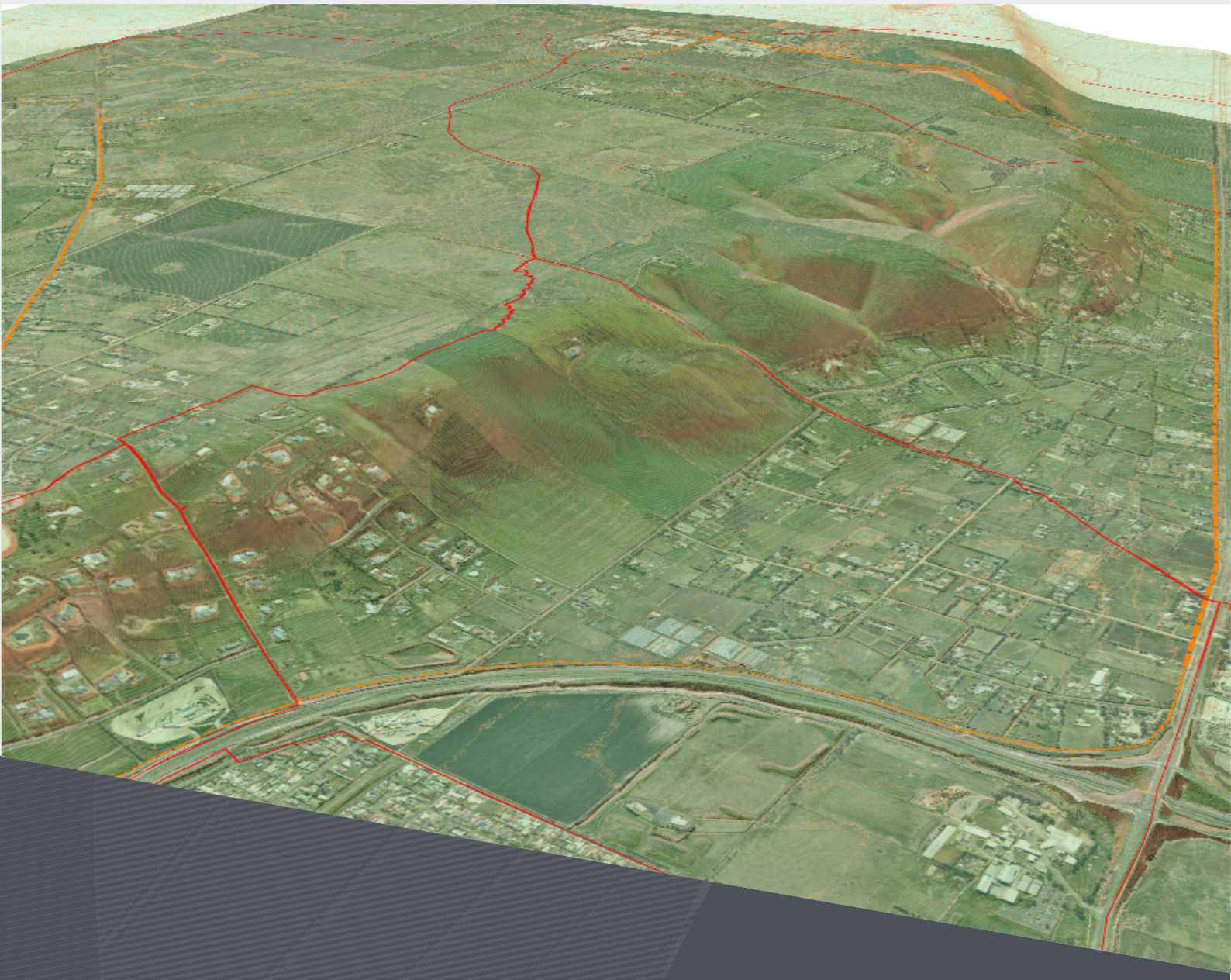
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Northern Geelong Growth Area

Flood Impact Assessment and Stormwater Management Strategy

Volume 2: Developed Conditions Report

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1 Introduction

1.1 General

SMEC Australia has been engaged to establish a site-based Flood Impact Assessment (FIA) and Stormwater Management Strategy (SMS) for the Northern Geelong Growth Area project (NGGA). The study has been undertaken to accord with requirements set out by the City of Greater Geelong (CoGG), who are committed to preparing an Integrated Infrastructure Delivery Plan (IIDP) and a Framework Plan for the region. The FIA and SMS form one of the technical input studies required to inform the IIDP.

The overall catchment strategy and the stormwater infrastructure identified in the SMS will be a key input to the establishment of the Framework Plan. It also provides CoGG a fully appreciation of the infrastructure requirements to develop the NGGA and ensure the impacts to existing developments downstream are mitigated within the study boundary.

The Study Area is approximately bound by the following landmarks:

- Staceys Road in the north;
- Bacchus Marsh Road in the east;
- Geelong Ring Road in the south; and
- Anakie Road in the south west.

During the course of the study, the original study area boundary as shown in the previous reports was amended to include additional areas along the western boundary. An outline of the revised study area is presented as Figure 1-1.

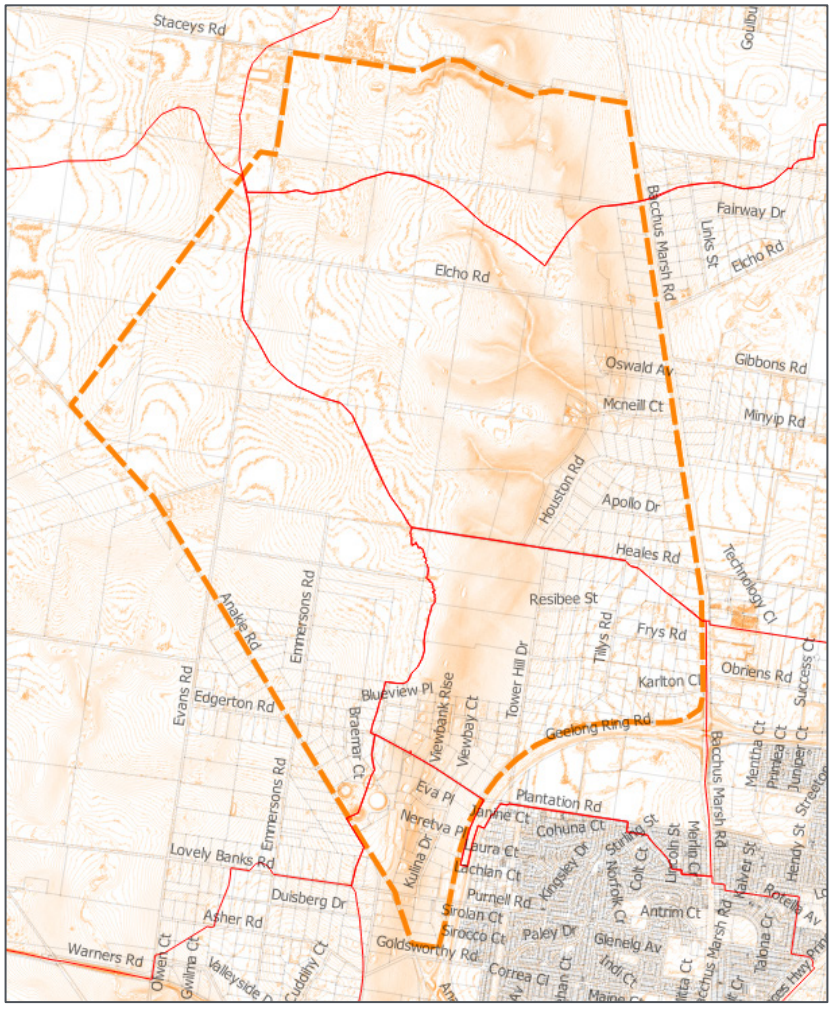


Figure 1-1: Study Area Boundary

SMEC has previously undertaken an assessment of the flooding associated with the investigation area under existing conditions, which is described in SMEC (2018). This report should be read in conjunction with the NGGA Flood Impact Assessment and Stormwater Management Strategy Volume 1: Existing Conditions Report (referred to as existing conditions report in the remainder of this report) and be considered as a continuation of the earlier study.

The purpose of this developed conditions report is to determine appropriate flood and stormwater quality risk reduction measures to allow development of the NGGA. The investigation area covers a greater extent than the study area and it has been defined as part of the project scope of work. The investigation area is detailed as a figure included as Appendix A3.

CoGG have established that the purpose of the FIA and SMS is to achieve the following outcomes:

- Manage the storage and movement of storm and flood water runoff through the site and downstream areas.
- Create an attractive and active community urban environment.
- Develop runoff management infrastructure which appropriately balances amenity, efficiency and safety.
- Ensure that the strategy does not result in any adverse impacts within the study and downstream areas.
- Integration of the runoff management infrastructure with other land uses and access requirements.
- Practicality in construction and maintenance for the infrastructure elements.
- Advice of orderly sequencing of development.

The original scope of works for the study as required by CoGG and Corangamite Catchment Management Authority (CCMA) is described in the briefing documents as follows:

- CoGG (2016) Northern and Western Geelong Growth Areas Project, Technical Reports – Scopes of Work, May 2016.
- CoGG (2016) Northern and Western Geelong Growth Areas Project, Flood Impact Assessment and Stormwater Management Strategy – File Note, 2nd June 2016.

Broadly, the study encompasses several phases:

- Phase 1 – Existing conditions modelling, followed by developed conditions modelling, and initial strategy development.
- Phase 2 – Workshops and additional modelling to refine the strategy.
- Phase 3 – Refinement of the strategy to a finalised document incorporating staging recommendations, costing, flood extents and final reporting.

This report is concerned, with the Phase 3 works describing flood and water quality management infrastructure associated with developed conditions and various considerations to enable the development of NGGA.

The scoping of Phase 3 was modified as the project progressed. The details of the scoping changes are covered in the document below:

- CoGG (2018) Northern Geelong Growth Area, Flooding and Drainage Phase 3 Scope (March 2018).

This report incorporates the added scope from Phase 3.

1.1.1 Catchments

There are in total five catchments which encompass the NGGA study boundary. These are defined as follows:

- Cowies Creek catchment (C153)
- Hovells Creek catchment (C157AX)
- Elcho Drain catchment (C157J)
- Wharf Road catchment (C156)
- St Georges Drain catchment (C155)

All of the catchments have been identified to have some degree of higher development except St Georges Drain catchment which is expected to remain low density residential living. The developed conditions study focuses on the four catchments within the NGGA boundary with some commentary on the St Georges Drain catchment.

1.2 Limitations

The development of the NGGA SMS has been undertaken at a broader catchment scale and a proof of concept level to ensure the above objectives and criteria can be met. The SMS should be used as an overall masterplan of the drainage for the growth area with opportunities for flexibility as more information becomes available. The exact infrastructure layouts, alignments and drainage configurations will change as the Framework Plan develops. There is potential for additional objectives to be identified and incorporated in the future. The proposed works is not intended to produce a final strategy but should provide a degree of certainty in the Framework Plan and the subsequent Precinct studies.

During the progression of this study, the assumptions with regards to the level of development, and CoGG ability to implement the SMS in terms of potential land acquisition requirements, are subject to further discussion and endorsement.

It is expected that a precinct scale stormwater management strategy for each four precincts would be completed subsequent to the implementation of the Framework Plan and IIDP. The next iteration should incorporate additional information which has not been covered in this report. Supplementary data to be considered should include a geotechnical investigation at the proposed locations of the retarding basins and wetlands. Some understanding of the ground conditions could provide a more economical solution in the long term.

The implications of sensitive environmental and biodiversity values downstream of the NGGA, one of which is the Ramsar Wetland in Corio Bay, is expected to be commissioned and addressed in the Precinct Structure Plan studies. The functional design of future retarding basins and wetlands, especially located in difficult sites with regards to relatively steep terrain and lack of drainage outfalls, should be examined in the next level of detail. This study has taken a conservative approach in terms of land required for future infrastructure works, as such there may be opportunities to reduce the land take reported in this study as part of the functional design.

In some cases, where a high embankment on a retarding basin is proposed, subsequent risk assessment and consequence analyses will be required to the standard of ANCOLD. Effort was made to minimise the number of retarding basins with a high embankment design.

A study on the potential for stormwater harvesting has been discussed in general in the Integrated Water Management Section of the report. It is recommended that the stormwater harvesting yield analysis be undertaken at the subsequent stage when there is more certainty on the implementation plan for delivering such assets. The ownership and management responsibilities of these infrastructures are still to be determined. However, it is considered that the various assets proposed in the SMS can be viewed as clear opportunities for harvesting of stormwater for other uses.

This report discusses for each catchment the additional studies that are recommended at the next level of detail of the stormwater management strategy.

1.3 Project Inputs

1.3.1 Background Reports

The developed conditions modelling has been informed by a range of existing reports as follows:

- Barwon Water (2018) – Report describing preferred approach to managing water across the site.
- Craigie (2017) – Report describing a conceptual arrangement for flood control and water quality infrastructure across the NGGA.
- SMEC (2017) – Memo describing risks to the downstream area from NGGA development.
- SMEC (2018) – Existing Conditions Report describing the flood extents associated with current conditions.

The existing conditions report and associated modelling has been used as the baseline document to which developed conditions modelling outcomes have been compared. The conceptual layout of water infrastructure presented in Craigie (2018) has formed the base starting position for the developed conditions modelling. The water management

report has been used to inform the developed conditions modelling to ensure that the proposed approach is consistent with the preferred strategy.

1.3.2 Site Strategies

The SMS for the NGGA is one of a number of studies and strategies which are being undertaken concurrently with this study. Inputs from those other strategies have been used in this study with the most relevant being as follows:

- Draft Framework plan for future urban development (Included as Appendix A1).
- Proposed Precinct network for NGGA (Included as Appendix A2)
- Proposed road network (provided electronically of CoGG)
- An alternative development layout used for sensitivity testing (provided as advice by CoGG)

The development analysis has been undertaken incorporating the above listed outputs.

1.3.3 Design Standards and Approach

The developed conditions modelling and SMS development has applied a range of industry standard document as listed below:

Flood Retardation Modelling

- Infrastructure Development Manual
- RORB Manual (Laurenson et.al., 2010)
- CoGG Design Notes
- Melbourne Water Waterway Corridors Guideline

Stormwater Quality Modelling

- Melbourne Water Wetland Design Manual
- Melbourne Water MUSIC Tool Guidelines 2018
- Stormwater Quality – Best Practice Guidelines (CSIRO, 2005)

1.4 Scope of Works

The scope of works for the study has incorporated the following tasks:

Development Infrastructure Strategy

- Review the water quality and retardation infrastructure locations nominated in Craigie (2017).
- Identify any constraints or opportunities to modify the infrastructure.
- Incorporate any modifications into the revised concept.

Hydrology

- Update the RORB rainfall runoff model developed for the existing conditions report.
- Modify the RORB model to represent the proposed developed conditions across the site.
- Further modify the RORB model to include retardation infrastructure.
- Modify the Retardation infrastructure to determine the storage volume required to meet the design requirements.

Flood Modelling

- Modify the Tuflow hydraulic models developed as part of the existing conditions report to represent existing conditions.
- Run the Tuflow model with inputs from the RORB model to confirm size requirements for retarding basins.
- Confirm the downstream impacts of the proposed development.

- Identify the required footprint and extent of earthworks required to construct the retardation infrastructure.

Water Sensitive Urban Design

- Create a MUSIC water quality model of the site representing developed conditions inclusive of water quality requirements.
- Determine the required size for various infrastructure elements to meet design requirements.
- Where feasible, co-locate the water quality infrastructure with retardation infrastructure and determine the overall footprint.

Staging and Integrating

- Review the proposed arrangement for separating the NGGA into precincts.
- Review the proposed staging for the various precincts.
- Identify any key constraints on precinct development with regard to staging, especially considering regions where catchments cross catchment boundaries.

Cost Estimate

- Develop broad scale cost estimates for the proposed works. (not included in this report but as a separate document)

Downstream Impact Risk Assessment

- Assess the various stormwater related risks to downstream areas of NGGA boundary.

2 Methodology

2.1 General

The various elements described in the scope of works involve varying degrees of complexity. The methodology for the hydrology, flood hydraulics and stormwater quality aspects of the works are described in further detail below.

2.2 Hydrology

2.2.1 Scope

The steps required to complete the hydrology aspects of the works are as follows:

- Amend hydrologic (RORB) existing conditions model to match the flows agreed with CoGG from the separate Tuflow model.
- Update the RORB model to represent developed conditions and produce the new set of increased developed conditions flows.
- Incorporate retarding basins into the RORB model in locations nominated in SMS and size the infrastructure to ensure target flows are achieved.

2.2.2 Amend Existing Conditions RORB Model

The RORB model applied in the existing conditions modelling (SMEC, 2018) assumes that attenuation throughout the model is directly proportional to stream length. The model was amended to ensure that the modelled delay matches that indicated by the Tuflow model at the edge of the study area and also where retarding basins are proposed to be constructed. The RORB model was amended by altering stream lengths to achieve the desired outcome.

The resulting RORB model provided similar peak flows at the nominated locations to those produced from the Tuflow model.

2.2.3 Incorporate Development into the RORB Model

The RORB model sub areas and stream types were amended to represent developed conditions. The developed conditions were represented through increased impervious areas and altering stream reaches from type 1 to type 2 where appropriate. The specific changes to developed areas which were made are as follows:

- The impervious fractions were identified by applying CoGG (2012a) along with the proposed development overlay.
- The proposed Urban Growth Zone (UGZ) was developed to its full extent with densities in the range of 15 d/ha to 20 d/ha. An average density of 15.4 d/ha was applied for modelling purposes.
- The existing conditions within the Lara Energetic Materials Manufacturing Plant (LEMMP) industry buffer, Electricity Powerline Easements and a small Gas pipeline buffer zone (~3m TBC) were modelled as unchanged in the developed conditions Scenario 1.
- The small section of Farming Zone (FZ) land close to the corner of Elcho Rd and Bacchus Marsh Road was modelled as developable with an average density of 15.4 d/ha.
- Areas that are designated as Rural Land Zone (RLZ) within the NGGA were modelled as typical rural density, but developed to the full potential that the zoning allows with an average density of 6.4 d/ha.
- The region currently zoned FZ to the west of Evans Road was modelled with a UGZ zoning, with an average density of 15.4 d/ha.
- Two potential employment scenarios were investigated as a sensitivity test for Elcho Drain and Hovells Creek catchments. The extents of the potential employment areas are shown in Appendix B3 & B4

The developed conditions RORB model was rerun to estimate the increase in runoff associated with the development.

2.2.4 Incorporate Retarding Basins into the Model

Retarding basins were added to the RORB model at locations nominated in the SMS. The basins were sized within RORB to ensure that there is no downstream adverse impact. An iterative process in adjusting the basin storage,

embankment height, outflow pipe and spillway configurations were trialled until the target flows were achieved. The basins were sized for a 1 in 100 Annual Exceedance Probability (AEP) event.

2.2.5 Design Flows for Infrastructure

The 1 in 100 AEP and 1 in 5 AEP events peak flow from the developed condition models with retarding basins, were used to estimate the design flow for the constructed waterways. In cases where a diversion pipe was proposed in Cowies Creek, the RORB model was adjusted to include a pipe diversion for the 1 in 5 AEP event runs.

2.3 Hydraulic Modelling

2.3.1 Scope

A hydraulic model was developed for the purposes of providing a cross check on the outcomes from the RORB modelling for the 1 in 100 and 1 in 2 AEP critical durations. The RORB model utilises a simplified form of hydraulic modelling to size retarding basins. The model's pipe and spillway formula and the one dimensional stage storage equation has the potential to underestimate the required storage volumes in cases where basins are relatively narrow and large compared to inflows. Further, the models may be less accurate in cases where the outflow relationship does not properly account for the effects of downstream water levels on the low-level outlet capacity.

The hydraulic model was also used to confirm that flood levels and extents in the region downstream of the study area boundary are not increased by the proposed development works.

2.3.2 Tuflow Development

The Tuflow model base used in the existing conditions report was used for the developed conditions modelling. The alterations made to the model were as follows:

- The terrain has been modified to represent the retarding basin shapes and associated outlet pipes located along the boundary of the study area.
- The inflows to the basins from the developed conditions RORB model have been input as a hydrograph in Tuflow. The hydrograph from the critical storm duration corresponding to the highest peak outflow was used as the inflow to the various retarding basins. For catchments which had multiple retarding basins, multiple storm duration events were undertaken.
- The retarding basins have been modelled as 2d z-shape modifications with side slopes of 5H :1V. The pipe configurations and spillways were modelled as 1d elements.

The models were run in existing and post development conditions to assess the downstream and upstream conditions. Adjustment to the outlet configuration were made where required to ensure that the outflow from the Tuflow model retarding basin is less than that estimated from the RORB model. As part of the design iteration, the storage and footprint area were increased to meet target flows.

Model runs were undertaken for 1 in 2 AEP and 1 in 100 AEP flood events with multiple durations to determine the critical durations. Runs were likewise undertaken for two development scenarios.

The 1 in 2 AEP modelling undertaken for this study was intended to demonstrate the potential issues of increased runoff volumes to downstream drainage systems including its impacts to existing retarding basins. Although this was demonstrated at a high level for each catchment it should be noted that the modelling was based on a simplistic assumption that the flow network of the 1 in 2 AEP event is the same as the 1 in 100 AEP. In reality the flow network will most likely be conveyed through pipes and therefore the results should be used as an approximation only. Furthermore, the outlet configuration and storage modelling applied in this assessment is considered to be conceptual as the detail cannot be known at this stage of the design. The issue of increased runoff volume in frequent events can be assessed in more detail as part of the precinct investigation.

2.4 Stormwater Quality Modelling

2.4.1 Scope

Stormwater quality treatment systems have been sized to determine the footprint required to achieve requirements of the Best Practice Environmental Management Guidelines (BPEMG) within the NGGA boundary. The stormwater pollutant reduction targets for urban developments as set out in the BPEMG are summarised below.

- 80% Total Suspended Solids

- 45% Total Nitrogen
- 45% Total Phosphorous
- 75% Gross Pollutants

The proposed systems have been modelled in MUSIC with the future development scenarios to confirm the size requirement.

2.4.2 Sedimentation Basins

The stormwater quality assets proposed in the SMS consist of a number of sedimentation basins and large wetland systems co-located within the base of the regarding basins. This approach has generally been carried forward from the initial concept strategy by Craigie (2017). The proposed conceptual design utilises the same space within the retarding basin footprint to have a secondary function as a stormwater quality treatment system. This approach minimises the land take required and the overall infrastructure cost. The design of these combined systems has the added complexities of bypass channels and combined outlet configurations, but they have been implemented successfully across the growth areas around Melbourne and is considered a reasonable approach to be adopted for the NGGA.

Sedimentation basins are proposed as primary treatment for all wetland systems. The modelling included multiple sediment basins for separate subcatchment areas. Several sedimentation basins are stand-alone systems which are intended to capture the sediments from the upstream development and end of pipe systems. The stand-alone sedimentation basins will minimise the sediments depositing along the main waterways. Sediment basins have been sized based on the methodology outlined in Stormwater Quality – Best Practice Guidelines (CSIRO, 2005) and the Melbourne Water Wetland Design Manual. Maintenance access tracks, bypass channels and sediment drying areas have been allowed for in determining the footprint areas. The sedimentation basins have been assumed to have a minimum depth of two meters to allow sufficient depth and cover for incoming stormwater pipes. A desired clean out frequency of every 5 years have been assumed for all sedimentation basins.

2.4.3 Wetlands

Wetlands with sedimentation basins have been proposed for all treatment systems. This has been adopted as it provides the most conservative land take required to meet Best Practice treatment targets. Treatment alternatives such as bioretention systems can be substituted at the functional design stages should CoGG deem it more appropriate.

Although the land required for wetlands are much larger than bioretention systems, constructed wetlands in urban areas provide multiple benefits beyond the primary purpose of water quality treatment. It provides flora and fauna habitats and opportunities for public interactions which contributes to the objectives of enhancing amenity and liveability to the surrounds.

All sedimentation basins and wetlands have been assumed to be online systems consistent with the treatment train approach. Offline systems can be adopted at the subsequent design stages should it be required by the CoGG. The layout proposed does not preclude the future design to adopting an offline design. An offline option should be considered during the functional design stages when more certainty on the catchment becomes available. An inundation frequency analysis and plant specification may need to be undertaken to confirm the suitability of the online system.

The wetland extended detention depth adopted across the study is 350mm with nominal extended detention time of 72 hrs. Allowance for maintenance access tracks, buffer zones, safety batters have been added as approximately 20% of the treatment area. This is in addition to the sedimentation basins and dry-out area. In locations where the topography is quite steep, additional investigation of the earthworks and typical cross sections were undertaken to ensure the land take required considers the additional excavation to achieve the safety batter requirement. The safety batters assumed is 1 in 5 as a minimum.

In most cases the wetland footprint area was the determining area in setting the footprint of the combined wetland/retarding basin system, rather than the area required for flood retardation.

2.4.4 MUSIC Parameters

Rainfall record and evapotranspiration patterns adopted in the MUSIC modelling were sourced from CoGG Design Notes (2012a). For the model runs which required 1 in 10 AEP rainfall inputs, the Melbourne Water reference data in

Little River were used. The parameters adopted in the wetland and sedimentation basin treatment nodes remained as default values.

Each land type was modelled as an urban node in MUSIC. The expected dwelling densities were translated to residential allotment size which were then converted to the appropriate fraction of imperviousness set out in Melbourne Water MUSIC Tool Guidelines. The soil parameters used in the modelling were based on the updated Melbourne Water Guidelines. The pollutant removal results were based on stochastic method and have been recorded in this report.

2.5 Constructed Waterways and Trunk Drainage

Constructed waterways have been designed to provide a controlled flood conveyance to the outlet of each catchments. The nominated constructed waterways widths are based on the hydraulic requirements and further land buffers around this to meet waterway specific objectives.

The hydraulic widths of the waterways are based on the channel capacity required to convey the design flow using the Manning's open channel equation. A trapezoidal channel to carry the 1 in 100 AEP design flow with a pilot channel to carry the 1 in 5 AEP event have been assumed, to get a rough estimate of the hydraulic requirements of the channels. The Melbourne Water Corridor Widths Guidelines were used to determine the total corridor widths which is based on the hydraulic widths.

An indicative alignment of the truck drainage has been shown in the layout of the SMS. These pipes indicate the general direction of the underground pipes as well as diversions pipes which forms the design intent of the SMS. In Elcho Drain catchment, a trunk drainage is proposed alongside an existing gully which are earmarked to be retained as a natural waterway. This trunk drainage is proposed to carry the regular flows (nominal 1 in 5 AEP) from the upstream catchment down the monocline with the purpose of eliminating the risk of erosion on the natural waterways from the regular stormwater flows. For the same reasoning mentioned, a drainage pipe is potentially required in Hovells Creek catchment Scenario 2 downstream of RB H into RB D.

3 Development Strategy

3.1 Site Constraints

The site drainage concept is constrained by a number of key features across the study area as follows:

- The monocline which runs parallel to the study areas eastern boundary
- The high pressure gas main which runs through the site along an approximate north east - south west alignment
- Buffer zones and non-developable areas which partially impact on various portions of the study area
- The power transmission lines which run through the south east quadrant of the study area
- Other constraints that have been considered in the development of the SMS includes:
- Existing title boundaries and road reserves
- Topographical constraints at the interface of Bacchus Marsh Road and Anakie Road
- Requirements to limit inflows into downstream systems which have been set in place by previous drainage strategies
- Flow capacities of downstream drainage systems

The above constraints impact upon all aspects of the framework plan and the SMS concept has been influenced accordingly.

3.2 SMS Infrastructure Concept

As discussed above, the stormwater management strategy described in Craigie (2017) was used as the initial basis for developing the final arrangement applied in this study. Minor modifications were made where opportunities were found to produce a better outcome. Modifications to the locations of the proposed works were made to ensure that the infrastructure layout does not conflict with the proposed road network. Considerations were made in locating the works to logically fit within existing title boundaries where possible. However, where it was not possible to do so, the natural terrain was used as the primary driver in setting the locations of the proposed infrastructure.

The assumptions in the allowable development within the catchment was a key factor to the overall change in this SMS compared to Craigie (2017). It has been assumed in the SMS that areas along the monocline are developable to standard density with commercial/industrial development on the lower catchment of the monocline, whereas the Craigie (2017) report assumed rural and low-density urban development.

Furthermore, the initial strategy aimed to avoid crossing the high pressure gas main with the rational being that underground drainage would need to go under the gas main which could be very costly. This could be avoided by diverting the frequent flows from the upstream catchment areas of Elcho Drain across catchments into Hovells Creek catchment. This assumption was reviewed in further detail in this SMS and it was determined that it is possible to cross the gas main by discharging at the surface of the existing gully which goes over the gas main north of Elcho Road.

A catchment based approach was adopted to the entire NGGA SMS. The drainage layout was modified to minimise the pipe diversions across catchment boundaries as discussed previously. The majority of the proposed works is largely influenced by the general topography of the land with the aim to follow the natural drainage lines as much as possible. Flatter terrains have been chosen for large retarding basins/wetlands to minimise the excavation works required. Major overland flow paths and existing gullies across the monoclines were designated to be the future constructed waterways. Some of the waterways are intended to be retained in a natural state where preservation can be achieved. In situations where flood conveyance was required, the natural gullies have been proposed to be formalised as constructed waterways with the intent of maintaining the natural look. The proposed constructed waterways will require specific design consideration of erosion protection since the grades are relatively steep and erosion is likely.

A balance of end of catchment regional systems and upper catchment treatments are proposed across the NGGA. Retarding basins have been spread across the upper and lower parts of the catchment. This approach provides the benefit of reducing the hydraulic width required for the waterways to convey the developed conditions flow and in turn reduce the infrastructure cost to the community. Allocating the retardation at various locations also spreads the overall risk of flooding at particular areas. Should one retarding basin exceeds the capacity and fails, there is another

retarding basin downstream which can provide flood protection. This philosophy is also applicable to the treatment capacity of the proposed wetlands and sedimentation basins.

The proposed layout of the retarding basins/wetlands in conjunction with the proposed constructed waterways provides an environmental corridor and habitat connectivity across the catchment. The proposed number and locations of the works also results in an effective distribution of assets that will provide the desired amount of open space and increased amenity across the various precincts.

The proposed road layout also influenced the locations of the retarding basins in that the asset locations provide some visual amenity adjacent to main road frontages.

Pipe drainage is proposed on the upper catchments across the NGGA. The conceptual alignments generally follow the overland flow paths and are proposed to connect into either a waterway or a retarding basin. The exact alignments of the future pipes will eventually follow the future road alignments which are yet to be finalised at this stage. There are a number of locations where the flows have been diverted across the natural terrain and redirected to other subcatchments and retarding basins within the same catchment in order to minimise the outfall locations adjacent to the NGGA boundary.

The overall layout of the SMS detailing the location of stormwater control infrastructure is included in Appendix B.

3.3 Development Scenarios

Two separate scenarios have been modelled for the study site as directed by COGG. The difference between the two modelled scenarios consisted of varying assumptions relating to the degree of development in the buffer zone in the north western portion of the site and also the degree of development in the Elcho Drain catchment.

The difference in the two scenarios are embodied as altered fractions impervious in the affected regions which are detailed on images included in Appendix B. Scenario 1 has less developable area than Scenario 2 with the second scenario having two additional employment areas in the catchment. A sensitivity assessment on Scenario 2 was completed as part of this study to identify the extent of the additional infrastructure required as a result of the two potential employment areas.

4 Cowies Creek (C153)

4.1 Site Description

The Cowies Creek catchment is located in the south western portion of the study area. The outlet of the Cowies Creek catchment is located at the railway bridge crossing. The total area of the catchment included in the investigation is 20.7 km^2, of which the study area comprises around 28%. There are seven separate waterways or drainage lines which discharge flows across the study area boundary, predominately across Anakie Road. A map of the sub catchment is included as Figure 4-1.

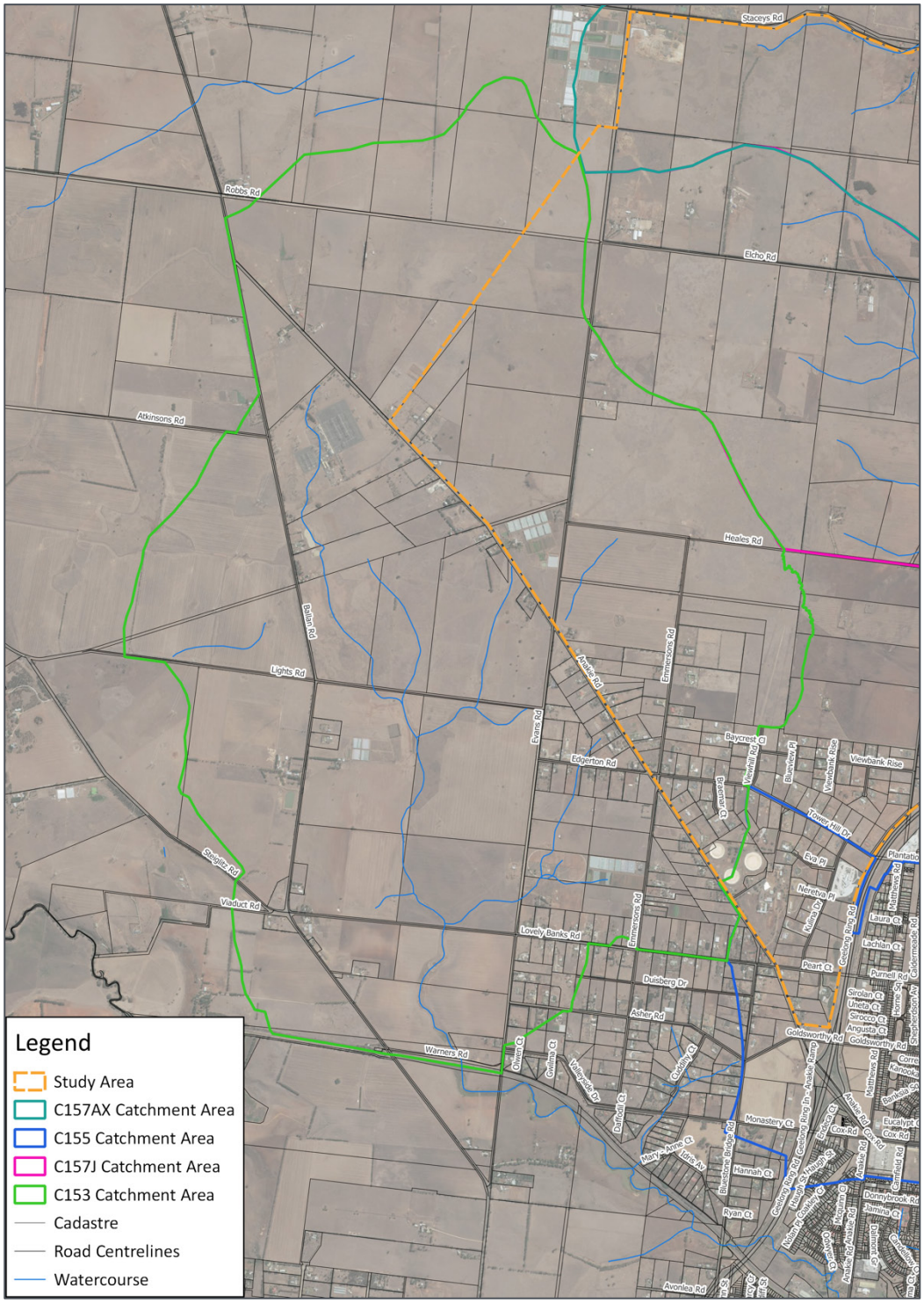


Figure 4-1: Cowies Creek Sub Area

4.2 Site SMS

The conceptual arrangement of site stormwater infrastructure is detailed in Figure 4-2.

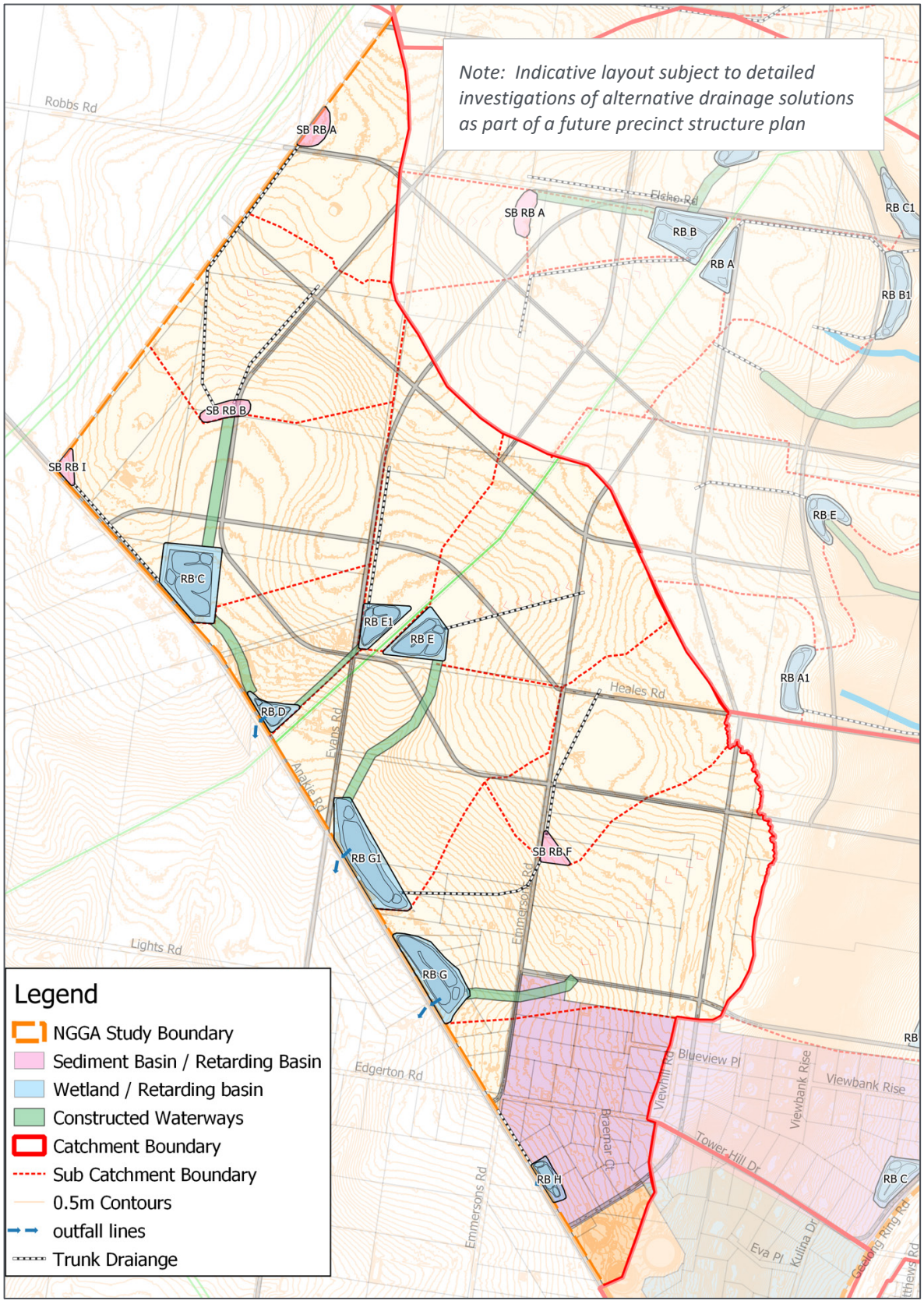


Figure 4-2: Cowies Creek SMS Infrastructure

4.3 Hydrologic Modelling

4.3.1 General

The hydrologic model for the Cowies Creek catchment was modified in a number of respects. Initially, the model was modified to ensure consistency between the RORB model existing conditions peak flows and the Tuflow existing conditions flows. The model was then further modified to reflect the proposed developed conditions.

4.3.2 Existing Conditions Adjustments

The modifications made to the existing conditions RORB model described in SMEC (2018) are as follows:

- The length of a select number of stream lengths was altered to change the relative delay in that portion of the catchment. Increasing the length of select stream sections has the effect of increasing attenuation and reducing peak flows. Reducing stream lengths has the opposite effect.
- In a number of cases, the direction of flow was re-aligned to be consistent with flow patterns observed in the Tuflow model.

The modifications made to the model are detailed on a figure included as Appendix C.

The modelled outcomes showing the adjusted peak RORB flows relative to the Tuflow outputs documented in SMEC (2018) are detailed in Table 4-1.

Table 4-1: Comparison Between RORB modelled flows and Tuflow Existing Conditions

OUTLET ID	CATCHMENT AREA (ha)	1 IN 100 AEP PEAK DISCHARGE (m^3/s)		1 IN 2 AEP PEAK DISCHARGE (m^3/s)	
		RORB Adjusted	**SMEC (2018) Tuflow**	**RORB Adjusted**	**SMEC Tuflow**
2	150	7.4	7.4	0.5	1.7
4	160	8.8	8.8	1.5	1.9
5	160	5.6	5.6	1.0	1.4
6	20	2.6	2.6	0.4	0.6
7	30	2.8	2.8	0.5	0.5

4.3.3 Developed Conditions Adjustments

The modifications to the RORB model to represent developed conditions were as follows:

- The proportion impervious of the catchment sub areas was modified to reflect the proposed density of development.
- In a number of cases, the direction of flow was re-aligned to reflect the use of stormwater pipes or open channels to redirect flows.
- Retardation basins were included into the model in line with the proposed development strategy.

The RORB model was run to determine the retardation infrastructure and the key outcomes are detailed in Table 4-2.

Table 4-2: 1 in 100 AEP Event Retardation Basin Impact

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A (SB)	36	2.4 (3hr)	1.3 (3hr)	-
B (SB)	94	3.6 (3hr)	1.9 (3hr)	-
C	180	7.5 (12hr)	4.9 (12hr)	-
E1	36	1.6 (12hr)	0.5 (12hr)	-
I (SB)	13	2.0 (1hr)	1.3 (1hr)	-

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D	**204**	**5.2 (12hr)**	**4.7 (12hr)**	**7.4**
E	65	6.6 (2hr)	5.5 (2hr)	-
F (SB)	47	2.9 (3hr)	1.8 (12hr)	-
G1	**179**	**8.0 (9hr)**	**5.4 (9hr)**	**8.8**
G	**157**	**5.7 (12hr)**	**4.1 (12hr)**	**5.6**
H	**56**	**2.7 (9hr)**	**1.7 (9hr)**	**2.8**

The basins in the above table have been presented in sub catchment groups. Target flows are reported at the outlet across the study area boundary.

The key characteristics of each retarding basin are detailed in Table 4-3. The total RB footprint area also includes additional area allowance for cut batters and embankment footprint.

Table 4-3: Retardation Basin Characteristics

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
A (SB)	1 No 1050mm	10,500	1.1	-
B (SB)	1 No 1200mm	13,500	1.2	-
C	1 No 525mm [10m SPILLWAY]	77,600	6.0	-
E1	1 No 600mm	15,300	2.2	-
I (SB)	3 No 1200mm	2,140	0.6	-
D	3 No 1200mm	14,200	1.4	1.6 m high, 300 m long
E	1 No 900mm [20m SPILLWAY]	8,340	3.3	-
F (SB)	1 No 1050mm	10,600	0.9	-
G1	1 No 900mm [10m SPILLWAY]	59,500	6.2	-
G	3 No 1050mm	49,000	4.9	-
H	1 No 1200mm	11,400	1.2	-

4.3.4 1 in 2 AEP Event Cross Check

The outlet configuration adopted in the 1 in 100 AEP have been run to assess the effectiveness in retarding the 1 in 2 AEP event. The results of the 1 in 2 AEP runs are presented in Table 4-4.

Table 4-4: 1 in 2 AEP Event Retardation Basin Impact

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A (SB)	0.67 (12hr)	0.42 (12hr)	-
B (SB)	0.9 (12hr)	0.7 (12hr)	-
C	1.7 (48hr)	0.4 (48hr)	-
E1	0.7 (12hr)	0.2 (12hr)	-
I (SB)	0.4 (9hr)	0.3 (9hr)	-

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D	**0.52 (48hr)**	**0.51 (48hr)**	**0.5**
E	0.7 (12hr)	0.2 (12hr)	-
F (SB)	0.8 (9hr)	0.6 (9hr)	-
G1	**2.4 (12hr)**	**0.8 (2hr)**	**1.5**
G	**1.8 (12hr)**	**1.0 (12hr)**	**1.0**
H	**0.9 (12hr)**	**0.5 (12hr)**	**0.5**

4.4 Hydraulic Modelling

4.4.1 1 in 100 AEP Event Modelling

A Tuflow model was developed for the purposes of confirming the outcomes from the retardation basin sizing undertaken using the RORB model. The model was modified to include the retarding basins described above for the 1 in 100 AEP flow event. Three durations were run of Cowies Creek which include 2hr, 9hr and 12hr duration corresponding to the existing conditions modelling. The outcomes from the modelling are detailed in Table 4-5.

Table 4-5: 1 in 100 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D	**4.7 (12hr)**	**0.5 (12hr)**	**7.4**
G1	**5.4 (9hr)**	**8.8 (2hr)**	**8.8**
G	**4.1 (12hr)**	**4.1 (12hr)**	**5.6**
H	**1.7 (9hr)**	**1.7 (9hr)**	**2.8**

In addition, the flood maps and flood inundation depths are included as Appendix D1.

The outputs indicate predominately that the flood flows and levels are either lowered or remain unchanged and can be mitigated by the proposed works.

The afflux maps indicate that there are some localised areas where the flood levels are increased by an insignificant amount. Consistent with the intended purpose of the retarding basin, the underlying concern with increased flood volume cannot be mitigated by the retarding basin design itself. As predicted, the result shows that there is some minor increase in flood level in areas of trapped low points where water does not escape. This is evident in the existing farm dams and local ponding behind roads without adequate drainage outlets. This issue becomes visible due to the increase in volume of runoff as a result of increased development. These areas of increased flooding are not critical and the outcome is considered to be generally acceptable. This outcome is further supported by the observation that:

- Flood flows at these locations are lower than in the existing conditions model.
- The vast majority of the flood extent shows that there is no increase in flood level in the developed conditions.

4.4.2 1 in 2 AEP Event Modelling

In order to demonstrate the impact of the upstream development, the 1 in 2 AEP event has been run in the hydraulic model. The model results are presented in Table 4-6.

Table 4-6: 1 in 2 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D	**0.51 (48hr)**	**0.5 (12hr)**	**0.5**
G1	**0.8 (2hr)**	**0.6 (12hr)**	**1.0**
G	**1.0 (12hr)**	**0.9 (12hr)**	**1.0**
H	**0.5 (12hr)**	**0.5 (12hr)**	**0.5**

The retarding basin and outlet configuration assumed in the flood modelling demonstrates that the peak developed flow in the frequent events can be controlled and mitigated. However, it should be noted that the modelling undertaken is based on a high level stage storage relationship. Detailed modelling will be required at a later stage to confirm the exact outlet configuration requirements. Further modelling and volume assessment could be built upon from this study.

4.5 Stormwater Quality Treatment (MUSIC)

A MUSIC model has been developed for the purposes of determining the required footprint to meet water quality objectives. Each of the water quality elements has been modelled as either a stand-alone sedimentation basin or a wetland with sedimentation basin. All water quality elements have been co-located with a retarding basin. The model schematic is included as Appendix D3 and the outcomes of the modelling at the study boundary are included Table 4-7.

Table 4-7: MUSIC Modelling Outcomes

ID	SB AREA (m^2)	WL TREATMENT AREA (ha)	NITROGEN REMOVAL (%)	PHOSPHOROUS REMOVAL (%)	TSS REMOVAL (%)
A (SB)	280	-	-	-	-
B (SB)	560	-	-	-	-
C	590	4.2	-	-	-
I (SB)	110	-	-	-	-
E1	260	1.3	-	-	-
D	**180**	**0.6**	**45.3**	**71.9**	**87.8**
E	480	1.7	-	-	-
F (SB)	370	-	-	-	-
G1	**460**	**3.7**	**49.4**	**74.9**	**90.9**
G	**840**	**2.8**	**46.1**	**71.3**	**87.3**
H	**430**	**0.5**	**45.0**	**69.9**	**88.8**

4.6 Infrastructure Characteristics

4.6.1 Treatment Device Footprint

The required footprint for treatment devices has been determined by summing the water surface area for the sedimentation basin and wetland based on MUSIC and multiplied by a factor of 1.2 to provide allowance for the variety of ancillary elements required around the wetland, such as access and dry out zones.

The total footprint areas of the retarding basins have been sized to account for the stormwater quality footprint areas. In most cases, the wetland footprint area has been adopted as the retarding basin base level with the air space above

utilised for retarding basin flood storage. Table 4-8 below shows the water quality footprint compared to the total retarding basin footprint.

Table 4-8: Treatment Device Footprint

ID	WATER QUALITY FOOTPRINT AREA (ha)	TOTAL FOOTPRINT AREA (ha)
A (SB)	0.03	1.1
B (SB)	0.07	1.2
C	5.1	6.0
E1	1.6	2.2
I (SB)	0.01	0.6
D	0.8	1.4
E	2.1	3.3
F (SB)	0.05	0.9
G1	4.4	6.2
G	3.5	4.9
H	0.7	1.2

4.6.2 Additional Infrastructure

A variety of additional infrastructure is judged to be required as part of the development, with the detail varying from catchment to catchment. The infrastructure relevant to this catchment is as follows:

- Waterway easements – stormwater runoff is directed to basins via pipes or waterways. Consideration has been given to the required waterway width which is a function of catchment area. Easement widths are between 30m to 45m. Details of channel widths are included in Table 4-9.
- Erosion Protection – discharge from the various basin outlets immediately downstream of the study area boundary are directed into drainage lines through private property for which there is currently no easement. The existing drainage lines run along a relatively steep longitudinal gradient. There will be an increase in the frequency and duration of flows from the retarding basins which will likely cause nuisance on the downstream properties through scouring and bogginess along the existing drainage lines. It is recommended that the existing drainage lines be modified with erosion protection. If the waterway is to become a CoGG asset then it may be appropriate to create an easement to allow the assets to be appropriately controlled. Alternatively, if there is funding available, provision for an underground pipe drainage to mitigate the nuisance potential could also be investigated in the future. This relates to the following point concerning drainage outfalls.
- Retarding Basin Outlets – the retarding basins located along Anakie Road all have proposed outlets which have larger diameters than the existing culverts under that road. Considering the survey information, it was confirmed that most of the culverts do not capacity for the 1 in 100 AEP existing conditions flows with the culvert sizes varying from a small 225mm pipe diameter to a 900W x 600H box culverts. Therefore, it was proposed to increase the culvert sizes and set the invert levels based on the retarding basin design. Sizing the retarding basins to meet the existing capacity of the culverts would have resulted in excessively large retarding basin storage with high embankments. The proposed outlet pipes are required to be constructed under the road and extended to a point where they can daylight into an outfall. Each of the outlet pipes will need to extend a nominal distance of up to 100m into the existing downstream privately owned land. The outlets will discharge to the downstream overland flow paths through that land referred to above. It is recommended to set aside land for a pipe easement until such time as an underground drainage outfall from Anakie Road to Cowies Creek is formalised. A temporary solution could be for a pipe and narrow road side

drain to be constructed within the existing road reserve of Anakie Road and south along Evans Road all the way to Cowies Creek. Note that this is only feasible for RB D, RB G1 and RB G. This pipe could be expensive to construct due to the distance required and the drainage line will have to go through some minor high points along Anakie Road to eventually get to Evans Road.

- Farm access roads – depending on how the downstream properties are used in terms of farming practices, there may be issues with property access across the overland flow paths and serviceability of the land due to increased wetness of the paddocks, as a result of increased runoff volumes and frequency of runoff from the upstream development. It can be seen from aerial photography that farm tracks exists across the overland flow paths and there may be a need to ensure that these tracks are serviceable by the farmers. However, no works are proposed as it is unknown at this stage of the planning if this is an issue to be resolved. There seem to be a distinguishable waterway reserve offset which is also related to the terrain form. This reserve is not being utilised in reaping activities which suggests that the impact to current practices is not affected by the increased runoff volume. This potential issue would be more likely on the downstream part of the catchment near Lovely Banks Road. Like the mitigation options offered above, a temporary (and potentially expensive) solution could be to manage the frequent flows from the study boundary into a formalised drainage pipes within the Council road reserve. i.e. along Evans Road. Should this issue arise as development progresses, a more detailed solution should be investigated in the future.
- Retarding Basin Embankment – one of the proposed basins RB D along Anakie Road will require an embankment which will be around 1.6 m high.
- Retarding Basin Spillways – two of the retarding basins along Anakie Road incorporate spillways which are proposed to operate in a 1 in 100 AEP flood event.
- Low flow diversion pipes along the western boundary of the NGGA are required from SBRB A and SBRB I. The purpose of these pipe diversions is to minimise the outfall requirements outside the NGGA boundary. These relatively small catchments are proposed to be diverted back into the main drainage system. These pipes will have to be built against the natural grade of the land with no more than a 2 m maximum depth.

Table 4-9: Waterway Widths

WATERWAY ID	LENGTH (m)	HYDRAULIC WIDTH (m)	CORRIDOR WIDTH (m)
C_1	550	25	45
D_1	360	17	40
D_2	370	9	30
G1_1	450	16	40
G1_2	220	15	40
G_1	240	15	40
G_2	240	15	40

4.6.3 Future Analyses

The detail of the assets described above will be further refined as part of the precinct development works. A variety of studies will be undertaken in association with the development. It is recommended that the following studies be considered as part of further design development:

- A detailed assessment of the waterway stability between the study boundary and Cowies Creek.
- A detailed assessment of the erosion protection features required to control erosion associated with design flows. Feasibility study of an alternative option to provide formal drainage along Evans Road should the above recommended option become too difficult.
- In the case where CoGG wish to minimise flood risk to Anakie Road in a 1 in 100 AEP event, the size of the retarding basin G1 with a spillway can be reviewed to increase storage and the outlet capacity.

5 Hovells Creek (C157AX)

5.1 Site Description

The Hovells Creek catchment is located in the north eastern portion of the study area. The catchment outlet is located at the proposed culvert crossing at O'Hallorans Road. The total area of the catchment included in the investigation is 9.3 km^2, of which the study area comprises around 40%. There are two separate waterways or drainage lines which discharge flows across the study area boundary at Staceys Road and Bacchus Marsh Road. A map of the sub catchment is included as Figure 5-1.

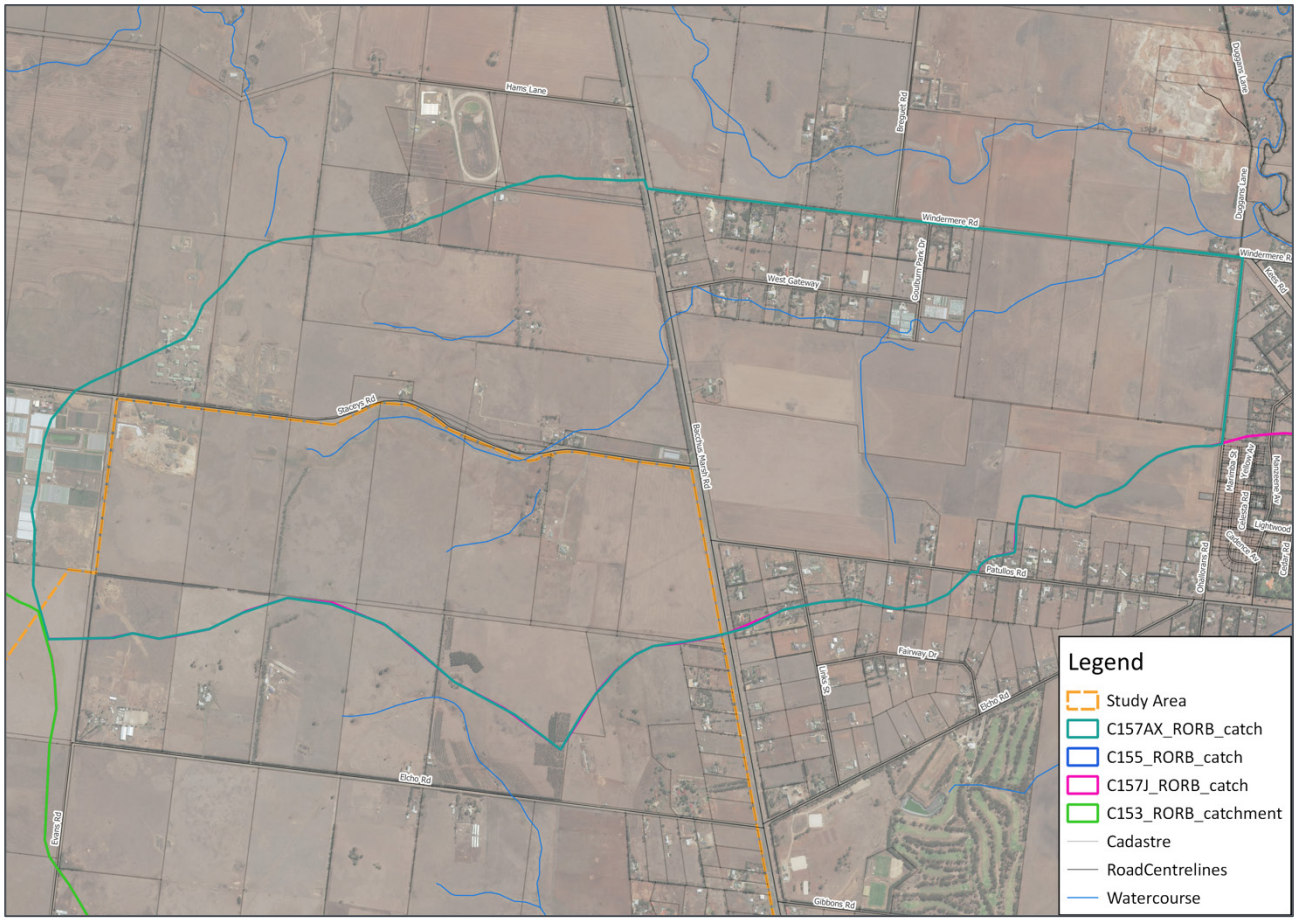


Figure 5-1: Hovells Creek Sub Area

5.2 Site SMS

The conceptual arrangement of site stormwater infrastructure is detailed in Figure 5-2.

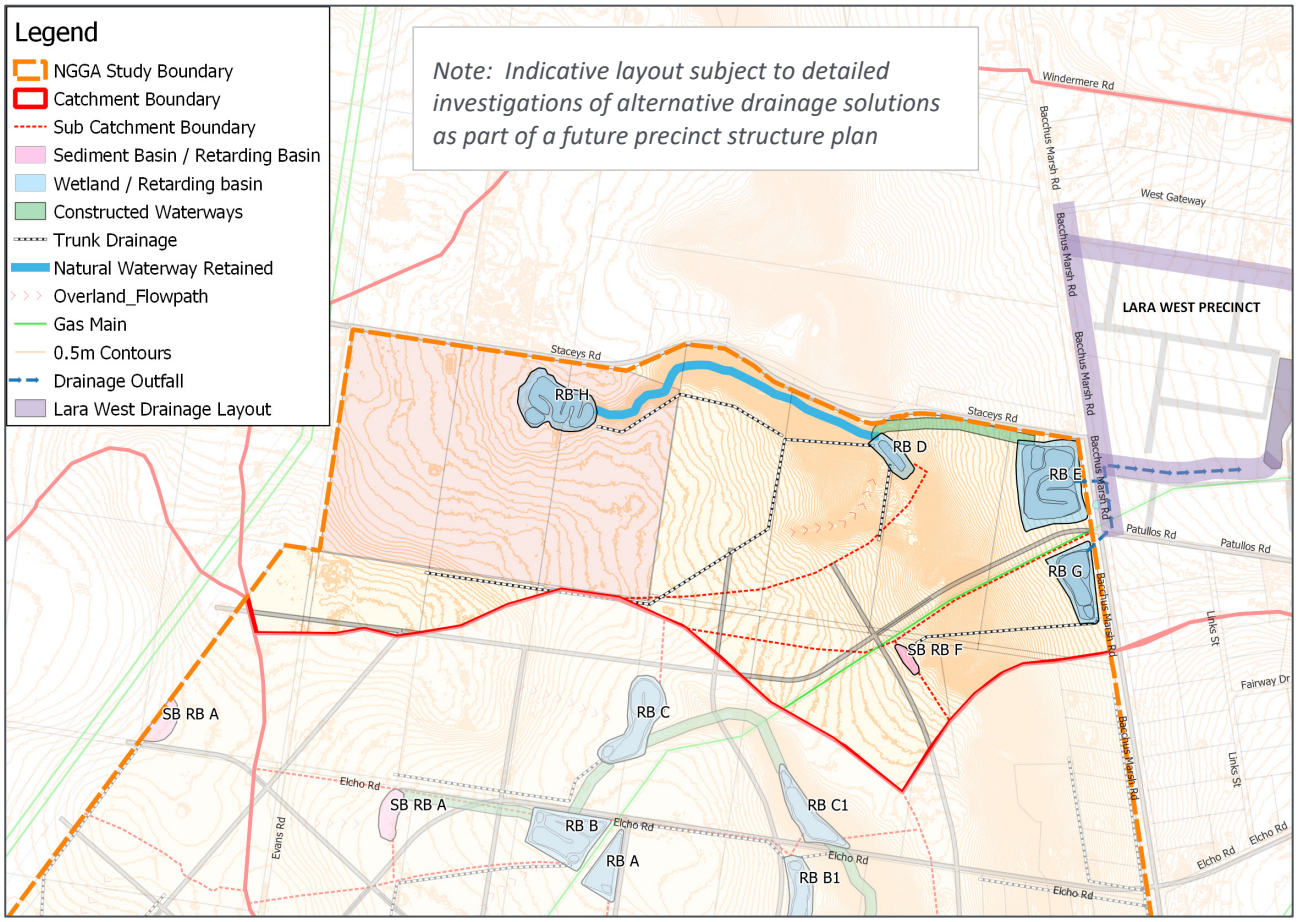


Figure 5-2: Hovells Creek SMS Infrastructure

The retarding basin labelled RB H in the above figure is an asset which is included with scenario 2 modelling only. The scenario 1 layout is shown in Appendix B3.

5.3 Hydrologic Modelling

5.3.1 General

The hydrologic model for the Hovells Creek catchment was modified in a number of respects. Initially, the model was modified to ensure consistency between the RORB model existing conditions peak flows and the Tuflow existing conditions flows. The model was then further modified to reflect the proposed developed conditions.

5.3.2 Existing Conditions Adjustments

The modifications made to the existing conditions RORB model described in SMEC (2018) are as follows:

- The length of a select number of stream lengths was altered to change the relative delay in that portion of the catchment. Increasing the length of select stream sections has the effect of increasing attenuation and reducing peak flows. Reducing stream lengths has the opposite effect.
- In a number of cases, the direction of flow was re-aligned to be consistent with flow patterns observed in the Tuflow model.

The modifications made to the model are detailed on a figure included as Appendix C.

The modelled outcomes showing the adjusted peak RORB flows relative to the Tuflow outputs documented in SMEC (2018) are detailed in Table 5-1.

Table 5-1: Comparison Between RORB modelled flows and Tuflow Existing Conditions

OUTLET ID	CATCHMENT AREA (ha)	1 IN 100 AEP PEAK DISCHARGE (m^3/s)		1 IN 2 AEP PEAK DISCHARGE (m^3/s)	
		RORB Adjusted	**SMEC (2018) Tuflow**	**RORB Adjusted**	**SMEC Tuflow**
1	380	13.0 (9hr)	12.9 (2hr)	2.9 (12hr)	1.8 (12hr)
2	230	11.7 (3hr)	11.7 (2hr)	2.5 (9hr)	1.5 (12hr)

5.3.3 Developed Conditions Adjustments

The modifications to the RORB model to represent developed conditions were as follows:

- The proportion impervious of the catchment sub areas was modified to reflect the proposed density of development.
- In a number of cases, the direction of flow was re-aligned to reflect the use of stormwater pipes or open channels to redirect flows.
- Retardation basins were included into the model in line with the proposed development strategy.

The RORB model was run to confirm the effectiveness of the retardation infrastructure and the key outcomes are detailed in Table 5-2.

Table 5-2: 1 in 100 AEP Event Retardation Basin Impact

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
H*	83	5.8 (9hr)	3.5 (9hr)	-
D (SB)	183	5.0 (2hr)	4.3 (2hr)	-
E	**243**	**10.3 (12hr)**	**8.6 (12hr)**	**12.9**
F (SB)	25	1.4 (3hr)	1.2 (3hr)	-
G	**52**	**1.7 (12hr)**	**1.3 (12hr)**	**-**

* - Scenario 2 only

The basins in the above table have been presented in sub catchment groups. Target flows are reported at the outlet across the study area boundary. The figures above correspond to the critical duration of the outflow.

It is noted that the previous hydrologic study in the Lara West Growth Area Stormwater Management Strategy (LWGA SWMS) reported on in Craigie (2012) has set a flow target of no more than 14.6 m^3/s at Bacchus Marsh Road for the 1 in 100 AEP event. The estimates from NGGA Existing Conditions and target flow for this study is less than the LWGA SWMS which meets the downstream flow requirements. Furthermore, the design in both RB E and RB G is much lower than the target outflow and therefore meets the outflow requirements.

The key characteristics of each retarding basin are detailed in Table 5-3.

Table 5-3: Retardation Basin Characteristics

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
H*	3 No 1200mm	35,800	4.4	-
D (SB)	3 No 1200mm	6,880	1.3	-
E	2 No 525mm [10m SPILLWAY]	105,000	7.1	2.4 m high, 300 m long

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
F (SB)	1 No 900mm	3,150	0.4	-
G	3 No 1200mm	11,500	3.2	-

5.3.4 1 in 2 AEP Event Cross Check

The outlet configuration adopted in the 1 in 100 AEP have been run to assess the effectiveness in retarding the 1 in 2 AEP event. The results are presented in Table 5-4.

Table 5-4: 1 in 2 AEP Event Retardation Basin Impact

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
H*	1.9 (12hr)	0.9 (12hr)	-
D (SB)	1.5 (2hr)	1.2 (2hr)	-
E	**3.1 (12hr)**	**0.9 (12hr)**	**1.8**
F (SB)	0.45 (9hr)	0.4 (9hr)	-
G	**0.5 (2hr)**	**0.3 (12hr)**	**1.8**

5.4 Hydraulic Modelling

5.4.1 1 in 100 AEP Event Modelling

A Tuflow model was developed for the purposes of confirming the outcomes from the retardation basin sizing undertaken using the RORB model. The model was modified to include the retarding basins described above for the 1 in 100 AEP flow event. The critical duration of 12hr duration was run for Hovells Creek. The outcomes from the modelling are detailed in Table 5-5.

Table 5-5: 1 in 100 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
E	**8.6 (12hr)**	**9.0 (12hr)**	**12.9**
G	**1.3 (12hr)**	**1.3 (12hr)**	**-**

In addition, the flood maps flood inundation depths are included as Appendix E1.

The outputs indicate predominately that the flood flows and levels are either lowered or remain unchanged and can be mitigated by the proposed works. There is however some increase in flood level on the downstream of RB E as evident in the afflux plan on Bacchus Marsh Road. The cause of this afflux is mainly due to the design of the retarding basin with the intention that the spillway will be engaged in the 1 in 100 AEP event. The increase is relatively minor but it may be required to be addressed nonetheless. It is possible to eliminate the overland flooding by adding more culverts under the main road to capture the overspill in addition to the 2 no 525mm diameter pipe as identified in Table 5-3. The detail of the basin outlet can be addressed during functional design.

5.4.2 1 in 2 AEP Event Modelling

In order to demonstrate the impact of the upstream development, the 1 in 2 AEP event has been run in the hydraulic model. The model results are presented in Table 5-6.

Table 5-6: 1 in 2 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
E	**0.9 (9hr)**	**1.0 (12hr)**	**1.8**

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
G	**0.3 (12hr)**	**0.34 (12hr)**	**1.8**

The retarding basin and outlet configuration assumed in the flood modelling demonstrate that the peak developed flow in the frequent events can be controlled and mitigated. However, it should be noted that the modelling undertaken is based on high level stage storage relationship. Detailed modelling will be required at a later stage to confirm the exact outlet configuration requirements.

5.5 Stormwater Quality Treatment (MUSIC)

A MUSIC model has been developed for the purposes of determining the required footprint to meet water quality objectives. Each of the water quality elements has been modelled as either a stand-alone sedimentation basin or a wetland with sediment basin. All water quality elements have been co-located with a retarding basin. The model schematic is included as Appendix E3 and the outcomes of the modelling at the study boundary are included Table 5-7.

Table 5-7: MUSIC Modelling Outcomes

ID	SB AREA (m^2)	WL AREA (ha)	NITROGEN REMOVAL (%)	PHOSPHOROUS REMOVAL (%)	TSS REMOVAL (%)
H*	635	3.0	-	-	-
D (SB)	790	-	-	-	-
E	**390**	**4.0**	**45**	**71.5**	**87.4**
F (SB)	200	-	-	-	-
G	**180**	**1.7**	**50**	**74.7**	**90.2**

5.6 Infrastructure Characteristics

5.6.1 Treatment Device Footprint

The required footprint for treatment devices has been determined by summing the water surface area for the sedimentation basin and wetland based on MUSIC and multiplied by a factor of 1.2 to provide allowance for the variety of ancillary elements required around the wetland, such as access and dry out zones.

The total footprint areas of the retarding basins have been sized to account for the stormwater quality footprint areas. In most cases, the wetland footprint area has been adopted as the retarding basin base level with the air space above utilised for retarding basin flood storage. Table 5-8 below shows the water quality footprint compared to the total retarding basin footprint.

Table 5-8: Treatment Device Footprint

ID	WATER QUALITY FOOTPRINT AREA (ha)	TOTAL FOOTPRINT AREA (ha)
H	3.7	4.4
D (SB)	0.09	1.3
E	4.8	7.1
F (SB)	0.02	0.4
G	2.0	3.2

5.6.2 Additional Infrastructure

A variety of additional infrastructure is judged to be required as part of the development, with the detail varying from catchment to catchment. The infrastructure relevant to this catchment is as follows:

- Waterway easements – stormwater runoff is directed to basins via pipes or waterways. Consideration has been given to the required waterway width which is a function of catchment area. Easement widths are either 30m or 40m. Details of channel widths are included in Table 5-9.
- Outlets – both of basins RB E and RB G will require a new outlet to be constructed under Bacchus Marsh Road. Additional culverts for RB E may be required to manage the overland flow coming from spillway during the 1 in 100 AEP event.
- Outlet Combination – while the outlets from basins RB E and RB G discharge across Bacchus Marsh Road independently, they are required to be combined into a single discharge waterway which is to form part of the proposed Lara West Precinct Structure Plan (PSP). The outlets are difficult to combine within the study area due to the presence of the high-pressure gas main alignment. It is judged that it is easier to combine the outlets on the east side of Bacchus Marsh Road. This option is supported by the proposed waterway reserve abutting Bacchus Marsh Road in the Lara West PSP. There would be no requirement to amend the Lara West PSP and drainage strategy. However, further design development is required to detail how the NGGA RB outlets will discharge to the proposed West Lara PSP waterway. This should include investigation to the depth of the gas main under the proposed waterway reserve within Lara West PSP. A number of alternatives can be investigated such as lowering of the gas main should it be necessary. Lowering the gas main could be more favourable and economical than further increasing the land take and constructing an embankment in steep terrain.
- Retarding Basin Embankment – RB E along Bacchus Marsh Road require an embankment with heights of around 2.4 m.
- The sole difference between scenario 1 and scenario 2 in this sub area is the construction of the combined wetland and retarding basin asset, RB H.
- The scenario 2 option may require further investigation to potential scour issue along the downstream gully which is proposed to be retained in scenario 1.

Table 5-9: Waterway Widths

WATERWAY ID	LENGTH (m)	HYDRAULIC WIDTH (m)	CORRIDOR WIDTH (m)
E_1	500	20	40
E_2	153	22	40

5.6.3 Future Analyses

The detail of the assets described above will be further refined as part of the precinct development works. A variety of studies will be undertaken in association with the development. It is recommended that the following studies be considered as part of further design development:

- An assessment and functional design of the retarding basin outlets and how it will discharge to the Lara West PSP waterway. The spillway design and additional culverts under the road should be considered.
- It may be required during the functional design to assess the risk of the retarding basin embankment and its consequence applying appropriate ANCOLD guidelines.
- Scenario 2 option would require further investigation of the potential for scour along the downstream gully from RB H.

6 Elcho Drain (C157J)

6.1 Site Description

The Elcho Drain catchment is located in the eastern portion of the study area. The outlet of catchment is located at the culvert crossing of Forest Road South. The total area of the catchment included in the investigation is 19.8 km^2, of which the study area comprises around 40%. There are three separate waterways or drainage lines which discharge flows across the study area boundary at Bacchus Marsh Road. A map of the sub catchment is included as Figure 6-1.

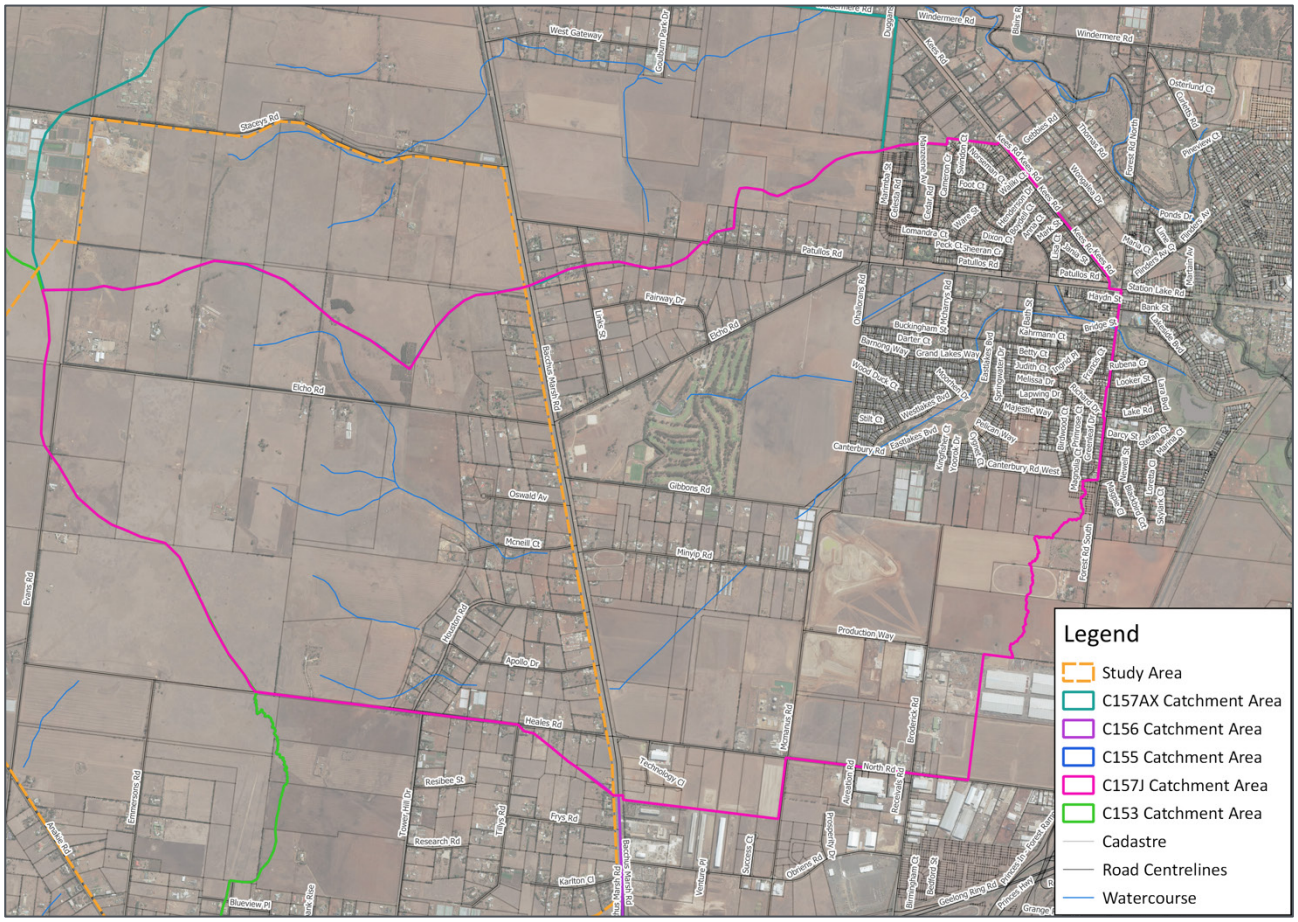


Figure 6-1: Elcho Drain Sub Area

6.2 Site SMS

The conceptual arrangement of site stormwater infrastructure is detailed in Figure 6-2. The SMS for Elcho Drain involves some key differences to the initial strategy which have been discussed in the previous sections of this report. Specifically, this involves maintaining the upper catchments to drain through the downstream area of Elcho Drain catchment. Further, it is proposed to direct the large waterway flows towards RB F compared to RB D in the initial strategy.

The reasons for this alignment are offered below:

- The natural overland flow direction predominantly flows to the south. Although, there is a flow split which has been identified in the NGGA existing conditions document.
- RB F site provides a relatively favourable gradually sloped topography compared to the steeper natural batters at RB D.
- RB F will discharge into a formalised outfall channel as part of the GREP development downstream which also includes a wetland treatment system downstream. In addition, this has a benefit of better conveyance of increased frequency of regular and high flows from Elcho Drain catchment. Whereas, a formal outfall will be required should the regular and high flows be diverted towards RB D.

- It was found throughout the modelling iteration that there are benefits of economies of scale to expand RB F considering the retarding basin is already designed to treat a larger portion of development in comparison to RB D.

It is recognised, however, that there are issues with this option in terms of building the retarding basin with the proposed sequencing of development. Development and acquisition of land for the retarding basin from a precinct which is earmarked to be developed at a much later date results in difficulty with provision of an outfall to the precincts which are planned to be developed first. The challenges here are discussed further in the development staging section of the report.

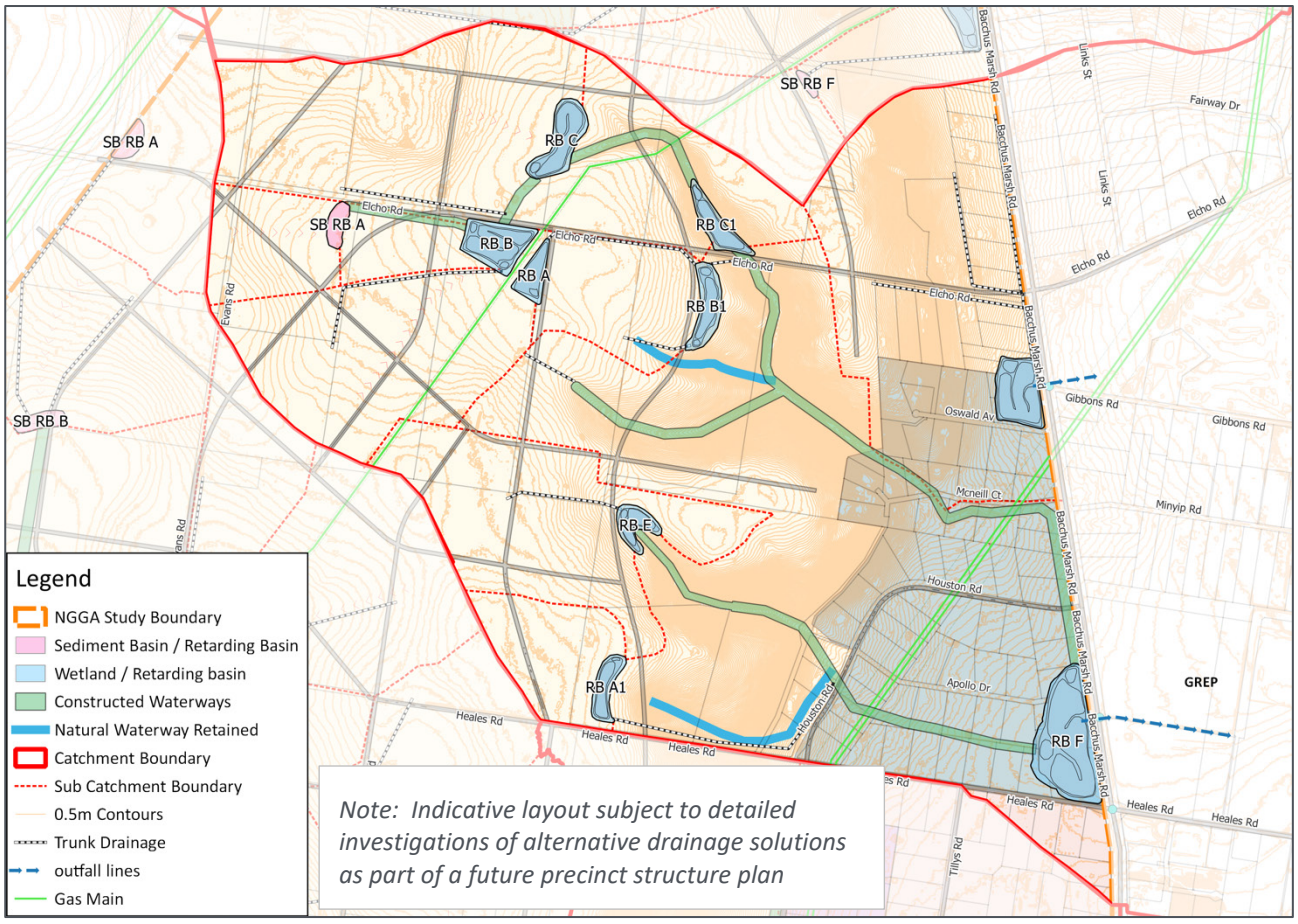


Figure 6-2: Elcho Drain SMS Infrastructure

The retarding basin labelled RB D in the above figure is an asset which is sized differently depending upon whether Scenario 1 or Scenario 2 is modelled. Scenario 1 and 2 layouts are included as Appendix B3 and B4.

6.3 Hydrologic Modelling

6.3.1 General

The hydrologic model for the Elcho Drain catchment was modified in a number of respects. Initially, the model was modified to ensure consistency between the RORB model existing conditions peak flows and the Tuflow existing conditions flows. The model was then further modified to reflect the proposed developed conditions.

6.3.2 Existing Conditions Adjustments

The modifications made to the existing conditions RORB model described in SMEC (2018) are as follows:

- The length of a select number of stream lengths was altered to change the relative delay in that portion of the catchment. Increasing the length of select stream sections has the effect of increasing attenuation and reducing peak flows. Reducing stream lengths has the opposite effect.

- In a number of cases, the direction of flow was re-aligned to be consistent with flow patterns observed in the Tuflow model.

The modifications made to the model are detailed on a figure included as Appendix C.

The modelled outcomes showing the adjusted peak RORB flows relative to the Tuflow outputs documented in SMEC (2018) are detailed in Table 6-1.

Table 6-1: Comparison Between RORB modelled flows and Tuflow Existing Conditions

OUTLET ID	CATCHMENT AREA (ha)	1 IN 100 AEP PEAK DISCHARGE (m^3/s)		1 IN 2 AEP PEAK DISCHARGE (m^3/s)	
		RORB Adjusted	**SMEC (2018) Tuflow**	**RORB Adjusted**	**SMEC Tuflow**
1	120	8.9 (1hr)	8.9 (2hr)	2.0 (9hr)	1.6 (9hr)
2	668	14.6 (9hr)	14.6 (9hr)	3.3 (12hr)	3.5 (9hr)
3	10	0.5 (2hr)	0.5 (2hr)	0.12 (12hr)	-

6.3.3 Developed Conditions Adjustments

The modifications to the RORB model to represent developed conditions were as follows:

- The proportion impervious of the catchment sub areas was modified to reflect the proposed density of development.
- In a number of cases, the direction of flow was re-aligned to reflect the use of stormwater pipes or open channels to redirect flows.
- Retardation basins were included into the model in line with the proposed development strategy.

The RORB model was run to confirm the effectiveness of the retardation infrastructure and the key outcomes are detailed in Table 6-2.

Table 6-2: 1 in 100 AEP Event Retardation Basin Impact

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A (SB)	22.6	1.8 (9hr)	0.9 (9hr)	-
A	107.1	8.5 (2hr)	4.5 (2hr)	-
A1	24.1	0.32 (48 hr)	0.06 (48hr)	-
B	38.9	0.92 (48hr)	0.28 (48hr)	-
B1	137.6	4.3 (9hr)	3.3 (9hr)	-
C	128.7	5.2 (12hr)	2.1 (12hr)	-
C1	175.7	4.5 (12hr)	3.1 (12hr)	-
E	67.6	1.2 (48hr)	0.6 (48hr)	-
F	**668.0**	**14.0 (48hr)**	**8.5 (48hr)**	**9.2**
D	**119.5**	**6.8 (9hr)**	**3.6 (9hr)**	**8.9**
D*	**119.5**	**6.7 (9hr)**	**4.1 (9hr)**	**8.9**

* - Scenario 1

The basins in the above table have been presented in sub catchment groups. Target flows are reported at the outlet across the study area boundary. The figures above correspond to the critical duration of the outflow.

It is noted that the target flow at location 2 have been based on the 1 in 100 AEP design flow of 9.2 m^2/s, which has been adopted for the downstream channel associated with the future GREP development. The retarding basin (RB F) have been sized to meet the requirements of the target flow.

The key characteristics of each retarding basin are detailed in Table 6-3.

Table 6-3: Retardation Basin Characteristics

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
A (SB)	1 No 900mm	8,280	1.2	-
A	3 No 1200mm	16,500	1.9	-
A1	1 No 225mm	8,280	2.0	-
B	1 No 450mm	23,900	4.3	-
B1	2 No 1200mm	23,200	2.9	-
C	1 No 1200mm	46,900	3.8	-
C1	2 No 1050mm	25,200	2.6	1.5m high, 200m long
E	1 No 525mm	23,800	2.0	-
F	3 No 1050mm	223,000	10.3	-
D	3 No 1200mm	42,900	6.5	2.5 m high, 220 m long
D*	3 No 1200mm	20,800	4.6	2.5 m high 290 m long

6.3.4 1 in 2 AEP Event Cross Check

Flood modelling was undertaken to determine the effectiveness of the basin in retarding flows for the 1 in 2 AEP event. The results are presented in Table 6-4.

Table 6-4: 1 in 2 AEP Event Retardation Basin Impact

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A (SB)	0.7 (9hr)	0.3 (9hr)	-
A	1.7 (9hr)	1.2 (9hr)	-
A1	0.2 (hr)	0.02 (24hr)	-
B	0.3 (24hr)	0.05 (24hr)	-
B1	1.4 (12hr)	1.0 (12hr)	-
C	1.9 (12hr)	0.6 (12hr)	-
C1	1.5 (12hr)	0.8 (12hr)	-
E	0.5 (12hr)	0.2 (12hr)	-
F	**4.0 (24hr)**	**2.6 (24hr)**	**3.5**
D	**2.2 (12hr)**	**0.8 (12hr)**	**1.6**

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D*	**2.3 (12hr)**	**1.1 (12hr)**	**1.6**

6.4 Hydraulic Modelling

6.4.1 1 in 100 AEP Event Modelling

A Tuflow model was developed for the purposes of confirming the outcomes from the retardation basin sizing undertaken using the RORB model. The model was modified to include the retarding basins described above for the 1 in 100 AEP flow event. Three durations were run of Elcho Drain which include 9hr, 12hr and 48hr duration. The outcomes from the modelling are detailed in Table 6-5.

Table 6-5: 1 in 100 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
F	**8.5 (48hr)**	**7.7 (48hr)**	**9.2**
D	**3.6 (9hr)**	**3.6 (9hr)**	**8.9**
D*	**4.1 (9hr)**	**4.2 (9hr)**	**8.9**

In addition, the flood maps flood inundation depths are included as Appendix F1.

The outputs indicate predominately that the flood flows and levels are either lowered or remain unchanged and can be mitigated by the proposed works. The afflux maps indicate that there are some localised areas where the flood levels are increased by a minor amount (< 10mm). As expected, there is some minor increase in flood level in areas of trapped low points where water does not escape. This is evident in the farm dams and local ponds or ponding behind roads without adequate drainage outlets. This issue is due to the increase in volume of runoff as a result of increased development. These minor affluxes are not considered to be critical.

As per CoGG remarks, CoGG accepts that there is a non-material impact on public land that is resilient to flooding and will not impact on public safety. Further planning phases may provide an opportunity to refine the model and minimise changes.

6.4.2 1 in 2 AEP Event Modelling

In order to demonstrate the impact of the upstream development, the 1 in 2 AEP event has been run in the hydraulic model. The model results are presented in Table 6-6.

Table 6-6: 1 in 2 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
F	**2.6 (24hr)**	**2.6 (12hr)**	**1.6**
D	**0.8 (12hr)**	**1.1 (12hr)**	**3.5**
D*	**1.1 (12hr)**	**1.0 (12hr)**	**3.5**

The retarding basin and outlet configuration assumed in the flood modelling demonstrates that the peak developed flow in the frequent events can be controlled and mitigated. Detailed modelling will be required at a later stage to confirm the exact outlet configuration requirements.

Further modelling and volume assessment could be built upon from this study to fully understand the effects to GREP and Grand Lakes area further downstream.

6.5 Stormwater Quality Treatment (MUSIC)

A MUSIC model has been developed for the purposes of determining the required footprint to meet water quality objectives. Each of the water quality elements has been modelled as either a sedimentation basin or a wetland. All

water quality elements have been co-located with a retarding basin. The model schematic is included as Appendix F3 and the outcomes of the modelling are included in Table 6-7.

Table 6-7: MUSIC Modelling Outcomes

ID	SB AREA (m^2)	WL AREA (ha)	NITROGEN REMOVAL (%)	PHOSPHOROUS REMOVAL (%)	TSS REMOVAL (%)
A (SB)	210	-	-	-	-
A	510	1.0	-	-	-
A1	180	1.1	-	-	-
B	90	2.7	-	-	-
B1	320	1.3	-	-	-
C	660	2.3	-	-	-
C1	320	1.4	-	-	-
E	530	1.1	-	-	-
F	**2,150**	**6.6**	**45.4**	**72.8**	**89**
D	**870**	**2.4**	**45**	**70.9**	**87.7**
D*	**870**	**3.3**	**46**	**72.2**	**88.7**

The wetland treatment area has been estimated through increasing the treatment area estimated in MUSIC by a factor of 1.2. This provides an allowance for the variety of ancillary elements which are required around a wetland such as access and dry out zones.

6.6 Infrastructure Characteristics

6.6.1 Treatment Device Footprint

The required footprint for treatment devices has been determined by summing the water surface area for the sedimentation basin and wetland based on MUSIC and multiplied by a factor of 1.2 to provide allowance for the variety of ancillary elements required around the wetland, such as access and dry out zones.

The total footprint areas of the retarding basins have been sized to account for the stormwater quality footprint areas. In most cases, the wetland footprint area has been adopted as the retarding basin base level with the air space above utilised for retarding basin flood storage. Table 6-8 below shows the water quality footprint compared to the total retarding basin footprint.

Table 6-8: Treatment Device Footprint

ID	WATER QUALITY FOOTPRINT AREA (ha)	TOTAL FOOTPRINT AREA (ha)
A (SB)	0.025	1.2
A	1.3	1.9
A1	1.3	2.0
B	3.2	4.3
B1	1.6	2.9
C	2.8	3.8
C1	1.8	2.6

ID	WATER QUALITY FOOTPRINT AREA (ha)	TOTAL FOOTPRINT AREA (ha)
E	1.3	2.0
F	8.2	10.3
D	4.8	6.5
D*	4.1	4.6

6.6.2 Additional Infrastructure

A variety of additional infrastructure is judged to be required as part of the development, with the detail varying from catchment to catchment. The infrastructure relevant to this catchment is as follows:

- Waterway easements – stormwater runoff is directed to basins via pipes or waterways. Consideration has been given to the required waterway width which is a function of catchment area. Easement widths are either 30m or 40m. Details of channel widths are included in Table 6-9.
- The design of the waterway in the vicinity of the gas main will require important consideration to ensure Outlets – both of basins RB D and RB F will require a new outlet to be constructed under Bacchus Marsh Road.
- Erosion Protection – constructed waterways within this sub catchment run down steep gullies. The flow is expected to be erosive and the existing gullies will be subject to erosion. Careful consideration will need to be given to the design of these waterway gullies and provision for appropriate erosion protection will be required. Erosion protection may take the form of rock lining and or a series of drop structures. Alternatively, it may be preferable to convey some portion of flows in a stormwater pipe adjacent to the waterway, but this is only feasible downstream of the gas main constraint as per this SMS.
- Retarding Basin Embankment – RB D along Bacchus Marsh Road will require an embankment which will be around 2.5 m high.
- The sole difference between scenario 1 and scenario 2 in this sub area is the size or the of the combined wetland and retarding basin asset, RB D.
- Elcho Road will need to be constructed to be higher than the existing elevations near the proposed RB C1. This road will form part of the basin structure and should be designed concurrently.

Table 6-9: Waterway widths

WATERWAY ID	LENGTH (m)	HYDRAULIC WIDTH (m)	CORRIDOR WIDTH (m)
B_1	490	15	40
C_1	570	16	40
C1_1	230	15	40
F_1	680	15	40
F_2	200	14	40
F_3	730	15	40
F_4	410	21	40
F_5	850	21	40
F_6	640	18	40
F_7	480	11	30

WATERWAY ID	LENGTH (m)	HYDRAULIC WIDTH (m)	CORRIDOR WIDTH (m)
F_8	290	13	40
F_9	460	16	40
F_10	610	14	40

6.6.3 Future Analyses

The detail of the assets described above will be further refined as part of the precinct development works. A variety of studies will be undertaken in association with the development. It is recommended that the following studies be considered as part of further design development:

- An assessment of the erosion protection required to control flows down the hydraulically steep gullies. In addition, the open waterway which runs adjacent to McNeill Court undergoes a 90 degree turn at Bacchus Marsh Road. Tuflow modelling indicates that the bend radius should be a minimum of 45m. The required radius should be confirmed as part of future analysis works.

7 Wharf Road Outfall (C156)

7.1 Site Description

The Wharf Road catchment is located in the south western portion of the study area. The outlet of catchment is located at the Bacchus Marsh Road south of the Geelong Ring Road. The total area of the catchment included in the investigation is 4.7 km^2, of which the study area comprises around 85%. There are three separate culverts which discharge flows across the study area boundary, at Geelong Ring Road. A map of the sub catchment is included as Figure 7-1.

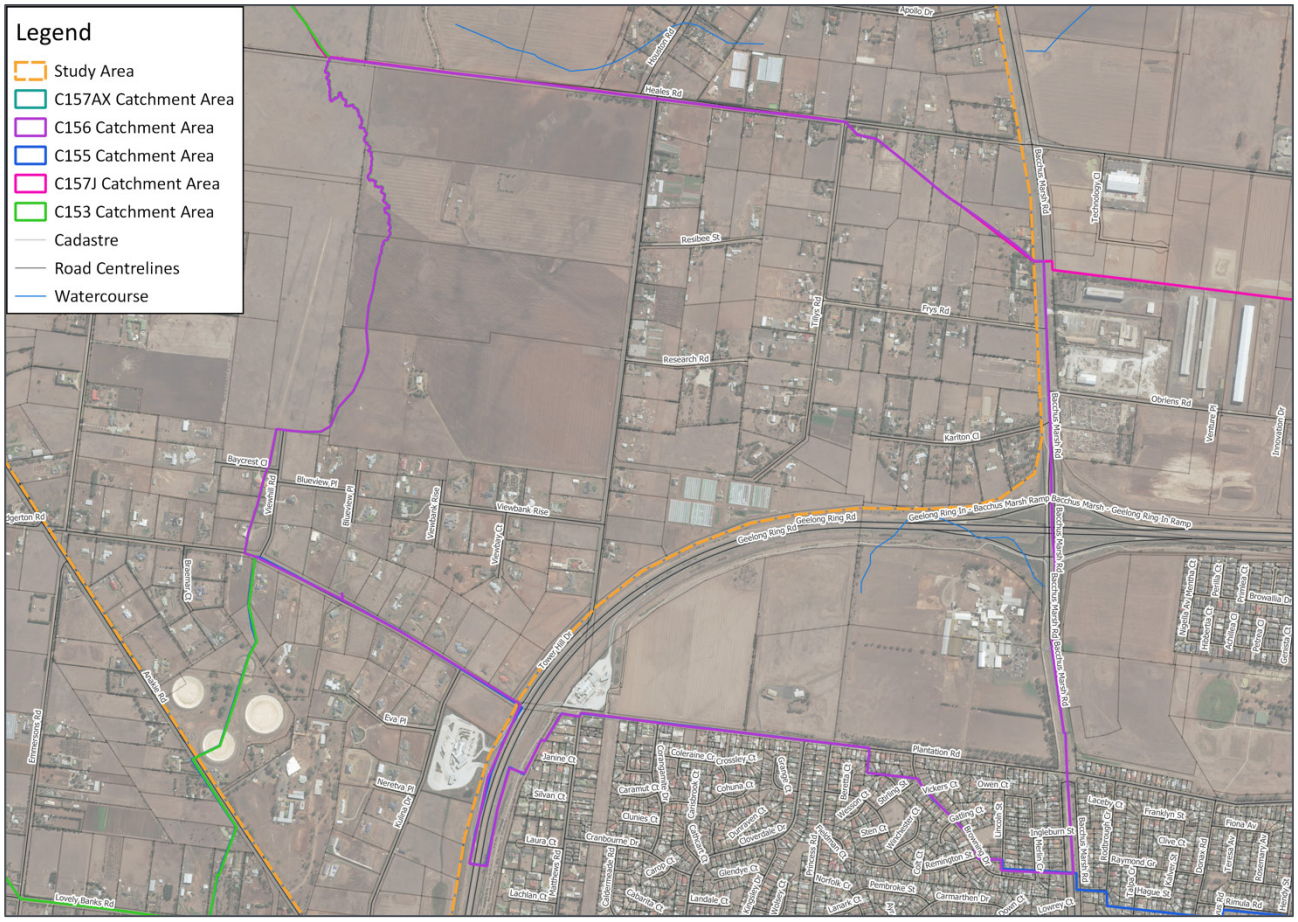


Figure 7-1: Wharf Road Sub Area

7.2 Site SMS

The conceptual arrangement of site stormwater infrastructure is detailed in Figure 7-2.

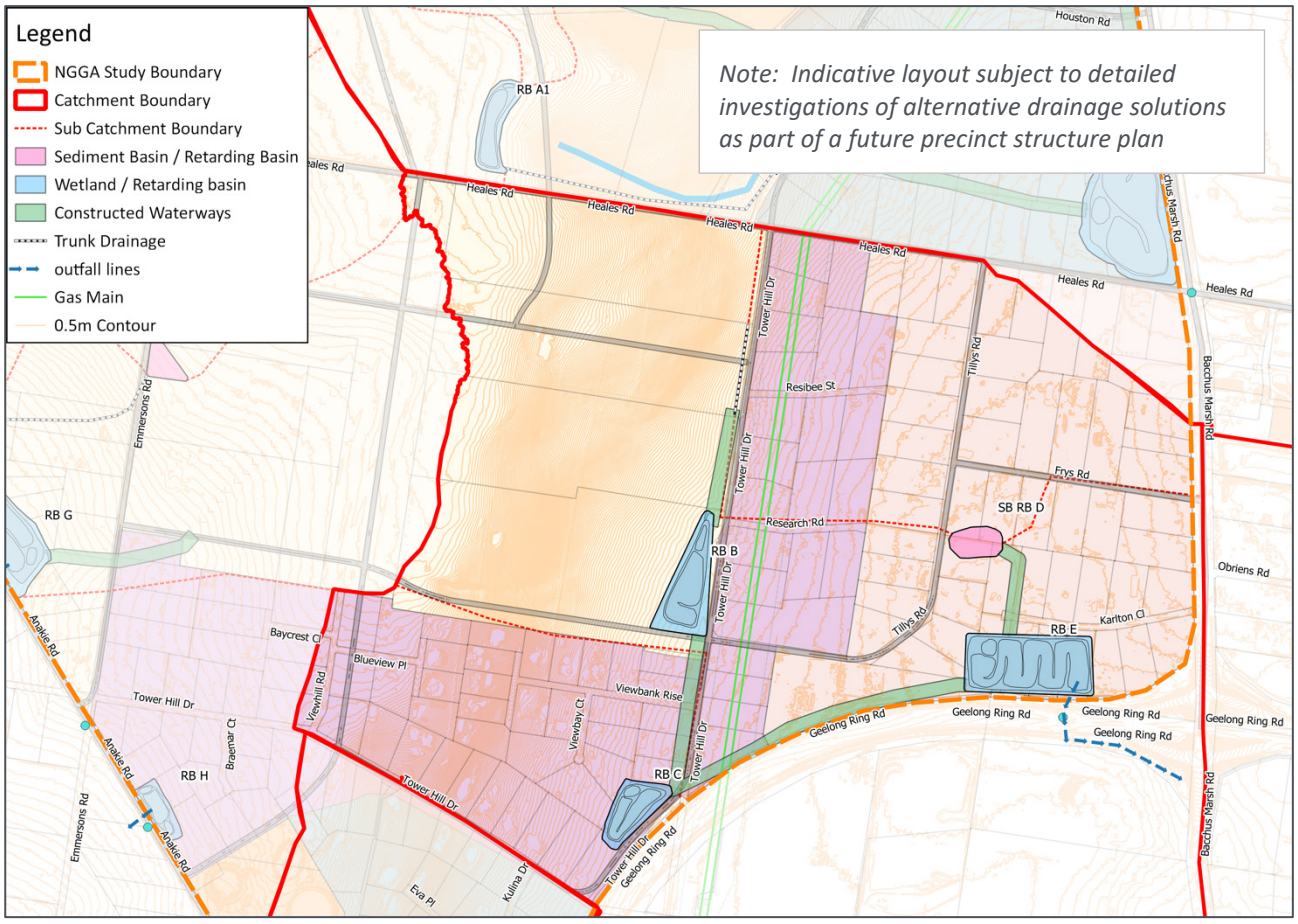


Figure 7-2: Wharf Road SMS Infrastructure

7.3 Hydrologic Modelling

7.3.1 General

The hydrologic model for the Wharf Road catchment was modified in a number of respects. Initially, the model was modified to ensure consistency between the RORB model existing conditions peak flows and the Tuflow existing conditions flows. The model was then further modified to reflect the proposed developed conditions.

7.3.2 Existing Conditions Adjustments

The modifications made to the existing conditions RORB model described in SMEC (2018) are as follows:

- The length of a select number of stream lengths was altered to change the relative delay in that portion of the catchment. Increasing the length of select stream sections has the effect of increasing attenuation and reducing peak flows. Reducing stream lengths has the opposite effect.
- In a number of cases, the direction of flow was re-aligned to be consistent with flow patterns observed in the Tuflow model.

The modifications made to the model are detailed on a figure included as Appendix C.

The modelled outcomes showing the adjusted peak RORB flows relative to the Tuflow outputs documented in SMEC (2018) are detailed in Table 7-1.

Table 7-1: Comparison Between RORB modelled flows and Tuflow Existing Conditions

OUTLET ID	CATCHMENT AREA (ha)	1 IN 100 AEP PEAK DISCHARGE (m^3/s)		1 IN 2 AEP PEAK DISCHARGE (m^3/s)	
		RORB Adjusted	**SMEC (2018) Tuflow**	**RORB Adjusted**	**SMEC Tuflow**
1	50	3.3	3.3	0.81	0.7

OUTLET ID	CATCHMENT AREA (ha)	1 IN 100 AEP PEAK DISCHARGE (m^3/s)		1 IN 2 AEP PEAK DISCHARGE (m^3/s)	
		RORB Adjusted	**SMEC (2018) Tuflow**	**RORB Adjusted**	**SMEC Tuflow**
2	110	3.7	3.7	0.89	0.8
3	240	10.1	10.1	2.5	2.5

7.3.3 Developed Conditions Adjustments

The modifications to the RORB model to represent developed conditions were as follows:

- The proportion impervious of the catchment sub areas was modified to reflect the proposed density of development.
- In a number of cases, the direction of flow was re-aligned to reflect the use of stormwater pipes or open channels to redirect flows.
- Retardation basins were included into the model in line with the proposed development strategy.

The RORB model was run to confirm the effectiveness of the retardation infrastructure and the key outcomes are detailed in Table 7-2

Table 7-2: 1 in 100 AEP Event Retardation Basin Impact

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
B	110.2	3.3 (9hr)	2.6 (9hr)	-
C	177.0	4.8 (9hr)	4.2 (9hr)	-
D (SB)	85.6	8.3 (2hr)	7.0 (2hr)	-
E	**347.5**	**10.6 (12hr)**	**9.9 (12hr)**	**10.1**

The basins in the above table have been presented in sub catchment groups. Target flows are reported at the outlet across the study area boundary. The figures above correspond to the critical duration of the outflow.

The key characteristics of each retarding basin are detailed in Table 7-3.

Table 7-3: Retardation Basin Characteristics

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
B	4 No 1200mm	15,300	3.7	2 m high, 300 m long
C	3 No 1200mm	16,300	2.2	-
D (SB)	3 No 1200mm	15,100	1.2	-
E	4 No 1200mm	84,100	6.4	1 m high, 100m long

7.3.4 1 in 2 AEP Event Cross Check

Flood modelling was undertaken to determine the effectiveness of the basin in retarding flows for the 1 in 2 AEP event. The results are presented in Table 7-4.

Table 7-4: 1 in 2 AEP Event Retardation Basin Impact

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
B	1.1 (12hr)	0.75 (12hr)	-
C	1.3 (12hr)	1.1 (12hr)	-

BASIN ID	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
D (SB)	2.3 (9hr)	2.1 (9hr)	-
E	**3.4 (12hr)**	**2.5 (12hr)**	**2.4**

7.4 Hydraulic Modelling

7.4.1 1 in 100 AEP Event Modelling

A Tuflow model was developed for the purposes of confirming the outcomes from the retardation basin sizing undertaken using the RORB model. The model was modified to include the retarding basins described above for the 1 in 100 AEP flow event. The critical duration for Wharf Road RB E was the 12hr duration based on the RORB modelling. corresponding to the existing conditions modelling. The outcomes from the modelling are detailed in Table 7-5.

Table 7-5: 1 in 100 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
E	**9.9 (12hr)**	**10.1 (9hr)**	**10.1**

In addition, the flood maps flood inundation depths are included as Appendix G1.

The outputs indicate that the flood flows and levels are either lowered or remain unchanged and can be mitigated by the proposed works.

7.4.2 1 in 2 AEP Event Modelling

In order to demonstrate the impact of the upstream development, the 1 in 2 AEP event has been run in the hydraulic model. The model results are presented in Table 7-6.

Table 7-6: 1 in 2 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
E	**2.5 (12hr)**	**2.4 (12hr)**	**2.5**

The retarding basin and outlet configuration assumed in the flood modelling demonstrates that the peak developed flow in the frequent events can be controlled and mitigated. However, it should be noted that the modelling undertaken is based on high level stage storage relationship. Detailed modelling will be required at a later stage to confirm the exact outlet configuration requirements. Further modelling and volume assessment could be built upon from this study.

7.5 Stormwater Quality Treatment (MUSIC)

A MUSIC model has been developed for the purposes of determining the required footprint to meet water quality objectives. Each of the water quality elements has been modelled as either a sedimentation basin or a wetland. All water quality elements have been co-located with a retarding basin. The model schematic is included as Appendix G3 and the outcomes of the modelling are included in Table 7-7.

Table 7-7: MUSIC Modelling Outcomes

ID	SB AREA (m^2)	WL AREA (ha)	NITROGEN REMOVAL (%)	PHOSPHOROUS REMOVAL (%)	TSS REMOVAL (%)
B	840	1.7	-	-	-
C	500	1.2	-	-	-
D (SB)	660	-	-	-	-

ID	SB AREA (m^2)	WL AREA (ha)	NITROGEN REMOVAL (%)	PHOSPHOROUS REMOVAL (%)	TSS REMOVAL (%)
E	**560**	**4.5**	**45**	**72**	**88.6**

7.6 Infrastructure Characteristics

7.6.1 Treatment Device Footprint

The required footprint for treatment devices has been determined by summing the water surface area for the sedimentation basin and wetland based on MUSIC and multiplied by a factor of 1.2 to provide allowance for the variety of ancillary elements required around the wetland, such as access and dry out zones.

The total footprint areas of the retarding basins have been sized to account for the stormwater quality footprint areas. In most cases, the wetland footprint area has been adopted as the retarding basin base level with the air space above utilised for retarding basin flood storage. Table 7-8 below shows the water quality footprint compared to the total retarding basin footprint.

Table 7-8: Treatment Device Footprint

ID	WATER QUALITY FOOTPRINT AREA (ha)	TOTAL FOOTPRINT AREA (ha)
B	2.1	3.7
C	1.4	2.2
D (SB)	0.08	1.2
E	5.4	6.4

7.6.2 Additional Infrastructure

A variety of additional infrastructure is judged to be required as part of the development, with the detail varying from catchment to catchment. The infrastructure relevant to this catchment is as follows:

- Waterway easements – stormwater runoff is directed to basins via pipes or waterways. Consideration has been given to the required waterway width which is a function of catchment area. Easement widths are 40m. Details of channel widths are included in Table 7-9.
- Retarding Basin Embankment – RB E incorporates an embankment and outlet which is separate to the Geelong Ring Road. RB B includes an embankment with a height of 2.0m. The embankment for RB E is estimated to be 1.0 m high.

Table 7-9: Waterway Widths

WATERWAY ID	LENGTH (m)	HYDRAULIC WIDTH (m)	CORRIDOR WIDTH (m)
B_1	320	14	40
C_1	400	17	40
E_1	320	16	40
E_2	600	17	40
E_3	220	22	40

7.6.3 Future Analyses

The detail of the assets described above will be further refined as part of the precinct development works. A variety of studies will be undertaken in association with the development. It is recommended that the following study be considered as part of further design development:

- Functional drainage design of the outfall between RB E through Geelong Ring Road and ultimately to the existing drain west of Bacchus Marsh Road. An easement may also be required for this drainage reserve.

8 St Georges Drain Outfall (C155)

8.1 Site Description

The St Georges Drain catchment is located in the south eastern portion of the study area. The outlet catchment is located along Princes Hwy. The total area of the catchment included in the investigation is 7.5 km^2, of which the study area comprises around 15%. There are two separate waterways or drainage lines which discharge flows across the study area boundary at the Geelong Ring Road. A map of the sub catchment is included as Figure 8-1.

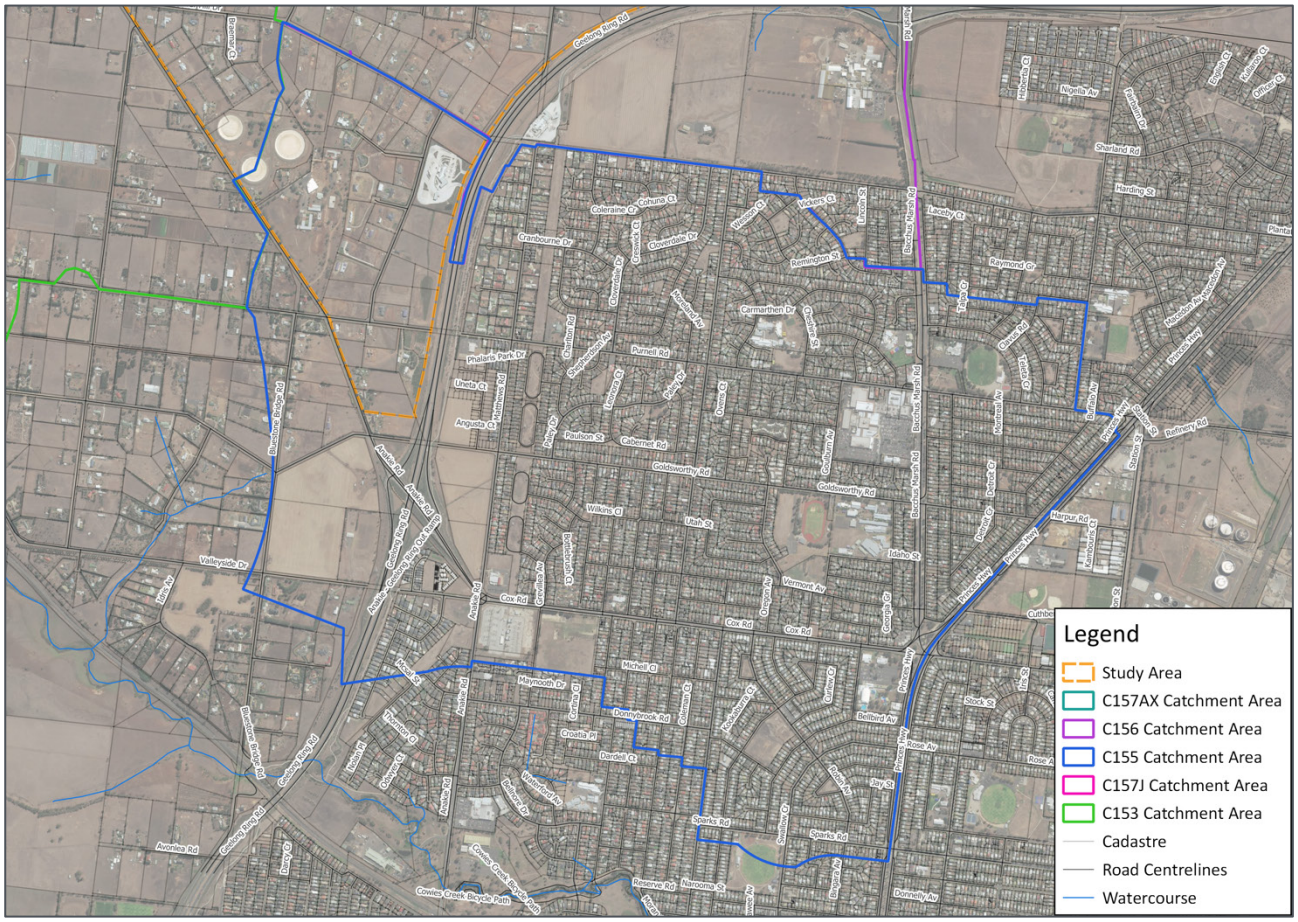


Figure 8-1: St Georges Drain Sub Area

8.2 Site SMS

The St Georges catchment represents a special case with respect to this analysis. Section 12 of this report describes a risk assessment which considers the impacts to the downstream region. The analysis identified that there is a high risk of impact to the densely developed area downstream of the Geelong Ring Road within the St Georges catchment. It was identified that a detailed hydrologic and hydraulic study of this catchment would be required to confirm the nature of any downstream impacts. The outcomes of such a study would be used to inform any decision on the ability to undertake additional development within this catchment.

For the purposes of this study, the analysis was limited to identifying the potential location and approximate sizing of infrastructure assets. The ultimate size of any infrastructure would be informed by a detailed downstream catchment study.

The conceptual arrangement of site stormwater infrastructure is detailed in Figure 8-2.

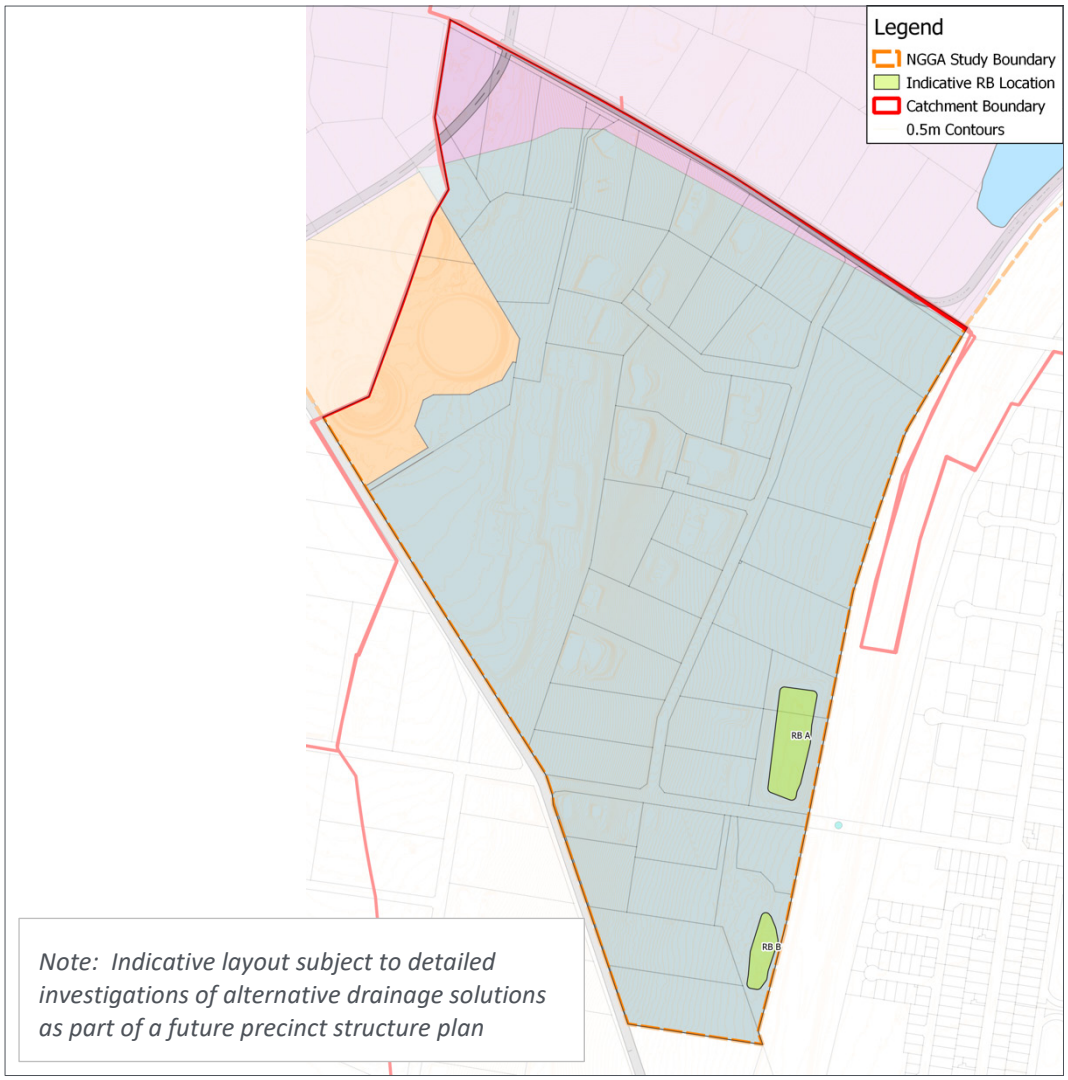


Figure 8-2: St Georges Drain SMS Infrastructure

8.3 Hydrologic Modelling

8.3.1 General

The hydrologic model for the St Georges Drain catchment was modified in a number of respects. Initially, the model was modified to ensure consistency between the RORB model existing conditions peak flows and the Tuflow existing conditions flows. The model was then further modified to reflect the proposed developed conditions.

8.3.2 Existing Conditions Adjustments

The modifications made to the existing conditions RORB model described in SMEC (2018) are as follows:

- The length of a select number of stream lengths was altered to change the relative delay in that portion of the catchment. Increasing the length of select stream sections has the effect of increasing attenuation and reducing peak flows. Reducing stream lengths has the opposite effect.
- In a number of cases, the direction of flow was re-aligned to be consistent with flow patterns observed in the Tuflow model.

The modifications made to the model are detailed on a figure included as Appendix C.

The modelled outcomes showing the adjusted peak RORB flows relative to the Tuflow outputs documented in SMEC (2018) are detailed in Table 8-1.

Table 8-1: Comparison Between RORB modelled flows and Tuflow Existing Conditions

OUTLET ID	CATCHMENT AREA (ha)	1 NI 100 AEP PEAK DISCHARGE (m^3/S)	
		RORB Adjusted	**SMEC (2018) Tuflow**
1	90	3.5 (3hr)	3.5 (2hr)
2	40	2.3 (2hr)	2.2 (2hr)

8.3.3 Developed Conditions Adjustments

The modifications to the RORB model to represent developed conditions were as follows:

- The proportion impervious of the catchment sub areas was modified to reflect the proposed density of development.
- In a number of cases, the direction of flow was re-aligned to reflect the use of stormwater pipes or open channels to redirect flows.
- Retardation basins were included into the model in line with the proposed development strategy.

The RORB model was run to confirm the effectiveness of the retardation infrastructure and the key outcomes are detailed in Table 8-2.

Table 8-2: 1 in 100 AEP Event Retardation Basin Impact

BASIN ID	CATCHMENT AREA (ha)	INFLOW (m^3/s)	OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A	90	4.1 (2hr)	3.4 (3hr)	3.5
B	40	1.1 (2hr)	0.9 (2hr)	2.2

The basins in the above table have been presented in sub catchment groups. Target flows are reported at the outlet across the study area boundary.

The key characteristics of each retarding basin are detailed in Table 8-3.

Table 8-3: Retardation Basin Characteristics

BASIN ID	OUTLET CONFIGURATION	STORAGE (m^3)	FOOTPRINT AREA (ha)	EMBANKMENT SIZE
A	2 No 900mm	13,100	1.0	-
B	1 No 750mm	2,590	0.04	-

No cross checks were undertaken for the 1 in 2 AEP flood event due to the current uncertainty with regard to the potential for development within this sub catchment.

8.4 Hydraulic Modelling

8.4.1 1 in 100 AEP Event Modelling

A Tuflow model was developed for the purposes of confirming the outcomes from the retardation basin sizing undertaken using the RORB model. The model was modified to include the retarding basins described above for the 1 in 100 AEP flow event. The critical duration for RB A and B was the 2hr duration corresponding with the RORB peak outflow modelling. This duration was run in Tuflow. The outcomes from the modelling are detailed in Table 8-4.

Table 8-4: 1 in 100 AEP Retardation Basin Cross Check

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
A	3.4 (3hr)	2.8 (2hr)	3.5

BASIN ID	RORB OUTFLOW (m^3/s)	TUFLOW OUTLFOW (m^3/s)	TARGET OUTFLOW (m^3/s)
B	0.9 (2hr)	0.9 (2hr)	2.2

The outputs indicate that the flood flows and levels are either lowered or remain unchanged.

It should be recognised that the absence of a clear impact in the 1 in 100 AEP flood event does not mean that there are no impacts to the downstream region. In particular, the potential impact of development on more frequent floods should be investigated in detail to confirm the potential for downstream impacts.

8.5 Stormwater Quality Treatment

For St Georges catchment, the treatment areas of the stormwater quality systems have been roughly estimated by assuming a similar proportion of treatment area to catchment area to the investigated catchments in this report. Further modelling should be done to confirm the treatment area required to meet best practice and that it is feasible to co-locate within the proposed retarding basins.

Table 8-5: Indicative Treatment Areas

ID	WL FOOTPRINT AREA (HA)
A	2.7
B	1.2

8.6 Infrastructure Characteristics

8.6.1 Additional Infrastructure

The St Georges catchment is relatively small and no substantial additional infrastructure has been identified as part of the concept strategy

8.6.2 Future Analyses

The detail of the assets described above will be further refined as part of the precinct development works. A variety of studies will be undertaken in association with the development. It is recommended that the following study be considered as part of further design development:

- As discussed above, any future development proposal should be informed by a detailed study of the downstream hydrology and hydraulics. Such a study should identify the impacts of development on downstream flooding over the full range of flood events. In particular, it would need to consider the impacts of additional stormwater runoff volumes.
- Stormwater Quality Treatment sizing should be done to confirm the area required for the potential redevelopment of the sub catchment.

9 Development Staging

9.1 General

Within each of the study sub catchments there is a variety of infrastructure elements which have been identified that are required to meet the project design objectives. When considering the order in which infrastructure elements should be constructed, there are a range of principles which should be applied. Some of the principles are generic and are routinely applied to developments, while others are specific to individual catchments and environments.

The overarching principle to be applied is that retardation and water quality devices should be in place to ensure to the extent practicable that design requirements are met at the completion of development works. Thus, water retardation measures must be in place to ensure that downstream property owners are not exposed to additional flooding risk at the time that impervious areas are created. With regards to stormwater quality, sedimentation basins should be in place prior to the commencement of construction activities and prior to construction of large waterway systems. The implementation of plantings associated with wetlands and bioretention elements are often delayed till later in the construction cycle to ensure that there is sufficient impervious runoff to sustain plantings and also to minimise the risk of smothering by excess sediment generated during construction activities.

In applying the above principles, it is logical to construct development stages progressively from downstream to upstream, progressively including additional SMS infrastructure as required. From time to time, temporary retardation or treatment measures may be implemented via agreement between CoGG and developers to facilitate development of individual lots ahead of natural sequencing. Alternatively, developers and CoGG may work together to produce a construction sequencing plan which suits the staging preferences of the developer and the design requirements of CoGG.

It is anticipated that the development will occur closer to the areas with existing roads which are generally near the downstream part of the catchments. If development occurs with this logic, then there would be fewer issues in terms of infrastructure staging.

The above principles are applied routinely during typical development processes and form part of the standard process for obtaining a permit from CoGG.

9.2 Sub Catchment Specific Considerations

9.2.1 General

While the general principles apply to all of the proposed development sub catchments, it is considered worthwhile to highlight a number key issues relevant to a number of those specific areas.

9.2.2 Cowies Creek

The development staging issue which is unique to the Cowies Creek catchment is the impact of urban development on the waterways through private land between the study boundary and the main Cowies Creek waterway downstream of the railway line which is located around 4 km south of the catchment. As discussed in previous sections, development will have the impact of increasing frequency and runoff volumes and it is, therefore to be expected that the relatively steep waterways through private land will be eroded over time. It is considered that erosion protection works should be completed in the downstream waterway prior to commencing upstream development. An expensive alternative could be to construct a pipe along Evans Road past the high point and narrow road side drain to Cowies Creek.

9.2.3 Hovells Creek

There are two issues of relevance to development of this catchment as follows:

- The analysis has been undertaken under the assumption that the downstream development and drainage works of the Lara West PSP has been completed. The development of the Hovells Creek sub catchment is contiguous with the Lara West main drainage works and effectively forms a precondition on development of the Hovells Creek sub catchment. Lara West drainage strategy provides the formal drainage connection from NGGA boundary to O'Hallorans Road and ultimately to Hovells Creek further downstream of Lara West PSP.
- As discussed in Section 5 above, it is proposed that an outlet design be designed and constructed across the gas main east of Bacchus Marsh Road. These works are proposed to be outside of the study area. The detail

of these works can be commissioned as part of the functional design of the relevant retarding basins as part of NGGA. There is no reason at this stage to change the Lara West PSP as there is an allowance for a waterway reserve at the outlet point. The levels of the outlet and gas main depth will need to be determined. If the waterway reserve is insufficient in terms of batter requirements, then an alternative solution on the NGGA boundary may be required. An obvious but costly option could be to lower the gas main locally. The functional design should be developed as part of the precinct stage investigations.

9.2.4 Elcho Drain

Based on the precinct development timing within this catchment, development will occur initially on the upstream side of the escarpment prior to downstream areas adjacent to Bacchus Marsh Road. At present there is no formalised drainage path downstream of the monocline. Two key ramifications for development are as follows:

- A formalised waterway will need to be designed and constructed down the monocline and through to Bacchus Marsh Road prior to upstream developments taking place. There are currently no waterway easements and these will also need to be created along the proposed waterway alignment.
- In association with the waterway creation, the investigation of erosion and design of protection measures down the steep monocline should be completed prior to upstream development.
- Upgrade works for Elcho Drain are expected to be completed as part of the GREP development east of Bacchus Marsh Road. The design of this drain sets a specific flow requirement from Elcho Drain catchment SMS. The drainage infrastructure in this SMS has been sized to retard the flows below the existing conditions and also the capacity requirements of Elcho Drain downstream. The modelling undertaken assumes that the upgrade will eventuate and therefore the flood depth and afflux results should be assessed based on this assumption. Without undertaking additional modelling, it is possible that without the Elcho Drain upgrade within GREP, the afflux could result in unacceptable outcomes. This can potentially occur especially since the downstream terrain is very flat and is likely to have areas of trapped low points and pooling where the afflux could become evident. Therefore, it would be prudent that the upgrade works downstream of Bacchus Marsh Road be considered essential in the development requirements of the Elcho Drain NGGA catchment.

9.3 Precinct Scale Considerations

9.3.1 General

The development of the NGGA would be undertaken sequentially as a series of discrete precincts which would each have an individual PSP. CoGG have proposed boundaries for the precincts and also relative timings for development of those precincts. The draft layout of the precincts is detailed on an image included as Appendix A2. The precinct layout has further been presented in conjunction with the SMS infrastructure and is presented on a figure included as Appendix B3 and B4.

The plan indicates that there are four precincts with one having a short-term timing, two with a medium-term timing and one with a long term timing. The precinct boundaries do not closely align with sub catchment boundaries and this has implications for the timing of works. The issues of relevance are presented below.

9.3.2 Short Term Precinct

This proposed precinct is located in the north-east quadrant of the NGGA and it encompasses the eastern half of the Hovells Creek sub catchment and around one third of the Elcho Drain catchment in the north east portion. Issues relevant to each sub catchment are as follows:

- Hovells Creek – This sub catchment is unaffected by the proposed precinct boundaries. The proposed infrastructure layout is well suited to the precinct layout. The portion outside of this precinct has a separate wetland/retarding basin which can be included as part of the medium-term precinct.
- Elcho Drain – Elcho Drain incorporates two larger sub areas, one being to the north and the other to the south. The downstream half of the northern area is included in this precinct and the SMS infrastructure fits quite neatly either side of the boundary. There is, however, a conflict between the infrastructure location between the short and long-term precincts. The SMS currently directs the majority of outflows through to a retarding basin/wetland (RB F) within the long-term precinct. It is suggested that the conflict could be resolved through the implementation of one of two options:

- Option 1 - Include the development of the waterway, and Elcho Drain RB F within the short-term precinct works.
- Option 2 - Revise the SMS and direct flows from the northern catchment to RB D which is located within the short-term precinct. If this option were to be progressed, the size of RB D would increase and additional stormwater volumes would be discharged in the vicinity of Gibbons Road, which is different to the current circumstance were flows are directed to Elcho Drain. The potential downstream impacts of the re-alignment would need to be investigated. There is the potential that additional downstream infrastructure would be required to address risks. Further to this, option 2 will be costlier than the proposed channel to RB F due to the relative increase in excavation required in RB D. This is especially the case for scenario 2 where RB D is much larger than in scenario 1.
- In addition to the above, it should be recognised that the SMS infrastructure has been sized to achieve the required outcomes at the study area boundary. The modelling outcomes would need to be reviewed to confirm that the sizing associated with individual elements achieves the required outcomes in the short-term conditions.
- A small portion of the precinct in the south west corner drains to the long-term precinct into RB E of Elcho Drain. This area could be excluded from the short-term precinct. Alternatively, further investigation could be undertaken to determine whether it would be possible to direct drainage from this area to the short-term precinct.

9.3.3 Medium Term Precincts

There are two precincts which are nominated to have a medium-term timing. The considerations for the medium-term development have been assumed to occur at different time frames and not necessarily concurrently.

The medium-term precinct on the North West quadrant captures portions of the Hovells Creek, Elcho Drain and Cowies Creek sub-catchments. Issues relevant to each sub catchment are as follows:

- Cowies Creek – Almost a quarter of the precinct area covers the Cowies Creek catchment sub area. Should this area on the south west corner of this precinct develop first, there is a requirement to build a stormwater treatment system and outfall connection which is proposed in the other medium term precinct and along Anakie Road (RB C). It is recommended that the South West Precinct be developed first or concurrently to resolve this issue.
- Hovells Creek – The upstream portion of the Hovells Creek catchment is included in the medium-term precinct. No staging issues have been identified with the spilt, as the majority of the area is treated by a single wetland in Scenario 2. In scenario 1, there is predominantly no development in this area and does not need to be resolved. However, some portion of this catchment south of the conservation zone will need to be drained through a pipe system and discharge to the short term precincts and ultimately to RB D in Hovells Creek catchment.
- Elcho Drain – As discussed above, there are two smaller catchments within the Elcho Drain sub area, being a northern and a southern catchment. The northern half of the catchment is situated on the upstream side of the escarpment. Approximately, the upstream half of the northern catchment is located within the medium-term precinct and infrastructure for that precinct is also located within the medium-term precinct boundary. The flows and treatment requirements for this area can be achieved prior to discharging downstream of the monocline. The northern catchment SMS infrastructure consisting of SBRB A, RB A, RB B, and parts of RB C of Elcho Drain is, therefore, well suited to the proposed precinct boundary. The drainage outfall from this point drains through the short term precinct downstream which is expected to be formalised by the time the medium precinct develops. The outfall is proposed on the long term precinct to RB F of Elcho Drain. Ideally the channel should be formalised prior to developing the upstream catchment. The same issue can be resolved as discussed in the short term precinct above.

The second medium-term precinct on the South West quadrant capture portions of the Elcho Drain and a large part of Cowies Creek sub-catchments. Issues relevant to each sub catchment are as follows:

- Elcho Drain - It is estimated that around one quarter of the upper portion of the southern catchment near RB A1 is included in the medium-term precinct. The SMS infrastructure is located in the long-term precinct and as a result, this upper catchment portion would not be able to discharge downstream without a formalised outfall. Therefore, the upper catchments cannot be developed in advance of the long-term precinct. A solution could be to either amend the precinct boundary to follow the new road alignment and adjustments

to sub catchment areas, or to include the major waterway channel through the Elcho Drain sub catchment as part of the medium-term precinct.

- Cowies Creek - In the south-east section of the precinct, a proposed waterway crosses through a corner of the long-term precinct. This issue may be resolved through either an amendment to the precinct boundary, or alternatively to investigate the potential to re-align the channel around the proposed boundary. Besides this issue, Cowies Creek catchment is generally well suited to the medium term precinct.

9.3.4 Long Term Precinct

The long-term precinct includes portions of all sub catchments with the exception of Hovells Creek. The potential issues are discussed below:

- Cowies Creek – A small portion of the southern tip of the Cowies Creek catchment is included in the precinct. The SMS is largely unaffected by the proposed boundary with the exception of the interface discussed above for the medium-term precincts.
- Elcho Drain – The long-term precinct does not create any issues for the Elcho Drain catchment other than those raised for the short and medium-term precincts.
- Wharf Road – The Wharf Road sub catchment is located entirely within the long-term precinct and as such, there are no staging issues which need to be resolved.

9.3.5 Elcho Drain Interface

The key staging issues for resolution relate to the Elcho Drain catchment. Both short and medium-term precincts incorporate catchment portions which drain through the long-term precinct and include SMS infrastructure within the long-term precinct. It is recommended that the either precinct boundaries be amended or that the drainage elements within the long-term precinct be included within the short and medium-term precinct plans respectively. An additional option would be to attempt to design a solution which is sympathetic to precinct boundaries rather than natural catchment boundaries and flow paths. This alternative is judged to be more challenging from an engineering perspective and likely to increase the infrastructure costs.

10 Integrated Water Management

A draft Integrated Water Management (IWM) position paper has been prepared for the NGGA and is documented in CoGG and Barwon Water (2018). The outcomes presented in that document have been considered as part of the SMS development process. Opportunities to address various aspects have been reviewed and are discussed below:

- Waterway Buffer Widths – The IWM principles include a flexible objective to provide waterway widths which meet or exceed typical minimums. The proposed waterway easements extend high up into the study area, commonly beyond the extents where there are any observable waterway channels in existing conditions. The proposed widths are consistent with current Melbourne Water guidelines. There is scope to increase widths up to 50 m or 100 m in total if it is considered to be desirable.
- Waterway Connectivity – The IWM principles include a flexible objective to improve the ecological condition of waterways. The proposed waterways are continuous from the study area boundary well up into the development region. With appropriate landscaping, this provides for habitat connectivity. Broader connectivity across sub catchments could be achieved depending upon open space planning. Limitations on the suitability of this environment would be the relatively low rainfalls and the general lack of habitat beyond the study area boundary.
- Distributed WSUD Assets - The IWM principles include a flexible objective to distribute stormwater assets throughout the study area. The proposed SMS layout provides multiple water retaining assets throughout the study area in concert with the well-connected waterways. While the landscape and existing development influence the SMS infrastructure layout, it is considered that the proposed layout provides for the desired outcomes.
- Stormwater Harvesting - The IWM principles include a flexible objective to provide alternative water to the region through stormwater harvesting where feasible. The proposed SMS provides multiple stormwater assets, with wetlands providing the most obvious sources for harvesting. In addition, the assets are located in green areas where there is potential to construct underground storage assets if desired. It should be recognised that the potential to harvest stormwater from wetlands is typically limited by timing of demand and the requirement to keep wetland plants alive. Demand for non-potable water is frequently higher during the summer months when there is less rainfall. In this same time period, there is commonly restriction on the amount of water which can be harvested, since a good supply is required to minimise the risk of mortality in wetland plants.

It is recommended that further study on the stormwater harvesting opportunities within NGGA is undertaken in the next iteration of the SMS at a precinct scale.

11 Downstream Impacts Risk Assessment

A risk assessment in relation to stormwater impacts downstream of the NGGA study boundary have been completed for each of the catchments as part of Phase 1 study. The methodology and outcomes are detailed below incorporating updates to the original risk assessment and based on this Phase 3 developed conditions study.

The risk assessment is undertaken at a relatively coarse scale, relying on the outputs from the existing and developed conditions hydrologic, hydraulic, stormwater quality modelling and judgement to evaluate relative risk. The risks have been reviewed and updated. Better understanding of the risks have been identified as part of the Phase 3 study.

11.1 Methodology

A risk assessment comprises an analysis of identified risk aspects which are characterised in terms of probability and impact. The risk aspects to be considered for the purposes of this assessment have been defined by CoGG and are listed below:

- Flow rate increase in a 1 in 100 Annual Exceedance Probability (AEP) event.
- Flow volume increase in a 1 in 100 AEP event.
- Flood rate of rise.
- Flood duration increase in a 1 in 100 AEP event.
- Increased flooding frequency.
- Increase in flood hazard during a 1 in 100 AEP event.
- Deterioration in stormwater quality.
- Environmental impact resulting from altered flow regime.

The CoGG guidance has additionally nominated simple scales upon which both probability (or likelihood) and impact (consequence) are to be measured as listed in Table 11-1.

Table 11-1: Likelihood and Consequences measuring scales

RATING	DESCRIPTION	
	LIKELIHOOD	CONSEQUENCE
1	Not likely	Impacts acceptable
2	Possible	Impacts potentially unacceptable
3	Likely	Impacts unacceptable

CoGG have further proposed an evaluation matrix for defining whether overall risk is considered to be acceptable. The matrix is presented as Table 11-2.

Table 11-2: Risk Evaluation Matrix

		Consequence		
		1	2	3
Likelihood	1	1	2	3
	2	2	4	6
	3	3	6	9

The definition of the colour codes is as follows:

Low risk, no treatment required

Moderate risk, treatment measures may be required

High risk, treatment measures required

In each case where treatment is a requirement, measures have been proposed and the overall risk has been re-evaluated.

11.2 Analysis

For the purposes of undertaking the risk assessment, the overall NGGA development zone and downstream region has been divided into a number of sub-units which are broadly associated with a consistent risk profile.

The risk assessment sub units for stormwater may be expected to coincide with watershed boundaries. For the purposes of this assessment, it is convenient to utilise the same boundaries which have been applied to the analysis of the SMS. The separate units which are presented diagrammatically as Appendix A3.

- C153 Cowies Creek
- C156 Wharf Road Drain
- C157J Elcho Drain
- C157AX Hovells Creek

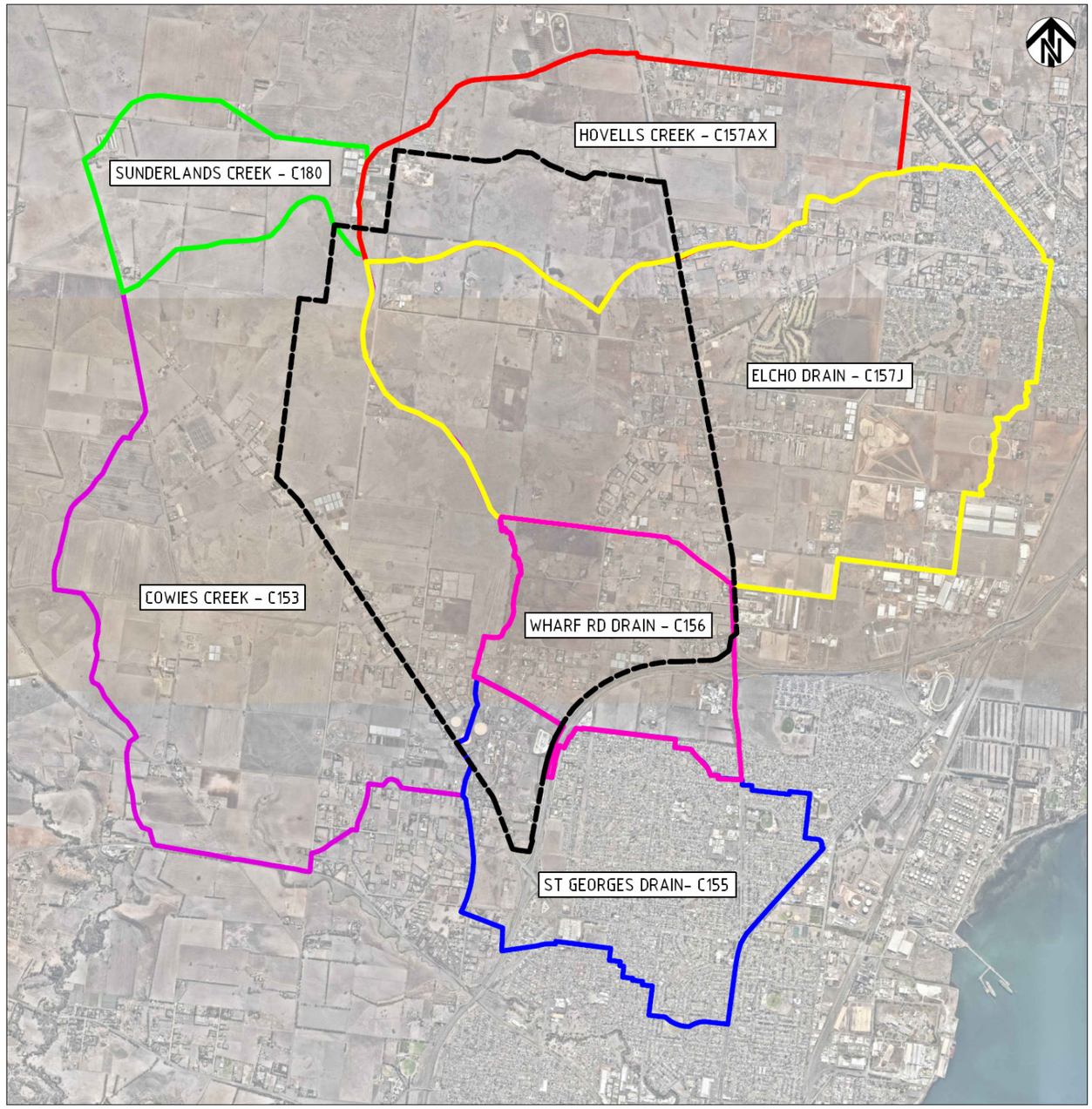
It is noted that St Georges Drain and Sunderlands Creek catchment have been removed from the assessment as these areas are no longer expected to be developed for the purposes of this study.

Risk assessment tables have been prepared for each of the above sub areas and are included as Table 12-1 to 12-4 below.

Risk Aspect	Sunderlands Creek C180 Untreated Risk
Flow Rate	1
Flow Volume	1
Rate of Flood Rise	1
Flood Duration	1
Flood Frequency	1
Flood Hazard	1
Stormwater Quality	1
Environmental Impact	2

Risk Aspect	Cowies Creek C153 Untreated Risk
Flow Rate	6
Flow Volume	3
Rate of Flood Rise	1
Flood Duration	2
Flood Frequency	6
Flood Hazard	2
Stormwater Quality	4
Environmental Impact	2

Risk Aspect	St Georges Drain C155 Untreated Risk
Flow Rate	9
Flow Volume	9
Rate of Flood Rise	9
Flood Duration	6
Flood Frequency	6
Flood Hazard	6
Stormwater Quality	4
Environmental Impact	2



Risk Aspect	Hovells Creek C157AX Untreated Risk
Flow Rate	9
Flow Volume	6
Rate of Flood Rise	9
Flood Duration	4
Flood Frequency	3
Flood Hazard	6
Stormwater Quality	4
Environmental Impact	2

Risk Aspect	Elcho Drain C157J Untreated Risk
Flow Rate	9
Flow Volume	6
Rate of Flood Rise	6
Flood Duration	4
Flood Frequency	3
Flood Hazard	6
Stormwater Quality	6
Environmental Impact	2

Risk Aspect	Wharf Rd Drain C156 Untreated Risk
Flow Rate	9
Flow Volume	6
Rate of Flood Rise	9
Flood Duration	4
Flood Frequency	3
Flood Hazard	6
Stormwater Quality	4
Environmental Impact	2

NOT FOR CONSTRUCTION

LEGEND

STUDY AREA
C155 CATCHMENT
C156 CATCHMENT
C157J CATCHMENT
C157AX CATCHMENT
C180 CATCHMENT
C153 CATCHMENT
LOW RISK
MODERATE RISK
HIGH RISK

NORTHERN GEELONG GROWTH AREA - DOWNSTREAM IMPACT RISK ASSESSMENT (NO MITIGATION OPTION)

PRELIMINARY - For Draft Framework Planning Purposes Only

INFORMATION DOCUMENT

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Figure 11-1: Risk Assessment Matrix

11.3 Commentary

11.3.1 General

The risk assessment analysis has been developed giving consideration to the SMS in this report developed for the site. The SMS provides two different scenarios for development. The second scenario includes development across the entire NGGA region. This risk assessment relates to the second scenario.

11.3.2 Catchments

The risk assessment incorporates consideration of a number of features which are unique to the various sub catchments. These features are discussed further below:

- Cowies Creek - The catchment may be considered as having two separate elements for some aspects. The areas are upstream of the railway line and downstream of the railway line. The upstream area is farm land with no formalised drainage infrastructure other than open drains. The downstream area is a creek, typically with a limited riparian zone running through a mixture of farmland, urban parkland and built up industrial zones.
- St Georges Drain - The portion of the sub catchment which is downstream of the Geelong Ring Road is heavily urbanised with limited potential to construct treatment measures other than relatively expensive drainage augmentation. It is a feature of this sub catchment that the existing drainage infrastructure at the top end of the urbanised portion of the catchment is notably undersized in comparison to the capacity at the downstream end. The catchment is relatively flat and the flood modelling gives the impression that the catchment flooding may be susceptible to increased runoff volumes.
- Elcho Drain - The proposed SWMS for the Elcho Drain catchment incorporates large catchment area which flows through the GREP area and existing Grand Lakes development downstream. It is proposed that, flood flows will maintain their current catchment alignment. The risks are related to downstream existing areas of Bacchus Marsh Road.
- Hovells Creek - As a corollary to the feature described for Elcho Drain, the risk for some aspects would be increased in the Hovells Creek sub catchment. The risk assessment of the Hovells Creek sub catchment applies assumptions which are consistent with those adopted for the flood impact assessment report. The most relevant of the assumptions to the risk assessment is that the downstream main drainage works of Lara West has been completed.

11.3.3 Risk Treatments

A variety of treatments are proposed for the various risk aspects. Further description of the treatment effectiveness is provided below.

Flow rate

- Retarding basins are the predominate treatment for controlling peak flows.
- Wetlands are not designed to attenuate flows, but they will, nevertheless, have an impact upon very frequent flows.
- Waterways or open drains within easements are less hydraulically efficient than formalised pipe networks and will have a limited attenuating function for urban runoff.
- Drainage network augmentation can ensure that higher flow rates bypass areas of highest impact.

Flow Volume

- Rainwater tanks provide an effective means by which runoff volumes can be reduced, noting that the most effective reduction measures require residences to be plumbed in to the stormwater tanks.
- Non-proprietary WSUD elements promote water retention in the form of infiltration or storage. In addition, there is some limited capacity to harvest from wetlands for re-use. The WSUD elements are more effective at reducing the volume of more frequent flood events than the larger 1 in 100 AEP floods.
- Waterways or open drains within easements tend to promote some infiltration, although as for WSUD elements, they are more effective at reducing frequent flood runoff than larger less frequent events.

- The total developable area can be restricted to limit the downstream impact.

Rate of Rise

- Retarding basins can control the rate of rise for flood events through a controlled release of flows which are attenuated relative to inflows.
- Wetlands are not designed to reduce the rate of rise, but they will, nevertheless, have reduce the rate of rise of very frequent flows.
- Waterways or open drains within easements are less hydraulically efficient than formalised pipe networks and will have a limited attenuating function for urban runoff which will reduce the rate of rise.
- Rainwater tanks which have capacity during a storm event will delay the onset of flooding and thus the rate of rise.

Duration of Inundation

- Retarding basins can control the rate at which flows are released and thus the duration of flood peaks above a design threshold. The duration below the design threshold may be increased, however, this is typically controlled within a designed hydraulic conveyance feature. The basins will be less effective in regions where flooding is predominately due to large storm volumes where drainage capacity of the flooded region is limited.
- Wetlands are not designed to reduce inundation duration, but they may, nevertheless, capture or retard modest volumes and have a beneficial effect.
- Rainwater tanks which have capacity during a storm event will offset the duration of inundation to a limited extent.
- Drainage network augmentation can reduce the duration of inundation where rate of drainage is influencing inundation. This treatment can only be considered where additional drainage infrastructure will allow more rapid drainage and also where draining more rapidly does not transfer the flooding problem to other stakeholders.

Frequency of Runoff

- Wetlands are not designed to store or attenuate flows, but they will, nevertheless, have an impact upon very frequent flows. In the case where wetlands are used for harvesting stormwater, they may also have a modest impact upon runoff frequency.
- Rainwater tanks provide an effective means by which frequency of runoff for minor events can be reduced, noting that the most effective reduction measures require residences to be plumbed in to the stormwater tanks.
- Drainage network augmentation will not reduce the frequency of runoff but can ensure that the runoff bypasses the areas of highest impact.
- Retarding basins control the frequency of out of bank or drain surcharging events downstream of the retarding basin, thereby reducing the nuisance associated with those floods. Depending upon the size of the catchment, it may be possible to attenuate high frequency events so that they are controlled to non-nuisance levels.
- Erosion protection elements will not, of themselves, reduce flooding frequency. They can, however, ameliorate one of the impacts of an increase in runoff frequency. The erosion protection elements may re

Flood Hazard

- Retarding basins are the predominate treatment for controlling flood hazard. Limiting peak flows in many circumstances will reduce flood hazard.
- Drainage network augmentation can reduce flood hazard by diverting flows from the street network into drainage infrastructure.

- Waterways or open drains within easements are typically designed to carry larger floods and eliminate the flood risk by transferring the flows to a formalised design element.

Stormwater Quality

- WSUD treatments are the most effective device for treatment water quality risk in the form of wetlands, bio-retention basins, swales and proprietary treatments. The NGGA SMS includes a majority of sediment basins and wetlands for this study's purposes.
- Waterways or open drains within easements offer some additional water quality benefits through attenuation and adsorption of nutrients.
- Stormwater re-use removes stormwater along and entrained pollutants from the stormwater system.

Environment

The watercourses associated with the sub catchments studied as part of this analysis are all in highly modified environments. None of the waterways are associated with high value environmental systems which need to be preserved as far as this study is aware. Notwithstanding this observation, there may be high value floral or faunal elements within the downstream environment which should be preserved. If any such elements are identified, then steps may be introduced to address the aspect as they may be identified.

Notwithstanding the above, to the extent possible, the proposed development should not limit the potential to improve watercourses by creating floral or faunal habitat features. The potential for incorporating such features would need to be identified in order to develop an appropriate response.

In the absence of any specific identified faunal or floral elements or potential future habitat features, it is suggested that control of stormwater water quality is an appropriate treatment to address the risk of higher nutrient loads to Corio Bay.

- WSUD elements would be the predominate control for environment aspects by minimising nutrient loads generated by urban development. Options for stormwater reuse have been discussed in the report also. Further detailed studies as part of the Precinct scale implementation is recommended.

11.4 Cowies Creek

	Cowies Creek C153 (NGGA)								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Proposed/Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: Development will increase peak downstream flow rates.	3	2	6	Flow rates are expected to increase, and development guidelines require that this impact be ameliorated, regardless of the impact.	Retarding Basins and potentially drainage pipes	1	1	1	
Flow Volume: Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.	3	1	3	Flow volumes are expected to increase as the total impervious area upstream of the railway line is estimated to increase by around 15%. This proportion naturally reduces further downstream. It is estimated that flood inundation impacts in this catchment would be driven predominately by high discharge rather than high runoff volume and the impacts of additional volume is estimated to be minor.	Potentially incorporate stormwater re-use into development Stormwater harvesting at wetlands.	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Modelling shows there is no increase in flood level impacting properties due to flow volume increase
Rate of Rise: Development will significantly increase the rate of rise of downstream flood levels.	3	2	6	While the rate of rise in the catchment will increase, the impact of that rate of rise will dissipate further downstream in the catchment. It is estimated that the rate of rise will have minimal impact in the regions immediately downstream of the study area since that land contains few residences and further downstream, the impacts will be far less severe.	Retarding Basin, creation of drainage easements in catchment downstream of development area	2	1	2	
Duration of Inundation: Development will cause a significant increase in duration of inundation in residential areas to the degree that it causes nuisance.	2	1	2	The development represents a small proportion of the overall catchment in the more densely developed regions further downstream in the catchment. In the region upstream of the railway line, the catchment relief is relatively steep, and the duration is not expected to be long in a flood event. Further, there are few properties likely to be impacted by a long duration event.	Potential Re-use, WSUD, d/s treatments, easements or potential diversion pipelines	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low
Frequency of Runoff: Development will result in an increased frequency of runoff causing downstream nuisance.	3	2	6	Downstream runoff frequency is expected to increase with the potential to initiate erosion in downstream gullies. Possible issues with landowners access across the waterway which will be subject to more runoff volume.	Creation of formal drainage easements or diversion pipelines and potential erosion protection in catchment downstream of development area, retarding basins, WSUD. Potentially some waterway crossings could be required to allow landowners to track across waterways	3	1	3	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Works outside the NGGA boundary have not been costed as part of the SMS.
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	1	2	There is little development downstream of the proposed developed area upstream of the railway line. Further downstream in the region where development occurs, the development represents a small proportion of the overall catchment and impacts are expected to be minor.	None	2	1	2	
Water Quality: Development will detrimentally impact on water quality.	2	2	4	Development in the catchment is expected to increase the level of suspended solids and pollutants in stormwater runoff.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	
Environment: Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria	3	2	6	A modified flow regime is likely to occur, however there are no downstream environmental values identified at this stage which would be impacted. The high risk rating is based upon the as yet unquantified potential to incorporate habitat features into the downstream waterway.	WSUD/opportunities for potential stormwater harvesting at wetlands	2	2	4	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low

11.5 Hovells Creek

	Hovells Creek C157AX								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Proposed/Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: Development will increase peak downstream flow rates.	3	3	9	Flow rates are expected to increase and development guidelines require that this impact be ameliorated, regardless of the impact.	Retarding Basin, constructed waterways, and drainage pipes	1	1	1	
Flow Volume: Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.	3	2	6	Flow volumes are expected to increase, however, the nature of the downstream terrain suggests that the consequence may not be significant.	Potentially incorporate stormwater re-use into development, reduce/control development footprint. Delay development until downstream Lara West PSP drainage works are completed. Completion of future infrastructure at Lara West should eliminate the risk of any increased flood volume	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Modelling shows there is no increase in flood level due to flow volume increase
Rate of Rise: Development will significantly increase the rate of rise of downstream flood levels.	3	3	9	the rate of rise is expected to increase with a high potential to increase risk to downstream areas.	Retarding Basin, delay development until downstream Lara West PSP drainage works are completed. Infrastructure at Lara West should eliminate the risk related to rate of rise to the downstream properties	1	1	1	
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	The increased volume of runoff is expected to prolong the inundation period, however, it is unclear whether the additional duration would be significant.	Potentially incorporate stormwater re-use into development. WSUD/opportunities for stormwater harvesting at wetlands, completion of future infrastructure at Lara West should eliminate the risk of any inundation to the downstream properties	2	1	2	
Frequency of Runoff: Development will result in an increased frequency of runoff causing downstream nuisance.	3	1	3	Downstream runoff frequency is expected to increase. Nuisance flows associated with more frequent events are directed to a formalised drainage network which is expected to be capable of carrying and containing those flows.	Delay development until downstream Lara West PSP drainage works are completed, retarding basin. Completion of future infrastructure at Lara West should eliminate the risk related to increased frequency of runoff to the downstream properties	2	1	2	
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	2	6	It is expected that flood hazard would be increased in the downstream areas. The relatively flat nature of the terrain, however, means that the increased hazard is not likely to be severe.	Retarding Basin, delay development until downstream Lara West PSP drainage works are completed.	2	1	2	
Water Quality: Development will detrimentally impact on water quality.	2	2	4	Development in the catchment is expected to increase the level of suspended solids and nutrients in stormwater runoff.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	
Environment: Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria	2	1	2	An altered flow regime is possible, but the highly modified downstream environment means that there are few environmental values to protect.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	

11.6 Elcho Drain

	Elcho Drain C157J (NGGA)								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Proposed/Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: Development will increase peak downstream flow rates.	3	3	9	Flow rates are expected to increase and development guidelines require that this impact be ameliorated, regardless of the impact.	Retarding Basin connecting into formal drainage channel	1	1	1	
Flow Volume: Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.	3	2	6	Flow volumes are expected to increase, however, the nature of the downstream terrain suggests that the consequence may not be significant	Potentially incorporate stormwater re-use into development. WSUD, reduce/control development footprint.	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Modelling shows there is no increase in flood level due to flow volume increase
Rate of Rise: Development will significantly increase the rate of rise of downstream flood levels.	3	2	6	the rate of rise is expected to increase with a high potential to increase risk to downstream areas. The flat nature of the downstream terrain and low density development reduces the potential consequences.	Retarding Basin, easements, upgrade of existing drainage infrastructure/creation of easements.	1	1	1	
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	The increased volume of runoff is expected to prolong the inundation period, however, it is unclear whether the additional duration would be significant.	Potentially incorporate stormwater re-use into development. WSUD	2	1	2	
Frequency of Runoff: Development will result in an increased frequency of runoff causing downstream nuisance.	3	1	3	Downstream runoff frequency is expected to increase. There is currently a plan to increase the capacity of the drainage channel downstream within GREP	Nuisance flows associated with more frequent events are directed to a formalised drainage channel in GREP, retarding basin, WSUD	2	1	2	
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	2	6	It is expected that flood hazard would be increased in the downstream areas. The relatively flat nature of the terrain, however, means that the increased hazard is not likely to be severe.	Retarding Basin	2	1	2	
Water Quality: Development will detrimentally impact on water quality.	2	3	6	Development in the catchment is expected to increase the level of suspended solids and nutrients in stormwater runoff.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	
Environment: Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria	2	1	2	An altered flow regime is possible, but the highly modified downstream environment means that there are few environmental values to protect.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	

11.7 Wharf Road Drain

	Wharf Road Drain C156								
	No Mitigation				Mitigation				
Assessment Criteria	**Likelihood**	**Consequence**	**Risk**	**Comment**	**Proposed/Possible Treatment**	**Likelihood**	**Consequence**	**Residual Risk**	**Comment**
Flow Rate: Development will increase peak downstream flow rates.	3	3	9	Flow rates are expected to increase, and development guidelines require that this impact be ameliorated, regardless of the impact.	Retarding Basin	1	1	1	
Flow Volume: Development will increase volume of runoff resulting in d/s increases in flood level in residential and commercial areas.	3	2	6	Flow volumes are expected to increase, however, the nature of the downstream terrain and existing infrastructure suggests that the consequence may not be significant	Potentially incorporate stormwater re-use into development, reduce/control development footprint.	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Modelling shows there is no increase in flood level due to flow volume increase.
Rate of Rise: Development will significantly increase the rate of rise of downstream flood levels.	3	3	9	the rate of rise is expected to increase with a high potential to increase risk to downstream areas.	Retarding Basin	1	1	1	Modelling shows there is no increase in flood level
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	The increased volume of runoff is expected to prolong the inundation period, however, it is unclear whether the additional duration would be significant.	Retarding basin, Potentially incorporate stormwater re-use into development. WSUD	2	1	2	Treatment measures can only be partially effective in reducing this risk, however the consequences remain low. Modelling shows there is no increase in flood level.
Frequency of Runoff: Development will result in an increased frequency of runoff causing downstream nuisance.	3	1	3	Downstream runoff frequency is expected to increase. Nuisance flows associated with more frequent events are directed to a formalised drainage network which is expected to be capable of carrying and containing those flows.	Potentially upgrade of existing drainage infrastructure (outside of SMS), retarding basin, WSUD	3	1	3	A retarding basin will only be partially effective in treating this risk due to the increased volume of runoff. Note: Upgrade of existing drainage infrastructure d/s has not been costed/proposed in the SMS
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	2	6	It is expected that flood hazard would be increased in the downstream areas. The relatively flat nature of the terrain, however, means that the increased hazard is not likely to be severe.	Retarding basin	2	1	2	
Water Quality: Development will detrimentally impact on water quality.	2	2	4	Development in the catchment is expected to increase the level of suspended solids and nutrients in stormwater runoff. The impact is likely to be minimal however, due to the large extent of existing development in the catchment.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	
Environment: Development causes altered flow regime that has unacceptable environmental impact not considered by other criteria	2	1	2	An altered flow regime is possible, but the heavily urbanised downstream environment means that there is little impact.	WSUD/opportunities for potential stormwater harvesting at wetlands	1	1	1	

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Neil M Craigie Pty Ltd (2012) Lara West Growth Area (LWGA) Surface Water Management Strategy, 9 June 2013.Melbourne Water (2017) Wetlands Design Manual, July 2017.

Melbourne Water (2018) Music Tool Guidelines 2018.

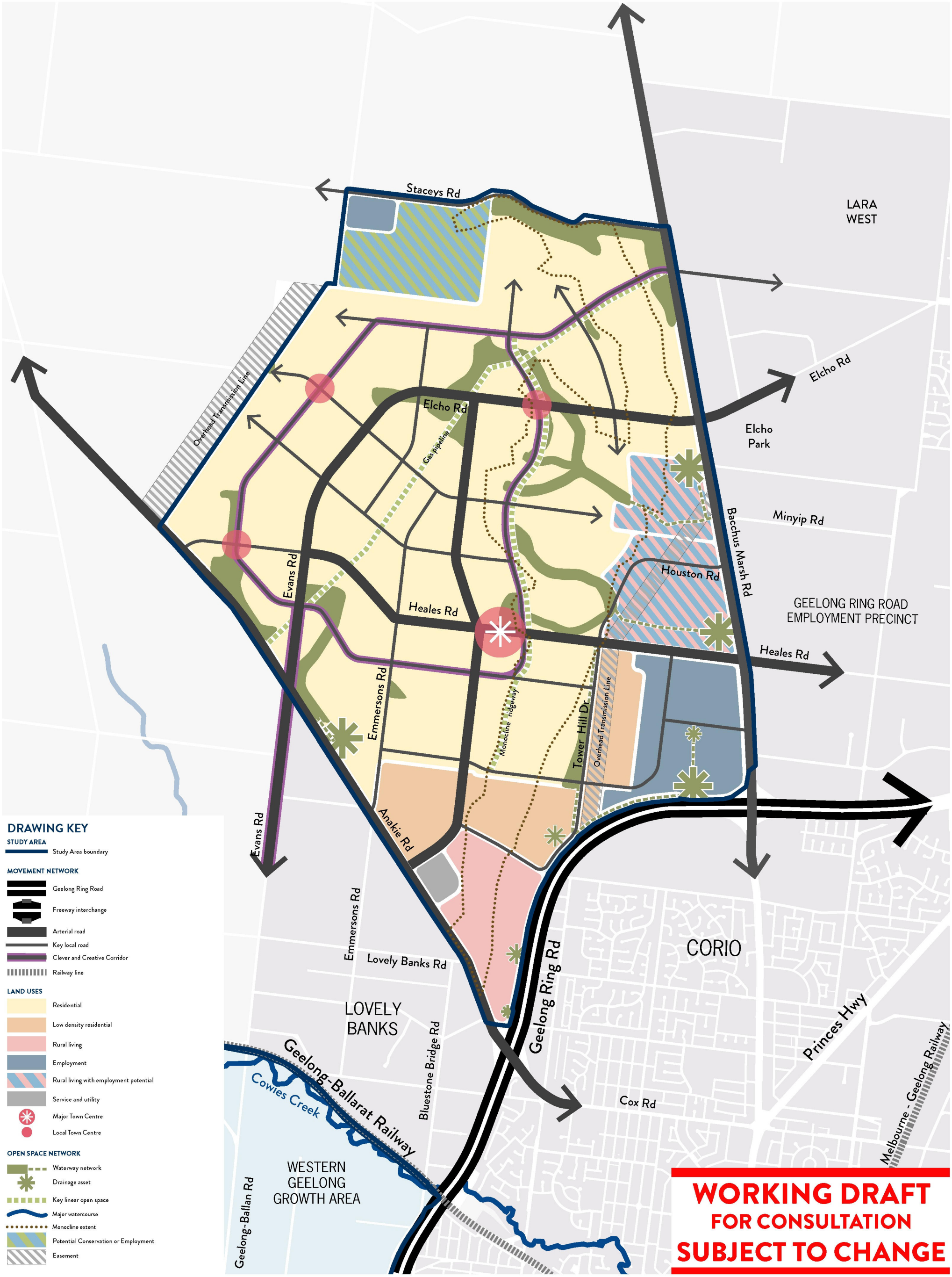
SMEC (2018) Northern Geelong Growth Area Flood Impact Assessment and Stormwater Management Strategy Volume 1: Existing Conditions Report, September 2018.

local people
global experience

SMEC is recognised for providing technical excellence and consultancy expertise in urban, infrastructure and management advisory. From concept to completion, our core service offering covers the life-cycle of a project and maximises value to our clients and communities. We align global expertise with local knowledge and state-of-the-art processes and systems to deliver innovative solutions to a range of industry sectors.



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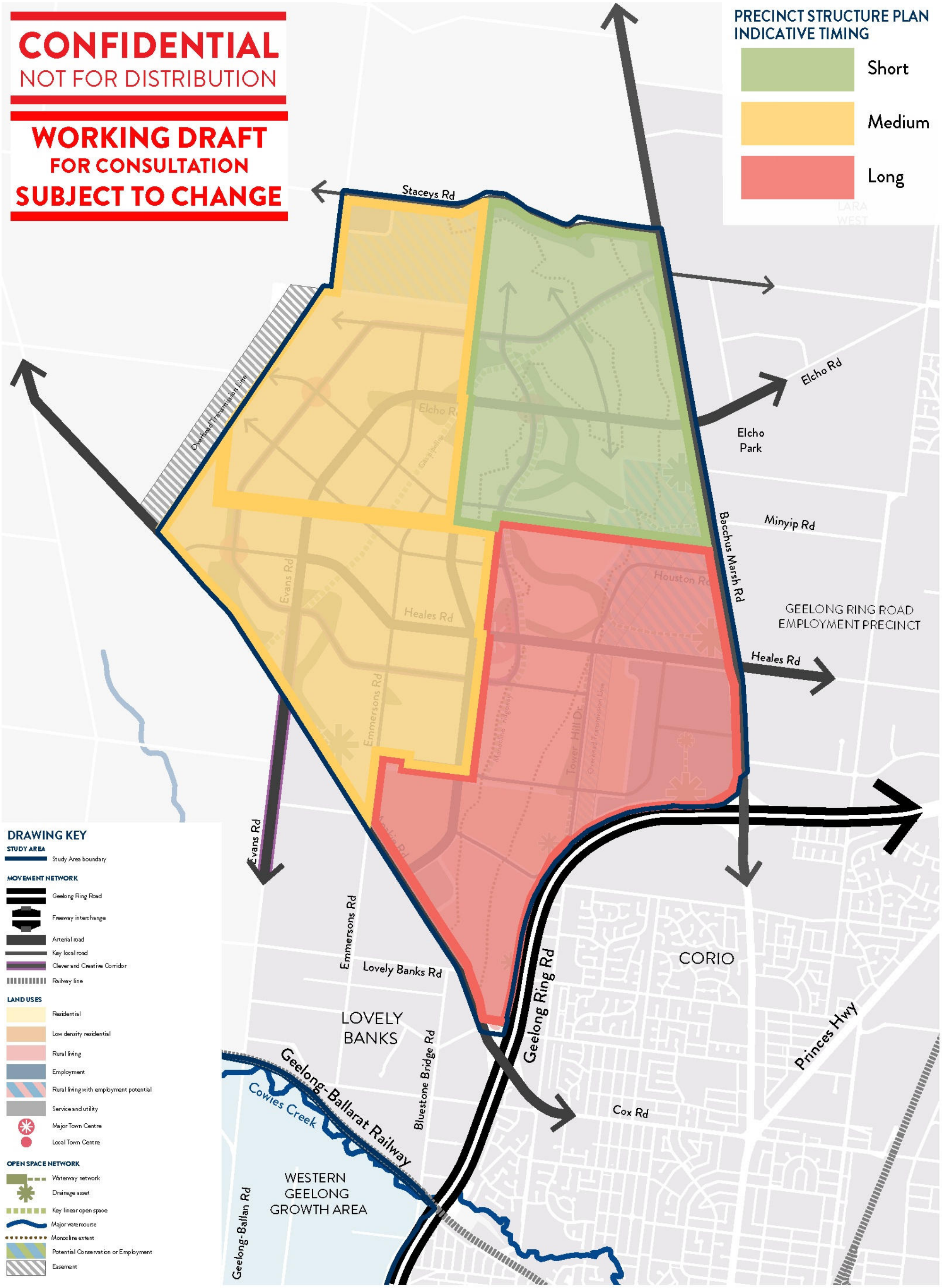


APPENDIX A1 **NORTHERN GEELONG GROWTH AREA**

FRAMEWORK PLAN

CONFIDENTIAL
NOT FOR DISTRIBUTION

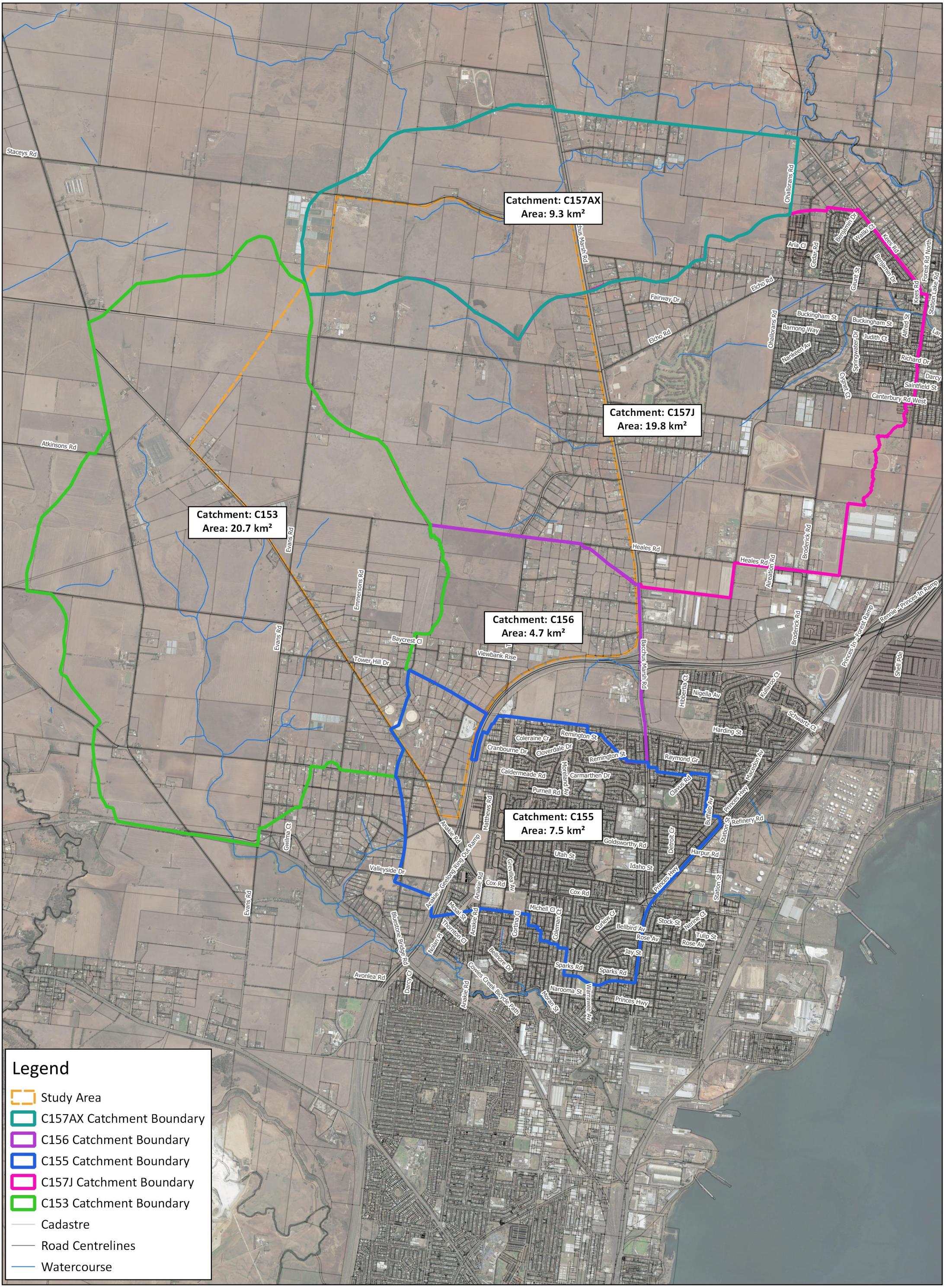
WORKING DRAFT
FOR CONSULTATION
SUBJECT TO CHANGE



NORTHERN GEELONG GROWTH AREA

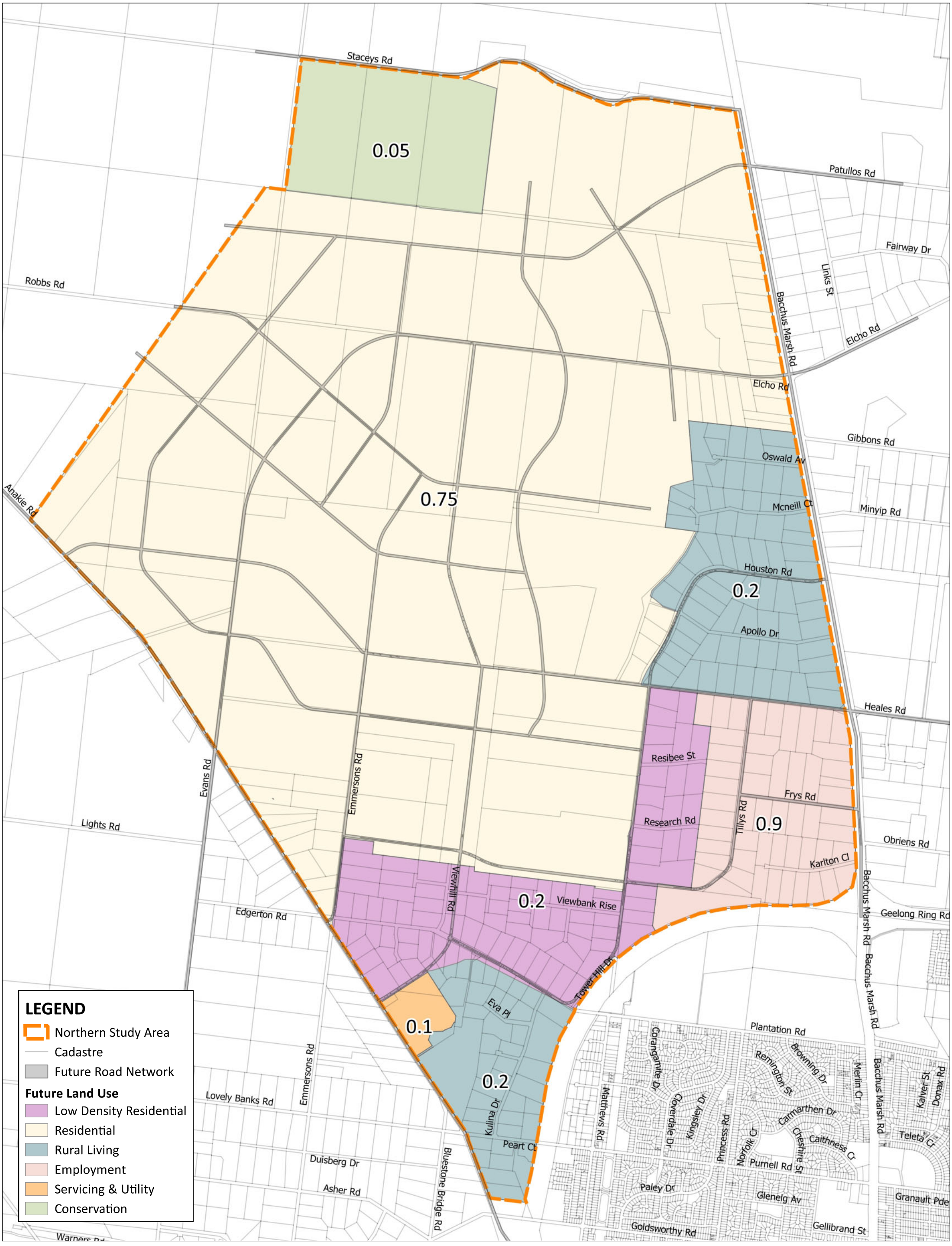
APPENDIX A2 **NORTHERN GEELONG GROWTH AREA**

PRECINCT STRUCTURE PLAN



APPENDIX A3 **NORTHERN GEELONG GROWTH AREA**

CATCHMENT LAYOUT



APPENDIX B1

DEVELOPED CONDITION

LAND USE | FRACTION IMPERVIOUS - SCENARIO 1
NORTHERN GEELONG GROWTH AREA

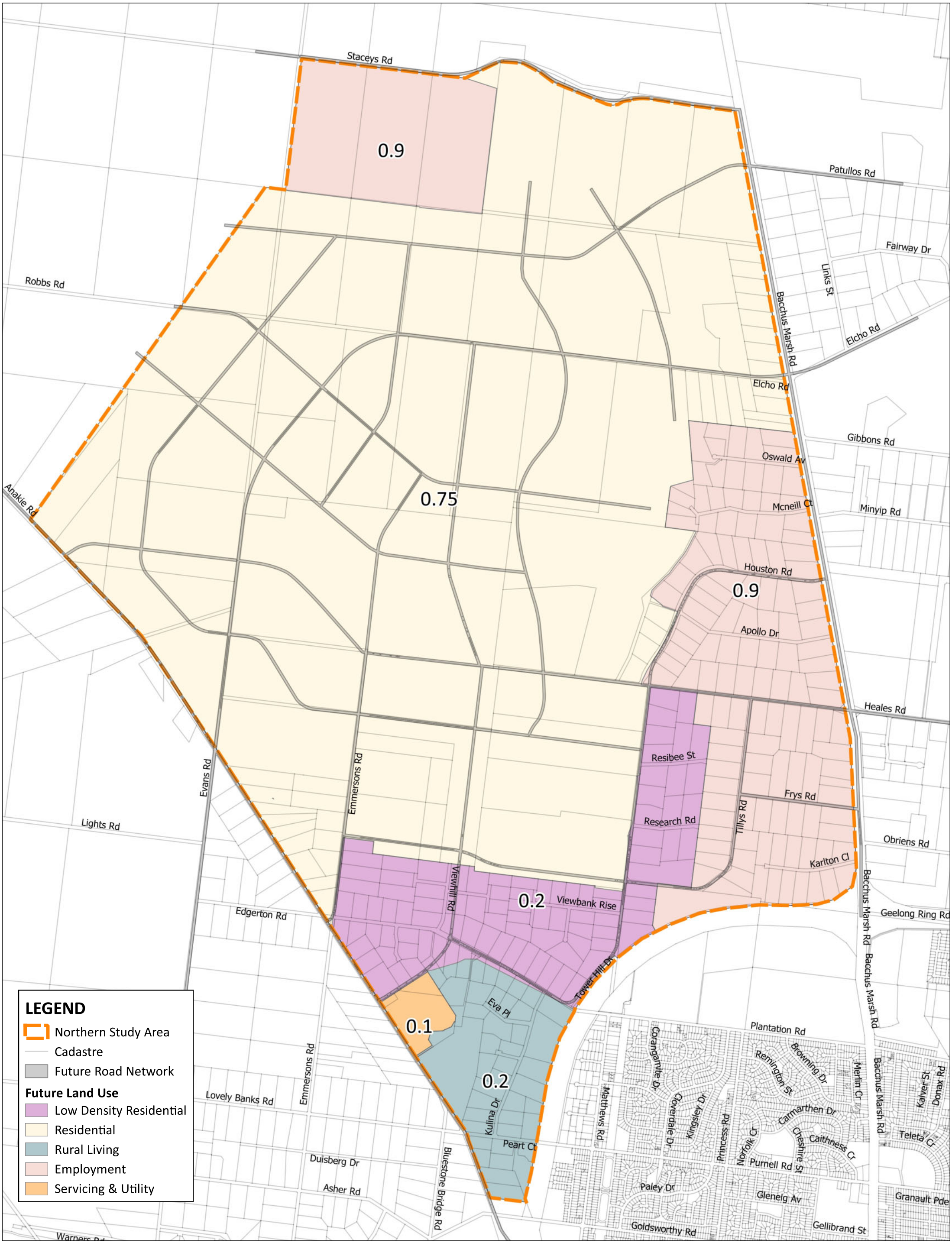
SMEC
Member of the Surbana Jurong Group

PROJECT NAME	NGGA FLOOD IMPACT
PROJECT NO	30042177W
DATE	19 Feb 2019
PAGE SIZE	A3
REVISION	C
PROJECTION	GDA94 MGA Zone 55

300 0 300 600 900 m

N

Scale 1:20000



APPENDIX B1

DEVELOPED CONDITION

LAND USE | FRACTION IMPERVIOUS - SCENARIO 2
NORTHERN GEELONG GROWTH AREA

SMEC
Member of the Surbana Jurong Group

PROJECT NAME	NGGA FLOOD IMPACT
PROJECT NO	30042177W
DATE	19 Feb 2019
PAGE SIZE	A3
REVISION	C
PROJECTION	GDA94 MGA Zone 55

300 0 300 600 900 m

N

Scale 1:20000

HOVELLS CREEK CATCHMENT C157AX

COWIES CREEK CATCHMENT C153

ELCHO DRAIN CATCHMENT C157J

WHARF RD OUTFALL CATCHMENT C156

ST GEORGES OUTFALL CATCHMENT C155

Staceys Rd
Patullos Rd
Robbs Rd
Fairway Dr
Links St
Elcho Rd
Gibbons Rd
Oswald Av
Bacchus Marsh Rd
Mcneill Ct
Minyip Rd
Houston Rd
Apollo Dr
Heales Rd
Resibee St
Frys Rd
Tillys Rd
Research Rd
Obriens Rd
Karlton Cl
Viewbank Rise
Viewhill Rd
Geelong Ring Rd
Tower Hill Dr
Plantation Rd
Outlet
Evans Rd
Emmersons Rd
Anakie Rd
Edgerton Rd
Lovely Banks Rd
Duisberg Dr
Asher Rd
Cuddihy Ct
Bluestone Bridge Rd
Kulina Dr
Peart Ct
Matthews Rd
Coolangatta Dr
Cloverdale Dr
Kingsley Dr
Princess Rd
Norfolk Ct
Purnell Rd
Cheshire St
Carmarthen Dr
Caithness Ct
Remington St
Browning Dr
Merlin Ct
Teleta Ct
Kalver St
Paley Dr
Glenelg Av
Goulburn
Goldsworthy Rd

SB RB A
SB RB B
SB RB I
SB RB F
RB A
RB A1
RB B
RB B1
RB C
RB C1
RB D
RB E
RB E1
RB F
RB G
RB G1
RB H
C153_2
C153_4
C153_5
C153_6
C153_7
C155_1
C155_2
C156_3
C157AX_1
C157J_1
C157J_2
C157J_3

LEGEND

- NGGA Study Boundary
- NGGA Precincts
- Catchment Boundary
- Subcatchment Boundary
- Outlets
- 0.5m Contours
- Gas Main/Power Lines
- Future Road Network
- Existing Property Boundary

Proposed Works

- Sediment Basin / Retarding Basin
- Wetland / Retarding Basin
- Indicative Retarding Basin Location
- Constructed Waterways
- Natural Waterway Retained
- Overland Flowpath
- Trunk Drainage

Future Land Use

- Employment
- Low Density Residential
- Conservation
- Residential
- Rural Living
- Servicing & Utility

Note: Indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX B3

NORTH GEELONG GROWTH AREA

STORMWATER MANAGEMENT STRATEGY

PROPOSED CONCEPT LAYOUT - SCENARIO 1
ONE EMPLOYMENT AREA

client: CITY OF GREATER GEELONG; Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	19 Feb 2019
REVISION	C
CREATED BY	KT

N

0 400 800 1200 m

MAP SCALE	1:25000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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HOVELLS CREEK CATCHMENT C157AX

COWIES CREEK CATCHMENT C153

ELCHO DRAIN CATCHMENT C157J

WHARF RD OUTFALL CATCHMENT C156

ST GEORGES OUTFALL CATCHMENT C155

Staceys Rd
Patullos Rd
Fairway Dr
Links St
Elcho Rd
Robbs Rd
Gibbons Rd
Oswald Av
Bacchus Marsh Rd
Mcneill Ct
Minyip Rd
Houston Rd
Apollo Dr
Heales Rd
Resibee St
Frys Rd
Research Rd
Tillys Rd
Obriens Rd
Karlton Cl
Viewbank Rise
Viewhill Rd
Geelong Ring Rd
Tower Hill Dr
Plantation Rd
Browning Dr
Remington St
Merlin Ct
Kalver St
Teleta Ct
Carmarthen Dr
Caithness Ct
Cheshire St
Purnell Rd
Princess Rd
Norfolk Ct
Kingsley Dr
Cloverdale Dr
Corangamite Dr
Matthews Rd
Paley Dr
Glenelg Av
Goulburn
Goldsworthy Rd
Hopkins
Lovely Banks Rd
Duisberg Dr
Asher Rd
Peart Ct
Kulina Dr
Bluestone Bridge Rd
Cuddihy Ct
Ballan Rd
Edgerton Rd
Anakie Rd
Evans Rd
Emmersons Rd
Ewings Rd

RB H
RB D
RB E
RB G
RB C
RB A
RB B
RB B1
RB C1
RB A1
RB E1
RB G1
RB F
RB D
RB E
RB C
RB H
RB G
RB A
RB B
SB RB A
SB RB A
SB RB B
SB RB I
SB RB F
SB RB F
SB RB D
C157AX_1
C157J_1
C157J_2
C157J_3
C153_2
C153_4
C153_5
C153_6
C153_7
C155_1
C155_2
C156_3
Outlet
Outlet

LEGEND

- NGGA Study Boundary
- NGGA Precincts
- Catchment Boundary
- Subcatchment Boundary
- Outlets
- 0.5m Contours
- Gas Main/Power Lines
- Future Road Network
- Existing Property Boundary

Proposed Works

- Sediment Basin / Retarding Basin
- Wetland / Retarding Basin
- Indicative Retarding Basin Location
- Constructed Waterways
- Natural Waterway Retained
- Overland Flowpath
- → → Trunk Drainage

Future Land Use

- Employment
- Low Density Residential
- Residential
- Rural Living
- Servicing & Utility

Note: Indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX B4

NORTH GEELONG GROWTH AREA

STORMWATER MANAGEMENT STRATEGY

PROPOSED CONCEPT LAYOUT - SCENARIO 2
THREE EMPLOYMENT AREAS

client: CITY OF GREATER GEELONG; Lovely Banks

consultant: SMEC Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	6 May 2019
REVISION	D
CREATED BY	KT

N

0 400 800 1200 m

MAP SCALE	1:25000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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C157_E_2
C157AX_E_1
C157J_C1_1
C157J_C_1
C157J_B_1
C157J_F_1
C157J_F_2
C157J_F_3
C157J_F_4
C157J_F_5
C157J_F_6
C157J_F_7
C157J_F_8
C157J_F_9
C157J_F_10
C153_C_1
C153_D_1
C153_D_2
C153_G1_1
C153_G1_2
C153_G_2
C153_G_1
C156_B_1
C156_C_1
C156_E_3
C156_E_2
C156_E_1

Legend

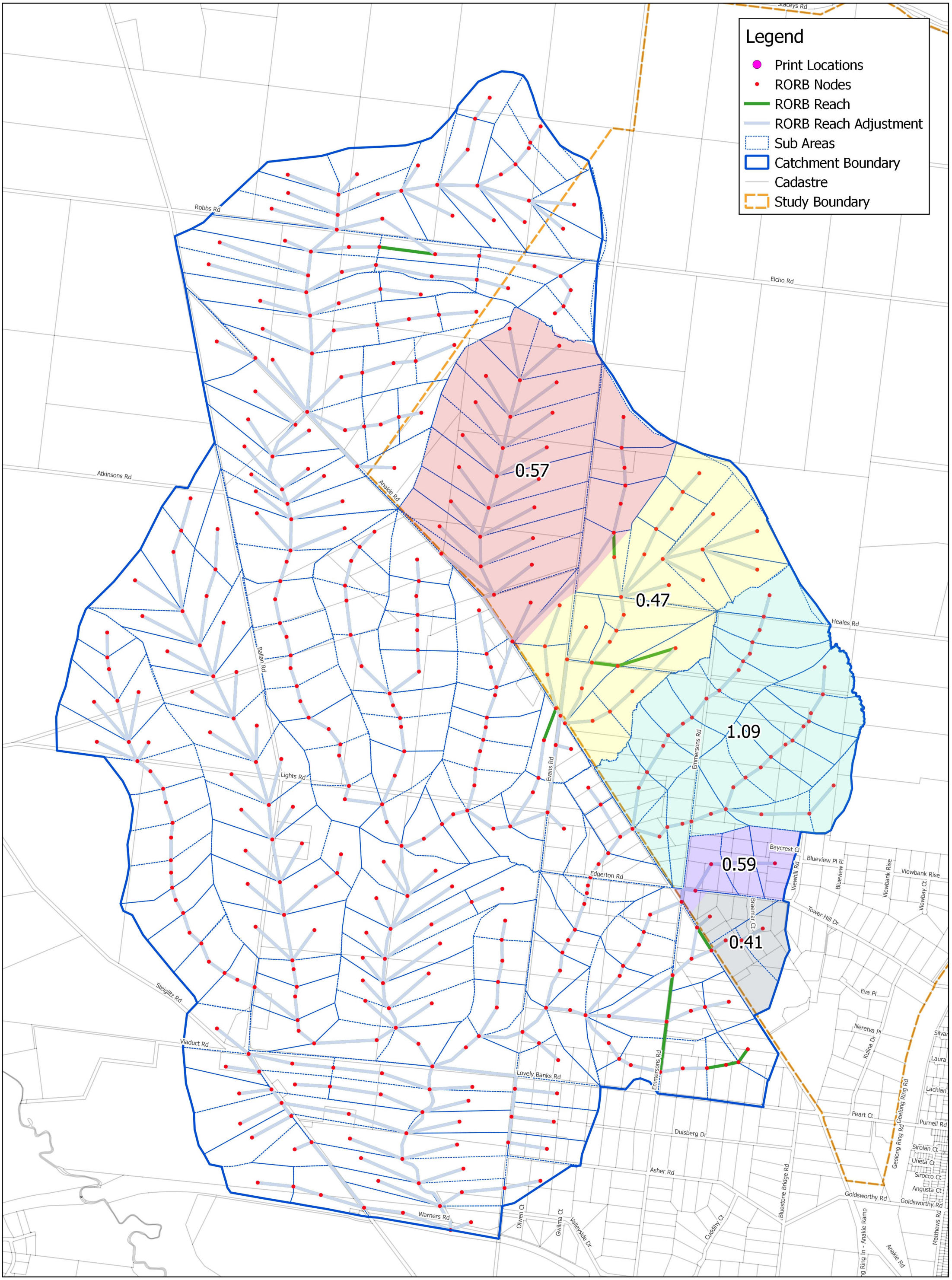
- Constructed Waterway
- Natural Waterway
- Wetland / Retarding Basin
- Sediment Basin / Retarding Basin
- Cadastre
- Study Boundary

Note: Indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

375 0 375 750 1125 1500 m

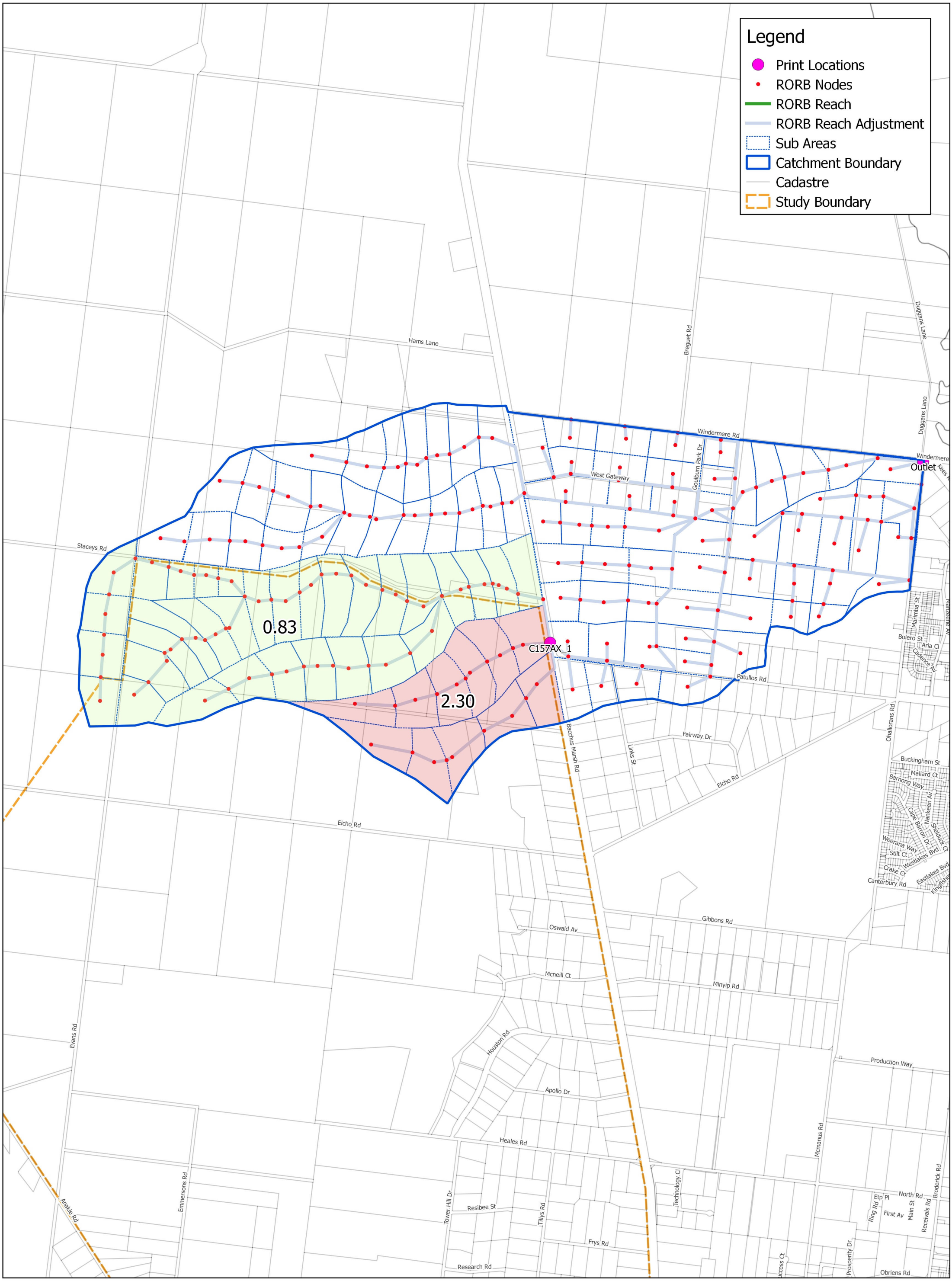
APPENDIX B5 **NORTHERN GEELONG GROWTH AREA**

PROPOSED CONSTRUCTED WATERWAYS



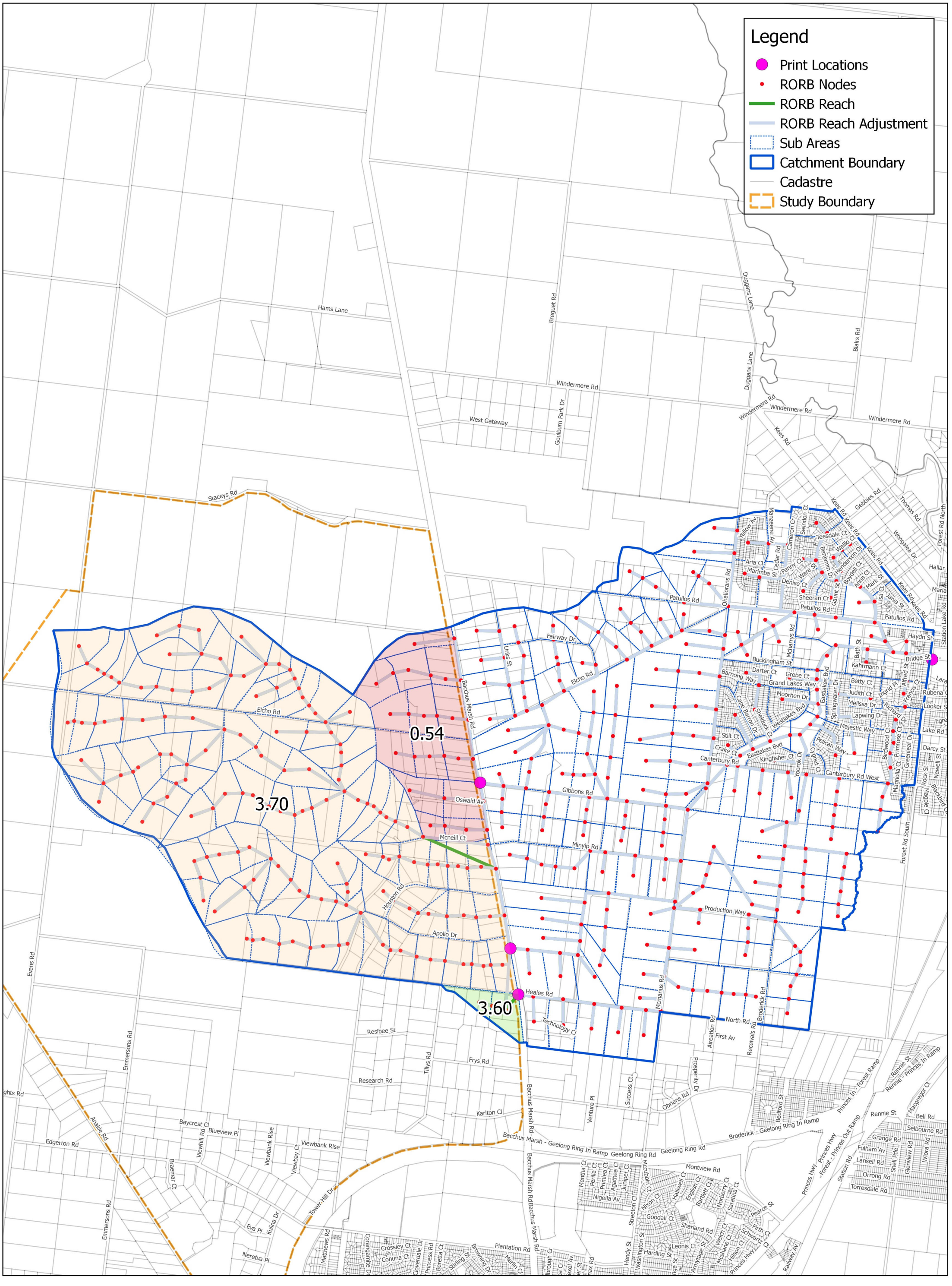
APPENDIX C1 **COWIES CREEK | C153**

RORB EXISTING CONDITIONS ADJUSTMENTS



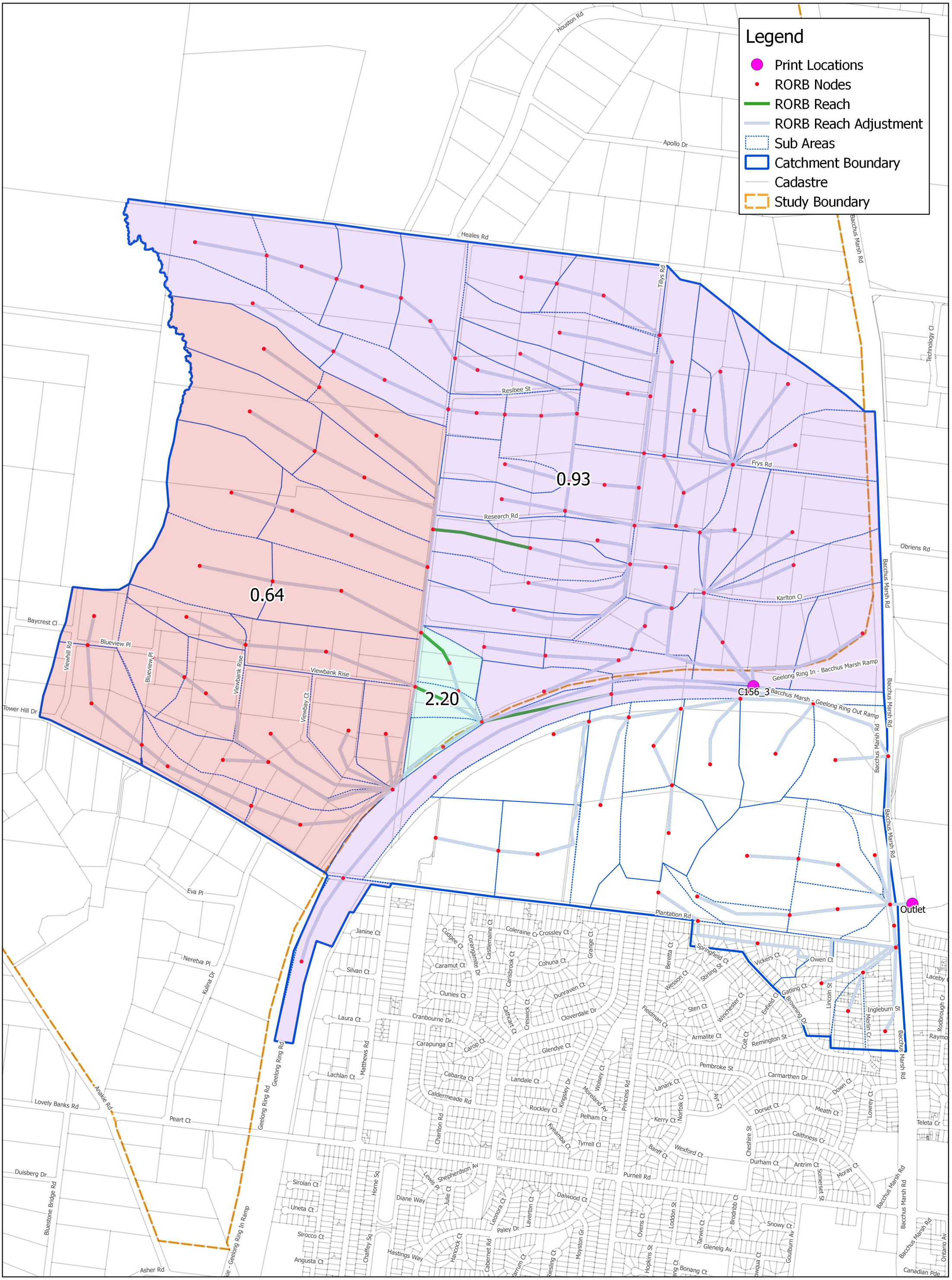
APPENDIX C2 **HOVELLS CREEK | C157AX**

RORB EXISTING CONDITIONS ADJUSTMENTS



APPENDIX C3 **ELCHO DRAIN | C157J**

RORB EXISTING CONDITIONS ADJUSTMENTS



APPENDIX C4 **WHARF ROAD OUTFALL | C156**

RORB EXISTING CONDITIONS ADJUSTMENTS

LEGEND

Base Map

- Cadastre
- Contours 0.5m
- Northern Study Area

Source (CoGG)

Depth (m)

- 0.0 - 0.2
- 0.2 - 0.5
- 0.5 - 2.0
- > 2.0 m

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX D1

COWIES CREEK | C153

DEVELOPED CONDITIONS | 1 IN 100 AEP FLOOD EXTENT

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	18 Feb 2019
REVISION	A
CREATED BY	KV

N

300 0 300 600 900 m

MAP SCALE	1:30000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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LEGEND

Base map

- Cadastre
- Contours 0.5m
- Northern Study Area

Source (CoGG)

Afflux (m)

- <= -0.500
- -0.500 - -0.250
- -0.250 - -0.100
- -0.100 - -0.030
- -0.030 - -0.010
- -0.010 - -0.005
- -0.005 - 0.005
- 0.005 - 0.010
- 0.010 - 0.030
- 0.030 - 0.100
- 0.100 - 0.250
- > 0.250
- was wet now dry
- was dry now wet

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX D2

COWIES CREEK | C153

DEVELOPED CONDITIONS | 1 IN 100 AEP AFFLUX

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG; Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

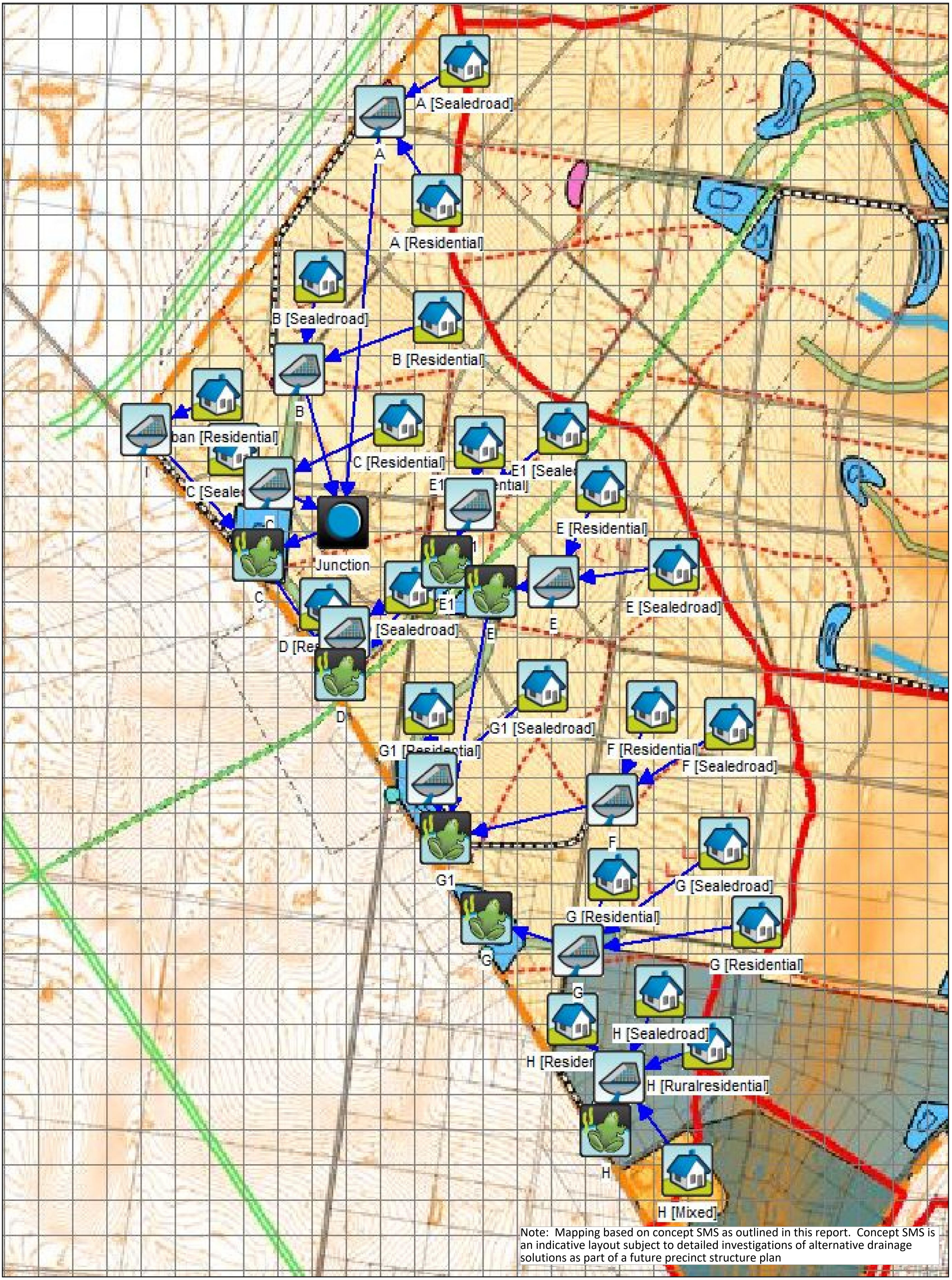
PROJECT NO	30042177W
DATE	13 Feb 2019
REVISION	B
CREATED BY	KV

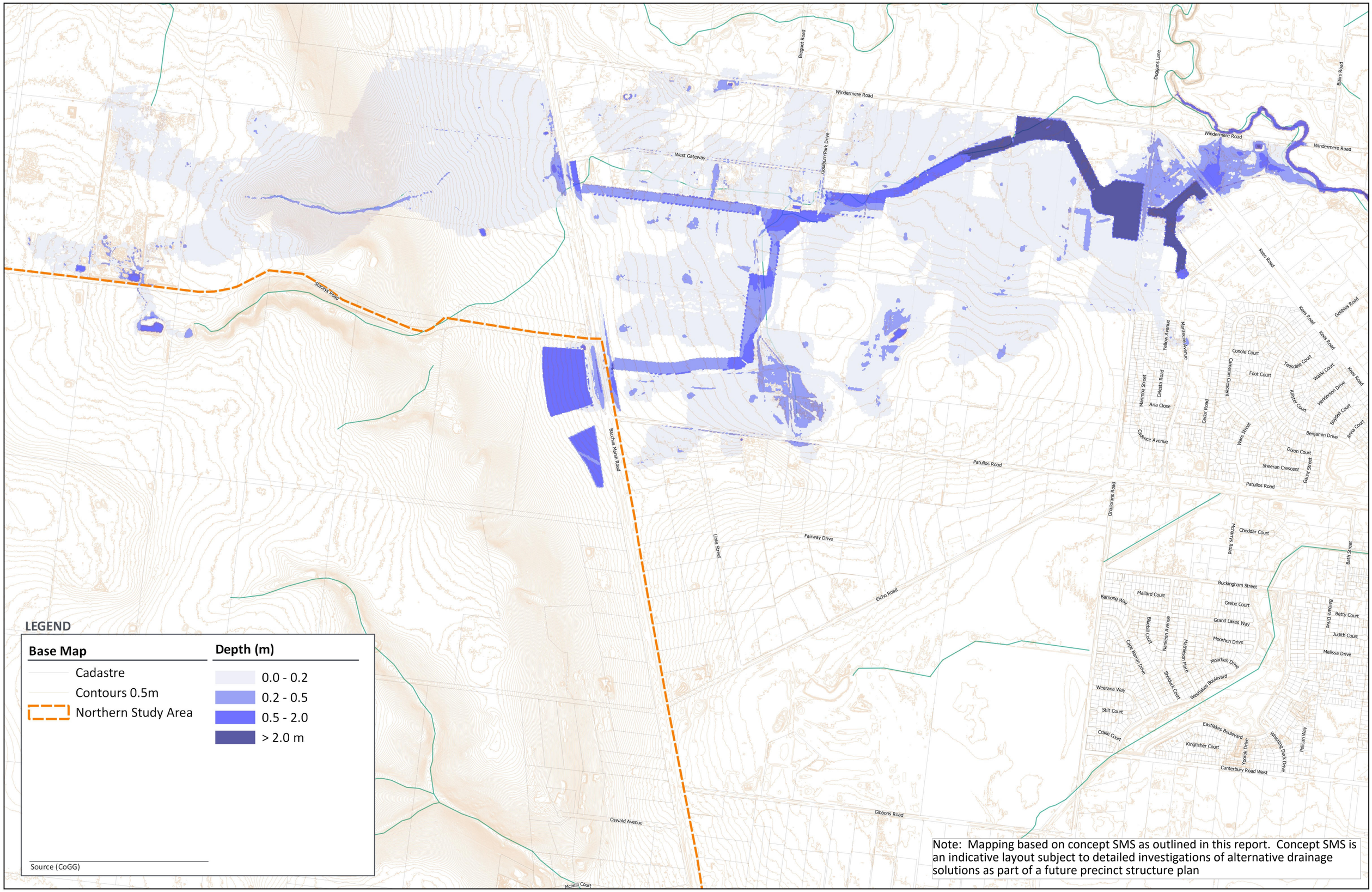
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300 0 300 600 900 m

MAP SCALE	1:30000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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A [Sealedroad]
A
A [Residential]
B [Sealedroad]
B [Residential]
B
ban [Residential]
C [Residential]
C [Seale
C
Junction
E1
E [Residential]
E [Sealedroad]
E
C
[Sealedroad]
D [Re
D
G1 [Sealedroad]
G1 [Residential]
F [Residential]
F [Sealedroad]
F
G1
G [Sealedroad]
G [Residential]
G
G [Residential]
H [Sealedroad]
H [Resider
H [RuralResidential]
H
H [Mixed]
Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan



LEGEND

Base Map	Depth (m)
Cadastre	0.0 - 0.2
Contours 0.5m	0.2 - 0.5
Northern Study Area	0.5 - 2.0
	> 2.0 m

Source (CoGG)

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX E1

HOVELLS CREEK | C157AX

DEVELOPED CONDITIONS | 1 IN 100 AEP FLOOD EXTENT

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC Member of the Surbana Jurong Group

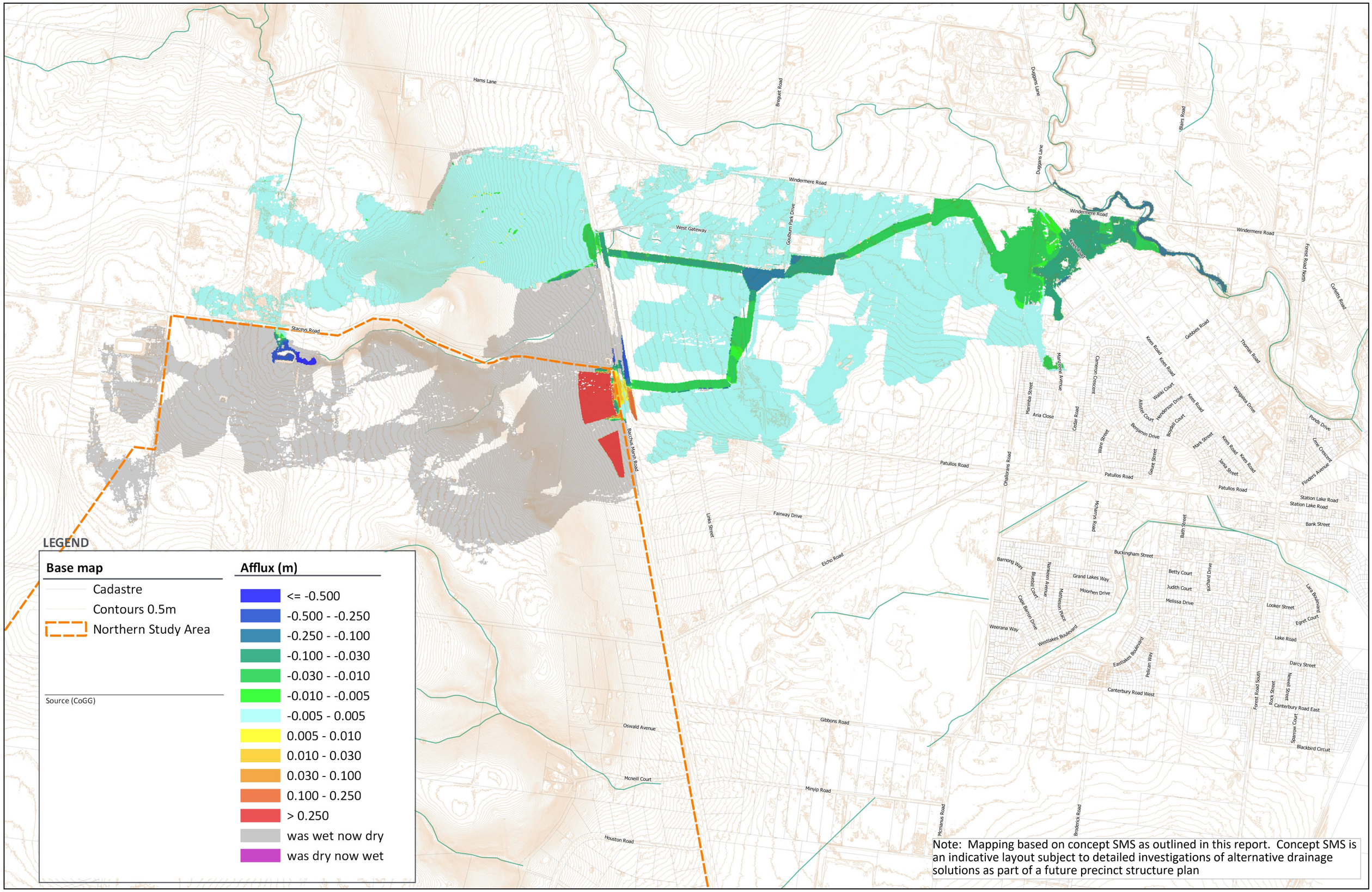
PROJECT NO	30042177W
DATE	18 Feb 2019
REVISION	A
CREATED BY	KV

N

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MAP SCALE 1:15000
PAGE SIZE A3
DATUM GDA94
PROJECTION MGA Zone 55

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LEGEND

Base map

- Cadastre
- Contours 0.5m
- Northern Study Area

Source (CoGG)

Afflux (m)

- <= -0.500
- -0.500 - -0.250
- -0.250 - -0.100
- -0.100 - -0.030
- -0.030 - -0.010
- -0.010 - -0.005
- -0.005 - 0.005
- 0.005 - 0.010
- 0.010 - 0.030
- 0.030 - 0.100
- 0.100 - 0.250
- > 0.250
- was wet now dry
- was dry now wet

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX E2

HOVELLS CREEK | C157AX

DEVELOPED CONDITIONS | 1 IN 100 AEP AFFLUX

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC Member of the Surbana Jurong Group

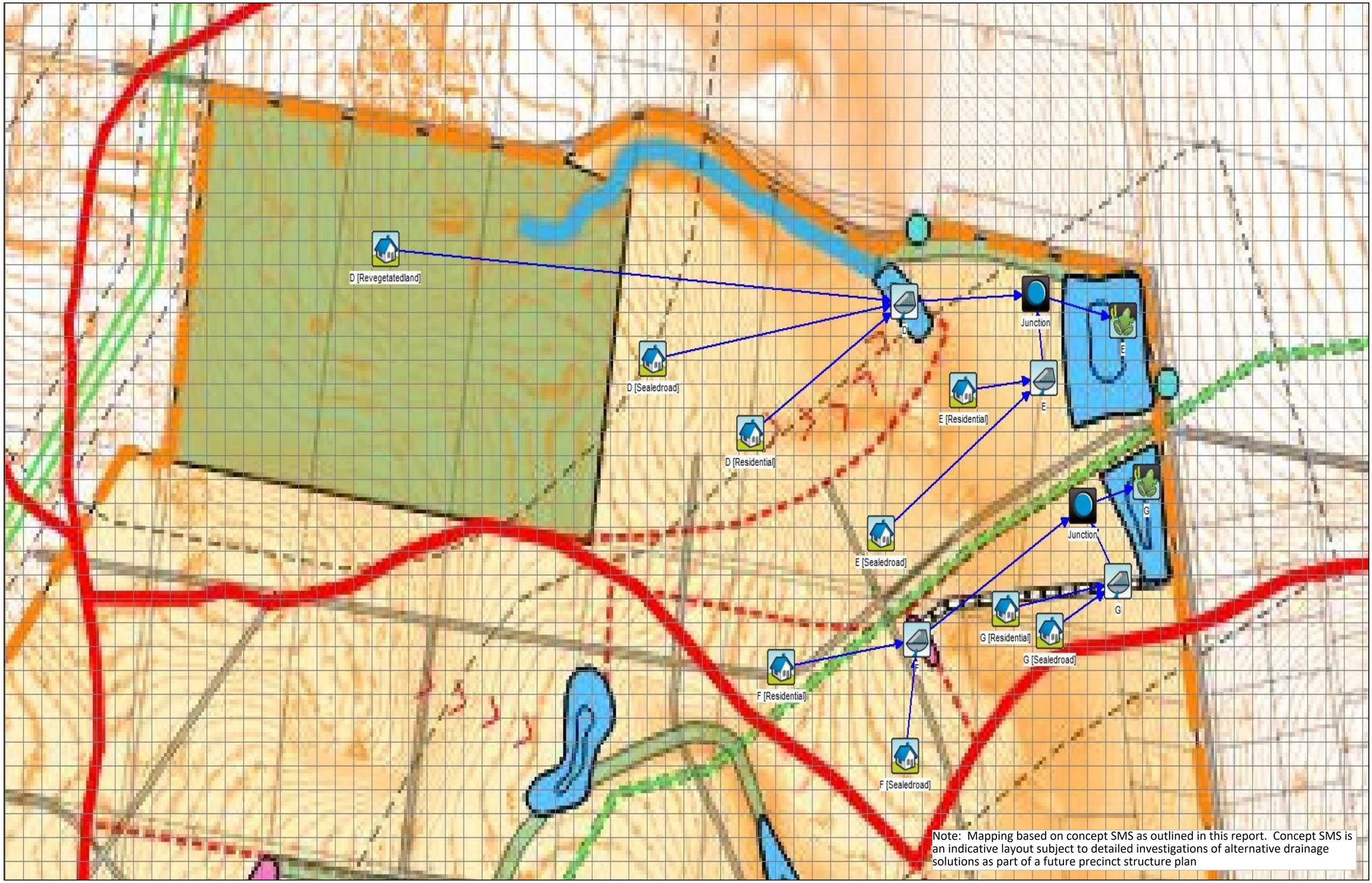
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DATE	18 Feb 2019
REVISION	B
CREATED BY	KV

N

200 0 200 400 600 m

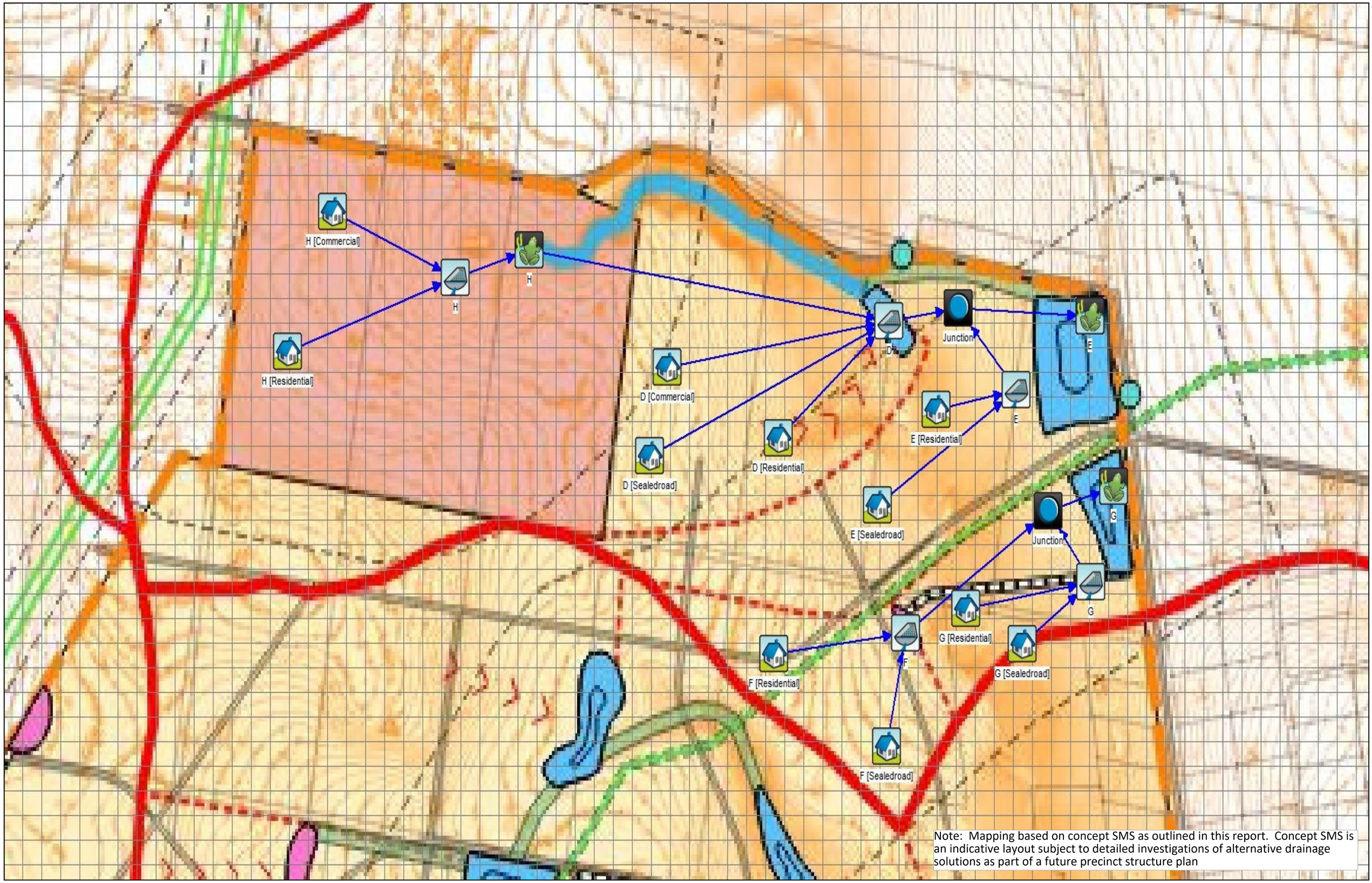
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PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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APPENDIX E3 **HOVELLS CREEK | C157AX**

MUSIC MODEL - SCENARIO 1



APPENDIX E4 **HOVELLS CREEK | C157AX**

MUSIC MODEL - SCENARIO 2

LEGEND

Base Map

- Cadastre
- Contours 0.5m
- Northern Study Area

Depth (m)

- 0.0 - 0.2
- 0.2 - 0.5
- 0.5 - 2.0
- > 2.0 m

Source (CoGG)

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX F1

ELCHO DRAIN | C157J

DEVELOPED CONDITIONS | 1 IN 100 AEP FLOOD EXTENT

Northern Geelong Growth Area | Flood Impact Assessment

client: City of Greater Geelong | Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	18 Feb 2019
REVISION	A
CREATED BY	KV

N

200 0 200 400 600 m

MAP SCALE	1:20000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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LEGEND

Base map

- Cadastre
- Watercourses
- Contour 0.5m
- Northern Study Area

Source (CoGG)

Afflux (m)

- <= -0.500
- -0.500 - -0.250
- -0.250 - -0.100
- -0.100 - -0.030
- -0.030 - -0.010
- -0.010 - -0.005
- -0.005 - 0.005
- 0.005 - 0.010
- 0.010 - 0.030
- 0.030 - 0.100
- 0.100 - 0.250
- > 0.250
- was wet now dry
- was dry now wet

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX F2

ELCHO DRAIN | C157J

DEVELOPED CONDITIONS | 1 IN 100 AEP AFFLUX

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

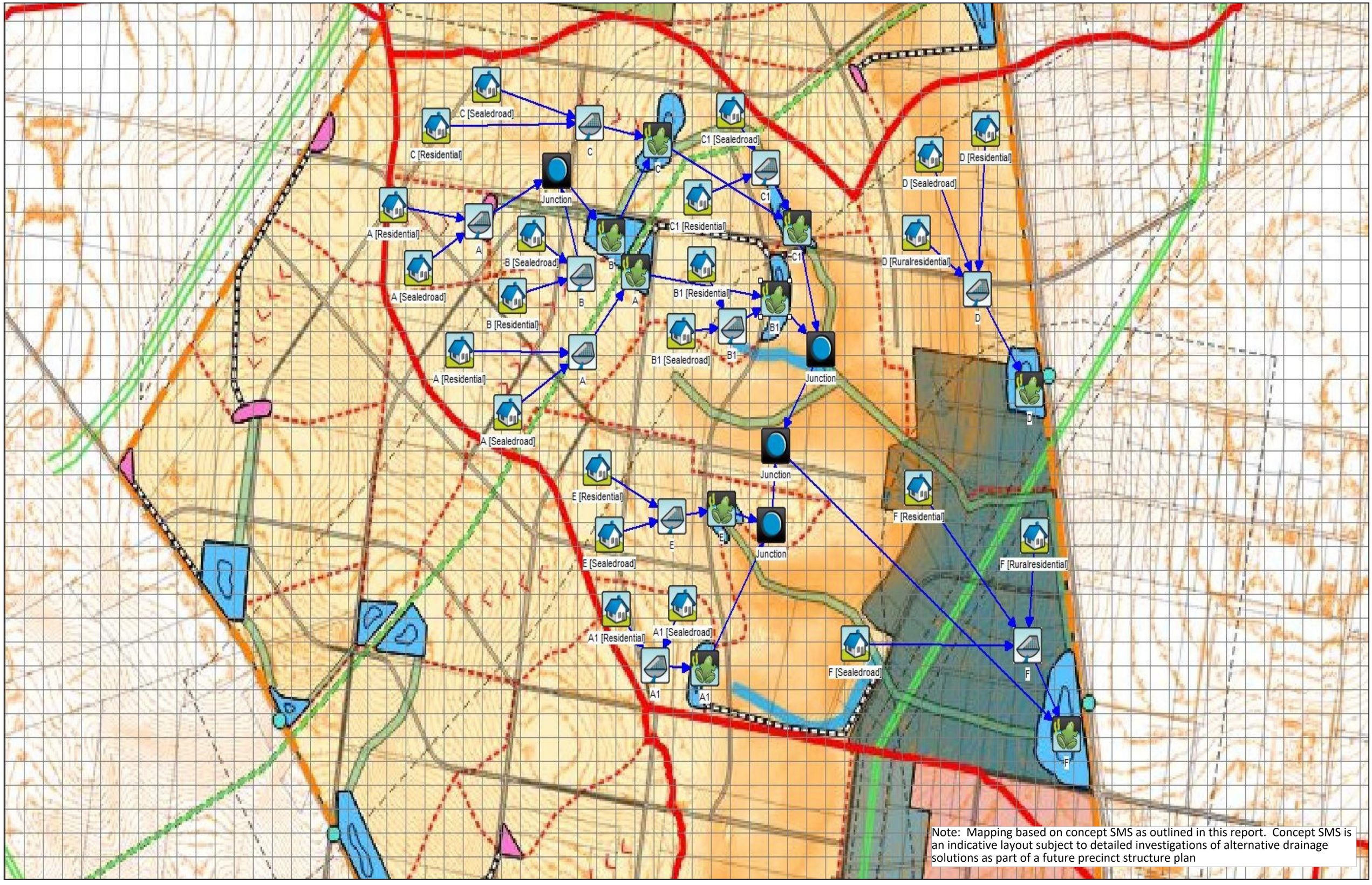
PROJECT NO	30042177W
DATE	19 Feb 2019
REVISION	B
CREATED BY	KV

N

200 0 200 400 600 m

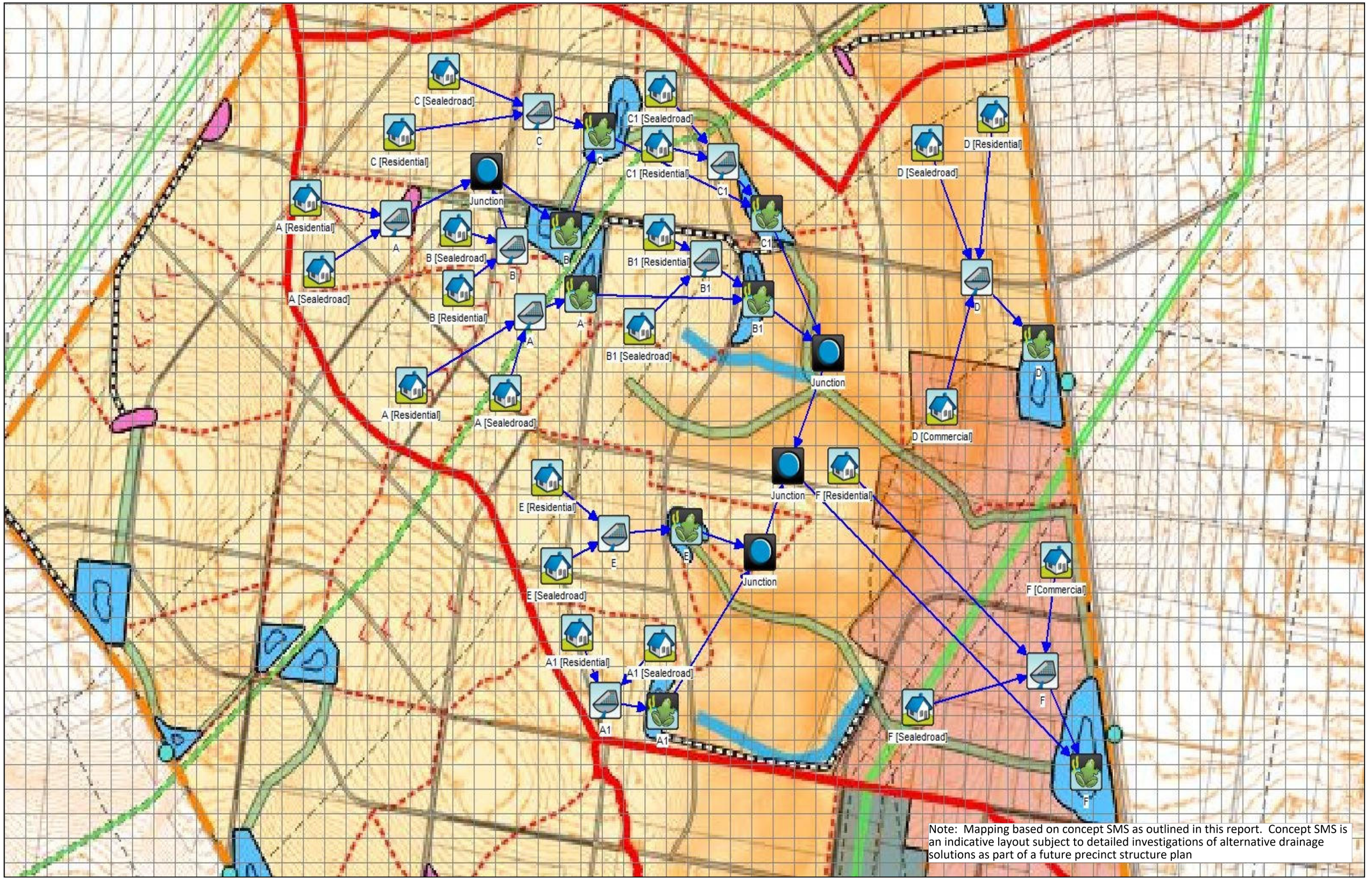
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PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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APPENDIX F3 **ELCHO DRAIN | C157J**

MUSIC MODEL - SCENARIO 1



APPENDIX F4 **ELCHO DRAIN | C157J**

MUSIC MODEL - SCENARIO 2

LEGEND

Base Map

- Cadastre
- Contours 0.5m
- Northern Study Area

Depth (m)

- 0.0 - 0.2
- 0.2 - 0.5
- 0.5 - 2.0
- > 2.0 m

Source (CoGG)

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

Evans Road
Emmersons Road
Anakie Road
Baycrest Close
Viewbank Rise
Tower Hill Drive
Braemar Court
Neretva Place
Asher Road
Uestone Bridge Road
Heales Road
Production Way
Broderick Road
Momanus Road
North Road
Ring Road
Aireation Road
Soda Court
First Avenue
Obriens Road
Success Court
Innovation Drive
Karlton Close
Geelong Ring Road
Geelong Ring Out-Bacchus Marsh Ramp
Princes Highway
Bedford Street
Birmingham Court
Browallia Drive
Hibbertia Court
Nigella Avenue
Streeton Close
English Court
Kullaroo Court
Officer Court
Prouse Court
Sharland Road
Coolidge Street
Firth Court
Schwartz Court
Harding Street
Beech Court
Mckinley Avenue
Plantation Road
Fiona Avenue
Rosemary Avenue
Hendy Street
Raymond Grove
Buangor Street
Ainslie Court
Selma Street
Kosciusko Avenue
Bogong Street
Leura Court
Purnell Road
Matthews Road
Corangamite Drive
Cohuna Court
Princess Road
Wesson Court
Vickers Court
Lincoln Street
Bacchus Marsh Road
Rodbrough Crescent
Cranbourne Drive
Carapunga Court
Creswick Court
Cloverdale Drive
Remington Street
Moreland Avenue
Caldermeade Road
Kingsley Drive
Charlton Road
Lanark Court
Carmarthen Drive
Norfolk Crescent
Dorset Court
Cheshire Street
Caithness Crescent
Taipa Crescent
Donax Road
Clavus Road
Toleta Crescent
Phalaris Park Drive
Uneta Court
Shepherdson Ave
Leonora Court
Paley Drive
Ovens Court
Glenelg Avenue

APPENDIX G1

WHARF ROAD DRAIN | C156

DEVELOPED CONDITIONS | 1 IN 100 AEP FLOOD EXTENT

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	18 Feb 2019
REVISION	A
CREATED BY	KV

N

100 0 100 200 300 400 500 m

MAP SCALE	1:15000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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LEGEND

Base map

- Cadastre
- contour
- Northern Study Area

Source (CoGG)

Afflux (m)

- <= -0.500
- -0.500 - -0.250
- -0.250 - -0.100
- -0.100 - -0.030
- -0.030 - -0.010
- -0.010 - -0.005
- -0.005 - 0.005
- 0.005 - 0.010
- 0.010 - 0.030
- 0.030 - 0.100
- 0.100 - 0.250
- > 0.250
- was wet now dry
- was dry now wet

Note: Mapping based on concept SMS as outlined in this report. Concept SMS is an indicative layout subject to detailed investigations of alternative drainage solutions as part of a future precinct structure plan

APPENDIX G2

WHARF ROAD DRAIN | C156

DEVELOPED CONDITIONS | 1 IN 100 AEP AFFLUX

Northern Geelong Growth Area | Flood Impact Assessment

client: CITY OF GREATER GEELONG | Lovely Banks

consultant: SMEC — Member of the Surbana Jurong Group

PROJECT NO	30042177W
DATE	13 Feb 2019
REVISION	B
CREATED BY	KV

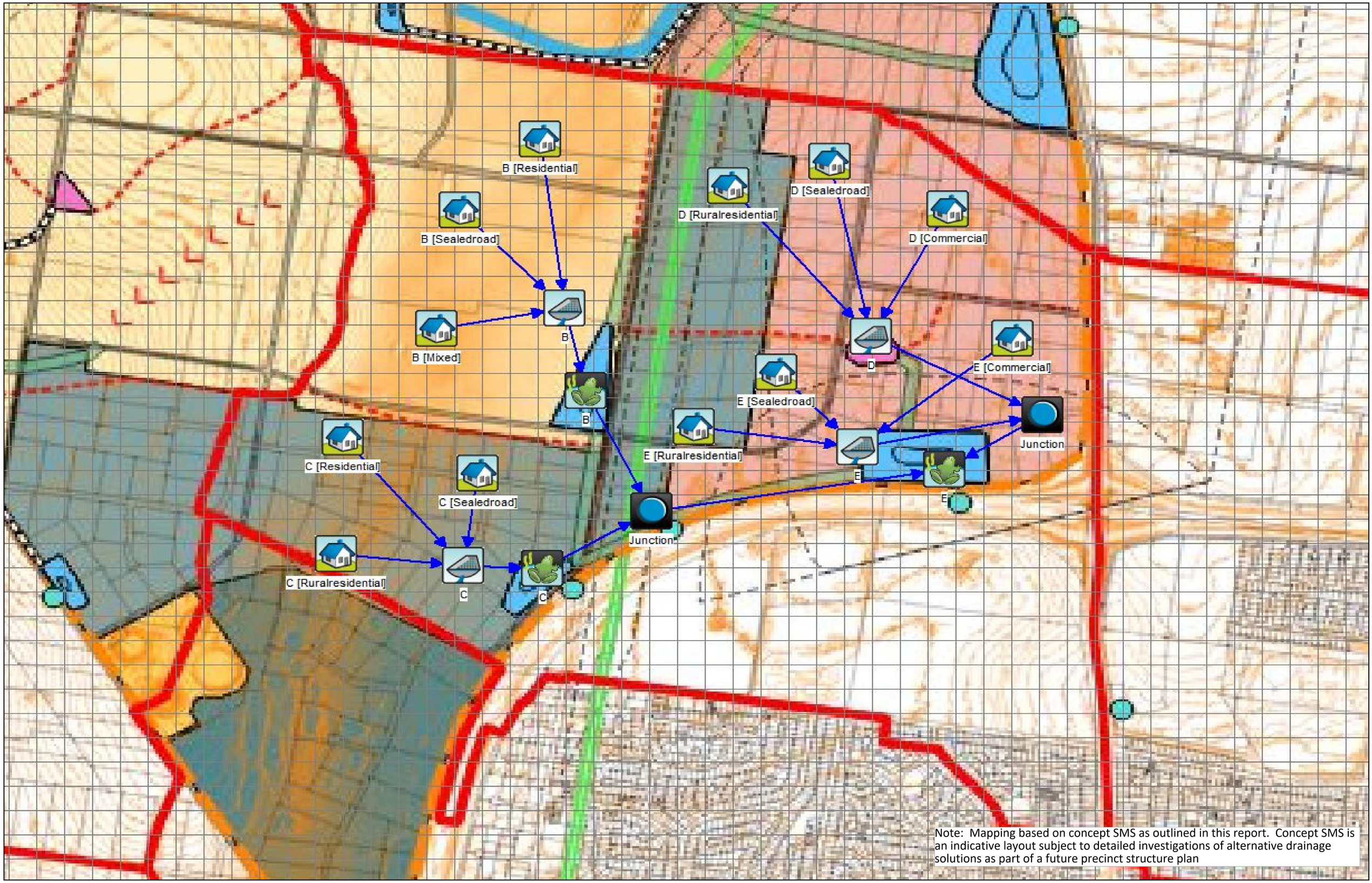
N

100 0 100 200 300 400 500 m

MAP SCALE	1:15000
PAGE SIZE	A3
DATUM	GDA94
PROJECTION	MGA Zone 55

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APPENDIX G3 **WHARF ROAD OUTFALL | C156**

MUSIC MODEL