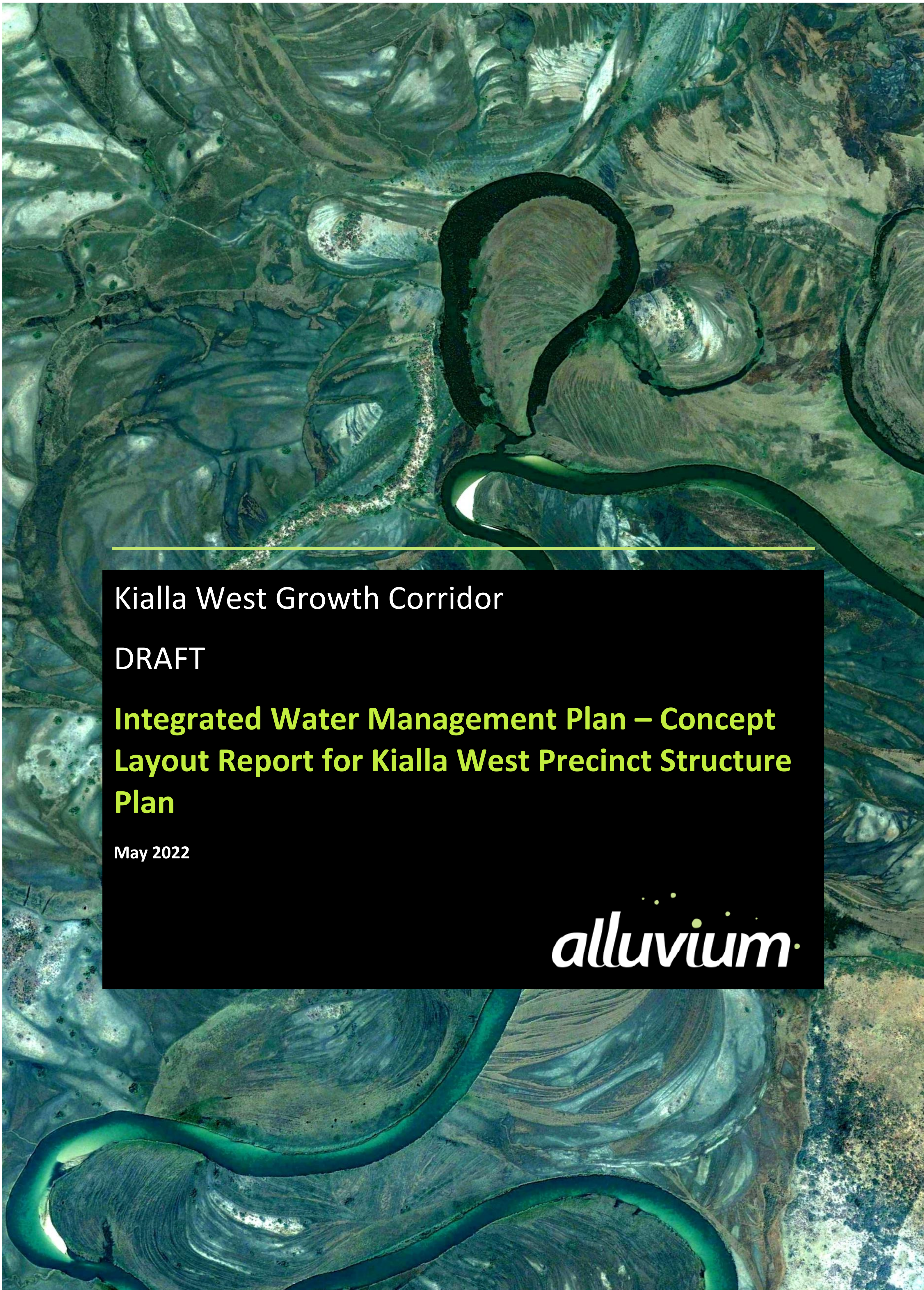

Kialla West Growth Corridor

DRAFT

Integrated Water Management Plan – Concept Layout Report for Kialla West Precinct Structure Plan

May 2022

alluvium

Document history

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Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for the Greater Shepparton City Council under the contract titled '2202 – KIALLA WEST GROWTH CORRIDOR INTEGRATED WATER MANAGEMENT PLAN' and Functional Designs and Costings.

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Abbreviations

Alluvium	Alluvium Consulting Australia Pty Ltd
DCP	Development Contributions Plan
DELWP	Department of Environment, Land, Water and Planning
GBCMA	Goulburn-Broken Catchment Management Authority
GMW	Goulburn-Murray Water
GSCC	Greater Shepparton City Council
IWM	Integrated Water Management
KWGC	Kialla West Growth Corridor
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
PSP	Precinct Structure Plan
PET	Potential Evapo-transpiration
SDS	Strategic Directions Statement
TO	Traditional Owners
VPA	Victorian Planning Authority
WSUD	Water Sensitive Urban Design

1 Introduction

Alluvium Consulting Australia Pty Ltd (Alluvium) has been engaged by Greater Shepparton City Council (GSCC) to develop the 'Integrated Water Management (IWM) Plan for the Kialla West Growth Corridor' (KWGC) formerly known as Investigation Area 2 (Raftery Road, Kialla).

Shepparton township to the north of Kialla, has been identified in the *Hume Regional Growth Plan 2014* as a regional city and major growth area for the region; and identified as one of ten regional cities in Victoria where significant growth will be supported under *Plan Melbourne 2017-2050.* Hence, the intrinsic future value of the Kialla West precinct in supporting these future regional growth aspirations, is critical to the overall picture.

The Kialla West precinct is one of six former residential Investigation Areas identified by the *Greater Shepparton Housing Strategy 2011* and Greater Shepparton Planning Scheme (Amendment C93). To the north-east of KWGC is the Kialla North Growth Corridor (KNGC) or former Investigation Area 3, just south of the Goulburn River (

Plan 6 Residential growth corridors

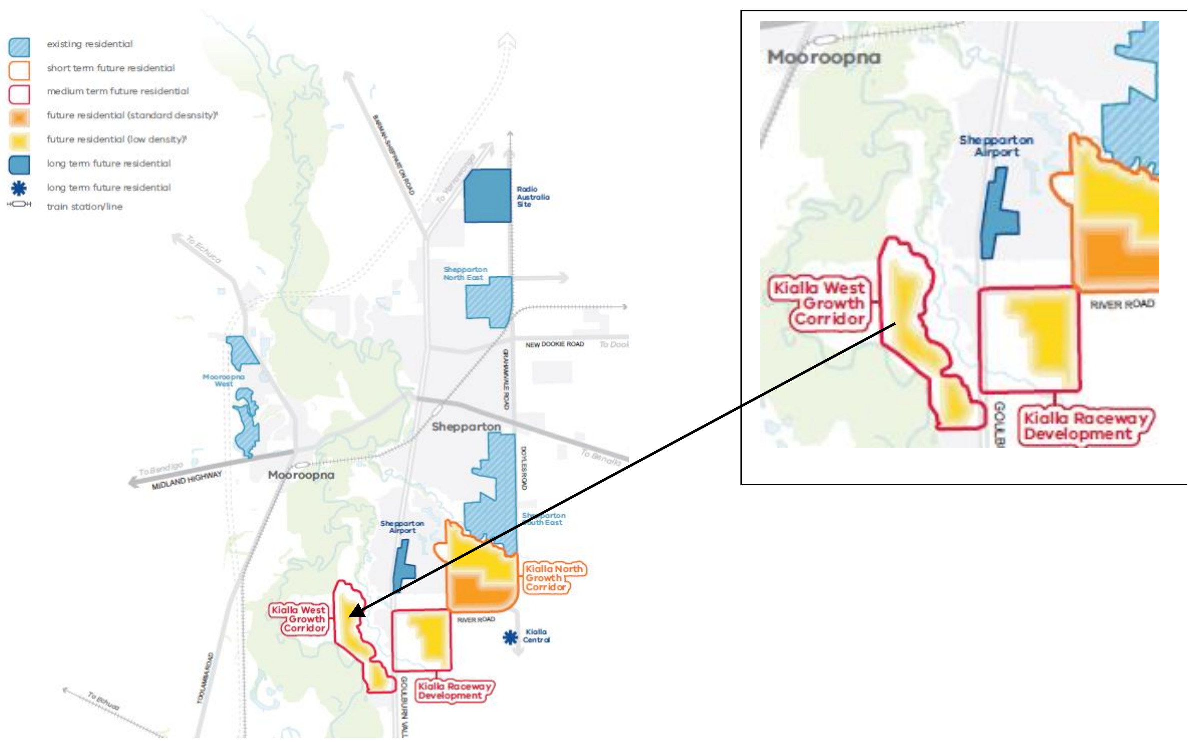


Figure 1). The development of an IWM Plan for the stormwater management of this PSP is currently being undertaken by Council (and Alluvium). Further north of KNGC is the Shepparton South East PSP (just north of the Goulburn River) which is also undergoing the development of an IWM Plan by the VPA (and Alluvium) for stormwater assets to service the PSP.

All three growth areas respond to the *Shepparton & Mooroopna 2050 Regional City Growth Plan* developed by Council and the Victorian Planning Authority (VPA) in 2020 to provide a vision for the area and guide their sustainable development through to 2050. The Growth Plan envisages that the KWGC could potentially accommodate 800 future residential dwellings and will be a combination of low and standard density residential development. The growth area is designated for medium-term growth within the next 5-10 years.

This is an opportunity to consider the broader overview of development in this region and how the three growth areas connect and transition in time.

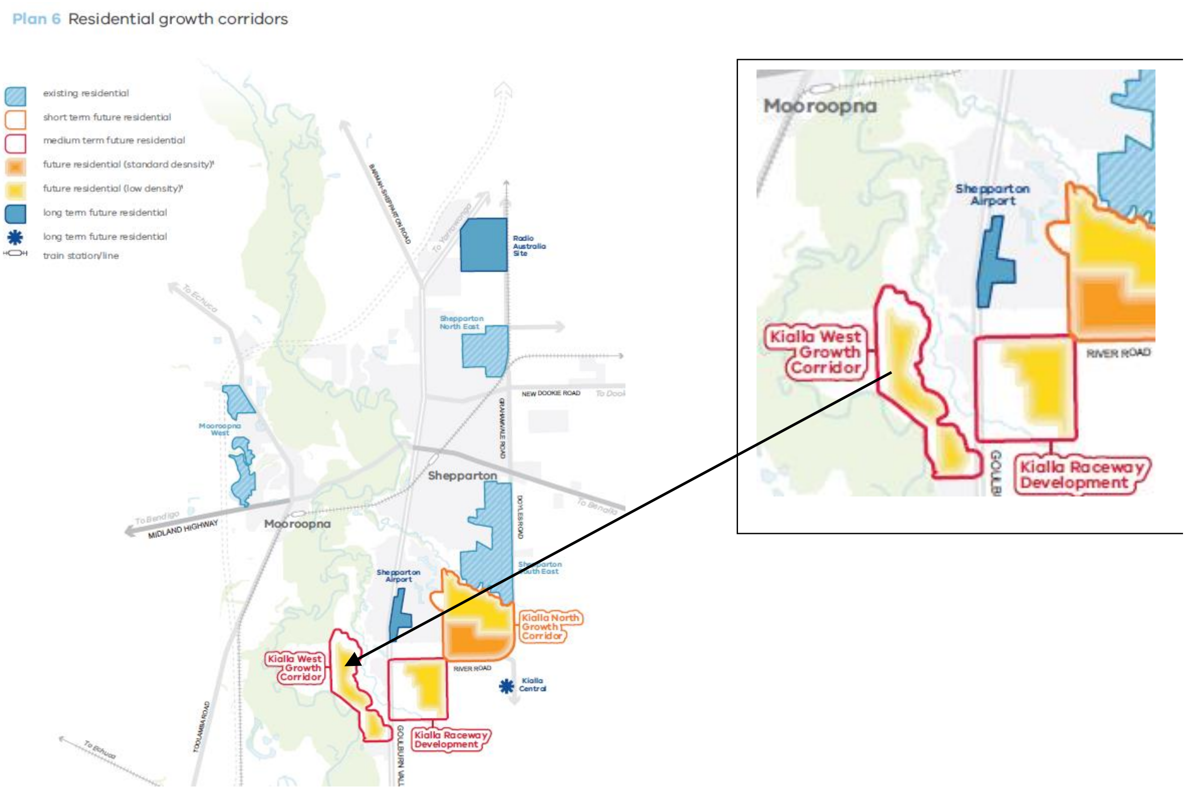


Figure 1. *Development growth locations around Shepparton, including the Kialla West Growth Corridor (VPA, 2020)*

The area is currently zoned Rural Living Zone with lot sizes restricted to a minimum of 8ha. Whether higher density development is suitable for the KWGC is the subject of this study, amongst other considerations relating to environmental and heritage values, flood risk, waterway protection, feasibility of service provision, site challenges and opportunities, and broader liveability outcomes.

Council has to date received several community and landowner requests to investigate the future development viability of this land and has undertaken several studies, including a model of flood behaviour that informs the future urban development (safe) density for the precinct. Further, Council is undertaking a traffic impact assessment and ecological assessment alongside the development of the KWGC IWMP (this study).

Alluvium has been engaged to:

- develop an Integrated Water Management Plan (IWMP) for the precinct as it relates to the management of urban surface water to sustainably accommodate future urban growth
- incorporate a considered assessment of IWM opportunities for the site
- undertake concept designs of stormwater management assets and
- undertake indicative cost estimates of all proposed stormwater infrastructure.

The overall package of work for this study will provide strategic direction (the IWMP) and feasible stormwater management design solutions (a functional design set) to inform the future PSP and guide future development growth for the area.

1.1 Project partners and background

Greater Shepparton Council (GSCC) is working in collaboration with the Goulburn Broken Catchment Management Authority (GBCMA) and Goulburn-Murray Water (GMW) to prepare the Kialla West Growth Corridor IWM Plan (this study) that will inform a future PSP and DCP that in turn will direct future, sustainable growth of the area while responding to site water management challenges, preservation and/or enhancement of intrinsic values, and working with the existing topographic constraints (a predominantly flat riverine landscape).

The IWMP will sustainably inform the future urban structure of the precinct, by integrating access, stormwater drainage services (including stormwater harvesting and reuse opportunities with respect to open space enhancements), biodiversity conservation and broader community liveability outcomes.

GSCC is the local drainage authority for all urban land in the region, while the GBCMA is the floodplain manager. GMW is the drainage authority for rural areas of the municipality within the GMW Drainage District. Together, they are key stakeholders (along with community/landowners) to this project.

There are numerous stakeholders to this study which include (but not limited to):

- The Victorian Planning Authority (VPA)
- Greater Shepparton City Council (GSCC)
- Goulburn Broken Catchment Management Authority (GBCMA)
- Goulburn-Murray Water (GMW)
- Department of Environment, Land, Water and Planning (DELWP)
- Traditional Owners (TO)
- Developers
- Community (includes residents, landowners, businesses, community/Friends/Landcare groups etc.).

1.2 State drivers and strategic influences on urban water planning

The Victorian IWM Framework (DELWP 2017) and Strategic Directions Statement (SDS) (DELWP 2018) are designed to help local governments and water sector partners meet water management objectives of the State water plan, *Water for Victoria* and ensure that our communities are resilient and liveable, now and into the future. The key premise of an IWM approach is the overall acceptance that managing urban liveability and resilience is a shared responsibility, and that water is a key enabler to achieving these shared outcomes.

> *Integrated water management is a collaborative approach to planning that brings together organisations that influence all elements of the water cycle, including waterways and bays, wastewater management, alternative and potable water supply, stormwater management and water treatment. It considers environment, social and economic benefits (IWM Framework 2017).*

The Victorian Framework supports the implementation of the State water plan at a local level by providing a consistent process and approach to collaborative IWM planning, with clear roles and responsibilities to deliver effective urban water management, including water supply, wastewater, flood resilience, urban waterway health and management of public spaces in Victorian cities and towns. It provides greater value to our communities by identifying and leveraging opportunities to optimise outcomes of water cycle planning and management.

Communities are central to the management of the water cycle. They are provided with water, protected from floods, interact with healthy waterways and benefit from cooler, greener cities and healthier environments. Community participation and contribution (locally and at the lot scale) can make a significant contribution to achieving these values and outcomes. These strategic outcomes and broader community benefits are outlined in the Goulbourn-Broken IWM Forum SDS (Figure 2).

This is further discussed in Section 1.3 (Stormwater conveyance), Section 5.4 (Optimising IWM application) and Section 10 (Water Harvesting Opportunities Assessment).

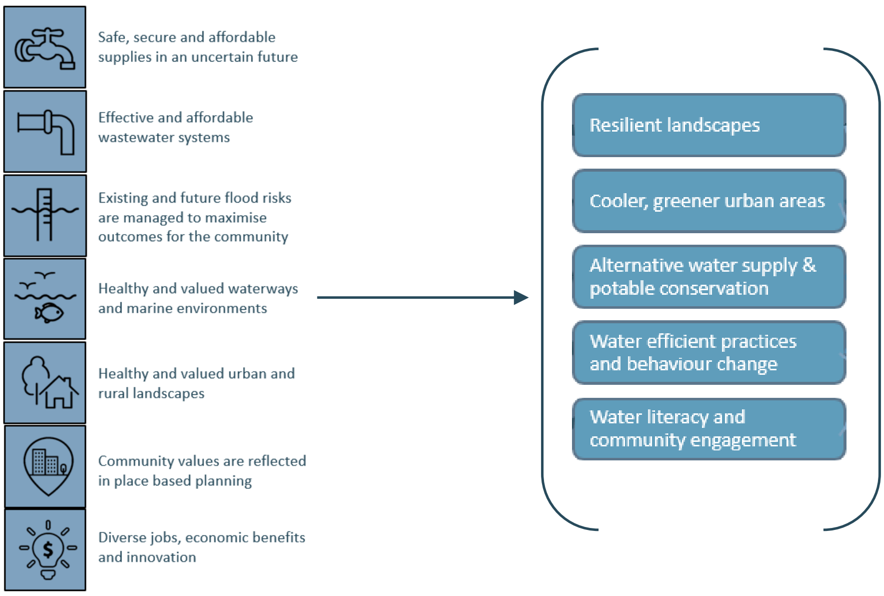


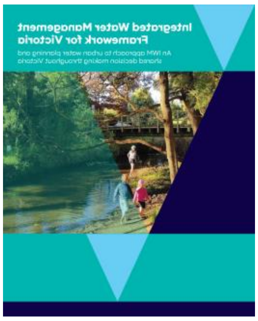
Figure 2. *Goulburn Broken IWM Forum Strategic Directions Statement (SDS) community outcomes (DELWP, 2018).*

Communities can also inform water cycle management by influencing the setting of service levels and place-based outcomes; determining willingness to pay, through their service providers and other stakeholders; and providing feedback on proposed solutions.

The Victorian Planning Authority in its Precinct Structure Plan Guidelines defines 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*.

A clear and shared vision is critical in setting the focus and achieving intended outcomes. Strategically, the foundations of a 'clear and shared vision' have been established for the KWGC and provides strategic influence to this study.

The following summarises key strategic documents that are directly relevant to, have influenced, and/or align with key outcomes of this study and vision for the KWGC PSP.

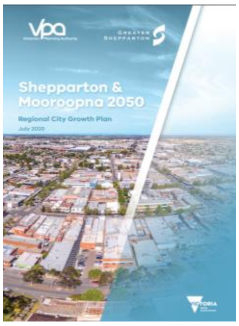


Integrated Water Management Framework 2017

The Victorian IWM Framework will help local governments and water sector partners to meet water management objectives of the state water plan, *Water for Victoria*, to ensure that our communities are resilient and liveable, now and in the future.

The Framework has been prepared with input from water corporations, local government and catchment management authorities, and will help support these sectors to implement *Water for Victoria* at a local level and include local communities in planning for current and future challenges and contribute to liveability and economy.

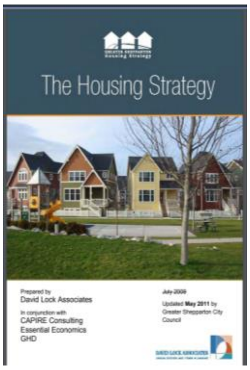
The Framework provides a consistent process and approach to collaborative IWM planning with clear roles and responsibilities to deliver effective urban water management, including water supply, wastewater, flood resilience, urban waterway health and management of public spaces.



Shepparton & Mooroopna 2050 Regional City Growth Plan (2020)

Council and the VPA developed the Shepparton & Mooroopna 2050 Regional City Growth Plan to provide a vision and guide the sustainable development of these areas to the year 2050.

The Growth Plan envisages that the KWGC potentially could accommodate 2,150 future residential dwellings and will be a combination of low and standard density residential development.



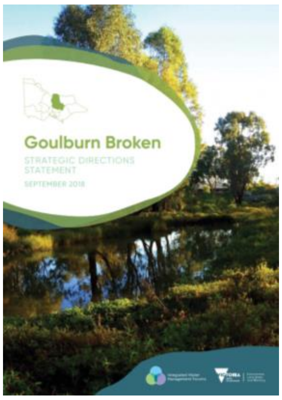
Greater Shepparton Housing Strategy (2011)

The GSHS was prepared to guide the long-term identification and provision of residential land within the City of Greater Shepparton. The strategy was embedded in the Greater Shepparton Planning Scheme in 2012 via Amendment C93.

Amendment C93 includes framework plans and identified residential Investigation Areas in the Planning Scheme to guide future sustainable development, subject to further investigations.

Formerly known as Investigation Area 3 in the Planning Scheme, the KWGC was the subject of a further Amendment (C195) in 2017 where approx. 474Ha was rezoned Urban Growth Zone-Part A to accommodate for future residential growth.

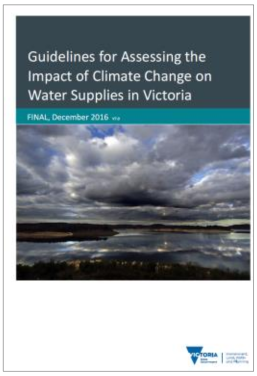
IWM Forum – Strategic Directions Statement (SDS, 2018)



The SDS has a region-specific vision, outcomes, objectives, and priority actions. Collaboration between Traditional Owners, Councils, Water Corps, CMAs, and DEWLP, with representatives from a cross section of these institutions has led to shared ideas, buy-in, and momentum.

Opportunities identified through this project will demonstrably align with the following outcomes and their associated objectives:

1. Safe secure and affordable supplies
2. Effective and affordable wastewater systems
3. Reduced flood risks
4. Healthy and valued waterways
5. Healthy and valued urban landscapes
6. Community values are reflected in place-based planning.
7. Jobs, economic benefits and innovation



Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria (DEWLP, 2016)

This document provides a guideline for planning for climate variability and climate change, translating Global Climate Models into projections for Victorian river basins. The document can inform the Kialla North Growth Corridor IWM Plan through assessment of future system reliability, urban water strategy planning and drought preparedness. The combined decrease in rainfall and increase in temperatures will result in a larger impact on runoff of 15.6%. Aquifer recharge will also be impacted.

This modelling and DELWP's recommendations will guide our understanding of issues, particularly for systems that are at risk with a reduction to rainfall and runoff, and our considerations of the effectiveness of climate dependent alternative water sources (such as rainwater and stormwater harvesting).

1.3 The social values of stormwater and liveability

The efficient management of water in the urban landscape is not just about capturing and draining it away, but more about retaining water within the landscape it falls and blending its benefits to the urban form, fundamentally achieving the key outcomes of IWM.

Building resilience across our cities to the impacts of climate change such as increasing overall temperatures, hotter summers, more frequent and intense storm events, and extreme heat waves, can be achieved through the integration of blue-green infrastructure into the urban landscape. Commonly referred to as water sensitive urban design (WSUD) these blue-green infrastructure approaches can work effectively to keep water safely within the landscape it falls and providing cooling systems to effectively improve heat thresholds through micro-climate benefits at the local scale. The principles, approaches and technologies should form part of a future PSP for KWGC.

The societal value of open spaces in urban development is also increasing as these provide refuge for community and wildlife; while urban waterways provide welcoming spaces to encourage recreation, safe interaction and community engagement and gatherings – connecting people (safely) to places where water meets.

The condition and value of natural assets (vegetation and waterways) and how we balance water within the precinct to support water dependent ecosystems, while accommodating urban growth and human connections, requires a whole of water cycle perspective – an integrated water management approach. The KWGC IWM Plan and proposed PSP should consistently respond to this design intent.

2 Kialla West Integrated Water Management (IWM) Plan

The IWM Plan (this study) for the KWGC has been driven by the *Shepparton & Mooroopna 2050 Regional City Growth Plan* (GSCC and VPA, 2020). It is recognised that water has been a key influence on the development of this region, through both pioneering irrigation practices that have enabled the town's growth and the significant flooding that has affected the area in 1916, 1974 and 1993; and more recently, key events in 2011 and 2013. It is understood that the sustainable management and use of surface waters (runoff) in the landscape, and the appropriate guidance for urban development adjacent to riverine floodplains, are vital to the continued sustainable growth and water resilience of the region.

The development of an IWM Plan for the KWGC forms part of Key Deliverable 4 (KD4) of this study.

Water infrastructure assets identified for the KWGC will meet flood detention requirements and best practice stormwater quality treatment as set out in the above strategic documents and Victorian Planning Provisions. They assets will be central to identifying opportunities to implement IWM approaches that provide green space connections in a sustainable urban layout to achieve outcomes that:

- Avoid or minimise existing and future flood risks
- Ensure healthy and valued waterways, wetlands and lakes
- Deliver healthy and valued urban and rural landscapes
- Reflect community values and expectations in place-based planning, and
- Encourage jobs, economy and innovation.

The long-term liveability of the precinct needs to support accessibility to the natural environment, movement, and connectivity through and between precincts, while delivering resilience to climate change and urban heat stress. All these elements can be enabled through a well-structured IWMP with supporting functional design solutions.

The IWMP for the Precinct will consider the following aspects:

- a combination of multi-functional stormwater assets that may include constructed waterways, surface overland flow paths, surface storages, drainage pipes, WSUD treatment systems etc to achieve current best practice requirements for the PSP
- identification at a high level of drainage implementation issues/challenges, including land take requirements, responsibilities, and potential costs
- wherever practical, minimise land take while meeting drainage requirements of the site and the surrounding drainage investigation area
- determine cost-effective solutions and locations that will facilitate future development staging of the PSP
- deliver multi-outcome solutions that seek to achieve broader community (existing and future) benefits.

3 Concept Layout Report

This **Concept Layout Report** responds to **Key Deliverable 3 (KD3)** – *a Descriptive report of findings overview and guiding principles to inform the PSP, and a high-level IWM Concept Layout Plan of water management infrastructure proposed for the PSP*.

The report summarises the background review undertaken to date, including a review of provided data and analysis of current conditions, and the findings of the site assessment (which formed KD2).

The report considers existing conditions and issues as they pertain to the management of urban surface waters in the project area and immediate surrounding catchment(s). The proposed concepts have considered the existing flood extents, overland flow paths, surface storages, blue-green corridors and widths, potential environmental and heritage values, land capability assessment of best suited areas for residential development, site-appropriate stormwater alignments, and the likely areas of open space relative to proposed water assets.

The layout considers the challenges and constraints of the site and seeks to ensure asset locations do not compromise future implementation (development staging) of the KWGC IWMP. This report also covers the analysis undertaken to develop stormwater management treatment assets (for downstream waterway protection) and integrated retarding systems (for flood protection), as well as future options for further water integration - for broader liveability benefits and IWM outcomes (e.g. through stormwater harvesting and urban greening opportunities).

Stakeholder feedback on this draft report and proposed Concept Layout Plan will inform the design stages of this study.

3.1 Project landscape

Kialla is a predominantly a rural area located 188km north of Melbourne (9km south of Shepparton township) in the City of Greater Shepparton. It includes areas known as Kialla Central, Kialla West, Kialla Green, and Kialla Lakes with a collective population of 6,800 residents (Census 2016). Kialla West Growth Corridor (KWGC) is currently zoned Rural Living Zone with lot sizes restricted to a minimum of 8ha potentially providing up to 800 dwellings.

KWGC is approximately 388 hectares and is physically bounded by the Goulburn Valley Highway and Seven Creeks to the east; Mitchell Road and the Goulburn River to the south/south-west; the Arcadia Downs residential subdivision to the west; and Raftery Road which forms the precinct's western and northern boundary.

A flood constrained "pinch point" exists between Seven Creeks and the Goulburn River just south of Raftery Road. Officially, the precinct extends a little further south (600m) to Bennetts Road, as per the *Shepparton & Mooroopna 2050 Regional City Growth Plan* (refer Figure 3).

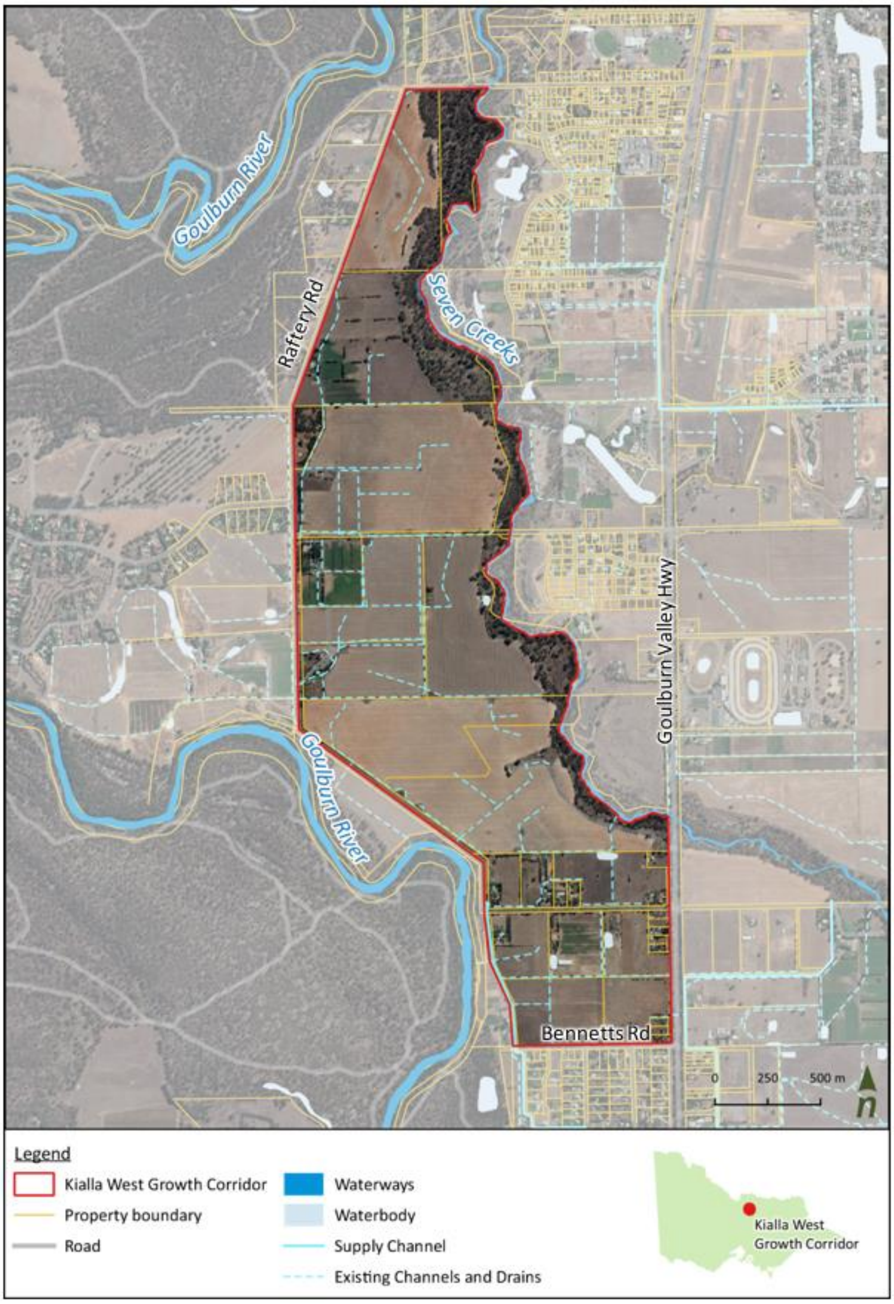


Figure 3. *Kialla West Growth Corridor (project study area)*

3.2 Waterways, irrigation channels and topographic features

The condition and value of natural assets such as existing vegetation communities, fauna, waterways, and habitats and how we balance water within the precinct to support water dependent ecosystems, while accommodating sustainable urban growth and human connections, requires a whole of water cycle perspective to build city resilience.

While several guidelines exist to guide the design of IWM systems and approaches to stormwater drainage through WSUD infrastructure in urban environments, this location faces some unique challenges that require tailored solutions due to its relatively flat riverine topography and proximity to both Seven Creeks and the Goulburn River.

Further, any design recommendations to optimally manage surface waters in the precinct needs to account for the interface between upstream and downstream catchments to ensure they continue to support urban living, environmental values, and agricultural economies. Considerations may include how existing irrigation channels, waterways, dams, and river systems integrate to provide irrigation water to service the region and its community. Identifying the potential for alternate water supplies to meet irrigation demands (e.g. recycled water and /or stormwater harvesting) is part of IWM planning.

The reality is urbanisation will increase stormwater runoff volumes. The challenge is, harnessing that excess and converting it from nuisance to resource value through innovative strategic and structural solutions to guide sustainable development growth.

The key challenges identified for the precinct:

- subject site is located immediately south of the confluence of the Goulburn River and Seven Creeks with a defined flood constrained pinch point
- combination of river confluence, pinch point, and relatively flat riverine topography means site is highly prone to flooding
- numerous agricultural open channels (drains) traverse the study area
- ensuring subdivisional drainage is possible and free draining to proposed water assets, existing drains with enhancements (e.g. G-MW assets where appropriate, potential asset handover), and downstream systems (including waterways)
- ensuring future servicing of these assets is manageable (as required)
- within waterway floodplains with poor landscape grade, (consideration of pumping systems (as appropriate)
- locating and staging of assets over a large area to allow for future development implementation
- site access and service provision, including bushfire management (key considerations) and
- working with and protecting Seven Creeks (the primary watercourse) which will receive flows from the PSP (designated waterway for BPEM protection).

4 Existing Conditions

The proposed concept layout responds to the existing challenges of heavy rainfall, floodplain restrictions, stormwater drainage capacity, and discharge quantity and quality to local waterways. Understanding the site's current conditions and intended future development intent, provides a line of sight to its design potential. This section defines the current land use and surface water management conditions and identifies the issues and constraints that may impact on the optimal stormwater drainage approach for the precinct.

4.1 Background data analysis

A review of all background information and datasets provided by Council, Goulburn-Murray Water, Goulburn-Broken CMA, and other sourced information, has been undertaken to best understand site opportunities and challenges. Previous modelling studies have been reviewed to identify key drainage flow paths, flood levels, velocities and depths. Existing LiDAR, flood behaviour reports and models have been analysed to determine capacity of the drainage system, drainage flow paths in the catchment, and how the landscape currently responds to various storm intensities.

4.2 Current land use

The site is currently a mix of low density, rural residential housing, paddocks, and agricultural uses. The parcels vary between 0.34ha and 55ha in size. There are a number of stormwater drainage and irrigation supply channels dividing land parcels throughout the subject area.

4.3 Topography

A map of the KWGC topography is provided in Figure 4 below. The PSP's existing topography may be summarised as follows:

- The site is generally flat, with grades ranging between 0.05% and 2%.
- Across most of the subject site there is a fall of only 2m from 115m AHD and 113m AHD, with a further fall of 5m along the bank of Seven Creeks. The landscape gently falls from the western extent (Raftery Rd) and southern extent (Bennetts Rd) across the site towards Seven Creeks.
- There is a GMW irrigation supply channel (No. 2 Channel) that runs parallel with the western boundary of the study area along from Mitchell and Raftery Rd intersection, southwards past Bennetts Rd (PSP's true southern boundary). The channel sits slightly higher than the surrounding landscape.
- The northern section of the study area is situated immediately south of the confluence of Seven Creeks and the Goulburn River. This area contains steeper slopes than most of the site, with a plateaued section that forms the bank of the Seven Creeks. In major rainfall events (1% AEP flows) this area is highly susceptible to inundation and as such has been classified as an Urban Flood Zone (UFZ) (discussed further in Section 4.7).

4.4 Catchments

Based on available contour data and proposed zoning areas, the study area was delineated into five catchments (Figure 5). All catchments ultimately outfall into the Seven Creeks, with existing irrigation channels acting as the main catchment boundaries. Raftery Road and Bennetts Road also act as catchment boundaries, preventing flows, external to the PSP, from entering the site.

This is a significant factor, as it provides clarity for future decisions surrounding 'reasonable apportionment' of PSP costs as part of the Development Contributions Plan (DCP) process.

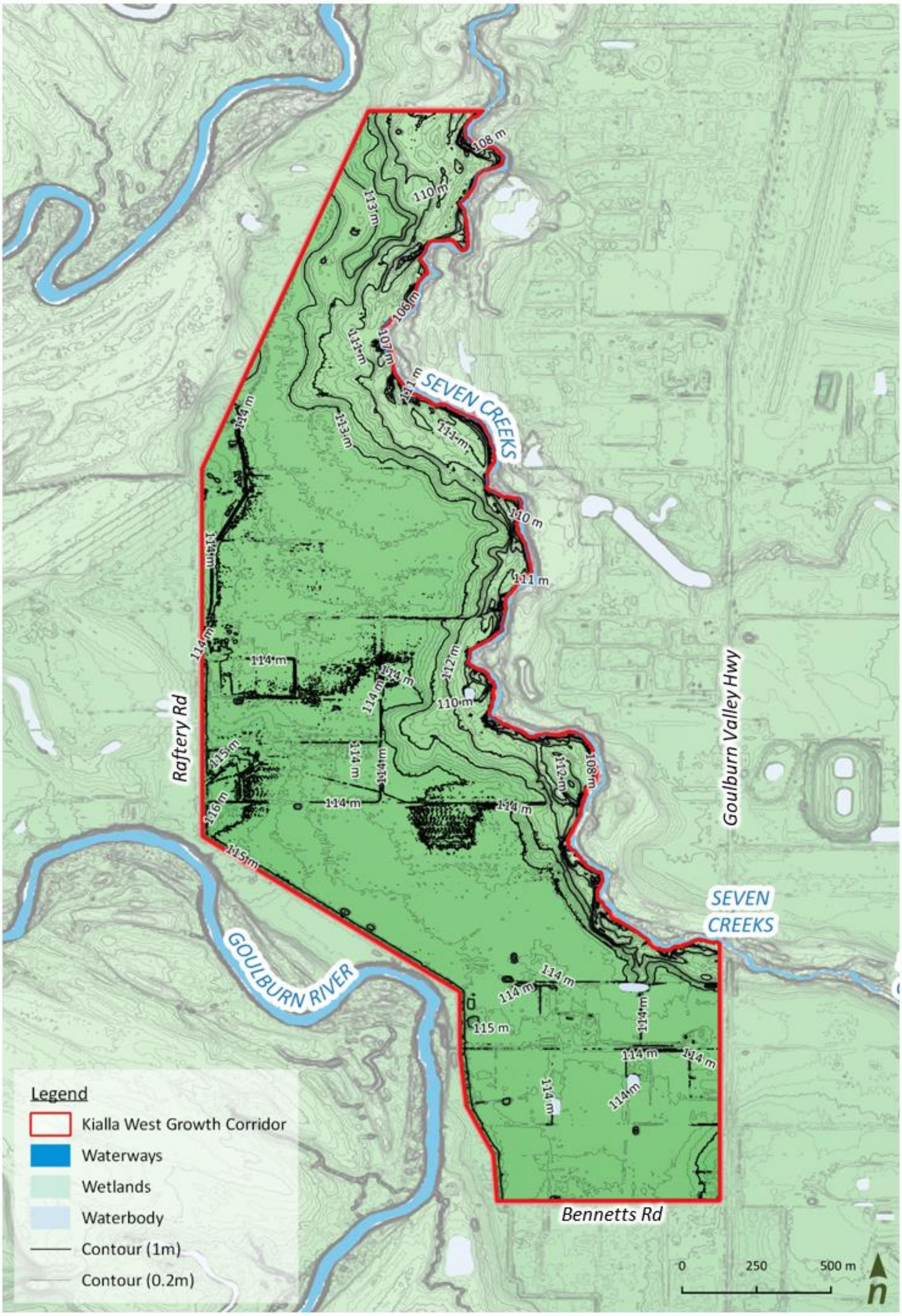


Figure 4. *Topography plan of KWGC (source: insert)*

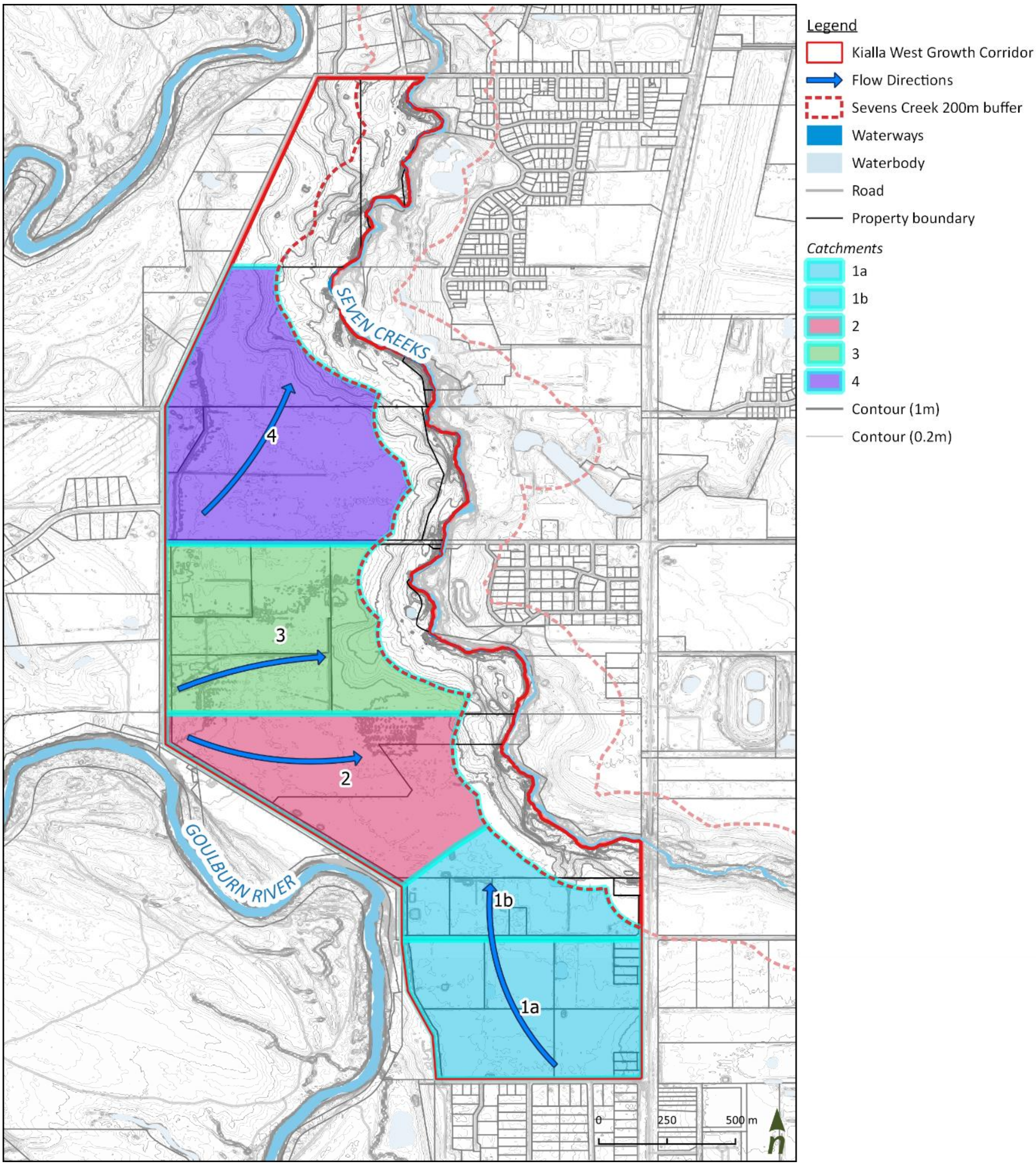


Figure 5. *Catchment plan of KWGC showing five PSP catchments and site fall towards Seven Creeks (source: insert)*

4.5 Site inspection

A site visit was conducted on February 16th 2022 to allow the project team to gain a better understanding of the local terrain, site constraints and opportunities. The site visit was attended by Caroline Carvalho, Dylan Brand and Olivia Blair-Holt (Alluvium), as well as Alex Smith (Council).

Consideration was given to the location, landscape form(s), local features, and structures (constructed and natural) including creeks, rivers, irrigation channels, overland flow paths, drainage alignments (within/external), significant trees and natural habitat features, existing recreational links around the site, and identification of blue-green corridors to encourage walkability/human movement, abutting road links and other services were also investigated. A summary of each location visited is provided below.

The Precinct is characterised by a generally flat riverine terrain, which gradually drains into Seven Creeks, this includes some farm drains which outfall towards the creek corridor. Overland flows into the creek are apparent along sections of the creek's banks where erosion is evident (Figure 6).

Several trees have fallen into the creek within the Precinct area (Figure 7) providing natural debris for channel stabilisation and habitat, although in some sections, stream braiding was apparent with 'islands' and sand deposition 'peninsulas' some of which infested by Weeping Willow.

The Creek appears to move slowly, pooling along sections of the alignment. Visually, water quality appears turbid (high sediment load) and likely a factor of agricultural / grazing land uses upstream, and at, the site.

Figure 6. *Overland flow paths to Seven Creeks*

Figure 7. *(a) Fallen trees and woody debris providing bank protection in Seven Creeks*

(b) with some stream braiding and 'islands' with weeping willow (Fig. below).

Some erosion control works have been completed along reaches of the creek, with rock beaching present at critical locations (Figure 8) and appear effective in stabilising soils and preventing bank undercutting in high flows. Other works within the Precinct area included deep farm channels throughout the precinct (Figure 9).

Figure 8. *Rock beaching along the Seven Creeks proving effective in stabilising banks and allowing vegetation establishment (some of which being weed species).*

Figure 9. *Existing farm channels traverse the study area*

4.6 Existing services and infrastructure

There is little in the way of sewer, water, or stormwater infrastructure at the site, as the current land uses are largely agricultural/rural residential living. Numerous agricultural irrigation (farm) channels traverse the site.

A GMW irrigation supply channel (No. 2 Channel) runs parallel to the western extent of the PSP from the intersection of Raftery and Mitchell Roads and travels south past the PSP extent (Bennetts Road). It is anticipated that this irrigation channel will remain in its current form and service function for the land area west of the PSP boundary which is to remain as 'Rural Living Zone'.

An APA high-pressure gas transmission pipeline runs east-west centrally through the site. It is expected a buffer / asset protection offset will be applied to protect the pipeline.

The presence of this pipeline precludes any stormwater assets or construction activities that could cause damage.

Therefore, the catchment delineations for the PSP have been determined using the gas pipeline as a catchment boundary. This will avoid any risk of pipe damage from drainage infrastructure crossing the pipeline. Figure 10 shows the existing services and infrastructure within the KWGC.

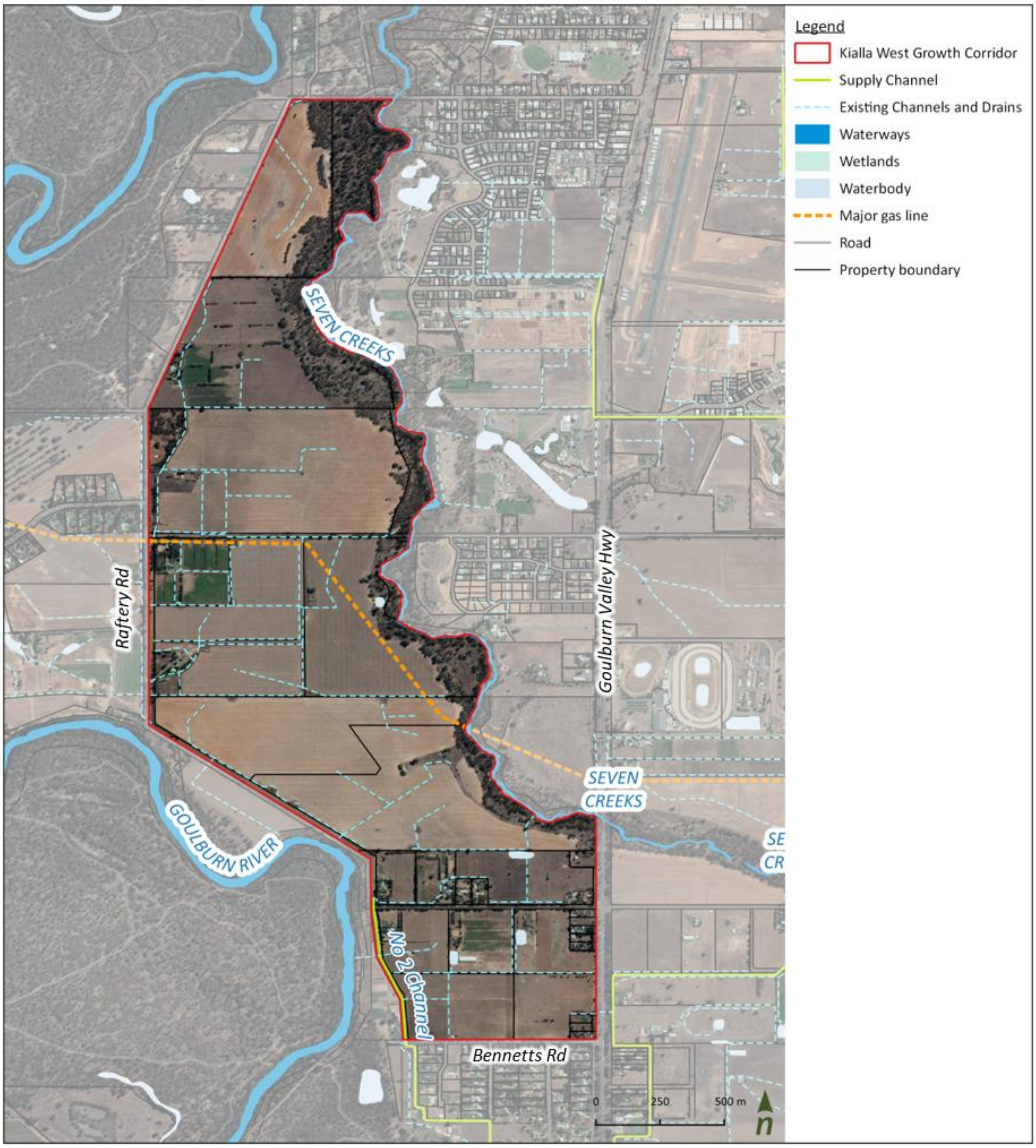


Figure 10. *Overview of existing services and infrastructure within KWGC PSP*

4.7 Flood modelling

Extensive flood modelling has been undertaken over recent years to understand flood behaviour in this region. A review of flood modelling studies and outcomes has been completed and informs the proposed concept layout of stormwater assets for the PSP. Understanding previously adopted model calibration approaches and adopted input parameters is important to best inform asset type, location and design. Findings from the flood modelling review is summarised below.

4.7.1 Shepparton East Overland Flow Urban Flood Study (BMT WBM, 2017)

BMT WBM were commissioned by the GBCMA to undertake a flood study, for the area east of Shepparton and north of Channel Road. The study required the development of both hydrologic and hydraulic models to generate the flood extent maps of the area.

- A RORB hydrologic model and TUFLOW hydraulic model were built. The results were used to develop flood mapping products to undertake a flood damage assessment, and to inform potential flood mitigation strategies.
- The modelling established existing conditions flood information (20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events), as well as sensitivity testing for increased urbanisation and climate change scenarios.
- Storm data was generated using Intensity Frequency Duration (IFD) parameters sourced from the Bureau of Meteorology (BoM) IFD program (BoM, 2012). A climate change scenario assuming a 32% increase in rainfall intensity was also run.
- The RORB model was calibrated to the Rational Method as the catchment is ungauged. It is understood that ARR 1987 was adopted for this study. The latest industry guidelines are ARR2019.
- An initial loss (IL) of 15mm and a continuing loss (CL) of 2mm/hr was adopted for agricultural areas, and an IL of 10mm and CL of 2mm/hr was adopted for urban areas.

Although the Shepparton East Overland Flow Urban Flood Study does not cover the proposed Kialla West Growth Corridor PSP, the findings from this flood study remain relevant due to proximity and similarity of the catchments. Specifically, the study is the most recent hydrological investigation to derive an initial loss and continuing loss for this area. As such, the parameter values were adopted in this instance.

4.7.2 Shepparton Mooroopna Flood Mapping and Flood Intelligence Study (Water Technology, 2019)

Water Technology was commissioned by Council to undertake the Shepparton Mooroopna Mapping and Flood Intelligence Study to provide a technical review and update to the previous flood study data, undertaken by SKM (2002). The flood mapping data is publicly available through an online mapping portal.

- The study involved detailed hydrologic and hydraulic (TUFLOW) modelling of the Goulburn River, Seven Creeks and the Broken River
- Flood Frequency Analysis of available stream gauges was used in the hydrologic modelling
- The report defines riverine flood timing

The existing 1% AEP maximum flood depths relative to the KWGC are shown in Figure 11 below.

Figure 11. *Existing conditions 1% AEP (source of flood levels: Shepparton Mooroopna Flood Mapping and Flood Intelligence Study, Water Technology, 2019 through online portal: https://my.floodreport.com.au/Gbcma/)*

4.7.3 Shepparton Mooroopna 1% AEP Flood Mapping Project (Water Technology, 2021)

Water Technology was engaged by Council and GBCMA in 2021 to undertake a flood mapping exercise for the Shepparton and Mooroopna area, as an update to the previous study undertaken in 2019 (as above). The key driver for this study was updated LiDAR captured in 2019, which provided a more accurate depiction of group topography compared to previous LiDAR data captured 10 years prior. The updated flood study results are to inform a planning scheme amendment in line with industry guidelines.

- Flood results are generally in line with the 2019 results, although captured at a much high resolution.
- The supplementary modelling reassessed flood risk for the Shepparton and Mooroopna areas and identified locations along the Goulburn River, Broken River and Seven Creeks that pose a high flood risk.
- Climate change modelling results suggest the peak flood levels throughout the study area increased by 150mm compared with existing conditions.

Based on findings from this study, Council updated and adopted the planning overlays and land zoning affecting the Kialla West Growth Corridor (shown in Figure 12). To increase the developable land within this area prone to flooding, large areas of the site are proposed for fill. Water Technology has defined the extent of fill that could be applied to the site, while remaining within required limits of increased flood levels downstream.

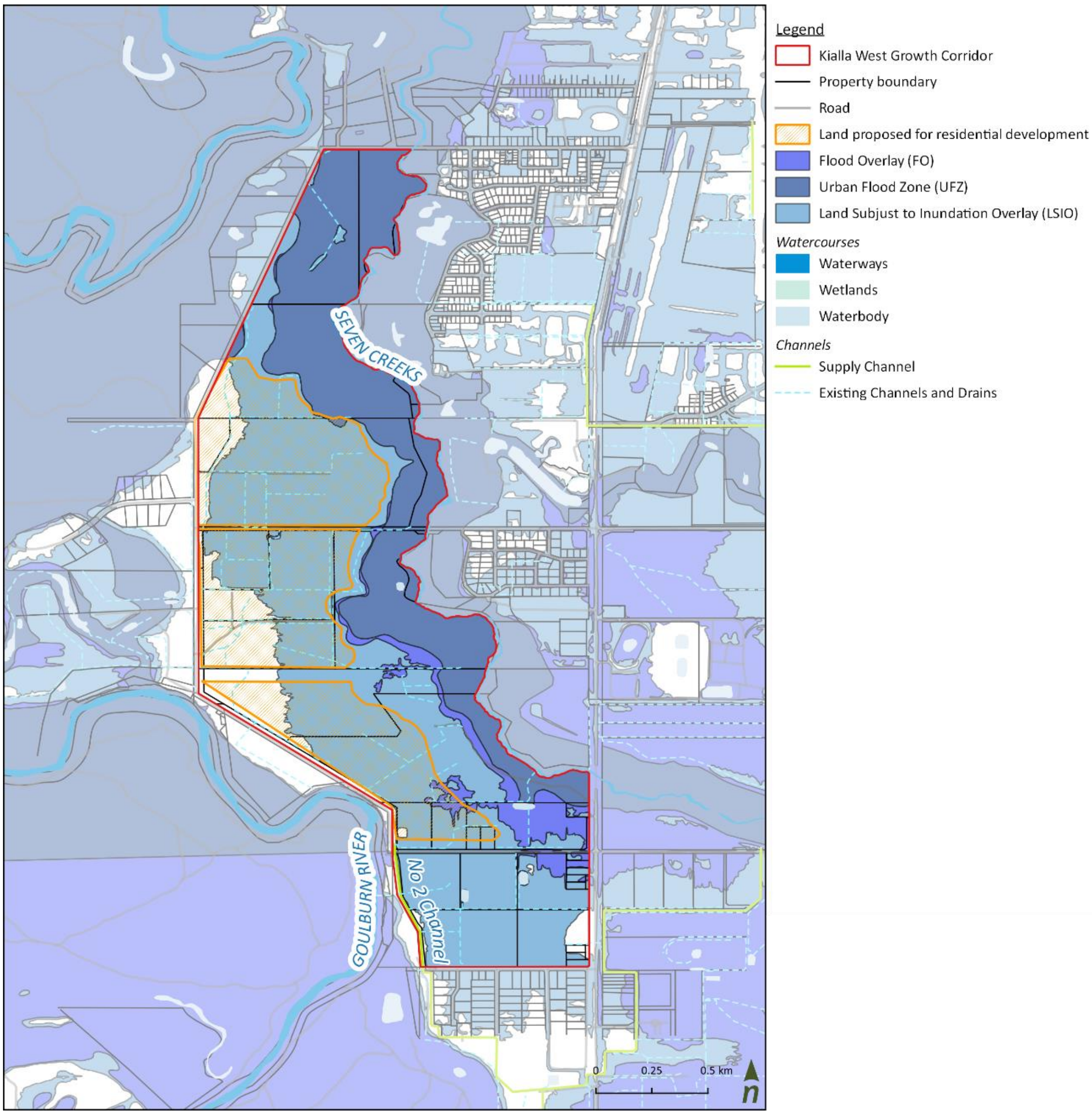


Figure 12. *Planning overlays and zoning within the study area (Water Technology 2021)*

4.8 Ecological values

DM Ecological Pty Ltd has been engaged by Council to undertake an Ecological Assessment for the Kialla West Growth Corridor in parallel with this study (Alluvium). The results from the ecological study will be critical to better inform designs for the proposed PSP stormwater assets at the functional design stage.

4.9 Cultural heritage

The Yorta Yorta (or Joti jota) Nation of First Peoples are the traditional owners of the area that spans the Murray River from north-eastern Victoria to southern NSW (refer map below; source: YYNAC website). It extends to the townships of Cohuna to the west, Albury-Wodonga to the east, just north of Euroa to the south, and Jerilderie (88kms NE of Deniliquin) to the north. The Yorta Yorta people have a continuing connection to the lands and waters of this region, within which Shepparton and KWGC (the PSP study area) fall within.

The Yorta Yorta are river-based people, their lifestyle and culture is centred around the forest-wetlands where the majority of their food supply was sourced from the network of local rivers, creeks, wetlands and billabongs of the central Murray-Goulburn region. The work of the Yorta Yorta Nation Aboriginal Corporation (YYNAC) is captured in the Yorta Yorta Whole-Of-Country Plan 2021-2030. YYNAC is the registered Aboriginal Party for the PSP and their feedback and input to this project is critical.

Like many other Indigenous Peoples, the Yorta Yorta People changed with the seasons - their culture and lifestyle explored all elements of the diverse land around them. While waterways (rivers and creeks) were typically travelling routes for Aboriginal peoples and likely to have a high potential for Aboriginal sensitivity, there were often numerous landforms other than waterways, and elevated land areas that can pose a high potential to yield Aboriginal material culture. Any high impact activity (such as the proposed land development for the PSP) within defined areas of Aboriginal cultural sensitivity, requires a mandatory Cultural Heritage Management Plan (CHMP).

Jo Bell Heritage Services Pty Ltd have been engaged by Council to undertake a parallel study for the PSP – an Aboriginal Cultural Heritage Impact Assessment (ACHIA). The results from the heritage study will be critical to better inform designs for the proposed PSP stormwater assets at the functional design stage.

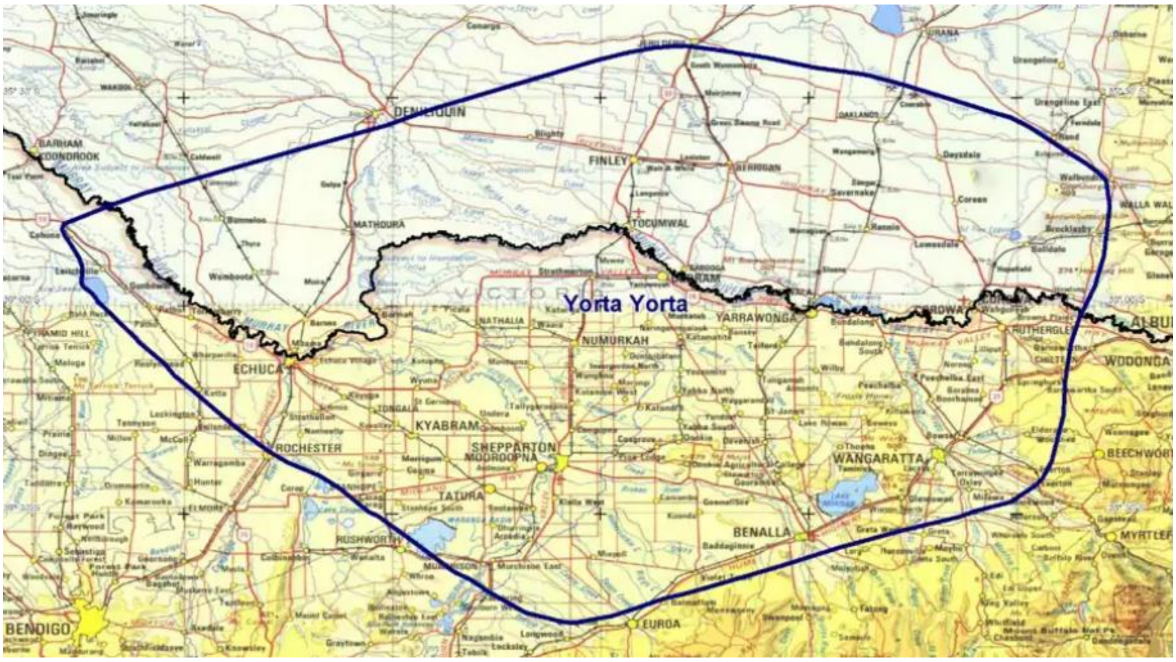


Figure 13. *Yorta Yorta Country (source: Goulburn Broken Catchment Management Authority website)*

5 Post Development Objectives and Conditions

The following sets out the aim, objectives and approach of the integrated stormwater drainage assessment for the post-development conditions at KWGC. For any surface water / stormwater drainage assessment the aim is to define the flood mitigation and stormwater quality management requirements for the post-developed conditions (the future land use of the site).

The stormwater quantity and stormwater quality assets required for the PSP, to control the impact of the proposed development on downstream receiving environments and flood conditions, has contributed to the proposed concept layout for KWGC. The layout seeks to minimise asset costs and land take through integration of assets (multi-functionality) to facilitate viable development opportunities.

The design and layout of the integrated stormwater management and treatment assets are provided at a conceptual level after consideration of the four main objectives of any surface water management plan:

- Stormwater quantity management
- Stormwater conveyance
- Stormwater quality treatment, and
- Integrated water management.

5.1 Stormwater quantity management

As per best practice requirements, the fully developed 1% AEP stormwater runoff rates are to be retarded back to the equivalent 1% AEP pre-development peak flow rates before discharging downstream. This is typically achieved through the implementation of detention or retardation systems within the catchment. This is to ensure receiving waters are protected, and that there are no adverse impacts on existing downstream flood conditions.

5.2 Stormwater conveyance

Stormwater conveyance is typically designed to a major and minor flow regime where:

- Minor flows, up to and including the 20% AEP storm event (approx. the 5-year ARI) are typically conveyed via the underground stormwater network
- Major flows, above the 20% AEP up to and including the 1% AEP storm event are conveyed at surface via roadways, overland flow paths, open channels, natural gullies, and waterways.

The subdivisional roads, and associated drainage network, do not form part of this study.

5.3 Stormwater quality treatment

Stormwater treatment concepts are required to meet the State pollution reduction targets as per the Victorian Planning Provisions (VPPs) and Urban Stormwater Best Practice Environmental Management (BPEM) Guidelines (CSIRO 1999) before being discharged into downstream stormwater networks and waterways. These targets are defined as:

- 70% removal of Total Gross Pollutant loads (TGP e.g. litter, coarse sediments, debris)
- 80% removal of Total Suspended Solids (TSS)
- 45% removal of Total Nitrogen (TN)
- 45% removal of Total Phosphorus (TP).

5.4 Optimising IWM application

Stormwater drainage assessments should seek to incorporate IWM opportunities to gain optimised outcomes that deliver multiple functions with multiple community benefits and landscape enhancement. The Concept Layout Plan delivered as part of this study includes an assessment of IWM opportunities associated with the proposed treatment and flood mitigation assets, including stormwater harvesting and reuse in public open space landscapes. In developing the Concept Layout Plan and proposed integrated infrastructure elements, we have considered:

- Landscape features and topography for asset locations, minimising need for fill wherever possible
- Relevant Planning Scheme overlays such as LSIO, SBO, FO, ESO, VPO etc
- Flood heights, flood modelling and appropriate siting of urban infrastructure
- Location of existing stormwater, water supply, sewage, and other service networks within and surrounding the site
- Scalable interventions (e.g. lot, street, precinct scale) that best suit site challenges (e.g. smart tanks)
- Locating active open space in proximity to potential detention systems for efficient stormwater harvesting (fit for purpose - irrigation reuse) to conserve potable supplies, while reducing runoff volumes and associated impacts to local waterways during a rain event.
- Waterway frontage enhancements to benefit landscape amenity, sight lines, riparian zone quality, and opportunities for safe human interactions with the natural environment while protecting species diversity and waterway health
- Linking water quality and flood mitigation assets through a linear waterway (where feasible) to enhance site amenity and precinct connectivity within and between surrounds
- Consider how Aboriginal water values (and story-telling) could be integrated into this plan/precinct to enhance the area's cultural essence
- Blue-green corridors, and relationship to the urban/residential footprint, and how these improve human thermal comfort, resilience, and connectivity between communities (including existing/future shared trail routes).
- Protection of local values – environmental, social, cultural, economic
- Enhance broader liveability outcomes locally and regionally.

5.5 Proposed future land use

To determine the stormwater quality requirements of the precinct, the post-development conditions of the site have been modelled. While it is understood that the layout and proposed land use concepts are subject to change over time (and that the stormwater assessment will inform the proposed layout), a preliminary layout is required for modelling assumptions.

The layout of the precinct, specifically the density of the proposed development and proportion of open space, will impact the volume of stormwater runoff and therefore the treatment and flood mitigation systems required (sizing and functional performance).

Given council is preparing for the future development layout of the PSP, hydrological modelling within this report was based on the planned zoning and overlays covering the study area.

The majority of the site is currently covered by a Land Subject to Inundation Overlay (LSIO), with the areas closer to banks of the Seven Creeks subject to an Urban Flood Zone (UFZ) Overlay.

To increase the developable land options for the PSP, much of the subject area is proposed to be in fill to increase the elevation of the site, to above the current floods levels. A requisite of this fill work is that it does not significantly worsen flood conditions downstream of the study area.

Water Technology modelled the flood conditions downstream of the subject area in several fill scenarios during their flood study (2021). It was determined that most of the site could be filled without significantly worsening downstream conditions.

This excluded the land south of Mitchell Road, where filling caused increased inundation for the development immediately south of Bennetts Road. After discussions with Council, it is understood that all land available for fill will adopt a General Residential Zoning (GRZ); while land south of Mitchell Road will adopt a Rural Living Zoning (RLZ); and the land north of Mitchell Road, and outside the proposed fill areas, will adopt a Public Park and Recreation Zone (PPRZ). With regard to the protection of the health and ecology of Seven Creeks, this PPRZ will likely provide a valuable open space buffer between the development interface and the core riparian zone of the creek.

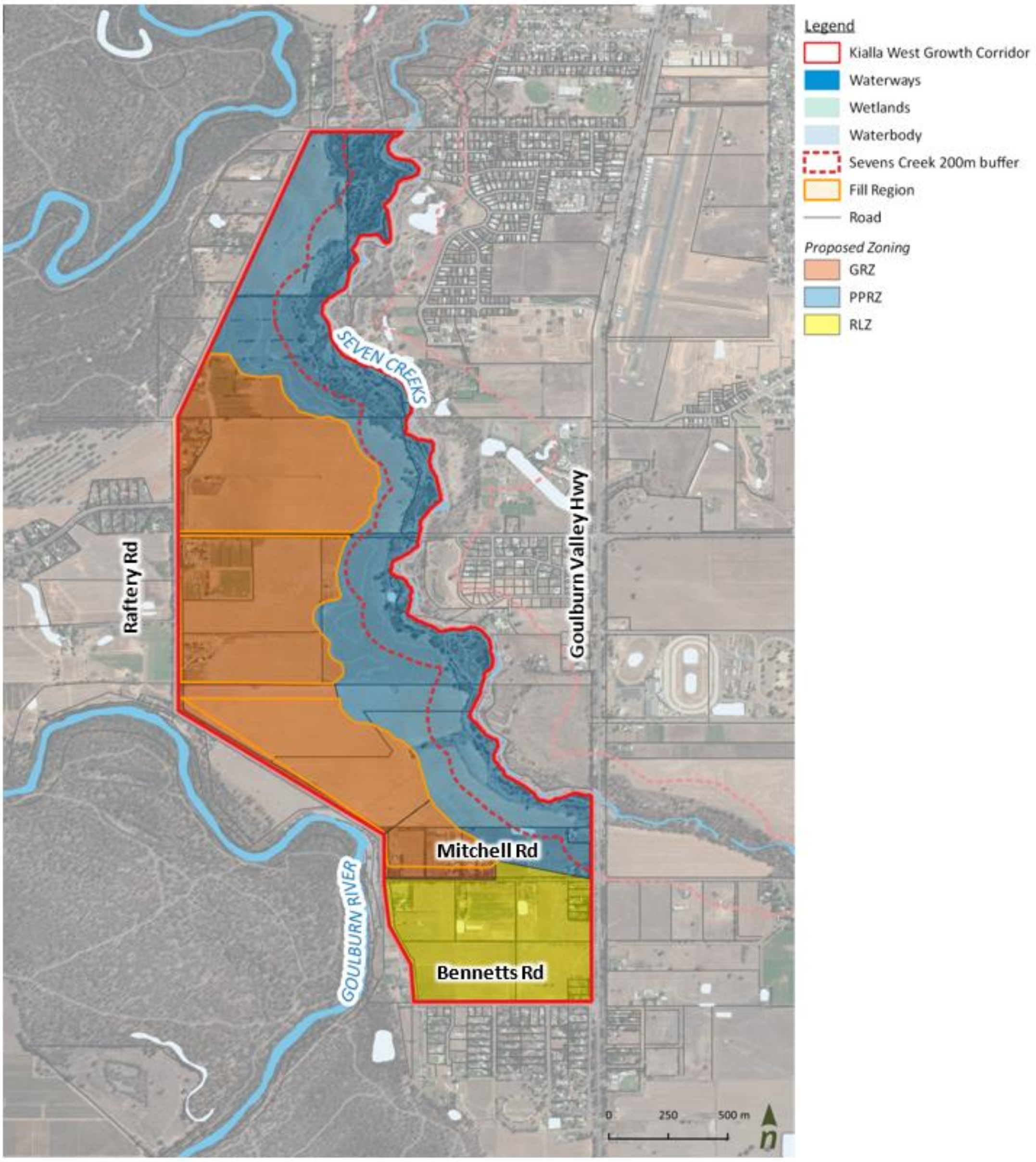


Figure 14. *Planned future land use at the KWGC based on propsoed zoning*

6 Stormwater Quantity – hydrologic analysis

In general terms, the approach to flood management is to equate post development and pre-development peak flow rates for the 1% AEP event such that the development is not having an adverse impact on downstream flooding. This is typically achieved through the addition of retention (or detention) storage within the relevant catchment. The hydrologic analysis is used to determine the storage capacities of proposed retarding basins required to retard the fully developed peak stormwater runoff rates back to pre-developed conditions.

6.1 Hydrologic modelling

The hydrologic analysis was undertaken using RORB (v6.31), which is a runoff-routing software designed to simulate attenuation and time of concentrations to produce flood estimates at specified catchment locations.

A RORB model was created for the PSP to determine:

- Existing peak flows
- The impact of development on peak flows
- The reduction in peak flows that is possible using retarding basin storage.
- The impact of climate change on peak flows

The RORB models were built by delineating the major catchments into sub-areas based on topography and potential road alignments. This section details the peaks flows and storage requirements for each catchment. The same fraction impervious values were adopted for the stormwater treatment modelling (in MUSIC).

6.2 Input parameters

Model inputs including temporal patterns and aerial reduction factors were obtained from the ARR2019 data hub and the Bureau of Meteorology's Intensity Frequency Duration (IFD) data. RORB models were built by delineating the area based on flow directions derived from LiDAR data and future preliminary development plans.

An overview of the model setup including catchments, reaches, and retention asset locations, is shown in Figure 15. Full details on inputs and assumptions used for the hydrologic modelling can be found in Appendix A.

Key inputs into the RORB modelling include:

- The model used an initial loss/continuing loss model with an initial loss of 10mm (urban) and a continuing loss of 2mm/hr. These parameters are in line with previous flood studies in the region (Shepparton East Overland Flow Urban Flood Study parameters were adopted). An initial loss of 15mm was adopted for agricultural areas for the existing conditions model.
- The Regional Flood Frequency Estimation Model (RFFEM) estimate of flood frequency curves for catchments is based on regional studies. ARR2019 preferred method is to, where possible, calibrate the catchment routing parameter (kc) to meet the peaks in the RFFEM. However, there are no data points of relative catchment size to the study area, which suggests the flow from the RFFE is not directly relatable, and a flow between the upper and lower confidence limit is more likely.
- Kc was determined by modelling the existing catchment (low fraction impervious values, natural reaches) with kc's calculated from different regional kc equations (Pearse et. al, ARR annual rainfall <800mm, Dyers 1994) and comparing the peak modelled flows with the rural rational method estimates. The Pearse et al equation was adopted as good representation of the rural rational method peak flows across the site. See Appendix A for more detail.

- Intensity Frequency Duration (IFD) data was sourced from the Bureau of Meteorology's (BoM) website, nearest grid cell 36.43159 (S), 145.37365 (E).
- Temporal patterns were sourced from the AR&R data hub, Murray Basin.
- Catchment areas were based on catchment delineation (refer Section 4.4) and proposed land use.
- Fraction impervious values were based on existing conditions and updated to proposed land uses/zoning discussed in Section 5.5. The developed conditions fraction impervious values were established by mapping out the various proposed land uses/zoning areas within the catchments and establishing an overall effective fraction impervious value. Fraction impervious values were adopted from Melbourne Water standard values. This was adopted for both the RORB and treatment modelling. The assumptions for each land use include:
    - GRZ = 0.60
    - RLZ = 0.15
    - PPRZ = 0.00
- The ensemble method was used to determine the critical flows at each flood retention location.
- Reaches were natural for the existing conditions model and updated to 'Excavated but not lined' (Type 2) for developed conditions model to establish the 1% AEP peak flows and size the RBs. Another version of the developed conditions model was created which adopted Type 3 – lined or piped – to establish the peak minor flows, which were used in the velocity and sediment capture efficiency calculations.
- Reach slopes through developed areas were updated to 0.5% (1 in 200) as a grade minimum.

A summary of catchment RORB inputs shown in Table 1. Full details on inputs and assumptions used for the hydrologic modelling can be found in Appendix A.

Table 1. RORB catchment inputs

Catchment	Area (ha)	Existing conditions Fraction impervious	Developed conditions Fraction impervious
1	103.48	0.05	0.219
2	27.66	0.05	0.520
3	68.80	0.05	0.479
4	42.09	0.05	0.494

6.3 Climate change scenario

Climate change scenarios have been adopted within the hydrologic models built. The purpose of adopting climate change scenarios is not to design assets to these increased peaks, but to perform a sensitivity check on how increased peak flows will move through the systems designed. For example, how an increased peak 1% AEP will sit within the provided freeboard in a proposed retarding basin.

The approach adopted for establishing climate change scenario has been:

- the use of Bureau of Meteorology (BoM) IFD curves derived for the site.
- that the IFD curves are adjusted to reflect increased intensity arising from climate change.

- ARR 2019 recommends the adoption of a 5% increase in rainfall intensity per degree of global warming (Book 1, Chapter 6) for events up to the 1% AEP.
- RCP 8.5 were adopted for climate change. The catchment is located within the Murray basin cluster, which estimates the temperature increase in the RCP 8.5 scenario of 4.0 degrees in the year 2090.
- This approach results in a 21.5% in rainfall intensity for 1% AEP event for the RCP 8.5 scenario
- The increase in rainfall intensity is not applied to events greater than the 1% AEP.

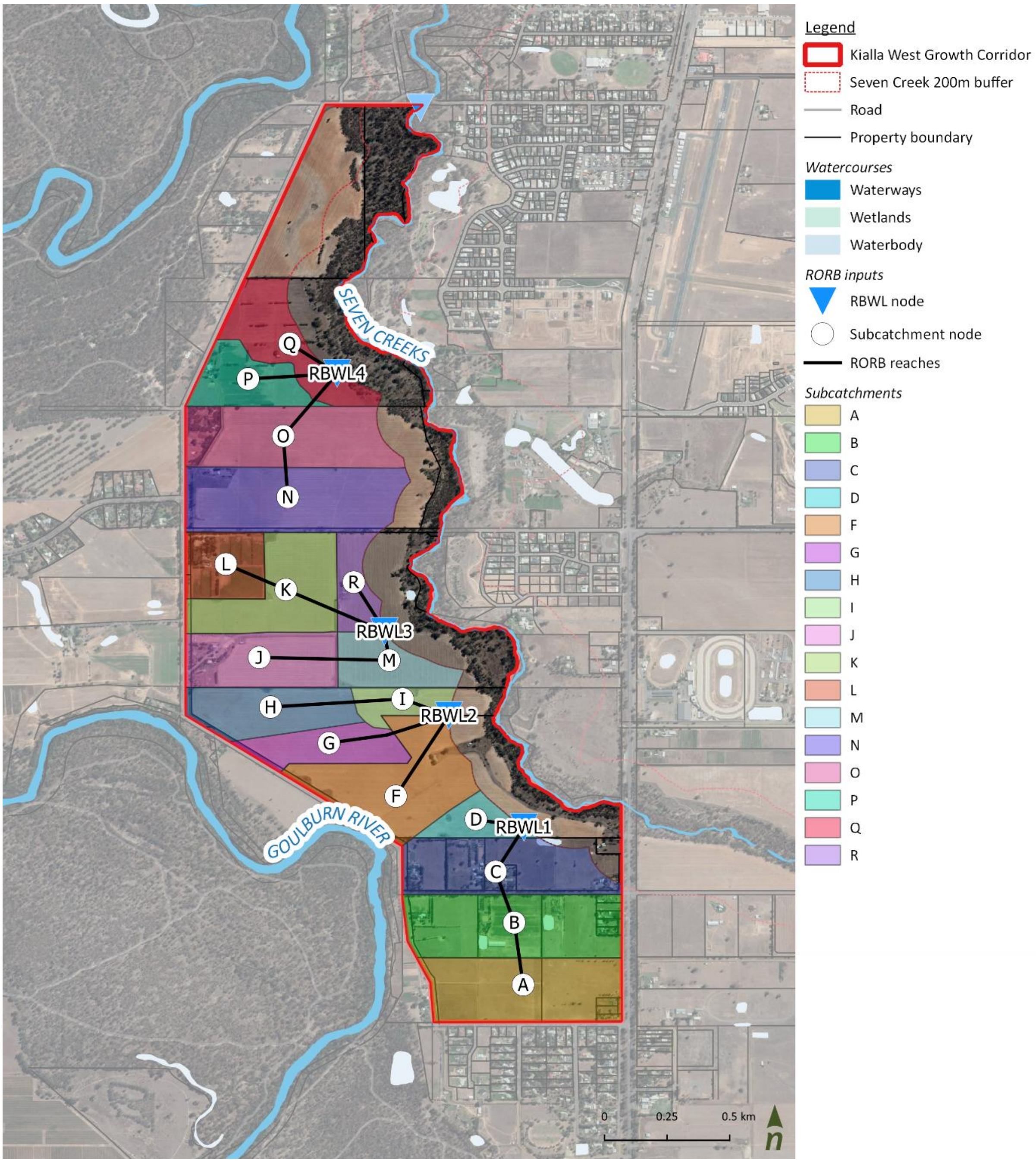


Figure 15. *RORB setup (asset locations are indicative only)*

6.4 RORB Model Results

The RORB model was computed for the pre and post developed conditions under the 1% AEP flood event with results as shown below.

Table 2. 1% AEP RORB modelling results

Asset	Catchment area	Rational rural method (ARR)	Existing conditions model (Pearse)		Developed conditions model (Pearse)	
	Ha	Peak flow (m^3/s)	Peak flow (m^3/s)	Storm duration (min)	Peak flow (m^3/s)	Storm duration (min)
RBWL1	78.8	5.25	6.52	60	14.26	45
RBWL2	55.8	4.01	4.14	60	9.35	45
RBWL3	63.3	4.43	4.93	45	10.96	45
RBWL4	77.8	5.20	6.59	45	14.93	45

Following the establishment of existing (pre) and post-development peak flows without mitigation, the retarding basins have then been modelled and sized to control the 1% AEP peak flow.

The total required area for each asset has been calculated assuming a 1(V):6(H) batter to existing surface, and an allowance of (preferably) 600mm of freeboard on top of the peak 1% AEP flood depth. The systems are designed so they are cut and not in fill (i.e. no loss of any flood storage).

- RB stage storage relationships were developed in a spreadsheet based on a base area equivalent to the NWL of the stormwater treatment assets for each sub-catchment (see Section 7), a 4:1 length to width ratio, and a batter slope of 1:6.
- Storage outlet sizes were adjusted until the peak 1% AEP outflows from the RB were equal or less than the current peaks. This was done through altering outlet properties in the hydrologic model (i.e. outlet pipe sizing or weir sizing) until the peak flows were less than, or close to the existing peak flows. The outlet pipe/weir arrangements are sized for peak RB outflows.

  Note: The functional design stage will include confirming actual *stage storage discharge relationships* using storage volumes obtained from the 3D earthworks modelling and updating these relationships in the hydrologic modelling. All peak outflow results will be refined during the refinement of the modelling during the functional design stage.
- Peak storage volumes and flood heights within the basins were extracted from representative hydrographs runs.

Table 3 shows the required capacities of the retarding basin based on the RORB modelling conducted.

Note: All retarding basins (RB) are integrated assets with a proposed wetland treatment floor (as per WL) to increase functionality and reduce asset numbers (single function systems) and associated land take and provide an aesthetic asset for improved landscape values and community benefit.

Table 3. Retarding basin requirements

Asset	Developed conditions flow rate (m^3/s)	Peak RB outflow (1% AEP) (m^3/s)	Peak RB storage (m^3)	Peak RB flood depth (m)	Freeboard above peak flood depth (mm)	Outlet structure	Surface Area (including freeboard) (m^2)
RBWL1	14.26	6.07	12,600	1.40	600	2 x 1050mm dia. pipes	13,614
RBWL2	9.35	3.98	9,610	1.44	600	1 x 1200mm dia. pipe	14,998
RBWL3	10.96	4.55	11,100	1.38	600	2 x 900mm dia. pipe	21,517
RBWL4	14.93	6.37	13,500	1.45	600	2 x 1050mm dia. pipes	27,371

The modelling undertaken in the concept design stage is preliminary only, and refinement will occur in the functional design stage when actual storage volumes, extracted from the earthworks model, are used in the hydrologic modelling.

The next stage will also include refinement of the outlet properties (i.e. RB outlet pipe/weir sizing). Given the RB floors (or wetland NWLs) are at a considerable depth due to the NWL elevations required to achieve free draining outfall from the development, there is the ability within the proposed assets to increase the peak flood depth. That is, outlet flows can be further choked (through smaller pipes/weirs) to reduce peak outflows to pre-developed peak flows. This will result in slightly higher peak RB flood depths, whilst still maintaining the required freeboard. The land take will not need to be increased.

This iterative process will be conducted in the functional design stage to ensure all outflows from the RBs are less than pre-developed peak 1% AEP flow rates. A plan overview of the RB locations and footprints are provided in Figure 16. This map also shows the integrated wetlands within the RBs that are required to meet State pollutant reduction targets (discussed in Section 7).

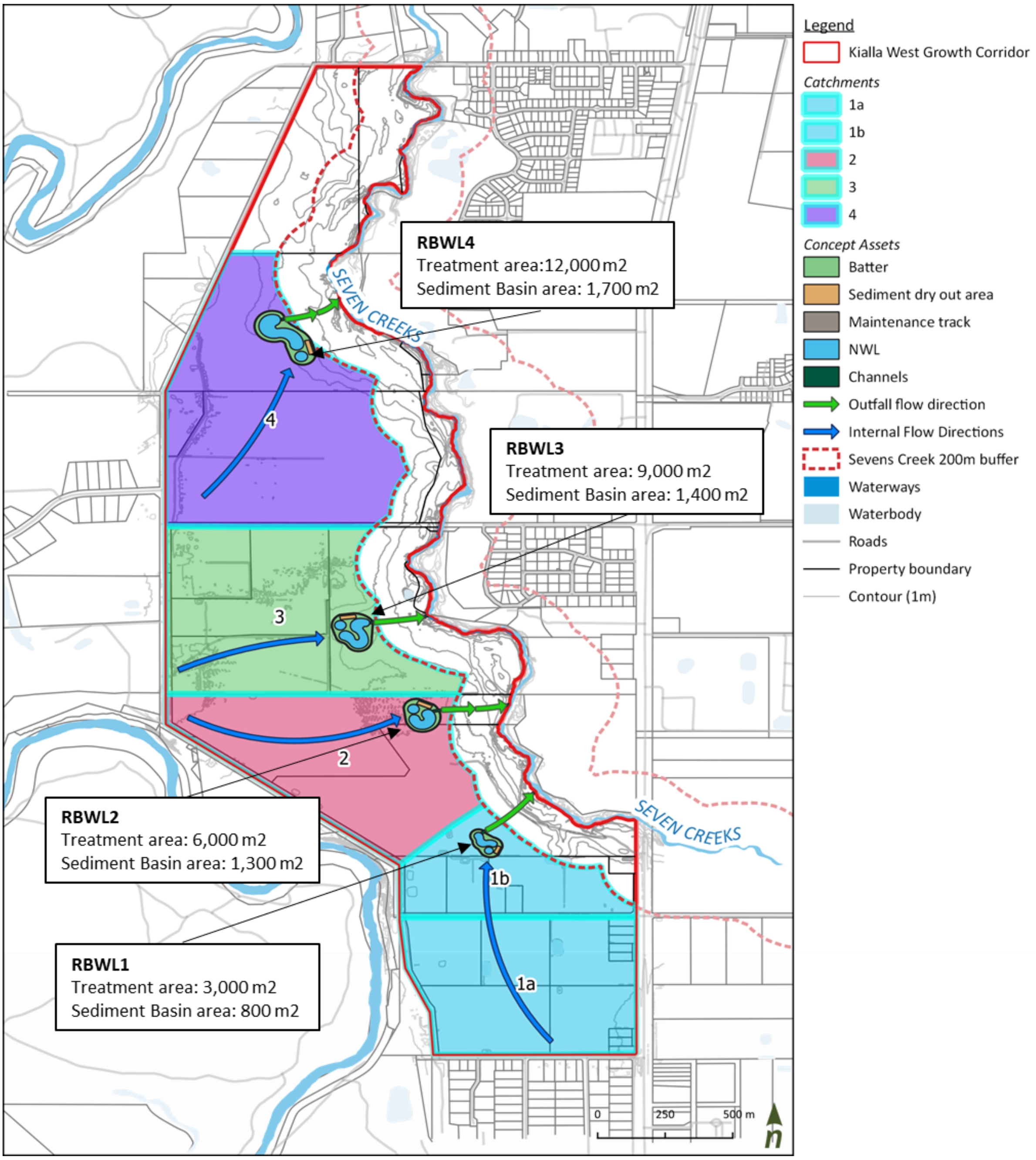


Figure 16. *Concept Retarding Basin / Wetland (RBWL) design overview*

7 Stormwater Quality Treatment

A key principle for the strategy is that all stormwater is to be treated in accordance with the Urban Stormwater Best Practice Environmental Management (BPEM) Guidelines (CSIRO 1999) before being discharged from the study area to the receiving environment. As such, the development site will require numerous treatment techniques to achieve the targeted reduction in pollutant load concentrations. The following BPEM targets have been adopted:

- 70% removal of the Total Gross Pollutant load
- 80% removal of Total Suspended Solids (TSS)
- 45% removal of Total Nitrogen (TN)
- 45% removal of Total Phosphorus (TP).

A MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model was developed to estimate the pollutant loads generated from the developed conditions scenario. This allowed us to understand the target pollutant load reduction, and therefore test the sizing and treatment capacity of various opportunities required to meet the pollutant reduction targets. Reduction requirements were determined for each catchment, and treatment system sizes were calculated accordingly to treat PSP flows.

7.1 Modelling inputs

The key modelling inputs for the MUSIC model are rainfall and evapotranspiration. Generally, for MUSIC a **10-year rainfall period** is selected for a site, which is a good representation of the annual average rainfall. The period adopted should consider a completeness of record, and representation of wet and dry periods.

Historic rainfall datasets at **6-minute intervals** were obtained from the BoM via eWater for the rainfall gauges at nearby Dookie (gauge #081013, from 1950-2010) and Tatura (gauge #81049) from 1960-2010.

The average annual rainfall over this entire period was established and used to select a ten-year period from the historic dataset which produced a similar annual average rainfall. The annual average rainfall from BoM is 553.5mm.

The Tatura gauge is closer to the study area, however there are large gaps in the records and no appropriate representative 10-year period reflecting the long-term average conditions was available. The **Dookie gauge** was therefore adopted, which provided several periods with a 10-year average close to the long-term average.

The period from **1961-1970** was selected which has an annual average rainfall of **527mm**, as this had the fewest gaps and was most consistent with the daily record.

The monthly average evaporation for Shepparton was also obtained from BoM and adopted for this modelling.

When modelling wetlands in MUSIC, an Extended Detention Depth (EDD) of 0.35m (350mm) is typically adopted and a detention time of 72 hours is the treatment duration aimed for. This allows sufficient contact time with the vegetation for biological processes to filter stormwater flows. For the wetlands proposed in this growth area we have adopted an EDD of 0.2m (200mm) due to the topographic constraints.

The inlet pond areas for each wetland were sized using the Fair and Geyer equation, where sediment basins are required to meet a 95% sediment capture efficiency of coarse particles ≥ 125 µm diameter for the peak 4EY (4 Exceedances per Year) event. The sediment basins were assumed to have an average depth of 1m, and the volume was used in the MUSIC modelling. The details of these calculations are provided in Appendix B.

The catchment nodes used in the model have been calculated based on the areas, land use, and associated fraction impervious values used in the RORB modelling (provided in **Table 1**). The MUSIC model layout is shown in Figure 17.

These assets have been sized to treat the loads being generated off the future developable area within the PSP to current best practice standards.

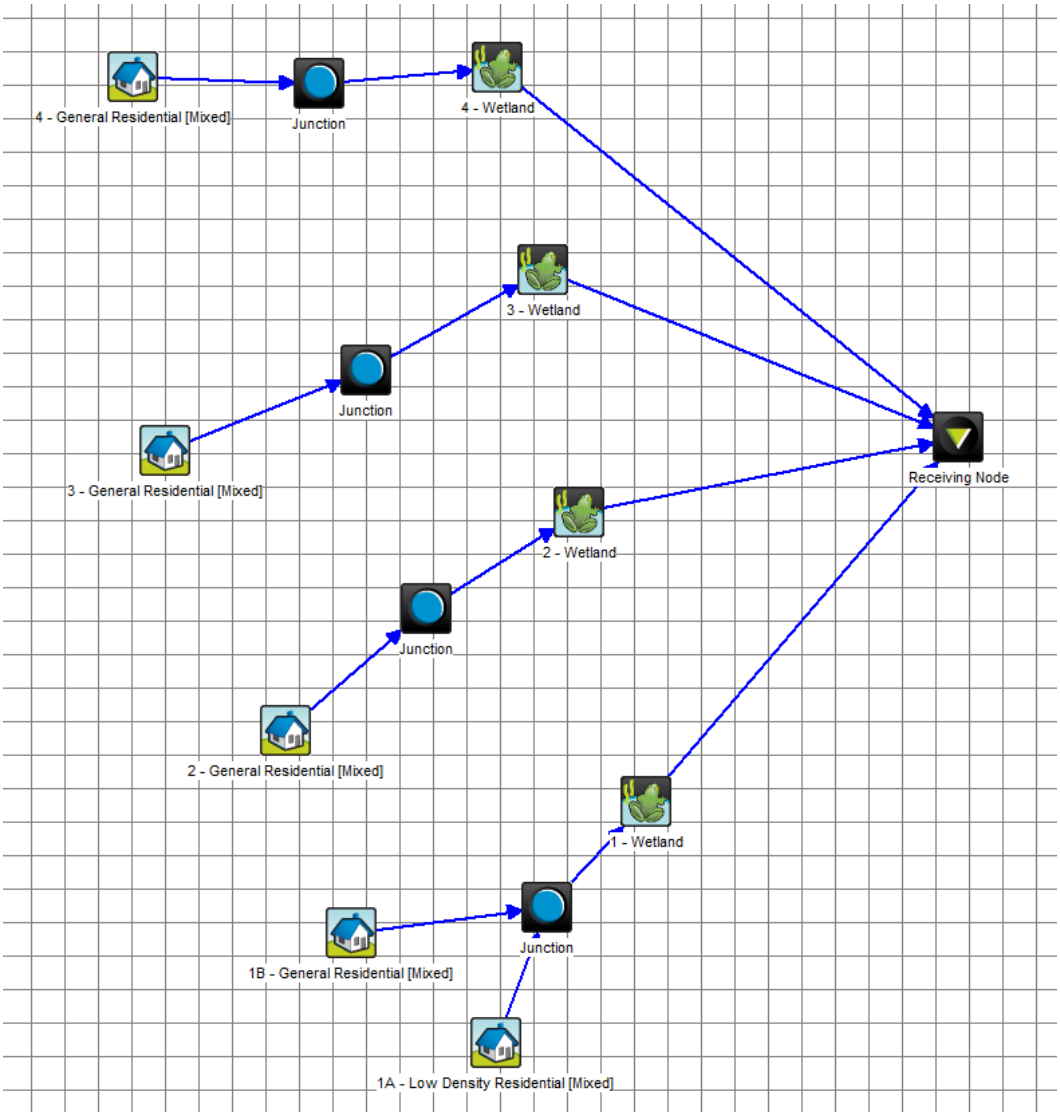


Figure 17. *MUSIC model layout*

7.2 Asset performance

The MUSIC modelling determined the sizing required for the wetland assets located at each of the catchment low points. The wetlands have been designed to inform the retarding basin stage-storage relationship described in Section 6. The details of the treatment systems are shown below.

Table 4. Treatment asset parameters for stormwater treatment wetlands.

	NWL area (m^2)	Inlet pond volume (m^3)	Average depth wetland (m)	Extended detention (m)	Extended detention time (hr)
WL1	3,000	800	0.4	0.35	72hrs
WL2	6,000	1,300	0.4	0.35	72hrs
WL3	9,000	1,400	0.4	0.35	72hrs
WL4	12,000	1,700	0.4	0.35	72hrs

The results of the MUSIC modelling analysis demonstrate that BPEM Guidelines / State pollutant reduction targets are met with the performance of those assets, as shown in Table 5.

The MUSIC model results for each individual wetland are provided in Appendix B.

Table 5. Overall MUSIC modelling results

	Source load	Residual load	% Reduction	kg/yr removed
Flow (ML/year)	538	492	8.5	46 (ML)
Total Suspended Solids (kg/yr)	97,300	19,700	79.7	77,600
Total Phosphorus (kg/yr)	207	66.7	67.8	140
Total Nitrogen (kg/yr)	1,510	814	46.2	696
Gross Pollutants (kg/yr)	22,200	0	100	22,200

8 Concept Designs

The overall study area lends itself to developing a more dedicated open space corridor for wildlife, people, and water movement along the eastern extent of the PSP, alongside the Seven Creeks floodplain. The landscape fall of the study area lends itself to locating surface water management assets parallel to the creek floodplain providing protection to the waterway zone. Locating the PSP stormwater assets along this section, as an interface between the future developed areas and the Seven Creeks corridor provides opportunity to centralise blue-green assets predominantly in areas subject to inundation, allowing development to occur in less prone areas of the PSP. It will provide a linear open space link that will ensure the core riparian zone of the Seven Creeks is protected from urban activity.

For the KWGC precinct this blue-green corridor will provide communities with integrated stormwater management solutions designed to be community valued pieces of social infrastructure that provides flood protection, water quality improvements, biodiversity enhancements, landscape amenity, likely market-improved values for lots along and overlooking this stretch, while also offering a safe, accessible area of interest that benefits community liveability, community connectedness and social inclusion.

The concept designs for the options investigated are presented within this section. Each option includes:

- The storage requirements as established in the hydrologic modelling
- The macrophyte treatment area (NWL) as established in MUSIC
- A Normal Water Level (NWL) identified by responding to site topography and freeboard allowance of 0.35m EDD.
- An approximate overall footprint based on the selected NWL and battering up to existing surface at a 1-in-6 grade.
- Indicative inlet pipe, transfer pipe, sediment basin to wetland, and outlet pipe locations.

Other factors that influenced the configuration of the asset included:

- Consideration of future subdivisional drainage requirements
- Ability to outfall safely and effectively
- Compliance with length to width ratios (sheer stress factors) of at least 4:1 [MZ4 in the Constructed Wetlands Manual], associated maximum widths, and design response to surrounding terrain
- Meet velocity requirements
- Minimising excavation requirements (where possible)
- Preference to not have the assets 'in fill', instead in cut (i.e. no reduction in overall flood storage).

The concept layout plan provides indicative stormwater mains (minor flows) running through each sub-catchment within the precinct, connecting to the proposed stormwater assets. The indicative pipe alignments are:

- Not based on any specific road layouts as there are no current development plans in place
- An approximate positioning, central to the catchment, noting that this is relatively flexible and able to be modified to suit future road layouts, given the flat nature of the landscape.

- A minimum 1 in 500 grade (as per the IDM) has been applied to ensure self-cleaning (at this stage, all have an assumed grade of 1 in 500)
- Upstream pipe invert level is based on the existing surface levels minus a 600mm (minimum) vertical cover, with an assumed 900mm diameter pipe.
- Downstream pipe invert level is based on the existing surface level at that downstream location, minus a 600mm (minimum) vertical cover, with an assumed 900mm diameter pipe. These assumptions allow for a realistic downstream NWL, assuming no fill in the catchments.
- Realistically, the stormwater mains will likely change as these will be influenced by:
    - Housing density – when determined and approved
    - Local drainage and subdivisional road layouts – when determined and approved
    - Street order (hierarchy)
    - Fraction impervious assumptions (which will influence runoff volumes / flows)
    - Any filling that is proposed at the subdivisional scale
    - Pipe sizing will change as you move downstream in the network.

A high-level costing of these stormwater mains has been included in the cost estimates based on the preliminary alignments shown, that respond to the PSP landscape (topography) and the key requirements above.

The configuration of these assets will be iteratively refined through the functional design stage. At this stage in the study, the concept designs of the key retardation and treatment assets provides a conservative indication of likely land take and highlights key infrastructure requirements for the precinct.

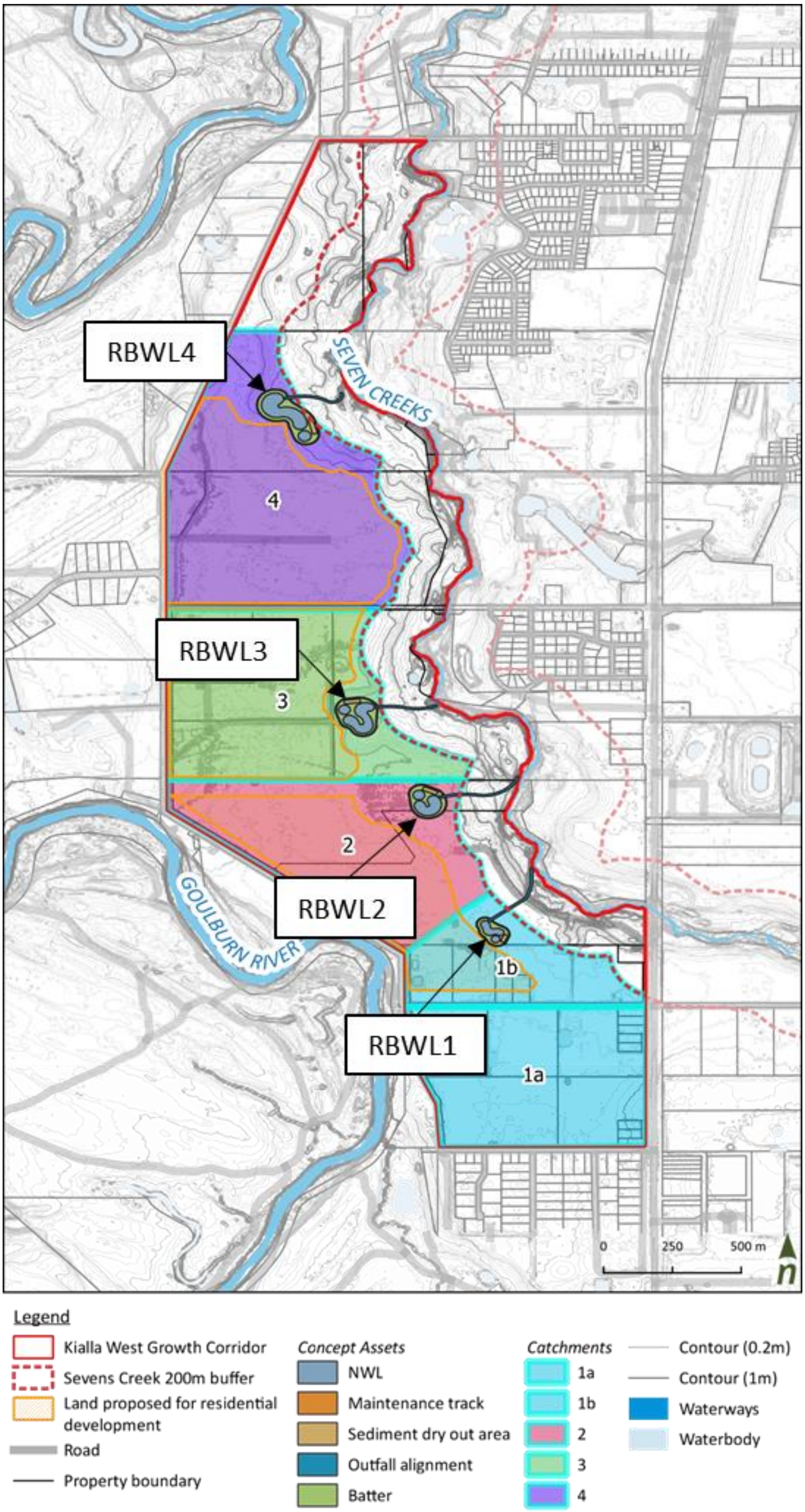
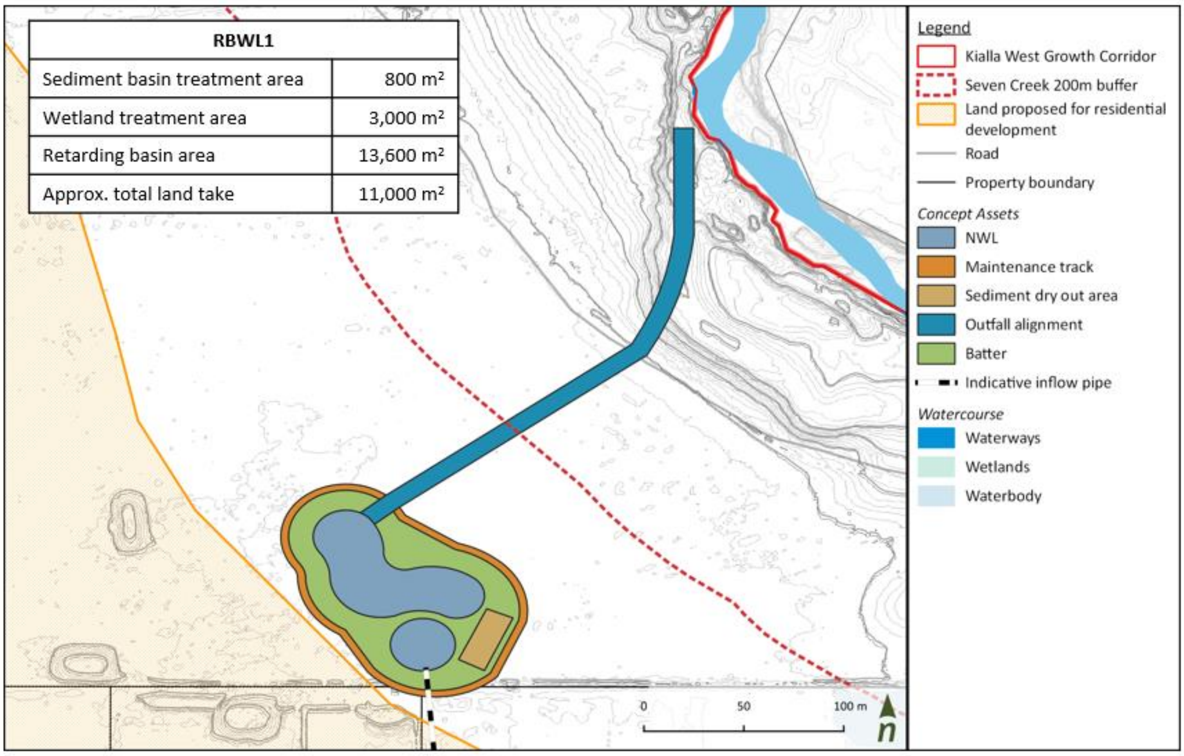
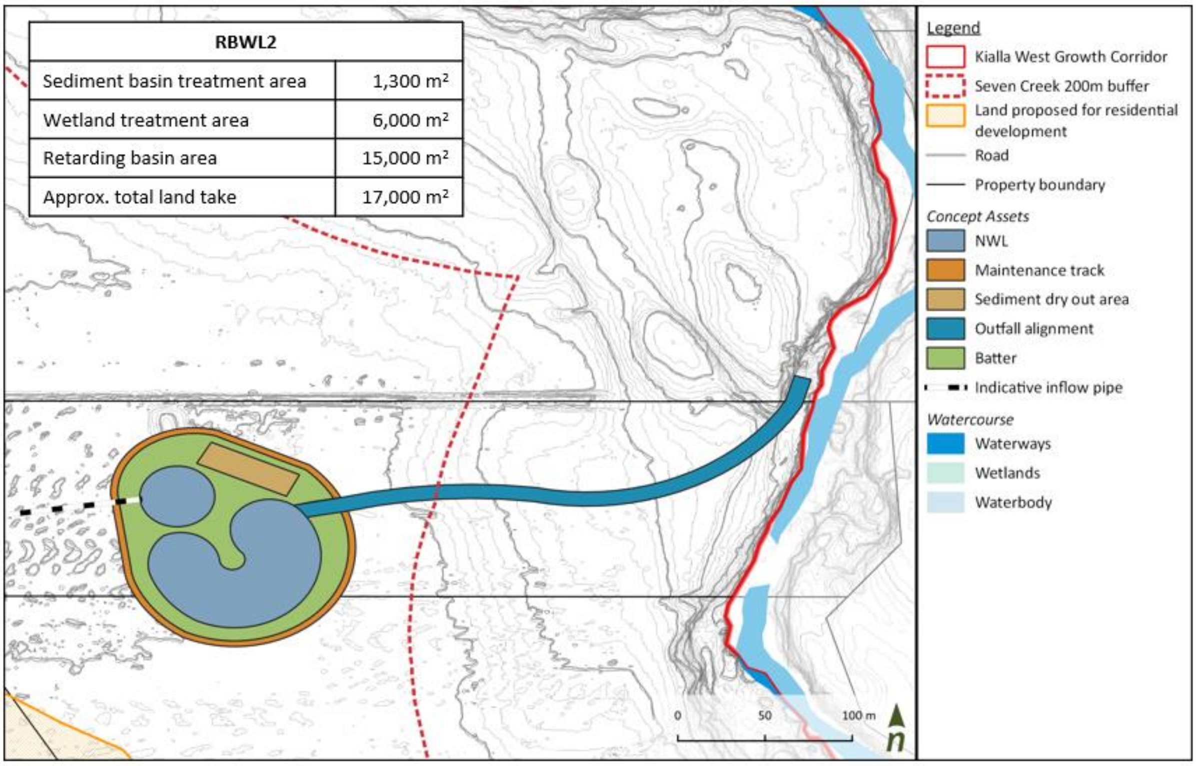


Figure 18. *Concept Layout Plan overview, Alluvium 2022*



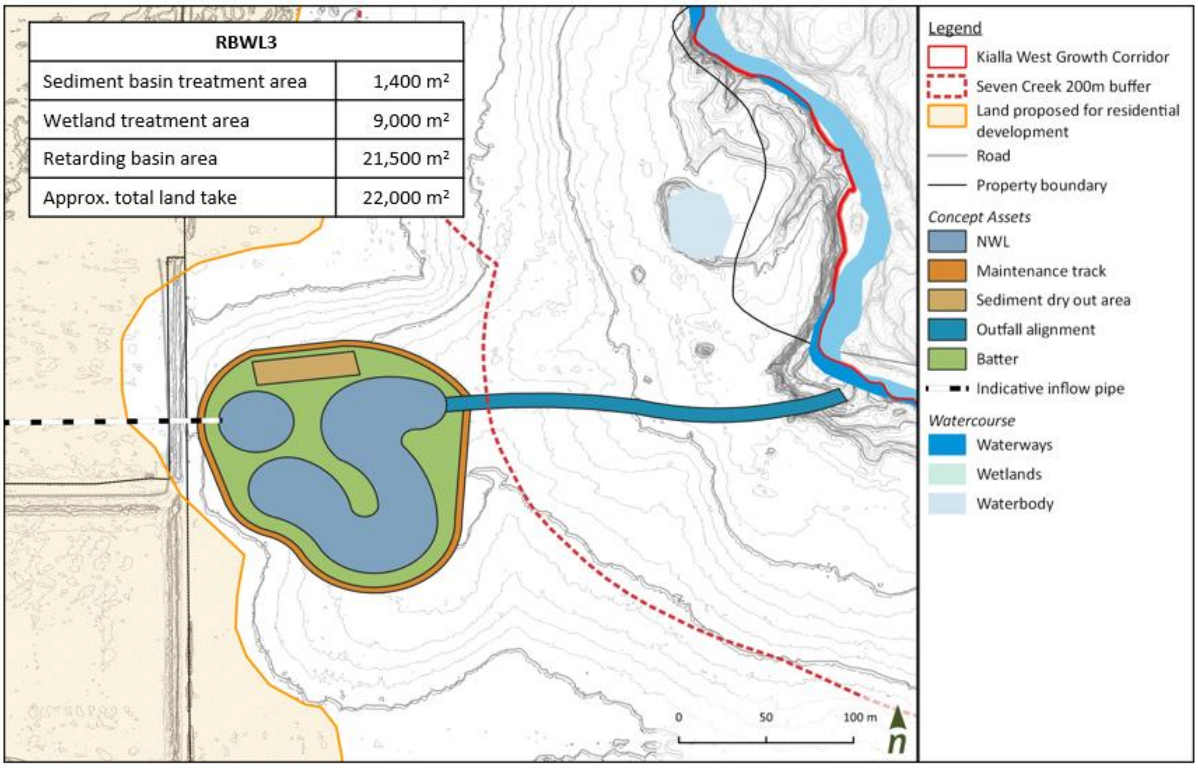
RBWL1	
Sediment basin treatment area	800 m²
Wetland treatment area	3,000 m²
Retarding basin area	13,600 m²
Approx. total land take	11,000 m²

Figure 19. *RBWL1 concept (note: asset location and design - indicative footprint only - to be refined at functional stage)*



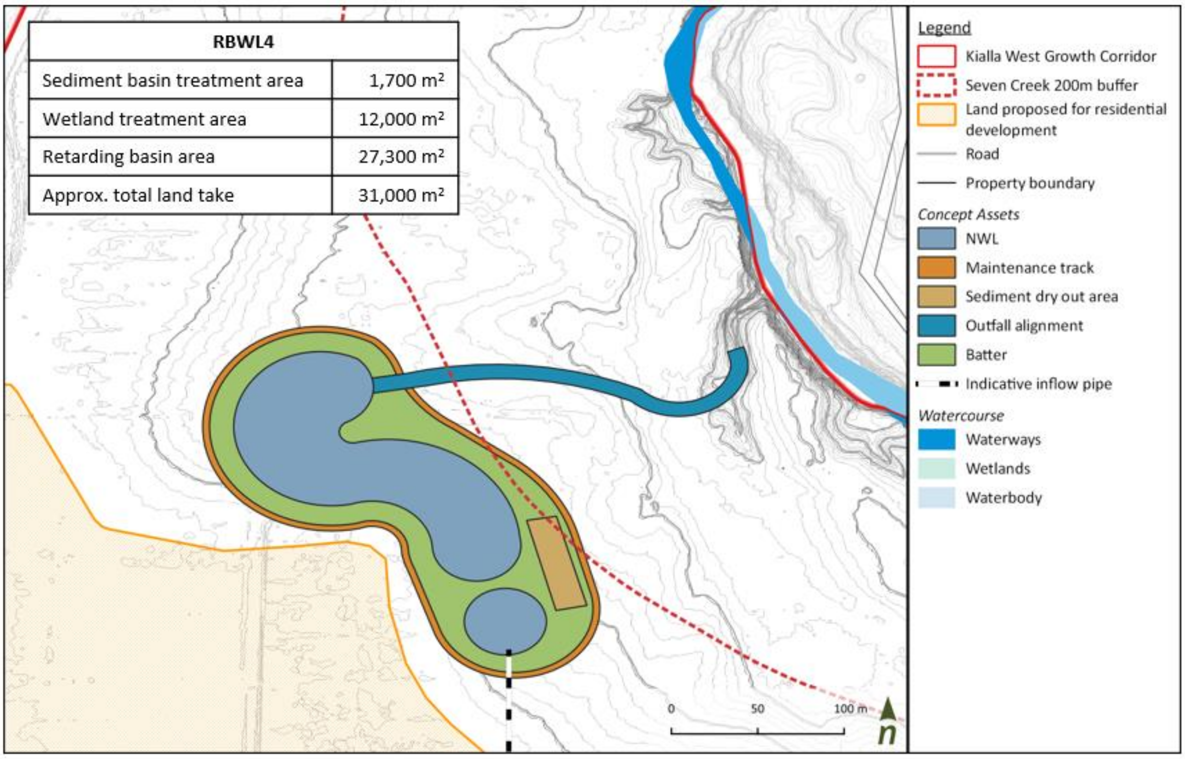
RBWL2	
Sediment basin treatment area	1,300 m²
Wetland treatment area	6,000 m²
Retarding basin area	15,000 m²
Approx. total land take	17,000 m²

Figure 20. *RBWL2 concept (note: asset location and design - indicative footprint only - to be refined at functional stage)*



RBWL3	
Sediment basin treatment area	1,400 m²
Wetland treatment area	9,000 m²
Retarding basin area	21,500 m²
Approx. total land take	22,000 m²

Figure 21. *RBWL3 concept (note: asset location and design - indicative footprint only - to be refined at functional stage)*



RBWL4	
Sediment basin treatment area	1,700 m²
Wetland treatment area	12,000 m²
Retarding basin area	27,300 m²
Approx. total land take	31,000 m²

Figure 22. *RBWL4 concept (note: asset location and design - indicative footprint only - to be refined at functional stage)*

9 High-level Cost Estimates

A high-level cost estimate has been determined, predominantly based on rates from Melbourne Water's *Water Sensitive Urban Design (WSUD) Life Cycle Costings Data Factsheet*, and excavation rates from a nearby project in Shepparton. Cost calculations for each asset are included in Appendix C. It should be noted that costings reflect the combined cost of an integrated RB and Treatment Wetland (so as not to 'double dip').

A 40% contingency has been included due to the difficult nature of estimating costs at such an early stage of asset design (conceptual only). Cost estimates and quantities (lengths etc) of materials will be refined further and form part of the Bill of Quantities at the Functional Design stage. The figures provided here are a high-level cost indicator only.

The total cost estimate is approximately **$6.83 million** (including 40% contingency). With a developed area of approximately 161ha (excluding the floodway), this equates to a per hectare cost of **$42,442**.

Table 6. Cost estimate – overall capital costs

Catchment	Assets	Capital cost
WLRB1	Wetland	$300,000
	Sediment basin	$160,000
	Retarding basin	$241,088
	Allowance for drainage infrastructure (pits, pipes, pumping station, rising main)	$20,000
	Asset Total	**$721,088**
WLRB2	Wetland	$600,000
	Sediment basin	$210,000
	Retarding basin	$245,616
	Allowance for drainage infrastructure (pits, pipes, pumping station, rising main)	$20,000
	Asset Total	**$1,075,616**
WLRB3	Wetland	$900,000
	Sediment basin	$210,000
	Retarding basin	$337,489
	Allowance for drainage infrastructure (pits, pipes, pumping station, rising main)	$20,000
	Asset Total	**$1,467,489**
WLRB4	Wetland	$900,000
	Sediment basin	$255,000
	Retarding basin	$441,657
	Allowance for drainage infrastructure (pits etc)	$20,000
	Asset Total	**$1,616,657**
	Sub-Total	$4,880,850
	40% Contingency	$1,952,340
	Total cost estimate	$6,833,190

10 Water Harvesting Opportunities Assessment

As outlined in Section 1.2 (State drivers and strategic influences on urban water planning) of this report, the core principles of the State IWM Framework (2017) are to be applied to the KWGC PSP in line with the State Water Plan to ensure ‘communities are resilient and liveable, now and into the future’.

10.1 Stormwater harvesting for public open space irrigation

Treated stormwater presents a valuable opportunity to reduce reliance on potable water for open space irrigation. A high-level assessment of potential demands and yields has been modelled for the precinct. It has been assumed that 5% of the general residential area within the PSP is public open space, with water demand calculated to consider seasonal variations based on average annual rainfall and potential evapotranspiration (PET) losses with plant water requirements. This model set up assumes the water storages are optimised to effectively work as a unit. The modelling only includes the four proposed RBWL assets in the proposed residential area.

Table 7 shows the key parameters and results from the stormwater harvesting model. Due to the seasonal nature of irrigation demands and stormwater availability, it is not feasible to design a stormwater harvesting (SWH) system that meets 100% of irrigation demand, all of the time. SWH is a rainfall dependent practice.

While the wetland systems are treating a combined total of 538ML of water every year for the precinct (which is then discharged to the Seven Creeks directly), most of this volume is through the winter months when there is limited (or no) irrigation demand.

Later, in the dry season, there are limited inflows from the catchments into the RBWL systems, which is also when demand for water is at its highest. This seasonal supply and demand imbalance creates a diminishing return associated with increasing storage sizes, therefore, wetland harvesting schemes are typically designed to meet 80% of the associated demands as they are ‘climate-dependent’ systems (rainfall dependent).

Table 7. Key parameters and results from stormwater harvesting model

Parameter	Value	Unit
General residential zone (GRZ) area (combined source catchment)	167	ha
Total irrigation area	8.4	ha
Annual irrigation rate (to support trees, shrubs, or warm season grasses)	5.9	ML/ha/year
Total demand	49.3	ML/year
Volume of treated stormwater	538	ML/year
Total storage ML to supply 80% reliability (52ML/year)	15	ML
Supply with 1ML storage per wetland as sourced from GRZ (4ML total)	39	ML/year
Reliability with 1ML storage per wetland	**60**	**% of demand**

The volume of storage required to capture enough water in the winter to completely meet the summer demands, is often unfeasible. Figure 23 shows the diminishing return curve for the study area where 80% reliability requires 3.7 ML of storage and delivers 39.44 ML of alternate water supply per annum for irrigation purposes.

By supplying 1 ML of storage at each wetland (in total 4 ML of storage for the precinct assets combined), a reuse supply of 40.08 ML/year or 81.3% of the annual demand can be met.

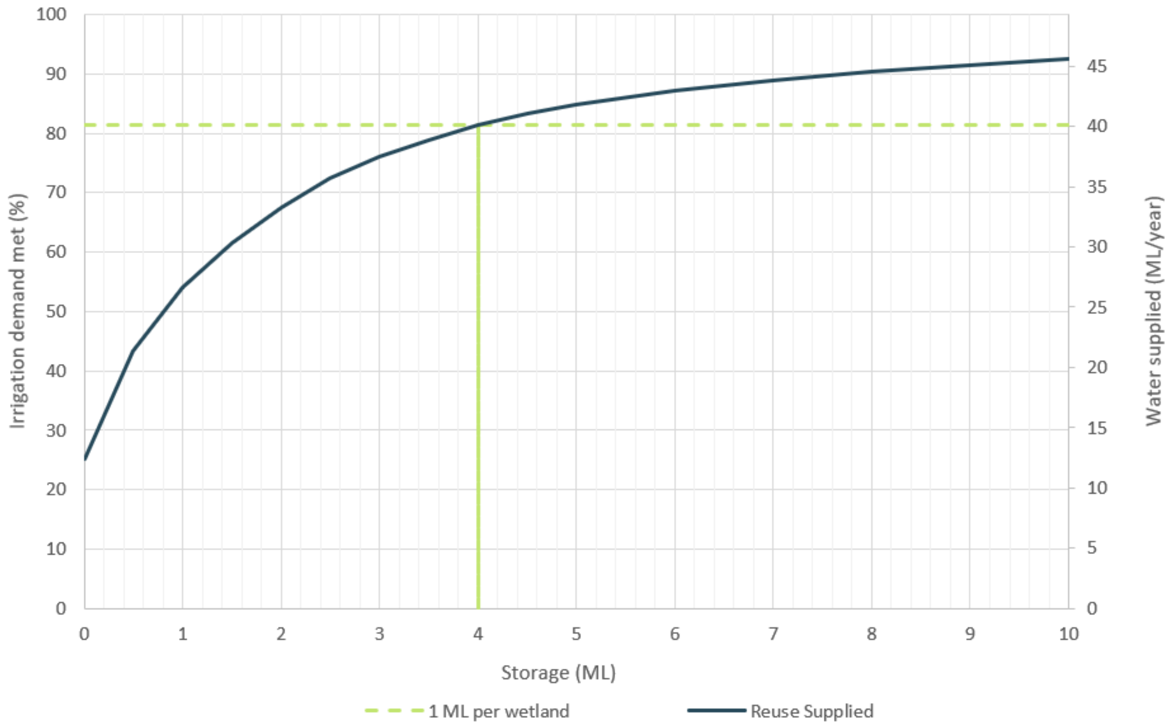


Figure 23. *Results of stormwater harvesting model*

Table 8. General residential area

General Residential Area	167	Ha
Total irrigation area	8.4	Ha
Annual irrigation rate (to support trees, shrubs, or warm season grasses)	5.9	ML/ha/year
Total demand	49.3	ML/year
Volume of treated stormwater	538	ML/year
Total storage ML to supply 80% reliability (49.3ML/year)	3.7	ML
Supply with 1ML storage per wetland (x 4 wetlands = 4ML) from GRZ (only)	40.08	ML/year
Reliability with 1ML storage per wetland	81.27	% of demand

Stormwater harvesting also requires tertiary treatment systems (e.g. UV treatment) to provide safe, alternate water supplies at an acceptable quality (to meet National public health requirements for stormwater reuse). Pumps will also be necessary to extract water from the wetlands and conveyed to future open space areas for irrigation use as an alternate water supply to conserve potable supplies. Water can be distributed through manual standpipes or carting methods, or through automated pump and pipe systems, which could be incorporated as part of the Development Plan stage in the future.

Note: Pump selection should consider the water-energy nexus to ensure savings and sustainable outcomes from alternate water uses, is not undone by high running costs of pumps. There are many energy-efficient, sustainable running, low maintenance cost pump products on the market and this should be part of Council's future considerations and development approvals process to ensure inherited assets are cost-effectively maintainable for the long term (labour and replacements).

10.2 Rainwater harvesting for private domestic use

Rainwater harvesting at a residential level can provide an alternate supply of water for domestic uses such as laundry, toilet, external irrigation etc without further treatment. With treatment (e.g. rain to hot water system) then internal uses can extend to all other water needs (e.g. showering, kitchen). This at source harvesting of rainwater from hard surfaces (house roofs) can reduce the amount of stormwater entering the local stormwater network and subsequently discharging to the Seven Creeks (receiving waterway).

With innovative technology (e.g. smart tanks or South East Water's TankTalk) flood retention planning (managed remotely) can also be a consideration of broader IWM benefits, using smart tanks as a potential distributed network of services, starting at the lot scale (at source controls). This is not currently a requirement, but certainly an avenue being pursued and implemented in some large-scale subdivisions presently (e.g. Docklands redevelopment, Aquarevo subdivision).

While rainwater harvesting is limited to the roof portion of the built form (impervious surfaces), therefore can't be used to mitigate runoff from roads or paved surfaces, when this volume is plumbed directly into households for internal end-uses, with year-round demand (e.g. toilets and laundry) it has an advantage over open space irrigation. If directly plumbed internally, the captured rainwater will be more readily used throughout the winter months (when typically more of it is available) and help place, and maintain, a regular demand on supplies (drawdown). This will also keep this post development additional volume of water from becoming stormwater discharges from private properties to the municipal stormwater network and subsequently, local waterways.

The study area has proposed residential densities (estimates) determined through previous work undertaken. These have been used to determine the number of houses in each sub-catchment. Based on the expected total imperviousness, and the roof sizes of dwellings in similar properties, the MUSIC model was altered to separate roof area from the catchments – this means the rainwater can be modelled separately from the ground surface (stormwater) runoff.

For all areas, a steady annual demand for indoor use has been calculated based on above values.

Table 9. Domestic indoor demand assumptions

	Source	Value	Unit
Residents per household	Greater Shepparton LGA (ABS, 2016 census)	2.5	
Toilet flushing	Melbourne Residential Water Use Studies (Smart Water Fund, 2013)	20	L/p/day
Laundry	Melbourne Residential Water Use Studies (Smart Water Fund, 2013)	21	L/p/day
	Total annual demand per household	**37.4**	**kL**

The stored rainwater could also be used for garden irrigation. We have assumed a watered garden area of 50m^2 per lot, with an irrigation rate of 5.9 ML/ha spread with the same seasonal distribution as the open space irrigation. For the GRZ this represents approximately 20% of the lot to remain permeable area (outdoor garden areas). It is noted that rural properties will have a larger total outdoor area, however there are limited metrics available on the amount of active garden watering done for a range of different sized properties. There will be a large amount of variability between properties.

With larger areas for irrigation, the domestic sized tanks modelled would not be able to meet the 80% reliability, however, a smaller reliability may not be as much of a barrier on a domestic scale, as would be on a municipal scale.

Table 10. Domestic demand across the study area (based on development layouts provided).

Wetland	Zone Type	Dwellings per ha	Area (ha)	Number of houses^	Annual indoor demand (kL)	Annual outdoor demand (kL)
WLRB1	General Residential	10	13.5	135	5,049	3,983
	Rural Living	0.5	54.3	27	1,015	801
WLRB2	General Residential	10	43.8	438	16,381	12,921
WLRB3	General Residential	10	50.7	507	18,962	14,957
WLRB4	General Residential	10	59	590	22,066	17,405
			Total	**1697**	**63,473**	**50,066**

^Note: proposed development densities (number of houses per zone type) is based residential densities of neighbouring areas.

Table 11. Domestic rainwater tank scenarios and results

Rainwater Tank Volumes (kL)	Irrigation Demands	Total demand ML/year	Average reliability (%)	Water supplied (ML/year)
2kL	Indoor only	62.5	89%	55.79
4kL	Indoor only	62.5	96%	60.69
4kL	Outdoor only	49.3	83%	41.4
4kL	Indoor and outdoor	111.7	75%	85.11
5kL	Indoor and outdoor	111.7	79%	89.23

Increasing storage provides increased reliability for the rainwater harvesting system. Water for indoor use has a higher reliability than outdoor use as the tanks are constantly drawn down in all seasons, thereby opening up storage capacity within each tank and allowing them to capture more rainfall – providing greater reliability of supply all year round. In terms of outdoor uses such as garden irrigation, the demands for supply are affected by seasonality. Garden irrigation is at a much higher demand during summer than in winter months. As these tanks are drawn down during summer garden irrigation, there is less consistent rainfall to then refill the tanks - thus leading to a lower reliability of supply for outdoor uses.

It should be noted that while these two harvesting opportunities can be used together, the impact is not simply additive. Rainwater harvesting on a domestic scale will divert some of the roof water, which would reduce the lot's stormwater runoff volumes, and collectively reduce the alternate water available for irrigation for the public open space irrigation system.

For example, pairing lot scale indoor and outdoor domestic uses with 4kL tanks (which captures up to 159.7 ML/year) with the 4ML of storage for public open space reuse scenario (which captured 40.08 ML/year - 81% of demand), the open space harvesting capture is reduced to 34ML/year (69% of demand). The cumulative total would be 119 ML/year.

10.3 Climate Change Impacts

To better understand the influence of climate change on rainwater harvesting in the KWGC Precinct, changes to the rainfall and PET (potential evapotranspiration) have been modelled using the median changes for PET and rainfall to estimate the impacts of climate change on rainwater harvesting in 2065 (based on the values from Section 7.1). This has been done by adjusting the climate input data in the MUSIC model and the seasonal demands for plant watering.

We have modelled the 4kL domestic rainwater tanks “indoor only” and “outdoor only” scenarios for comparison. The indoor demand for toilet flushing and laundry use has been assumed to remain steady over time, though it may decrease as appliances become more water efficient (and/or household person profiles/makeups change). Table 12 shows a comparison of results for the historical climate and the 2065 future scenario.

The reduced rainfall has a direct impact on the amount of inflow into the tanks in both scenarios, as well as the demand for outdoor watering. Garden irrigation demand increased, as there is a larger shortfall between water requirements (demand) and water availability (supply) due to the combination of:

- increased water demand from increased PET, and
- a reduced ability of rainfall to meet the plant irrigation requirements.

Table 12. Results of model testing impact of climate change on rainwater harvesting

Scenario	Parameter	Historical climate	2065 Future climate
Both	Total inflow (ML/year)	429	426
4kL tanks, Indoor demand only	Total demand (ML/year)	63.3	63.3
	Average reliability (%)	96%	96.2%
	Water supplied (ML/year)	60.69	60.79
4kL tanks, Outdoor demand only	Total demand ML/year	50.1	55
	Average reliability (%)	83%	80%
	Water supplied (ML/year)	41.4	44.87

The results show that the impact on the indoor water availability is minimal, however there is a noticeable change in the water reliability for outdoor use. Harvesting for indoor reuse is not as sensitive to the overall reductions in rainfall expected under climate change. It is important to reiterate that this modelling has not considered the seasonal impacts of climate change which would likely further reduce reliability.

11 Conclusions

To be formulated following functional designs and consultation period as part of Final IWMP.

12 References

BMT WBM, March 2017. *Shepparton East Overland Flow Urban Flood Study – Final Report.*

CSIRO, 1999, *Urban Stormwater Best Practice Environmental Management (BPEM) Guidelines (Victorian Stormwater Committee).*

Geoscience Australia, 2019. *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia.

Melbourne Water Corporation, Water Sensitive Urban Design Life Cycle Costing Data, Healthy Waterways.

The State of Victoria Department of Environment, Land, Water and Planning, 2018, *Goulburn Broken Strategic Directions Statement.*

The State of Victoria Department of Environment, Land, Water and Planning, 2017, *Integrated Water Management Framework for Victoria.*

The State of Victoria Department of Environment, Land, Water and Planning, 2016, *Water for Victoria – Water Plan.*

Water Technology, March 2019. *Shepparton Mooroopna Flood Mapping and Flood Intelligence Study*.

Water Technology, August 2021. *Shepparton Mooroopna 1% AEP Flood Mapping Project.*

Yorta Yorta Nation Aboriginal Corporation website: www.yynac.com.au.

Appendix A
Stormwater Quantity Modelling (RORB)

A.1 Input parameters

Model inputs were obtained from the ARR2019 data hub and the Bureau of Meteorology's IFD data. An initial loss /continuing loss model configuration was adopted.

For all models:

- Temporal Patterns – Murray Basin (Vic/NSW)
- Catchment fraction imperviousness based on values from Section 5.5 (above).

Table 13 RORB input variable sources

RORB input variable	Source
IFD data	Murray Basin (Vic/NSW)
Temporal patterns	Murray Basin (Vic/NSW)
Kc	*K_c=1.25 * dav (for Victorian catchments Pearse et al. 2002)*
IL	Shepparton East Overland Flow Urban Flood Study
CL	Shepparton East Overland Flow Urban Flood Study

The kc values adopted for each model are shown in

Table 14, as are the initial loss (IL) and continuing loss (CL) values. The justification of the kc equation adopted for the models is provided in the calibration section below.

Table 14. RORB models and parameters values

RORB catchment	Total Area (km^2)	Kc	m	Predeveloped IL (mm)	CL (mm/hr)
WLRB1	0.788	0.64	0.8	15	2
WLRB2	0.558	0.63	0.8	15	2
WLRB3	0.633	0.60	0.8	15	2
WLRB4	0.778	0.57	0.8	15	2

A.2 Method

The RORB models were used to estimate key design flows throughout the catchment and size retarding basin storages. In accordance with best practice modelling procedures, at least 4 sub-areas exist upstream from the point of interest.

The hydrologic modelling considered an ensemble simulation for the 1% Annual Exceedance Probability (AEP) event, for durations 10 minutes to 72 hours. From the ensemble simulation, ten temporal patterns were used to determine peak runoffs for each duration. The median flows (i.e. 6^{th} highest peak flow) for each storm duration was determined, and the peak critical flow with respect to storage, was calculated.

Following the release of the updated Australian Rainfall & Runoff (ARR 2019) Guidelines in April (2019) a new approach is to be undertaken when estimating peak runoff from a specified catchment. Key changes that will influence the hydrologic modelling outputs include:

- Updated Intensity Frequency Duration (IFD) data based on updated rainfall data from several rainfall stations. This is sourced from BoM's website.

- Running the model based upon a Monte Carlo simulation, with a set of ten temporal patterns sourced from the AR&R data hub, to determine the statistical peak flow for a given storm event and duration, rather than using a single temporal pattern. The Monte Carlo method is a mathematical technique used to quantitatively analyse degree of event risk.
- Using an Initial Loss / Continuing Loss model, rather than a Runoff Coefficient model.

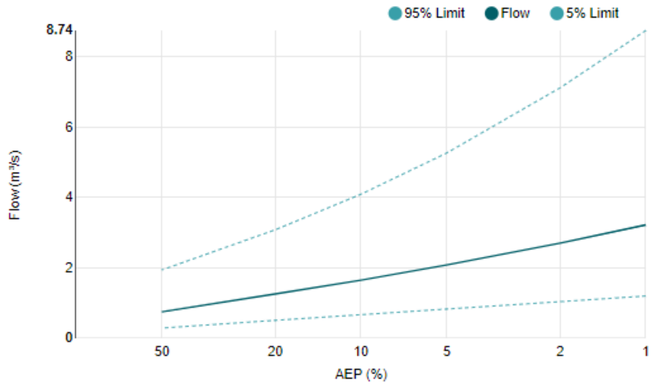
A.3 Rainfall estimation calibration

In line with the Australian Rainfall & Runoff (2019), calibration of the hydrologic model (i.e. RORB model) was undertaken to determine the estimation of rainfall intensities for a specific site.

The Australian Rainfall & Runoff 2019 guidelines suggests that the model be calibrated in line with the Regional Flood Frequency Estimation model (RFFE), whilst using Initial Loss (IL) & Continuing Loss (CL) values provided from the ARR datahub.

Separate RFFE models were produced for each of the four catchments in this study. The input data and results for Catchments 1-4 can be found in Figure 24, Figure 25, Figure 26 and Figure 27, respectively.

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	0.750	0.290	1.94
20	1.26	0.510	3.08
10	1.65	0.670	4.09
5	2.08	0.830	5.26
2	2.70	1.04	7.11
1	3.22	1.20	8.74

Statistics

Variable	Value	Standard Dev
Mean	-0.285	0.556
Standard Dev	0.606	0.207
Skew	0.100	0.029

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

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

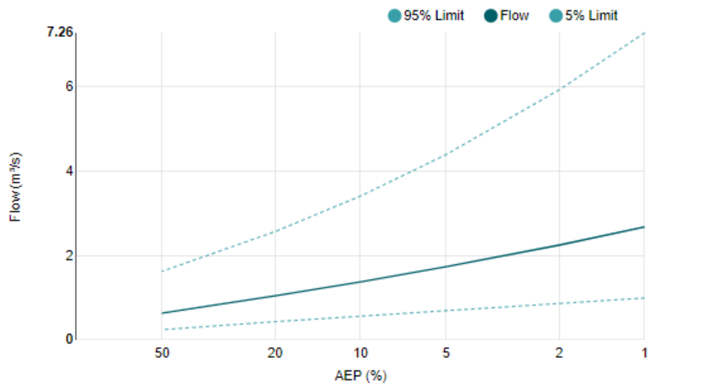
Note: These statistics are common to each region. Details.

Input Data

Date/Time	2022-03-11 12:31
Catchment Name	Catchment1
Latitude (Outlet)	-36.45
Longitude (Outlet)	145.383
Latitude (Centroid)	-36.455
Longitude (Centroid)	145.383
Catchment Area (km^2)	0.789
Distance to Nearest Gauged Catchment (km)	20.0
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.824228
2% AEP 6 Hour Rainfall Intensity (mm/h)	10.522966
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.63
Interpolation Method	Natural Neighbour
Bias Correction Value	0.512

Figure 24. *Catchment 1 - RFFE model inputs and results*

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	0.630	0.240	1.62
20	1.04	0.430	2.56
10	1.37	0.560	3.40
5	1.73	0.690	4.38
2	2.24	0.860	5.91
1	2.67	0.990	7.26

Statistics

Variable	Value	Standard Dev
Mean	-0.450	0.556
Standard Dev	0.606	0.207
Skew	0.100	0.029

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

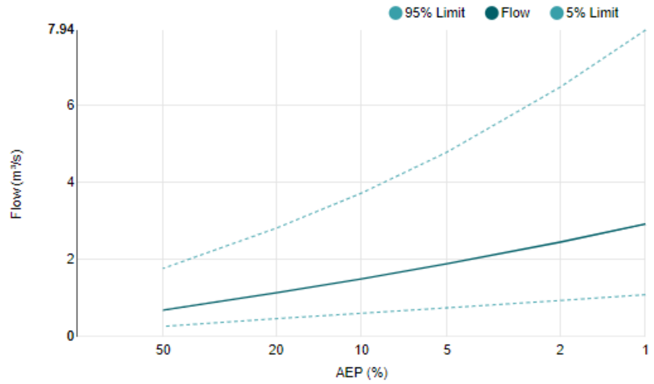
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

Input Data	
Date/Time	2022-03-11 12:33
Catchment Name	Catchment2
Latitude (Outlet)	-36.438
Longitude (Outlet)	145.377
Latitude (Centroid)	-36.442
Longitude (Centroid)	145.371
Catchment Area (km^2)	0.557
Distance to Nearest Gauged Catchment (km)	21.1
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.786015
2% AEP 6 Hour Rainfall Intensity (mm/h)	10.385831
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.93
Interpolation Method	Natural Neighbour
Bias Correction Value	0.52

Figure 25. *Catchment 2 - RFFE model inputs and results*

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	0.690	0.270	1.77
20	1.14	0.470	2.81
10	1.50	0.610	3.72
5	1.89	0.750	4.78
2	2.45	0.940	6.46
1	2.92	1.09	7.94

Input Data

Date/Time	2022-03-11 12:35
Catchment Name	Catchment3
Latitude (Outlet)	-36.432
Longitude (Outlet)	145.375
Latitude (Centroid)	-36.432
Longitude (Centroid)	145.369
Catchment Area (km^2)	0.663
Distance to Nearest Gauged Catchment (km)	21.7
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.786015
2% AEP 6 Hour Rainfall Intensity (mm/h)	10.385831
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.66
Interpolation Method	Natural Neighbour
Bias Correction Value	0.525

Statistics

Variable	Value	Standard Dev
Mean	-0.376	0.556
Standard Dev	0.606	0.207
Skew	0.100	0.029

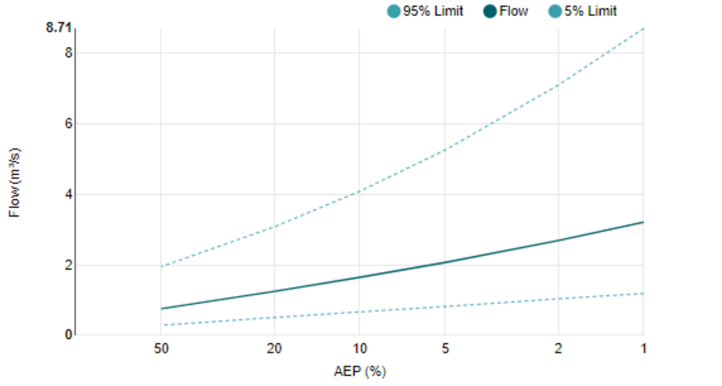
Note: These statistics come from the nearest gauged catchment. Details.

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

Figure 26. *Catchment 3 - RFFE model inputs and results*

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	0.760	0.290	1.95
20	1.25	0.510	3.08
10	1.65	0.670	4.09
5	2.07	0.820	5.26
2	2.69	1.04	7.10
1	3.21	1.19	8.71

Input Data

Date/Time	2022-03-11 12:36
Catchment Name	Catchment4
Latitude (Outlet)	-36.423
Longitude (Outlet)	145.377
Latitude (Centroid)	-36.427
Longitude (Centroid)	145.373
Catchment Area (km^2)	0.757
Distance to Nearest Gauged Catchment (km)	22.71
50% AEP 6 Hour Rainfall Intensity (mm/h)	4.786015
2% AEP 6 Hour Rainfall Intensity (mm/h)	10.385831
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.66
Interpolation Method	Natural Neighbour
Bias Correction Value	0.534

Statistics

Variable	Value	Standard Dev
Mean	-0.284	0.556
Standard Dev	0.606	0.207
Skew	0.100	0.029

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

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

Figure 27. *Catchment 4 - RFFE model inputs and result*

Several Kc formulas were investigated to determine their accordance with RFFE results. The annual rainfall for the closest region centre (Shepparton) is less 800mm according to the BoM website. As such the following Kc formulas were explored:

- $Kc = 0.49 \times A^{0.65}$ (for regions with mean annual rainfall less than 800mm)
- $Kc = 1.25 \times D_{av}$ (for Victorian catchments, Pearse et al. 2002)
- $Kc = 1.14 \times D_{av}$ (for Australia wide catchments Dyer 1994)

The resulting Kc values for each of the catchments are shown in Table 15.

Table 15 Kc values for each catchment

Catchment	Less than 800mm ($Kc = 0.49 \times A^{0.65}$)	Pearse et al. 2002 ($Kc = 1.25 \times D_{av}$)	Dyer 1994 ($Kc = 1.14 \times D_{av}$)
1	0.42	0.64	0.58
2	0.34	0.63	0.58
3	0.36	0.60	0.55
4	0.42	0.57	0.52

Comparing the results from the RORB models with RFFE results, all RORB equations produced results within the confidence limits of the RFFE, however none were aligning with the median RFFE value (see Figure 28).

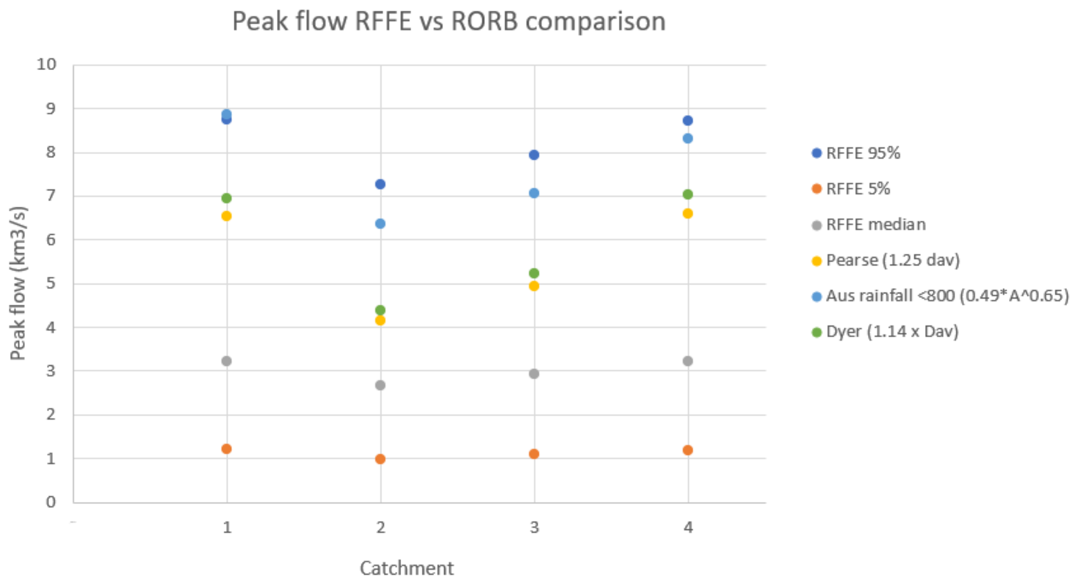


Figure 28. *RFFE vs RORB comparison (Kc calibration)*

When running the RFFE model, there appear to be no data points of relative catchment size to the study area. Figure 29 shows the catchment as an outlier compared to the catchment in the model on all the measures, which does suggest the flow from RFFE is not directly relatable, and a flow between the upper and lower confidence limit is more likely (Figure 29).

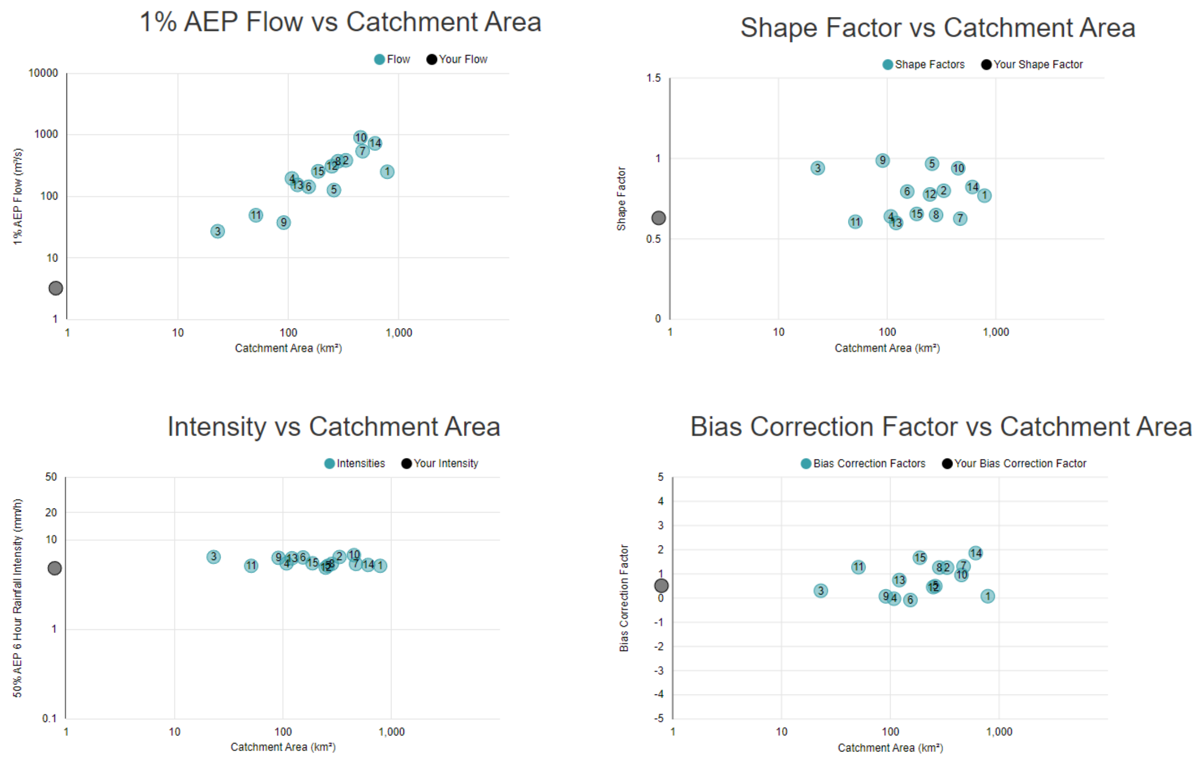


Figure 29. *RFFE rainfall station statistics for Catchment 1 (largest catchment)*

As a result, a check was performed using the rational method and factored this up for a rural catchment, whilst applying an area size factor (Fa) and the ARI factor (Fy) from the VicRoads drainage manual, where:

$$P_Y = P_{10}\, F_Y\, F_A$$

Where

P_Y = the discharge factor for "Y" year ARI

P_{10} = the 10 year ARI factor read from Figure 7.2.1 (rural catchments only)

F_Y = an ARI factor read from Table 7.2.8
F_A = an area size factor, which may be read from Figure 7.2.2 or calculated from:

$F_A = 1.0$ (F_A Not Applicable)
If A > 5000 ha

$F_A = \{1.6 - 0.6(A\text{-}1000)/4000\}$
If 1001 < A < 5000 ha

$F_A = \{2.1 - (A/2000)\}$
301 < A < 1000 ha

$F_A = 2.0$ approx.
If 0 < A < 300 ha

Fy is taken from the table inset below.

Average recurrence Interval (years)	F_Y
1	0.65
2	0.75
5	0.90
10	1.00
20	1.10
50	1.20
100	1.30

Source: After Table 5.4 of ARR 1987 (Ref 13)

Where P_{10} = 0.148

When applying the above factors, the rational flow resulted in a peak 1% AEP flow for Catchment 1 of 5.25 m^3/s (AR&R Vic). In comparison, when not applying the areal factors, rational results for Catchment 1 was 2.63 m^3/s.

Following an analysis of the RFFE tool and rational method, the Pearse et al formula for Victorian catchments (i.e. 1.25 * dav), correlated the most with the rational method flows, which still lies within the confidence limit of the RFFE, while remaining relatively similar to the rational calculations when areal reduction factors are considered.

Table 16. Summary of Kc calibration flows for the 1% AEP

Catchment	Rural Rational (applying VicRoads Areal factors)	Pearse Eq.	Dyer (1994)	Vic <800 Eq.
1	5.25	6.52	6.93	8.87
2	4.01	4.14	4.37	6.35
3	4.43	4.93	5.23	7.06
4	5.2	6.56	7.04	8.32

As a result, the Pearse et al. formula for Victorian catchments was adopted for the Kc, and flows were determined using RORB.

Appendix B
Treatment Modelling (MUSIC)

B.1 Modelling inputs

The MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model developed for each scenario included the following input parameters:

- A historic rainfall dataset was obtained from BoM for the Dookie rainfall gauge (#081013, from 1950-2010). The average annual rainfall over this entire period was obtained from BoM and used to select a ten-year period from the historic dataset, which produced a similar average annual rainfall. The average annual rainfall from BoM was 506mm. The period from 1961-1970 was adopted, which has an annual average rainfall of 527mm.
- The monthly average evaporation for Shepparton was also obtained from BoM.
- MUSIC models were run at 6-minute timestep.
- Fraction impervious values and areas for sub catchments consistent with Figure 30.
- Wetlands designed to not exceed 72.0 hours detention time, to prevent terrestrial and aquatic vegetation from 'drowning'.

The iterative process of sizing the treatment infrastructure in MUSIC for the PSP is outlined below.

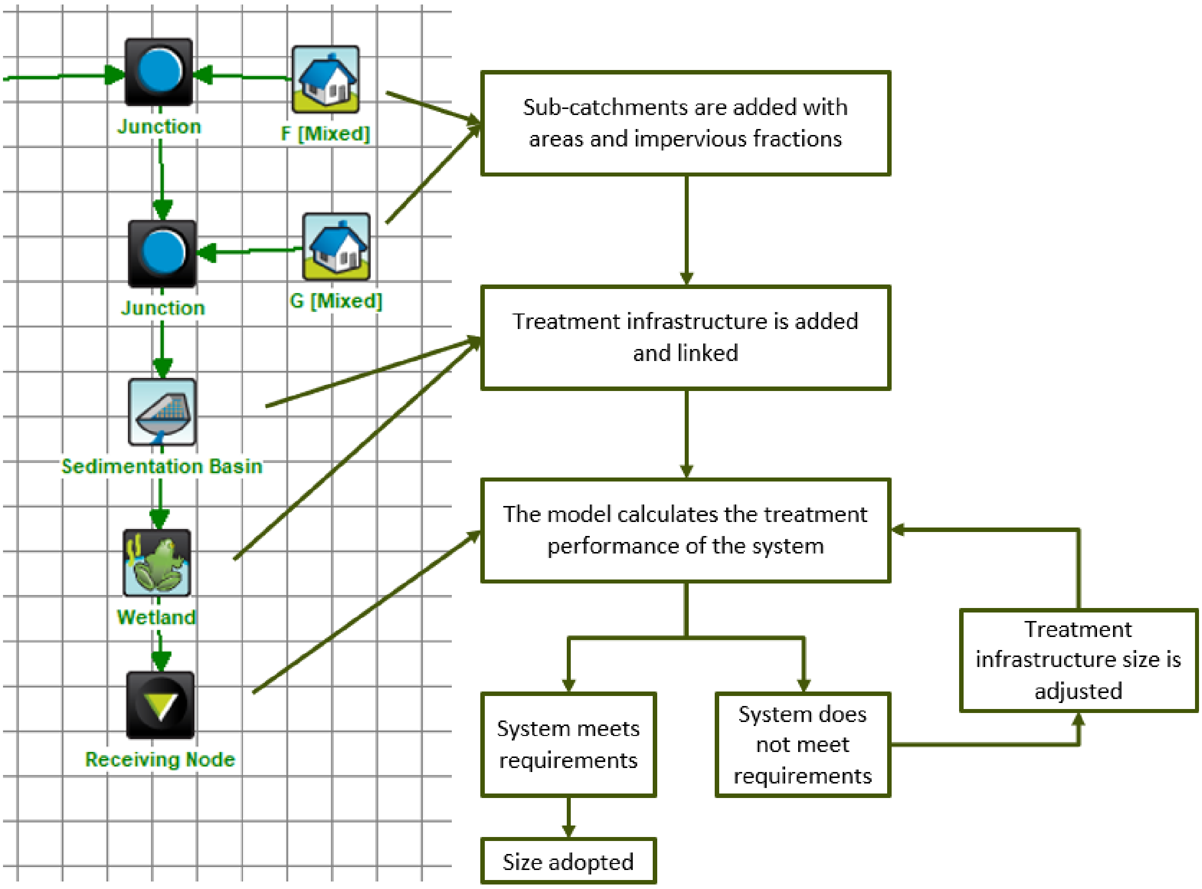


Figure 30. *Simplified MUSIC Method*

B.2 Sediment Basin sizing

The sediment basins in the treatment modelling have been sized using the Fair and Geyer equation, where sediment basins are required to meet the following criteria:

- Capture 95% of coarse particles ≥ 125 µm diameter for the peak three-month ARI event.

The sediment basin sizing was used for the inlet pond in the wetland node (assuming an average depth of 1m).

Table 17. Sediment basin sizing

	Parameter	RBWL1	RBWL2	RBWL3	RBWL4
Conditions	Contributing Catchment (ha)	67.8^	43.8	50.7	59.0
	Area of Basin (m^2)	800	1300	1400	1700
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11	11	11	11
	Hydraulic Efficiency (λ)	0.11	0.11	0.11	0.11
	Permanent Pool Depth, dp (m)	0.7	0.7	0.7	0.7
	Extended detention depth, de	0.35	0.35	0.35	0.35
	Number of CTSR's, n	1.1	1.1	1.1	1.1
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	0.7	0.7	0.7	0.7
	Design Discharge (m^3/s) [Q3-month]	0.480	0.670	0.832	0.932
	Capture Efficiency	96%	97%	96%	96%
	Check (>95%)	Ok	Ok	Ok	Ok
Sediment Storage	Sediment Loading rate, Lo (m^3/ha/yr) (varied relative to a 'standard' urban catchment)	2	2	2	2
	Desired clean-out frequency, Fr	5	5	5	5
	Storage volume required, St	240	423	487	568
	Available sediment storage volume	280	455	490	595
	Available storage > required storage	Ok	Ok	Ok	Ok
Sediment dewatering	Depth for dewatering area (m)	0.5	0.5	0.5	0.5
	Area required for dewatering (m^2)	480	846	973	1136

^Of the contributing catchment for RBWL1, only 25ha is considered developed (with the remaining 42.8 ha zoned for low density rural living)

Table 18. WL1 treatment results

	Source load	Residual load	% Reduction	Kg/yr removed
Total Suspended Solids (kg/yr)	14800	4480	69.8*	10320
Total Phosphorus (kg/yr)	34.6	15	56.7	19.6
Total Nitrogen (kg/yr)	273	177	35.3*	96
Gross Pollutants (kg/yr)	3390	0	100	3390

*slight shortfall to targets – to be refined further at functional stage

Table 19. WL2 treatment results

	Source load	Residual load	% Reduction	Kg/yr removed
Total Suspended Solids (kg/yr)	23600	5370	77.2*	18230
Total Phosphorus (kg/yr)	49.4	17.2	65.3	32.2
Total Nitrogen (kg/yr)	350	200	42.9*	150
Gross Pollutants (kg/yr)	5370	0	100	5370

*slight shortfall to targets – to be refined further at functional stage

Table 20. WL3 treatment results

	Source load	Residual load	% Reduction	Kg/yr removed
Total Suspended Solids (kg/yr)	26700	4700	82.4	22000
Total Phosphorus (kg/yr)	56.6	17	70	39.6
Total Nitrogen (kg/yr)	405	208	48.6	197
Gross Pollutants (kg/yr)	6210	0	100	6210

Table 21. WL4 treatment results

	Source load	Residual load	% Reduction	Kg/yr removed
Total Suspended Solids (kg/yr)	31600	4880	84.6	26720
Total Phosphorus (kg/yr)	65.5	17.6	73.1	47.9
Total Nitrogen (kg/yr)	472	226	52.1	246
Gross Pollutants (kg/yr)	7230	0	100	7230

Appendix C
Stormwater Asset Cost Estimates

Table 22. Retarding Basin cost estimates

Catchment		Area (m2)	Excavation Volume (m3)	Terrestrial planting area (total area minus treatment area) (m2)	Rate	Total
WLRB1	Total Area	13,614				
	Excavation cost		16,500		$4.50 per m3	$74,250.00
	Planting cost			9,814	$17.00 per m2^	$166,838.00
					TOTAL	**$241,088.00**
WLRB2	Total Area	14,998				
	Excavation cost		25,500		$4.50 per m3	$114,750.00
	Planting cost			7,698	$17.00 per m2^	$130,866.00
					TOTAL	**$245,616.00**
WLRB3	Total Area	21,517				
	Excavation cost		33,000		$4.50 per m3	$148,500.00
	Planting cost			11,117	$17.00 per m2^	$188,989.00
					TOTAL	**$337,489.00**
WLRB4	Total Area	27,371				
	Excavation cost		46,500		$4.50 per m3	$209,250.00
	Planting cost			13,671	$17.00 per m2^	$232,407.00
					TOTAL	**$441,657.00**
	Total (all assets)	77,499	121,500	42,300		$1,265,850.00

^Note: per square meter figure for planting costs is based on industry standards for 'supply and install' and consists of $5/m^2 jute matting, $4/m^2 mulch and $8/m^2 plants @ 4per m^2 (@$2 each).

Table 23. Combined asset cost estimates

Catchment	Assets		Size NWL (m^2)	Estimated overall footprint (m^2)	Capital rate (per m^2)	Capital cost
RBWL1	Wetland		3,000		$100	$300,000
	Sediment basin		800		$200	$160,000
	Retarding basin*			13,614		$241,088
	Allowance for drainage infrastructure (pits etc)					$20,000
		TOTAL	**18,530**	**26,220**		**$721,088**
RBWL2	Wetland		6,000		$100	$600,000
	Sediment basin		1,400		$150	$210,000
	Retarding basin*			14,998		$245,616
	Allowance for drainage infrastructure (pits etc)					$20,000
		TOTAL	**13,720**	**20,020**		**$1,075,616**
RBWL3	Wetland		9,000		$100	$900,000
	Sediment basin		1,400		$150	$210,000
	Retarding basin*			21,517		$337,489
	Allowance for drainage infrastructure (pits etc)					$20,000
		TOTAL	**13,220**	**17,560**		**$1,467,489**
RBWL4	Wetland		12,000		$75	$900,000
	Sediment basin		1,700		$150	$255,000
	Retarding basin*			27,371		$441,657
	Allowance for drainage infrastructure (pits etc)					$20,000
		TOTAL	**12,760**	**18,090**		**$1,616,657**

*RB estimates from Table 22

Table 24. High level total cost estimate – concept stage only

Asset	Cost
RBWL1	$721,088
RBWL2	$1,075,616
RBWL3	$1,467,489
RBWL4	$1,616,657
Sub-Total	**$4,880,850**
40% Contingency	**$1,952,340**
Total Cost Estimate	**$6,833,190**
Developable area (ha)	161
Cost per hectare ($/ha)	$42,442

Appendix D
Life Cycle Costing Data (MW)

Water sensitive urban design
Life cycle costing data

Melbourne Water has recently developed a life cycle costing data table to assist councils in estimating costs associated with stormwater treatment asset planning during the design, construction, establishment, maintenance and renewal phases. The data will inform council budgets and ensure allowances for stormwater treatment assets are based on whole of life cycle costs.

The life cycle cost information is grouped according to asset type, size, service level (maintenance frequency) and, where possible, contracted rates versus in-house works. Other factors including traffic management and access issues are also considered.

A summary of the life cycle costs for asset construction, maintenance (establishment and ongoing) and renewal is provided overleaf.

BENEFITS OF WATER SENSITIVE URBAN DESIGN

Water Sensitive Urban Design aims to integrate the urban water cycle into urban design. The social and environmental benefits of stormwater treatment systems are widely recognised and include:

- improved urban waterways
- greener open spaces and enhanced urban landscapes
- reduced localised flooding
- improved amenity in our local communities
- alternative water supply option.

HOW COUNCILS CAN USE THE DATA

The life cycle costing data can be used by councils to refine stormwater treatment asset management planning. In particular, the life cycle costs will enable councils to better plan for maintenance of stormwater treatment assets and refine budgets for life cycle costs of individual stormwater treatment assets. This includes informing and assisting councils to better forecast budgets for the management of stormwater treatment assets.

The incorporation of realistic maintenance costs into council budgets will help ensure that stormwater treatment assets are adequately maintained; and therefore help reduce the financial burden to councils associated with rectifying assets that are failing due to inadequate maintenance.

It is expected that the maintenance cost estimates provided will assist councils to get better value for money when negotiating maintenance contracts.

For more information on inspection and maintenance schedules and sample maintenance contract documentation please refer to the Melbourne Water WSUD Maintenance Guidelines on our website **melbournewater.com.au**

For access to the full Life Cycle Costing Report, please contact the Melbourne Water Stormwater Team at livingrivers@melbournewater.com.au

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ASSET	ASSET PARAMETERS	CONSTRUCTION[1]	MAINTENANCE		RENEWAL
			ESTABLISHMENT (FIRST TWO YEARS)	ONGOING	
WETLANDS[2]	< 500 m^2 500 to 10,000 m^2 > 10,000 m^2	\$150/m^2 \$100/m^2 \$75/m^2		\$10/m^2/yr \$2/m^2/yr \$0.5/m^2/yr	No data
SEDIMENT BASINS[2]	< 250 m^2 250 to 1000 m^2 > 1000 m^2	\$250/m^2 \$200/m^2 \$150/m^2		\$20/m^2/yr \$10/m^2/yr \$5/m^2/yr	Remove and dispose of: Dry waste = \$250/m^3 Liquid waste = \$1,300/m^3
ON-STREET RAINGARDENS[3]	< 50 m^2 50 to 250 m^2 > 250 m^2	\$2000/m^2 \$1000/m^2 \$500/m^2		\$30/m^2/yr \$15/m^2/yr \$10/m^2/yr	Minor reset = \$50 to \$100/m^2
BIORETENTION BASINS[3]	< 100 m^2 100 to 500 m^2 > 500 m^2	\$1000/m^2 \$350/m^2 \$250/m^2		\$5/m^2/yr	No data
TREE PITS[3]	< 10 m^2 total 10 to 50 m^2 total > 50 m^2 total	\$8000/m^2 \$5000/m^2 \$1000/m^2	Two to five times ongoing maintenance cost	No access issues = \$150/asset/yr Traffic issues or specialist equipment required = \$500/asset/yr	No data
GRASS SWALES AND BUFFER STRIPS[4]	Seeded – no subsoil drain Seeded – subsoil drain Turfed – no subsoil drain Turfed – subsoil drain Native grasses established	\$15/m^2 \$25/m^2 \$20/m^2 \$35/m^2 \$60/m^2		\$3/m^2/yr	No data
VEGETATED SWALES AND BIORETENTION SWALES[4]		150/m^2		\$5/m^2/yr	No data
IN-GROUND GPTS	< 300 L/s 300 to 2000 L/s > 2000 L/s	\$50,000/asset \$150,000/asset \$250,000/asset	N/A	Inspection = \$100/visit Cleanout = \$1000/visit	No data

1 Includes planning and design
2 Area at normal water level
3 Area of filter media at bottom of extended detention
4 Total vegetated area

Disclaimer: The cost estimates provided should be considered as a starting point only and represent the best cost estimates available based on current information (Oct 2013). The cost estimates will be reviewed and refined over time as better data becomes available. It should be noted that data are generally based on 'standard residential' developments and the cost of equipment hire is not included in the estimates.