

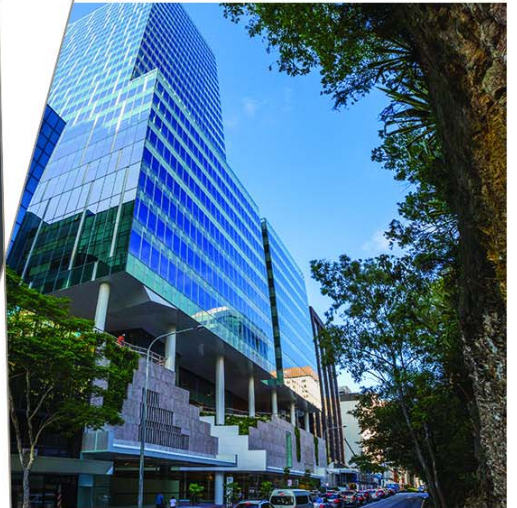
Flood Modelling Report

Ti Tree Creek

V181917

Prepared for
Melbourne Water

7 February 2020



Contact Information

Cardno Victoria Pty Ltd

ABN 47 106 610 913

Level 4

501 Swanston Street

Melbourne VIC 3000

Australia

www.cardno.com

Phone +61 3 8415 7777

Fax +61 3 8415 7788

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Author(s):

Rob Guest

Senior Engineer

Sumari Smith

Engineer

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Approved By:

Rob Swan

Manager

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1 Introduction

Melbourne Water (MW) is progressively evaluating flood risk across all catchments and investigating options to mitigate flooding in higher risk regions. As part of this process, Cardno was engaged by Melbourne Water and City of Casey to undertake the flood mapping of Ti Tree Creek.

1.1 Purpose of this Document

This project consists of a number of stages including:

- > Data Review – assessing the data available and determining the most appropriate information to take forward to the flood modelling
- > Hydrological Modelling – deriving flows which represent flood events so that these can be introduced to the hydraulic model
- > Hydraulic Modelling – determining flood risk in the catchment as a result of these flows (for example flood depth, velocity and hazard)
- > Flood Mapping – preparing GIS and mapped outputs to illustrate the hydraulic modelling findings

This document details all work that has been undertaken as part of this study.

1.2 Related Documents

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

- > Melbourne Water Corporation Flood Mapping Projects Guidelines and Technical Specifications, November 2018 (Technical Specifications). All approaches adopted in this study have been aligned with this guideline document with changes made in regards to adopting new approaches from Australian Rainfall and Runoff 2016 (ARR16);
- > Data Review report – dated 24 January 2019 (file reference V181917_Casey_Data_Review-Ti_Tree.docx)

1.3 Study Area

The study area is shown in Figure 1 in Appendix A, which indicates:

- > The study area catchment extent – this has been developed based on both topography and the underground drainage network
- > Melbourne Water pipes and channels which includes:
 - O'Sheas Road D.S (MW Asset ID 614)
 - Cranbourne East D.S (MW Asset ID 618)
 - Ti-Tree Creek DS (MW Asset ID 619)
 - Lower Cardinia Creek DS (MW Asset ID 1310)
- > Melbourne Water waterbodies and retarding basins which include:
 - Greaves Rd Sediment Pond, Wetland, Lake and Retarding Basin (MW Asset ID 0619/07)
 - Beaumont Waters Sediment Pond, Lake and Wetland (MW Asset ID 0619/17)
 - Kimberley Downs Wetland (MW Asset ID 0619/48)
 - Gera Estate Ti Tree Creek Sediment Pond and Wetlands (MW Asset ID 0619/51)
 - Emu Way Linear Wetlands (MW Asset ID 0619/80)
 - Ti Tree Creek Sediment Pond and Wetland (MW Asset ID 0619/22)
 - Grices Rd Channel Sediment Pond (MW Asset ID 0619/52)

- Berwick Waters Sediment Pond, Wetland and Retarding Basin (MW Asset ID 0619/76)
 - Arboulea East Sediment Pond and Wetland (MW Asset ID 0619/86)
 - Arboulea West Sediment Pond and Wetland (MW Asset ID 0619/78)
 - Kilora Park Waterway Ponds (MW Asset ID 1310/10)
 - Linsell Blvd Sediment Pond and Lake (MW Asset ID 0619/27)
 - Linsell Blvd Wetlands (MW Asset ID 0619/45)
 - Ti Tree Creek Sediment Pond and Wetland (MW Asset ID 0619/16)
- > Council's drainage network

2 Available Information

2.1 Introduction

This section summarises the key information that has been used in the analysis. A full data review can be found in the data review report (dated 24/01/19) which includes all information provided at project inception.

2.2 Digital Terrain Model

A comprehensive Digital Terrain Model (DTM) was compiled from the LiDAR survey data (2017). The digital elevation model (DEM) was then constructed as a rectangular grid of elevations sampled from this DTM. Ridge lines (along embankments) and gully lines (along drainage channel) were utilised to ensure that the sampled DEM adequately represented these features.

The DEM defines the topography of the catchment and has been used in the hydrological analysis to delineate the catchment / sub-catchments. The DEM was also used in the hydraulic modelling stages to define the 2D model topography and report the subsequent results.

2.3 Parcel and Land Use Data

Parcel and land use data was downloaded from Vic Data Online. This data was used as follows:

- > As contextual base map information
- > To ensure the catchment was edge matched to property boundaries. Note: in some instances, the topography and pipes showed it was appropriate to not have sub-catchments edge matched
- > In the derivation of fraction impervious based on the land use type of the parcel

2.4 Aerial Photography

Current Nearthmap Aerial Photography was accessed for January 2019. These datasets were used to confirm fraction impervious values and as base map contextual information.

2.5 Pipe Data

The data review document (dated 24/01/19) details the pipe data supplied. The location of pipes (MW and Council) were used to help to define catchments and sub-catchments, and in topographically flat areas they assisted in determining the direction of flow. They were also input into the hydraulic model as a 1d network.

3 Hydrological Modelling

3.1 Hydrological Model Establishment

The hydrological model RORB (version 6.42) was implemented in this flood mapping project. RORB calculates flood hydrographs from storm rainfall hyetographs and can be used for modelling natural, part urban and fully urban catchments. RORB is an industry standard hydrological model that has been used widely in previous studies undertaken by Melbourne Water.

The base hydrological model was created in GIS, utilising the MapInfo plug-in, MiRORB. The methodology implemented in MiRORB is outlined in Sections 3.2, 3.3, 3.4 and 3.5. Furthermore, the RORB methodology has been outlined in Section 3.7.

3.2 Catchment / Sub-Catchment Delineation

Melbourne Water provided a draft catchment as part of tendering these works and at project initiation. This catchment was reviewed and refined based on topographic data, drainage asset data and property information.

Topography and drainage asset data was used to ensure all areas that can contribute flow in the 1% AEP storm were included in the catchment, regardless of the flow mechanism (pipe or overland). Occasionally topographical flow paths contradict pipe flow directions and therefore, topographic flow paths were preferred for catchment delineation. Following the derivation of the catchment, it was matched to the edge of property boundaries using property GIS information. The data review document (dated 24/01/19) details this optimised catchment boundary.

Sub-catchments were delineated using topographic and drainage asset data. Unlike the catchment boundary, the sub-catchments were not necessarily edge matched to property boundary information.

The catchment and subarea boundaries are illustrated in Figure 2 of Appendix A.

3.3 Nodes and Reaches

Nodes were located as required at centroids of subareas, at the downstream end of each subarea and at any confluence. The nodes were placed so that they made some allowance for the time taken for subarea flows to reach the main channel. Flow routing from sub-catchments used control codes appropriate to the flow routing required.

Reach types were selected to represent the likely routing properties of the subareas. Reach types used in the hydrological model were type 1 (natural channel) to represent the farming and grassy areas in the central region of the catchment and reach type 2 (excavated but unlined) to represent reaches in the urban area of the catchment.

Figure 3 of Appendix A illustrates the sub-catchments, nodes and reaches.

3.4 Storages

Storages were included in the hydrologic model at all existing Melbourne Water waterbodies and retarding basins, as well as any topographically distinct informal basins identified from aerial imagery and the DEM. Twelve storages were included in the RORB model, with the aim of accurately representing the retention of flows/volumes within the hydraulic model. This allows for a more accurate estimation of the critical durations to be undertaken within RORB.

Storage parameters for RORB were sourced from existing models, Melbourne Water Design Plans, LiDAR and pipe data. Where existing models were not available, stage-storage relationships and outlet information were derived from retarding basin design plans, as well as Council and Melbourne Water pipe data. If neither were available, parameters were derived from LiDAR and pipe data.

3.5 Fraction Impervious Methodology

ARR 2016 advises the loss model is made of three impervious types.

- > Effective Impervious Areas (EIA) – where rainfall is directly transformed to runoff, after an initial storage loss
- > Indirectly Connected Impervious Areas (ICIA) – where rainfall runs from an impervious surface across another surface where some continuing losses occur
- > Pervious Areas (PA) – where rainfall falls on pervious areas

ARR 2016 discusses that using GIS techniques to identify directly connected impervious areas (identifying road, roof and driveway areas) show that the EIA is typically between 70% and 80% of the measured impervious area. However, this may trend to 100% as the catchment imperviousness increases to 100%. When measured at a catchment scale, without considering connectedness, the EIA is approximately 55-65% of the Total Impervious Area (Phillips et al, 2014).

For this assessment, we have assumed that the FI values given in Melbourne Water's Technical Specification are the measured impervious areas (from GIS) for each land use type. An EIA factor was then calculated for each area based on land use type and visual inspection of aerial images.

The EIA for a land use type in the sub-catchment was then calculated using the following formula:

$$\text{EIA} = (\text{total land use area}) * \text{TechSpecFI} * \text{EIAFactor}$$

The sub-catchment EIA was then calculated as the sum of the EIAs for each land use type within the given sub-area. Table 3-1 shows fraction impervious values, MW measured FI values and EIA factors for each of the land use types. Factors labelled "Varying" can be found in the GIS tables. The individual land use zone EIA values were assessed against Table M1 of the Melbourne Water Technical Specification (MW 2018) and found to be within reasonable margin of variation.

Table 3-1 Fraction Impervious Factors Adopted

Zone	Zone Code	MW measured FI (Tech spec)	EIA Factor	EIA reasoning
Commercial Zone	C1Z and C2Z	Varying	Varying	ARR predicts a high level of connectivity for highly impervious commercial areas. Commercial zones in less developed areas have higher proportions of pervious areas and lower EIA factors due to the trend mentioned above. The C2Z areas were undeveloped and low imperviousness and connectivity were assigned as a result.
General Residential	GRZ1	0.7	0.8	It is estimated that the majority of runoff from impervious areas will enter directly into the pipe system through roof drainage.
Low Density Residential	LDRZ	0.25	0.4	The proportion of impervious cover in low density areas varies with block size. Larger blocks are expected to have lower connectivity to Council pipe networks.
Activity Centre Zone	ACZ1	Varying	Varying	Areas have relatively high imperviousness and connectivity, varying slightly across the catchment.
Public Park and Recreation Zone	PPRZ	Varying	Varying	For areas where the majority of the area is pervious, with little to no Council pipes present, it is expected the majority of these areas are indirectly connected. Areas with extensive sports facilities have higher impervious coverage, and more

				Council pipes, and are therefore more directly connected.
Farming Zone	FZ1	0.1	0.1	With the majority of the area being pervious, and little to no Council pipes in the areas, it is expected that the majority of water is indirect.
Public Use – Education	PUZ2	Varying	Varying	There are 5 schools in the catchment, with impervious cover varying with size of grassed and vegetated areas.
Public Use – Transport	PUZ4	0.5	0.2	Includes grassed areas of the rail reserve. Rail is located to the south of Ti Tree Creek catchment, with only minimal sections serviced by drainage.
Public Use – Local Government	PUZ6	Varying	Varying	Land use varies, from high impervious cover with a moderate degree of connection to drainage, to low impervious cover with minimal connection to drainage
Public Use – Service and Utility	PUZ1	Varying	Varying	The majority of the areas are pervious and it is expected that the majority of the areas are indirectly connected with little to no Council pipes. There are some areas with buildings and carparks which possess moderate to high imperviousness and connectivity.
Road Zone 1	RDZ1	0.7	0.95	It is expected that a high proportion of the roads in the catchment will drain directly into road drainage, especially for major roads.
Road Zone 2	RDZ2	0.7	0.9	It is expected that a high proportion of the roads in the catchment will drain directly into road drainage.
Urban Growth Zone	UGZ1, UGZ2, UGZ10 and UGZ14	Varying	Varying	There is a large discrepancy between level of development in Urban Growth Zones. Developed areas have a high level of imperviousness and connectivity. Whilst, undeveloped areas have low imperviousness and connectivity.
Special Use Zone	SUZ3, SUZ4 and SUZ 6	Varying	Varying	Special Use Zones are predominantly low to medium pervious areas, with some sporting fields, carparks and buildings having connectivity to the drainage network. In some instances, these zones are under construction.
Urban Floodway Zone	UFZ	Varying	Varying	Includes floodway of Troups and Ti Tree Creeks

Figure 4 of Appendix A illustrates the Effective Fraction Imperviousness across the catchment. Furthermore, Appendix B summarises the sub-catchment characteristics, including ID, Area and Fraction Impervious.

3.6 Hydrological Modelling Scenarios

The modelled scenarios are outlined in Table 3-2. This is consistent with the MW Technical Specifications and project brief.

Table 3-2 Scenarios Modelled

	Event AEP								Key drivers for models
	20%	10%	5%	2%	1%	0.5%	0.2%	0.05%	
A. Base Case	√	√	√	√	√				Land development advice, planning controls, updating parcel encumbrances, and assessment of flood risk.
D. Climate Change 3 – Increase Rainfall Intensity	√	√			√				To understand sensitivity of catchment to increased rainfall intensities.

3.7 RORB Model Parameters and Validation

3.7.1 RORB Model Parameters

3.7.1.1 Intensity Frequency Duration (IFD) Relationships

Current Climate

ARR 2016 'Intensity Frequency Duration' (IFD) values were adopted for this study. Standard and non-standard durations were used, ranging from 10 minutes to 168 hours.

Data was downloaded from the Bureau of Meteorology (BoM) website for frequent, infrequent and rare storms.

Future Climate

ARR 2016 also gives new guidance on the estimation of the effects of climate change on rainfall intensity. It recommends the use of a 5% increase in rainfall intensity per °C. Projected rainfall intensity or equivalent depth (I_p) is therefore obtained from the following equation:

$$I_p = I_{ARR} \times 1.05^{T_m}$$

Where:

I_{ARR} is the design rainfall intensity (or depth) for current climate conditions; and

T_m is the temperature midpoint of the selected class interval.

As per the Melbourne Water Technical Specifications (Section 4.4), both methods of calculating percentage increase were used. This included estimating percentage rainfall increase by interpolation beyond 2090 to 2100, and calculating the rainfall increase based on the equation above for 2100.

The increase in rainfall intensity for 2100 was adopted as 19.5%, as it was the more conservative of the two calculations.

3.7.1.2 Hydrological Loss Model and Parameters

The initial loss/continuing loss model has been applied as per Section 4.3.4 of MW Technical Specifications (2018).

Regional rural loss estimates were downloaded from the ARR Data Hub for the region. These were estimated as initial loss = 27 mm and continuous loss = 4.4 mm/h. In reference to loss estimates for ICA, Section 3.5.3.2 of ARR 2016 Book 5 recommends that 60-80% of the rural estimate be used for the initial loss. Cardno have adopted 70% of the rural ARR Data Hub estimate as an average of this recommended initial loss range.

ARR also states that values between 1-4mm/h would be an appropriate estimate for continuous loss in Australia, with 2.5mm/h for most urban areas. Therefore, a continuous loss of 2.5mm/h was deemed appropriate for the predominantly urbanised catchment area.

Therefore, the loss estimates adopted for Ti Tree Creek were:

- > Initial Loss = 18.90mm (70% of rural estimate of 27mm)
- > Continuous Loss = 2.5 mm/hr

3.7.1.3 Continuing loss and model time step

The continuing loss has not been adjusted for model time step. This is not required as the continuing loss has been compared to the nearby catchment of Edrington which has been calibrated to gauge data using the modelled time steps. This calibration process is discussed in the Edrington Flood Study Report (Cardno 2019). The data for continuing loss is based on rainfall data recorded at 6 minute intervals, and as such the loss rates are compatible with the RORB model minimum timestep.

As per the procedures of ARR2019, continuing loss rates from a nearby gauged catchment should be relied upon in preference to those from statistical methods contained within the ARR data hub. Given that Ti Tree Creek is a more urbanised catchment area, the adoption of a continuous loss of 2.5mm/hr is in keeping with this guidance.

3.7.1.4 Pre-burst rainfalls

Pre-burst rainfalls have not been applied as the losses. The preburst loss can be applied as a reduction in the initial loss or through RORB's preburst module and both of these methods have been tested to verify the exclusion of preburst losses in Ti Tree Creek.

The critical durations for the Ti Tree Creek catchment range from 20 minutes to 12 hours. For critical durations of 12 hours at the end of the catchment, the 1% AEP median preburst loss as provided ARR Data Hub (12/02/2019) is 5.4mm as shown in Table 3-3.

Table 3-3 Median Preburst depths obtained from Australian Rainfall & Runoff Data Hub (12/02/2019)

%AEP		50		20		10		5		2		1	
Duration (min)	Duration (hr)	Depth (mm)	Ratio (%)	Depth (mm)	Ratio (%)	Depth (mm)	Ratio (%)	Depth (mm)	Ratio (%)	Depth (mm)	Ratio (%)	Depth (mm)	Ratio (%)
60	1	3.5	20	2.8	12	2.3	8	1.8	6	1.5	4	1.3	3
90	1.5	3.6	18	2.8	10	2.2	7	1.7	5	1.9	4	2	4
120	2	2.3	11	2.5	8	2.6	7	2.7	7	2	4	1.5	3
180	3	3.9	15	3.5	10	3.3	8	3	7	2.8	5	2.7	5
360	6	2.9	9	3.1	7	3.3	7	3.5	6	4.4	7	5.1	7
720	12	0.4	1	1.2	2	1.6	3	2.1	3	4	5	5.4	6
1080	18	0	0	0.6	1	0.9	1	1.3	2	1.6	2	1.9	2
1440	24	0	0	0.1	0	0.2	0	0.2	0	0.6	1	0.8	1
2160	36	0	0	0	0	0	0	0	0	0	0	0	0
2880	48	0	0	0	0	0	0	0	0	0	0	0	0
4320	72	0	0	0	0	0	0	0	0	0	0	0	0

In effective impervious areas, comprising about 42% of the upstream catchment area, ARR2019 recommends an initial loss of 1mm. RORB modelling adopts a 0mm initial loss for these areas, catering for the full value of the pre-burst loss. The remaining areas have been modelled as indirectly connected areas adopting an initial loss rate that is 70% of the regional value from ARR2019. ARR2019 recommends that value of between 60 and 80% regional loss rate. We have adopted the 70% value. This equates to a loss of 18.9mm. The range of appropriate initial loss rates is between 16.2mm and 21.6mm. Including the pre-burst

loss would have the effect of reducing the expected initial loss range in the 1% AEP for the 12-hour critical storm to 10.8 to 16.2 mm.

For the reduction in initial loss method, no additional rainfall has been included prior to the start of the burst rainfall, whereas the RORB preburst module applies rainfall in a single increment before the design storm.

Sensitivity analysis was therefore conducted to assess the impacts of applying a reduced initial loss of 13.5mm/h and 16.2mm/h in order to satisfy this range. As shown in Figure 3-1, the adoption of a reduced initial loss produced a 1.1% increase and 0.75% reduction in peak flow for initial losses of 13.5mm/h and 16.2mm/h, respectively. Applying the median preburst losses from ARR data hub in RORB resulted in a 5.9% increase in peak flow.

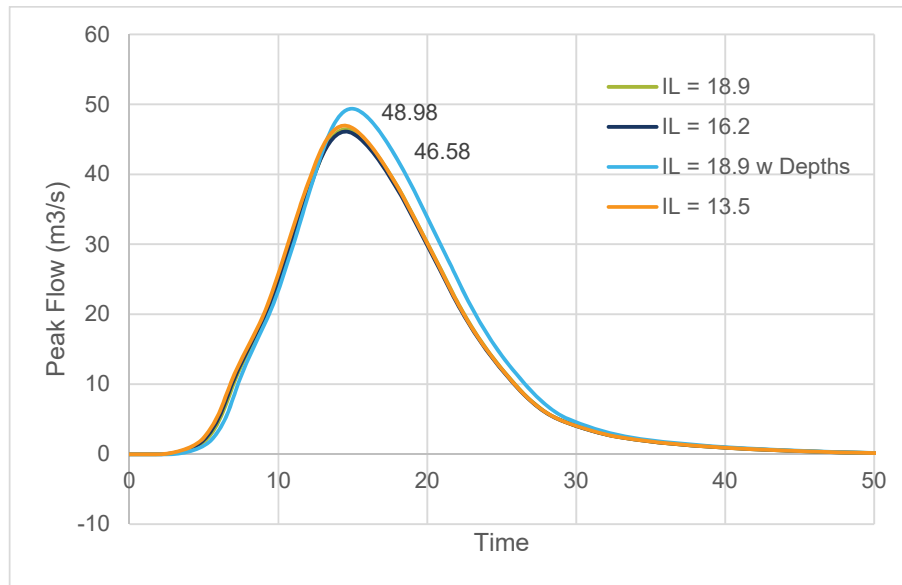


Figure 3-1 Comparison of initial losses and preburst depths for 1% AEP 12-hour with temporal pattern 26

The range of maximum flow values for the 12-hour duration are illustrated in Figure 3-2. The adopted initial loss of 18.9mm/h produces a peak flow within a reasonable margin of variation with the two methods of applying preburst losses. The relatively low sensitivity of the catchment to pre-burst loss is unlikely to have any significant impact on peak flow estimates, given that the catchment has a significant proportion of effective impervious areas. The adopted losses are, therefore, considered total storm losses which is inclusive of the pre-burst loss.

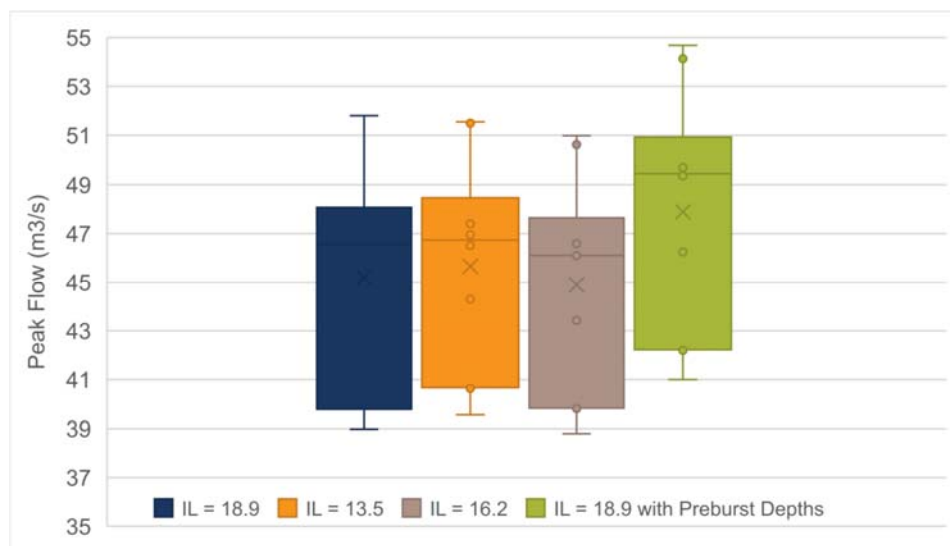


Figure 3-2 Comparison of peak flow ranges for 1% AEP 12-hour

3.7.1.5 Areal Reduction Factor (ARF)

The total catchment size of the Ti Tree Creek model is 33.68km². However, the average catchment discharging into Ti Tree Creek is actually less than 1 km².

The hydraulic model also incorporates inflows from major upstream sub-catchment discharging into Ti Tree Creek. In order to accurately represent these two major upstream inflows and estimate the critical duration and temporal patterns occurring at each of these major convergences, the RORB model was run with three different ARF values:

1. An ARF of 10 km² was used to assess the critical durations and temporal patterns at the convergence of the western and southern upstream catchments.
2. An ARF of 35km² was used to determine the end of model outflow.
3. An ARF of 1 km² was used to generate the inflows from each catchment within the hydraulic model boundary. The implication of selecting this value is that for flows along Ti Tree Creek and areas where the catchment is greater than 1km², results will be slightly conservative.

3.7.1.6 Rainfall Temporal Patterns

An ensemble of 10 temporal patterns was downloaded from the ARR data hub as shown in Appendix E. Given the catchment area does not exceed 75 km², areal temporal patterns were not required. Critical temporal patterns were determined by Monte Carlo Assessment in Section 3.7.4.2.

3.7.1.7 Rainfall Spatial Patterns

Three locations throughout the catchment were checked for spatial variance by comparing the respective rainfall depths against each other. The rainfall depths at all of these locations did not vary by more than 2% for the required rainfall events and therefore it was deemed that spatial variation has little impact on this study area. As such, no spatial variation was applied to rainfall.

See Appendix E for adopted IFD data at the centroid of the catchment.

3.7.1.8 Routing parameters

The *m* routing parameter has been set to 0.8 as per ARR guidance.

3.7.2 RORB Calibration

3.7.2.1 Gauge Analysis

There are no streamflow gauges within the catchment boundaries for the model. The closest gauges are the Cardinia Creek Gauge (228382A), approximately 1km east of the catchment and Hallam Valley Gauge (228231A), approximately 7.5km downstream of the study area. The Cardinia Creek Gauge has been utilised to calibrate the Edrington Park D.S model (Cardno Draft Deliverables 21/06/2019).

The gauge positioning can be seen in Figure 5 in Appendix A.

Given there are no gauges within the catchment area, recorded flows are unable to be used to calibrate the *k_c* value for the catchment.

3.7.2.2 *K_c* Analysis

To determine an appropriate *k_c* value for the catchment, several different *k_c* values were tested. These *k_c* values were either calculated within the following formulas (Table 3-4), or by using values from the previous MW RORB model by adjusting the *k_c/d_{av}* ratio. The subsequent catchment value was scaled to the catchment using a *d_{av}* value of 5.47.

A Monte-Carlo analysis was run for each *k_c* value, with the results being reported at 13 different locations across the Ti Tree Creek study area as illustrated in Figure 6 of Appendix A. The peak flows calculated for

each location, using each of these methods for the 20% and 1% AEP event are shown in Figure 3-3 and Figure 3-4, respectively.

Table 3-4 Equations used to calculate k_c

Method	Equation for k_c calculation
MAR > 800 mm (1986)	$k_c = 2.57 \times A^{0.45}$
MAR < 800 mm (1986)	$k_c = 0.49 \times A^{0.65}$
Pearse (2002)	$k_c = 1.25 \times d_{av}$
RORB Manual (1987)	$k_c = 2.2 \times A^{0.5}$
Dandenong Valley Authority (DVA)	$k_c = 1.53 \times A^{0.55}$

Table 3-5 Existing parameters used to derive k_c

Existing Model	Existing Model Parameters
Ti Tree Creek	$k_c=7$, $d_{av}=4.82$

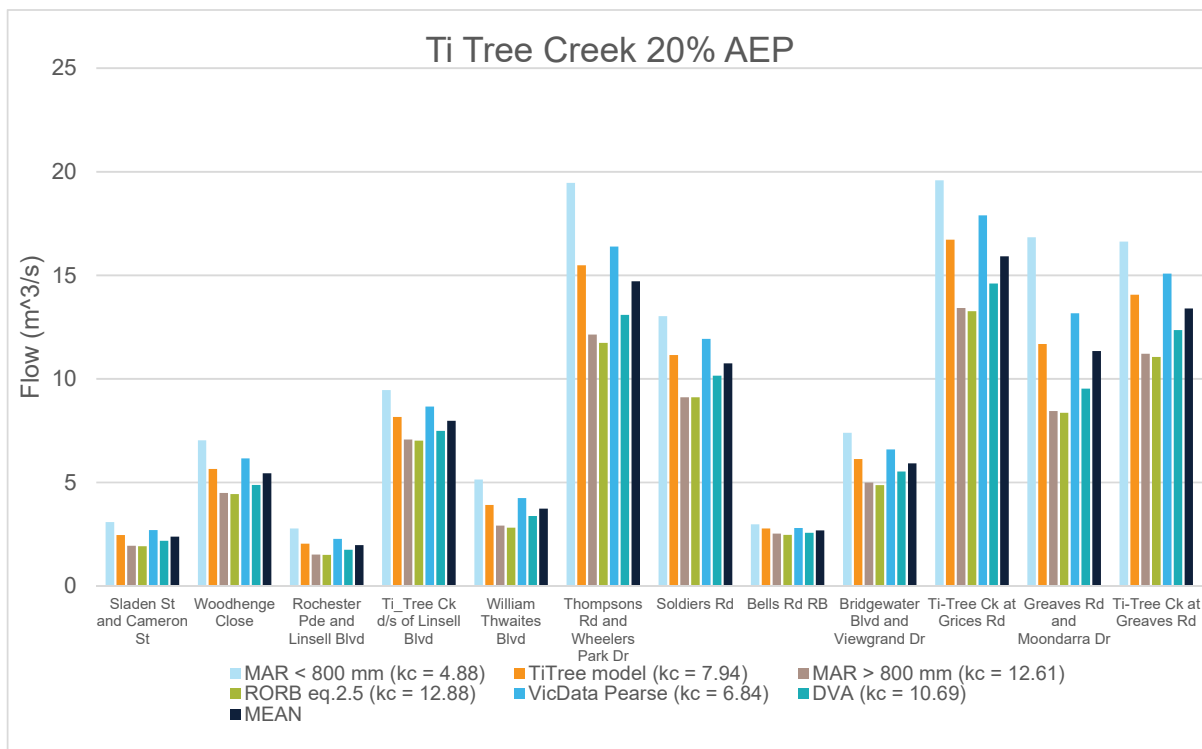


Figure 3-3 Kc Validation 20% AEP

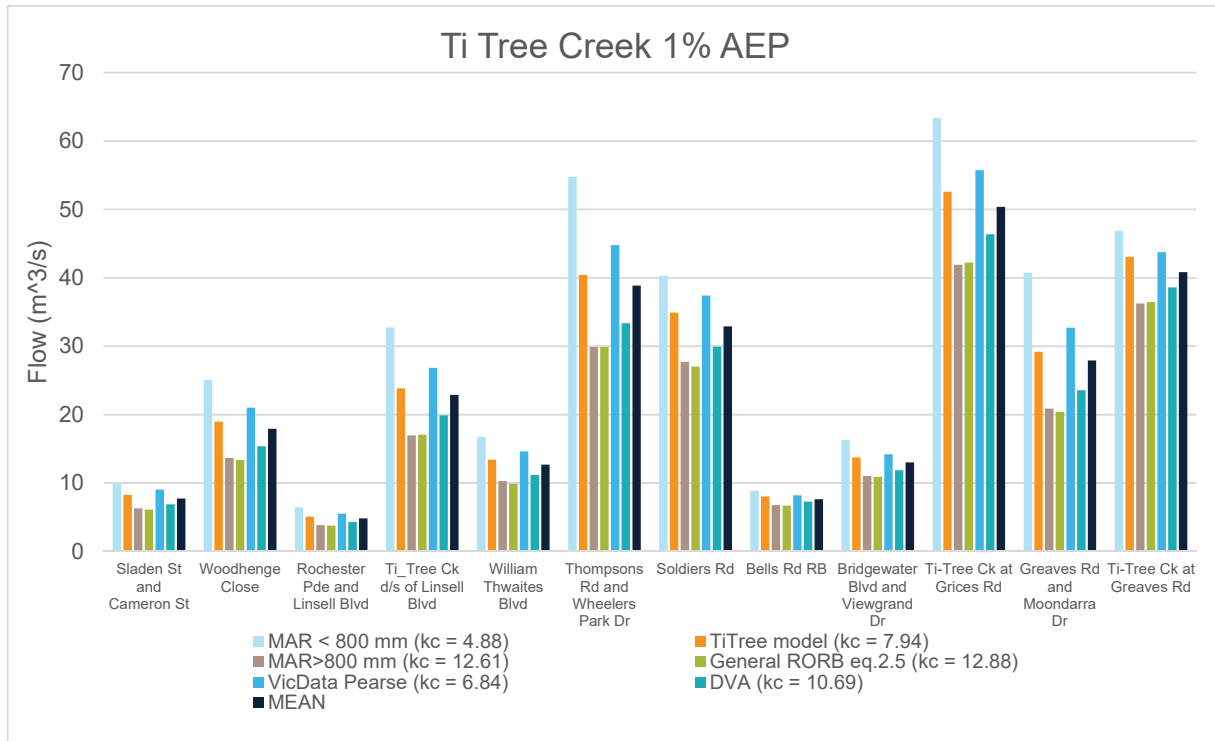


Figure 3-4 Kc Validation 1% AEP

From the figures above, the scaled kc value determined from the previous model gave the closest match to the mean of all the methods. Without any reliable gauges to calibrate the kc, a value of 7.94 was therefore adopted based on the previous model.

3.7.3 Determination of Design Flow Events

A probabilistic (Monte Carlo) assessment was completed to determine the design flow events. This methodology includes:

- > Undertaking multiple runs, using parameters, while sampling from the defined temporal patterns
- > Undertaking 2,500 runs for each duration storm
- > Extracting the average or median design event for each duration and locations, using statistics to derive the appropriate flood frequency curve
- > Specifying the critical duration at strategically chosen locations within the RORB model and outlining the rainfall temporal pattern that can reproduce the flood event

This methodology is a more efficient, more defensible and robust approach for deriving the appropriate flood frequency curve (and hence appropriate design events) for the catchment. It is also reproducible, as the sampling size is suitably large to reduce the uncertainty in the derived flood frequency curve.

The process described above was undertaken for 13 strategically chosen locations throughout the catchment, as shown in Figure 6 of Appendix A. These locations were chosen throughout the catchment, in order to capture sub-area variances. It is especially important to select a wide range of locations, representing upper areas (likely to have shorter critical durations) and main branch flow areas, as well as areas of differing fraction imperviousness.

3.7.4 Monte Carlo Assessment Methodology

The Monte Carlo approach was undertaken using the following steps:

- > ARR parameters were downloaded from the Data Hub including, temporal patterns, aerial reduction factors and rainfall pre-burst information
- > BoM IFD parameters (2016 version) were also downloaded
- > Monte Carlo analysis was run using k_c , m and fixed losses as derived by the ARR data hub and using the methodology described above

The Monte Carlo assessment was run using the MC analysis module in RORB. The module divides the rainfall distribution into 50 discretised intervals and runs 50 samples from each interval. This results in a total of 2,500 runs per storm duration. The flood frequency curve is then derived using exceedance probability calculations based on the total probability theorem.

An example of the outputs from the runs undertaken for a set of rainfall is shown in Figure 3-5. This shows a wide range of flood hydrographs at a specific location depending on the parameters adopted including rainfall temporal pattern selected and/or loss rates. From this sample, a distribution of likely hydrograph peaks can be assessed and an expected peak flow rate assigned to the flood probability. This is shown as the red distribution in Figure 3-5.

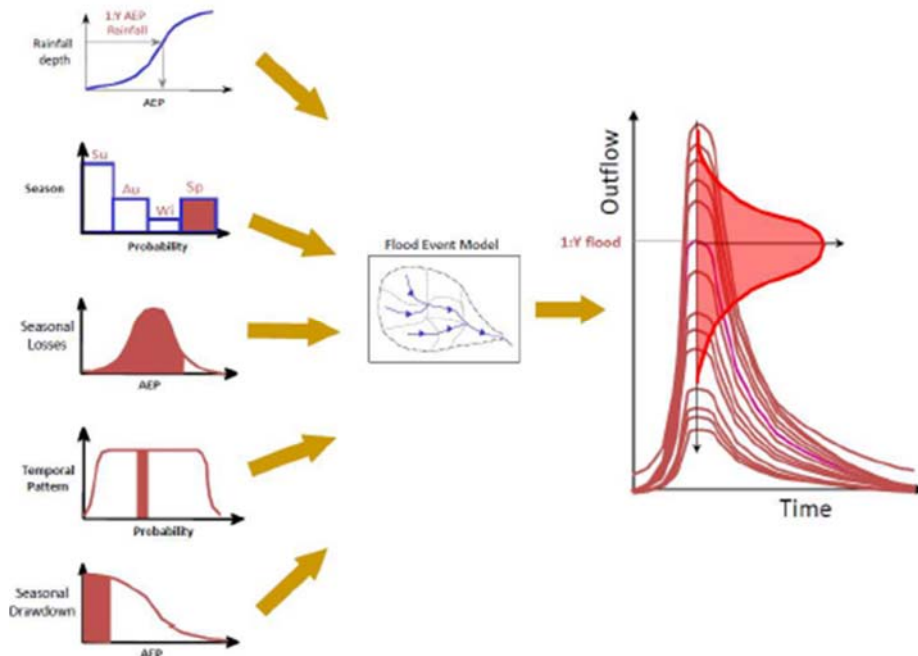


Figure 3-5 Example Monte Carlo Input Sampling (HARC, 2016)

The example above shows the assessment for a given location and expected rainfall probability. This approach can be extended across the full range of the rainfall frequency curve by breaking the curve down into intervals (in this case 50 intervals) and sampling a number of times from each interval. This result is an estimate of the distribution of the peak flow for each rainfall interval. Taking the expected peak flow for each interval yields the flood frequency curve. This curve can then be used to derive the appropriate selection of design flood events to represent the expected behaviour of the system. Figure 3-6 shows the flood frequency derivation process.

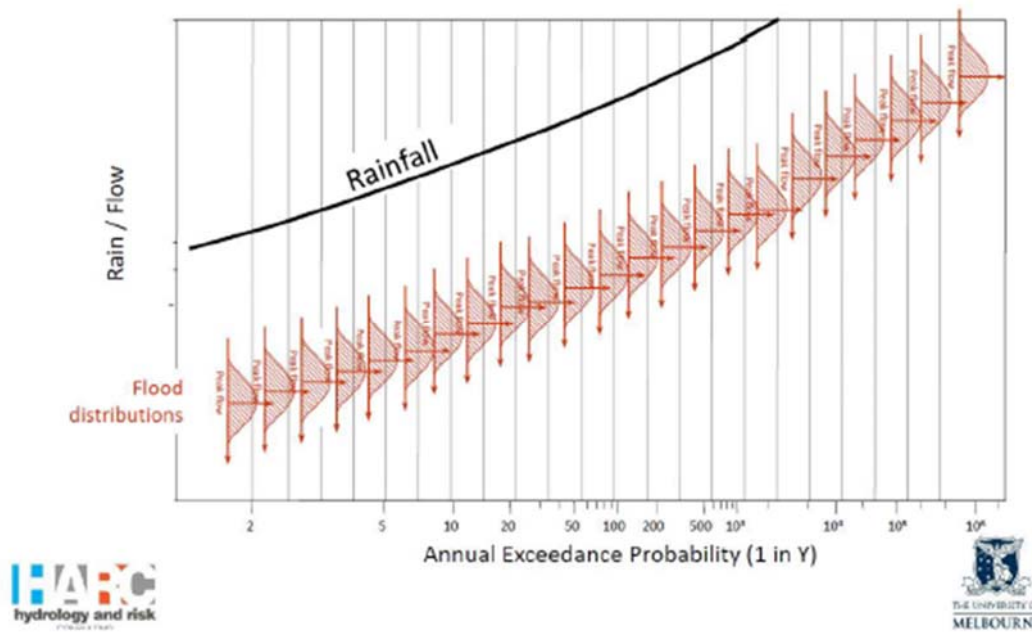


Figure 3-6 Deriving the Flood Frequency Curve (HARC, 2016)

3.7.4.2 Critical Storm Events and Associated Temporal Patterns

Using the above methodology, critical storm events (and associated temporal patterns) were identified for the catchment. These are shown in Table 3-6. These were extracted using the Monte Carlo module of RORB which derives the expected flood frequency curve for each identified location and provides a corresponding peak flow rate. Figure 3-7 shows an example of the RORB Monte Carlo output.

Summary of Runs for Critical Duration Analysis

Peak 01: Calculated hydrograph, Cardinia Creek Inflow																					
Run	AEF (1/T)	10 min	15 min	20 min	25 min	30 min	45 min	1 hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour	18 hour	24 hour	30 hour	36 hour	Maximum	Territ
1	2	4.77	5.43	5.59	5.87	6.44	5.69	5.55	5.79	6.16	6.08	11.56	11.75	13.23	0.51	3.27	1.69	1.17	0.79	13.229	9 hour
2	5	7.23	8.31	8.92	9.08	10.09	10.22	13.38	16.90	19.12	22.74	28.77	32.43	34.15	31.83	22.23	18.59	12.41	13.86	34.147	9 hour
3	10	9.06	10.76	12.05	14.41	14.35	17.09	21.64	27.05	33.77	39.75	47.66	49.82	52.09	49.04	37.17	29.30	22.05	28.28	52.091	9 hour
4	20	10.92	15.14	17.35	19.16	20.52	26.66	31.92	42.97	50.57	55.96	66.35	69.59	71.58	64.74	55.20	43.42	35.75	44.76	71.551	9 hour
5	50	16.49	23.90	26.85	27.53	31.40	44.63	50.50	64.66	73.52	82.82	92.61	97.82	97.75	102.62	79.87	74.78	61.31	69.17	102.619	12 hour
6	100	22.85	30.17	33.98	41.23	47.55	61.66	68.99	87.54	91.45	106.65	119.56	122.53	126.45	128.51	108.90	97.45	82.65	85.57	126.446	9 hour
7	200	29.82	39.04	49.95	58.97	67.08	83.27	93.61	109.42	121.37	135.39	152.43	157.28	163.20	167.04	132.59	127.70	109.44	126.78	167.059	12 hour
8	500	39.56	56.53	72.68	85.70	94.85	115.73	127.75	146.65	160.02	181.44	201.95	210.76	213.95	216.11	160.34	146.73	150.08	173.92	216.108	12 hour
9	1000	49.79	73.49	93.39	107.88	120.25	141.87	157.44	179.53	196.42	219.87	246.54	258.22	253.87	260.20	215.81	201.90	185.87	224.44	260.199	12 hour
Peak 02: Calculated hydrograph, Manuka Road																					
Run	AEF (1/T)	10 min	15 min	20 min	25 min	30 min	45 min	1 hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour	18 hour	24 hour	30 hour	36 hour	Maximum	Territ
1	2	1.87	1.87	1.99	1.82	1.88	1.73	1.71	1.40	1.34	0.83	0.70	0.49	0.82	0.42	0.23	0.20	0.18	0.14	1.993	20 min
2	5	2.33	2.81	3.10	3.00	3.01	2.85	3.06	2.75	2.15	1.40	1.12	1.10	0.74	0.70	0.40	0.41	0.31	0.33	3.097	20 min
3	10	2.89	3.51	3.76	4.11	3.89	3.87	3.69	3.61	2.83	2.01	1.58	1.41	0.91	0.95	0.61	0.45	0.39	0.46	4.113	25 min
4	20	3.41	4.73	5.02	4.97	5.04	4.67	4.19	4.28	3.47	2.40	1.97	1.70	1.18	1.12	0.74	0.57	0.46	0.58	5.042	30 min
5	50	4.72	6.31	6.87	6.84	6.19	5.63	4.85	5.71	5.31	3.85	3.45	3.20	1.84	1.54	0.85	0.68	0.57	0.73	6.871	20 min
6	100	6.02	7.66	8.03	7.20	7.16	6.23	5.59	6.25	6.23	3.22	2.85	2.62	2.10	1.85	0.96	1.08	0.70	0.83	8.032	20 min
7	200	7.87	9.21	9.43	8.58	8.48	7.03	6.44	6.69	6.91	3.94	3.18	3.21	2.57	2.11	1.16	1.25	0.88	0.94	9.431	20 min
8	500	10.28	11.33	11.54	10.78	10.31	8.54	7.99	7.35	7.45	4.55	3.48	3.84	3.14	2.49	1.44	1.55	1.04	1.20	11.554	20 min
9	1000	12.32	13.14	13.28	12.43	11.85	9.94	9.11	7.90	8.95	5.27	4.25	4.50	3.59	2.84	1.71	1.79	1.23	1.51	13.278	20 min
Peak 03: Calculated hydrograph, Bryn Haver Blvd																					
Run	AEF (1/T)	10 min	15 min	20 min	25 min	30 min	45 min	1 hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour	18 hour	24 hour	30 hour	36 hour	Maximum	Territ
1	2	0.54	0.67	0.69	0.70	0.71	0.73	0.76	0.80	0.83	0.84	0.84	0.82	0.81	0.74	0.54	0.42	0.35	0.29	0.842	3 hour
2	5	0.70	0.73	0.75	0.77	0.81	0.88	0.94	0.98	1.00	1.01	0.99	0.98	0.96	0.93	0.86	0.80	0.64	0.71	1.009	3 hour
3	10	0.73	0.77	0.84	0.89	0.92	1.00	1.05	1.10	1.13	1.12	1.12	1.10	1.07	1.02	0.95	0.87	0.63	0.88	1.120	2 hour
4	20	0.77	0.87	0.94	0.98	1.03	1.11	1.15	1.20	1.23	1.23	1.24	1.21	1.17	1.12	1.04	0.94	0.50	0.98	1.239	4.5 hour
5	50	0.86	0.99	1.07	1.12	1.16	1.24	1.32	1.37	1.35	1.38	1.39	1.33	1.30	1.30	1.14	1.11	1.02	1.10	1.356	4.5 hour
6	100	0.94	1.09	1.16	1.22	1.26	1.33	1.37	1.42	1.44	1.45	1.45	1.32	1.45	1.47	1.27	1.22	1.16	1.21	1.796	4.5 hour
7	200	1.04	1.19	1.23	1.33	1.37	1.44	1.48	1.53	1.46	1.47	1.44	1.25	1.45	1.40	1.26	1.20	1.25	1.471	3 hour	
8	500	1.17	1.32	1.41	1.52	1.59	1.69	1.72	1.74	1.49	1.41	1.32	1.09	1.28	1.24	1.01	1.01	1.51	1.75	3.485	2 hour
9	1000	1.26	1.42	1.49	1.67	1.74	1.84	1.88	1.94	1.77	1.74	1.67	1.34	1.44	1.39	1.27	1.24	1.88	2.29	3.749	2 hour

Figure 3-7 Example RORB Monte Carlo Output

Table 3-6 Critical Storm Durations and Temporal Patterns for Hydrological and Hydraulic Model Runs

Event AEP (%)	Critical Durations	Temporal Patterns
20	30	6
	60	4,5,8
	90	3,6
	120	9
	180	5
	270	2,5
	720	5
	1080	5
10	30	13
	45	19
	60	16,19
	90	14,15
	120	17
	180	16
	540	12
	720	20
	1080	20
5	30	13
	45	19
	90	13,14,15
	120	19
	180	15,17
	540	15
	720	20
	1080	20
2	20	26
	45	26
	60	29
	90	27,29
	120	28
	180	28
	720	26,29
	1080	26, 29
1	20	26
	30	25,26
	45	27
	60	27,28
	120	28
	180	28
	720	22,26
	1080	22, 26
20 (Climate Change)	30	6
	60	4,5,6
	90	6,7

Event AEP (%)	Critical Durations	Temporal Patterns
	180	5
	270	2,5
	540	6
	720	4
	1080	4
10 (Climate Change)	25	16
	45	16
	60	16
	90	13,14,15,18
	120	19
	180	16
	540	15
	720	12
	1080	12
1 (Climate Change)	20	26,27
	30	25
	45	27
	60	23,27
	120	27
	180	28
	720	21
	1080	21

4 Hydraulic Modelling

A 1D/2D hydraulic model was developed for the Ti Tree Creek catchment. This type of model allows for dynamic links between the overland flow and pipe components based on the capacity of the drainage system. As such, once the drainage system is exceeded, the resultant overland flow patterns are determined by the two-dimensional hydraulic model. TUFLOW 2D and ESTRY 1D hydraulic models (version 2018-03-AD\TUFLOW_iDP_w64.exe) were used as per the requirements of the Melbourne Water Guidelines and Technical Specifications.

The setup of the hydraulic model has been illustrated in Figure 7 of Appendix A.

Key components to the model include:

- > The Ti Tree Creek D.S Drain, which runs through the centre of the catchment and attenuates flow through an extensive series of linear retarding basins, wetlands and lakes
- > O'Sheas Rd D.S. Drain converges with Ti Tree Creek D.S Drain at the downstream boundary, where flows meet Hallam Valley Drain

4.1 Overview

The model elements and inputs are summarised in Table 4-1.

Table 4-1 Hydraulic Model Input Summary

Element / Input	Description
Overland Flow Paths	These have been represented as 2D elements in the model. Water flows in the 2D elements, according to the hydraulic properties of the land surface, as defined by the 2D grid topography and roughness. The DEM was based on 2017 LiDAR data (refer Section 2.2). Figure 7 in Appendix A shows the 2D model topography used. A 3-meter grid cell size was adopted throughout in order to accurately represent the creek channels. Ridge lines (along embankments) and gully lines (along drainage channel) were utilised to ensure that the sampled DEM adequately represented these features. The 2D floodplain hydraulic roughness was determined using property data, planning zones and aerial photography, with the Manning's 'n' values being consistent with the Melbourne Water Guidelines and Technical Specifications. The modelled roughness categories and associated values are shown in Figure 8 in Appendix A.
Underground Drainage Network	All Council and MW pipes have been modelled explicitly as 1D elements in the model. The data integrity checks and infill of the pipe data is discussed in Section 4.2. As the lined pipe/channel network condition is unknown, a conservative roughness manning's 'n' value of 0.015 was selected. The typical 'n' value for concrete pipes in good condition is 0.011 (Chow, 1973). It was assumed that the pits were of sufficient capacity to fill the pipes (i.e. the pipes were the limiting factor not the pits). As such, "R" type pits were used with a large capacity to transfer water between the 1d and 2d domain. Furthermore, no pit losses were applied.
Upstream Boundary Conditions	Storm inputs for the design events have been introduced directly to the 1D pipe network. The hydrographs derived from the RORB model, have been evenly distributed between all the pits, within each sub-catchment.

Element / Input	Description
	Due to the low level of development within some sub-catchments, it was not possible to introduce the rainfall directly to the 1D pipe network. Therefore, each sub-catchment was individually assessed as to whether it had enough pits and that they were adequately distributed throughout the catchment to accurately distribute the flows using a 1d_bc layer. In areas where it was deemed that there were an inadequate distribution/number of pits, the hydrographs were evenly distributed across the sub-catchments using a 2d_sa (ALL) layer. The events simulated are discussed in Section 4.5.
Excess Rainfall	Excess Rainfall was translated from RORB hydrological outputs to TUFLOW inflows (m ³ /s). Excess Rainfall was distributed evenly to all pits in 69 sub-catchments, where it was determined there were enough pits to evenly distribute the excess rainfall. There were 17 sub-catchments which either did not contain pits or contained very few pits. For these sub-catchments, excess rainfall was distributed to all cells within the subarea.
Downstream Boundary Conditions	A 1% slope downstream boundary condition was applied at the Hallam Valley Drain outflow location as requested by MW (2018/2019). Additional 1% slope boundaries were included where glasswalling was occurring in draft model runs. The model was extended a significant distance downstream of the study area so that this boundary condition does not influence the results within the area of interest. Cardno are therefore confident that this will provide accurate flood results at the downstream end of the study area.
Upstream Inflows	There were no direct upstream inflows applied to the model. Excess rainfall inflows were derived from the RORB model as stated above. The 17 distributed rainfall sub-catchments are indicated in Figure 9 of Appendix A.

4.2 Pipe Infilling

As mentioned in the Data Review Report (dated 24/01/19), a significant amount of received pipe data had missing inverts and diameters. The diameters and inverts of these pipes were therefore, needed to be estimated. Additionally, some inverts provided in the dataset were altered to facilitate model running, as they were likely incorrectly input into the GIS dataset.

Further areas of discrepancy were detected between pipe inverts and surface levels, particularly in areas that have recently changed due to development. Despite pipe inverts potentially being correct, they needed altering, so as not to break the surface and allow the model to run.

Pipes which were originally supplied without inverts or sizes, were primarily infilled from design plans that were received from Council once these pipes were identified. Where Council were not able to provide design plans, engineering judgment was used. Unknown diameters were infilled based on surrounding diameters and location of the pipe. Unknown inverts were estimated by subtracting the diameter and 600mm cover from ground surface levels. Thereafter, they were matched in with surrounding pipe inverts to ensure a realistic pipe network, and so all pipes were able to flow downhill.

4.3 Pit Sizing

Pits were located in the model according to Melbourne Water and Council data, as outlined in the Data Review Report (dated 24/01/19). Additional pits added where connections should be, but have not been

present in data received. This was usually the case where a Council network was connected to a Melbourne Water pipe but there was no pit located in the Melbourne Water dataset. In these instances, the Melbourne Water pipe was split and a junction pit added to enable a connection.

The following assumptions have been made regarding the modelled pits:

- Pits were assumed to be rectangular (R), with height and width equal to 1m
- Pit inverts were assumed to be the bottom of the pipe invert
- Pits have been modelled as 2D sx connections.
- Entry losses are equal to 0.5.
- Exit losses are equal to 1.

The above attributes were applied in order to align with the overall assumption that the pits were of sufficient capacity to fill the pipes (i.e. the pipes were the limiting factor not the pits) as further discussed above in Table 4-1.

4.4 Layered Flow Constriction Shapes

Based on our experience of modelling urban pipe networks, we typically include large culverts and bridges within the 2d domain as layered flow constriction shapes (lfcsh). The main reason for this is that we have found that they are less prone to causing instabilities and erroneous flow values than their 1d counterparts. In order to use lfcsh files, various blockage and flow constriction factors are required for each layer (i.e. below the soffit, the bridge deck itself and railings above the bridge deck). These values were all estimated using the following (depending on availability):

- > Design drawings
- > Measurements from the site visit
- > Site visit photos
- > Aerial photos
- > Google Street View photos

Furthermore, all flow constriction factor values were calculated using the methodologies outlined in Hydraulics of Bridge Waterways (1978).

All attributes used in the estimation of blockage and flow constriction factors can be found in Appendix C.

4.5 Storm Events Modelled

4.5.1 Average Recurrence Intervals and Scenarios

The rainfall events to be modelled by the completion of the project are outlined in Table 4-2, with Table 3-6 in Section 3.7.4.2 identifying the critical durations and temporal patterns selected for each event. The 1% and 20% Base Case scenarios have been modelled for the draft deliverable phase.

Table 4-2 Events Modelled

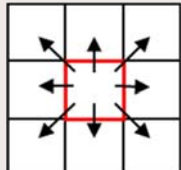
	Event AEP							Key drivers for models
	20%	10%	5%	2%	1%	0.5%	0.2%	
A Base Case	√	√	√	√	√			Hydraulic modelling results required for provisions of land development advice ¹ , Planning Scheme amendments ² , updating of parcel encumbrances ² and assessment of flood risk ¹ .
D Climate Change 3 – Increase Rainfall Intensity	√	√			√			Hydraulic modelling required to gain an understanding of catchment sensitivity to increased rainfall intensities.
1. All AEP events utilised 2. 1% AEP event is the key focus								

5 Hydraulic Modelling and Results

5.1 Results Processing

Flood modelling raw outputs were processed using the methodology outlined in Table 5-1.

Table 5-1 Result Processing Methodology

Process	Description
Depth filtering	Consistent with the most recent Melbourne Water technical specifications, results were filtered to <u>remove</u> any cells where the depth of flooding (D) is less than 0.05 m
Area filtering	An area filter was applied to remove isolated 'wet puddles' or 'dry islands' from the flood extent and provide a more cohesive shape. The area threshold was 100 m², as recommended in the MW technical specifications. In assessing the area of wet puddles or dry islands, it was assumed that diagonal connections constituted a connection. The schematic below shows all cells considered as neighbours and includes diagonal connections. 
Smoothing	To remove the staircase effect from the edge of the flood extent, the shape was smoothed using a process developed by Cardno and approved by Melbourne Water. This is the final step in the generation of the flood extent.
Provide grid results of the flood extent	The grid cells, which remain within the smoothed flood extent, are extracted to provide a dataset of flood modelling results.

5.2 Results Figures

Results have been presented in the following figures:

- > Figure 10 Base Case 20% AEP in Appendix A; Maximum Flood Depth (Scenario A)
- > Figure 11 Base Case 1% AEP in Appendix A, Maximum Flood Depth (Scenario A)

5.3 Results and Findings

Flooding in the 1% AEP event is largely contained within the road reserves, along drainage easements and Ti Tree Creek, as well as throughout major storages within the catchment, such as the large retarding basin and wetland on Greaves Road.

Peak flood depths between 3.68m and 3.48m are occurring at the Greaves Rd retarding basin outlet. Flood depths exceeding 3m are occurring at the following road crossings:

- > Flood depths of between 3.01m and 3.24m are occurring at the Glasscocks Rd crossing
- > Flood depths of approximately 3.33m are occurring beneath the Broad Oak Dr Bridge that crosses the Broad Oak Wetlands
- > Flood depths of between 3.04 and 3.41m are occurring at the Homestead Rd crossing inlet pit

Flooding is also occurring in private properties, where flooding is not contained within the road reserve and where properties lie within an overland flow path. Private properties inundated in the 1% AEP event are located at:

- > The residential area surrounding Greaves Rd Retarding Basin
- > Stanhope Ave
- > Ridgemont Dr
- > The residential area surrounding Hunt Club Wetlands
- > The residential area surrounding Broad Oak Wetlands
- > Donohue St
- > The residential area either side of Oshea Rd, particularly Balanka Ct, Bridgewater Blvd and Northdate Dr
- > The residential area along Albrecht Ave and Barton Mews
- > Edgbaston Cirt
- > Homestead Rd
- > Kelburn Rd
- > The residential area north of Kangan Dr

A relatively large area of undeveloped and developing land in the centre of the catchment is experiencing inundation in the 1% AEP event. The Clyde Road Reserve and Cranbourne East School properties are also experiencing substantial flooding, which may affect buildings. Farm land inundation is predominantly concentrated on the eastern side of Pound Rd and upstream of Thompsons Rd.

Similarly, in the 20% AEP event, inundation occurs in the undeveloped and developing land in the centre of the catchment, as well as north of Kangan Dr, Albrecht Ave, Edgbaston Cirt, Homestead Rd and the areas surrounding Hunt Club and Broad Oak Wetlands. The urban pipe network appears to convey the remainder of the flow in the 20% event.

5.4 Model Instabilities

After all model runs were completed, model instabilities (negative depths) were occurring at one location within the 2D domain.

A typical reason why the instabilities occur include:

- > Steep/Poor Topography – In steep areas the Courant number can be exceeded. Solutions can include reducing the time step and/or the grid size

The instabilities have been assessed, with none deemed to be adversely affecting model results. These instabilities occur at the Greaves Rd Retarding Basin outlet and the culvert crossing at Homestead Rd. As negative depths occurred at only two locations due to topography it was not deemed appropriate to either reduce the grid cell size or the time step.

No model run had a cumulative mass balance error that exceeded 0.61%.

5.5 Sensitivity Analysis

At the request of Melbourne Water two separate sensitivity analysis have been undertaken, which are outlined in the section below:

5.5.1 Blockage Sensitivity Analysis

A blockage assessment was undertaken for the catchment as outlined in ARR2019 Book 6 section 6.4.4 in order to gauge whether a blockage sensitivity model run was required. This risk assessment outlined in Table 5-2 below.

Table 5-2 Blockage Assessment

Analysis Type	Analyst Comment	Recommend Blockage Scenario Adopted (Yes/No)
Urban Pipe Network	Urban pipe network consists largely of assets that have relatively shallow slopes: -Slopes range from 0% (flat) to 80% -Average and median pipe slopes are 1.8% and 1.0% respectively	No
	Flat pipes are predominately large diameter culverts under roads with limited chance of blockage	
	Urban catchment largely consists of recently developed and currently under development urban residential areas with limited ability to generate sediment loaded runoff that could cause blockage.	
	Considering that the urban areas are relatively newly developed, it is expected that they would have limited chance of blockage. Therefore, it is recommended that a blockage scenario is not required	
Major Waterway Crossings	The catchments of the upper sections of Ti Tree Creek mainly contain some recently developed residential areas and open grassland and therefore are likely not to generate enough debris to cause blockage of crossings. The only crossing to seriously consider would be at Thompsons but water already significantly overtops the road in the 100yr event and so blocking the pipe will likely not cause much difference to the flood behavior.	No
	The upper sections of Cardinia Creek (Lower) contain a number of large crossings at regular intervals. Furthermore, the catchment mainly contains recently developed residential areas and farmland and therefore is likely not to generate enough debris to cause blockage of crossings.	

As the table above suggests, the risk assessment identified that there were no blockage scenarios required for the Ti Tree Creek study area.

5.5.2 HPC Sensitivity Analysis

A sensitivity analysis was also undertaken using TUFLOW HPC (Heavily Parallelised Compute). This was undertaken in order to assist Melbourne Water in their assessments of the benefits of adopting TUFLOW HPC for future studies.

Due to differences between the solvers used for TUFLOW classic and HPC, the number of HQ boundaries were reduced to allow the HPC model to run.

The only other change undertaken to the TUFLOW model was updating the solver from TUFLOW Classic to TUFLOW HPC.

The 1% and 20% AEP events produced the greatest number of critical depths and were, therefore, selected for this analysis. These events were:

- > 1% AEP 720 Minute 26 Temporal Pattern
- > 20% AEP 720 Minute 7 Temporal Pattern

The sensitivity analysis identified that TUFLOW HPC produced significantly different results in limited areas, than those produced by TUFLOW Classic within the study area as shown in Appendix D. Table 5-3 outlines the key changes in flooded area and flood depths between TUFLOW Classic and TUFLOW HPC in the 1% AEP event.

Table 5-3 Key Criteria Differences Between TUFLOW Classic and TUFLOW HPC in the 1% AEP event

Criteria	Result
Change in Flooded Area (%)	+1.74
Maximum Increase in Depth (m)	+0.57
Maximum Decrease in Depth (m)	-0.4
Average Change in Flood Depth (m)	+0.02
Median Change in Flood Depth (m)	+0.00

The causes of the limited areas with minor differences were found to be due to changes in the way HQ boundaries and surface water depths are calculated between TUFLOW Classic and TUFLOW HPC. In TUFLOW Classic the slope is averaged along the length of the boundary line, whereas within TUFLOW HPC the slope is calculated at each cell. When flow doesn't run exactly perpendicular to the boundary, TUFLOW HPC can sometimes artificially introduce flow into the model. Furthermore, the HPC solver can cause flow "bouncing" within deep channel sections when the flow direction is not aligned with the grid orientation.

To resolve the boundary issue, changes to the model would be required. These may include:

- > Changes to the location of the boundaries so that they run exactly perpendicular to direction of flow
- > Digitising shorter segments of HQ boundaries
- > Including the command "Boundary Viscosity Factor == 5" within the tcf file
- > Replacing the HQ boundary with another type (e.g. HT) if possible

However, it should be noted that none of the above potential changes are guaranteed to fix this issue and the channel orientation solver issue cannot be rectified at this time. It is worth noting that TUFLOW are in the process of developing a 2019 HPC solver to provide "channel edge smoothing" which they expect will mitigate these issues.

6 Deliverables

The final deliverables have been prepared for the 2016 Technical Specifications and 2018 Technical Specifications in Table 6-1 and Table 6-2, respectively.

Table 6-1 2016 Tech Specs Final Deliverables Summary

Deliverable	Location
A - Reports	
1 x PDF (Unlocked) Draft Report	A_Reports \V181917_F01_TiTreeCreek_FinalReport.pdf
1 x Microsoft Word (Unlocked) Draft Report	A_Reports \V181917_F01_TiTreeCreek_FinalReport.docx
B - Photographs, Figures and Plans	
Site Visit photos – as appropriate	B_Photographs_Figures_Plans
Figures or plans - as appropriate	B_Photographs_Figures_Plans
C- RORB Models (.catg) and Associated files	
IFD tables – Base case (2016 IFD design rainfalls)	C_RORB_Model\RORB_Rainfall_Files\ARR19
IFD tables – Climate Change 3	C_RORB_Model\RORB_Rainfall_Files\ARR19
Data Hub parameters – Base Case and Climate Change 3	C_RORB_Model\RORB_Rainfall_Files\ARR19
ARR87 IFD parameters	C_RORB_Model\RORB_Rainfall_Files\ARR87
ARR19 RORB Parameter Files	C_RORB_Model\RORB_Parameter_Files\ARR19
ARR87 RORB Parameter Files	C_RORB_Model\RORB_Parameter_Files\ARR87
ARR19 RORB Model Catg	C_RORB_Model\RORB_Catg\ARR19
ARR87 RORB Model Catg	C_RORB_Model\RORB_Catg\ARR87
ARR19 RORB Model Results	C_RORB_Model\RORB_Results\ARR19
ARR87 RORB Model Results	C_RORB_Model\RORB_Results\ARR87
RORB Storage Data	C_RORB_Model\RORB_Storages
Temporal Pattern Analysis – Base case (2016 IFD design rainfalls)	C_RORB_Model
Temporal Pattern Analysis – Climate Change 3	C_RORB_Model
D - TUFLOW Models	
Batch file that runs all AEPs and durations	D_TUFLOW_Models\runs
Check files	D_TUFLOW_Models\check
Model files	D_TUFLOW_Models\model
Inflow files	D_TUFLOW_Models\bcdbase
DTM Raster	D_TUFLOW_Models

Deliverable	Location
Digital Elevation Model (DEM) Raster	D_TUFLOW_Models
Scenario A Results (Base case) – 1% AEP to 20% AEP	D_TUFLOW_Models\results
Climate Change 3 Results – 1% AEP and 20% AEP	D_TUFLOW_Models\results
ARR87 Results – 1% AEP and 20% AEP	D_TUFLOW_Models\results
E - RORB Model MapInfo Tables	
Catchment boundary	E_RORB_Model_MapInfo_Tables\ARR19
ARR19 Subarea boundaries	E_RORB_Model_MapInfo_Tables\ARR19
ARR87 Subarea boundaries	E_RORB_Model_MapInfo_Tables\ARR87
Nodes	E_RORB_Model_MapInfo_Tables\ARR19
Reach alignments	E_RORB_Model_MapInfo_Tables\ARR19
F - MiRORB Tables	
Catchment boundary	F_MiRORB_Tables\ARR19
ARR19 Subarea boundaries	F_MiRORB_Tables\ARR19
ARR87 Subarea boundaries	F_MiRORB_Tables\ARR87
Nodes	F_MiRORB_Tables\ARR19
Reach alignments	F_MiRORB_Tables\ARR19
Storages	F_MiRORB_Tables\ARR19
Inflow / Outflow reaches	F_MiRORB_Tables\ARR19
Elevation layer	F_MiRORB_Tables\ARR19
ARR19 Impervious Fraction layer	F_MiRORB_Tables\ARR19
ARR87 Impervious Fraction layer	F_MiRORB_Tables\ARR87
RORB Settings file	F_MiRORB_Tables\ARR19
Print Locations	F_MiRORB_Tables\ARR19
G - Hydraulic Model 3 Metre Points MapInfo Tables	
Scenario A (Base case) – 1% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 2% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 5% AEP	G_Hydraulic_Model_DEM_Points\ARR19

Deliverable	Location
Scenario A (Base case) – 10% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 20% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario D (Climate Change 3) - 1% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario D (Climate Change 3) - 20% AEP	G_Hydraulic_Model_DEM_Points\ARR19
ARR87 – 1% AEP	G_Hydraulic_Model_DEM_Points\ARR87
ARR87 – 20% AEP	G_Hydraulic_Model_DEM_Points\ARR87
H- 2D Flow Values MapInfo Tables	
Scenario A (Base case) Flow Values	H_Flow_Values\ARR19
Scenario D (Climate Change 3) Flow Values	H_Flow_Values\ARR19
ARR87 Flow Values	H_Flow_Values\ARR87
I- 2D Flood Contours MapInfo Tables	
Scenario A (Base case) – 1% AEP	I_2D_Flood_Contours\ARR19
Scenario D (Climate Change 3) – 1% AEP	I_2D_Flood_Contours\ARR19
ARR87 – 1% AEP	I_2D_Flood_Contours\ARR87
J- 2D Model Flood Extent MapInfo Tables	
Scenario A (Base case) – 1% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 2% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 5% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 10% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 20% AEP	F_Flood_Extents\ARR19
Scenario D (Climate Change 3) - 1% AEP	F_Flood_Extents\ARR19
Scenario D (Climate Change 3) - 20% AEP	F_Flood_Extents\ARR19
ARR87 – 1% AEP	F_Flood_Extents\ARR87
ARR87 – 20% AEP	F_Flood_Extents\ARR87
K – Parcels Flooded MapInfo Tables	
Scenario A (Base case) – 1% AEP	K_Parcels_Flooded\ARR19
Scenario D (Climate Change 3) – 1% AEP	K_Parcels_Flooded\ARR19
ARR87 – 1% AEP	K_Parcels_Flooded\ARR87

Deliverable	Location
L – Building Footprints Flooded MapInfo Tables	
Scenario A (Base case) – 1% AEP	L_Building_Footprints_Flooded\ARR19
Scenario D (Climate Change 3) – 1% AEP	L_Building_Footprints_Flooded\ARR19
ARR87 – 1% AEP	L_Building_Footprints_Flooded\ARR87
M – Level of Service MapInfo Tables	
Scenario A (Base case)	M_Level_of_Service\ARR19
Scenario D (Climate Change 3)	M_Level_of_Service\ARR19
ARR87	M_Level_of_Service\ARR87
N – Safety Risk in Roads MapInfo Tables	
Scenario A (Base case) – 1% AEP	N_Safety_Risk_in_Roads\ARR19
Scenario D (Climate Change 3) – 1% AEP	N_Safety_Risk_in_Roads\ARR19
ARR87 – 1% AEP	N_Safety_Risk_in_Roads\ARR87
O – Unclipped Results (Raw and Processed) MapInfo Tables	
Scenario A (Base case) – 1% AEP	O_Unclipped_Results
Scenario A (Base case) – 2% AEP	O_Unclipped_Results
Scenario A (Base case) – 5% AEP	O_Unclipped_Results
Scenario A (Base case) – 10% AEP	O_Unclipped_Results
Scenario A (Base case) – 20% AEP	O_Unclipped_Results
Scenario D (Climate Change 3) - 1% AEP	O_Unclipped_Results
Scenario D (Climate Change 3) - 20% AEP	O_Unclipped_Results
ARR87 – 1% AEP	O_Unclipped_Results
ARR87 – 20% AEP	O_Unclipped_Results
P – Clipped Results (Processed) MapInfo Tables	
Scenario A (Base case) – 1% AEP	P_Clipped_Results
Scenario A (Base case) – 2% AEP	P_Clipped_Results
Scenario A (Base case) – 5% AEP	P_Clipped_Results
Scenario A (Base case) – 10% AEP	P_Clipped_Results
Scenario A (Base case) – 20% AEP	P_Clipped_Results

Deliverable	Location
Scenario D (Climate Change 3) - 1% AEP	P_Clipped_Results
Scenario D (Climate Change 3) - 20% AEP	P_Clipped_Results
ARR87 – 1% AEP	P_Clipped_Results
ARR87 – 20% AEP	P_Clipped_Results
Q – Flood Study Area MapInfo Tables	
Scenario A (Base case) – 1% AEP	Q_Flood_Study_Area\ARR19
Scenario D (Climate Change 3) – 1% AEP	Q_Flood_Study_Area\ARR19
ARR87 – 1% AEP	Q_Flood_Study_Area\ARR87
R – Quality Assurance Documentation	
Deliverable Checklist	R_QA_Documentation
Cardno QA Spreadsheet	R_QA_Documentation
Draft Deliverables Comment Register	R_QA_Documentation

Table 6-2 2018 Tech Specs Final Deliverables Summary

Deliverable	Location
A - Reports	
1 x PDF (Unlocked) Draft Report	A_Reports \V181917_F01_TiTreeCreek_FinalReport.pdf
1 x Microsoft Word (Unlocked) Draft Report	A_Reports \V181917_F01_TiTreeCreek_FinalReport.docx
B - Photographs, Figures and Plans	
Site Visit photos – as appropriate	B_Photographs_Figures_Plans
Figures or plans - as appropriate	B_Photographs_Figures_Plans
C- RORB Models (.catg) and Associated files	
IFD tables – Base case (2016 IFD design rainfalls)	C_RORB_Model\RORB_Rainfall_Files\ARR19
IFD tables – Climate Change 3	C_RORB_Model\RORB_Rainfall_Files\ARR19
Data Hub parameters – Base Case and Climate Change 3	C_RORB_Model\RORB_Rainfall_Files\ARR19
ARR87 IFD parameters	C_RORB_Model\RORB_Rainfall_Files\ARR87
ARR19 RORB Parameter Files	C_RORB_Model\RORB_Parameter_Files\ARR19
ARR87 RORB Parameter Files	C_RORB_Model\RORB_Parameter_Files\ARR87
ARR19 RORB Model Catg	C_RORB_Model\RORB_Catg\ARR19
ARR87 RORB Model Catg	C_RORB_Model\RORB_Catg\ARR87

Deliverable	Location
ARR19 RORB Model Results	C_RORB_Model\RORB_Results\ARR19
ARR87 RORB Model Results	C_RORB_Model\RORB_Results\ARR87
RORB Storage Data	C_RORB_Model\RORB_Storages
Temporal Pattern Analysis – Base case (2016 IFD design rainfalls)	C_RORB_Model
Temporal Pattern Analysis – Climate Change 3	C_RORB_Model
D - TUFLOW Models	
Batch file that runs all AEPs and durations	D_TUFLOW_Models\runs
Check files	D_TUFLOW_Models\check
Model files	D_TUFLOW_Models\model
Inflow files	D_TUFLOW_Models\bcdbase
DTM Raster	D_TUFLOW_Models
Digital Elevation Model (DEM) Raster	D_TUFLOW_Models
Scenario A Results (Base case) – 20% AEP to 1% AEP	D_TUFLOW_Models\results
Climate Change 3 Results – 1% AEP, 10% AEP and 20% AEP	D_TUFLOW_Models\results
ARR87 Results – 1% AEP and 20% AEP	D_TUFLOW_Models\results
E - RORB Model MapInfo Tables	
Catchment boundary	E_RORB_Model_MapInfo_Tables\ARR19
ARR19 Subarea boundaries	E_RORB_Model_MapInfo_Tables\ARR19
ARR87 Subarea boundaries	E_RORB_Model_MapInfo_Tables\ARR87
Nodes	E_RORB_Model_MapInfo_Tables\ARR19
Reach alignments	E_RORB_Model_MapInfo_Tables\ARR19
F - MiRORB Tables	
Catchment boundary	F_MiRORB_Tables\ARR19
ARR19 Subarea boundaries	F_MiRORB_Tables\ARR19
ARR87 Subarea boundaries	F_MiRORB_Tables\ARR87
Nodes	F_MiRORB_Tables\ARR19
Reach alignments	F_MiRORB_Tables\ARR19

Deliverable	Location
Storages	F_MiRORB_Tables\ARR19
Inflow / Outflow reaches	F_MiRORB_Tables\ARR19
Elevation layer	F_MiRORB_Tables\ARR19
ARR19 Impervious Fraction layer	F_MiRORB_Tables\ARR19
ARR87 Impervious Fraction layer	F_MiRORB_Tables\ARR87
RORB Settings file	F_MiRORB_Tables\ARR19
Print Locations	F_MiRORB_Tables\ARR19
G - Hydraulic Model 3 Metre Points MapInfo Tables	
Scenario A (Base case) – 1% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 2% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 5% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 10% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario A (Base case) – 20% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario D (Climate Change 3) - 1% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario D (Climate Change 3) - 10% AEP	G_Hydraulic_Model_DEM_Points\ARR19
Scenario D (Climate Change 3) - 20% AEP	G_Hydraulic_Model_DEM_Points\ARR19
ARR87 – 1% AEP	G_Hydraulic_Model_DEM_Points\ARR87
ARR87 – 20% AEP	G_Hydraulic_Model_DEM_Points\ARR87
H- 2D Flow Values MapInfo Tables	
Scenario A (Base case) Flow Values	H_Flow_Values\ARR19
Scenario D (Climate Change 3) Flow Values	H_Flow_Values\ARR19
ARR87 Flow Values	H_Flow_Values\ARR87
I- 2D Flood Contours MapInfo Tables	
Scenario A (Base case) – 1% AEP	I_2D_Flood_Contours\ARR19
Scenario A (Base case) – 2% AEP	I_2D_Flood_Contours\ARR19
Scenario A (Base case) – 5% AEP	I_2D_Flood_Contours\ARR19
Scenario A (Base case) – 10% AEP	I_2D_Flood_Contours\ARR19
Scenario A (Base case) – 20% AEP	I_2D_Flood_Contours\ARR19

Deliverable	Location
Scenario D (Climate Change 3) – 1% AEP	I_2D_Flood_Contours\ARR19
Scenario D (Climate Change 3) – 10% AEP	I_2D_Flood_Contours\ARR19
Scenario D (Climate Change 3) – 20% AEP	I_2D_Flood_Contours\ARR19
ARR87 – 1% AEP	I_2D_Flood_Contours\ARR87
ARR87 – 20% AEP	I_2D_Flood_Contours\ARR87
J- 2D Model Flood Extent MapInfo Tables	
Scenario A (Base case) – 1% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 2% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 5% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 10% AEP	F_Flood_Extents\ARR19
Scenario A (Base case) – 20% AEP	F_Flood_Extents\ARR19
Scenario D (Climate Change 3) - 1% AEP	F_Flood_Extents\ARR19
Scenario D (Climate Change 3) - 10% AEP	F_Flood_Extents\ARR19
Scenario D (Climate Change 3) - 20% AEP	F_Flood_Extents\ARR19
ARR87 – 1% AEP	F_Flood_Extents\ARR87
ARR87 – 20% AEP	F_Flood_Extents\ARR87
K – Parcels Flooded MapInfo Tables	
Scenario A (Base case) – 1% AEP	K_Parcels_Flooded\ARR19
Scenario D (Climate Change 3) – 1% AEP	K_Parcels_Flooded\ARR19
ARR87 – 1% AEP	K_Parcels_Flooded\ARR87
L – Parcels Excess Velocity MapInfo Tables	
Scenario A (Base case) – 1% AEP	L_Parcels_Excess_Velocity\ARR19
Scenario D (Climate Change 3) – 1% AEP	L_Parcels_Excess_Velocity\ARR19
ARR87 – 1% AEP	L_Parcels_Excess_Velocity\ARR87
M – Building Footprints Flooded MapInfo Tables	
Scenario A (Base case) – 1% AEP	L_Building_Footprints_Flooded\ARR19
Scenario D (Climate Change 3) – 1% AEP	L_Building_Footprints_Flooded\ARR19
ARR87 – 1% AEP	L_Building_Footprints_Flooded\ARR87

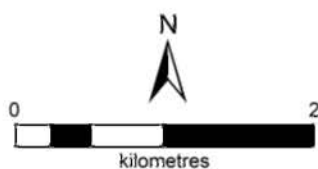
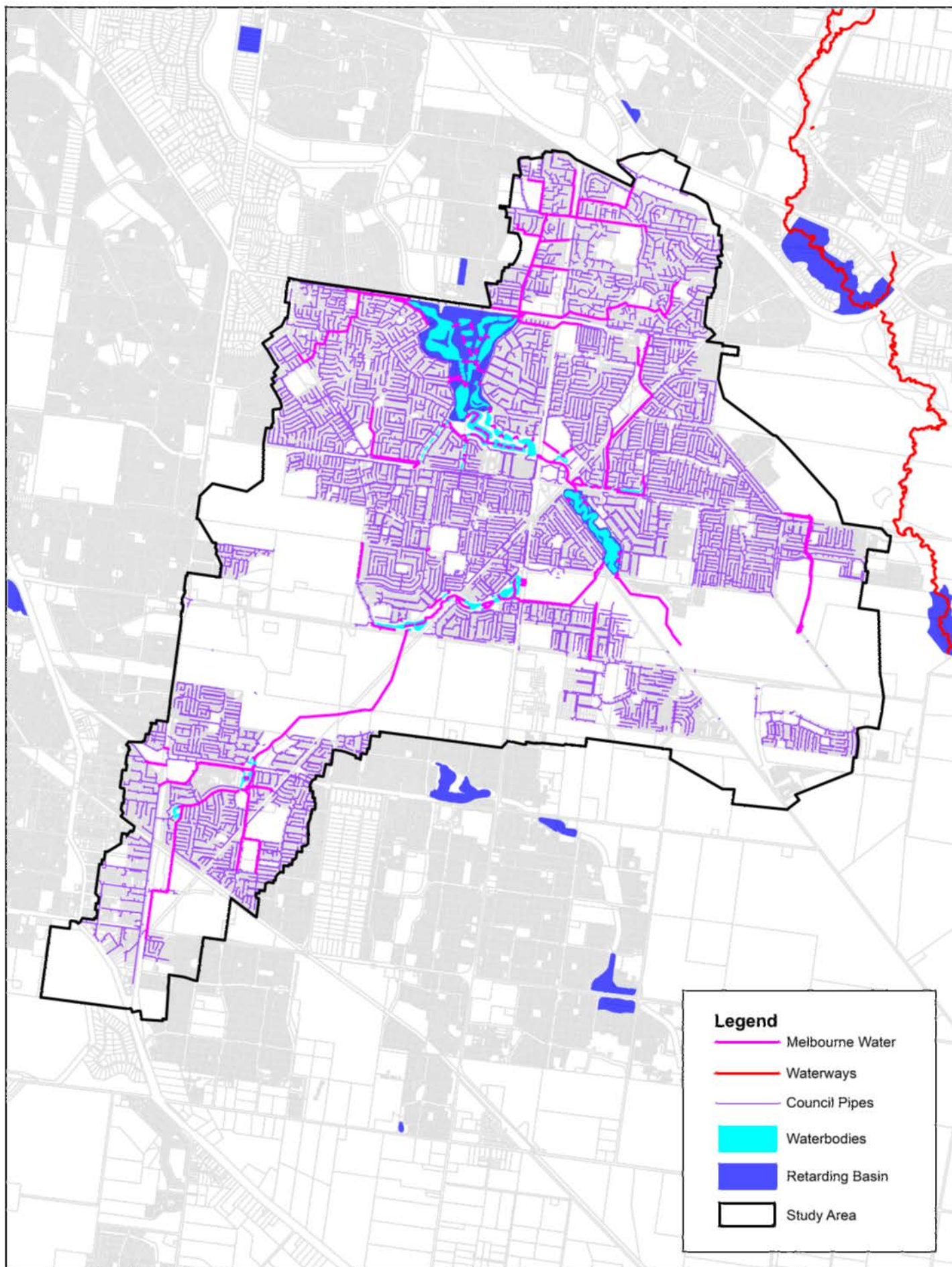
Deliverable	Location
N – Level of Service MapInfo Tables	
Scenario A (Base case)	M_Level_of_Service\ARR19
Scenario D (Climate Change 3)	M_Level_of_Service\ARR19
ARR87	M_Level_of_Service\ARR87
O – Flood Hazard Safety MapInfo Tables	
Scenario A (Base case)	O_Flood_Hazard_Safety\ARR19
Scenario D (Climate Change 3)	O_Flood_Hazard_Safety\ARR19
ARR87	O_Flood_Hazard_Safety\ARR87
P – Flood Study Area MapInfo Tables	
Scenario A (Base case) – 1% AEP	P_Flood_Study_Area\ARR19
Scenario D (Climate Change 3) – 1% AEP	P_Flood_Study_Area\ARR19
ARR87 – 1% AEP	P_Flood_Study_Area\ARR87
Q – Unclipped Results (Raw and Processed) MapInfo Tables	
Scenario A (Base case) – 1% AEP	Q_Unclipped_Results
Scenario A (Base case) – 2% AEP	Q_Unclipped_Results
Scenario A (Base case) – 5% AEP	Q_Unclipped_Results
Scenario A (Base case) – 10% AEP	Q_Unclipped_Results
Scenario A (Base case) – 20% AEP	Q_Unclipped_Results
Scenario D (Climate Change 3) - 1% AEP	Q_Unclipped_Results
Scenario D (Climate Change 3) - 10% AEP	Q_Unclipped_Results
Scenario D (Climate Change 3) - 20% AEP	Q_Unclipped_Results
ARR87 – 1% AEP	Q_Unclipped_Results
ARR87 – 20% AEP	Q_Unclipped_Results
R – Clipped Results (Processed) MapInfo Tables	
Scenario A (Base case) – 1% AEP	R_Clipped_Results
Scenario A (Base case) – 2% AEP	R_Clipped_Results
Scenario A (Base case) – 5% AEP	R_Clipped_Results
Scenario A (Base case) – 10% AEP	R_Clipped_Results

Deliverable	Location
Scenario A (Base case) – 20% AEP	R_Clipped_Results
Scenario D (Climate Change 3) - 1% AEP	R_Clipped_Results
Scenario D (Climate Change 3) - 10% AEP	R_Clipped_Results
Scenario D (Climate Change 3) - 20% AEP	R_Clipped_Results
ARR87 – 1% AEP	R_Clipped_Results
ARR87 – 20% AEP	R_Clipped_Results
S – Quality Assurance Documentation	
Deliverable Checklist	S_QA_Documentation
Melbourne Water QA Spreadsheet	S_QA_Documentation
Cardno QA Spreadsheet	S_QA_Documentation
Draft Deliverables Comment Register	S_QA_Documentation

APPENDIX

A

FIGURES



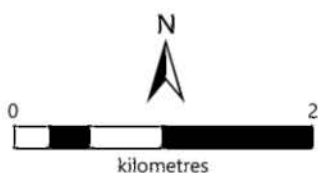
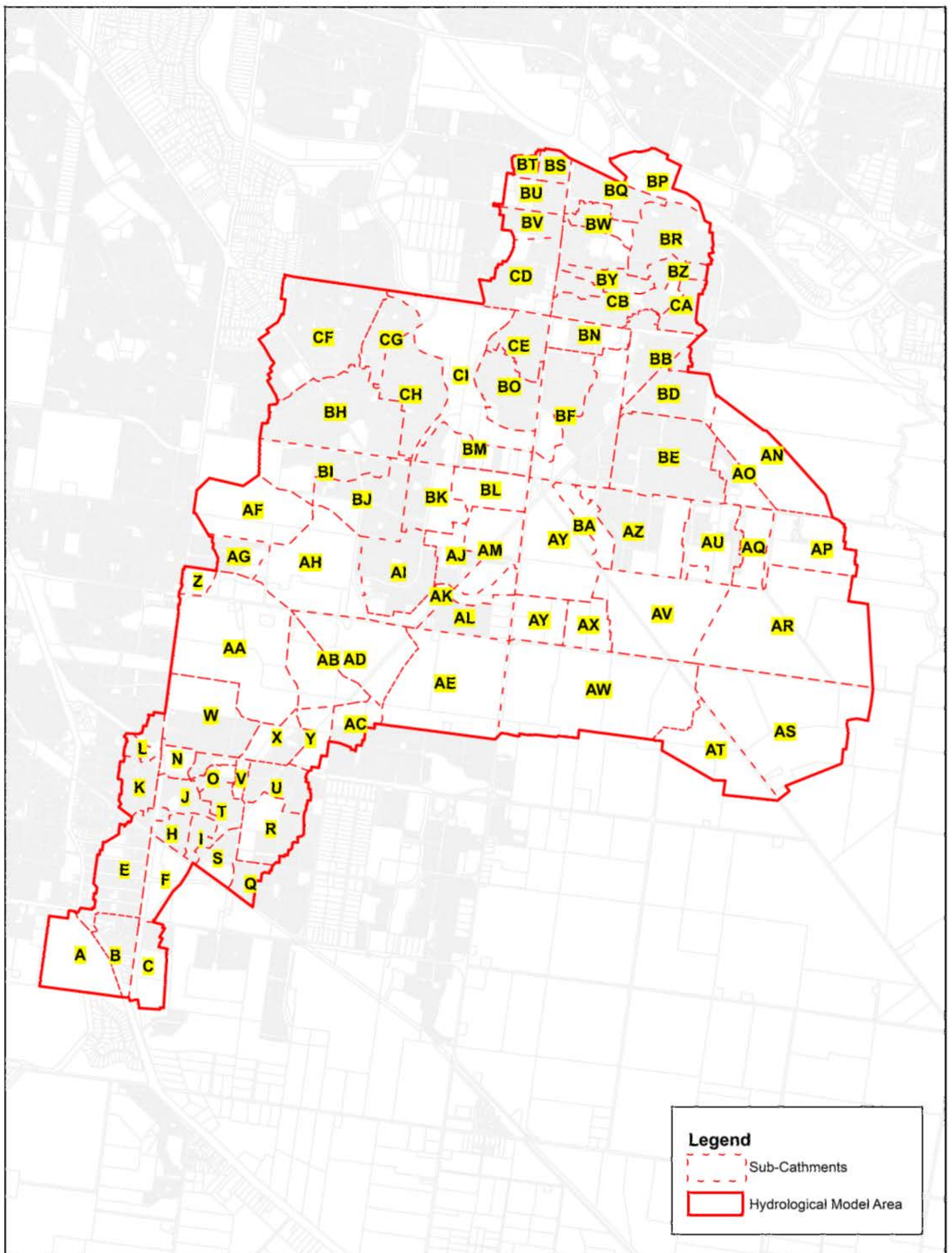
Ti Tree Creek

Study Area

Figure 1



Map Produced by Cardno Victoria
 Date: 28/06/2019
 Coordinate System: MGA94 Zone 55
 Project: V181917
 Map: TiTree_Creek_DraftReport_Figures.wor 01



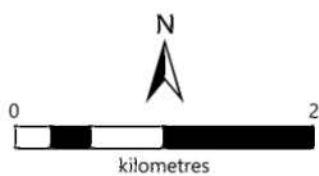
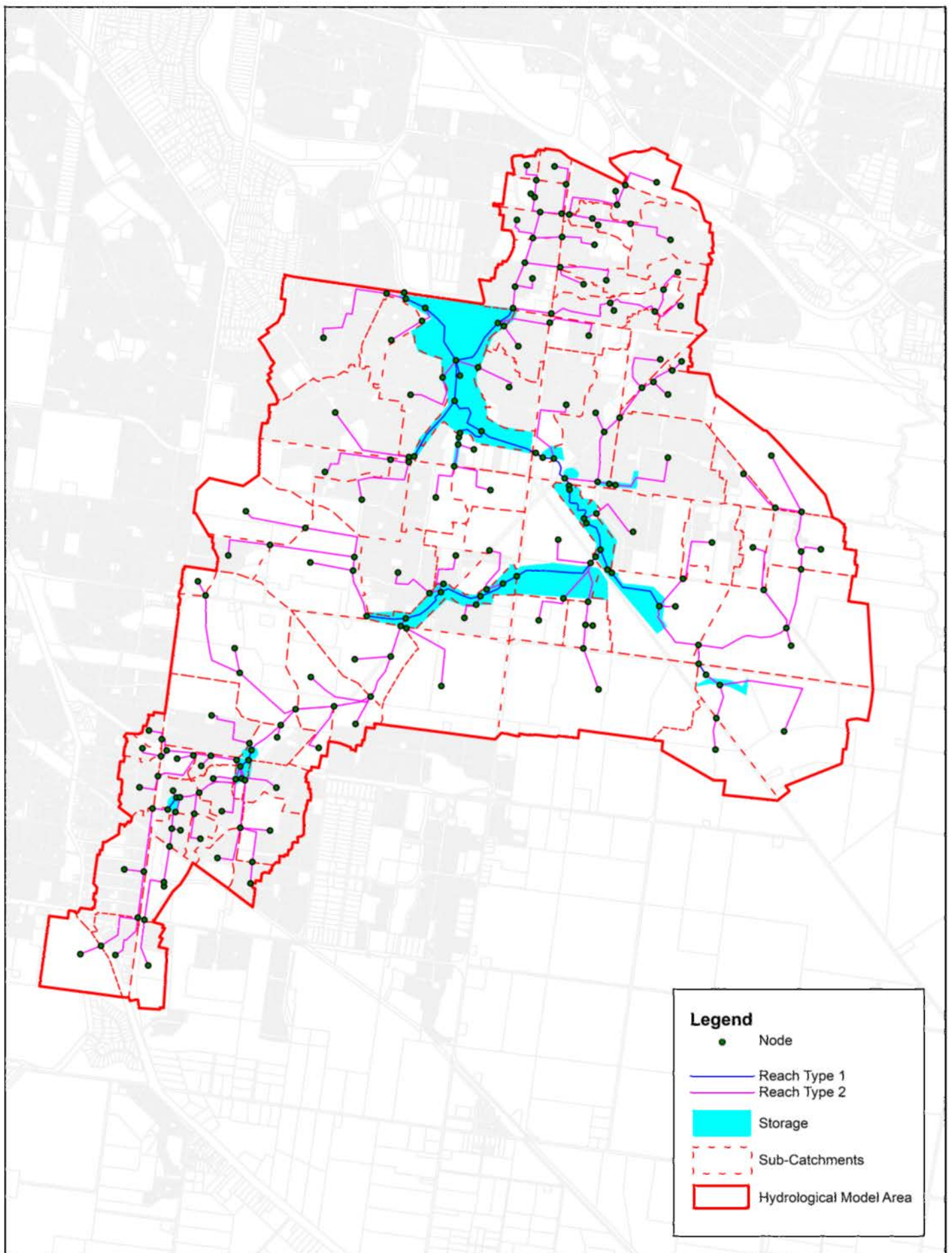
Ti Tree Creek

Hydrological Model
Catchments

Figure 2



Map Produced by Cardno Victoria
Date: 28/06/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_DraftReport_Figures.wor 01



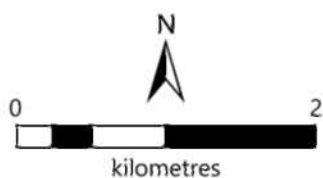
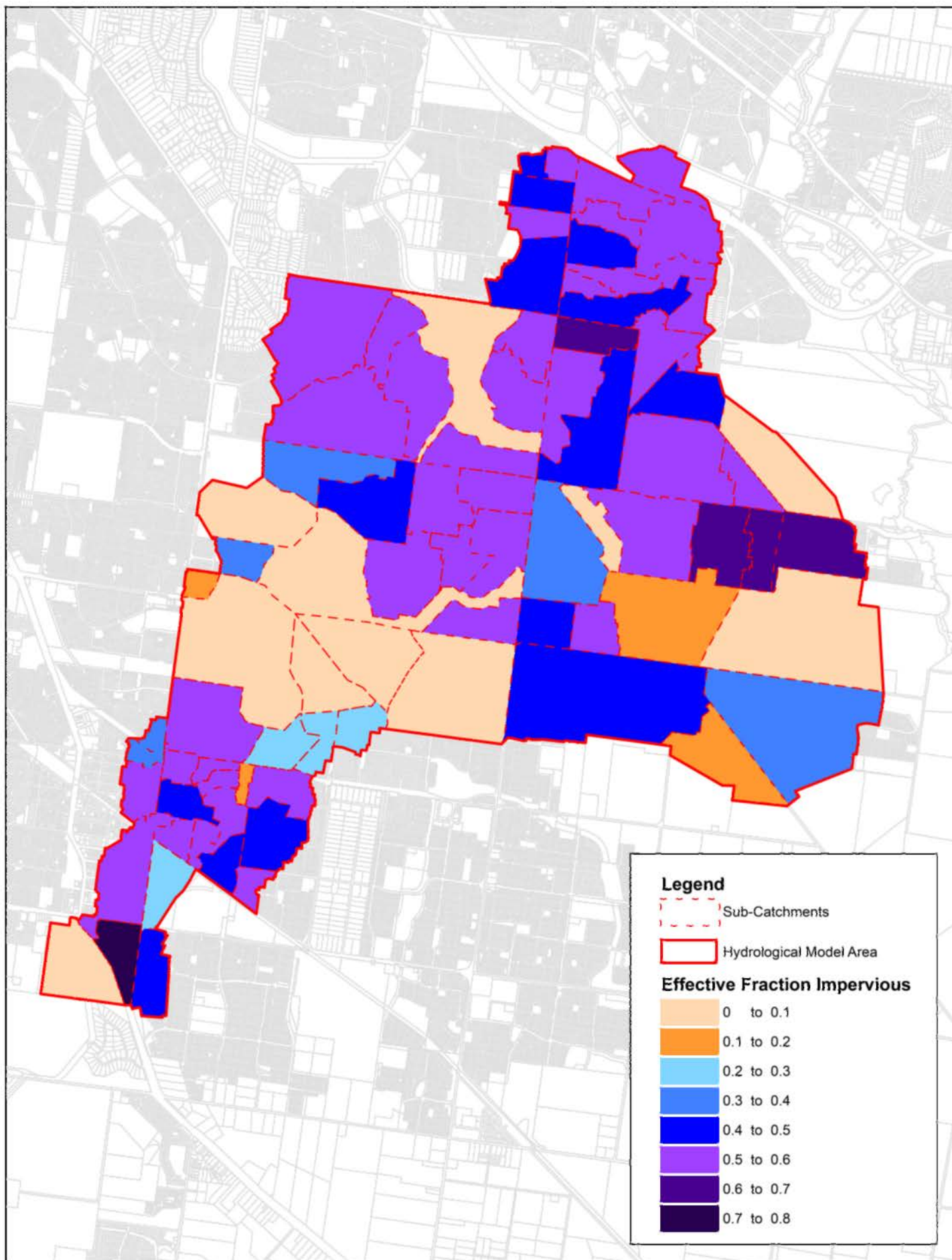
Ti Tree Creek

Hydrological Model
Setup

Figure 3



Map Produced by Cardno Victoria
Date: 28/06/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_DraftReport_Figures.wor 01

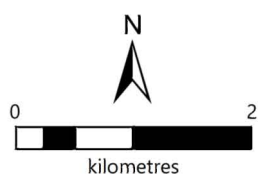
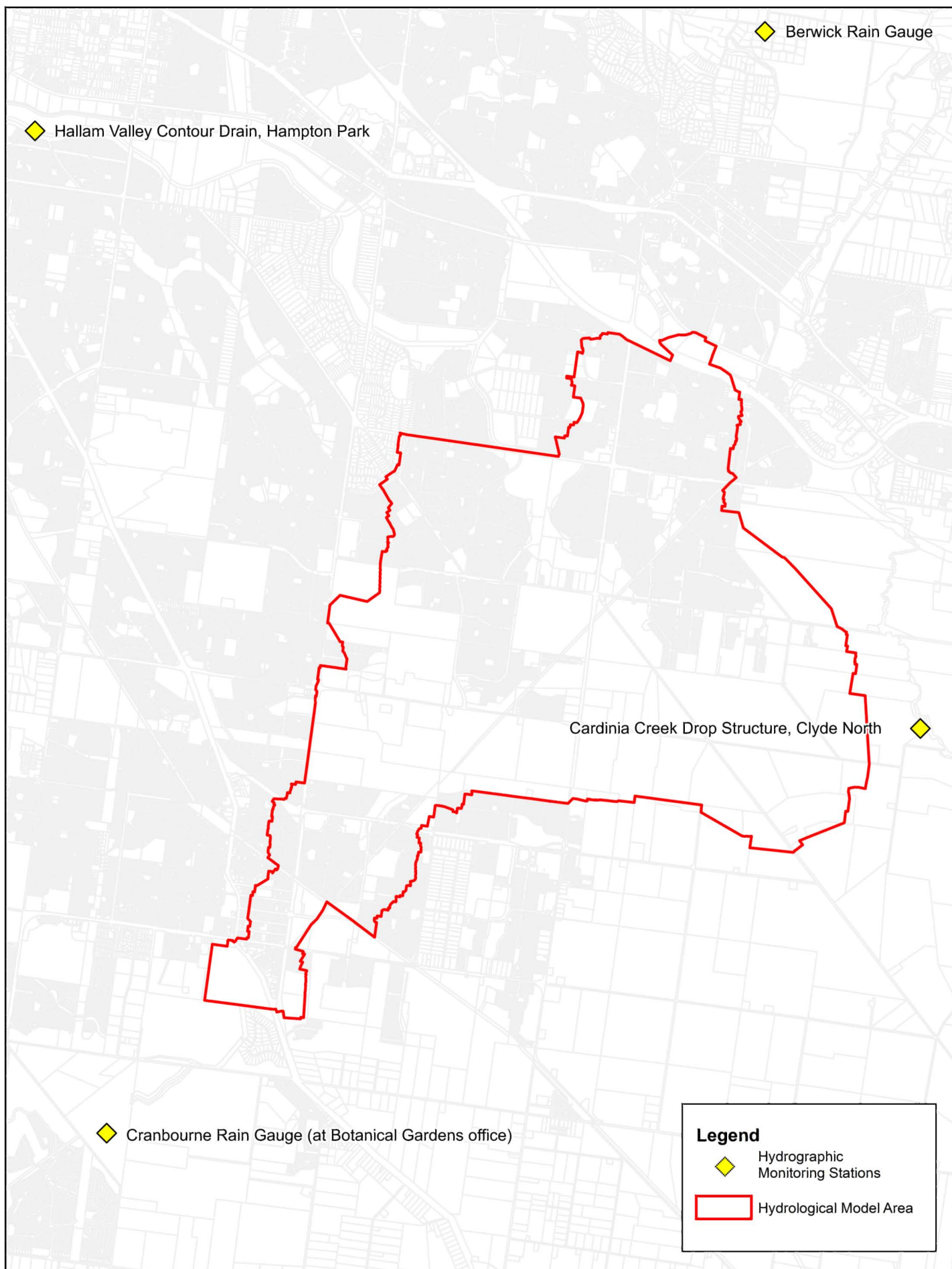


Ti Tree Creek
Effective Fraction Impervious
by Sub-Catchments

Figure 4



Map Produced by Cardno Victoria
Date: 28/06/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_DraftReport_Figures.wor 01



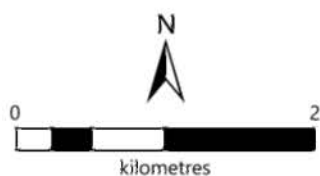
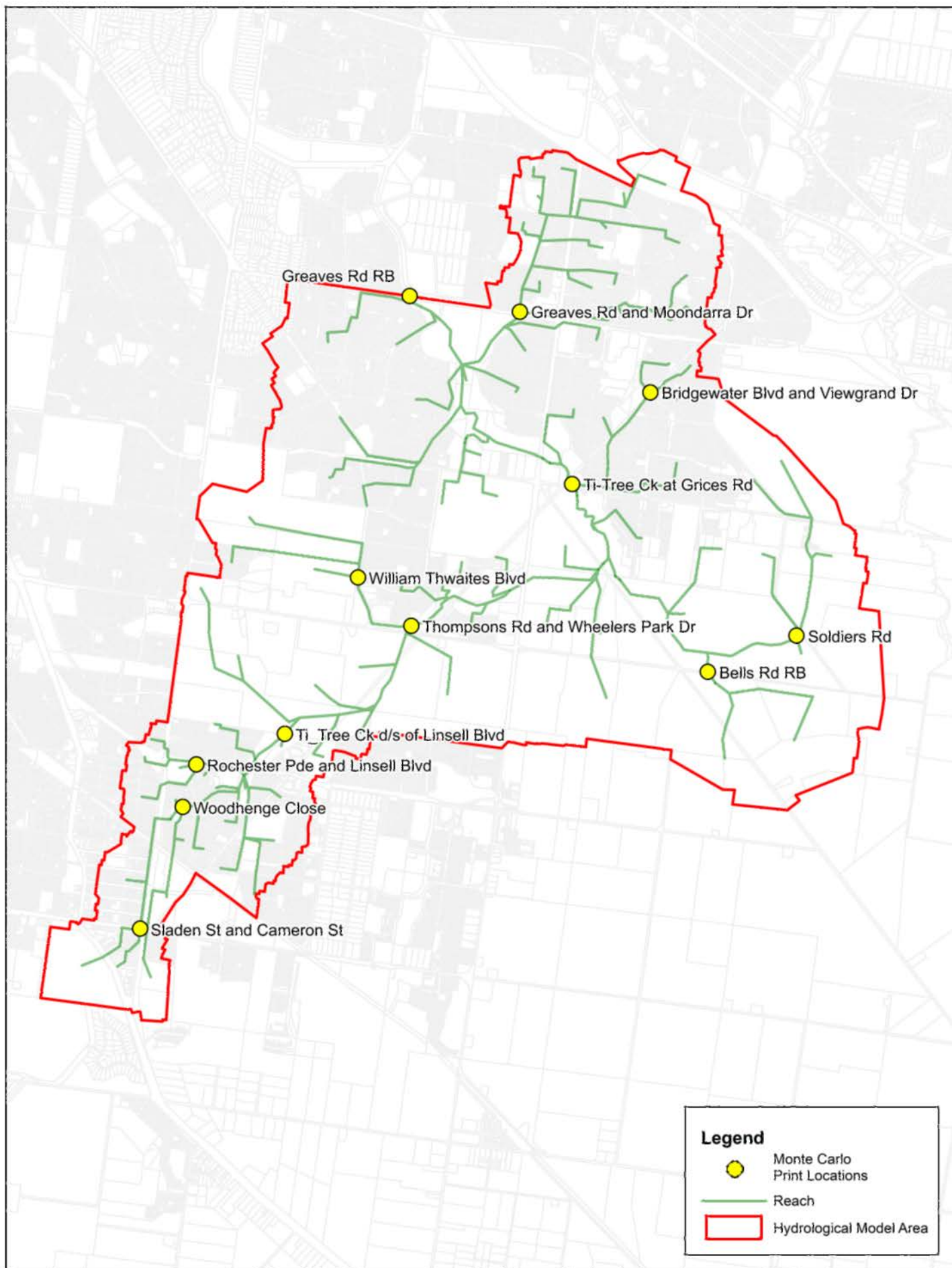
Ti Tree Creek

Hydrographic Monitoring
Locations

Figure 5



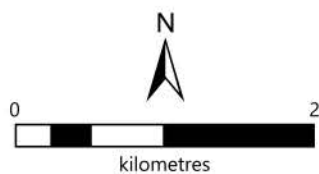
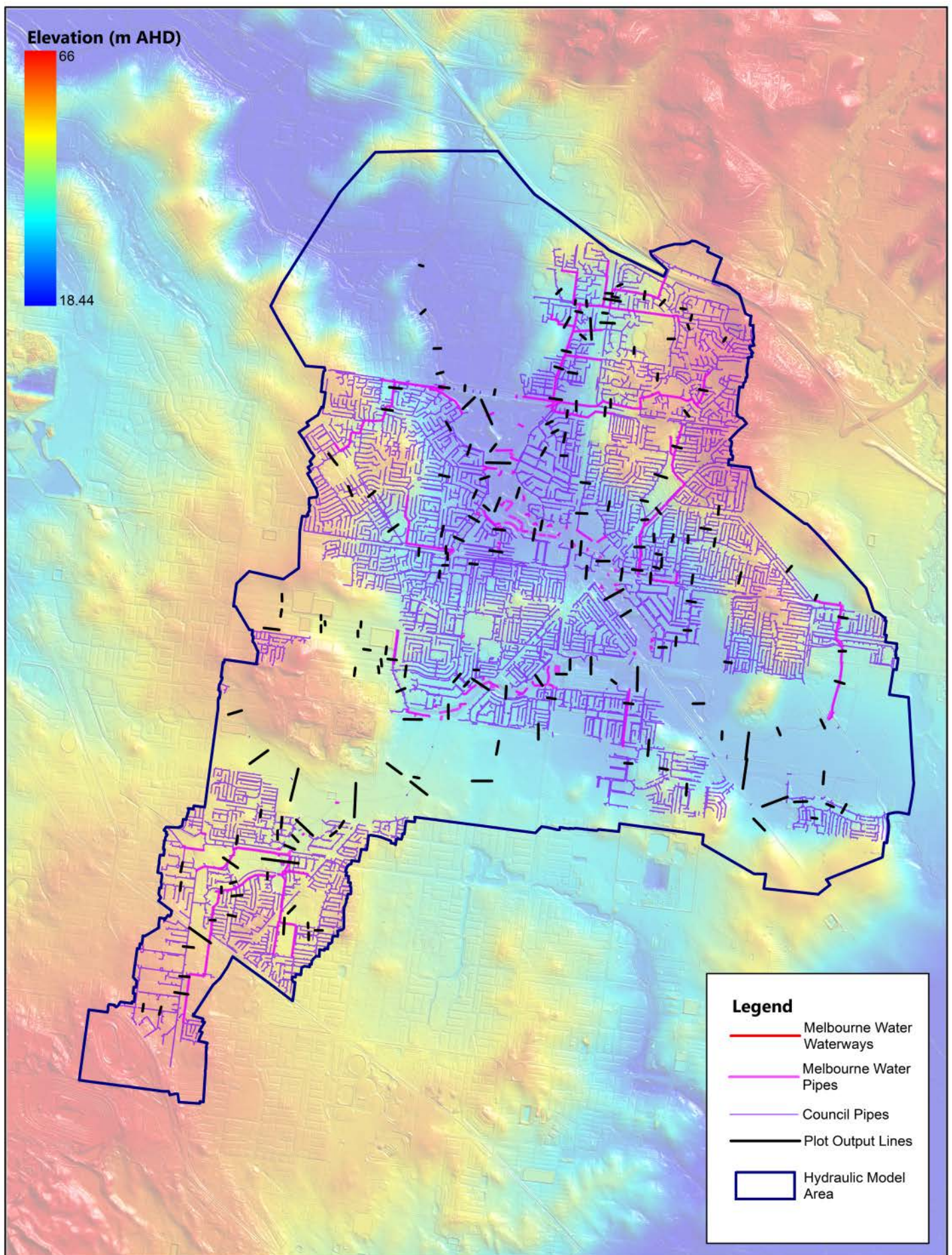
Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_Final_Deliverables.wor 01



Ti Tree Creek
Monte Carlo Print Locations

Figure 6



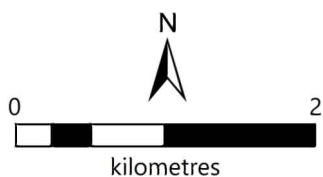
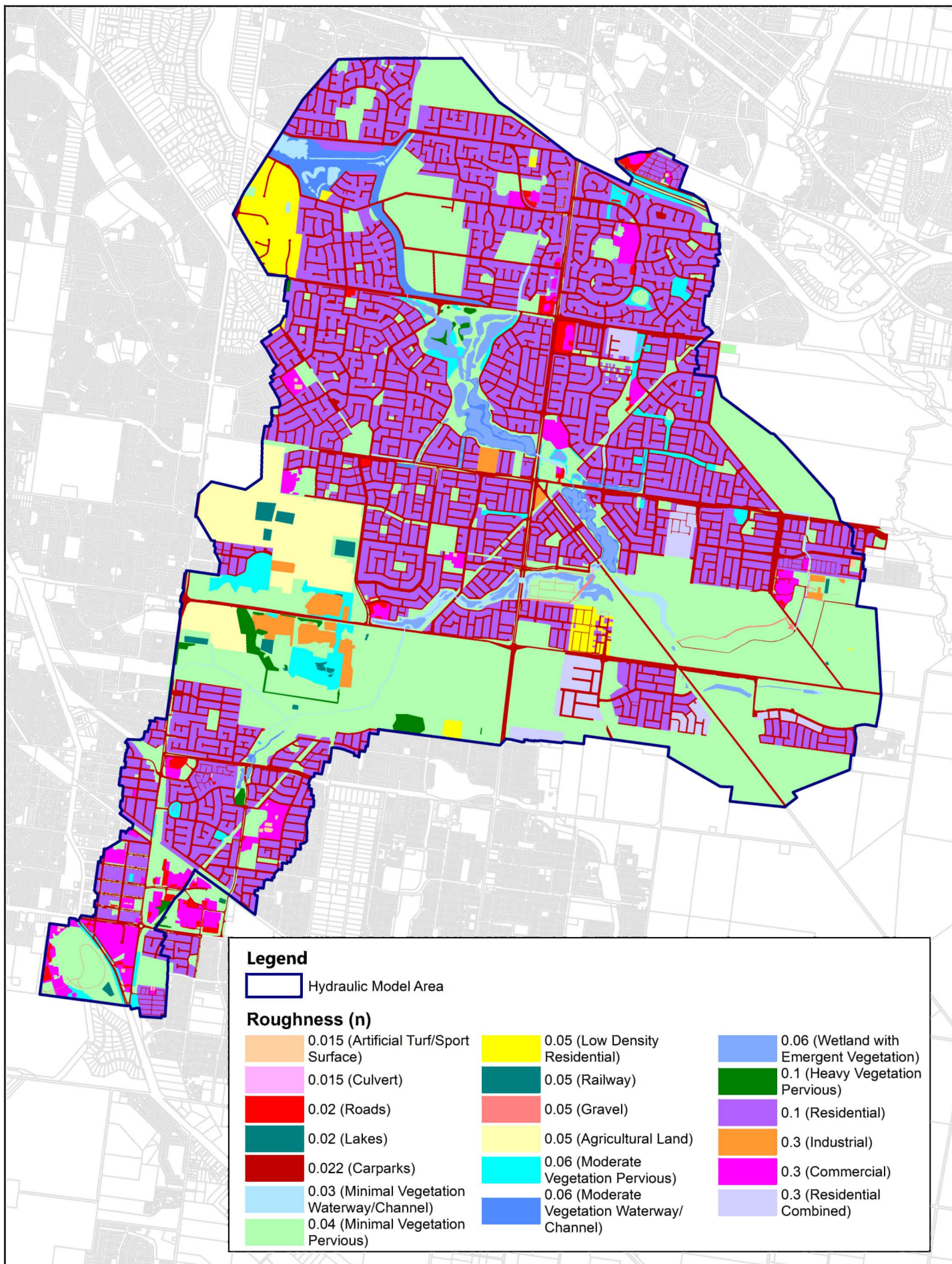


Ti Tree Creek
Hydraulic Model Setup

Figure 7



Map Produced by Cardno Victoria
Date: 10/07/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_DraftReport_Figures.wor 01

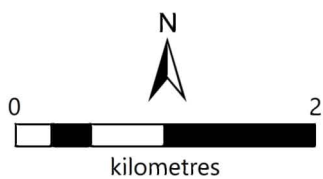
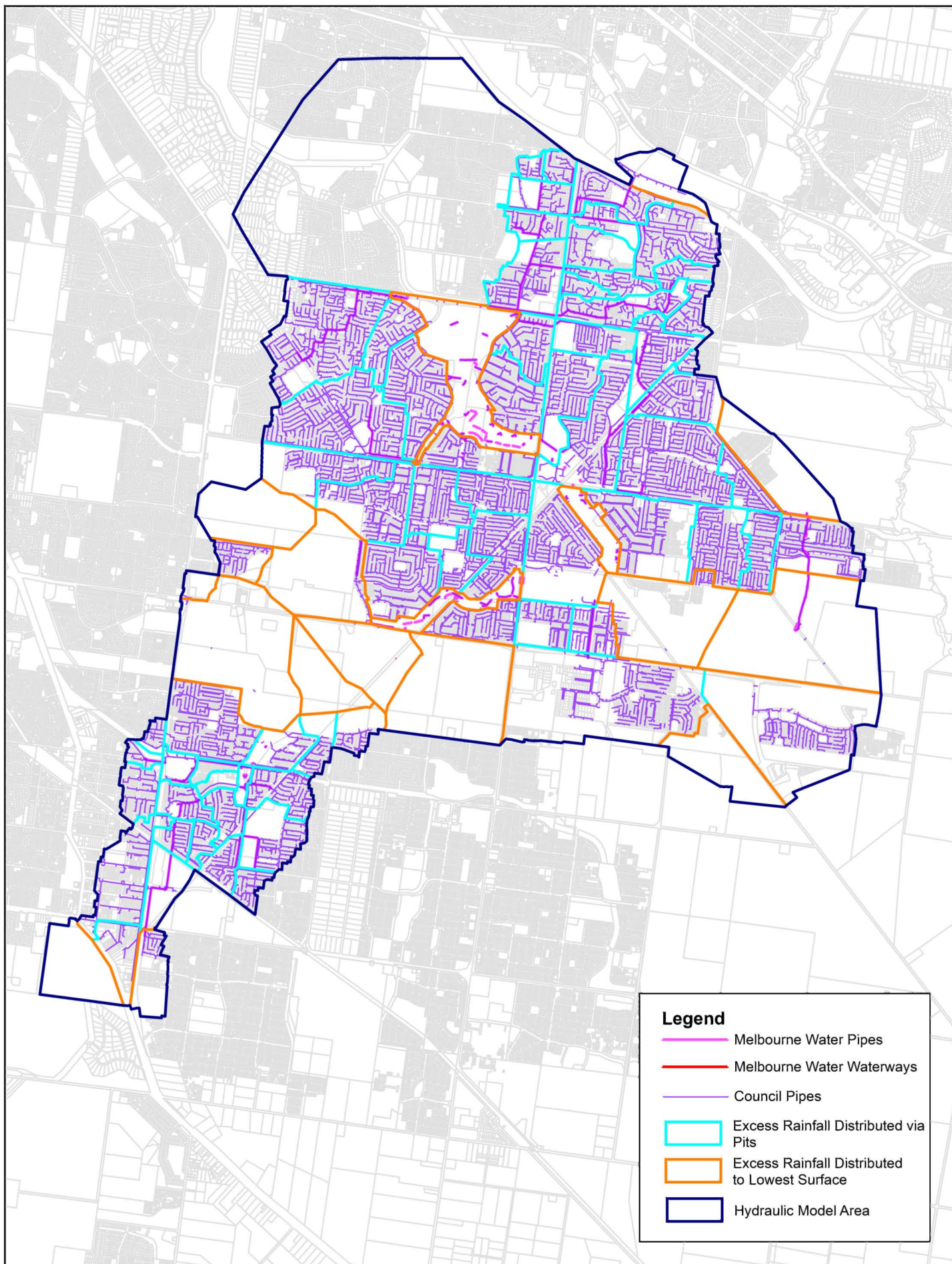


Ti Tree Creek
Manning's Roughness (n)

Figure 8



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_Final_Deliverables.wor 01

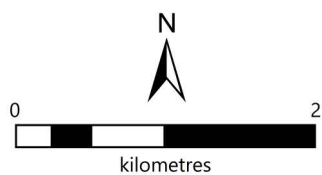
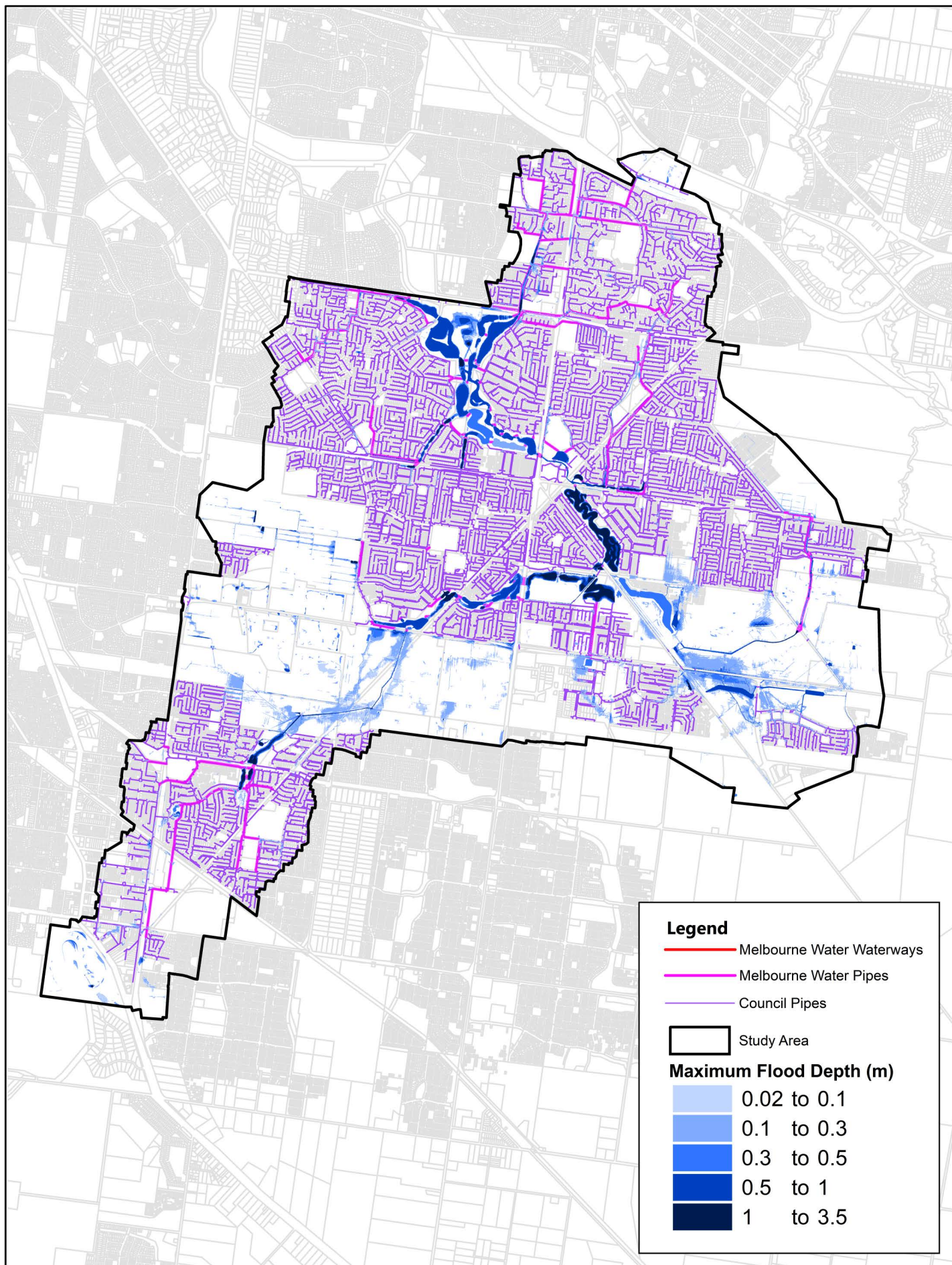


Ti Tree Creek
Hydraulic Model
Excess Rainfall Locations

Figure 9



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_Final_Deliverables.wor 01



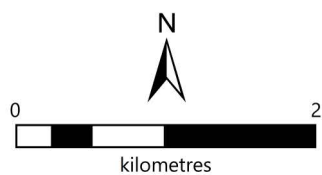
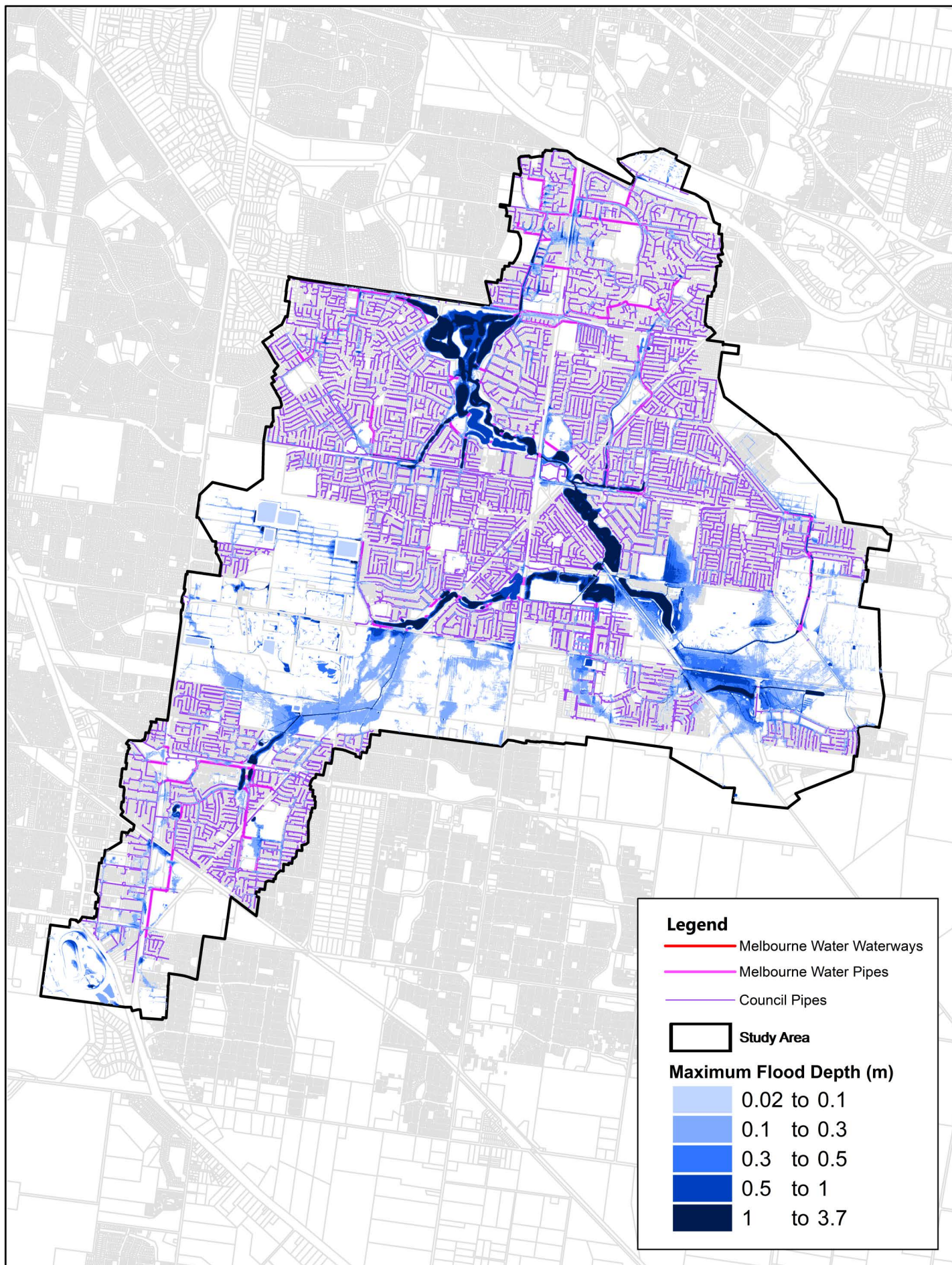
Ti Tree Creek

Base Case 20% AEP
Maximum Flood Depth

Figure 10



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_Final_Deliverables.wor 01



Ti Tree Creek

Base Case 1% AEP
Maximum Flood Depth

Figure 11



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_Creek_Final_Deliverables.wor 01

APPENDIX

B

SUB-CATCHMENT CHARACTERISTICS

Subarea Number	Subarea ID	Area km ²)	Fraction Impervious
1	A	0.454	0.082
2	B	0.232	0.744
3	C	0.261	0.416
5	E	0.503	0.552
6	F	0.251	0.27
8	H	0.11	0.507
9	I	0.096	0.571
10	J	0.165	0.481
11	K	0.197	0.561
12	L	0.063	0.373
13	M	0.066	0.325
14	N	0.104	0.544
15	O	0.067	0.55
16	P	0.064	0.567
17	Q	0.107	0.56
18	R	0.347	0.405
19	S	0.155	0.478
20	T	0.153	0.551
21	U	0.247	0.552
22	V	0.048	0.107
23	W	0.591	0.542
24	X	0.223	0.232
25	Y	0.168	0.261
26	Z	0.083	0.121
27	AA	1.301	0.011
28	AB	0.386	0.008
29	AC	0.18	0.227
30	AD	0.6	0.024
31	AE	1.068	0.024
32	AF	0.598	0.015
33	AG	0.178	0.373
34	AH	0.827	0.049
35	AI	0.535	0.551
36	AJ	0.211	0.524
37	AK	0.23	0.066
38	AL	0.292	0.584
39	AM	0.383	0.543
40	AN	0.582	0.01
41	AO	0.187	0.584
42	AP	0.463	0.629
43	AQ	0.236	0.63
44	AR	1.561	0.044
45	AS	1.376	0.32
46	AT	0.499	0.104
47	AU	0.408	0.622

48	AV	0.916	0.115
49	AW	1.63	0.449
50	AX	0.217	0.548
51	AY	0.246	0.414
52	AY	0.741	0.399
53	AZ	0.669	0.518
54	BA	0.183	0.088
55	BB	0.33	0.518
56	BC	0.038	0.576
57	BD	0.358	0.487
58	BE	0.83	0.567
59	BF	0.686	0.458
60	BG	0.424	0.525
61	BH	0.88	0.527
62	BI	0.464	0.389
63	BJ	0.498	0.44
64	BK	0.356	0.549
65	BL	0.278	0.562
66	BM	0.328	0.524
67	BN	0.232	0.635
68	BO	0.379	0.582
69	BP	0.263	0.587
70	BQ	0.297	0.527
71	BR	0.46	0.55
72	BS	0.095	0.582
73	BT	0.062	0.489
74	BU	0.201	0.471
75	BV	0.162	0.511
76	BW	0.149	0.535
77	BX	0.25	0.488
78	BY	0.155	0.532
79	BZ	0.12	0.537
80	CA	0.162	0.57
81	CB	0.326	0.492
82	CC	0.089	0.582
83	CD	0.449	0.476
84	CE	0.266	0.583
85	CF	0.972	0.536
86	CG	0.255	0.558
87	CH	0.497	0.572
88	CI	0.915	0.052

APPENDIX

C

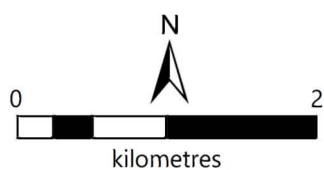
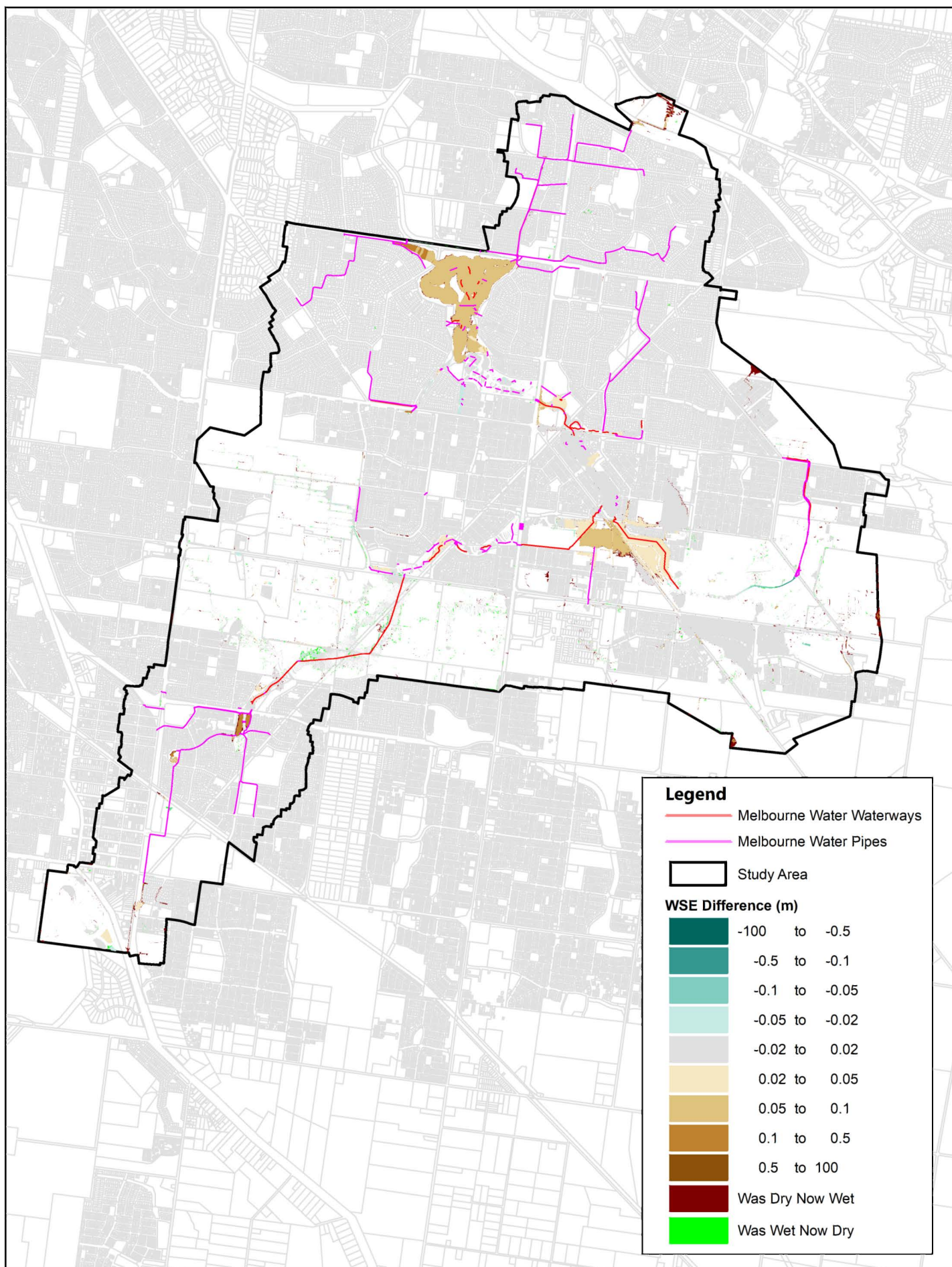
LAYERED FLOW CONSTRICTION SHAPES DATA

LFCSH PARAMETERS														BRIDGE LOSS CALCULATION DETAILS									
ID	Invert	Δ Shape	Width or ΔMax	Shape Options	L1 Obvert	L1 pBlockage	L1 LFC	L2 Depth	L2 pBlockage	L2 LFC	L3 Depth	L3 pBlockage	L3 FLC	Notes	Bridge Type	Bridge Width	Pier Width	J	Delta K	Bridge Length	FLC	Bridge Deck Height	Other
TTC_1	34.8			MIN NO MERGE	37.5	2.78	0.001233987	1.2	100	0.039542484	1	5.769230769		0 TTC_1	7	10.8	0.3	0.028	0.05	30.6	0.001233987	38.7	railings from street view
TTC_2	35			MIN NO MERGE	37.5	3.60	0.001229508	1.54	100	0.031762295	1	50		0 TTC_2	7	7.5	0.27	0.036	0.06	48.8	0.001229508	39.04	have averaged the pipes to be 2.9x2.5
TTC_3	29.08			MIN NO MERGE	29.83	5.83	0.004955168	0.73	100	0.034922133	1	10		0 TTC_3	7	3.6	0.21	0.058	0.105	21.19	0.004955168	30.56	street view no railing - railings from aerial
TTC_4	26.8			MIN NO MERGE	28	6.67	0.00364077	1.3	100	0.038399531	1.2	30		0 TTC_4	7	18	1.2	0.067	0.125	34.115	0.00364077	29.3	railings off the scale. Complex bridge on angle - polygon with points on each corner
TTC_4	27.25			MIN NO MERGE	28.45	6.67	0.005	0.95	100	0.0384	1.2	30		0 TTC_4 North Point								28.2	
TTC_4	27.25			MIN NO MERGE	28.45	6.67	0.005	0.95	100	0.0384	1.2	30		0 TTC_4 North West Point								28.2	
TTC_4	26.9			MIN NO MERGE	28.45	6.67	0.005	0.95	100	0.0384	1.2	30		0 TTC_4 South East Point								27.85	
TTC_4	26.9			MIN NO MERGE	28.45	6.67	0.005	0.95	100	0.0384	1.2	30		0 TTC_4 South West Point								27.85	
TTC_5	25.75			MIN NO MERGE	26.662	10.59	0.01198	0.418	100	0.023300125	0.5	58		0 TTC_5	7	56.074	5.94	0.106	0.22	18.369	0.0119767	27.08	
TTC_6	20.03			MIN NO MERGE	20.93	5.63	0.012747327	1.25	100	0.217316316	1.5	33.32666667		0 TTC_6	7	4.8	0.27	0.056	0.1	5.798	0.012747327	22.18	
TTC_7	21.8			MIN NO MERGE	22.75	9.33	0.044186047	0.36	100	0.086046512	1.5	33.32666667		0 TTC_7	7	9	0.84	0.093	0.19	4.3	0.044186047	23.11	
TTC_8	21.65			MIN NO MERGE	22.95	2.58	0.001069519	0.74	100	0.020053476	1.2	25		0 TTC_8	7	15.5	0.4	0.026	0.04	37.4	0.001069519	23.69	don't believe culverts
TTC_9	19.9			MIN NO MERGE	21.4	5.71	0.006069364	1.2	100	0.069942197	1	10		0 TTC_9	7	4.2	0.24	0.057	0.105	17.3	0.006069364	22.6	assumed railings
TTC_10	19.98			MIN NO MERGE	21.78	2.67	0.002777778	1.02	100	0.057222222	1.5	50		0 TTC_10	7	9	0.24	0.027	0.05	18	0.002777778	22.8	
TTC_11	23.03			MIN NO MERGE	24.23	3.33	0.000838415	1.57	100	0.024085366	1.5	29.54545455		0 TTC_11	7	7.2	0.24	0.033	0.055	65.6	0.000838415	25.8	assumed railings
TTC_12	23.6			MIN NO MERGE	24.2	5.83	0.002380952	1.25	100	0.03	1.5	29.54545455		0 TTC_12	7	3.6	0.21	0.058	0.1	42	0.002380952	25.45	assumed railings
TTC_13	19.65			MIN NO MERGE	20.75	9.60	0.044186047	0.35	100	0.08372093	1	10		0 TTC_13	7	26.25	2.52	0.096	0.19	4.3	0.044186047	21.1	assumed railing from street view - can barely be seen
TTC_14	17			MIN NO MERGE	19.65	7.28	0.0028	2.05	100	0.0412	0	0		0 TTC_14	7	9.06	0.66	0.073	0.14	50	0.0028	21.7	railing below street height invert from plan 0619-07-011
TTC_15	20.23			MIN NO MERGE	21.13	10.48	0.007115385	0.57	100	0.023307692	0.75	85.00000000		0 TTC_15	7	10.5	1.1	0.105	0.185	26	0.007115385	21.7	railings off the scale/Victoria's guerdence type B
TTC_16	30.97			MIN NO MERGE	31.87	5.33	0.005729412	0.84	100	0.0487	0	0		0 TTC_16	7	9	0.48	0.053	0.1	17.45	0.005729412	32.71	No railings on nearmap/streetview
TTC_17	30.7			MIN NO MERGE	31.9	3.33	0.0034375	1.2	100	0.075625	0	0		0 TTC_17	7	7.2	0.24	0.033	0.055	16	0.0034375	33.1	No railings on nearmap/streetview
TTC_18	30.44			MIN NO MERGE	32.34	5.00	0.007058159	1.36	100	0.09606761	0	0		0 TTC_18	7	14.4	0.72	0.050	0.1	14.168	0.007058159	33.7	No railings on nearmap/streetview
TTC_19	29.99			MIN NO MERGE	31.49	4.44	0.006147541	0.33	100	0.02786852	1	10		0 TTC_19	7	10.8	0.48	0.044	0.075	12.2	0.006147541	31.82	assumed railings - viable but no street view
TTC_20	29.75			MIN NO MERGE	30.95	5.19	0.004090909	0.77	100	0.035454545	1	10		0 TTC_20	7	8.1	0.42	0.052	0.09	22	0.004090909	31.72	assumed railings - viable but no street view
TTC_21	29.43			MIN NO MERGE	30.63	4.85	0.00925	0.32	100	0.0165	1	10		0 TTC_21	7	9.9	0.48	0.048	0.185	20	0.00925	30.95	assumed railings - viable but no street view
TTC_22	25.96			MIN NO MERGE	27.16	5.33	0.001248164	1.69	100	0.024963289	0	0		0 TTC_21	7	9	0.48	0.053	0.085	68.1	0.001248164	28.85	No railings on nearmap/streetview
TTC_23	25.4			MIN NO MERGE	26.15	9.93	0.005714286	0.74	100	0.021428571	0.5	36.84615385		0 TTC_21	7	2.7	0.368	0.099	0.2	35	0.005714286	26.89	
TTC_24	19.245			MIN NO MERGE	20.32	0.00	0	1.2	100	0.080666667	1.2	30		0 TTC_24	No Piers	48.3	0	0.000	0	15	0	21.52	No Details
TTC_25	-99999			MIN NO MERGE	20.93	0.00	0	0.3	100	0.103333333	1	4.166666667		0 TTC_24	No Piers	42.6	0.000			3	0	21.23	assumed to be single span no details - railings blockage measureable
TTC_26	-99999			MIN NO MERGE	22.1	0.00	0	0.3	100	0.103333333	1	10		0 TTC_26	No Piers	26.36	0.000			3	0	22.4	assumed to be single span no details
TTC_27	-99999			MIN NO MERGE	22.2	0.00	0	0.3	100	0.0775	1	10		0 TTC_27	No Piers	30.45	0.000			4	0	22.5	
TTC_28	22.6			MIN NO MERGE	23.8	0.00	0	0.3	100	0.017714286	1.2	0.8		0 TTC_28	No Piers	10	0	0.000		17.5	0	24.1	No Details
TTC_29	25.83			MIN NO MERGE	27.2	0.00	0	0.3	100	0.012156863	1	20		0 TTC_29	No Piers	10	0	0.000		25.5	0	27.5	No Details
TTC_31	-99999			MIN NO MERGE	24.65	0.85	0.00625	0.3	100	0.0775	1	10		0 TTC_31	7	71	0.6	0.008	0.025	4	0.00625	24.95	no details
TTC_32	-99999			MIN NO MERGE	23.85	0.00	0	0.3	100	0.091176471	1	10.71428571		0 TTC_32	No Piers	20	0.000			3.4	0	24.15	only street view for details
TTC_34	-99999			MIN NO MERGE	31	0.00	0	0.3	100	0.096875	1	10		0 TTC_34	No Piers	12.5	0.000			3.2	0	31.3	no data no street view
TTC_35	30.1			MIN NO MERGE	31.6	4.44	0.006147541	0.31	100	0.026229508	1	10		0 TTC_35	7	10.8	0.48	0.044	0.075	12.2	0.006147541	31.91	No Data
TTC_36	-99999			MIN NO MERGE	31.65	0.00	0	0.3	100	0.086111111	1	10		0 TTC_36	No Piers	30	0.000			3.6	0	31.95	No Data
TTC_37	30.24			MIN NO MERGE	31.24	5.80	0.007586207	0.79	100	0.055172414	0	0		0 TTC_37	7	13.8	0.8	0.058	0.11	14.5	0.007586207	32.03	No Google Street View, parameters extracted from nearmap
TTC_39	23.6			MIN NO MERGE	24.85	5.63	0.003636364	0.4	100	0.018636364	0	56.66666667		0 TTC_39	7	4.8	0.27	0.056	0.08	22	0.003636364	25.25	assumed to be 2x2.4x1.2 from nearmap
TTC_42	28.4			MIN NO MERGE	29	11.11	0.007142857	1	100	0.036071429	1.5	45		0 TTC_42	7	3.6	0.4	0.111	0.2	28	0.007142857	30	based on street view and the doernstram culvert assumed to be 3x1.2x6
TTC_44	-99999			MIN NO MERGE	29.1	1.47	0.01	0.3	100	0.0775	1.5	13.33333333		0 TTC_44	7	68	1	0.015	0.04	4	0.01	29.4	got data from street view
TTC_55	-99999			MIN NO MERGE	36.74	6.14	0.0525	0.4	100	0.205	1	2.5		0 TTC_55	5	2.05	0.44	0.061	0.105	2	0.0525	37.14	All data assumed from street view
TTC_56	-99999			MIN NO MERGE	36.65	6.43	0.055	0.4	100	0.205	1	2.5		0 TTC_56	5	28	1.8	0.064	0.11	2	0.055	37.05	All data assumed from street view
TTC_59	28.89			MIN NO MERGE	29.49	9.78	0.070588235	0.21	100	0.08627451	0	0		0 TTC_59	7	2.25	0.22	0.098	0.18	2.55	0.070588235	29.7	No railings on nearmap/streetview
TTC_60	-99999			MIN NO MERGE	26.55	10.00	0.117142857	0.3	100	0.088571429	1.5	20.02380952		0 TTC_60	5	114	11.4	0.100	0.41	3.5	0.117142857	26.85	All data assumed from street view
TTC_61	-99999			MIN NO MERGE	23.6	0	0	0.3	100	0.088571429	1	10		0 TTC_61	No Piers	26.2	0	0	0	0	0	23.9	Foot Bridge data assumed from aerial imagery
TTC_62	-99999			MIN NO MERGE	23.16	0	0	0.3	100	0.114814815	1	10		0 TTC_62	No Piers	55.2	0	0	0	2.7	0	23.46	Foot Bridge data assumed from aerial imagery
TTC_63	23.4			MIN NO MERGE	23.85	4.95	0.001580497	0.4	100	0.008100045	1	10		0 TTC_63	7	20.2	1	0.050	0.08	50.617	0.001580497	25.31	New development. All data assumed from Aerial imagery. L2 and L3 assumed, yet to be constructed.
TTC_64	22.25			MIN NO MERGE	23.075	0	0	0.6	100	0.063541667	0.75	0.5		0 TTC_64	No Piers	26.8	0	0	0	9.6	0	23.675	No railings on nearmap/streetview

APPENDIX

D

TUFLOW HPC SENSITIVITY ANALYSIS

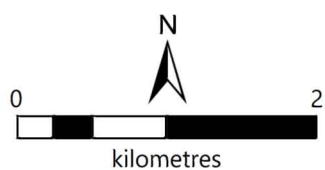
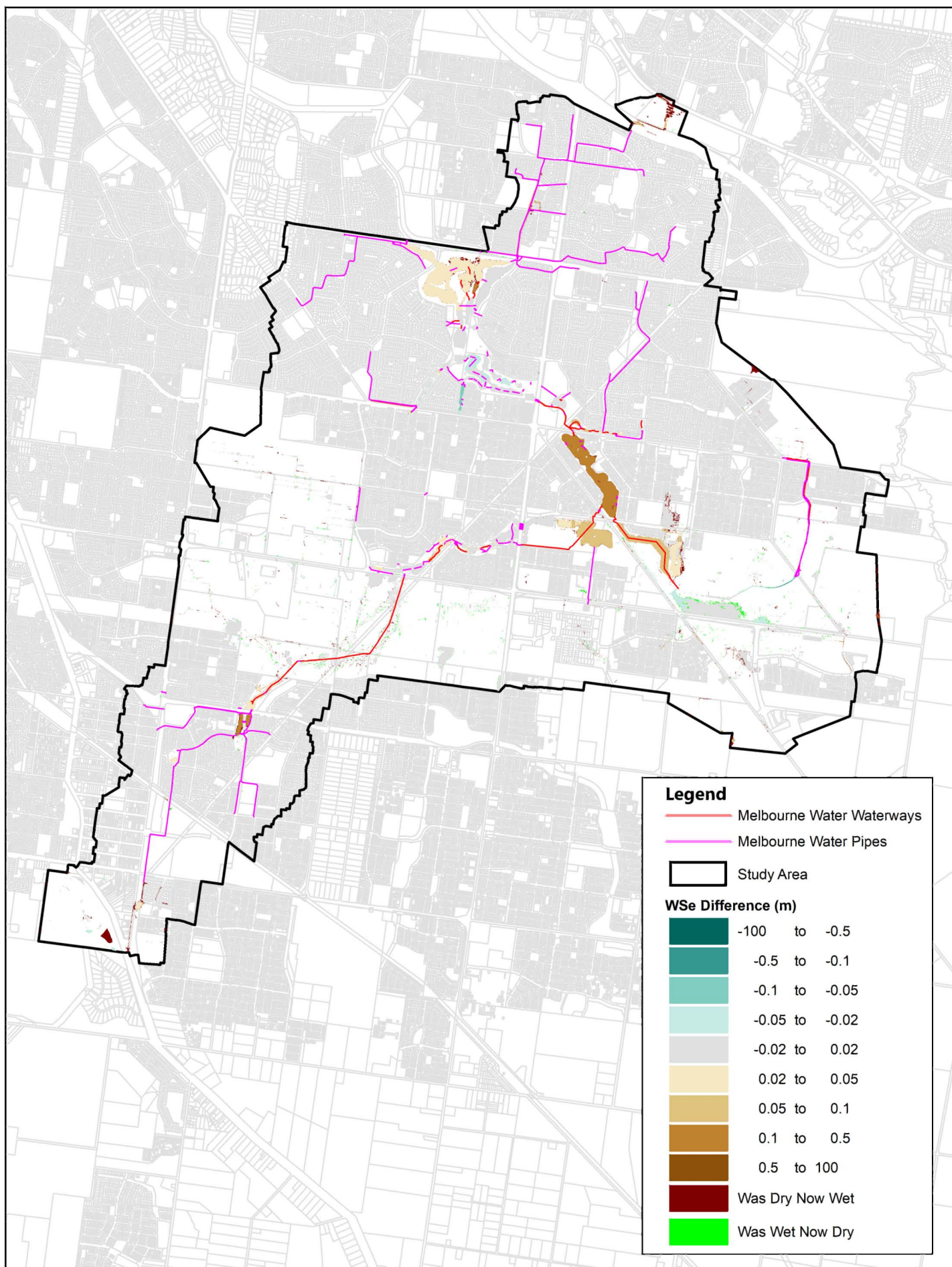


Ti Tree Creek

HPC 1% AEP
WSE Difference Plot



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TITree_FinalReport_Figures_Sensitivity.wor 01



Ti Tree Creek

HPC 20% AEP
WSE Difference Plot



Map Produced by Cardno Victoria
Date: 08/11/2019
Coordinate System: MGA94 Zone 55
Project: V181917
Map: TiTree_FinalReport_Figures_Sensitivity.wor

APPENDIX

E

ARR DATA HUB INFORMATION

IFD Design Rainfall Depth (mm)

Issued: 12-Feb-19

Location Label:

Requested Latitude -38.08 Longitude 145.3343

Nearest gri Latitude 38.0875 (S) Longitude 145.3375 (E)

Annual Exceedance Probability (AEP)

Duration	Duration in min	63.20%	50%	20%	10%	5%	2%	1% 1 in 200	1 in 500	1 in 1000	1 in 2000	
10 min	10	7.05	8.09	11.5	13.9	16.5	20.1	23	27	31.9	36.1	40.8
15 min	15	8.58	9.85	14	17.1	20.2	24.7	28.4	33.2	39.4	44.6	50.3
20 min	20	9.76	11.2	15.9	19.3	22.9	27.9	32.1	37.5	44.4	50.3	56.7
25 min	25	10.7	12.3	17.4	21.2	25	30.4	34.8	40.7	48.2	54.5	61.4
30 min	30	11.6	13.2	18.7	22.7	26.7	32.4	37	43.2	51.1	57.7	65
45 min	45	13.6	15.5	21.6	26.1	30.6	36.7	41.5	48.4	57.2	64.5	72.6
1 hour	60	15.2	17.2	23.8	28.6	33.3	39.7	44.7	52	61.4	69.3	77.9
1.5 hour	90	17.7	19.9	27.2	32.3	37.4	44.1	49.3	57.4	67.7	76.3	85.8
2 hour	120	19.7	22.1	29.7	35.1	40.5	47.5	52.9	61.6	72.7	82.1	92.3
3 hour	180	22.8	25.4	33.8	39.6	45.4	53	58.9	68.8	81.3	91.8	103
4.5 hour	270	26.3	29.2	38.5	44.8	51.2	59.8	66.5	77.9	92.3	104	118
6 hour	360	29	32.2	42.3	49.1	56	65.6	73.1	85.9	102	115	130
9 hour	540	33.1	36.8	48.2	56.1	64	75.5	84.6	99.7	118	134	152
12 hour	720	36.3	40.3	53	61.8	70.6	83.9	94.5	111	132	150	169
18 hour	1080	40.9	45.5	60.4	70.8	81.5	97.6	111	130	154	174	197
24 hour	1440	44.2	49.3	66	78	90.3	109	124	144	171	193	217
30 hour	1800	46.9	52.3	70.5	83.8	97.5	118	134	157	186	211	236
36 hour	2160	49	54.8	74.3	88.7	104	125	143	167	197	222	249
48 hour	2880	52.5	58.7	80.2	96.4	113	137	156	180	211	237	263
72 hour	4320	57.5	64.3	88.1	106	126	152	172	194	224	249	274
96 hour	5760	61.4	68.6	93.4	112	133	159	181	200	230	253	278
120 hour	7200	64.9	72.1	97.1	116	137	164	185	204	233	257	281
144 hour	8640	68.1	75.3	99.8	118	139	165	187	206	236	259	284
168 hour	10080	71.2	78.4	102	119	139	166	188	208	238	263	288

Results - ARR Data Hub
[STARTTXT]

Input Data Information
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Latitude,-38.080047
Longitude,145.334349
[END_INPUTDATA]

River Region
[RIVREG]
division,South East Coast (Victoria)
rivregnum,5
River Region,Bunyip River
[RIVREG_META]
Time Accessed,12 February 2019 10:52AM
Version,2016_v1
[END_RIVREG]

ARF Parameters
[LONGARF]
Zone,Southern Temperate
a,0.158
b,0.276
c,0.372
d,0.315
e,0.000141
f,0.41
g,0.15
h,0.01
i,-0.0027
[LONGARF_META]
Time Accessed,12 February 2019 10:52AM
Version,2016_v1
[END_LONGARF]

Storm Losses
[LOSSES]
id,18138.0
Storm Initial Losses (mm),27.0
Storm Continuing Losses (mm/h),4.4
[LOSSES_META]
Time Accessed,12 February 2019 10:52AM
Version,2016_v1
[END_LOSSES]

Temporal Patterns
[TP]
code,SSmainland
Label,Southern Slopes (Vic/NSW)
[TP_META]
Time Accessed,12 February 2019 10:52AM
Version,2016_v2

[END_TP]

Areal Temporal Patterns

[ATP]

code,SSmainland

arealabel,Southern Slopes (Vic/NSW)

[ATP_META]

Time Accessed,12 February 2019 10:52AM

Version,2016_v2

[END_ATP]

BOM IFD Depths

[BOMIFD]

No data,No data found at this location!

[BOMIFD_META]

Time Accessed,12 February 2019 10:52AM

[END_BOMIFD]

Median Preburst Depths and Ratios

[PREBURST]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),3.5 (0.202),2.8 (0.116),2.3 (0.080),1.8 (0.055),1.5 (0.038),1.3 (0.028),
90 (1.5),3.6 (0.182),2.8 (0.103),2.2 (0.070),1.7 (0.046),1.9 (0.043),2.0 (0.041),
120 (2.0),2.3 (0.105),2.5 (0.083),2.6 (0.074),2.7 (0.066),2.0 (0.042),1.5 (0.029),
180 (3.0),3.9 (0.154),3.5 (0.104),3.3 (0.082),3.0 (0.066),2.8 (0.053),2.7 (0.046),
360 (6.0),2.9 (0.089),3.1 (0.074),3.3 (0.067),3.5 (0.062),4.4 (0.067),5.1 (0.070),
720 (12.0),0.4 (0.011),1.2 (0.022),1.6 (0.027),2.1 (0.030),4.0 (0.048),5.4 (0.058),
1080 (18.0),0.0 (0.000),0.6 (0.009),0.9 (0.013),1.3 (0.016),1.6 (0.017),1.9 (0.017),
1440 (24.0),0.0 (0.000),0.1 (0.002),0.2 (0.002),0.2 (0.003),0.6 (0.005),0.8 (0.007),
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),

[PREBURST_META]

Time Accessed,12 February 2019 10:52AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST]

10% Preburst Depths

[PREBURST10]

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),

[PREBURST10_META]

Time Accessed,12 February 2019 10:52AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST10]

25% Preburst Depths

[PREBURST25]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),0.2 (0.009),0.1 (0.004),0.0 (0.002),0.0 (0.000),0.0 (0.000),0.0 (0.000),
90 (1.5),0.6 (0.029),0.3 (0.012),0.2 (0.005),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),0.1 (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),

[PREBURST25_META]

Time Accessed,12 February 2019 10:52AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST25]

75% Preburst Depths

[PREBURST75]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),10.0 (0.581),14.1 (0.592),16.8 (0.589),19.4 (0.583),12.5 (0.316),7.4 (0.165),
90 (1.5),11.1 (0.559),11.9 (0.438),12.4 (0.384),12.9 (0.345),13.0 (0.295),13.1 (0.266),
120 (2.0),14.2 (0.643),16.3 (0.549),17.7 (0.505),19.1 (0.472),16.1 (0.338),13.8 (0.260),
180 (3.0),11.7 (0.459),14.2 (0.421),15.9 (0.402),17.6 (0.387),15.8 (0.298),14.5 (0.246),
360 (6.0),11.5 (0.357),13.3 (0.316),14.6 (0.297),15.8 (0.282),19.6 (0.298),22.4 (0.306),
720 (12.0),5.1 (0.126),9.3 (0.176),12.2 (0.197),14.9 (0.211),18.2 (0.217),20.6 (0.218),
1080 (18.0),2.7 (0.059),7.0 (0.116),9.8 (0.139),12.6 (0.154),13.2 (0.135),13.7 (0.124),
1440 (24.0),2.4 (0.048),5.8 (0.088),8.1 (0.104),10.2 (0.114),11.2 (0.103),11.9 (0.097),
2160 (36.0),0.3 (0.005),1.3 (0.018),2.0 (0.022),2.6 (0.025),4.1 (0.032),5.1 (0.036),
2880 (48.0),0.0 (0.000),0.3 (0.004),0.5 (0.005),0.7 (0.006),2.0 (0.014),2.9 (0.018),
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),

[PREBURST75_META]

Time Accessed,12 February 2019 10:52AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST75]

90% Preburst Depths

[PREBURST90]

min (h)\AEP(%),50,20,10,5,2,1,

60 (1.0),22.0 (1.275),27.6 (1.156),31.3 (1.094),34.8 (1.044),27.6 (0.696),22.2 (0.497),
90 (1.5),20.8 (1.046),24.8 (0.912),27.4 (0.848),29.9 (0.799),31.3 (0.711),32.4 (0.658),
120 (2.0),25.3 (1.146),28.3 (0.950),30.2 (0.860),32.1 (0.793),36.2 (0.763),39.3 (0.742),

180 (3.0),25.5 (1.004),33.4 (0.988),38.7 (0.976),43.7 (0.963),38.6 (0.728),34.7 (0.589),
360 (6.0),31.1 (0.966),30.3 (0.718),29.8 (0.607),29.4 (0.525),35.1 (0.535),39.4 (0.539),
720 (12.0),20.3 (0.504),24.1 (0.455),26.6 (0.431),29.1 (0.411),33.2 (0.396),36.4 (0.385),
1080 (18.0),16.6 (0.364),19.0 (0.314),20.6 (0.290),22.1 (0.271),26.3 (0.269),29.4 (0.266),
1440 (24.0),14.4 (0.292),19.5 (0.295),22.8 (0.293),26.0 (0.289),26.3 (0.242),26.5 (0.215),
2160 (36.0),9.2 (0.168),11.2 (0.150),12.5 (0.141),13.7 (0.133),23.7 (0.190),31.2 (0.219),
2880 (48.0),8.1 (0.137),6.6 (0.083),5.7 (0.059),4.8 (0.042),11.4 (0.083),16.3 (0.104),
4320 (72.0),2.1 (0.032),3.2 (0.036),3.9 (0.037),4.7 (0.037),15.5 (0.102),23.7 (0.137),

[PREBURST90_META]

Time Accessed,12 February 2019 10:52AM

Version,2018_v1

Note,Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

[END_PREBURST90]

Interim Climate Change Factors

[CCF]

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%),

[CCF_META]

Time Accessed,12 February 2019 10:52AM

Version,2016_v1

Note,ARR recommends the use of RCP4.5 and RCP 8.5 values

[END_CCF]

[ENDTXT]

Intensity-Frequency-Duration Table

Location: 38.075S 145.325E NEAR.. Titree Issued: 24/9/2019

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

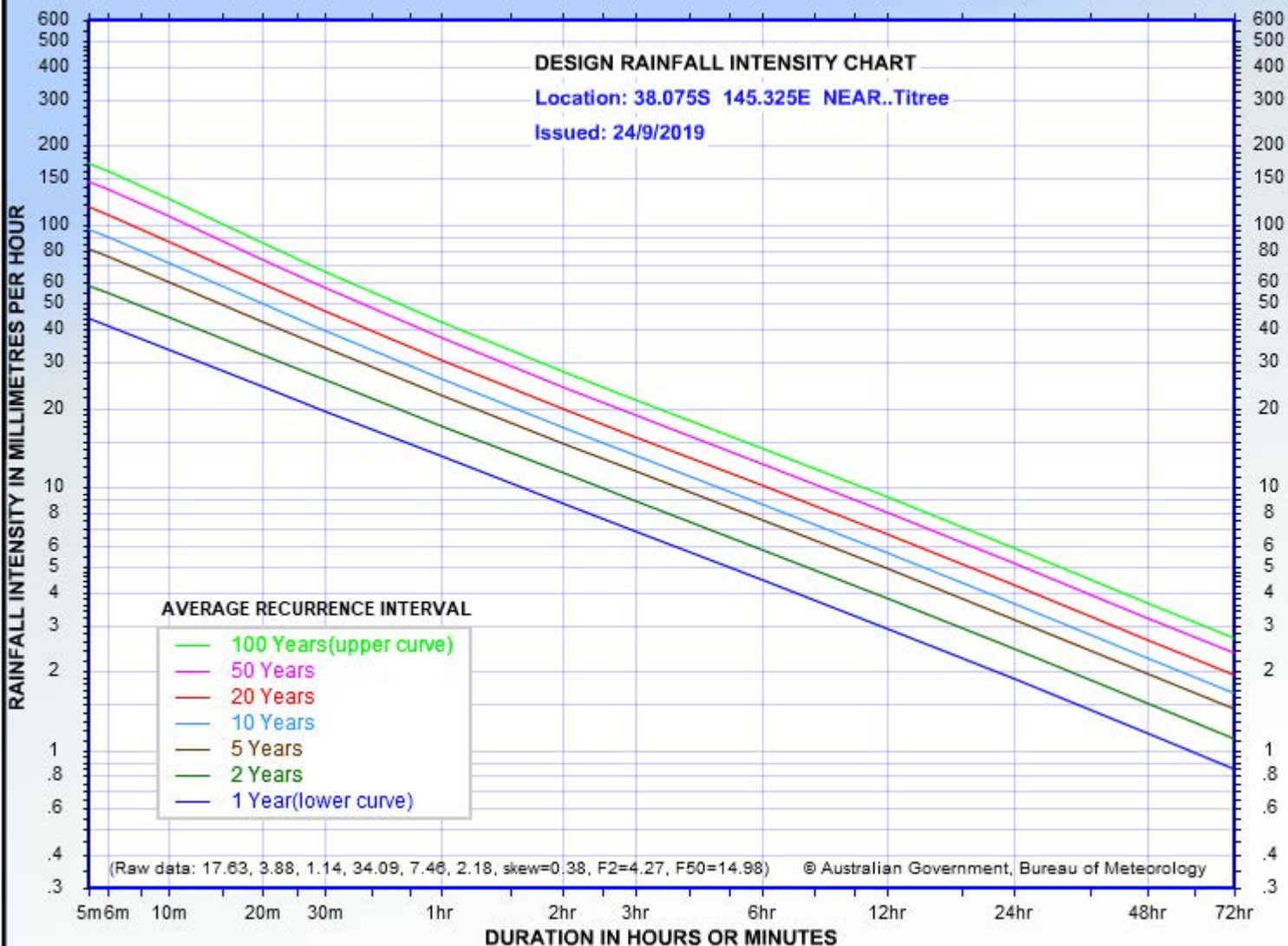
Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	44.0	58.7	80.8	96.2	117	146	171
6Mins	41.2	54.9	75.5	89.8	109	136	160
10Mins	33.5	44.5	60.6	71.7	86.4	108	126
20Mins	24.2	31.9	42.6	49.9	59.5	73.4	84.9
30Mins	19.5	25.7	34.0	39.5	46.9	57.5	66.1
1Hr	13.2	17.2	22.5	26.0	30.6	37.3	42.7
2Hrs	8.71	11.4	14.7	16.9	19.9	24.1	27.6
3Hrs	6.80	8.87	11.5	13.2	15.5	18.8	21.5
6Hrs	4.45	5.80	7.52	8.64	10.2	12.3	14.1
12Hrs	2.90	3.78	4.91	5.63	6.64	8.04	9.19
24Hrs	1.87	2.43	3.14	3.61	4.25	5.15	5.88
48Hrs	1.16	1.51	1.95	2.24	2.63	3.18	3.63
72Hrs	.851	1.11	1.44	1.65	1.94	2.35	2.68

(Raw data: 17.63, 3.88, 1.14, 34.09, 7.46, 2.18, skew=0.38, F2=4.27, F50=14.98)

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Copy Table



APPENDIX

F

QUALITY ASSURANCE

Comment ID	Document Type	Reviewer Name	Reviewer Organisation	Reviewer Comment	Document Reference Clause/Section/Page	Comment Date	Comment Category	Cardno Response	Cardno Response Date	Action Completed (Yes/No)	MW's Response
1	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	The Flood Mapping Guidelines recommends that 2d_zsh is used rather than 2d_zln. Is there a reason for adopting the 2d_zln?	Terrain Representation (2d Domain)	August 26, 2019	Tuflow Checking	Yes, a zln was used because it was considered more representative of the channel/ridge being applied in the model. We would prefer to use a zsh when an larger area requires z to be adjusted. In this case, as it was a smaller adjustment to the DEM within a small width, a zln was more applicable. Suggest no change required	9/09/2019	YES	Noted
2	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	Please explain in the report the 1d pit and pipe entrance and exit loss applied. There are no losses applied. Presumably this approach have been agreed with MW? Please confirm	Drainage Network Representation (1d Domain)	August 26, 2019	Tuflow Checking	This was an oversight. Losses will be adjusted to 0.5 and 1 for final model runs	9/09/2019	YES	Noted. Will be interesting to see the difference in the outputs. If the extents are significantly different, this should be raised to MW as a note.
3	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	Provide commentary in the report with regards to the reasoning in determining the outlet boundary conditions. HQ changed to HT or effects of adjacent catchments?	Boundary Condition Representation	August 26, 2019	Tuflow Checking	HQ boundary is applied at the downstream boundary as requested by MW on other 2018/2019 flood modelling packages. It should be noted that boundary is located far enough downstream as to not have any impact on the study area. Further details on this will be added to the final report	9/09/2019	YES	Noted
4	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	should IWL within the wetlands/ponds be set at the start of the model simulation? Does lidar/terrain capture water level within wetlands? Was there any pre wetting applied to model in areas where the Rainfall was applied to the catchment area.	Boundary Condition Representation	August 26, 2019	Tuflow Checking	Spot checks on the levels of the wetlands were undertaken on the LIDAR data which confirmed that it was picking up the noraml water surface levels. As such, no IWLs were required. Suggest no change is required	9/09/2019	YES	Noted
5	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	See last tab, some buildings cover substantial width of flood extent, might need blockage to better represent the flow path. There is a fair bit of fragmentation of the flood extent which will be resolve as part of Final Delivery stage? Levee overtopping where surveyed level is higher.	Results	August 26, 2019	Tuflow Checking	Buildings: These buildings are represented in the model as higher roughness's. Inspection of these areas show that they are large warehouses which would allow water to flow through them in large events. As such, it is suggested that the draft flood extents are a reasonable representation of the predicted flood behaviour in this area. Suggest no change required Flood Extent: The flood extent has been filtered as per the requirements in the technical specifications. Fragmentation does occur due to changes in terrain, slopes, material types, surcharging pits, etc. Suggest no change required Survey: This area (noth of Greaves Road) is actually not part of the study area. The small amount of water overtopping the levee is unlikely to impact the results south of Greaves Road. However, we will include a zln of this levee in the final model runs	9/09/2019	YES	Noted
6	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	See last tab, Check Orientation and location of PO lines to make sure it's perpendicular to flow and it is location within an overland flow path	Results	August 26, 2019	Tuflow Checking	PO lines will be checked and updated prior to final model runs	9/09/2019	YES	Noted
7	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	Default, however the data is not substantial. Could have made Material 25(roads) as default	Manning's n - Paved Roads / Driveways	August 26, 2019	Tuflow Checking	Default value on applied due to TUFLOW requirements (actually not used). GIS layer of materials covers entire catchment Suggest no change is required	9/09/2019	YES	Noted
8	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Has there been check if the new storage-discharge relationship from RORB is consistent with the available as constructed drawings?	Section 3.4 - Storages	August 26, 2019	R001	Yes, as outlined in the report. Stage-storage-discharge relationships were adopted from design drawings where available. If no were available, LIDAR was used. Suggest no change is required.	9/09/2019	YES	Noted
9	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Should IFD values be reported on? such as the exact location of where it was extracted from. The IFD data from the modelling files/data hub input do contain these information but it is considered important enough to be included in the report also.	Section 3.7.1.1 - Intensity Frequency Duration (IFD) Relationships	August 26, 2019	R001	This information will be included in the final report	9/09/2019	YES - added as appendix E	Noted
10	R001_TITreeCreek_DraftReport	velask	Melbourne Water	have the IL been reduced to take into account that the IL from data hub is for complete storm. Please provide commentary on the design storm modelled in RORB if this is a burst storm of not.	Section 3.7.1.2 - Hydrological Loss Parameters	August 26, 2019	R001	IL has been reduced as per ARR2019 guidance. Additional commentary on this will be added to the final report	9/09/2019	YES	Noted
11	R001_TITreeCreek_DraftReport	velask	Melbourne Water	should this be called regional parameter or previous model parameter?	Section 3.7.2.2 - Kc Analysis Table	August 26, 2019	R001	This will be reworded in the report	9/09/2019	YES	Noted
12	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Keep the terminology consistent with the project. Use % as AEP	Section 3.7.2.2 - Kc Analysis Figure	August 26, 2019	R001	Report will be updated to only reference AEP	9/09/2019	YES	Noted
13	R001_TITreeCreek_DraftReport	velask	Melbourne Water	in min	Section 3.7.4.1 - Critical Storm Events and Associated Temporal Patterns Table	August 26, 2019	R001	Table will be updated accordingly	9/09/2019	YES	Noted
14	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Clarify that RE in this case is derived from RORB in the form of m3/s	Section 4.1 - Overview Table (Excess Rainfall)	August 26, 2019	R001	This will be clarified in the report	9/09/2019	YES	Noted
15	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Upstream inflow could not be found easily in Figure 9.	Section 4.1 - Overview Table (Upstream Flows)	August 26, 2019	R001	There is no single defined upstream inflow to this catchment. The "upstream inflows" referred to in this report are those where excess rainfall is being applied. This will be made clearer in the report	9/09/2019	YES	Noted
16	R001_TITreeCreek_DraftReport	velask	Melbourne Water	reporting on the pit sizes in the model as per 5.6.3.4 of MW flood mapping guidelines	Section 4.2 - Pipe Infilling	August 26, 2019	R001	Assumptions on pits sizes will be added to the report.	9/09/2019	YES	Noted
17	R001_TITreeCreek_DraftReport	velask	Melbourne Water	relatively small area?	Section 5.3 - Results and Findings	August 26, 2019	R001	Grammatical error. Report will be updated accordingly	9/09/2019	YES	Noted
18	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Will there be commentary on the Peak Flows at key locations from the TUFLOW results? maybe in comparison to RORB model? Commentary in this seems important considering that the critical event sampling were done in RORB and assumed to be applicable in TUFLOW.	Section 5.3 - Results and Findings	August 26, 2019	R001	Further commentary will be included in the final report	9/09/2019	YES	Noted
19	R001_TITreeCreek_DraftReport	velask	Melbourne Water	Labels for locations of hydrographic stations	Appendix A - Figure 5	August 26, 2019	R001	Figure will be updated to include labels	9/09/2019	YES	Noted
20	R001_TITreeCreek_DraftReport	velask	Melbourne Water	PO stands for Plot output Legend on the elevation	Appendix A - Figure 7	August 26, 2019	R001	Legend will be updated accordingly	9/09/2019	YES	Noted
21	R001_TITreeCreek_DraftReport	velask	Melbourne Water	is the depth result shown on this plan with filtering to 0.05m? If so, the legend should reflect this.	Appendix A - Figure 11	August 26, 2019	R001	Yes it is. Legend will be updated accordingly	9/09/2019	YES	Noted
22	Melbourne Water Tuflow Model Review Spreadsheet	KV	Cardno	Layered flow constrictions, some have very small percentage of blockage 0.5%. Just a query on what these are? And confirm if they are correct and not a typo. how have the IL coefficients been determined? Please provide commentary on report on the use of this approach rather than 1d rnk.	Results	August 26, 2019	R001	Blockages and FC values have all been estimated from design plans and site investigations. Discussions of these along with a table showing how they have been estimated will be supplied in the final report	9/09/2019	YES	Noted

Project Number
Project Name

	Scoping	Data Review	Model Setup	Calibration / Verification	Results
Objective	To ensure clear scope and requirements for the modelling project are identified. This will include: • Purpose of the modelling project and objectives • Any specific special features of the study area to be incorporated • Any key requirements from the client	A review of all available data and identification of key data sources to be included in the model	A review of model setup, ensuring that the model meets the requirements of the scoping and parameter stage. Checking to include all model data sources, representation of existing or proposed design, numerical stability indications etc. Typically undertaken following initial run through with one 100 year ARI event or similar.	Calibration of the model to historical events, or comparison of the model to previous modelling assessments. Can also include general checking and verification of the model, such as for structures.	Review of model results to ensure that model is representing flood behavior and meetings requirements of scoping. Checking of key issues such as differences between ARIs, consistency of figures and results etc
Required	Always	Always. Note can be undertaken in conjunction with model setup phase, particularly if the project is small or low risk. This is up to the discretion of the PM	Always	Always	Always
Documentation	Preparation of a short (half page or less) document to highlight requirements, as well as highlight when reviews will occur during the modelling.	Make sure all data used in modelling has been included and discussed in the Model Setup Sheets	Complete: • Setup_Hydrology • Setup_2D • Setup_1D • Setup_Other • AfterPrelimRun	Conduct meeting with PM / Tech Review to discuss and prove model results.	Complete: • AfterFinalRuns
Responsibility	To be initiated by the PM. Scoping ideally undertaken in a meeting with modeler (s). Modeller (s) to prepare scoping document for review by PM.	Modeller	Modeller	Modeller	Modeller
Completed	<u>Name and Date</u>	<u>Name and Date</u>	<u>Name and Date (for each element)</u>	<u>Name and Date (for each element)</u>	<u>Name and Date</u>
Peer Reviewed	<u>Not required</u>	<u>Not required</u>	<u>As per PM Instruction</u>	<u>As Per PM Instruction</u>	<u>Initials</u>
PM/Task lead Signoff					

Expectations:

Provide as much concise evidence of checks as possible.
The amount of detail and checks should be discussed with the reviewer/project manager prior to commencing analysis. They should be aligned with the scope and the required outputs of the project
All Setup_Checks to be conducted prior to running prelim runs
After prelim runs - must complete AfterPrelimRun sheet and get authorisation before proceeding to final runs
After final runs - must complete AfterFinalRuns checks before spending time on generating deliverables and figures
Must keep PM informed of key decisions and re-runs (prior to kicking off)
Any changes must result in an update of this sheet, add more columns on to have a complete log of initial checks through to final.

NOTES

Need to find appropriate number. X sub-catchments per km2

MIRORB Elements	Check Required	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do the minimum sub-catchment areas fall within the AR&R guidelines?		e.g. yes	Catchment is 34.3 sq km. It contains 88 subcatchments which have been mainly defined based on MW and council pipe data, with topo also used.	ok				
Are all the sub-catchments about the same size?	Check min, max and mean sizes in MIRORB table	e.g. yes	88 Subcatchments min: 0.048 sqkm average: 0.390 sqkm max: 1.63 sqkm	ok				
Are there any overlaps or gaps in the sub-catchments?	Check by summing the subarea areas and comparing to the catchment area	e.g. No	No, have used the automated catchment generator to check for holes, and also used the check regions for gaps and overlaps with no issues highlighted. Catchment area = 34,296 sq km Sub-Catchment area = 34,297 sq km	ok				
What channel types are being used?		List of channel types. If varying, check for logic	Type 2 for all urban reaches, and Type 1 for natural reaches	OK - as per recommendations from MW				
Have nodes been placed at all junctions, subarea boundaries, inflow, outflows, gauging stations and/or points of interest?		e.g. yes	nodes have been placed at all centroids (moved if centroid is not appropriate) and all subarea boundaries	ok				
have reaches been drawn in the direction of flow?		e.g. yes		Yes				
Do reach slopes and lengths match those from Maps/GIS?		check 10% of reaches		Checked 10 reaches, seemed fine. Some reaches had a 0 slope or negative slope. These were mostly located within wetlands and were altered to having a 0.05% slope				
Do number of reaches relate to number of nodes?	Number of reaches = (number of nodes) - (number of outlets in catchment)	e.g 245 nodes, 2 outlets, 243 reaches	Yes, 220 nodes, 12 storages, 207 reaches, 1 outlet	Yes, 220 nodes, 12 storages, 207 reaches, 1 outlet				
Are fraction impervious values correct? Do they all lie between 0 and 1?	Ensure a general FI values, and an EIA value are used in producing the final FI for each subcatchment	e.g. yes	Range from 0.008 - 0.758. FI has been thematically mapped and is seems to match the range in which I would expect with aerial photo	Range from 0.008 - 0.758. FI has been thematically mapped and is seems to match the range in which I would expect with aerial photo				
Have all table columns been updated to account for edits made prior ro exporting to .catg RORB file?		e.g. yes		Yes				
RORB Model Settings	Check Required	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What m factor is being used?		number quoted		0.8 OK				
Are IFD tables setup correctly?	For MW projects, assure non-standard durations are downloaded If flows are needed for storms >1% AEP event, "growth factors" need to be applied.	e.g. yes, up tp 0.1% AEP accounted for.	Yes, up to 0.05% AEP event being accounted for	ok as per MW tech specs				
What rainfall loss model is being used?		e.g. constant loss model	IL\CL	ok - as per ARR2016				
What pattern details are being used?	For models requiring only a peak flow, a monte carlo simulation will be sufficient For models requiring a TUFLOW model, a monte carlo is required to find the durations, and ensemble required to find the temporal patterns need to be run. A seperate speadsheet should be used to document this process	e.g. temporal pattern zone, location	Patterns being used can be found in "Temp_Pattern_Analysis" spreadsheet	ok - have reviewed spreadsheet long events are being run for all durations this will ensure that the effects of any storage within the study area will be captured				
Are the loss values in the ranges recommended by AR&R?	Urban Catchment - IL = 60-80% of rural loss from ARR data hub CL = 1-3 mm/h, usually 2.5mm/h	e.g. the number and why they have been adopted	IL=18.9mm, CL=2.5mm\h	ok - these do not seem excessive compared to ARR datahub				
Are aerial reduction factors needed?		Brief description why/why not needed, what method is being used	3 Catchment areas have been used to determine ARFS based on ARR 2016 equation. These were 35km2 for the downstream outlet,10km2 for the upstream catchments and 1km2 (for local catchment flooding)	ok				
Are print locations correct?	Check that there are appropriate print locations for either areas of interest, or for each sub-catchment. Ensure these locations are appropriately named.	e.g. yes	Yes, all subareas for excess, and MC print locations	ok				
What is the calibrated/design Kc?	If no gauge flows are available for calibration, use kc that gives median flows across the catchment	number quoted and methodology used	7.94. Estimated using a range of equations/methodologies with that producing the viaue closest to the mean being adopted (scaled kv value from previous modelling of Ti Tree Creek)	ok				
Result Checks	Check Required	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Have gauged flows been checked against modelled flows?		e.g. yes, numbers quoted	No gauge flows available in catchment	ok				
Has the peak flow been compared to an alternate approach?		e.g. yes, approach compared to, key findings	No	OK - no calibration data available/Rational Method is no longer a supported method as per ARR2016				
Are 100 year flows greater than 50 year flows for all subcatchments?		e.g. yes	Yes	OK				
Scope	Check Required	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?		e.g. yes, explanation	Yes	OK				
Additional Requirements	Check Required	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3

Topography	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Short summary of the raw topo data used:	<i>Link to folder(s) and short desc. inc. source / year</i>	LiDAR data received from MW	ok LiDAR is from the 2017 LiDAR data set				
What process was used to prepare the DEM?	<i>A few sentences on how DEM was prepared</i>	LiDAR was used as the base, with ridge and gully z-lines used to ensure the channel base and storages were modelled correctly. A couple of z-shapes were used to smooth out channel and ensure water flow through a few culverts	ok - spot checks undertaken on surface changes using DEM_Z and seem to be input as to the model as expected				
What sensibility checks have been conducted on the DEM?	<i>e.g. cross sections have been drawn through to ensure no spikes in the data, spot checks have been conducted against the raw data at A, B and C, channel inverts have been inspected at D and found to be broadly representative.</i>	Checked storages and channel bases have been modelled correctly. Checked road kerbs were picked up	OK - spot checks undertaken. No issues found				
For projects with more than 1 DEM, provide a link to the topo log:	<i>hyperlink or include in this sheet.</i>						
Un-nested Grids	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What is the Grid Extent? Does it cover the		Grid extent covers entire	OK				
What is grid cell size and why was it chosen?	<i>e.g. 3 m, to ensure less than 1M cells and to represent road flows</i>	3m, within MW urban flood mapping range	OK				
Has this been approved with the PM?	<i>e.g. yes, date / evidence</i>	Yes	OK				
Is the grid rotated, if so why?	<i>e.g. no</i>	No	OK				
What is the origin of the grid and why was it chosen?	<i>e.g. 999,999 to align with neighbouring catchment</i>	2d_loc line running east-west	OK - checked				
Nested Grids	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What are the grid cell size and why were they chosen?	<i>e.g. 3 m in townships, to ensure less than 1M cells and to represent road flows. 6 m in rural where less resolution is required.</i>	N\A	OK				
Has this been approved with the PM?	<i>e.g. yes, date / evidence</i>	N\A	OK				
Is the grid rotated, if so why?	<i>e.g. no</i>	N\A	OK				
How have you ensured the grids transfer flow?	<i>Short description</i>	N\A	OK				
What is the origin of each of the grids?	<i>locations</i>	N\A	OK				
Roughness	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
How has the roughness grid been prepared	<i>land uses, aerial, survey etc.</i>	Planning zone and MW building layers were used as a base, with alterations made to these based upon aerial imagery.	OK - spot checks undertaken. Accuracy seems to be adequate				
Are the roughness values chosen consistent with other specific projects (if yes - list a few)		Yes, and MW recommendations	OK - consistent with latest MW tech specs				
Does the roughness cover the full model area?	<i>e.g. yes, has been checked in GIS</i>	Yes	OK	Roughness extended to cover new 2d_code	OK		
Flow Lines	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Have preliminary flow lines been placed within the model along identified flow paths?	<i>e.g. yes</i>	Preliminary PO flow lines have been placed along primary flow paths identified by the ROG model. Additional PO lines should be allocated after the 100Y model simulation including the drainage network	OK - please ensure these are updated prior to final model runs	Updated for draft	OK - please ensure these are updated prior to final model runs		
Hydraulic Inputs	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do the hydrology outputs match the hydraulic inputs? How is it being applied? Do they approach zero?	<i>e.g. yes, brief explanation of method of applying flow</i>	yes	OK	Excess rainfall applied to surface across 17 subareas and excess rainfall applied to pits in 69 subareas. Yes, they approach zero.			
Boundary Conditions	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What are downstream boundary types being used (both 1d and 2d)?	<i>value quoted, brief explanation of why it was chosen</i>	Initial DS Boundary set to 1% slope, downstream catchment is Hallam which is currently being modelled.	A DS slope boundary is at the edge of our area of interest is not adequate for this assessment. Suggest extending the model boundary 2.5km (approx) downstream as this is at a point where the downstream boundary should not effect the results in the area of interest	Downstream boundary and 2d_code updated. 1% HQ slope line added for Hallam Valley Drain and Berwick South D.S channel bank to bank boundary. Additional 1% HQ lines applied to alleviate glasswalling	Ok		

How were the boundary files created and does they vary with case?	Brief description	OUTLETS: 2d_bc_Outlets INLETS: 1d_bc and 2d_sa layers linked to a database. 2d_sa layers used where there are not enough pits in subarea. Upstream catchments from RORB model hydrographs as a 2d_sa.	OK - 2d_sa layers are applying water to all cells as required				
How were the flow input files created and does they vary with case?	Brief description, including file locations	RORB, with manual manipulation to get results into TUFLOW format	ok - spot checks undertaken				
1d/2d Connectivity	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Are all 1d elements snapped?	e.g. yes	Yes. An in-house FME code was used to ensure all pipes and pits have been connected to a defined outlet	OK				
How is the connectivity between 1d and 2d elements being modelled?	brief description	Through sx connections on either pits or sx lines	OK - spot checks undertaken and seems ok				

Scope	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?	e.g. yes, explanation	yes	NO	Yes	OK		

Additional Requirements	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3

Pipes/Channels	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Short summary of 1d network used	<i>Link to folder(s) and short desc. inc. source / year</i>	Pit and pipe data supplied by MW, includes both MW and Council data.	OK - manipulation/infilling of this data was undertaken as outlined below				
Have pipes/channels been drawn in the correct direction?	<i>e.g. yes</i>	Yes, automated process to ensure all pipes flow towards a defined outlet. A single outlet was created, with dummy pipes connecting to the dummy outlet from the actual pipes. Pipes made to all flow to the single outlet.	OK - spot checks undertaken				
Do pipes/channels increase in diameter as the network progresses downstream?	<i>e.g. yes (if not, supply reasoning as to why)</i>	For the majority, Yes. Consecutive pipes that have decreasing diameters supplied by MW and Council have been unchanged unless an obvious error/analmy has been identified. These errors have been flagged and discussed with the PM for additional advice	OK - spot checks undertaken				
Do pipes/channels flow downhill?	<i>e.g. yes</i>	Yes	OK - spot checks undertaken				
Are there any areas where pipes/channels appear to be missing from network?	<i>e.g. no (if yes, supply reasoning as to why)</i>	NO	OK - spot checks undertaken				
Where any pipe/channel attributes missing and how have they been assumed?	<i>if yes, provide explanation on what method was used in their assumption</i>	Have been infilled by a group of automated processes to infill inverts and diameters. Inverts assumed to have a 600mm cover. Manual changes then made to ensure pipes flowing downhill and that pipes are below ground	OK				
Are friction types consistent for all pipes/chennels?	<i>e.g. ye, quote number/s</i>	yes, 0.015	OK				
Pits	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Are pits generally located at low points?	<i>e.g. yes</i>	Pits located according to council and MW data. Additional pits added where connections should be, but have not been present in data received.	OK				
Where any pit attributes missing and how have they been assumed?	<i>if yes, provide explanation on what method was used in their assumption</i>	Yes, pit inverts assumed to be bottom of pipe invert, and hieght and width equal to 1m	OK				
Cross Sections	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do final cross sections match input data?	<i>e.g. yes</i>	N/A	OK				
What cross section friction definition has been used?	<i>brief description</i>	N/A	OK				
Hydraulic Inputs	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do the hydrology outputs match the hydraulic inputs? How is it being applied? Do they approach zero?	<i>e.g. yes, brief explanation of method of applying flow</i>	Yes, RORB outputs translated straight to tuflow form. Inflows all approach 0m3/s	OK	As before			
Boundary Conditions	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What are downstream boundary types being used (both 1d and 2d)?	<i>value quoted, brief explanation of why it was chosen</i>	One pipe discharges outside of the code and the HT has been set to the upstream obvert of the pipe (1d_bc_Pipes)	See comment on extending downstream model boundary	Model has been extended. HQ downstream boundary set in place of HT, as per MW comment for Edrington.	OK		
How were boundary input files created and do they vary between runs?	<i>Brief description</i>	1d_bc and 2d_sa layers linked to a database. 2d_sa all layers used where there are not enough pits in subarea	OK				
How was lateral.dat file created and does it vary with case?	<i>Brief description</i>	RORB, with manual manipulation to get results into TUFLOW format	OK				

Scope	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?	<i>e.g. yes, explanation</i>	Yes	NO	Yes	OK		

Additional Requirements	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
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Model Settings	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
What is the 1d timestep? Is it 1/10 to 1/5 of the 2d timestep?	<i>number quoted and confirmation</i>	0.1 seconds. Yes, 1/10 of 2d timestep	OK	Changed to 0.2 as per MW feedback on Edrington Park D.S Flood Mapping project	Ok		
What is the 2d timestep? Is it 1/4 to 1/2 of the grid size?	<i>number quoted and confirmation</i>	1 second. Yes, 1/3 of grid cell size	OK				
What is the saving timestep?	<i>number quoted</i>	300 seconds	OK				
What is the saving value?	<i>e.g. max</i>	Max only	OK				
What are the saving max grids?	<i>e.g. h, V, q, d</i>	hVqdFEZ0ZMW2MB1MB2	OK				
What is the simulation duration? Does it cover the duration of inflows?	<i>number quoted, yes, evidence</i>	Will check again after model re-run	Please ensure these are checked prior to final model runs	Simulation durations increased as per file:///M:\2018\1501_2000\V181917_MW_FM_Casey\Water\Engineering\Hydrology_Hydraulics\TUFLOW\MW_Titree\Runtimes_Check.xlsx	OK		
Reporting Stations, Level and Flow	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Are level reporting stations specified to meet project needs (e.g. at gauges)	<i>e.g. yes where?</i>	No gauge within 2d model area	OK				
Are flow reporting stations (PO lines) specified to meet project needs?	<i>e.g. yes where?</i>	Yes, will add or subtract based on preliminary 100y results	Please ensure these are updated prior ro final model runs	Update for final run	OK		
Scope	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?	<i>e.g. yes, explanation</i>	Yes	OK	Yes	OK		
Additional Requirements	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3

General Checks	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do the model durations allow the peak flows to travel to the outlet?	<i>e.g. yes, evidence</i>	Yes, have checked all runs to ensure the peak has gone through. Extended some run lengths	OK	OK.			
What are the critical durations?	<i>Construct a thematic map of the peak levels and list the % coverage of each duration</i>	Critical durations range from 20 min to 720 mins. 1% AEP: 20m - 26% 30m - 11% 45m - 1% 60m - 10% 120m - 19% 180m - 11% 720m - 22% 45m duration can potentially be removed for future 1% runs 20% AEP: 30m - 0.3% 60m - 20% 90m - 9% 120m - 21% 180m - 8% 270m - 13% 720m - 30% 30m duration can potentially be removed for future 20% runs. Greater majority of critical durations are 720m. Should consider including greater durations in final runs	Please include events greater than 720m duration in final model runs	1080m setup for second draft runs. Critical durations range from 20 min to 720 mins. 1% AEP: 20m - 32% 30m - 10% 45m - 1% 60m - 9% 120m - 6% 180m - 14% 720m - 28% 45m duration can potentially be removed for future 1% runs. Greater majority of critical durations are 20m and 720m. 20% AEP: 30m - 0.1% 60m - 11% 90m - 0.8% 120m - 16% 180m - 9% 270m - 14% 720m - 48% 30m and 90m durations can potentially be removed for future 20% runs. Greater majority of critical durations are 720m.	OK		
Compare flows just downstream of the inflow points to the hydrology. Do they match?	<i>e.g. yes, evidence</i>	TITree does not have a upstream creek inflow. Inflows are applied as excess direct rainfall. No routing was applied	OK				
Does the total inflow volume match the hydrology?	<i>e.g. yes, evidence</i>	Checked 1% AEP 60m TP27 Volume in from ttf = 1,045,686 m3 Volume in from bc_dbase = 1,055,921 m3	OK				
Are there any simulation checks, warnings and/or errors? If so, can they be explained / meeting with PM & Tech Review to discuss.	<i>e.g. yes, evidence & meeting</i>	Yes, gone through checks and all are ok, will need to re-check once the new model additions have been run in final runs	Please ensure that these are checked when model is re-run	Yes, gone through checks and all are ok, will need to re-check once the new model additions have been run in final runs	OK		
Is the mass balance error less than 1%?	<i>e.g. yes, provide explanation if not</i>	100Y - All runs < 1% except 720m_26TP with -Final cumulative ME - 1.07% -Peak cumulative ME - 1.33% 5Y - 270m_5TP with -Final cumulative ME - 1.12% -Peak cumulative ME - 1.17% 5Y - 30m_6TP with -Final cumulative ME - 1.15% -Peak cumulative ME - 1.15% 5Y - 720m_7TP with -Final cumulative ME - 0.74% -Peak cumulative ME - 1.61%	OK - close enough to 1% for prelim runs	Yes., max = -0.36%	OK		
Are there any negative depths in model?	<i>e.g. no, provide explanation if not</i>	There is 1 negative depth in 5Y_270m_2TP&5TP. Appears to be a slight instability with the lfcsh and the topo. Lfcsh can be extended to remove slight instability	OK - wont be affecting overall results	There are 2D negative depths in 14/22 events at Greaves Rd RB, at the basin batter slope: 100y_720m_26TP, 5y_720m_7TP, 5y_270m_2TP, 5y_270m_5TP, 100y_1080m_22TP, 100y_180m_28TP, 100y_1080m_26TP, 5y_60m_4TP, 100y_60m_27TP, 100y_45m_27TP, 5y_1080m_7TP, 100y_30m_26TP, 100y_720m_22TP and 100y_30m_25TP. Highly unlikely to affect results.	Agree - OK		
1d Sensibility Checks	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Are pipes running full?	<i>e.g. yes, provide explanation if not</i>	Yes, 14717 out of 16262 (90%) pipes are running full in 100y60m27tp event	OK	Yes, 14706 out of 16253 (90%) pipes are running full in 100y60m27tp event. 62% of 5y60m8TP running full.	OK		
Are pipe connections being modelled correctly?	<i>e.g. yes, evidence</i>	Yes, majority of pipes are running at least +90% full in the 1% event. No anomalies can be seen in the pipe network	OK	Yes, majority of pipes are running at least +90% full in the 1% event. No anomalies can be seen in the pipe network	OK		
Is the headloss over all major structures reasonable?	<i>e.g. yes, quote numbers, provide evidence including which program has been used to verify head loss (e.g. culvert-w, hecras, MIKE11, flowmaster)</i>	N/A	OK	N/A	OK		
2d Sensibility Checks	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Is the 2d flow constrained?	<i>e.g. no</i>	Overall water appears to be flowing out of the catchment freely. There is some minor glasswalling on the south-east end of the code layer. This area is still in construction so therefore could potentially be trimmed out	Please see comments RE extending downstream boundary of model. 2d_bc outlets should also be added where major glass walling is occurring prior to final model runs	OK - boundary has been extended as already discussed	OK		
Does the overland flow make sense?	<i>e.g. yes, evidence</i>	Longer durations are critical in basins and storages. Overland flow extents appear valid	OK - but longer durations appear to be required	Yes	OK		

Is the maximum 2d water level higher for larger AEPs?	<i>e.g. yes, evidence</i>	Yes, only 1% and 20% run for draft. 1% consistently higher	OK	Yes, only 1% and 20% run for draft. 1% consistently higher	OK		
Are flood extents within larger AEPs?	<i>e.g. yes</i>	Yes, only 1% and 20% run for draft. 1% extent larger	OK	Yes, only 1% and 20% run for draft. 1% extent larger	OK		
Flow Lines	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Do preliminary flow lines cover the entire flow area?	<i>e.g. yes</i>	Major flow paths have been captured. Some additional flow lines can be included to capture and analyse local flooding	Please update these prior to final model runs	Update for final run	OK		
Are there an adequate number of flow lines in the model?	<i>e.g. yes, evidence</i>	Yes, also see above	OK	Yes, see also above	OK		
Do flows increase for larger AEPs?	<i>e.g. yes, evidence</i>	Yes, compared the 1% & 20% 120m POMM results files. All 1% AEP maximums flows are larger than the 20%	OK	Yes	OK		
Remaining Runs	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Have all changes been documented in this spreadsheet?	<i>e.g. yes</i>	Yes	OK	Yes	OK		
Has model been backed up?	<i>e.g. yes, provide location. Make sure file/folder structure has been sorted</i>	Yes, on H and M drives	OK	Yes, on H and M drives	OK		
Has checker and PM authorised final model runs?	<i>e.g. yes</i>	No	Final model runs cannot be run until identified issues have been rectified and approval has been gained from client				
Has expected model completion time been communicated to PM?	<i>e.g. yes, quote time</i>	No	OK	Yes, see tif files in log folder			
Scope	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?	<i>e.g. yes, explanation</i>	Yes	NO	Yes	OK		
Additional Requirements	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3

Comparisons Between Events	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Is the maximum 2d water level higher for larger AEPs?	<i>e.g. yes, evidence</i>	yes have run through the sequential checker	OK				
Are flood extents within larger AEPs?	<i>e.g. yes</i>	yes have run through the sequential checker	OK				
Do flows increase for larger AEPs?	<i>e.g. yes, evidence</i>	yes have run through the sequential checker and no issues found	OK				
Administration Tasks	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Is the folder structure and naming convention consistant?	<i>e.g. yes, list folder structure</i>	as per TUFLOW convention	OK				
Have residual models been deleted?	<i>e.g. yes</i>	yes	OK				
Has a handover meeting been conducted with the PM?	<i>e.g. yes</i>	yes	OK				
Errors & Logs	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Are there any simulation checks, warnings and/or errors? If so, can they be explained / meeting with PM & Tech Review to discuss.	<i>e.g. yes, evidence & meeting</i>	yes, have been checked and can be explained as per prelim run comments	OK - have checked and seem ok				
Is the mass balance error less than 1%?	<i>e.g. yes, provide explanation if not</i>	yes, max error is 0.61%	OK				
Are there any neagtive depths in model?	<i>e.g. no, provide explanation if not</i>	Yes 2D negative depths are occuring at two locations inside the study area (Greaves Rd RB and Homestead Dr road crossing), these are not adversely affecting results and have been explained within the report	OK - have checked and agree with analysis				
Scope	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3
Does the Model Conform to Scope?	<i>e.g. yes, explanation</i>	yes, model is fit for delivery	OK				
Additional Requirements	Minimum Requirements	Modellers Comments v1	Reviewers Comments v1	Modellers Comments v2	Reviewers Comments v2	Modellers Comments v3	Reviewers Comments v3

TUFLOW QA Instructions

Purpose of spreadsheet:

Document review of model in accordance with "TUFLOW QA Framework" document

Info\Info\Enterprise\Waterways and Drainage\2. Team Folders (Waterways & Land)\Floodplain Services\Flood Mapping & Mitigation\Guidelines & Technical Specifications\TUFLOW QA Framework\TUFLOW QA Framework v2.docx

Instructions for Spreadsheet

- 1) Complete yellow highlighted cells in "Hydrology Checking" tab - add to this tab or add tabs as necessary to explain comments or issues (i.e. replace "<INSERT NAME of Issue Example>" tab with a tab that has an appropriate name)
- 2) Complete yellow highlighted cells in "TUFLOW Checking" and "TUFLOW Run Files" tab - add tabs as necessary to explain comments or issues (i.e. replace "<INSERT NAME of Issue Example>" tab with a tab that has an appropriate name)
- 3) Complete yellow highlighted cells in "Review Methodology" tab, which summarises the outcomes of the above 2 steps. Also, add "Severity of Issue" classifications for each line.
- 4) Undertake discussion with review approver
- 5) Print "Review Methodology" tab and sign required fields to complete review. Save on job.

TUFLOW QA Guiding Questions and Focus Areas

Guiding Questions to frame the model review

- (1) What is purpose of modelling (incl. perspective of all stakeholders)?
- (2) How do you best represent reality within the model?

Focus Areas

(A) Hydrology

- ☒ Have we allowed for all areas that contribute pipe and/or overland flow?
- ☒ Does there need to be routing off subarea or subareas?
- ☒ Is applied impervious fraction representative and in line with guidelines?
- ☒ Are losses appropriate – especially in "rain on grid" models

(B) Terrain

- ☒ Is grid size and orientation appropriate?
- ☒ Does model need terrain modifications to improve representation of flow controlling aspects within

(C) Roughness

- ☒ Is applied roughness representative and in line with guidelines?
- ☒ Is it consistent across catchment?
- ☒ Are narrow areas of roughness continuous (i.e. creek thalweg or laneway)?

(D) Network

- ☒ Are hydraulic properties of assets modelled correctly (i.e. irregular shaoed assets)?
- ☒ Are there decreases in conveyance as you move down the system?
- ☒ Are there any connectivity or grade issues?
- ☒ Are losses appropriate and what method is being used?
- ☒ Pits – where are these modelled, is inlet capacity being modelled and how are we allowing for unmodelled connections (i.e. houses)

(E) Inflows

- ☒ Is flow distribution appropriate?
- ☒ Does inflow location match RORB printout location (i.e. in terms of routing)?
- ☒ Is correct hydrograph referenced in bc_dbase?
- ☒ Is 100% of all hydrographs being applied (i?e? are any factors applied in bc_dbase)?

(F) Downstream Boundary Conditions

- ☒ Are boundary condition far enough away from model area of interest?
- ☒ Are 1D and 2D boundaries consistent?
- ☒ Should boundaries vary with AEP?

(G) Initial Conditions

- ☒ Are 1D or 2D IWL required?
- ☒ Have undrained depressions in catchment been filled (i.e. to avoid double counting some of initial loss and hence underestimating runoff)?

(H) Model Runs

- ☒ Are there any non-standard commands or changes to defaults in model run files?
- ☒ Are sufficient storms/durations run for model to appropriately determine peak levels throughout the
- ☒ Have undrained depressions in catchment been filled (i.e.to avoid double counting some of initial loss and

(H) Results

- ☒ Check if pipes are full where they are expected to be full (use "ccA" results)?
- ☒ Check if extents are in the correct order (i.e. 1% > 2% > 5% > 10% > 20% AEP)?

SUMMARY OF REVIEW

Project:	Ti Tree Creek
Catchment:	0619
Consultant:	Cardno
Date of Modelling:	1/11/2019
ProjeCy status:	Final
Reviewed by:	Robert Guest
Review Date:	4/11/2019
Reviewer Signoff:	Robert Guest

Review Discussion Date:	4/11/2019
Review Discussed with (at least Approver):	Rob Swan
Approver Signoff:	Rob Swan

Review Complete Date	4/11/2019
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Model Status Summary

Is model "fit for purpose" for planning applications?	Yes
Is model "fit for purpose" for other applications (i.e. FRAF)?	N/A
Overall comments on model suitability	Valid method for producing urban flood mapping results

Review Process Summary

Severity of Issue	Description	Number of Issues in Category	Examples of Issues
1	No issue	29	n/a
2	MINOR ISSUE - Likely to have only a minor impact on results and is somewhat subjective - Fix if model is being re-run for other reasons	0	1) Hydrology issues: minor adjustment in catchment or subarea boundaries and/or impervious fraction 2) 1d_nwk issues: minor invert mismatches 3) Roughness issues: relative roughness of various land uses along flowpaths 4) Terrain issues: grid orientation
3	MODERATE ISSUE - Likely to have some impact on results (local or wider) - Strongly consider fixing (definitely fix if re-running for other reasons)	0	1) Hydrology issues: Application of ARFs, incorrect reach type, assumptions regarding storages/diversions 2) 1d_nwk issues: flat grade on pipes, large invert mismatches and messages regarding application of automatic manholes for losses 3) Roughness issues: consistency of roughness along flowpaths 4) Terrain issues: additional terrain modifications along other controlling features (i.e. gully lines or ridges where modelled elevations don't match the control)
4	MAJOR ISSUE - An error or omission that will noticeably affect results (local or wider) - Must be fixed	0	1) Hydrology issues: large missing catchment area, major misrepresentation of impervious fraction, incorrect losses (RORB or rain-on-grid TUFLOW), or incorrect printout read into hydraulic model (wrong hydrograph or application in TUFLOW duplicates routing) 2) 1d_nwk issues: snapping, cover (pipes sticking out of ground), adverse grade, incorrect hydraulic properties, and incorrect or missing 1D/2D connections 3) Roughness issues: incorrect or discontinuous roughness classification within flood extent (eg. large hardstand areas within industrial areas or open space on large properties) 4) Terrain issues: poorly applied terrain modifications and key missing terrain modifications (i.e. gully lines or ridges along MWC assets where modelled elevations don't match the control)

Mapinfo Workspace	<Insert link to GIS based review workspace>
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Task No	Task	Severity of Issue	Date Complete	Comment	Links to checks (maps, figures, etc.)	Discussion Comments	Resolution
1	HYDROLOGY REVIEW (refer to "Hydrology Checking tab)						
1.1	Check overall catchment boundary	1	10/07/2019		C_RORB_Models\MIRORB_Tables		
1.2	Check subcatchment boundaries	1	10/07/2019		C_RORB_Models\MIRORB_Tables		
1.3	Check subcatchment impervious fraction	1	10/07/2019		A_Reports\F01_TiTreeCreek_FinalReport\Appendix A\Figure 4		
1.4	Check RORB network structure	1	10/07/2019		C_RORB_Models\MIRORB_Tables		
1.5	Check RORB catchment file and losses	1	10/07/2019		C_RORB_Models\RORB_Catg		
1.6	Check printouts match BC application in TUFLOW model	1	10/07/2019	Yes, RORB outputs translated straight to TUFLOW form. Inflows all approach 0m3/s	D_TUFLOW_Models\bc_dbase		
2	TUFLOW REVIEW (refer to "TUFLOW Checking tab)						
2.1	Check terrain representation (2D Domain)						
2.1.1	Grid size and orientation	1	10/07/2019	Grid Cell Size 3m, No rotation	D_TUFLOW_Models\runs\TiTreeCk.tgc		
2.1.2	Terrain modifications (Are any needed or are they performing as intended?)	1	26/07/2019		D_TUFLOW_Models\model\2d_zsh_TopoFix D_TUFLOW_Models\model\2d_zin_RidgeLines D_TUFLOW_Models\model\2d_zin_GullyLines D_TUFLOW_Models\model\mi		
2.1.3	Catchment Roughness	1	10/07/2019				
2.2	Check 1D network for issues (1D Domain)						
2.2.1	Connectivity	1	25/07/2019	Sx connections on either pits or sx lines to connect 1D with 2D elements	D_TUFLOW_Models\model\mi		
2.2.2	Grade and cover (does system grade downstream? Are flat sections critical?)	1	25/07/2019				
2.2.3	Sizes (does it increase as move down system)	1	25/07/2019				
2.2.4	Losses	1	25/07/2019	Entry and Exit Losses are assumed as 0.5 and 1, respectively. Friction set to 0.015 for pipes. Form losses set to zero.			
2.2.5	Location and method of modelling pits	1	25/07/2019	Pits located according to council and MW data. Additional pits added where connections should be, but have not been present in data received. Unknown pit inverts assumed to be bottom of pipe invert, height equal to 1m and width equal to 0.9m.			
2.3	Check boundary conditions						
2.3.1	Are inflows applied correctly based on hydrology printouts (i.e. appropriately spread and referenced correctly in bc_dbase)	1	25/07/2019		D_TUFLOW_Models\bc_dbase		
2.3.2	Are downstream boundaries suitable?	1	10/07/2019	HQ 1% slope boundaries applied downstream at Hallam Valley Drain outlet and at areas where glasswalling was occurring	D_TUFLOW_Models\model\mi\2d_bc_Outlets		
2.3.3	Do boundary conditions require application of IWLs in 1D or 2D domain?	1	25/07/2019	No IWL			
2.4	Check TUFLOW run files						
2.4.1	TCF	1	1/11/2019		See TufLOW Checking		
2.4.2	ECF	1	1/11/2019		D_TUFLOW_Models\runs\TiTreeCk.ecf		
2.4.3	TGC	1	1/11/2019		D_TUFLOW_Models\runs\TiTreeCk.tgc		
2.4.4	TEF	1	1/11/2019		D_TUFLOW_Models\runs\TiTreeCk.tef		
2.4.5	TMF	1	1/11/2019		D_TUFLOW_Models\model\Materials.tmf		
2.4.6	TBC	1	1/11/2019		D_TUFLOW_Models\model\TiTreeCk.tbc		
2.4.7	BC_DBASE	1	1/11/2019		D_TUFLOW_Models\bc_dbase		
2.4.8	TCF_OVERRIDE	1	1/11/2019	Not used and deleted from model folders.			
2.5	Check TUFLOW outputs						
2.5.1	Review check files	1	1/11/2019				
2.5.2	Review messages, warnings and mass error	1	1/11/2019				
2.5.3	Review map and TS output	1	1/11/2019				
2.5.4	Review deliverables	1	1/11/2019				

SUMMARY OF HYDROLOGY MODEL CHECKS

FILE LOCATIONS

Design report: A_Final_Report
Model files: C_RORB_Models, E_RORB_Model_MapInfo_Tables and F_MiRORB_Tables
Review workspace: <Insert link to GIS [N/A](#)

Item	Is current setup appropriate? (Yes or No)	Comment
Catchment boundary	Yes	Snapped to parcel boundaries and matched with adjacent MW catchment boundaries
Subcatchment boundaries	Yes	Determined by topography and pipe network flow paths
Fraction Impervious	Yes	Max = 0.744. Low values in undeveloped regions and high values in developed regions, which appear reasonable.
Network Structure	Yes	
RORB Catchment File	Yes	Hydrological Model is 33.68km2
Printouts	Yes	All subareas for excess and MC print locations (see MC Print Node Locations.tab)
Losses	Yes	Initial losses calculated as 70% of rural losses (18.9mm/hr) and continuous losses as 2.5mm/hr as per ARR2016
Critical Duration/Storm Selection	Yes	Critical durations determined by Monte Carlo analysis. Patterns being used can be found in "Temp_Pattern_Analysis" spreadsheet.

TUFLOW MODEL RUN FILE EXPLANATION

Base Model Files

File	Name	Comment
TCF	TiTreeCk_~e1~_~e2~_~e3~.tcf for Base Case.	runs folder
	TiTreeCk_CC_~e1~_~e2~_~e3~.tcf for Climate Change 3.	
	TiTreeCk_ARR87_~e1~_~e2~.tcf for ARR87.	
	TiTreeCreek_HPC_~e1~_~e2~_~e3~.tcf for HPC Sensitivity Analysis.	
ECF	TiTreeCk.ecf	runs folder
TEF	TiTreeCk.tef	runs folder
TGC	TiTreeCk.tgc	model folder
TBC	TiTreeCk.tbc	model folder
BC_DBASE	bc_dbase	bc_dbase folder for Base Case (ARR16), Climate Change 3 and ARR87 inflow files
TMF	Materials.tmf	model folder
OVERRIDE_TCF	TUFLOW_Override.tcf	Not used and file deleted after TUFLOW automatic generation.

TMF

Are manning's n values within recommended ranges	Yes
If the Initial and Continuing Losses have been set in the .tmf are they reasonable?	N/A

Material	Manning's n	IL (mm)	CL (mm/hr)	Description	Recommended Range
1	0.3			Residential High Density Urban Combined Parcel and Building	0.2-0.5
2	0.1			Residential Lower Density Rural Combined Parcel and Building	0.1-0.2
3	0.1			Residential High Density Urban Separate Parcel and Building	0.08-0.12
4	0.05			Residential Lower Density Rural Separate Parcel and Building	0.04-0.06
5	0.5			Building	0.2-0.5
6	0.3			Industrial	0.2-0.5
7	0.3			Commercial	0.2-0.5
8	0.04			Open Pervious Areas Minimal Grassed Vegetation	0.03-0.05
9	0.06			Open Pervious Areas Moderate Shrubbed Vegetation	0.05-0.07
10	0.1			Open Pervious Areas Thick Treed Vegetation	0.07-0.12
11	0.03			Waterways / Channels Minimal Vegetation	0.02-0.04
12	0.06			Waterways / Channels Moderate Vegetation	0.04-0.1
13	0.09			Waterways / Channels Heavy Vegeation	0.04-0.1
14	0.02			Concrete Lined Channels	0.015-0.02.
15	0.02			Paved Roads / Driveways	0.02-0.03
16	0.02			Lakes No Emergent Vegetation	0.015-0.35
17	0.06			Wetlands Emergent Vegetation	0.05-0.08
18	0.03			Estuaries / Oceans	0.02-0.04
19	0.05			Railway Lines	0.05-0.2
20	0.05			Singificant Drainage Easement	0.02-0.08
21	0.05			Gravelled Surface Rural Road	
22	0.015			Artificial Turf / Handstand Sporting Surface	
23	0.015			Culvert	
24	0.05			Agriculture / Farmland	0.03-0.05
25	0.022			Carparks	0.02-0.03
26	0.12			Upper End of Heavy Vegetation	0.12

<Insert more lines for above table as necessary>

Event definition

Variable	Comment on definition
	5, 10, 20, 50, 100 events for Base Case. 5,10,100 for CC. 5 and 100 for ARR87. 5, 100 for HPC.
~e1~	
~e2~	durations matching ARI events (see Runs.bat file)
~e3~	TP matching ARI events (see Runs.bat file) for ARR16. No e3 for ARR87 runs.

SUMMARY OF TUFLOW MODEL CHECKS

FILE LOCATIONS

Design report:	A_Final_Report	
Model files:		D_TUFLOW_Models
	MWC Checks	<Insert link to modified or copied model data used as part of review>
Review workspace:	<Insert link to GIS based review workspace>	

This column should be a value or either 'Yes' or 'No'

MODEL		
Tuflow version:	2018-03-AD	Comments (if required):
Does model run?	Yes	
Does model produce results in accordance with Consultant's results?	NA - Consultant filling in form	

Terrain Representation (2d Domain)		
Cell size (m)	3	Comments (if required):
Is grid orientation appropriate?	Yes	
Are applied terrain modification layers working as intended?	Yes	
Are all required terrain modifications applied?	Yes	
Is the default Material correct?	Yes	
Is / are the Materials Layer(s) reasonable?	Yes	

Drainage Network Representation (1d Domain)		
Are pipes connected throughout system?	Yes	Comments (if required):
Is network free of grade or cover issues?	Yes	
Do drainage network asset sizes make sense (i.e. increase as move down system)?	Yes	
Is loss modelling appropriate?	Yes	
Is pit modelling approach appropriate?	Yes	

Boundary Condition Representation		
Do tailwater level(s) or slope for HQ appear correct?	Yes	Comments (if required): No Upstream Inflows. Excess Rainfall directly applied at pits, which appear OK.
Do inflows appear correct?	Yes	
Are reasonable IWL conditions applied?	Yes	

TUFLOW Run Files		
1D time-step (sec):	0.2	Comments (if required):
2D time-step (sec):	1	
Is 1D time-step within 1/5 and 1/2 of the 2D time-step and not less than 0.5 sec?	Yes	
Is 2D time-step within 1/5 and 1/2 of the grid cell size?	Yes	
Do run files seem reasonable? (i.e. change to defaults or non-standard commands)	Yes	

LOG FILE		
Does MI Projection Check == Error (not Warning)?	Yes	Comments (if required): There are 2D negative depths occurring at two locations within the study area at Greaves Rd RB and Homestead Dr road crossing. These have been assessed and are not found to impact model results.
Does MI Save Date == Error (not Warning or Off)	Yes	
Is maximum Mass Error appropriate (usually not > 1.2%)?	Yes, max ME = 0.61%.	
Is the in / out volume change gradual?	Yes	
Are there no Negative Depth Warnings?	See comment	
Have Warnings in the .msg file been addressed?	Yes	

RESULTS		
Are pipes flowing full where expected (refer to _CCA.mif)?	Yes	Comments (if required): 14746 out of 16251 (90%) pipes are running full in 100y60m27tp event. 62% of 5y60m8TP running full.
Do Maximum Water Surface Levels appear OK?	Yes	
Do Maximum Velocities appear OK?	Yes	
Do flows in pipes and channels appear OK?	Yes	
Do extents seem reasonable and appear in correct order (Q100 >Q50>Q20, etc)	Yes, all events have been sequentially checked to ensure that Q100>=Q50>=Q20>=Q10>=Q5	