MELBOURNE WATER AND CITY OF MELBOURNE

Arden Macaulay Precinct & Moonee Ponds Creek Flood Modelling

Model Build Report

August 2020

V3000_080-REP-001-1

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1. INTRODUCTION

This report documents the flood modelling undertaken by Engeny Water Management (Engeny) on behalf of the City of Melbourne and Melbourne Water that has been used as the basis for the preparation of planning scheme overlays for Moonee Ponds Creek and contributing local catchments south of Racecourse Road, including the Arden Macaulay Precinct.

The flood modelling is based on a RORB hydrological model and a TUFLOW hydraulic model.

The TUFLOW model that has been adopted by Engeny was originally developed by AECOM in 2013 as part of planning for major developments within the study area. AECOM's model development is documented in the report titled Hydrologic and Hydraulic Modelling of Arden Street and E-Gate (AECOM, September 2013), which is provided in **Appendix A**.

The AECOM model was provided to Engeny by Melbourne Water for use in flood and drainage planning for the Arden Macaulay Precinct. Engeny made numerous refinements to the model so that it reflected the best available data and was fit for purpose for the Arden Macaulay Precinct planning.

The modelling has been undertaken to predict flooding in a 1 % annual exceedance probability (AEP) event, inclusive of an 18.5 % increase in rainfall intensity due to climate change and 0.8 metres of sea level rise. This is a consistent approach across the numerous models used to inform the current planning scheme amendment for the City of Melbourne and Melbourne Water.

This report documents the modelling methodology that has been adopted to prepare the modelling results that have been used as the basis of the planning scheme overlays.

2. BACKGROUND INFORMATION

2.1 Catchment Overview and Study Area

The extent of the flood modelling is located at the downstream end of the Moonee Ponds Creek catchment, extending from the confluence of Moonee Ponds Creek and the Yarra River to Moonee Ponds Creek at Mt Alexander Road. The flood modelling includes the local catchments draining to this section of Moonee Ponds Creek, which covers parts of the suburbs of Kensington, Parkville, Docklands, North Melbourne and West Melbourne.

Figure 2.1 provides an overview of the Moonee Ponds Creek catchment the location of the extent of the flood model.

The Moonee Ponds Creek catchment covers an area of approximately 139 square kilometres. The northernmost 89 square kilometres of the catchment drains to the Jacana Retarding Basin (a Melbourne Water asset), located at the Western Ring Road. This retarding basin provides an effective control of runoff from the upper section of the Moonee Ponds Creek catchment.

The section of the Moonee Ponds Creek catchment between the Jacana Retarding Basin and the Yarra River is highly urbanised with no significant formalised flood storage assets. This lack of flood storage assets is typical to some older urban areas of Melbourne and is due to systems being designed in the past to convey runoff efficiently to a receiving waterway, in this case Moonee Ponds Creek, via a piped drainage system and increasing the capacity of the receiving waterway through measures such as re-construction as a concrete lined waterway.

While the flood model covers a small area outside of the City of Melbourne (within the City of Moonee Valley), only results from the section of the model within the City of Melbourne is to be used for the current planning scheme amendment. Within the City of Melbourne section of the flood model, some areas of the model are not to be used to inform the planning scheme amendment due to low reliability in the setup of the model in these areas only.

Figure 2.2 provides an overview of the extent of the flood model and the contributing local catchments draining to Moonee Ponds Creek. This plan also highlights the area of the flood model from which results are to be used to inform the planning scheme amendment (the mapping extent).

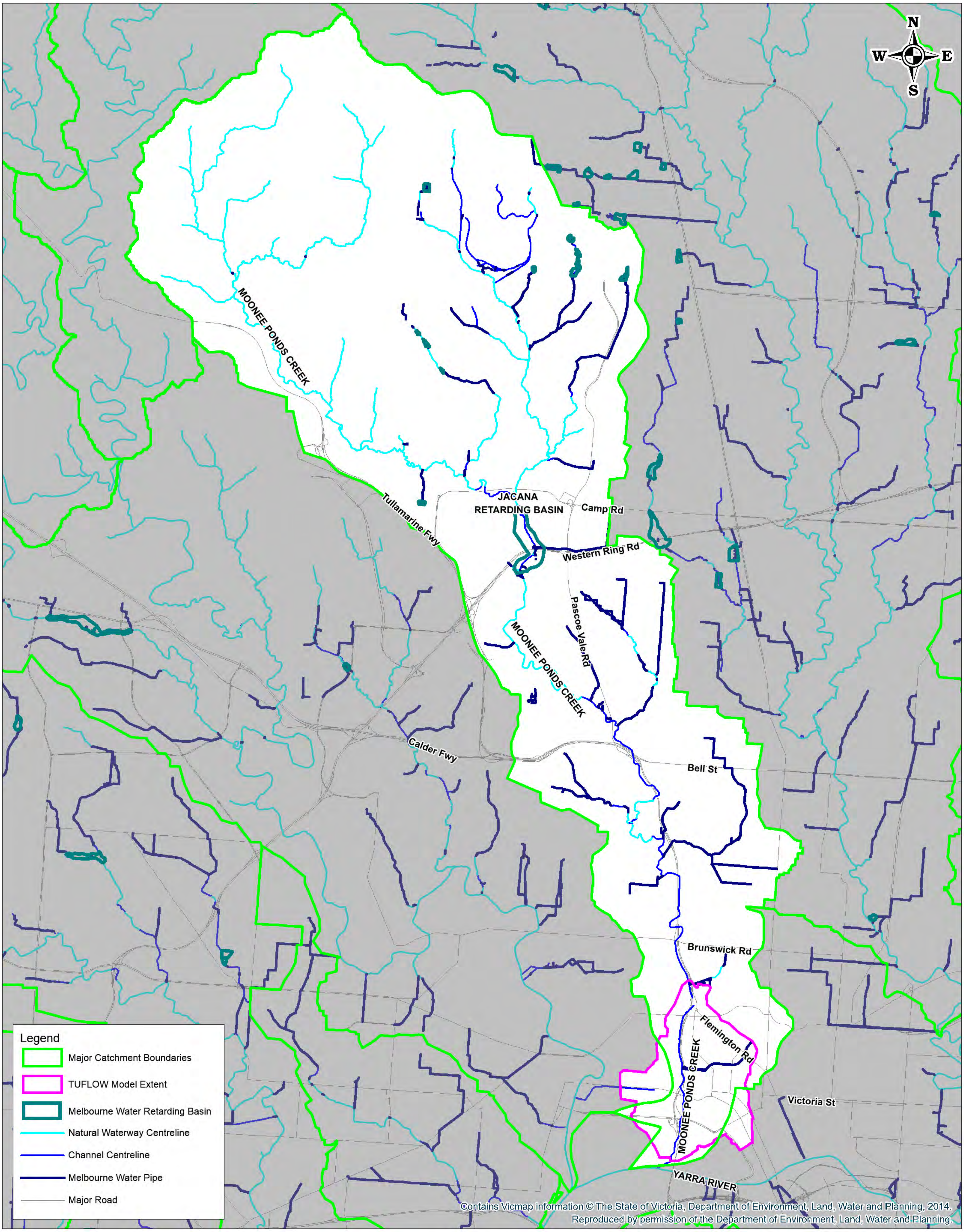

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Figure 2.1
Overview of the Moonee Ponds Creek Catchment

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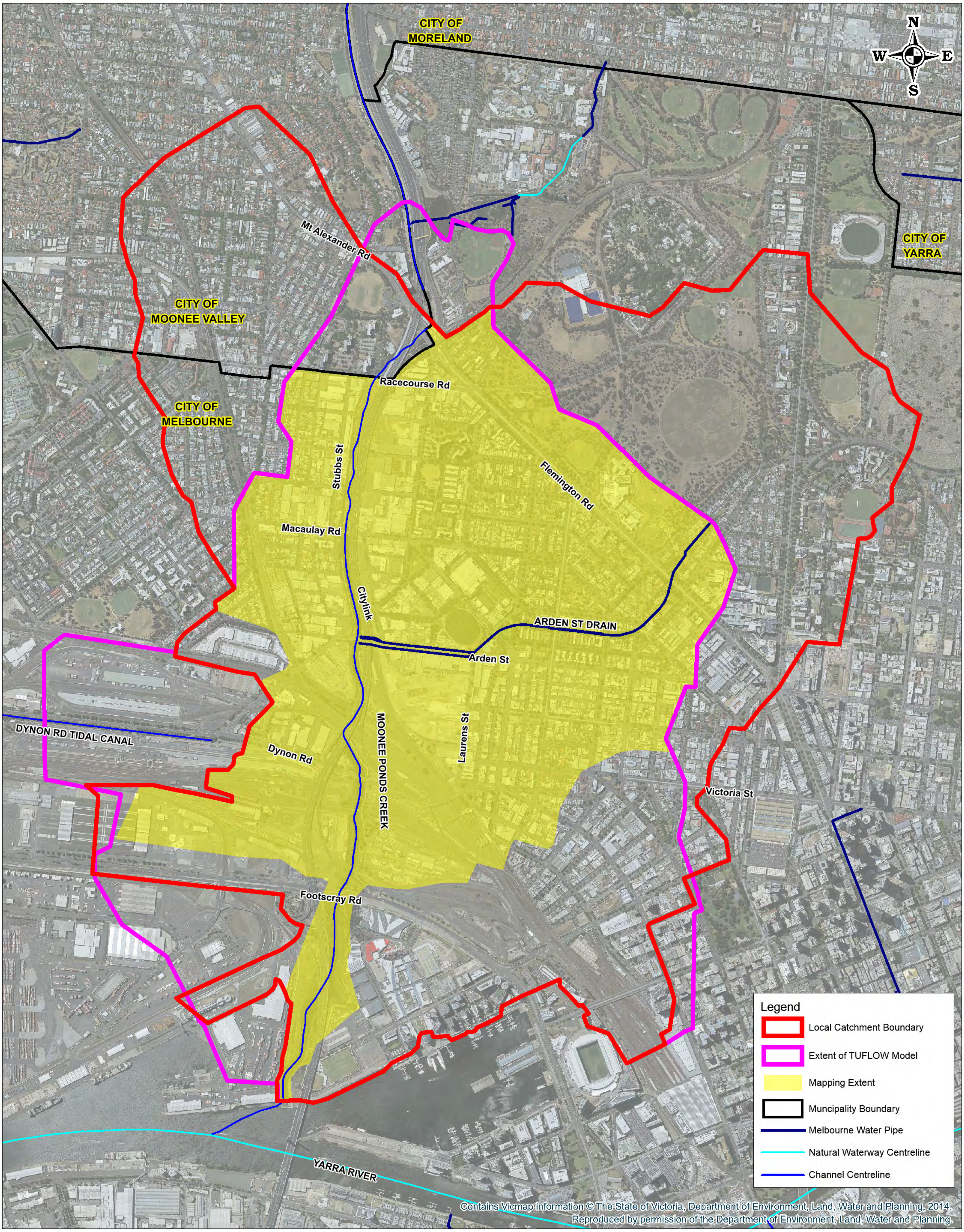

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Figure 2.2
Flood model extent
and the local catchment

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2.2 Flood Modelling Methodology Overview

The flood modelling has been completed in accordance with Australian Rainfall and Runoff 1987 using a combination of hydrologic and hydraulic modelling. The hydrologic modelling converts design rainfall events to flood hydrographs, with the flood hydrographs then applied to the hydraulic model to produce a range of flood related information.

Hydrological modelling has been undertaken using RORB. Two RORB models have been used for the flood modelling, which are:

- An overall Moonee Ponds Creek model, which has been used to apply routed hydrographs for Moonee Ponds Creek at Mt Alexander Road to the hydraulic model.
- A local catchment RORB model for the catchments draining into Moonee Ponds Creek downstream of Mt Alexander Road, which has been used to apply routed hydrographs to the hydraulic model at the boundary of the hydraulic model, as well as rainfall excess hydrographs within the extent of the hydraulic model.

Hydraulic modelling has been undertaken using TUFLOW.

2.3 The Existing Drainage System and Topography

A key component of the drainage system are the levees on both the eastern and western banks of Moonee Ponds Creek. The levees extend from Racecourse Road to Arden Street. As shown in Figure 2.3, the levees are typically an earthen embankment with either a masonry blockwork or precast concrete parapet wall on top of the earthen embankment. The levees aim to prevent creek flows entering the low-lying areas adjacent to this section Moonee Ponds Creek.

Figure 2.3 Existing levee on eastern side of Moonee Ponds Creek between Arden Street and Macaulay Road

Moonee Ponds Creek is a highly modified channel with a reserve width of approximately 50 metres between the levees. Within the model extent, Moonee Ponds Creek is partially covered by the Citylink Freeway, which has numerous piers within the creek corridor. There are several road and rail bridge crossings of Moonee Ponds Creek, some of which impose a significant hydraulic constraint on creek flows due to low bridge decks and hydraulically inefficient pier structures. Figure 2.4 is a photo of the first rail bridge downstream of Arden Street, with the bridge deck relatively low to the creek level. This photo also shows the Citylink Freeway above Moonee Ponds Creek.

Figure 2.4 Rail bridge downstream of Arden Street (looking downstream)

Behind the creek's levees, both Melbourne Water and City of Melbourne manage underground drainage assets to convey local runoff into Moonee Ponds Creek. The catchment of Melbourne Water's Arden Street drain extends as far east as the Melbourne Cemetery. The Arden Street drain starts at Morrah St in North Melbourne as a 900 millimetre diameter pipe, increasing in size as the contributing catchment increases before splitting into two parallel drains along Arden Street, with an 1830 millimetre pipe on the southern side of the road and 2440 millimetre wide by 2260 millimetre high arch drain on the northern side of the road. The Arden Street Drain discharges directly to Moonee Ponds Creek.

In significant storms events the performance of City of Melbourne's drainage system in the parts of the model extent is dependent on six pump stations to lift and discharge flow from low lying areas into Moonee Ponds Creek. The pump stations are required as the flood level of Moonee Pond Creek often exceeds the flood level of the local drainage system, meaning that the drainage system's conventional gravity outlets to Moonee Ponds Creek are not able to discharge local catchment flows into the creek.

Figure 2.5 provides an overview of the existing drainage system within the model extent, which also shows the topography of the area and the locations of the existing pump stations.

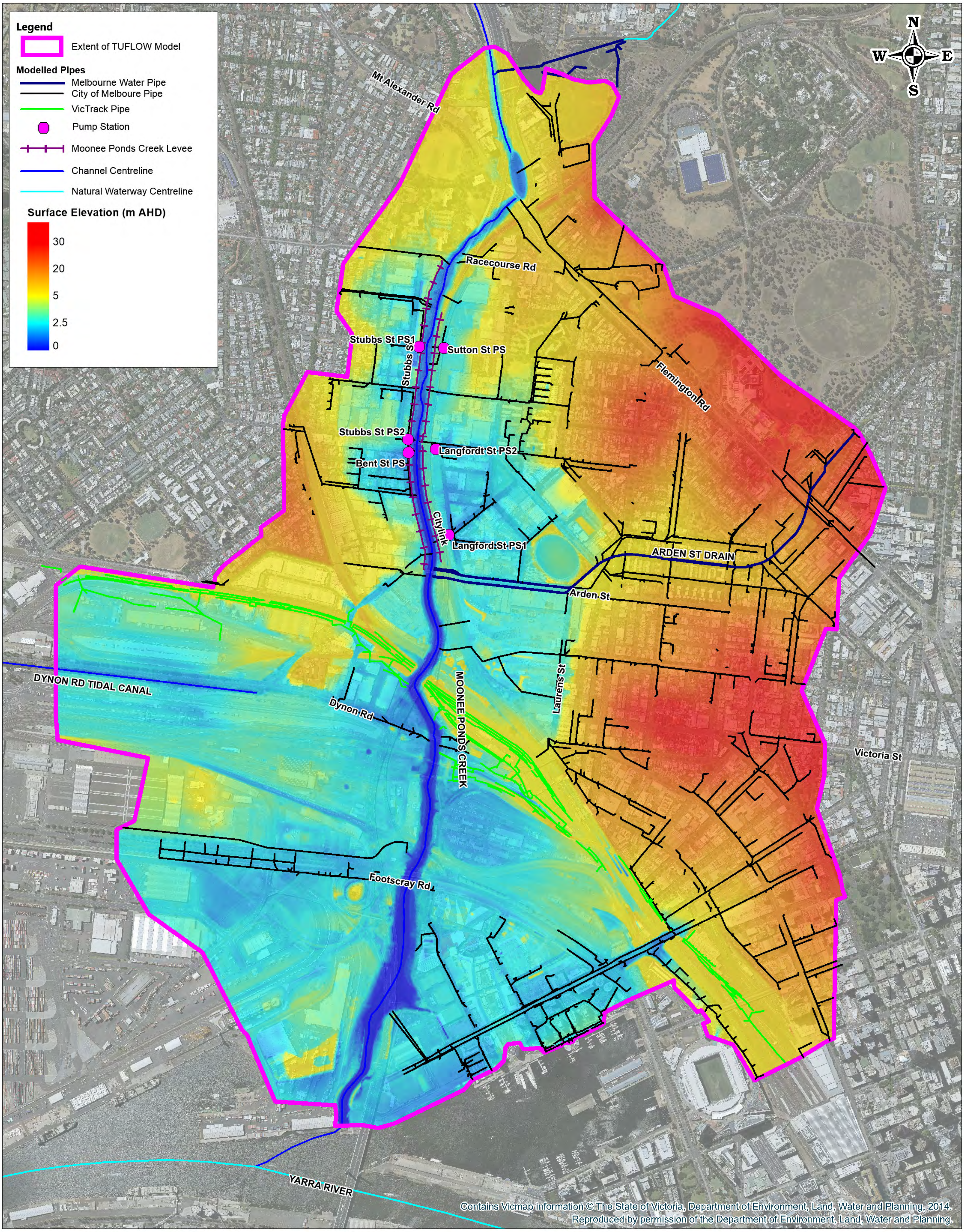

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Figure 2.5
Existing Drainage System and Topography

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2.4 Available Information

The following data has been used to develop and refine the flood model:

- Aerial photography
- LiDAR terrain data (capture date 2007)
- Moonee Ponds Creek levee survey data
- Moonee Ponds Creek survey
- GIS pipe asset data from Melbourne Water
- As constructed plans for the Arden Street Drain, provided by Melbourne Water
- GIS pit and pipe asset data from the City of Melbourne
- Catchment boundaries
- Contours
- Planning zones
- Cadastre boundaries

3. HYDROLOGY MODELLING

3.1 Overview

The key objective of hydrological modelling in this study is to produce routed hydrographs and rainfall excess hydrographs for use in the TUFLOW hydraulic model. The hydrological modelling has been undertaken in accordance with Australian Rainfall and Runoff 1987.

Hydrological modelling has been undertaken using RORB. Two RORB models have been used for the flood modelling, which are:

- An overall Moonee Ponds Creek model, which has been used to apply routed hydrographs for Moonee Ponds Creek at Mt Alexander Road to the hydraulic model.
- A local catchment RORB model for the catchments draining into Moonee Ponds Creek downstream of Mt Alexander Road, which has been used to apply routed hydrographs to the hydraulic model at the boundary of the hydraulic model, as well as rainfall excess hydrographs within the extent of the hydraulic model.

The following sections of this report provide an overview of both hydrological models.

3.2 Moonee Ponds Creek Catchment RORB Model

3.2.1 Model Delineation

The Moonee Ponds Creek RORB model was provided to Engeny by Melbourne Water. The model includes a total of 17 subareas, 7 of which cover the catchment downstream of the Jacana Retarding Basin.

GIS tables for the Moonee Ponds Creek RORB model's subareas, reaches, nodes and catchment boundary are not available. A catchment layout plan image was provided to Engeny, which is included in Figure 3.1, with annotations to show the location of the hydraulic model extent and some key catchment features.

Reach types in the model are type 3 (lined channel or pipe) downstream of the Jacana Retarding Basin and generally type 1 (natural) upstream of the Jacana Retarding Basin.

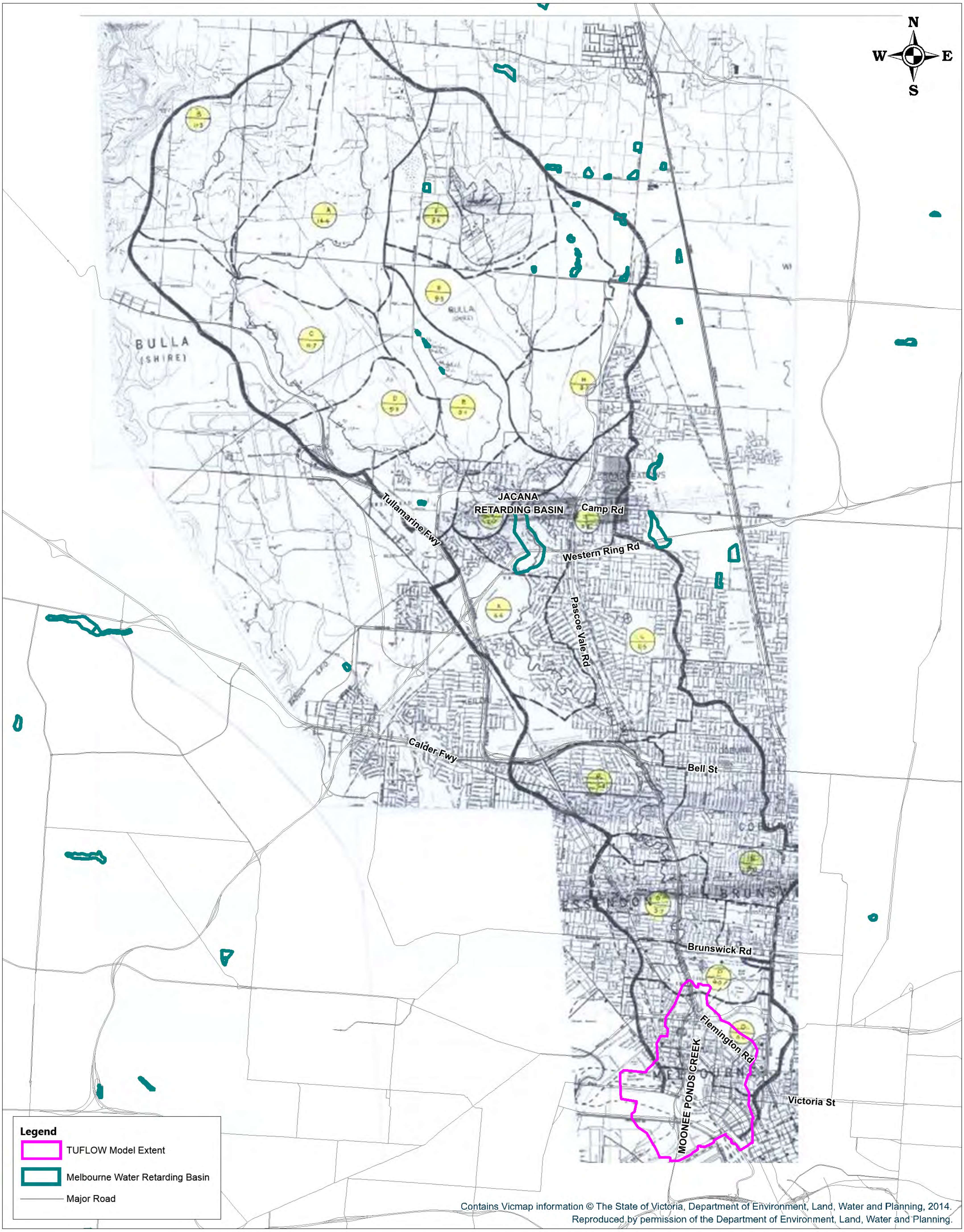

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Figure 3.1
Moonee Ponds Creek RORB Model
Layout Plan

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3.2.2 Catchment Imperviousness

The fraction impervious values in the Moonee Ponds Creek are summarised below:

- Downstream of the Jacana Retarding Basin, the fraction impervious values range from 0.5 to 0.55.
- Upstream of Jacana Retarding Basin, the fraction impervious values range from 0 to 0.5, with the more urban areas of this section of the catchment close to Jacana Retarding Basin reflected by the fraction impervious values of 0.5 and the rural upper sections of the catchment having impervious values of 0 to 0.1.

No changes have been made by Engeny to the fraction impervious values in the Moonee Ponds Creek RORB model.

3.2.3 Intensity-Frequency-Duration Data

The Intensity-Frequency-Duration (IFD) data adopted in the Moonee Ponds Creek RORB model is reflective of the centroid of the catchment (co-ordinates 37.70 degrees south and 144.90 degrees east).

Table 3.1 provides the IFD parameters obtained from the Bureau of Meteorology online tool for existing rainfall conditions. Table 3.1 also provides the factored IFD parameters to account for the 18.5 % increase in rainfall intensity. The F2 and F50 parameters have been increased in accordance with the approach in Australian Rainfall and Runoff 1987.

Table 3.1 Moonee Ponds Creek RORB model IFD parameters

Parameter	Existing Conditions	18.5 % Rainfall Intensity Increase
Intensity - 1 hour duration, ARI = 2 years (${}^{2}I_{1}$)	19.22	22.78
Intensity - 12 hour duration, ARI = 2 years (${}^{2}I_{12}$)	3.94	4.67
Intensity - 72 hour duration, ARI = 2 years (${}^{2}I_{72}$)	1.07	1.27
Intensity - 1 hour duration, ARI = 50 years (${}^{50}I_{1}$)	40.16	47.59
Intensity - 12 hour duration, ARI = 50 years (${}^{50}I1_{2}$)	7.13	8.45
Intensity - 72 hour duration, ARI = 50 years (${}^{50}I_{72}$)	2.19	2.60
Skew (G)	0.35	0.35
F_2	4.29	4.36
F_{50}	14.95	16.00

3.2.4 Model Parameters

The adopted Moonee Ponds Creek RORB model simulation parameters are based on the parameter file provided to Engeny by Melbourne Water. The simulation parameters are:

- Initial loss: 15 millimetres
- 1 % AEP runoff coefficient: 0.65
- m = 0.8
- kc = 26.0
- Aerial reduction factors based on ARR87 Bk II, Figs 1.6 and 1.7
- Unfiltered temporal patterns
- Uniform areal patterns

3.2.5 Model Validation and Results

The Moonee Ponds Creek RORB model predicts the following peak 1 % AEP flows at Mt Alexander Road (the inflow location to the TUFLOW model):

- Existing conditions: 217 m^3/s, critical duration 2 hours
- 18.5 % rainfall intensity increase: 263 m^3/s, critical duration 2 hours

A critical duration of 2 hours is relatively short for a catchment with the size of Moonee Ponds Creek (139 square kilometres). The short critical duration reflects that runoff from the developed catchment downstream of Jacana Retarding Basin is controlling peak flows due to the hydraulically efficient drainage system and no formal flood storage in this section of the catchment. Runoff from the catchment upstream of Jacana Retarding Basin has very little influence on the predicted peak flows in Moonee Ponds Creek at Mt Alexander Road.

There is uncertainty regarding how the Moonee Ponds Creek RORB model was validated. To understand whether the peak flows were reasonable, Engeny undertook a flood frequency analysis on flow gauge data provided by Melbourne Water for Moonee Ponds Creek at Mt Alexander Road. The flood frequency analysis identified a 1 % AEP flow of 207 m^3/s. The predicted existing conditions peak flow of 217 m^3/s is well within the confidence limits of the flood frequency analysis.

Engeny's review of the Moonee Ponds Creek RORB model deemed it sufficiently reliable for use in the flood modelling.

3.3 Local Catchment RORB Model

3.3.1 Model Delineation

The local catchment RORB model was developed by AECOM as part of the study documented in the report Hydrologic and Hydraulic Modelling of Arden Street and E-Gate (AECOM, September 2013). The following sections of this report provide an overview of key aspects of the local catchment RORB model and further details can be found in AECOM's 2013 report in **Appendix A**.

Figure 3.2 provides a layout of the local catchment RORB model.

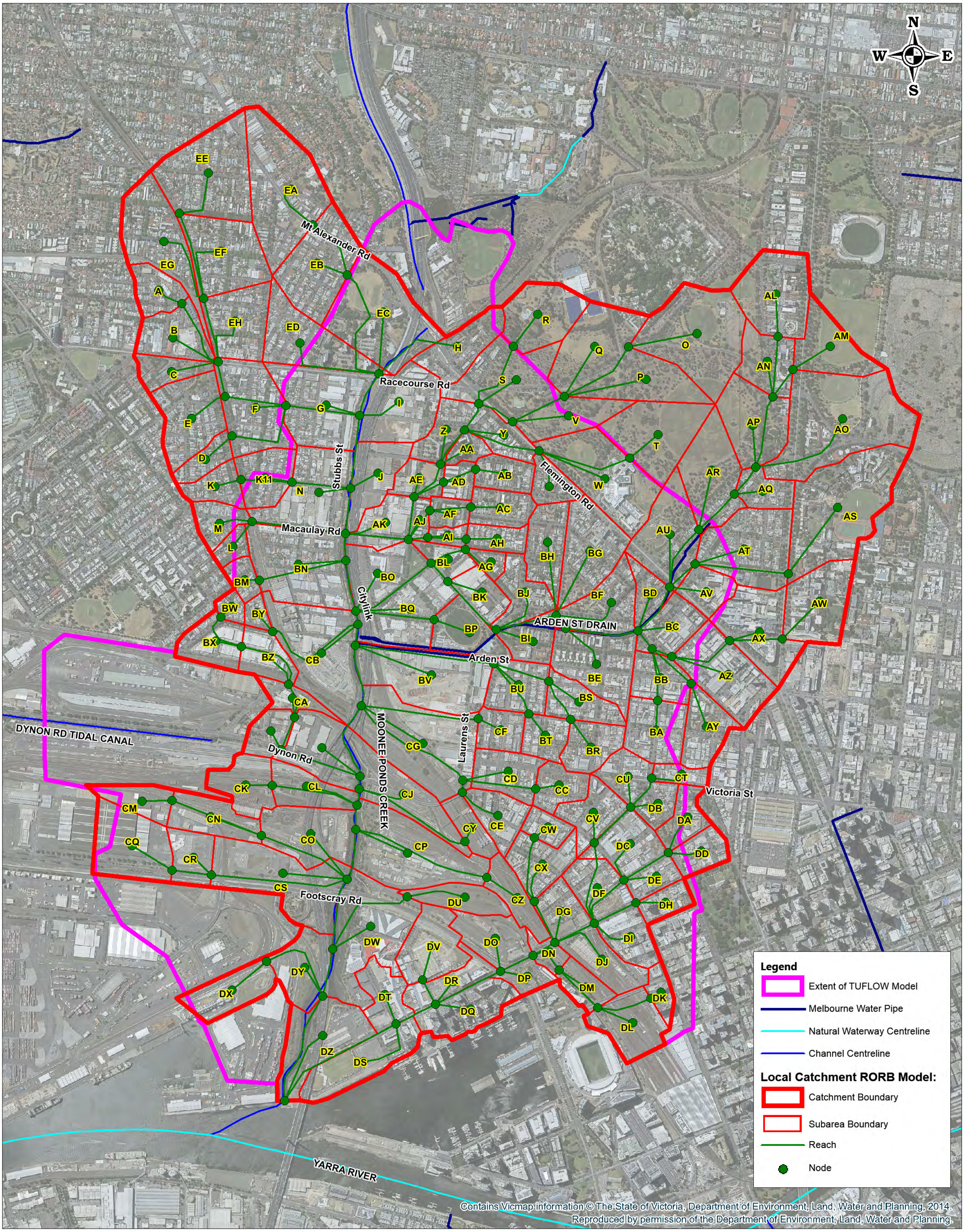

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Figure 3.2
Local catchment RORB model layout plan

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3.3.2 Catchment Imperviousness

The adopted imperviousness in the local catchment RORB model is reflective of existing site conditions, including the developed urban, commercial and industrial areas along the Moonee Ponds Creek corridor, as well as the large open spaces associated with Royal Park.

Figure 3.3 shows the variation in imperviousness throughout the local catchment RORB model.

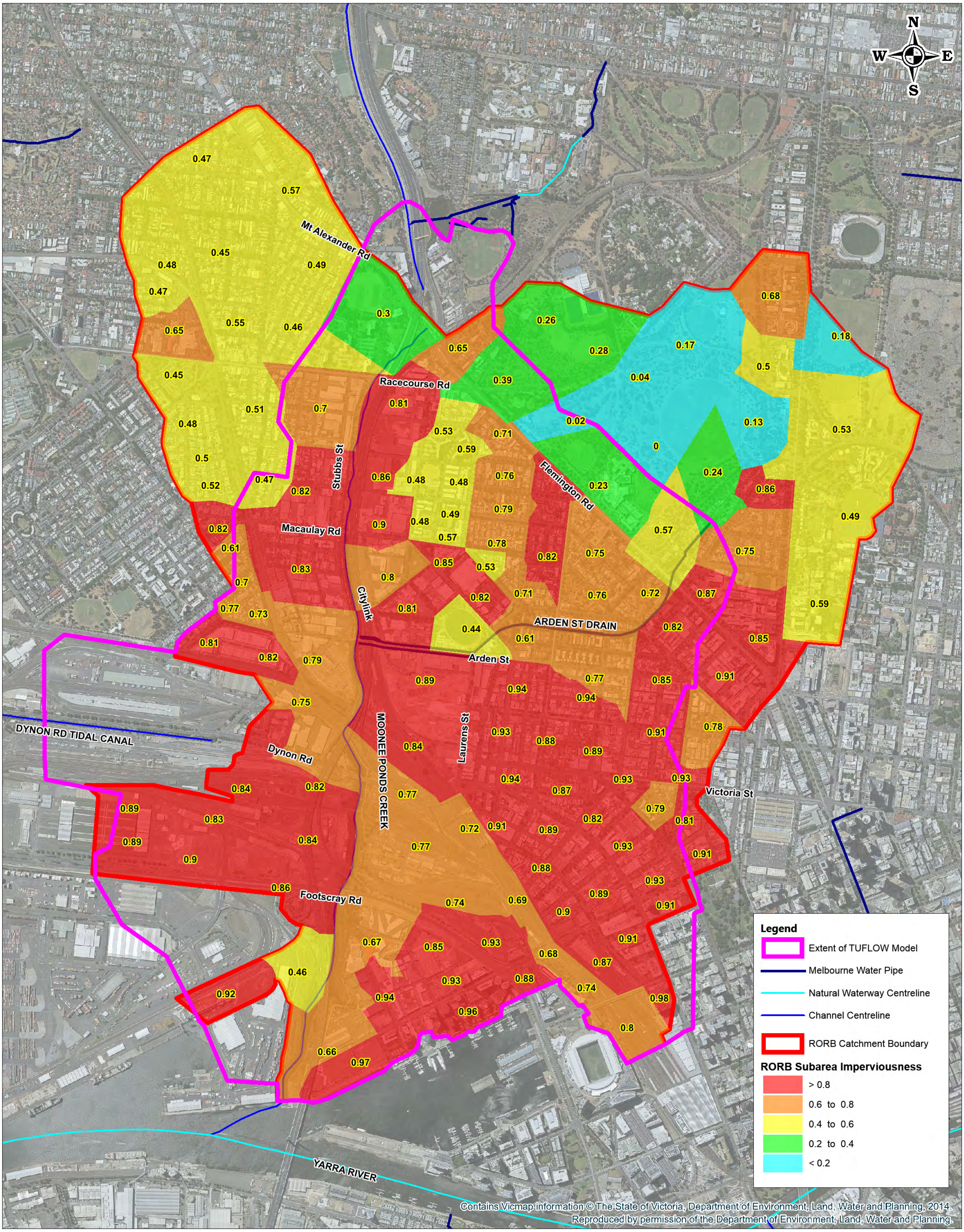

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Figure 3.3
Local catchment RORB
Imperviousness

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3.3.3 Intensity-Frequency-Duration Data

The Intensity-Frequency-Duration (IFD) data adopted in the local catchment RORB model is reflective of the centroid of the local catchment (co-ordinates -37.80 degrees south and 144.95 degrees east).

Table 3.2 provides the IFD parameters obtained from the Bureau of Meteorology online tool for existing rainfall conditions (which correlate to the IFD parameters adopted by AECOM). Table 3.2 also provides the factored IFD parameters to account for the 18.5 % increase in rainfall intensity. The F2 and F50 parameters have been increased in accordance with the approach in Australian Rainfall and Runoff 1987.

Table 3.2 Local catchment RORB model IFD parameters

Parameter	Existing Conditions	18.5 % Rainfall Intensity Increase
Intensity - 1 hour duration, ARI = 2 years (${}^{2}I_{1}$)	18.96	22.47
Intensity - 12 hour duration, ARI = 2 years (${}^{2}I_{12}$)	3.74	4.43
Intensity - 72 hour duration, ARI = 2 years (${}^{2}I_{72}$)	1.11	1.32
Intensity - 1 hour duration, ARI = 50 years (${}^{50}I_{1}$)	39.18	46.43
Intensity - 12 hour duration, ARI = 50 years (${}^{50}I_{12}$)	7.10	8.41
Intensity - 72 hour duration, ARI = 50 years (${}^{50}I_{72}$)	2.21	2.62
Skew (G)	0.36	0.36
F_2	4.29	4.36
F_{50}	14.95	16.00

3.3.4 Model Parameters

The adopted simulation parameters in the local catchment RORB model are based on the AECOM parameter file provided to Engeny by Melbourne Water. The simulation parameters are:

- Initial loss: 10 millimetres
- 1 % AEP runoff coefficient: 0.6
- m = 0.8
- kc = 3.4

- Aerial reduction factors based on ARR87 Bk II, Figs 1.6 and 1.7
- Filtered temporal patterns
- Uniform areal patterns

3.3.5 Model Validation

The local catchment RORB model was validated by AECOM using Rational Method Calculations, which is an approach in accordance with Australian Rainfall and Runoff 1987. Three validation points were adopted and a good match (within +/- 2 %) was achieved at the three validation points.

The adopted kc of 3.4 is within the expected range for an area the size of the local catchment RORB model.

Full details of the local catchment RORB model are provided in the AECOM's report in **Appendix A**.

Engeny's review of the local catchment RORB model deemed it sufficiently reliable for use in the flood modelling.

4. HYDRAULIC MODELLING

4.1 Model Layout

The TUFLOW hydraulic model was developed by AECOM as part of the study documented in the report Hydrologic and Hydraulic Modelling of Arden Street and E-Gate (AECOM, September 2013). Engeny has updated and refined the AECOM TUFLOW model.

Figure 4.1 shows key features of the TUFLOW model and the following sections of this report provide an overview of the model setup.

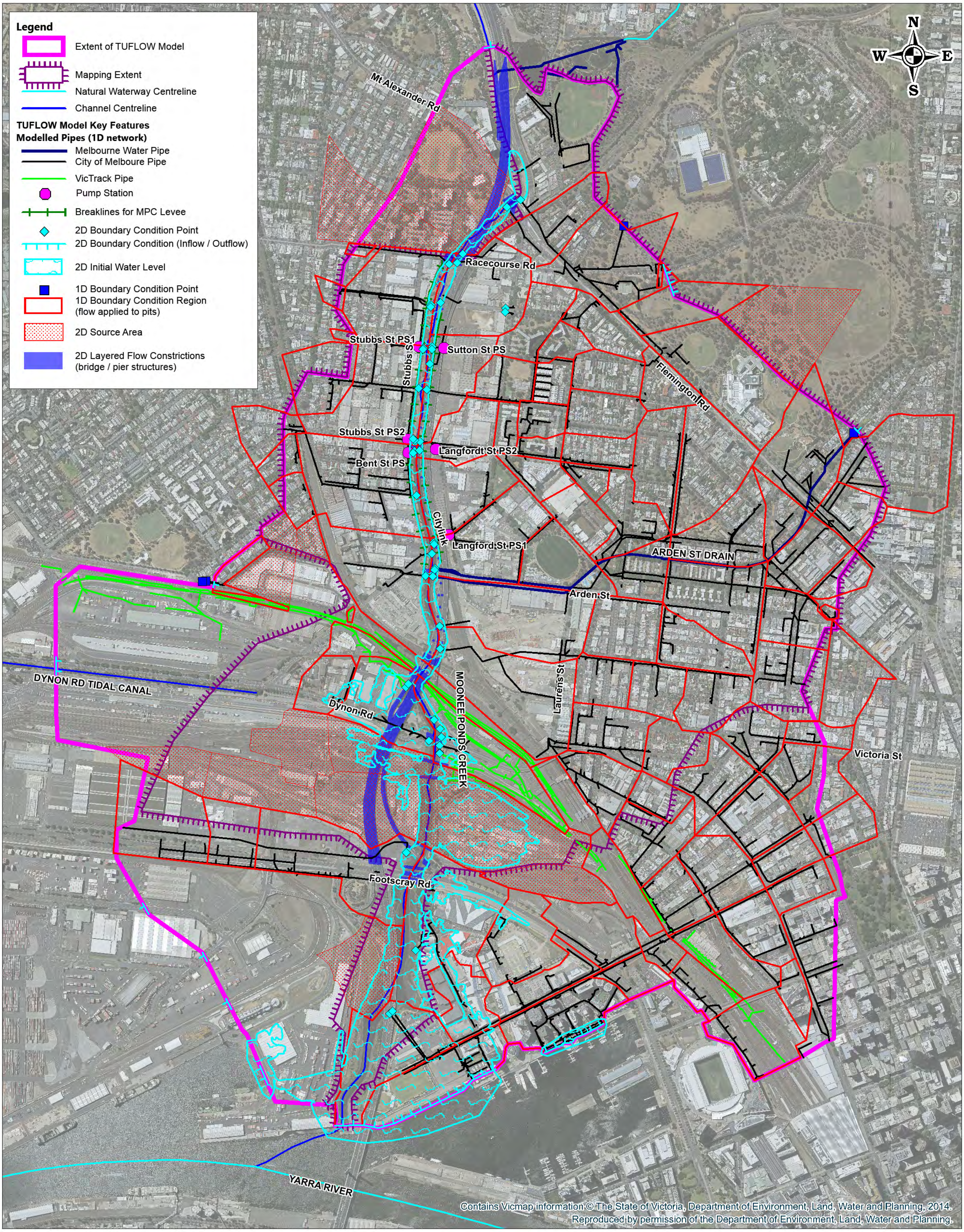

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Figure 4.1
TUFLOW model layout plan

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4.2 Model Cell Size

The AECOM setup of the TUFLOW model included a four metre cell size. Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (September, 2018) recommend a cell size of two to three metres for urban flood modelling.

Engeny considered reducing the model cell size in order to satisfy the Melbourne Water recommendation. A four metre cell size was retained, due to the fact that the four metre cell size, in combination with break lines to define some key topographical features based on feature survey, allows for an adequate representation of catchment topography and overland flow paths in in the model.

4.3 Representation of Moonee Ponds Creek

Moonee Ponds Creek has been represented in the 2D domain of the TUFLOW model. The width of Moonee Ponds Creek between the levees is approximately 50 metres. As the model adopts a 4 metre cell size, this allows for approximately 12 cells to represent the creek profile in the 2D domain, which is sufficient.

A survey tin has been read into the model in order to define sections of the creek profile and break lines have been adopted to represent the crest level of the levees, based on feature survey.

4.4 Surface Roughness

Within TUFLOW, a land use (materials) layer is utilised to represent the surface roughness impacting overland flows in the 2D domain of the model.

The model's surface roughness was initially developed by AECOM and was based on:

- Use of the City of Melbourne's 2007 Land Cover data, where available.
- Planning scheme overlays for areas of the model outside of the City of Melbourne.
- Aerial photography to manually digitise large areas of uniform roughness.
- For Moonee Ponds Creek, the adopted Manning's was defined based on achieving a match of the hydraulic grade line with Melbourne Water's HEC-RAS model of the Moonee Ponds Creek.

Engeny reviewed and refined some areas of the model's surface roughness based on aerial photography. In some instances, the City of Melbourne 2007 Land Cover data defined significant areas of trees in road reserves, which may have led to an over estimation of surface roughness. Adjustments were made to reduce roughness in these areas in order to improve the representation of flows path along roads.

4.5 Pit and Pipe Network

The underground drainage system is represented in the 1D domain of the TUFLOW model. Different sections of the underground drainage system within the model extent is managed by:

- Melbourne Water (the Arden Street Drain)
- City of Melbourne
- VicTrack, for the drainage system associated with rail assets

Engeny made a series of refinements to the representation of the pit and pipe network in the model in order to:

- Rectify inconsistent invert levels and asset data.
- Add missing pipe data.
- Use the most current GIS data provided by City of Melbourne in January 2016 and September 2017.

City of Melbourne identified that there are some sections of the drainage asset GIS data with low confidence in the accuracy of the data. This includes the drainage system around Docklands Drive. While these areas are still represented in the TUFLOW model, the model's results in these areas are not to be used to inform the planning scheme amendments and are not influencing results in the areas that are being included. Updates to the model based on field inspections of the drainage system would be required in order to improve the confidence in the model setup in these areas. Previously provided Figure 2.2 shows the model's mapping extent, with the low confidence areas of the model outside of the mapping extent.

4.6 Pit and Pipe Losses

A manhole layer within TUFLOW can be either automatically or manually created and used to apply the losses to the nodes created in the 1-dimensional network layers in a variety of different ways. The TUFLOW model uses an automatically generated manhole layer, applying losses using the Engelund method. This method recalculates losses at each time step using the angle of the entry and exit culverts, water levels and flow distributions. The losses calculated by this automatic approach have been checked to ensure that they appear reasonable.

4.7 Pump Station Operation

Six pump stations are located within the model extent. The intention of the pump stations is to lift and discharge flow from low lying areas over the levees and into Moonee Ponds Creek.

The model's representation of the pump station capacities is based on information provided by City of Melbourne, including a report titled Arden Macaulay Precinct Flood Investigation (Cardno, April 2012). The capacities of the pump stations are:

- Stubbs Street Pump Station 1 (corner of Stubbs St and Smith St): 560 L/s
- Stubbs Street Pump Station 2 (corner of Stubbs St and Macaulay Rd): 1196 L/s
- Bent St Pump Station (corner of Bent St and Little Hardiman St): 700 L/s
- Langford St Pump Station 1 (corner of Langford St and Gracie St): 700 L/s
- Langford St Pump Station 2 (corner of Langford St and Macaulay Rd): 700 L/s
- Sutton St Pump Station (west end of Sutton St): 700 L/s

Pump stations have the potential to be unreliable in storm events if they lose power. A key objective of the flood related planning scheme overlays is to manage the setting of floor levels for future developments in flood prone areas. Due to potential unreliability of the pump stations, Melbourne Water and City of Melbourne intend to set floor levels on the assumption that the pump stations have failed.

Based on this, the modelling used for the basis of delineating the planning scheme overlays reflects that the pumps fail to operate in the 1 % AEP storm event.

There is some uncertainty in the pump station operating levels (i.e. the flood levels that result in the pumps turning on and off) and further investigation of these levels is recommended prior to using the model with the pumps operational.

4.8 Downstream Boundary Condition

The downstream end of the flood model is the confluence of Moonee Ponds Creek and the Yarra River. This section of the Yarra River is heavily influenced by the tide level in Port Phillip Bay and this tidal impact extends up through Moonee Ponds Creek.

The AECOM model was based on a static tail water level to represent the influence of downstream tide levels. The updated model includes a cyclical tide boundary condition in order to represent the dynamic impact of the Port Phillip Bay tide level on flooding within the model extent. The boundary condition is based on a 10 % AEP tide, with an allowance of 0.8 metres of sea level rise. The peak of the cyclical tide is 1.975 m AHD.

The timing of the cyclical tide has been tailored for each duration storm event so that the peak of the tide occurs at the end of the rainfall event. This means that for the 2 hour storm event, the peak tide occurs 2 hours into the model simulations and for the 9 hour event the peak tide occurs 9 hours into the model simulation.

While there is some variance between the different storm durations, the adopted approach results in the peak tide level occurring when flows in Moonee Ponds Creek are close to their peak.

Figure 4.2 shows the RORB hydrograph for flow in Moonee Ponds Creek at Mt Alexander Road, as well as the applied cyclical tide boundary. The graph shows the peak flow at Mt Alexander Road occurring just prior to the peak tide level. As the creek flows move through the hydraulic model extent, the peak creek flow has a closer match to the timing of the peak tide.

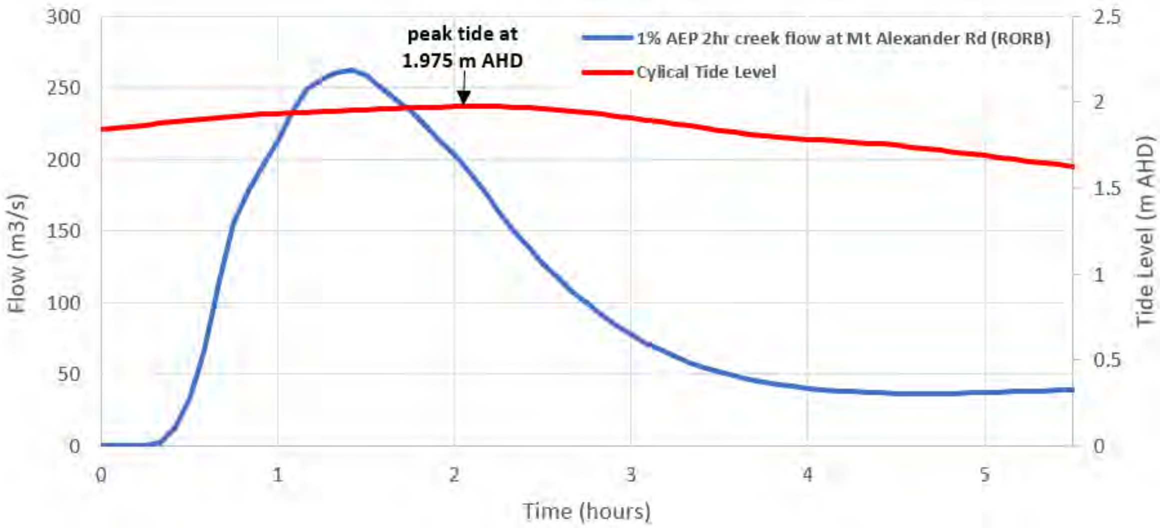


Figure 4.2 1 % AEP 2 hour storm event (including 18.5 % rainfall intensity increase), Moonee Ponds Creek hydrograph and cyclical tide boundary

4.9 Initial Water Levels

Initial water levels have been adopted to prevent a "backflow wave" from the downstream boundary condition. As the downstream boundary condition is a cyclical tide boundary, the water level of the cyclical tide at the start of the model simulation is unique to each duration event. Therefore, individual initial water levels have been adopted for each duration storm event to match the starting water level of the cyclical tide.

4.10 Application of Inflows

The Moonee Ponds Creek RORB model and the local catchment RORB model have been used to apply inflow hydrographs to the TUFLOW model for each duration storm event. The application of inflows consists of:

- From the Moonee Ponds Creek RORB model:
  - Routed hydrographs applied to Moonee Ponds Creek just upstream of Mt Alexander Road. A 2D boundary condition type QT has been used to apply this hydrograph.

- From the local catchment RORB model:
    - Routed hydrographs applied at the boundary of the hydraulic model representing the inflows from the areas of the local catchment beyond the flood model extent. These hydrographs have been applied using a combination of 1D boundary conditions type QT to apply external flows to pipe and 2D boundary conditions type QT to apply external flows to the 2D domain. In some instances, factors have been used in the model's boundary condition database to split the RORB hydrograph to 1D and 2D boundary conditions or to split the RORB hydrograph for application to separate sections of the model's drainage system.
    - Rainfall excess hydrographs within the extent of the hydraulic model. The rainfall excess hydrographs have typically been applied to pits using 1D boundary conditions, with some rainfall excess hydrographs applied as 2D source areas for areas of large open space.

4.11 Bridge Structures

There are numerous bridge crossings of Moonee Ponds Creek that impact the conveyance capacity of the creek.

The bridge structures, including piers, bridge decks and railings have been represented in the TUFLOW model using 2D layered flow constrictions. The bridge structure data is based on:

- Available survey data.
- The representation of the bridges in Melbourne Water's HEC-RAS model.

The form loss coefficients were defined by AECOM so that the head loss across the structures in TUFLOW matched the head loss in the HEC-RAS model. Engeny reviewed the form loss coefficients and head loss across the structures to check that the results were reasonable.

4.12 Version of TUFLOW

The TUFLOW model has been run in TUFLOW version 2013-12-AE-w64 double precision, which was the version of TUFLOW used by AECOM. Engeny did a trial run of the model in a later version of TUFLOW, with changes to the model's results observed, particularly along Moonee Ponds Creek. Upon investigation, it was found that this was due to a different approach to applying form losses in the new versions of TUFLOW. It was therefore decided to continue to run the TUFLOW model in version 2013-12-AE-w64 to avoid impacting the validation of the form loss coefficients.

The 2013-12-AE-w64 version of TUFLOW is sufficiently reliable for the purpose of the flood modelling.

4.13 Model Timesteps

The TUFLOW model adopts the following time steps:

- 2D time step: 1 second
- 1D time step: 0.25 seconds

Melbourne Water's Flood Mapping Guidelines and Technical Specification (September 2019) states that the 2D time step should normally be between 1/5 and 1/2 of the grid size and the 1D time step should be a multiple of the 2D timestep, and generally not less than 0.5 seconds. As the TUFLOW model uses a 4 metres grid size, the 2D timestep is within the recommended range. The 1D timestep is just below the recommendation range, but Engeny believes that the 1D timestep is reasonable and adjusting the timestep would have little impact on the modelling outputs.

4.14 TUFLOW Warning Messages

The TUFLOW model produces 1533 pre-simulation warning messages. These are described below:

- Warning 1262: 1,477 instances. This warning relates to a 1D Manning's roughness below expectations and is due to the Manning's value of 0.009 that has been applied to the Regional Rail Link pipes. A Manning's value of 0.009 is just below the expected range for a concrete pipe and may have been applied by AECOM if the pipes were made of a more hydraulically efficient material than concrete, such as plastic. Results from this section of the model are not being used for the planning scheme overlays and therefore the low Manning's value is of little consequence.

- Warning 2118: 23 instances. This warning is produced by TUFLOW at 2D SX boundaries where adjustments of the cell elevation are made by TUFLOW to match a pipe's inlet / outlet inverts. This does not impact on the accuracy of reliability of the model.

- Warning 1313: 19 instances. This warning is produced by TUFLOW when there is more than 1 outgoing pipe from a pit. All instances of this warning are in sections of the model that are not being used for the planning scheme overlays.

- Warning 2124: 11 instances. This warning is produced by TUFLOW when a pit or node does not have a connection to the 2D domain. This is common for junction pits and therefore the warning is not of concern.

- Warning 1100: 7 instances. This warning is produced by TUFLOW where there is an increase or fall in invert levels through a pit (i.e. the incoming pipe to a pit enters at a higher level than the outgoing pipe, or vice versa). This is not an uncommon feature of a drainage system and this aspect of the model setup does not impact on the accuracy of reliability of the model.

- Warning 2122: 1 instance. This warning is produced by TUFLOW where there is pit that it outside of the active code of the model. The isolated instance of this warning is in an area of the model (Docklands) where the results are not being used for the planning scheme overlays and therefore the warning is not of concern.

4.15 Model Health

No errors were recorded for any simulation to be used as the basis of the planning scheme overlays. There are no instances of 1-D or 2-D negative depths in the TUFLOW model.

Melbourne Water's Flood Mapping Guidelines and Technical Specification (September 2019) states that models should have total, 1D and 2D mass errors within +/- 1 %. All peak mass errors for the TUFLOW model are within +/- 1 %.

There are two sections of the model with high velocities in the pipe network, which can at times be an indicator of potential model insatiability. These areas are:

- A section of pipe along Parsons St in Kensington. This is an existing pressure pipe to convey flow from the higher area of the catchment into Moonee Ponds Creek. The high velocities in the pressure pipe are reasonable. The model's velocities show a steady rise / fall, indicating sound model stability.

- A section of the Arden St Main Drain near Curzon St. This is a large drainage asset with a relatively steep grade (1 in 80) and the high velocities are reasonable. The model's velocities show a steady rise / fall, indicating sound model stability.

Overall, Engeny is confident in the reliability of the model is believes the model's results are appropriate to form the basis of the planning scheme overlays.

5. FLOOD MAPPING

The TUFLOW model has been simulated for standard storm durations ranging from 10 minutes to 12 hours. The critical storm duration in Moonee Ponds Creek is the 2 hour event and the simulation of storm events up to the 12 hour duration event is sufficient to capture critical flood levels across the model.

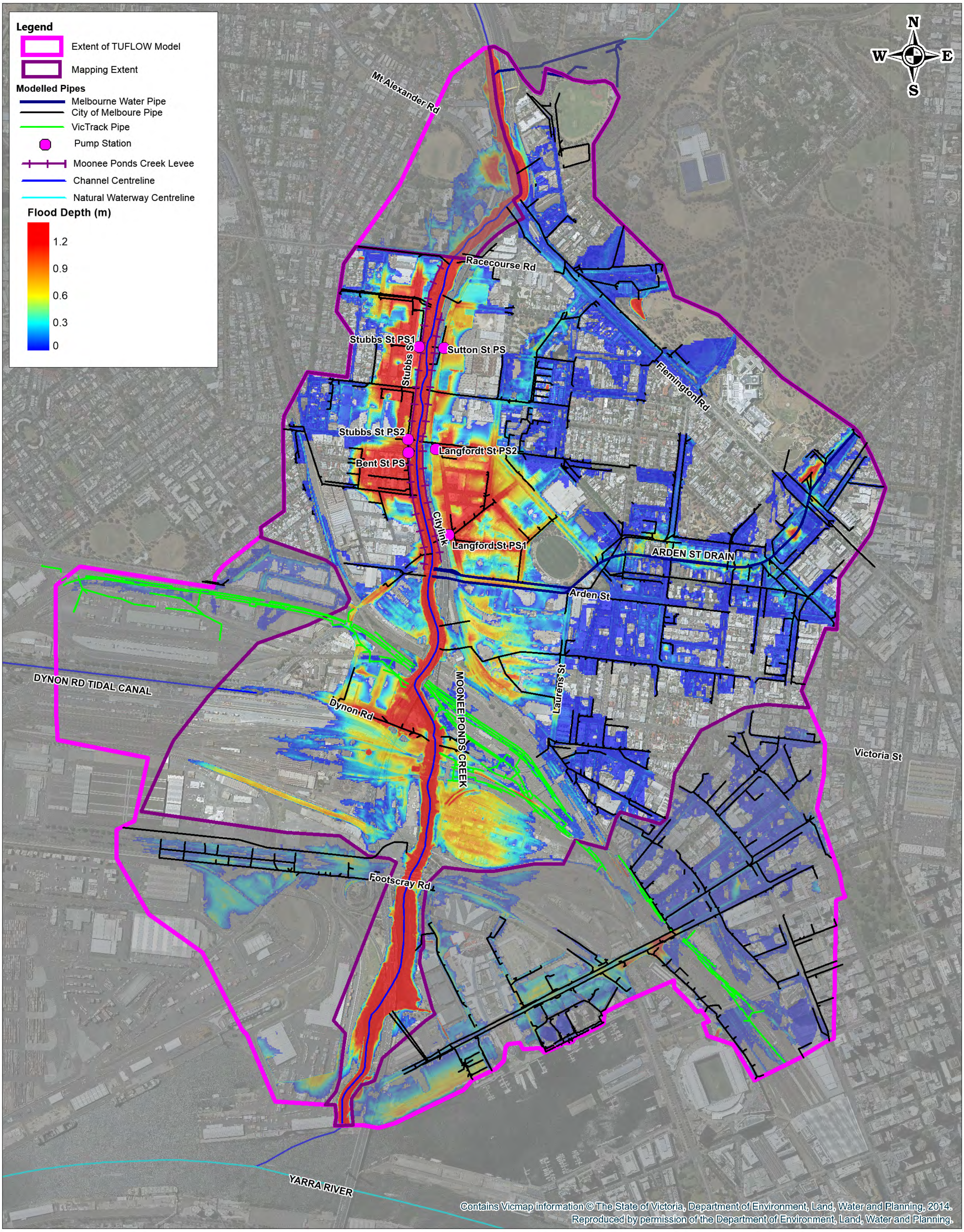
Figure 5.1 provides a 1 % AEP flood map, representing:

- An 18.5 % rainfall intensity increase.
- A 10 % AEP Yarra River cyclical tide, accounting for 0.8 metres of sea level rise.

The results in Figure 5.1 will form the basis of the delineation of planning scheme overlays.

The flood modelling predicts extensive inundation of low-lying areas adjacent to Moonee Ponds Creek. This is attributed to:

- High flows in Moonee Ponds Creek overtopping the creek's levees and inundating the low-lying areas behind the levees.
- Local catchment flows draining to the low-lying areas behind creek's levees, and once runoff is in the low-lying areas the drainage system is unable to convey flow into Moonee Ponds Creek due to a higher water level in the creek than the ground level in the local catchment. This impact is exacerbated by the modelled failure of the pump stations.



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ENGENY WATER MANAGEMENT

CITY OF MELBOURNE

0 250 500

Scale in metres (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994.
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Arden Macaulay Precinct &
Moonee Ponds Creek Flood Modelling

Figure 5.1
1 % AEP flood map, 18.5 % rainfall intensity increase & 0.8 m sea level rise

Job Number: V3000_080
Revision: 0
Drawn: PC
Checked: GO
Date: 3 June 2020

6. SUMMARY

This report documents the flood modelling on behalf of City of Melbourne and Melbourne Water that is to be used as the basis for the preparation of planning scheme overlays for Moonee Ponds Creek and contributing local catchments south of Racecourse Road, including the Arden Macaulay Precinct.

The flood modelling is based on a RORB hydrological model and a TUFLOW hydraulic model. The TUFLOW model that has been adopted by Engeny was originally developed by AECOM in 2013 as part of planning for major developments within the study area.

Engeny has updated and refined the modelling so that it reflects the best available data and is fit for purpose. Some areas of the model are not to be used to inform the planning scheme amendment due to low reliability in the setup of the model in these areas. Previously provided Figure 2.2 shows the model's mapping extent (i.e. the area of the flood model which is sufficiently reliable for use in the planning scheme amendment).

The modelling has been undertaken to predict flooding in a 1 % annual exceedance probability (AEP) event, inclusive of an 18.5 % increase in rainfall intensity due to climate change and 0.8 metres of sea level rise.

Six pump stations are located within the model extent. Pump stations have the potential to be unreliable in storm events if they lose power. A key objective of the flood related planning scheme overlays is to manage the setting of floor levels for future developments in flood prone areas. Due to potential unreliability of the pump stations, Melbourne Water and City of Melbourne intend to set floor levels on the assumption that the pump stations have failed. Based on this, the modelling used for the basis of delineating the planning scheme overlays reflects that the pumps do not operate in the 1 % AEP storm event.

The flood modelling predicts extensive inundation of low-lying areas adjacent to Moonee Ponds Creek. This is attributed to:

- High flows in Moonee Ponds Creek overtopping the creek's levees and inundating the low-lying areas behind the levees.
- Local catchment flows draining to the low-lying areas behind creek's levees, and once runoff is in the low-lying areas the drainage system is unable to convey flow into Moonee Ponds Creek due to a higher water level in the creek than the ground level in the local catchment. This impact is exacerbated by the modelled failure of the pump stations.

Overall, Engeny is confident in the reliability of the model and believes the model's results are appropriate to form the basis of the planning scheme overlays.

7. QUALIFICATIONS

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

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

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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    (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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g. This report does not provide legal advice.

8. REFERENCES

Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (September, 2018)

Hydrologic and Hydraulic Modelling of Arden Street and E-Gate (AECOM, September 2013)

Arden Macaulay Precinct Flood Investigation (Cardno, April 2012)

APPENDIX A

AECOM 2013 Model Build Report

AECOM

Hydrologic and Hydraulic Modelling of Arden Street and E-Gate

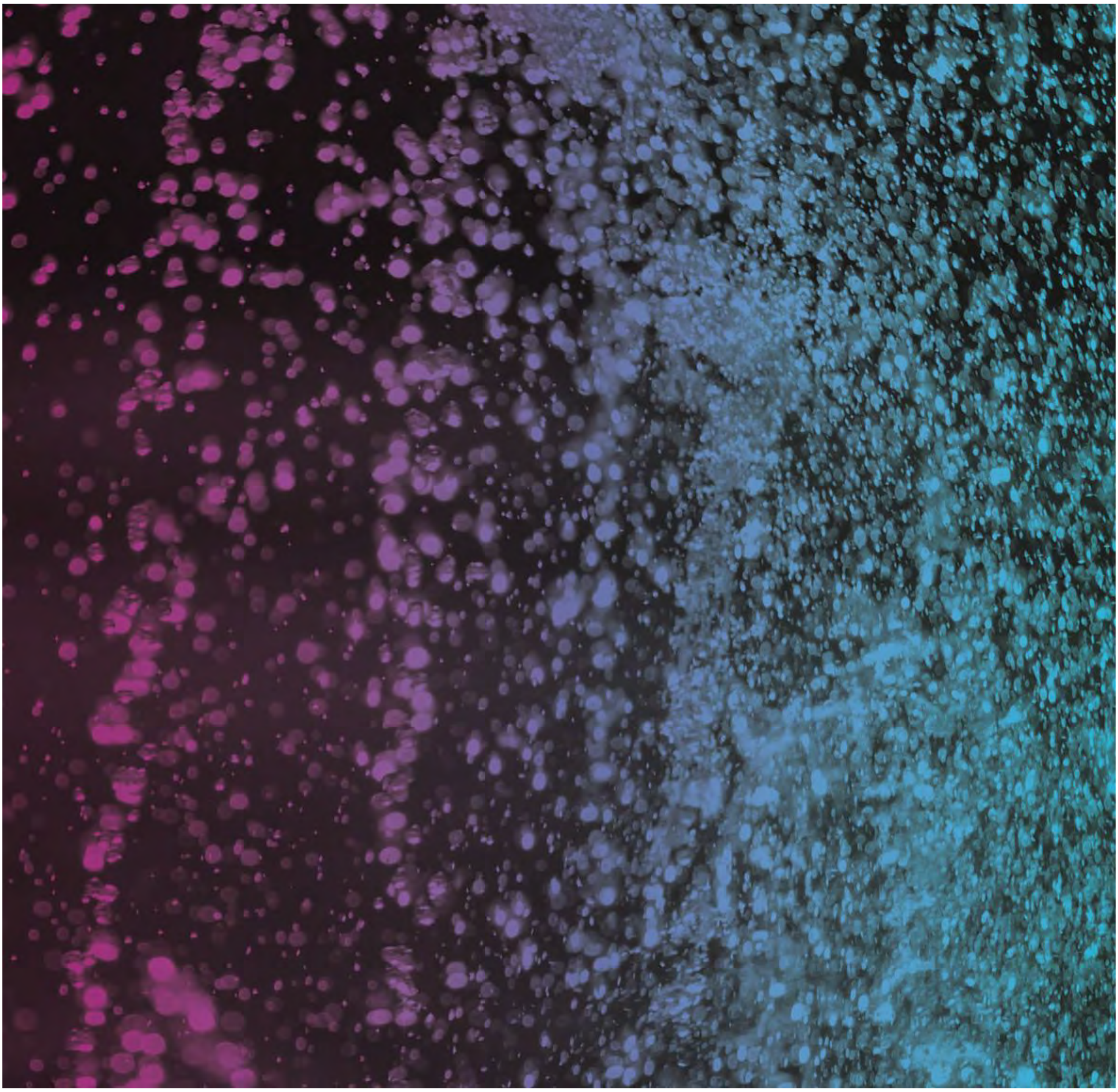
Department of Transport, Planning and Local Infrastructure Victoria

10-Sep-2013

D R A F T

Arden Street and E-Gate

Hydrologic and Hydraulic Modelling



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Arden Street and E-Gate

Hydrologic and Hydraulic Modelling

Client: Department of Transport, Planning and Local Infrastructure Victoria

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Date	10-Sep-2013
Prepared by	Sam Marginson and James Baker
Reviewed by	Melanie Collett

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Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
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Executive Summary

To be included in the next revision of this report.

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1.0 Introduction

1.1 Objectives and Scope

AECOM has been commissioned to undertake detailed flood modelling of the study area for the Department of Transport, Planning and Local Infrastructure's Arden Street Urban Renewal project, as well as the E-Gate site. Hydrologic modelling was undertaken using RORB, with the intention of providing inflows to the hydraulic model. Hydraulic modelling was undertaken using TUFLOW, with the intention of producing water levels and flood maps for the study area. Please note that the results of these models should not be used for any other purposes.

This study also involved the simulation of the impacts of climate change in 2040, 2070 and 2100. Climate change conditions have been assumed to be as specified in Melbourne Water Corporation's "Flood Mapping Projects Guidelines and Technical Specifications – December 2011". This involves an increase in extreme sea level of 0.8m and an increase in extreme rainfall intensity of 32% by 2100. We have assumed that these changes will occur linearly and consequently linear interpolation has been used to establish sea level rise and rainfall intensity increase for 2040 and 2070 scenarios.

1.2 Information Used

The following data has been used in this study:

- LiDAR data from the City of Melbourne (2007);
- Moonee Ponds Creek levee field survey data (2012) taken by Surfcoast Survey and Drafting Services, provided by the City of Melbourne;
- Proposed final surface (as of August 2013) TIN data from Region Rail Link Package B (RRL);
- GIS pipe data from Melbourne Water (provided June 2013);
- GIS pit and pipe data from the City of Melbourne (provided June 2013);
- GIS pipe data from RRL (as of August 2013);
- Landuse / Land Cover data from the City of Melbourne (2007);
- Building outlines and planning scheme zones for the City of Melbourne (accessed August 2013).

1.3 Limitations

Given that the objective of modelling and mapping this site was to produce flood maps as part of a constraints analysis of the study area, flood levels outside the study area are indicative only. The flow of water out of the study area via the rail tunnels to the south-east of North Melbourne station has not been simulated by assuming the tunnel mouths to be blocked. The result of this is a conservative estimation of flood levels in the vicinity of the mouths of the rail tunnels.

Additionally, discussions with the City of Melbourne led to the agreement that a conservative assumption should be made with regards to the operation of pump stations. Consequently it was assumed that these pumps would not be operational during the flood events modelled. Finally, the simulation of the effectiveness of the City of Melbourne drainage network could be improved if data were to be gathered regarding invert levels and pit dimensions.

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2.0 Site Inspection

On 7 August 2013, two AECOM staff members conducted a site visit to the Arden Street and E-Gate site. The site inspection consisted of walking the length of Moonee Ponds Creek within the study area, where observations were made regarding surrounding vegetation, hydraulic structures and the general interface between the creek, roads and rail. Additionally the study area was drive to observe the broader area where observations of property types and drainage infrastructure were made.

The top row of the picture panel below shows the northern end of Moonee Ponds Creek which has been paved during the development of CityLink. The bottom row shows the more natural sections of the creek and its interactions with various hydraulic structures.

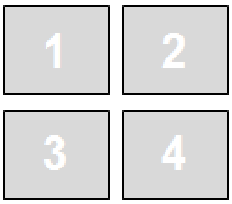

Photo 1: Northern end of Moonee Ponds Creek prior to crossing under CityLink.

Photo 2: Northern end of Moonee Ponds Creek prior to crossing Mt. Alexander Road.

Photo 3: Looking South from Arden Street Bridge.

Photo 4: Southern end of Moonee Ponds Creek passing under the rail line and CityLink.

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3.0 Hydrologic Modelling

A hydrograph for the 1% Annual Exceedance Probability (AEP), 2 hour duration event at Flemington Road was obtained from Melbourne Water's RORB model of Moonee Ponds Creek. This was scaled to produce inflows for events of other AEPs and durations. A RORB model of the local catchments was then developed using MIRORB to generate sub-catchment hydrographs to be used as inflows in the hydraulic model.

3.1 Catchment Delineation

The Arden Street and E-Gate catchment was delineated using LiDAR data (City of Melbourne, 2007) and 1m contours (VicMap, 2009). This resulted in a combined local catchment area of approximately 9.4km^2 as shown in Figure 1. The catchment was then divided into sub-catchments based on topography, the location of structures on Moonee Ponds Creek, the underground drainage network and the need to produce inflows for the hydraulic model near the edge of the study area. These sub-catchments are also shown in Figure 1.

3.2 Fraction Impervious

Within the City of Melbourne, impervious areas were designated using the Land Cover data (City of Melbourne, 2007). Outside the City of Melbourne, fraction impervious was designated according to Planning Scheme Zone as shown in Table 1. Values were assigned based on Melbourne Water's Music Guidelines and a visual inspection of aerial photos.

Table 1 Fraction Impervious Values for Planning Scheme Zones

Zone Type	Adopted Fraction Impervious Value
Business and Industrial	0.9
Mixed Use	0.9
Public Park and Recreation	0.1
Public Use	0.7
Residential	0.45
Road	0.7

Planning Scheme Zone polygons were split according to the sub-catchments then combined to produce sub-catchments with fraction impervious values that were weighted averages of those of the Planning Scheme Zones within them.

3.3 Rational Method Calculations

Due to the absence of historical flood data for this site, the RORB model flows were calibrated to the Rational Method as per the Modified Friend's Equation for the time of concentration detailed in Australia Rainfall and Runoff (Institution of Engineers Australia, 2001). Figure 2 shows the layout of the RORB model and the locations where calibration was undertaken.

Intensity-Frequency-Duration (IFD) factors were generated from the Bureau of Meteorology website and are shown in Table 2. Factors for climate change scenarios were then linearly interpolated based on a 32% increase in extreme rainfall intensity by 2100, as per Melbourne Water's "Flood Mapping Project Guidelines and Technical Specifications – December 2011".

The major source of flooding in the study area is from Moonee Ponds Creek, which has a critical storm duration of two hours. Consequently the F_2 and F_{50} values have not been modified for the climate change scenarios, as these values are only changed for storm durations less than one hour.

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Table 2 IFD Factors for the Arden and E-Gate Study Area (Including Climate Change Adjustments)

Annual Recurrence Interval	Intensity (mm/hour)		
	1 hour	12 hour	72 hour
2 year (current)	18.96	3.74	1.11
50 year (current)	39.18	7.10	2.21
2 year (2040)	20.98	4.14	1.23
50 year (2040)	43.36	7.86	2.45
2 year (2070)	23.00	4.54	1.35
50 year (2070)	47.54	8.61	2.68
2 year (2100)	25.03	4.94	1.47
50 year (2100)	47.54	8.61	2.68
	Skew (G) = 0.36	F_2 value = 4.29	F_{50} value = 14.95

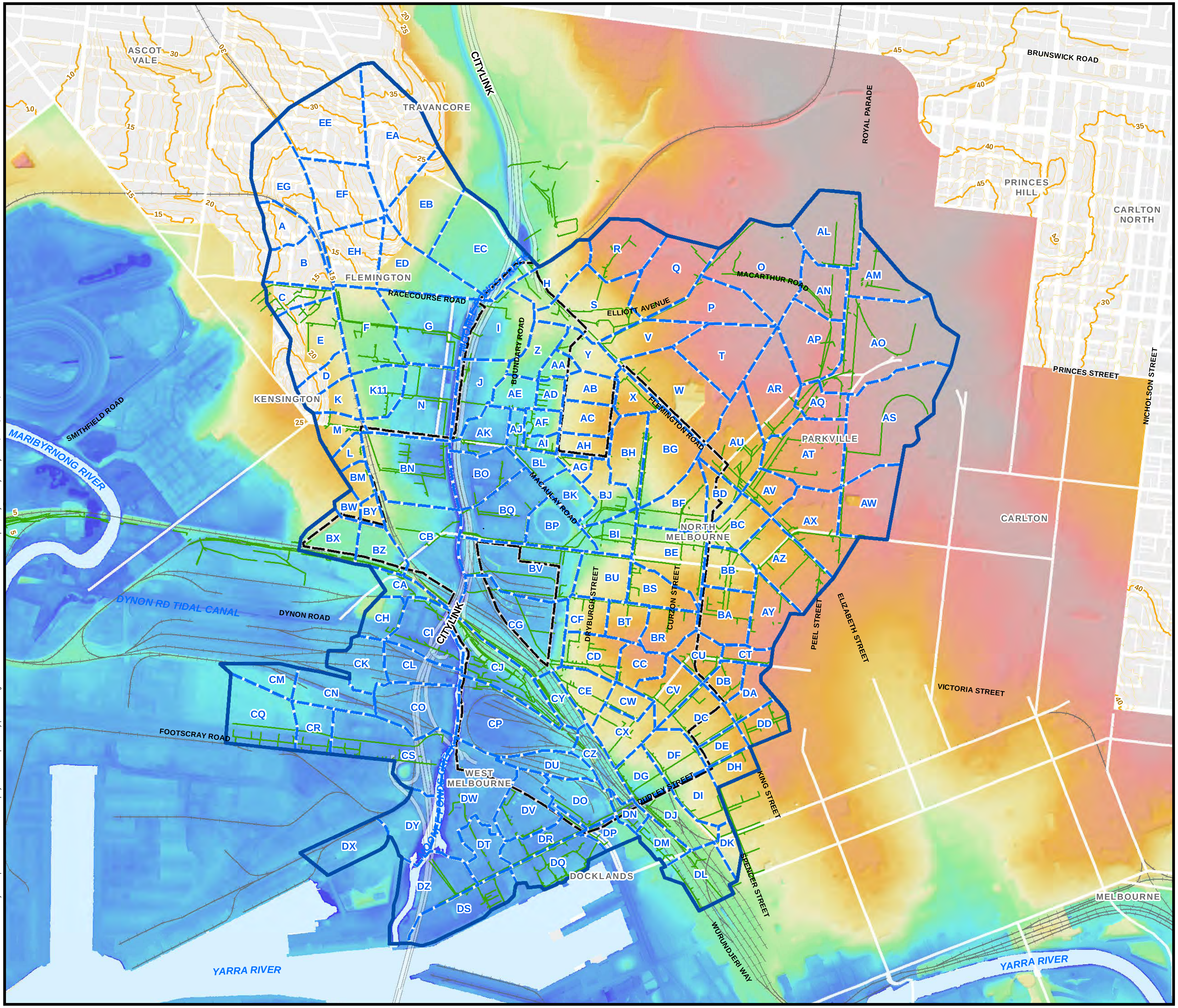
Table 3 shows the details of the Rational Method calculations of the 1% AEP flows at the calibration points.

Table 3 Rational Method Calculations

Calibration Point	Area (km^2)	Fraction Impervious	Adopted t_c (min.)	Runoff Coefficient C_{10}	1% AEP Frequency Factor	Runoff Coefficient C_{100}	1% AEP Intensity for t_c (mm/hr)	Peak 1% AEP Flow (m^3/s)
F1	0.81	0.50	29	0.61	1.2	0.73	77.1	12.7
AR1	0.68	0.44	31	0.57	1.2	0.69	74.0	9.6
AZ1	0.30	0.79	21	0.77	1.2	0.93	92.9	7.1

3.4 RORB Model

The RORB model was created in MiRORB and is shown in Figure 2. Appendix A supplements this figure by providing sub catchment data in tabular form.



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 200 400 800
metres
1:18,000 (when printed at A3)

LEGEND

- Catchment Boundary
- Sub-Catchment
- Study Area
- Pipe network
- Freeway
- Existing Rail
- Major contour
- Minor contour
- Cadastre

Elevation (mAHD)
High : 51.01
Low : 0

Data sources:
Base Data: (c) 2012 DEPI
DEM: (c) 2007 City of Melbourne

CATCHMENT DELINEATION

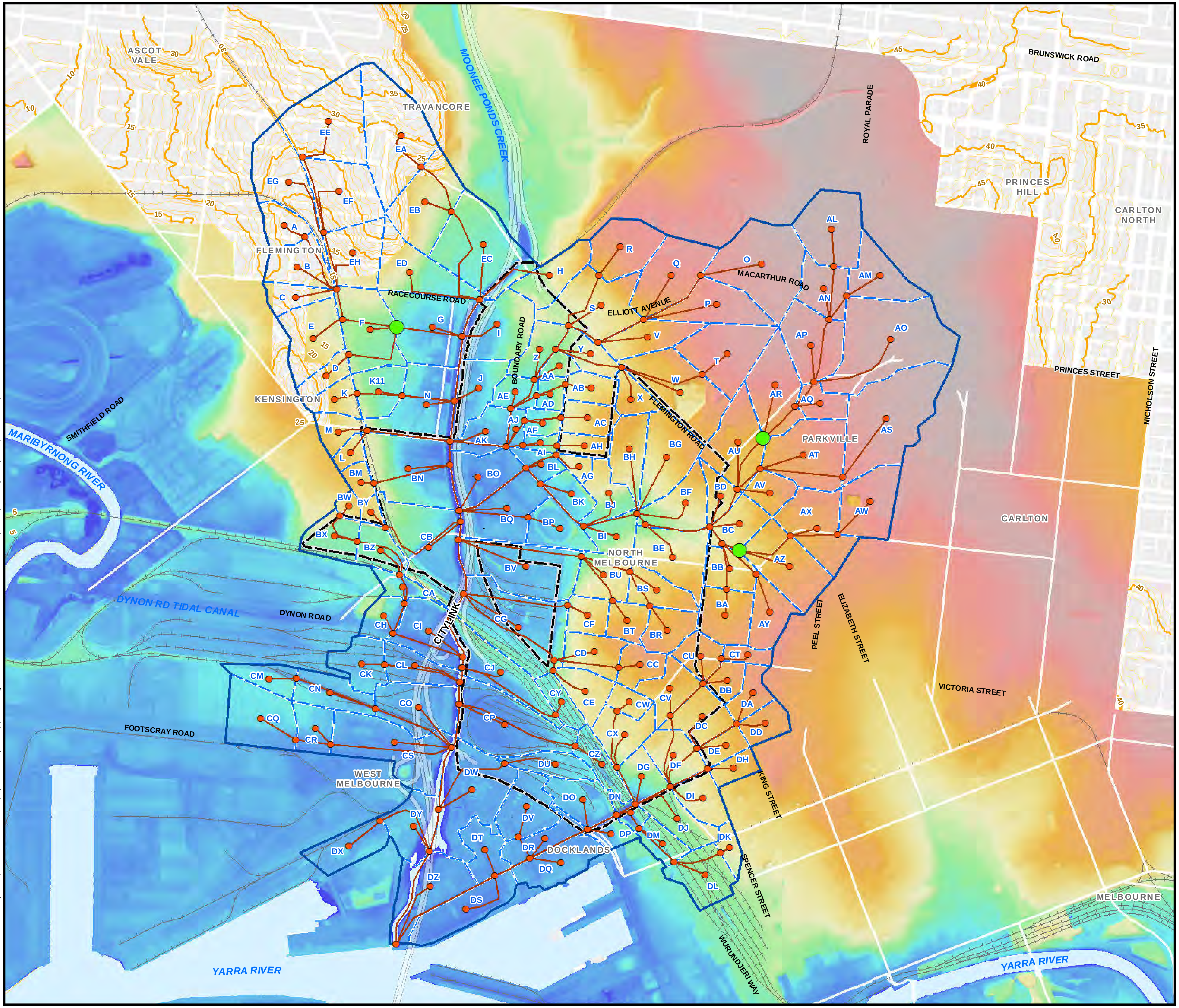
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F1

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M001_Catchmnet_Delineation_20130905a.mxd)

A3 size



PROJECT ID 60304612
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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 200 400 800
metres
1:18,000 (when printed at A3)

LEGEND

- Calibration Point
- Node
- Reach
- Catchment Boundary
- Sub-Catchment
- Study Area
- Freeway
- Existing Rail
- Major contour
- Minor contour
- Cadastre

Elevation (mAHD)
High : 51.01
Low : 0

Data sources:
Base Data: (c) 2012 DEPI
DEM: (c) 2007 City of Melbourne

ROR B MODEL WITH CALIBRATION POINTS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F2

DRAFT

3.5 Calibration

The purpose of calibrating the RORB model is to gain confidence in the results from the hydrological model that provides input to the hydraulic model. In the absence of historical rainfall-runoff data for the catchment, calibration using the Rational Method flow estimate has been undertaken. The following factors from the Melbourne Water Technical Specifications and Requirements were used in the calibration of the RORB model:

- A value of 0.8 has been used for the exponent m in the reach storage equation, $S = k_cQ^m$;
- k_c was adjusted to match the Rational Method flow estimate;
- The Institution of Engineers' 1987 Australian Rainfall and Runoff (AR&R) method used for the Areal Reduction Factor;
- Initial Loss =10mm (urban catchment);
- Temporal Patterns fully filtered; and,
- Runoff coefficients as per Table 4 below.

Table 4 Runoff Coefficients for Range of AEP Events

AEP	Runoff Coefficient
10%	0.35
1%	0.60
0.5%	0.60
0.2%	0.60

Please note that the value specified for the 1% AEP event has been used for larger events.

Through a process of trial and error, the value for k_c was adjusted until RORB results matched the peak flows estimated using the Rational Method. The k_c recommended using equation 2.4 in the RORB manual is 6.75 and the recommendation using equation 3.22 (for areas of Victoria with mean annual rainfall less than 800mm) in Book 5 of AR&R is 2.11. It was found that the lowest sum of percentage error occurred with a k_c value of 3.4 as highlighted in Table 5. This value is within the range of those recommended and was therefore adopted for this study.

Table 5 Calibration of k_c for RORB Model

k_c	Calibration Point	F1	AR1	AZ1
	Rational Method 1% AEP Flow (m^3/s)	12.7	9.6	7.1
	Rational Method t_c (min)	24	26	16
3.3	RORB 1% AEP Flow	12.7	9.7	7.3
	RORB peak storm duration (min)	60	120	15
	% Error	0	1	3
3.4	**RORB 1% AEP Flow**	**12.5**	**9.5**	**7.2**
	RORB peak storm duration (min)	**90**	**120**	**15**
	% Error	**-2**	**-1**	**1**
3.5	RORB 1% AEP Flow	12.3	9.4	7.1
	RORB peak storm duration (min)	90	120	15
	% Error	-3	-2	0

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The k_c value of 3.4 that was found to produce flows with an acceptable level of accuracy at the calibration points when compared to the Rational Method was then used in conjunction with other values listed in above to generate hydrographs for each sub-catchment for the full range of AEP events.

3.6 Results

The RORB model was used to produce sub-catchment inflows under existing conditions, as well as climate change conditions in 2040, 2070 and 2100, for the following AEPs using the 2 hour storm event to correspond with flooding in the Moonee Ponds Creek:

- 10%;
- 1%;
- 0.5%; and,
- 0.2%.

A comparison between the inflows to the TUFLOW model in the 2 hour duration, 1% AEP event under both existing and climate change conditions can be seen in Appendix B.

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4.0 Hydraulic Modelling

The objective of creating a hydraulic model of the study area was to develop flood extents to feed into the Arden Street Urban Renewal project and assist in the planning of the E-Gate development. The extent of flooding has been determined for a range of recurrence intervals for the existing extent of development in both existing and climate change conditions. Hydraulic modelling allows for the following:

- Identification of properties at risk of flooding;
- Identification of inadequacies in the existing stormwater network; and,
- Identification of locations where future works may be implemented in order to reduce the severity of flooding.

The hydraulic modelling software package TUFLOW was used to undertake the hydraulic modelling. The following steps outline the tasks undertaken to develop a TUFLOW model of the study area and to obtain results:

1) Generate a Digital Elevation Model (DEM)
2) Use the RORB model to compile hydrographs for 16 possible combinations of AEP and climate change conditions for existing levels of development:
    - 10%, 1%, 0.5% and 0.2% AEP events; and
    - Climate conditions as they are now as well as in how they are projected to be in 2040, 2070 and 2100. These conditions were modelled based on the assumption that there will be a 32% increase in extreme rainfall intensity in the period from 2010 to 2100, as per Melbourne Water's "Flood Mapping Project Guidelines and Technical Specifications – December 2011" and that increases in extreme rainfall intensity up until 2100 will be linear.
3) Input surface roughness (materials layer)
4) Input and verify data for the one-dimensional network
5) Set boundary conditions for the one and two-dimensional domains
6) Input open channel structure data and calibrate head losses to the results of the existing Melbourne Water HEC-RAS model, as provided by Melbourne Water and is understood to have been developed in 2010/2011.
7) Compile, interpret and validate the results
8) Run TUFLOW for all 16 possible combinations of AEP and climate change conditions for existing levels of development
    - 10%, 1%, 0.5% and 0.2% AEP events; and
    - Climate conditions as they are now as well as in how they are projected to be in 2040, 2070 and 2100. These conditions were modelled based on the assumption that there will be an increase of 0.8m in extreme sea level in the period from 2010 to 2100, as per Melbourne Water's "Flood Mapping Project Guidelines and Technical Specifications – December 2011" and that increases in extreme sea level up until 2100 will be linear.

Figure 3 shows the main features of the TUFLOW model. Further sections elaborate on elements of the model that are of importance, which are as follows:

- Digital Elevation Model (DEM);
- Two-dimensional grid;
- One-dimensional network data; and,
- Levee banks.

It should be noted that we have not attempted to simulate the flow of water out of the study area via the rail tunnels to the south-east of North Melbourne station, instead simply representing the tunnel mouths as blocked. The result of this is a conservative estimation of flood levels in the vicinity of the mouths of the rail tunnels.

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4.1 Digital Elevation Model (DEM)

The 2007 LiDAR data supplied by the City of Melbourne was used for this investigation and a DEM with a resolution of 1m was produced from this data. This was read directly into TUFLOW. Figure 4 shows the DEM generated for the study.

4.2 Two-Dimensional Grid

A 4m grid size was used in order to strike a balance between model accuracy and run times. The extent of the final 417,788 grid cell model is shown in Figure 4. The proposed final design surface (as of August 2013) in Triangular Irregular Network (TIN) format was obtained from RRL package B works and was incorporated into the model. The extent of the design surface is also shown in Figure 4.

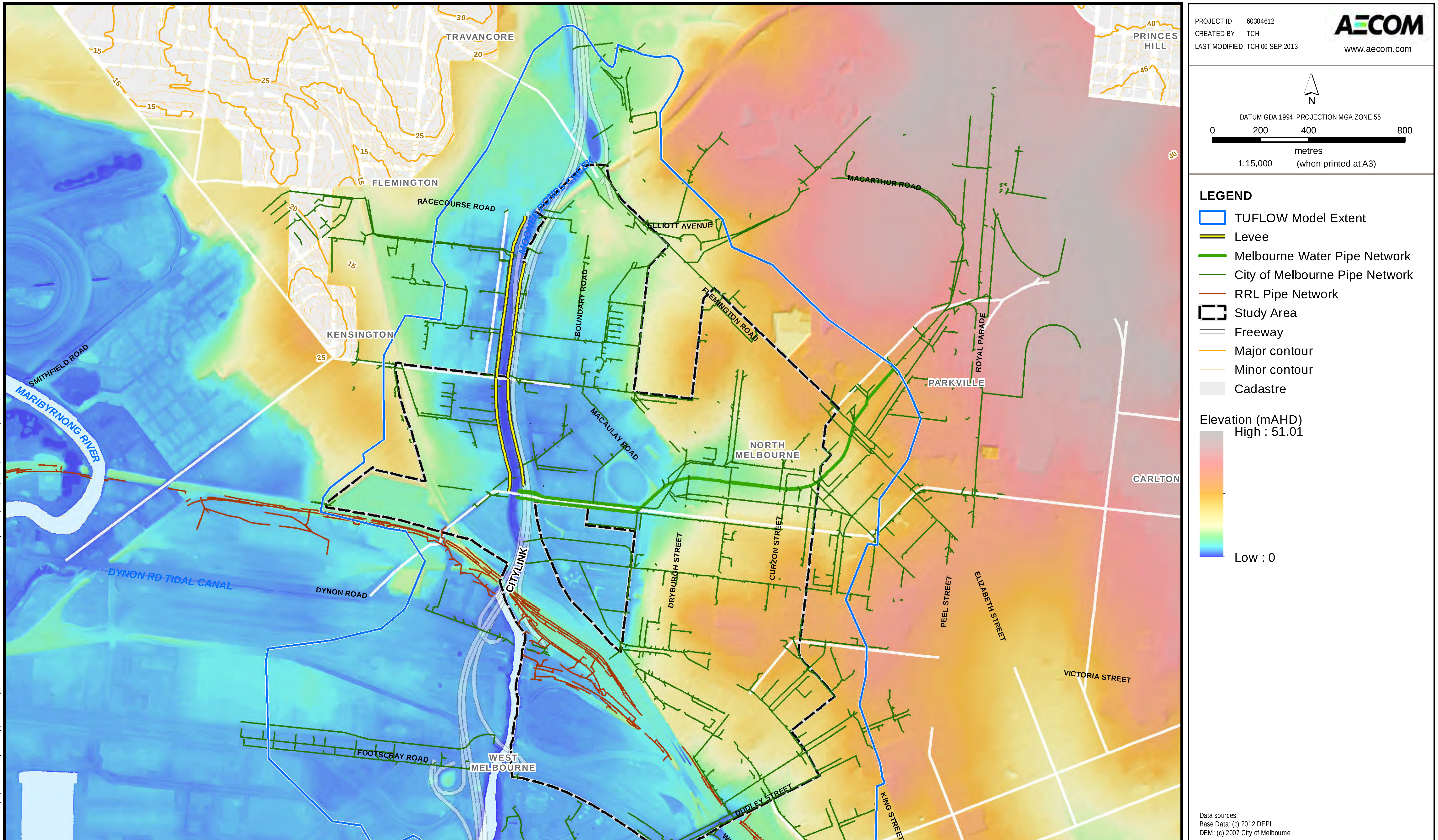
The locations shown as “Interpolated Areas” are where the design surface crosses a flow-path that has necessitated the flow-path being “cut” through the TIN in order to be represented in the model. The exception to this is the Royal Children’s Hospital on Flemington Road. As this site was undergoing excavation when the LiDAR data was gathered, there is a false hole in the DEM where the hospital now sits. This has been smoothed over in the TUFLOW model by interpolating between surface levels surrounding the erroneous data, resulting in topography consistent with the adjacent land.

Bathymetric data was obtained from Melbourne Water’s HEC-RAS model of Moonee Ponds Creek and used to create a TIN. The Surfcoast Survey and Drafting Services 2012 survey of the Moonee Ponds Creek levees was provided by the City of Melbourne and used to restrict flow to and from the creek below the levee level, as the LiDAR data did not adequately capture the levee. These features are shown in Figure 4.

4.3 Open Channel Structures

Bridges and piers in Moonee Ponds creek have been modelled using TUFLOW’s Layered Flow Constriction Shapes, which allow resistance to flow between grid cells to vary depending on the water level. Structure data was obtained from Melbourne Water’s HEC-RAS model and Form Loss Coefficients were adjusted such that head loss across structures in TUFLOW replicated those in the HEC-RAS model, with the exception of the Dynon Road bridge, where significant overland flow to the west bypasses the bridge itself.

Where survey data from the City of Melbourne appeared to conflict with the topography within the HEC-RAS model, the survey data was given preference. This is most relevant for the northern-most rail crossing of Moonee Ponds Creek where the incorporation of more detailed survey of this structure into the model would minimise any uncertainty regarding outcomes if this structure were to become the site of any mitigation opportunities.



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Data sources:
Base Data: (c) 2012 DEPI
DEM: (c) 2007 City of Melbourne

TUFLOW MODEL OVERVIEW

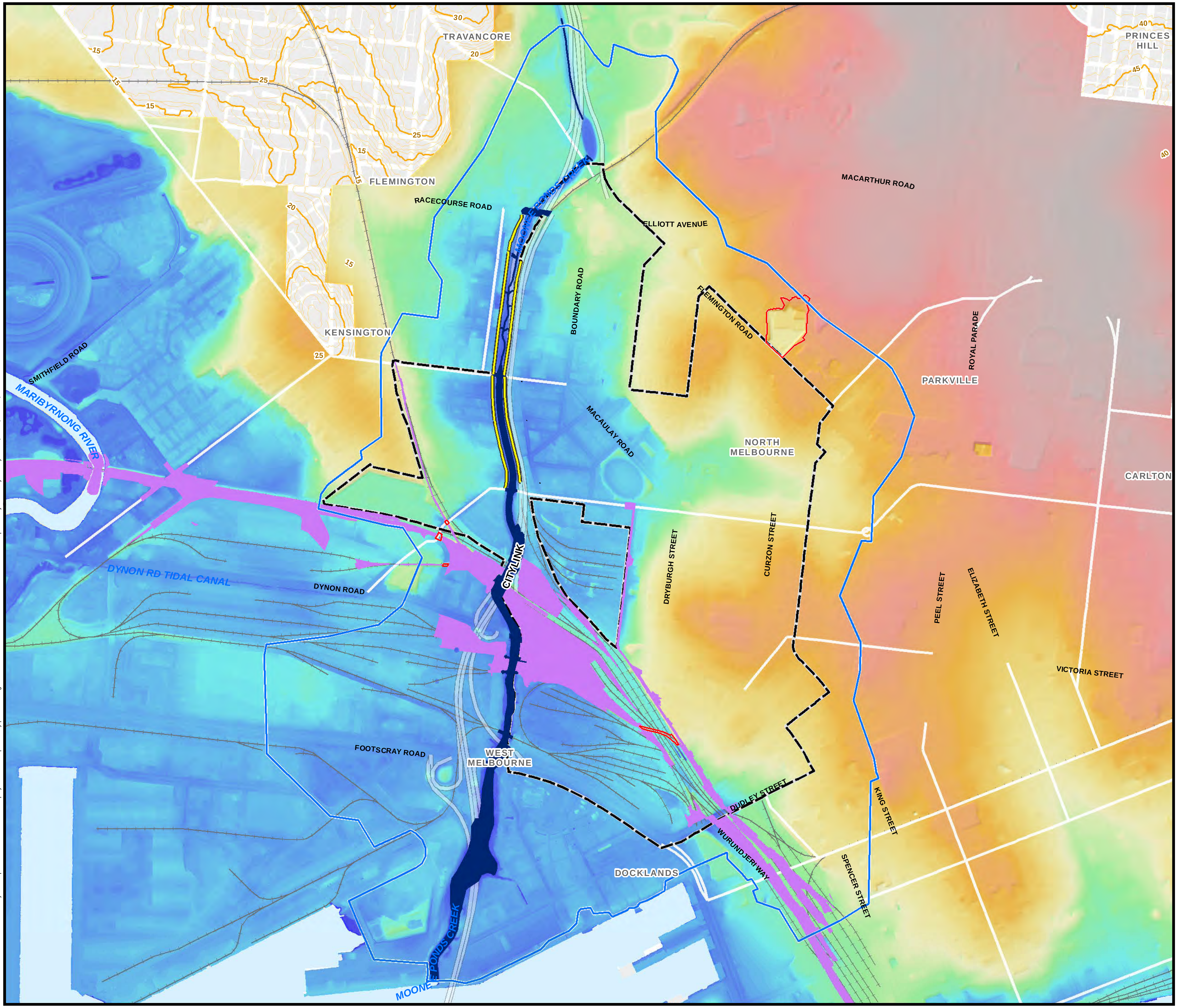
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure F3

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M003_TUFLOW_Model_20130905.mxd)

A3 size



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DATUM GDA 1994, PROJECTION MGA ZONE 55

0 200 400 800
metres
1:15,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Levee
- Creek TIN
- Interpolated Areas
- Regional Rail Link Design TIN extent
- Study Area
- Freeway
- Existing Rail
- Major contour
- Minor contour
- Cadastre

Elevation (mAHD)
High : 51.01
Low : 0

Data sources:
Base Data: (c) 2012 DEPI
DEM: (c) 2007 City of Melbourne

TUFLOW MODEL TOPOGRAPHY

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F4

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M004_TUFLOW_Topography_20130905.mxd)

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4.4 One-Dimensional Network Data

GIS data for the existing Melbourne Water, City of Melbourne and RRL drainage infrastructure network was obtained directly from these agencies in 2013. Verification and manipulation of this data in GIS packages was necessary, as detailed below.

4.4.1 Melbourne Water Underground Drainage

Melbourne Water's only underground asset included in the model was the Arden Street Drain. Where objects in Melbourne Water's GIS data for this drain were lacking invert levels, these were interpolated based on the upstream or downstream levels of adjacent pipes.

4.4.2 City of Melbourne Drainage

City of Melbourne GIS asset data supplied in 2013 was utilised to obtain pipe locations and diameters however no invert levels were available. Information regarding pit connections was utilised to obtain surface levels from the level of the DEM at the pit location at the upstream and downstream ends of the pipe network, as well as at junctions.

A cover of 600mm from the natural surface to the top of the pipe was assumed to obtain invert levels using these surface levels. All grated pits were considered to be 1.2 m wide by 0.5 m high and all other pits were considered to be 1.2 m wide by 0.15 m high. Pits labelled "System Node" and "Junction" were not considered to facilitate an exchange of water between the surface and the pipe network, due to conclusions drawn based on visual inspections at a number of these locations.

Discussions with the City of Melbourne led to the agreement that a conservative assumption should be made with regards to the operation of pump stations. Consequently it was assumed that these pumps would not be operated during the flood events modelled.

4.4.3 RRL Drainage

The drainage network from the RRL project in the model area was obtained in 2013. Diameters and inverts were used as supplied, however the pipes were constructed as slotted polyethylene, which cannot be easily incorporated into a TUFLOW model. Consequently 1.2m wide by 0.15m high pits were introduced at the end of each pipe object to facilitate interaction between the surface and pipe drainage.

4.5 Surface Roughness

Within TUFLOW, a land use (materials) layer is utilised to import surface roughness information into the model. A materials layer for the model area was constructed by using the City of Melbourne's 2007 Land Cover data, where available. Use of this data may be conservative in some areas due to the presence of trees in the road reservations.

Outside of the City of Melbourne, Planning Scheme Zones were used to assign roughness values to city blocks and large areas of uniform roughness were digitised by hand. Additionally, Manning's "n" values in Moonee Ponds Creek were initially based on those from Melbourne Water's HEC-RAS model, though these were adjusted to provide a better match to the hydraulic grade between the two models. The Manning's "n" values used are shown in Table 6.

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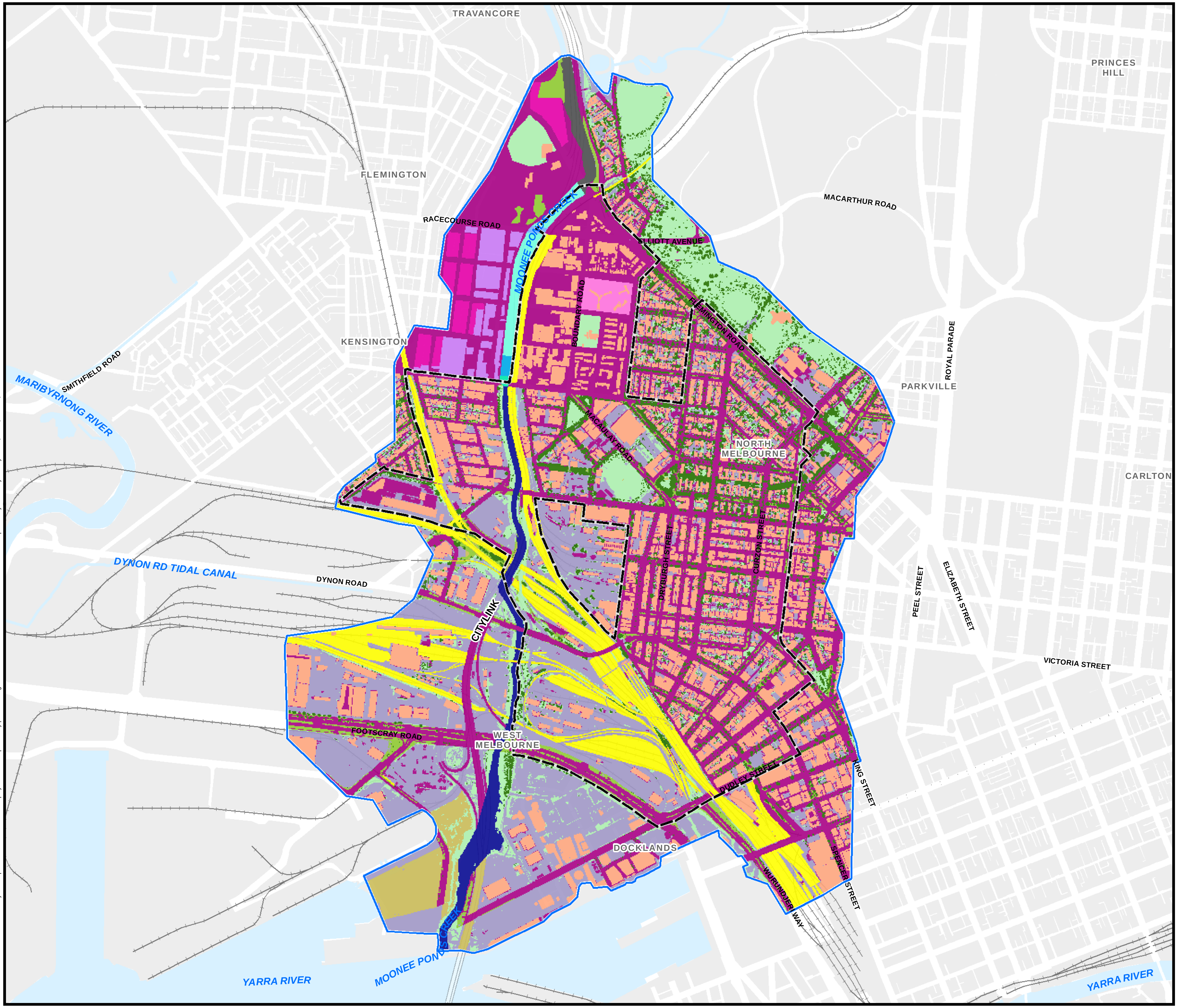
Table 6 Roughness Coefficients

Material	Manning's n
Industrial	0.200
Bare Soil	0.025
Grass Areas	0.035
Hard Surfaces	0.030
Nature Strips	0.050
Railway	0.100
Road	0.020
Trees	0.070
Water Bodies	0.021
Buildings	0.500
Concrete	0.018
Open Channel 1	0.033
Open Channel 2	0.024
Open Channel 3	0.040
Open Channel 4	0.0206
Residential (Buildings Separate)	0.080
High Density Residential (Including Buildings)	0.300



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 200 400 800

metres

1:16,000 (when printed at A3)

LEGEND

- Study Area
- TUFLOW Model Extent

Material

- Bare Soil
- Buildings
- Concrete
- Grass Areas
- Hard Surfaces
- Industrial
- Nature Strips
- Open Channel 1
- Open Channel 2
- Open Channel 3
- Open Channel 4
- Railway
- Road
- Trees
- Water Bodies
- High Density Residential (Including Buildings)
- Residential (Buildings Separate)

Data sources:
Base Data: (c) 2012 DEPI
DEM: (c) 2007 City of Melbourne

TUFLOW MODEL MATERIALS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F5

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M005_TUFLOW_Model_Materials_20130905.mxd)

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D R A F T

4.6 Boundary Conditions

4.6.1 Outflows

Two-dimensional boundary conditions were applied at the outlet of Moonee Ponds Creek to the Yarra River and along the edge of the model at Victoria Harbour. This tail water level was set to the 10% AEP extreme sea level in Port Phillip Bay of 1.22 m AHD for current conditions, as per Melbourne Water specifications for models that outlet to the bay. Thus the difference between the Yarra River level and the level in the bay at the outlet of Moonee Ponds Creek was considered negligible.

Sea level rise was then applied on top of this downstream water level for climate change conditions, which was 0.8 m by 2100, with rises by 2040 and 2070 linearly interpolated. The only other location where water was allowed to leave the model was on Childers Street, where two pipes lead to the Maribyrnong River. These were also assumed to have a tail water level of 1.22 m AHD.

4.6.2 Inflows

In the majority of the model, the inflows are the un-routed hydrographs from the RORB model, which were applied to the bottom of the pits in the one-dimensional network. This approach ensures that the pipe network should be at or close to capacity before any water spills into the two-dimensional domain.

The flow from each of the sub-catchments is split evenly over all of the pits within each sub-catchment. In sub-catchments where this resulted in an excessive amount of flow being applied to some pits (such as the RRL drainage network), flow was applied only to the City of Melbourne network.

In some locations, the application of routed hydrographs was appropriate. This was the case where the TUFLOW model extent fell significantly short of the catchment extent, but was also the case for some sub-catchments that only contained an underground drainage network at their most downstream boundary. The Moonee Ponds Creek inflow was applied across the width of the open channel at the upstream extent of the TUFLOW model.

4.6.3 Connections between One- and Two-Dimensional Domains

Boundaries have been assigned to the pits to allow discharge of water from the pipe network to flow to the two-dimensional grid cells representing the ground surface and vice versa. This allows for the simulation of real world processes such as when flow drains from a road into a pit, or when the piped network reaches capacity and flow begins to spill back out of the pits respectively.

4.7 Model Checking

The log files of all simulations were checked to ascertain mass balance errors at the peak and end of the event. Mass balance error in the model is acceptably low (less than 1%) for all TUFLOW simulations.

4.8 Flood Mapping

The maximum depths of inundation for each AEP for each set of climate change conditions were calculated to produce the final results of the study. These depths are presented in the following figures:

- Appendix C shows water depths for 10%, 1%, 0.5% and 0.2% AEP events in existing conditions
- Appendix D shows water depths for 10%, 1%, 0.5% and 0.2% AEP events in 2040 climate change conditions
- Appendix E shows water depths for 10%, 1%, 0.5% and 0.2% AEP events in 2070 climate change conditions
- Appendix F shows water depths for 10%, 1%, 0.5% and 0.2% AEP events in 2100 climate change conditions

D R A F T

5.0 Discussion

Floodplains on both sides of Moonee Ponds Creek experience flooding as a result of run-off from local sub-catchments exceeding the capacity of the underground drainage network and flowing overland towards the creek. Flows are then prevented from entering the creek by the levees resulting in pooling, with flood waters outside of the levee being higher than those in the creek in the existing case, 1% AEP event south of Macauley Road.

It should be noted that the topography of the railway line underneath CityLink has not been accurately captured by the LiDAR data. It is recommended that this be surveyed and incorporated into the model if this area is to become the site of mitigation works.

The most significant constriction on flow in Moonee Ponds Creek is the northern-most rail bridge, which crosses the creek underneath CityLink. The obvert of this bridge is 2.06 m AHD and the existing case, 1% AEP flood level on the upstream side is estimated to be 2.99 m AHD. There is also some uncertainty about the cross-section of the bridge opening, with data obtained from Melbourne Water's HEC-RAS model not being verified by the City of Melbourne's survey of the area. If this is to become the location of any mitigation works, it is recommended that the structure be surveyed and revised in the model.

There is some uncertainty about the Dynon Road Bridge as the dimensions do not appear to be accurately reflected in the structure data in Melbourne Water's HEC-RAS model. As a result almost 50 m^3/s of flow in Moonee Ponds Creek is diverted onto the western floodplain at this location in the 1% AEP event under existing conditions. This means that the flow rate passing under the Dynon Road Bridge differs between this TUFLOW model and the existing HEC-RAS model, thus calibration of the Dynon Road structure could not be undertaken.

Flooding of the Docklands area is extensive and relatively deep at the eastern end of Docklands Drive, with Waterfront Way under almost 2 m of water at the intersection with Docklands Drive in the existing case, 1% AEP event. This is caused by a lack of capacity in the underground drainage network (as well as the absence of a dedicated overland flow-path), though the hydraulic grade along the Dudley Street drain is relatively flat, with head drop in the order of 70 cm between this location and the outlet of the drain in Moonee Ponds Creek. Despite this, the flow through the underpass is approximately $14m^3/s$ in the existing case, 1% AEP event. It should be noted that invert levels of this drain are not available and the accuracy of results would benefit from survey of these levels.

Flooding in the southern part of E-Gate is predominantly from Moonee Ponds Creek, with run-off from the rail yards to the east peaking at about 0.2 m^3/s in the existing case, 1% AEP event. In the northern section of E-Gate, immediately to the south of Dynon Road, overland flow originating in the rail yards is more significant, peaking at 1.4 m^3/s. However, flooding from the creek is also responsible for some of the inundation towards the western end of this area.

D R A F T

Appendix A

RORB Sub Catchment Details

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Appendix A RORB Sub Catchment Details

Sub-Area	Area (km^2)	Fraction Impervious	Sub-Area	Area (km^2)	Fraction Impervious	Sub-Area	Area (km^2)	Fraction Impervious
B	0.06	0.65	AV	0.04	0.87	CP	0.15	0.77
C	0.04	0.45	AW	0.09	0.59	CQ	0.10	0.89
D	0.03	0.50	AX	0.10	0.85	CR	0.04	0.90
E	0.09	0.48	AY	0.06	0.78	CS	0.14	0.86
F	0.11	0.51	AZ	0.11	0.91	CT	0.02	0.93
G	0.13	0.70	BA	0.07	0.91	CU	0.04	0.93
H	0.06	0.65	BB	0.05	0.85	CV	0.05	0.82
I	0.10	0.81	BC	0.05	0.82	CW	0.03	0.89
J	0.07	0.86	BD	0.03	0.72	CX	0.06	0.88
K	0.04	0.52	BE	0.10	0.77	CY	0.03	0.72
K11	0.06	0.47	BF	0.07	0.76	CZ	0.04	0.69
L	0.02	0.61	BG	0.10	0.75	DA	0.04	0.81
M	0.04	0.82	BH	0.06	0.82	DB	0.03	0.79
N	0.11	0.82	BI	0.04	0.61	DC	0.06	0.93
O	0.16	0.17	BJ	0.05	0.71	DD	0.04	0.91
P	0.08	0.04	BK	0.04	0.82	DE	0.03	0.93
Q	0.10	0.28	BL	0.03	0.85	DF	0.06	0.89
R	0.08	0.26	BM	0.02	0.70	DG	0.04	0.90
S	0.12	0.39	BN	0.14	0.83	DH	0.03	0.91
T	0.11	0.00	BO	0.07	0.80	DI	0.05	0.91
V	0.06	0.02	BP	0.06	0.44	DJ	0.06	0.87
W	0.13	0.23	BQ	0.10	0.81	DK	0.02	0.98
X	0.03	0.84	BR	0.05	0.89	DL	0.07	0.80
Y	0.04	0.71	BS	0.05	0.94	DM	0.03	0.74
Z	0.05	0.53	BT	0.04	0.88	DN	0.02	0.68
AA	0.02	0.59	BU	0.06	0.94	DO	0.06	0.93
AB	0.04	0.76	BV	0.14	0.89	DP	0.03	0.88
AC	0.04	0.79	BW	0.01	0.77	DQ	0.07	0.96
AD	0.02	0.48	BX	0.05	0.81	DR	0.05	0.93
AE	0.03	0.48	BY	0.01	0.73	DS	0.09	0.97
AF	0.02	0.49	BZ	0.05	0.82	DT	0.05	0.94
AG	0.02	0.53	CA	0.03	0.75	DU	0.04	0.74
AH	0.03	0.78	CB	0.15	0.79	DV	0.08	0.85
AI	0.01	0.57	CC	0.04	0.87	DW	0.15	0.67

D R A F T

Sub-Area	Area (km^2)	Fraction Impervious	Sub-Area	Area (km^2)	Fraction Impervious	Sub-Area	Area (km^2)	Fraction Impervious
AJ	0.02	0.48	CD	0.06	0.94	DX	0.06	0.92
AK	0.05	0.90	CE	0.05	0.91	DY	0.07	0.46
AL	0.11	0.68	CF	0.04	0.93	DZ	0.11	0.66
AM	0.07	0.18	CG	0.17	0.84	EA	0.17	0.57
AN	0.06	0.50	CH	0.04	0.83	EB	0.11	0.49
AO	0.21	0.53	CI	0.08	0.80	EC	0.16	0.30
AP	0.09	0.13	CJ	0.09	0.77	ED	0.10	0.46
AQ	0.04	0.86	CK	0.06	0.84	EE	0.15	0.47
AR	0.10	0.24	CL	0.05	0.82	EF	0.11	0.45
AS	0.19	0.49	CM	0.04	0.89	EG	0.11	0.48
AT	0.12	0.75	CN	0.06	0.83	EH	0.08	0.55
B	0.06	0.65	AV	0.04	0.87	CP	0.15	0.77

D R A F T

Appendix B

Peak TUFLOW Inflows for 2 Hour, 1% AEP Events

D R A F T

Appendix B Peak TUFLOW Inflows for 2 Hour, 1% AEP Events

Please note that this table contains some flows from routed and / or lumped hydrographs.

Catchment	Flow (m^3/s)				Catchment	Flow (m^3/s)			
	Existing	2040	2070	2100		Existing	2040	2070	2100
Moonee Ponds Creek	207.4	234.4	263.4	290.4					
F	12.4	13.8	15.3	16.7	BX	1.5	1.7	1.9	2.0
G	3.5	3.9	4.3	4.6	BY	0.3	0.4	0.4	0.4
H	1.7	1.9	2.1	2.3	BZ	1.1	1.2	1.4	1.5
I	2.9	3.2	3.5	3.8	CA	0.7	0.8	0.9	1.0
J	1.9	2.1	2.3	2.5	CB	4.2	4.6	5.1	5.5
K11	1.9	2.2	2.4	2.6	CC	1.0	1.2	1.3	1.4
L	0.5	0.5	0.6	0.6	CD	1.7	1.8	2.0	2.2
M	1.0	1.1	1.2	1.3	CE	1.4	1.6	1.7	1.9
N	3.2	3.6	3.9	4.2	CF	1.1	1.2	1.3	1.4
Q	5.5	6.2	6.8	7.5	CG	5.0	5.5	6.0	6.6
R	1.7	1.9	2.0	2.2	CH	0.9	1.0	1.1	1.2
S	2.9	3.2	3.5	3.8	CI	2.3	2.5	2.8	3.0
T	1.3	1.5	1.7	1.9	CJ	2.6	2.9	3.1	3.4
V	0.6	0.6	0.7	0.8	CK	1.3	1.5	1.6	1.8
W	2.9	3.3	3.6	3.9	CL	1.5	1.7	1.9	2.0
X	0.9	1.0	1.1	1.2	CM	1.0	1.2	1.3	1.4
Y	1.1	1.2	1.4	1.5	CN	1.7	1.9	2.1	2.3
Z	1.1	1.3	1.4	1.5	CO	2.7	3.0	3.3	3.6
AA	0.5	0.5	0.6	0.7	CP	4.2	4.6	5.1	5.5
AB	1.0	1.1	1.2	1.4	CQ	2.9	3.2	3.5	3.8
AC	1.2	1.4	1.5	1.6	CR	1.3	1.4	1.6	1.7
AD	0.5	0.6	0.7	0.7	CS	4.1	4.6	5.0	5.5
AE	0.8	0.9	1.0	1.1	CT	0.6	0.7	0.7	0.8
AF	0.6	0.6	0.7	0.8	CU	1.2	1.3	1.5	1.6
AG	0.4	0.4	0.5	0.5	CV	1.5	1.7	1.8	2.0
AH	0.8	0.9	1.0	1.1	CW	0.7	0.7	0.8	0.9
AI	0.4	0.4	0.4	0.5	CX	1.7	1.9	2.0	2.2
AJ	0.4	0.4	0.5	0.5	CY	0.9	1.0	1.1	1.2
AK	1.4	1.6	1.7	1.9	CZ	1.2	1.3	1.4	1.5
AR	9.5	10.7	11.9	13.1	DA	1.1	1.2	1.3	1.4
AT	5.7	6.4	7.0	7.7	DB	0.8	0.9	1.0	1.0

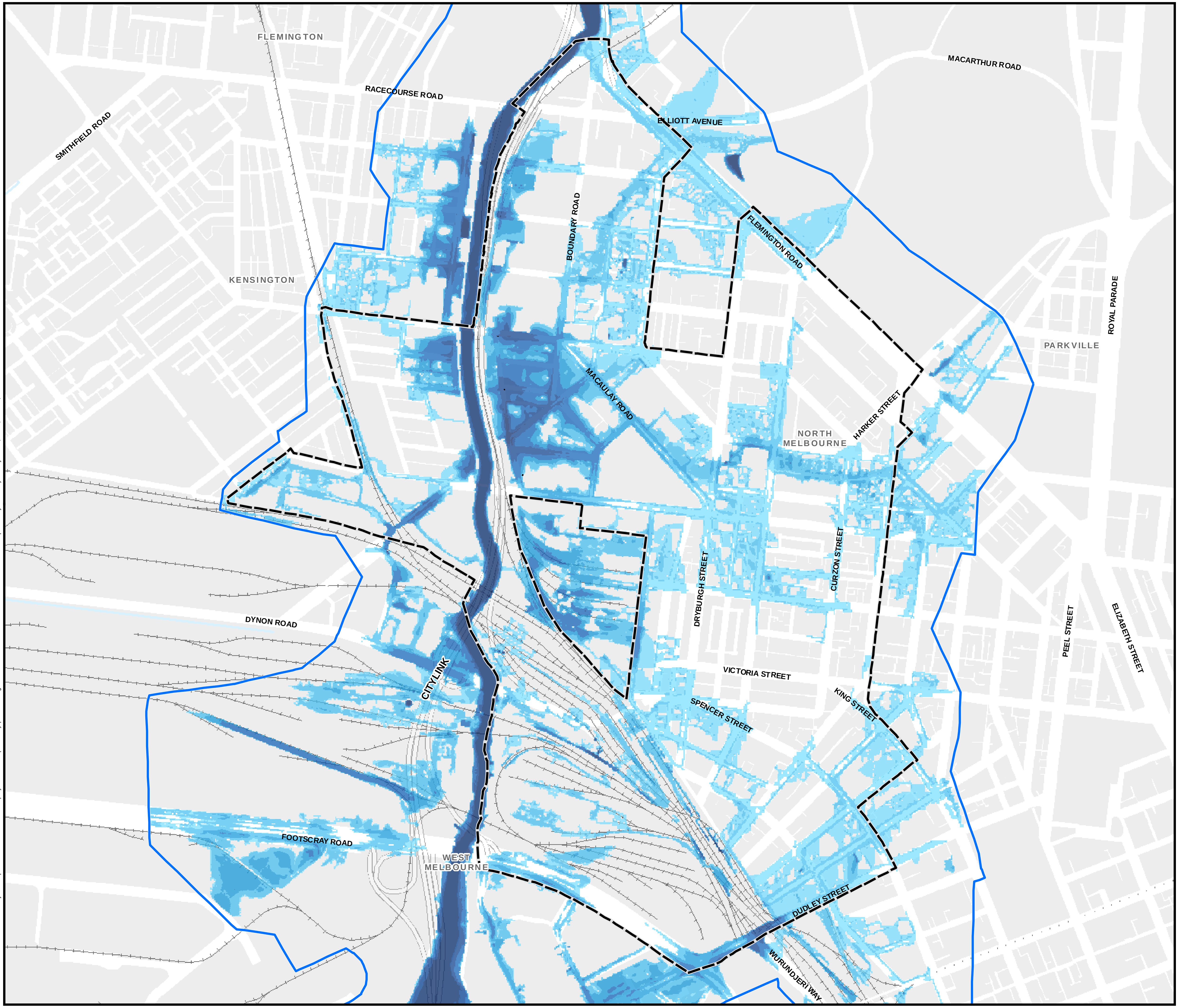
DRAFT

Catchment	Flow (m^3/s)				Catchment	Flow (m^3/s)			
	Existing	2040	2070	2100		Existing	2040	2070	2100
AU	2.5	2.8	3.1	3.3	DC	1.8	2.0	2.2	2.4
AV	1.1	1.2	1.3	1.4	DD	1.1	1.2	1.3	1.4
AY	1.4	1.6	1.7	1.9	DE	0.9	0.9	1.0	1.1
AZ	6.3	7.0	7.7	8.4	DF	1.7	1.8	2.0	2.2
BA	2.0	2.3	2.5	2.7	DG	1.3	1.4	1.5	1.7
BB	1.4	1.6	1.7	1.9	DH	0.8	0.9	1.0	1.1
BC	1.8	1.9	2.1	2.3	DI	1.4	1.6	1.7	1.9
BD	0.9	1.0	1.1	1.2	DJ	1.6	1.8	2.0	2.2
BE	2.6	2.9	3.2	3.5	DK	0.6	0.7	0.8	0.8
BF	2.0	2.2	2.5	2.7	DL	2.0	2.2	2.4	2.6
BG	2.6	2.9	3.2	3.5	DM	0.9	1.0	1.1	1.2
BH	1.8	1.9	2.1	2.3	DN	0.5	0.6	0.6	0.7
BI	1.1	1.2	1.3	1.5	DO	1.3	1.5	1.7	1.8
BJ	1.4	1.6	1.7	1.9	DP	0.8	0.8	0.9	1.0
BK	0.7	0.8	0.9	1.0	DQ	2.1	2.3	2.6	2.8
BL	0.8	0.9	0.9	1.0	DR	1.4	1.5	1.6	1.8
BM	0.5	0.6	0.6	0.7	DS	2.5	2.8	3.1	3.4
BN	4.0	4.5	4.9	5.3	DT	1.4	1.6	1.7	1.9
BO	2.1	2.3	2.5	2.7	DU	0.7	0.8	0.9	1.0
BP	1.4	1.6	1.8	1.9	DV	2.2	2.4	2.6	2.8
BQ	2.8	3.1	3.4	3.7	DW	4.0	4.5	4.9	5.3
BR	1.5	1.6	1.8	1.9	DX	0.8	0.9	1.0	1.1
BS	1.5	1.6	1.8	2.0	DY	1.3	1.4	1.6	1.7
BT	1.1	1.2	1.3	1.4	DZ	2.8	3.1	3.4	3.7
BU	1.8	2.0	2.2	2.3	EB	2.5	2.8	3.1	3.5
BV	4.0	4.5	4.9	5.3	EC	3.6	4.0	4.4	4.8
BW	0.4	0.4	0.4	0.5	ED	1.7	2.0	2.2	2.4

D R A F T

Appendix C

Water Depths for 10%, 1%, 0.5% and 0.2% AEP Events in Existing Conditions



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

EXISTING CONDITIONS 10% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

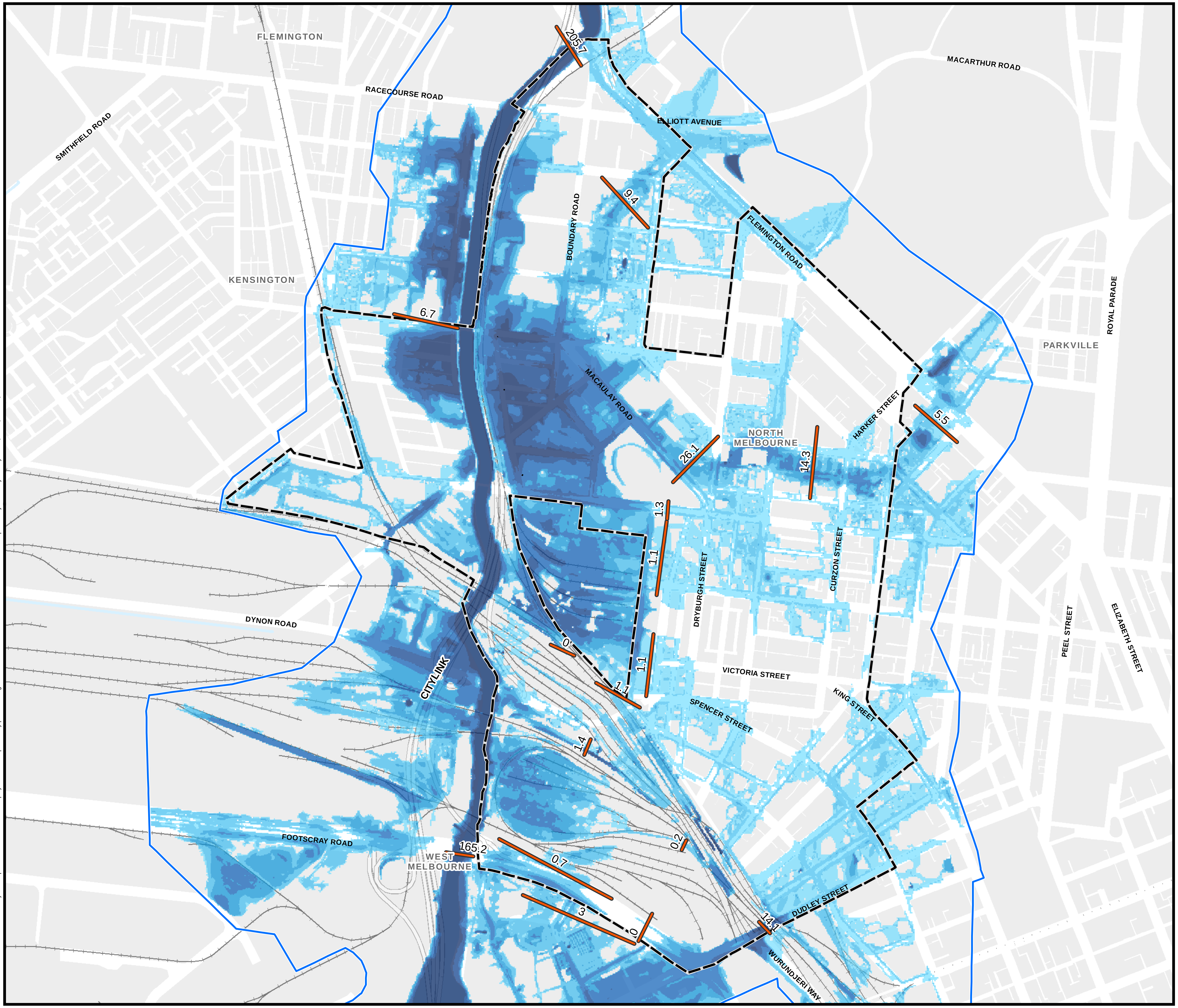
Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F6

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_EXG_Q010)

A3 size



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LAST MODIFIED TCH 11 SEP 2013

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DATUM GDA 1994, PROJECTION MGA ZONE 55
0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

TUFLOW Model Extent
Study Area
1% AEP Existing Flow Rate (m³/s)
Water Depth (metres)
0 - 0.05
0.06 - 0.25
0.26 - 0.5
0.51 - 1
1.01 - 1.5
> 1.51

Data sources:
Base Data: (c) 2012 DEPI

EXISTING CONDITIONS 1% AEP WATER DEPTHS

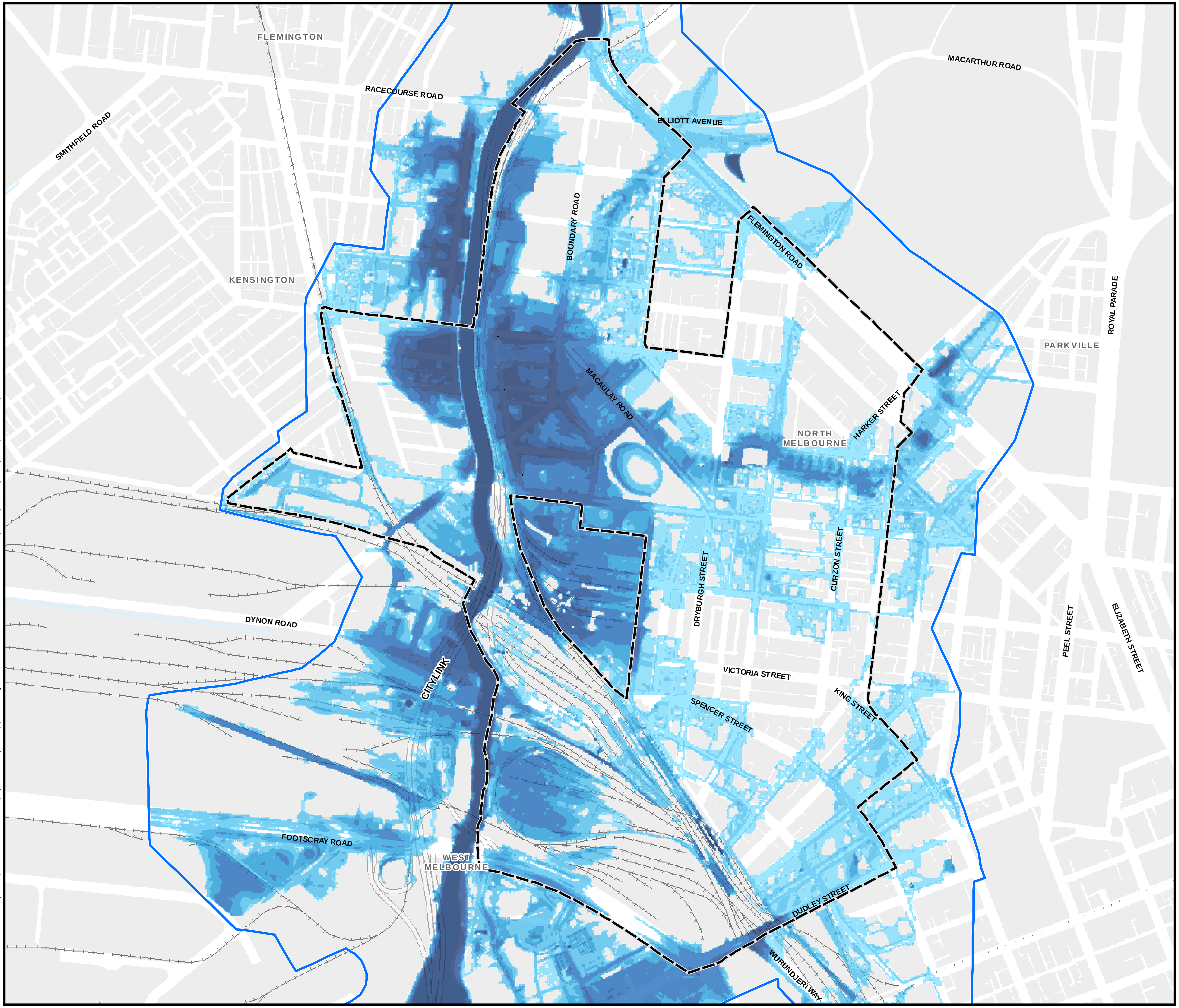
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure F7

Map Document: (\\aumel1fp001\projects\60304612\4. Tech work area\4.99 GIS\02_Maps\M007_Depths_ExCond_20130911.mxd - D_EXG_Q100)

A3 size



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0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

EXISTING CONDITIONS 0.5% AEP WATER DEPTHS

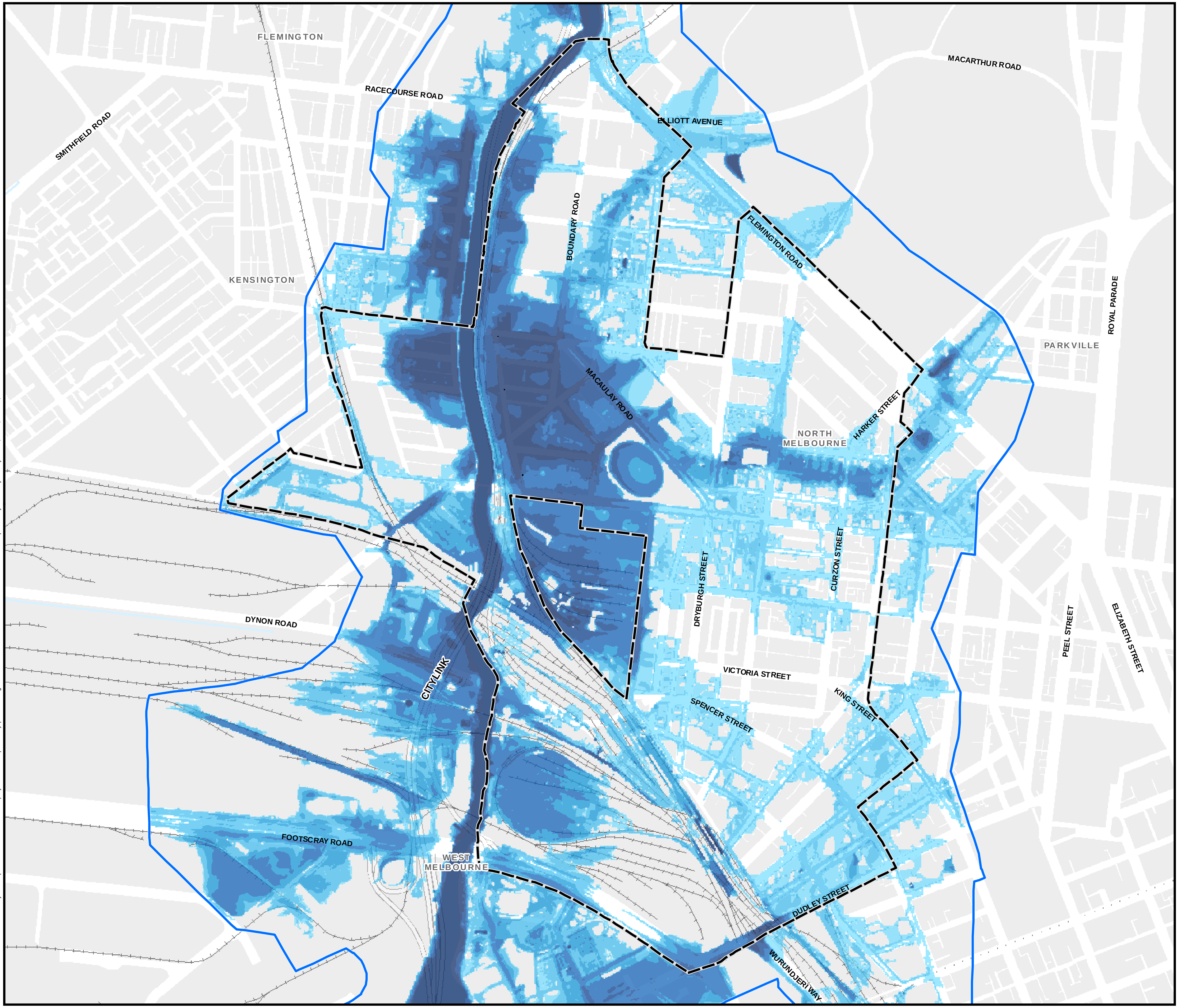
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F8

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_EXG_Q200)

A3 size



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DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres

1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

EXISTING CONDITIONS 0.2% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

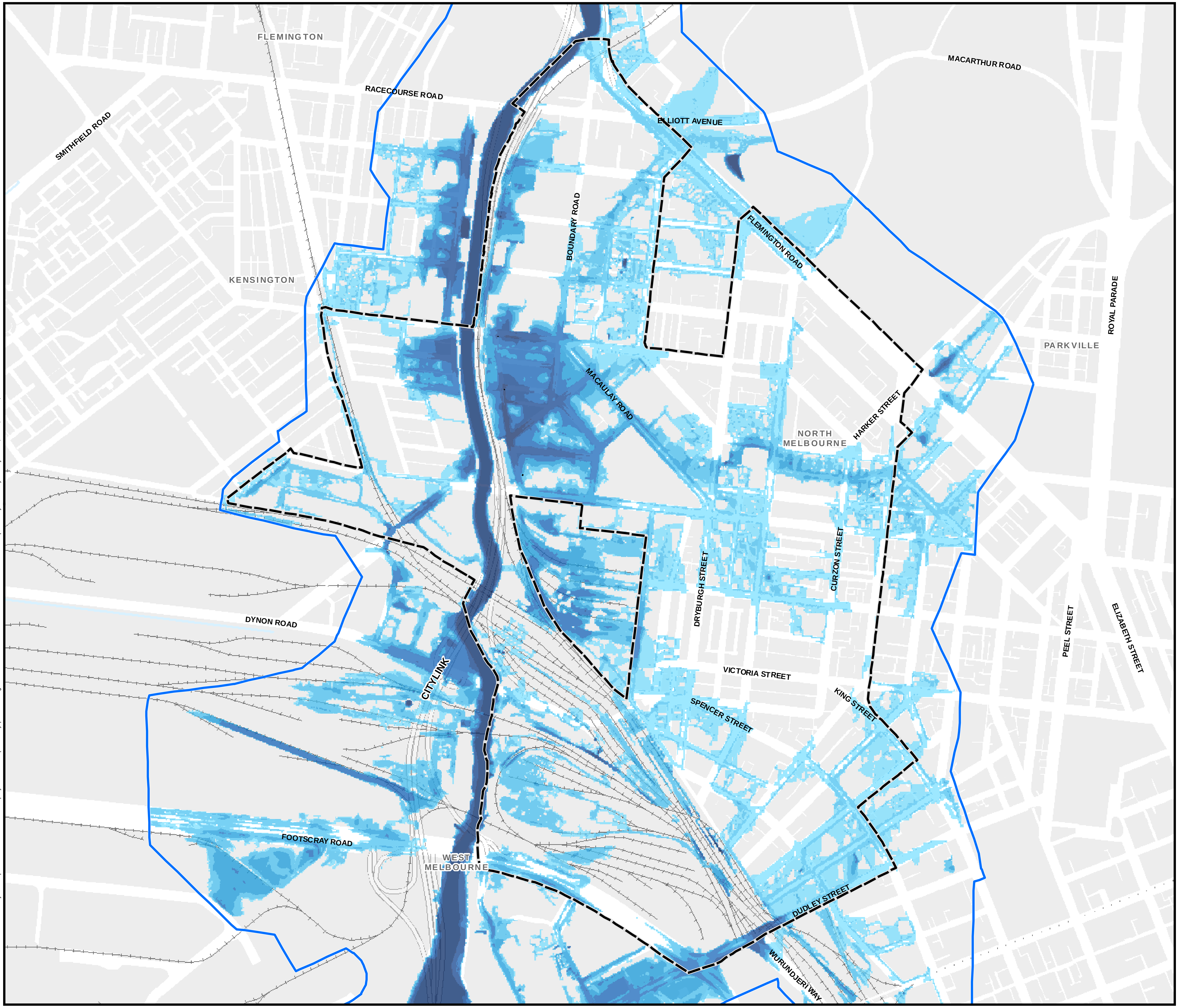
F9

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_EXG_Q500)

A3 size

Appendix D

Water Depths for 10%, 1%, 0.5% and 0.2% AEP Events in 2040 Climate Change Conditions



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DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400

metres

1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2040 CONDITIONS 10% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

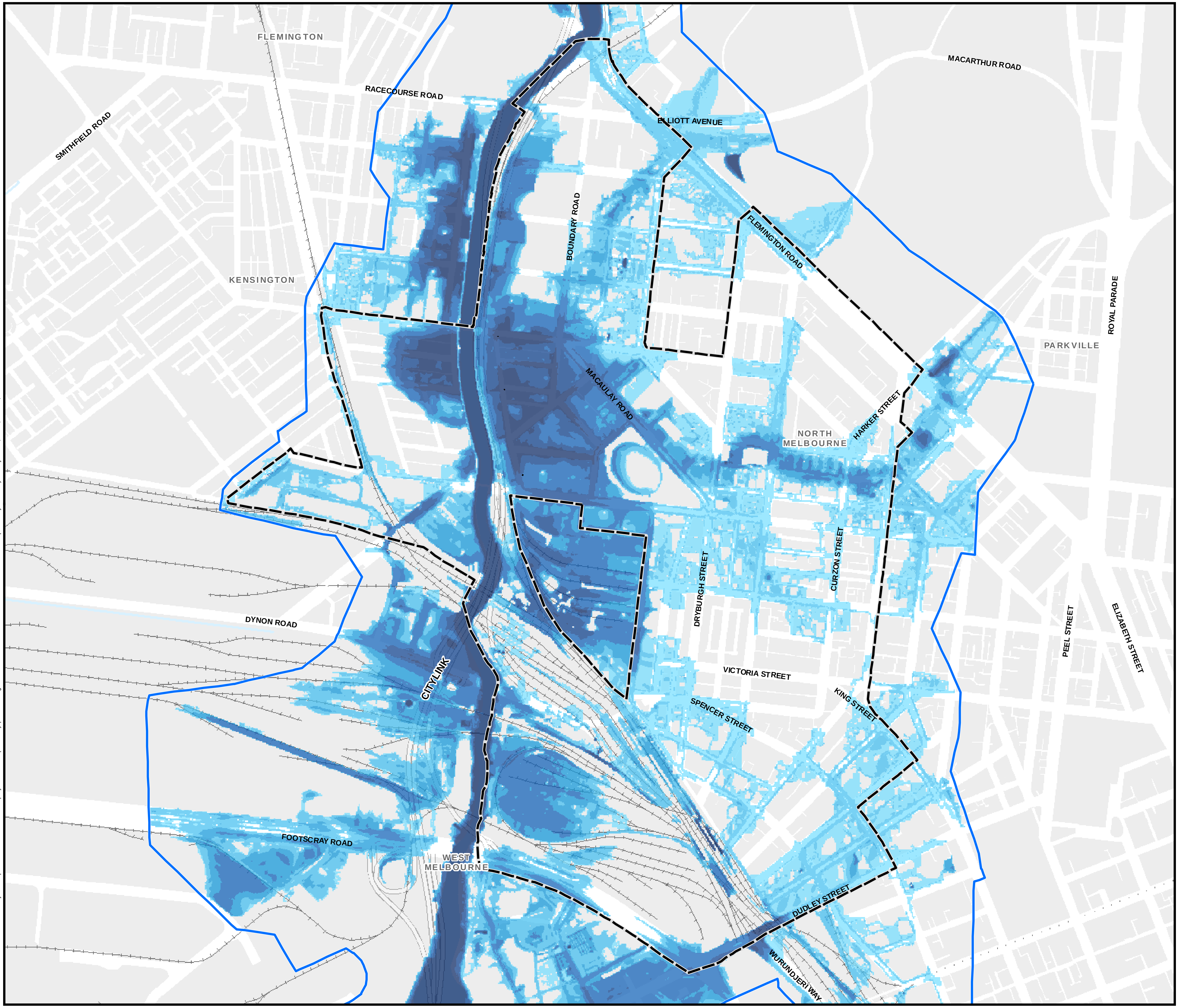
Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F10

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2040_Q010)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2040 CONDITIONS 1% AEP WATER DEPTHS

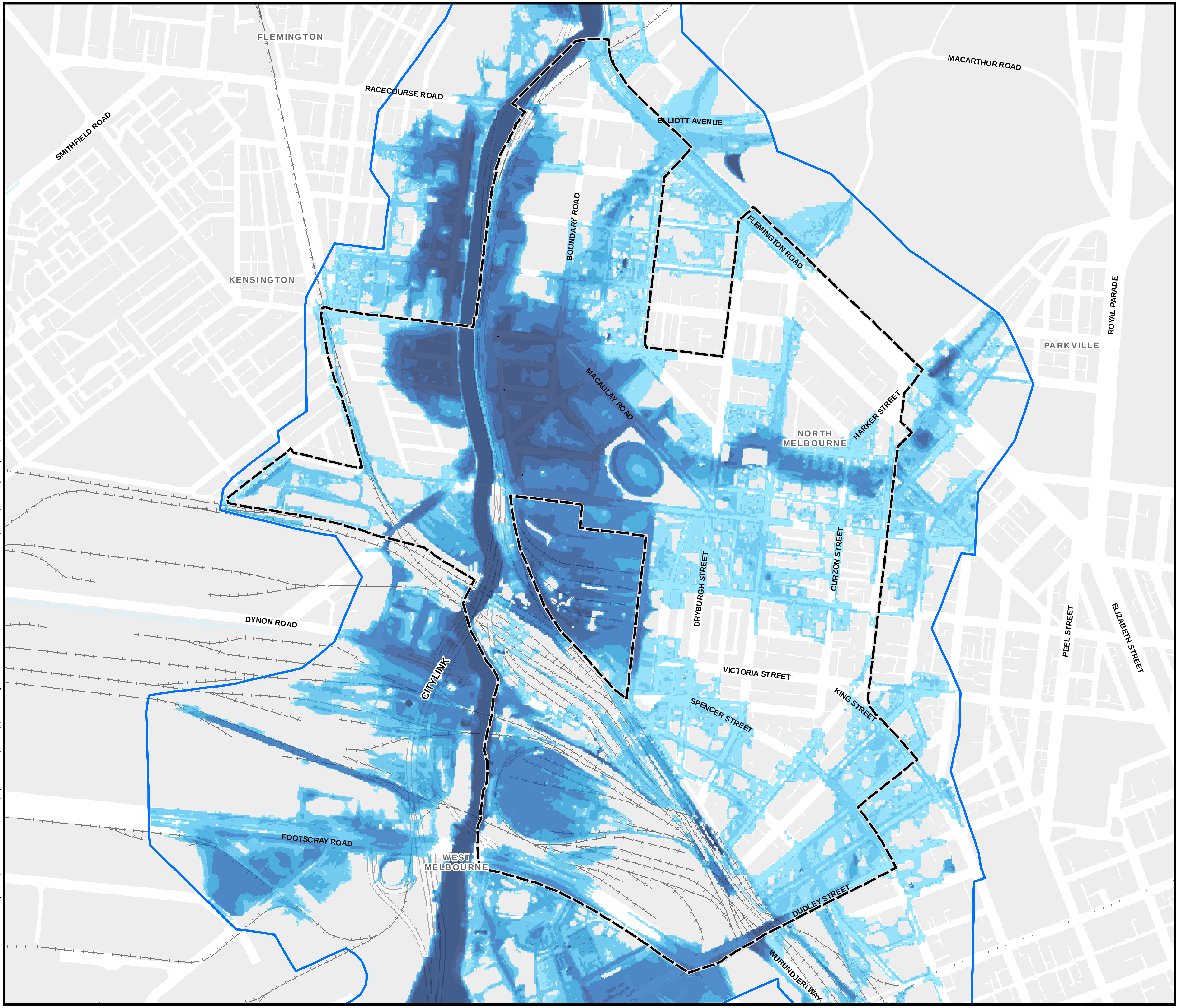
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F11

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2040_Q100)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55
0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2040 CONDITIONS 0.5% AEP WATER DEPTHS

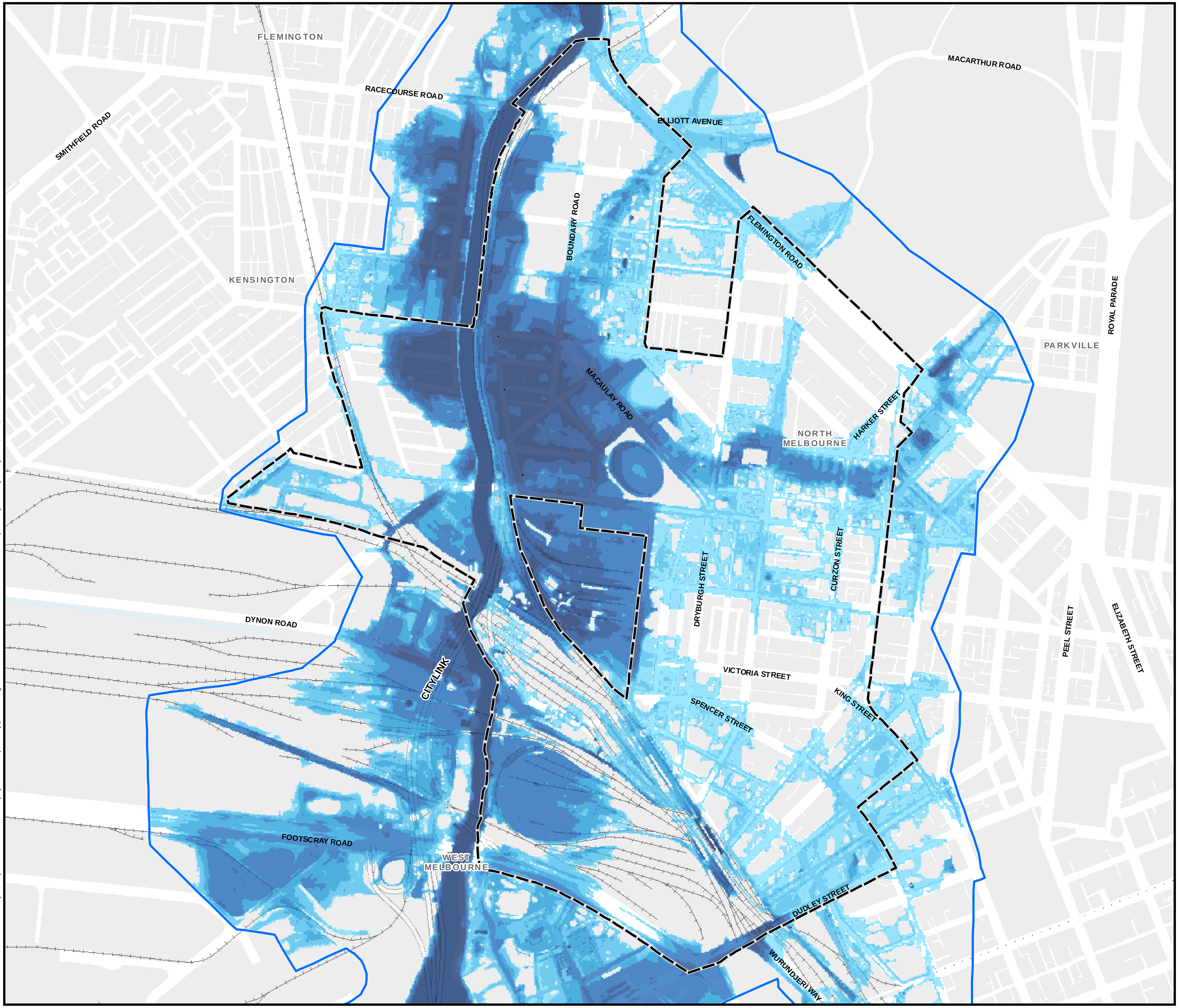
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F12

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2040_Q200)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55
0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

TUFLOW Model Extent
Study Area
Water Depth (metres)
0 - 0.05
0.06 - 0.25
0.26 - 0.5
0.51 - 1
1.01 - 1.5
> 1.51

Data sources:
Base Data: (c) 2012 DEPI

2040 CONDITIONS 0.2% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

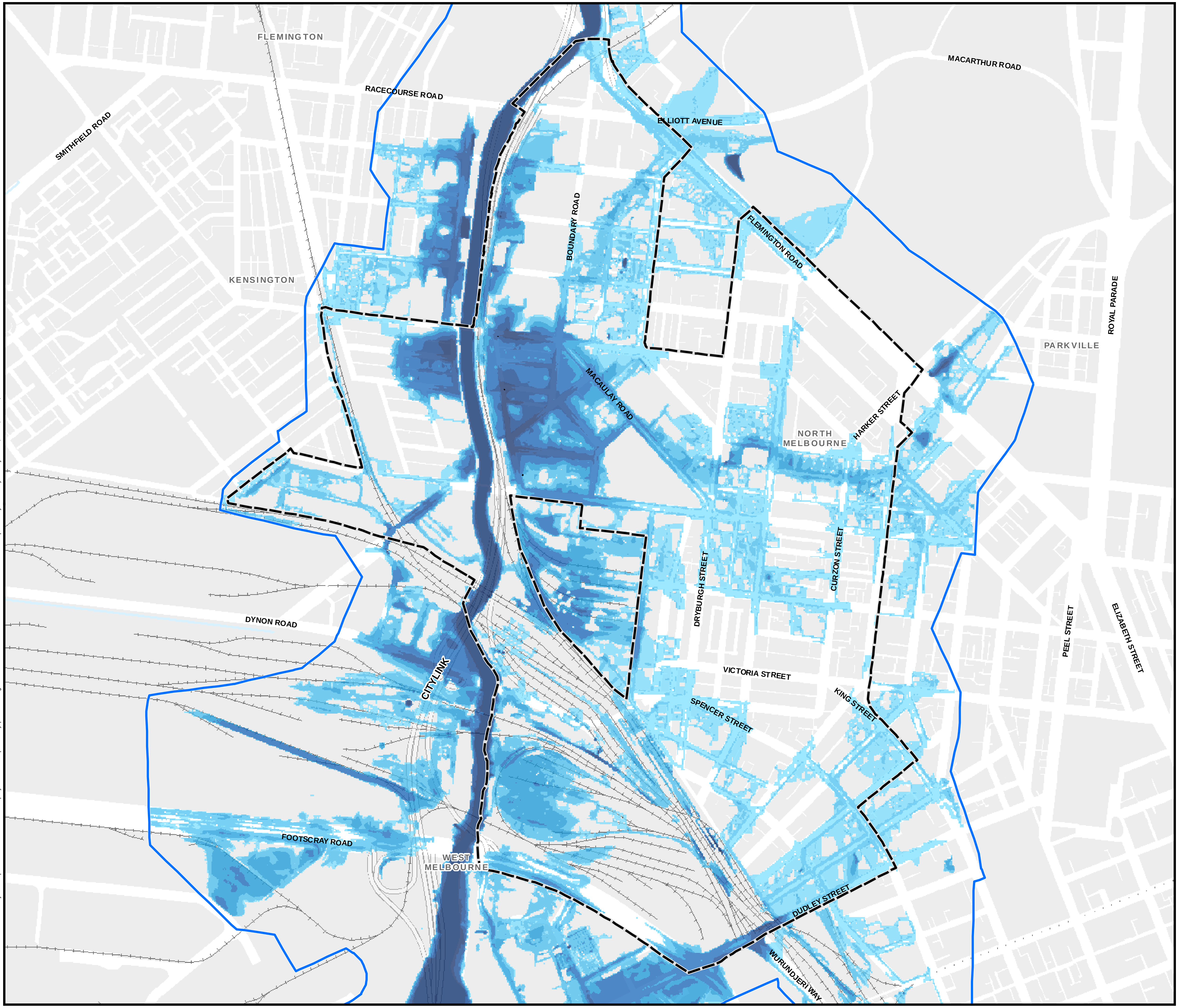
Figure
F13

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2040_Q500)

A3 size

Appendix E

Water Depths for 10%, 1%, 0.5% and 0.2% AEP Events in 2070 Climate Change Conditions



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2070 CONDITIONS 10% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

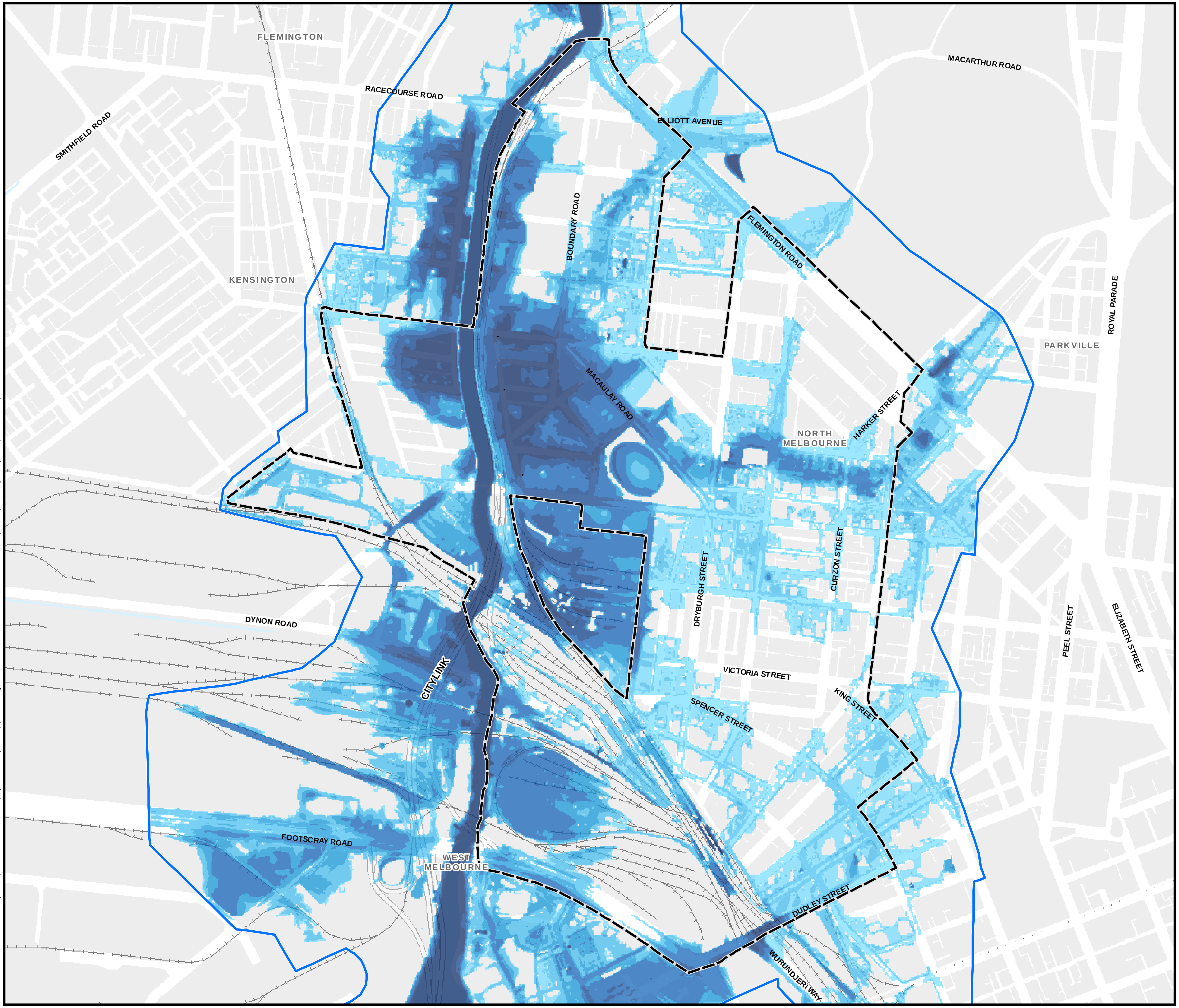
Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F14

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2070_Q010)

A3 size



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0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

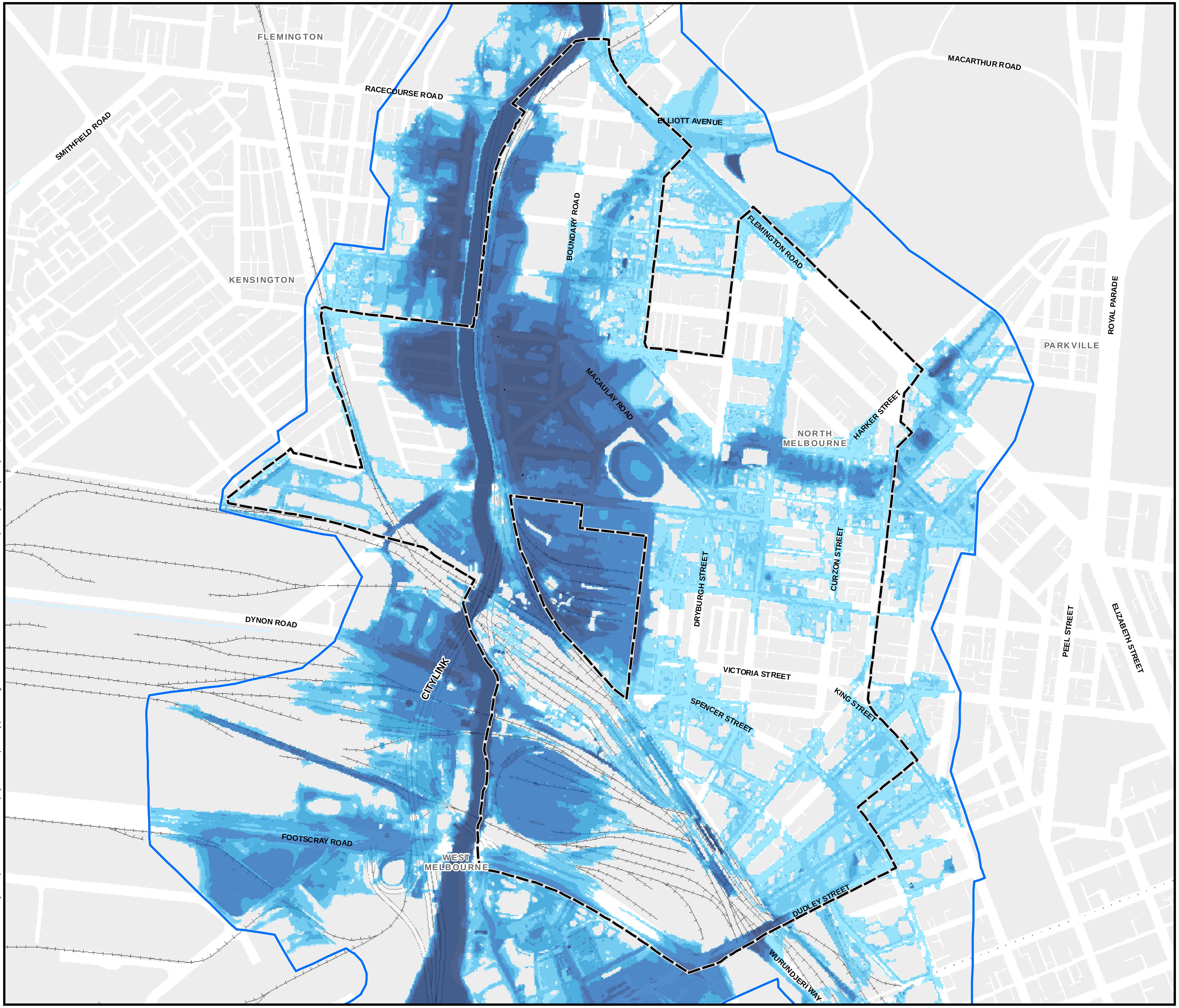
Data sources:
Base Data: (c) 2012 DEPI

2070 CONDITIONS 1% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F15



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DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2070 CONDITIONS 0.5% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

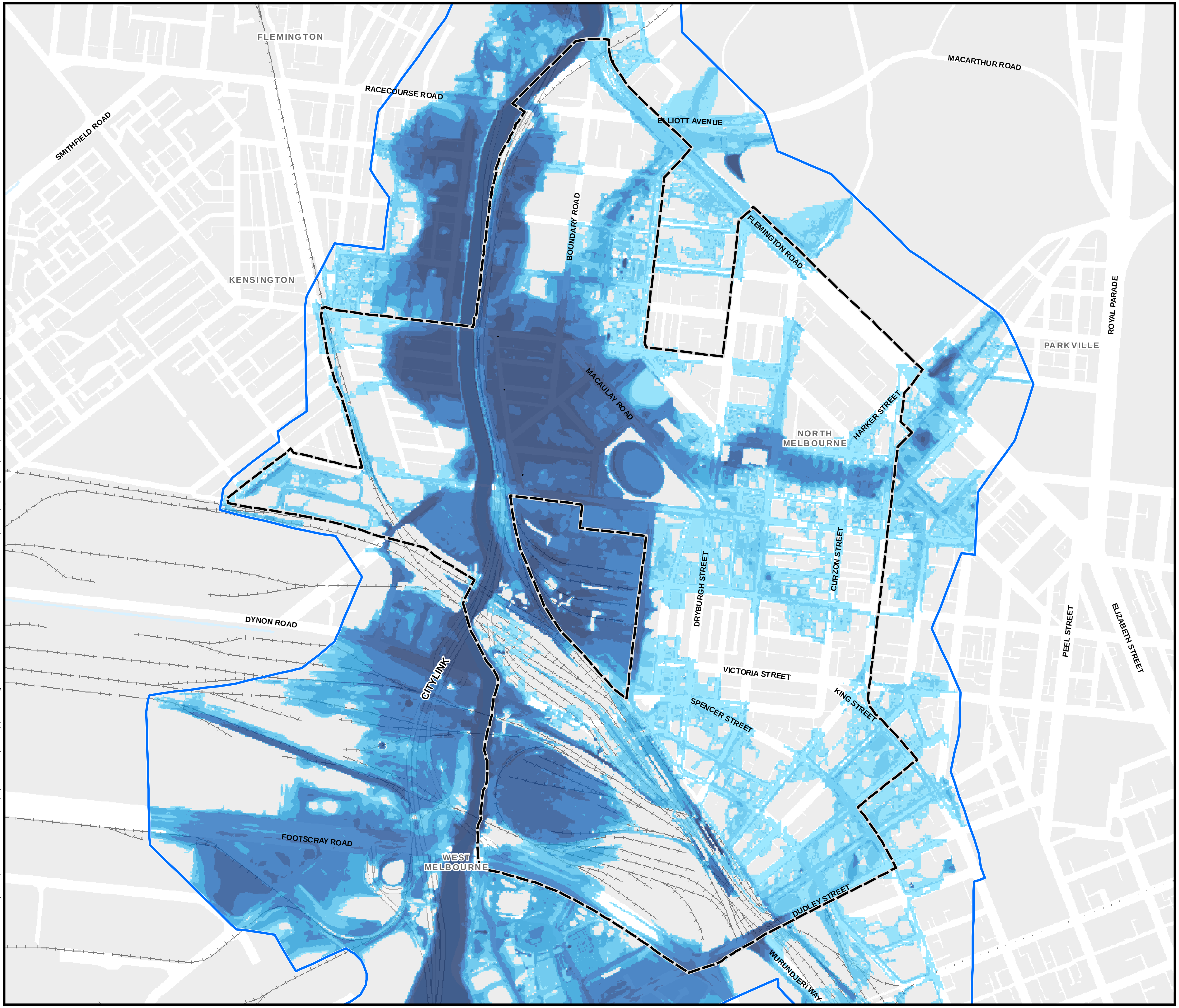
Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure

F16

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2070_Q200)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2070 CONDITIONS 0.2% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F17

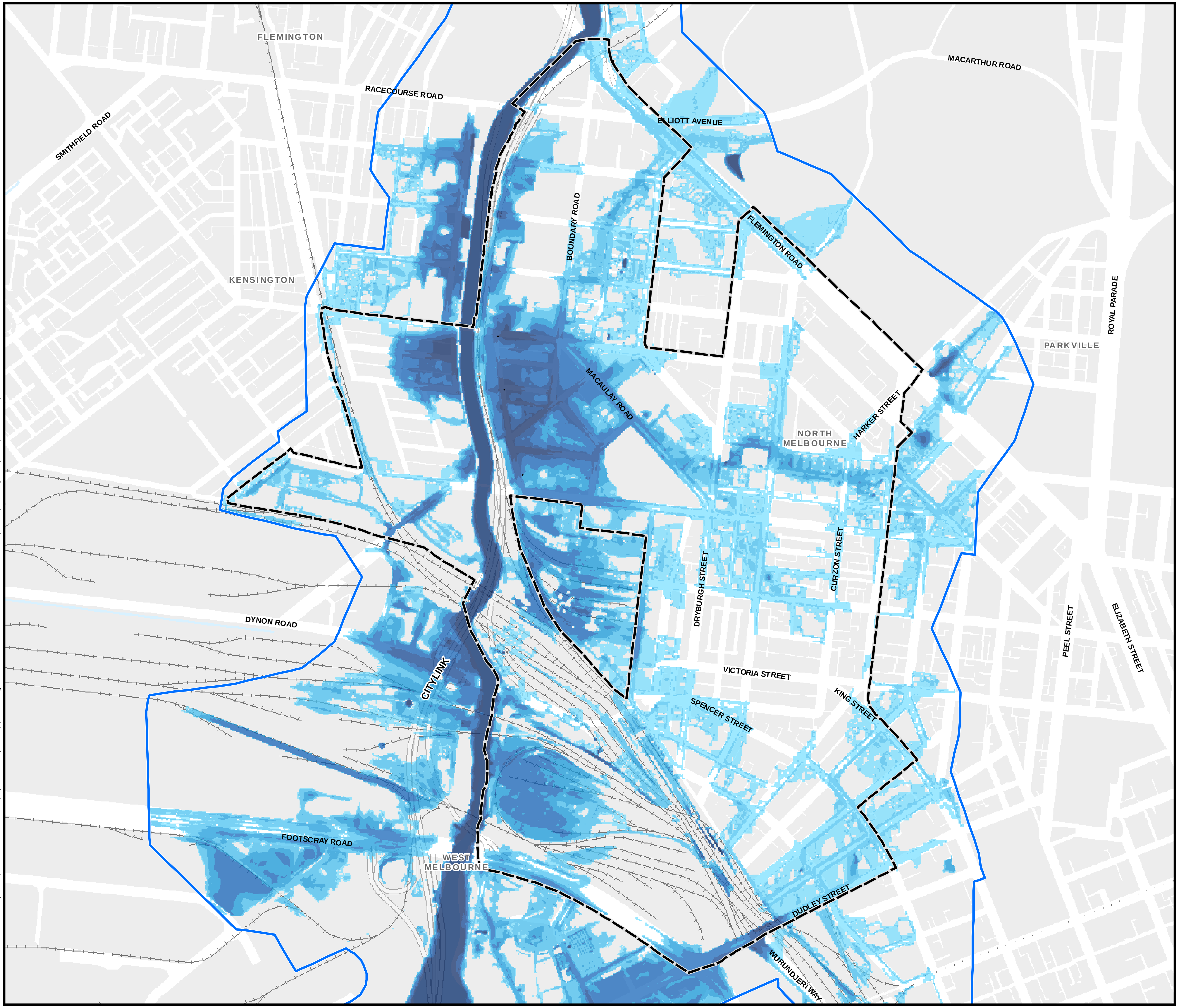
Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2070_Q500)

A3 size

D R A F T

Appendix F

Water Depths for 10%, 1%, 0.5% and 0.2% AEP Events in 2100 Climate Change Conditions



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LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2100 CONDITIONS 10% AEP WATER DEPTHS

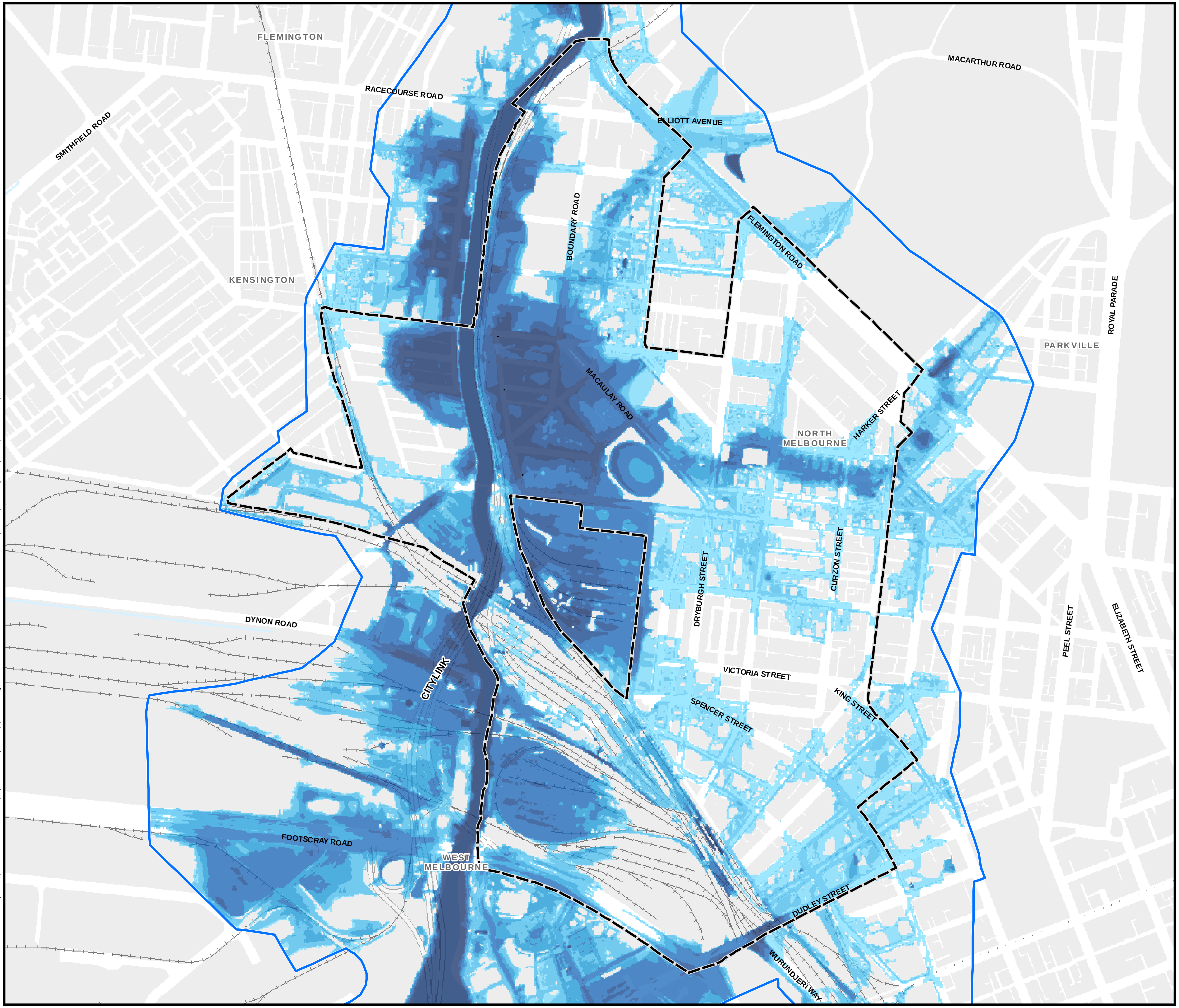
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F18

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2100_Q010)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2100 CONDITIONS 1% AEP WATER DEPTHS

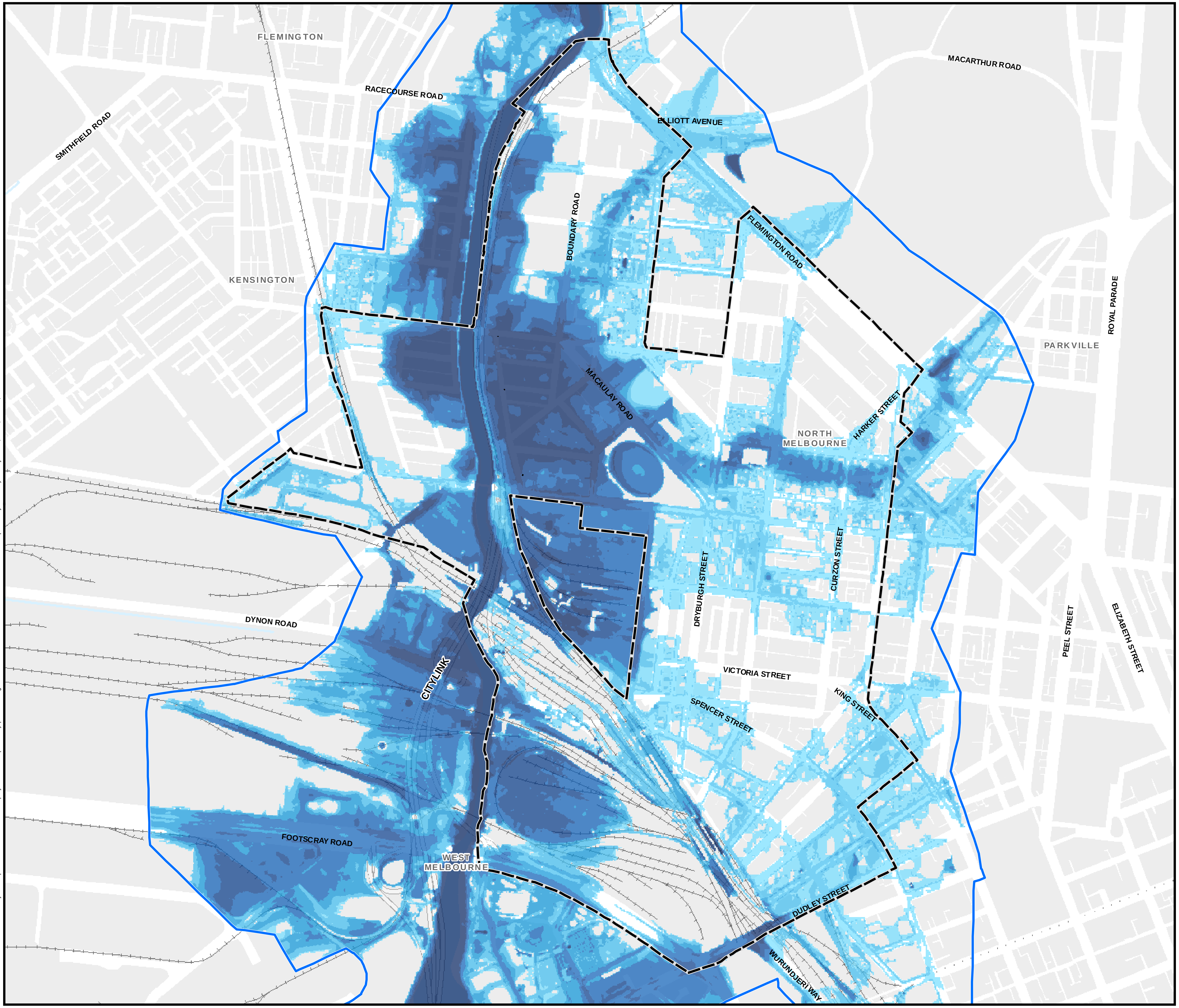
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F19

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2100_Q100)

A3 size



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N

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 100 200 400
metres

1:11,000 (when printed at A3)

LEGEND

TUFLOW Model Extent
Study Area
Water Depth (metres)
0 - 0.05
0.06 - 0.25
0.26 - 0.5
0.51 - 1
1.01 - 1.5
> 1.51

Data sources:
Base Data: (c) 2012 DEPI

2100 CONDITIONS 0.5% AEP WATER DEPTHS

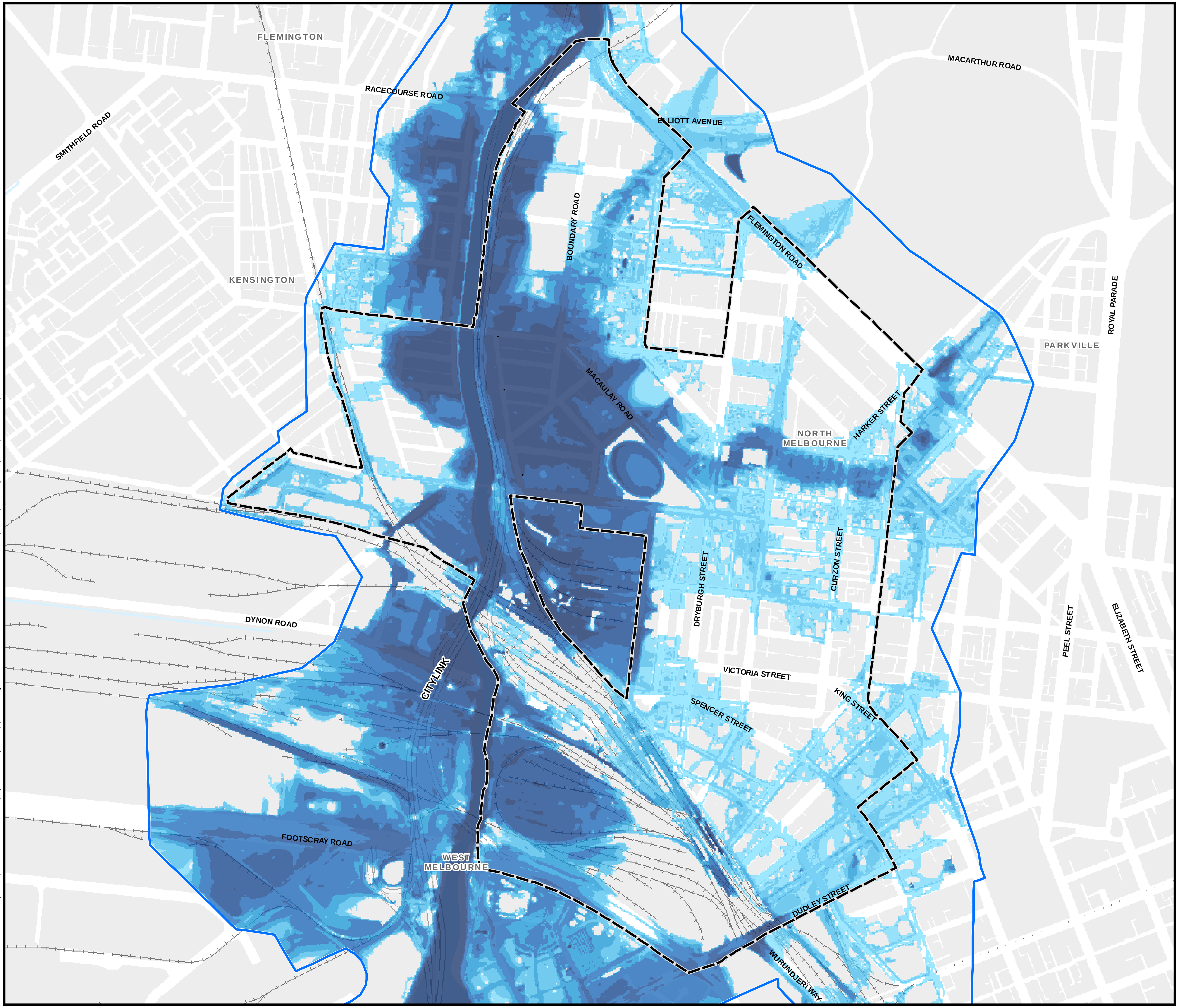
Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F20

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2100_Q200)

A3 size



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PROJECT ID 60304612
CREATED BY TCH
LAST MODIFIED TCH 06 SEP 2013

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DATUM GDA 1994, PROJECTION MGA ZONE 55
0 100 200 400
metres
1:11,000 (when printed at A3)

LEGEND

- TUFLOW Model Extent
- Study Area

Water Depth (metres)

- 0 - 0.05
- 0.06 - 0.25
- 0.26 - 0.5
- 0.51 - 1
- 1.01 - 1.5
- > 1.51

Data sources:
Base Data: (c) 2012 DEPI

2100 CONDITIONS 0.2% AEP WATER DEPTHS

Department of Transport, Planning and Local Infrastructure

Hydrologic and Hydraulic Modelling of Arden and E-Gate

Figure
F21

Map Document: (P:\60304612\4. Tech work area\4.99 GIS\02_Maps\M006_Depths_20130906.mxd - D_2100_Q500)

A3 size