WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Western Geelong Growth Area

Flood Impact Assessment and Stormwater Management Strategy

Volume 2: Developed Conditions Report

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NOTE

This report (Volume 2) and all diagrams herein represent the stormwater management concept strategy, including developed conditions analysis with hydrological / water quality modelling, design principles, staging / sequencing opportunities, construction and maintenance aspects based on the draft framework land use plan.
An initial report (Volume 1) setting up the existing conditions including hydrological and hydraulic initial modelling should be read in conjunction with this final report.

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CONTENTS

APPENDICES

4664-04_R01_v03.docx

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Project Scope

The City of Greater Geelong (CoGG) is preparing a Framework Plan for the future development of the Northern and Western Geelong Growth Areas providing high-level direction on future land uses, major networks of transport, open space and activity centres. The objective of the stormwater strategy is to “develop a clear strategy for managing floodwater and stormwater in the Study Area, in the context of a broader Integrated Water Management (IWM) approach” (CoGG Project Brief, May 2016).

Since 2016, Water Technology has been working with CoGG and a range of stakeholders on the Western Geelong Growth Area (referred as WGGA) and presented in Figure 1-1.

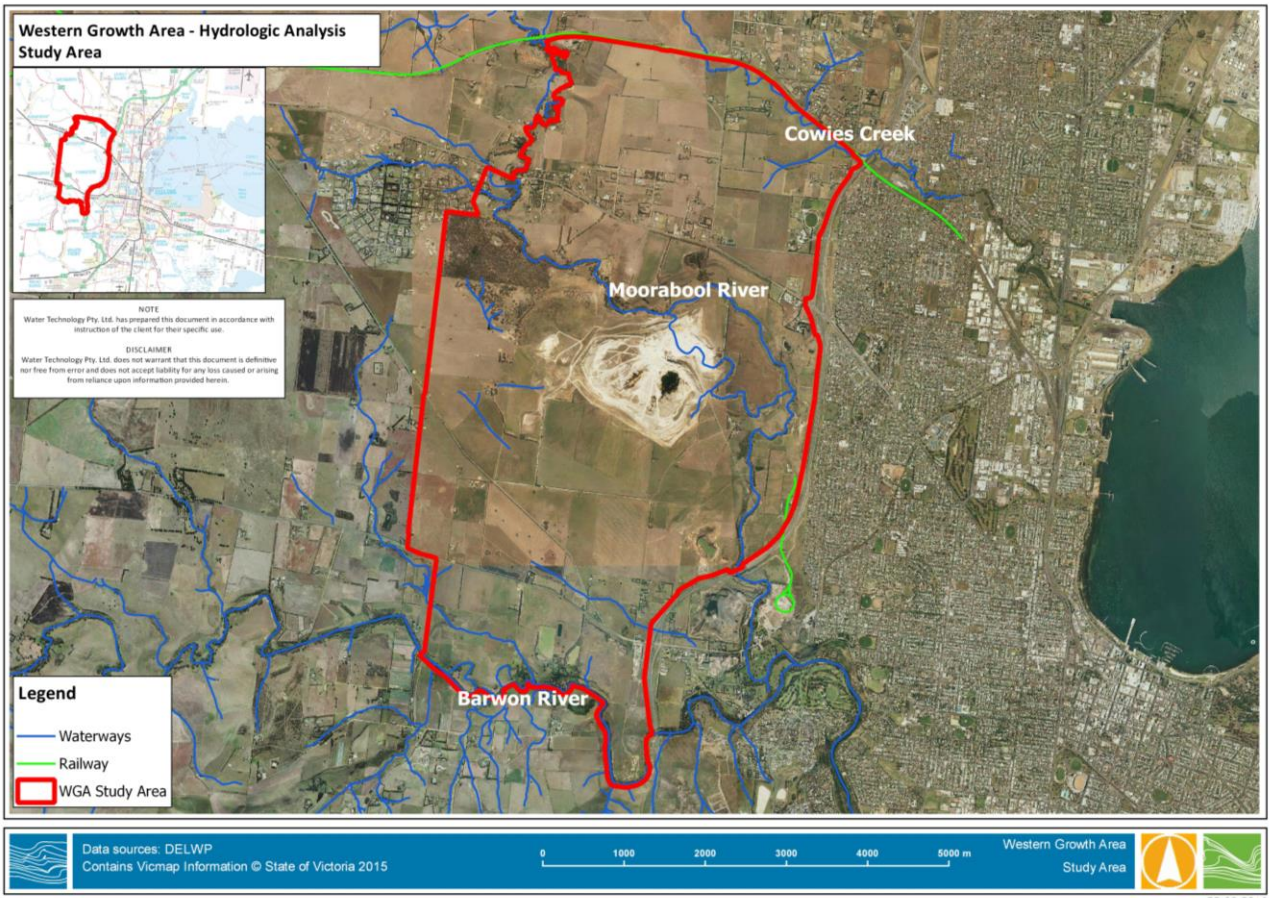


Figure 1-1 Study Area

The overall scope of work includes three phases presented in Figure 1-2. An Existing Conditions Final Report (Water Technology, January 2019) was prepared as an initial phase including preliminary existing condition flood modelling, opportunities and constraints. This was followed by a Downstream Impact Assessment with risk matrix and mapping that considered developed conditions impacts based on preliminary assumptions for a future urban structure plan.

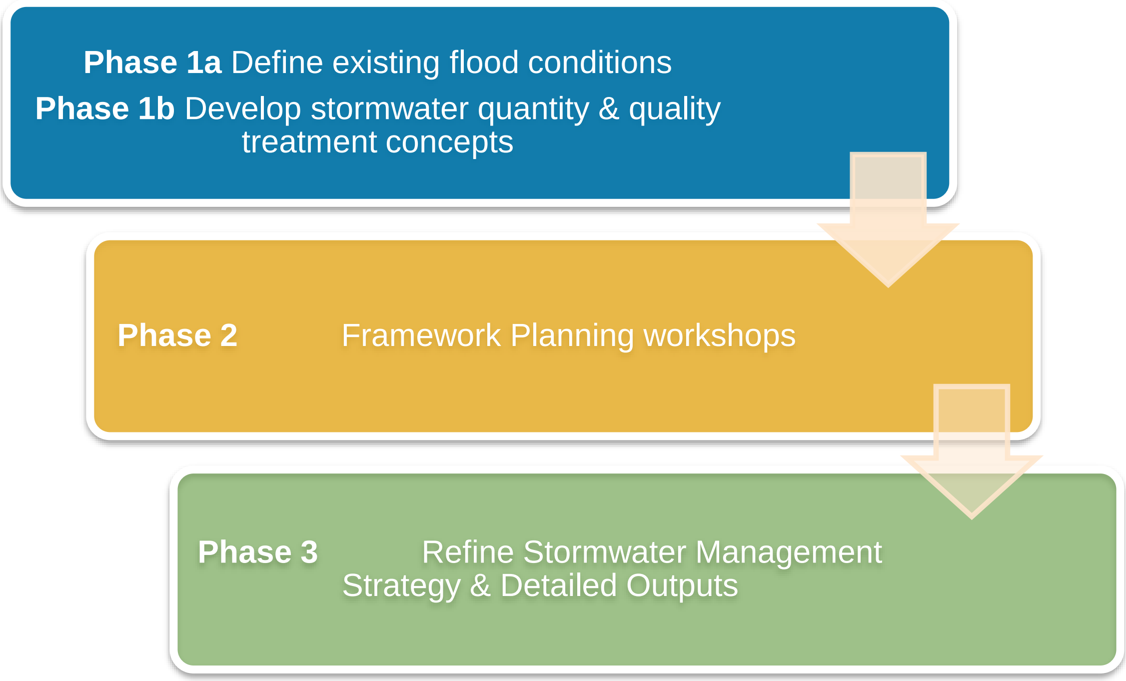


Figure 1-2 Flooding and Stormwater Project Phases

This report focuses on Phase 3 of the drainage and flooding assessment and include the following scope of works;

- Review of Neil Craigie's Phase 1 draft concept Stormwater Management Strategy (SWMS)
- Preliminary RORB (using ARR 1987) and MUSIC modelling to develop concept mitigation strategy based on the draft Framework Plan (Working Draft For Consultation, 28 March 2018) including preliminary asset sizing.
- Refinement of the concept strategy to incorporate findings from the workshops, refine assets sizing (i.e. outlet sizing, waterway width, pipe sizing). It includes the concept design of approximately 19 combined wetland/retarding basins, 8 combined sediment basin/retarding basins, 13 waterway corridors and 52 piped sections.
- Provision of staging /sequencing opportunities and constraints advice including advice on land use to facilitate efficient provision of drainage infrastructure including opportunities to leverage off existing assets.
- Documentation of design principles, standards and technical commentary on construction and maintenance aspects of the key drainage elements.
- Provision of stormwater assets information suitable for preliminary full costing to be completed by an external consultant.
- Reporting and engagement with CoGG, Corangamite Catchment Management Authority (CCMA) and other key stakeholders throughout the project including stormwater management strategy design workshop and integrated water management workshop.

1.2 Background information

This report should be read in conjunction with the following existing documents;

- WGGA Conceptual Layout for Stormwater Management Strategy Draft Version 7 (Neil M Craigie Pty Ltd, 28 September 2017);
- Existing Conditions Drainage and Flooding Final Report (Water Technology, January 2019);
- Integrated Water Management (IWM) Position Paper – Northern and Western Geelong Growth Areas (CoGG & Barwon Water, September 2018); and
- The Draft Framework Plan (Working Draft For Consultation, 28 March 2018) presented in Figure 1-3.

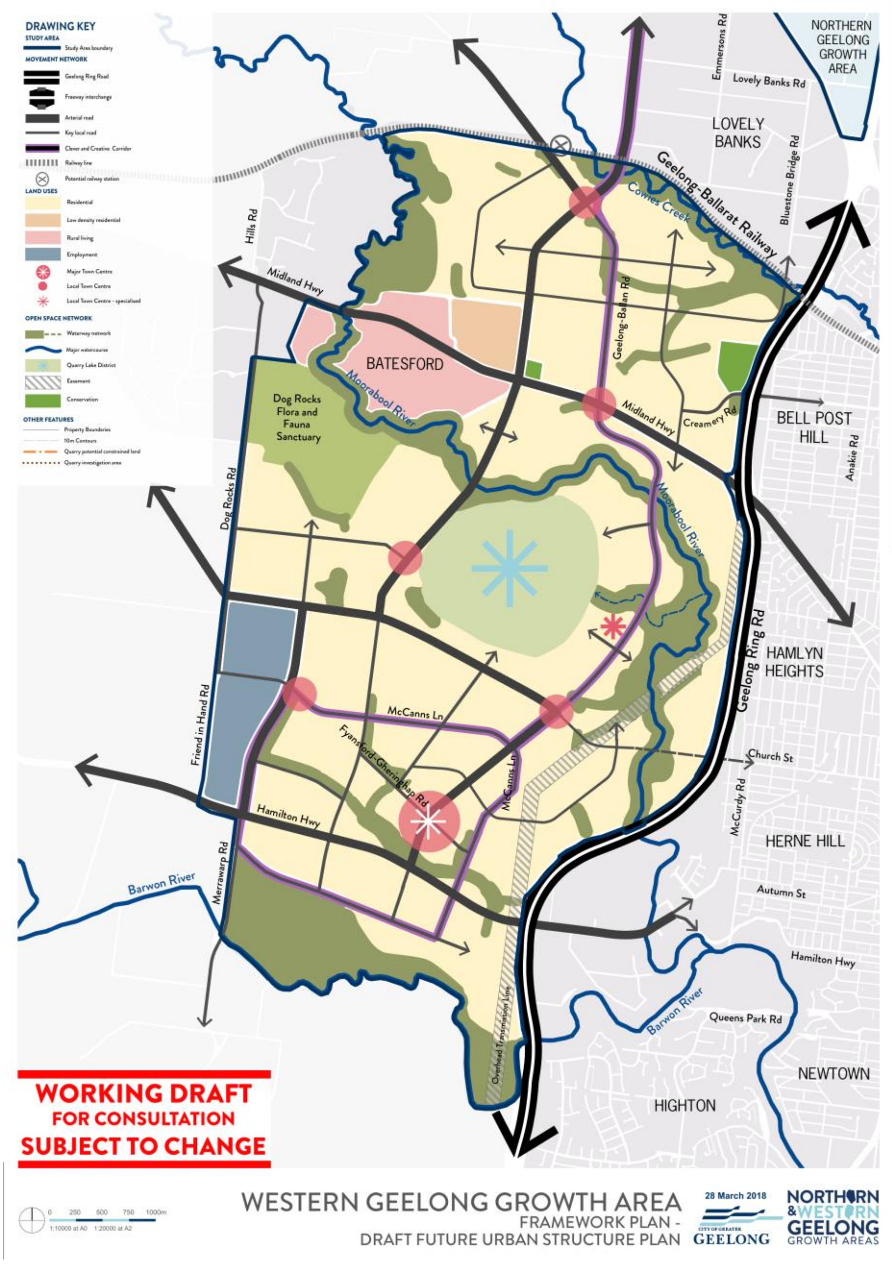


Figure 1-3 Draft Framework Plan (28 March 2018)

2 DEVELOPED CONDITIONS MODELLING

2.1 Hydrologic RORB Modelling

2.1.1 Overview and Approach

The existing conditions diverted RORB models developed and approved during the Phase 1 (refer to Existing Conditions Drainage and Flooding Final Report) were used as the base to derive the developed conditions RORB models and assess flood storage requirements. The existing conditions RORB model subareas were delineated using the current terrain information from the LiDAR dataset. The following three existing conditions diverted RORB models covering the study area were used;

- Cowies RORB model
- Moorabool RORB model
- Barwon RORB model

2.1.2 Developed RORB models Set-up

The RORB models were subject to several changes regarding the subarea delineation, fraction impervious (FI) value and redirection of flow.

2.1.2.1 Subarea and Reach Type Changes

The three RORB models' subareas GIS layers were overlayed with the Draft Framework Plan and Neil Craigie's concept SWMS for comparison. Subareas delineation and reach drainage characteristics were adjusted to reflect the proposed developed conditions.

Reach types were adjusted to reflect developed conditions with proposed pipes, road reserves and open waterways to convey stormwater runoff. The existing conditions RORB model reach type was in most cases set to Type 1 "Natural". Under developed conditions, the RORB model reach type was set to;

- Type 3 "Lined channel or pipe" when the stormwater runoff is proposed to be conveyed underground via drainage pipes and/or overland via the roadway;
- Type 2 "Excavated but unlined" when the stormwater runoff is proposed to be conveyed by open waterways

Maps of the RORB model set-up under existing and developed conditions for each of the three areas (Cowies, Moorabool and Barwon) are respectively presented in Figure 2-1, Figure 2-2 and Figure 2-3.

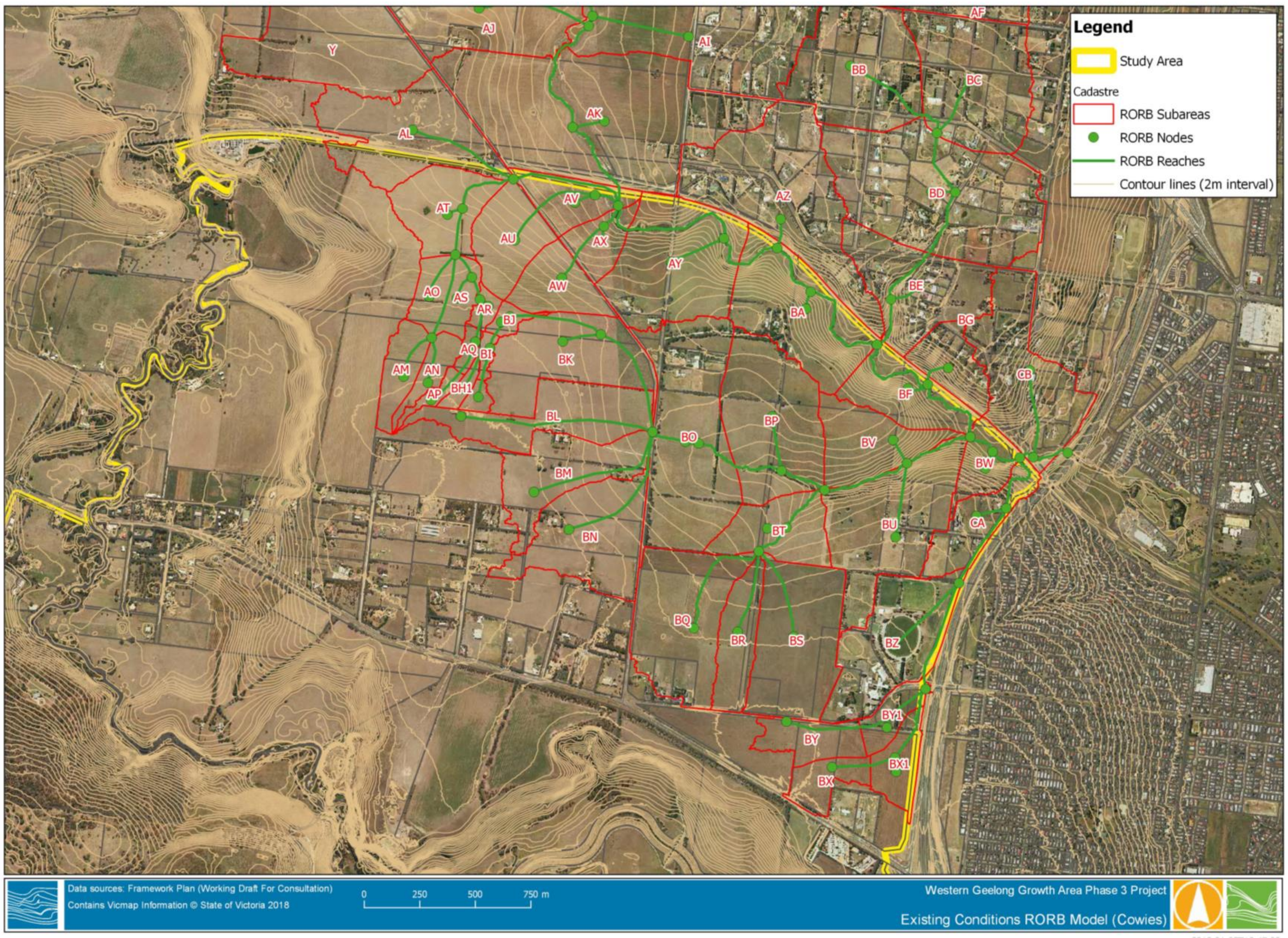
2.1.2.2 Fraction Imperviousness Changes

FI values were updated to reflect developed conditions as per the Draft Framework Plan assuming that land set to be developed along existing steep escarpments and quarries were being developed. The FI values were taken from the Melbourne Water MUSIC Guidelines (2018). The ultimate developed conditions FI map is presented in **Appendix A** with the FI rate presented in Table 2-1.

Table 2-1 Land uses and Fraction Impervious assumptions

Land use Type	FI Rate
Vegetated Land	0.05 – 0.10
Rural Living Residential	0.20
Residential (low density)	0.45
Road (minor)	0.50
Township Residential	0.55
Quarry	0.60
Road (major)	0.70
Residential (medium density)	0.75
Residential (high density)	0.85
Commercial/Industrial	0.90

Existing RORB Model



Developed RORB Model

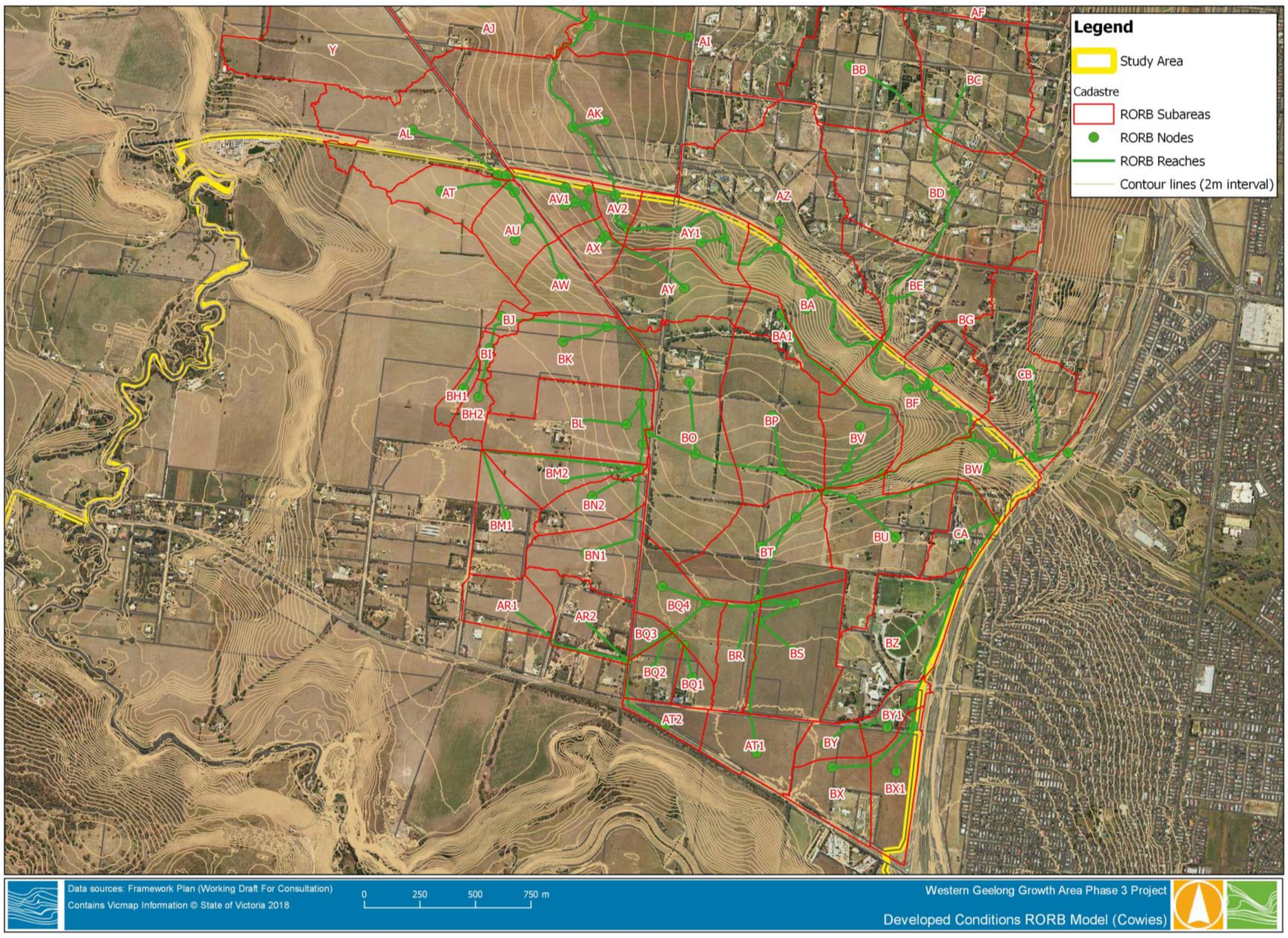


Figure 2-1 Cowies RORB Model (Existing, top – Developed, bottom)

Existing RORB Model

Developed RORB Model

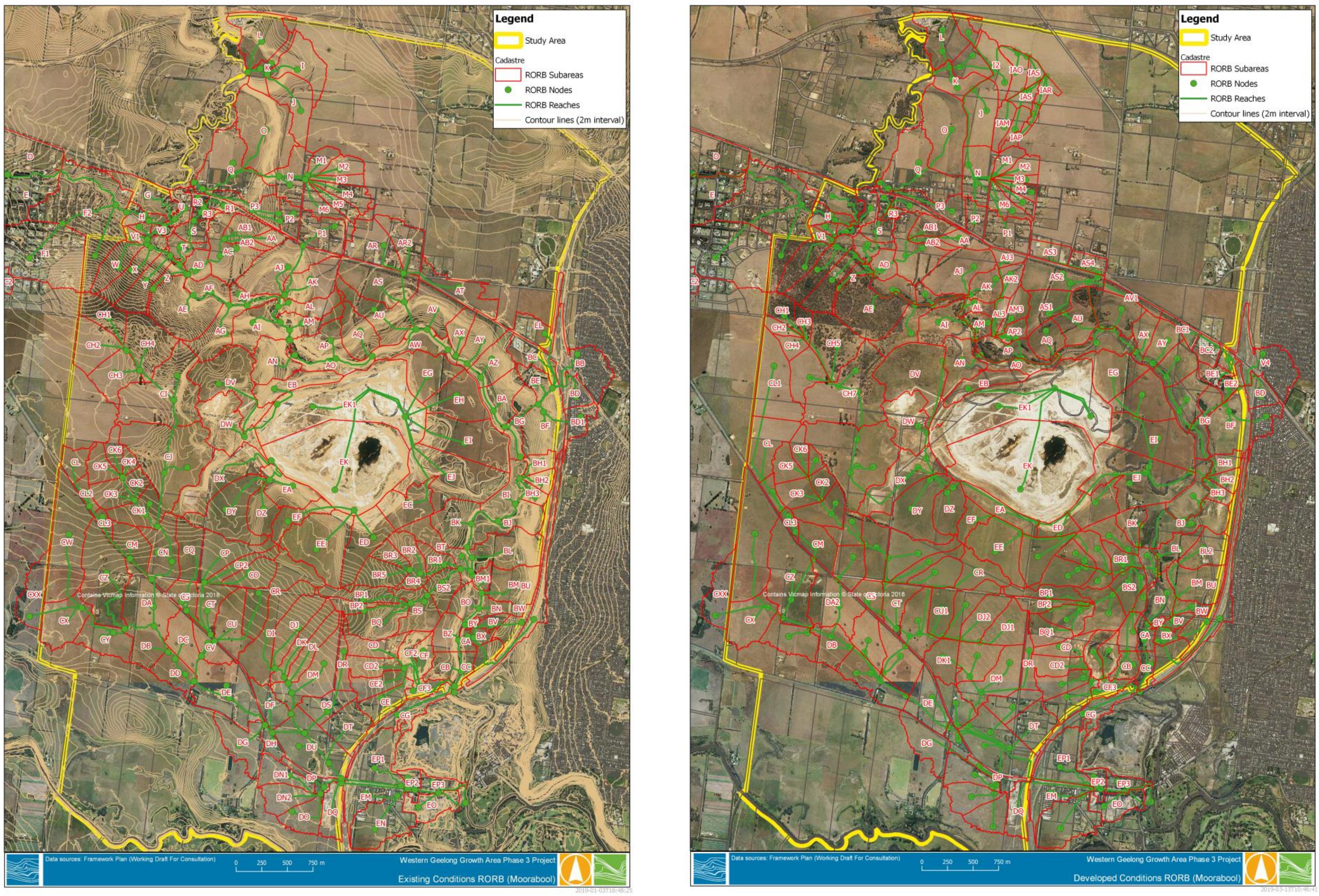


Figure 2-2 Moorabool RORB Model (Existing, left – Developed, right)

Existing RORB Model

Developed RORB Model

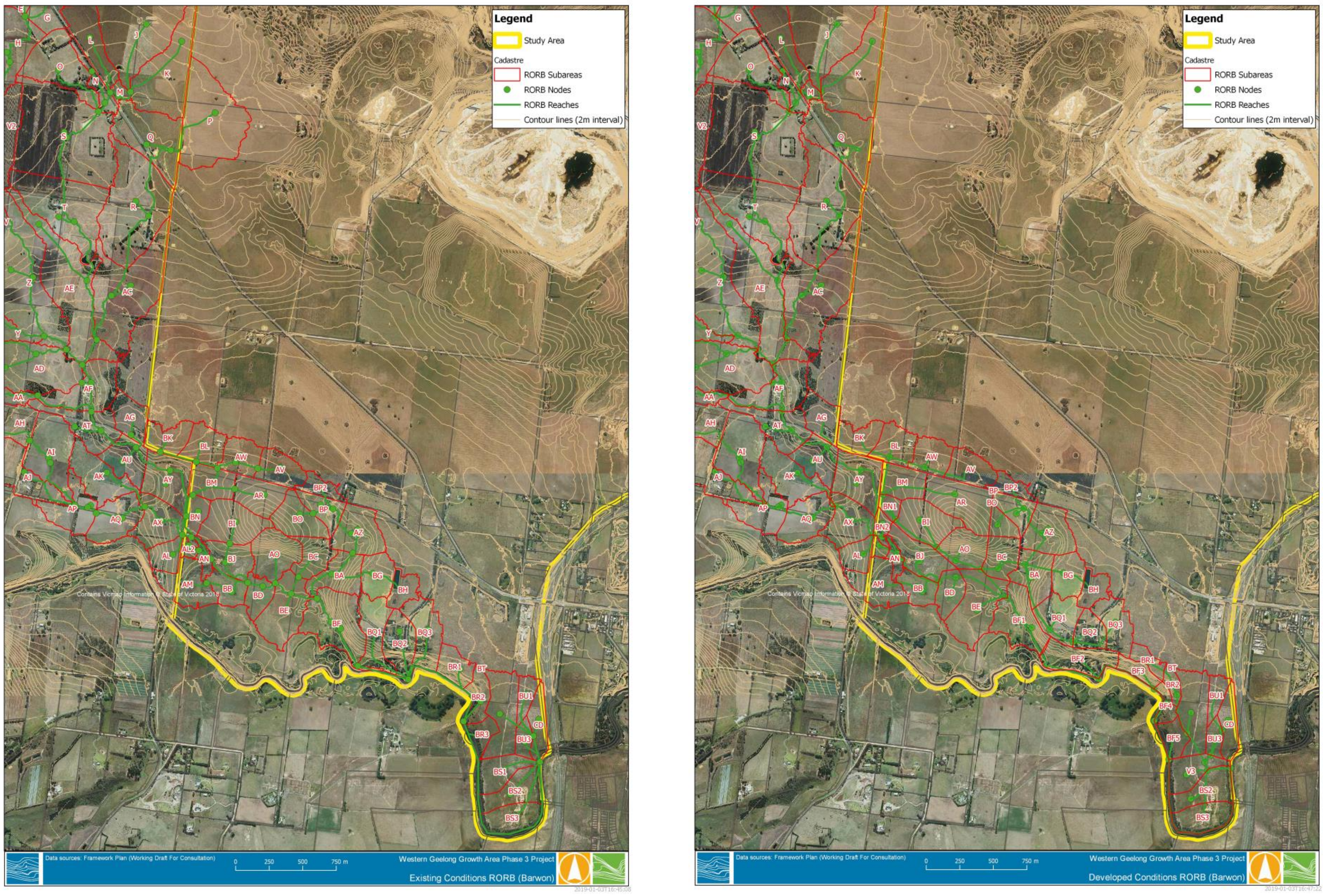


Figure 2-3 Barwon RORB Model (Existing, left – Developed, right)

Cowies Creek Catchment:

- The Cowies catchment includes subareas in the Geelong Northern Growth area which parameters were left unchanged from the existing conditions model.
- RORB subareas AM, AN, AO, AP, AQ, AR and AS were redirected into Moorabool River model to match with the proposed drainage infrastructure set in the Draft Framework Plan. Subarea AT was added to the Cowies Creek model from Moorabool River model as this subarea is separated from the Moorabool River model by the Midland highway and it is assumed that the area would be drained north into the Cowies Creek model via additional culverts under the highway.
- RORB subareas BX, BX1, BY, BY1, BZ and CA (near Bingley Court) have had substantial changes to their existing subarea and reach delineation with subarea CA and subareas upstream of CA redirected to Cowies WLRB G as per the concept SWMS.
- Cowies WLRB F has been designed to retard all upstream flows removing the need for future diversion under the Princess Highway as proposed in the concept SWMS.

Moorabool River Catchment:

- RORB subareas P1 and P2 within the township of Batesford have been redirected towards the north under developed conditions to reflect the land development proposed in the Draft Framework Plan. These two subareas are set to be developable land draining towards a future flood retardation and treatment asset before ultimately draining to the Moorabool River as it was previously but further downstream the River.
- RORB subareas M1 to M6 were found to cross one of the arterial roads shown in the Draft Framework Plan. These subareas were split along the north-south arterial road with the eastern subareas now redirected towards the Cowies Creek catchment.
- Some areas within the Moorabool River catchment are designated for development as per the Draft Framework Plan although their current topography may not be suitable as presented below;
    - The existing quarry located north of Geelong Ring Road at the end of Thoona Lane is designated to be developed within the Draft Framework Plan. To comply with this assumption, the quarry was assumed to be filled with a reach slope comparable to the surrounding subareas reach slope and fully developed.
    - Considerable changes in drainage delineation have taken place along the Geelong Lime Quarry. In the existing conditions model most of the surrounding RORB subareas drained directly to the quarry itself. Under developed conditions, the proposed developable land has been redirected to stormwater assets discharging to the Moorabool River. Given the changes in subareas delineation, the Moorabool River outfall comparison point at this location has slightly been shifted downstream to allow to a valid 1% peak flow assessment pre and post development.
    - All subareas located with terrain steep escarpments have been split to dissociate the portion of land set to be developed from the land to remain undeveloped. The portion of land at the top end of the escarpment was directed to flood storages for retardation. The treatment of the land along identified steep terrain escarpments are further discussed in Section 3.3.

Barwon River: Catchment

- RORB subarea P was removed from the Barwon River RORB model and redirected towards the Moorabool River catchment following direction of the Draft Framework Plan
- All RORB subareas located along the steep escarpments of the Barwon river were split to dissociate the portion of land set to be developed from the land to remain undeveloped. The portion of land at the top end of the escarpment was directed to flood storages for retardation. The other portion of the land were left to drain directly to the Barwon River as previously modelled under the existing conditions. Given the

changes in subareas delineation, the Barwon River outfall comparison point has slightly been shifted downstream to allow to a valid 1% peak flow assessment pre and post development.

2.1.3 Developed RORB models Validation

For consistency, the developed RORB models were run using the same parameters using in the existing conditions model as summarised below;

- IFD from the Australian Rainfall and Runoff 1987
- Initial loss/continuing loss model was applied
  - The initial loss (IL) and continuing loss (CL) for the pervious areas respectively set to;
    - Cowies and Barwon catchments: IL= 15 mm and CL= 2 mm/hr
    - Moorabool catchment: IL= 20 mm and CL= 3 mm/hr
  - The initial loss (IL) and continuing loss (CL) for the impervious areas respectively set to;
    - $IL_i = (1-F_i) * IL_{perv}$
    - $CL_i = (1 - F_i) * CL_{perv}$
    - Where *i* and *perv* indicates the i^{th} sub-area and the pervious area respectively.
- RORB m value is a measure of catchment non-linearity and is typically set at 0.8
- Revise the impervious properties of the subcatchments by updating the FI values to represent the changes in land use as described in **Appendix A** with the FI rate presented in Table 2-1.
- Vary routing parameters by interstation area (Kc value at the outlet)

The developed RORB models were run by adjusting the Kc value for each of the model to maintain Kc/D_{av} ratio the same as the one set under existing conditions. The final kc values of 3.4, 15 and 10.3 were adopted for the Moorabool River, Cowies Creek and Barwon River catchments respectively in the developed conditions.

2.1.4 Preliminary Flood Storage RORB Modelling

Preliminary flood modelling was undertaking in RORB to verify reserve storage areas were adequate. This was achieved by adding Storage Nodes to present SBRB and WLRB using Stage/storage relationship derived from Neil Craigie's SWMS. Preliminary surface areas were taken from Neil Craigie's report, the surface areas were then buffered in 15 metres with a batter slope of 1:8 (1% AEP depth of 1.6 m + 0.3 m freeboard) to give the base surface area of each waterbody. Stage storages were then derived and input into the RORB model for each of these assets.

Iterative Storage Design was used to compare the 1% AEP peak flow at Creek/River outfalls between existing and developed conditions to verify that the pre-developed 1% AEP flows were not exceeded and that reserve areas were adequate for storage requirements. Outfall flow requirements were met at all sites with the exception of Moorabool WLRB D1 where extensive changes in subcatchment delineation and direction meaning that the 1% AEP peak flow is no longer comparable to the one estimated in the existing conditions model at the same Moorabool River outfall location. In this case, significant subcatchment areas have been redirected to new outfall locations along the Moorabool River.

2.2 Water Quality MUSIC Modelling

Large scale constructed wetlands and sediment basins are proposed as the delivery method for water quality treatment within the WGGA framework plan area. The rationale behind the selection of wetland sediment basins for the assessment is attributed to the following:

- Large scale bioretention systems have had limited success over the past few decades with multiple authorities within the Victorian region no longer accepting responsibilities for such assets.
- Base areas of retarding basins are utilised for wetland/sediment basin treatment. This best utilises the already encumbered reserves set out to perform the hydraulic/hydrologic functions to service the new growth areas. By placing the wetland/sediment basins within the future retarding basin footprints, a more cohesive and aesthetic public asset is created whereby the whole community can utilise the drainage reserve.
- Additional distributed treatment systems may be implemented in the future, however there is a significant uncertainty associated with regards to their locations or if thy will be actually constructed. For more certainty, the regional wetland/sediment basin treatment system have been assessed as the cost and land take requirements are a known quantity giving surety to the reserves and costs allocated in the Framework Plan.

The following three existing MUSIC models preliminarily set up by Neil Craigie in September 2017 were used as a base to assess water quality in the WGGA;

- Cowies MUSIC model
- Moorabool North MUSIC model
- Barwon & Moorabool South MUSIC model

To safeguard the water quality of the future large scale lake proposed within the Batesford quarry pit, all development flows from future urban development areas are proposed to bypass the future lake area and outfall to the Moorabool River. The future lake is to be fed by groundwater inflows which are incomparable to small potential stormwater inflow volume. Developed area stormwater redirection into the future lake therefore only provides a potential pollution source to the future lake, consequently stormwater flows have not been directed into the future lake. The uncertainty surrounding the cessation of the quarry activities were also taken in consideration in the decision to bypass developed flows from the Batesford quarry pit.

Neil Craigie existing MUSIC models were reviewed and deemed fit for purpose. Each of the model is set-up using the following assumptions;

- 10 years meteorological data (rainfall and evapo-transpiration) set in the original MUSIC model by Neil Craigie have been reviewed and found suitable for water quality analysis.
  - The Burau of Meteorology (BoM) weather stations within the WGGA recorded a Mean Annual Rainfall (MAR) ranging from **442 mm/year** (for Barwon River at Pollocksford station 87162, with dataset covering a period between 2001 to 2017) to **544 mm/year** (for Barwon Head Golf Club station 87135, with dataset covering a period from 2002 to 2019). The BoM Breakwater (Geelong Racecourse) station 87184 only has annual rainfall records from 2012 to 2018 with a MAR of **521 mm/year**.
  - The MW MUSIC Guidelines rainfall template correspond to the Melbourne Airport Station Name which has a MAR of **575 mm/ year**.
  - The rainfall timeseries (set by Neil Craigie) applied in the MUSIC models cover a 10 year period from 1st January 1980 to 31st December 1989 and has a mean annual rainfall equal to **521 mm/year** which is comparable to the MW MUSIC Guidelines (refer to Table 2-2) and BoM nearby stations records.

Table 2-2 Annual Rainfall (mm/year) comparison table

Year	Annual Rainfall (mm) Neil Craigie MUSIC Models	Year	Annual Rainfall (mm) MW MUSIC Guidelines
1980	417	1971	606

Year	Annual Rainfall (mm) Neil Craigie MUSIC Models	Year	Annual Rainfall (mm) MW MUSIC Guidelines
1981	627	1972	478
1982	277	1973	654
1983	556	1974	797
1984	461	1975	579
1985	513	1976	463
1986	535	1977	598
1987	599	1978	815
1988	626	1979	418
1989	603	1980	346
Mean	**521**	**Mean**	**575**

- The evapo-transpiration monthly data (set by Neil Craigie) applied in the MUSIC models are comparable to the MW MUSIC guidelines template values as shown in Table 2-3.

Table 2-3 Monthly evapo-transpiration (mm/month) comparison table

Month	Evapo-transpiration (mm/day) Neil Craigie MUSIC Models	Evapo-transpiration (mm/day) MW MUSIC Guidelines
January	5.13	5.45
February	4.50	5.11
March	3.19	3.29
April	2.07	1.87
May	1.23	1.03
June	1.00	0.70
July	1.06	0.77
August	1.39	1.35
September	2.20	2.33
October	3.52	3.45
November	4.47	4.43
December	4.52	5.16
Mean	**2.90**	**2.90**

- All treatment nodes exfiltration rate was set to 0 mm/hour.
- All MUSIC models were run at a 6-minute timestep.
- ‘Urban” source nodes were used to represent the developed catchments
    - Surface Area (ha) and fraction impervious was set to match the RORB model based on the Draft Framework Plan as described in Section 1.2.
    - Zoning was set to “residential”

- Soil parameters are set as 120 mm and 50 mm for soil storage capacity and field capacity respectively as per the MW MUSIC Guidelines.
- "Sedimentation Basin" treatment nodes were set with the following parameter;
  - Surface area (m^2) was set to 90% of the retarding basin base surface area and corresponds to the sedimentation basin Normal Water Level
  - Extended Detention Depth was set to 0.35 m
  - Permanent pool volume (m^3) was set assuming an average depth of 1 metre below NWL
  - Initial volume (m^3) was set to match the permanent pool volume to assume the sedimentation basin water level is at Normal Water level at the start of the simulation.
  - Sedimentation basin outlet properties were sized outside of MUSIC using an Orifice Calculation spreadsheet to meet the 12 hours detention time. The use of an external spreadsheet was done due to an error in the orifice calculation within MUSIC which fails to take into account reducing outflow rate has head acting on the orifice reduces.
  - Smaller sediment basin within the major wetland systems are modelled as an inlet volume with the MUSIC wetland nodes as detailed further below.
- "Wetland" treatment nodes were set with the following parameter;
  - Inlet Pond Volume (m^3) was set by calculating volume required to accommodate the 5 year accumulated sediment volume from the untreated upstream developed catchments. The corresponding total sediment basin inlet volume required was then derived input into the wetland treatment node. The wetland inlet pond corresponds to future subdivision sedimentation ponds at the inlets to the wetland/RB.
  - Surface area (m^2) was set to 90% of the retarding basin base surface area and corresponds to the wetland Normal Water Level
  - Extended Detention Depth was set to 0.35 m, except in the case of COWIES WLRB G and MOORABOOL WLRB D where the EDD has been set at 0.5 metres due to site constrains where existing valleys confine the future wetland extents.
  - Permanent pool volume (m^3) was set assuming an average depth of 0.4 metres below NWL.
  - Initial volume (m^3) was set to match the permanent pool volume to assume the wetland water level is at Normal Water level at the start of the simulation.
  - Wetland outlet properties were sized outside of MUSIC using a Wetland Orifice Calculation spreadsheet to meet the 72 hours detention time as the detention time calculation in MUSIC is incorrect.

A view of the MUSIC models set up is presented in Figure 2-4,Figure 2-5 and Figure 2-6.

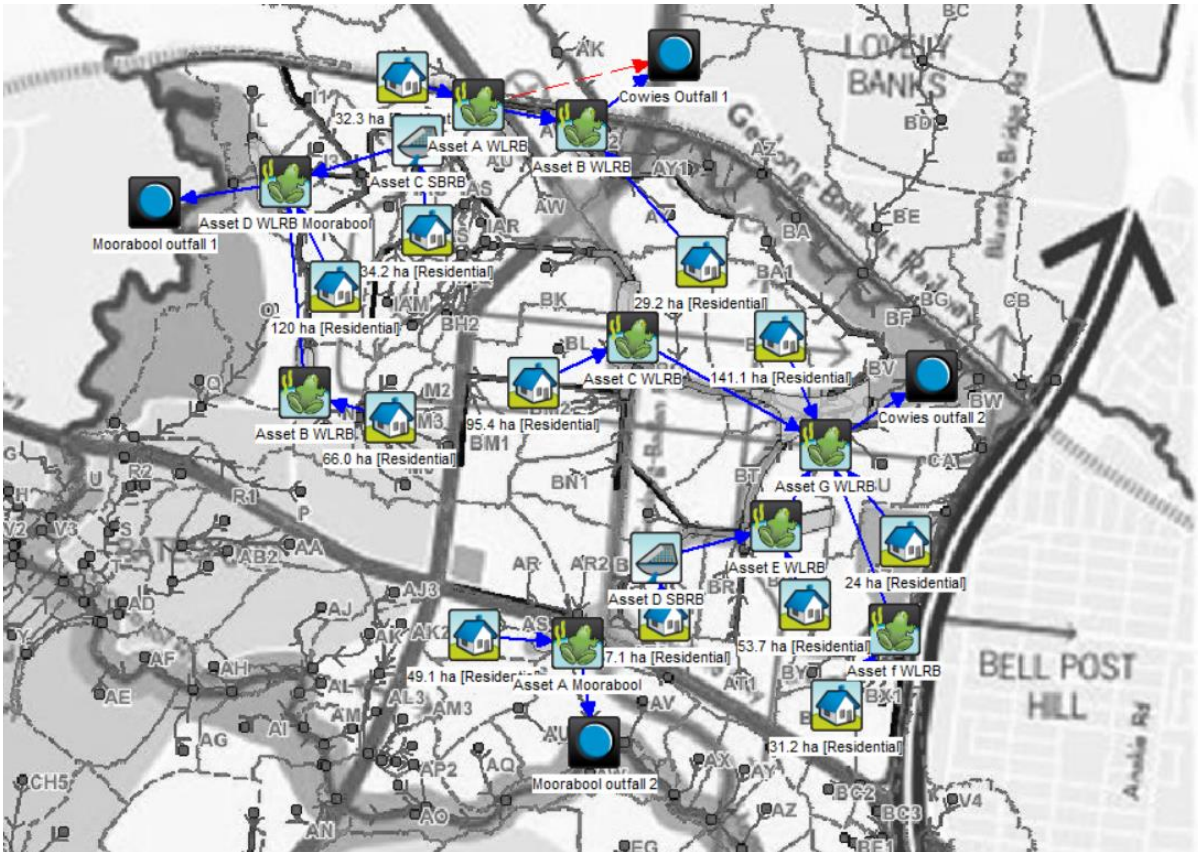


Figure 2-4   Cowies MUSIC model set-up

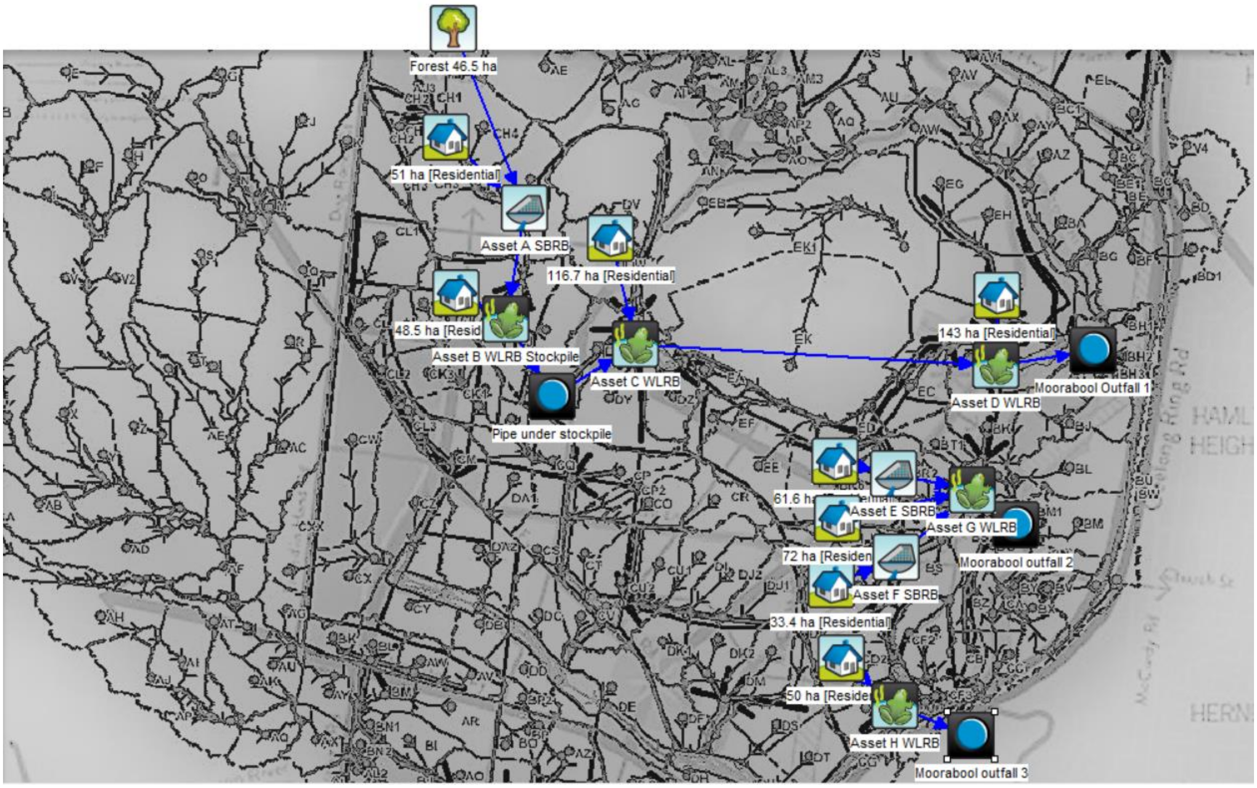


Figure 2-5   Moorabool North MUSIC model set-up

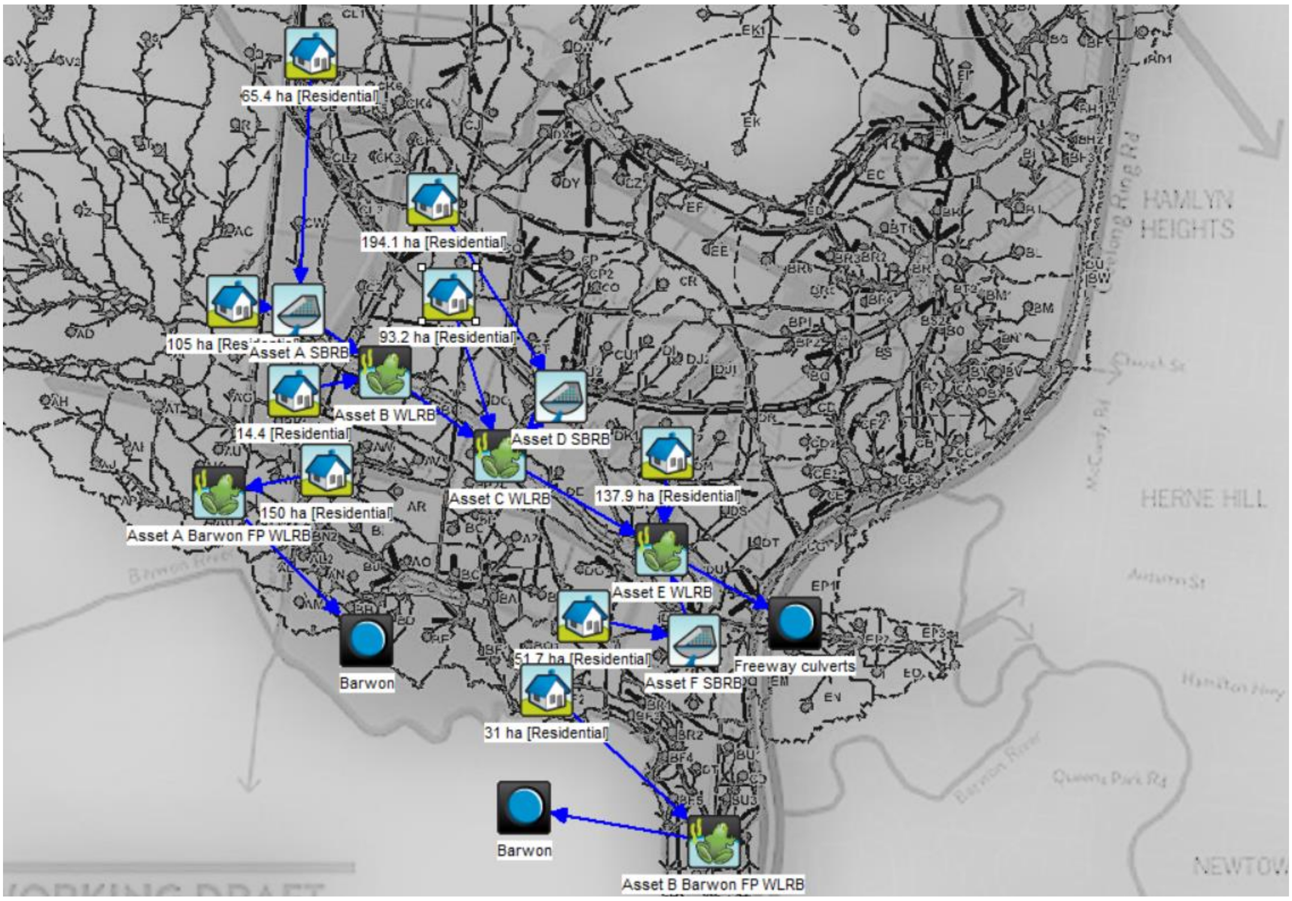


Figure 2-6 Barwon & Moorabool South MUSIC model set-up

The MUSIC models were run to verify that the treatment train effectiveness meets urban stormwater Best Practice Environmental Management (BPEM) objectives set in the Victorian Planning Provisions with 80%, 45% and 45% removal rates for respectively Total Suspended Solids (TSS), Total Phosphorus (TP) and TN (Total Nitrogen).

Further water quality assets sizing refinement was undertaken once final 12d model and RORB modelling stage-storage relationships were established as presented in Section 3.4. This section also presents the final nutrients removal rates at the outfalls at Cowies Creek, Barwon and Moorabool River demonstrating that the proposed treatment train satisfies the BPEM objectives.

3 STORMWATER ASSETS SIZING

3.1 3D Terrain Modelling

Storages were designed using 12d Terrain Model with the location and shape of each storage informed by the Draft Framework Plan and the concept SWMS. The SBRB (Sedimentation Basin/Retarding Basin) and WLRB (Wetland/Retarding Basin) extent from the Framework Plan and Neil Craigie's Stormwater Management Strategy (SWMS) was used as a starting point to give general size and shape of asset footprints. These were then overlayed onto the terrain.

Each storage was primarily designed with a depth of 2 metres (1.6 m of retention plus 0.4 m freeboard) except for Cowies WLRB G which has additional storage due to site constraints and basins within the floodplain which were modelled with a depth of 1.6 metres (no freeboard provided). Basins were primarily modelled with 1 in 8 batter slopes. In locations where the allocated area was insufficient to allow for 1 in 8 batters, the design batters were reduced to 1 in 7 or 1 in 6 as required. In areas where the existing terrain was steeper than 1 in 6, the asset was designed so that the steep escarpment was left unchanged and the rest of the design assumed side batter slopes in accordance with the above approach (1 in 8 preferably). These design assumptions were later refined for each stormwater asset individually to fit the asset footprint within the designated areas marked on the Draft Framework Plan and specific terrain constraints. Stage-storage relationships were subsequently extracted from 12d and used as input into the developed conditions RORB models.

Cowies WLRB G has been designed with a depth of 3 metres (2 m of retention plus 1 m freeboard). The proposed asset is located within an existing waterway with a steep gully which will require a substantial amount of fill to construct the downstream bund wall. To reduce fill requirements, the base of the base was set to 50 m AHD with a top water level of 52 m AHD and a top of bank at 53 m AHD allowing additional freeboard and flexibility for the design refinement phase. For instance, there is opportunity to either raise the base of the wetland through additional fill or reduce the height of the bund wall in future detailed design.

In areas where the design stage-storage was over capacity (assessed using RORB) the depth and surface area of the asset were adjusted until the optimal design was found, for retardation of flows and water treatment requirements. In some areas asset surface area was the limiting factor as this area was required for wetland and wetland service access requirements.

Flood storages within the floodplain were designed in cut only to ensure flows across the floodplain were not restricted by embankments. These basins also had site specific depth constraints as these assets require adequate grade from the base to the outfall. Where necessary basin depth was reduced to maintain enough grade to the outfall of each asset.

While not explicitly modelled in RORB or 12d model, the developable land will be filled with residential, commercial and industrial areas set above the 1% AEP flood level (including some freeboard) and the road level set to a lower level to allow safe conveyance of the 1% AEP stormwater runoff in large storm events.

Outfalls from some of the basin assets are located at the top of steep escarpments, this is particularly the case at MOORABOOL WLRBA. Specific design measures will be required to address flows down the escarpments which may include extending the pipe outlet to the base of the escarpment or providing rockwork within the narrow gully line down the escarpment, or a combination of both. Specific details of the outlet arrangements will be required as part of the detailed design stage of the basins and is not investigated in detail as part of this report, however a potential long section of the of the MOORABOOL WLRBA is shown in Figure 3-1, whereby combined low flow outlet pipe and rockwork is proposed.

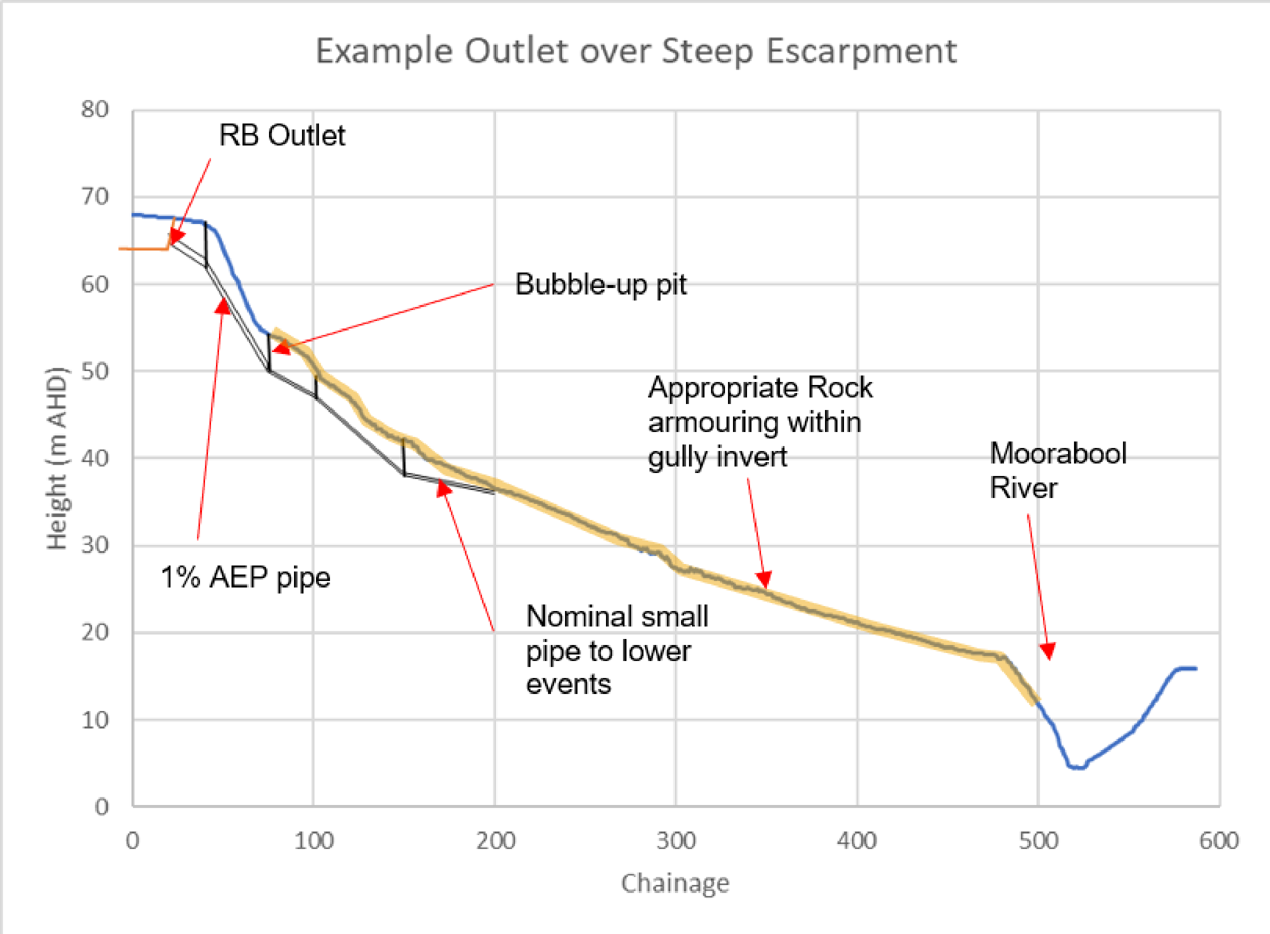


FIGURE 3-1 EXAMPLE RB OUTLET AT ESCARPMENT LOCATION

3.2 Flood Storages Sizing

An iterative approach was taken to verify sizing for each asset for the 1% AEP event using both 12d Model and RORB. Working from the upstream parts of each catchment, each asset had its outlets adjusted to restrict the 1% AEP peak flow. Outlet sizes were taken from standard pipe sizes between 300 mm up to 1,050 mm diameter. Flow rates at the outlet of each asset were adjusted to utilise the preliminarily capacity of the asset estimated in Neil Craigie's concept SWMS. The peak 1% AEP flows at outlets to the Moorabool River, Cowies Creek and Barwon River were then compared to the peak 1% AEP existing conditions flows to ensure the pre-development peak flows were not exceeded.

Where downstream 1% AEP peak flow at the outfall is lower than the pre-development target flow, the upstream stormwater assets sizes were reduced (i.e. stage/storage relationship, spillway height, etc.) in RORB to prevent oversizing the assets and achieving the target flow at the outfall to the creek or river.

Where downstream 1% AEP peak flow at the outfall is higher than the pre-development target flow, the upstream stormwater assets sizes were increased (i.e. stage/storage relationship, spillway height, etc.) in RORB to prevent under-sizing the assets and achieving the target flow at the outfall to the creek or river.

In some instances, significant changes to the subareas delineation and reach redirection resulted in outfalls to the creek/river not being located at the same outfall location as the pre-development outflow. In these cases, comparison points were nominated at immediately downstream locations in the creek/river allowing for comparison between pre and post-development 1% AEP peak flow.

For most assets, the preliminary footprint set in the concept SWMS only slightly changed taking into consideration terrain constraint and refined batter slope except for Cowies WLRB A. However, Cowies WLRB A has the same total surface area as the one proposed in Neil's SWMS with only the shape being reconfigured to take in consideration the site constraints.

Moorabool WLRB E, which is proposed to be built along the Hamilton Highway upstream of the Geelong Ring Road, was designed with an embankment and an outlet pipe to control the outflow discharging to the existing Geelong Ring Road embankment and culverts. Therefore, the current road embankment and culverts were not used as primary and single outlet to the basin. The basin outlet arrangement has been designed to retard the peak 1% AEP flow to the pre-development flow to be discharged through the Geelong Ring Road existing culverts which have enough capacity to convey the outflow. Moorabool WLRB E and SBRB F were modelled in RORB as one single flood storage node as WLRB E is designed to be connected to SBRB F via balance pipe(s) to increase flood storage.

The Moorabool River RORB catchment model has developable land proposed in the Draft Framework Plan located on steep escarpment terrain. These locations pose unique challenges and have been investigated separately. Details about these developed escarpments are further discussed in section 3.3 with indicative sizing, location and further retarding opportunities outlined for each area.

Figure 3-2, Figure 3-3 and Figure 3-4 presents the flood retardation and flood storage key values determined through 12d and RORB modelling including the pre and post-development 1% AEP peak flows at the outfalls to the creek/river, the retarding basin peak volume (m3), water level and cut/fill balance (m3). It is important to note that the cut/fill volume values correspond to the volume required to construct the retarding basin component of the asset only and does not include the additional cut required to construct the sedimentation basin and wetland below. Any cut/fill volume value negative means that there is more cut required than fill; any cut/fill volume value positive means that there is more fill required than cut. As a general rule; retarding basins cut in the existing terrain will require more cut than fill to be constructed. This rule is even more applicable in flat areas around Fyansford-Gheringhap Road. However, some specific assets like Cowies WLRB G proposed in an existing terrain depression will require more fill than cut associated to the construction of terrain bunds.

The final retarding basin sizing can be summarised in Table 3-1. The Top Water Level represents the maximum water level reached under the peak 1% AEP event in each basin. The retarding basins have been designed with additional airspace above the Top Water Level to allow for a minimum of 300 mm freeboard.

Table 3-1 Retarding Basin Size Summary Table

Asset ID	Retarding Basin Volume (m^3)	Bottom Water Level (m AHD)	Top Water Level (m AHD)	Depth (m)	Cut/Fill Balance (m^3)
BARWON WLRB A	72,600	20.8	22.5	1.7	-92,200
BARWON WLRB B	11,800	19.6	20.7	1.1	-26,500
COWIES WLRB A	14,600	53.0	54.5	1.5	-44,900
COWIES WLRB B	11,100	45.0	46.2	1.2	-38,700
COWIES WLRB C	27,200	58.7	59.3	0.6	-82,600
COWIES SBRB D	4,650	66.2	67.3	1.1	-10,000
COWIES WLRB E	22,900	63.6	64.6	1.0	-61,200
COWIE WLRB F	8,300	66.3	67.0	0.7	-20,300
COWIES WLRB G	79,800	50.0	52.0	2.0	122,900
MOORABOOL WLRB A	8,800	64.8	65.5	0.7	-22,100
MOORABOOL WLRB B	21,600	67.0	68.5	1.5	-67,200
MOORABOOL SBRB D	11,100	62.5	64.2	1.7	-27,200
MOORABOOL WLRB D	28,500	23.5	23.8	0.3	-30,200
MOORABOOL SBRB A	13,400	58.0	59.6	1.6	-89,500
MOORABOOL WLRB B1	61,000	57.0	58.6	1.6	109,600
MOORABOOL WLRB C1	61,700	39.0	40.6	1.6	-43,500
MOORABOOL WLRB D1	90,300	9.0	10.6	1.6	67,500
MOORABOOL SBRB E	9,700	34.0	35.6	1.6	-38,100
MOORABOOL SBRB F	5,500	30.2	31.1	0.9	-14,100
MOORABOOL WLRB G	56,700	11.0	12.6	1.6	-197,200
MOORABOOL WHRB H	23,500	31.0	32.5	1.5	-52,100
MOORABOOL SBRB A1	20,200	37.5	39.1	1.6	-15,500
MOORABOOL WLRB B2	47,900	37.0	38.6	1.6	-44,800
MOORABOOL WLRB C2	186,000	36.5	38.5	2.0	-158,300
MOORABOOL SBRB D	33,200	37.0	38.6	1.6	-21,600
MOORABOOL WLRB E	136,000	34.5	36.2	1.7	-135,000
MOORABOOL SBRB E1	14,000	34.5	36.2	1.7	-15,000

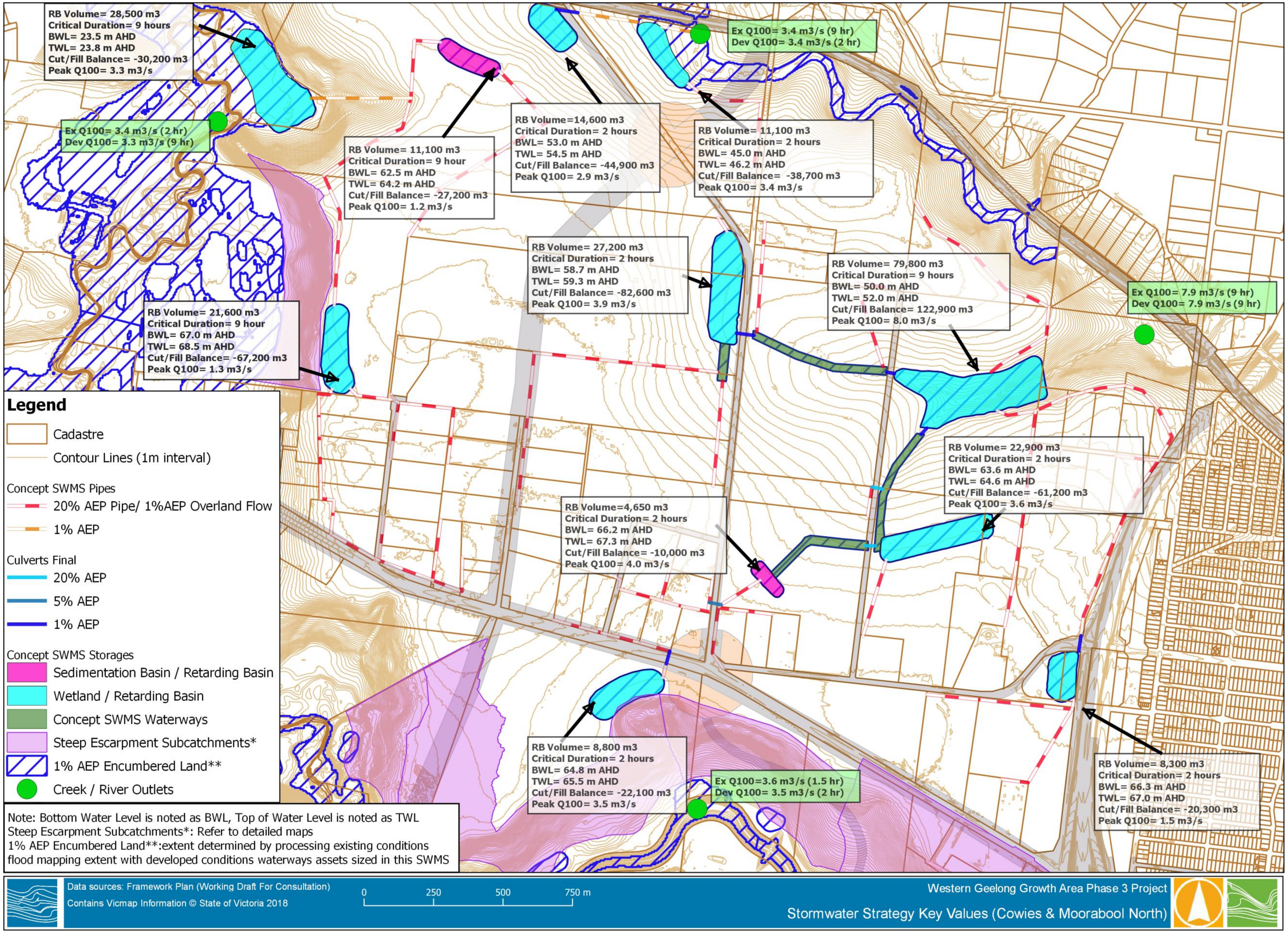


Figure 3-2 Stormwater Strategy Peak Flows and Flood Storage Key Values (Cowies & Moorabool North)

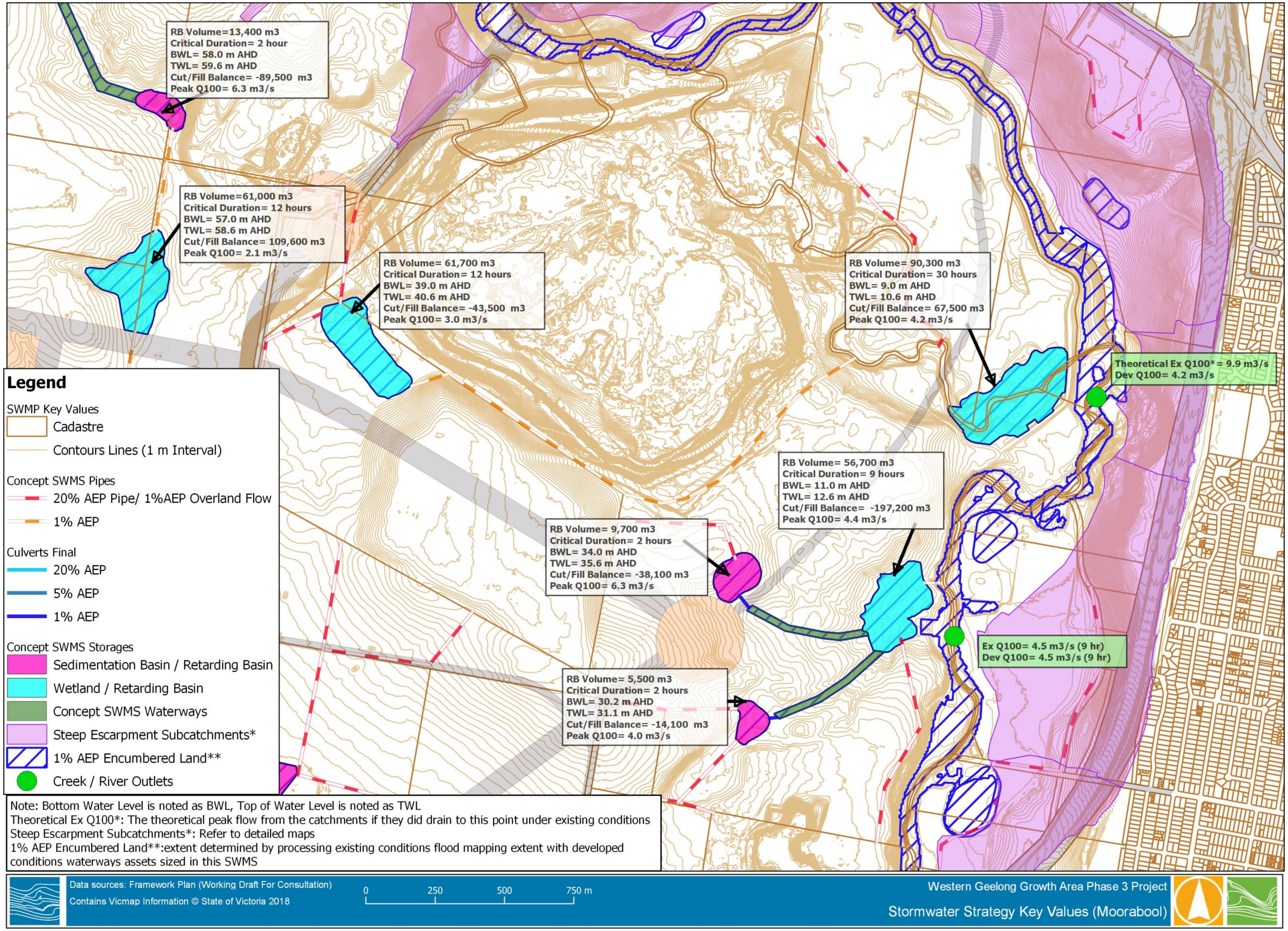


Figure 3-3 Stormwater Strategy Peak Flows and Flood Storage Key Values (Moorabool)

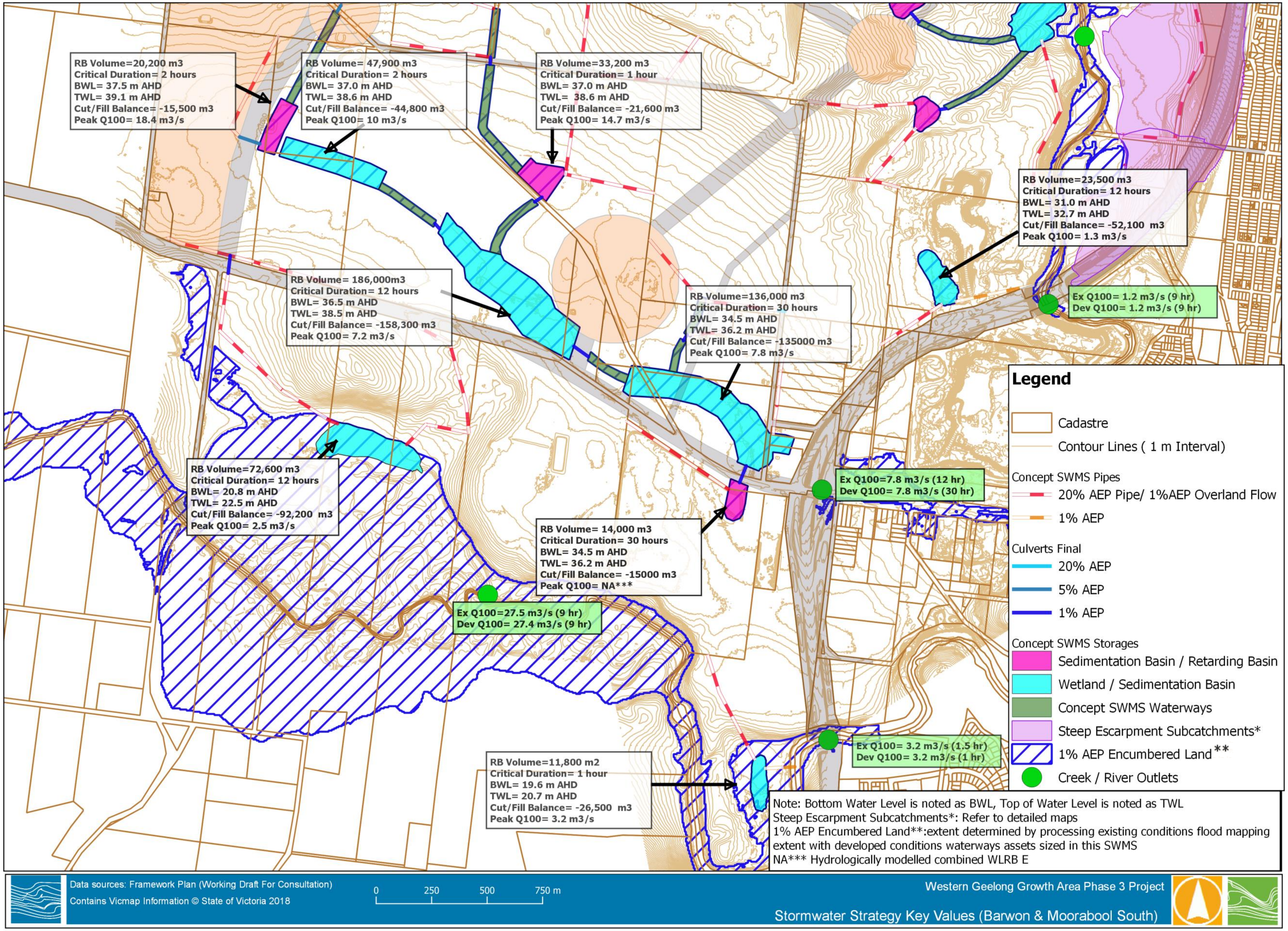


Figure 3-4 Stormwater Strategy Peak Flows and Flood Storage Key Values (Barwon & Moorabool South)

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3.3 SWMS along Steep Escarpment

Some developable land in the Draft Framework Plan has not been considered in Neil Craigie's concept SWMS and therefore no flood retardation and stormwater quality treatment options had yet been proposed. Those areas (or subcatchments) are located along the escarpments of the Moorabool River. While some flood retardation and treatment options may be possible, there is certainly some constructability limitations associated with the steepness of the terrain. Some initial and indicative flood storage options have been assessed based on the methodology presented below.

Subcatchments along steep escarpments were grouped in Areas (1 to 9) based on their ability to drain to the same location. There is also opportunity to split/combine these areas depending on the land development.

Terrain analysis including a review of the slope to the River outfall was undertaken to identify suitable locations for the construction of potential flood retardation and/or treatment assets. With preliminary asset locations identified, an indicative volume of flood storage was calculated based on the topography constraints as shown in Table 3-2. In some cases, the flood storage volume achieved is larger than the volume required to retard the peak 1% AEP flow from the upstream subcatchments and therefore the flood storage could be further optimised in the next iteration of the design. While in other cases, the flood storage volume achieved is smaller than the volume required to retard the peak 1% AEP flow from the upstream subcatchments meaning that flood retardation is not meant. To meet flood retardation requirements at the outfall to the River, additional flood retardation mechanisms may be designed (i.e. underground tank storage/pump, upstream distributed flood storages, etc.) or the subcatchments and drainage direction may also be altered.

Table 3-2 Steep Escarpments Retarding Basin Storage Details

Location	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9
Catchment Area (ha)	14	9	43	20	73	14	52	22	21
Estimated RB capacity required* (m^3)	5,500	4,000	17,000	8,000	29,000	5,500	21,000	9,000	8,500
Storage Capacity achieved (m^3)	7,000	5,000	11,500	3,000	30,000	-	26,000	21,000	12,000

* RB capacity was estimated assuming 400 m^3 is required for each ha of development upstream

In Figure 3-5 and Figure 3-6, the blue polygons show indicative flood storage footprints and the yellow points show potential additional locations for flood storages when retardation requirements are not met at the outfall to the River based on the assumed subcatchments arrangement.

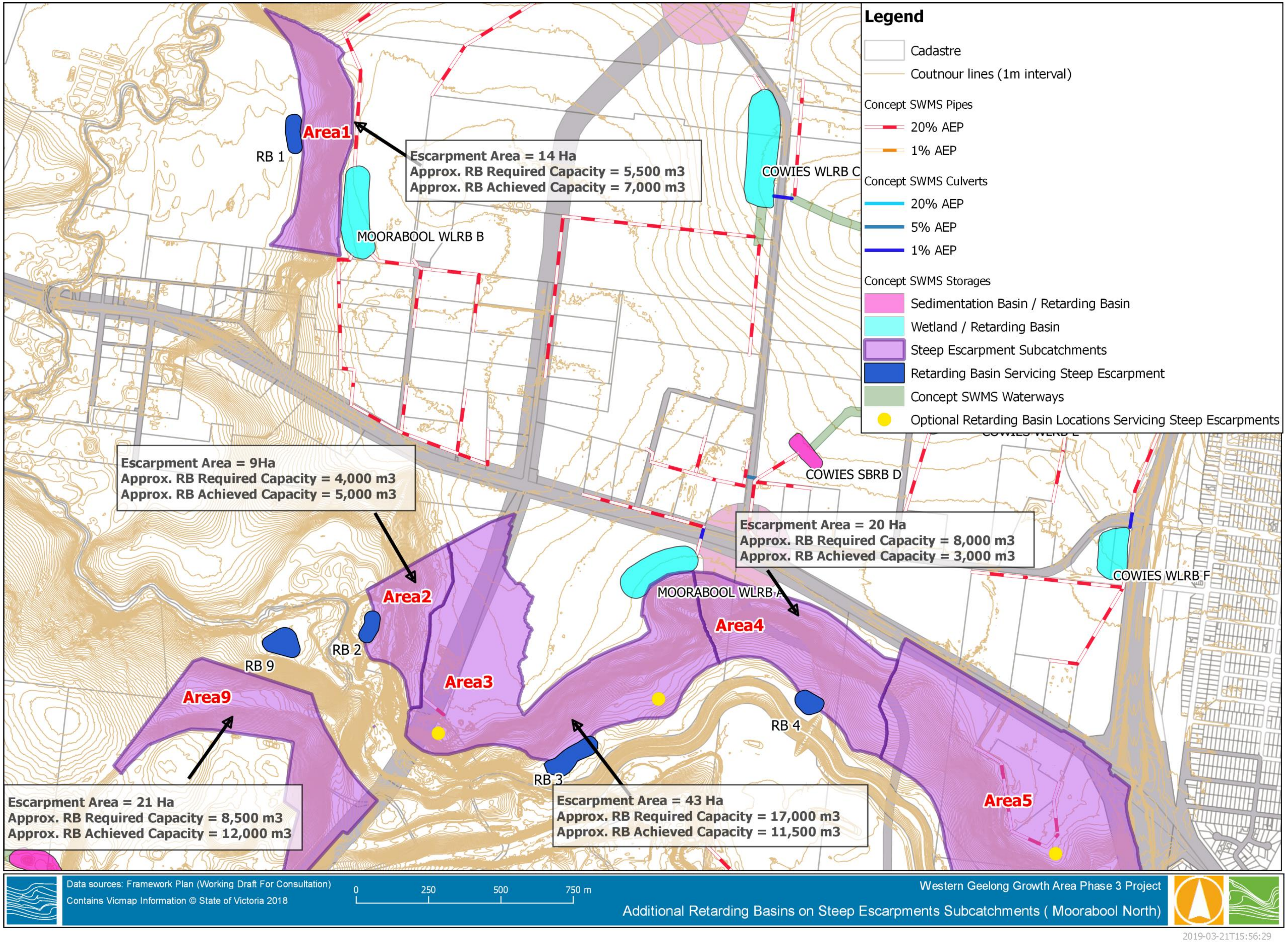

Figure 3-5 Options for Retarding Basins servicing Steep Escarpments (Moorabool North)

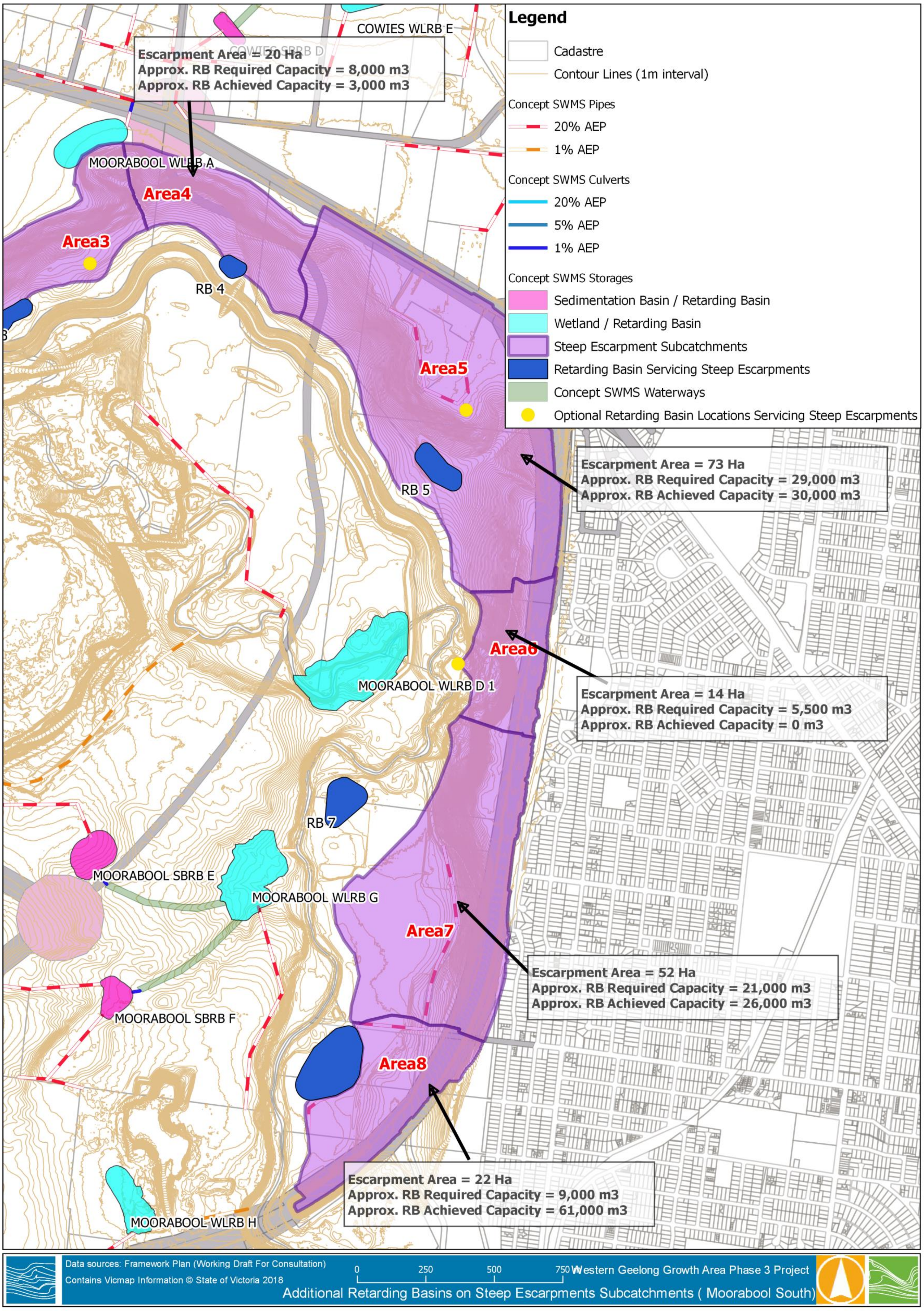

Figure 3-6 Options for Retarding Basins servicing Steep Escarpments (Moorabool South)

Each area identified as developable along the steep escarpments of the Moorabool has undergone a high-level assessment of the stormwater challenges and opportunities the areas offer.

- **Area 1**, on the steep escarpment to the north of Batesford is approximately 14 ha in area and is expected to require a retarding basin of approximately 5,500 m^3. This area has a large reserve immediately to the west of it (Figure 2-1). This reserve is more than adequate to fit a retarding basin to service the developments needs in the 1% AEP.
- **Area 2**, to the south east of Batesford is approximately 9 ha in area and is expected to require a retarding basin of approximately 4,000 m^3. The area has suitable area for a retarding basin at the base of the escarpment. Approximately half of this area is currently allocated to development. A retarding basin with a capacity of approximately 5000 m^3 can fit within this area.
- **Area 3** is one of the larger sections of steep escarpment along the Moorabool River at 43 ha. It has two locations at the base of the escarpment that may be suitable for locating a retarding basin. Around 19 ha of the west side of the contributing catchment is above the escarpment and could potentially have its own retarding basin at the top of the escarpment. Area 3 is expected to require a retarding basin with a capacity of approximately 17,000 m^3. An area at the base of the escarpment can fit a basin of approximately 11,500 m^3 capacity. This area also has an external catchment that isn’t expected to impact basin(s) designed for this area as the flows from the external catchment have been accounted for by asset WLRB A and its interaction with Area 3 is purely for conveyance.
- **Area 4** has a contributing catchment of around 20 ha, it is expected that this area will require a basin with a capacity of approximately 8,000 m^3. There is limited space at the bottom of the escarpment with suitable grades to locate a retarding basin. However, a small basin of approximately 3,000 m^3 can fit on the edge of the river reserve as shown in Figure 3-5. This basin is expected to cater for less than half of the areas retardation requirements, and further measures will have to be put in place to retard flows if the area is to be developed to the desired density.
- **Area 5** has a contributing catchment of around 73 ha, and an expected retarding basin requirement of approximately 29,000 m^3. Currently this proposed RB area contains a dam that could be increased in capacity (up to approximately 30,000 m^3) to meet the catchments requirements. The position of this asset however means that a small portion of the downstream catchment would not be able to drain to the retarding basin. A basin could also be located further down the escarpment to account for this. There is also opportunity to retard some of the flows at the top of the escarpment as shown in Figure 3-6.
- **Area 6** has an extremely steep and narrow escarpment with a contributing catchment of approximately 14 ha. There is opportunity for some of this area to be combined with Area 7.
- **Area 7** has a contributing catchment of around 52 ha. This area has a suitable location for a retarding basin at the bottom of the escarpment within the Moorabool river reserve. A basin of approximately 26,000 m^3 can be implemented in this area, which would provide enough capacity to retard expected flows in the area.
- **Area 8** has a contributing catchment of around 22 ha. The area already has a flood offset (Riverlee Basin) within the Moorabool river reserve that currently services a development to the South East. This retarding basin could easily be increased in capacity up to approximately 61,000 m^3 (which is more than the volume required) while still fitting within the reserve area. This is expected to be more than adequate to cater for both Area 8 and the flood offset required for development to the South East.
- **Area 9** has a contributing catchment of around 21 ha. This area has a substantial space along the Moorabool river that could be suitable for locating a retarding basin. The area is expected to require a basin with capacity of approximately 8,500 m^3. An approximately 12,000 m^3 basin can fit within this area as shown in Figure 3-5.

- **Areas 3, 4 and 6** were found to not meet the required retarding basin capacities, with current designs. In these areas there are opportunities to:
  - Install engineered underground retarding assets, noting that this may also be complicated by steep slopes.
  - Reduce density of developments.
  - Reduce the portion of the catchment being developed.
  - Not meet target flow requirements at these points (e.g. accepting no retardation or adopting a reduced retardation requirement).
  - Offset impacts through adjacent or further downstream catchment assets.

These areas are expected to require water quality assets. In areas where retarding basins meet the catchment requirements it is expected that the area of the base of these basins will allow for wetlands of adequate size within the basins to treat incoming stormwater to best practice. In areas where there is insufficient space to accommodate treatment assets in the base of the retarding basins, standalone treatment options could be used in these areas. These could include swales, tree pits along streets and rain gardens. There is also the option to increase wetland sizes in other areas to compensate for a lack of treatment where area for treatment is limited. All areas mentioned will require consideration regarding erosion protection, particularly at the discharge points to the Moorabool river but also along the escarpment itself. This can be achieved through rock chutes, strategic planting, and careful positioning of outlet points to ensure river banks are protected.

CCMA and CoGG require all discharge points are treated to best practice requirements.

3.4 Water Quality Assets Sizing

As discussed in Section 2.2, the sedimentation basin and wetland surface areas have been refined based on the final terrain modelling and design for the flood storages. The final MUSIC models were run to verify that the treatment train effectiveness meets BPEM objectives with 80%, 45% and 45% removal rates for respectively Total Suspended Solids (TSS), Total Phosphorus (TP) and TN (Total Nitrogen) at the outfall to the Cowies Creek, Barwon and Moorabool River as presented in Figure 3-7, Figure 3-8 and Figure 3-9.

All water quality assets (sedimentation basins and wetlands) have been sized assuming a 350 mm extended detention depth in accordance with the most recent Constructed Wetlands design manual (Melbourne Water, July 2017). The final surface area (in m^2) and permanent pool volume (in m^3) for each water quality asset is summarised in Table 3-3.

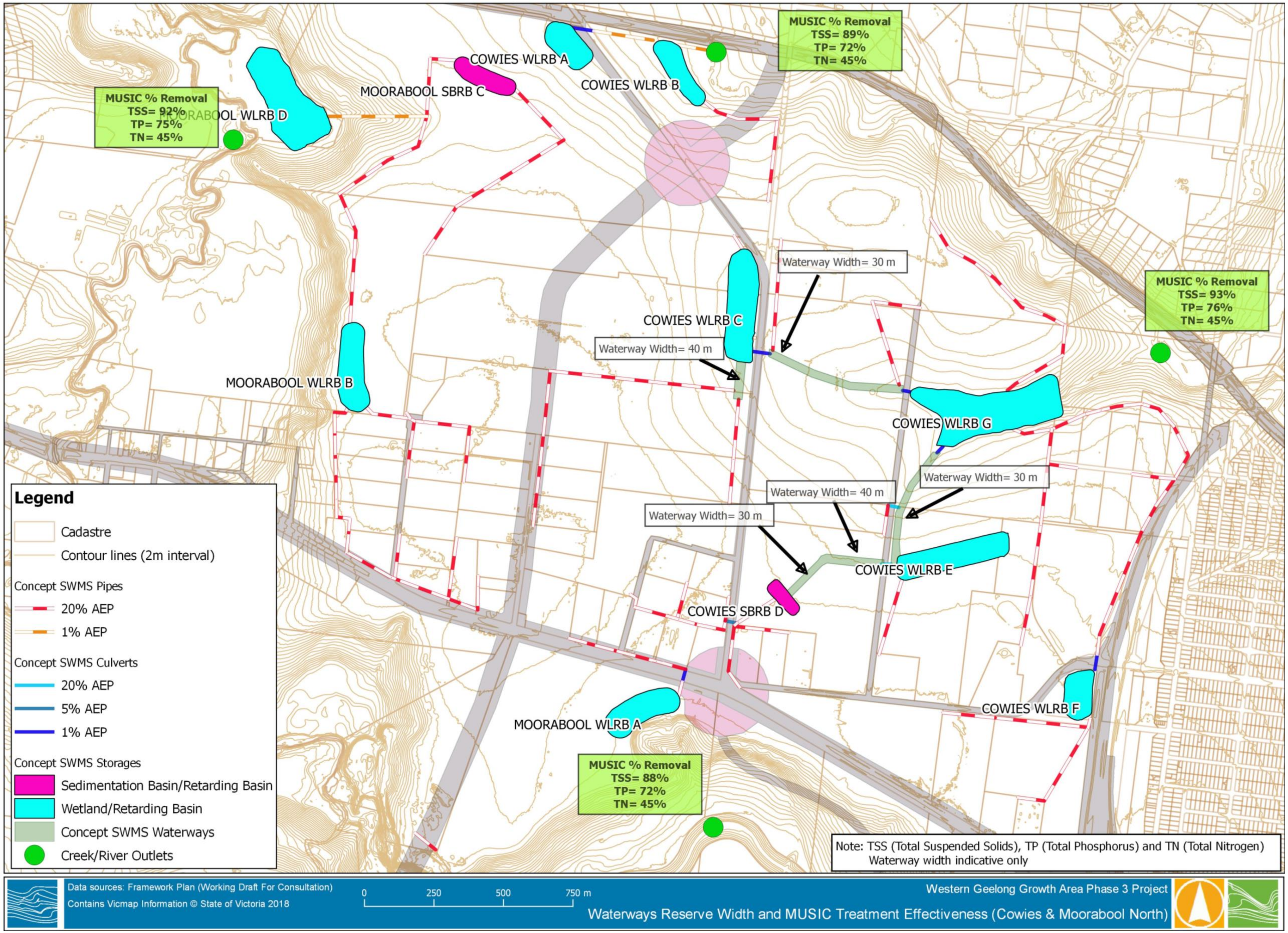

Figure 3-7 Waterways Width & MUSIC Treatment Effectiveness (Cowies Ck & Moorabool River North)

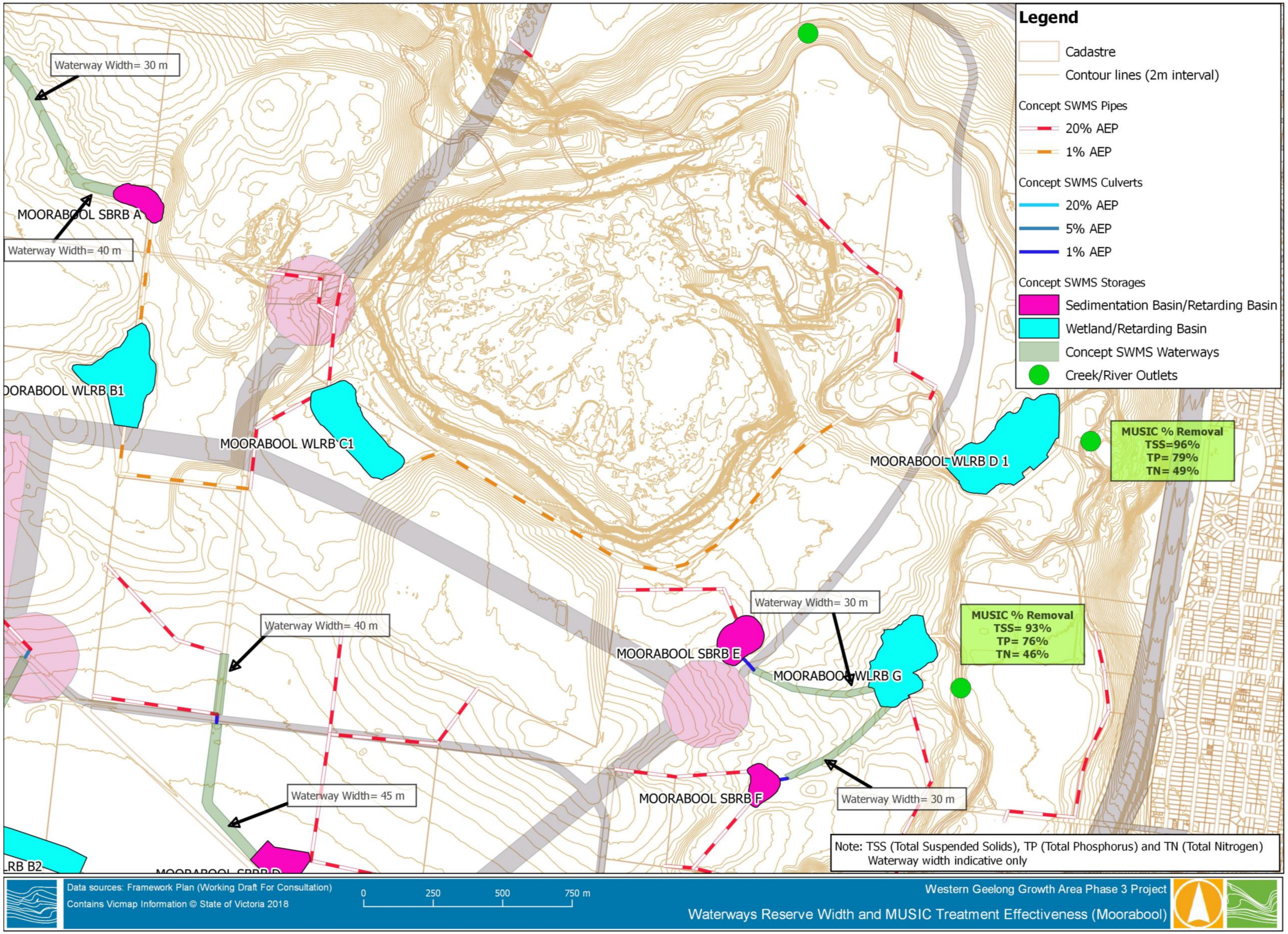

Figure 3-8 Waterways Width & MUSIC Treatment Effectiveness (Moorabool River area)

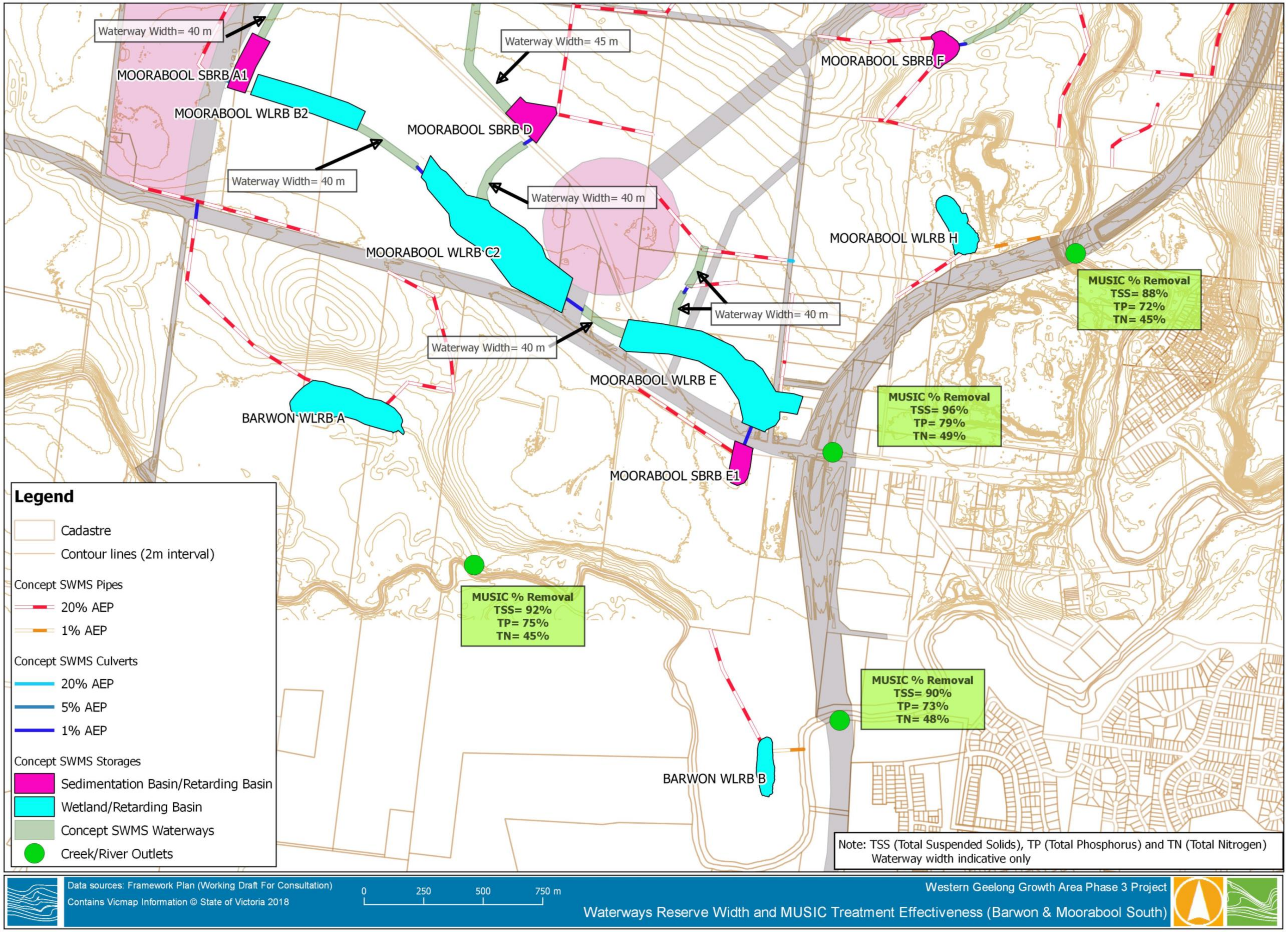

Figure 3-9 Waterways Width & MUSIC Treatment Effectiveness (Barwon & Moorabool River South area)

Table 3-3 Sedimentation basin and Wetlands Sizing Summary Table

Asset	Surface area (m^2)	Permanent Pool Volume (m^3)
BARWON WLRB A	30,000	12,000
BARWON WLRB B	6,900	2,760
COWIES SBRB D	2,920	2,920
COWIES WLRB A	6,370	2,550
COWIES WLRB B	6,120	2,450
COWIES WLRB C	22,960	9,180
COWIES WLRB E	18,210	7,280
COWIES WLRB F	9,080	3,630
COWIES WLRB G	32,700	13,090
MOORABOOL SBRB A	5,470	2,190
MOORABOOL SBRB A1	9,300	9,300
MOORABOOL SBRB C	3,247	1,800
MOORABOOL SBRB D	9,900	9,900
MOORABOOL SBRB E	3,550	3,550
MOORABOOL SBRB F	4,610	4,610
MOORABOOL SBRB F1	5,400	5,400
MOORABOOL WLRB A	9,510	3,800
MOORABOOL WLRB B	8,480	3,390
MOORABOOL WLRB B1	23,060	9,220
MOORABOOL WLRB B2	24,300	9,700
MOORABOOL WLRB C1	28,300	11,320
MOORABOOL WLRB C2	81,600	32,600
MOORABOOL WLRB D	30,000	12,000
MOORABOOL WLRB D1	44,180	17,670
MOORABOOL WLRB E	61,200	24,480
MOORABOOL WLRB G	28,120	11,250
MOORABOOL WLRB H	9,810	3,590

CCMA and CoGG require all discharge points are treated to best practice requirements.

3.5 Waterways Sizing

The 1% AEP flow values associated with each waterway were extracted from the developed conditions RORB model, with appropriate waterway lengths and slopes determined. A minimum grade within the waterways of 2% has been assumed.

Manning's Calculations were undertaken for each waterway section to determine the applicable hydraulic widths (top width of 1% AEP flood level within channel).

A typical channel cross section was assumed for each section whereby a low flow pilot channel was sized to convey the 63.2% AEP (or 1-year ARI) flow rate, whilst the remaining channel cross section catered for the flows up to the 1% AEP flow. Pilot channel batter slopes of 1 in 5 were assumed whilst batter slopes in the remainder of the channel were assumed to equal 1 in 8. Pilot channel and main channel depths were iteratively altered to ensure hydraulic capacity was achieved. Minimum depth and width within the pilot channel was assumed to be 0.4 and 2.0 metres respectively.

Melbourne Water's Waterway Corridors Guideline was used to determine the appropriate reserve width for each section of waterway as presented in Figure 3-10. As mentioned in the guideline, the reserve widths assume that an active edge is alongside each waterway reserve. It is envisaged that this would take the form of future subdivisional roads in the WGGA stormwater management strategy.

Table 3. Sliding scale for calculating constructed waterway corridor widths – assumes active edges (roads) that allow vehicle access along entire corridor length, on both sides of the corridor.

HYDRAULIC WIDTH (M)	CRZ WIDTH (M)	VB WIDTH (M)	CORRIDOR WIDTH (M)
5	20	10	30
10	20	10	30
15	25	15	40
20	25	15	40
25	30	15	45
30	30	15	45
35	30	15	45
40	30	20	50
45	35	20	55
50	35	20	55
55	40	20	60
60	40	20	60
65	40	25	65
70	45	25	70

Figure 3-10 Waterway Width from MW's Waterway Corridors Guidelines (2013)

Figure 3-7 to Figure 3-9 in the above section present the final constructed open waterways width adopted in the WGGA stormwater management strategy.

3.6 Pipe and Culvert Sizing

The stormwater runoff 20% AEP (minimum) peak flows from the developed catchments are designed to be conveyed underground with, in most cases, the excess flow conveyed overland within the future subdivision's road reserve and open drains layout. In some specific cases, when the excess flow cannot be conveyed overland, the drainage pipes were sized to convey the 1% AEP peak flow. In three instances, culverts under minor Council roads have been sized to convey the 5% AEP peak flow.

The pipe and culvert inflow were largely calculated via Rational Method estimations based on the upstream catchment size and characteristics (i.e. fraction impervious, slope and distance to catchment divide). Where flows could be extracted from the developed RORB models, these flows were used to determine design flow rates for the proposed pipes/culverts.

The pipe and culvert sizes are presented in **Appendix B** via a series of maps and a table.

4 HYDRAULIC FLOOD MODELLING IMPACTS ASSESSMENT

The Phase 1 Flood Impact Assessment identified that private land along the Hamilton Highway located east of the Geelong Ring Road currently receives stormwater runoff from the study area (WGGA) prior to discharging into the Moorabool River as delineated in the orange polygon in Figure 4-1.

CoGG advised that for the design of the channel works through the Fyansford West development a peak 1% AEP flow rate of 9.5 m^3/s from the Geelong Ring Road reserve north of the Hamilton Highway at Fyansford was adopted. Therefore, the peak developed flow rate entering the ring road culverts from the growth area, i.e. the outflow from Moorabool WLRB E, should be the lessor of 9.5 m^3/s or the existing conditions peak flow calculated for the growth area. The existing conditions flow rate was calculated to be 7.8 m^3/s and the outflow from Moorabool WLRB E under developed conditions is also 7.8 m^3/s and hence this requirement is satisfied.

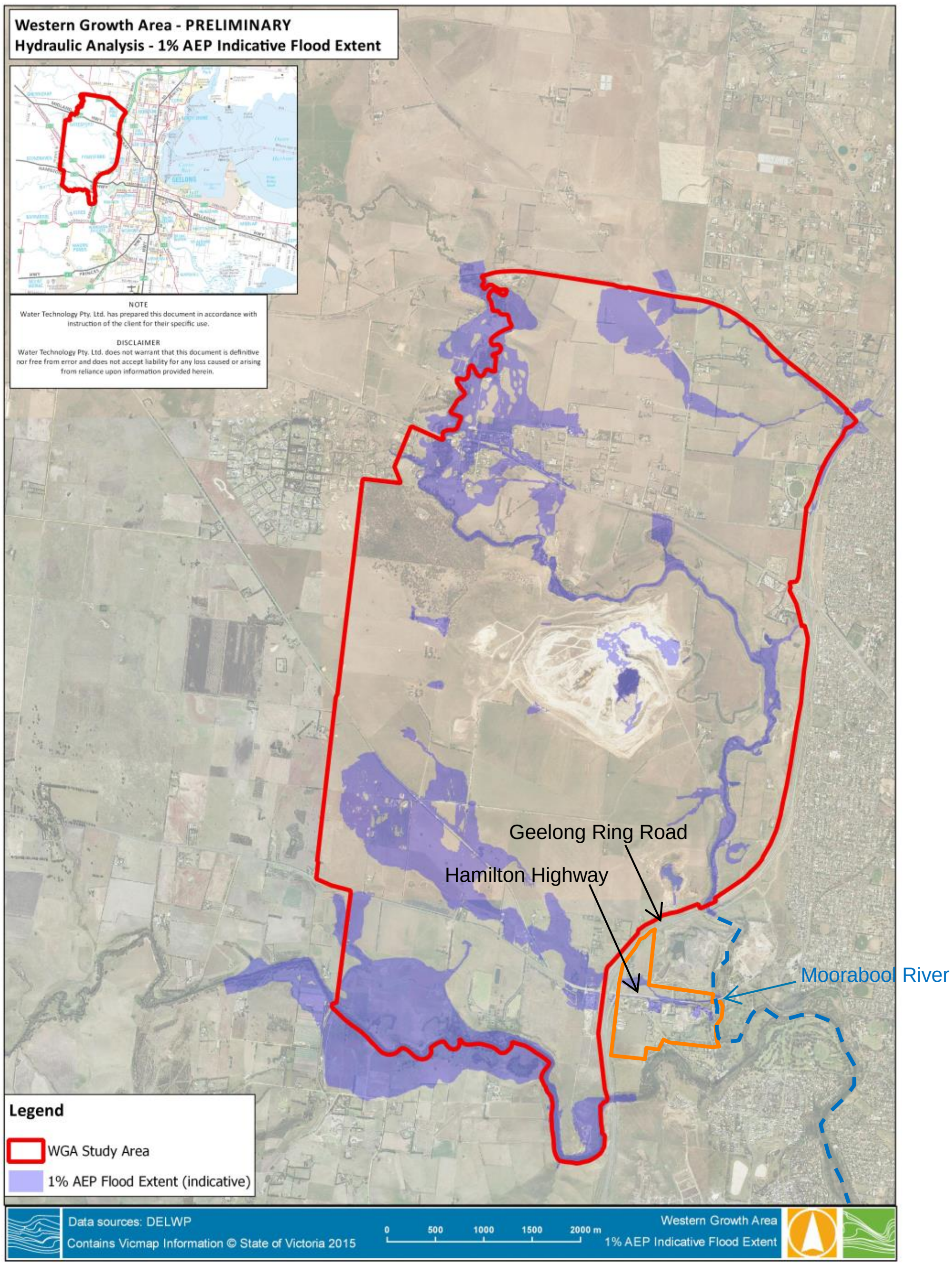

Figure 4-1 1% AEP Indicative Flood Extent of the WGGA (Existing Conditions)

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The existing conditions Moorabool TUFLOW model was cropped downstream of the proposed WLRB E, to undertake the flood impacts assessment of the private land under both the existing and fully developed conditions. A view of the TUFLOW model set-up is presented in Figure 4-2. The 1% AEP flow were represented using an inflow boundary (2d SA polygon) associated with the 1% AEP flow hydrographs extracted from the RORB model. It is important to note that under both scenario (existing and fully developed), the topography was derived from the LiDAR which does not account the new residential development currently being constructed on Clarkes Road.

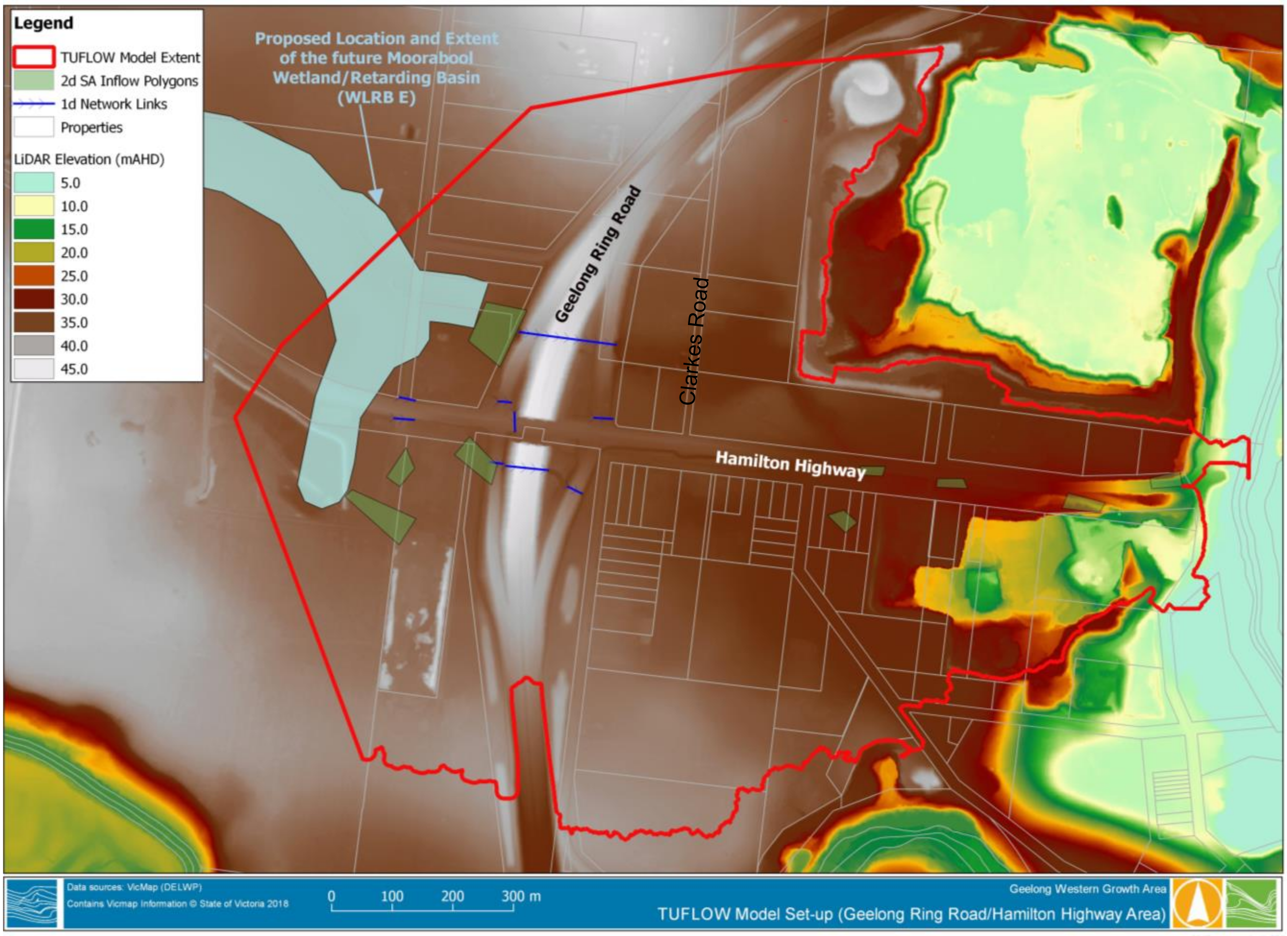

Figure 4-2 Downstream WLRB E TUFLOW Model Set-up

Under existing conditions, stormwater surface runoff enters all culverts (north and south of Hamilton Highway) under Geelong Ring Road before reaching the Moorabool River via private land. The existing conditions 1% AEP peak flow hydrographs from RORB (corresponding to the 12-hour storm event) were extracted and used as inflow to each respective 2d SA polygon in the TUFLOW model. The maximum 1% AEP flood depth map under existing conditions is presented in Figure 4-3.

Under fully developed conditions, stormwater is proposed to be directed and retarded in a combined sedimentation basin/wetland retarding basin (refer to WLRB E in Figure 4-2) with a single outlet that discharges towards the northern Geelong Ring Road culverts. The developed conditions 1% AEP peak flow hydrographs from RORB (corresponding to the 30-hour storm event) were extracted and used as inflows to each respective 2d SA polygon in the TUFLOW model. The maximum 1% AEP flood depth map under fully developed conditions is presented in Figure 4-4.

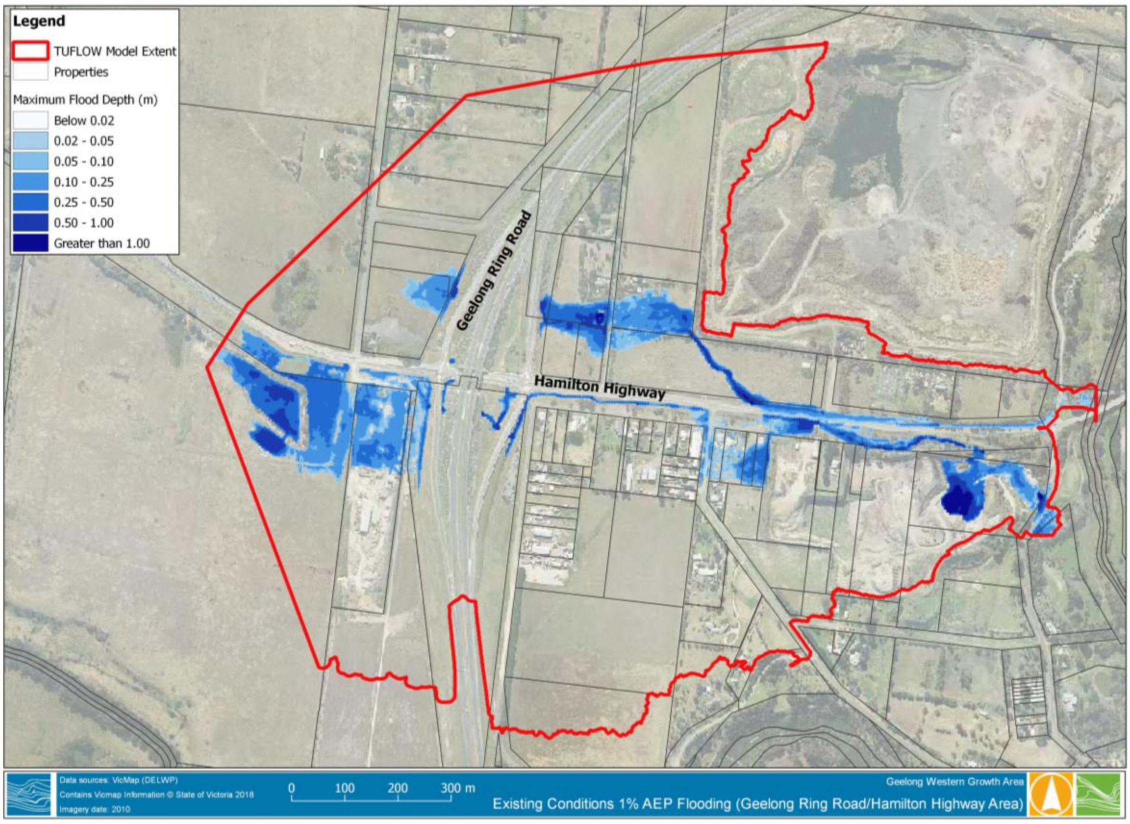

Figure 4-3 Existing Conditions 1% AEP Maximum Water Depth Map (Downstream WLRB E)

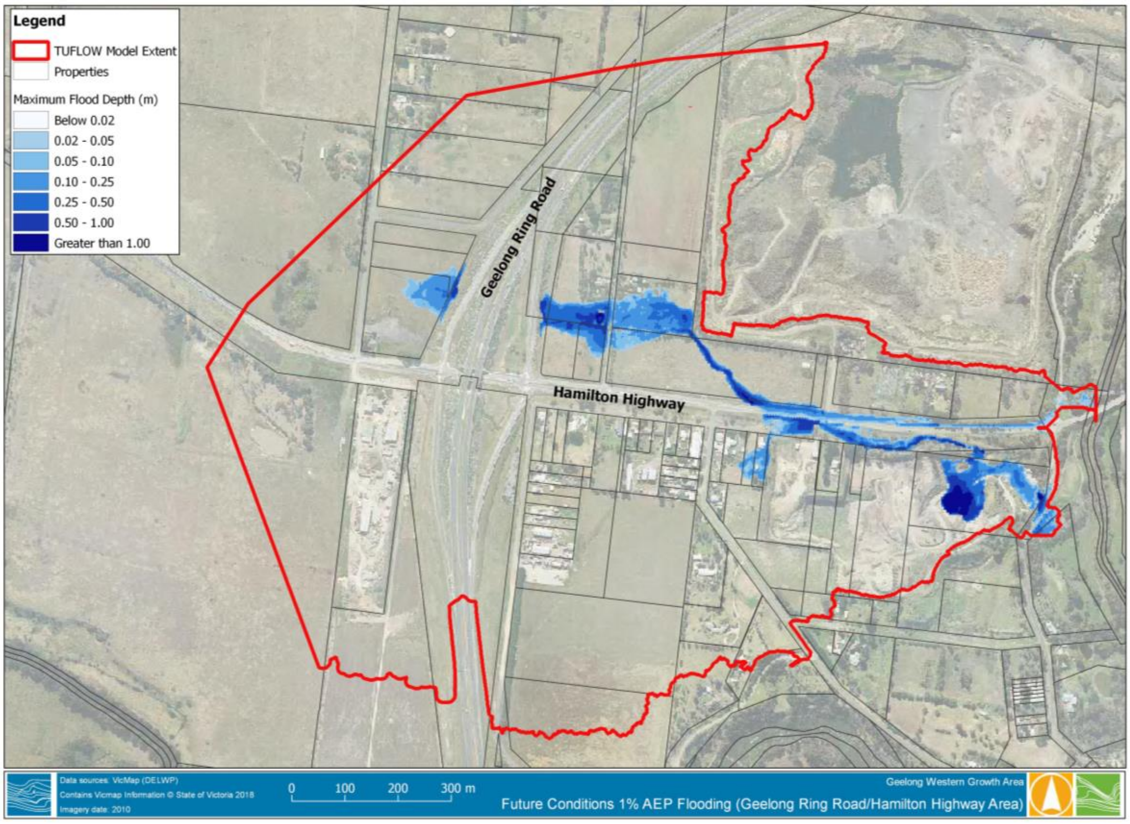

Figure 4-4 Developed Conditions 1% AEP Maximum Water Depth Map (Downstream WLRB E)

To assess potential flooding impacts associated to the full development of the WGGA and associated construction of the WLRB E, the maximum flood levels were compared to identify any areas with increase or decrease in overland flooding. The 1% AEP flood level difference plot under existing and fully developed conditions is presented in Figure 4-5. Any negative values on this difference plot correspond to a reduction in flood level while positive values show an increase in flood level. In addition, areas subject to inundation extent changes are respectively coloured in bright pink and blue.

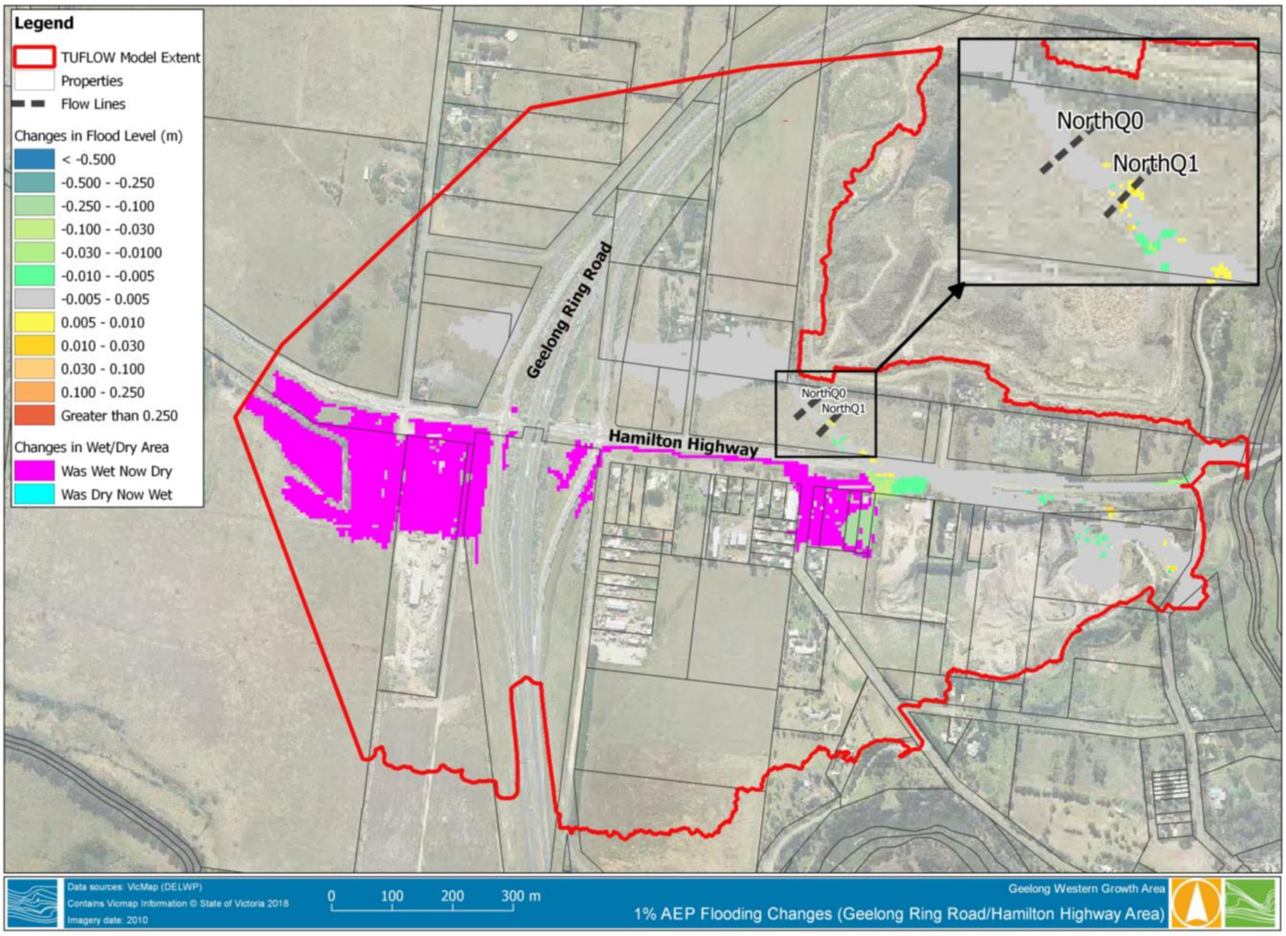

Figure 4-5 1% AEP Difference in Flood Levels (Downstream WLRB)

With the concept stormwater strategy now retarding and discharging flows to the Geelong Rind Road northern culverts, the previous/existing inundated areas south of Hamilton Highway are no longer flooded. CoGG and the CCMA require hydraulic modelling to have zero downstream impacts and to work to a modelling tolerance of +/-5mm. Figure 4-5 generally show that there is no unacceptable increase in 1% AEP overland flooding as a result of the upstream development over land privately owned.

The TUFLOW model results show that the 1% AEP flood level has increased by just above 5 mm at two localised areas in the model extent which is caused by localised model instabilities. For instance, the 1% AEP flow hydrograph at flow lines 'NorthQ0' and 'NorthQ1' under existing and developed conditions are respectively presented in Figure 4-6 and Figure 4-7. It shows that the flow hydrograph immediately upstream the localised instability area at flow line 'NorthQ0' is stable with 1% AEP developed conditions flow not exceeding the 1% AEP existing conditions flow of 7.8 m^3/s. However, the 1% AEP developed conditions flow at flow line 'NorthQ1' is unstable causing the peak flow to slightly exceed the 1% AEP existing conditions flow. The model instabilities are very localised and do not compromise the overall flood modelling impacts assessment.

No specific steps were taken to try removing the localised instability in the TUFLOW model. The existing conditions hydraulic model was used as a base before being cropped and updating the inflow boundary conditions. The detailed assessment and review of the flood modelling results including hydrographs at specific flow lines demonstrate the localised modelling instability without compromising the integrity of the results.

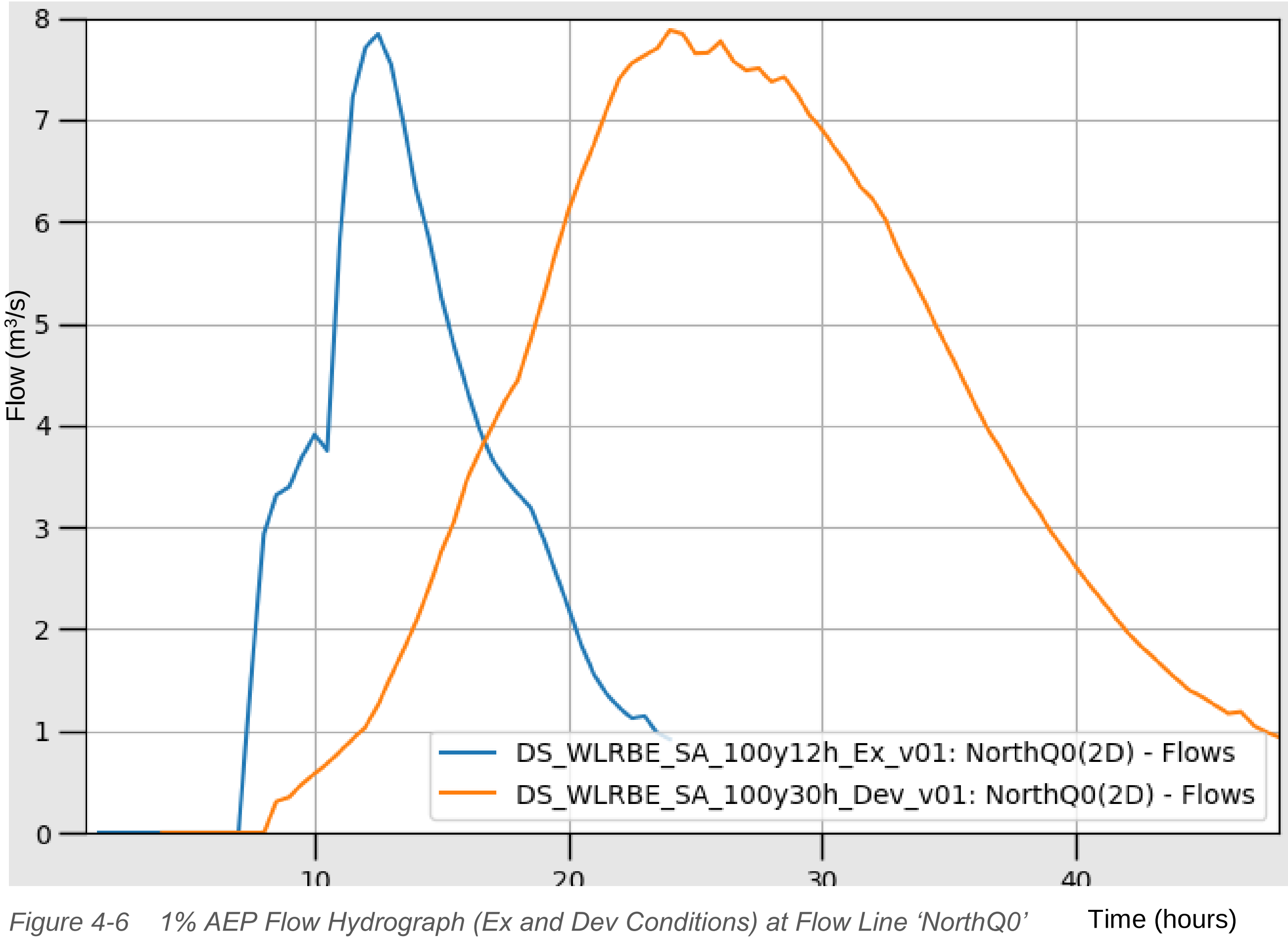

Figure 4-6 1% AEP Flow Hydrograph (Ex and Dev Conditions) at Flow Line 'NorthQ0'

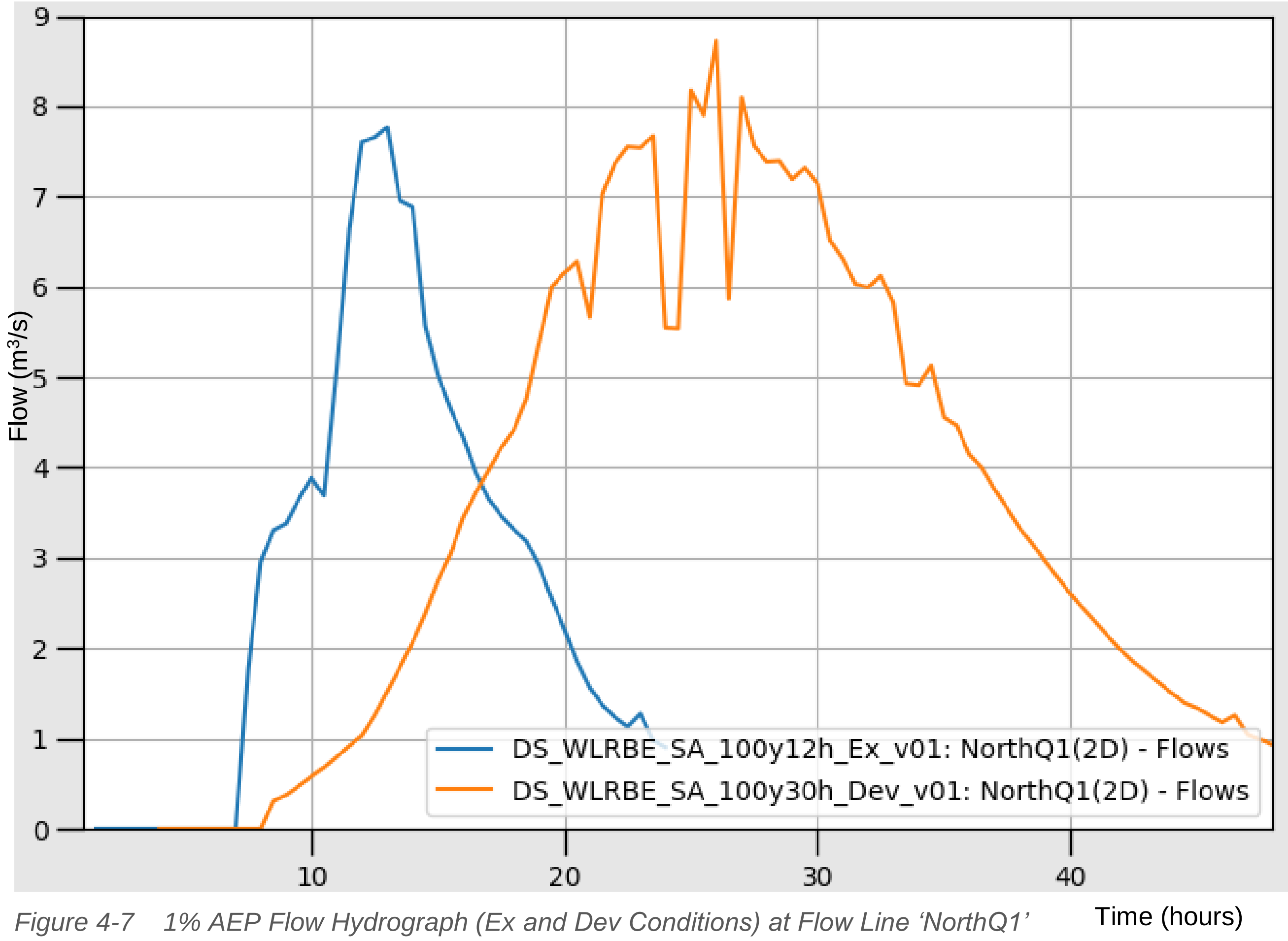

Figure 4-7 1% AEP Flow Hydrograph (Ex and Dev Conditions) at Flow Line 'NorthQ1'

5 DOWNSTREAM IMPACTS RISK ASSESSMENT UPDATE

During the Phase 1 of the project following the existing conditions flood modelling, Water Technology completed a preliminary downstream impacts risk assessment in the form of risk matrix tables.

The downstream impacts risk assessment was developed to identify the potential risks and constraints of developing the WGGA land with reference to downstream areas that may be sensitive to changes in catchment runoff. A risk matrix was developed under two scenarios; with and without mitigation following the developed of the WGGA land based on the draft Framework Plan and for the following five areas presented in Figure 5-1;

- Cowies Creek upstream the Geelong Ring Road
- Moorabool River at Batesford
- Moorabool River upstream the Geelong Ring Road
- Dogs Rock Reserve to Fyansford upstream the Geelong Ring Road
- Barwon River upstream the Geelong Ring Road

Likelihood and consequence score 1 to 3 (refer to Table 5-1) were applied to each of the following assessment criteria;

- **Flow Rate**: Development will increase peak downstream flow rates.
- **Flow Volume**: Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.
- **Rate of Rise**: Development will significantly increase the rate of rise of downstream flood levels.
- **Duration of Inundation**: Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.
- **Frequency of Runoff**: Development will result in an increased frequency of runoff causing downstream nuisance.
- **Flood Hazard**: Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.
- **Water Quality**: Development will detrimentally impact on water quality.
- **Environment**: Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.

Table 5-1 Risk ratings and definition

Score	Likelihood	Consequence
1	Not Likely	Impacts likely to be acceptable
2	Possible	Impacts may not be acceptable
3	Likely	Impacts will not be acceptable

With the Framework Planning workshop and refinement of the overall stormwater management strategy now completed, the downstream impacts risk assessment can be finalised to verify and demonstrate that the necessary requirements related to offset impacts are met as shown from Table 5-2 to Table 5-6.

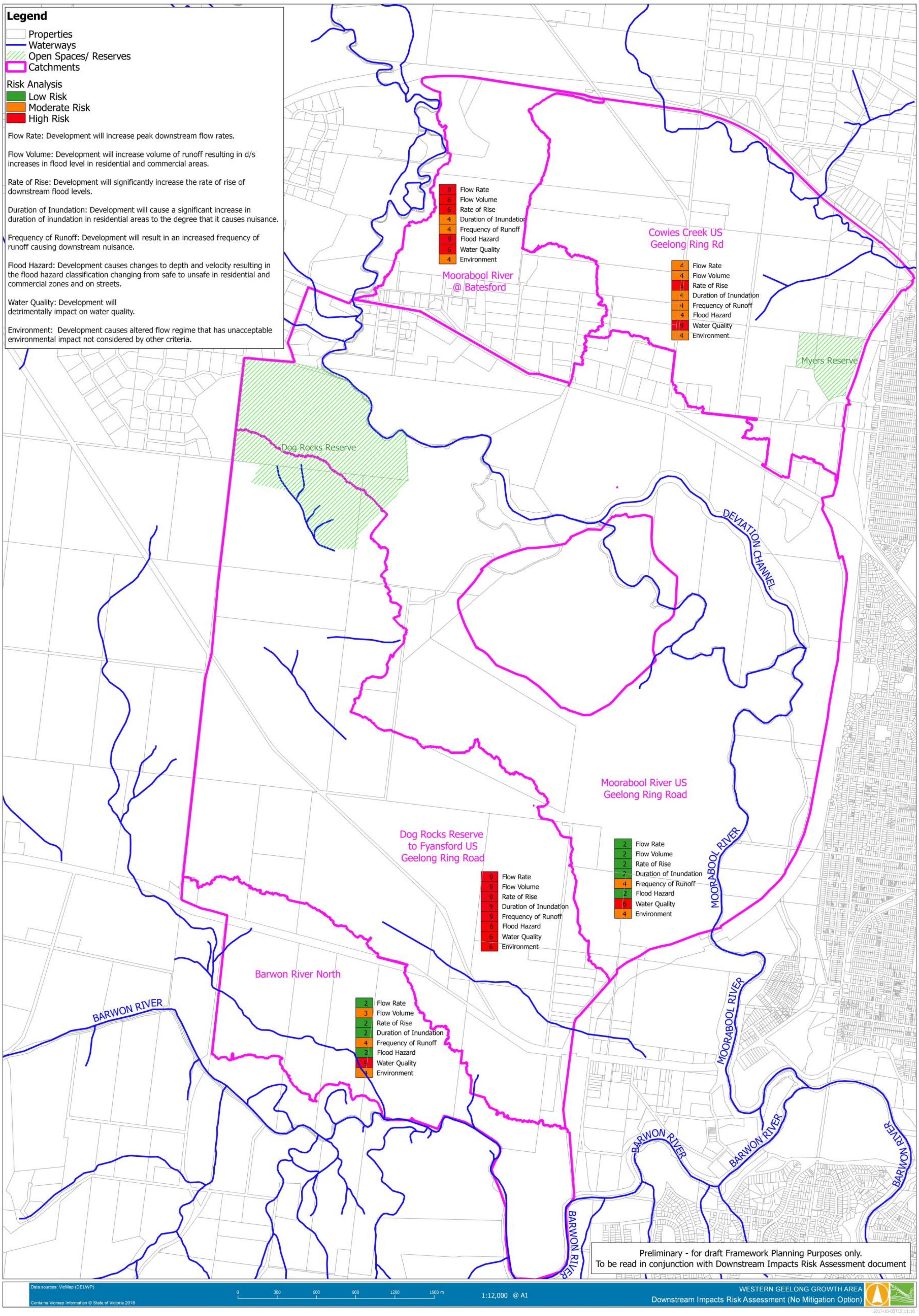

Figure 5-1 Downstream Impacts Risk Assessment without mitigation

Table 5-2 Cowies Ck upstream the Geelong Ring Road Impacts Risk Assessment Matrix

	Cowies Creek US Geelong Ring Road								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: *Development will increase peak downstream flow rates.*	2	2	4	The 'Cowies Creek US Geelong Ring Road' catchment represents approximately 15% of the overall catchment discharging to Cowies Creek at Geelong Ring Road. Assuming that the Rural Living Zone at the downstream end of the catchment is not redeveloped, the peak flow from the 'Cowies Creek US Geelong Ring Road' catchment may significantly increase the downstream flow rates.	Retarding Basins	1	1	1	The series of retarding basins are designed to limit peak flow to match pre-development conditions.
Flow Volume: *Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.*	2	2	4	The increase in flood level as a result of the catchment development (without mitigation) can possibly increase flood levels in the immediate downstream areas resulting in downstream increases in flood level in residential areas. Some properties within the Rural Living areas immediately downstream the catchment are currently affected by 1% AEP flooding. Developping the 'Cowies Creek US Geelong Ring Road' catchment may increase downstream flooding.	Retarding Basins, Rainwater tanks, stormwater harvesting and re-use	1	1	1	The Integrated Water Cycle Management (IWCM) selected option includes the use of WSUD and water harvesting and reuse. Retarding basins will spread the increased stormwater volume over longer timeframe that will minimise d/s impact.
Rate of Rise: *Development will significantly increase the rate of rise of downstream flood levels.*	3	2	6	Rate of rise of the Cowies Creek upstream catchment is likely to significantely increase due to the large increase in urban area with fast response runoff, resulting in peakier hydrographs.	Retarding Basin	1	1	1	The designed retarding basins will significantly reduce the rate of rise associated to the the increase in imperviousness. Runoff volume will be stored in retarding basins discharging a peak 100 year ARI outflow not greater than the pre-development 100 year ARI outflow. While the rate of rise will be greately reduced; however volume of runoff and duration of discharge will increase in the downstream receiving waterways.
Duration of Inundation: *Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.*	2	2	4	Combination of rural and urban flow inputs to the downstream catchment may increase the duration of inundation. Extending the duration may have some impact on downstream areas.	Waterways corridors with buffers	1	1	1	The IWCM selected option aims to retain water within the urban landscape as close as possible to the source through large buffer widths along waterways and extensive use if open drainage for major drainage flows. Inundation nuisance is likely to be acceptable through appropriate sizing of flood storages and waterways with freeboard.
Frequency of Runoff: *Development will result in an increased frequency of runoff causing downstream nuisance.*	2	2	4	The frequency of runoff at the Cowies Creek outfall may increase and cause nuisance impacts like bank erosion if unmanaged.	Rainwater tanks, stormwater harvesting and re-use, porous pavements etc	1	1	1	IWCM will seek to lessen the impacts of development on flow frequency. Increases in flow frequency will still occur. Waterway assessments can determine any areas of potential risk and local mitigation measures put in place (address nick points or areas of likely bank erosion)
Flood Hazard: *Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.*	2	2	4	It is expected to see increase in flood depth and velocities in the immediate downstream areas at the bottom of the catchment (existing Rural Living areas not redeveloped) as a result of developing the 'Cowies Creek US Geelong Ring Road' catchment. The hazard classification may change from safe to unsafe.	Retarding Basins	2	1	2	Peak flow will be limited to pre-development levels, ensuring flood hazard is not worsened.
Water Quality: *Development will detrimentally impact on water quality.*	3	3	9	Assuming that the Rural Living Zone at the downstream end of the catchment is not redeveloped, the urbanisation of the catchment upstream is likely to detrimentally impact on water quality within Cowies Creek and its tributary if left untreated.	Best Practice WSUD	1	1	1	Sedimentation basins and wetlands have been designed to meet BPEM objectives and ensure d/s WQ is not impacted as demonstrated with the MUSIC models assessment. (Refer to Section 3.3 of the Developed Conditions Report)
Environment: *Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.*	2	2	4	Developing this catchment may impact the flow regime of the Creek. Cowies Creek is already a highly modified catchment downsteram and hence impacts may or may not be significant.	Retarding Basin, WSUD, IWCM	2	1	2	Developing the catchment will change the flow regime. Retarding basins will ensure the peak flow rate is retarded back to the pre-development conditions and harvesting etc. will mitigate some of the impacts on volume/frequency; however the overall flow regime is likely to be changed.

Table 5-3 Moorabool River at Batesford Impacts Risk Assessment Matrix

	Moorabool River @ Batesford								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: *Development will increase peak downstream flow rates.*	3	3	9	The Moorabool River 1% AEP peak flow is likely to be much higher than the contributing catchment 1% AEP peak flow. Assuming that the Rural Living Zone (RLZ) and Township Zone (TZ) are not redeveloped, the impacts are likely to increase the peak flow rates in the RLZ and TZ downstream areas.	Retarding Basin	1	1	1	The series of retarding basins are designed to limit peak flow to match pre-development conditions.
Flow Volume: *Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.*	3	2	6	The downstream peak flood levels (outside the site) in the Moorabool River are likely to remain unchanged. Within the Moorabool River there is some potential for minor, more frequent flood levels to increase marginally due to the high inputs from short duration storms from urban development compared to the rural catchment. However, the flood level is likley to increase in the downstream areas (more particularly in the Township Zone) which is unlikely to be acceptable.	Retarding Basins, Rainwater tanks, stormwater harvesting and re-use	1	1	1	The Integrated Water Cycle Management (IWCM) selected option includes the use of WSUD and water harvesting and reuse. Retarding basins will spread change in volume over longer timeframe that will minimise d/s impact.
Rate of Rise: *Development will significantly increase the rate of rise of downstream flood levels.*	3	2	6	Rate of rise of the Moorabool River downstream catchment is likely to remain effectively unchanged. However the rate of rise of the flood level in the downstream area (RLZ and TZ) is likely to increase as a results of urbanisation in the upstream unmitigated catchment.	Retarding Basin	1	1	1	The designed retarding basins will significantly reduce the rate of rise associated to the the increase in imperviousness. Runoff volume will be stored in retarding basins discharging a peak 100 year ARI outflow not greater than the pre-development 100 year ARI outflow. While the rate of rise will be greately reduced; however volume of runoff and duration of discharge will increase in the downstream receiving waterways.
Duration of Inundation: *Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.*	2	2	4	With the downstream flood levels likely to increase in the downstream areas (RLZ and TZ), the duration of inundation in the downstream area may increase to the degree that causes nuisance.	Underground drainage network and overland flow path	2	1	2	Inundation nuisance in the downstream areas (RLZ and TZ) is proposed to be mitigated with appropriate drainage pipe network and overland flow paths (roadway) to ensure the duration of inundation does not cause nuisance in the downstream residential areas.
Frequency of Runoff: *Development will result in an increased frequency of runoff causing downstream nuisance.*	2	2	4	The frequency of runoff at the Moorabool River outfall may increase and cause nuisance impacts like bank erosion if unmanaged.	Rainwater tanks, stormwater harvesting and re-use, porous pavements etc	2	1	2	IWCM will seek to lessen the impacts of development on flow frequency. Increases in flow frequency will still occur. Local mitigation measures will need to be put in place (i.e. areas of likely bank erosion) to avoid erosion alon steep escarpment proposed to be developed.
Flood Hazard: *Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.*	3	3	9	With the downstream flood level likely to increase and the steep drop between the Rural Living Zone and the Township Zone increasing velocities, the flood hazard classification is likely to change from safe to unsafe in the residential areas and streets.	Reduce development footprint	2	1	2	Reduce development footprint to the edge of the River steep embankment. Steep terrain may cause high velocity and safety issues which will need to be mitigated when deisgning the subdivisions located along steep escarpments.
Water Quality: *Development will detrimentally impact on water quality.*	3	2	6	Only a small area of the catchment can be developed (approx.75 ha) when taking into account the waterway buffer corridor and assuming that the Rural Living Zone and Township Zone are not redeveloped. The urbanisation of this area is likely to detrimentally impact on water quality if left untreated.	Best Practice WSUD	1	1	1	Sedimentation basins and wetlands have been designed to meet BPEM objectives and ensure d/s WQ is not impacted as demonstrated with the MUSIC models assessment. (Refer to Section 3.3 of the Developed Conditions Report)
Environment: *Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.*	2	2	4	While the development of the small developable land in this catchment is unlikely to impact the peak flow rate, it may impact the flow regime of the River causing unacceptable impacts on the environment with more frequent and fast response flows entering the River.	Retarding Basin	1	1	1	Developing the catchment may change the flow regime. Given the size of the upstream catchment maintaining the Moorabool River base flow, the impact on flow regime downstream of study area is likely to be negligible.

Table 5-4 Moorabool River upstream the Geelong Ring Road Impacts Risk Assessment Matrix

	Moorabool River US Geelong Ring Road								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: *Development will increase peak downstream flow rates.*	1	2	2	The Moorabool River 1% AEP peak flow is likely to be much higher than the contributing catchment 1% AEP peak flow. It is unlikely to result in significantly increased peak flow rates.	Retarding Basin	1	1	1	The series of retarding basins are designed to limit peak flow to match pre-development conditions.
Flow Volume: *Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.*	1	2	2	The downstream flood levels are likely to remain unchanged. New residential subdivisions are being built immediately downstream the site and quite low in the floodplain; hence the consequence of an increase in flood level is unlikely to be acceptable.	Retarding Basins, Rainwater tanks, stormwater harvesting and re-use	1	1	1	The Integrated Water Cycle Management (IWCM) selected option includes the use of WSUD and water harvesting and reuse. Retarding basins if sized appropriately will spread the increased stormwater volume over longer timeframe that will minimise d/s impact.
Rate of Rise: *Development will significantly increase the rate of rise of downstream flood levels.*	1	2	2	Rate of rise of the Moorabool River upstream catchment is unlikely to be significantely changed. The 1% hydrograph is likely to have two peaks; one early smaller peak associated to the urbanised catchment immediately upstream and another large peak corresponding to the upper catchment response.	Retarding Basin	1	1	1	The designed RBs will significantly reduce the rate of rise associated to the the increase in imperviousness. Runoff volume will be stored in retarding basins discharging a peak 100 year ARI outflow not greater than the pre-development 100 year ARI outflow. Rate of rise greater reduced; however volume of runoff and duration of discharge will increase in the downstream receiving waterways.
Duration of Inundation: *Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.*	1	2	2	With the downstream flood level likely to remain unchanged, new residential subdivisions built immediately downstream the site are unlikely to have increased duration of inundation.	Waterways corridors with buffers	1	1	1	The IWCM selected option aims to retain water within the urban landscape as close as possible to the source through large buffer widths along waterways and extensive use if open drainage for major drainage flows. Inundation nuisance is likely to be acceptable through appropriate sizing of flood storages and waterways with freeboard.
Frequency of Runoff: *Development will result in an increased frequency of runoff causing downstream nuisance.*	2	2	4	The frequency of runoff at the Moorabool River outfall may increase and cause nuisance impacts like bank erosion if unmanaged.	Rainwater tanks, stormwater harvesting and re-use, porous pavements etc	2	1	2	IWCM will seek to lessen the impacts of development on flow frequency. Increases in flow frequency will still occur. Waterway assessments can determine any areas of potential risk and local mitigation measures put in place (address nick points or areas of likely bank erosion)
Flood Hazard: *Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.*	1	2	2	With the downstream flood level likely to remain unchanged and the relatively flat slope, the increase in flood hazard downstream the site is unlikely.	Waterway design including energy dissipation measures.Reduce development footprint	1	1	1	Reduce development footprint to the edge of the River steep embankment. Steep terrain may cause high velocity and safety issues which will need to be mitigated when deisgning the subdivisions located along steep escarpments.
Water Quality: *Development will detrimentally impact on water quality.*	3	2	6	Developing this catchment may detrimentally impact on water quality if left untreated.	Best Practice WSUD	1	1	1	Sedimentation basins and wetlands have been designed to meet BPEM objectives and ensure d/s WQ is not impacted as demonstrated with the MUSIC models assessment. (Refer to Section 3.3 of the Developed Conditions Report)
Environment: *Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.*	2	2	4	While the development of the small developable land in this catchment is unlikely to impact the peak flow rate, it may impact the flow regime of the River causing unacceptable impacts on the environment with more frequent and fast response flows entering the River.	Retarding Basin	1	1	1	Developing the catchment may change the flow regime. Given the size of the upstream catchment maintaining the Moorabool River base flow, the impact on flow regime downstream of study area is likely to be negligible.

Table 5-5 Dog Rocks Reserve to Fyansford upstream the Geelong Ring Road Impacts Risk Assessment Matrix

	Dog Rocks Reserve to Fyansford US Geelong Ring Road								
	No Mitigation				Mitigation				
Assessment Criteria	Likelihood	Consequence	Risk	Comment	Possible Treatment	Likelihood	Consequence	Residual Risk	Comment
Flow Rate: *Development will increase peak downstream flow rates.*	3	3	9	Developed conditions peak flow rate at the Geelong Ring Road near McCanns Lane and Thoona Lane will be much higher than undeveloped flows and are unlikely to be acceptable.	Retarding Basin	1	1	1	The series of retarding basins are designed to limit peak flow to match pre-development conditions.
Flow Volume: *Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.*	3	3	9	The increase in flood level as a result of the catchment development (without mitigation) is likely to increase the flood level in the donwstream residential and industrial areas east of Geelong Ring Road. Proposed new residential subdivisions (on Clarke Road) are proposed to be built and industrial properties are located downstream the site; hence the consequence of an increase in flood level is unlikely to be acceptable.	Retarding Basins, Rainwater tanks, stormwater harvesting and re-use; reduced development footprint; Flow Diversion	1	1	1	The Integrated Water Cycle Management (IWCM) selected option includes the use of WSUD and water harvesting and reuse. Retarding basins will spread change in volume over longer timeframe that will minimise d/s impact. Retarding basins are designed to retard the peak flows back to the pre-development flows and hold back the increased volume of runoff. Hydraulic flood modelling demonstrated that while the flow volume will inevitably increase as a results of the increase in imperviousness, the 100 year ARI flood level is not worsen in the private land east of the geelong Ring Road (Refer to Section 4 of the Developed Conditions report)
Rate of Rise: *Development will significantly increase the rate of rise of downstream flood levels.*	3	3	9	Urbanised catchment runoff is much faster, hence the rate of rise of this catchment is likely to be significantely increased.	Retarding Basin	1	1	1	The designed RBs will significantly reduce the rate of rise associated to the the increase in imperviousness. Runoff volume will be stored in retarding basins discharging a peak 100 year ARI outflow not greater than the pre-development 100 year ARI outflow. Rate of rise greater reduced; however volume of runoff and duration of discharge will increase in the downstream receiving waterways.
Duration of Inundation: *Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.*	3	3	9	With the downstream flood levels and volume likely to increase, the duration of inundation in the downstream proposed residential subdividion and exisiting industrial area is likely to increase.	Waterways corridors with buffers	2	2	4	The IWCM selected option aims to retain water within the urban landscape as close as possible to the source through large buffer widths waterways and extensive use of open drainage for major drainage flows. Duration of overland flooding is going to increase downstream the catchment as a result of the stormwater runoff volume being generated off the increased impervious surfaces. In the existing privately land downstream the Geelong Ring Road (at Hamilton Highway), further flood investigations will be required to identify the magnitude of flood duration and potential mitigation measures if required.
Frequency of Runoff: *Development will result in an increased frequency of runoff causing downstream nuisance.*	3	3	9	Developing the catchment is likely to increase the frequency of runoff causing nuisance flooding downstream if there are no mitigation measures to provide for the additional flow.	Linear waterways and flood storages. Rainwater tanks, stormwater harvesting and re-use, porous pavements etc.	2	2	4	The Concept SWMS proposes a linear floodway interspected with storages to contains floodwaters. IWCM will lessen the impacts of development on flow frequency. Local waterway mitigation measures could be put in place to address areas of risk making the consequence acceptable. Frequency of overland flooding is going to increase downstream the catchment as a result of the stormwater runoff volume being generated off the increased impervious surfaces. In the existing privately land downstream the Geelong Ring Road (at Hamilton Highway), further flood investigations will be required to identify the magnitude of flood frequency and potential mitigation measures if required.
Flood Hazard: *Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.*	2	3	6	Given that downstream flood levels and depths are likely to increase and that the catchment is relatively flat, the flood hazard downstream of the site may also increase from safe to unsafe. A flat catchment would suggest that flood waters remain shallow with low velocities.	Waterway design including energy dissipation measures.	2	1	2	Peak flow will be limited to pre-development levels, ensuring flood hazard is not worsened.
Water Quality: *Development will detrimentally impact on water quality.*	2	3	6	The catchment waterway may provide some level of treatment before discharging donwstream the site. However the development of this catchment may detrimentally impact on water quality due to the urbanisation impacts over a large catchment area.	Best Practice WSUD	1	1	1	Sedimentation basins and wetlands have been designed to meet BPEM objectives and ensure d/s WQ is not impacted as demonstrated with the MUSIC models assessment. (Refer to Section 3.3 of the Developed Conditions Report)
Environment: *Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.*	3	2	6	Developing this catchment is likely to impact the flow regime of the waterway and may cause unacceptable impacts on the environment. Given the existing waterway values in the downstream catchment are compromised, the impact may be less than would be the case fro a high-value waterway.	Retarding Basin	1	1	1	Developing the catchment may change the flow regime. Given the size of the upstream catchment maintaining the Moorabool River base flow, the impact on flow regime downstream of study area is likely to be negligible.

Table 5-6 Barwon River upstream the Geelong Ring Road Impacts Risk Assessment Matrix

	Barwon River @ Geelong Ring Road								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: *Development will increase peak downstream flow rates.*	1	2	2	The Barwon River 1% AEP peak flow is likely to be much higher than the contributing catchment 1% AEP peak flow. It is unlikely to observe significant increases in peak flow rates. Although there is some development in the Barwon further downstream in Geelong, this is a significant distance downstream and any impacts are likely to dissipate.	Retarding Basin	1	1	1	The series of retarding basins are designed to limit peak flow to match pre-development conditions.
Flow Volume: *Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.*	1	3	3	The downstream flood levels are likely to remain unchanged. Existing flooding in south Geelong may be exacerbated; hence the consequence of an increase in flood level is unlikely to be acceptable.	Retarding Basins, Rainwater tanks, stormwater harvesting and re-use	1	1	1	The Integrated Water Cycle Management (IWCM) selected option includes the use of WSUD and water harvesting and reuse. Retarding basins if sized appropriately will spread the increased stormwater volume over longer timeframe that will minimise d/s impact.
Rate of Rise: *Development will significantly increase the rate of rise of downstream flood levels.*	1	2	2	Rate of rise of the Barwon River upstream catchment is unlikely to be significantely changed. The 1% hydrograph is likely to have two peaks; one early smaller peak associated to the urbanised catchment immediately upstream and another large peak corresponding to the upper catchment response.	Retarding Basin	1	1	1	The designed RBs will significantly reduce the rate of rise associated to the the increase in imperviousness. Runoff volume will be stored in retarding basins discharging a peak 100 year ARI outflow not greater than the pre-development 100 year ARI outflow. Rate of rise greater reduced; however volume of runoff and duration of discharge will increase in the downstream receiving waterways.
Duration of Inundation: *Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.*	1	2	2	With the downstream flood level likely to remain unchanged, existing properties in South Geelong at flooding risk are unlikely to have increased duration of inundation.	Waterways corridors with buffers	2	1	2	The IWCM selected option aims to retain water within the urban landscape as close as possible to the source through large buffer widths along waterways and extensive use if open drainage for major drainage flows. Inundation nuisance is likely to be acceptable through appropriate sizing of flood storages and waterways with freeboard.
Frequency of Runoff: *Development will result in an increased frequency of runoff causing downstream nuisance.*	2	2	4	Developing this catchment is likely to increase the frequency of runoff in the river. However, relative to the river capacity these flows are likely to be small and not result in nuisance flooding.	Rainwater tanks, stormwater harvesting and re-use, porous pavements etc	2	1	2	IWCM will seek to lessen the impacts of development on flow frequency. Increases in flow frequency will still occur. Waterway assessments can determine any areas of potential risk and local mitigation measures put in place (address nick points or areas of likely bank erosion)
Flood Hazard: *Development causes changes to depth and velocity resulting in the flood hazard classification changing from safe to unsafe in residential and commercial zones and on streets.*	1	2	2	With the downstream flood level likely to remain unchanged and the relatively flat slope, the increase in flood hazard downstream of the site is unlikely.	Waterway design including energy dissipation measures.	2	1	2	Peak flow will be limited to pre-development levels, ensuring flood hazard is not worsened.
Water Quality: *Development will detrimentally impact on water quality.*	3	3	9	Developing this catchment may detrimentally impact on water quality if left untreated. The urban development will generate additional pollutant loads.	Best Practice WSUD	1	1	1	Sedimentation basins and wetlands have been designed to meet BPEM objectives and ensure d/s WQ is not impacted as demonstrated with the MUSIC models assessment. (Refer to Section 3.3 of the Developed Conditions Report)
Environment: *Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria.*	2	2	4	While the development of the small developable land in this catchment is unlikely to impact the peak flow rate, it may impact the flow regime of the River causing unacceptable impacts on the environment with more frequent and fast response flows entering the River.	Retarding Basin	1	1	1	Developing the catchment may change the flow regime. Given the size of the upstream catchment maintaining the Barwon River base flow, the impact on flow regime downstream of study area is likely to be negligible.

6 TECHNICAL COMMENTARY

6.1 IWM Opportunities

The Integrated Water Management (IWM) Position Paper for the Northern and Western Geelong Growth areas, has been reviewed with the applicability of the current WGGA design assessed against Package D within the Position Paper. Package D for the WGGA is show below in Figure 6-1.

ELEMENT	Package D	Advantages	Disadvantages
Waterways, wetlands, floodplains	Highest level possible of improvement in ecological condition through rehabilitation; buffer widths consistent with and exceed MW Guidelines in some areas; high amenity flood storage and/or conveyance; natural water assets have outstanding multifunctional values.	Provides an extensive improvement in waterway protection and enhancement, with extensive multifunctional values.	Higher cost of establishment and maintenance. Reduction in developable land.
Major drainage	Major drainage strategy includes predominantly open major drainage pathways with significant multifunctional values; major drainage pathways and distributed detention are a vital part of the active open space linkages in the site.	Introduces extensive green spaces to the precinct, which are likely to be highly valued given the topography. Likely to be lower cost than extensive daylighting or full undergrounding of major drainage.	Higher cost of establishment and maintenance. Reduction in developable land.
Land use & open space	Land use plan maximises responsiveness to natural landform and shows outstanding synergy with water cycle assets; providing extensive blue-green links with diverse multi-functional use and offering regional and broader scale benefits.	Improved liveability through increased synergy between land use plan and water cycle assets.	Higher cost of establishment and maintenance. Reduction in developable land.
Stormwater management	Stormwater management plan provides outstanding distribution of stormwater retardation, treatment and infiltration across the site, property and streetscape scale; much reduced extent of end of line wetlands with a blue/green feel to the urban precinct through extensive WSUD.	Significant efforts to retain water in the urban landscape. Given the topography and likely impact of heat island effect, this could be a major liveability benefit.	Higher cost of establishment and maintenance. Reduction in developable land.
Alternative water	Safe, reliable and quality alternative water provided by precinct scale sources reducing total precinct drinking water demand by approximately 30% and/or potentially providing alternative water for off site use (e.g. Class A recycled water via dual pipe, use of major stormwater wetlands for extensive internal demand nodes).	Introduces water retention into the area at hub scale. Can potentially reduce some storm flow intensity and drinking water demands for the development.	Stormwater reused may not achieve reliability sufficient to justify internal network during all seasons and during drought.
Drinking water	Safe, reliable and quality drinking water provided via connection to regional drinking water network.	Likely to be least capital and operating costs. Existing capacity in network to provide.	Places greater demand on regional water sources.
Sewerage	Safe, reliable and quality sewerage services provided connection to local sewerage system.	Eases pressure on regional network. Provides opportunity for localised recycled water use.	Likely to be challenging for gain environmental approvals and more costly.

Figure 6-1 IWM Position paper Package D for WGGA

The key elements on how this proposed strategy compares to the aspirational outcomes of Package D are summarised in Table 6-1.

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Table 6-1 IWM Package D applicability to Drainage Strategy

Element	Package D	Applicability to Drainage Strategy
Waterways, wetlands, floodplains	Highest level possible of improvement in ecological condition through rehabilitation; buffer widths consistent with and exceed MW Guidelines in some areas; high amenity flood storage and/or conveyance; natural water assets have outstanding multifunctional values.	Minimum waterway reserve widths have been specified in the strategy in accordance with MW Guidelines. Combined wetland/storage assets have a proven track record of providing exceptional community assets.
Major drainage	Major drainage strategy includes predominantly open major drainage pathways with significant multifunctional values; major drainage pathways and distributed detention are a vital part of the active open space linkages in the site.	Combined treatment and detention assets are proposed in the strategy whereby multifunctional assets will be created within will provide great value to the future community.
Land use & open space	Land use plan maximises responsiveness to natural landform and shows outstanding synergy with water cycle assets; providing extensive blue-green links with diverse multi-functional use and offering regional and broader scale benefits.	Water quality and quantity assets are distributed throughout the strategy to enable greater access to neighbourhood scale drainage assets.
Stormwater Management	Stormwater management plan provides outstanding distribution of stormwater retardation, treatment and infiltration across the site, property and streetscape scale; much reduced extent of end of line wetlands with a blue/green feel to the urban precinct through extensive WSUD.	Open waterways incorporated throughout strategy where appropriate to provide key blue-green links. Future refinement of treatment assets could occur when more information is available regarding more distributed treatment (street scale) measures.
Alternative water	Safe, reliable and quality alternative water provided by precinct scale sources reducing total precinct drinking water demand by approximately 30% and/or potentially providing alternative water for offsite use (e.g. Class A recycled water via dual pipe, use of major stormwater wetlands for extensive internal demand nodes).	WLRB E in Cowies Creek catchment has potential for future stormwater harvesting of Myers Reserve. Additional wetlands have capacity to supply harvest stormwater once future demand locations are determined.
Drinking water	Safe, reliable and quality drinking water provided via connection to regional drinking water network.	Not Applicable to Drainage Strategy
Sewerage	Safe, reliable and quality sewerage services provided connection to local sewerage system.	Not Applicable to Drainage Strategy

The “Stormwater Management” objective of the IWM calls for the distributed treatment systems, which to a degree has been met by this strategy where practical. The SWMS has led to do numerous basins, wetlands and sedimentations basins throughout the WGGA, however majority of these systems could be classed as moderate to large neighbourhood systems in terms of upstream catchment area. The water quality treatment assets have been co-located in these large basins for optimal use of dedicated reserve areas, however opportunity does still exist for future water quality assists to be further distributed within the future subdivisions, though at-surface treatment device such as passively irrigated street trees, minor bioretention basins or treatment swales. The water quality modelling has assumed that there is no minor water quality asset in the upper catchments.

Should future distributed water quality systems be proposed within the WGGA, the neighbourhood scale wetland assets could be further refined to offset the further pollutant reductions within the catchment if current best practice requirements for pollutant reduction still be the minimum target at that time.

A preliminary assessment has been undertaken to assess the possible water supply available from the treatment wetlands within the WGGA. Assuming a 200 kL storage tank is located adjacent to each wetland with a target reliability of 80%, it was found that an annual demand of 2,000 kL/year could potentially be harvested from each wetland system. This harvesting potential would be consistent for each wetland within the WGGA if a 200 kL tank is utilised. Whilst the inflows available from the wetland system could be accommodated by a larger harvesting rate, the limiting factor will be the storage capacity. It was thought that a 200 kL tank was a good estimation of the most practical tank size available for stormwater harvesting and reuse activities such as CoGG open space irrigation.

To enable higher harvesting rates, large storage capacity options such as dedicated water pondages at the end of the wetland treatment line would be required. These types of systems would require additional land take from what has been assumed in the analysis to date and would need to be considered in future designs, should future harvesting demand in the vicinity deem it appropriate. A 200 kL per annum harvesting rate is a starting point for analysing available alternative water supply without the need to alter the current land take estimates.

WLRB E within the Cowies Creek catchment has potential for as a future location for stormwater harvesting due primarily to its proximity to Myers Reserve, with the design and location of the asset tailor to suit future harvesting requirements.

The future pit lake within the Batesford Quarry also presents an excellent opportunity to harvest stormwater runoff for the WGGA. From a stormwater perspective, the future pit lake has been kept separate from the drainage network to ensure lake water quality is not impacted, however, the potential for other positive Integrated Water Outcomes are apparent should it be deemed there is nearby demand. IWM opportunities from the pit lake are not investigated in this report.

6.2 Staging Constraints and Opportunities

CoGG have provided Water Technology with a Precinct Structure Plan Indicative Timing map (CONFIDENTIAL) showing the following five large stages (arbitrary Water Technology ID’s of A to E) and three high level timeframes, as shown in Figure 6-2;

- **Stage A** discharging to Cowies Creek bounded by the Midland Highway to the south, the Geelong-Ballan Road to the west and the Geelong-Ballarat Railway to the north (Short-term)
- **Stage B** discharging to the Barwon River south of the Hamilton Highway (Short-term)
- **Stage C** discharging to the Moorabool River bounded by the Midland Highway to the south, the Geelong-Ballan Road to the east and the Geelong-Ballarat Railway to the north (Medium-term)

- **Stage D** discharging to the Moorabool River bounded by the Hamilton Highway to the south, the Fyansford-Gheringhap Road and McCanns Lane to the north (Medium-term)
- **Stage E** (the largest stage) discharging to the Moorabool River bounded by the Midland Highway to the north and the Fyansford-Gheringhap Road and McCanns Lane to the south (long-term)

We understand that the current staging is indicative only and subject to change. As such, Water Technology has not commented on or modelled the potential impacts of staging the flood retardation and water quality works within each of the five stages. Water Technology also do not know the current land ownership arrangements and cannot comment on the most appropriate staging given the constraints in land ownership.

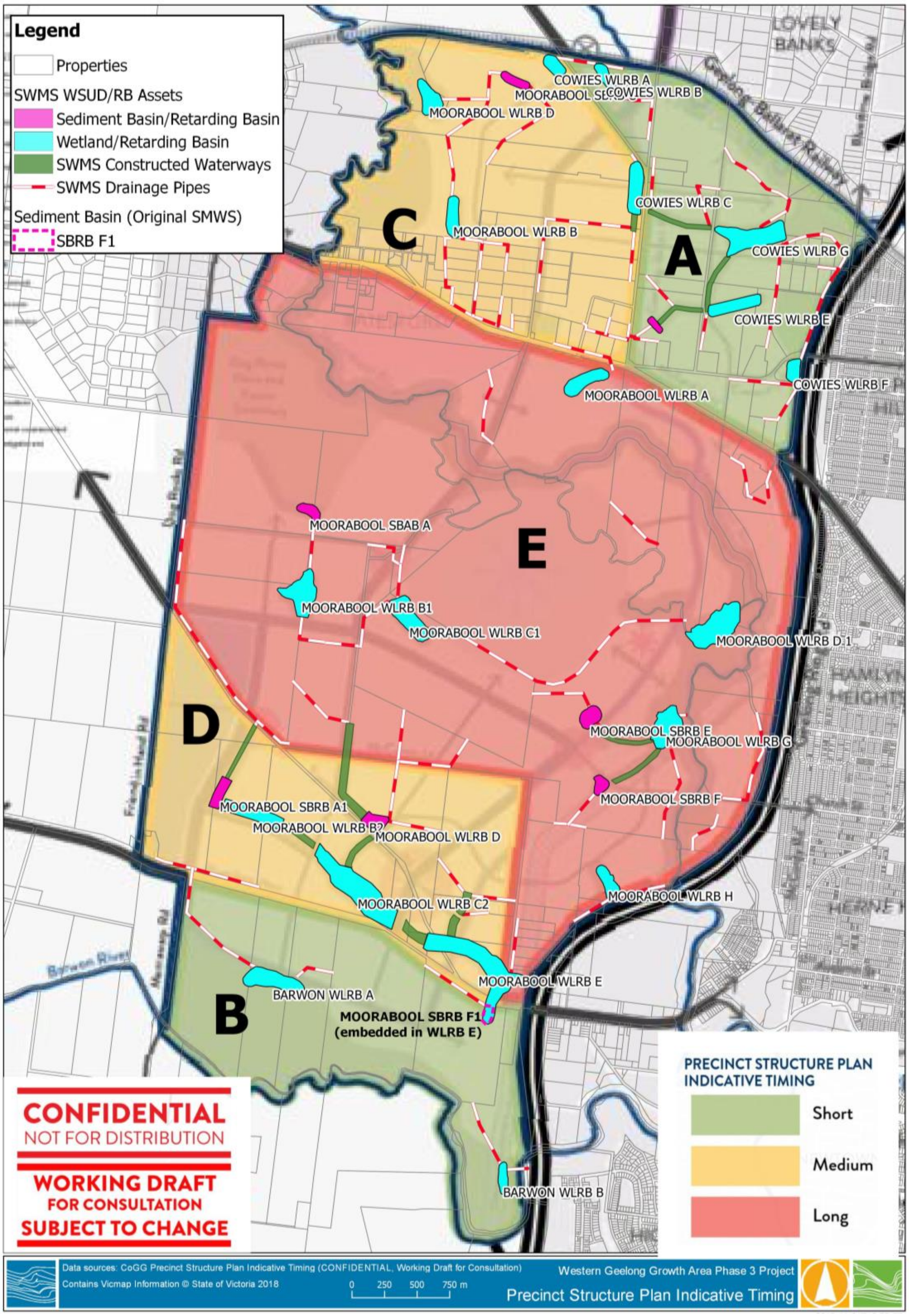


Figure 6-2 WGGA SWMS and Indicative Staging Timing (2018, CONFIDENTIAL)

It is important to note that the current indicative stages generally match the catchments delineation. Staging construction with downstream WSUD/flood retardation assets occurring first is often preferable to enable free drainage outfalls for developing areas. This is the case for eastern portion of Stage C which drains into Stage A.

For instance, it is assumed that Cowies WLR B, SBRB D, WLRB E, WLRB B and associated connecting waterways (Stage A) will be fully constructed before the construction of Cowies WLRB A, WLRB C and upstream catchments (Stage C) will occur which will avoid having to construct temporary drainage work downstream to allow for drainage to the outfall within land yet developed. The construction of temporary drainage works in downstream properties is not ideal as it must be undertaken following discussions with the affected landowner(s) and consideration must be given to factors such as;

- Access/stock crossings; and safety fences.
- Stockpiles or removal of excavated material.
- Stabilisation of bed and banks of temporary channel.
- Impacts on the flooding conditions associated to the upstream development and temporary works.

While it is not always possible to avoid the construction of temporary works, it is often preferable to start with the construction of the downstream WSUD and flood retardation assets as generally proposed within this current indicative staging plan.

There are only two locations in the WGGA study area which are likely to require the construction of temporary drainage works;

- The land upstream the proposed Moorabool WLRB A which is proposed to be developed (as part of Stage C) before the construction of the wetland/retarding basin and downstream outfall to the Moorabool River (Stage E) as shown in dotted black in Figure 6-3. The upstream development land is relatively small (approx. 15 ha) and temporary outfall to discharge the upstream site stormwater runoff to the Moorabool River is likely to only affect one parcel of land (so potentially one land owner being affected) without any existing properties or infrastructures to be impacted.

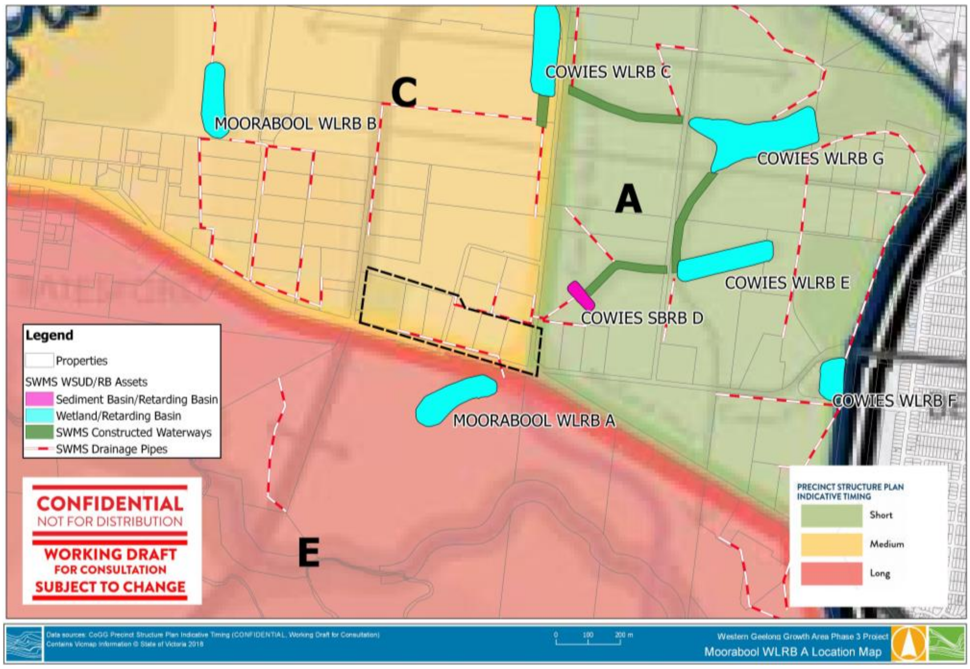


Figure 6-3 Moorabool WLRB A Staging Location Map

- The land west of the Geelong Ring Road and north of the Hamilton Highway (shown in dotted black in Figure 6-4) is proposed to be developed in the long-term after the construction of upstream catchments south of Hamilton Highway and along Fyansford-Gheringhap Road. Temporary drainage works will be required to drain the Moorabool SBRB F1 outflow to the Moorabool River. Under the existing conditions, stormwater runoff generated south of Hamilton

Highway is draining east towards the Geelong Ring Road south culverts and along the south side road drain along the highway. Under the 1% AEP peak event, there is overland flooding occurring in industrial land zones (IN1Z) and the Fyansford Waste Disposal as shown in Figure 6-5.

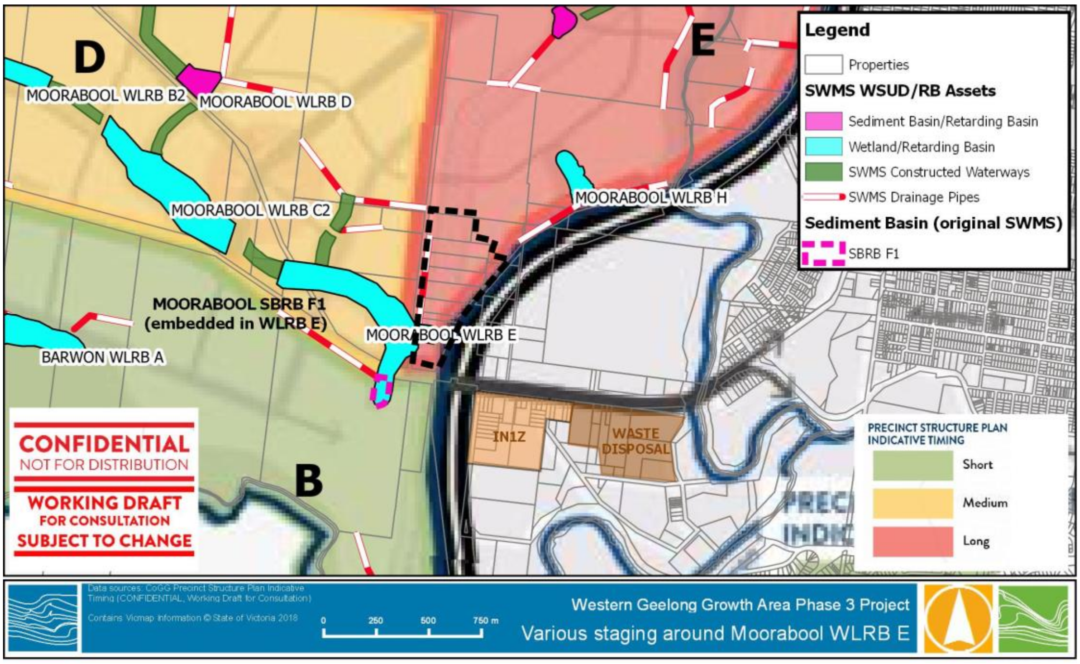


Figure 6-4 Geelong Ring Road/Hamilton Highway Staging Location Map

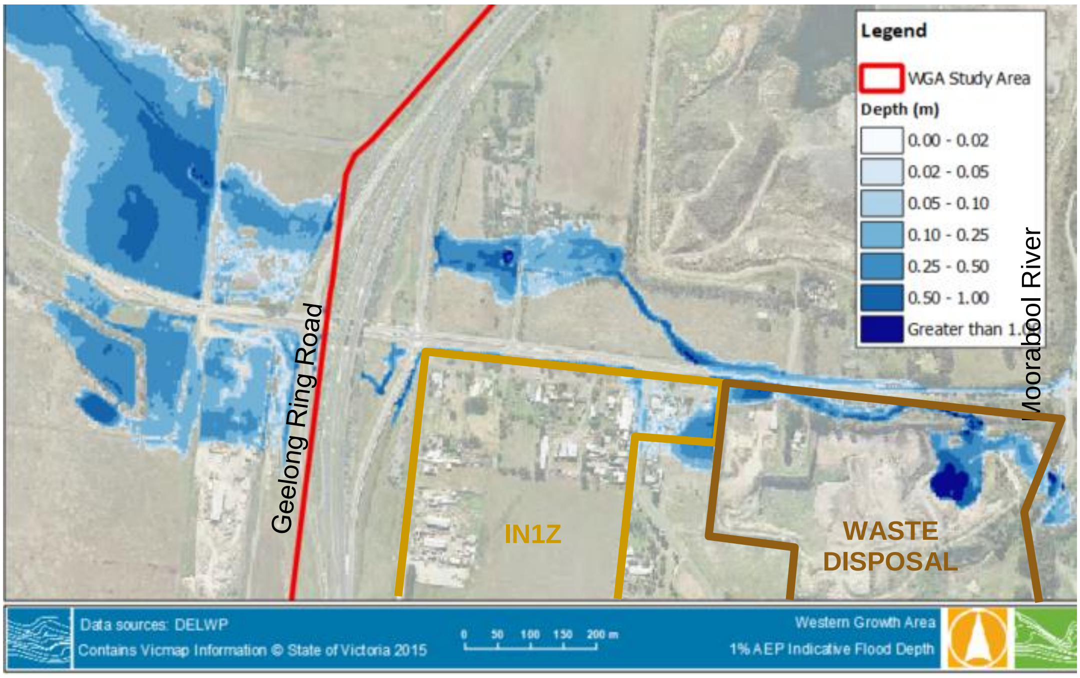


Figure 6-5 Existing Conditions 1% AEP Flooding East of Geelong Ring Road Along the Hamilton Highway

As part of the Moorabool SBRB F1 and associated upstream catchment development, the outflow from SBRB F1 can either;

- Be temporarily discharged through the south Geelong Ring Road culverts before reaching the Moorabool River or;

- Be discharged to the north into a partially constructed WLRB E draining to the north Geelong Ring Road culverts before reaching the Moorabool River.

The 1% AEP overland flooding impacts will need to be assessed to make sure the proposed interim drainage works do not increase overland flooding in the properties downstream the Geelong Ring Road. As the ultimate development scenario include the construction of Moorabool WLRB E downstream, it is possible that the SBRB F1 asset alone does not have enough flood storage volume.

It was verified in the RORB model that SBRB F1 asset alone does not have enough flood volume to retard the peak 1% AEP flow back to the pre-development flow. Therefore, the stormwater runoff from SBRB F1 (as part of Stage B) may need to be further retarded into temporary flood storage. In this case, it would be recommended to discharge outflow from SBRB F1 north of the Hamilton Highway and into the Moorabool WLRB E partially constructed.

The overall WSUD treatment train including sedimentation basins, wetlands and constructed waterways allow for urban stormwater quality best practice performance objectives to be met at the downstream receiving waterways (Cowies Creek, Moorabool River and Barwon River) as required by the Victorian Planning Provisions (Clause 56). However, this does not necessarily mean that stormwater quality best practice objectives are met at various locations throughout the development. Therefore, progressive construction of the WSUD assets will be required to ensure that the catchment as it gets developed meets stormwater quality best practice.

In practice, it is not recommended to build and establish vegetation in the WSUD assets before the construction of the associated upstream urban catchment as the plants may not receive enough inflow to ensure their establishment. It is recommended to construct the sedimentation basins ahead of the development to capture any sediment from the construction which have not been intercepted by the construction sediment control measures. The wetland and/or retarding basin earthworks can be completed ahead or in line with the upstream urban catchment development to ensure flows are retarded downstream. The wetland planting should only be completed once significant upstream catchments have been developed/constructed.

The site-specific constraints and opportunities that may impact the staging of the drainage works are summarised in Table 6-2.

Table 6-2 Staging Constraints and Opportunities

Constraints	Opportunities
■ Retarding basins proposed across steep terrain are more complex to design and construct. They are likely to require both cut and fill; and might be difficult to partially construct to cater for the upstream level of development. This constraint is particularly applicable for Cowies WLRB A and WLRB B.	■ Cowies WLRB G asset is proposed at the location of an existing terrain depression meaning that minimal cut is required to achieve the final basin design. There is an option to temporarily build a dam wall downstream of the existing depression (at WLRB G) and gradually raise the wall embankment level as the upstream catchment gets developed. ■ Similar opportunities can be drawn from assets Moorabool SBRB A, WLRB B1 and WLRB G proposed at the location of existing farm dams.

Constraints	Opportunities
	■ Flood storages proposed across flat terrain grade require simple terrain cut from the existing terrain elevation with minimal terrain changes including fill to construct the asset. This means that these flood storages (Moorabool SBRB A1, WLRB B2, WLRB C2, WLRB E and Barwon WLRB A) can partially be constructed to cater for the level of development upstream without undertaking redundant drainage works as the development progresses.

6.3 Design Principles and Standards

Water quality treatment assets in the drainage strategy have been sized to comply with current pollutant removal targets set out in *Urban Stormwater Best Practice Environmental Management Guidelines* (BPEMG), with expected fraction imperviousness within the WGGA catchments assumed in MUSIC modelling. Current MW guidelines for MUSIC modelling have been followed, albeit with a local rainfall data set used. Guidance from the MW Wetland Design Manual has also been followed where appropriate.

All retarding basins have been designed to cater for the 1% AEP rainfall event utilising ARR 1987 design storm events as requested by CoGG. Retarding basin outlet structures have been preliminary sized to convey the 1% AEP basin outflows, with spillways set at the design 1% AEP flood level within each basin which will be engaged in events greater than the 1% AEP ; or should blockage of the outlets occur. Retarding basins designs have also ensured the co-located assets (Sedimentation basin/wetlands) can also be adequately located in the basin footprints.

Batter slopes within each basin design has considered future maintenance/user path requirements, as well as minimum batter slopes for maintenance purposes. Where appropriate, cut and fill requirements have been taken into consideration in the design, as have future filling requirements within the future development areas. Filling requirements are of particular interest in the southern Moorabool River catchment (Wetlands B, C and E) due to the extensive area of filling required to service development due to existing flat terrain.

Where 20% AEP pipelines are specified, it is assumed that the overland gap flow (1% AEP minus 20% AEP) will be conveyed overland by the local drainage network, to be design at a later stage once development progresses, with associated cost for the roads to be borne by either the developers, or a future Development Contributions Plan. Due to the extensive blue-green links within the drainage strategy, catchments leading to pipe infrastructure have been minimised to generally less than 30 ha, resulting in manageable expected flow rates to be catered overland within future subdivisions. Generally, the pipeline locations have been dictated by existing cadastral and terrain information with minimal information available at this time regarding future road locations. It is believed that the manageable overland flow requirements associated with the future 20% AEP pipelines will allow for flexibility within future road and pipe layouts, therefore specific road locations to cater for overland flows have not been showed in the strategy to allow for future flexibility in road layouts. It must be noted that any 20% AEP pipeline will also have an overland flow component associated, which will need to be catered for in future road and drainage designs.

Road and pipe designs will be required to be in accordance with the Infrastructure Design Manual, or relevant design standards that become available in the future.

6.4 Construction and Maintenance

All drainage infrastructure within this strategy are proposed to become future assets of the CoGG. This includes future pipes, constructed waterways, sedimentation basins, wetlands and retarding basins. Each of these assets will require ongoing maintenance by CoGG. Hard engineering assets such as the roads and drainage pipelines have a well-known maintenance cost associated, whilst the soft engineering assets proposed will require more ongoing maintenance by CoGG to ensure they are operating optimally. MW has some available guidance on expected maintenance regimes for WSUD assets including wetlands and sediment basins which are re-produced in Figure 6-6.

ASSET	ASSET PARAMETERS	CONSTRUCTION[1]	MAINTENANCE		RENEWAL
			ESTABLISHMENT (FIRST TWO YEARS)	ONGOING	
WETLANDS[2]	< 500 m² 500 to 10,000 m² > 10,000 m²	$150/m² $100/m² $75/m²		$10/m²/yr $2/m²/yr $0.5/m²/yr	No data
SEDIMENT BASINS[2]	< 250 m² 250 to 1000 m² > 1000 m²	$250/m² $200/m² $150/m²		$20/m²/yr $10/m²/yr $5/m²/yr	Remove and dispose of: Dry waste = $250/m³ Liquid waste = $1,300/m³

Figure 6-6 Melbourne Water Water Sensitive Urban Design Life Cycle Costing Data

The above figure gives a basic guide to expected on-going costs that will be borne by CoGG for the water quality treatment assets. Ongoing costs associated with remaining assets proposed within the strategy are well known to CoGG and have not been investigated as part of this report.

Development is proposed on old quarry stockpile areas adjacent to the Batesford Quarry. It has been assumed that these stockpiles are suitable for development, however this will be required to be confirmed by a geotechnical assessment. Significant pipes are proposed in these areas to allow free drainage outfalls for upstream areas, therefore confirmation of the geology of these stockpiles should be undertaken in the next phase of analysis for the WGGA.

There are assets within the strategy that required significant levels of fill to be placed within existing gullies/depressions to enable the formation or the wetland bases. The primary examples of these are WLRB B1 in the Moorabool River catchment and WLRB G in the Cowies Creek catchment. WLRB G requires the construction of a significant earthen embankment to enable flood airspace above the proposed wetland asset. These assets may require specialist contractors to construct the assets in the future.

Proposed development areas located on steep terrain on the upslope from the Moorabool River will require specific design solutions where road and pipe longitudinal grade are expected to be high and require attention within future layout design. Drainage specifically in these areas will be problematic with mitigating velocities through measures such as pit drop structures and outlet erosion control measures likely to be required. Retarding basins and water quality treatment asset designs generally need flat terrain to function, therefore locations for such assets will be limited to flatter areas within the Moorabool River floodplain, such areas may also be problematic in terms of outfall grades to the river. Generally subdivisional works in these areas would cost additional due to the additional terrain manipulation required.

7 CONCLUSION

Developed design flow conditions within the WGGA have been defined through terrain, hydrologic and water quality modelling to determine the sizing of the proposed Stormwater Management Strategy assets including retarding basins, sedimentation basins, wetlands, constructed waterways and drainage pipes/culverts.

Three developed conditions RORB hydrologic models have been developed for study area following the existing conditions hydrologic and hydraulic modelling work completed during the Phase 1 of the project. The developed conditions RORB models were established based on the existing conditions diverted RORB models previously developed for the for the Barwon River, Moorabool River and Cowies Creek catchments (Existing Conditions Drainage and Flooding Final Report, Water Technology, January 2019).

Storages were designed using 12d Terrain Model software, with the location and shape of each storage informed by the Draft Framework Plan and the Concept SWMS. Individual assets shape and depths were refined to fit within the constraints of each individual site and within the allocated areas outlined within the Draft Framework Plan. Stage storage relationships extracted from 12d were used an input into the hydrological models to size the storage and proposed outfalls following an iterative approach. The flood storages were sized to ensure that the 1% AEP peak flows at outfalls to the Barwon River, Moorabool River and Cowies Creek did not exceed the pre-development 1% AEP peak flows at each respective outfall location.

Some land along steep escarpments of the Moorabool River are deemed developable under the Draft Framework Plan, however, were not considered in the preliminary Concept SWMS developed by Neil Craigie. These parcels of land have unique challenges regarding flood detention and treatment options and have been investigated at a high level to asses stormwater asset options.

In one specific area, the WGGA does not discharge directly to the Moorabool River at Hamilton Highway/Geelong Ring Road, but instead stormwater runoff is conveyed through private land. TUFLOW hydraulic modelling was used to verify that the proposed development of the WGGA of Geelong does not increase flooding in downstream private properties.

A Downstream Risk Impact Assessment was also completed to assess the impacts of the Stormwater Management Strategy assets design on a range of stormwater indicators such as flow rate, volume, duration of inundation, hazard or water quality.

The flood storage sizing informed the revision of the preliminary MUSIC models completed by Neil Craigie to reflect the Concept SMWS. The refined MUSIC models were run to verify that the treatment train effectiveness meets Urban Stormwater Best Practice Environmental Management pollutant targets at the outlets to the Creek and Rivers.

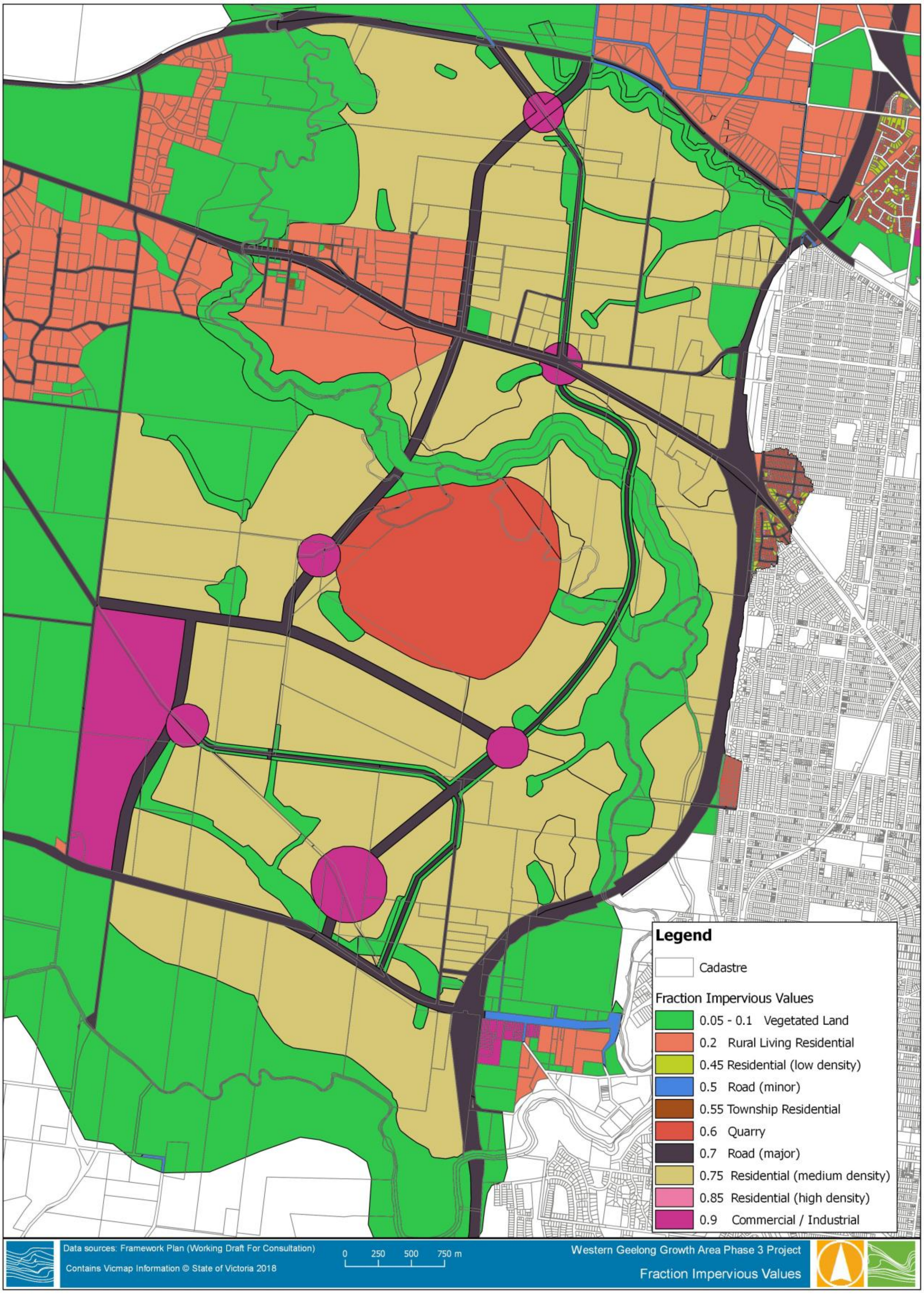
With the Stormwater Management Strategy assets design completed, the following preliminary considerations in terms of staging of the work, constructability and integrated water management opportunities were expressed to assist the development of the next stage of the strategy;

- To avoid construction of temporary drainage works, it is preferable to start with the construction of the most downstream WSUD and flood storage assets as generally proposed by the current indicative staging plan.
- Cowies WLRB G asset is proposed at the location of an existing terrain depression meaning that minimal cut is required to achieve the final basin design. There is an option to temporarily build a dam wall downstream of the existing depression (at WLRB G) and gradually raise the wall embankment level as the upstream catchment develops.
- Flood storages proposed across flat terrain grade (i.e. Fyansford area) are likely to require simple terrain cut from the existing terrain elevation with minimal terrain changes or imported fill; and can partially be constructed to cater for the level of development upstream without undertaking redundant drainage works as development progresses.

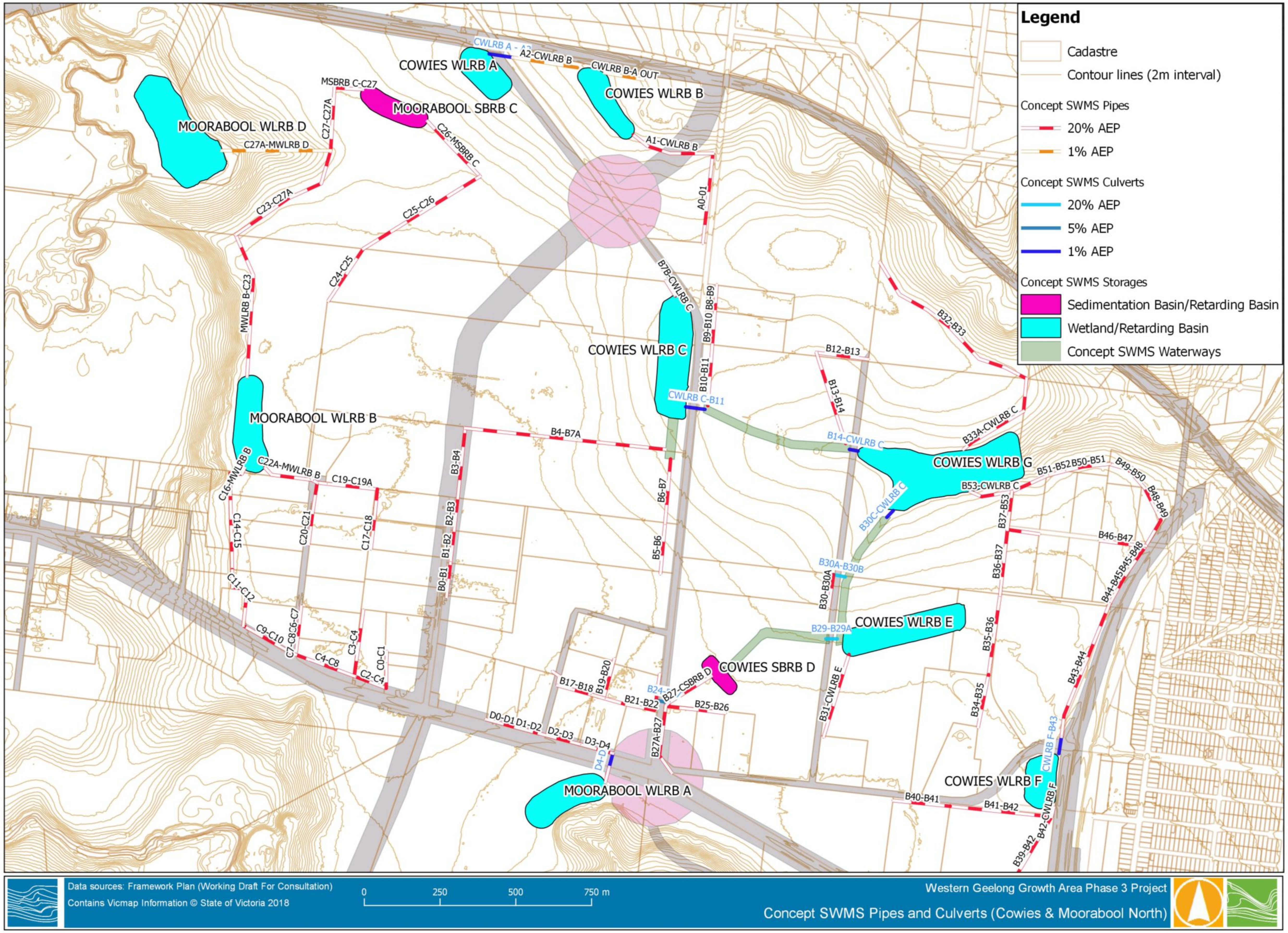
- Retarding basins proposed across steep terrain will likely be more difficult to construct to cater for the upstream level of development.
- Initial stormwater harvesting opportunities have been identified at WLRB E within the Cowies Creek catchment and the future pit lake at Batesford Quarry which will need to be investigated in the future stages of the strategy along with other stormwater harvesting opportunities at a subdivision level when the future location of open spaces is identified.

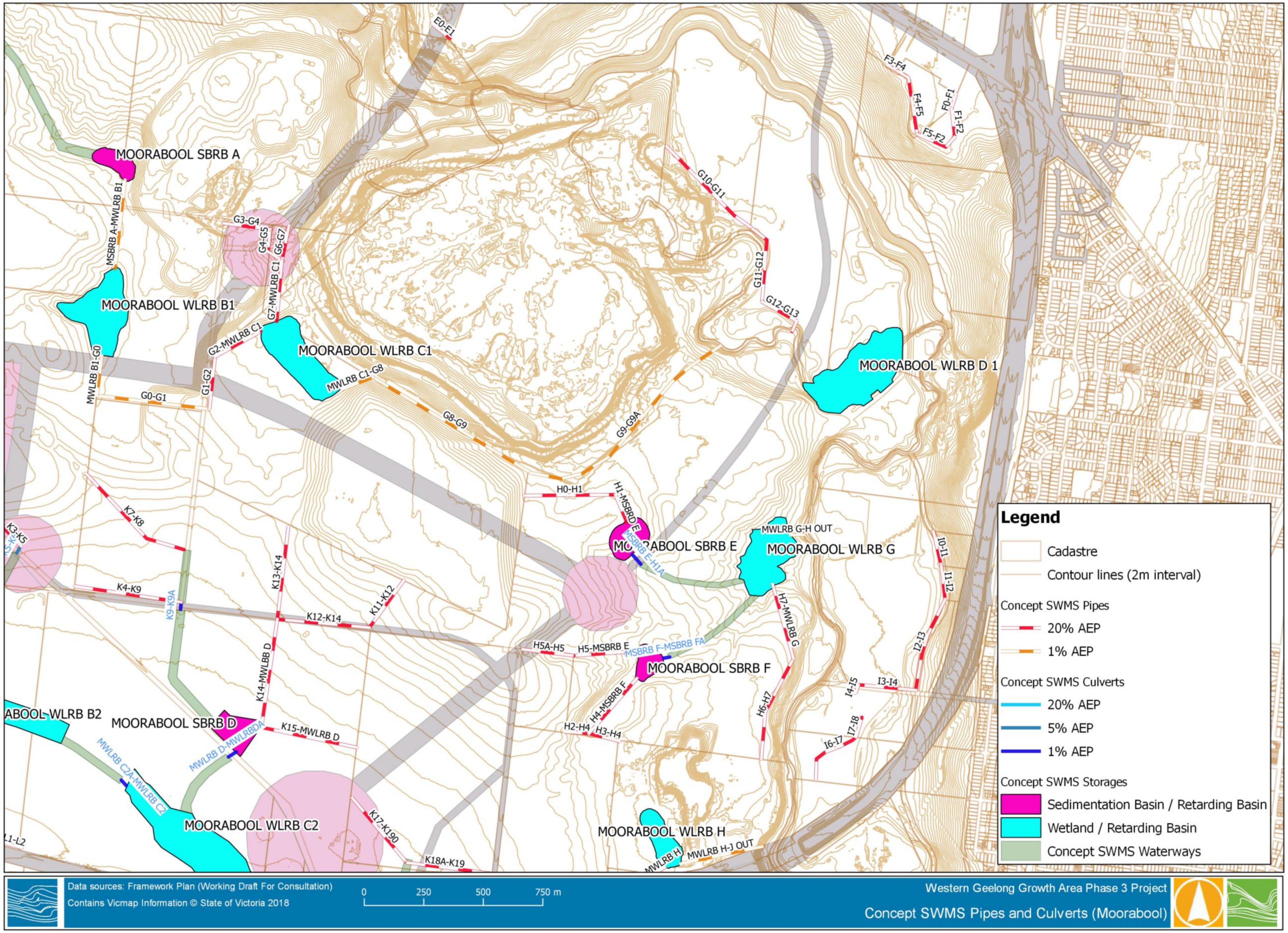
Once further structure plans for the WGGA are undertaken, the location and sizing of the assets within this strategy will be required to be further reviewed to ensure that the finings within this report are still applicable with future planning and zoning for the region.

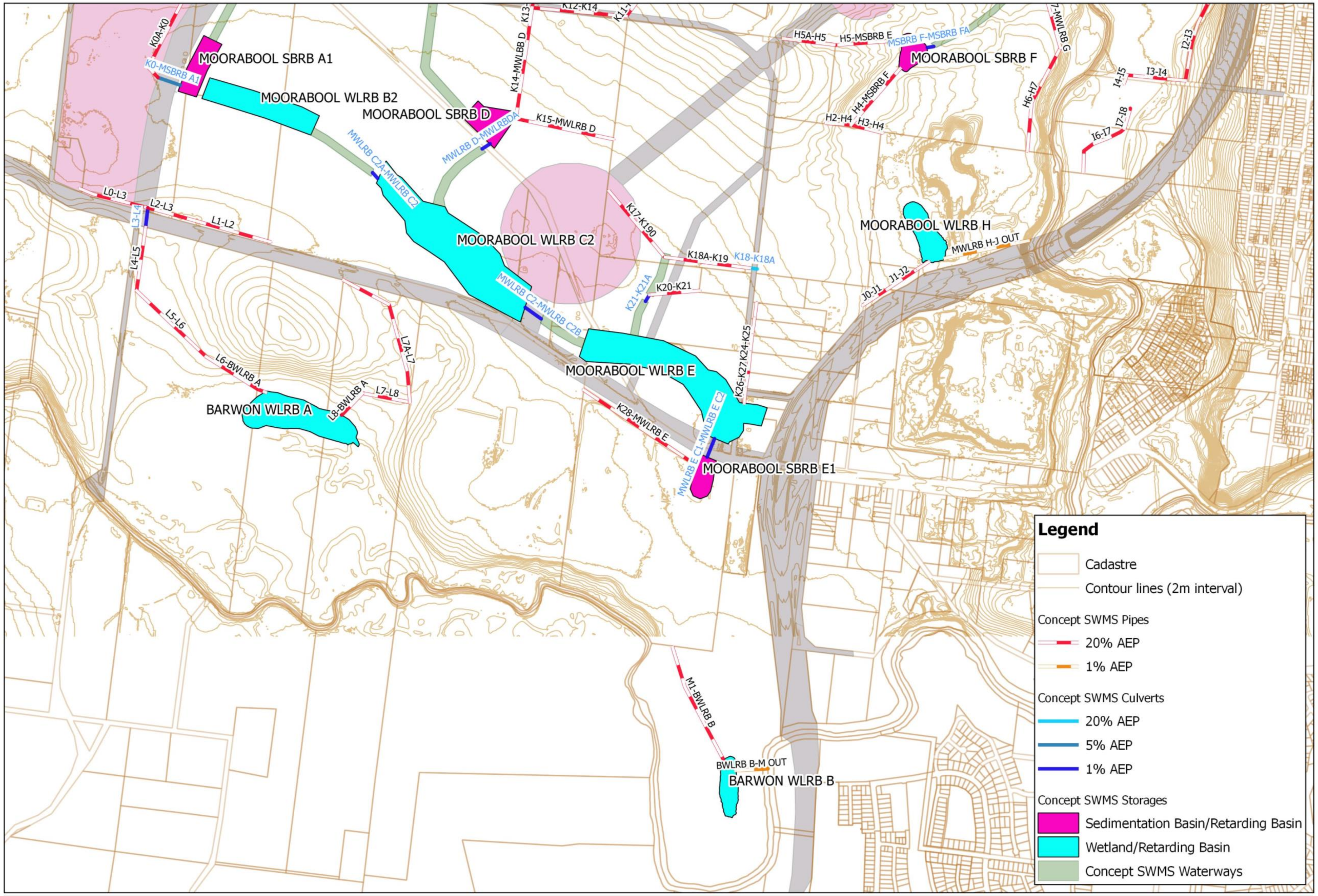
APPENDIX A
DEVELOPED CONDITIONS FRACTION IMPERVIOUS MAP


Legend
Cadastre
Fraction Impervious Values
0.05 - 0.1 Vegetated Land
0.2 Rural Living Residential
0.45 Residential (low density)
0.5 Road (minor)
0.55 Township Residential
0.6 Quarry
0.7 Road (major)
0.75 Residential (medium density)
0.85 Residential (high density)
0.9 Commercial / Industrial
Data sources: Framework Plan (Working Draft For Consultation)
Contains Vicmap Information © State of Victoria 2018
0 250 500 750 m
Western Geelong Growth Area Phase 3 Project
Fraction Impervious Values

APPENDIX B
CONCEPT SWMS PIPE AND CULVERT SIZING


Legend
Cadastre
Contour lines (2m interval)
Concept SWMS Pipes
20% AEP
1% AEP
Concept SWMS Culverts
20% AEP
5% AEP
1% AEP
Concept SWMS Storages
Sedimentation Basin/Retarding Basin
Wetland/Retarding Basin
Concept SWMS Waterways
MOORABOOL WLRB D
MOORABOOL SBRB C
COWIES WLRB A
COWIES WLRB B
COWIES WLRB C
MOORABOOL WLRB B
COWIES WLRB G
COWIES WLRB E
COWIES SBRB D
COWIES WLRB F
MOORABOOL WLRB A
Data sources: Framework Plan (Working Draft For Consultation)
Contains Vicmap Information © State of Victoria 2018
0 250 500 750 m
Western Geelong Growth Area Phase 3 Project
Concept SWMS Pipes and Culverts (Cowies & Moorabool North)


MOORABOOL SBRB A
MOORABOOL WLRB B1
MOORABOOL WLRB C1
MOORABOOL WLRB D 1
MOORABOOL SBRB E
MOORABOOL WLRB G
MOORABOOL SBRB F
MOORABOOL SBRB D
MOORABOOL WLRB C2
MOORABOOL WLRB H
ABOOL WLRB B2
Legend
Cadastre
Contour lines (2m interval)
Concept SWMS Pipes
20% AEP
1% AEP
Concept SWMS Culverts
20% AEP
5% AEP
1% AEP
Concept SWMS Storages
Sedimentation Basin / Retarding Basin
Wetland / Retarding Basin
Concept SWMS Waterways
Data sources: Framework Plan (Working Draft For Consultation)
Contains Vicmap Information © State of Victoria 2018
0 250 500 750 m
Western Geelong Growth Area Phase 3 Project
Concept SWMS Pipes and Culverts (Moorabool)



Data sources: Framework Plan (Working Draft For Consultation)
Contains Vicmap Information © State of Victoria 2018

Western Geelong Growth Area Phase 3 Project
Concept SWMS Pipes and Culverts (Barwon & Moorabool South)

Pipe ID	Length	Barrels	Pipe Diameter	% AEP	Pipe ID	Length	Barrels	Pipe Diameter	% AEP
A0-01	297	1	375	20	F1-F2	121	1	525	20
A1-CWLRB B	280	1	675	20	F5-F2	189	1	750	20
A2-CWLRB B	216	1	750	1	MSBRB A-MWLRB B1	375	2	1,350	1
CWLRB B-A OUT	130	1	900	1	MWLRB B1-G0	169	1	900	1
B0-B1	112	1	525	20	G0-G1	476	1	900	1
B1-B2	109	1	675	20	G1-G2	221	1	525	20
B2-B3	108	1	750	20	G2-MWLRB C1	220	1	675	20
B3-B4	232	1	825	20	G3-G4	197	1	525	20
B4-B7A	664	1	825	20	G4-G5	94	1	600	20
B5-B6	168	1	675	20	G5-G7	70	1	750	20
B6-B7	212	1	825	20	G6-G7	149	1	900	20
B16-B17	57	1	525	20	G7-MWLRB C1	256	1	1,200	20
B17-B18	120	1	600	20	MWLRB C1-G8	140	1	1,200	1
B18-B20	38	1	600	20	G8-G9	776	1	1,350	1
B19-B20	134	1	600	20	G9-G9A	1,017	1	1,350	1
B20-B21	78	1	900	20	G10-G11	490	1	1,050	20
B21-B22	94	1	900	20	G11-G12	348	1	1,350	20
B23-B24	87	1	525	20	G12-G13	214	1	675	20
B22-B24	33	1	900	20	H0-H1	383	1	1,050	20
B27-CSBRB D	165	1	1,200	20	H1-MSBRD E	128	1	1,500	20
B25-B26	93	1	525	20	H2-H4	104	1	525	20
B26-B27	110	1	675	20	H3-H4	133	1	450	20
B30-B30A	106	1	375	20	H4-MSBRB F	307	1	1,200	20
B31-CWLRB E	285	1	450	20	H5-MSBRB E	259	1	450	20
B34-B35	177	1	525	20	H6-H7	452	1	600	20

Pipe ID	Length	Barrels	Pipe Diameter	% AEP	Pipe ID	Length	Barrels	Pipe Diameter	% AEP
B35-B36	267	1	675	20	H7-MWLRB G	325	1	825	20
B40-B41	188	1	750	20	MWLRB G-H OUT	57	1	1,050	1
B41-B42	337	1	1,050	20	I0-I1	148	1	600	20
B38-B39	95	1	525	20	I1-I2	142	1	675	20
B39-B42	308	1	675	20	I2-I3	405	1	750	20
B42-CWLRB F	31	1	1,350	20	I3-I4	242	1	750	20
B43-B44	468	1	600	20	I4-I5	37	1	900	20
B44-B45	110	1	825	20	I6-I7	279	1	525	20
B45-B48	117	1	825	20	I7-I8	86	1	750	20
B46-B47	100	1	375	20	J0-J1	118	1	525	20
B47-B48	53	1	450	20	J1-J2	153	1	525	20
B48-B49	217	1	1,200	20	J2-MWLRB H	53	1	600	20
B49-B50	147	1	1,200	20	MWLRB H-J OUT	354	1	900	1
B50-B51	153	1	1,200	20	K1-K2	384	1	1,050	20
B51-B52	58	1	1,200	20	K2-K3	283	1	1,350	20
B52-B53	128	1	1,200	20	K3-K5	1,083	1	1,350	20
B53-CWLRB C	142	1	1,200	20	K7-K8	537	1	1,200	20
B12-B13	172	1	525	20	K13-K14	391	1	525	20
B13-B14	315	1	675	20	K11-K12	247	1	525	20
B7B-CWLRB C	58	1	525	20	K12-K14	388	1	750	20
B8-B9	88	1	600	20	K14-MWLBB D	460	1	1,050	20
B9-B10	110	1	750	20	K15-MWLRB D	409	1	1,350	20
B10-B11	202	1	825	20	L0-L3	291	1	450	20
B32-B33	635	1	675	20	L1-L2	418	1	675	20
B33-B33A0	108	1	675	20	L2-L3	104	1	900	20

Pipe ID	Length	Barrels	Pipe Diameter	% AEP	Pipe ID	Length	Barrels	Pipe Diameter	% AEP
B33A-CWLRB C	235	1	675	20	L4-L5	263	1	1,050	20
C0-C1	42	1	450	20	L5-L6	393	1	1,350	20
C1-C2	79	1	450	20	L6-BWLRB A	286	1	1,350	20
C2-C4	113	1	525	20	L7-L8	198	1	1,200	20
C3-C4	220	1	450	20	L8-BWLRB A	124	1	1,200	20
C6-C7	104	1	375	20	K28-MWLRB E	551	1	1,350	20
C7-C8	56	1	450	20	K17-K190	355	1	900	20
C4-C8	206	1	675	20	K18A-K19	352	1	675	20
C8-C9	19	1	675	20	K20-K21	206	1	525	20
C9-C10	180	1	750	20	K22-K23	64	1	450	20
C10-C11	82	1	750	20	K23-K24	69	1	525	20
C11-C12	88	1	750	20	K24-K25	70	1	675	20
C12-C13	58	1	750	20	K25-K26	83	1	750	20
C13-C14	87	1	750	20	K26-K27	67	1	900	20
C14-C15	83	1	825	20	K27-MWLRB E	61	1	1,050	20
C15-C16	78	1	825	20	M1-BWLRB B	511	1	675	20
C16-MWLRB B	131	1	825	20	BWLRB B-M OUT	133	1	1,050	1
C17-C18	100	1	450	20	D0-D1	100	1	525	20
C18-C19	97	1	525	20	D1-D2	81	1	675	20
C19-C19A	172	1	825	20	D2-D3	137	1	675	20
C20-C21	105	1	375	20	D3-D4	115	1	900	20
C21-C22	100	1	525	20	D5-MWLRB A	52	1	900	20
C22A-MWLRB B	168	1	900	20	E0-E1	95	1	750	20
MWLRB B-C23	481	1	600	20	B36-B37	217	1	675	20
C23-C27A	443	1	750	20	B37-B53	126	1	675	20

Pipe ID	Length	Barrels	Pipe Diameter	% AEP	Pipe ID	Length	Barrels	Pipe Diameter	% AEP
C24-C25	207	1	750	20	B37A-B37	106	1	525	20
C25-C26	453	1	900	20	C19A-C22	28	1	825	20
C26-MSBRB C	251	1	900	20	C22-C22A	19	1	900	20
MSBRB C-C27	93	1	525	20	C22B-C22A	24	1	600	20
C27-C27A	208	1	525	20	K4-K9	450	1	900	20
C27A-MWLRB D	359	1	1,350	1	H5A-H5	216	1	525	20
F3-F4	51	1	450	20	L7A-L7	624	1	675	20
F4-F5	294	1	525	20	K0A-K0	521	1	1,200	20
F0-F1	64	1	525	20	B27A-B27	250	1	675	20

Culvert ID	Length	Barrels	Pipe Diameter	% AEP
CWLRB A - A2	79	1	825	1
CWLRB C-B11	64	1	1,350	1
CWLRB F-B43	57	1	900	1
B24-B27	44	1	1,050	5
B29-B29A	37	1	1,350	20
B30A-B30B	39	1	825	20
B14-CWLRB C	29	1	1,350	1
B30C-CWLRB C	31	1	1,200	1
D4-D5	47	1	1,200	1
MSBRB E-H1A	53	2	1,200	1
MSBRB F-MSBRB FA	26	1	1,350	1
K18-K18A	30	1	675	20
K21-K21A	31	3	1,350	1
MWLRB C2-MWLRB C2B	80	2	1,200	1
MWLRB C2A-MWLRB C2	31	2	1,050	1
MWLRB D-MWLRBDA	39	4	1,200	1
K5-K6	32	3	1,200	5
L3-L4	81	1	1,350	1
MWLRB E C1-MWLRB E C2	81	4	1,200	1
K9-K9A	30	5	1,350	1
K0-MSBRB A1	97	3	1,200	5
K3-K3A	50	2	1,350	1

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