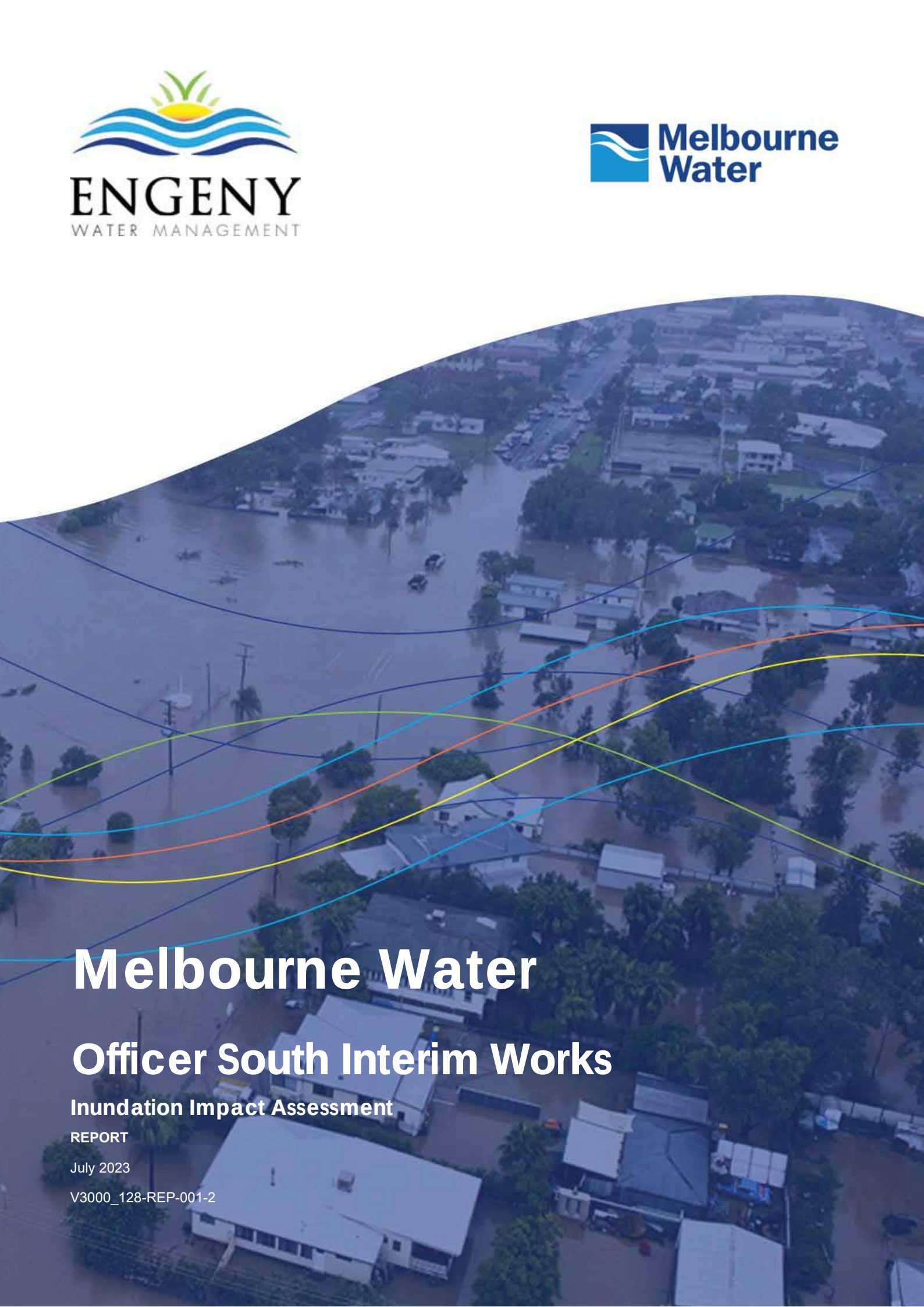


Melbourne Water

Officer South Interim Works

Inundation Impact Assessment

REPORT

July 2023

V3000_128-REP-001-2

Job no. and Project Name: V3000_128 Officer South Temp Works
Doc Path File: \\online.com\files\ManagementMelbourne\Projects\V3000_Melbourne Water\V3000_128 Officer South Temp Works\07 Deliv\Docs\Report\V3000_128-REP-001-1-OfficerSouthTempWorks.docx

Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
0	12/12/2022	Client Issue	Vanessa Wong / Daniel Hatzihristodoulou	Paul Clemson	Vanessa Wong	Paul Clemson
1	19/06/2023	Revised issue following Melbourne Water feedback	Vanessa Wong	Paul Clemson	Vanessa Wong	Paul Clemson
2	10/07/2023	Revised issue following Melbourne Water feedback in June 2023	Vanessa Wong	Paul Clemson	Vanessa Wong	Paul Clemson
Signatures						

DISCLAIMER

Contents

Appendices

List of Tables

List of Figures

1 INTRODUCTION

1.1 OVERVIEW AND OBJECTIVES

Melbourne Water engaged Engeny Water Management (Engeny) to undertake an investigation into stormwater inundation issues in Officer South and Cardinia, which may have been exacerbated due to development that has occurred in the Officer Precinct Structure Plan (PSP) and Cardinia Road PSP. This investigation also includes identification of potential interim drainage works to reduce the extent and duration of inundation experienced.

Based on provided information, it is understood that some landowners in Cardinia have experienced undesirable levels of inundation, associated with relatively minor storm events. Accordingly, the project's key objectives are denoted as follows:

- Develop an understanding of the factors that may have contributed to or exacerbated the observed inundation, including upstream development that has occurred and drainage works that have been implemented to service development.
- Identify potential interim drainage works (which could be implemented prior to full scheme works being constructed) that may help to reduce the regular inundation affecting properties.

1.2 STUDY AREA

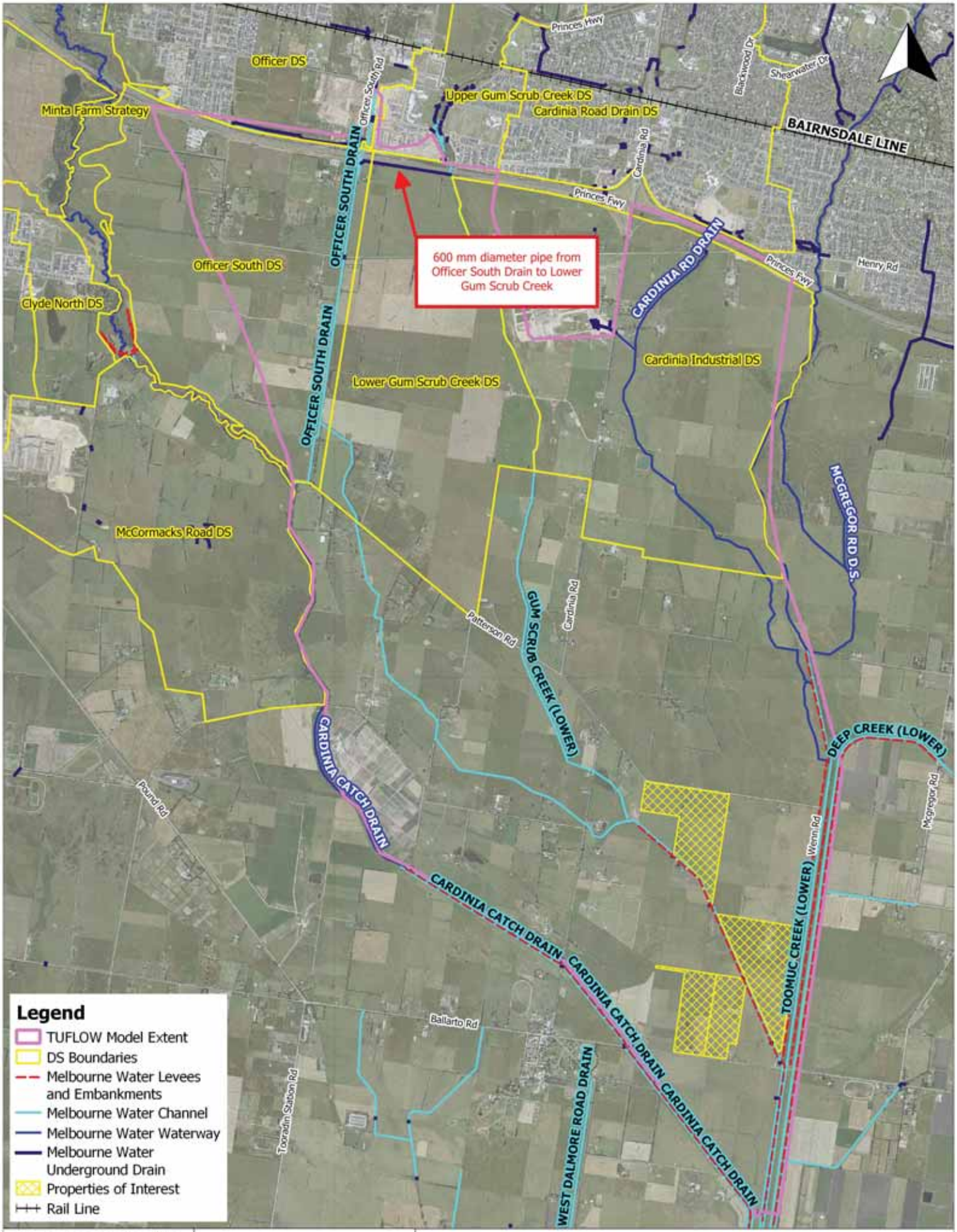
Officer South and Cardinia are located within the Cardinia municipality, south-west of the Pakenham town centre. The study area is bounded by Cardinia Creek to the west / south-west, Toomuc Creek to the east and the Princes Freeway to the north, with the land largely comprising agricultural zoned areas. Lower Gum Scrub Creek bisects the catchment in a north to south-east direction, with the lower section located east of Cardinia Road leveed to provide some level of flood protection to the adjacent properties. The lower section of Officer South Drain, an open drain which runs along the eastern side of Officer South Road through to Cardinia Creek, is also located in the north-west section of the study area.

The properties reporting inundation in minor storm events are located along the downstream sections of Lower Gum Scrub Creek, just upstream of the confluence with the Cardinia Outfall leveed system where Lower Gum Scrub Creek, Toomuc Creek and Deep Creek run parallel. Further south, the parallel leveed system is joined by the downstream reaches of Cardinia Creek, with the waterways running a further 6.4 km through the Koo Wee Rup Flood Protection District and eventually discharging into Western Port Bay.

The south-west section of Officer, located immediately north of Princes Freeway and which is serviced by the Officer South Drain, has been subject to residential development over the last decade (approximately comprising the period of 2010 to 2020) as part of the Officer PSP, which is serviced by the Officer Development Services Scheme (DSS). Works on Officer South Drain were undertaken as part of the residential development north of Princes Freeway (comprising wetland construction and channel widening works), but these works terminate just south of the Princes Freeway, with the lower section of Officer South Drain through to the Cardinia Creek outfall comprising the original roadside open drain. To temporarily assist with the increased runoff from the Officer DSS, a 600 mm diameter drain was constructed from the end of the channel widening works just south of Princes Freeway, with the pipe conveying regular flows from Officer South Drain into Lower Gum Scrub Creek until the planned scheme works on the lower section of Officer South Drain are complete.

Over the last decade, urban development has also occurred in the adjacent Cardinia Road PSP (located to the east of the Officer PSP), which is serviced by the Upper Gum Scrub Creek DSS and Cardinia Road Drain DSS. This area discharges into Lower Gum Scrub Creek and Cardinia Road Drain, resulting in increased runoff volumes in these waterways.

An overview of the waterways, levees, DSS boundaries and locations of the properties of interest within the study area are provided in Figure 1.1.



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12182, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 8888 6978
F: 03 9630 2601
E: melb@engeny.com.au
ENGENY

Melbourne Water

600 0 600 m

Scale in metres (1:30,000@ A3)

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

Officer South Interim Works Inundation Investigation

Figure 1.1
General Layout Plan

Job Number: V3000_128
Revision: 2
Drawn: VW
Checked: PC
Date: 26/6/2023

1.3 SCOPE OF WORKS

The agreed scope of work completed as part of this study is detailed below:

- Project inception meeting via MS Teams with Melbourne Water undertaken in August 2020
- Collation and review of available data, inclusive of but not limited to previous modelling and reports, inundation observations from landowners, flow and rainfall gauge data, survey data and GIS information.
- Completion of a flood frequency analysis to quantify the probability of the observed storm event which resulted in reported inundation.
- Site investigations to understand local conditions.
- Meetings with landowners on site and virtually, to better understand the observations in recent storm events and potential issues that may have contributed to reported inundation.
- Development of validated hydrological modelling (RORB) of the observed rainfall event.
  - The validated hydrological model was then run for various development scenarios (representing existing conditions, pre-development conditions and fully developed conditions) and selected design events (20 % and 10 % AEP events).
- Development of hydraulic modelling (TUFLOW) for existing conditions, predeveloped conditions and fully developed conditions.
- Analysis of the modelling results to identify the issues that may have contributed to the observed inundation.
- Meeting with Melbourne Water via MS Teams to undertake optioneering for interim mitigation works options.
- Modelling of the preferred concept mitigation scenario(s), as agreed with Melbourne Water.
- Preparation of a report (this report) documenting the investigation undertaken.

2 PROVIDED INFORMATION

2.1 PREVIOUS MODELS

Melbourne Water provided a copy of the RORB model of the Cardinia Outfall System developed by Stormy Water Solutions in 2021, which covers the following watercourses:

- Cardinia Creek
- Officer South Drain
- Gum Scrub Creek
- Cardinia Road Drain
- Toomuc Creek
- Deep Creek
- McGregor Road Drain

The RORB model was accompanied by a report by Stormy Water Solutions, Cardinia Outfall Drain Event Based Hydrologic Modelling (2021), documenting the key inputs and outputs.

This RORB model has been used for the following functions:

1. To represent runoff from catchments upstream of the TUFLOW model extent, routed inflows have been adopted from RORB and applied to the upstream end of waterways represented in TUFLOW.
2. To represent runoff for areas within the TUFLOW model extent, rainfall excess hydrographs have been extracted from RORB for the relevant subareas.

The RORB model parameters have been refined by Engeny to better reflect the observed storm event based on a validation to available gauge data, which is further discussed in Section 5.

2.2 GIS LAYERS

Melbourne Water provided the following spatial data:

- Aerial photography dated April 2020
- Melbourne Water drainage assets
- Council drainage assets

Additional aerial imagery circa 2010 (i.e., at the time of the upstream PSPs being gazetted) was sourced from DELWP / Nearmap to understand the level of development applicable for pre-development scenario modelling.

The data has been used for both the hydrologic and hydraulic modelling undertaken for this study.

2.3 GAUGE DATA

Rainfall and / or streamflow data was obtained from five gauging stations located with the Cardinia Creek, Lower Gum Scrub Creek and Toomuc Creek catchments. Data was requested for the full period of record through to the date of the data request (September 2020). Subsequently, anecdotal and photo evidence was provided for rainfall events that occurred in September 2020 and October 2020 and an additional data request was made for gauge data covering the time period of May 2020 to March 2021. The following provides a summary of the rainfall and streamflow gauges used in this study:

- Beaconsfield Minor Reservoir WH90 at Officer (ID: 228268A) – rainfall data only
- Cardinia Creek at Chasemore Road, Cardinia Township (ID: 228228A) – rainfall and streamflow data
- Cardinia Creek Drop Structure, Officer South (ID: 228382A) – rainfall and streamflow data
- Gum Scrub Creek at Princes Highway, Officer (ID: 228365A) – rainfall and streamflow data
- Toomuc Creek at Princes Highway, Pakenham West (ID: 228217C) – streamflow data only

The information from these gauges was used to develop rainfall input files for RORB to represent the selected minor rainfall event and to complete a flood frequency analysis to evaluate the magnitude of the selected rainfall event. Refer to Section 5 for further details regarding the hydrologic model development.

Tidal gauge (water level) data was also obtained for Western Port at Evans Inlet, Tooradin (Site ID: 228399A), for the period of January 2020 to April 2021. This data was used to develop a downstream boundary condition for the observed storm event. Please refer to Section 6 for further details regarding the downstream boundaries adopted within the TUFLOW model.

2.4 SURVEY DATA

Melbourne Water provided the following survey data:

- SES 1334 – Officer South Road Drain, Cardinia Creek Upstream to Rix Road, Officer South (August 2008)
- SES 1335 – Gum Scrub Creek, Patterson Road Upstream to Princes Freeway, Officer South (August 2008)
- SES 1795 - Cross section survey of Deep Creek Catch, Cardinia Creek Catch, Hagelthornes, McGregors, Koo Wee Rup South and Gum Scrub Creek (Lower) Drains (December 2013)

This information has generally been used to reinforce the thalweg of key waterways and represent key bridge structures and road (culvert) crossings included within the hydraulic (TUFLOW) model.

2.5 DESIGN / AS CONSTRUCTED PLANS AND DESIGN SURFACES

Detailed design / as constructed plans and, in some cases, design surfaces have been provided for waterways and stormwater assets at the following locations:

- Arcadia Estate
- Kaduna Estate
- Quirks Road Retarding Basin

Flood storage assets (retarding basins) located upstream of the TUFLOW model extent have been represented as storages in the RORB model. The Arcadia Estate waterway design surface has also been incorporated into the TUFLOW model to directly represent the storage capacity of the expanded Officer South Drain around the Princes Freeway.

2.6 ANECDOTAL EVIDENCE

Melbourne Water provided email correspondence from various landholders in Cardinia, relating to reports of inundation, the dates of occurrence, and in some cases, photos taken of the inundation resulting from the rainfall events.

This information has been used to identify an appropriate rainfall event to model and provide a source for validation of modelled inundation. Please refer to Section 6.2.1 for further discussion regarding the model validation to photographic evidence.

2.7 ADDITIONAL DATA SUPPLIED MAY 2023

Additional information, in the form of photographs supplied by local landholders of an event occurring on the 13 October 2022 and rainfall gauge data for October 2022, was supplied by Melbourne Water as part of this report's update in June 2023.

A total of approximately 40 mm of rainfall (as recorded at the Gum Scrub Creek at Princes Highway, Officer gauge (228365A)) was noted to fall on the 13 October 2022 on a wet catchment due to previous rainfall leading up to this event (50 mm of rainfall was observed at the Gum Scrub Creek at Princes Highway, Officer gauge over the period of the 5 October to 12 October 2022). Figure 2.1 provides a summary of the rainfall on 13 October 2022, whilst Figure 2.2 to Figure 2.5 provide photos taken following the rainfall event, showing the inundation of farmland and Gum Scrub Creek in the days following this rainfall event.

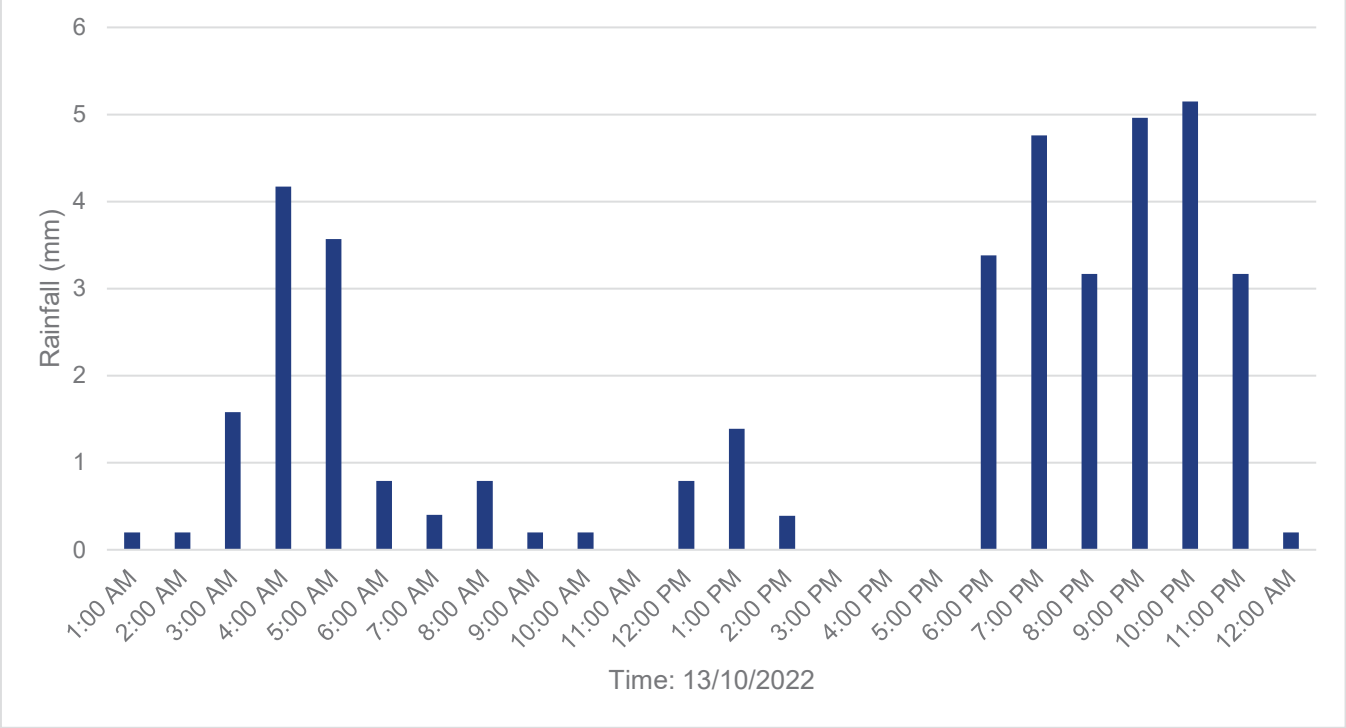


Figure 2.1: Hourly Rainfall on 13 October 2022

Figure 2.2: 450 Cardinia Road Officer South (Meat Me at the Gate) (photo taken at 2pm on the 14 October 2022)

Figure 2.3: Model Field and North West Farms (photo taken at 10 am on 15 October 2022)

Figure 2.4: Inundation of farms in Officer South (Photo taken at 10am on 15 October 2022)

Figure 2.5: Wenn Road, Ballarto Road and Lower Gum Scrub Creek (Photo taken at 10am on 15 October 2022)

3 SITE INSPECTIONS AND LANDHOLDER ENGAGEMENT

3.1 SITE VISIT

Engeny undertook a site visit to the Officer South and Cardinia areas on 22 March 2021, with representatives of Melbourne Water, James Hodgens and Tom Le Cerf. The site visit was used to better understand site conditions and to confirm the dimensions and features of key drainage assets throughout the study area.

A landholder was met on site near Lower Gum Scrub Creek near Wenn Road, who provided some local context with regards to overland inundation in the 'triangle' of land between Lower Gum Scrub Creek, Fowler Road and Deep Creek / Toomuc Creek.

The following images provide photos taken during the March 2021 site visit.

Figure 3.1: The downstream end of the Officer South Drain – the headwall of the 600 mm diameter pipe to Lower Gum Scrub Creek is shown in the right-hand side of the image (looking north)

Figure 3.2: The 'farmers diversion' along Officer South Drainwhere the lower branch of Gum Scrub Creek (lower) commences - located at 395 Officer South Road, Officer South

Figure 3.3: Lower Gum Scrub Creek, looking south-east towards the Ballarto Road bridge, south of Wenn Road

3.2 LANDHOLDER ENGAGEMENT

A landholder engagement meeting was undertaken virtually via Zoom on 4 August 2022, with attendance by representatives of Engeny, Melbourne Water, Spiire, Jacobs and various landowners (names withheld).

At the meeting, Engeny presented an overview of modelling undertaken to date, inclusive of the inundation maps for existing (October 2020) conditions, pre-development conditions (2010 development levels in Officer, north of Princes Freeway) and fully developed conditions (the latter comprising a scenario with no mitigation works proposed).

Confirmation was provided by the landowners that the October 2020 existing conditions inundation mapping approximately replicated what they had observed in the October 2020 event, validating the model's results.

Also noted by the landholder representatives was that inundation of properties may also be affected by sedimentation of the waterways, overgrown vegetation within the waterways and issues with existing flood gates not working as intended. Acknowledgement was made of recent maintenance works undertaken by Melbourne Water, with additional works requested by the landholders to further improve waterway capacity.

4 OVERVIEW OF MODELLING METHODOLOGY

4.1 MODELLING METHODOLOGY

The modelling approach adopted for this study involves both hydrologic and hydraulic modelling. The objective of the hydrological modelling is to produce rainfall excess hydrographs for each subarea delineated within the study area, as well as routed flow hydrographs to represent flows from the catchment upstream of the study area. These hydrographs are then used as inputs into the TUFLOW hydraulic model to undertake flow routing and estimate flow dynamics within the study area.

For this study, Engeny altered the existing Cardinia Outfall System RORB model (by Stormy Water Solutions) to represent the rainfall and development levels as at October 2020, when a rainfall event resulted in inundation of a number of properties. Outputs of the RORB model were validated to gauged flows to determine the hydrological model parameters, which is further discussed in Section 5.

The hydraulic model was developed in TUFLOW, for the model extent presented previously in Figure 1.1. Outputs from this model have been used to generate inundation maps and the other items analysed within this report.

4.2 MODEL SCENARIOS

Modelling has been completed for a range of development scenarios and rainfall events.

The following storm events have been modelled:

- October 2020 – The focus of this study was the modelling of an observed rainfall event which resulted in inundation of a number of properties. Based on the available rainfall gauge data, alongside the provided anecdotal and photo evidence from the landholders, the storm event occurring on the 24 October 2020 was selected as the observed event. Comparison to rainfall intensity-frequency-duration (IFD) data from the Bureau of Meteorology's (BoM) online database, alongside completion of a flood frequency analysis (FFA), estimated that this event was a 1 exceedance per year (EY) / 63.21 % AEP event. Further detail regarding representation of this storm event is provided in Section 5.
- Design Storm Events – The baseline / existing conditions development scenario (i.e., the level of development in October 2020) has also been run for the 20 % and 10 % AEP design storm events. This was undertaken to analyse flood behaviour of Lower Gum Scrub Creek.

The following development scenarios have been modelled:

- Baseline / Existing Conditions (October 2020) – The baseline conditions scenario intends to replicate development levels as of 2020. This was considered to equate to 'existing' conditions, with a storm event from October 2020 which resulted in inundation of the subject properties along the lower reaches of Lower Gum Scrub Creek modelled in TUFLOW.
- Pre-developed Conditions – This scenario represents conditions in 2010, which predates when the Officer PSP was gazetted (in 2011). At this time, the area of Officer north of Princes Freeway was largely undeveloped. The aim of this scenario is to allow for analysis of how overland flows through Officer South and Cardinia have changed as a result of upstream development in the Officer PSP, by comparing this scenario (2010) with the baseline / existing conditions scenario (2020). As this scenario is intended to reflect pre-developed conditions, the TUFLOW model excludes the 600 mm diameter pipe from Officer South Drain to Gum Scrub Creek (Lower) as this asset was constructed in 2019, after the Officer PSP was gazetted. The modelling also excludes representation of the flood storages that have been constructed to service development within the Officer PSP since 2010.
- Future Development Conditions – This scenario represents all catchments north of Princes Freeway as fully developed and inclusive of the proposed DSS works (flood storages). Fraction impervious values for future conditions north of Princes Freeway vary between 0.65 and 0.9 pending the proposed land use. The area south of Princes Freeway has maintained the current development levels (i.e., same fraction imperious values as per the existing conditions scenario). Accordingly, this scenario does not include development of the Officer South Employment PSP catchment. Please refer to Stormy Water Solutions' Report, "Cardinia Outfall System: Event Based Hydrologic Modelling" (2021) for an overview of the storages included in the future conditions modelling.

Figure 4.1 through to Figure 4.3 provide a comparison of the fraction impervious values adopted in each of the development scenarios.

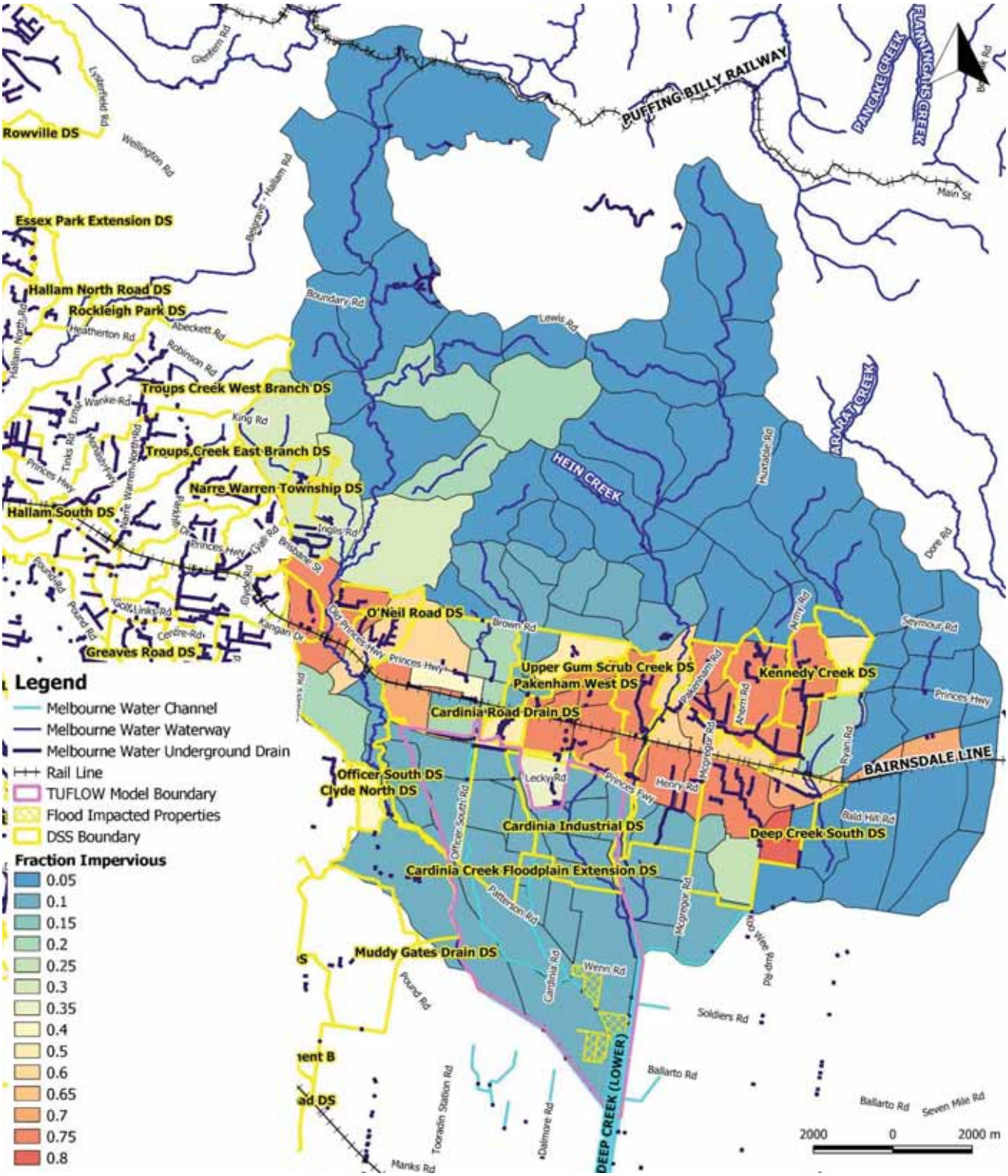


Figure 4.1: Overview of Adopted Fraction Impervious Values for the Baseline / Existing Conditions Scenario(October 2020)

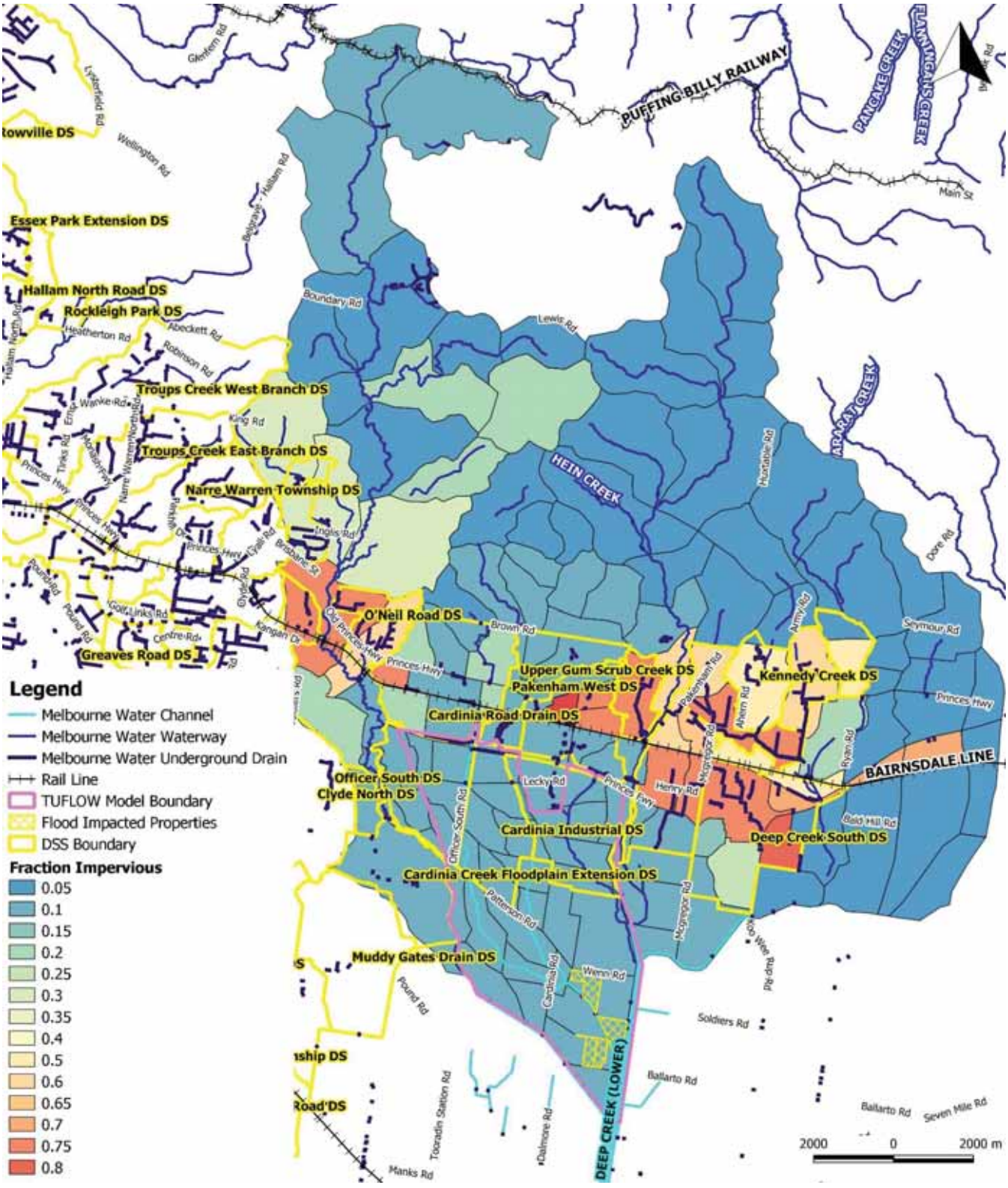


Figure 4.2: Overview of Adopted Fraction Impervious Values for the Pre-developed Conditions Scenario (2010)

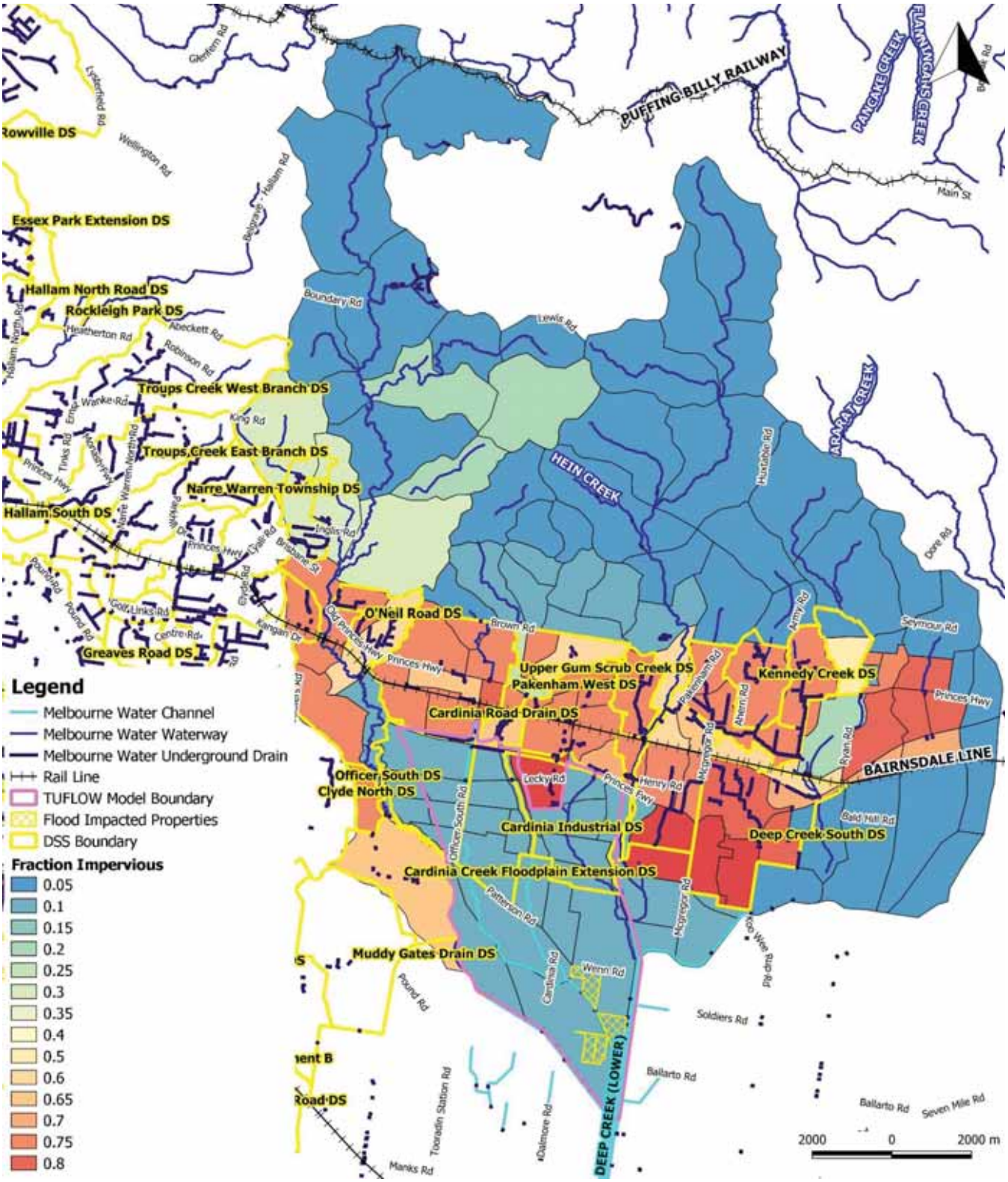


Figure 4.3: Overview of Adopted Fraction Impervious Values for the Future Development Conditions Scenario (expected development in all PSPs north of the Princes Freeway)

5 HYDROLOGICAL MODELLING

5.1 SELECTED RAINFALL EVENT

Based on discussions with Melbourne Water, Engeny understands that inundation of numerous properties adjacent to Lower Gum Scrub Creek had occurred in relatively minor rainfall events. The key area of interest relates to properties adjacent to Lower Gum Scrub Creek between Cardinia Road and Ballarto Road (identified in Figure 1.1).

Following above average rainfall throughout 2020, two rainfall events occurred in this catchment in September 2020 and October 2020, after which inundation was reported by landowners for both events. Following Engeny's analysis of the available observations and anecdotal data that could be used for model validation, the October 2020 was selected as the preferred rainfall event. Melbourne Water provided Engeny with rainfall data for four gauges within or close to the Gum Scrub Creek catchment. The Gum Scrub Creek at Princes Highway (Station ID: 228365A) gauge data was utilised for this investigation as it was located within the Gum Scrub Creek catchment and also recorded a total rainfall depth for the storm event that was closest to the average rainfall depths across the four gauging stations.

Figure 5.1 presents the rainfall depths (recorded at the Gum Scrub Creek at Princes Highway gauge) over time on 24 October 2020, for the storm event which was identified by landowners to cause inundation. A total of 38 mm fell over 13 hours. Utilising Intensity-Frequency-Duration (IFD) data from the Bureau of Meteorology (BoM)'s online database this correlated to a 1 Exceedance Year (EY) (63.21 % AEP) storm event.

It is noted that this October 2020 rainfall event occurred during a wetter than usual Spring season. Wet antecedent conditions within the study area are likely to have exacerbated the extent and duration of inundation experienced by the properties.

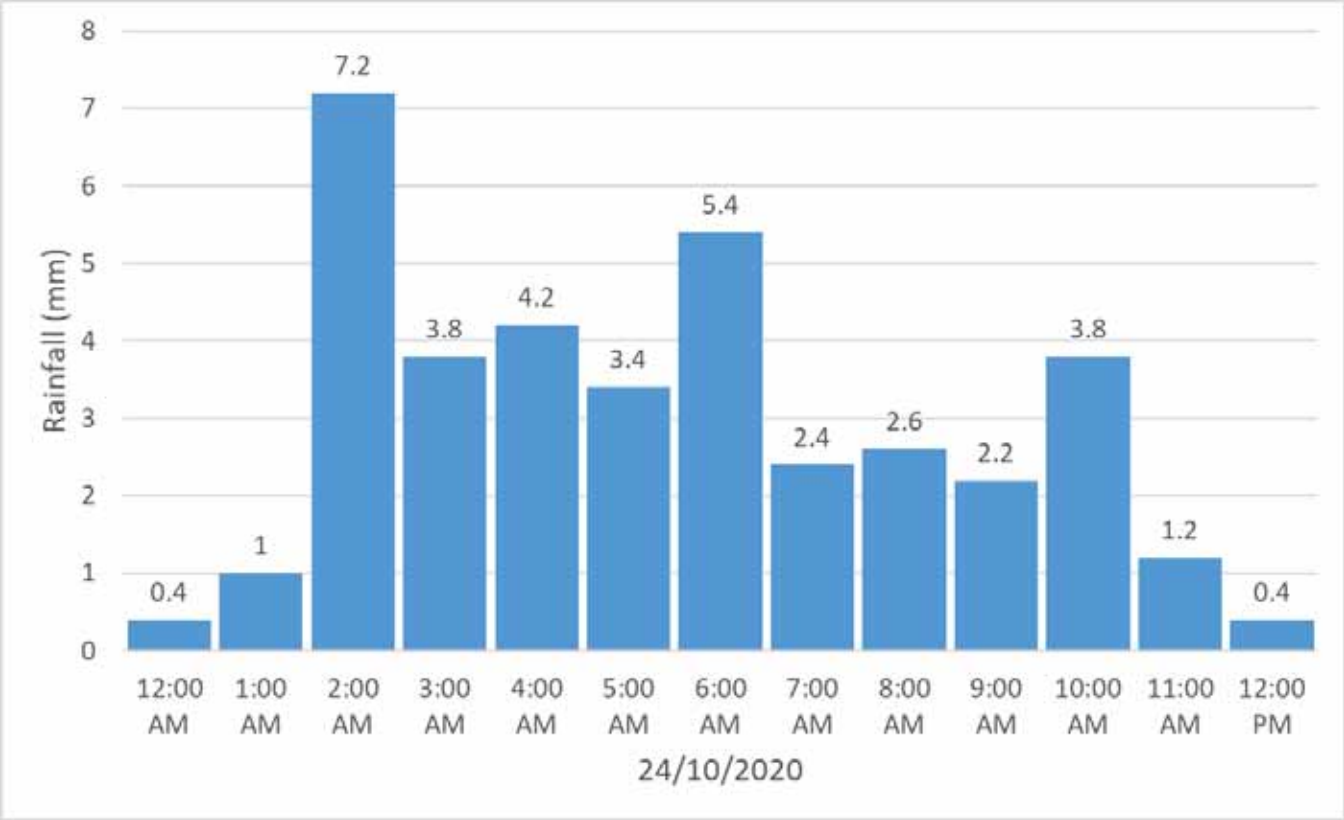


Figure 5.1: October 2020 Hourly Rainfall Data (24 October 2020)

5.2 ANALYSIS OF THE EXISTING RORB MODEL

The existing Cardinia Outfall (2030_Card_Outfall_Current_RORB_V2_14Jan21.cat) RORB model (created by Stormy Water Solutions and supplied by Melbourne Water to Engeny) covers the Cardinia Creek, Officer South Drain, Lower Gum Scrub Creek, Toomuc Creek and Deep Creek catchments to Ballarto Road in Cardinia. The modelling parameters provided to Engeny were based on Australian Rainfall and Runoff (ARR) 2019 and adopted a lumped fraction impervious approach (i.e., it does not delineate between Effective Impervious Areas (EIA) and Indirectly Connected Areas (ICA) areas). Engeny has not adjusted the existing Cardinia Outfall RORB model to represent EIA and ICA. Figure 5.2 presents the Cardinia Outfall RORB model layout plan (Stormy Water Solutions, 2021).

The Stormy Water Solutions report (2021) associated with the RORB model notes that the model "*is not appropriate for use in providing flood flow estimates within the upper regions of the catchments and should only be used to provide estimates directly into the Cardinia Outfall System.*" The report (Stormy Water Solutions, 2021) also notes that "*The model has only been formulated for major (roughly 1% AEP) flood events with reach types not modified to reflect minor flood events.*"

As part of Engeny's investigation, key hydrological parameters in the Stormy Water Solutions RORB model have been reviewed and adjusted based on a comparison of the RORB model's outputs to flow gauge data on Lower Gum Scrub Creek at the Princes Highway (Station ID: 228365A), recorded for the October 2020 event. The following sub-sections detail Engeny's investigations with regards to the RORB model setup and parameters for the October 2020 storm event. For the finalised model parameters used, please refer to Sections 5.4 (October 2020 event modelling) and 5.5 (design storm modelling) respectively.

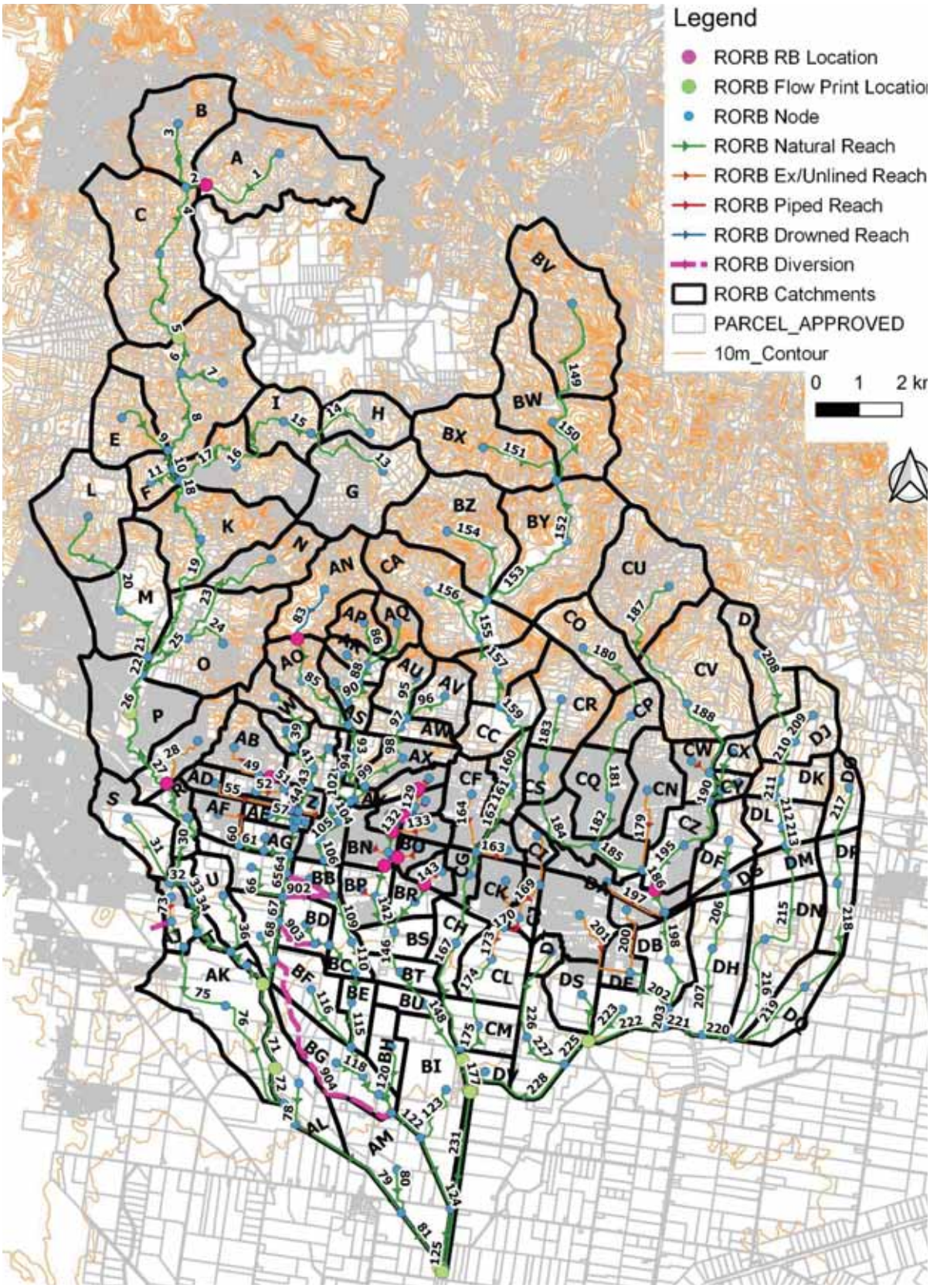


Figure 5.2: Cardinia Outfall RORB model layout (source: Cardinia Outfall System Event Based Hydrologic Modelling, Stormy Water Solutions, 2021)

5.2.1 Analysis of the Existing Model's Catchment Losses

The existing Cardinia Outfall RORB model adopted an initial loss of 10 mm and a continuing loss of 2.5 mm/hr. The Stormy Water Solutions report states that the initial loss value adopted was determined from the Melbourne Water Southeast Areas equation and is assumed to account for pre-burst rainfall losses. The SWS report also states that Melbourne Water's Flood Mapping Technical Specifications (Melbourne Water, 2018) is the basis for the selection of continuing loss. As part of the RORB validation to the October 2020 rainfall event undertaken by Engeny, initial loss values ranging from 10 to 35 mm and continuing loss values between 1 and 4.5 mm/hr have been assessed. The ARR DataHub provides a recommended pervious (rural) initial loss value of 25 mm and continuing loss value of 4.4 mm/hr for this region.

For a summary of the fina loss parameters adopted, please refer to Sections 5.4 and 5.5, for the October 2020 event and design storm events respectively.

5.2.2 Analysis of the Existing Model's Routing Parameter (k_c)

The existing Cardinia Outfall RORB model adopted a k_c value of 23.3. Engeny understands that the kc value is based on the South East area (Dandenong Valley Authority) k_c equation.

The Cardinia Outfall RORB model includes Cardinia Creek, Gum Scrub Creek, Toomuc Creek and Deep Creek. Engeny understands that two sets of parameters have been utilised within the model (controlled by interstation points), one for the Cardinia and Gum Scrub Creek catchments, and one for the Toomuc and Deep Creek catchments. This approach was adopted by Stormy Water Solutions (2021) "*as each of these catchment delineations has different catchment shapes and hence responses to rainfall*". However, the k_c value and loss factors adopted in the Stormy Water Solutions model are the same for both interstation areas. Engeny has focused its investigations on the Gum Scrub Creek catchment component of the model only.

Engeny has considered a range of valid k_c equations and has investigated the relationship of k_c and Average Flow Distance (d_{av}) to assess the validity of changing the k_c. The d_{av} of the Cardinia Creek and Gum Scrub Creek portion of the Cardinia Outfall RORB model is 22.46 km and the total catchment area is 141.2 km^2. Table 5.1 provides a summary of the valid kc equations considered and each of the calculated k_c values and k_c/ d_{av} relationships.

Table 5.1: Routing Parameter (k_c) Values Calculated

Equation No.	Equation Formula	Application	Source	Calculated K_c	K_c/D_{av}
1	kc = 0.49 x $A^{0.65}$	Areas with annual rainfall < 800 mm	ARR2019 Book 7, Chapter 6.2.1.3	12.23	0.54
2	kc = 2.57 x $A^{0.45}$	Areas with annual rainfall > 800 mm	ARR2019 Book 7, Chapter 6.2.1.3	23.84	1.06
3	kc = 2.2 x $A^{0.5}$	General	RORB V6 User Manual Equation 2-5	26.14	1.16
4	kc = 1.25 x d_{av}	Victoria	Pearse et al. (2002)	28.08	1.25
5	kc = 1.19 x $A^{0.56}$	Yarra and Maribyrnong Areas	Melbourne Water	19.03	0.85
6	kc =1.53 x $A^{0.55}$	South East area (Dandenong Valley Authority)	Melbourne Water	23.29	1.04

Studies (Pearse et al, 2002; Yu, 1989 and CRCCH) have determined the expected k_c/d_{av} relationship for RORB hydrological models, which has been summarised in Table 5.2.

Table 5.2: Summarised k_c/d_{av} relationships for RORB hydrological models

Group	Victorian (Pearse et al, 2002)	Yu, 1989	CRCCH
Expected	1.25	0.96	1.14
Low (-1 SD in log)	0.75	0.47	0.61
High (+1 SD in log)	2.07	1.94	2.13

Given that the average annual rainfall for Officer South (the key focus area of this study) is 811 mm (as at the Cranbourne Botanic Gardens Rainfall Station, ID: 86375), equations 2, 3, 4 and 5 in Table 5.1 have been deemed most appropriate for determining an appropriate k_c value. Each of these kc equations produce a k_c/d_{av} relationship within the expected ranges presented in Table 5.2, with a k_c value between 23 and 35.

Furthermore, Engeny has investigated the impacts on flows at the Lower Gum Scrub Creek at the Princes Highway gauge station of implementing an interstation point in the RORB model at the gauge station. The d_{av} and catchment area upstream of this gauge station were calculated as 4.04 km and 17.0 km^2 respectively, while the d_{av} and catchment area in the remainder of the Cardinia Creek and Gum Scrub Creek catchments are 23.23 km and 124.3 km^2 respectively. Table 5.3 provides a summary of the k_c and k_c/d_{av} values considered for this investigation.

Table 5.3: Summary of k_c and d_{av} for the interstation points of the RORB model

K_c Equation No.	Source	Upstream of GSC Gauge Station		Remainder of Cardinia Crk and GSC Catchments		Rest of Model (Toomuc Crk and Deep Crk Catchments)	
		k_c	k_c/d_{av}	k_c	k_c/d_{av}	k_c	k_c/d_{av}
1	ARR2019 Book 7, Chapter 6.2.1.3	3.09	0.76	11.26	0.48	12.22	0.73
2	ARR2019 Book 7, Chapter 6.2.1.3	9.20	2.28	22.51	0.97	23.83	1.42
3	RORB V6 User Manual Equation 2-5	9.07	2.25	24.53	1.06	26.12	1.56
4	Pearse et al. (2002)	5.05	1.25	29.04	1.25	20.91	1.25
5	Melbourne Water (Yarra & Marib.)	5.82	1.44	17.72	0.76	19.02	1.14
6	Melbourne Water (DVA)	7.27	1.80	21.71	0.93	23.27	1.39

Each of the kc equations in Table 5.3 produces a k_c/d_{av} relationship within the expected ranges presented in Table 5.2 except for equations 2 and 3 (for upstream of the Gum Scrub Creek Princes Highway gauge), with a k_c value between 3.5 and 5.0 expected upstream of the gauge station and 22.0 and 30.0 expected in the remainder of the Cardinia Creek and Gum Scrub Creek catchments.

Sections 5.4 and 5.5 detail the adopted kc value for the modelling and the basis for their selection.

5.2.3 Analysis of the Existing Model's Storages

Engeny has reviewed NearMap aerial imagery from September and November 2020, which has identified that the Kaduna Estate Retarding Basin and Quirks Road Retarding Basin (partially) were constructed at the time of the October 2020 storm event. These assets were not included in the existing conditions Cardinia Outfall RORB model supplied by Melbourne Water. To improve the accuracy of the RORB model at the Gum Scrub Creek at Princes Highway gauging station, Engeny has added these assets into the existing conditions RORB model (using information supplied by Melbourne Water).

The Cardinia Outfall RORB model has also been updated to better reflect the stage-storage relationship and outfall configuration of the Beaconsfield Reservoir, as per information provided by Melbourne Water.

5.3 RORB MODEL VALIDATION

Melbourne Water provided streamflow and rainfall data for five gauges (four of which have streamflow data and four of which have rainfall data) located within the Cardinia Creek, Lower Gum Scrub Creek and Toomuc Creek catchments. See Figure 5.3 below for the locations of these gauges in relation to the study area. Engeny has undertaken an FFA on the streamflow data and the results of the FFA have been used to estimate the frequency (i.e., AEP) of the October 2020 storm event. Engeny's analysis has determined that this storm event is equivalent to a 1 EY (63.21 % AEP) storm event. This analysis is based on streamflow data on Lower Gum Scrub Creek at Princes Highway (station ID: 228365A). Flow that passes through this gauge will flow downstream to the properties that have experienced inundation and are the focus of this investigation.

Engeny has simulated the Cardinia Outfall RORB model for several scenarios to test the sensitivity of the hydrological parameters, with Table 5.4 summarising the methodologies and parameters used. The objective of the sensitivity analysis is to select hydrological parameters to calibrate the Cardinia Outfall RORB model to the October 2020 storm event using flow gauge data on Lower Gum Scrub Creek at Princes Highway (station ID: 228365A). The k_c values presented in Table 5.4 consider the Cardinia Creek and Gum Scrub Creek portion of the Cardinia Outfall RORB model only (parameters for the Toomuc and Deep Creek catchments have not been altered). The addition of an interstation point at the Gum Scrub Creek at Princes Highway gauge station has altered the d_{av} of the RORB model for areas upstream of the original 'End of Cardinia Creek Model' interstation point. Therefore, the originally supplied k_c values adopted for Scenario 1 have been altered to maintain the same k_c/d_{av} relationship for this section of the RORB model as the supplied RORB model from Melbourne Water. In this table, Scenario 1 represents the simulation parameters and model setup in the SWS model as provided by Melbourne Water to Engeny, while Scenarios 2 to 5 represent alternative modelling parameters and model setup analysed by Engeny as part of this investigation. A brief description of each modelled scenario is provided below:

- Scenario 1: Baseline parameters in the SWS model, as provided by Melbourne Water to Engeny (adjusted to maintain original k_c/d_{av} after the interstation point was added).
- Scenario 2: Pearse et al. k_c, increased initial loss and reduced continuing loss compared to baseline parameters.
- Scenario 3: Maximum recommended k_c considering k_c/D_{av} ratio, adjusted losses compared to baseline parameters.
- Scenario 4: Increased k_c and initial loss compared to baseline parameters to provide close match to gauge flow.
- Scenario 5: Parameters as per recent Jacobs Officer South Employment PSP study (August 2021).

Table 5.4: RORB Scenarios Modelled and RORB Parameters Adopted for Model Validation

Scenario	K_c Upstream of GSC Gauge	K_c Remainder of GSC and Cardinia Creek Catchments	K_c in Rest of Model	m	Initial Loss (mm)	Continuing Loss (mm/hr)
Scenario 1	4.19	24.10	23.30	0.8	10.0	2.5
Scenario 2	5.05	29.03	20.92	0.8	31.0	2.25
Scenario 3	8.36	48.09	34.63	0.8	26.5	2.0
Scenario 4	11.69	67.23	65.0	0.8	20.0	2.5
Scenario 5[1]	12.0	12.5	12.5	0.8	25.0	3.0

[1] *The Jacobs study included an additional interstation point on Cardinia Creek at Chasemore Road, which adopted a different kc upstream of this location to what is listed in the table above. The difference in flows that this is expected to result in for Cardinia Creek is not important for the outcomes of this study. The Jacobs study also delineated impervious surfaces into directly and indirectly connected areas, which is not consistent with this study. Results presented in this document adopt a lumped fraction impervious approach for all scenarios investigated.*

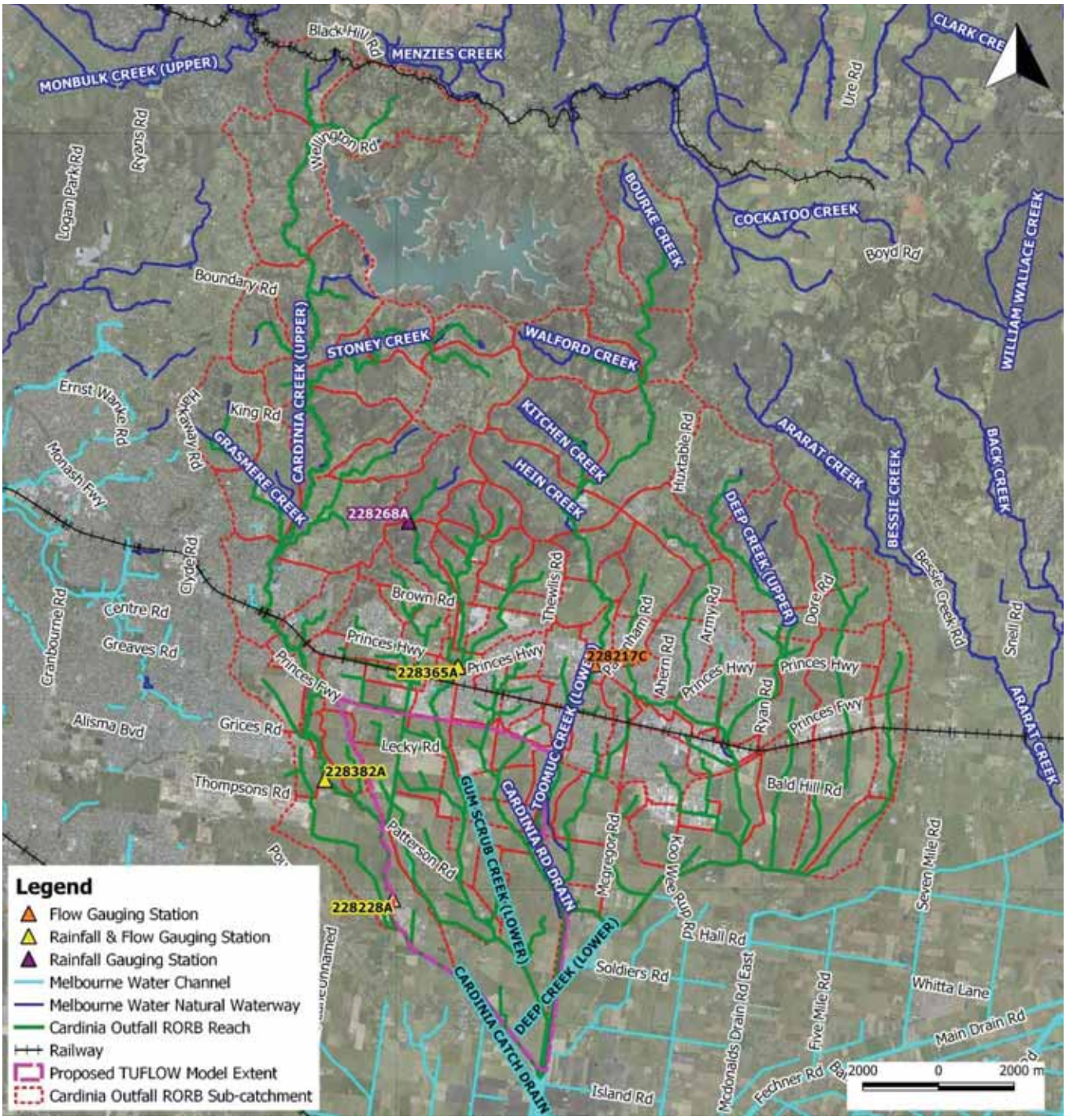


Figure 5.3: Streamflow and Rainfall Gauge Locations

The findings of the modelled scenarios in terms of peak flows, timing and total flow volumes are summarised in Table 5.5, with the results of the FFA also provided. All results are based on existing catchment conditions as of October 2020.

Table 5.5: Gauge Data, FFA and RORB October 2020 Peak Flow and Volume Comparison for Lower Gum Scrub Creek at Princes Highway Gauging Station (% Difference to Gauge Data)

Scenario	Peak flow rate (m^3/s)	Time of peak flow rate (hr)	Total flow volume (m^3)
FFA (1 EY / 63.21 % AEP event)	1.63 (-1.8%)	-	-
Gauge data	1.66	15.5	123,825
Scenario 1	5.48 (+230%)	11.0 (-29%)	155,600 (+26%)
Scenario 2	1.57 (-5%)	15.0 (-3%)	46,280 (-63%)
Scenario 3	1.75 (+5%)	15.5 (0%)	79,950 (-35%)
Scenario 4	1.67 (+0.6%)	16.0 (+3%)	101,375 (-18%)
Scenario 5	0.67 (-60%)	15.0 (-3%)	43,750 (-65%)

Figure 5.4 presents a comparison of flow hydrographs between the various scenarios modelled in RORB and the actual flow hydrograph as per the gauge data provided by Melbourne Water for the Lower Gum Scrub Creek at Princes Highway gauging station.

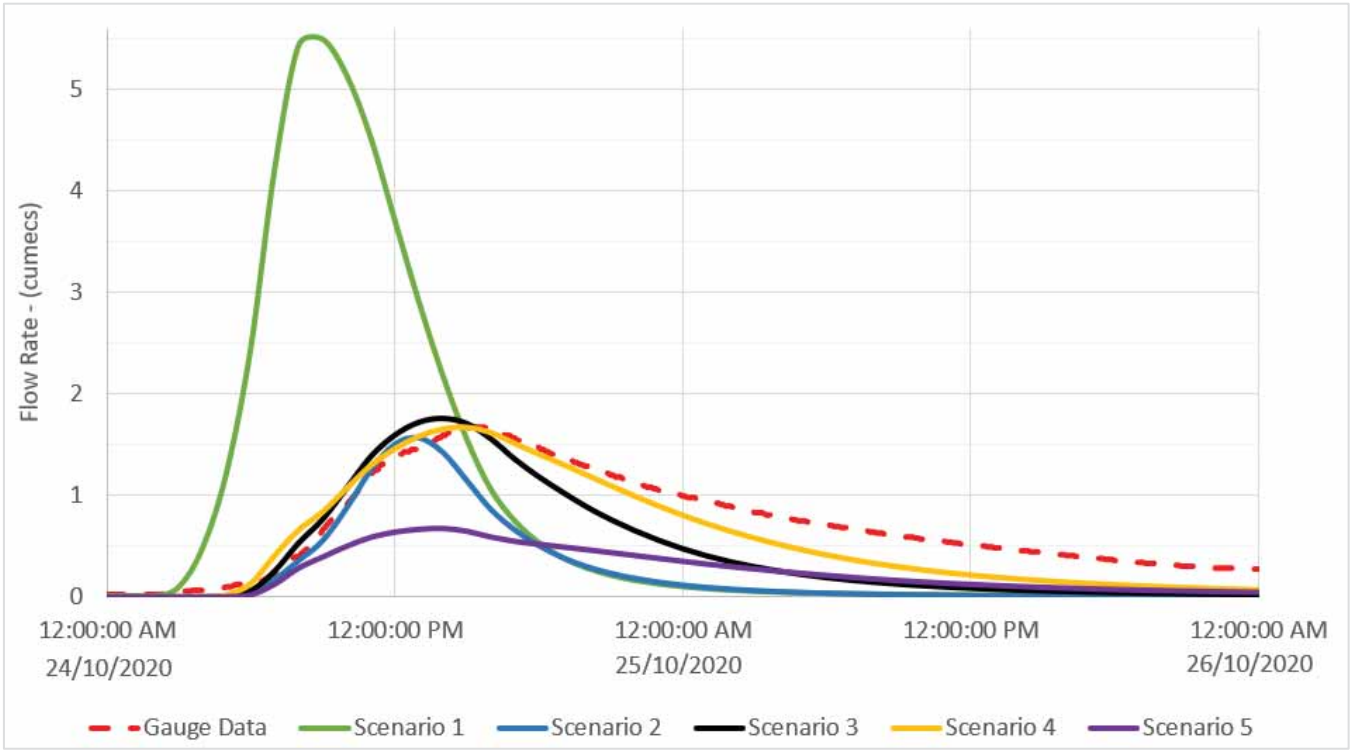


Figure 5.4: Lower Gum Scrub Creek at Princes Highway Flow Hydrograph Comparison

As presented in Table 5.5 and Figure 5.4 above, peak flow rates, peak flow timing and flow volumes are sensitive to the RORB modelling parameters adopted. The following summarises the findings of the RORB modelling investigations:

1. All scenarios provide a similar peak flow rate to the gauge data except for Scenario 1 (baseline Stormy Water Solutions parameters), which produces a peak flow rate of over three times the value of the gauge flow, and Scenario 5 (Jacobs parameters), which produces a peak flow less than half of the gauge flow.
2. All scenarios provide a similar timing of the peak flow occurring expect for Scenario 1, which occurs 3.5 hours earlier than the gauge flow.

3. Over the 50 hours that have been modelled for the storm event, Scenario 1 results in approximately 26 % more total flow volume than the gauge data. While Scenarios 2, 3 and 5 result in 63 %, 35 % and 65 % less total flow volume compared to the gauge data respectively. Scenario 4 provides the closest total flow volume to the gauge data, with a predicted 18 % lower total flow volume.
4. The analysis indicates that Scenarios 1 (baseline Stormy Water Solutions parameters) and 5 (Jacobs parameters) do not provide a good representation of the flows at this gauge for the October 2020 event.
5. The analysis indicates that Scenario 4 provides the closest match to the gauge data. All scenarios struggle to represent the gauge data for the tail end of the storm, but Scenario 4 provides the best overall match.

The initial loss (20 mm) and continuing loss (2.5 mm/hr) for Scenario 4 fall within the expected range of losses as previously noted in Section 5.2.1. The k_c value (11.69 upstream of the Gum Scrub Creek at Princes Highway gauge) for Scenario 4 is higher than the expected range. A higher-than-expected k_c may be required in order to represent the greater attenuation of flow in a lower intensity rainfall event such as the October 2020 rainfall event, as well as the potential impact of farm dams and other catchment storage that is not explicitly represented in the RORB model.

The RORB results of the various modelling parameter scenarios have also been compared to the Cardinia Creek at McCormacks Road gauging station (Station ID: 228382A). Figure 5.5 presents a comparison of flow hydrographs between the various scenarios modelled in RORB and the gauge flow as per information provided by Melbourne Water for the Cardinia Creek at McCormacks Road gauging station.

The results in Figure 5.5 show that none of the scenarios provide a good match to the gauge data at Cardinia Creek. Scenario 4 provides a reasonable match of the shape of the hydrograph but is well below the gauge's peak flow and overall flow volume. While Scenario 5 provides a very close match of peak flow, the timing and flow volumes significantly differ from the gauge data. Engeny notes that modelling of Cardinia Creek will not be undertaken as part of the Officer South Interim Works study (anecdotal observations indicate that Cardinia Creek did not directly influence inundation of the subject properties for the October 2020 rainfall event).

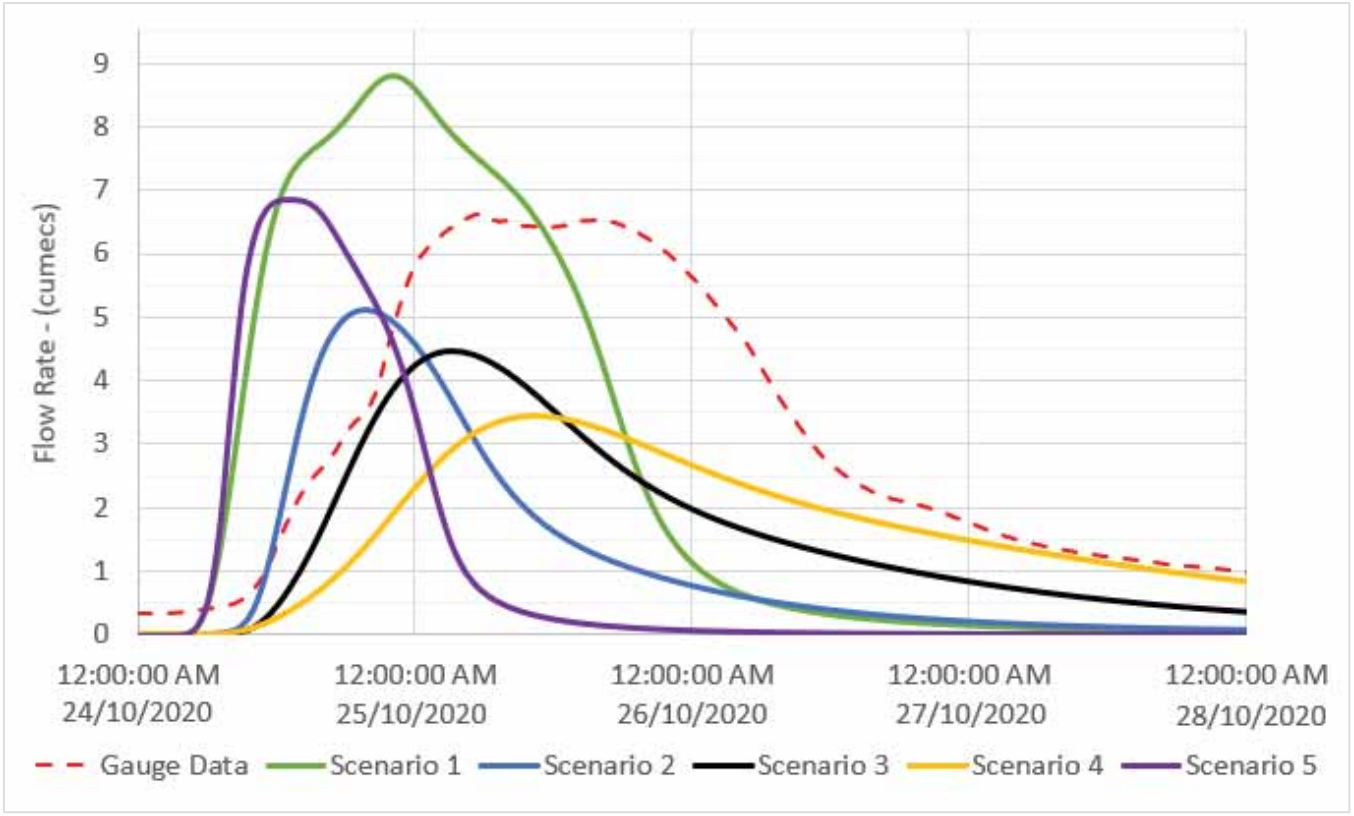


Figure 5.5: Cardinia Creek at McCormacks Road Flow Hydrograph Comparison

5.4 OCTOBER 2020 EVENT

Based on the analysis completed, as documented in the previous sections and subsequent discussions with Melbourne Water, Scenario 4 was adopted for the representation of October 2020 (rainfall and development conditions) event. This was based on the following key conclusions:

- The initial loss and continuing losses are within standard ranges.
- The peak flow rate, timing of peak flow and total volume predicted provides a good match to the gauge data for the October 2020 storm event.

Accordingly, the following methodologies and parameters have been adopted for the October 2020 storm event:

- ARR2019 methodologies
- k_c upstream of GSC at Princes Highway gauge = 11.69
- k_c in the remainder of the Gum Scrub Creek and Cardinia Creek catchments = 67.23
- k_c for rest of RORB model (Toomuc Creek and Deep Creek) = 65
- Initial loss = 20 mm
- Continuing loss = 2.5 mm/hr
- Represent catchment imperviousness as FI rather than EIA/ICA/Rural breakdown.

These hydrology parameters are only appropriate for the Gum Scrub Creek area of the RORB model for modelling of events in the order of the 1 EY (63.21 % AEP) event and should not be used for other purposes in this model without further verification.

5.5 DESIGN STORM EVENTS

In addition to modelling of the historical October 2020 storm event, selected design storm events were also simulated using the hydroloical model, including the 20 % AEP and 10 % AEP storm events.

The design storms were simulated for baseline / existing development conditions (October 2020).

For the design storm events, RORB model parameters were based on the concurrent study of Officer South being completed by Jacobs, as documented in “Officer South Employment Hydrological Report: Pre-Development Hydrological Assessment” (Jacobs, March 2022). This was undertaken as the previously determined model parameters used for the October 2020 rainfall event had been adjusted to match the gauge data specific to the 2020 event and may not be appropriate for a design storm event of larger magnitude.

Accordingly, the RORB model parameters summarised in Table 5.6 were adopted for the design storm events. The k_c values have been calculated based on the k_c/d_{av} ratios provided in the Jacobs (2022) report for each of the interstation areas. The Jacobs model adopts an additional interstation point (Cardinia Creek at the McCormacks Road Gauge) as compared to the RORB model run by Engeny for the October 2020 event.

Table 5.6: Summary of RORB Model Parameters Adopted for the Design Storm Events

Location	k_c	m	Initial Loss	Continuing Loss
Gum Scrub Creek at the Princes Highway Gauge	5.43	0.8	25 mm	3.0 mm/hr
Cardinia Creek at the McCormacks Road Gauge	20.62	0.8	25 mm	2.5 mm/hr
Remainder of the Gum Scrub Creek and Cardinia Creek Catchments	8.59	0.8	25 mm	3.0 mm/hr
Toomuc Creek and Deep Creek Catchments	65.0	0.8	25 mm	3.0 mm/hr

6 HYDRAULIC MODELLING

6.1 MODEL SETUP

Engeny developed a TUFLOW hydraulic model for this study. TUFLOW is a combined one-dimensional (1D) and two-dimensional (2D) dynamic hydraulic modelling software package used to estimate water levels, extents, flows and other hydraulic variables for a range of scenarios and historical and design storm events.

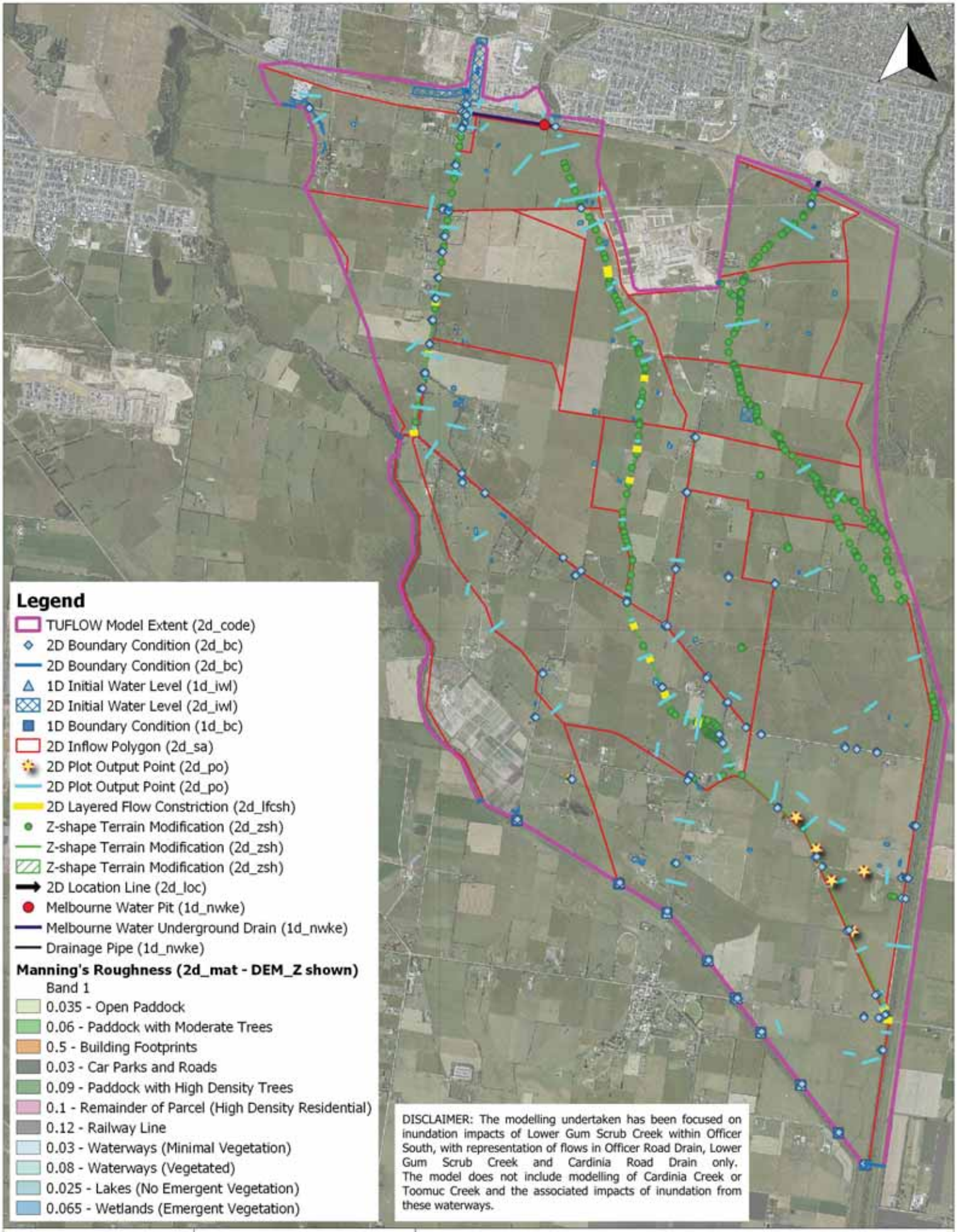
The hydraulic modelling was performed using the latest version of TUFLOW software available at the time of the model runs (2020-10-AD-iSP-w64) and generally in accordance Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (September 2020).

The following steps outline the tasks undertaken to develop the TUFLOW model for the study catchment and to obtain results and outputs which were analysed as part of this study:

- Generate Digital Elevation Model (DEM) from DELWP LiDAR captured in 2017-18.
- Apply the inflow hydrographs generated in RORB for the historical October 2020 storm event as well as a range of storm durations and temporal patterns for the modelled design storm events, including both the rainfall excess hydrographs and routed inflow hydrographs. Rainfall excess flows from RORB were applied to the TUFLOW model as rain on grid (2d_sa_all), which allows the topography to dictate overland flow patterns.
- Input surface roughness (materials layer) based on current planning zone land uses and refined based on aerial photographs and site visit observations on the condition of waterways (such as the level of vegetation).
- Input and verify data for the 1-D network (culverts) based on GIS data, design plans and survey supplied by Melbourne Water. Where data gaps were present, drainage information was informed by the site visit undertaken by Engeny and Melbourne Water on 22 March 2021.
- Set 1-D and 2-D boundary conditions for to link pipes / pits to the 2-D domain and downstream boundaries for pipes and overland flow paths where required, including use of tide levels recorded at the Western Port at Evans Inlet, Tooradin (Site ID: 228399A) gauge for the October 2020 rainfall event.
- The TUFLOW model was simulated the October 2020 historical storm event as well as a range of design storm events, durations and temporal patterns, as summarised in Table 6.1. For the design storm events, the temporal patterns chosen represent a middle loaded hyetograph. Engeny has undertaken a sensitivity investigation into the influence of temporal patterns (and their different distributions / shapes of rainfall) on flood depths and have found that middle loaded temporal patterns typically provide the median flood depth for a given location. A detailed analysis of temporal patterns for the design storm events hasn't been undertaken for this study as the main focus is on the October 2020 observed storm event (which uses recorded rainfall date rather than design storms).
- The model was run with a 3 metre grid incorporating a 1 metre sub-grid using TUFLOW Heavily Parallelised Compute (HPC).
- A layout plan of the TUFLOW model setup is provided as Figure 6.1.

Table 6.1: Design storm duration and temporal pattern summary

Duration	20% AEP temporal pattern	10% AEP temporal pattern
60 minute	6	18
120 minute	9	17
180 minute	4	15
360 minute	6	17
720 minute	6	11



Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
P: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

600 0 600 m

Scale in metres (1:30,000@ A3)

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

Officer South Interim Works Inundation Investigation

Figure 6.1
TUFLOW Model Layout Plan
Baseline (2020) Modelling Scenario

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023

6.1.1 Pipe Methodology

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

- A Manning's roughness value of 0.013 was adopted for the concrete underground drainage pipes and road culverts.
- Pipes were snapped together where they were found to be graphically disconnected.
- The Engelund method of automatically created manholes has been used for determining pit losses. This approach considers the incoming pipe invert levels, diameters and pipe bends. The following provides a summary of the losses applied when no manhole is created:
  - Height contraction coefficient = 0 for circular pipes and 0.6 for rectangular pipes
  - Width contraction coefficient = 1.0 for circular pipes and 0.9 for rectangular pipes
  - Entry loss coefficients for underground pipes = 1
  - Exit loss coefficients for underground pipes = 1
- For headwall / endwall structures, loss coefficients vary based on their structure type and shape. The Federal Highway Administration's Hydraulic Design of Highway Culverts Manual (1985) indicates that loss coefficients can vary between 0.2 and 0.9 for headwall and endwall structures. However, the following coefficients are recommended and have been adopted for this study:
  - Entry loss coefficient for culverts = 0.5
  - Exit loss coefficient for culverts = 1.0

6.1.2 Pit Methodology

There are only two pits in the TUFLOW model, which are represented as "Q" type pits to accurately represent the inlet capacity of the pit structure. Both pits are grated and are represented by stage-discharge relationships for their respective inlet dimensions. The calculations are based on the Section 4.4.5.4 of HEC 22 (FHA, 2013).

6.1.3 Surface Roughness

Within TUFLOW a materials layer is utilised to define surface roughness information in the model. The GIS parcel layer available from the Department of Environment, Land Water and Planning (DELWP) was used as a basis for the materials layer. The materials layer was created by assigning a Manning's roughness value to land parcels according to the land use from planning zones. The roughness values were then refined based on the land use shown in the 2018/19 aerial photographs to allow for delineation between residential areas, open space and/or carparks. The roughness values for waterways, including Lower Gum Scrub Creek, were assigned based on observations on the site visit and photos provided by Melbourne Water.

The typical roughness values are listed in Table 6.2.

Table 6.2: Manning's n Roughness Values Adopted

Type of Zone	Mannings' Roughness (n)
Open Paddock	0.035
Open Paddock with Moderate Trees	0.06
Commercial & Residential Building Footprints	0.5
Carpark / Road (Asphalt)	0.03
Remainder of Parcel	0.10
Waterways with Minimal Vegetation	0.03
Waterways with Moderate Vegetation	0.08
Lakes (No Emergent Vegetation)	0.025

Type of Zone	Mannings' Roughness (n)
Lakes (with Emergent Vegetation)	0.065
Waterways with Maintained Vegetation	0.045

6.1.4 Boundary Conditions

All RORB rainfall excess flows have been applied to the TUFLOW model's 2D surface as 2D_sa_all polygons covering the entire hydraulic model boundary.

Routed inflows from the RORB model have been applied to the appropriate waterways at the upstream end / locations of the TUFLOW model.

As part of the 1-D network, 2-D SX (source of flow from a 1D model) boundaries were assigned to the pits to allow surcharge of water from the pipe network to the 2-D surface and capture of water from the 2-D surface back into the pipe network. 2-D SX points were also applied to culverts at road crossings and culverts positioned within levees. Culverts positioned on the western side of the Toomuc Relief Drain levee were set up to allow stormwater to freely enter and exit the culvert for flows travelling west to east. However, most of these culverts have tide gates on them which prevents back flow from the waterway, preventing flow from travelling east to west.

A series of 1-D HT (head versus time) boundary conditions have been applied to pipes which exit the model into Cardinia Creek with appropriate tailwater levels set. For the October 2020 storm event, tidal gauge data recorded at Western Port at Evans Inlet, Tooradin (Site ID: 228399A) during the storm event was used to replicate water levels that occurred within Western Port Bay and therefore the potential tidal influence at the area of interest.

A combination of 2-D CN and 2-D SX boundaries were utilised on large culverts where appropriate to ensure the capacity of the assets weren't inappropriately constrained at the inlet / outlet.

2-D HQ (head versus flow) have been adopted where overland flow exits the model. This approach was taken to avoid water ponding against the 2-D code boundary. TUFLOW calculates the predicted outflow based on the boundary's terrain cross-section and the input longitudinal slope for the given water surface elevation.

Downstream Boundary Conditions

<u>October 2020 Event</u>

For the historical October 2020 storm event, the boundary condition adopted at the model outlet near the convergence of the waterways at Ballarto Road is based on tidal gauge data recorded at Western Port at Evans Inlet, Tooradin (Site ID: 228399A) during the storm event to replicate water levels that occurred within Western Port Bay and therefore represent the potential tidal influence at the area of interest. The boundary condition is dynamic, representing the change in tide level that occurred throughout the October 2020 storm event.

The maximum tide level recorded at the gauge during the October 2020 rainfall event is 1.71 m AHD, while the invert of Lower Gum Scrub Creek just upstream of Ballarto Road is 1.18 m AHD, meaning that part of the waterway was inundated by the peak tide level during the October 2020 event. This tidal inundation of the waterway would reduce Lower Gum Scrub Creek's capacity to convey flows from the upstream catchment.

The minimum terrain level within the properties of interest (within the property bound by Lower Gum Scrub Creek to the southwest and Wenn Road to the east) is approximately 3.25 m AHD, meaning that the properties of interest were not inundated by the peak tide level during the October 2020 event.

<u>Design Flood Events</u>

For the design flood events (i.e., the 20 % and 10 % AEP event), investigation of the standard highest and lowest astronomical tide levels (HAT and LAT levels) for Western Port (at Stony Point) in 2020 identified a HAT of 1.62 m AHD and LAT of -1.69 m AHD (VCRA, 2020). Notably, the October 2020 event recorded a peak level at Tooradin (of 1.71 m AHD), which is greater than the HAT level at Stony Point (1.62 m AHD).

In reviewing the HAT levels and terrain levels within the properties of interest, whilst the HAT level may influence peak water levels within Lower Gum Scrub Creek, inundation within the properties of interest would not be caused directly by tidal inundation by the HAT given the difference in level.

For the design rainfall events, the boundary condition adopted at the model outlet near the convergence of the waterways at Ballarto Road is based on the capacity of the waterway (using its cross-sectional area and slope) using a 2-D HQ boundary condition in TUFLOW. This allows for the water level at the downstream end of the model to rise and fall based on the capacity of the downstream section of the waterway. The approach adopted for the 20% and 10% AEP design rainfall events does not represent the potential tidal influence.

Boundary Condition Uncertainty

All hydraulic modelling incorporates a level of uncertainty. The adopted tidal boundary condition for the October 2020 event provides a constraint on the capacity of Lower Gum Scrub Creek and the model results have been validated to observations of inundation behaviour for the storm event. Sensitivity testing could be undertaken to understand how higher or lower boundary condition levels influence inundation in the subject properties, particularly for the design storm events.

6.1.5 TUFLOW Parameters

Engeny has simulated the TUFLOW model using the Heavily Parallelised Compute (HPC) solution scheme, which uses an adaptive timestep. However, the initial timesteps assigned to the model are:

- 2-D: 0.75 seconds
- 1-D: 0.1875 seconds

The storm events modelled are the same that were simulated in the RORB hydrological model as discussed in previous sections of this report.

6.1.6 Quality Assurance

The TUFLOW model was reviewed at different stages of its development using Quality Assurance (QA) processes developed by Engeny. The QA processes are designed to provide confidence that consistent best practice modelling has been applied and that the model is as accurate as reasonably possible. An internal review of the TUFLOW hydraulic model was undertaken by a suitably qualified principal engineer as part of the QA process.

6.1.7 Assumptions and Limitations

The following assumptions and limitations apply to the modelling and outputs, including the inundation maps:

- The LiDAR terrain data used as a basis for the TUFLOW DEM has a horizontal accuracy of ± 20 cm and a vertical accuracy of ± 10 cm. The definition of waterway bathymetry capture is noted to be limited by vegetation and / or water levels present at the time of survey. Where available, Engeny has used additional waterway survey to reinforce the invert of key waterways to improve the representation of flow conveyance.
- The piped drainage system was based on the GIS data provided by Melbourne Water. Drainage plans have been provided to Engeny for some locations within the catchment however, limitations and inaccuracies associated with the original GIS data could impact the results of the flood modelling.

6.2 OCTOBER 2020 STORM EVENT

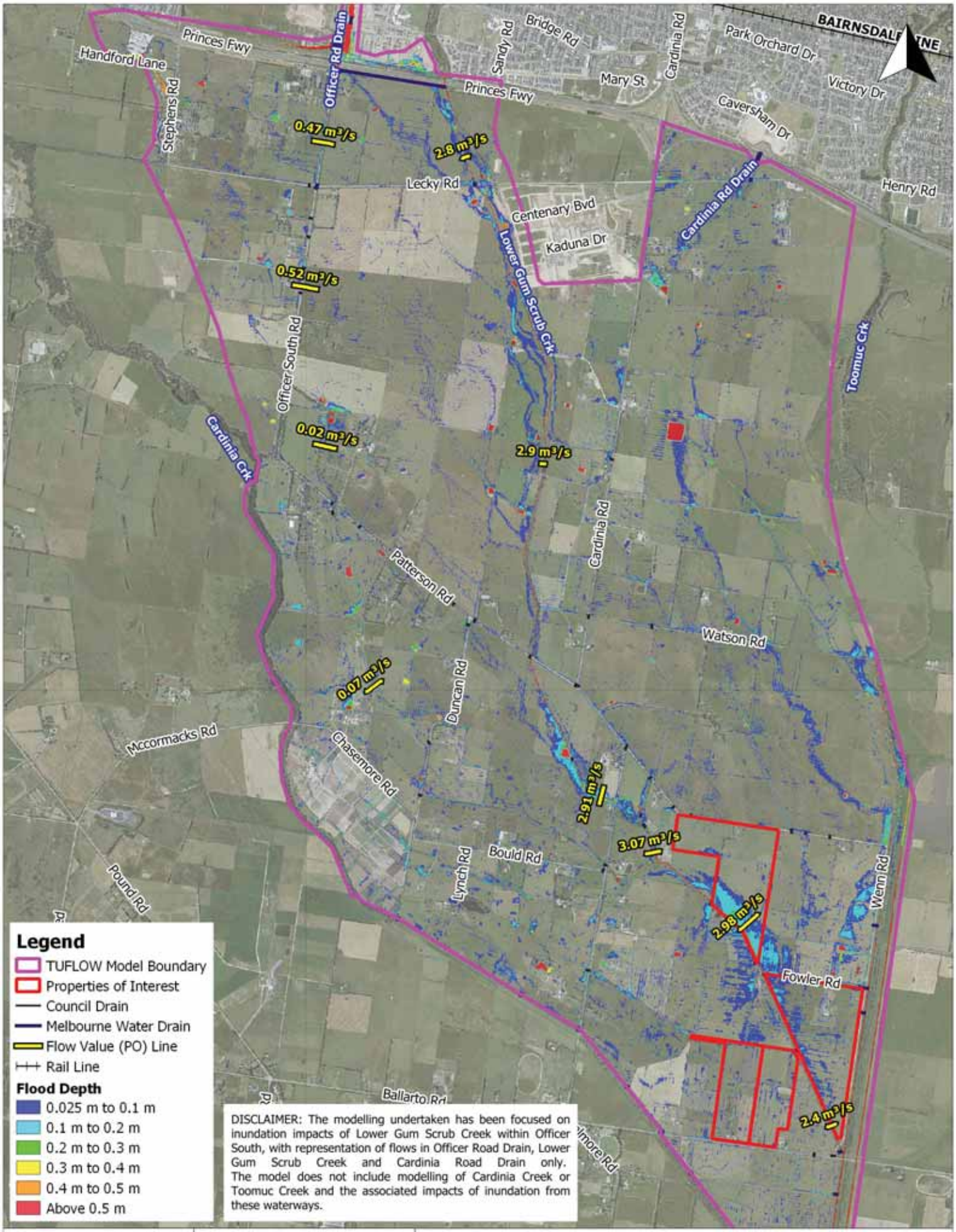
6.2.1 Baseline / Existing Conditions

As previously mentioned, the baseline scenario comprised development conditions of the catchment as at October 2020.

An inundation map for the existing conditions for the October 2020 rainfall event is provided below as Figure 6.2. Peak overland flow rates at various locations throughout the study area are also marked on the inundation map provided.

Overall, the modeling October 2020 rainfall event (approximately a 1 EY / 63.21 % AEP event) for development conditions at the time of the event, generally predicts flows to exceed the capacity of the Gum Scrub Creek (Lower) waterway, with overland flow paths noted to traverse on either side of the waterway throughout the majority of the modelled extent between Princes

Highway and Ballarto Road. Some inundation is noted in the two properties of interest north of Gum Scrub Creek (lower), however minimal inundation is predicted for the properties of interest south of the waterway.



Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

Figure 6.2
October 2020 Storm Event Peak Inundation Depth
Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 3
Drawn: VW
Checked: PC
Date: 26/6/2023

Validation of the October 2020 Event Modelling Results

A series of photos from the October 2020 storm event was supplied to Melbourne Water by various landholders. Commentary on the modelled results versus a selection of the supplied photos is provided in Table 6.3. Overall, the modelled results are generally reflective of the photos provided, which supports the model's representation of on-site conditions for the October 2020 rainfall event.

The results of the modelling were also presented to relevant landowners during a virtual meeting via Zoom on 4 August 2022, with attendance by representatives of Engeny, Melbourne Water, Spiire, Jacobs and landowners, (names withheld). Confirmation was provided by the landowners that the October 2020 existing conditions inundation mapping approximately replicated what they had observed in the October 2020 event, validating the model's results.

Table 6.3: Comparison of the October 2020 Storm Event Modelling Results to Photos Supplied

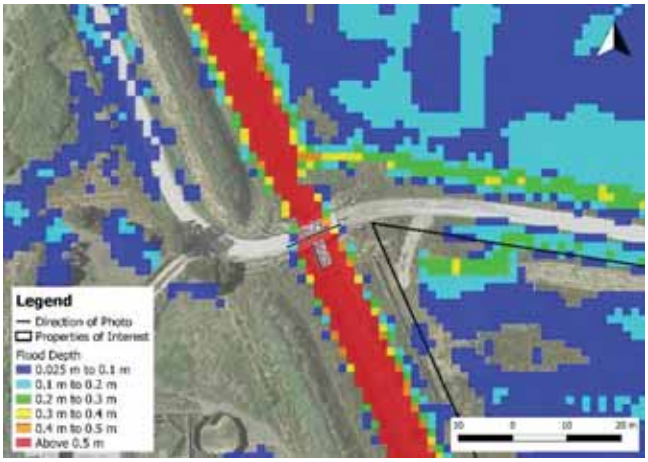
Photo	October 2020 Storm Event Modelling Results
Pic28 – Gum Scrub Creek at Fowler Road (11am on 25/10/2020), looking south 	 There is reasonable consistency between the inundation observations and the model results at this location. Gum Scrub Creek is full, with some inundation behind the eastern levee and the western levee not being overtopped.
Pic29 – Fowler Road Bridge (11am on 25/10/2020) 	*Refer to the inundation map and commentary for Pic28 above*

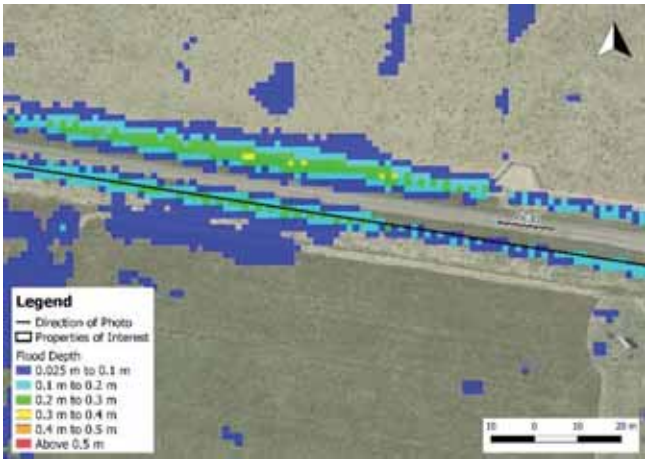
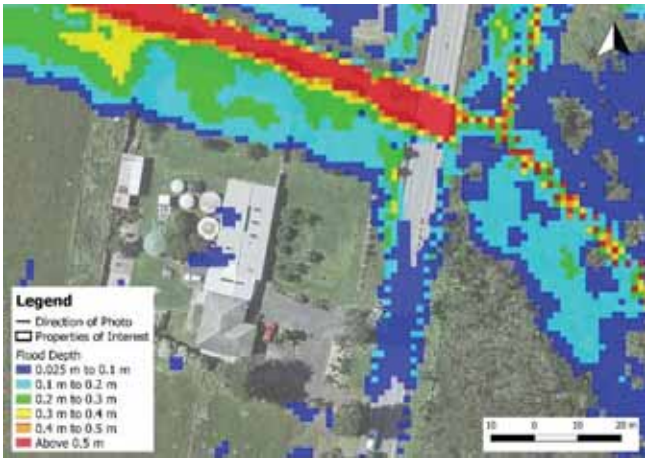
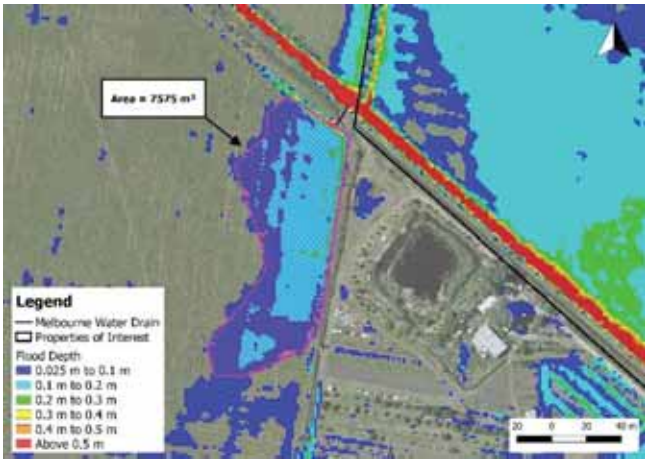
Photo	October 2020 Storm Event Modelling Results
Pic30 – Inundation of Fowler Road (10am on 25/10/2020) 	 There is reasonable consistency between the inundation observations and the model results at this location, with inundation noted on either side of Fowler Road. The model does not show inundation on Fowler Road, however the results filter out inundation depths below 25 mm.
Pic34 – Inundation of Cardinia Road 	 There is reasonable consistency between the inundation observations and the model results at this location, with Cardinia Road shown to be overtopped.

Photo	October 2020 Storm Event Modelling Results
Markup supplied by Tom Le Cerf (Melbourne Water) 	 The markup shown to the left was an approximate inundation extent provided by Melbourne Water as based on available photos from the October 2020 event. While the shape of the inundation extent does not exactly match, inundation was predicted by the model in approximately the same location. Further, the extent of the inundation as based on the modelling generally exceeds that of the estimation (7,575 m^2 versus 5,135 m^2). This was presented to Melbourrne Water and the hydraulic modelling generally considered to be sufficiently representative of on-site conditions during the October 2020 event.

Analysis of Flows within the Pipe to Gum Scrub Creek

The TUFLOW models predicts that the peak flow within the 600 mm diameter pipe between Officer South Drain and Gum Scrub Creek is 0.37 m^3/s in the October 2020 storm event. Figure 6.3 provides an overview of the flow hydrograph of the 600 mm pipe, based on the TUFLOW model, alongside a comparison to flows within the widened section of Officer South Drain crossing beneath Princes Freeway (PO_42) and flows continuing south towards Cardinia Creek via Officer South Drain.

Overland flows peak relatively early in the storm (approximately 14 hours into the modelled storm event) but continue discharging through the 600 mm diameter pipe (albeit slightly decreasing over time) well after the rainfall event finished.

Comparison of the flows conveyed east towards Lower Gum Scrub Creek versus the flows directed south towards Cardinia Creek via Officer South Drain indicates that approximately 80 % of the runoff volume from the catchment upstream of Princes Freeway is conveyed towards Lower Gum Scrub Creek via the 600 mm pipe, with the remaining 20 % directed south to Cardinia Creek via Officer South Drain.

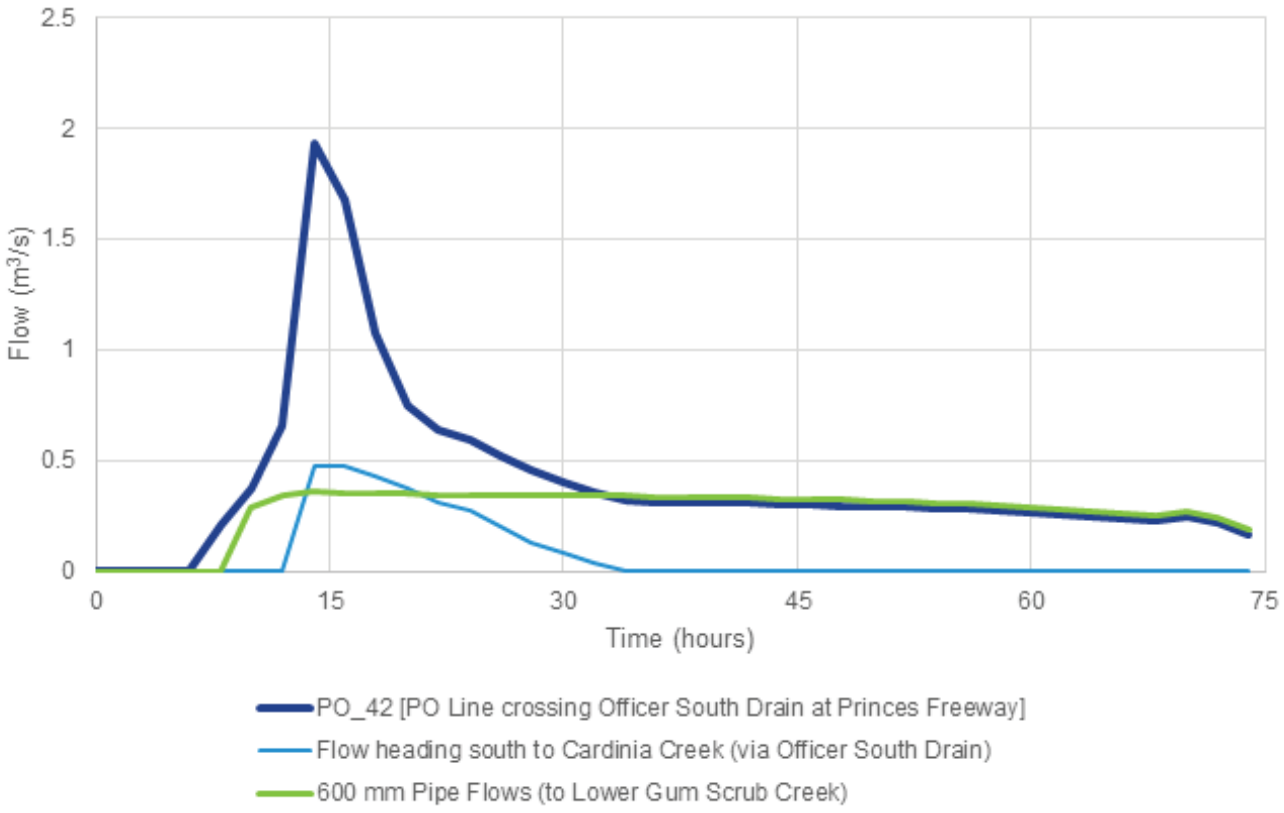


Figure 6.3:Peak Flow Hydrograph of Flows in Officer South Drain and the 600 mm Diameter Pipe (October 2020 Storm Event)

Duration of Property Inundation

While the October 2020 rainfall event generally spanned a 24 hour period, the model has been run for a period of 74 hours (i.e. just over three days) to allow for the modelling to represent the time it takes for runoff to flow through the catchment and accordingly to ensure peak flows and depths throughout the study area are captured. Running the model for a long period also allows for analysis of how long certain areas of the study area are inundated for.

Figure 6.4 and Figure 6.5 provide an overview of three locations where flow depths have been assessed across the length of the modelled event. The results indicate that in these three locations, the inundation depths are not anticipated to fully recede as these low points do not completely drain naturally via gravity back to Gum Scrub Creek. For example, at locations PO_77 and PO_79 (locations shown on Figure 6.4), approximately 30 mm of water is predicted to not be able to drain approximately 30 hours following the end of the October 2020 rainfall event, whilst at location PO_81, just north of Fowlers Road, an inundation depth of approximately 275 mm is predicted to remain constantly after the rainfall event. In reality, the remaining inundation would be expected to infiltrate or evaporate over time, however the TUFLOW model does not represent evaporation or infiltration. This also correlates to the anecdotal evidence suggesting that these areas were inundated for significantly long periods (i.e., beyond the 74 hour period modelled / shown in the hydrograph) following the October 2020 event. The duration of inundation would be influenced by ground, climatic and downstream tailwater conditions both preceding and following the rainfall event. For example, wet conditions preceding a rainfall event could extend the duration of inundation of properties (as the water table may be raised and therefore infiltration rates may be reduced). Similarly, if the water levels within the receiving waterways remain elevated for an extended period (e.g., a high tide causing a backwater effect within the downstream channels), the ability for the Gum Scrub Creek to outfall would be limited which in turn may extend the duration of inundation experienced.

Figure 6.6 provides an overview of the predicted residual inundation depth within the lower section of the flood model at the end of the model simulation for the October 2020 storm event (61 hours after the October 2020 rainfall event had finished). This information may be used to assist in identifying localised areas that may be subject to extended periods of inundation following

a storm event. Inundation depths below 25 mm have been filtered from the results presented in Figure 6.6 to more clearly identify the localised depressions.

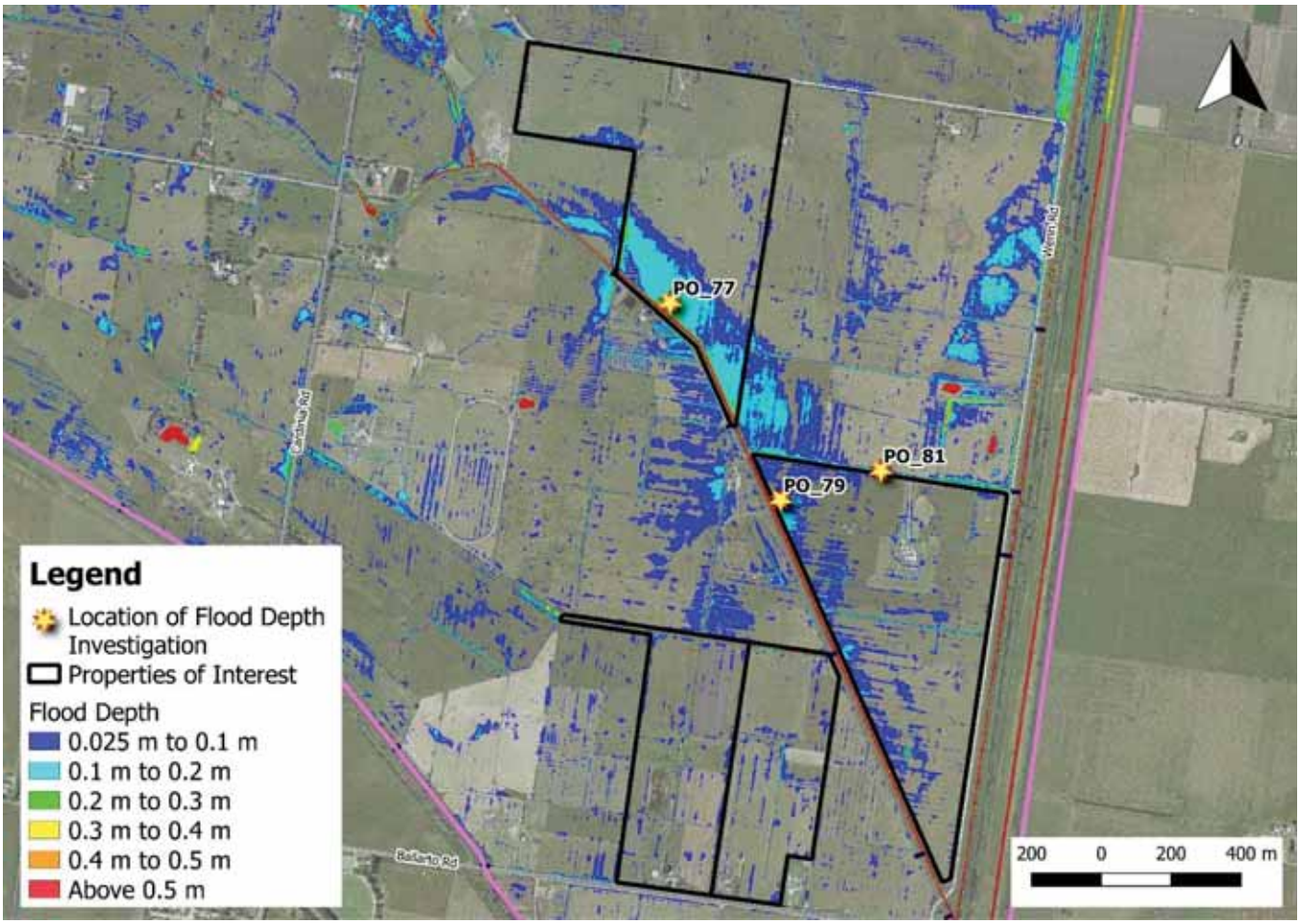


Figure 6.4: Locations identified for Inundation Depth Analysis

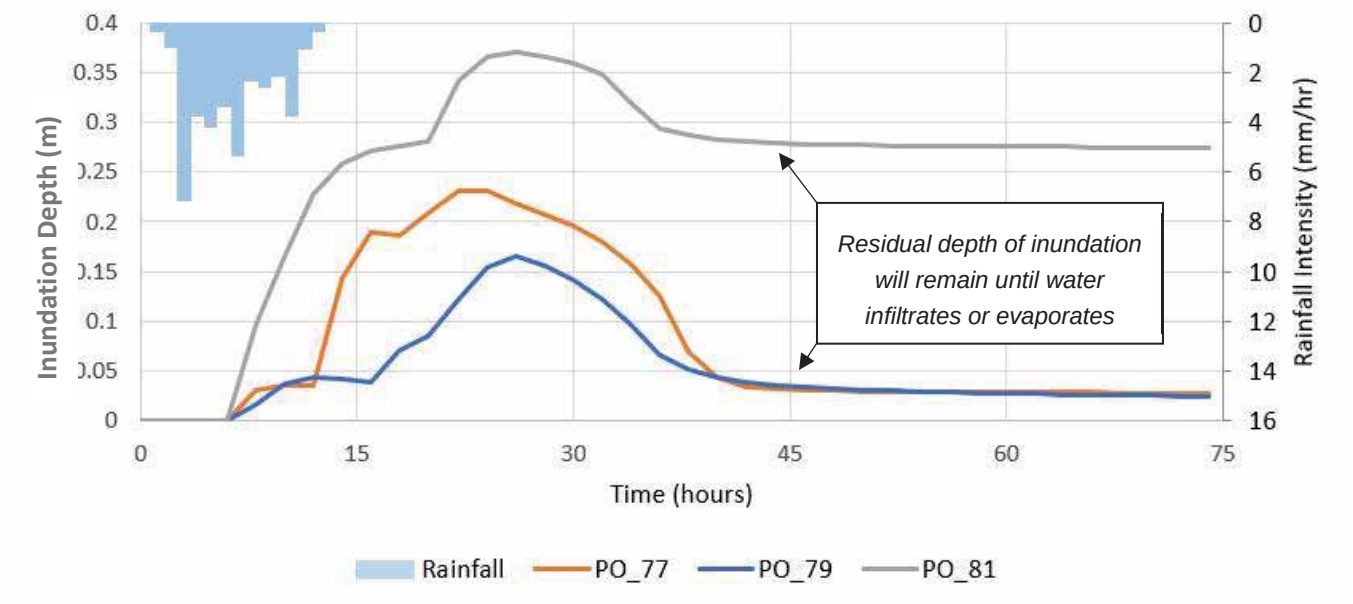


Figure 6.5: October 2020 Storm Event Timeseries Data (Depth versus Time)

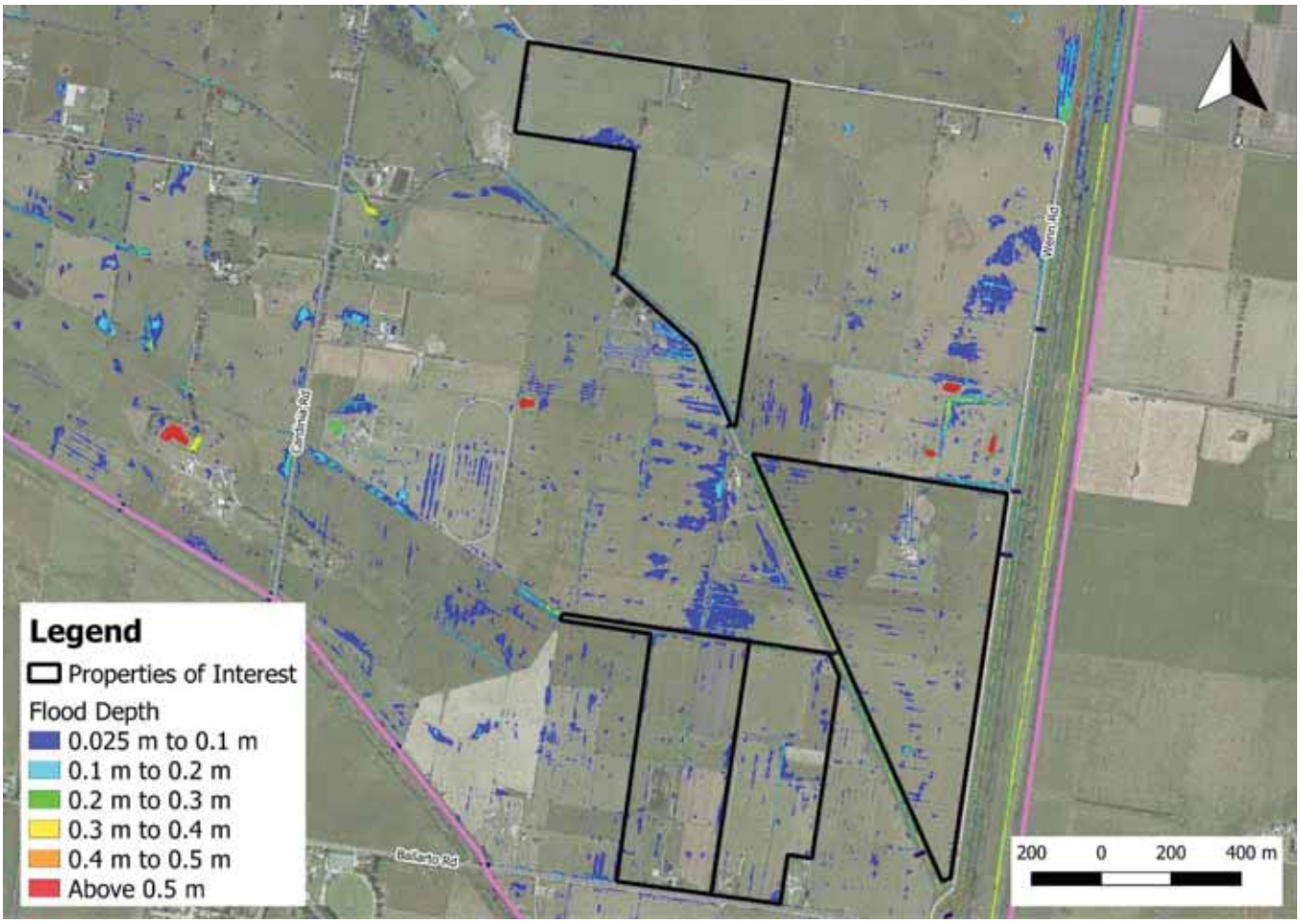
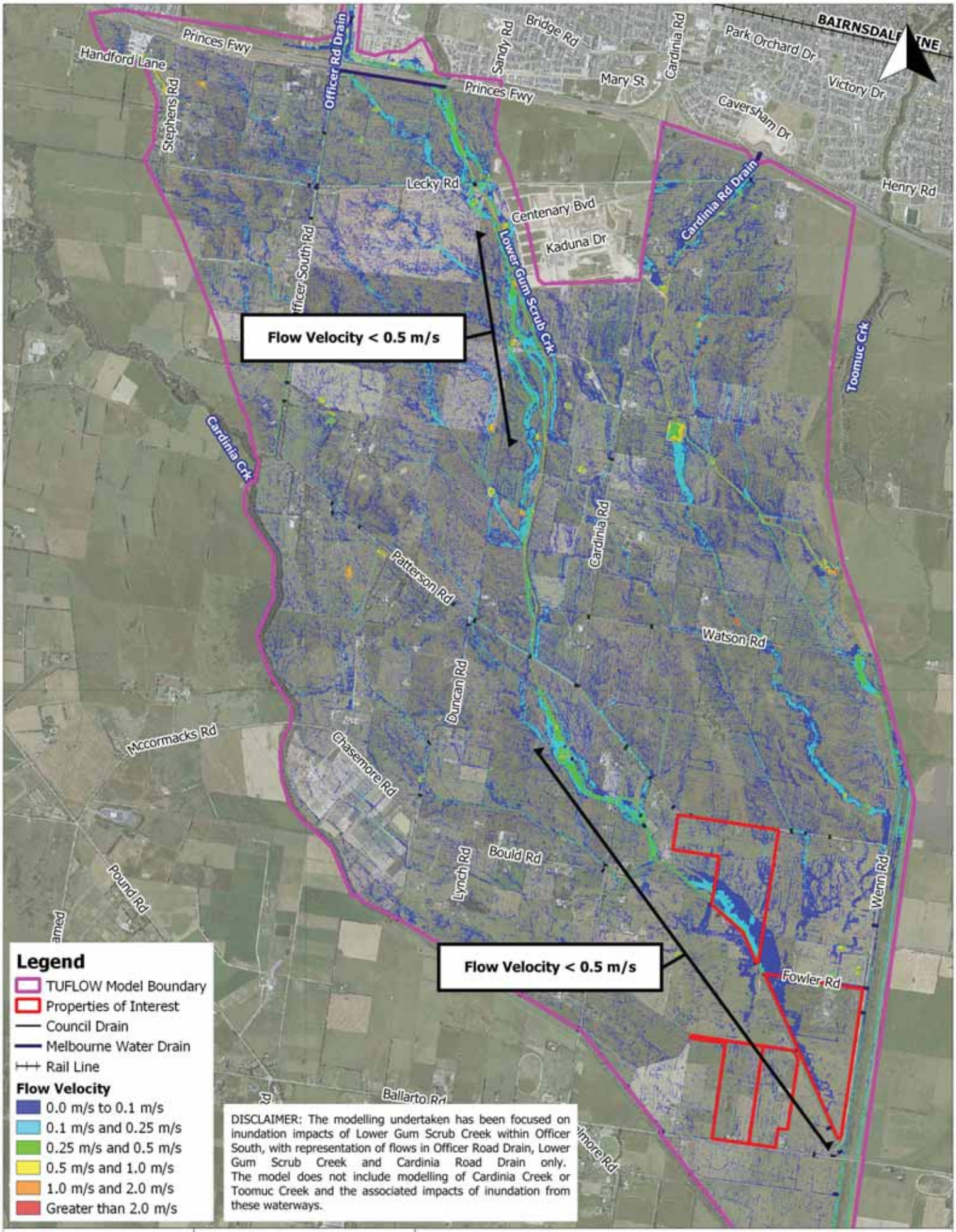


Figure 6.6: Overview of Existing Localised Depressions in / around the Properties of Interest (as based on the October 2020 Storm Event at 74 hours into the Model Simulation)

6.2.2 Siltation of Gum Scrub Creek

Analysis of the peak flow velocities along Gum Scrub Creek for the October 2020 storm event identified a maximum velocity of approximately 0.8 m/s, while approximately 50% of the waterway has a peak flow velocity of less than 0.5 m/s. The two prominent sections of Gum Scrub Creek where low peak flow velocities occur are shown in Figure 6.7. These locations would be most susceptible to siltation and may require more frequent desilting to ensure the waterway is performing effectively.

Figure 6.8 provides the velocity plot for the October 2020 event, focusing on the section of Lower Gum Scrub Creek, in and around the properties of interest.



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9866 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

Figure 6.7
October 2020 Storm Event Peak Flow Velocity
Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023

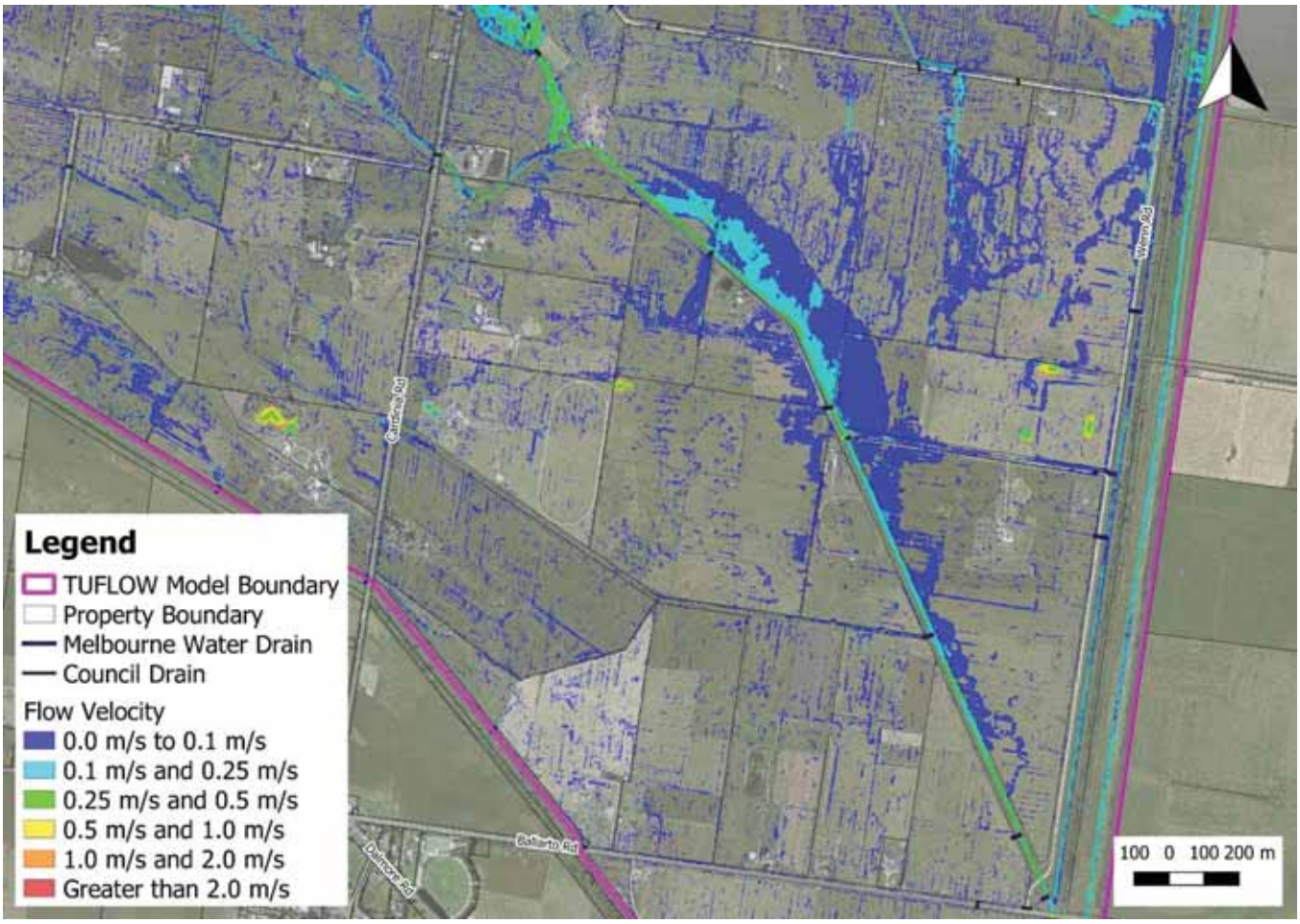


Figure 6.8: Peak Flow Velocity – October 2020 Event (Lower Section of Gum Scrub Creek)

6.2.3 Pre-developed Conditions

The pre-developed conditions scenario represents catchment development levels as of circa 2010, with the October 2020 storm event modelled for rainfall input. The intent of this scenario is to evaluate how flows have changed through the catchment as a result of both upstream development (comparing 2010 and 2020 development levels), retarding basins constructed to manage flows from development, as well as the implementation of the 600 mm diameter pipe from Officer South Drain to Gum Scrub Creek (Lower).

Appendix B contains inundation depth (including peak overland flow values at a selection of locations) and inundation difference (afflux, comparing pre-developed with existing conditions results for the October 2020 storm event) maps for the pre-development scenario.

Comparison of the results between the two scenarios notes an increase in peak overland flow rates along Lower Gum Scrub Creek. The extent and depth of inundation of the two properties of interest north of Lower Gum Scrub Creek are predicted to have increased by up to 120 mm for the October 2020 events in baseline conditions (2020) compared to pre-developed conditions (2010). A comparison of the timeseries data for the three locations identified previously in Figure 6.5 is provided in Figure 6.9. The graph shows the pre-developed (2010) conditions scenario estimates lower inundation depths comparative to the baseline (2020) model results. Extended periods of inundation post-storm event (due to localised depressions) are still predicted in the pre-developed conditions scenario.

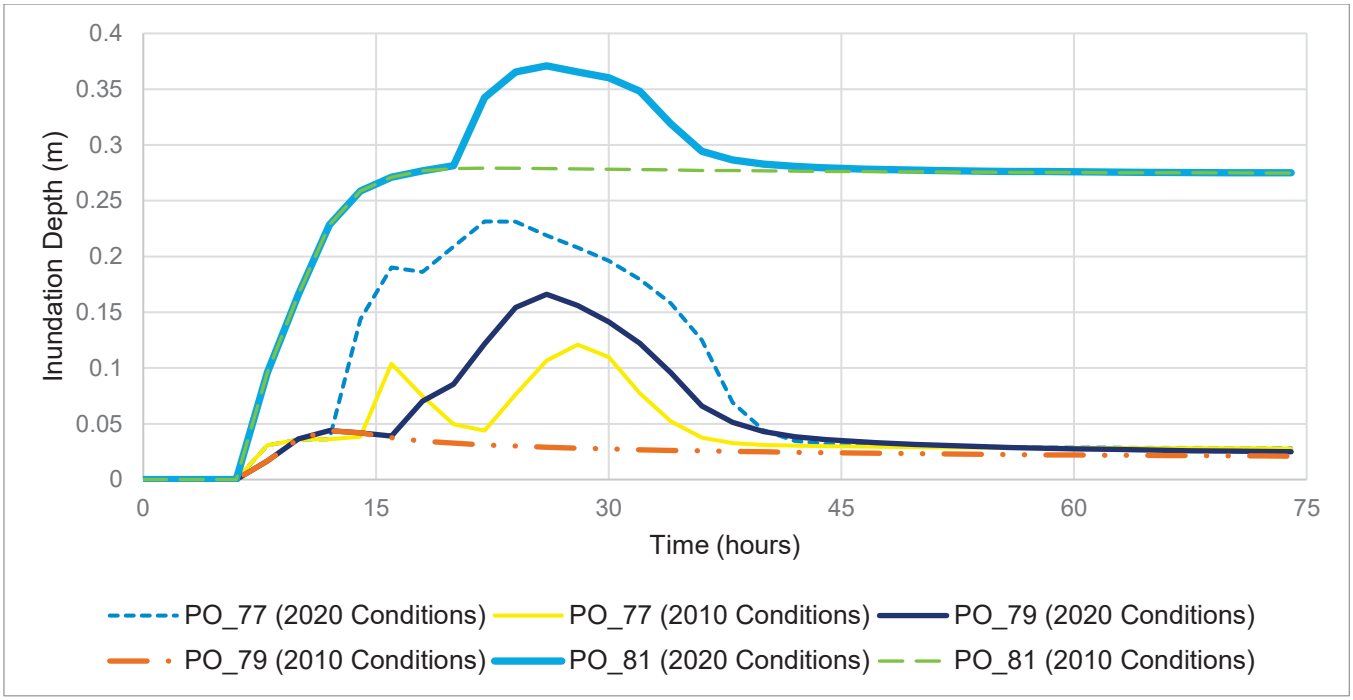


Figure 6.9: October 2020 Storm Event Timeseries Data (Depth versus Time) – comparison to Pre-developed Conditions

The comparison of the pre-development (2010) and existing development (2020) modelling of the October rainfall 2020 event predicts that if the October 2020 rainfall event had occurred in 2010, when the upstream development and associated drainage works had not occurred, the severity of inundation in the downstream area would have been less. Based on this, it can be concluded that the development that has occurred and the construction of the 600 mm diameter pipe from Officer South Drain to Lower Gum Scrub Creek, have contributed to increased inundation of downstream properties in frequent rainfall events such as the October 2020 rainfall event.

6.2.4 Future Development Conditions

The future developed conditions model reflects a scenario in which the full upstream catchment (north of Princes Freeway) is developed with proposed flow retardation assets as per Stormy Water Solution's future scenario RORB modelling and existing conditions are maintained in Officer South / Cardinia (south of Princes Freeway). This scenario has been run to estimate the future impact of inundation downstream of the Princes Freeway once all development within the study area's catchment north of Princes Freeway has occurred and the proposed DSS works (i.e., retarding basins based on the Stormy Water Solutions RORB model) within the Officer DSS, Upper Gum Scrub Creek DSS and Cardinia Road Drain DSS have been constructed. The October 2020 storm event has been used as a rainfall input for this scenario.

Appendix C contains inundation depth (including marked overland flow values at a selection of locations) and inundation difference (afflux, comparing the future development conditions scenario with existing conditions (2020) results for the October 2020 storm event) maps for the future development scenario.

As anticipated, the future development scenario results in increases to overland flows along Lower Gum Scrub Creek. Inundation depth increases of 80 to 110 mm are predicted within the properties of interest in this scenario, comparative to existing / baseline (2020) conditions. This is due to the increased residential development represented north of Princes Freeway, which results in a greater volume of runoff and increased peak flows being generated as compared to 2020 development conditions.

6.3 DESIGN STORM EVENTS

As the October 2020 storm event reflects a relatively minor storm event (approximately a 1 EY / 63.21 % AEP event), the following design storm events have also been run:

- 20 % AEP event

- Run for baseline / existing (2020) conditions
- Run for an alternate version of baseline / existing (2020) conditions with the 'farmer's diversion' at 395 Officer South Road, Officer South on Officer South Drain blocked off, so that flows preferentially run south towards Cardinia Creek
  - This scenario was modelled per direction from Melbourne Water who identified a lockable wooden gate at the western end of the southern branch of Lower Gum Scrub Creek, as identified Figure 6.10
  - When closed, this gate preferentially diverts flows south to continue along Officer South Drain to Cardinia Creek. Conversely, when open, flow from Officer South Drain can also flow east along the southern branch of Lower Gum Scrub Creek. Given the poor condition of the structure observed during the site visit, the assumption was made that under baseline conditions this gate does not exist, such that flows may run either south towards Cardinia Creek or east towards the main branch of Lower Gum Scrub Creek.
  - The alternate scenario assumes this gate is closed to preferentially send flows south to Cardinia Creek. Flows can still flow east towards Lower Gum Scrub Creek if they exceed the top of bank of Officer South Drain.
  - This blocked diversion scenario was not run for the October 2020 storm event as the peak flows being diverted east into the farmer's diversion are minimal (i.e. the peak flows diverted in the baseline October 2020 event are approximately 0.02 m^3/s, compared to 0.59 m^3/s running south along Officer South Drain to Cardinia Creek).

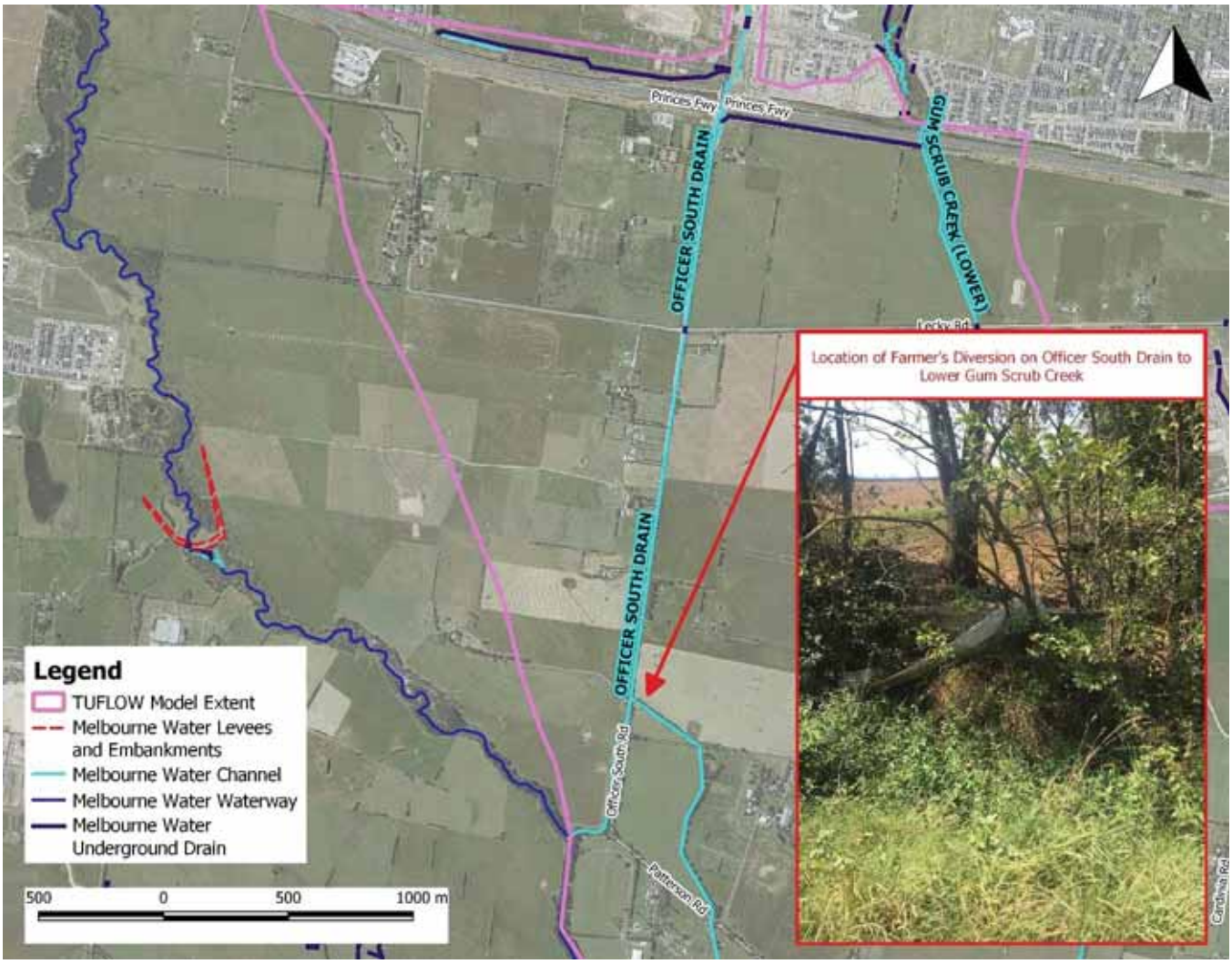


Figure 6.10: Overview of Farmer's Diversion (395 Officer South Road, Officer South) to Lower Gum Scrub Creek

- 10 % AEP event
  - Run for the baseline / existing (2020) conditions scenario only.

Each storm duration has been run for a single mid-loaded temporal pattern for all standard ARR 2019 durations between the 1 hour and 12 hour events, inclusive.

Inundation depth maps for the design event baseline / existing conditions scenarios are provided in **Appendix A** and include peak overland flow rates marked at various locations throughout the study area. In both the 20% AEP and 10% AEP design event, all four properties of interest are predicted to be subject to extensive inundation, with the triangular property immediately south of Fowler Road predicted to experience depths exceeding 500 mm in both the 20 % and 10 % AEP event.

Appendix D contains inundation depth and inundation difference / afflux maps for the baseline scenario inclusive of the blockage of the farmer's diversion at 395 Officer South Road, Officer South.

For the 20 % AEP design storm event, the modelling predicts that blocking of the farmer's diversion drain does not have an impact on peak inundation levels for the four properties of interest. Whilst blocking off the farmers' diversion does prevent flows tipping into Lower Gum Scrub Creek directly, the blocking of this diversion is also predicted to locally raise water levels such that immediately north and south of the blockage, some flows could overtop the eastern bank of Officer South Drain and spill into the properties on either side of the farmer's diversion. Figure 6.11 provides an afflux map, showing the change in inundation depth due to the blocking of the farmers diversion for the 20% AEP design storm event.

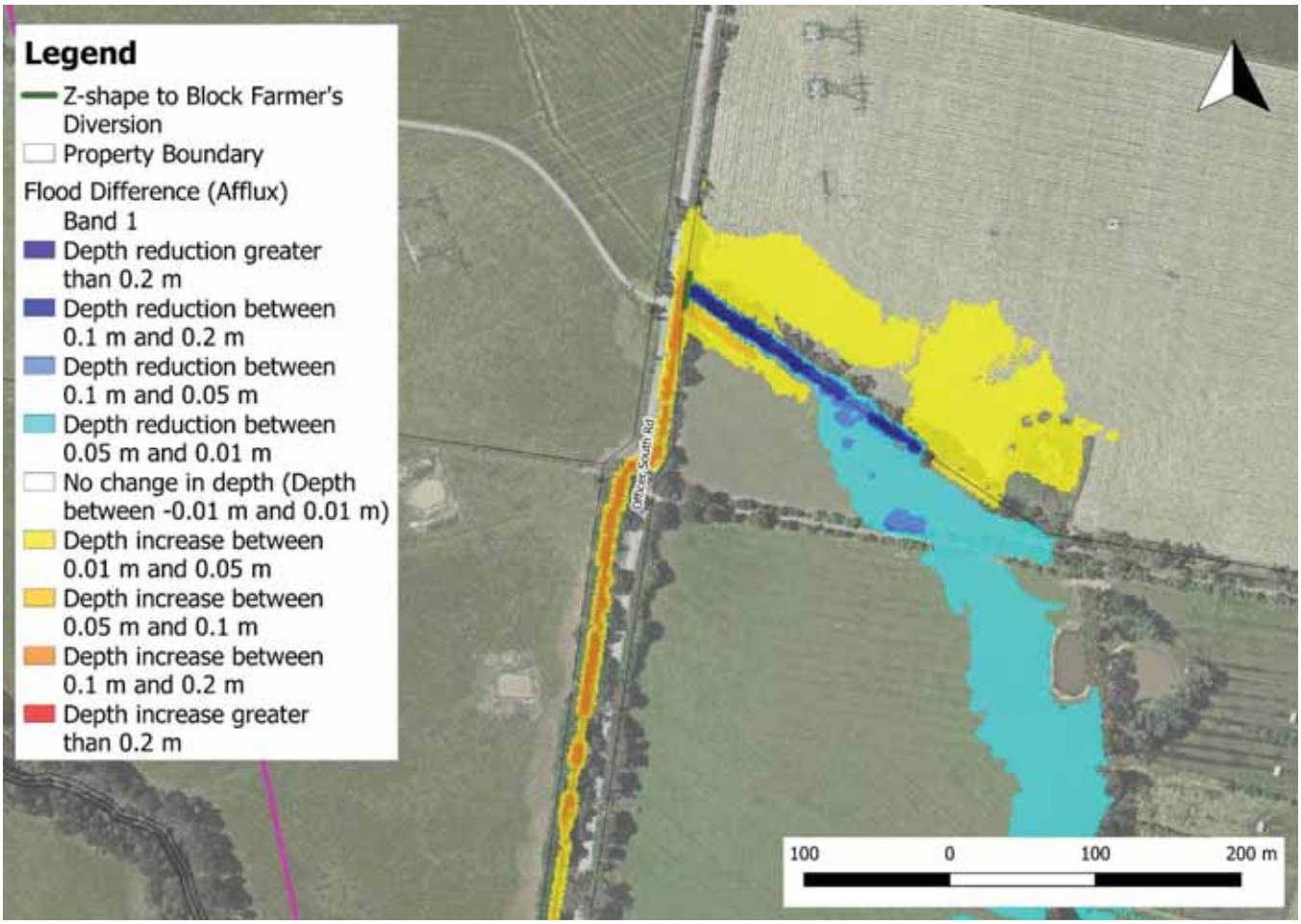


Figure 6.11: Inundation Difference (Afflux) of 20 % AEP Scenario with the Farmer's Diversion Gate at 395 Officer South Road, Officer South modelled as closed as compared to baseline (2020) scenario

7 OPTIONEERING INVESTIGATION

7.1 POTENTIAL MITIGATION OPTIONS

Upon completion of the preliminary modelling results for baseline, pre-developed and future development conditions, a meeting was held via MS Teams in June 2022 with various representatives of Melbourne Water to present the findings to date and discuss mitigation scenario options to be modelled. From this meeting, the following key items were discussed:

- Tom LeCerf (Melbourne Water) identified that the following works have already been undertaken, which were to be incorporated in any subsequent mitigation scenario to be run:
  - A gap in the levee, east of Bould Road, which had contributed to inundation of a property south of Lower Gum Scrub Creek, had been closed by reinstating the missing section at a similar level to the adjacent sections of the levee.
    - This was modelled via z-shape to close off the gap in the levee
  - Channel maintenance works had been undertaken in the downstream section of Lower Gum Scrub Creek to improve the waterway's conveyance capacity.
    - It was advised by Melbourne Water that the 'maintained' section was to be modelled with a Manning's n value of 0.045, reduced from the originally adopted value of 0.08 in existing conditions as based on site conditions prior to the maintenance works.
- Mitigation works would seek to preferentially direct flows southward along the Officer South Drain towards the Cardinia Creek outfall as a temporary measure, until ultimate drainage scheme works are constructed as part of the Officer South PSP. Options discussed included the following:
  - Implementation of a pit to replace the current headwall at the inlet to the 600 mm diameter pipe. This pit would only allow flow to enter the 600 mm diameter pipe once high flow depths occurred in the Officer South Drain, south of the Princes Freeway. This would reduce the volume of flow diverted towards Lower Gum Scrub Creek from Officer South Drain.
  - Conveyance of regular flows south along Officer South Drain, with a new pipe or a widening of the channel from south of the Princes Freeway to Lecky Road.
    - The existing physical constraints were considered in determining if a pipe or channel would be feasible in this situation. Particularly the requirements for land acquisition, the difference in invert levels between the waterway crossing Princes Freeway and the Officer Road Drain at Lecky Road and the safety considerations of putting a widened waterway adjacent to a roadway were all considered.
    - Accordingly, a new pipe has been adopted rather than a widened channel for safety and land acquisition cost considerations.
- The mitigation works proposed are intended to provide an interim reduction to the regular flow inundation experienced by the properties of interest along Lower Gum Scrub Creek until further development of the local and upstream drainage schemes is undertaken such that drainage assets proposed as part of these schemes can provide a long term solution, as well as managing the impacts of future development.
- Three alternate objectives were considered with regards to the benefit provided by the interim works to reduce regular flow inundation. These are outlined as follows:
  - Objective 1: Reduction of regular inundation in the subject properties to match 2010 pre-developed conditions for a 1 EY / 63.21 % AEP storm event (approximately equivalent to the October 2020 event).
  - Objective 2: Works to fully mitigate inundation in the subject properties for a 1 EY – 63.21 % AEP storm event (i.e. equivalent to the October 2020 rainfall event), so that flows are typically contained to Lower Gum Scrub Creek.
  - Objective 3: Provide a 0.5 EY (39.35 % AEP) to 1 EY (63.21 % AEP) level of service within Lower Gum Scrub Creek. Within the Koo Wee Rup Flood Protection District, local precept drains are generally maintained to provide a level of service with a 1 or 2 year ARI (63.21 % to 39.35 % AEP) (i.e. flows should be contained to the banks of the waterway in either a 1 or 2 year ARI (63.21 % to 39.35 % AEP) event, before spilling into the floodplain).

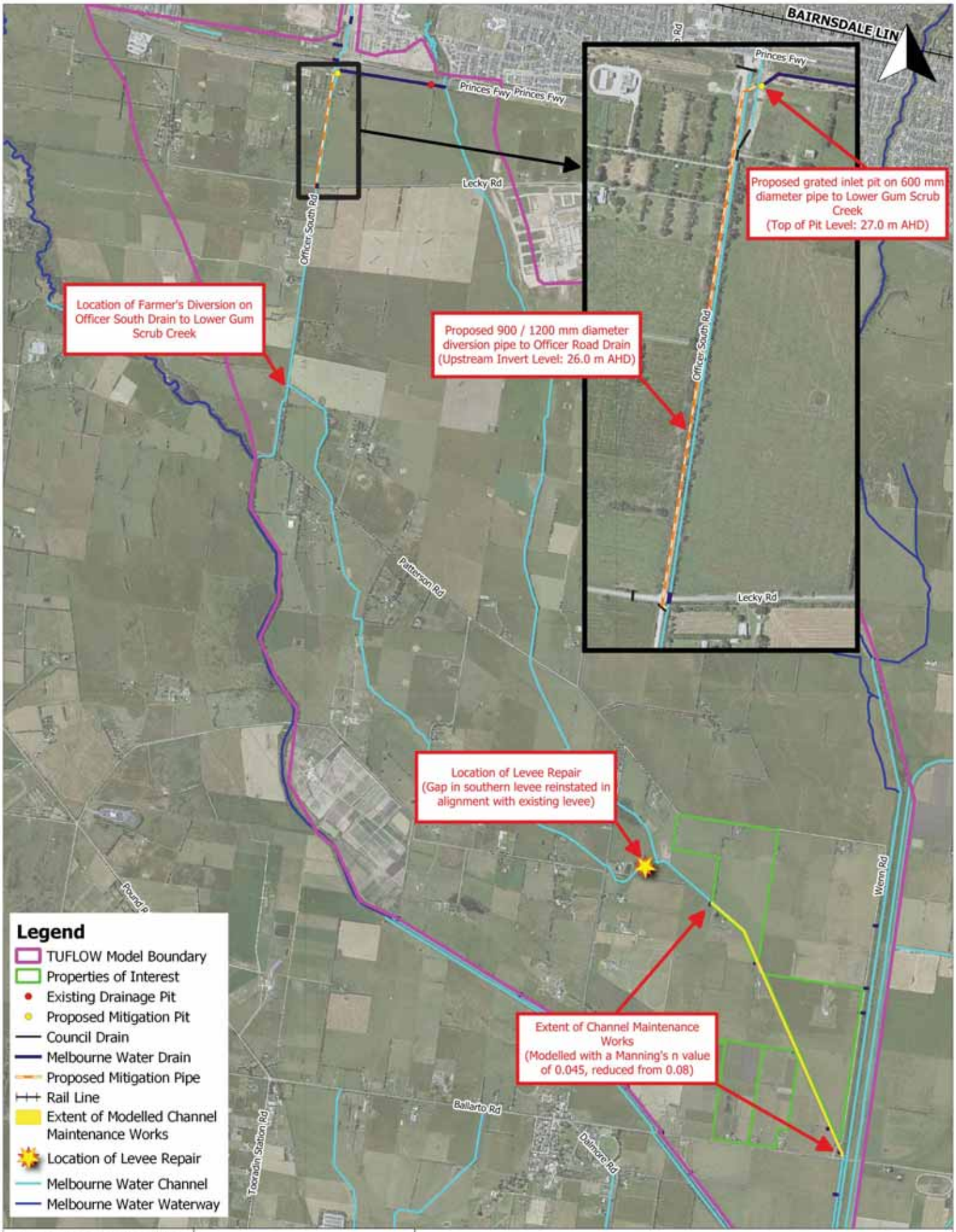
Three mitigation scenario options have been tested for the October 2020 rainfall event (assuming existing (2020) development levels), which are:

- Mitigation Option A, which includes:

  - Levee works to fix the gap in the levee (east of Bould Road) in the lower section of Lower Gum Scrub Creek.
  - Waterway maintenance works (vegetation removal) to increase the capacity of Lower Gum Scrub Creek.
  - Addition of an inlet pit to replace the current headwall at the inlet to the 600 mm diameter pipe from Officer South Drain to Lower Gum Scrub Creek
  - A new 900 mm pipe to preferentially direct flow to continue along Officer South Drain and reduce the volume of flow heading east via the 600 mm diameter pipe to Lower Gum Scrub Creek. The new 900 mm diameter pipe would start in the Officer South Drain, south of the Princes Freeway and discharge flow back into the Officer South Drain south of Lecky Road.

- Mitigation Option B, which includes the mitigation works proposed for Mitigation Option A, but with new Officer South Drain pipe increased from 900 mm diameter to a diameter of 1200 mm. This was proposed given that Melbourne Water had identified a possible re-use opportunity, for redundant pipes from a nearby area.
- Mitigation Option C, which includes the mitigation works proposed for Mitigation Option B, but also includes:
  - Blocking the ‘farmer’s diversion’ at 395 Officer South Road, Officer South so that flows within Officer South Drain preferentially flow south towards the Cardinia Creek outfall, rather than towards Lower Gum Scrub Creek.

Figure 7.1 provides a layout plan of the works proposed for the various mitigation option scenarios. To confirm that a 1200 mm diameter pipe is feasible given onsite considerations with regards to cover and invert requirements, Figure 7.2 provides a conceptual long-section of the proposed Officer South Drain pipe, as based on the modelled invert levels. This long-section identifies that sufficient cover is available. At this stage, an investigation into possible conflicting underground services within Officer South Road has not been undertaken.



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12182, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 8888 6978
F: 03 9630 2601
E: melb@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000 @ A3)

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

Officer South Interim Works Inundation Investigation

Figure 7.1
Mitigation Works Scenarios
Proposed Works Layout Plan

Job Number: V3000_128
Revision: 2
Drawn: VW
Checked: PC
Date: 26/6/2023

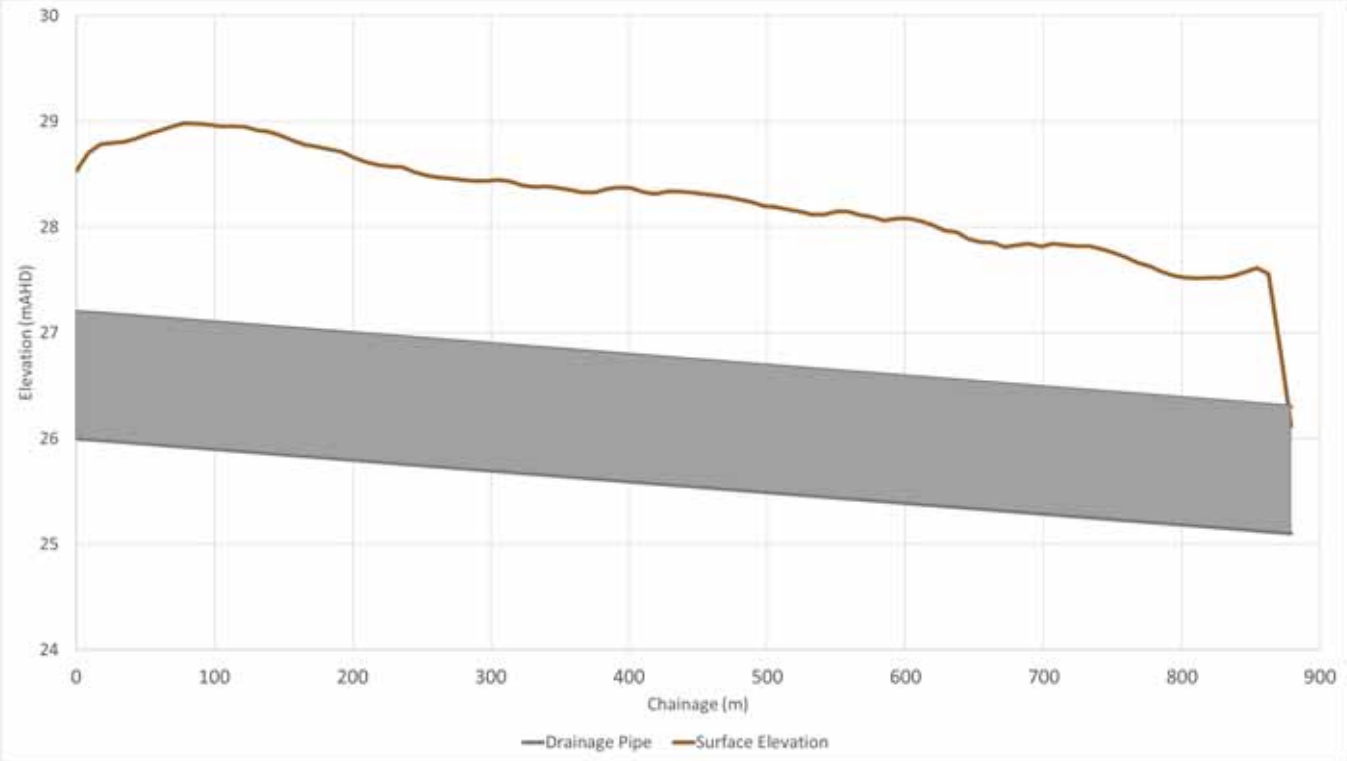


Figure 7.2: Concept long-section of Proposed 1200 mm Diameter Pipe for Mitigation Options B and C

7.2 MITIGATION SCENARIO OPTION A

Appendix E provides a copy of the inundation depth and afflux maps for Mitigation Scenario Option A, tested for the October 2020 rainfall event. Inundation difference (afflux) maps have been prepared for:

- The mitigation option modelled under existing (2020) development conditions compared to the existing drainage system under existing (2020) development conditions.
- The mitigation option modelled under existing (2020) development conditions compared to the existing drainage system under pre-developed (2010) development conditions. This map shows whether the proposed mitigation works can reduce the level of regular flow inundation of the properties along the downstream section of Gum Scrub Creek back to close to pre-development conditions (i.e., offset the impact of development that has occurred between 2010 and 2020).

In comparing this mitigation option to the baseline scenario, inundation depth decreases are predicted along the main branch of Lower Gum Scrub Creek, between Princes Freeway and Ballarto Road, with the two properties of interest north of Lower Gum Scrub Creek subject to inundation depth reductions of up to 150 mm due to the modelled works. For the two properties south of Lower Gum Scrub Creek, similar inundation depth reductions are noted along the drain running along the northern boundaries of these two properties.

As a result of conveying additional flows south along Officer South Drain, flows are predicted to break out of Officer South Drain and head east via the 'farmer's diversion' at 395 Officer South Road, Officer South (i.e., the southern branch of Lower Gum Scrub Creek), eventually joining back to the main branch of Lower Gum Scrub Creek, east of Cardinia Road. The peak flow within the farmer's diversion (as measured approximately 580 m downstream of the diversion) is estimated to be in the order of 0.37 m^3/s, increased from 0.02 m^3/s in baseline October 2020 conditions.

In comparing this mitigation option to the pre-developed conditions scenario, the proposed mitigation works are able to provide similar inundation levels to the pre-development conditions modelling within the properties of interest. A minor depth reduction of up to 25 mm is predicted in the northernmost property of interest.

In comparing the outcomes of Mitigation Option A to the three alternate mitigation objectives considered:

- Objective 1: Mitigation Option A achieves the objective of reducing inundation within the properties of interest to approximately replicate pre-developed conditions. Increased inundation however is predicted for a number of properties located along the southern branch of Lower Gum Scrub Creek, between Officer South Road and the confluence of the two branches of Lower Gum Scrub Creek east of Cardinia Road.
- Objective 2: Mitigation Objective 2 was to determine if inundation could be fully mitigated for the 1 EY (63.21 % AEP) storm event. Three of the four properties of interest are generally considered to have achieved this objective, with Lower Gum Scrub Creek not predicted to spill into the properties. For the northernmost property of interest, a minor area of inundation was still predicted in the southwest corner of the property in the October 2020 (~1 EY / 63.21 % AEP) event, however the inundation depths were predicted to be significantly reduced (generally predicted to be below 100 mm in depth).
- Objective 3: Mitigation Objective 3 was to determine if a 1-2 year ARI (63.21 % to 39.35 % AEP) level of service could be provided for Lower Gum Scrub Creek (in line with the general recommendations for local precept drains within the Koo Wee Rup Flood Protection district). For the sections of Lower Gum Scrub Creek adjacent to the properties of interest, this is generally achieved, however flow is still predicted to exceed the capacity of Lower Gum Scrub Creek and spill into the adjacent properties upstream of this area. The increased diversion of flows south along Officer South Drain increases the breakout of flows along the southern branch of Lower Gum Scrub Creek via the farmer's diversion.

7.3 MITIGATION SCENARIO OPTION B

Mitigation Option B is the same as Mitigation Option A, with the one difference being the sizing of the proposed pipe along Officer South Road. The pipe diameter has been increased from 900 mm (in Mitigation Option A) to 1200 mm (in Mitigation Option B). **Appendix F** presents the inundation depth and afflux maps for Mitigation Scenario Option B. The inundation difference (afflux) maps have been prepared comparing the mitigation option to baseline / existing development conditions and to pre-development conditions.

Mitigation Scenario B and Mitigation Option A predict near identical inundation level reductions of up to approximately 150 mm within all four properties of interest compared to baseline conditions for the October 2020 storm event. As a result of Mitigation Option B diverting additional flows south along Officer South Drain compared to Mitigation Option A, the peak flow at the farmer's diversion at 395 Officer South Road, Officer South is predicted to increase to be in the order of 0.68 m^3/s, increased from 0.02 m^3/s in baseline October 2020 conditions and 0.37 m^3/s in Mitigation Option A.

In comparing the outcomes of Mitigation Option B to the three alternate mitigation objectives considered:

- Objective 1: Similar to Mitigation Option A, Mitigation Option B achieves the objective of reducing inundation within the properties of interest to approximately replicate pre-developed conditions. Increased inundation however is predicted for a number of properties located along the southern branch of Lower Gum Scrub Creek, between Officer South Road and the confluence of the two branches of Lower Gum Scrub Creek east of Cardinia Road.
- Objective 2: Mitigation Objective 2 was to determine if inundation could be fully mitigated for the 1 EY (63.21 % AEP) storm event. As per Mitigation Option A, in Mitigation Option B three of the four properties of interest are generally considered to have achieved this objective, with Lower Gum Scrub Creek not predicted to spill into the properties. For the northernmost property of interest, a minor area of inundation was still predicted in the southwest corner of the property in the 1 EY event, however the inundation depths were predicted to be significantly reduced (generally predicted to be below 100 mm in depth).
- Objective 3: Mitigation Objective 3 was to determine if a 1-2 year ARI (39.35 % to 63.21 % AEP) level of service could be provided for Lower Gum Scrub Creek (in line with the general recommendations for local precept drains within the Koo Wee Rup Flood Protection district). For the sections of Lower Gum Scrub Creek adjacent to the properties of interest, this is generally achieved, however flow is still predicted to exceed the capacity of Lower Gum Scrub Creek and spill into the adjacent properties upstream of this area. Similar to Mitigation Option A, the increased flow south along Officer South Drain increases the breakout of flows along the southern branch of Lower Gum Scrub Creek via the farmer's diversion, with a notable increase in peak flows through the farmers diversion from 0.02 m^3/s (baseline conditions) to 0.37 m^3/s (Mitigation Option A) and 0.68 m^3/s in Mitigation Option B.

7.4 MITIGATION SCENARIO OPTION C

Mitigation Option C is the same as Mitigation Option B, with the inclusion of blocking off the farmers diversion drain to preferentially convey flow in a southerly direction towards Cardinia Creek rather than travelling eastward to the properties of interest. **Appendix G** presents the inundation depth and afflux maps for Mitigation Scenario Option C. The inundation depth difference (afflux) maps have been prepared comparing the mitigation option to baseline / existing development conditions and pre-developed conditions.

For the October 2020 storm event, Mitigation Scenario C predicts inundation level reductions of up to approximately 150 mm within all four properties of interest compared to baseline conditions. This is similar to both Mitigation Option A and B. As a result of blocking off the farmer's diversion on Officer South Drain (at 395 Officer South Road, Officer South), a reduced peak flow of 0.31 m^3/s is predicted to flow along the southern branch of Lower Gum Scrub Creek (as compared to Mitigation Option B where a peak flow of 0.68 m^3/s was predicted). This is still noted as an increase compared to baseline conditions (0.02 m^3/s) and results from flow overtopping the eastern bank of Officer South Drain on either side of the blocked diversion and spilling back into the lower branch of Lower Gum Scrub Creek. Figure 7.3 provides an overview the afflux plot (Mitigation Scenario C compared to Baseline 2020 conditions), focusing on the area of the farmer's diversion at 395 Officer South Road, Officer South.

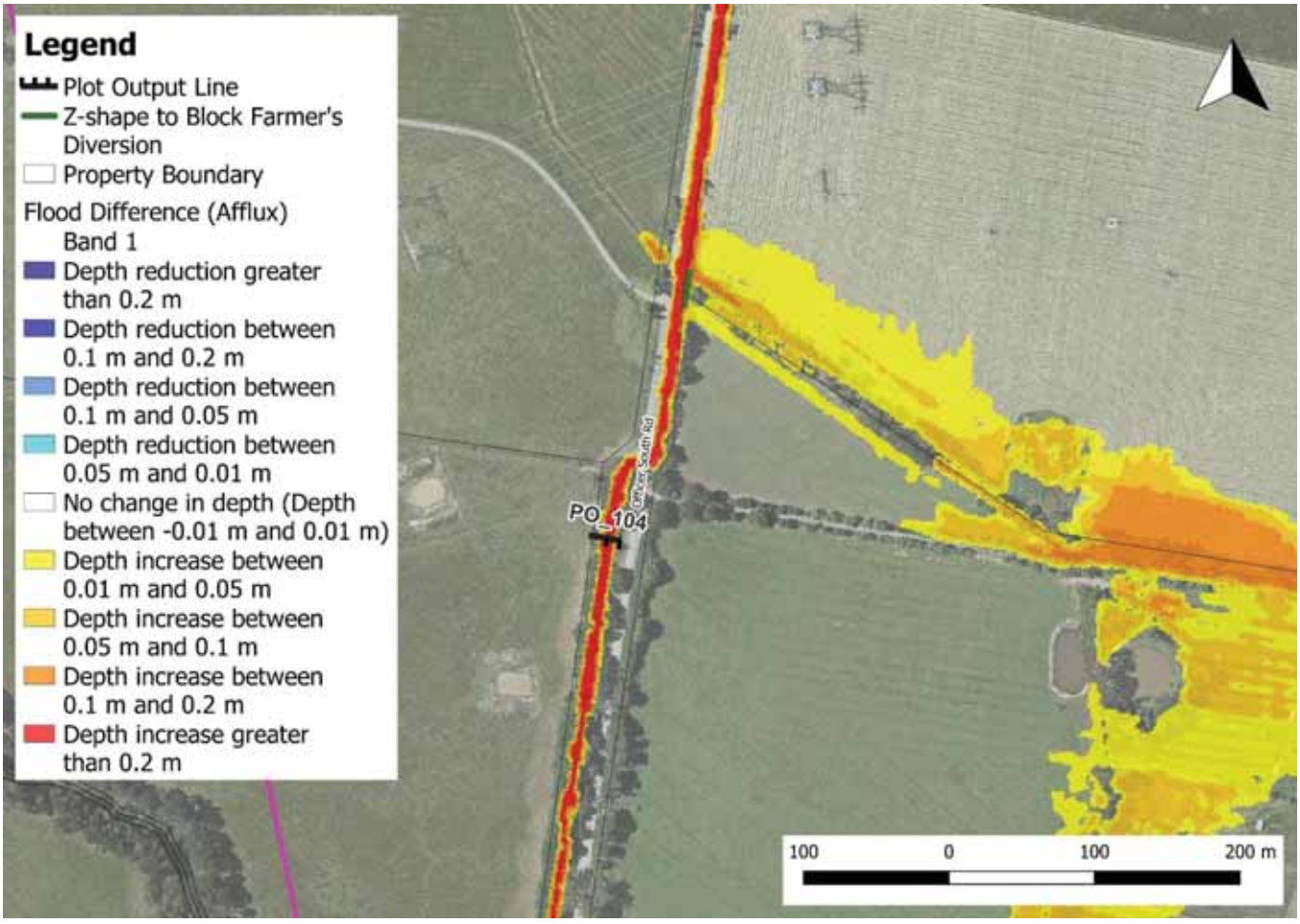


Figure 7.3: Inundation difference (Afflux) Plot showing flow overtopping from Officer South Drain into the lower branch of Lower Gum Scrub Creek (Mitigation Scenario C minus Baseline 2020 Conditions)

In comparing the outcomes of Mitigation Option C to the three alternate mitigation objectives considered:

- Objective 1: As per the previous two mitigation options, Mitigation Option C achieves the objective of reducing inundation within the properties of interest to approximately replicate pre-developed conditions. Increased inundation however is predicted for a number of properties located along the southern branch of Lower Gum Scrub Creek, between Officer South Road and the confluence of the two branches of Lower Gum Scrub Creek east of Cardinia Road. The afflux along these

properties is reduced compared to Mitigation Option B (due to blocking the farmer's diversion), but slightly greater than Mitigation Option A due to the increased volume of flow diverted in the 1200 mm diameter drain (as compared to the 900 mm diameter drain in Mitigation Option A).

- Objective 2: Mitigation Objective 2 was to determine if inundation could be fully mitigated for the 1 EY (63.21 % AEP) storm event. As per the previous mitigation scenarios, in Mitigation Option C three of the four properties of interest are generally considered to have achieved this objective, with Lower Gum Scrub Creek not predicted to spill into the properties. For the northernmost property of interest, a minor area of inundation was still predicted in the southwest corner of the property in the 1 EY (63.21 % AEP) event, however the inundation depths were predicted to be significantly reduced (generally anticipated to be below 100 mm in depth).
- Objective 3: Mitigation Objective 3 was to determine a 1-2 year ARI level of service could be provided for Lower Gum Scrub Creek (in line with the general recommendations for local precept drains within the Koo Wee Rup Flood Protection district). For the sections of Lower Gum Scrub Creek adjacent to the properties of interest, this is generally achieved, however flow is still predicted to exceed the capacity of Lower Gum Scrub Creek and spill into the adjacent properties upstream of this area. Similar to the other mitigation options, the increased flow south along Officer South Drain increases the breakout of flows along the southern branch of Lower Gum Scrub Creek via the farmer's diversion, with a notable increase in peak flows from 0.02 m^3/s (baseline conditions) to 0.31 m^3/s (Mitigation Option C).

7.5 GENERAL COMMENTS REGARDING ALL MITIGATION OPTIONS ASSESSED

As previously noted, three alternate mitigation objectives were considered:

- Objective 1: Reduction of inundation in the subject properties to match 2010 pre-developed conditions for a 1 EY (63.21 % AEP) storm event (approximately equivalent to the October 2020 event).
- Objective 2: Works to fully mitigate inundation in the subject properties for a 1 EY (63.21 % AEP) storm event (i.e., equivalent to the October 2020 event).
- Objective 3: Provide a 1-2 year ARI (63.21 % to 39.35 % AEP) level of service within Lower Gum Scrub Creek (flows to be contained to within the banks of the precept drain as per the general recommendations for assets within the Koo Wee Rup Flood Protection District).

All three mitigation options tested were largely able to achieve Objectives 1 and 2 as relating to inundation within the properties of interest. It is noted however that even in pre-developed conditions, Objective 3 is generally not met for Lower Gum Scrub Creek between Princes Freeway and Wenn Road.

All three mitigation options also result in an increased inundation in and adjacent to the southern branch of Lower Gum Scrub Creek, due to the increased flows conveyed south along Officer South Drain (and then east via the farmer's diversion at 395 Officer South Road, Officer South). It is recommended that Melbourne Water consider if this increase is appropriate (given this scope largely encompassing interim works until the development of the Officer South DS and Lower Gum Scrub Creek DS is undertaken). If this increase in inundation is not considered appropriate, further assessment of potential drainage works are recommended and may include but are not limited to proposed storages within the study area and channel works on Officer South Drain to improve conveyance of flows through to Cardinia Creek.

With regards to the volume of flow conveyed eastward to Lower Gum Scrub Creek via the 600 mm diameter drain, Figure 7.4 provides an overview of the peak flow hydrographs in each of the modelled scenarios. The results show that the predicted peak flow rate in the 600 mm pipe is relatively consistent for all three options and baseline conditions. The volume of flow conveyed is significantly reduced in all mitigation scenarios (as compared to the Baseline 2020 scenario), resulting the reduced inundation of the properties at the downstream end of Lower Gum Scrub Creek.

With regards to the increased conveyance of flows towards Cardinia Creek along the Officer South Drain, Figure 7.5 provides an overview of the predicted changes to peak flows that would have occurred for the October 2020 rainfall event (approximately a 63.21 % AEP event) if the three mitigation options were implemented. Flows are compared south of the farmer's diversion at PO_104 (location as depicted previously in Figure 7.3). Notably, Mitigation Scenario C (which includes the blockage of the farmer's diversion) results in the greatest increase in peak flows along Officer Road Drain.

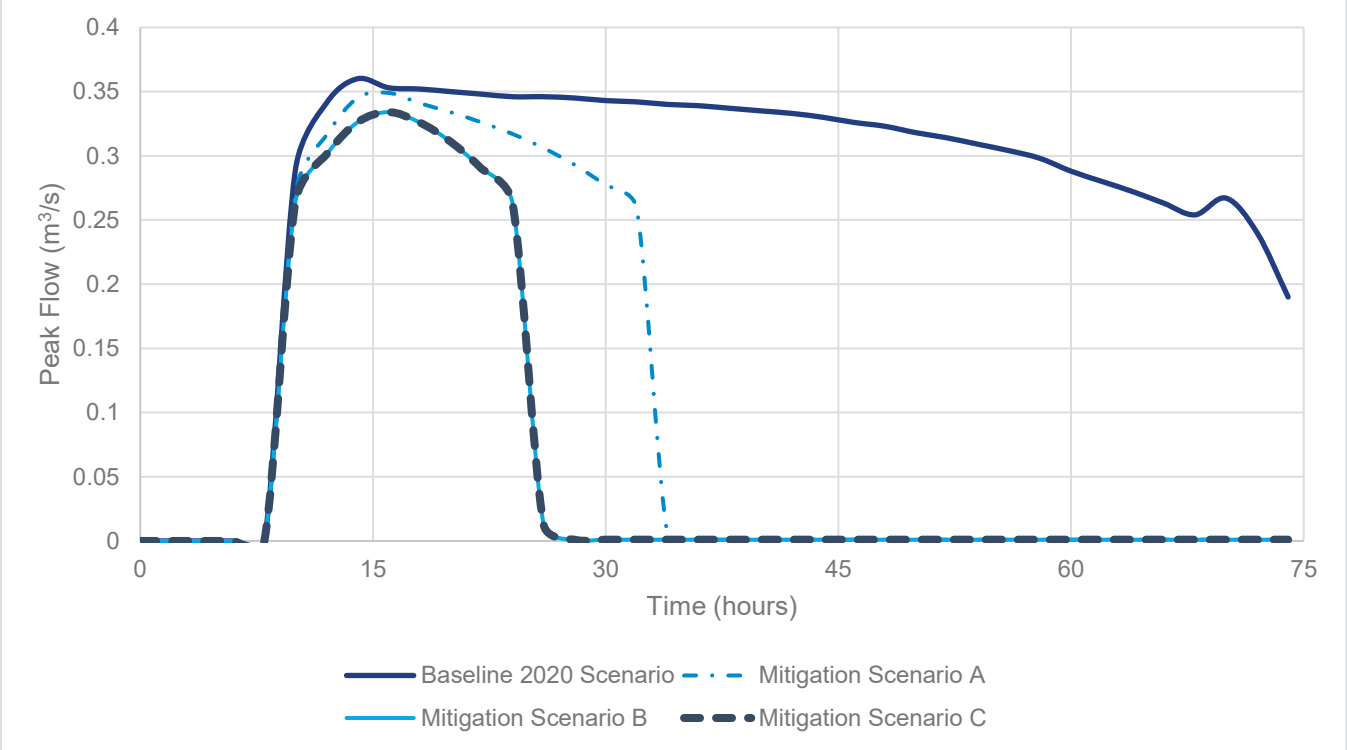


Figure 7.4: 600 mm diameter Pipe from Officer South Drain to Gum Scrub Creek Peak Flow Hydrograph – October 2020 Event (63.21 % AEP)

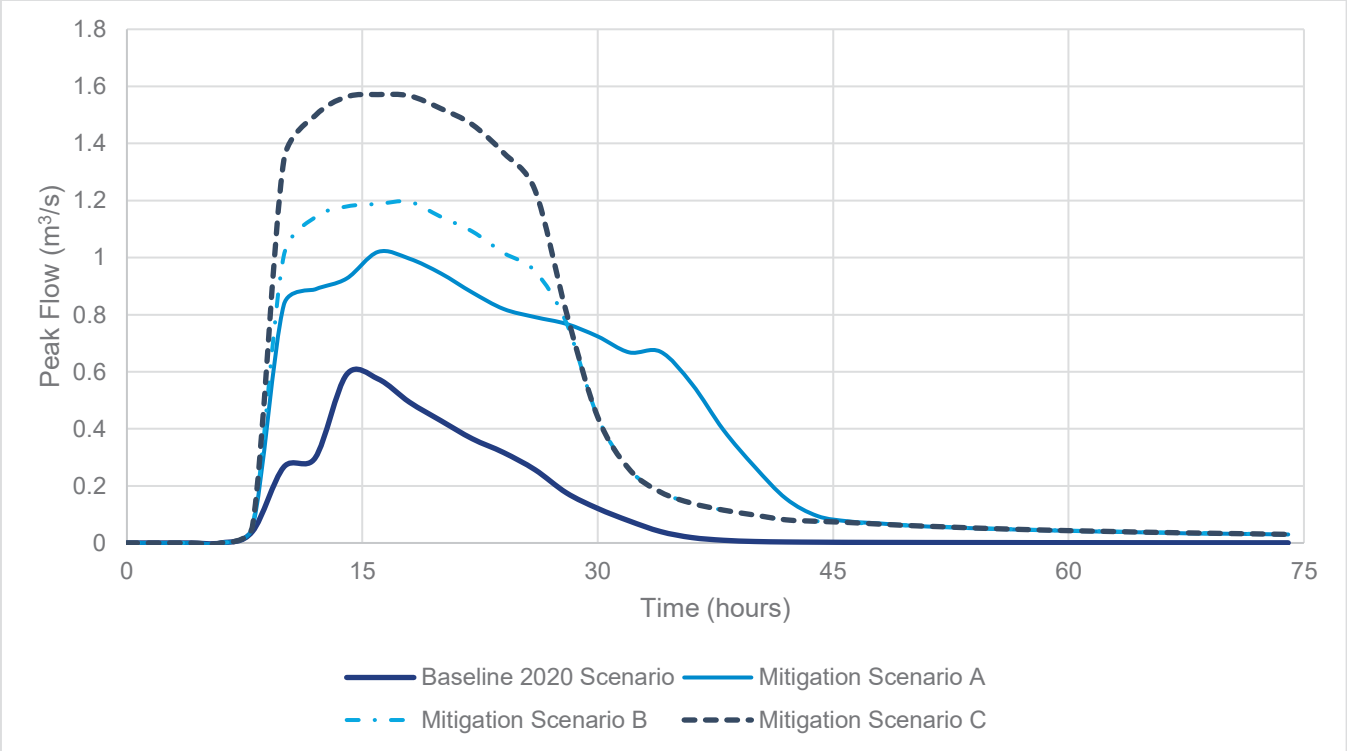


Figure 7.5: Officer South Drain Peak Flow Hydrographs at PO_104 (south of the Farmer's Diversion at 395 Officer South Road, Officer South) – October 2020 Event (63.21 % AEP)

8 CONCLUSIONS AND RECOMMENDATIONS

Engeny provides the following key conclusions following this investigation:

1. Engeny has reviewed and used the information provided by Melbourne Water to develop a hydraulic model that closely reflects anecdotal evidence observed during the October 2020 storm event, in accordance with ARR 2019 guidelines and methodologies.
2. Engeny has determined inundation patterns for existing / baseline (2020), pre-development (2010) and future development conditions (including full development of all PSPs / DSSs upstream of Princes Freeway) scenarios and analysed the modelling results to identify mitigation options to reduce the magnitude and frequency of inundation to the key properties of interest. This modelling was undertaken for both the October 2020 storm event (approximately equal to a 1 EY / 63.21 % AEP event) as well as 20 % and 10 % AEP design storm events.
3. Modelling of the different development scenarios for the October 2020 storm event (63.21 % AEP event) is summarised as follows:
    a) Modelling of the October 2020 storm event was completed for three development scenarios, baseline (2020 conditions), pre-developed (2010) conditions and future development conditions.
    b) Peak inundation depths are predicted to have increased by up to 120 mm within the properties of interest under the baseline development (2020) conditions compared to pre-development (2010) conditions. This is attributable to the increased stormwater runoff from the development of catchments upstream of Princes Freeway, alongside the implementation of a 600 mm drain from Officer South Drain to Lower Gum Scrub Creek. In some locations, predicted peak overland flow rates along Lower Gum Scrub Creek have doubled between 2010 (pre-developed) and 2020 (baseline) scenarios.
    c) Peak inundation depths are predicted to increase by up to 110 mm within the properties of interest under future development conditions compared to baseline development (2020) conditions as a result of continued development upstream increasing the volume of stormwater runoff. The modelled scenario for future development conditions assumes that the 600 mm diameter pipe from Officer South Drain to Lower Gum Scrub Creek is retained and that works are not completed along Officer South Drain to improve its conveyance capacity through to Cardinia Creek.
    d) The modelling is consistent with the anecdotal evidence that the properties of interest are inundated for extended periods following regular rainfall events (the October 2020 event being approximately equivalent to a 63.21 % AEP event). Specifically, the model predicts that a number of localised depressions in the landform are not drained by gravity back to Lower Gum Scrub Creek. The residual inundation in these low points would be expected to infiltrate or evaporate over time and may persist for long periods following a rainfall event. As evaporation and infiltration processes are not represented within the TUFLOW model, the expected full period of inundation could not be determined. The duration of inundation would be influenced by ground, climatic and downstream tailwater conditions both preceding and following the rainfall event. For example, wet conditions preceding a rainfall event could extend the duration of inundation of properties (as the water table may be raised and therefore infiltration rates may be reduced). Similarly, if the water levels within the receiving waterways remain elevated for an extended period (e.g., a high tide causing a backwater effect within the downstream channels), the ability for the Gum Scrub Creek to outfall would be limited which in turn may extend the duration of inundation experienced.
4. Modelling of design storm events was completed for the 20 % and 10 % AEP events for existing / baseline (2020) development conditions.
    a) Significant inundation exceeding 0.5 metres in depth is predicted within parts of the four properties of interest in both a 20 % and 10 % AEP flood event.
    b) Near the southern end of Officer South Drain, a farmer's diversion at 395 Officer South Road, Officer South conveys a portion of flows east along the southern branch of Lower Gum Scrub Creek. A scenario was run for the 20 % AEP event where this diversion was blocked off to preferentially send flows south to Cardinia Creek. No changes to peak depths of inundation within the properties of interest was noted by blocking off this diversion. The model predicts that blocking the diversion structure would result in the water level rising within Officer South Drain to the immediate north and south

of the diversion such that flows are predicted to overtop the eastern bank of Officer South Drain and flow east regardless of whether the farmer's diversion is open or blocked.

5. There alternate objectives were considered with regards to the benefits offered by the mitigation scenarios:
   a) Objective 1: Reduction of regular inundation in the subject properties to match 2010 pre-developed conditions for a 1 EY (63.21 % AEP) storm event (approximately equivalent to the October 2020 event).
   b) Objective 2: Works to fully mitigate inundation in the subject properties for a 1 EY (63.21 % AEP) storm event (i.e. equivalent to the October 2020 event)
   c) Objective 3: Provide a 1-2 year ARI (63.21 % to 39.35 % AEP) level of service within Lower Gum Scrub Creek (flows to be contained to within the banks of the precept drain as per the general recommendations for assets within the Koo Wee Rup Flood Protection District).

6. Modelling of three mitigation options was completed for the October 2020 event, each including some maintenance and levee repair works along Lower Gum Scrub Creek (for the section downstream of the confluence of the two branches of the creek), alongside diversion drainage works on Officer South Drain near Princes Freeway. The works proposed and the key outcomes are summarised as follows:
   a) Mitigation Option A included a 900 mm diversion pipe from the widened section of Officer South Drain through to Lecky Road to preferentially direct flows to continue south along Officer South Drain.
      i) The works facilitate reductions to flow in Lower Gum Scrub Creek as compared to baseline (2020) conditions, but the peak levels in Lower Gum Scrub Creek are still noted to be greater than in pre-developed (2010) conditions between Princes Freeway and the confluence of the two branches of Lower Gum Scrub Creek.
      ii) Reductions of up to 150 mm are noted in the four properties of interest as compared to baseline conditions. The inundation levels within all four properties of interest under this mitigation option are similar to pre-developed conditions.
      iii) A portion of the increased flows directed south along Officer South Drain is diverted east along the southern branch of Lower Gum Scrub Creek via the farmer's diversion, increasing peak flows through the farmer's diversion from 0.02 m^3/s (baseline conditions) to 0.37 m^3/s. This results in increased inundation of a number of properties between Officer South Road and Cardinia Road, through which the southern branch of Lower Gum Scrub Creek traverses.
   b) Mitigation Option B modelled the diversion drain to Lecky Road as a 1200 mm diameter pipe, given a possible re-use opportunity of redundant assets from a nearby area.
      i) Within the properties of interest, this mitigation option produces relatively similar reductions in inundation depth (of up to 150 mm as compared to Option A) and a similar inundation extent to pre-developed conditions.
      ii) The increased volume of flow directed south along Officer South Drain (via the 1200 mm diameter diversion pipe) results in an estimated increased peak flow in the southern branch of Lower Gum Scrub Creek of up to 0.68 m^3/s, with increased inundation of the properties adjacent to this waterway comparative to Mitigation Option A as a result.
   c) Mitigation Option C comprised the same works as Mitigation Option B, but with the farmer's diversion at 395 Officer South Road, Officer South on Officer South Drain blocked off to preferentially convey flow south towards Cardinia Creek.
      i) Within the properties of interest, the inundation depths predicted for Mitigation Option C are very similar to Mitigation Options A and B, producing inundation levels similar to pre-developed (2010) conditions for the October 2020 rainfall event.
      ii) The blocking of the farmer's diversion reduces flow in the southern branch of Lower Gum Scrub Creek to around 0.31 m^3/s which is reduced comparative to Mitigation Option B, but still an increase compared to baseline conditions.
   d) All mitigation options were considered to reasonably achieve Objectives 1 and 2 (reducing inundation within the properties of interest to pre-developed conditions / effectively mitigating inundation in an event equivalent to the 1 EY (63.21 % AEP) event). Objective 3 (containing the 1-2 year ARI (63.21 % to 39.35 % AEP) event to the banks of Lower Gum Scrub Creek) was generally achieved within the immediate vicinity of the properties of interest, however breakout flow was still noted to occur upstream of this area. All mitigation options were also noted to increase inundation along the southern branch of Lower Gum Scrub Creek due to the increase flow into this branch from Officer South Drain via the farmer's diversion at 395 Officer South Road, Officer South.

Engeny provides the following key recommendations following this investigation for Melbourne Water's consideration:

1. Melbourne Water to consider if the benefit provided by the proposed mitigation works are justified against the increased flows conveyed along and adjacent to the southern branch of Lower Gum Scrub Creek. It should be noted that these works are proposed only as an interim measure until the development of the Officer South DSS and Lower Gum Scrub Creek DSS.
2. Should the increased flows not be considered acceptable, Melbourne Water may need to consider alternate options, which may include, but are not limited to, the provision of interim retarding basins or other flood storage assets to manage the peak flows predicted throughout the catchment and / or channel works along Officer South Drain and / or Lower Gum Scrub Creek to increase conveyance capacity.
3. This study has focused on a minor (approximately 1 EY (63.21 % AEP)) storm event. It is suggested that Melbourne Water tests the mitigation works for other standard design storm events to ensure no undesirable outcomes occur.
4. All hydraulic modelling incorporates a level of uncertainty. Sensitivity testing could be undertaken to understand how higher or lower boundary condition levels influence inundation in the subject properties, particularly for the design storm events.

9 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:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or
   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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

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

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

g) This Report does not provide legal advice.

10 REFERENCES

Brisbane City Council, November 2003, Natural Channel Design Guidelines, Issue B.

Melbourne Water, July 2020, Flood Mapping Projects Specification.

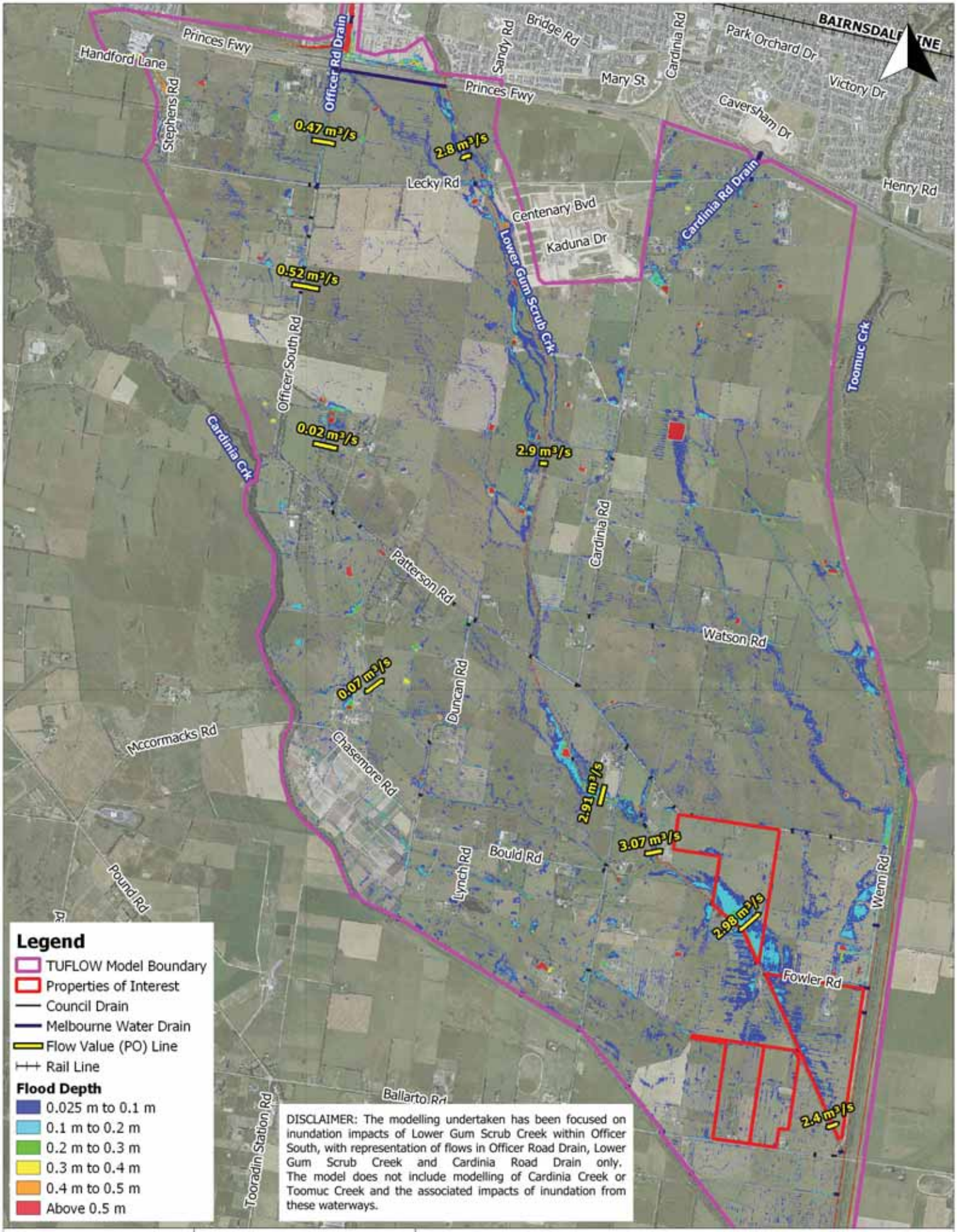
Melbourne Water Corporation, November 2018, Flood Mapping Projects Guidelines and Technical Specifications Version 9: Final.

Stormy Water Solutions, January 2021, Cardinia Outfall System – Event Based Hydrologic Modelling.

Victorian Regional Channels Authority (VCRA), 2020, VIC Tides 2020, Edition 4.

ENGENY
WATER MANAGEMENT

Appendix A:
Existing Conditions Inundation Maps



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9866 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

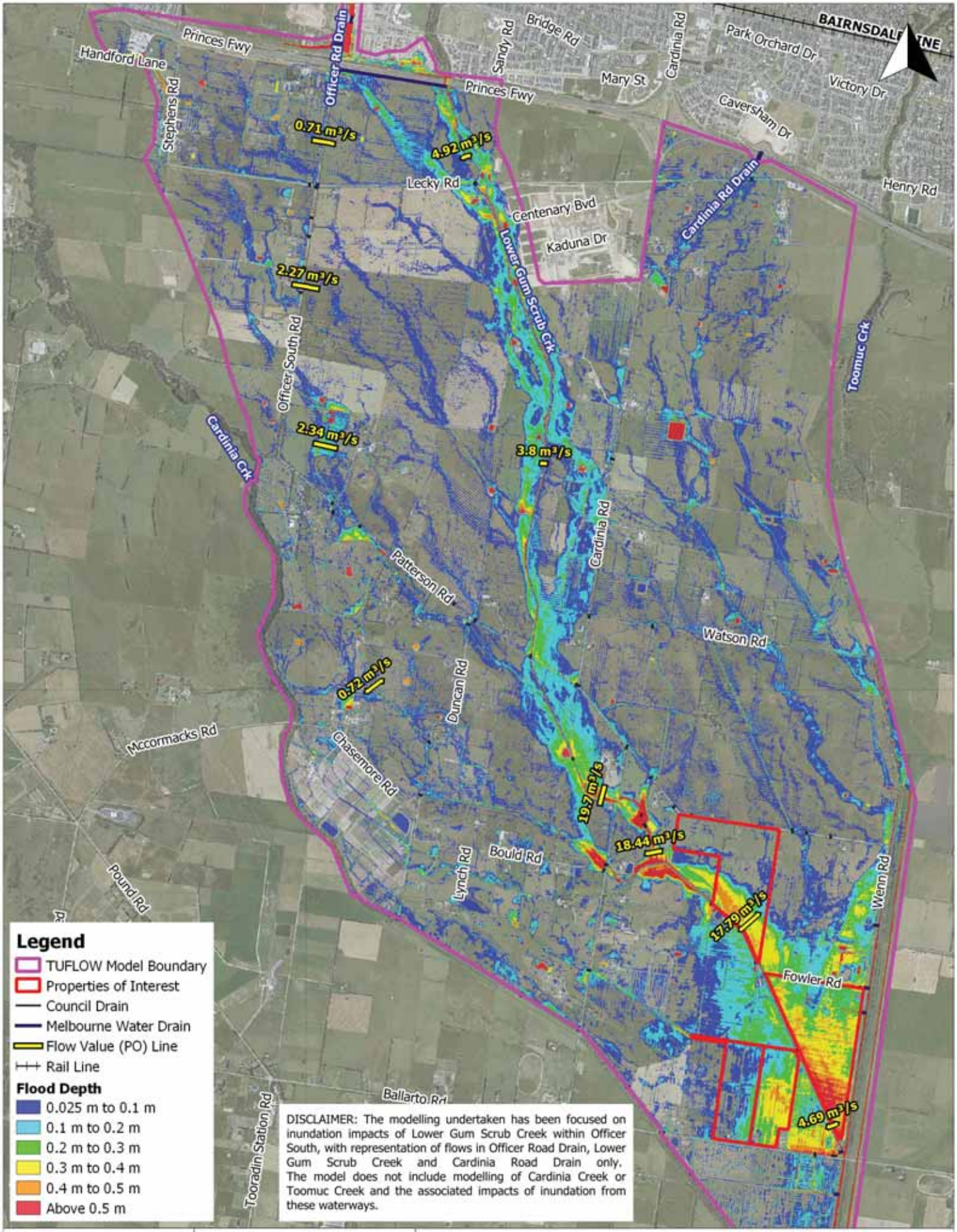
Scale in metres (1:25,000 @ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Legend

- TUFLOW Model Boundary
- Properties of Interest
- Council Drain
- Melbourne Water Drain
- Flow Value (PO) Line
- Rail Line

Flood Depth

- 0.025 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

DISCLAIMER: The modelling undertaken has been focused on inundation impacts of Lower Gum Scrub Creek within Officer South, with representation of flows in Officer Road Drain, Lower Gum Scrub Creek and Cardinia Road Drain only. The model does not include modelling of Cardinia Creek or Toomuc Creek and the associated impacts of inundation from these waterways.

Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

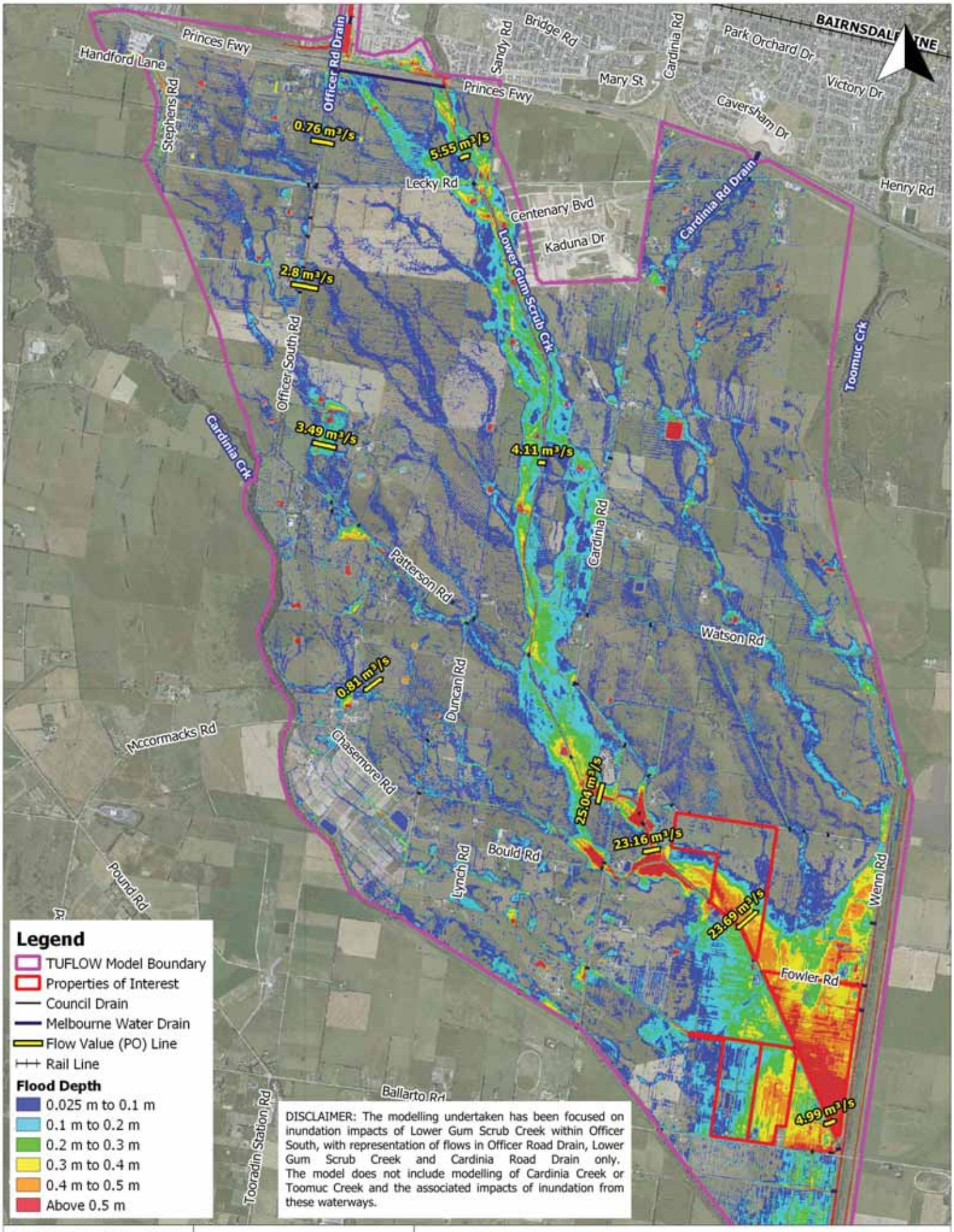
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

20 % AEP Peak Inundation Depth
Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Legend

- TUFLOW Model Boundary
- Properties of Interest
- Council Drain
- Melbourne Water Drain
- Flow Value (PO) Line
- Rail Line

Flood Depth

- 0.025 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

DISCLAIMER: The modelling undertaken has been focused on inundation impacts of Lower Gum Scrub Creek within Officer South, with representation of flows in Officer Road Drain, Lower Gum Scrub Creek and Cardinia Road Drain only. The model does not include modelling of Cardinia Creek or Toomuc Creek and the associated impacts of inundation from these waterways.

Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

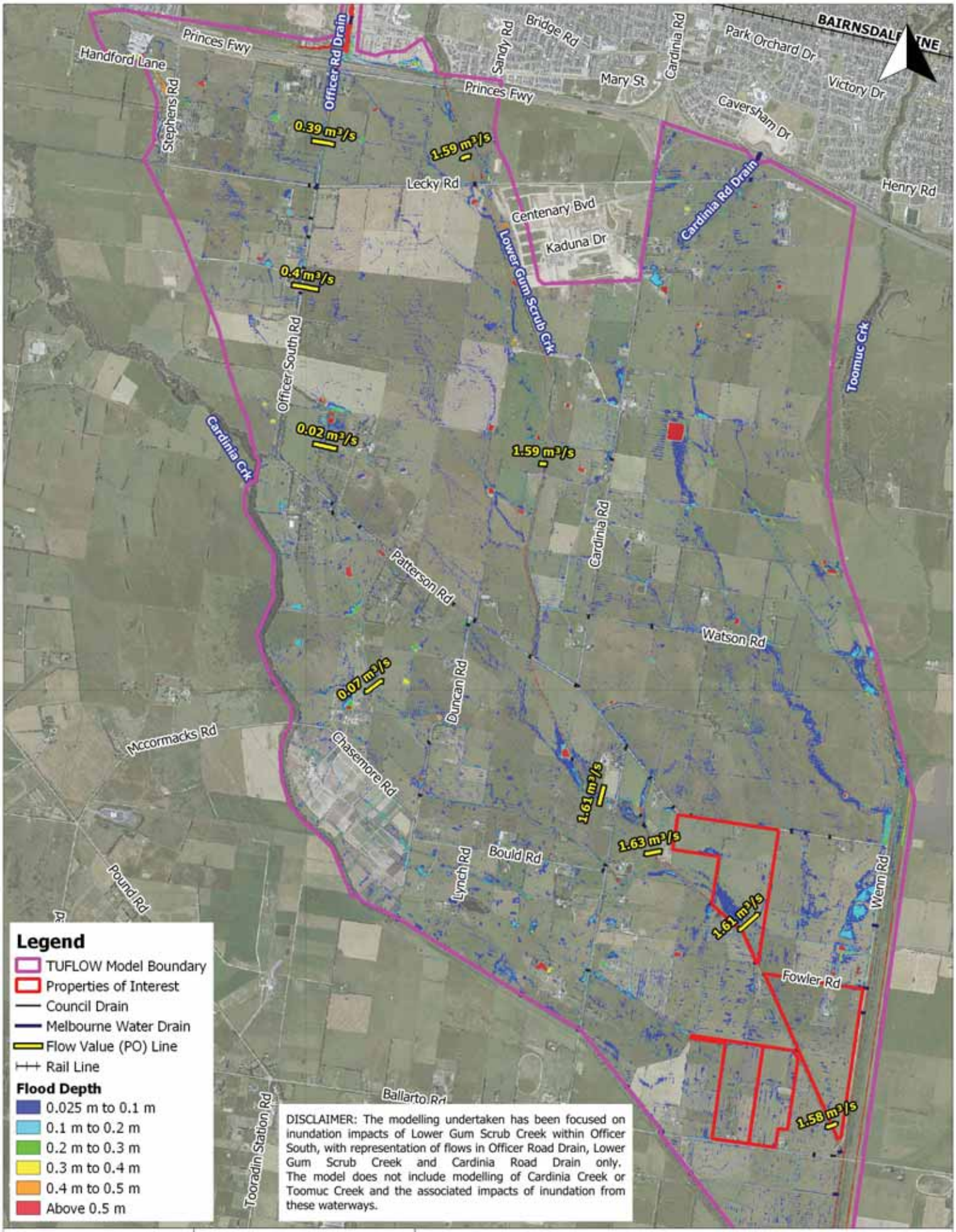
Officer South Interim Works Inundation Investigation

10 % AEP Peak Inundation Depth
Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023

ENGENY
WATER MANAGEMENT

Appendix B:
Pre-developed Conditions (2010) Inundation Maps



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
P: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

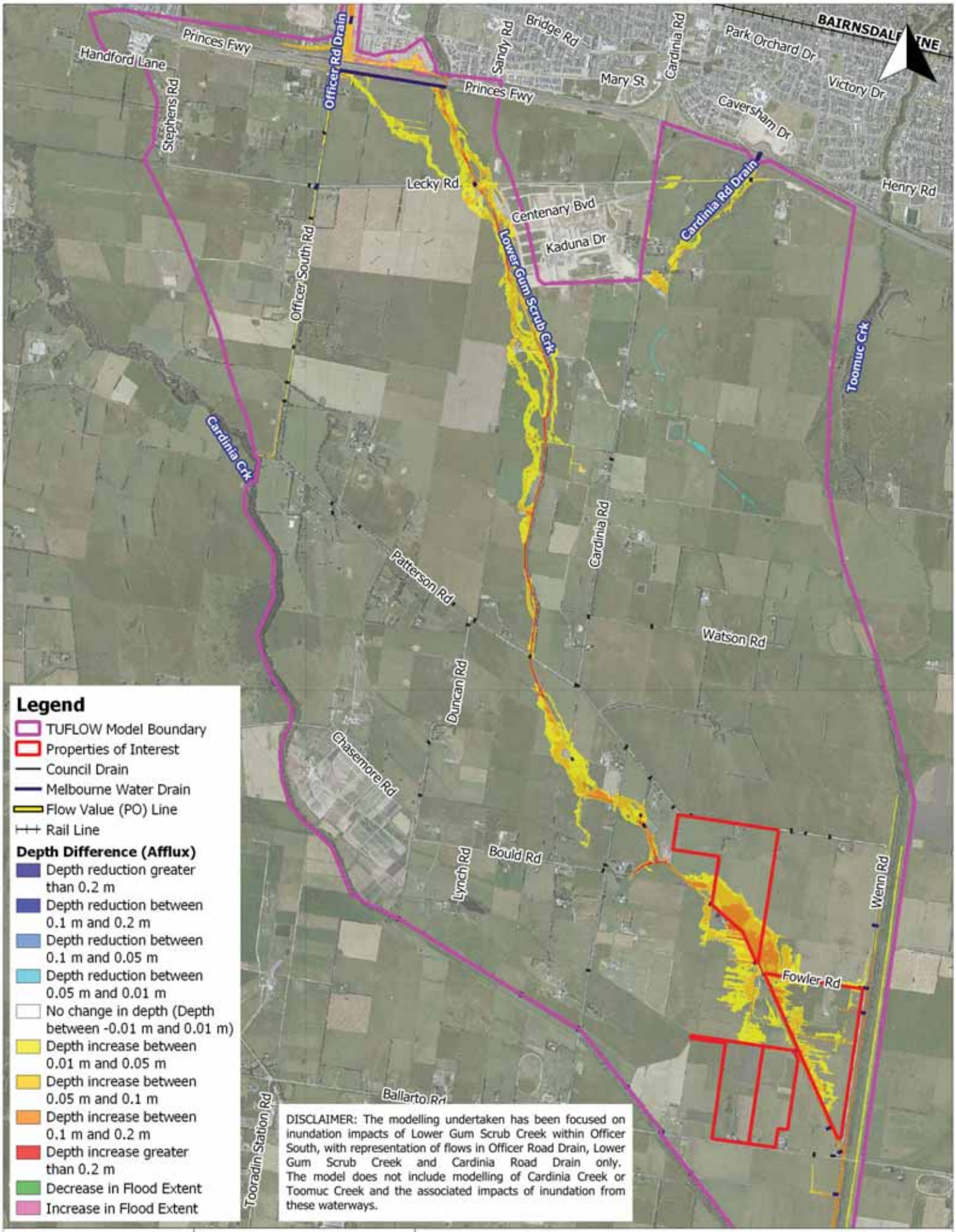
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Pre-Development (2010) Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000 @ A3)

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

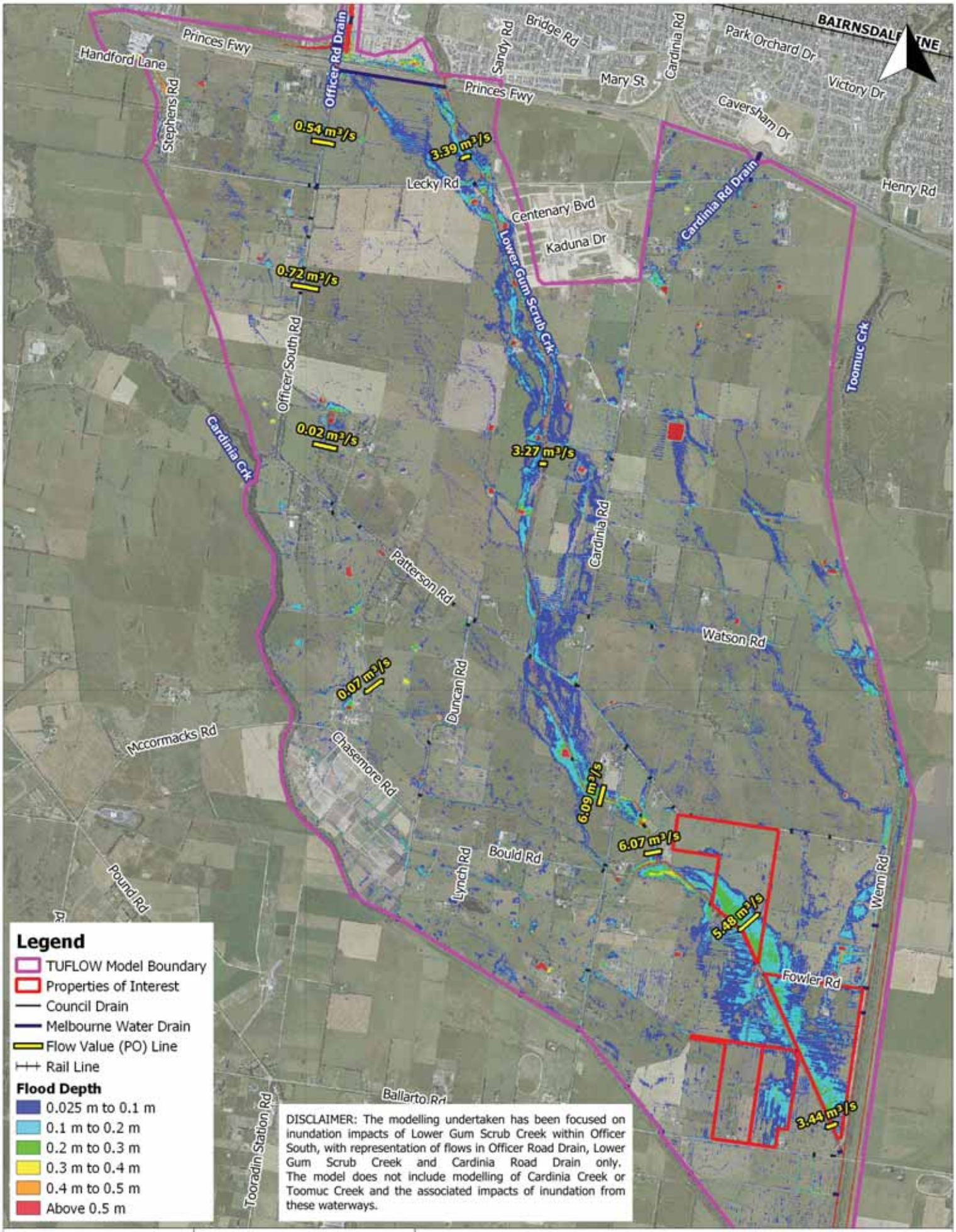
Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Baseline (2020) Development Conditions minus Pre-Development (2010) Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

Appendix C:
Developed Conditions Inundation Maps



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
P: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

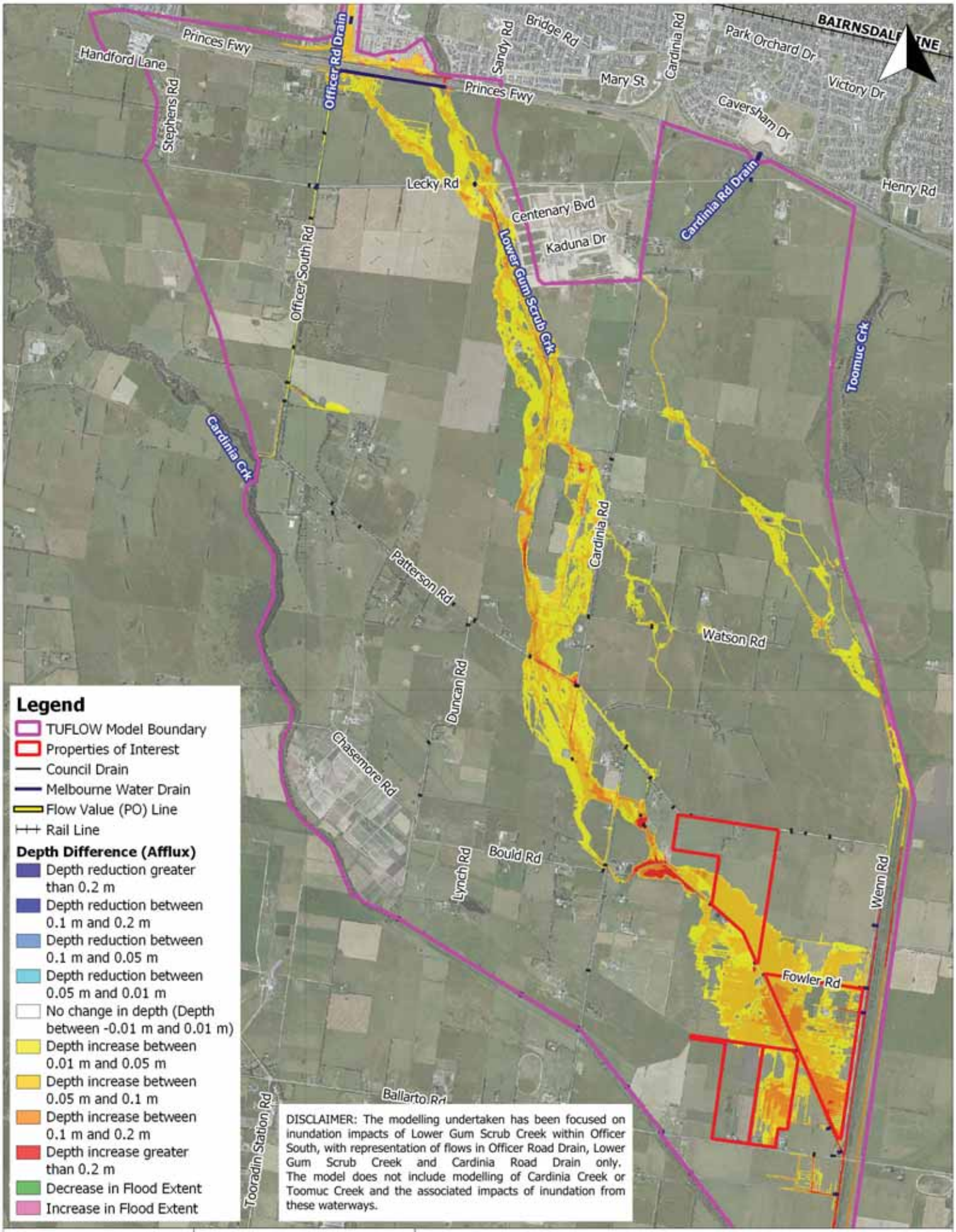
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Future Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000 @ A3)

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

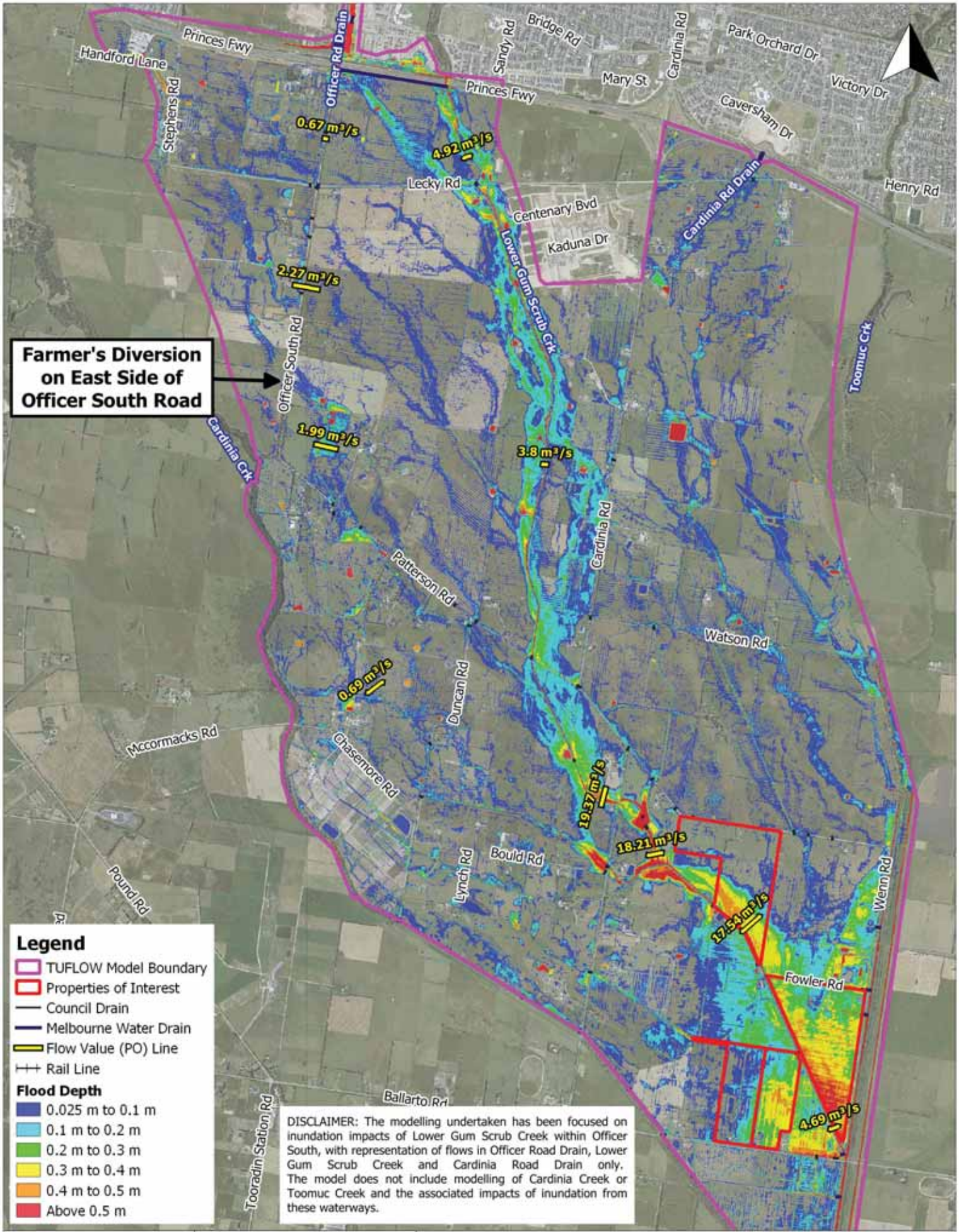
Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Future Development Conditions minus Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

Appendix D:
Baseline Scenario with Farmer's Diversion at 395 Officer South Road, Officer South Blocked Inundation Maps



Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
P: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

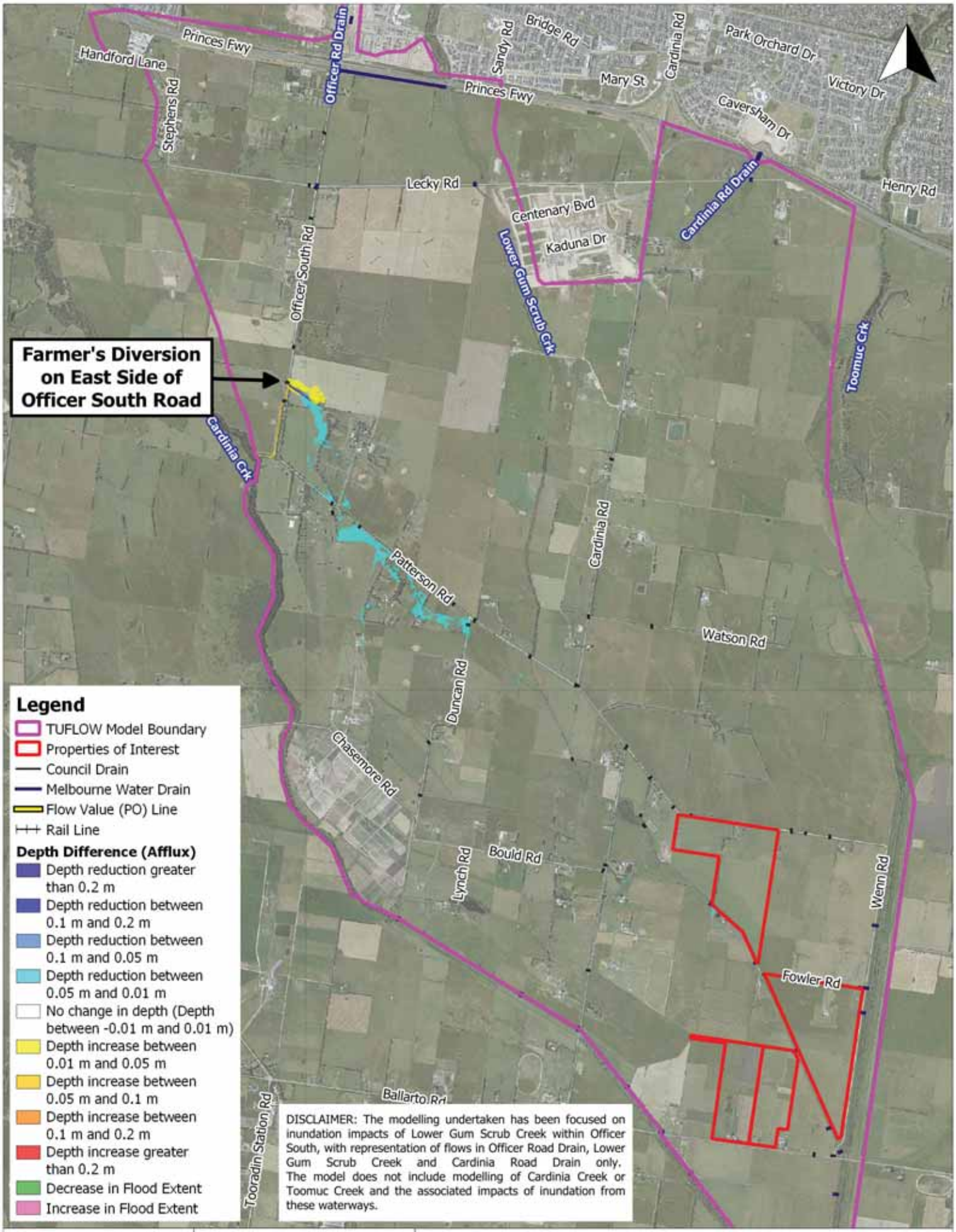
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

20 % AEP Peak Inundation Depth
Baseline (2020) Development Conditions with Blocked Farmers Diversion

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

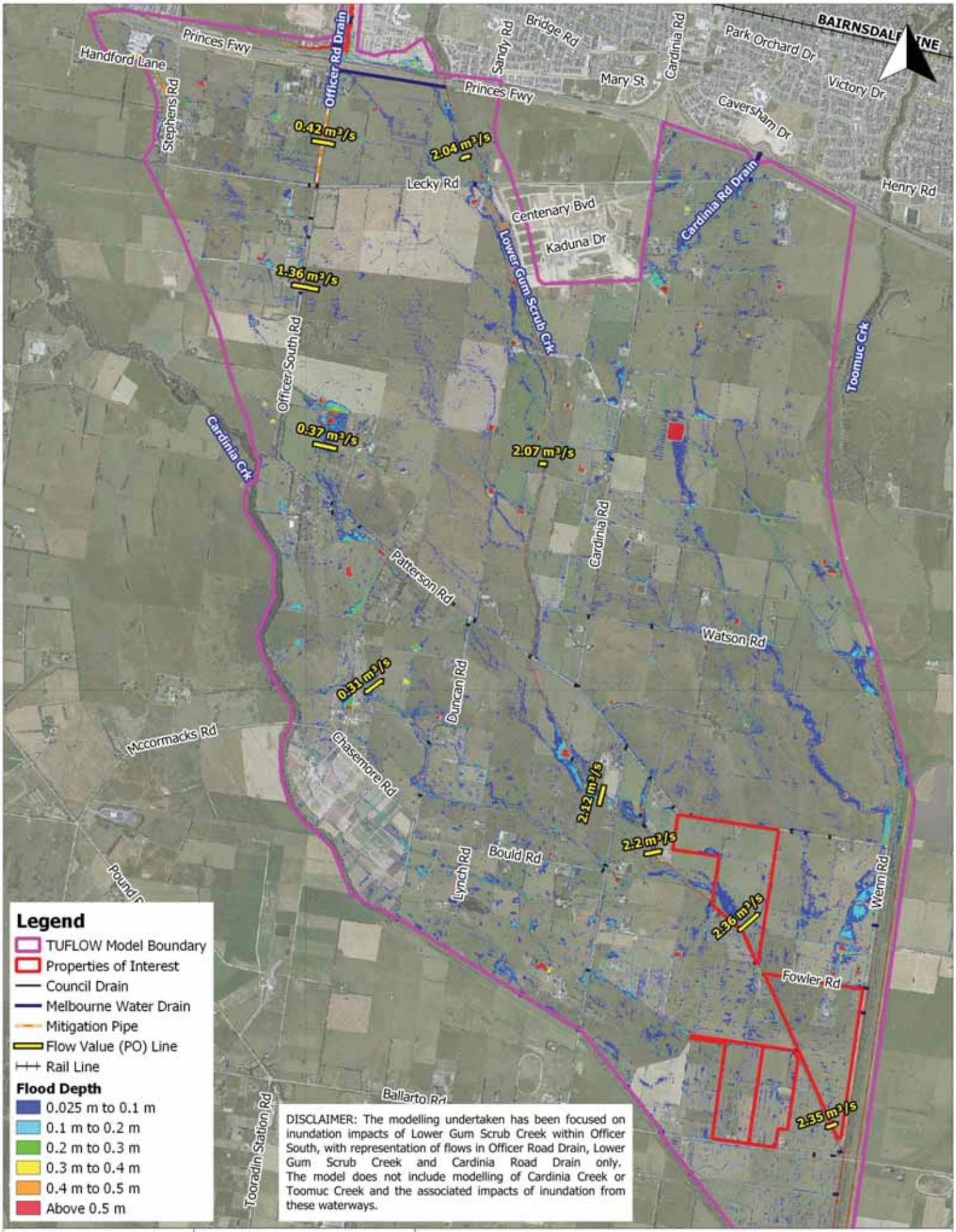
Officer South Interim Works Inundation Investigation

20 % AEP Peak Inundation Difference (Afflux)
Baseline (2020) Development Conditions with Blocked Farmers Diversion minus Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

Appendix E:
Mitigation Scenario A Inundation Maps



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

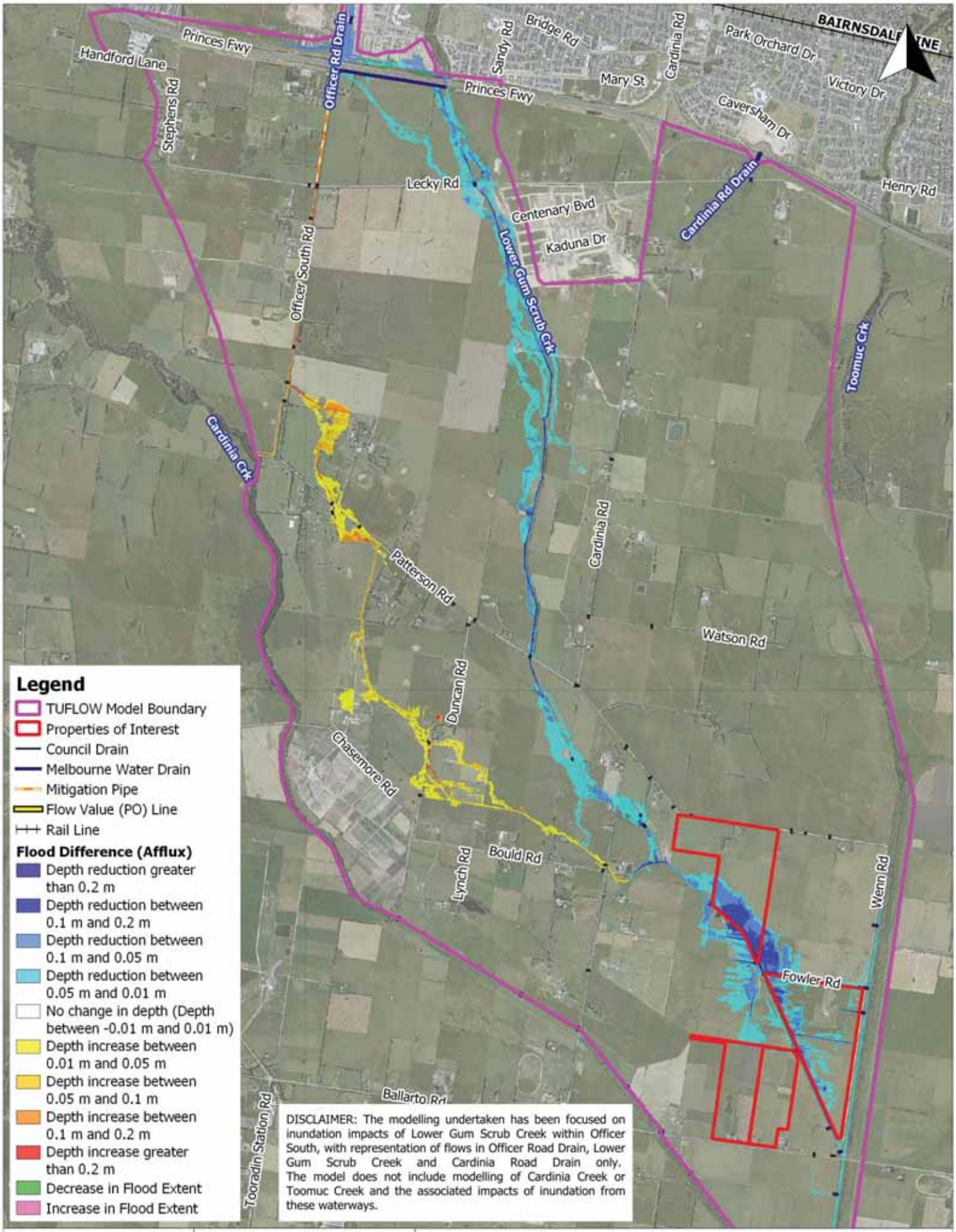
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Mitigation Works Scenario A

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

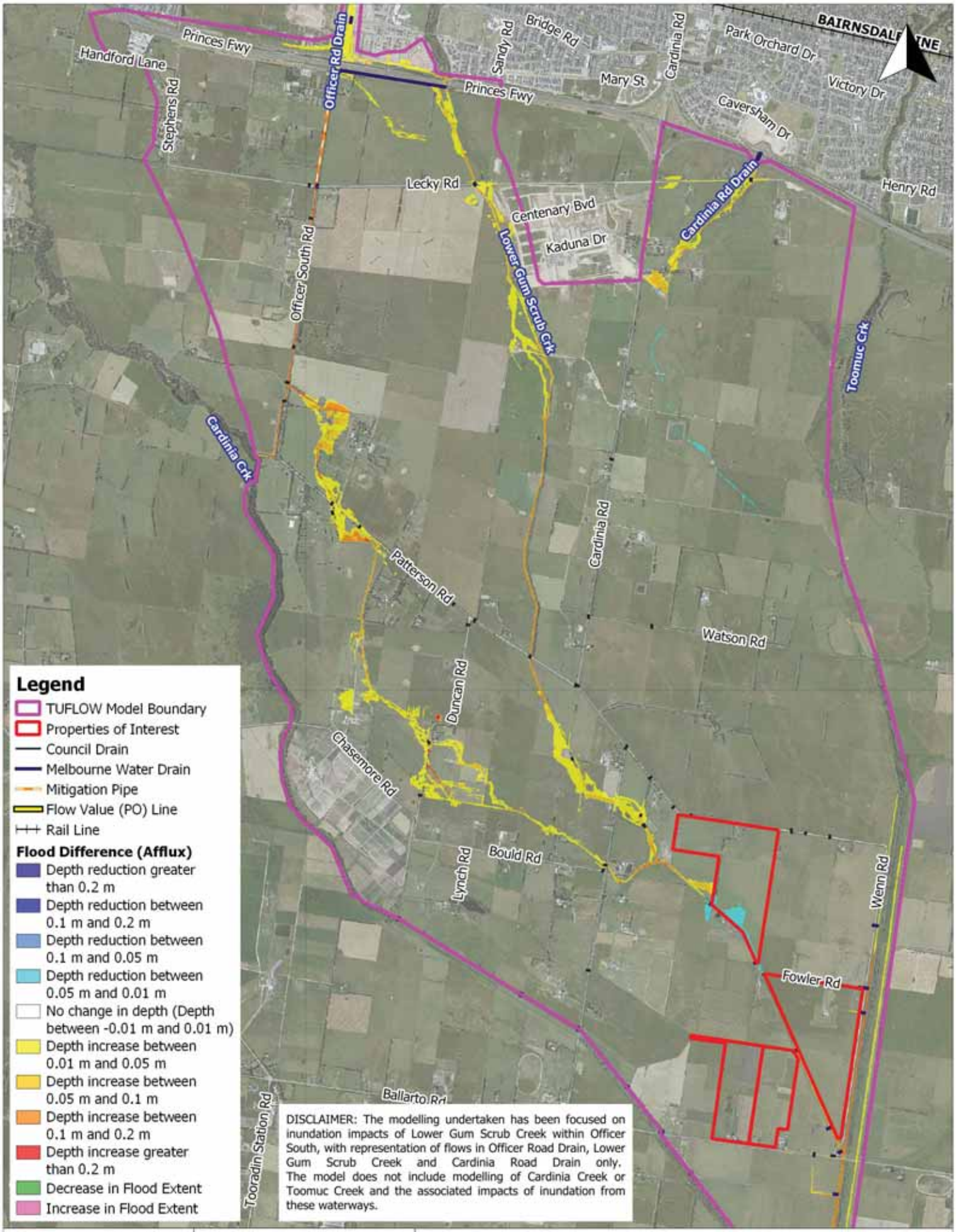
Scale in metres (1:25,000 @ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario A minus Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023



Level 34, 15, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

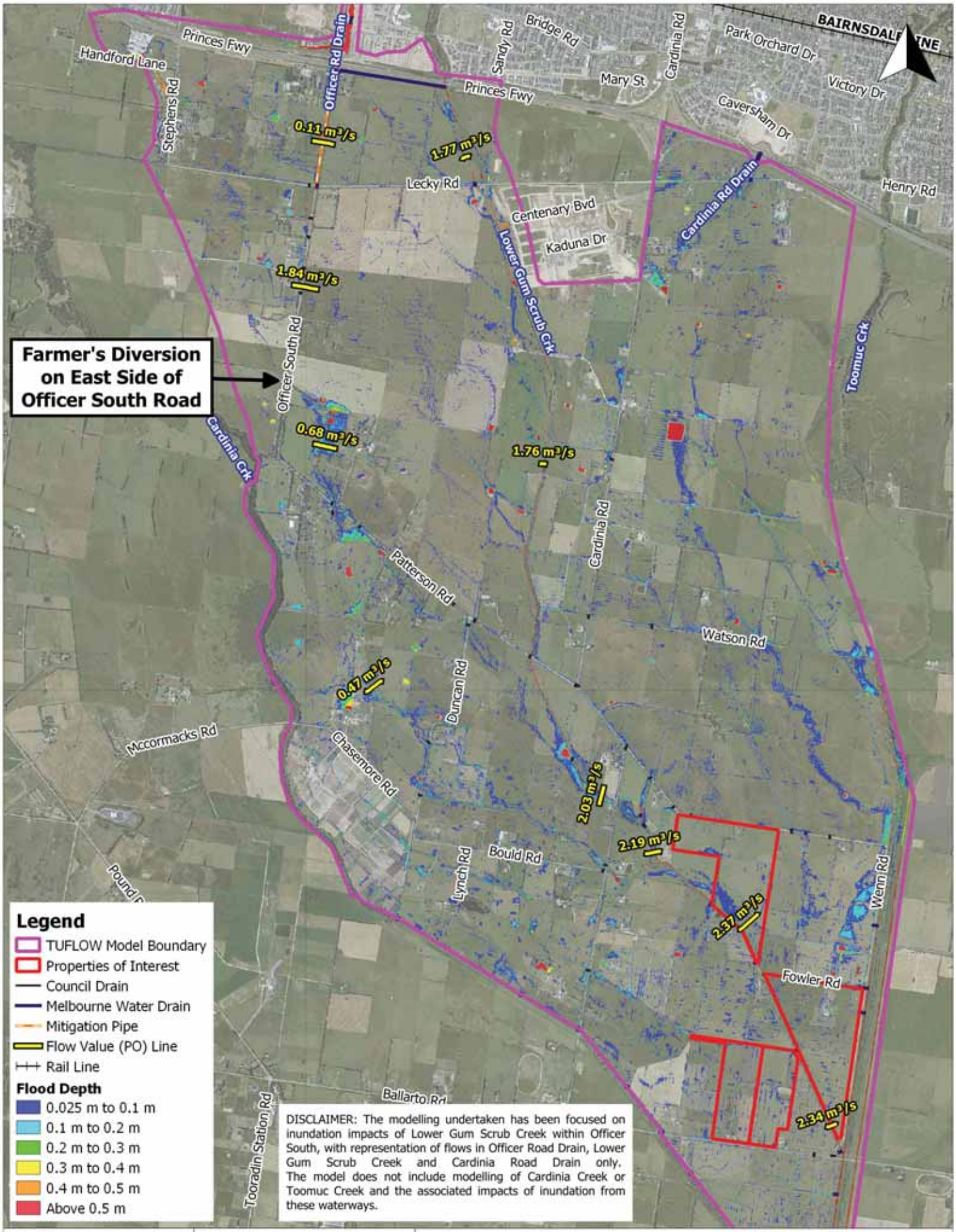
Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario A minus Pre-development (2010) Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

Appendix F:
Mitigation Scenario B Inundation Maps



Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
P: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

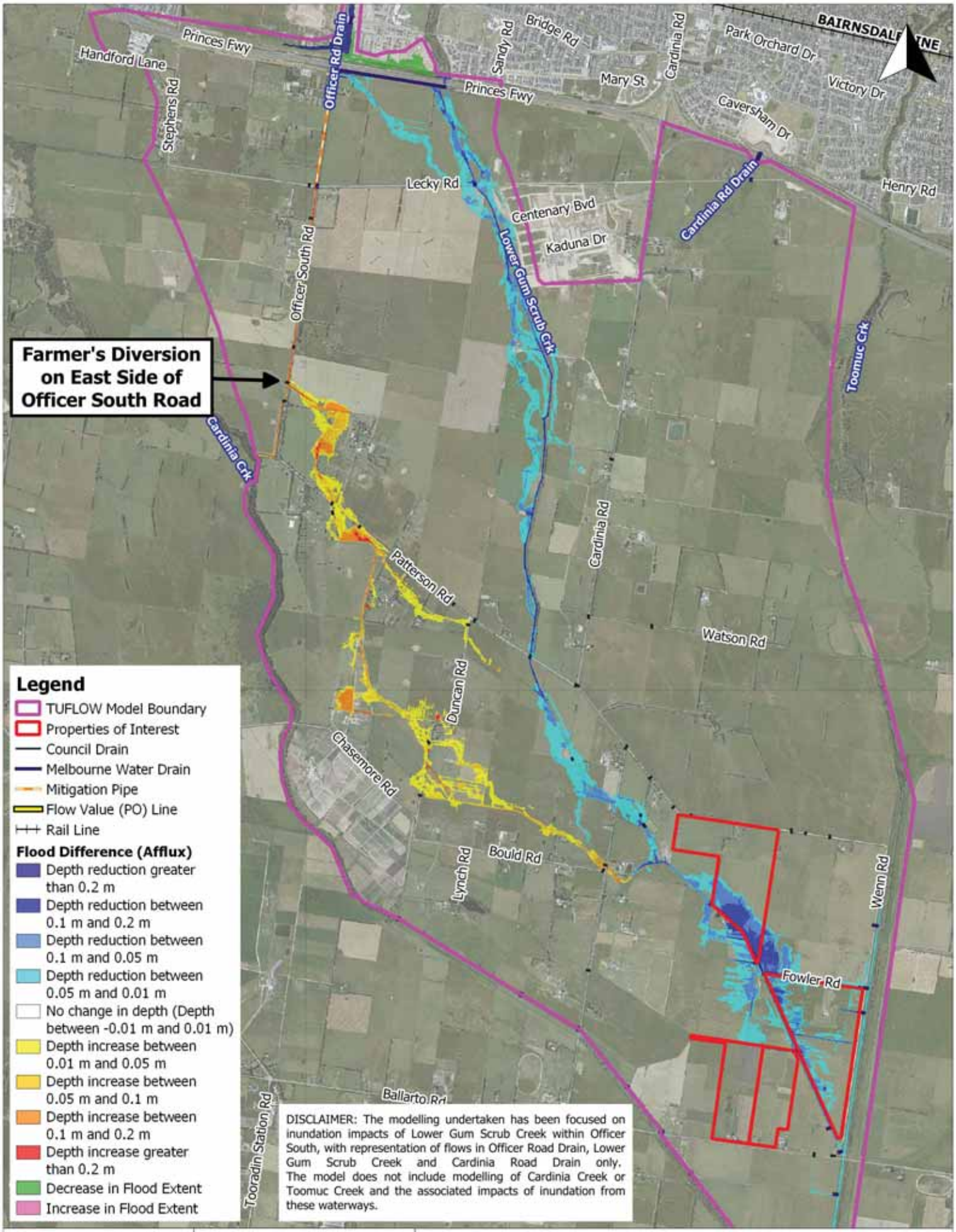
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Mitigation Works Scenario B

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

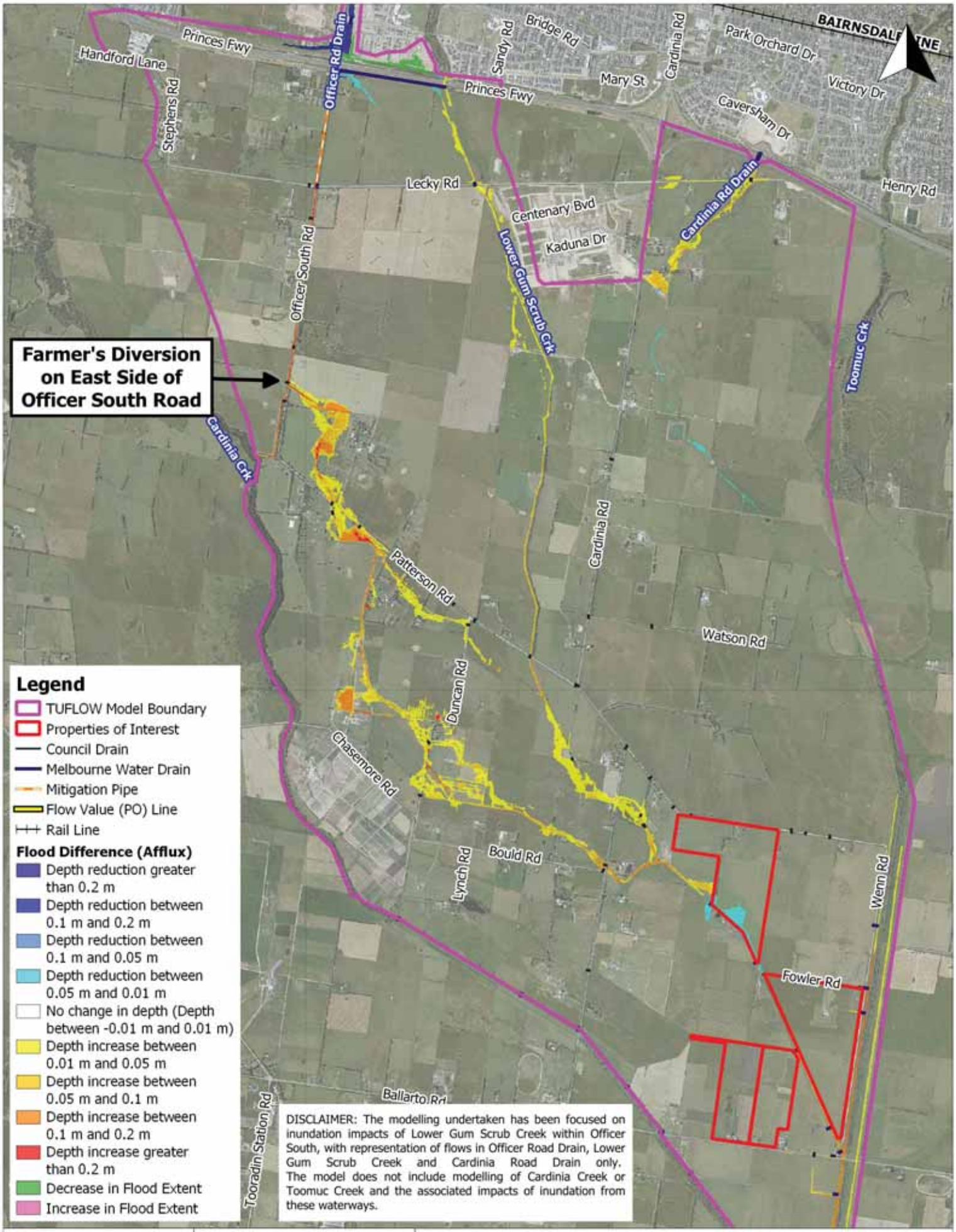
Scale in metres (1:25,000 @ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario B minus Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9866 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000 @ A3)

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

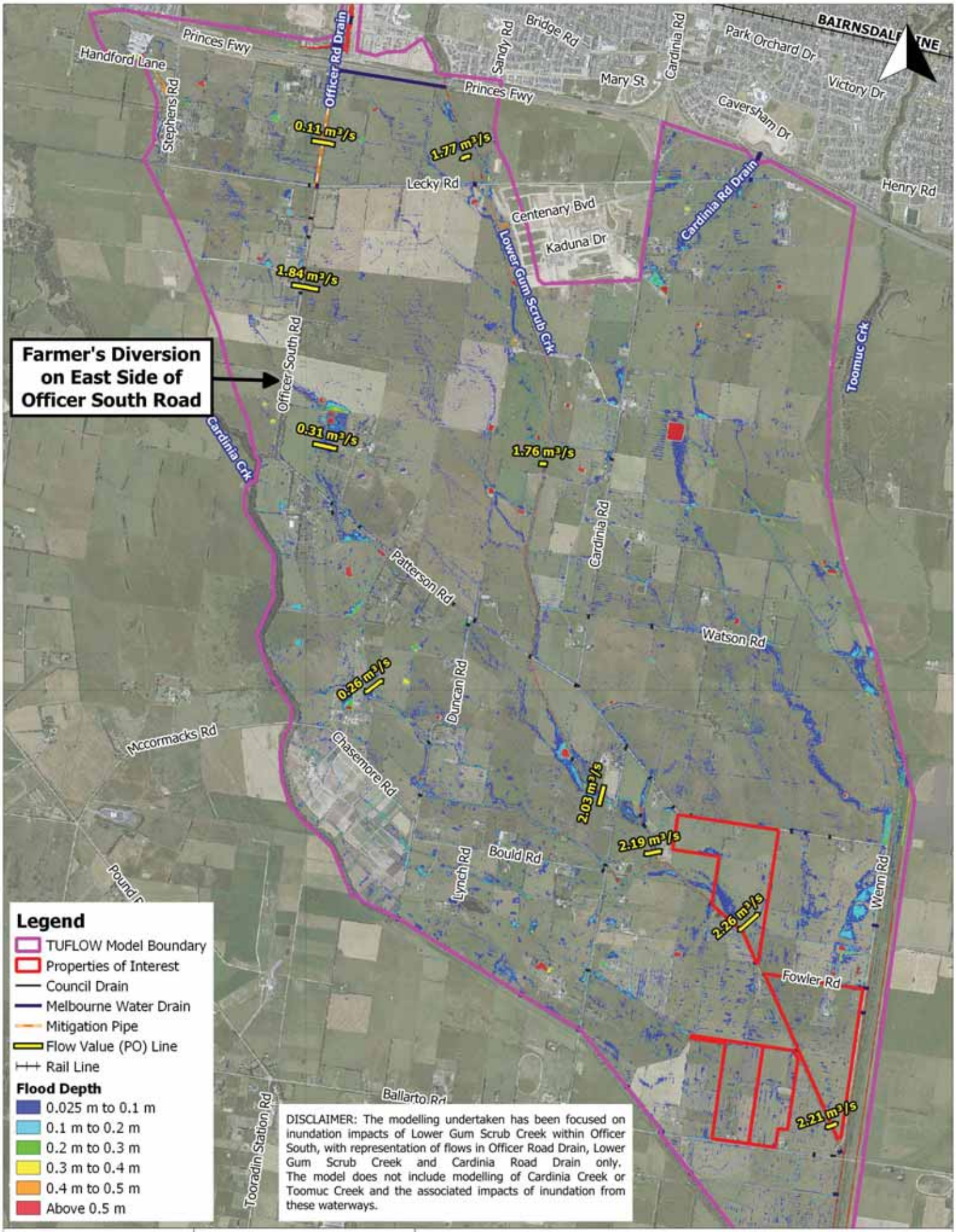
Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario B minus Pre-development (2010) Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

Appendix G:
Mitigation Scenario C Inundation Maps



Level 34, 75, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

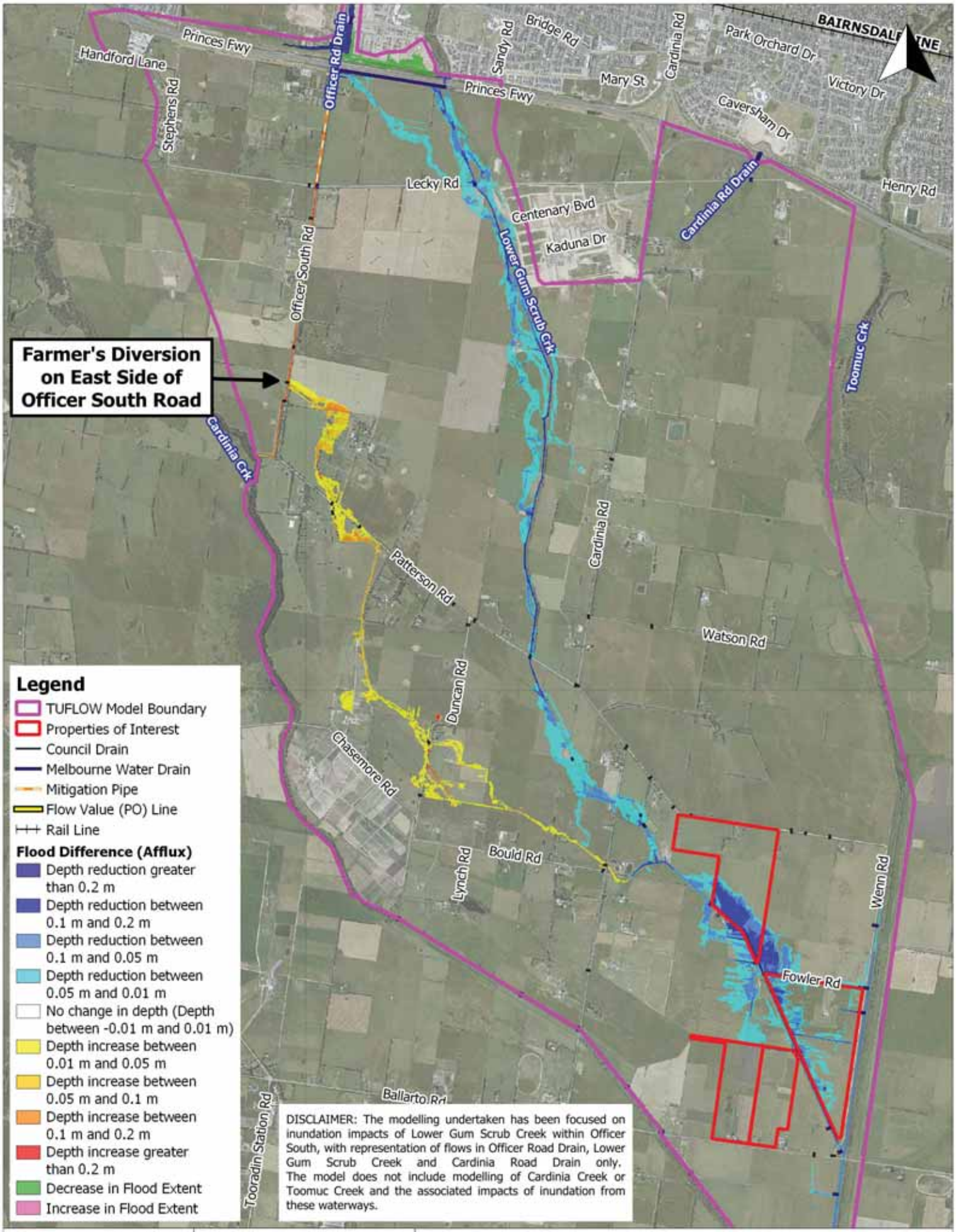
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Depth
Mitigation Works Scenario C

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 26/6/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

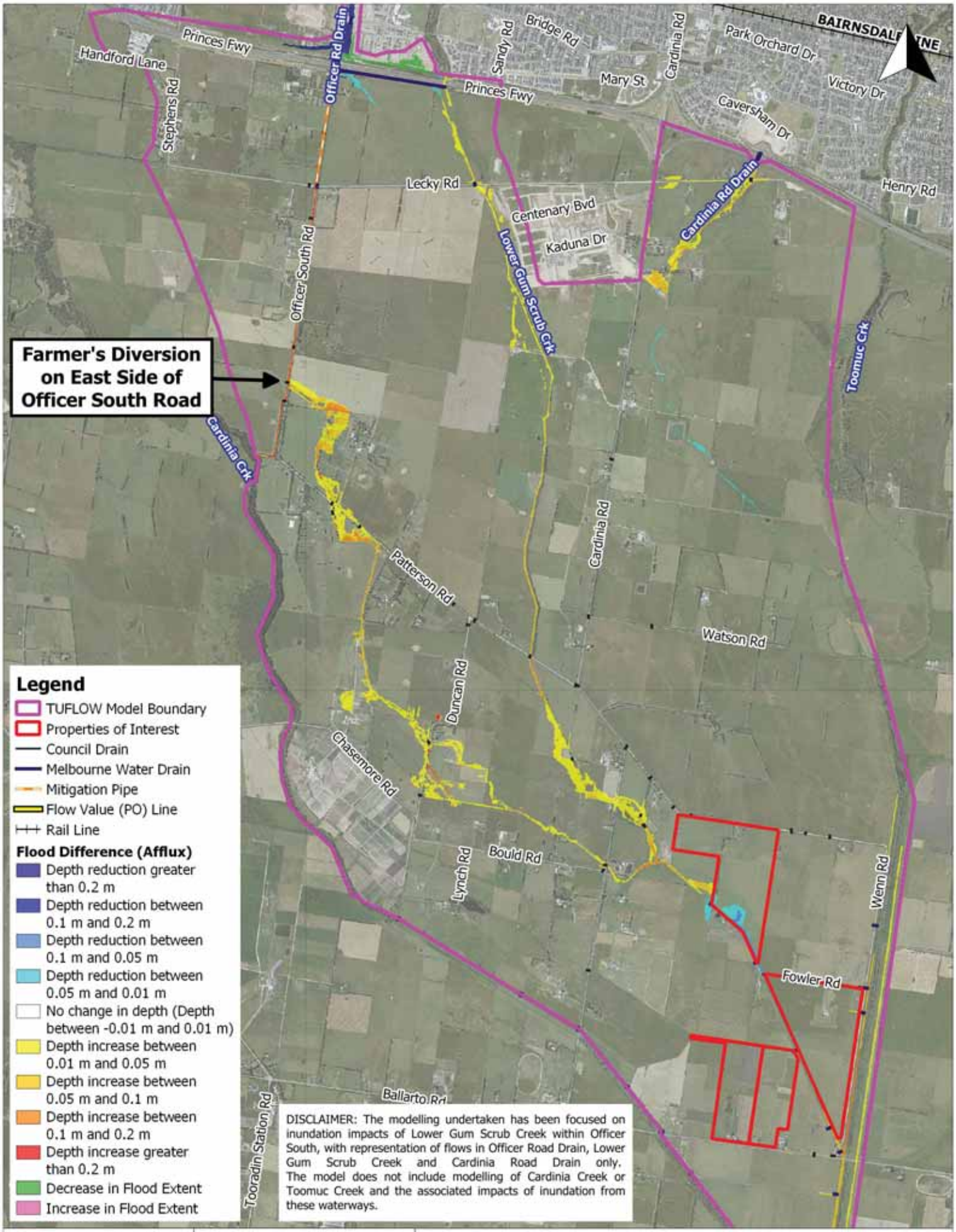
Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario C minus Baseline (2020) Development Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023



Level 34, TS, 360 Elizabeth St, Melbourne VIC 3000
PO Box 12732, A'Beckett St VIC 8006
www.engeny.com.au
P: 03 9898 6078
F: 03 9830 2601
E: mail@engeny.com.au
ENGENY

Melbourne Water

500 0 500 m

Scale in metres (1:25,000@ A3)

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

Officer South Interim Works Inundation Investigation

October 2020 Storm Event Peak Inundation Difference (Afflux)
Mitigation Works Scenario C minus Pre-development (2010) Conditions

Job Number: V3000_128
Revision: 1
Drawn: VW
Checked: PC
Date: 10/7/2023

ENGENY
WATER MANAGEMENT

engeny.com.au

P: 03 9888 6978
Level 34, Tenancy 5, 360 Elizabeth Street, Melbourne VIC 3000 | PO Box 12192 Melbourne VIC 8006