FINAL REPORT:

Yarrawonga Framework Plan:

Stormwater Drainage Strategy

September 2019

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Executive Summary

Moira Shire Council, in collaboration with the Victorian Planning Authority (VPA) is preparing the Yarrawonga Framework Plan. Alluvium has been engaged by the Moira Shire Council to complete a Stormwater Drainage Strategy to inform the Framework. The drainage assessment determines the assets required to:

- Manage minor flows via a sub-surface drainage network
- Convey major flows (floodwaters) via roadways and a linear waterway / wetland system, and
- Treat stormwater to meet best practice requirements.

Areas for future development in Yarrawonga have been identified by the VPA to support the next 50 years of industrial and residential growth. This stormwater drainage strategy began with a 'situational analysis' report, which defined current land use and surface water management conditions within the areas earmarked for development and identified issues and constraints that may influence the drainage assessment.

A draft urban structure plan was compiled from the various development plans proposed within the framework boundary. This plan provided guidance on future land use, proposed asset placement and future drainage corridors. The site drains north toward Lake Mulwala and the Murray River.

Drainage, stormwater treatment and flood management options for the Yarrawonga development area have been established in consultation with stakeholders, with principles adopted during this process that guided the development of drainage options, including:

- Protection of receiving waters
- Assets that contribute to resilient and liveable communities
- Meeting current best practice environmental management (BPEM) stormwater treatment (currently under revision)
- Minimise land take associated with stormwater management
- Minimise the use of pumped detention basins where possible
- Avoid draining into the Yarrawonga Main Channel
- Manage flooding from future developments back to predevelop conditions, and
- Avoid filling where possible.

The analysis undertaken to develop concept designs included hydrologic modelling and stormwater treatment modelling. This concluded that a series of linear wetlands would be most appropriate for the site, given the existing landscape and constraints. This drainage assessment is conducted at a concept level to inform the general drainage layout and likely infrastructure requirements. More refined modelling will be required to confirm asset and infrastructure sizing.

The key assets and works proposed include:

- A series of linear wetland systems situated within retarding basins to convey the 1% AEP whilst managing longitudinal slopes and treating stormwater. Where possible, these are located within existing depressions within the study area.
- Due to the flat grade across the site, mechanical pumping will be required to convey stored flows
- Minor filling may be required to help direct some sub-catchment flows into the proposed assets. Further analysis is recommended following the confirmation of development plans.

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Abbreviations

Alluvium	Alluvium Consulting Australia Pty Ltd
IDM	Infrastructure Design Manual
MSC	Moira Shire Council
VPA	Victorian Planning Authority

1 Introduction

Alluvium has been engaged by the Victorian Planning Authority (VPA), in collaboration with Moira Shire Council (MSC) to prepare a Stormwater Drainage Strategy (SDS) to support the Yarrawonga Framework Plan.

This assessment has been developed considering stakeholder aspirations for the site as well as their plans and requirements. The process included understanding the context of the site, undertaking a site analysis (and a site visit), developing and evaluating options and preparation of a future urban structure incorporating drainage, stormwater treatment and flood detention assets.

The assessment also recognises the contribution of stakeholders in the development of this assessment including the Goulburn Broken Catchment Management authority (CBCMA), Goulburn Murray Water (GMW), North East Water, the Department of Environment, Land, Water and Planning (DELWP) Integrated Water Management team and Transport for Victoria.

1.1 Location

Yarrawonga is a Victorian country town, located on the Murray River at Lake Mulwala, approximately 260km north-east of Melbourne. The Yarrawonga Framework Plans covers an area of 2,400 ha, including the existing township and 1135 ha of future residential and industrial development (Figure 1).

The framework area can be defined by:

- The Murray River to the north,
- Keenans Road to the east
- Brears Road to the west, and
- A variable southern border, predominantly aligning with Channel Road and Cahills Road.

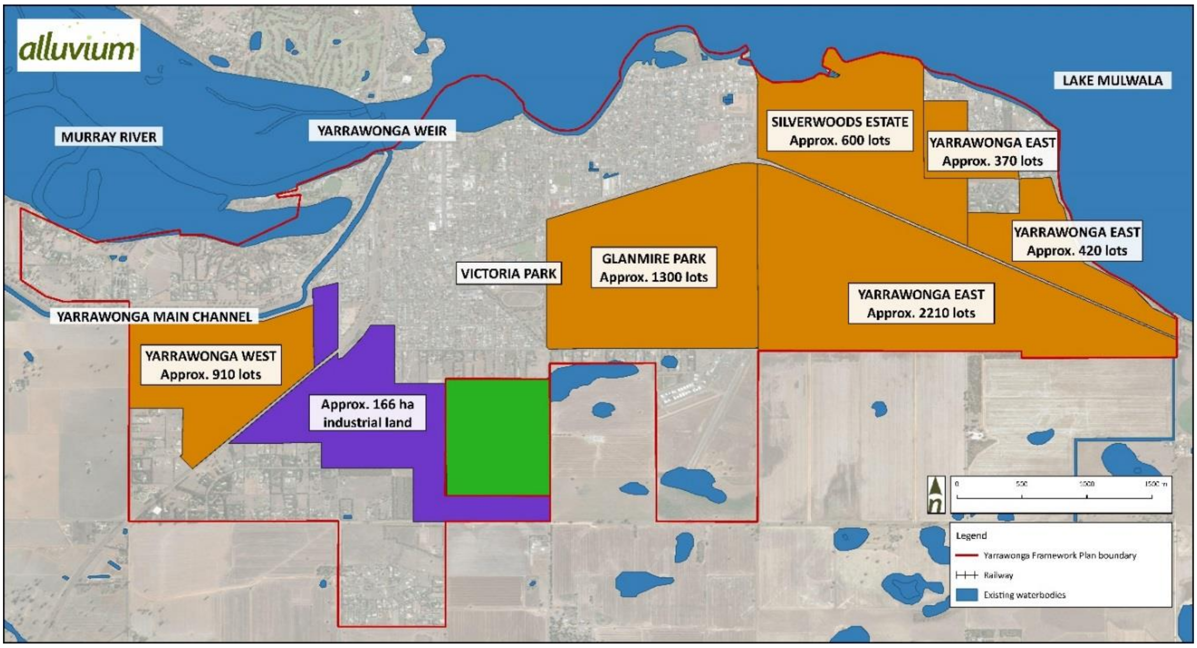

Figure 1. *Scope of works – Yarrawonga growth areas*

1.2 Background

Yarrawonga sits within the municipality of Moira and is subject to the provisions of the Moira Planning Scheme. Yarrawonga was identified for moderate or incremental growth within the Hume Regional Growth Plan, noting the lifestyle and natural attractions of the area as unique growth opportunities.

The Yarrawonga Growth Management Strategy was prepared by MacroPlan Dimasi on behalf of the VPA and adopted by Moira Shire Council in 2017. The key findings from this work included:

- Growth scenarios for Yarrawonga anticipate that the local population will increase to 12,159 people by the year 2030, a growth in population of 85%.
- This population growth has serious implications for local social and community services.
- Population projections to 2030 for both Yarrawonga and Mulwala support the expectation that demand levels for all community services will increase (albeit at varying rates)

The Moira Shire Council Plan 2017-2021 developed goals to “improve the flood resilience of the catchment’s people, infrastructure, land, water and biodiversity through partnerships with community and stakeholders.” This project focuses on the solving the first of many planning initiatives as recommended in the Growth Management Strategy and Council plan – drainage within Yarrawonga.

2 Stormwater management framework

2.1 Need for a drainage strategy

A drainage strategy is required to inform the preparation of a Framework Plan for this site and to guide urban growth within the township. This will need to guide proposed development within Yarrawonga to respond to complex flood conditions in the area and propose a strategy of drainage assets, including works such as pipelines, overland flow paths, retarding basins, waterways, wetlands and gross pollution traps, so that identification of land can be set aside for these purposes and downstream properties and the receiving environment protected.

A drainage strategy ensures that planning for urban development is conducted on a catchment basis and meets appropriate standards for flood protection and environmental performance, including protection and enhancement of waterway and biodiversity values.

The Goulburn Broken Strategic Direction Statement (SDS) (2018) was developed following the Goulburn Broken Integrated Water Management (IWM) forum. The SDS identified IWM opportunities throughout the region which have been considered as part of the drainage strategy development. Where applicable, IWM practices highlighted in the Integrated Water Management Framework for Victoria (2017) and Water for Victoria: Water Plan (2016) have been engaged, with an aim to help create multifunctional assets which contribute to liveable and resilient communities.

Victorian Planning Provisions (VPP) has specific details regarding stormwater retardation, water treatment, flood mitigation, integrated water management and drainage network management (clauses 56.07, 19.03, 53.18 etc) which inform the design and location of a stormwater management system. All designs proposed in the Yarrawonga drainage strategy meet the requirements stipulated by the VPP.

While the strategy proposed in this document does not set to resolve existing flood issues and infrastructure constraints within existing developed area, proposed actions to manage future stormwater runoff does consider these existing issues and where possible looks to improve service capacity of the system.

2.2 Infrastructure Design Manual - Drainage Requirements

The Infrastructure Design Manual is a joint Council initiative to deliver consistent standards for infrastructure design. Key objectives are set out under urban drainage and stormwater treatment. Details of the parameters under each of these headings has been extracted to form a set of guiding principles to inform developers.

This considers four main areas:

- Strategic approach
- Flow management
- Management of water quality
- Consideration of IWM opportunities

2.3 Yarrawonga Stormwater Management Principles

In accordance with the IDM, the following principles are used to manage stormwater runoff for future development within the Yarrawonga growth areas.

Strategic approach

<u>The developer will provide a drainage strategy for approval that outlines a catchment wide approach to managing urban stormwater runoff.</u> The strategy must ensure planning for urban development is conducted on a catchment basis, staging requirements and meets appropriate standards for flood protection and environmental performance, including protection and enhancement of waterway and biodiversity values. At

the development/lot scale the strategy should also identify interface opportunities with neighbouring developments including green space linkages, shared paths and community assets.

Flow Management

The developer will provide a drainage strategy for approval that addresses both minor and major flows. The major-minor pipe design principle is to be adopted as part of this strategy. Pipes should be designed to convey the 5-year ARI runoff event, with excess flows surcharging to existing or future-developed road reserves.

Development within a catchment shall not result in a reduction to the existing level of drainage service. The existing level of drainage service relates to both the frequency of flooding instances as well as to the existing 100-year ARI flood level and extent. Infrastructure is to be sized to ensure that the 100-year ARI flood level, extent and frequency are not increased due to development. This ensures that the level of drainage service for smaller events is not diminished, as the magnitude of peak flow change is greatest for the 100-year event.

The Developer will be required to deliver the infrastructure necessary to cater for upstream rural flows. Existing conditions of a site will need to be considered in the development of any property. Existing conditions may include drainage lines conveying upstream rural flow. It is considered reasonable that a developer should fund works to cater for existing conditions on their property.

The Developer will be required to deliver works to retard flows in their own property if necessary, to protect downstream development. In addition to the above principles, works to ensure that a development does not create a flood risk for downstream properties will be funded by the developer and located on their own property. Current BPEM guidelines require discharges for the 1.5-year ARI storm event to be maintained at predevelopment levels. The developer will need to demonstrate through a suitable runoff routing method and/or hydraulic modelling that the proposed development will not have an impact on downstream flooding. Where possible pump systems are to be avoided.

Management of water quality

The Developer will be required to meet water quality treatment works to best practice as a part of the development. Developers will be required to deliver and construct on site water quality treatment to meet Best Practice Objectives for the removal of litter, total suspended solids, total nitrogen and total phosphorus. The current best practice targets set out in the Best Practice environmental Management Guidelines (BPEMG) include:

- 45% reduction in total nitrogen (TN) from typical urban loads
- 45% reduction in total Phosphorus (TP) from typical urban loads
- 80 % reduction in total Suspended Solids (TSS) from typical urban loads
- 70% reduction in litter from typical urban loads

As the BPEMG are updated, changes to objectives will need to be considered by developers. Water quality treatment systems considered for use in Yarrawonga are limited to GPTs, wetlands and sediment basins only. Bio-retention systems with a saturated zone may be accepted where suitable outfall grades can be achieved. Design parameters adopted for the wetland and sediment basin sizing are to be based on the final Melbourne Water Wetland Design Manual and Waterway Corridor Guidelines.

If available, the developer may choose to contribute to council water quality offset scheme.

The Developer will be required to consider the design of infrastructure so that it is cost effective from a maintenance and operational perspective. Development of treatment options should consider the staging and construction of developments.

Consideration of IWM opportunities
The Developer will undertake a high-level integrated water management (IWM) plan to identify potential opportunities and recommended alternative stormwater drainage management options (where practical). The plan should consider:

Principles and objectives for IWM (such as the Integrated Water Management Framework for Victoria, Goulburn Broken Strategic Directions Statement and Water for Victoria which sets out desired outcomes for liveable communities).

- The use of the outcomes tabled within Integrated Water Management Framework for Victoria, Goulburn Broken Strategic Directions Statement and Water for Victoria as a framework for a discussion around issues and opportunities.
- Generation of IWM opportunities, reviewing these as a group through the lens of associated issues and derived principles and objectives.
- A qualitative evaluation of each opportunity and implement those practical.

IWM opportunities should also consider Urban Cooling principles where the introduction of more trees and shrubs and stormwater, through reuse and watering, can make it feel cooler and supports tree health. Irrigated grass is also about 15 degrees cooler than dry grass and surrounding pavement and can bring night-time temperatures down by one degree per hour. Vegetation and water used to cool green spaces can also provide habitat, improve amenity and help manage stormwater flows to waterways, making them healthier. By working together with stakeholders and the community, we can create greener and cooler places to enjoy all year round.

3 Situational Analysis

The 'Situational Analysis' defines the current land use and surface water management conditions within the precinct, identifying issues and constraints that may impact upon the drainage assessment.

3.1 Topography

The Yarrawonga township is part of the Riverine Plains. The soil type typically varies with topography between a Red-brown Chromosol overlying parent material on the rise and slopes, to a Brown Sodosol with a medium clay subsoil on the foot and base of the ridges. Shallow soils underlain with weathered rock occur on the rises and heavy clay soils in the low-lying areas.

Fall across subject area was analysed using LiDAR, site inspections and existing drainage infrastructure layers provided by MSC. Typical of the Riverine plains the subject area is gently undulating with low relief floodplains. No defined waterways exist within the subject area and drainage is typically classified by a series of shallow swales across the landscape with widespread sheet flood common in large rainfall events.

The resultant fall of land and corresponding flow paths is shown in Figure 2.

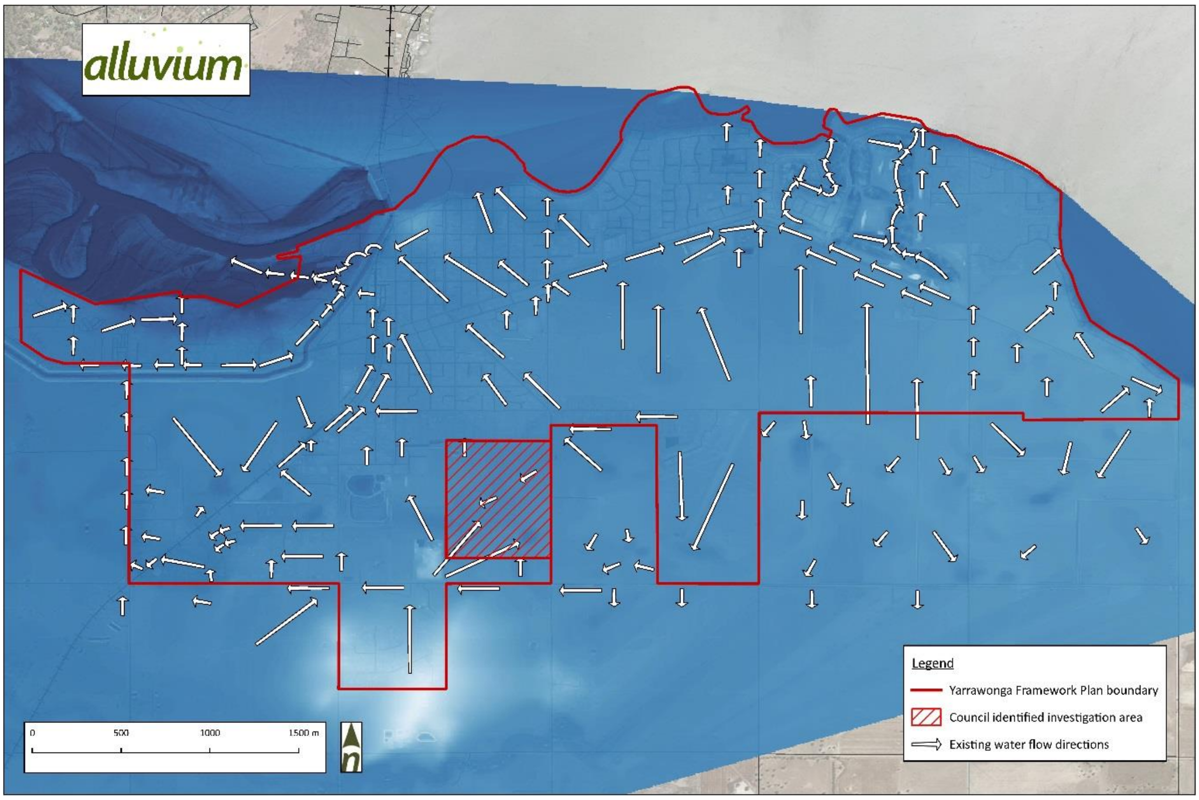

Figure 2. *Existing drainage flow paths*

3.2 Existing development

The majority of the framework area above Murray Valley Highway has been developed into residential estates, including the historic township and Silverwoods Estate. These developments have their own drainage infrastructure in place, with a combination of wetlands, swales and other WSUD measures installed. Moira Shire Council have indicated, however, that many of the older drainage systems throughout the township may be undersized or inadequately maintained to properly transfer stormwater, leading to regular localised flooding. Additionally number of existing drainage channels operated by North East Water exist within the project area that will need to be considered in the strategy (Figure 4).

Land south of Murray Valley Highway is largely highly modified pastoral land, with various farm buildings and associated infrastructure. The majority of the framework area is currently zoned as General Residential (GRZ), Low Density Residential and Farming (FZ) zones (see Figure 3).

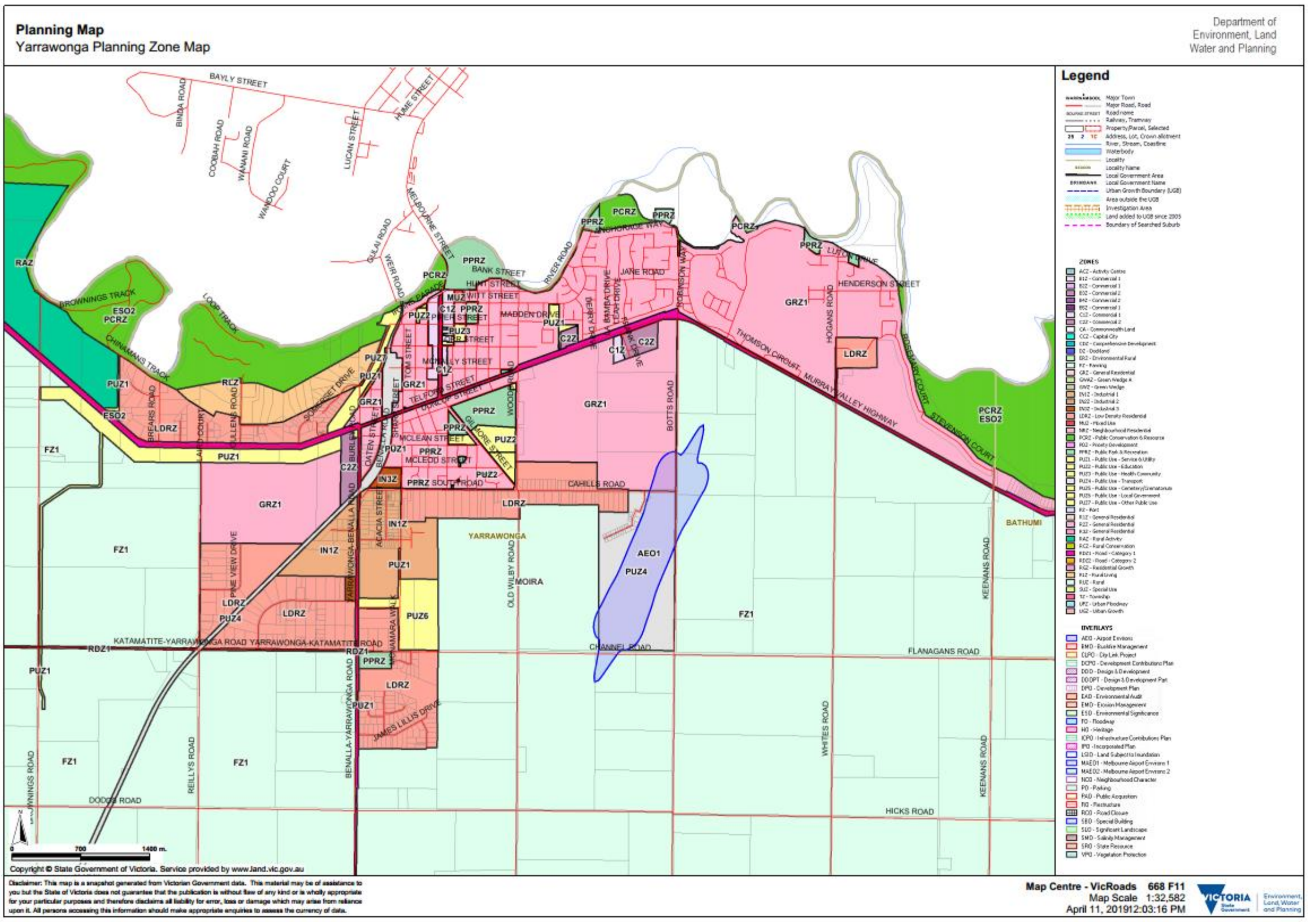

Figure 3. *Existing land use zoning*

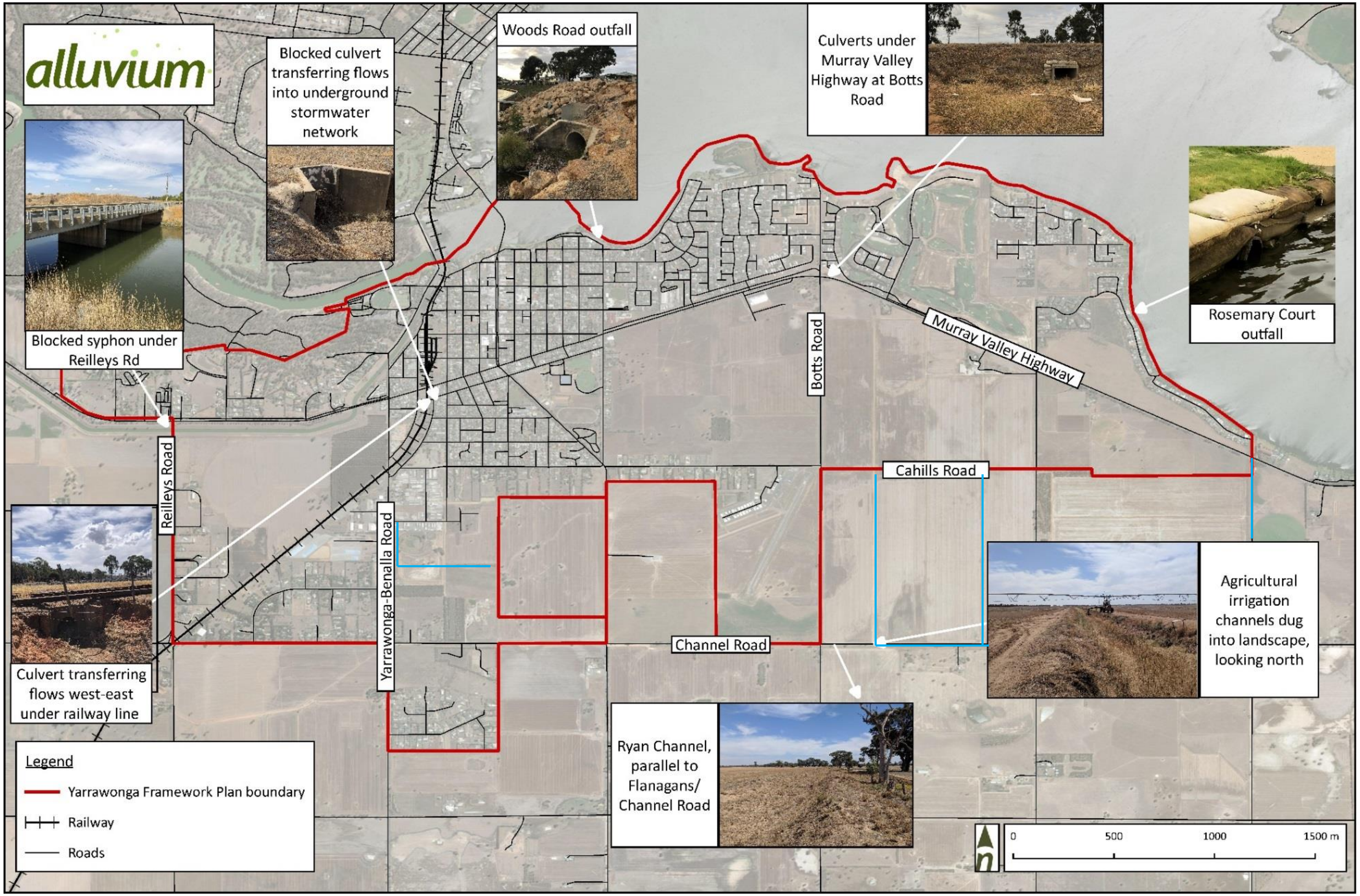

Figure 4. *Yarrawonga site map with existing infrastructure features*

3.3 Site values

The Murray River
The site drains into both Lake Mulwala and the Murray River. The Murray River, which forms part of the northern border of Yarrawonga, is a waterway of national importance.

Lake Mulwala has been subject to Blue Green Algae outbreaks as recently as February 2016, which is a symptom of generally low river flows, increased nutrients (nitrogen and phosphorous) and prolonged dry, warm weather. It is therefore crucial that the quantity and quality of the stormwater generated underdeveloped conditions is managed such that it has no detrimental impacts on the health of this receiving waterway.

The Yarrawonga Weir was constructed in 1939, impounding the water to form Lake Mulwala. The weir retards and raises water levels, allowing for flows to be diverted along the Yarrawonga Main Chanel and the Mulwala Canal (the largest irrigation canal in the southern hemisphere).

Cultural and heritage values
Overlays from the VPA Planning Maps tools show the presence of a registered heritage site on the future Glanmire development, just south of Murray Valley Highway (site shown in orange, Figure 5). The heritage overlay was triggered by the site of a former blacksmith's workshops, now in a dilapidated condition (H8125-0014). The site was suggested to provide insight into private smithing practices.

Many areas of cultural significance (shown in purple, Figure 5) are apparent throughout the framework area. Further investigation may be needed to provide insight into the precise quality, value and location of these areas. Elders from the Yorta Yorta community may be engaged to help inform WSUD asset placement and future outfall locations.

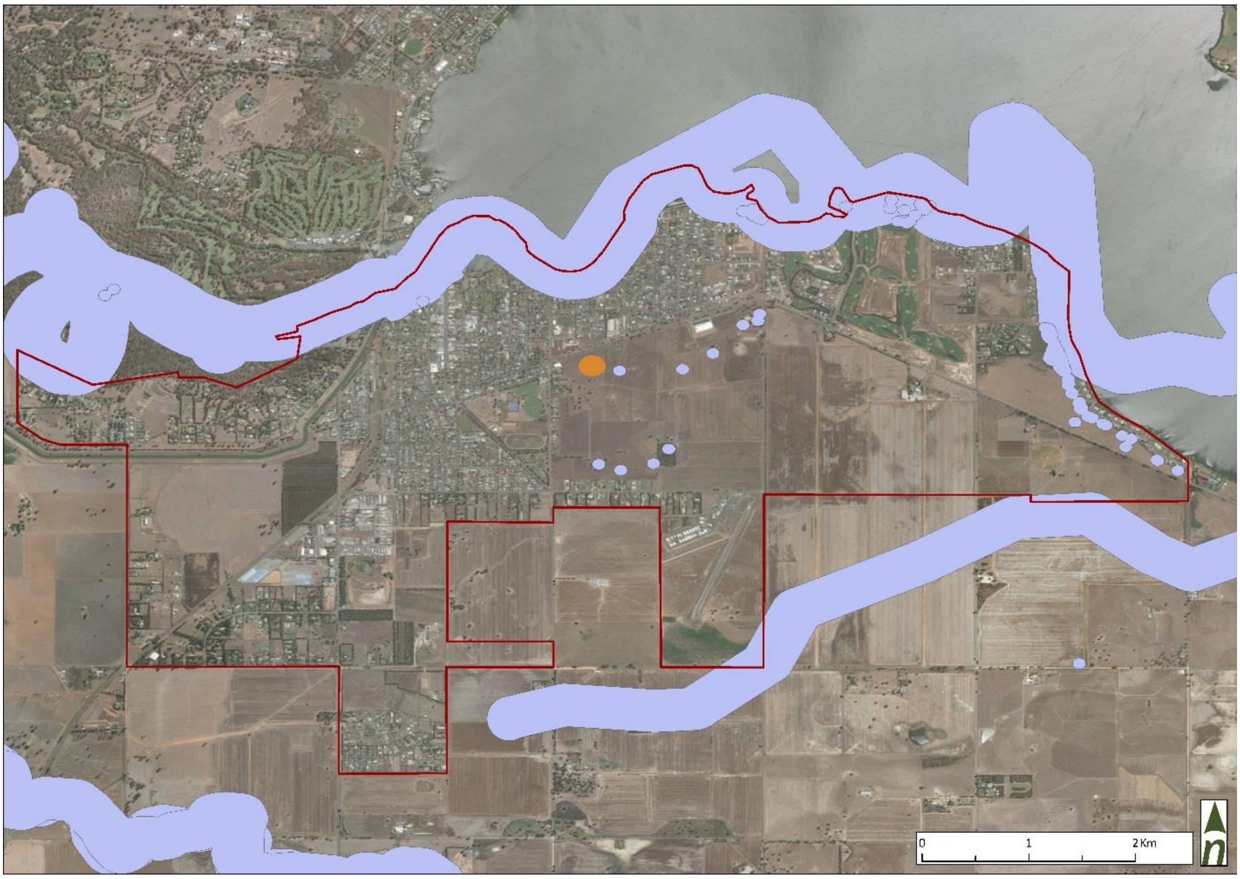

Figure 5. *Cultural significance and heritage overlays within the Yarrawonga growth area*

Native vegetation and biodiversity values
The Yarrawonga Landscape Zone is located within the Goulburn Broken Catchment of Victoria. The Zone, which is approximately 111,830 hectares, is within the Murray Fans Bioregion and the Local Government area of Moira Shire. Since European settlement much of the vegetation in the Zone has been cleared, leaving a fragmented landscape, with many of the remnant that remains being highly modified.

Existing values across the site have been mapped as part of the Yarrawonga Biodiversity Action Plan (BAP) Zone Conservation Plan (Figure 6). Three key areas fall within the study area which have a High to Very High BAP site priority rating. These are shown in the table below:

Table 1. Yarrawonga Biodiversity Action Plan Zone Conservation Plan – Priority Zones

BAP Zone	Yarrawonga	Yarrawonga	Yarrawonga
Site No	812544_266	812544_264	802511_150
Site Name	SthMVHwyMulwala	Lake_Mulwala	Benalla_YarraRailwayLine
Priority	H	VH	VH
Area (hectares)	5.78	771.15	27.14
Bioregion	MF	MF	MF
EVC	74	255	803
EVC Conservation Status	E	V	E
Biodiversity Assets:	Plains Woodland	Waterway	Public Land
	Wetland	RiverineWoodland	OpenWoodland_Grassland
Threatened Fauna:	None_Recorded_FIS_databas e	MurrayCod_SilverPerch_Gold enPerch_Riverblackfish	AssumeGrasses_MuskDuckBr olgaShoveller_1km
Threatened Flora	see Th_fauna records	see Th_fauna records	see Th_fauna records
Threatened Vegation Community:			
Notable Species:	Grey_Box	Variety_of_WaterBirds_Freckl edDucks	NativeGrasses
Focal Species:	Bush_Stone_Curlew	MurrayCod	Bush_Stone_Curlew
	DiamondFiretail		

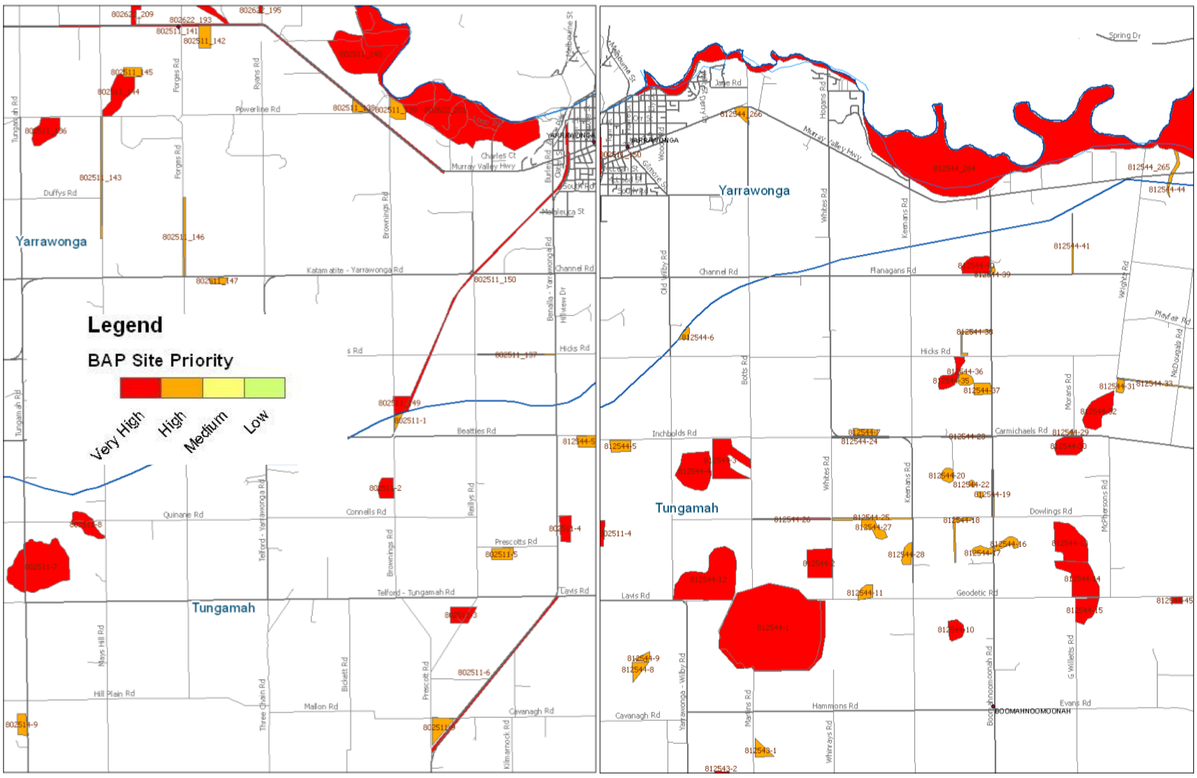

Figure 6. *Mapped values within the Yarrawonga Biodiversity Action Plan Zone Conservation Plan (https://www.gbcma.vic.gov.au/land_and_biodiversity/resources_publications/bap/bap_yarrawonga)*

Actions to protect these assets are included within the BAP, which outline specific actions for each asset type. These actions generally include restoring natural flow regimes, fencing, creating linkages and clusters.

Muckatah Depression

The Muckatah Depression is a wetland of national significance, located approximately 11km south of Yarrawonga. The catchment for the depression covers an area of 2909 ha (2017 ha depression, 892 off depression) (see Figure 7).

The Muckatah Depression is a long, continuous wetland system flowing from Dowdles Swamp, west of Bundalong, meandering for ~60 km along the Muckatah depression before joining Broken Creek through Kinnairds Swamp at Numurkah. Grade within the catchment is minimal, with the depression incision rarely deeper than 0.5m. The wetlands are of ecological significance to the area, providing an important breeding ground for waterfowl, ibis and other water birds. The Great Egret (*Egretta Alba*) has been recorded in the area, alongside threatened species such as Barren Cane Grass (*Eragrostis Infecuda*) and Yellow-tongue Daisy (*Brachyscome chrysoglossa*). In major rainfall events, such as the 2012 floods in Yarrawonga, the Muckatah Depression exceeds capacity, causing back logging, with overflows entering the southern areas of Yarrawonga around Havenstock Drive (see Figure 17).

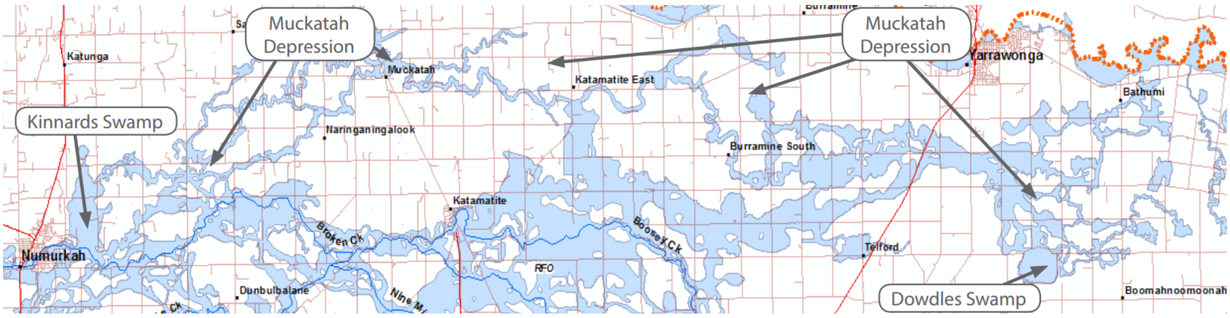

Figure 7. *The Muckatah Depression (Floodsafe fact sheet, SES)*

3.4 Site visit

A site visit was undertaken on 28th March 2019 to gain a better understanding of the local terrain, site constraints and opportunities in regard to the current drainage system. This was attended by Stuart Cleven (Alluvium), Stephanie Amy (Alluvium), Peter Stenhouse (Moria Shire Council) and Simon Carson (Moria Shire Council). A summary of the asset conditions is provided below.

Drainage throughout the fringes of the urban area generally consists of a series of spoon drains and small capacity culverts, with serval being partially blocked with sediment build up (Figure 8).

Figure 8. *Example of typical spoon drain and blocked culvert found through the study area.*

The existing drainage channel along Botts Road is proposed to become a major outlet for stormwater in future urban developments, such as Glanmire Park. The existing Botts Road drain is an open, unvegetated drain with steep banks, subject to erosion and undercutting (see Figure 9, Figure 10 and Figure 11). The operation, maintennace and stability of Botts Road is currently a mjor issuere for MSC. The close proximinity to the road, depth and current erosion poses a safety risk to the community and ongoing managing challenge fro MSC. While not part of scope of this stratgety, further investigation may be necessary to ensure the drain is not compromised by ongoing erosion. As part of this strategy it will essentail to ensure future residntial runoff does not worsen the conditon of the channel.

Figure 9. *High and low flow culverts under Murray Valley Highway at Botts Road, looking south.*

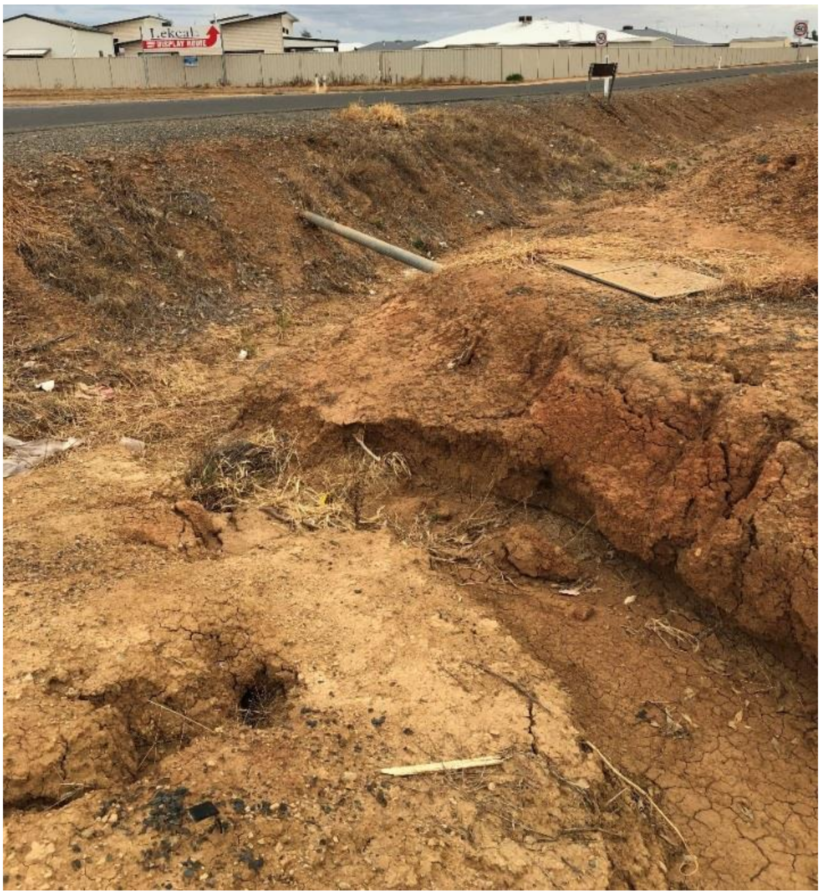

Figure 10. *Botts Road open drainage channel, characterised by unvegetated banks, undercutting and erosion, looking north-west.*

Figure 11. *Culvert and streambed in Botts Road channel, looking south. Note steep, exposed banks and evidence of erosion.*

A small dam exists at Murray Valley Highway, on the site of Glanmire Estate, receiving sheetflow across the paddock to its south (see Figure 12). Flow from this dam is directed under Murray Valley Highway and along Botts Road to the outfall at Lake Mulwala.

Figure 12. *Culverts under Murray Valley Highway, looking south towards existing dam on the property of the future Glanmire Park.*

A historic irrigation channel runs along the southern edge of the Flanagan's Road and Channel Road reserve, which currently acts as a ridge to hold stormwater back (to the south) from the Yarrawonga precinct in major flood events (see Figure 13). The channel stops (and has been infilled) approximately 350m east of the Old Wilby Road intersection. Flood mapping from BMT shows stormwater conveyed from the south, around the end of the channel in a northerly direction parallel to Old Wilby Road, potentially compromising downstream properties (see Figure 19).

Figure 13. *Historic channel south of Flanagans Road, Yarrawonga, looking west*

Referred to as the Pierce Street catchment in the Bainbridge report, additional flow south of the defined catchment area along Burley Road is directed under a culvert and open drain running along Oaten Street before dropping into the underground system (Figure 14).

Figure 14. *Culvert under the railway crossing at Burley Road, looking north.*

A siphon exists at Reilleys Road, under the Yarrawonga Main Channel. Investigation found the siphon to be likely blocked or set at an incorrect elevation, causing water to pool.

Figure 15. *Location of Reilleys Road syphon which appears to be blocked*

3.5 Existing services and infrastructure

Existing development along the foreshore of Lake Mulwala, combined with a flat site grade, limits the drainage outfall options for future southern developments. Within the proposed future residential and industrial areas, there are few services that will impact drainage.

There is no existing underground stormwater network within the proposed development areas.

The only other major service asset within the framework area is the Yarrawonga Main Channel, which is 957km long and services the Murray Valley irrigation region, from Yarrawonga to Barmah. There are three known stormwater crossings which traverse under this asset and service the western part of the Yarrawonga catchment.

Figure 16. *Yarrawonga Main Channel*

3.6 Flooding

Existing drainage issues
Moira Shire has a long history of flooding, including the record-breaking flood event in 2012 which impacted most townships and vast areas of rural farmland resulting in extensive flood damage across the municipality. Yarrawonga was hit particularly hard, receiving 277.4 mm of rainfall in less than a seven-day period (see Figure 17).

Information from Moira Shire Council indicates that in major storm events, rainfall fills the shallow Muckatah Depression and proceeds to flow toward the Yarrawonga township. It is suggested that the Flanagans-Channel Road channel previously acted as a levee and helped to reduce the impact of these floodwaters, particularly on areas such as Havenstock Drive.

Modelling undertaken through the Yarrawonga Flood and Drainage Masterplan (BMT WBM, 2015) provides an outline of the existing flow paths and flooding behaviour within Yarrawonga and surrounds (Figure 19). The 1% AEP flood extent from this modelling, shows significant portions of Yarrawonga surrounds being impacted by flooding.

Drainage issues identified for major roads exist at the intersections of:

- Telford Street and Belmore Street
- Dunlop Street and Gilmore Street
- Orr Street and Irvine Parade

Recommendations to address these problem areas as well as nine others were made in the Yarrawonga Drainage Data Review and Strategy Development report (Andrew Bainbridge, 2016).

Blocked or undersized road culverts and the lack of overland flow paths being maintained through development of land are likely to influence volume and peak of overland floodwaters through the area. Due to the generally flat characteristics of the area, drainage infrastructure such as pumps and road culverts are also likely to influence flood depths and risks.

Figure 17. *Aerial imagery of Havenstock Drive during the 2012 Yarrawonga floods (Yarrawonga Chronicle, 2014)*

Localised hydrological and hydraulic models done in past reports (such the Yarrawonga flood and drainage masterplan) will be used to ensure new development will not impact on the flood extent within the existing developed framework area.

Flood modelling

Following a major flood from high intensity storm in Yarrawonga in February 2012 (Figure 20), a flood management assessment was commissioned by Moira Shire Council to identify and alleviate intolerable flood risk from local urban runoff (Yarrawonga Flood and Drainage Masterplan. BMT WBM, 2015). For the purpose of this assessment, intolerable flood risk was defined as flooding on any properties in the 18% AEP design flood event (Figure 22). The 1% AEP flood model is detailed in Figure 19. A number of flood mitigation options were proposed to reduce the risk of flooding in 9 zones throughout Yarrawonga, identified by council as issue areas (Table 2). The options were ranked for cost effectiveness and the number of properties mitigated from 18% AEP flooding.

A new retarding basin was recommended to be constructed in the Victoria Park precinct, on Gilmore Street. Alongside this, drainage infrastructure was recommended be installed along Cahills Road, and the drains running along Hume Street and Orr Street to be increased in capacity. This would serve to reduce frequent flooding north of Cahills Road, east of Woods Road where no formal drainage is currently in place, and at the Belmore Street and Telford Street roundabout, in the Yarrawonga town centre. Stormwater from the roundabout would be redirected to the new Victoria Park retarding basin before being pumped out through an outlet pipe that outfalls to the Murray River. Enhancement of the Botts Road drain was not shown to reduce intolerable flood risk in Yarrawonga, and instead served to create a new flow path in 1% AEP events, increasing the overall level of flood risk. For this reason, expansion and enhancement of the Botts Road drain was not recommended in the report. At the time of writing this report none of these initiatives had been implemented on ground.

Table 2. Recommended flood mitigation options from WBM BMT flood study (WBM BMT 2015)

Table 2 Yarrawonga Flood and Drainage Master Plan

Rank	Location	Section	Management Measure	Cost	Properties Saved	
					5 year ARI	100 year ARI
1	Telford Street/Belmore Roundabout and Benalla Road railway embankment	Option 2	New retarding basin with improved drainage	$5,475,000.00	45	163
1	Cahills Road near aerodrome	Option 1	Improved drainage	$1,918,000.00	10	4
2	Irvine Prade at Orr Street	Option 5	Raise footpath	$20,000.00	2	3
3	Cahill & Hargrave Court	Option 6	New retarding basin and associated drainage works	$594,000.00	9	1
4	Rosemary & Stevenson Court	Option 4	Improved drainage	$906,000.00	9	9
5	Murphy Street	Option 9	Improved drainage	$1,385,000.00	3	19
6	Shannon Court	Option 7	Improved drainage	$133,000.00	0	0
-	Wetland Court	Wetlands Court	Improved drainage	$50,000.00	0	0
-	Botts Road	Botts Road	Improved drainage	$104,000.00	0	0
-	Murray Valley Highway near Derry Drive	Option 3	Raise Murray Valley Highway	$140,000.00	0	0
-	Parsons Cresent	Option 8	Improve retarding basin capacity	$18,000.00	0	0

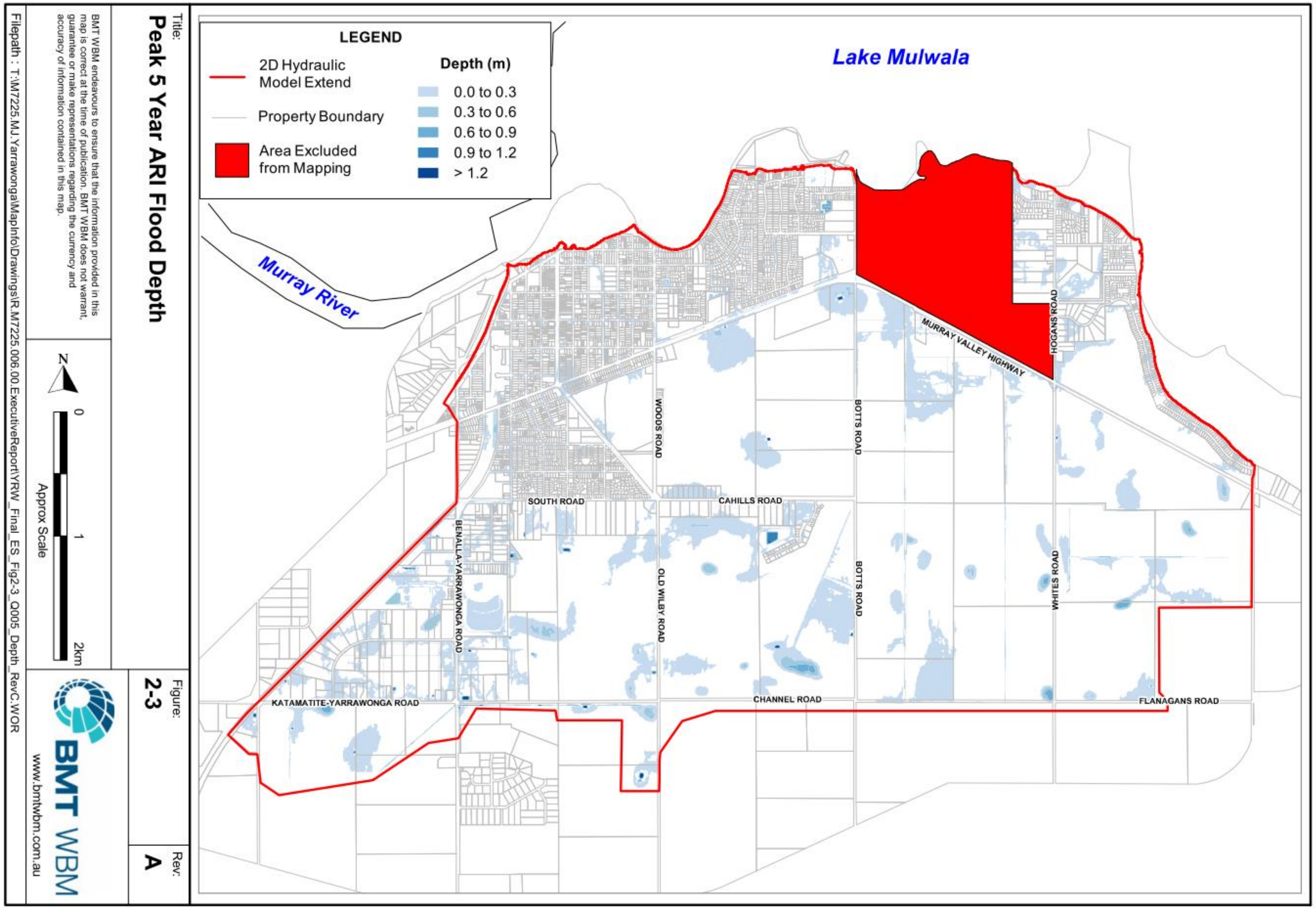

Figure 18. *Peak 18% AEP Flood depth map for Yarrawonga (BMT WBM, 2015)*

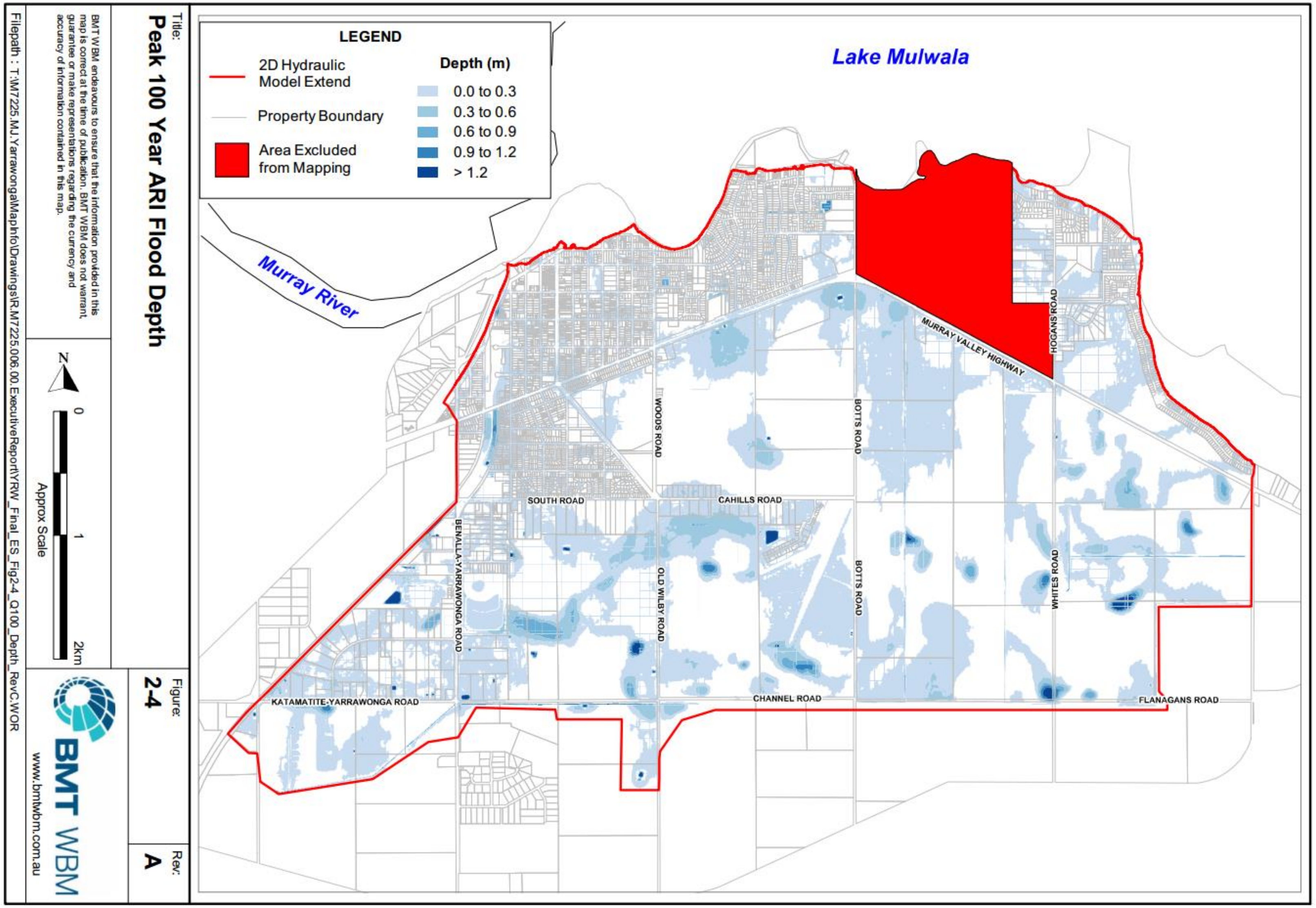

Figure 19. *Peak 1% AEP Flood depth map for Yarrawonga (BMT WBM, 2015)*

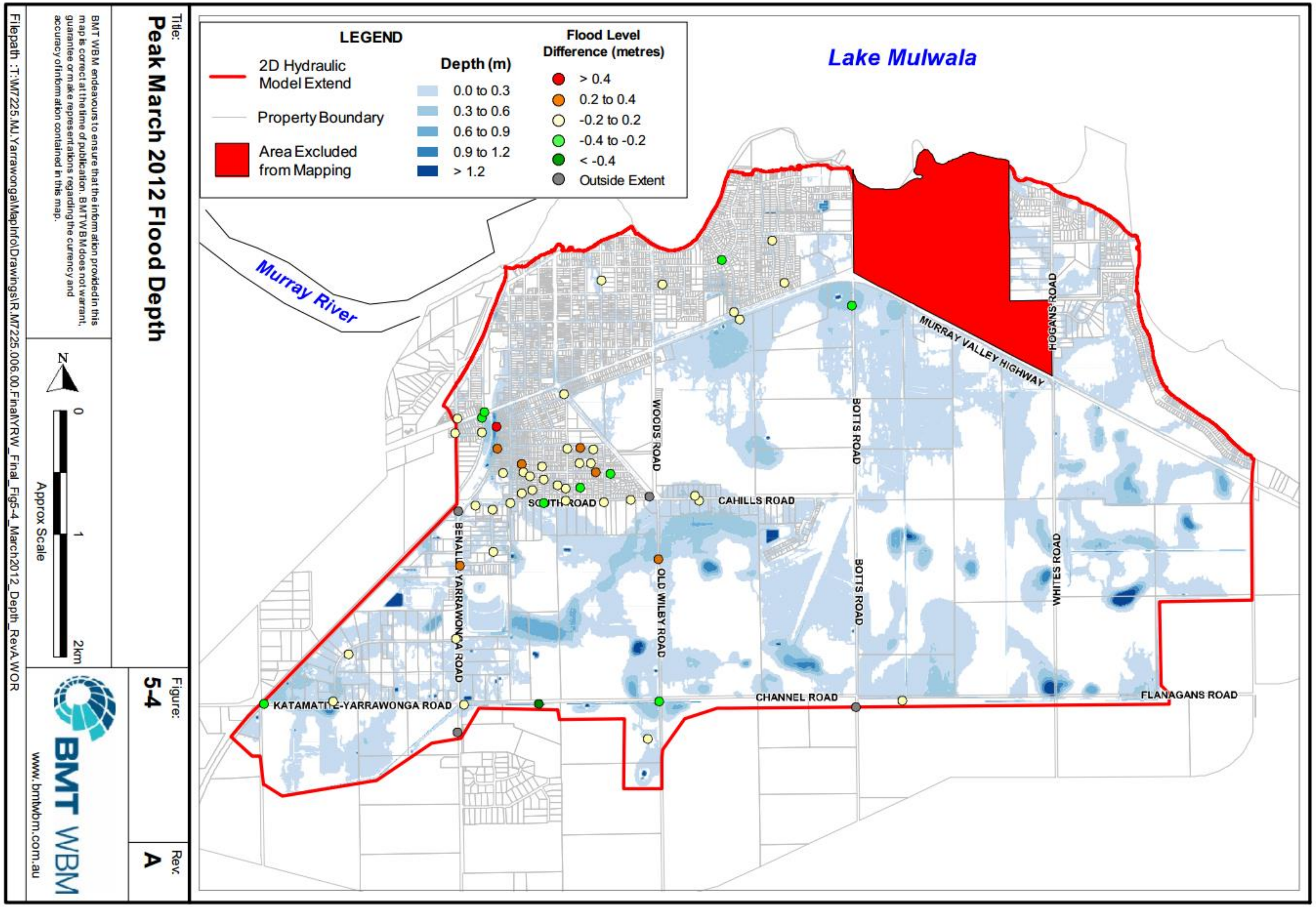

Figure 20. *Peak March 2012 Flood depth map for Yarrawonga (BMT WBM, 2015)*

3.7 Planned future land uses

Many future major developments have been proposed throughout the framework area. Key developments include:

- Glanmire Park residential estate
- Victoria Park community hub
- Silverwoods residential and commercial estate
- Kialla Business Park
- Yarrawonga West residential estate
- Hogans Road Precinct
- Yarrawonga East residential estate

These developments are intended to accommodate population growth, and will require major infrastructure upgrades to existing roads, bridges and utilities. To facilitate for growing populations, future commercial and industrial estates will be developed, alongside major infrastructure upgrades to existing roads, bridges and utilities.

For the purpose of developing a surface water management strategy the draft Future Growth Areas (Figure 1) has been used to provide some guidance regarding type and proportion of land use. The stormwater drainage assessment will focus on the future growth areas, with reference to ensuring no impact on existing urban areas. Key focuses will be on storing and treating storm water from future urban developments in major flood events without compromising any existing infrastructure. This assessment will also consider the impacts from southern (upstream) catchments for 1% AEP events.

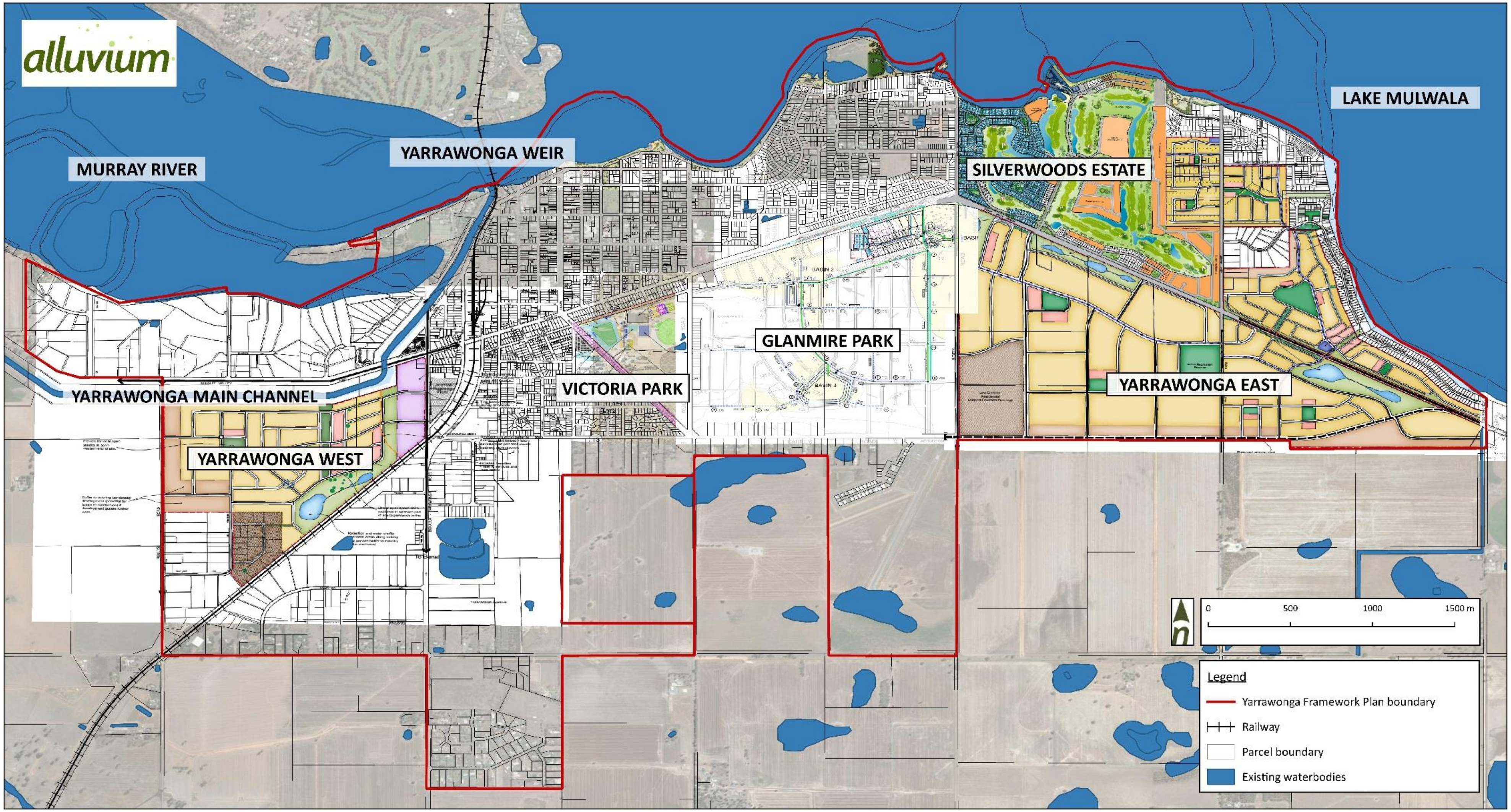

Figure 21. *Yarrawonga growth area with proposed development plans superimposed*

Detailed drainage assessments undertaken for Glanmire Estate indicate that the discharge from the Glanmire development will be via a pumped outfall to the existing Botts Road drain, however, when the basin capacity is exceeded the surface relief solution will involve a sheet flow discharge across Botts Road via a formal floodway. Kialla Business Park, located in the north-east corner of the site at the Botts Road and Murray Valley Highway intersection will also drain through this system (see Figure 22).

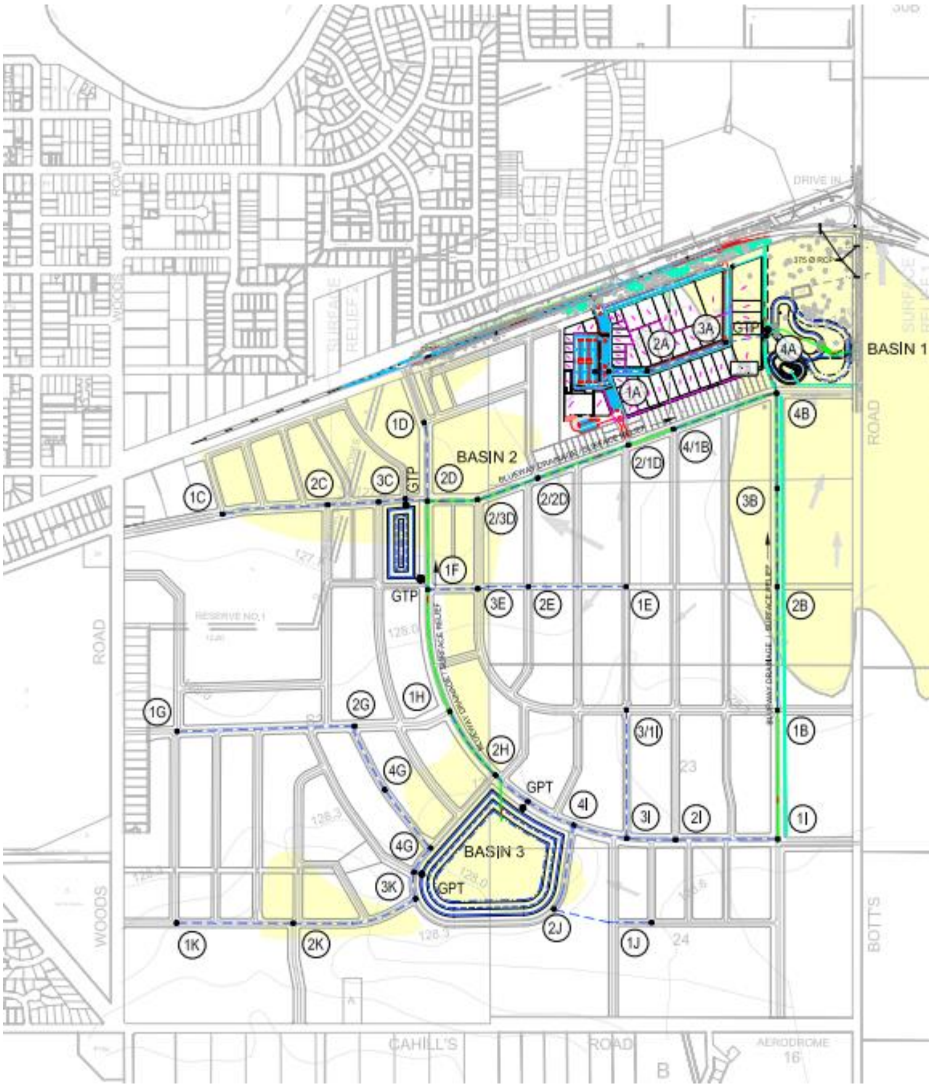

Figure 22. *Proposed layout of Glanmire Estate, Yarrawonga (GMR Engineering Services, 2007)*

4 Stakeholder consultation

Initial stakeholder consultation (in addition to MSC and VPA) was undertaken as part of developing the strategy to understand any insights to area or studies the stakeholders recently undertook, or any assets or values that need to be considered would also be of interest. The following stakeholders were consulted and summary of key points for consideration are included below:

4.1 Goulburn Broken CMA

- Any new development must consider the state-wide *Guidelines for assessing development in flood affected areas (February 2019)*. This document provide guidelines, amongst other things, for Greenfield sites in terms of "permissible" depths, velocity and hazard for development.
- It is recommended that VPA seeks local knowledge in relation to any localised drainage issues. Development along natural depression lines should be actively managed to allow the transference of floodwater across the landscape, with drainage of these areas to retain the natural drainage path where practicable and minimise the impact on rural drainage.
- In terms of waterway health, waterways and surrounds need to be protected from encroachment. Yarrawonga Investigation Area [encompasses] the Murray River. Therefore, we would want to see buffers applied from development to protect this waterway and riparian zone. In this regard please refer to the *Guidelines for the Protection of Water Quality (NEPRC, 2016)*
- The Goulburn Broken CMA would like to see landscape values and amenities protected from any future development, including the need to avoid and minimise and native vegetation and biodiversity impacts within these growth areas. […] Moira Shire Council [has] adopted the *Goulburn Broken Catchment Roadside Biodiversity Risk Management Protocols* to preserve biodiversity related to roadsides and to manage associated activities and risk.

4.2 Goulburn Murray Water

- GMW does not allow the direct discharge of stormwater from urban development to Lake Mulwala. Stormwater must be directed to Council's legal point of discharge and appropriately treated prior to discharging to Lake Mulwala.
- GMW does not allow stormwater from urban development to enter the Yarrawonga Main Channel.
- The water quality of any stormwater discharged to Lake Mulwala, GMW irrigation drains or any other waterways must meet the urban runoff management objectives in clause 56.07-04 of the Victorian planning provisions and standard C25 which specifies current Best Management Practice objectives of 80% retention suspended solids, 45% retention of phosphorous and 45% nitrogen.
- Development of formal drainage and enforcement of stormwater retention is considered integral to the maintaining water quality and minimalizing flooding in rainfall events.

4.3 North East Water

- Of particular interest to North East Water at this early stage of development of a Drainage Strategy would be:
    - Scope
    - Objectives
    - Principles on which the statutory is to be built
    - Approach to decision making (i.e. sequencing of development?)
    - Scenario planning

- Drought Plan
- Catchment outline
- System overview.
- System history (i.e. floods when, where what impact)

4.4 Transport for Victoria

- Consideration of future road and roundabout upgrades planned for the area and potential interface with proposed water retention and water quality assets.

4.5 DELWP

Consultation with representatives from the DELWP Regional Integrated Water Management team indicated that there are two projects that are currently being undertaken in the area for consideration:

- The Murray River Connect Project, which is being driven by Moira Shire Council, will investigate the feasibility and design of a 'RiverConnect' approach in the Moira Shire region. This is to establish the connection between the community and the Murray River, and as such could have an impact on this project.
- The Place-based Small Town Wastewater Management Project, which is being driven by Goulburn Valley Water, is looking to create a decision-making matrix for small town sewage problems. The STWMP will primarily focus on ensuring that the region (and broader Victoria) are provided with a long-term solution to provide effective and affordable wastewater systems to all communities in the state.

4.6 Stakeholder workshop

The draft strategy was presented to stakeholders on 20 June 2019 and feedback sought. Responses received from each of the stakeholders on the draft strategy has been collated and fed back into the report.

5 Existing conditions hydrologic modelling

This section details the hydrological analysis investigation in estimating existing the 1% Average Exceedance Probability (AEP) peak flows and flood extents within framework boundary.

- Flood estimation has been conducted in accordance with Australian Rainfall and Runoff 2016 (ARR 2016) guidelines, and
- Hydrologic modelling was conducted using RORB (v6.42). RORB is a runoff-routing model that simulates attenuation and delay of a hydrograph to produce flood estimates at specified catchment locations. A RORB model was established for the existing catchment outlets at Botts Road, Brears Roads and Rosemary Court.

Hydrologic analysis has been undertaken in this project to identify the existing 1% AEP peak flows, the future developed 1% AEP peak flows and requirement for retardation.

5.1 RORB

RORB models were built by delineating the area into three major catchments using existing road networks, pipe and channel network data, future development plans and LiDAR data. RORB models were built for the major discharge points for the framework: Yarrawonga East (east of Hogans Rd), Botts Road (between Hogans Rd and Woods Rd, south of Murray Valley Highway) and Yarrawonga West (west of Woods Rd) (Figure 23).

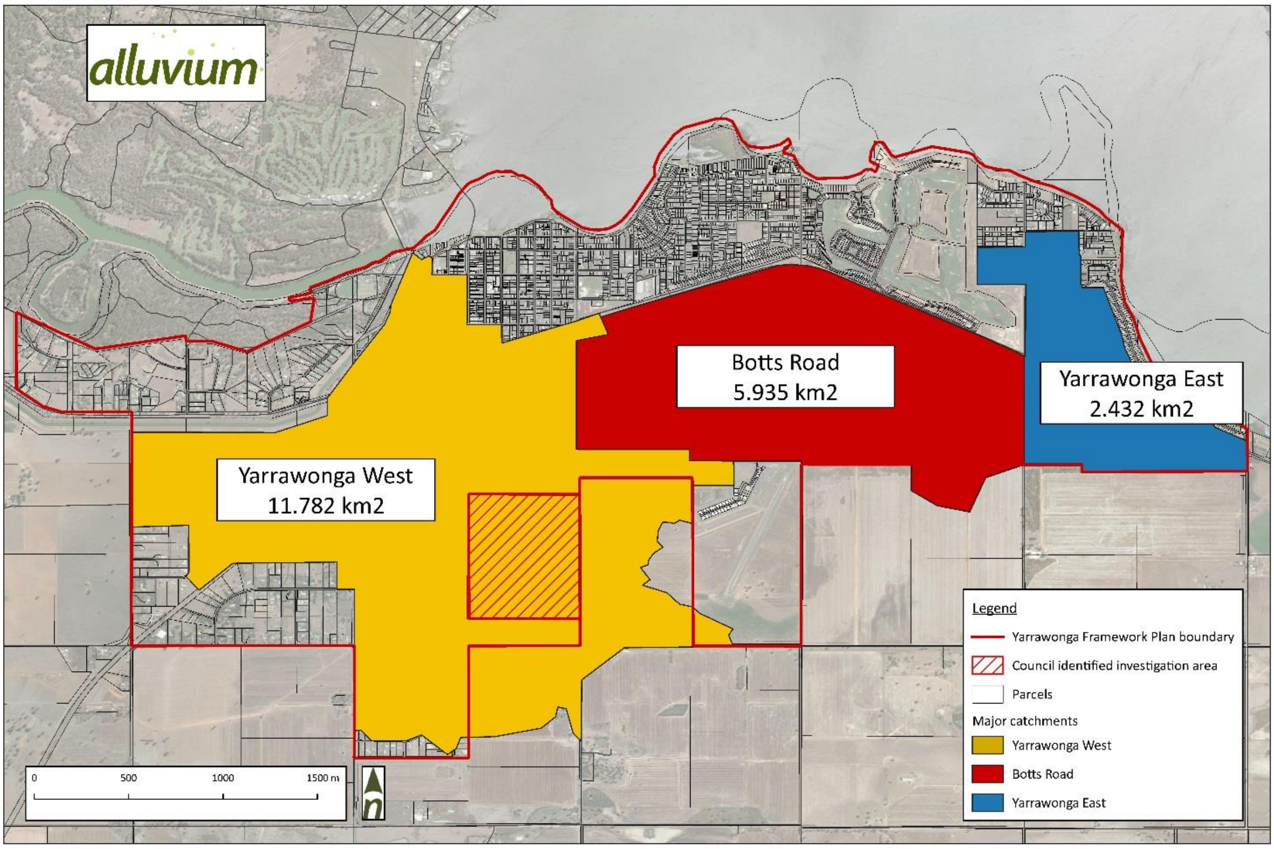

Figure 23. *RORB catchment overview*

The fraction impervious adopted for the models are detailed in Table 3.

Table 3. Fraction impervious adopted for hydrologic modelling

Location	Fraction impervious
Farming Zone (FZ)	0.1
Low Density Residential Zone (LDRZ)	0.4
Residential Zone (RZ)	0.6
Industrial Zone (IZ)	0.9

The catchment reaches and nodes used to build the RORB model are shown in Figure 24.

Further detail on RORB modelling method is provided in Appendix A.

Modelling inputs
Rainfall inputs in the form of Bureau of Meteorology (BoM) 2016 Intensity Frequency Durations (IFDs) were used for all flood estimation, with temporal patterns and aerial reduction factors from ARR 2016.

Key inputs into RORB modelling include:

- Initial catchment routing parameter Kc was determined through the RORB regional estimates (selected as Pearse data et all) and modified based on falling within the confidence limits of the Regional Flood Frequency Estimation Model (RFFEM)
- Updated Intensity Frequency Duration (IFD) data based on updated rainfall data from a number of rainfall stations. This is sourced from the Bureau of Meteorology's (BoM) website.
- Running the model based upon an ensemble of temporal patterns sourced from the AR&R data hub and determining the median peak flow for a given storm event and duration, rather than using a single temporal pattern.
- Using Areal Reduction Factors from a modified version of the Bell's method, which is sourced from the ARR data hub, rather than using Areal Reduction Factors sourced from AR&R 87 (Siriwardena and Weinmann).
- Using an Initial Loss / Continuing Loss model, rather than a Runoff Coefficient model.
    - Where Initial Loss values 24 mm/h (based on ARR Datahub) are modified to account for pre burst rainfall through initial loss minus the pre burst depth (based on ARR Datahub),
    - and Continuing Loss values of 3.5 mm/h (based on ARR Datahub).

A summary of the inputs derived are shown in Table 4.

Table 4. RORB modelling parameters for the ARR 2019 sensitivity analysis

Model parameter	ARR2019
kc	2.79 (Yarrawonga West), 1.93 (Botts Road), 0.66 (Yarrawonga East)
m	0.80
IL	23.8 (Yarrawonga West), 23.2 (Botts Road), 22.6 (Yarrawonga East)
CL	3.5
IFD location	Latitude: -36.027, Longitude: 146.035
Aerial reduction factors	ARR Data hub

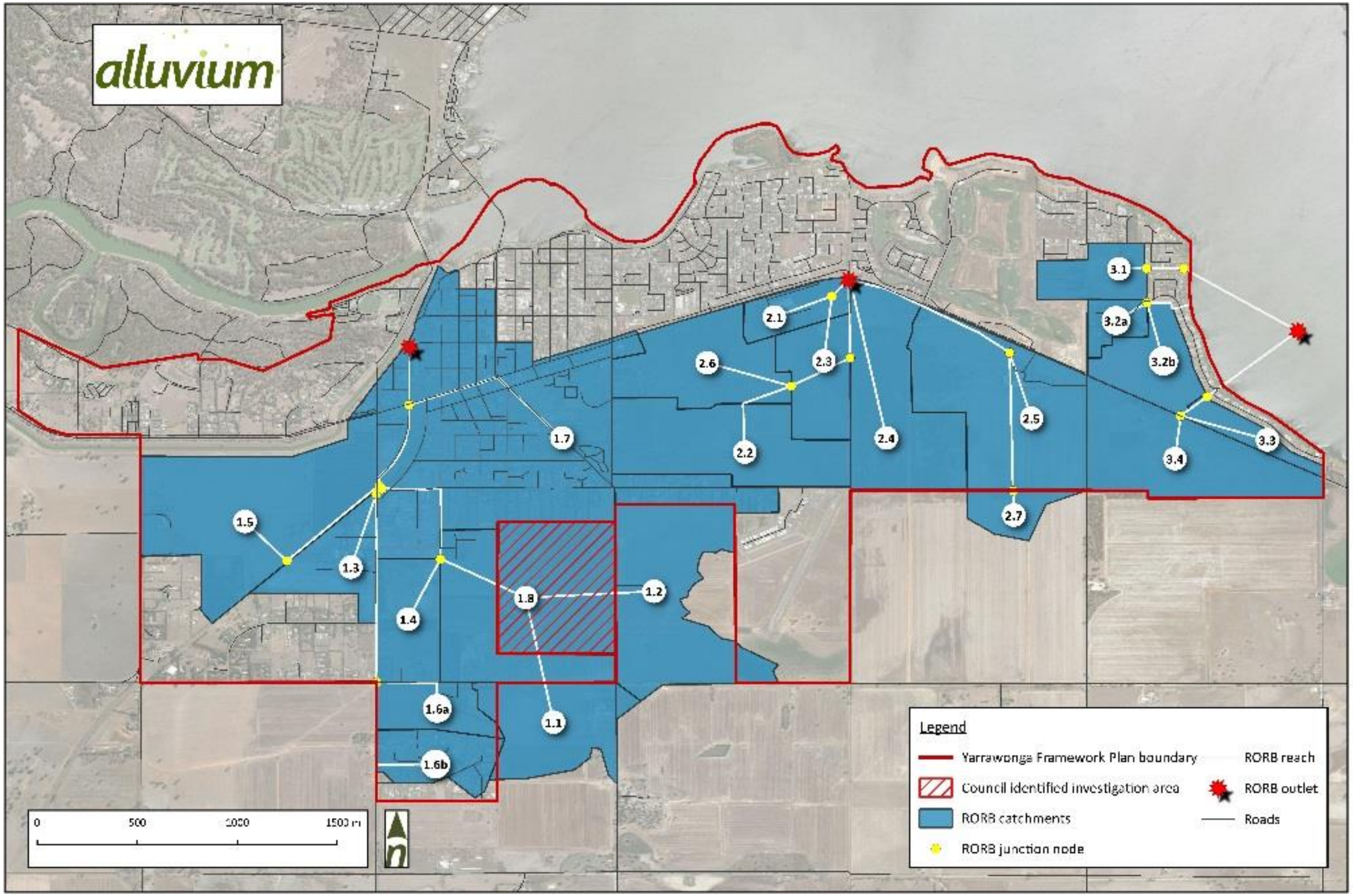

Figure 24. *Yarrawonga growth area with RORB catchment breakdown*

5.2 Results

Based on the above parameters, the RORB model was run using an ensemble simulation for the 1% AEP event (i.e. formerly known as the 100 year ARI event), for durations 10 minutes to 168 hours. From the ensemble simulation, ten temporal patterns were used to determine peak runoffs for each duration. The median peak flows (i.e. 6th highest peak flow) for each storm duration was determined, and the peak critical flow was calculated (Table 5).

Note climate change scenarios have not been applied to the existing condition models as to set the current benchmark. Refer to section 6.4 for climate change modelling considered within RORB.

Table 5. Peak flowrate results under existing conditions (Ensemble simulation)

Location	1%AEP Peak flow	$T_{critical}$
Yarrawonga East (Combined outfall)	13.4 m^3/s	1.5 hr
Botts Road (@ Botts Rd and Murray Valley HWY)	19.7 m^3/s	6 hr
Yarrawonga West (@ Yarrawonga Main Channel)	38.0m^3/s	6 hrs

Based upon the analysis for this catchment, the peak flows calculated following the ARR 2019 guidelines represents a slightly more conservative approach compared to ARR 87. ARR 2019 recognises the temporal variability in potential rainfall events and its influence on the conversion of rainfall to peak flows compared to ARR87 which considered only a single design event temporal pattern. As a result, ARR2019 requires the use of 10 temporal patterns which allows the model to produce a range of peak flows for each rainfall duration of a storm event. The median (or 60th percentile) peak flow for a given duration is recorded as the 'critical flow' (refer to Table 5 for critical flow derived).

The relatively short critical storm durations for the 1% storm event for the Yarrawonga area is due to the rural nature and small size of the sub-catchment, and corresponding low fraction impervious.

The peak flow events established in this hydrological analysis are compared to the developed conditions peak flows and critical storm durations in Section 6.4 to understand detention requirements and any existing infrastructure limitations.

6 Options development

Drainage, stormwater treatment and flood management options for Yarrawonga have been developed in consultation with stakeholders. Drainage options were presented to the VPA on the 10th of May 2019 to present drainage constraints and opportunities and identify a preferred approach.

The design principles that have been adopted following this consultation process include:

- Protection of receiving waters
- Meeting best practice environmental management (BPEM) stormwater treatment
- Identify opportunities for stormwater harvesting and reuse
- Environmental Sustainable Design (ESD) Principles including identifying assets that can adapt with climate change, enhance ecology through species diversity and habitat creation
- Identify assets that deliver community recreational and amenity values and contribute to resilient and liveable communities
- Minimise land take associated with stormwater management
- Align design arrangement within proposed development plans, where possible
- Manage flooding, and
- Avoid filling where possible.

6.1 Challenges

A number of site constraints and challenges where identified during the site inspection which will influence the formation of drainage options including:

- The flat grade across the site
- Existing infrastructure (including roads and culverts) at drainage outlet points. Whether they can be upgraded will significantly influence options development (i.e. dictating outlet invert levels and tailwater conditions)
- The options must ensure sub-divisional drainage serviceability (i.e. sub-divisions need to be able to be drained)
- Achieving minimum velocities within drainage pipes which may be challenging given the lack of grade

6.2 Approach

When designing for a site so flat in nature, there are typically two ways to approach drainage solutions on site. The first is often dubbed the ‘sump and pump’ method, in which wetland/ retarding basin are dug into the landscape to store flows with subsequent pumping to the drainage network (Figure 25). The second approach is to create a linear series of wetlands exist within the retarding basins to concurrently treat low flows and provide storage for larger rainfall events. An example of a linear wetland system can be seen in Figure 26.

Figure 25. *Example of a sump and pump arrangements in Echuca (Source: Google Earth)*

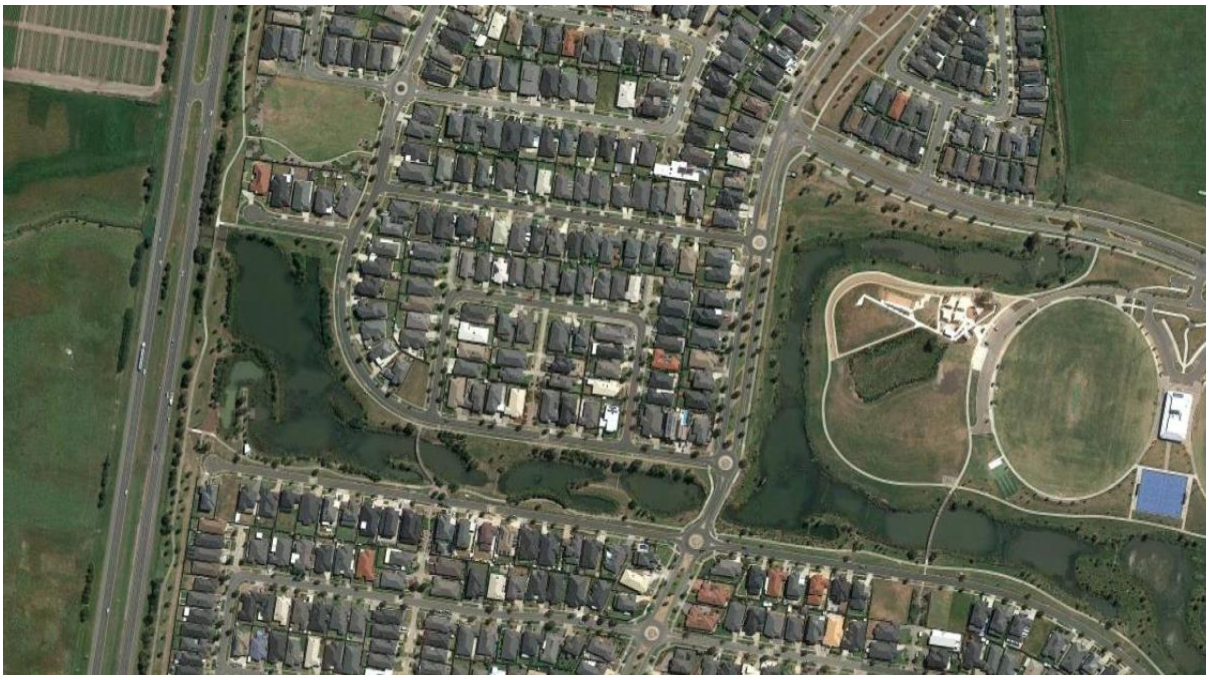

Figure 26. *Linear wetland example at Marriott Boulevard, Lyndhurst, Melbourne*

A pros and cons comparison of the two systems can be seen in Table 6.

Table 6. Drainage approaches: Pros and cons

Approach	Pros	Cons
Sump and pump system	Allows a deeper outlet for sub-divisional drainage	Ongoing maintenance
	Option for 'centralised servicing' i.e. a single asset at the bottom of the catchment	Potential for mechanical failure
	Smaller footprint	Limited recreation potential or aesthetic value
	Can be integrated into a stormwater harvesting network to allow to water reuse within the landscape	
Linear wetland system	Suitable to manage flat longitudinal grades (noting grade of less than 1 in 800 should be a series of linear pools)	Wetland systems are flat, requiring careful design and landscaping
	Recreational opportunities (e.g. connectivity within developments)	Likely to require downstream infrastructure upgrades
	Enhanced amenity values (i.e. waterways and wetlands as opposed to basins)	Requires careful plant selection due to higher inundation frequencies
	Integrates stormwater treatment and flood conveyance)	Should not be used to convey 1%AEP flows due to the risk of scour and vegetation loss. Wetlands must be separate from waterways
	Can be aligned along road reserves and therefore integrated with the remainder of the development	

Within each of the drainage approaches conveyance through the proposed developments was analysed to see if there was a need for a constructed waterway. That is a constructed waterway is required where the capacity of the pipe system and overland flow path (typically road) is exceeded for the 1% AEP. As there are no defined waterways or drainage lines across the project area and due to the flat nature of the site conveyance of flows through the developable areas consist of sheet flows and will typically run through a series of road networks and underground pipe networks.

Whilst consultation with the VPA indicated a preference toward a waterways, due to the numerous amenity co-benefits, initial hydrologic checks indicated that a waterway system is no required within the framework area. Additionally, due to shallow downstream infrastructure constraints, issues with connecting future subdivisional drainage, fill requirements and staged property development a central waterway system is not suited to the site.

However, while a waterway system might not be the most feasible option, options proposed below include a liner 'sump and pump' method and combined wetland method that provides similar stormwater service, ecological, sustainability and community outcomes.

6.3 Drainage Options

The alternative methods were pursued in further detail to service the area. To increase amenity and meet the proposed stormwater quality management requirements, linear wetlands have been proposed within each retarding. This will allow for stormwater to be treated to best practice before discharge into Lake Mulwala and the Murray River.

Based on the above three alternative drainage layout options were considered for the site:

Option one – Development Plan Alignment - 'sump and pump' method
Option one considered the alignment of water quality assets and retarding basins within the provided development plans. Assets were sized to ensure they were able to function appropriately and meet the framework principles. Largely, assets were able to be located wholly within the reserves proposed within the development plans based on the 'sump and pump' method.

Where development plans did not allow for stormwater treatment, assets were proposed and aligned most closely with the lowest part of the sub-catchment and open space reserves.

Option two – Optimum positioning of assets – Linear wetlands/retarding basins
Option two realigned the assets to be placed in the optimum location, thus disregarding the development plans. This included locating linear assets that can act as a wetland/retarding basin either at the bottom of the sub catchment, or in line with existing infrastructure. From a liveability perspective this approach has the potential to deliver significant improved community assets and linear linkages through the site. The vision is for these linear wetlands is to connect different sections of the Yarrawonga community, while additional assets like shared paths or reserves run along the alignments and connect the wetlands, providing a valuable recreational asset.

Option three – IWM, Smart system storage and harvesting
Option 3 builds on option 2, in that it includes the use of stormwater harvesting and smart system storage within the retarding basins to store nuisance flooding (up to the 20% AEP) and supply water for irrigation. The main principle behind this strategy is to minimise runoff, address nuisance flooding and allow harvesting. A smart storage and tank system is proposed that can monitor weather patterns and pump water from the retarding basin to header tanks during rainfall events, once the header tanks are full the retarding basin can temporarily store up to the 20% AEP and then dump water after the peak flow event has passed. Stored tank water could then be used for irrigation of adjacent open space.

However due to the extended storage of water within the wetlands careful vegetation selection would need to be considered to ensure it can withstand up to 3 days of inundation.

The modelling and formation of the plans are described in the following sections.

6.4 Developed conditions hydrologic modelling

This section details the hydrological analysis required to estimate peak flows within Yarrawonga under developed conditions. Comparing the existing and developed condition RORB models illustrates the change in peak flows, and therefore the detention requirements to bring peak developed flows back to equal or below pre-development levels.

Retardation of peak flows back to (or lower than) predevelopment conditions has been undertaken to protect key downstream residential areas and public infrastructure, such as the Murray valley Highway, from additional flooding.

The strategy also provides initial culvert upgrade recommendations for flows under the Murray Valley Highway. That is culvert recommendations have been provided to convey the 1% AEP under the Murray Valley Highway and Benalla-Yarrawonga Road how to protect the level of service and safety of the arterial road network.

Inputs

The same parameter values were used for the developed and existing conditions model (see section 5). The catchments and structure of the model was retained. The reach type connecting the residential sub-catchments to waterway outfalls was updated from 'natural' to 'piped'. The fraction impervious values were updated as per Table 3 to reflect any change in future land use indicated in development plans (Figure 27). Land within the framework boundary that did not have any development plans proposed was modelled in accordance with the industrial and residential zone overlays indicated by the VPA in Figure 1.

Due to the flat nature of the site and the depth of underground services it was determined that any areas draining away from the proposed discharge points would be able to connect to the much higher existing drainage system.

Climate Change

Future climate variation was incorporated into the hydrologic modelling used to assess 1% AEP flow volumes and size retarding basins. The increase in rainfall was determined in accordance with the AR&R 2019 Guidelines, with the following inputs and assumptions:

- Yarrawonga is located within the Murray Basin Natural Resource Management cluster;
- Assets are to have a 50-year design life, to 2070;
- Maximum Global Climate Model (GCM) consensus cases for concentration pathway of RCP4.5 (this provides for a "hotter" consensus case with 29 of 40 GCMs, see AR&R table 1.6.5);
- Class interval of 1.5 to 3.0 ◦C, therefore mean temperature (Tm) = 2.25◦C

Projected rainfall intensity (I_p) = Design rainfall intensity (I_{ARR}) * 1.05^{Tm} *(AR&R equation 1.6.1)*

$$I_p = I_{ARR} * 1.05^{2.25} = 1.116 \ ^{\#}$$

Therefore, design rainfall intensity was increased by 11.6 % . This change in rainfall intensity has been accounted for in the design, with all retarding basins/tanks sized to adequately to ensure storage of flows.

#Note this would be the same for 2070 with RCP8.5.

Results

The results (Table 7) show peak flows for the Q100 ARI event and critical times. All systems have peak flows that have increased significantly when compared to existing conditions. Critical event times have shortened due to the increase in the area of hard surfaces.

Table 7. Key peak design flow results from Ensemble simulation under developed conditions (without RBs)

Location	Q100 Peak flow (rural)	Tcritical (rural)	Q100 Peak flow (developed)	Tcritical (developed)	Q100 Peak flow (developed with climate change)	Tcritical (developed with climate change)
Yarrawonga East (Combined outfall)	13.4 m^3/s	1.5 hr	25.2 m^3/s	20 mins	29.43 m^3/s	20 mins
Botts Road (@ Botts Rd and Murray Valley HWY)	19.7 m^3/s	6 hr	40.3 m^3/s	1 hr	46.69 m^3/s	1 hr
Yarrawonga West (@ Yarrawonga Main Channel)	38.01 m^3/s	6 hrs	54.3 m^3/s	1 hr	63.9 m^3/s	1 hr

The developed conditions model for the Yarrawonga West model includes minor flows form the north west corner of the catchment, at Murray Valley Highway and Woods Road. It assumed these flows will not be redirected east following development.

A comparison of the peak flows for the 1% AEP event at all outlets show that the peak has increased significantly.

Retardation

Analysis of the required detention storage was conducted for the Option 1 scenario to understand if the flow could be brought back to pre-development flows, in line with BPEMG objectives. A stage-storage-discharge relationship was therefore developed using:

- Pre-developed flows from RORB
- A high-level design DEM developed using the proposed wetland geometry and existing LiDAR to obtain storage volumes within the LSIO boundary

The results (Table 8) show that with the implementation of wetland/retarding basins within the proposed developments it is possible to hold post development flows (for the 1% AEP) back below predeveloped conditions. Outflow from the proposed wetland/ retarding basin is limited due the need for pumping on the site. All retarding basin were modelled with set pumped outflow rates at 0.2 cumecs (assumed typical pump capacity), with a higher flow spillway in a 1% AEP storm event to ensure adequate storage was available to for flows while pumps work to drain the basins. The system is modelled assuming all pumps will be working effectively during the storm event.

The resultant flow reductions and retarding basin sizes for Option 1 can be seen in Table 8 and Table 9.

Table 8. Key peak design flow results from Ensemble simulation under developed conditions (with RBs – Option 1)

Location	Q100 Peak flow (rural)	Q100 Peak flow (developed)	Q100 Peak flow (developed/retarded/Climate Change)	Tcritical
Yarrawonga East (Combined outfall)	13.4 m^3/s	25.2 m^3/s	8.54 m^3/s	920 mins
Botts Road (@ Botts Rd and Murray Valley HWY)	19.7 m^3/s	40.3 m^3/s	8.31 m^3/s	9 hrs
Yarrawonga West (@ Yarrawonga Main Channel)	38.01 m^3/s	54.3 m^3/s	35.53 m^3/s	1 hr

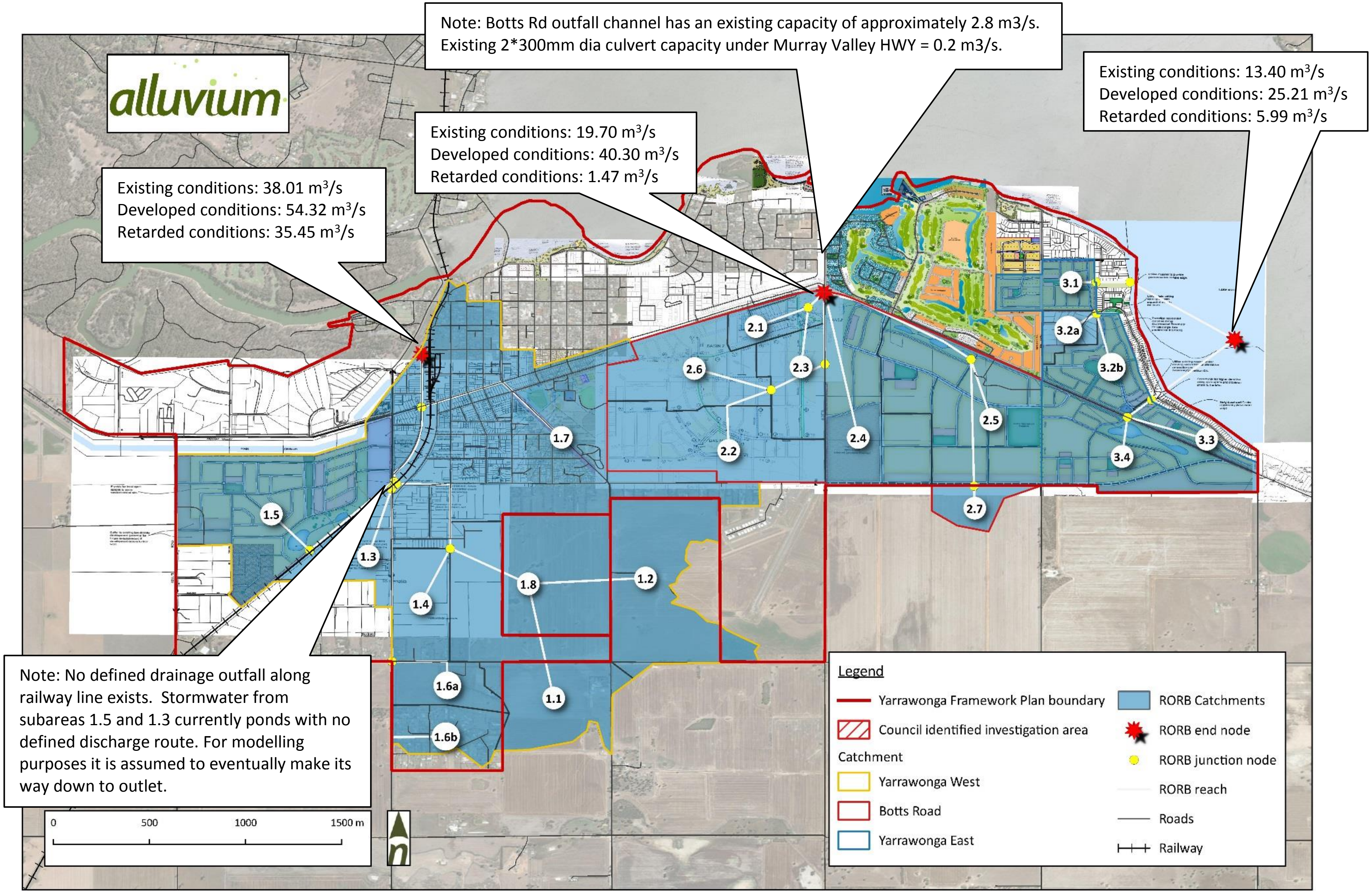

Figure 27. *RORB delineation and flow retardation achieved for Option 1 – developed*

Table 9. Retarding basin design parameters derived (Option 1)

RB number	Zones treated	Critical inflow (m3/s)	Critical inflow duration	Critical outflow (m3/s)	Critical outflow duration	RB volume	RB depth	RB batter slope	RB surface area (m2)
1	1.4	6.67	45 min	1.10	9 hrs	2.29E+04 m³	1.25 m	1 in 6	20,239
2	1.5	27.00	25 min	2.13	36 hrs	9.33E+04 m³	1.56 m	1 in 6	64,796
3	1.6a	4.98	25 min	0.63	12 hrs	1.46E+04 m³	1.23 m	1 in 6	26,671
4	1.8	21.52	1 hr	3.0	36 hrs	1.49E+05 m³	1.67 m	1 in 6	98,776
5	2.1	11.16	45 min	1.97	6 hrs	3.40E+04 m³	1.49 m	1 in 6	25,724
6	2.2	18.19	25 min	1.27	12 hrs	5.61E+04 m³	1.30 m	1 in 6	46,483
7	2.4	12.15	45 min	1.27	36 hrs	6.79E+04 m³	1.59 m	1 in 6	46,521
8	2.5	22.65	45 min	1.39	9 hrs	7.90E+04 m³	1.39 m	1 in 6	61,182
9	2.6	14.35	25 min	2.63	6 hrs	2.71E+04 m³	1.63 m	1 in 6	26,973
10	3.2b	7.42	25 min	1.08	9 hrs	2.15E+04 m³	1.74 m	1 in 6	14,496
11	3.4	21.5	15 min	1.43	12 hrs	6.04E+04 m³	1.51 m	1 in 6	45,584
12	3.3	2.79	45 min	0.32	36 hrs	5.17E+04 m³	1.53 m	1 in 6	37,714

6.5 Stormwater treatment modelling

The developments within the framework will need to meet best practice environmental management (BPEM) stormwater treatment targets before being discharged into the receiving waters. In line with the propose Yarrawonga Stormwater Management Strategy, these targets are:

- 80% reduction in the annual load of Total Suspended Solids (TSS)
- 45% reduction in the annual load of Total Phosphorus (TP)
- 45% reduction in the annual load of Total Nitrogen (TN)
- 70% reduction in the annual load of Gross Pollutants (GP)

A MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model was developed to estimate the pollutant loads generated from developed catchments and to size the wetland assets required to meet the pollutant reduction targets.

Inputs

Climate data (daily rainfall) was obtained from the Tatura Bureau of Meteorology (BoM) rainfall station (81049). Shepparton monthly mean evaporation rates were also used.

The MUSIC model includes both internal and external catchments, based on the draft urban layout. The fraction impervious value for each land use type has been adopted based on the Melbourne Water MUSIC Guidelines and the same values modelled in RORB. Although some limited external flow is apparent on site, the load removal targets are based on the loads generated by the internal framework catchments only.

The proposed design schematic for the Yarrawonga system is provided in Figure 28.

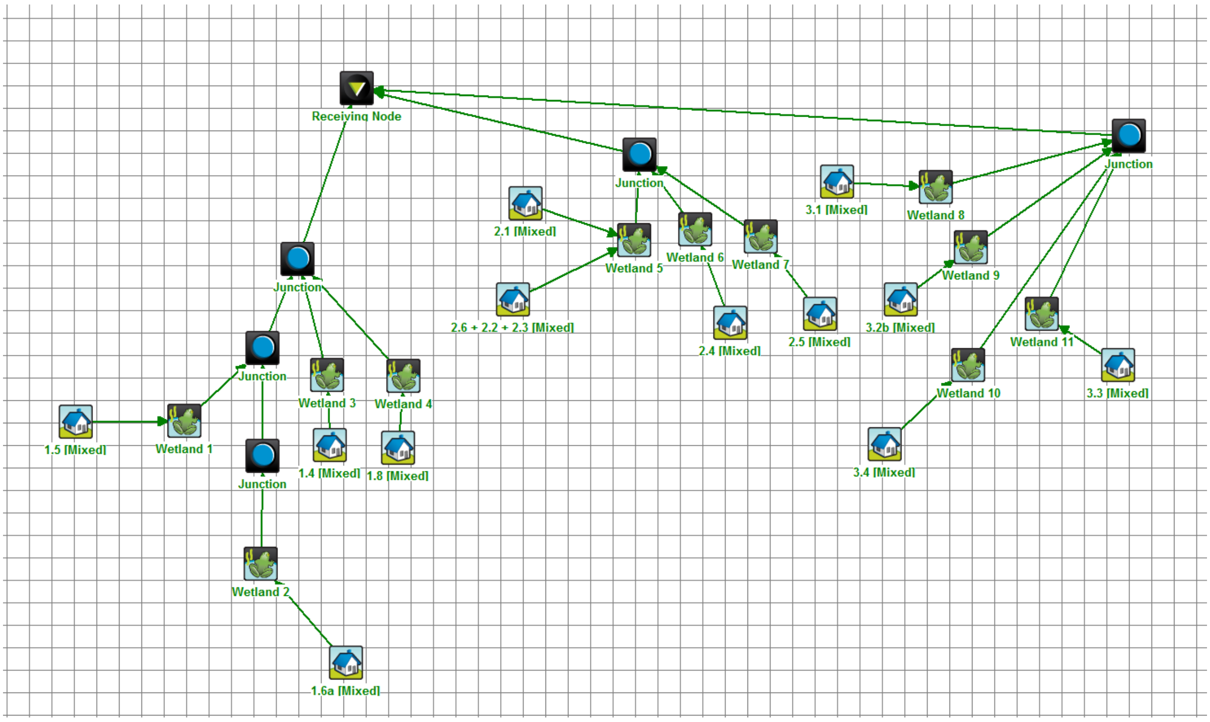

Figure 28 *Example MUSIC model for proposed Yarrawonga treatment assets*

All new proposed developments have had a wetland system designed to treat stormwater runoff. Existing residential and industrial developments within the framework area have not had a water quality asset proposed. The wetland areas proposed to address the framework area are tabled in Table 10.

Table 10. Wetland design parameters derived

Wetland number	Zones treated	Contributing catchment area (ha)	Wetland NWL surface area (m^2)
1	1.5	148.55	28,000
2	1.6a	30.37	7,200
3	1.4	44.74	12,000
4	1.8	158.59	30,000
5	2.1, 2.2, 2.3, 2.6	233.52	55,000
6	2.4	96.49	20,000
7	2.5	129.11	22,000
8	3.1	29.98	5,500
9	3.2b	40.64	8,000
10	3.3	16.51	3,400
11	3.4	93.96	18,000

Results

The results for the overall system can be seen in Table 11 below. Results for each catchment are detailed in Table 11, Table 12 and Table 13.

Table 11. MUSIC modelling results for Yarrawonga West catchment

	Initial load (kg/yr)	Residual load (kg/yr)	% Reduction	Load reduction (kg/yr)
Total Suspended Solids (kg/yr)	82052.5	24620	83.175	57432.5
Total Phosphorus (kg/yr)	273.9	78.49	73.025	195.41
Total Nitrogen (kg/yr)	1905	1291.8	53.9	613.2
Gross Pollutants (kg/yr)	29630	0	100	29630

Table 12. MUSIC modelling results for Botts Road catchment

	Initial load (kg/yr)	Residual load (kg/yr)	% Reduction	Load reduction (kg/yr)
Total Suspended Solids (kg/yr)	191000	38100	80	152900
Total Phosphorus (kg/yr)	390	119	69.4	271
Total Nitrogen (kg/yr)	2700	1370	49.2	1330
Gross Pollutants (kg/yr)	41800	0	100	41800

Table 13. MUSIC modelling results for Yarrawonga East catchment

	Initial load (kg/yr)	Residual load (kg/yr)	% Reduction	Load reduction (kg/yr)
Total Suspended Solids (kg/yr)	63900	12200	81	51700
Total Phosphorus (kg/yr)	130	37.6	71.1	92
Total Nitrogen (kg/yr)	907	432	52.4	475
Gross Pollutants (kg/yr)	14100	0	100	14100

Table 14. Overall MUSIC modelling results for Yarrawonga system

	Initial load (kg/yr)	Residual load (kg/yr)	% Reduction	Load reduction (kg/yr)
Total Suspended Solids (kg/yr)	336952	74920	81.4	262032
Total Phosphorus (kg/yr)	793	235	71.2	558
Total Nitrogen (kg/yr)	5512	3093	51.8	2418
Gross Pollutants (kg/yr)	85530	0	100	85530

Outputs form the MUSIC modelling were run through *MUSIC Auditor*, an analysis tool developed to highlight any modelling errors and discrepancies. All wetland nodes were resolved to be modelled appropriately.

Inundation frequency analysis
Melbourne Water wetland design guidelines recommend the water level in the wetland not to exceed half the average mature plant height for more than 20% of the time. This condition exists to achieve optimum plant health and function and can inform plant species selection in the shallow zone and deep marsh zones. The wetland guidelines also specify a residence time of three days (72 hours).

The “wetland analysis tool” enables data from MUSIC to be used to assess if a wetland meets these requirements. A review showed that the wetlands are exhibiting long residence times, and in some cases an effective NWL (where the design NWL is exceeded for 50% of the time) well above the design NWL. This is particularly the case in the more downstream wetlands in a given chain of wetlands, which are at risk of not getting drying periods due to constant flow from upstream wetlands.

There are options to manage residence times and ensure healthy plant establishment and growth within these systems including:

- Decrease the extended detention depth (EDD) to create more ‘flow-through’ in the system
- Raise the planting zone depths, as water will sit above the design NWL for long periods of time
- Increase weir length
- Adjust plant selection (i.e. select plants appropriate for both shallow and deep marsh zones).

These options should be considered in the functional design of the wetlands.

6.6 North East Water assets

The current North East Water WTP channels have been considered in the development of the options with the potential impacts outlined below:

- Impact on decommissioned WWTP site on Benalla-Yarrawonga Road – flows are proposed to be directed away from the decommissioned channels and chocked back prior to connection into the existing drainage system. No impact.
- Impact on waterway drainage channels passing through our Yarrawonga WTP site – The existing channels along Channel Road will not be impacted by future development, as all developed flows run north away from the channels. However, some of the channels running north off the channel along Channel Rd will be decommissioned as development progresses.

6.7 Smart system storage

Option 3 considers the use of smart storage system that can pump water to header tanks for reuse, monitor weather patterns and dump water prior to rainfall events ensuring enough storage capacity for nuisance flooding (up to the 63.2% AEP – 3 month ARI), or temporarily hold water back to allow the downstream local drainage system to pass flows prior to discharging. Table 15 shows the required storage to store the 20% AEP events for each retarding basin.

Table 15. Storage/harvesting opportunities based on the 63.2% AEP (3 month ARI)

RB Number	Contributing catchment	Critical outflow (m3/s)	Critical duration	Peak storage volume available for harvesting (m3)
1	1.4	0.15	12 hrs	5.15E+03 m^3
2	1.5	0.09	24 hrs	2.54E+04 m^3
3	1.6a	0.13	12 hrs	3.32E+03 m^3
4	1.8	0.15	24 hrs	3.00E+04 m^3
5	2.1	0.14	18 hrs	1.40E+04 m^3
6	2.2	0.11	18 hrs	1.16E+04 m^3
7	2.4	0.09	18 hrs	1.92E+04 m^3
8	2.5	0.18	24 hrs	2.49E+04 m^3
9	2.6	0.15	12 hrs	8.05E+03 m^3
10	3.2b	0.17	12 hrs	4.57E+04 m^3
11	3.4	0.18	12 hrs	1.34E+04 m^3
12	3.3	0.10	36 hrs	7.95E+03 m^3

6.8 Option layouts

Based on the above modelling the tasks the following plans illustrate how the options present across the subject area.

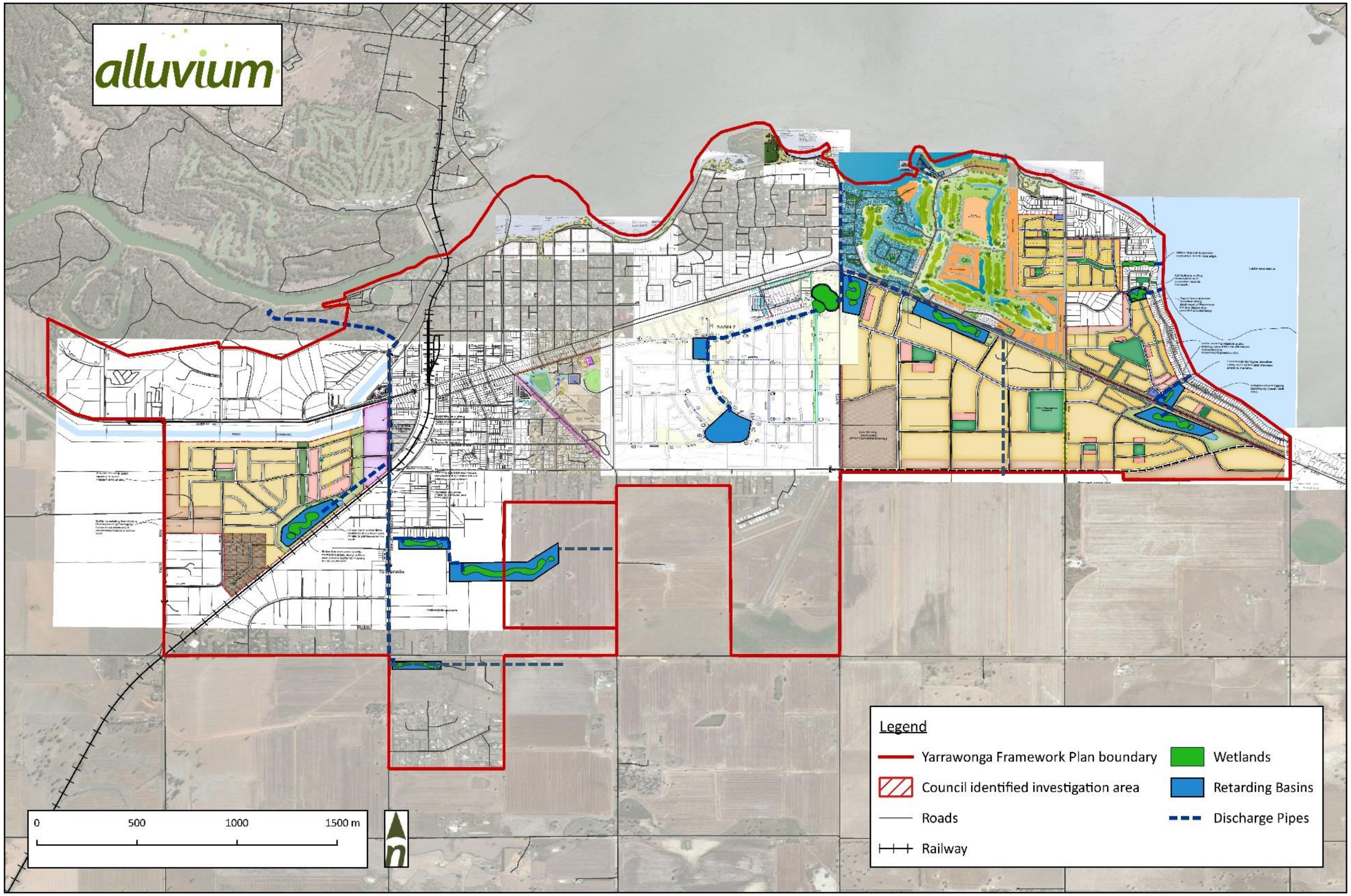

Figure 29. *Proposed drainage asset placement – Option one overlaid on the developer plans*

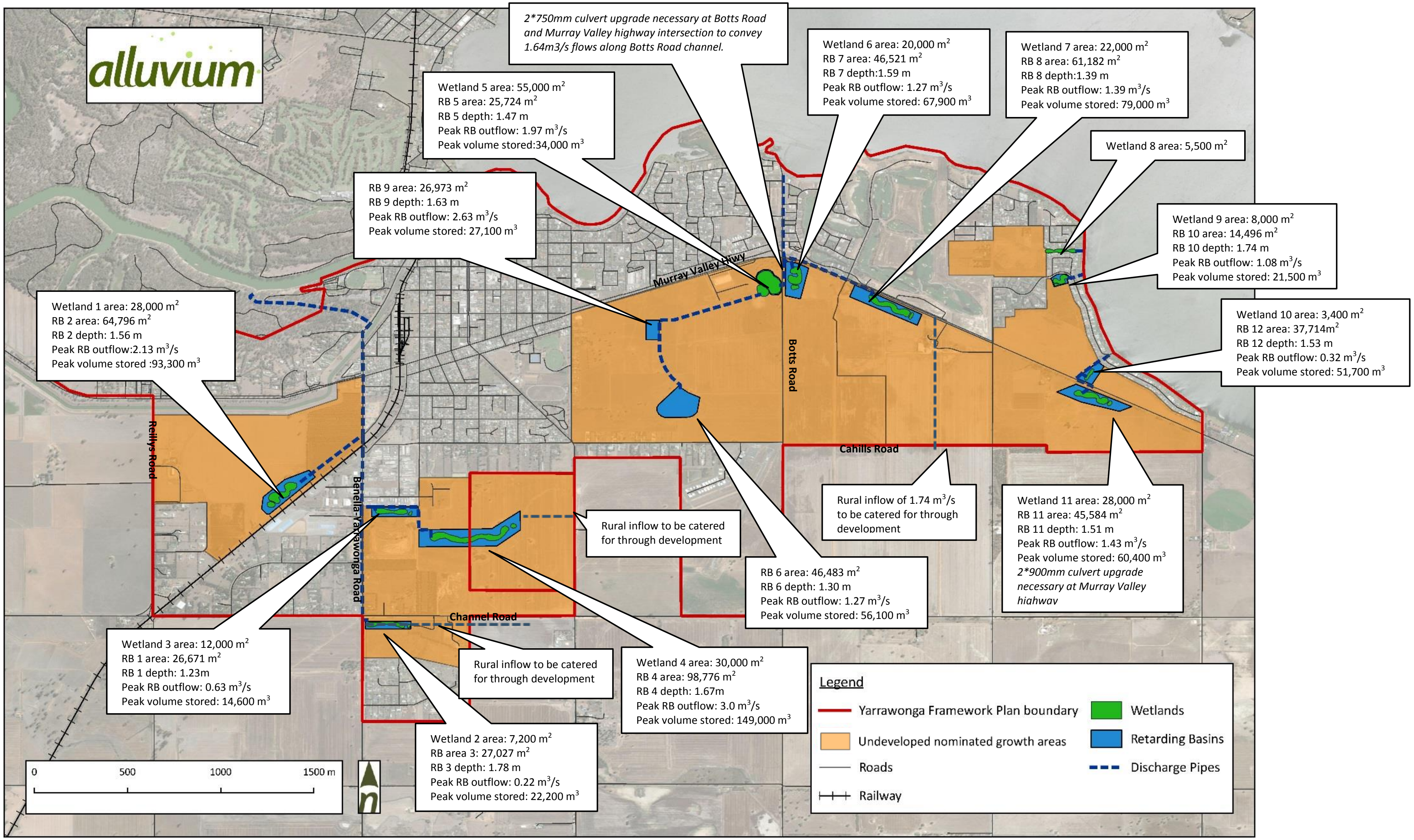

Figure 30. *Proposed drainage asset placement – Option one*

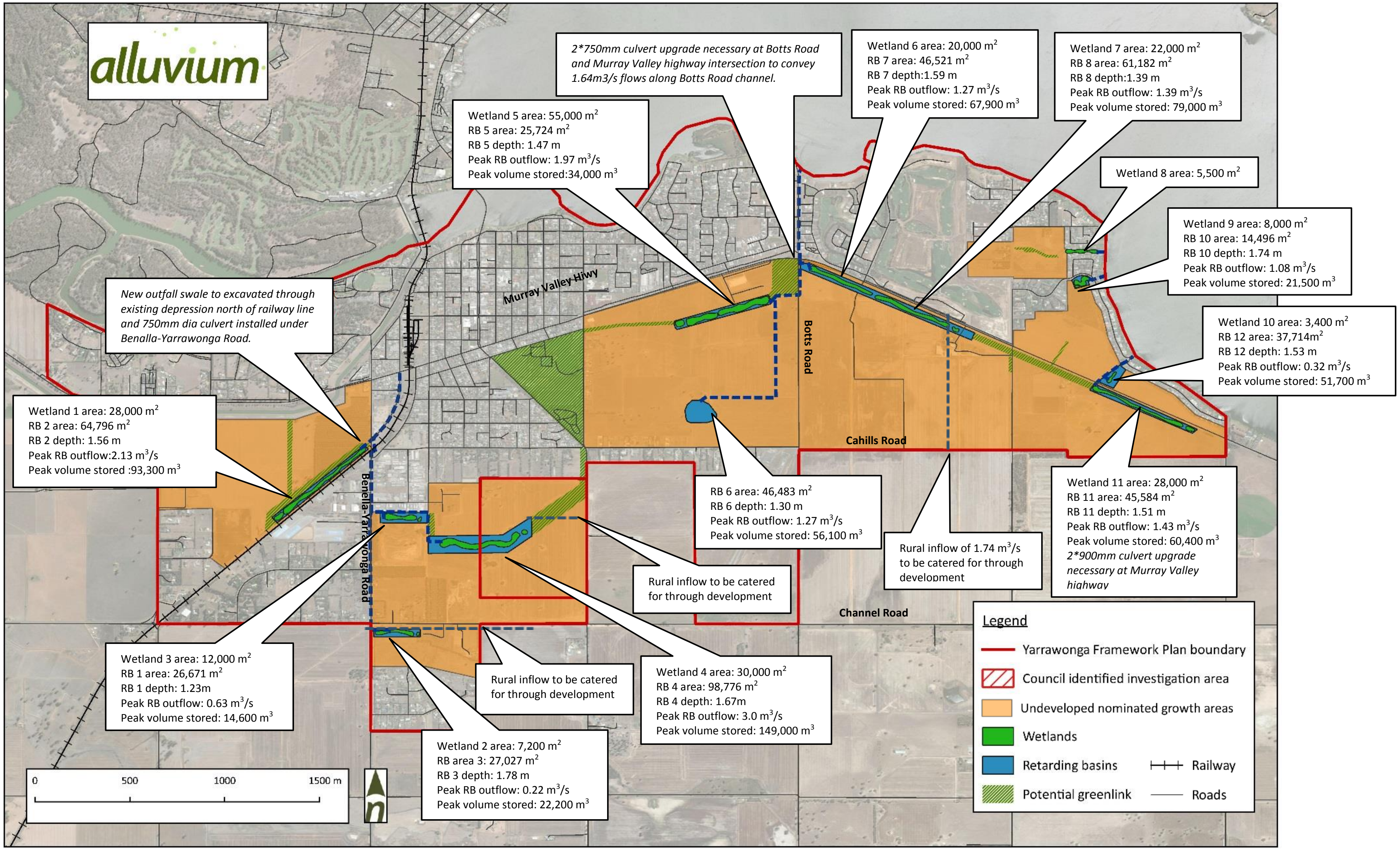

Figure 31. *Proposed drainage asset placement – Option two*

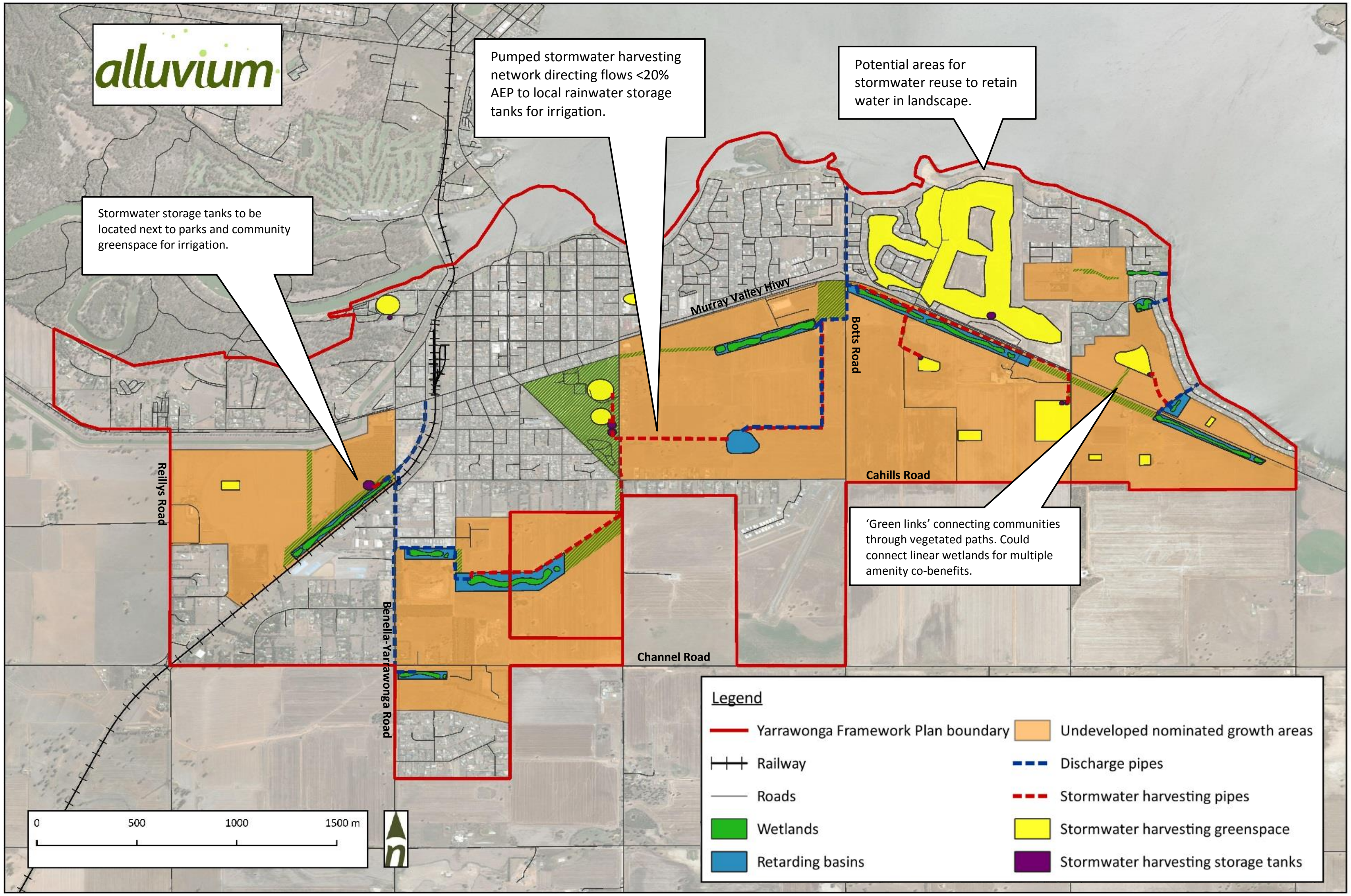

Figure 32 *Proposed drainage asset placement – Option three*

7 Estimate of probable costs

Table 16 provides a summary of the modelling outcomes for each option and asset, and high-level cost estimates using Melbourne Water's "*Water sensitive urban design life cycle costing data*" for both construction and maintenance costs. The cost estimates are based on the construction of the wetland/sediment basin only. Retarding basin costs associated with excavation and batters to natural surface, as well as land acquisition costs have not been considered. It is therefore likely that option 2 will have much larger overall costs due to a larger overall land take area.

Table 16. Estimate of costs based on Options 1 or 2

Option	Assets	Overall land take (ha)	Retarding Basin Volume	Retarding Basin Capital cost ($/m3)	Retarding Basin Estimated capital cost	Asset Wetland NWL area (m2)	Wetland Capital cost ($/m2)	Wetland Estimated capital cost	Total capital cost	Estimated maintenance cost per year	Design fee (3%)
	WL1/RB 2	9.3	64,000	$50	$ 3,200,000	25,200	$75	$1,890,000	$5,090,000	$46,500	
	Inlet pond WL1	-				2,800	$100	$280,000	$280,000		
	WL2/RB 3	2.7	14,600	$50	$ 730,000	6,480	$100	$648,000	$1,378,000	$13,300	
	Inlet pond WL3	-				720	$100	$72,000	$72,000		
	WL3/RB 1	2.2	22,900	$50	$ 1,145,000	10,800	$75	$810,000	$1,955,000	$11,000	
	Inlet pond WL3	-				1,200	$100	$120,000	$120,000		
	WL4/RB 4	9.9	149,000	$50	$ 7,450,000	27,000	$75	$2,025,000	$9,475,000	$49,350	
	Inlet pond WL4	-				3,000	$100	$300,000	$300,000		
	WL5/RB 5	2.6	34,000	$50	$ 1,700,000	26,550	$75	$1,991,250	$3,691,250	$12,850	
	Inlet pond WL5	-				2,950	$100	$295,000	$295,000		
	RB 6	4.6	56,100	$50	$ 2,805,000					$23,000	
		-									
	WL6/RB 7	4.6	67,900	$50	$ 3,395,000	14,400	$75	$1,080,000	$4,475,000	$23,000	
1	Inlet pond WL6	-				1,600	$100	$160,000	$160,000		
	WL7/RB 8	6.1	79,000	$50	$ 3,950,000	14,400	$75	$1,080,000	$5,030,000	$30,500	
	Inlet pond WL7	-				1,600	$100	$160,000	$160,000		
	WL8	1.0				4,950	$100	$495,000	$495,000	$20,000	
	Inlet pond WL8	-				550	$100	$55,000	$55,000		
	RB 9	2.7	27,100	$50	$ 1,355,000					$13,500	
		-									
	WL9/RB 10	1.4	21,500	$50	$ 1,075,000	7,200	$100	$720,000	$1,795,000	$7,000	
	Inlet pond WL9	-				800	$100	$80,000	$80,000		
	WL10/RB 12	3.8	51,700	$50	$ 2,585,000	2,700	$100	$270,000	$2,855,000	$19,000	
	Inlet pond WL10	-				300	$150	$45,000	$45,000		
	WL11/RB 11	4.6	60,400	$50	$ 3,020,000	25,200	$75	$1,890,000	$4,910,000	$23,000	
	Inlet pond WL11	-				2,800	$100	$280,000	$280,000		
	Total:	**41.9**			**$32,410,000**			**$14,746,250**	**$42,996,250**	**$292,000**	**$442,388**

8 IWM opportunities

VPA
The Victorian Planning Authority in its precinct structure plan guidelines define Integrated Water Management (IWM) as an approach that "*seeks opportunities beyond 'business as usual' to foster innovation and to provide better environmental, health, economic and liveability outcomes in all aspects of water management, supply and disposal*".

Water for Victoria
Chapter 5 of the Victorian Government's Water for Victoria (2016) also sets out water's role in supporting the development of 'Resilient and liveable cities and towns' (see Figure 33). These five outcomes are largely consistent with the approach expressed by the VPA.

Figure 33. *Water's role in resilient and liveable cities and towns (Source: Water for Victoria, 2018)*

While 'safe, secure and affordable' water supplies, and 'effective and affordable wastewater systems' are best managed by Barwon Water, the development's approach to stormwater management can contribute to:

- Effective stormwater management to protect downstream environments
- Creating healthy and valued urban landscapes, and
- Reflecting the values of the community in place-based planning.

DELWP IWM Forums
The IWM Framework for Victoria is designed to help local governments, water corporations, Catchment Management Authorities, Traditional Owners and other organisations work together to ensure the water cycle efficiently contributes to the urban liveability of the region, with communities at the centre of decision making.

The Murray River Connect plan is action GB1 of the Goulburn Broken IWM forum. The opportunities to be investigated as party of action GB1 includes Connecting Community, Connecting Environment, Connecting Aboriginal People and Connecting Education.

Goulburn Broken Strategic Directions Statement
The Murray River Connect plan is identified as one of the 13 priority projects in the Goulburn Broken area. The plan aims to will build on the successful River Connect project in Shepparton and surrounds to determine a similar model can be applied to the Moira and Campaspe sections of the Murray River. The output will be a scoped proposal for the Murray River Connect to seek ongoing funding.

The assets defined previously will meet flood detention requirements and best practice stormwater quality requirements set out in the Victorian Planning Provisions. They will also be central to identifying opportunities to implement IWM approaches, provide green space connections to achieve the outcomes described above.

8.1 Effective stormwater management

In addition to constructed wetlands, the harvesting, reuse and irrigation of stormwater acts to protect downstream environments.

Stormwater harvesting for open space

This opportunity is to use treated stormwater from the wetlands for the irrigation of open space within the precinct. Irrigating open space with captured storm water will reduce potable water demand, improve amenity and contribute to a cooler urban environment. A possible harvesting and distribution arrangement is shown in Option 3 of this report.

Decentralised rainwater harvesting and re-use: building scale

There is also an opportunity to harvest and reuse rainwater from building rooves. The good quality of that water means that treatment isn't required for rainwater to be used for internal uses like toilet flushing. This will reduce potable water use.

8.2 Healthy and valued urban landscapes

This outcome has been interpreted as using water generated within the site to support the delivery of green streetscapes and healthy vegetation.

Street scale biofiltration

Biofilters can have flexible dimensions making them ideal for integration into the urban landscape: from pockets of curb-side vegetation to larger features in parks and open spaces. The systems can be built to treat water "at source" and at surface before it enters the stormwater network or at a point downstream in the system to treat a larger part of the catchment. They also serve to green the streetscape and improve amenity.

Some example of street-scale biofilters are provided below. As well providing the benefits listed above, they will contribute to achieving BPEM stormwater pollution reduction targets, resulting in the potential to reduce the area of the downstream wetland. Further analysis on this point should be undertaken when there is greater certainty around the site layout.

Figure 34. *Street-scale biofilter examples*

Passive irrigation of street trees

Under Clause 56.07-4 of the Victorian Planning Provisions the requirements include "stormwater management that contributes to cooling, local habitat improvements and provision of attractive and enjoyable spaces".

While stormwater harvesting will enable open spaces to remain green while reducing potable water use, using stormwater to passively irrigate street trees and garden beds can also contribute significantly to streetscape greening, amenity and shading. Typically, street trees are irrigated for approximately two years after planting, at which time tree health and maintenance becomes the responsibility of Council. Passive irrigation can provide a mechanism to support tree health post-handover. This becomes all the more relevant in a potentially much drier future climate and reduces the need for emergency watering and mulching.

Local Governments across Melbourne have been investigating approaches to passive irrigation, with some committing to it in new developments, notably the City of Melton. The increase in shade through healthy trees is the single most important contribution to mitigating the urban heat island effect. VicRoads have also recognised the contribution of trees to amenity and liveability of neighbourhoods and streets through providing guidance on non-road infrastructure in their 'Management of infrastructure in road reserves' Code of Practice.

Passive irrigation works through having underground storage such as partially lined (to prevent road movement) gravel trenches capturing runoff from roads and footpaths. Trees can access the water through the roots, providing enhanced tree growth and shading. Passive irrigation can be combined with street-scale biofiltration systems. Careful species selection should be conducted so the plants are appropriate for the region. A schematic long section and cross section are shown in Figure 35 and Figure 36.

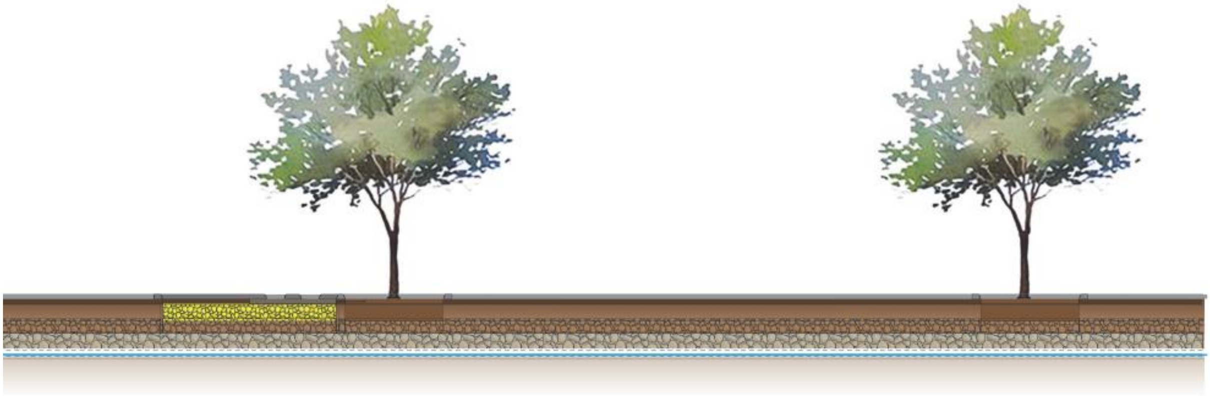

Figure 35. *Passive tree irrigation long section*

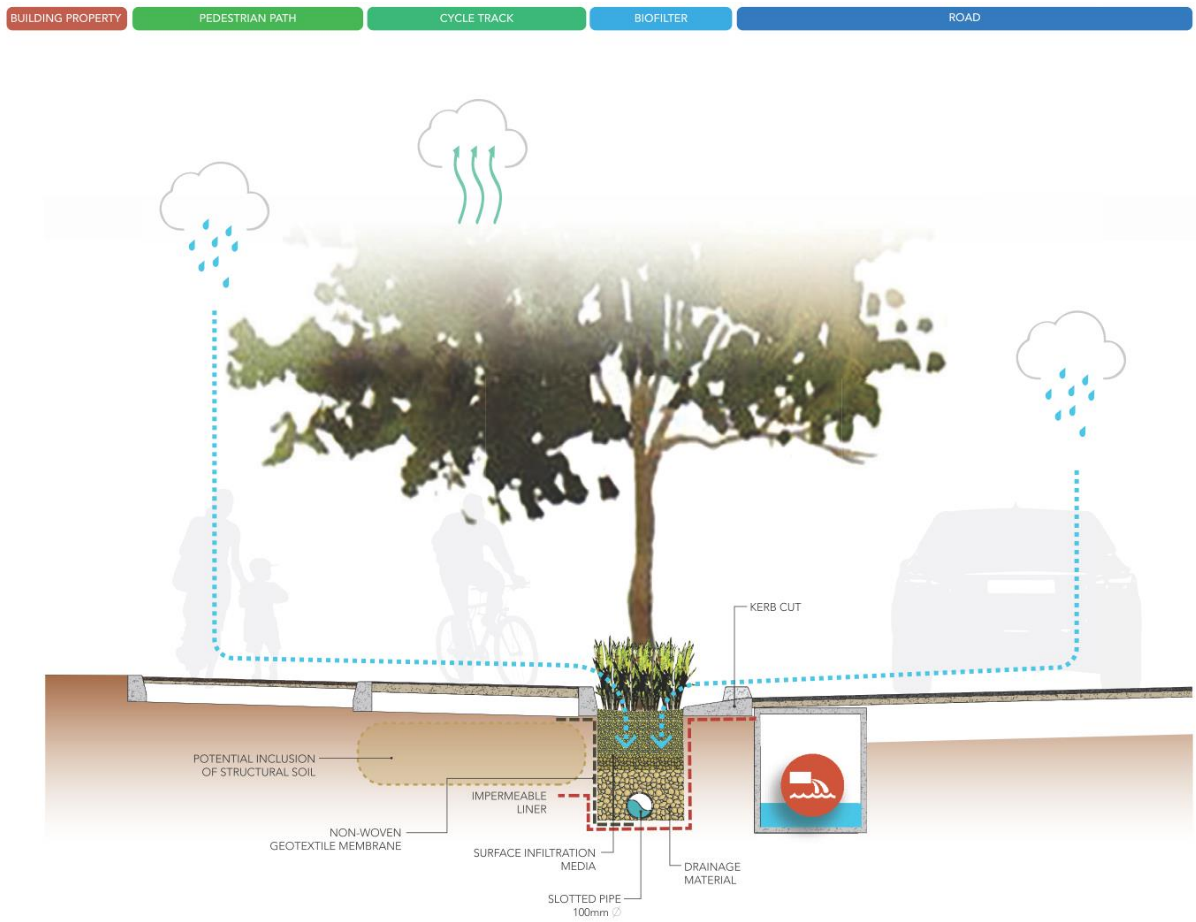

Figure 36. *Passive tree irrigation cross section*

A concern around passive tree irrigation usually centres around the potential for blockages due to litter and leaf litter. It is important to be clear that these, as per other water sensitive urban design assets, require maintenance to retain their performance and aesthetic appearance. It is important to note that maintenance at this point of the catchment avoids litter entering the Murray River.

8.3 Community values reflected in place-based planning

Each of the initiatives described above are aimed at reflecting the values of those who will reside and work within the precinct, by providing a resilient and liveable environment. The place-based elements will be reflected in greater detail as the master plan evolves, however the critical considerations for the successful implementation of IWM include:

- Streetscape and services design that incorporates an allowance for passive irrigation assets along busy boulevards and main streets
- Allowance for space adjacent to the wetland/retarding basins for stormwater storage (tanks) to enable the harvesting and reuse of stormwater for irrigation
- Further analysis on the potential space available for street-scale biofiltration, and therefore the impact on downstream treatment areas

9 Amenity and urban cooling opportunities

When designing a new development for urban cooling, several best practice principles based on building and street design and plant physiology can be taken into account to optimise the cooling outcomes.

Light coloured surfaces

One of the most effective ways to cool the urban microclimate is to increase the reflectivity of the artificial surfaces such as roofs, pavements and roads. Light or white coloured surfaces, either through the materials themselves, painting them white light or having highly reflective paint (e.g. on a dark roof) reflect the incoming sunlight away back into the atmosphere reducing the amount of heat absorbed by the buildings and roads and reducing the urban heat island effect.

Building height and street width

The height of a building affects the urban microclimate in two ways. First, a taller building can store more heat during the day to contribute to the urban heat island effect. However, the height of a building can also effect the street level microclimate through shading. When the building is tall enough it can shade the street creating cooler conditions for pedestrians. This effect reaches its maximum if the building height is 4 times higher than the width of the road (e.g. H=40m, W=10m) as increasing the building height to above this ratio has no additional cooling benefit to pedestrians (Yang et al. 2016). Achieving a building height width ratio greater than 4 is uncommon outside of a central business district indicating that additional measures such as street trees are usually required to provide shade to people at street level, particularly those with wide open streets.

Tree clustering

It is important to cluster trees together for urban cooling outcomes as this creates a dense canopy of shade for people to walk under, and this is one of the largest factors in determining how cool people fee (Thom et al. 2016). Tree clustering also has the dual benefit of reducing the radiative load on the trees as single tress in an urban environment experience increased water demand from high temperatures and high vapour pressure deficits. However, while the dense tree canopies of shade provide cooler conditions during the day, they reduce ventilation at night trapping longwave radiation and heat that is emitted by the urban surface. To counteract this effect clustering trees with gaps between the clusters is recommended to increase nocturnal cooling and ventilation (Thom et al. 2016).

Irrigation

Irrigating plants and trees creates a larger healthier canopy where the denser vegetation is able to block incident solar radiation from reaching the ground, creating a cooler urban microclimate. Irrigation is also able to increase the water available to the plant for evapotranspiration, increasing its environmental cooling abilities (Broadbent et al. 2018).

Street orientation

East-west oriented streets are exposed to more solar radiation during the day and should be prioritised over north-south streets when planting street trees (Thom et al. 2018). This is because the sun is overhead throughout the day on east-west streets. If only one side of the east-west streets must be chosen then prioritise planting on the southern side of the street. For trees planted on north-south oriented streets it is recommended to plant them on the eastern side of the street as it is exposed to the afternoon sun. As it is hotter during this time of day shading on this side of the street will provide more relief. The figure below highlights the ideal placement of trees to improve street level microclimate outcomes.

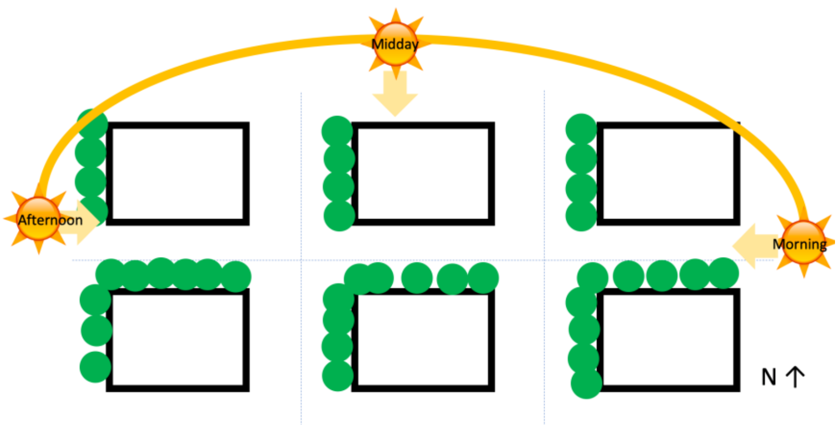

Figure 37. *Passive tree irrigation long section*

10 Conclusions

Guiding principles

Principles outlined in this report will provide a guide for developers and direction on the range of issues that need consideration when preparing a strategy. It is recommended that MSC provide the outlined principles as a checklist to developers to ensure any proposed strategy responds to the complex flood conditions in the area and proposes a strategy of drainage assets to manage future stormwater runoff to best practice standards and where possible consider the existing issues and improve system capacity.

The application of these principles will result in achievement of the framework goals including:

- Solving the first of many planning initiatives as recommended in the Growth Management Strategy and Council plan – drainage within Yarrawonga.
- "improve the flood resilience of the catchment's people, infrastructure, land, water and biodiversity through partnerships with community and stakeholders."

Strategy options

The drainage strategy options outlined within this report vary in their achievement of the guiding principles set. The merits of each option and their shortfalls are outlined below:

- Option 1 – provides a traditional drainage arrangement, wetlands and pumped storage systems, which generally demonstrates that the existing development plans can work. However, the strategies have been developed as standalone schemes, with a lack of focus on interfacing/linking between developments and road frontages. The existing development plans also have some shortfalls for water quality provision allowances.
- Option 2 – provides a modified take on Option 1 but addresses shortfalls in WQ provisions and provides an alternative alignment for linear wetland/retarding basins that helps build linear corridors along key interfaces.
- Option 3 - provides an alternative strategy arrangement based on option 2, that incorporates stormwater harvesting and smart system storage to reduce the outflow from each parcel and re-use stormwater onsite. Option 3 directly addresses the strategy principles around IWM opportunities with the added benefit of further reducing the impact on nuisance flooding.

While all of the three proposed options generally meet the drainage strategy principles, only Options 2 and 3 provide go beyond traditional drainage thinking and look to a more integrated solution. Options 2 and 3 have potential to combine additional assets like shared paths or reserves that run along the alignments and provide the ability to connect different sections of the Yarrawonga community, providing a valuable recreational asset. These options also provide the best alignment with other Councils strategies and plans namely the Wellbeing Strategy, Recreation Strategy and Moira Shire Council Cycling & Walking Strategy. It is also consistent with Clause 18 and 19 of the State Planning Policy Framework and the general principles of the Transport Integration Act.

Options 2 and 3 provide a much more coordinated drainage strategy for proposed development within Yarrawonga that better responds the complex flood conditions, flat topography and existing drainage issues facing the township. IWM is also incorporated into Option 3 to provide long-term water demand and availability for greening and cooling given competing demands for water to ensure non-potable supply sources are planned and secured to create a greener, cooler Yarrawonga – critically during periods of low rainfall.

Option 3 also articulates a shift in the way stormwater is considered and managed to contribute to a more sustainable, prosperous, liveable and healthy community. It provides multiple community outcomes that may be achieved by implementing integrated stormwater management solutions and outlines the an example method for managing stormwater to protect and improve the health of waterways, Lake Mulwala and the Murray River.

To achieve this, it is recommended that MSC adopt outlined principles and provide to developer's along with the drainage strategy options to respond to as part of any development application. This will help to ensure that future designs completed as part of development proposal should be considered in light with addressing the current drainage issues downstream. This includes looking at options to stabilise and enhance outfall channels such as the Botts Road channel, which is key management issues for MSC.

This will ensure that the planning shortfalls previous implemented are avoided and assets built that provide a strategic approach to stormwater management.

11 References

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Appendix A
RORB modelling

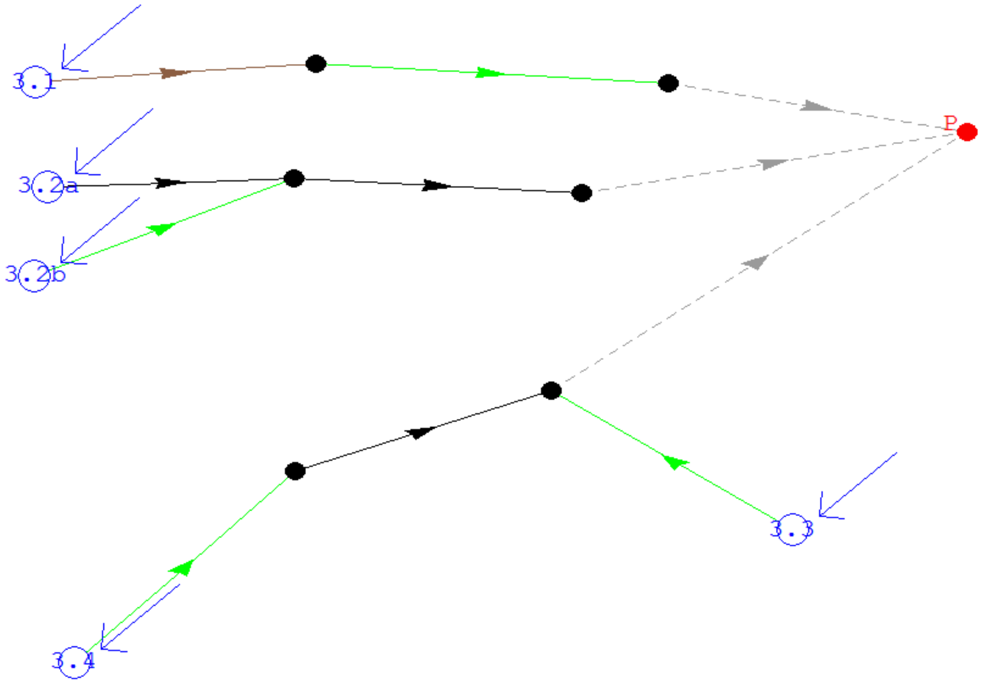

Figure 38 *Yarrawonga East existing conditions RORB model*

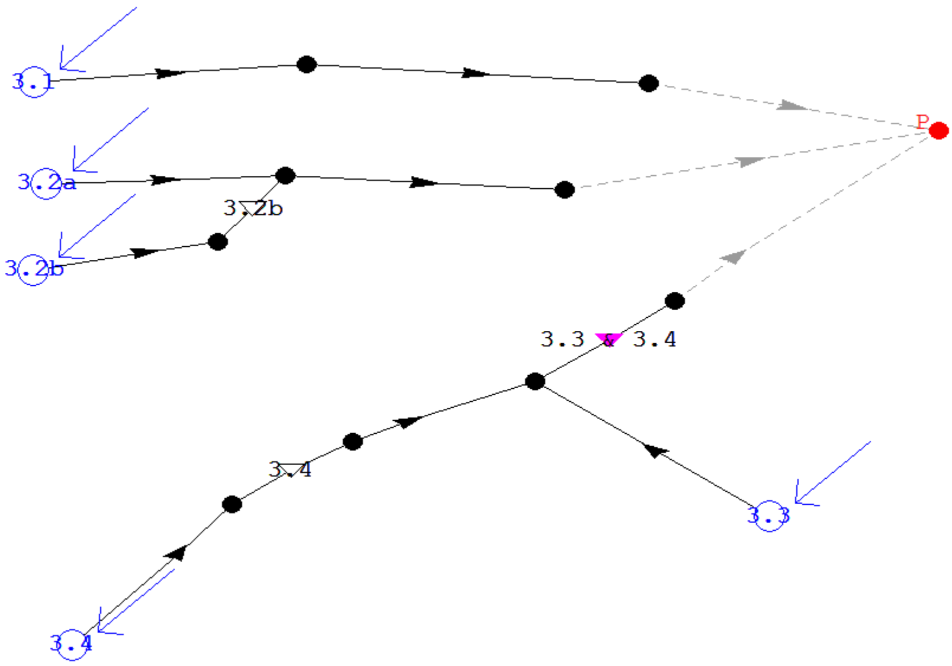

Figure 39. *Yarrawonga East developed conditions RORB model*

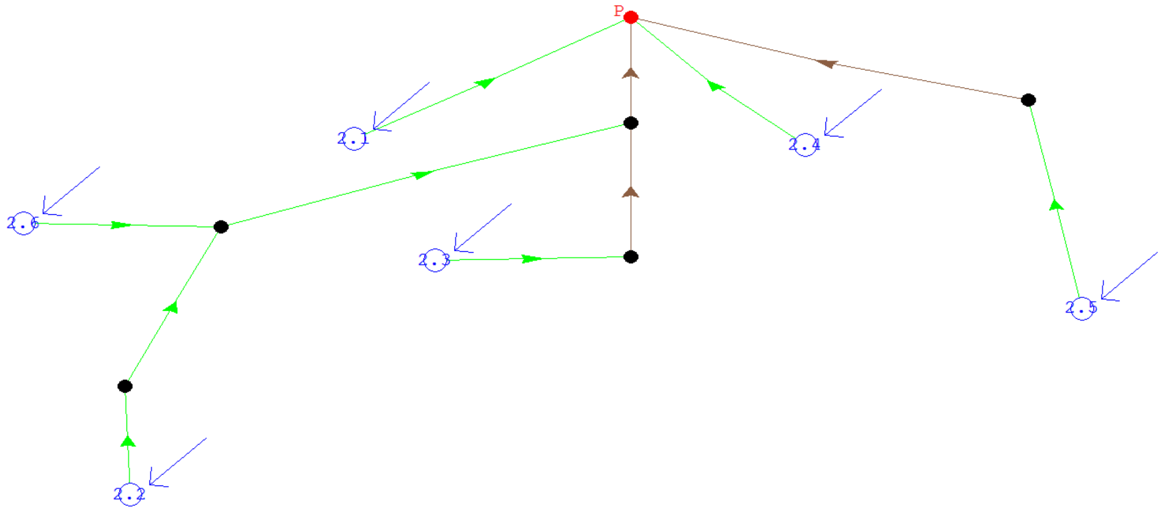

Figure 40 *Botts Road existing conditions RORB model*

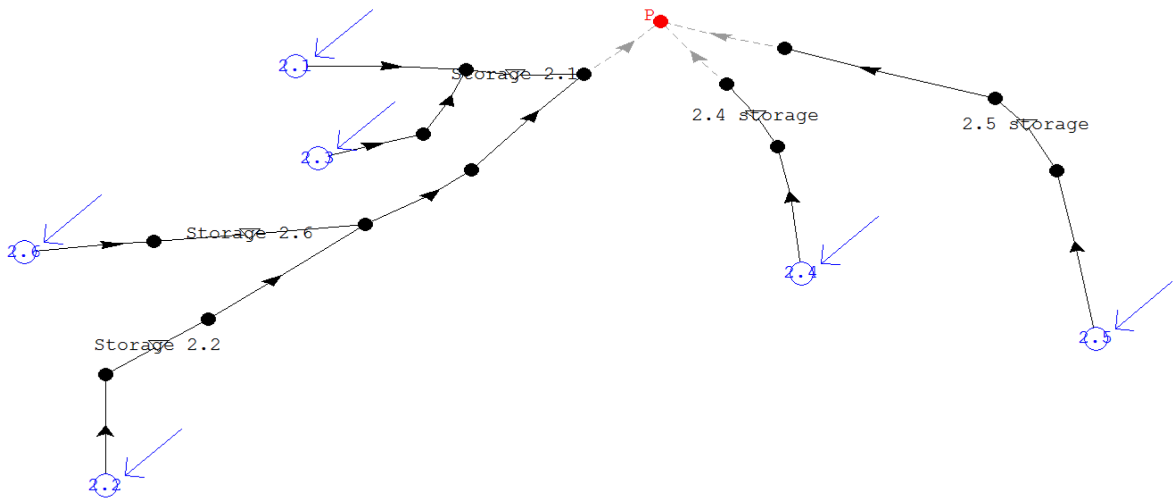

Figure 41. *Botts Road developed conditions RORB model*

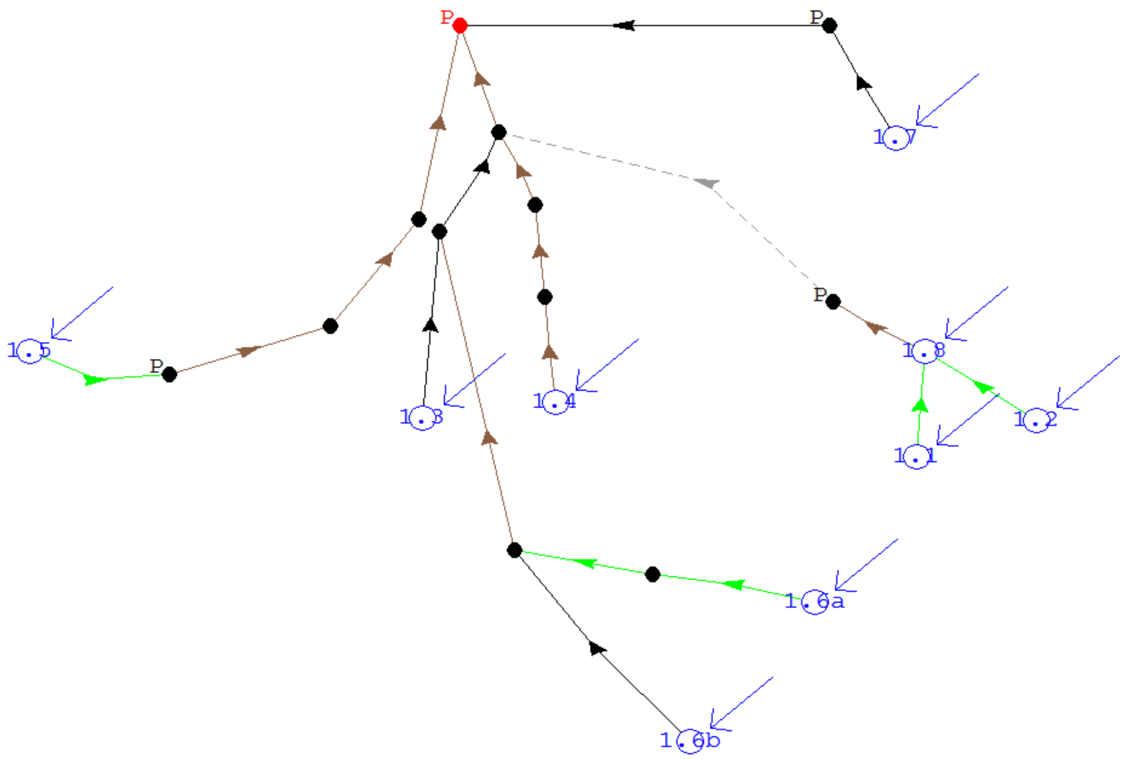

Figure 42 *Yarrawonga West existing conditions RORB model*

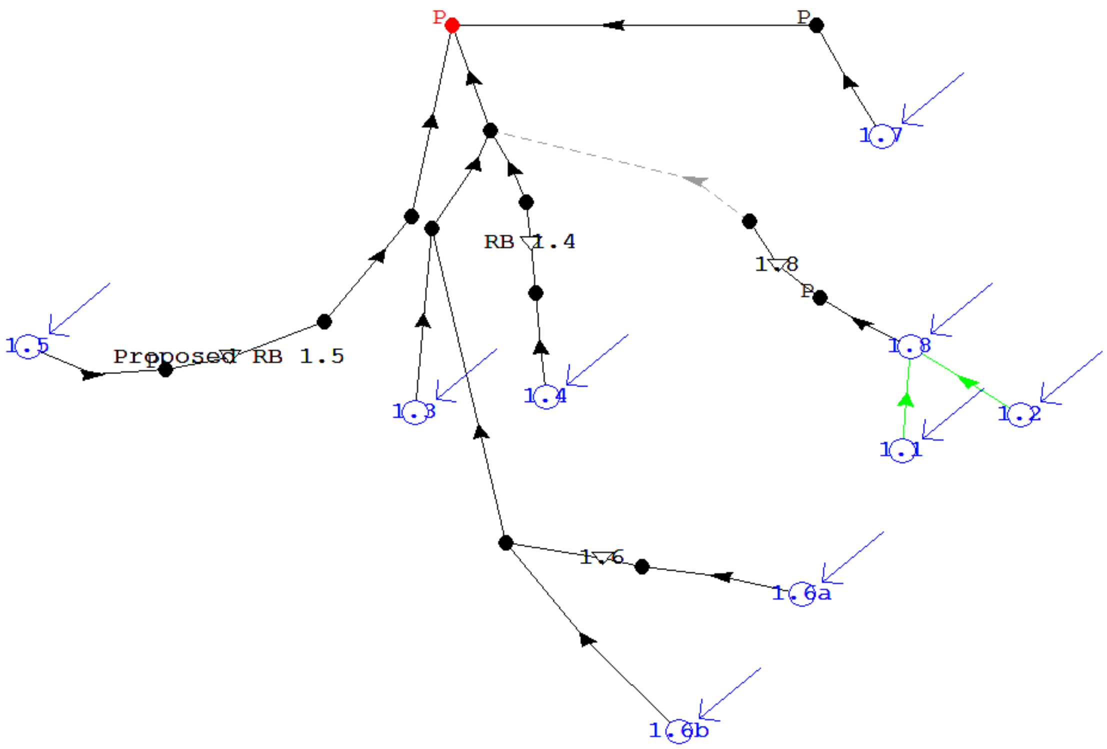

Figure 43 *Yarrawonga West developed conditions RORB model*

Appendix B
BMT WBM Yarrawonga Flood & Drainage Masterplan