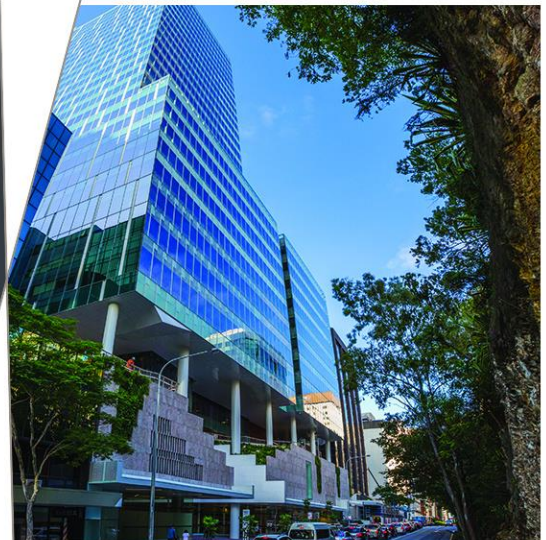


Flood Assessment

672-690 Portarlington Rd, Leopold

NW30247



Prepared for
H4 Project Group Pty Ltd

22 November 2021

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Executive Summary

CardnoTGM previously undertook a flood study at the neighbouring 31-49 Melaluka Road, Leopold based on the methodology and processes described in ARR2019. The 672-690 Portarlington Road site is contained within the same catchment as the previous modelling undertaken and so was largely used as a basis for this assessment. The previous flood study was documented in the report *31-49 MELALUKA ROAD – FLOOD IMPACT ASSESSMENT*, which forms the basis of the current document.

Study objectives

Given the close proximity to the proposed development site, Cardno were engaged by H4 Project Group Pty Ltd to undertake an investigation on the existing flood conditions of the property located at 672-690 Portarlington Rd, Leopold to further facilitate its development and proposed subdivision.

This report provides an assessment of existing drainage conditions, identifies likely stormwater requirements for the development and delivers a high-level strategy detailing how drainage and stormwater may be managed within the site.

The key findings of the assessment are as follows:

- The 1% AEP existing flood extent is predominantly confined to the western boundary of the site, with partial intrusions along the northern and southern boundaries, as well as a narrow intrusion between the existing earth mounds.
- The 1% AEP flood hazard envelope map shows that safe access (egress) can be achieved to and from the subject site via the 3 existing driveways.
- The flood extent south of the subject site offers the potential of further investigating the existing open space and drainage reserve as a storage option. Further assessment is required to determine whether this is a viable option.
- An on-site detention basin providing approximately 500m³ of storage would likely be required to be constructed in order to achieve no worsening downstream flood impacts as a result of the proposed development. Minimum batter slopes must be achieved and service proofing must be carried out to determine the likely storage depth and area needed for the detention basin.
- The basin area, properties and detention storage location must be confirmed and may be optimised during the SSMP design stage.
- This will enable the subdivision to meet the conditions and requirements set in the planning scheme for stormwater management. The objectives outlined in Section 1.1 should inform stormwater designs and ensure that stormwater quantity and quality targets are achieved and maintained.
- The stormwater analysis undertaken as part of this assessment has not identified any reasons as to why the initial subdivision of the site cannot proceed. Beyond this, future Planning Permits issued for the ultimate development and/or subdivision of the land should include appropriate engineering conditions including the preparation of a Site Stormwater Management Plan (SSMP).

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1 Background

CardnoTGM previously undertook a flood study at the neighbouring 31-49 Melaluka Road, Leopold based on the methodology and processes described in ARR2019. The 672-690 Portarlington Road site is contained within the same catchment as the previous modelling undertaken and so was largely used as a basis for this assessment. The previous flood study was documented in the report *31-49 MELALUKA ROAD – FLOOD IMPACT ASSESSMENT [FIA 2019]*, which forms the basis of the current document.

Given the close proximity to the proposed development site, Cardno were engaged by H4 Project Group Pty Ltd to undertake an investigation on the existing flood conditions of the property located at 672-690 Portarlington Rd, Leopold to further facilitate its rezoning, development and proposed subdivision. This report provides an assessment of existing drainage conditions, identifies and discusses high level potential stormwater conceptual options for development including consideration of likely detention and water quality requirements and potential locations for detention basin(s), water quality assets including bio-retention swales / wetlands etc.

The study area covers upstream and downstream contributing catchments, including the property at 692-700 Portarlington Rd, Leopold, located immediately east of the subject site.

1.1 Objectives and Requirements

Establishing the existing flood conditions allows an understanding of the availability of developable land and identification of regional stormwater constraints associated with the subject site. The defined predeveloped (existing) flood characteristics should form the 'base-case' for further investigation and flood impact analysis of the proposed site development.

A site stormwater management plan should be further developed to demonstrate that the site can be developed using best practice stormwater management principles and techniques. This will enable the subdivision to meet the conditions and requirements set in planning permits for stormwater management. The objectives should inform stormwater designs and ensure that stormwater quantity targets are achieved and maintained.

1.1.1 Existing Flooding Objectives

The overriding objectives of the existing flood investigation are to –

- Prepare existing flood mapping for the designated storm event;
- Establish the predeveloped 'base case' flood characteristics for the site; and
- Identify the associated flood risks.

1.1.2 Site Stormwater Requirements

The site stormwater requirements are:

1. Best Practice reductions for Water Quality
 - 80% reduction in Suspended solids (SS)
 - 45% reduction in total nitrogen (TN)
 - 45% reduction in total phosphorus (TP)
 - 70% reduction in gross pollutants (GP)
2. No-worsening stormwater peak discharges
 - Ensure pre-development site discharges are maintained
3. Storage for regional flood
 - Provide enough reserve area (storage) to accommodate regional flood

Development of the site must not have an adverse impact on the surrounding and downstream area during the 1% Annual Exceedance Probability (AEP) regional flood event, as detailed below:

- Flood extents – No worsening of flood extents;
- Velocities and flow characteristics – Velocity-Depth product must not exceed safety limits for people and vehicle access;
- Cumulative flooding impact – No worsening of overall flood impacts.

2 Study Area

The proposed site is 672-690 Portarlington Rd, Leopold, covering an area of approximately 2.05 ha. It is currently designated as a Farming Zone (FZ). The site surroundings include: Portarlington Rd (RDZ1 to the north), Farming Zone (FZ to the west and east), Public Park & Recreation Zone (PPRZ) and General Residential Zone (to the south and far east), as can be seen in Figure 2.1. No current Flood Overlay is impacting on the site.

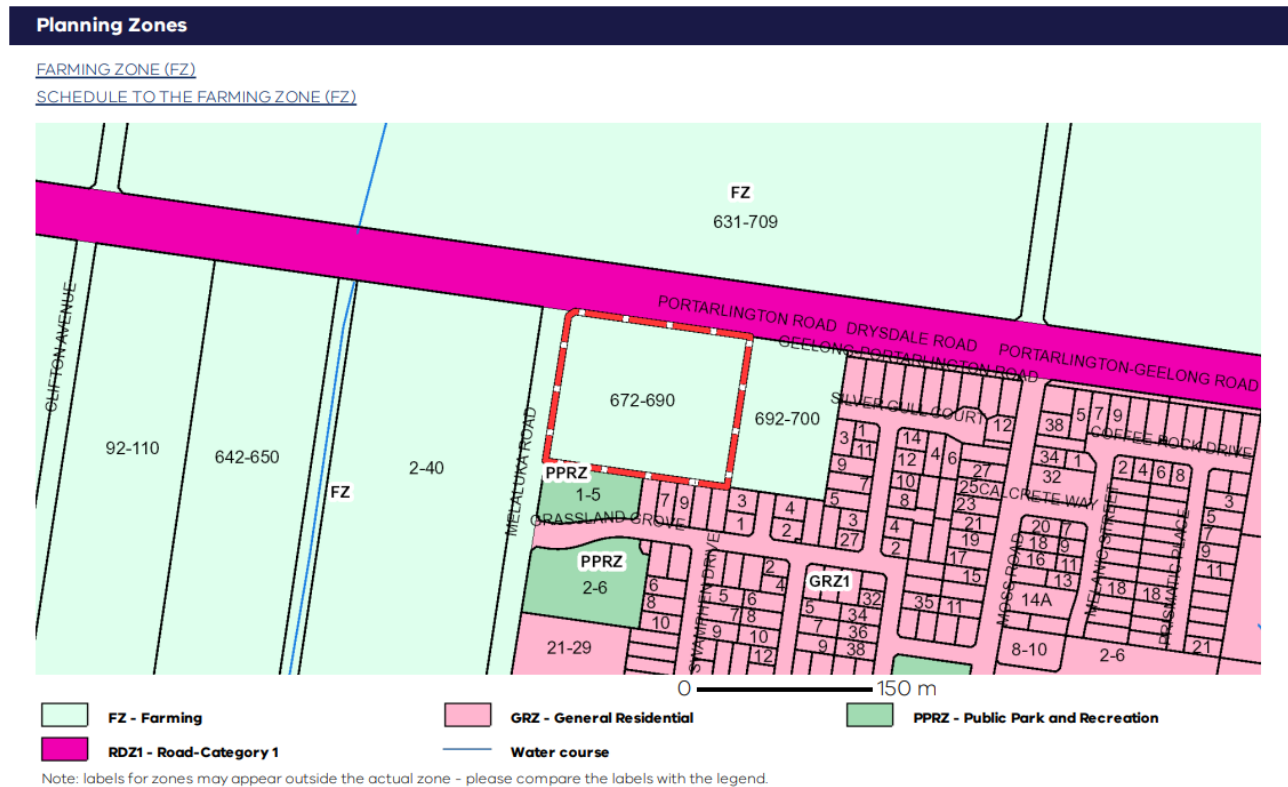


Figure 2.1: The site and Existing Planning Zone Context¹

It is understood that an initial application is proposed for a two lot subdivision and the rezoning of the subject site.. The development will likely include a combination of commercial and residential lots and a local road connection to Grassland Grove to the south along with a local road connection to a separate development immediately east of the site, located at 692-700 Portarlington Rd, Leopold.

The site of proposed development can be seen in Figure 2.2.

¹ Planning Maps Online, <https://mapshare.vic.gov.au/vicplan/>. Accessed on 8 Nov 2021.



Figure 2.2: Proposed Plan of Subdivision

3 Hydrological Model

The hydrological analysis was simulated with XP-STORM by applying the rainfall-runoff, Laurenson routing, and one-dimensional (1D) hydraulic channel techniques based on the ARR2019 methodology. XP-STORM provides features to efficiently interface with the ARR Data Hub and Bureau of Meteorology (BOM) to obtain IFD and rainfall data to generate temporal patterns for a range of event probabilities.

Two (2) regional hydrological models were set up for the greater study area using XP-STORM:

1. A lumped hydrological model of the study catchment - used for model parameter sensitivity analysis; and
2. A distributed hydrological model of the study catchment - used to compute the stormwater hydrographs used as inflow boundary conditions in the 2D hydraulic model.

It should be noted that for the catchment of the site itself and the immediate property on the east, runoff excess was modelled and exported without routing, to avoid double-routing when modelling with the hydraulic model.

3.1 Subcatchment Delineation

Delineation of subcatchments was carried out by applying a mathematical algorithm called TauDEM^{2,3} (Terrain Analysis Using Digital Elevation Models) to topographic data sets.

TauDEM is a suite of Digital Elevation Model (DEM) tools for the extraction and analysis of hydrologic information from topography as represented by a DEM. Please refer to Section 4.1 for a detailed description of the DEM used in this study.

TauDEM provides the distinctive advantage of applying an objective technique to calculate the stream flow paths and directions, the contributing areas using both single and multiple flow direction methods, as well as to delineate the watersheds and sub-watersheds draining to each stream segment.

The LiDAR DEM, analysed in TauDEM, extended far enough to ensure that the entire contributing catchment area was defined.

² <http://hydrology.usu.edu/taudem/taudem5/index.html> .

³ Tarboton, D. G., (1997), "A New Method for the Determination of Flow Directions and Contributing Areas in Grid Digital Elevation Models," *Water Resources Research*, 33(2): 309-319.

3.1.1 Analysed Subcatchments

The subcatchment delineation defined in **[FIA 2019]** was revised according to site boundary and existing urban drainage networks. Catchment 03, 54 and 56 have been further divided to better represent the areas of interest (for details please see Figure 4.2). The catchment “Site” includes the site area, while the “ExtSite” includes the property immediately to the east and the road adjacent to the north boundary of the property.

The final 76 subcatchments are illustrated in Figure 3.1, with areas detailed in the table below.

Catchment	Area (ha)	Catchment	Area (ha)	Catchment	Area (ha)
C01	5.85	C26	20.81	C51	3.82
C02	5.51	C27	10.07	C52	2.16
C03	2.86	C28	14.18	C53	4.69
C04	10.57	C29	14.27	C54A	0.63
C05	10.01	C30	6.21	C54B	9.90
C06	6.15	C31	7.08	C54C	0.99
C07	9.16	C32	2.82	C55	8.28
C08	7.54	C33	20.74	C56A	0.66
C09	8.93	C34	6.13	C56B	5.00
C10	9.68	C35	9.99	C57	11.44
C11	12.67	C36	2.57	C58	8.64
C12	8.87	C37	8.36	C59	9.64
C13	11.65	C38	1.55	C60	16.66
C14	10.18	C39	7.45	C61	12.28
C15	1.37	C40	8.36	C62	15.00
C16	18.79	C41	6.05	C63	5.03
C17	11.68	C42	7.36	C64	12.44
C18	1.58	C43	2.59	C65	16.41
C19	10.33	C44	8.53	C66	3.09
C20	1.85	C45	6.14	C67	1.58
C21	26.41	C46	13.97	C68	3.28
C22	15.04	C47	10.40	C69	3.92
C23	12.36	C48	4.71	C70	3.77
C24	9.75	C49	6.81	Site	2.05
C25	21.76	C50	1.19	ExtSite	1.18
S1	2.51				

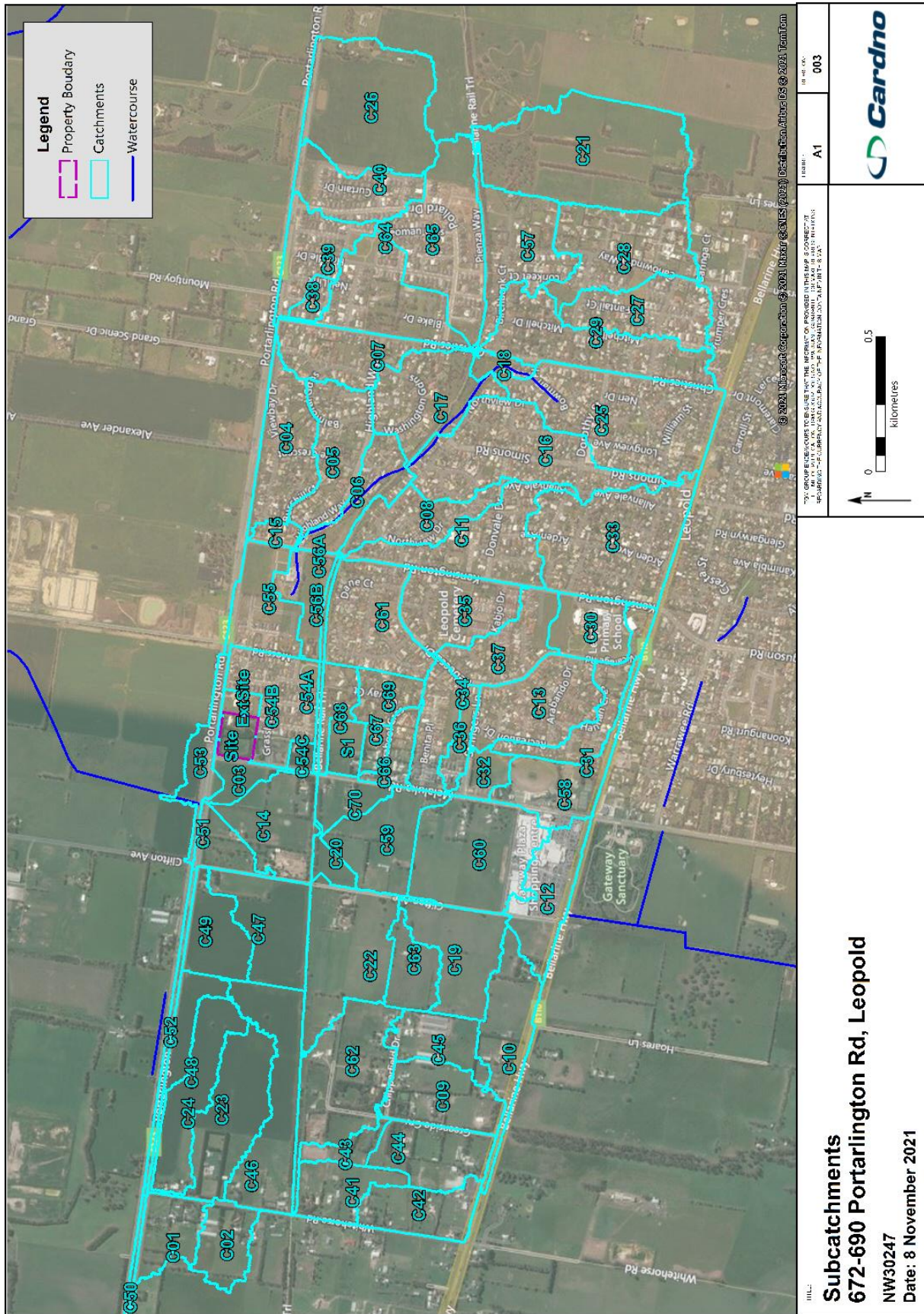


Figure 3.1: Subcatchments Delineation for the Study Area

3.2 Model Parameters

3.2.1 Permeability and Fraction Impervious

A fraction impervious percentage was assigned to the subcatchments to reflect expected permeability based on planning context and actual land use characteristics.

Planning zone mapping and the most recent aerial imagery was used to identify land use and assign a fraction impervious, reflecting the total impervious area (TIA), based on zone classifications detailed in guidelines by Melbourne Water⁴.

However, use of the TIA, which includes impervious areas with no direct connection to the drainage network, can result in the overestimation of urban runoff volumes and peak flows. Identifying the effective impervious area (EIA) provides a more realistic measure of the impervious area that generates runoff at the catchment outlet⁵.

Urban sub-catchments include directly connected impervious areas (DCIA), indirectly connected impervious areas (IDCIA) and pervious areas as described in ARR2019, Section 3.4 (Estimation of Effective Impervious Area)⁶. Classification of the sub-catchment areas are as follows -

- Directly Connected Areas, which consist of:
 - Impervious areas (e.g. roofs and paved areas) which are directly connected to the drainage system – referred to as Direct Connected Impervious Areas (DCIA).
- Indirectly Connected Areas, which consist of:
 - Impervious areas which are not directly connected, runoff from which flows over pervious surfaces before reaching the drainage system (e.g. a roof that discharges onto a lawn) – referred to as Indirectly Connected Impervious Areas (ICIA).
 - Pervious areas that interact with Indirectly Connected Impervious Areas, such as nature strips, garden areas next to paved patios, etc.
- Pervious areas consisting of parklands and bushland that do not interact with impervious areas.

For large urban catchments, isolating the separate hydrologic effects of these two types of impervious surfaces is challenging.

Recent commercial development to the east and south of the subject site has been undertaken in 2009 and the TIA has been increased significantly. However, the EIA is much lower due to the addition of stormwater mitigation and WSUD measures – the creation of a natural drainage reserve just south of the subject site.

The estimated EIA value for a catchment is calculated and then applied to hydrologic calculations using the adopted modelling software. Therefore, a conservative Effective Impervious Area (EIA) fraction was calculated, representing 70% of the Total Impervious Area (TIA) fraction. This information is summarised in Table 3.1.

⁴ Melbourne Water (2018). MUSIC Guidelines – Input parameters and modelling approaches for MUSIC users in Melbourne Water's service area 2018.

⁵ Ball J, Weinmann E, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia. Book 5 Flood Hydrograph Estimation, Chapter 3 Losses, Section 3.4.1.2 Challenges with Total Impervious Area

⁶ Ball J, Weinmann E, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia. Book 5 Flood Hydrograph Estimation, Chapter 3 Losses, Section 3.4 Estimation of Effective Impervious Area

Table 3.1: Total Impervious Area vs Effective Impervious Area for Planning Scheme Zones

Zone	Fraction Impervious	
	TIA	EIA
Commercial 1 Zone	0.9	0.63
Farming Zone	0	0
General Residential Zone	0.75	0.525
Low Density Residential Zone	0.2	0.14
Public Park & Recreation Zone	0.1	0.07
Rural Living	0.2	0.14
Major Road	0.7	0.7

3.2.2 Loss Parameters

XP-STORM was run as an Initial Loss and Continuing Loss (IL/CL) model using parameters provided from the ARR Data Hub⁷.

The hydrologic losses adopted in this study are summarised in Table 3.2 below.

Table 3.2: Adopted Hydrological Loss Parameters

Surface	Storm Initial Loss (mm)	Pre-burst Depth (mm)	Adopted Losses	
			Burst Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	19	1.55	17.45	3
Impervious	0		0	0

3.2.3 Manning's Roughness Coefficients

In the hydrological model, all subcatchments are also characterised by Manning's 'n' coefficients, which describe the hydraulic roughness properties of the soil surfaces.

The Manning's coefficients adopted in this study are summarised in Table 3.3.

Table 3.3: Manning's Coefficients 'n' Adopted in the Hydrological Model

Surface	Manning's Coefficients 'n'
Pervious	0.03 – 0.05
Impervious	0.018

The Manning's coefficients for the pervious surface have been further analysed through the sensitivity analysis process (Section 3.3).

⁷ ARR Data Hub, <http://data.arr-software.org/>. Accessed on 9 January 2019.

3.3 Sensitivity Analysis

As described in *[FIA 2019]*, the parameters of hydrological models are usually determined through a calibration procedure to optimise the model performances in relation to a specific site. Indeed, the choice of the hydrological model parameters usually reflect the characteristics of the site and the soil properties.

The most used calibration procedure in rainfall-runoff hydrological models involves the comparison between observed and computed data. In the calibration phase, hydrological model parameters are adjusted to attain an output that matches the observed data. However, in absence of gauged data, both calibration and validation are not possible.

The Regional Flood Frequency Estimation (RFFE) tool provided by ARR2019 indicates peak flood estimates for **rural catchments** and cannot be applied to urban catchments (where more than 10% of the catchment is affected by residential or urban development).⁸ The RFFE cannot be used to define the expected runoff discharge from the 'existing catchment', however, it can be used to define expected runoff discharges from a 'pre-urban development' catchment.

The RFFE tool was employed as a point of reference in the assessment of the suitability and sensitivity of the selected hydrological parameters.

The sensitivity analysis was setup to reflect rural or pre-development catchments to allow the comparison with flood estimation techniques. More in detail, all subcatchments have been considered as rural, and the pervious fraction has been set at 100%.

A key element of the sensitivity analysis process is the identification of the stormwater catchments that impact on the study area, the characteristics of those catchments and the configuration of waterways.

Factors such as availability of observed rainfall data, soil type, soil conditions, land use and local knowledge were considered in this investigation.

The sensitivity analysis has been undertaken to the 10% AEP event identified using the ARR2019 RFFE tool for the lumped catchment.

The 10% AEP event was selected – as the recorded data used to generate the RFFE discharges have a larger sample and more robust records of 10% AEP events. This provides a more reliable flood frequency estimate.

The sensitivity analysis procedure has been performed by changing the Manning coefficient 'n' for the pervious surfaces to better represent the energy losses within the study area.

A further analysis of the model predictability has been carried out by comparing the XP-STORM model and the RFFE predicted peak discharges for the 1%, 2%, 5%, 20% and 50% AEP events.

⁸ARR - Limits of Applicability - <https://rfe.arr-software.org/limits.html>, viewed on 12/03/2019

3.3.1 ARR2019 Regional Flood Frequency (RFFE) Model

The ARR2019 RFFE model^{9,10} available online at <http://arr.ga.gov.au/>; was used to provide peak flow estimates for the study catchments. The RFFE model interface, input parameters and statistical outputs can be seen in the Appendix A.

The RFFE model provides peak flood estimates for rural catchments, therefore, the lumped model was initially considered to be undeveloped (pre-development) to allow comparison.

3.3.2 Storm Burst Pattern Ensemble

The XP-STORM model applied ensemble rainfall patterns, storm burst loss factors and runoff estimation techniques from ARR2019¹¹ to the study catchment area to generate runoff hydrographs and predict the volume of stormwater generated.

As detailed in ARR2019¹² the majority of hydrograph estimation methods used for flood estimation require a temporal pattern that describes how rainfall falls over time as a design input.

The importance of temporal patterns has increased as the practice of flood estimation has evolved from peak flow estimation to full hydrograph estimation.

An ensemble of 240 storms was analysed within the XP-STORM model for each storm event probability. For the sensitivity analysis process, the study catchment was set up as a rural catchment with no impervious surfaces.

Using the burst initial loss and continuing loss identified in Table 3.2, and known catchment characteristics, i.e. area, slope, overland flow path profiles, etc. the model was run using all 240 storm burst patterns for each AEP.

The Median, Average, Maximum and Minimum peak flow output hydrographs were identified for each storm duration using a statistical spreadsheet. The results are presented in a box and whiskers plot in Figure 3.2.

ARR2019 states that the temporal pattern that represents the worst (or best) case should not be used by itself for design. Testing has demonstrated that on most catchments large number of events in the ensemble patterns are clustered around the mean and median¹³.

⁹ Rahman, A, et al (2013). New Regional Flood Frequency Estimation (RFFE) Method for the whole of Australia: Overview of progress. Paper. Flood plain conference 2013.

¹⁰ Rahman, A, Haddad, K, Kuczera, G and Weinmann, E, 2016, Peak Flow Estimation, Chapter 3 Book 3 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia.

¹¹ Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia.

¹² Babister, M, Retallick, M, Loveridge, M, Testoni, I, and Podger, S, 2016. Temporal Patterns, Chapter 5 Book 2 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

¹³ Babister, M, Retallick, M, Loveridge, M, Testoni, I, and Podger, S, 2016. Temporal Patterns, Chapter 5 Book 2 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

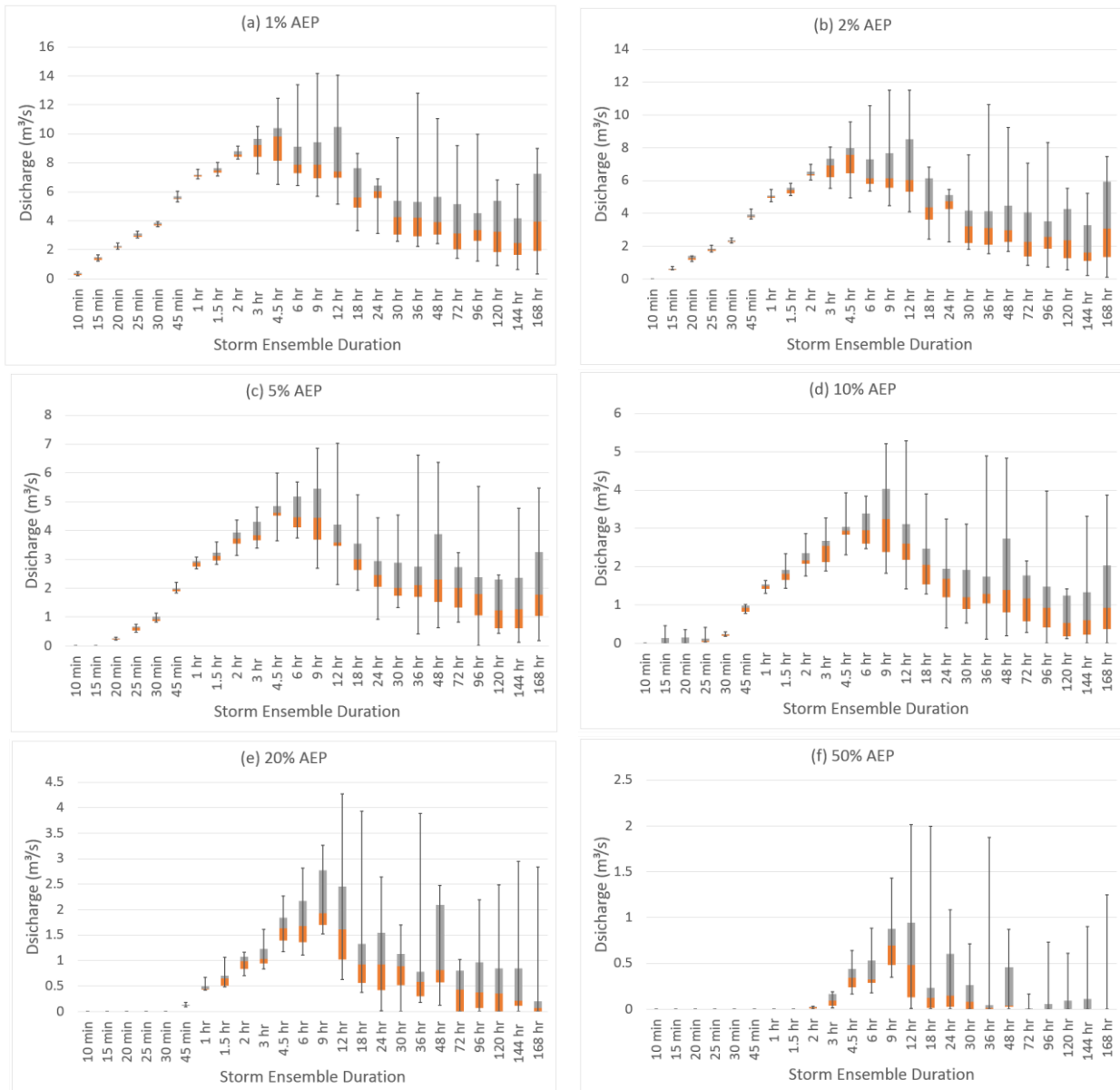


Figure 3.2: Sensitivity Analysis - Temporal Pattern Box and Whiskers Plots

3.3.3 Result Summary

Based on the sensitivity analysis, the Manning’s ‘*n*’ was refined. The comparison between the peak discharges generated with the XP-STORM model and the estimated RFFE model for the catchment is summarised in Table 3.4 and shown in Figure 3.3.

The hydrological parameters defined by the catchment characteristics, were capable of generating discharges within an acceptable range of the predicted RFFE discharge targets for all event probabilities.

Table 3.4: Manning's 'n' and Peak Discharges

Event AEP (%)	Area (ha)	Manning's 'n' adopted	RFFE Discharge (m³/s)	XP-STORM Discharge (m³/s)
50	389.459	0.035	1.25	0.70
20			2.29	1.93
10			3.18	3.25
5			4.19	4.62
2			5.74	7.57
1			7.10	9.80

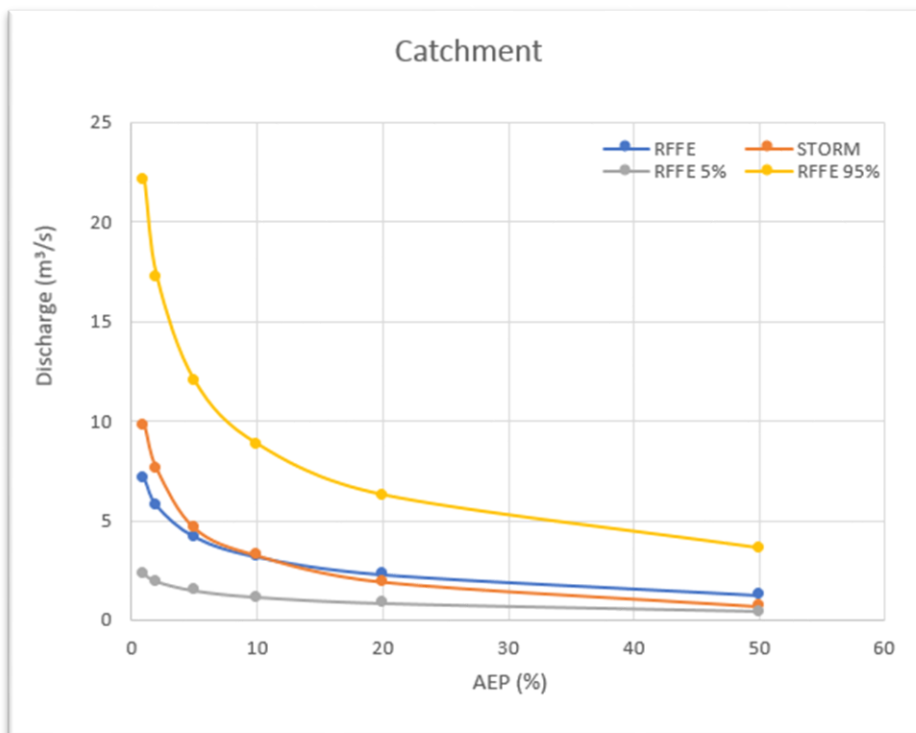


Figure 3.3: Estimated Peak Discharge - XP-STORM vs RFFE

3.3.4 RFFE Accuracy Considerations

A RFFE technique essentially represents a 'transfer function' that converts predictor variables to a flood quantile estimate. It is assumed that the use of a limited number of predictor variables (e.g. catchment area and design rainfall intensity) combined with an optimised transfer function captures the general nature of the rainfall-runoff relationship for flood events and hence provides flood quantile estimates of 'acceptable' accuracy.

ARR2019 identified ongoing concerns about estimation of parameter values (such as runoff coefficient and time of concentration) that are the basis of using the Probabilistic Rational Method¹⁴.

The use or application of the Probabilistic Rational Method, including the VicRoads variant, is no longer supported or recognised in ARR2019 as being a suitable RFFE technique^{15,16}.

All RFFE techniques are subject to uncertainty, which, generally, is likely to be greater than for at-site Flood Frequency Analysis when a good quality and long record of streamflow data set is available at the location of interest.

The RFFE model estimates of regional flood frequency included substantial error bounds and are considered to be a best estimate of rarer events that cannot be described in the ungauged catchment. Recent studies¹⁷ show how hydrological parameters from gauged catchments can be transferred to nearby ungauged catchments with similar natural characteristics.

Note: Due to the absence of a Gauged Catchment (i.e. appropriate stream and rainfall gauges) close to our site, the RFFE (Regional Flood Frequency Analysis) was used to obtain estimates of expected flows and subsequent losses within the site catchment. These values were used to validate the data as a sensitivity analysis for the parameters used in the XP Storm Hydrological model.

Geelong North Station (087133) is the closest rainfall gauge to our site and should be used for water quality modelling in MUSIC. MUSIC is a continuous simulation program that uses available rainfall gauge pluviography data for qualitative assessment. This allows BOM gauges close to the subject site to be used.

¹⁴ Coombes P.J., Babister M., and McAlister A., (2015), *Is the Science and Data underpinning the Rational Method Robust for use in Evolving Urban Catchments*. 36th Hydrology and Water Resources Symposium, Engineers Australia, Hobart.

¹⁵ Rahman, A, Haddad, K, Kuczera. G and Weinmann, E, 2016, Peak Flow Estimation, Chapter 3 Book 3 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

¹⁶ Coombes, P, Babister, M, McAlister, T, 2015, Is the Science and Data underpinning the Rational Method Robust for use in Evolving Urban Catchments, Conference Paper. Hydrologic Water Resource Symposium.

¹⁷ Coombes, P, Colegate, M, Barber, L, Babister, M, 2016, Modern perspective on hydrology processes of two catchments in Regional Victoria. 37th Hydrologic and Water Resource Symposium 2016.

3.4 Temporal Pattern Selection

3.4.1 Temporal Pattern Concept

As mentioned in [FIA 2019], in order to properly understand the concept of temporal pattern, it is necessary to understand the components of a storm event and how they relate to Intensity Frequency Duration Data (IFD) and catchment response.

Components of a typical storm pattern have been characterised in Figure 3.4. It is important to note the components can be characterised either by IFD relationships or by catchment response and are highly dependent on the definitions used. The components of a storm include:

1. Antecedent rainfall - is rainfall that has fallen before the storm event and is not considered part of the storm but can affect catchment response. This is important to understand when calibrating to or modelling historic events.
2. Pre-burst rainfall - is storm rainfall that occurs before the main burst. With the exception of relatively frequent events, it generally does not have a significant influence on catchment response but is very important for understanding catchment and storage conditions before the main rainfall burst. Pre-burst rainfall often accounts for a proportion of the initial losses within a catchment. Pre-burst depths need to be quantified when only modelling storm burst patterns.
3. The burst - represents the main part of the storm but is very dependent on the definition used. Bursts have typically been characterised by duration. The burst could be defined as the critical rainfall burst, the rainfall period within the storm that has the lowest probability, or the critical response burst that corresponds to the duration which produces the largest catchment response for a given rainfall Annual Exceedance Probability (AEP).
4. Post-burst rainfall - is rainfall that occurs after the main burst and is generally only considered when aspects of hydrograph recession are important. This could be for drawing down a dam after a flood event or understanding how inundation times affect flood recovery, road closures or agricultural land.
- 5.

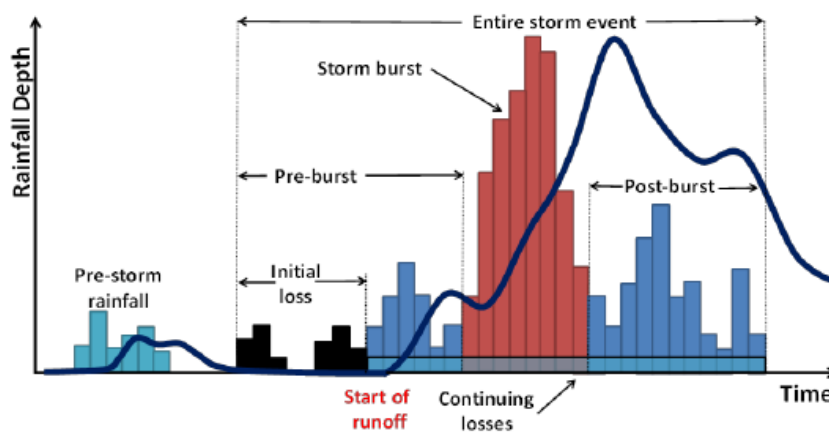


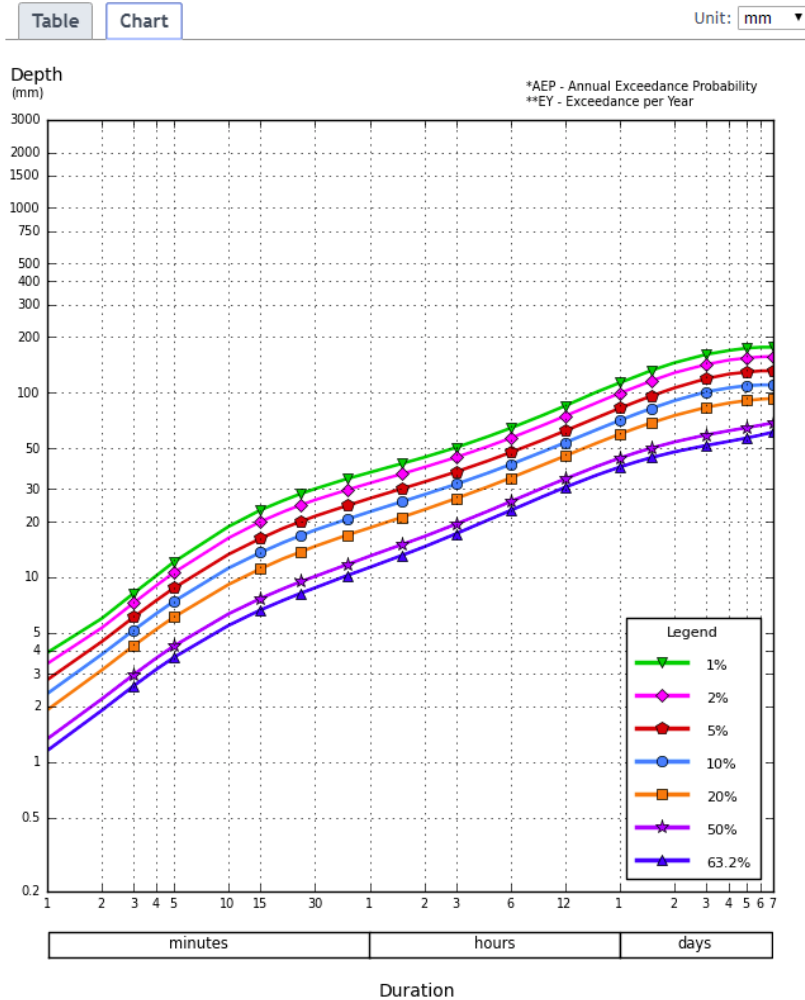
Figure 3.4: Elements of a Complete Storm Event and Hydrological Practice¹⁸

For this study, the Bureau of Meteorology’s 2016 IFD data and ARR2019 temporal patterns were used to produce an ensemble of storm burst patterns which were analysed for a whole catchment response.

¹⁸ Coombes, P, Colegate, M, Barber, L, Babister, M, 2016, A modern perspective on the hydrology processes of Armstrong Creek and Canadian Creek catchments in Regional Victoria. 4th National Conference on Urban Stormwater Management 2016.

3.4.2 IFD Data

The 2016 rainfall intensity frequency duration (IFD) climatic data used in the hydrological model was extracted from the Bureau of Meteorology (BOM) website¹⁹. The IFD curves are shown in Figure 3.5.



Note:

- The 50% AEP IFD does not correspond to the 2-year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
- The 20% AEP IFD does not correspond to the 5-year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

Figure 3.5: 2016 IFD Curves – Bureau of Meteorology 2019

3.4.3 Critical Storm Burst Pattern Selection

The historical process of using peak flows derived from a single critical storm burst does not account for the hydrological processes generated by the reality of complete (full volume) storms as demonstrated in Figure 3.4. It is important to understand the hydrological losses within the catchment and the relationship of the losses to both full storms and storm bursts.

For this analysis, 10 storm burst temporal patterns were extracted for 24 duration periods, for the 1% AEP event. By analysing the hydrological response to the ensemble temporal patterns, one critical pattern was selected for the 24 durations. The fixed temporal patterns over the entire study area for design flood estimation were implemented and the spatial variation was not considered. The analysed events and durations are shown in Table 3.5.

¹⁹ Bureau of Meteorology, <http://www.bom.gov.au/water/designRainfalls/>. Accessed on 14 November 2018.

Table 3.5: Analyzed Rainfall Patterns, Durations and Events

Number of Storm Burst Patterns in Ensemble (per event duration)	Storm Durations Analysed (minutes)			Event Probability Range Analysed (AEP)	
	(%)	(1 in x)			
10	10	120	1,800	1	100
	15	180	2,160		
	20	270	2,880		
	25	360	4,320		
	30	540	5,760		
	45	720	7,200		
	60	1,080	8,640		
	90	1,440	10,080		

The median value of the peak discharges generated for 10 temporal patterns under pre-developed conditions has been calculated. The critical temporal pattern was selected by identifying the temporal pattern characterised by the peak discharge closest to the median for the 24 durations.

The box-plot is shown in Figure 3.6 to illustrate the variation of the discharge predicted by the ensemble patterns.

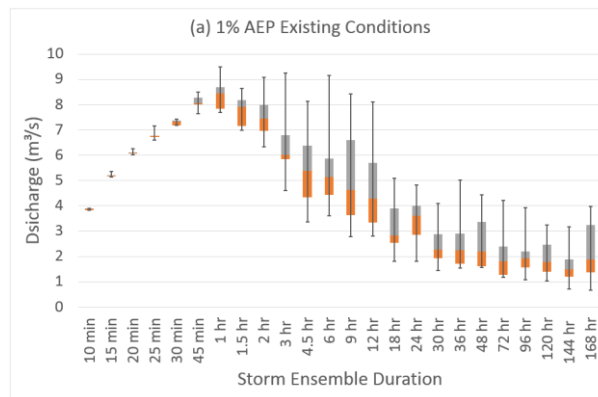


Figure 3.6: Temporal Pattern Box and Whiskers Plots

Sensitivity analysis models applied 100% pervious surfaces within the catchments. Impervious surfaces and urban characteristics were integrated into the temporal pattern selection and existing conditions hydrological models.

The modelling work was conducted through the study area for the 1% AEP. The hydrographs of 76 subcatchments simulated by the rainfall-runoff model were then used as inputs (boundary conditions) to the 2D hydraulic model.

The adopted storm burst patterns are shown in Table 3.6.

Table 3.6: Adopted Storm Burst Patterns

Duration	1% AEP	Duration	1% AEP	Duration	1% AEP	Duration	1% AEP
10 min	9	1 hour	9	9 hours	7	48 hours	6
15 min	5	1.5 hours	7	12 hours	7	72 hours	4
20 min	2	2 hours	7	18 hours	3	96 hours	4
25 min	3	3 hours	7	24 hours	6	120 hours	6
30 min	5	4.5 hours	6	30 hours	6	144 hours	1
45 min	3	6 hours	8	36 hours	5	168 hours	5

3.5 Local Hydrological Model

A local XP-STORM model was used to estimate the permissible site discharges (PSDs) for the sub-catchment based on the existing undeveloped conditions.

3.5.1 Existing Site Conditions ‘base-case’

An ensemble of storm events was used to simulate the 1% AEP event and evaluate the stormwater peak discharges generated by the contributing catchment areas.

For this study, the all temporal patterns durations for the 1% AEP event were analysed.

The critical peak discharge rates for the 1% AEP event should be used as PSDs for internal stormwater design.

3.5.2 Developed Conditions

Due to proposed development on the site, it is expected that peak runoff from the site will increase.

The assumption for effective fraction impervious of the developed site is the same as defined in Section 3.2.1. A conservative approach was taken and the change in fraction impervious for the developed site is shown in Table 3.7.

Table 3.7: Change in Impervious Surfaces

Sub Catchment/Area	Area (ha)	Effective Fraction Impervious (%)	Impervious Area (ha)	Pervious Area (ha)
Existing	2.052	0.04	1.962	0.090
Developed	2.052	0.63	0.759	1.293

4. Hydraulic Model

The extent of flooding within the study area was evaluated by employing outputs from the hydrological model in the two-dimensional hydraulic model TUFLOW HPC (build 2020-01-AB\TUFLOW_iSP_w64) using Graphics Processing Unit (GPU).

The 1D elements have been adopted to represent underground drainage network.

In addition, 1D elements are employed to represent the hydraulic devices that control the flood dynamics within the study area, such as culverts, weirs, sluice gates, pumps, etc.

A 2-metre model of the area of interest was set up for this study. This model was used to:

- Identify the critical duration storm events impacting the site. This allowed for simulation of the full 24 duration event ensembles within reasonable runtimes;
- Generate the predicted flood extents to be employed as the existing conditions 'base case' for this stage of the project. This model only applied the critical storm durations impacting the study area.

The mathematical derivation of the shallow water equations solved by TUFLOW requires that the adopted 2D cell size is greater than the local water depth. For this reason, a cell size of 2 m has been adopted to adequately represent the 2D domain from a numerical modelling perspective in the fine grid model.

Moreover, the 2-metre grid enabled detailed definition of the variable terrain topography, road network, overland flow paths and various hydraulic obstructions. This grid size was also determined to be of suitable size to allow accurate definition of the terrain without adversely affecting the simulation run times.

4.1 Digital Elevation Model

A bottom elevation value was assigned to each cell of the hydraulic model using the most updated digital elevation model (DEM) available for the area of interest.

The DEM was generated using LIDAR data from the *Vicmap Digital LiDAR Elevation DEM* dataset and 2014 *Bellarine Peninsula LiDAR Improved Accuracy* dataset. The 2014 *Bellarine Peninsula LiDAR Improved Accuracy* dataset DEM, shown in Figure 4.1 was flown in 2011 and further work was conducted between September and November 2014 by AAM using original 2011 *Melbourne Structural Vegetation LiDAR* data as source data. It has a resolution of 1 m with a horizontal and a vertical accuracy of ± 10 cm.

A surface elevation of the basin (located north of the Bellarine Rail Trail, approximately 320 m east of the subject site) was provided by Spiire in August 2021 and was merged with the existing LiDAR (as shown in Figure 4.1 below) to better reflect current conditions.

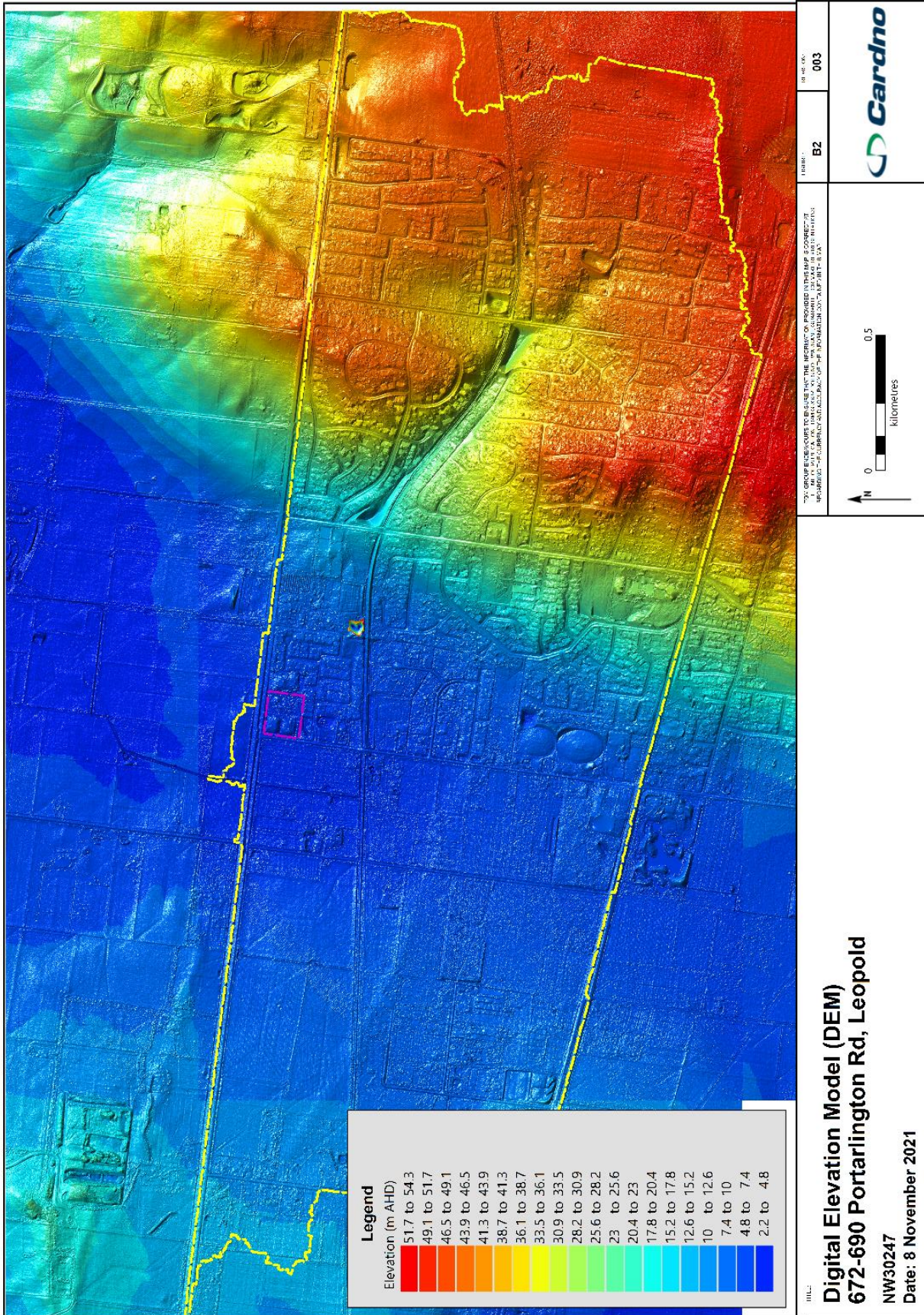


Figure 4.1: Digital Elevation Model (DEM)

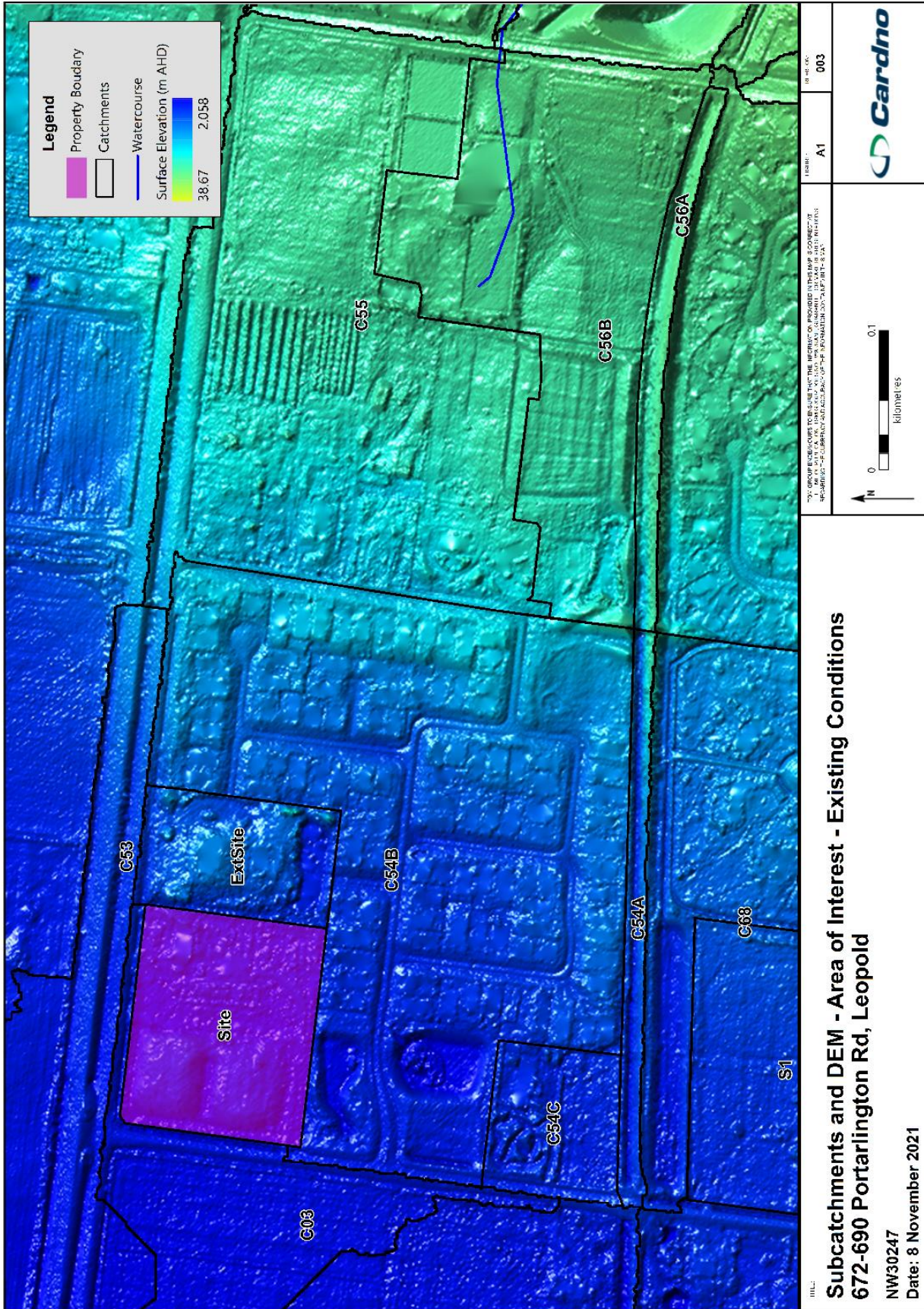


Figure 4.2: Digital Elevation Model (DEM) – AOI

4.2 Underground Drainage Network

Underground drainage systems are an integral factor in urban flooding. The capacity of the underground system to accommodate stormwater runoff will directly impact the overland flows.

City of Greater Geelong Geographic Information Systems (GIS) drainage tables were downloaded from the Australian Governments National Map website and used to identify the location and characteristics of the underground drainage systems.

It is noted that the GIS drainage database does not provide invert levels of underground drainage systems. The invert levels of the underground pipe network were determined at pit locations on the basis of the ground elevations extracted from the DEM. Minimum grade and minimum cover requirements were used to estimate the pipe inverts throughout the system.

Key features of the drainage system in the area of interest, such as bridge culverts, trunk systems, pipes with a diameter ≥ 300 mm and associated drainage pits, were selected and represented as 1D elements in the TUFLOW hydraulic model.

It is recommended to undertake additional survey and inspection of the underground drainage system at key locations during functional design. Exact service location, cover and clearances must be confirmed especially around the subject site.

The extent of the GIS underground pipe network integrated into the 2D hydraulic model can be seen in Figure 4.3, where different pipe sizes are highlighted with relevant widths and colours.

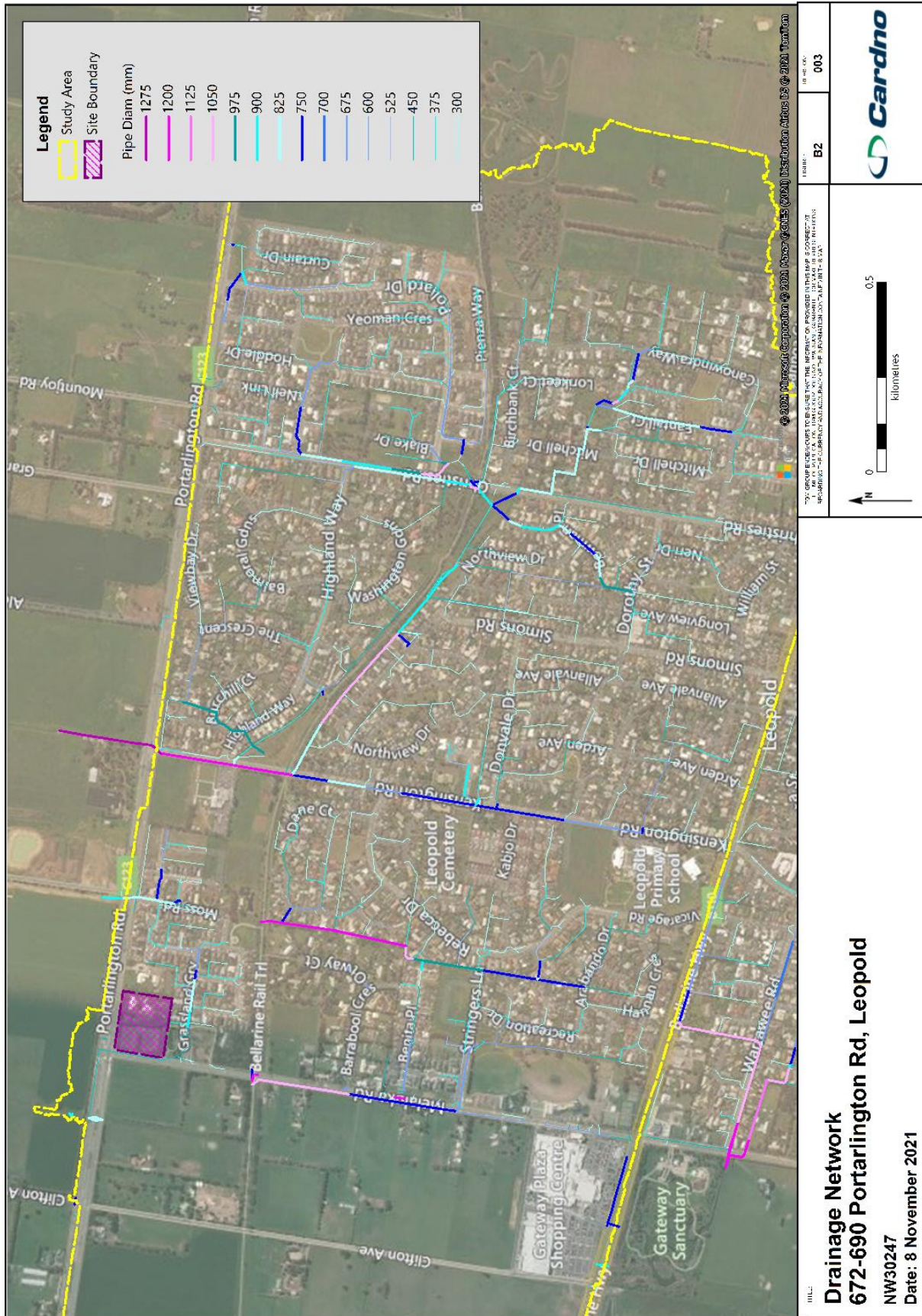


Figure 4.3: Underground Drainage Network

4.3 Manning’s Roughness Coefficients

Manning’s roughness coefficients were adopted for the TUFLOW hydraulic model with variation in roughness to reflect the urban development and gravel, sealed and asphalt road networks. The Manning’s roughness coefficients applied in this study are shown in Table 4.1.

Table 4.1: Manning’s Roughness Coefficients ‘n’

Land Use	Manning’s n
Buildings	0.15
Gravel roads	0.029
Asphalt roads / road reserve	0.016
Pasture / Rural Living	0.035

4.4 Boundary Conditions

The output hydrographs from the XP-STORM hydrological model were applied as inflow boundary conditions into the TUFLOW hydraulic model. A series of stage-discharge relationships along the outflow cross-sections of the hydraulic model have been adopted as outflow boundary conditions.

The outflow boundary condition is a HT (Water Level versus Time) used at the margins/outflow of the model (as per recommended BC arrangements in the TUFLOW Manual).

The inflow boundary conditions were modelled by applying 2d_sa, 2d_sa_pit and 2d_sa_ALL polygons as required for flows that were routed with Laurenson method, flows conveyed in the pits and unrouted flows, respectively.

The locations of the inflow and outflow boundary conditions are shown in Figure 4.4.

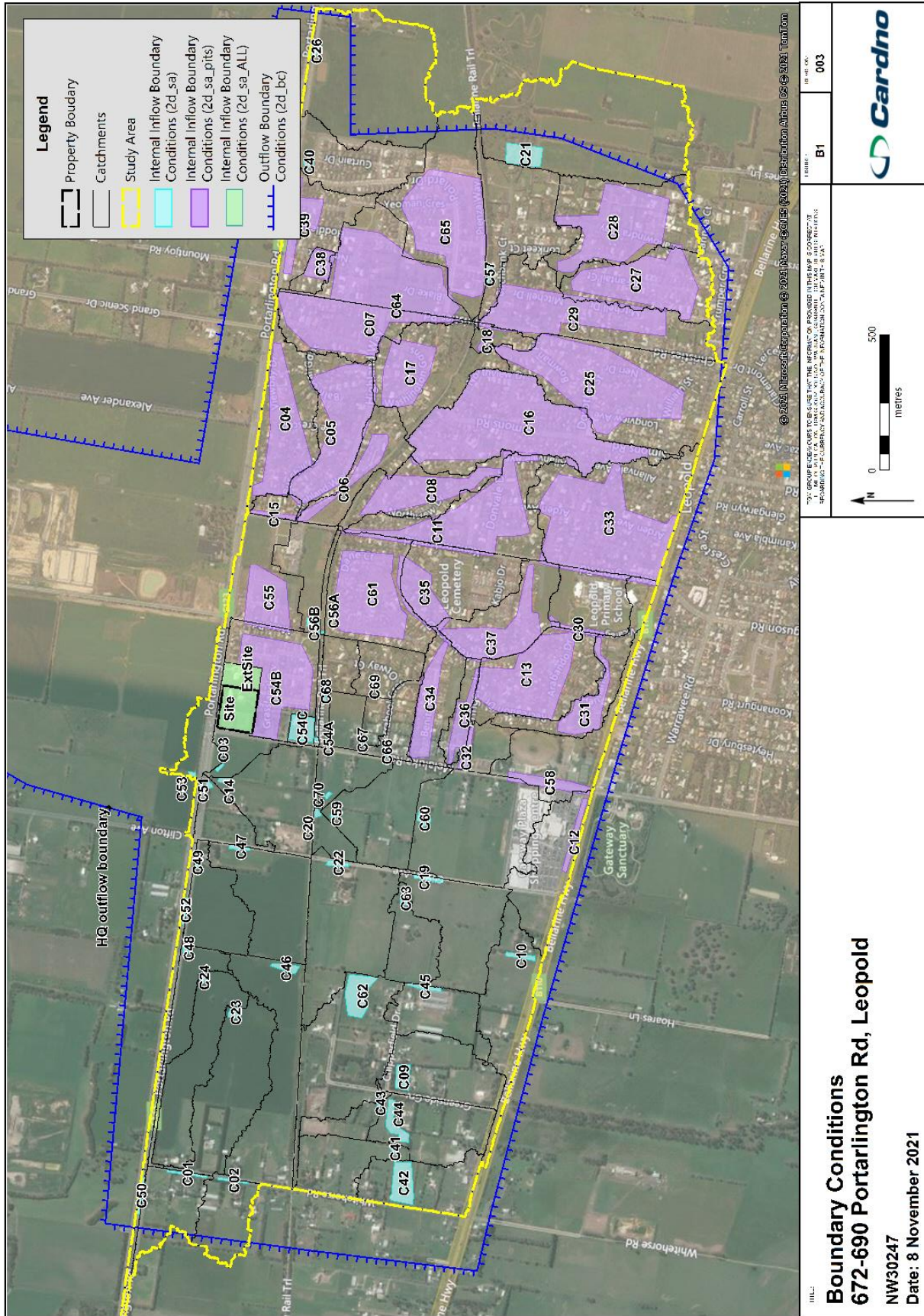


Figure 4.4: 2D Hydraulic Model – Boundary Conditions

5. Modelling Results

The results of the hydrological and hydraulic analysis are discussed in the following sections.

5.1 Hydrological Modelling Results

5.1.1 Existing Site Discharge

The permissible site discharge (PSD) from the LPOD for the 1% AEP event was determined using the local hydrological model under existing conditions. The runoff hydrograph is shown in Figure 5.1. The critical peak discharge is 0.043 m³/s (critical duration of 1 hour up to 2 hours).

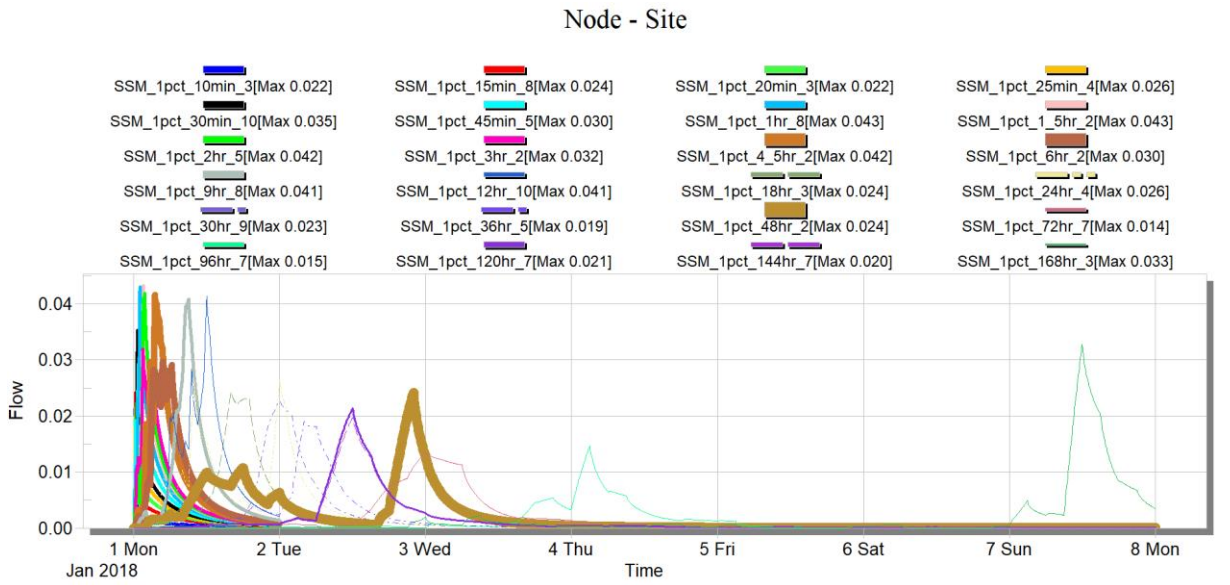


Figure 5.1: 1% AEP Hydrograph (Existing Site)

5.1.2 Developed Site Discharge

The runoff hydrograph before mitigation for 1% AEP is shown in Figure 5.2.

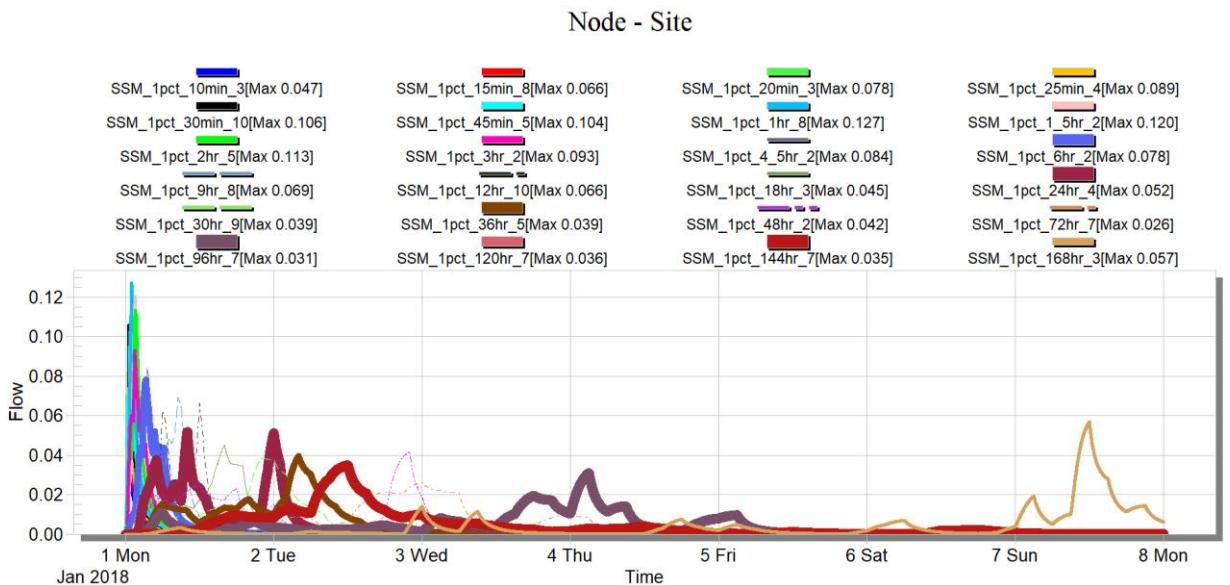


Figure 5.2: 1% AEP Hydrograph (Developed Site)

As shown in the figure above, the peak discharge for the developed site without any mitigation is 0.127 m³/s (critical duration of 1 hour).

As the site is located within an existing developed area, it is anticipated that Council will require stormwater flows generated from the development to be restricted back to the capacity of the surrounding drainage infrastructure prior to discharge from the site. Cardno has adopted the 1% AEP flow for a high-level detention sizing estimation in order to achieve this.

A potential stormwater conceptual option to achieve the ‘no worsening’ discharge objective in the hydraulic model could include a drainage reserve along the western boundary of the site. The required storage volume of this asset has been conservatively estimated using high-level storage estimation methodologies which result in the requirement for an on-site detention basin providing approximately 500m³ of storage.

The drainage reserve must be sized to provide flood storage on the site and include consideration of additional runoff from the site as a result of development. Minimum batter slopes must be adopted from the invert of the drainage reserve to the existing surface levels along the property boundaries. The basin will be required to connect to the existing underground drainage asset beneath Melaluka Road. As such, the basin depth will be limited by the invert level of this asset in order for it to be able to freely drain. As the invert levels of this drainage pipe are currently unknown, service proofing of this asset must be carried out to determine the possible storage depth and area needed for the detention basin.

Further consideration should be given to future road extensions and allowance for compensatory storage and conveyance to the downstream catchment should be provided. The possibility to connect to the existing network (375mm pipe) just south of the property should also be further investigated.

5.2 Hydraulic Model Results

The existing flood characteristics of the regional flood extents are detailed in this section.

5.2.1 Critical Duration Selection

Runoff hydrographs, for each of the 168 event durations, were extracted from the regional hydrological model, and modelled as inflow boundary conditions in the 2D hydraulic TUFLOW model to identify the critical duration(s) impacting the site for each event probability.

The critical 1% AEP event durations for the entire catchment and the critical urban area are summarised in Table 5.1, however, all durations were run for the existing conditions.

To optimise model runtimes, running critical storm durations is proposed for future flood modelling (detailed design phase).

Table 5.1: Critical Storm Durations Analysed in the Fine Grid (2 m) Model

Durations	1%
10min	x
15min	x
20min	
30min	x
45min	

Durations	1%
1hr	x
1_5hr	x
2hr	x
4_5hr	x
6hr	
9hr	x
12hr	x
24hr	

5.2.2 Flood Extent Mapping

The envelope of the computed flood depths (≥ 50 mm) of the entire modelled area for the existing conditions in the 1% AEP event are shown in Figure 5.3 (overall flood extent) and Figure 5.4 (site specific).

In assessing the stormwater runoff, west to east, it can be seen that flood extent is predominantly confined to the western boundary, although there are intrusions along the northern and southern boundaries as well as a narrow intrusion between the existing earth mounds. The flood extent of the eastern half of the site is limited to small patches within the tree-line and open area, as can be seen in Figure 5.4.

5.2.3 Flood Hazard Mapping

The hazard maps have been created in accordance with the Safety and Hazard Criteria defined by ARR2019²⁰, which state that flow velocity, depths and the product of velocity and depth must not exceed safety limits for people and vehicle access (egress) to (from) the site. The criteria are as follows:

1. Site Safety (People)
 - Depth must be no greater than or equal to 0.5 metres;
 - Velocity must be no greater than or equal to 3.0 m/s; and
 - The product of depth multiplied by velocity must be no greater than or equal to 0.4 m²/s.
2. Access Safety (Vehicles)
 - Depth must be no greater than or equal to 0.3 metres;
 - Velocity must be no greater than or equal to 3.0 m/s; and
 - The product of depth multiplied by velocity must be no greater than or equal to 0.3 m²/s.

As safety for vehicles sets the lower threshold on acceptable hazard limits, it will be adopted in this study as the safety criteria.

²⁰ Smith, G, Cox, R, 2016. Safety Design Criteria. Chapter 7 Book 6 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

The 1% AEP flood hazards, with the consideration of all the criteria listed above (flood depth $\geq 50\text{mm}$) for existing conditions is presented in Figure 5.5.

The hazard envelope map shows that safe access (egress) can be achieved to and from the site via the 3 existing driveways (depicted in Figure 2.2).

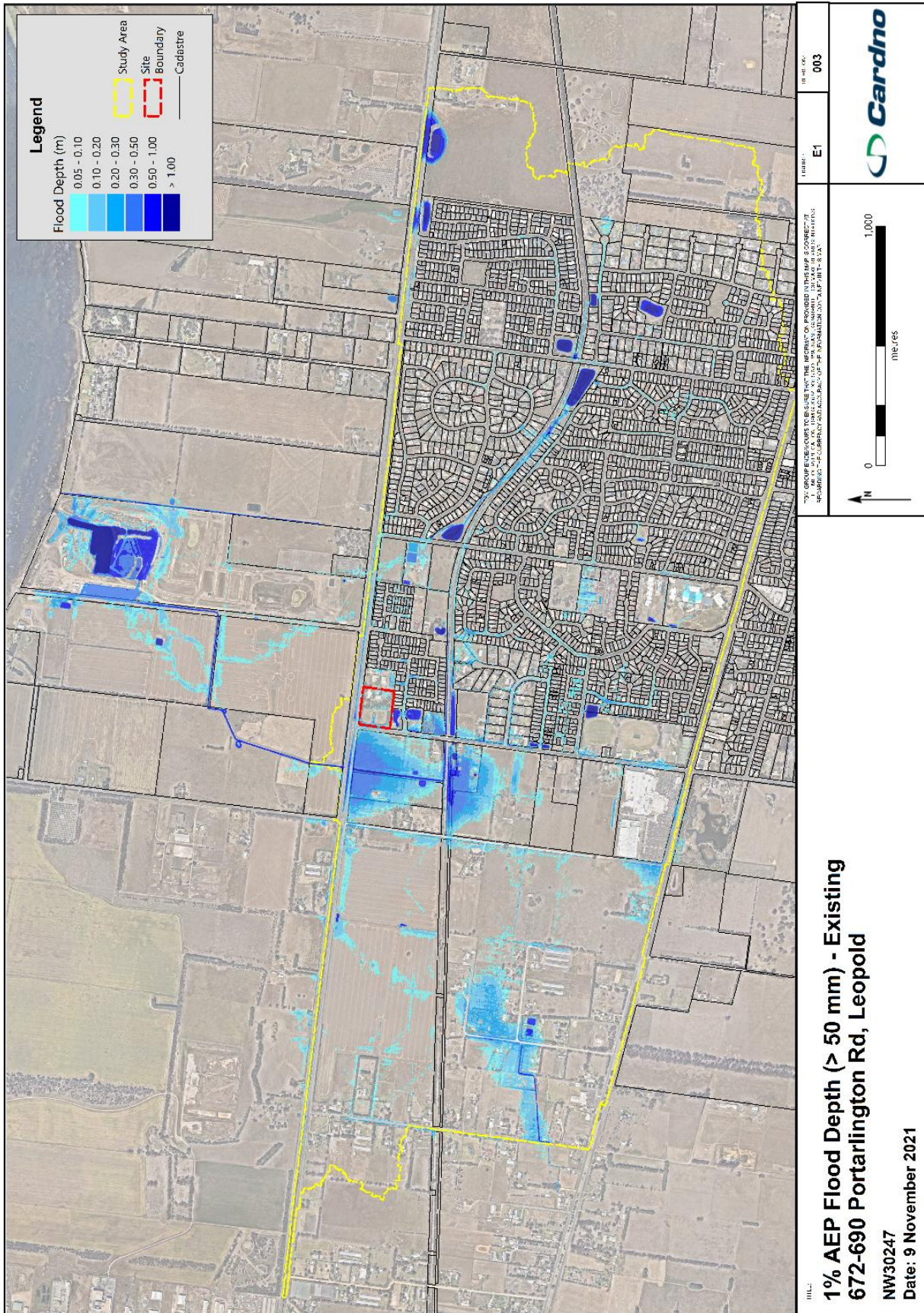


Figure 5.3: Existing Conditions - 1% AEP Flood Extent and Depths >50mm

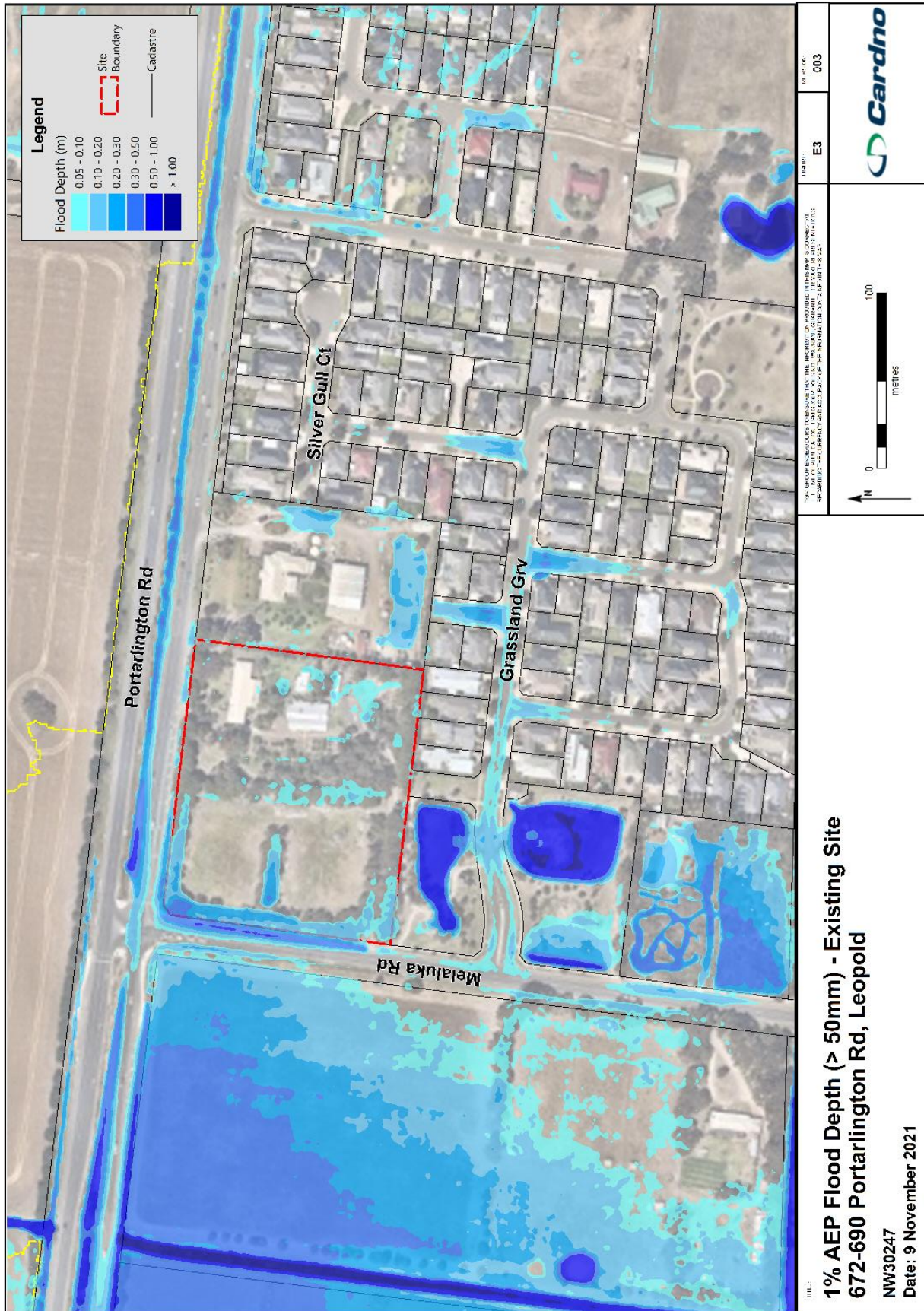


Figure 5.4: Existing Conditions - 1% AEP Flood Extent and Depths >50mm (site specific)



Figure 5.5: Existing Conditions - 1% AEP Hazard Envelope (site specific)

6. Conclusions and Recommendations

Cardno concludes that the rainfall and flood estimation techniques employed in this study are consistent with ARR2019 current industry best practice.

The mathematical modelling output is an accurate representation, based on the best available data, of the estimated regional flood extent impacting the site during the 1% AEP design storm event with a range of critical storm durations.

The predeveloped (existing) flood characteristics should form the 'base-case' for further investigation and flood impact analysis of the proposed site development.

The 1% AEP existing flood extent is predominantly confined to the western boundary, with partial intrusions along the northern and southern boundaries, as well as a narrow intrusion between the existing earth mounds.

The 1% AEP flood hazard envelope map shows that safe access (egress) can be achieved to and from the subject site via the 3 existing driveways.

The flood extent south of the subject site offers the potential of further investigating the existing open space and drainage reserve as storage option. Further assessment is required to determine if this is a viable option.

An on-site detention basin providing approximately 500m³ of storage will likely be required as part of the ultimate development of the land within the study area to ensure no worsening downstream flood impacts as a result of the proposed development. This may be provided either within the study area and/or adjacent land including the Council Reserve (dependant on further analysis and approval) and can be considered as part of the ultimate development of the land.

A site stormwater management plan (SSMP) should be further developed to demonstrate that the site can be developed using best practice stormwater management principles and techniques. This will enable the further subdivision and development of the site to meet the conditions and requirements set in the planning scheme for stormwater management. Due to site constraints and unknown existing pipe depths on Melaluka Road, further investigation is required to determine an achievable detention storage depth. The basin area, properties and exact location must be confirmed during the design stage. An SSMP should be a condition of the permit for the ultimate development and/or subdivision of the land and is not necessary for the rezoning or initial two lot subdivision.

The objectives outlined in Section 1.1 should inform stormwater designs and ensure that stormwater quantity and quality targets are achieved and maintained. Water quality assets (including bio-retention swales and/or wetlands) should be considered at this stage.

The new development must meet Best Practice performance objectives, as contained in the Urban Stormwater – Best Practice Environmental Management Guidelines (Victorian Stormwater Committee 1999) and should incorporate Water Sensitive Urban Design (WSUD) features that meet the requirements mentioned in Section 1.1.2.

It is understood that the proposed development will likely include a local road connection to Grassland Grove to the south along with a local road connection to the separate development immediately east of the site (692-700 Portarlington Road). However, the adjoining site to the east and the subject site itself (672-690 Portarlington Rd) can be developed independently from each other.

The stormwater analysis undertaken as part of this assessment has not identified any reasons as to why the initial subdivision of the site cannot proceed. Beyond this, future Planning Permits issued for the ultimate development and/or subdivision of the land should include appropriate engineering conditions including the preparation of a Site Stormwater Management Plan (SSMP). It is recommended that this assessment would include the presentation of appropriate stormwater designs and evidence that the stormwater quality and quantity targets are met.

7. Appendix

7.1 Appendix A: Regional Flood Frequency Estimation Model

Regional Flood Frequency Estimation Model

Release Version of the Regional Flood Frequency Estimation Model for the 4th edition of Australian Rainfall and Runoff.



Input Data

Basic **Advanced**

Catchment Name

Melaluka

Catchment Outlet Latitude

-38.173

Catchment Outlet Longitude

144.461

Catchment Centroid Latitude

-38.184

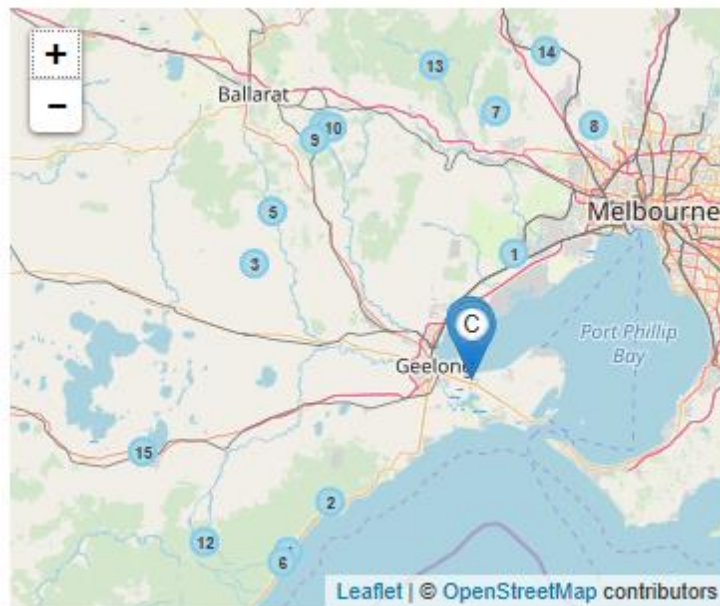
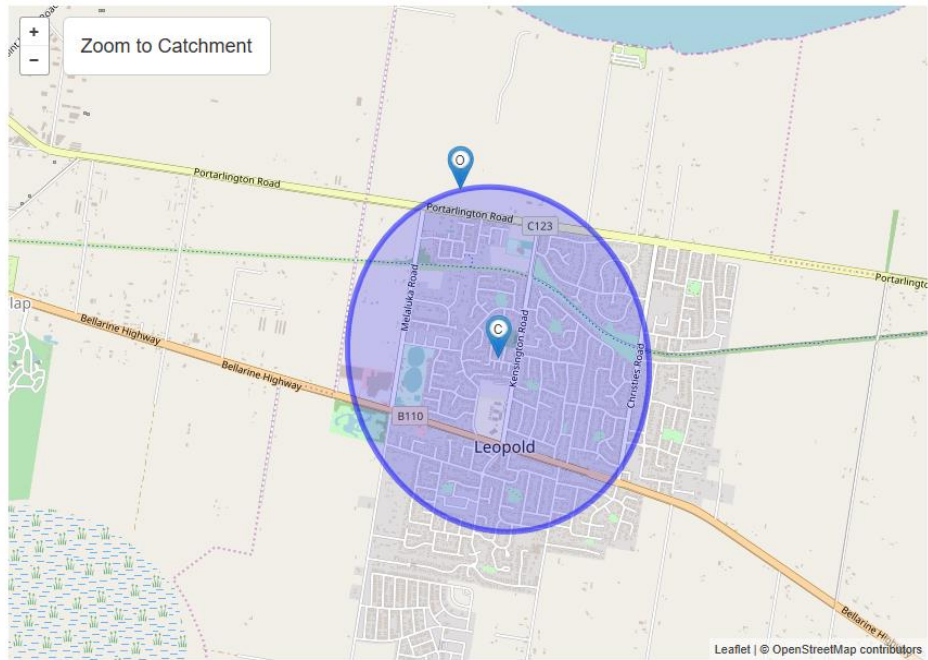
Catchment Centroid Longitude

144.464

Catchment Area (km²)

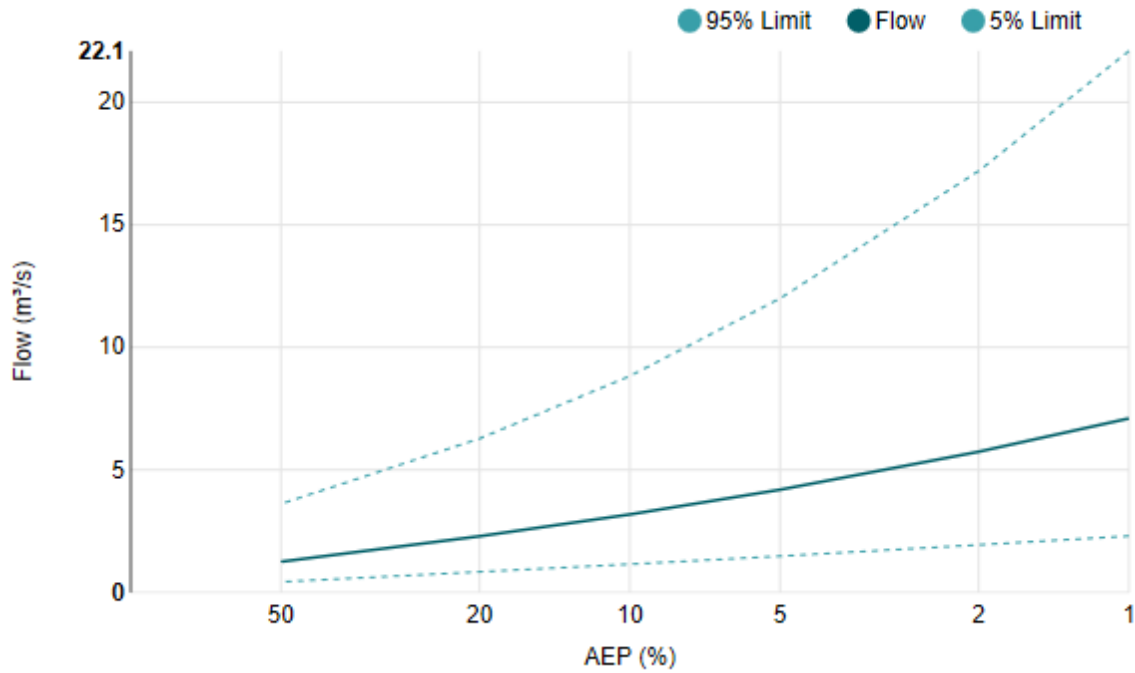
3.89459

Submit



Input Data

Date/Time	2019-01-10 15:43
Catchment Name	Melaluka
Latitude (Outlet)	-38.173
Longitude (Outlet)	144.461
Latitude (Centroid)	-38.184
Longitude (Centroid)	144.464
Catchment Area (km ²)	3.89459
Distance to Nearest Gauged Catchment (km)	31.05
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.283169
2% AEP 6 Hour Rainfall Intensity (mm/h)	9.406396
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.63
Interpolation Method	Natural Neighbour
Bias Correction Value	0.233



AEP (%)	Discharge (m³/s)	Lower Confidence Limit (5%) (m³/s)	Upper Confidence Limit (95%) (m³/s)
50	1.25	0.430	3.61
20	2.29	0.840	6.28
10	3.18	1.15	8.83
5	4.19	1.48	12.0
2	5.74	1.94	17.2
1	7.10	2.30	22.1

Statistics

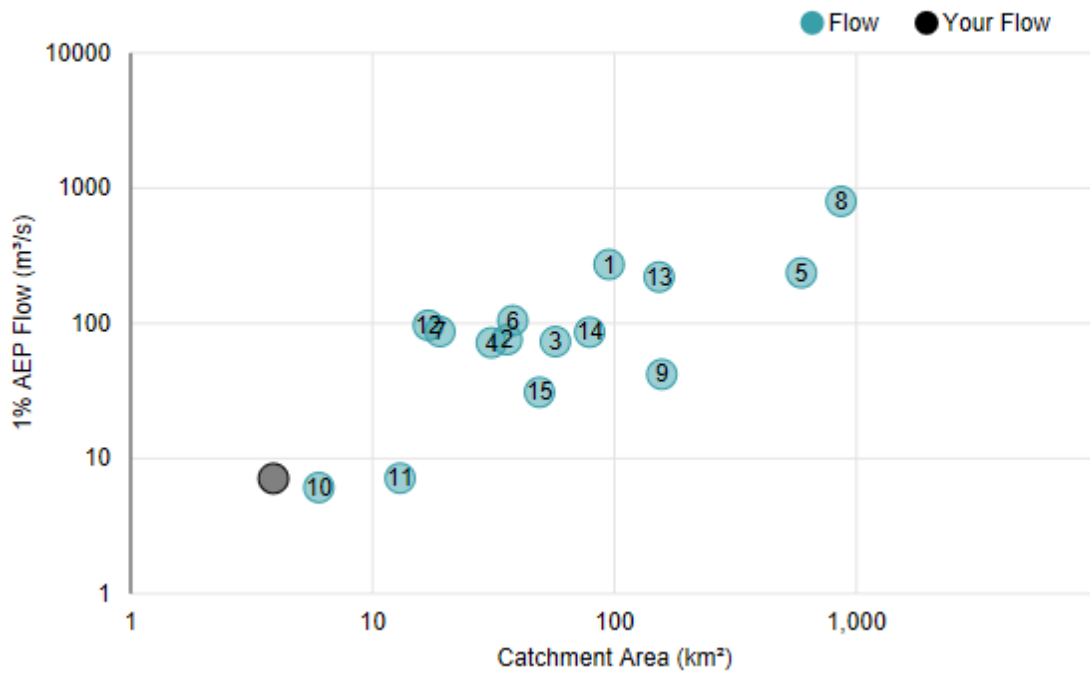
Variable	Value	Standard Dev
Mean	0.323	0.654
Standard Dev	0.664	0.217
Skew	0.141	0.030

Note: These statistics come from the nearest gauged catchment. [Details.](#)

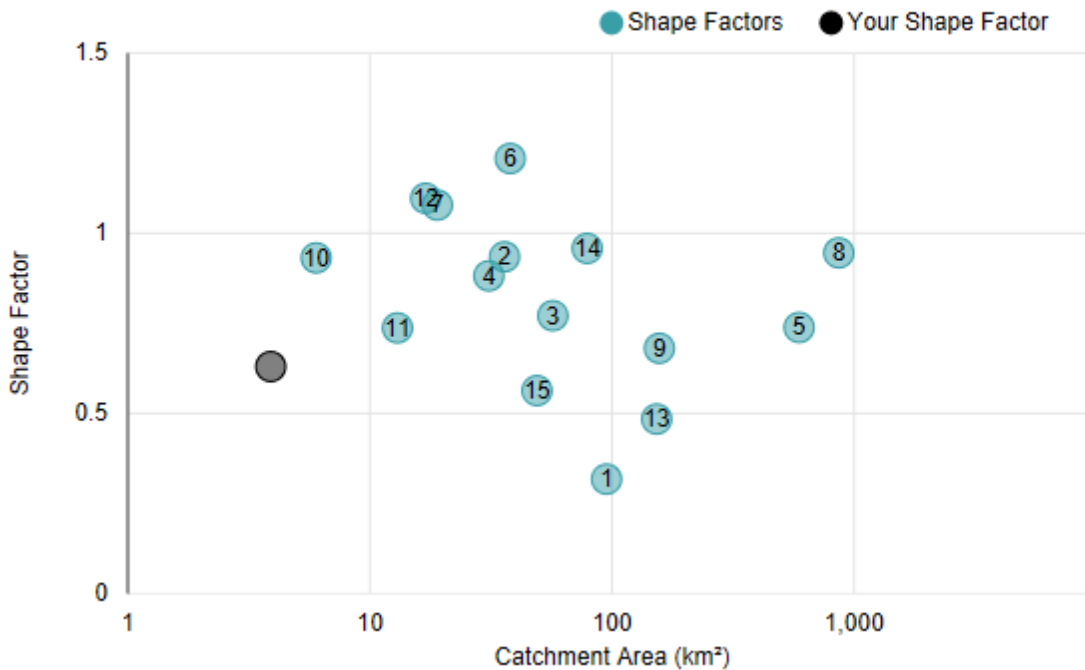
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. [Details.](#)

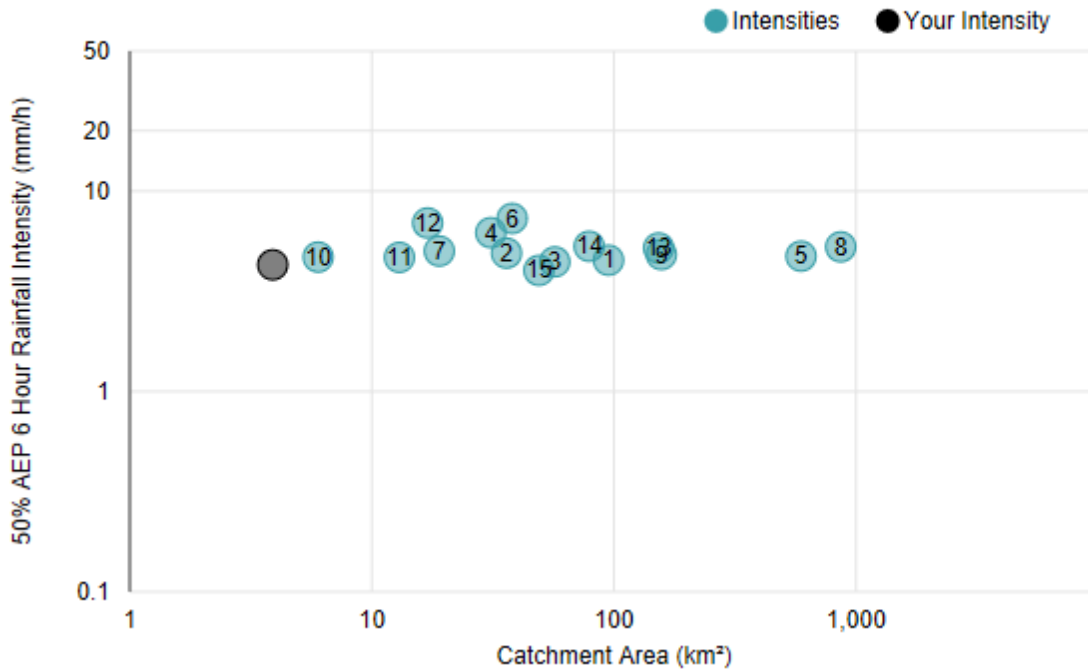
1% AEP Flow vs Catchment Area



Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area

