size). This widening will help prevent overtopping of the Old Hume Highway in the 1% AEP storm, reducing flows towards Cobham Street and Harley Street properties via redirecting flows to the north-east past the southern end of Chandos Road.

Option 1B builds upon the works outlined in Option 1A, which is part of the West Invest Project focused on pedestrian links and infrastructure upgrades along Hartley Street and Chandos Road. The works are intended to address overland stormwater flows through Yanderra at the key areas identified in drainage complaints received by Council.

8.3.2 TUFLOW Modelling

The proposed works were included in the TUFLOW model. The post-works model was used to simulate the 50%, 10% and 1% AEP floods. Blockage factors were applied to the proposed culverts consistent with the approach adopted for existing conditions modelling (refer **Table 6-3**).

The proposed kerb and gutter along Chandos Road and Cobham Street was modelled as a "gully line" in TUFLOW to enforce a small depression along the edge of the roads, such that guides the overland runoff into the proposed inlet pits. As shown in **Figure 8-3**, a large number of inlet pits are modelled along Cobham Street and Chandos Road, which is to ensure maximum runoff capture according to the adopted TUFLOW modelling approach. However, the proposed number of pits to be constructed would be reduced according to an average spacing of 30 metres along new kerb and gutter which will guide runoff to the pits.

As outlined above, the proposed works for Option 1 were modelled as a combination of both Option 1A and Option 1B works.

FIGURE 8-3

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OPTION 1B – STREET DRAINAGE UPGRADES SOUTH OF HARLEY STREET

8.3.3 Post-Works Flood Mapping

Refer to **Figures B1 to B12** in **Appendix B** for flood depth and flood level difference mapping to show the impact of the works for each design event.

The flood mapping for Option 1B demonstrates significant improvements in stormwater management within the study area. The installation of pits and pipes along Cobham Street and Chandos Road captures a significant portion of overland runoff that would otherwise flow across properties to the north and south of Cobham Street at the eastern end of the village, which is where several of the drainage complaints were concentrated.

The effect of this runoff capture and redirection to the north along Chandos Road also translates to a reduction in flood levels along the main overland flow path through the town, particularly downstream from Mortimer Street.

Additionally, the widened drainage swale along the south side of the Old Hume Highway conveys additional water to the north-east, effectively preventing water from spilling over the highway towards the urban area in the 1% AEP event. While there is some redirection of flows to the north-east toward Bargo, assessment of the local topography at the southern edge of Bargo indicates that this flow will be guided to the south towards the Nepean River, rather than spill to the north towards Bargo.

The proposed drainage network along Berkeley Street and into Harley Street is expected to reduce overland flows through properties on the east side of Berkeley Street, while also avoiding any significant adverse impacts on the property to the north of Harley Street.

8.3.4 Flood Damages Reduction

The flood damage curves were applied to the flood model results from the Option 1B works scenario and compared with flood damages for existing conditions (refer **Table 8-1**).

Table 8-1 Option 1B flood damages reduction

Design Event	Existing Flood Damages	Option 1B Flood Damages	Flood Damages Reduction	Change
1% AEP	$2,687,000	$2,196,000	-$491,000	-18.3%
10% AEP	$1,525,000	$1,243,000	-$282,000	-18.5%
50% AEP	$791,000	$672,000	-$119,000	-15.0%

Option 1B reduces Average Annual Damage (AAD) from about $850,000 to $700,000, providing a net annual benefit of about $150,000.

8.3.5 Cost of the Works

A cost estimate was prepared for the works based on unit rates from Rawlinsons Construction Handbook and industry prices where available (refer **Appendix C**).

The works are estimated to cost about **$1.4m**, which includes an allowance for further design and approvals, and a construction contingency of 20%.

8.4 Option 2 – Trunk Drainage Upgrades

8.4.1 Proposed Works

This option targets flooding along the main trunk drainage line positioned in the natural overland flowpath of Yanderra by incorporating enhancements to the trunk drainage system in the vicinity of Mortimer Street (refer **Figure 8-4**)

Option 2 would involve the following trunk drainage works:

- Upgraded inlet pits and stormwater pipe sizes (750mm diameter) south of Mortimer Street to reduce the depth and extent of stormwater ponding in depressions on the south side of the road.
- Installation of additional inlet pits and connecting pipes on the north side of Mortimer Street, feeding into the main trunk line.
- Upgraded stormwater pipe system north of Mortimer Street (twin 1050 mm diameter pipes) to accommodate larger flow rates to reduce overland flows through properties to the north of Mortimer Street.

As indicated in **Figure 8-4**, the post-works scenario for Option 2 incorporated recent site survey data for the property at 15 Mortimer Street. The survey captures some localised landform changes north of the buildings, which are not reflected in the available LiDAR data.

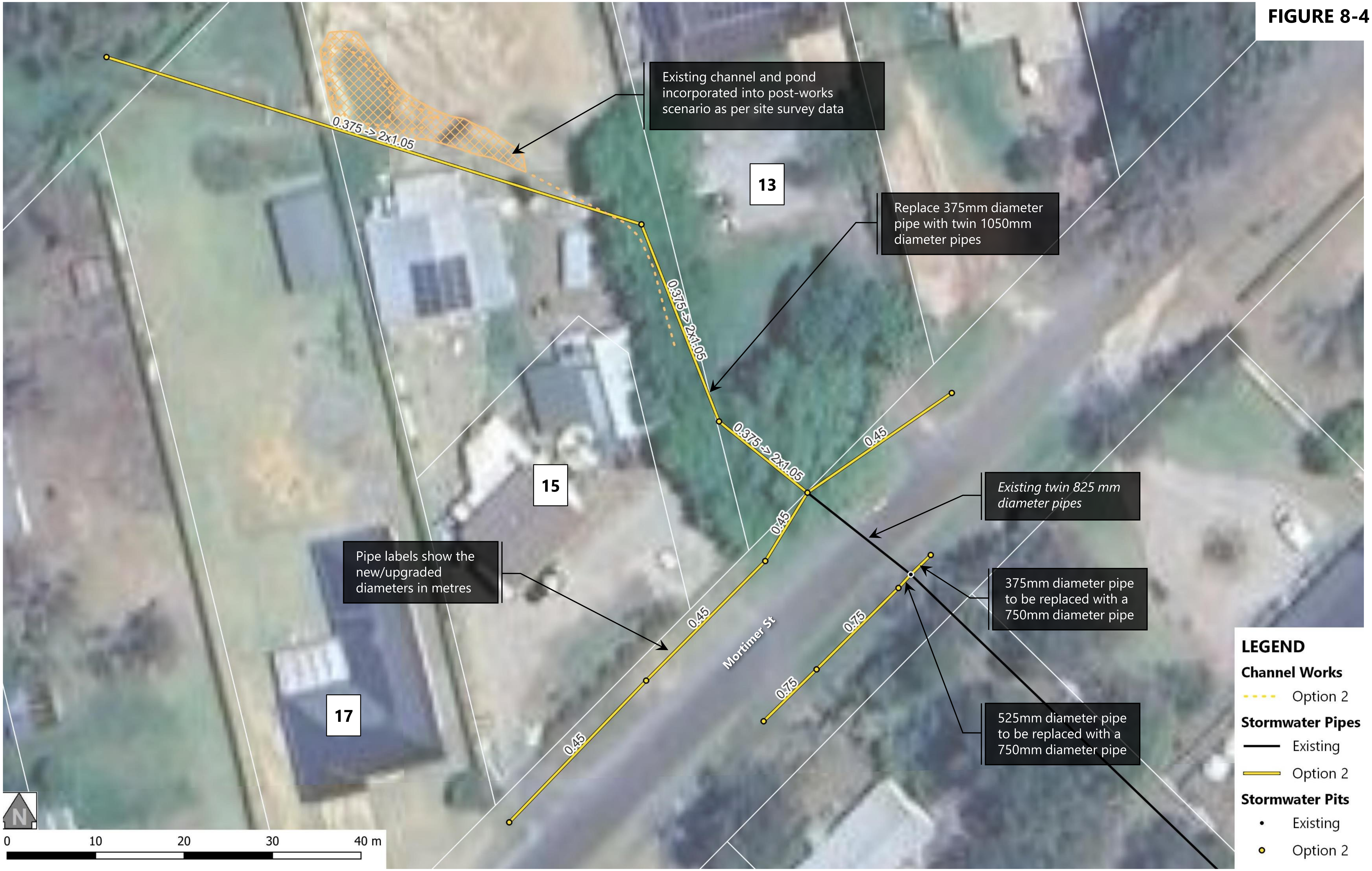
8.4.2 TUFLOW Modelling

The proposed works were included in the TUFLOW model. The post-works model was used to simulate the 50%, 10% and 1% AEP floods.

Blockage factors were applied to the proposed culverts consistent with the approach adopted for existing conditions modelling (refer **Table 6-3**).

The alignment of the proposed twin 1050 mm diameter pipes shown in **Figure 8-4** is modelled indicatively. Any further design would need to consider appropriate depths of cover and exact alignment to avoid existing structures if possible.

FIGURE 8-4



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OPTION 2 – TRUNK DRAINAGE UPGRADES

8.4.3 Post-works Flood Mapping

Refer to **Figures B13 to B18** in **Appendix B** for flood depths and flood level difference mapping to show the impact of the Option 2 works for each design storm.

The flood mapping shows decent reductions in inundation extent during the 50% AEP storm, including areas north and south of Mortimer Street. In the 10% AEP event a significant reduction in flood extent is expected through properties on the north side of the street, but only relatively minor reductions in flood level on the south side of the road.

During the 1% AEP storm the Option 2 works will result in some significant reductions in flood levels (up to about 300mm). However, the extent of flooding is not expected to be impacted significantly.

The magenta area shown at the northern end of 15 Mortimer Street is reflective of the site survey data incorporated into the post-works modelling, which includes some additional cut in this location, and is not a reflection of any adverse flood impacts.

8.4.4 Flood Damages Reduction

The flood damage curves were applied to the flood model results from the Option 2 works scenario and compared with flood damages for existing conditions (refer **Table 8-2**).

Table 8-2 Option 2 flood damages reduction

Design Event	Existing Flood Damages	Option 2 Flood Damages	Flood Damages Reduction	Change
1% AEP	$2,687,000	$2,632,000	-$55,000	-2.0%
10% AEP	$1,525,000	$1,480,000	-$45,000	-3.0%
50% AEP	$791,000	$733,000	-$58,000	-7.3%

Option 2 provides a relatively minor reduction in AAD of $40,000.

8.4.5 Cost of the Works

The works are estimated to cost about **$798,000**, which includes an allowance for further design and approvals, and a construction contingency of 20% (refer **Appendix C**).

9. Benefit-Cost Assessment of Options

The Benefit-Cost Ratio (BCR) is a key metric used to assess whether the benefits of a proposed flood mitigation option outweigh the costs of its implementation. Specifically, it compares the reduction in Average Annual Damages (AAD) achieved by the works to the total costs, including both capital and ongoing maintenance costs. A BCR greater than 1 indicates that the benefits, in terms of reduced flood damages, justify the costs of the project, making it a worthwhile investment. Conversely, a BCR of less than 1 would suggest that the costs of the works are not justified by the benefits, and the project may not be a cost-effective solution.

The calculation of the Net Present Value (NPV) considers the long-term costs and benefits, applying a 7% discount rate over a 30-year period. This reflects the present value of future costs and benefits, with the assumption that the flood mitigation works will provide ongoing benefits over the lifespan of the infrastructure. In addition to the capital costs, the NPV includes the annual maintenance costs for each option, which are essential for maintaining the functionality of the proposed stormwater systems.

The assumed annual maintenance costs for each option are as follows:

- Annual maintenance for Option 1A: $2,000
- Annual maintenance for Option 1B: $5,000
- Annual maintenance for Option 2: $2,000

The higher annual maintenance costs for Option 1B, projected at $5,000, are due to the increased number of pits and pipes, requiring more frequent clearing of debris. These maintenance costs are included in the total NPV for each option. A summary of the BCR calculation for the drainage upgrade options is provided in **Table 9-1**. As discussed above, no significant reduction in damages is expected for Option 1A in isolation.

Table 9-1 BCR summary for options

	Option 1A	Option 1B	Option 2	Combined Options
NPV of AAD Reduction	-	$1,796,000	$491,400	$2,287,400
NPV of Costs	$563,100	$1,465,400	$822,800	$2,851,300
BCR	-	1.23	0.60	0.80

The results show that Option 2 has a BCR significantly less than 1.0, which is a reflection on the relatively low damages reduction compared to costs.

The BCR for Option 1B is favourable at 1.2. However, given the Option 1B works are to be constructed in conjunction with Option 1A works, the overall BCR for the combined Option 1 would be about 0.9. This BCR is not much less than 1.0 and therefore, the combined Option 1 may still be worthwhile to pursue subject to obtaining construction funding.

When all three options are combined, the proposed works yield an overall BCR of 0.8.

10. Drainage Master Plan

10.1 Recommended Works and Staging

The proposed works and staging that form recommendations of the Yanderra Drainage Master Plan are outlined below.

10.1.1 Phase 1A Works

This phase would comprise the Option 1A drainage system upgrades along Chandos Road (north of Harley Street) and Harley Street, including stormwater inlet pits, pipes and drainage swales.

Although a BCR has not been calculated for these works in isolation, they are considered worthwhile given the overlap with the West Invest project to provide pedestrian connectivity between Yanderra and Bargo. They are also essential to accommodate stormwater flows captured by future Phase 1B works.

Accordingly, it is recommended these works be completed prior to other components of this Master Plan.

10.1.2 Phase 1B Works

This phase would comprise the Option 1B drainage system upgrades at Cobham Street, Chandos Road (south of Harley Street) and Berkeley Street, in combination with drainage swale widening along the south side of the Old Hume Highway.

The combined Phase 1A + 1B works are estimated to have a BCR of about 0.9, which indicates the flood damages reduction benefit is only slightly outweighed by the cost of works.

It is envisaged that further work on the West Invest project may result in a reduced cost of works for Phase 1A, particularly if there is overlap on aspects of the work, such as site establishment, kerb and gutter construction, traffic management and site clean-up.

In this case the combined Phase 1A + 1B works are likely to have a BCR greater than 1.0, which indicates they are justified from an economic investment perspective.

10.1.3 Phase 2 Works

This phase would comprise the Option 2 works. The substantial cost of works for limited reduction in damages afforded at a very local scale at Mortimer Street properties leads to a BCR of only 0.6.

Accordingly, the Phase 2 works are not considered a priority. They could be considered for implementation further into the future if additional funding and resources become available after Phases 1A and 1B are completed.

10.2 Additional Recommendations

It is recommended that further concept and detailed design of the proposed drainage system upgrade works involve the following:

- Consideration of the West Invest project timeline and scope of works, particularly in identifying potential overlap with the proposed Phase 1A works.
- Investigations to determine the alignment and depth of existing underground and overhead utility services at the locations of the proposed works, ideally to avoid as part of the proposed works or to otherwise account for services relocation works.
- Detailed stormwater modelling (i.e., DRAINS modelling) to account for the proposed kerb and gutters in confirming the required stormwater inlet pit spacing and pipe sizes to optimise performance.

11. References

- Australian Emergency Management Institute (2013), '*Managing the floodplain: a guide to best practice in flood risk management in Australia*'.
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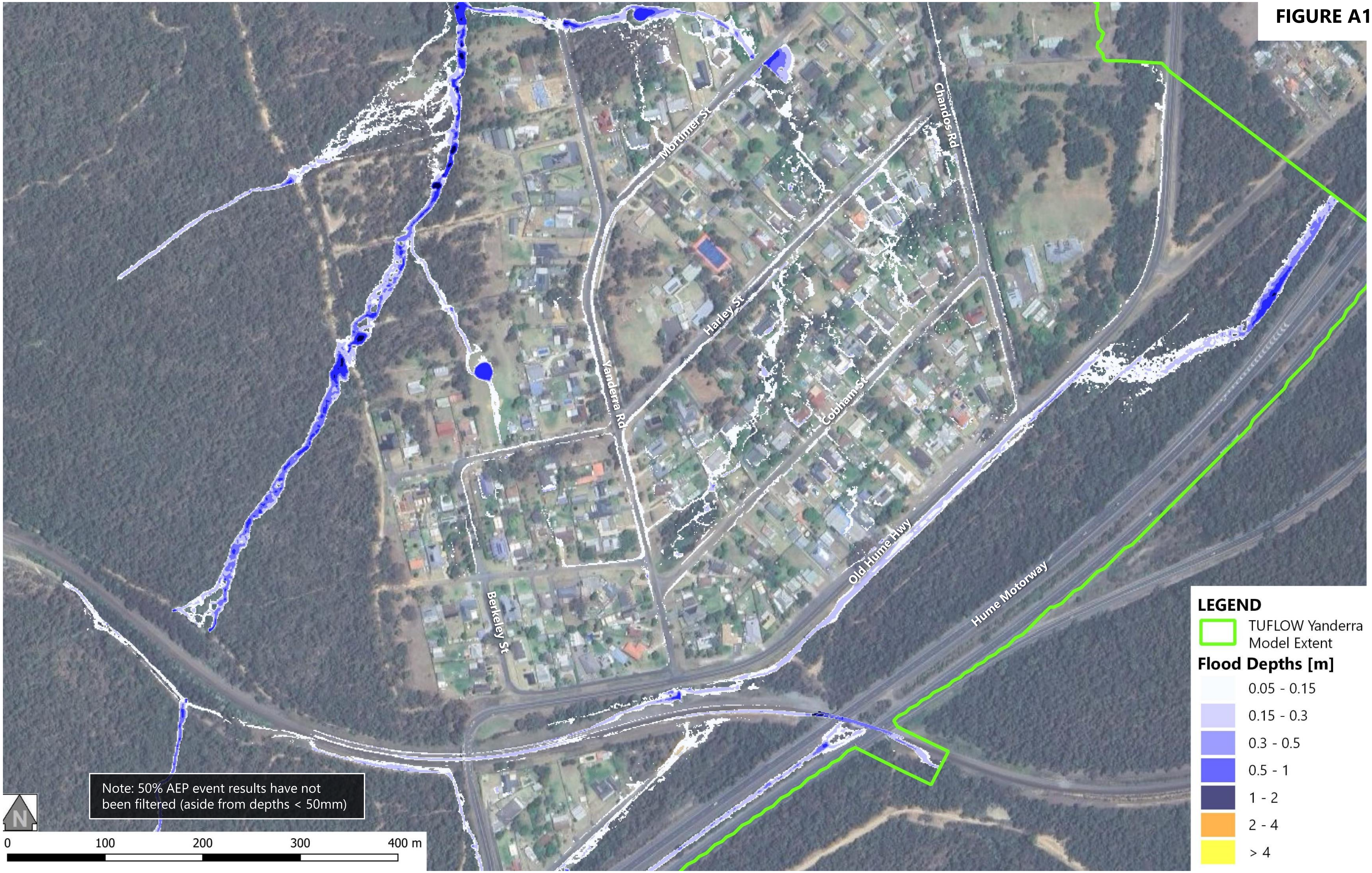
Appendix A. Existing Conditions Flood Mapping

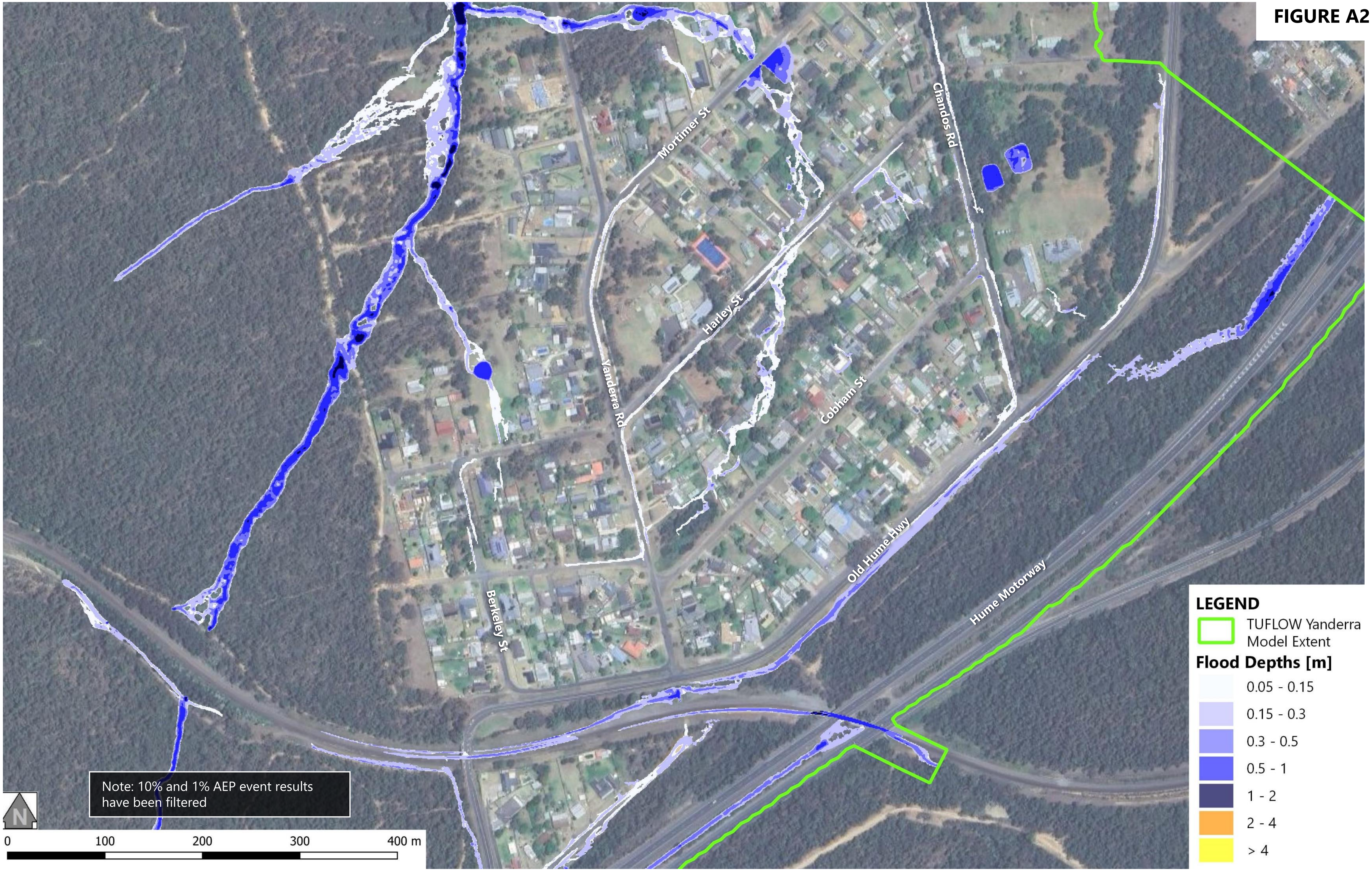
FIGURE A1



Prepared by:

EXISTING CONDITIONS
50% AEP FLOOD DEPTHS

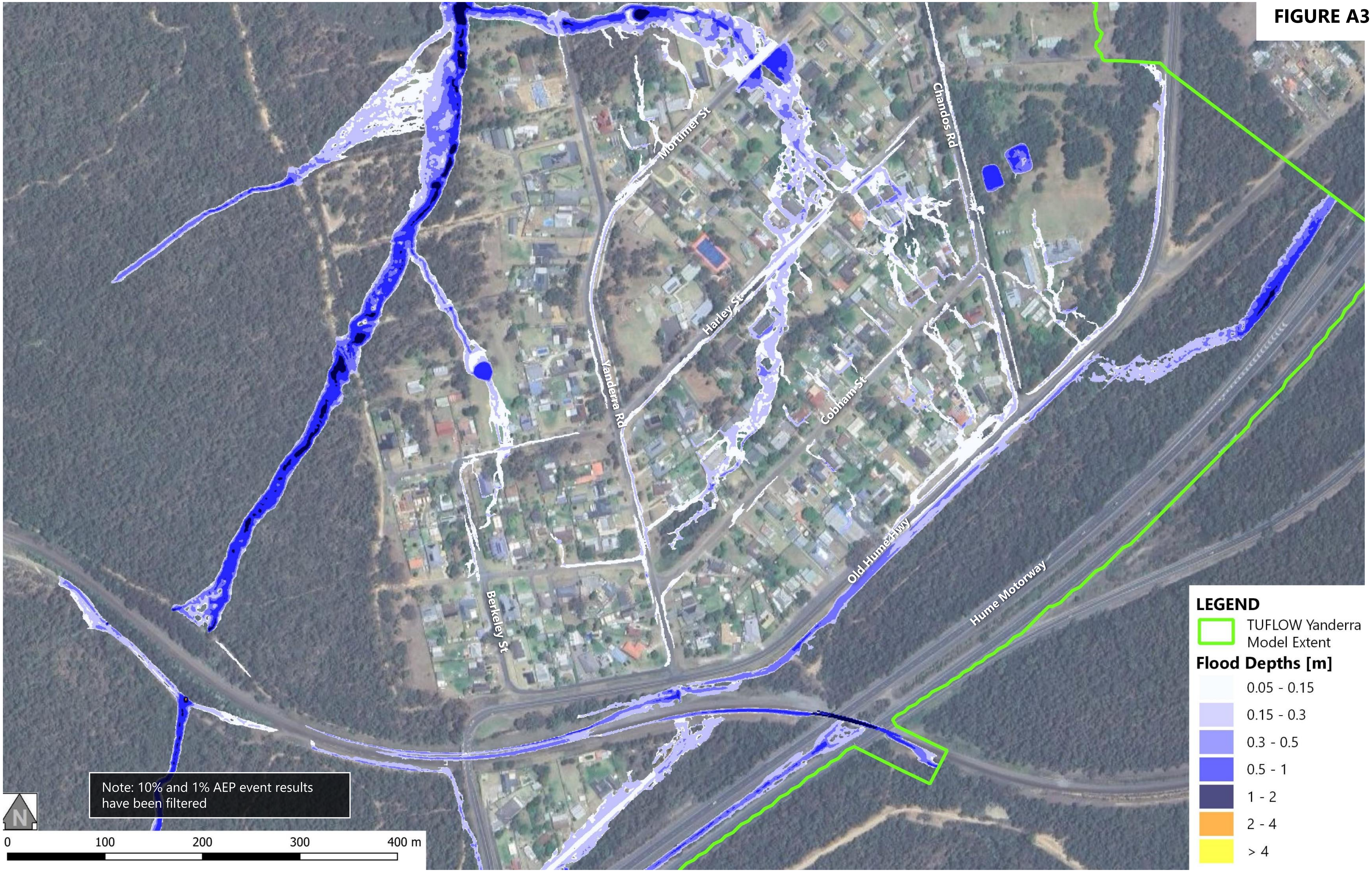
FIGURE A2



Wollondilly Shire Council

Prepared by: worley consulting

EXISTING CONDITIONS
10% AEP FLOOD DEPTHS



Wollondilly Shire Council

Prepared by: worley consulting

EXISTING CONDITIONS
1% AEP FLOOD DEPTHS

Appendix B. Drainage Options Flood Mapping

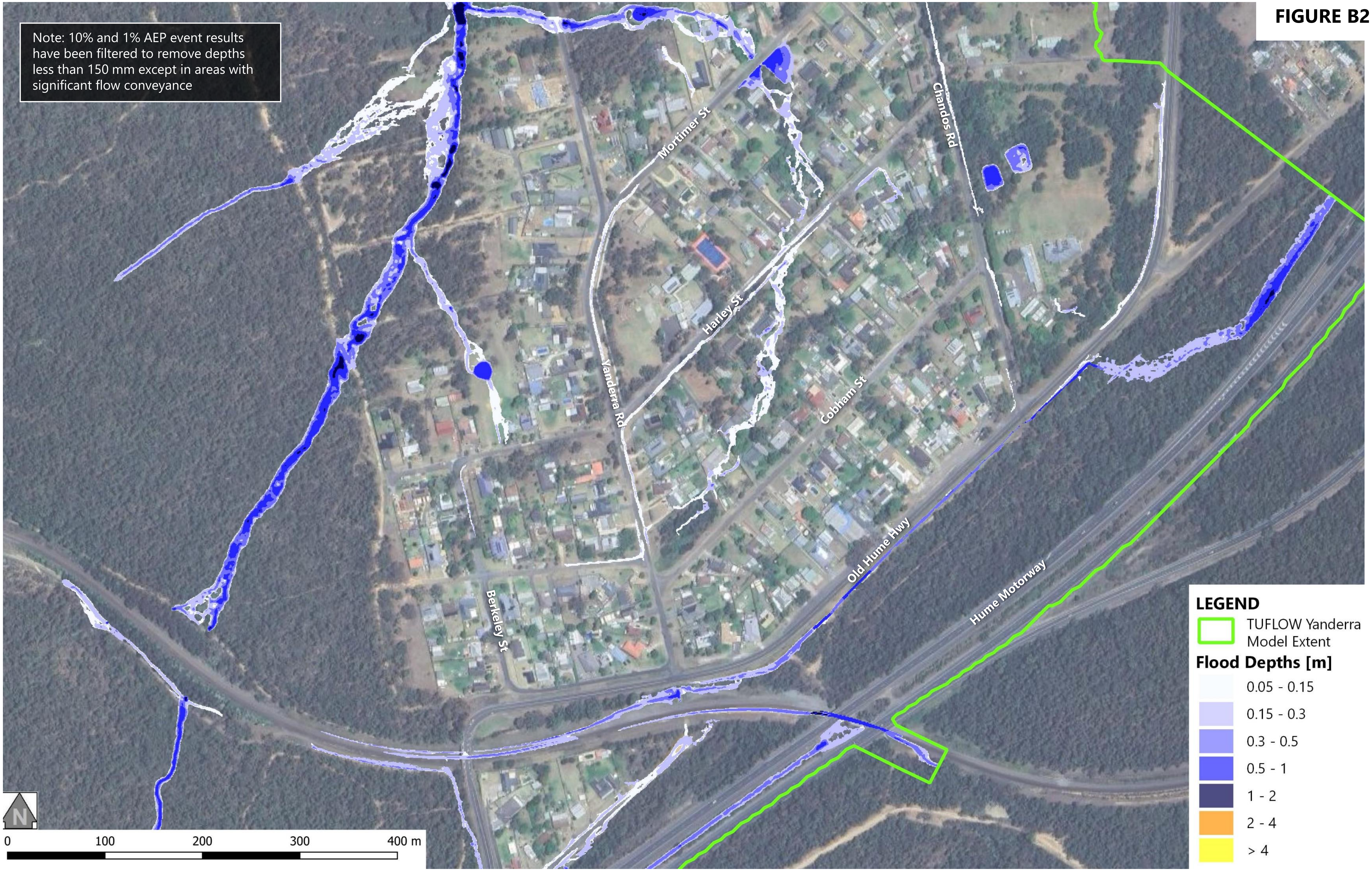
FIGURE B1

Prepared by:

Wollondilly Shire Council

worley consulting

OPTION 1 – STREET DRAINAGE SYSTEM UPGRADES
50% AEP FLOOD DEPTHS

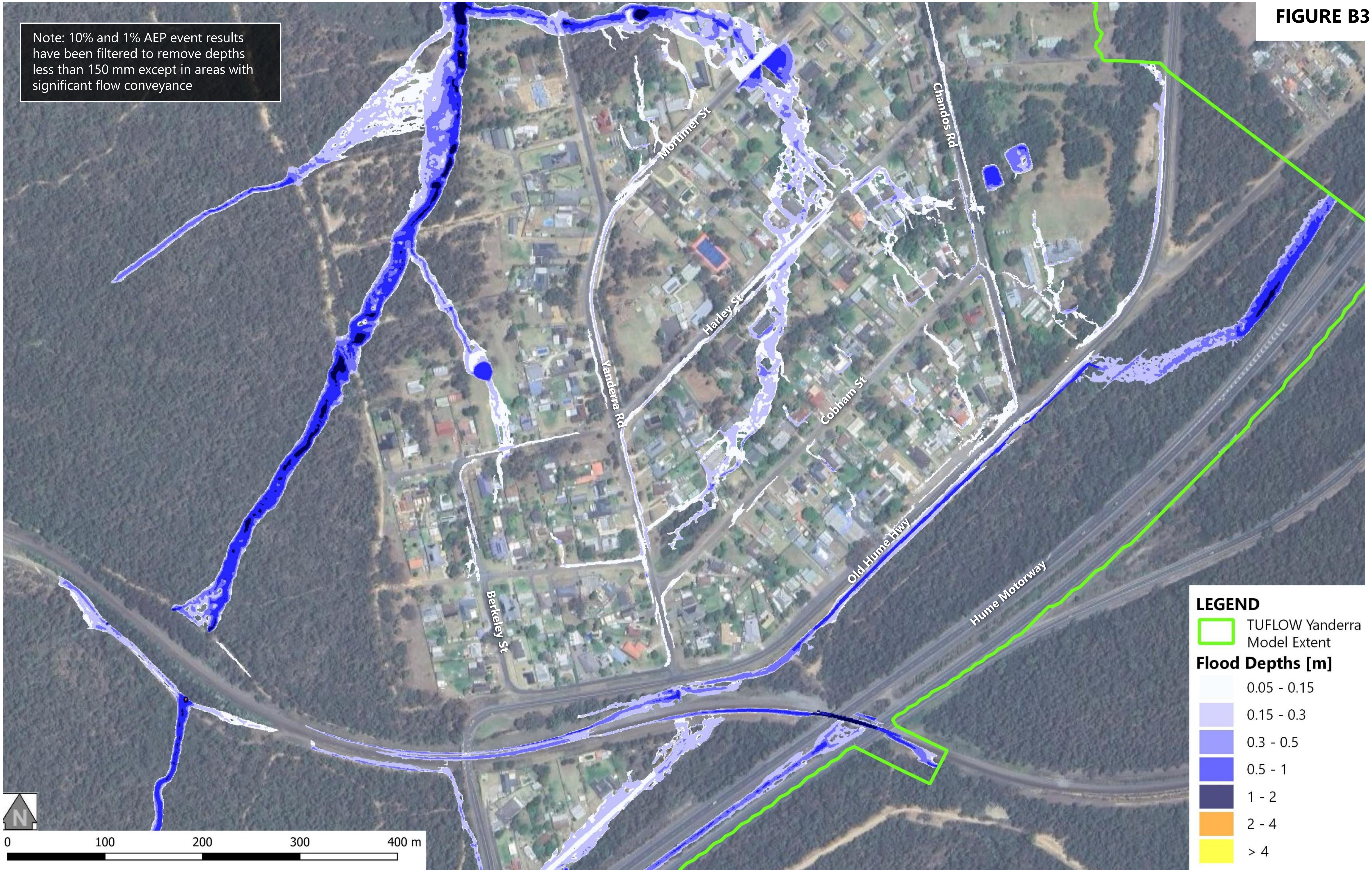


Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1 – STREET DRAINAGE SYSTEM UPGRADES
10% AEP FLOOD DEPTHS

FIGURE B3



Prepared by:

OPTION 1 – STREET DRAINAGE SYSTEM UPGRADES
1% AEP FLOOD DEPTHS

Wollondilly Shire Council

Prepared by:

worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 50% AEP FLOOD LEVELS [CHANDOS RD]

FIGURE B5

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 10% AEP FLOOD LEVELS [CHANDOS RD]

FIGURE B6

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 1% AEP FLOOD LEVELS [CHANDOS RD]

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 50% AEP FLOOD LEVELS [HARLEY ST]

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 10% AEP FLOOD LEVELS [HARLEY ST]

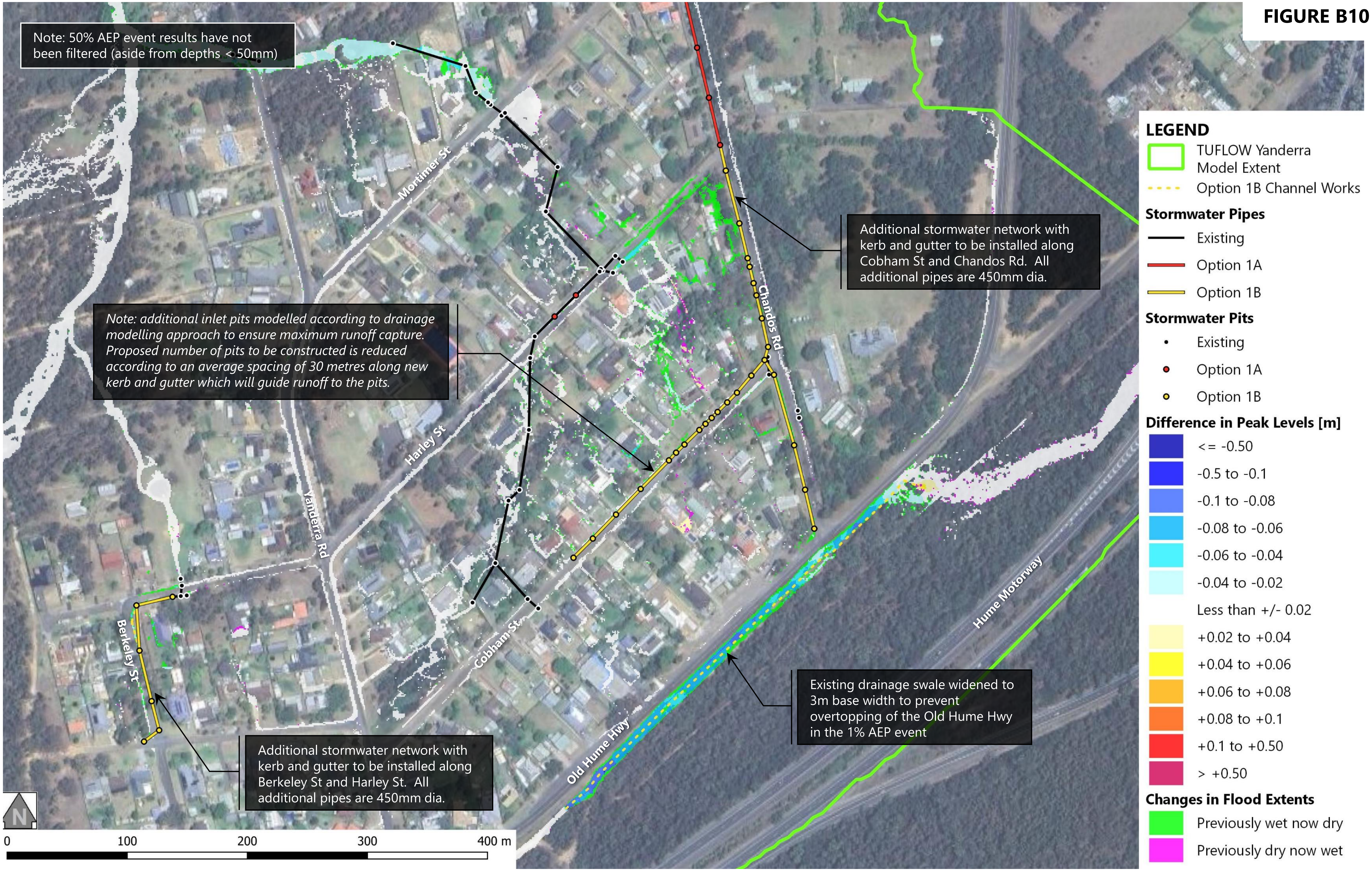
FIGURE B9

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 1A – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 1% AEP FLOOD LEVELS [HARLEY ST]

FIGURE B10

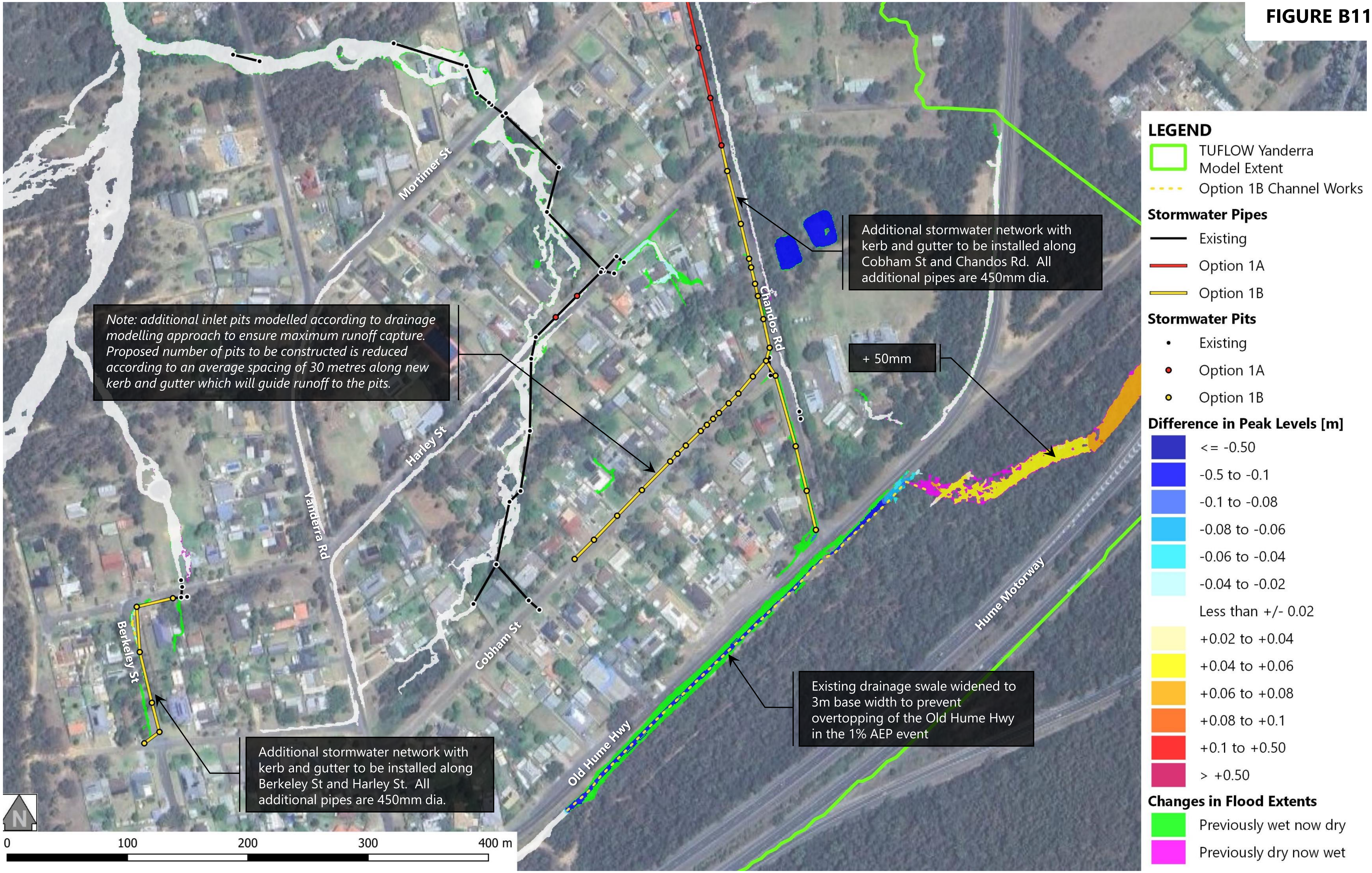


Wollondilly Shire Council

Prepared by: worley consulting

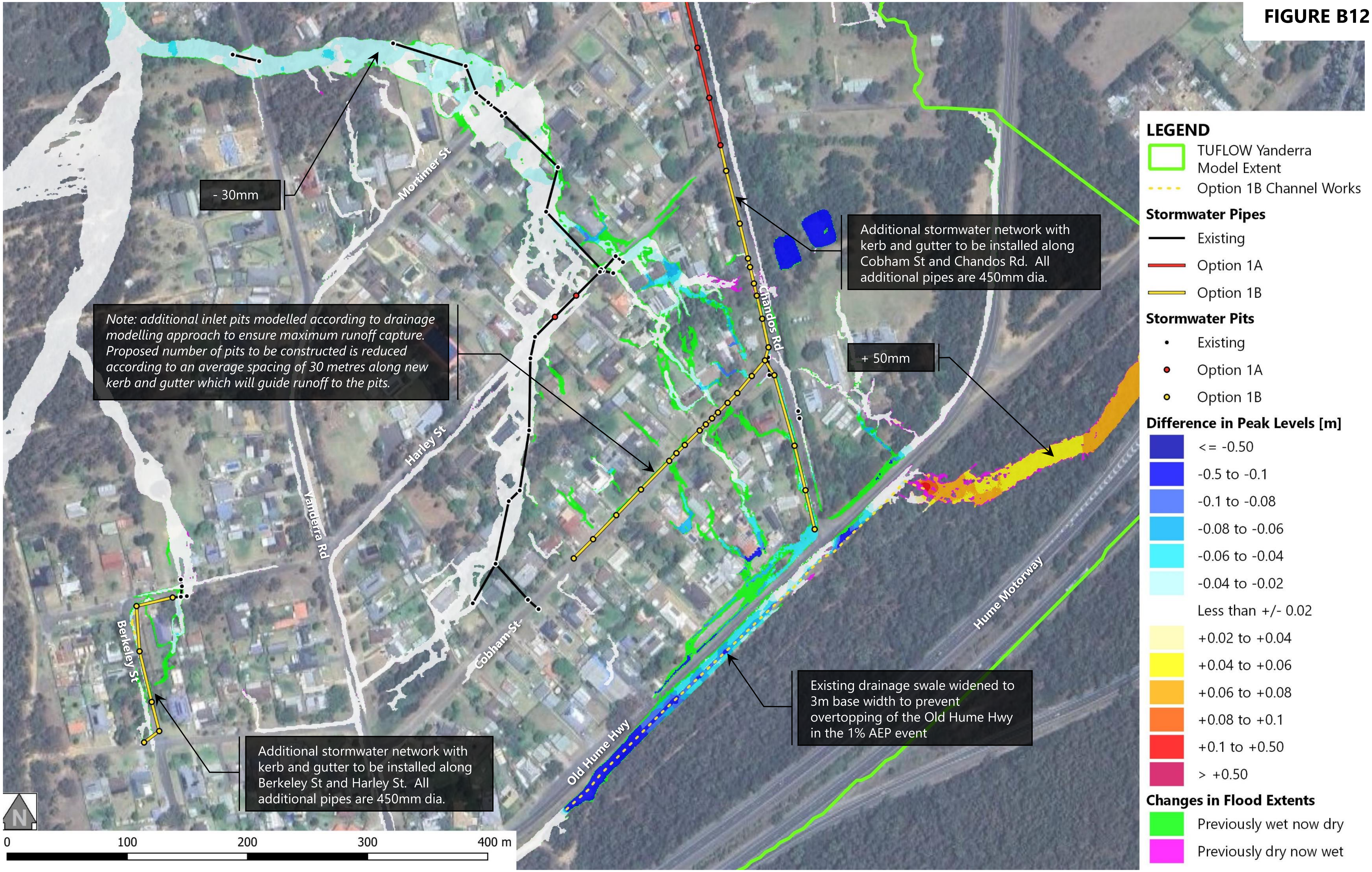
OPTION 1B – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 50% AEP FLOOD LEVELS

FIGURE B11



Prepared by:

OPTION 1B – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 10% AEP FLOOD LEVELS



Prepared by:

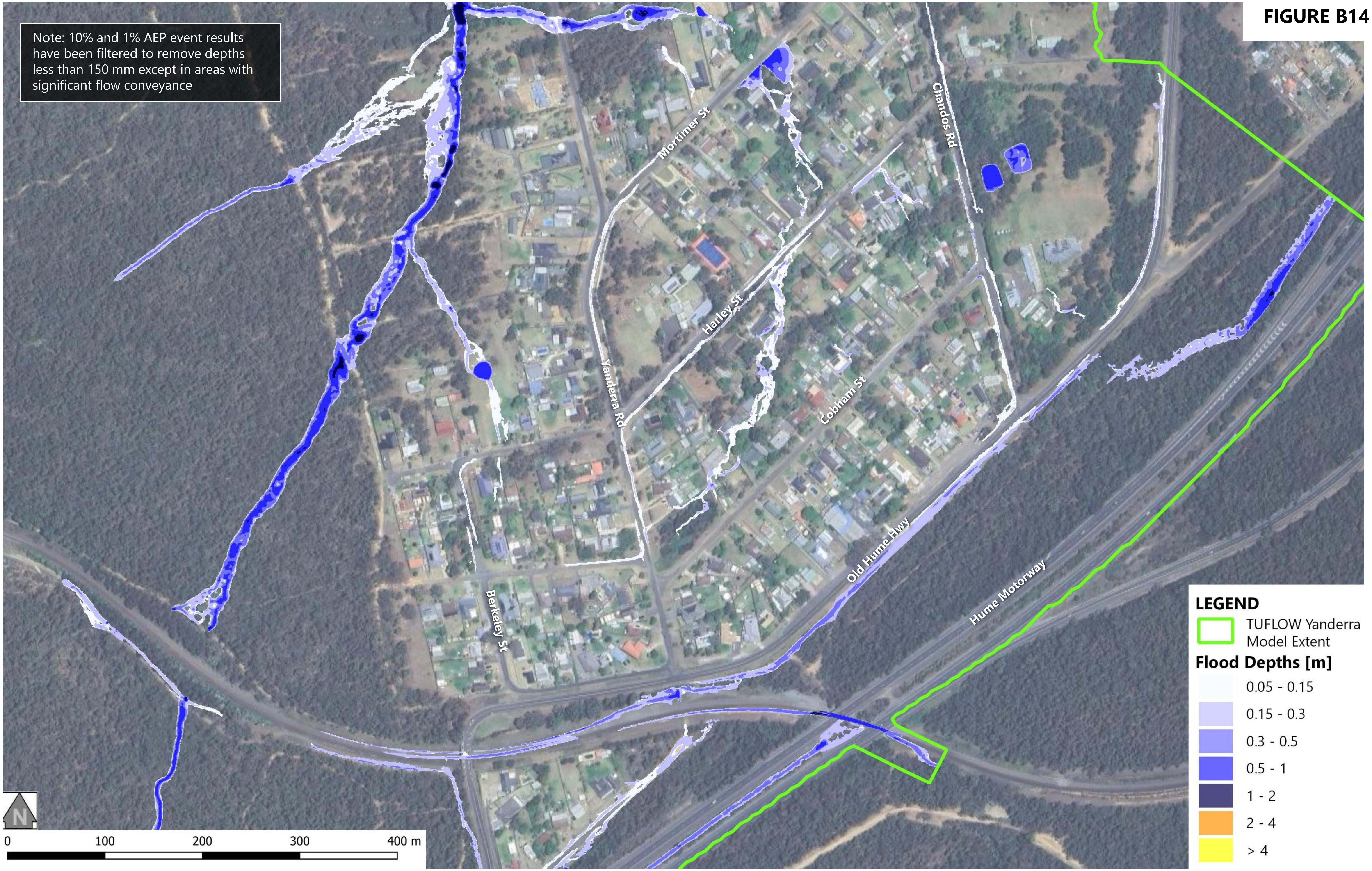
OPTION 1B – STREET DRAINAGE SYSTEM UPGRADES
IMPACT ON 1% AEP FLOOD LEVELS

Wollondilly Shire Council

Prepared by: worley consulting

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
50% AEP FLOOD DEPTHS

FIGURE B14



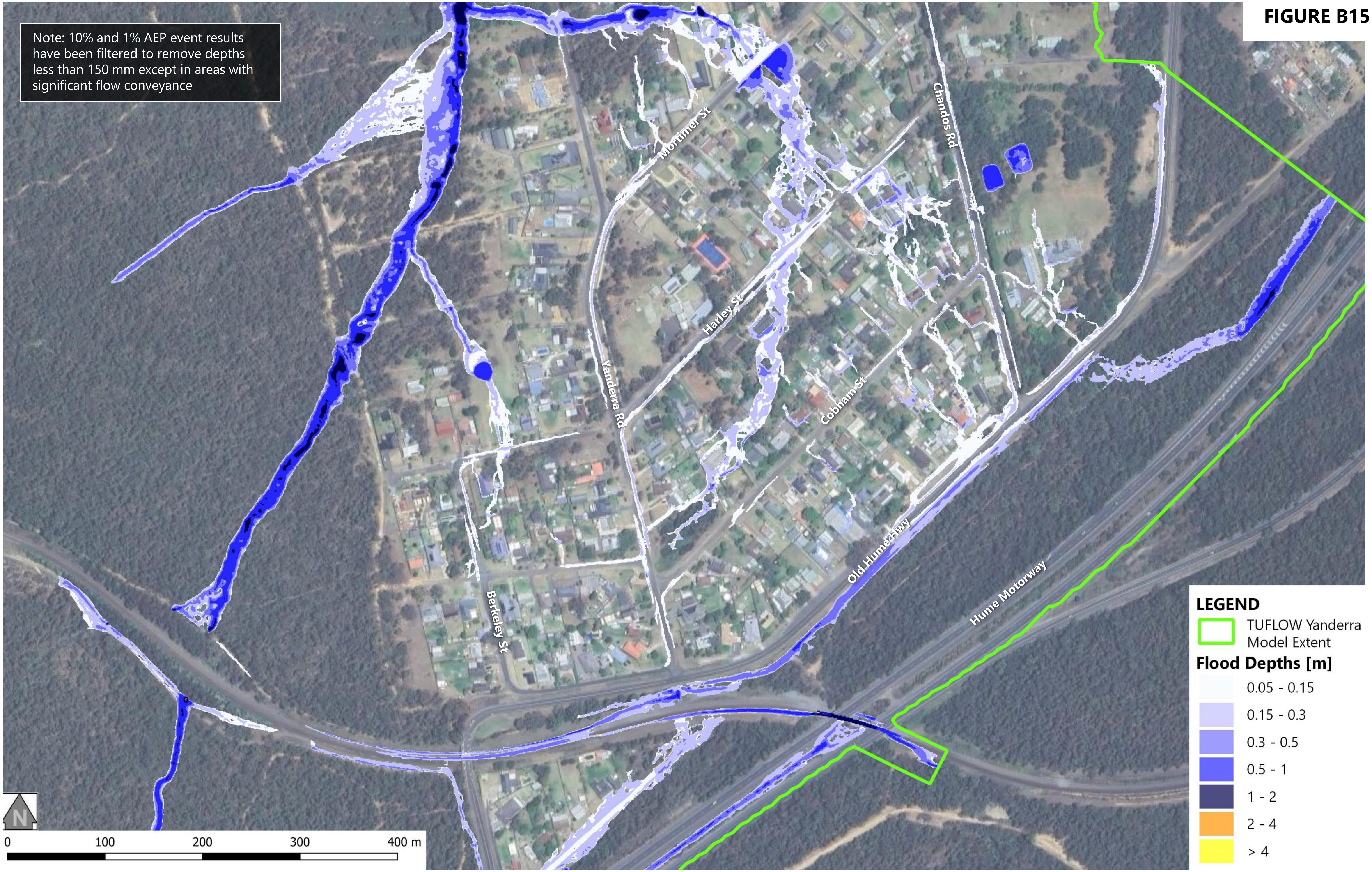
Wollondilly Shire Council

Prepared by:

worley consulting

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
10% AEP FLOOD DEPTHS

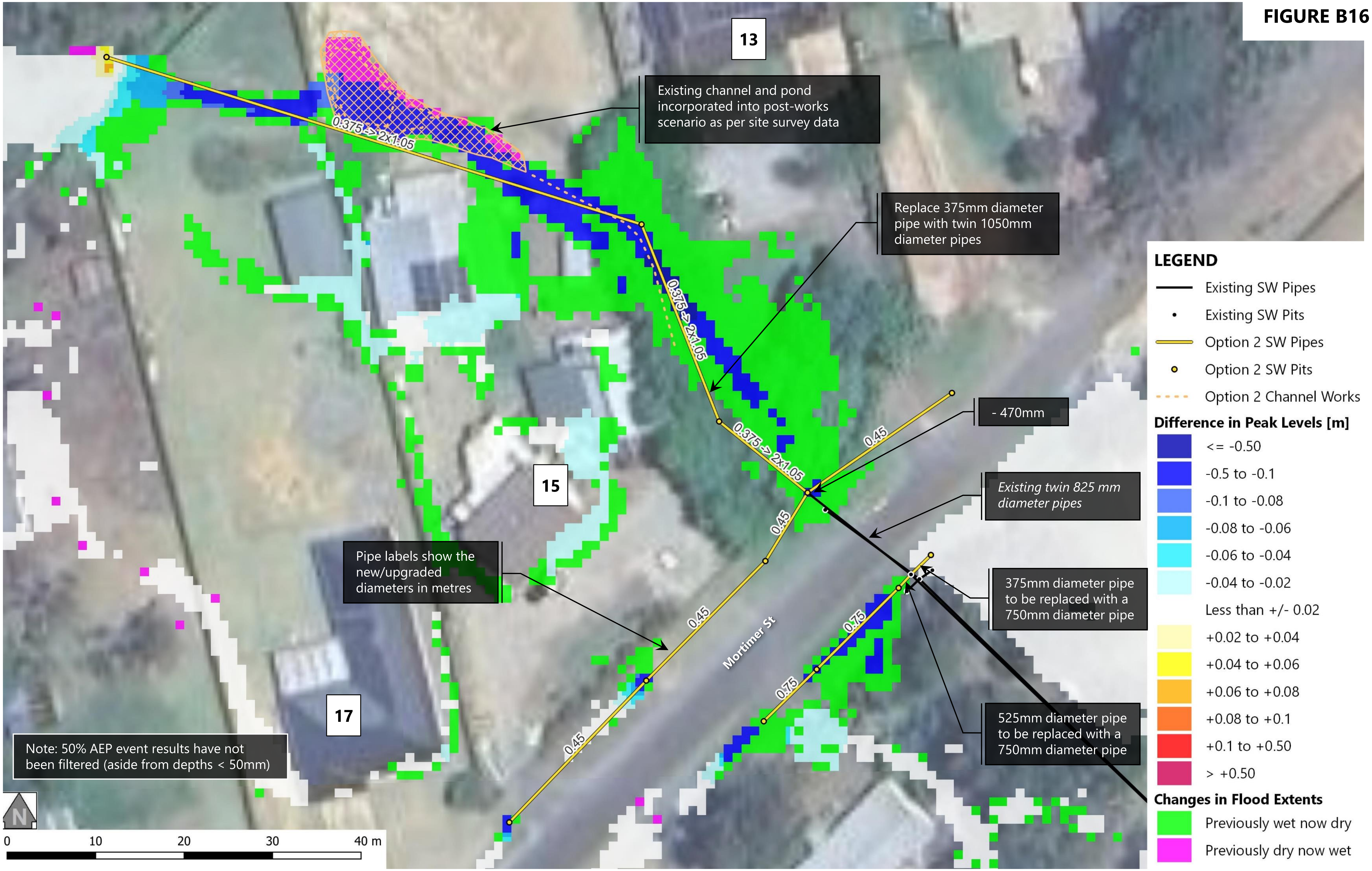
FIGURE B15



Prepared by:

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
1% AEP FLOOD DEPTHS

FIGURE B16

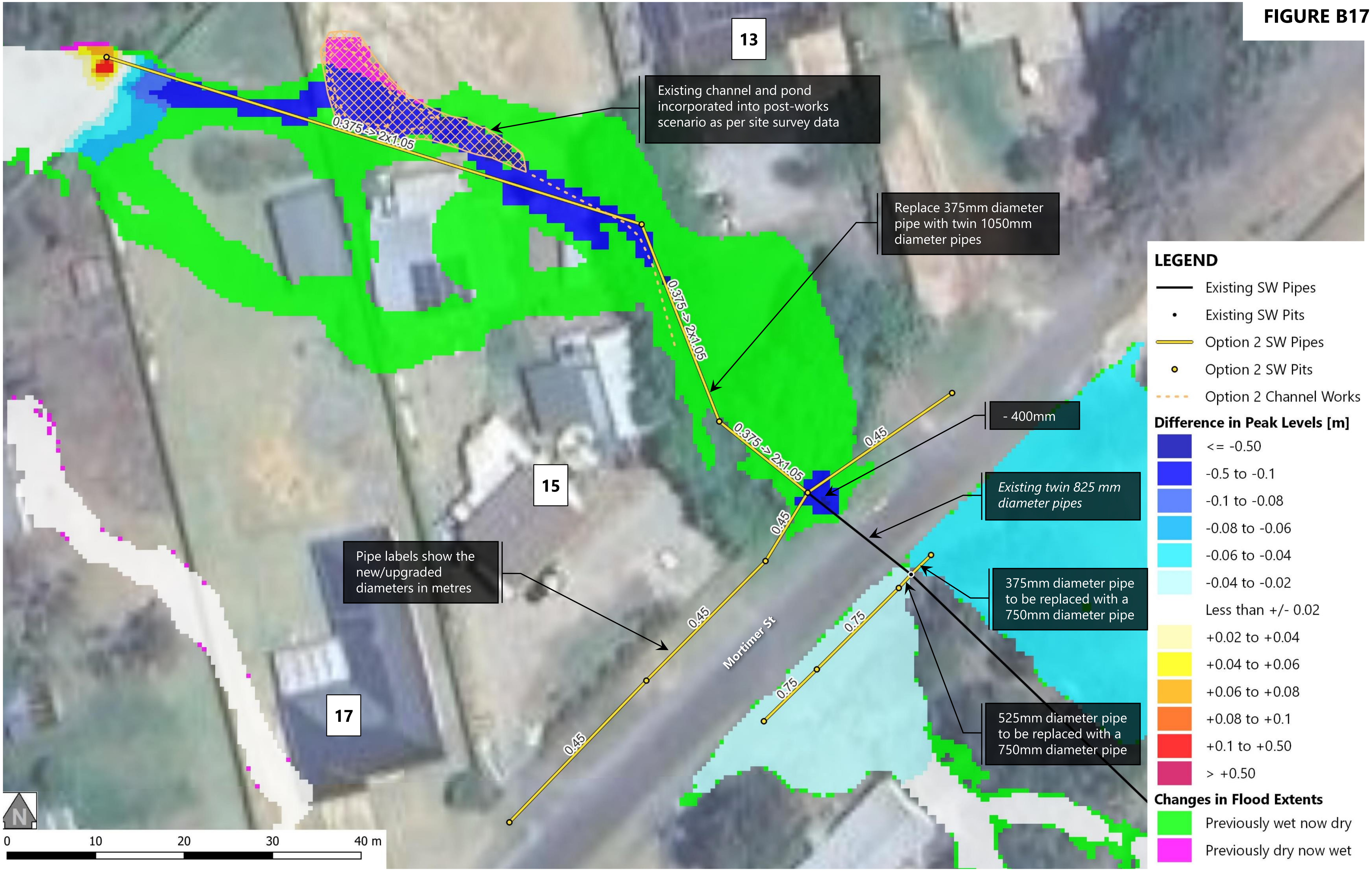


Wollondilly Shire Council

Prepared by: worley consulting

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
IMPACT ON 50% AEP FLOOD LEVELS [MORTIMER ST]

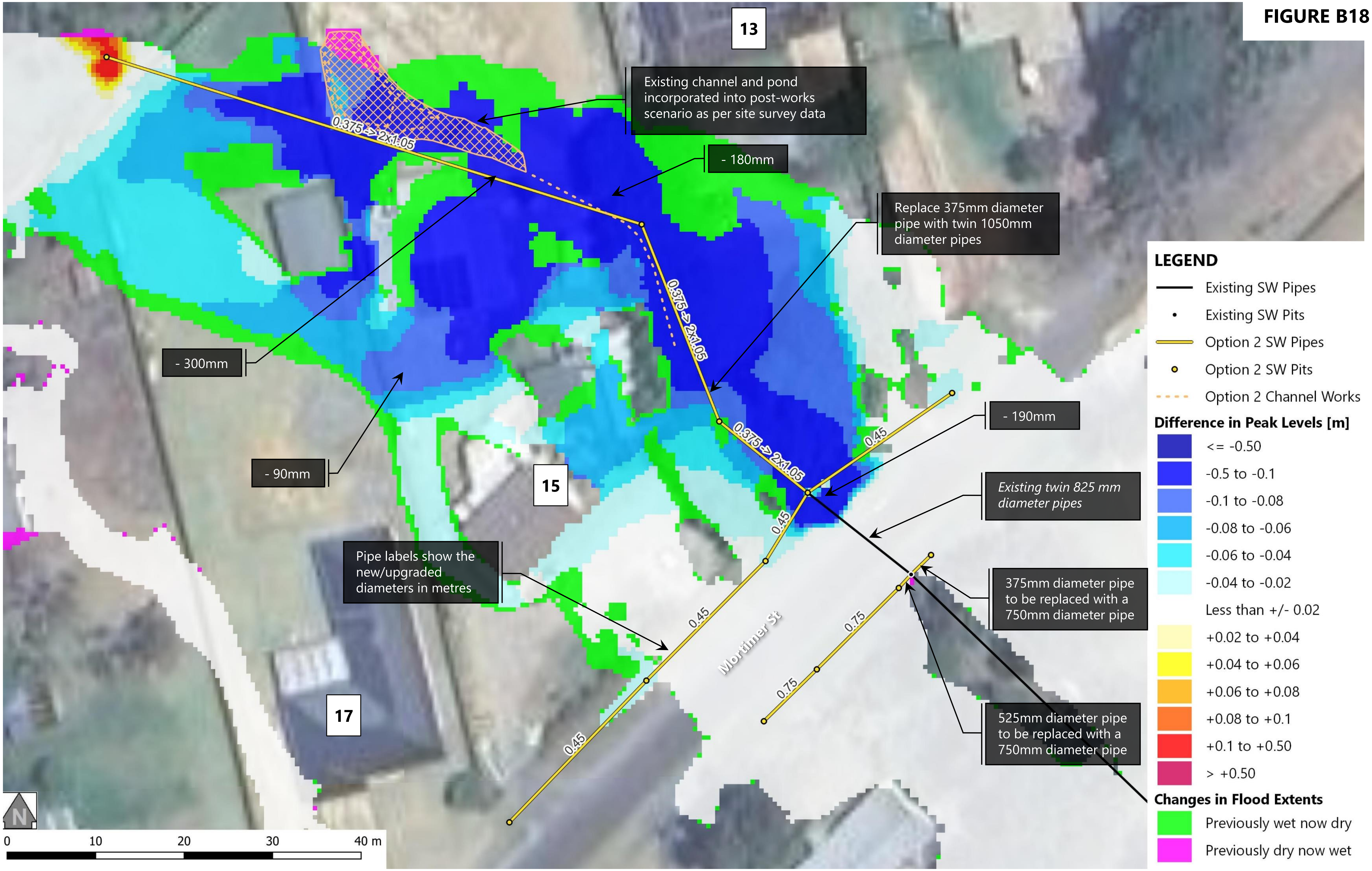
FIGURE B17



Wollondilly Shire Council

Prepared by: worley consulting

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
IMPACT ON 10% AEP FLOOD LEVELS [MORTIMER ST]



Wollondilly Shire Council

Prepared by: worley consulting

OPTION 2 – TRUNK DRAINAGE LINE UPGRADES
IMPACT ON 1% AEP FLOOD LEVELS [MORTIMER ST]

Appendix C. Cost Estimates

Yanderra Drainage Master Plan

Cost Estimate

OPTION 1A

Rev 1: Jan 2025

SUMMARY OF COSTS

Item	Item Description	Amount
1.0	General Preliminaries	$15,000
2.0	Establishment	$36,000
3.0	Demolition and Earthworks	$80,000
4.0	Stormwater Drainage	$144,800
5.0	Roadworks	$40,000
6.0	Chandos Rd Drainage Swale Excavation	$52,800
7.0	Miscellaneous	$80,000
	Sub Total	**$448,600**
	Contingency	**20%**
	TOTAL (ex. GST)	**$538,320**

Item	Item Description	Qty	Unit	Rate	Amount
1.0	*General Preliminaries*	1	Item	$15,000	$15,000
2.0	*Establishment*				$36,000
2.1	Site / office / depot setup				
2.2	Survey and setout				
2.3	Supply and install perimeter fencing during construction and remove it after construction				
2.4	Prepare Traffic Management Plan and obtain approvals				
2.5	Construction Stage Traffic control including all signage, lane & detour marking				
2.6	Install and maintain pedestrian safety measures				
2.7	Prepare and manage Site Construction Environmental Management Plan				
2.8	Stormwater diversion during construction				
2.9	Sediment and Erosion Control				
3.0	*Demolition and Earthworks*			*Sub-total*	*$80,000*
3.1	Saw cut and demolish existing road pavement to sub-grade level and cart to stockpile	400	m^2	$80	$32,000
3.2	Culvert trenching. Excavate/box out to the required bulk earthworks surface. Supply and place fill material next to and above culverts/pipes (stabilised fill)	600	m^3	$80	$48,000
4.0	*Stormwater Drainage*			*Sub-total*	*$144,800*
4.1	Install new stormwater pipes	240	m	$400	$96,000
4.2	Install headwalls and scour protection apron	1	units	$4,000	$4,000
4.3	Install kerb inlet pits	8	units	$5,600	$44,800
5.0	*Roadworks*			*Sub-total*	*$40,000*
5.1	Supply, place and compact crushed sandstone, (or approved equivalent) sub-base course under pavements: 200 mm thick DGS40 or approved crushed sandstone (compacted thickness)	400	m^2	$30	$12,000
5.2	Supply, place and compact DGB20 base course 150mm thick (compacted thickness)	400	m^2	$30	$12,000
5.3	Surfacing of road pavement with Asphaltic concrete (AC10) 40mm thick plus 10mm primer seal	400	m^2	$40	$16,000
6.0	*Chandos Rd Drainage Swale Excavation*			*Sub-total*	*$52,800*
6.1	Excavate soil	240	m^3	$70	$16,800
6.2	Disposal of cut material to landfill	360	t	$90	$32,400
6.3	Lining with grass	240	m^2	$15	$3,600
7.0	*Miscellaneous*			*Sub-total*	*$80,000*
7.1	Remove temporary works and clean up site	1	Item	$20,000	$20,000
7.2	Allowance for utility services investigation and management	1	Item	$20,000	$20,000
7.3	Detailed design and Project Management costs	1	Item	$40,000	$40,000

Yanderra Drainage Master Plan

Cost Estimate

OPTION 1B

Rev 1: Jan 2025

SUMMARY OF COSTS

Item	Item Description	Amount
1.0	General Preliminaries	$15,000
2.0	Establishment	$96,000
3.0	Demolition	$114,200
4.0	Bulk Earthworks	$136,000
5.0	Stormwater Drainage	$424,800
6.0	Roadworks	$168,000
7.0	Old Hume Hwy Drainage Swale Excavation	$55,500
8.0	Miscellaneous	$160,000
	Sub Total	**$1,169,500**
	Contingency	**20%**
	TOTAL (ex. GST)	**$1,403,400**

Item	Item Description	Qty	Unit	Rate	Amount
1.0	*General Preliminaries*	1	Item	$15,000	$15,000
2.0	*Establishment*				$96,000
2.1	Site / office / depot setup				
2.2	Survey and setout				
2.3	Supply and install perimeter fencing during construction and remove it after construction				
2.4	Prepare Traffic Management Plan and obtain approvals				
2.5	Construction Stage Traffic control including all signage, lane & detour marking				
2.6	Install and maintain pedestrian safety measures				
2.7	Prepare and manage Site Construction Environmental Management Plan				
2.8	Stormwater diversion during construction				
2.9	Sediment and Erosion Control				
3.0	*Demolition*			*Sub-total*	*$114,200*
3.1	Saw cut and demolish existing road pavement to sub-grade level and cart to stockpile	1,200	m^2	$80	$96,000
3.2	Demolish existing pipes and cart to stockpile	3	m^3	$400	$1,200
3.3	Demolish existing pits, kerb and gutter (including laybacks) and cart to concrete stockpile	8	m^3	$400	$3,200
3.4	Disposal of demolition material to landfill	30	t	$460	$13,800
4.0	*Bulk Earthworks*			*Sub-total*	*$136,000*
4.1	Culvert trenching. Excavate/box out to the required bulk earthworks surface. Supply and place fill material next to and above culverts/pipes (stabilised fill)	1,700	m^3	$80	$136,000
5.0	*Stormwater Drainage*			*Sub-total*	*$424,800*
5.1	Install new stormwater pipes	740	m	$400	$296,000
5.2	Install kerb inlet pits	23	units	$5,600	$128,800
6.0	*Roadworks*			*Sub-total*	*$168,000*
6.1	Supply, place and compact crushed sandstone, (or approved equivalent) sub-base course under pavements: 200 mm thick DGS40 or approved crushed sandstone (compacted thickness)	1,200	m^2	$30	$36,000
6.2	Supply, place and compact DGB20 base course 150mm thick (compacted thickness)	1,200	m^2	$30	$36,000
6.3	Surfacing of road pavement with Asphaltic concrete (AC10) 40mm thick plus 10mm primer seal	1,200	m^2	$40	$48,000
6.4	Supply all materials and construct kerbs and gutters to Council's Standard, including vehicular crossings	800	m	$60	$48,000
7.0	*Old Hume Hwy Drainage Swale Excavation*			*Sub-total*	*$55,500*
7.1	Excavate soil	200	m^3	$60	$12,000
7.2	Disposal of cut material to landfill	300	t	$80	$24,000
7.3	Lining with grass	1,300	m^2	$15	$19,500
8.0	*Miscellaneous*			*Sub-total*	*$160,000*
8.1	Remove temporary works and clean up site	1	Item	$40,000	$40,000
8.2	Allowance for utility services investigation and management	1	Item	$40,000	$40,000
8.3	Detailed design and Project management costs	1	Item	$80,000	$80,000

Yanderra Drainage Master Plan

Cost Estimate

OPTION 2

Rev 1: Jan 2025

SUMMARY OF COSTS

Item	Item Description	Amount
1.0	General Preliminaries	$15,000
2.0	Establishment	$55,000
3.0	Demolition	$44,000
4.0	Bulk Earthworks	$60,000
5.0	Stormwater Drainage	$391,000
6.0	Roadworks	$20,000
7.0	Miscellaneous	$80,000
	Sub Total	**$665,000**
	Contingency	**20%**
	TOTAL (ex. GST)	**$798,000**

Item	Item Description	Qty	Unit	Rate	Amount
1.0	*General Preliminaries*	1	Item	$15,000	$15,000
2.0	*Establishment*				$55,000
2.1	Site / office / depot setup				
2.2	Survey and setout				
2.3	Supply and install perimeter fencing during construction and remove it after construction				
2.4	Prepare Traffic Management Plan and obtain approvals				
2.5	Construction Stage Traffic control including all signage, lane & detour marking				
2.6	Install and maintain pedestrian safety measures				
2.7	Prepare and manage Site Construction Environmental Management Plan				
2.8	Stormwater diversion during construction				
2.9	Sediment and Erosion Control				
3.0	*Demolition*			*Sub-total*	*$44,000*
3.1	Saw cut and demolish existing road pavement to sub-grade level and cart to stockpile	200	m^2	$80	$16,000
3.2	Demolish existing pipes and cart to stockpile	9	m^3	$370	$3,400
3.3	Demolish existing pits, kerb and gutter (including laybacks) and cart to concrete stockpile	10	m^3	$370	$3,600
3.4	Disposal of demolition material to landfill	50	t	$420	$21,000
4.0	*Bulk Earthworks*			*Sub-total*	*$60,000*
4.1	Culvert trenching. Excavate/box out to the required bulk earthworks surface. Supply and place fill material next to and above culverts/pipes (stabilised fill)	600	m^3	$100	$60,000
5.0	*Stormwater Drainage*			*Sub-total*	*$391,000*
5.1	Install new 1.05m dia stormwater pipes	210	m	$1,300	$273,000
5.2	Install new 750mm dia stormwater pipes	30	m	$700	$21,000
5.3	Install new 450mm dia stormwater pipes	80	m	$400	$32,000
5.4	Install headwalls and scour protection apron	2	units	$4,000	$8,000
5.5	Install kerb inlet pits	10	units	$5,700	$57,000
6.0	*Roadworks*			*Sub-total*	*$20,000*
6.1	Supply, place and compact crushed sandstone, (or approved equivalent) sub-base course under pavements: 200 mm thick DGS40 or approved crushed sandstone (compacted thickness)	150	m^2	$30	$4,500
6.2	Supply, place and compact DGB20 base course 150mm thick (compacted thickness)	150	m^2	$30	$4,500
6.3	Surfacing of road pavement with Asphaltic concrete (AC10) 40mm thick plus 10mm primer seal	150	m^2	$40	$6,000
6.4	Supply all materials and construct kerbs and gutters to Council's Standard, including vehicular crossings	100	m	$50	$5,000
7.0	*Miscellaneous*			*Sub-total*	*$80,000*
7.1	Remove temporary works and clean up site	1	Item	$20,000	$20,000
7.2	Allowance for utility services investigation and management	1	Item	$10,000	$10,000
7.2	Detailed design and Project management costs	1	Item	$50,000	$50,000