Melbourne Water and Yarra City Council

City of Yarra Flood Mapping Project

Final Report

16/10/2025

V3000_151-REP-001-7

Document Revision Details:

Rev	Date
0 – Initial Report	28/09/2023
1	28/05/2024
2	14/06/2024
3	05/12/2024
4	21/03/2025
5	27/03/2025
6	10/10/2025
7 – Final Report	16/10/2025

DISCLAIMER

This Report has been prepared on behalf of and for the exclusive use of Melbourne Water and Yarra City Council and is subject to and issued in accordance with Melbourne Water and Yarra City Council instruction to Engeny Australia Pty Ltd (Engeny). The content of this Report was based on previous information and studies supplied by Melbourne Water and Yarra City Council.

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this Report by any third party. Copying this Report without the permission of **Melbourne Water and Yarra City Council** or Engeny is not permitted.

LIST OF TERMS & ABBREVIATIONS

The following terms and abbreviations are used in this report.

Term (Abbreviation)	Explanation
Annual Exceedance Probability (AEP)	Refers to the probability or risk of a rainfall event of a given magnitude (intensity and duration) occurring or being exceeded in any given year. A 90 % AEP event has a high probability of occurring or being exceeded; it would occur quite often and would be a relatively minor rainfall event. A 1 % AEP event has a low probability of occurrence or being exceeded; but is likely to cause extensive damage. A 1 % AEP event has the same probability as a 1 in 100-year ARI.
AEP Bin	According to ARR v4.1, AEP bins are groupings of standard rainfall temporal patterns based on the AEP of a storm event. Each AEP bin contains 10 temporal patterns that provide realistic storm shapes for flood modelling and take into consideration storm location and duration.
Areal Reduction Factor (ARF)	The ratio between the design values of areal average rainfall and point rainfall (measured at a single location), computed for the same duration and Annual Exceedance Probability (AEP), is called the Areal Reduction Factor (ARF). This coefficient is used to convert point rainfall data to an average rainfall value over a larger area. The ARF accounts for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Australian Rainfall and Runoff 2019 version 4.1 (ARR v4.1)	Australian Rainfall and Runoff (ARR v4.1) is the national guideline for flood estimation in Australia, providing updated, evidence-based methods and data for assessing rainfall, runoff, and flood risk across diverse catchments.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given storm event magnitude occurring or being exceeded. For instance, a 100-year ARI event is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Bureau of Meteorology (BoM)	Australia's national agency responsible for providing weather forecasts, warnings, monitoring, and climate information. Since 2008, the Bureau of Meteorology (BoM) has been responsible for delivering water data throughout Australia.
Department of Energy, Environment and Climate Action (DEECA)	Formerly known as DELWP (pre-January 2023), DEECA is a Victorian Government department responsible for managing energy policy, environmental protection, climate action, biodiversity, water resources, and land management.
Digital Elevation Model (DEM)	A digital representation of the Earth's surface topography, showing elevation data in a grid format. Each cell in the model contains a value representing ground height above a reference level.
Effective Impervious Area (EIA) or Directly Connected Area (DCA)	Impervious areas which are directly connected to underground drains or concrete lined channels. Examples include roofs with downpipes connecting to drains, road pavement and large carparks.
Freeboard	A factor of safety above the relevant design standard (e.g., 1 in 100 year) stormwater level. Is typically used for setting of floor levels or crest heights of levees. It is usually expressed as a height above the level of the design storm event.
Feature Manipulation Engine (FME)	A spatial data integration platform that enables the translation and conversion of geospatial data across different formats and systems. FME supports spatial and non-spatial data types, allowing users to create repeatable workflows for data cleaning, validation, and translation without extensive coding.
Fraction Impervious (FI)	The ratio of area covered by impervious surfaces to the total land area in each site or catchment. It is a dimensionless value between 0 and 1 that indicates how much of the land does not allow water to infiltrate, impacting runoff and drainage characteristics.
Geographic Information System (GIS)	A computer-based system used to create, manage, analyse, and display spatial or geographic data. GIS connects data to a map. Two of the most used GIS platforms are: QGIS - an open-source GIS platform and ArcGIS - a commercial GIS platform
Hydraulics	The term given to the study of water flow in a river, channel, or pipe. In particular, for the evaluation of flow parameters - such as depth and velocity.
Hydrology	Terms given to the study of the rainfall and runoff. Determining how much rain is likely to fall in each event and how much of that rain will become runoff.
Impervious	A ground covering or surface which water cannot pass though. Examples include roofs, concrete and asphalt. The opposite of impervious is pervious.
Indirectly Connected Area (ICA)	Includes all small pervious areas within a catchment (gardens, nature strips, pocket parks, lawns) and impervious areas which are not directly connected to an underground drain or concrete channel (runoff flows onto a pervious surface). Examples of impervious areas which are not directly connected include footpaths next to a nature strip, concrete

Term (Abbreviation)	Explanation
	or gravel paths through parks, roof of a garden shed where water falls onto the garden, most residential driveways and landscaped paving.
Intensity Frequency Duration (IFD)	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
Land Subject to Inundation Overlay (LSIO)	A land subject to inundation overlay is used to designate areas that are subject to overland flow from waterways.
Light Detection and Ranging (LiDAR)	Airborne surveying technology that provides a regularly spaced grid (one metre horizontal interval in this case) of ground levels. The data allows for the representation of elevations along waterways and other key topographical features across the study area.
Melbourne Water AM ST 6200 Flood Mapping Project Specifications (Melbourne Water Project Specification [20xx])	This document provides key project specifications and requirements to the City of Yarra Flood Mapping Project. In this report, this document will be referred to as the 'Melbourne Water Project Specifications [YEAR OF RELEASE]'. As both the Melbourne Water Project Specifications 2019 document and the Melbourne Water Project Specifications 2021 Updates document are used, the shorthand will specify which release is being referenced.
Pervious Area (PA)	A ground covering or surface which water can pass though. Examples include gardens, grass (lawns, nature strips, ovals) and other green landscaped areas. The opposite of pervious is impervious.
Planning Scheme Amendment (PSA)	A formal change or update to a local government's planning scheme, which sets out land use policies, zoning, and development controls. Amendments are made to respond to new planning needs, policy changes, or environmental considerations. Planning schemes may be modified to reflect updated flood data or risk assessments.
RORB (RunOff Routing Burroughs)	Hydrological modelling software used in this study to calculate the runoff generated for rainfall events.
Special Building Overlay (SBO)	Special Building Overlays designate areas at risk of flooding when the capacity of Melbourne Water and council infrastructure is exceeded.
Sub-Grid Sampling (SGS)	Sub-grid sampling (SGS) enables TUFLOW to incorporate high-resolution Digital Terrain Models (DTMs) or Triangulated Irregular Networks (TINs) by sampling terrain at sub-cell resolution, improving the representation of topography within each computational cell.
Total Impervious Area (TIA)	The sum of all impervious surfaces within a defined land area or catchment.
TUFLOW	Hydraulic modelling software used in this study to simulate the flow of stormwater through the study area. The model uses numerical equations to describe the water movement.
Victoria State Emergency Service (VICSES)	A volunteer-based emergency service which plays a pivotal role in emergency management, focusing on preparedness, response, and recovery. VICSES provides information on flood 'hotspot' locations.

Contents

LIST OF TERMS & ABBREVIATIONS **II**

1 INTRODUCTION **1**

1.1 STUDY OVERVIEW 1

1.2 BACKGROUND INFORMATION 1

1.2.1 Planning and Jurisdiction 1

1.2.2 Catchment Description 2

1.2.3 Project Objectives 3

1.3 PROJECT SCOPE 3

2 DATA COLLATION AND REVIEW **4**

2.1 OVERVIEW 4

2.2 AVAILABLE DATA 4

2.3 DATASET INFORMATION 4

2.4 DRAINAGE SURVEY 4

2.5 SITE INSPECTION 5

3 OVERVIEW OF MODELLING APPROACH **6**

4 RORB HYDROLOGICAL MODELLING **7**

4.1 SCOPE 7

4.2 APPROACH 7

4.3 RORB HYDROLOGICAL MODELLING LIMITATIONS 7

4.3.1 RORB Routing Parameter, k_c 7

4.4 INITIAL AND CONTINUING LOSS VALUES 7

4.4.1 Adopted Values 7

4.5 CLIMATE CHANGE 8

4.6 2022 HYDROLOGICAL UPDATES 8

5 HYDRAULICS **10**

5.1 METHODOLOGY 10

5.1.1 Overview 10

5.2 TUFLOW HPC VERSUS CLASSIC COMPARISON 11

5.3 TEMPORAL PATTERN SENSITIVITY ANALYSIS 11

5.4 MODELLED STORM TEMPORAL PATTERNS, DURATIONS AND EVENTS 11

5.5 2022 HYDRAULIC UPDATES 12

5.6 2024 HYDRAULIC UPDATES 12
5.7 QUALITY ASSURANCE 13
6 FLOOD MAPPING 14
6.1 MODEL CALIBRATION AND VALIDATION 14
6.1.1 Historical Flood Events 14
6.1.2 Rainfall Gauges 14
6.1.3 Flooding Verification 14
6.2 DEVELOPMENT OF FLOOD EXTENTS 21
6.2.1 Melbourne Water and Council Flood Extents 21
6.2.2 Flood Extent Demarcation 21
6.3 GRIDDED OUTPUT EXTENTS 21
6.4 FLOOD MAPPING DELIVERABLES 21
6.5 PARCELS IMPACTED BY FLOOD EXTENTS 21
6.6 PARCEL CADASTRE GIS UPDATE 22
7 QUALIFICATIONS 23
8 REFERENCES 24

Appendices

Appendix A 2020 Site Inspection Photos

Appendix B RORB Hydrological Model Layout Plans

Appendix C RORB Hydrological Model Development Details

Appendix D TUFLOW Hydraulic Model Development Details

Appendix E Front Middle Back vs Ensemble Temporal Patterns Afflux

Appendix F Flood Extent Plans

List of Tables

Table 5-1: TUFLOW Modelling Scenarios 11

Table 5-2: Front, Middle, and Back Modelled Storm Temporal Patterns for each duration and AEP. 12

Table 6-1: Summary of Historical Storm Magnitudes 14

Table 6-2: Summary of Flood Affected Parcels 22

List of Figures

Figure 1-1: Land Use Zones (DEECA, Aug 2023) 1

Figure 1-2: Key Melbourne Water Drainage Assets 2

Figure 6-1 : Flooding within Swan Street, Richmond 3121 in December 2018 (Source: K 8 via Youtube, 2018) 15

Figure 6-2: Flooding within Glass Street, Richmond 3121 in December 2018 (Source: Twitter) 15

Figure 6-3: TUFLOW Results Flood Extent - Glass Street, Richmond 3121 16

Figure 6-4: Comparison of 1% AEP flood Modelling Results to the Existing Melbourne Water SBO 17

Figure 6-5: Flooding Hotspot - Swan Street at Railway Line 18

Figure 6-6: Flooding Hotspot - Langridge Street and Charles Street 18

Figure 6-7: Flooding Hotspot - Turner Street and Rich Street 19

Figure 6-8: Flooding Hotspot - Station Street and Lee Street 19

Figure 6-9: Flooding Hotspot - Drummond Street and Pigdon 20

Figure 6-10: Flooding Hotspot - Napier Street and Westgarth Street 20

1 INTRODUCTION

1.1 STUDY OVERVIEW

The City of Yarra Flood Mapping Project commenced in 2020 with Yarra City Council (Council) commissioning the flood mapping of the City of Yarra Municipality (City of Yarra). In 2022, Melbourne Water became a stakeholder of the project and conducted a technical peer review of the 2020 flood models. The findings of the technical peer review were used to update the 2020 models that were then submitted to Melbourne Water and Council. Additionally, in 2024, Engeny was provided with new flood information upstream of the 2022 flood model which led to flood model updates of the Fairfield Main Drain catchment methodology and modelling approach.

Please note that the initial project work during 2020 referred to the Melbourne Water Project Specifications from September 2019, while the project work during 2022 as well as the 2024 flood model updates were undertaken in accordance with the Melbourne Water Project Specifications of October 2021. Following the flood model updates, GIS deliverables (flood information) were generated in accordance with Melbourne Water Project Specifications of August 2023. All project works were completed in general accordance with ARR v4.1.)

1.2 BACKGROUND INFORMATION

1.2.1 Planning and Jurisdiction

The City of Yarra is located directly east of Melbourne's Central Business District (CBD). The City of Yarra municipality covers a total area of approximately 19.5 square kilometres and comprises of general residential, commercial, public use, public park and recreation land use zones as depicted in Figure 1-1 below.

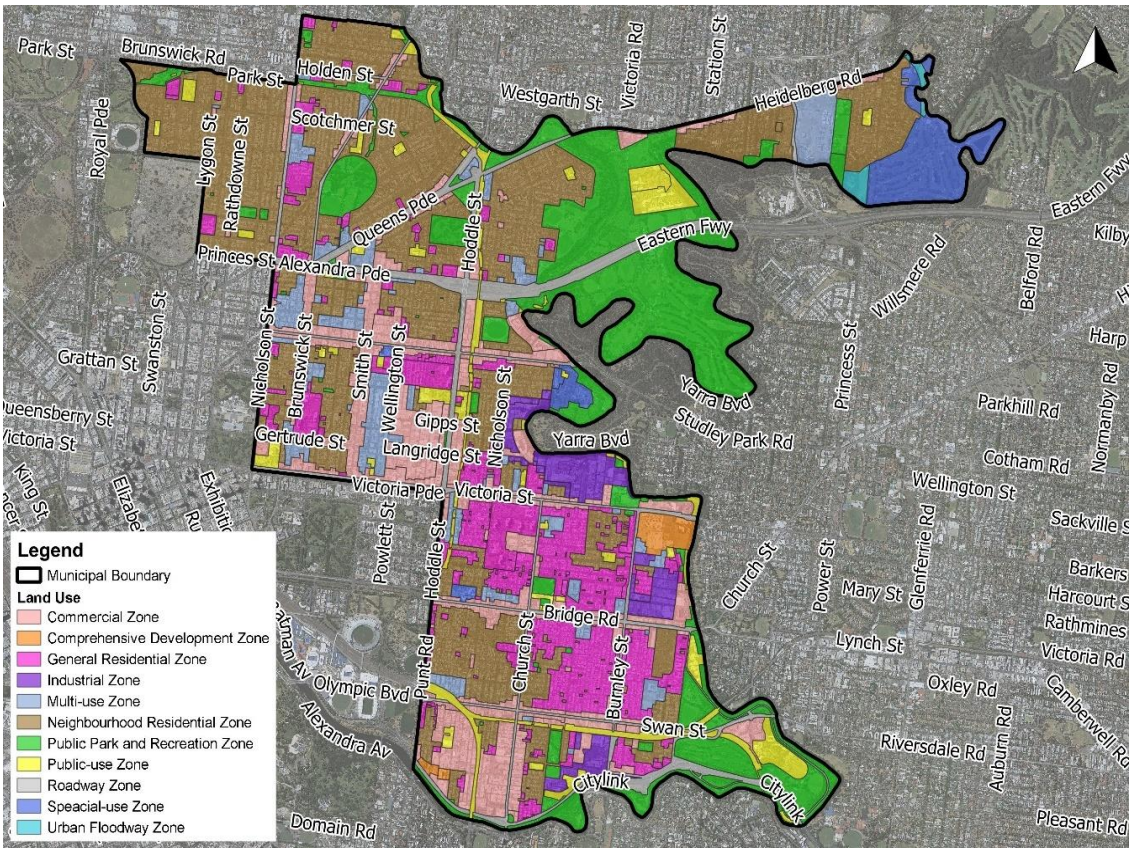


Figure 1-1: Land Use Zones (DEECA, Aug 2023)

1.2.2 Catchment Description

The City of Yarra is an inner-city municipality that is downstream of three municipalities: the City of Melbourne to the west, the City of Merri-bek to the north-west and the City of Darebin to the north-east. The City of Yarra is low-lying with ground elevations ranging from 44.0 m AHD in the north-west, to approximately 2.0 m AHD in the south-west (-0.1 mA HD in the Yarra River itself).

There are approximately 11,500 underground drains within the City of Yarra. Key Melbourne Water underground drains in the study area include:

- Alexandra Parade Main Drain (MW asset ID: 4413), which is 4.5 km long and originates in the City of Merri-bek before collecting stormwater inflows from within the City of Yarra and ultimately discharging into the Yarra River near Gray Street.
- Richmond Quarry Main Drain (MW asset ID: 4405), which has a total length of 0.6 km originating in Swan Street before discharging into the Yarra River near Barkly Avenue Road.
- Fairfield Main Drain (MW asset ID: 4501), which is 3.6 km long and originates in the City of Darebin before collecting stormwater inflows from within the City of Yarra and ultimately discharges into the Yarra River at Yarraford Avenue.
- Lygon Street Main Drain / Park Street Diversion (MW asset ID: 4416), which has a total length of 2.2 km starting at Barkly Street and discharging into the Merri Creek near Rushall Reserve.
- North Fitzroy Main Drain (MW asset ID: 4414), which has a total length of 1.1 km originating at Scotchmer Street and discharges into the Alexandra Parade Main Drain at the intersection of Alexandra Parade and George Street.
- Harper Street Main Drain (MW asset ID: 4411), which is 0.3 km long and starts at Marine Parade and discharges into the Yarra River near Harper Street.
- Palmer Street Main Drain (MW asset ID: 4406), which covers a total distance of 2.4 km and originates near the intersection of Church Street and Kent Street. The drain carries flow in two directions, with the flows being taken 0.8 km to the north and discharging into the Yarra River near Mayfield Street Reserve, and flows being taken 1.6 km south-east and discharging into the Yarra River near Richmond Park.

Figure 1-2 presents the key Melbourne Water drainage assets within the study area.

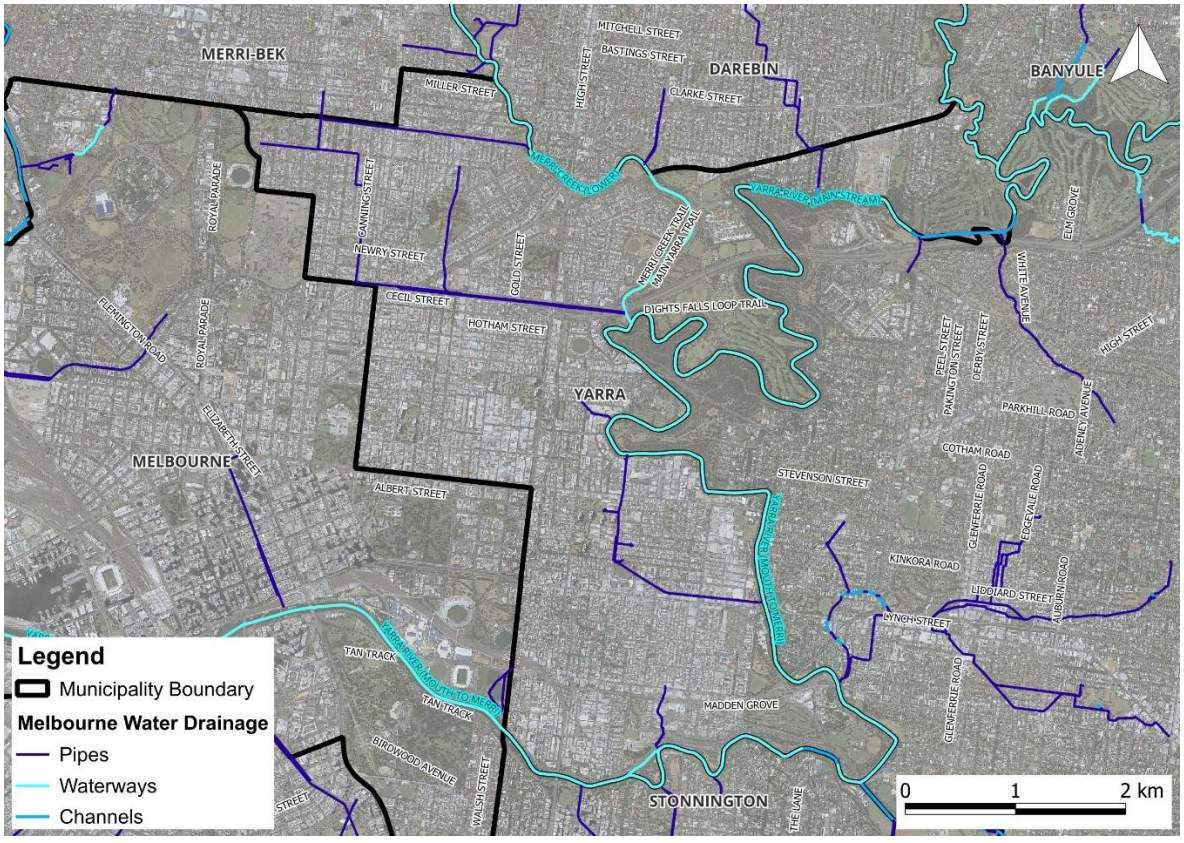


Figure 1-2: Key Melbourne Water Drainage Assets

1.2.3 Project Objectives

The objective of this study is to provide technical information to support future decision-making regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning.

1.3 PROJECT SCOPE

The following key tasks have been competed as part of this project.

1. Data collection and analysis including
    a) Collation of drainage information from Council and Melbourne Water to include in the flood modelling.
    b) Site inspection of key drainage assets.
    c) Collation of Melbourne Water review comments of hydraulic and hydrology models for all 3 catchments.
2. Generate RORB hydrological models for the study area.
3. Generate TUFLOW hydraulic models for the study area.
4. Hydrological and hydraulic modelling for the 1 %, 2 %, 5%, 10 %, and 20 % Annual Exceedance Probability (AEP) Storm Events (Base Case Scenario).
5. Hydrological and hydraulic modelling for the 1 %, 10 %, and 20 % AEP Storm Events considering increased rainfall intensity (Climate Change Scenario).
6. TUFLOW Classic versus TUFLOW Heavily Parallelised Compute (HPC) comparison of the 1 % AEP storm event.
7. Comparison between Front, Middle and Back-loaded temporal patterns (3) vs full ensemble temporal patterns (10).
8. Production of GIS deliverables in accordance with Melbourne Water Project Specifications (August 2023) for Melbourne Water and Council flooded areas.
9. Preparation of a detailed report (this report) to document modelling methodology, assumptions and outcomes.

As stated in the proposal, explicit mapping of the Yarra River waterway is outside the scope of the current study. GIS deliverables (flood information) for this study exclude areas along this waterway. Refer to Figure 1.2 for a map of the City of Yarra that identifies the Yarra River waterway.

2 DATA COLLATION AND REVIEW

2.1 OVERVIEW

This section summarises the data that informed this flood mapping study and the investigations undertaken by Engeny to confirm that the data was fit for purpose.

2.2 AVAILABLE DATA

Data for this study has been obtained from the following sources:

- Yarra City Council.
- Melbourne Water.
- DEECA.
- VicRoads.
- Bureau of Meteorology (BoM).
- ARR Data Hub.
- Site inspection.

The data received included the following:

- Aerial imagery.
- Pit and pipe GIS data.
- Council, Melbourne Water, and VicRoads drainage plans/information.
- Light detection and Ranging (LiDAR) terrain data captured as of 28 November 2017.
- Catchment boundaries GIS data.
- Planning zones GIS data.
- Building footprints GIS data.
- Property boundary GIS data.
- Parcel boundary GIS data.
- ARR 2019 (v4.1) rainfall Intensity, Frequency and Depth (IFD) data.
- Fairfield Main Drain SOBEK modelling results (Melbourne Water).
- Fairfield Main Drain RORB and TUFLOW modelling results (Melbourne Water).

2.3 DATASET INFORMATION

GIS data sets of the drainage network were provided by Council and Melbourne Water for use in the flood study. The data sets contain georeferenced graphical representations of Council and Melbourne Water owned and managed drainage assets including pits, underground drains, and open drains. Objects within the data sets included measurements such as invert elevation, pit depths, pipe lengths and pipe size diameters. Engeny used the drainage network GIS data to inform the setup of the TUFLOW hydraulic model for the study area.

2.4 DRAINAGE SURVEY

Council provided a GIS data set detailing their drainage network as of 2022 in the study area, however some locations required further information for accurate modelling. In 2020, Council engaged the Environmental Services Group (ESG) to collect and validate drainage information at these locations. These locations were identified based on Council's knowledge of the study area as well as the draft modelling results created from the 2020 City of Yarra Flood Mapping Project. Locations were chosen based on the following criteria:

1. Drainage assets in the location had not been surveyed previously and were located within a predicted flood prone area in storm events as frequent as the 20 % AEP,
2. The pipe capacities in the data set did not increase downstream, particularly in predicted flood prone areas,
3. The provided data had connectivity uncertainties, particularly in predicted flood prone areas; and
4. The data had unknown pipe dimensions, particularly in predicted flood prone areas.

2.5 SITE INSPECTION

During the initial model build in 2020, Engeny completed site inspections at key locations within the study area. The purpose of these site inspections was to obtain information about key hydraulic control structures so that the flood model representation was accurate. Some photos taken during the site inspections are depicted in **Appendix A.**

3 OVERVIEW OF MODELLING APPROACH

In 2020, the City of Yarra study area was split into three catchments to simplify and streamline the modelling process. Each of the catchments had their own RORB hydrological and TUFLOW hydraulic model.

These models are:

1. Alexandra Parade Main Drain Catchment (ALEX),
2. Fairfield Main Drain Catchment (FAIR); and
3. Richmond Quarry Main Drain Catchment (RICH).

Figure 3.1 Figure 1-2presents the three catchment models within the study area.

In 2022, these models were updated in accordance with technical peer review comments provided by Melbourne Water.

The hydrologic models were completed using RORB software in accordance with ARR v4.1 and Melbourne Water's Flood Mapping Projects Specification (October 2021). Figures of the RORB hydrological model can be found in **Appendix B.** The RORB hydrological models produced rainfall-excess hydrographs for the sub-catchments within the study area for base case and climate change scenarios for all required AEP events, storm durations, and a full ensemble set of ten temporal patterns. Section 5 and **Appendix C** provide a detailed description of the RORB hydrological model and key assumptions made.

The TUFLOW hydraulic models were completed in accordance with Melbourne Water's Flood Mapping Projects Specification (October 2021) using the most up-to-date version of TUFLOW HPC available at the time of modelling (version2020-10-AC-iSP-w64). Section 6 and **Appendix D** provide a detailed description of TUFLOW hydraulic model development, including the TUFLOW HPC results analysis to select temporal patterns and quality assurance undertaken for the study.

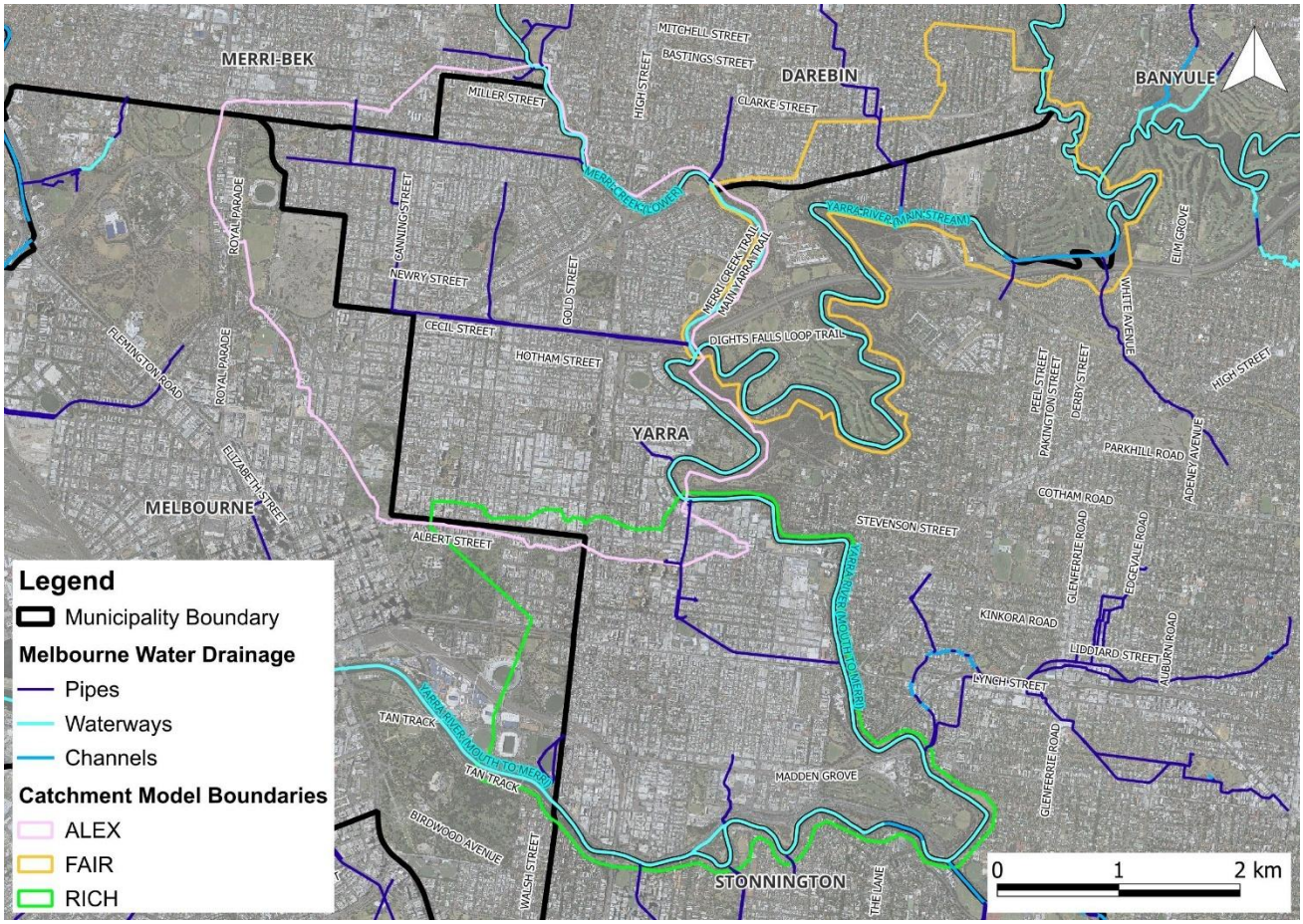


Figure 3.1: Catchment Model Boundaries

4 RORB HYDROLOGICAL MODELLING

4.1 SCOPE

The objective of RORB hydrological modelling was to produce rainfall excess hydrographs for use in the TUFLOW hydraulic model. The RORB hydrological model was simulated for the 1 %, 2 %, 5 %, 10 % and 20 % AEP storm events for base case climate conditions using methodologies recommended by ARR v4.1 and performed using the latest version of RORB software available (version 6.45) at the time of this study. A climate change scenario (increase in rainfall intensities) was also simulated for the 1 %, 10 % and 20 % AEP storm events.

The following sections describe the key tasks and assumptions in the development of the RORB hydrological models.

4.2 APPROACH

RORB is an interactive runoff and streamflow routing program that calculates catchment losses and streamflow hydrographs resulting from rainfall events. A RORB hydrologic model has been developed to produce inflow hydrographs for the 1D/2D TUFLOW hydraulic model that was created to estimate flood patterns within the study area.

RORB calculates a rainfall excess hydrograph from each sub-catchment by applying the catchment pervious area losses and impervious area losses to each sub-catchment using an initial loss / continuing loss model specified by the user. The user can also define the land use in each sub-catchment by adjusting the proportion of pervious and impervious area. After deducting losses, it converts the hyetograph to 'hydrographs' of rainfall-excess on the sub-catchments which can be used in TUFLOW hydraulic modelling.

Three (3) RORB catchment models (FAIR, ALEX, RICH) were constructed to cover the entire City of Yarra. The extent and catchment delineation of each of the models are presented in **Appendix B.**

4.3 RORB HYDROLOGICAL MODELLING LIMITATIONS

The RORB hydrological models were created in accordance with methodologies outlined in ARR v4.1 and so use an initial loss / continuing loss (IL / CL) model approach. The RORB hydrological models were simulated using the ensemble approach including all 10 temporal patterns for the 10-minute to the 168-hour storm. ARR v4.1 provides a methodology to calculate initial loss and continuing loss values for different land uses. These loss values are calculated based on the concepts of Effective Impervious Area (EIA), Indirectly Connected Areas and Pervious Areas detailed in *Chapter 3.4 of Book 5 of ARR v4.1*.

Interrogation of RORB outputs revealed that the modelling software averages losses which has been shown to have a significant impact on rainfall excess hydrographs for events with lower total depths of rainfall (i.e., short duration storms and higher probability storm event). To overcome this limitation, Engeny has developed separate RORB hydrological models to best account for the representation of hydrological losses, such that they are not averaged.

Appendix C provides a technical description of the RORB hydrological model setup and adopted parameters.

4.3.1 RORB Routing Parameter, k_c

For the RORB hydrological models covering the City of Yarra itself, all routing of flow was undertaken in the TUFLOW hydraulic models and therefore, routing using the RORB hydrological models and selection of an appropriate k_c was not required.

4.4 INITIAL AND CONTINUING LOSS VALUES

4.4.1 Adopted Values

The loss values adopted by Engeny for this study are as follows:

- Rural (pervious surfaces) initial loss: 12.0 mm
- Rural (pervious surfaces continuing loss: 1.9 mm / h
- Indirectly Connected Areas (ICA) initial loss: 8.4 mm

- ICA continuing loss: 1.9 mm / h
- Effective Impervious Areas (EIA) initial loss: 1.5 mm
- EIA continuing loss: 0.0 mm /h

The above loss values were derived by considering the loss values suggested by the ARR Data Hub and the recommended methodology from ARR v4.1, as follows:

- Storm (pervious) Initial Loss: 12.0 mm
- Continuing Loss: 1.9 mm/hr

4.5 CLIMATE CHANGE

The ARR Data Hub provides interim climate changes factors for calculation of increased rainfall scenarios. For the catchment's centroid coordinates, the Data Hub estimates an increase of 3.09°C in temperature by 2090. This correlates to 16.3 % increase in rainfall by 2090, within the RCP8.5 scenario. These values have been extrapolated to determine the 2100 climate conditions, resulting in a temperature increase of 3.461°C which correlates to an increase in rainfall of 18.4 %. ARR v4.1 Chapter 6.3.5 recommends using the following equation to determine the percentage increase in rainfall intensity for the year 2100:

$$p = 100(1.05^{\Delta T} - 1)\ \%$$

Where,

ΔT is the temperature increase to 2100

p is the percentage increase in rainfall intensity

The resultant percentage increase in rainfall for the year 2100 using this method is 18.5 %, ARR v4.1 recommends adopting the higher percentage increase out of these two methods and therefore 18.5 % was implemented for the climate change investigation.

The RCP8.5 scenario is the 'business as usual' climate change scenario wherein minimal curbing of emissions is undertaken. This scenario was adopted per Melbourne Water's Addendum 2 to the Melbourne Water Project Specifications (October 2021).

4.6 2022 HYDROLOGICAL UPDATES

The RORB hydrological models were built in 2020 and were revised and updated in 2022. The 2020 RORB hydrological models were independently peer reviewed in 2021, and model updates were recommended to ensure the model represented the current conditions and latest industry recommendations. The updates included:

- Complete storm approach has been adopted to eliminate the use and uncertainty of duration factors within the RORB hydrological model,
- The three RORB hydrological models are in different loss regions (Figure 4.1) according to ARR v4.1 as documented in "Benchmarking ARR2019 for Victoria, Technical Report (Version 2, October 2020)" and so have different pre-burst value. A 75th percentile pre-burst depth has been adopted for the ALEX and FAIR models, while a median percentile pre-burst depth for the RICH model was adopted. This document was not available at the time the model runs were being completed in 2020 and so were made as part of the 2022 flood model updates; and
- Fraction impervious values have been updated per guidance from the technical peer review comments.

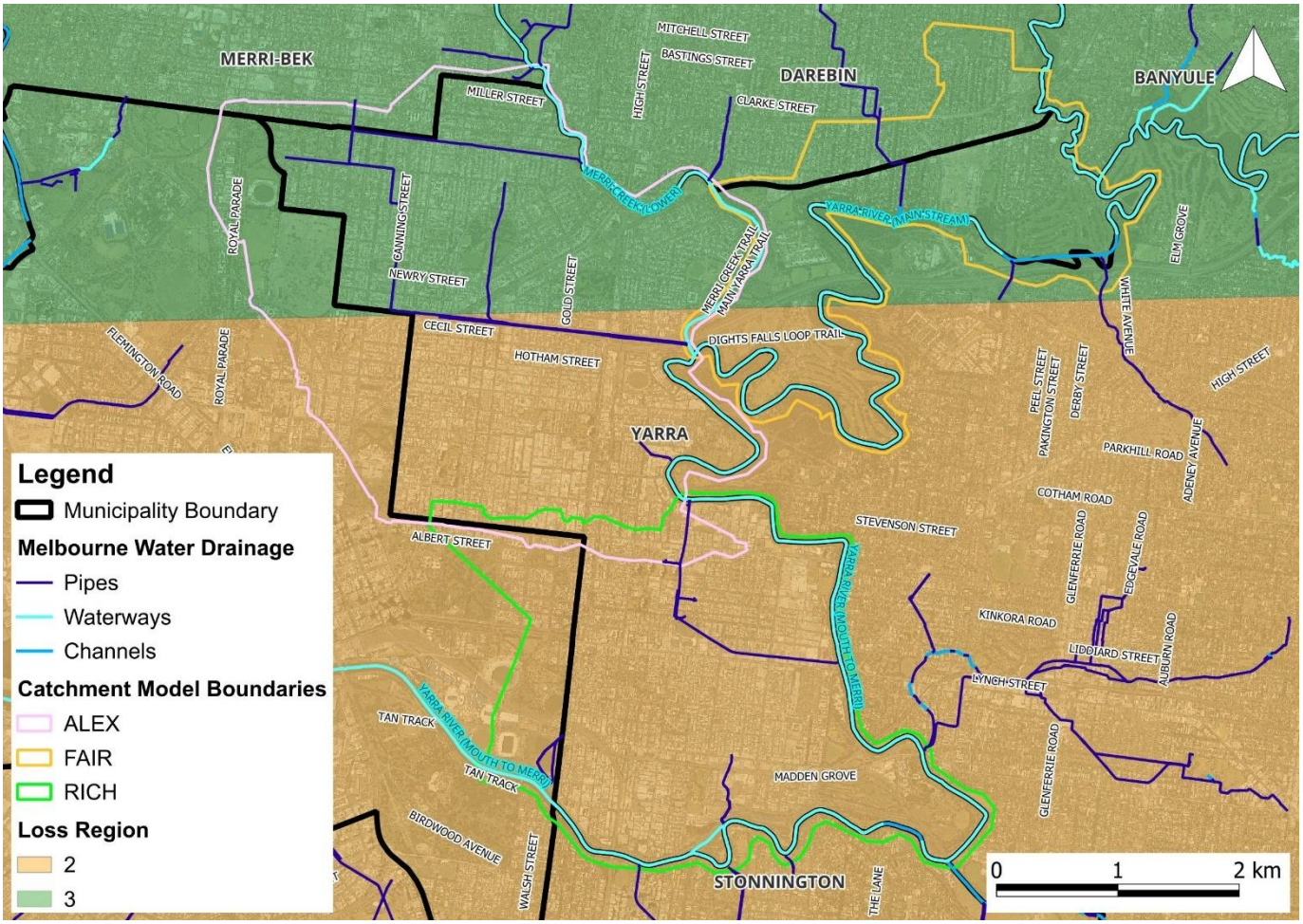


Figure 4.1: Model Loss Regions (ARR v4.1)

5 HYDRAULICS

5.1 METHODOLOGY

5.1.1 Overview

Three (3) one-dimensional (1D) and two-dimensional (2D) dynamic TUFLOW hydraulic models of the study area were created and simulated using TUFLOW version 2020-10-AC-iSP-w64 to estimate flood water levels, extents, flows and other hydraulic variables for a range of scenarios and design events.

The following steps outline the tasks undertaken to develop the TUFLOW hydraulic models for the study area and to obtain results and outputs which were used for flood mapping.

- Generate Digital Elevation Model (DEM)
- Compile rainfall excess hydrographs for the range of storm durations for the 20 %, 10 %, 5 %, 2 % and 1 % AEP storm events for base case conditions using ARR Data Hub IFD data (from RORB hydrological model).
- Compile rainfall excess hydrographs for climate change conditions (increased rainfall intensities, year 2100) for the 20 %, 10 % and 1 % AEP storm events.
- Input surface roughness (materials layer)
- Input and verify data for the 1-D network
- Apply z-shapes to shape overland flow paths where LiDAR data was unable to (e.g. at railway overpasses where flows beneath the overpass were unrealistically blocked).
- Set 1-D and 2-D boundary conditions
- Where available flood level information for Melbourne Water Waterways (provided by Melbourne Water) was utilised to appropriately assign downstream tailwater levels using 1d_bc nodes on underground drains discharging to the Yarra River waterway. The Fairfield Main drain model has pipes discharging above the provided water levels for the Yarra River, in these instances no 1d_bc nodes were placed on these pipes. Instead, 2d_bc SX points were applied to allow flow to discharge from the pipes onto the ground surface before out-falling to the Yarra River waterway.
- The following storms were simulated in TUFLOW:
  - ALEX and RICH models were run for all standard durations up to 180 minutes (10 min, 15 min, 30 min, 60 min, 120 min, 180 min). The models require inflows from a TUFLOW hydraulic model created externally (originating in the Merri-bek municipality, north of the City of Yarra). Critical durations along main flow paths were found not to exceed the 120-minute storm duration.
  - FAIR Model was run for the standard durations up to the 720 minutes (10 min, 15 min, 45 min, 60 min, 90 min, 120 min, 180 min, 360 min, 720 min). Critical durations along main flow paths were found to not exceed the 360-minute storm duration.
- To reduce model simulation run times, all three flood models were simulated using TUFLOW HPC. A comparison of the results to those produced by TUFLOW Classic was undertaken to identify the variance (if any) in peak flood levels to confirm the appropriateness of using TUFLOW HPC. This is discussed further in Section 5.2**.**
- Update models based on Melbourne Water technical peer review comments.
- To further reduce model simulation run times, a comparison between front, middle and back-loaded temporal patterns versus full ensemble (10 temporal patterns) was completed.
- Prepare flood maps and GIS deliverables from the TUFLOW HPC model results, in line with Melbourne Water's Flood Mapping Project Specification (October 2021).

Table 5-1 provides a summary of the AEP events run for each modelling scenario.

Table 5-1: TUFLOW Modelling Scenarios

	AEP Event				
Scenario	20 %	10 %	5 %	2 %	1 %
A: Base Case	✓	✓	✓	✓	✓
D: Climate Change 3 – Increase Rainfall Intensity	✓	✓			✓

Appendix D contains technical details regarding the development of the TUFLOW hydraulic models.

5.2 TUFLOW HPC VERSUS CLASSIC COMPARISON

The 2020 TUFLOW hydraulic models were built using TUFLOW Classic modelling software which was the industry standard at the time. Following the initial project submission, a new version (solution scheme) of the modelling software was becoming increasingly accepted for use in the industry - TUFLOW HPC, which has recently become the primary solution scheme - replaced TUFLOW Classic as the industry standard. For this reason, the 2022 and 2024 flood models were run using TUFLOW HPC.

To ensure that the modelling approach was appropriate for the project, a comparison of the HPC and Classic modelling solution schemes was conducted during 2022. The comparison found little difference between the TUFLOW HPC and TUFLOW Classic flood model results, so it was agreed with Melbourne Water and Council that TUFLOW HPC would be used for the final flood model simulations.

5.3 TEMPORAL PATTERN SENSITIVITY ANALYSIS

To reduce model runs times without affecting accuracy of results, a temporal pattern analysis was completed on all three flood models.

The peak flood depths from the front, middle, and back (FMB) loaded temporal patterns for standard durations (10 min, 15 min, 30 min, 60 min, 120 min, 180 min) for the 1 % AEP storm event were compared against the peak flood depths for the full ensemble (10) temporal patterns for the standard durations in the 1 % AEP event. Flood level difference (afflux) plots for each catchment for the 1 % AEP event can be found in **Appendix E.**

These results support the decision to run the models using FMB temporal patterns instead of the full ensemble. This decision was verified through the external peer review process in April 2023. The final selection of FMB temporal patterns were identified based on visual and calculated analysis of the rainfall distribution of 10 temporal patterns of each duration and AEP bin.

5.4 MODELLED STORM TEMPORAL PATTERNS, DURATIONS AND EVENTS

Table 5-2 presents the front, middle and back-loaded temporal patterns simulated for each storm duration and event. Temporal patterns are listed as a correlation to the ARR Datahub increments csv file.

Table 5-2: Front, Middle, and Back Modelled Storm Temporal Patterns for each duration and AEP.

Duration (min)	AEP (Base Case)					
	1% (climate change)	1%	2%	5%	10%	20%
10	22,26,29	22,26,29	22,26,29	15,16,19	15,16,19	4,1,7
15	21,28,29	21,28,29	21,28,29	11,17,20	11,17,20	2,8,10
30	23,28,30	23,28,30	23,28,30	14,18,20	14,18,20	3,6,10
60	22,28,30	22,28,30	22,28,30	14,18,19	14,18,20	1,6,9
120	22,25,30	22,25,30	22,25,30	12,17,11	12,17,11	2,9,10
180	22,28,30	22,28,30	22,23,30	13,15,19	13,15,19	2,4,9
360	24,28,30	24,28,30	24,28,30	11,17,20	11,17,20	1,6,10
720	23,25,29	23,25,29	23,25,29	11,15,20	11,15,20	1,6,10

5.5 2022 HYDRAULIC UPDATES

During 2022, the original 2020 TUFLOW hydraulic models were updated based on a technical peer review conducted by Melbourne Water to ensure the flood models were accurate and current.

The key updates included:

- Fixing LiDAR topographical issues outlined by Melbourne Water. An example is when LiDAR data captured over large buildings, factories and underground carparks garages can cause artificial depressions, blockages, and unrealistic storages to the resultant Digital Elevation Model (DEM). These issues were rectified in the 2022 TUFLOW hydraulic model by using terrain modification to flatten or smooth depressions.
- Update of drainage asset information (i.e., diameters and inverts of underground drains) based on Councils latest (2022) asset data (via Utility Track).

5.6 2024 HYDRAULIC UPDATES

In July 2024, Engeny was provided with an external TUFLOW hydraulic model (referred to as the Darebin model) that included flood mapping the upstream section of the Fairfield Main Drain flowpath contained within the City of Darebin and extending into the City of Yarra. The Darebin model was used to inform inflows into the FAIR City of Yarra TUFLOW hydraulic model, and the Darebin model also provided drainage information contained within the City of Darebin that was not previously modelled as agreed.

Flow hydrographs from the Darebin flood model were applied as Q-T (Flow versus Time) boundaries in 2D-domain (overland flow) and H-T (Head versus Time) boundaries for the 1D-network at the upstream boundary of Engeny's TUFLOW hydraulic model, located at the intersection of the Fairfield Main Drain and Heidelberg Railway Line.

As agreed with Melbourne Water, Engeny has not undertaken a review of the Darebin flood mapping model provided. Melbourne Water did confirm that this modelling (completed by others) had been peer reviewed and had been accepted by Melbourne Water so was deemed suitable for providing upstream inflows for the City of Yarra Flood Mapping Project.

5.7 QUALITY ASSURANCE

Engeny performed a Quality Assurance (QA) process before each submission made as part of this project. The QA processes are designed to provide confidence that the flood modelling undertaken is as accurate as reasonably possible. The flood models were constructed and tested for stability using both TUFLOW's Classic and HPC solution schemes. TUFLOW Classic mass cumulative error was found to be within +/-1% for all three models. The QA process is an internal and external review system that consists of guided model health and stability checks to examine the final model and results. The model is initially reviewed and updated by the modeller, then passed to an internal certified senior or principal engineer for review. After any updates are made, the model is submitted to Melbourne Water for an external review through an independent peer reviewer contracted by Melbourne Water. The peer reviewer provides review comments to the modeller for updates until the model setup is complete.

Some checks undertaken as part of this review process include:

- Review and fixing of TUFLOW Warnings, Checks, and Errors produced during TUFLOW model simulations.
- HPC model stability checks to ensure the TUFLOW hydraulic model is stable and functioning as expected.
- A Control Number Sensitivity (CNS) analysis which acts as a stress test for the TUFLOW hydraulic models. The CNS analysis lowers the tolerance of TUFLOW so that it can verify that the model can function under stricter conditions.
- Checking the model setup against a Melbourne Water created checklist that verifies the setup is structurally sound.

The TUFLOW hydraulic models were finalised through this review process and have been closed out officially in conjunction with Melbourne Water and the independent peer reviewer, indicating that the model setup is stable and functioning as expected.

6 FLOOD MAPPING

6.1 MODEL CALIBRATION AND VALIDATION

6.1.1 Historical Flood Events

Several storm events have significantly impacted parcels within the City of Yarra and can be used to verify the flood model setup through a comparison of real and modelled data. A selection of the more recent storm events include:

- 14th December 2018
- 6th November 2018
- 3rd December 2017
- 29th December 2016
- 1st June 2013
- 26th December 2011
- 3rd December 2003

6.1.2 Rainfall Gauges

Analysis of catchment IFD information and historical rainfall data presented in the City of Yarra's Storm and Flood Emergency Plan (February 2020) has allowed Engeny to estimate the magnitude of recent storm events that have impacted the City of Yarra. The rainfall gauges included as part of this analysis include 'Yarra River at Alphington (Gauge ID: 229143B)', 'Yarra River at Burnley (Gauge ID: 229621A)' and 'Merri Creek at Northcote (Gauge ID: 229149A)'.

Table 6-1 summarises the findings of this analysis.

Table 6-1: Summary of Historical Storm Magnitudes

Storm Event	Average Rainfall Depth from Gauges	Average Duration of Storm from Gauges	Estimated Storm Magnitude (AEP)
14th December 2018	29 mm	30 min	10 % to 1 %
6th November 2018	41 mm	2 hrs	5 %
3rd December 2017	67 mm	24 hrs	50 % to 10 %
29th December 2016	35 mm	10 hrs	50 % to 20 %
1st June 2013	65 mm	16 hrs	20 % to 10 %
26th December 2011	42 mm	10 hrs	≤ 20 %

6.1.3 Flooding Verification

The TUFLOW hydraulic models were setup with flow reporting lines to provide peak flows at numerous key locations throughout each catchment. These flows have been compared to the flow estimates against known area to flow relationships. The results closely match the expected flows and provide confidence that the hydraulic and hydrologic model flows are of the order expected and are in reasonable agreement.

The City of Yarra was affected by flooding which occurred during December 2018. The peak intensity of rainfall from this event (35 mm in 18 minutes) was approximately equivalent to the 1 % AEP 15-minute duration storm event at the Burnley rainfall gauge. Figure 6-1 below depicts flooding within Swan Street, Richmond during the December 2018 storm event and Figure 6-12 depicts Glass Street, Richmond 3121 during the same storm.



Figure 6-1 : Flooding within Swan Street, Richmond 3121 in December 2018 (Source: K 8 via Youtube, 2018)



Figure 6-2: Flooding within Glass Street, Richmond 3121 in December 2018 (Source: Twitter)

Figure 6-3 and Figure 6-5 depict the peak 1 % AEP flood extent at Glass Street and Swan Street respectively, as produced by this flood study. The locations shown in the Figure 6-3 and Figure 6-5 show flooding occurring at the same locations as the Dec 2018 photographs above (Figure 6-1 and 6-2). The alignment between physical flooding seen in the photographs and the results of this flood study provides confidence in the flood modelling results.

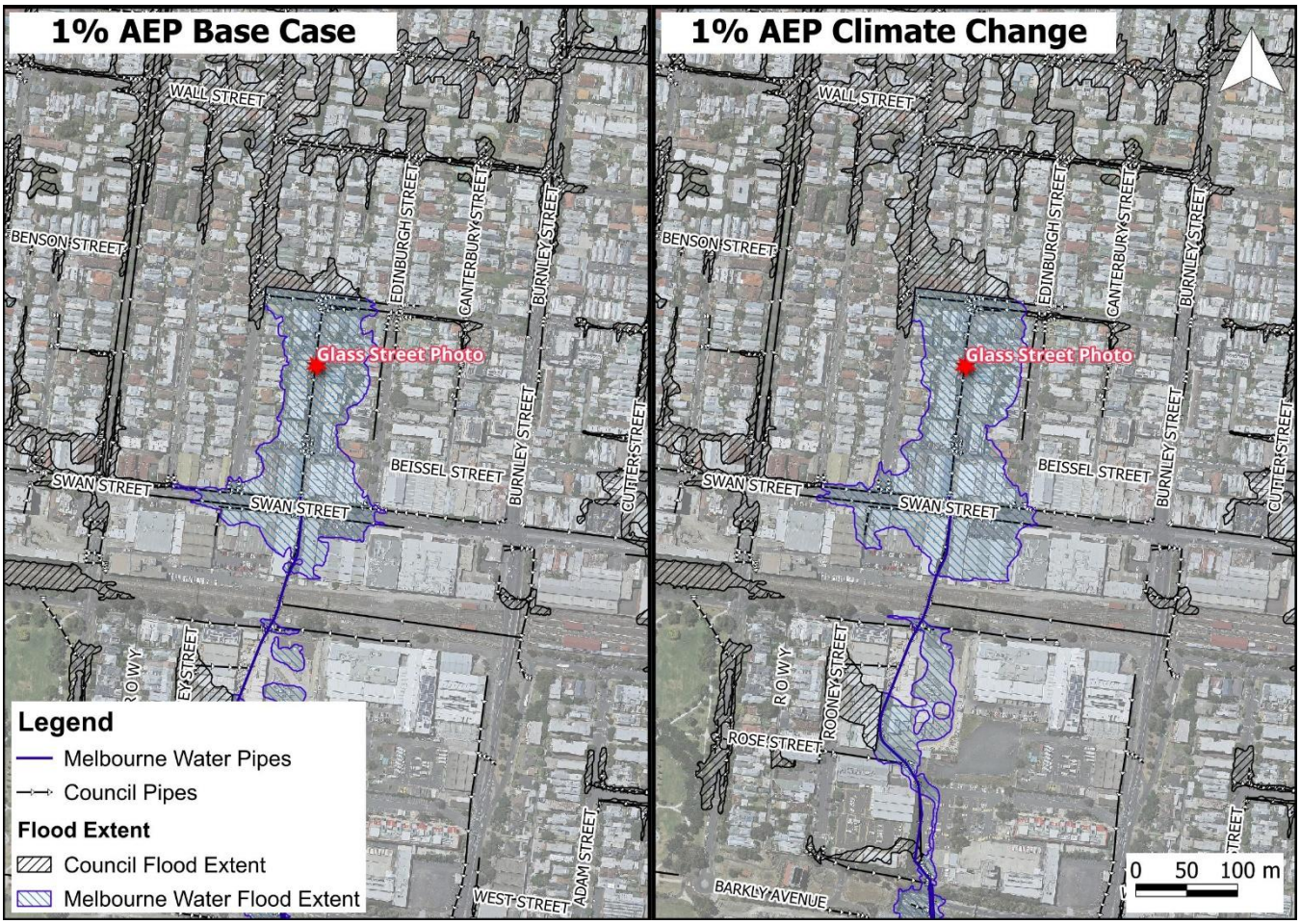


Figure 6-3: TUFLOW Results Flood Extent - Glass Street, Richmond 3121

The 1 % AEP flood model results derived from this study match closely to the extent of flooding defined by Melbourne Water's existing SBO within the Alexandra Parade Main Drain catchment. An example of this close match in flood extent is presented in Figure 6-4 below near Alexandra Parade, between Nicholson Street and Hoddle Street, Richmond 3121.

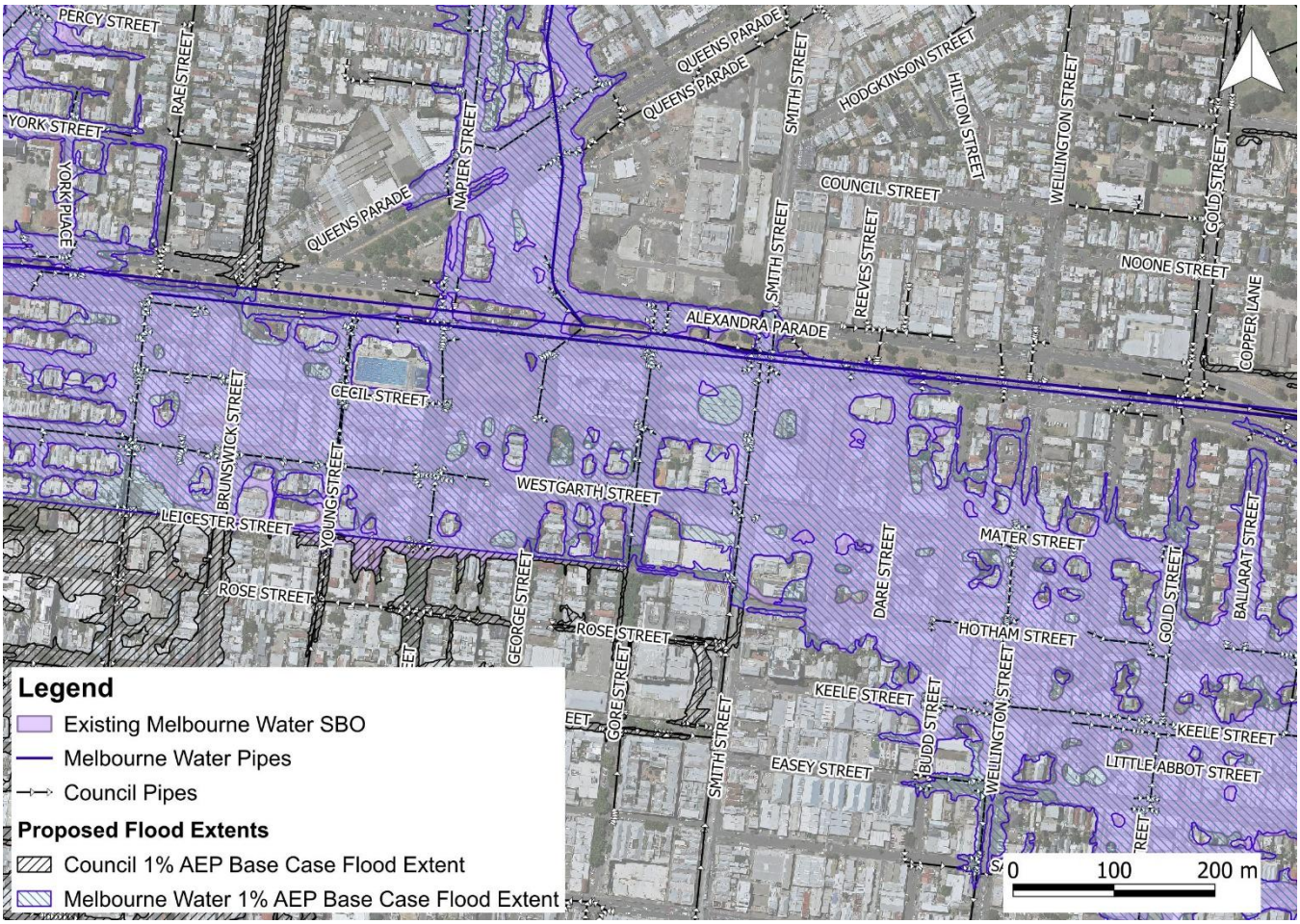


Figure 6-4: Comparison of 1% AEP flood Modelling Results to the Existing Melbourne Water SBO

Engeny has also compared the flood model results to Council's flood hotspots register and have verified that the flood modelling results show flooding at several of the recorded hotspot locations. Flood extents for the 1 % AEP Climate Change and Base Case Climate storm events are provided for some of the locations listed in Council's flood hotspot register in the following figures (Figure 6-5 to Figure 6-10).

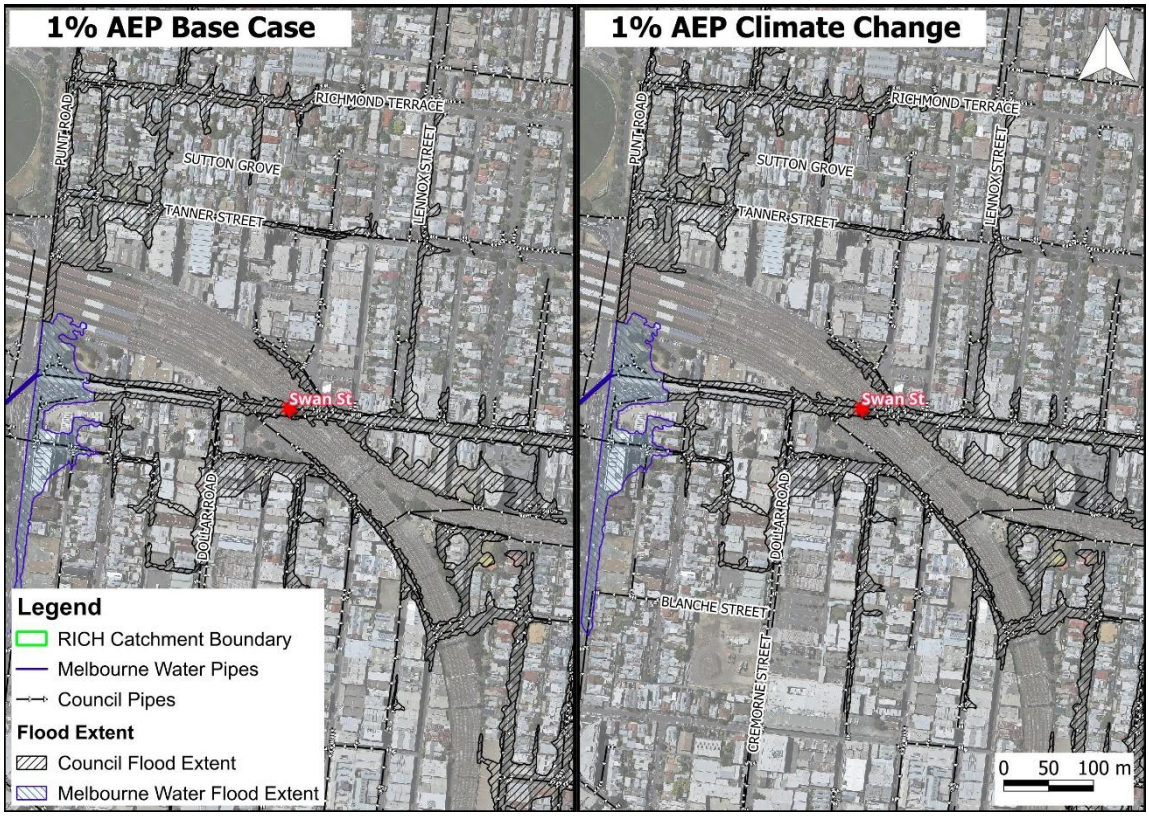


Figure 6-5: Flooding Hotspot - Swan Street at Railway Line

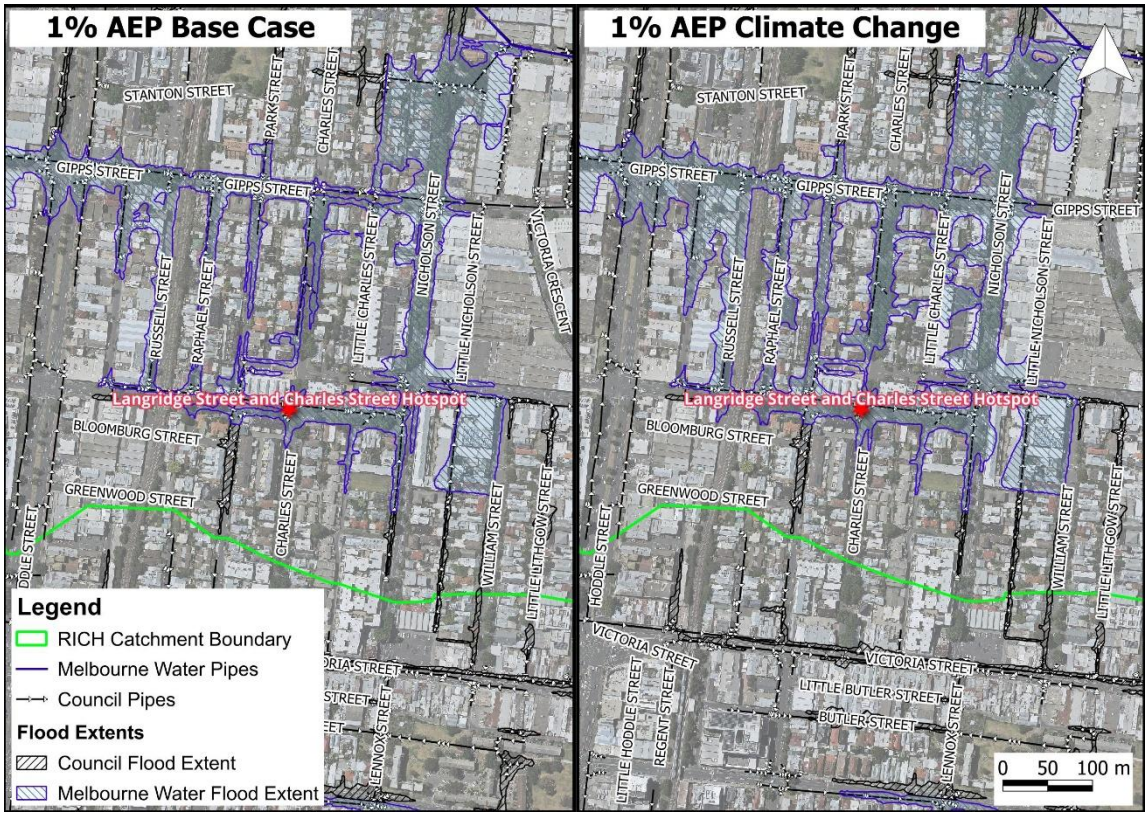


Figure 6-6: Flooding Hotspot - Langridge Street and Charles Street

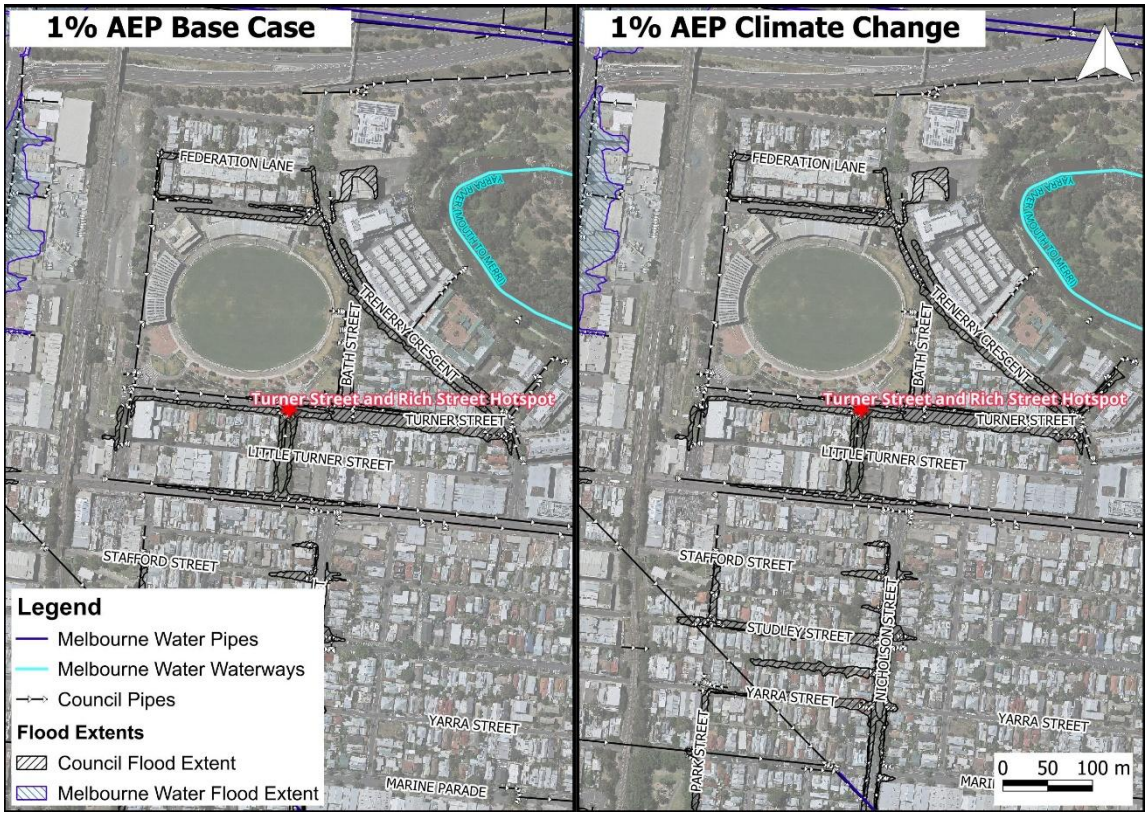


Figure 6-7: Flooding Hotspot - Turner Street and Rich Street

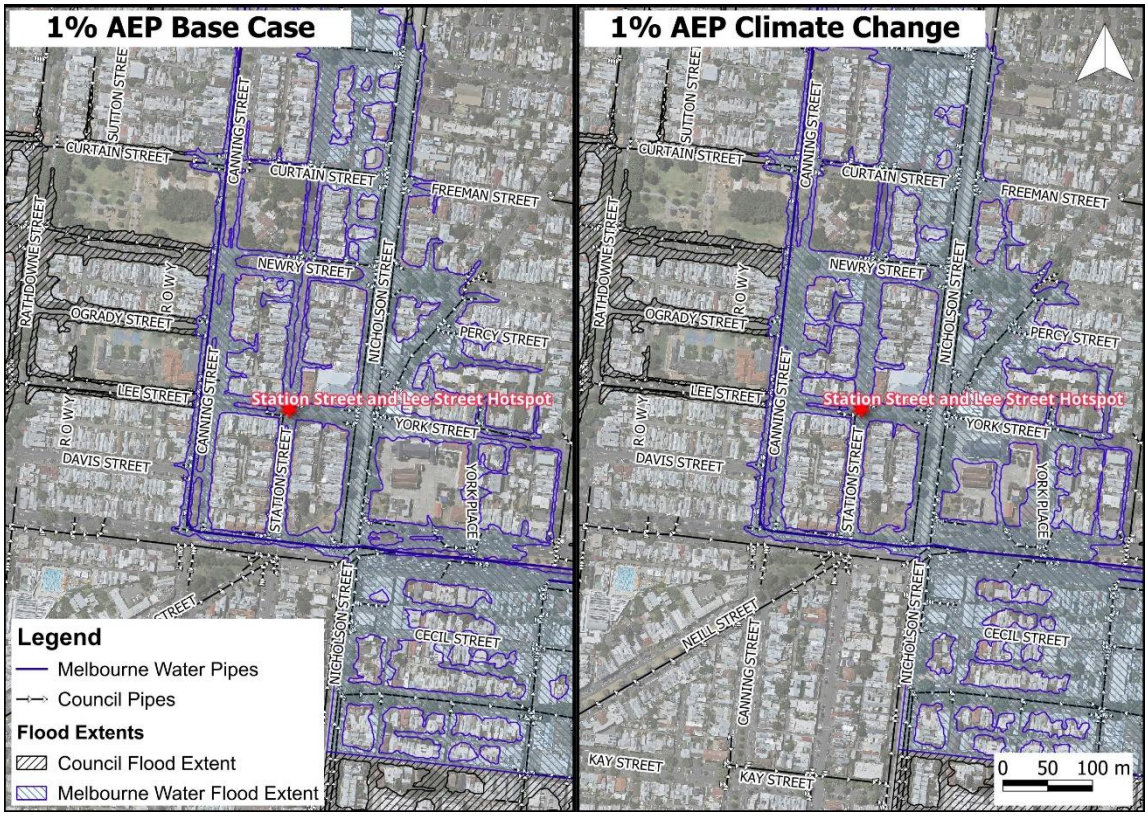


Figure 6-8: Flooding Hotspot - Station Street and Lee Street

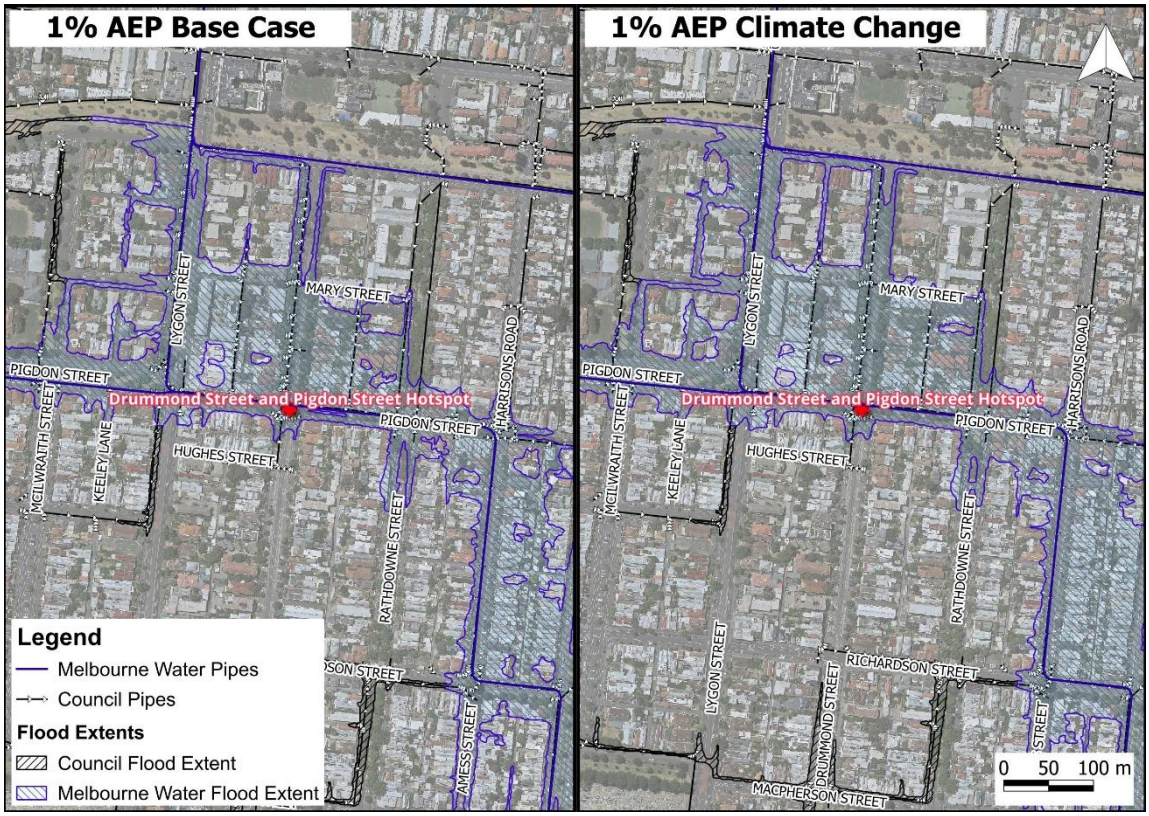


Figure 6-9: Flooding Hotspot - Drummond Street and Pigdon

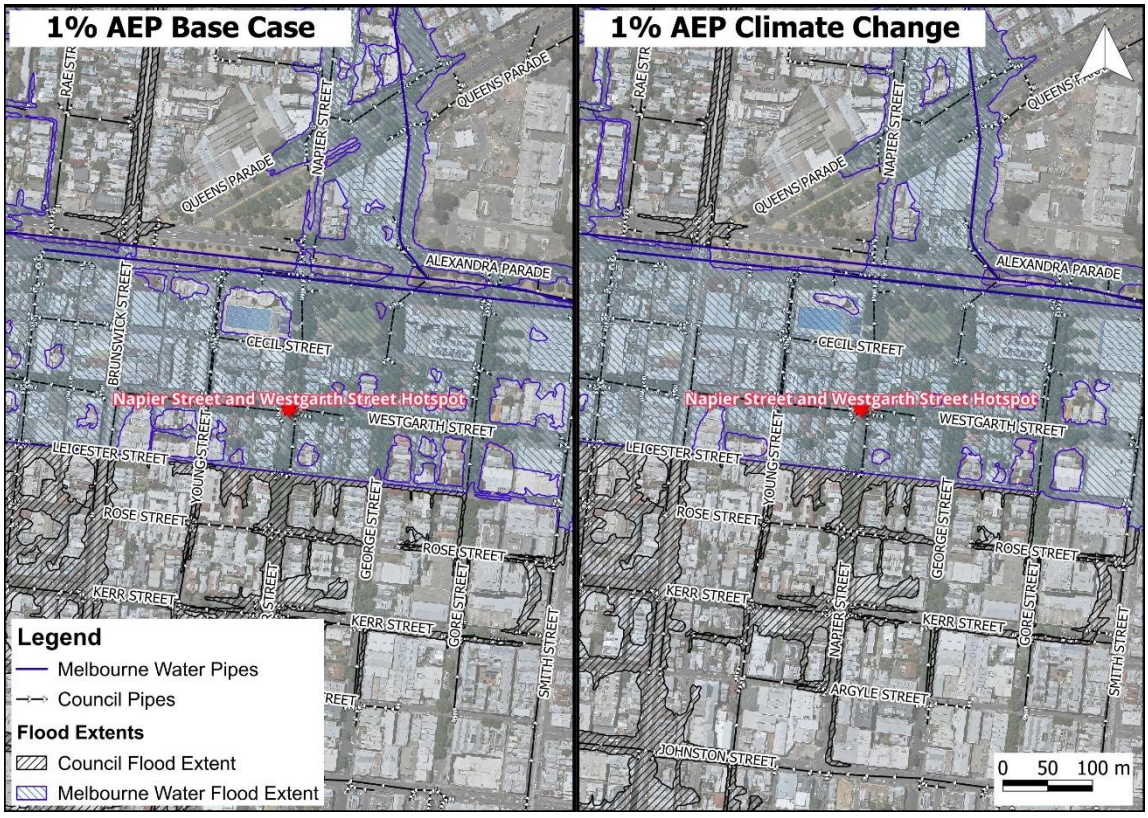


Figure 6-10: Flooding Hotspot - Napier Street and Westgarth Street

6.2 DEVELOPMENT OF FLOOD EXTENTS

6.2.1 Melbourne Water and Council Flood Extents

Melbourne Water's filtering guidelines have been applied to the flood model results when developing flood extents across the following design storms, in accordance with the Melbourne Water Project Specifications (October 2021):

- 1 %, 2 %, 5 %, 10 %, and 20 % AEP storm events (Base Case Scenario)
- 1 %, 10 %, and 20 % AEP storm events under the conditions of increased rainfall intensity (Climate Change Scenario)

Flood modelling can sometimes produce results that show very shallow water or isolated puddles that do not represent a genuine flood hazard. To ensure the flood maps are meaningful and relevant to the community safety, Melbourne Water applies filtering rules to remove these minor features. Specifically:

- Water depths less than 0.05 m are considered too shallow to pose a real hazard and so are excluded from the flood extent.
- Isolates areas of inundation smaller than 100 m^2 are also excluded.

These filters help remove technical "noise" so the maps focus on areas where flooding could cause problems during a major storm.

Melbourne Water uses these rules based on the needs of its regional floodplains. Local Councils do not have to follow the same approach and can elect to use different criteria that better reflects local conditions and community expectations.

The Melbourne Water and Council 1% AEP climate change scenario flood extents have been independently peered reviewed and accepted by Melbourne Water and Council.

6.2.2 Flood Extent Demarcation

Flood extents for each AEP and scenario have been delineated between 'Council' and 'Melbourne Water' flood extents to identify the responsible drainage authority. Melbourne Water flood extents are generally also delineated into the categories of flooding from 'underground drains' and 'waterways' in accordance with the Melbourne Water Project Specifications (October 2021). Engeny facilitated meetings with Melbourne Water and Council to discuss demarcation, to have an open discussion and confirm the assignment of flooding referral authorities to flood affected areas. The objective of this discussion aimed to ensure a one parcel and one referral authority outcome (where possible), with agreeance between Melbourne Water and Council with regards to which authority is responsible for areas of flooding across the City of Yarra.

6.3 GRIDDED OUTPUT EXTENTS

The gridded outputs (supplied as "ASC" type raster files) comprise the maximum flood results from the model on a per AEP event basis. **Appendix F** contains the outputs of the final TUFLOW HPC runs in the form of the maps showing the flood extents for the 1% AEP storm event run for both base case and climate change scenarios.

6.4 FLOOD MAPPING DELIVERABLES

GIS flood mapping deliverables have been derived in accordance with Melbourne Water's Flood Mapping Projects Specifications (October 2021) and includes final flood extents, flood hazard, and parcels flooded.

6.5 PARCELS IMPACTED BY FLOOD EXTENTS

The City of Yarra contains approximately 70,000 parcels and 41,000 buildings (according to DEECA's [VICMAP Property – VPARCEL MP] data and Melbourne Water's GIS data, respectively). Table 6-2 below summarises the flood modelling parcel impacts as determined from this study using the flood model results. Parcels have been deemed flood affected if they are intersected by the filtered 1% AEP storm climate change scenario flood extent.

Table 6-2: Summary of Flood Affected Parcels

City of Yarra Catchment	Approx. Area (ha)	Number of Parcels in SBO Layer		Number of Parcels in BR153
Authority		*Council*	*Melbourne Water*	*Council Only*
ALEX	1,297	6,529	6,227	10,774
FAIR	583	146	112	294
RICH	892	7,015	1,884	10,335
Total		**13,690**	**8,223**	**21,403**

6.6 PARCEL CADASTRE GIS UPDATE

After submission of the final deliverables for the project as of 2022, spatial VicMap parcel cadastre updates were made by the Department of Transport and Planning (DTP) on July 10th, 2023, as part of the Digital Cadastre Modernisation Project (DCMP). Review of the updated VicMap parcel cadastre layer identified a spatial shift between 0 and 1.5 metres in the positioning of parcel boundaries compared to the previous parcel cadastre layer that was originally used to inform the generation of GIS deliverable outputs from the flood study. Engeny has updated Council and Melbourne Water flood overlays and associated flood mapping GIS deliverables to ensure all GIS outputs align with the latest parcel cadastre layer (dated July 10th, 2023).

7 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:
   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or
   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

8 REFERENCES

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia)

Hughes, E. and Stephens, D. (2020). *Benchmarking ARR2019 for Victoria: Technical Report Version 2.* Hydrology and Risk Consulting (HARC). October 2020

Melbourne Water Corporation, 2019, *Flood Mapping Projects – Guidelines and Technical Specifications Version 10 September 2019.*

Melbourne Water Corporation, 2021, *Flood Mapping Projects Specification Version 12 October 2021.*

Melbourne Water Corporation, 2023, *Flood Mapping Projects Specification Version 13 August 2023.*

Unknown, 2018, *Swan Street Richmond Flood 14/12/2018 [video], K 8, Available at: https://www.youtube.com/watch?v=4JnZUrHmoQ4*

ENGENY

Appendix A
2020 Site Inspection Photos



Figure A-1: Open Drain Within Coate Park, Alphington 3078



Figure A-2: Drainage Outfall to Open Drain within Coate Park, Alphington 3078



Figure A-3: Outfall of Melbourne Water's Fairfield Main Drain at Yarraford Avenue, Alphington 3078



Figure A-4: Outfall of Melbourne Water's Fairfield Main Drain at Yarraford Avenue, Alphington 3078



Figure A-5: Open Drain Downstream of Fairfield Main Drain Outfall



Figure A-6: Pedestrian Crossing Over Open Drain Downstream of Fairfield Main Drain at Yarra River



Figure A-7: Outfall of Melbourne Water's Palmer Street Main Drain at Yarra River



Figure A-8: Outfall of Melbourne Water's Richmond Quarry Main Drain at Yarra River, Barkley Avenue



Figure A-9: Large Inlet Pit on Richmond Quarry Main Drain on Northern Side of Citylink



Figure A-10: Overland Flows can Path Beneath Building in Rail Reserve Adjacent Broomfield Ave, Fairfield 3078



Figure A-11: Open Drain Within Rail Reserve North of Heidelberg Road / Grange Road 3078



Figure A-12: Headwall Connecting Open Drain to Drainage Network North of Heidelberg Road / Grange Road 3078



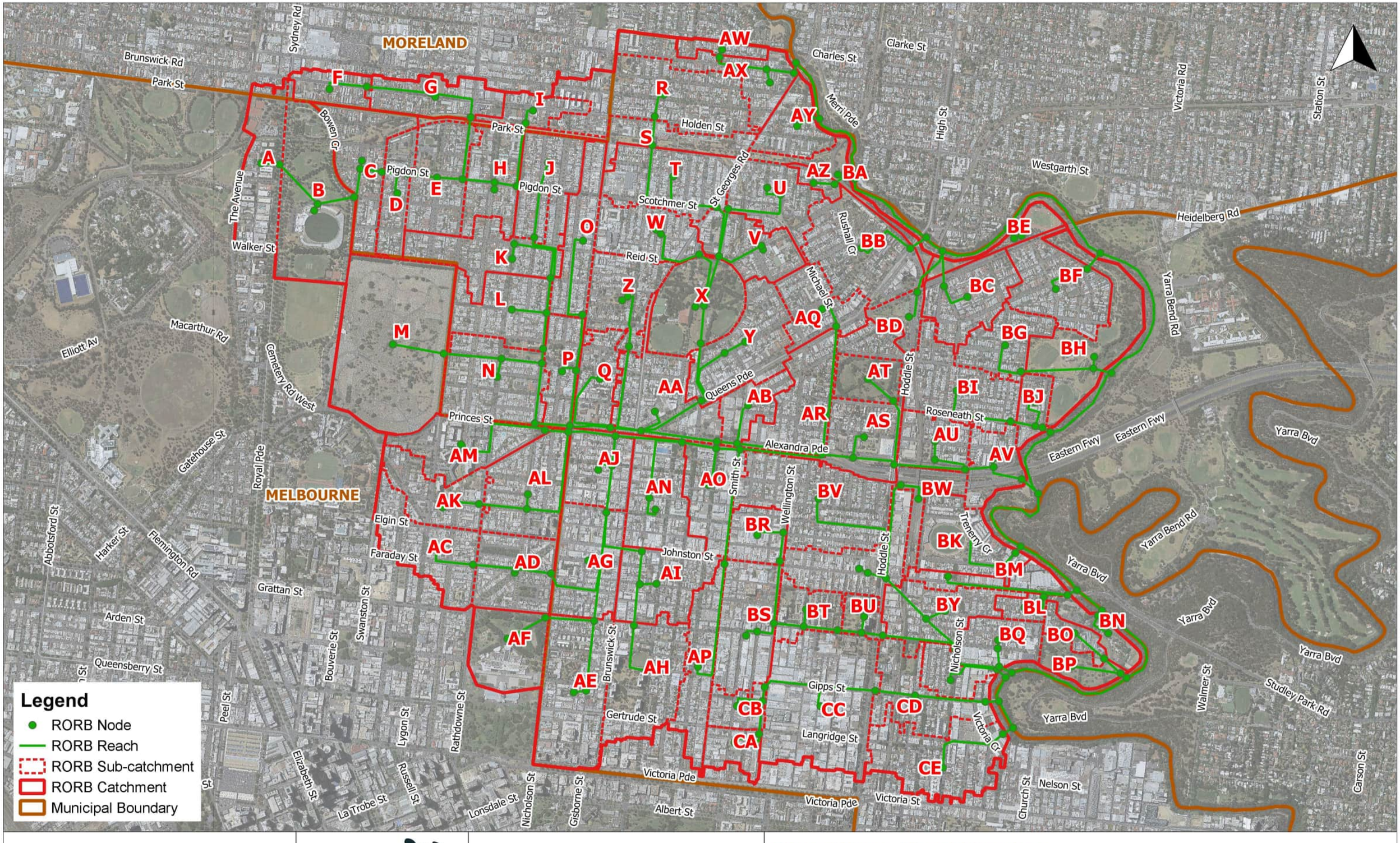
Figure A-13: Bluestone Lined Open Drain Immediately South of Station Street, Fairfield 3078



Figure A-14: Open Drain South of Station Street near Outfall to Yarra River, Fairfield 3078

ENGENY

Appendix B
RORB Hydrological Model Layout Plans



Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

CITY OF YARRA

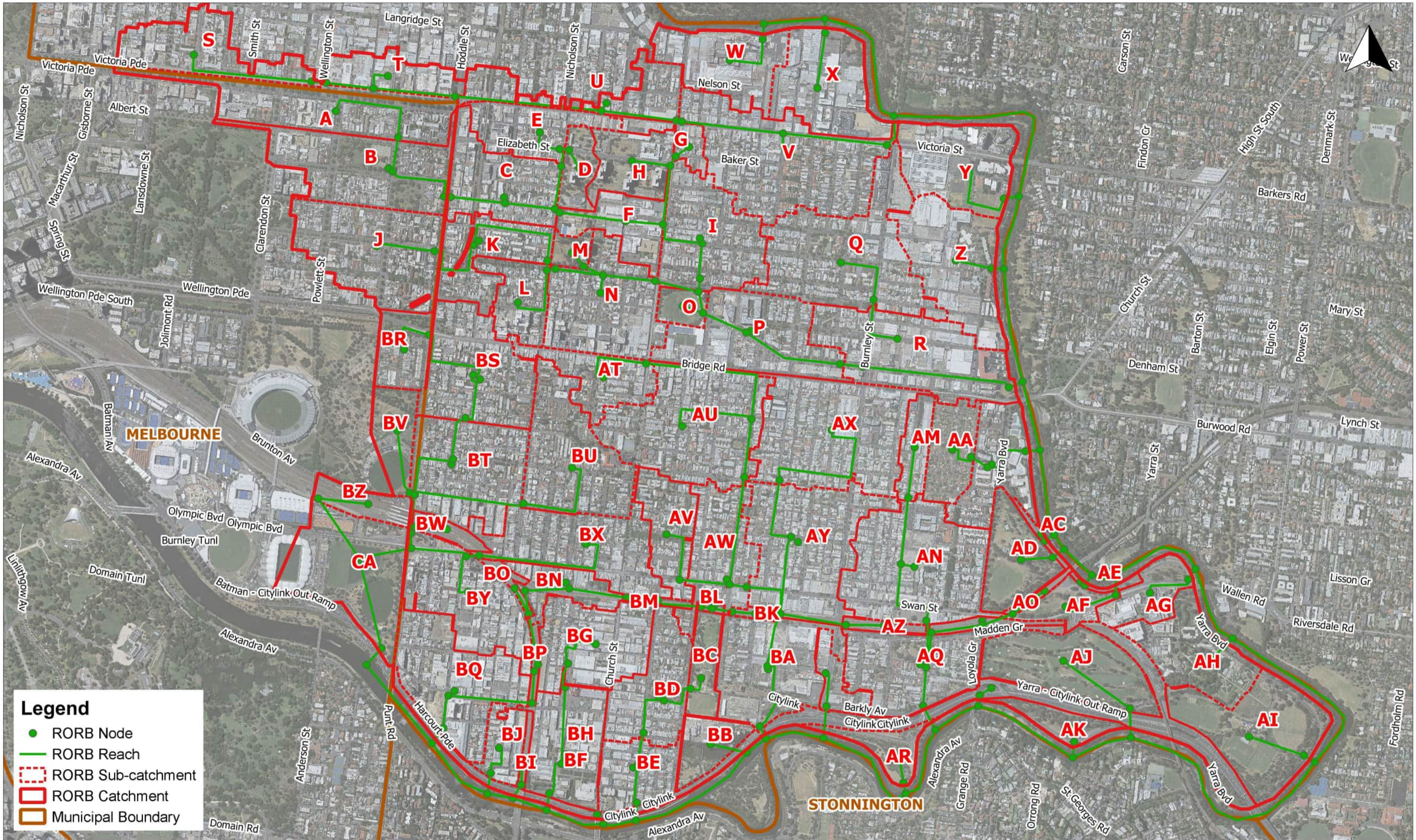
100 0 100200300400 m

Scale in metres (1:17000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

Alexandra Parade Main Drain Catchment
RORB Model Layout



Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

CITY OF YaRRA

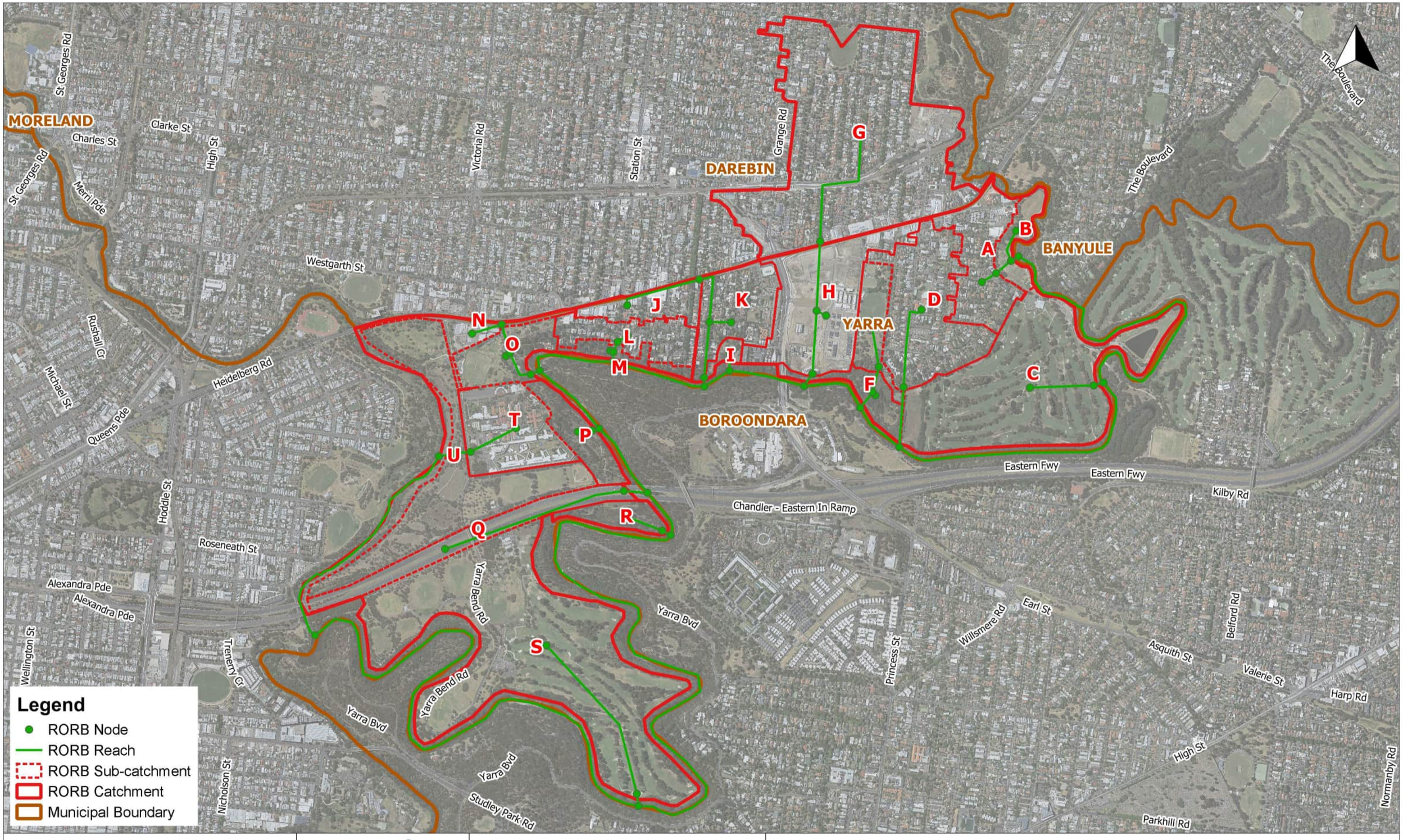
100 0 100 200 300 400 m

Scale in metres (1:13000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

Richmond Quarry Main Drain Catchment
RORB Model Layout



Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY WATER MANAGEMENT

CITY OF YARRA

100 0 100 200 300 400 m

Scale in metres (1:15000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

Fairfield Main Drain Catchment
RORB Model Layout

ENGENY

Appendix C
RORB Hydrological Model Development Details

C.1. MODEL DEFINITION

C.1.1 Catchment and Sub-Catchment Delineation

The study catchments and sub-catchment boundaries were delineated considering the following information:

- DEM generated from LiDAR data (captured November 28, 2017) and contours from the DEM,
- Land use identified in the Victorian Planning Scheme,
- Property and parcel boundaries,
- Aerial photography; and
- Council, Melbourne Water and VicRoads drainage asset details.

Where possible, due consideration for the predicted 1 % AEP overland flow paths has been incorporated in developing the model layouts however, a higher priority has been applied to the piped catchment and to keeping consistent land uses in the same sub-catchment. This has been done to improve the accuracy of the flood modelling once the rainfall excess runoff hydrographs are used as an input to the flood modelling. Separating urban residential impervious areas and rural pervious areas to account for the different loss factors attached to each surface type reduces the effect of averaging runoff volumes across a sub-catchment.

Refer to **Appendix B** for the hydrologic model layouts.

C.1.2 Fraction Impervious

The initial fraction impervious (FI) values were assigned at a parcel scale based on the recommended values for different planning zones (Appendix M of Melbourne Water Project Specifications [October 2021]). The FI applied at parcel scale was then further reviewed and refined based on 2020 aerial photography with consideration of both zoned land use and current development levels. The sub-catchment FI (TIA) was then calculated as a weighted average of imperviousness of the different land parcels that were contained in the sub-catchment. Additional updates to the FI layer were also made following the 2023 peer review by Melbourne Water.

C.2. RORB HYDROLOGICAL MODEL PARAMETERS

C.2.1 Summary

Table C- 1 provides a summary of the final parameters adopted for each RORB hydrological model. The following sections provide information on the methodology used to determine each parameter.

Table C- 1: RORB Hydrological Model Parameter Specification

Parameter	Value
kc	n/a (RORB hydrological models used for rainfall excess only)
m	0.8
Initial Loss (Rural and Urban Pervious Areas)	12.00 mm
Continuing Loss (Rural and Urban Pervious Areas)	1.9 mm/hr
Initial Loss (Indirectly Connected Areas)	8.40 mm
Continuing Loss (Indirectly Connected Areas)	1.9 mm/hr
Initial Loss (Effective Impervious Areas)	1.50 mm
Continuing Loss (Effective Impervious Areas)	0.00 mm/hr

C.2.2 Intensity-Frequency-Duration (IFD) Data

ARR v4.1 IFD data for the study was sourced from the Bureau of Meteorology (BoM) using the online 2019 Rainfall IFD request system. Data was requested for the centroid of each of the three models, below is the RICH model IFD data represented by the coordinates of -37.82° south and 145.00° east. The resultant IFD's for the study catchments are shown in Table C- 2 below.

Table C- 2: Rainfall Depths in Millimetres

	Annual Exceedance Probability (AEP)				
Duration	20 %	10 %	5 %	2 %	1 %
10 min	11.6	14.1	16.8	20.9	24.4
15 min	14.2	17.2	20.6	25.7	30.1
30 min	18.9	22.9	27.3	33.9	39.7
1 hour	23.9	28.7	34	41.8	48.6
2 hour	29.5	35.2	41.3	50.2	57.8
3 hour	33.5	39.7	46.3	56	64.3
6 hour	42	49.5	57.4	69	78.7
12 hour	53.7	63.2	73	87.6	99.6
24 hour	69	81.6	94.3	113	128
48 hour	86.5	103	120	143	162
72 hour	95.9	115	134	160	180
96 hour	101	122	142	169	190
120 hour	104	125	147	174	195
144 hour	105	127	149	177	198
168 hour	106	127	149	177	198

C.2.3 Pre-burst Depth Rainfall

While the design rainfall values (IFDs) from the Bureau of Meteorology are for bursts, the initial loss values from the ARR Data Hub are for complete storms, not bursts. As agreed with Melbourne Water, full storms were modelled. The 75th percentile pre-burst depth was added to the burst rainfall (from BoM) for the FAIR and ALEX hydrologic models, whilst the median pre-burst rainfall depths were added to the RICH burst rainfall, in accordance with the latest Victoria-specific ARR v4.1 guidelines (with the City of Yarra being located within loss region 2 and 3).

As pre-burst depths are not provided for storm durations of less than 60 minutes, the pre-burst rainfall is assumed to be the same for durations of 60 minutes and less in accordance with Appendix H of Melbourne Water Project Specifications (October 2021).

The 75th percentile pre-burst rainfall depths adopted for FAIR and ALEX hydrologic models and median pre-burst rainfall depths for the RICH model are summarised in Table C- 3 and Table C- 4 respectively.

Table C- 3: RICH Median Pre-Burst Rainfall Depth (mm)

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
1 hour	2.9	2.5	2.1	1.5	1
1.5 hour	3	2.5	2	1.4	1
2 hour	2.6	2.7	2.8	1.9	1.2
3 hour	2.7	2.7	2.7	5.5	7.5
6 hour	1.7	2.2	2.6	4.6	6
12 hour	0.8	1.2	1.5	5.1	7.9
18 hour	0.3	0.5	0.7	2.2	3.2
24 hour	0.1	0.2	0.3	0.5	0.6
36 hour	0	0	0	0	0.1
48 hour	0	0	0	0	0
72 hour	0	0	0	0	0

Table C- 4: ALEX and FAIR 75th Percentile Pre-Burst Rainfall Depth (mm)

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
1 hour	12.3	13.5	14.6	11.4	9
1.5 hour	13.6	13.9	14.1	14.6	15
2 hour	13	15.1	17.1	15.4	14.2
3 hour	11.8	13.1	14.3	19.4	23.2
6 hour	12.7	15.5	18.1	20	21.4
12 hour	9.7	12	14.3	20.3	24.8
18 hour	6.1	8.2	10.3	14.5	17.7
24 hour	4.5	5.7	6.8	10.2	12.7
36 hour	1.5	2.1	2.8	6.8	9.9
48 hour	0.5	0.8	1.1	2.3	3.2
72 hour	0	0	0	0.5	0.9

C.2.4 Areal Reduction Factor

The IFD data provided by the BoM is applicable for rainfall in small catchments. As catchment size increases the chance of the average intensity of rainfall occurring over the entire catchment decreases. To address this issue an Areal Reduction Factor (ARF) can be applied to the IFD data to account for the larger catchment area. The catchments were modelled in accordance with ARR v4.1. The ARF values were applied with consideration of the study catchment sizes, and those values were deemed acceptable by Melbourne Water and independent peer reviewers.

C.2.5 Temporal Rainfall Patterns

ARR v4.1 temporal patterns, downloaded from the ARR Data Hub, were adopted for the RORB hydrological models. ARR v4.1 states that point temporal patterns should be used for catchments less than 75 km^2. As all three catchments are less than 75 km^2, point temporal patterns were adopted for this study.

C.2.6 Spatial Rainfall Patterns

In accordance with ARR v4.1, as the three catchments modelled are less than 20 km^2, uniform spatial patterns were adopted for each RORB hydrological model.

C.2.7 Initial and Continuing Loss Model

The RORB hydrological models adopted an initial loss / continuing loss model approach, in accordance with the recommendations of ARR v4.1. ARR v4.1 provides a methodology to calculate initial loss and continuing loss values for different land uses. These loss values are calculated based on the concepts of Effective Impervious Area (EIA), Indirectly Connected Areas (ICA) and pervious areas, which are detailed in Chapter 3.4 of Book 5 of ARR v4.1.

Table C- 5 summarises the adopted loss values correlating to each of the area types.

Table C- 5: RORB Hydrological Model Loss Values for Impervious and Pervious Areas

Loss	Effective Impervious Areas (EIA)		Indirectly Connected Areas (ICA)		Pervious Areas	
	ARR v4.1 Guidance	Value Adopted	ARR v4.1 Guidance	Value Adopted	ARR v4.1 Guidance	Value Adopted
Initial Loss	1-2 mm	1.5 mm	60-80 % of pervious area value from AR&R data hub	8.4 mm (70 % of pervious area value from AR&R data hub)	Derive from AR&R online data hub	12 mm for the coordinates -37.81°, 144.99°
Continuing Loss	0 mm/hr	0 mm/hr	Typical value of 2.5 mm/hr, with a range of 1-3 mm/hr adjusted by engineering judgement	1.9 mm	Derive from AR&R online data hub	1.9 mm for the coordinates -37.81°, 144.99°

Land use within the City of Yarra was allocated to three categories:

- largely pervious areas (e.g. Council Reserves),
- medium to high density residential and road areas (grouped together); and
- commercial / industrial areas.

Loss values were calculated for each of these categories to account for the variation in imperviousness within each sub-catchment. In accordance with ARR v4.1, the following methodology was utilised to calculate the initial loss and continuing loss values for each category:

1. Determine the total impervious area (TIA). The fraction impervious values for each sub-catchment were utilised as the TIA.
2. Estimate EIA for each sub-catchment based on a ratio of EIA to TIA. ARR v4.1 states that in areas where the TIA is less than 70 % (most residential areas) the EIA is 60 % of the TIA. There is some variation on this between different catchments but it is usually within 10 % of the amount. For areas where the TIA is greater than 80 %, a higher fraction of EIA to TIA can be assumed. This applies to commercial and industrial areas.
3. Estimate ICA for each sub-catchment. For sub-catchments with medium to high levels of development (residential / roads and commercial / industrial categorised sub-catchments) areas within each sub-catchment not considered EIA were deemed ICA. For low density residential areas, ICA was calculated as the portion of the sub-catchment classified as TIA, but not EIA. The remainder of these sub-catchments were deemed pervious area.

ENGENY

Appendix D
TUFLOW Hydraulic Model Development Details

D.1 DIGITAL ELEVATION MODEL (DEM)

LiDAR data has been used to generate a DEM for the study area. The LiDAR was provided to Engeny and is from the 2017-18 Greater Melbourne LiDAR project. Figure D- 1, Figure D- 2 and Figure D- 3 below present the generated DEMs for the ALEX, FAIR, and RICH catchments covering the study area, which has a 1 metre (cell size) resolution. The red areas indicate areas of higher elevation, and the blue areas designate the areas of lower elevation.

It is important to note that LiDAR data is not representative of final constructed levels through the Yarra Bend development and along the Chandler Highway upgrade. The LiDAR data was captured prior to the finalisation of those projects and at the timing of preparing this report the levels within the Yarra Bend development are still subject to change and finalisation. As agreed with Council, flood extents would not apply to this area.

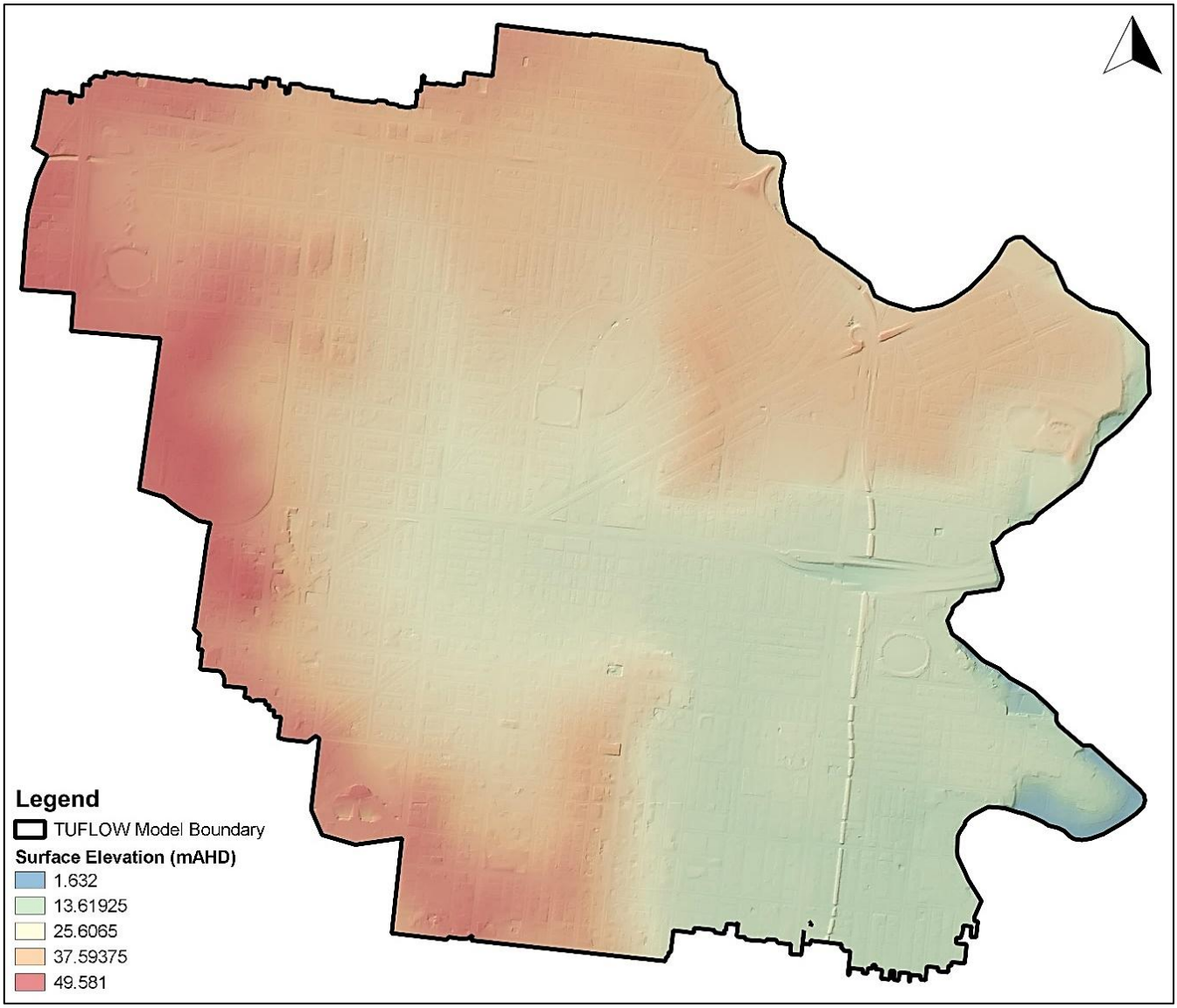


Figure D- 1: Alexandra Parade Main Drain Catchment DEM

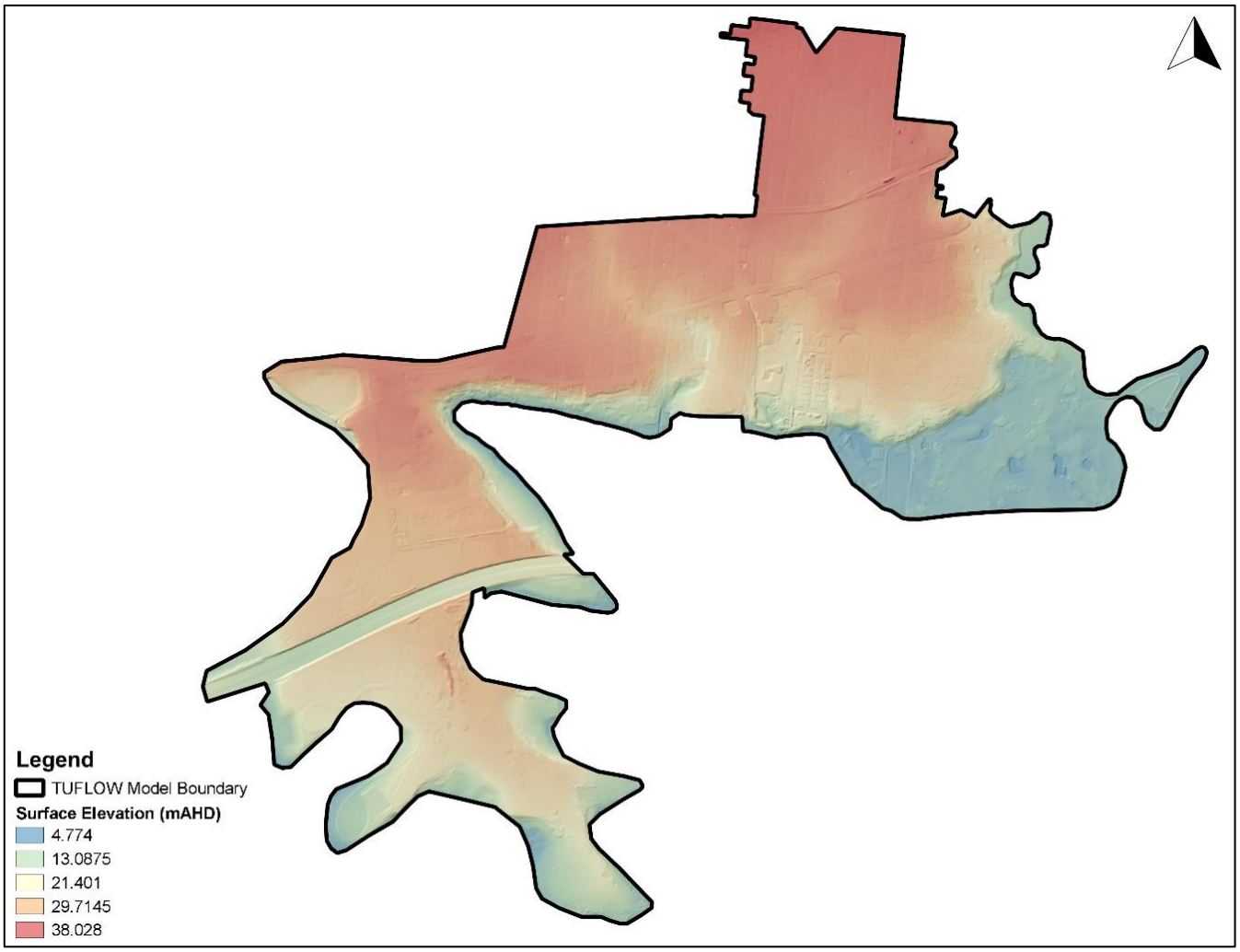


Figure D- 2: Fairfield Main Drain Catchment DEM



Figure D- 3: Richmond Quarry Main Drain Catchment DEM

D.1.1 2-D Cell Size

A 3-metre cell size has been adopted for the final runs of the TUFLOW hydraulic model. Melbourne Water's Flood Mapping Guidelines & Technical Specification (October 2021) recommends a cell size of two to three metres for urban flood modelling. A 3-metre cell size is sufficiently small to enable the effects of raised roadside verges and medians to be modelled while at the same time providing reasonable model simulation times.

D.2 1-D NETWORK DATA

Council has provided Engeny with their 2022 pipe and pit drainage data which formed the drainage network of all three TUFLOW hydraulic models. Any identified drainage queries regarding the drainage network were submitted to Council during the development of the flood model, and through preliminary modelling, to provide clarification with respect to some drainage asset sizes, locations, and connectivity. Survey data, site visits, and design plans provided by Melbourne Water, VicRoads and Council were used to confirm and inform accurate representation of key drainage structures and features.

D.2.1 Pipes

The following outlines the key tasks, methods and assumptions adopted by Engeny regarding the 1-D pipe network data:

- The assumptions used to estimate unknown pipe sizes were:
  - Where the pipe diameter was missing for a single pipe, but the upstream and downstream diameters were available, the pipe in the middle was assumed to be the same size or at least equal to the size of the upstream pipe.
  - If the pipe was within a road reserve and had no other upstream pipes a diameter of 300 mm was applied.

- When the drainage data sets provided had unknown invert levels, Engeny assumed a cover of 600 mm using the surface elevation at each pipe junction and then ensured all pipes grade towards the outfall.
- A Manning's roughness value of 0.013 was adopted for the concrete underground drainage pipes and road culverts. A value of 0.02 was adopted for brick drains, an example of which is provided below in Figure D-4: Example of Brick Line Underground Drain.



Figure D-4: Example of Brick Line Underground Drain

- Pipe directions were corrected as necessary to ensure that all pipes were digitised in the correct direction (i.e. flowing downhill).
- Pipes were snapped together where they were found to be graphically disconnected.
- The Engelund method of automatically created manholes has been used for determining pit losses. Where manholes were not created, the following losses will apply to the pipe data:
  - Height contraction coefficient = 0 for circular pipes and 0.6 for rectangular pipes
  - Width contraction coefficient = 1.0 for circular pipes and 0.9 for rectangular pipes
  - Entry loss coefficient for culverts = 0.5
  - Entry loss coefficients for underground pipes = 1.0
  - Exit loss coefficient for culverts = 1.0
  - Exit loss coefficients for underground pipes = 1.0

D.2.2 Pits

Interrogation of Council's pit drainage data revealed approximately 12,667 pits within the City of Yarra. Table D- 1 provides a summary of the different pit types found within Council's dataset for the study area, including pit type and count of different combinations.

Table D- 1: Drainage Pit Details Summary

Pit Type	Occurrences
Junction Pit (JP)	4,931
Double Grated Side-Entry Pit (DGSEP)	3
Double Side-Entry Pit (DSEP)	4
Grated Pit (GP)	2,195
Grated Side-Entry Pit (GSEP)	3,551
Side-Entry Pit (SEP)	1,983

To improve accuracy of modelling results, inlet pits were modelled as "Q" types in TUFLOW, with a relationship between depth of ponding and inlet capacity calculated using a pit inlet capacity spreadsheet. Pits have typically not been modelled on Melbourne Water's system, however there were some instances where large, grated pits owned by Melbourne Water were identified and these were added to the model to reflect on-the-ground existing conditions.

D.2.3 Initial and Tailwater Water Levels

The potential impact of the Yarra River waterway system on the performance of both Council's and Melbourne Water's underground drainage system within the City of Yarra was investigated to inform flood patterns and conditions during the 1 % AEP storm event. Melbourne Water's available 1 % AEP peak flood level contour data for the Yarra River had a noticeable impact on the drainage system within the study area. Flood level contour data was analysed at two key locations, the Fairfield Main Drain outfall into the Yarra River and the Alexandra Parade Main Drain outfall into the Yarra River, is presented in Table D-2. However, applying a 1 % AEP tailwater level within the Yarra River when modelling the 1 % AEP storm for the catchments within the study area was not viable given the very large differences in catchment sizes and resultant times of concentration.

Therefore, Engeny undertook a thorough hydrological investigation of the Yarra River utilising Melbourne Water's Yarra River RORB hydrological model and related the peak flow results of this model back to the available peak flood level contour information. Findings of this hydrological investigation is presented for the Fairfield Main Drain in Table D-3 and Table D- 4 and the Alexandra Parade Main Drain in Table D- 5 and Table D- 6 below.

Table D-2: Melbourne Water Yarra River Flood Level Information

AEP	Fairfield Main Drain (m AHD)	Alexandra Parade Main Drain (m AHD)
63 % (1-year ARI)	8.88	5.41
38 % (2-year ARI)	10.26	6.57
20 %	11.83	7.91
10 %	12.90	8.89
5 %	14.23	10.10
2 %	15.82	11.54
1 %	17.20	12.76

Table D-3: Yarra River RORB Peak Flows - Yarra River Critical Duration at Fairfield Main Drain Outfall

Storm Event	Peak Flow (m^3/s)	Time to Peak (hrs)	Peak Flood Level at Drain Outfall
72 hr, 1 % AEP	1,303.0	84	17.2
72 hr, 10 % AEP	601.2	88	12.9
72 hr, 20 % AEP	465.9	84	11.83

Table D- 4: Yarra River RORB Peak Flows – Fairfield Main Drain Critical Duration at Outfall to Yarra River

Duration (AEP)	Peak Flow (m3/s)	Time to Peak (h)
2 hr, 1 % AEP	202.1	7.67
2 hr, 10 % AEP	88.03	7.42
2 hr, 20 % AEP	66.23	7.58

Table D-3 and Table D- 4 provide a comparison of flows between the Yarra River and the Fairfield Main Drain as informed by the Yarra River RORB hydrological model at the outfall location of the Fairfield Main Drain for the critical storm durations for the 1 %, 10 % and 20 % AEP storm events. As can be seen in Table D- 4 the peak RORB flow for the 2-hour 1 % AEP storm, which is critical duration for the local Fairfield Main Drain catchment, is considerably less than the peak 72 hour 20 % AEP flow in the Yarra River, which is critical for the Yarra River catchment at this outfall location for the 20 % AEP storm event. The Yarra River RORB hydrological model did not contain the information necessary to run events more frequent than the 20 % AEP however, a rough rule of thumb is that the peak flow doubles for every order of magnitude increase. For example, the 1 % AEP flow is double the 10 % AEP flow (1303 m^3/s, compared to 601 m^3/s shows this is approximately correct). The 10 % flow is also expected to be roughly double the 1-year AEP (63 % AEP) flow, which would give a peak 1-year AEP flow rate of roughly 300 m^3/s for the Yarra River at this outfall location. This flow rate is significantly above the 2-hour 1 % AEP flow rate, so adopting a 1-year AEP (63 % AEP) peak flood level in the Yarra River is a conservative assessment. Table D-2: Melbourne Water Yarra River Flood Level Information shows peak flood level for the 1-year AEP (63 % AEP) storm is 8.88 m AHD at the Fairfield Main Drain outfall location.

Table D- 5: Yarra River RORB Peak Flows - Yarra River Critical Duration at Alexandra Parade MD Outfall

Duration (AEP)	Peak Flow (m^3/s)	Time to Peak (hrs)	Peak Flood Level at Drain Outlet
72 hr, 1 % AEP	1395.0	80	12.76
72 hr, 10 % AEP	642.0	88	8.89
72 hr, 20 % AEP	502.8	84	7.91

Table D- 6: Yarra River RORB Peak Flows – Alexandra Parade MD Critical Duration at Outfall to Yarra River

Duration (AEP)	Peak Flow (m^3/s)	Time to Peak (hrs)
2 hr, 1 % AEP	299.3	8.33
2 hr, 10 % AEP	120.1	8.33
2 hr, 20 % AEP	94.62	4.17

Table D- 5 and Table D- 6 provide a comparison of flows between the Yarra River and the Alexandra Parade Main Drain as informed by the Yarra River RORB hydrological model at the outfall location of the Alexandra Parade Main Drain for the critical storm durations for the 1 %, 10 % and 20 % AEP storm events. As can be seen in Table D- 5 the peak RORB flow for the 2-hour 1 % AEP storm, which is critical duration for the local Alexandra Parade Main Drain catchment, is considerably less than the peak 72 hour 20 % AEP flow in the Yarra River, which is critical for the Yarra River catchment at this outfall location for the 20 % AEP storm event. As indicated above, the Yarra River RORB hydrological model did not contain the information necessary to run events more frequent than the 20 % AEP. So, a rough rule of thumb was used to estimate the 1-year ARI (63 % AEP) storm event flow rate, which equates to roughly 320 m³/s for the Yarra River at this location. This flow rate is significantly above the 2-hour 1 % AEP flow rate for the Yarra River, so adopting a 1-year AEP (63 % AEP) peak flood level in the Yarra River is a conservative assessment. Table D-2 shows the peak flood level for the 1-year AEP (63 % AEP) storm is 5.41 m AHD at the Alexandra Parade Main Drain outfall location.

Peak flood levels along the Yarra River were interpolated between Melbourne Water's flood contours using the 1-year ARI (63 % AEP) to inform initial and tailwater levels for the Yarra River waterway for this study.

It should also be noted that the timing of the peaks on the Yarra River and the local Fairfield Main Drain and Alexandra Parade Main Drain catchments, even in similar duration events is quite different. The local catchments typically peak at about the 2-hour point of a 2-hour duration storm however; the Yarra River does not peak until approximately 8.5 hours into a 2-hour duration storm at the local outfall locations (6.5 hours after the rainfall has stopped and been drained out of the local catchment). This adds to the conservative nature of the boundary condition that has been assumed to represent the Yarra River waterway for this study, and thus the impact of the waterway on the local drainage system within the City of Yarra.

D.3 2-D NETWORK DATA

D.3.1 Open Water Bodies

2-D initial water levels were specified where ponds, dams, and lakes were located throughout the study area to fill these storages throughout the models, providing a conservative flood modelling result. 2017 LiDAR data was used to set the 2-D initial water level.

D.4 SURFACE ROUGHNESS

A materials layer is utilised to define surface roughness information in the TUFLOW hydraulic model. The GIS parcel layer available from the Department of Environment, Land Water and Planning (DEECA) was used as a base for setting up the materials layer. The materials layer was created by assigning a Manning's roughness value to land parcels according to the land use based initially on planning zone. The roughness values were refined further based on the land use shown in the aerial photograph such as open space areas or carparks originally categorised as residential in the planning zones layer. These roughness values are listed in Table D- 7.

Table D- 7: Manning's n Roughness Values Adopted for this Study

Material Number	Land Use Type	Manning's Roughness
3	Open space with no trees	0.035
4	Open space with moderate trees	0.06
5	Commercial & residential building footprints	0.50
6	Car Park / Road	0.03
7	Open space with high density trees	0.09
8	Remainder of parcel (residential high density)	0.10
9	Railway line	0.12
10	Yarra River / waterway / waterbodies	0.022
11	Concrete lined channels	0.018
12	Bluestone lined channels	0.032

D.5 BOUNDARY CONDITIONS

D.5.1 1-D Inflows

The 1-D boundary condition layer (1d_bc) has been used to read in RORB inflow hydrographs for the individual sub-catchments. The sub-catchment polygons created for the RORB hydrological model were broken down into smaller sub-catchments and input into this layer. This allows for the total hydrograph for the RORB sub-catchment to be more appropriately distributed to the drainage network within each sub-catchment.

Some sub-catchments do not contain any pits and therefore flow cannot be applied to the model using 1-D boundary conditions. In these instances, 2-D source areas (2d_sa) were utilised.

Routed piped inflows entering the ALEX TUFLOW hydraulic model from the City of Merri-bek have been applied directly to the Melbourne Water's underground drain near the intersection of Lygon Street and Barkly Street. Engeny recently completed flood mapping of Merri-bek City Council's municipality, to which Merri-bek City Council has allowed Engeny to use flood modelling outputs from their study in the City of Yarra Flood Mapping Project.

Routed piped inflows entering the FAIR TUFLOW hydraulic model from Darebin City Council have been applied directly to Melbourne Water's underground drain asset near the intersection of Railway Place and Fairfield Road. Engeny received TUFLOW hydraulic model results from Melbourne Water to inform City of Yarra Flood Mapping Project. These results along with the FAIR hydraulic were used to produce inflow hydrographs for Engeny's FAIR TUFLOW hydraulic model (City of Yarra area only).

The RICH TUFLOW hydraulic model did not use routed inflows.

D.5.2 2-D Inflows

Some RORB sub-catchments used to define the RORB hydrological model do not have any inlet pits. Alternatively, some RORB sub-catchments include few pits that are not well distributed through the sub-catchment. These include areas such as large parks and open spaces. In these instances, 2-D source areas (2d_sa) were used to apply flow directly to the 2-D domain of the TUFLOW hydraulic model.

Similar to the 1-D inflows entering the City of Yarra from neighbouring municipalities, Engeny has applied 2-D overland flow inputs as determined by Engeny's previous flood mapping of the Merri-bek municipality and another consultancy's modelling of the Fairfield Main Drain catchment in Darebin's municipality. This is discussed further in Section 4.2.

D.5.3 1-D / 2-D Links

As part of the 1-D network, 2-D SX (source of flow from a 1-D model) boundaries were assigned to the pits to allow surcharge of water from the pipe network to the 2-D surface. For instances where minor structures are present, a combination of SX and Connection (CN) lines was used to select multiple grid cells to ensure the conveyance capacity of the drainage asset was not unintentionally hindered. Council has several minor culverts crossing roadways to allow kerb flow to pass through road intersections.

D.5.4 2-D Outflows

2-D HQ (head versus flow) and 2-D HT model boundaries have been adopted where overland flow exits the models. This is to avoid water ponding against the 2-D code boundary.

D.6 TUFLOW PARAMETERS

D.6.1 Time Step

Engeny has adopted a 2-D and a 1-D time step of 0.75 seconds and 0.125 seconds respectively for all models. These time steps were found to provide a good balance between achieving reasonable simulations times and maintaining errors to acceptable limits. This was the basis for TUFLOW Classic simulations. However, TUFLOW HPC was ultimately adopted to produce the model outputs, and TUFLOW HPC applies an adaptive timestep regime.

These time steps are consistent with recommendations in Melbourne Water's Flood Mapping Guidelines (October 2021) for a 2-D model grid size of three metres. Afflux

ENGENY

Appendix E
Front Middle Back vs Ensemble Temporal Patterns Afflux

Legend

- TUFLOW Model Boundary

Difference in Flood Depth (Afflux)

- Depth reduction greater than 0.1 m
- Depth reduction between 0.05 m and 0.1 m
- Depth reduction between 0.025 m and 0.05 m
- Depth reduction between 0.025 m and 0.01 m
- No change in depth (Depth between -0.01 m and 0.01 m)
- Depth increase between 0.01 m and 0.025 m
- Depth increase between 0.025 m and 0.05 m
- Depth increase between 0.05 m and 0.1 m
- Depth increase greater than 0.1m
- Decrease in Flood Extent
- Increase in Flood Extent

Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

500 0 500 m

Scale in metres (1:18,000@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping 2022

ALEX Model - 1% AEP Peak Flood Depth Temporal Pattern Sensitivity Anaylysis (10 TP minus FMB TP)

Legend

- TUFLOW Model Boundary

Difference in Flood Depth (Afflux)

- Depth reduction greater than 0.1 m
- Depth reduction between 0.05 m and 0.1 m
- Depth reduction between 0.025 m and 0.05 m
- Depth reduction between 0.025 m and 0.01 m
- No change in depth (Depth between -0.01 m and 0.01 m)
- Depth increase between 0.01 m and 0.025 m
- Depth increase between 0.025 m and 0.05 m
- Depth increase between 0.05 m and 0.1 m
- Depth increase greater than 0.1m
- Decrease in Flood Extent
- Increase in Flood Extent

Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

500 0 500 m

Scale in metres (1:15,000@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping 2022

FAIR Model - 1% AEP Peak Flood Depth Temporal Pattern Sensitivity Anaylysis (10 TP minus FMB TP)



Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

500 0 500 m

Scale in metres (1:15,000@ A3)

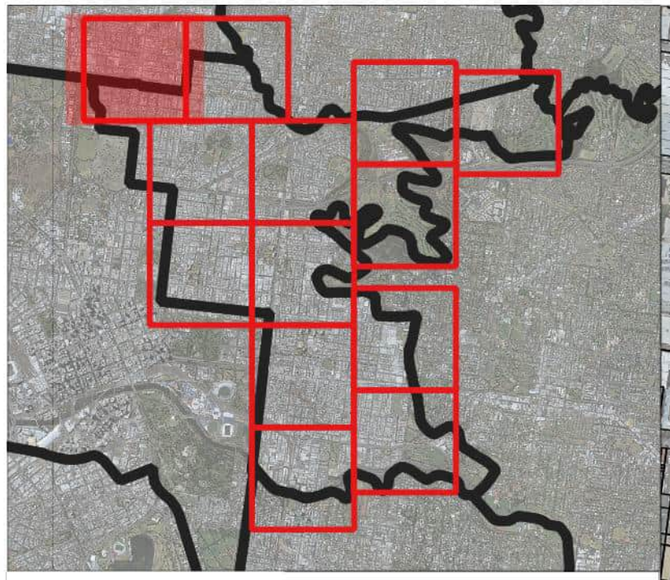
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping 2022

RICH Model - 1% AEP Peak Flood Depth Temporal Pattern Sensitivity Anaylysis (10 TP minus FMB TP)

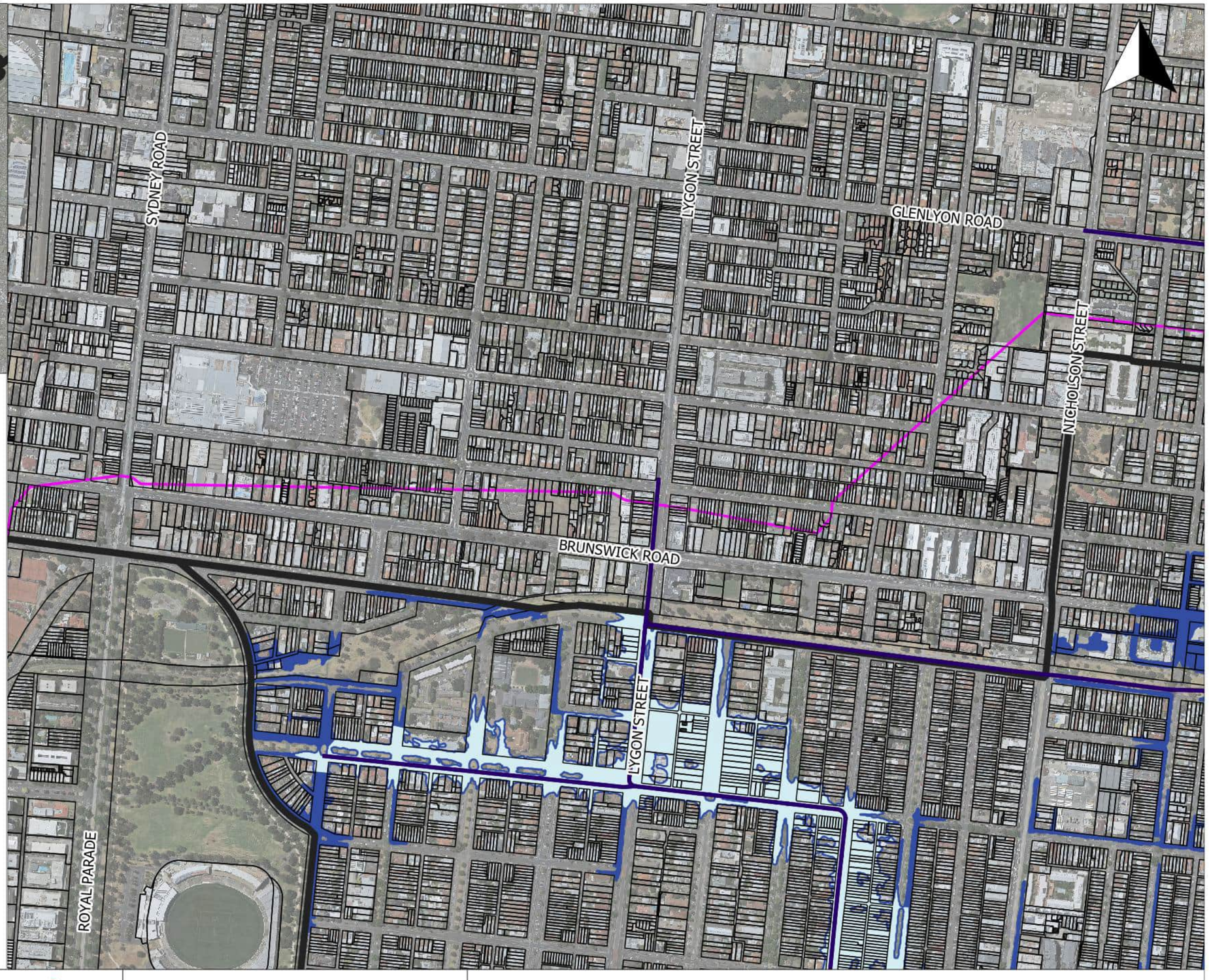
ENGENY

Appendix F
Flood Extent Plans



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains



Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YARRA

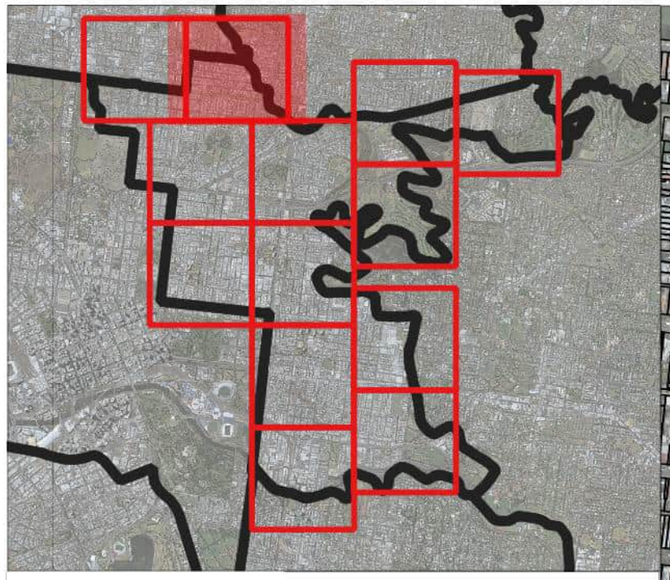
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

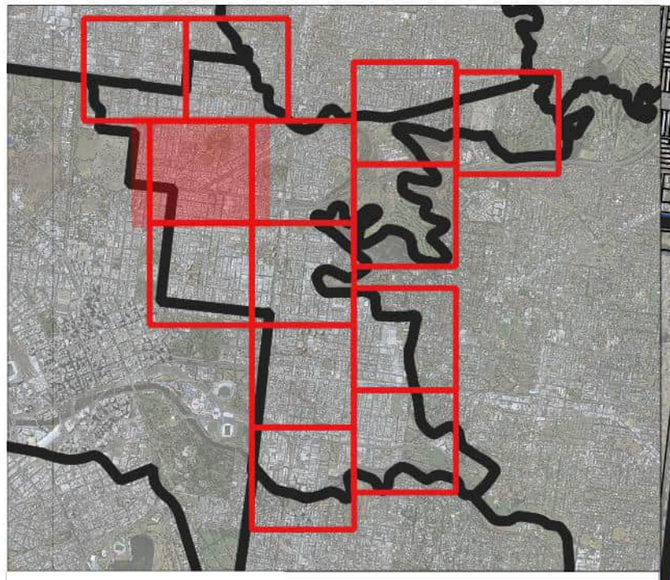
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

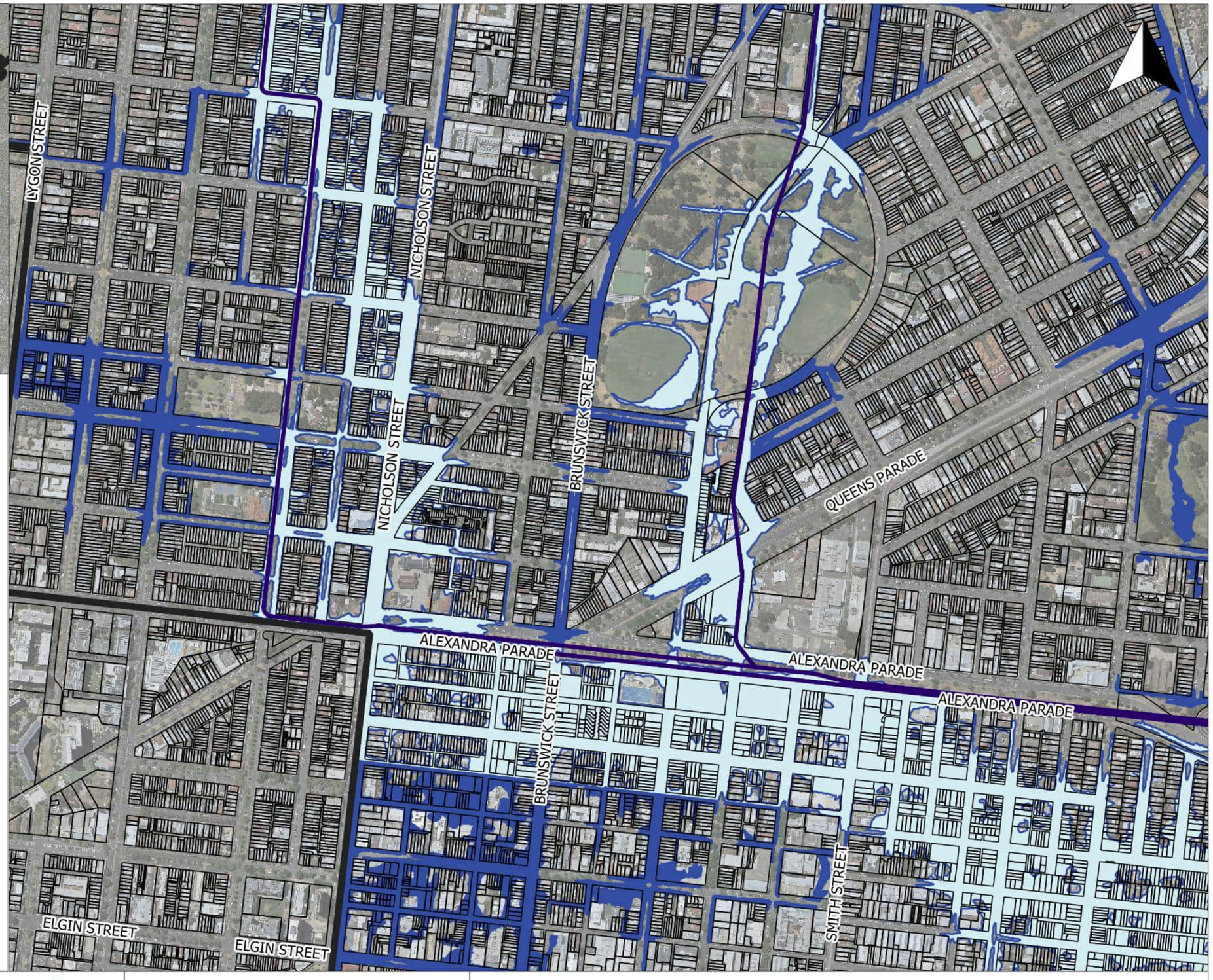
City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains



Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YARRA

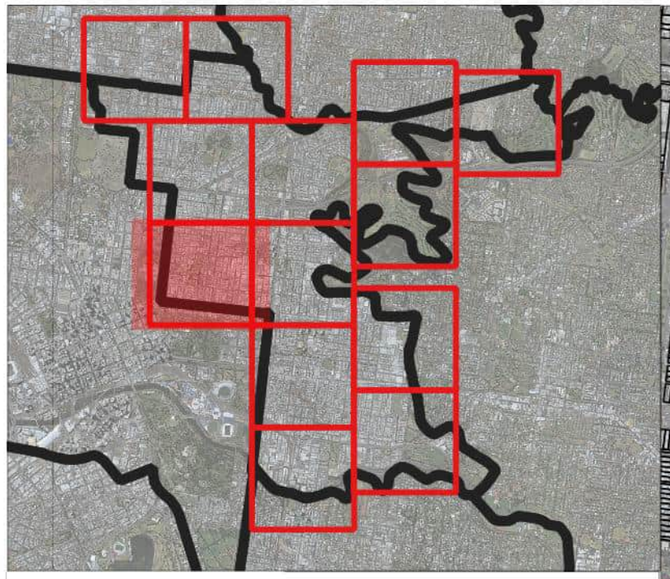
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

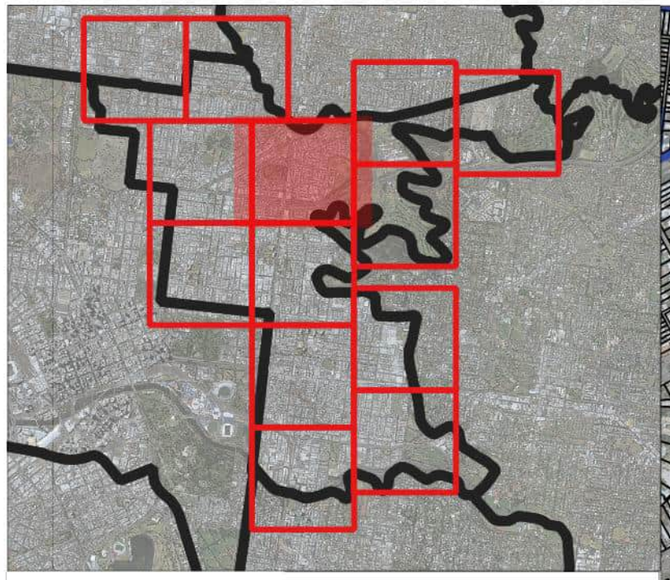
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

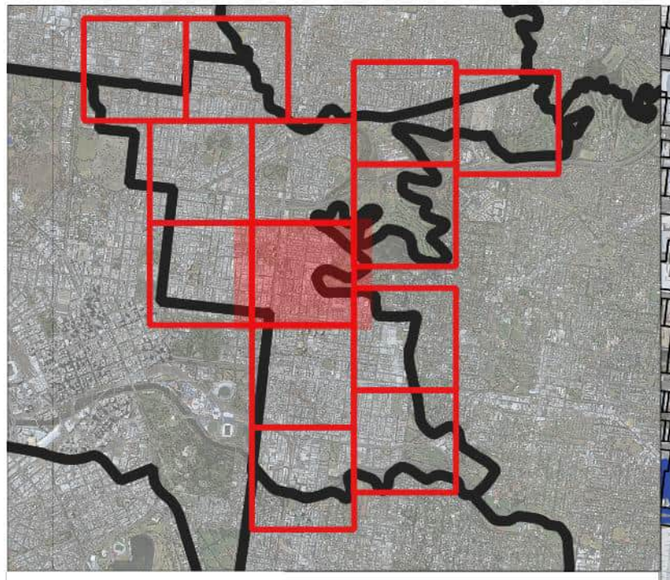
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

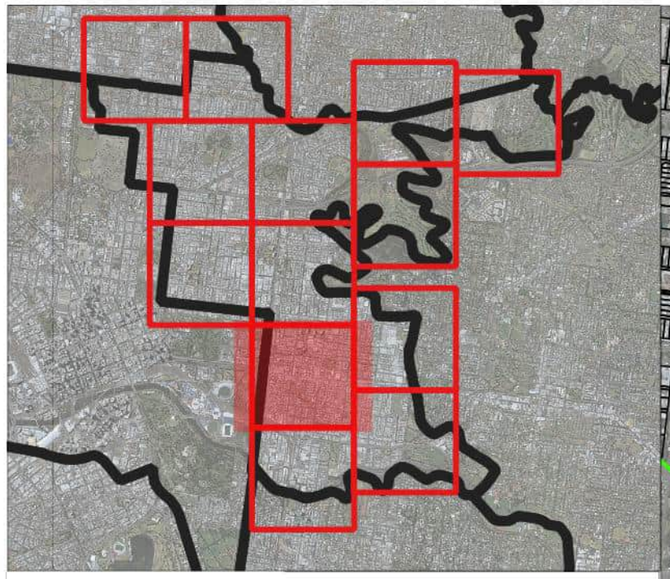
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YARRA

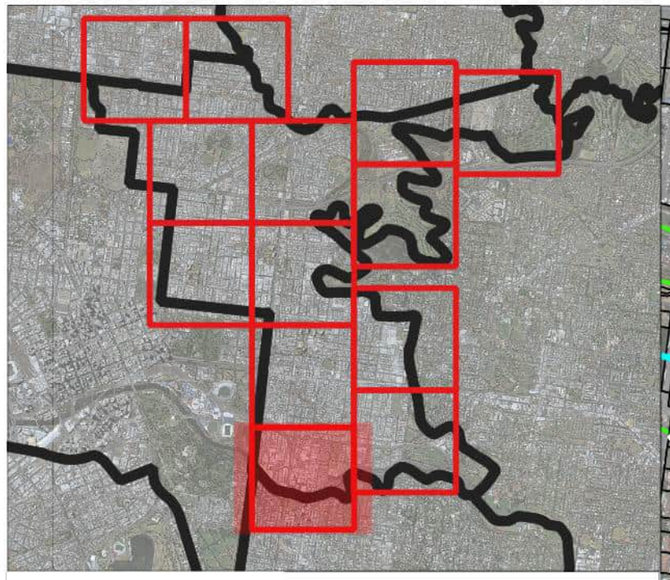
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

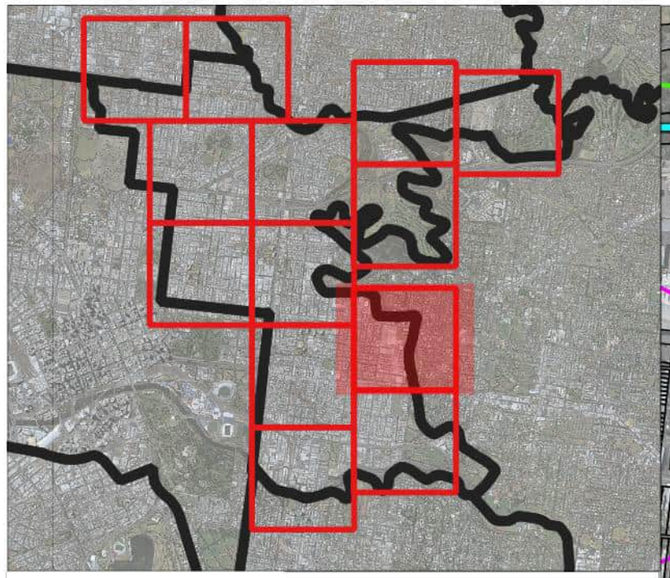
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

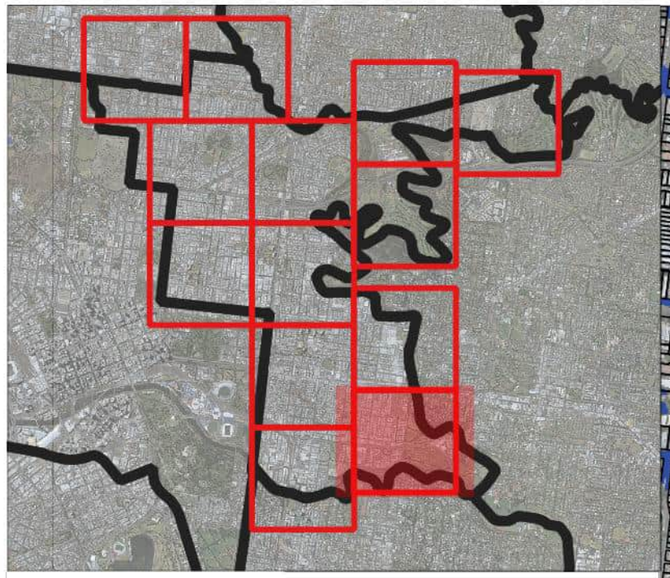
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

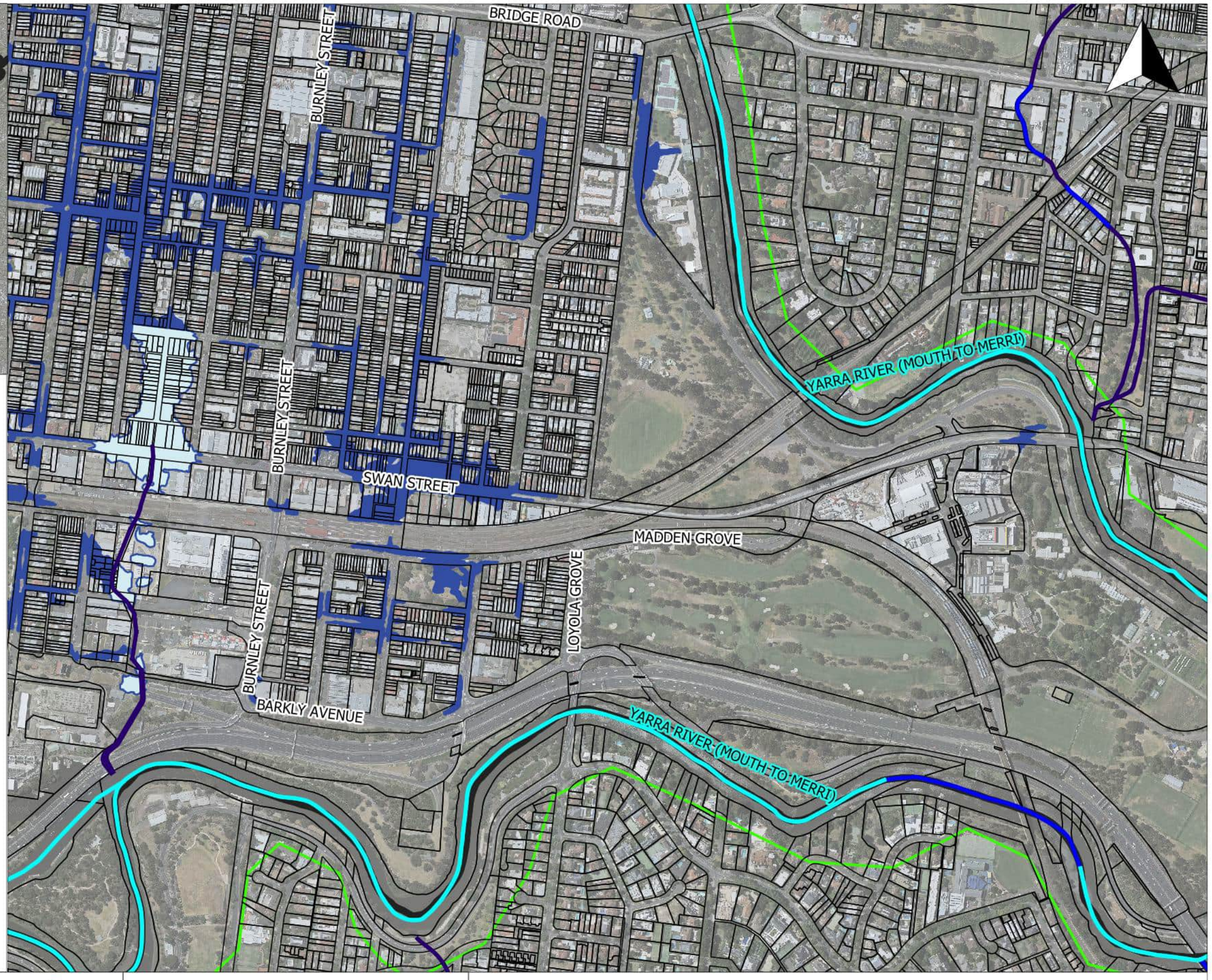
City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains



Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

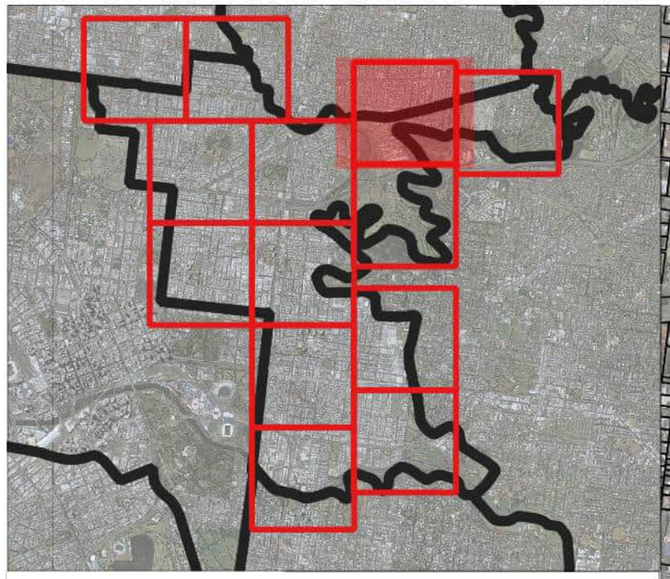
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

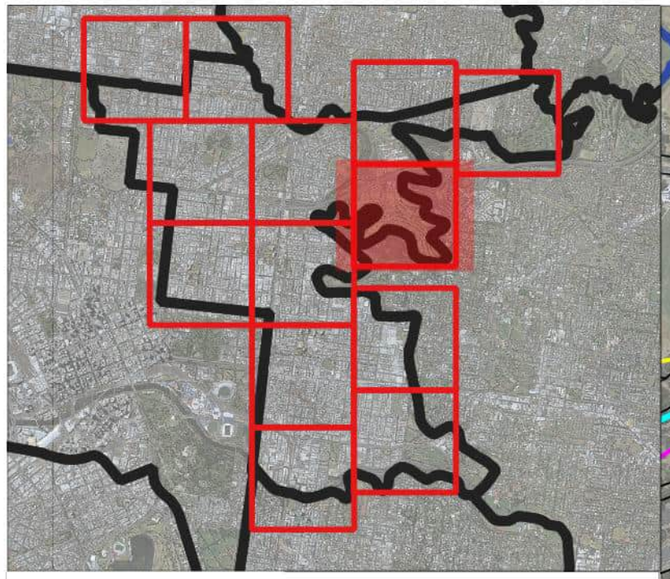
80 0 80 160 240 m

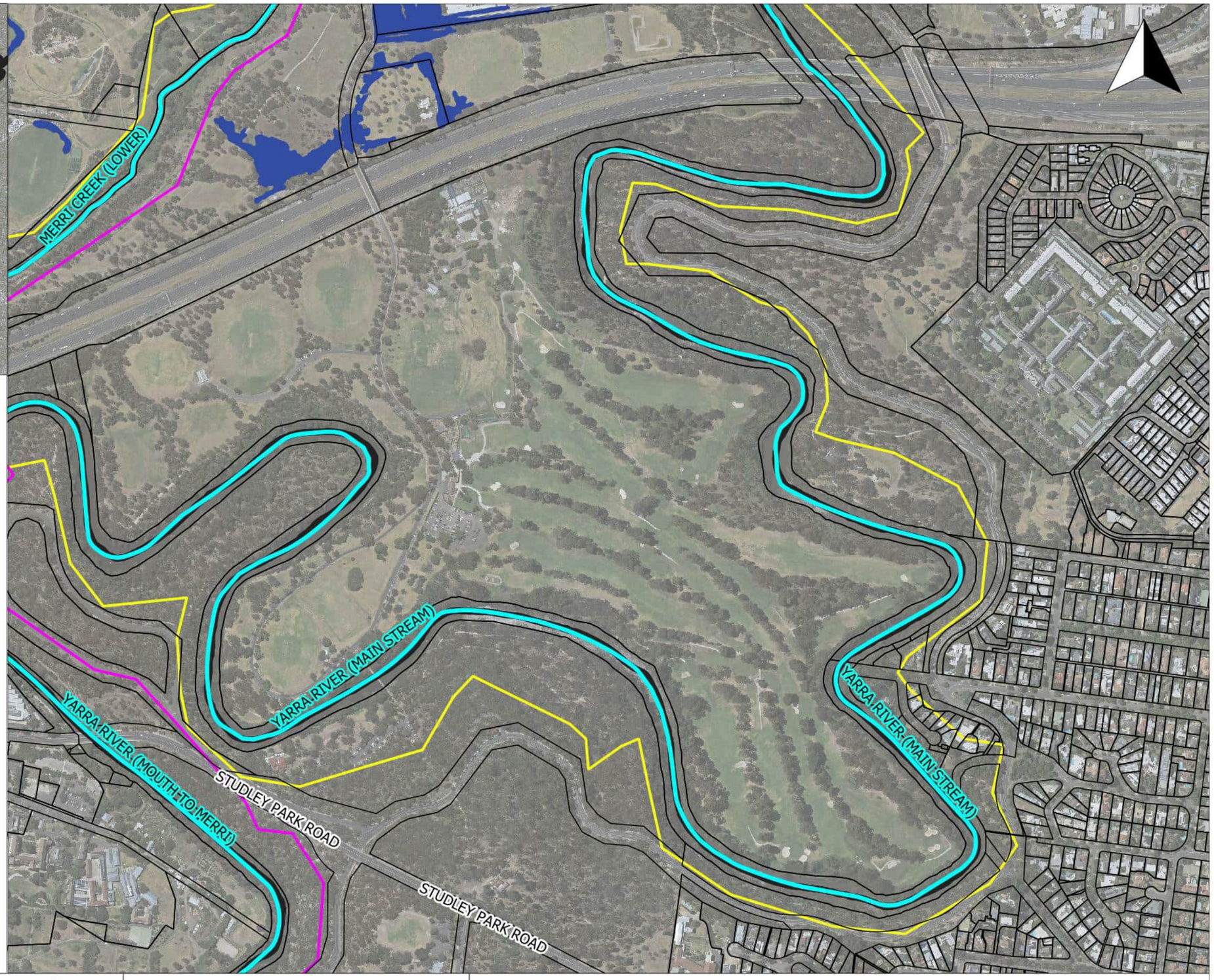
Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case





Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

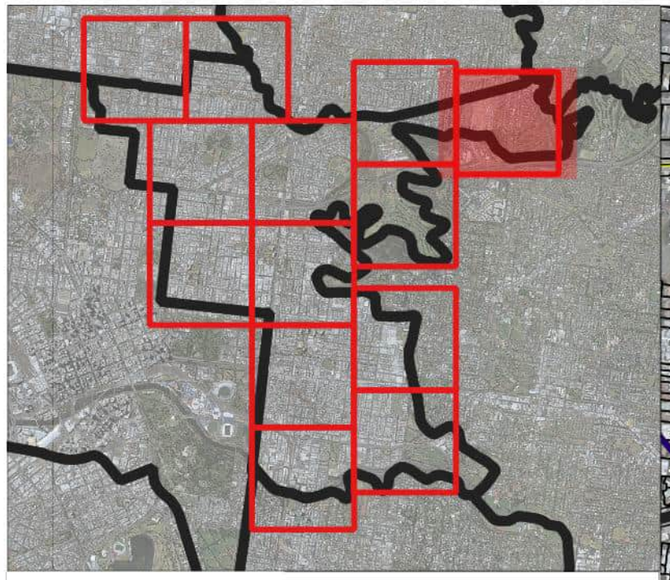
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

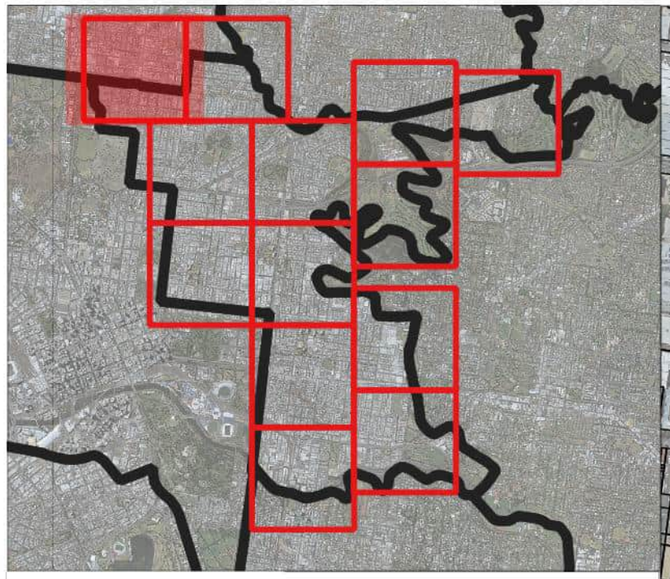
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

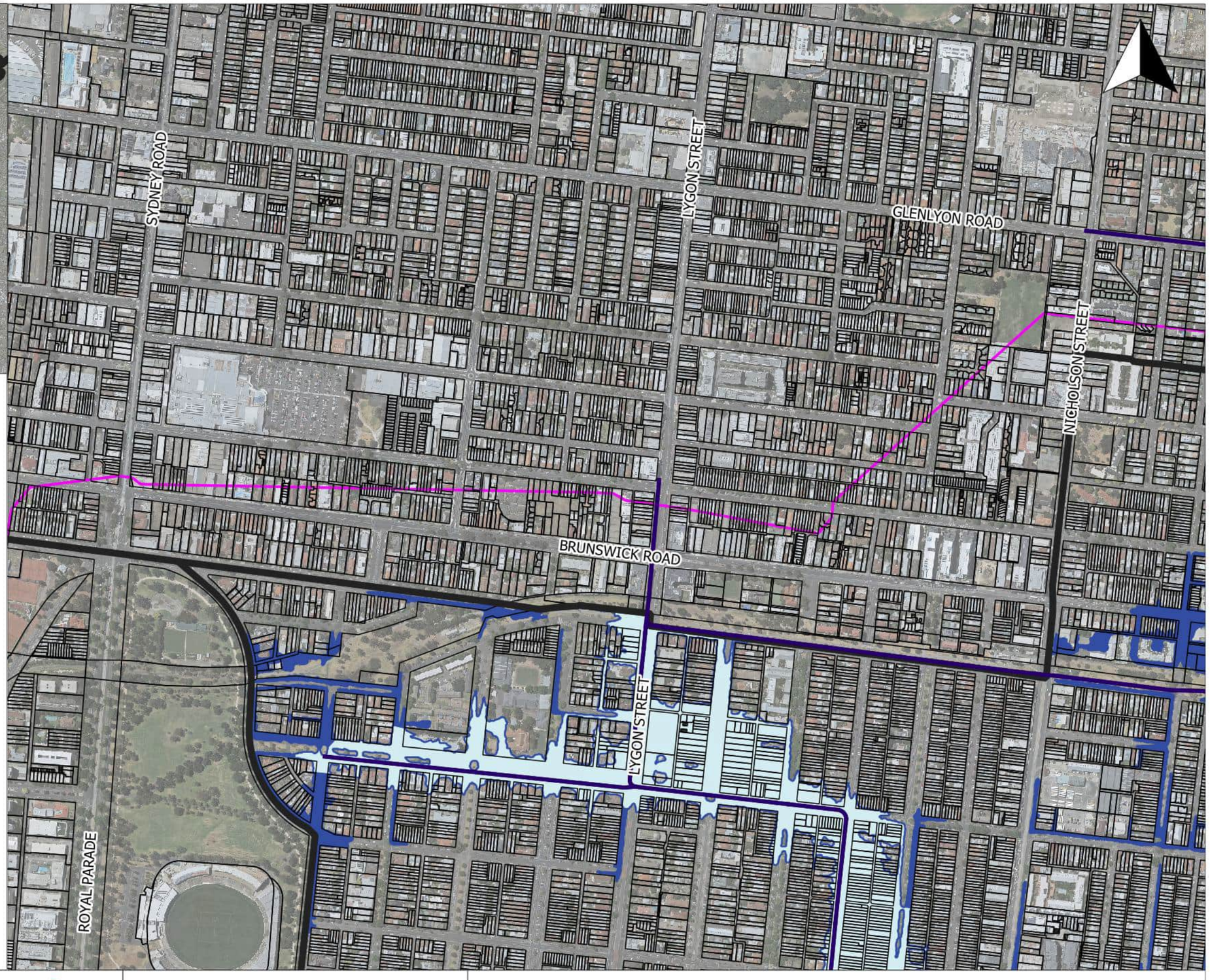
City of Yarra Flood Mapping

1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains



Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

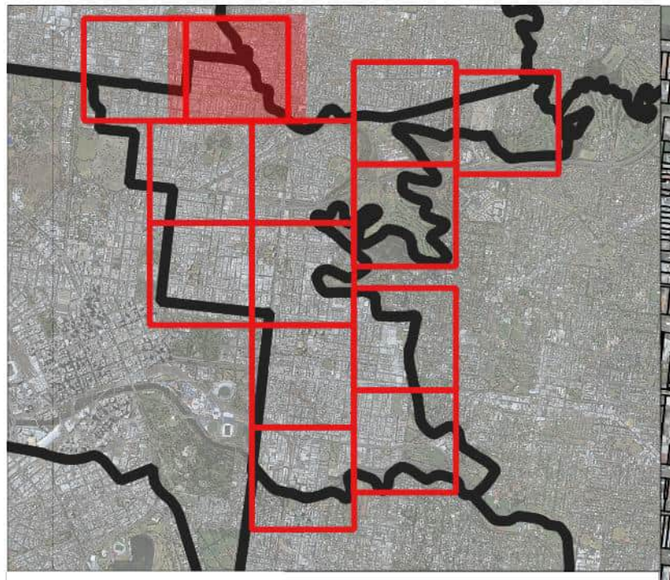
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

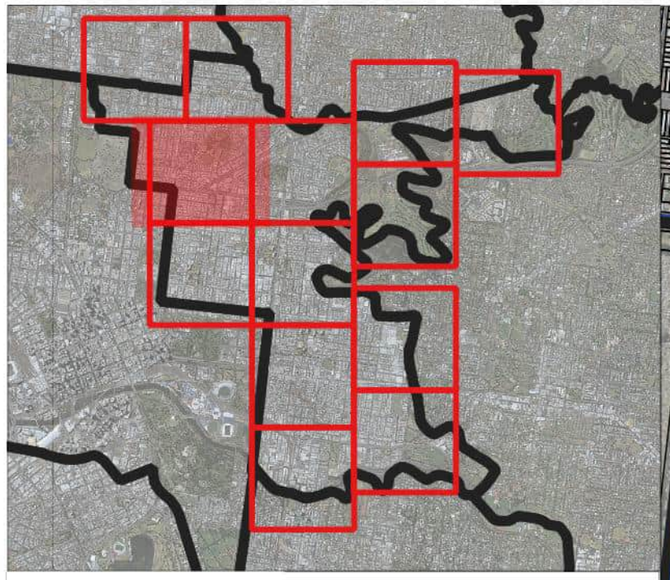
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YARRA

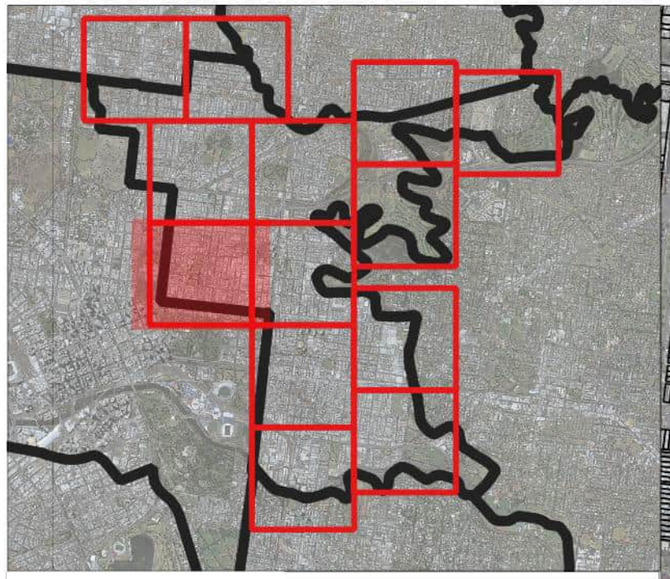
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

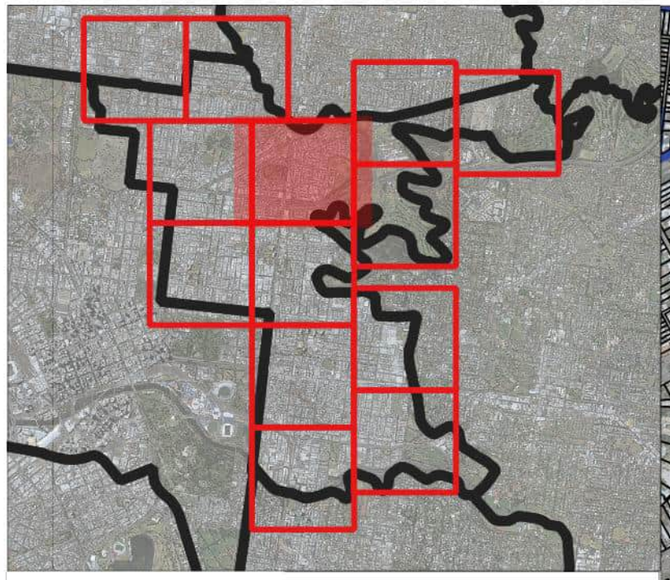
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

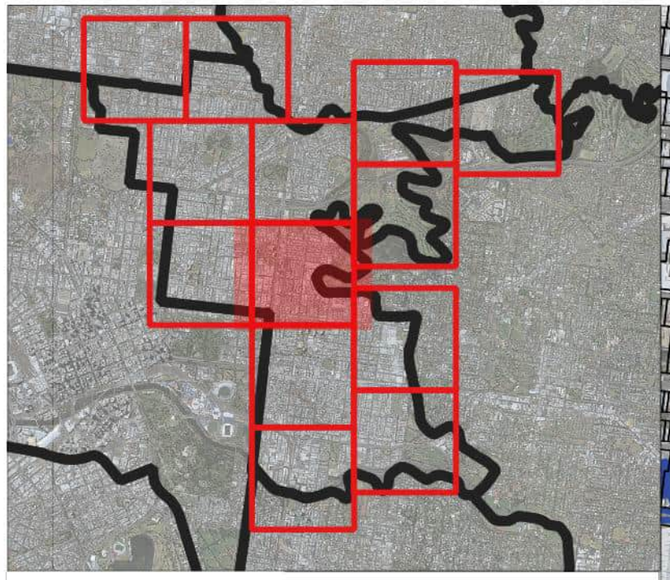
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

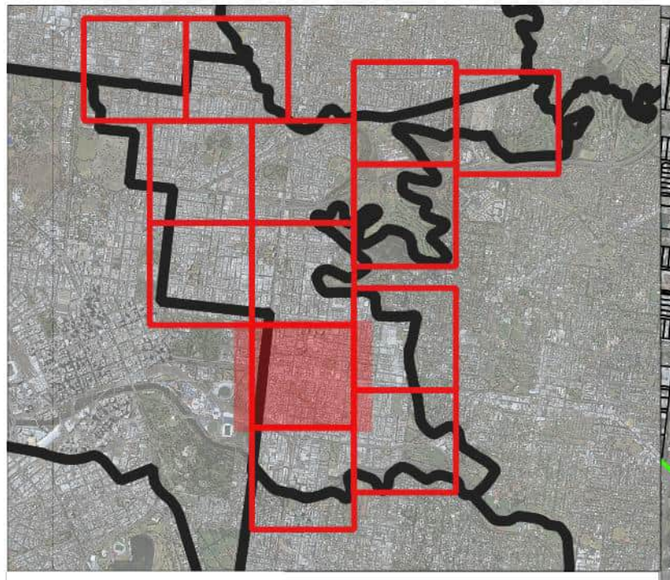
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YARRA

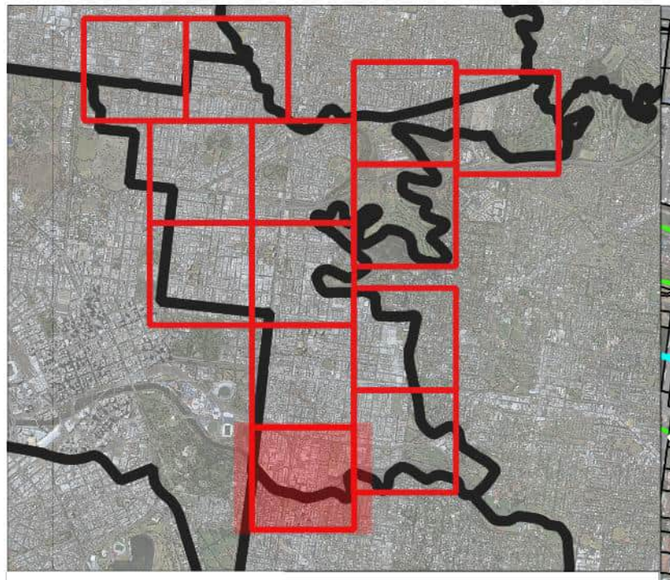
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

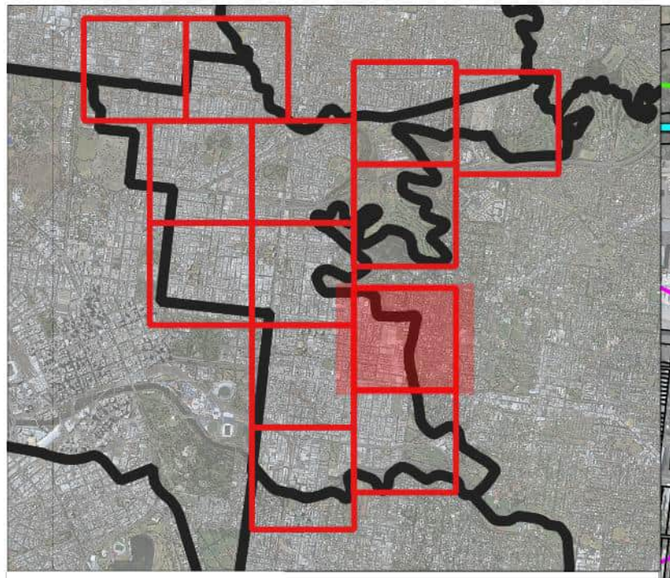
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

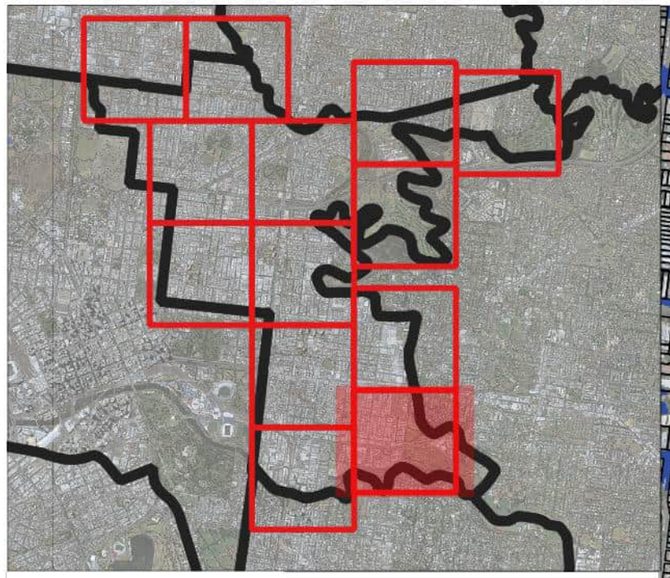
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

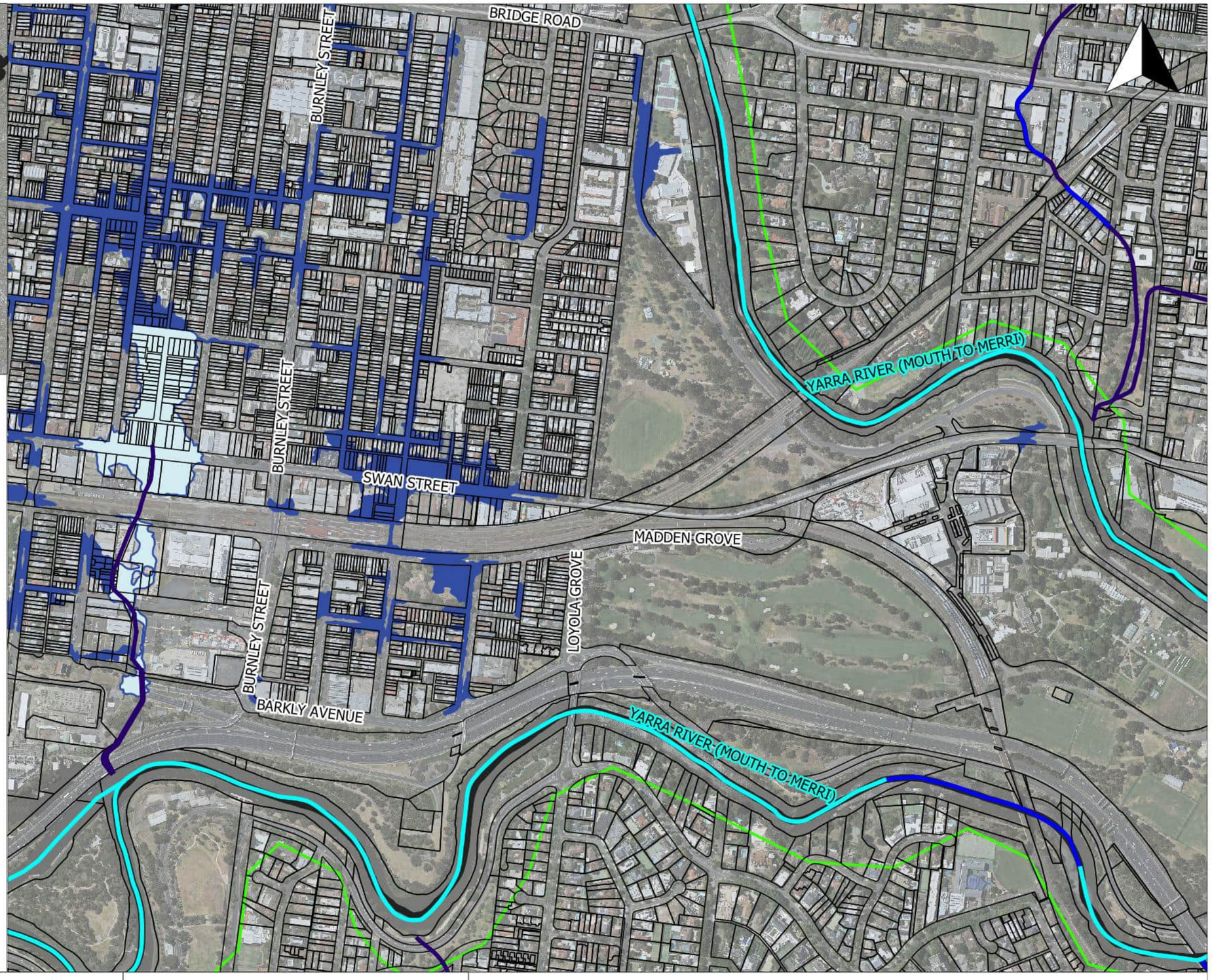
City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains



Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

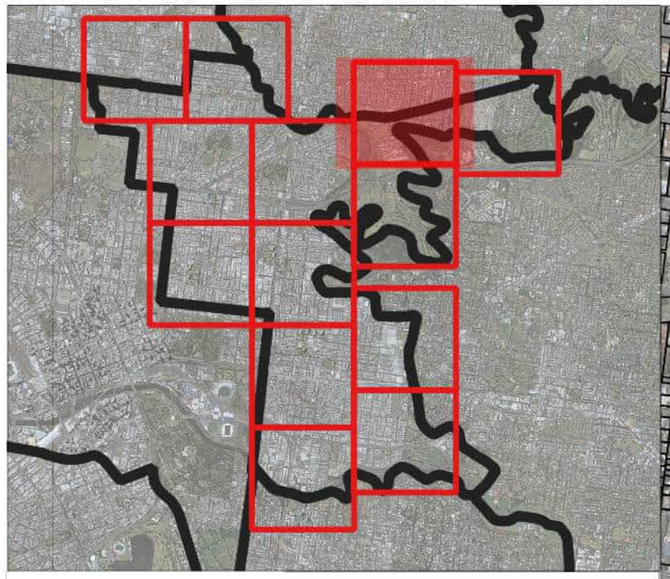
80 0 80 160 240 m

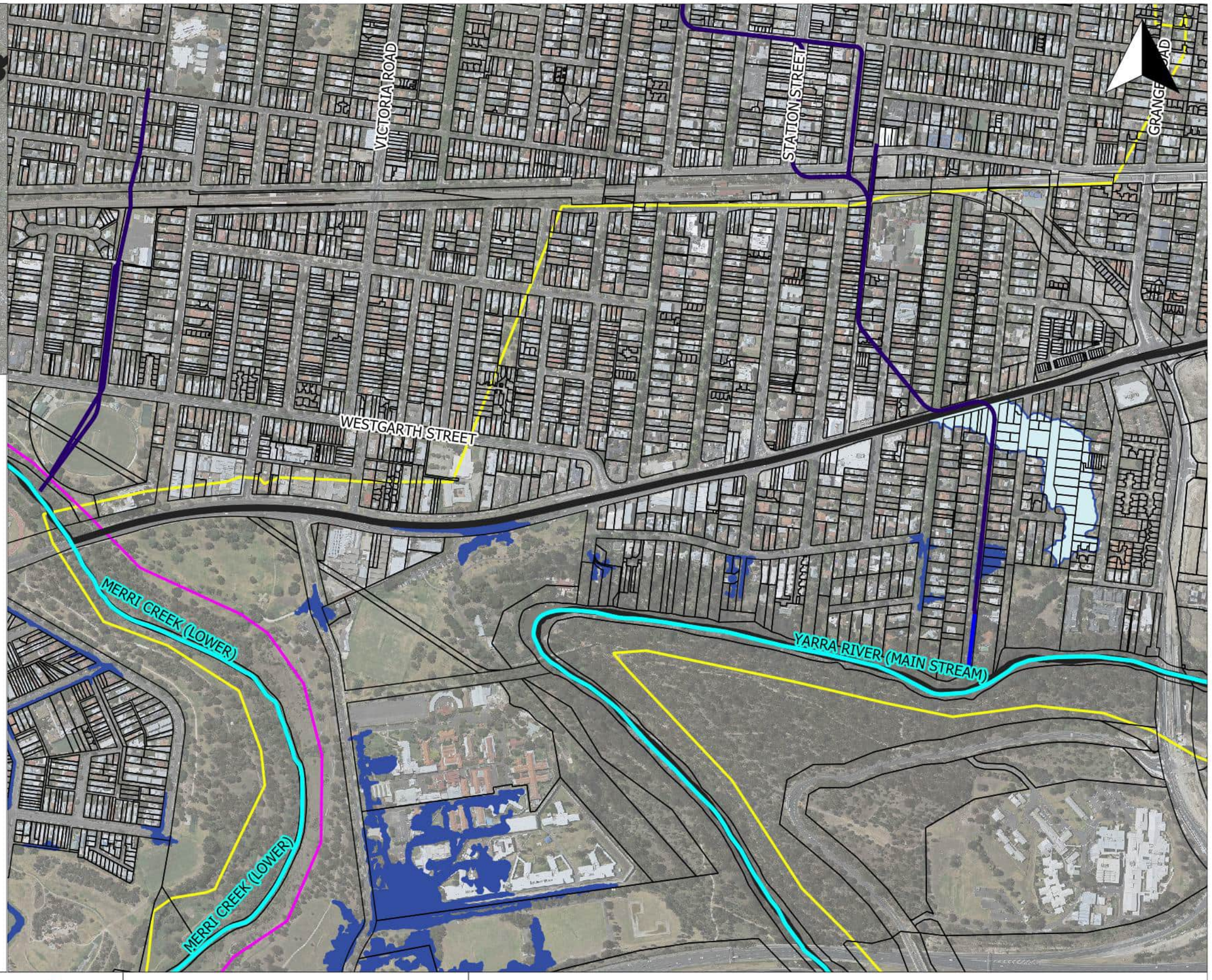
Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)





Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

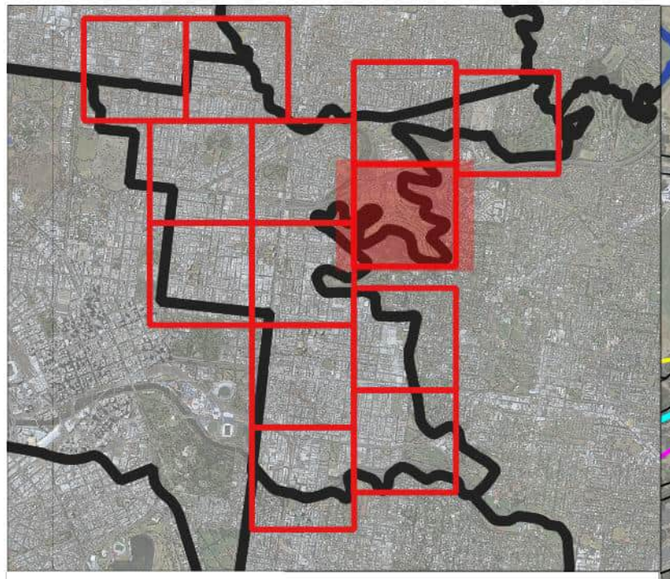
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

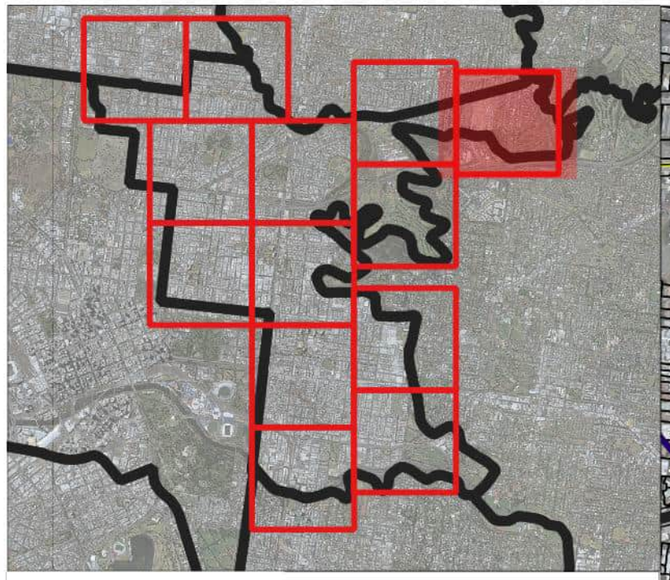
80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- ALEX Model TUFLOW Model Boundary
- FAIR Model TUFLOW Model Boundary
- RICH Model TUFLOW Model Boundary
- Melbourne Water Underground Drain
- Melbourne Water Natural Channel
- Melbourne Water Channel
- Flood Extent Council
- Flood Extent UG Drains

Level 43, Tenancy 2, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

CITY OF YaRRA

80 0 80 160 240 m

Scale in metres (1:6,800 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Yarra Flood Mapping

1 % AEP Flood Extent Climate Change (Scenario D)