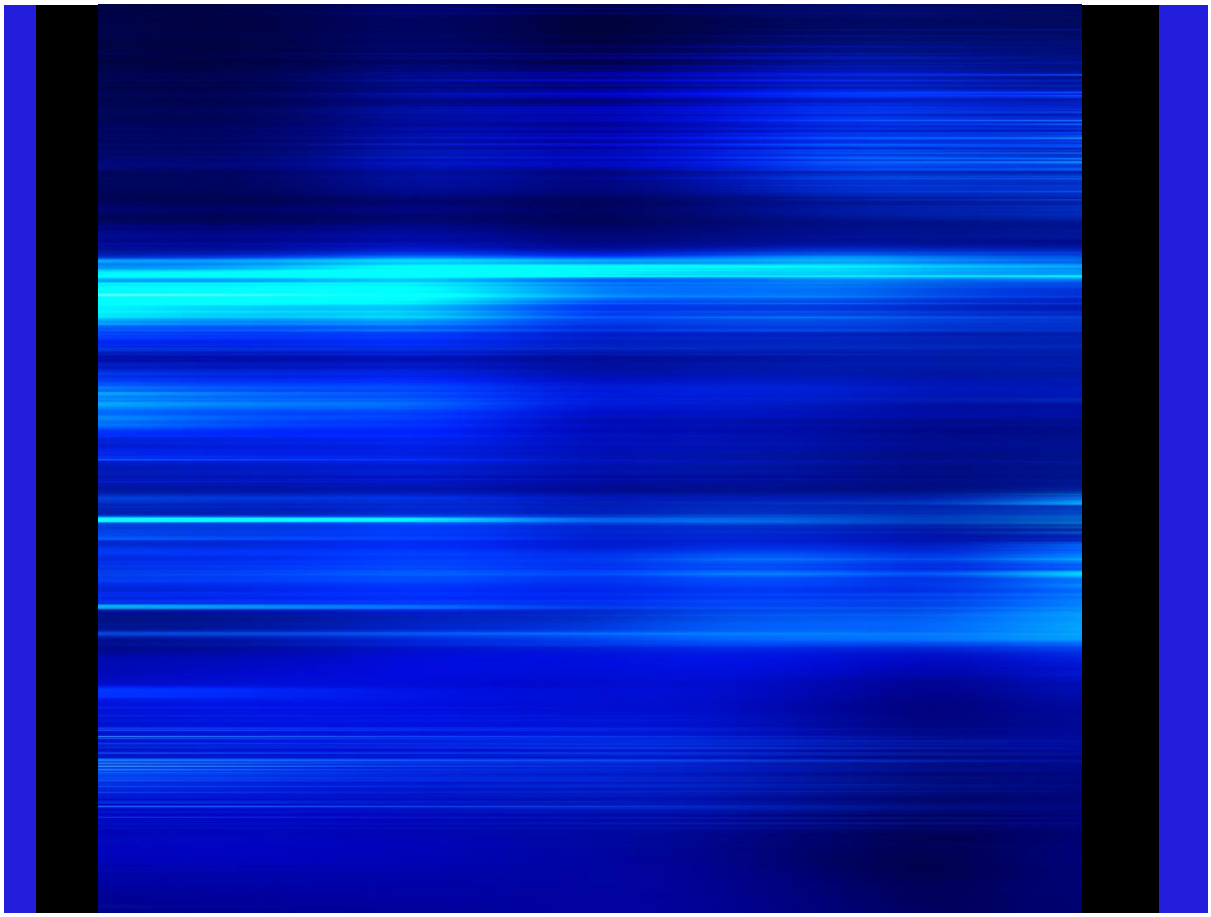
Melbourne Water Flood Mapping Project Hobsons Bay and Brimbank LGAs

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Melbourne Water Flood Mapping Study - Brimbank and Hobsons Bay
5 June 2026



Melbourne Water Flood Mapping Project Hobsons Bay and Brimbank LGAs

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Executive Summary

Jacobs was appointed by Melbourne Water to update flood information across the Hobsons Bay and Brimbank Local Government Area (LGA), located 5 to 25 km west and north-west of Melbourne's CBD. This project includes flood mapping and the generation of planning scheme-ready flood extents to update planning overlays within each LGA. The study presents the modelling approach and results of investigations undertaken on the catchments within the LGA.

The objective of this study is to support future decisions regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning. The hydrological and hydraulic modelling has been undertaken in general accordance with the Melbourne Water Flood Mapping Projects Specifications (AM STA 6200, October 2021) and the Australian Rainfall and Runoff 2019 guidelines (ARR 2019 Version 4.1). The climate change scenario adopted was RCP 8.5 (Section 3.5.6) which assumed an 18.5% increase in rainfall intensities for 2100. The adopted hydrological modelling software was RORB (Version 6.47), and the hydraulic software was TUFLOW (Version: 2020-10-AF). Models have undergone an independent peer review by an external consultant in line with the project requirements.

The project updates flood information across approximately 188 km^2 and incorporates a combination of council drainage networks, Melbourne Water main drains, retarding basins, and overland flow paths located within the Hobsons Bay and Brimbank LGAs. The Maribyrnong River, Skeleton Creek, Stony Creek, Cherry Creek, Laverton Creek and Kororoit Creek are waterways which interact with the study area. The Cherry Creek and Laverton Creek waterways have been modelled and mapped by this study. The Maribyrnong River, Skeleton Creek, Stony Creek and Kororoit Creek waterways have been included as boundary conditions in the hydraulic modelling and any flood extents along these waterways are not to be considered representative of the peak flood extent. Melbourne Water are undertaking separate studies for these waterways.

The study area includes several retarding basins and storage assets including the following retarding basins and storages: Cherry Lake retarding basin, Truganina Swamp retarding basin, Millennium retarding basin and Laverton Creek retarding basin. A number of Melbourne Water main drains are also located within the study area. Major infrastructure projects located with the study area are associated with road and rail infrastructure upgrades, specifically this includes the Deer Park Level Crossing Removal project.

TUFLOW HPC with sub-grid sampling was adopted for the hydraulic modelling. Modelled scenarios include the 1% Annual Exceedance Probability (AEP), the 1% AEP plus climate change scenario, and a range of frequent events, consistent with Melbourne Water's standard modelling approach.

The RORB and TUFLOW models were constructed from 2022 to 2026. The TUFLOW models were constructed based on data inputs provided in 2022. The models include the 2017/18 Greater Melbourne LiDAR dataset as a base model topographic data source. The Laverton TUFLOW model adopts project specific LiDAR captured in September 2023. The Kororoit South TUFLOW model also adopts a small area of project specific LiDAR along the Maribyrnong captured in August 2023. This was captured due to the significant change in landform compared to the 2017/18 LiDAR dataset. Manning's "n" values have been adopted to represent land use surface roughness throughout the model. Values have been adopted in accordance with the Melbourne Water Flood Mapping Projects Specifications (AM STA 6200, 2021) and inspection of aerial imagery from 2022. Site inspections were conducted to verify hydraulic structure details, confirm land use types and improve understanding of key flow paths across the study area. No feature survey was conducted as part of this study.

GIS flood mapping deliverables have been derived in accordance with the Melbourne Water Flood Mapping Projects Specifications (AM STA 6200, October 2021). As requested, the flood extents and subsequent GIS deliverables were filtered to a depth of 50 mm in Melbourne Water and Hobsons Bay Council areas. Deliverables were filtered to a depth of 100 mm in the Brimbank Council areas.

Hydraulic model performance checks were undertaken to the extent supported by available data and were designed to provide confidence in the model's representation of catchment response, rather than to achieve an exact reproduction of historical flood magnitudes.

The generated flood extents have been compared to available flood hotspot data, with the model outputs generally aligning well with the available hotspot information.

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Abbreviations and definitions

Terminology	Definition
1D Hydraulic Model	1-Dimensional hydraulic model where flood levels are determined by cross sections perpendicular to the flow path.
2D Hydraulic Model	2-Dimensional hydraulic model based on terrain/elevation data at a specified grid size. Capable of modelling floods across a floodplain where flow direction varies in space and time.
1D/2D Hydraulic Model	Coupled 1D/2D modelling, typically the floodplain would be represented in 2D and the main flow paths in 1D together with small scale hydraulic structures.
AEP	Annual Exceedance Probability. The probability that an event of a given size will be equaled or exceeded in a given year.
ARR 2019	2019 release of Australian Rainfall & Runoff Guidelines Version 4.1. Version 4.2 relates to changes to the guidelines primarily associated with climate change guidance (Book 1 chapter 6) released in 2024.
ARF	Areal Reduction Factor
BoM	Bureau of Meteorology
CL	Continuing Loss
DEECA	Victorian Department of Energy, Environment and Climate Action
DELWP	Victorian Department of Environment, Land, Water and Planning (now DEECA)
DEM	Digital Elevation Model
Design event	A theoretical flood event representing a specific likelihood of occurrence (for example the 1% AEP flood).
FFA	At-Site Flood Frequency Analysis
Flood depth	The height or elevation of floodwaters above ground level.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum).
GIS	Geographic Information System
HPC	TUFLOW functionality Heavily Parallelized Compute solver
Hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
Hydrograph	A time series of flow which changes at each timestep and naturally captures the peak flood flow.

Terminology	Definition
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
IL	Initial Loss
LGA	Local Government Area
LiDAR	Light Detection and Ranging is a remote sensing method that uses light in the form of a pulsed laser to measure distance to the Earth.
m AHD	Meters Australian Height Datum
m/s	Meters per second (a measure of speed/velocity)
m^3/s	Cubic meters per second (a measure of flow)
Manning's "n" value	A coefficient which represents the roughness of terrain on which water flows over.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
RB	Retarding Basin
RFFE	Regional Flood Frequency Estimate
RORB	Runoff routing computer model for hydrologic analysis of catchment runoff
SGS	Sub-Grid Sampling TUFLOW functionality
SES	State Emergency Services
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.
Velocity	The speed at which the floodwaters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section if a one-dimensional solution is used; and depth average if a two-dimensional solution is used.
Water Surface Elevation	Water Surface Elevation, the surface of the water at a given point.

1. Introduction

1.1 Study Overview and Objectives

The Melbourne Water 2022/2023 Flood Mapping Study Project – Brimbank and Hobsons Bay (the Study) – has been undertaken by Jacobs for Melbourne Water in order to update existing flood mapping extents and flood overlays within the region in accordance with the Melbourne Water Flood Mapping Projects Specifications (AM STA 6200, October 2021) and Australian Rainfall and Runoff (ARR 2019) guidelines.

The project drivers are to update Melbourne Water flood mapping information for the LGAs of Brimbank and Hobsons Bay, including flood mapping to represent Melbourne Water and Council drainage assets and overland flow paths. Key objectives of this flood mapping project include assessing the performance of the existing drainage network and identifying flood prone areas across the municipality. These objectives are addressed by the development of computer-based flood models which produce a range of outputs that can be utilised by Melbourne Water and Council.

1.1.1 Study Approach

The purpose of the study was to produce flood mapping products to support a variety of Melbourne Water business functions. The flood models underpin all study outcomes. The flood models for the Brimbank and Hobsons Bay LGAs combine an event-based hydrologic model (RORB) and a hydraulic model (TUFLOW).

RORB is a runoff and streamflow routing program that was used to calculate flood hydrographs from rainfall and catchment characteristics parameters. The model subtracts losses from rainfall to determine rainfall excess hydrographs across the modelling domain. RORB is a spatially distributed, non-linear model applicable to both urban and rural catchments. It accounts for both temporal and spatial distribution of rainfall depths and relies on catchment losses, catchment geometry, and routing data defined in a catchment file and the program. The event-based flood model was used to estimate flood flows for various probabilities of occurrence, enabling the assessment of flood risk.

The RORB outputs were then applied to the hydraulic model which calculates the extent, depth, velocity and other hydraulic properties. Seven (7) 2-D TUFLOW hydraulic models with embedded 1-D elements were developed for the Brimbank and Hobsons Bay LGAs. The mapping extent is illustrated in Figure 1-1 and Figure 1-2.

The flood mapping encompasses both LGAs, however excludes the mapping of the Maribyrnong River, Stony Creek, Kororoit Creek and Skeleton Creek. The flood extents associated with these waterways have been included as boundary conditions to the respective models. The flood mapping of these waterways is being completed in separate studies commissioned by Melbourne Water.

Cherry Creek and Laverton Main Drain are included in the flood mapping outputs for this Study.

1.2 Background

The Study area covers drainage catchments within the two municipalities of the City of Brimbank and City of Hobsons Bay Councils, the regions of which are presented in Figure 1-1 and Figure 1-2. The total area to flood map for this project is approximately 123 km^2 (Brimbank) and 65 km^2 (Hobsons Bay). The Study area also covers the municipalities of the City of Wyndham Council, Melton City Council, City of Hume Council, City of Maribyrnong Council and Moonee Valley City Council for catchments that overlap on the western, northern and eastern boundary of the Study municipalities. The Melbourne Water catchments modelled for the Study area are summarised in Table 1-1. The catchments include both Melbourne Water Main Drains/waterways and council drainage assets.

The catchments include a combination of Melbourne's river catchments which range from fully urban or industrial with large impervious areas and underground drainage networks, to fully rural forested areas in the upper reaches of the Maribyrnong and Kororoit Creek catchments.

Table 1-1: Melbourne Water catchments within the Brimbank and Hobsons Bay LGAs.

Catchment/model	Melbourne Water Catchments/Assets Overlapping the Model Catchment	
Maribyrnong River (4220)	4230 Steele Creek 4233 Airport West Drain 4234 Steele Creek North 4236 Keilor Park Drain 4240 Maribyrnong River (middle) 4242 Stenson Rd Drain 4250 Taylors Creek 4251 Kealba Park Drain 4252 Wanaka Dr Drain 4253 Agonis Dr Drain 4254 Sydenham Drain	4255 Honeyeater Cres Drain 4256 Victoria Rd Drain 4257 Sydenham West Drain 4260 Maribyrnong River (upper) 4265 Keilor M.D. 4268 Trib of Maribyrnong River 6801 Jacksons Creek 6804 Tame St Drain 6805 Trib of Tame St Drain 6806 Trib of 6805
Kororoit Creek (4110)	9880 Council Drainage Direct to Bay 4216 Sunshine M.D. 4217 Cumberland St Drain 4130 Kororoit Creek (Middle) 4131 Jones Creek 4132 Gladstone St Drain 4133 St Albans West Drain 4134 Furlong Rd Drain 4135 Station Rd North Drain 4136 Christie St Drain 4137 Billingham Rd Drain 4138 Kurung Park Drain 4146 Coalville Rd Drain 4104 Cherrys Diversion Drain 4110 Kororoit Creek (Lower) 4111 Trib of Kororoit Creek	4213 Francis St M.D. 4112 Fairbairn Rd Drain 4114 Chambers Rd Drain 4118 Kellaway St Drain 4119 Central Ave Drain 4120 Anderson Rd Diversion Drain 4193 Newport Workshops Drain 4121 Westmoreland Rd Drain 4122 St Albans East Drain 4123 St Albans South Drain 4124 Stony Creek (Upper) 4191 Blenheim Rd Drain 4192 Challis St M.D. 4190 Paisley Drain
Stony Creek	4202 Burleigh St Drain 4210 Stony Creek (Lower) 4212 Schutts Estate M.D. 4113 Millers Rd Drain 4115 Burgess St Drain	4116 Glengala Drain 4217 Cumberland St Drain 4248 Cumberland St Diversion Drain 9880 Council Drainage Direct to Bay

Catchment/model	Melbourne Water Catchments/Assets Overlapping the Model Catchment	
Laverton Creek (4080) (including Cherry Creek)	9883 Council Drainage Direct to Bay 4078 Notla Estate M.D. 4080 Laverton M.D. 4082 Campbells M.D. 4083 Thompson M.D. 4084 Dunes Drain 4085 Robinsons Drain 4088 Hohertys Drain 4089 Cropleys Drain 4090 Kayes Drain	4091 Laverton East M.D. 4092 Imms Drain 4097 Galvin Diversion Drain 4098 Mulga Ave Drain 4099 Nellie St M.D. 4100 Cherrys M.D. 4101 Brooklyn M.D. 4102 Humes M.D. 4103 Derrimut Drain
Skeleton Creek (4070)	4046 South Saltworks Moat 4047 Cheetham Creek	4070 Skeleton Creek 4071 Trib of Skeleton Creek

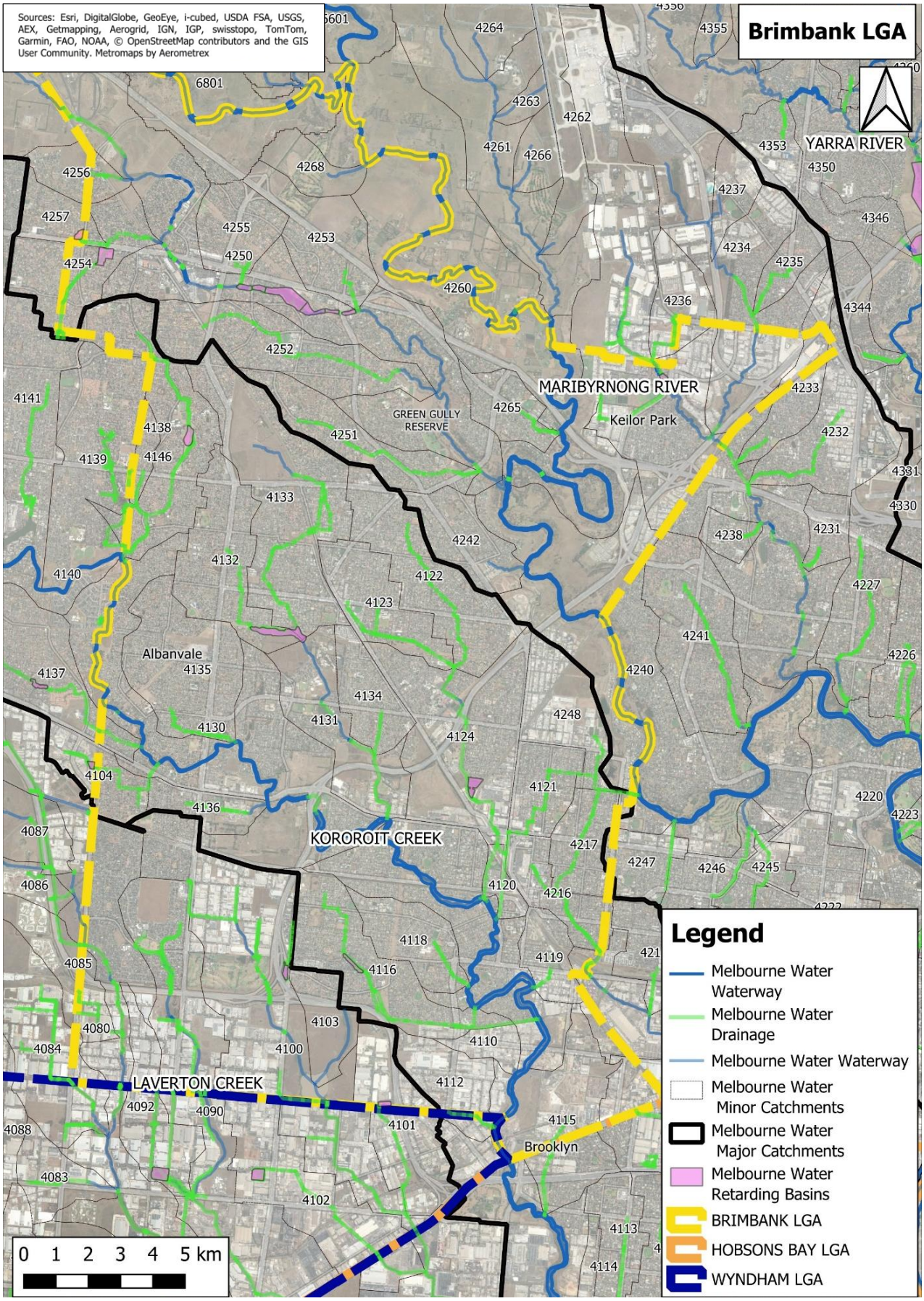


Figure 1-1: Brimbank Local Government Area (LGA) region of the Study area.

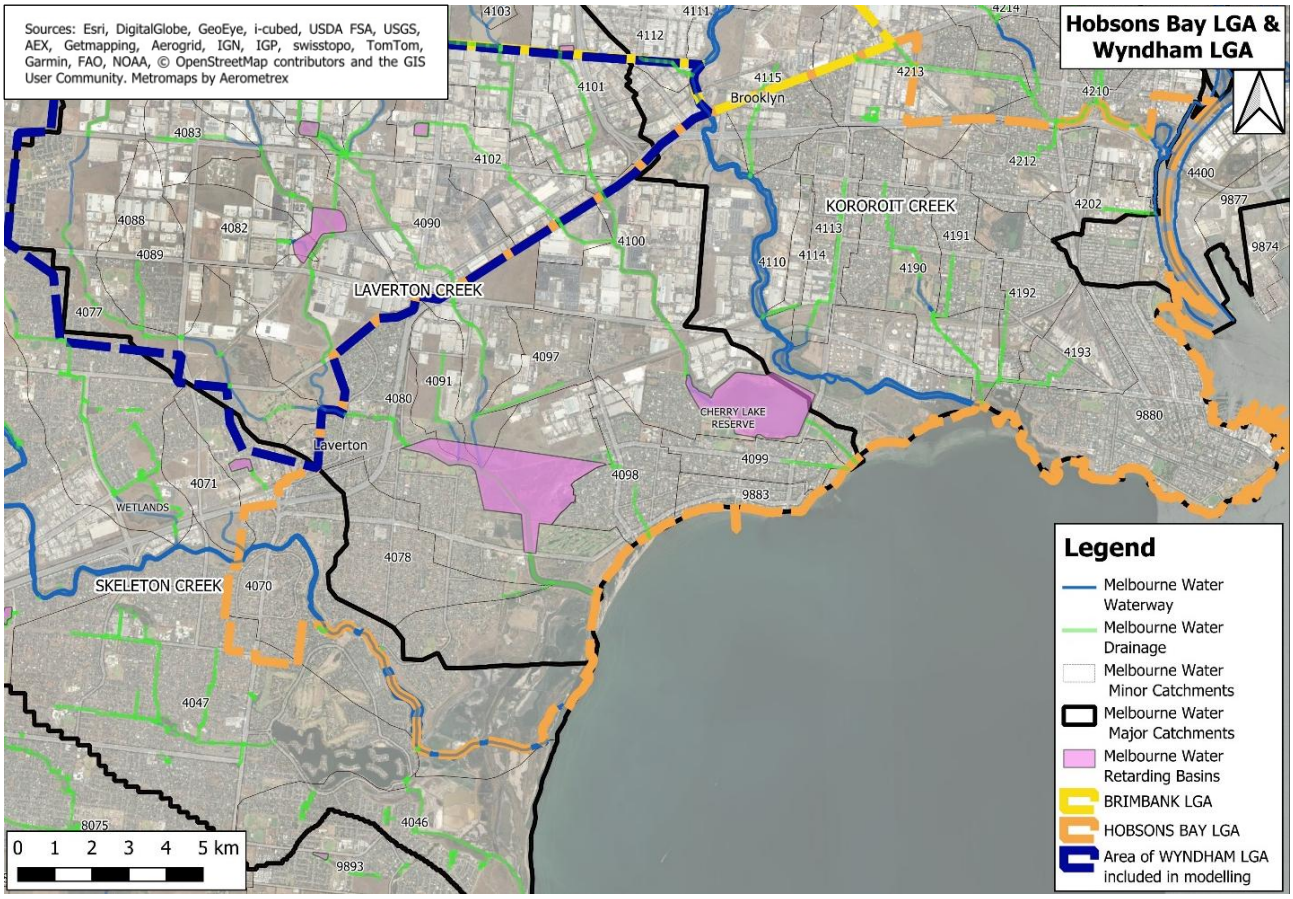


Figure 1-2: Hobsons Bay Local Government Area (LGA) and part of Wyndham LGA regions of the Study area.

1.2.1 Addition of part of Wyndham Council LGA

An area of Wyndham Council LGA area (approx. 35km^2) that falls within the Study catchment areas of Laverton, Cherry and Kororoit Creek was added into the project flood mapping scope after discussion and collaboration with Melbourne Water (Figure 1-2). The benefits of including this in the current Study were identified as follows:

- Took advantage of the opportunity to treat the additional areas holistically on a catchment scale.
- Allowed continuous modelling and mapping of assets within the Melbourne Water floodplain, providing continuity in flood extents, enhancing the value of current study deliverables.
- Improved efficiencies and cost benefits.
- Section of Wyndham area LGA flood mapped earlier than it would be as part of new study.

1.3 Report Layout

This report provides a summary of the data collation and the hydrologic and hydraulic modelling work undertaken for the Study. The report has been structured as follows:

- Section 2: Data Collection and Review.
- Section 3: Hydrologic Modelling:
  - Includes a summary of the hydrologic modelling completed, including description of project-wide approaches.
- Section 4: Hydraulic Modelling:
  - Includes a summary of the hydraulic modelling completed, including description of project-wide approaches
- Section 5: GIS Deliverables:
  - An overview of the storm events modelled, and details of GIS deliverables that have been provided as per Melbourne Water Flood Mapping Projects Specifications.
- Section 6: Recommendations:
  - An outline of some of the key possible limitations, assumptions, and recommendations for future work.
- Technical Appendices (Appendices A-G):
  - A technical Appendix has been provided for each RORB model (7 in total) and each TUFLOW model (7 in total).
  - These describe the catchment-specific technical details for the development and results of each RORB model, including calibration, Flood Frequency Analysis if applicable. Technical details of the catchment relating to the TUFLOW model are also presented here
  - Whilst each technical Appendix should be read in conjunction with the main body of this report, it can also be read independently from other technical Appendices.
- Supplementary information Appendices (Appendices H-N):
  - IFD (Intensity-Frequency Duration) data, DataHub outputs, RORB subarea impervious fractions and RFFE outputs;
  - Site Visit photos (Site photos has been removed due to privacy considerations)
  - Model sensitivity testing.
  - Model performance.

1.4 Assumptions and Limitations

The sole purpose of this report and the associated services performed by Jacobs is to undertake a local flood assessment for the Brimbank and Hobsons Bay LGA catchment area, in accordance with the scope of services set out in the contract between Jacobs and Melbourne Water (the Client). As described in this report, the scope of services was developed with the Client.

In preparing this report, Jacobs has relied upon and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate, or incomplete, then it is possible that our observations and conclusions, as expressed in this interim report, may change.

Jacobs derived the data in this report from information sourced from the Client, third parties, and/or available in the public domain at the time or times outlined in this interim report. The passage of time, manifestation

of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations, and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full, and no excerpts are to be taken as representative of the final findings. Jacobs accepts no responsibility for using any part of this report in any other context.

Topographic data used in this study includes that sourced from the 2017/2018 LiDAR, which was carried out by third parties and provided by Melbourne Water for the use of this project. Undertaking independent checks on the accuracy of the topographic data was outside Jacobs's scope of work for this study, except where otherwise stated in the report.

The sole purpose of the flood modelling undertaken for this report is to define flood behaviour across the study area. Flood extents and flood behaviour around the boundary of the TUFLOW hydraulic model domain should be interpreted with caution.

This report has been prepared on behalf of, and for the exclusive use of, Melbourne Water, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Melbourne Water. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

The assumptions and limitations associated with the Study are as follows:

- The best available information with regards to RORB storages and retarding basins has been used in this Study. No site inspections have been completed on structures or retarding basins were undertaken for this study. Where it was not possible to verify storage-discharge and/or height-storage details provided in existing RORB models, they were assumed to be correct and appropriate for use in the RORB models developed for this Study.
- The naming of subareas, reaches and nodes has not been updated in those areas of the Study models where previous model structure was retained.
- The Laverton Creek RORB modelling and hydrology was not updated using new LiDAR collected for the project in September 2023. This agreement was reached in collaboration with Melbourne Water to minimize unnecessary re-work given the minimal risk of impact on final deliverables (rainfall excess hydrographs are the main input of flows into the Laverton Creek TUFLOW model, which would be unaffected by updates in LiDAR).
- A comprehensive list of individual hydraulic structures and assets in the Study area has been compiled, that listed assumptions to be adopted in the absence of information/data relating to them. This was provided to Melbourne Water and assumptions confirmed as appropriate.
- Most of the hydrological modelling for this project was completed, reviewed and approved between late 2022 and early 2023. As such the works completed in this study for the Maribyrnong River are superseded by the hydrological assessment completed by Jacobs for the Lower Maribyrnong River Flood Mapping Study which was completed in 2024.

2. Data collection and review

This section documents the data collected and reviewed for the Study.

2.1 Guidelines and Specifications

The following should be referred to in conjunction with this report:

- Melbourne Water (October 2021) AM STA 6200 Flood Mapping Projects Specification October 2021:
  - It is noted that the adopted tailwater conditions in the hydraulic modelling aligns with the August 2023 version of the AM STA Flood Mapping Projects Specifications.
- Australian Rainfall and Runoff: A Guide to Flood Estimation 2019 (ARR19).

2.2 Previous Flood Studies

Previous flood studies were undertaken within the Study area, as listed in Table 2-1.

Table 2-1: Previous flood studies.

Study	Service provider & date	Alignment with this Study	Comment
Hobsons Bay Flood Modelling	Cardno, 2018	Flood modelling (RORB & TUFLOW) completed for LGA of interest in this Study.	Reporting documents, MiRORB files and TUFLOW models received for this work. Some of the TUFLOW model were reviewed and adopted for use in this Study, including the pit and pipe data, which required some updates (see Section 4.2.7). Council confirmed this data was suitable for use in the current Study and the reporting notes that much of the drainage information was based on survey undertaken in 2019. Absence of RORB model files meant that it was impossible to re-run RORB models and re-produce/compare results for the current Study.
Hobsons Bay Flood Modelling Update Project	Cardno, 2019	Flood modelling update of Cardno 2018 study (RORB & TUFLOW) completed for LGA of interest in this Study.	
Taylors Creek Review of Flood Mapping for Kings Road and Water Garden Shopping	Melbourne Water, 2013	Mapping project used a previous RORB model to estimate discharges to Taylors Creek, located in the Study area.	The retarding basin data from this RORB model was adopted for use on the current Study.
Various major infrastructure project hydrological studies	Rail Projects Victoria (RPV), various	Hydrological (RORB) studying covering catchments in the Study area.	Eight existing RORB models were identified and provided for use in this Study. Details are provided in Section 3.1.

2.3 Available Data

This section summarises the data that was utilised to inform this flood mapping Study and the investigations undertaken to confirm the data was fit for purpose.

2.3.1 Topographical Data

The following topographical data was available for the Study.

- 2017/18 LiDAR DEM with 1m grid resolution covering the Study area (stated vertical accuracy of 0.1m).
- Survey data of Melbourne Water structures received from Melbourne Water.
- Bespoke LiDAR flown in September 2023 as part of new data acquisition for this project covering the Laverton Creek catchment. This was flown following large areas of the catchment being identified as having undergone development (including some waterway re-routing), which meant they were no longer well-represented in the 2017/18 LiDAR dataset:
  - 1m DEM created from 5 points per square metre airborne LiDAR, using manual and automated ground and non-ground classification.
- Bespoke LiDAR flown in August 2023 as part of new data acquisition for the Lower Maribyrnong flood mapping project (Jacobs, 2024). This was adopted for the area along the banks of the Maribyrnong River which had been identified as undergoing development with significant earthworks changes from the 2017/18 LiDAR dataset.)

2.3.2 Hydraulic Structures and GIS Data

Hydraulic structures across the Study area are managed by several government agencies. The quality and application of this data is discussed further in the hydraulic modelling section of this report. The data received for use in this Study is listed in Table 2-2.

Table 2-2: Hydraulic structures and GIS data used in the Study.

Source	Data	Quality/Comments
Melbourne Water	▪ Underground drainage network ▪ Waterways/channel network ▪ Retarding basin data (including GIS and as-built data/ inspection reports, where available) ▪ Levee and embankment data ▪ Melbourne Water owned data of area wide council drainage network ▪ Surrounding councils' drainage network data (Wyndham, Melton, Moonee Valley and Maribyrnong Councils) ▪ SES flood hotspot GIS data	▪ Appropriate for use in Study ▪ Further details on retarding basins can be found in the Technical Appendices A-G ▪ Melbourne Water-owned council drainage network to be used in the absence of Council owned asset data ▪ Hume Council drainage network not received at time of writing
City of Brimbank	▪ Underground drainage network ▪ Bridge and culvert locations ▪ WSUD data	Underground drainage network data requires pre-processing and infilling to address data gaps/errors prior to use.
City of Hobsons Bay	*Determining Catchments for Hobsons Bay City Council* Data (GRACE, 2022) including: ▪ Catchments GIS data ▪ Roofs GIS data ▪ Council flood mapping data, including flood extents and level of service drainage network data outputs from Cardno (2018 and 2019) flood study (see Table 2-1) ▪ Drainage design drawings provided by Hobsons Bay Council on 04/12/2025	▪ Application of GRACE (2022) data limited for use in this Study (not applicable to RORB or TUFLOW). ▪ Used to infill data gaps in underground drainage data
Victorian Spatial Data online portal	Planning scheme zones – used to define catchment land use for determination of fractions impervious and materials layers Property parcels – used for application within the materials layer	–

2.3.3 Gauge data

Several rainfall and streamflow gauges are located within the Study area and Study catchments. This data was made available by Melbourne Water unless otherwise stated. The gauge data was used to carry out calibration of the hydrological models developed for the Study (full details can be found in the Technical Appendices A-G).

2.3.3.1 Rainfall

The rain gauges located in the Study area are listed in Table 2-3.

Table 2-3: Rain gauge data for the Study area.

Catchment	Station	Data type	Period of record	Comment
Maribyrnong	230105A – Maribyrnong at Keilor	Sub–daily (6 min)	1975-Current	Used in hydrologic model calibration Data received for the recent event (13-14th October 2022) at this gauge has not been quality checked (by the collecting Agency) given its recency. Data quality assumed acceptable for this Study
Maribyrnong	230105A – Maribyrnong at Keilor	Daily Max	1975-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Maribyrnong	587117 – Romsey Rain Gauge	Sub–daily (6 min)	1976-Current	Used in hydrologic model calibration
Maribyrnong	587117 – Romsey Rain Gauge	Daily Max	1976-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22
Maribyrnong	587126– Mount Macedon Rain Gauge	Sub–daily (6 min)	1999-Current	Used in hydrologic model calibration
Maribyrnong	587126– Mount Macedon Rain Gauge	Daily Max	1999-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Maribyrnong	230100A – Deep Creek at Darraweit Guim	Sub–daily (6 min)	1976-Current	Used in hydrologic model calibration
Maribyrnong	230100A – Deep Creek at Darraweit Guim	Daily Max	1976-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Maribyrnong	230103A – Jacksons Creek at Rosslynne Reservoir Head Gauge	Sub–daily (6 min)	1978-Current	Used in hydrologic model calibration
Maribyrnong	230103A – Jacksons Creek at Rosslynne Reservoir Head Gauge	Daily Max	1978-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Maribyrnong	230104A – Jacksons Creek at Sunbury Road Sunbury	Sub–daily (6 min)	1976-Current	Used in hydrologic model calibration

Catchment	Station	Data type	Period of record	Comment
Maribyrnong	230104A – Jacksons Creek at Sunbury Road Sunbury	Daily Max	1976-Current	Used in hydrologic model calibration (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Stony/ Kororoit	230112A – Stony Creek at Spotswood	Sub–daily (6 min)	1999-Current	Used in hydrologic model calibration. Gauge is located near the intersection of the Westgate Freeway near Williamstown Road.
Stony	587004 – Sunshine Rain Gauge	Sub–daily (6 min)	1981-Current	Used in hydrologic model calibration
Kororoit	230112A – Stony Creek at Spotswood	Daily Max	1999-Current	Used in hydrologic model calibration. Gauge is located near the intersection of the Westgate Freeway near Williamstown Road (downloaded from https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ on 29/09/22)
Kororoit	231106A – Kororoit Creek at Holden Road Diggers Rest	Sub–daily (6 min)	1980-Current	Used in hydrologic model calibration
Kororoit	231106A – Kororoit Creek at Holden Road Diggers Rest	Daily Max	1980- Current	Used in hydrologic model calibration (downloaded from https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ on 29/09/22)
Kororoit	231107A – Kororoit Creek at Brooklyn	Sub–daily (6 min)	1980-Current	Used in hydrologic model calibration
Kororoit	231107A – Kororoit Creek at Brooklyn	Daily Max	1980-Current	Used in hydrologic model calibration (downloaded from https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ on 29/09/22)
Kororoit	231104A – Kororoit Creek at Millbank Drive Deer Park	Sub–daily (6 min)	1980-Current	Used in hydrologic model calibration
Kororoit	231104A – Kororoit Creek at Millbank Drive Deer Park	Daily Max	1980-Current	Used in hydrologic model calibration (downloaded from https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ on 29/09/22)
Kororoit	231105B – Kororoit Creek at Leakes Road Rockbank	Sub–daily (6 min)	2006-Current	Used in hydrologic model calibration
Kororoit	231105B – Kororoit Creek at Leakes Road Rockbank	Daily Max	2006-Current	Used in hydrologic model calibration (downloaded from https://www.melbournewater.com.au/water-data-and-education/rainfall-and-river-levels#/ on 29/09/22)

2.3.3.2 Streamflow

The streamflow gauges located in the Study area are listed in Table 2-4.

Table 2-4: Streamflow gauge data for the Study area.

Catchment	Station	Data type	Period of record	Comment
Maribyrnong	230105A – Maribyrnong at Keilor	Sub–daily (6 min)	1975-Current	Used in hydrologic model calibration. Gauge is located within Brimbank LGA.
Maribyrnong	230105A – Maribyrnong at Keilor	Daily Max	1975-Current	Used in hydrologic model calibration – see Appendix A for more details. (downloaded from http://www.bom.gov.au/waterdata/ on 29/09/22)
Stony	230112A – Stony Creek at Spotswood	Sub–daily (6 min)	1999-Current	Used in hydrologic model calibration. Gauge is located near the intersection of the Westgate Freeway near Williamstown Road. Supplied by Melbourne Water for this Study.
Stony	230112A – Stony Creek at Spotswood	Daily Max	1999-Current	Used in hydrologic model calibration. Gauge is located near the intersection of the Westgate Freeway near Williamstown Road
Kororoit	231107A – Kororoit Creek at Brooklyn	Sub–daily (6 min)	1980-Current	Used in hydrologic model calibration
Kororoit	231107A – Kororoit Creek at Brooklyn	Daily Max	1980-Current	Used in hydrologic model calibration
Kororoit	231104A – Kororoit Creek at Millbank Drive Deer Park	Sub–daily (6 min)	1980-Current	Used in hydrologic model calibration
Kororoit	231104A – Kororoit Creek at Millbank Drive Deer Park	Daily Max	1980-Current	Used in hydrologic model calibration

2.3.4 Historic information

Information on historic flooding within the Study LGAs has been used where available in the Flood Frequency Analysis conducted and to validate the hydrological modelling for the Study.

An extensive review of historic flooding along the Maribyrnong River has been carried out as part of the Flood Frequency Analysis undertaken for the Study, detailed in Appendix A. In addition, known flooding hotspots have been provided by Brimbank and Hobsons Bay Councils (SES hotspot data). Flooding hotspots are compared to the flood model outputs in Section 4.2.13.

2.3.5 Site visits

Three project site visits were undertaken by Jacobs in early 2023:

- 21 February 2023 – Hobsons Bay site visit – attended by Jacobs, Melbourne Water and Council staff.
- 27 March 2023 – Brimbank site visit – attended by Jacobs, Melbourne Water and Council staff.
- 15 May 2023 – Wyndham site visit – attended by Jacobs and Council staff.

Key areas of interest were inspected to confirm hydraulic structures, identify land use types and gain a better understanding of conditions across the catchments and major waterways. Site visit photos are provided in Appendix H (Appendix H is not included in the report due to privacy considerations).

3. Hydrologic modelling

The purpose of hydrologic modelling is to convert rainfall to runoff for a given probability, that then provides the flow time series for input to the hydraulic model. For this Study, the hydrologic modelling software RORB Version 6.47 was used. RORB is a widely recognised software package across Victoria that has the ability to incorporate inputs from ARR 2019. Rainfall excess outputs from RORB have been used in the TUFLOW models. Routed inflows are also adopted as boundary inflows into the TUFLOW models.

This section provides an overview of the approach used in the development of the hydrologic models across the Study area and summarises the key input parameters. Full technical details for the development of each RORB model are documented in technical Appendices as listed in Table 3-1.

Table 3-1: Catchment-specific technical Appendices detailing model development.

Catchment	Technical Appendix
Maribyrnong River	Appendix A
Kororoit Creek	Appendix B
Stony Creek	Appendix C
Cherry Creek	Appendix D
Laverton Creek (includes Kayes Drain)	Appendix E
Skeleton Creek	Appendix F
Sub catchment 9880 – Council Drainage Direct to Bay	Appendix G

3.1 Previous RORB modelling

Eight existing RORB models were identified and provided for use in this Study, as listed in Table 3-2. The models were reviewed and updated to ensure they are 'fit for purpose' and align with the guidance provided in the Flood Mapping Projects Specifications and ARR 2019.

Table 3-2: Existing RORB models identified for use in the Study area, and their access status at the time of writing.

RORB model	Source	Comments
Maribyrnong River	RPV – Melbourne Airport Rail (2020)	Rail Projects Victoria (RPV) granted permission for the use of the RORB models originally developed for their purposes on the current project. Full RORB models (including GIS and RORB model files) and reporting accessed, updated and/or extended to cover the entire Study area. Upon review of this information, it was found that these models could not be adopted 'as received'. Considerable updates were required to ensure models were fit for purpose for this Study.
Steele Creek	RPV – Melbourne Airport Rail (2020)	
Stony Creek	RPV – Melbourne Airport Rail (2021)	
Kororoit Creek	RPV – Geelong Fast Rail (2020)	
Cherry Creek	RPV – Geelong Fast Rail (2021)	
Laverton Creek and Kayes Drain	RPV – Geelong Fast Rail (2020)	
Skeleton Creek	RPV – Geelong Fast Rail (2020)	
Hobsons Bay region assumed Yarra catchment	Cardno (2018)	MiRORB GIS data only provided by Hobsons Bay City. Full RORB model files not provided.

3.2 Approach

The overall modelling approach utilised rainfall-runoff models developed in RORB according to ARR 2019 and the Melbourne Water Flood Mapping Projects Specifications to generate rainfall excess hydrographs at a sub-catchment scale across the Brimbank and Hobsons Bay LGAs. These rainfall excess hydrographs

were then incorporated into hydraulic models (TUFLOW). In some cases, a RORB routed hydrograph from a catchment external to the relevant LGA were added as an inflow boundary to the TUFLOW models.

Where practical, calibration of historic storm events has been undertaken using streamflow gauge data to determine routing parameters for given models and develop appropriate losses for the Study. Following acceptable RORB model calibration and/or validation, design floods have been simulated in the RORB and TUFLOW models for the required scenarios utilising the parameters adopted in the calibration/validation stage and in line with the Flood Mapping Projects Specifications.

3.3 Study RORB Models

Upon review of available data and existing RORB models provided for use in the Study, the Maribyrnong River and Steele Creek models were combined into one model. The remainder of the models have been retained as standalone RORB models. This approach was chosen to best facilitate model calibration/validation, optimise RORB model runs and provide a valuable product that can be used again in the future by Melbourne Water. Seven RORB models were therefore developed to cover the Study area, as listed in Table 3-3 and shown in Figure 3-1. Where necessary, RORB models have been extended to Port Phillip Bay to ensure they cover the Study area.

Table 3-3: RORB models for the Study.

RORB model	Description
Maribyrnong River	Area: 1409 km^2 The catchment primarily consists of rural/regional land use upstream of Keilor Township and urban/impervious/heavily modified land use downstream of Keilor. Whilst the Maribyrnong River catchment extends to the Yarra River, the area of interest for this Study only extends as far as the Avondale Heights/Braybrook area. This was used to define the RORB modelling extent for the current Study. At this location, the Maribyrnong River catchment is made up of the smaller catchments of Deep Creek, Emu Creek, Jacksons Creek, Taylors Creek and Steele Creek. The stream gauge Maribyrnong at Keilor (230105A) was used to calibrate the model.
Kororoit Creek	Area: 298 km^2 The Kororoit Creek catchment is a peri-urban catchment, west of Melbourne. The catchment primarily consists of rural/regional land use upstream of Deer Park and urban/impervious/heavily modified land use downstream Deer Park. There are two streamflow gauges located on Kororoit Creek; Deer Park (231104) and Brooklyn (231107) that have been used to calibrate the model. The Kororoit Creek catchment model includes an area that overlaps with the Stony Creek model due to the presence of diversions that transfer flow out of the Stony Creek catchment and into Kororoit Creek.
Stony Creek	Area: 35 km^2 The Stony Creek is an urban catchment to the west of Melbourne. The catchment primarily consists of urban/impervious/heavily modified land use. The only stream gauge located on Stony Creek is situated at Spotswood (230112A). The gauge is owned and operated by Melbourne Water and was established in 1998 near Benbow Street. This gauge is of relevance to this Study for RORB model calibration purposes, given its location within the Hobsons Bay Council LGA. The Stony Creek catchment model includes an area that overlaps with the Kororoit Creek model due to the presence of diversions that transfer flow out of the Stony Creek catchment and into Kororoit Creek.

RORB model	Description
Cherry Creek	Area: 25 km^2 The Cherry Creek catchment is a largely urban and industrial catchment with some localised regions of pervious areas, west of Melbourne which sits between the Kororoit Creek and Laverton Creek catchments. The catchment contains the Humes Main Drain and Brooklyn Main Drain which feed into Cherry Creek. The catchment contains several storage areas including two natural wetlands, Lake Stanley and Cherry Lake. There are no streamflow gauges in the catchment and therefore there is limited information to calibrate or validate flows against. Model calibration was therefore not carried out for the Cherry Creek catchment as part of this Study. The model outputs were instead verified through validation against regional estimates.
Laverton Creek (includes Kayes Drain)	Area: 66 km^2 The Laverton Creek catchment is a peri-urban and industrial catchment with some localised regions of pervious areas, west of Melbourne which sits between the Cherry Creek and Skeleton Creek catchments. The catchment contains the Kayes Drain catchment which feeds into Laverton Creek. Much of the urban catchment on the northern and eastern side of the catchment is zoned for industrial land use, and much of the rural areas are within the Urban Growth Zone and will be developed in the future (existing conditions considered in the current Study). There are no streamflow gauges in the catchment and therefore there is limited information to calibrate or validate flows against. Model calibration could therefore not be carried out for the Laverton Creek catchment as part of this Study. The model outputs were instead verified through validation against regional estimates.
Skeleton Creek	Area: 119 km^2 The Skeleton Creek catchment is located west of Melbourne and covers areas of urban development as well as less developed agricultural areas further north. Only a small portion (approx. 5 km^2) of the Skeleton Creek catchment falls within the Hobsons Bay area of interest for this Study (no interaction with Brimbank LGA). The key outputs of the RORB modelling will be excess rainfall hydrographs for subareas within the LGA and tailwater levels for Skeleton Creek in the TUFLOW hydraulic models for the catchment area. There is a streamflow gauge located within the catchment on the main reach of Skeleton Creek (Skeleton Creek at Sayers Road Hoppers Crossing (231110A)), however this gauge is significantly upstream of the Study area. Given the distance of the gauge to the Study area and that the current Study will not utilise routed flows, model calibration to observed streamflow data at Sayers Road was not completed as part of this work. The model outputs were instead verified through validation against regional estimates and checks against a previous study's FFA.
Sub catchment 9880 – Council Drainage Direct to Bay	Area: 6 km^2 Small area that includes the urban areas of Williamstown and Newport. The model area is comprised of local council drainage that drains to Port Phillip Bay, with no major surface water channels. As such, excess rainfall hydrographs (no routed flows) have been extracted from this model.

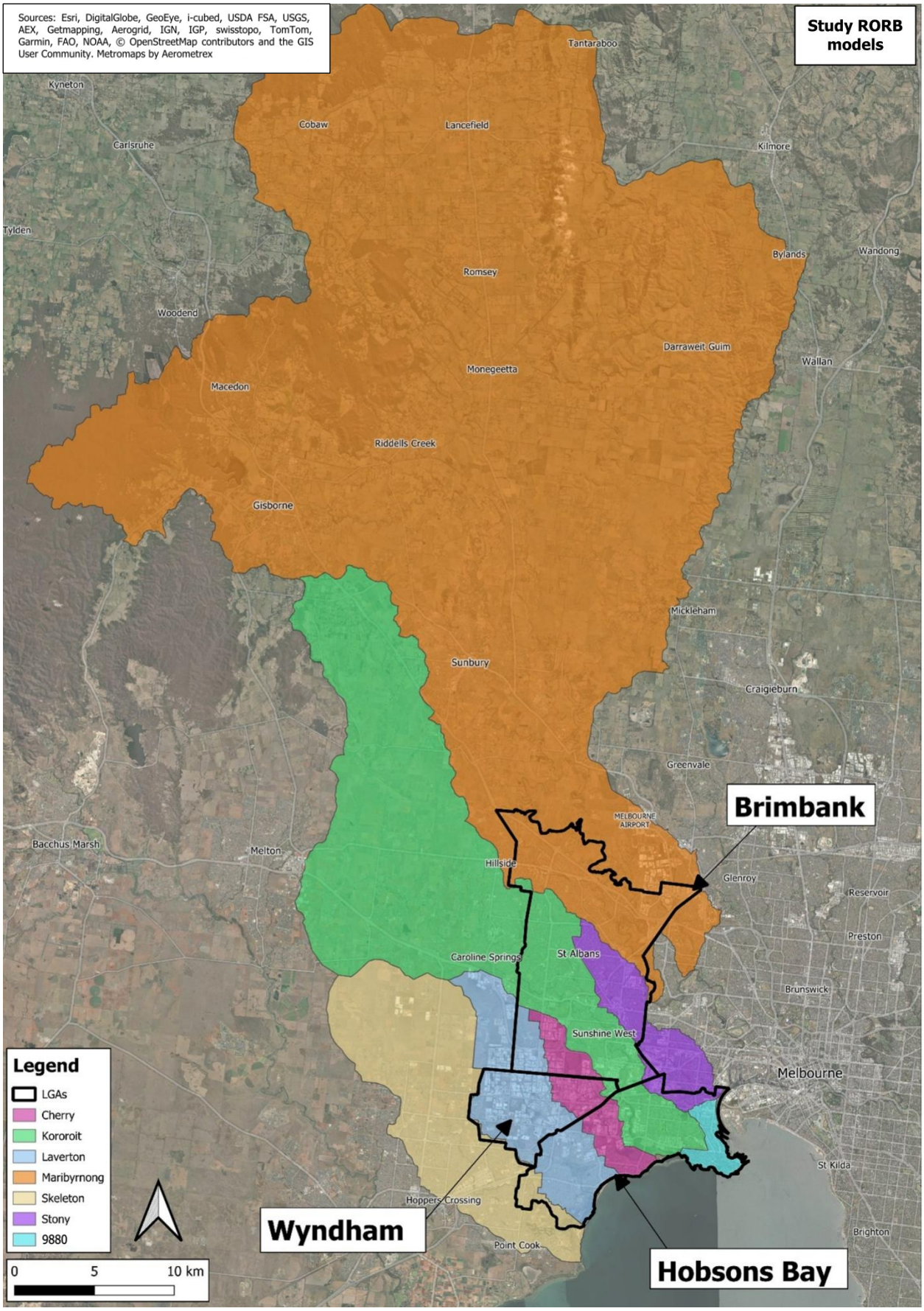


Figure 3-1: Study RORB models.

3.3.1 RORB model setup

The Study RORB models' setup was generally based on existing RORB models and associated GIS files. A summary of changes is as follows:

- The existing GIS files for the catchment and subareas were reviewed against VicMap LiDAR (DELWP, 2017/2018) and aerial imagery, with adjustments made where necessary, including edge-matching to neighboring catchments.
- A review of existing RORB models identified the need to re-delineate large areas, particularly those falling within the LGAs of interest, to reduce and standardise subarea size in preparation for extraction of hydrographs for input into TUFLOW. RORB models were built to provide a consistent, high resolution subarea breakdown across the LGAs of interest. For the Study's larger RORB models (Maribyrnong River and Kororoit Creek), interstation areas (ISA) were added at locations where subarea size changes, to cater for flows in the rural/upstream parts of the model.
- Where adjustments or RORB model extensions were required, catchment delineation was based on a combination of surface topography, watershed analysis in QGIS and alignment of existing pit and pipe networks. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas or large storage areas. The combined approach (topography, RoG model results and pipe alignment) allowed the identification of catchment and sub-catchment areas as well as flow path interactions in the Study areas.
- Catchment delineation considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.
- The reaches and node-link network of existing RORB models were reviewed and updated using project LiDAR where required to meet the ARR 2019 Guidelines and Flood Mapping Projects Specifications.
- Storages present in the existing models have been reviewed and retained where appropriate. Storage details were checked against up-to-date information provided by Melbourne Water where available (i.e. details of retarding basins, etc.). Storages or drainage scheme assets that have not yet been constructed have not been included in the RORB models developed.
- Diversions present in the existing RORB models were reviewed and retained where appropriate.

3.4 Site-Wide Impervious Fractions

ARR 2019 and the Melbourne Water Flood Mapping Projects Specifications identify three types of land use with respect to impervious area, these are:

- **Effective Impervious Area (EIA) or directly connected areas (DCA)** – these are considered to be impervious areas that are directly connected to a drainage path. These areas have low losses; typically, 1mm for initial loss and 0mm/hr for continuing losses. This area is the same as Effective Impervious Area.
- **Indirectly connected area (ICA)** – these are considered to be a combination of impervious areas not connected directly to a drainage path and other pervious areas such as gardens etc. These areas have initial losses that are typically a proportion of 0.6 - 0.8 of pervious initial losses and continuing losses that are between 1 and 3 mm/hr.
- **Pervious areas (PA)** – these are considered to be large open space, rural or forested areas. These areas have losses that are the same as the rural losses.

To determine the impervious fractions, the procedure outlined in the Melbourne Water Flood Mapping Projects Specifications was followed. The planning zone mapping layers were obtained for the Study area and land use types were assigned a Total Impervious Area (TIA) value in-line with those presented in the Flood

Mapping Projects Specifications This is presented in Table 3-4 and Figure 3-2 – Figure 3-4. Aerial imagery was used where no value was provided such as special use zones.

The EIA was then calculated by factoring the TIA using the relationship specified in the Melbourne Water Flood Mapping Projects Specifications, in most cases, EIA = 0.6 x TIA, linearly increasing to 1 for TIAs above 80%.

The ICA and PA were determined based on the following logic:

- If a pervious area was identified: ICA = TIA – EIA.
- If no pervious area was present: ICA = 1 – EIA.

The Pervious Area (PA) was then determined as:

- PA = 1 - TIA (if pervious area was present).
- PA = 0 (if no pervious area was present).

This approach ensures the sum of EIA, ICA, and PA for each land type equals 1.

The weighted average EIA, ICA and PA values for each sub-catchment were determined for input to the RORB model using the directly and indirectly connected impervious areas functionality in the Graphical Editor.

For this assessment it has been assumed the Fraction Impervious (FI) values given in Melbourne Water's Flood Mapping Projects Specifications are the measure of impervious area. The EIA has been calculated to estimate areas that are either directly or indirectly connected. This approach has been adopted to simplify the RORB calculation process and enable a single equivalent fraction impervious value to be modelled in RORB. A grid of the catchment EIA was then produced and sampled for each RORB model's subarea, and a weighted EIA for each subarea calculated. The grid of the EIA across the Study area is provided in Figure 3-5 – Figure 3-7. This value has been input into the RORB '.catg' file.

Table 3-4: Proposed TIA and EIA values for different land uses.

Zone Description	Zone Code	TIA	TIA	EIA
Activity Centre Zone – Schedule 1	ACZ	Assess from aerial imagery	0.9	0.72
Commercial 1/2 Zone	C1Z/ C2Z	0.7-0.9	0.9	0.72
Commonwealth Land Not Controlled by Planning Scheme	CA	Assess from aerial imagery	0.05-0.5	0.03-0.3
Comprehensive Development Zone – Schedule 1, 2, 3,4	Varies	Assess from aerial imagery	0.7	0.42
Farming Zone – Schedule 1, 2, 3	Varies	0.05-0.1	0.05-0.1	0.03-0.06
General Residential Zone – Schedule 1, 2, 3. 4, 5, 6, 7, 8	Varies	0.6-0.9	0.4-0.75	0.24-0.45
Green Wedge A Zone	GWZ	Assess from aerial imagery	0.1	0.06
Industrial Zone – 1, 3	IN1Z/ IN3Z	0.7-0.95	0.6-0.9	0.36-0.72
Low Density Residential Zone	LDRZ	0.1-0.4	0.2	0.12
Mixed Use Zone	MUZ	0.5-0.8	0.6	0.36
Neighbourhood Residential Zone – Schedule 1, 2, 4, 5, 6, 7, 8, 9, 10	Varies	Assess from aerial imagery	0.4-0.75	0.24-0.45
Priority Development Zone – Schedule 1	PDZ1	Assess from aerial imagery	0.1-0.75	0.06-0.45
Public Conservation and Resource Zone	PCRZ	Assess from aerial imagery	0.05-0.1	0.03-0.06
Public Park and Recreation Zone	PPRZ	Assess from aerial imagery	0.1-0.2	0.06-0.12
Public Use Zone – Cemetery/Crematorium	PUZ5	Assess from aerial imagery	0.1-0.5	0.06-0.3
Public Use Zone – Education	PUZ2	Assess from aerial imagery	0.4-0.75	0.24-0.45
Public Use Zone – Health and Community	PUZ3	Assess from aerial imagery	0.6	0.36
Public Use Zone – Local Government	PUZ6	Assess from aerial imagery	0.6-0.9	0.36-0.72
Public Use Zone – Other Public Use	PUZ7	Assess from aerial imagery	0.6-0.9	0.36-0.72
Public Use Zone – Service and Utility	PUZ1	Assess from aerial imagery	0.1	0.06
Residential Growth Zone – Schedule 1	RGZ1	Assess from aerial imagery	0.7	0.42
Rural Conservation Zone 0, 1, 2, 3, 4	RCZ	Assess from aerial imagery	0.05-0.1	0.03-0.06
Rural Living Zone – 1, 2, 3, 4, 5	RLZ	0.05-0.2	0.1-0.2	0.06-0.12
Special Use Zone – 1, 2, 3,4 ,5 6, 7, 8, 10	SUZ	Assess from aerial imagery	0.1-0.9	0.06-0.72
Township Zone	TZ	Assess from aerial imagery	0.1-0.5	0.06-0.3
Transport Zone 1 – State Transport Infrastructure	TRZ1	Assess from aerial imagery	0.9	0.72
Transport Zone 2 – Principal Road Network	TRZ2	Assess from aerial imagery	0.9	0.72
Transport Zone 3 – Significant Municipal Road	TRZ3	Assess from aerial imagery	0.9	0.72
Urban Floodway Zone	UFZ	0-0.05	0.05	0.03
Urban Growth Zone – 1, 3, 4, 5, 7, 8, 9, 10, 11, 12 13, 15	UGZ	Assess from aerial imagery	0.1-0.8	0.06-0.48

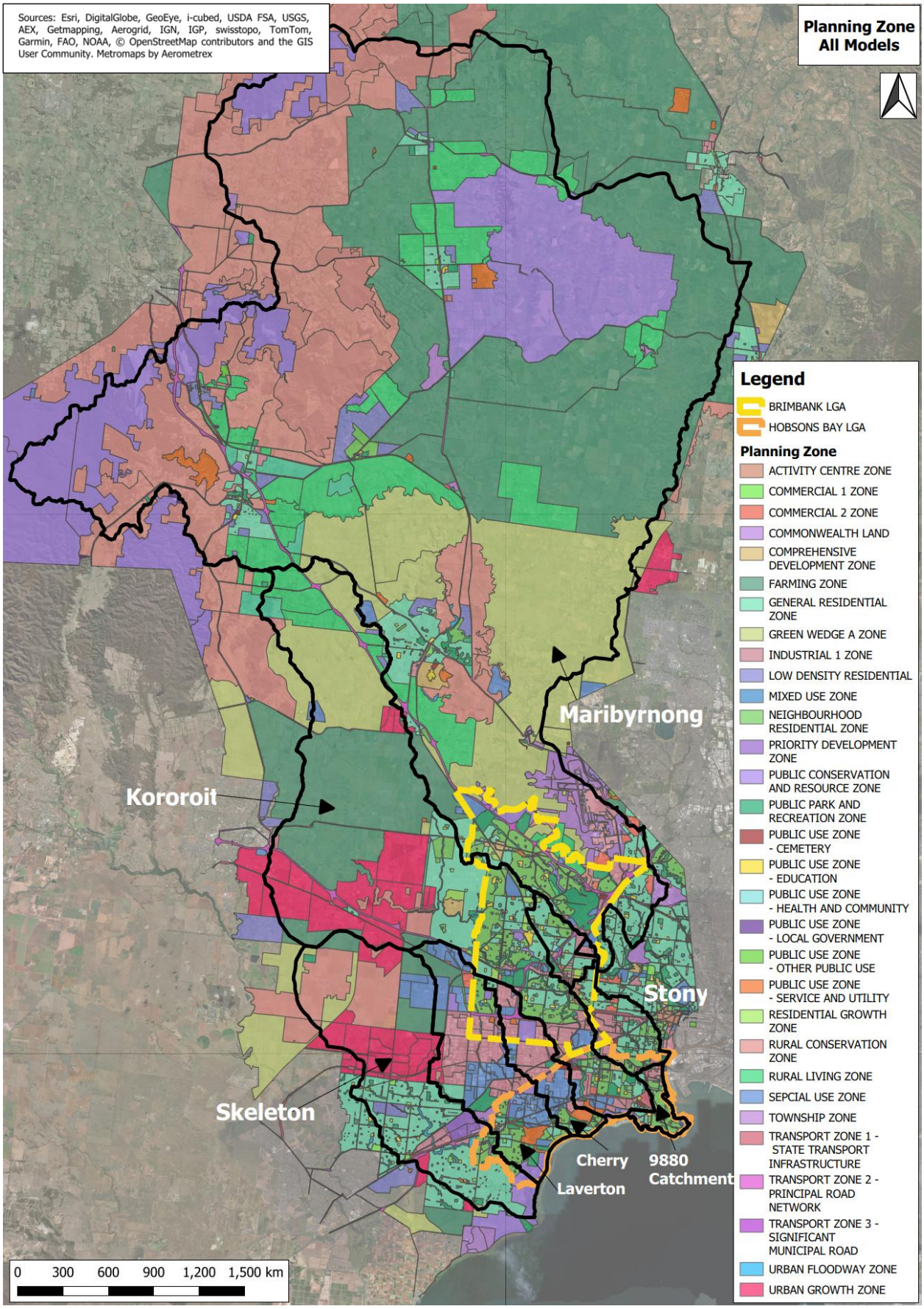


Figure 3-2: Planning zones – entire Study catchment overview.

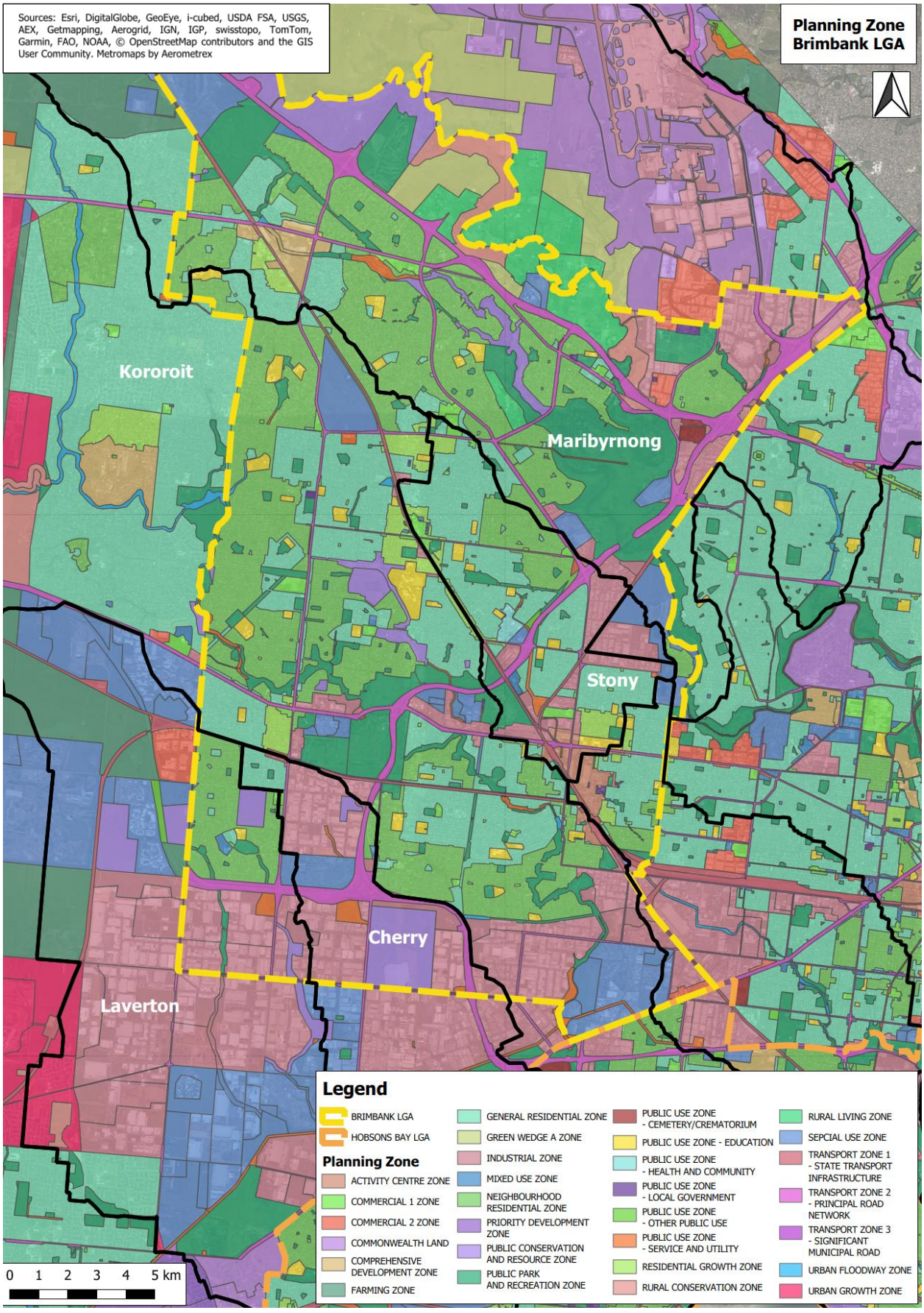


Figure 3-3: Planning zones – Brimbank LGA.

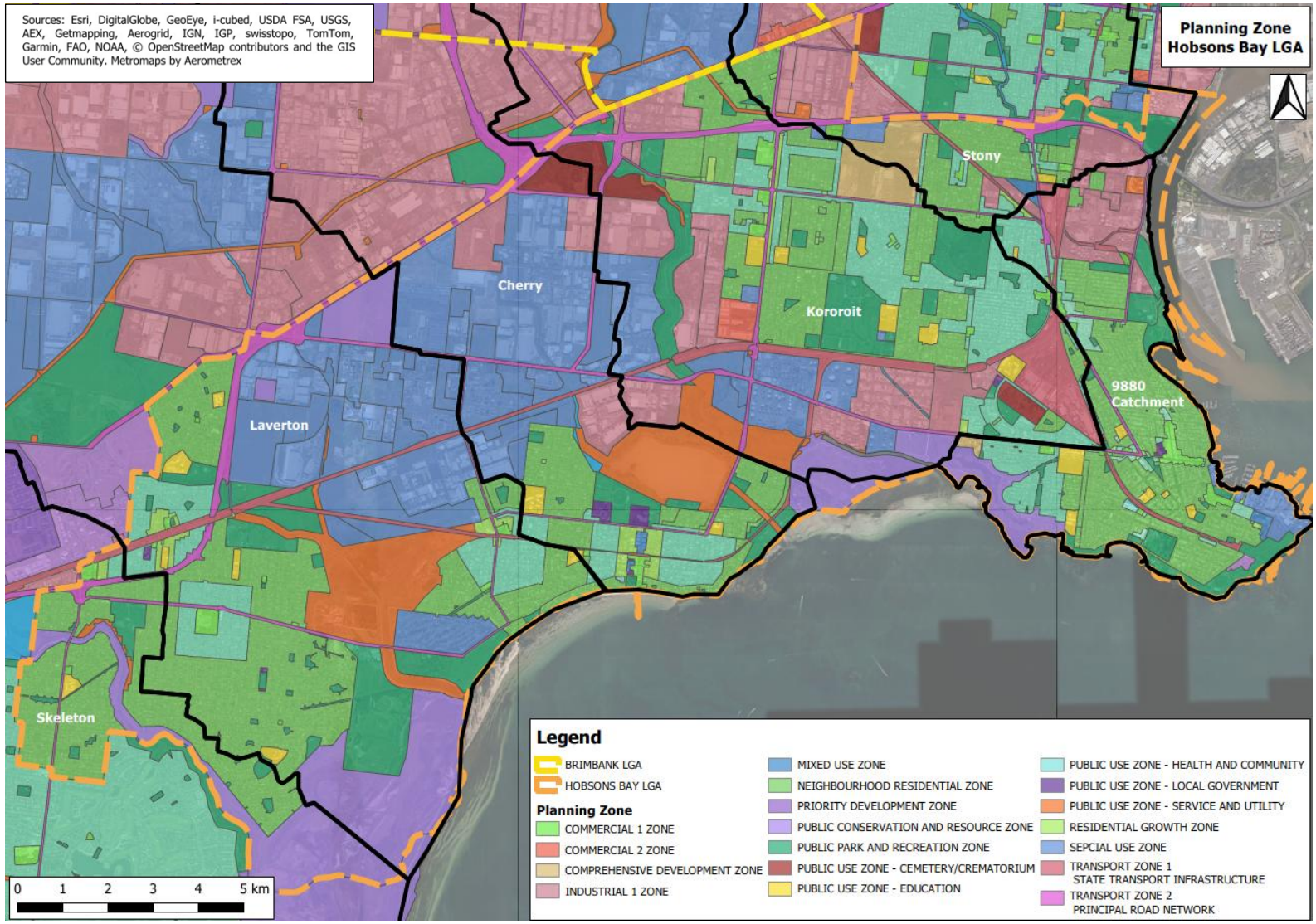


Figure 3-4: Planning zones – Hobsons Bay LGA.

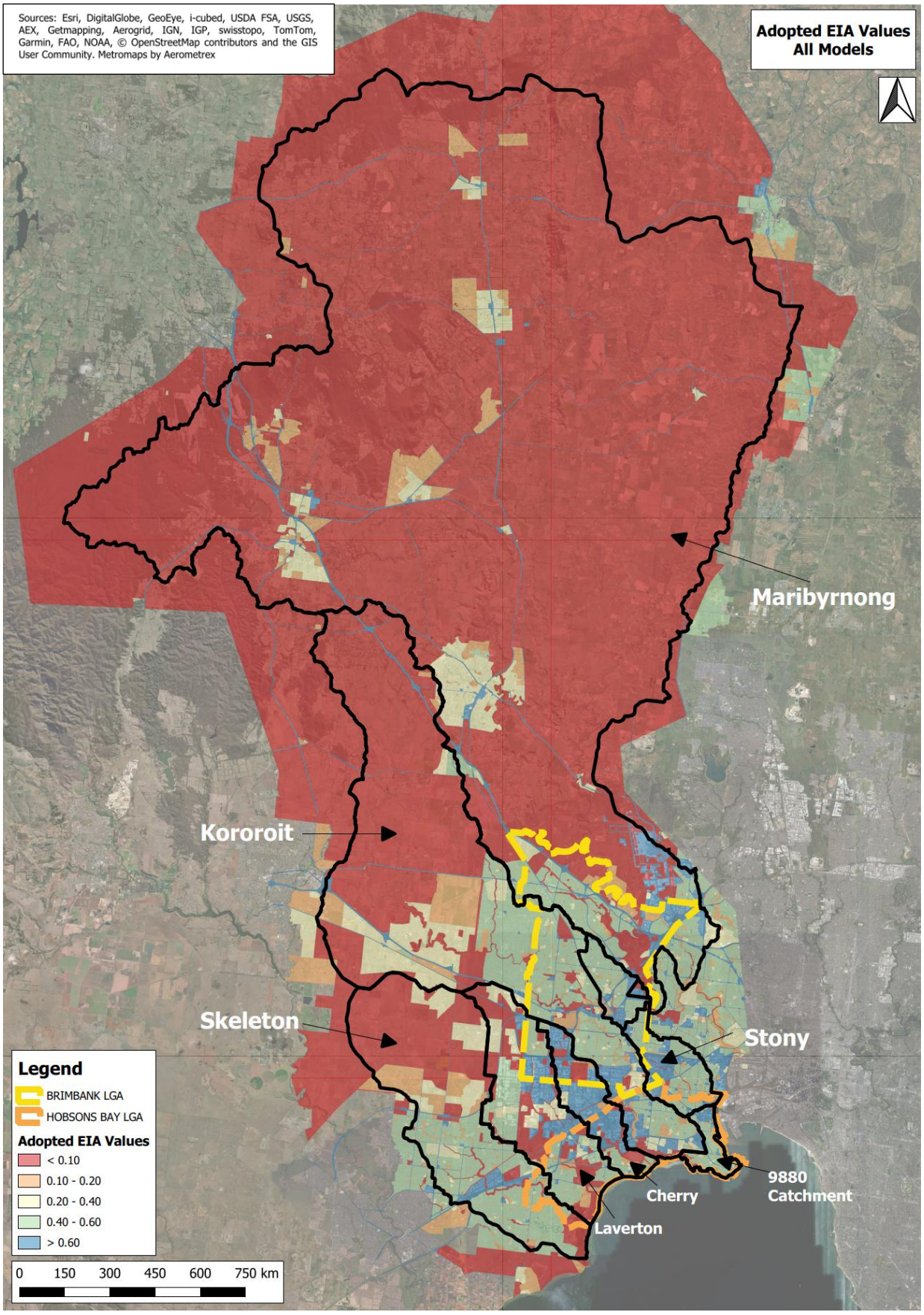


Figure 3-5: EIA values – entire Study catchment overview.

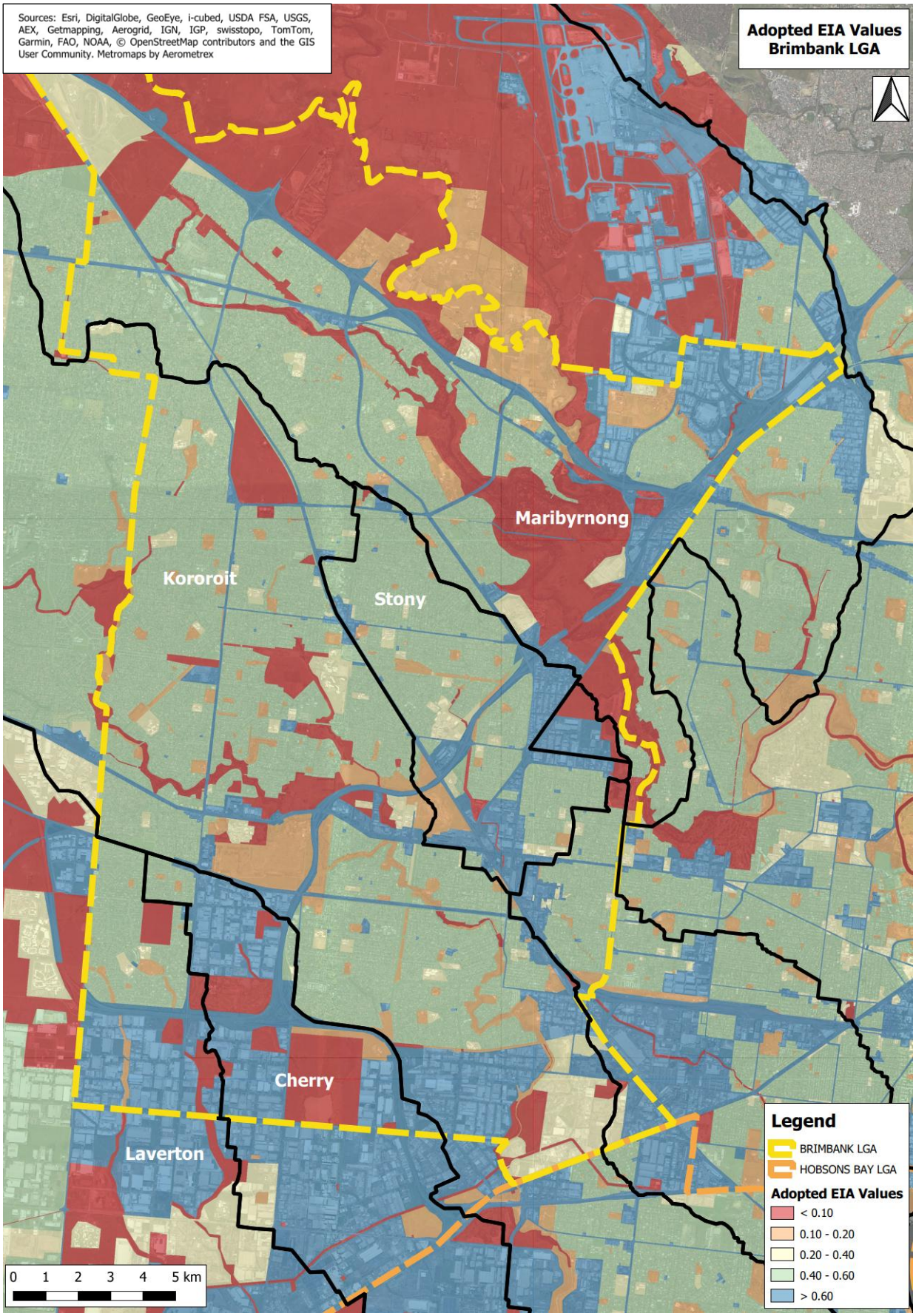


Figure 3-6: EIA values – Brimbank LGA overview.

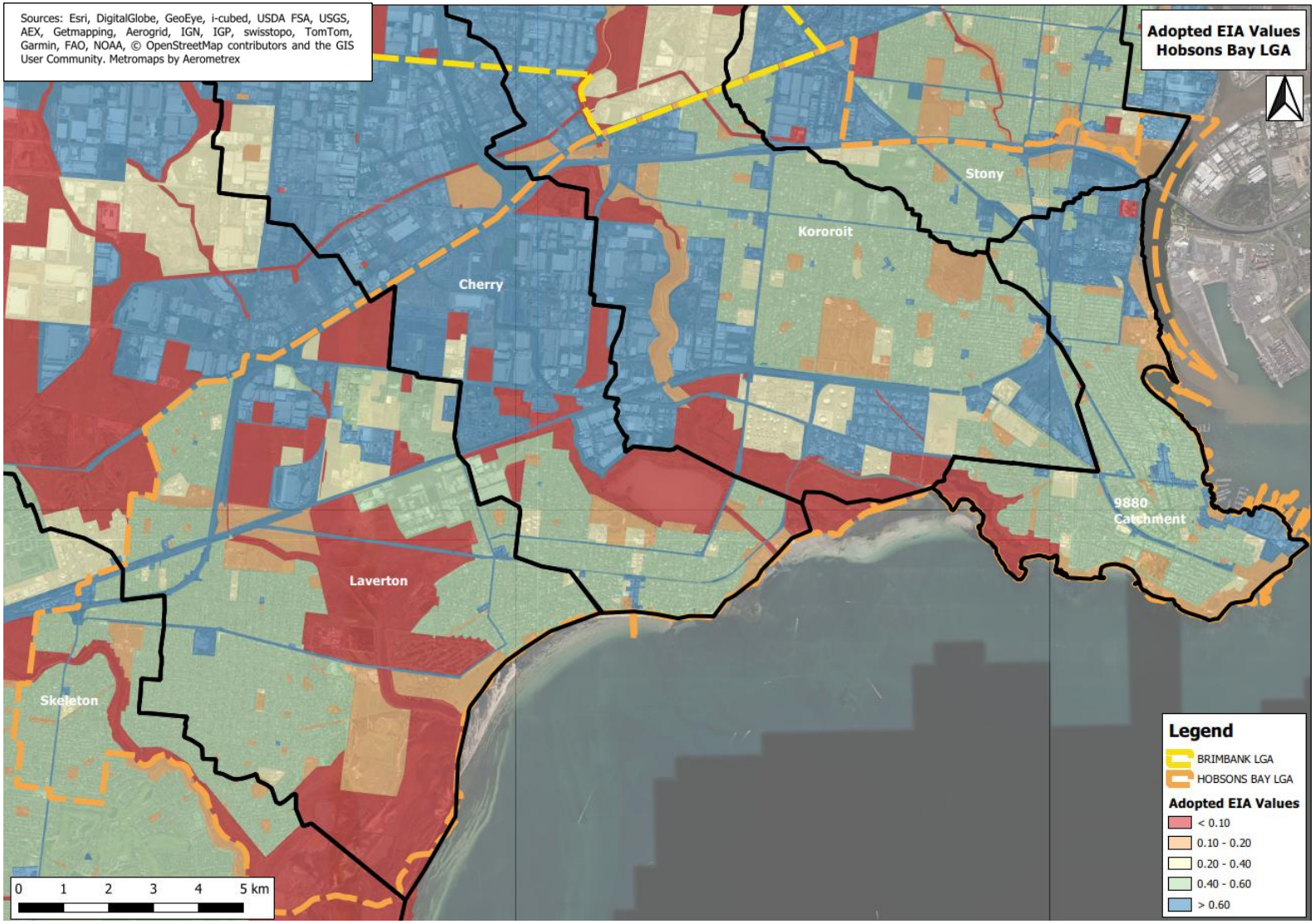


Figure 3-7: EIA values – Hobsons Bay LGA overview.

3.5 RORB input parameters

3.5.1 IFD Rainfall Data

Intensity-Frequency-Duration (IFD) rainfall data was downloaded from Bureau of Meteorology (Bureau of Meteorology, 2022) for each RORB model for the latitude and longitude that represents the catchment's centroid. Gridded rainfall data was also downloaded from the Bureau of Meteorology for the Study's larger RORB models, and a sensitivity assessment was carried out on the variance of rainfall throughout the catchment using the 1% AEP gridded rainfall data and the data at the catchment centroid, to check which represented IFD depths more accurately. Table 3-5 lists the IFD data adopted for the Study catchments.

Table 3-5: IFD rainfall data application method.

Catchment	IFD rainfall data application method
Maribyrnong River	Gridded rainfall data
Kororoit Creek	Gridded rainfall data
Stony Creek	Rainfall data for catchment centroid
Cherry Creek	Rainfall data for catchment centroid
Laverton Creek	Rainfall data for catchment centroid
Skeleton Creek	Rainfall data for catchment centroid
Subcatchment 9880	Rainfall data for catchment centroid

3.5.2 Pre-Burst

The Study area consists of catchments that fall within Loss region 2 and 3 (ARR 2019). The Maribyrnong River catchment falls largely within Loss Region 3, where ARR 2019 recommends 75th percentile pre-burst values, and the remainder falls within Loss Region 2, where it recommends median pre-burst values (HARC, 2020). The recommended pre-burst application was followed in this Study according to the loss region recommendations of ARR 2019. When applied to short durations of less than 60 minutes, the 60-minute pre-burst values have been adopted. Pre-burst temporal patterns from Minty and Meighan (1999) and Jordan et al (2005) were applied.

3.5.3 Spatial Patterns

A uniform spatial pattern was applied to Study RORB models with a catchment area <20km^2 as specified by ARR 2019. Spatial patterns were applied to catchments >20 km^2 with one exception: the application of a spatial pattern for the Stony Creek catchment was found to have no significant difference on flows during the calibration process, therefore a uniform pattern was applied (Appendix C). Table 3-6 summarises the application of spatial patterns for the Study catchments.

Table 3-6: Spatial patterns applied for Study catchments.

Catchment	Area (km^2)	Method applied
Maribyrnong River	1370	Spatial pattern
Kororoit Creek	298	Spatial pattern
Stony Creek	35	Uniform pattern
Cherry Creek	25	Spatial pattern
Laverton Creek	66	Spatial pattern
Skeleton Creek	119	Spatial pattern
Subcatchment 9880	6	Uniform pattern

3.5.4 Temporal Patterns

ARR DataHub temporal patterns were used for the Study catchments (10 temporal patterns for each AEP and storm duration) and were filtered for embedded bursts using the inbuilt RORB function. Point and areal temporal patterns were obtained and applied based on the catchment areas as follows:

- Areal temporal patterns for catchments greater than 75 km^2.
- Point temporal patterns for catchments smaller than 75 km^2.

3.5.5 Areal Reduction Factors

Areal Reduction Factors (ARF) were based on ARR 2019 equations and applied using RORB inbuilt function. Appropriate ARF's have been determined across the Study area based on an assessment of critical durations and contributing areas using point ARFs. Details of the adopted ARFs for different contributing areas at key locations across durations and AEPs can be found in the Technical Appendices A-G for each model.

3.5.6 Climate Change

Climate change factors were calculated for the year 2100 following the Melbourne Water Projects Specifications. This states that, using equation 1.6.1 from ARR 2019 Version 4.1 Chapter 6.3.5, the percentage increase in rainfall intensity is calculated to be 18.5%. An 18.5% rainfall intensity increase (applied to IFD rainfall depths) was adopted for the climate change scenario.

Climate change allowances applied in this study are based on the ARR 2019 guidance and Melbourne Water practice current at the time of model development. Rainfall intensity increases were applied using a single high-emissions scenario (RCP 8.5–based allowance), consistent with Melbourne Water flood mapping practice prior to the formal adoption of ARR 2019 Version 4.2.

ARR 2019 Version 4.2, which introduces SSP-based climate change scenarios and updated scaling methods, is acknowledged in the report as the recommended approach for future updates; however, SSP-based rainfall, loss, and sea-level rise adjustments have not been explicitly implemented in the current modelling.

The adopted approach remains appropriate for flood mapping and planning purposes, noting that future updates may refine climate change allowances in line with evolving Melbourne Water policy.

3.6 Routing Parameters

Routing parameters for the Study RORB models were derived through model calibration for the Maribyrnong River, Kororoit Creek and Stony Creek models. Routing parameters for the Cherry Creek, Laverton Creek and Skeleton Creek models were derived based on regional estimates as listed in Table 3-7. Routing parameter verification and validation was carried out for all models, with further details provided in Technical Appendices A-G.

Table 3-7: RORB model routing parameters adopted for the Study.

RORB model	Routing parameter k_c	k_c derivation	Routing parameter m
Maribyrnong River	64	Model calibration	0.8
Kororoit Creek	21 (Deer Park ISA) 12 (Brooklyn ISA & Outlet)	Model calibration	
Stony Creek	16 (Spotswood ISA) 4.4 (Outlet)	Model calibration	
Cherry Creek	8.29	Pearse et al. (2002)	
Laverton Creek	11.24	Yarra & Maribyrnong areas (Melbourne Water Flood Mapping Projects Specifications)	

RORB model	Routing parameter k_c	k_c derivation	Routing parameter *m*
Skeleton Creek	7.55 (Hoppers Crossing ISA) 11.17 (Outlet)	Areas with annual rainfall < 800mm (ARR 2019)	
Subcatchment 9880 – Council Drainage Direct to Bay	3.8	Yarra & Maribyrnong areas (Melbourne Water Flood Mapping Projects Specifications) *Note: only excess rainfall hydrographs have been extracted and routed flows not utilised given small size of catchment and direct drainage to Port Phillip Bay.*	

3.7 Storm Losses

Storm losses were identified through the calibration exercise of the Maribyrnong River, Kororoit Creek and Stony Creek models. A good level of agreement was observed between the resulting losses of the Study's calibrated models (i.e. rural area initial loss (IL) range: 12.0-18.0 mm; continuing loss (CL): 2.3-3.0 mm/h). As such, given their close proximity, these losses were applied to the remainder of Study catchments, as detailed in Table 3-8. Storm loss verification and validation was carried out for calibrated models, with further details provided in Technical Appendices A-C. Loss parameters derived from the calibration process of the Study's calibrated Kororoit Creek RORB model have been transferred to the uncalibrated catchments in the Study area in place of the DataHub values, as recommended by ARR 2019 (HARC, 2020).

Table 3-8: RORB model storm losses adopted for the Study.

RORB model	Initial Loss (IL) (mm)	Continuing Loss (CL) (mm/h)	Derivation
Maribyrnong River	12 *DataHub: 25*	2.3 *DataHub: 2.7*	Model calibration
Stony Creek	13.5 *DataHub: 8*	2.5 *DataHub: 1.1*	Model calibration
Kororoit Creek	18.0 (Deer Park ISA) 13.5 (Brooklyn ISA) *DataHub: 11*	3.0 (Deer Park ISA) 2.5 (Brooklyn ISA) *DataHub: 0.3*	Model calibration
Cherry Creek	13.5 *DataHub: 5*	2.5 *DataHub: 0.6*	Transferred from Kororoit Creek / Maribyrnong River and verified via model validation to regional equations and previous flow estimates.
Laverton Creek	13.5 *DataHub: 5*	2.5 *DataHub: 0.6*	
Skeleton Creek	18.0 (Hoppers Crossing ISA) 13.5 (Outlet) *DataHub: 5*	3.0 (Hoppers Crossing ISA) 2.5 (Outlet) *DataHub: 0.6*	
Subcatchment 9880 – Council Drainage Direct to Bay	13.5 *DataHub: 6*	2.5 *DataHub: 0.8*	

3.8 Critical Duration and Temporal Patterns

The combined area of the study is in the order of 200 km^2. Flooding across the study area is influenced from these primary sources:

- Major rivers/creek, likely to have critical durations beyond 6 hours.

- Local urban flooding – critical durations likely to be less than 6 hours.
- Impact of coastal conditions – primarily Hobsons Bay.

It was critical for a practical and defensible approach to be adopted to determine critical durations and temporal patterns for key locations in the Study area. As such, the selection of critical durations and temporal patterns was completed in RORB. Print nodes have been added to the .catg files at key locations across each model and the models run in Ensemble mode to identify critical durations. Adjustments were then made to the Areal Reduction Factor (ARF) based on the critical durations and contributing catchment areas. An appropriate combination of ARF, durations and temporal patterns that represent critical events has been determined for each RORB model, detailed in the technical Appendices of this report.

Where identified checks on critical temporal patterns and durations have been completed in TUFLOW models in areas where there are:

- Retarding basins.
- Informal floodplain storages (i.e. embankments).
- The influences of Port Phillip Bay tailwater – primarily Hobsons Bay.

In the relevant Technical Appendices, a comparison of the RORB critical durations has been compared to the results from TUFLOW for the 1% AEP with climate change scenario.

4. Hydraulic Modelling

Seven 1D/2D hydraulic TUFLOW models were developed over the Study area, covering the LGAs of Brimbank, Hobsons Bay and a part of Wyndham. This section provides an overview of the approach used in the development of the hydraulic models across the Study area. Catchment-specific technical details for the development of each TUFLOW model are documented in technical Appendices as listed in Table 3-1.

4.1 Previous TUFLOW modelling

Existing TUFLOW hydraulic models were identified for use in this Study. Where available, these were reviewed and updated where necessary to align with Melbourne Water Flood Mapping Projects Specifications to ensure they are fit for purpose. Table 4-1 lists the existing TUFLOW models within the Study area and their status for use on the current project.

Table 4-1: Existing TUFLOW hydraulic models identified within the Study area, and their access status.

TUFLOW model	Source	Status at time of writing
Hobsons Bay Flood Modelling TUFLOW models (includes 5 models covering the Hobsons Bay LGA area)	Cardno (2018) (original) Cardno (2019) (updated)	Models provided for use on 12/01/2023. From available reporting, it is understood that the original modelling completed in 2018 was updated in 2019, following a detailed survey of all pit and pipes in the municipality's drainage network. Cardno updated the pit and pipe network in their hydraulic models using this survey information. It is understood that the updated (2019) version of the TUFLOW models have been shared with Jacobs for use in the current Study.
Steele Creek TUFLOW model	Engeny (2022)	Models provided for use on 18/01/2023. This model provided coverage of Steele Creek, of which part of its catchment falls within Brimbank Council LGA. The status of the modelling and report shared with Jacobs was understood to be for 'Client issue with Draft deliverables'.

4.2 Hydraulic Model Set Up

4.2.1 TUFLOW Version and Solver

The 2020-10-AF (November 2022) release of TUFLOW was used in this Study because it offers up-to-date functionality and bug fixes, with the Heavily Parallelised Compute (HPC) solver adopted and the Sub-Grid Sampling (SGS) functionality enabled.

4.2.1.1 Quadtree Mesh

The Quadtree mesh functionality available with HPC was used in the Maribyrnong River TUFLOW model only given this model contains areas where there is a mix of rural and urban land use (see Technical Appendix A). This improved model run times whilst allowing a smaller grid size to be used in urban areas, where the detailed features of an urban environment require representation via a finer grid size.

4.2.2 Model Extents

The Study TUFLOW models are listed in Table 4-2 and their extents are shown in Figure 4-1. Seven TUFLOW models were developed; the overall approach and elements considered in determining these extents were as follows:

- Retain RORB model catchment splits where practicable.
- Where possible, larger catchment-wide TUFLOW models were preferred to minimize the need for multiple smaller models with hydraulic interactions and dependencies (i.e. from upstream

to downstream). The outputs from multiple smaller models also present challenges in merging and/or aligning flood extents at the mapping stage of the Study.

- Consideration of model run times, which will be a constraint to project timelines should models become too large.
- The Kororoit Creek model size within the LGAs of interest is >90 km2. This has therefore been split in two, as shown in Figure 4-1, to reduce model run times. The split location was the M80 Western Ring Road given this is a natural floodplain barrier, facilitating a clear separation of flood extents. Flows leaving the upstream (Northern) model at the downstream boundary have been used as a boundary condition for the downstream (Southern) model.
- Model extents have been trimmed to provide the appropriate amount of buffer around the LGA boundaries. Where the LGA boundary does not follow catchment/sub-catchment boundaries, areas of neighboring LGAs have been included in the models. In some cases, the TUFLOW models overlap to capture hydraulic interaction in an area between two models (i.e. between Stony Creek and Kororoit Creek models).

Table 4-2: Study TUFLOW models.

TUFLOW model	LGA(s) covered	Size
Maribyrnong River Catchment	Brimbank	61 km^2
Kororoit Creek North Catchment	Brimbank	38 km^2
Kororoit Creek South Catchment	Brimbank, Hobsons Bay, Wyndham	41 km^2
Stony Creek Catchment (Note that this includes the area covered by the 9880 catchment RORB model)	Brimbank and Hobsons Bay	21 km^2
Cherry Creek Catchment	Brimbank, Hobsons Bay, Wyndham	27 km^2
Laverton Creek Catchment	Brimbank, Hobsons Bay, Wyndham	56 km^2
Skeleton Creek Catchment	Hobsons Bay	9 km^2

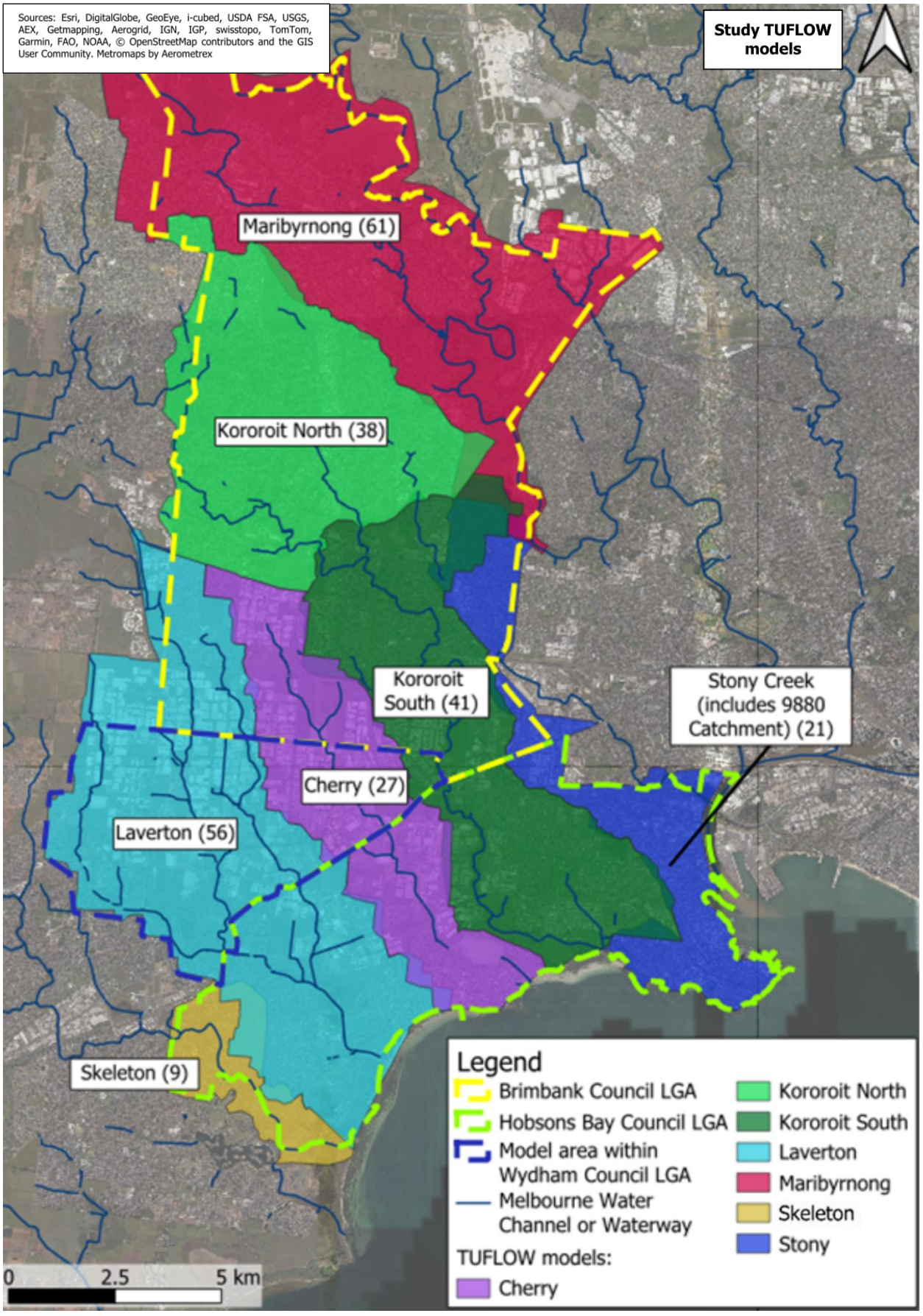


Figure 4-1: Study TUFLOW models.

4.2.3 Grid Size

The TUFLOW models used a 3 m grid size with SGS enabled. The 3 m grid size is considered appropriate for urban environments and consistent with Melbourne Water Flood Mapping Projects Specifications recommendations. Where Quadtree has been used (Maribyrnong River model only), a 3 m grid size is used in urban areas/key waterways, with a 6m grid size for more natural/rural areas.

With SGS the model stores volume/elevation curves and flow area/stage curves for every cell face rather than a single storage elevation/relationship for every cell. This functionality enables the sub-grid (in this case 1m within the 3 m grid cell) representation of the topography within the model. SGS can only be enabled in TUFLOW with the HPC solver. SGS was enabled to improve the representation of narrow continuous drainage lines within the model area.

4.2.4 Topography

The topography of the TUFLOW models was based on the Melbourne Water supplied 2017/2018 LiDAR. The two exceptions to this were the Laverton Creek model, which used the bespoke LiDAR collected in September 2023 specifically for use in this Study and the Kororoit South model, which used small areas of additional LiDAR collected in August 2023 for the area around the Maribyrnong River. Both LiDAR datasets have a resolution of 1m.

In addition to the LiDAR, further definition has been added to the model terrain, including the following:

- Break lines (ridges) for key hydraulic structures, crests and embankments (note that gully lines are not recommended with SGS as their use results in additional water volume storage in the 2D cell).
- Adjustments to the terrain to ensure bridges were appropriately removed/added from the model terrain to align with the model setup.
- Adjustments to the terrain to remove depressions due to poor surface formation/interpolation or artefacts in the LiDAR DEM.
- To inform terrain modifications, levels have been obtained from design plans or extracted from the LiDAR DEM.
- Levels from survey or drawings to be built into models, where available.

Full details of terrain modifications can be found the Technical Appendices A-G for each hydraulic model.

4.2.5 Bridges

Bridges have been modelled as layered flow constrictions in the 2D domain, with inputs based on detailed drawings, where available. The catchment site visits have also been used to understand where key bridges are located along flow paths within the catchments and measurements, observations and photographs were taken of these structures. When detailed drawings are unavailable, appropriate estimates have been made using this information collected on the site visits. The following assumptions have been adopted for all bridges:

- 'Portion' (Method B) approach used in TUFLOW (modelled as a polyline).
- No blockage for Layer 1.
- 100% blockage and factored form loss coefficient of 1.56 for Layer 2 (bridge deck).
- Pier Form losses were calculated based on the Bradley (1978) (Hydraulics of Bridge Waterways – Figure 7)

In the absence of as constructed details (i.e. from site visit, survey data or drawings) and/or visibility of any/all attributes from online sources, values have been assumed for road bridges and footbridges as follows:

For road bridges:

- Bridge deck depth = 1m
  - Based on our understanding and knowledge this is conservative thickness.
- Size of Piers Perpendicular to Flow (dia.) = 0.5m
  - Based on our understanding and knowledge this is suitably representative.
- No. of Pier Sets Perpendicular to Flow = 1
- Pier Shape = Square x5
- Railing depth = 1m
- Railing blockage = 30%

For footbridges:

- Bridge deck depth = 0.5m
- Size of Piers Perpendicular to Flow (dia.) = 0.5m
- No. of Pier Sets Perpendicular to Flow = 1
- Pier Shape = Square x5
- Railing depth = 1m
- Railing blockage = 30%

A list of individual structures and assets was compiled that listed assumptions to be adopted in the absence of information/data relating to them. This was reviewed by Melbourne Water and assumptions confirmed to be appropriate. The details of these structures can be found the Technical Appendices A-G for each hydraulic model.

4.2.6 Model Roughness

Each 2D cell in the model domain was assigned a roughness parameter (Manning's "n" value) to enable the calculation of hydraulic characteristics. Roughness values for the TUFLOW model have been applied spatially based on land use. Initially, planning zones and the cadastre were used as a base. Further detail was then included using aerial imagery and site visit observations to represent areas such as vegetation or open spaces.

Building footprints were applied to represent the cell roughness associated with buildings. Upon review, the 2018 Roofs data for both Brimbank and Hobsons Bay Councils received from Jasper Kunapo (engaged by Hobsons Bay Council (GRACE, 2022)) has been found to be an extensive and up-to-date dataset spatially representing building footprints across the Study area. This dataset was adopted to represent building footprints in the TUFLOW models. Building footprints were modelled using a high roughness value as per the guidance in the Flood Mapping Projects Specifications.

The Manning's "n" value adopted for each surface area type is reported in Table 4-3, in line with Melbourne Water Flood Mapping Projects Specifications. Maps showing the application of Manning's "n" spatially for each model can be found in Technical Appendices A-G.

Table 4-3: Model roughness values adopted (based on the Melbourne Water Flood Mapping Projects Specifications).

Land use	Manning's "n" value
Open Pervious Areas (minimal vegetation)	0.035
Open Pervious Areas (moderate vegetation)	0.06
Open Pervious Areas (thick vegetation)	0.09
Urban high density residential parcel when building footprint is modelled separately	0.1
Urban high density residential (building footprint) – also adopted for commercial buildings)	0.35
Urban – low density residential (parcel)	0.05
Industrial/commercial	0.4
Open Concrete Channel	0.015
Waterway/channel vegetated	0.065
Waterway/channel minimal vegetation	0.035
Rail	0.12
Roads	0.02
Wetlands (emergent vegetation)	0.06
Lakes (no emergent vegetation)	0.02

4.2.7 1D Drainage Network

Underground pit and pipe networks and culverts were represented in 1-D in the model. Specific sources of data used to build the 1D network for the Study area and observations following data reviews are listed in Table 4-4 below.

Table 4-4: Drainage network data received for use on the Study.

Data source	Applicability	Comments
Brimbank Council drainage network (pits and pipes layers)	Council drainage network data across Brimbank LGA.	Data quality is poor, particularly with respect to pipe direction. Errors also found in network connectivity and invert levels. Approximately 75% of pipe inverts present in the dataset appear unreliable or incorrect. Pipe connections at major infrastructure crossings (i.e. major road and rail lines) appear to be absent from the dataset in many areas. Missing structures were reviewed and modelled using information provided by Melbourne Water and both Councils. Refer to Section 4.2.7.2 for further details. Significant effort was required to produce a functional drainage network in TUFLOW ready format. See below for processing steps applied to produce a functional drainage network.
Melbourne Water drainage network (pipes layer)	Melbourne Water drainage network data across Brimbank and Hobsons Bay LGAs.	Data quality is good. Use to cross-check any data already in TUFLOW format.
Hobsons Bay TUFLOW models (x5) drainage network (pits and pipes layers) (Cardno, 2019)	Drainage network data in TUFLOW format for Hobsons Bay LGA.	Report notes that the TUFLOW drainage network was based off survey data, and an infilling process was followed to produce a functional drainage network. This was often adopted as is following QA processes show data is satisfactory. Where data was not satisfactory (i.e. inverts did not flow from high to low upstream to downstream) adjustments were made to produce a functional drainage network. R type pits used -updated to Q type.

Data source	Applicability	Comments
Steele Creek TUFLOW model drainage network (pits and pipes layers) (Engeny, 2022)	Drainage network data in TUFLOW format for small part of Brimbank LGA.	Engeny model has a Draft status. Report notes that an intensive infilling process has been followed to produce a functional drainage network. Data checks and QA showed that data is satisfactory, and the network was largely adopted as is.
Hume Council drainage network	Covers part of the Maribyrnong River/Steele Creek catchment	Used to cross-check the Engeny Steele Creek model pipes.
Maribyrnong Council drainage network	Covers fringe areas of the Kororoit and Stony Creek catchments	Data quality is poor, particularly with respect to pipe direction and invert levels. Effort was required to produce functional drainage network in TUFLOW ready format. See below for processing steps applied to produce a functional drainage network.
Melton Council drainage network	Covers upstream areas of the Maribyrnong River, Kororoit and Laverton Creek catchments	Data quality is poor, particularly with respect to pipe direction and invert levels. Effort was required to produce functional drainage network in TUFLOW ready format. See below for processing steps applied to produce a functional drainage network. Pits are polygons rather than points. Additional processing was required to convert to points for use in TUFLOW. Snapping distance tolerances were applied.
Moonee Valley Council drainage network	Covers upstream areas of the Maribyrnong River and Kororoit Creek catchments	Data quality is poor, particularly with respect to pipe direction and invert levels. Effort was required to produce functional drainage network in TUFLOW ready format. See below for processing steps applied to produce a functional drainage network.
Wyndham Council drainage network (pits and pipes layers)	Covers upstream areas of the Kororoit, Cherry, Laverton and Skeleton Creek catchments.	Data quality is poor, particularly with respect to pipe direction and invert levels. Effort was required to produce functional drainage network in TUFLOW ready format. See below for processing steps applied to produce a functional drainage network. Pits are polygons rather than points. Additional processing was required to convert to points for use in TUFLOW. Snapping distance tolerances were applied.
Jasper Kunapo GIS layers (GRACE, 2022)	Covers Hobsons Bay LGA – not applicable for TUFLOW.	Application of GRACE (2022) data limited for use in this Study – not used.
Hobsons Bay Council – drainage design drawings (04/12/2025)	Design drawings covering gaps in drainage network identified with Council	Data quality allowed for review and update of Hobsons Bay drainage network with details and drainage alignments.

Significant effort was made to infill any data gaps in the drainage network. To develop robust stable models, the following adjustments and checks were carried out for the 1D network of the Study models:

- Pipes were snapped where there were disconnections.
- Pipe directions were corrected where necessary to ensure that all pipes were digitized in the correct direction (i.e., downstream towards outfall).
- Where pipe data included missing diameters, engineering judgement was applied to fill in data gaps where possible. The upstream (smaller) pipe dimensions were used to infill the missing dimensions unless the data suggests otherwise (i.e. the missing dimension is downstream of a junction pit). Typically, diameters were set to 300 mm in the absence of any surrounding pipe sizes.
- Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. Assumed pipes are documented the Technical Appendices A-G for each model.
- Where pipe invert information was missing, appeared unreliable or incorrect, pipe inverts were assigned using a QGIS plug-in tool created specifically for the project. This tool calculated inverts based on ground elevations, 600mm of cover (where possible), minimum/maximum pipe grades, flow direction and known upstream/downstream invert elevations. A high proportion of Council pipe data was processed to assign inverts using this tool.
- Checks were completed using the TUFLOW 1D Integrity GIS toolbox to ensure a functional network that flows from upstream to downstream with minimal changes in pipe inverts at pit locations.
- Parts of the drainage network were identified as only having junction pits snapped to their uppermost branches (example shown in Figure 4-2, in this figure the pits and pipes shown in yellow do not receive flow and were therefore excluded from the TUFLOW models). Given that junction pits are not connected to the 2D domain, these pipes would not receive any flow in the TUFLOW model. Pipes with no means of receiving flow (i.e. connected only to junction pits upstream) were removed from the network as agreed with Melbourne Water and relevant Councils. This step prevented the creation of backflow and artificial inefficiencies in the drainage network. Pipes removed via this step were typically small (≤300 mm), therefore the loss of storage capacity in the network is expected to be minimal with little to no sensitivity of the 1% AEP (and 1% AEP with climate change) flood event to their exclusion. The method used produces a 1D drainage network that is fit for purpose for the Study and its objectives.
- In instances where there are 1D stability issues, a nodal area was added to pits to achieve stability.
- Adopted losses and contraction coefficients:
  - 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 = 0.5.
  - Exit loss coefficient = 1.0.

Culverts were modelled following the standard 1d culvert approach described in Section 4.2.7.

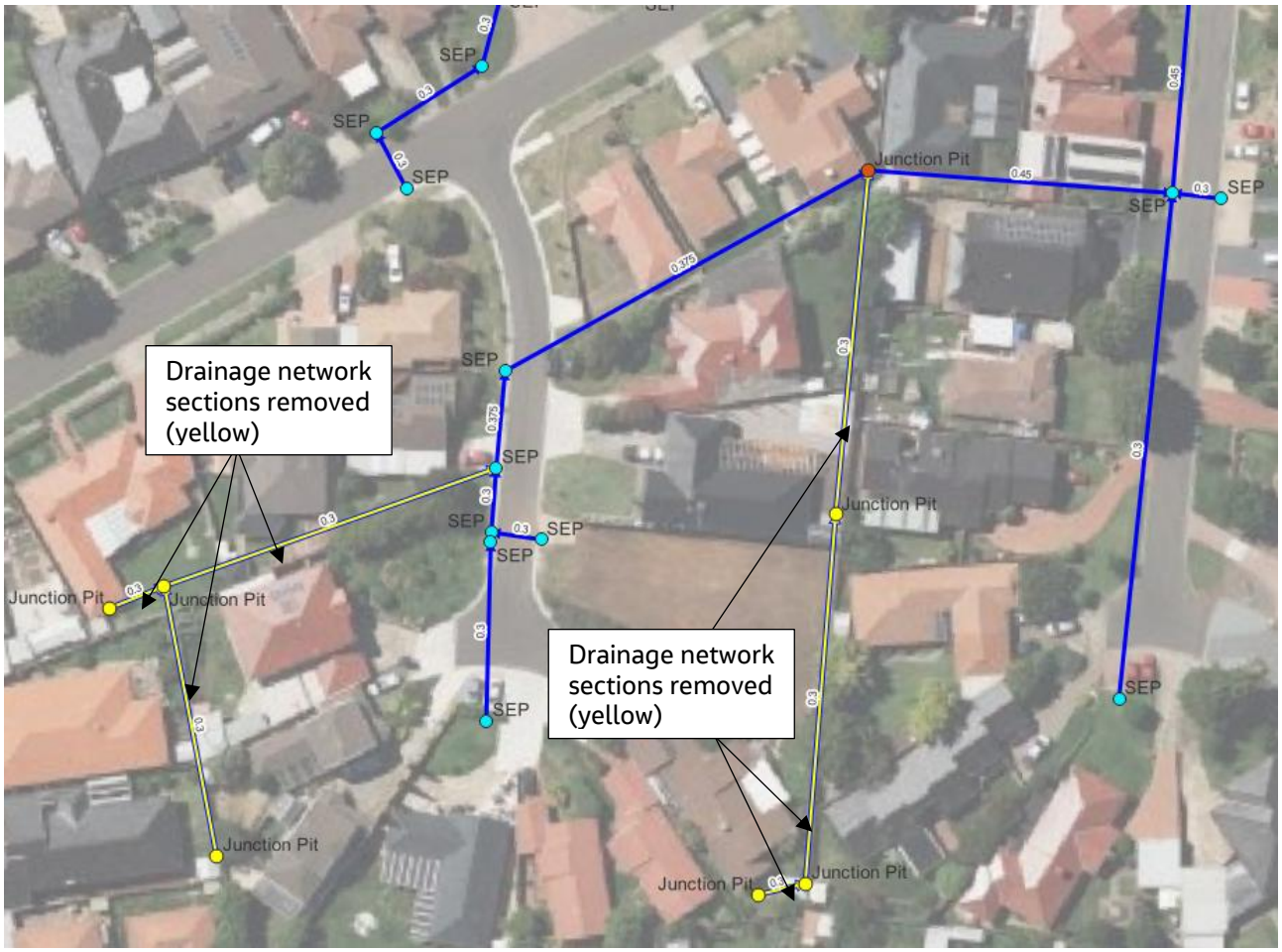


Figure 4-2: Example of sections of the drainage network that were removed.

Further key elements of the pit and pipe network of the Study TUFLOW models are as follows:

- Pits were modelled as 'Q' Type and based on a set of standard depth-discharge curves to allow flow to enter pits and the pipe network.
- Junction pits were modelled as nodes and not connected to the 2D domain. This is to prevent the flooding of properties in areas that would overall have a low to no flood risk.
- Standard pipe entry and exit coefficients were applied and the Engelund loss approach to manholes was adopted.
- Pipe roughness was set to 0.013, as per the Melbourne Water Flood Mapping Projects Specifications.
- To represent the flood behaviour and peak flows more accurately in the LGAs of interest, parts of neighbouring LGAs (and their drainage networks) were included in the TUFLOW models in some instances. Whilst these areas have been included in the hydraulic models, formal flood mapping has been carried out for Brimbank and Hobsons Bay LGAs and the relevant part of Wyndham LGA which falls within Study models.

4.2.7.1 Pits

The assignment of pit types was based on supplied Council and Melbourne Water data. The pits were set to be 0.1 m below the DEM to emulate the concentration of flows at pit locations. The Study adopted the following pit types in TUFLOW models:

- Side entry pits (Standard Drawing 1301 – Side Entry Pit – B Type kerb – 1m Inlet).
- Grated side entry pits (Standard Drawing 1322 – Grated Side Entry Pit – B Type kerb – 1m Inlet).
- Grated pits (Standard Drawing 431 – Grated Pit – Flush Steel Grate – 1m x 1m Inlet – Grate Type B).
- Junction pits (modelled as Node with no connection to the 2D domain).
- 'Double' or 'Triple' pits modelled by increasing the 'Number_of' attribute accordingly.
- Irregular or large pits (i.e. RB inlet structures) were assessed and modelled on an individual basis, by either creating a custom pit inlet curve based on dimensions or utilising a 2d CN/SX line/point.

A review of the Brimbank Council pit data identified 11 different pit types across a total of 45,944 pits. Table 4-5 lists the different types and their treatment in TUFLOW modelling.

Table 4-5: Brimbank Council pit data review and proposed treatment in TUFLOW.

Pit Type from Brimbank Council Dataset	% of total	Treatment	VicRoads standard pit type
End Wall/Head Wall	0.7	2d point or 2d CN/SX lines (for culverts larger than the model grid size)	–
Side Entry Pit	53.7	Side Entry Pit	Standard Drawing 1301 – Side Entry Pit – B Type kerb – 1m Inlet
Double Side Entry Pit	3.9	Side Entry Pit – 'Number_of' = 2	
Junction Pit	34.1	Junction Pit – Node with no connection to 2D domain	–
Grated Top & Side Entry Pit	1.4	Grated Side Entry Pit	Standard Drawing 1322 – Grated Side Entry Pit – B Type kerb – 1m Inlet
Grated Pit	3.9	Grated Pit	Standard Drawing 431 – Grated Pit – Flush Steel Grate – 1m x 1m Inlet – Grate Type B
Double Grated Pit	0.1	Grated Pit – 'Number_of' = 2	
Unknown	1.0	Remove from network – checks show no pits or connection to surface present.	–
End Pipe	1.0		
Gross Pollutant Trap	0.1		
Pumping Station	0.1		

A review of the Wyndham Council pit data identified 13 different pit types across a total of 4,856 pits. Table 4-6 lists the different types and their treatment in TUFLOW modelling.

Table 4-6: Wyndham Council pit data review and proposed treatment in TUFLOW.

Pit Type from Wyndham Council Dataset	% of total	Treatment	VicRoads standard pit type
Side Entry Pit	49.2	Side Entry Pit	Standard Drawing 1301 – Side Entry Pit – B Type kerb – 1m Inlet
Junction Pit	38.8	Junction Pit – Node with no connection to 2D domain	–
Grated Pit	5.1	Grated Pit	Standard Drawing 431 – Grated Pit – Flush Steel Grate – 1m x 1m Inlet – Grate Type B
Double Side Entry Pit	3.6	Side Entry Pit – 'Number_of' = 2	Standard Drawing 1301 – Side Entry Pit – B Type kerb – 1m Inlet
Grated Side Entry Pit	1.8	Grated Side Entry Pit	Standard Drawing 1322 – Grated Side Entry Pit – B Type kerb – 1m Inlet
End Wall	0.7	2d point or 2d CN/SX lines (for culverts larger than the model grid size)	–
Double Grated Side Entry Pit	0.3	Grated Side Entry Pit – 'Number_of' = 2	Standard Drawing 1322 – Grated Side Entry Pit – B Type kerb – 1m Inlet
End Pipe, Head Wall	0.1	2d point or 2d CN/SX lines (for culverts larger than the model grid size)	–
TP	0.1	Remove from network – checks show no pits or connection to surface present.	–
Gross Pollutant Trap	0.1		
PE	<0.1		
RPG	<0.1		

Pits from the Cardno (2019) TUFLOW model within Hobsons Bay Council area were reviewed and found to be representative from spot checks, therefore largely adopted as is for the Study.

Technical Appendices A-G provide further information on the adopted pit types in each of the TUFLOW models and maps of their full drainage network.

4.2.7.2 Rail Structures

Potentially missing rail culvert crossings were identified by reviewing the flood extents along the rail alignment identified in each model. Fifteen rail structures were identified as not being present in the received datasets across all model areas, and data requests were submitted to Melbourne Water and both councils for available information on these rail structures. The rail structures were classified into two categories:

- Rail cross drainage culverts, and
- Rail pedestrian underpasses.

Rail pedestrian underpasses were represented in the 2D hydraulic domain as layered flow constrictions, with geometry inputs informed by site visit measurements, observations, and photographs. The bridge modelling assumptions outlined in Section 4.2.5 were also applied to these structures. In addition, local terrain adjustments were incorporated to enable conveyance through the pedestrian underpasses. Further information on the configuration and treatment of rail pedestrian underpasses is provided in Technical Appendices A–G for each hydraulic model.

4.2.8 Boundary Conditions

The boundary conditions across the Study models are presented in Technical Appendices A-G for each model.

4.2.8.1 Inflows

Hydrographs from the RORB models were applied as inflow boundary conditions using the following methods:

- Pipe inflows and connections – areas with good coverage of pit and pipes:
  - Rainfall-excess hydrographs from the respective RORB models were applied to the pit and pipe network that overlap with the RORB sub catchments. This method applied inflows to the top of pits (2d_sa PITS option) which enabled pit curves to be engaged. Pipes discharging into the 2D domain were connected either with 2d point or 2d CN/SX lines (for culverts larger than the model grid size).
- Pipe inflows and connections – areas with sparse/clustered coverage of pit and pipes:
  - RORB subareas were split into areas with pit/pipes coverage and areas without. Areas with pit/pipes were treated as above with a factor applied to excess rainfall hydrographs in the bc_dbase. Areas with no pipes were addressed as using the overland flow method below.
- Overland flows in regions with no pipes:
  - In regions where there are very limited pit numbers, streamlines were used to apply excess rainfall hydrographs to flow paths and/or channels. This ensured that flows were concentrated along realistic catchment routing paths.
- Routed flows for major watercourses:
  - For major creeks and watercourses entering the TUFLOW model, RORB routed hydrographs from the upstream catchments external to the relevant LGA were added as inflow boundaries to the TUFLOW models.
- Interaction between Study TUFLOW models – Kororoit Creek:
  - As noted in Section 4.2.2, the Kororoit Creek catchment has been split into two separate TUFLOW models. In this case, flows leaving the Kororoit North (upstream) TUFLOW model at the downstream boundary are used as the inflow boundary condition for the Kororoit South (downstream) model.

4.2.9 Downstream boundaries

For Study TUFLOW models that do not end at Port Phillip Bay (Maribyrnong River and Kororoit North), downstream boundaries were set at a suitable distance from the end of the areas of interest to ensure that the boundary condition does not create a modelling artefact.

For TUFLOW models that end at Port Phillip Bay (Kororoit South, Stony Creek, Cherry Creek, Laverton Creek and Skeleton Creek), an updated tidal level was applied using the Melbourne Water Flood Mapping Projects Specifications (Melbourne Water 2023).

At the request of Melbourne Water updated tailwater level guidance from the 2023 update to the Melbourne Water Flood Mapping Projects Specifications has been used to assess the tailwater levels applied to the model. The adoption of the tailwater level guidance was requested by Melbourne Water and applied to all relevant models. These tailwater levels are summarised in Table 4-7. Specific locations aligning with the outfall location of each model were sampled from Port Phillip Bay sea level time-series data, as specified in Appendix 3 of the Melbourne Water Flood Mapping Projects Specifications (2023).

Given that the longest critical duration for the Study catchments that interact with Port Phillip Bay is 12 hours (Kororoit Creek), which is shorter than the duration of a full tide (or storm tide) cycle and/or event, a static tailwater level for Port Phillip Bay was applied for all TUFLOW models. This application of a static tailwater level was discussed at length with project stakeholders including Melbourne Water and Hobson Bay Council

(given by their tidally influenced location). Agreement was reached on the use of a static tailwater level given this follows the general Flood Mapping Projects Specifications guidance.

A sensitivity test with one model run for the Kororoit Creek South model was completed using a dynamic tide level. Refer to Section 4.2.14 for details of the dynamic tailwater level sensitivity analysis.

Table 4-7: Tailwater levels at Port Phillip Bay adopted across different TUFLOW models.

Modelling Scenario (As per Table 11 in Flood Mapping Projects Specifications Appendix 3	AEP Event	Tailwater Level	Yarra River outlet (Stony Creek model)	Kororoit Creek (Kororoit South model only)	Cherry Creek	Laverton Creek	Skeleton Creek
A (Base case)	1%	10% AEP Levels	1.168	1.165	1.162	1.152	1.152
	2%	10% AEP levels	1.168	1.165	1.162	1.152	1.152
	5%	20% AEP levels (calculated as 0.92 times the 10% AEP)	1.075	1.072	1.069	1.060	1.060
	10%	20% AEP levels	1.075	1.072	1.069	1.060	1.060
	20%	20% AEP levels	1.075	1.072	1.069	1.060	1.060
B (climate change sea level rise)	1%	10% AEP SLR level	1.995	1.991	1.989	1.980	1.978
	10%	20% AEP SLR level calculated as 0.92 times the 10% AEP SLR level	1.835	1.832	1.830	1.822	1.820
	20%	20% AEP SLR level calculated as 0.92 times the 10% AEP SLR level	1.835	1.832	1.830	1.822	1.820

4.2.10 Initial Water Levels

Initial water levels (IWL) were applied at the relevant tide level at the start of the TUFLOW simulation, with care taken to ensure that the IWL adoption does not artificially inundate large areas that are not otherwise connected to the tidally influenced region of the bay/foreshore. This included 2D IWLs applied to the 2D grid and 1D IWLs applied to the pit and pipe network around Port Phillip Bay with inverts below the applicable tidal level to stabilise the TUFLOW models.

A 2D IWL was also applied where permanent water bodies exist, including lakes and wetlands, set according to the permanent lake/wetland levels where this information is available (i.e. asset drawings). Where permanent water bodies exist and water level data is not available, the initial water level was set using engineering judgment to fill storages but not cause them to start spilling.

4.2.11 Temporal Pattern Review

The selection of temporal patterns was completed in RORB (hydrological model) and is documented in Section 3.8 along with more model-specific details provided in each Technical Appendix (A-G). As part of the review process the validity of the critical temporal patterns selected in RORB were reviewed in TUFLOW, by simulating all ten temporal patterns for the critical durations of the Skeleton Creek model. This assessment was conducted for the 20% AEP event and the 1% AEP with climate change event.

The temporal pattern review found that the peak flood level results from the temporal patterns simulated from the RORB temporal pattern selection closely matched the median peak water level from the ten temporal patterns simulated in the TUFLOW model for each duration. The majority of the model catchment area remained within +/- 10 mm of the critical temporal patterns identified in RORB, with small areas

of up to 20 mm difference in the 1% AEP with climate change event and small areas of up to +/- 30mm difference in the 20% AEP event. This review is documented in Appendix M.

4.2.12 Critical Duration Assessment

The selection of critical durations and temporal patterns was completed in RORB and is documented in Section 3.8 along with more model-specific details provided in each Technical Appendix (A-G). This also enabled the selection of appropriate ARFs to adopt across the catchments. Critical events were identified by assessing the durations and temporal patterns that produced the median peak flow at key locations across the Study catchments.

The storms to be simulated in TUFLOW are listed in each Technical Appendix (A-G). Checks were carried out in areas where embankments (or similar) are present that could not be formally represented in the RORB models, to ensure the storm durations that produce the maximum water levels have been run and captured, respectively. These critical duration checks are documented in each Technical Appendix (A-G).

4.2.13 Model Performance

The performance of the hydraulic models was assessed to the extent supported by available data and was designed to provide confidence in the model's representation of catchment response, rather than to achieve an exact reproduction of historical flood magnitudes. The performance of the hydraulic models was informed by a combination of:

- Documented flood behaviour.
- Council and Melbourne Water records.
- Anecdotal and photographic evidence where formal measurements were unavailable.
- Available rainfall data.

In line with Australian Rainfall and Runoff 2019, it is acknowledged that:

- Available historic events information is generally smaller than the 1% AEP design event.
- Performance checks against frequent or in-bank events does not, on its own, guarantee performance for rarer floods.

However, Australian Rainfall and Runoff 2019 recognises that in urban catchments with limited long-term gauged data, verification using smaller events is often the only practical approach, provided its limitations are clearly acknowledged and appropriate checks are undertaken.

Accordingly, confidence in a model for design application is based on:

- Consistency of parameters with regional benchmarks.
- Stability of model behaviour across a wide range of storm durations and temporal patterns.
- Sensitivity testing of key parameters.
- Comparison of design flood estimates with independent approximate methods and regional expectations.

Specific to this study the performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and each council. Specifically:

- **Comparison with Melbourne Water flooding hotspot database:** Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- **Comparison with State Emergency Service road flooding hotspot database:** Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.

The key outcomes of these performance checks are summarised below, with details presented in Appendix N.

- **Overall model performance:** The performance checks indicate that across the modelled catchments the flood model outputs generally align with historical flood hotspots. These findings were also confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

4.2.14 Sensitivity Analysis

4.2.14.1 Tailwater levels

A sensitivity test for a single dynamic tidal level model run of the Kororoit Creek South model was conducted to assess the sensitivity of the model. The 1% AEP with climate change 6-hour event for the Kororoit Creek South model was assessed with the dynamic tidal level for Port Phillip Bay at Kororoit Creek provided in the Melbourne Water Flood Mapping Projects Specifications (2023) Appendix 18. The 6-hour event was selected for the sensitivity test as it was the longest duration event run for the Kororoit South model.

The model results of this sensitivity test were compared with the static tailwater level model result. The sensitivity tests produced model results that were up to 90 mm lower within the Kororoit Creek waterway from the bay up to Millers Road. Flood levels further upstream of Millers Road were not changed. Flood levels in the urban area around Kororoit Creek were also slightly reduced by up to 35 mm, and typical reduced by less than 20 mm. These results indicate that the model results in the vicinity of the bay are sensitive tailwater level assumptions, it is recommended that sensitivity testing of dynamic tidal levels is also conducted for the riverine Kororoit Creek flood mapping project.

This sensitivity check is documented in Appendix M.

4.2.15 Quality Assurance

The TUFLOW models have been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks have been assessed as not likely to adversely affect the model results and are summarised in Technical Appendices A-G.

In addition to the above, the TUFLOW HPC models were simulated with the control number factor reduced to 0.8 which factors down the courant, wave celerity and diffusion control numbers. The change in peak water levels was found to be minimal across the model areas.

5. Deliverables

5.1 AEPs and Scenarios

The results for this study were generated for the following storm events modelled in accordance with the project brief (Table 5-1).

Table 5-1: Modelled Scenarios.

Storm Event Scenarios		AEP Design Flood Event				
A	Base Case	✓	✓	✓	✓	✓
B	Climate Change – Increase Rainfall Intensity and Sea Level Rise	✓	✓			✓

5.2 GIS Deliverables

Key deliverables for the project are summarised in Table 5-2. In accordance with Melbourne Water's requirements flood mapping outputs have been delivered to Melbourne Water for all AEP events and scenarios modelled. The data has been delivered in GDA 2020, Zone 55 MGA projection. Melbourne Water provided the following file: 2023_MelbourneWater_FloodMapping_Template_v4.gdb and the outputs detailed in Table 5-3 have been populated in the geodatabase. With respect to this project the following is also noted:

- The waterways for the Maribyrnong River, Kororoit Creek, Stony Creek and Skeleton Creek have been excluded as the flood mapping of these waterways will be captured in separate studies by Melbourne Water.
- Across the models there are overlapping flood model results from each catchment. To address this Jacobs have reviewed these overlapping areas and selected the model which produces the higher flood level/greater extent. The GIS Deliverables have been clipped to this boundary. This was agreed with Melbourne Water.
- During the demarcation workshops the allocation of flood extents to either Melbourne Water or council required discussions on the appropriate allocation. As a result, the allocation of the authority to the flood extent may align more with these decisions than the methodology outlined in the Melbourne Water Flood Mapping Projects Specifications. The demarcation boundary has been agreed between Melbourne Water, Hobsons Bay and Brimbank Councils. The following principles guided the process of determining the demarcation boundary:
  - Demarcation based on the 1% AEP with climate change flood extent.
  - Land parcels affected by flooding were allocated to either Melbourne Water or Council based on the dominant source of flooding:
    - Melbourne Water flood extents relate to overland flows from waterways or underground main drains managed by Melbourne Water.
    - Council flood extents reflect flooding driven by Council-managed infrastructure, including local roads, open spaces, and pit-and-pipe networks.
    - In locations where flooding is primarily caused by tidal or estuarine tailwater and no Melbourne Water drainage asset is present, the extent has been attributed to the Council.

- Where applicable, one parcel per referral authority has been maintained to support consistent planning advice and minimise administrative uncertainty. This principle was applied unless multiple sources of flooding impact a parcel in a way that cannot be realistically separated. These areas of flooding were discussed with Melbourne Water and the respective Councils to confirm that these parcels would be classify Melbourne Water and Council as the referral authority.
- Where a parcel contains multiple units, a shared assignment to a single authority was preferred, provided it aligns with the underlying flooding source and modelled flow paths.
- The transition between Melbourne Water and Council extents has been reviewed to ensure there are no gaps or overlaps, and that the floodplain is represented as a continuous extent.

5.3 Flood Maps

Refer to the GIS deliverable output files for flood map information.

Table 5-2: Deliverables.

Deliverable	Comment
Hydrology model	The RORB model including the setup files and outputs have been provided to Melbourne Water.
Hydraulic model	The TUFLOW model build files and results (zipped) have been provided to Melbourne Water. Post processing grids of the results (i.e., the calculation of the max-max grid for each AEP) have also been provided).
GIS deliverable files	Refer to Table 5-3.
Flood Maps	Flood maps are provided as part of the Esri geodatabase GIS deliverable files.

Table 5-3: GIS Deliverables.

GIS Deliverable	Comment
RORB GIS Information	GIS information has been provided as per the requirements in the Melbourne Water Flood Mapping Projects Specifications.
Model Grid Points	Filtered and unfiltered grid points at 1 m resolution have been provided for each AEP flood event as per the requirements in the Melbourne Water Flood Mapping Projects Specifications.
Flow Values	As per the requirements in the Melbourne Water Flood Mapping Projects Specifications flow values were extracted from TUFLOW models for the drainage network and overland flows.
Plot Output Lines	Flow values were extracted from the plot output lines from TUFLOW as per the requirements in the Melbourne Water Flood Mapping Projects Specifications.
Level of Service	As per the requirements in the Melbourne Water Flood Mapping Projects Specifications the level of service output has been populated based on the TUFLOW model results. The 1D TUFLOW results, including peak flows in the TUFLOW 1d_ccA_L (pipe percent full) output file, have been referenced to determine the asset capacity AEP range attribute. The asset capacity has also been determined based on percent full information.
Flood Extents	The TUFLOW results for the simulated temporal patterns and storm durations for each AEP flood event and scenario have been combined to identify the maximum results at each model cell. As per Melbourne Water's requirements the following filtering was incorporated: ▪ Depth filtering. This is applied to the peak depth grids generated by TUFLOW. It is considered a post processing task. ▪ Melbourne Water and Hobsons Bay Council demarcated areas Depth<50 mm filtered. ▪ Brimbank Council demarcated areas Depth<100 mm filtered. ▪ Isolated areas of flooding<100m^2 removed from the flood extent. ▪ Some areas less than 100m^2 remain where there is a split between the council and Melbourne Water demarcation and the split results in a flood extent less than 100m^2. ▪ Fill or remove 'holes' in the flood extent that are < 100m^2. ▪ Extent smoothed using the feature manipulation engine (FME) tool provided by Melbourne Water. Extents have been demarcated as either Melbourne Water (underground drain or waterways) or council based on the procedure outlined in the Flood Mapping Projects Specifications.
Flood Contours	Flood contours were produced at 0.5 m intervals based on the maximum water levels (h max) grid for each AEP flood event. The contours were smoothed with discontinuous and circular sections removed with additional adjustments also applied in alignment with requirements.
Flood Study area	This output was produced for the 1% AEP with climate change extent and the 1% AEP extent.
Flood Hazard safety	The flood hazard output has been determined for each AEP flood event based on the ZAEM1 TUFLOW output. This represents the flood hazard category as outlined by the Australian Emergency Management Institute.
Parcels Flooded	Two layers were generated to capture the flooded parcels. One for the 1% AEP with climate change and one for the 1% AEP. The flooded parcels were determined by intersecting the provided parcels layer with the respective flood extent across the modelled area. Parcels were then reviewed and categorised as either Melbourne Water or Council depending on the source of flooding. Parcels were removed from this layer where the flood extent coverage was less than 2% of a parcel's area. If the parcel was road facing and more than 25% of that length was exposed to flooding from the road, then the parcel was kept in the layer.
Buildings Flooded	Two layers were generated to capture the buildings flooded. One for the 1% AEP with climate change and one for the 1% AEP. Flooded buildings were determined by intersecting the provided buildings layer with the respective flood extent across the modelled area. The building footprints were provided by Melbourne Water.

GIS Deliverable	Comment
Proposed Planning Scheme overlays	Proposed Planning Scheme overlays LSIO, SBO 1 and SBO 2 have been generated. The layers represent adjusted flood extents which have been adjusted to remove extents where the parcels flooded criteria has been applied.

6. Recommendations

The flood models have been developed in accordance with the Melbourne Water Flood Mapping Projects Specifications (October 2021), ARR 2019 guidelines and consultation with Melbourne Water. The flood models and the associated datasets should be used to update and inform planning overlays, emergency response, climate change adaptation and floodplain management activities that typically follow a flood mapping study.

6.1 Data recommendations

- It is recommended that a procedure be developed for capturing flood data immediately following flood events. It is envisaged that this would include capturing social media feeds, newspaper articles, SES call out records, road closures, information collected by Council as well as data collection such as flood marks, aerial photography (oblique and plan), drone survey etc.
- Updated LiDAR dataset and aerial photography should inform any future study revisions.

6.2 Hydrology recommendations

- It is recommended that the hydrology rainfall inputs and loss parameters be revised in the next round of modelling to incorporate future updates to design rainfall guidelines included in Australian Rainfall and Runoff 2019 Version 4.2.

6.3 Floodplain management

It is recommended that:

- The relevant Victorian SES flood guides are revised and updated considering the new information generated from this study
- The Flood sub-plan of the Municipal Emergency Management Plan for relevant Councils should be updated using the information generated from this study
- The results from this study should be used to update the planning scheme, in particular, the Land Subject to Inundation Overlay (LSIO) and the Special Buildings Overlays (SBO1 and SBO2).
- A flood mitigation study be undertaken to inform developing a program of works and measures for reducing flood risk in the study area. This would occur as part of Melbourne Water's on-going flood risk reduction programming. This and the flood damages assessment could be delivered as part of a floodplain management plan for the study area.

6.4 Future flood mapping studies

- It is recommended that modelling be revised every 5 years, or sooner if a major flood event occurs. Revisions to modelling should also adhere to new guidance on climate change, flood hydrology and flood hydraulics. This should include reviewing any calibration and the use of gauge flow data including any changes to rating curve performance.

7. References

1. Ball J., Babister M., Nathan R., Weeks W., Weinmann E., Retallick M., Testoni I. (Editors), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, © Commonwealth of Australia (Geoscience Australia), Version 4.1, 2019.
2. Bradley (1978), *Hydraulics of Bridge Waterways*.
3. Bureau of Meteorology (2022), *Design Rainfall Data System*.
4. Cardno (2018), *Hobsons Bay Flood Modelling Project*, Prepared for Hobsons Bay City Council (V170209).
5. Cardno (2019), *Hobsons Bay Flood Modelling Update Project,* Prepared for Hobsons Bay City Council (V190284).
6. Datahub website (2019), Accessed online at VIC Specific Data, *ARR DataHub* (arr-software.org).
7. Engeny (2022), *Moonee Valley Flood Mapping 2021/22 Steele Creek*, Prepared for Melbourne Water (V3000_139-REP-008-2) (Status: Client issue with Draft Deliverables).
8. Grace (2022), *Determining Catchments for Hobsons Bay City Council*, Dr Joshphar Kunapo (Jasper).
9. Harc (2020), *Benchmarking ARR 2019 for Victoria – Technical Report. Version 2*, October 2020.
10. Hoang, T. M. T., *Tide level frequency analysis of St Kilda Marina (Site No: 229670)*, 2011.
11. Jacobs (2024), *2024 Maribyrnong River Flood Modelling Project Summary Report*.
12. Jordan P., Nathan R., Mittiga L., Taylor B. (2005), *Growth curves and temporal patterns of short duration design storms for extreme events*.
13. Melbourne Water (2021), *Melbourne Water AM STA 6200 Flood Mapping Projects Specification* (October 2021).
14. Melbourne Water (2023), *Melbourne Water AM STA 6200 Flood Mapping Projects Specification* (August 2023).
15. Minty and Meighen (1999), *Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia*, HRS Report No.06.
16. Pearse M., Jordan P., Collins, Y. (2002), *A simple method for estimating RORB model parameters for ungauged rural catchments*. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002*., pp. 128–134, Institution of Engineers, Australia: Barton, A.C.T.
17. RPV (Rail Projects Victoria) (2021), *AJM JV Melbourne Airport Rail Technical Advice Note – Stony Creek Hydrology*.
18. RPV (Rail Projects Victoria) (2020), *AJM JV Geelong Fast Rail – Laverton Creek Hydrology Modelling*.
19. RPV (Rail Projects Victoria) (2020), *AJM JV Geelong Fast Rail – Skeleton Creek Hydrology Modelling*.
20. RPV (Rail Projects Victoria) (2020), *AJM JV Geelong Fast Rail Technical Advice Note - Kororoit Creek (Lower) Hydrology Modelling.*
21. RPV (Rail Projects Victoria) (2020), *AJM JV Melbourne Airport Rail – Maribyrnong Upper Hydrology Update*.
22. RPV (Rail Projects Victoria) (2021), *AJM JV Geelong Fast Rail – Cherrys Main Drain Hydrology Modelling*.
23. The Bureau of Meteorology (2022), *Design Rainfall Data System* (http://www.bom.gov.au/water/designRainfalls/revised-ifd/).

Appendix A. Maribyrnong River

The waterway for the Maribyrnong River has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

Appendix A. Maribyrnong River Hydrological Model and Hydraulic Model

This appendix details the RORB and TUFLOW model development for the Maribyrnong catchment and full technical details of adopted parameters and results.

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A.1 Catchment Description and Study Area

The Maribyrnong River catchment is a major catchment to the north-west of Melbourne, with a total catchment area of 1409 km^2. The catchment primarily consists of rural/regional land use upstream of Keilor Township and urban/impervious/heavily modified land use downstream of Keilor.

There are a number of streamflow gauges located throughout the catchment; the Maribyrnong River at Keilor gauge (230105A) is of relevance to this Study for RORB model calibration purposes, given its location within the Brimbank Council LGA. The catchment and location of the gauge used to calibrate the RORB model parameters to observed data are shown in Figure A-1.

Whilst the Maribyrnong River catchment extends to the Yarra River, the area of interest for this Study only extends as far as the Avondale Heights/Braybrook area. This was used to define the RORB modelling extent for the current Study. At this location, the Maribyrnong River catchment is made up of the smaller catchments of Deep Creek, Emu Creek, Jacksons Creek, Taylors Creek and Steele Creek.

In addition to the above most of the hydrological modelling for this project was completed, reviewed and approved between late 2022 and early 2023. The works completed in this study for the Maribyrnong River are superseded by the hydrological assessment completed by Jacobs for the Lower Maribyrnong River Flood Mapping Study completed in 2024. Flood mapping of the Maribyrnong River is also captured in the Lower and Mid Maribyrnong River flood studies completed by Jacobs.

The waterway for the Maribyrnong River has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

A.1.1 Previous RORB Model

An existing RORB model for the Maribyrnong River catchment was accessed for use in this Study. This model was originally developed by Melbourne Water in 1986 (MMBW, 1986). Melbourne Water updated the model in 2006 and 2014 before RPV updated it from ARR 1987 to ARR 2019 and Melbourne Water Flood Mapping Projects Specifications (RPV, 2020). The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Maribyrnong River TUFLOW models covering Brimbank Council LGA (note the Maribyrnong River does not interact with Hobsons Bay LGA). The updates undertaken to the model are outlined in the sections below.

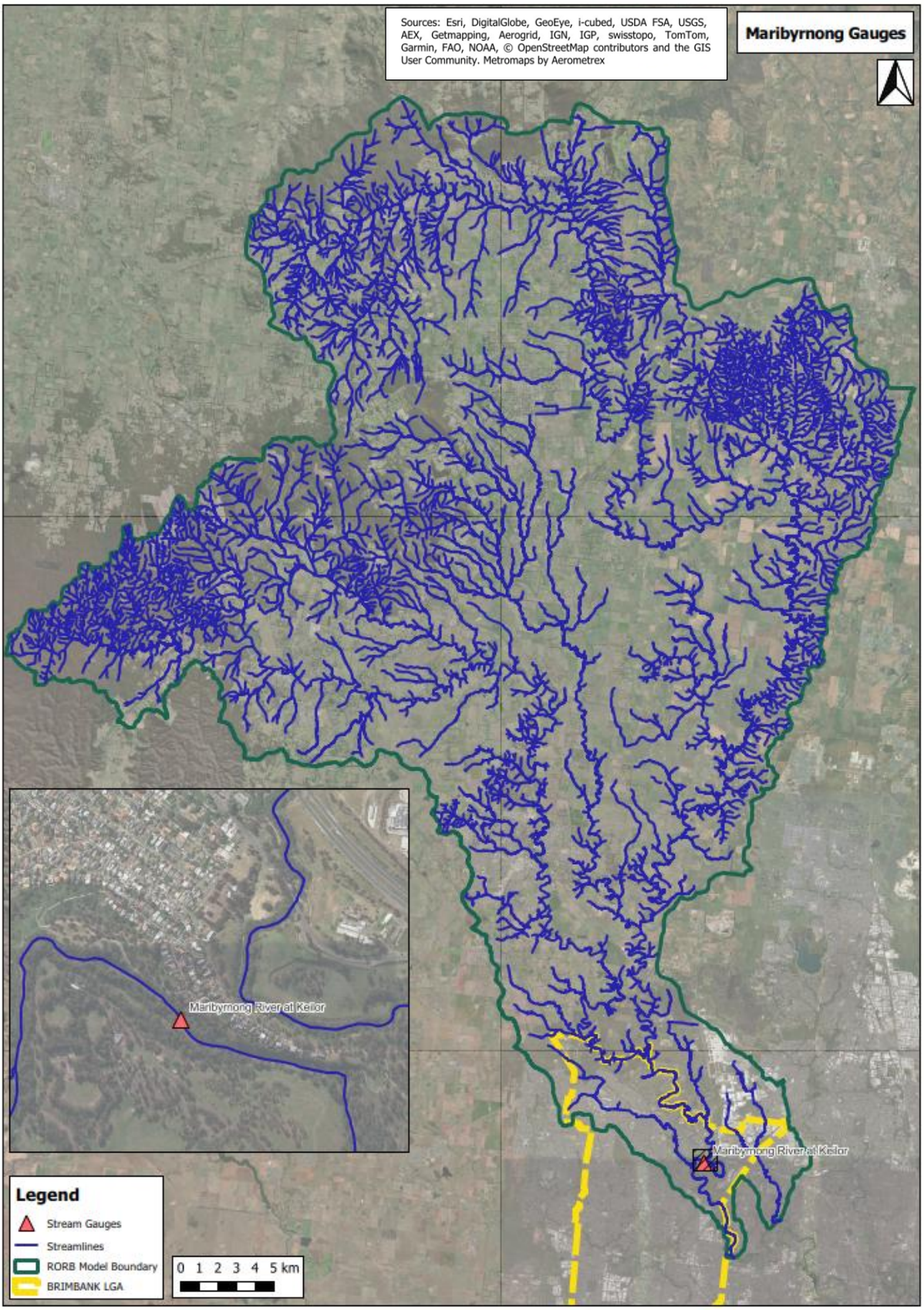


Figure A-1: Maribyrnong River catchment and location of the gauge used to calibrate the Study RORB model.

A.2 RORB Model Setup

The development of the RORB model is represented in Figure A-2 and Figure A-3 and described in the following sub-sections.

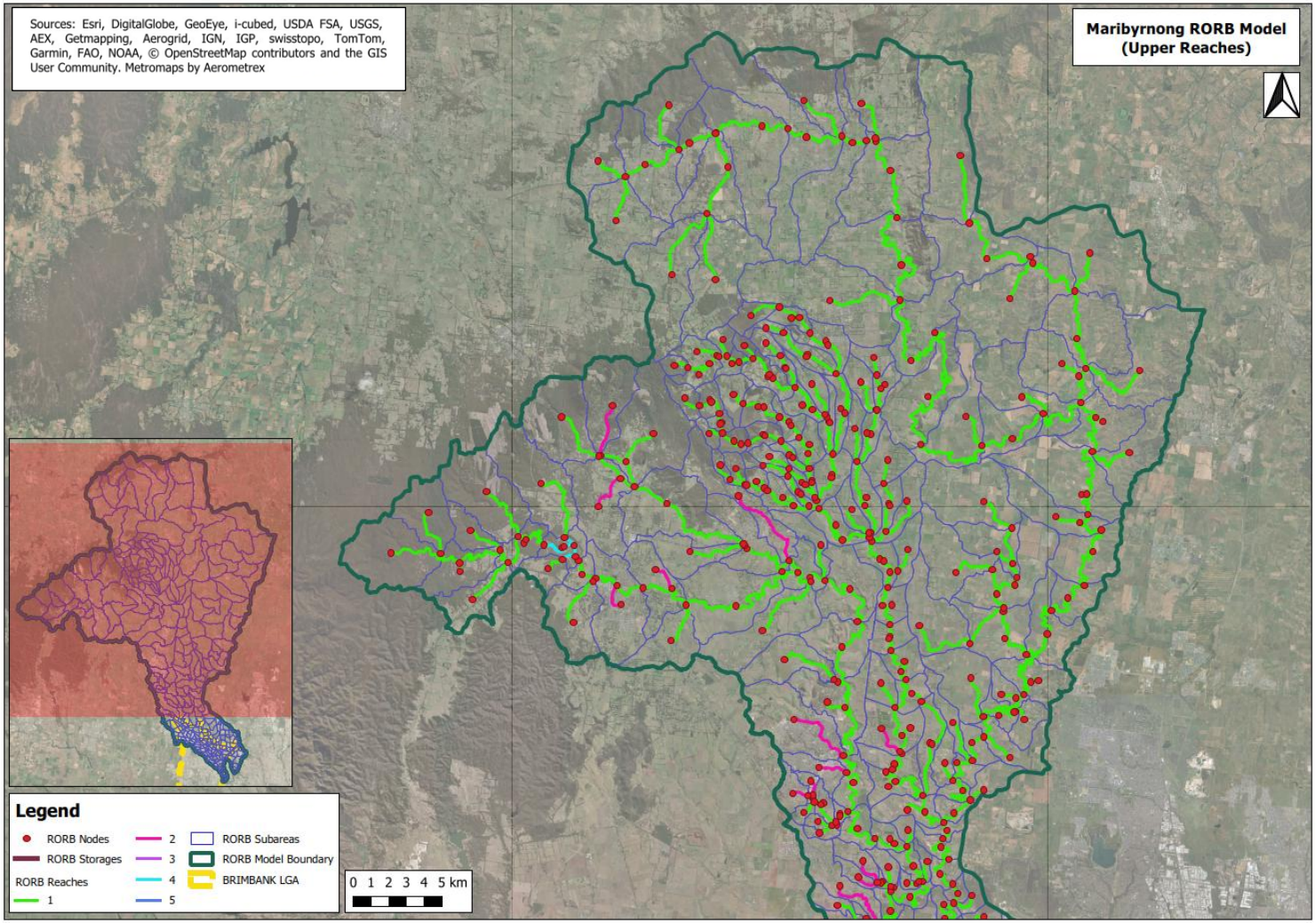


Figure A-2: Maribyrnong River RORB model setup (upper reaches).

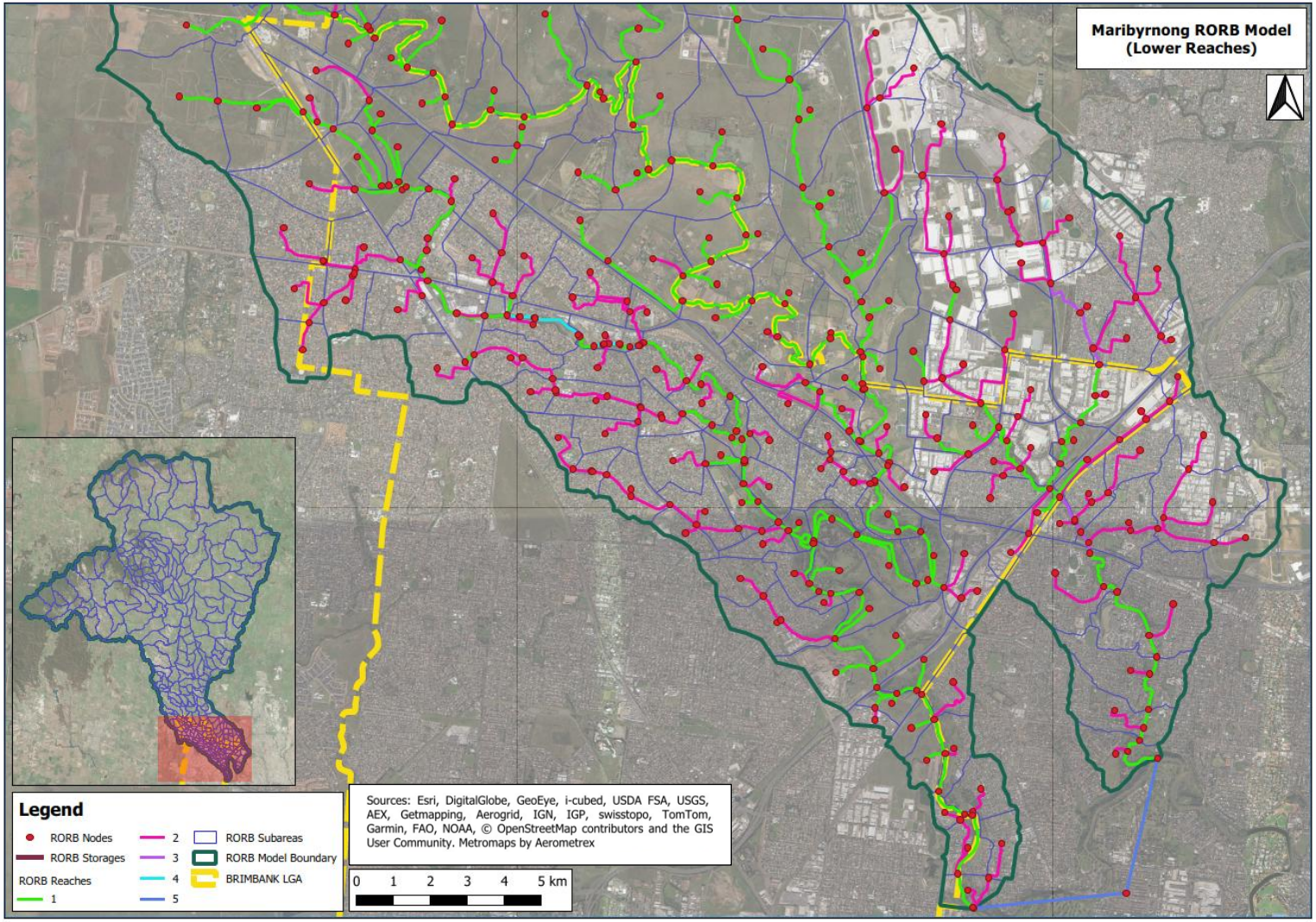


Figure A-3: Maribyrnong River RORB model setup (lower reaches).

A.2.1 Catchment and Subarea Boundaries

A review of the previous RORB model identified the need to re-delineate large areas, particularly those falling within the LGAs of interest. Subareas within Brimbank LGA were reduced and standardised in preparation for extraction of hydrographs for input into TUFLOW. As such, subarea sizes upstream of the Brimbank LGA were largely retained as per the previous RORB GIS files, given that these are upstream of the area which is modelled in TUFLOW. Interstation area nodes have been used to split the catchment and vary routing parameters where subarea sizes change.

Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks as well as aerial imagery to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas, or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Finally, catchment delineation considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

It is noted that the RORB model contains a select number of small subareas upstream of Brimbank LGA. Given that the model has been calibrated to the Keilor stream gauge located within the Study area, and validation checks of the 1% AEP flows have been carried out, this approach is considered suitable for the purposes of the Study, whereby the Maribyrnong River flows will largely be used as tailwater levels in the TUFLOW hydraulic models for the catchment area.

The final catchment and subarea boundaries are shown in Figure A-2 and Figure A-3.

A.2.2 Node-link network

The node-link network shown in Figure A-2 and Figure A-3 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

A.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
    - Type 1 – Natural channels, used for major creek reaches
    - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
    - Type 3 – Lined channel or pipe – these were used to represent flow paths associated with major underground Melbourne Water trunk drains and lined channels
    - Type 4 – Drowned – these were used upstream of storages or major waterbodies
    - Type 5 – Dummy – used to connect independent catchments (i.e. Steele Creek) to a single outlet node

The final reach alignments and types are shown in Figure A-2 and Figure A-3.

A.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB), as listed in Table A-1.

Table A-1 Storages in the Maribyrnong River RORB model.

Storage	Data source and checks
Rosslynne Reservoir	Storage details adopted as per RPV model (2020), H-S and S-Q relationships retained. No further information available for further checks or updates.
Sydenham RB	Storage was not previously represented in the RPV model (2020). As such, the storage details were adopted from a Taylors Lake RORB model supplied by Melbourne Water (Section 2.3.2) for use on this study. Checks on spillway height, length and outlet pipes confirmed by GHD (2016a); checks also carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information and inspection reports – this check identified a minor update required to one of the RB outlet pipe lengths – this was updated in the RORB model. No further information available for further checks or updates (i.e. on H-S relationship).
Sydenham West RB	Storage was not previously represented in the RPV model (2020). As such, the storage details were adopted from a Taylors Lake RORB model supplied by Melbourne Water (Section 2.3.2) for use on this study. Storage details confirmed by GHD (2016b); checks also carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information and inspection reports. No further information available for further checks or updates (i.e. on H-S relationship).
Taylors Lakes RBs (includes a series of 6 storages in the RORB model: Lake Heron, Lake Ibis, Lake Kingfisher, Taylors Lake, Lake Shellduck and Lake Spoonbill)	Storage was not previously represented in the RPV model (2020). As such, the storage details were adopted from a Taylors Lake RORB model supplied by Melbourne Water (Section 2.3.2) for use on this study. Checks on spillway height, length and outlet pipes confirmed by GHD (2016c) and Melbourne Water inspection reports; checks also carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S relationship).

A.2.5 Diversions

No diversions are present in the Maribyrnong River RORB model.

A.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

A.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow

calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

A.2.8 RORB version

RORB version 6.47 was used for modelling.

A.3 Flood Frequency Analysis (FFA)

An at-site Flood Frequency Analysis (FFA) for the Maribyrnong River at Keilor Gauge was undertaken according to the guidelines provided in Book 3 Chapter 2 of ARR 2019. The FFA was undertaken using the Flike software package. Flike provides a Bayesian framework for comprehensive at-site flood frequency estimation that allows the inclusion of ungauged historical events.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

1. Prepare data:
    a. Collect gauged streamflow data
    b. Collect historic data, including the review of previous studies
    c. Undertake standard data checks on the stream flow data including checking error codes, cataloguing data gaps, undertaking visual inspections and reviewing the rating curve
    d. Determine the water year
    e. Extract the annual maximum series and check peaks for independence
2. Using Flike, fit an extreme value distribution to the annual maximum series, including the influence of:
    a. Historic data (data that exists beyond the extent of the annual maximum series)
    b. Censoring low flows with a multiple Grubbs Beck test

A summary of the FFA and findings are included below.

In addition to the FFA completed for the Maribyrnong at Keilor, an FFA was carried out for both Jacksons Creek at Sunbury and Deep Creek at Bulla as part of the Study to check model performance and flow values upstream of the Study area. As this only formed part of a checking exercise, the details of the Jacksons Creek and Deep Creek FFAs have not been documented here.

A.3.1 Annual Maxima Flows

The Maribyrnong River at Keilor (230105A) stream gauge has records available from different sources, listed in Table A-2.

Table A-2: Streamflow data sources available for the Maribyrnong River at Keilor

Data	Period of record	Source
DELWP Maribyrnong at Keilor continuous streamflow data	1908 – 2022	data.water.vic.gov.au
The Bureau Maribyrnong at Keilor continuous streamflow data	1975 – 2022	www.bom.gov.au/waterdata/

Data	Period of record	Source
Maribyrnong at Keilor continuous streamflow data	1975 – 2022	Provided by Melbourne Water
MMBW partial series of flows for Maribyrnong at Keilor – used to extend the recorded gauge levels record	1871 – 1986	Metropolitan Board of Work (MMBW) Maribyrnong River Flood Mitigation Study (March 1986)

A review was carried out, whereby annual maximum flows were extracted from continuous flow records and crosschecked against all data for discrepancies. Section A.3.6.1 provides the full annual maxima series for each data source, along with details on data gaps and justification on adopted values. The DELWP gauge record was found to be suitable for use in most instances, a plot of the available data is shown in Figure A-4. DELWP gauge records were the most complete with the following characteristics:

- A relatively complete record from 1908 to 1934 with some gaps as shown in Figure A-4.
- No data from 1934 to 1948
- Continuous data from 1948 to present although there are some significant data gaps between 1956 and 1968.

Review of this gauge found that there were 27 years of missing annual maxima data due to missing years or gaps in the continuous flow record. Data from either MMBW or The Bureau/Melbourne Water's records were adopted in some instances (5 years) where uncertainty around DELWP's records was present due to missing data. The adopted annual maxima series consists of 90 years from 1906 to 2022 as presented in Figure A-5 and listed in Table A-3.

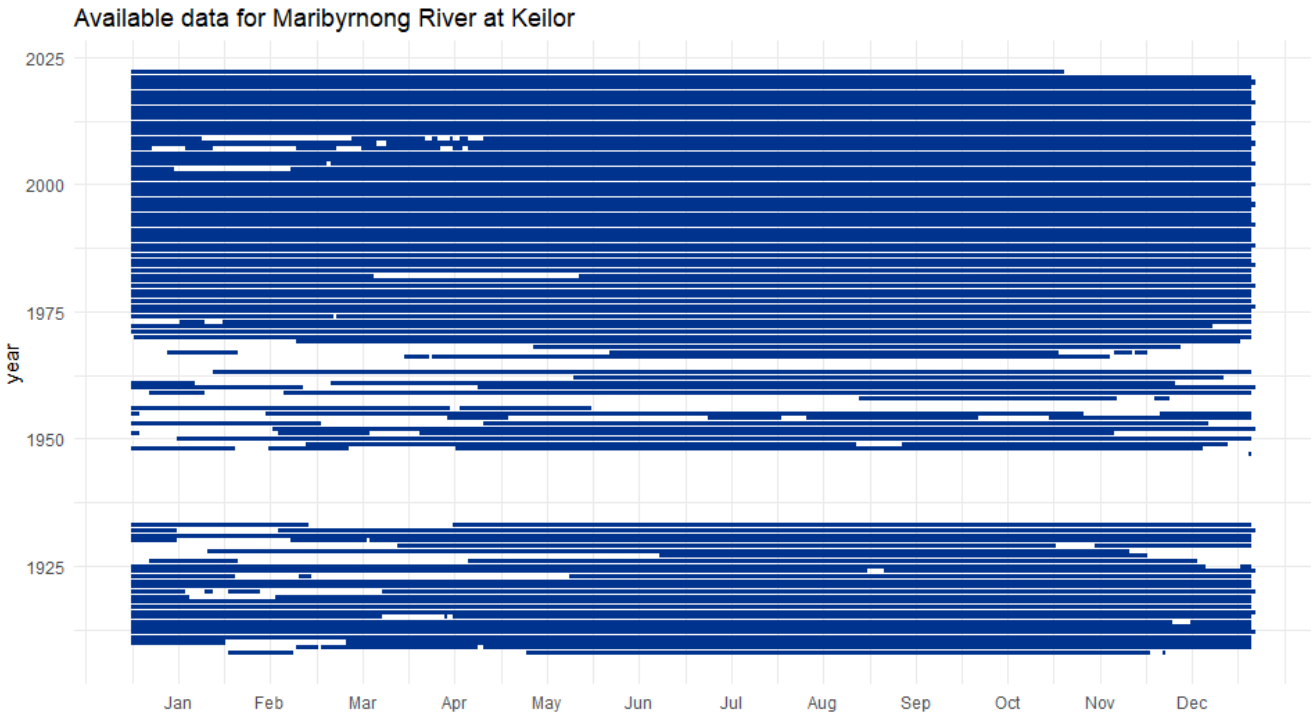


Figure A-4: Available data plot Maribyrnong River at Keilor

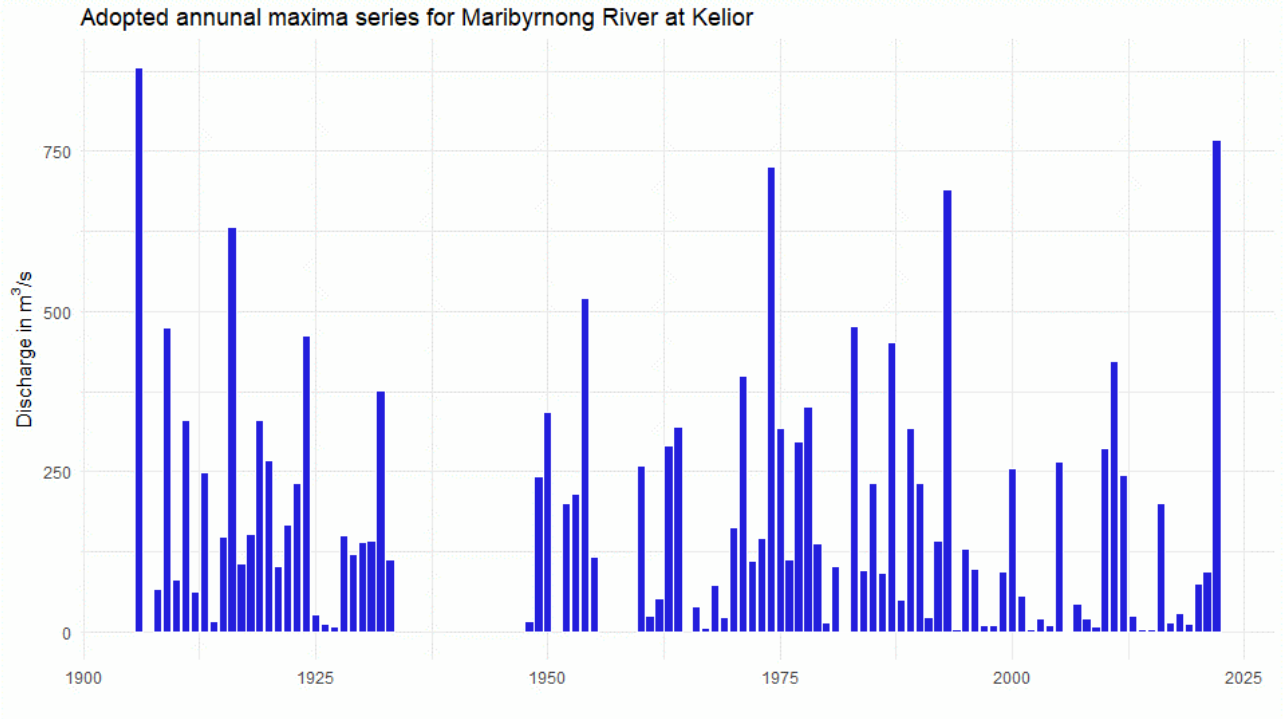


Figure A-5: Maribyrnong River at Keilor adopted annual maxima series.

Table A-3: Maribyrnong River at Keilor adopted annual maximum flows.

Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)
1906	880	1933	112	1983	476	2008	20
1908	66	1949	243	1984	96	2009	9
1909	474	1950	343	1985	233	2010	287
1910	81	1952	201	1986	91	2011	423
1911	330	1951	314	1987	451	2012	245
1912	62	1953	215	1988	50	2013	25
1913	249	1954	520	1989	317	2014	3
1914	17	1955	116	1990	232	2015	5
1915	149	1959	43	1991	22	2016	201
1916	632	1960	260	1992	143	2017	14
1917	106	1963	291	1993	690	2018	30
1918	153	1964	320	1994	4	2019	12
1919	330	1969	22	1995	129	2020	76
1920	268	1970	164	1996	99	2021	93
1921	103	1971	399	1997	10	2022	768
1922	168	1972	110	1998	10		
1923	232	1973	146	1999	93		
1924	461	1974	726	2000	256		

Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)	Year	Flow (m^3/s)
1925	28	1975	317	2001	57		
1926	13	1976	112	2002	3		
1928	151	1977	297	2003	20		
1929	121	1978	352	2004	11		
1930	139	1979	138	2005	265		
1931	143	1980	14	2006	2		
1932	376	1981	103	2007	43		

A.3.2 Rating Curve Review

To ensure that the rating tables were producing reasonable flow estimates for high flows, a review of the rating tables obtained for the Keilor gauge (230105A (Bureau of Meteorology, 2022)) was carried out. The rating curve is shown in Figure A-6. It is understood that new gauging measurements were collected by Melbourne Water during a recent high flow event in October 2022, and the rating table was revised and extended; this is shown in Figure A-6. The flow estimates of the October 2022 event are therefore considered reliable. High flow estimates in excess of 316 m^3/s prior to this event are known to have exceeded the rating table.

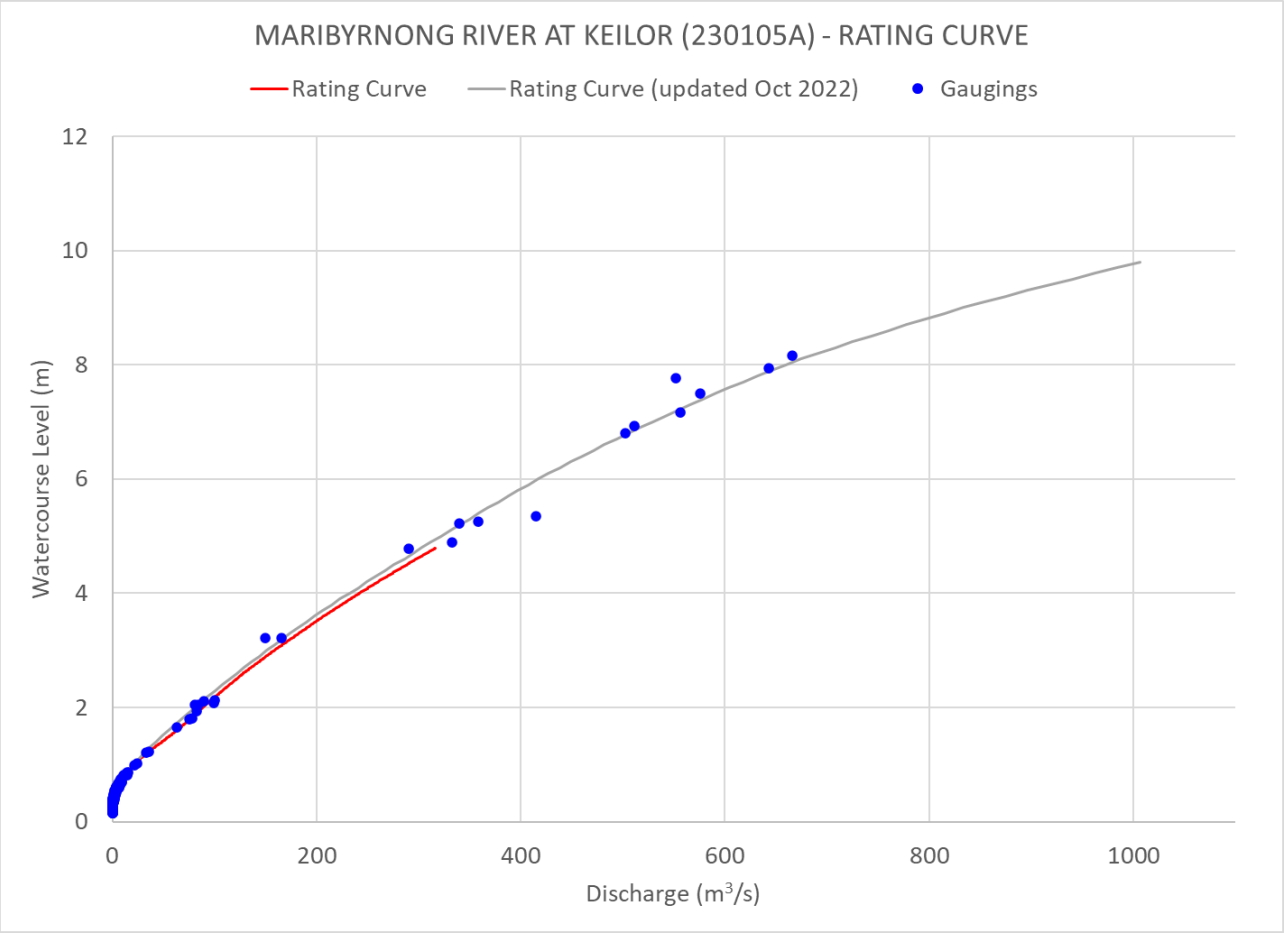


Figure A-6: Rating table for Maribyrnong River at Keilor.

A.3.3 Historic information

A review of historic information was completed to validate the annual maxima series, with particular focus on the early period of record (as there was greater uncertainty in earlier records prior to commencement of continuous gauging). The review included data from newspaper archives and media reports obtained from Trove (trove.nla.gov.au, accessed on 2/11/2022) and information listed in the Melbourne and Metropolitan Board of Work (MMBW) Maribyrnong River Flood Mitigation Study (March 1986). A number of historic flood events were reported in newspapers from as early as 1883. Table A-4 summarises key reports relating to large flood events on the Maribyrnong River prior to 1960.

This review resulted in the incorporation of the 1871, 1891, 1901 and 1906 flood events in the FFA as historic events. This review also confirmed the 1954 flood and indicated that there were no records of large flood in the large data gap from 1956 to 1968.

Table A-4: Summary of historic information and newspaper reports relating to large historic flood events on the Maribyrnong River.

Year	Flow (m^3/s) (rank)	Report	Report date	Source & hyperlink
1871	600 (6)	Reports in 1906 (rank 1) confirm that flooding reached a level 'higher than the flood of 1871'. This confirms the original ranking and occurrence of a major event during this year. Maribyrnong River also referred to as the Saltwater River.	10/9/1906	The Argus
1883	-	Reports in 1891 refer to observing the 'biggest flood for eight years' – however there are no records with sufficient information to validate this. This could be an error and the report meant in 20 years.	26/6/1891	The Age
1891	560 (7)	Heavy flooding reported in June 1891– threat to life and property. The impact of bridges on the river damming back waters was noted by newspapers.	26/6/1891 18/7/1891	The Age Independent
1901	320 (21)	Reports in 1932 noted the 'heaviest rainfall since 1901'. No further reports to provide additional details.	14/10/1932	The Age
1906	880 (1)	Numerous newspaper reports on the magnitude, impact and devastation of this event in September 1906 – largest flood on record. Notable remarks: River reached half a mile wide at Maribyrnong Road bridge Water reached depth of 7ft at Burton Crescent (measured against lamppost) Unprecedented damage to property and livestock Loss of life Weakness of city's drainage network noted Rain fell continuously for 12 hours with the total falls ranging from 70mm at Maribyrnong to 125mm at Deep Creek in the upper catchment (MMBW, 1986) The railway bridge was 'ascribed the bulk of the damage', which held back tons of debris and 'dammed back the force of the water and drove it along the railway embankment'	15/9/1906 10/09/1906 15/9/1906	Independent The Argus Leader

Year	Flow (m^3/s) (rank)	Report	Report date	Source & hyperlink
		Photographs of devastation and damage published. Several reports about calls for funding and flood mitigation increased since this event.		
1909	474 (10)	Reports of flooding where the river rose 9ft in a few hours. The report mentions that September 1906 flood was 4ft higher than this flood.	20/9/1909	The Herald Leader
1910	-	New Maribyrnong Bridge almost completed – report notes that old bridge was acting as barrier to flow. The new bridge will positively impact flood levels up and downstream, benefiting the low-lying land on the west side of the bridge.	24/8/1910	The Herald
1916	632 (5)	Anxiety of residents reported upon in newspapers with relatively recent memory of the 1906 event. Reports note the change in flood conditions since the upgrade of the railway bridge at Footscray and the old Maribyrnong Road bridge – removal of obstructions, flow and channel now unimpeded. However, they also note that compared to the last large flood (1906) there had been more development/properties built on low-lying land/floodplain areas. Further calls for flood relief channels and levees to be built.	27/9/1916 28/9/1916	The Age The Essendon Gazette and Keilor, Bulla and Broad-meadows Reporter
1924	461 (11)	Reports of flood events in August and October 1924. Property and businesses flooded.	27/8/1924 7/11/1924	The Herald The Argus
1932	376 (15)	Reports of this event being the 'largest flood since 1916'. This is an inconsistency given that 1924's flood was larger, however reasons for this could include the speed at which waters rose and/or lack of prior warning of a flood, making the impact more pronounced. Heavy rains combined with saturated ground and snow melt in upper catchment. Quick event – very little/no warning. The river went from normal levels to +over 8ft in 4 hours.	30/8/1932 31/8/1932	The Herald The Age
1942	-	Report confirming that a flood as large as 1906 had not occurred since. Houses were now built in areas that were flooded back in 1906 – residents were worried about potential flooding if a large event were to happen again.	24/4/1942	Sunshine Advocate
1954	520 (8)	Flooding reported with significant damage to property for several events over Nov-Dec period. Some properties flooded 4 times in 7 weeks. Evacuations, rescues, power outages and travel disruptions (airport closed) reported.	13/12/1954 14/12/1954	The Age The Argus

A.3.4 Removal of Probable Influential Low Flows

During the period of record there were several low flow years. Low flows were censored from the dataset to ensure that these did not unduly affect the fit of the flood frequency curve. A low flow discharge threshold of 76 m^3/s was determined by using the multiple Grubbs-Beck test which resulted in 27 events being censored.

A.3.5 Flood Frequency Analysis Results

The results of the FFA for the Maribyrnong River at Keilor gauge are shown in Table A-5 and Figure A-7. The best fit to the annual maximum data series was achieved using Bayesian framework and a Log Pearson III (LP3) probability model.

Table A-5: Maribyrnong River at Keilor FFA expected quantiles.

AEP 1 in Y	FFA Quantile (m^3/s)	Lower 90% CL (m^3/s)	Upper 90% CL (m^3/s)
5	285	240	340
10	420	360	500
20	565	470	690
50	760	610	1005
100	915	705	1320
200	1070	785	1700

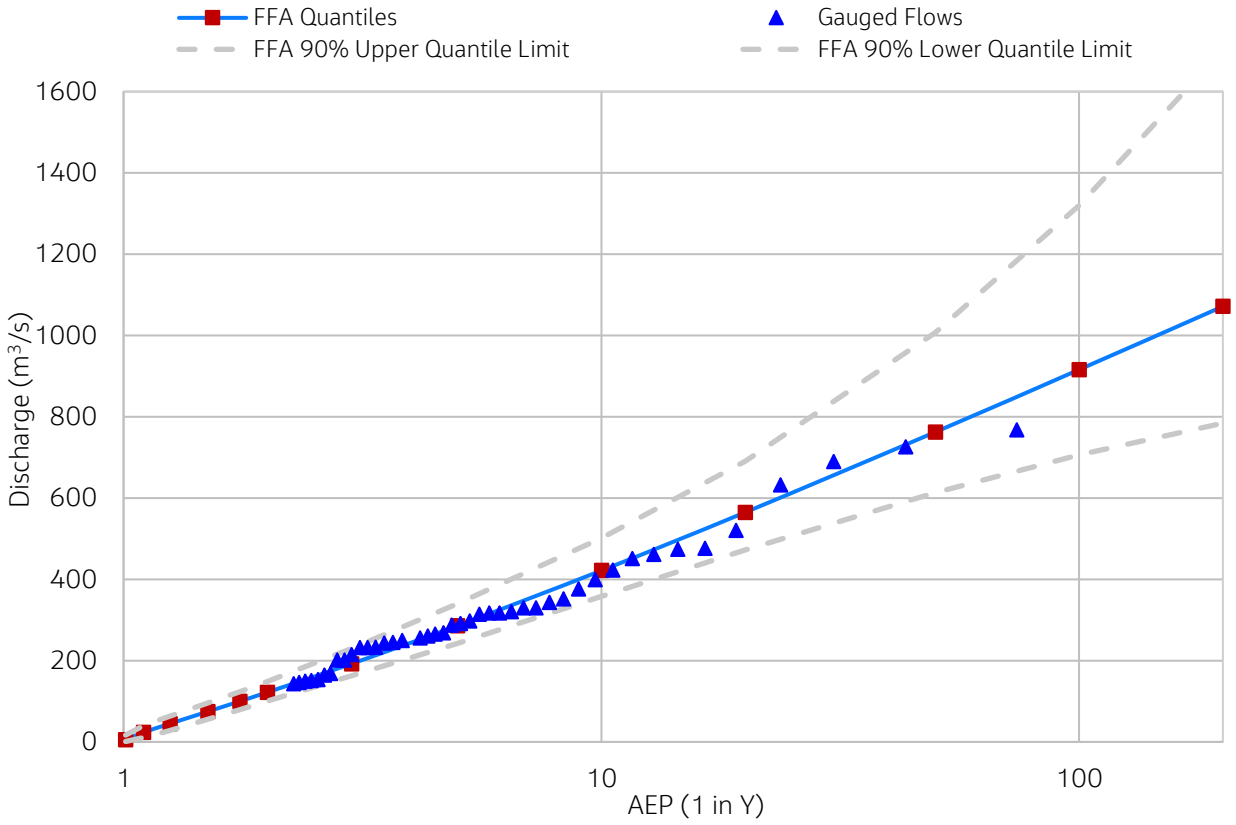


Figure A-7: Maribyrnong River at Keilor FFA results.

A.3.6 Comparison to previous estimates

The current FFA results were compared to the flood quantiles estimated by MMBW (1986) (shown in Table A-6). The estimates produced from the current study are greater than those from the previous work by between 5-9%. This is due to:

- The additional 40 plus years of data
- More sophisticated analysis techniques

- A Bayesian approach versus a method of moment approach
- The ability to safely censor low flows
- The incorporation of historic information

This increase in the discharge for flood quantiles can be intuitively explained by considering the occurrence of major flood events since 1986. In the period 1871 to 1986, effectively 115 years, there were two observed peak flows in excess of 650 m^3/s (1908 - rank 1 and 1974 – rank 3). In the period since (36 years), there have been an additional two events greater than 650 m^3/s (1993 - rank 4 and 2022 - rank 2). The FFA results from the current study are therefore considered reasonable, in alignment with expectations and observed/reviewed data.

Table A-6: Maribyrnong River FFA Comparison to previous estimates.

AEP1 in Y	MMBW (1986) FFA Quantile (m^3/s)	Current FFA Expected Quantile (m^3/s)	% Change
5	270	285	+6%
10	400	420	+5%
20	530	565	+7%
50	710	760	+7%
100	840	915	+9%

A.3.6.1 Annual Maxima Series Review

Table A-7 shows the annual maxima series for each data source, details on data gaps and justification on adopted values.

Table A-7: Annual maxima series review for the Maribyrnong at Keilor.

Year	Adopted AMAX (m^3/s)	DELWP (m^3/s)	MMBW (m^3/s)	BOM (m^3/s)	Melbourne Water (m^3/s)	DELWP no. missing days	Comments
1871	input as historic		600				Prior to commencement of DELWP gauging - MMBW value adopted
1891	input as historic		560				
1901	input as historic		320				
1906	880		880				
1907	Excl						Missing year of DELWP data - excluded
1908	66	66				110	
1909	474	474	495			57	
1910	81	81				39	
1911	330	330	329			0	
1912	62	62				0	
1913	249	249	253			0	
1914	17	17				6	
1915	149	149				22	
1916	632	632	642			0	
1917	106	106				0	
1918	153	153				0	

Year	Adopted AMAX (m^3/s)	DELWP (m^3/s)	MMBW (m^3/s)	BOM (m^3/s)	Melbourne Water (m^3/s)	DELWP no. missing days	Comments
1919	330	330	329			28	
1920	268	268	269			51	
1921	103	103				0	
1922	168	168				0	
1923	232	232				105	
1924	461	461	462			5	
1925	28	28				11	
1926	13	13				99	
1927	Excl	9				206	Incomplete DELWP data - excluded
1928	151	151				66	
1929	121	121				100	
1930	139	139				38	
1931	143	143				0	
1932	376	376	380			33	
1933	112	112				47	
1934	Excl					365	Missing years of data in all records - excluded
1935	Excl					365	
1936	Excl					366	
1937	Excl					365	
1938	Excl					365	
1939	Excl					365	
1940	Excl					366	
1941	Excl					365	
1942	Excl					365	
1943	Excl					365	
1944	Excl					366	
1945	Excl					365	
1946	Excl					365	
1947	Excl					364	
1948	Excl	17				63	Incomplete DELWP data - excluded
1949	243	243				80	
1950	343	343				15	
1951	314	314				106	
1952	201	201				46	
1953	215	215				67	
1954	520	343	520			199	DELWP records missing part of year - MMBW value adopted
1955	116	116				66	
1956	Excl	99				219	Incomplete DELWP data - excluded
1957	Excl					365	Missing year of DELWP data - excluded
1958	Excl	47				276	Incomplete DELWP data - excluded
1959	43	43				32	

Year	Adopted AMAX (m^3/s)	DELWP (m^3/s)	MMBW (m^3/s)	BOM (m^3/s)	Melbourne Water (m^3/s)	DELWP no. missing days	Comments
1960	260	156	260			57	DELWP records missing part of year - MMBW value adopted
1961	Excl	24				69	Incomplete DELWP data - excluded
1962	Excl	53				153	Incomplete DELWP data - excluded
1963	291	223	291			27	DELWP records missing part of year - MMBW value adopted
1964	320		320			366	DELWP records missing year - adopt MMBW value
1965	Excl					365	Missing year of DELWP data - excluded
1966	Excl	39				136	Incomplete DELWP data - excluded
1967	Excl	6				186	Incomplete DELWP data - excluded
1968	Excl	73				155	Incomplete DELWP data - excluded
1969	22	22				58	
1970	164	164				1	
1971	399	399	407			0	
1972	110	110				14	
1973	146	146				22	
1974	726	726	714			1	
1975	324	288	320	324	324	0	BoM/Melbourne Water value adopted given this was nearer to the MMBW value
1976	112	112		135	135	0	
1977	297	297	296	310	310	0	
1978	352	352	358	356	356	0	
1979	138	138		141	141	0	Significant BoM rating change in 1979 - assumed the rating pre-1979 is correct
1980	14	14		14	14	0	
1981	103	103		94	94	0	
1982	Excl	2		1	1	67	Incomplete DELWP data - excluded
1983	476	476	456	464	464	0	
1984	96	96		97	97	0	
1985	233	233		233	233	0	
1986	91	91		91	91	0	
1987	451	451		451	451	0	
1988	50	50		50	50	0	
1989	317	317		317	316	0	
1990	232	232		232	232	0	
1991	22	22		22	22	0	
1992	143	143		143	143	0	
1993	690	690		690	690	0	
1994	4	4		4	4	0	
1995	129	129		129	129	0	
1996	99	99		99	99	0	
1997	10	10		10	10	0	
1998	10	10		10	10	0	

Year	Adopted AMAX (m^3/s)	DELWP (m^3/s)	MMBW (m^3/s)	BOM (m^3/s)	Melbourne Water (m^3/s)	DELWP no. missing days	Comments
1999	93	93		93	93	0	
2000	256	256		256	256	0	
2001	57	57		57	57	0	
2002	3	3		3	3	0	
2003	20	20		20	20	38	
2004	11	11		11	11	1	
2005	265	265		254	265	0	
2006	2	2		2	2	0	
2007	43	43		32	43	52	
2008	20	20		20	20	3	
2009	9	9		9	9	62	
2010	287	287		33	287	0	
2011	423	423		35	423	0	
2012	245	245		87	245	0	
2013	25	25		25	25	0	
2014	3	3		3	3	0	
2015	5	5		5	5	0	
2016	201	201		17	201	0	
2017	14	14		14	14	0	
2018	30	30		30	30	0	
2019	12	12		12	12	0	
2020	76	76		76	76	0	
2021	93	93		93	101	0	
2022	768	768		766	767	0	This was a significant event that resulted in significant flooding downstream.

A.4 Baseflow

The gauged data from the Maribyrnong River at Keilor gauge (see Figure A-8) was reviewed and no evidence of significant baseflow contribution was found.

While the flow duration curve shows that 2 m^3/s is exceeded roughly 20% of the time, in the days leading up to peak flow events, there is little to no flow recorded, indicating that baseflow contribution was not a significant factor in the flooding process at the site and as such was not considered.

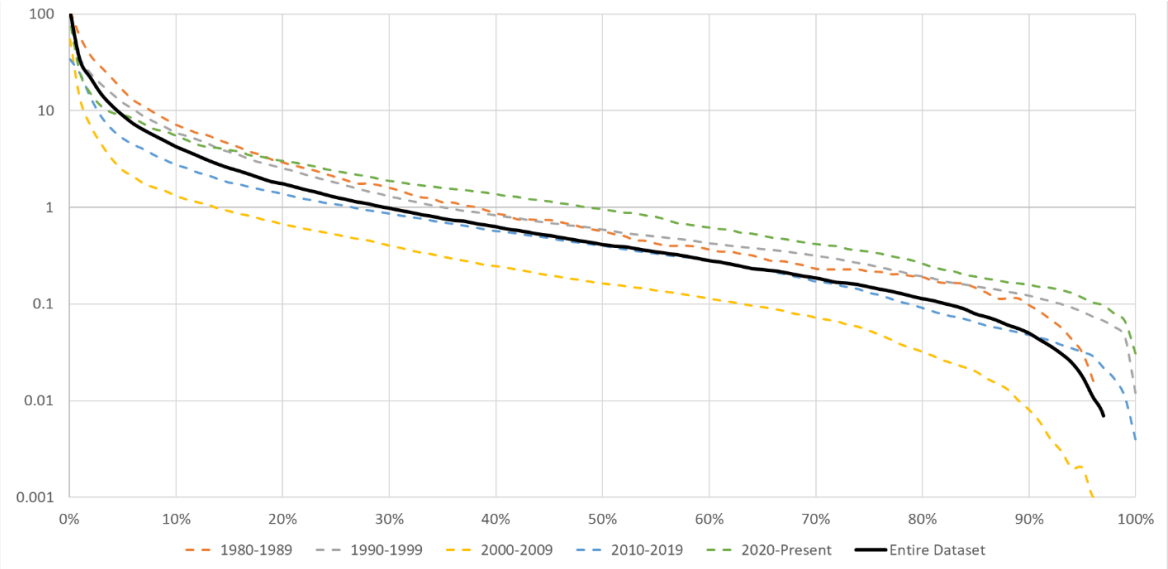


Figure A-8: Flow duration curve for Maribyrnong River at Keilor.

A.5 RORB Design Inputs

A.5.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.441, Long 144.738) was sourced from the Bureau of Meteorology (Appendix I) As per the Melbourne Water Flood Mapping Projects Specifications, rainfalls were increased by 18.5% to establish climate change rainfalls.

A sensitivity assessment was undertaken on the variance of rainfall throughout the catchments using the 1% AEP gridded rainfall data. This assessment indicated that the variation in depths was less than 3% (on average less than 1 mm). The gridded rainfall data was adopted despite the small variation when comparing both datasets due to the size of the catchment.

A.5.2 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located largely in Loss region 3. ARR 2019 recommends for loss region 3 the 75th percentile-burst values should be adopted (HARC, 2020). The 75th percentile pre-burst has been adopted by pre-pending the depths to the beginning of the storm. Whilst it is noted that some areas of the catchment are in Loss region 2 (where median pre-burst depths are recommended), Loss region 3 approach was selected given that the majority is located in Loss region 3 and the calibration was based on 75th percentile pre-burst depths.

For durations below the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

A.5.3 Temporal Patterns

Given the catchment area at the Keilor gauge exceeds 75km^2, areal temporal patterns were used in calibration RORB runs. For the design runs, areal temporal patterns were used to extract flows from locations with ARF > 75 km^2). Point temporal patterns were used to extract flows from locations with ARF < 75 km^2.

A.5.4 Spatial Patterns

A spatial rainfall distribution was determined to ensure that variation in rainfall depth across the catchment was accounted for. This was calculated by comparing the catchment average rainfall to the average rainfall for each sub-catchment using the design rainfall grids (Bureau of Meteorology, 2022). This was then implemented in the RORB model as a 'non-uniform' spatial pattern for each duration.

The spatial variation across the catchment is illustrated in Figure A-9 for the 1% AEP 18 hour rainfall event, the critical duration for the Keilor gauge.

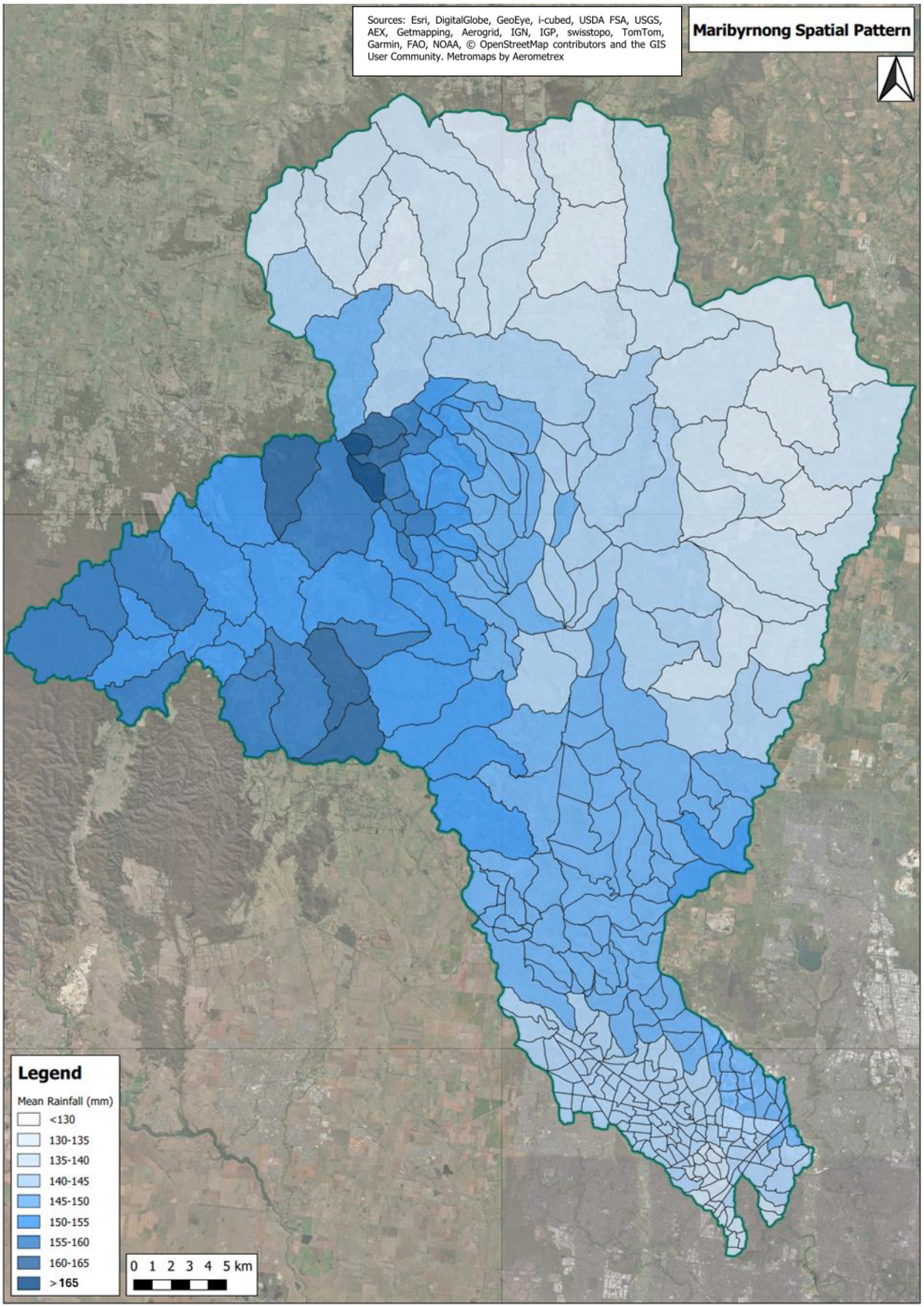


Figure A-9: Spatial rainfall pattern for the Maribyrnong River RORB model for the 1% AEP, 18hr storm.

A.5.5 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Section A.8. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment are presented in Table A-8.

Table A-8: Adopted ARF values for the Maribyrnong River RORB model.

Duration (AEP)	ARF area (km^2)	Justification
10m (1% AEP) 15m (1% - 5% AEP) 20m (all AEPs) 30m (10% AEP)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
30m (all AEPs) 45m (all AEPs) 1h (all AEPs) 1.5h (10% AEP)	3	
1.5h (all AEPs) 2h (all AEPs)	9	
2h (20% AEP) 3h (all AEPs) 4.5h (1% - 10% AEP)	19	
12h (all AEPs)	386	
12h (20% AEP) 18h (1% - 10% AEP)	1230	

A.6 Model Calibration

Calibration of the model was undertaken in the following stages:

- Calibration to individual events to determine the routing parameters (k_c, with m being fixed to 0.8).
- Calibrating the at-site Flood Frequency results from the gauges to the RORB model Monte Carlo Flood Frequency results to determine the loss parameters.
- Calibration efforts were focused on the Maribyrnong at Keilor gauge given this was relevant for the Study.

Once model parameters were determined through calibration, the RORB model was split into different interstation areas at locations where subarea size changed to ensure alignment with the Melbourne Water Flood Mapping Projects Specifications (see Section A.6.3). Design events for the 1% AEP were then simulated to develop inputs to the TUFLOW model.

A.6.1 Routing Parameter k_c

Historic flood events were used to determine suitable k_c routing parameters for the model, while the recommended value for m of 0.8 was adopted for this Study.

The selection of historic events for model calibration was guided by the following factors:

- The magnitude of flood events, with priority given to the largest flow events in the last 30 years, as they are representative of the events modelled and catchment conditions for this assessment.
- Completeness of good quality gauged streamflow records
- Pluviograph coverage for a given event

The historic events selected for calibration were:

- September 1993
- January 2011
- October 2022

The total rainfall and peak streamflow for the selected events are shown in Table A-9. Pluviograph data from the Jacksons Creek at Rosslynne, Mt Macedon, Romsey, Deep Creek at Darraweit Guim, Jacksons Creek at Sunbury and Maribyrnong River at Keilor gauges were used to input rainfall temporal patterns.

Table A-9: Rainfall and streamflow from historic events used for calibration of the Maribyrnong RORB model

	Sep 1993		Jan 2011		Oct 2022	
Gauge	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)
Jacksons Creek at Rosslynne Res.	130.6	-	67.8	-	50.6	-
Mt Macedon	-	-	119.0	-	138.4	-
Romsey	76.4	-	71.6	-	97.2	-
Deep Creek at Darraweit Guim	43.2	-	54.8	-	80.4	-
Jacksons Creek at Sunbury	90.0	-	51.2	-	41.2	-
Maribyrnong River at Keilor	58.6	689.7	50.0	423.1	26.8	767.0

Calibration of routing parameters is achieved by determining the k_c and m parameters that produce the best fit between the modelled and observed hydrographs. To calibrate the model, a range of k_c values for the interstation area at the Keilor gauge were sampled through the model based on regional estimates that are documented in Table A-10. The m parameter was fixed at 0.8.

Table A-10: k_c estimates based on regional equations

Interstation area	VIC >800mm annual rainfall	VIC <800mm annual rainfall	RORB manual	Melbourne Water Yarra & Maribyrnong
Maribyrnong at Keilor	65	52.1	79.3	66.3

The k_c parameter was varied and the resultant hydrograph shape, peak flow, volume and Nash-Sutcliffe Efficiency (NSE) were assessed to determine an appropriate k_c value for the model. The NSE is a statistical measure used to evaluate a model's performance against recorded data. A value of 1 indicates a perfect fit to the model data, whereas a value of 0 indicates simply modelling the average value would perform equally well. A value of less than 0 indicates poor model performance. NSE is defined as:

$$NSE = 1 - \frac{var(Res)}{var(Hyd)}$$

Where var(Res) is the variance of the model residuals or the difference between the observed and calculated flows, var(Hyd) is the variance of the observed hydrograph. Ladson (2008) provides a guide to assessing model performance based on NSE as shown in Table A-11.

Table A-11: NSE Calibration (Ladson, 2008)

Classification	NSE
Excellent	> 0.93
Good	0.80 – 0.93
Satisfactory	0.70 – 0.80
Passable	0.60 – 0.70
Poor	< 0.60

The k_c and NSE values that gave the best match to the observed hydrographs for each historic event are shown in Table A-12.

Table A-12: k_c and resultant NSE for historic events using the Maribyrnong RORB model

	Sep 1993		Jan 2011		Oct 2022	
Interstation area	k_c	NSE	k_c	NSE	k_c	NSE
Maribyrnong River at Keilor	64.4	0.98	66.5	0.87	65	0.91

The NSE values returned, consider the calibration of either 'excellent' or 'good' quality for all events. The resultant fits between the modelled and observed hydrographs are shown in Figure A-10, Figure A-11 and Figure A-12 to allow visual inspection of fits. The returned k_c values were consistent for the events, increasing confidence in the parameters.

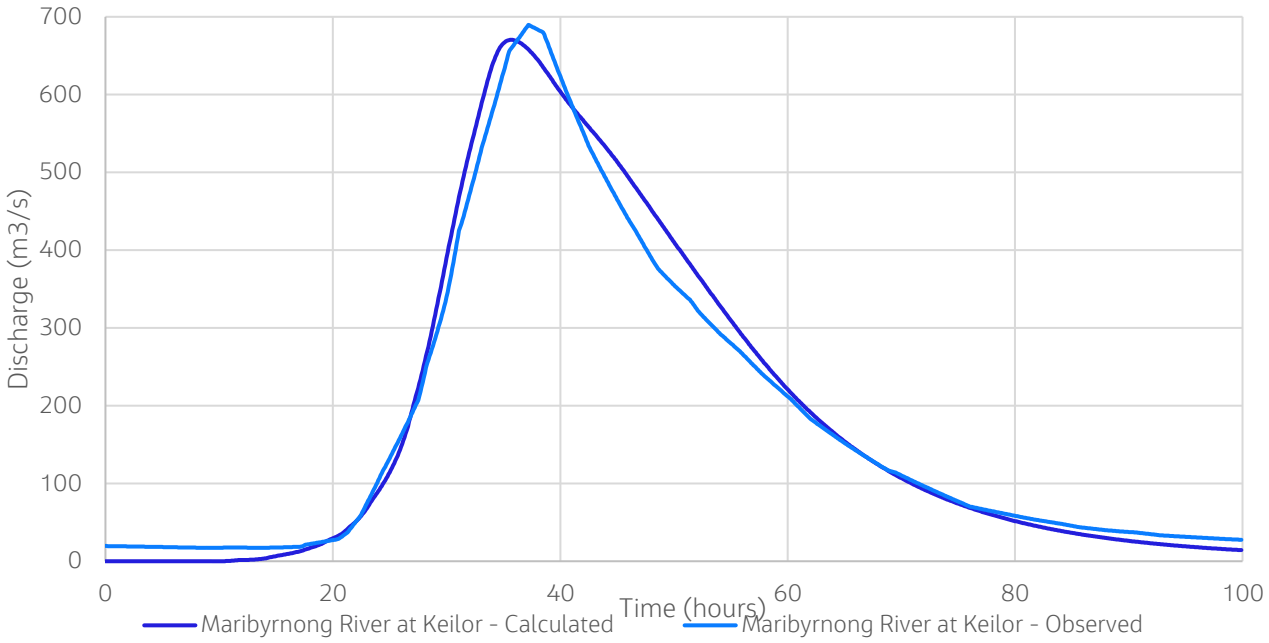


Figure A-10: Modelled and observed hydrographs for Maribyrnong at Keilor, September 1993.

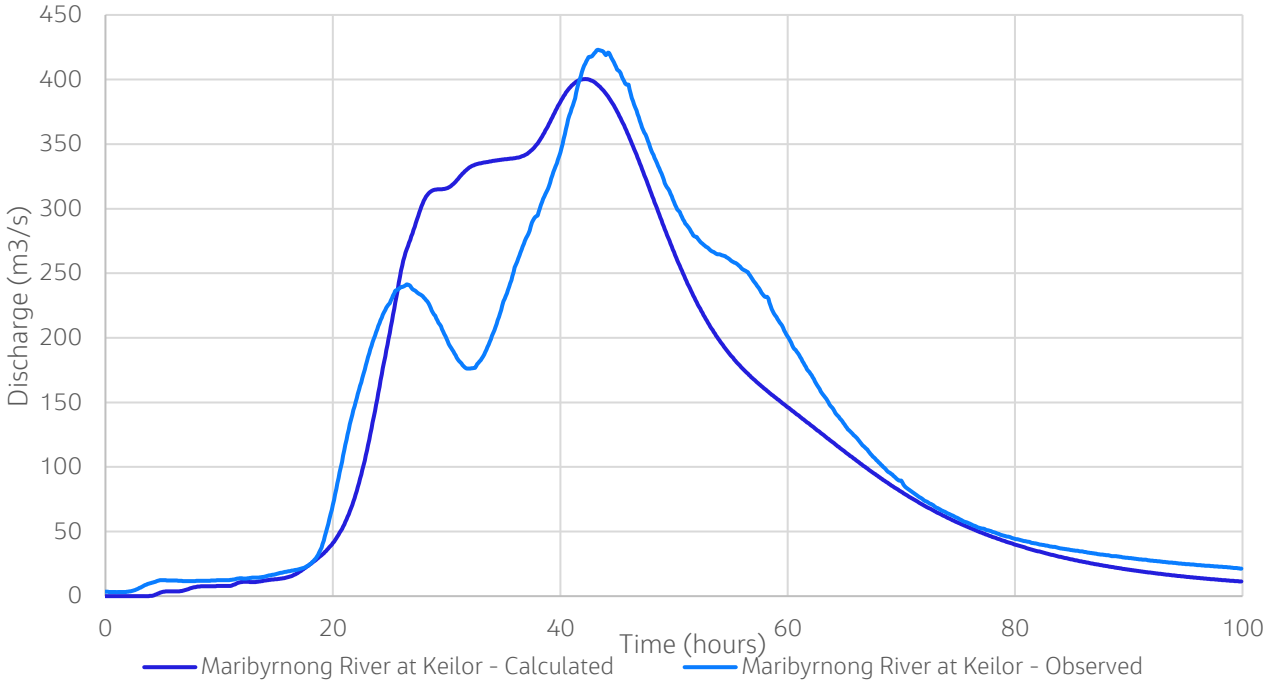


Figure A-11: Modelled and observed hydrographs for Maribyrnong at Keilor, January 2011.

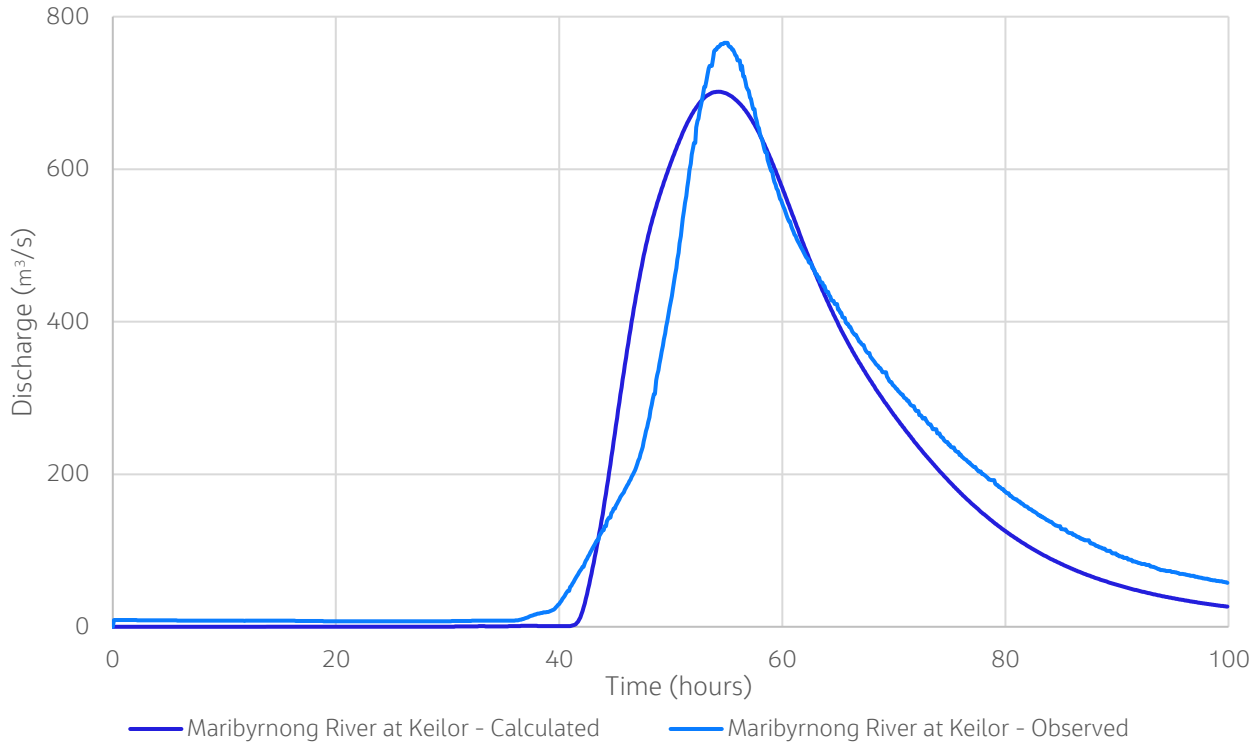


Figure A-12: Modelled and observed hydrographs for Maribyrnong at Keilor, October 2022.

The adopted k_c parameter shown in Table A-13 was based on the range of k_c values derived from the calibration runs with consideration given to NSE. The adopted k_c falls within the range of k_c values produced by regional estimates (Table A-10) and is comparable to the k_c of 67 used by MMBW (1986).

Table A-13: Adopted k_c parameters for the Maribyrnong River RORB model

Interstation area	k_c adopted
Keilor	64

A.6.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Pre-burst (75th percentile – see Section A.5.2) was also included in the RORB runs that calculated appropriate storm losses. The loss values adopted were obtained through calibration of the RORB Monte Carlo peaks to the at-site Flood Frequency Curve (FFC) at the Keilor gauge. This involved varying the initial loss and continuing loss parameters until an acceptable match between the Monte Carlo peak flows and the FFC was achieved. Given the length of the gauge record used to produce the FFA is significant, matching AEP events up to and including the 1% AEP flow quantiles is considered appropriate and allows reasonable flow estimates to be produced with the RORB model. The fit between the FFC and RORB Monte Carlo peaks is presented in Figure A-13. The fit is within the FFA confidence intervals for the 20% - 1% AEP and considered acceptable.

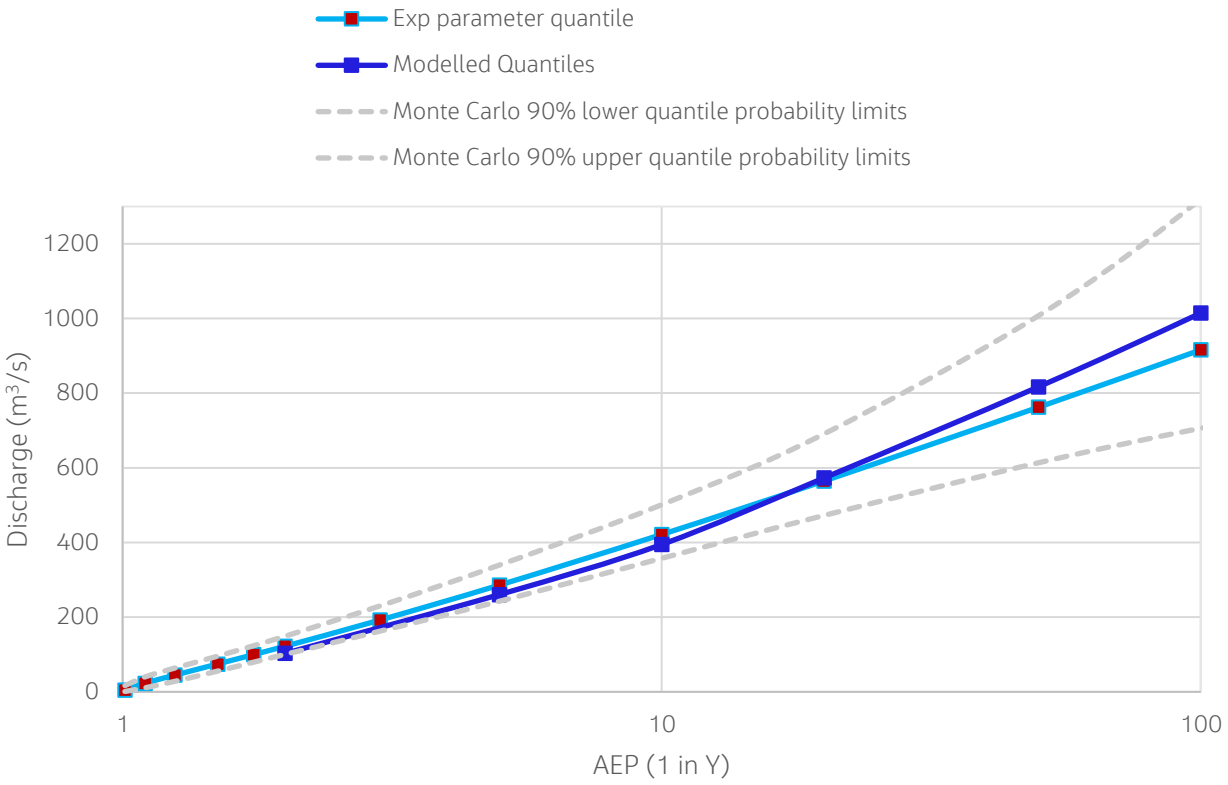


Figure A-13: At-site Flood Frequency Analysis and Maribyrnong River RORB Monte Carlo Peaks (Keilor gauge)

The adopted loss parameters obtained through the calibration at the Keilor gauge (rural upstream area) are shown in Table A-14. These are compared to the Datahub values for the catchment (ARR 2019). Whilst the loss values derived via the calibration exercise differ from the Datahub values, they fall within the range for rural catchments (Ball et al., 2019), those listed in the Melbourne Water Flood Mapping Projects Specifications and are also in alignment with the loss parameters derived via the calibration of the Kororoit Creek model as part of this Study (Kororoit IL: 13.5 - 18.0 mm and CL: 2.5 - 3.0 mm/hr). Furthermore, the selection of losses based on reconciliation to a site-specific FFA (rather than DataHub) is supported by ARR (2019) (HARC, 2020).

Table A-14: Adopted Maribyrnong RORB loss parameters obtained through calibration

Interstation area	IL (mm)	CL (mm/hr)
Maribyrnong at Keilor	12.0	2.3
Maribyrnong_Outlet	12.0	2.3
DataHub	25.0	2.7

A.6.3 Adopted Interstation Areas

Once model parameters were determined through calibration, the RORB model was split into different interstation areas at locations where subarea size changed to ensure alignment with the Melbourne Water Flood Mapping Projects Specifications. The k_c selected through calibration was used to determine the k_c given to the interstation areas added to the model upstream of the Keilor gauge in the rural section of the model, defined using the k_c /d_{av} ratio at Keilor. Table A-15 lists the details of the additional interstation areas and the k_c adopted.

Table A-15: Maribyrnong River RORB model interstation areas and adopted k_c

Interstation area	K_c	d_{av}	K_c / d_{av}	Comment
Maribyrnong at Keilor (original ISA used in calibration)	10.2	14.7	0.70	Original K_c and d_{av} from the calibrated Maribyrnong RORB model.
Deep Creek Upstream	43.9	63.0	0.70	Values calculated based on the calibrated Maribyrnong RORB model values.
Deep Creek Outlet	9.9	14.2	0.70	
Emu Creek Upstream	7.6	10.9	0.70	
Emu Creek Outlet	14.6	20.9	0.70	
Jacksons Creek Upstream	26.8	38.5	0.70	
Jacksons Creek Outlet	10.6	15.2	0.70	
Maribyrnong at Keilor (Adjusted for new model interstation areas)	10.4	14.7	0.70	
Taylors Creek Outlet	5.1	7.4	0.70	
Steele Creek Outlet	5.0	7.2	0.70	
Lower Maribyrnong Outlet	3.1	4.5	0.70	

A.6.4 Verification to Other Gauge Data

The FFA curves for Jacksons Creek at Sunbury and Deep Creek at Bulla produced as part of a checking exercise are shown in Figure A-14 and Figure A-15 along with the Study RORB model Monte Carlo outputs at each location. The plots show there is agreement between the expected FFA quantiles at both gauges and the model outputs.

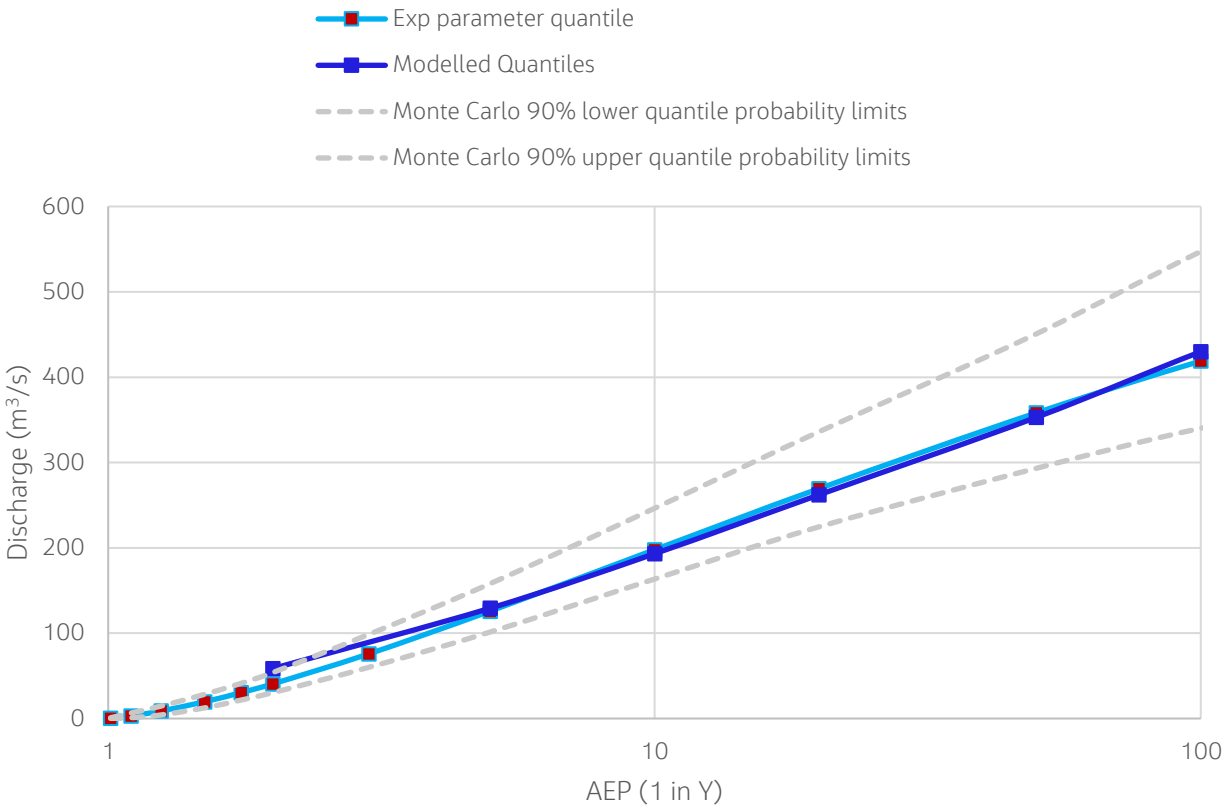


Figure A-14: Checks of the FFA for Jacksons Creek at Sunbury against model Monte Carlo outputs.

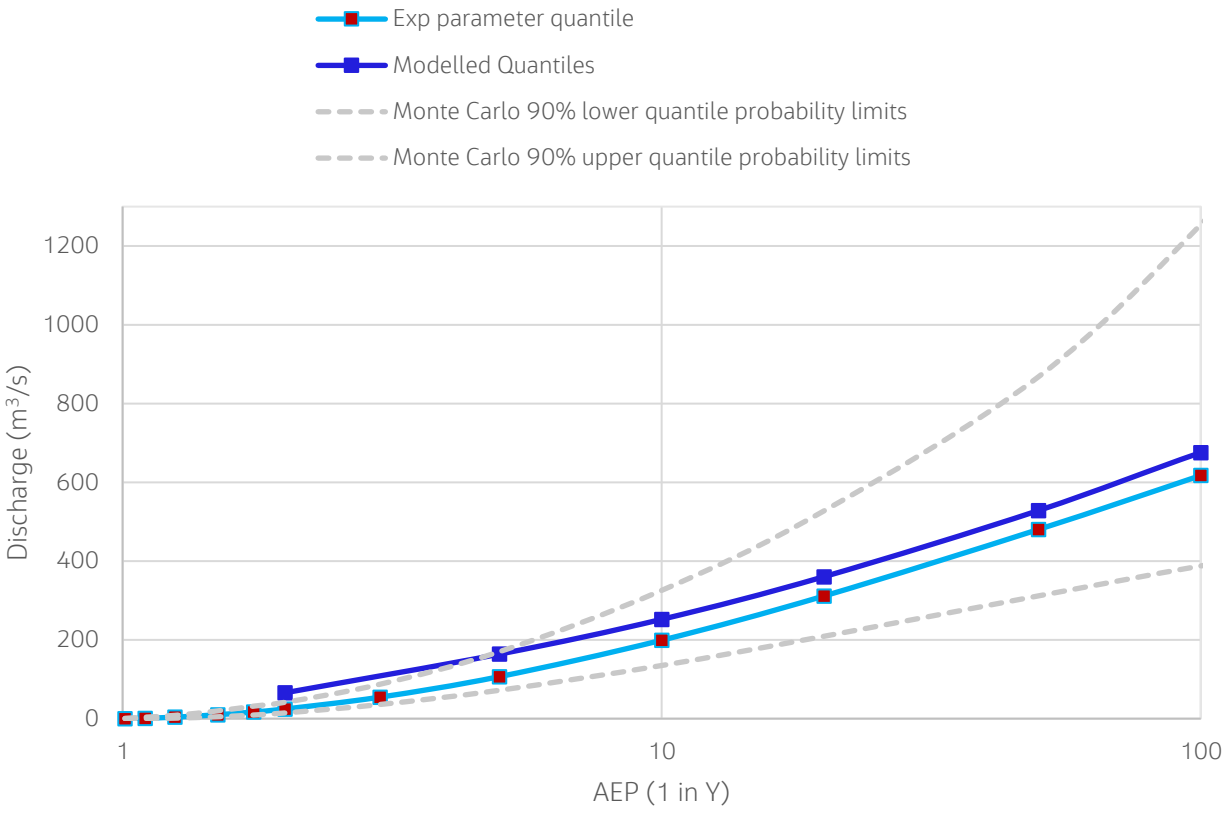


Figure A-15: Checks of the FFA for Deep Creek at Bulla against model Monte Carlo outputs.

A.7 RORB Results and Verification

The RORB model was simulated using the parameters determined through calibration and the results are presented below. Table A-16 shows the RORB model peak flows along with the Flood Frequency Analysis and regional estimates peak flows for the Maribyrnong at Keilor. Table A-17 also shows the model flow outputs for the Taylors Creek outlet (at the Maribyrnong River), which, whilst downstream of the Keilor gauge, is within Brimbank LGA and therefore relevant for the model verification exercise.

The approximate 1% AEP flows using the Nikolaou/von't Steen equation were calculated using the following equations:

For rural catchments $Q_{1\%} = 4.67A^{0.763}$
For urban catchments $Q_{1\%} = 10.29A^{0.71}$

The peak flows at Keilor were calculated and compared to the RORB model outputs. The Nikolaou/von't Steen estimates are largely based on catchment area and are therefore unlikely to capture the large and complex nature of the Maribyrnong River catchment. RORB model flows for Jacksons Creek at Bulla and Sunbury were also cross checked and validated against an FFA completed for these gauges, which were seen to perform well.

A Regional Flood Frequency Estimation (RFFE) was performed using the RFFE tool (https://rffe.arr-software.org). Output files from the RFFE are shown in Appendix L. Given that the RFFE is recommended for entirely rural catchments up to 1000 km^2, the method is not recommended given the catchment area to Keilor is approximately 1300 km^2. Despite this, the estimates are comparable to the RORB outputs and the FFA. The Melbourne Water rule of thumb method is known to not perform well in catchments with large green space areas, and generally overpredicts peak flows for these catchments. It is noted that a series of retarding basins (Taylors Lakes) are present in the Taylors Creek catchment which are designed to reduce peak flows. The flows in Table A-17 are therefore expected to be lower than those estimated by regional equations, as observed below.

Table A-16: Maribyrnong at Keilor (rural upstream area) peak flow comparison

AEP	RORB design peak flow (m^3/s)	FFA (m^3/s)	RFFE (m^3/s)	Nikolaou/Von't Steen – Rural flow (m^3/s)	Melbourne Water rule of thumb (rural)
20%	260	285	313	-	-
10%	395	420	425	-	-
5%	572	565	549	-	-
2%	816	760	736	-	-
1%	1014	915	896	1117	3934

Table A-17: Taylors Creek at Maribyrnong (urban upstream area) peak flow comparison

AEP	RORB design peak flow (m^3/s)	Nikolaou/Von't Steen – Urban flow (m^3/s)	Melbourne Water rule of thumb (urban)
20%	25	-	-
10%	33	-	-
5%	41	-	-
2%	53	-	-
1%	62	103	258

A.8 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARF to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table A-8. This enabled the identification of how critical durations were likely to alter based on the contributing catchment area. Key locations across the catchment are shown in Figure A-16. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW.
- Locations upstream or within urban areas.
- Locations upstream and downstream of model storages.
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave.
- Points located within Study LGAs, providing good coverage across Study area.

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Figure A-16 and Table A-18. Table A-19 lists the storms simulated in TUFLOW. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

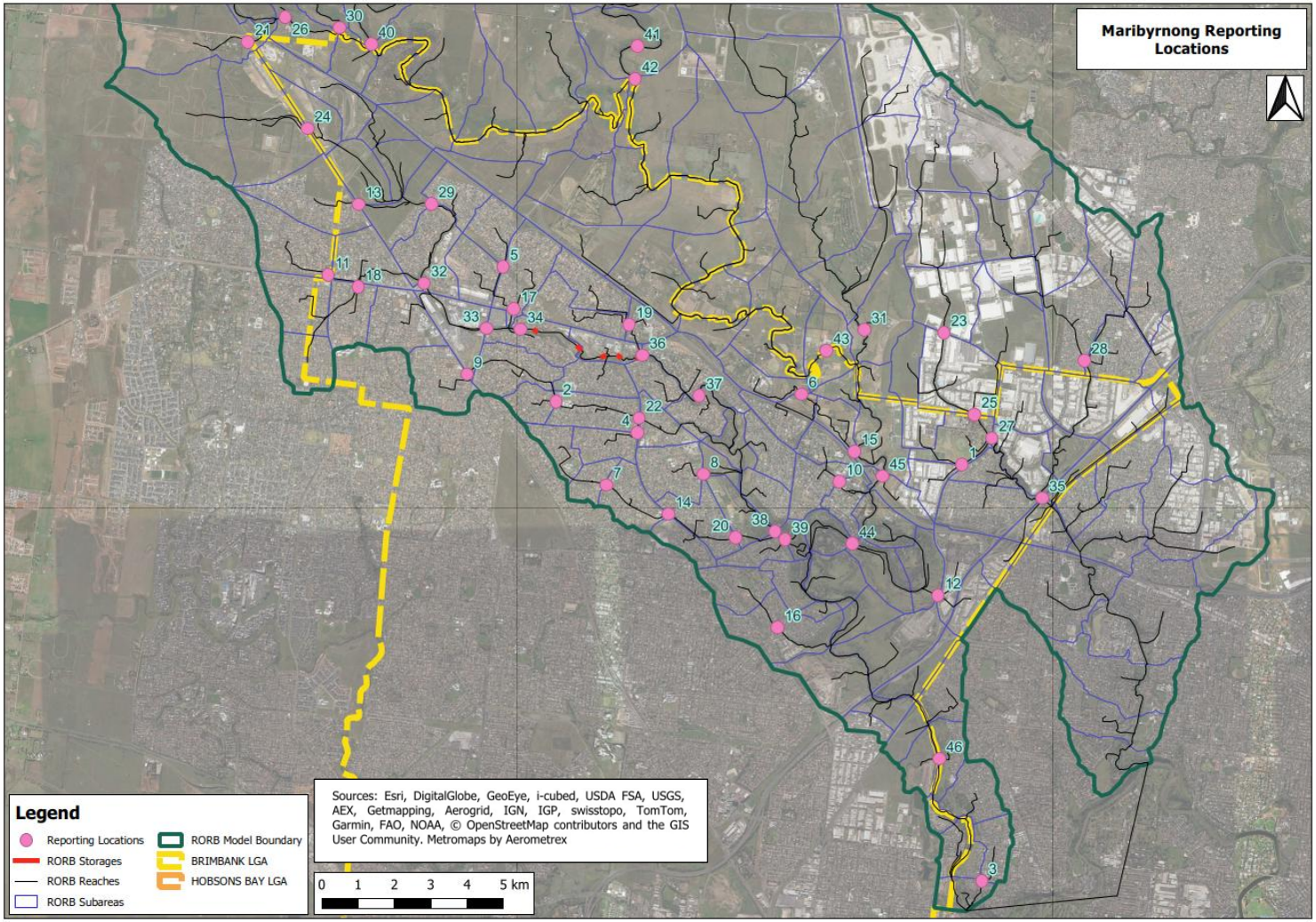


Figure A-16: Maribyrnong River RORB reporting locations

Table A-18: Analysis of critical durations and peak flows at key location using the Maribyrnong River RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Keilor Park Dr N	0.3	20min	13	20min	11	20min	9	20min	7	20min	6
2	Lionheart Av	0.3	30min	28	30min	23	25min	18	30min	15	45min	13
3	Avondale Heights	0.4	20min	10	20min	8	20min	6	30min	5	20min	4
4	Lady Nelson Way	0.4	15min	11	15min	9	20min	7	20min	6	20min	5
5	Kings Rd	0.4	20min	12	20min	10	20min	8	30min	7	20min	5
6	Calder Fwy	0.5	20min	9	20min	7	30min	6	30min	5	45min	4
7	Copernicus Way	0.6	20min	14	20min	12	30min	9	30min	8	20min	6
8	Green Gully Close	0.6	20min	17	20min	14	20min	11	20min	9	20min	8
9	Sydenham Rd	0.7	20min	17	20min	15	20min	12	20min	10	20min	8
10	Keilor MD	0.8	15min	25	15min	21	15min	17	15min	14	20min	12
11	Melton Hwy Syd W RB	0.8	45min	7	30min	6	30min	6	30min	6	45min	6
12	Keilor Park Dr S	0.9	20min	25	20min	22	20min	18	20min	15	20min	12
13	Victoria Rd	1.0	10min	28	15min	24	20min	20	20min	16	20min	13
14	Sunshine Av	1.1	20min	22	20min	19	30min	15	30min	12	20min	10
15	Calder Fwy U/S Maribyrnong	1.2	45min	14	45min	12	1hour	9	1hour	8	1.5hour	6
16	Harefield Cres Res	1.4	10min	48	10min	40	15min	30	15min	25	20min	21
17	Taylors Ck trib U/S Taylors Lakes	1.7	20min	40	20min	34	20min	27	20min	22	20min	17
18	Melton Hwy/ Syd RB	1.7	3hour	6	3hour	5	1.5hour	5	1.5hour	5	1.5hour	5

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
19	Melton Hwy 3	1.7	20min	26	20min	22	30min	17	30min	14	20min	11
20	Green Gully Reserve	2.2	20min	36	20min	31	30min	24	30min	20	45min	16
21	Trib of 6805	2.3	45min	22	45min	19	1.5hour	15	1.5hour	12	1.5hour	10
22	Wanaka Dr Drain	2.5	45min	35	45min	30	45min	24	45min	20	1.5hour	16
23	Steele Ck Upper	2.6	30min	41	30min	35	30min	28	30min	23	45min	19
24	Taylors Ck inflow	3.2	45min	37	45min	31	1hour	24	1hour	19	1.5hour	17
25	Steele Ck W inflow	5.5	30min	77	30min	66	30min	52	30min	42	45min	36
26	Trib of Tame St Drain W	5.8	2hour	80	1.5hour	67	1.5hour	56	1.5hour	46	1.5hour	35
27	Steele Ck at Keilor Park Dr	6.2	30min	79	30min	67	1hour	52	1hour	43	45min	37
28	Steele Ck E inflow	6.6	30min	106	30min	90	25min	72	30min	59	45min	50
29	Taylors Ck Upper	6.9	1.5hour	55	1.5hour	47	2hour	37	2hour	31	1.5hour	24
30	Trib of Tame St Drain E	8.8	1.5hour	21	1.5hour	18	1.5hour	14	1.5hour	12	1.5hour	9
31	Arundel Ck inflow	11	2hour	74	2hour	62	2hour	49	2hour	40	1.5hour	31
32	Taylors Ck at Melton Hwy	11.3	2hour	69	2hour	60	1.5hour	50	1.5hour	41	1.5hour	33
33	Taylors Ck at Kings Rd	12.6	2hour	74	2hour	63	1.5hour	50	1.5hour	41	2hour	34
34	U/S Taylors Lakes	14.9	2hour	84	3hour	72	1.5hour	58	1.5hour	48	2hour	39
35	Steele Ck at Western Ring Rd	16.4	1hour	166	1hour	142	1hour	113	1hour	94	1hour	73
36	D/S Taylors Lakes	17.4	3hour	85	3hour	73	3hour	57	2hour	47	2hour	38
37	Taylors Ck at Burrowye Cres	18.4	3hour	90	3hour	77	3hour	60	3hour	49	3hour	39

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
38	Taylors Ck at Green Gully Rd	23.4	3hour	107	3hour	92	3hour	72	3hour	59	3hour	47
39	Taylors Ck U/S Maribyrnong	26	3hour	117	3hour	100	3hour	77	3hour	63	3hour	50
40	Jacksons Ck inflow Brimbank LGA	386	12hour	435	12hour	355	12hour	260	12hour	194	12hour	133
41	Deep Ck inflow	879	18hour	687	18hour	542	12hour	374	12hour	270	12hour	177
42	Maribyrnong D/S Deep Ck	1288	18hour	1095	18hour	877	18hour	618	12hour	442	12hour	296
43	Maribyrnong U/S Arundel Ck	1298	18hour	1093	18hour	875	18hour	617	12hour	442	12hour	296
44	Maribyrnong at Keilor	1303	18hour	1093	18hour	875	18hour	617	12hour	441	12hour	295
45	Maribyrnong at Calder Fwy	1311	18hour	1091	18hour	876	18hour	617	12hour	442	12hour	295
46	Maribyrnong Lower	1338	18hour	1092	18hour	873	18hour	617	12hour	442	12hour	295

Table A-19: Critical durations and selected temporal patterns.

AEP	10min	15min	20min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour	18 hour
1%	TP23	TP22	TP27	TP28	TP26	TP27	TP27	TP29	TP27	TP28	-	-	TP4	TP2
2%	-	TP22	TP28	TP28	TP26	TP27	TP28	TP25	TP27	TP28	-	-	TP4	TP2
5%	-	TP12	TP12	TP18	TP19	TP13	TP18	TP16	TP15	TP18	-	-	TP4	TP8
10%	-	-	TP12	TP16	TP18	TP13	TP18	TP14	TP15	TP18	-	-	TP3	TP8
20%	-	-	TP7	TP5	TP5	TP7	TP2	TP6	TP5	-	-	-	TP4, TP9	-

A.9 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Maribyrnong River catchment.

A.9.1 Hydraulic Model Set Up

The TUFLOW model for the Maribyrnong catchment was set up to include quadtree mesh functionality. This enabled two grid sizes to be adopted across the model domain. The setup assumes 6 m grid across rural/riverine areas and a 3 m grid size through the urban/council area. The quadtree boundary is presented in Figure A-17, Figure A-18 and Figure A-19.

A.9.1.1 Terrain modifications

Figure A-17, Figure A-18, Figure A-19 present the Maribyrnong River catchment TUFLOW model terrain modifications, which are also listed in Table A-20 where these have been based on drawings, plans or other available detailed information. The terrain modifications include adjustments made to the base LiDAR either due to:

- Lidar Adjustments: Sections of the LiDAR that may contain significant depressions that are not permanent, i.e. if the LiDAR was flown during the construction of a building then the excavation would be captured and should be removed to ensure no rainfall pools in this depression.
- Terrain Modifications: Removal of bridges or blockages to enable the structure to be hydraulically modelled.
- Reinforcement of hydraulic controls (roads, levees, embankments) within the overland flow paths.

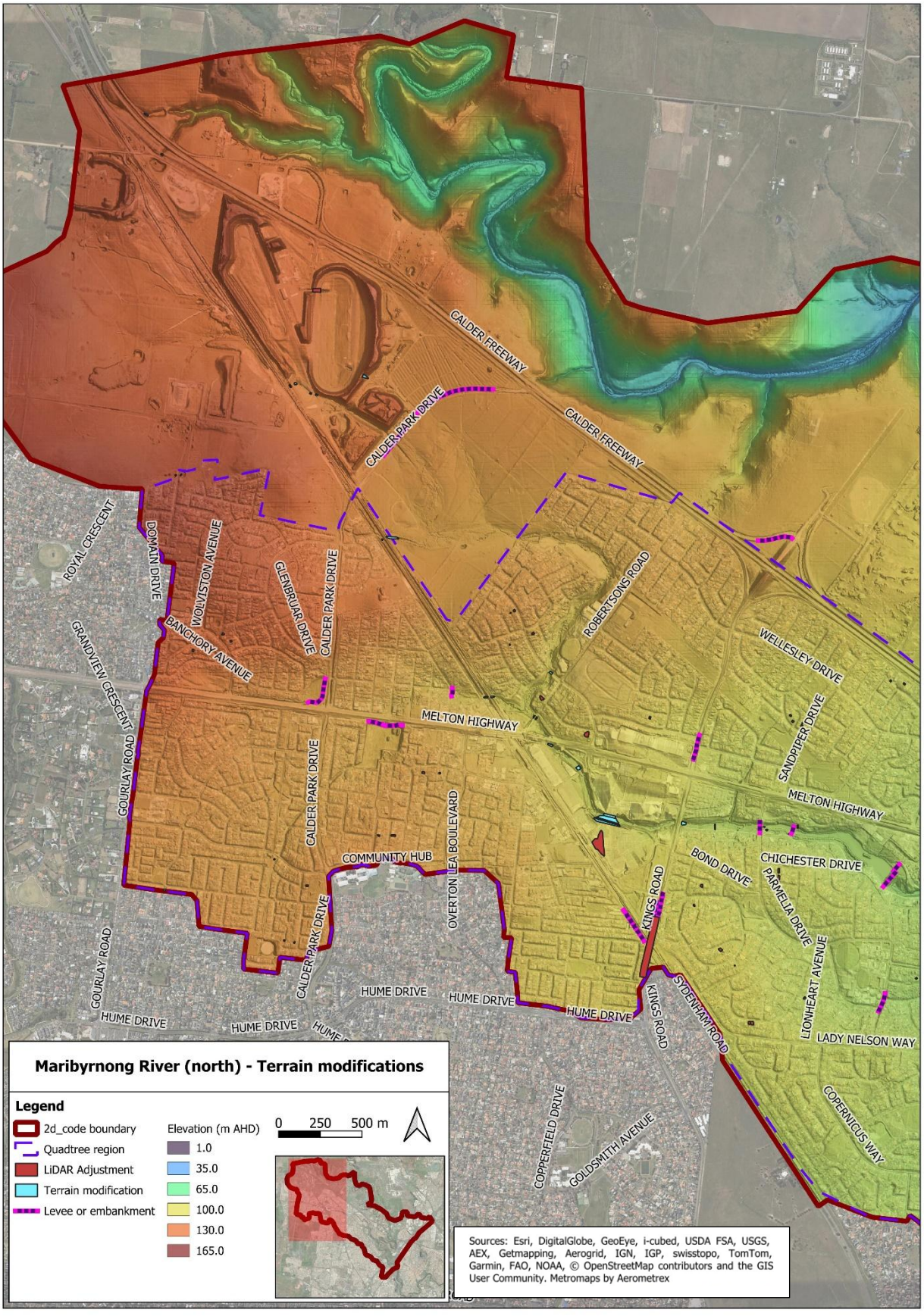


Figure A-17: Maribyrnong River TUFLOW model terrain modifications (north).

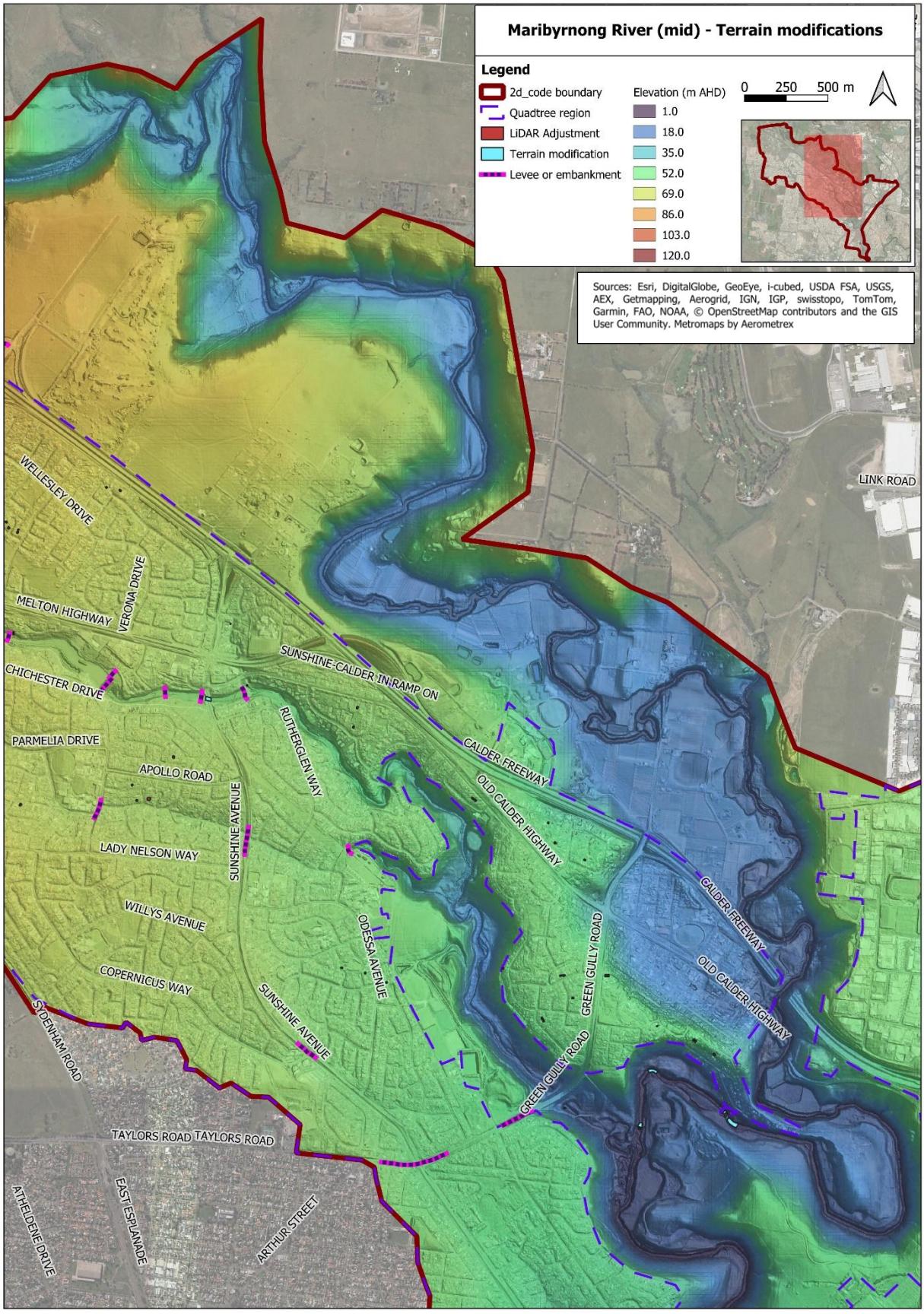


Figure A-18: Maribyrnong River TUFLOW model terrain modifications (mid).

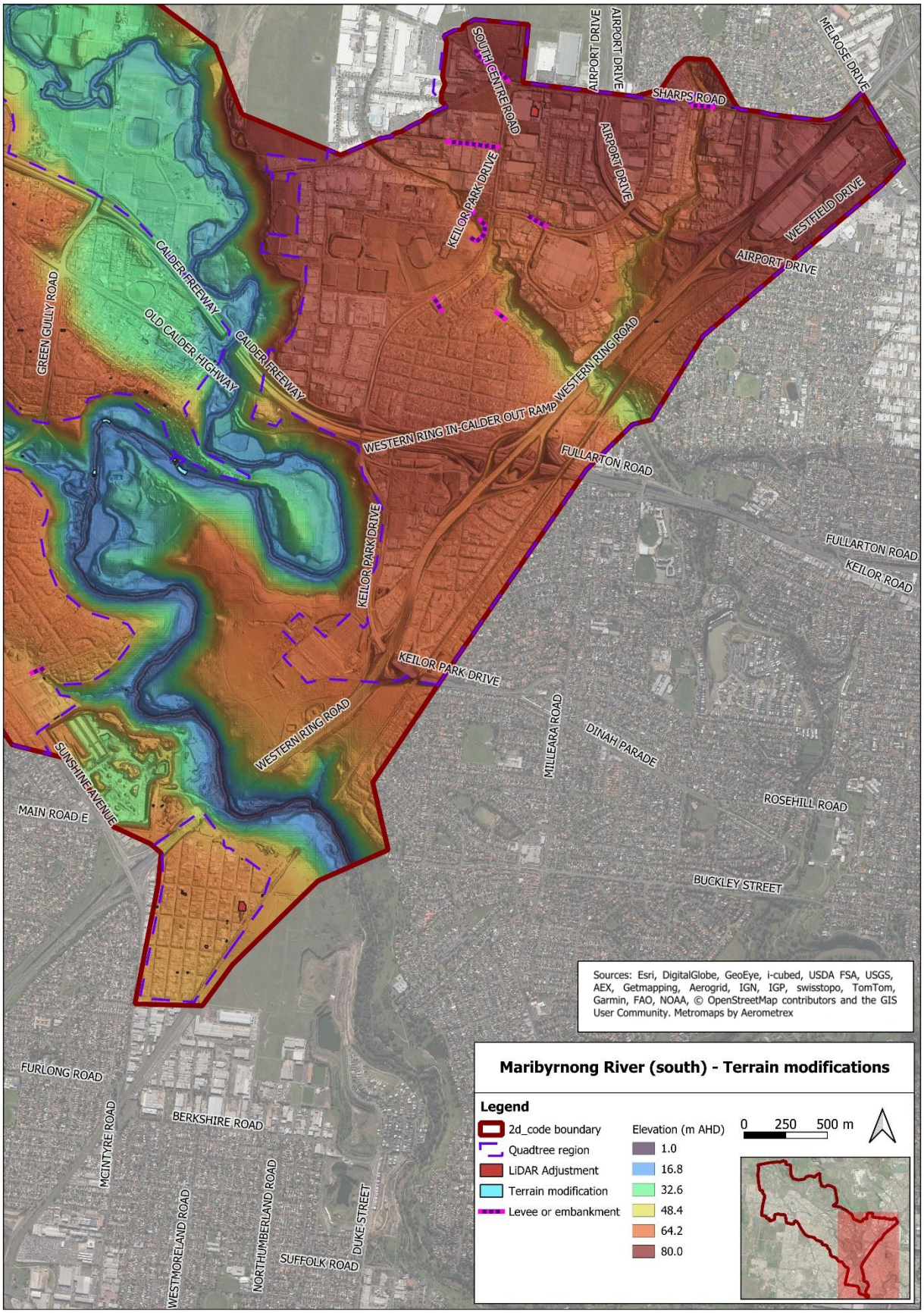


Figure A-19: Maribyrnong River TUFLOW model terrain modifications (south).

Table A-20: Maribyrnong catchments TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Ibis Lake Embankment	GHD (2016) Risk Assessments of Taylors Lakes Retarding Basins - Lake Heron, Lake Ibis, Lake Kingfisher, Lake Shelduck and Lake Spoonbill Prepared for Melbourne Water October 2016	Reinforcement of embankment crest in LiDAR; details of inlet/outlet pit inverts also used for drainage connections and permanent lake levels inferred from low flow outlet RL's to set lake IWLs at the start of the simulations.
Lake Kingfisher Embankment		
Lake Shelduck Embankment		
Lake Spoonbill Embankment		
Lake Heron Embankment		
Taylors Lake Embankment		
Sydenham Retarding Basin Embankment	GHD (2016) Retarding Basins Upgrade Program, Risk Assessment of Sydenham Retarding Basin, Prepared for Melbourne Water October 2016	Reinforcement of embankment crest and primary spillway in LiDAR.
Sydenham West Retarding Basin Embankment	GHD (2016) Retarding Basins Upgrade Program, Risk Assessment of Sydenham West Retarding Basin, Prepared for Melbourne Water October 2016	Reinforcement of embankment crest in LiDAR.
Parmelia Dr Bridge data	Fraser Consultants (1988), Lake and Weir Arrangement & Parmelia Drive Bridge, Drawing: 85042M-26-01, 85042M-26-02	Bridge details used to inform bridge representation in TUFLOW model.
Watergardens Shopping Centre Bridge		LiDAR has been smoothed along Taylors Creek and the underground carpark road to remove the blockage posed by the shopping centre. In the absence of detailed drawings (not available from Council), several 2d_zsh polygons and points have been digitised in an attempt to accurately represent the different elevations of the waterway and adjacent road that passes alongside the watercourse under the shopping centre, using best engineering judgment. This judgement has been based on Google Streetview. Two layered flow constriction lines were defined, to capture the different flow conditions along the creek and road. Maximum Height Clearance signs were used to inform bridge soffit levels.

A.9.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table A-21.

Table A-21: Maribyrnong catchments TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Maribyrnong River Viaduct	0.02	51.20	1.00	1.00	30
Western Ring Rd	0.08	52.21	2.00	3.00	30
Older Calder Hwy	0.03	25.99	1.00	1.00	30
Older Calder Hwy (Iron Bridge)	0.00	24.45	1.00	1.00	100
Calder Fwy Upstream	0.08	32.89	1.00	1.00	60
Calder Fwy Downstream	0.08	33.01	1.00	1.00	60
Flora St	0.08	16.10	1.00	1.00	30
Arundel Rd	0.08	30.29	1.00	1.00	30
Arundel Rd Trestle	0.05	26.31	0.50	1.00	30
Parmelia Dr	0.11	93.05	0.45	1.00	30
Chichester Dr Footbridge	0.05	89.33	0.30	1.00	30
Forrest Pl Footbridge	0.19	109.36	0.30	1.00	30
Sunshine Ave	0.27	78.70	0.60	1.00	30
Watergardens circuit Rd	0.07	97.54	0.60	1.00	30
Watergardens Shop	0.24	100.13	1.00	5.00	100
Watergardens Rd	0.05	99.85	0.50	5.00	100

A.9.1.3 Model roughness

Maps available in Figure A-20, Figure A-21, Figure A-22 show the Maribyrnong River TUFLOW model Manning's roughness.

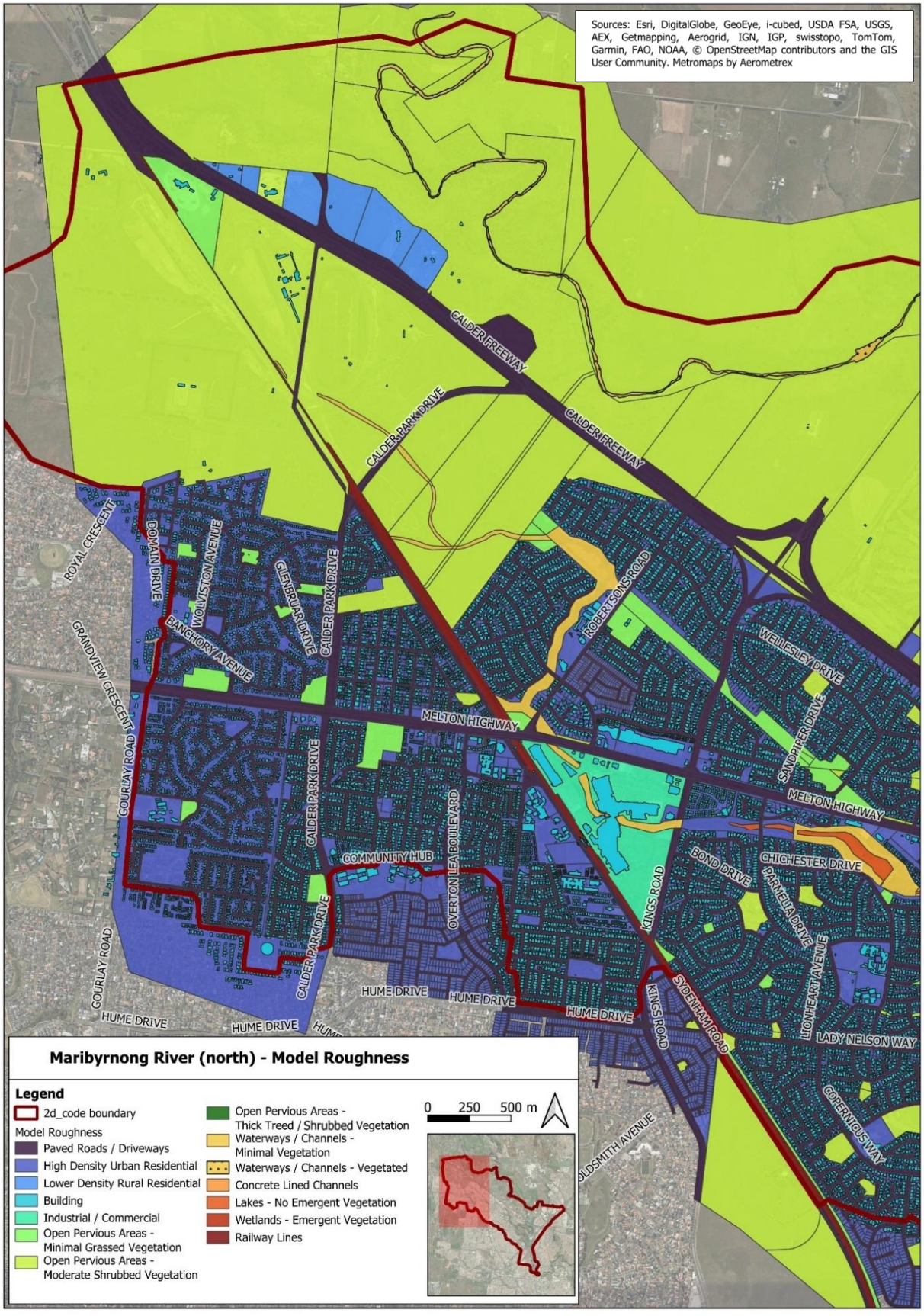


Figure A-20: Maribyrnong River TUFLOW model Manning's roughness (north).

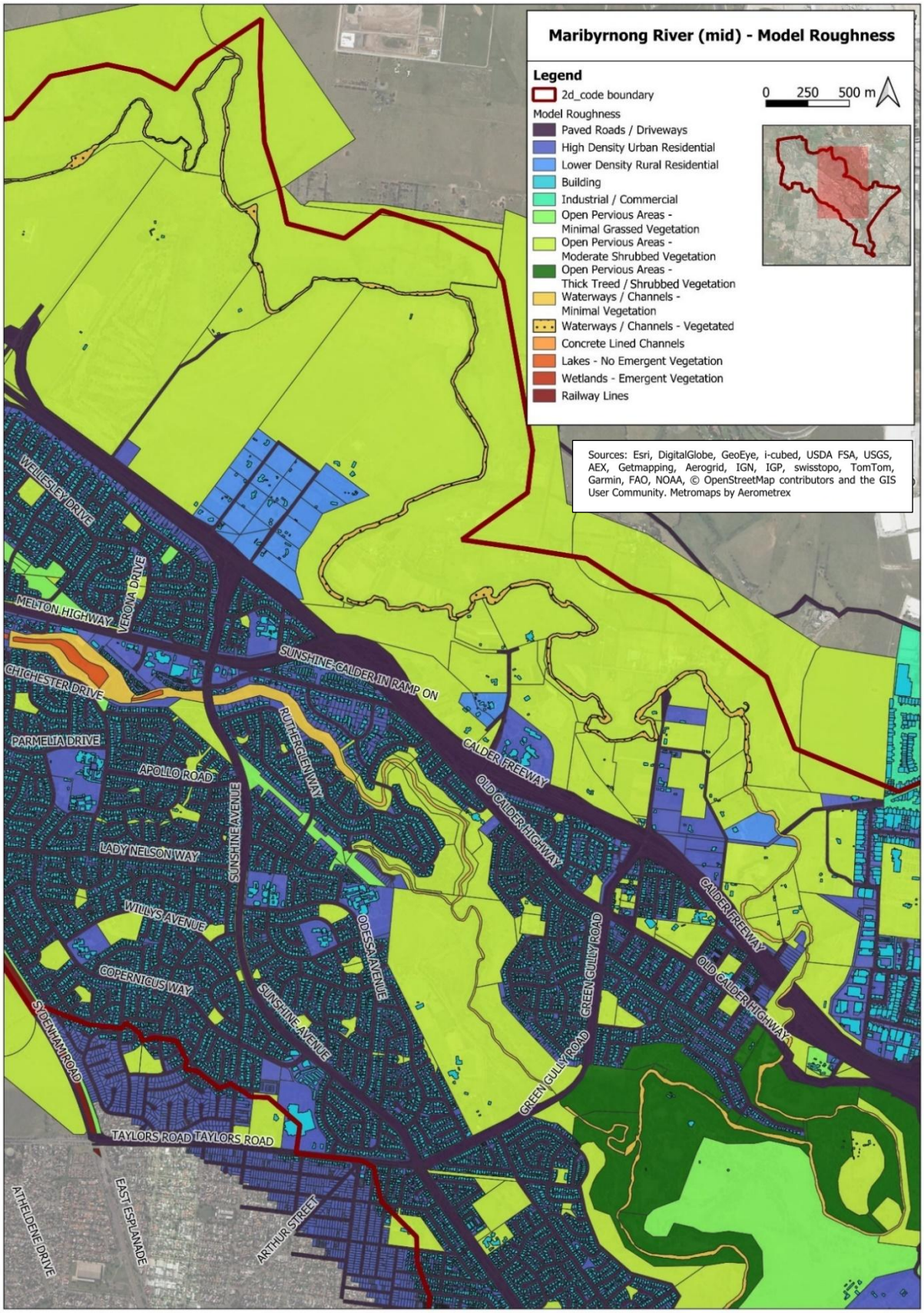


Figure A-21: Maribyrnong River TUFLOW model Manning's roughness (mid).

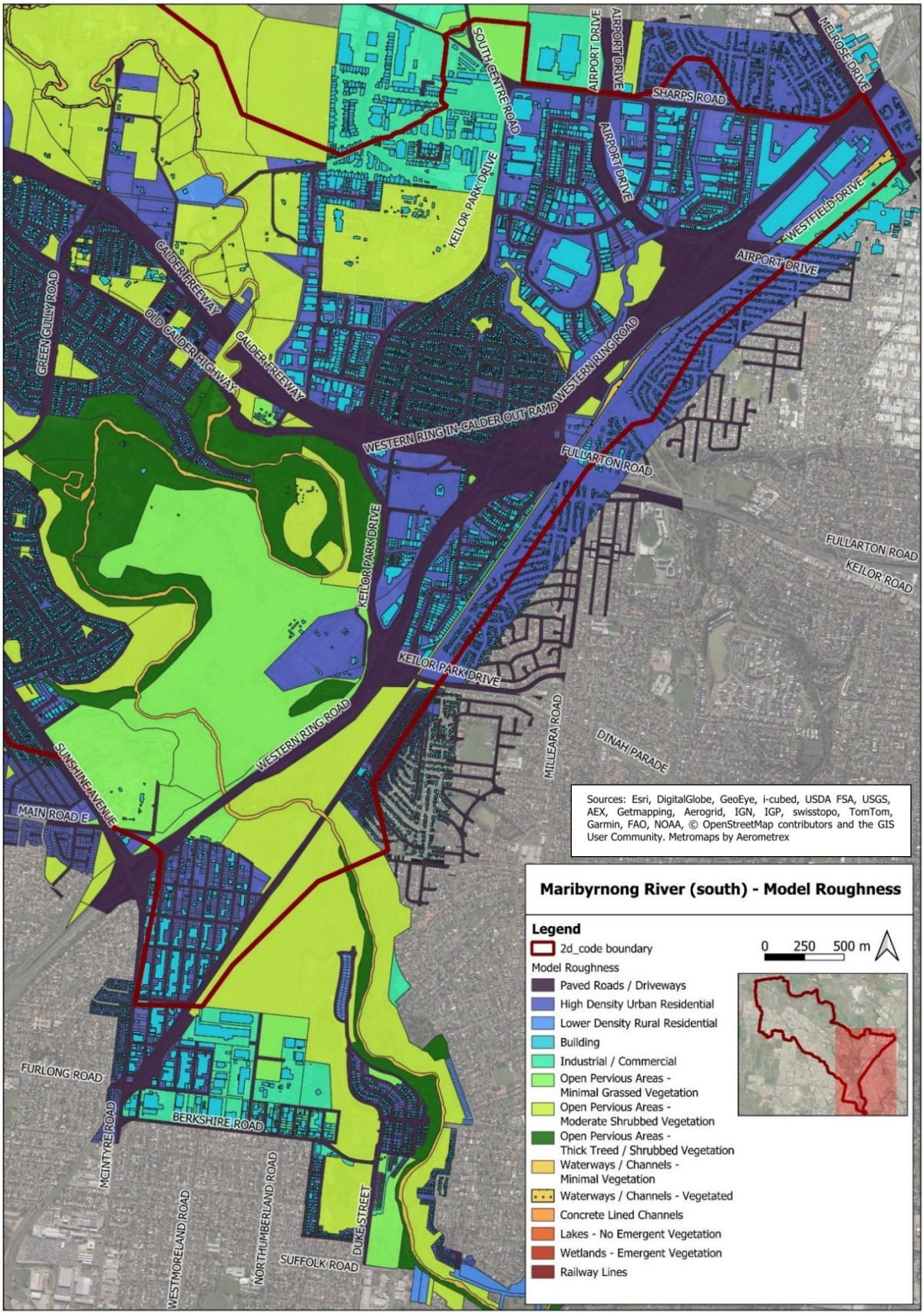


Figure A-22: Maribyrnong River TUFLOW model Manning's roughness (south).

A.9.1.4 1-D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table A-22. A full count of the adopted pit types in the TUFLOW model is listed in Table A-23 and Table A-24 for Melbourne Water pits. The pit sizes were determined from the supplied council and Melbourne Water information. Figures of the full drainage network are presented in Figure A-23, Figure A-24 and Figure A-25.

Table A-22: Maribyrnong catchments TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Justification/Location
Add_30	Melbourne Water	R	3	0.5	A presumed culvert has been digitised to facilitate the flow of water from an unmarked drainage channel that runs parallel to the Metropolitan Ring Road, near the Western Ring Path, towards an unnamed pond downstream on the opposite side of the motorway, adjacent to the Western Ring Road. The inlet of this culvert is clearly visible in Google Satellite imagery, and both the unnamed drain and the culvert inlet are discernible in the 1m DEM of the terrain. However, further verification or examination through street view imagery is not available. These assumptions have been derived from measurements taken from satellite imagery and the DEM data."
Add_02	Unknown, should be private	R	7	1.4	Assumed conveyor for a road underpass investigated from 1m DEM. Within Calder Park Motorsport Complex.
Add_03			16	2	
Add_31, Add_32	Brimbank Council/ Melton Council	R	1.5	4	A railway culvert conveyor was investigated and assumed using aerial imagery and 1m DEM, directing water from the upstream railway near Victoria Road to the downstream Taylors Creek channel.
Add_05	Brimbank Council	C	4		Assumed pipe beneath Burrowye Crescent as part of Taylors Creek waterway, and the pipe diameters assumed based on 1m DEM flow area.
Add_06, Add_07	Brimbank Council	C	0.3		Assumed pipes around the intersection of Sunshine Avenue and Malcolm Court. A side entry pit is in the database, but there was no pipe connected to it. After investigating the street view, it appears that the pit is in place, suggesting the presence of pipes with a similar dimension as adjacent pipes, connected to the downstream network.
Add_08, Add_09, Add_10	Brimbank Council	C	0.3		Assumed pipes receiving water from the west/upstream side of Sunshine Avenue through a roadside entry pit. Street view and 1m DEM data were utilised to determine if the flow should connect to the east or west side of the Sunshine Avenue network.
Add_11, Add_24, Add_25, Add_27, Add_28, Add_29	Brimbank Council	C	0.3		Assumed pipes are linked to upstream road side pits which were lacking downstream connections. Street view was investigated to confirm the presence of these pits in the network. Locations with added pipes include Catherine Drive, Hopkins Avenue, Chris Court, Sunshine Avenue (north-bound), and Melton Highway (east-bound).

Table A-23: Maribyrnong catchments TUFLOW model 1D drainage adopted pit types.

Pit Type	Count (Melton City Council dataset)	Count (Brimbank council data set)
Side Entry Pit (standard)	979	6,479
Side Entry Pit (0.9 m wide)	-	54
Side Entry Pit (1.2 m wide)		1
Side Entry Pit (1.8 m wide)		5
Double side entry pit (Number_of: 2)	19	980
Grated Side Entry		65
Grated Pit (1m x 1m)	33	438
Double Grated Pit (1m x 1 m) (Number_of: 2)		4
Grated Pit (0.9 m x 0.9 m)		10
Grated Pit (0.9 m x 0.6 m)		65
Grated Pit (2 m x 2 m)		2
Grated Pit (1.8 m x 0.9 m)		1
Grated Pit (1.8 m x 0.6 m)		1
Junction Pit (node)	278	2391

Table A-24: Melbourne Water pit types along the Melbourne Water drainage network

Pit Type	Count
Grated Pit 1m x 1m	16
Grated Pit 1.8 m x 0.9 m	1
Grated Pit 2 m x 2 m	2
Grated Pit 3 m x 4.8 m	1
Grated Pit 3.9 m x 3.9 m	1
Grated Side entry pit 2 m x 1 m	1
Grated Pit 1.5 x 1 m	3
Grated Pit 1.8 m x 3.4 m	1
Side Entry Pit 1.5 m wide	4
Side Entry Pit 1.8 m wide	3
Side entry pit 0.9 m wide	14
Grated Pits (m x m) 2 x 2, 2.5 x 2, 2.8x 1, 3 x2.4 , 3x2.8, 3.3x1.5, 4.5x1.8x, 5.3x1.75, 7.2 x 6.6	11

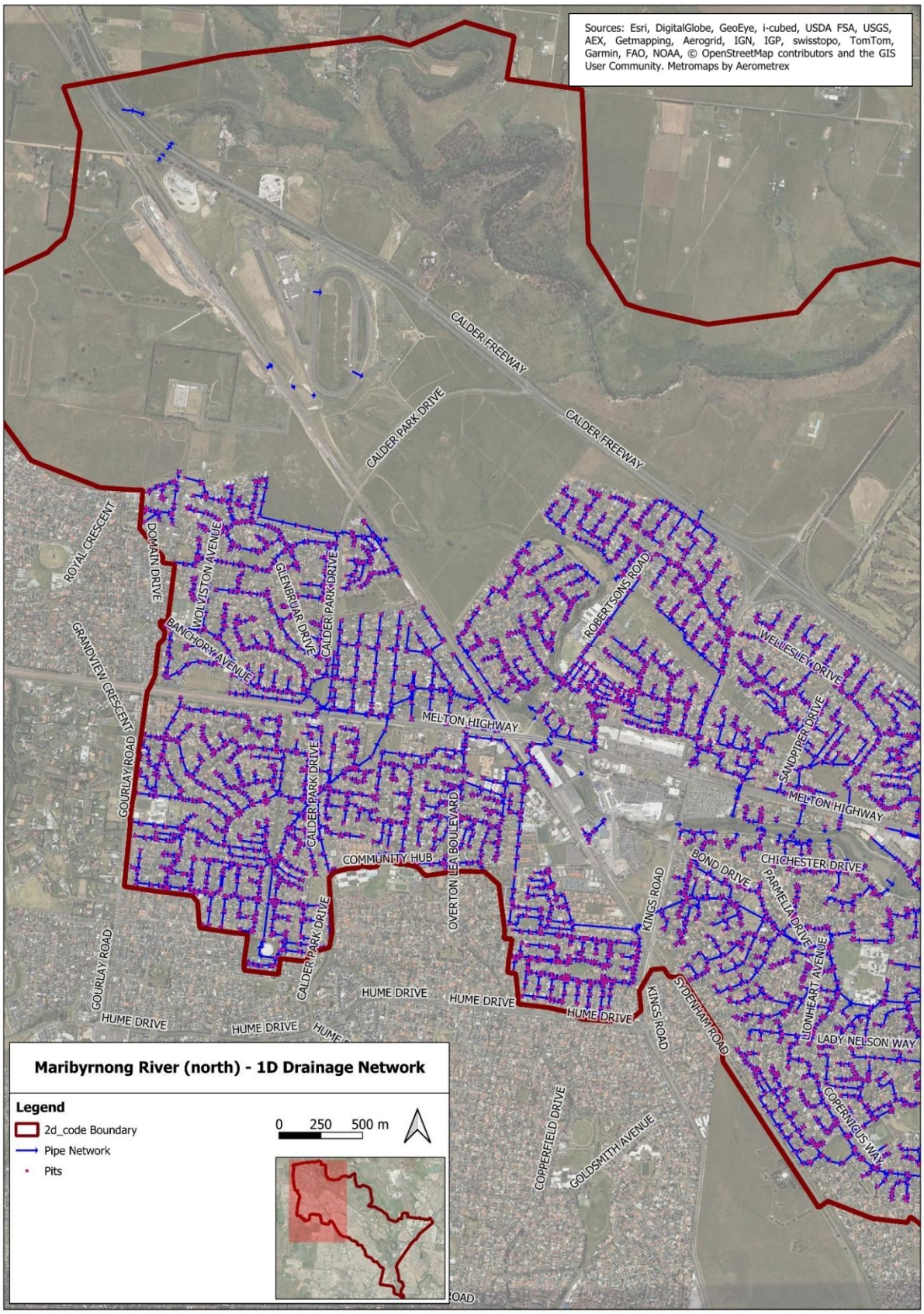


Figure A-23: Maribyrnong River TUFLOW model 1D drainage network (north).

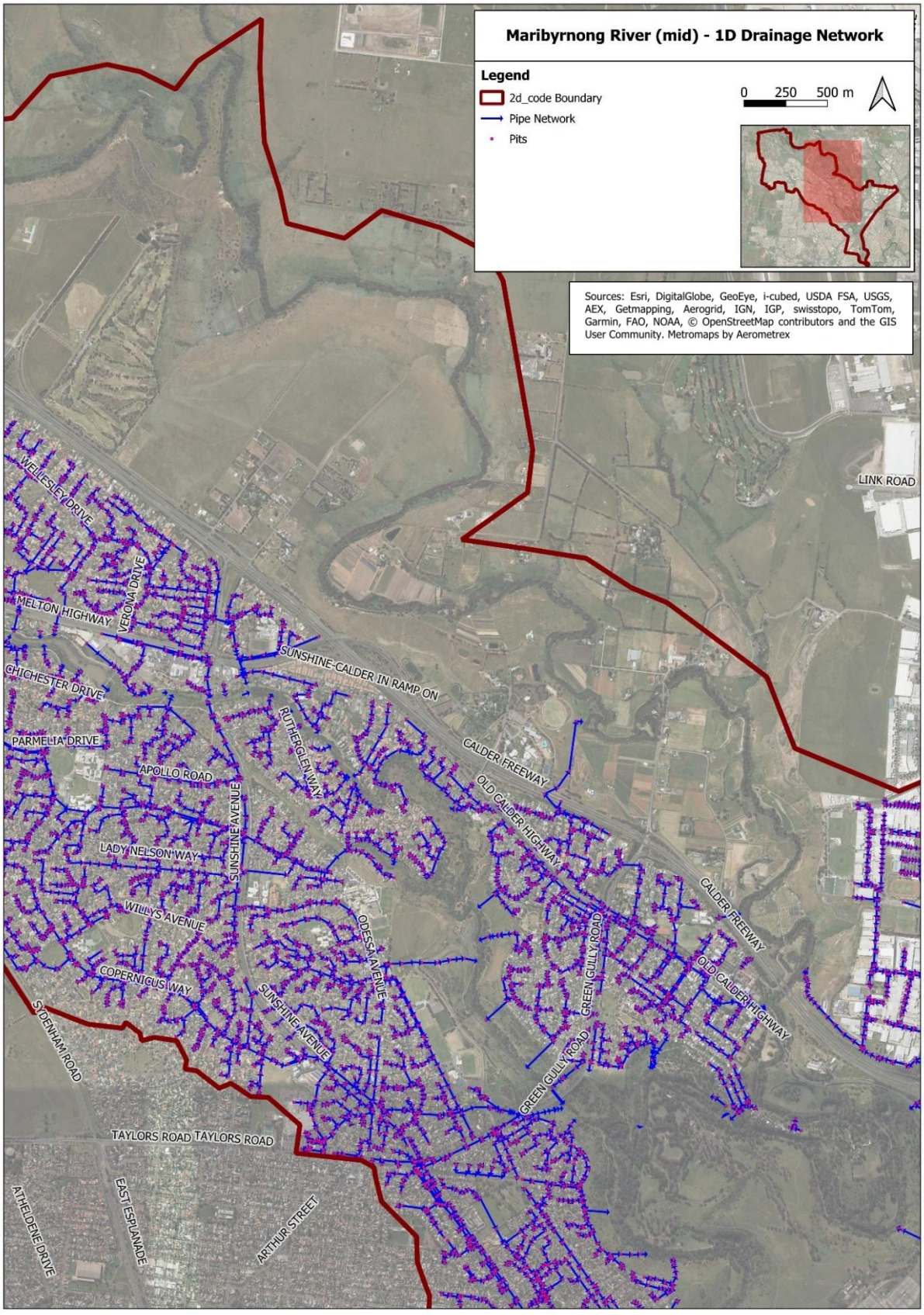


Figure A-24: Maribyrnong River TUFLOW model 1D drainage network (mid).

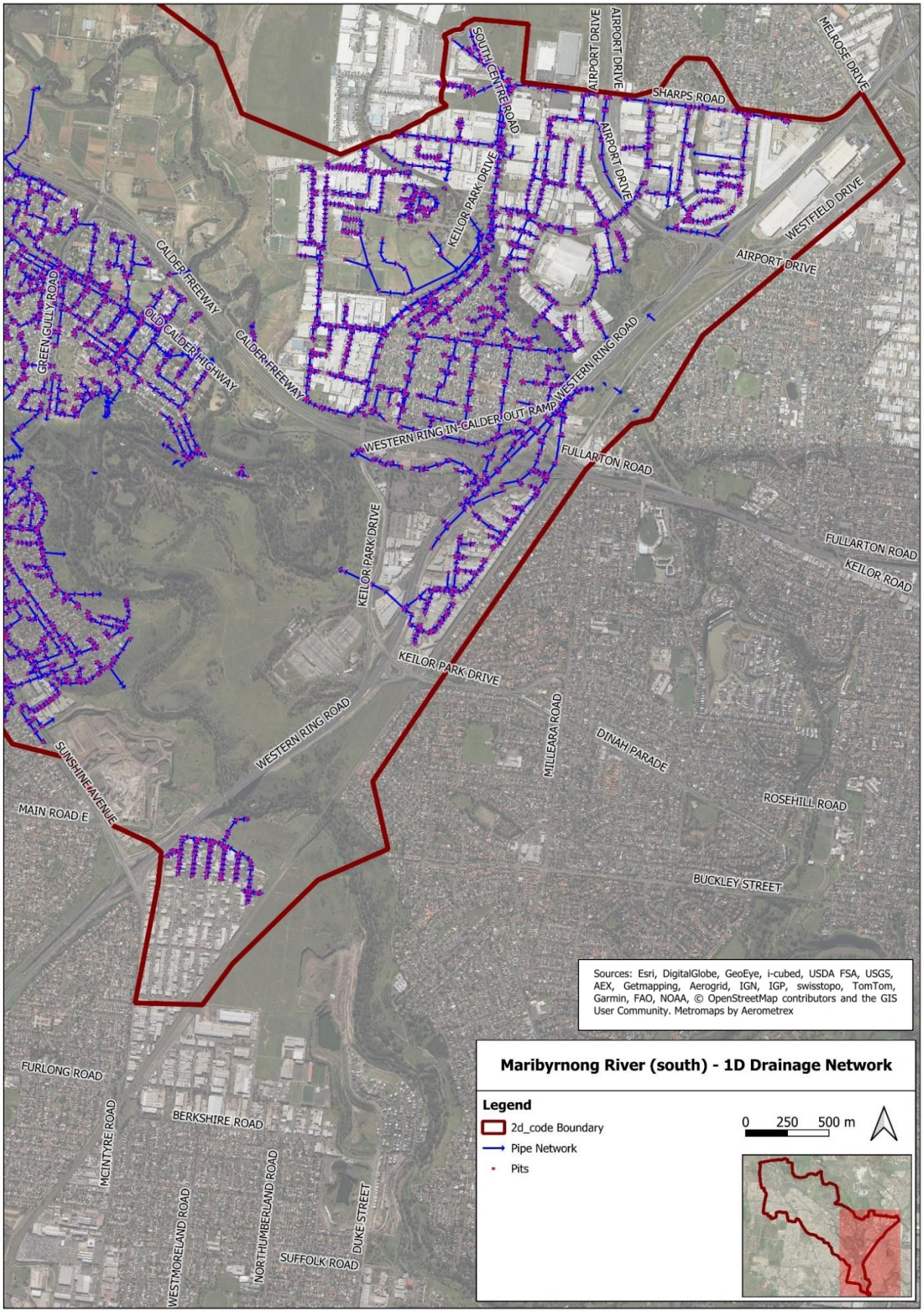


Figure A-25: Maribyrnong River TUFLOW model 1D drainage network (south).

A.9.1.5 Boundary conditions

The boundary conditions for the Maribyrnong River TUFLOW model are presented in Figure A-26, Figure A-27 and Figure A-28.

(a) Inflow boundary for the Maribyrnong River

To represent the boundary condition inflows for the Maribyrnong River, flows taken from the Study's RORB model at the Keilor gauge were applied at the upstream end of the TUFLOW model at the two major tributary inflow points (Jacksons Creek and Deep Creek) that join to form the Maribyrnong River. The Keilor flow was split across these two inflow locations, factored according to the Deep and Jacksons Creek catchment areas:

- Deep Ck: approx. 850km^2 (71% of upstream catchment area)
- Jacksons Ck: approx. 350km^2 (29% of upstream catchment area)

As per the Melbourne Water Flood Mapping Projects Specifications, the 10% AEP flow for the Maribyrnong River has been used for modelling the 1% and 2% AEP events for the study, and the 20% AEP flow for the 5-20% AEP events (given the Study area is above the tidally influenced zone). This approach was approved by Melbourne Water.

The study has applied an offset to these inputs so the peak of the flood event in the Maribyrnong River approximately matches the peak of the catchment runoff.

In addition, a gridded IWL is applied to the main Maribyrnong River channel. The IWL fills the base of the channel and represent a 'baseflow' in the river prior to the main inflows being added via the main tributaries (i.e. Deep Creek, Jacksons Creek, Arundel Creek). This gridded IWL also serves to stabilise the model when larger event flows are added in the simulation.

It is noted that riverine mapping of Maribyrnong River is captured in a separate Melbourne Water project.

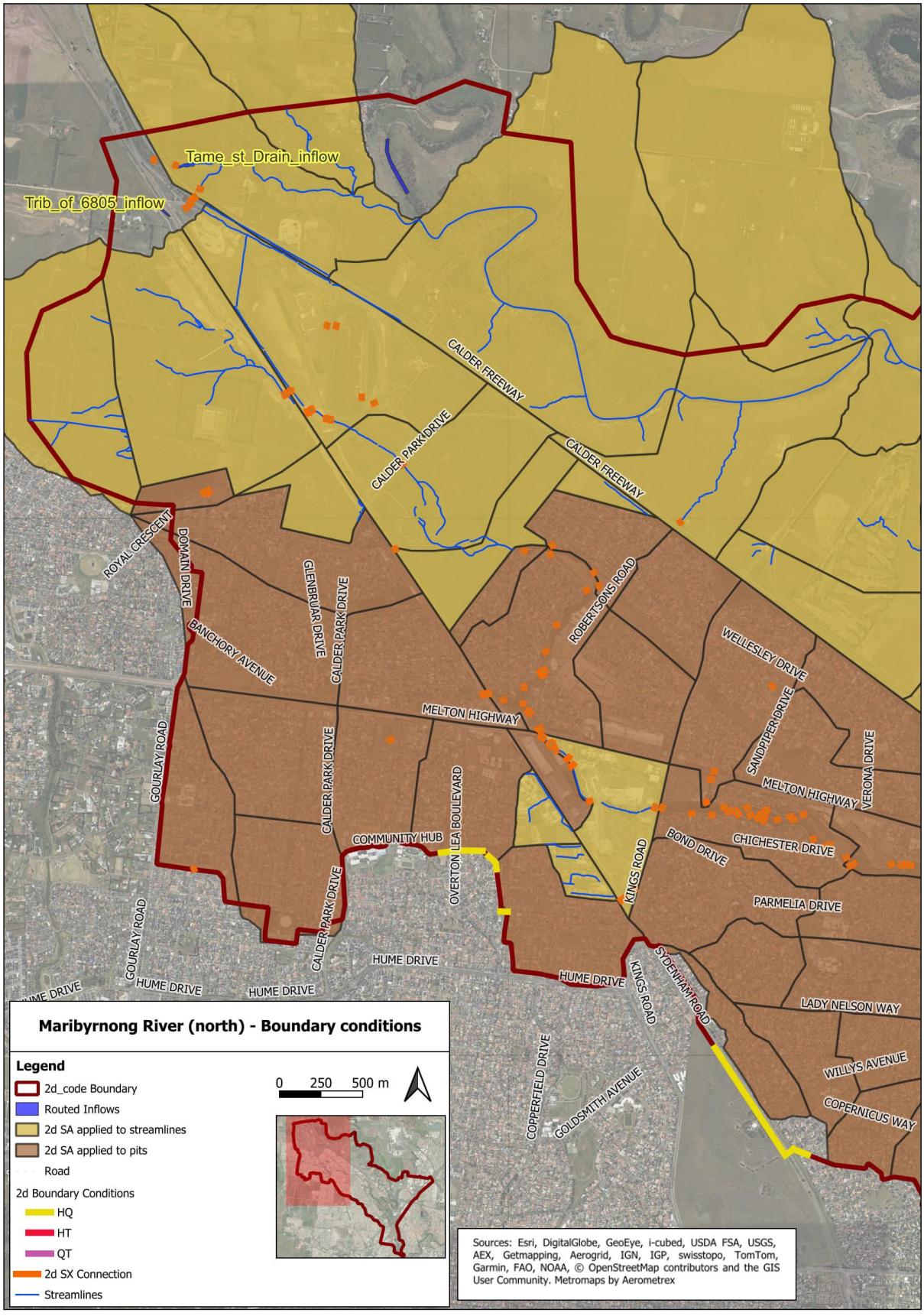


Figure A-26: Maribyrnong River TUFLOW model boundary conditions (north).

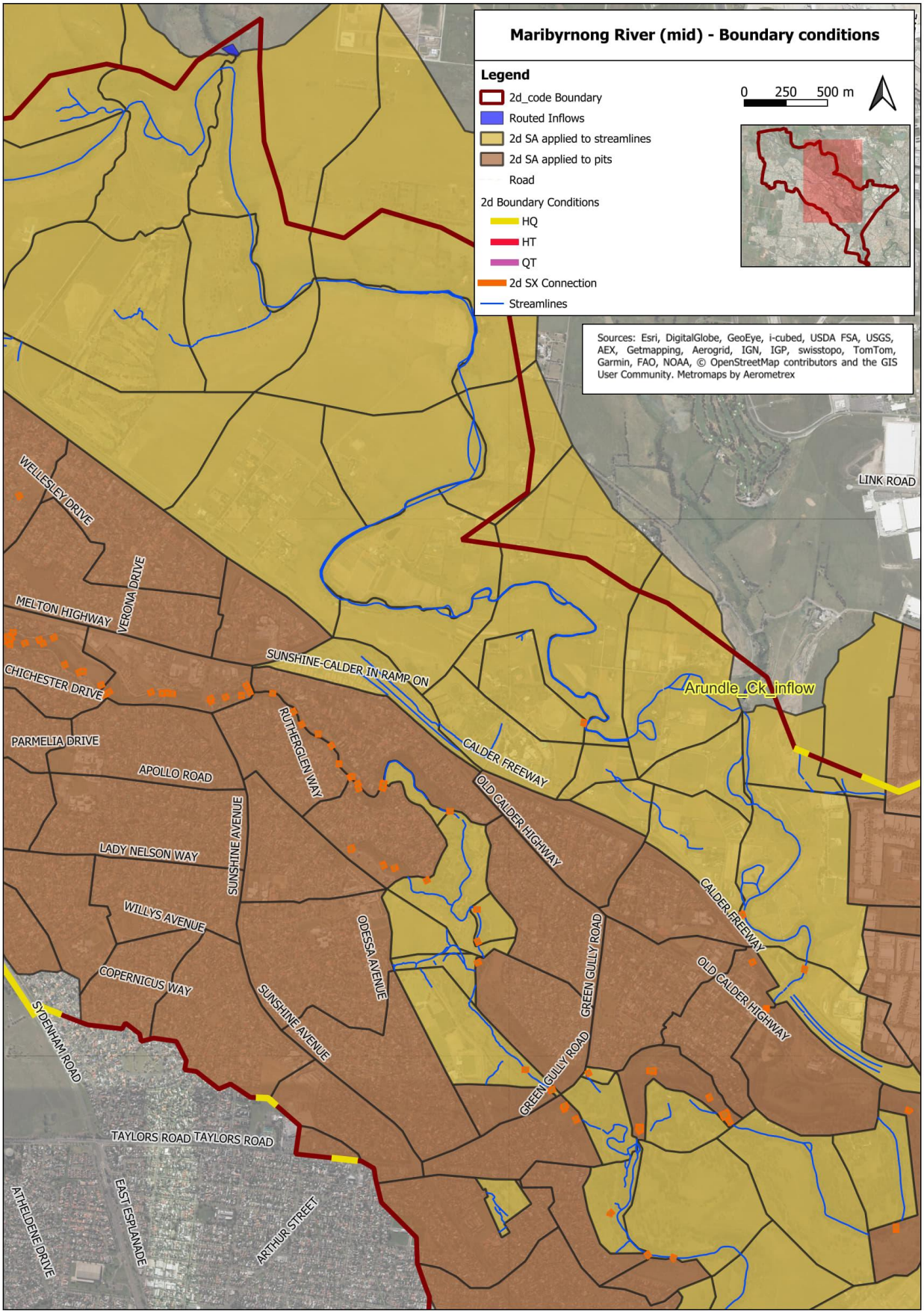


Figure A-27: Maribyrnong River TUFLOW model boundary conditions (mid).

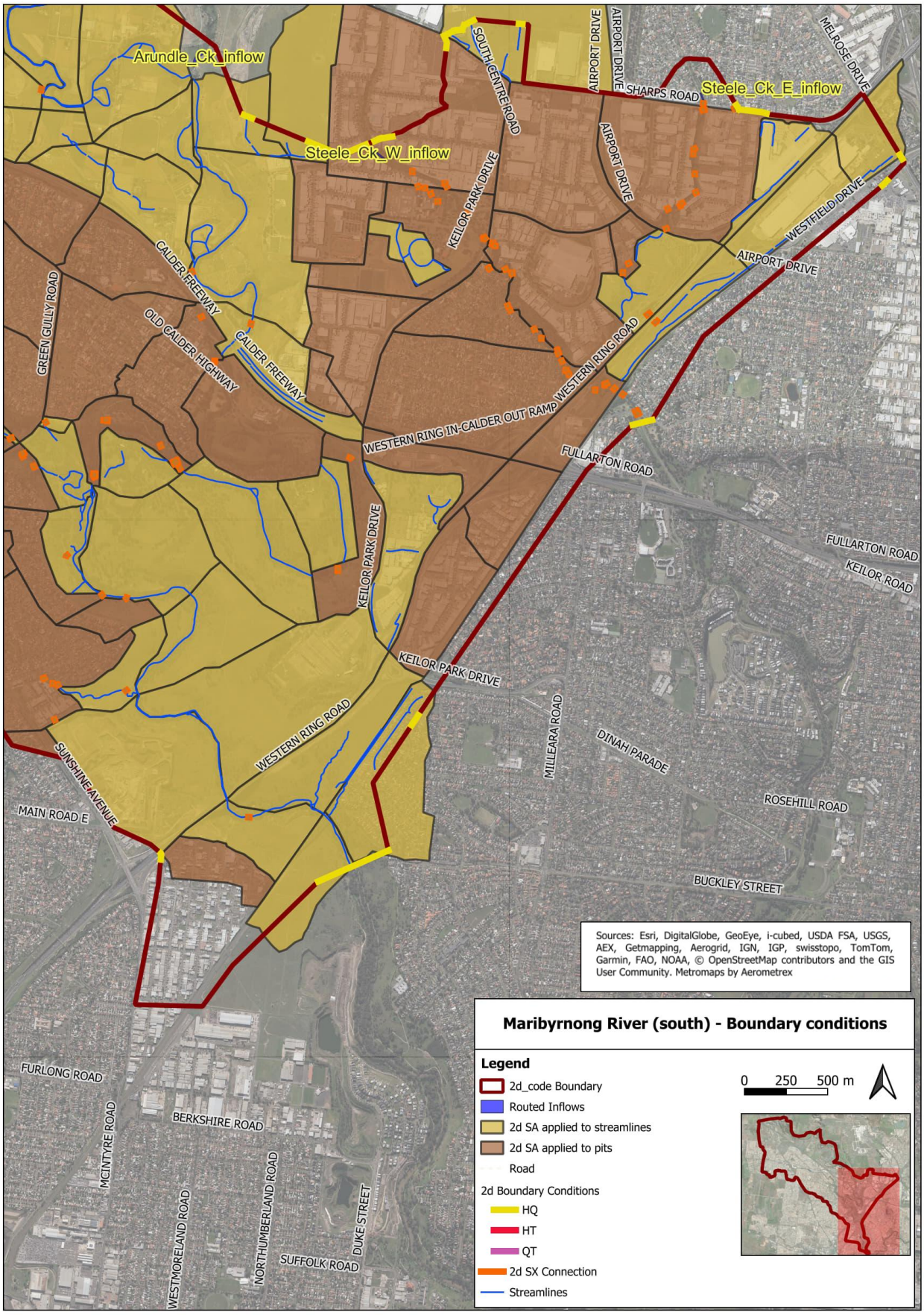


Figure A-28: Maribyrnong River TUFLOW model boundary conditions (south).

(b) Steele Creek and Arundel Creek inflows

Routed inflows for Steele Creek and Arundel Creek have been applied to the TUFLOW model (Figure A-29). The RORB model was simulated to generate routed inflows based on the upstream catchment areas. For this model this includes:

- 11km^2 for Arundel Creek
- 6 km^2 for Steele Creek

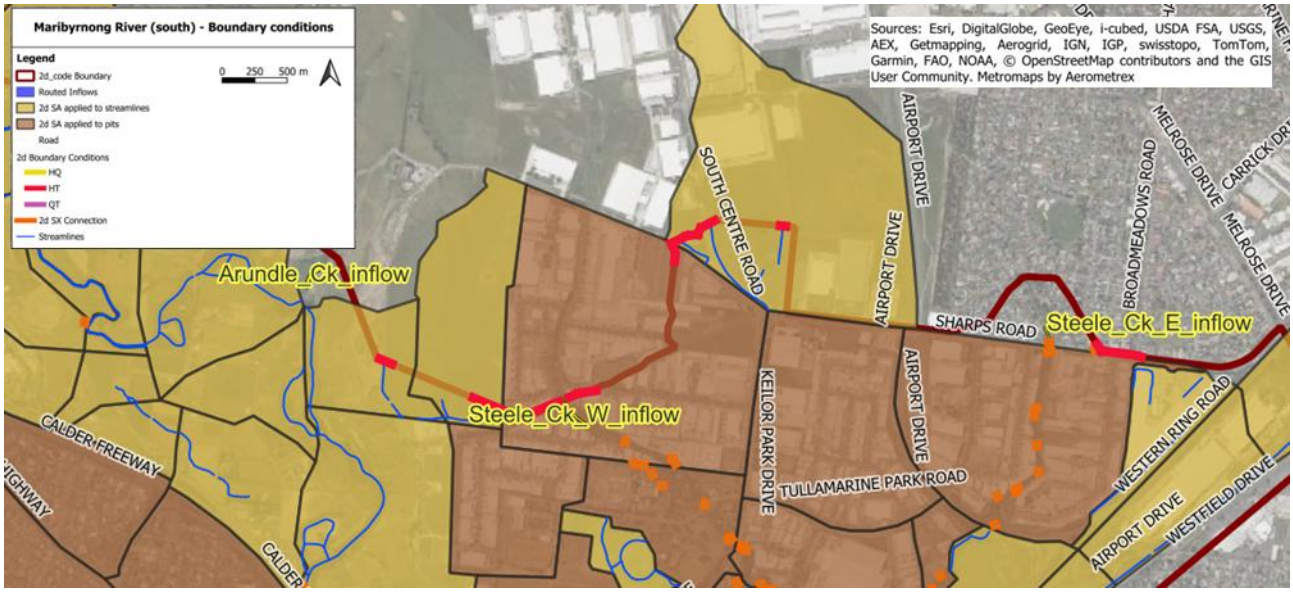


Figure A-29: Location of Arundel Creek and Steele Creek inflows.

(c) Downstream boundaries

The downstream boundaries for the model were set to HQ (height versus flow) boundaries with a slope determined based on the water level profile. The main downstream boundary is on the Maribyrnong River however across the model various HQ boundaries have been adopted where there is flow interaction with the model boundary.

A.9.1.6 Sensitivity testing of adopted AEP for Maribyrnong River tailwater level

A sensitivity check was carried out whereby the 1% AEP (event: 20 min, TP 28; representing the critical event for most of the model's urban area) was run with a constant 5% AEP critical peak flow (Figure A-30) and 20% AEP critical peak flow (Figure A-31) in the Maribyrnong River.

The results of the sensitivity test indicate changes to the boundary conditions in the Maribyrnong River does not have an impact on the broader catchment flood levels and the changes are isolated to the waterway. This is presented in Figure A-30 and Figure A-31. In addition, flows in pipes draining directly to the river were not observed to significantly change, confirming they are not sensitive to the Maribyrnong River TUFLOW model boundary condition for the modelled 1% AEP event.

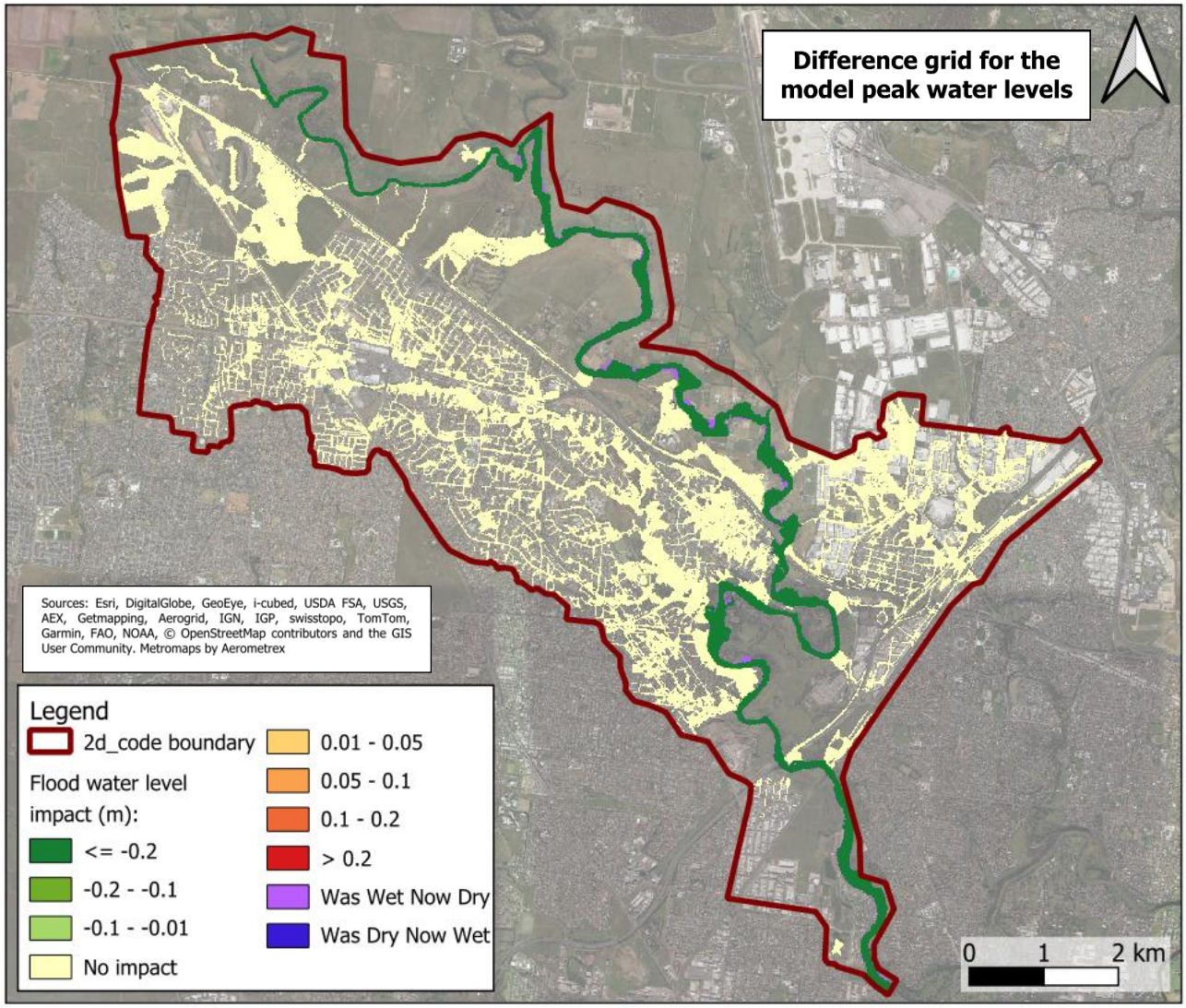


Figure A-30: Difference grid for the model peak water levels; 10% AEP flow minus 5% AEP flow scenario. The green indicates the peak water levels are lower in the 10% AEP event.

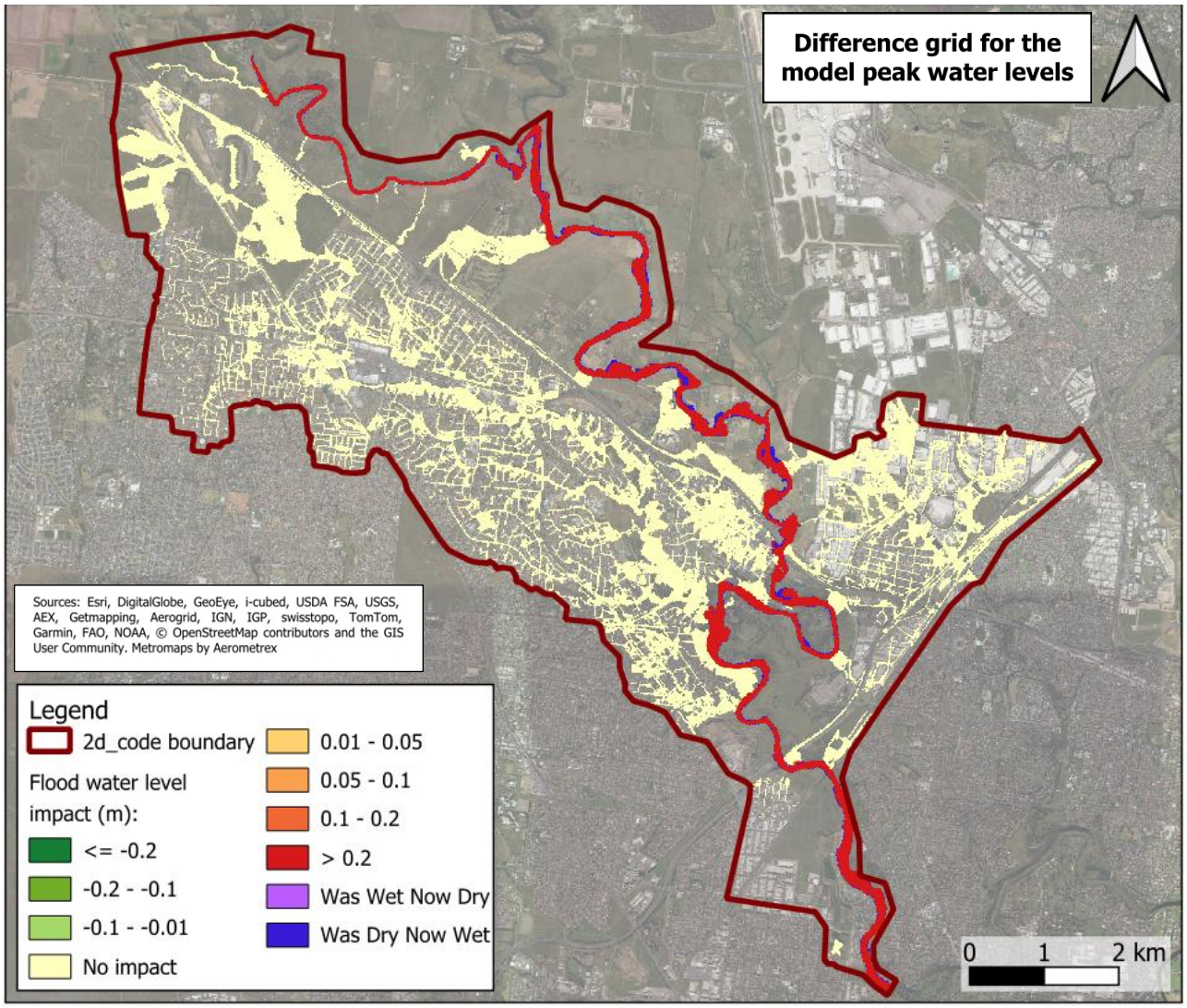


Figure A-31: Difference grid for the model peak water levels; 10% AEP flow minus 20% AEP flow scenario. The red indicates the peak water levels are higher in the 10% AEP event.

A.9.2 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in Section A.8. These are summarised in Table A-25.

Table A-25: Adopted Durations, temporal patterns and ARF areas for the Maribyrnong catchment model

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP28	1	TP28	1	TP18	1	TP12	1	TP7	1
30 minute	TP28	1	TP28	1	TP17	1	TP13	1	TP7	1
45 minute	TP26	3	TP26	3	TP19	3	TP19	3	TP6	1
1 hour	TP27	3	TP27	3	TP16	3	TP16	3	-	-
1.5 hour	TP27	9	TP25	3	-	-	TP16	3	TP7	3
2 hour	TP21	9	TP21	9	TP17	9	TP17	9	TP4	9
3 hour	TP25	9	TP29	9	TP15	19	TP15	19	TP9	19
4.5 hour	TP28	19	TP28	19	TP18	19	TP18	19	-	
6 hour	-	-	-	-	TP13	19	TP14	19	-	

A.9.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section A.8. The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment. This is presented in Table A-26.

Results from the RORB and TUFLOW models show that shorter durations (around 20–30 minutes) are critical in the upper urban areas, while longer durations (2–3 hours) dominate in the lower floodplains. A comparison of the RORB and TUFLOW model results indicates that the critical durations are generally consistent between RORB and TUFLOW, with minor variations across the catchment. In most locations, the TUFLOW critical durations closely align with those from RORB. Minor differences observed at point 18 for example is attributed to local storage effects and flow routing within the 2D model. Overall, the assessment confirms that the adopted RORB critical durations are appropriate and representative for the generation of the flood mapping outputs.

Table A-26: Comparison of RORB critical durations and TUFLOW critical durations for the 1% AEP with climate change event

RORB location (Figure A-16)	Location	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
1	Keilor Park Dr N	20 min	30 min	
2	Lionheart Av	30 min	30 min	
3	Avondale Heights	20 min	-	Outside of the TUFLOW model
4	Lady Nelson Way	15 min	20 min	
5	Kings Rd	20 min	30 min	
6	Calder Fwy	20 min	30 min	
7	Copernicus Way	20 min	20 min	
8	Green Gully Close	20 min	20 min	
9	Sydenham Rd	20 min	1 hour	
10	Keilor MD	15 min	1 hour	The influence of Old Calder Hwy is likely increasing the TUFLOW critical duration.
11	Melton Hwy Syd W RB	45 min	30 min	
12	Keilor Park Dr S	20 min	20 min	
13	Victoria Rd	10 min	20 min	
14	Sunshine Av	20 min	20 min	
15	Calder Fwy U/S Maribyrnong	45 min	4.5 hour	In the TUFLOW model this point is located in the Maribyrnong River.
16	Harefield Cres Res	10 min	20 min	
17	Taylors Ck trib U/S Taylors Lakes	20 min	30 min	
18	Melton Hwy/ Syd RB	3 hour	2 hour	
19	Melton Hwy 3	20 min	20 min	
20	Green Gully Reserve	20 min	30 min	
21	Trib of 6805	45 min	30 min	
22	Wanaka Dr Drain	45 min	30 min	

RORB location (Figure A-16)	Location	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
23	Steele Ck Upper	30 min	-	Outside of the TUFLOW model
24	Taylors Ck inflow	45 min	30 min	
25	Steele Ck W inflow	30 min	30 min	
26	Trib of Tame St Drain W	2 hour	1 hour	
27	Steele Ck at Keilor Park Dr	30 min	30 min	
28	Steele Ck E inflow	30 min	30 min	
29	Taylors Ck Upper	1.5 hour	1 hour	
30	Trib of Tame St Drain E	1.5 hour	20 min	
31	Arundel Ck inflow	2 hour	-	Outside of the TUFLOW model
32	Taylors Ck at Melton Hwy	2 hour	2 hour	
33	Taylors Ck at Kings Rd	2 hour	2 hour	
34	U/S Taylors Lakes	2 hour	2 hour	
35	Steele Ck at Western Ring Rd	1 hour	1 hour	
36	D/S Taylors Lakes	3 hour	2 hour	
37	Taylors Ck at Burrowye Cres	3 hour	2 hour	
38	Taylors Ck at Green Gully Rd	3 hour	3 hour	
39	Taylors Ck U/S Maribyrnong	3 hour	3 hour	
40	Jacksons Ck inflow Brimbank LGA	12 hour	45 min	The RORB results represent the catchment wide critical peak flow which is not modelled in TUFLOW. The main waterway functions as a boundary.
41	Deep Ck inflow	18 hour	-	
42	Maribyrnong D/S Deep Ck	18 hour	2 hour	
43	Maribyrnong U/S Arundel Ck	18 hour	4.5 hour	
44	Maribyrnong at Keilor	18 hour	4.5 hour	
45	Maribyrnong at Calder Fwy	18 hour	4.5 hour	
46	Maribyrnong Lower	18 hour	-	Outside of TUFLOW model domain

A.9.4 Quality Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model

warnings and checks are summarised in Table A-27. They have been assessed as not likely to adversely affect the model results. Reviews completed by Melbourne Water's external reviewer are provided in Appendix N.

Table A-27: TUFLOW checks and warning messages

Message	Count	Message content	Comment
Message 1100	2	WARNING 1100 - Structure XX crest/invert (XX) is below bed (XX) of primary upstream channel XX	Typical for a drainage network for pipe inverts to not align with decreasing gradient.
Message 1313	2	WARNING 1313 - No inlet culvert connected to Manhole "XX". Manhole not used/applied.	Present on two small pipes (375 dia or less) which are connected to only one pipe. Not considered critical for flood mapping purposes.
Message 1401	2	CHECK 1401 - 1 culvert(s) not used for determining losses at Manhole "XX". Check culvert inverts and directions.	Standard check. Not considered critical to resolve for flood mapping purposes.
Message 1402	9	CHECK 1402 - More than one culvert connected but could not create manhole at Node "XX". Check culvert inverts and directions.	Standard check. Not considered critical to resolve for flood mapping purposes.
Message 2073	10	WARNING 2073 – Object ignored. Only Points, Lines, Polylines & Region Centers used.	Indicates there are GIS files with null shapes. No influence on the model.
Message 2118	185	CHECK 2118 - Lowered SX ZC Zpt by XXm to 1D node bed level.	All within the Melbourne Water criteria of less than 0.5 m
Message 2210	40	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = XX; Top of First FC Layer = XX	Minor locations were layered flow constrictions (bridges) cross under the terrain. No influence on the results.
Message 2807	1	WARNING 2807 – Trying to apply more than 1 level boundary to cell.	Not located at a critical location.
Message 2815	1	WARNING 2815 – Write PO Online not yet supported in Quadtree.	No influence on the model.
Message 2834	4	WARNING – 1d node/pit SX connection is not an active Quadtree cell	No influence on the model.
Message 3505	2	CHECK 3505 - SGS TIN outside model domain. Skipping…	No influence on the model.
Message 3520	1	CHECK 3520 - Minimum V elevation must be higher than the minimum cell centre elevations on both sides in SGS. ZCmin lower = 77.064, ZVmin = 77.089, ZCmin upper = 77.695.	One location. No influence on the model.

A.10 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through

workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

A.11 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.

GHD (2016a) Melbourne Water Corporation Retarding Basins Upgrade Program - Risk Assessment of Sydenham Retarding Basin.

GHD (2016b) Melbourne Water Corporation Retarding Basins Upgrade Program - Risk Assessment of Sydenham West Retarding Basin.

GHD (2016c) Melbourne Water Corporation Retarding Basins Upgrade Program - Risk Assessment of Taylors Lakes Retarding Basins – Lake Heron, Lake Ibis, Lake Kingfisher, Lake Shellduck and Lake Spoonbill.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Metropolitan Board of Works (MMBW) (1986) Maribyrnong River Flood Mitigation Study.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

RPV (Rail Projects Victoria) (2020) AJM JV Melbourne Airport Rail – Maribyrnong Upper Hydrology Update.

The Bureau of Meteorology (2022) Design Rainfall Data System

The Bureau of Meteorology (2022) Rating table data – Maribyrnong at Keilor
http://www.bom.gov.au/waterdata/

Appendix B. Kororoit Creek

The waterway for Kororoit Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

Appendix B. Kororoit Creek Hydrological Model and Hydraulic Model

This appendix details the RORB and TUFLOW model development for Kororoit Creek catchment and full technical details of adopted parameters and results.

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B.1 Catchment Description and Study Area

Kororoit Creek catchment is a peri-urban catchment, west of Melbourne. The total catchment area is 322 km^2. The catchment primarily consists of rural/regional land use upstream of Deer Park and urban/impervious/heavily modified land use downstream of Deer Park. Two streamflow gauges located on Kororoit Creek; Deer Park (231104) and Brooklyn (231107) are within the study area. The catchment and location of the gauges used to calibrate the RORB model parameters to observed data are shown in Figure B-1.

The Kororoit Creek catchment model includes an area that overlaps with the Stony Creek model due to the presence of diversions that transfer flows out of the Stony Creek catchment and into Kororoit Creek.

The waterway for Kororoit Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

B.1.1 Previous RORB Model

An existing RORB model for the Kororoit Creek catchment was accessed for use in this Study. This model was originally developed by Melbourne Water in 1986, updated by GHD in 2002, then RPV in 2020 (RPV, 2020). The recent updates included developing a modelling approach consistent with ARR 2019 and the Melbourne Water Flood Mapping Projects Specifications. The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Kororoit Creek TUFLOW models covering Brimbank and Hobsons Bay LGAs. The updates undertaken to the model are outlined in the sections below.

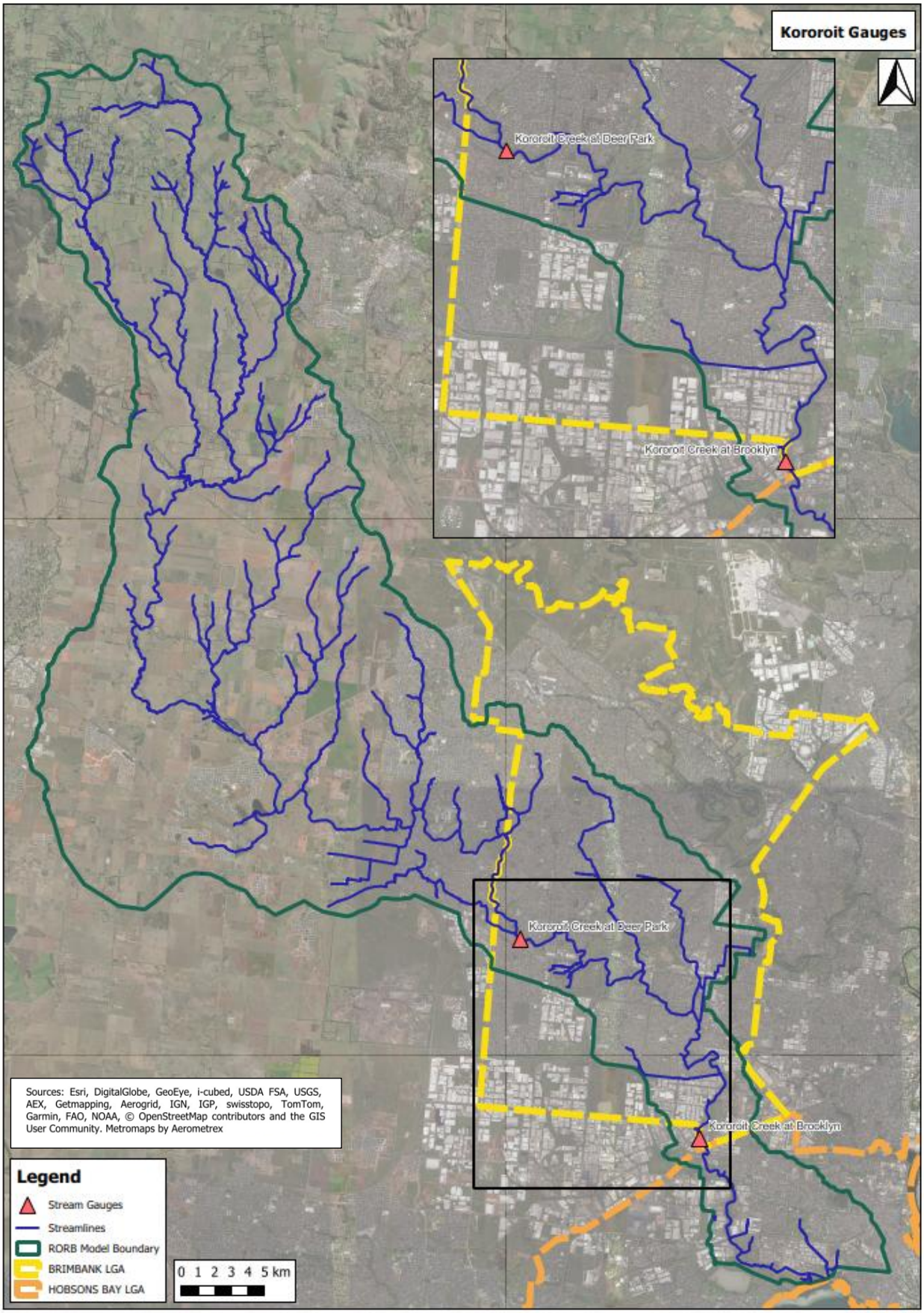


Figure B-1. Kororoit Creek catchment and location of the gauge used to calibrate the Study RORB model.

B.2 RORB Model Setup

The development of the RORB model is represented in Figure B-2 and Figure B-3 described in the following sub-sections.

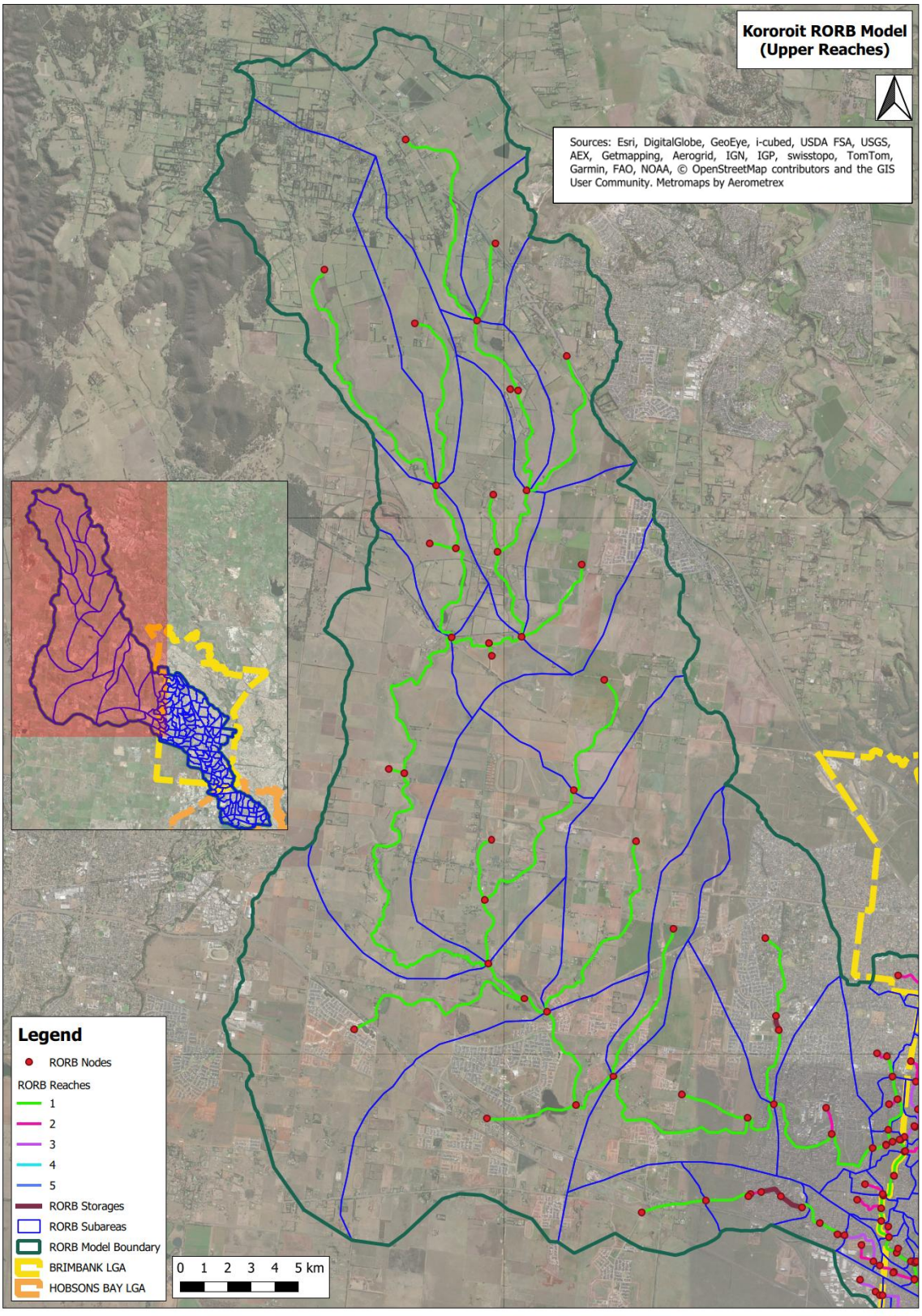


Figure B-2. Kororoit Creek RORB model setup (upper reaches)

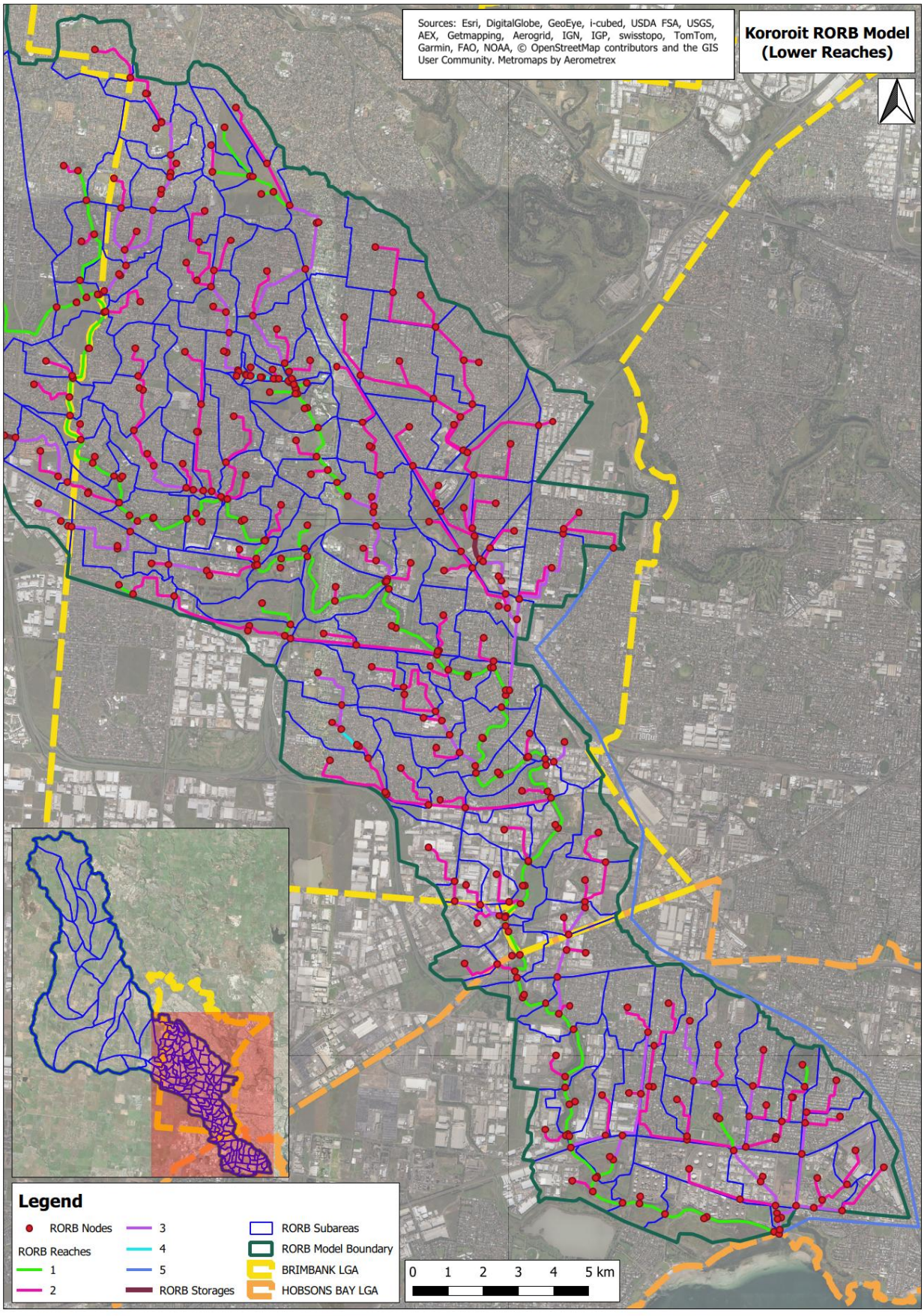


Figure B-3. Kororoit Creek RORB model setup (lower reaches).

B.2.1 Catchment and Subarea Boundaries

A review of existing RORB models identified the need to re-delineate large areas, particularly those falling within the LGAs of interest. Subareas within Brimbank and Hobsons Bay LGA were reduced and standardised in preparation for extraction of hydrographs for input into TUFLOW. As such, subarea sizes upstream of the Brimbank LGA were largely retained as per the previous RORB GIS files, given that these are upstream of the area which are modelled in TUFLOW. An interstation area node has been used to split the catchment and vary routing parameters where subarea size changes. As the model has been calibrated to the Deer Park stream gauge located approximately 3.5 km downstream of this interstation area and validation checks of the 1% AEP flows have been carried out, this approach is considered appropriate in representing the flows into the Study LGA areas.

Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery (Bing) to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas, or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Catchment delineation considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

The final catchment and subarea boundaries are shown in Figure B-2 and Figure B-3.

B.2.2 Node-link network

The node-link network shown in Figure B-2 and Figure B-3 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

B.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
    - Type 1 – Natural channels, used for major creek reaches
    - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
    - Type 3 – Lined channel or pipe – these were used to represent flow paths associated with major underground Melbourne Water trunk drains and lined channels
    - Type 4 – Drowned – these were used upstream of storages or major waterbodies
    - Type 5 – Dummy – used to connect smaller independent catchments (i.e. Paisley Drain) to a single outlet node

The final reach alignments and types are shown in Figure B-2 and Figure B-3.

B.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB), as listed in Table B-1. Waigani RB was not included in the RORB model as H-S/S-Q relationship information was not available to represent this storage.

Table B-1. Storages in the Kororoit Creek RORB model.

Storage	Data source and checks
Callaway Park RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. Pipe outlet information confirmed against Melbourne Water underground asset information. No further information available for further checks or updates (i.e. on H-S relationship).
Gladstone Street RB (includes a series of 6 storages in the RORB model)	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S relationship).
Chisholm Park RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. Pipe outlet information confirmed against Melbourne Water underground asset information and inspection reports. No further information available for further checks or updates (i.e. on H-S relationship).
Serpentine No 1, 2 and 3 RB (represented by 2 storages in the RORB model	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. Pipe outlet information confirmed against underground asset information and inspection reports. No further information available for further checks or updates (i.e. on H-S relationship).
Frost Drive RB	Storage details adopted as per RPV model (2020). Checks on spillway height and length confirmed by GHD (2016); checks also carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information and inspection reports – this check identified an update required in the RORB model to one of the RB outlet pipes (1.8m dia updated to 1 m dia). No further information available for further checks or updates (i.e. on H-S relationship).
Caroline Springs RB (also referred to Taylors RB)	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. Pipe outlet information confirmed against Melbourne Water underground asset information and inspection reports. No further information available for further checks or updates (i.e. on H-S relationship).
Gilmour Road (also included in the Stony Creek model due to models' overlap)	Storage details adopted as per RPV model (2020), represented using S-Q flow relationship. No further information available for further checks or updates.

B.2.5 Diversions

A diversion into Kororoit Creek from Stony Creek was accounted for in the previous RPV model by including the relevant portion of the Stony Creek catchment in the Kororoit Creek model. This was retained.

The Westmoreland Road pipe diversion, originally only a part of the Stony Creek RPV model (RPV, 2021), was added to the Kororoit Creek model as a result of the catchment re-delineation exercise. The RORB inflow-outflow diversion details for Westmoreland Road pipe (Table B-2) are consistent in both the Kororoit Creek and Stony Creek models for the Study. In the Kororoit Creek model, the diversion directs 3.4 m^3/s to Reach no. 392, with the remainder of flow directed towards an outfall node joined to the outlet via a Type 5 'Dummy' reach (this flow is accounted for in the Stony Creek model).

Table B-2. Diversions in the Kororoit Creek RORB model

Diversion	RPV (2021) Calculated and Adopted Pipe Capacity (m^3/s)
Westmoreland Road pipe diversion (900 mm dia Melbourne Water pipe)	3.4

B.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

B.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

B.2.8 RORB version

RORB version 6.47 was used for modelling.

B.3 Flood Frequency Analysis (FFA)

An at-site Flood Frequency Analysis (FFA) was undertaken for the Deer Park (231104) and Brooklyn (231107) streamflow gauges according to the guidelines provided in Book 3 Chapter 2 of ARR 2019. The FFA was undertaken using the Flike software package. Flike provides a Bayesian framework for comprehensive at-site flood frequency estimation that allows the inclusion of ungauged historical events.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

1. Prepare data:
    a. Collect gauged streamflow data
    b. Collect historic data, including the review of previous studies
    c. Undertake standard data checks on the stream flow data including checking error codes, cataloguing data gaps, undertaking visual inspections and reviewing the rating curve
    d. Determine the water year
    e. Extract the annual maximum series and check peaks for independence
2. Using Flike, fit an extreme value distribution to the annual maximum series, including the influence of:
    a. Historic data (data that exists beyond the extent of the annual maximum series)
    b. Censoring low flows with a multiple Grubbs Beck test
    c. Inputting prior parameters information from the RFFE (Deer Park only)

A summary of the FFA and findings are included below for both gauges.

B.3.1 Annual Maxima Flows

The details of data available from both gauges is shown in Table B-3. An annual maximum flow series of 38 years (Deer Park) and 29 years (Brooklyn) were available, and missing data can be seen in Table B-4 and Table B-5. An analysis of the flow series indicated that the calendar year can be used as the water year.

Table B-3. Data availability for Deer Park and Brooklyn gauges.

Gauge	Period of record	Missing years of data
Deer Park (231104)	1980 – 2022 (42 years)	4 years of missing data between 1991-1994
Brooklyn (231107)	1980 – 2022 (42 years)	12 years with significant gaps between 1980-1992

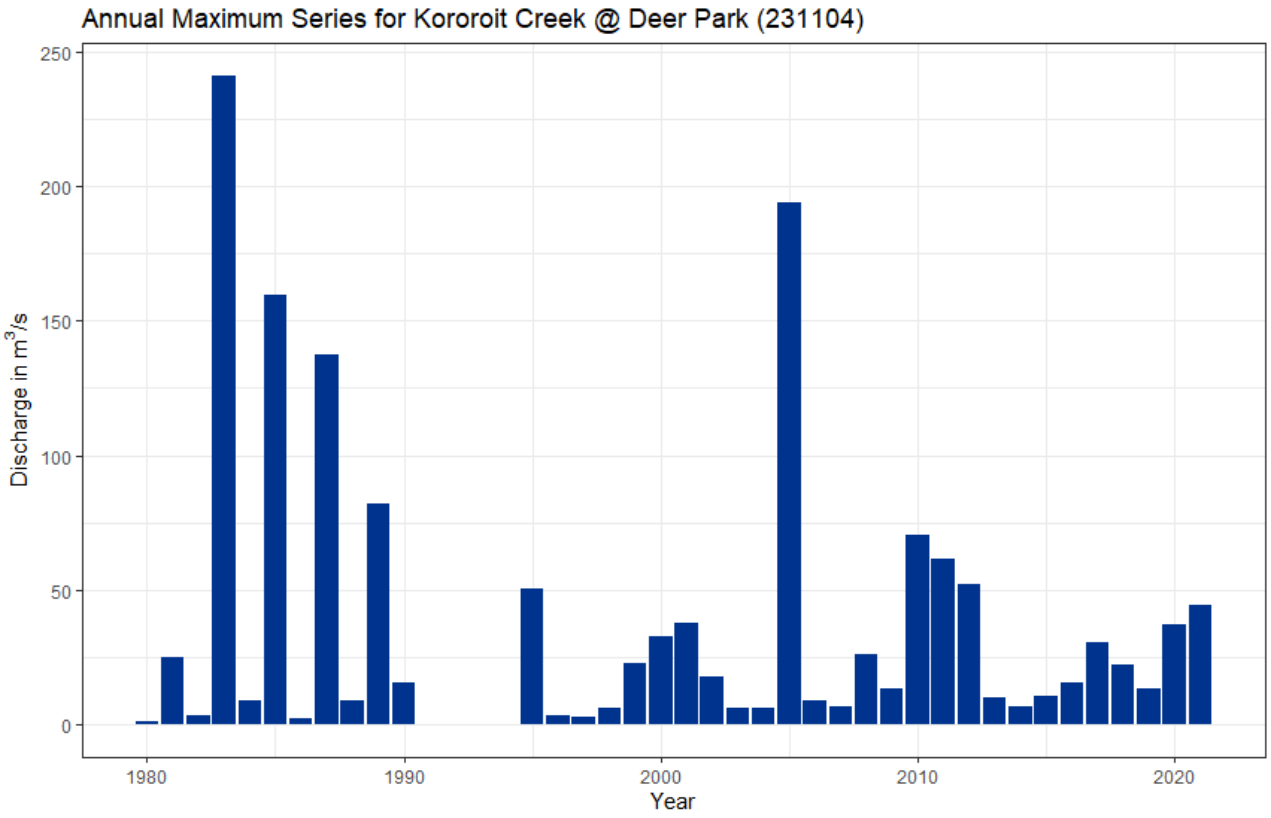


Figure B-4. Annual Maximum Series for Kororoit Creek at Deer Park.

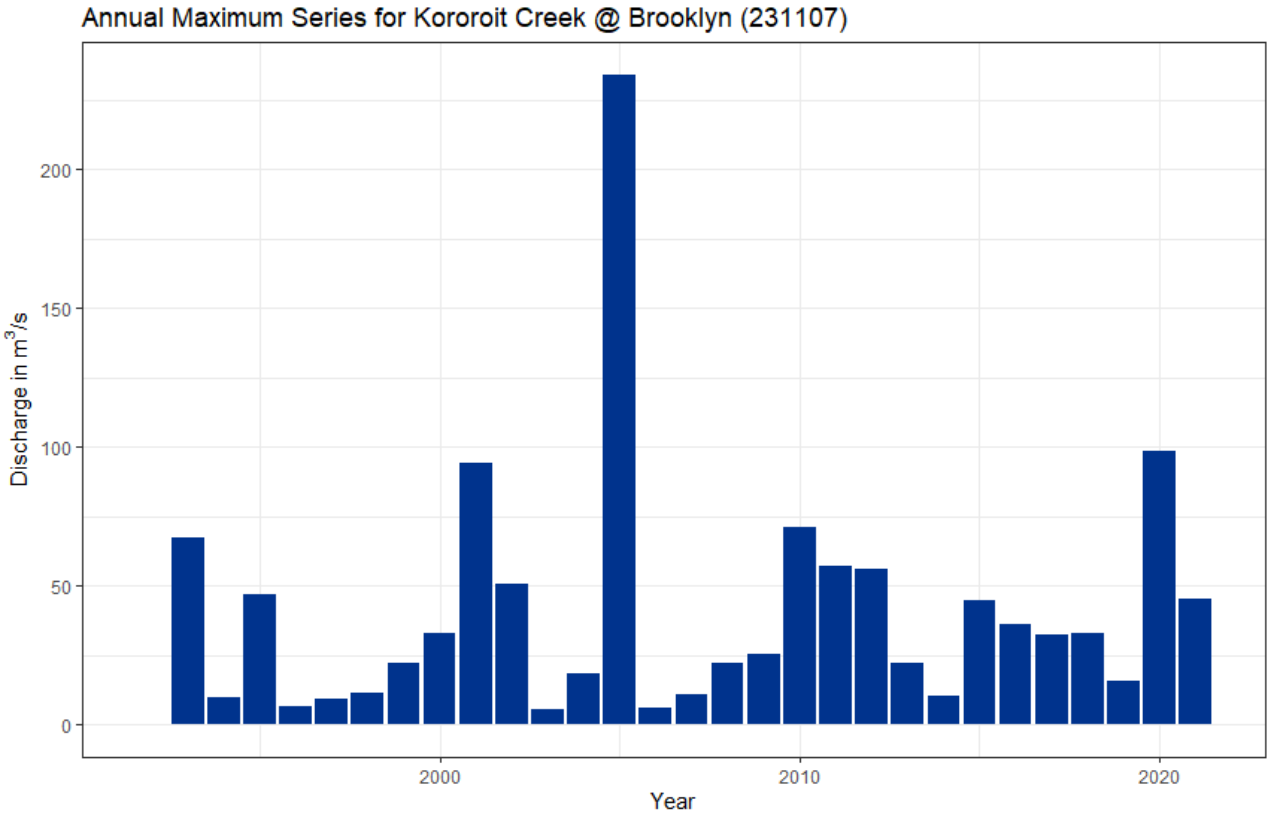


Figure B-5. Annual Maximum Series for Kororoit Creek at Brooklyn.

B.3.2 Rating Curve Review

To ensure that the rating tables were producing reasonable flow estimates for high flows, a review of the rating tables obtained for both gauges (Deer Park 231104 and Brooklyn 231107 (Bureau of Meteorology, 2022)) was carried out. The rating curves for the two gauges are shown in Figure B-6 and Figure B-7.

Kororoit Creek at the location of the two gauges is well incised, with flows confined to the channel. A previous review using the two rating curves undertaken by RPV (2020) assessed their performance using a localised TUFLOW 2D model. Results indicated that the rating tables produce reasonable flow estimates for high flows at both gauge locations, it was therefore assumed appropriate to adopt the recorded discharge values for this Study.

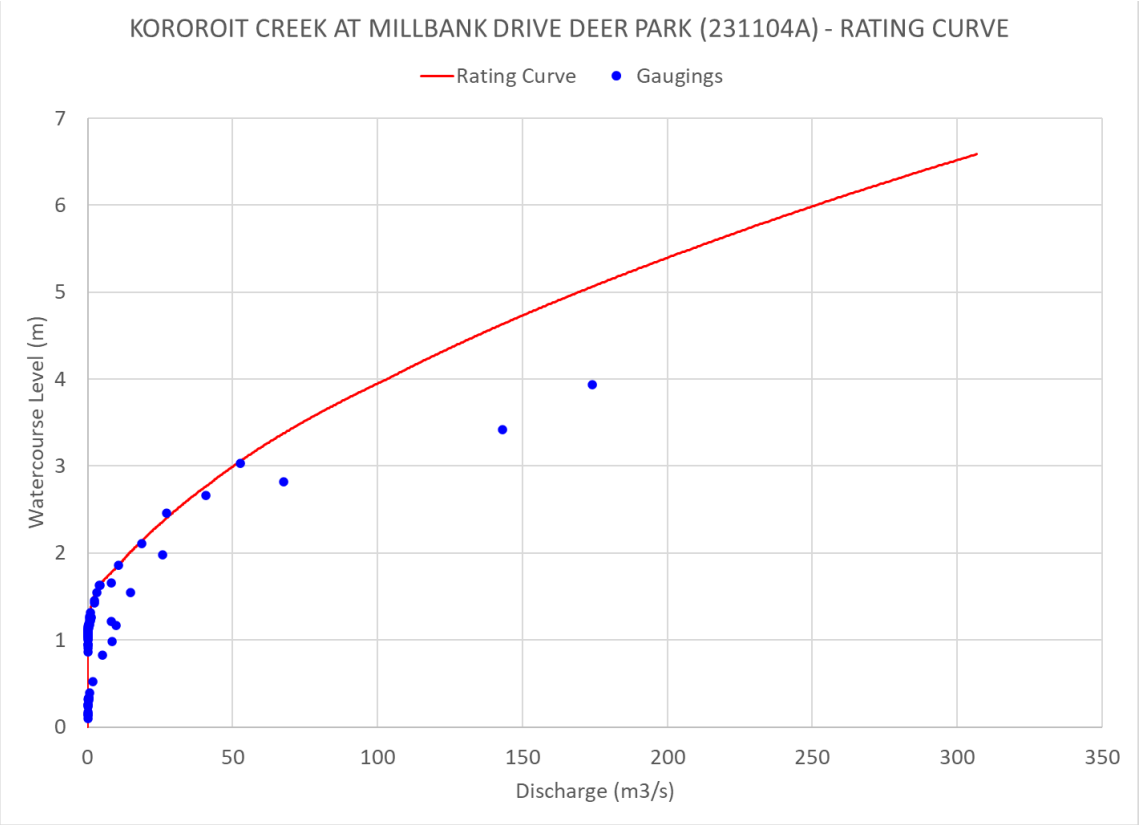


Figure B-6. Rating table for Kororoit Creek at Deer Park.

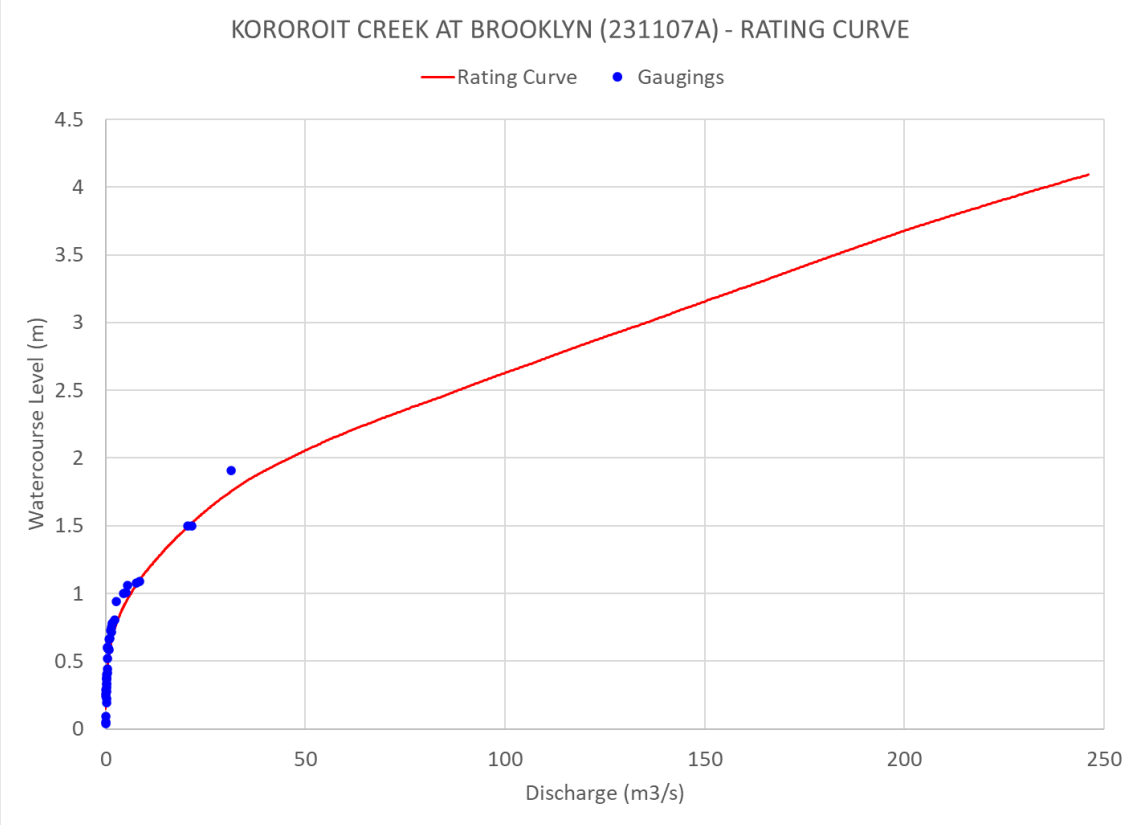


Figure B-7. Rating table for Kororoit Creek at Brooklyn.

B.3.3 Historic Information

No historic information for the catchment was available for either gauge.

B.3.4 Removal of Probable Influential Low Flows

The annual maxima series was reviewed and no Probable Influential Low Flows (PILFs) were identified for either gauge. This was confirmed using the multiple Grubbs Beck Test incorporated in Flike.

B.3.5 Prior Parameters Information

Prior parameters for the LP3 distribution together with their co-variance matrix were obtained from the RFFE software for the Deer Park gauge (Appendix L). These were incorporated into Flike with one change. The standard deviation of the Mean parameter was set to an arbitrarily large value to allow Flike to determine the mean flow from the data rather than a regional estimate. Prior parameters were not used in the FFA for the Brooklyn gauge given they are derived from regional parameters.

B.3.6 Flood Frequency Analysis Results

The results of the at-site FFA for the Deer Park and Brooklyn gauges are shown in Table B-4, Table B-5, Figure B-8 and Figure B-9. The results demonstrate the fitted LP3s are an acceptable fit to the data.

Table B-4. Deer Park Flood Frequency Analysis Expected Quantiles

AEP 1 in Y	FFA Quantile (m^3/s)	Lower 90% Continuing Loss (m^3/s)	Upper 90% Continuing Loss (m^3/s)
2	18.3	13.3	25.2
5	52.1	37.0	75.9
10	90.7	61.7	140.7
20	144.0	93.8	237.7
50	243.6	149.7	434.7
100	346.7	204.4	651.3

Table B-5. Brooklyn Flood Frequency Analysis Expected Quantiles

AEP 1 in Y	FFA Quantile (m^3/s)	Lower 90% Continuing Loss (m^3/s)	Upper 90% Continuing Loss (m^3/s)
2	26.4	18.7	36.9
5	62.7	43.4	94.9
10	100.6	65.9	176.7
20	150.2	91.0	324.4
50	238.8	126.2	692.7
100	327.5	154.0	1225.8

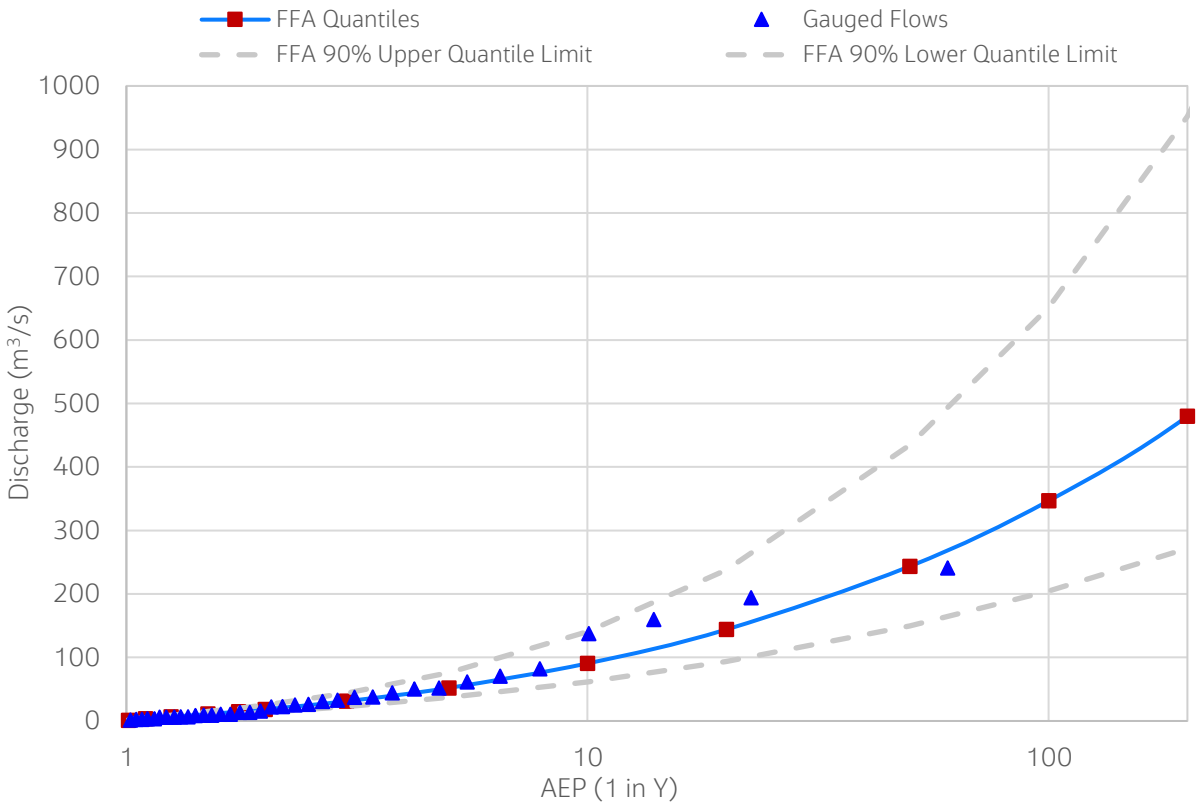


Figure B-8. Flood Frequency Analysis Deer Park

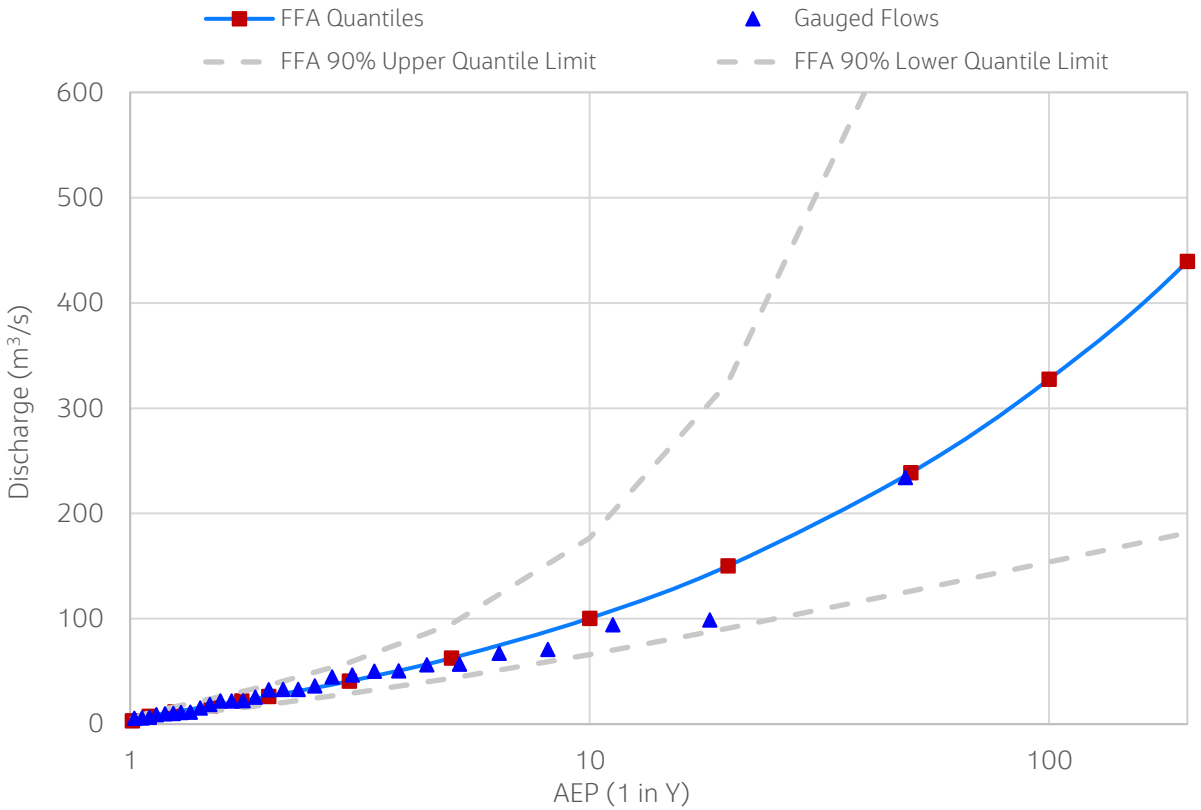


Figure B-9. Flood Frequency Analysis Brooklyn

B.3.7 Comparison to previous estimates

The current FFA results were compared to the flood quantiles estimated by RPV (2020) (Table B-6 and Table B-7). The estimates produced from the current study are greater than those from the previous work. This due to:

- The additional 2 years of data (in which the Brooklyn gauge experienced its rank 2 highest flow)
- The exclusion of prior parameters for the Brooklyn gauge, which were previously used in Flike to produce the RPV (2020) FFA results.

The FFA results from the current study are therefore considered reasonable, in alignment with expectations and observed/reviewed data.

Table B-6. Deer Park FFA comparison to previous estimates

AEP 1 in Y	RPV (2020) FFA Quantile (m^3/s)	Current FFA Expected Quantile (m^3/s)
5	48.7	52.1
10	83.6	90.7
20	131.3	144.0
50	219.3	243.6
100	309.5	346.7

Table B-7. Brooklyn FFA comparison to previous estimates

AEP 1 in Y	RPV (2020) FFA Quantile (m^3/s)	Current FFA Expected Quantile (m^3/s)
5	56.1	62.7
10	84.0	100.6
20	117.6	150.2
50	172.5	238.8
100	223.2	327.5

B.4 Baseflow

The gauge data at Kororoit Creek at Brooklyn (see Figure B-10) was reviewed and no evidence of significant baseflow contribution was found.

While the flow duration curve shows that 1 m^3/s is exceeded roughly 20% of the time, in the days leading up to peak flow events, there is little to no flow recorded, indicating that baseflow contribution was not a significant factor in flooding process at the site and it was not considered.

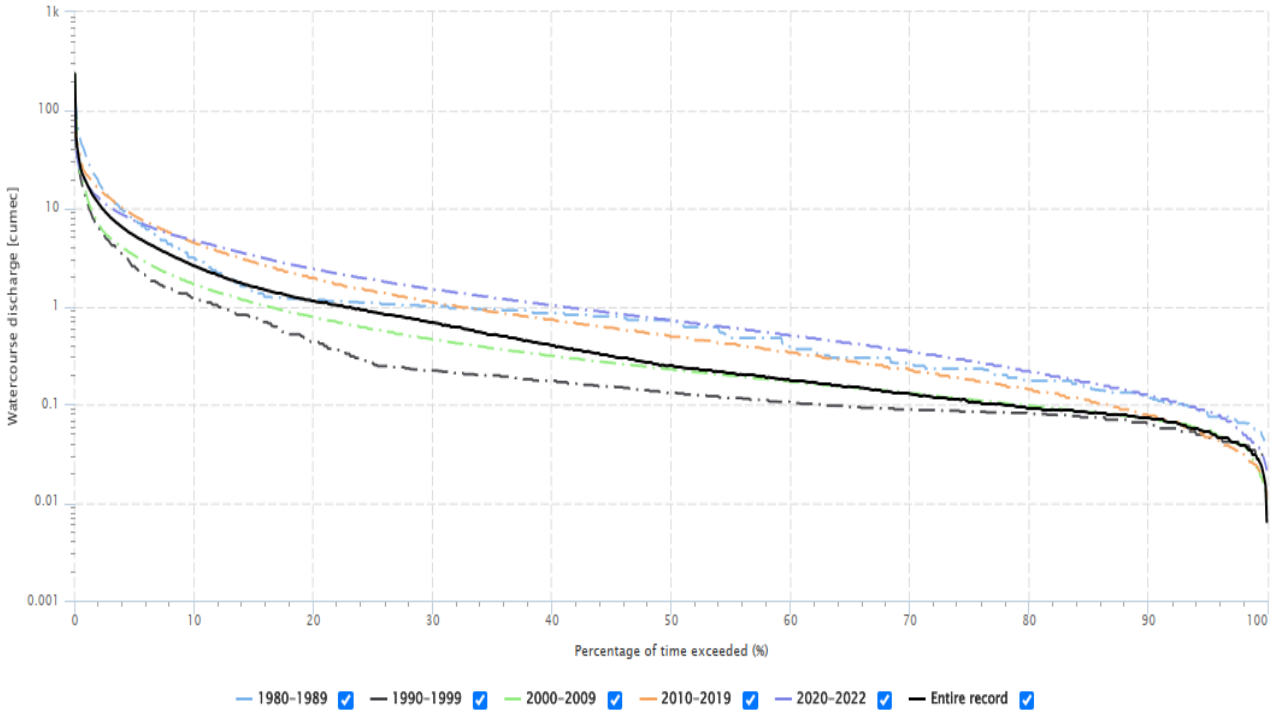


Figure B-10. Flow duration curve for Kororoit Creek at Brooklyn (source: Water Data Online; The Bureau of Meteorology, 2022).

B.5 RORB design inputs

B.5.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.688, Long 144.703) was sourced from the Bureau of Meteorology (Appendix I). As per the Melbourne Water Flood Mapping Projects Specifications rainfalls were increased by 18.5% to establish climate change rainfalls.

A sensitivity assessment was undertaken on the variance of rainfall throughout the catchments using the 1% AEP gridded rainfall data. This assessment indicated that the variation in depths was less than 2%. The gridded rainfall data was however adopted despite the small variation when comparing both datasets due to the size of the catchment.

B.5.2 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations below the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

B.5.3 Temporal Patterns

Given the catchment area exceeds 75km^2, areal temporal patterns were used. However, areal temporal patterns from the Datahub are limited to storm durations of 12 hours or longer. During calibration of the

losses, it was evident that the 12 hour duration was critical and as such, shorter duration storms were required to ensure that durations below the 12 hour were not producing greater peak flows. Given this, the calibration was completed using point temporal patterns to ensure that the critical duration was adequately selected.

For the design runs, areal temporal patterns were used to extract the 12 hour event (critical duration) and point temporal patterns were used to select inflows for critical durations less than 12 hours. A sensitivity test was undertaken that showed minimal variance in the Monte Carlo peaks and the selection of point or areal temporal patterns for the catchment, particularly for the 1% AEP (Figure B-11 and Figure B-12).

Both point and areal temporal patterns were filtered for embedded bursts.

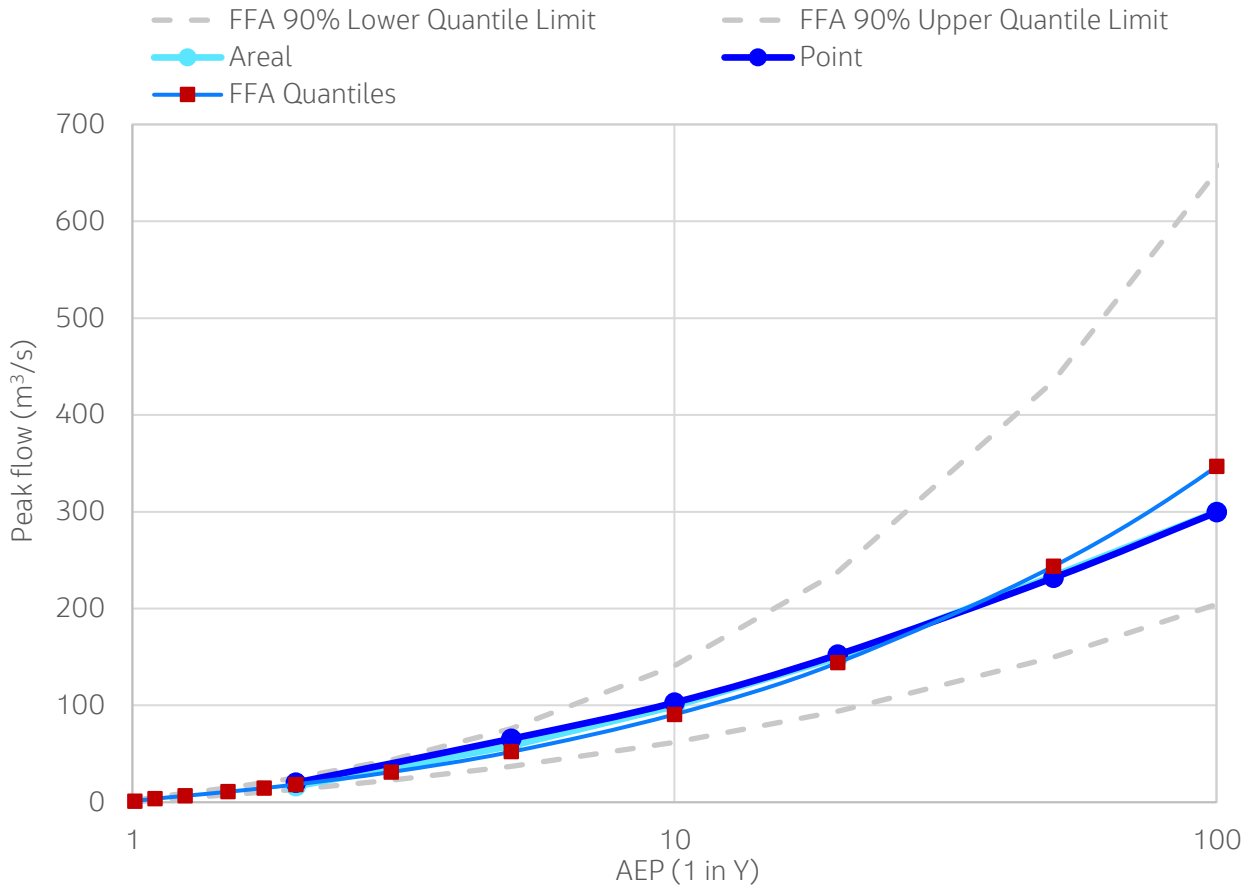


Figure B-11. Sensitivity testing between Monte Carlo peaks and the use of point or areal temporal patterns (Deer Park).

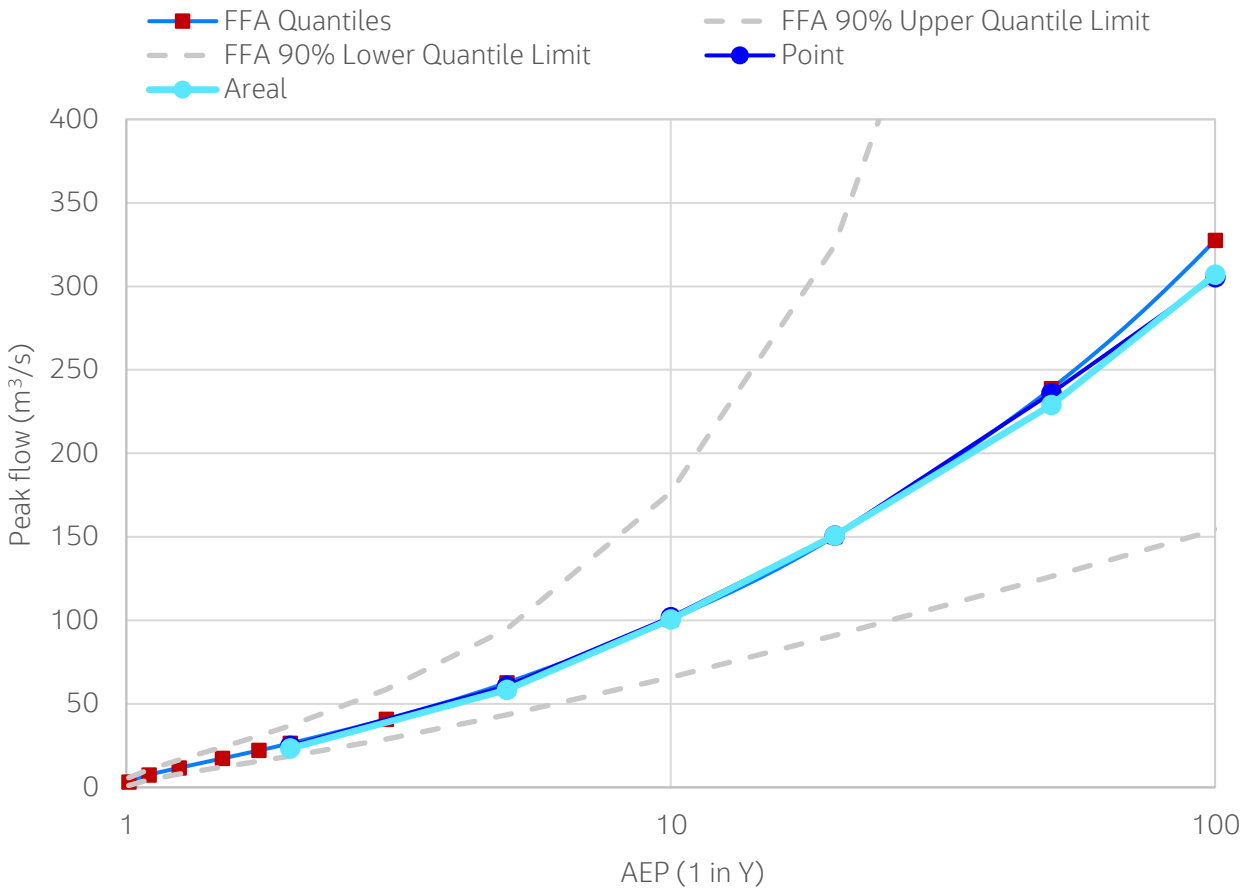


Figure B-12. Sensitivity testing between Monte Carlo peaks and the use of point or areal temporal patterns (Brooklyn).

B.5.4 Spatial Patterns

A spatial rainfall distribution was determined to ensure that variation in rainfall depth across the catchment was accounted for. This was calculated by comparing the catchment average rainfall to the average rainfall for each sub-catchment using the design rainfall grids (Bureau of Meteorology, 2022). This was then implemented to the RORB model as a 'non-uniform' spatial pattern for each duration.

The spatial variation across the catchment is illustrated in Figure B-13 for the 1% AEP 12 hour rainfall event, the critical duration for both the gauges used during calibration.

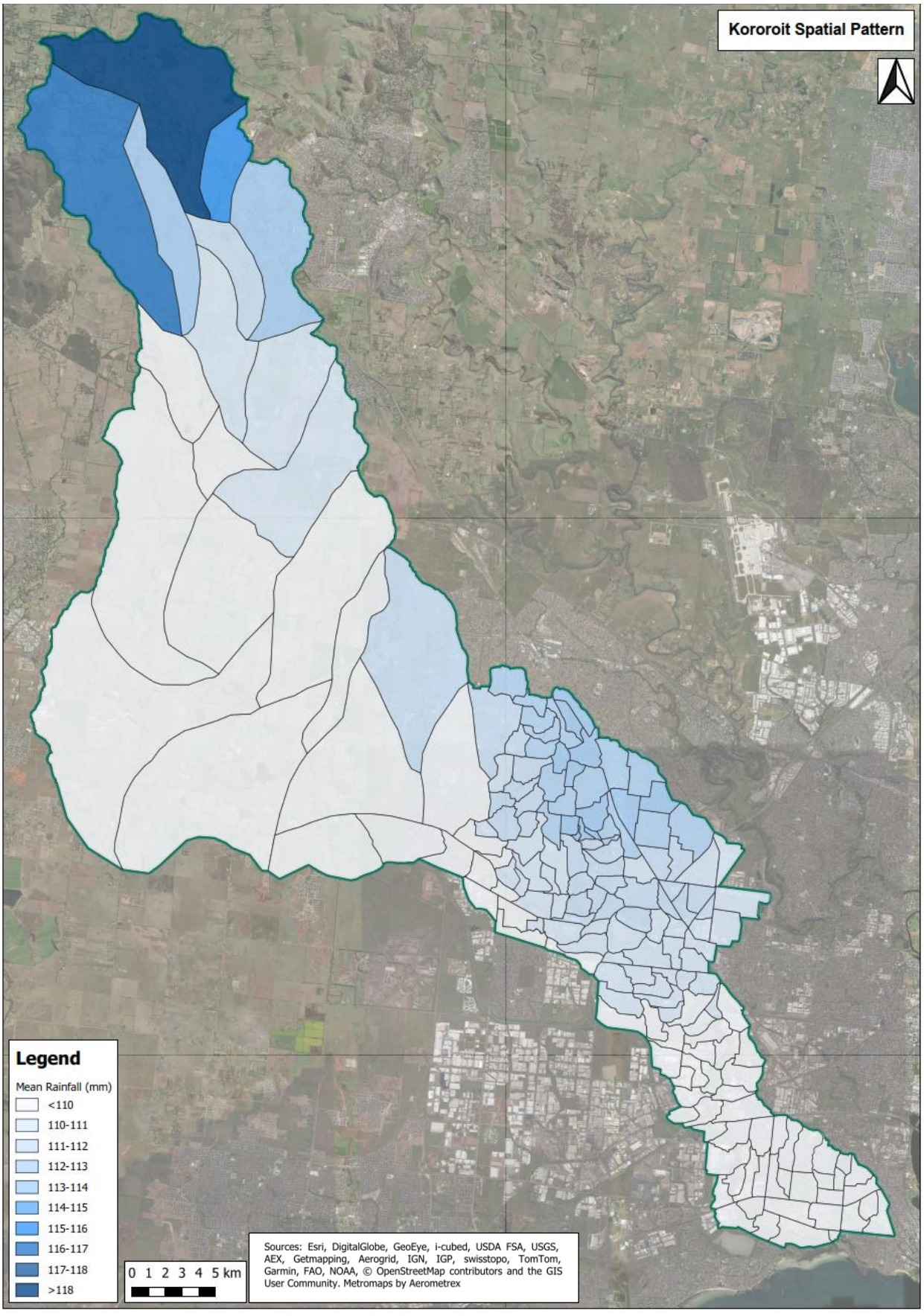


Figure B-13. Spatial rainfall pattern for the Kororoit Creek RORB model for the 1% AEP, 12 hr storm.

B.5.5 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Table B.8. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment are presented in Section B.8.

Table B-8. Adopted ARF values for the Kororoit Creek RORB model.

Duration	ARF area (km^2)	Justification
20m (1%, 2% AEP) 30m (all AEPs) 45m (1%, 5%, 10%, 20% AEP) 1h (5%, 20% AEP)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
45m (2% AEP) 1h (1%, 2% AEP) 1.5h (1%, 5%, 10%, 20% AEP)	3	
1.5h (2% AEP) 2h (all AEPs) 3h (1%, 2%, 20% AEP) 4.5h (1%, 2% AEP) 6h (all AEPs)	9	
12h (all AEPs)	240	

B.6 Model Calibration

Calibration of the model was undertaken in the following stages:

- Calibration to individual events to determine the routing parameters (k_c, with m being fixed to 0.8).
- Calibrating the at-site Flood Frequency results from the gauges to the RORB model Monte Carlo Flood Frequency results to determine the loss parameters.
- Once model parameters were determined through calibration, design events for the 1% AEP were simulated to develop inputs to the TUFLOW model.

B.6.1 Routing Parameter k_c

Historic flood events were used to determine suitable k_c routing parameters for the model, while the recommended value for m of 0.8 was adopted for this Study. The model was divided into three interstation areas to enable use of available streamflow gauging stations; Deer Park (231104) and Brooklyn (231107). The selection of historic events for model calibration was guided by the following factors:

- The magnitude of flood events, with priority given to the largest flow events in the last 20 years, as they are representative of the events modelled and catchment conditions for this assessment

- Completeness of good quality gauged streamflow records
- Pluviograph coverage for a given event

The historic events selected for calibration were:

- February 2005
- November 2010
- March 2020
- November 2021

The total rainfall and peak streamflow for the selected events are shown in Table B-9. Pluviograph data from the Brooklyn, Deer Park, Diggers Rest, Rockbank and Spotswood gauges were used to input rainfall temporal patterns. It should be noted that rainfall gauging information was unavailable for Brooklyn in the March 2020 event and as such the pluviography from Spotswood was used.

Table B-9. Rainfall and streamflow from historic events used for calibration of Kororoit Creek RORB model

	Feb 2005		Nov 2010		Mar 2020		Nov 2021	
Gauge	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)
Deer Park	146.4	194.0	33.6	70.4	54.8	33.2	34.0	44.2
Brooklyn	109.4	234.1	28.2	70.8	-	98.8	26.6	50.4
Diggers Rest	124.6	-	44.0	-	48.4	-	31.6	-
Rockbank	-	-	37.0	-	40.6	-	27.4	-
Spotswood	-	-	-	-	53.8	-	-	-

Calibration of routing parameters is achieved by determining the k_c and m parameters that produce the best fit between the modelled and observed hydrographs. To calibrate the model, a range of k_c values were sampled through the model based on regional estimates that are documented in Table B-10. The m parameter was fixed at 0.8.

Table B-10. Kororoit Creek RORB kc estimates based on regional equations

Interstation area	Vic <800mm rainfall	RORB Manual	Pearse et al. (2002)
Deer Park	16.58	30.11	31.46
Brooklyn	6.29	13.26	13.19
Kororoit Outlet	2.03	5.09	6.64

The k_c parameter was varied and the resultant hydrograph shape, peak flow, volume and Nash-Sutcliffe Efficiency (NSE) were assessed to determine an appropriate k_c value for the model. The NSE is a statistical measure used to evaluate a model's performance against recorded data. A value of 1 indicates a perfect fit to the model data, whereas, a value of 0 indicates simply modelling the average value would perform equally well. A value of less than 0 indicates poor model performance. NSE is defined as:

$$NSE = 1 - \frac{var(Res)}{var(Hyd)}$$

Where var(Res) is the variance of the model residuals or the difference between the observed and calculated flows, var(Hyd) is the variance of the observed hydrograph. Ladson (2008) provides a guide to assessing model performance based on NSE as shown in Table B-11.

Table B-11. NSE Calibration (Ladson, 2008)

Classification	NSE
Excellent	> 0.93
Good	0.80 – 0.93
Satisfactory	0.70 – 0.80
Passable	0.60 – 0.70
Poor	< 0.60

The kc and NSE values that gave the best match to the observed hydrographs for each historic event are shown in Table B-12.

Table B-12. Kororoit Creek RORB kc and resultant NSE for historic events

	Feb 2005		Nov 2010		Mar 2020		Nov 2021	
Interstation area	k_c	NSE	k_c	NSE	k_c	NSE	k_c	NSE
Deer Park	26.0	0.95	26.5	0.62	18.7	0.91	22.1	0.79
Brooklyn	8.6	0.94	9.3	0.78	7.1	0.93	13.2	0.85

A range of NSE values were returned, ranging from 'excellent' (February 2005 and March 2020), 'good'/satisfactory' (November 2021), to 'satisfactory'/'passable' (November 2010). The resultant fits between the modelled and observed hydrographs are shown in Figure B-14, Figure B-15, Figure B-16 and Figure B-17 to allow visual inspection of fits. Calibrating the model to ensure an appropriate fit to both gauges presented challenges, particularly for the Brooklyn gauge. However overall, the calibration fit for the Brooklyn gauge is considered acceptable. For both interstation areas, the returned k_c values were in a consistent range.

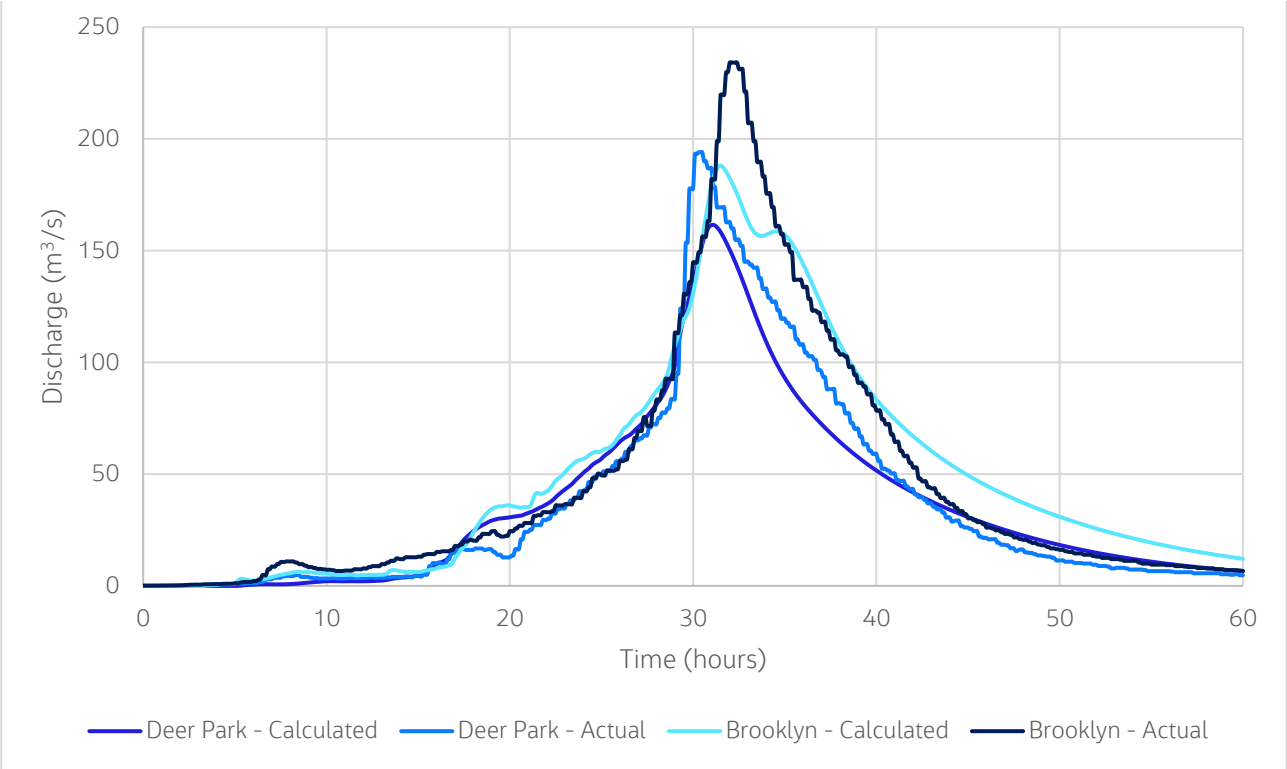


Figure B-14. Modelled and observed hydrographs for Deer Park and Brooklyn gauges, February 2005.

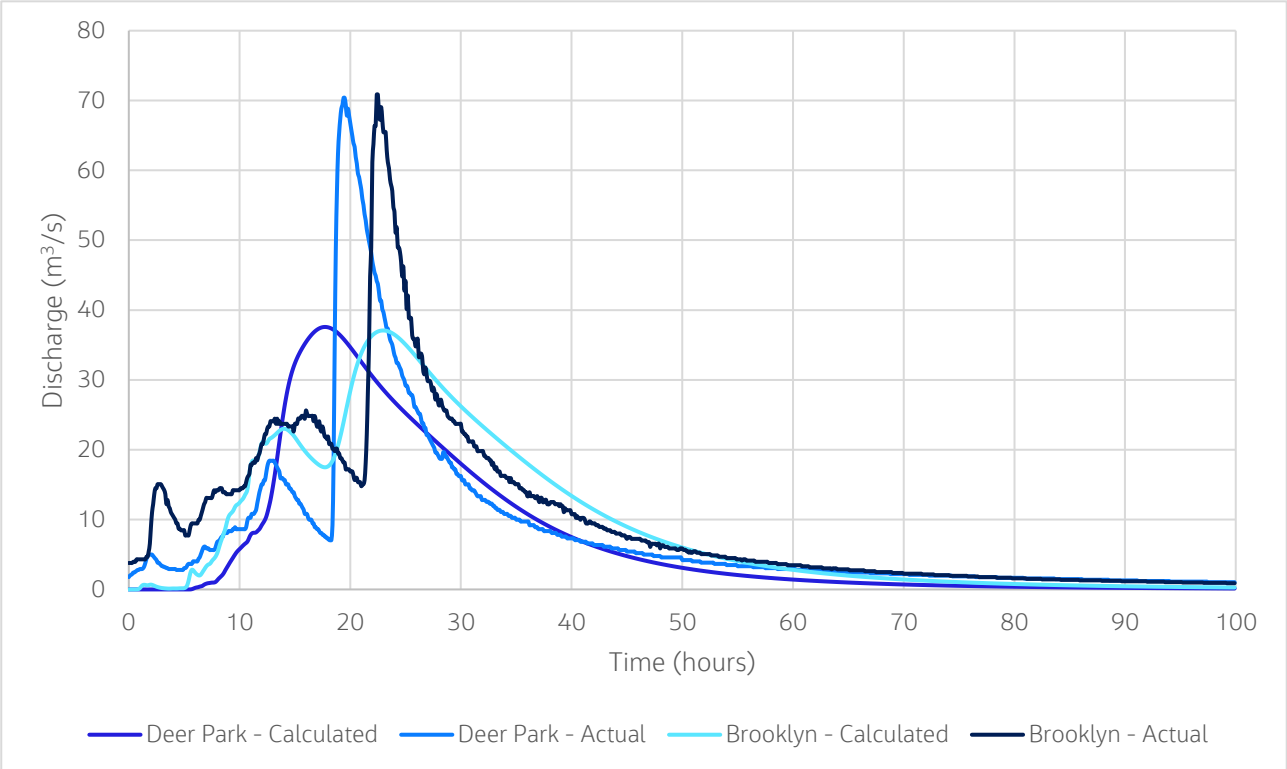


Figure B-15. Modelled and observed hydrographs for Deer Park and Brooklyn gauges, November 2010.

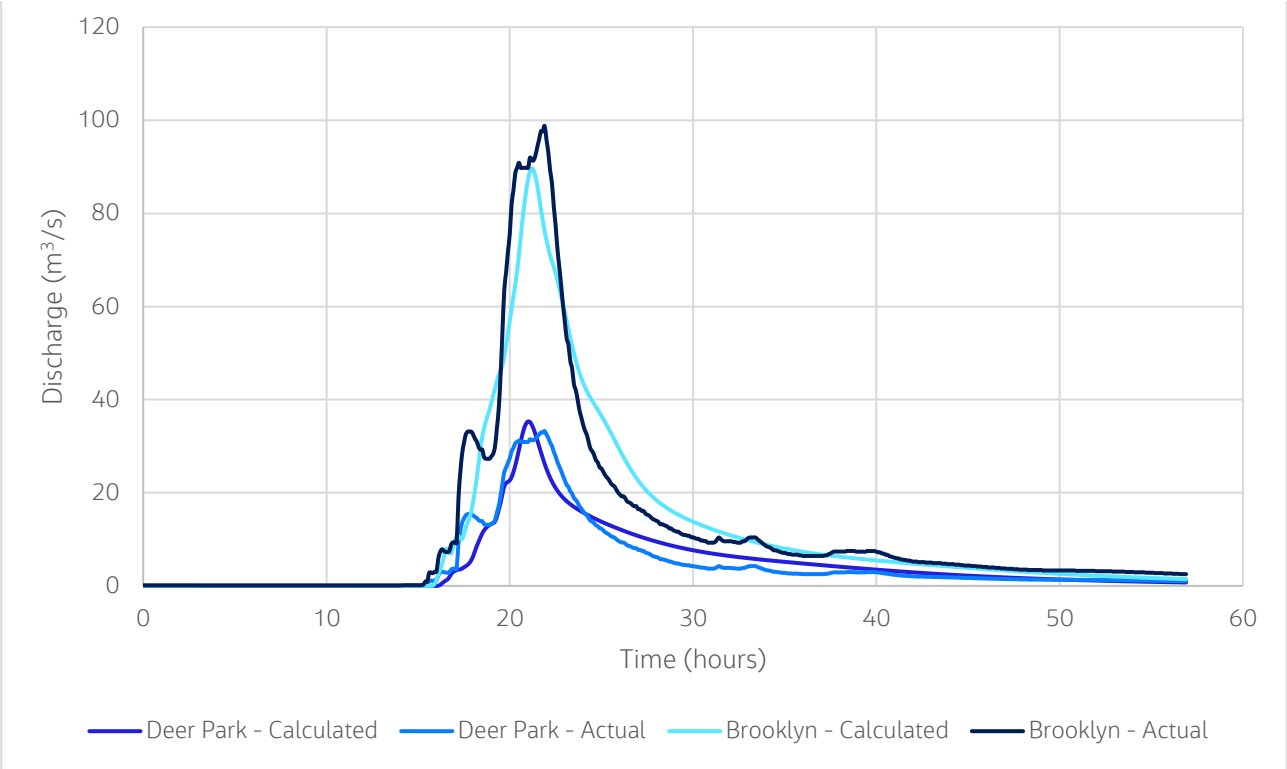


Figure B-16. Modelled and observed hydrographs for Deer Park and Brooklyn gauges, March 2020.

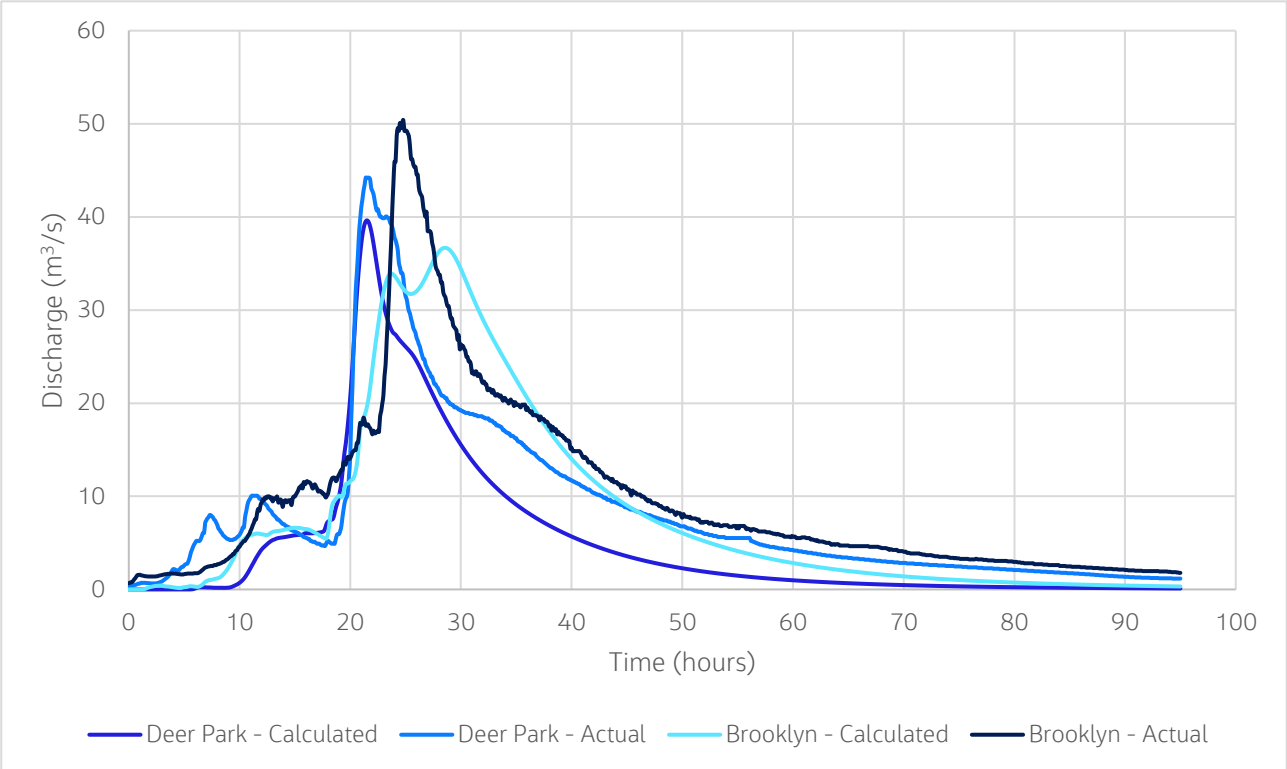


Figure B-17. Modelled and observed hydrographs for Deer Park and Brooklyn gauges, November 2021.

The adopted k_c parameters shown in Table B-13 were based on the range of k_c values derived from the calibration runs with consideration given to NSE. The adopted k_c values fall within the range of k_c values produced by regional estimates (Table B-10). Given no gauging information was available for the areas downstream of the Brooklyn gauge, the k_c values adopted for these regions was calculated using the k_c/ d_{av}

ratio of the calibrated section of the model. Where d_{av} is the average flow distance in the channel network of sub area inflows and is output as part of RORB (Pearse et al, 2002).

Table B-13. Adopted kc parameters for the Kororoit Creek RORB model

Interstation area	k_c adopted
Deer Park	21
Brooklyn	12

B.6.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Pre-burst (median values – see Section B.5.2 was also included in the RORB runs that calculated appropriate storm losses. The values adopted were obtained through calibration of the RORB Monte Carlo peaks to the at-site Flood Frequency Curve (FFC) at both the Deer Park and Brooklyn gauges. This involved varying the initial loss and continuing loss parameters until an acceptable match between the Monte Carlo peak flows and the FFC was achieved. A greater weight was given to matching the AEP events with probabilities (or return periods) more frequent than the length of the gauge record (i.e. less than 1 in 50, given gauge record length is 42 years).

Loss parameters were calibrated to the upstream (Deer Park) gauge first. The losses for Brooklyn (downstream gauge) were then varied until an appropriate fit was found. Good fits between the FFC and RORB Monte Carlo peaks were achieved for both gauges. The fit between the FFC and RORB Monte Carlo peaks is presented in Figure B-18 and Figure B-19.

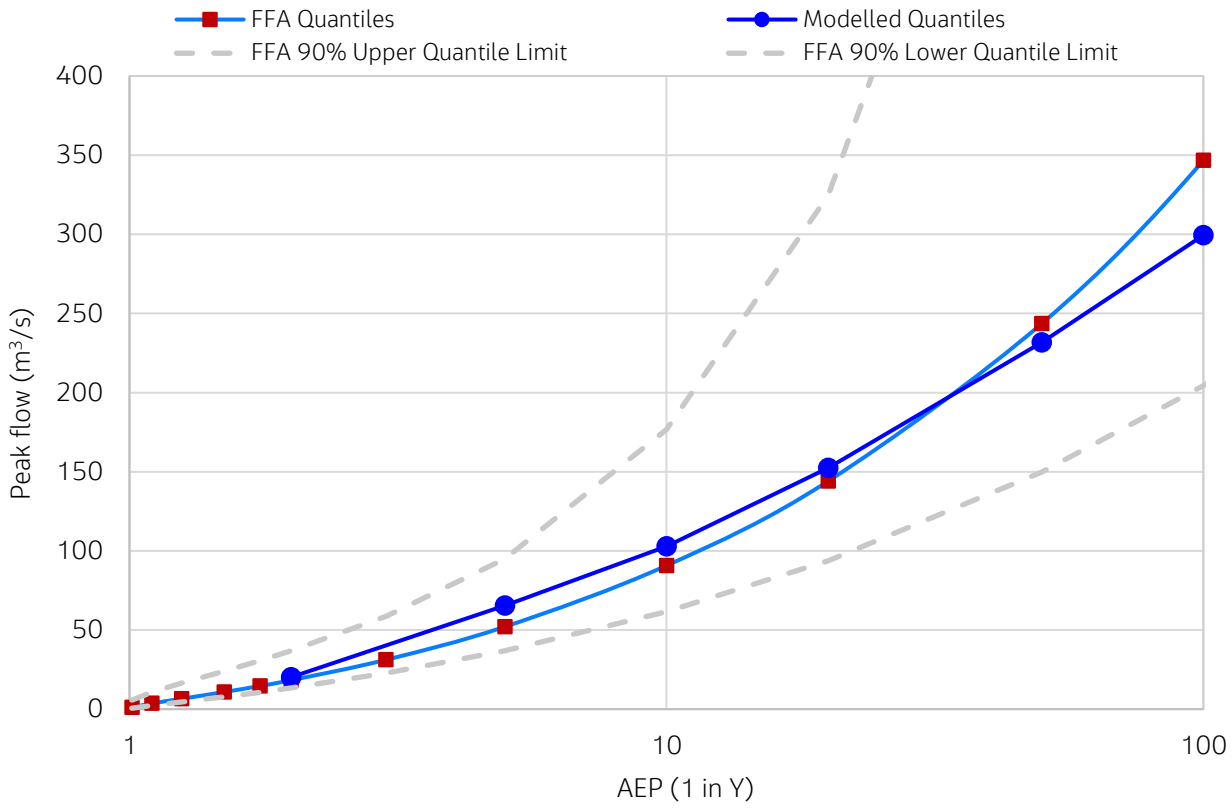


Figure B-18. At-site Flood Frequency Analysis and RORB Monte Carlo Peaks (Deer Park)

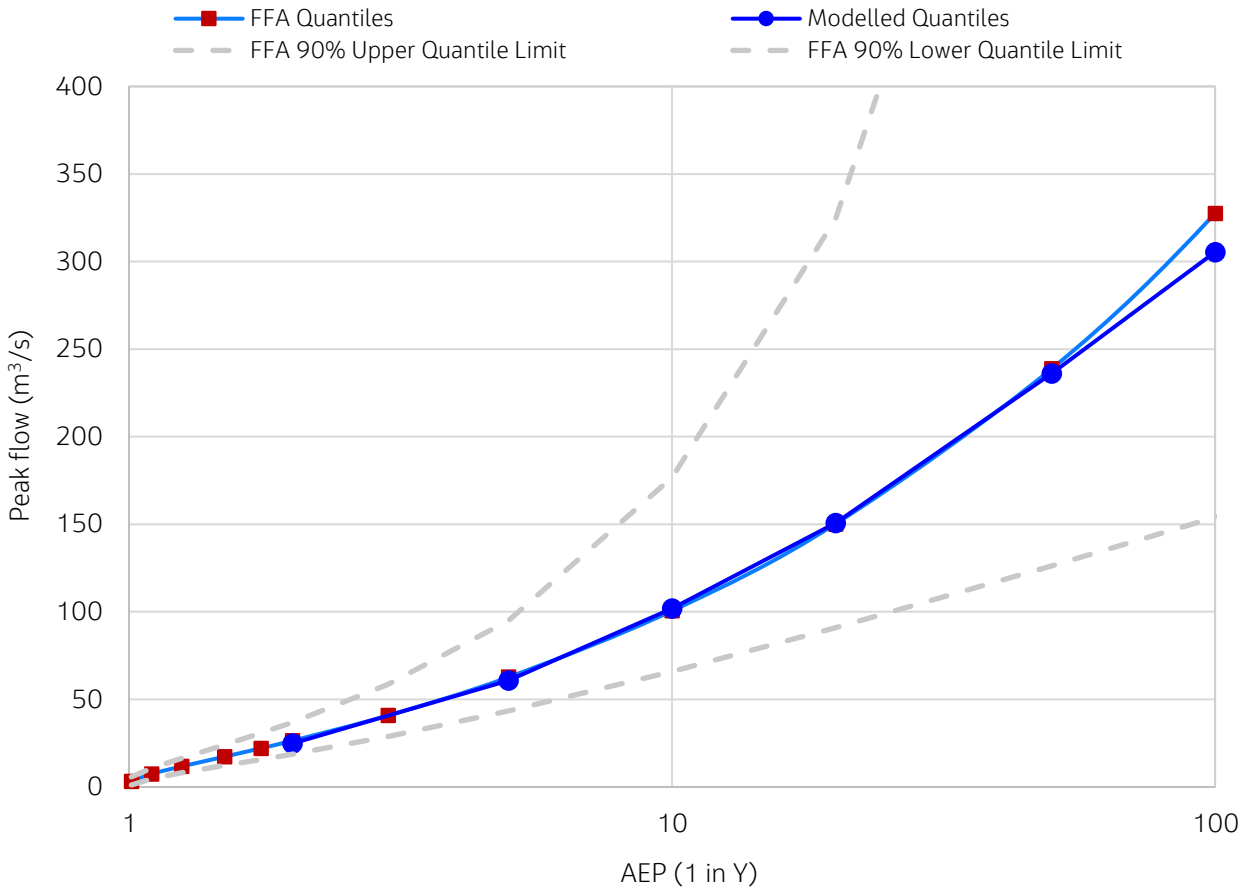


Figure B-19. At-site Flood Frequency Analysis and RORB Monte Carlo Peaks (Brooklyn)

The adopted loss parameters obtained through the calibration are shown in Table B-14. These are compared to the Datahub values for the catchment and in all locations, return values greater than those from the Datahub (ARR, 2019). Initial loss values upstream of Deer Park fall within the range for rural catchments (Ball et al., 2019), those listed in the Melbourne Water Flood Mapping Projects Specifications and are also in alignment with the loss parameters derived via the calibration of the Maribyrnong River model at Keilor gauge (rural catchment area) as part of this Study (Maribyrnong at Keilor IL: 16.0 mm and CL: 2.8 mm/h). Furthermore, the selection of losses based on reconciliation to a site-specific FFA (rather than DataHub) is supported by ARR (2019) (HARC, 2020).

Table B-14. Adopted Kororoit Creek RORB loss parameters obtained through calibration

Interstation area	IL (mm)	CL (mm/hr)
Deer Park	18.0	3.0
Brooklyn	13.5	2.5
Outlet	13.5	2.5
DataHub	11	0.3

B.6.3 Adopted Interstation Areas

Once model parameters were determined through calibration, the RORB model was split into different interstation areas at locations where subarea size changed to ensure alignment with the Melbourne Water

Flood Mapping Projects Specifications as well as to represent the Kororoit and Paisley Drain outflow and overall model outflow.

The k_c selected through calibration was used to determine the k_c given to the interstation area added to the model upstream of the Deer Park gauge in the rural section of the model, defined using the k_c /d_{av} ratio at Deer Park. The Kororoit and Paisley Drain outflow as well as the overall model outflow k_c values were similarly derived using the k_c /d_{av} ratio at the Brooklyn gauge due to their shared urban land use. Table B-15 lists the details of the additional interstation areas and the k_c adopted.

Table B-15. Kororoit Creek RORB model interstation areas and adopted k_c

Interstation area	K_c	d_{av}	K_c / d_{av}	Comment
Kororoit at Deer Park (original ISA used in calibration)	21.0	25.2	0.83	Original K_c and d_{av} from the calibrated Kororoit RORB model. Note this interstation area (IA) in not used in the design model. It was replaced by the Burnside_Interstation.
Burnside_Interstation	18.9	22.6	0.83	Values calculated based on the calibrated Kororoit RORB model values. Method adopted due to the same rural land use for the new IA.
Kororoit at Brooklyn (original ISA used in calibration)	12.0	10.55	1.14	Original K_c and d_{av} from the calibrated Kororoit RORB model.
Kororoit at Brooklyn	14.7	12.9	1.14	Values calculated based on the calibrated Kororoit RORB model values. Though the location of this IA did not move, the change of upstream IA from the Deer Park gauge to Burnside_Interstation altered the d_{av} at this point.
Kororoit Outflow	6.04	5.3	1.14	Values calculated based on the calibrated Kororoit RORB model values.
Paisley Drain Outflow	2.86	2.5	1.14	As above.
Model Outflow	1.40	1.23	1.14	Values calculated based on the calibrated Kororoit RORB model values. Note that this represents only the area between the Kororoit Outflow node and the Paisley Drain Outflow node. This value was added for consistency of methodology. No reporting locations are used in this area.

B.7 RORB Results and Verification

The RORB model was simulated using the parameters determined through calibration and the results are presented below. Table B-16 and Table B-17 show the RORB model peak flows along with the Flood Frequency Analysis and regional estimates peak flows for Deer Park and Brooklyn respectively.

The approximate 1% AEP flows using the Nikolaou/von't Steen equation was calculated using the following equations:

For rural catchments $Q_{1\%} = 4.67A^{0.763}$
For urban catchments $Q_{1\%} = 10.29A^{0.71}$

The peak flows at both Deer Park and Brooklyn were calculated and compared to the RORB model outputs. The Nikolaou/von't Steen estimates are largely based on catchment area and are therefore unlikely to capture the complex nature of the Kororoit Creek catchment.

A Regional Flood Frequency Estimation (RFFE) was performed using the RFFE tool for Deer Park (https://rffe.arr-software.org). Output files from the RFFE are shown in Appendix L. Given that the RFFE is recommended for entirely rural catchments, the method is not recommended for the Brooklyn gauge (urban upstream area). The modelled peak flows at Deer Park are greater than the RFFE estimates, as expected given that some of the catchment upstream of Deer Park is urbanised. The Melbourne Water rule of thumb method (for urban areas) is known to not perform well in catchments with large green space areas, and generally overpredicts peak flows for these catchments; this is seen in the results for this Study. Resulting peak flows for Deer Park are comparable to FFA quantiles, RFFE and Nikolaou/von't Steen estimates. Peak flows at Brooklyn agree well with FFA quantiles but sit below regional estimates, likely due to the complex nature of the catchment and impact of Retarding Basins not accounted for in these estimation methods.

Table B-16. Deer Park (rural upstream area) peak flow comparison

AEP	RORB design peak flow (m^3/s)	FFA (m^3/s)	RFFE (m^3/s)	Nikolaou/von't Steen – Rural flow (m^3/s)	Melbourne Water rule of thumb (rural) (m^3/s)
20%	65.5	52.1	81	-	-
10%	102.9	90.7	110	-	-
5%	152.3	144.0	142	-	-
2%	231.6	243.6	191	-	-
1%	299.4	346.7	232	291	676

Table B-17. Brooklyn (largely urban upstream area) peak flow comparison

AEP	RORB design peak flow (m^3/s)	FFA (m^3/s)	Nikolaou/von't Steen – Urban flow (m^3/s)	Nikolaou/von't Steen – Rural flow (m^3/s)	Nikolaou/von't Steen – Rural flow (m^3/s) (accounting for urban / rural areas)	Melbourne Water rule of thumb (m^3/s) (accounting for urban / rural areas)
20%	60.8	62.7	-	-	-	-
10%	101.9	100.6	-	-	-	-
5%	150.8	150.2	-	-	-	-
2%	236.0	238.8	-	-	-	-
1%	305.4	327.5	557	340	459	1183

B.8 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARF to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table B-18. This enabled the identification of how critical durations were likely to alter based on the contributing catchment area. Key locations across the catchment are shown in Figure B-20. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW

- Locations upstream or within urban areas
- Locations upstream and downstream of model storages
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave
- Points located within Study LGAs, providing good coverage across Study area

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Table B-18. Table B-19 lists the storms simulated in TUFLOW. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

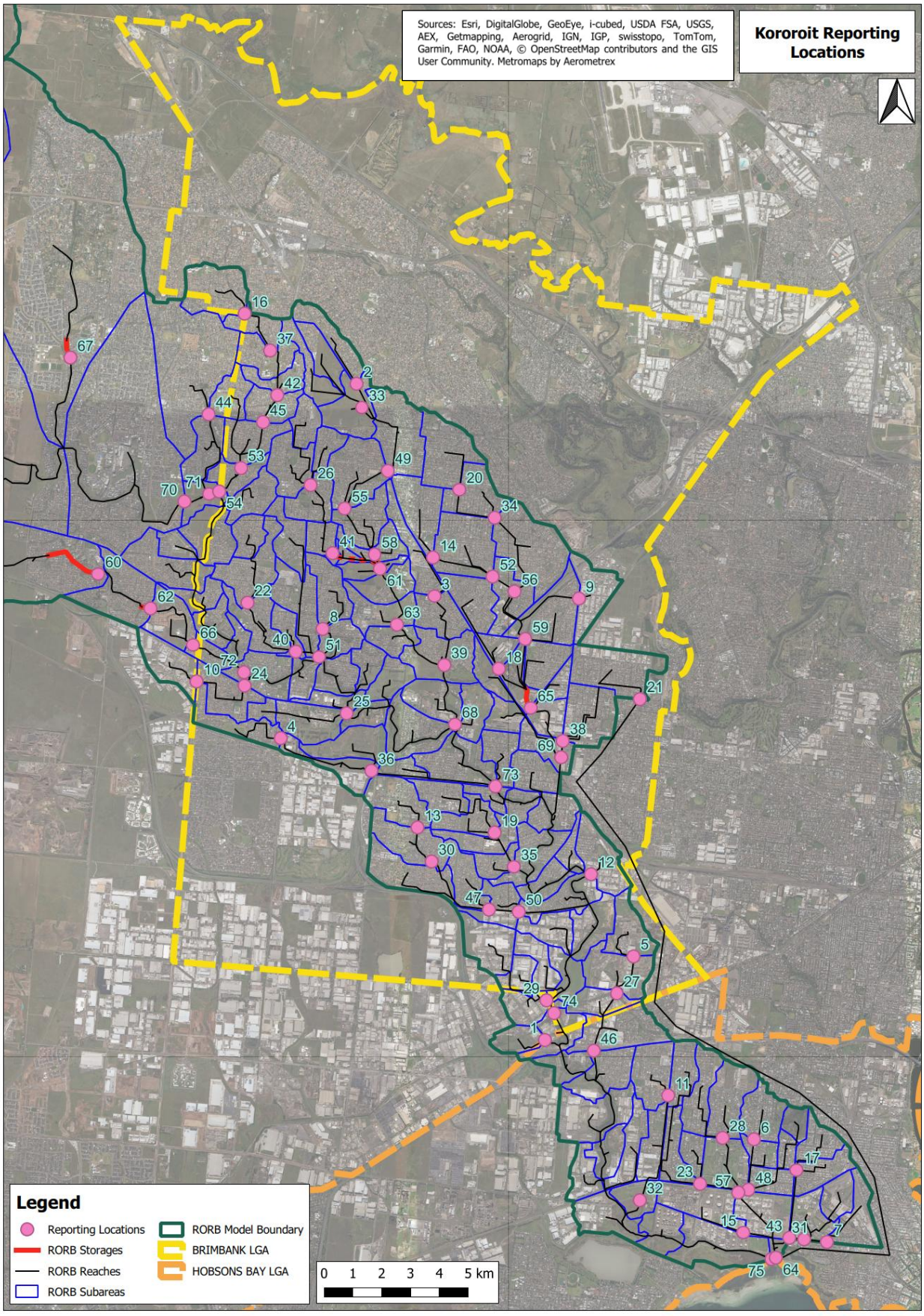


Figure B-20. Kororoit Creek RORB reporting locations

Table B-18. Analysis of critical durations and peak flows at key locations using the Kororoit Creek RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Princes_Hwy_Inflow	0.35	20min	7	30min	6	30min	5	30min	4	30min	3
2	Sydenham_Rd	0.52	30min	9	30min	7	45min	6	45min	5	1.5hour	4
3	Kingsley_St	0.57	30min	9	30min	7	45min	6	45min	5	1.5hour	4
4	Wood_St	0.58	1hour	6	1hour	5	1hour	4	2hour	3	1.5hour	2
5	Bunting_Rd	0.59	30min	10	30min	8	45min	7	45min	5	1.5hour	4
6	Mason_St	0.6	30min	13	30min	11	45min	8	45min	7	30min	5
7	Myrtle_St	0.6	45min	7	45min	6	45min	5	45min	4	1hour	3
8	Furlong_Rd	0.62	30min	10	30min	8	45min	6	45min	5	1.5hour	4
9	McIntyre_Rd	0.65	30min	17	30min	15	30min	12	30min	10	20min	8
10	Robinsons_Rd_Inflow	0.67	20min	19	20min	16	45min	12	45min	10	30min	8
11	Walker_Cl	0.69	20min	15	20min	12	30min	10	30min	8	30min	6
12	Hall_St	0.72	30min	18	30min	15	45min	11	45min	9	30min	7
13	Western_Ave	0.72	10min	25	10min	20	30min	16	15min	14	15min	11
14	Percy_St	0.78	30min	15	30min	12	30min	9	45min	8	30min	6
15	Kororoit_Creek_Rd	0.79	30min	12	30min	10	45min	8	45min	6	1.5hour	5
16	Hume_Dr	0.88	20min	16	30min	14	30min	10	45min	8	30min	6
17	Woods_St	0.9	30min	17	30min	14	45min	11	45min	9	45min	7
18	St_Albans_Rd	0.92	45min	13	45min	11	45min	9	45min	7	1hour	5

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
19	Gum_St	0.94	45min	13	45min	11	45min	8	45min	6	1.5hour	5
20	Biggs_St	0.95	30min	15	30min	13	45min	10	45min	8	1.5hour	6
21	Middlesex_St	1.07	30min	14	30min	11	30min	8	45min	6	45min	4
22	Nova_Ave	1.14	30min	19	30min	16	45min	13	45min	10	1.5hour	8
23	Ross_Rd	1.2	1.5hour	12	1.5hour	10	45min	7	1.5hour	6	1.5hour	5
24	Christie_St_Drain	1.3	30min	15	30min	13	45min	10	45min	8	1.5hour	6
25	Western_Hwy	1.3	30min	23	30min	19	45min	15	45min	12	1.5hour	9
26	Kings_Rd	1.31	30min	24	30min	20	45min	16	45min	13	45min	10
27	Federation_Trail	1.37	30min	20	30min	17	45min	14	45min	11	1.5hour	9
28	Paisley_Park	1.41	45min	19	45min	16	45min	12	45min	10	1hour	7
29	Silverton_Cl	1.46	30min	27	30min	23	30min	18	30min	15	30min	11
30	Callaway_RB	1.47	45min	22	45min	18	1.5hour	11	2hour	8	1.5hour	5
31	Walter_St	1.5	30min	23	30min	19	45min	15	45min	12	1hour	10
32	Millers_Rd_Drain	1.55	30min	27	30min	22	30min	17	45min	14	45min	11
33	St_Albans_West_Drain	1.61	45min	17	45min	14	1.5hour	11	1.5hour	9	1.5hour	6
34	Station_Ave	1.64	45min	23	45min	20	45min	15	45min	12	1.5hour	9
35	Fairbairn_Rd	1.72	30min	28	30min	23	45min	19	45min	15	1.5hour	11
36	Tilburn_Rd	1.76	1.5hour	16	1.5hour	14	1.5hour	11	1.5hour	9	1.5hour	6
37	Yeats_Dr	1.82	20min	29	20min	24	45min	20	45min	16	30min	12

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
38	Ballarat_Rd	1.93	30min	17	30min	15	45min	13	45min	11	1.5hour	9
39	Denton_Ave	2.05	30min	35	30min	30	45min	24	45min	20	30min	15
40	Station_Rd	2.09	45min	30	45min	25	45min	20	45min	16	1.5hour	12
41	Glandstone_St	2.12	30min	34	30min	28	45min	22	45min	18	1.5hour	14
42	Frost_RB	2.19	1.5hour	20	1.5hour	15	2hour	12	2hour	11	1.5hour	9
43	Hygeia_Ave	2.4	30min	36	30min	30	45min	24	45min	19	1hour	15
44	Taylors_Rd_Inflow	2.62	30min	40	30min	33	45min	27	45min	21	1.5hour	16
45	Kurung_Dr	2.68	1hour	23	1hour	19	45min	17	45min	14	1.5hour	11
46	Crofts_Reserve	2.7	30min	39	30min	32	45min	26	45min	21	1.5hour	16
47	Jones_Ct	2.82	1.5hour	27	1.5hour	22	2hour	15	2hour	11	1.5hour	8
48	Rosshire_Rd	2.83	30min	26	30min	21	45min	17	45min	14	1.5hour	10
49	East_Esplanade	3.23	1hour	33	1hour	28	1.5hour	22	1.5hour	18	1.5hour	12
50	Glengala_Drain	3.3	1.5hour	30	1.5hour	23	2hour	17	1.5hour	13	2hour	9
51	Grassy_Point_Rd	3.43	30min	46	45min	39	45min	31	45min	24	1.5hour	19
52	Mulhall_Dr	3.49	30min	25	45min	22	45min	17	45min	13	1.5hour	11
53	Gillespie_Rd	3.78	30min	42	30min	36	45min	30	45min	25	1.5hour	20
54	Cunningham_Chase	4.19	30min	48	30min	40	45min	32	45min	27	1.5hour	21
55	James_St	4.21	30min	45	30min	38	45min	31	45min	24	1.5hour	18
56	St_Albans_East_Drain	4.84	45min	59	45min	49	45min	39	1.5hour	31	1hour	24

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
57	PAS@Ross_Rd	4.92	1hour	51	1hour	42	1.5hour	33	1.5hour	27	1.5hour	20
58	Pennell_Ave	5.11	30min	56	30min	47	45min	37	45min	29	1.5hour	23
59	Meadowbank_Dr	7.09	1hour	68	1hour	56	2hour	44	2hour	36	1.5hour	26
60	Serpentine_RB	7.34	4.5hour	23	4.5hour	19	4.5hour	13	6hour	10	6hour	6
61	Gladstone_RB	7.57	1.5hour	68	1.5hour	58	2hour	44	2hour	34	1.5hour	24
62	Chisholm_RB	8.39	6hour	23	6hour	19	6hour	13	6hour	10	12hour	6
63	Kevin_Flint_Reserve	8.83	2hour	60	2hour	50	2hour	39	2hour	30	2hour	21
64	PAS@Outlet	8.89	1hour	84	1hour	69	2hour	53	2hour	43	1.5hour	33
65	Gilmour_RB	8.94	1.5hour	65	1.5hour	55	2hour	44	2hour	38	1.5hour	33
66	Westwood_Dr_Inflow	9.03	6hour	25	6hour	21	6hour	14	9hour	10	12hour	7
67	Caroline_Springs_RB	11.58	1.5hour	88	1.5hour	73	2hour	54	1.5hour	42	2hour	28
68	Jones_Creek	11.86	3hour	66	3hour	56	2hour	39	3hour	30	3hour	22
69	STN@Outlet	12.53	2hour	79	1.5hour	68	2hour	59	2hour	52	1.5hour	43
70	Burnside_Inflow	205.14	12hour	279	12hour	213	12hour	135	12hour	90	12hour	53
71	Burnside_Interstation	208.69	12hour	282	12hour	216	12hour	137	12hour	91	12hour	53
72	KOR@Deer_Park	225.37	12hour	303	12hour	232	12hour	148	12hour	99	12hour	57
73	KOR@Forrest_St	251.08	12hour	309	12hour	237	12hour	154	12hour	102	12hour	58
74	KOR@Brooklyn	276.03	12hour	307	12hour	235	12hour	156	12hour	103	12hour	58
75	KOR@Outlet	286.78	12hour	305	12hour	233	12hour	154	12hour	102	12hour	57

Table B-19. Critical durations and selected temporal patterns using the Kororoit Creek RORB model.

AEP	20min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour
1%	TP27	TP28	TP26	TP27	TP27	TP28	TP27	TP28	TP29	-	TP4
2%	TP27	TP28	TP26	TP27	TP27	TP28	TP27	TP28	TP21	-	TP4
5%	-	TP18	TP19	TP17	TP13	TP15	-	-	TP20	-	TP5
10%	-	TP19	TP19	-	TP13	TP17	-	-	TP13	-	TP5
20%	-	TP4	TP8	TP4	TP7	TP7	TP6	-	-	-	TP5

B.9 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Kororoit Creek catchment.

B.9.1 Kororoit Creek North Hydraulic Model Set Up

B.9.1.1 Terrain modifications

Maps available in Figure B-21, Figure B-22, Figure B-23 show Kororoit Creek North TUFLOW model terrain modifications, which are also listed in Table B-20 where these have been based on drawings, plans or other available detailed information. The terrain modifications include adjustment made to the base LiDAR either due to:

- Lidar Adjustments: Sections of the LiDAR that may contain significant depressions that are not permanent, i.e. if the LiDAR was flown during the construction of a building then the excavation would be captured and should be removed to ensure no rainfall pools in this depression.
- Terrain Modifications: Removal of bridges or blockages to enable the structure to be hydraulically modelled.
- Reinforcement of hydraulic controls (roads, levees, embankments) within the overland flow paths.

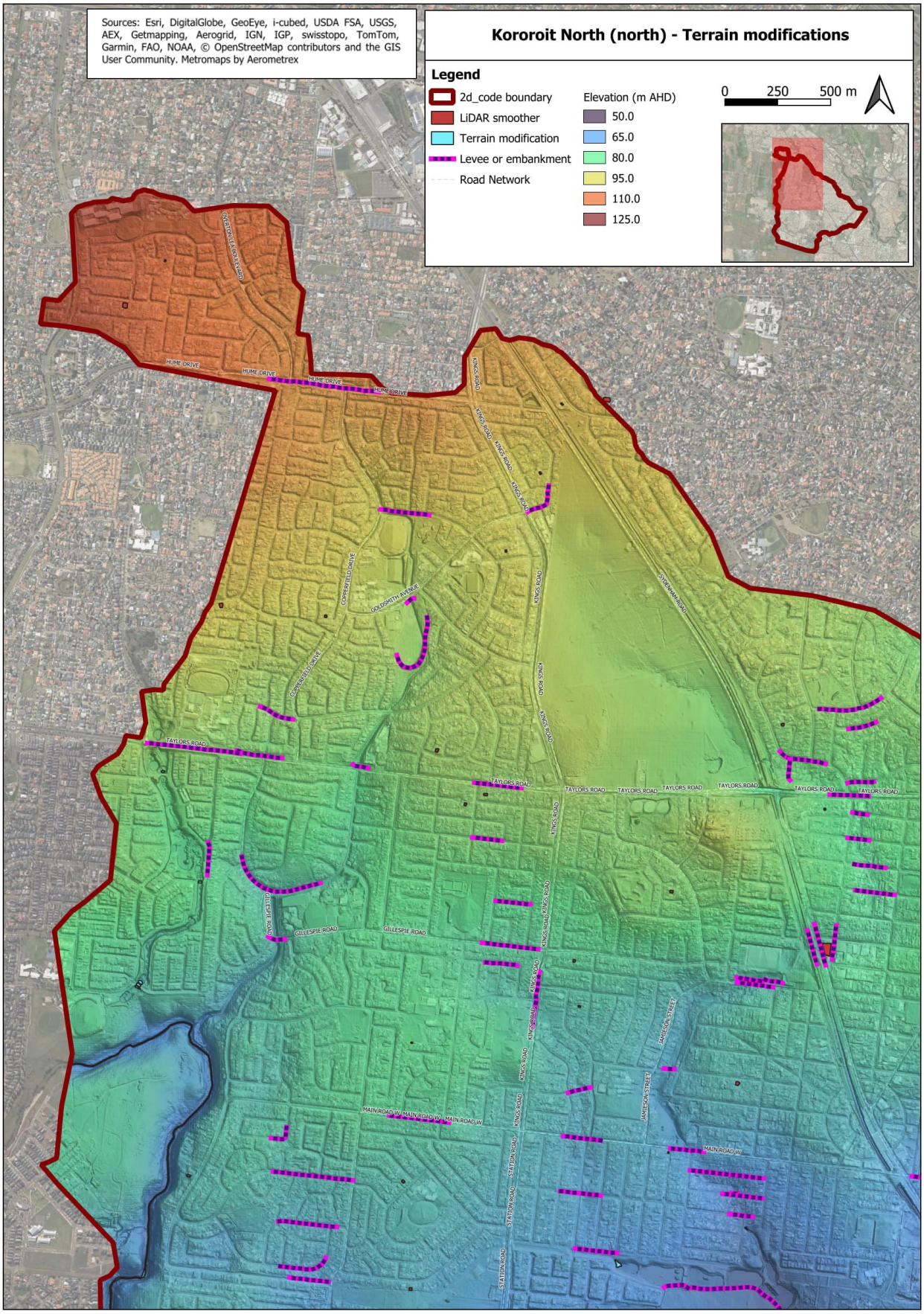


Figure B-21. Kororoit Creek North TUFLOW model terrain modifications (north).

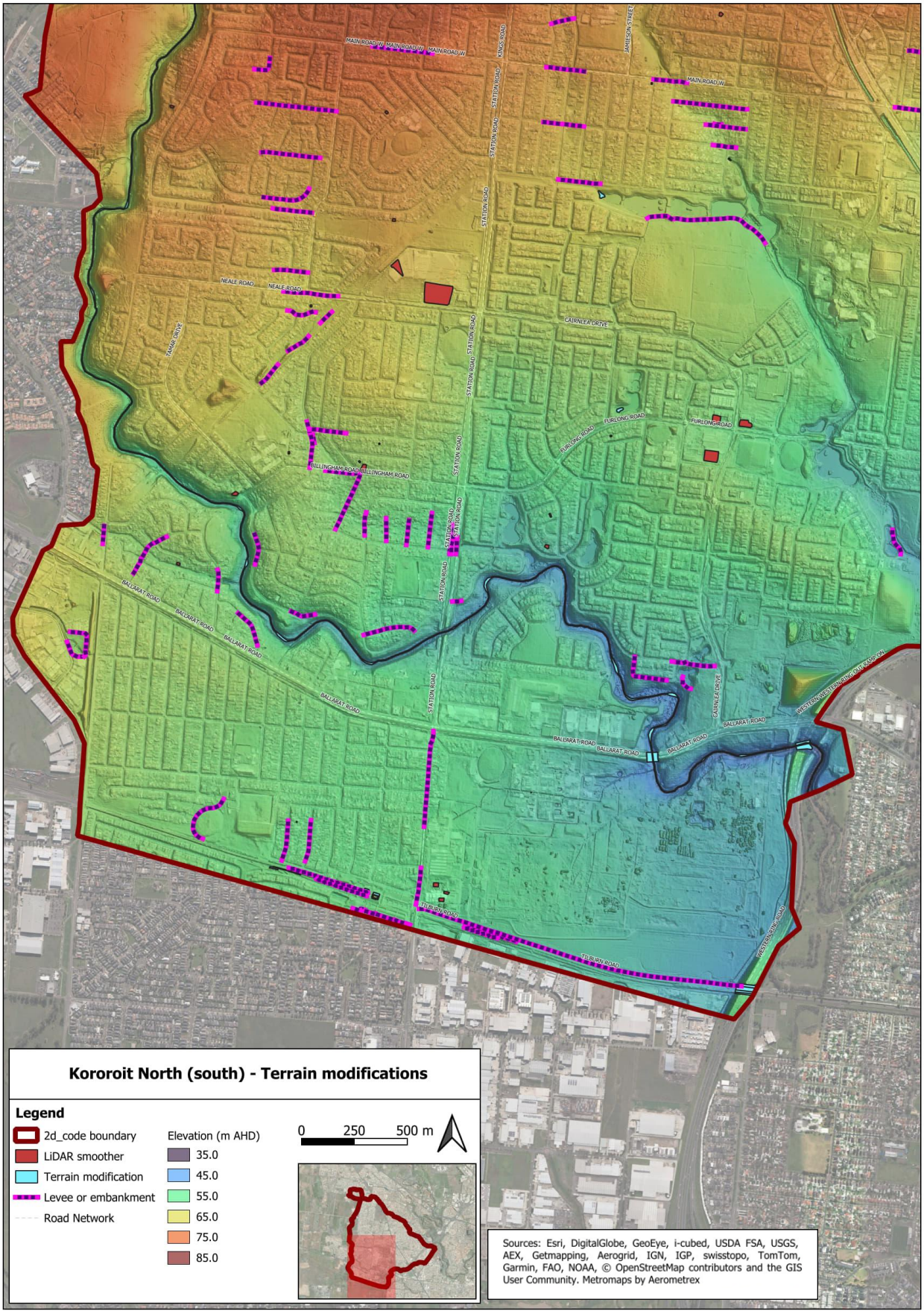


Figure B-22. Kororoit Creek North TUFLOW model terrain modifications (south).

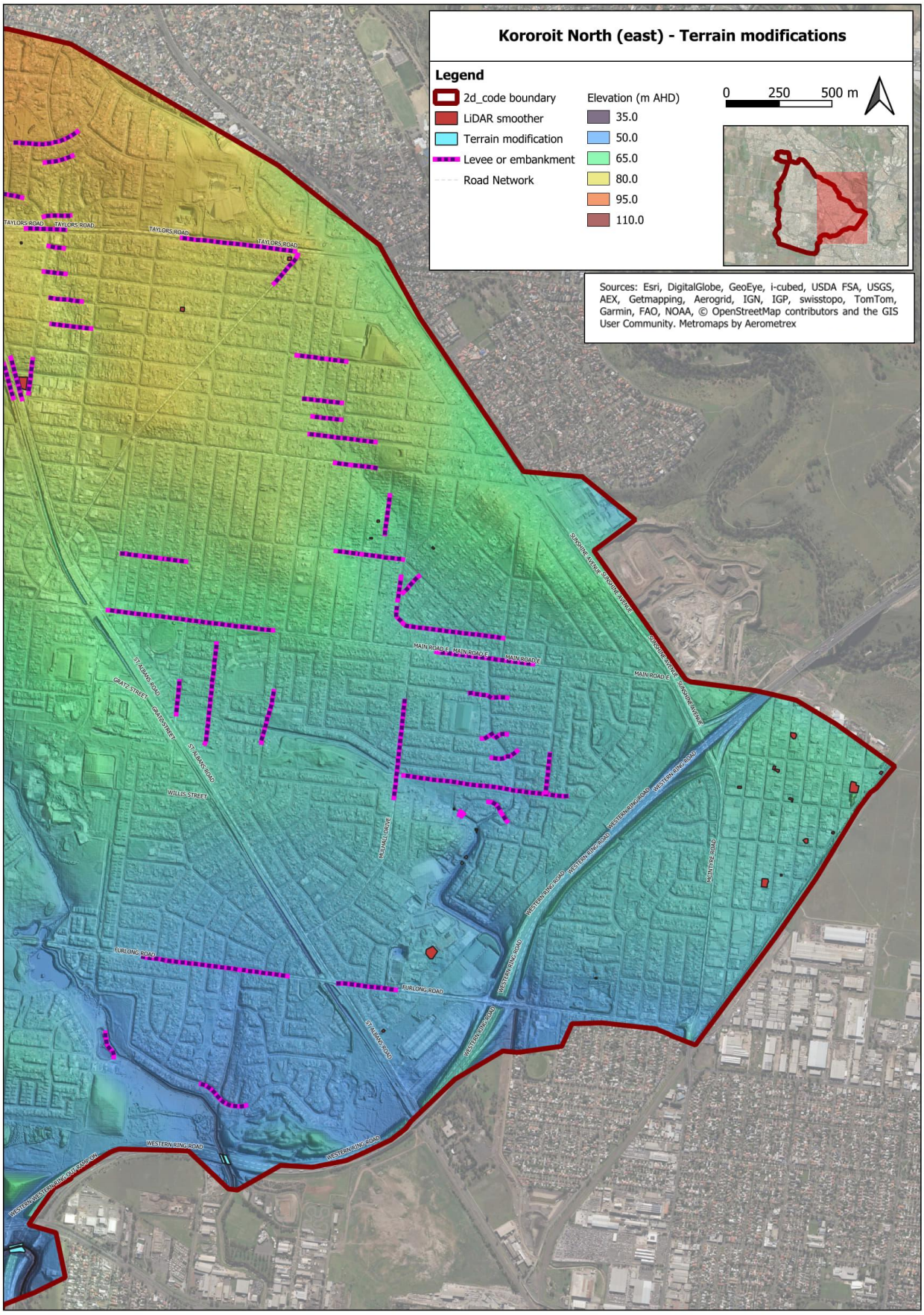


Figure B-23. Kororoit Creek North TUFLOW model terrain modifications (east).

Table B-20. Kororoit Creek North TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Gladstone St Retarding Basin embankment elevation	Melbourne Water (2012) GLADSTONE STREET RETARDING BASIN, INTERMEDIATE INSPECTION REPORT, Date of Inspection: 17th August 2012, Asset No: RB180, File No: Melbourne Water 2010 - 3253	The embankment has been reinforced in the LiDAR.
Waigani Ave Retarding Basin embankment elevation	SMEC (2020) Waigani Ave Retarding Basin 2019/20 Retarding Basin Intermediate Inspections. Reference No. VP160525 Prepared for Melbourne Water 24 March 2020	Embankment and spillway reinforced in LiDAR. Outlet drainage arrangement adopted in model.
Frost Dr Retarding Basin embankment elevation	Melbourne Water (2009), FROST DRIVE RETARDING BASIN, INTERMEDIATE INSPECTION REPORT, Date of Inspection: 4th December 2009, Asset No: RB116, File No: 404/138/5001 GHD (2016) Retarding Basin Upgrade Program, Risk Assessment of Frost Dr RB.	The embankment has been reinforced in the LiDAR.
Lake Chamoun/Lake Jerkovic	Coomes Consulting Group (2000) Urban and Regional Land Corporation (2003)	Various drainage asset plans applied to between a series of wetlands and Kororoit Creek.
Davitt Dr footbridge, Kororoit Crk trail footbridge, Station Road bridge	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571012.	Bridge details used to inform bridge representation in TUFLOW model.
Western Ring Rd bridges, Orica unused bridge	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571010A.	
Ballarat Road bridge	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571011.	

B.9.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in **Table B-21**.

Table B-21. Kororoit Creek North TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Tilburn Rd	0.03	55.03	1.00	1.00	60
Footbridge Jones Crk Trl	0.19	57.58	0.50	1.00	30
Furlong Rd	0.09	54.16	1.00	1.00	30
Pimelea Terrace	0.00	51.62	0.30	1.00	30
Footbridge M80 Trl	0.00	46.95	0.50	1.00	30
Western Ring Rd Jones Crk	0.14	49.97	1.00	1.00	60
Footbridge Lyons Ave	0.04	80.91	0.40	1.00	30
Footbridge Parkes Way	0.05	78.87	0.15	0.00	0
Footbridge Blaxland St	0.14	79.62	0.15	1.00	30
Footbridge Waterside Dr	0.08	79.51	0.30	1.00	30

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Creekview Dr	0.04	50.39	1.00	1.00	30
Footbridge Davitt Dr	0.09	52.77	0.30	0.80	30
Footbridge Kororoit Crk Trl	0.09	50.37	1.00	1.00	30
Station Rd Downstream	0.12	51.99	0.83	0.83	30
Station Rd Upstream	0.12	50.55	0.83	0.83	30
Western Ring Rd On Ramp	0.01	46.95	1.30	1.00	60
Western Ring Rd	0.03	55.11	1.00	1.00	60
Western Ring Rd Off Ramp	0.01	47.50	1.13	1.00	60
Orica Bridge Unused	0.05	44.40	1.00	1.00	30
Ballarat Rd Downstream	0.14	49.66	1.20	1.00	30
Ballarat Rd Upstream	0.14	49.34	1.30	1.00	30
Grassy Point Rd	0.15	49.86	0.16	1.00	30
Taylors Rd	0.00	83.70	1.50	1.00	100

B.9.1.3 Model roughness

Maps available in Figure B-24, Figure B-25, Figure B-26 show the Kororoit Creek North TUFLOW model Manning's roughness.

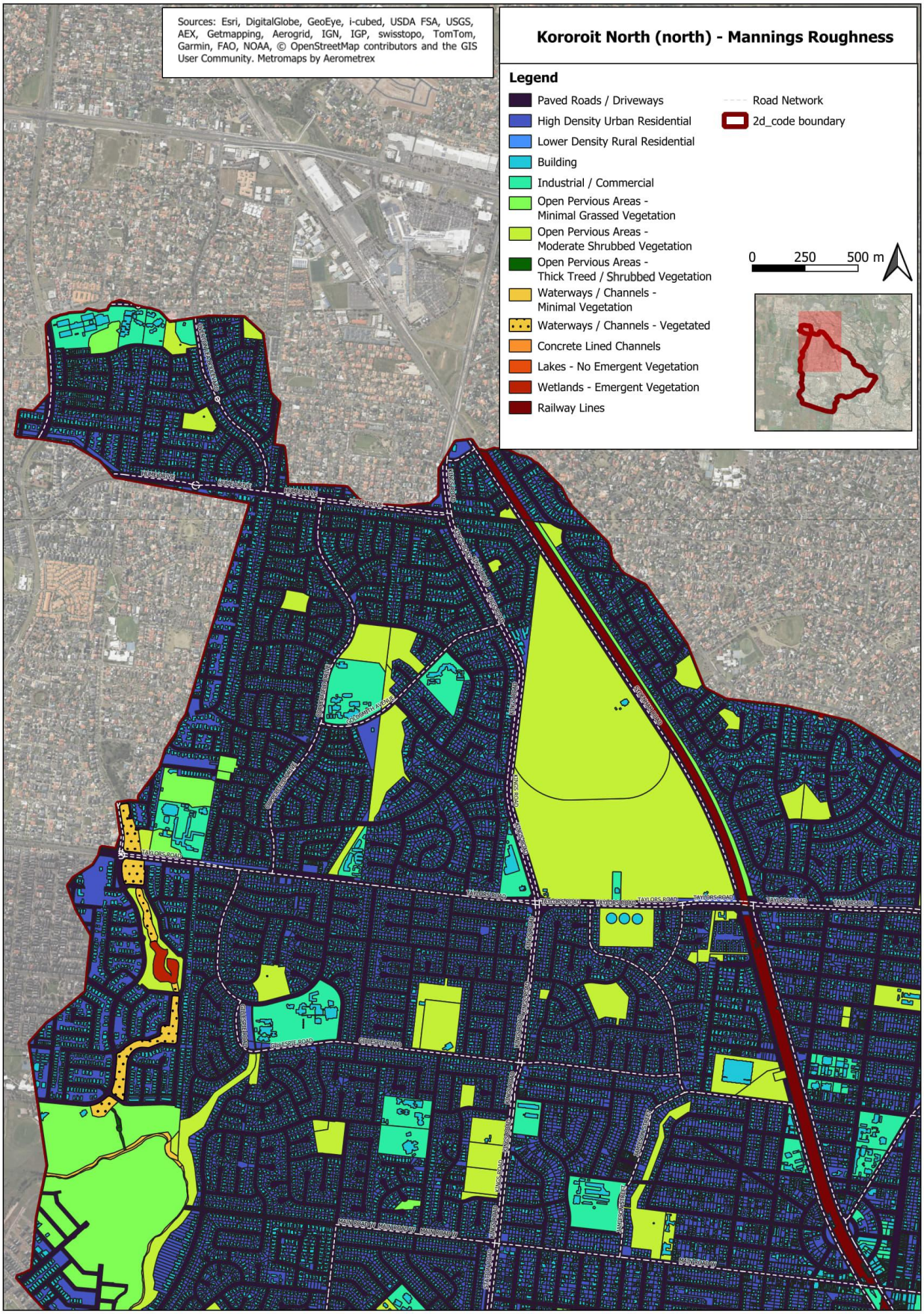


Figure B-24. Kororoit Creek North TUFLOW model Manning's roughness (north).

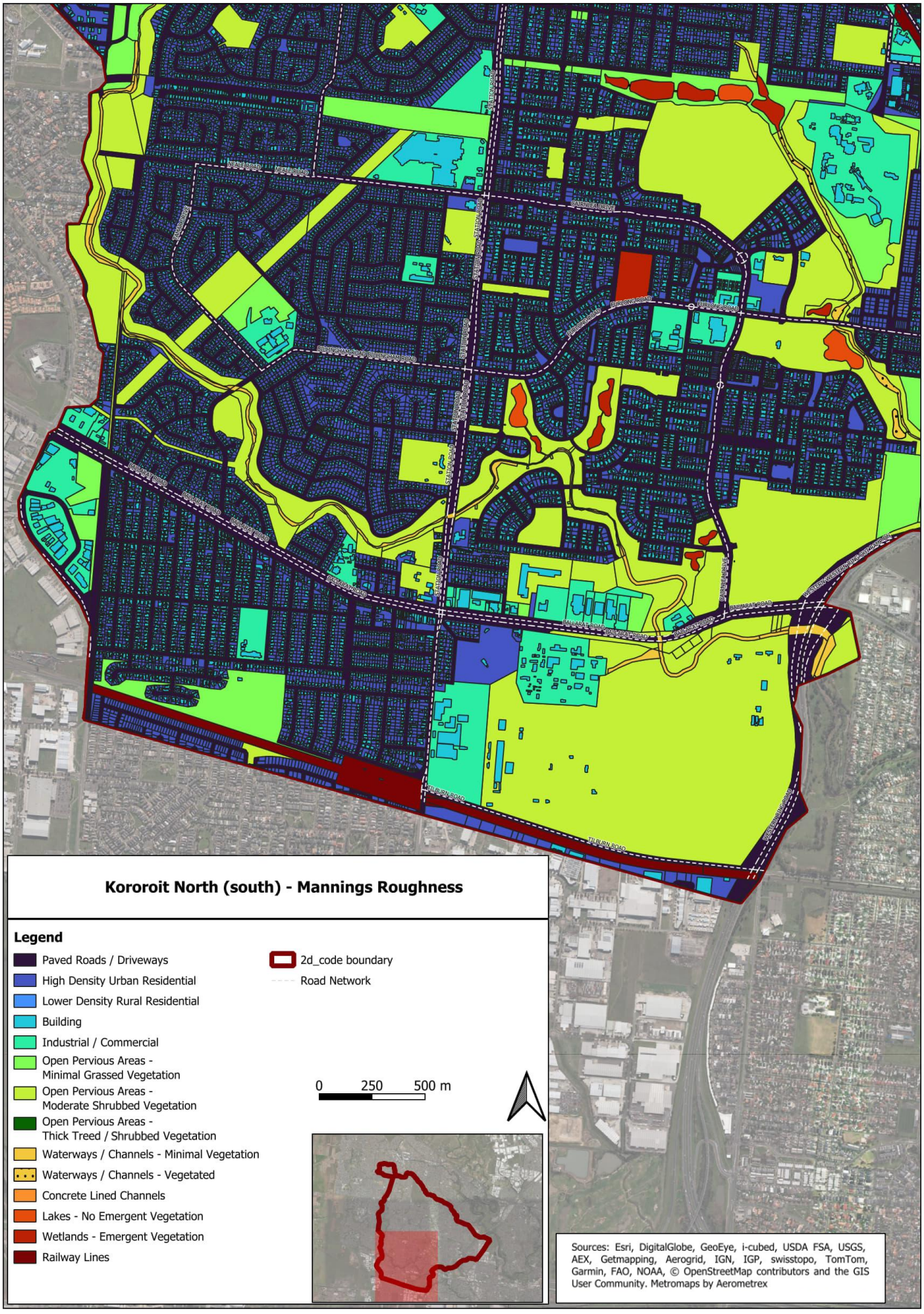


Figure B-25. Kororoit Creek North TUFLOW model Manning's roughness (south).

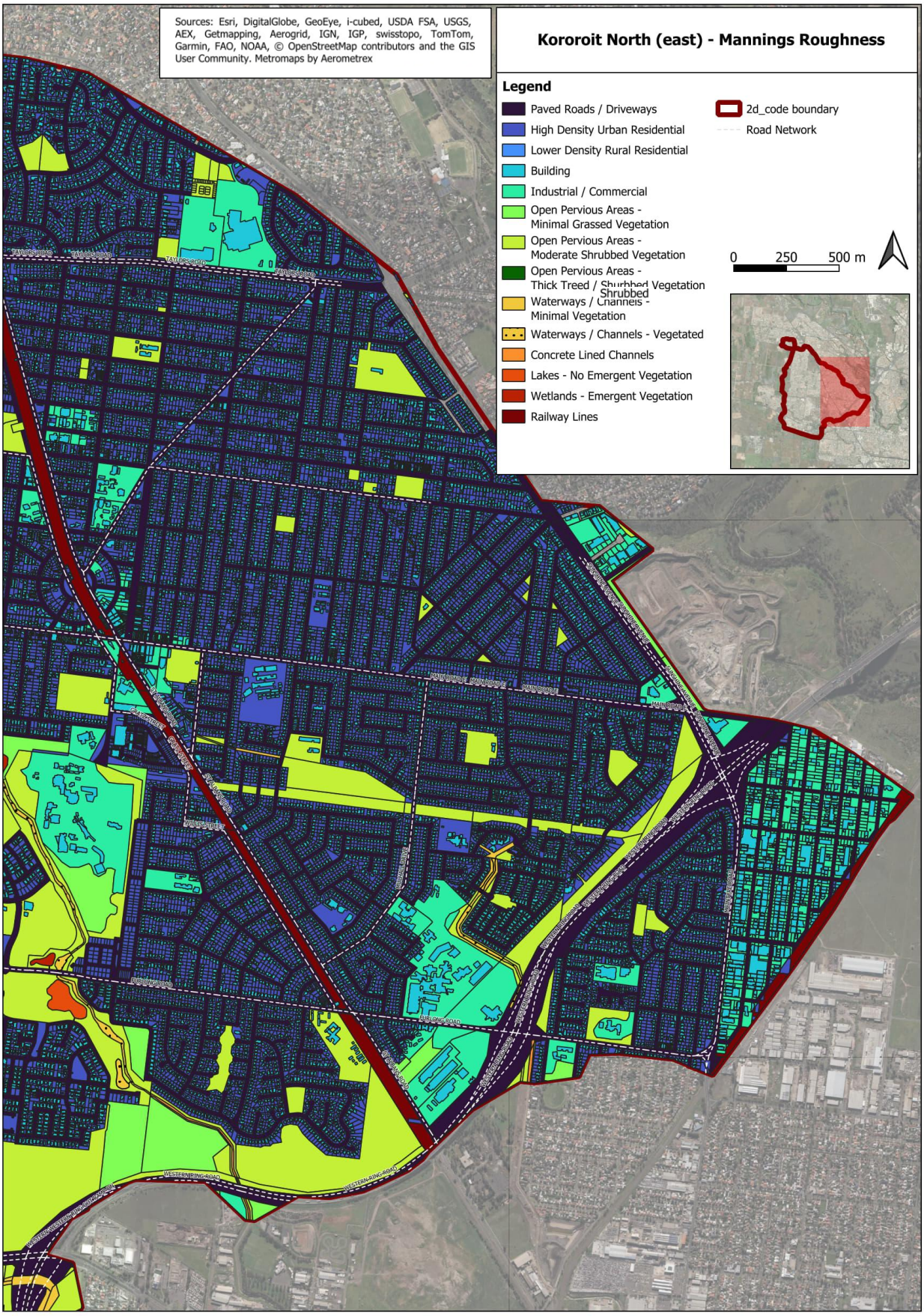


Figure B-26. Kororoit Creek North TUFLOW model Manning's roughness (east).

B.9.1.4 1D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table B-22. A full count of the adopted pit types in the TUFLOW model is listed in Table B-23. Maps of the full drainage network can be found in Figure B-27, Figure B-28 and Figure B-29.

Table B-22. Kororoit Creek North TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Justification/Location
FM_P_17112	Brimbank Council	C	1.8		Council pipe dataset shows 1.8m pipe that outlets onto Western Ring Rd. Assumed pipe digitised to connect this pipe to a nearby subnetwork of the same dimension, which discharges into Stony Creek.
Melbourne Water_pipe_607	Melbourne Water	R	1.2	0.6	Culvert visible from aerial imagery. Pipe size adopted from Melbourne Water culverts further upstream of Christies drain.
pipe_5608	Brimbank Council	C	0.9		Assumed pipe digitised to connect upstream pipe to a subnetwork that discharges to stony creek. According to council dataset upstream pipe outlets along Cromer Av adjacent to a carpark. Outlet not visible from aerial imagery or google streetview, suggesting missing data at this location.
pipe_5609, pipe_5610, pipe_5611	Brimbank Council	C	1.8		Council pipe network extended downstream to pipe outlet location at Stony Creek, which was identified from aerial imagery and lidar. Pipe widths assumed based on upstream pipe dimensions.
A_23456	Brimbank Council	C	0.375		Additional pipe digitised to allow 1d subnetwork to outlet to Kororoit Creek. Previous pipe network configuration showed subnetwork without downstream outlet. Pipe width based on upstream pipe dimensions.
A_98345	Brimbank Council	C	0.45		Council pipe network extended downstream to outlet location at Kororoit Creek. Pipe widths assumed based on upstream pipe dimension.
Assumed_523	Brimbank Council	C	1.2		Previous drainage subnetwork configuration had pipe outlet location adjacent to Deer Park Railway Station. Additional pipe assumed, which extends out of the model area, in the direction of a drainage subnetwork of greater cross-sectional area. Assumed pipe width based on upstream pipe dimension.

Table B-23. Kororoit Creek North TUFLOW model 1D drainage adopted pit types.

Pit Type	Count
Side Entry Pit	10736
Double side entry pit	451
Grated Side Entry	254
Grated Pit	641
Double Grated Pit	6
Junction Pit (node)	2779
Bespoke pits	9

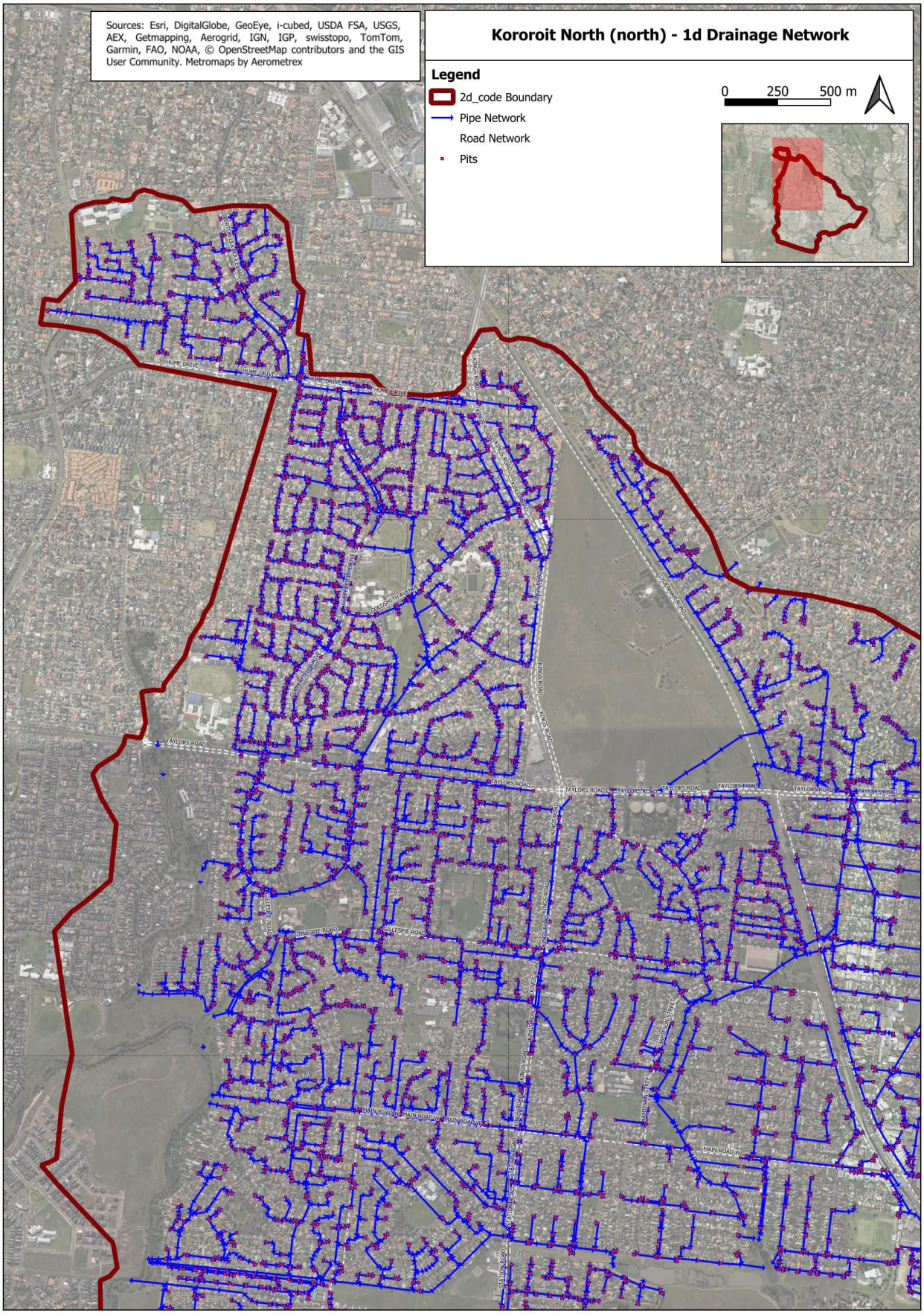


Figure B-27. Kororoit Creek North TUFLOW model 1D drainage network (north).

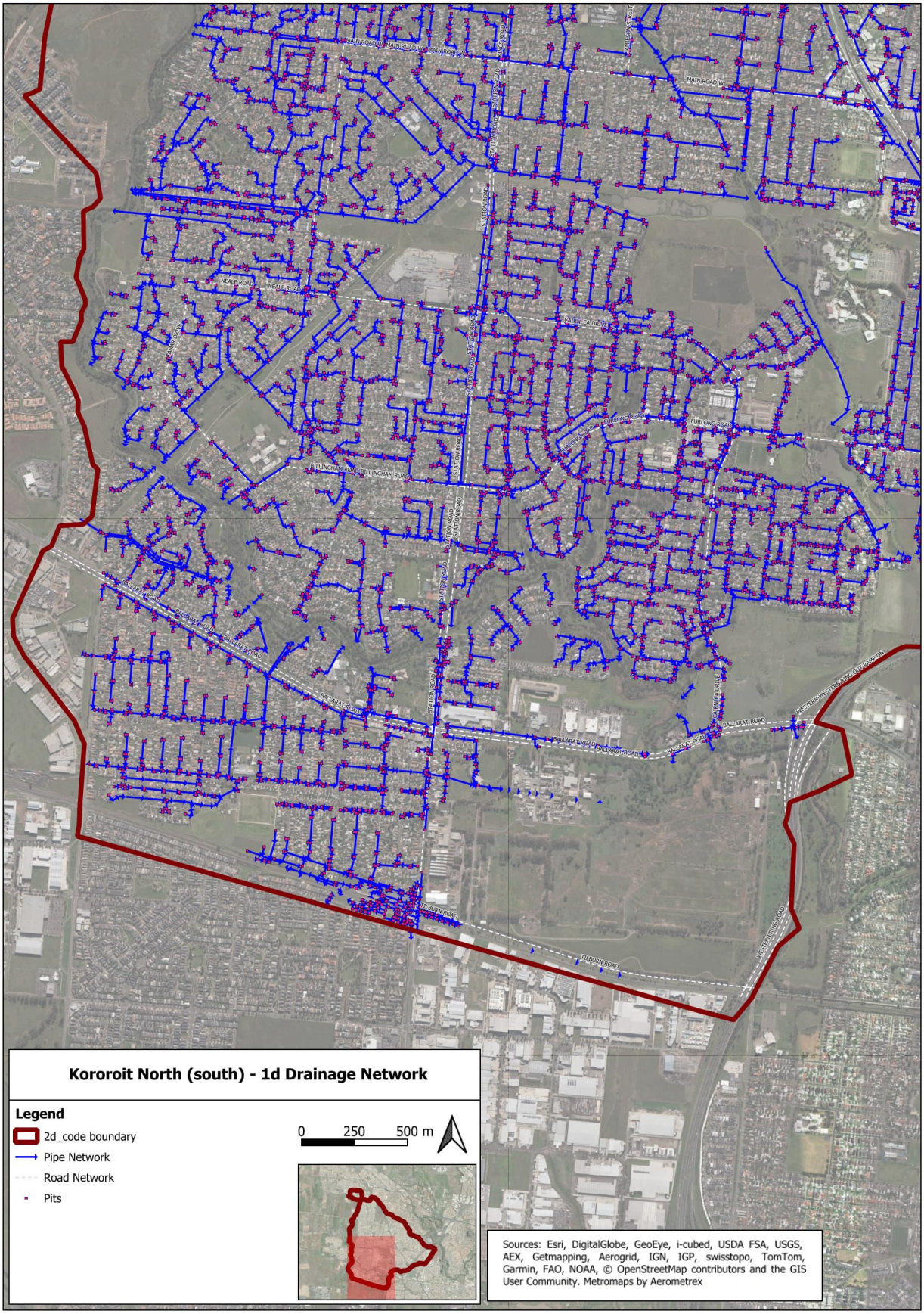


Figure B-28. Kororoit Creek North TUFLOW model 1D drainage network (south).

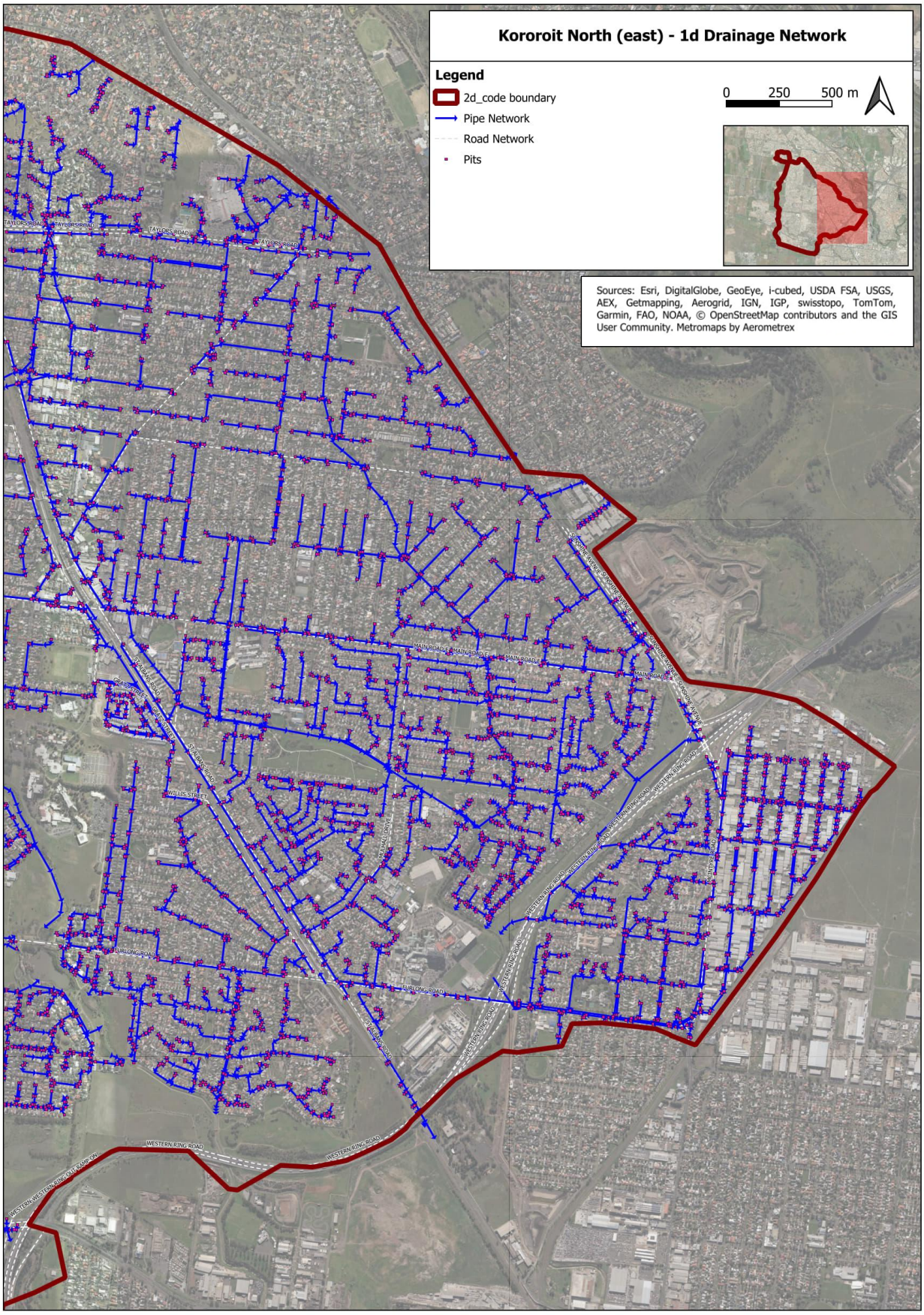


Figure B-29. Kororoit Creek North TUFLOW model 1D drainage network (east).

B.9.1.5 Boundary conditions

The boundary conditions for the Kororoit Creek TUFLOW model are presented in Figure B-30, Figure B-31 and Figure B-32.

To represent the boundary condition inflows for Kororoit Creek, flows taken from the Study's RORB model were applied at the upstream end of the TUFLOW model at the major tributary inflow point. Additional external inflows from smaller urban subcatchments have been sourced from the Kororoit North TUFLOW model.

As per the Melbourne Water Flood Mapping Projects Specifications, the 10% AEP flow for Kororoit Creek has been used for modelling the 1% and 2% AEP events for the study, and the 20% AEP flow for the 5-20% AEP events (given the Study area is above the tidally influenced zone). This approach was approved by Melbourne Water.

The study has applied an offset to these inputs so the peak of the flood event in Kororoit Creek approximately matches the peak of the catchment runoff.

The downstream boundaries for the model were set to HQ (height versus flow) boundaries with a slope determined based on the water level profile. The main downstream boundaries are across Kororoit Creek, Jones Creek, Stony Creek (Upper) and several major roads. In addition, various HQ boundaries have been adopted where there is flow interacting with the model boundary.

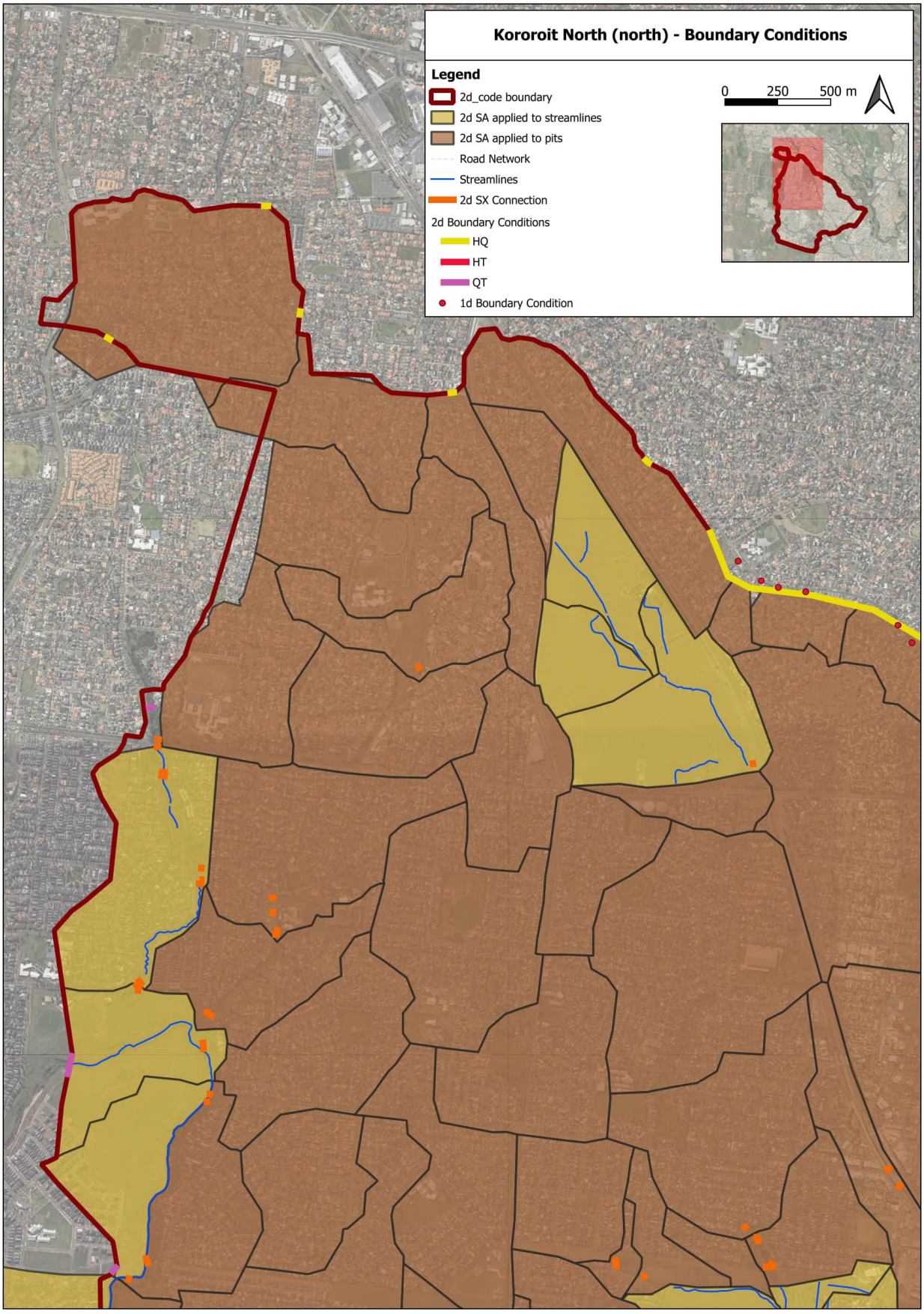


Figure B-30. Kororoit Creek North TUFLOW model boundary conditions (north).

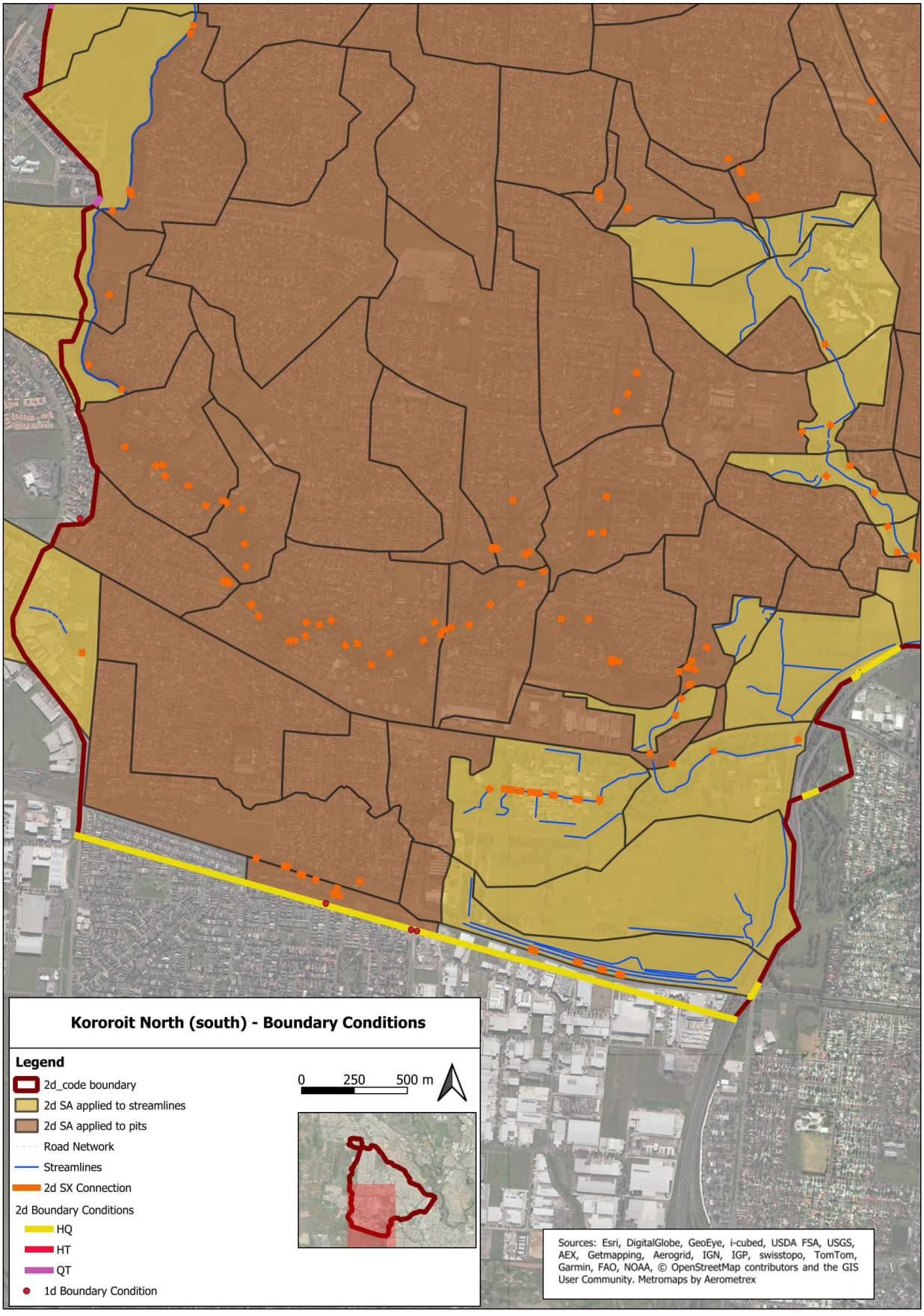


Figure B-31. Kororoit Creek North TUFLOW model boundary conditions (south).

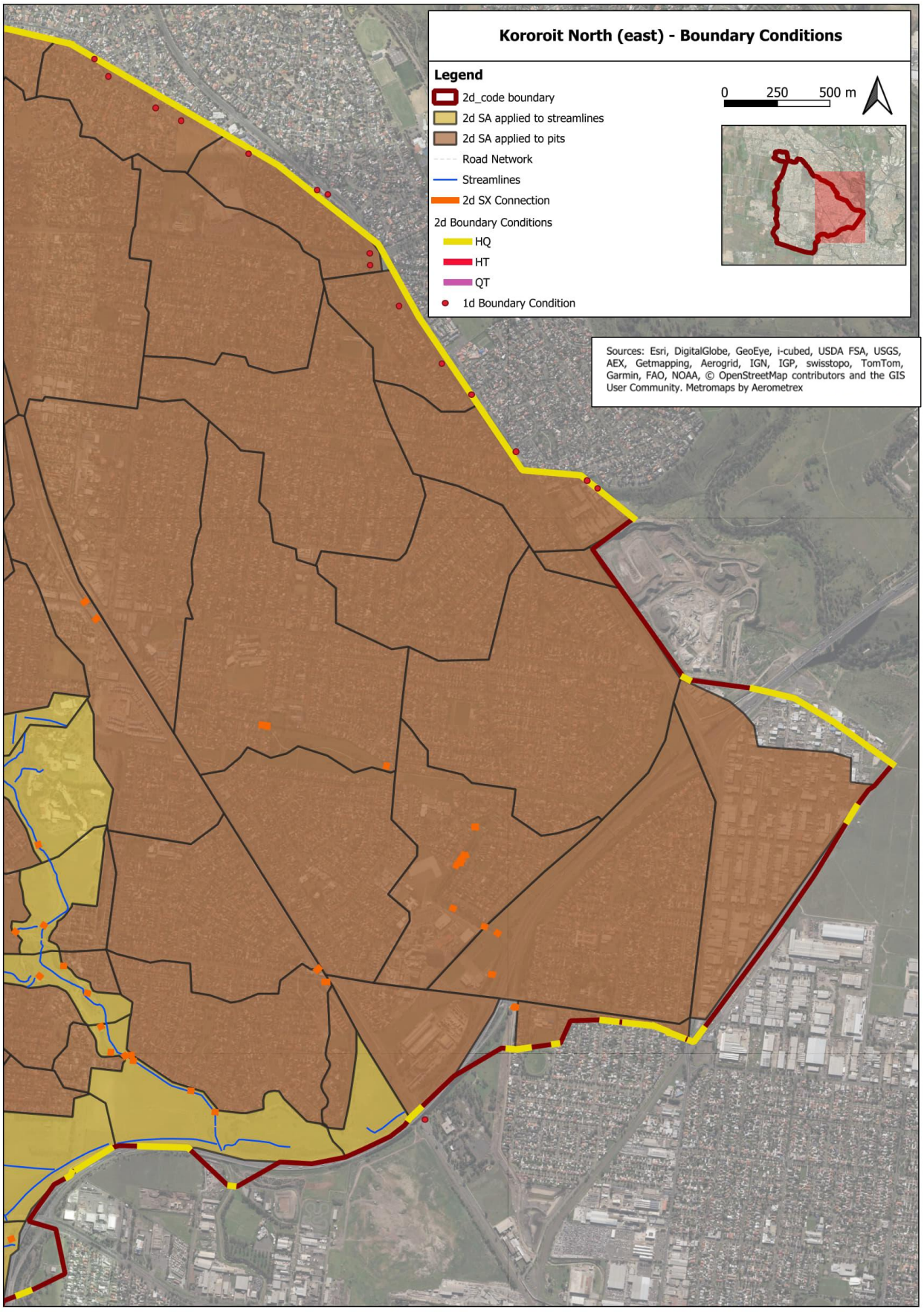


Figure B-32. Kororoit Creek North TUFLOW model boundary conditions (east).

B.9.1.6 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table B-24.

As part of the separation of riverine waterway and council flood mapping for Kororoit Creek, the critical durations selected in RORB were reviewed for application to the TUFLOW model. The 12 hour duration was found to not be critical for any of the Kororoit Creek council areas mapped as part of this report. The 12 hour durations have been removed from the adopted durations summarised in Table B-24.

Table B-24. Adopted Durations, temporal patterns and ARF areas for the Kororoit Creek North model

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP27	1	TP27	1	-		-		-	
30 minute	TP28	1	TP28	1	TP18	1	TP19	1	TP4	1
45 minute	TP26	1	TP26	3	TP19	1	TP19	1	TP8	1
1 hour	TP27	3	TP27	3	TP17	1	-		TP4	1
1.5 hour	TP27	3	TP27	9	TP13	3	TP13	3	TP7	3
2 hour	TP28	9	TP28	9	TP15	9	TP17	9	TP7	9
3 hour	TP27	9	TP27	9	-		-		TP6	9
4.5 hour	TP28	9	TP28	9	-		-		-	
6 hour	TP29	9	TP21	9	TP20	9	TP13	9	-	

B.9.1.7 QA Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks are summarised in Table B-25. They have been assessed and reviewed by Melbourne Water's external reviewer (see Appendix N).

Table B-25. Kororoit Creek North - TUFLOW checks and warning messages

Message	Count	Message content
Message_2470	69	CHECK 2470 - Neither LFC default approach nor Shape_Option is set. Using PORTION approach
Message_2073	2	WARNING 2073 - Object ignored. Only Points, Lines, Polylines, Regions & Region Centers used. GIS Object = Null Shape
Message_1111	4	CHECK 1111 - Overwriting channel M_pipe_71 with same ID channel from "J:\IE\Projects\03_Southern\IA5000KV\07 Technical\02 Hydraulics\01 TUFLOW\Kororoit_North\TUFLOW\model\gis\1d_nwk_council_pipes_KOR
Message_1402	5	CHECK 1402 - More than one culvert connected but could not create manhole at Node "PT012107". Check culvert inverts and directions.
Message_1401	2	CHECK 1401 - 1 culvert(s) not used for determining losses at Manhole "PT038065". Check culvert inverts and directions.
Message_1313	18	WARNING 1313 - No inlet culvert connected to Manhole "PT002860". Manhole not used/applied.
Message_2118	150	CHECK 2118 - Lowered SX ZC Zpt by 0.02m to 1D node bed level.
Message_2122	3	WARNING 2122 - Pit or node does not connect to an active cell within any 2D domain - 2D link ignored.
Message_2039	1	WARNING 2039 - Ignored 3 pit/node (SX) connections from 1d_nwk nodes for 2D Domain Domain_001
Message_2210	279	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = 50.39; Top of First FC Layer = 49.66
Message_1100	35	WARNING 1100 - Structure PP003186 crest/invert (58.860) is below bed (59.020) of primary upstream channel PP003170.
Message_3520	1	CHECK 3520 - Found SGS cell face that has minimum Face elevation lower than the minimum cell centre elevations on both sides.

B.9.2 Kororoit South Hydraulic Model Set Up

B.9.2.1 Terrain modifications

Maps available in Figure B-33, Figure B-34, Figure B-35 show Kororoit Creek South TUFLOW model terrain modifications, which are also listed in Table B-26 where these have been based on drawings, plans or other available detailed information. The terrain modifications include adjustment made to the base LiDAR either due to:

- Lidar Adjustments: Sections of the LiDAR that may contain significant depressions that are not permanent, i.e. if the LiDAR was flown during the construction of a building then the excavation would be captured and should be removed to ensure no rainfall pools in this depression.
- Terrain Modifications: Removal of bridges or blockages to enable the structure to be hydraulically modelled.
- Reinforcement of hydraulic controls (roads, levees, embankments) within the overland flow paths

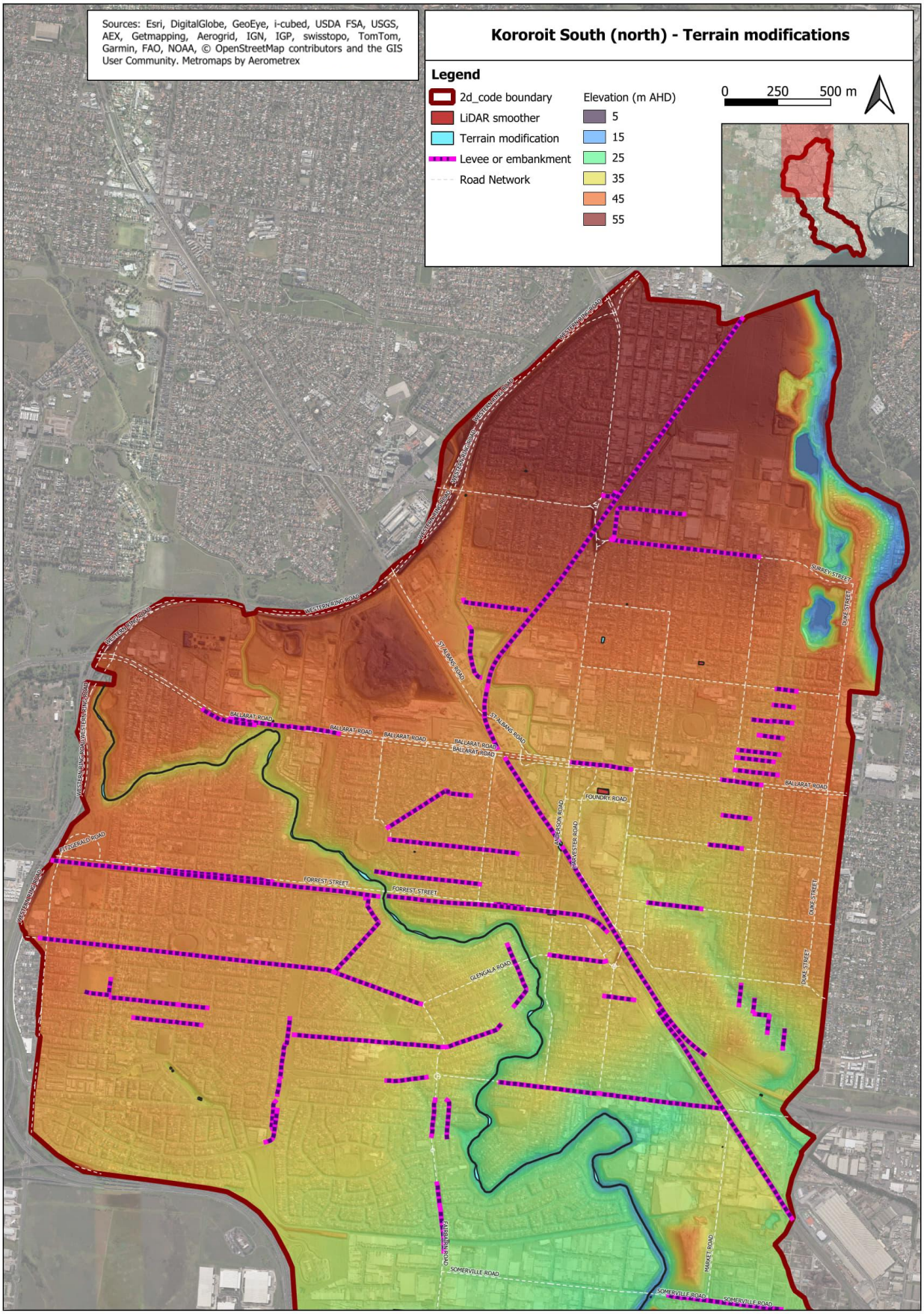


Figure B-33. Kororoit Creek South TUFLOW model terrain modifications (north).

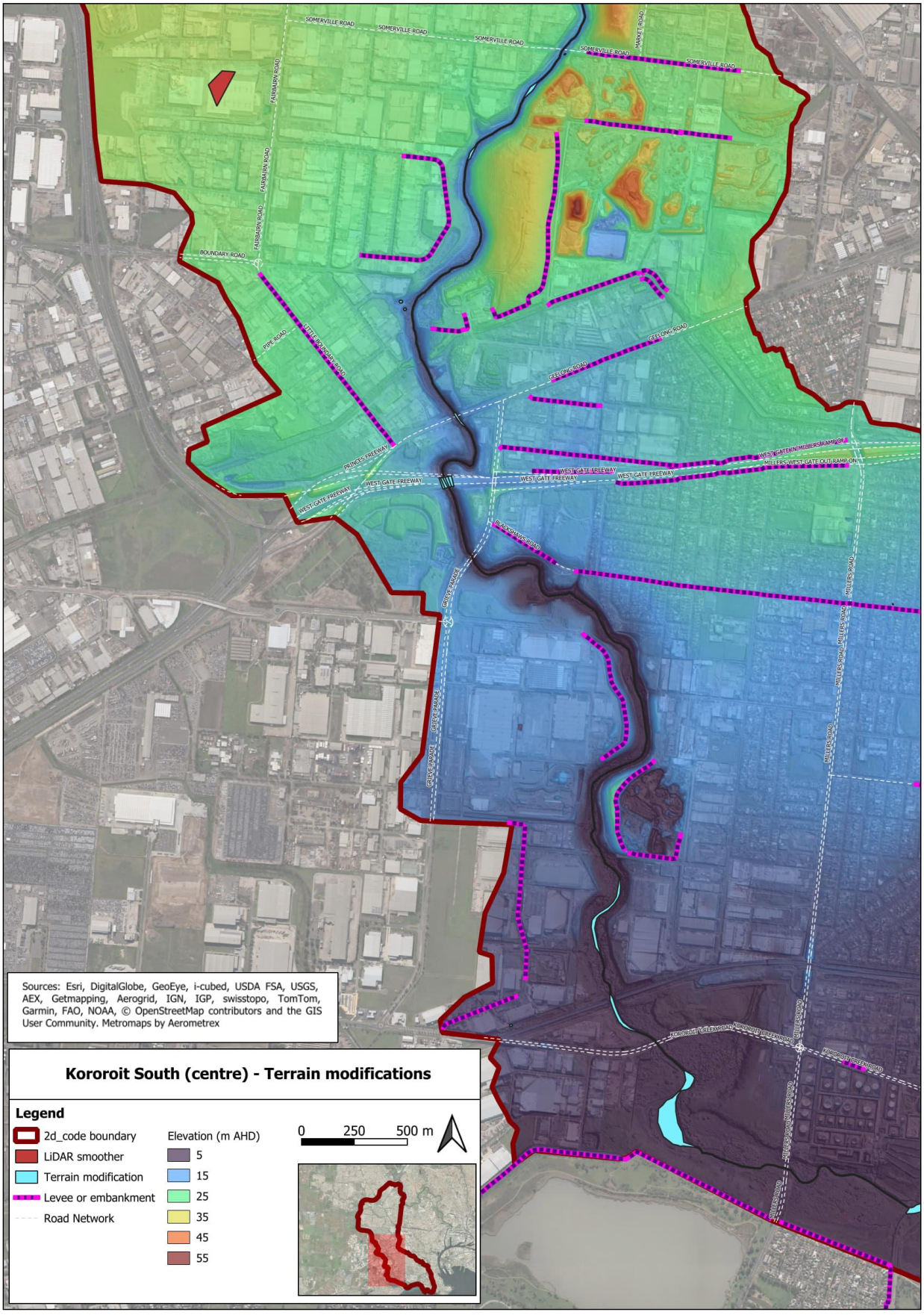


Figure B-34. Kororoit Creek South TUFLOW model terrain modifications (centre).

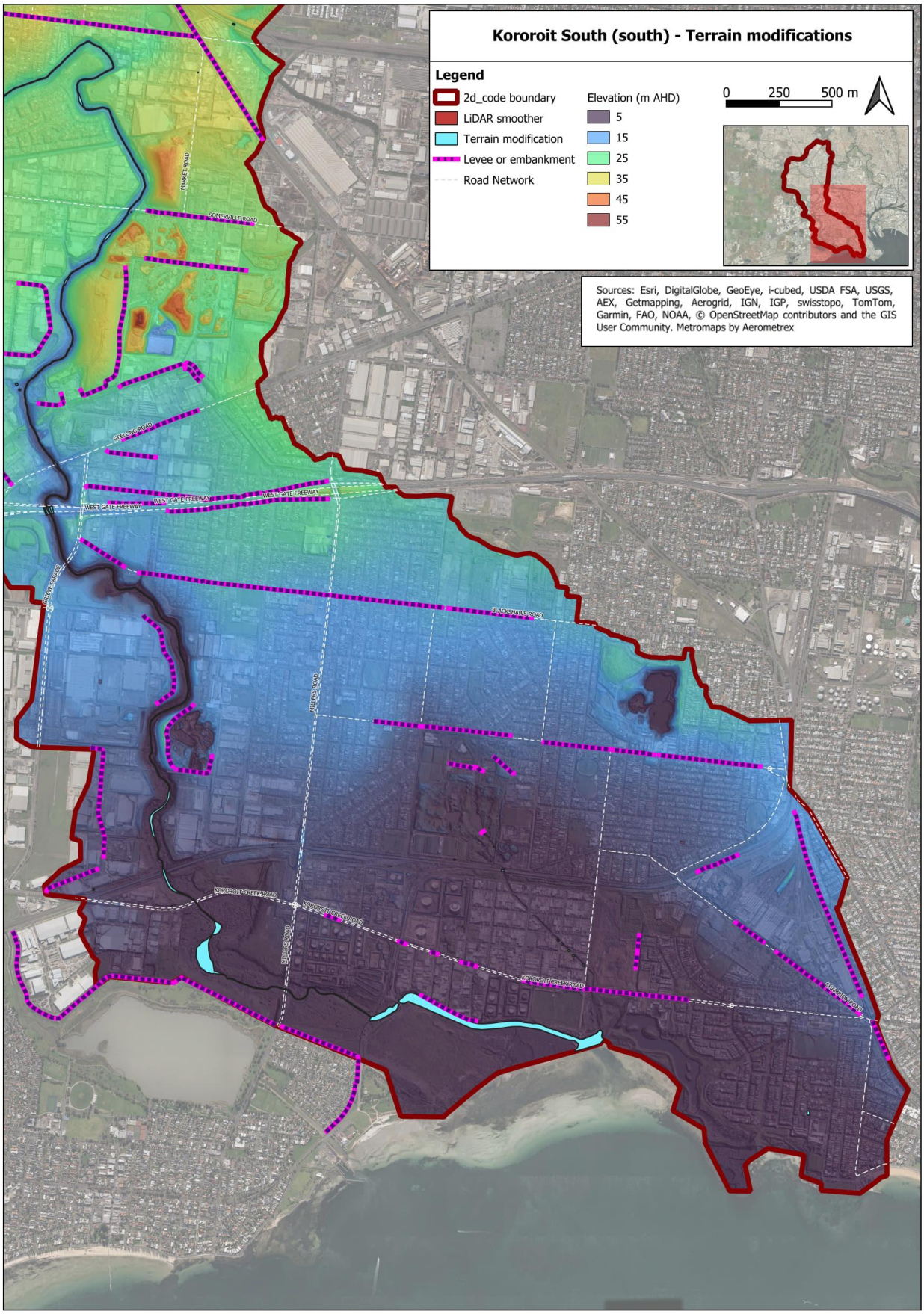


Figure B-35. Kororoit Creek South TUFLOW model terrain modifications (south).

Table B-26. Kororoit Creek South TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Ballarat Rd Road Bridge	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571011.	Bridge details used to inform bridge representation in TUFLOW model.
Tressel Bridge upstream of Kororoit Creek Rd	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571005.	
Forrest St Road Bridge	Fisher Stewart (2001) Survey Cross Sections of Kororoit Creek Altona to Rockbank. Drawing SES0571009A.	

B.9.2.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table B-27.

Table B-27. Kororoit Creek South TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Barnes rd	0.03	7.81	1	1	30
Teesdale ct	0.12	22.67	0.5	1	30
Forrest St bridge	0.03	34.72	1.17	1	30
Paisley DS	0.46	2.02	0.5	1	30
Paisley US	0.3	1.86	0.5	1	30
Kor Crk trl 1	0.03	25.33	1	1	30
Yallourn st footbridge	0.12	38.35	0.5	1	30
State Route Road Bridge	0.05	36.31	2	1	30
West Gate Fwy Bridge	0.0021	14.3	1.4	0.8	50
Kor Crk trl 2	0.18	9.2	2.6	1	50
Kororoit Creek Viaduct	0.25	17.2	4.38	1	50
Princes Hwy Dual Bridge	0.09	12.75	1.25	0.8	50
State Route Dual Bridge	0.13	10.97	1.5	1.2	50
Millers rd DS	0.08	3.39	1.1	1	30
Millers rd US	0.08	3.39	1.1	1	30
Kororoit crk rd US	0.14	3.536	1.2	1	30
Kororoit crk rd DS	0.14	3.55	1.2	1	30
Geelong Rail Bridge Downstream	0	3.58	2.62	1	30
Geelong Rail Bridge Upstream	0	3.58	2.62	1	30
Tressel	0.05	4.45	0.3	1	30
Somerville rd	0.03	2.696	1.54	1	30
Wright st	0.05	30.21	1.77	1	30
Derby rd	0.29	26.72	1	1	30
Glengala rd	0.07	30.78	1.1	1	30
Jehovahs	0.2	27.95	0.2	1	30
Smart st	0.22	29.74	0.2	1	30
Forrest st Rail Bridge US	0.41	34.62	1.37	1	10
Forrest st Rail Bridge DS	0.41	34.62	1.37	1	10

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Lawrence st	0	36.02	0.99	1	30
West st	0	38.05	0.79	1	30
Altona Rail Bridge	0.31	2	0.6	1	5
Stony Creek Rail Bridge	0	28.215	2.05	1	30
Anderson_rd_bridge_calc_b	0.05	40	1	1	30
Anderson_rd_bridge_calc_a	0.05	39.99	1	1	30
Hampshire_rd_bridge_calc_b	0.14	39.96	1	1	50
Hampshire_rd_bridge_calc_a	0.03	39.4	1	1	50

B.9.2.3 Model roughness

Maps available in Figure B-36, Figure B-37, Figure B-38 show the Kororoit Creek South TUFLOW model Manning's roughness.

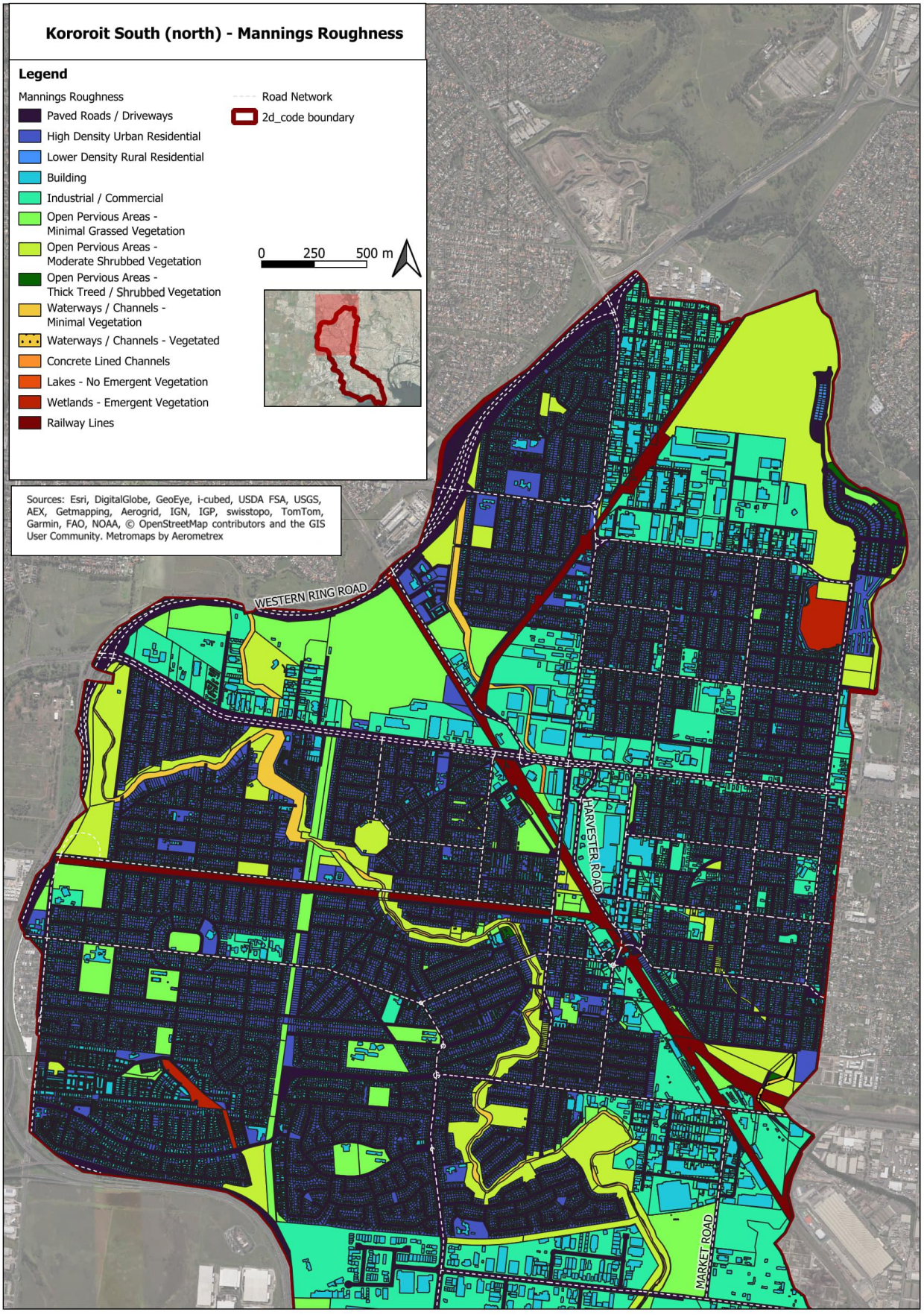


Figure B-36. Kororoit Creek South TUFLOW model Manning's roughness (north).

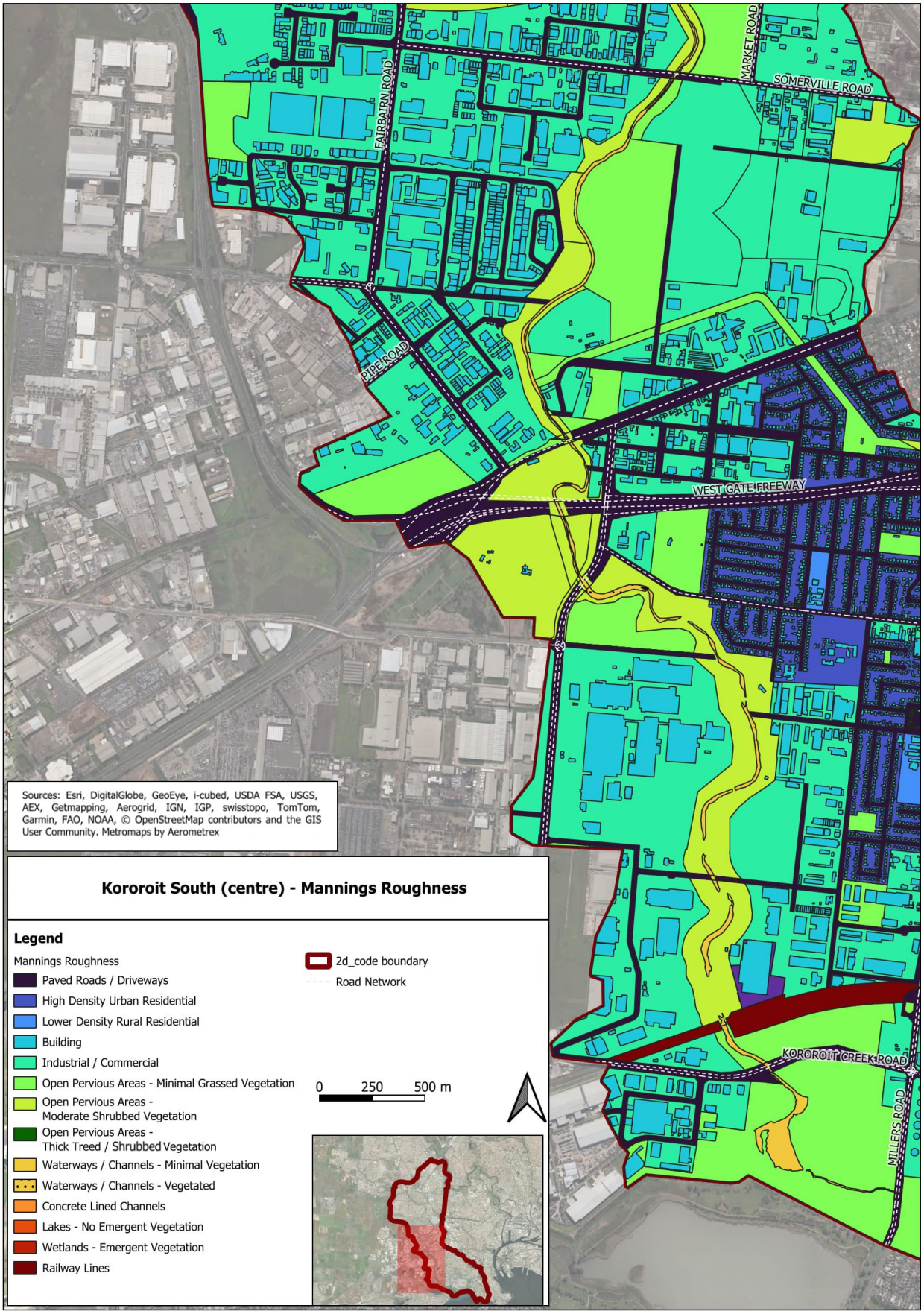


Figure B-37. Kororoit Creek South TUFLOW model Manning's roughness (centre).

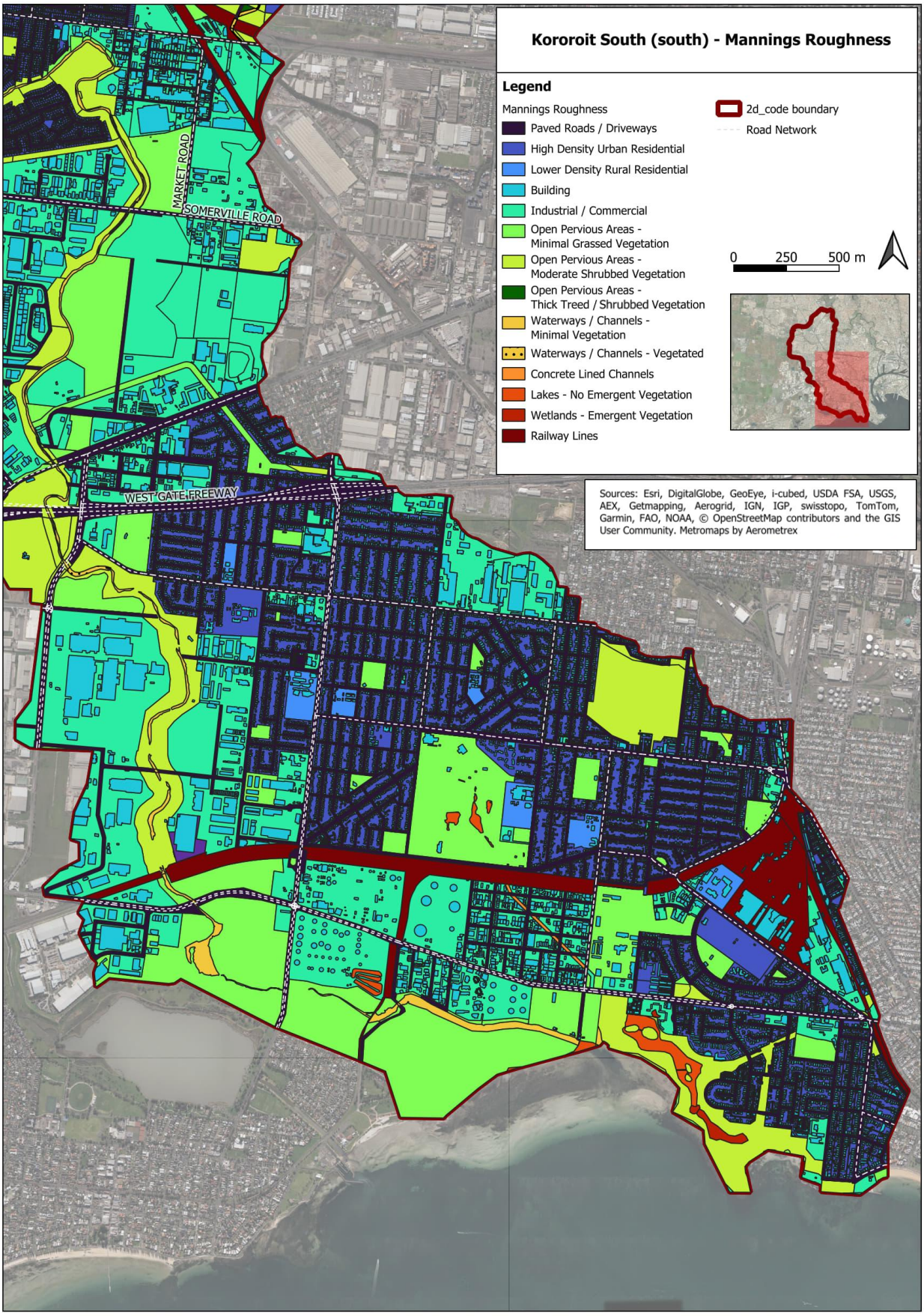


Figure B-38. Kororoit Creek South TUFLOW model Manning's roughness (south).

B.9.2.4 1D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table B-28. A full count of the adopted pit types in the TUFLOW model is listed in Table B-29. Maps of the full drainage network can be found in Figure B-39, Figure B-40 and Figure B-41.

Table B-28. Kororoit Creek South TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Justification/Location
Assumed_93241, Assumed_982, Assumed_98423, A_PP042964	Council	C	0.3		A pipe subnetwork was identified, which had an invalid outlet location, as shown by google Streetview, aerial and lidar. A pipe connection to a nearby pipe subnetwork further downstream was assumed, to allow council pipes to drain to an observable outlet location.
A_23432, A_70842, A_82345, A_8245, Assumed_02356, Assumed_03524, Assumed_7324,	Council	C	0.225-1.5		Council pipe network extended downstream to outlet location at Kororoit Creek. Pipe widths assumed based on upstream pipe dimension.
A_87975, Assumed_02834, Assumed_34635, Assumed_89023	Council	C	0.3-0.675		Pipe snapped to another pipe situated further upstream to ensure continuation of 1d pipe network from the source (1d-2d inlet conn) to likely outlet location.

Table B-29. Kororoit Creek South TUFLOW model 1D drainage adopted pit types.

Pit Type	Count
Side Entry Pit	8932
Double side entry pit	173
Grated Side Entry	703
Grated Pit	1226
Double Grated Pit	6
Junction Pit (node)	2504
Bespoke pits	18

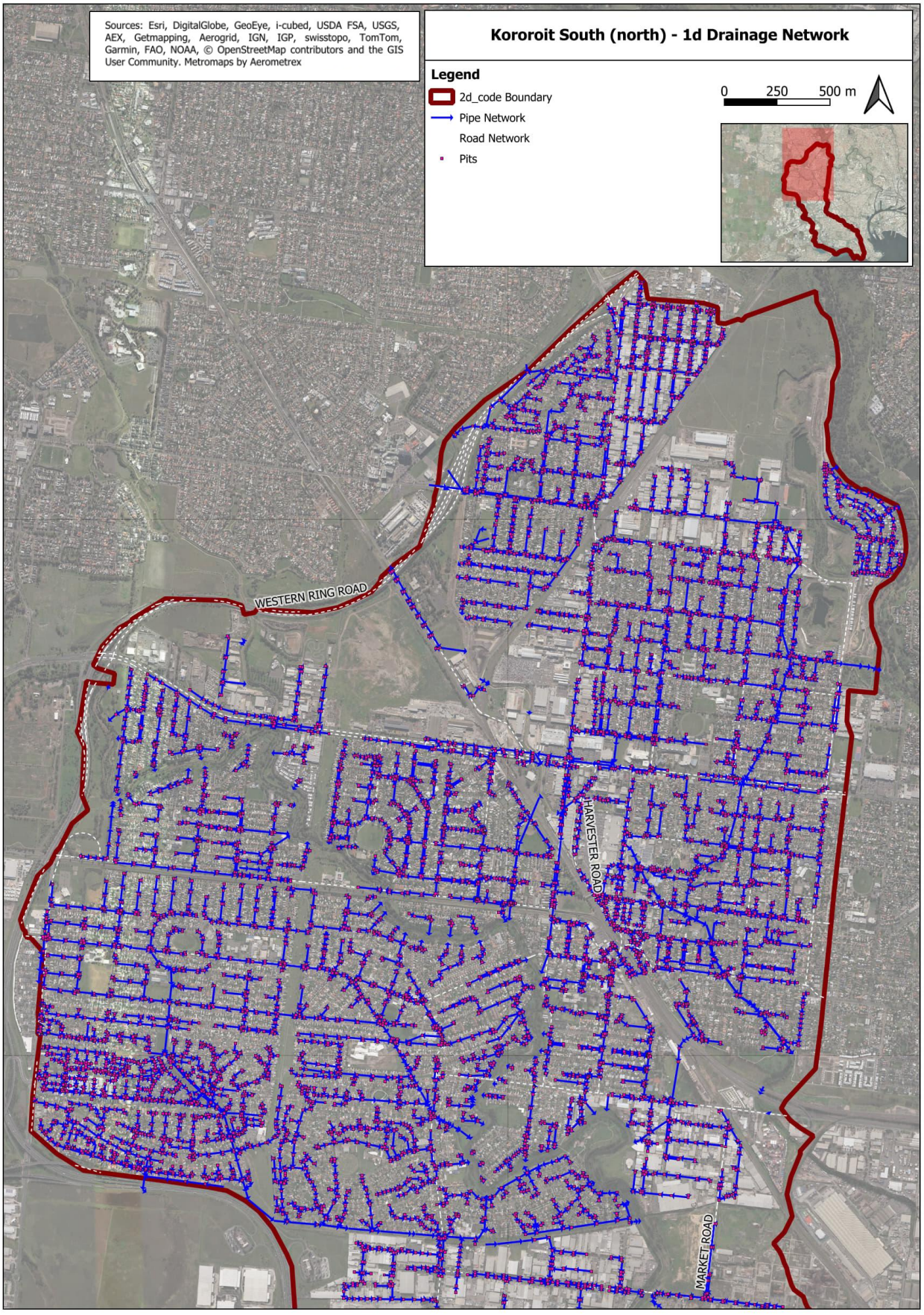


Figure B-39. Kororoit Creek South TUFLOW model 1D drainage network (north).

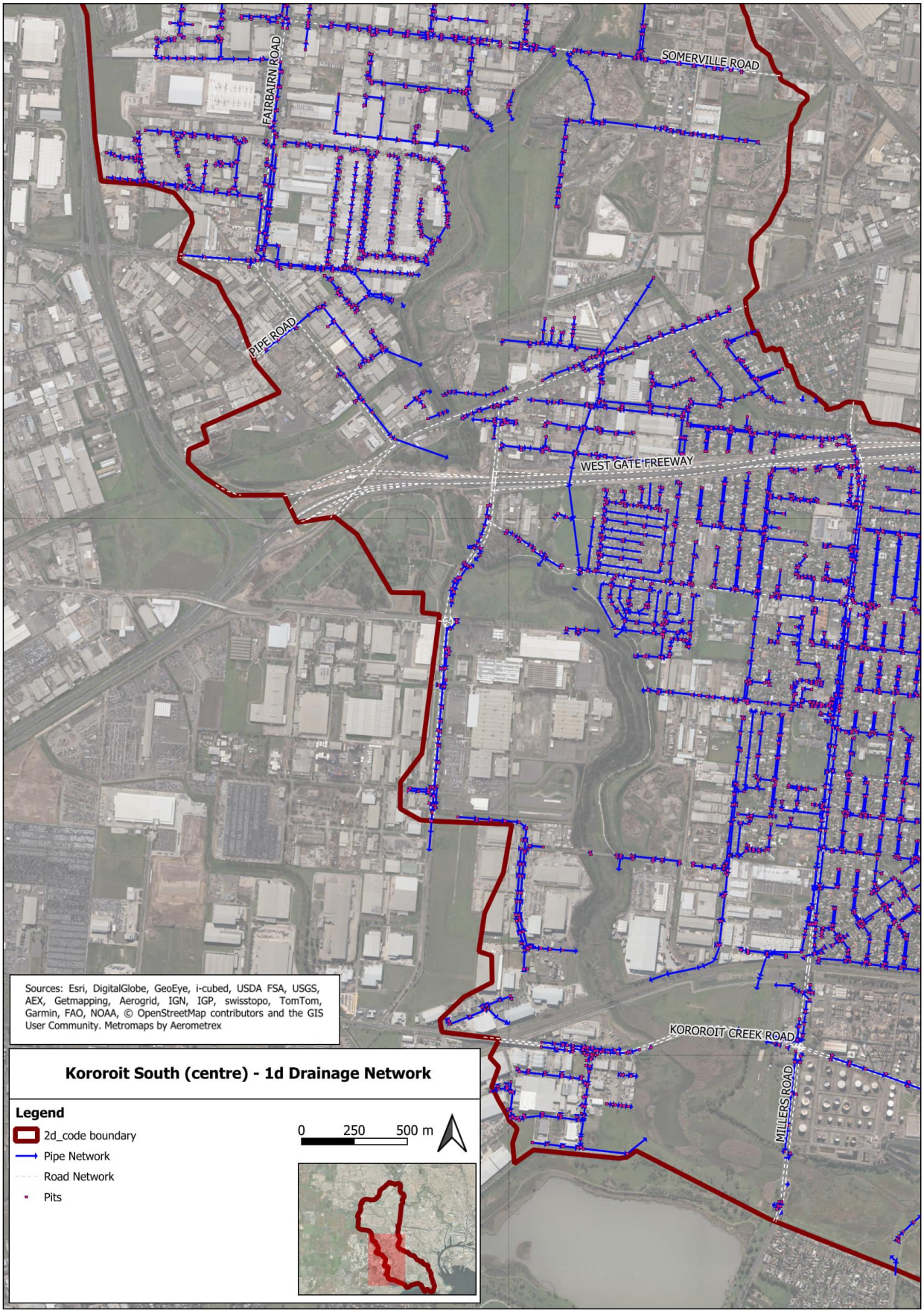


Figure B-40. Kororoit Creek South TUFLOW model 1D drainage network (centre).

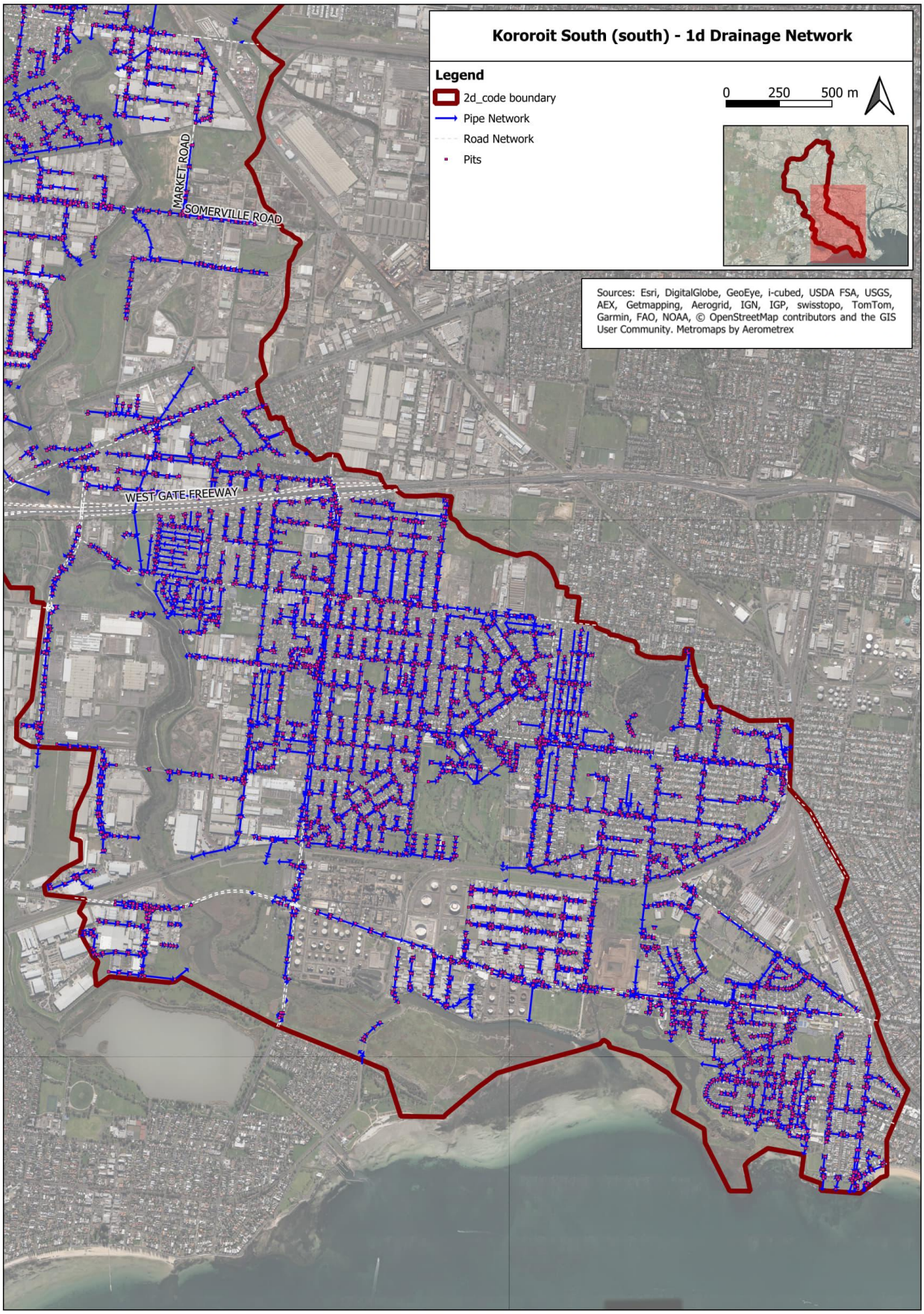


Figure B-41. Kororoit Creek South TUFLOW model 1D drainage network (south).

B.9.2.5 Boundary conditions

The boundary conditions for the Kororoit Creek South TUFLOW model are presented in Figure B-42, Figure B-43 and Figure B-44.

To represent the boundary condition inflows for Kororoit Creek, flows taken from the Study's RORB model were applied at the upstream end of the TUFLOW model at the major tributary inflow point.

As per the Melbourne Water Flood Mapping Projects Specifications, the 10% AEP flow for Kororoit Creek has been used for modelling the 1% and 2% AEP events for the study, and the 20% AEP flow for the 5-20% AEP events. This approach was approved by Melbourne Water.

Static tailwater levels have been adopted at the downstream boundary with Port Phillip Bay, as per Table B-30. HQ (flow vs level) boundaries have been used in locations were there is minor flow interaction with the model boundary.

The study has applied an offset to these inputs so the peak of the flood event in Kororoit Creek approximately matches the peak of the catchment runoff.

Table B-30. Kororoit Creek South TUFLOW model adopted static tailwater levels at Port Phillip Bay for each RORB catchment

Modelling scenario	AEP	Kororoit	Yarra River Outlet
A (Base Case)	1%	1.165	1.168
	2%	1.165	1.168
	5%	1.072	1.075
	10%	1.072	1.075
	20%	1.072	1.075
B (Climate change – sea level rise and increase in rainfall intensity)	1%	1.991	1.995
	10%	1.832	1.835
	20%	1.832	1.835

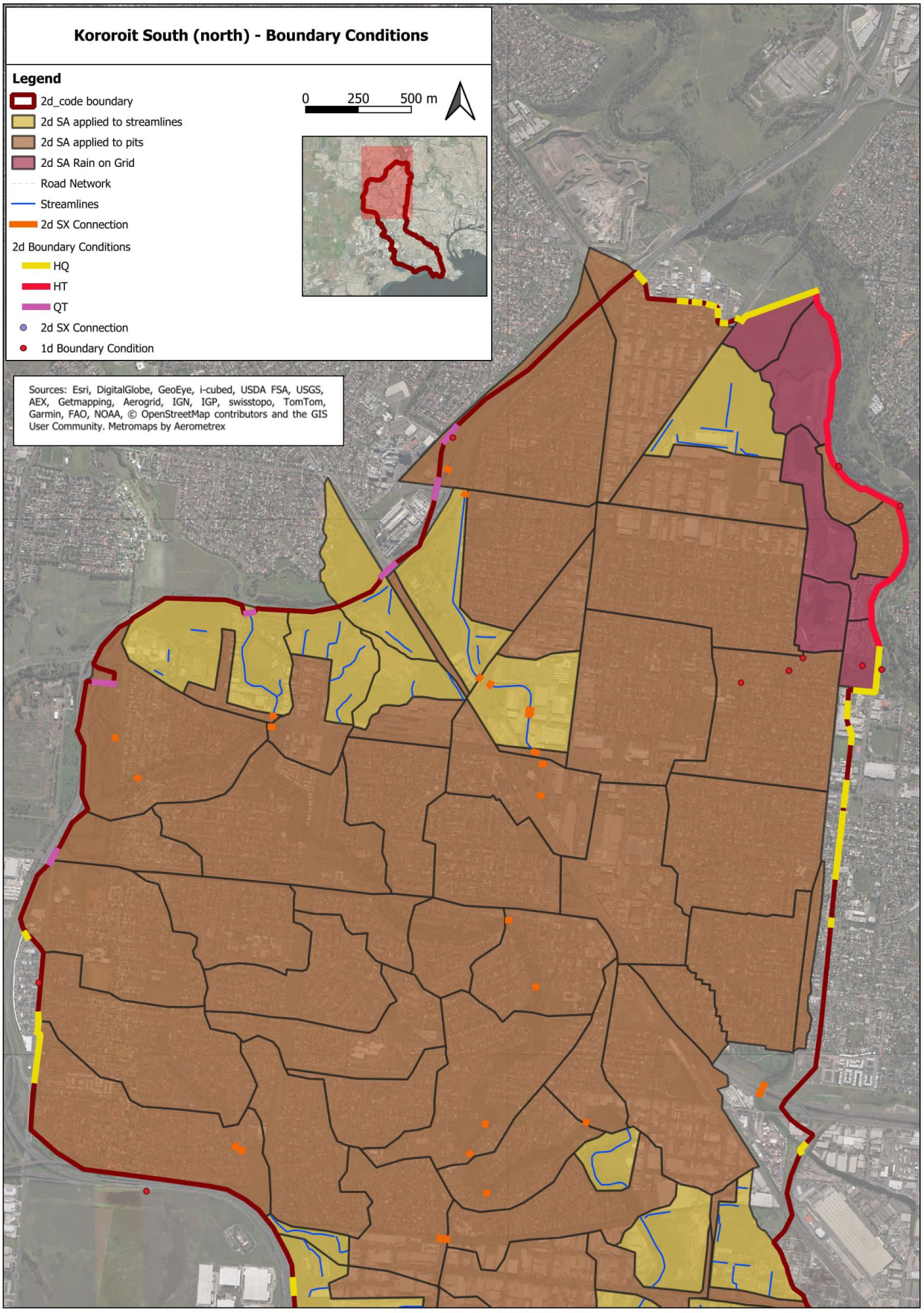


Figure B-42. Kororoit Creek South TUFLOW model boundary conditions (north).

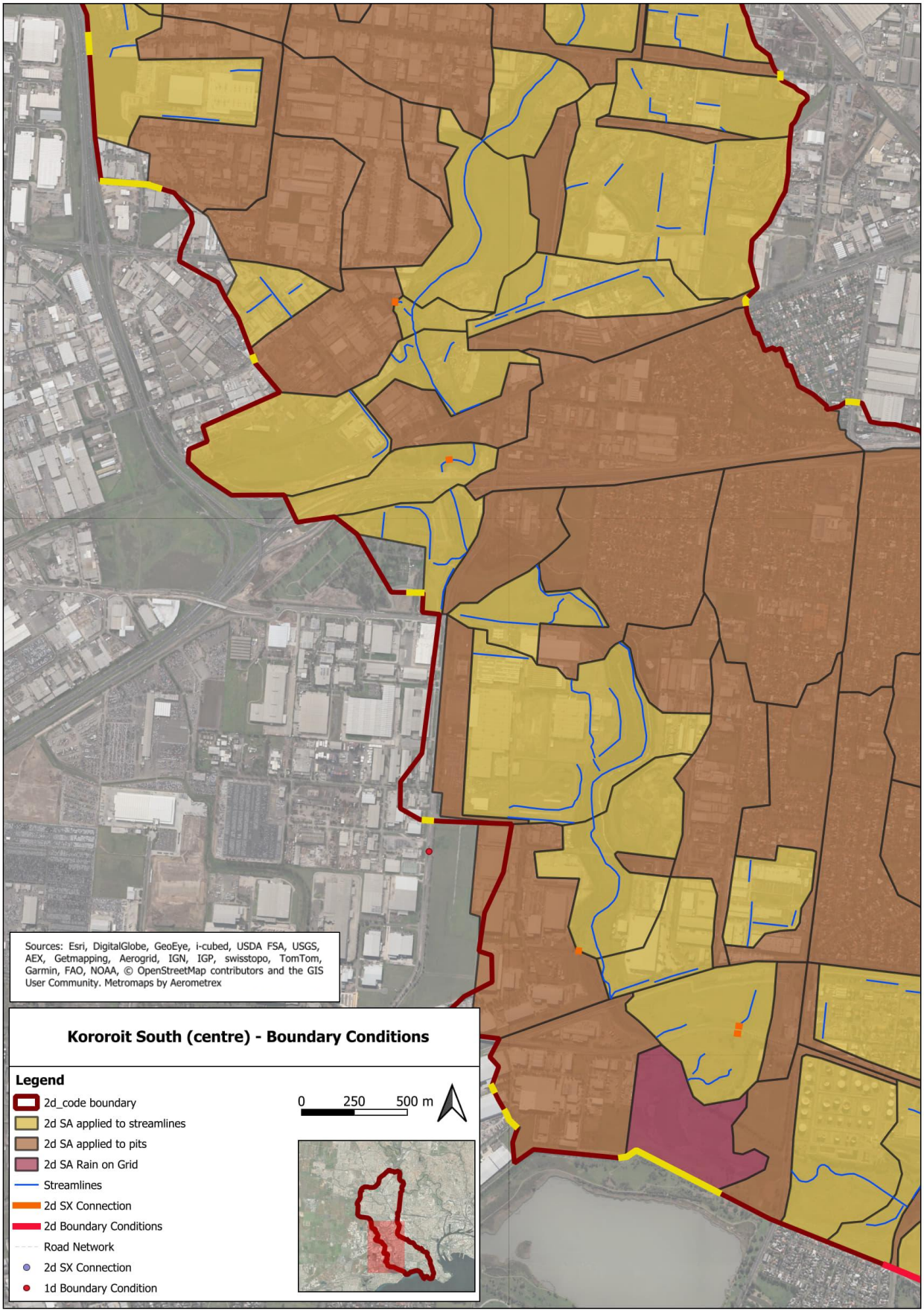


Figure B-43. Kororoit Creek South TUFLOW model boundary conditions (centre).

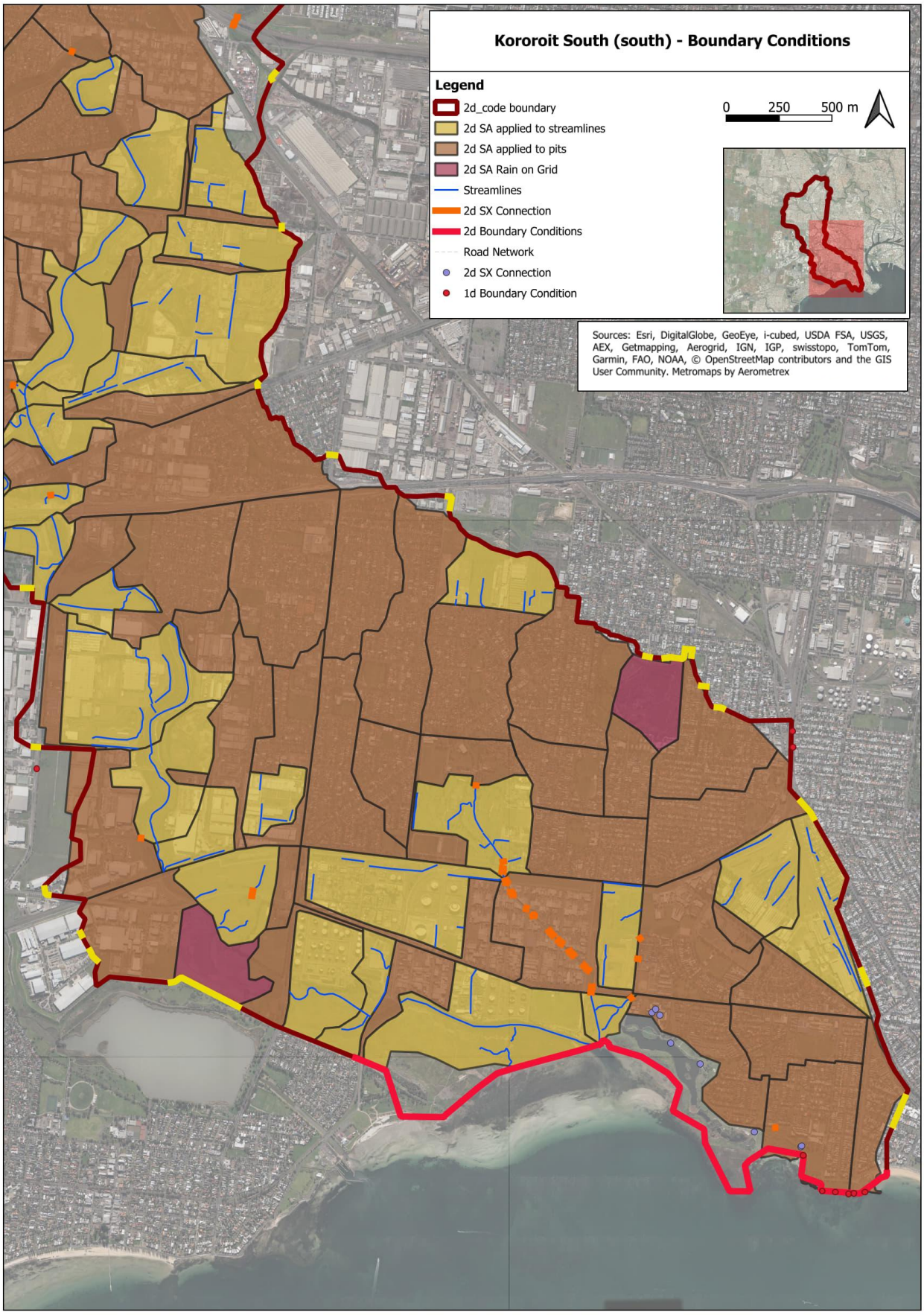


Figure B-44. Kororoit Creek South TUFLOW model boundary conditions (south).

B.9.2.6 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table B-31.

As part of the separation of riverine waterway and council flood mapping for Kororoit Creek, the critical durations selected in RORB were reviewed for application to the TUFLOW model. The 12 hour duration was found to not be critical for any of the Kororoit Creek council areas mapped as part of this report. The 12 hour durations have been removed from the adopted durations summarised in Table B-31.

Table B-31. Adopted Durations, temporal patterns and ARF areas for the Kororoit Creek South model

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP27	1	TP27	1	-		-		-	
30 minute	TP28	1	TP28	1	TP18	1	TP19	1	TP4	1
45 minute	TP26	1	TP26	3	TP19	1	TP19	1	TP8	1
1 hour	TP27	3	TP27	3	TP17	1	-		TP4	1
1.5 hour	TP27	3	TP27	9	TP13	3	TP13	3	TP7	3
2 hour	TP28	9	TP28	9	TP15	9	TP17	9	TP7	9
3 hour	TP27	9	TP27	9	-		-		TP6	9
4.5 hour	TP28	9	TP28	9	-		-		-	
6 hour	TP29	9	TP21	9	TP20	9	TP13	9	-	

B.9.2.7 TUFLOW Checks and Warnings

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks are summarised in Table B-32. They have been assessed and reviewed by Melbourne Water's external reviewer (see Appendix N).

Table B-32. Kororoit Creek South - TUFLOW checks and warning messages

Message	Count	Message content
Message_2470	108	CHECK 2470 - Neither LFC default approach nor Shape_Option is set. Using PORTION approach
Message_1402	11	CHECK 1402 - More than one culvert connected but could not create manhole at Node "XX". Check culvert inverts and directions. Standard check. Not considered critical to resolve for flood mapping purposes.
Message_1313	2	WARNING 1313 - No inlet culvert connected to Manhole "XX". Manhole not used/applied. Believed to be associated with x-connection, which has been setup appropriately.
Message_2118	173	CHECK 2118 - Lowered SX ZC Zpt by XXm to 1D node bed level. Within the Melbourne Water criteria of less than 0.5 m
Message_2210	529	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = XX; Top of First FC Layer = XX. Minor locations were layered flow constrictions (bridges) cross under the terrain. No influence on the results.
Message_1100	42	WARNING 1100 - Structure PP003186 crest/invert (XX) is below bed (XX) of primary upstream channel XX.
Message_3520	1	CHECK 3520 - Found SGS cell face that has minimum Face elevation lower than the minimum cell centre elevations on both sides. Not influence on deliverables.
Message_2370	3	CHECK 2370 - Ignoring coincident point found in Z Shape SGS layer. No impact on flood deliverables.
Message_2077	6	CHECK 2077 - Beginning of 3D line is dangling. Dangling Value = XX. No impact on results.
Message_2078	9	CHECK 2078 - End of 3D line is dangling. Dangling Value = XX. No impact on results.
Message_1191	3	WARNING 1191 - Initial Water Level point is not snapped to a node. No impact on results, these points are artefacts of previous model versions.
Message_1100	42	WARNING 1100 - Structure XX crest/invert (XX) is below bed (XX) of primary upstream channel XX. Typical for a drainage network for pipe inverts to not align with decreasing gradient.

B.9.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section B.8 The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment. This is presented in **Table B-33**.

For Kororoit Creek South model, results from the RORB and TUFLOW models also show that the critical durations are generally consistent between the two models, where the main differences occur at Points 30 and 48, where road embankments create upstream storage, resulting in longer critical durations in TUFLOW. Overall, the assessment confirms that the adopted TUFLOW critical durations are reasonable and consistent with the RORB model outcomes.

Table B-33. Comparison of selected RORB critical durations and TUFLOW critical durations for the 1% AEP with climate change event

RORB location (Figure B 20)	Location (RORB)	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
1	Princes_Hwy_Inflow	20 min	30 min	
2	Sydenham_Rd	30 min	30 min	
3	Kingsley_St	30 min	20 min	
4	Wood_St	1 hour	1.5 hour	
5	Bunting_Rd	30 min	1.5 hour	Likely influenced by floodplain storage associated with industrial earthworks.
6	Mason_St	30 min	30 min	
7	Myrtle_St	45 min	20 min	
8	Furlong_Rd	30 min	30 min	
9	McIntyre_Rd	30 min	30 min	
10	Robinsons_Rd_Inflow	20 min	30 min	
11	Walker_Cl	20 min	45 min	
12	Hall_St	30 min	1.5 hour	Influenced by the interaction with Kororoit Creek
13	Western_Ave	10 min	45 min	
14	Percy_St	30 min	30 min	
15	Kororoit_Creek_Rd	30 min	4.5 hour	Influenced by the tidal assumptions in the TUFLOW model
16	Hume_Dr	20 min	30 min	
17	Woods_St	30 min	30 min	
18	St_Albans_Rd	45 min	45 min	
19	Gum_St	45 min	45 min	
20	Biggs_St	30 min	30 min	
21	Middlesex_St	30 min	30 min	
22	Nova_Ave	30 min	45 min	
23	Ross_Rd	1.5 hour	1.5 hour	
24	Christie_St_Drain	30 min	1 hour	
25	Western_Hwy	30 min	1.5 hour	
26	Kings_Rd	30 min	45 min	
27	Federation_Trail	30 min	1.5 hour	
28	Paisley_Park	45 min	45 min	
29	Silverton_Cl	30 min	30 min	
30	Callaway_RB	45 min	1.5 hour	
31	Walter_St	30 min	45 min	

RORB location (Figure B 20)	Location (RORB)	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
32	Millers_Rd_Drain	30 min	3 hour	Influenced by Kororoit Creek
33	St_Albans_West_Drain	45 min	45 min	
34	Station_Ave	45 min	1hour	
35	Fairbairn_Rd	30 min	1hour	
36	Tilburn_Rd	1.5 hour	45 min	
37	Yeats_Dr	20 min	30 min	
38	Ballarat_Rd	30 min	30 min	
39	Denton_Ave	30 min	1 hour	
40	Station_Rd	45 min	1.5 hour	
41	Gladstone_St	30 min	1.5 hour	
42	Frost_RB	1.5 hour	1 hour	
43	Hygeia_Ave	30 min	45 min	
44	Taylors_Rd_Inflow	30 min	30 min	
45	Kurung_Dr	1 hour	1 hour	
46	Crofts_Reserve	30 min	30 min	
47	Jones_Ct	1.5 hour	1 hour	
48	Rosshire_Rd	30 min	1.5 hour	
49	East_Esplanade	1 hour	4.5 hour	Influenced by the rail embankment
50	Glengala_Drain	1.5 hour	1.5 hour	
51	Grassy_Point_Rd	30 min	1.5 hour	
52	Mulhall_Dr	30 min	1.5 hour	
53	Gillespie_Rd	30 min	1 hour	
54	Cunningham_Chase	30 min	1 hour	
55	James_St	30 min	1.5 hour	
56	St_Albans_East_Drain	45 min	1.5 hour	
57	PAS@Ross_Rd	1 hour	1.5 hour	
58	Pennell_Ave	30 min	1.5 hour	
59	Meadowbank_Dr	1 hour	1 hour	
60	Serpentine_RB	4.5 hour	-	Outside the TUFLOW boundary
61	Gladstone_RB	1.5 hour	1.5 hour	
62	Chisholm_RB	6 hour	-	Outside the TUFLOW boundary
63	Kevin_Flint_Reserve	2 hour	1.5 hour	
64	PAS@Outlet	1 hour	20 min	
65	Gilmour_RB	1.5 hour	1.5 hour	
66	Westwood_Dr_Inflow	6 hour	6 hour	

RORB location (Figure B 20)	Location (RORB)	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
67	Caroline_Springs_RB	1.5 hour	-	Outside the TUFLOW boundary
68	Jones_Creek	3 hour	3 hour	
69	STN@Outlet	2 hour	3 hour	
70	Burnside_Inflow	12 hour	-	The TUFLOW model does not simulate the peak flows in the Kororoit Creek as this will be captured in a separate stud.
71	Burnside_Interstation	12 hour	1 hour	
72	KOR@Deer_Park	12 hour	1.5 hour	
73	KOR@Forrest_St	12 hour	30min	
74	KOR@Brooklyn	12 hour	3 hour	
75	KOR@Outlet	12 hour	30 min	

B.9.4 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

B.10 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.

GHD (2002) Waterway Mapping Project, Kororoit Creek.

GHD (2016) Melbourne Water Corporation Retarding Basin Upgrade Program Risk Assessment of Frost Drive Retarding Basin.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal pattens of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

RPV (Rail Project Victoria) (2021) AJM JV Melbourne Airport Rail Technical Advice Note – Stony Creek Hydrology.

RPV (Rail Projects Victoria) (2020) AJM JV Geelong Fast Rail Technical Advice Note - Kororoit Creek (Lower) Hydrology Modelling.

The Bureau of Meteorology (2022) Design Rainfall Data System

The Bureau of Meteorology (2022) Rating table data – Deer Park and Brooklyn

The Bureau of Meteorology (2022) Water Data Online, Kororoit Creek at Brooklyn and Kororoit Creek at Deer Park, http://www.bom.gov.au/waterdata/

Appendix C. Stony Creek

The waterway for Stony Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

Appendix C. Stony Creek

This appendix details the RORB and TUFLOW model development for the Stony Creek and full technical details of adopted parameters and results.

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C.1 Catchment Description and Study Area

The Stony Creek Catchment is an urban catchment to the west of Melbourne, with a total catchment area of 35 km^2. The catchment primarily consists of urban/impervious/heavily modified land use.

The only stream gauge located on Stony Creek is situated at Spotswood (230112A). The gauge is owned and operated by Melbourne Water and was established in 1998 on Stony Creek near the end of Bena Street, just upstream from the Williamstown Road culvert crossing. This gauge is of relevance to this Study for RORB model calibration purposes, given its location within the Hobsons Bay Council LGA. The catchment and location of the gauge used to calibrate the RORB model parameters to observed data are shown in Figure C-1.

The Stony Creek catchment model includes an area that overlaps with the Kororoit Creek model due to the presence of diversions that transfer flows out of the Stony Creek catchment and into Kororoit Creek. In addition, a supplementary subcatchment (Subcatchment 9880) was included in the model to capture runoff contributing to the Stony Creek TUFLOW model. Further details regarding Subcatchment 9880 and its linkage to the Stony Creek model are provided in Appendix G.

The waterway for Stony Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

C.1.1 Previous RORB Model

An existing RORB model for the Stony Creek catchment was accessed for use in this Study. This model was originally developed by Water Technology (2013) and updated by Engeny (2019) before RPV updated it from ARR 1987 to ARR 2019 and Melbourne Water Projects Specifications (RPV, 2021). The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Stony Creek TUFLOW models covering Brimbank Council and Hobsons Bay Council LGA. The updates undertaken to the model are outlined in the sections below.

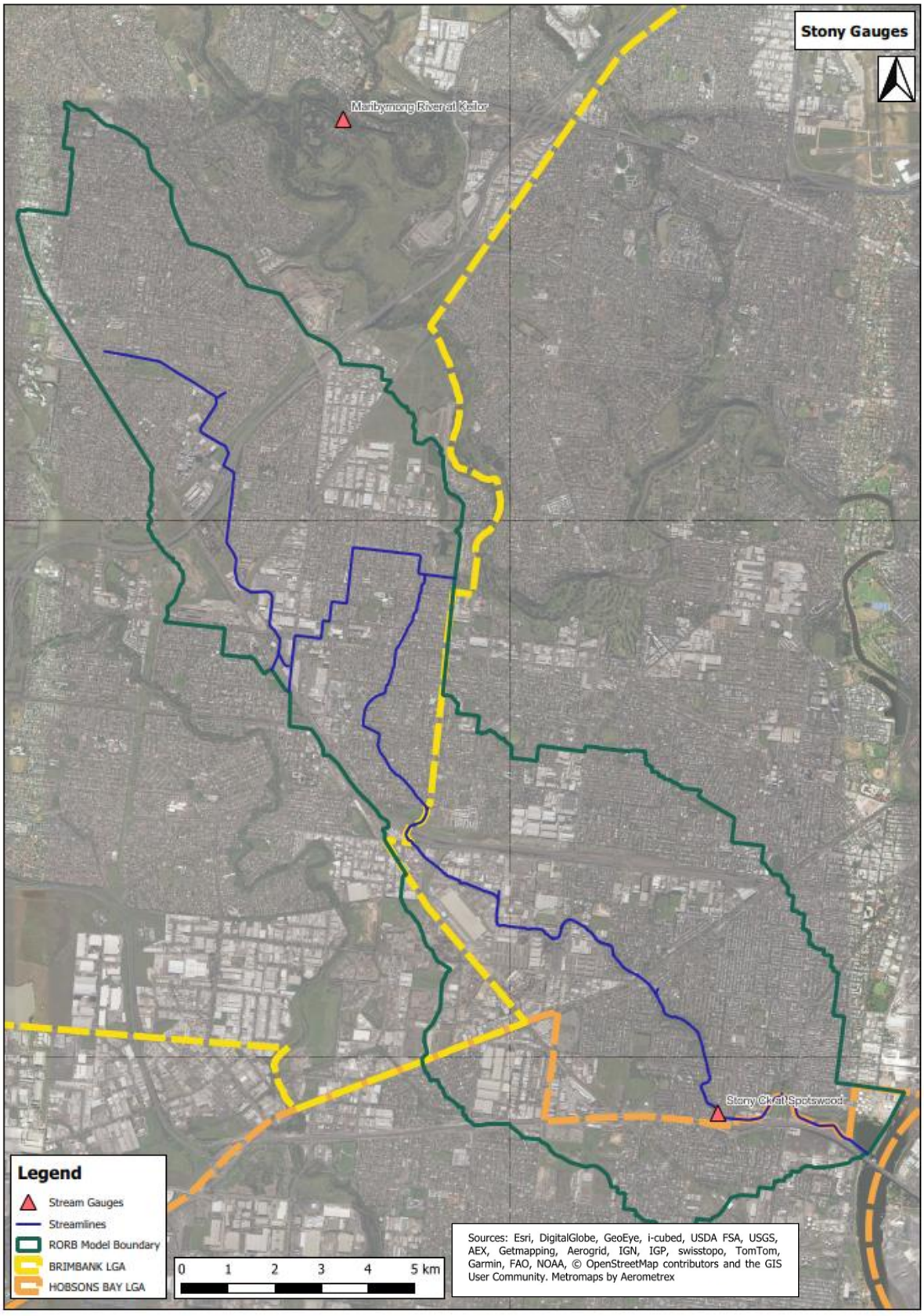


Figure C-1: Stony Creek catchment and location of the gauge used to calibrate the Study RORB model.

C.2 RORB Model Setup

The development of the RORB model is represented in Figure C-2 and described in the following sub-sections.

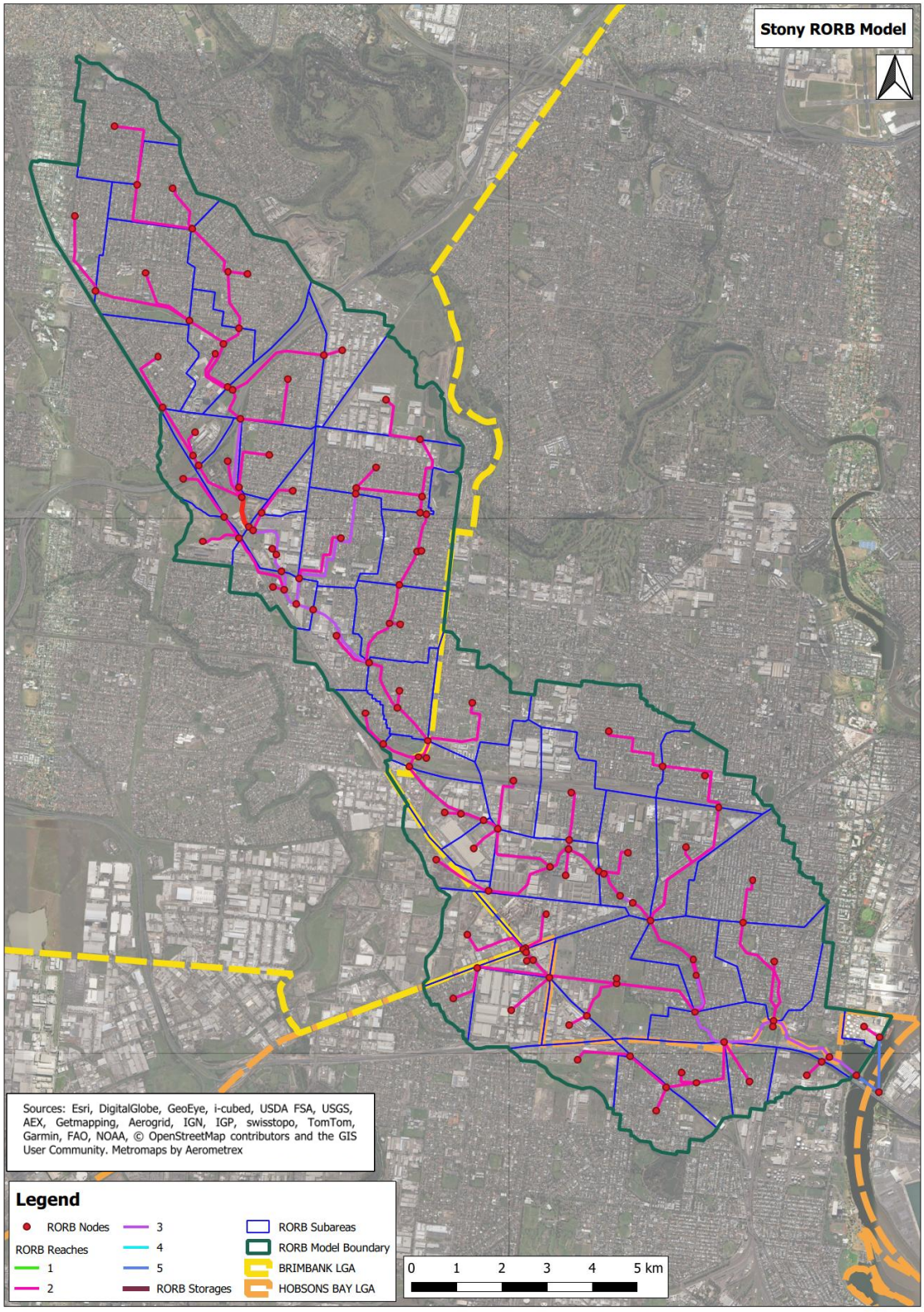


Figure C-2: Stony Creek RORB model setup.

C.2.1 Catchment and Subarea Boundaries

A review of previous RORB models identified the need to re-delineate large areas to reduce and standardise the size of subareas in preparation for extraction of hydrographs for input into TUFLOW. Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas, or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Catchment delineation also considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

The final catchment and subarea boundaries are shown in Figure C-2. An additional subcatchment (Subcatchment 9880) was included in this model to capture runoff from an area not represented in this model, with further details provided in Appendix G.

C.2.2 Node-link network

The node-link network shown in Figure C-2 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

C.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
    - Type 1 – Natural channels, used for major creek reaches
    - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
    - Type 3 – Lined channel or pipe – these were used to represent flowpaths associated with major lined channels
    - Type 4 – Drowned – these were not used in the model
    - Type 5 – Dummy – used to connect independent catchments (i.e. at Port Philip Bay) to a single outlet node

C.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB), as listed in Table C-1.

Table C-1 Storages in the Stony Creek RORB model.

Storage	Data source and checks
Gilmour Road (also included in the Stony Creek model due to models overlap)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Benbow Street (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Francis Street (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Geelong Road (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Railway Bypass (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Western Ring Road (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.
Laurel Street (major floodplain storage)	Storage details adopted as per RPV model (2021), represented using S-Q/S-H flow relationships. No further information available for further checks or updates.

C.2.5 Diversions

Three diversions from Stony Creek into other catchments were included in the previous RPV model. The diversions represent MW pipes, three of which divert water out of the Stony Creek catchment (one into Maribyrnong River and two into Stony Creek at Anderson Road). RPV (2021) included them as outflows, extracting flow from the running hydrograph up to their pipe capacity, which was calculated and verified using TUFLOW. These were retained and adopted in the RORB model for the current Study. One large MW diversion pipe trunk drain, also present in the Stony Creek RORB model for the Study, was also retained.

It should be noted that modelling the Stony Creek catchment has demonstrated that the majority of flows generated upstream of these diversions are diverted to Stony Creek up to the 1% AEP.

Table C-2 Diversions in the Stony Creek RORB model

Diversion	RPV (2021) Calculated and Adopted Pipe Capacity (m^3/s)
Anderson Street diversion (4120/01)	18.2
Anderson Street diversion (4120/02)	50.4
Cumberland Street diversion (4248/01)	10.0
Westmoreland Road pipe diversion (4121)	3.4

C.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

C.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

C.2.8 RORB version

RORB version 6.47 was used for modelling.

C.3 Flood Frequency Analysis (FFA)

An at-site Flood Frequency Analysis (FFA) for Stony Creek at Spotswood Gauge was undertaken according to the guidelines provided in Book 3 Chapter 2 of ARR 2019. The FFA was undertaken using the Flike software package. Flike provides a Bayesian framework for comprehensive at-site flood frequency estimation that allows the inclusion of ungauged historical events.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

1. Prepare data:
    a. Collect gauged streamflow data
    b. Collect historic data, including the review of previous studies
    c. Undertake standard data checks on the stream flow data including checking error codes, cataloguing data gaps, undertaking visual inspections and review the rating curve
    d. Determine the water year
    e. Extract the annual maximum series and check peaks for independence
2. Using Flike, fit an extreme value distribution to the annual maximum series, including the influence of:
    a. Historic data (data that exists beyond the extent of the annual maximum series)
    b. Censoring low flows with a multiple Grubbs Beck test

A summary of the FFA and findings are included below.

C.3.1 Annual Maxima Flows

The details of data available from the Spotswood gauge is shown in Table C-3: . An annual maximum flow series of 24 years were used as presented in Figure C-3. An analysis of the flow series indicated that the calendar year can be used as the water year.

Table C-3: Data availability for Spotswood gauge.

Gauge	Period of record	Missing years of data
Spotswood (230112A)	1998 – 2022 (24 years)	None

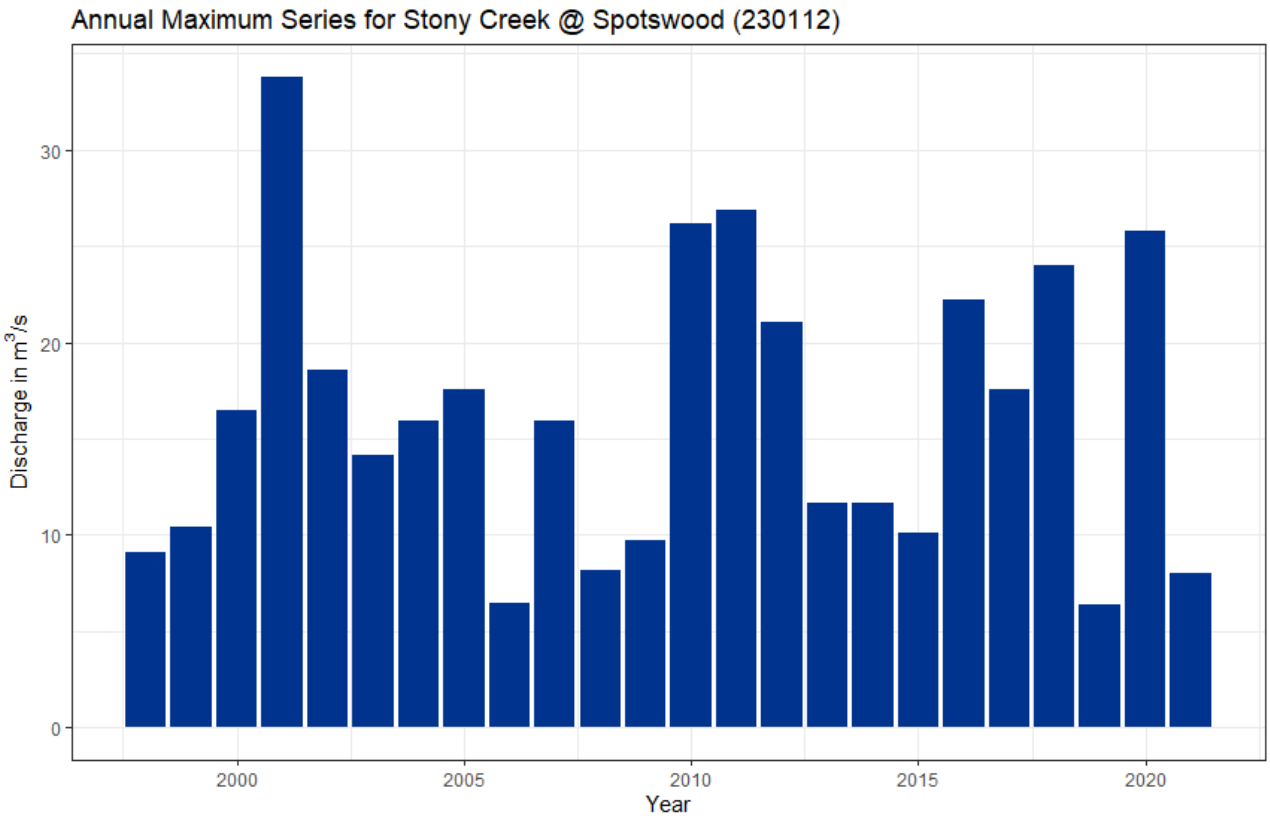


Figure C-3: Annual Maximum series for Stony Creek at Spotswood.

C.3.2 Rating Curve Review

To ensure that the rating tables were producing reasonable flow estimates for high flows, a review of the rating tables obtained for the Spotswood gauge 230112A (Bureau of Meteorology, 2022) was carried out. The rating curve is shown in Figure C-4.

The stream gauge has approximately 24 years of complete record and has had 52 separate stream gauge measurements taken over its history. The majority of these measurements (i.e. 67%), have been taken in low flow conditions (gauge height of less than 0.2 m and flow of less than 0.1 m^3/s). The highest stream gauge measurement at the site was taken during the March 2001 flood event, which is the flood of record at the site. The stream gauge height was measured as 1.88 m with a corresponding flow measurement of 19.7 m^3/s. This results in a rating ratio (maximum observed flow/maximum measured flow) for this stream gauge of 58%, which is considered reasonable for a small urban catchment considering its quick runoff response time.

The extent of the rating curve in Figure C-4 illustrates the fact that the downstream Williamstown Road culvert influences the curve above 3.0 m gauge height. The obvert of the culvert is projected onto the plot. There is no evidence to suggest that the latest rating curve at the Spotswood Gauge is unreliable up to the obvert of the Williamstown Road culvert. The current rating curve does not extend beyond this height but a detailed hydraulic assessment would be required to define the rating to above the Williamstown Road crest level due to the complex hydraulic condition that would be generated as the flow impacts the culvert superstructure.

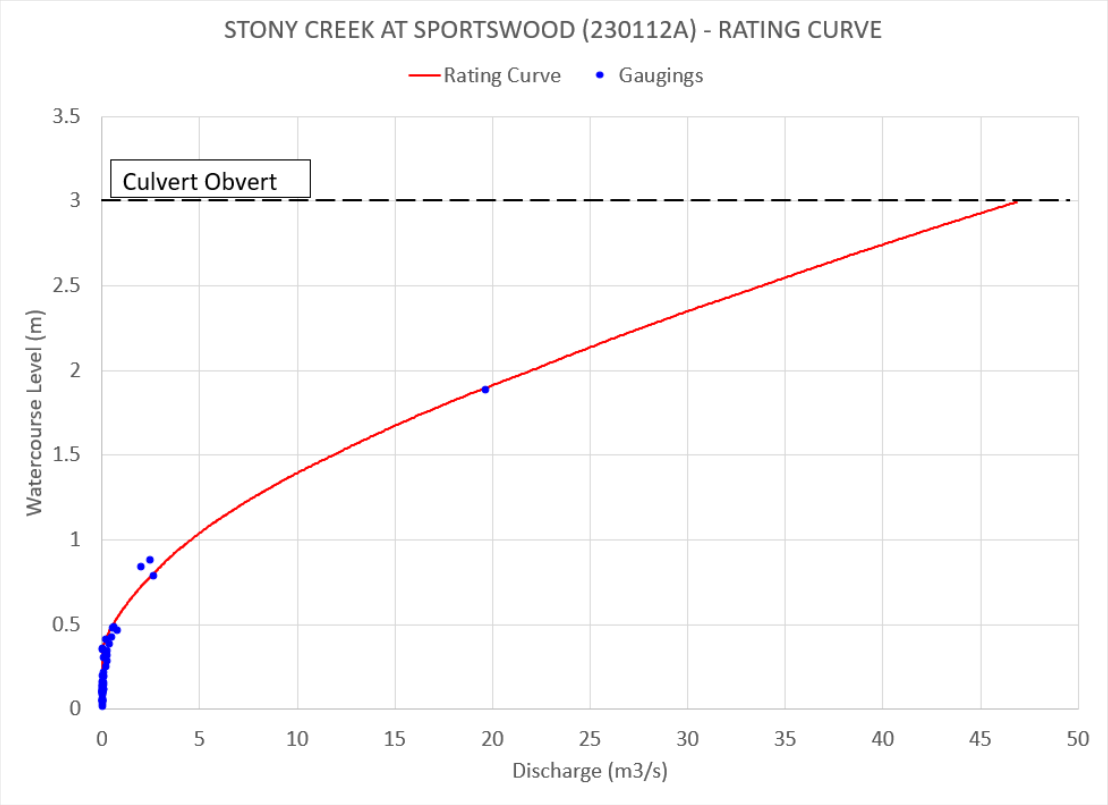


Figure C-4: Rating table for Stony Creek at Spotswood

C.3.3 Historic information

During the previous FFA undertaken by RPV (2021), it was recognised that the record length at the Spotswood gauge is quite limited and that other notable historical events have occurred prior to the commencement of records at this site. It was noted that there were major floods that occurred in Yarraville in 1891, 1919, 1934, 1974, 1983, 1993, 2001, 2005 and 2011; six of those prior to the commencement of the Spotswood gauge record. These floods were included in the RPV FFA in accordance with the ARR 2019 procedures for dealing with known historic events, but it was noted that the results from that FFA did not change significantly. As such, the original at-site FFA was adopted for the RPV assessment. This approach was taken forward for the current Study given it was confirmed that inclusion of these events would not significantly change the predicted flood quantiles.

C.3.4 Removal of Probable Influential Low Flows

From the observed values, no Probable Influential Low Flows (PILFs) were identified for the Spotswood gauge using the multiple Grubbs Beck Test incorporated in Flike, however in previous work undertaken by RPV (see Section C.1.1 above) a threshold of 10m^3/s was applied. This was also applied in the FFA for this Study, which resulted in censoring six years of flood peaks.

C.3.5 Flood Frequency Analysis Results

The results of the at-site FFA for the Spotswood gauge are shown in Table C-4 and Figure C-4. The results demonstrate that the fitted LP3s are an acceptable fit to the data.

Table C-4: Stony Creek at Spotswood FFA expected quantiles.

AEP 1 in Y	FFA Quantile (m^3/s)	Lower 90% Continuing Loss (m^3/s)	Upper 90% Continuing L (m^3/s)
5	22.4	18.5	27.4

AEP 1 in Y	FFA Quantile (m^3/s)	Lower 90% Continuing Loss (m^3/s)	Upper 90% Continuing L (m^3/s)
10	27.8	22.6	36.4
20	33.1	26.1	48.5
50	40.0	29.8	68.1
100	45.4	32.0	89.1

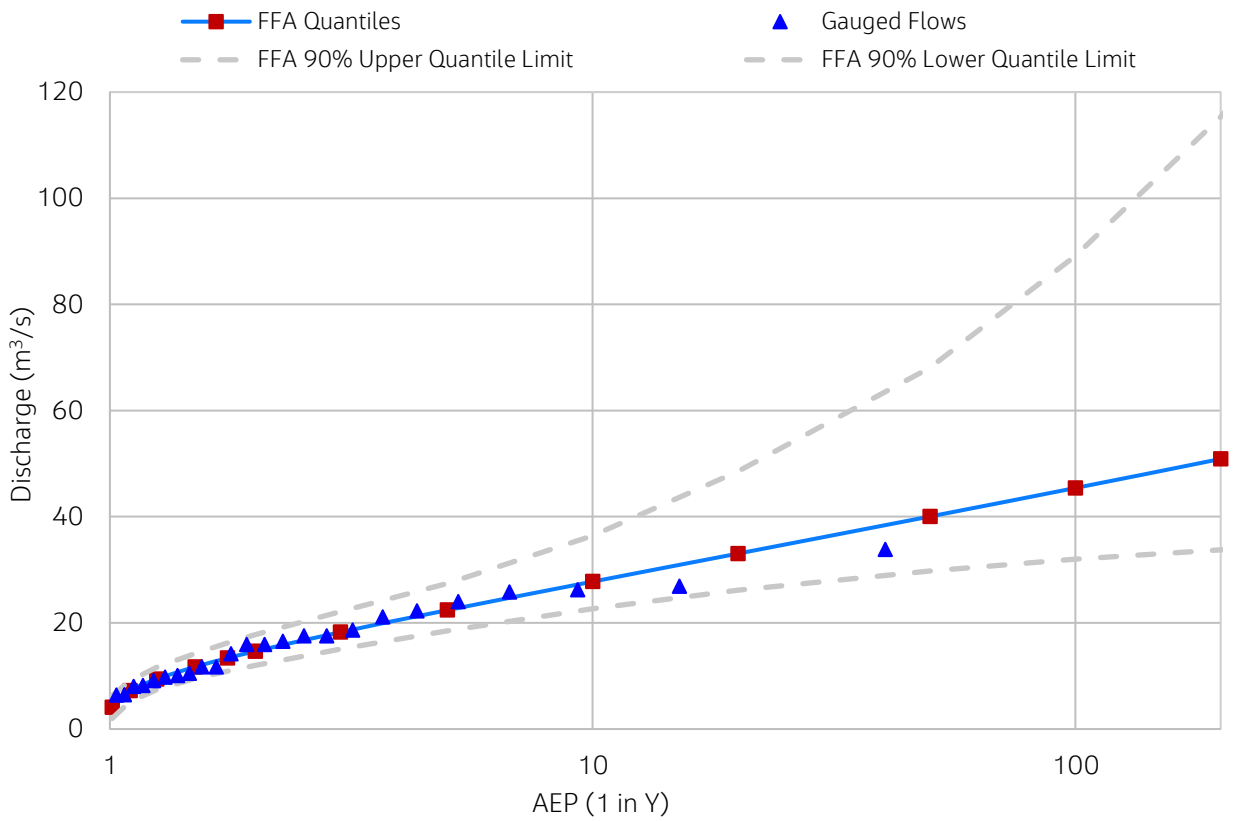


Figure C-5: Stony Creek at Spotswood FFA results.

C.3.6 Comparison to previous estimates

The current FFA results were compared to the flood quantiles estimated by RPV (2021) (shown in Table C-5). The estimates produced from the current study are lower than those from the previous work. This is due to:

- The additional 2 years of data
- The exclusion of prior parameters, which were previously used in Flike to produce the RPV (2021) FFA results.

The FFA results from the current study are therefore considered reasonable, in alignment with expectations and observed/reviewed data.

Table C-5: Stony Creek at Spotswood FFA comparison to previous estimates

AEP 1 in Y	RPV (2021) FFA Quantile (m^3/s)	Current FFA Expected Quantile (m^3/s)
5	22.3	22.4

AEP 1 in Y	RPV (2021) FFA Quantile (m^3/s)	Current FFA Expected Quantile (m^3/s)
10	27.6	27.8
20	32.5	33.1
50	38.8	40.0
100	43.3	45.4

C.4 Baseflow

The gauge data at Spotswood (see Figure C-6) was reviewed and no evidence of significant baseflow contribution was found. This demonstrated that baseflow contribution was not a significant factor in the flooding process at the site as expected in an urban catchment and baseflow was therefore not considered further.

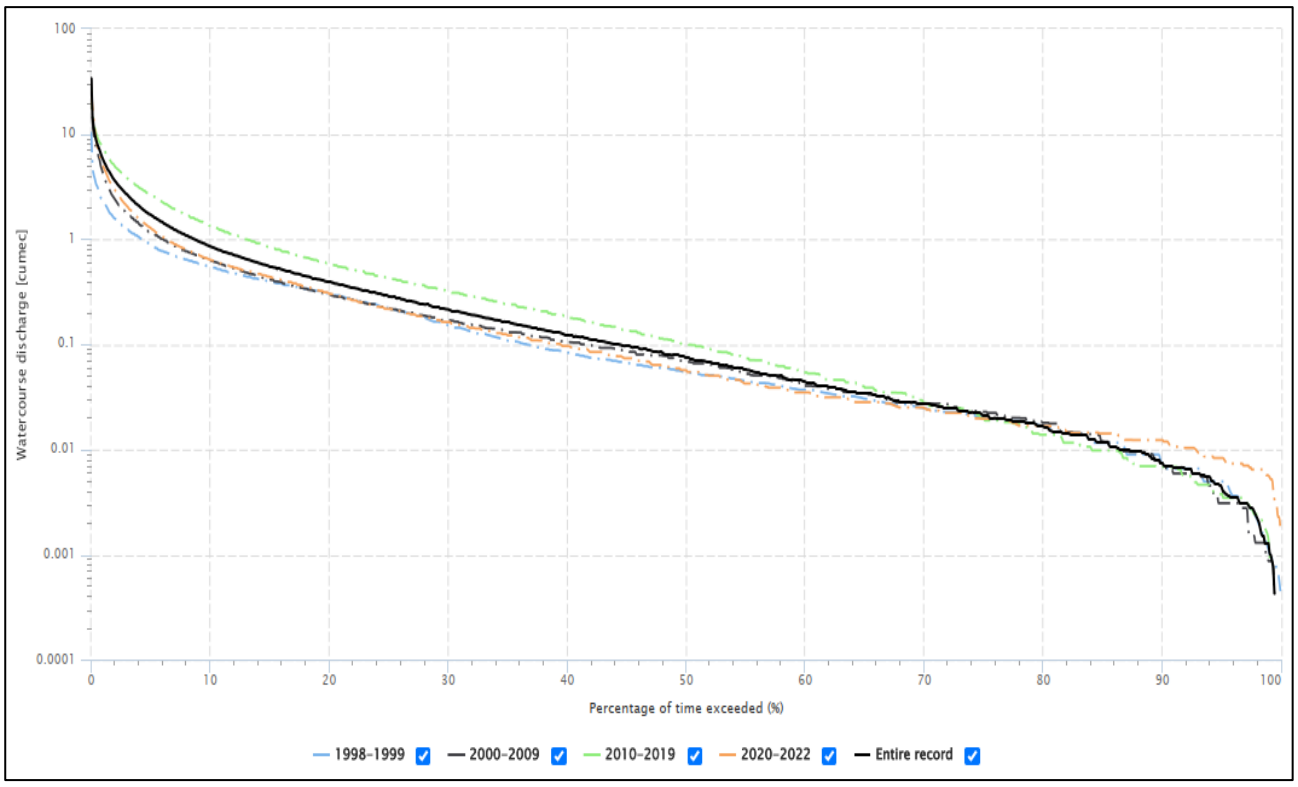


Figure C-6: Flow duration curve for Stony Creek at Spotswood (source: Water Data Online; The Bureau, 2022)

C.5 RORB design inputs

C.5.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (-37.787, 144.848) was sourced from the Bureau of Meteorology (Appendix I). As per the Melbourne Water Flood Mapping Projects Specifications, rainfalls were increased by 18.5% to establish climate change rainfalls.

C.5.2 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations below the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

C.5.3 Temporal Patterns

Point temporal patterns were obtained from the ARR DataHub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies) and adopted given the catchment area is smaller than 75 km^2. Temporal patterns were filtered for embedded bursts using the option in RORB.

C.5.4 Spatial Pattern

As the catchment area is greater than 20 km^2 a spatial pattern was applied to the RORB model. It is noted that during the calibration process the spatial pattern was compared against a uniform spatial pattern. Results showed no significant change and therefore a uniform pattern was applied. The spatial variation of rainfall depth for the 1% AEP 30 minute and 60 minute storms are presented in Figures C-7 and Figure C-8. Generally there is a minor variation in rainfall depth across the catchment.

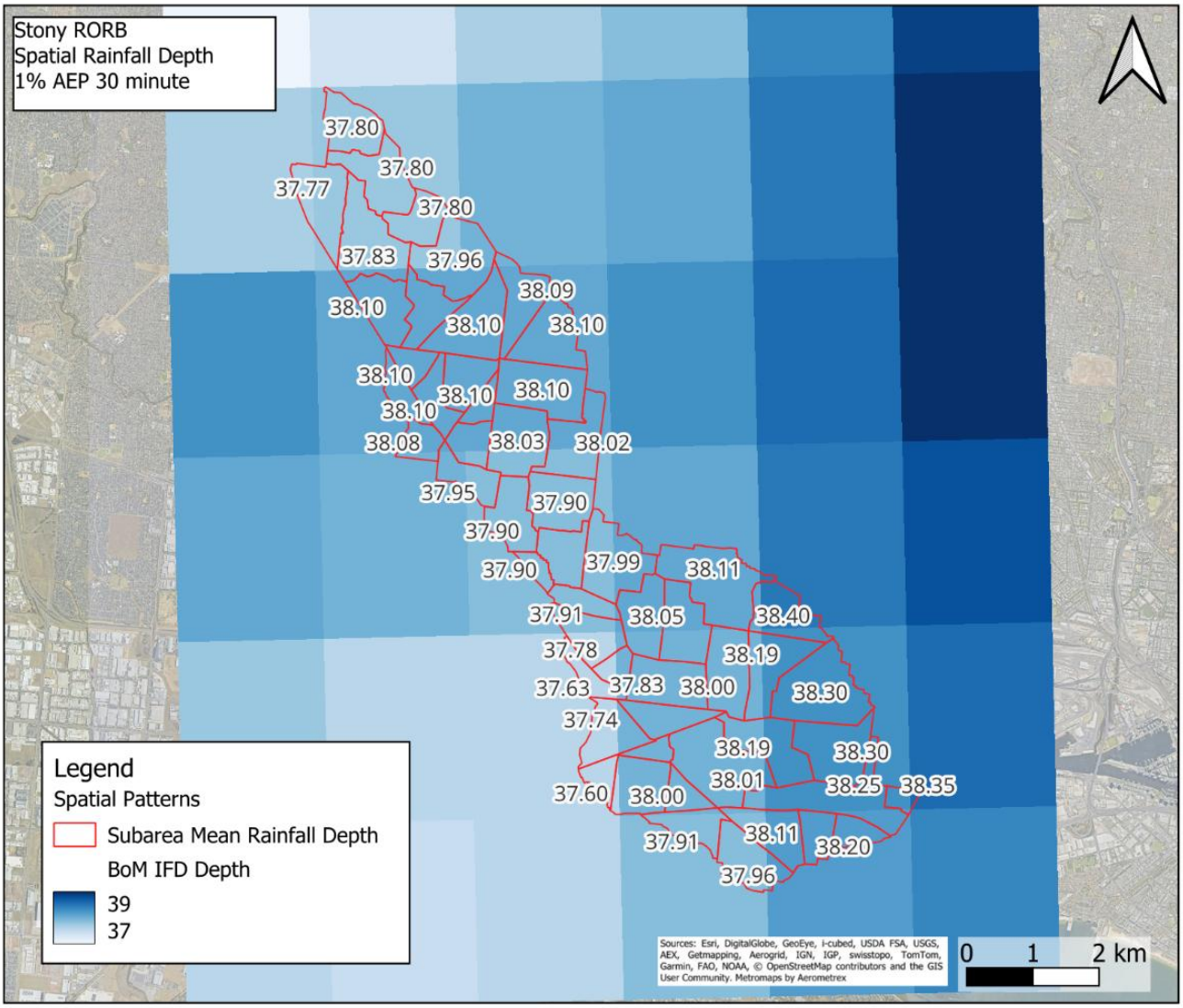


Figure C-7: Stony Creek spatial rainfall variation for 1% AEP 30 minute event

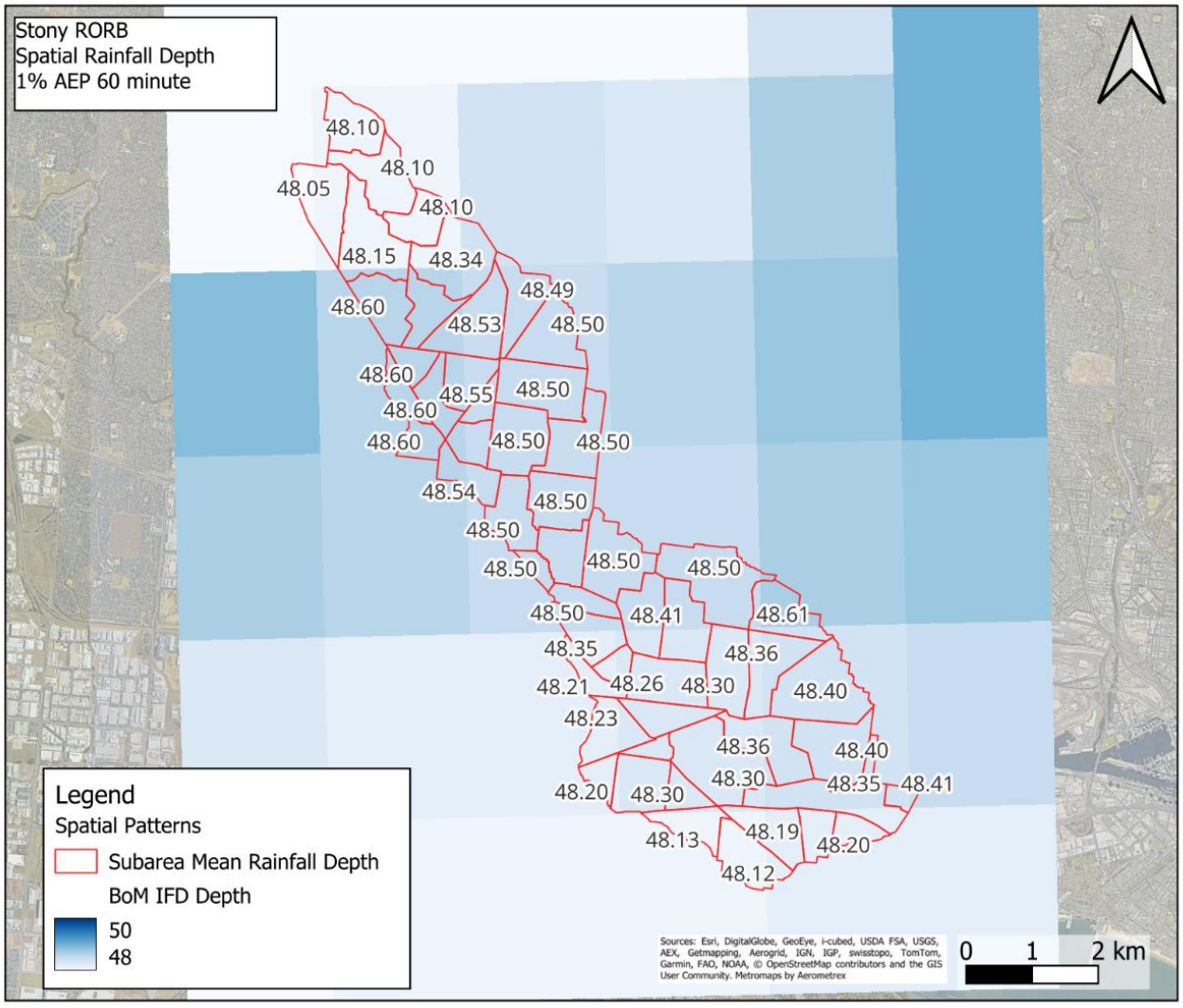


Figure C-8: Stony Creek spatial rainfall variation for 1% AEP 60 minute event

C.5.5 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Section C.8. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment are presented in Table C-6.

Table C-6: Adopted ARF values for the Stony Creek RORB model.

Duration	ARF area (km^2)	Justification
20min (1%, 2% AEP) 25min (5%, 10% AEP) 30min (1%, 2%, 20% AEP) 45min (20%)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
20min (20% AEP) 30min (10% AEP) 45min (5%, 10% AEP) 2h (1%, 2% AEP)	4	
1.5h (1%, 2%, 5%, 10% AEP) 2h (5%, 10%, 20% AEP) 3 hour (all AEPs)	18	

C.6 Model Calibration

Calibration of the model was undertaken in the following stages:

- Calibration to individual events to determine the routing parameters (k_c, with m being fixed to 0.8).
- Calibrating the at-site Flood Frequency results from the gauges to the RORB model Monte Carlo Flood Frequency results to determine the loss parameters.

Once model parameters were determined through calibration, design events for the 1% AEP were simulated to develop inputs to the TUFLOW model.

C.6.1 Routing Parameter k_c

Historic flood events were used to determine suitable k_c routing parameters for the model, while the recommended value for m of 0.8 was adopted for this Study. The selection of historic events for model calibration was guided by the following factors:

- The magnitude of flood events
- Completeness of good quality gauged streamflow records
- Pluviograph coverage for a given event

The historic events selected for calibration were:

- March 2001
- February 2011
- March 2020

The total rainfall and peak streamflow for the selected events are shown in Table C-7. Pluviograph data from the Spotswood, Sunshine and Maribyrnong at Keilor gauges were used to input rainfall temporal patterns.

Table C-7: Rainfall and streamflow from historic events used for calibration of the Stony Creek RORB model.

	Mar 2001		Feb 2011		Mar 2020	
Gauge	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)	Rainfall (mm)	Streamflow (m^3/s)
Stony at Spotswood (230112A)	75	33.8	63	26.9	59	25.8
Sunshine RG (587004)	110	-	24	-	63	-
Maribyrnong @ Keilor (230105)	121	-	34	-	59	-

Calibration of routing parameters was achieved by determining the k_c and m parameters that produce the best fit between the modelled and observed hydrographs. To calibrate the model, a range of k_c values were sampled through the model based initially on regional estimates that are documented in Table C-8. The m parameter was fixed at 0.8. A fit could not be found with the range of k_c estimates based on regional equations and as such, the range was extended to find an acceptable fit.

Table C-8: Stony Creek RORB model kc estimates based on regional equations.

	Vic <800mm rainfall	Vic >800mm rainfall	RORB Manual	Yarra & Maribyrnong	Pearse et al. 2002
k_c - Stony Creek at Spotswood	4.7	12.3	12.1	8.4	10.2

The k_c parameter was varied and the resultant hydrograph shape, peak flow, volume and Nash-Sutcliffe Efficiency (NSE) were assessed to determine an appropriate k_c value for the model. The NSE is a statistical measure used to evaluate a model's performance against recorded data. A value of 1 indicates a perfect fit to the model data, whereas, a value of 0 indicates simply modelling the average value would perform equally well. A value of less than 0 indicates poor model performance. NSE is defined as:

$$NSE = 1 - \frac{var(Res)}{var(Hyd)}$$

Where var(Res) is the variance of the model residuals or the difference between the observed and calculated flows, var(Hyd) is the variance of the observed hydrograph. Ladson (2008) provides a guide to assessing model performance based on NSE as shown in Table C-9.

Table C-9: NSE Calibration (Ladson, 2008)

Classification	NSE
Excellent	> 0.93
Good	0.80 – 0.93
Satisfactory	0.70 – 0.80
Passable	0.60 – 0.70
Poor	< 0.60

The k_c and NSE values that gave the best match to the observed hydrographs for each historic event are shown in Table C-10.

Table C-10: Stony Creek RORB k_c and resultant NSE for historic events

	March 2001		Feb 2011		March 2020	
Interstation area	k_c	NSE	k_c	NSE	k_c	NSE
Stony Creek at Spotswood	11.14	0.58	19.83	0.63	14.79	0.72

The NSE values returned consider the calibration of either 'satisfactory', 'passable' or 'poor'. The resultant fits between the modelled and observed hydrographs are shown in Figure C-9, Figure C-10 and Figure C-11 to allow visual inspection of fits. Calibration at the Spotswood gauge presented challenges, however the final calibration is considered acceptable. For both interstation areas, the returned k_c values were consistent, increasing confidence in the parameters.

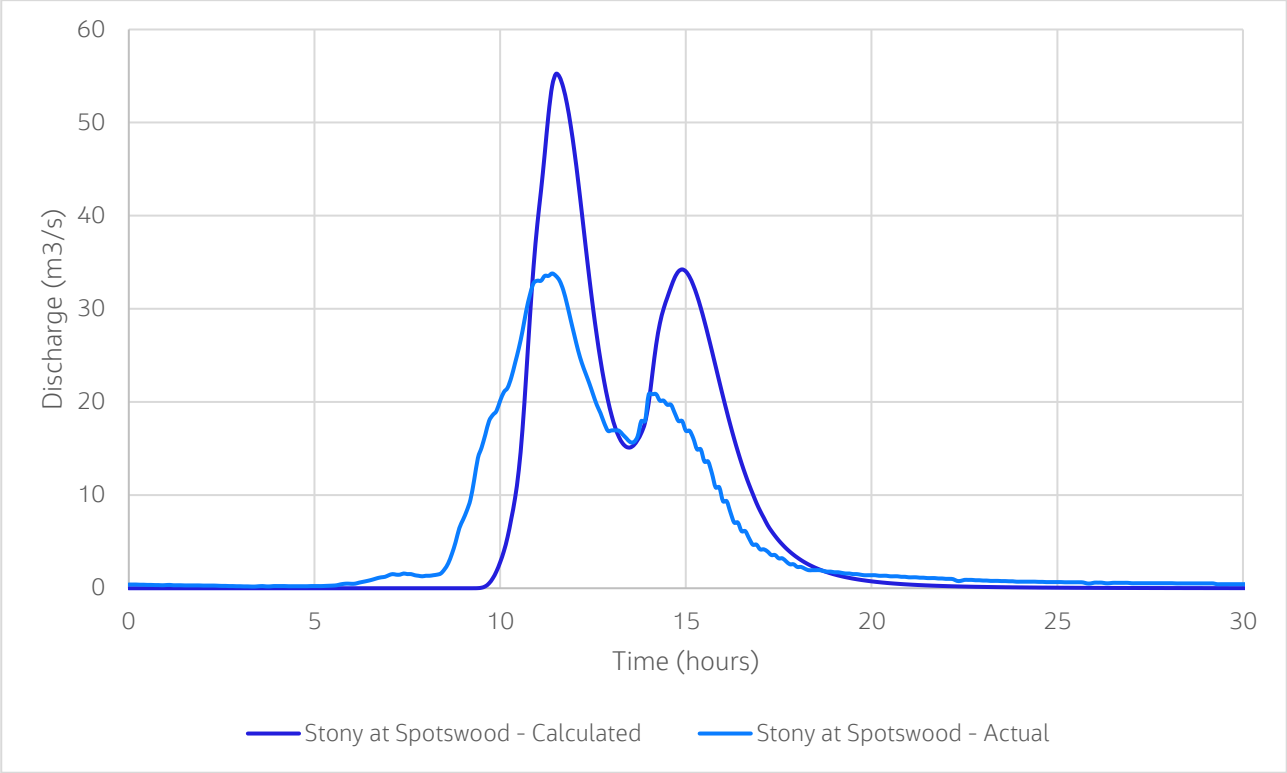


Figure C-9: Modelled and observed hydrographs for Stony Creek at Spotswood, March 2001

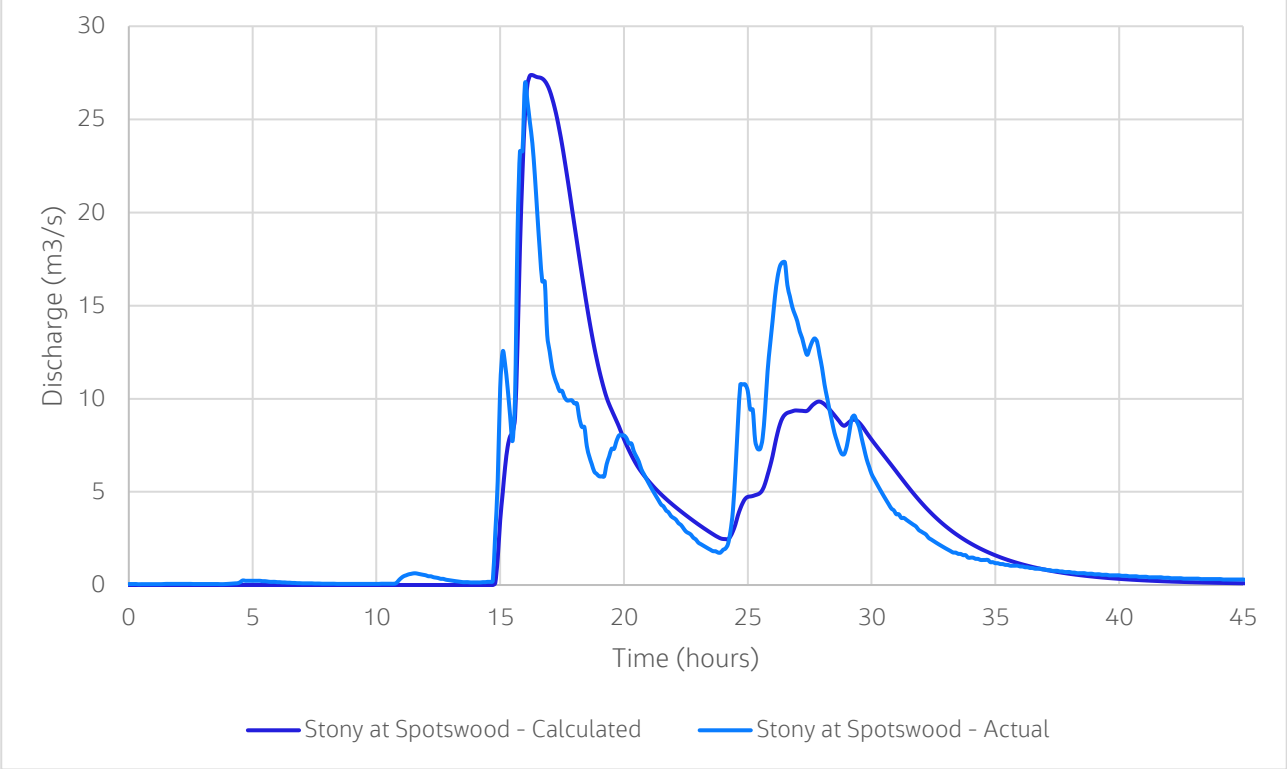


Figure C-10: Modelled and observed hydrographs for Stony Creek at Spotswood, Feb 2011

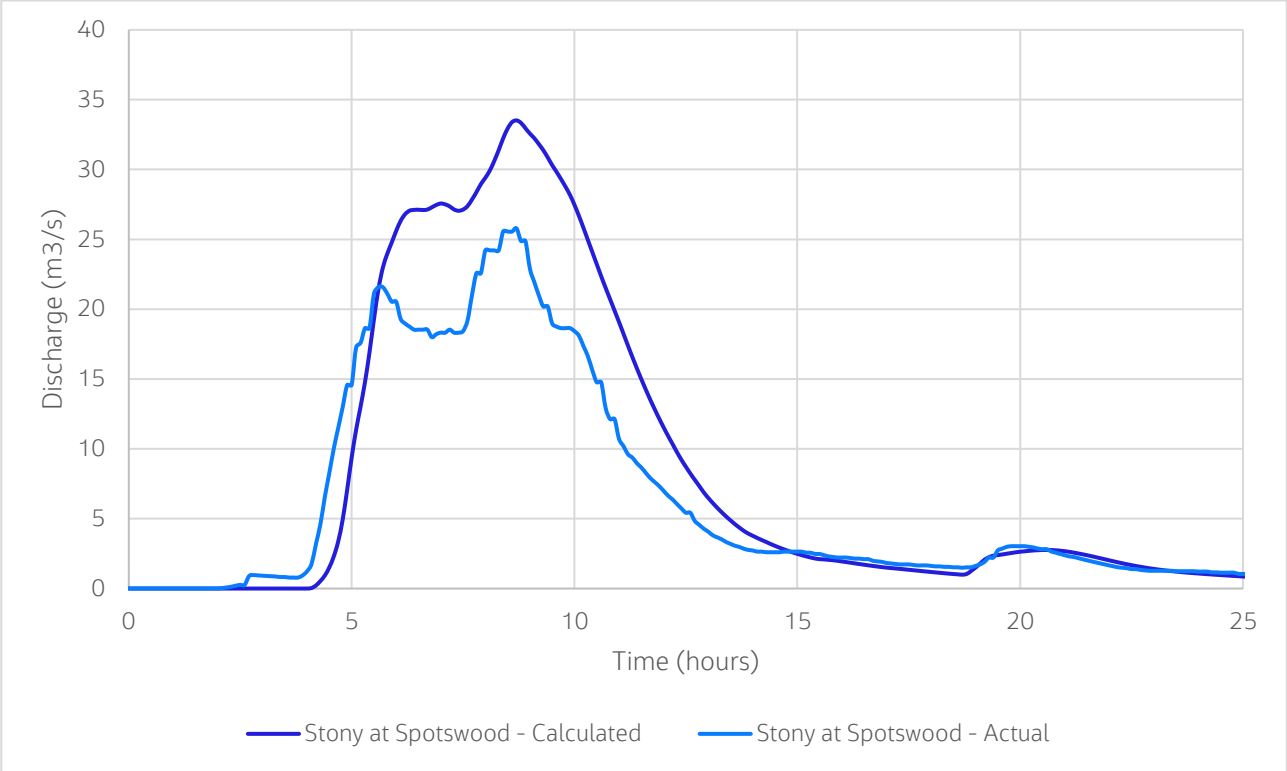


Figure C-11: Modelled and observed hydrographs for Stony Creek at Spotswood, March 2020

The adopted k_c parameters shown in Table C-11 were based on the range of k_c values derived from the calibration runs with consideration given to NSE. The adopted k_c values fall within the range of k_c values produced by regional estimates (Table C-8). Given no gauging information was available for the areas

downstream of the Spotswood gauge and its location near the end of the catchment, the k_c values adopted for this region was proportional to the k_c /d_{av} ratio upstream of the calibration point

Table C-11: Adopted k_c parameters for the Stony Creek RORB model.

Interstation area	k_c adopted
Stony Creek at Spotswood	16
Outlet	4.4

C.6.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Pre-burst (median values – see Section C.5.2) was also included in the RORB runs that calculated appropriate storm losses. The values adopted were obtained through calibration of the RORB Monte Carlo peaks to the at-site Flood Frequency Curve (FFC) at the Spotswood gauge. This involved varying the initial loss and continuing loss parameters until an acceptable match between the Monte Carlo peak flows and the FFC was achieved. A greater weight was given to matching the AEP events with probabilities (or return periods) more frequent than the length of the gauge record. The fit between the FFC and RORB Monte Carlo peaks is presented in Figure C-12. The RPV (2021) modelled quantiles are also shown for comparison, which show agreement with the current Study quantiles. The fit is considered acceptable, either within or close to the FFC upper quantile limit.

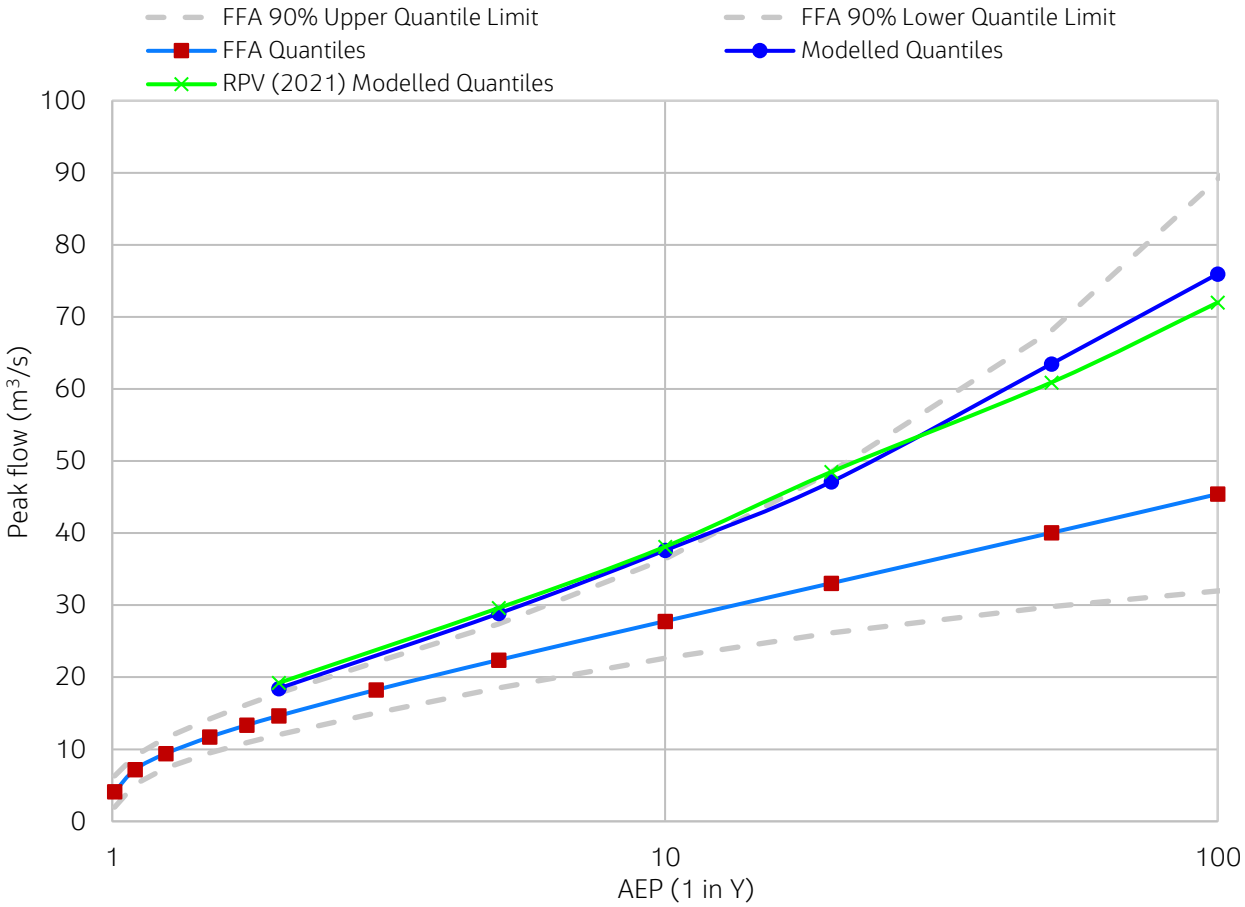


Figure C-12: At-site Flood Frequency Analysis and RORB Monte Carlo Peaks

The adopted loss parameters obtained through the calibration at the Spotswood gauge are shown in Table C-12. These are compared to the Datahub values for the catchment (ARR 2019). Whilst the loss values derived via the calibration exercise differ from the Datahub values, they fall within the range for rural catchments (Ball et al., 2019), those listed in the Melbourne Water Flood Mapping Projects Specifications and are also

consistent with the loss parameters derived via the calibration of the Stony Creek model at Brooklyn (urban catchment area) as part of this Study (Stony Creek at Deer Park IL: 13.5 mm and CL: 2.5 mm/hr).

Table C-12: Adopted loss parameters obtained through calibration for the Stony Creek RORB model

Interstation area	IL (mm)	CL (mm/hr)
Stony Creek at Spotswood	13.5	2.5
Outlet	13.5	2.5

C.7 RORB Results and Verification

The RORB model was simulated using the parameters determined through calibration and the results are presented below. Table C-13 shows the RORB model peak flows along with the Flood Frequency Analysis and regional estimates peak flows for Spotswood.

The approximate 1% AEP flows using the Nikolaou/von't Steen equation was calculated using the following equations:

For rural catchments $Q_{1\%} = 4.67A^{0.763}$
For urban catchments $Q_{1\%} = 10.29A^{0.71}$

The peak flows at the Spotswood gauge were calculated and compared to the RORB model outputs. The Nikolaou/von't Steen estimates are largely based on catchment area and are therefore unlikely to capture the complex and urban nature of the Stony Creek catchment. The Regional Flood Frequency Estimation (RFFE) was not performed given it is recommended for entirely rural catchments (Stony Creek at Spotswood has an urban upstream catchment). The MW rule of thumb method (for urban areas) is known to not perform well in catchments with large green space areas, and generally overpredicts peak flows for this catchment.

RORB design flows show greater consistency with the FFA at lower AEPs and alignment with the previous modelling undertaken by RPV (2021). The short length of the gauge record (24 years) could be limiting the applicability of the FFA quantiles for rarer events, possibly explaining the difficulty in finding an improved fit. A further limiting factor of the FFA is the culvert at Williamstown Road just downstream of the Spotswood gauge, which could also be influencing high flows in excess of 45 m^3/s (see Section C.3.2).

Table C-13: Stony Creek at Spotswood peak flow comparison

AEP	RORB design peak flow (m^3/s)	FFA (m^3/s)	RPV (RPV, 2021)	Nikolaou/von't Steen (urban) (m^3/s)	MW rule of thumb (urban) (m^3/s)
20%	28.8	22.4	29.6	-	-
10%	37.6	27.8	38.1	-	-
5%	47.1	33.1	48.5	-	-
2%	63.5	40.0	60.9	-	-
1%	76.0	45.4	72.0	121.8	324.9

C.8 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARF to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table C-6. This enabled the identification of how critical durations were likely to alter based on the

contributing catchment area. Key locations across the catchment are shown in Figure C-13. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW
- Locations upstream or within urban areas
- Locations upstream and downstream of model storages
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave
- Points located within Study LGAs, providing good coverage across Study area

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Table C-14. Table C-16 lists the storms that were simulated in TUFLOW at the hydraulic modelling phase of this Study. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

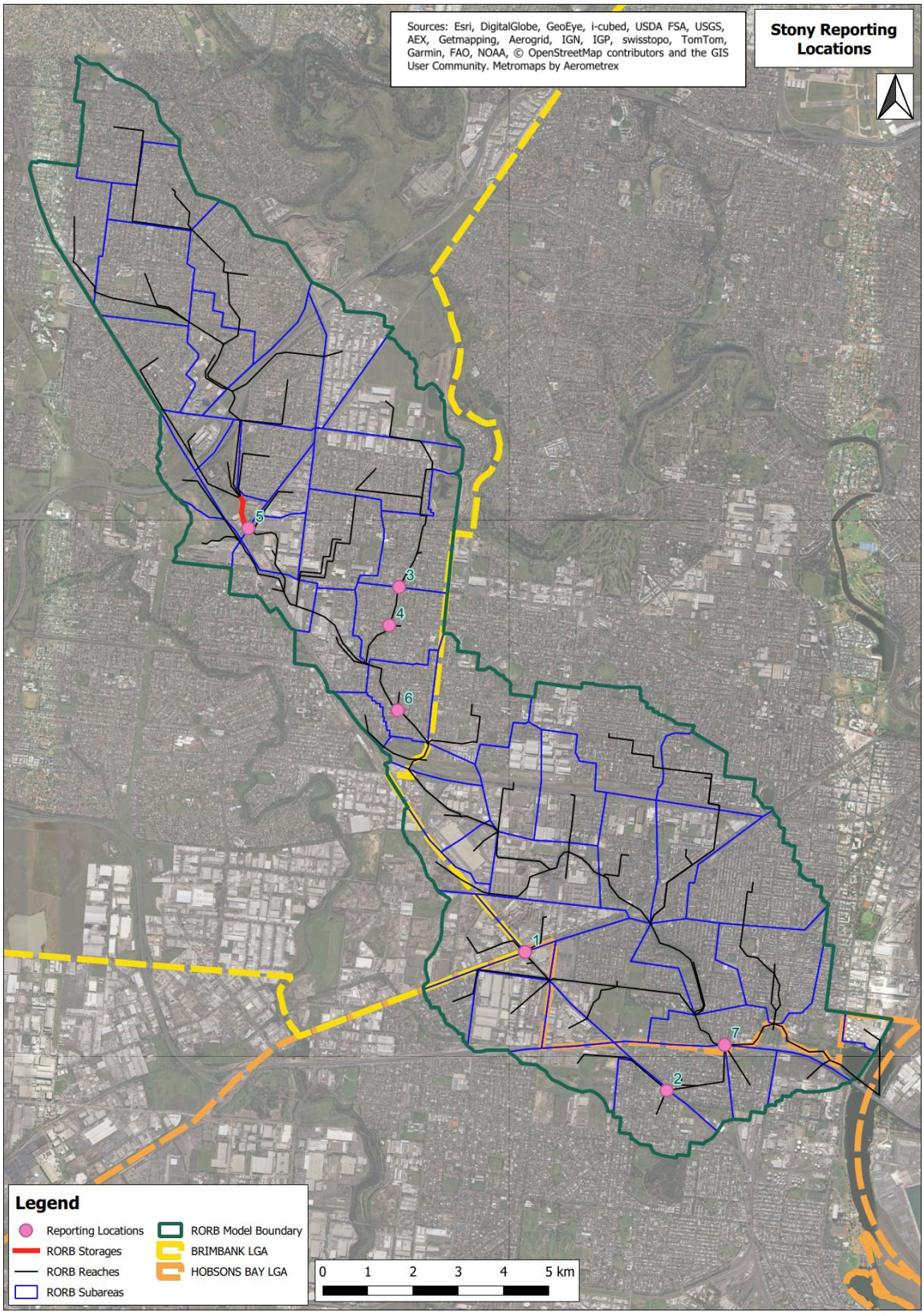


Figure C-13: Stony Creek RORB reporting locations

Table C-14: Analysis of critical durations and peak flows at key locations in the Stony Creek RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Princes Highway	1.2	30min	16.6	30min	14.1	45min	11.3	45min	9.3	45min	7.9
2	Kernot St	1.2	20min	17.3	20min	14.4	25min	10.6	25min	8.6	30min	6.7
3	Ballarat Road	2.81	20min	23.5	20min	19.8	20min	15.4	30min	12.6	20min	11.7
4	Hertford Road	3.61	3hour	23.2	20min	19.6	45min	15.5	45min	12.7	20min	10.9
5	Gilmour Rd RB Inflow	8.3	3hour	55.1	2hour	44.7	2hour	35.1	2hour	28.0	2hour	20.8
6	Cornwall Road	14.8	1.5hour	20.9	1.5hour	17.5	1.5hour	14.1	1.5hour	11.3	2hour	8.2
7	Spotswood Gauge	34	3hour	76.5	3hour	63.7	2hour	46.7	2hour	37.6	3hour	29.6

Table C-15: Critical durations and selected temporal patterns for the Stony Creek RORB model.

AEP	20min	25min	30min	45min	1hour	1.5 hour	2 hour	3 hour
1%	TP 27	-	TP 28	-	-	TP 27	TP 27	TP 27
2%	TP 27	-	TP 28	-	-	TP 26	TP 21	TP 27
5%	-	TP 16	-	TP 19	-	TP 13	TP 20	TP 17
10%	-	TP 16	TP 13	TP 19	-	TP 14	TP 20	TP 17
20%	TP 5	-	TP 4	TP 5	-	-	TP 7	TP 4

C.9 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Stony Creek catchment. The purpose of the hydraulic model is to produce flood extents for the catchments of Stony Creek and 9880 (Williamstown). As per the project scope the entire length of the Stony Creek waterway has been captured in this hydraulic model. Flood extents associated with the Stony Creek waterway are captured in a separate MW project. For this project any flood extents generated along Stony Creek have been omitted from the GIS Deliverables.

In addition the northern section of the Stony Creek catchment associated with the Anderson Road Diversion Drain has not been included in this hydraulic model and is included in the Kororoit Creek (south) hydraulic model.

C.9.1 Hydraulic Model Set Up

C.9.1.1 Terrain modifications

Maps available in Figure C-12, Figure C-13, Figure C-14 show Stony Creek catchment TUFLOW model terrain modifications, which are also listed in Table C-16 where these have been based on drawings, plans or other available detailed information. The terrain modifications include adjustments made to the base LiDAR either due to:

- Terrain adjustments:
    - Sections of the LiDAR that may contain significant depressions that are not permanent, i.e. if the LiDAR was flown during the construction of a building then the excavation would be captured and should be removed to ensure no rainfall pools in this depression.
    - Removal of bridges or blockages to enable the structure to be hydraulically modelled.
- Reinforcement of hydraulic controls (roads, levees, embankments) within the overland flow paths.

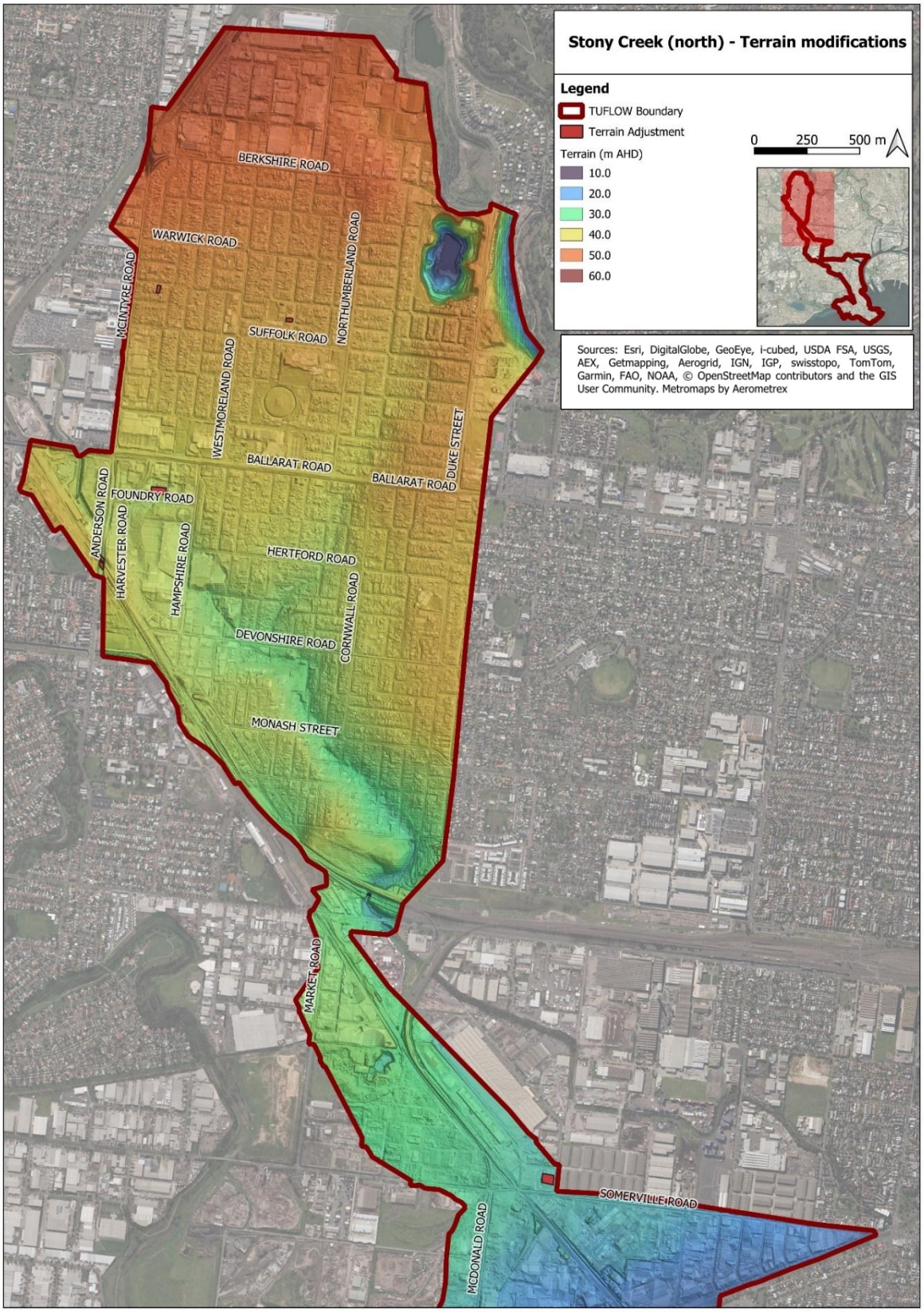


Figure C-14: Stony Creek TUFLOW model terrain modifications (north).

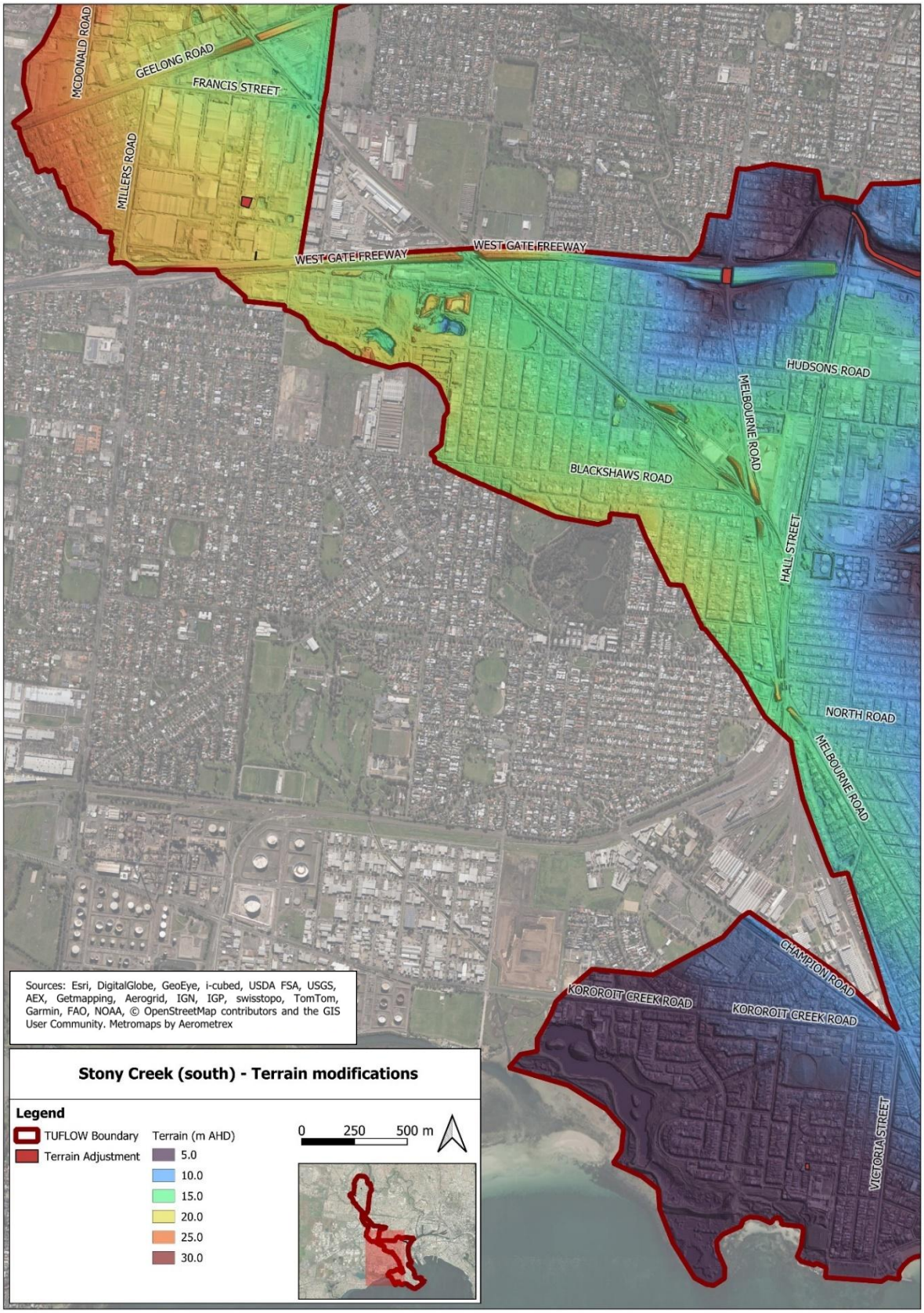


Figure C-15: Stony Creek TUFLOW model terrain modifications (south).

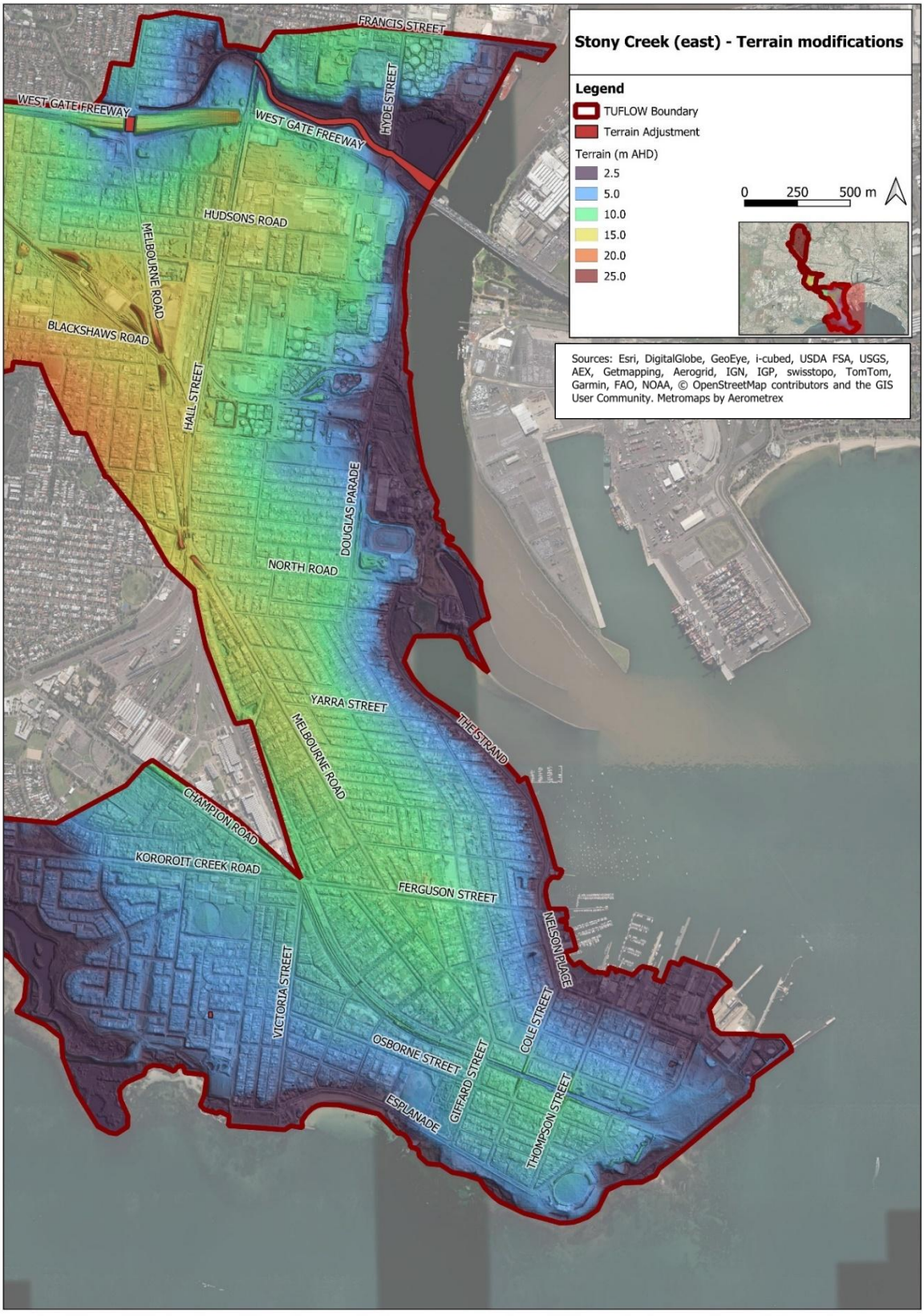


Figure C-16: Stony Creek TUFLOW model terrain modifications (east)

Table C-16: Stony Creek TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Tottenham Railbridge	TOT_S1715 TOT_S1750 TOT_C1487	Bridge details used to inform bridge representation in TUFLOW model
Stony Creek Culvert across Williamstown rd	W.S. 40112 W.S. 4015 W.S. 40159 W.S. 40164 W.S. 40165 W.S. 40166 W.S. 48-30 W.S. 48-32 W.S. 48-33 W.S. 48-60	Culvert details applied to the model

C.9.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table C-17.

Table C-17: Stony Creek TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Tottenham Railbridge (Stony Creek)	0	28.215	2.05	1	30
Carder Pl Railbridge	0.09	6.73	1	1	30
Tourist Dr Roadbridge	0.09	1.41	1	1	30
West Gate Fwy Bridge A	0.05	12.13	1	1	90
West Gate Fwy Bridge B	0.05	11.55	1	1	30
West Gate Fwy Bridge C	0.21	21.71	1	1	50
West Gate Fwy Bridge D	0.21	21.82	1	2	30
Geelong Rd Bridge A	0.27	21.63	1	1	60
Geelong Rd Bridge B	0.27	21.66	1	1	60
Anderson Rd Bridge A	0.05	39.99	1	1	30
Anderson Rd Bridge B	0.05	40	1	1	30

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Hampsire Rd Bridge A	0.03	39.4	1	1	50
Hampsire Rd Bridge B	0.14	39.96	1	1	50
West Gate Golf Footbridge	0.27	1.26	0.5	1	30
Fyans Morven Reserve Footbridge	0.54	8.8	0.5	1	30

C.9.1.3 Model roughness

Maps available in Figure C-15 show the Stony Creek TUFLOW model Manning's roughness.

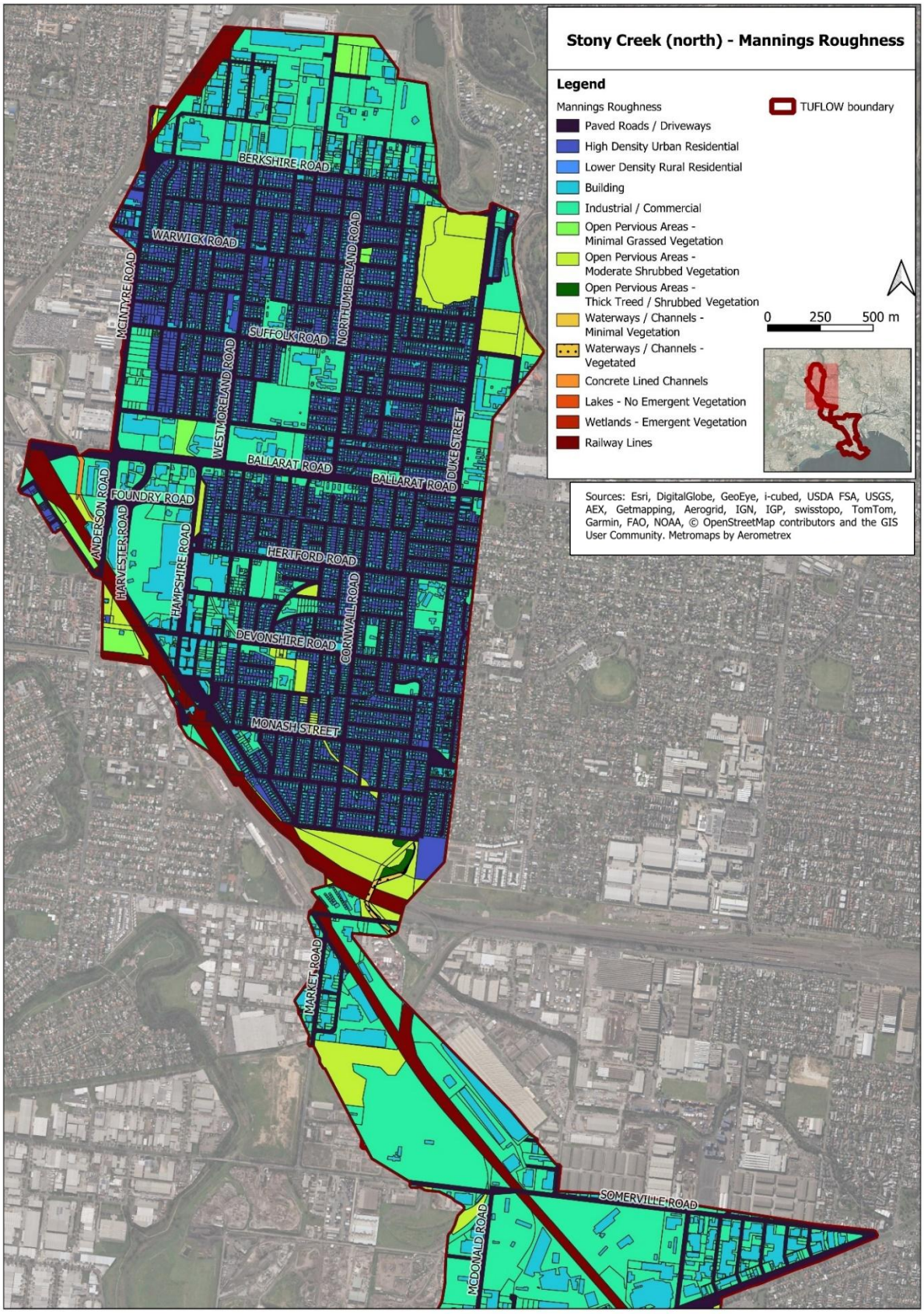


Figure C-17: Stony Creek TUFLOW model Manning's roughness (north).

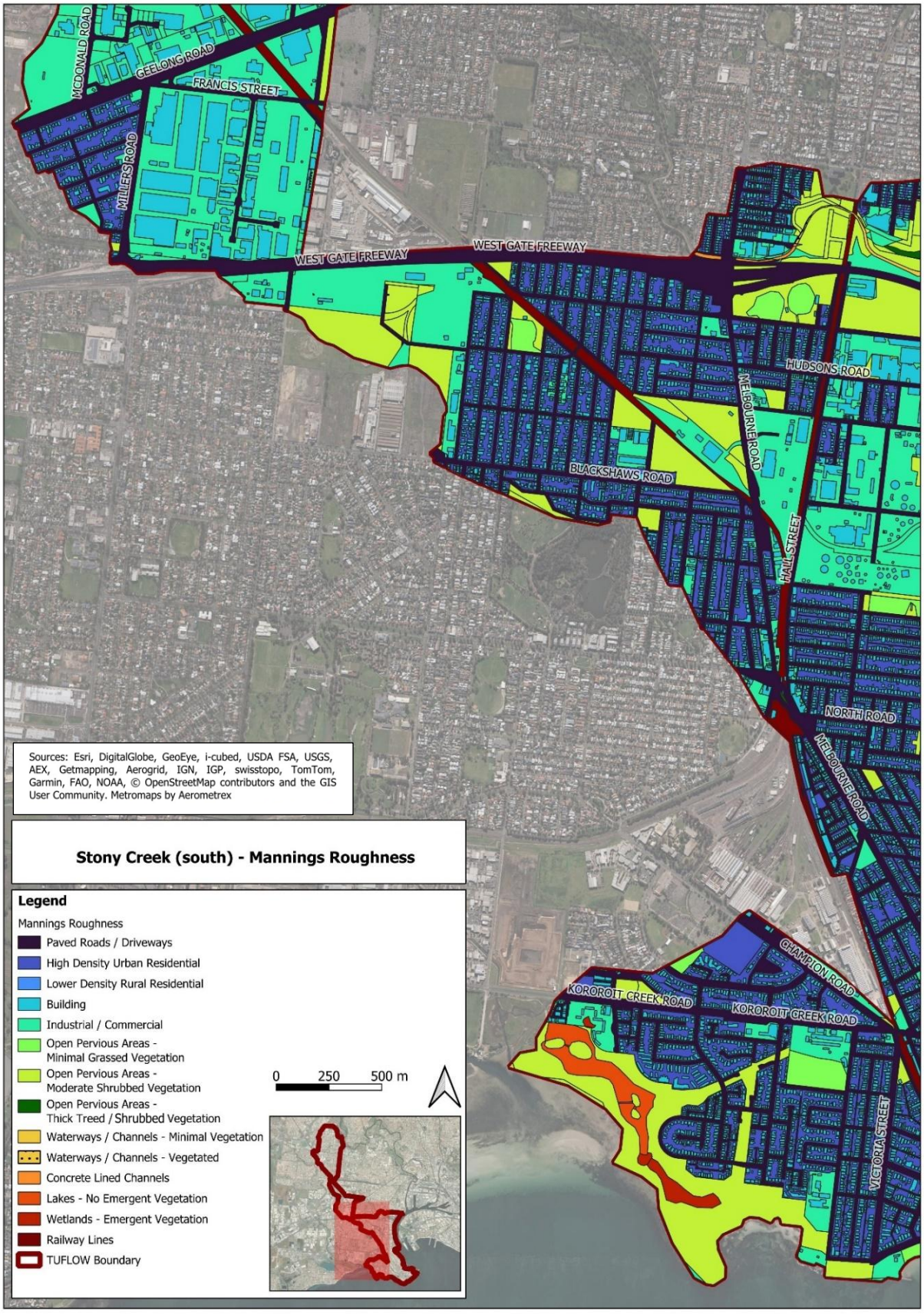


Figure C-18: Stony Creek TUFLOW model Manning's roughness (south).

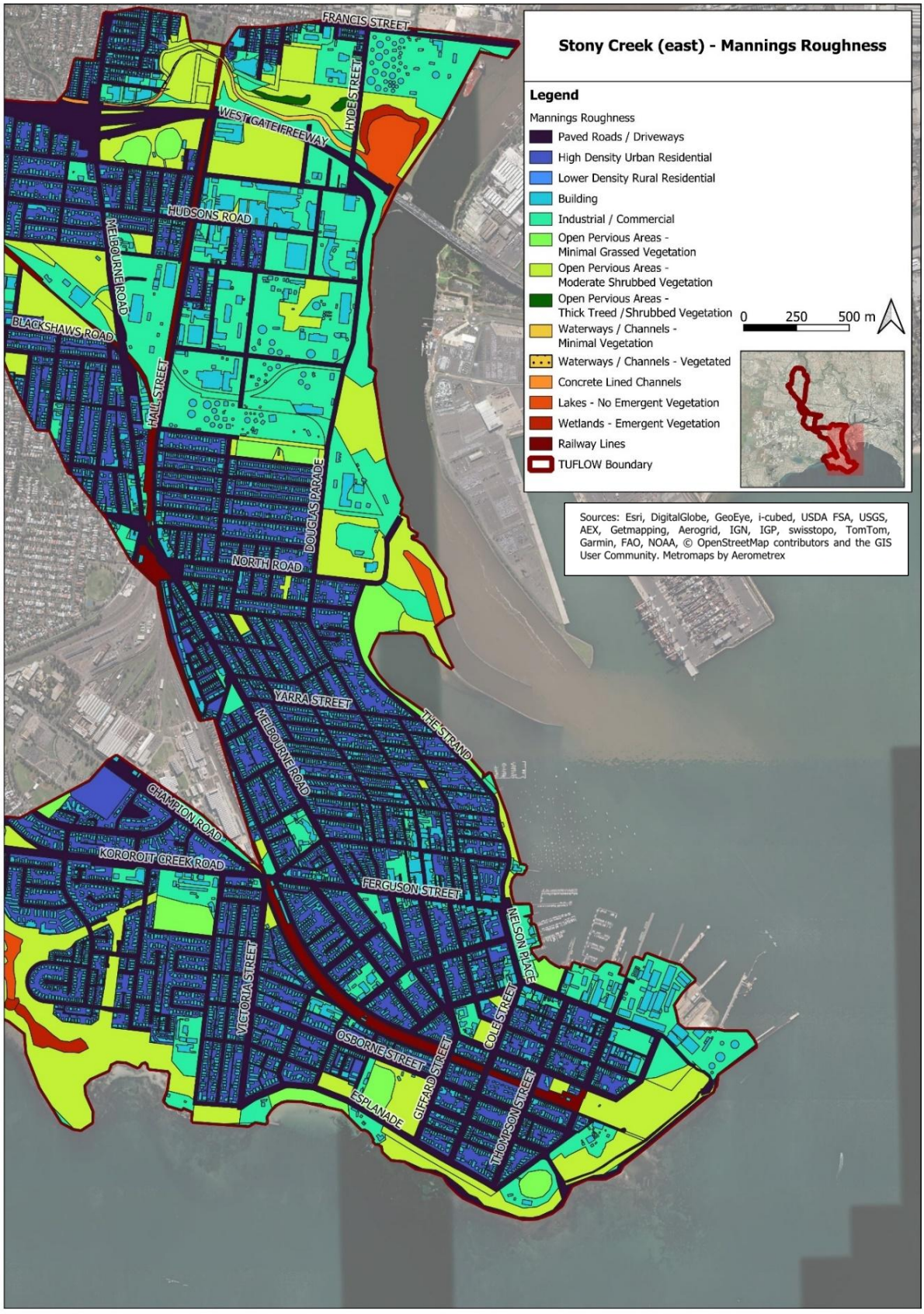


Figure C-19: Stony Creek TUFLOW model Manning's roughness (east).

C.9.1.4 1D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table C-18. A full count of the adopted pit types in the TUFLOW model is listed in Table C-19. Maps of the full drainage network can be found in Figure C-18, Figure C-19 and Figure C-20.

Table C-18: Stony Creek TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Justification
A_02341, A_09245, A_09252, A_25461, A_58235, A_982345, A_98345	Council	C	0.6		A pipe subnetwork was identified, which had an invalid outlet location, as shown by Google Street View, aerial and LiDAR. Several pipes were digitised to connect subnetwork to a nearby pipe subnetwork further downstream, to allow council pipes to drain to Stony Creek (Lower).
A_05423	Council	C	0.225		Pipe spatial orientation has been adjusted to connect council pit to pipe drainage system.
A_82523, A_82523_a	Council	C	0.6		
A_4567	Council	C	0.6		A pipe subnetwork was identified, which had an invalid outlet location, as shown by Google Street View, aerial and LiDAR. A pipe connection to a nearby pipe subnetwork further downstream was assumed, to allow council pipes to drain to an observable outlet location.
A_73462	Council	R	0.45	0.15	
A_82051	Council	C	0.45		
A_97345	Council	C	0.375		
A_9735	Council	C	0.675		
A_98234a	Council	C	0.3		
Assumed_150	Council	C	0.375		
AssumedPipe_01, AssumedPipe_02	Council	C	0.3		
A_0234	Council	C	0.375		
Assumed_93241, Assumed_982, Assumed_98423	Council	C	0.3		

Table C-19: Stony Creek TUFLOW model 1D drainage adopted pit types.

Pit Type	Count
Side Entry Pit	3,698
Double side entry pit	88
Grated Side Entry	586
Grated Pit	886
Double Grated Pit	1
Junction Pit (node)	936
Grated Pit (1.8 m x 0.9 m)	1
Grated Pit (1.9 m x 0.7 m)	1
Grated Pit (2.4 m x 1.2 m)	1
Grated Pit (3.8 m x 1.9 m)	1
Grated Pit (4.25 m x 6 m)	1

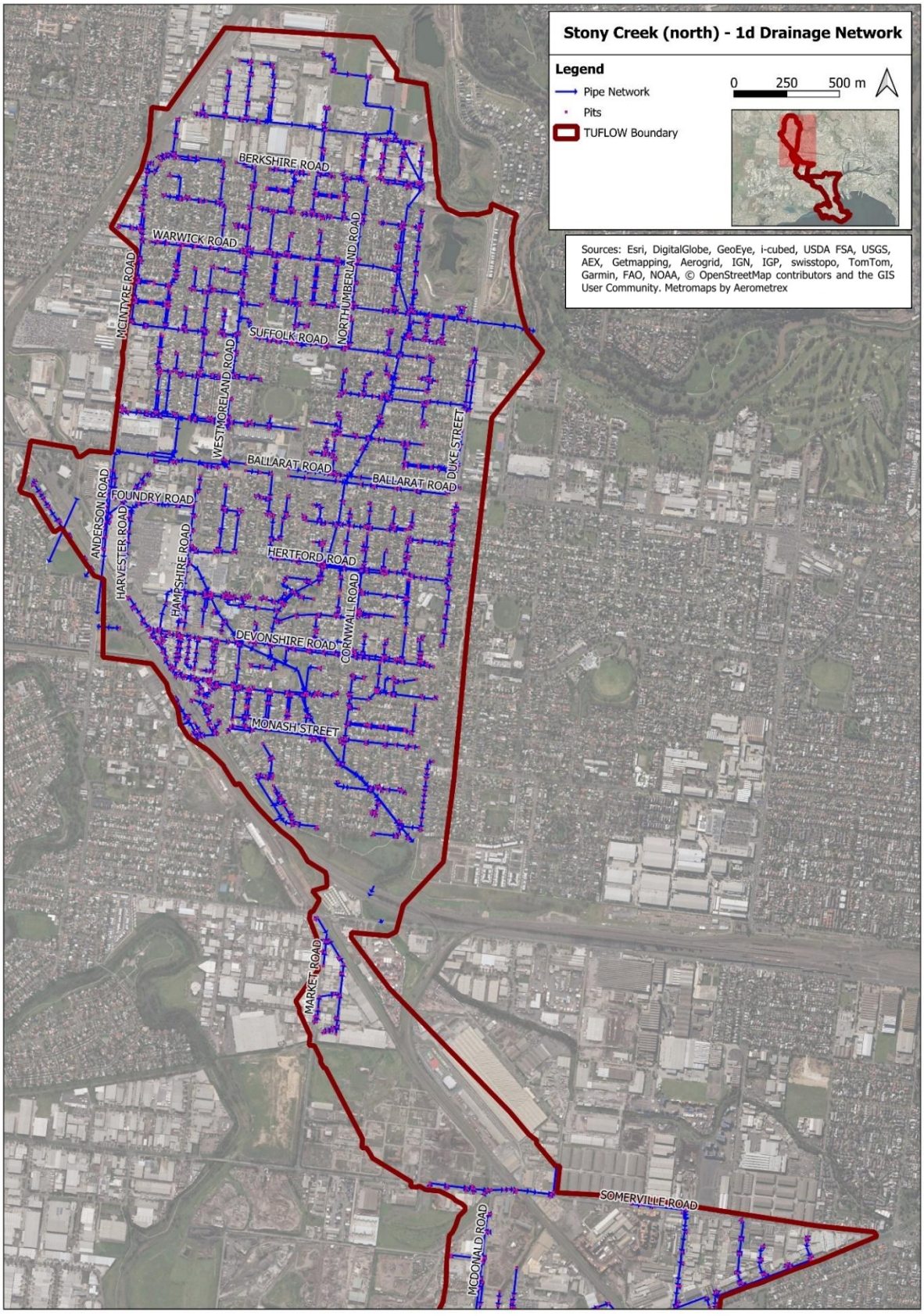


Figure C-20: Stony Creek TUFLOW model 1D drainage network (north)

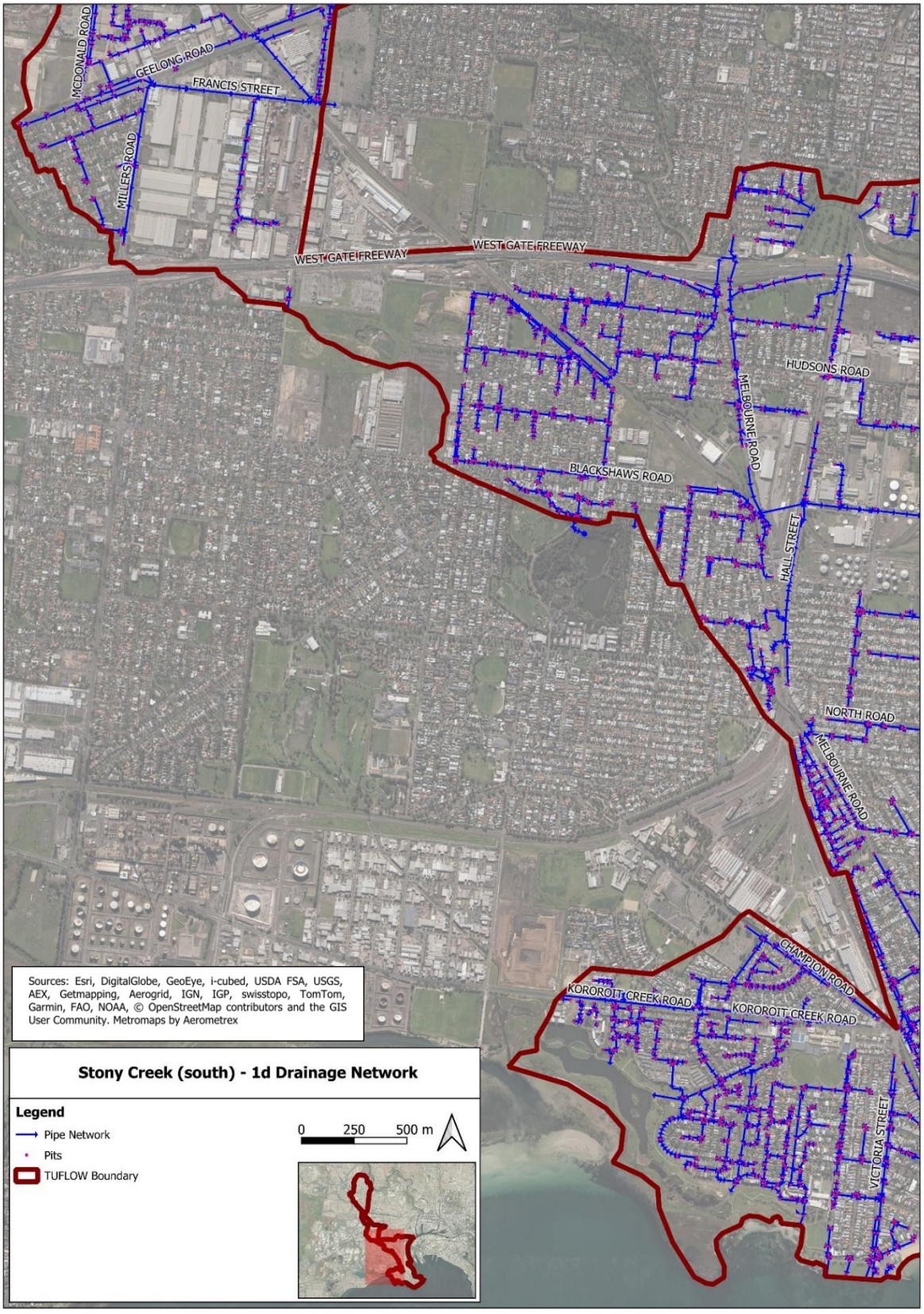


Figure C-21: Stony Creek TUFLOW model 1D drainage network (south).

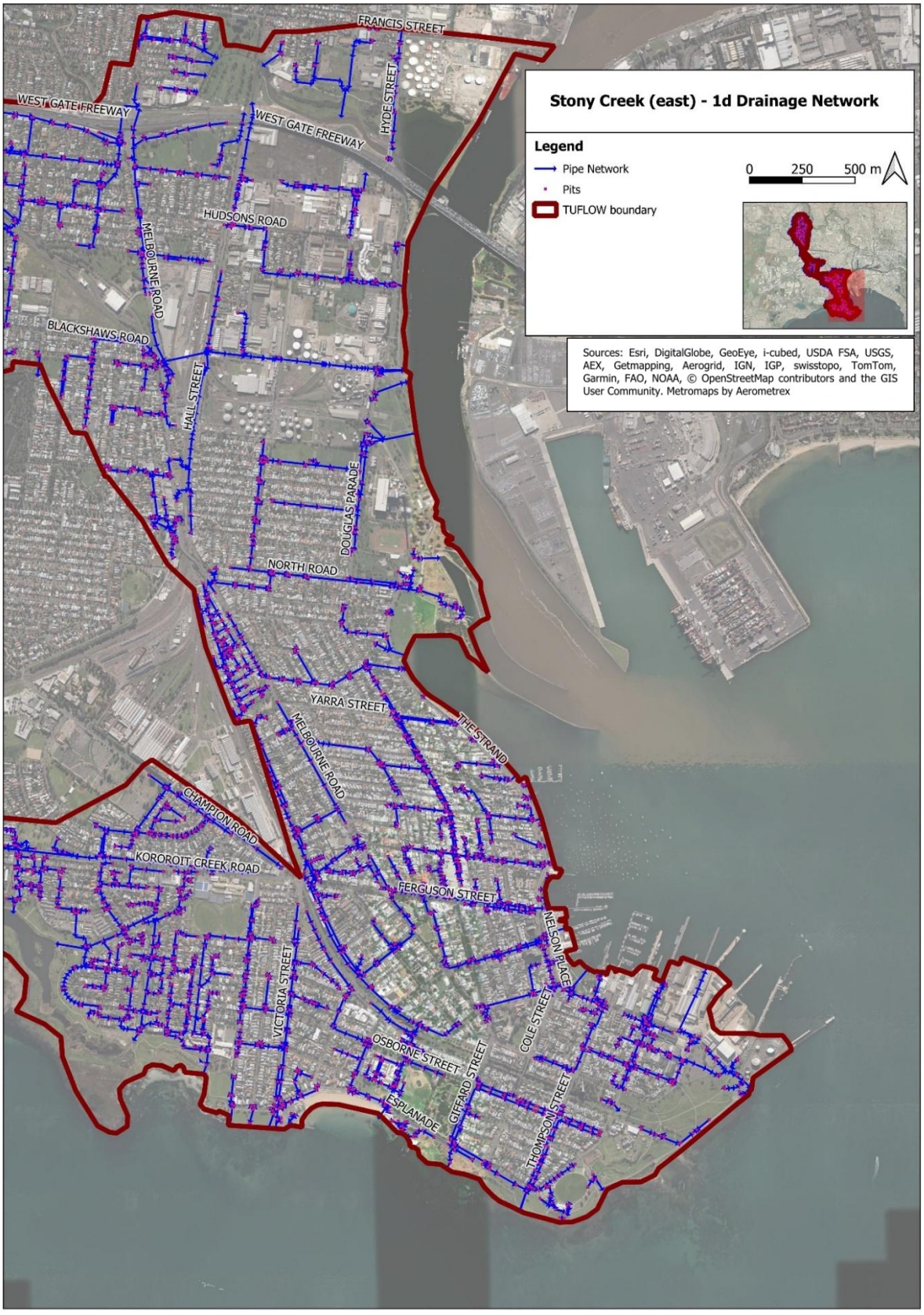


Figure C-22: Stony Creek TUFLOW model 1D drainage network (east).

C.9.1.5 Boundary conditions

The boundary conditions for the Stony Creek TUFLOW model are presented in Figure C-21, Figure C-22 and Figure C-23.

(a) Inflow Boundary for Stony Creek

To represent the boundary condition inflows for Stony Creek, flows generated from the Study's RORB model were applied at the upstream boundary of the TUFLOW model at Ballarat Road. The Stony Creek model does not extend to the most upstream reaches of the catchment, instead, the RORB inflow at Ballarat Road represents the cumulative upstream runoff entering the model domain.

HQ (Head-Flow) were applied near McIntyre Road and Ballarat Road to set water level conditions at the upstream boundary of the model. HQ represents the influence of upstream drainage entering the model area and to control water levels where the model begins.

Subcatchment 9880 (Appendix G) was modelled separately using its own RORB model. The resulting excess-rainfall hydrographs were applied as inflow boundaries to the downstream extent of the Stony Creek TUFLOW model, representing contributions from the Williamstown and Newport urban areas.

A gridded Initial Water Level (IWL) was applied along the main Stony Creek channel to represent pre-event base water levels and aid stable model spin-up.

Riverine mapping of Stony Creek is being delivered under a separate Melbourne Water package of works.

(b) Downstream Boundary for Stony Creek

A static HT (Height versus Time) boundary condition was applied where the model outlets to Port Phillip Bay. Several HQ (height versus flow) boundaries were defined based on slope where there is flow interacting with the model boundary.

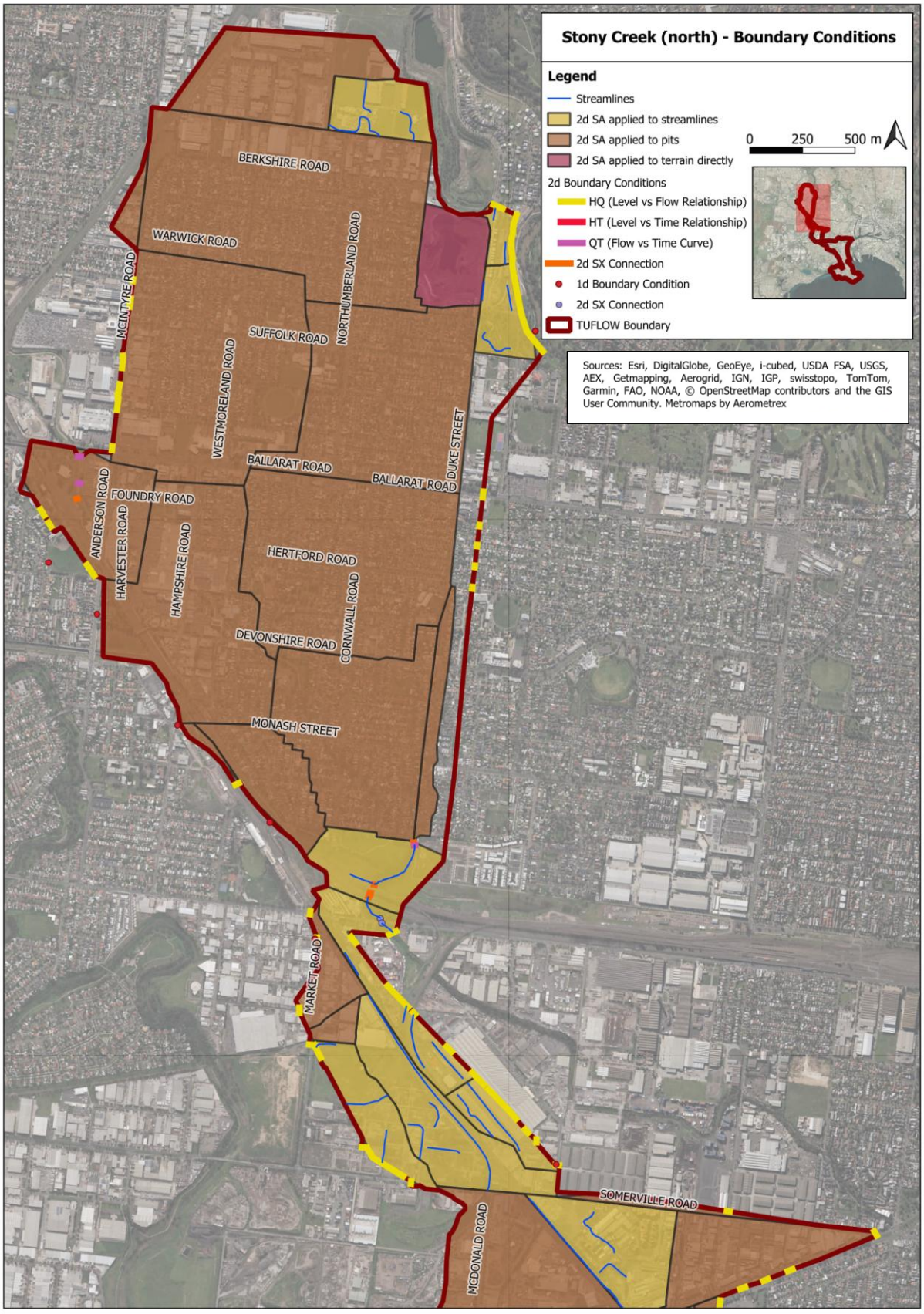


Figure C-23: Stony Creek TUFLOW model boundary conditions (north).

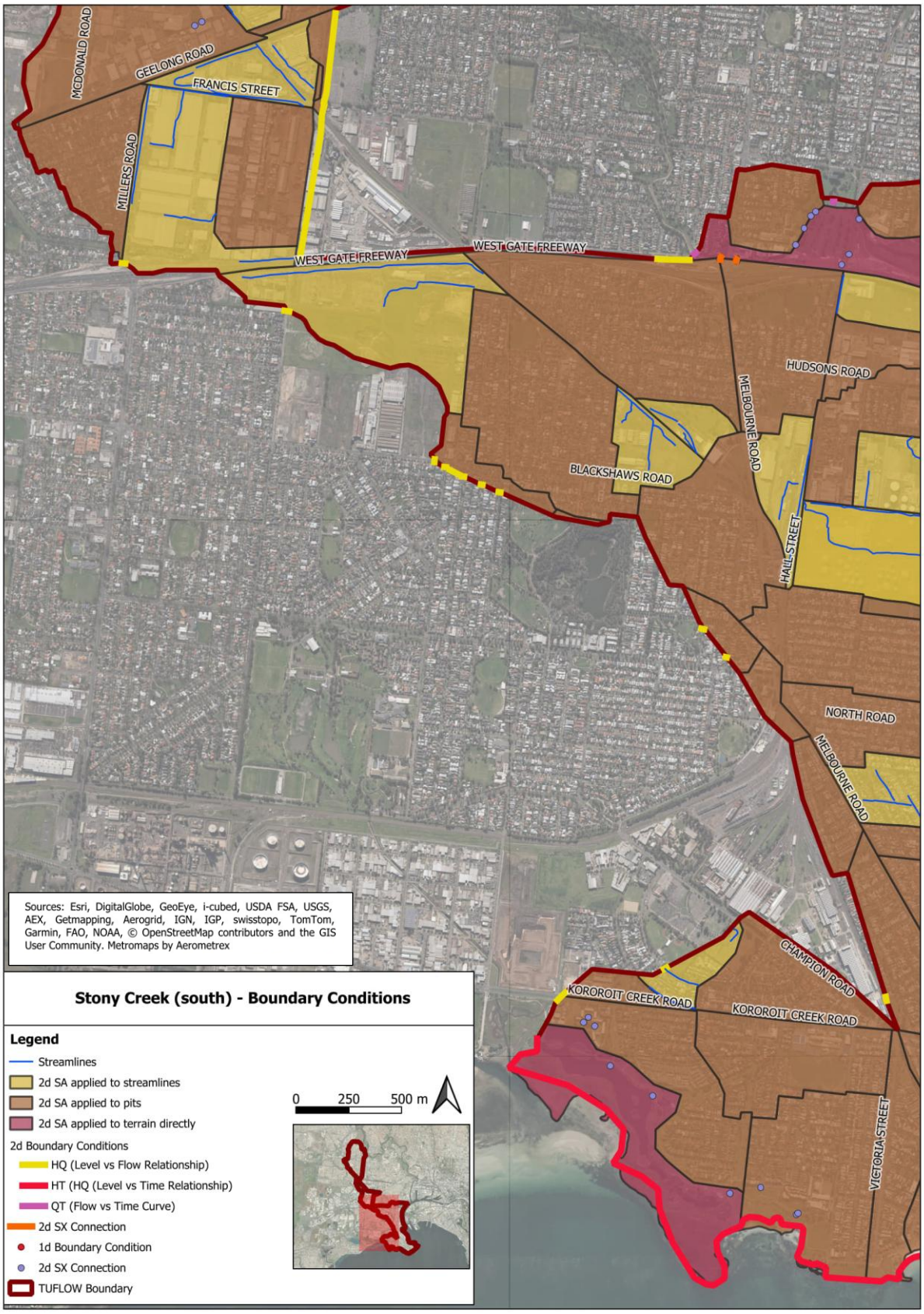


Figure C-24: Stony Creek TUFLOW model boundary conditions (south).

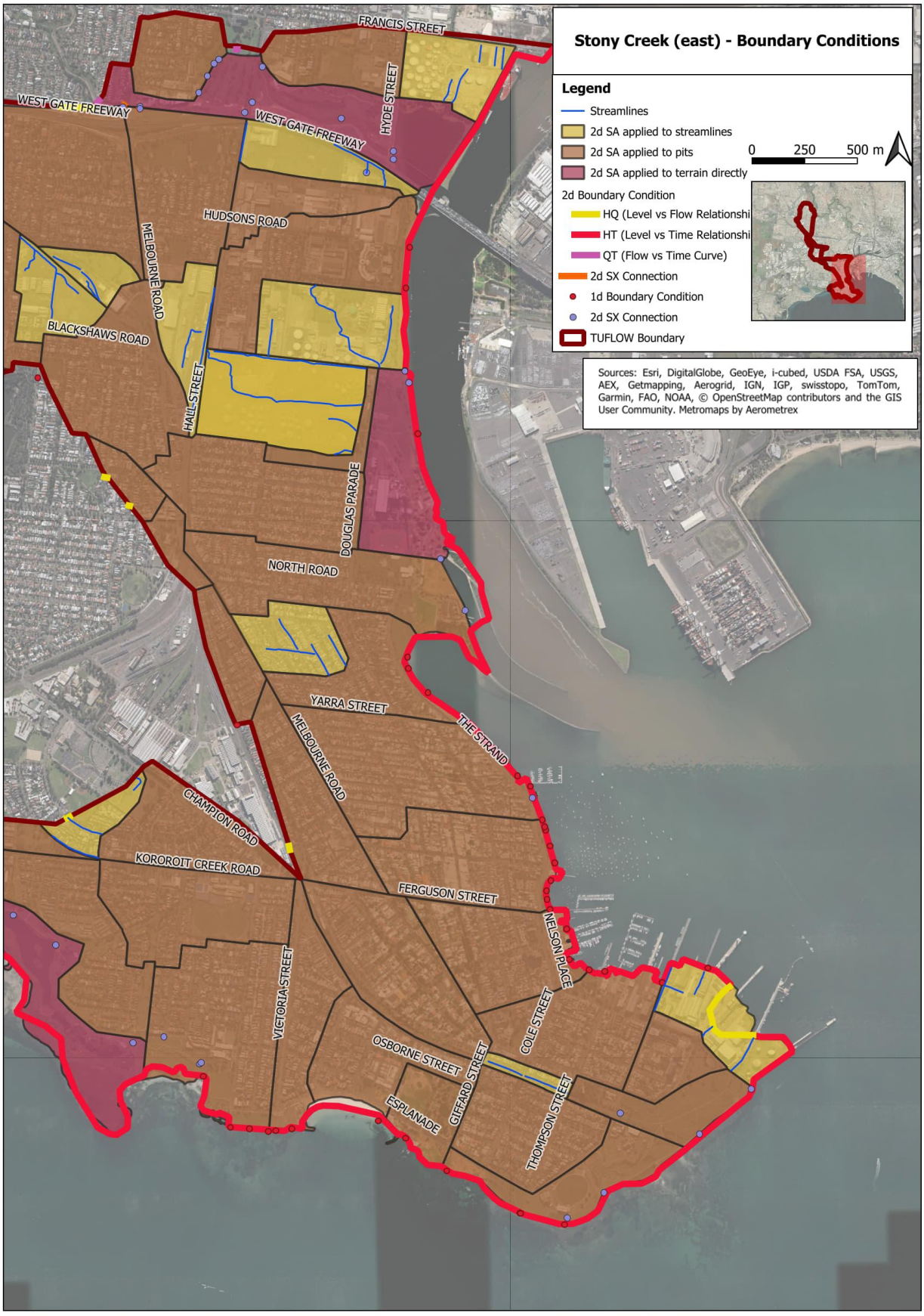


Figure C-25: Stony Creek TUFLOW model boundary conditions (east).

C.9.2 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table C-20.

Table C-20: Adopted Durations, temporal patterns and ARF areas for the Stony Creek and catchment 9980 (Bold text) models

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	**TP27**	1	**TP27**	1	-	-	-	-	TP5	1
25 minute	-	-	-	-	TP16	1	TP16	1	-	-
30 minute	**TP28**	1	**TP28**	1	**TP18**	1	TP19	1	**TP4**	1
45 minute	**TP26**	1	**TP26**	1	**TP19**	1	TP19	1	TP5/**TP8**	1
1 hour	**TP27**	1	**TP27**	1	**TP17**	1	-	-	**TP4**	1
1.5 hour	TP27	18	TP26	18	TP13	18	TP14	18	-	-
2 hour	TP27	4	TP21	4	TP20	18	TP20	18	TP7	18
3 hour	TP27	18	TP27	18	TP17	18	TP17	18	TP4	18

C.9.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section C.8. The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment. This is presented in Table C-21.

Results from the RORB and TUFLOW models show that the critical durations are generally consistent between the two models, with minor variations. The highly urbanised nature of this catchment, combined with extensive road networks and drainage infrastructure, influences local flow patterns and storage. These interactions can slightly alter the timing of peak flows, resulting in some variation between the RORB and TUFLOW critical durations at points such as Point 1, 3, and 6. Overall, the differences remain small which confirms that the adopted TUFLOW critical durations are appropriate and representative of the hydrologic model results.

Table C-21: Comparison of RORB critical durations and TUFLOW critical durations for the 1% AEP with climate change event

RORBLocation (Figure C-11)	Location	RORB 1% AEP duration	TuFLOW 1% AEP climate Change	Comment
1	Princes Highway	30min	1hour	
2	Kernot St	20min	3hour	The TUFLOW results are influenced by storage behind the rail embankment
3	Ballarat Road	20min	1hour	In RORB the peak flows across the 20 min to 3 hour storm are in a similar range. The TUFLOW results are in this range.
4	Hertford Road	3hour	1hour	
5	Gilmour Rd RB Inflow	3hour	-	Not in TUFLOW model
6	Cornwall Road	1.5hour	1hour	
7	Spotswood Gauge	3hour	3hour	

C.9.4 TUFLOW Checks and Warnings

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks are summarised in Table C-22. They have been assessed as not likely to adversely affect the model results. Reviews completed by Melbourne Water's external reviewer are provided in Appendix N.

Table C-22: TUFLOW checks and warning messages

Message	Count	Message content	
Message 1100	23	WARNING 1100 - Structure XX crest/invert (XX) is below bed (XX) of primary upstream channel XX	Typical for a drainage network for pipe inverts to not align with decreasing gradient.
Message 1402	2	CHECK 1402 - More than one culvert connected but could not create manhole at Node "XX". Check culvert inverts and directions.	Standard check. Not considered critical to resolve for flood mapping purposes.
Message 2073	1	WARNING 2073 – Object ignored. Only Points, Lines, Polylines & Region Centers used.	Indicates there are GIS files with null shapes. No influence on the model.

Message	Count	Message content	
Message 2089	1	WARNING 2089 – Object ignored. Looking for Line, Polyline or Region in 2d_loc_layer. GIS Object == Null Shape	No influence on the model
Message 2099	1	Check 2099 – Ignored repeat application of boundary to 2D cell. BC Type = HQ	Duplication of boundary at one cell. No influence on the model outputs.
Message 2118	57	CHECK 2118 - Lowered SX ZC Zpt by XXm to 1D node bed level.	All within the MW criteria of less than 0.5 m
Message 2210	141	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = XX; Top of First FC Layer = XX	Minor locations were layered flow constrictions (bridges) cross under the terrain. No influence on the results.
Message 2467	15	Check 2467 – Layered Flow Constriction Shape overlap with Flow Constriction Shape at ZV point	Not located at a critical location. At the model boundary.
Message 2470	45	WARNING 2815 – Write PO Online not yet supported in Quadtree.	No influence on the model.

C.10 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

C.11 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.

Bureau of Meteorology (2022) Water Data Online, Stony Creek at Spotswood http://www.bom.gov.au/waterdata/

Engeny, (2019) Stony Creek Model Files and Results., Email Correspondence 18 December 2018 and File Transfer, February 2019.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

RPV (Rail Project Victoria) (2021) AJM JV Melbourne Airport Rail Technical Advice Note – Stony Creek Hydrology.

The Bureau of Meteorology (2022) Design Rainfall Data System

The Bureau of Meteorology (2022) Rating table data – Stony Creek at Spotswood

Water Technology (2013) Stony Creek Flood Modelling and Mapping Report, Version:02. Melbourne Water, May 2013.

Appendix D. Cherry Creek

Appendix D. Cherry Creek

This appendix details the RORB and TUFLOW model development for the Cherry Creek and full technical details of adopted parameters and results.

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D.1 Catchment Description and Study Area

The Cherry Creek catchment is a largely urban and industrial catchment with some localised regions of pervious areas, west of Melbourne which sits between the Cherry Creek and Laverton Creek catchments. The total catchment area is approximately 25 km^2. The catchment contains the Humes Main Drain and Brooklyn Main Drain which feed into Cherry Creek. The catchment contains several storage areas including two natural wetlands, Lake Stanley and Cherry Lake.

There are no streamflow gauges in the catchment and therefore there is limited information to calibrate or validate flows against. Model calibration was therefore not carried out for the Cherry Creek catchment as part of this Study.

D.1.1 Previous RORB Model

An existing RORB model for the Cherry Creek catchment was accessed for use in this Study. This model is understood to have been originally developed by GHD in 2006, then updated by RPV in 2021 (RPV, 2021). The recent updates included developing a modelling approach consistent with ARR 2019 and the Melbourne Water Flood Mapping Projects Specifications. The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Cherry Creek TUFLOW models covering Brimbank and Hobsons Bay LGAs. The updates undertaken to the model are outlined in the sections below.

D.2 RORB Model Setup

The development of the RORB model is described in the following sub-sections and presented in Figure D-1.

D.2.1 Catchment and Subarea Boundaries

A review of previous RORB models identified the need to re-delineate some areas to standardise the size of subareas falling within Brimbank and Hobsons Bay LGA in preparation for extraction of hydrographs for input into TUFLOW. Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas, or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Catchment delineation also considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

The final catchment and subarea boundaries are shown in Figure D-1.

D.2.2 Node-link network

The node-link network shown in Figure D-1 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

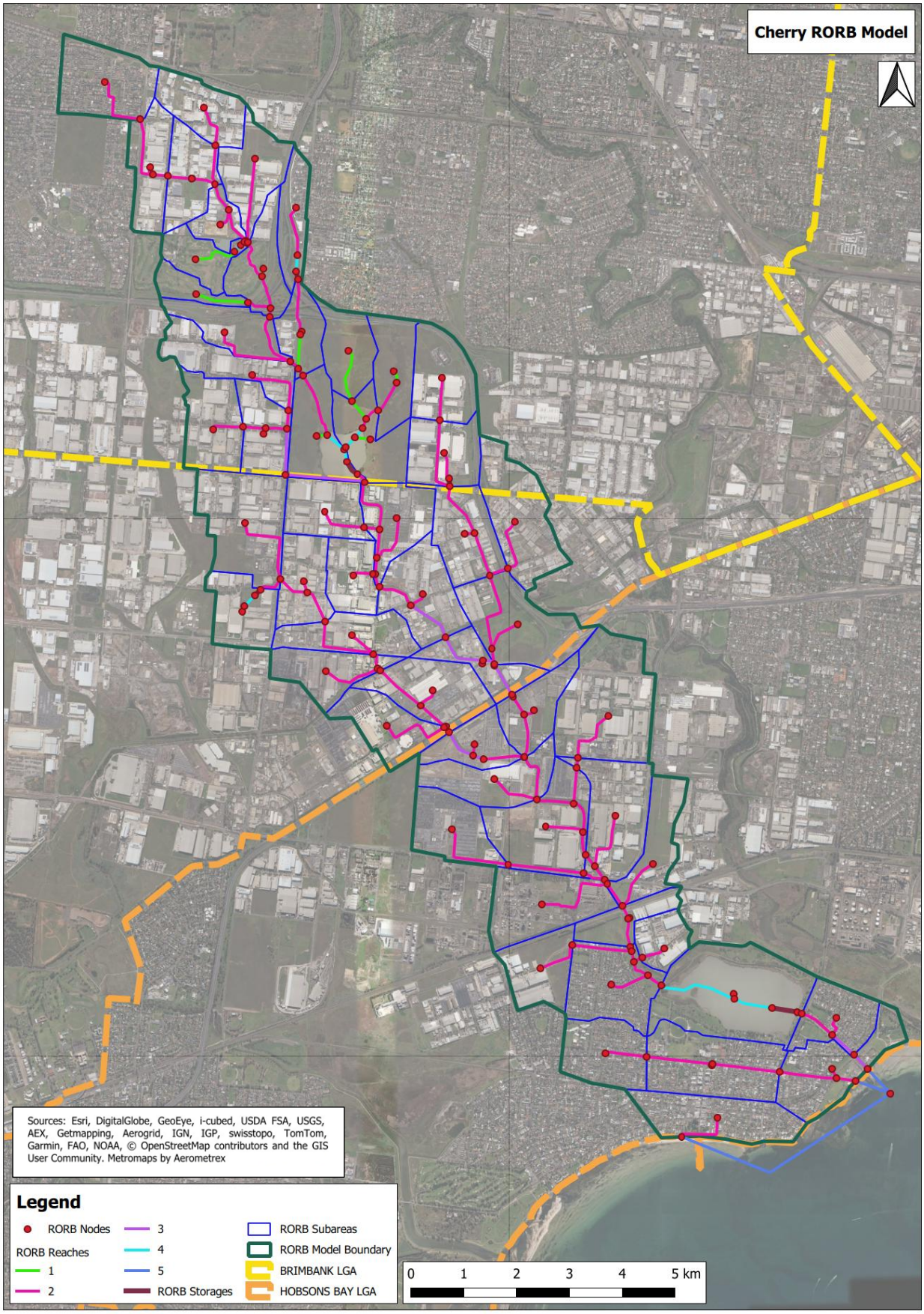


Figure D-1: Cherry Creek RORB model setup.

D.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
  - Type 1 – Natural channels, used for major creek reaches
  - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
  - Type 3 – Lined channel or pipe – these were used to represent flowpaths associated with lined channels
  - Type 4 – Drowned – these were used upstream of storages or major waterbodies
  - Type 5 – Dummy – used to connect independent catchments (i.e. at Port Phillip Bay) to a single outlet node

The final reach alignments and types are shown in Figure D-1

D.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB), as listed in Table D-1. No H-S/S-Q relationship information was available to represent Derrimut RB and the wetland area around Derrimut Golf Course as storages in the RORB model.

Table D-1: Storages in the RORB model

Storage	Data source and checks
Cherry Lake	Storage details adopted as per RPV model (2021). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S relationship). The H-S and S-Q relationships were extended by extrapolating using the existing data points/trend to allow higher flows to be modelled.
Lake Stanley	Storage details adopted as per RPV model (2021). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S relationship).
Boundary Rd RB (also sometimes referred to as Brooklyn RB)	Storage details adopted as per RPV model (2021). Checks on spillway height carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information, HARC (2017) and inspection reports – this check identified an update required to some of the parameters of the RB outlet pipes (length, slope and D/S invert updated according to Melbourne Water data) – this was updated in the RORB model. No further information available for further checks or updates (i.e. on H-S relationship).
Millennium Rd RB	Storage details adopted as per RPV model (2021). Checks on spillway height carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information and inspection reports – this check identified an update

Storage	Data source and checks
	required to some of the parameters of the RB outlet pipes (pipe size, length and slope updated according to Melbourne Water data) – this was updated in the RORB model. No further information available for further checks or updates (i.e. on H-S relationship).
Fitzgerald Rd RB	Storage details adopted as per RPV model (2021). Checks on spillway height carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information and inspection reports – this check identified an update required to some of the parameters of the RB outlet pipes (pipe size, length and slope updated according to Melbourne Water data) – this was updated in the RORB model. No further information available for further checks or updates (i.e. on H-S relationship).

D.2.5 Diversions

Data reviews noted that the previous Cherry Creek RORB model includes a number of RORB diversions intending to represent parts of the catchment's major underground drainage network. As this approach is no longer consistent with industry standards, diversions were removed and reaches redrawn. With these updates, the Study RORB model represents undiverted flows along key flowpaths active in the 1% AEP event.

D.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

D.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

D.2.8 RORB version

RORB version 6.47 was used for modelling.

D.3 RORB design inputs

D.3.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.827, Long 144.804) was sourced from the Bureau of Meteorology (Appendix I). As per the Melbourne Water Flood Mapping Projects Specifications rainfalls were increased by 18.5% to establish climate change rainfalls.

D.3.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Given that this Study has derived storm losses for neighbouring catchments via model calibration to observed events (including Kororoit Creek, Stony Creek and Maribyrnong River), loss parameters have been transferred from the Kororoit Creek model to the Cherry Creek model (as proposed in the Method Statement). Specifically, the loss parameters derived for the Kororoit Creek at Brooklyn gauge have been transferred and applied to Cherry Creek given that the upstream area at Brooklyn is largely urban and therefore most consistent with the land use of the Cherry Creek catchment. The transfer of parameters from a neighbouring catchment's calibrated RORB model is supported by ARR 2019 (HARC, 2020) over the adoption of DataHub loss parameters as the transferred losses are likely to represent the runoff behaviour of a catchment in the same local geography more accurately. The adopted storm losses are listed in Table D-2.

Table D-2: Cherry Creek model storm losses

	IL (mm)	CL (mm/hr)
Transferred from Kororoit Creek Creek (adopted)	13.5	2.5
DataHub	5.0	0.6

D.3.3 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations below the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

D.3.4 Temporal Patterns

Point temporal patterns were obtained from the ARR DataHub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies) and adopted given the catchment area is smaller than 75 km^2. Temporal patterns were filtered for embedded bursts using the option in RORB.

D.3.5 Spatial Patterns

A spatial rainfall distribution was determined to ensure that variation in rainfall depth across the catchment was accounted for. This was calculated by comparing the catchment average rainfall to the average rainfall for each sub-catchment using the design rainfall grids (Bureau of Meteorology, 2022). This was then implemented to the RORB model as a 'non-uniform' spatial pattern for each duration.

The spatial variation across the catchment is illustrated in Figure D-2 for the 1% AEP 12 hour rainfall event.

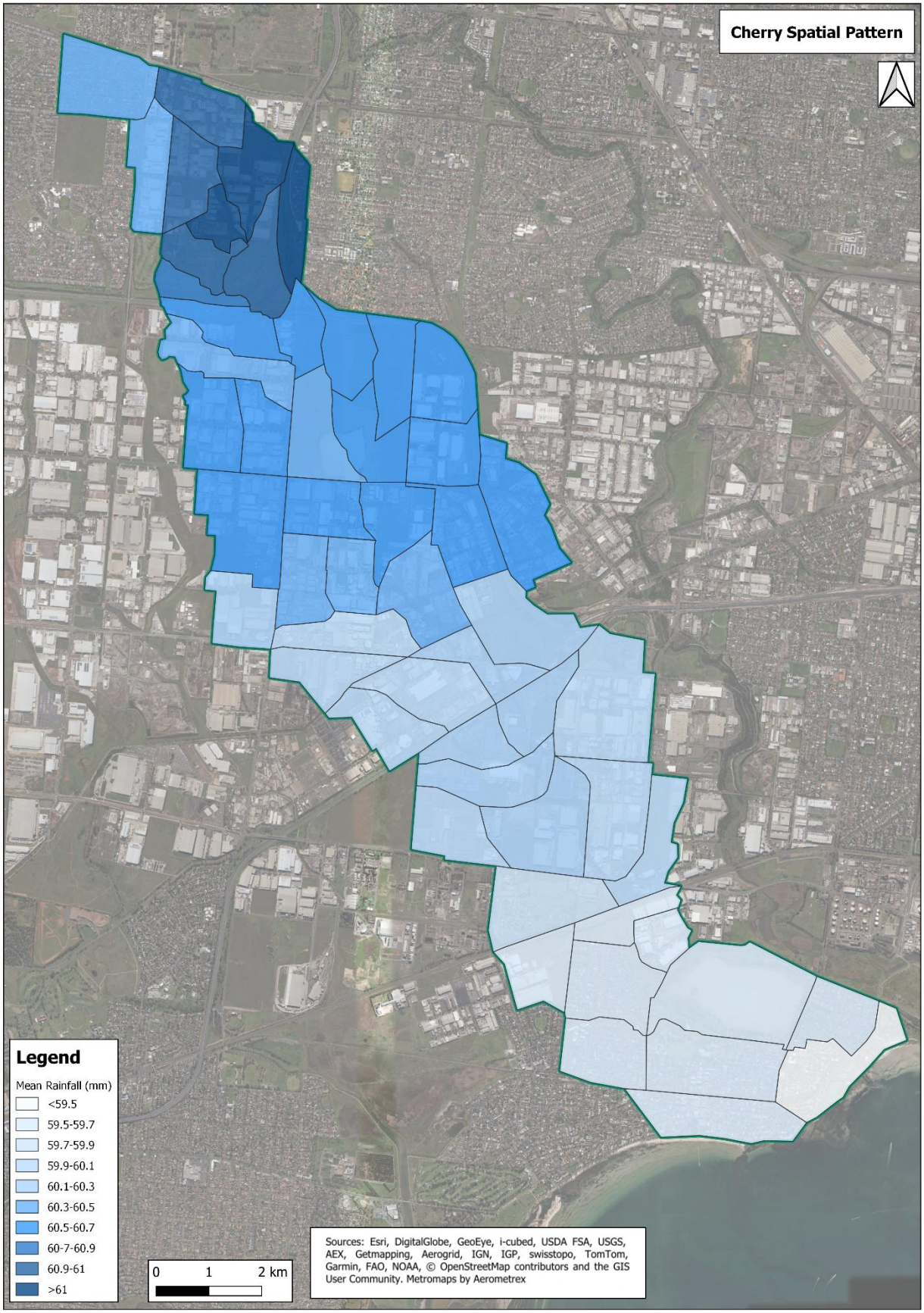


Figure D-2: Spatial rainfall pattern for the Cherry Creek RORB model for the 1% AEP, 12 hr storm.

D.3.6 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Section D.5. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment is presented in Table D-3.

Table D-3: Adopted ARF values for the Cherry Creek RORB model.

Duration	ARF area (km^2)	Justification
20 min (1%, 2%, 5%, 20% AEP) 25 min (5%, 10% AEP) 45 min (all AEPs)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
1 hour (all AEPs) 4.5 hour (1% AEP)	4	
1.5 hour (1%, 2%, 5% AEP) 2 hour (5%, 10%, 20% AEP)	15	
2 hour (1%, 2% AEP) 6 hour (1% AEP) 9 hour (2%, 5%, 10%, 20% AEP) 12 hour (1%, 2% AEP)	22	

D.4 RORB Verification and Input Parameters

To determine the appropriate parameters for generating the hydraulic model inputs, RORB was run in Monte Carlo mode for the Study area to establish peak flow estimates at the catchment outlets for the 1% AEP event. The Monte-Carlo technique as recommended by ARR (Ball et al., 2019) was used to calculate flood quantiles. This technique involves randomly sampling different flood forming variables to create flood frequency outputs whilst also replicating natural processes. This technique inherently accounts for interactions between the various flood forming variables, providing a more realistic representation of the flood hydrograph generation processes.

The routing calculation in RORB uses two parameters, k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. The m parameter was set at as the default value of 0.8 as per advice in the Melbourne Water's Flood Mapping Projects Specifications .

Peak flow estimates where k_c was varied for the Cherry Creek RORB model are provided in Table D-4. The proposed inputs are summarised in Table D-5. The Regional Flood Frequency Estimation (RFFE) was not performed given it is recommended for entirely rural catchments (Cherry Creek has a largely urban upstream catchment). The Cherry Lake RB inflow was chosen as the validation location given the model outlet is downstream of this and flows would be impacted by RB flow attenuation.

Table D-4: k_c estimates and peak flow values at the Cherry Lake Inflow

	Pearse et al. 2002	Yarra & Maribyrnong (Melbourne Water)	Nikolaou/ von't Steen (urban)	Nikolaou/ von't Steen (rural)	Melbourne Water rule of thumb (urban)	Melbourne Water rule of thumb (rural)
k_c	8.29	6.62	-	-	-	-
Q_{100} flow at Cherry Lake inflow (m^3/s)	103.3	122.0	90.7	48.4	214.4	64.3

Table D-5: Adopted k_c for the Cherry Creek RORB Model

Adopted k_c	Comment
8.29 (Pearse et al., 2002)	Flows generally align with previous estimates (RPV, 2020 Q_{100}: 108.8 m^3/s). Slightly lower flows are expected due to higher storm losses applied in this Study, derived through calibration of models in nearby catchments. Flows are within range of regional estimates.

D.5 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARF to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table D-3. This enabled the identification of how critical durations were likely to alter based on the contributing catchment area. Key locations across the catchment are shown in Figure D-3. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW
- Locations upstream or within urban areas
- Locations upstream and downstream of model storages
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave
- Points located within Study LGAs, providing good coverage across Study area

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Table D-6. Table D-7 lists the storms that were simulated in TUFLOW at the hydraulic modelling phase of this Study. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

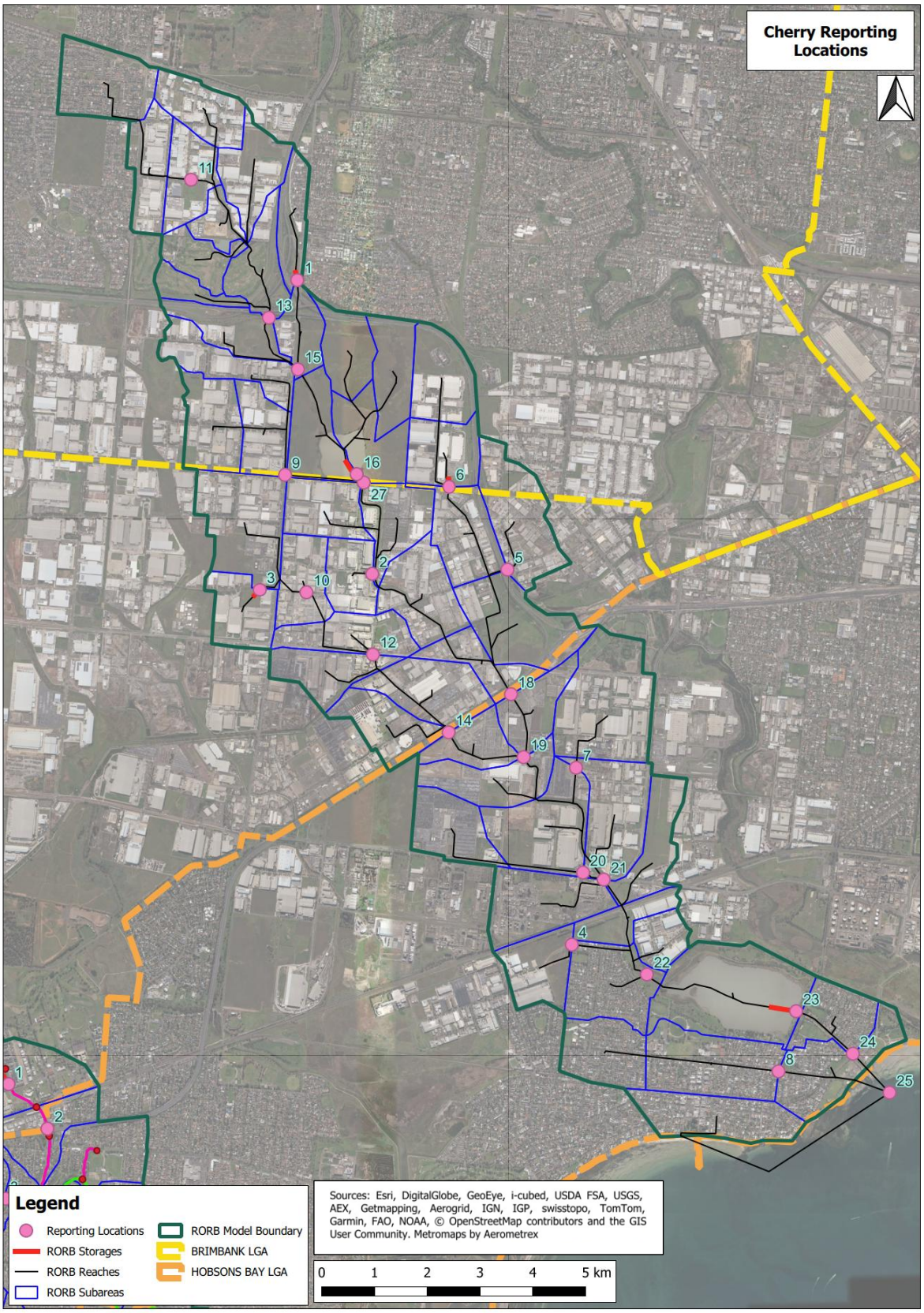


Figure D-3: Cherry Creek RORB reporting locations

Table D-6: Analysis of critical durations and peak flows at key locations in the Cherry Creek RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Millennium RB - Inflow	0.3	20min	5.8	20min	4.8	25min	3.7	25min	3.0	30min	2.4
2	Hume Road	0.3	20min	10.0	20min	8.6	20min	7.0	20min	5.8	20min	4.7
3	Fitzgerald Rd RB - Inflow	0.4	20min	12.8	15min	10.7	15min	9.0	15min	7.0	20min	5.9
4	Charles Road	0.4	20min	6.8	25min	5.6	45min	4.5	45min	3.6	1hour	2.9
5	West Ring Road	0.7	20min	14.8	20min	12.6	20min	9.5	20min	7.8	20min	6.4
6	Boundary Rd RB (Brk) - Inflow	0.9	20min	10.6	20min	9.0	20min	6.7	20min	5.5	20min	4.7
7	Stuber Road	1	20min	18.3	30min	15.4	25min	11.9	25min	9.8	45min	8.2
8	Millers Road	1.2	45min	14.1	1hour	11.6	45min	8.9	45min	7.2	1hour	5.6
9	Boundary Road 1	1.3	30min	18.8	30min	16.0	45min	12.7	45min	10.5	45min	8.8
10	Industrial Area	1.5	45min	16.5	45min	14.1	45min	11.5	45min	9.5	30min	7.3
11	Paramount Boulevard	1.7	45min	18.1	45min	15.3	25min	12.0	25min	9.9	20min	8.8
12	Doherty's Road	1.9	1.5hour	15.1	1.5hour	12.8	1.5hour	10.2	2hour	8.0	1hour	6.3
13	Western Freeway	3.2	1hour	30.1	1hour	25.2	2hour	19.8	2hour	16.3	1hour	12.4
14	Princes Freeway 1	3.2	1hour	31.6	1hour	26.7	1hour	21.3	1hour	17.6	1hour	14.4
15	Fitzgerald Road	4.1	1.5hour	35.0	1.5hour	29.5	2hour	23.1	2hour	19.0	1hour	13.7
16	Lake Stanley - Inflow	7	1.5hour	43.0	2hour	35.7	1.5hour	27.8	2hour	21.9	2hour	16.6
17	Boundary Road 2	7	4.5hour	26.8	9hour	21.1	2hour	10.8	1hour	8.7	45min	7.1
18	Princes Freeway 2	11.7	1.5hour	51.3	1.5hour	43.9	1.5hour	35.2	1.5hour	28.7	1hour	22.7
19	Pinnacle Road	14.9	1.5hour	80.2	1.5hour	68.5	1.5hour	53.5	2hour	44.4	1hour	35.8

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
20	Cherry Creek Road 1	17.5	1.5hour	3.7	1.5hour	3.2	2hour	2.5	2hour	2.1	1hour	1.6
21	Cherry Creek Road 2	18.1	1.5hour	96.3	1.5hour	82.0	2hour	66.9	2hour	55.6	1hour	40.3
22	Cherry Creek 1	20.6	2hour	104.8	2hour	89.3	2hour	71.2	2hour	58.4	2hour	43.5
23	Cherry Lake - Inflow	21	2hour	107.3	2hour	91.6	2hour	72.6	2hour	59.1	2hour	45.3
24	Cherry Creek 2	22.1	12hour	31.2	12hour	27.5	9hour	22.8	9hour	20.6	9hour	16.2
25	Cherry Outlet	24.5	6hour	37.5	9hour	33.9	9hour	27.4	9hour	22.7	9hour	16.9

Table D-7: Critical durations and selected temporal patterns for the Cherry Creek RORB model.

AEP	20min	25min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour
1%	TP 27	-	-	TP 29	TP 27	TP 27	TP 28	-	TP 22	TP 30	-	TP 29
2%	TP 28	-	-	TP 29	TP 27	TP 27	TP 28	-	-	-	TP 28	TP 29
5%	TP 18	TP 14	-	TP 19	TP 18	TP 16	TP 15	-	-	-	TP 16	-
10%	-	TP 14	-	TP 19	TP 17	-	TP 16	-	-	-	TP 12	-
20%	TP 7	-	-	TP 5	TP 4	-	TP 3	-	-	-	TP 6	-

D.6 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Cherry Creek catchment.

D.6.1 Hydraulic Model Set Up

D.6.1.1 Terrain modifications

Maps available in Figure D-4, Figure D-5, Figure D-6 show Cherry Creek TUFLOW model terrain modifications, which are also listed in Table D-8 where these have been based on drawings, plans or other available detailed information.

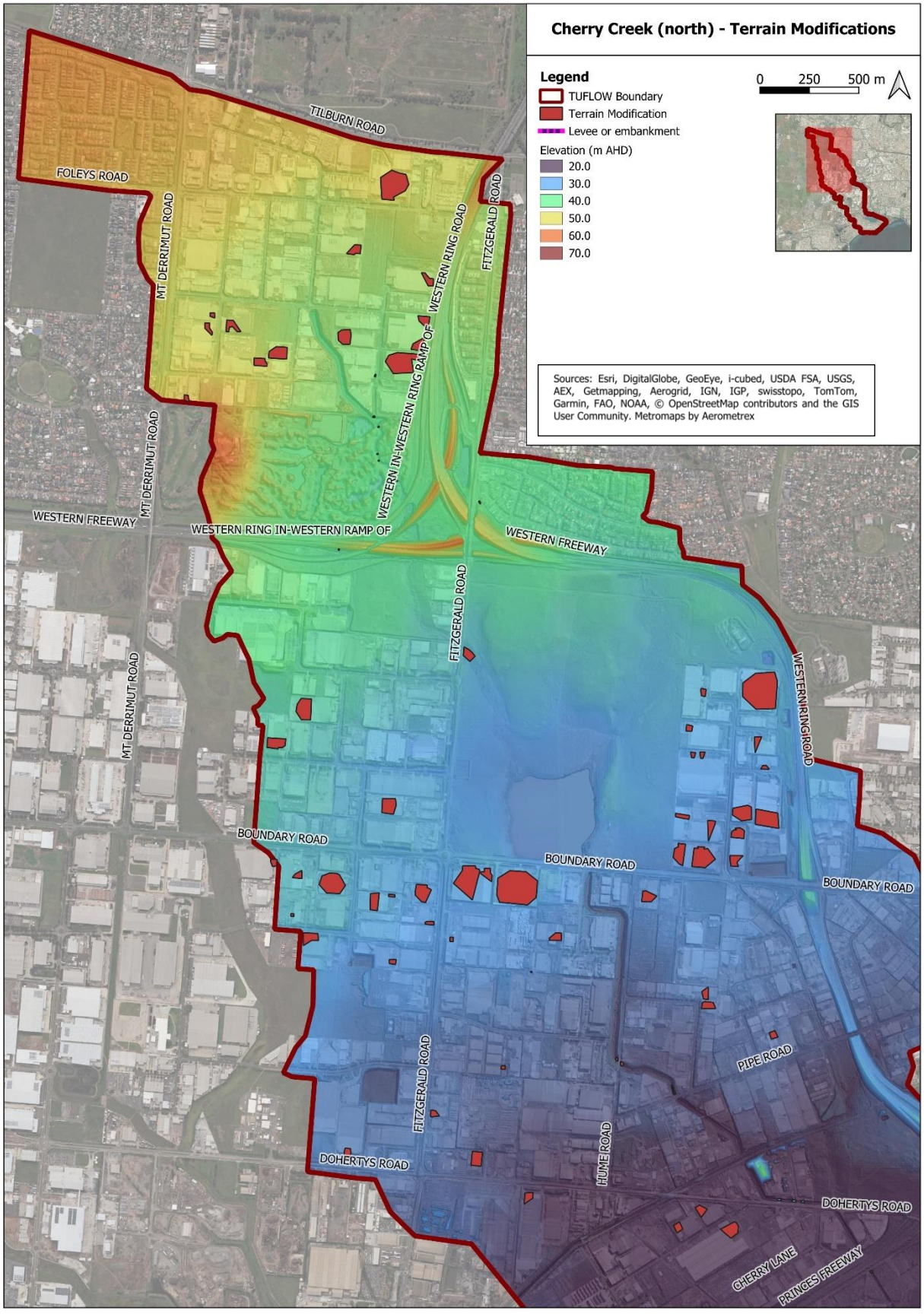


Figure D-4: Cherry Creek TUFLOW model terrain modifications (north).

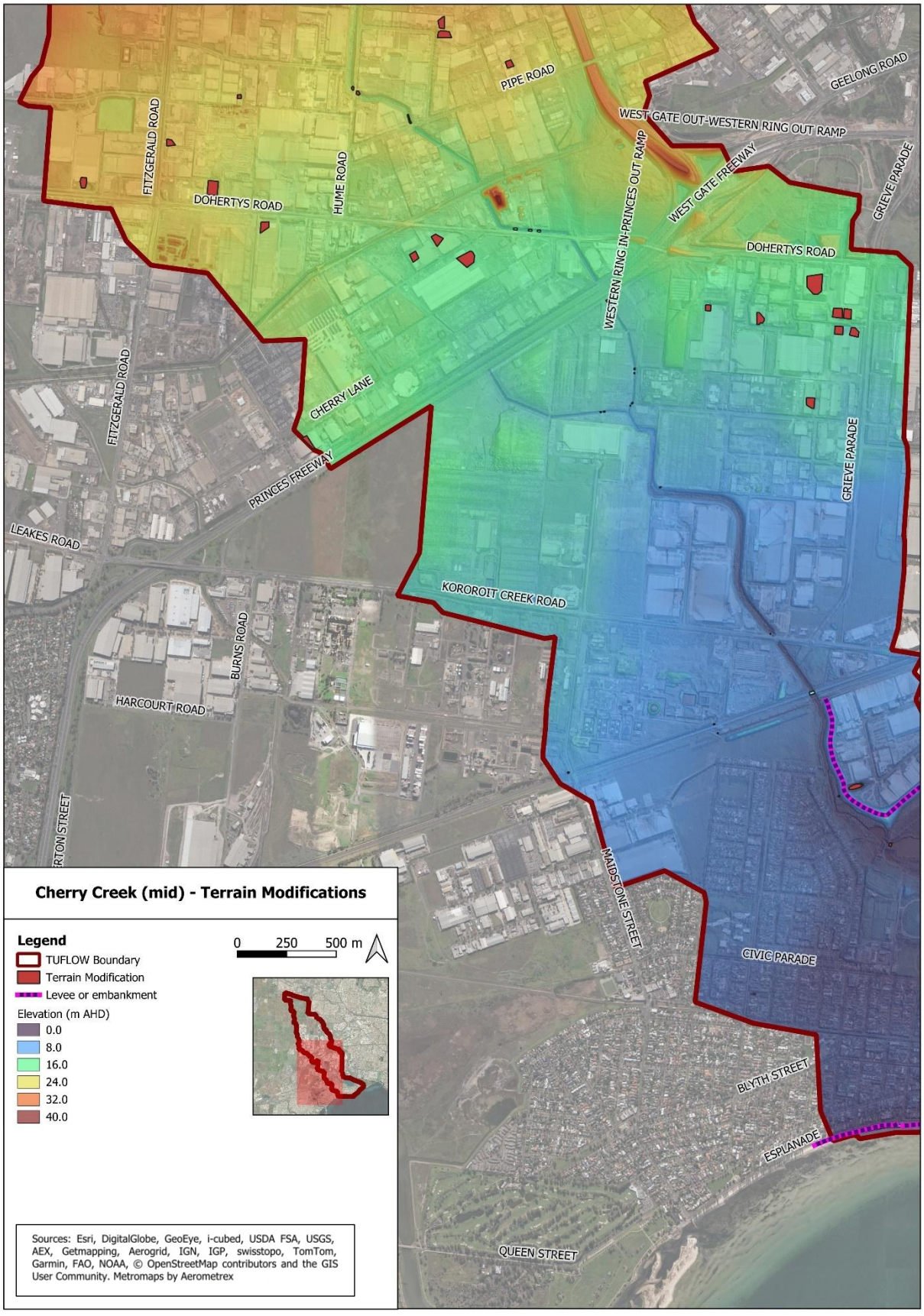


Figure D-5: Cherry Creek TUFLOW model terrain modifications (mid).

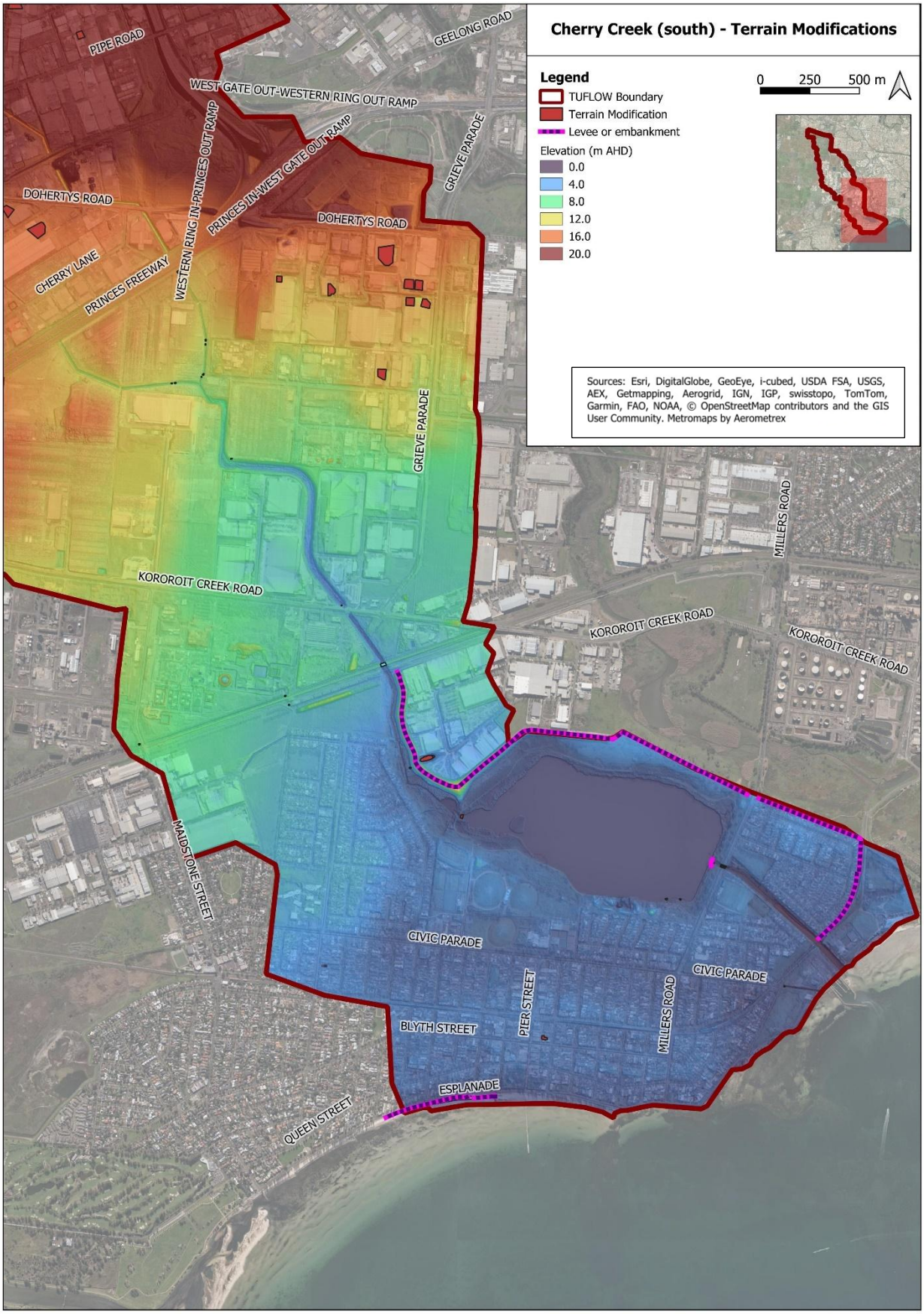


Figure D-6: Cherry Creek TUFLOW model terrain modifications (south).

Table D-8: Cherry Creek TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Cherry Lake footpath and outfall	Connel Wagner (2001), Cherry Lake Outfall Altona Feature Survey, Drawing: SES 565/2	The TUFLOW model accurately depicts the outfall of Cherry Lake, as indicated by the survey. This is particularly crucial for strengthening the design of hydraulic control levels, especially in areas where the 1m LiDAR falls short in capturing details. The model incorporates outlet control levels, drop structures, a concrete apron, a concrete channel, and a timber footbridge. In the model, the timber footbridge is depicted as a layered flow constriction line, with the footpath connected to its two sides represented by 2D_zsh lines.
Millers Road Bridge (downstream of Cherry Lake)	Connel Wagner (2001), Cherry Lake Outfall Altona Feature Survey, Drawing: SES 565/2	Reinforcement of the engineered channel downstream of Cherry Lake beneath the Millers Road bridge is essential, especially since the channel morphology is more accurately portrayed than with 1D LiDAR.
Cherry Creek Levee - East of Millers Road, West of Millers Road, and creek floodwall	Melbourne Water Waterway Assets - Levee and Embankment (Shapefile for levee alignment)	Reinforcement of the Melbourne Water levee crest using LiDAR involves incorporating several 2D_zsh lines into the model. These lines are constructed based on the levee alignments provided by the Melbourne Water asset database. The elevations of 2D_zsh points, snapped to these lines, are derived from a combination of 1m LiDAR data and some informed judgment, compensating for the lack of additional information. For the levee sections situated to the east and west of Millers Road, they are simply composed of earth bunds. Notably, the section of the levee that runs alongside the railway line (Cherry Creek Floodwall) features a concrete wall joining and connecting to the earth bund starting from the eastern end of the Millers Road levee. Site observations, along with streetview data, indicate that the Cherry Creek Floodwall appears to be tied in at the same elevation as the eastern earth bund of the Millers Road levee.
Unnamed Levee - North of Cherry Lake	N/A	Reinforcement of the levee crest involves aligning it based on aerial imagery, with elevation levels sampled from 1m LiDAR due to the lack of additional information.
Altona Foreshore Seawall	Cardno (2022), Altona Beach Three Stage Foreshore Upgrade, Drawing: 59919099-WE	Two z-shapes have been generated in LiDAR to represent the removal of the existing Altona foreshore seawall and implement the new design.
Others including the refinement of waterways, retarding basins and holes	N/A	Approximately 30 z-shapes have been created to enhance waterway and retarding basin details, and an additional 70 hole-filling patches have been applied to rectify inaccuracies in the 1m LiDAR data, thereby improving the overall quality of the area.

D.6.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table D-9.

Table D-9: Cherry Creek TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Altona Rd	0.09	1.2	0.5	1	30
Altona Rd Rail	0.26	0.5	1.5	1	30
Bay trail	0	1.14	0.3	1.1	60
Cherry Lake Footbridge	0.05	1.72	0.3	1	30
Cherry Lake Inlet	0	1.29	0.5	1	30
Cherry Lake Outlet	0	1.9	0.5	1	30
Dohertys Rd Crossing 1	0	15.77	0.3	1.7	60
Dohertys Rd Crossing 2	0	15.7	0.3	1.7	60
Dohertys Rd Crossing 3	0	15.6	0.3	1.7	30

D.6.1.3 Model roughness

Maps available in Figure D-7 show the Cherry Creek TUFLOW model Manning's roughness.

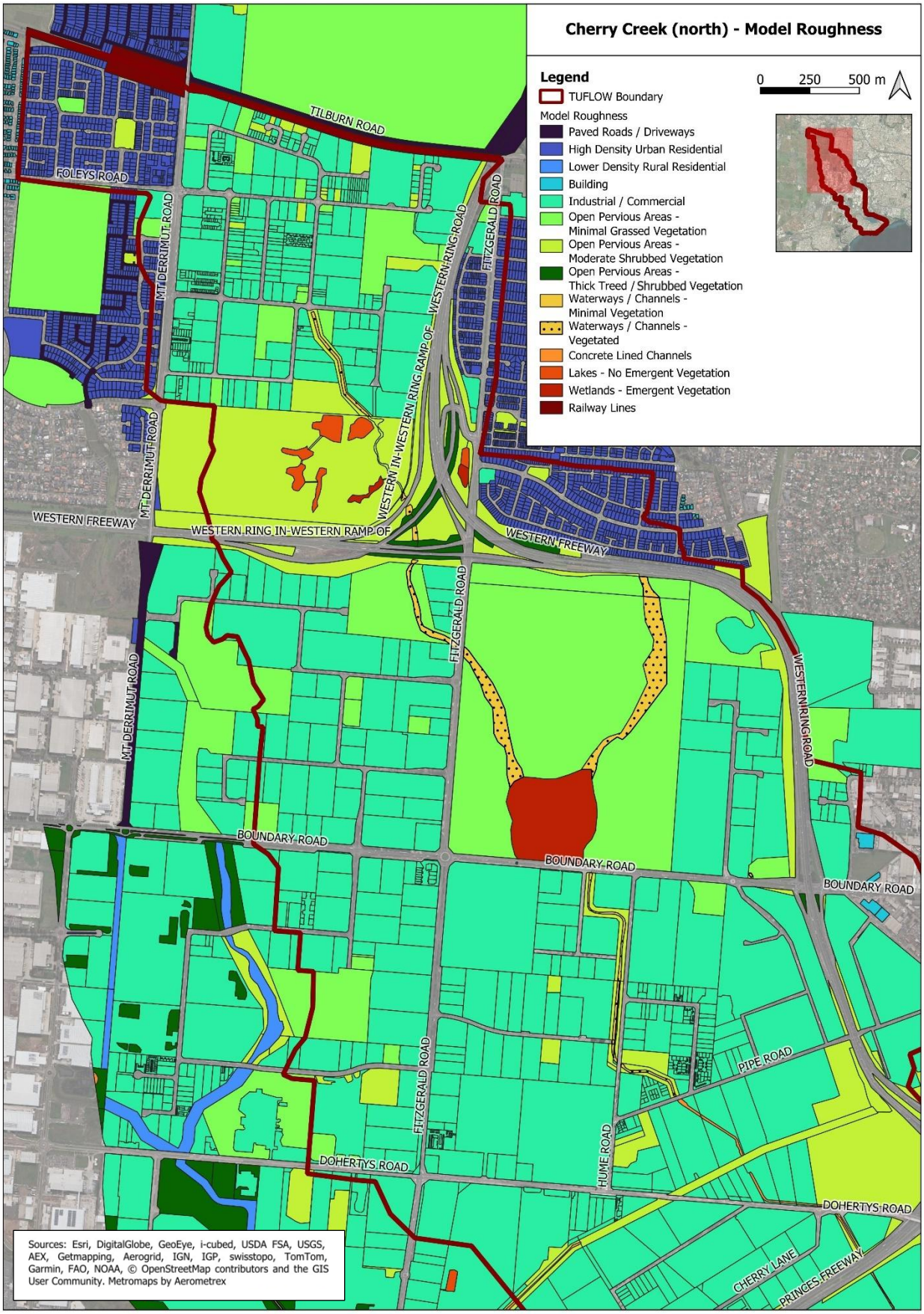


Figure D-7: Cherry Creek TUFLOW model Manning's roughness (north).

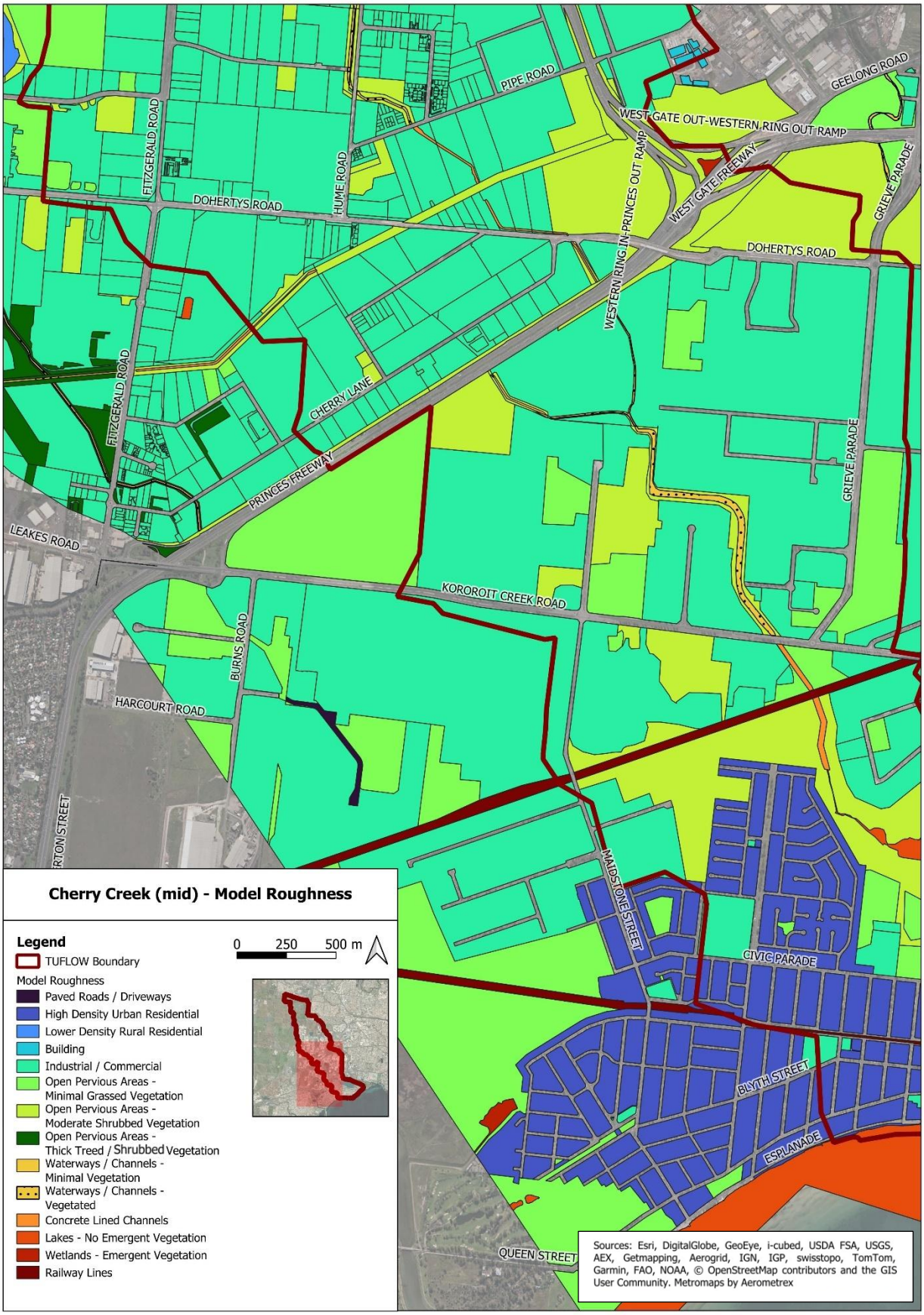


Figure D-8: Cherry Creek TUFLOW model Manning's roughness (mid).

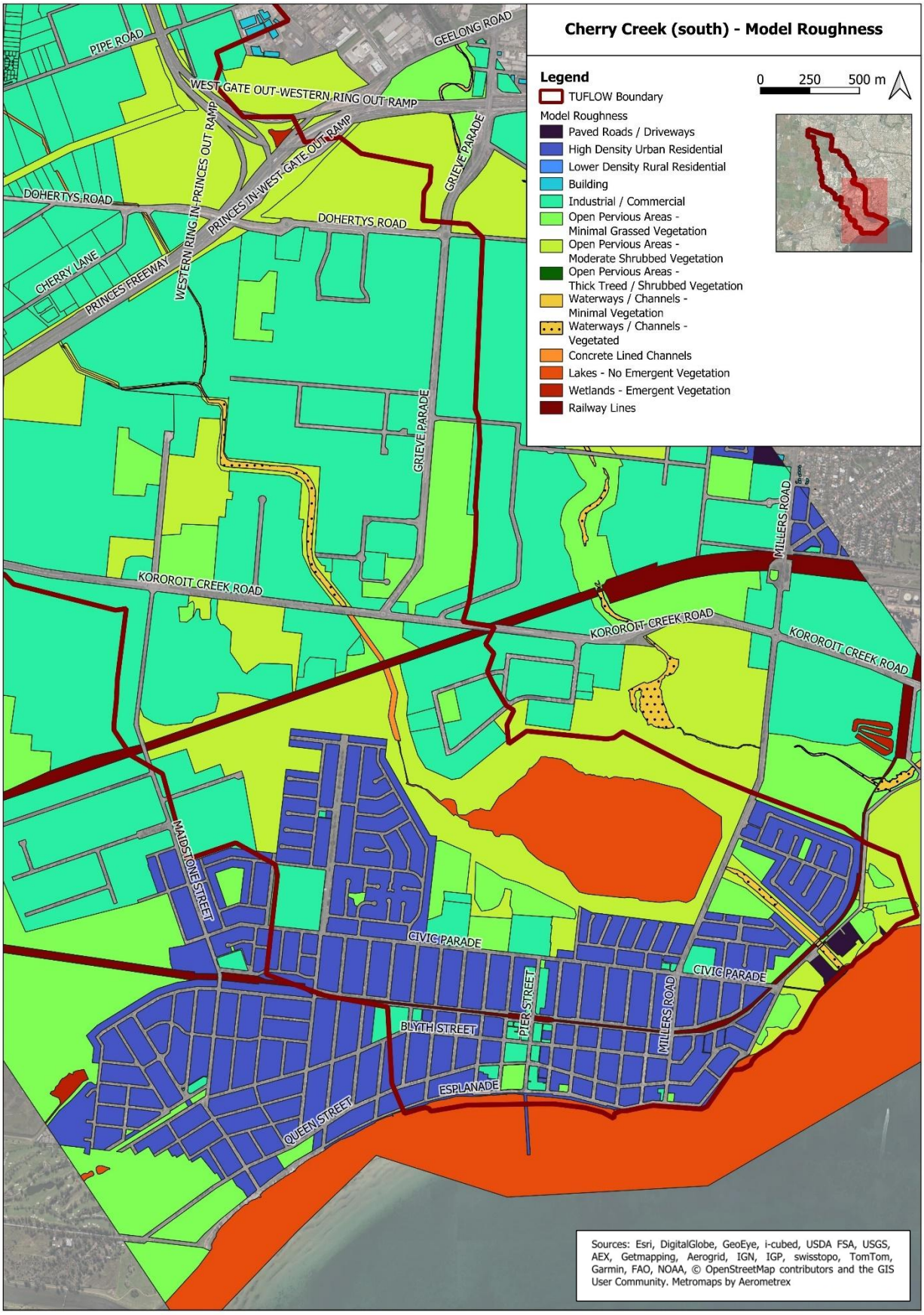


Figure D-9: Cherry Creek TUFLOW model Manning's roughness (south).

D.6.1.41D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table D-10. A full count of the adopted pit types in the TUFLOW model is listed in Table D-11 and Table D-12. Maps of the full drainage network can be found in Figure D-10, Figure D-11 and Figure D-12.

Table D-10: Cherry Creek TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Number of cell	Justification
Add_Culvert_001, Add_Culvert_002, Add_Culvert_003	Unknown, should be private	R	3.3	0.9	1	Assumed crossing with a box culvert underneath in Manheim Auctions investigated from 1m DEM, no streetview is available for a close look.
Add_Culvert_004	City of Wyndham	R	3	1.8	3	Assumed box culvert beneath Hume Road as part of Cherry Creek waterway which the headwall could be seen from the streetview. The culvert diameters are assumed based on 1m DEM flow area.
Add_Culvert_005	VicRoads/ Brimbank Council	R	3	0.9	1	Assumed Western Freeway Offramp/ Onramp culvert investigated using 1m DEM and aerial imagery.
Add_Culvert_006	VicRoads/ Brimbank Council	R	2.7	0.6	1	Assumed Western Freeway culvert investigated using 1m DEM and aerial imagery.
Add_Culvert_007	VicTrack/ Hobsons Bay Council	R	3	0.6	1	A railway culvert was investigated and assumed using 1m DEM and aerial imagery, directing water from the upstream of railway near private road within Qenos Pty Ltd to the downstream of railway which DHL Supply Chain is at.
Add_Pipe_001, Add_Pipe_002, Add_Pipe_003, Add_Pipe_004, Add_Pipe_005, Add_Pipe_006	VicRoads/ Brimbank Council	C	0.3	0	1	Assumed pipes beneath Western Ring Road and the ramps investigated using 1m DEM and aerial imagery.
Add_Pipe_007	Hobsons Bay Council	R	4.2	2.4	1	Assumed discharge from Cherry Swamp to Cherry Creek.

Table D-11: Cherry Creek TUFLOW model 1D drainage adopted pit types.

Pit Type	Count
Side Entry Pit	2204
Double Side Entry Pit	71
Grated Side Entry Pit	33
Grated Pit	339
Double Grated Pit	0
Junction Pit (node)	672

Table D-12: Cherry Creek TUFLOW model 1D drainage adopted pit types (Melbourne Water)

Pit Type	Count
Grated Side Entry Pit	2
Grated Pit	10
Grated Pit (1.7 m x 1.5 m)	2
Grated Pit (2.2 m x 1.7 m)	1
Grated Pit (3.9 m x 1.4 m)	1
Junction Pit (node)	28

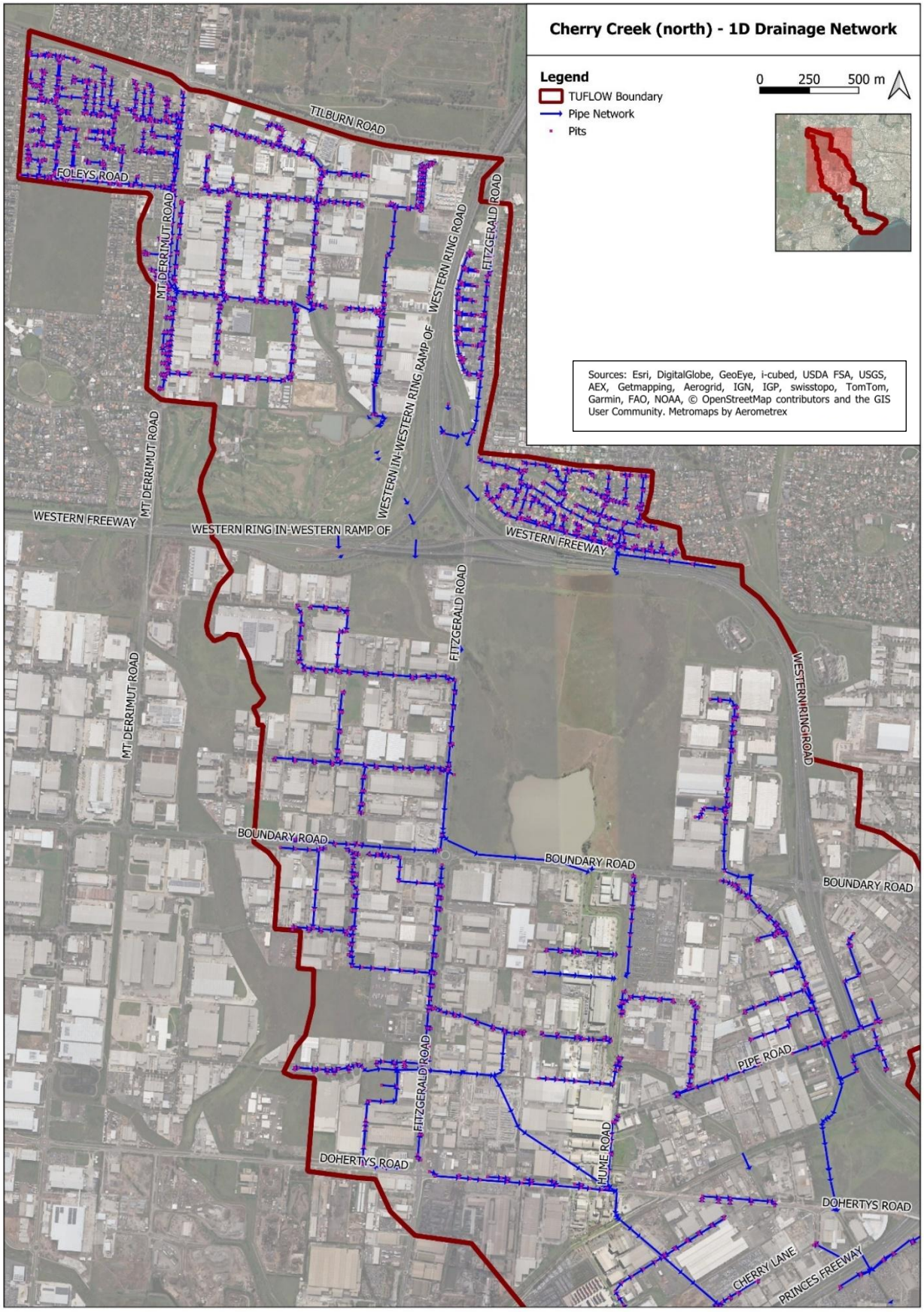


Figure D-10: Cherry Creek TUFLOW model 1D drainage network (north).

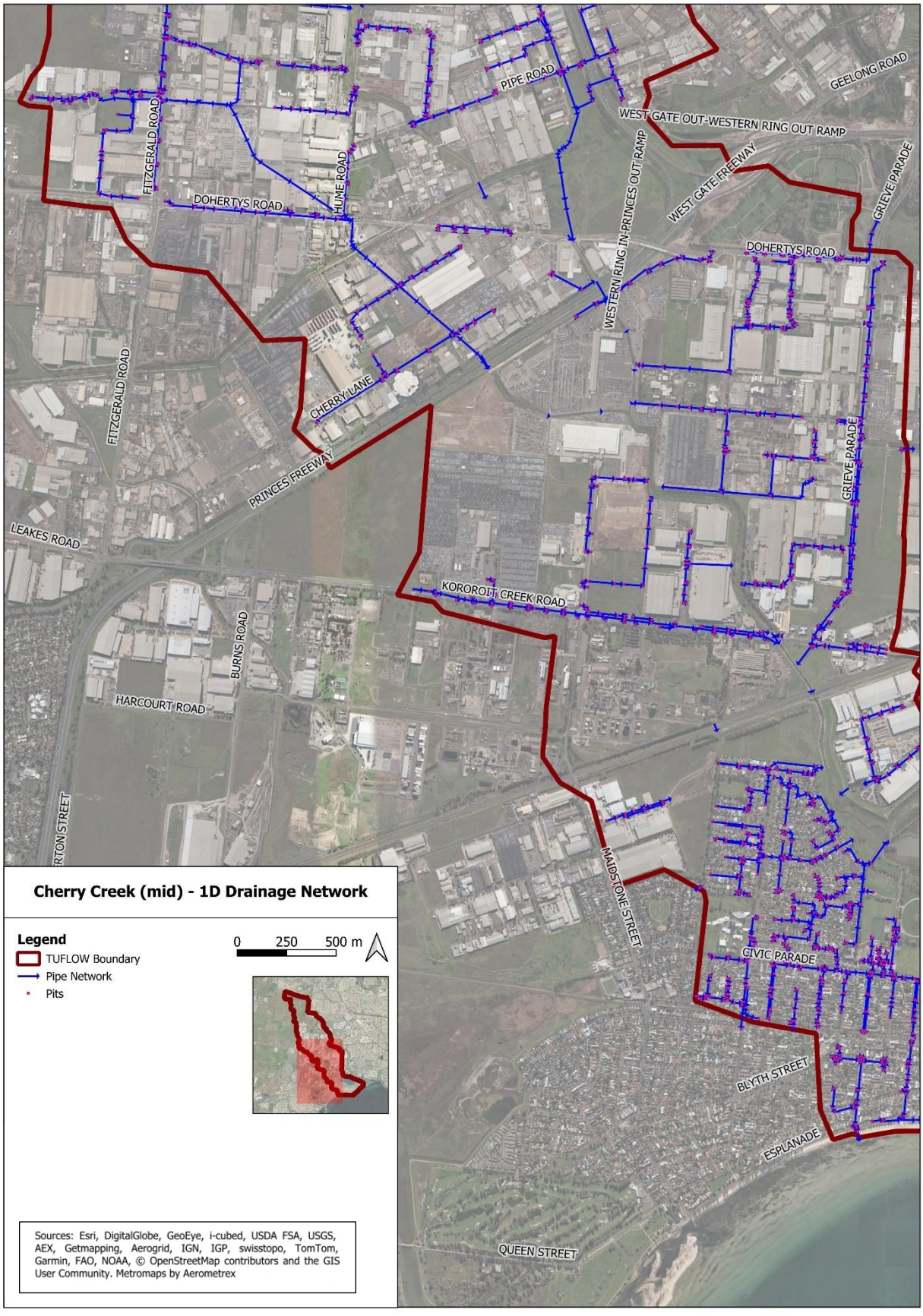


Figure D-11: Cherry Creek TUFLOW model 1D drainage network (mid).

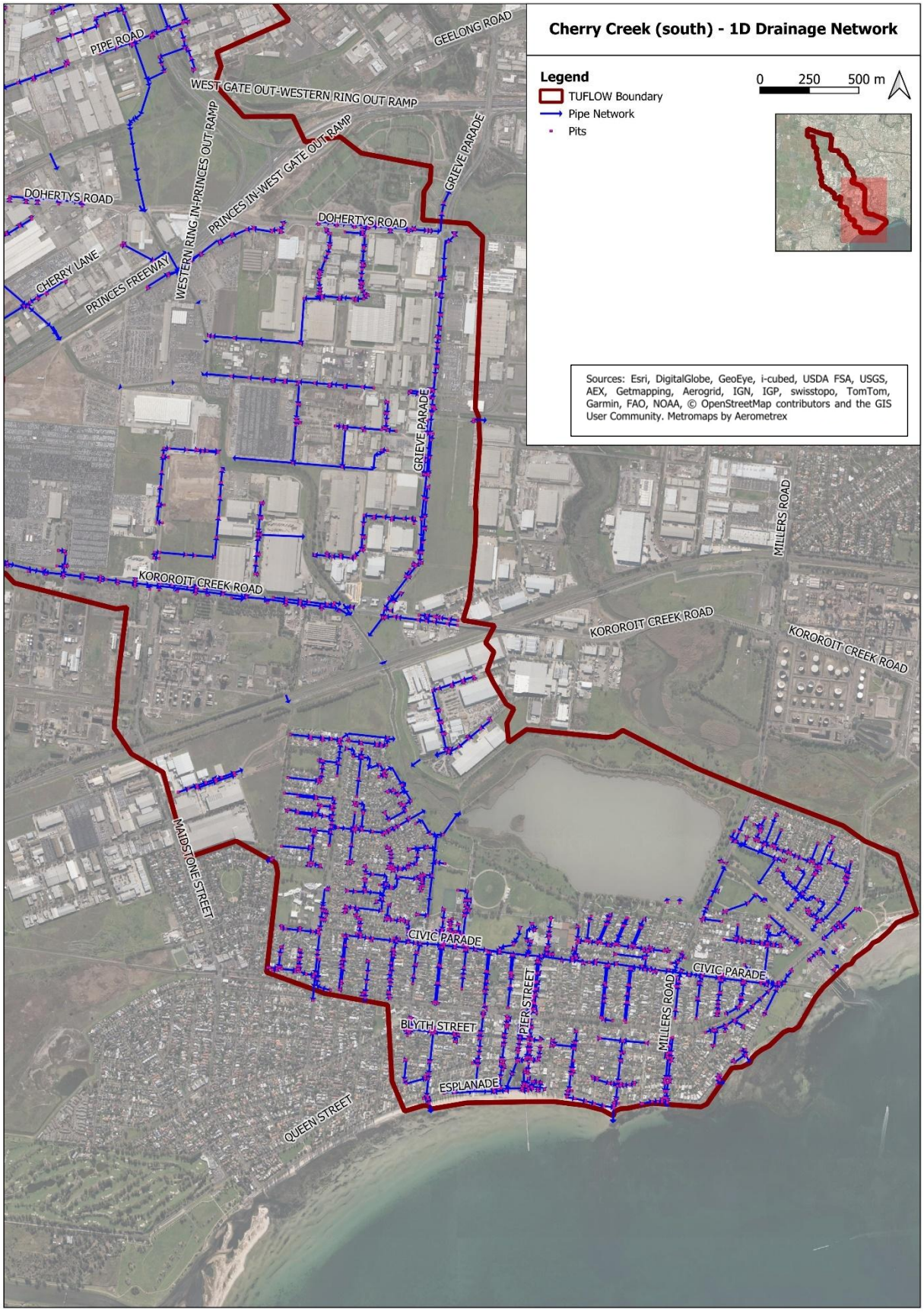


Figure D-12: Cherry Creek TUFLOW model 1D drainage network (south).

D.6.1.5 Boundary conditions

The boundary conditions for the Cherry Creek TUFLOW model are presented in Figure D-13, Figure D-14 and Figure D-15.

(a) Inflow Boundary for Cherry Creek

To represent the boundary condition inflows for Cherry Creek, rainfall excess outputs from the Study's RORB model were applied across the TUFLOW domain.

(b) Downstream Boundary for Cherry Creek

A static HT (Height versus Time) boundary condition was applied where the model outlets to Port Phillip Bay. Several HQ (height versus flow) boundaries were defined based on slope where there is flow interacting with the model boundary.

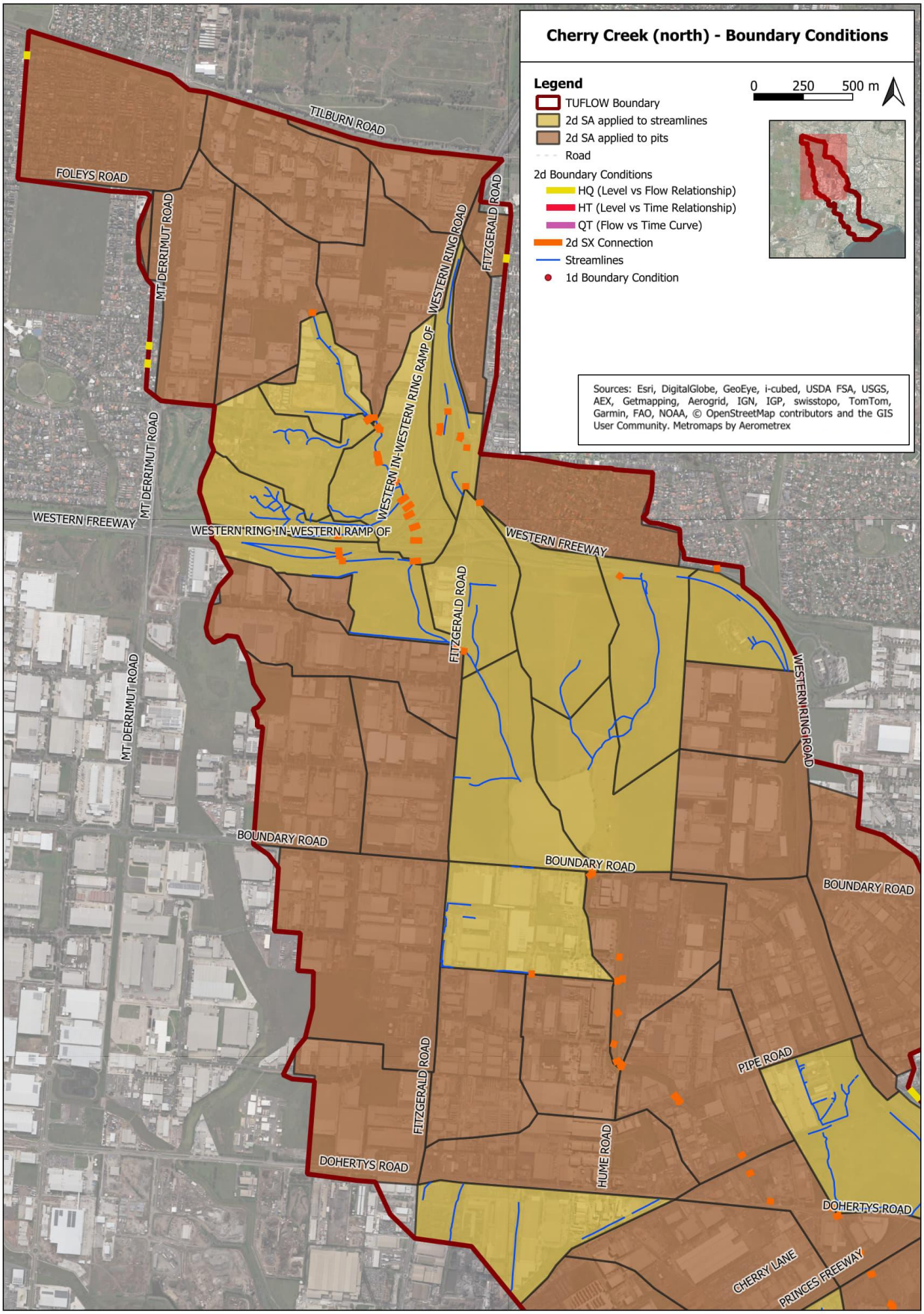


Figure D-13: Cherry Creek TUFLOW model boundary conditions (north).

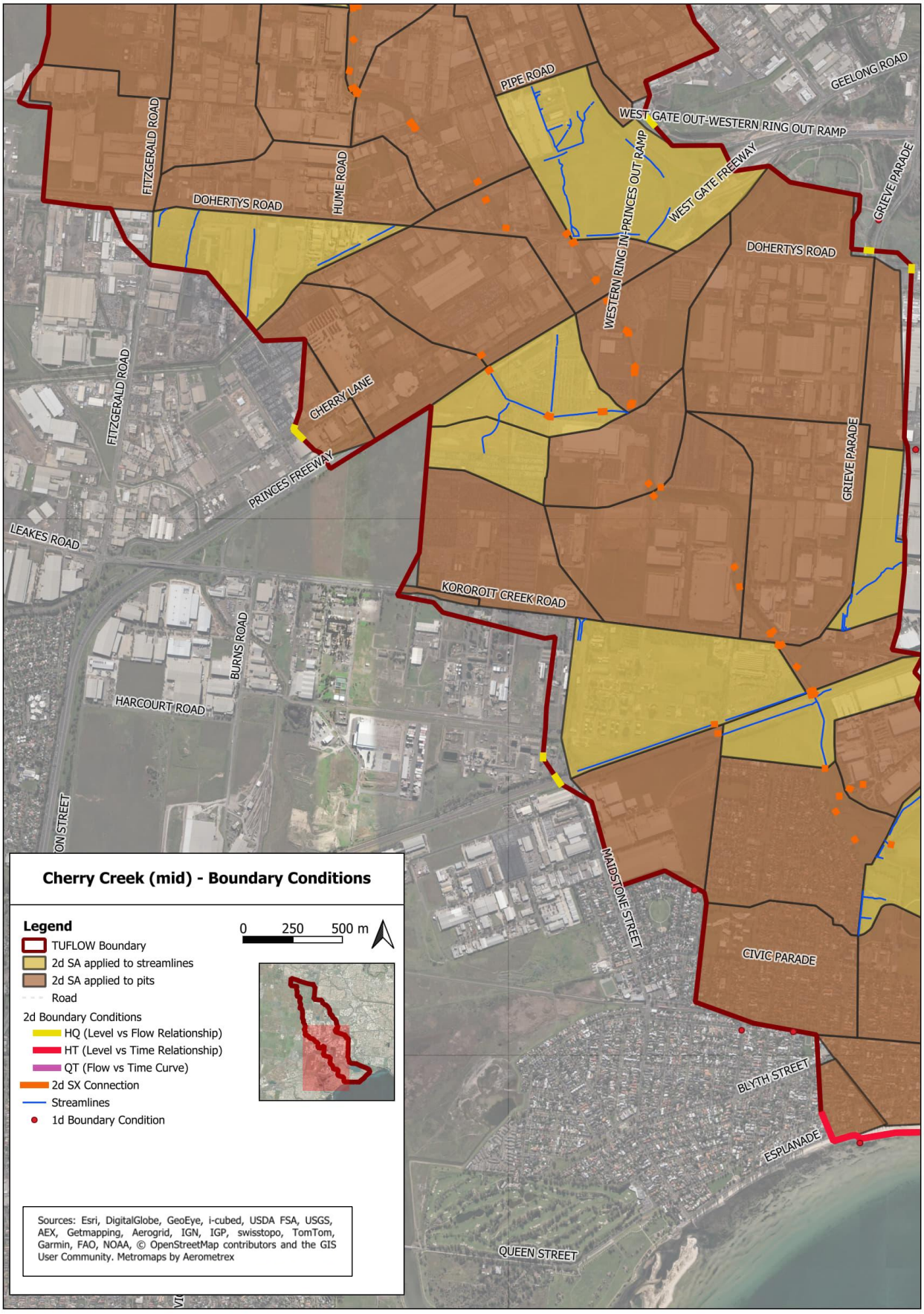


Figure D-14: Cherry Creek TUFLOW model boundary conditions (mid).

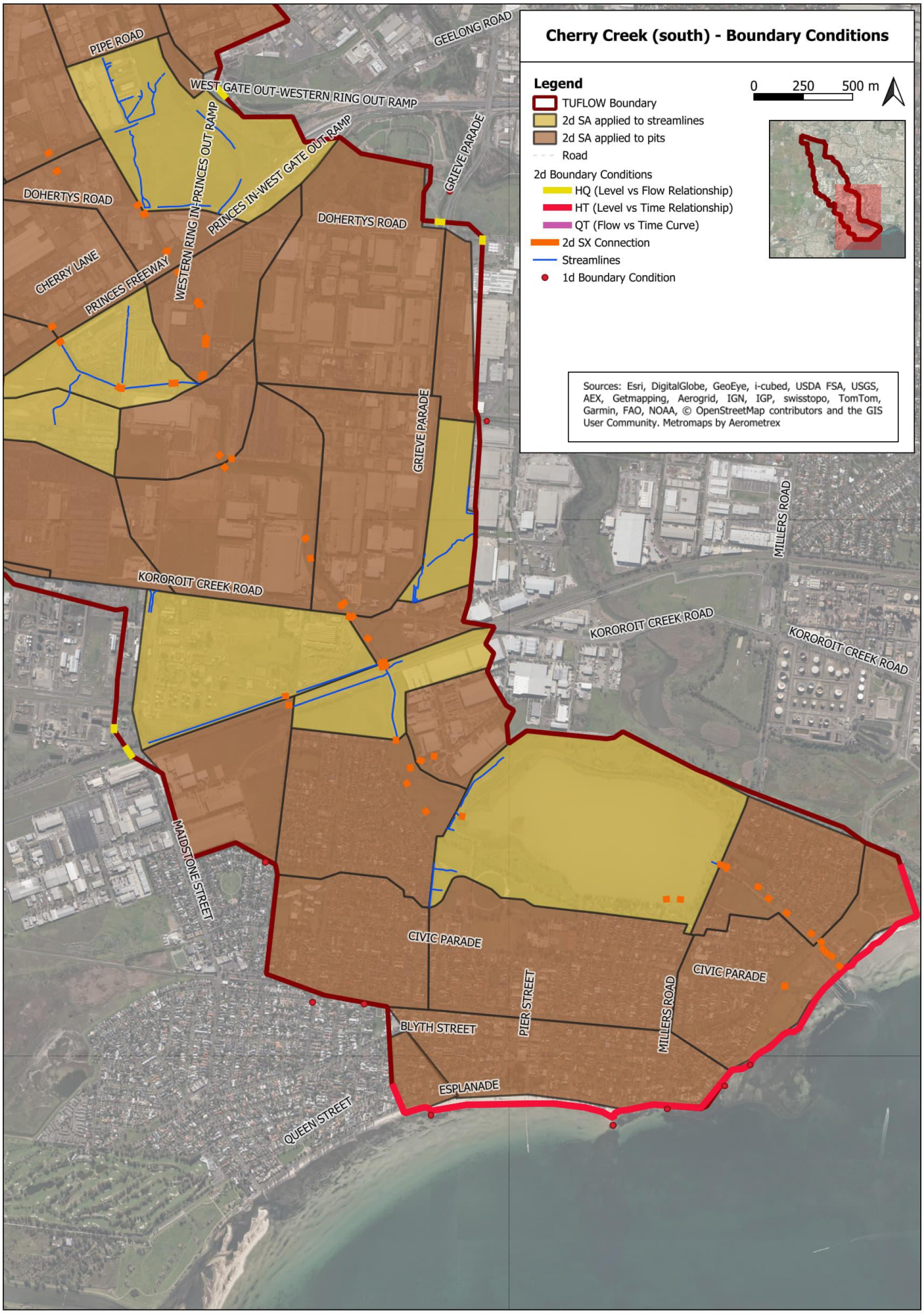


Figure D-15: Cherry Creek TUFLOW model boundary conditions (south).

D.6.2 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table D-13.

Table D-13: Adopted Durations, temporal patterns and ARF areas for the Cherry Creek model

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP27	1	TP28	1	TP18	1	-	-	TP7	1
25 minute	-	-	-	-	TP18	1	TP14	1	-	-
30 minute	-	-	-		-		-		-	-
45 minute	TP29	1	TP29	1	TP19	1	TP19	1	TP5	1
1 hour	TP27	4	TP27	4	TP18	4	TP17	4	TP4	4
1.5 hour	TP27	15	TP27	15	TP16	1	-	1	-	1
2 hour	TP28	15	TP28	15	TP15	15	TP16	15	TP3	15
3 hour	-	-	-		-	-	-	-	-	-
4.5 hour	TP22	4	-		-	-	-	-	-	-
6 hour	TP30	22	-		-	-	-	-	-	-
9 hour	-	22	TP28	22	TP16	22	TP12	22	TP6	22
12 hour	TP29	22	TP29	22	-	-	-	-	-	-

D.6.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section D.5. The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment. This is presented in Table D-14.

Results from the RORB and TUFLOW models show that the critical durations are generally consistent however there is variation near storages where road embankments influence the floodplain storage. The tidal assumptions in the TUFLOW model also have an influence at the downstream end of the model. As presented in Figure D-16, differences at points such as 5 and 17 are primarily due to major road embankments that restrict overland flow and create localised storage upstream. In these areas, hydraulic connectivity is controlled by culverts, which influence the timing of flow conveyance and result in longer critical durations in TUFLOW. Overall, the results confirm that the TUFLOW model appropriately captures these hydraulic effects and the simulation of longer durations in this catchment was required.

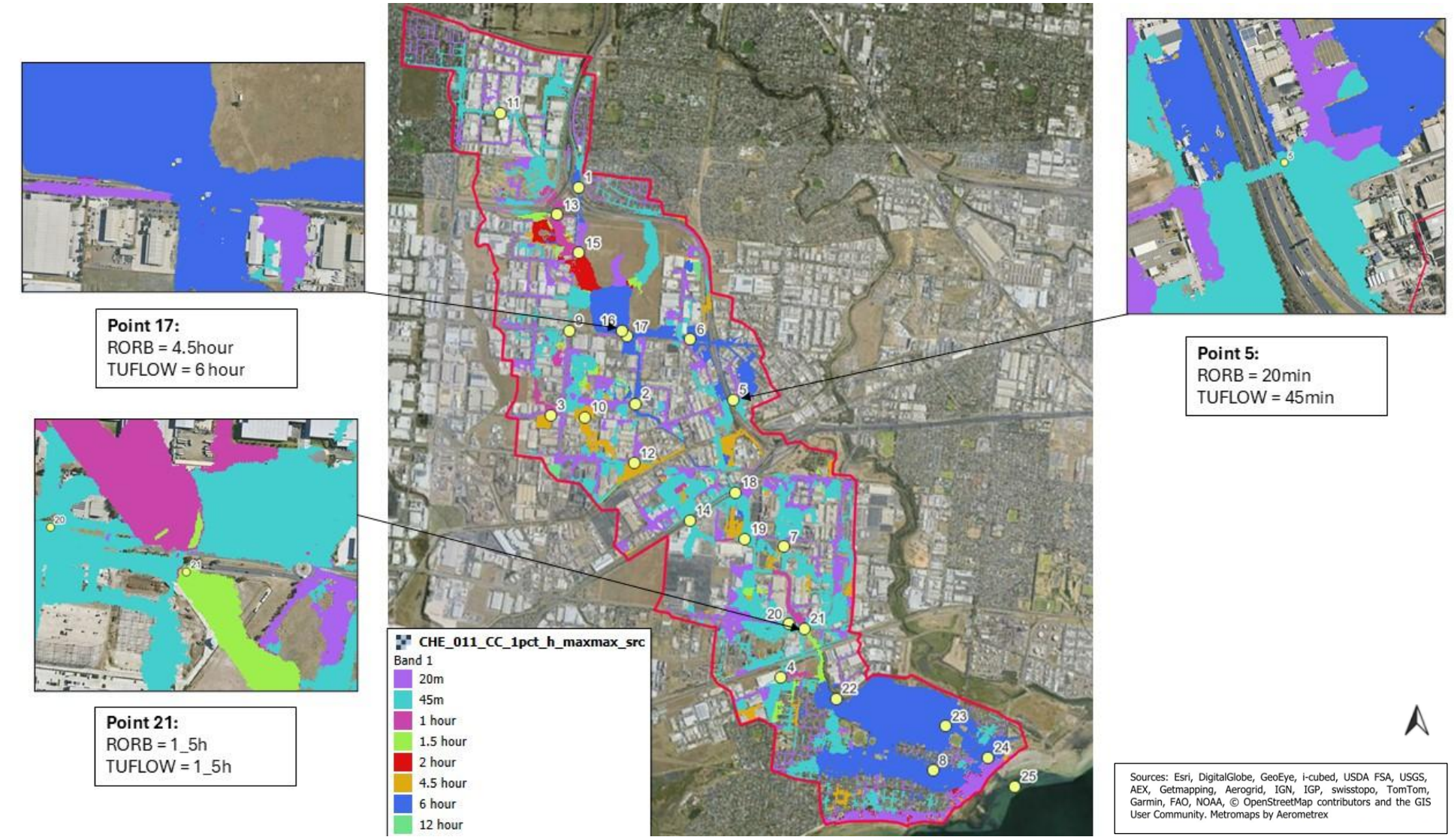


Figure D-16: Critical duration assessment for Cherry Creek

Table D-14: Comparison of RORB critical durations and TUFLOW critical durations for the 1% AEP with climate change event

Sample point	Location	RORB 1% AEP duration	TUFLOW 1% AEP with climate change	Comment
1	Millennium RB - Inflow	20min	6hour	TUFLOW model is influenced by the Millennium RB at the sample location noting upstream of this point in TUFLOW is 45min.
2	Hume Road	20min	6hour	Influenced by upstream storage that is Andersons Swamp (storage not modelled in RORB)
3	Fitzgerald Rd RB - Inflow	20min	20 min	Noting the sample point is near the RB extent which has a critical duration of 4.5 hour.
4	Charles Road	20min	20min	
5	West Ring Road	20min	45min	Influence by the floodplain storage behind the Metropolitan Ring Road.
6	Boundary Rd RB (Brk) - Inflow	20min	6hour	Influenced by Boundary Road RB.
7	Stuber Road	20min	20min	
8	Millers Road	45min	6hour	Influenced by Cherry Lake and the tidal zone.
9	Boundary Road 1	30min	45 min	
10	Industrial Area	45min	4.5hour	Influenced by floodplain storage behind a depression in the LiDAR.
11	Paramount Boulevard	45min	45min	
12	Doherty's Road	1.5hour	4.5hour	Influenced by floodplain storage behind the federation trail embankment.
13	Western Freeway	1hour	1hour	
14	Princes Freeway 1	1hour	45 min	
15	Fitzgerald Road	1.5hour	1hour	
16	Lake Stanley - Inflow	1.5hour	6hour	Influenced by upstream storage that is Andersons Swamp (storage not modelled in RORB)
17	Boundary Road 2	4.5hour	6hour	Influenced by upstream storage that is Andersons Swamp (storage not modelled in RORB)
18	Princes Freeway 2	1.5hour	45 min	
19	Pinnacle Road	1.5hour	45min	

Sample point	Location	RORB 1% AEP duration	TUFLOW 1% AEP with climate change	Comment
20	Cherry Creek Road 1	1.5hour	45min	
21	Cherry Creek Road 2	1.5hour	1.5hour	
22	Cherry Creek 1	2hour	6hour	Influenced by Cherry Lake and the tidal zone.
23	Cherry Lake - Inflow	2hour	6hour	Influenced by Cherry Lake and the tidal zone.
24	Cherry Creek 2	12hour	6hour	Influenced by Cherry Lake and the tidal zone.

D.6.4 Quality Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks are summarised in Table D-15. They have been assessed as not likely to adversely affect the model results. Reviews completed by Melbourne Water's external reviewer are provided in Appendix N.

Table D-15: TUFLOW checks and warning messages

Message	Count	Message content	Comment
Message 1313	4	WARNING 1313 - No inlet culvert connected to Manhole "XX". Manhole not used/applied.	Present on two small pipes (375 dia or less) which are connected to only one pipe. Not considered critical for flood mapping purposes.
Message 1402	6	CHECK 1402 - More than one culvert connected but could not create manhole at Node "XX". Check culvert inverts and directions.	Standard check. Not considered critical to resolve for flood mapping purposes.
Message 2073	7	WARNING 2073 – Object ignored. Only Points, Lines, Polylines & Region Centers used.	Indicates there are GIS files with null shapes. No influence on the model.
Message 2118	126	CHECK 2118 - Lowered SX ZC Zpt by XXm to 1D node bed level.	All within the Melbourne Water criteria of less than 0.5 m
Message 2210	47	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = XX; Top of First FC Layer = XX	Minor locations were layered flow constrictions (bridges) cross under the terrain. No influence on the results.
Message 2236	130	WARNING 2236 – Input file name is different from TIN XF File. XF file not being used.	No influence on the model.
Message 3520	1	CHECK 3520 - Minimum V elevation must be higher than the minimum cell centre elevations on both sides in SGS. ZCmin lower = 77.064, ZVmin = 77.089, ZCmin upper = 77.695.	One location. No influence on the model.

D.7 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

D.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.

HARC (2017) Consequence Assessments for Low Consequence Retarding Basins.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

RPV (Rail Projects Victoria) (2021) AJM JV Geelong Fast Rail – Cherrys Main Drain Hydrology Modelling.

The Bureau of Meteorology (2022) Design Rainfall Data System

Appendix E. Laverton Creek

Appendix E. Laverton Creek

This section details the RORB and TUFLOW model development for the Laverton Creek catchment and full technical details of adopted parameters and results.

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E.1 Catchment Description and Study Area

The Laverton Creek catchment is a peri-urban and industrial catchment with some localised regions of pervious areas, west of Melbourne which sits between the Cherry Creek and Skeleton Creek catchments. The total catchment area is approximately 66 km^2. The catchment contains the Kayes Drain catchment which feeds into Laverton Creek. Much of the urban catchment on the northern and eastern side of the catchment is zoned for industrial land use, and much of the rural areas are within the Urban Growth Zone and will be developed in the future. The catchment outlets into Port Phillip Bay.

There are no streamflow gauges in the catchment and therefore there is limited information to calibrate or validate flows against. Model calibration could therefore not be carried out for the Laverton Creek catchment as part of this Study.

E.1.1 Previous RORB Model

An existing RORB model for the Laverton Creek catchment was accessed for use in this Study. This model is understood to have been developed by RPV in 2020. The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Laverton Creek TUFLOW models covering Brimbank and Hobsons Bay LGAs. The updates undertaken to the model are outlined in the sections below.

E.2 RORB Model Setup

The development of the RORB model is described in the following sub-sections and presented in Figure E-1.

E.2.1 Catchment and Subarea Boundaries

A review of previous RORB models identified the need to re-delineate some areas to standardise the size of subareas falling within the Brimbank and Hobsons Bay LGAs in preparation for extraction of hydrographs for input into TUFLOW. Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Catchment delineation considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

The final catchment and subarea boundaries are shown in Figure E-1.

E.2.2 Node-link network

The node-link network shown in Figure E-1 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

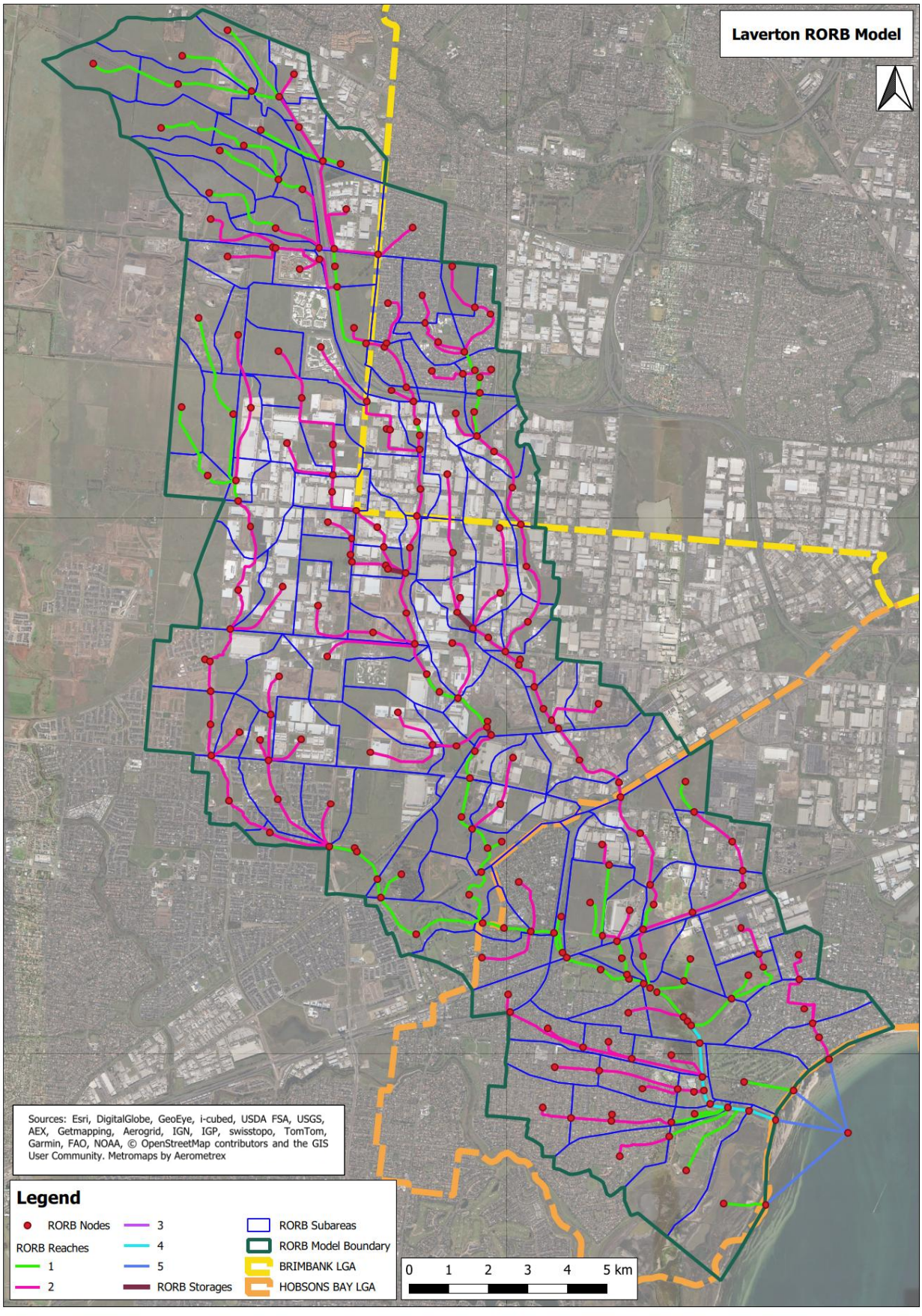


Figure E-1: Laverton Creek RORB model setup.

E.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
  - Type 1 – Natural channels, used for major creek reaches
  - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
  - Type 3 – Lined channel or pipe – these were used to represent flowpaths associated with major underground Melbourne Water trunk drains and lined channels
  - Type 4 – Drowned – these were used upstream of storages or major waterbodies
  - Type 5 – Dummy – used to connect independent catchments (i.e. at Port Phillip Bay) to a single outlet node

E.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB), as listed in Table E-1.

Table E-1: Storages in the Laverton Creek RORB model

Storage	Data source and checks
Truganina Swamp RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. Plot from URS (2012) provided a visual view of both the H-S relationship and some approximate checks along the curve identified that the existing relationship in the RORB model provided was sufficient.
Dunes Drain RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S and S-Q- relationships)
Laverton Creek RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S and S-Q- relationships)
Foundation Road RB	Storage details adopted as per RPV model (2020). Checks on spillway heights carried out against project LiDAR and confirmed as reasonable. No further information available for further checks or updates (i.e. on H-S and S-Q- relationships)

E.2.5 Diversions

No diversions are present in the Laverton Creek RORB model.

E.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

E.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

E.2.8 RORB version

RORB version 6.47 was used for modelling.

E.3 RORB design inputs

E.3.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.826, Long 144.763) was sourced from the Bureau of Meteorology (Appendix I). As per the Melbourne Water Flood Mapping Projects Specifications, rainfalls were increased by 18.5% to establish climate change rainfalls.

E.3.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Given that this Study has derived storm losses for neighbouring catchments via model calibration to observed events (including Kororoit Creek, Stony Creek and Maribyrnong River), loss parameters have been transferred from the Kororoit Creek model to the Laverton Creek model (as proposed in the Method Statement). Specifically, the loss parameters derived for the Kororoit Creek at Brooklyn gauge have been transferred and applied to Laverton Creek given that the upstream area at Brooklyn is largely urban and therefore most consistent with the land use of the Laverton Creek catchment. The transfer of parameters from a neighbouring catchment's calibrated RORB model is supported by ARR 2019 (HARC, 2020) over the adoption of DataHub loss parameters as the transferred losses are likely to represent the runoff behaviour of a catchment in the same local geography more accurately. The adopted storm losses are listed in Table E-2.

Table E-2: Laverton Creek model storm losses

	IL (mm)	CL (mm/hr)
Transferred from Kororoit Creek (adopted)	13.5	2.5
DataHub	5.0	0.6

E.3.3 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations below the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen

(1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

E.3.4 Temporal Patterns

Point temporal patterns were obtained from the ARR DataHub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies) and adopted given the catchment area is smaller than 75 km^2. Temporal patterns were filtered for embedded bursts using the option in RORB.

E.3.5 Spatial Patterns

A spatial rainfall distribution was determined to ensure that variation in rainfall depth across the catchment was accounted for. This was calculated by comparing the catchment average rainfall to the average rainfall for each sub-catchment using the design rainfall grids (Bureau of Meteorology, 2022). This was then implemented to the RORB model as a 'non-uniform' spatial pattern for each duration.

The spatial variation across the catchment is illustrated in Figure E-2 for the 1% AEP 9 hour rainfall event.

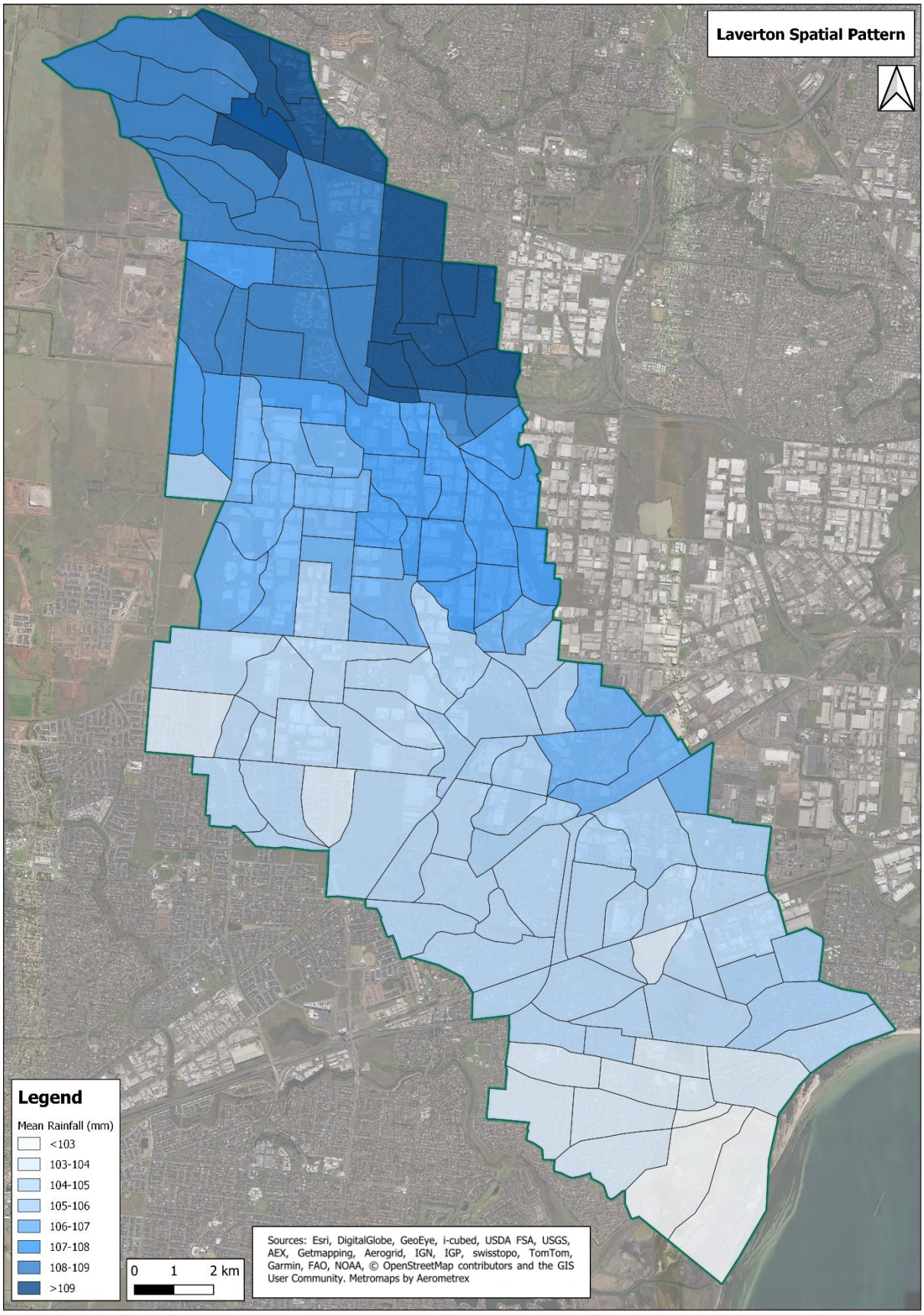


Figure E-2: Spatial rainfall pattern for the Laverton Creek RORB model for the 1% AEP, 9 hr storm.

E.3.6 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Section E.5. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment are presented in Table E-3.

Table E-3: Adopted ARF values for the Laverton Creek RORB model.

Duration	ARF area (km^2)	Justification
20 min (1%, 2% AEP) 25 min (5%, 10% AEP) 30 min (1%, 2%, 20% AEP) 45 min (5%, 10%, 20% AEP) 1 hour (20% AEP)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
45 min (1%, 2% AEP) 1.5 hour (1%, 2%, 5%, 10% AEP) 2 hour (2%, 20% AEP)	3	
2 hour (5%, 10% AEP) 3 hour (1%, 2%, 20% AEP)	12	
4.5 hour (1%, 5%, 10% AEP) 6 hour (2%, 20% AEP)	23	
6 hour (1%, 5%, 10% AEP) 9 hour (2% AEP)	38	
4.5 hour (2% AEP) 9 hour (1%, 5%, 10%, 20% AEP)	56	

E.4 RORB Verification and Input Parameters

To determine the appropriate parameters for generating the hydraulic model inputs, RORB was run in Monte Carlo mode for the Study area to establish peak flow estimates at the catchment outlets for the 1% AEP event. The Monte-Carlo technique as recommended by ARR (Ball et al., 2019) was used to calculate flood quantiles. This technique involves randomly sampling different flood forming variables to create flood frequency outputs whilst also replicating natural processes. This technique inherently accounts for interactions between the various flood forming variables, providing a more realistic representation of the flood hydrograph generation processes.

The routing calculation in RORB uses two parameters, k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. The m parameter was set at as the default value of 0.8 as per advice in the Melbourne Water Flood Mapping Projects Specifications.

Peak flow estimates where k_c was varied for the Laverton Creek RORB model are provided in Table E-4. The proposed inputs are summarised Table E-5. The Regional Flood Frequency Estimation (RFFE) was not performed given it is recommended for entirely rural catchments (Laverton Creek has a partly urban upstream catchment). The Truganina Swamp RB inflow was chosen as the validation location given the model outlet is downstream of this and flows would be impacted by RB flow attenuation.

Table E-4: k_c estimates and peak flow values at Truganina swamp inflow.

	Vic >800mm rainfall	RORB Manual	Pearse et al. 2002	Yarra & Maribyrnong (Melbourne Water)	Nikolaou/von't Steen (urban)	Nikolaou/von't Steen (rural)	Melbourne Water rule of thumb (urban)	Melbourne Water rule of thumb (rural)
k_c	15.62	16.34	11.53	11.24	-	-	-	-
Q_{100} flow at Truganina swamp inflow (m^3/s)	92.5	90.0	106.4	114.4	177.5	99.6	165.6	55.2

Table E-5: Adopted k_c for the Laverton Creek RORB model.

Adopted k_c	Comment
11.24 (Yarra & Maribyrnong (Melbourne Water))	Flows generally align with previous estimates (RPV, 2020 Q_{100}: 106.9 m^3/s). Flows are within range of regional estimates.

E.5 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARFs to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table E-3. This enabled the identification of how critical durations were likely to alter based on the contributing catchment area. Key locations across the catchment are shown in Figure E-3. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW
- Locations upstream or within urban areas
- Locations upstream and downstream of model storages
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave
- Points located within Study LGAs, providing good coverage across the study area

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Table E-6. Table E-7 lists the storms that were simulated in TUFLOW at the hydraulic modelling phase of this Study. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

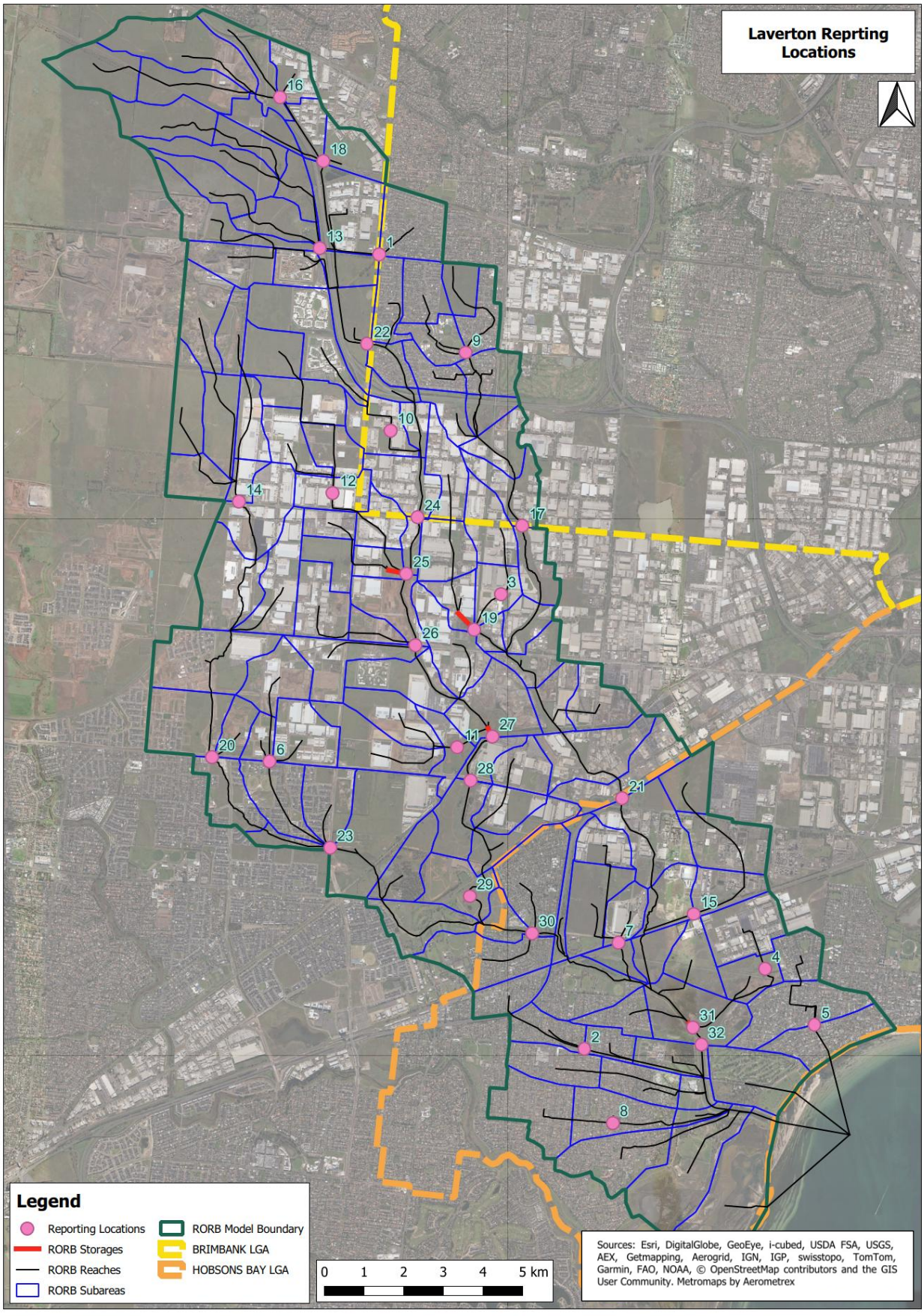


Figure E-3: Laverton Creek RORB reporting locations

Table E-6: Analysis of critical durations and peak flows at key locations in the Laverton Creek RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Robinsons Road	0.7	1.5hour	50.6	1.5hour	41.5	1.5hour	30.2	2hour	23.5	1hour	17.1
2	Queen Street	0.8	30min	10.1	30min	8.5	45min	6.8	45min	5.5	45min	4.4
3	William Angliss Drive	0.9	20min	8.5	20min	7.1	25min	5.6	25min	4.6	30min	3.7
4	Railway 3	1.0	30min	12.2	30min	10.1	25min	7.5	45min	6.3	45min	5.2
5	Blyth Street	1.1	20min	18.6	20min	15.3	25min	11.5	45min	9.4	30min	7.2
6	Leakes Road 3	1.3	20min	23.8	20min	19.5	25min	14.7	45min	12.0	30min	9.2
7	Railway 1	1.3	1hour	13.4	1hour	11.1	1.5hour	8.7	1.5hour	6.7	1hour	5.0
8	Victoria_St_Nelson_Ave	1.3	20min	14.5	20min	11.9	25min	9.0	25min	7.1	30min	5.6
9	Balmoral Park	1.4	30min	20.0	30min	16.5	45min	13.1	45min	10.5	1hour	8.3
10	Stony Way	1.5	1hour	21.0	1hour	17.5	45min	13.7	45min	10.9	20min	8.3
11	Foundation Road	1.6	30min	18.7	30min	15.3	45min	12.4	45min	9.8	1hour	7.7
12	Staintly Drive	2.2	45min	20.4	45min	16.8	1.5hour	12.8	1.5hour	10.0	1hour	7.5
13	Riding Boundary Road	2.5	2hour	13.8	2hour	11.2	1.5hour	8.8	1.5hour	6.4	2hour	4.4
14	Boundary Road 2	2.8	1.5hour	19.7	1.5hour	16.2	2hour	12.1	2hour	9.4	2hour	6.5
15	Railway 2	2.8	45min	14.9	45min	12.4	45min	9.6	1hour	7.7	1hour	6.4
16	Western Freeway 1	2.9	1.5hour	16.2	1.5hour	13.2	1.5hour	9.8	2hour	7.4	2hour	5.4
17	Boundary Road 1	3.4	3hour	22.9	2hour	18.4	2hour	13.8	2hour	10.7	2hour	8.5
18	Western Freeway 2	3.9	1.5hour	22.4	1.5hour	18.3	1.5hour	13.5	2hour	10.1	2hour	7.7

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
19	Foundation Rd RB - Inflow	4.5	20min	19.2	20min	16.2	30min	12.6	30min	10.4	30min	8.4
20	Leakes Road 2	7	1.5hour	44.0	1.5hour	37.0	2hour	28.3	2hour	22.9	1hour	16.7
21	Princes Freeway	9.1	3hour	42.6	3hour	35.4	2hour	26.4	2hour	22.9	2hour	17.0
22	Laverton Main Drain 1	9.8	3hour	43.7	3hour	35.0	2hour	26.5	2hour	21.4	3hour	14.6
23	Palmers Road	10.1	1.5hour	58.5	1.5hour	48.8	2hour	37.2	2hour	29.5	2hour	22.1
24	Boundary Road 3	12.8	3hour	54.5	3hour	43.6	4.5hour	31.1	4.5hour	29.5	3hour	17.0
25	Dunes Drain RB - Inflow	16.3	20min	11.2	1hour	9.6	45min	8.2	45min	6.7	45min	5.3
26	Dohertys Road	17.6	3hour	77.3	3hour	62.3	2hour	44.7	2hour	35.5	2hour	26.0
27	Laverton Ck RB - Inflow	21.9	4.5hour	81.6	4.5hour	67.0	4.5hour	47.3	4.5hour	36.6	3hour	27.0
28	Leakes Road 1	22.2	4.5hour	69.8	4.5hour	49.8	9hour	32.1	9hour	15.7	6hour	12.6
29	Laverton Creek 1	24.6	4.5hour	66.6	6hour	48.3	9hour	30.2	9hour	16.4	12hour	13.0
30	Laverton Creek 2	38.2	6hour	93.9	9hour	71.2	6hour	45.0	6hour	36.3	9 hour	27.7
31	Truganina Swamp RB - Inflow	55.9	9hour	116.7	4.5hour	94.7	6hour	71.3	6hour	56.4	6hour	41.0
32	Laverton Creek 3	56.3	9hour	100.6	9hour	77.6	9hour	57.3	9hour	45.7	9hour	33.3

Table E-7: Critical durations and selected temporal patterns for the Laverton Creek RORB model.

AEP	20min	25min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour
1%	TP 27	-	TP 28	TP 26	-	TP 27	-	TP 27	TP 28	TP 23	TP 21
2%	TP 27	-	TP 28	TP 26	-	TP 27	TP 24	TP 27	TP 22	TP 23	TP 21
5%	-	TP 16	-	TP 19	-	TP 14	TP 17	-	TP 18	TP 16	TP 15

AEP	20min	25min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour
10%	-	TP 16	-	TP 19	-	TP 14	TP 17	-	TP 18	TP 16	TP 12
20%	-	-	TP 8	TP 5	TP 4	-	TP 9	TP 4	-	TP 5	TP 4

E.6 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Laverton catchment.

E.6.1 Hydraulic Model Set Up

E.6.1.1 Terrain Modifications

Maps available in Figure E-4, Figure E-5, Figure E-6 show Laverton TUFLOW model terrain modifications, which are also listed in Table E-8 where these have been based on drawings, plans or other available detailed information. The terrain modifications include adjustments made to the base LiDAR either due to:

- Lidar Adjustments: Sections of the LiDAR that may contain significant depressions that are not permanent, i.e. if the LiDAR was flown during the construction of a building then the excavation would be captured and should be removed to ensure no rainfall pools in this depression.
- Terrain Modifications: Removal of bridges or blockages to enable the structure to be hydraulically modelled.
- Reinforcement of hydraulic controls (roads, levees, embankments) within the overland flow paths.

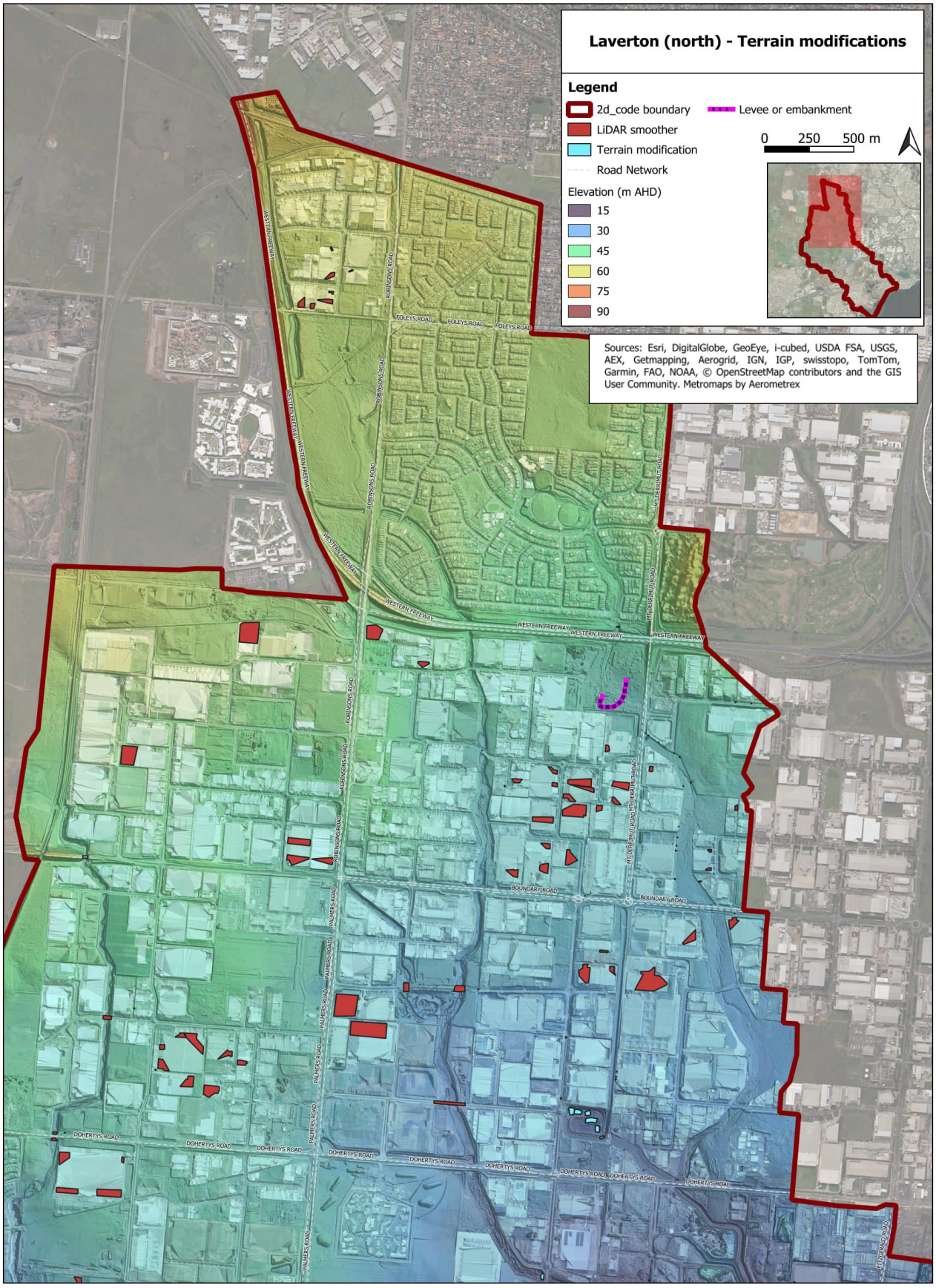


Figure E-4: Laverton TUFLOW model terrain modifications (north).

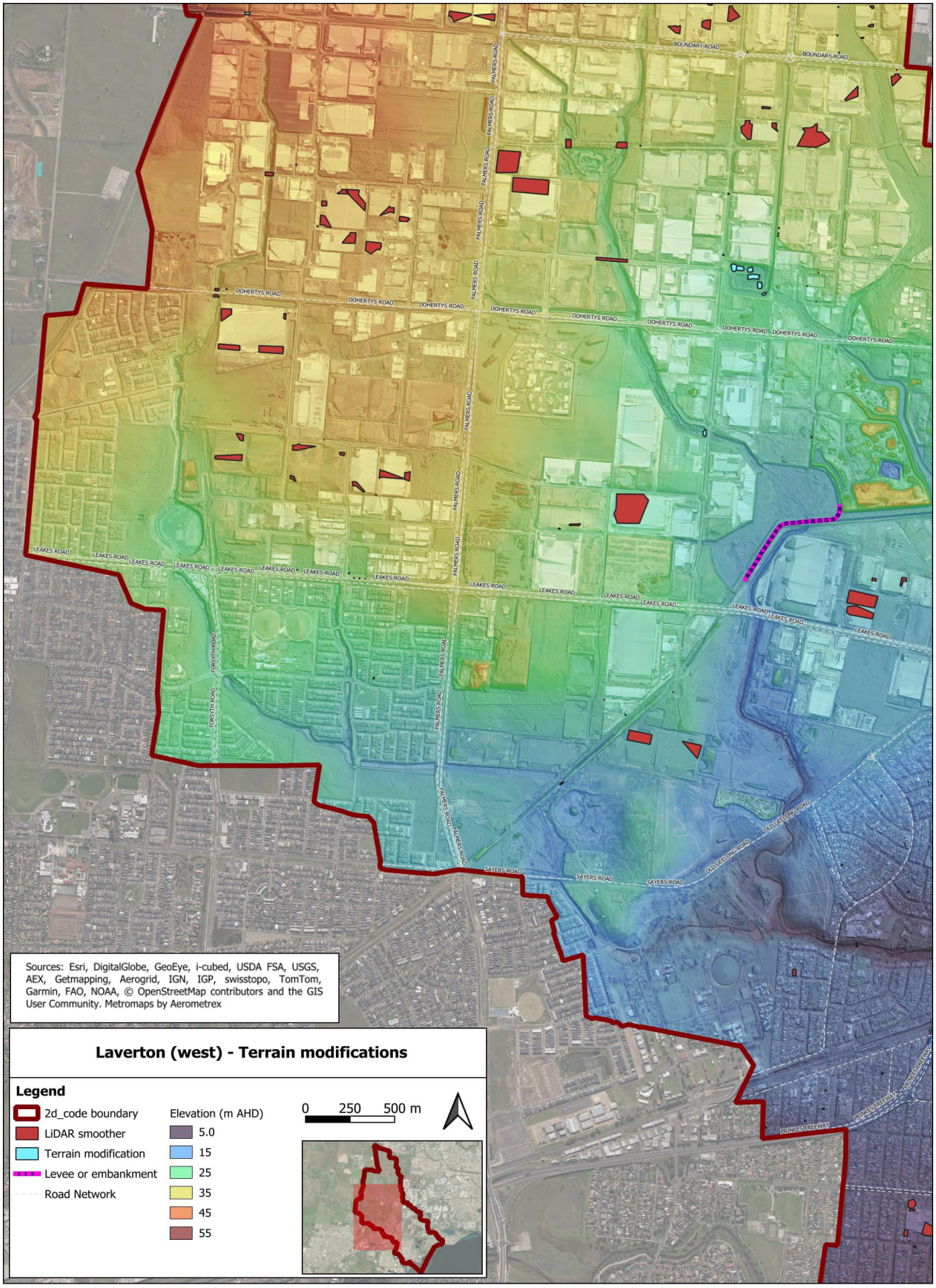


Figure E-5: Laverton TUFLOW model terrain modifications (west).

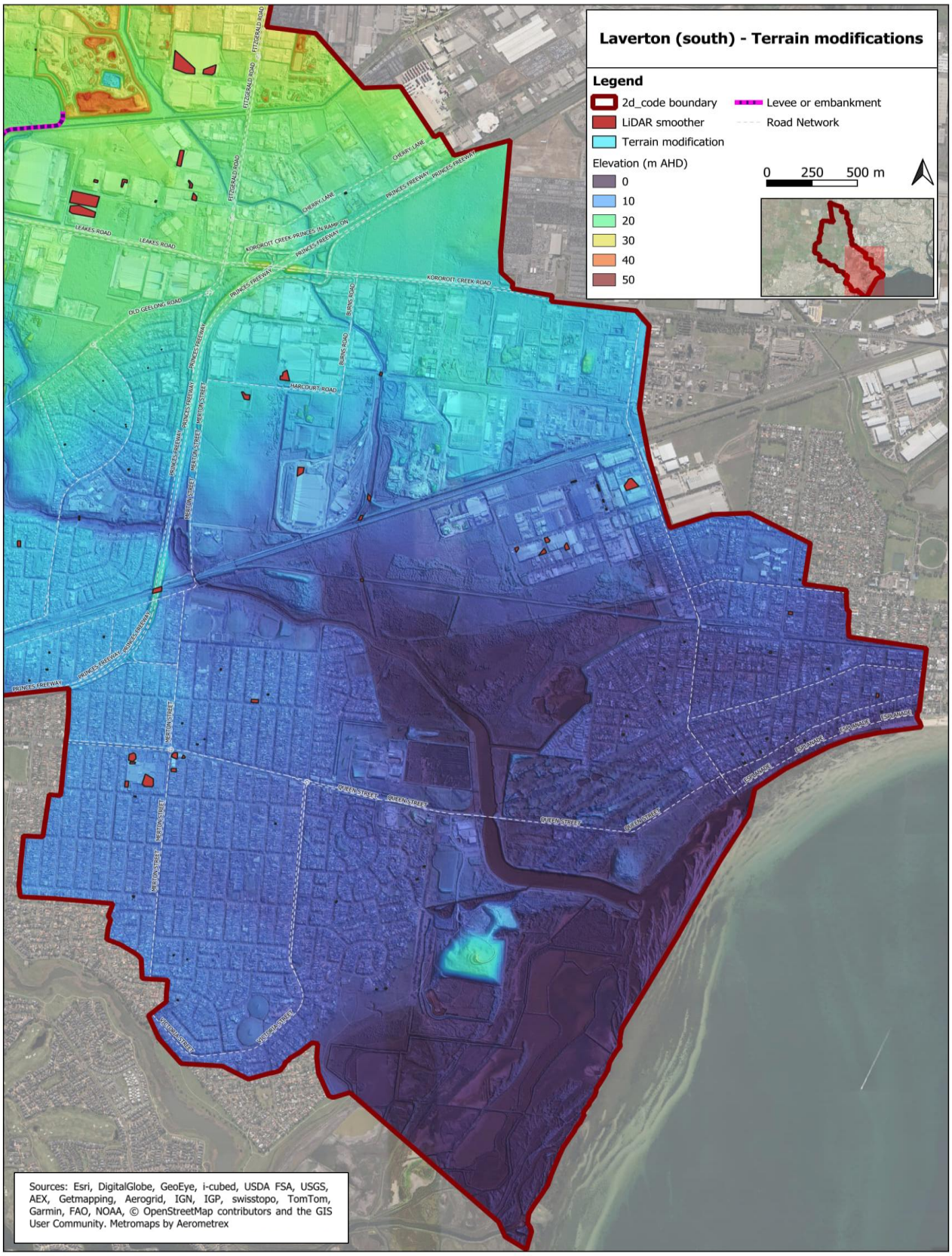


Figure E-6: Laverton TUFLOW model terrain modifications (south).

Table E-8: Laverton TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Laverton Crk Retarding Basin embankment elevation	URS (2012), Stage 4 - Retarding Basin Spillway Capacity Assessment, Prepared for Melbourne Water 14 September 2012	The embankment has been reinforced in the LiDAR.
Dohertys Drain culvert across Federation Trl	Cardno (2022) 40 Palmers Road Doherty's Drain, Section 27. Drawing No. 4088/27/06 4088/27/07 4088/27/08 4088/27/09 4088/27/10 4088/27/11 4088/27/12 4088/27/13 4088/27/14 4088/27/15 4088/27/16 4088/27/17 328305-MISC-CF	Culvert details applied to model.
Laverton Main Drain culvert across Dohertys Road	VicRoads (2021) Western Roads Upgrade – Project 6 Drawing No. 58519-STR-DRG-06-11011 58519-STR-DRG-06-11012 58519-STR-DRG-06-11020 58519-STR-DRG-06-11021 58519-STR-DRG-06-11022 58519-STR-DRG-06-11031 58519-STR-DRG-06-11032 58519-STR-DRG-06-11033 58519-STR-DRG-06-11035 58519-STR-DRG-06-11036	
Laverton Main Drain culvert across Leakes Road	VicRoads (2021) Western Roads Upgrade – Project 4 Drawing No. 58519-STR-DRG-04-31011 58519-STR-DRG-04-31012 58519-STR-DRG-04-31013 58519-STR-DRG-04-31018 58519-STR-DRG-04-31021 58519-STR-DRG-04-31022 58519-STR-DRG-04-31023 58519-STR-DRG-04-31031 58519-STR-DRG-04-31041 58519-STR-DRG-04-31047	

E.6.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table E-9.

Table E-9: Laverton TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Queen St	0.03	1.82	1	1	30
Blading St	0.09	7.3	1	1	30
Kayes Drain Railtrack	0.09	7.1	1	1	30
Kayes Drain Railtrack 2	0.14	2.54	1	1	30
Merton Rd Laverton Crk A	0.2	6	1	1	10
Merton Rd Laverton Crk B	0.18	5.74	1	1	10
Merton Rd Laverton Crk C	0	5.5	1	1	10
Modal Pl	0.21	9.73	1	1	30
Hobsons Bay Coastal Trl	0.14	1.79	0.5	1	30
Boundary Rd	0.09	46.74	1	1	60
Kayes Drain Trk	0.09	5.55	1	1	30
Hobsons Bay Coast Trl Footbridge	0.03	1.86	0.5	1	30
Andrew Park Dr	0.34	2.29	1	1	30
Notla Estate	0.13	1.47	1	1	5
Distribution Laverton Crk Bridge	0.03	31.7	1	1	30
Distribution Drain Bridge	0.09	31.66	1	1	30

E.6.1.3 Model Roughness

Maps available in Figure E-7, Figure E-8, Figure E-9 show the Laverton TUFLOW model Manning's roughness.

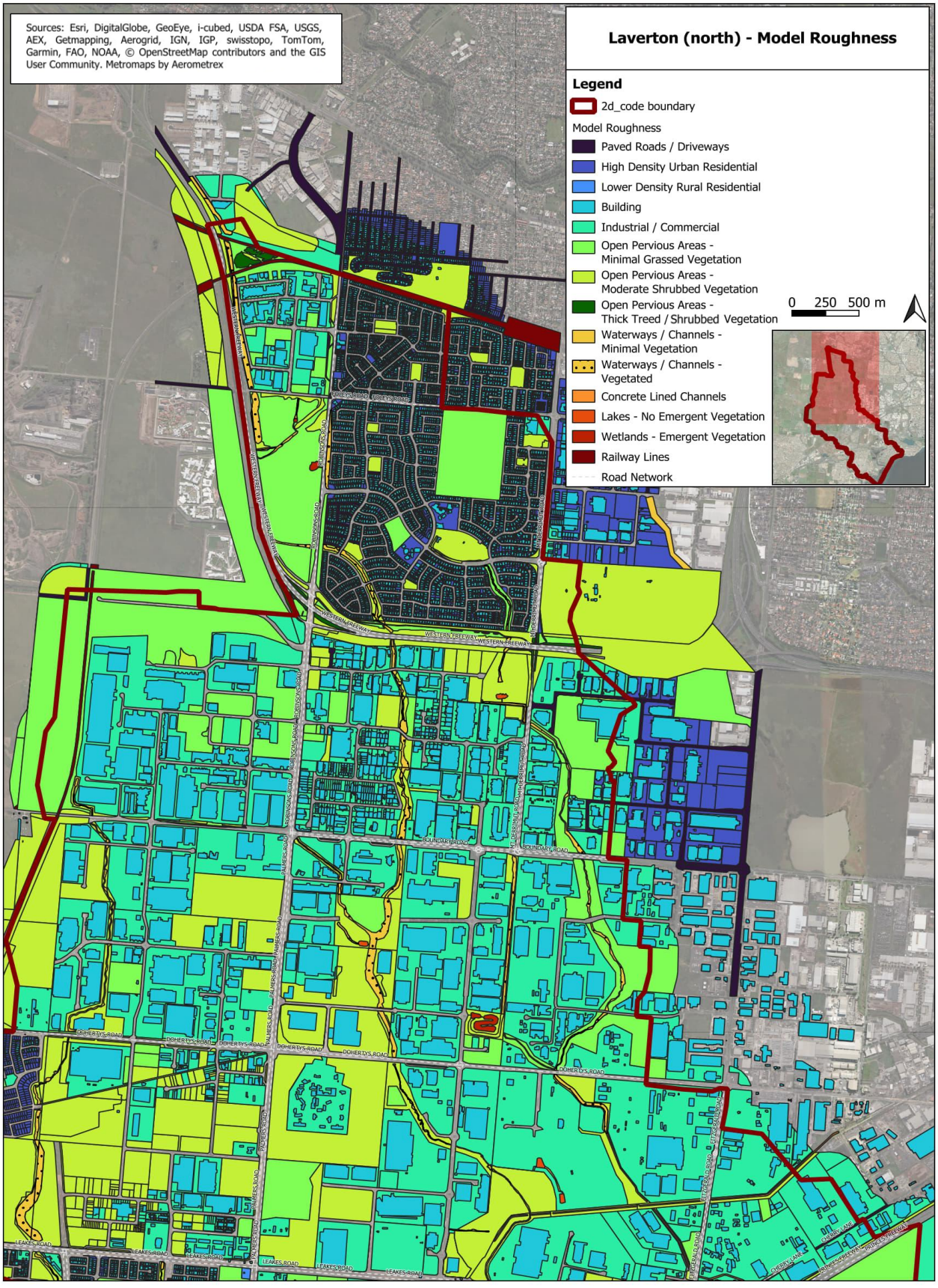


Figure E-7: Laverton TUFLOW model Manning's Roughness (north).

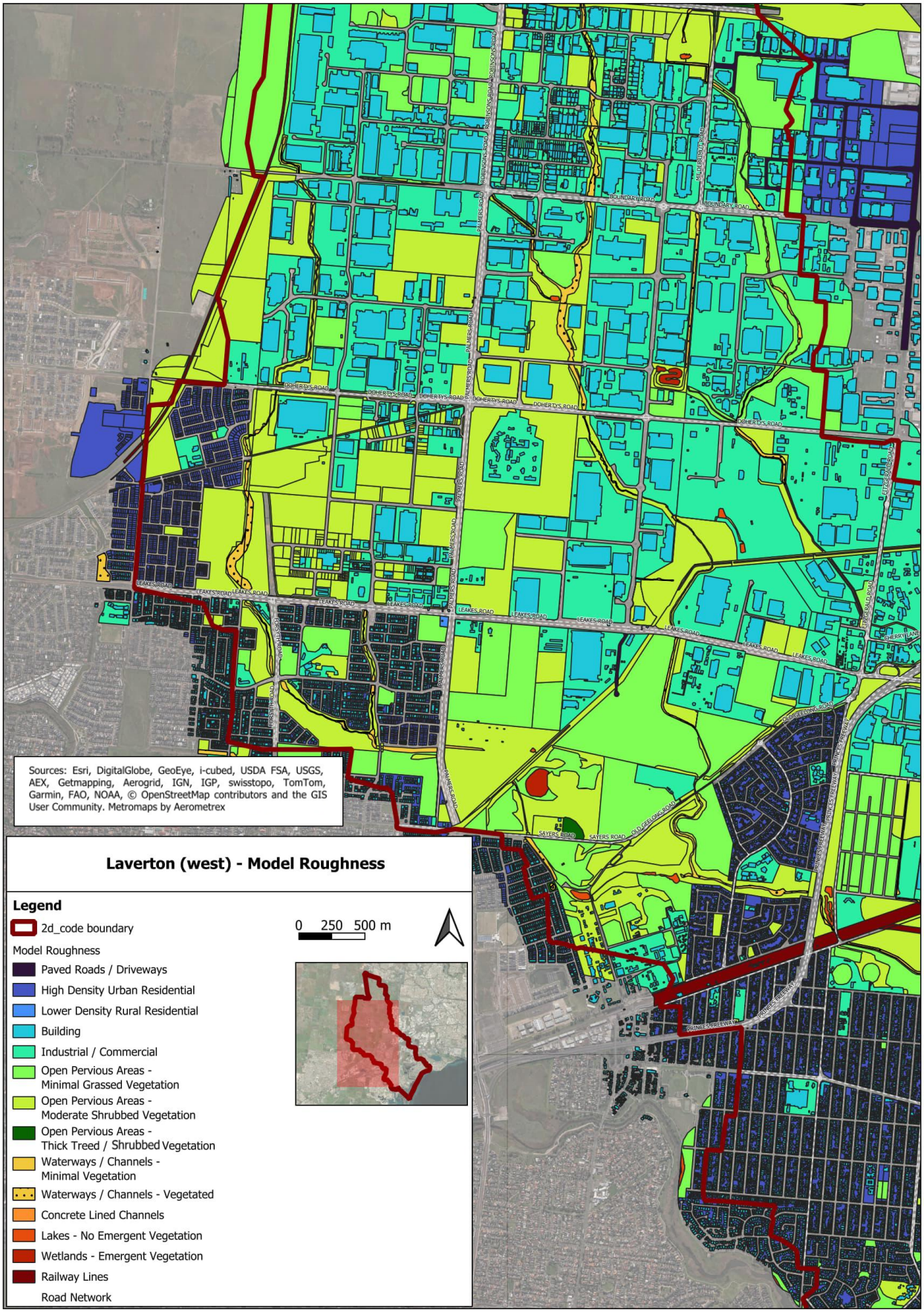


Figure E-8: Laverton TUFLOW model Manning's Roughness (west).

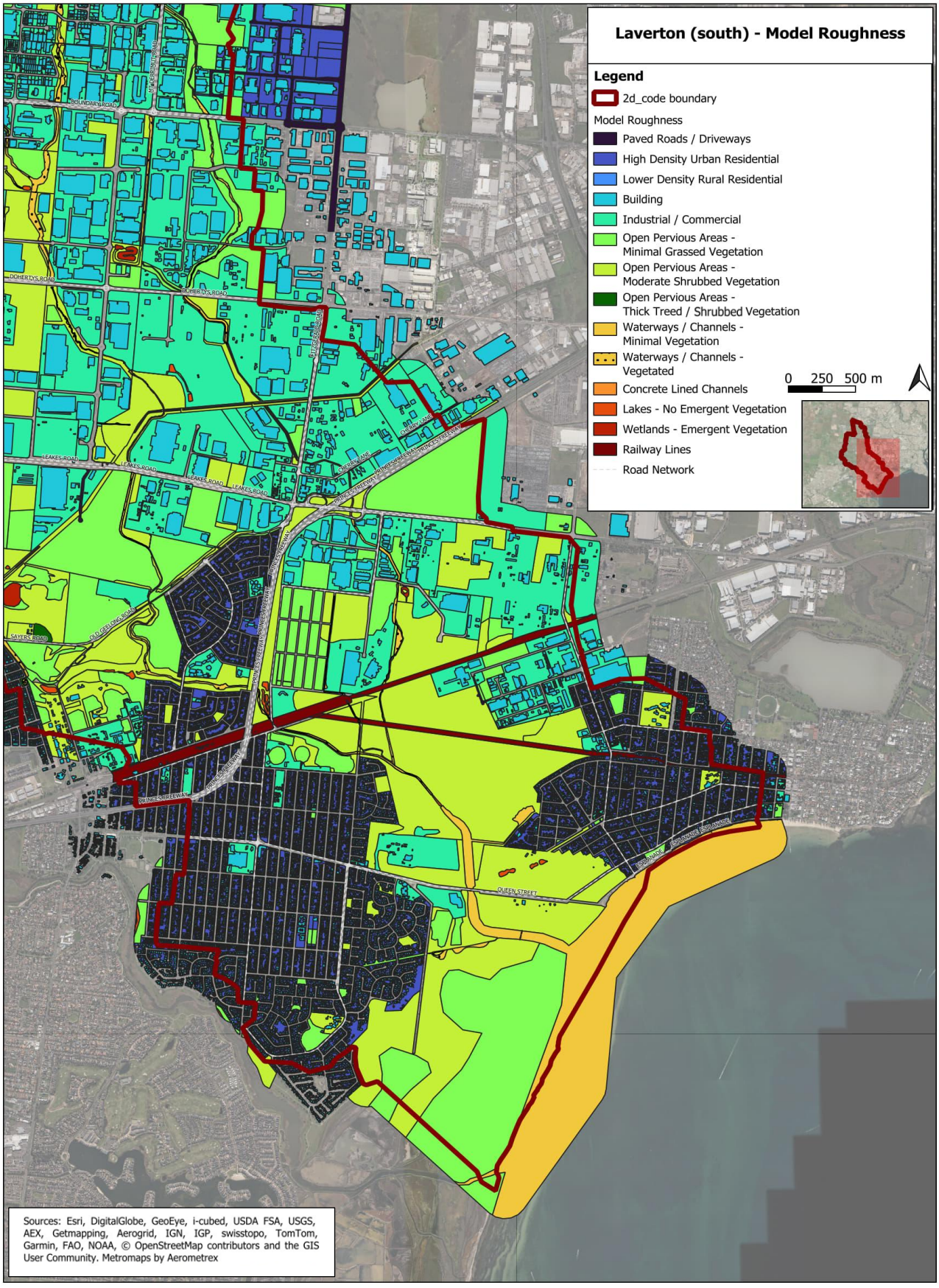


Figure E-9: Laverton TUFLOW model Manning's Roughness (south).

E.6.1.4 1D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table E-10. A full count of the adopted pit types in the TUFLOW model is listed in Table E-11. Maps of the full drainage network can be found in Figure E-10, Figure E-11 and Figure E-12.

Table E-10: Laverton TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Pipe type	Width (m)	Height (m)	Justification
Melbourne Water_pipe_87234, Melbourne Water_pipe_399, Melbourne Water_93421	R	1.5	0.7	Culverts evident from Google Street View not represented in council or Melbourne Water underground pipe network dataset. 14 culverts having dimensions assumed based on measurements made using aerial, a Humes box culvert size range, Melbourne Water culverts downstream, and photos of the culverts received from Melbourne Water.
Pipe_12139	C	0.9	0	Pipes have been assumed to ensure pipe network connectivity where council and Melbourne Water GIS drainage data is lacking.
Pipe_1276	C	1.2	0	
Pipe_2931	C	1.35	0	
Pipe_9384	C	1.2	0	
Pipe_2919	C	0.9	0	
Pipe_8545	C	1.2	0	
Assumed	C	1.35	0	
Pipe_2039	C	0.975	0	
Assumed_29034	C	1	0	
Assumed_78251	C	1	0	
Assumed_72934	C	0.75	0	
Assumed_77934	C	1.35	0	
Pipe_11530	C	0.75	0	
Pipe_11751	C	1.5	0	
Pipe_11752	C	1.5	0	
Pipe_11851	C	0.6	0	
Pipe_12138	C	0.9	0	
Pipe_13955	C	1.5	0	
Pipe_2930	C	1.05	0	
Pipe_2932	C	1.65	0	
Pipe_8531	C	1.2	0	

TUFLOW pipe ID	Pipe type	Width (m)	Height (m)	Justification
Pipe_8532	C	1.2	0	
Pipe_8533	C	1.2	0	
Pipe_8534	C	1.2	0	
Pipe_8535	C	1.2	0	
Pipe_8536	C	1.2	0	
Pipe_8537	C	1.2	0	
Pipe_8538	C	0.6	0	
Pipe_8539	C	0.6	0	
Pipe_8540	C	0.6	0	
Pipe_8541	C	0.6	0	
Pipe_8542	C	0.6	0	
Pipe_8543	C	0.6	0	
Pipe_8544	C	0.6	0	
Pipe_8547	C	1.2	0	
Pipe_8632	C	1.65	0	
Pipe_8633	C	1.65	0	
Pipe_9373	C	1.2	0	
Pipe_9374	C	1.2	0	
Pipe_9382	C	1.2	0	
Pipe_9383	C	1.2	0	

Table E-11: Laverton TUFLOW model 1D drainage adopted pit types.

Pit Type	VicRoads standard pit type	Count
Side Entry Pit	Standard Drawing 1301 - Side Entry Pit - B Type kerb - 1m Inlet	6914
Double Side Entry Pit		460
Grated Side Entry Pit	Standard Drawing 1322 - Grated Side Entry Pit - B Type kerb - 1m Inlet	293
Double Grated Side Entry Pit		52
Grated Pit	Standard Drawing 431 - Grated Pit - Flush Steel Grate - 1m x 1m Inlet - Grate Type B	820
Double Grated Pit		33
Junction Pit (node)	-	3635
Bespoke Melbourne Water pits	Including dimensions; 10.5 m x 0.9 m , 1.05 m x 1.2 m 1.2 m x 1.2 m, 1.6 m x1.6 m, 1.8 m x 1.2 m, 2.5 m x 2.5 m, 3.0 m x 1.5 m	78

Pit Type	VicRoads standard pit type	Count
	3.4 m x 3.4 m , 0.75 m x 0.75 m, 0.9 x 0.6 m, 0.9 m x 0.9 m, 1.8m x 5 m	

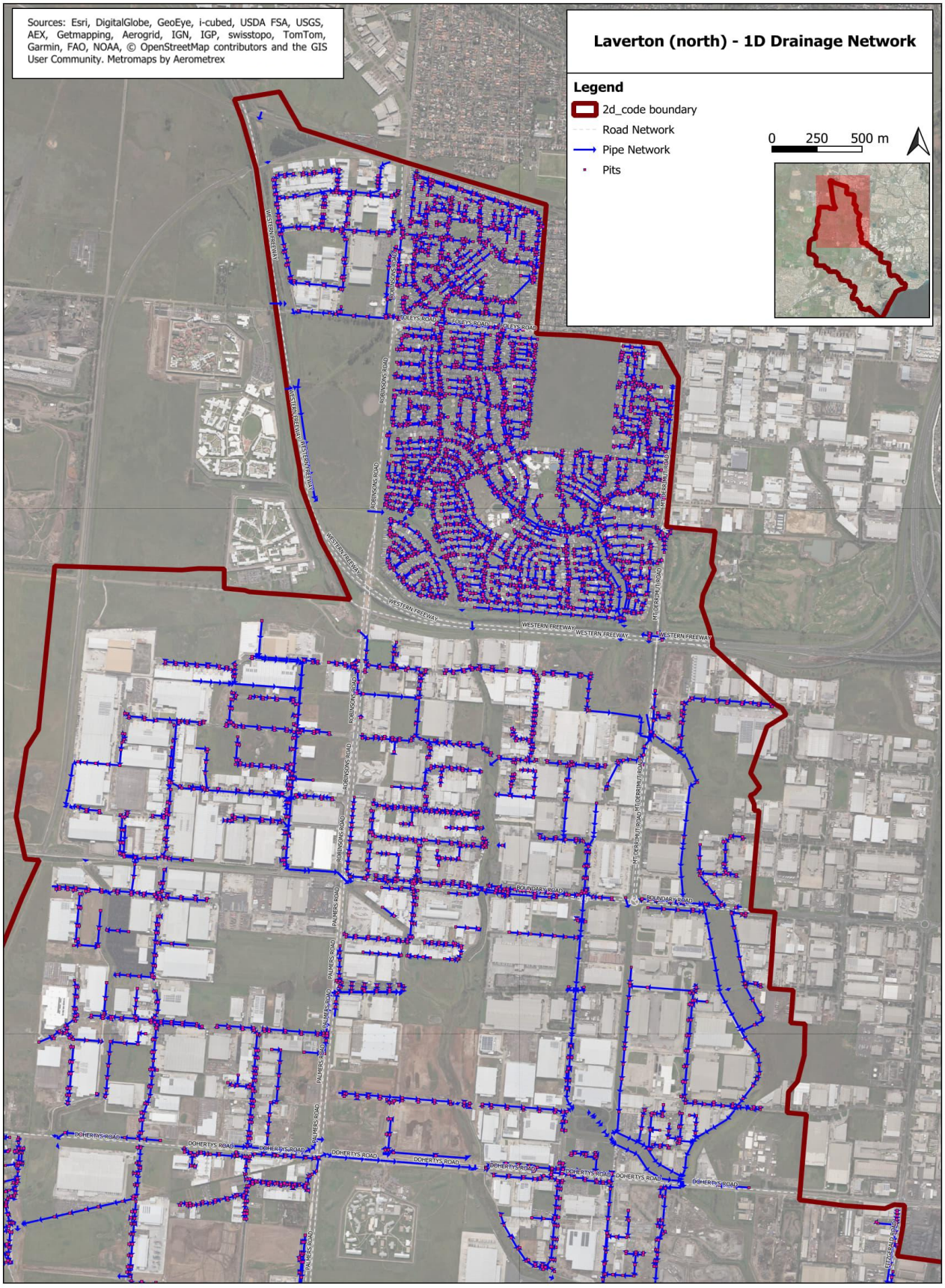


Figure E-10: Laverton TUFLOW model 1D drainage network (north).

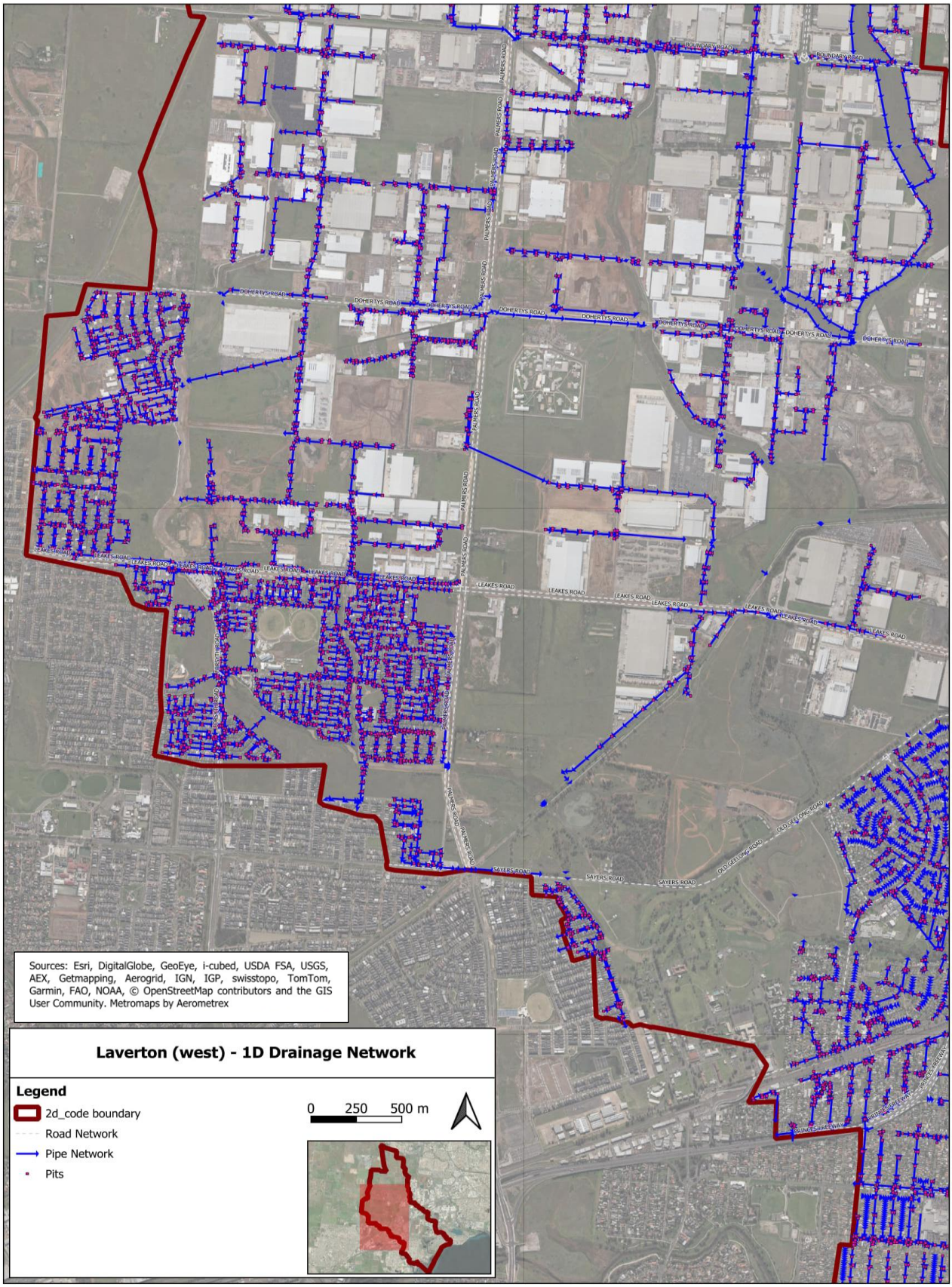


Figure E-11: Laverton TUFLOW model 1D drainage network (west).

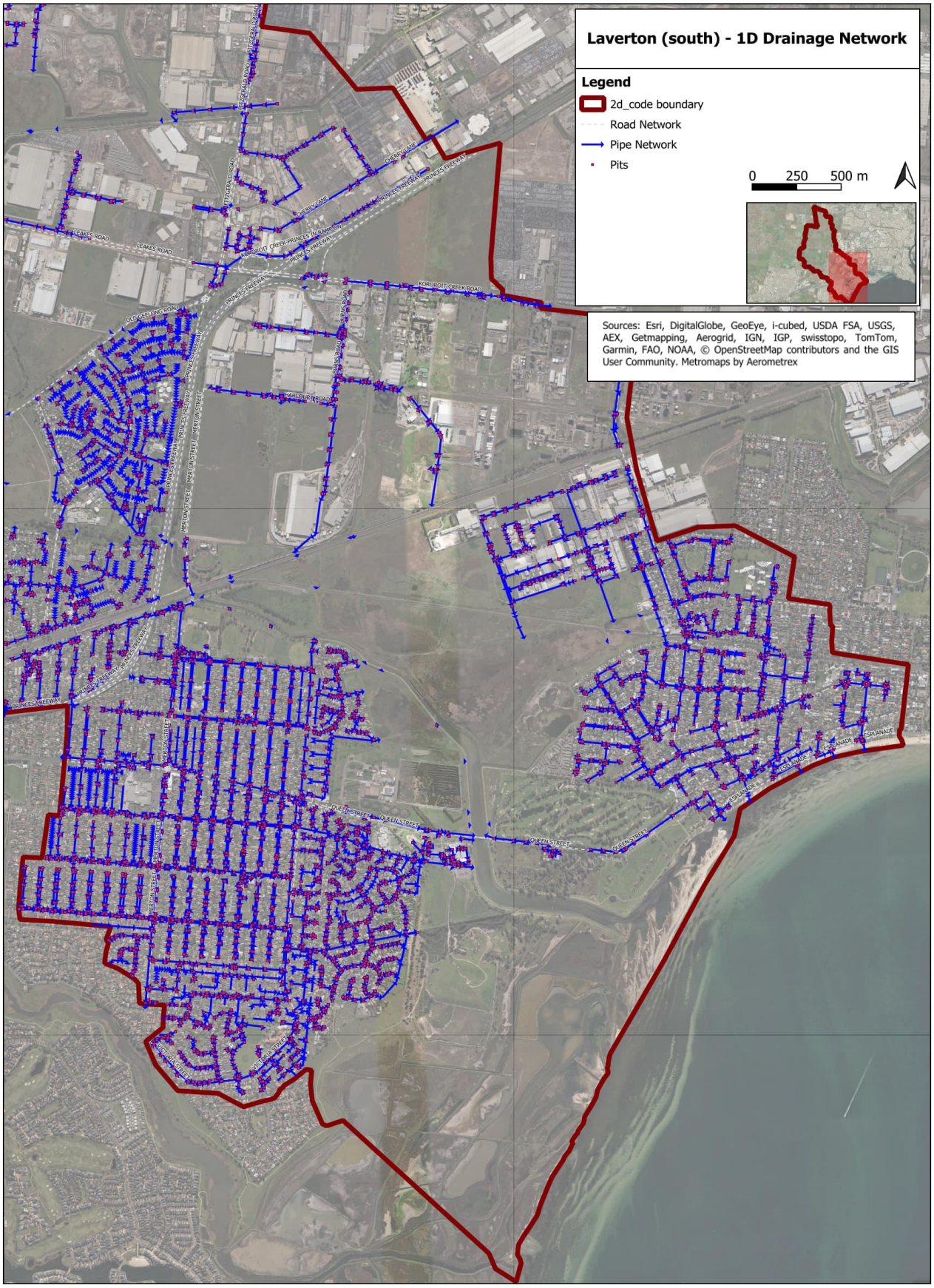


Figure E-12: Laverton TUFLOW model 1D drainage network (south).

E.6.1.5 Boundary conditions

The boundary conditions for the Laverton TUFLOW model are presented in Figure E-13, Figure E-14 and Figure E-15.

(a) Inflow Boundary for Laverton Creek

To represent the boundary condition inflows for the model, rainfall excess outputs from the Study's RORB model were applied across the TUFLOW domain. Routed inflows were also applied at the upstream end of the TUFLOW model to represent inflows entering the model outside of the Study area.

(b) Downstream Boundary for Laverton Creek

A static HT (Height versus Time) boundary condition was applied where the model outlets to Port Phillip Bay. Several HQ (height versus flow) boundaries were defined based on slope where there is flow interacting with the model boundary.

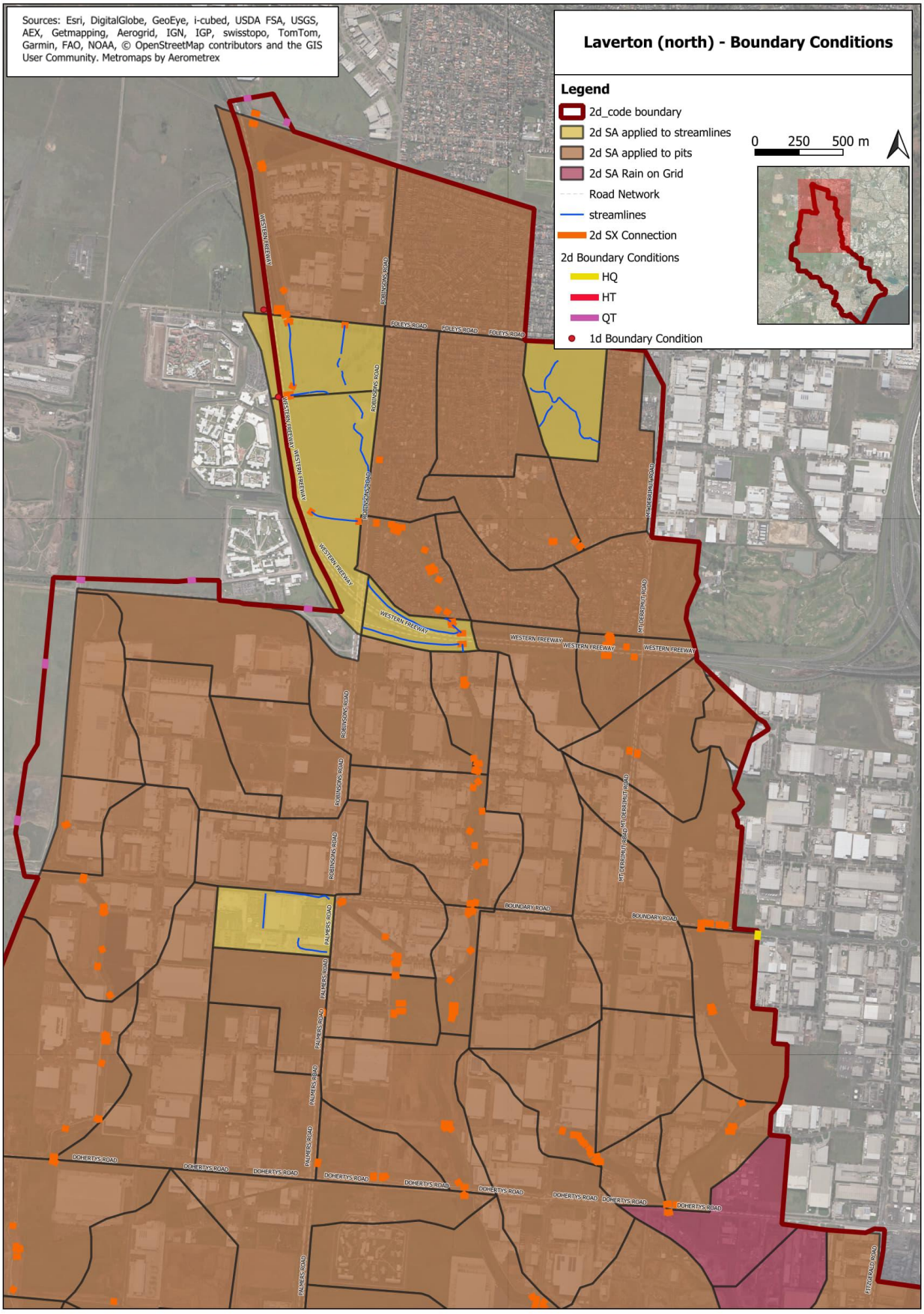


Figure E-13: Laverton TUFLOW model boundary conditions (north).

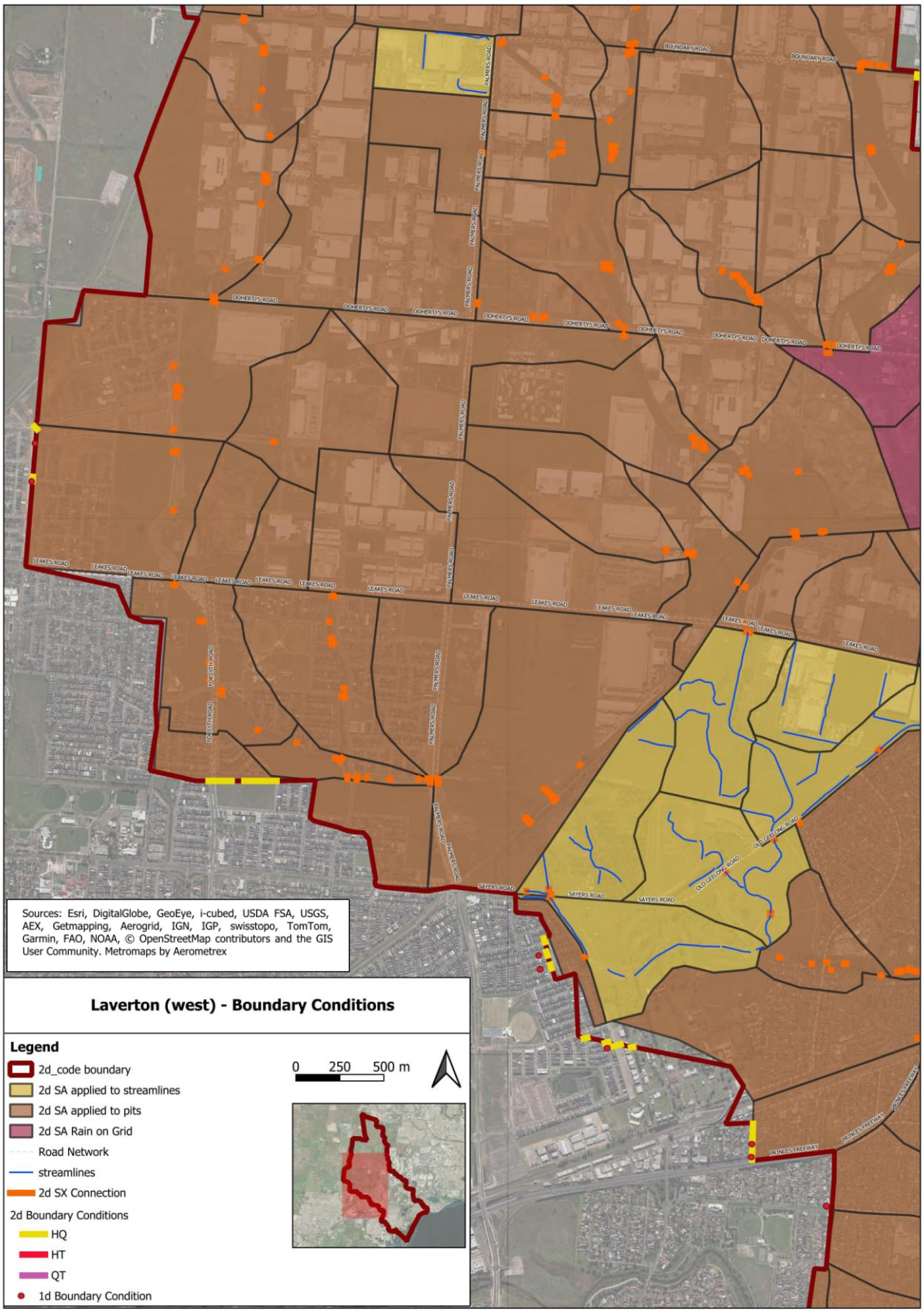


Figure E-14: Laverton TUFLOW model boundary conditions (west).

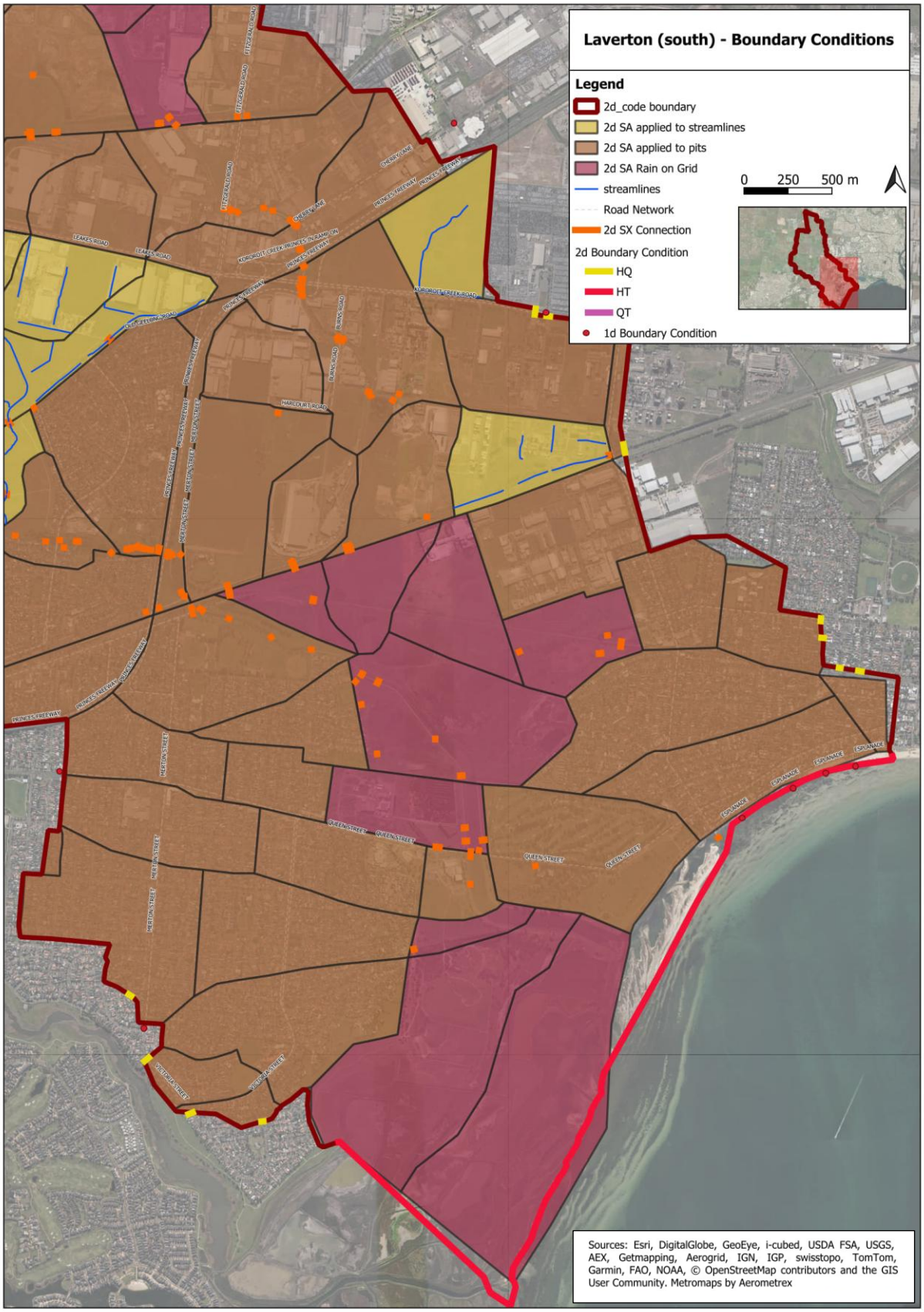


Figure E-15: Laverton TUFLOW model boundary conditions (south).

E.6.2 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table E-12.

Table E-12: Adopted Durations, temporal patterns and ARF areas for the Laverton Drain

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP 27	1	TP 27	1	-	-	-	-	-	-
25 minute	-	-	-	-	TP 16	1	TP 16	1	-	-
30 minute	TP 28	1	TP 28	1	-	-	-	-	TP 8	1
45 minute	TP 26	3	TP 26	3	TP 19	1	TP 19	1	TP 5	1
1 hour	-	-	-	-	-	-	-	-	TP 4	1
1.5 hour	TP 27	3	TP 27	3	TP 14	3	TP 14	3	-	-
2 hour	-	-	TP 24	3	TP 17	12	TP 17	12	TP 9	3
3 hour	TP 27	12	TP 27	12	-	-	-	-	TP 4	12
4.5 hour	TP 28	23	TP 22	56	TP 18	23	TP 18	23	-	-
6 hour	TP 23	38	TP 23	23	TP 16	38	TP 16	38	TP 5	23
9 hour	TP 21	56	TP 21	38	TP 15	56	TP 12	56	TP 4	56

E.6.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section E.5. The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment. This is presented in Table E-13.

Results from the RORB and TUFLOW models are generally consistent, with minor variations. Across the catchment the highly urbanised industrial precinct regions contain hardstand areas, large building footprints, and major road/rail embankments that divide the flow paths and restrict movement between sub-areas. Hydraulic connectivity is largely culvert-controlled and there are local storages (e.g., basins and low-lying yards), which extend routing times. These effects are reflected at Points 19, 20, and 21, where TUFLOW indicates longer critical durations (6 h vs 4.5 h; 3 h vs 1.5 h; and 4.5 h vs 3 h respectively) compared to RORB. Overall, the differences remain small and expected for this setting, confirming that the adopted TUFLOW critical durations are appropriate and consistent with the hydrologic model outcomes.

Table E-13: Comparison of RORB critical durations and TUFLOW critical durations for the 1% AEP with climate change event

Sample Point	Location (Figure E-3)	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
1	Robinsons Road	1.5 hour	1.5 hour	
2	Queen Street	30 min	45 min	
3	William Angliss Drive	20 min	20 min	
4	Railway 3	30 min	45 min	
5	Blyth Street	20 min	30 min	
6	Leakes Road 3	20 min	30 min	
7	Railway 1	1 hour	9 hour	The TUFLOW model results are influenced by the flooding from Laverton Creek
8	Victoria_St_Nelson_Ave	20 min	1.5 hour	An overland flow path along this location is altering the RORB vs TUFLOW critical durations
9	Balmoral Park	30 min	30 min	
10	Stony Way	1 hour	1.5 hour	
11	Foundation Road	30 min	30 min	Noting that to the east is a retarding basin with a TUFLOW critical duration of 6 hours.
12	Staintly Drive	45 min	30 min	
13	Riding Boundary Road	2 hour	1.5 hour	
14	Boundary Road 2	1.5 hour	1.5 hour	
15	Railway 2	45 min	6 hour	

Sample Point	Location (Figure E-3)	RORB 1% AEP duration	TUFLOW 1% AEP climate change	Comment
16	Western Freeway 1	1.5 hour	-	Outside of the TUFLOW domain
17	Boundary Road 1	3 hour	3 hour	
18	Western Freeway 2	1.5 hour	1.5 hour	
19	Foundation Rd RB - Inflow	20 min	6 hour	Sample point is within the Retarding Basin so the TUFLOW values are sampled. The Inflows to the basin have 20-30min critical durations.
20	Leakes Road 2	1.5 hour	3 hour	The TUFLOW model is influenced by storage behind Leaks Road.
21	Princes Freeway	3 hour	4.5 hour	
22	Laverton Main Drain 1	3 hour	3 hour	
23	Palmers Road	1.5 hour		From the TUFLOW model this is either 20-30min on the road or 6 hours in Dohertys Drain
24	Boundary Road 3	3 hour	4.5 hour	
25	Dunes Drain RB - Inflow	20 min	6 hour	In TUFLOW the results are influenced by the retarding basin.
26	Dohertys Road	3 hour	6 hour	At a location where the upstream critical duration is 6 hours in TUFLOW and 1.5 hours downstream indicating critical durations are in this range.
27	Laverton Ck RB - Inflow	4.5 hour	4.5 hour	
28	Leakes Road 1	4.5 hour	6 hour	
29	Laverton Creek 1	4.5 hour	6 hour	
30	Laverton Creek 2	6 hour	6 hour	
30	Truganina Swamp RB - Inflow	9 hour	9 hour	
31	Laverton Creek 3	9 hour	9 hour	

E.6.4 Quality Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model

warnings and checks are summarised in Table E-14. They have been assessed as not likely to adversely affect the model results. Reviews completed by Melbourne Water's external reviewer are provided in Appendix N.

Table E-14: TUFLOW checks and warning messages

Message	Count	Message content	Comment
Message 1100	44	WARNING 1100 - Structure Pipe_8668 crest/invert (47.730) is below bed (48.130) of primary downstream channel Pipe_13457.	Standard check. Not considered critical or influential to model performance.
Message 1313	1	WARNING 1313 - No inlet culvert connected to Manhole "Melbourne Water_399.1". Manhole not used/applied.	Present on two small pipes (375 dia or less) which are connected to only one pipe. Not considered critical for flood mapping purposes.
Message 1401	1	CHECK 1401 - 1 culvert(s) not used for determining losses at Manhole "Pit_3187". Check culvert inverts and directions.	Standard check. Not considered critical or influential to model performance.
Message 1402	20	CHECK 1402 - More than one culvert connected but could not create manhole at Node "Pit_2037". Check culvert inverts and directions.	Standard check. Not considered critical to resolve for flood mapping purposes.
Message 2118	603	CHECK 2118 - Lowered SX ZC Zpt by 0.00m to 1D node bed level.	All within the MW criteria of less than 0.5 m to node bed level.
Message 2210	463	CHECK 2210 - Top of first FC Layer is below ground level.	Minor locations were layered flow constrictions (bridges) under the terrain. No influence on the results.
Message 3520	1	CHECK 3520 - Found SGS cell face that has minimum Face elevation lower than the minimum cell centre elevations on both sides.	One location. No influence on the model.

E.6.5 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

E.7 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.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

RPV (Rail Projects Victoria) (2020) AJM JV Geelong Fast Rail – Laverton Creek Hydrology Modelling.

The Bureau of Meteorology (2022) Design Rainfall Data System

URS (2012) Final Report – Stage 4 – Retarding Basin Spillway Capacity Assessment – Technical Report. September 2012.

Appendix F. Skeleton Creek

The waterway for Skeleton Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

Appendix F. Skeleton Creek

This section details the RORB and TUFLOW model development for the Skeleton Creek catchment and full technical details of adopted parameters and results.

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F.1 Catchment Description and Study Area

The Skeleton Creek catchment is approximately 119 km^2 in size, located west of Melbourne. The catchment covers areas of urban development such as Tarneit, Hoppers Crossing and Williams Landing, as well as less developed agricultural areas further north including parts of Mount Cottrell and Truganina. The drainage network is relatively complex in that it includes several retention basins as well as a significant diversion south of Leakes Road. Furthermore, much of the rural areas are within the Urban Growth Zone and will be developed in the future. The catchment is shown in Figure F-1.

Only a small portion (approx. 5 km^2) of the Skeleton Creek catchment falls within the Hobsons Bay area of interest for this Study (no interaction with Brimbank LGA). The key outputs of the RORB modelling are excess rainfall hydrographs for the subareas in the area of interest and flows for Skeleton Creek in the TUFLOW hydraulic models for the catchment area.

There is a streamflow gauge located within the catchment on the main reach of Skeleton Creek (Skeleton Creek at Sayers Road Hoppers Crossing (231110A)), however this gauge is significantly upstream of the Study area. It was agreed with Melbourne Water that model calibration to observed streamflow data at Sayers Road would not be completed as part of this work given waterway mapping of Skeleton Creek is being undertaken by others. Previous FFA information was however used to validate the hydrologic model.

The waterway for Skeleton Creek has been excluded from the GIS deliverables of this study, as it is captured by a separate study by Melbourne Water.

F.1.1 Previous RORB Model

An existing RORB model for the Skeleton Creek catchment was accessed for use in this Study (RPV, 2020). This model was developed by Melbourne Water in 2018 and updated by RPV in 2020. The supplied model was reviewed and refined to be fit for purpose to provide hydrologic inflows to the Skeleton Creek TUFLOW models covering Hobsons Bay LGA. The updates undertaken to the model are outlined in the sections below.

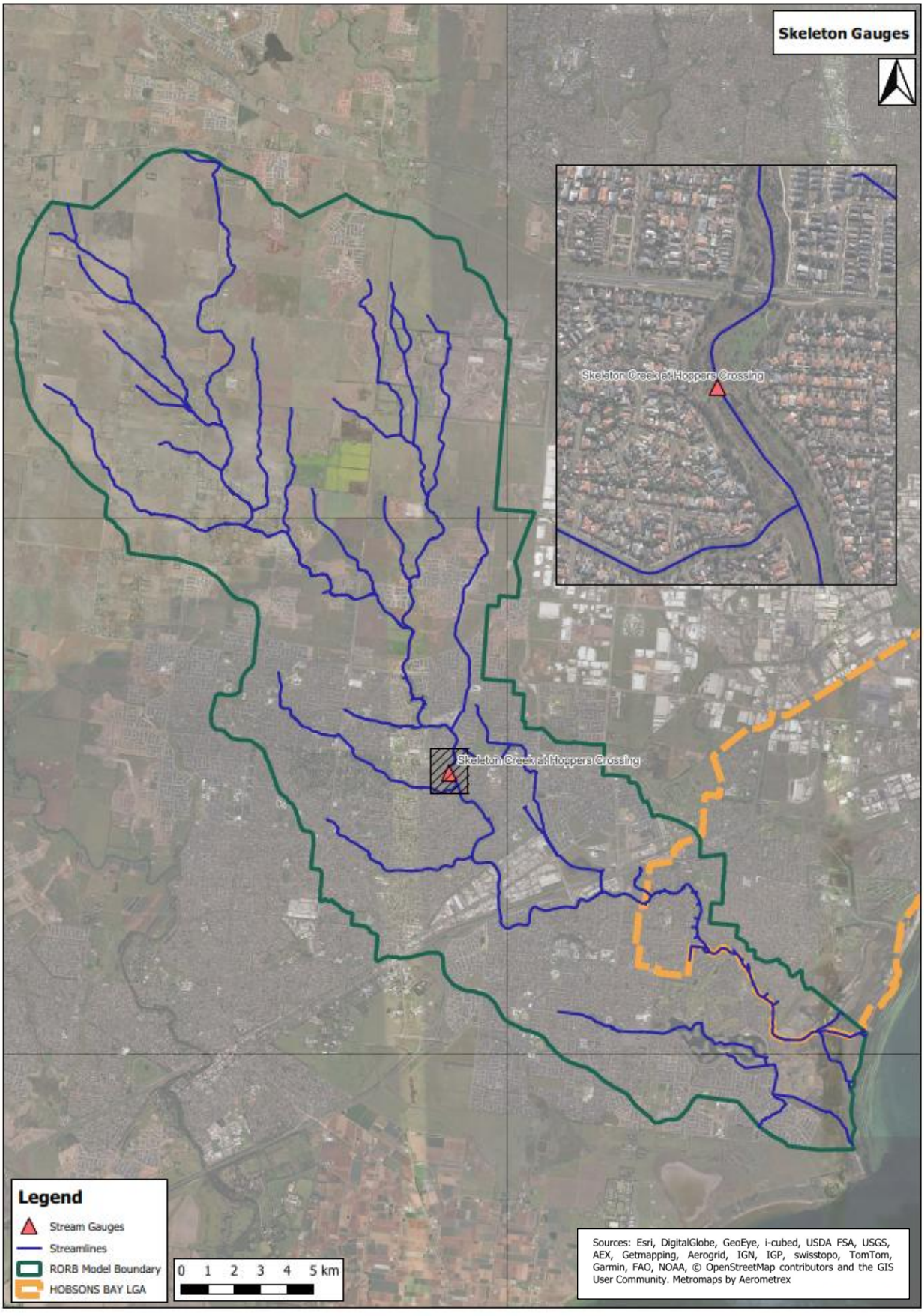


Figure F-1: Skeleton Creek catchment.

F.2 RORB Model Setup

The development of the RORB model is described in the following sub-sections and presented in Figure F-2.

F.2.1 Catchment and Subarea Boundaries

A review of existing RORB models identified the need to re-delineate some areas to standardise the size of subareas falling within Hobsons Bay LGA in preparation for extraction of hydrographs for input into TUFLOW. Where updates were required, catchment boundaries and subareas were determined using 1m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. In addition, preliminary coarse Rain-on-Grid (RoG) models were developed for parts of the Study area, as needed to assist catchment delineation. The preliminary RoG flood modelling results were used in the catchment delineation process by identifying key flow paths across the study areas, or large storage areas. Catchment boundaries were also edge-matched to neighbouring catchments. Catchment delineation considered the requirements, location and application of subarea flow to the required TUFLOW models, with division of subareas and print statements placed in suitable locations.

The final catchment and subarea boundaries are shown in Figure F-2.

F.2.2 Node-link network

The node-link network shown in Figure F-2 was checked and where updates were required, determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

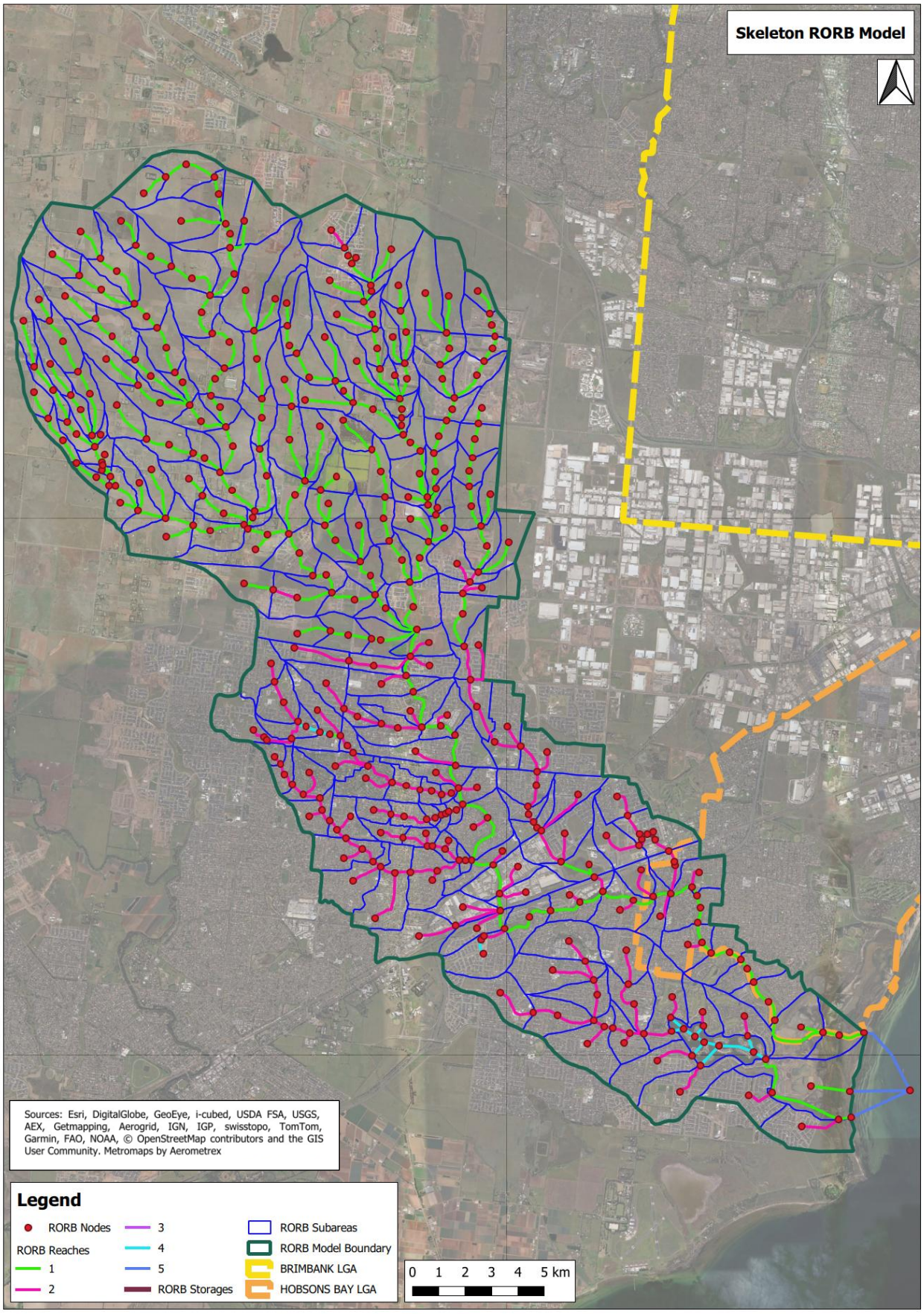


Figure F-2: Skeleton Creek RORB model setup.

F.2.3 Reaches

Reaches from the existing RORB model were checked and updates were applied where required (i.e. to align with updated catchment delineation). Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours, aerial imagery and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
  - Type 1 – Natural channels, used for major creek reaches
  - Type 2 – Excavated but unlined – primary reach used across the catchments to represent flow in urban areas.
  - Type 3 – Lined channel or pipe – these were not used in the model
  - Type 4 – Drowned – these were used upstream of storages or major waterbodies
  - Type 5 – Dummy – used to connect independent catchments (i.e. at Port Phillip Bay) to a single outlet node

F.2.4 Storages

Storages were used in the RORB model to represent retarding basins (RB). One storage was present in the existing RORB model, which was updated as listed in Table F-1. No H-S/S-Q relationship information was available to represent Harrington Avenue RB, Waldorf RB, Reflections Wetlands RB, Mt Atkinson RB or Sanctuary Lakes as storages in the RORB model.

Table F-1: Storages in the Skeleton Creek RORB model

Storage	Data source and checks
Addison Wetland RB	Storage details adopted as per RPV model (2020). Checks on spillway height carried out against project LiDAR and confirmed as reasonable. Pipe outlet information checked against Melbourne Water underground asset information. No further information available for further checks or updates (i.e. on H-S relationship). The H-S relationship was extended by extrapolating using the existing data points/trend to allow higher flows to be modelled.

F.2.5 Diversions

No diversions are present in the Skeleton Creek RORB model.

F.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

F.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

F.2.8 RORB version

RORB version 6.47 was used for modelling.

F.3 RORB design inputs

F.3.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.824, Long 144.699) was sourced from the Bureau of Meteorology (Appendix I). As per the Melbourne Water Flood Mapping Projects Specifications, rainfalls were increased by 18.5% to establish climate change rainfalls.

F.3.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Given that this Study has derived storm losses for neighbouring catchments via model calibration to observed events (including Kororoit Creek, Stony Creek and Maribyrnong River), loss parameters have been transferred from the Kororoit Creek model to the Skeleton Creek model.

Specifically, the loss parameters derived for the Kororoit Creek at the Deer Park gauge have been transferred and applied to Skeleton Creek at the Hoppers Crossing inter-station area given that the upstream area at Deer Park is largely rural and therefore most consistent with the land use of the Skeleton Creek catchment upstream of Hoppers Crossing. The transfer of parameters from a neighbouring catchment's calibrated RORB model is supported by ARR 2019 (HARC, 2020) over the adoption of DataHub loss parameters as the transferred losses are likely to represent the runoff behaviour of a catchment in the same local geography more accurately. The adopted storm losses are listed in Table F-2.

Table F-2: Skeleton Creek model storm losses

	IL (mm)	CL (mm/hr)
Transferred from Kororoit Creek (adopted)	18.0 (Hoppers Crossing ISA – rural U/S area) 13.5 (Outlet)	3.0 (Hoppers Crossing ISA – rural U/S area) 2.5 (Outlet)
DataHub	5.0	0.6

F.3.3 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the Study area is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations shorter than the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighan (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

F.3.4 Temporal Patterns

Areal and point temporal patterns were obtained from the ARR DataHub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies). These were compared via a single storm run for the critical duration (12-hour and 18-hour storm compared) to determine if an areal temporal pattern showed a significant difference in results. Resulting hydrographs show minimal differences for either duration

at both the gauge and catchment outlet and therefore point temporal patterns were applied. Temporal patterns were filtered for embedded bursts using the option in RORB.

F.3.5 Spatial Patterns

The size of the catchment is 119 km^2 which is larger than the size recommended for the application of spatial patterns. A spatial rainfall distribution was determined to ensure that variation in rainfall depth across the catchment was accounted for. This was calculated by comparing the catchment average rainfall to the average rainfall for each sub-catchment using the design rainfall grids (Bureau of Meteorology, 2022). This was then implemented to the RORB model as a 'non-uniform' spatial pattern for each duration.

The spatial variation across the catchment is illustrated in Figure F-3 for the 1% AEP 12 hour rainfall event.

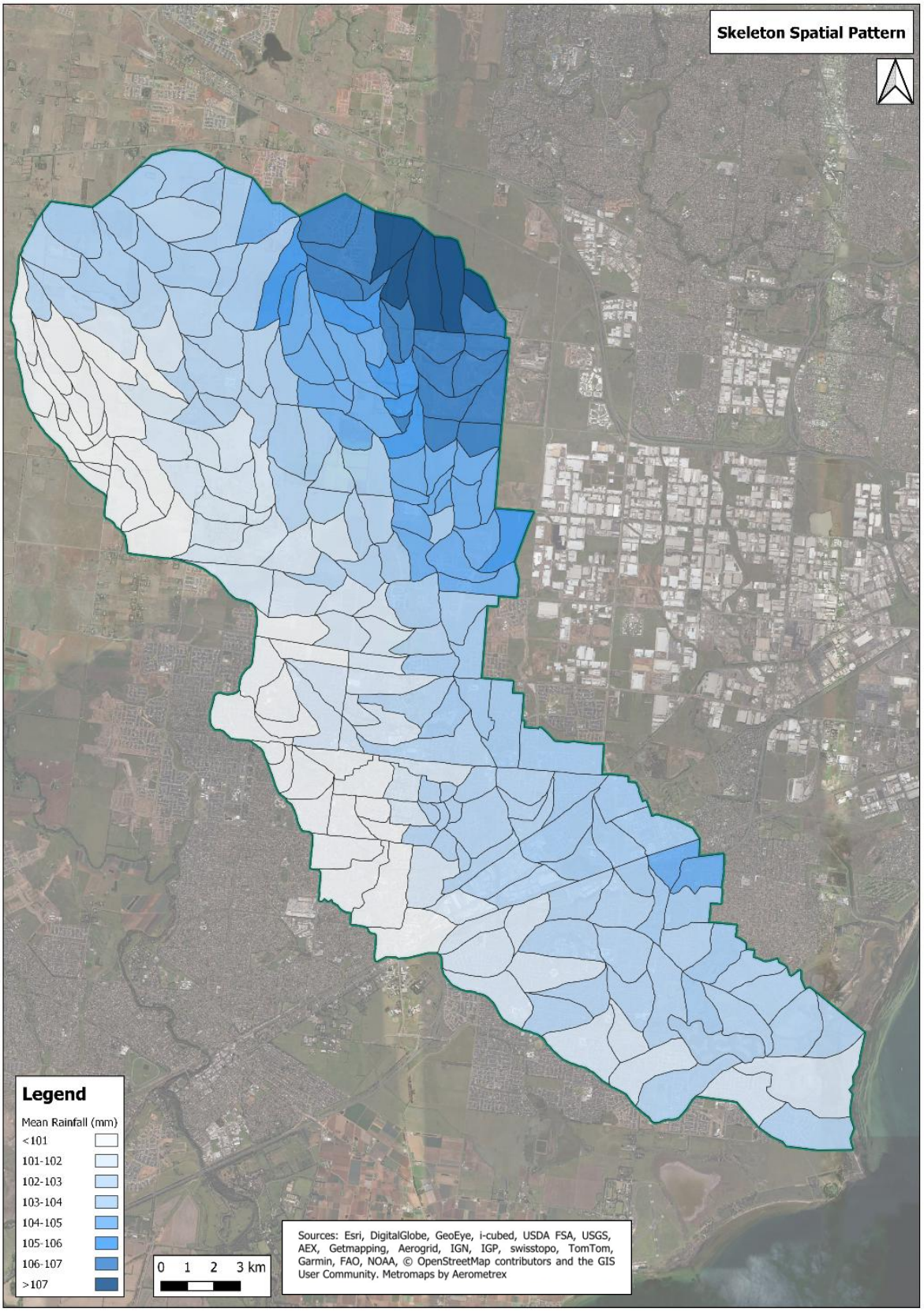


Figure F-3: Spatial rainfall pattern for the Skeleton Creek RORB model for the 1% AEP, 12 hr storm.

F.3.6 Areal Reduction Factor (ARF)

As catchment size increases, average rainfall intensity decreases. To address this, an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1 km^2 ARR 2019 recommends no reduction in the design rainfalls. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process ARFs have been considered across each catchment. Adopted ARFs have been considered with respect to the critical storm durations analysis presented in Section F.5. To determine the appropriate ARF to adopt, the RORB models were run for a range of ARF values based on contributing areas. The critical durations were then analysed across ARFs and a representative set of ARFs, and durations for each AEP were determined. The results of this assessment are presented in Table F-3.

Table F-3: Adopted ARF values for the Skeleton Creek RORB model.

Duration	ARF area (km^2)	Justification
20 min (1%, 2%, AEP) 45 min (5%, 10% AEP) 1.5 hour (20% AEP) 4.5 hour (1%, 2%, AEP) 6 hour (20% AEP) 9 hour (5%, 10% AEP)	1	Based on critical durations identified in the Ensemble analysis. ARF areas selected to represent the range of contributing catchment areas at key locations.
12 hour (all AEPs)	100	

F.4 RORB Verification and Input Parameters

To determine the appropriate losses for generating the hydraulic model inputs, RORB was run in Monte Carlo mode for the Study area to establish peak flow estimates at the catchment outlets for the 1% AEP event. The Monte-Carlo technique as recommended by ARR (Ball et al., 2019) was used to calculate flood quantiles. This technique involves randomly sampling different flood forming variables to create flood frequency outputs whilst also replicating natural processes. This technique inherently accounts for interactions between the various flood forming variables, providing a more realistic representation of the flood hydrograph generation processes.

The routing calculation in RORB uses two parameters, k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. The m parameter was set at the default value of 0.8 as per advice in the Melbourne Water's Flood Mapping Projects Specifications. A Regional Flood Frequency Estimation (RFFE) was performed using the RFFE tool (https://rffe.arr-software.org) for the Hoppers Crossing gauge (largely rural catchment). Output files from the RFFE are shown in Appendix L. Given that the RFFE is recommended for entirely rural catchments, the method is not recommended for the catchment at the model outlet and as such was not completed for this location.

Peak flow estimates where k_c was varied for the Skeleton Creek RORB model are provided in Table F-4. The proposed inputs are summarised in Table F-5.

Table F-4: k_c estimates and peak flow values at Hoppers Crossing and the outlet

	Vic < 800mm	Vic < 800mm & Pearse et al. 2002	Vic < 800mm & Yarra Maribyrnong	RFFE	Nikolaou /von't Steen (urban)	Nikolaou /von't Steen (rural)	Melbourne Water rule of thumb (urban)	Melbourne Water rule of thumb (rural)
k_c (Hoppers Crossing gauge / Outlet)	7.55 / 11.17	7.55 / 11.98	7.55 / 17.6	-	-	-	-	-
Q_{100} flow at Hoppers Crossing (m^3/s)	167	167	168	95.4	204	116	672	202
Q_{100} flow at outlet (m^3/s)	194	190	169	-	313	183	1228	368

Table F-5: Adopted k_c for the Skeleton Creek model.

Adopted k_c	Comment
7.55 / 11.17 (Vic < 800mm annual rainfall)	Flows generally align with previous estimates and FFA completed by RPV for the Hoppers Crossing gauge (Q_{100}: 187.5 m^3/s) (RPV, 2020). Slightly lower flows are expected due to higher storm losses applied in this Study, derived through calibration of models in nearby catchments. Flows are within range of Nikoloau/vont Steen estimates. Catchment average rainfall is <800mm (Bureau of Meteorology, 2022b)

F.5 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal patterns was completed in RORB. This also enabled the selection of appropriate ARFs to adopt across the catchments. The RORB model was run in Ensemble mode. The model was run several times, each with a different ARF based on varying catchment areas as listed in Table F-3. This enabled the identification of how critical durations were likely to alter based on the contributing catchment area. Key locations across the catchment are shown in Figure F-4. These were identified as follows:

- Locations where inflows are required to be applied in TUFLOW
- Locations upstream or within urban areas
- Locations upstream and downstream of model storages
- Locations where hydraulic structures and/or infrastructure (i.e. major roads, embankments, rail lines) are present that will impact the behaviour of the flood wave
- Points located within Study LGAs, providing good coverage across the Study area

The corresponding critical durations identified from assessing and selecting the event that produced the median peak flow at key locations across the catchment are presented in Table F-6. The subareas in the Skeleton Creek model that fall within the Hobsons Bay LGA are urban in nature and hydrologically similar to

neighbouring subareas in the Laverton Creek catchment. Given their similarity and proximity, the durations and temporal patterns critical for the nearby Laverton Creek catchment urban areas (with small upstream catchment areas (< 1km ^{2})) will also be adopted for the Skeleton Creek model. Table F-7 lists the storms that were simulated in TUFLOW at the hydraulic modelling phase of this Study. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

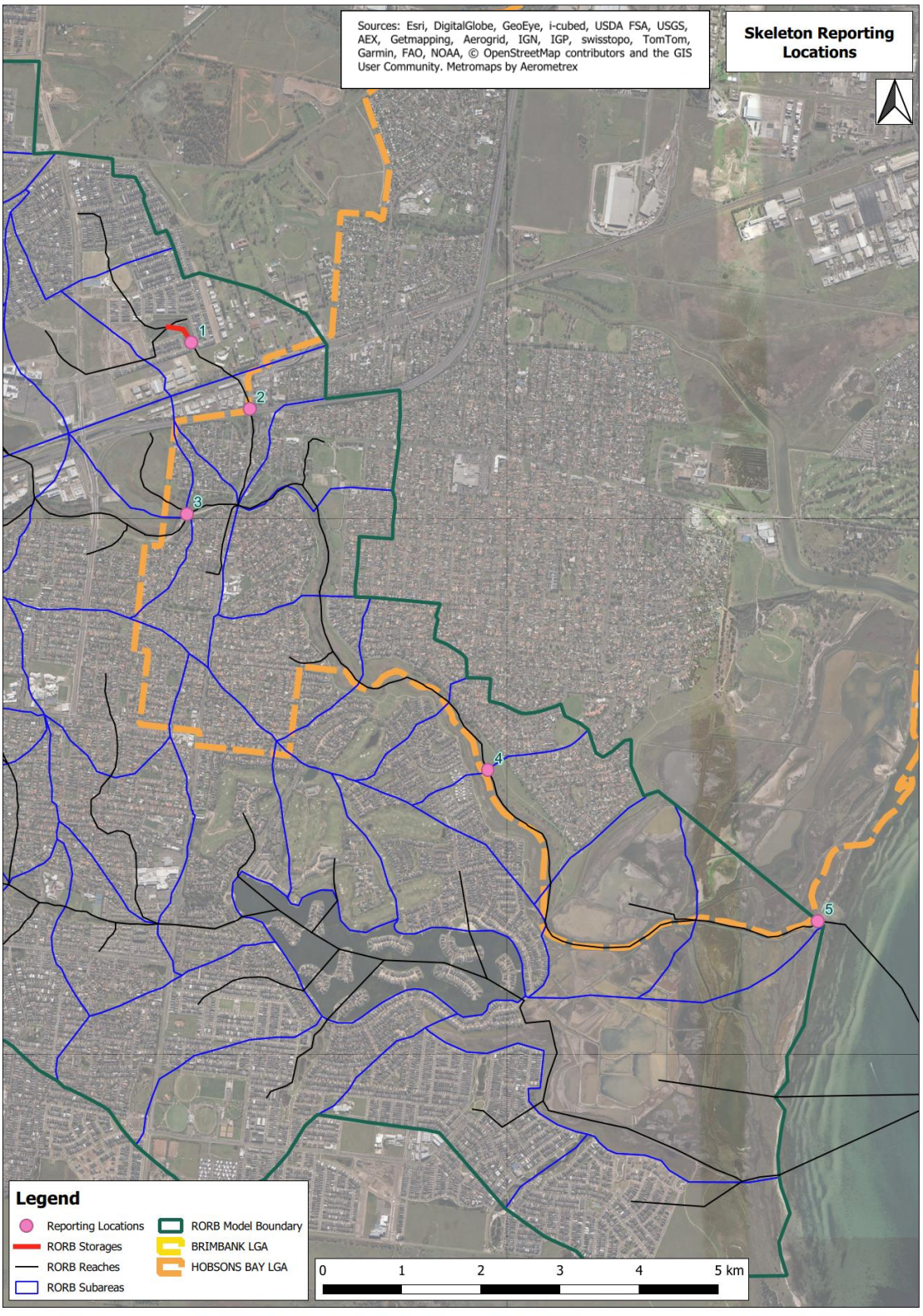


Figure F-4: Skeleton Creek RORB reporting locations

Table F-6: Analysis of critical durations and peak flows at key locations for the Skeleton Creek RORB model.

ID	Location	U/S area km^2	1% AEP duration/peak flow (m^3/s)		2% AEP duration/peak flow (m^3/s)		5% AEP duration/peak flow (m^3/s)		10% AEP duration/peak flow (m^3/s)		20% AEP duration/peak flow (m^3/s)	
1	Addison Wetland RB - Inflow	1.4	20min	3.2	20min	2.6	45min	2.0	45min	1.6	1.5hour	1.2
2	Princes Freeway	2.4	4.5hour	4.7	4.5hour	2.8	9hour	2.2	9hour	1.8	6hour	1.0
3	Skeleton Creek 1	99	12hour	176.6	12hour	145.1	12hour	99.9	12hour	68.3	12hour	43.1
4	Skeleton Creek 2	105.2	12hour	180.2	12hour	144.3	12hour	101.0	12hour	68.4	12hour	43.6
5	Skeleton Creek 3	107.5	12hour	178.5	12hour	142.5	12hour	98.7	12hour	66.8	12hour	43.0

Table F-7: Critical durations and selected temporal patterns for the Skeleton Creek RORB model.

AEP	20min	25min	30min	45min	1hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour
1%	TP 27	-	* TP 28	-	-	-	-	-	TP 22	-	-	TP 10
2%	TP 27	-	* TP 28	-	-	-	-	-	TP 22	-	-	TP 8
5%	-	* TP 16	-	TP 16	-	-	-	-	-	-	TP 12	TP 7
10%	-	* TP 16	-	TP 16	-	-	-	-	-	-	TP 12	TP 5
20%	-	-	* TP 8	-	-	TP 2	-	-	-	TP 7	-	TP 9

*Duration/TP combination transferred from neighbouring Laverton Creek catchment to represent critical event for similar urban areas with small contributing catchment area.

F.6 Hydraulic Modelling

This section provides supplementary information for the hydraulic modelling of the Skeleton Creek catchment.

F.6.1 Hydraulic Model Set Up

F.6.1.1 Terrain modifications

Maps available in Figure F-5 show Skeleton Creek TUFLOW model terrain modifications, which are also listed in Table F-8 where these have been based on drawings, plans or other available detailed information.

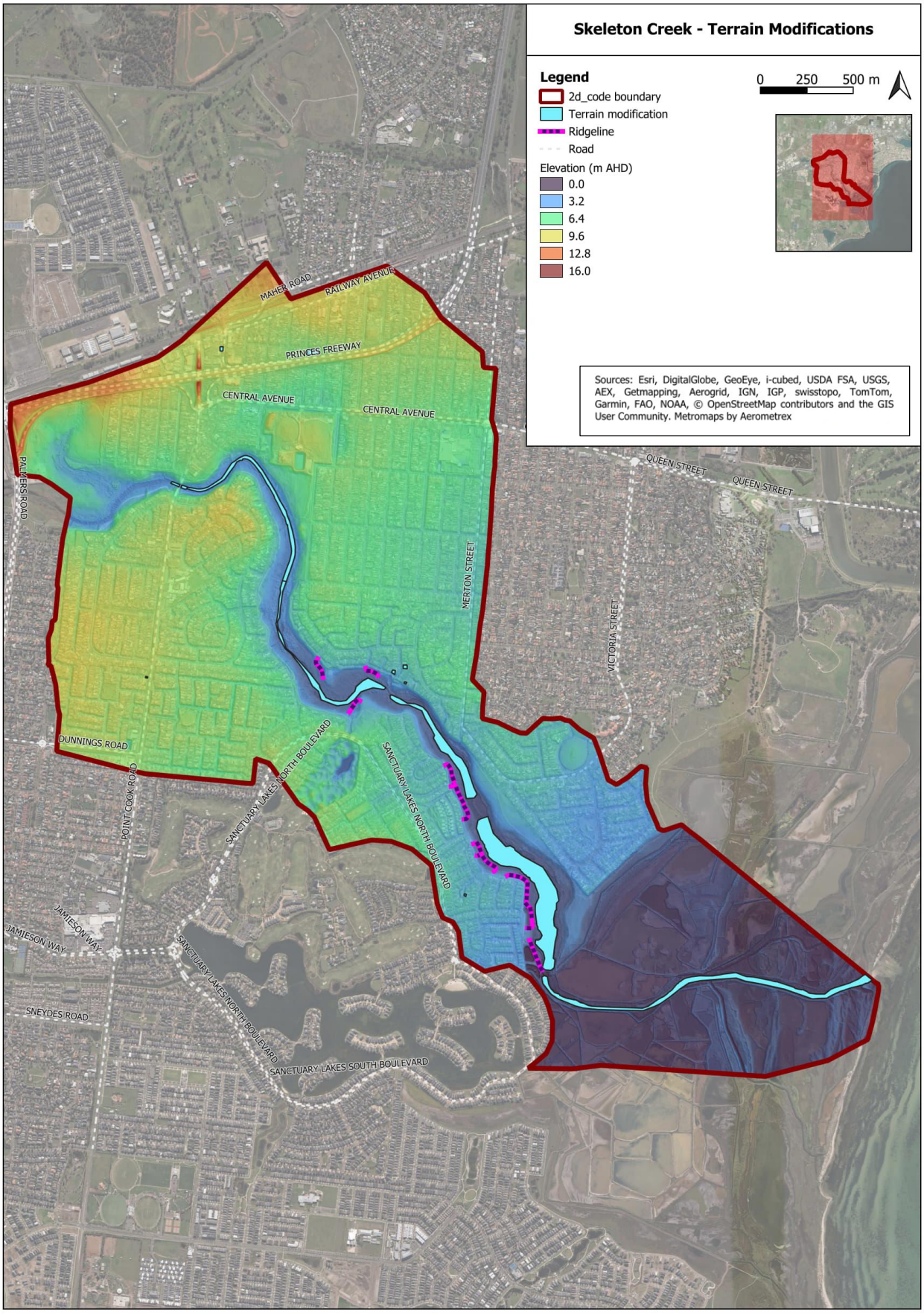


Figure F-5: Skeleton Creek TUFLOW model terrain modifications.

Table F-8: Skeleton Creek TUFLOW model terrain modifications.

Data	Reference	Application in this Study
Ridgelines along Skeleton Creek	N/A	
Terrain refinement for holes	N/A	7 hole-filling patches have been applied to rectify inaccuracies in the 1m LiDAR data.
Skeleton Creek Cross Section data	Melbourne Water survey dataset: SE970004 Melbourne Water survey dataset: SE970089	Inverts of the waterway have been added to the model to stamp in the channel profile. Some locations have been inferred based on upstream and downstream survey data.

F.6.1.2 Bridges

Bridges have been modelled as 2d layered flow constrictions, the details of which are listed in Table F-9

Table F-9: Skeleton Creek TUFLOW model bridges.

Location	Pier Form loss	Soffit level (m AHD)	Deck thickness (m)	Assumed railing height (m)	Railing blockage
Point Cook Road Bridge	0.03	5.3	0.55	1	30
Footbridge near Ravenswood Court	0.16	3.46	0.18	1.45	35
Skeleton Creek Trail Footbridge	0.03	1.37	0.5	1	30

F.6.1.3 Model roughness

Maps available in Figure F-6 show the Skeleton Creek TUFLOW model Manning's roughness.

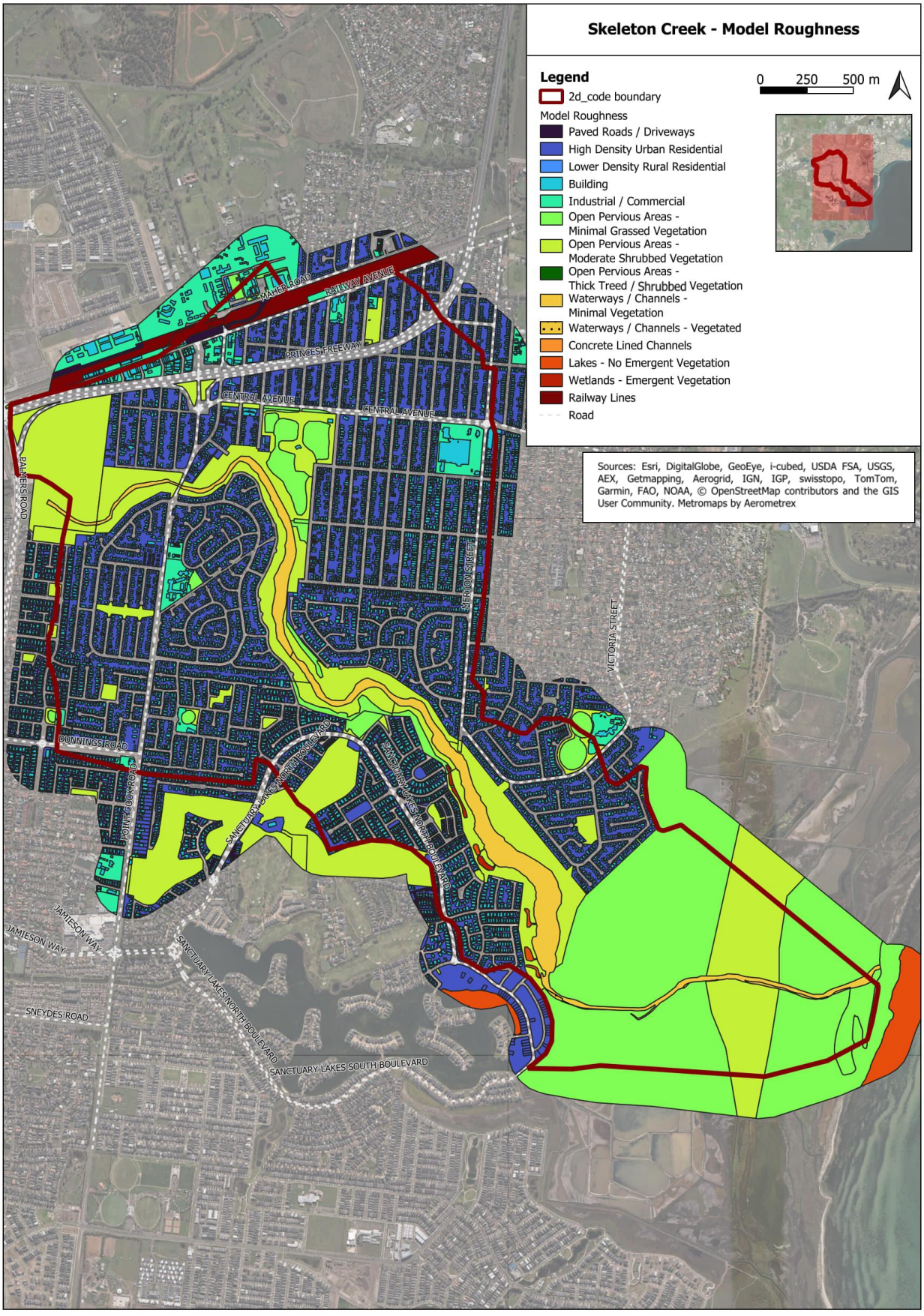


Figure F-6: Skeleton Creek TUFLOW model Manning's roughness.

F.6.1.4 1D Drainage network

Where pipe connections were identified or suspected as being missing from the network, these were added in with assumed details to ensure network connectivity. These are listed in Table F-10. A full count of the adopted pit types in the TUFLOW model is listed in Table F-11. Maps of the full drainage network can be found in Figure F-7.

Table F-10: Skeleton Creek TUFLOW model 1D drainage network assumed pipes.

TUFLOW pipe ID	Assumed asset owner	Pipe type	Width (m)	Height (m)	Number of cells	Justification
Cul_1	VicRoads/ City of Wyndham	R	2.5	2.5	0	Assumed culvert for representing pedestrian underpass across Sanctuary Lakes North Boulevard.
Assumed_001	Hobsons Bay Council	C	0.75	0	1	Assumed pipe alongside Skeleton Creek Trail near Groome Court.
Assumed_002	Hobsons Bay Council	C	0.525	0	1	Assumed pipe alongside Neville Avenue.
A_02581, A_02954, A_09234, A_12384, A_24542, A_34543, A_73423, A_80543, A_90825, A_92546	City of Wyndham	C	0.45	0	1	Assumed pipe network along Trident Court, Seafarer Way and discharge toward Skeleton Creek.
A_23451	City of Wyndham	C	0.675	0	1	Assumed pipe across Rockfeller Way.
A_35345, A_71442, A_88351	City of Wyndham	C	0.45	0	1	Assumed pipe network along Half Moon Terrace.
A_82542	Hobsons Bay Council	C	0.3	0	1	Assumed pipe along Point Cook Road.
A_98234	Hobsons Bay Council	C	0.3	0	1	Assumed pipe in Bruce Comben Reserve.

Table F-11: Skeleton Creek TUFLOW model 1D drainage adopted pit types.

Pit Type	VicRoads standard pit type	Count
Side Entry Pit	Standard Drawing 1301 - Side Entry Pit - B Type kerb - 1m Inlet	2078
Double Side Entry Pit		0
Grated Side Entry Pit	Standard Drawing 1322 - Grated Side Entry Pit - B Type kerb - 1m Inlet	44
Grated Pit	Standard Drawing 431 - Grated Pit - Flush Steel Grate - 1m x 1m Inlet - Grate Type B	536
Double Grated Pit		0
Junction Pit (node)	-	600

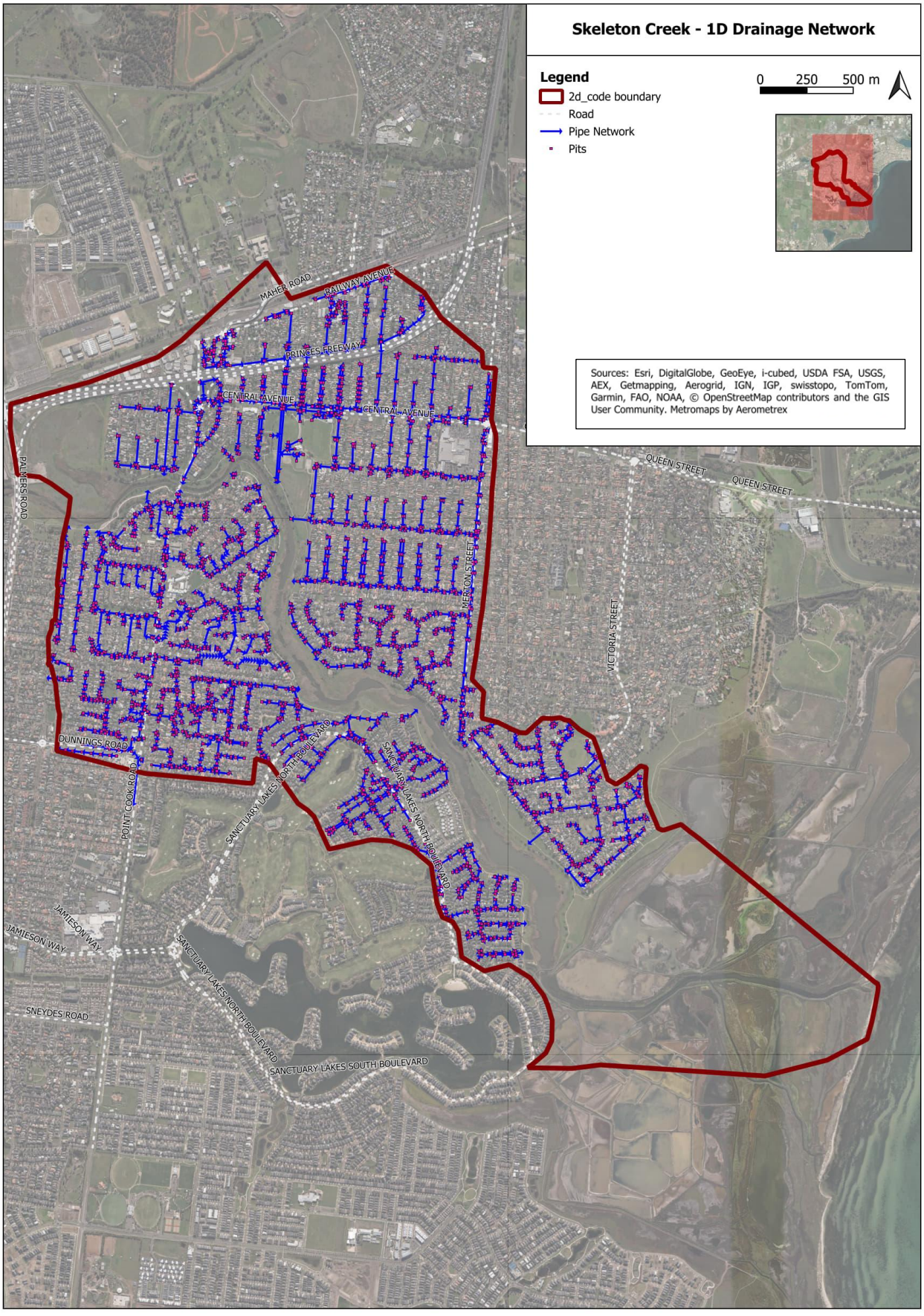


Figure F-7: Skeleton Creek TUFLOW model 1D drainage network.

F.6.1.5 Boundary conditions

The boundary conditions for the Skeleton Creek TUFLOW model are presented in Figure F-8.

(a) Inflow Boundary for Skeleton Creek

To represent the boundary condition inflows for Skeleton Creek, flows taken from the Study's RORB model were applied at the upstream end of the TUFLOW model at the major tributary inflow point (Skeleton Creek).

As per Appendix 3, Table 12 of the Melbourne Water Flood Mapping Projects Specifications, the 10% AEP flow for Skeleton Creek has been used for modelling the 1% and 2% AEP events for the study, and the 20% AEP flow for the 5-20% AEP events (given the Study area is above the tidally influenced zone). This approach was approved by Melbourne Water.

The study has applied an offset to these inputs so the peak of the flood event in Skeleton Creek approximately matches the peak of the catchment runoff.

In addition, a gridded IWL is applied to the main Skeleton Creek channel. The IWL fills the base of the channel and represents a 'baseflow' in the river prior to the main inflows being added. This gridded IWL also serves to stabilise the model when larger event flows are added in the simulation.

This study will not produce a flood extent along the Skeleton Creek waterway as part of the GIS Deliverables set. Riverine mapping of Skeleton Creek is being delivered under a separate Melbourne Water package of works.

(b) Downstream Boundary for Skeleton Creek

A static HT (Height versus Time) boundary condition was applied where the model outlets to Port Phillip Bay. These boundary levels represent maximum water levels extracted from Table 35 in Appendix 18 of the Melbourne Water Flood Mapping Projects Specifications (August 2023), and are summarised in Table 4.7 Several HQ (height versus flow) boundaries were defined based on slope where there is flow interacting with the model boundary.

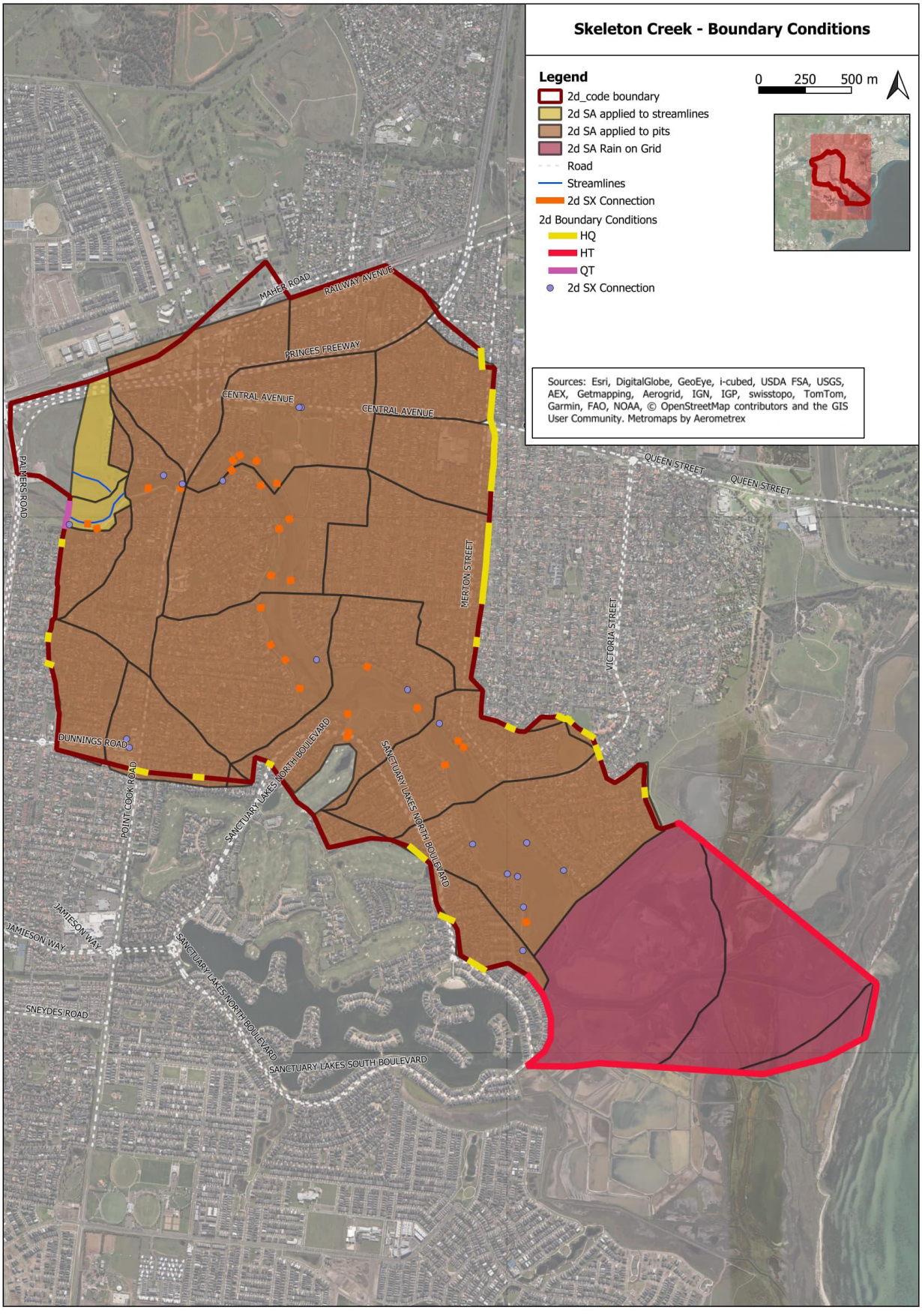


Figure F-8: Skeleton Creek TUFLOW model boundary conditions.

F.6.2 Adopted Areal Reduction Factors, Critical Durations and Temporal Patterns

The simulation of the hydraulic model to generate flood extents for flood mapping purposes was completed using the defined ARF, critical durations and temporal patterns developed in the hydrological model. These are summarised in Table F-12.

Table F-12: Adopted Durations, temporal patterns and ARF areas for the Skeleton Creek RORB model

	1% AEP and 1 % AEP with Climate change		2% AEP		5% AEP		10% and 10% AEP with climate change		20% and 20% AEP with climate change	
Duration	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)	Adopted Temporal pattern	ARF area (km^2)
20 minute	TP 27	1	TP 27	1	-	-	-	-	-	-
25 minute	-	-	-	-	* TP 16	1	* TP 16	1	-	-
30 minute	* TP 28	1	* TP 28	1	-	-	-	-	* TP 8	1
45 minute	-	-	-	-	TP 16	1	TP 16	1	-	-
1 hour	-	-	-	-	-	-	-	-	-	-
1.5 hour	-	-	-	-	-	-	-	-	TP 2	1
2 hour	-	-	-	-	-	-	-	-	-	-
3 hour	-	-	-	-	-	-	-	-	-	-
4.5 hour	TP 22	1	TP 22	1	-	-	-	-	-	-
6 hour	-	-	-	-	-	-	-	-	TP 7	1
9 hour	-	-	-	-	TP 12	1	TP 12	1	-	-
12 hour	TP 10	1	TP 8	1	TP 7	1	TP 5	1	TP 9	1

*Duration/TP combination transferred from neighbouring Laverton Creek catchment to represent critical event for similar urban areas with small contributing catchment area.

F.6.3 Critical Duration Assessment

The selection of critical durations was completed in RORB which is documented in Section F.5. The TUFLOW grid of the maximum water level across all modelled durations for the 1% AEP with climate change scenario has been compared to the critical durations identified in the RORB assessment.

Results from the RORB and TUFLOW models are generally consistent in the waterway. As shown in Figure F-9, one difference occurs at Point 2, where TUFLOW indicates a shorter critical duration compared to RORB. This is due to the sample point location and the 4.5 hour duration is critical near this point. The critical duration map of Figure F-9 shows the 20 min and 30 min storms are critical across the majority of the urban area which is consistent with the other catchments in this study. It is noted the waterway critical duration is not an accurate representation as the peak Skeleton Creek flow has not been simulated in this project. This will be captured in a separate study.

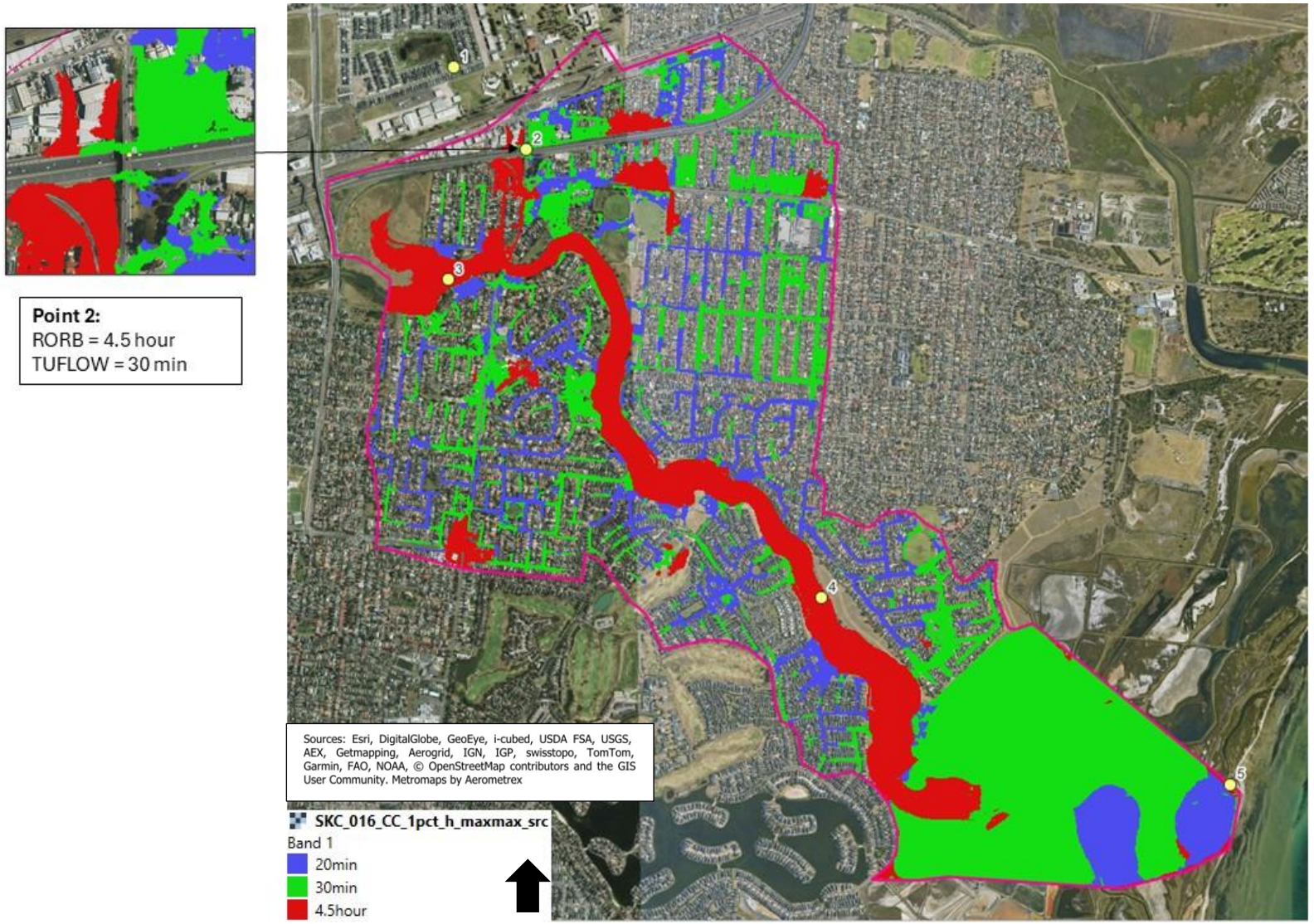


Figure F-9: Critical duration assessment for Skeleton Creek

F.6.4 Quality Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet. An internal review of the TUFLOW model was completed by a senior engineer. Improvements identified by the reviewer were integrated back into the model. The remaining TUFLOW model warnings and checks are summarised in Table F-13. They have been assessed as not likely to adversely affect the model results. Reviews completed by Melbourne Water's external reviewer are provided in Appendix N.

Table F-13: TUFLOW checks and warning messages

Message	Count	Message content
Message_2073	5	WARNING 2073 - Object ignored. Only Points, Lines, Polylines, Regions & Region Centres used. GIS Object = Null Shape
Message_1402	5	CHECK 1402 - More than one culvert connected but could not create manhole at Node "PT012107". Check culvert inverts and directions.
Message_2118	23	CHECK 2118 - Lowered SX ZC Zpt by 0.02m to 1D node bed level.
Message_2210	25	CHECK 2210 - Top of first FC Layer is below ground level. Ground Level = 50.39; Top of First FC Layer = 49.66
Message_1100	1	WARNING 1100 - Structure PP003186 crest/invert (58.860) is below bed (59.020) of primary upstream channel PP003170.
Message_3520	1	CHECK 3520 - Found SGS cell face that has minimum Face elevation lower than the minimum cell centre elevations on both sides.
Message_1044	2	Invert interpolated for culvert 'a'

F.7 Model Performance

The performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and the relevant councils. The key outcomes of these performance checks are summarised below, with full details presented in Appendix N.

- Comparison with Melbourne Water flooding hotspot database: Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- Comparison with State Emergency Service road flooding hotspot database: Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.
- Overall model performance: The performance checks indicate that the flood model outputs generally align with historical flooding observations across the study area. These findings were confirmed through workshops with Brimbank Council and Hobsons Bay Council, in which the results presented in Appendix N were discussed.

F.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.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

RPV (Rail Projects Victoria) (2020) AJM JV Geelong Fast Rail – Skeleton Creek Hydrology Modelling.

The Bureau of Meteorology (2022a) Design Rainfall Data System

The Bureau of Meteorology (2022b) Average annual, seasonal and monthly rainfall

Appendix G. 9880 Catchment

Appendix G. Sub catchment 9880 – Council Drainage Direct to Bay

This section details the RORB model development for the 9880 catchment which drains to Port Phillip Bay and full technical details of adopted parameters and results. The TUFLOW modelling for this area is detailed in Appendix C as part of the Stony Creek catchment model.

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G.1 Catchment Description and Study Area

The 9880 catchment is a small area of 6 km^2 that includes the urban areas of Williamstown and Newport. The model area is comprised of local council drainage that drains to Port Phillip Bay, with no major surface water channels. Consequently, the model generated only excess rainfall hydrographs, which were used as direct inflow inputs to the downstream Stony Creek TUFLOW model.

The previous RORB model for this area was developed by Cardno (2018) as part of the 2018 Hobsons Bay Flood Mapping project. Only the MiRORB GIS tables were supplied (and not the RORB model files) for use in the current Study. The RORB model for the 9880 drainage catchment was therefore developed by Jacobs for the current Study.

G.2 RORB Model Setup

The development of the RORB model is described in the following sub-sections and presented in Figure G-1.

G.2.1 Catchment and Subarea Boundaries

Catchment boundaries were determined using the 1 m LiDAR DEM supplied for the project. Initial boundaries were determined using watershed analysis in QGIS and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. Catchment boundaries were also edge-matched to neighbouring catchments.

Subarea boundaries were determined using the 1m LiDAR DEM, contours generated from the DEM and the Melbourne Water and council pit and pipe networks. Where possible, boundaries were delineated separating areas of underground pipe network and open space to enable better application of flows to the TUFLOW models.

The final catchment and subarea boundaries are shown in Figure G-1.

G.2.2 Node-link network

The node-link network shown in Figure G-1 was determined using the LiDAR DEM, contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment. Links were created using the ArcRORB software package.

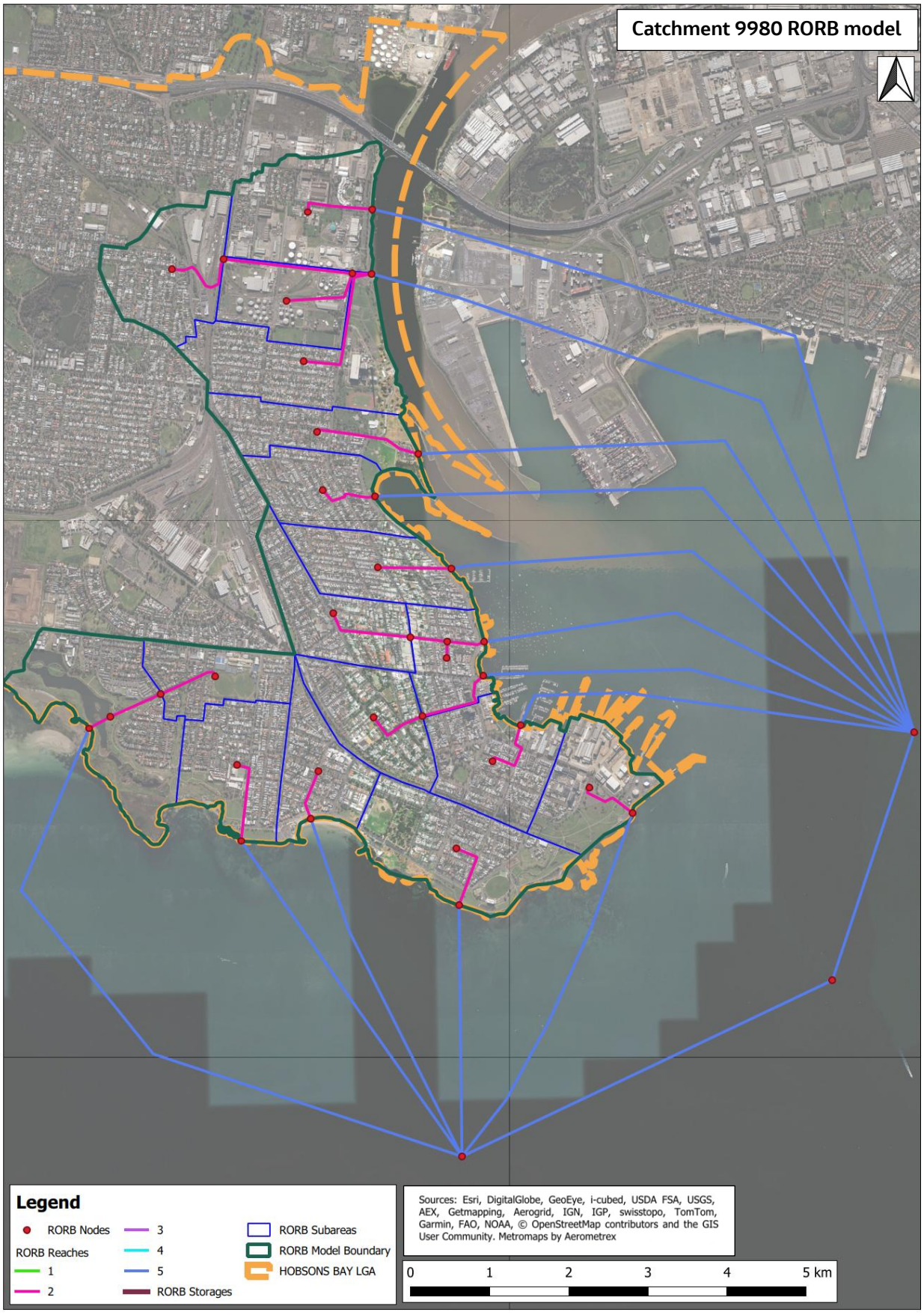


Figure G-1: Sub catchment 9880 RORB model setup.

G.2.3 Reaches

Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on LiDAR DEM, contours and pipe alignments and considered:

- Representation of the flow path from the centroid
- The alignment of reaches to flow
- Reach type:
  - Type 1 – Natural channels – these were not used in this model
  - Type 2 – Excavated but unlined – reach used across the catchments to represent flow in urban areas.
  - Type 3 – Lined channel or pipe – these were not used in the model
  - Type 4 – Drowned – these were not used in this model
  - Type 5 – Dummy – used to connect independent catchments (i.e. at Port Phillip Bay) to a single outlet node

G.2.4 Storages

No storages are present in the 9880 catchment RORB model.

G.2.5 Diversions

No diversions are present in the 9880 catchment RORB model.

G.2.6 Impervious fractions

Details on the methodology for determining RORB model impervious fractions can be found in Section 3.4. The adopted sub-catchment impervious fractions are documented in Appendix K.

G.2.7 Printout locations

Print statements were added at the outlet of the model, at gauge locations, upstream of LGA boundaries, key junctions and other areas of interest (i.e. retarding basins). This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

G.2.8 RORB version

RORB version 6.47 was used for modelling.

G.3 RORB design inputs

G.3.1 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for the catchment centroid (Lat -37.854, Long 144.892) was sourced from the Bureau of Meteorology. As per the Melbourne Water Flood Mapping Projects Specifications, rainfalls were increased by 18.5% to establish climate change rainfalls.

G.3.2 Losses

The rainfall loss model applied was the Initial Loss/Continuing Loss model. Given that this Study has derived storm losses for neighbouring catchments via model calibration to observed events (including Kororoit Creek, Stony Creek and Maribyrnong River), loss parameters have been transferred from the Kororoit Creek model to the 9880 catchment model. Specifically, the loss parameters derived for the Kororoit Creek at Brooklyn

gauge have been transferred and applied given that the upstream area at Brooklyn is largely urban and therefore most consistent with the land use of the 9880 catchment. The transfer of parameters from a neighbouring catchment's calibrated RORB model is supported by ARR 2019 (HARC, 2020) over the adoption of DataHub loss parameters as the transferred losses are likely to represent the runoff behaviour of a catchment in the same local geography more accurately. The adopted storm losses are listed in Table G-1.

Table G-1: 9880 RORB model storm losses

	IL (mm)	CL (mm/hr)
Transferred from Kororoit Creek (adopted)	13.5	2.5
DataHub	6.0	0.8

G.3.3 Pre-burst

The application of pre-burst depths is required as the storm losses provided on the Datahub site are based on complete storms whilst the IFD data is based on a burst depth. Based on data provided on the Datahub website (https://data.arr-software.org/vic_specific), the 9880 catchment is located in Loss region 2. ARR 2019 recommends for loss region 2 the median burst values should be adopted (HARC, 2020). The median pre-burst has been adopted by pre-pending the depths to the beginning of the storm.

For durations shorter than the 1 hour storm, the pre-burst ratios were assumed to be the same as the 1 hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used. This assessment has applied the pre-burst depths in RORB using the temporal patterns from Minty and Meighen (1999) and Jordan et al. (2005). The median percentile pre-burst percentages of rainfall depth are provided in Appendix J.

G.3.4 Temporal Patterns

Point temporal patterns were obtained from the ARR DataHub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies) and adopted given the catchment area is smaller than 75 km^2. Temporal patterns were filtered for embedded bursts using the option in RORB.

G.3.5 Spatial Patterns

The catchment area is less than 20km^2. As per the Melbourne Water Flood Mapping Projects Specifications and ARR 2019, a uniform spatial pattern was therefore adopted.

G.3.6 Areal Reduction Factor (ARF)

As catchment size increases, the change of average intensity of rainfall decreases. To address this an Areal Reduction Factor (ARF) is applied to the IFD data (design rainfalls). For catchments less than 1km^2 ARR 2019 recommends no reduction in the design rainfalls. For catchments between 1km^2 and 10km^2, ARR 2019 recommends the calculation of ARFs with the resultant ARF varying across duration and AEP. Adopted ARFs also vary across storm durations. The consideration of ARFs across a catchment has the potential to add a high level of complexity to an assessment. To consolidate this process, ARFs have been considered with respect to the critical storm durations analysis presented in Section G.5. The adopted ARF across the catchment is ARF area 1 km^2 given the small size of subareas.

G.4 RORB Verification and Input Parameters

To determine the appropriate routing parameter for the model, RORB was run in Monte Carlo mode for the Study area to establish peak flow estimates at the catchment outlets for the 1% AEP event. The Monte-Carlo technique as recommended by ARR (Ball et al., 2019) was used to calculate flood quantiles. This technique involves randomly sampling different flood forming variables to create flood frequency outputs whilst also

replicating natural processes. This technique inherently accounts for interactions between the various flood forming variables, providing a more realistic representation of the flood hydrograph generation processes.

The routing calculation in RORB uses two parameters, k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. The m parameter was set at the default value of 0.8 as per advice in the Melbourne Water's Flood Mapping Projects Specifications.

Peak flow estimates where k_c was varied for the 9880 catchment RORB model are provided in Table G-2. The proposed inputs are summarised in Table G-3. It is noted that whilst these routed flows will not be utilised in the hydraulic modelling phase of the Study, the validation checks were still completed. The Regional Flood Frequency Estimation (RFFE) was not performed given it is recommended for entirely rural catchments.

Table G-2: k_c estimates and peak flow values 9880 catchment RORB outlet

	Vic > 800mm rainfall	Pearse et al. 2002	Yarra & Maribyrnong (Melbourne Water)	Nikolaou/ von't Steen (urban)	Nikolaou/ von't Steen (rural)	Melbourne Water rule of thumb (urban)	Melbourne Water rule of thumb (rural)
k_c	1.89	0.76	3.8	-	-	-	-
Q_{100} flow at outlet (m^3/s)	85.1	135.4	56.9	36.7	18.3	60.0	18.0

Table G-3: Adopted k_c for the 9880 catchment RORB outlet

Adopted k_c	Comment
3.8 (Yarra & Maribyrnong (Melbourne Water))	Flows fall within range of Nikolaou/Von't Steen urban and Melbourne Water rule of thumb estimates.

G.5 Critical Duration and Temporal Pattern Analysis

The model's small catchment (6 km^2) and subarea size (< 1 km^2) requires the ARF adopted across the catchment to be based on an ARF area of 1 km^2. The durations and temporal patterns critical for an ARF based on an area of 1 km^2 for the Kororoit Creek catchment were adopted for the 9880 RORB model, given their close proximity and similar urban nature (loss and runoff behaviour therefore likely to be similar). Table G-4 lists the storms that were simulated in TUFLOW at the hydraulic modelling phase of this Study. The events identified as critical for the 1% AEP have been used for the 1% AEP with climate change RORB model runs.

Table G-4: Critical storm durations and selected temporal patterns for the 9880 catchment RORB model.

AEP	20min	30min	45min	1hour
1%	TP27	TP28	TP26	TP27
2%	TP27	TP28	TP26	TP27
5%	-	TP18	TP19	TP17
10%	-	TP19	TP19	-
20%	-	TP4	TP8	TP4

G.6 Hydraulic Modelling

For the hydraulic model build and outcomes for this catchment refer to the Stony Creek model build (Appendix C).

G.7 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.

Cardno (2018) Hobsons Bay Flood Modelling Report (V170209) prepared for Hobsons Bay City Council.

HARC (2020) Benchmarking ARR2019 for Victoria – Technical Report. Version 2. October 2020.

Jordan, P., Nathan, R., Mittiga, L., and Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events

Ladson (2008), Hydrology an Australian Introduction. Oxford University Press.

Minty and Meighen (1999) Rainfall antecedent to large and extreme rainfall bursts over Southeast Australia, HRS Report No.06.

Pearse, M., Jordan, P., & Collins, Y. (2002). A simple method for estimating RORB model parameters for ungauged rural catchments. *Water Challenge: Balancing the Risks: Hydrology and Water Resources Symposium 2002.*, pp. 128–134. Institution of Engineers, Australia: Barton, A.C.T

Rail Projects Victoria (2020) AJM JV Geelong Fast Rail – Skeleton Creek Hydrology Modelling.

The Bureau of Meteorology (2022a) Design Rainfall Data System

The Bureau of Meteorology (2022b) Average annual, seasonal and monthly rainfall

Appendix H. Site Visit Photos

The site visit photos have been removed from the report due to privacy considerations.

Appendix I. IFD Data

Appendix I. IFD Data

I.1 Maribyrnong River RORB model

Lat: 37.4375 (S) Long: 144.7375 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.4311	1.6293	2.2909	2.7761	3.2805	3.9953	4.5802
2 min	2	2.358	2.6673	3.7074	4.4786	5.288	6.4473	7.411
3 min	3	3.2107	3.6352	5.0624	6.119	7.225	8.8067	10.118
4 min	4	3.954	4.4847	6.2641	7.5767	8.9476	10.905	12.515
5 min	5	4.6019	5.2279	7.3213	8.8606	10.467	12.748	14.632
10 min	10	6.9156	7.885	11.116	13.473	15.924	19.386	22.207
15 min	15	8.4008	9.5843	13.526	16.405	19.396	23.608	27.045
20 min	20	9.4917	10.823	15.27	18.523	21.899	26.66	30.548
25 min	25	10.359	11.809	16.635	20.174	23.854	29.054	33.3
30 min	30	11.086	12.629	17.765	21.541	25.465	31.028	35.582
45 min	45	12.807	14.541	20.376	24.675	29.168	35.577	40.854
1 hour	60	14.144	16.026	22.362	27.063	31.988	39.038	44.88
1.5 hour	90	16.286	18.39	25.509	30.826	36.431	44.513	51.257
2 hour	120	18.056	20.343	28.104	33.922	40.085	49.014	56.489
3 hour	180	21.012	23.604	32.454	39.131	46.223	56.545	65.226
4.5 hour	270	24.643	27.629	37.867	45.61	53.853	65.87	75.979
6 hour	360	27.682	31.025	42.475	51.135	60.359	73.779	85.046
9 hour	540	32.661	36.63	50.186	60.409	71.26	86.93	100.01
12 hour	720	36.661	41.182	56.534	68.048	80.232	97.652	112.07
18 hour	1080	42.809	48.244	66.55	80.134	94.394	114.43	130.79
24 hour	1440	47.371	53.549	74.181	89.354	105.13	127.05	144.65
30 hour	1800	50.904	57.686	80.192	96.605	113.61	136.82	155.3
36 hour	2160	53.727	61.009	85.047	102.46	120.39	144.66	163.76
48 hour	2880	57.961	66	92.33	111.26	130.54	156.11	176.09
72 hour	4320	63.287	72.227	101.24	121.77	142.52	169.62	190.45
96 hour	5760	66.654	76.021	106.3	127.56	148.96	176.83	198.2
120 hour	7200	69.18	78.728	109.43	131.01	152.68	181.09	202.96
144 hour	8640	71.351	80.91	111.67	133.32	155	183.96	206.4
168 hour	10080	73.4	82.876	113.44	134.96	156.73	186.18	209.18

I.2 Kororoit Creek RORB model

Lat: 37.6875 (S) Long: 144.7125 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.3561	1.5537	2.2127	2.6971	3.2043	3.9212	4.5112
2 min	2	2.2327	2.542	3.5867	4.3545	5.1571	6.2971	7.2461
3 min	3	3.0349	3.4588	4.8855	5.9349	7.0282	8.5882	9.8853
4 min	4	3.7365	4.2639	6.0349	7.3363	8.6945	10.63	12.227
5 min	5	4.3476	4.9669	7.0459	8.5741	10.168	12.435	14.302
10 min	10	6.5316	7.4908	10.69	13.041	15.484	18.965	21.806
15 min	15	7.9349	9.1084	13.027	15.906	18.904	23.149	26.61
20 min	20	8.9671	10.294	14.727	17.986	21.371	26.178	30.104
25 min	25	9.7908	11.229	16.049	19.604	23.306	28.557	32.841
30 min	30	10.469	12.004	17.155	20.935	24.894	30.504	35.118
45 min	45	12.098	13.829	19.676	24	28.52	34.992	40.331
1 hour	60	13.347	15.224	21.571	26.298	31.265	38.378	44.298
1.5 hour	90	15.369	17.453	24.569	29.896	35.527	43.676	50.508
2 hour	120	17.004	19.261	26.992	32.812	38.988	47.998	55.573
3 hour	180	19.735	22.286	31.045	37.684	44.769	55.176	63.986
4.5 hour	270	23.055	25.978	36.029	43.702	51.937	64.049	74.32
6 hour	360	25.818	29.069	40.278	48.849	58.043	71.561	83.01
9 hour	540	30.302	34.149	47.371	57.482	68.318	84.094	97.376
12 hour	720	33.863	38.235	53.22	64.633	76.843	94.343	108.96
18 hour	1080	39.273	44.547	62.494	76.043	90.424	110.53	127.04
24 hour	1440	43.216	49.239	69.604	84.816	100.91	122.63	140.41
30 hour	1800	46.227	52.861	75.214	91.778	109.2	132.12	150.59
36 hour	2160	48.586	55.747	79.743	97.424	115.86	139.71	158.61
48 hour	2880	52.049	59.992	86.51	105.85	125.86	150.82	170.2
72 hour	4320	56.21	65.102	94.533	115.76	137.61	163.53	183.22
96 hour	5760	58.684	68.004	98.649	120.8	143.43	169.76	189.67
120 hour	7200	60.488	69.906	100.81	123.12	146.2	172.78	192.8
144 hour	8640	61.982	71.331	101.96	124.16	147.37	174.29	194.59
168 hour	10080	63.398	72.545	102.43	124.47	147.61	174.88	195.73

I.3 Stony Creek RORB model

Lat: 37.7875 (S) Long: 144.8375 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.46	1.66	2.35	2.87	3.41	4.19	4.85
2 min	2	2.46	2.79	3.91	4.75	5.65	6.98	8.09
3 min	3	3.32	3.77	5.29	6.42	7.64	9.42	10.9
4 min	4	4.06	4.61	6.48	7.88	9.37	11.5	13.3
5 min	5	4.7	5.34	7.53	9.16	10.9	13.4	15.5
10 min	10	6.98	7.97	11.3	13.8	16.4	20.1	23.2
15 min	15	8.49	9.7	13.8	16.8	20	24.6	28.4
20 min	20	9.63	11	15.6	19.1	22.7	27.9	32.3
25 min	25	10.5	12	17.1	20.9	24.9	30.6	35.4
30 min	30	11.3	12.9	18.3	22.4	26.6	32.8	37.9
45 min	45	13.1	14.9	21.1	25.8	30.7	37.9	44
1 hour	60	14.5	16.5	23.2	28.3	33.8	41.8	48.5
1.5 hour	90	16.7	18.9	26.5	32.2	38.4	47.6	55.4
2 hour	120	18.4	20.8	29	35.3	42.1	52.2	60.8
3 hour	180	21.2	23.9	33.1	40.2	47.9	59.4	69.3
4.5 hour	270	24.4	27.4	37.9	46	54.8	67.9	79.2
6 hour	360	27	30.3	41.9	50.9	60.5	74.9	87.1
9 hour	540	31.1	35	48.4	58.7	69.8	86	99.8
12 hour	720	34.2	38.6	53.6	65.1	77.3	95	110
18 hour	1080	38.9	44.1	61.8	75.1	89.2	109	125
24 hour	1440	42.3	48.2	68.1	82.8	98.3	119	137
30 hour	1800	44.9	51.4	73.1	89	106	128	146
36 hour	2160	47	54	77.1	94	112	135	153
48 hour	2880	50.2	57.8	83.3	102	121	145	164
72 hour	4320	54.2	62.7	90.9	111	132	157	177
96 hour	5760	56.8	65.6	94.9	116	138	164	183
120 hour	7200	58.7	67.5	96.9	119	142	167	187
144 hour	8640	60.2	68.9	97.7	120	143	169	188
168 hour	10080	61.6	70	97.8	120	144	169	188

I.4 Cherry Creek RORB model

Lat: 37.8375 (S) Long: 144.8125 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.47	1.67	2.35	2.85	3.39	4.16	4.8
2 min	2	2.5	2.82	3.95	4.78	5.68	6.98	8.07
3 min	3	3.36	3.8	5.32	6.44	7.65	9.4	10.9
4 min	4	4.1	4.64	6.5	7.88	9.35	11.5	13.2
5 min	5	4.73	5.36	7.52	9.13	10.8	13.3	15.3
10 min	10	7	7.97	11.2	13.7	16.2	19.9	22.9
15 min	15	8.51	9.7	13.7	16.7	19.8	24.3	28
20 min	20	9.65	11	15.5	18.9	22.5	27.6	31.9
25 min	25	10.6	12	17	20.7	24.6	30.3	35
30 min	30	11.4	12.9	18.2	22.2	26.4	32.5	37.5
45 min	45	13.2	15	21.1	25.7	30.6	37.6	43.6
1 hour	60	14.6	16.6	23.2	28.3	33.6	41.5	48.1
1.5 hour	90	16.9	19	26.5	32.2	38.3	47.3	54.9
2 hour	120	18.6	21	29.1	35.3	41.9	51.8	60.1
3 hour	180	21.4	24	33.1	40.1	47.6	58.8	68.4
4.5 hour	270	24.5	27.5	37.8	45.7	54.2	66.9	77.7
6 hour	360	27	30.3	41.6	50.3	59.6	73.4	85.2
9 hour	540	30.8	34.6	47.6	57.6	68.3	83.9	97.1
12 hour	720	33.7	38	52.5	63.5	75.2	92.2	106
18 hour	1080	37.9	43	60	72.7	86.2	105	121
24 hour	1440	40.9	46.6	65.6	79.8	94.7	115	131
30 hour	1800	43.2	49.4	70.2	85.5	101	123	140
36 hour	2160	45.1	51.7	73.8	90.1	107	129	147
48 hour	2880	47.8	55	79.4	97.2	116	139	157
72 hour	4320	51.4	59.4	86.4	106	127	151	170
96 hour	5760	53.7	62.1	90.1	111	133	158	176
120 hour	7200	55.6	64	92.1	113	136	161	180
144 hour	8640	57.2	65.4	93.1	115	138	162	181
168 hour	10080	58.8	66.7	93.3	115	138	162	181

I.5 Laverton Creek RORB model

Lat: 37.8375 (S) Long: 144.7625 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.42	1.62	2.3	2.82	3.36	4.15	4.81
2 min	2	2.42	2.74	3.87	4.72	5.63	6.91	8.02
3 min	3	3.26	3.7	5.22	6.37	7.59	9.32	10.8
4 min	4	3.97	4.51	6.38	7.78	9.27	11.4	13.2
5 min	5	4.58	5.21	7.38	9.02	10.7	13.2	15.3
10 min	10	6.76	7.73	11	13.5	16.1	19.9	23
15 min	15	8.21	9.4	13.4	16.5	19.7	24.3	28.1
20 min	20	9.3	10.6	15.2	18.7	22.3	27.6	32
25 min	25	10.2	11.7	16.7	20.4	24.4	30.2	35
30 min	30	11	12.5	17.9	21.9	26.2	32.4	37.6
45 min	45	12.8	14.5	20.7	25.3	30.2	37.4	43.4
1 hour	60	14.1	16.1	22.8	27.9	33.3	41.1	47.8
1.5 hour	90	16.3	18.5	26	31.7	37.8	46.8	54.4
2 hour	120	18.1	20.4	28.5	34.7	41.4	51.2	59.6
3 hour	180	20.8	23.4	32.5	39.5	47	58.1	67.6
4.5 hour	270	23.9	26.9	37.1	45	53.5	66.1	76.9
6 hour	360	26.4	29.6	40.9	49.5	58.8	72.6	84.3
9 hour	540	30.1	33.9	46.8	56.7	67.3	82.9	96
12 hour	720	32.9	37.1	51.5	62.4	74.1	91.1	105
18 hour	1080	37	41.9	58.7	71.4	84.9	104	119
24 hour	1440	39.8	45.3	64.1	78.2	93.2	113	130
30 hour	1800	41.9	47.9	68.4	83.7	99.8	121	138
36 hour	2160	43.5	50	71.8	88.1	105	127	144
48 hour	2880	46	53	77	94.9	114	136	154
72 hour	4320	49.1	56.9	83.4	103	124	148	166
96 hour	5760	51.3	59.3	86.9	108	130	154	172
120 hour	7200	53.1	61.2	88.9	110	133	157	175
144 hour	8640	54.7	62.7	90	111	134	158	176
168 hour	10080	56.4	64.1	90.5	111	134	159	176

I.6 Skeleton Creek RORB model

Lat: 37.8125 (S) Long: 144.6875 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.34	1.54	2.21	2.71	3.24	4	4.64
2 min	2	2.26	2.58	3.66	4.48	5.32	6.53	7.53
3 min	3	3.05	3.48	4.96	6.06	7.21	8.86	10.2
4 min	4	3.73	4.27	6.08	7.43	8.86	10.9	12.6
5 min	5	4.32	4.94	7.06	8.64	10.3	12.7	14.7
10 min	10	6.42	7.37	10.6	13	15.6	19.2	22.3
15 min	15	7.79	8.95	12.9	15.9	19	23.5	27.3
20 min	20	8.81	10.1	14.6	18	21.5	26.6	30.9
25 min	25	9.64	11.1	16	19.6	23.5	29.1	33.8
30 min	30	10.3	11.9	17.1	21	25.2	31.2	36.1
45 min	45	12	13.8	19.7	24.2	28.9	35.8	41.5
1 hour	60	13.3	15.2	21.7	26.6	31.7	39.2	45.5
1.5 hour	90	15.3	17.5	24.7	30.2	36	44.5	51.6
2 hour	120	17	19.3	27.1	33	39.4	48.6	56.4
3 hour	180	19.6	22.2	30.9	37.6	44.7	55.2	64.1
4.5 hour	270	22.8	25.6	35.5	43	51.1	63	73.2
6 hour	360	25.2	28.4	39.2	47.5	56.4	69.5	80.6
9 hour	540	29.1	32.8	45.3	54.8	65.1	80	92.7
12 hour	720	32.1	36.2	50.1	60.7	72.1	88.5	102
18 hour	1080	36.4	41.2	57.6	70.1	83.3	102	117
24 hour	1440	39.4	44.8	63.3	77.2	92	112	128
30 hour	1800	41.7	47.6	67.8	82.9	98.9	120	137
36 hour	2160	43.4	49.8	71.4	87.5	105	126	143
48 hour	2880	46	53	76.8	94.6	113	136	153
72 hour	4320	49.1	56.9	83.4	103	124	147	165
96 hour	5760	51.2	59.3	87	108	129	153	171
120 hour	7200	52.9	61.1	89	110	132	156	174
144 hour	8640	54.4	62.6	90.1	111	133	157	176
168 hour	10080	56	63.9	90.6	111	133	158	176

I.7 Catchment 9880 RORB model

Lat: 37.8625 (S) Long: 144.8875 (E)

Duration	Duration in min	63.2%	50%	20%	10%	5%	2%	1%
1 min	1	1.54	1.73	2.4	2.9	3.43	4.19	4.83
2 min	2	2.64	2.95	4.02	4.82	5.69	6.87	7.89
3 min	3	3.54	3.97	5.42	6.5	7.68	9.29	10.7
4 min	4	4.3	4.83	6.62	7.96	9.4	11.4	13.1
5 min	5	4.96	5.58	7.67	9.24	10.9	13.3	15.3
10 min	10	7.34	8.28	11.5	13.9	16.5	20.2	23.3
15 min	15	8.93	10.1	14	17	20.1	24.7	28.5
20 min	20	10.1	11.4	15.9	19.3	22.9	28.1	32.4
25 min	25	11.1	12.6	17.4	21.1	25	30.7	35.5
30 min	30	12	13.5	18.7	22.6	26.8	32.9	38
45 min	45	13.9	15.7	21.6	26.1	30.9	37.9	43.7
1 hour	60	15.4	17.3	23.8	28.7	33.9	41.5	47.9
1.5 hour	90	17.8	19.9	27.1	32.6	38.4	46.9	54.1
2 hour	120	19.6	21.8	29.6	35.6	41.9	51.1	58.9
3 hour	180	22.4	25	33.7	40.3	47.4	57.6	66.4
4.5 hour	270	25.6	28.5	38.3	45.8	53.7	65.3	75.1
6 hour	360	28.2	31.4	42.2	50.3	58.9	71.6	82.2
9 hour	540	32.1	35.8	48.3	57.7	67.4	81.9	93.8
12 hour	720	35.1	39.3	53.3	63.7	74.4	90.3	103
18 hour	1080	39.6	44.7	61.3	73.3	85.7	104	118
24 hour	1440	43	48.7	67.4	80.8	94.6	114	130
30 hour	1800	45.6	51.8	72.4	87	102	123	139
36 hour	2160	47.7	54.4	76.5	92	108	130	147
48 hour	2880	50.9	58.4	82.9	100	118	141	159
72 hour	4320	55.3	63.6	91	110	130	155	174
96 hour	5760	58.1	66.8	95.4	116	137	163	182
120 hour	7200	60.2	68.9	97.7	119	140	167	186
144 hour	8640	61.8	70.4	98.7	120	142	169	188
168 hour	10080	63.2	71.4	98.7	121	142	169	189

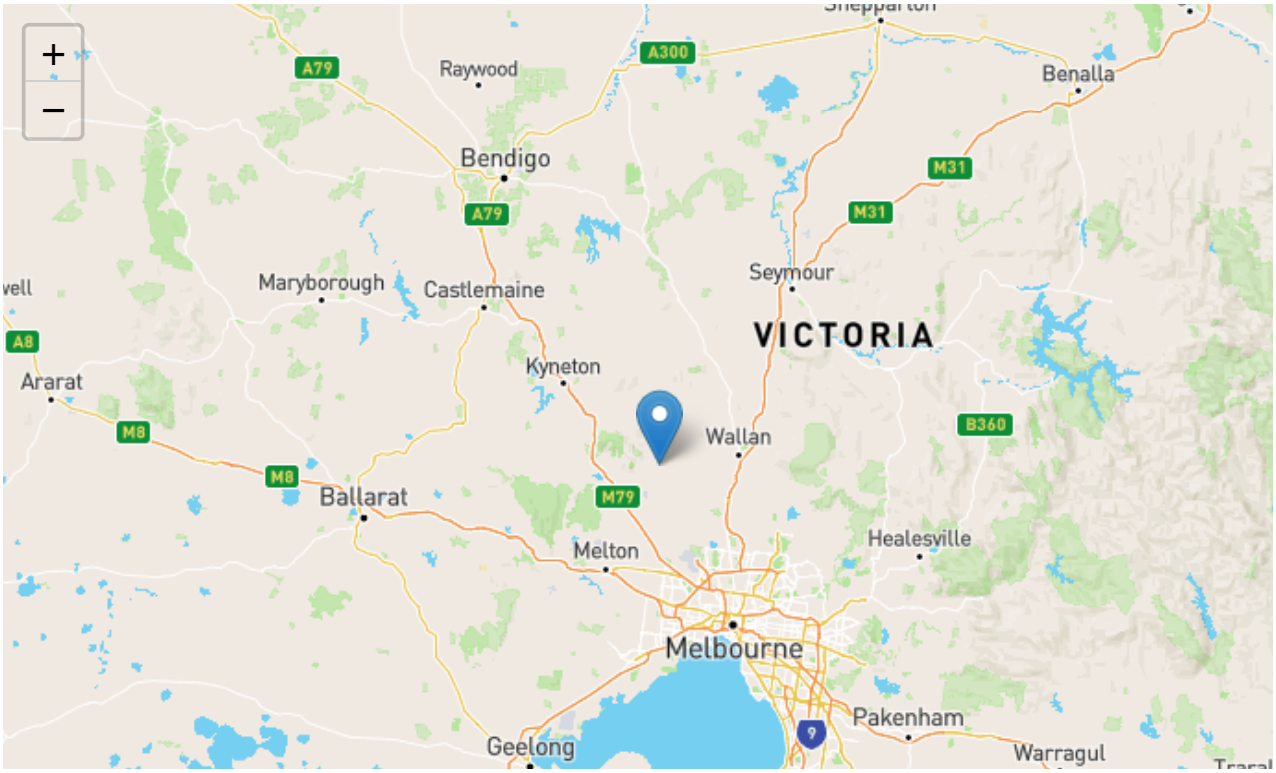
Appendix J. Data Hub

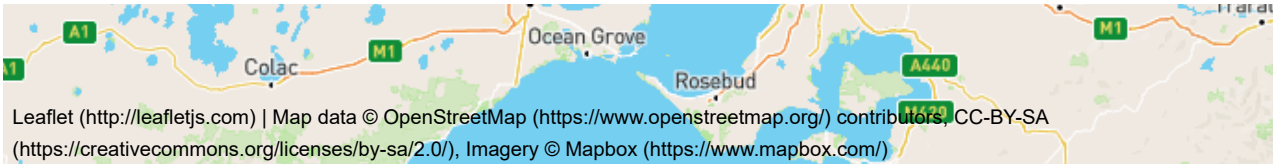
Australian Rainfall & Runoff Data Hub - Results

Maribyrnong River

Input Data

Longitude	144.738
Latitude	-37.441
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	28583.0
Storm Initial Losses (mm)	25.0
Storm Continuing Losses (mm/h)	2.7

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.441&longitude=144.738&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	29 September 2022 12:08PM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.5 (0.094)	1.3 (0.060)	1.2 (0.046)	1.1 (0.036)	1.3 (0.033)	1.4 (0.032)
90 (1.5)	3.6 (0.200)	2.5 (0.100)	1.8 (0.059)	1.1 (0.030)	1.2 (0.027)	1.3 (0.025)
120 (2.0)	2.7 (0.135)	2.1 (0.074)	1.6 (0.049)	1.2 (0.031)	1.2 (0.025)	1.2 (0.021)
180 (3.0)	1.5 (0.063)	2.0 (0.062)	2.3 (0.060)	2.7 (0.058)	5.2 (0.092)	7.0 (0.108)
360 (6.0)	0.7 (0.021)	1.2 (0.029)	1.6 (0.031)	2.0 (0.032)	5.5 (0.074)	8.1 (0.095)
720 (12.0)	0.2 (0.005)	1.8 (0.032)	2.8 (0.042)	3.8 (0.048)	6.9 (0.071)	9.3 (0.082)
1080 (18.0)	0.0 (0.000)	0.8 (0.011)	1.3 (0.016)	1.7 (0.018)	3.1 (0.027)	4.2 (0.032)
1440 (24.0)	0.0 (0.000)	0.4 (0.006)	0.7 (0.008)	0.9 (0.009)	2.9 (0.023)	4.4 (0.030)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.6 (0.004)	1.1 (0.007)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.002)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	7.9 (0.500)	8.7 (0.395)	9.2 (0.346)	9.8 (0.310)	11.1 (0.290)	12.2 (0.275)
90 (1.5)	11.3 (0.624)	12.3 (0.488)	12.9 (0.425)	13.6 (0.376)	13.4 (0.305)	13.3 (0.263)
120 (2.0)	12.3 (0.613)	12.3 (0.444)	12.4 (0.368)	12.4 (0.312)	14.4 (0.296)	15.9 (0.283)
180 (3.0)	10.8 (0.461)	13.5 (0.418)	15.3 (0.392)	17.0 (0.369)	19.7 (0.348)	21.7 (0.332)
360 (6.0)	9.9 (0.323)	13.6 (0.322)	16.1 (0.314)	18.4 (0.304)	22.8 (0.307)	26.1 (0.304)
720 (12.0)	4.8 (0.119)	9.7 (0.172)	12.9 (0.190)	16.0 (0.199)	23.5 (0.239)	29.1 (0.257)
1080 (18.0)	5.1 (0.106)	8.8 (0.133)	11.3 (0.141)	13.7 (0.145)	17.1 (0.149)	19.7 (0.150)
1440 (24.0)	1.9 (0.037)	5.5 (0.074)	7.8 (0.088)	10.0 (0.096)	14.8 (0.117)	18.3 (0.127)
2160 (36.0)	0.0 (0.000)	2.2 (0.026)	3.7 (0.036)	5.1 (0.042)	10.3 (0.072)	14.2 (0.088)
2880 (48.0)	0.0 (0.000)	0.6 (0.006)	0.9 (0.008)	1.3 (0.010)	3.7 (0.024)	5.6 (0.032)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.7 (1.565)	27.3 (1.241)	29.1 (1.091)	30.8 (0.976)	26.2 (0.681)	22.7 (0.515)
90 (1.5)	22.5 (1.240)	30.3 (1.201)	35.4 (1.162)	40.4 (1.119)	33.2 (0.754)	27.9 (0.550)
120 (2.0)	27.8 (1.384)	26.8 (0.964)	26.2 (0.779)	25.6 (0.643)	41.2 (0.846)	53.0 (0.942)
180 (3.0)	22.7 (0.975)	28.5 (0.885)	32.3 (0.830)	36.0 (0.781)	42.7 (0.756)	47.8 (0.732)
360 (6.0)	29.0 (0.942)	31.7 (0.750)	33.6 (0.657)	35.4 (0.584)	45.6 (0.614)	53.3 (0.621)
720 (12.0)	20.7 (0.507)	27.2 (0.482)	31.5 (0.462)	35.6 (0.442)	52.5 (0.534)	65.1 (0.576)
1080 (18.0)	16.1 (0.338)	20.3 (0.307)	23.1 (0.289)	25.7 (0.273)	33.2 (0.289)	38.7 (0.295)
1440 (24.0)	14.6 (0.277)	19.2 (0.261)	22.2 (0.250)	25.1 (0.240)	31.2 (0.246)	35.8 (0.248)
2160 (36.0)	4.3 (0.071)	12.5 (0.149)	18.0 (0.178)	23.2 (0.195)	31.1 (0.217)	37.0 (0.228)
2880 (48.0)	2.4 (0.037)	7.6 (0.084)	11.1 (0.101)	14.4 (0.112)	23.5 (0.153)	30.3 (0.175)
4320 (72.0)	0.9 (0.013)	9.9 (0.100)	15.8 (0.133)	21.5 (0.155)	21.6 (0.131)	21.7 (0.117)

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	11203
Area (km2)	1422.01152
Catchment Number	11132
Volume Factor	0.127588
Peak Factor	0.021693

Layer Info

Time Accessed	29 September 2022 12:08PM
Version	2016_v1

Download TXT (downloads/69132361-78f7-43d2-8cda-4cd428bac3d5.txt)

Download JSON (downloads/1cc6022d-b83d-44e7-8d76-a0c879a88000.json)

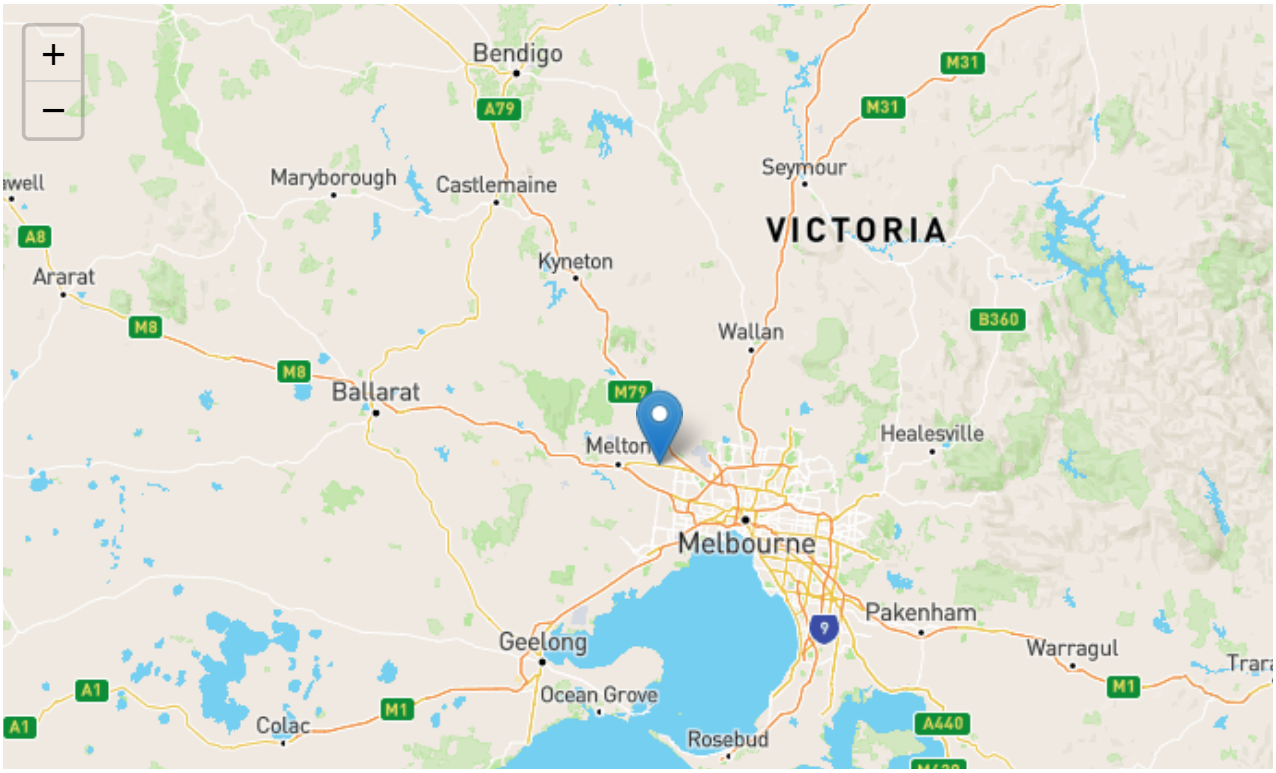
Generating PDF... (downloads/46a9c6d5-a631-4ae2-ac83-b31d440e8aee.pdf)

Australian Rainfall & Runoff Data Hub - Results

Kororoit Creek

Input Data

Longitude	144.703
Latitude	-37.688
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	7
River Name	Werribee River

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	3553.0
Storm Initial Losses (mm)	11.0
Storm Continuing Losses (mm/h)	0.3

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.688&longitude=144.703&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	29 September 2022 11:57AM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.4 (0.095)	1.3 (0.060)	1.2 (0.045)	1.1 (0.035)	1.2 (0.031)	1.2 (0.028)
90 (1.5)	3.4 (0.196)	2.5 (0.101)	1.9 (0.063)	1.3 (0.036)	1.5 (0.034)	1.6 (0.032)
120 (2.0)	2.4 (0.126)	2.1 (0.080)	2.0 (0.060)	1.8 (0.046)	1.4 (0.030)	1.2 (0.021)
180 (3.0)	1.2 (0.053)	1.8 (0.059)	2.3 (0.060)	2.7 (0.059)	4.6 (0.084)	6.1 (0.095)
360 (6.0)	0.9 (0.030)	1.9 (0.046)	2.5 (0.051)	3.1 (0.054)	5.7 (0.080)	7.7 (0.092)
720 (12.0)	0.1 (0.003)	1.5 (0.027)	2.3 (0.036)	3.2 (0.042)	6.3 (0.066)	8.5 (0.078)
1080 (18.0)	0.0 (0.000)	0.9 (0.015)	1.5 (0.020)	2.1 (0.024)	3.1 (0.028)	3.8 (0.030)
1440 (24.0)	0.0 (0.000)	0.3 (0.004)	0.5 (0.006)	0.7 (0.007)	2.8 (0.023)	4.4 (0.031)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.7 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.002)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	7.5 (0.494)	8.5 (0.394)	9.2 (0.349)	9.8 (0.314)	9.9 (0.258)	10.0 (0.224)
90 (1.5)	11.3 (0.653)	12.2 (0.499)	12.8 (0.430)	13.4 (0.378)	13.7 (0.313)	13.9 (0.275)
120 (2.0)	12.4 (0.646)	13.5 (0.502)	14.3 (0.435)	15.0 (0.384)	15.6 (0.323)	16.0 (0.286)
180 (3.0)	6.4 (0.289)	10.1 (0.326)	12.6 (0.333)	14.9 (0.333)	18.7 (0.338)	21.6 (0.335)
360 (6.0)	9.0 (0.314)	13.1 (0.326)	15.8 (0.323)	18.3 (0.315)	20.7 (0.288)	22.4 (0.268)
720 (12.0)	3.9 (0.103)	8.4 (0.158)	11.4 (0.176)	14.2 (0.184)	22.1 (0.233)	28.0 (0.255)
1080 (18.0)	2.0 (0.045)	6.6 (0.106)	9.6 (0.126)	12.5 (0.138)	19.3 (0.174)	24.5 (0.192)
1440 (24.0)	0.9 (0.018)	3.9 (0.056)	5.9 (0.070)	7.8 (0.078)	12.7 (0.103)	16.4 (0.116)
2160 (36.0)	0.2 (0.004)	1.1 (0.013)	1.6 (0.016)	2.1 (0.018)	7.5 (0.054)	11.6 (0.073)
2880 (48.0)	0.0 (0.000)	0.5 (0.006)	0.9 (0.008)	1.2 (0.010)	3.5 (0.023)	5.3 (0.031)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.002)	0.7 (0.004)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.1 (1.332)	24.2 (1.128)	27.0 (1.027)	29.6 (0.947)	25.3 (0.659)	22.1 (0.498)
90 (1.5)	27.7 (1.603)	33.2 (1.357)	36.9 (1.234)	40.4 (1.135)	34.1 (0.778)	29.4 (0.579)
120 (2.0)	20.9 (1.092)	25.4 (0.946)	28.5 (0.868)	31.4 (0.804)	43.8 (0.910)	53.1 (0.952)
180 (3.0)	14.1 (0.636)	20.4 (0.659)	24.6 (0.653)	28.6 (0.638)	39.4 (0.712)	47.5 (0.738)
360 (6.0)	16.5 (0.571)	21.6 (0.537)	25.0 (0.511)	28.2 (0.485)	41.9 (0.582)	52.1 (0.623)
720 (12.0)	19.1 (0.505)	24.6 (0.464)	28.2 (0.437)	31.7 (0.412)	48.2 (0.508)	60.6 (0.552)
1080 (18.0)	17.6 (0.399)	20.8 (0.334)	22.9 (0.302)	24.9 (0.275)	32.5 (0.293)	38.2 (0.299)
1440 (24.0)	12.7 (0.262)	16.3 (0.236)	18.7 (0.220)	20.9 (0.207)	28.8 (0.234)	34.6 (0.246)
2160 (36.0)	10.1 (0.183)	12.2 (0.154)	13.6 (0.140)	14.9 (0.128)	26.2 (0.187)	34.7 (0.218)
2880 (48.0)	7.8 (0.132)	9.5 (0.110)	10.6 (0.100)	11.6 (0.092)	21.5 (0.142)	28.9 (0.169)
4320 (72.0)	1.1 (0.016)	9.8 (0.104)	15.5 (0.135)	21.1 (0.153)	20.7 (0.126)	20.3 (0.111)

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	588.676288
Catchment Number	11166
Volume Factor	0.124986
Peak Factor	0.041299

Layer Info

Time Accessed	29 September 2022 11:57AM
Version	2016_v1

Download TXT (downloads/e7de5642-f56d-4cb1-a276-ea5f19a12ba2.txt)

Download JSON (downloads/cfd455e2-9540-430c-8548-811e49f383f7.json)

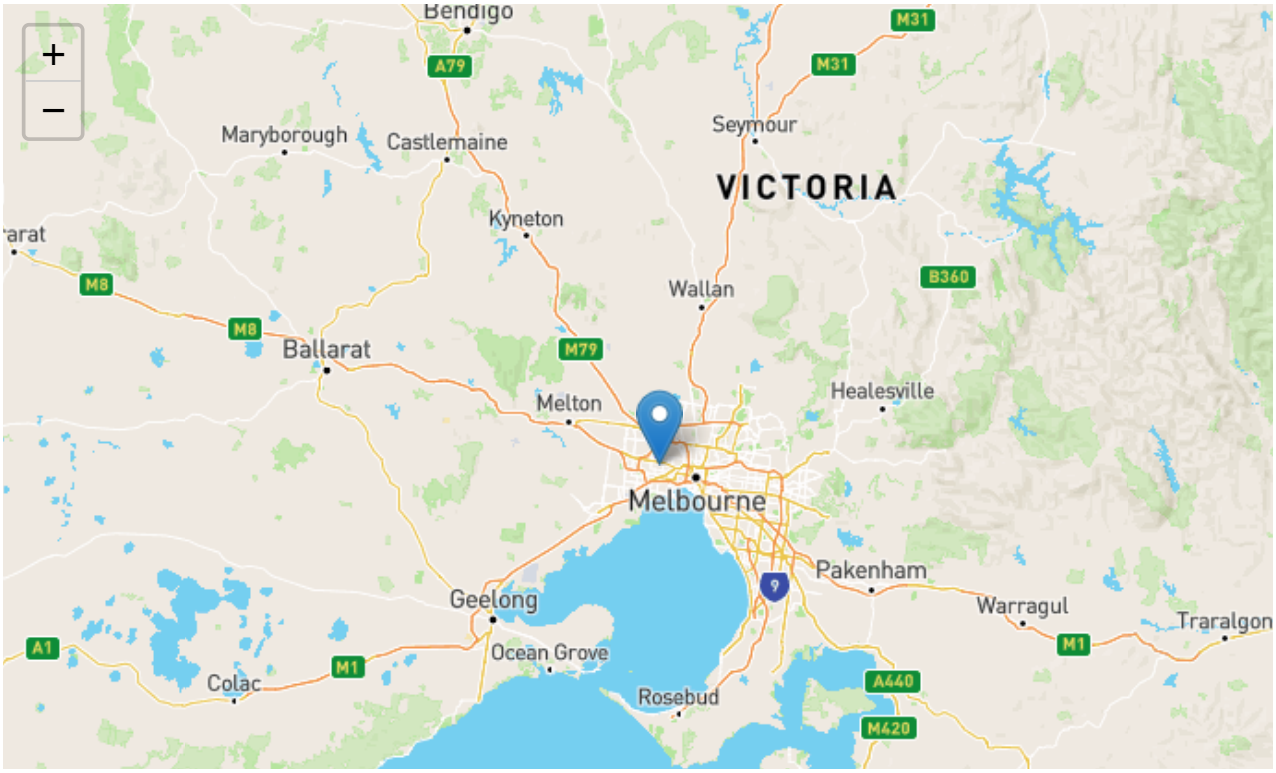
Generating PDF... (downloads/3fd87f65-3750-4b8d-b5e8-af33d37bd0fc.pdf)

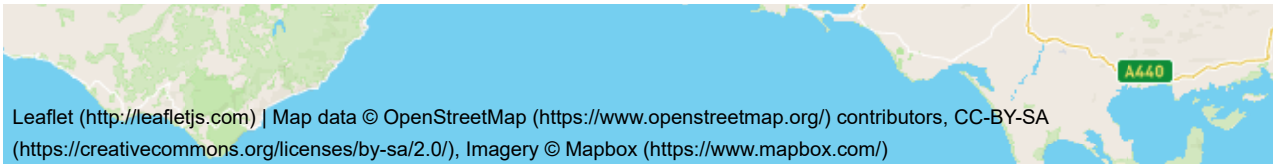
Australian Rainfall & Runoff Data Hub - Results

Stony Creek

Input Data

Longitude	144.848
Latitude	-37.787
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	31379.0
Storm Initial Losses (mm)	8.0
Storm Continuing Losses (mm/h)	1.1

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.787&longitude=144.848&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	29 September 2022 11:48AM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	4.1 (0.249)	3.2 (0.138)	2.6 (0.093)	2.1 (0.061)	1.4 (0.033)	0.9 (0.018)
90 (1.5)	1.5 (0.081)	1.9 (0.073)	2.2 (0.068)	2.4 (0.063)	1.5 (0.032)	0.9 (0.016)
120 (2.0)	4.0 (0.194)	3.5 (0.120)	3.1 (0.089)	2.8 (0.066)	1.9 (0.036)	1.2 (0.019)
180 (3.0)	2.4 (0.103)	2.6 (0.078)	2.7 (0.067)	2.8 (0.058)	5.8 (0.097)	8.0 (0.116)
360 (6.0)	0.8 (0.026)	1.4 (0.034)	1.8 (0.036)	2.2 (0.037)	5.9 (0.078)	8.6 (0.098)
720 (12.0)	0.3 (0.007)	1.5 (0.029)	2.4 (0.037)	3.2 (0.041)	6.3 (0.066)	8.6 (0.078)
1080 (18.0)	0.0 (0.000)	0.7 (0.011)	1.1 (0.015)	1.5 (0.017)	2.8 (0.025)	3.7 (0.029)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.004)	0.5 (0.005)	1.8 (0.015)	2.7 (0.020)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.1 (0.731)	13.2 (0.570)	14.0 (0.495)	14.8 (0.437)	11.7 (0.281)	9.4 (0.195)
90 (1.5)	8.1 (0.428)	11.0 (0.416)	13.0 (0.402)	14.8 (0.385)	15.1 (0.317)	15.3 (0.276)
120 (2.0)	13.8 (0.665)	15.3 (0.527)	16.2 (0.460)	17.1 (0.407)	17.7 (0.340)	18.2 (0.299)
180 (3.0)	12.7 (0.533)	13.2 (0.399)	13.5 (0.337)	13.9 (0.289)	18.6 (0.312)	22.1 (0.319)
360 (6.0)	10.2 (0.336)	13.3 (0.317)	15.3 (0.302)	17.3 (0.286)	23.6 (0.315)	28.3 (0.325)
720 (12.0)	7.9 (0.205)	10.7 (0.199)	12.5 (0.192)	14.2 (0.184)	22.1 (0.233)	28.0 (0.255)
1080 (18.0)	2.6 (0.058)	6.5 (0.105)	9.0 (0.120)	11.5 (0.129)	17.3 (0.159)	21.7 (0.173)
1440 (24.0)	1.2 (0.025)	3.6 (0.052)	5.1 (0.062)	6.6 (0.067)	11.0 (0.092)	14.2 (0.104)
2160 (36.0)	0.0 (0.001)	1.2 (0.016)	2.0 (0.022)	2.8 (0.025)	7.1 (0.053)	10.3 (0.067)
2880 (48.0)	0.0 (0.000)	0.5 (0.006)	0.9 (0.008)	1.2 (0.010)	2.4 (0.017)	3.4 (0.021)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.5 (0.003)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.8 (1.502)	28.4 (1.224)	30.9 (1.089)	33.2 (0.982)	29.3 (0.701)	26.3 (0.543)
90 (1.5)	20.1 (1.065)	22.5 (0.850)	24.0 (0.746)	25.6 (0.665)	28.9 (0.608)	31.5 (0.569)
120 (2.0)	24.4 (1.171)	28.9 (0.995)	31.9 (0.903)	34.7 (0.825)	39.7 (0.761)	43.5 (0.715)
180 (3.0)	23.4 (0.980)	26.6 (0.804)	28.8 (0.715)	30.8 (0.643)	43.1 (0.726)	52.4 (0.756)
360 (6.0)	26.7 (0.878)	32.8 (0.784)	36.9 (0.727)	40.9 (0.675)	50.2 (0.671)	57.2 (0.657)
720 (12.0)	22.8 (0.592)	26.7 (0.498)	29.3 (0.450)	31.7 (0.410)	48.3 (0.508)	60.7 (0.552)
1080 (18.0)	17.4 (0.394)	20.1 (0.325)	21.9 (0.292)	23.6 (0.265)	31.0 (0.285)	36.6 (0.292)
1440 (24.0)	10.3 (0.213)	17.0 (0.250)	21.4 (0.259)	25.7 (0.261)	29.6 (0.248)	32.5 (0.238)
2160 (36.0)	9.1 (0.168)	11.5 (0.149)	13.0 (0.139)	14.5 (0.130)	25.2 (0.187)	33.1 (0.217)
2880 (48.0)	7.8 (0.135)	8.8 (0.106)	9.5 (0.093)	10.1 (0.084)	15.1 (0.104)	18.9 (0.115)
4320 (72.0)	0.5 (0.007)	1.9 (0.020)	2.8 (0.025)	3.7 (0.028)	7.3 (0.047)	10.1 (0.057)

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	7640.514124
Catchment Number	11203
Volume Factor	0.237764
Peak Factor	0.049393

Layer Info

Time Accessed	29 September 2022 11:48AM
Version	2016_v1

Download TXT (downloads/97b913a1-46d2-4746-8f5e-3fc694e7c498.txt)

Download JSON (downloads/30beb90c-dc4b-43b5-b154-6edac1014b3e.json)

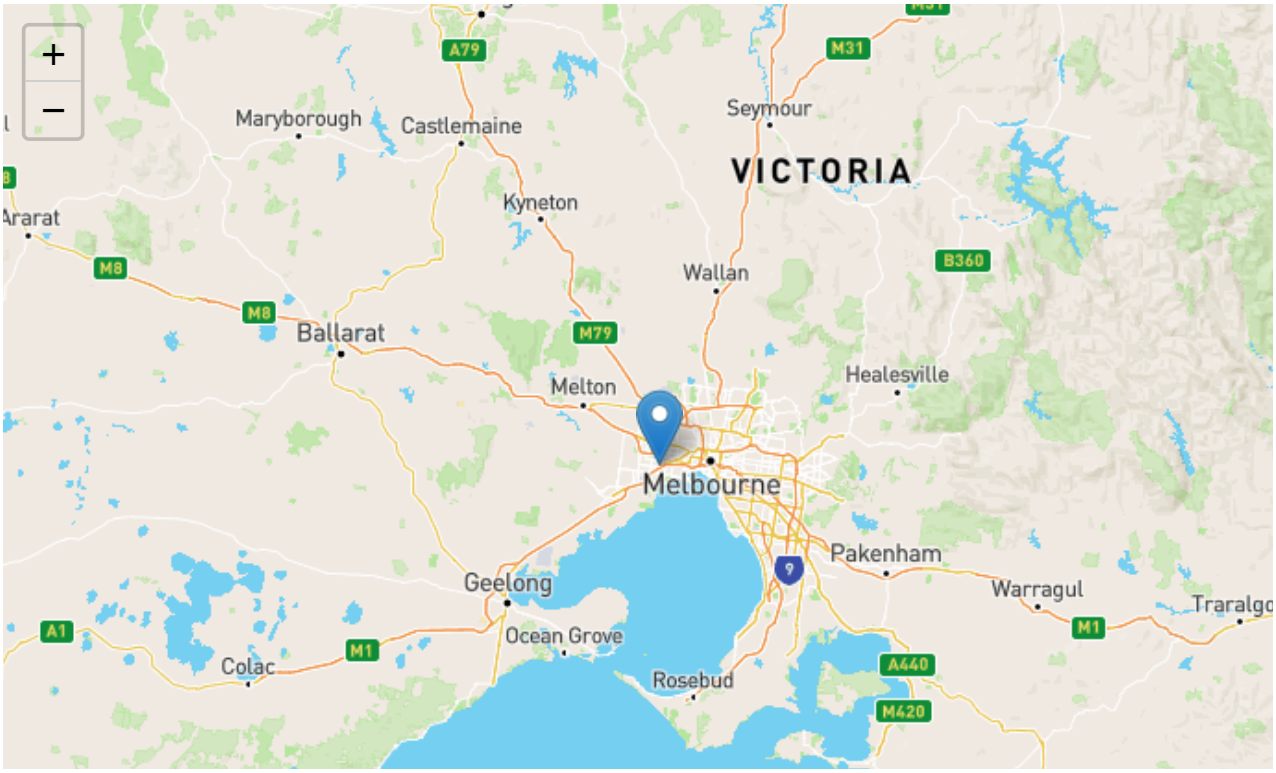
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Australian Rainfall & Runoff Data Hub - Results

Cherry Creek

Input Data

Longitude	144.804
Latitude	-37.827
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	7
River Name	Werribee River

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	15218.0
Storm Initial Losses (mm)	5.0
Storm Continuing Losses (mm/h)	0.6

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.827&longitude=144.804&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	29 September 2022 11:18AM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	4.1 (0.248)	3.2 (0.138)	2.6 (0.093)	2.1 (0.061)	1.4 (0.033)	0.9 (0.018)
90 (1.5)	1.5 (0.080)	1.9 (0.073)	2.2 (0.068)	2.4 (0.063)	1.5 (0.033)	0.9 (0.016)
120 (2.0)	4.0 (0.193)	3.5 (0.120)	3.1 (0.089)	2.8 (0.066)	1.9 (0.036)	1.2 (0.019)
180 (3.0)	2.4 (0.102)	2.6 (0.078)	2.7 (0.067)	2.8 (0.058)	5.8 (0.098)	8.0 (0.117)
360 (6.0)	0.8 (0.027)	1.4 (0.034)	1.8 (0.037)	2.2 (0.037)	5.9 (0.080)	8.6 (0.100)
720 (12.0)	0.3 (0.007)	1.5 (0.029)	2.4 (0.038)	3.2 (0.043)	6.3 (0.068)	8.6 (0.080)
1080 (18.0)	0.0 (0.000)	0.7 (0.011)	1.1 (0.015)	1.5 (0.018)	2.8 (0.026)	3.7 (0.031)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.005)	0.5 (0.005)	1.8 (0.015)	2.7 (0.021)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.1 (0.727)	13.2 (0.569)	14.0 (0.496)	14.8 (0.438)	11.7 (0.282)	9.4 (0.196)
90 (1.5)	8.1 (0.425)	11.0 (0.416)	13.0 (0.402)	14.8 (0.387)	15.1 (0.319)	15.3 (0.278)
120 (2.0)	13.8 (0.660)	15.3 (0.526)	16.2 (0.460)	17.1 (0.409)	17.7 (0.343)	18.2 (0.303)
180 (3.0)	12.7 (0.530)	13.2 (0.399)	13.5 (0.338)	13.9 (0.291)	18.6 (0.316)	22.1 (0.323)
360 (6.0)	10.2 (0.337)	13.3 (0.320)	15.3 (0.305)	17.3 (0.290)	23.6 (0.321)	28.3 (0.332)
720 (12.0)	7.9 (0.209)	10.7 (0.203)	12.5 (0.196)	14.2 (0.189)	22.1 (0.240)	28.0 (0.264)
1080 (18.0)	2.6 (0.059)	6.5 (0.108)	9.0 (0.124)	11.5 (0.134)	17.3 (0.165)	21.7 (0.180)
1440 (24.0)	1.2 (0.026)	3.6 (0.054)	5.1 (0.064)	6.6 (0.070)	11.0 (0.096)	14.2 (0.108)
2160 (36.0)	0.0 (0.001)	1.2 (0.017)	2.0 (0.023)	2.8 (0.026)	7.1 (0.055)	10.3 (0.070)
2880 (48.0)	0.0 (0.000)	0.5 (0.007)	0.9 (0.009)	1.2 (0.010)	2.4 (0.018)	3.4 (0.022)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.5 (0.003)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.8 (1.494)	28.4 (1.223)	30.9 (1.091)	33.2 (0.986)	29.3 (0.706)	26.3 (0.548)
90 (1.5)	20.1 (1.057)	22.5 (0.848)	24.0 (0.747)	25.6 (0.667)	28.9 (0.612)	31.5 (0.574)
120 (2.0)	24.4 (1.163)	28.9 (0.993)	31.9 (0.903)	34.7 (0.828)	39.7 (0.767)	43.5 (0.723)
180 (3.0)	23.4 (0.975)	26.6 (0.804)	28.8 (0.717)	30.8 (0.647)	43.1 (0.733)	52.4 (0.766)
360 (6.0)	26.7 (0.880)	32.8 (0.790)	36.9 (0.735)	40.9 (0.686)	50.2 (0.684)	57.2 (0.671)
720 (12.0)	22.8 (0.602)	26.7 (0.509)	29.3 (0.461)	31.7 (0.421)	48.3 (0.524)	60.7 (0.570)
1080 (18.0)	17.4 (0.405)	20.1 (0.335)	21.9 (0.301)	23.6 (0.274)	31.0 (0.296)	36.6 (0.303)
1440 (24.0)	10.3 (0.221)	17.0 (0.259)	21.4 (0.268)	25.7 (0.271)	29.6 (0.257)	32.5 (0.247)
2160 (36.0)	9.1 (0.176)	11.5 (0.155)	13.0 (0.145)	14.5 (0.136)	25.2 (0.195)	33.1 (0.226)
2880 (48.0)	7.8 (0.141)	8.8 (0.111)	9.5 (0.097)	10.1 (0.087)	15.1 (0.109)	18.9 (0.120)
4320 (72.0)	0.5 (0.008)	1.9 (0.021)	2.8 (0.026)	3.7 (0.029)	7.3 (0.049)	10.1 (0.059)

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	588.676288
Catchment Number	11166
Volume Factor	0.124986
Peak Factor	0.041299

Layer Info

Time Accessed	29 September 2022 11:18AM
Version	2016_v1

Download TXT (downloads/73ce93d4-5b94-42d9-81e7-dcfb33f562e0.txt)

Download JSON (downloads/b6201667-b472-4eee-b9d1-1507f086f255.json)

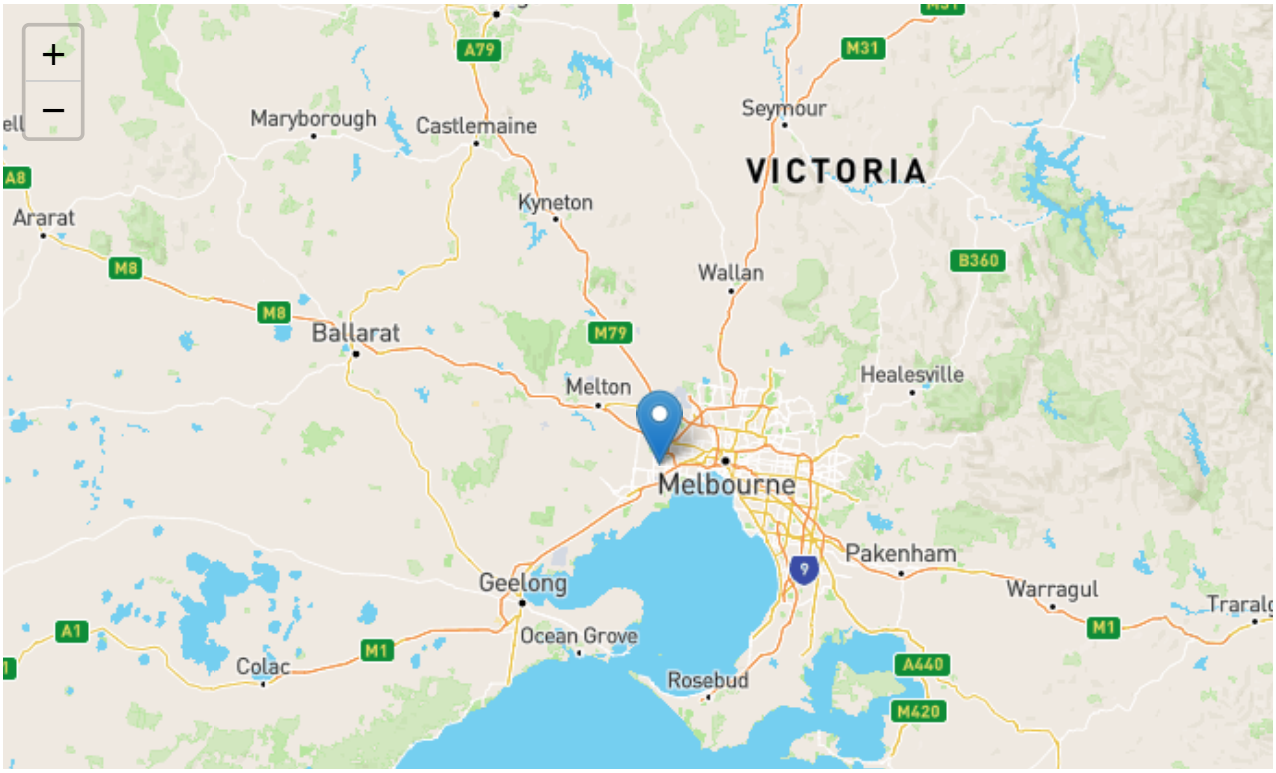
Generating PDF... (downloads/a99e01da-66a7-458c-8cd1-5173500989d1.pdf)

Australian Rainfall & Runoff Data Hub - Results

Laverton Kayes

Input Data

Longitude	144.763
Latitude	-37.826
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	7
River Name	Werribee River

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	15218.0
Storm Initial Losses (mm)	5.0
Storm Continuing Losses (mm/h)	0.6

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.826&longitude=144.763&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	27 September 2022 11:57AM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	4.1 (0.255)	3.2 (0.141)	2.6 (0.094)	2.1 (0.062)	1.4 (0.033)	0.9 (0.018)
90 (1.5)	1.5 (0.083)	1.9 (0.074)	2.2 (0.069)	2.4 (0.064)	1.5 (0.033)	0.9 (0.016)
120 (2.0)	4.0 (0.198)	3.5 (0.122)	3.1 (0.090)	2.8 (0.067)	1.9 (0.036)	1.2 (0.020)
180 (3.0)	2.4 (0.104)	2.6 (0.080)	2.7 (0.068)	2.8 (0.059)	5.8 (0.099)	8.0 (0.119)
360 (6.0)	0.8 (0.027)	1.4 (0.035)	1.8 (0.037)	2.2 (0.038)	5.9 (0.081)	8.6 (0.102)
720 (12.0)	0.3 (0.007)	1.5 (0.030)	2.4 (0.038)	3.2 (0.043)	6.3 (0.069)	8.6 (0.081)
1080 (18.0)	0.0 (0.000)	0.7 (0.011)	1.1 (0.016)	1.5 (0.018)	2.8 (0.027)	3.7 (0.031)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.005)	0.5 (0.006)	1.8 (0.016)	2.7 (0.021)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.1 (0.750)	13.2 (0.581)	14.0 (0.503)	14.8 (0.443)	11.7 (0.285)	9.4 (0.197)
90 (1.5)	8.1 (0.438)	11.0 (0.424)	13.0 (0.408)	14.8 (0.391)	15.1 (0.322)	15.3 (0.280)
120 (2.0)	13.8 (0.678)	15.3 (0.536)	16.2 (0.467)	17.1 (0.414)	17.7 (0.347)	18.2 (0.305)
180 (3.0)	12.7 (0.543)	13.2 (0.406)	13.5 (0.343)	13.9 (0.295)	18.6 (0.320)	22.1 (0.327)
360 (6.0)	10.2 (0.344)	13.3 (0.325)	15.3 (0.310)	17.3 (0.294)	23.6 (0.325)	28.3 (0.336)
720 (12.0)	7.9 (0.213)	10.7 (0.207)	12.5 (0.200)	14.2 (0.192)	22.1 (0.243)	28.0 (0.267)
1080 (18.0)	2.6 (0.061)	6.5 (0.110)	9.0 (0.127)	11.5 (0.136)	17.3 (0.167)	21.7 (0.182)
1440 (24.0)	1.2 (0.027)	3.6 (0.056)	5.1 (0.066)	6.6 (0.071)	11.0 (0.097)	14.2 (0.110)
2160 (36.0)	0.0 (0.001)	1.2 (0.017)	2.0 (0.023)	2.8 (0.027)	7.1 (0.056)	10.3 (0.071)
2880 (48.0)	0.0 (0.000)	0.5 (0.007)	0.9 (0.009)	1.2 (0.010)	2.4 (0.018)	3.4 (0.022)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.5 (0.003)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	24.8 (1.539)	28.4 (1.248)	30.9 (1.108)	33.2 (0.997)	29.3 (0.712)	26.3 (0.551)
90 (1.5)	20.1 (1.088)	22.5 (0.865)	24.0 (0.758)	25.6 (0.675)	28.9 (0.619)	31.5 (0.578)
120 (2.0)	24.4 (1.194)	28.9 (1.012)	31.9 (0.917)	34.7 (0.838)	39.7 (0.776)	43.5 (0.730)
180 (3.0)	23.4 (0.999)	26.6 (0.819)	28.8 (0.728)	30.8 (0.655)	43.1 (0.742)	52.4 (0.775)
360 (6.0)	26.7 (0.900)	32.8 (0.804)	36.9 (0.747)	40.9 (0.696)	50.2 (0.692)	57.2 (0.679)
720 (12.0)	22.8 (0.615)	26.7 (0.519)	29.3 (0.469)	31.7 (0.428)	48.3 (0.530)	60.7 (0.577)
1080 (18.0)	17.4 (0.415)	20.1 (0.343)	21.9 (0.307)	23.6 (0.278)	31.0 (0.299)	36.6 (0.307)
1440 (24.0)	10.3 (0.227)	17.0 (0.265)	21.4 (0.274)	25.7 (0.276)	29.6 (0.261)	32.5 (0.250)
2160 (36.0)	9.1 (0.182)	11.5 (0.160)	13.0 (0.148)	14.5 (0.138)	25.2 (0.198)	33.1 (0.229)
2880 (48.0)	7.8 (0.147)	8.8 (0.114)	9.5 (0.100)	10.1 (0.089)	15.1 (0.111)	18.9 (0.123)
4320 (72.0)	0.5 (0.008)	1.9 (0.022)	2.8 (0.027)	3.7 (0.030)	7.3 (0.050)	10.1 (0.061)

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	588.676288
Catchment Number	11166
Volume Factor	0.124986
Peak Factor	0.041299

Layer Info

Time Accessed	27 September 2022 11:57AM
Version	2016_v1

Download TXT (downloads/987f758f-54fb-42be-9577-49dd1478bbec.txt)

Download JSON (downloads/6fcac165-dc4d-40f9-9cd1-e204437e00af.json)

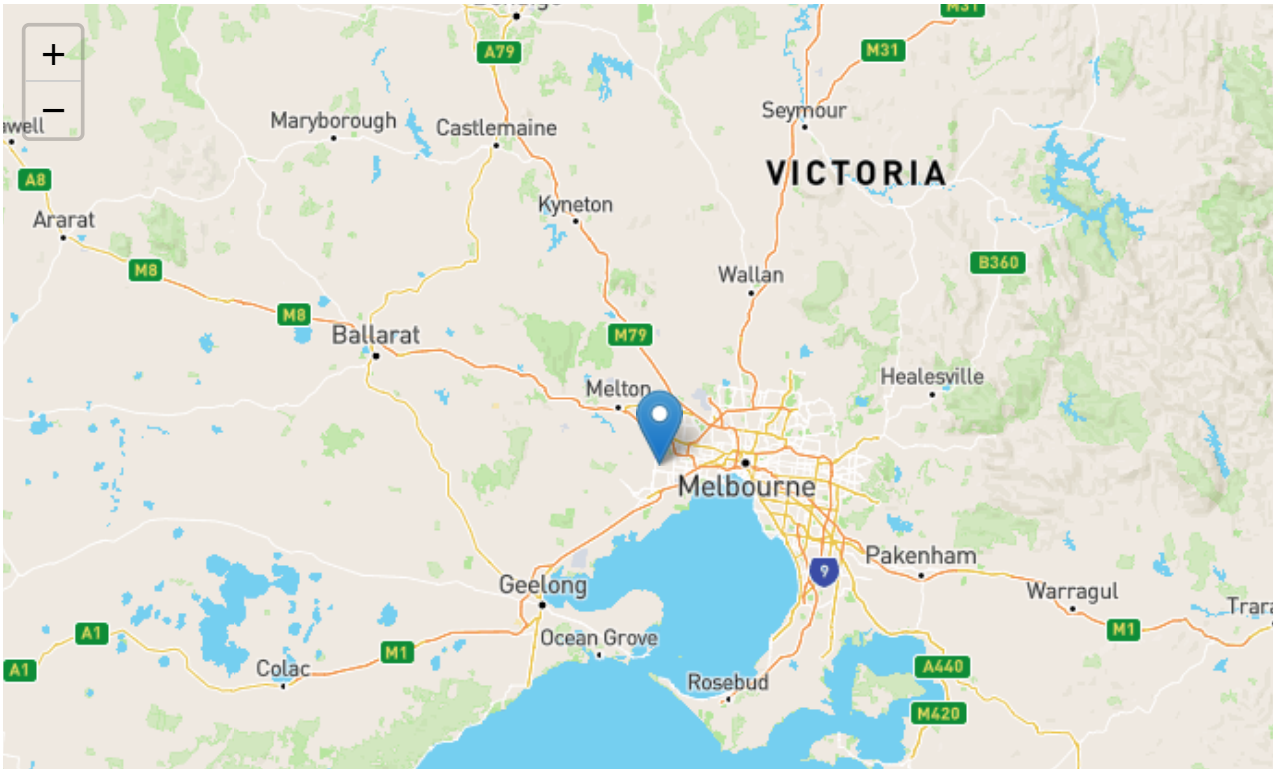
Generating PDF... (downloads/5d1aec42-e3ac-4d8e-a4f1-172f06544406.pdf)

Australian Rainfall & Runoff Data Hub - Results

Skeleton Creek

Input Data

Longitude	144.699
Latitude	-37.824
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show





Data

River Region

Division	South East Coast (Victoria)
River Number	7
River Name	Werribee River

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

ID	23925.0
Storm Initial Losses (mm)	5.0
Storm Continuing Losses (mm/h)	0.6

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.824&longitude=144.699&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	29 September 2022 10:50AM

Median Preburst Depths and Ratios

Note: As this point is in Victoria the advice provided on losses and pre-burst in the VIC specific tab of the ARR Data Hub should be considered.

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.7 (0.113)	1.6 (0.075)	1.6 (0.059)	1.5 (0.048)	1.3 (0.034)	1.2 (0.026)
90 (1.5)	3.6 (0.207)	2.9 (0.118)	2.5 (0.082)	2.0 (0.056)	1.6 (0.036)	1.3 (0.025)
120 (2.0)	2.6 (0.135)	2.0 (0.074)	1.6 (0.049)	1.2 (0.032)	1.9 (0.039)	2.4 (0.042)
180 (3.0)	0.6 (0.025)	1.3 (0.043)	1.8 (0.049)	2.3 (0.052)	5.5 (0.100)	7.9 (0.123)
360 (6.0)	1.0 (0.036)	1.7 (0.043)	2.1 (0.044)	2.5 (0.045)	5.4 (0.078)	7.6 (0.095)
720 (12.0)	0.0 (0.000)	0.7 (0.013)	1.1 (0.018)	1.6 (0.022)	4.8 (0.054)	7.2 (0.071)
1080 (18.0)	0.0 (0.000)	0.3 (0.006)	0.5 (0.008)	0.7 (0.009)	2.3 (0.023)	3.5 (0.030)
1440 (24.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)	0.2 (0.002)	1.0 (0.009)	1.5 (0.012)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.1 (0.004)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.002)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	8.0 (0.528)	10.7 (0.492)	12.4 (0.467)	14.1 (0.444)	12.0 (0.305)	10.4 (0.228)
90 (1.5)	12.7 (0.728)	14.1 (0.570)	15.0 (0.496)	15.8 (0.440)	15.1 (0.338)	14.5 (0.280)
120 (2.0)	11.2 (0.580)	12.9 (0.477)	14.1 (0.426)	15.2 (0.386)	16.3 (0.336)	17.2 (0.305)
180 (3.0)	7.4 (0.331)	10.3 (0.334)	12.3 (0.328)	14.2 (0.318)	19.5 (0.353)	23.4 (0.365)
360 (6.0)	9.9 (0.349)	12.7 (0.323)	14.5 (0.305)	16.2 (0.288)	19.7 (0.283)	22.3 (0.276)
720 (12.0)	3.2 (0.087)	8.0 (0.160)	11.3 (0.185)	14.3 (0.199)	19.3 (0.218)	23.0 (0.225)
1080 (18.0)	2.8 (0.068)	6.0 (0.104)	8.1 (0.116)	10.1 (0.121)	16.4 (0.161)	21.1 (0.180)
1440 (24.0)	2.2 (0.050)	3.5 (0.055)	4.3 (0.055)	5.1 (0.055)	9.6 (0.086)	12.9 (0.101)
2160 (36.0)	0.0 (0.000)	1.2 (0.016)	1.9 (0.022)	2.7 (0.025)	5.0 (0.039)	6.7 (0.047)
2880 (48.0)	0.0 (0.000)	0.4 (0.005)	0.6 (0.006)	0.8 (0.007)	1.6 (0.012)	2.1 (0.014)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	27.6 (1.818)	31.3 (1.442)	33.7 (1.267)	36.0 (1.133)	29.2 (0.744)	24.1 (0.529)
90 (1.5)	30.7 (1.758)	31.0 (1.254)	31.2 (1.033)	31.4 (0.871)	29.3 (0.660)	27.8 (0.539)
120 (2.0)	25.4 (1.317)	26.4 (0.974)	27.1 (0.819)	27.7 (0.704)	36.9 (0.760)	43.8 (0.777)
180 (3.0)	13.8 (0.620)	21.6 (0.698)	26.8 (0.713)	31.8 (0.710)	41.8 (0.757)	49.3 (0.769)
360 (6.0)	18.2 (0.643)	22.7 (0.579)	25.6 (0.540)	28.5 (0.505)	41.8 (0.601)	51.8 (0.642)
720 (12.0)	18.9 (0.524)	23.4 (0.466)	26.3 (0.433)	29.1 (0.403)	36.3 (0.410)	41.7 (0.407)
1080 (18.0)	14.5 (0.351)	17.6 (0.306)	19.7 (0.281)	21.7 (0.261)	28.7 (0.282)	33.9 (0.290)
1440 (24.0)	14.2 (0.316)	19.1 (0.302)	22.4 (0.290)	25.6 (0.278)	29.1 (0.260)	31.7 (0.247)
2160 (36.0)	14.1 (0.284)	14.7 (0.206)	15.0 (0.172)	15.4 (0.147)	25.1 (0.199)	32.5 (0.227)
2880 (48.0)	0.5 (0.009)	3.3 (0.043)	5.2 (0.055)	6.9 (0.061)	13.4 (0.098)	18.2 (0.118)
4320 (72.0)	0.4 (0.007)	2.1 (0.025)	3.3 (0.032)	4.4 (0.035)	5.4 (0.036)	6.1 (0.037)

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	588.676288
Catchment Number	11166
Volume Factor	0.124986
Peak Factor	0.041299

Layer Info

Time Accessed	29 September 2022 10:50AM
Version	2016_v1

Download TXT (downloads/af5aa08f-c43f-4d2e-9318-a77cd3b7711f.txt)

Download JSON (downloads/f6ad4a4a-46a3-46c5-a521-aa9bfbbb0858.json)

Generating PDF... (downloads/20054f09-e56f-4eb5-a7bc-0eb18b25f51f.pdf)

Australian Rainfall & Runoff Data Hub - Results

9880 Catchment

Input Data

Longitude	144.892
Latitude	-37.854
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
Interim Climate Change Factors	show
Baseflow Factors	show

Region Information

Reading data from shape 1 of 1 in FM_YAR_001_Catchment_Boundary_WGS84.shp

Data Category	Region
River Region	Werribee River
ARF Parameters	Southern Temperate
Temporal Patterns	Southern Slopes (Vic/NSW)

Data

River Region

division	South East Coast (Victoria)
rivregnum	7
River Region	Werribee River
per_intersect	0.6943

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v1

ARF Parameters

Long Duration ARF

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - \mathrm{c}\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i	per_intersect
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027	0.9313

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \mathrm{x}\ 10^{-3}\ \mathrm{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \mathrm{x}\ Area^{0.213}\ \mathrm{x}\ 10^{-0.021\frac{(Duration-180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR USE** in urban areas

Storm Initial Losses (mm)	6.0
Storm Continuing Losses (mm/h)	0.8

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v1

Temporal Patterns | Download (.zip) (./temporal_patterns/tp/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)
per_intersect	1.0

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./temporal_patterns/areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)
per_intersect	1.0

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v2

BOM IFD Depths

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.8537388231&longitude=144.891550842&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

No data	No data found at this location!

Layer Info

Time Accessed	24 November 2022 01:32PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.0 (0.113)	2.9 (0.121)	2.5 (0.086)	2.1 (0.061)	1.5 (0.037)	1.1 (0.024)
90 (1.5)	3.5 (0.175)	3.2 (0.117)	3.0 (0.093)	2.9 (0.076)	2.1 (0.045)	1.5 (0.028)
120 (2.0)	3.3 (0.152)	3.3 (0.111)	2.8 (0.080)	2.4 (0.057)	1.7 (0.034)	1.2 (0.020)
180 (3.0)	2.6 (0.104)	2.9 (0.086)	2.8 (0.070)	2.7 (0.058)	4.2 (0.073)	5.3 (0.080)
360 (6.0)	1.2 (0.038)	1.6 (0.039)	1.9 (0.039)	2.2 (0.038)	4.8 (0.067)	6.0 (0.072)
720 (12.0)	0.3 (0.008)	1.4 (0.026)	2.1 (0.032)	2.7 (0.037)	4.1 (0.045)	5.6 (0.054)
1080 (18.0)	0.0 (0.000)	0.6 (0.009)	0.9 (0.013)	1.3 (0.015)	1.6 (0.015)	2.2 (0.018)
1440 (24.0)	0.0 (0.000)	0.3 (0.004)	0.4 (0.005)	0.6 (0.006)	0.6 (0.005)	0.6 (0.005)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2018_v1

Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.1 (0.007)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.1 (0.004)	0.1 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.002)	0.2 (0.003)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	8.6 (0.496)	12.8 (0.539)	13.9 (0.485)	15.0 (0.441)	11.7 (0.280)	9.2 (0.191)
90 (1.5)	10.9 (0.552)	12.2 (0.450)	13.2 (0.406)	14.2 (0.369)	14.1 (0.299)	14.0 (0.257)
120 (2.0)	14.1 (0.646)	14.9 (0.505)	15.0 (0.422)	15.0 (0.358)	14.8 (0.289)	14.6 (0.247)
180 (3.0)	13.1 (0.525)	12.8 (0.381)	13.6 (0.339)	14.4 (0.304)	19.0 (0.329)	22.5 (0.337)
360 (6.0)	8.9 (0.284)	12.1 (0.287)	14.2 (0.282)	16.3 (0.275)	20.7 (0.288)	22.6 (0.273)
720 (12.0)	5.8 (0.149)	9.6 (0.179)	12.0 (0.188)	14.4 (0.192)	18.5 (0.204)	21.4 (0.206)
1080 (18.0)	2.0 (0.045)	5.7 (0.094)	8.2 (0.112)	10.6 (0.123)	14.6 (0.140)	17.3 (0.145)
1440 (24.0)	2.6 (0.054)	4.3 (0.064)	5.5 (0.067)	6.5 (0.069)	10.2 (0.089)	11.9 (0.091)
2160 (36.0)	0.8 (0.016)	1.7 (0.022)	2.3 (0.024)	2.8 (0.026)	4.9 (0.037)	5.3 (0.036)
2880 (48.0)	0.0 (0.000)	0.4 (0.004)	0.6 (0.006)	0.9 (0.007)	2.2 (0.016)	3.2 (0.020)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

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Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.1 (0.931)	26.9 (1.133)	29.3 (1.021)	31.5 (0.928)	28.2 (0.677)	25.6 (0.534)
90 (1.5)	21.2 (1.071)	24.8 (0.916)	25.5 (0.784)	26.2 (0.682)	27.1 (0.577)	27.8 (0.512)
120 (2.0)	25.0 (1.151)	30.8 (1.042)	32.0 (0.900)	33.0 (0.788)	45.0 (0.878)	53.9 (0.912)
180 (3.0)	23.6 (0.952)	32.7 (0.973)	33.4 (0.829)	34.0 (0.717)	41.5 (0.717)	47.1 (0.706)
360 (6.0)	24.6 (0.786)	29.1 (0.690)	32.0 (0.636)	34.9 (0.591)	45.2 (0.628)	53.5 (0.647)
720 (12.0)	20.7 (0.527)	26.1 (0.489)	29.7 (0.464)	33.1 (0.443)	35.0 (0.386)	39.4 (0.380)
1080 (18.0)	16.8 (0.376)	19.0 (0.310)	20.5 (0.279)	22.0 (0.255)	26.8 (0.257)	30.8 (0.259)
1440 (24.0)	12.7 (0.260)	18.4 (0.273)	22.2 (0.274)	25.9 (0.272)	28.5 (0.248)	27.3 (0.209)
2160 (36.0)	14.0 (0.257)	14.7 (0.192)	15.1 (0.164)	15.6 (0.144)	25.0 (0.192)	32.3 (0.219)
2880 (48.0)	5.4 (0.092)	7.0 (0.085)	8.1 (0.081)	9.2 (0.078)	14.5 (0.103)	18.5 (0.116)
4320 (72.0)	2.0 (0.032)	2.2 (0.024)	2.3 (0.021)	2.4 (0.018)	16.2 (0.105)	24.9 (0.143)

Layer Info

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Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.719 (3.6%)**	0.739 (3.7%)	**0.822 (4.1%)**
2040	**0.925 (4.6%)**	0.915 (4.6%)	**1.119 (5.6%)**
2050	**1.123 (5.6%)**	1.085 (5.4%)	**1.449 (7.2%)**
2060	**1.271 (6.4%)**	1.294 (6.5%)	**1.865 (9.3%)**
2070	**1.394 (7.0%)**	1.526 (7.6%)	**2.333 (11.7%)**
2080	**1.477 (7.4%)**	1.778 (8.9%)	**2.776 (13.9%)**
2090	**1.527 (7.6%)**	2.009 (10.0%)	**3.21 (16.1%)**

Layer Info

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Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

Baseflow Factors

downstream	0
area_sqkm	588.676288
catch_no	11166
Volume Factor	0.124986
Peak Factor	0.041299
per_intersect	0.6439

Layer Info

Time Accessed	24 November 2022 01:32PM
Version	2016_v1

Download TXT (downloads/1669257125.txt) Generating PDF... (downloads/1669257125.pdf)

Appendix K. Adopted Impervious Fractions

Appendix K. Adopted Impervious Fractions

K.1 Maribyrnong River RORB Model

Node Name	Adopted Fraction Impervious (EIA)	Node Name	Adopted Fraction Impervious (EIA)
A	0.084	AT	0.04
F	0.041	AQ	0.04
G	0.039	AR	0.04
H	0.041	AS	0.04
B	0.036	AU	0.04
C	0.039	AV	0.04
D	0.024	AW	0.04
E	0.037	AX	0.04
I	0.041	AY	0.04
J	0.125	BA	0.041
K	0.108	AZ	0.04
M	0.087	BB	0.04
N	0.448	L	0.258
O	0.245	AK	0.04
P	0.555	AL	0.159
Q	0.103	AP	0.043
R	0.042	DN	0.04
V	0.189	DO	0.079
W	0.105	DP	0.148
X	0.04	DQ	0.065
Y	0.043	DR	0.051
Z	0.043	DS	0.04
AA	0.074	DT	0.04
AB	0.235	DU	0.021
S	0.042	DV	0.02
T	0.041	DVa	0.033
U	0.142	DXa	0.028
AC	0.234	DY	0.21
AD	0.04	EA	0.101
AE	0.041	ED	0.137
AF	0.04	EI	0.123
AG	0.04	EK	0.066
AH	0.04	EP	0.442
AI	0.04	EN	0.782
AJ	0.041	EJ	0.502
AM	0.458	EF	0.903
AO	0.242	EH	0.544
AN	0.309	EQ	0.043

Node Name	Adopted Fraction Impervious (EIA)	Node Name	Adopted Fraction Impervious (EIA)
EV	0.042	DW	0.036
EU	0.04	DX	0.049
ES	0.297	ER	0.601
EO	0.766	MB	0.281
EW	0.144	LZ	0.532
EX	0.492	LX	0.492
EZ	0.312	MA	0.465
FK	0.097	LU	0.523
FM	0.04	LT	0.364
FY	0.399	LV	0.681
FW	0.071	LQ	0.467
FJ	0.231	LW	0.469
FA	0.679	LY	0.503
GH	0.04	LB	0.167
FP	0.04	KP	0.196
FV	0.128	LD	0.05
FX	0.071	LH	0.134
FQ	0.94	KR	0.225
FR	0.94	LC	0.205
FS	0.405	KO	0.255
FT	0.326	KN	0.499
FN	0.04	LA	0.21
FU	0.04	LE	0.279
FO	0.04	KJ	0.668
FL	0.08	HV	0.043
FF	0.915	HM	0.224
FG	0.908	HQ	0.107
FH	0.917	JT	0.301
FI	0.323	HN	0.438
FE	0.515	JR	0.421
FD	0.868	JQ	0.507
FC	0.838	JF	0.5
FB	0.494	JE	0.544
EY	0.582	JD	0.533
ET	0.264	IT	0.412
EG	0.654	IR	0.547
EM	0.126	IS	0.488
EE	0.662	IV	0.465
EC	0.19	IU	0.517
EB	0.137	IW	0.45
DZ	0.592	IO	0.444
EL	0.056	IF	0.5

Node Name	Adopted Fraction Impervious (EIA)	Node Name	Adopted Fraction Impervious (EIA)
IG	0.451	CD	0.04
IE	0.144	CG	0.025
IK	0.538	BE	0.035
IN	0.484	BF	0.04
IM	0.552	BW	0.62
JA	0.553	BY	0.029
JC	0.55	CA	0.076
JB	0.535	CR	0.059
JM	0.558	CS	0.052
JN	0.549	CT	0.041
JP	0.55	CH	0.03
HZ	0.328	CV	0.048
IC	0.075	CU	0.048
IB	0.61	CB	0.042
HJ	0.541	BZ	0.038
IP	0.484	BL	0.029
KM	0.44	BK	0.04
KL	0.493	CL	0.551
KK	0.59	BG	0.041
KG	0.94	BH	0.04
KI	0.423	BM	0.175
KH	0.3	CM	0.283
KE	0.459	CN	0.044
KA	0.225	CJ	0.791
JW	0.489	BO	0.35
HU	0.054	BI	0.364
HT	0.068	CK	0.441
IJ	0.491	CO	0.273
HX	0.308	BP	0.062
BQ	0.024	BN	0.327
BS	0.02	CI	0.032
BT	0.02	CW	0.18
BR	0.024	CX	0.042
BC	0.02	CP	0.048
BU	0.02	CQ	0.044
CE	0.666	CY	0.04
BV	0.042	CZ	0.041
CC	0.036	DA	0.043
CF	0.329	DB	0.129
BD	0.036	DC	0.043
BJ	0.035	DD	0.047
BX	0.036	DG	0.04

Node Name	Adopted Fraction Impervious (EIA)	Node Name	Adopted Fraction Impervious (EIA)
DE	0.04	GS	0.489
DF	0.04	GV	0.887
DI	0.04	GU	0.873
DH	0.047	JL	0.49
DK	0.255	JK	0.343
DJ	0.29	JI	0.543
DL	0.164	IH	0.581
DM	0.278	IL	0.53
GN	0.042	II	0.535
GY	0.055	LR	0.495
GZ	0.061	LS	0.352
HA	0.084	LG	0.32
GK	0.04	JY	0.042
GI	0.031	JV	0.262
GC	0.038	JU	0.049
GF	0.076	JX	0.422
FZ	0.056	JO	0.555
LN	0.28	JJ	0.09
HI	0.519	IX	0.481
LL	0.28	IY	0.394
HG	0.081	IZ	0.389
GW	0.724	JH	0.47
HH	0.88	JG	0.061
HK	0.78	HP	0.456
HL	0.274	JS	0.049
GQ	0.878	HO	0.461
GM	0.114	KC	0.113
GL	0.032	KD	0.287
GJ	0.038	KF	0.768
GE	0.04	GX	0.063
GD	0.109	HF	0.044
GG	0.02	HE	0.094
GA	0.07	HC	0.156
GB	0.036	HD	0.162
IA	0.662	HB	0.277
HY	0.666	LO	0.32
HW	0.053	HR	0.283
ID	0.481	JZ	0.323
GT	0.216	KB	0.335
GO	0.851	LP	0.323
GP	0.147	HS	0.455
GR	0.101	KX	0.491

Node Name	Adopted Fraction Impervious (EIA)	Node Name	Adopted Fraction Impervious (EIA)
KY	0.284	KQ	0.133
LM	0.322	KS	0.193
KZ	0.323	KU	0.478
LJ	0.28	KV	0.359
KW	0.374	LF	0.228
LK	0.507	LI	0.177
KT	0.332	IQ	0.485

K.2 Kororoit Creek RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
sA	0.451	G	0.424
sB	0.441	BC	0.452
sR	0.482	E	0.226
sS	0.418	F	0.193
sU	0.462	CL	0.343
sD	0.393	CO	0.388
sC	0.454	DQ	0.416
sE	0.468	DR	0.445
sT	0.715	CF	0.209
sF	0.455	DS	0.442
sAB	0.506	BQ	0.467
sAC	0.454	CC	0.326
sG	0.696	AR	0.06
sZ	0.394	AS	0.064
sY	0.258	AP	0.06
sV	0.671	AV	0.12
sW	0.447	A	0.062
sX	0.671	AU	0.097
sH	0.649	AQ	0.096
AB	0.471	BA	0.115
EE	0.688	BB	0.327
EH	0.266	AZ	0.084
AN	0.215	D	0.124
EG	0.559	AT	0.06
AG	0.475	C	0.067
AH	0.263	B	0.066
BO	0.205	AW	0.123
BP	0.282	CY	0.332
AY	0.071	CZ	0.297
AX	0.084	BI	0.437

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
DC	0.086	CW	0.434
DG	0.517	CB	0.415
H	0.103	BW	0.411
Q	0.326	BV	0.448
CD	0.448	BU	0.468
CM	0.235	K	0.361
DA	0.297	CU	0.467
BD	0.394	CV	0.427
DO	0.429	BX	0.428
DM	0.436	DB	0.446
X	0.387	CE	0.306
DV	0.708	BY	0.463
DX	0.72	DF	0.462
W	0.427	BR	0.513
V	0.383	BM	0.434
CP	0.288	DK	0.451
O	0.399	BH	0.393
P	0.359	CT	0.313
CJ	0.427	BL	0.45
CK	0.432	BG	0.409
R	0.513	CQ	0.339
S	0.225	CI	0.454
DN	0.42	N	0.366
DT	0.418	BS	0.477
L	0.335	DD	0.492
M	0.318	CA	0.426
I	0.283	DJ	0.447
J	0.405	U	0.384
CH	0.209	BF	0.45
BN	0.45	DE	0.452
CS	0.212	AA	0.352
CG	0.485	DY	0.72
DU	0.523	Z	0.385
DH	0.435	DP	0.598
CR	0.466	EA	0.435
DL	0.459	Y	0.457
CN	0.267	AC	0.41
CX	0.438	AD	0.412
BK	0.406	DZ	0.518
BJ	0.436	BE	0.437
BZ	0.434	ED	0.562
T	0.402	EF	0.502

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
AF	0.665	pO	0.431
EB	0.331	pR	0.64
DW	0.719	pG	0.435
AE	0.262	pD	0.545
AM	0.458	pI	0.408
EC	0.312	pJ	0.389
AJ	0.587	pS	0.564
AL	0.644	pQ	0.414
AK	0.475	pE	0.045
AI	0.376	pP	0.462
DI	0.15	pK	0.445
BT	0.282	pC	0.193
AO	0.235	pH	0.434
pA	0.474	pN	0.476
pM	0.399	pB	0.448
pL	0.144	pF	0.431

K.3 Stony Creek RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
A	0.451	P	0.383
B	0.441	AP	0.372
R	0.482	AN	0.603
S	0.418	AS	0.681
U	0.462	AZ	0.455
D	0.393	AX	0.453
C	0.454	AV	0.477
E	0.468	AH	0.598
T	0.715	AL	0.468
F	0.455	O	0.519
AA	0.475	AK	0.506
AB	0.506	AY	0.461
AC	0.454	Q	0.35
AE	0.464	G	0.696
I	0.604	Z	0.394
J	0.435	Y	0.258
AF	0.452	V	0.671
L	0.684	W	0.447
AJ	0.608	X	0.671
N	0.676	H	0.649
AM	0.566	AI	0.646

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
M	0.687	AW	0.499
K	0.418	BA	0.708
AQ	0.714	AG	0.5
AR	0.477	AD	0.389
AT	0.72	BB	0.708
AU	0.415	AO	0.72

K.4 Cherry Creek RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
G	0.42	R	0.394
AE	0.71	O	0.71
W	0.103	AX	0.56
F	0.446	AU	0.359
X	0.571	AR	0.672
B	0.707	AQ	0.706
A	0.485	V	0.719
I	0.718	C	0.717
AL	0.72	AI	0.716
AB	0.04	AN	0.72
AD	0.104	Y	0.293
AC	0.145	AM	0.509
H	0.071	AK	0.688
AF	0.719	AJ	0.548
AO	0.591	AH	0.72
N	0.591	AG	0.663
BD	0.572	AP	0.72
M	0.653	J	0.699
AW	0.663	K	0.695
L	0.684	BC	0.456
AT	0.72	U	0.307
AV	0.71	BA	0.45
AS	0.71	BB	0.398
T	0.374	P	0.346
Z	0.574	AZ	0.72
Q	0.434	E	0.453
S	0.08	D	0.551
AY	0.347		

K.5 Laverton Creek RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
A	0.034	AG	0.223
B	0.456	AH	0.281
CN	0.322	CV	0.474
C	0.362	CW	0.493
D	0.467	AI	0.221
E	0.503	AJ	0.375
CO	0.72	AK	0.575
F	0.514	AL	0.221
G	0.396	CX	0.449
H	0.464	AM	0.652
I	0.719	AN	0.552
J	0.719	AO	0.113
CP	0.338	AP	0.09
K	0.508	AQ	0.397
CQ	0.315	AR	0.52
CR	0.308	AS	0.72
L	0.506	AT	0.718
M	0.694	AU	0.258
N	0.442	AV	0.486
O	0.4	AW	0.067
P	0.033	AX	0.224
Q	0.407	AY	0.507
R	0.441	AZ	0.301
S	0.133	BA	0.648
CS	0.436	BB	0.241
CT	0.07	BC	0.261
T	0.144	BD	0.293
U	0.095	BE	0.184
V	0.18	BF	0.438
W	0.258	BG	0.72
X	0.238	CY	0.428
Y	0.231	BH	0.111
Z	0.18	BI	0.511
CU	0.623	BJ	0.298
AA	0.071	BK	0.459
AB	0.096	BL	0.299
AC	0.06	BM	0.074
AD	0.116	BN	0.097
AE	0.102	BO	0.074
AF	0.146	BP	0.47

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
BQ	0.323	CK	0.162
CZ	0.557	DI	0.605
BR	0.48	CL	0.482
BS	0.446	DJ	0.41
BT	0.337	DK	0.459
DA	0.033	DL	0.45
BU	0.324	DM	0.146
BV	0.183	CM	0.72
DH	0.118	DN	0.685
DB	0.075	DO	0.445
DC	0.514	DP	0.595
BW	0.483	DQ	0.108
BX	0.45	DR	0.629
BY	0.329	DS	0.162
BZ	0.221	DT	0.433
DD	0.269	DU	0.124
CA	0.159	DV	0.47
CB	0.241	DW	0.066
CC	0.369	DX	0.453
CD	0.434	DY	0.105
CE	0.311	DZ	0.4
CF	0.066	EA	0.428
CG	0.408	EB	0.134
DE	0.425	EC	0.467
DF	0.267	ED	0.383
DG	0.452	EE	0.328
CH	0.72	EG	0.718
CI	0.72	EF	0.3
CJ	0.487		

K.6 Skeleton Creek RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
SJ	0.294	SB	0.31
SI	0.06	SA	0.218
SH	0.06	S	0.428
SF	0.071	ME	0.342
SG	0.06	MD	0.437
SD	0.289	MC	0.378
SE	0.121	MB	0.413
SC	0.344	MA	0.432

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
N	0.392	AC	0.06
M	0.326	XB	0.12
KA	0.496	XD	0.09
K	0.169	XC	0.1
ZZ	0.06	XF	0.06
ZY	0.06	XG	0.06
DDD	0.354	XI	0.06
BY	0.06	XJ	0.06
BW	0.083	XK	0.06
BV	0.075	XN	0.06
BS	0.06	XO	0.06
BT	0.06	XQ	0.06
BU	0.06	XL	0.06
BR	0.06	XH	0.06
BQ	0.06	XZ	0.06
BP	0.06	XR	0.06
BO	0.06	XS	0.06
BB	0.06	XM	0.06
BN	0.06	XE	0.097
BM	0.06	TP	0.06
BK	0.06	TN	0.06
BL	0.06	TO	0.06
BJ	0.06	TM	0.085
BI	0.06	TL	0.338
BH	0.06	TK	0.246
BE	0.06	TI	0.227
BC	0.06	TH	0.198
BF	0.06	W	0.218
BG	0.06	WA	0.094
BD	0.06	TJ	0.269
BA	0.06	WC	0.06
AI	0.06	WD	0.102
XU	0.098	TG	0.174
AG	0.101	WB	0.06
AA	0.12	U	0.318
XT	0.12	YR	0.205
XA	0.12	YQ	0.234
X	0.144	YS	0.137
AJ	0.06	YP	0.095
AE	0.098	YO	0.179
AF	0.098	YN	0.06
AD	0.06	YM	0.075

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
YT	0.253	Q	0.459
YW	0.26	PI	0.239
YU	0.184	PJ	0.254
YV	0.072	QB	0.406
YJ	0.065	PA	0.415
Y	0.078	PB	0.45
UD	0.068	PC	0.45
UJ	0.06	PD	0.462
UK	0.06	PE	0.448
Z	0.061	OJ	0.441
ZA	0.297	OH	0.419
ZB	0.3	OM	0.422
ZF	0.3	O	0.312
ZG	0.3	L	0.317
ZC	0.3	JF	0.672
ZI	0.079	JC	0.534
ZE	0.065	JE	0.561
ZD	0.069	JB	0.445
ZH	0.185	JA	0.358
UF	0.139	J	0.505
UE	0.12	P	0.362
UL	0.196	OI	0.455
UA	0.12	OG	0.305
UB	0.125	OF	0.471
UC	0.077	OE	0.443
T	0.301	OD	0.435
TA	0.464	OC	0.431
RE	0.398	OB	0.42
RA	0.414	OA	0.418
RB	0.415	JH	0.651
RC	0.355	JG	0.672
RF	0.479	H	0.383
RD	0.448	I	0.288
R	0.462	IA	0.287
PK	0.369	G	0.588
PL	0.406	IB	0.395
PF	0.349	IC	0.449
PG	0.403	E	0.355
PH	0.335	DD	0.06
QD	0.447	DB	0.368
QC	0.361	DA	0.354
QA	0.421	D	0.298

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
CH	0.442	YF	0.068
CG	0.46	YE	0.064
CM	0.421	YK	0.215
CL	0.429	YG	0.06
CK	0.439	YD	0.06
CE	0.449	YC	0.06
CN	0.428	YB	0.06
CJ	0.423	YA	0.077
CI	0.412	UH	0.073
CF	0.406	UI	0.06
CD	0.45	BX	0.227
CA	0.45	TD	0.138
CC	0.438	TE	0.195
B	0.03	TB	0.237
A	0.03	TC	0.35
CB	0.317	TF	0.358
F	0.402	AB	0.088
DC	0.377	UG	0.073
YL	0.139	C	0.437
YI	0.06	AAA	0.096
YH	0.06	CCC	0.269
OL	0.461	BBB	0.444
OK	0.424	AH	0.06

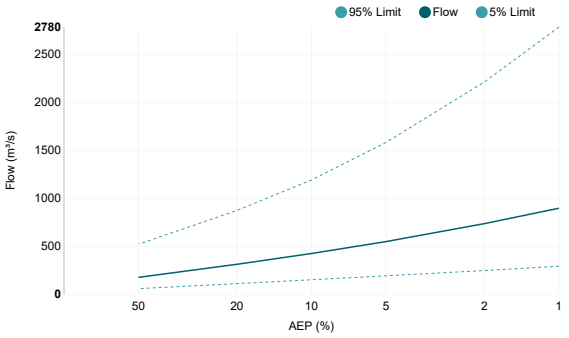
K.7 Catchment 9880 RORB Model

Node name	Adopted Fraction Impervious (EIA)	Node name	Adopted Fraction Impervious (EIA)
F	0.454	H	0.501
I	0.492	B	0.557
P	0.448	C	0.639
Q	0.196	D	0.391
O	0.373	E	0.369
N	0.446	G	0.468
L	0.502	M	0.311
K	0.508	A	0.609
J	0.519		

Appendix L. RFFE

Results | Regional Flood Frequency Estimation Model

Maribyrnong River



*The catchment is outside the recommended catchment size of 0.5 to 1,000 km^2. Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	177	59.6	521
20	313	112	873
10	425	152	1190
5	549	193	1580
2	736	248	2210
1	896	293	2780

Input Data	
Date/Time	2022-12-05 12:59
Catchment Name	Maribyrnong at Keilor
Latitude (Outlet)	-37.728
Longitude (Outlet)	144.838
Latitude (Centroid)	-37.441
Longitude (Centroid)	144.738
Catchment Area (km^2)	1303.0*
Distance to Nearest Gauged Catchment (km)	11.4
50% AEP 6 Hour Rainfall Intensity (mm/h)	5.123758
2% AEP 6 Hour Rainfall Intensity (mm/h)	12.384003
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.92
Interpolation Method	Natural Neighbour
Bias Correction Value	0.249

Statistics

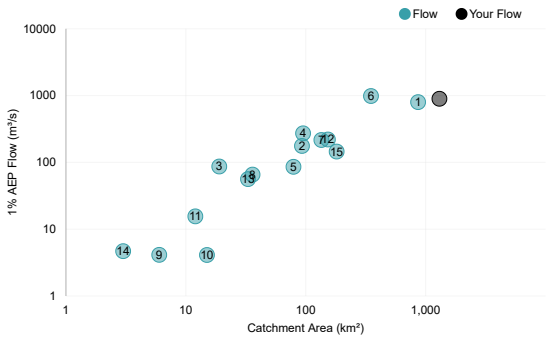
Variable	Value	Standard Dev
Mean	5.168	0.683
Standard Dev	0.669	0.204
Skew	0.095	0.029

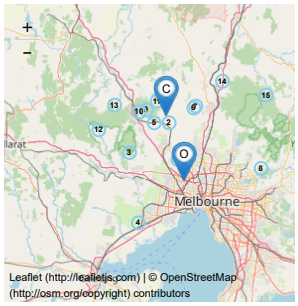
Note: These statistics come from the nearest gauged catchment. Details.

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

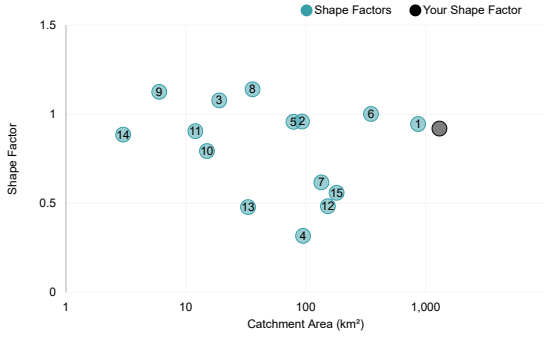
Note: These statistics are common to each region. Details.

1% AEP Flow vs Catchment Area

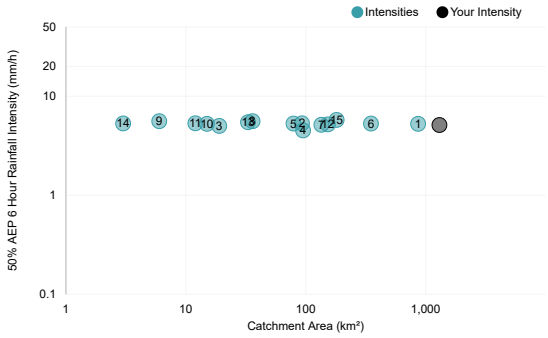




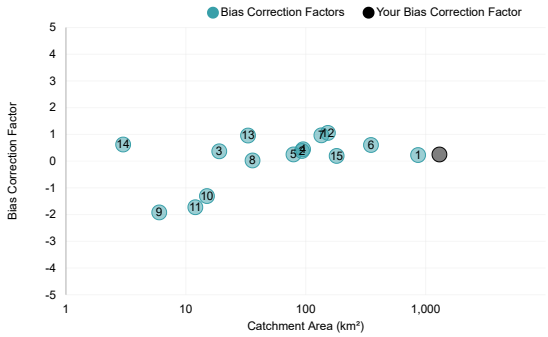
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

TXT Nearby JSON

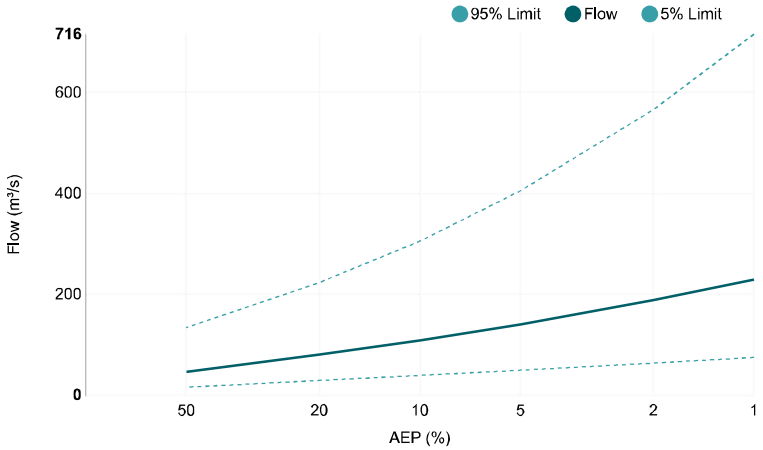
Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

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Results | Regional Flood Frequency Estimation Model

Kororoit Creek



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	45.1	15.2	133
20	79.9	28.6	223
10	108	38.7	305
5	140	49.0	405
2	188	63.1	566
1	229	74.4	716

Statistics

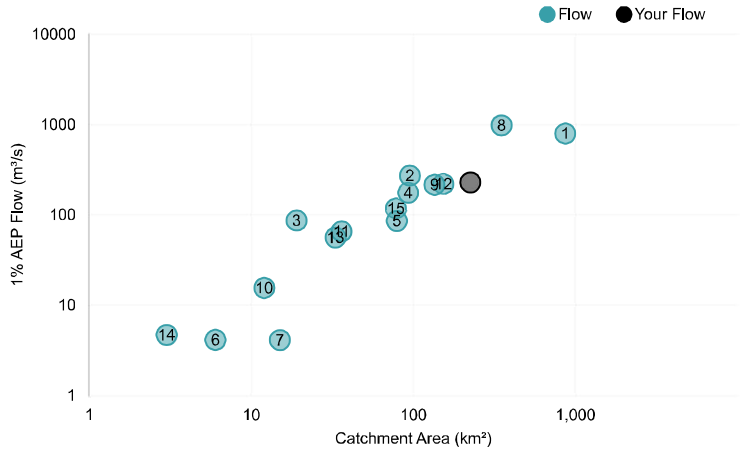
Variable	Value	Standard Dev
Mean	3.778	0.683
Standard Dev	0.669	0.204
Skew	0.095	0.029

Note: These statistics come from the nearest gauged catchment. Details.

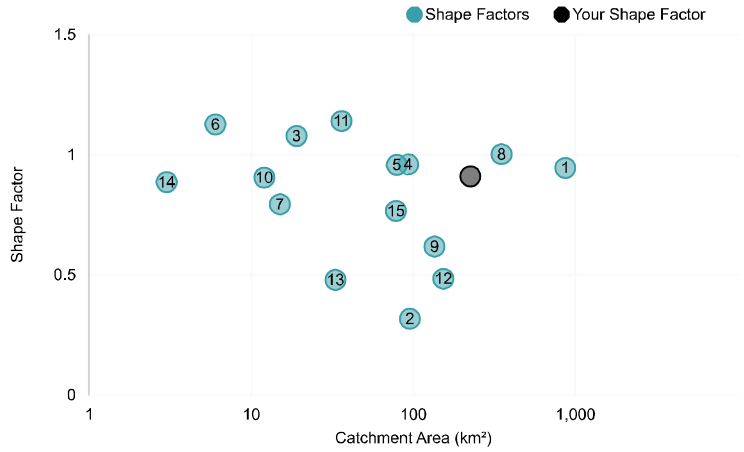
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

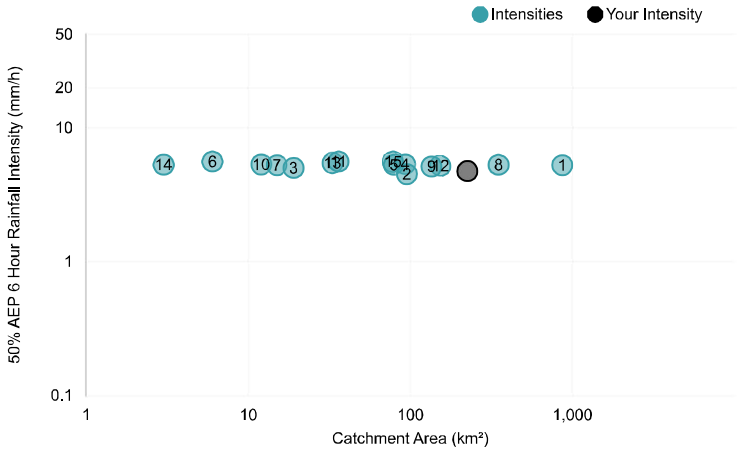
1% AEP Flow vs Catchment Area



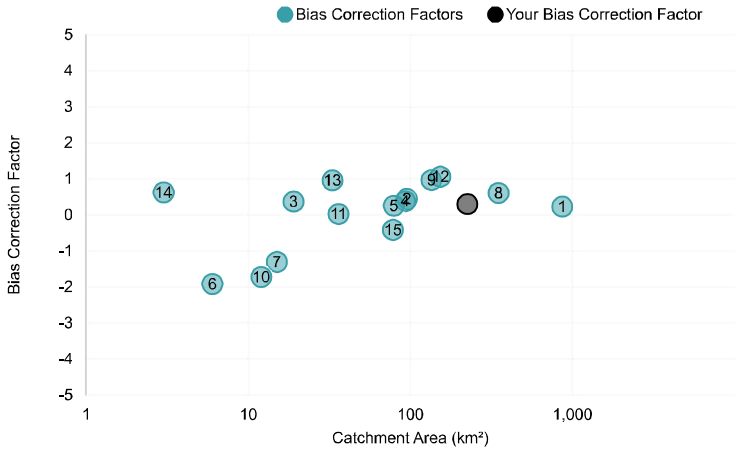
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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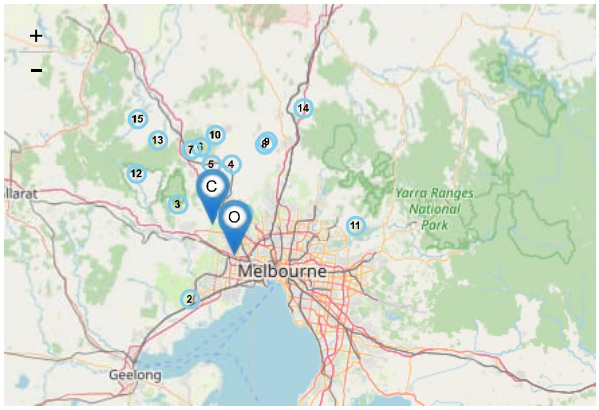
TXT Nearby JSON

Input Data

Date/Time	2022-12-06 16:30

Input Data

Catchment Name	Kororoit@Deer_Park
Latitude (Outlet)	-37.764
Longitude (Outlet)	144.765
Latitude (Centroid)	-37.664
Longitude (Centroid)	144.676
Catchment Area (km^2)	225.0
Distance to Nearest Gauged Catchment (km)	15.22
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.758536
2% AEP 6 Hour Rainfall Intensity (mm/h)	11.783557
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.91
Interpolation Method	Natural Neighbour
Bias Correction Value	0.298



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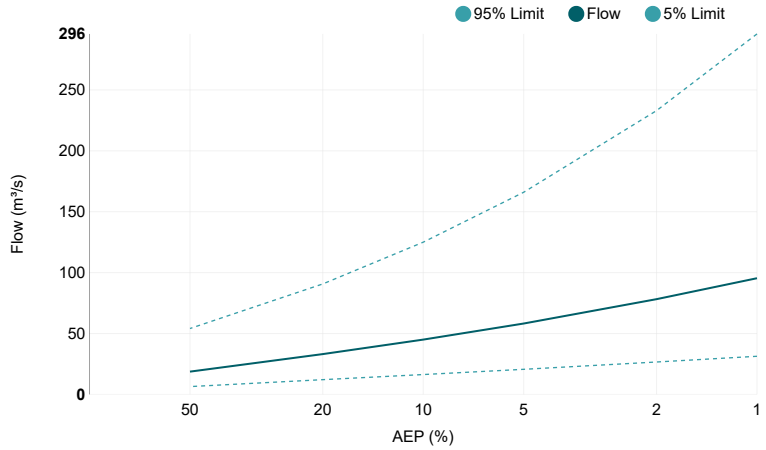
Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

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Results | Regional Flood Frequency Estimation Model

Skeleton Creek



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	18.7	6.41	54.1
20	33.1	12.1	90.7
10	45.0	16.3	125
5	58.2	20.6	166
2	78.2	26.6	233
1	95.4	31.3	296

Statistics

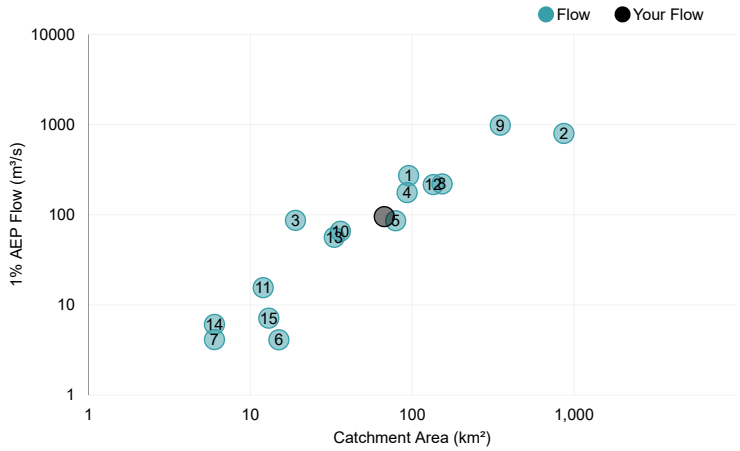
Variable	Value	Standard Dev
Mean	2.993	0.654
Standard Dev	0.664	0.217
Skew	0.141	0.030

Note: These statistics come from the nearest gauged catchment. Details.

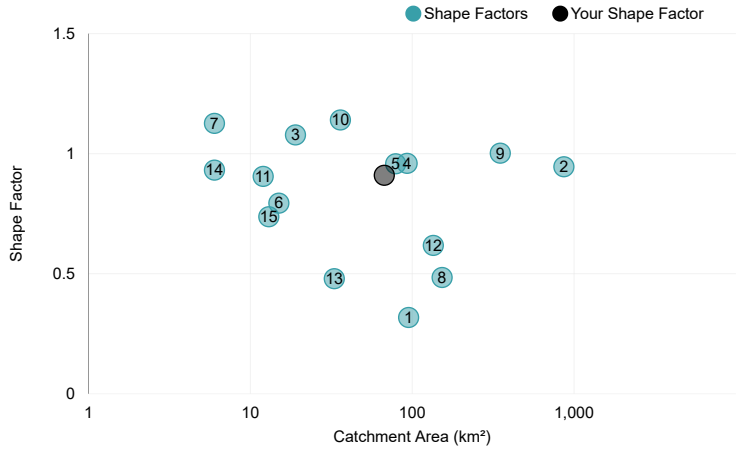
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

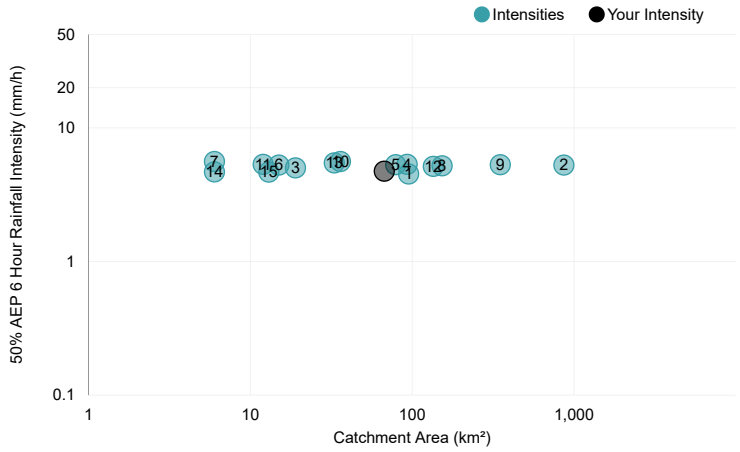
1% AEP Flow vs Catchment Area



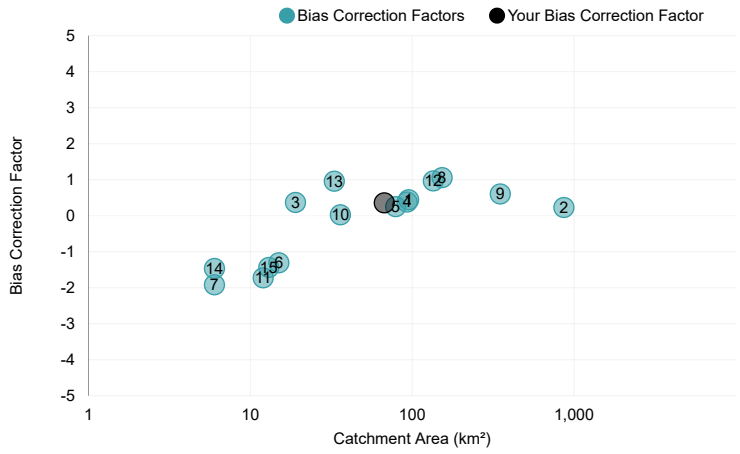
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

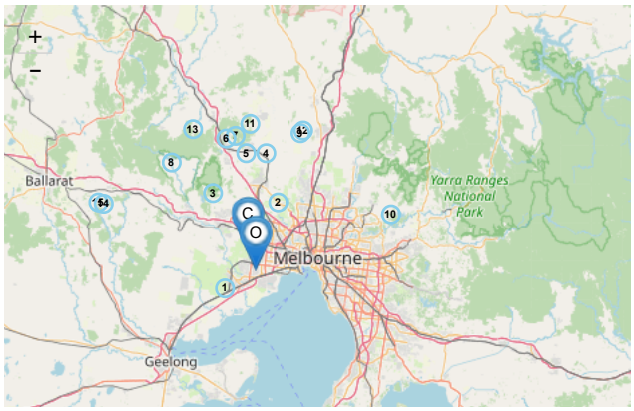
TXT Nearby JSON

Input Data

Date/Time	2022-11-22 11:04

Input Data

Catchment Name	Skeleton Creek (to Sayers)
Latitude (Outlet)	-37.85155
Longitude (Outlet)	144.71352
Latitude (Centroid)	-37.79147
Longitude (Centroid)	144.67639
Catchment Area (km^2)	67.2
Distance to Nearest Gauged Catchment (km)	13.4
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.739586
2% AEP 6 Hour Rainfall Intensity (mm/h)	11.644359
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.91
Interpolation Method	Natural Neighbour
Bias Correction Value	0.357



Leaflet (http://leafletjs.com) | © OpenStreetMap (http://osm.org/copyright) contributors

Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

Appendix M. Model Sensitivity

Appendix M. Model Sensitivity

M.1 Dynamic Tidal Level

A sensitivity test for a single dynamic tidal level model run of the Kororoit Creek South model was conducted to assess the sensitivity of the peak water levels produced by the model. The 1% AEP with climate change rainfall and 10% AEP sea level rise 6 hour duration event for the Kororoit Creek South model was assessed with the dynamic tidal level for the bay at Kororoit Creek provided in the Melbourne Water Flood Mapping Projects Specifications. The adopted tidal level is presented in Figure M-1. The tidal curve was simulated to start at 1.29 m AHD with a peak of 1.99 m AHD. The static tailwater level for the 1% AEP with climate change event was 1.99 m AHD.

An initial water level of 1.99 m AHD was applied to the model, the sensitivity of the model to a lower initial water level of 1.29 m AHD will be tested before the final revision of this report.

The model results of peak water level for this sensitivity test were compared with the static tailwater level peak water level results. The sensitivity test produced model results that were up to 90 mm lower within the Kororoit Creek waterway from the bay up to Millers Road. Flood levels further upstream of Millers Road were not changed. Flood levels in the urban area around Kororoit Creek were also slightly reduced by up to 35 mm, and typical reduced by less than 20 mm (Figure M-2).

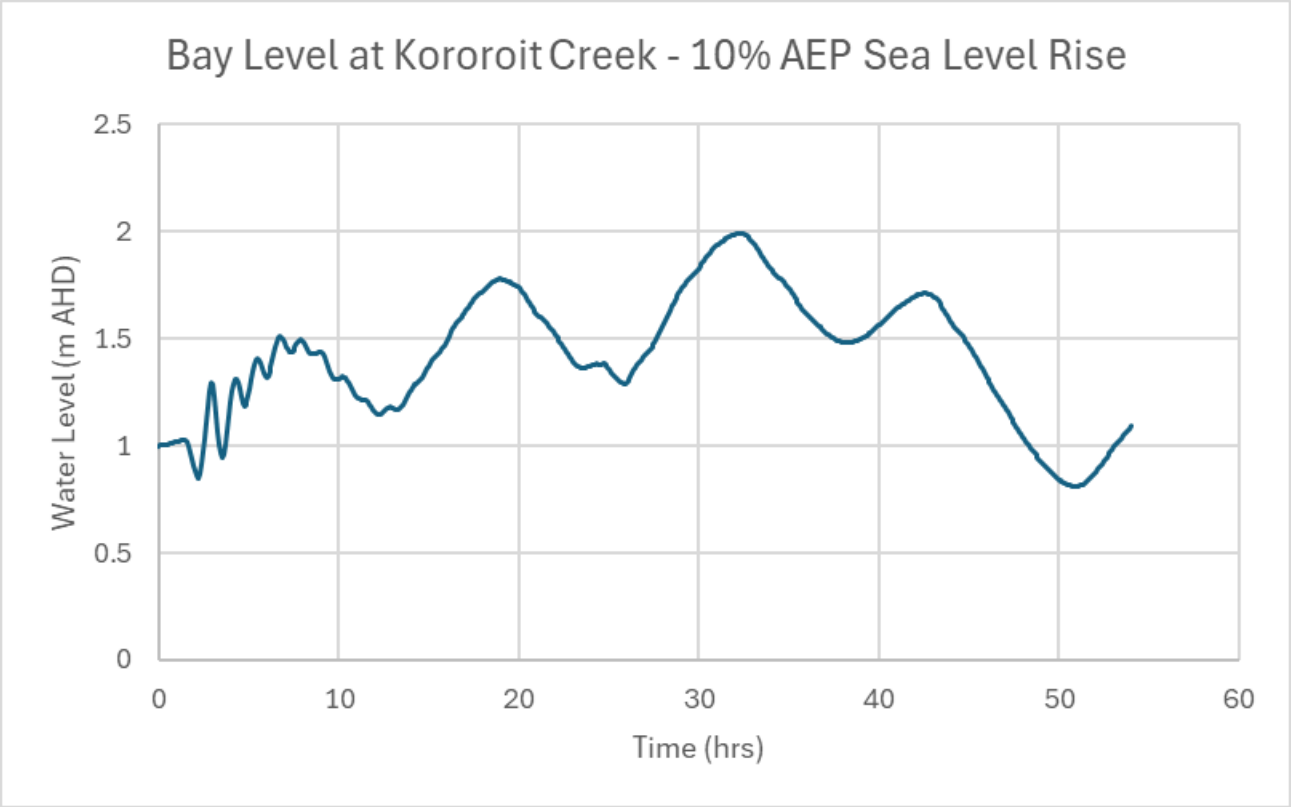


Figure M-1. Dynamic tidal level at Kororoit Creek – 10% AEP sea level rise

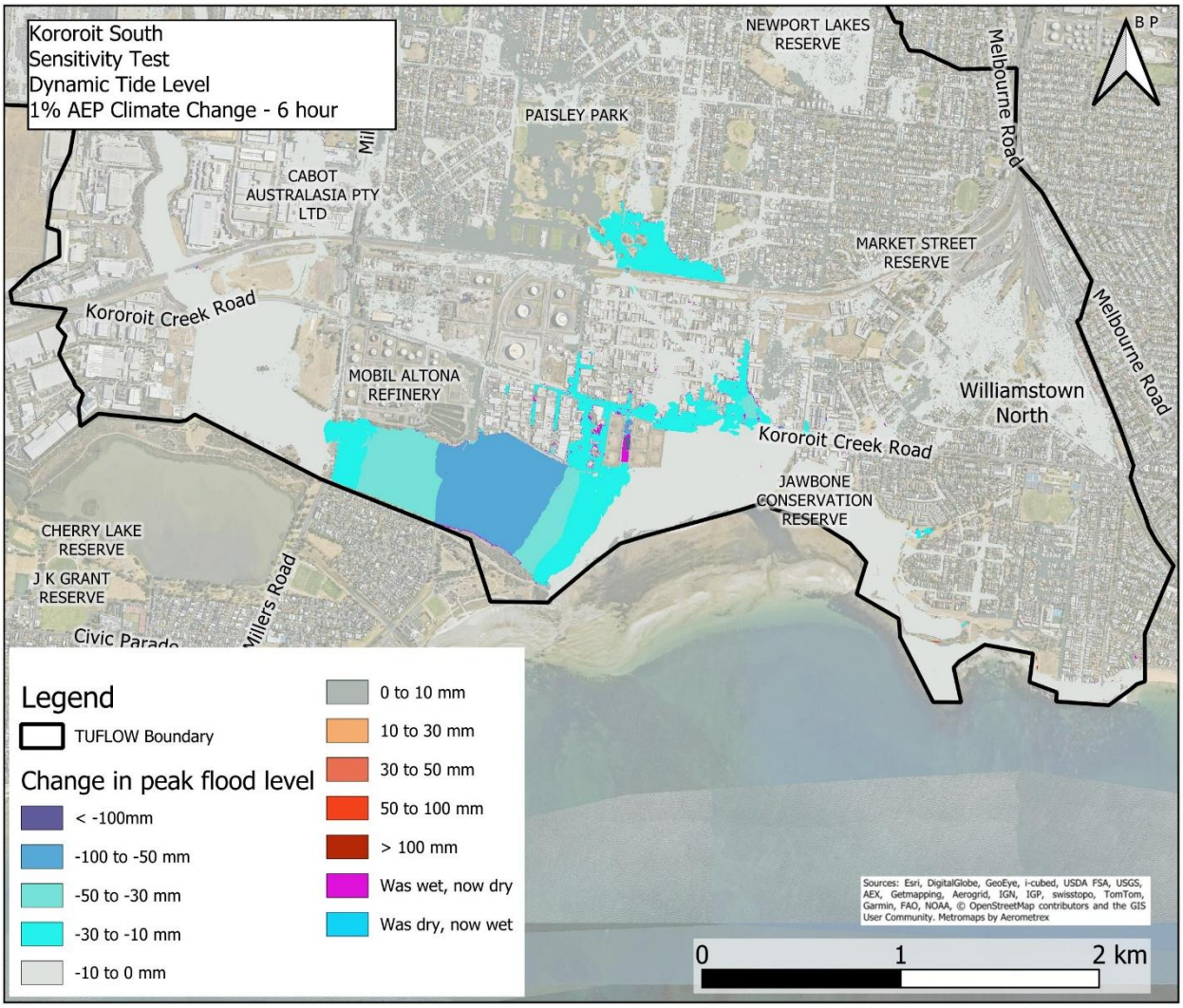


Figure M-2. Kororoit South dynamic tide level sensitivity test – 1% AEP with climate change 6 hour duration

M.1 Temporal Patterns

The selection of temporal patterns was completed in RORB and is documented in Section 3.8, with additional model-specific detail provided in Technical Appendices A–G. As part of the review process, the validity of the RORB-selected critical temporal patterns was assessed in TUFLOW by simulating all ten temporal patterns for the critical durations of the Skeleton Creek model. This review was undertaken for both the 20% AEP event and the 1% AEP event incorporating climate change and sea level rise.

The temporal pattern assessment found that peak flood levels from the TUFLOW sensitivity tests generally aligned with those associated with the adopted RORB temporal patterns across the Skeleton Creek project area. Most of the modelled catchment area was within ±10 mm of the critical temporal patterns identified from the RORB model. Small areas showed differences of up to 20 mm for the 1% AEP with climate change event (Figure M-3) and up to ±30 mm for the 20% AEP event (Figure M-4).

Based on these findings, the temporal patterns selected using RORB are considered appropriate and represent a reasonable assumption for this study.

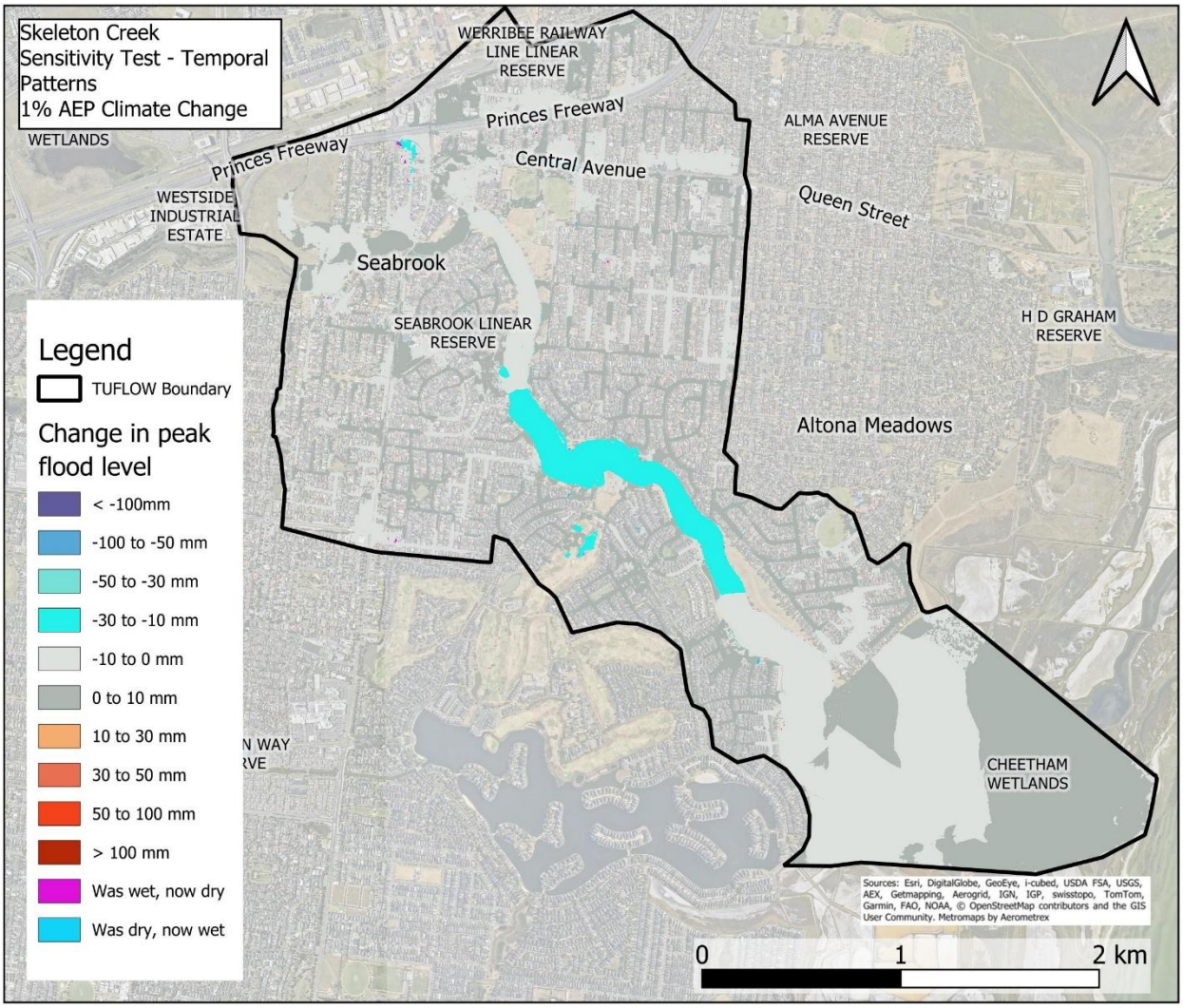


Figure M-3. Skeleton Creek temporal pattern sensitivity test – 1% AEP with climate change and sea level rise

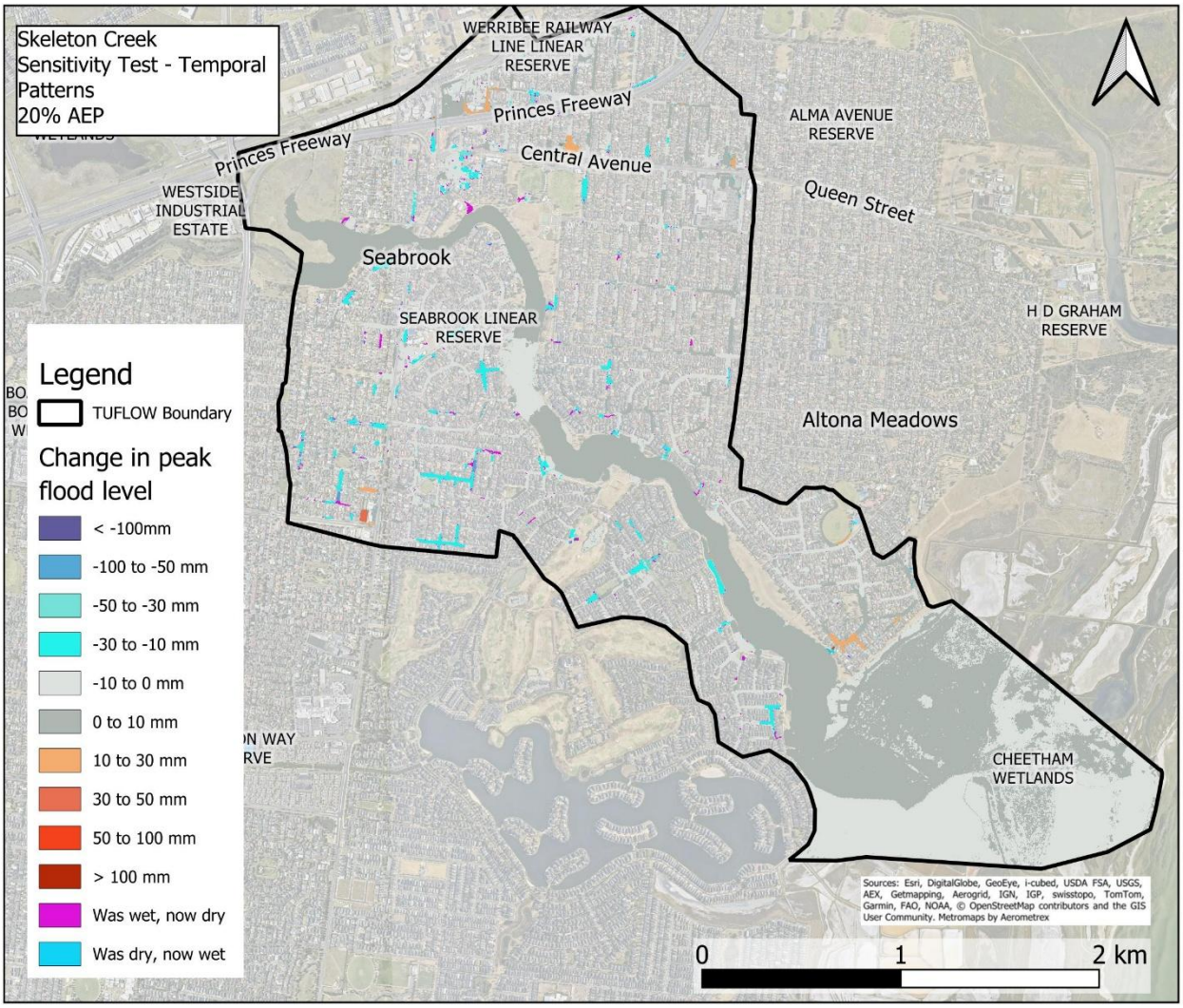


Figure M-4. Skeleton Creek temporal pattern sensitivity test – 20% AEP

Appendix N. Model Performance

Appendix N. Model Performance

The performance of the hydraulic models was assessed to the extent supported by available data and was designed to provide confidence in the model's representation of catchment response, rather than to achieve an exact reproduction of historical flood magnitudes. The performance of the hydraulic models was informed by a combination of:

- Documented flood behaviour.
- Council and Melbourne Water records.
- Anecdotal and photographic evidence where formal measurements were unavailable.
- Available rainfall data.

In line with Australian Rainfall and Runoff 2019, it is acknowledged that:

- Available historic events information is generally smaller than the 1% AEP design event.
- Performance checks against frequent or in-bank events does not, on its own, guarantee performance for rarer floods.

However, Australian Rainfall and Runoff 2019 recognises that in urban catchments with limited long-term gauged data, verification using smaller events is often the only practical approach, provided its limitations are clearly acknowledged and appropriate checks are undertaken.

Accordingly, confidence in a model for design application is based on:

- Consistency of parameters with regional benchmarks.
- Stability of model behaviour across a wide range of storm durations and temporal patterns.
- Sensitivity testing of key parameters.
- Comparison of design flood estimates with independent approximate methods and regional expectations.

Specific to this study the performance of the flood models was assessed by comparing model outputs with historical flooding information provided by Melbourne Water and each council. Specifically:

- **Comparison with Melbourne Water flooding hotspot database:** Historical flooding hotspot locations were compared against the modelled 1% AEP with climate change flood extent to evaluate whether observed flood locations aligned with the predicted extents.
- **Comparison with State Emergency Service road flooding hotspot database:** Road flooding hotspots supplied by Melbourne Water were assessed against the modelled 1% AEP with climate change flood extent. For each recorded event, nearby rain gauge data was reviewed to estimate total rainfall volume, and available event photography was also examined to support the comparison.

Overall model performance: The performance checks indicate that across the modelled catchments the flood model outputs generally align with historical flood hotspots. These findings were also confirmed through workshops with Brimbank Council and Hobsons Bay Council. The following sections summarise the assessment for each Council area.

N.1 Hobsons Bay Council

Historical flooding hotspots for Hobsons Bay Council are presented in Figure N-1. SES road flooding records and rain gauge data is summarised in Table N-1.

Historical flooding hotspots where found to closely align with the 1% AEP flood extent, with the vast majority of observed hotspots in the Hobsons Bay Council area being located within the 1% AEP flood extent.

SES flood records were also found to closely align with the 1% AEP flood extent. These records are shown in pink highlighted labels and lines in Figure N-1.

Disclaimer: Produced by Jacobs for Melbourne Water. This map should read in conjunction with the relevant model report. In preparing for this map, Jacobs has relied upon, and presumed accurate, certain information. Except as otherwise stated, Jacobs has not attempted to verify the accuracy on completeness of any such information. Jacobs does not warrant that this document is definitive nor free of errors and does not accept liability for any loss caused, or arising from, reliance upon information provided herein.

Note: The Kororoit Creek and Skeleton Creek flood extents shown are interim only and will be superseded by updated modelling being undertaken as part of a separate Melbourne Water riverine flood mapping project.

Legend

- MW Waterways
- MW Channel
- Council Pipe

Proposed Demarcation

- MW UG Drains
- MW Waterways
- Council

- LGA Boundary
- Flood Hotspots
- Road Flood Hotspots

2022-2023 Flood Mapping Study - Brimbank and Hobsons Bay

Hobsons Bay City Council LGA
Flood Map 1% AEP with Climate Change

Jacobs

0 0.8 1.6 km

A1 1:18000 MGA 55

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community.

Table N-1: Summary of photos from flood hotspots across Hobsons Bay LGA (Photos have been removed from the report due to privacy considerations)

2014 June 24	
Approximately 5-6 mm at the Altona Rain Gauge (587047)*	Flooding along Altona Esplanade
2016 December 29	
60-70 mm recorded over 1 hour at the Altona Rain Gauge (587047)*	Flooding in Altona, McIntyre Drive
2017 December 03	
25 mm recorded on the 2 December, 50 mm recorded on the 3 December at the Altona Rain Gauge (587047)*	▪ Flood in Altona, Racecourse Road ▪ Flooding in Altona, Merton Street
2018 December 13 and 14	
45 mm recorded on the 13 December, 50 mm recorded on the 14 December at the Altona Rain Gauge (587047)*	▪ Flooding along Blackshaws Road, Newport ▪ Flooding at the corner of Mason St and Melbourne Road, Newport
2021 December 1	
15 mm on recorded over a 24 hour period*	Flooding along the Westgate Freeway in Spotswood

*Based on the Altona Rain Gauge https://www.bom.gov.au/waterdata/

N.1 Brimbank Council

Historical flooding hotspots for Brimbank Council are presented in Figure N-2. SES road flooding records and rain gauge data is summarised in Table N-2.

Historical flooding hotspots where found to closely align with the 1% AEP flood extent, with the vast majority of observed hotspots in the Hobsons Bay Council area being located within the 1% AEP flood extent.

SES flood records were also found to closely align with the 1% AEP flood extent. These records are shown in pink highlighted labels and lines in Figure N-2 below.

Disclaimer: Produced by Jacobs for Melbourne Water. This map should read in conjunction with the relevant model report. In preparing for this map, Jacobs has relied upon, and presumed accurate, certain information. Except as otherwise stated, Jacobs has not attempted to verify the accuracy on completeness of any such information. Jacobs does not warrant that this document is definitive nor free of errors and does not accept liability for any loss caused, or arising from, reliance upon information provided herein.

Note: The Kororoit Creek flood extents shown are interim only and will be superseded by updated modelling being undertaken as part of a separate Melbourne Water riverine flood mapping project.

Legend

- MW Waterways
- MW Channel
- MW Underground Drains
- Council Pipe

Proposed Demarcation

- MW UG Drains
- MW Waterways
- Council

- LGA Boundary
- Flood Hotspots
- Road Flood Hotspots

2022-2023 Flood Mapping Study - Brimbank and Hobsons Bay

Brimbank City Council LGA
Flood Map 1% AEP with Climate Change

Jacobs

0 1 2 km

A1 1:22500 MGA 55

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community.

Table N-2: Summary of photos from flood hotspots across Brimbank LGA (Photos have been removed from the report due to privacy considerations)

2018 December 14	
Approximately 32 mm in 3 hours*	Flooding along Taylors Road in Keilor Downs
2011 January 15	
Total Rainall of 105 mm*	▪ Flooding recorded at Leilani Court Kelior Downs, this location aligns with the flood map. ▪ Flooding recorded on Main Road East, St Albans, this area is flooded in the model.
2010 December 19 and 2010 October 30	
Rainfalls up to 7.5 mm (Dec 19) and 40 mm (Oct 30)*	Flooding recorded at Kodre Street, St Albans, Main Road East, St Albans and Buchanan Street St Albans, these locations align with the flood maps.

*Based on the Altona Rain Gauge https://www.bom.gov.au/waterdata/