1 HENRY ST, BELMONT

STAGED MULTI LOT SUBDIVISION
SITE STORMWATER MANAGEMENT PLAN

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Front Cover Image – 1 Henry St, Belmont (Courtesy Nearmap)

Executive Summary

Cardno, now Stantec has been engaged by Belmont Projects Pty Ltd to provide a Site Stormwater Management Plan (SSMP) in support of a planning permit application for a multi-lot subdivision for land at 1 Henry Street, Belmont. Belmont Projects Pty. Ltd. initially intend to apply for a town planning permit for Stage 1 of the development (Refer Figure 2.9), however they wish to ensure that runoff from the overall site can be managed in accordance with stormwater best practice and to the satisfaction of the City of Greater Geelong(CoGG).

The subject area is a 6.21 hectare land parcel currently the site of the decommissioned CSIRO Textile and Fibre Technology Laboratory. The subject land will represent an infill development that will be redeveloped from a former industrial site into a mixed density residential site.

The CoGG has identified significant capacity constraints with the existing downstream stormwater drainage system, specifically in Reynolds Road and High St. Consequently, the permissible site discharge rates for the site, particularly the section of the site that naturally drains westwards, are set relatively low when compared to existing conditions. For example, the PSD for the 20% AEP rainfall event for the westerly draining area is 1.5% of the rate for the easterly draining area, however the western catchment represents approximately 27% of the total site. This has resulted in the need for additional stormwater detention capacity located in the western catchment.

The targets supplied by CoGG 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. Achieve Permissible Site Discharge (PSD) targets[1]

   East Catchment PSD –

   - 1% AEP = 1.23 m³/s
   - 20% AEP = 0.63 m³/s

   West Catchment PSD –

   - 1% AEP = 0.05 m³/s
   - 20% AEP = 0.01 m³/s

Despite these challenges, this SSMP demonstrates that it is possible to manage stormwater runoff onsite from the proposed development at 1 Henry St Belmont to ensure the peak discharge does not exceed the permissible rates as nominated by the CoGG and the quality of the runoff can be treated to best practice environmental management guidelines.

[1] Set by City of Greater Geelong Council as a reflection of downstream drainage system capacity. [CoGG Letter dated 10 Nov. 2015]

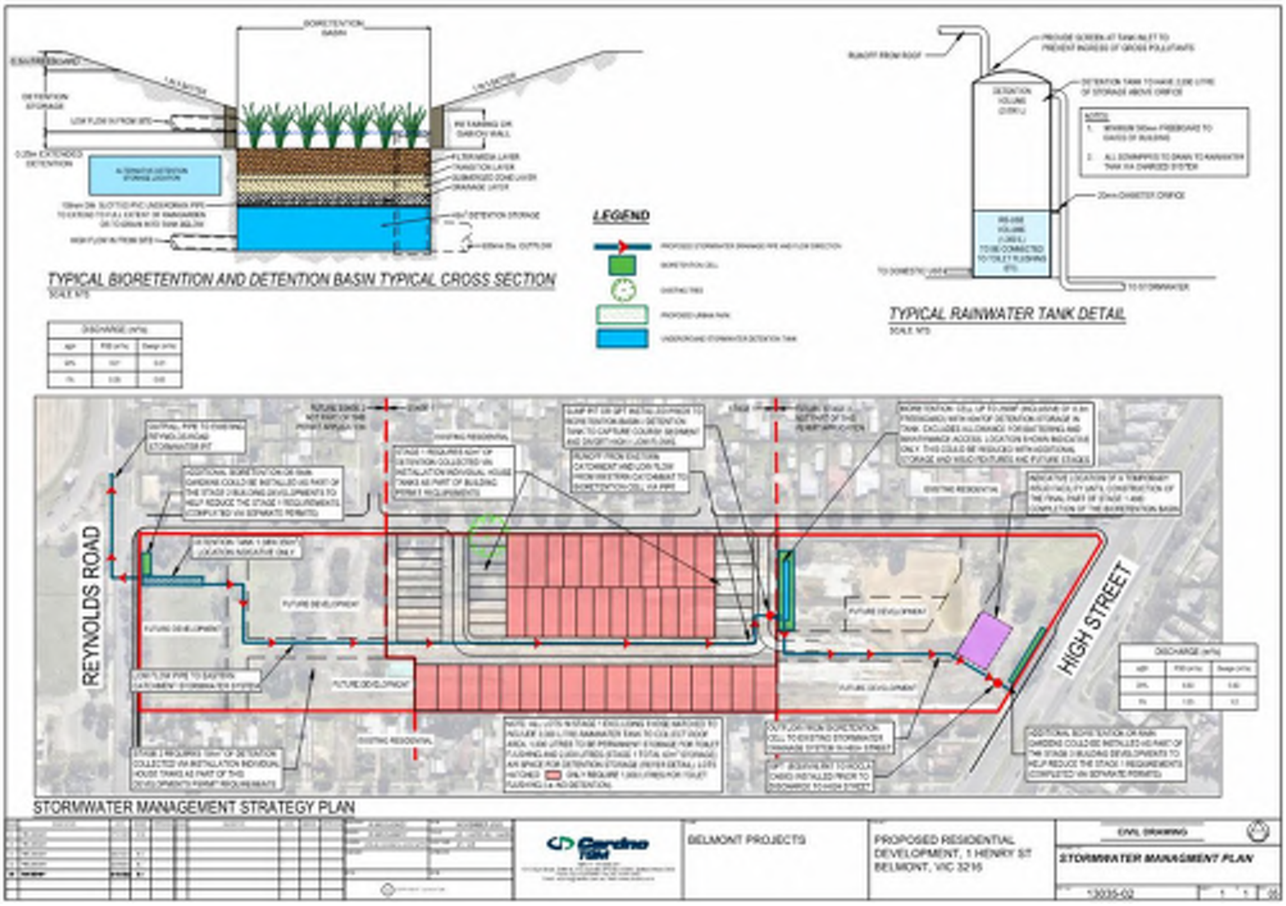
The objective of the stormwater management plan is to demonstrate how the development will meet the conditions and requirements as set by the CoGG without any 'short comings' held against future development. The planning application for stormwater management systems are designed to ensure that stormwater quality and quantity targets are met using a combination of;

- Rainwater Tank Detention and Toilet Flushing Tanks for the townhouse developed sites which construction would be controlled by the developer and additional permits for buildings
- Rainwater Toilet Flushing Tanks (no detention) for standard residential lots
- A Bioretention and Detention Basin
- Gross Pollutant Traps.

And for the future eastern and western future development sites which this SSMP allows for but would be developed with additional permits;

- Detention Tanks (possibly underground)
- Potentially additional bioretention / rain gardens
- Connection of the western outfall back to the eastern part of the site.

Construction can also be managed for Stage 1 and the future stages to protect the drainage assets from being overwhelmed by additional sedimentation produced from construction works.



Stormwater Management Plan

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Tables

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1 Introduction

Cardno now Stantec has been engaged by Belmont Projects Pty. Ltd. (the client) to prepare a site stormwater management plan (SSMP) to support the redevelopment of land located at 1 Henry Street, Belmont, currently the site of the decommissioned CSIRO Textile and Fibre Technology Laboratory. Initially our client intends to apply to develop Stage 1 of the development, with the balance of the site to be covered by future town planning applications.

It is proposed to ultimately redevelop the former industrial site into a mixed density residential and commercial subdivision with increased pervious surfaces, consistent with the Victorian governments '*Cleaner Environments – Smarter Urban Renewal*' reforms to redevelop existing brownfield sites into cleaner, more environmentally sustainable residential developments with the intent of enhancing the surrounding community.

The subject site is situated approximately 4.2 km south west of Geelong CBD, as depicted in Figure 1.1, below.

Figure 1.1: 1 Henry St Redevelopment site location

2 Study area

2.1 Site Description

The subject site is a 6.21-hectare land parcel previously the location of the CSIRO Textile and Fibre Laboratories. The CSIRO laboratory buildings previously occupied the site, and demolition created a highly impervious area with high runoff potential. An aerial photo of the site prior to building demolition can be seen in Figure 2.1, below.

Figure 2.1: Site and surrounding urban development

The site has three street frontages - Henry Street which runs the length of the northern boundary, High Street to the east and Reynolds Road to the west. The southern boundary backs onto established residential properties.

2.2 Catchment Characteristics

The subject site is located within the suburban area of Belmont. The majority of the site is situated at the top of a catchment feeding a tributary of the Waurn Ponds Creek, however, stormwater flows within the catchment are primarily conveyed within the urban drainage system. The characteristics of the catchment can be seen in Figure 2.2.

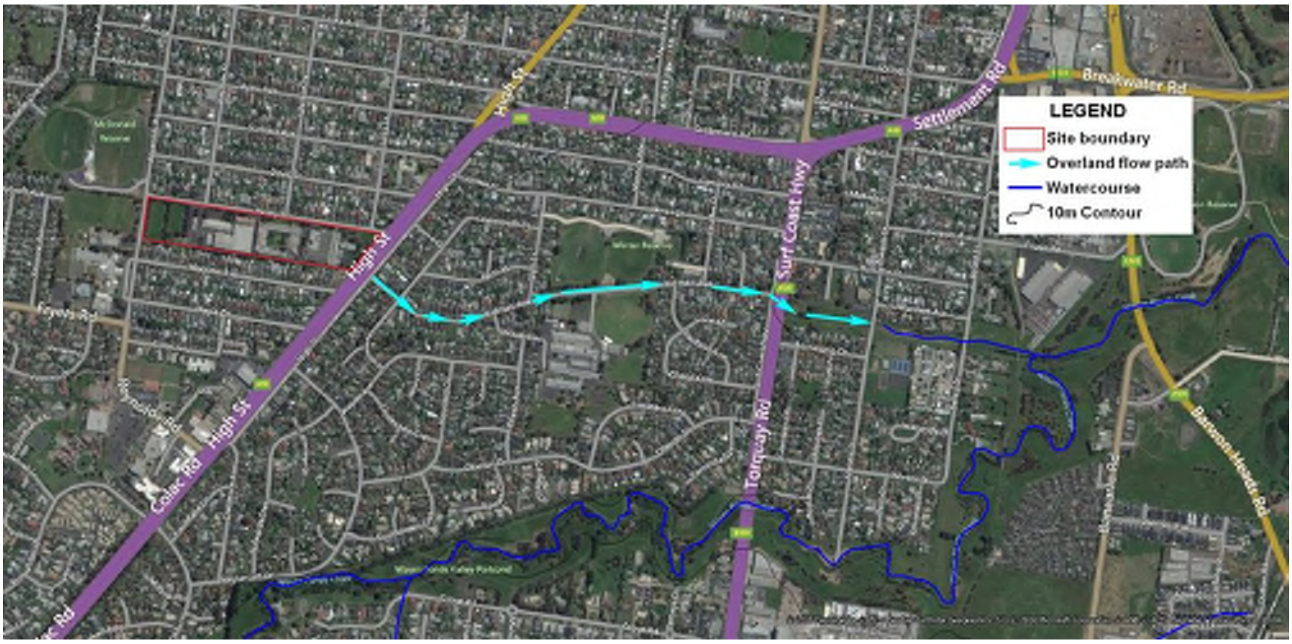

Figure 2.2: Catchment Characteristics

2.3 Internal Stormwater Catchments

2.3.1 Existing Site

The overall existing site can be broken up into 2 catchments, east and west, according to topography and point of discharge. The internal catchments are shown in Figure 2.3 and detailed in Table 2.1

Figure 2.3: Internal sub-catchments & Discharge Locations

Catchment	Area (Ha)	Point of Discharge
East	4.85	High St
West	1.36	Reynolds Road

Table 2.1: Sub-catchment Types Summary

Cardno now Stantec has undertaken detailed survey of the site and the internal catchment areas are confirmed. The feature survey is depicted in Figure 2.4 to Figure 2.8.

The majority of the CSIRO building structures were situated within the larger ‘east’ catchment currently resulting in 84% impervious surfaces. The existing ‘west’ catchment contains a few hard stands but no major building structures and resulting in much fewer impervious surfaces at roughly 21% of the area.

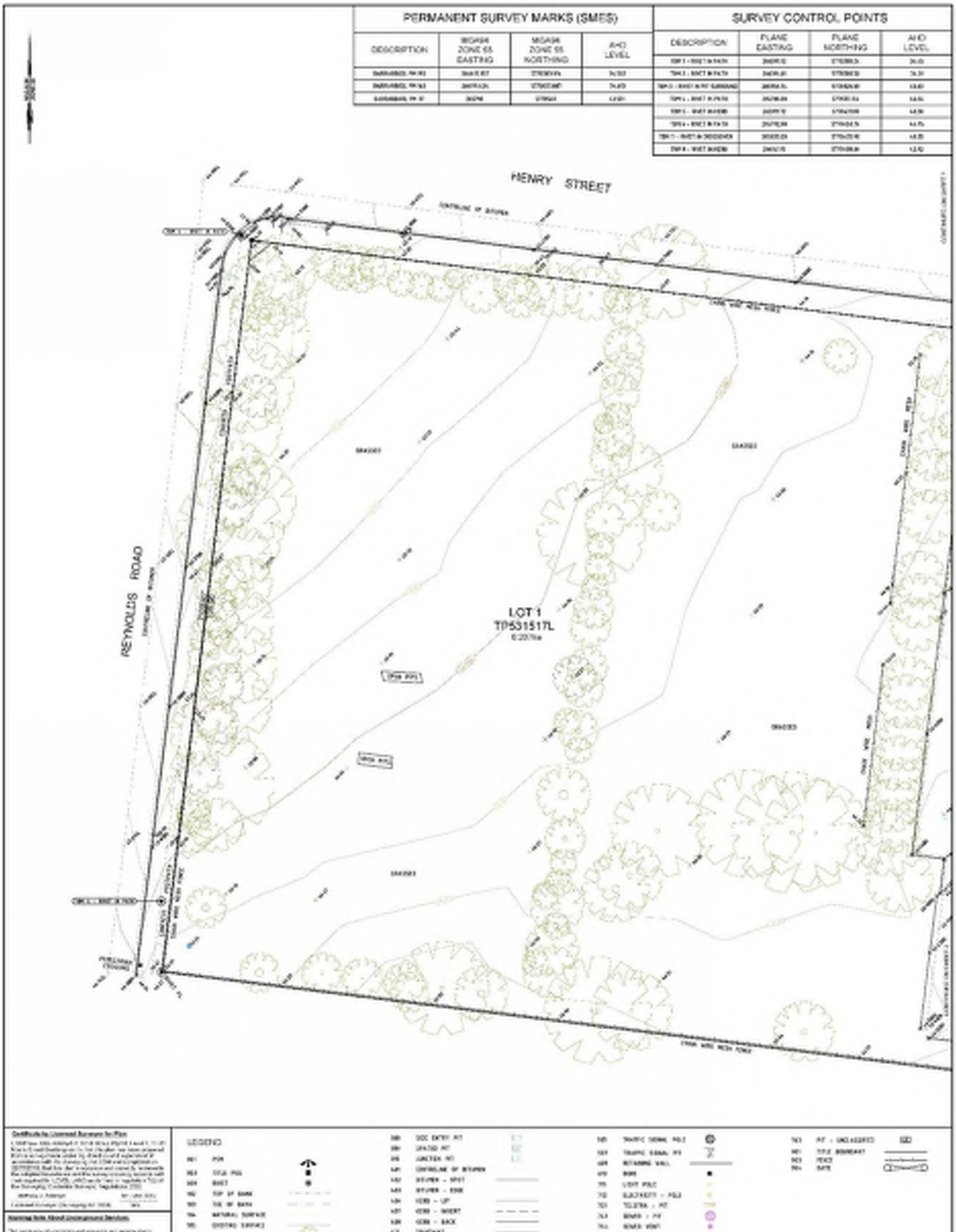

Figure 2.4: Site Feature and Level Survey (Sheet 1)

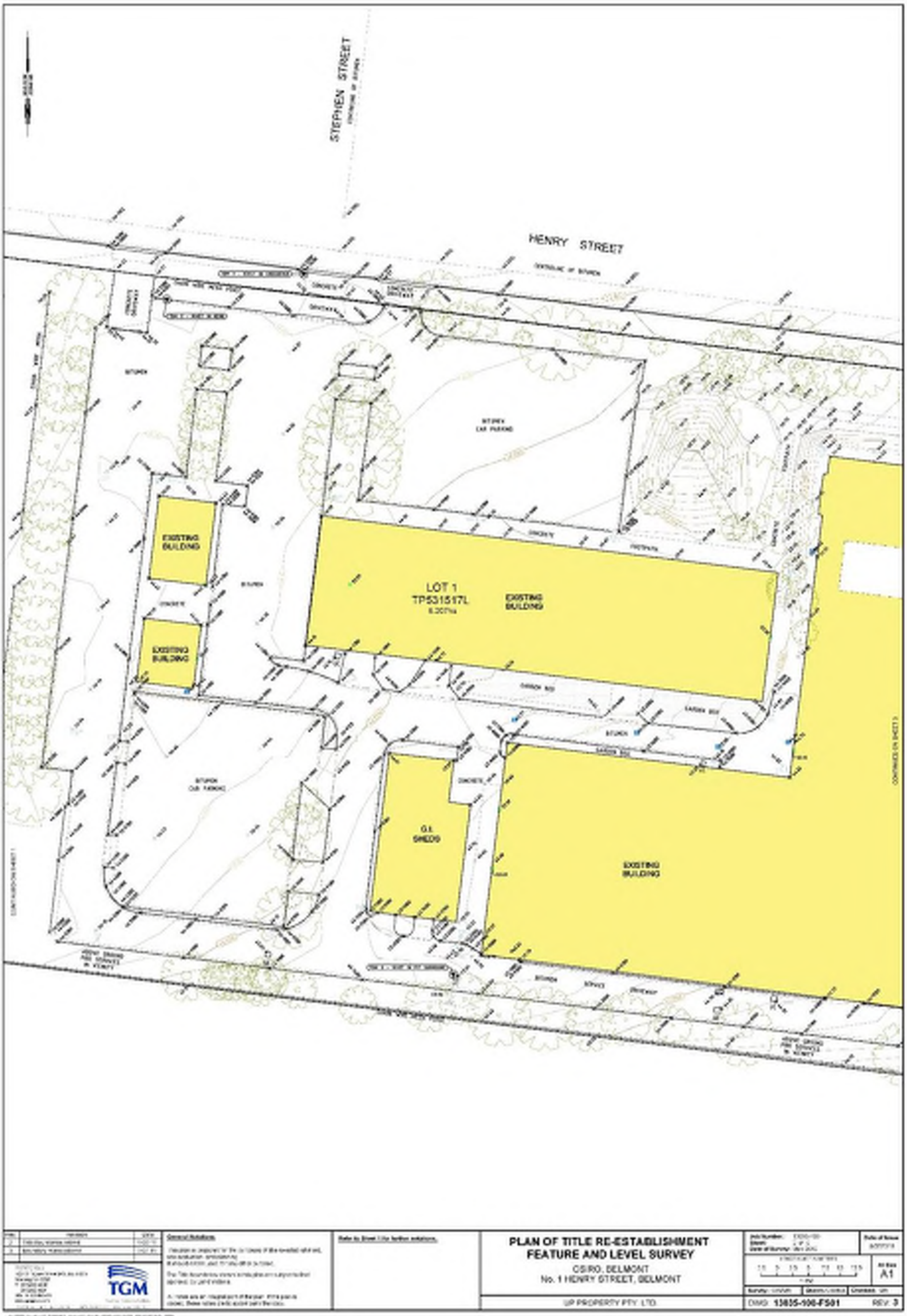

Figure 2.5: Site Feature and Level Survey (Sheet 2)

Figure 2.6: Site Feature and Level Survey (Sheet 3)

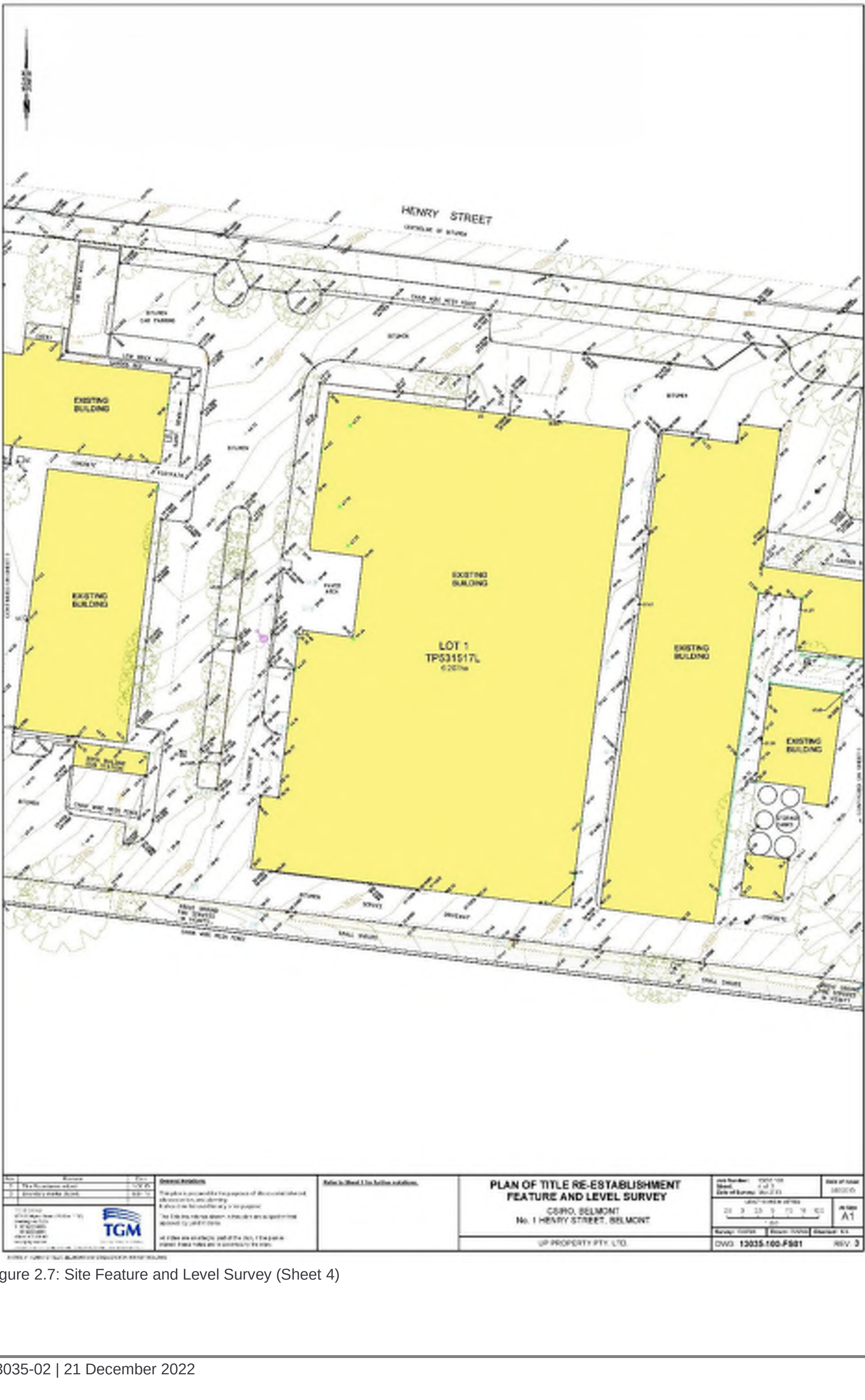

Figure 2.7: Site Feature and Level Survey (Sheet 4)

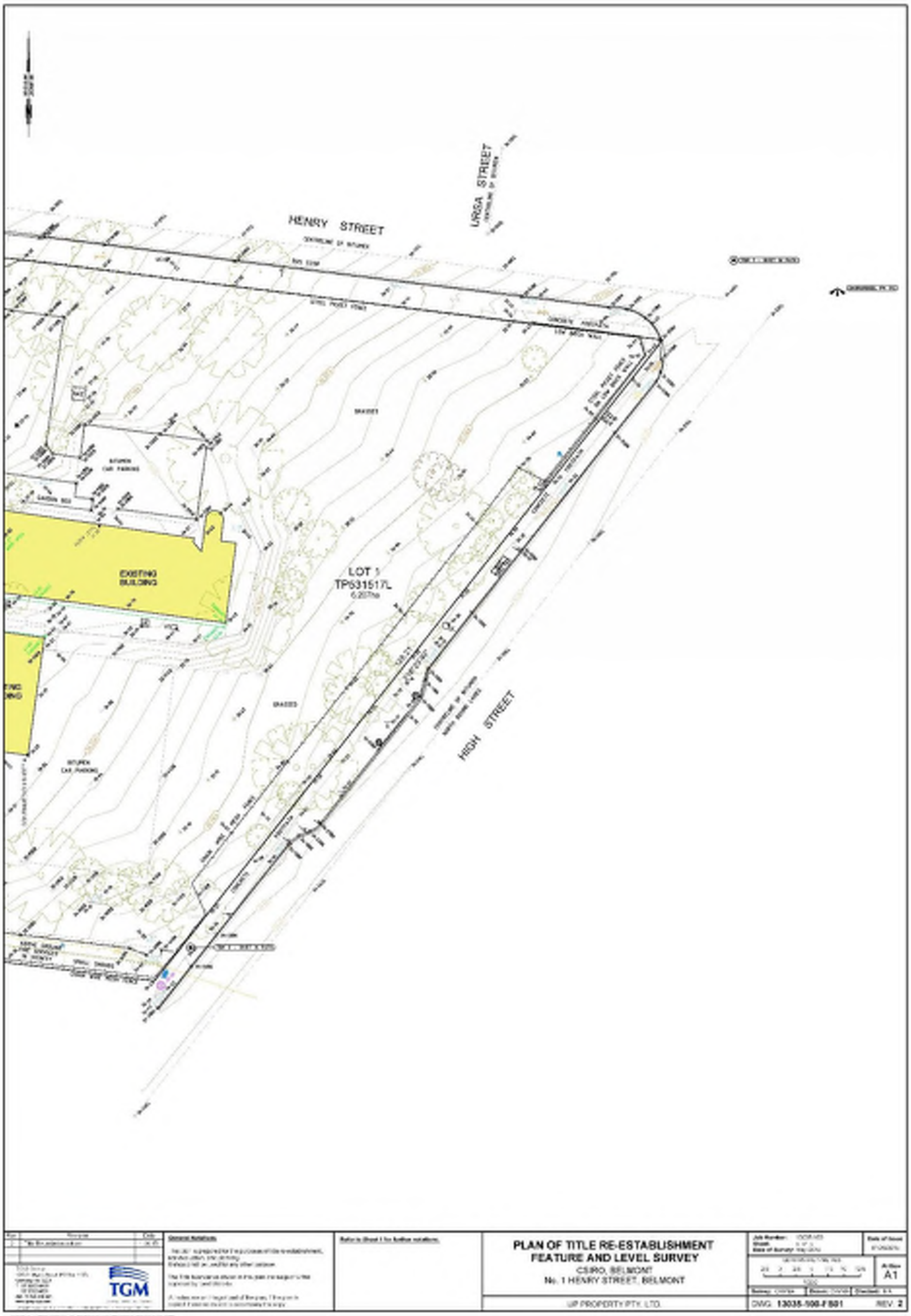

Figure 2.8: Site Feature and Level Survey (Sheet 5)

2.3.2 Staging Catchments

It is proposed to delineate the stormwater drainage system to align with the proposed Stages of the development so that they align with the East and West catchments to enable effective separation of the urban drainage systems connected to each legal point of discharge (LPOD) and to facilitate an organised progression of development of the site. The proposed staging of the development will result in approximately 80% of the site falling towards the east LPOD and 20% falling to the west. The stormwater management strategy proposes diverting low flows that represent the ‘first flush’ from rainfall events from the western catchment to the east. Further details are provided in Section 6.2

The staging catchment delineation is depicted in

Figure 2.9.

Figure 2.9: Staging Plan

The entire site catchment has been analysed as part of this study and SSMP, however the development will proceed in stages starting with the current relevant Stage 1. It is expected that stormwater detention and runoff quality treatment would be progressed in accordance with individual stage requirements.

It should be noted that the future stages shown in

Figure 2.9 above are subject to change. Therefore the catchment analysis outlined in Table 2.2 and Table 2.3 reflect the development potential of the site within the Development Plan Overlay. The Western Stage is nominated as the western catchment and the Eastern Future Stage is the future stage of the eastern catchment.

2.3.3 Developed Site

Buildings have been removed from the site and the site has been cleared prior to development. The sub-catchments analysed will reflect the mixed density building clusters, separated by the road reserve. The re-developed layout and sub-catchment delineation is depicted in

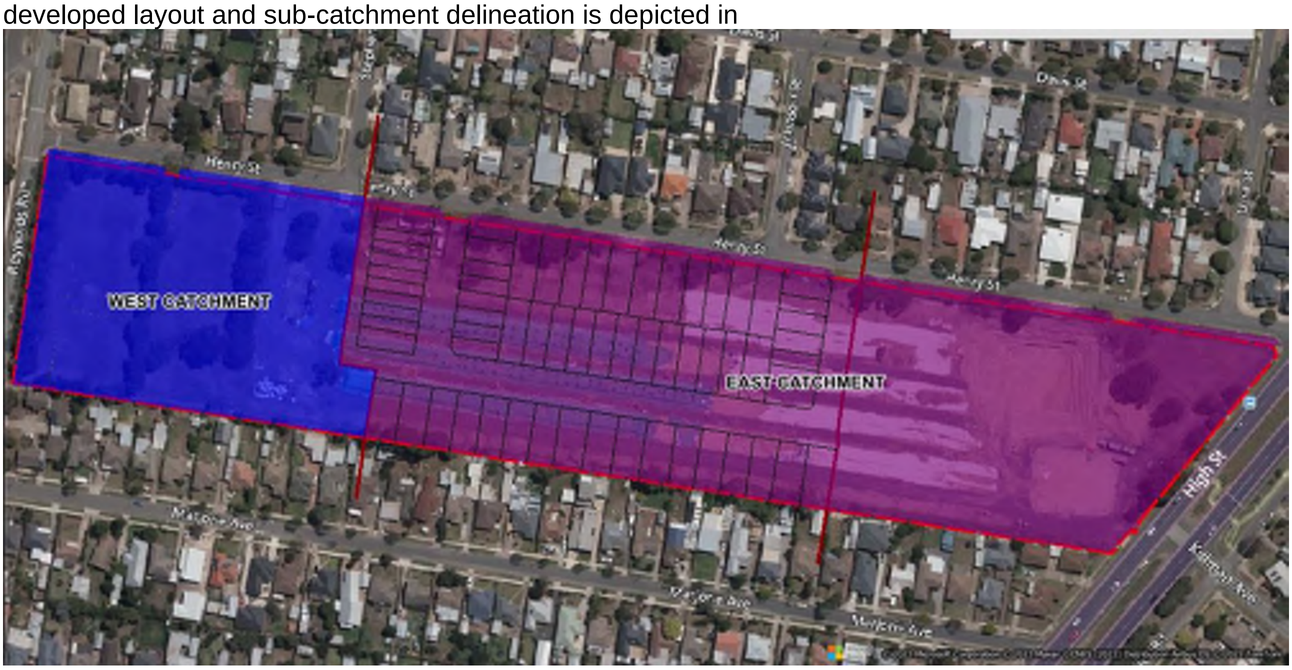

Figure 2.10.

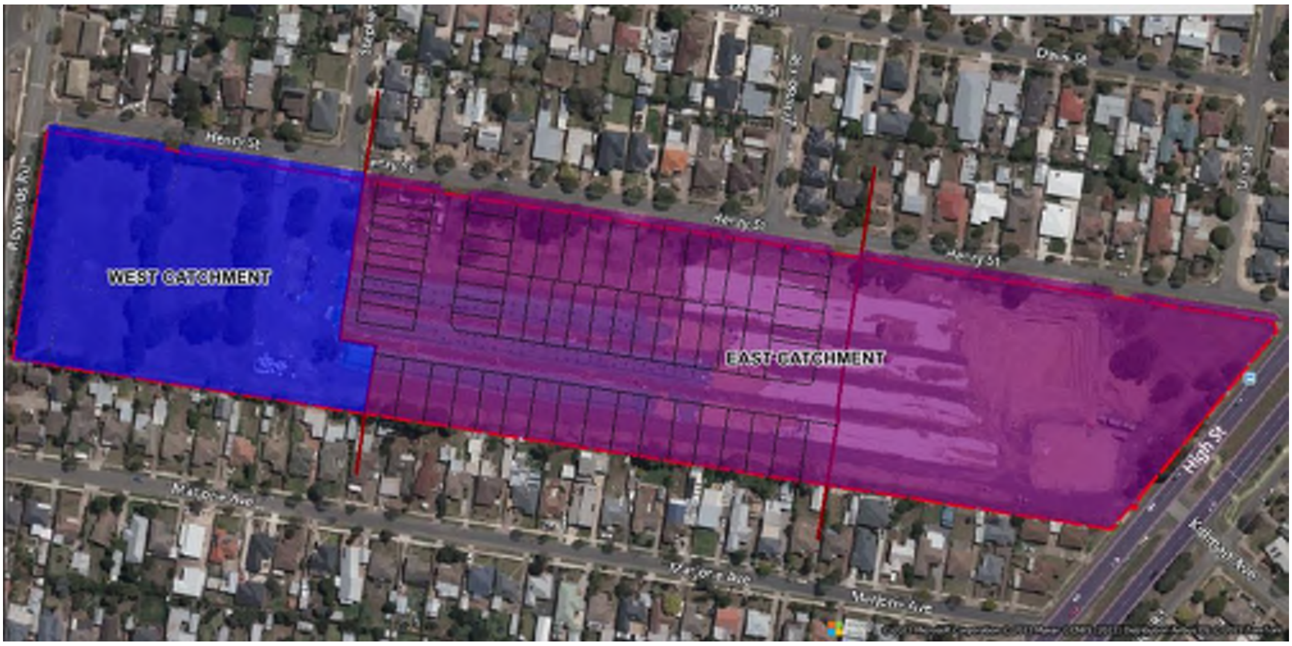

Figure 2.10: Developed Site Layout

An estimated breakdown of the impervious areas for the proposed development is given in Table 2.2 and Table 2.3 below.

Estimated Eastern Sub-catchment Surface Types	Area (ha)	Impervious Fraction (%)	Roof Area to Harvesting Tanks (Ha)	Roof Area to OSD Tanks (Ha)
Stage 1 Road Pavement	0.30	100	NA	NA
Stage 1 Footpath	0.42	100	NA	NA
Stage 1 Reserve	0.02	0	NA	NA
Stage 1 (Residential)	1.38	82	0.75	NA
Stage 1 (Townhouse/Residential)	0.46	68	0.25	0.25
Eastern Future Stage	1.98	64	NA	NA

Table 2.2: Eastern Sub-catchment Types and Details

Estimated Western Sub-catchment Surface Types	Area (ha)	Impervious Fraction (%)	Roof Area to Harvesting Tanks (Ha)	Roof Area to OSD Tanks (Ha)
Western Stage	1.86	72	0.65	0.65

Table 2.3: Estimated Western Sub-catchment Summary

Stages 2 & 3 are currently subject to preliminary design and review and therefore considered at a conceptual design level for the purposes of undertaking this SSMP for the overall site.

The City of Greater Geelong set permissible site discharge rates for the site based on estimates of the capacity of the downstream stormwater drainage system.

3 Hydrology & Routing Model

The hydrologic analysis was performed using the Watercom's DRAINS software and applying the RAFTS runoff routing technique as well as an initial loss and continuing loss hydrological model. DRAINS 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. It also analyses, assesses and selects runoff hydrographs in accordance with Book 9 of Australian Rainfall and Runoff.

The DRAINS model applied ensemble rainfall patterns, storm burst loss factors and runoff estimation techniques from Australian Rainfall & Runoff 2019[2] to the study catchment area to generate runoff hydrographs and predict the volume of stormwater generated.

As detailed in ARR2019[3] 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. Traditionally a single burst temporal pattern has been used for each rainfall event duration. The use of a single pattern has been questioned for some time[4] as the analysis of observed rainfall events from even a single pluviograph shows that a wide variety of temporal patterns is possible.

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

3.1 Hydrology Model Parameters

A DRAINS hydrology model applying an Initial and Continuing Loss method was built to define hydrological processes and critical temporal patterns for the site.

The hydrological characteristics of each sub-catchment, in terms of permeability, losses and surface roughness and slope formed model input parameters.

3.1.1 Model Calibration

The parameters of hydrological models are usually determined through a calibration procedure to optimise the model performance 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 reliable 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.

The Regional Flood Frequency Estimation (RFFE) tool provided by ARR2019 provides a reliable alternative to calibration to observed data. It 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).[5] 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, which in turn can used to inform parameters applied to the pervious areas of a development.

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[2] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia.

[3] Babister M, Retallick M, Loveridge M, Testoni I, and Podger S, 2019, Temporal Patterns, Chapter 5 Book 2 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

[4] Nathan R.J. and Weinmann P.E, 1995, The estimation of extreme floods - the need and scope for revision of our national guidelines. Aus J Water Resources, Volume 1(1), pp.40-50.
[5] ARR - Limits of Applicability - https://rffe.arr-software.org/limits.html, viewed on 27/08/2019

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

The calibration/sensitivity analysis was **setup to reflect rural or pre-development catchments** to allow the comparison with flood estimation techniques. More in detail, all sub-areas have been **considered as rural,** and the **pervious fraction has been set at 100%** to match the pre-condition of comparison with the RFFE tool**.**

A key element of the calibration 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.

3.1.2 Calibration Model

The site is located within the Barwon River and Waurn Ponds Creek catchments. The site is insignificant in size when compared to the Barwon River catchment therefore a realistic comparison of critical events for the site is not possible, and the Waurn Ponds Creek catchment is ungauged. The Regional Flood Frequency Estimation (RFFE) techniques, as described above, were therefore required for the study site, applying a data-driven approach, in order to transfer flood characteristics from a group of gauged catchments to the study site.

Comparison of computed flows of the developed site with those estimated by the Probabilistic Rational Method was also undertaken to provide an additional perspective on the calibrated values though these were not used for calibration purposes.

The ARR2019 RFFE model[6,7] available online at http://arr.ga.gov.au/; was used to provide peak flow estimates for the study catchment. These were then used to calibrate the peak flow whole catchment response hydrographs generated by the ensemble rainfall patterns within the DRAINS model.

There are 15 gauged regional catchments within a 100 km radius surrounding the site. These gauged catchments make up the sample group for the statistical analysis used in the calibration model. The nearest gauged catchment is 37km away. The RFFE model interface, input parameters and statistical outputs can be seen in the Appendix A.

The RFFE model interface, input parameters and statistical outputs can be seen in Appendix A: Regional Flood Frequency Estimation Model. The RFFE model provides peak flood estimates for rural catchments, therefore, for the validation process the study catchment was considered to be undeveloped (pre-development).

[6] 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.

[7] Rahman, A, Haddad, K, Kuczera. G and Weinmann, E, 2019, Peak Flow Estimation, Chapter 3 Book 3 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia.

Table 3.1: RFFE Model - Estimated Peak Discharge Targets for the Study Site (Lumped)

			RFFE Discharge (m³/s)		
Event AEP (%)	Catchment	Area (ha)	Mean	5th Percentile	95th Percentile
50	Study Site (pre-development)	6.232	0.04	0.01	0.11
20			0.07	0.03	0.19
10			0.09	0.03	0.27
5			0.13	0.04	0.36
2			0.17	0.06	0.52
1			0.21	0.07	0.67

3.1.3 Loss Parameters

DRAINS was run as an Initial Loss and Continuing Loss (IL/CL) lumped catchment model using parameters provided from the ARR Data Hub (http://data.arr-software.org/).

The ARR Data Hub is a tool which utilises all the research of the updated ARR2019 methodology to provide design inputs for modelling. The ARR Data Hub uses prediction equations to define the IL/CL parameters for all of Australia.

The full storm IL/CL parameters from the ARR Data Hub are shown in Table 3.2 for pervious surfaces.

Table 3.2: Hydrological Pervious Surface Loss Parameters – ARR Data Hub

Source	Full Storm Initial Loss (mm)	Continuing Loss (mm/hr)
ARR Data Hub	17	3.0

The Prediction equations used to develop the recommended loss values utilised attributes from the Australian Water Resource Assessment – Landscape (AWRA-L) model system which was developed by CSIRO and the Bureau of Meteorology[8].

The ARR2019 parameters derived using the loss prediction equations and the AWRA-L model were adopted for this analysis in conformance with the ARR2019 flood estimation methodology and processes applied in this study.

It is noted that the identified ARR initial losses reflect the full storm IL values and should only be applied to hydrology models that are running full storm patterns.

The following study analysed storm burst pattern ensembles, therefore, the storm initial loss (ILs) nominated in Table 3.2 was adjusted to account for the impact of pre-burst rainfall to create a burst initial loss (ILb) using the following simple equation –

$IL_s - \text{Pre-Burst} = IL_b$ *[equation 1]*

[8] Ball, J, and Weinmann, E, 2019, Flood Hydrograph Estimation, Chapter 3 Book 5 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

ARR2019 states[9] that in locations and for durations that do not have significant pre-burst, the pre-burst depth can be ignored when applying temporal patterns. Therefore, the Burst IL (IL_b) can be taken as the Storm IL (IL_s).

The Pre-Burst depths for various AEP events and durations for the study catchment in Belmont was downloaded directly from the ARR Data Hub. Where pre-burst depths for selected storm durations were unavailable, the median pre-burst depth was adopted. DRAINS then applies these pre-burst depths to the ensemble storms to produce the storm burst rainfall hyetographs for all temporal patterns.

Determination of the median pre-burst depths is summarised in Table 3.3.

	Pre-Burst Depth (mm) for AEP (%)					
Duration (min)	50	20	10	5	2	1
60	1.4	1.7	1.9	2.2	2.8	3.3
90	0.8	1.8	2.5	3.1	2.5	2
120	1.1	1.9	2.4	2.8	2.6	2.3
180	1.2	2.4	3.2	4	2.8	1.8
360	0.2	0.5	0.7	1	1.9	2.6
720	0	0.5	0.8	1.2	0.9	0.7
1080	0	0	0	0	0.8	1.5

Table 3.3: Pre-Burst Rainfall Depths– ARR Data Hub

The full storm continuing losses and the pre-burst rainfall depths were utilised as part of the calibration process for the hydrological model. Definition of hydrological parameters enabled calibration to RFFE estimated peak discharges for the pre-developed site. Please refer to Section 3.1.6 for a detailed description of the calibration process.

3.1.4 Calibration Process

A key element of the calibration process is understanding the characteristics of the study catchment and the catchment(s) used in the RFFE analysis. Significant variation in topography, geology, climatic conditions and characteristics between the gauged catchment(s) and the study catchment can inform the calibration process.

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

Calibration of the model focused on the 10% AEP event identified using the ARR2019 Regional Flood Frequency Estimation (RFFE) tool. Comparison to the probabilistic rational method was also undertaken, although it was not used for calibration purposes.

The 10% AEP event was selected for the calibration process 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.

[9] Babister, M, Retallick, M, Loveridge, M, Testoni, I, and Podger, S, 2019. Temporal Patterns, Chapter 5 Book 2 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

The calibration model was setup to reflect rural or pre-development catchments to allow the comparison with flood estimation techniques. More in detail, for calibration purposes only, all sub-catchments have been considered as rural forested, and the pervious fraction has been set at 100%.

The calibration procedure has been performed by changing the Manning coefficient 'n', and the pervious area initial loss to better represent the energy and hydrologic losses of the characteristics of the undeveloped site. The adopted surface roughness conditions for the site are summarised in Table 3.4.

Table 3.4: **Calibration Conditions - Surface Characteristics**

Catchment	Area (ha)	Pervious Area (ha)	Impervious Area (ha)	Manning's ***'n'***
Lumped Site	6.232	6.232	0.00	0.06

A proper validation process was not possible for this study as no observed or historic data is available. Therefore, a verification of the model predictability has been carried out by comparing the calibrated DRAINS model and the RFFE predicted peak discharges for the 1%, 2%, 5%, 10%, 20% AEP events.

3.1.5 Storm Burst Pattern Ensembles

An ensemble of storm bursts was analysed within the DRAINS model for each storm event probability impacting the site.

Adjustment and identification of the catchment hydrological loss and roughness parameters, detailed above, was undertaken using all 121 storm burst patterns for each AEP until the critical Median peak discharge matched the RFFE peak flow estimates.

The variation of peak flows based on duration and temporal patterns, as well as the selected temporal pattern for each duration, can be seen in the plot of ensemble catchment flows in Figure 3.1 below;

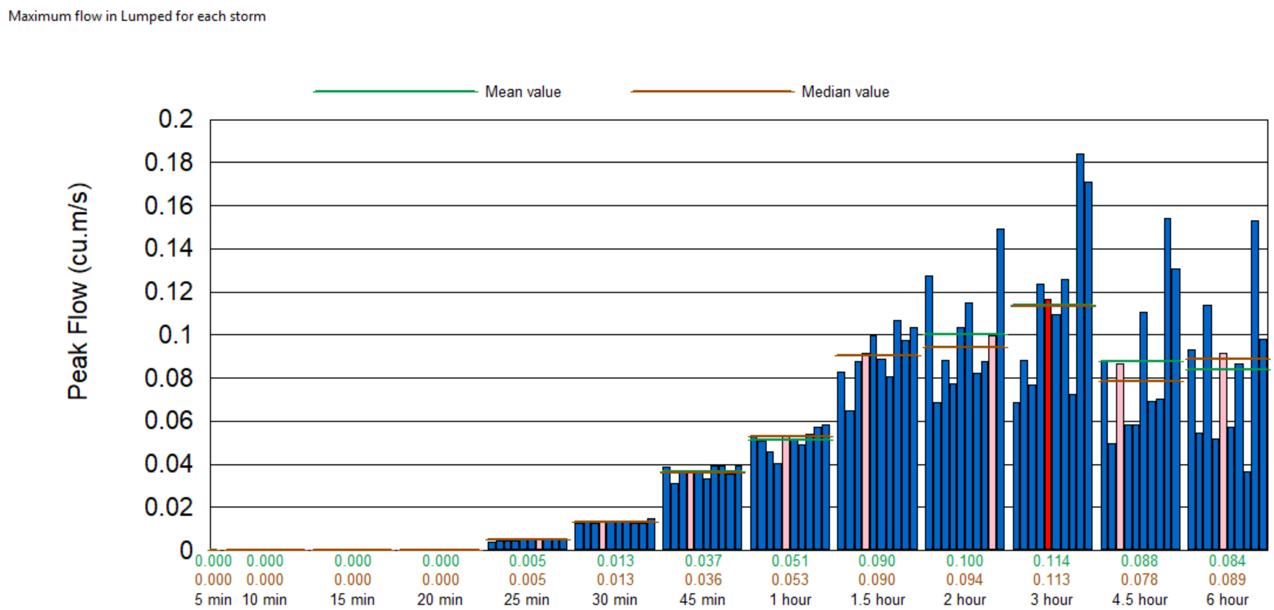

Figure 3.1: Calibration Conditions - Temporal Pattern Box and Whiskers Plot – 10% AEP Event

3.1.6 Calibration Summary

The hydrologic losses adopted in this study are summarised in Table 3.5.

Table 3.5: **Adopted Hydrological Loss Parameters**

Surface	Adopted Losses

	Full Storm Initial Loss (mm)	**Pre-burst Depth (mm)**	Full Storm Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	17	As per ARR Data Hub	Varies	4
Impervious	0	0	0	0

The comparison between the peak discharges generated with the calibrated DRAINS model and the estimated RFFE model for the site are summarised in Table 3.6 and shown in Figure 3.2.

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 3.6: Study Site – Peak Discharges

Event AEP (%)	Area (Ha)	5th Percentile	RFFE Discharge (m³/s) Median	95th Percentile	DRAINS Discharge (m³/s)
20	6.232	0.03	0.07	0.19	0.05
10		0.03	0.09	0.27	0.12
5		0.04	0.13	0.36	0.17
2		0.06	0.17	0.52	0.27
1		0.07	0.21	0.67	0.34

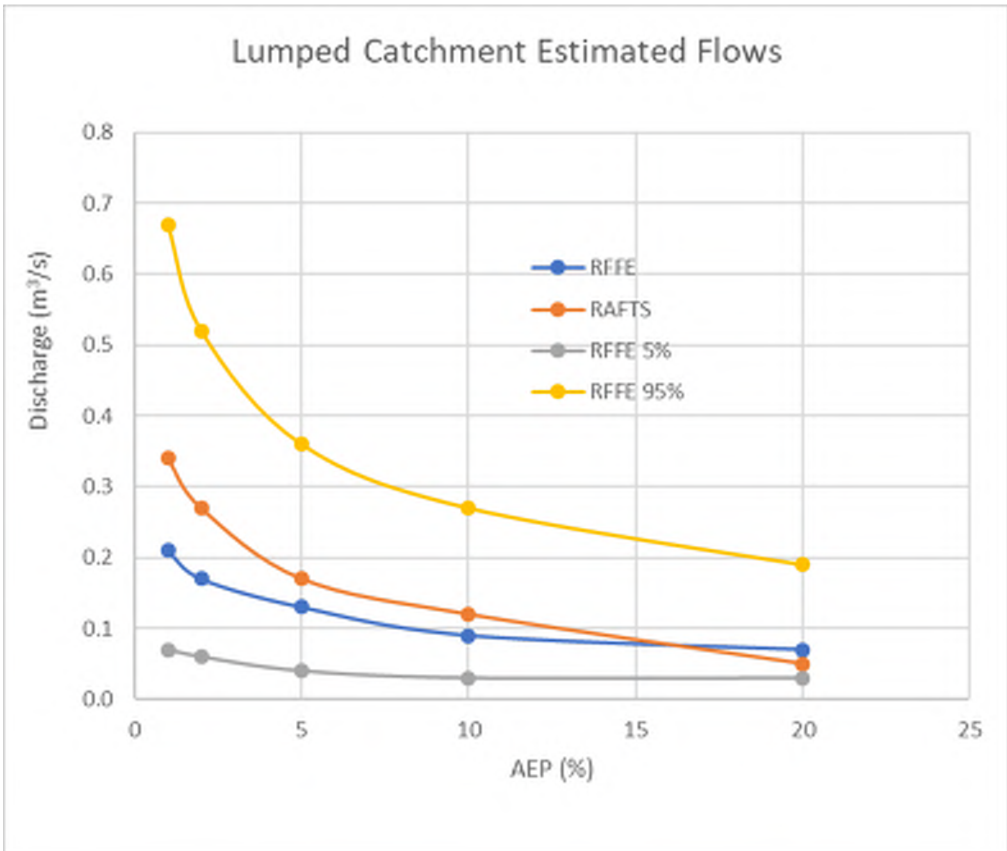

Figure 3.2: Estimated Peak Discharge – DRAINS (RAFTS) vs RFFE

3.1.7 RFFE Accuracy Considerations and Limitations

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.

It should be noted that the proposed development has a relatively high percentage fraction imperviousness (Refer Table 2.2 and Table 2.3) so flow results of the developed model has a relatively low sensitivity to the calibrated hydrologic parameters, which only apply to the pervious areas.

ARR2019 identified ongoing concerns about estimation of parameter values (such as runoff co-efficient and time of concentration) that are the basis of using the Probabilistic Rational Method[10].

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[11,12].

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[10] 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.
[11] 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
[12] 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.

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 studies[13] show how hydrology parameters from gauged catchments can be transferred to nearby ungauged catchments with similar natural characteristics.

3.2 Temporal Pattern Selection

Due to the size of the site, fixed temporal patterns were applied over the entire site for design flood estimation. Spatial variation was not required.

In order to properly understand the concept of temporal patterns, 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 3.3. 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:

> 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.

> 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.

> 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).

> 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.

[13] 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.

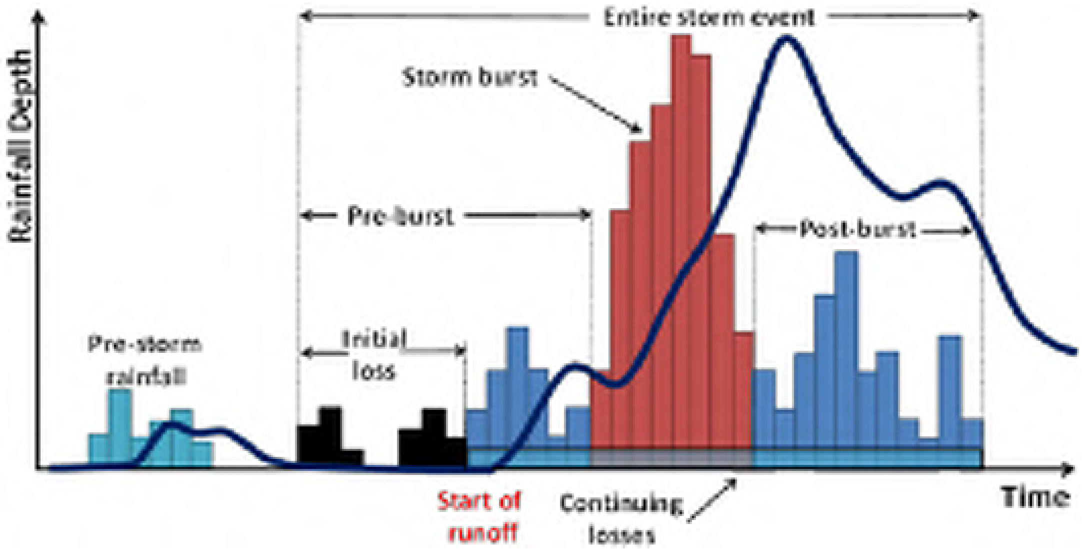


Figure 3.3: Elements of a complete storm event and hydrological practice

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 site catchment response.

3.2.1 IFD Data

The 2016 rainfall intensity frequency duration (IFD) climatic data used in the hydrology model was extracted from the Bureau of Meteorology (BOM) website (http://www.bom.gov.au/water/designRainfalls).

The IFD curves are shown in Figure 3.4, below.

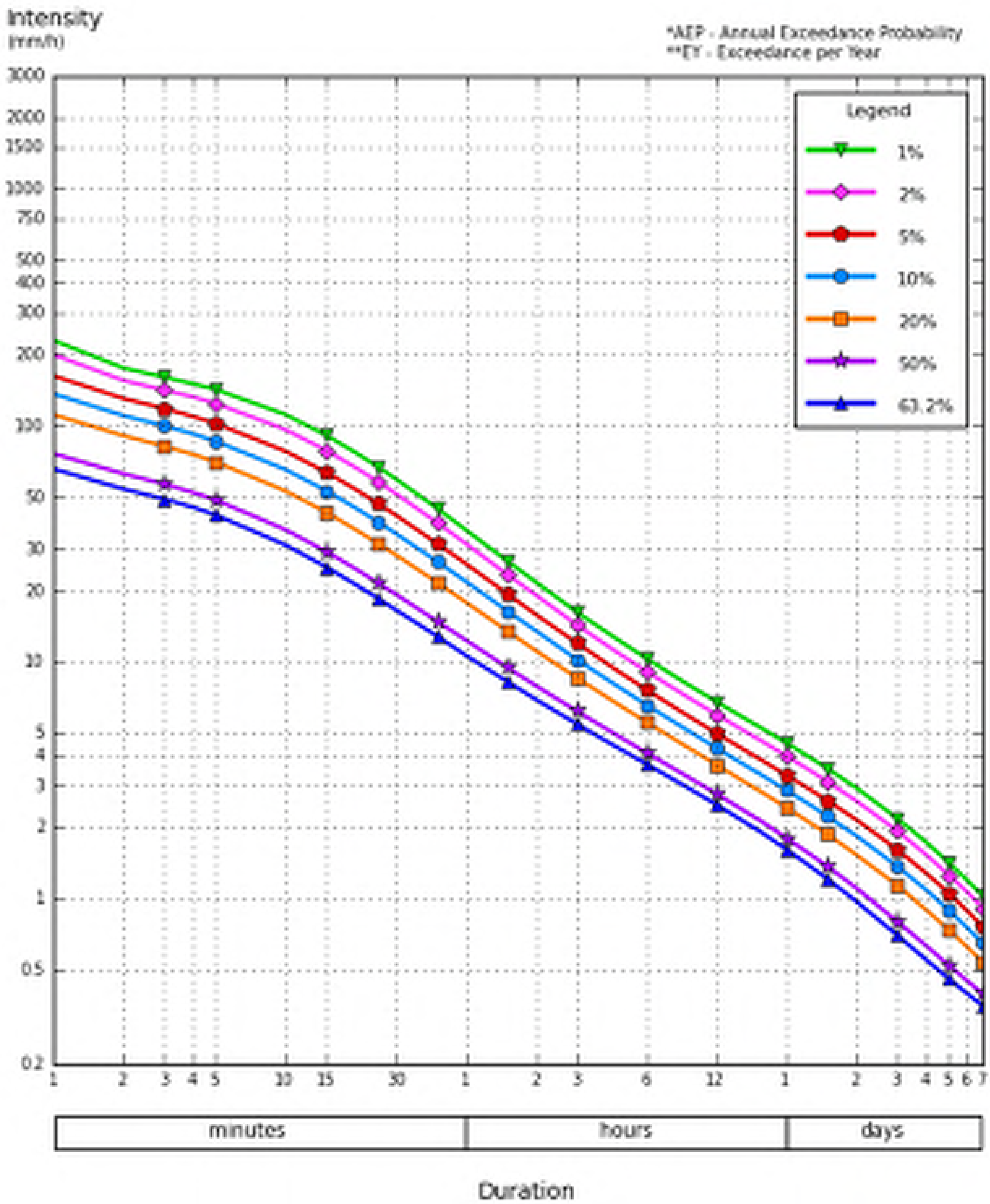


Figure 3.4: 2016 IFD Curves – Bureau of Meteorology 9th November 2020

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.

3.2.2 Ensemble Storm Burst Patterns

The historical process of using peak flows derived from a single critical storm burst does not account for the hydrology processes generated by the reality of complete (full volume) storms as demonstrated in Figure 3.3.

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 13 duration periods, for each event AEP.

A total of 121 storm burst patterns were analysed for each AEP event. The analysed events and durations are shown in Table 3.7.

The median value of the peak discharges generated for 10 temporal patterns has been calculated. The critical temporal pattern has been selected by identifying the temporal pattern characterised by the peak discharge closest to the median for each of the 24 durations, except where the mean was more than 10% greater than the median in which case the temporal pattern with a peak closest to the mean was selected. The procedure has then been repeated for each event probability.

The procedure described in this Section has been applied to both the calibration process and the existing conditions simulations.

Table 3.7: Analysed Rainfall Patterns, Durations and Events

Number of Storm Burst Patterns in Ensemble (per event duration)	Storm Durations Analysed (minutes)		Event Probability Range Analysed (AEP) (%)
10*	5	60	1
	10	90	2
	15	120	5
	20	180	10
	25	270	20
	30	360	50
	45		

*Only one temporal pattern analysed for the 5 minute duration events.

4 Existing Hydraulic Conditions

As noted in the Executive Summary, the permissible site discharge for the site was set by the City of Greater Geelong based on the capacity of the downstream stormwater drainage system, which is understood to be constrained. Therefore, estimation of pre-development runoff from the site is not necessary.

5 Developed Hydraulic Conditions

5.1 Western Stage & 3 Developed Conditions Computations

In order to assess the site as a whole the stormwater detention and runoff quality computations are based on a preliminary layout provided by the client however the layout is subject to change and not the subject of the current town planning application and therefore not illustrated in this report.

5.2 Comparison with Rational Method

A comparison of runoff generated from the developed conditions hydraulic model with the rational method was undertaken to provide an additional perspective on the estimated flow rates and to highlight any potential issues with the calibration process. For the purposes of comparison the RAFTS model did not include any stormwater detention.

Table 5.1: Comparison of Peak Flow Estimation Methods - Western Catchment

STORM EVENT	20% AEP	10% AEP	2% AEP	1% AEP
Rational Method	0.20	0.27	0.42	0.57
RAFTS	0.22	0.28	0.40	0.46

Table 5.2: Comparison of Peak Flow Estimation Methods - Eastern Catchment

STORM EVENT	20% AEP	10% AEP	2% AEP	1% AEP
Rational Method	0.53	0.72	1.14	1.55
RAFTS	0.58	0.71	1.03	1.18

5.3 1D Dynamically Linked Hydraulic Model

A 1D dynamically linked hydraulic model was produced to represent the surface conditions of the proposed development. The model included the various impervious surface types, proposed rainwater tanks connected to dwelling roof drainage and any underground tanks.

Details of the impervious area following development of the site are included in Section 2.3.3.

A schematic diagram of the 1D model is shown in Figure 5.1 below.

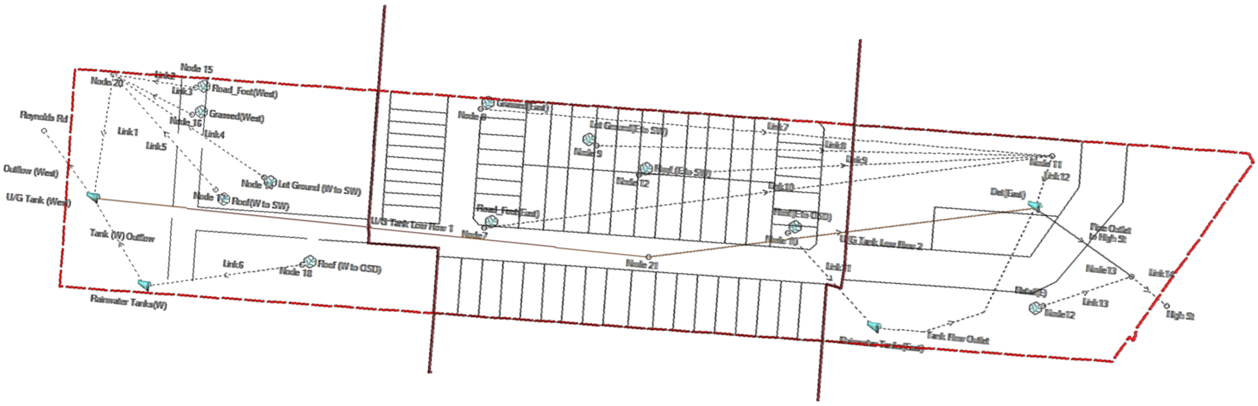


Figure 5.1: DRAINS 1D Hydraulic Model of Western Catchment

The model includes a low flow pipe from the proposed underground tank in the Western Catchment to the Eastern Catchment. This pipe is intended to take low flows from the Western Catchment to a proposed bioretention cell at the eastern end of the site for treatment. More details are provided in Section 6.

5.4 Temporal Pattern Selection

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 a large number of events in the ensemble patterns are clustered around the mean and median[14].

A 121 storm burst pattern ensemble was simulated within the Developed Conditions 1D model for the 1% and 20% AEP. A plot of all peak output flows for the western and eastern catchments are shown in Figure 5.2 and Figure 5.3 below;

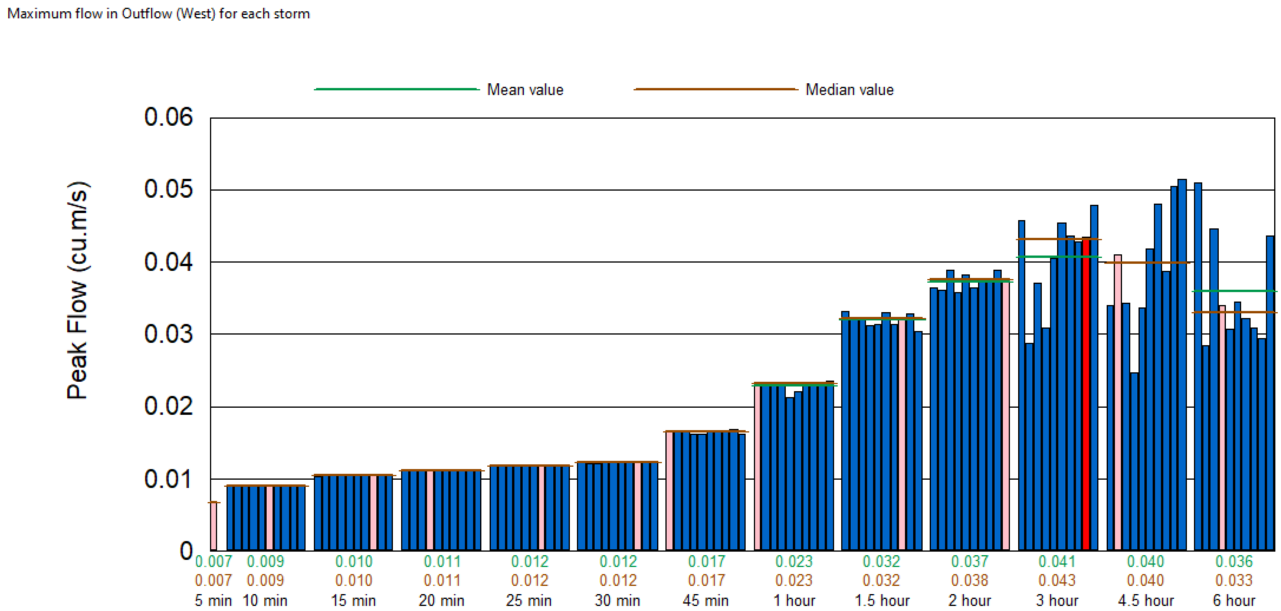


Figure 5.2: Peak 1% AEP Developed Flow for Western Catchment

[14] 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

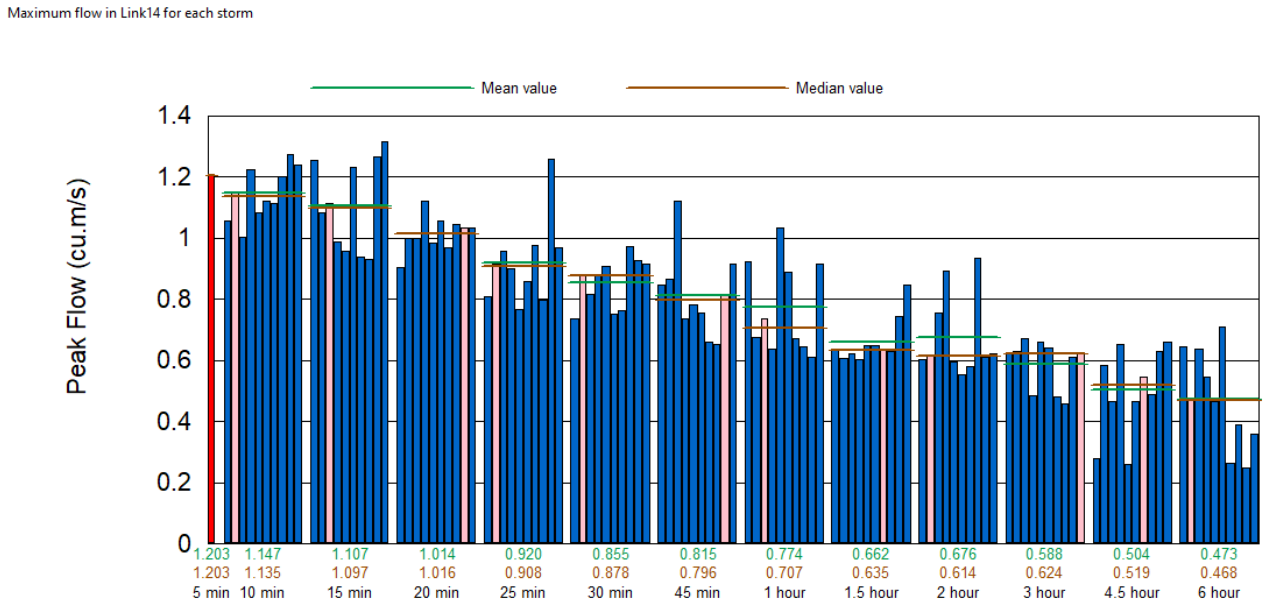


Figure 5.3: 1% AEP Peak Developed Flow for Eastern Catchment

DRAINS reports the peak flow rate closest to the highest median or mean value of the ensemble. The selected 1% AEP storm is indicated as a red bar. Pink bars represent the selected storm for each duration. Details of the mean, median and selected storm pattern are shown in Table 5.3 below.

Table 5.3: Adopted 1% AEP Storm Burst Patterns – Developed Western Catchment

Duration	Discharge (m^3/s)			Storm Burst Pattern No.
	Median	Mean	Adopted	
5 min	-	-	0.007	1
10 min	0.009	0.009	0.009	6
15 min	0.01	0.01	0.01	8
20 min	0.011	0.011	0.011	4
25 min	0.012	0.012	0.012	7
30 min	0.012	0.012	0.012	8
45 min	0.017	0.017	0.017	1
1 hour	0.023	0.023	0.023	1
1.5 hours	0.032	0.032	0.032	8
2 hours	0.038	0.037	0.038	10
3 hours	0.043	0.041	0.043	9
4.5 hours	0.04	0.04	0.04	2
6 hours	0.033	0.036	0.034	4

Table 5.4: Adopted 1% AEP Storm Burst Patterns – Developed Eastern Catchment

Duration	Discharge (m^3/s)			Storm Burst Pattern No.
	Median	Mean	Adopted	
5 min			1.2	1
10 min	1.135	1.147	1.149	2
15 min	1.097	1.107	1.113	3
20 min	1.016	1.014	1.032	9
25 min	0.908	0.92	0.916	2
30 min	0.878	0.855	0.881	2
45 min	0.796	0.815	0.811	9
1 hour	0.707	0.774	0.737	3
1.5 hours	0.635	0.662	0.635	7
2 hours	0.614	0.676	0.616	2
3 hours	0.624	0.588	0.625	10
4.5 hours	0.519	0.504	0.547	7
6 hours	0.468	0.473	0.471	2

6 Stormwater Objectives

The objective of the stormwater management plan is to meet the conditions and requirements set in the planning application for stormwater management. These requirements ensure that appropriate design and stormwater mitigation is applied to ensure that stormwater quality and quantity targets are achieved and maintained.

1. Best Practice reductions for Water Quality
    a. 80% reduction in Total Suspended solids (TSS)
    b. 45% reduction in total nitrogen (TN)
    c. 45% reduction in total phosphorus (TP)
    d. 70% reduction in gross pollutants (GP)
2. No-worsening stormwater peak discharges
    a. Up to and including the 1% AEP design storm event.
3. Achieve Permissible Site Discharge (PSD) targets as set by the CoGG,

   East Catchment PSD –
      i. 1% AEP = 1.23 m^3/s
      ii. 20% AEP = 0.63 m^3/s

   West Catchment PSD –
      iii. 1% AEP = 0.05 m^3/s
      iv. 20% AEP = 0.01 m^3/s

6.1 Stormwater Peak Mitigation

6.1.1 Western Catchment (Western Stage)

The City of Greater Geelong have advised that the capacity of the stormwater drainage system downstream of the site in Reynolds Road is very constrained. It is proposed that rainwater tanks be installed on dwellings within Western Stage and the majority (at least 90%) of the dwelling roof area drained to the tanks*.

Stormwater mitigation computations have assumed that discharge from the rainwater tanks will be controlled via a 20mm diameter outlet, which is considered the smallest practical diameter as it is similar to a standard domestic connection. Various configurations for the outlet are possible and would be considered in detailed design.

*Subject to future town planning application.

The rate of discharge of stormwater from the western catchment will be controlled by;

- the installation of rainwater tanks detention storage of 154m^3* in Western Stage that include 20mm diameter outlets in the walls of the tanks,
- all eave guttering and downpipes connected to the rainwater tanks must have a minimum flow capacity for the 1% AEP rainfall event designed in accordance with AS3500.3,
- installation of a 350m^3 capacity underground tank with an orifice outlet.

Modelling undertaken for this study indicates that two orifice outlets from the underground tank will be necessary to ensure the permissible rate of discharge for the 20% and 1% AEP events are both achieved as follows;

- 100mm diameter orifice at the invert of the underground tank discharging to Reynolds Road,
- 100mm diameter orifice at the invert of the underground tank (at the inflow point) to direct low flows to the proposed bioretention cell at the eastern end of the site (Refer Section 6).
- 140mm diameter orifice at 0.4m above the invert of the underground tank discharging to Reynolds Road,

Orifice outlet details should be confirmed in detailed design.

Stormwater detention in tanks connected to residential dwellings will be facilitated through installation by the developer and verified via the planning and building approval regulatory processes.

A schematic representation of the provision of stormwater detention via rainwater tanks is shown in Figure 6.1 below.

*Subject to change based on the final development layout.

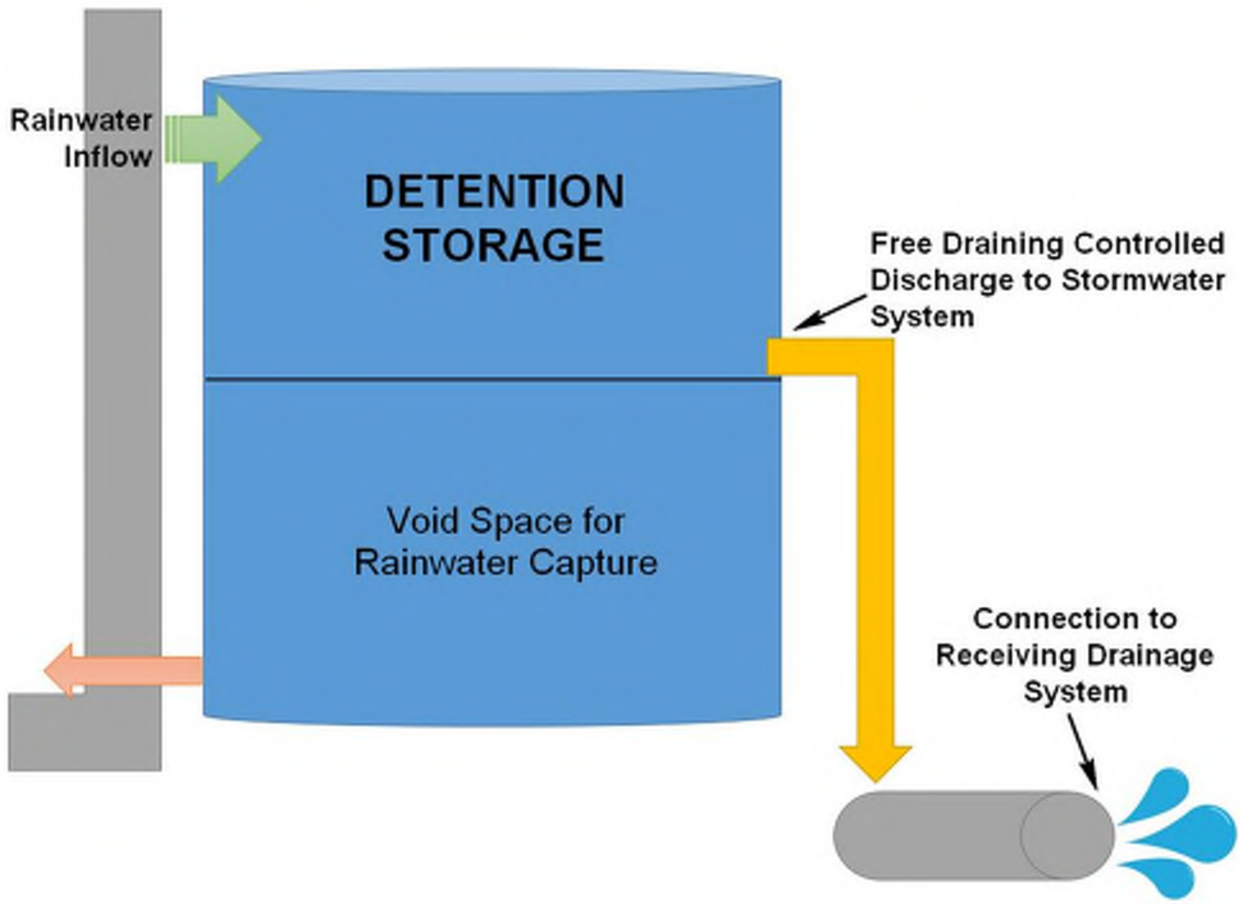


Figure 6.1: Illustration of Stormwater Detention via Rainwater Tanks

A summary of detention volumes for the western catchment is provided in Table 6.1 below.

Table 6.1: Summary of Detention Volume Western Catchment

Location	Combined Volume (m^3)
Rainwater Tanks	154
Underground Tanks	350
TOTAL	**504**

*Volume shall be subject to the final approved layout of the Western Stage.

The 1% & 20% AEP outflow hydrographs of the Western Catchment for the selected storms are shown in Figure 6.2 and Figure 6.3 below.

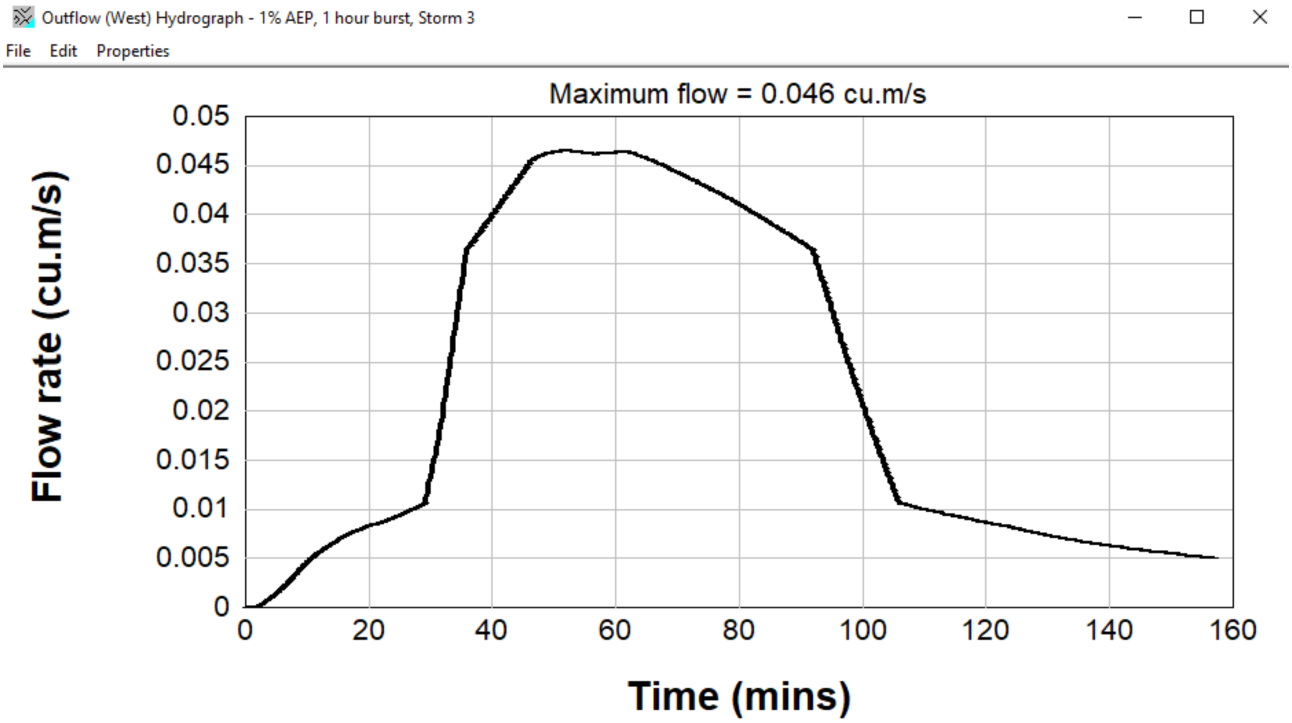


Figure 6.2: Selected 1% AEP storm outflow hydrograph – Western Catchment

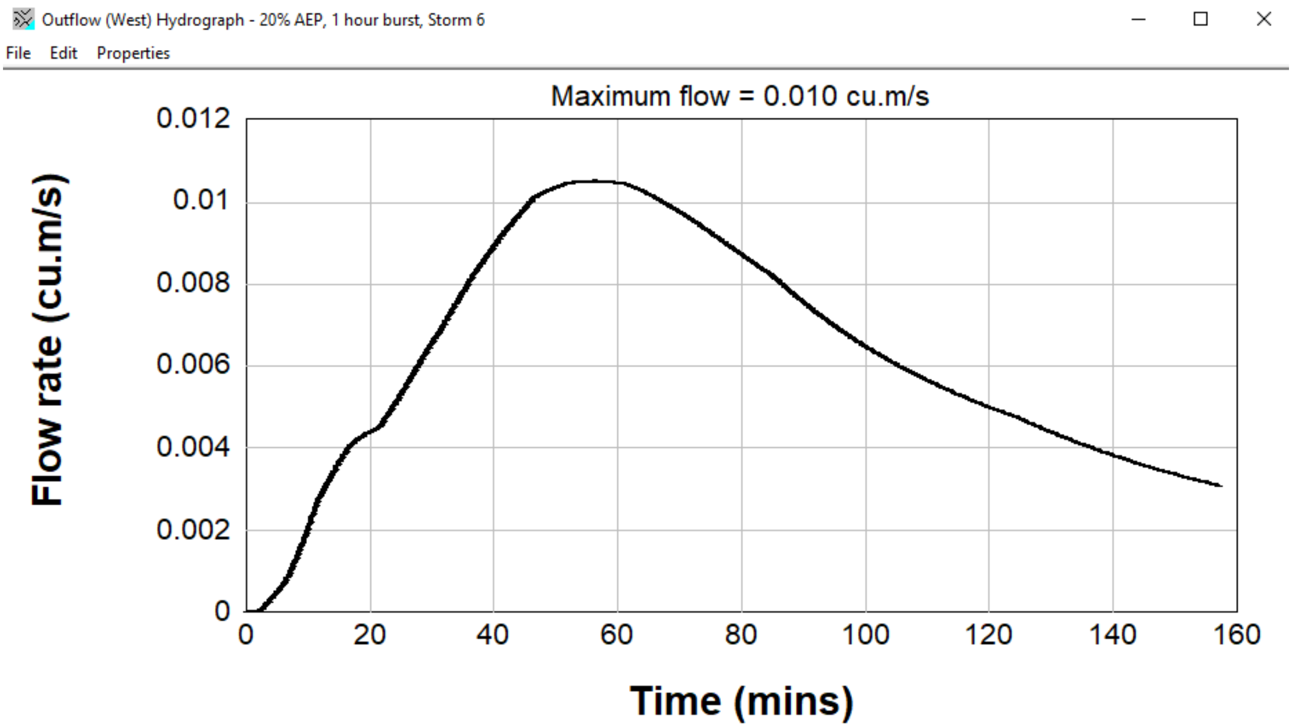


Figure 6.3: Selected 20% AEP storm outflow hydrograph – Western Catchment

A summary of design outflow compared to the PSD for the Western Catchment is provided in Table 6.2 below.

Table 6.2: Summary of Detention Volume Western Catchment

AEP (%)	PSD (m^3/s)	Design Outflow (m^3/s)
1	0.05	0.05
20	0.01	0.01

6.1.2 Eastern Catchment

The rate of discharge from the eastern catchment will be managed by a combination from rainwater tanks that collect roof runoff on several dwellings, and a detention basin co-located with a proposed bioretention cell. In details, the rate of discharge of stormwater from the western catchment will be controlled by;

- the installation of 62m^3 of detention storage in rainwater tanks to townhouses that include 20mm diameter outlets in the walls of the tanks and at least 2m^3 of air space (above storage for toilet flushing purposes) for stormwater detention purposes.
- all eave guttering and downpipes connected to the rainwater tanks must have a minimum flow capacity for the 1% AEP rainfall event designed in accordance with AS3500.3,
- at least 90% of townhouse roof areas must drain directly to the rainwater tanks,

*Note: Approximate only, subject to confirmation following approval of future Eastern Future Stage town planning permit.

Stormwater detention in tanks will be facilitated through installation by the developer and verified via the planning and building approval regulatory processes.

A summary of detention volumes for the eastern catchment is provided in Table 6.3 below.

Table 6.3: Summary of Detention Volume Eastern Catchment

Location	Combined Volume (m^3)
Rainwater Tanks	62
Detention Tank	40
TOTAL	**102**

The outflow hydrographs of the Eastern Catchment for the selected storms are shown in Figure 6.2 and Figure 6.5 below.

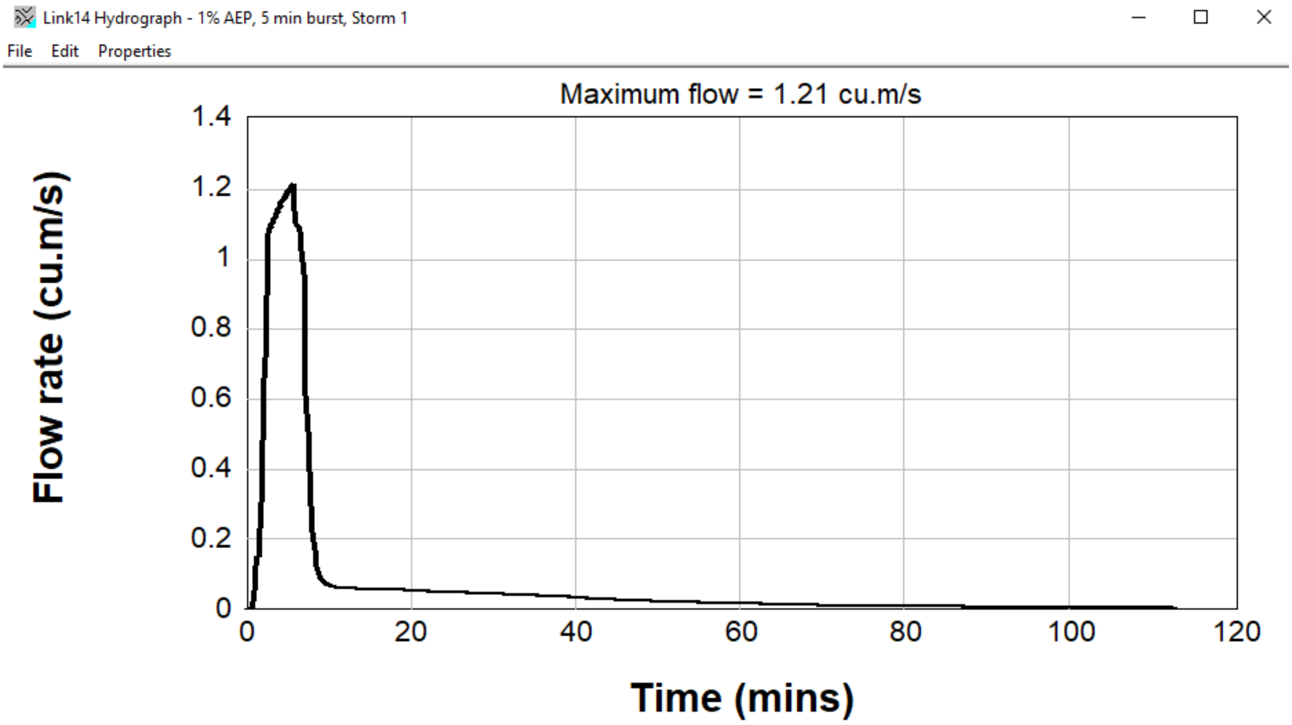


Figure 6.4: Selected 1% AEP storm outflow hydrograph – Eastern Catchment

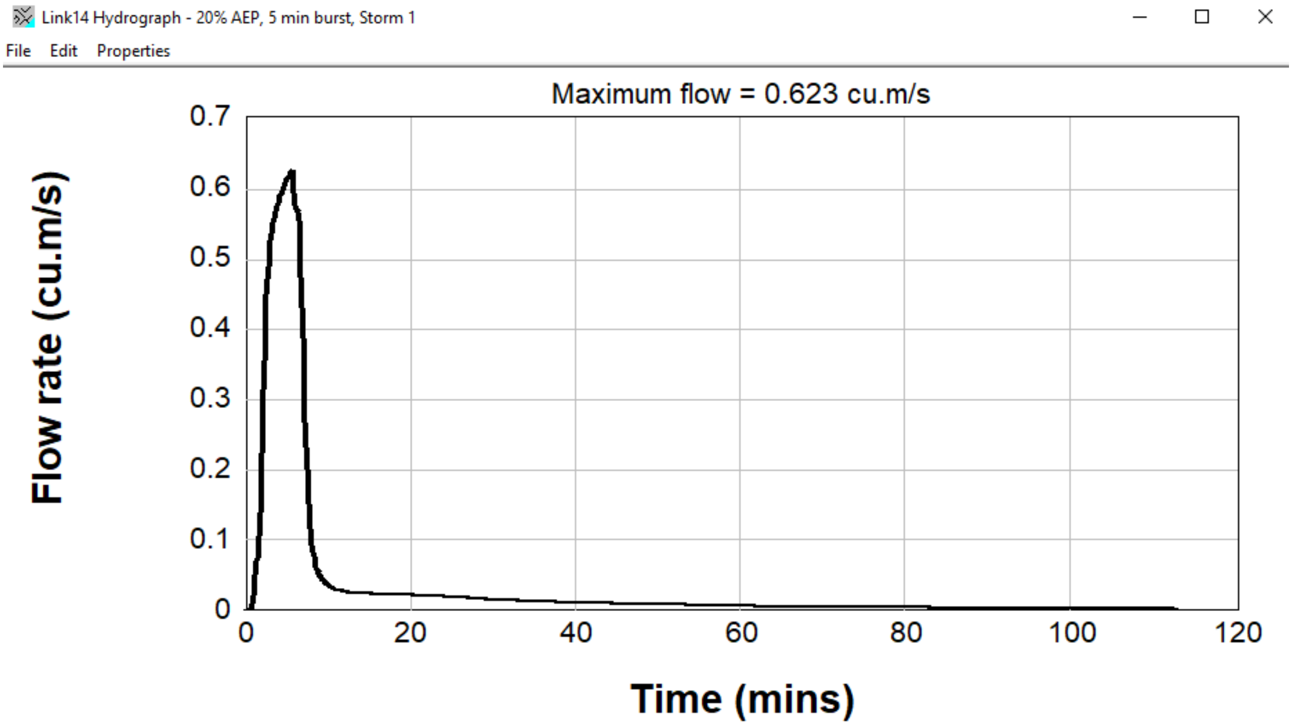


Figure 6.5: Selected 20% AEP storm outflow hydrograph – Eastern Catchment

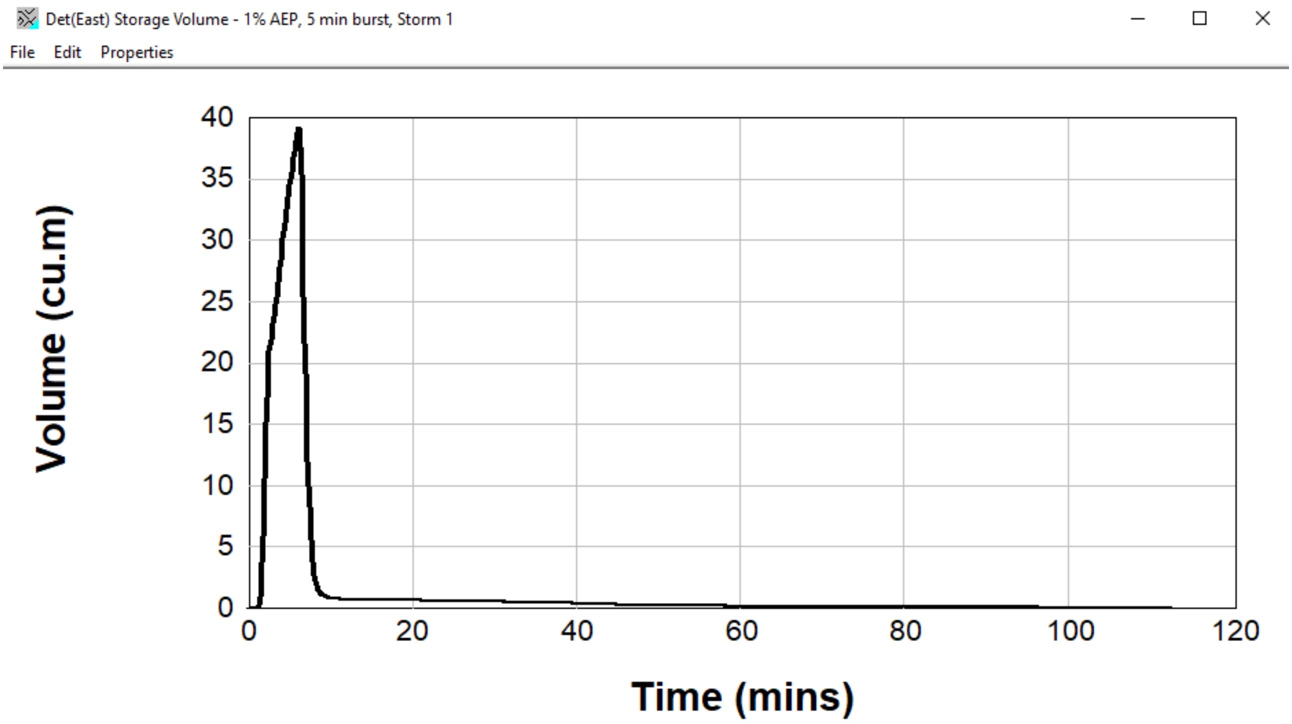


Figure 6.6: 1% AEP peak detention tank volume – Eastern Catchment

A summary of design outflow compared to the PSD for the Western Catchment is provided in Table 6.2 below.

Table 6.4: Summary of Detention Volume Eastern Catchment

AEP (%)	PSD (m^3/s)	Design Outflow (m^3/s)
1	1.23	1.21
20	0.63	0.62

6.2 RUNOFF QUALITY

Stormwater runoff from the proposed development will be improved by combination of harvesting for toilet flushing in dwellings and treatment via a bioretention cell.

A schematic representation of the proposed runoff treatment system for the site is shown in Figure 6.7 below.

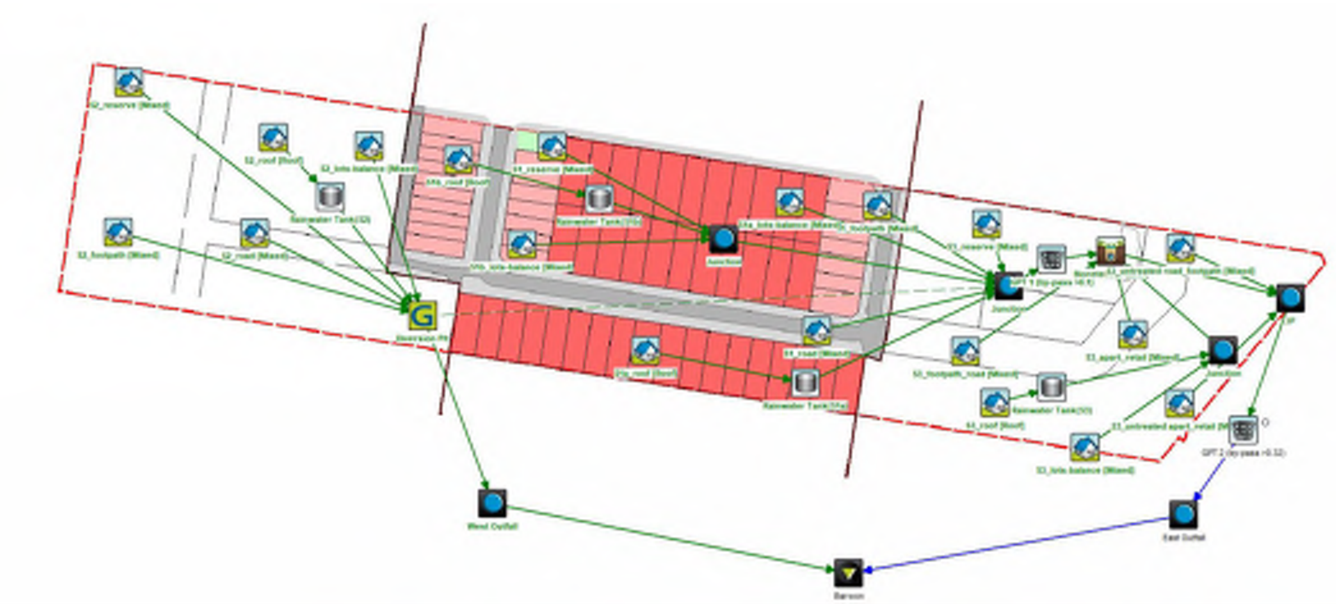


Figure 6.7: Schematic representation of runoff treatment system

6.2.1 Stormwater Harvesting

At least 1m^3 of storage capacity will be set aside within the proposed rainwater tanks specified for detention purposes in Section 6.1 above for use in toilet flushing[15].

A summary of stormwater harvesting results is shown in Figure 6.8 and Figure 6.11 below.

[15] Toilet flushing demand based on Table 11-2 Estimation of Reduction in Water Demand by Water Efficient Appliances [adapted from NSW Department of Infrastructure Planning and Natural Resources, 2004], WSUD Engineering Procedures for Stormwater Management in Tasmania 2012.

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	2.79	74.11	0.42	6.25	113.69
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Pipe Out	2.75	43.90	0.37	5.01	0.00
Weir Out	0.00	0.00	0.00	0.00	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.04	0.54	0.01	0.07	0.00
Reuse Requested	0.04	0.00	0.00	0.00	0.00
% Reuse Demand Met	100.00	0.00	0.00	0.00	0.00
% Load Reduction	1.57	40.76	11.67	19.75	100.00

Figure 6.8: Rainwater Tank Water Balance – Western Catchment

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	3.20	85.46	0.49	7.14	130.46
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Pipe Out	3.07	58.40	0.43	6.12	0.00
Weir Out	0.00	0.00	0.00	0.00	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.13	1.68	0.02	0.22	0.00
Reuse Requested	0.13	0.00	0.00	0.00	0.00
% Reuse Demand Met	100.00	0.00	0.00	0.00	0.00
% Load Reduction	4.10	31.67	11.02	14.24	100.00

Figure 6.9: Rainwater Tank Water Balance – Eastern Catchment Stage 1a

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	1.06	28.58	0.16	2.37	43.31
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Pipe Out	0.93	16.09	0.13	1.77	0.00
Weir Out	0.00	0.00	0.00	0.00	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.13	1.64	0.02	0.21	0.00
Reuse Requested	0.13	0.00	0.00	0.00	0.00
% Reuse Demand Met	100.00	0.00	0.00	0.00	0.00
% Load Reduction	12.34	43.71	20.14	25.47	100.00

Figure 6.10: Rainwater Tank Water Balance – Eastern Catchment Stage 1b

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	0.24	6.60	0.04	0.55	9.95
ET Loss	0.00	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
Pipe Out	0.07	1.40	0.01	0.14	0.00
Weir Out	0.00	0.00	0.00	0.00	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.18	2.36	0.02	0.33	0.00
Reuse Requested	0.45	0.00	0.00	0.00	0.00
% Reuse Demand Met	39.68	0.00	0.00	0.00	0.00
% Load Reduction	73.03	78.74	74.16	73.85	100.00

Figure 6.11: Rainwater Tank Water Balance – Eastern Catchment Future Stage,

6.2.2 Bioretention Cell

Some stormwater runoff from the eastern catchment and low flows from the western catchment will drain towards a proposed bioretention cell (BRC) at the eastern end of the development site. Low flows from the western catchment will be diverted to the east by the inclusion of a diversion pipe from the proposed underground detention tank at the western end of the site.

The BRC should include plants to maintain the hydraulic conductivity of the filter media.[16] A list of suitable plants is provided below;

- Baumea rubiginosa (sedge)
- Carex appressa (sedge)
- Goodenia ovata (ground cover)

[16] Virahsawmy et al. 2013

- Juncus amabilis (rush)
- Juncus flavidus (rush)
- Juncus pallidus (rush)
- Juncus subsecundus (rush)

Results of the BRC water balance is shown in Figure 6.12 below.

Node Water Balance - Bioretention(East)

	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Flow In	14.44	903.18	4.40	36.00	84.83
ET Loss	0.48	0.00	0.00	0.00	0.00
Infiltration Loss	0.00	0.00	0.00	0.00	0.00
Low Flow Bypass Out	0.00	0.00	0.00	0.00	0.00
High Flow Bypass Out	0.51	49.75	0.16	1.28	3.91
Pipe Out	11.43	28.77	0.99	7.63	0.00
Weir Out	2.00	67.30	0.39	4.83	0.00
Transfer Function Out	0.00	0.00	0.00	0.00	0.00
Reuse Supplied	0.00	0.00	0.00	0.00	0.00
Reuse Requested	0.00	0.00	0.00	0.00	0.00
% Reuse Demand Met	0.00	0.00	0.00	0.00	0.00
% Load Reduction	3.44	83.86	65.04	61.82	95.39

Decimal Places 2

Figure 6.12: Bioretention Cell Water Balance

6.2.2.1 Bioretention Cell – Detailed Design

The BRC is to be constructed in a reserve in the future Eastern Stage. Detailed Design of the BRC should allow for coarse sediment capture (via sediment forebay, sump pit, GPT or other), battering and access for maintenance purposes. The developer may choose to deliver the BRC in stages as the site develops to ensure the development continues to meet urban stormwater best practice guidelines management guidelines objectives.

In summary, the ultimate BRC will require an extended Detention Area of 250m², inclusive of the filter media area of 200m².

The size of the filter media will be subject to confirmation through functional design which will need to include soil moisture analysis, velocity check, and other design criteria outlined in the City of Greater Geelong WSUD Design Note 3 and relevant biofiltration design and construction guidelines. The orthophosphate content of the filter media should also not exceed 30mg/kg.

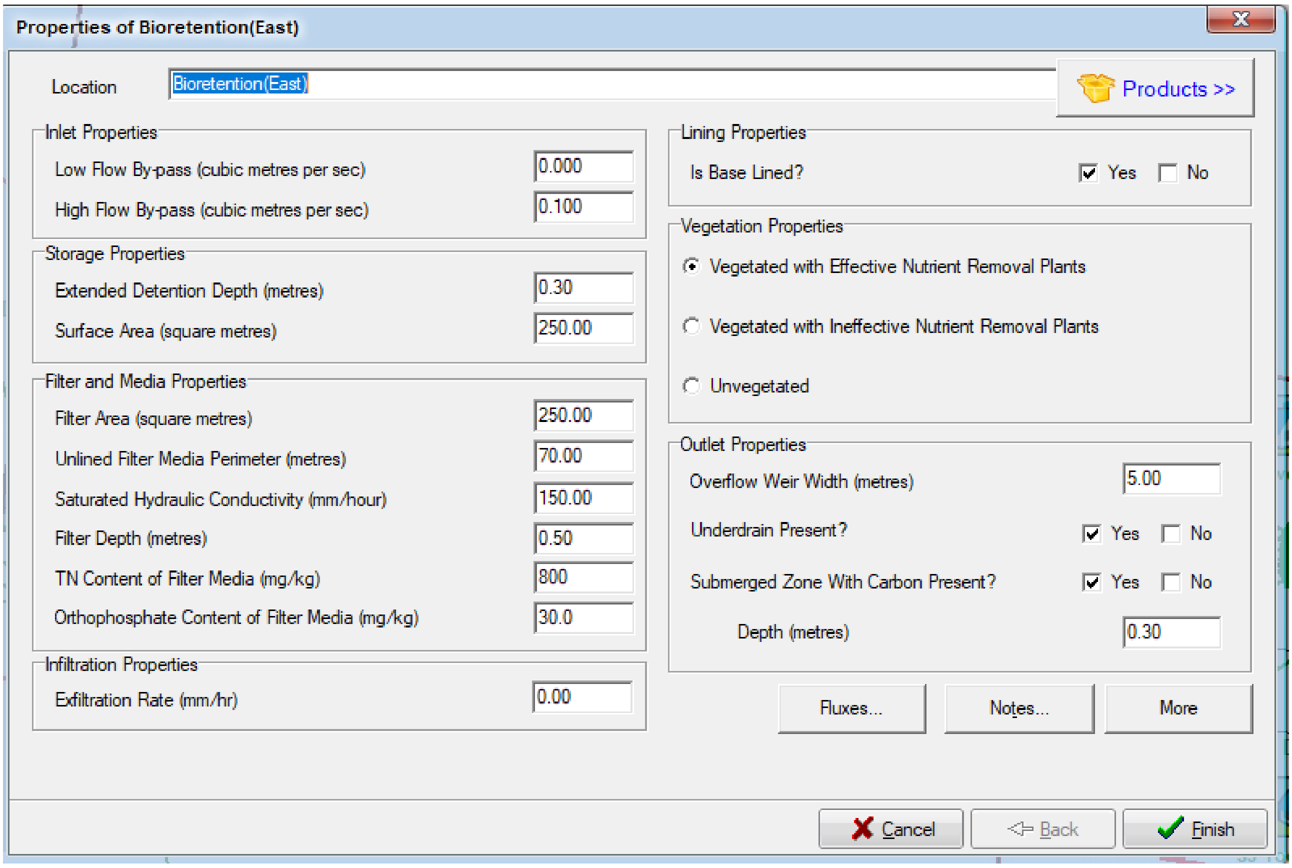


Figure 6.13: Bioretention Cell properties

6.2.3 Gross Pollutant Traps

Two GPT's are proposed for the development. A small GPT immediately upstream of the Bioretention Cell and another before discharging to High St a GPT. The properties of the GPT are detailed below.

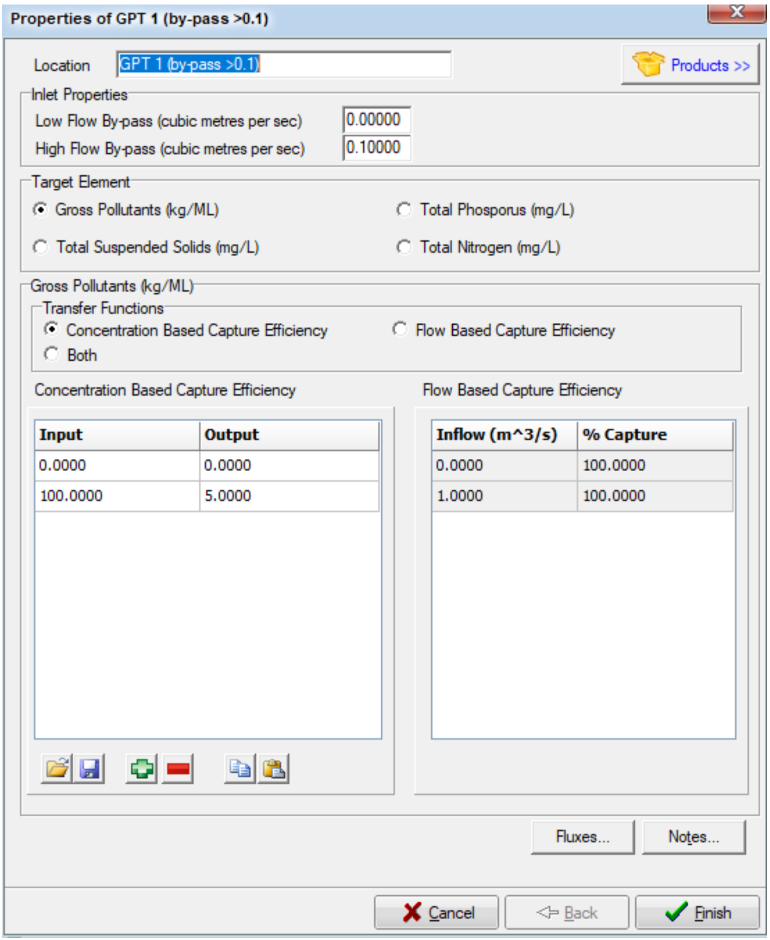


Figure 6.14: GPT 1 properties

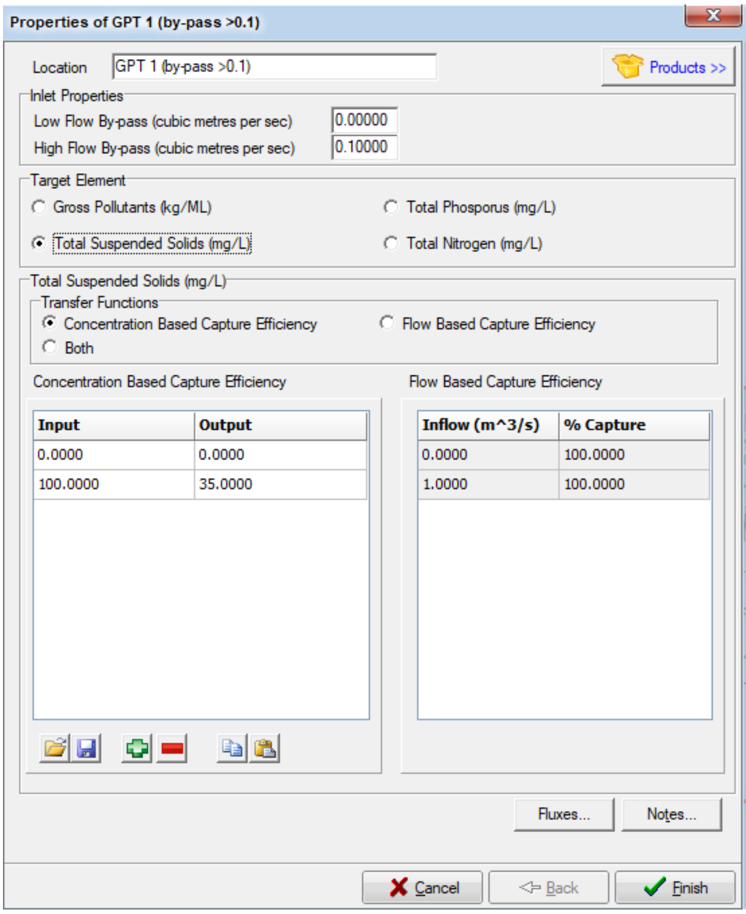


Figure 6.15: GPT 1 properties

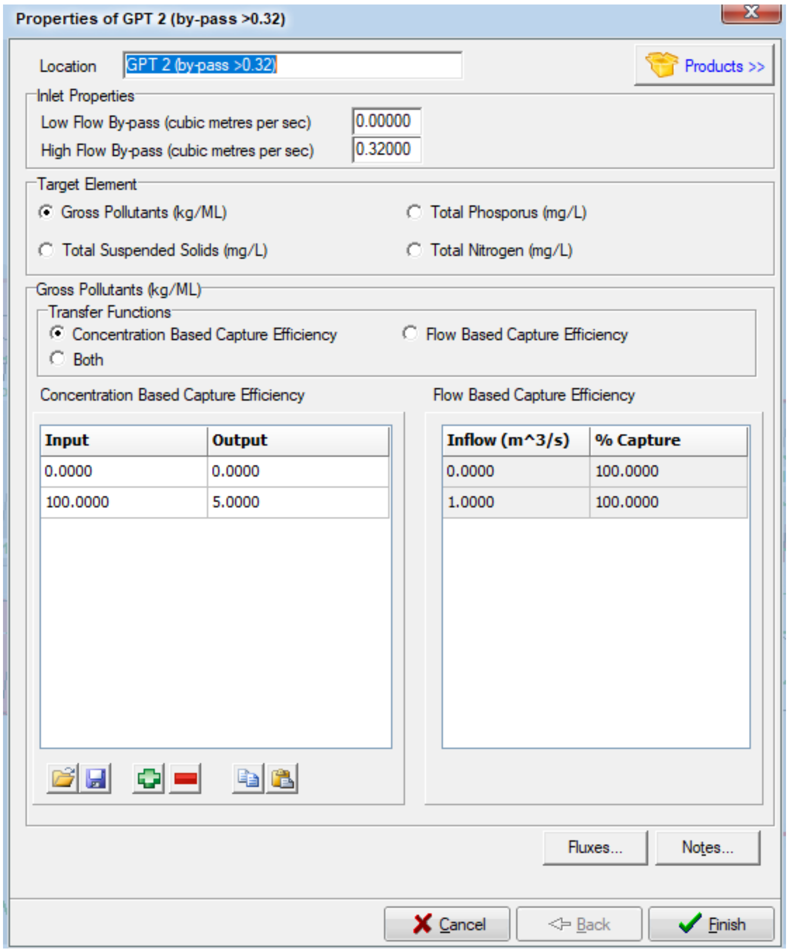


Figure 6.16: GPT 2 properties

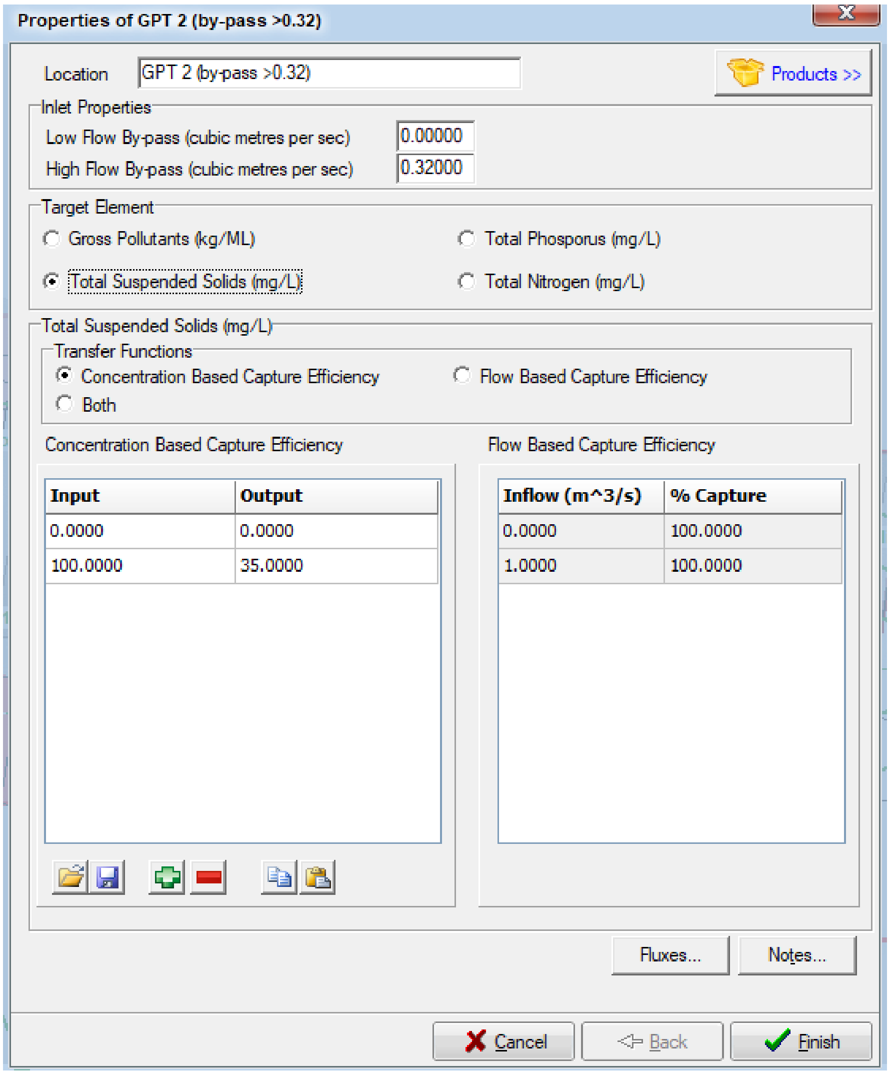
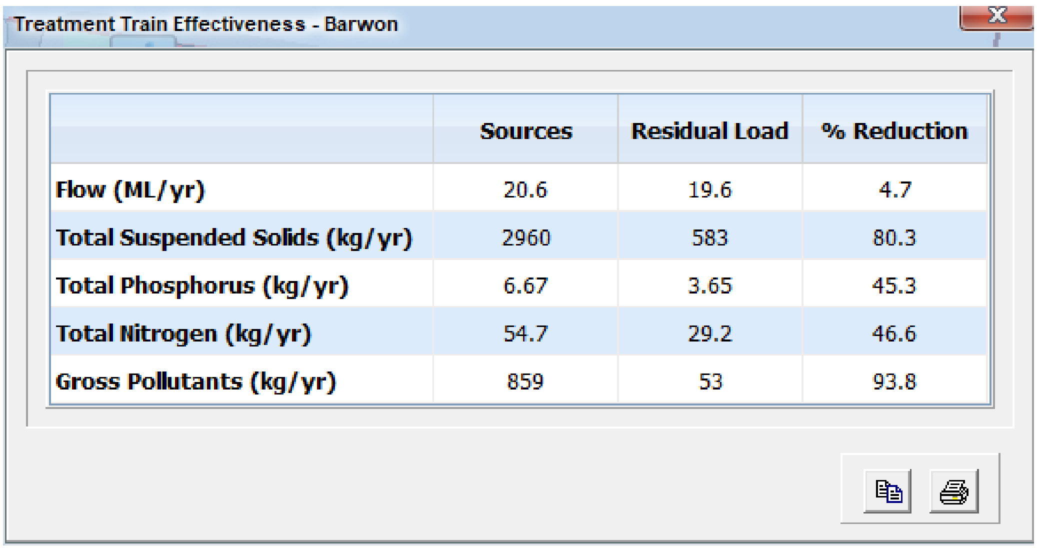


Figure 6.17: GPT 2 properties

6.2.4 Runoff Treatment Results

Through diversion of roof runoff to potable water substitution measures and treatment via a bioretention cell best practice stormwater management objectives can be met on site. A summary of runoff treatment results is shown in Figure 6.18 below.


Treatment Train Effectiveness - Barwon

	Sources	Residual Load	% Reduction
Flow (ML/yr)	20.6	19.6	4.7
Total Suspended Solids (kg/yr)	2960	583	80.3
Total Phosphorus (kg/yr)	6.67	3.65	45.3
Total Nitrogen (kg/yr)	54.7	29.2	46.6
Gross Pollutants (kg/yr)	859	53	93.8

Figure 6.18: Runoff Treatment System Effectiveness

7 Conclusions

Cardno now Stantec conclude that the stormwater runoff from the proposed residential development at 1 Henry St Belmont can be managed on-site to ensure the peak discharge does not exceed the permissible rates as nominated by the City of Greater Geelong and the quality of the runoff can be treated to best practice environmental management guidelines.

Peak runoff rates from the site shall be managed through the implementation of the following;

- 216m^3 of detention capacity provided by rainwater tanks installed on dwellings across Stages 1, 2 and 3,
- Underground tank/s with 350m^3 of detention capacity installed within the Western Stage,
- Detention tank located underneath the proposed Bioretention Cell within the Eastern Future Stage to provide 40m^3 of detention storage,

Runoff Quality from the site shall be managed through the implementation of the following;

- 148m^3 of storage capacity provided by rainwater tanks installed on dwellings to provide potable water substitution in the form of toilet flushing,
- Construction of a bioretention cell in the Eastern Future Stage

7.1 Stage 1

It is recommended that a temporary treatment and detention facility be provided during the construction and build out phase of Stage 1 to manage the elevated levels of sediment generated during the stage of the project. The decommissioning of the temporary treatment and detention facility should be guided by the progress of construction and extent of impervious area introduced as part of Stage 1. This approach will avoid damage to the ultimate bioretention cell and avoid blockage during the construction and build out phase and facilitate management of construction stage pollutants of Stage 1.

The proposed staging of works is described in Figure 7.1, however it is indicative only and should be revised to suit the progress of the development and the nature and design of the future stages as they occur.

The proposed basin to be constructed on the eastern side of Stage 1 could be included as a Council drainage reserve within Stage 1 or kept as a private asset until completion of the future development works. The future east and west development works could also be managed to protect the existing assets from major maintenance works by the way of diversions or temporary facilities to help clear construction sediment from clogging the drainage assets. We note that with the existing high point of the land located on the west boundary of Stage 1 both the future stage works naturally fall away from the proposed basin works.

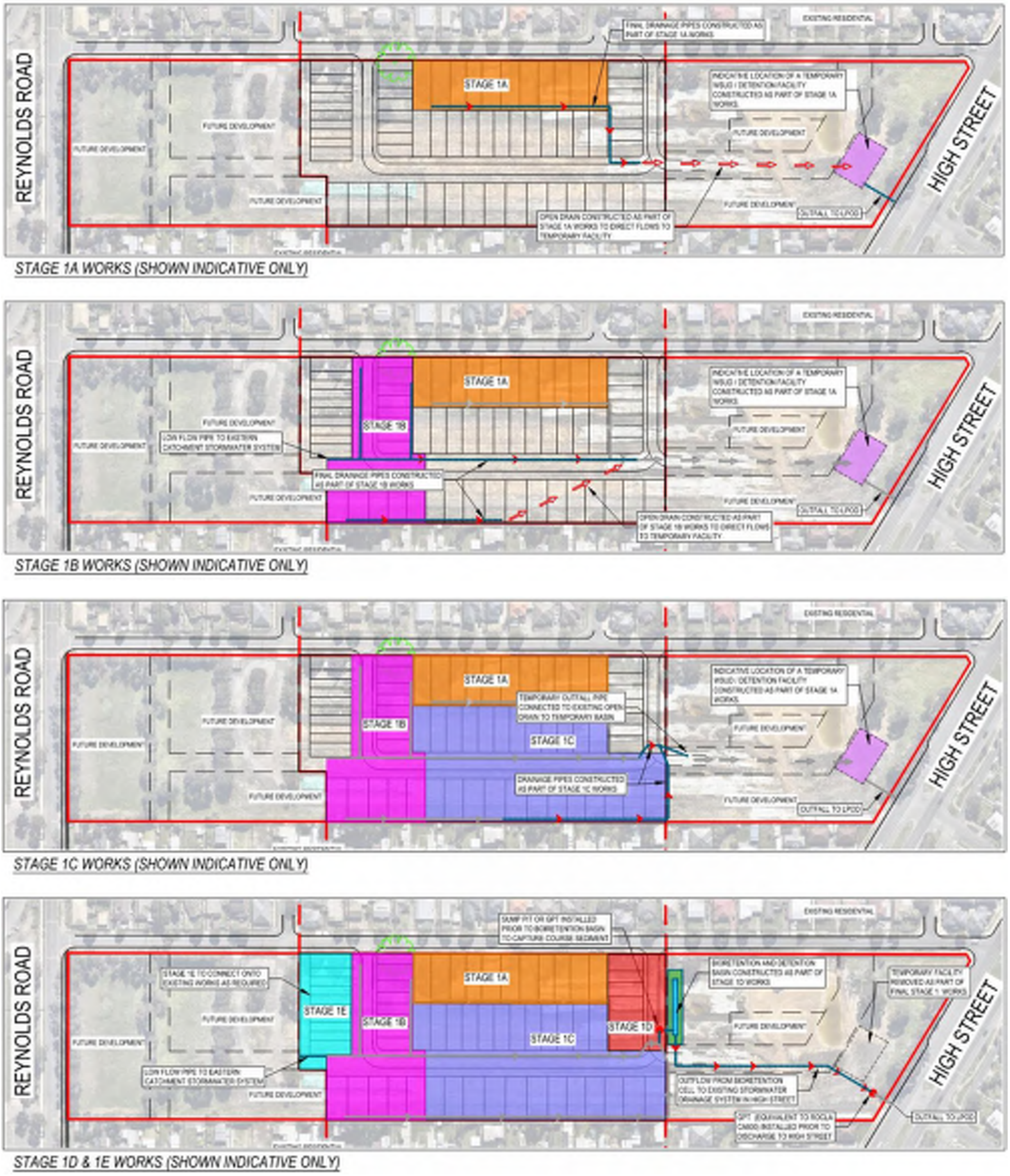
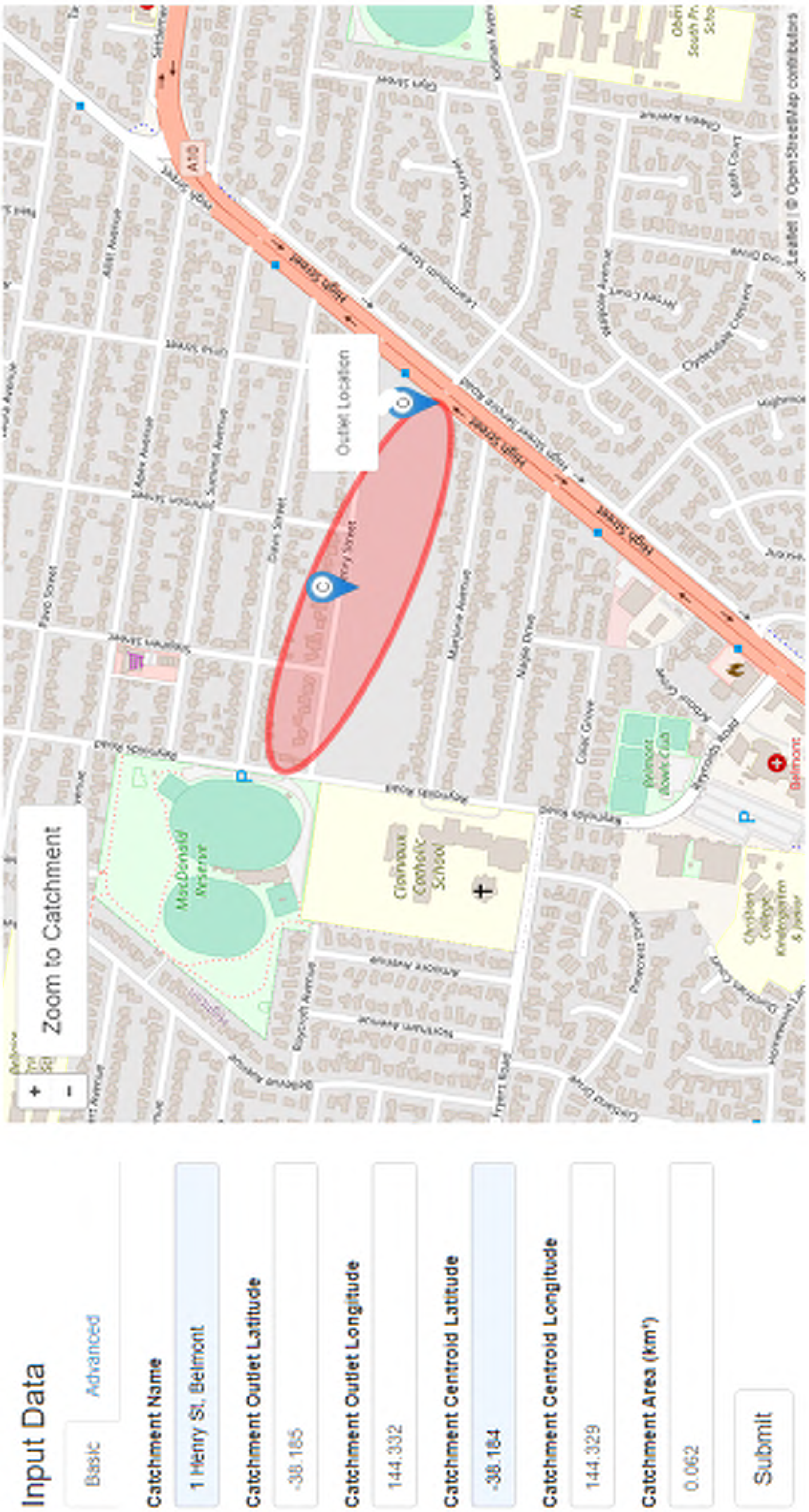
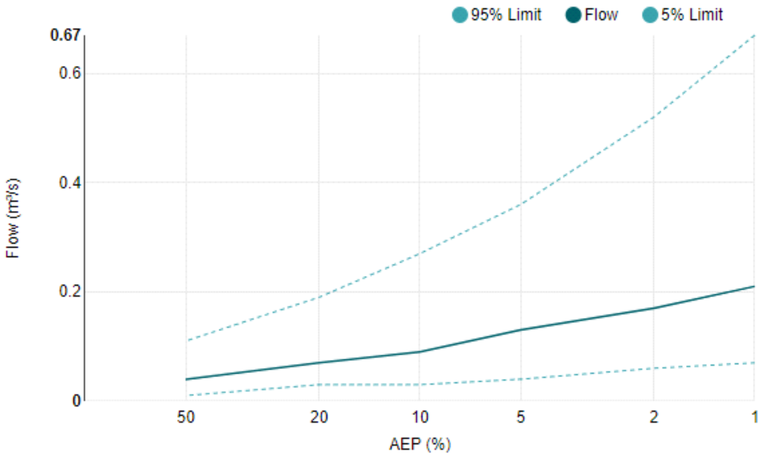


Figure 7.1: Proposed Staging of the runoff quality treatment system

Appendix A: Regional Flood Frequency Estimation Model





*The catchment is outside the recommended catchment size of 0.5 to 1,000 km^2. Results have lower accuracy and may not be directly applicable in practice.

*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

Input Data

Date/Time	2020-10-29 14:45
Catchment Name	1 Henry St, Belmont
Latitude (Outlet)	-38.185
Longitude (Outlet)	144.332
Latitude (Centroid)	-38.184
Longitude (Centroid)	144.329
Catchment Area (km^2)	0.062*
Distance to Nearest Gauged Catchment (km)	36.68
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.114043
2% AEP 6 Hour Rainfall Intensity (mm/h)	9.038759
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.14*
Interpolation Method	Natural Neighbour
Bias Correction Value	0.218

Statistics

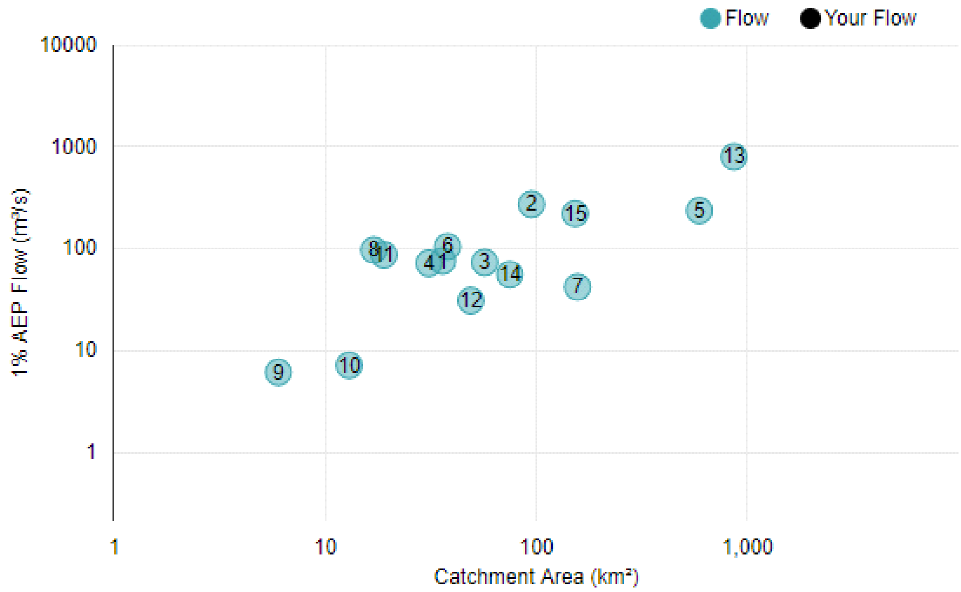
Variable	Value	Standard Dev
Mean	-4.718	0.520
Standard Dev	0.722	0.235
Skew	0.136	0.030

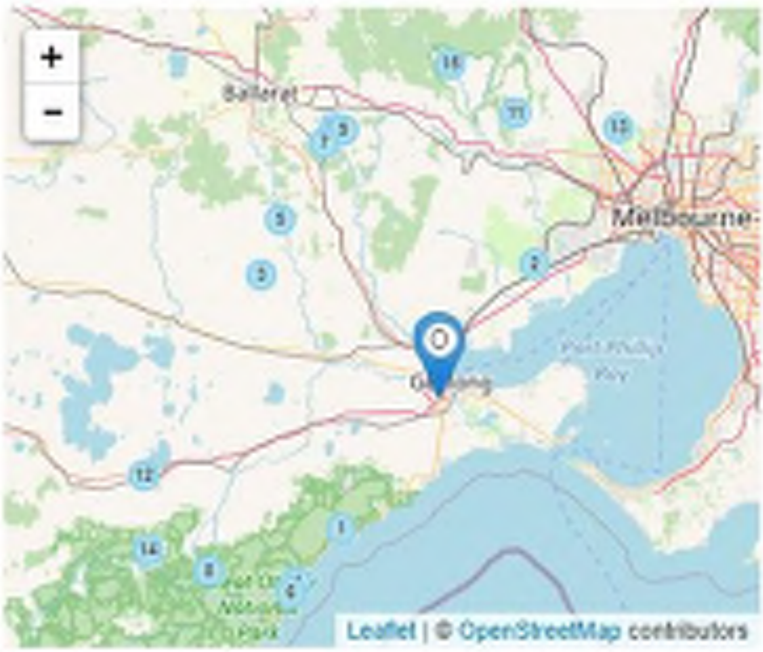
Note: These statistics come from the nearest gauged catchment. Details.

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

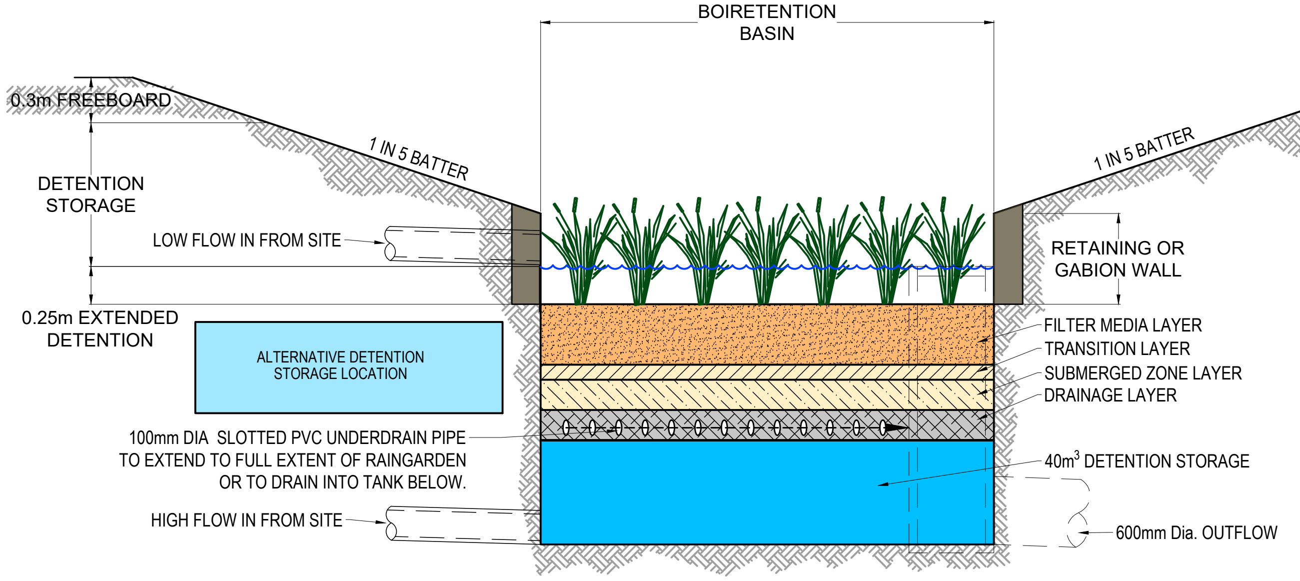
Note: These statistics are common to each region. Details.

1% AEP Flow vs Catchment Area




Ballarat
Melbourne
Leaflet | © OpenStreetMap contributors

Appendix B: Stormwater Management Plan



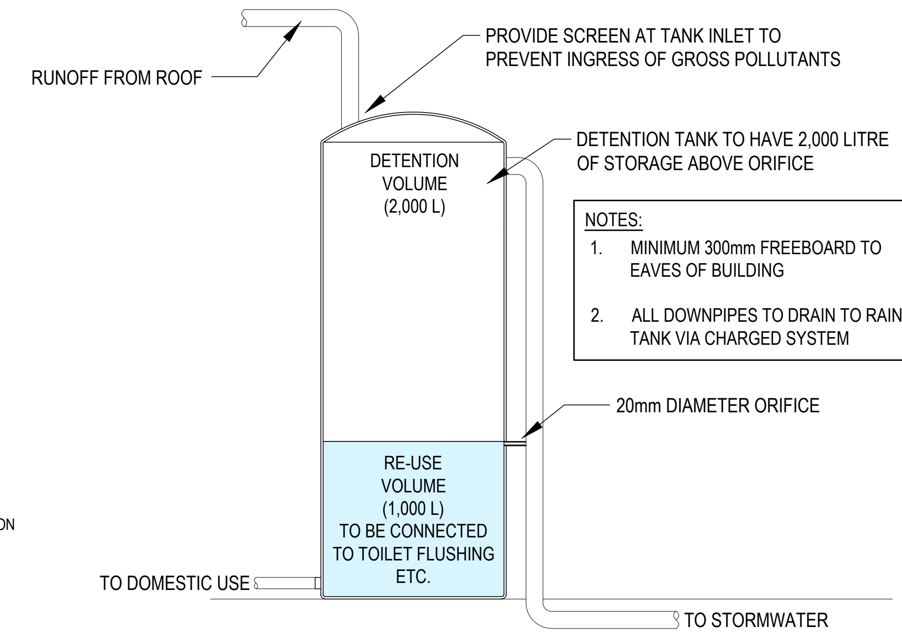
TYPICAL BIORETENTION AND DETENTION BASIN TYPICAL CROSS SECTION

SCALE: NTS

DISCHARGE (m³/s)		
AEP	PSD (m³/s)	Design (m³/s)
20%	0.01	0.01
1%	0.05	0.05

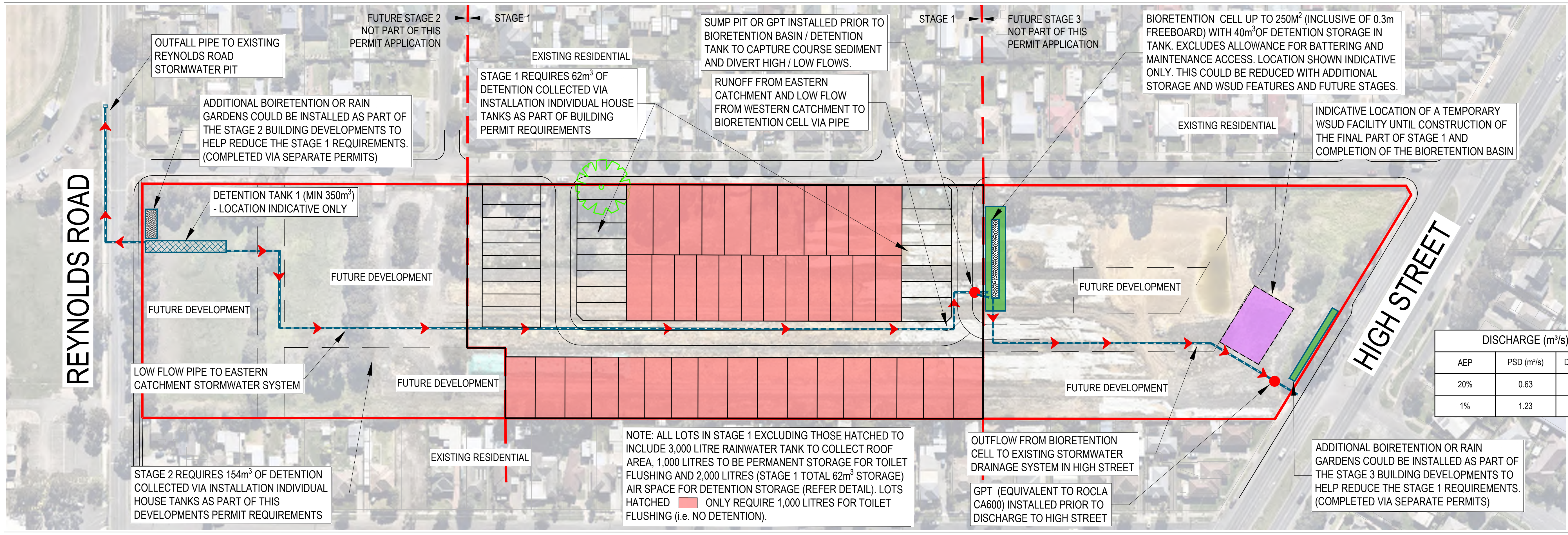
LEGEND

- PROPOSED STORMWATER DRAINAGE PIPE AND FLOW DIRECTION
- BIORETENTION CELL
- EXISTING TREE
- PROPOSED URBAN PARK
- UNDERGROUND STORMWATER DETENTION TANK



TYPICAL RAINWATER TANK DETAIL

SCALE: NTS



DISCHARGE (m³/s)		
AEP	PSD (m³/s)	Design (m³/s)
20%	0.63	0.63
1%	1.23	1.2

STORMWATER MANAGEMENT STRATEGY PLAN

ISSUE	ISSUED FOR	DATE	DRAWN	APPROVED	ISSUE	ISSUED FOR	DATE	DRAWN	APPROVED
01	PRELIMINARY	17/11/2020	W.M						
02	PRELIMINARY								
03	PRELIMINARY	29/07/2022	M.C						
04	PRELIMINARY	24/08/2022	B.J.						
05	FOR REPORT	20/12/2022	B.J.						

DESIGNED: W.MCCUSKEY	DATE: NOVEMBER 2020
DRAWN: W.MCCUSKEY	SCALE: A1: 1in200 A3: 1in400
SURVEY: ADRAIN CUMMINS & ASSOCIATES	SHEET SIZE: A1 / A3
CHECKED:	APPROVED:
DATE:	DATE:

Cardno TGM
ABN 11 125 568 461
1315 Sturt Street, Ballarat, VIC Australia (PO Box 563W, Ballarat West) 3350
Phone +61 3 5330 8888 Fax +61 3 5333 3815
Email: victoria@cardno.com.au Web: www.cardno.com

CLIENT: BELMONT PROJECTS

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT, 1 HENRY ST BELMONT, VIC 3216

CIVIL DRAWING

NORTH

DRAWING TITLE: **STORMWATER MANAGMENT PLAN**

REF. No.: 13035-02 | SHEET: 1 OF 1 | REV: 05

Appendix C: City of Greater Geelong Advice

CITY OF GREATER GEELONG
PO BOX 104
GEELONG VIC 3220 AUSTRALIA
DX 22063 GEELONG

TELEPHONE 03 5272 5272
FACSIMILE 03 5272 4277
www.geelongaustralia.com.au

CITY OF GREATER GEELONG

Jess Noonan
Senior Town Planner
Tract Consultants Pty Ltd
195 Lennox Street
RICHMOND VIC 3121

10 November 2015

Doc No: DW05235380
Our Ref: C251

Sent via email to JNoonan@tract.net.au

Dear Jess

Re: Greater Geelong Planning Scheme Amendment C251
CSIRO Commonwealth Land, Belmont – Water Strategy

I write in response to the email dated 13 October 2015 from Ben Johnson of TGM to Council's Senior Development Engineer Bojan Ritonja. The email outlines your clients' preferred stormwater treatment strategy for the proposed Henry Street development.

I advise that there is general support for the strategy and Council will not be seeking additional land to be set aside for stormwater retardation. Council however does not accept the use of bio-retention gardens within the streetscape.

Council engineers advise that:

Following assessment of the existing downstream drainage of the CSIRO site the following permissible site discharges (PSD) are applicable:

Eastern catchment (High St LPOD)
5 year ARI: PSD = 0.63 m^3/s
100 year ARI: PSD = 1.23 m^3/s

Western catchment (Reynolds Rd LPOD)
5 year ARI: PSD = 0.01 m^3/s
100 year ARI: PSD = 0.05 m^3/s

In achieving the permissible discharge, Council will accept the use of individual household rainwater tanks plumbed into the internal water supply for toilet flushing and garden watering. A reliability of 85% is to be used in determining the tank size required based on mean annual rainfall.

A 173 agreement is to be registered against individual titles for the installation, use and ongoing maintenance/repair of rainwater tanks. The 173 agreement must be in place prior to individual titles being released.

In assessing and designing the WSUD elements for this project, Council will not accept treatment devices within both existing/future public roads and open space. Council will consider for approval the use of proprietary products.

The preparation of an Integrated Water Management Plan will be underpinned by these principles and I encourage TGM to consult further with our engineers to finalise the strategy. The strategy should be submitted together with the application.

AABL-AP

We will review the draft DPO however consider that a formal application can now be lodged as outlined in the 14 July 2015 correspondence.

If you have any queries please contact Peter Schembri of the City of Greater Geelong by email: pschembri@geelongcity.vic.gov.au or telephone 03 5272 4496.

Yours sincerely

PETER SMITH
COORDINATOR STRATEGIC IMPLEMENTATION

CITY DEVELOPMENT

Copy To: Bojan Ritonja, Senior Development Engineer, Engineering Services
Roger Munn, Team Leader Senior Statutory Planner, City Development