

Kensington Creek Flood Mapping Project

Hydrology and Hydraulics Report

City of Ballarat

22 December 2023





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EXECUTIVE SUMMARY

Water Technology was engaged by the City of Ballarat (CoB) to review and update the existing hydrologic and hydraulic models used to develop Land Subject to Inundation (LSIO), Floodway Overlay (FO), Special Building Overlay (SBO) layers covering several waterways within the CoB municipality. The following report details the updated hydrologic and hydraulic modelling for Kensington Creek based on the changes made in response to recent development and newly available data within the catchment. A summary of the changes made to the hydrological and hydraulic models are listed below.

- **Hydrological Model (RORB) Changes.**
 - Increase to Fraction Impervious (FI) north of Sturt Street to match FI adopted in neighbouring developed catchments.
 - Increase to FI north of Ballarat-Carngham Road and west of Kensington Creek where development of Ballymanus and Alfredton Grove estates has occurred.
 - Increase to FI south and north of the Glenelg Highway due to the development of the Pinnacle and Winterfield residential estates.
 - Reach types in the RORB model were also updated to reflect the above developments by changing reach types from 'natural' to 'excavated but unlined'.
 - Additional print nodes were included in the upper catchment of the model to provide inflow hydrographs north of Sturt Street.
- **Hydraulic Model (TUFLOW) Changes.**
 - Base terrain for the model was updated to include LiDAR data captured in October 2019 with a 1-metre grid cell size.
 - The TUFLOW model was updated to the latest build (2023-03-AB) and run as HPC. This ensured that the updated model was utilising the most recent modelling approaches within the TUFLOW software package and the use of HPC reduced model run times.
 - Inflow locations were added north of Sturt Street in the Insignia Estate and the Ballarat Golf Club basins.
 - Addition of stormwater pits and pipes in Insignia Estate, primarily along Insignia Boulevard and Sturt Street.
 - The design surface for Insignia Estate was used to verify basin sizes and catchment extents. The DEM was not included in the model as this estate was fully developed when the 2019 LiDAR dataset was captured.
 - Inflows immediately south of Sturt Street have been dispersed to include more pits in their respective subareas along main branches of the stormwater network.
 - Design surface for the Ballymanus wetland inserted into the model, along with inlet and outlet stormwater pipe data.
 - The design surface for the Carringum Estate basin was represented in the model by manipulating the terrain within TUFLOW using the as constructed plans.
 - Feature level survey and design surface for Lot 2 Ballarat-Carngham Road was included.
 - This site was subject to a flood impact assessment in 2021 with the CCMA.
 - The survey for this site also covered the open channel of the Kensington Creek between Ballarat-Carngham Road and Icon Drive and provided a more detailed representation of the waterway than the LiDAR dataset. It was subsequently adopted in the model.



- Revised inflow locations between Greenhalghs Road and Glenelg Highway to reflect residential development either side of the waterway.
- Representation of the Winterfield basin (RB6A) was done by manipulating the terrain in TUFLOW using the approved basin design plans.
- Inflow locations south of Glenelg Highway, that represent flows from the Pinnacle Estate, were located within the waterway. It is Water Technology's understanding that the final design of these basins is not yet complete.

The 1% AEP mapping was produced for review by Council and CCMA. After approval, Water Technology will finalise the modelling by completing the remaining design events including climate change scenarios.



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1 INTRODUCTION

1.1 Background

Water Technology was commissioned by City of Ballarat (CoB) to carry out the Kensington Creek Flood Modelling Update Project in 2018. The original project was commissioned to improve the flood risk knowledge, address information gaps and provide valuable planning and flood intelligence within the Kensington Creek catchment.

Kensington Creek drains from Alfredton and through the south-west of Ballarat. Alfredton is a residential suburb in the upper catchment of Kensington Creek, with the mid and lower reaches flowing through currently undeveloped land and some industrial development. Kensington Creek flows into Winter Creek north of Bells Road, which then flows south-east to the Yarrowee River.

There is continued development pressure along Kensington Creek and City of Ballarat have identified the need to improve their flood risk knowledge along the waterway. A map of the Kensington Creek catchment is shown in Figure 1-1.

The flood modelling and mapping undertaken in this project was based on the updated guidelines outlined in Australian Rainfall and Runoff 2016¹. As identified above, this report has been updated based on changes made to the hydrologic and hydraulic models in response to recent development and newly available data within the catchment.

1.2 Structure of the Report

This report outlines the following:

- Hydrologic modelling of the Kensington Creek catchment including modelling methodology, results and inputs to the hydraulic model.
- Hydraulic modelling of Kensington Creek including modelling methodology and results.
- Flood depth mapping for the 1% AEP flood event.

¹ Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia



Figure 1-1 Kensington Creek Catchment and Waterways



2 AVAILABLE INFORMATION

2.1 Overview

This section documents the data collated by Water Technology for the study. Data was sourced data from number of agencies and sources, including:

- City of Ballarat.
- Regional Roads Victoria (formerly VicRoads).
- Department of Energy, Environment and Climate Action (formerly DELWP).

2.2 Topography Data

The topography data largely comprised of Light Distance and Ranging (LiDAR) data, which was used to generate a Digital Elevation Model (DEM). The DEM enabled delineation of the catchment for the hydrological model, completed in 2018, utilising LiDAR data captured in 2011. The hydraulic model utilised LiDAR data captured in 2019 (Ballarat2019Oct25_dem1m_v10cm).

2.3 Planning Scheme

The City of Ballarat Planning Scheme layers were used in conjunction with the available aerial photography to define the range of land uses within the catchment. The layers were used in the hydrologic and hydraulic models to define the Fraction Impervious (FI) and hydraulic roughness (Manning's 'n') respectively.

2.4 Drainage Information

City of Ballarat provided a GIS database containing information of Council drainage assets in the municipality, this included pit and pipe information. The provided layers were reasonably complete with pipe dimensions and pit depths. However, pit/pipe inverts were generally missing from the data sets. Where pit depths were available, inverts were assumed by subtracting these depths from the ground surface (based on LiDAR). Where the dataset was missing pit depths, invert levels were assumed by subtracting pipe diameter and standard pipe cover depth. The standard cover depth based on the pipe size outlined in Table 2-1.

Table 2-1 Standard cover levels for stormwater pipes

Pipe Size	Standard Cover Depth
≤ 900 mm	600 mm
≥ 900 mm	750 mm



3 HYDROLOGY

3.1 Overview

RORB was adopted as the hydrology modelling software package for this study and the other flood mapping assessments being undertaken for Council. RORB was used to calculate inflow hydrographs from the available rainfall and catchment data. RORB is a non-linear rainfall runoff and streamflow routing model for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reaches and storage areas. Observed or design storm rainfall is input to the centroid of each subarea. Specific initial and continuing losses are then deducted, and the excess runoff is routed through the reach and storage network.

The adopted methodology was based on current guidelines described in the 2019 revision of Australian Rainfall and Runoff (ARR2019). The 20%, 10%, 5%, 2%, 1% and the 0.5% AEP flood events were modelled using Monte-Carlo and Ensemble approaches as recommended in ARR2019. There were no streamflow gauges within the catchment.

3.2 RORB Model Development

A RORB model is comprised of several key data inputs to produce accurate results, these include:

- Catchment delineation.
- Fraction impervious.
- Routing parameter (kc)
- Design inputs
 - Rainfall depth
 - Temporal patterns
 - Spatial pattern
 - Losses

Each of these inputs are discussed in the following sections.

3.3 Catchment Delineation

The Kensington Creek catchment was delineated based on 1-metre LiDAR data captured in 2011. The catchment (10.5 km²) was delineated into 57 sub-catchments, see Figure 3-1. The available LiDAR data was used as a basis for the delineation, ensuring an even distribution of similar sized catchments with a minimum of three sub catchments upstream of each print point used as an inflow location to the hydraulic model.

A series of nodes and reaches were defined in the RORB model to represent the model routing characteristics. Runoff hydrographs were used as inflows in the hydraulic model. The model reaches were defined as 'natural', 'lined channel' or 'pipe' based on the typical flow regime along each section of the catchment. These definitions were derived from expected flow characteristics based on the aerial photography and the site visit.

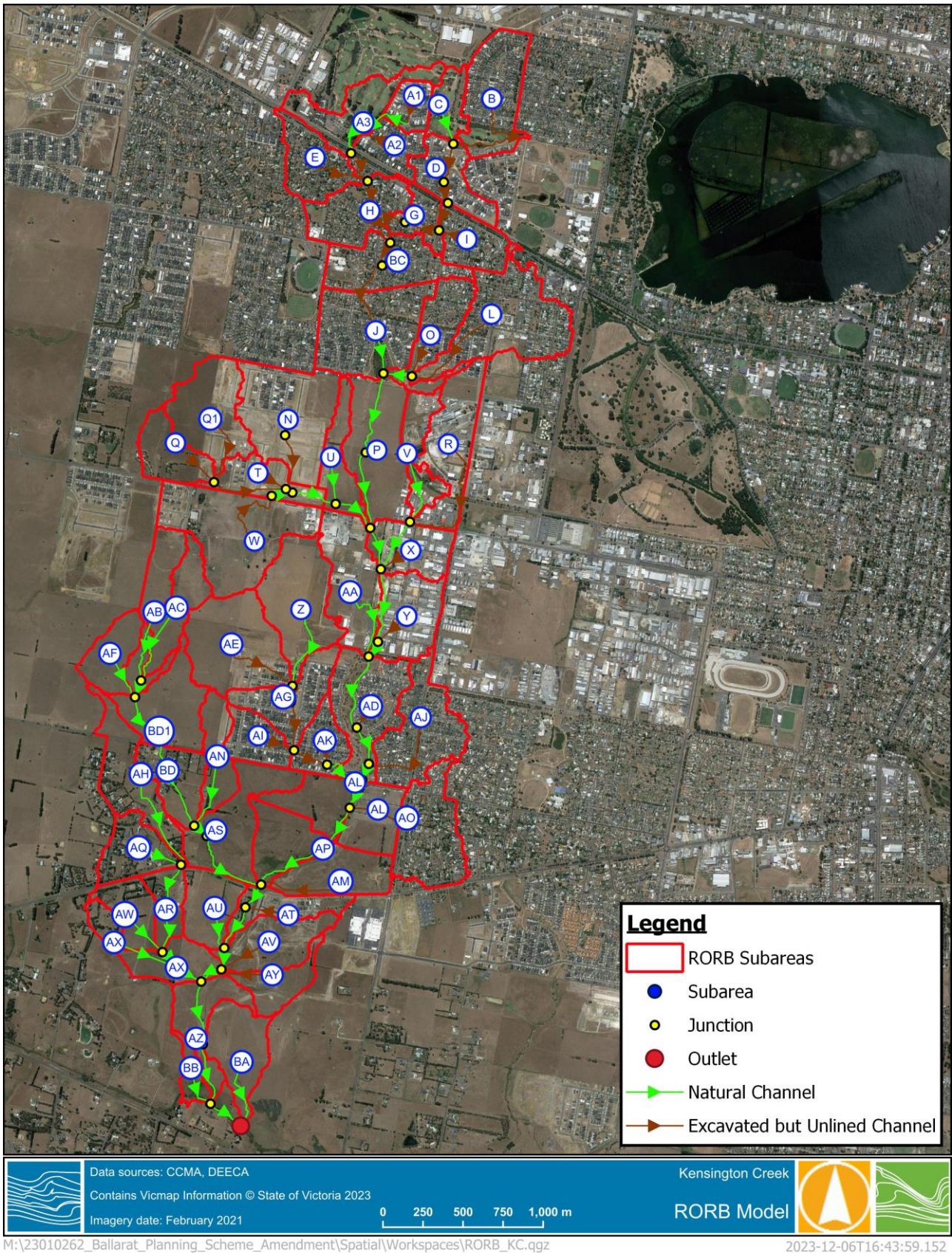


Figure 3-1 Kensington Creek Delineated Catchment



3.3.1 Fraction Impervious

Impervious fractions values were determined for the different land use types across the catchment within each sub catchment, represented by a Fraction Impervious (FI). FI values were determined according to CoB planning zones as per Melbourne Water's Guidelines² and verified against aerial imagery. The catchment was largely separated into three main land uses; open space (including farming), residential and industrial. The adopted values for each are provided in Table 3-1, a map of the designated land uses is shown in Figure 3-2, with the adopted sub catchment FI values shown in Figure 3-3. A fraction impervious greater than zero was adopted for areas of open space due to the presence of constructed drains in both the parks and agricultural areas.

Table 3-1 Adopted FI Values for the Kensington Creek RORB Model

Land use	Adopted FI
Open space including farming	0.1
Residential	0.75
Industrial	0.9

² Melbourne Water (2010), Melbourne Water's MUSIC Guidelines

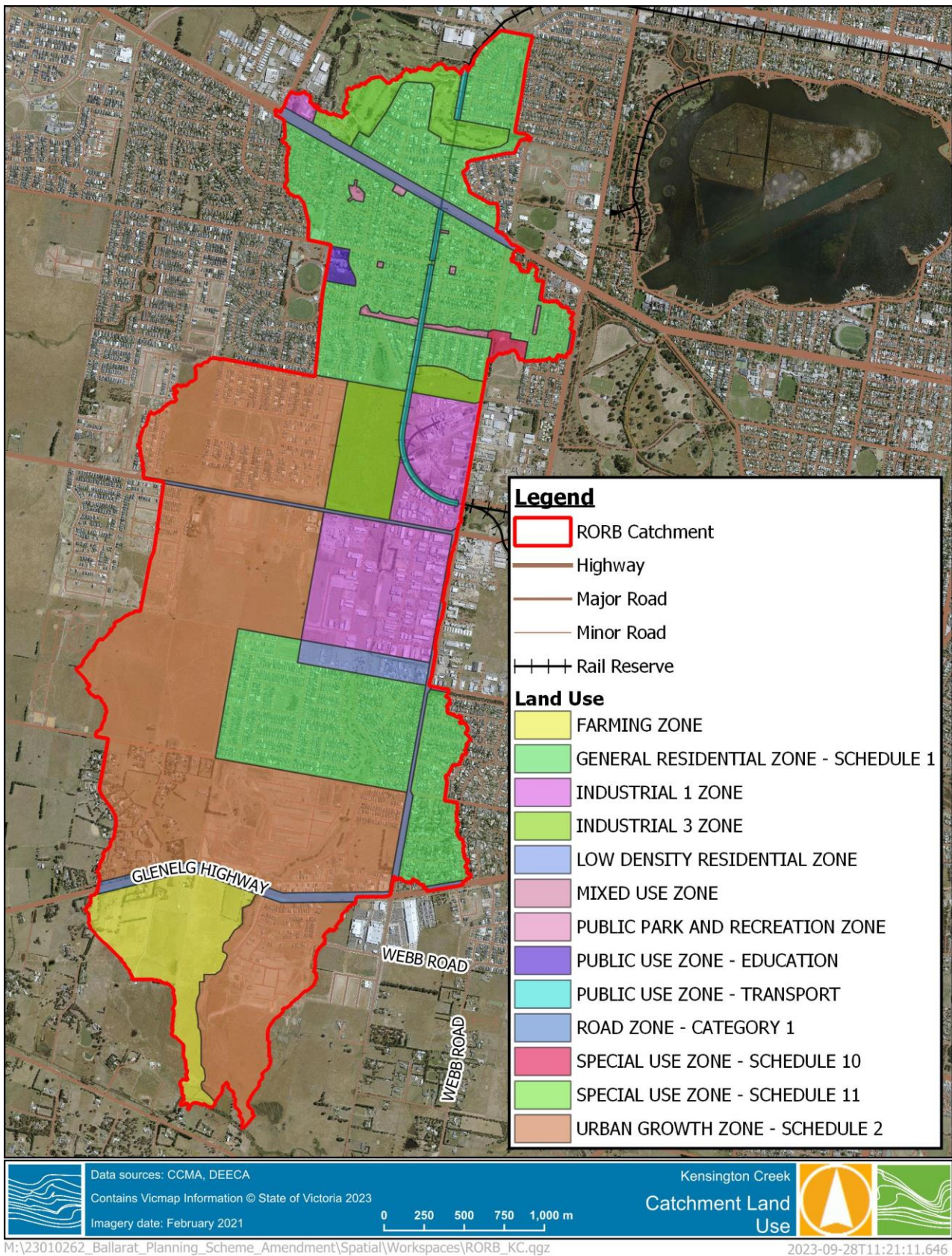


Figure 3-2 Land Use Area within Catchment

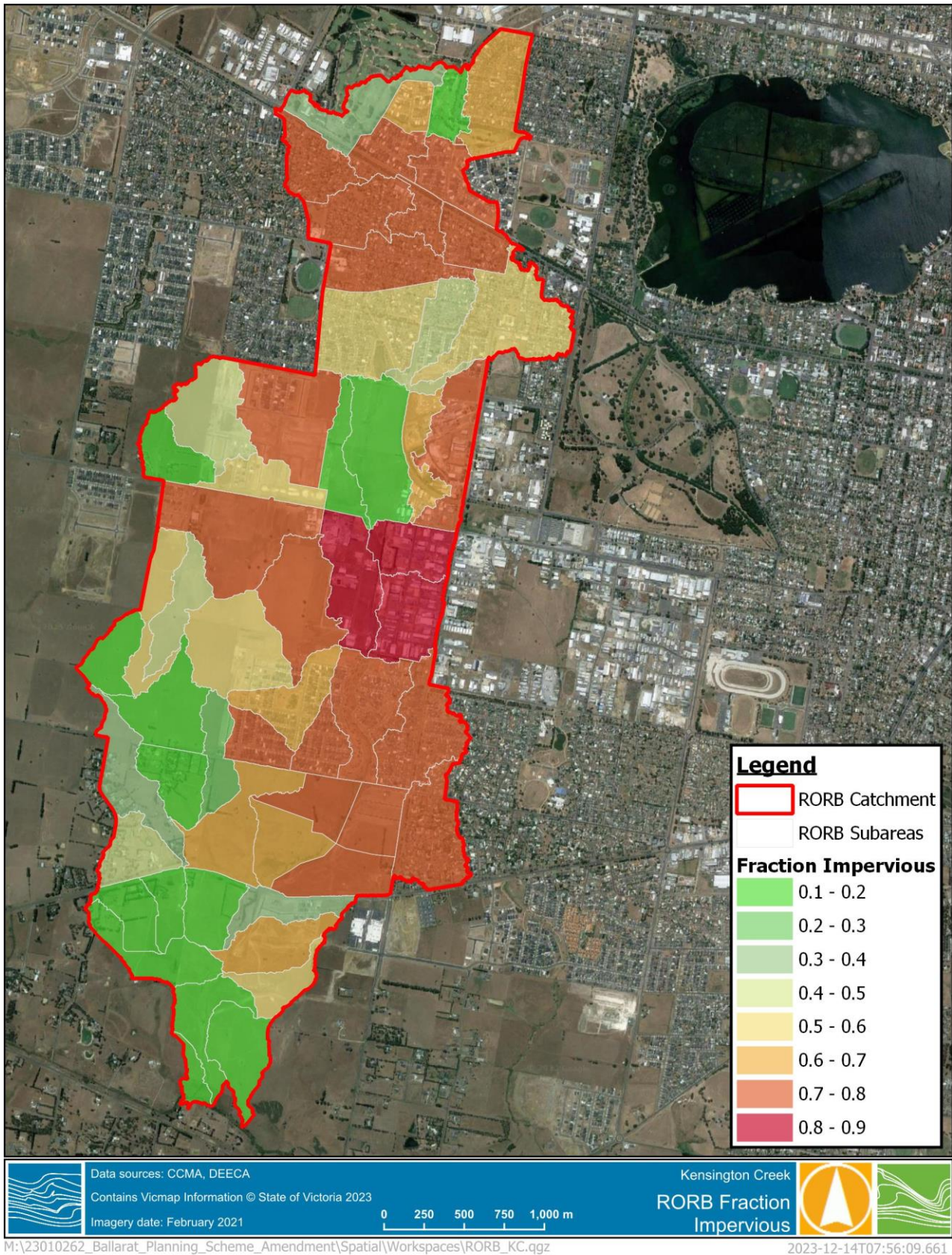


Figure 3-3 Sub Catchment FI Values



3.3.2 Routing Parameter (k_c)

k_c is a RORB model routing parameter that dictates attenuation along the model reaches. In gauged catchments the k_c value is one of the major parameters used to calibrate the RORB model, varying peak flow and timing. In ungauged catchments (such as Kensington Creek) there are several ways to estimate the k_c value, these include empirical equation-based estimates of k_c and the adoption of a k_c value based on nearby calibrated RORB models.

Within RORB there are several equation-based estimates available for Victoria, these are outlined in Table 3-2. The equations are reliant on the following parameters:

$$A = \text{Area (km}^2\text{)}$$

$$D_{av} = \text{Average reach distance (km)}$$

Table 3-2 Equation Based k_c Estimates

Description	Equation	k_c estimate
Victoria (Mean Annual Rainfall <800mm)*	$k_c = 0.49 * A^{0.65}$	2.3
Victorian based data (Pearse et al, 2002)	$k_c = 1.25 * D_{av}$	5.6
Australian based data (Dyer, 1994)	$k_c = 1.14 * D_{av}$	5.2
Australian based data (Yu, 1989)	$k_c = 0.96 * D_{av}$	4.3

* Ballarat has a mean annual rainfall of 689.9mm.

For the Kensington Creek catchment, the Pearse et. Al. (2002) estimation method of k_c was chosen to be adopted. The data the equation is based on is most relevant (Victorian based) and in Water Technology's experience with gauged catchments, the Pearse et. al. equation has shown to match gauge Flood Frequency Analysis data best. Given that d_{av} equals 4.52 km for the RORB model, k_c value of 5.6 was adopted for the study.

This estimate of k_c was compared against nearby catchments from the previous studies. There are several RORB models have been developed near the project area. These models include the Yarrowee River, Canadian Creek, Chase Waterway and Bonshaw Creek catchments. The Yarrowee River is the only gauged catchment of these. The ratio of k_c and d_{av} used in these models was used to confirm the adopted k_c value for this study site. Their adopted k_c values and k_c / d_{av} ratio is shown in Table 3-3, along with a calculated k_c value for the Kensington Creek RORB model based on a d_{av} of 4.52 km. The adopted k_c value was within the range of those previously adopted.

Table 3-3 Estimates of k_c Based on Nearby Existing RORB Models

Model	k_c	d_{av} (km)	k_c / d_{av} ratio	Calculated Kensington Creek k_c
Yarrowee River (lower)	30	14.76	2.03	9.19
Canadian Creeks	8.46	3.56	2.38	10.76
Chase Waterway	6.10	4.90	1.24	5.62
Bonshaw Creek	5.37	4.58	1.17	5.29



The RORB model m was set at 0.8. This is the recommended value for ungauged catchments³.

3.3.3 Design Rainfall

3.3.3.1 Rainfall depths

Burst Depth

Design rainfalls were derived for burst durations between 0.25 and 6 hours, based on the expectation that the critical storm duration for the study area catchment would be relatively short, given the small catchment area.

The rainfall burst depths for AEPs between 20% AEP and 0.5% AEP were extracted for the centroid of the catchment using the 2016 ARR IFD analysis available from the Bureau of Meteorology⁴.

Areal Reduction Factors

The point rainfall estimates were converted to catchment average values using the areal reduction factors developed for Victoria during the revision of ARR 2016⁵. Conceptually, this factor accounts for larger catchments which are less likely to experience high intensity rainfall over the whole of the catchment. Given the size of the Kensington Creek catchment, areal reduction was not applied.

The design rainfall totals for the catchment are shown in Table 3-4.

Table 3-4 Design Rainfall Depths in mm for Varying Event Durations and AEP

Duration\AEP	20%	10%	5%	2%	1%	0.5%
15-min	13.6	16.9	20.4	25.5	29.8	33.3
30-min	17.8	22.2	26.7	33.3	38.8	43.4
1-hr	22.2	27.4	32.9	40.6	47	52.5
2-hr	27.3	33.3	39.5	48.3	55.5	62
3-hr	31	37.5	44.1	53.6	61.3	68.5
6-hr	39.3	46.8	54.5	65.5	74.5	83.3

3.3.3.2 Temporal patterns

The 10 temporal patterns as downloaded from ARR 2019 Data Hub⁶ were used to simulate the distribution of burst rainfall depth during each storm duration modelled.

3.3.3.3 Spatial patterns

The ARR2019 guidelines recommend non-uniform spatial patterns for catchment areas of more than 20 km². The catchment upstream of the study area is 10.5km², therefore a uniform spatial pattern was applied in design modelling.

³ E.M. Laurenson, R.G. Mein, and R.J. Nathan (2010), RORB User Manual

⁴ <http://www.bom.gov.au/water/designRainfalls/ifd/>

⁵ Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia, Book2, Chapter 4

⁶ <http://data.arr-software.org/>



3.3.3.4 Design losses

An initial/continuing loss model was applied for the RORB modelling. The initial losses were determined based the ARR online datahub⁷ suggested losses of 24 mm initial loss and 4.5 mm/hr continuing loss.

The Kensington Creek outfalls into the Winter Creek, approximately 4.5 km upstream of its confluence with the Yarrowee River. Calibration of the Yarrowee River and Gnarr Creek hydrological model was completed in a 2019 study and determined that the Datahub recommended losses were too high and continual loss of 2.0 mm/hr was more appropriate for the broader Ballarat area.

Considering the proximity of the Kensington Creek to the Yarrowee River catchment, and the Ballarat region, the calibrated continual loss of 2.0 mm/hr was adopted for this catchment.

A summary of the adopted initial and continuing losses and routing parameters for the Kensington Creek are shown in Table 3-5 below.

Table 3-5 Adopted RORB Model Parameters for Design Flood Modelling

Parameter	Adopted value
m	0.8
kc	5.6
Median initial loss (mm)	24
Continuing loss (mm/h)	2.0

3.4 Design Modelling

A RORB Monte Carlo analysis was used to determine the design peak flows at several key locations within project catchment. A Monte Carlo simulation was run in RORB to determine the maximum peak flow for each design event and their correlating critical duration. RORB Version 6.45 has the option to select the representative hydrograph from the 10 temporal pattern and the critical duration at the selected output location for the specified AEP. The temporal pattern chosen resulted in the peak flow immediately higher than the median flow peak flow from Monte Carlo simulation. RORB first focuses on selecting an individual run that matches the peak flow for the determined critical duration, then focuses on matching the burst depth for the correct AEP. The closest rainfall depth matches within 5% tolerance. If more than one hydrograph is found, the tolerance is lowered.

RORB was run with the selected temporal pattern for each AEP event and critical duration. The flow chart outlined in Figure 3-4 demonstrates the modelling process.

⁷ <http://data.arr-software.org/>

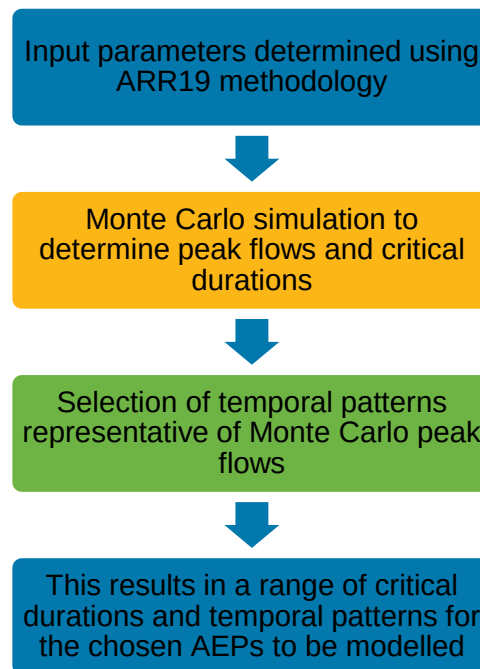


Figure 3-4 Design Modelling Process Diagram

3.4.1 Monte Carlo Analysis

The RORB Monte Carlo analysis was undertaken adopting the determined losses and k_c value discussed in Section 3.3.2. During a Monte Carlo analysis, the RORB model runs many times, sampling for an extensive range of temporal patterns and rainfall initial loss. This is completed in combination with the other set of model parameters of spatial pattern, continuing loss, aerial reduction factors, k_c and m . The model then takes the hydrographs from all model runs and produces a statistical design peak flow at each RORB output location. A schematic diagram of Monte Carlo approach is presented in Figure 3-5. The critical duration for several important locations throughout the model is shown in Table 3-6.

Six output locations were placed in the RORB model along Kensington Creek in the upper, mid and lower reaches, see Figure 3-6. The Monte Carlo analysis showed over the modelled AEPs the critical duration varied from 30 mins to 6 hours.

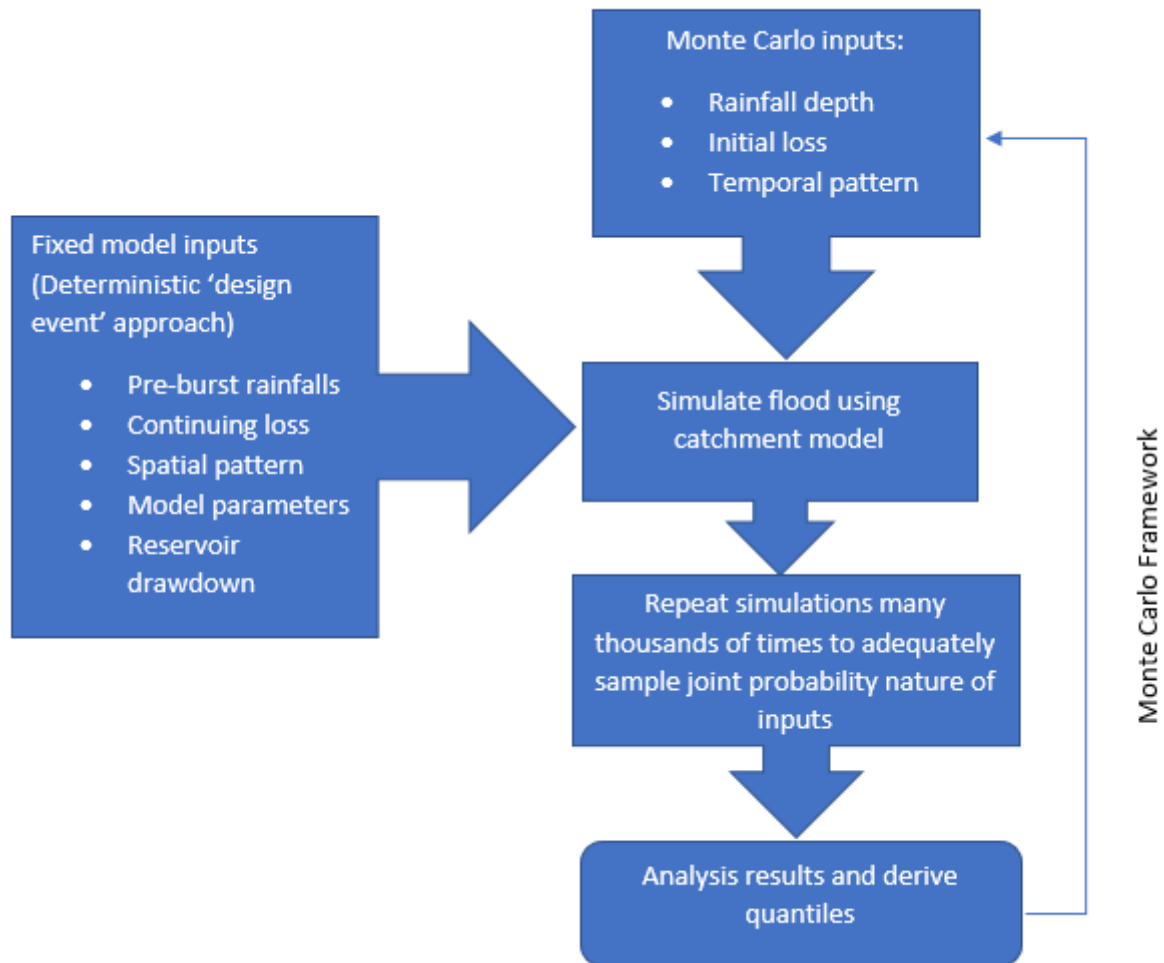


Figure 3-5 Overview of Monte Carlo Analysis

Table 3-6 RORB Critical Durations along Kensington Creek

Location	Critical Duration					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
Upper Catchment 01	1-hr			30-min	1-hr	
Upper Catchment 02	1-hr	2-hr		1-hr		
Mid Catchment 01	2-hr					
Mid Catchment 02	3-hr			2-hr	3-hr	
Lower Catchment 01	6-hr			3-hr		
Lower Catchment 02 (end of model)	6-hr			3-hr		

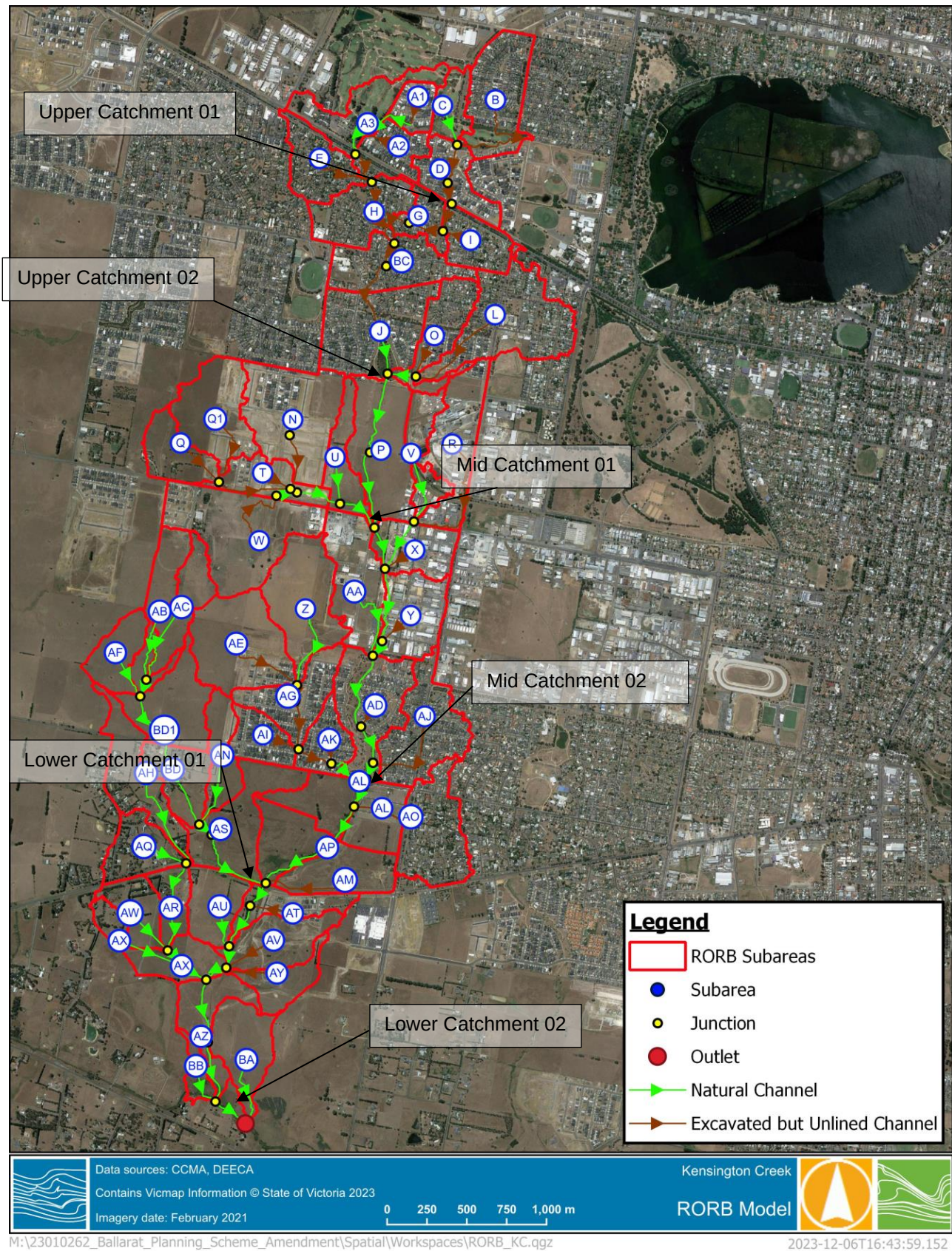


Figure 3-6 Kensington Creek Hydrograph Print Locations



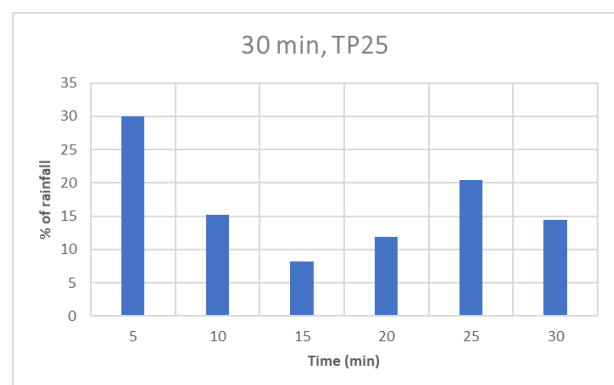
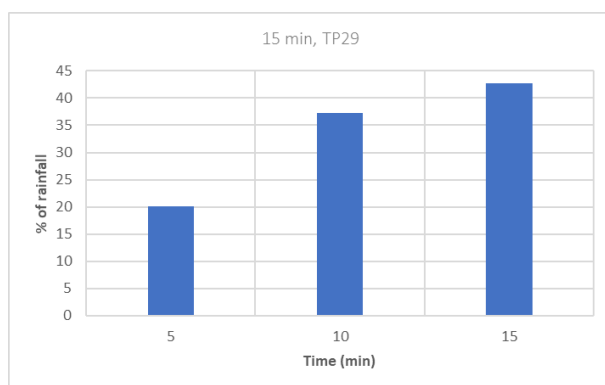
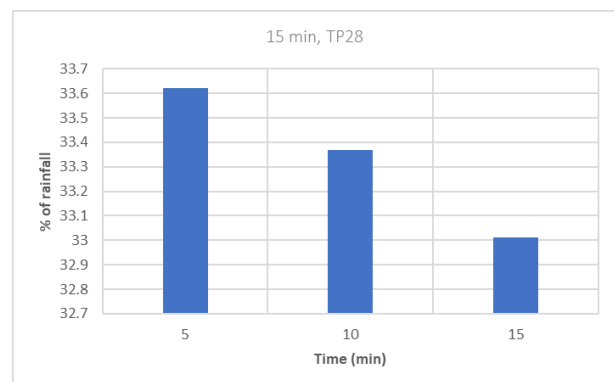
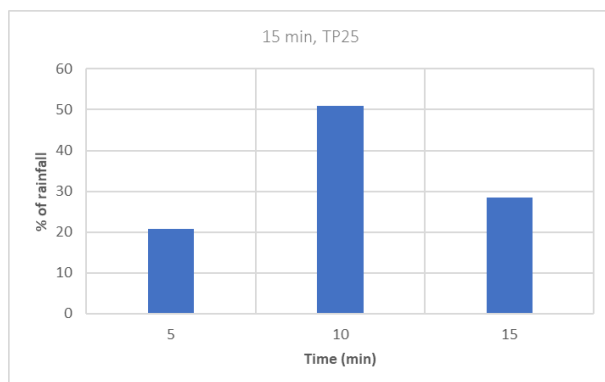
3.4.2 Ensemble Analysis

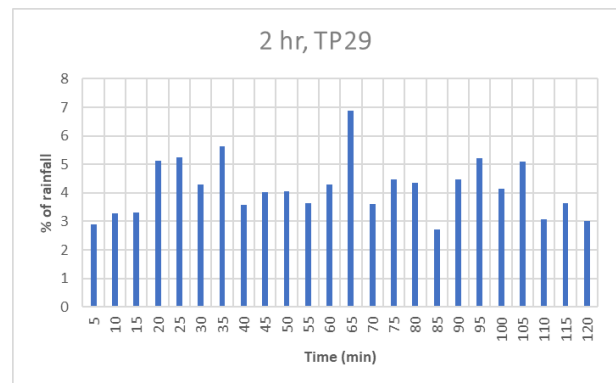
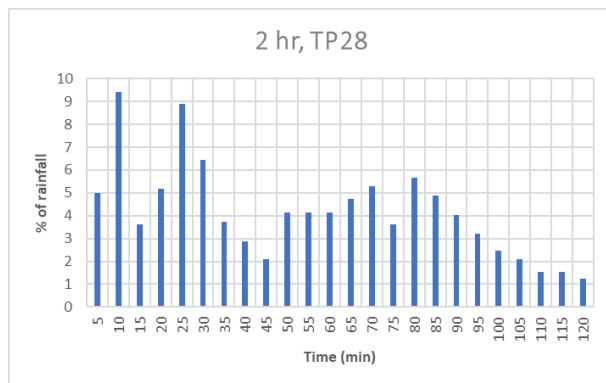
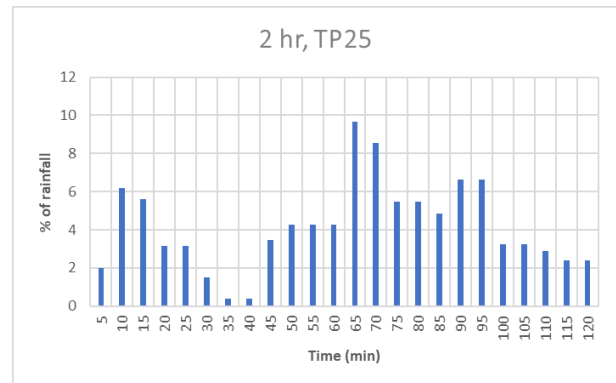
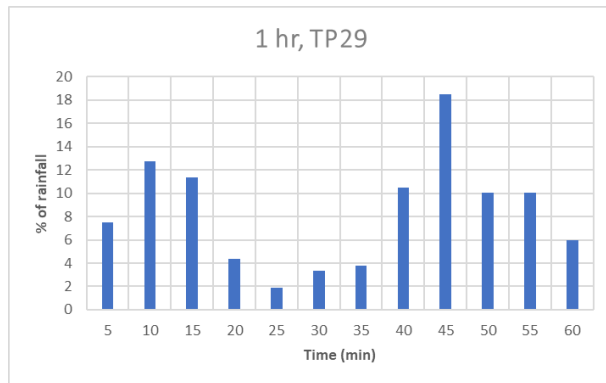
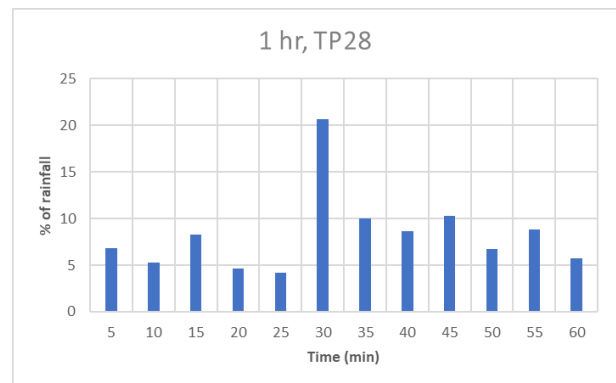
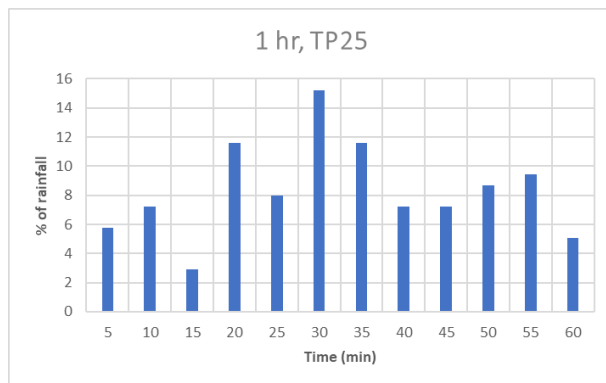
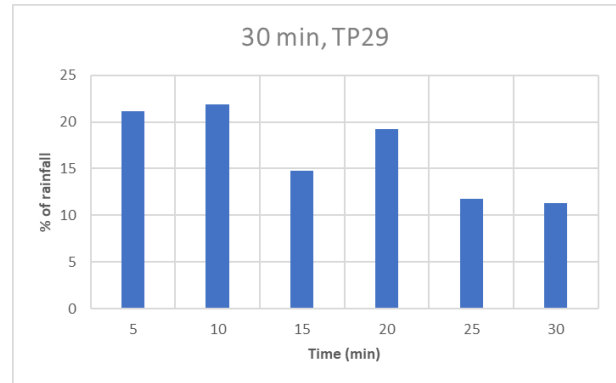
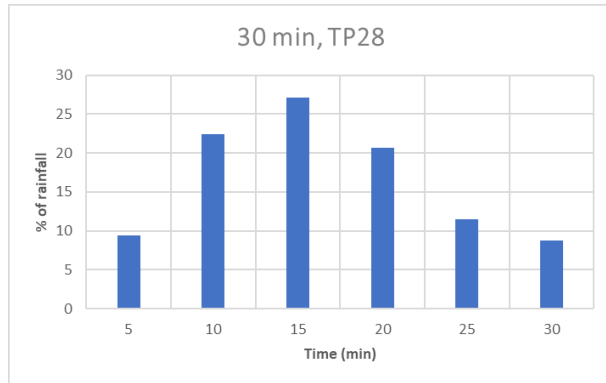
The RORB model was run as an Ensemble Analysis following the Monte Carlo analysis. Using the determined kc value of 5.6 and calibrated losses of 24 mm initial loss and 2.0 mm/hr continuing loss, the RORB Ensemble Analysis was run for all 10 ARR2016 recommended temporal patterns for each event duration and AEP. For this case, six design events were modelled, resulting in 60 design event temporal patterns for each of the six durations, 360 model simulations.

The temporal pattern resulting in an Ensemble Analysis peak flow closest to the Monte Carlo analysis peak flow was selected for each output location. Based on the critical durations presented in Table 3-6 it was determined to adopt the durations 15 min, 30 min, 1 hr, 2 hr, 3 hr and 6 hr for each of the design events. Table 3-7 shows the adopted temporal patterns for each design event, resulting in a total of 132 design model runs across all events. The distribution of rainfall for the adopted temporal patterns in the 1% AEP event displayed in Table 3-7.

Table 3-7 Chosen Representative Critical Durations and Temporal Patterns

	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
Critical Duration & Temporal Pattern	TP01	TP15	TP13	TP25	TP25	TP23
	TP06	TP16	TP15	TP28	TP28	TP25
	TP07	TP19	TP16	TP29	TP29	TP28
	TP09		TP19			
	TP10		TP20			





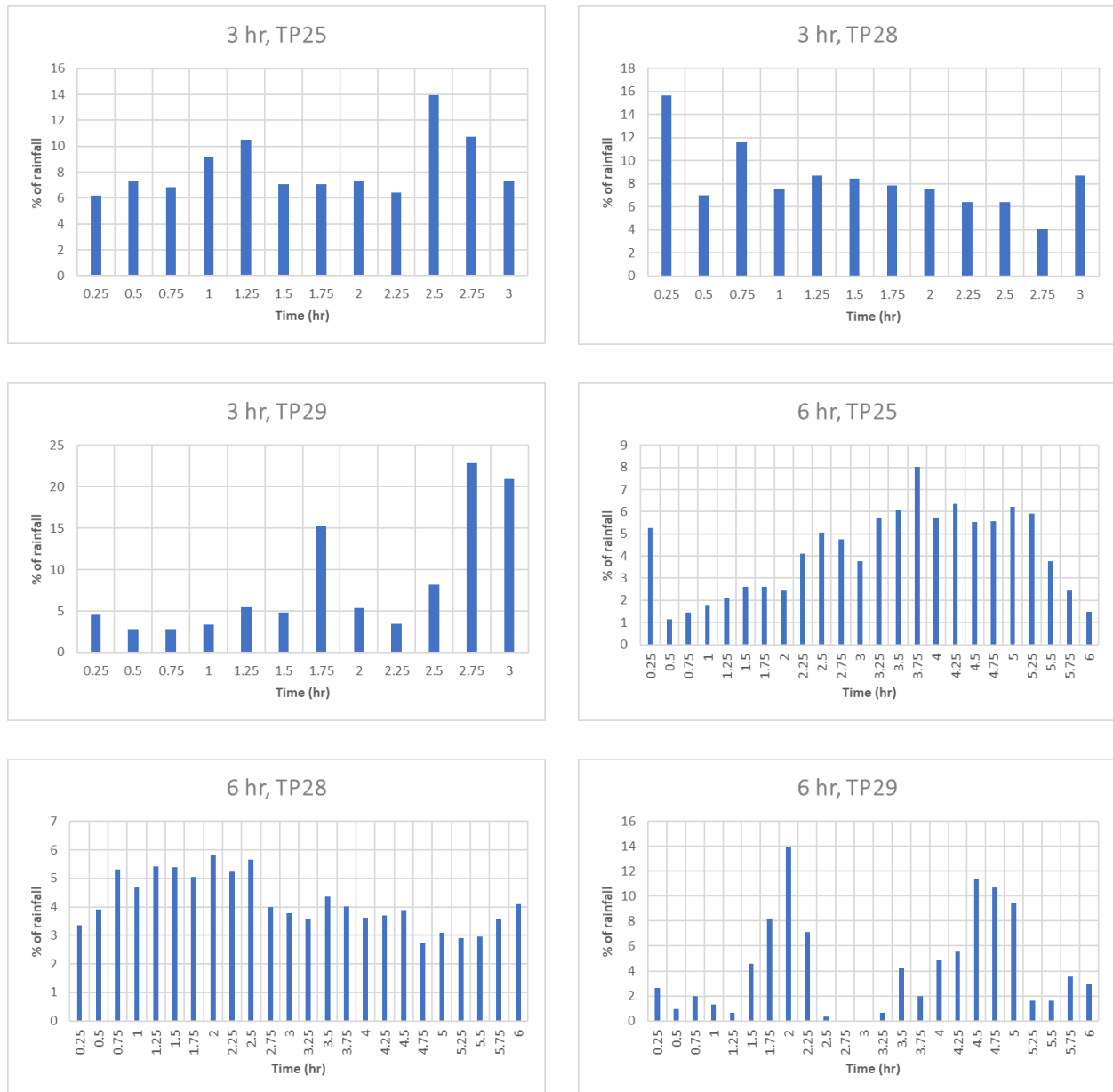


Figure 3-7 Adopted Temporal Patterns for Design Modelling (1% AEP)

3.4.3 Design Simulations

The RORB model was used to produce inflows along Kensington Creek, the inflow points will be discussed further in the hydraulic modelling report. The hydraulic model was run for six event durations (15 mins, 30 mins, 1 hr, 2 hr, 3 hr and 6 hr) across the six AE's. The RORB model outflow of Kensington Creek into Winter Creek for the determined critical durations is shown below in Figure 3-8.

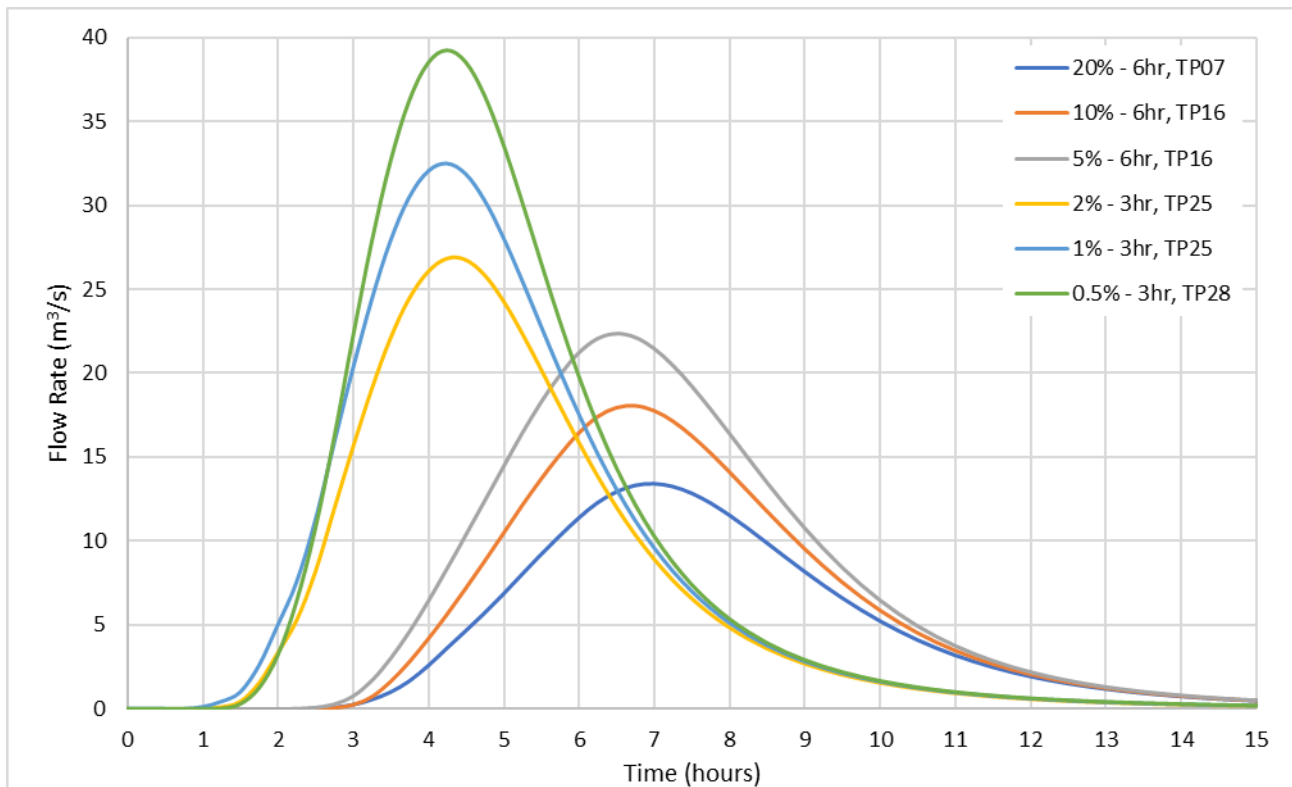


Figure 3-8 Kensington Creek Model Outflows for Determined Critical Durations



4 HYDRAULICS

This section provides the description of the TUFLOW hydraulic model setup. Model runs were performed with a Highly Parallelised Computing (HPC) solution scheme using the 2023-03-AB build of TUFLOW. HPC technology enables 2D models to utilise the parallel processing ability of graphics cards, with many thousand processors operating in unison, significantly speeding up simulation run times compared to TUFLOW Classic.

Design flood modelling included the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events along with the 1% AEP with the inclusion of climate change scenarios for the year 2100 under RCP 4.5, RCP 6 and RCP 8.5. Currently only the 1% AEP events have been modelled.

4.1 2D Domain

The model topography was based on topographic LiDAR data captured over multiple LiDAR datasets from 2009 to 2012, as part of the Rivers, Corangamite, and CHW projects. The LiDAR data was resampled to a 3-m grid resolution for input to the hydraulic model, as shown in Figure 4-1.

One of the key considerations in establishing a 2D hydraulic model relates to the selection of an appropriate grid size. Grid size affects the representation of the physical properties of the study area as well as the size of the model and its resulting run times. Selecting a very small grid size will result in both higher resolution and longer model run times. In adopting the grid size for the model, the above issues were considered in conjunction with the final objectives of the study. A 4-m resolution was considered sufficient to represent Kensington Creek and floodplain flood behaviour. The raw LiDAR data was available at a 1 metre grid resolution, this was resampled to a 4-metre grid for inclusion in the hydraulic model. The model topography is shown in Figure 4-1.

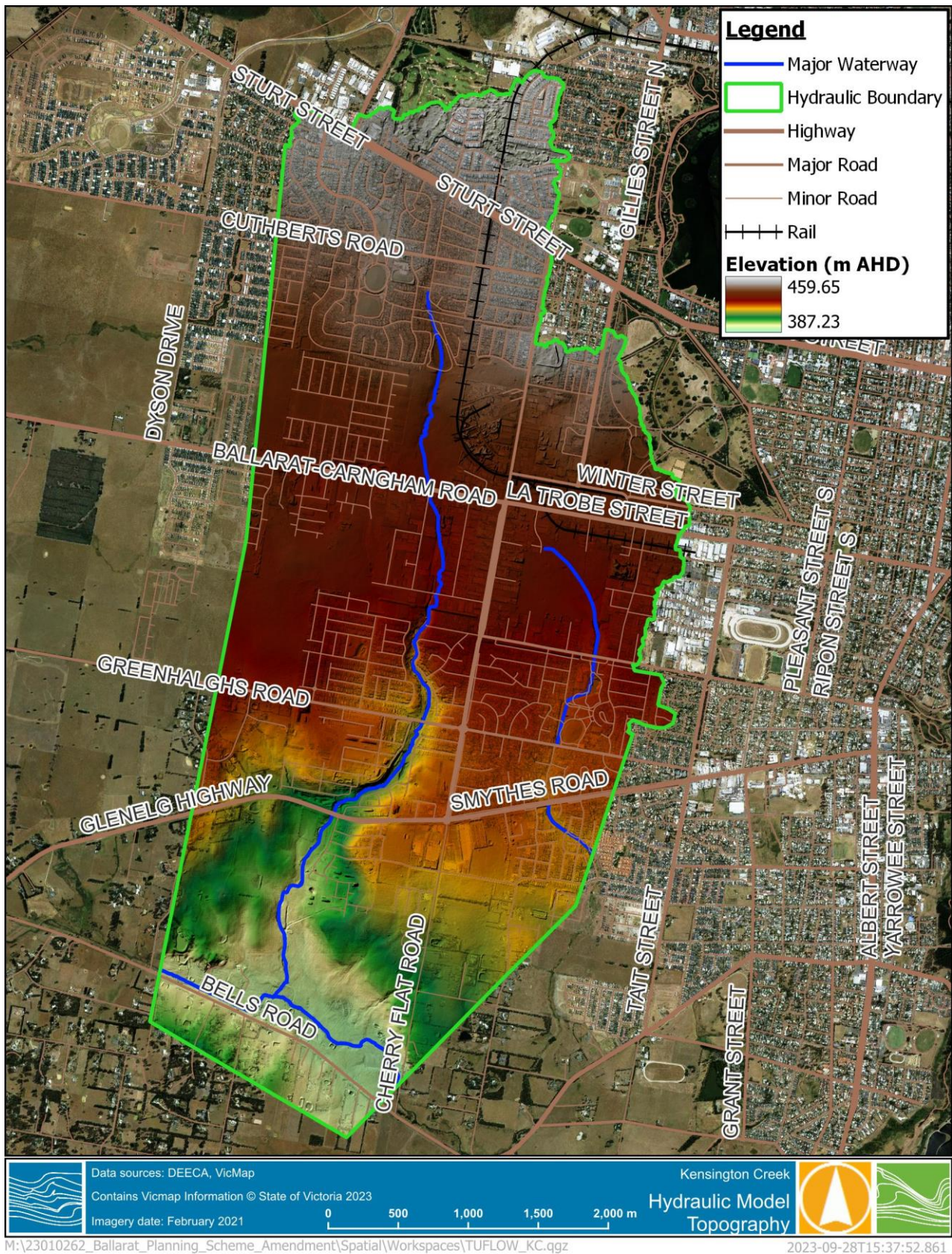


Figure 4-1 TUFLOW Model Topography



4.2 Surface Roughness

Hydraulic roughness was determined using planning layers and verified using aerial imagery. The Manning's 'n' roughness values adopted for each land use in the hydraulic model is presented in Table 4-1 and shown in Figure 4-2. The adopted roughness values were based on those used in recent nearby studies as well as industry guidelines. Figure 4-2 shows areas where Manning's value for open spaces with minimal vegetation extends into recently developed areas. This extension of low Manning's value is considered acceptable as inflows into the hydraulic model and the extents of flooding are contained within the reserves.

The Icon Park Industrial Precinct, immediately south of Ballarat-Carngham Road along the Kensington Creek, has seen rapid development since the outset of the Kensington Creek Flood Study update. The decision to model part of the precinct with high roughness, reflecting industrial buildings, and others with low roughness's was based on what information was captured in the 2019 LiDAR dataset and design surfaces/surveys made available. Where information was available on developed surface levels, Manning's value was adjusted accordingly, but if no information was available it was assumed the site was undeveloped and modelled as such.

Table 4-1 Manning's Roughness Used in Hydraulic Model

Land Type	Manning's Value (n)
Residential – Urban (higher density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.350
Residential – Rural (lower density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.150
Industrial/Commercial or large buildings	0.300
Open Space or Waterway – minimal vegetation	0.040
Open Space or Waterway – moderate vegetation	0.060
Open Space or Waterway – heavy vegetation	0.090
Car park/pavement/wide driveways/roads	0.020
Reserves	0.040

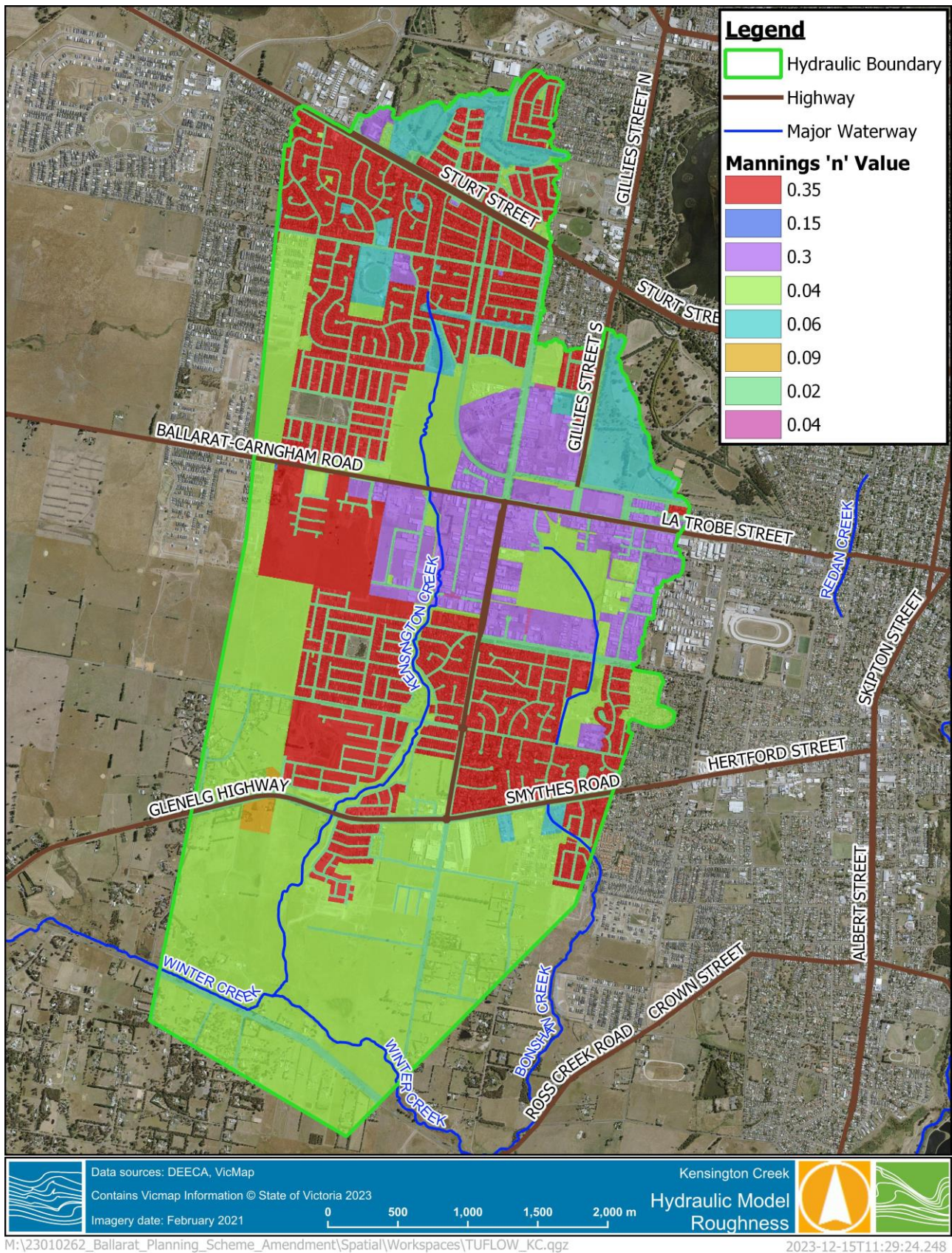


Figure 4-2 Detailed Hydraulic Roughness Mapping



4.3 1D Network

Key hydraulic structures were modelled using a 1D pipe network. This enables the road deck and span of each culvert to be accounted for accurately. 1D structures were linked to the 2D floodplain domain allowing water to flow through the structures. All structures were tested for stability.

There were two types of hydraulic structures modelled along Kensington Creek:

- The pipe network in the upper reaches; and
- The culverts traversing Kensington Creek.

Numerous site visits, City of Ballarat infrastructure layers and previous Ballarat studies were used as the basis for structure details. No 2D bridge structures were included in the hydraulic model. The location of 1D structures included in the hydraulic modelling are shown in Figure 4-3.

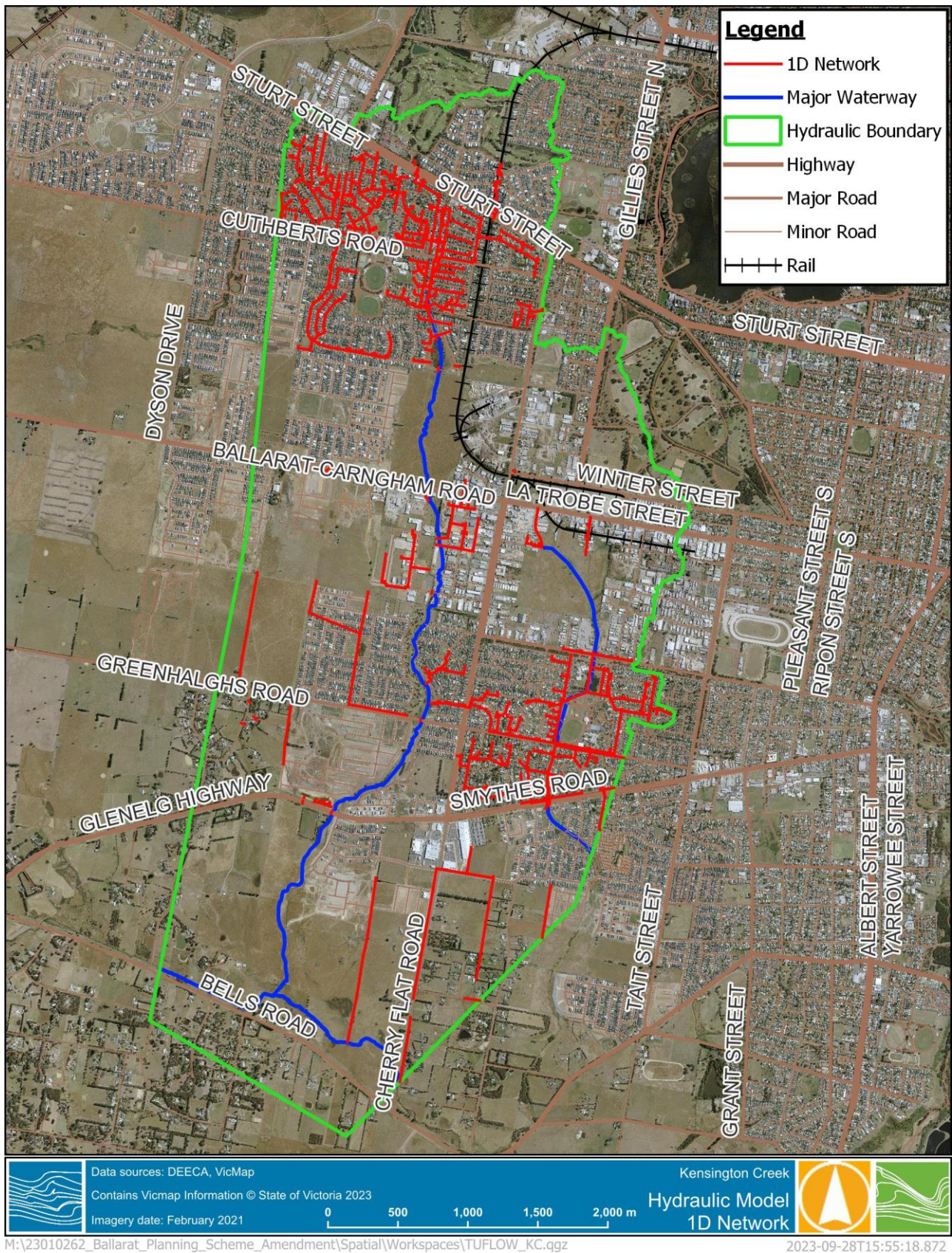


Figure 4-3 Key Hydraulic Structures



4.4 Boundary Conditions

The hydraulic model requires inflow and outlet boundaries to allow water into and out of the model. External inflow boundaries account for flow generated from outside of the model extent, whereas internal boundaries account for the runoff generated from within the model extent.

The TUFLOW model contained 36 inflow points, broken up into inflow pits and regions. Inflow pits simulated direct inflows into the stormwater pipe network at the northern end of the model where there is no defined section of Kensington Creek. The remaining inflows simulated catchment contributions along Kensington Creek. Inflows were extracted from the RORB model (as detailed in Section 3.3) at various locations along the watercourse. The hydraulic model inflow locations are shown in Figure 4-4.

The hydraulic model extent covered the confluence between Kensington Creek and Winter Creek, inflows to Winter Creek across each of the design events were modelled as a steady state inflow at 30.0 m³/s, this flow is reflective of a 1% AEP flow. The mapping completed during this project focuses on Kensington Creek and modelling of Winter Creek was intentionally conservative until a project focusing on the waterway itself is completed.

The Winter Creek outflow was located upstream of Cherry Flat Road near Bells Road prior to the hydraulic control under Cherry Flat Road. The boundary was modelled as a Head/Time (HT), this condition assigns a water level to the cells based on the water level verses time curve.

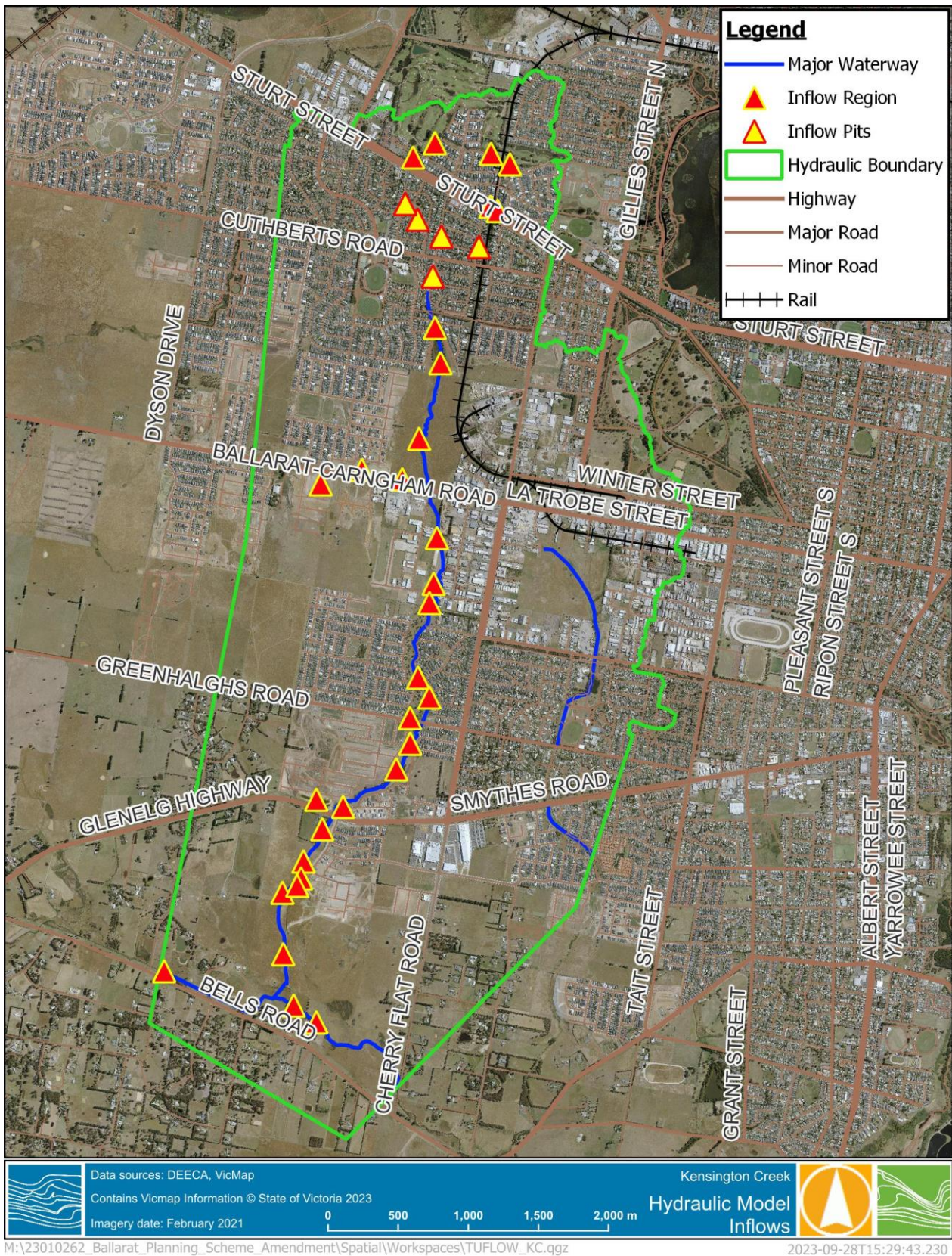


Figure 4-4 Model Inflow Boundaries



5 HYDROLOGIC/HYDRAULIC MODEL COMPARISON

Design hydraulic modelling was completed adopting the hydraulic model roughness values, and hydraulic structures determined during the model setup. Modelling was completed for a suite of design events including 20%, 10%, 5%, 2%, 1% and 0.5 AEP, each for durations varying from 30-mins to 6-hours.

RORB and TUFLOW model hydrographs were compared to confirm routing across both model types was similar. Hydrographs at Mid Catchment 02 and the Outlet of the Kensington Creek for both models is shown in Figure 5-1 and Figure 5-2 below. Both sets of hydrographs were extracted from the 1% AEP, 3-hour TP25 event.

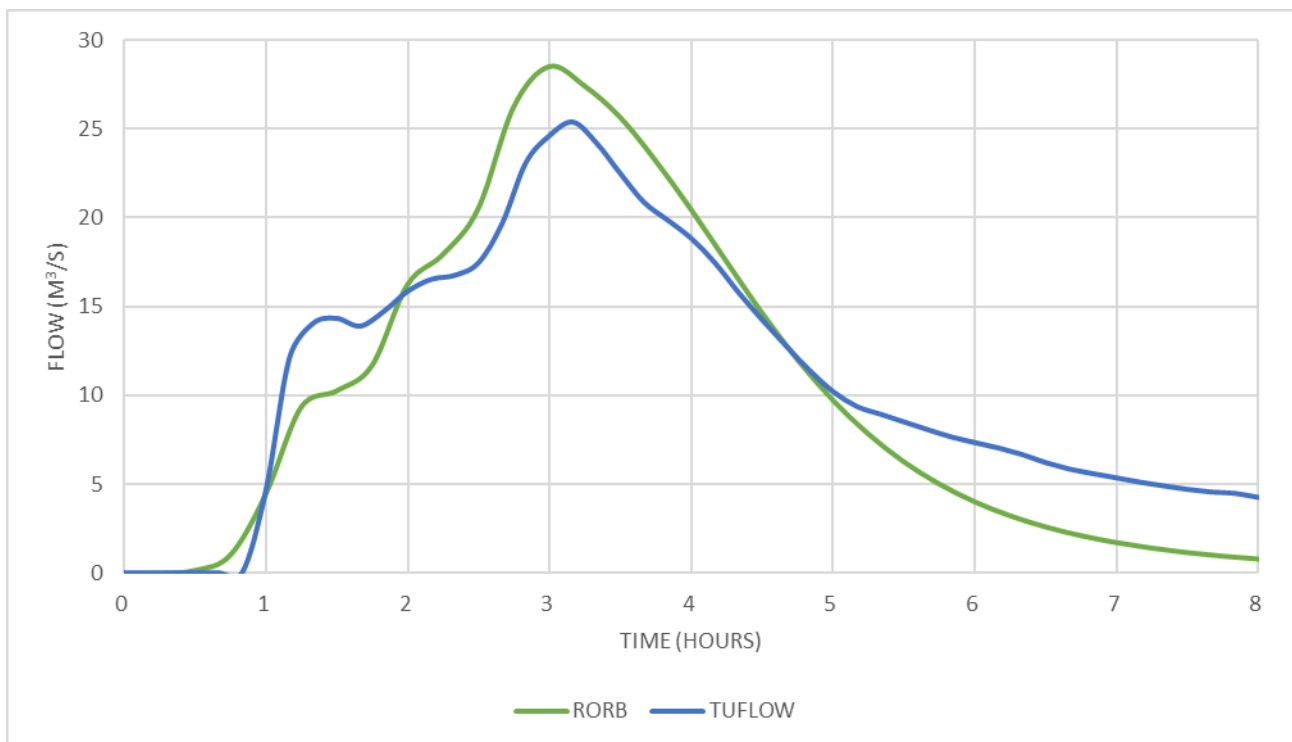


Figure 5-1 Kensington Creek RORB and TUFLOW Hydrograph Comparison – Mid Catchments 02

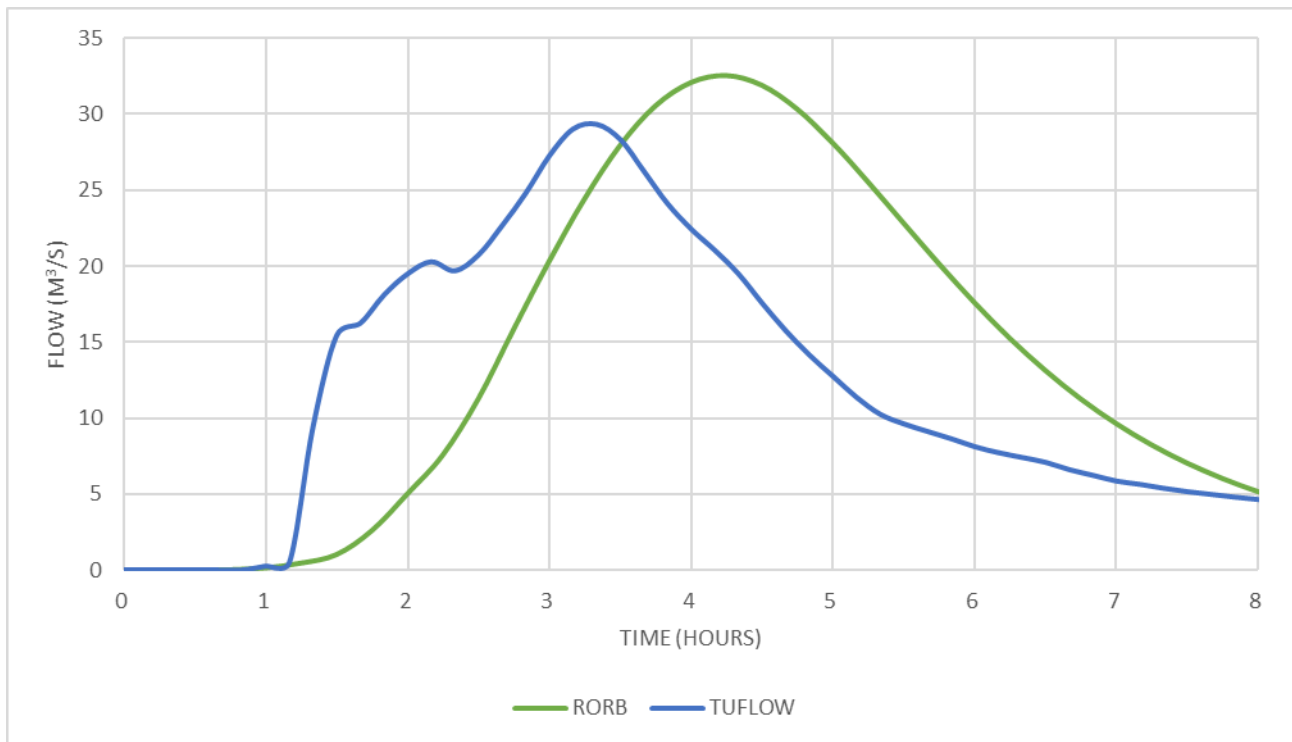


Figure 5-2 Kensington Creek RORB and TUFLOW Hydrograph Comparison – Model Outlet

Figure 5-1 represents the hydrographs at Mid Catchment 02 from the RORB model and the corresponding PO line from the TUFLOW model at the Glenelg Highway. The two flows are similar in shape and flow rate, with the RORB hydrograph exceeding the TUFLOW hydrograph by approximately 3 m³/s. This difference in peak flows is due to hydraulic structures along the waterway retarding flows in the Kensington Creek. The same hydraulic structures are also responsible for the sharper peak of the TUFLOW hydrograph.

At the outlet of the Kensington Creek catchment, it can be seen in Figure 5-2 that the peak flows in the TUFLOW model are still approximately 3 m³/s lower than the RORB model, but it shows a greater volume of flow earlier in modelled duration. The dramatic increase of flows earlier in the modelled duration are due to a faster response time from the catchment and increase flow conveyance through pipe networks. Despite this, the models tend to show a very strong correlation, with observed differences as expected.



6 FLOOD MAPPING AND RESULTS

Mapping of the Kensing Creek flood outputs underwent post-processing whereby all modelled durations and temporal for each design event (i.e., 1% AEP) were compared and the maximum results being extracted to form the peak outputs. Peak outputs from this study include depth, velocity, water surface elevation, and flood hazard. Mapping of the 1% AEP peak depths are presented in Figure 6-1 to Figure 6-5 below, with the remaining outputs to be delivered to the City of Ballarat as separate appendices.



Figure 6-1 Kensington Creek 1% AEP Flood Depth – Map 1



Figure 6-2 Kensington Creek 1% AEP Flood Depth – Map 2



Figure 6-3 Kensington Creek 1% AEP Flood Depth – Map 3



Figure 6-4 Kensington Creek 1% AEP Flood Depth – Map 4

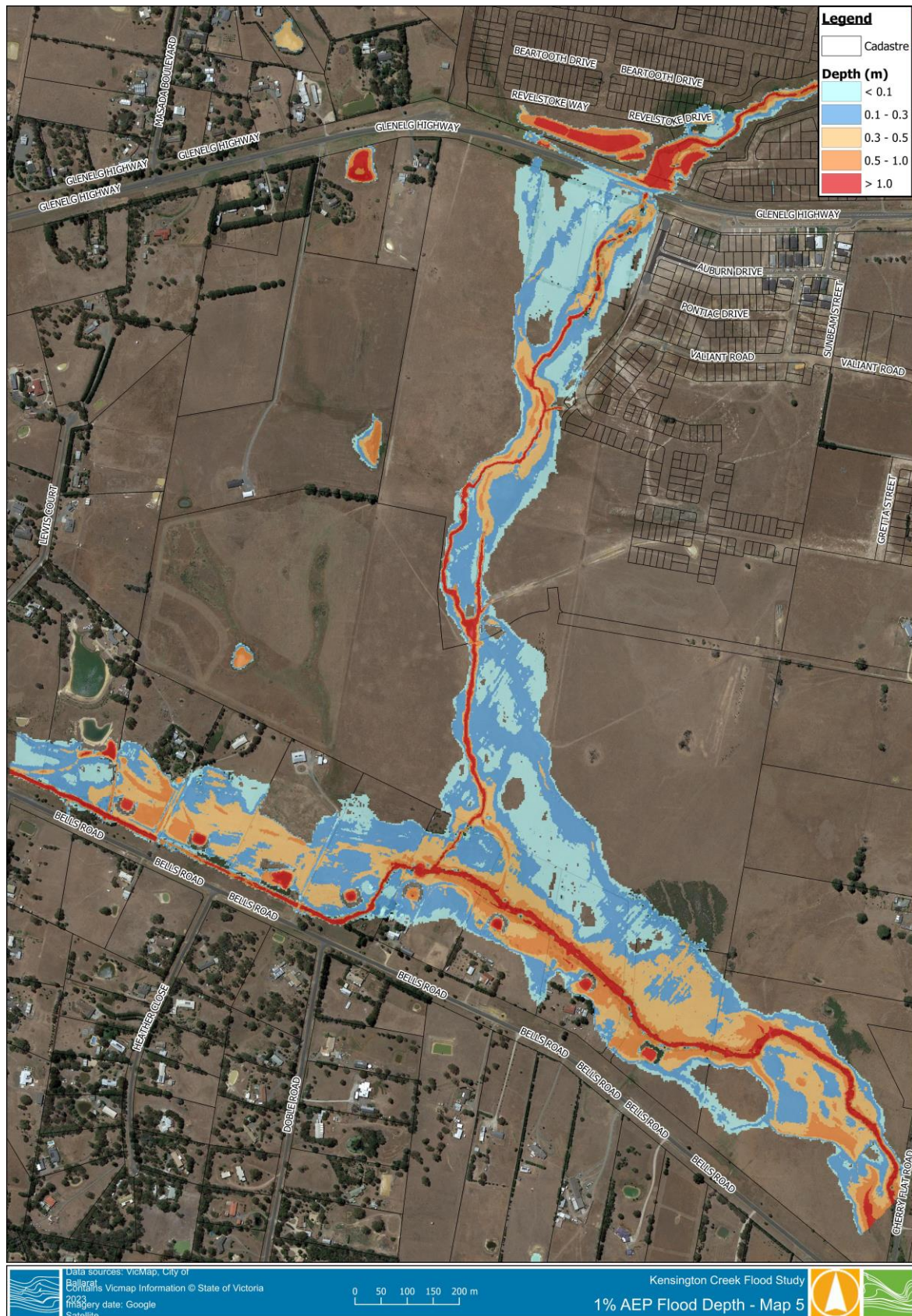


Figure 6-5 Kensington Creek 1% AEP Flood Depth – Map 5

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