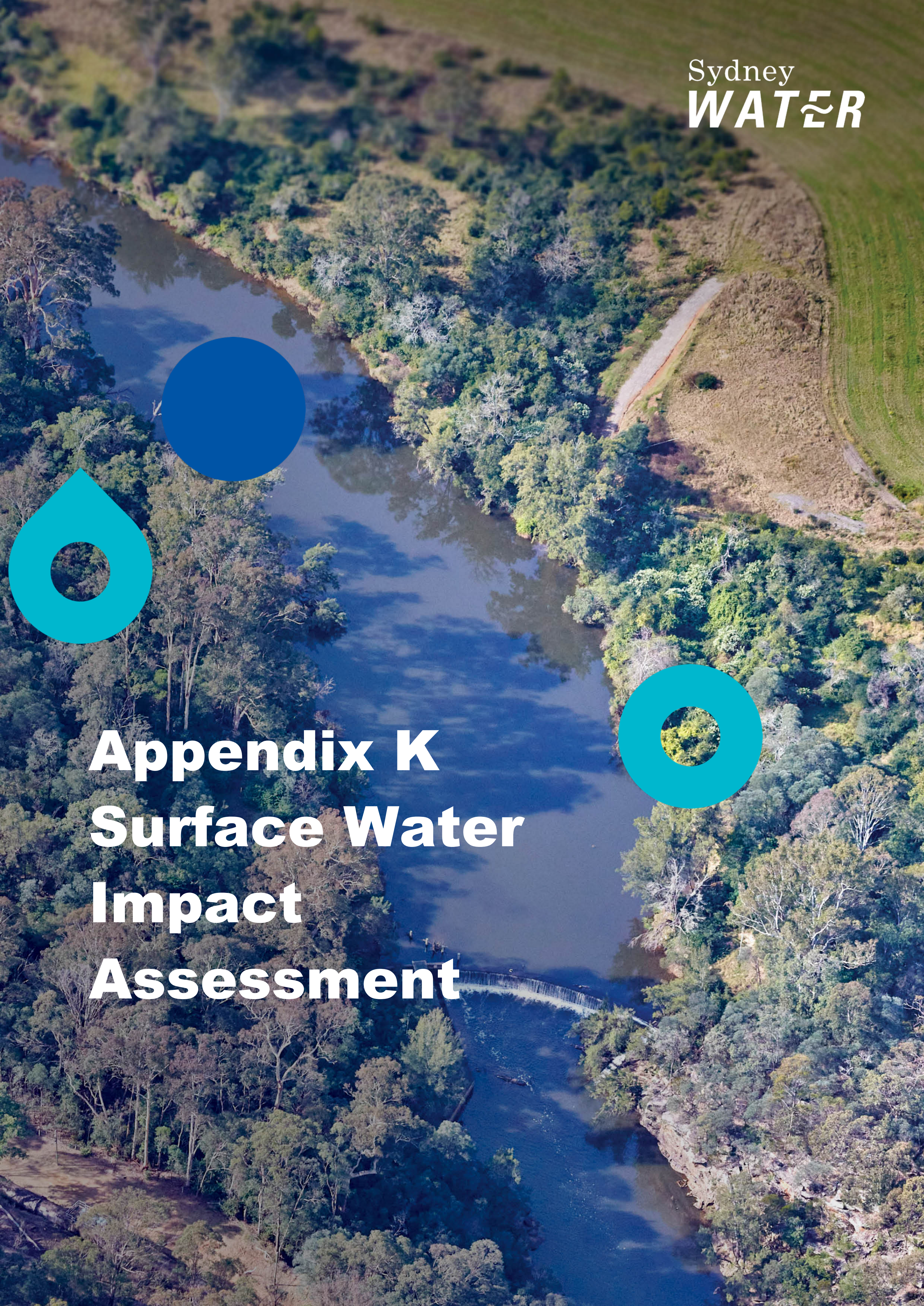

Appendix K Surface Water Impact Assessment

Upper South Creek Advanced Water Recycling Centre

Surface Water Impact Assessment

Final

Executive Summary

The objective of the Environmental Impact Statement – Surface Water Impact Assessment is to assess and address potential surface water impacts associated with stormwater runoff generated during the construction and operational phases of the Upper South Creek Advanced Water Recycling Centre (AWRC), water pipelines and ancillary infrastructure (the Project). It also aims to provide guidance on ways of mitigating and managing the potential impacts on waterway health and protect environmental values in downstream waterways. It should be noted that treated water discharges from the treatment process are assessed in the *Hydrodynamic and Water Quality Impact Assessment* and the *Eco-hydraulic and Geomorphology Assessment*. The *Flood Impact Assessment* documents the potential impacts on flood behaviour in the downstream floodplain.

The key areas covered in this report are:

- Potential impacts of stormwater runoff from the Project on the water quality of any receiving bodies of water
- Potential changes that stormwater runoff from the Project would have on waterway hydrology
  - Environmental water balance (specifically relating to average discharge and recharge rates)
  - Peak stormwater discharge rates

Available surface water quality data for the watercourses located within the study area was collated and compared to the applicable guideline values, which include the Project's waterway objectives for Wianamatta-South Creek and the Nepean and Warragamba Rivers.

The AWRC reference design includes sediment management basins, stormwater infrastructure and water sensitive urban design elements (including bioretention, wetlands, passively irrigated biofiltration street trees and rainwater harvesting), and food detention basins that have been sized to achieve the relevant water quality, and low flow and flood flow objectives. The EIS thereby finds that the Project reference design for the AWRC would have an acceptable impact on downstream waterway health and flood conditions.

A Project reference design of water pipelines and ancillary infrastructure has also been prepared. Surface water impacts associated with these components of the Project are limited to construction works around waterways. The impact assessment of the pipeline reference design finds that construction and trenching works around waterways requires specific environmental management plans to minimise the potential impacts that cannot be completely mitigated through design. The temporary nature and relatively small footprints of construction works, and the relatively routine nature of those works means that the impacts would be unlikely and non-permanent.

Overall, with the implementation of the proposed mitigation measures, the impacts of stormwater discharges associated with Project would be acceptable during both the construction and operation phases.

Additional monitoring is recommended to occur prior to and during construction to confirm stormwater management objectives are being achieved as intended.

Job title	Upper South Creek Advanced Water Recycling Centre	**Job number** 505018	
Document title	Surface Water Impact Assessment	**File reference:** as above	
Document ref			

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		Signature			

Issue Document Verification with Document ✓

Glossary and Abbreviations

Term	Abbreviation	Definition
Advanced Water Recycling Centre	AWRC	Proposed centre for treatment of the wastewater prior to reuse applications or discharge, which includes liquids treatment, advanced water treatment, solids treatment, odour treatment, and residuals management
Ancillary infrastructure	-	This is permanent infrastructure to support operation of the AWRC and may include a range of infrastructure such as access roads and provision of utilities such as power.
Annual Exceedance Probability	AEP	The Annual Exceedance Probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. A one per cent event is a rainfall event with a one per cent chance of being exceeded in magnitude in any year.
Australian Height Datum	AHD	A common reference level used in Australia which is approximately equivalent to the height above sea level in meters.
Average Dry Weather Flow	ADWF	ADWF consists of average daily wastewater flows. ADWF is the average flow that occurs on a daily basis with no evident reaction to rainfall.
Average Recurrence Interval	ARI	The Average Recurrence Interval, like the Annual Exceedance Probability, is a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a 100-year average recurrence interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is an average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random.
Brine pipeline	-	A pipeline to transport brine (salty/concentrated wastewater). Brine water is a by-product of reverse osmosis in the wastewater treatment process.
Construction Environmental Management Plan	CEMP	A CEMP describes how activities undertaken during the construction phase of development will be managed to avoid or mitigate environmental or nuisance impacts, and how those environmental management requirements will be implemented.
Critical State Significant Infrastructure	CSSI	Critical State significant infrastructure projects are high priority infrastructure projects that are essential to the State for economic, social or environmental reasons.
Desktop assessment area	-	The area defined for footprint-related specialist desktop assessments.
Dissolved Oxygen	DO	The oxygen level present in water expressed as percentage saturation

Term	Abbreviation	Definition
Dry Weather Overflows	DWO	When the wastewater network is blocked or becomes full, wastewater can 'overflow' from pipes to the local environment or within private properties. Dry weather overflows are caused by blockages in wastewater pipes. Most are caused by tree roots.
Early works	-	Before construction commences, Sydney Water may need to optimise and finalise alignments, and to confirm design and constructability, such as survey works, condition surveys, or investigating utilities.
Environmental Impact Statement	EIS	An Environmental Impact Statement is a publicly available document that provides information on a project, including its environmental impacts and mitigation measures, and is used to inform development consent decisions
Environmental flows	E-flows	Environmental flows refer to water released from a dam or weir to sustain healthy rivers. Some of the Sydney Water wastewater treatment and water recycling facilities also release treated wastewater into creeks and rivers. This can help improve conditions for native fish, frogs, birds, plants and other animals. It can also reduce the likelihood of algal blooms and enhance recreational uses. Environmental Flows from the AWRC may be used, supplement or replace flows that would have been released from Warragamba Dam.
Environmental Values	EVs	Environmental Values for water are the qualities that make it suitable for supporting aquatic ecosystems and human water uses. These qualities need to be protected from the effects of habitat alteration, waste releases, contaminated run-off and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use.
Highly treated water	-	What wastewater becomes after it has been treated. Wastewater is treated so clean water can be safely returned to the environment or re-used. The water is then filtered and disinfected with chlorine or ultraviolet light (UV). This kills any remaining microorganisms. It is then forced at high pressure through reverse osmosis membranes to remove even smaller bacteria and particles. This is the finest level of filtration.
Horizontal Directional Drilling	HDD	Horizontal directional drilling is a minimal impact trenchless method of installing underground utilities such as pipes in a relatively shallow arc or radius along a prescribed underground path using a surface-launched drilling rig.
Impact assessment area	-	The area within which project impacts may occur. This will be larger than the actual impact area to give some flexibility with regards to exact construction locations.

Term	Abbreviation	Definition
		This may be refined as the infrastructure reference design progresses.
Impact area	-	This refers to the actual area impacted by construction and operation. An expected impact corridor of 25 metres either side along the pipeline alignments has been noted.
Mean Annual Precipitation	MAP	The average total rainfall depth occurring over a year.
Mean Annual Runoff Volume	MARV	The average volume of stormwater runoff or stream flow occurring over a year
Megalitres per day	ML/d	Megalitres per day
Nephelometric Turbidity Unit	NTU	Unit for measuring turbidity
On-site Stormwater Detention	OSD	On-site stormwater detention temporarily stores stormwater run-off. This means the run-off rate and volume can be controlled to ensure the receiving system is not overloaded.
Probable Maximum Flood	PMF	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Property management activities	-	Sydney Water may undertake a range of activities following acquisition of the AWRC site. These activities are separate to the proposal and subject to separate approvals. These include: • Aboriginal Heritage Due Diligence assessment • access track creation for investigations • demolition works • establishing site security • geotechnical and contamination investigations • land remediation activities. • relocating/adjusting/installing property utility connections • site drainage management • vegetation management • vermin/animal control.
Project	-	The construction and operation of the Upper South Creek Advance Water Recycling Centre (AWRC), pipelines and all ancillary infrastructure. Construction of the AWRC is subject to environmental approval and has been identified as critical infrastructure. There are many stages and currently the project is at the very early planning stage. Detailed construction staging will be established by the detailed design contractor. Noting that the timelines aren't finalised, it's expected that construction will start in mid-2022.

Term	Abbreviation	Definition
Reverse Osmosis (highly treated water)	RO	A process where a solution is forced (under pressure) through a semi-permeable membrane separating pure water from dissolved salts.
Release of water	-	To release water into a creek, river or the ocean
Secretary's Environmental Assessment Requirements	SEARs	These are issued by the Secretary of the NSW Department of Planning and Environment for projects declared by the Minister of Planning as Critical State Significant Infrastructure. These SEARS provide the technical requirements for the impact assessment of each potential key issue, including the desired performance outcome, requirement and current guidelines.
Service area	-	The intention is to treat wastewater from Western Sydney Airport, Western Sydney Aerotropolis Growth Area (WSAGA) and South West Growth Area (SWGA). Additional areas may be transferred over time, pending growth distribution and servicing efficiency analysis. Sydney Water is currently planning for the major wastewater pipelines and other infrastructure required to transfer wastewater from these servicing areas to the AWRC site for treatment.
Stormwater Retention	-	The capture of stormwater within rainwater tanks, in soil stores and water bodies such that this water does not reach a downstream waterway.
Study area	-	General location or region where work may be undertaken.
Temporary ancillary facilities	-	These are temporary facilities to support construction including: • access roads • construction compounds • laydown areas • parking • site offices and amenities.
Total Nitrogen	TN	Total Nitrogen
Total Phosphorus	TP	Total Phosphorus
Total Suspended Solids	TSS	Total Suspended Solids
Treated water pipeline	-	The pipelines that will convey the highly treated water to the existing environment. The pipelines will transport water from the AWRC to the discharge points at the Nepean and Warragamba Rivers. These pipelines will range in size from about 0.6 m to 1.5 m in diameter and will generally consist of steel, glass reinforced plastic and polyethylene pipe materials.
Upper South Creek	USC	The catchment in which the AWRC will be located. South Creek discharges to the Nepean River which flows directly into the Hawkesbury River and then discharges out to the Pacific Ocean

Term	Abbreviation	Definition
Wastewater	-	The used water from baths, showers and washing machines (‘greywater’) and toilets (‘blackwater’) and enters into the sewerage system. About 99% of this is water with the remaining 1% composed of the components added to water during the previous use.
Water Sensitive Urban Design	WSUD	Water sensitive urban design is a land planning and engineering design approach aimed at improving the ability of urban environments to capture, clean and re-use stormwater before it has the chance to pollute and degrade the receiving creeks and rivers.
Water Quality Objectives	WQO	Water Quality Objectives are long-term goals for water quality management. They are measures, levels or narrative statements of indicators of water quality that protect EVs. They define what the water quality should be to protect the EVs—after consideration of the socio-economic assessment of protecting the water quality.
Wet Weather Overflows	WWO	During heavy rainfall the wastewater system can be impacted. Usually stormwater is separate, however it can sometimes enter through cracks in the wastewater pipes. If a lot of stormwater enters, the system can become overloaded.

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Appendices

1 Introduction

1.1 Background

This Surface Water impact assessment has been developed to support the Environmental Impact Statement (EIS) for the Upper South Creek Advanced Water Recycling Centre (AWRC) along with its treated water pipelines and ancillary infrastructure (collectively referred to as ‘the Project’). The AWRC will be located in the Kemps Creek precinct of the Western Sydney Aerotropolis, NSW, with discharge pipelines traversing Western Sydney from the Nepean River in the west, to the Georges River, Cabramatta in the east (**Figure 1-1**).

This report provides an assessment of how stormwater runoff from the Project would impact on the local surface water environment during the construction and operation phases and an overview of how mitigation measures would minimise any residual impacts on waterways through the implementation of stormwater retention and detention. Detailed demonstrations of how mitigation measures may function, as applied to the Project reference design, are provided in **Appendix A** and **Appendix B**. This report also identifies that specific environmental management plans would be required as part of the Projects construction to manage potential impacts of various environmental constraints that cannot be mitigated through design.

The Project is State Significant Infrastructure (SSI) and the Secretary of the Department of Planning, Industry and Environment has issued project specific environmental assessment requirements (SEARs). This report addresses SEARs relating to surface water including hydrology and water quality (see **Section 3**).

This report is one of several that assess impacts of the Project on receiving waters as shown in **Figure 1-2** below.

1.2 Project description

Sydney Water proposes to build and operate new wastewater infrastructure to service the South West and Western Sydney Aerotropolis Growth Areas. The proposed development would include a wastewater treatment plant in Western Sydney, known as the Upper South Creek Advanced Water Recycling Centre (AWRC), which, together with the associated treated water and brine pipelines, is referred to as the ‘Project’. An overview of the location of the proposed infrastructure is provided in **Figure 1-1**. Further details of each component of the Project are provided below.

Advanced Water Recycling Centre (AWRC)

- a wastewater treatment plant with the capacity to treat up to 50 ML of wastewater per day, with ultimate capacity of up to 100ML per day
- the AWRC would produce:
  - high-quality treated water suitable for a range of uses including recycling and environmental flows
  - renewable energy, including through the capturing of heat for cogeneration
  - biosolids suitable for beneficial reuse
  - brine, as a by-product of reverse osmosis treatment

Treated water pipelines

- a pipeline about 17 km long from the AWRC to the Nepean River at Wallacia Weir, for the release of treated water
- infrastructure from the AWRC to South Creek to release excess treated water and wet weather flows
- a pipeline about five kilometres long from the main treated water pipeline at Wallacia to a location between the Warragamba Dam and Warragamba Weir, to release high-quality treated water to the Warragamba River as environmental flows.

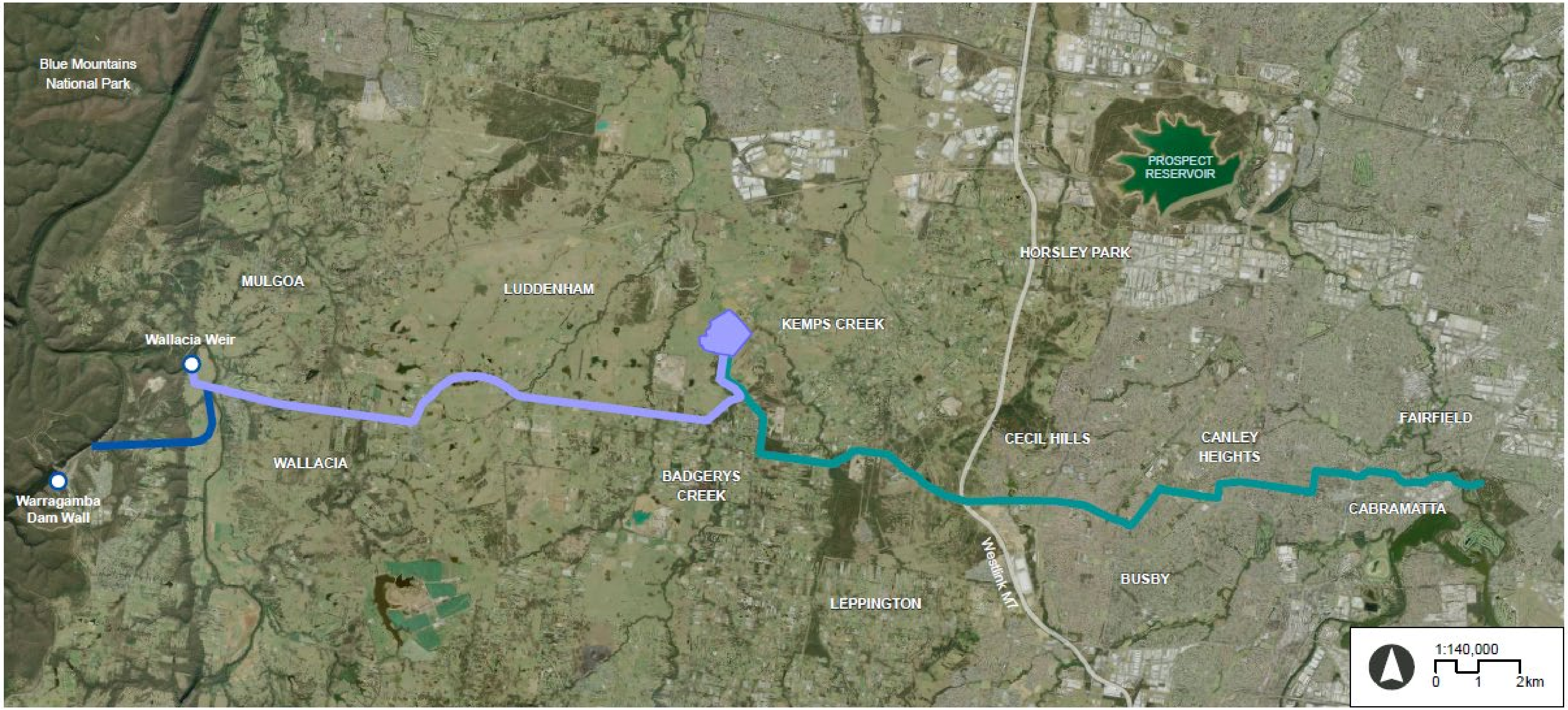
Brine pipeline

- a pipeline about 24 km long that transfers brine from the AWRC to Lansdowne, in south-west Sydney, where it connects to Sydney Water’s existing Malabar wastewater network

Sydney Water is planning to deliver the Project in stages, with Stage 1 comprising:

- building and operating the AWRC to treat an average dry weather flow of up to 50ML per day
- building all pipelines to their ultimate capacity, but only operating them to transport and release volumes produced by the Stage 1 AWRC

The timing and scale of future stages would be phased to respond to drivers including population growth rate and the most efficient way for Sydney Water to optimise its wastewater systems.



Upper South Creek Advanced Water Recycling Centre

Treated Water Pipeline

Brine Pipeline

Environmental Flows Pipeline

Projection: GDA 1994 MGA Zone 56
Project infrastructure locations are indicative and will be refined during design

Figure 1-1 USC AWRC Project Overview

1.3 Study objectives

The objective of the Surface Water Impact Assessment is to assess and address potential surface water impacts associated with the construction and operational phases of the Project. It also aims to provide guidance on ways of mitigating and managing the potential impacts to minimise potential environmental degradation.

The assessment covers the AWRC site as well as a defined impact assessment area centred along the pipeline alignments (treated water pipeline, brine pipeline and environmental flows pipeline) including the construction compounds and temporary access roads. The buffer area has been included to allow for uncertainty within the current pipeline alignment and changes that may occur during detailed design.

A reference design for the Project has been developed which informs the various impact assessments. Several studies have been undertaken in parallel to cover various aspects relating to the potential water environment impacts. These studies and the extent of each study's considerations are indicated in **Figure 1-2**.

Surface Water Impact Assessment	Hydrodynamic and Water Quality Impact Assessment	Flood Assessment	Groundwater Impact Assessment	Ecohydraulic and Geomorphology Assessment	Aquatic and Riparian Ecosystem Assessment
• Construction and operational impacts related to local runoff and stormwater management at the AWRC site as well as along the pipeline routes	• Treated water releases and impacts on the chemistry and water quality of the Warragamba and Nepean rivers and South Creek	• Assessment of potential impacts on local and downstream flooding regimes associated with discharge infrastructure and landform changes, and temporary construction activies along pipelines	• Construction and operational impacts to local and regional groundwater sources related to proposed activities at the AWRC site as well as along the pipeline routes	• Potential impacts to ecohydrology and geomorphology of the Warragamba and Nepean rivers and Wianamatta-South Creek	• Potential impacts associated with the proposed works on riparian and aquatic flora and fauna

Figure 1-2 Specific water cycle impacts addressed by each study in this EIS

2 Legislation, policy and guidelines

2.1 General legislation, policy and guidelines

This section summarises the current legislative requirements and guidelines relevant to surface water considerations for the Project.

Table 2-1 Legislation and policy context

Legislation/Policy	Brief description and intent	Relevance
NSW Water Management Act (2000)	The objects of the Water Management Act (WMA) 2000 are to provide for the sustainable and integrated management of the water sources of the state for the benefit of both present and future generations. In NSW, the regulator and policy maker for water resource management develops natural resource management policy frameworks, strategies and plans related to water management. DPIE Water and NRAR are accountable for water sharing plans (WSPs), which define the rules for sharing the water resources of each regulated river valley between consumptive users and the environment. WSPs are made under the Water Management Act 2000.	Consideration of the Project against the objects, water management principles and the applicability of access licence dealing principles under the Water Management Act, 2000.
NSW Water Management (General) Regulation 2018 (NSW Government, 2018)	The WMA requires water users in NSW to hold and comply with the conditions of a water access licence (WAL) to take water. WALs must also be obtained for any activity involving the taking of water from a water source unless an exemption under the Water Management (General) Regulation 2018 (NSW) is applicable.	As the Project has been declared as State Significant Infrastructure (SSI) and requires approval under environmental planning legislation, additional water use approvals are not required for harvesting of stormwater from the Project.
NSW Water Resources Council (1993): NSW State Rivers and Estuaries Policy	The State Rivers and Estuaries Policy established the framework for the management of rivers and estuaries of NSW and related ecosystems, such as wetlands. It is based on the "Total Catchment Management" philosophy defined in the Catchment Management Act 1989. The policy is founded on the following management principles: • Those uses of rivers and estuaries which are non-degrading should be encouraged. • Non-sustainable resource uses which are not essential should be progressively phased out. • Environmentally degrading processes and practices should be replaced with more efficient and less degrading alternatives. • Environmentally degraded areas should be rehabilitated, and their biophysical functions restored.	The third principle is most applicable and should be adhered to during the development and operation of the Project. As per the policy: “Strategies for achieving this objective would encourage and facilitate the adoption of the best available management practices.”

Legislation/Policy	Brief description and intent	Relevance
	• Remnant areas of significant environmental values should be accorded special protection. An ethos for the sustainable management of river and estuarine resources should be encouraged in all agencies and individuals who own, manage or use these resources, and its practical application enabled.	
NSW Office of Environment and Heritage (2017): Risk-based framework for considering waterway health outcomes in strategic land-use planning decisions (Dela-Cruz et al, 2017)	The Risk Based Framework brings together existing principles and guidelines recommended in the National Water Quality Management Strategy, which the federal and all state and territory governments have adopted for managing water quality. The purpose of the Risk Based Framework is to: • ensure the community's environmental values and uses for our waterways are integrated into strategic land-use planning decisions • identify relevant objectives for the waterway that support the community's environmental values and uses, and can be used to set benchmarks for design and best practice • identify areas or zones in waterways that require protection • identify areas in the catchment where management responses cost-effectively reduce the impacts of land-use activities on our waterways • support management of land-use developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.	Numerical water quality and flow objectives for Wianamatta South Creek have been established through the application of the Framework and these will ultimately be included in the Western Sydney Aerotropolis Development Control Plans that will apply to the final site design. By designing a stormwater management approach that achieves the numerical water quality objectives, the Project applies the principles of the Risk Based Framework. The new objectives are likely to replace existing stormwater pollution reduction targets and stream erosion indices for stormwater discharges to waterways.
Managing Urban Stormwater, Soils and Construction **Volume 1 (Landcom, 2004)** **Volume 2 (DECC, 2008)**	These guidelines, commonly known as the 'Blue Book', provide support for councils and industry to reduce the impacts of land disturbance activities on waterways by better management of soil erosion and sediment control.	During the construction and operation phases of the Project due consideration is required to manage erosion and sediment and prevent pollution of the downstream waterways.

Legislation/Policy	Brief description and intent	Relevance
NSW Water Quality and River Flow Objectives (DEC, 2006)	The NSW WQOs are the agreed environmental values and long-term goals for NSW's surface water (DECCW, 2006). They set out: • The community's values and uses (i.e. healthy aquatic ecosystem, water suitable for recreation or drinking water etc) for the NSW waterways (rivers, creeks, lakes and estuaries) • A range of water quality indicators to assess whether the current condition of the waterway supports these values and uses.	Water quality guidelines have been included where relevant in the specific set of objectives for the Project.
Healthy Rivers Commission (HRC) Inquiry	The HRC was established in 1995 by the NSW Government to make recommendations on: • Suitable objectives for water quality, flows and other goals central to achieving ecologically sustainable development in a realistic time frame • The known or likely views of stakeholder groups on the recommended objectives • The economic and environmental consequences of the recommended objectives • Strategies, instruments and changes in management practices that are needed to implement the recommended objectives	The Inquiry established environmental values for the catchment, however these were superseded by the ANZECC Guidelines as part of the National Water Quality Management Strategy (NWQMS), listed below. The HRC guidelines provide additional clarification on environmental values to be protected and were considered in the development of the waterway objectives for the Project.
Department of Agriculture and Water Resources (2018): National Water Quality Management Strategy (NWQMS)	The NWQMS (ANZECC and ARMCANZ 2000a) provides a nationally consistent approach to water quality management and the information and tools to help water resource managers, planning and management agencies, regulatory agencies and community groups manage and protect their water resources. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.	Construction and operational phases of the AWRC have the potential to impact water quality within the adjacent creeks. As such, construction and operational phases should integrate water quality management strategies (consistent with NWQMS) such that the environmental values of the sensitive receiving waterways are not adversely impacted. These should be included in the construction and operational EMPs.

Legislation/Policy	Brief description and intent	Relevance
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)	The Water Quality Guidelines provide authoritative guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. The 2018 revision of the Water Quality Guidelines is presented as an online platform, to improve usability and facilitate updates as new information becomes available.	Given the absence of site-specific guideline values for the Nepean and the Warragamba Rivers, the ANZG's give directions to default guideline values (DGVs) for a range of stressors relevant to different community values, such as aquatic ecosystems, human health, and primary industries. As regional physical and chemical stressor default guideline values are not yet provided for the Project's ecoregion and local jurisdictions have not yet derived finer scale guideline values, these guidelines direct back to the regional DGVs provided in the ANZECC & ARMCANZ (2000) guidelines (see below).
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)	The ANZECC Water Quality Guidelines provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters and list a range of environmental values assigned to that waterbody. The ANZECC Water Quality Guidelines provide recommended trigger values for various levels of protection which have been considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly to moderately disturbed ecosystems.	The ANZECC Water Quality Guidelines provide recommended trigger values for various levels of protection which have been considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly disturbed ecosystems in NSW Lowland Rivers in south-east Australia
Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006)	The ANZECC guidelines document is a large one, containing detailed scientific information and instructions for a vast array of water-quality issues. The booklet was developed to explain the principles behind the ANZECC guidelines and how to apply them.	The ANZECC Water Quality Guidelines have been applied with guidance from this booklet to understand the current health of the waterways in the vicinity of the Project and the ability to support nominated environmental values, particularly the protection of aquatic ecosystems.

Legislation/Policy	Brief description and intent	Relevance
Guidelines for managing risks in recreational water (NHMRC, 2008)	The primary aim of these guidelines is to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. These guidelines should be used to ensure that recreational water environments are managed as safely as possible so that as many people as possible can benefit from using the water. These guidelines are not mandatory.	Listed indicators and associated guidelines values have been used to inform the relevant waterway objectives, with regards to recreational value.
Sydney Regional Environmental Plan No. 20 – Hawkesbury-Nepean River (No 2-1997)	The purpose of the Sydney Regional Environment Plan No. 20 – Hawkesbury-Nepean River – (No2-1997) (NSW) (SREP20) is to “protect the environment of the Hawkesbury-Nepean River system by ensuring that the impacts of future land uses are considered in a regional context”. It covers environmentally sensitive areas, water quality and quantity and controls development that has the potential to impact on the river environment.	The AWRC site and the largest portion of the pipeline alignments are located within the South Creek catchment which ultimately drains to the Hawkesbury River. The Local Government Areas (LGAs) of Penrith, Liverpool and Fairfield are identified as three of the 15 LGAs to which the SREP20 – Hawkesbury-Nepean River applies and specific planning policies and recommended strategies for consideration in this project are detailed in Clause 6 of SREP 20.

2.2 Waterway objectives

2.2.1 Nepean River, Warragamba River and Wianamatta-South Creek

Table 2-2 provides a summary of the waterway objectives for the Nepean and Warragamba Rivers and Wianamatta-South Creek.

The objectives are specific to this project and were developed in accordance with the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (OEH, 2017). The numerical criteria are sourced from existing guidelines and objectives. Predicted impacts from the Project have been assessed against the waterway objectives.

The Risk Based Framework defines waterway objectives as consisting of:

- community's environmental values and uses of the water
- indicator(s) and corresponding numerical criteria to assess whether the waterway will support a particular environmental value or use.

The values and uses adopted for the Nepean and Warragamba Rivers and South Creek are:

- aquatic ecology
- recreation and aesthetics
- primary industries
- drinking water (Nepean River only).

Management goals and numerical criteria for each of these values have been informed by the following guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000 and ANZG 2018)
- Guidelines for managing risks in recreational water (NHMRC, 2008)
- Australian Drinking Water Guidelines 2011, Version 3.5 Updated August 2018 (NHMRC, NRMMC 2011)
- Regulating nutrients from STPs in Lower Hawkesbury Nepean River catchment (EPA 2019)
- Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020)

The Department of Planning, Industry and Environment (DPIE) has developed draft water quality and flow objectives (**Table 2-3**) as part of the precinct planning work for the Aerotropolis. These draft objectives include performance criteria that have been included in our objectives for South Creek.

Table 2-2 Waterway objectives for Nepean and Warragamba Rivers and Wianamatta-South Creek

Values and uses & associated management goals	Indicator	Numerical criteria/metric	
		Nepean & Warragamba Rivers	Wianamatta-South Creek (values in brackets/blue text are DPIE criteria)
1. Aquatic Ecosystems Management goal: Protect, maintain and restore the ecological condition of aquatic systems and their riparian zones overtime.	Total nitrogen (TN)	0.35 mg/L[1]	0.35 mg/L[1] (1.72 mg/L)[2]
	TN Loads	Yarramundi Subzone 2 - 55,300 kg/yr[3]	Sackville Zone 2 - 126,100 kg/yr[3,4]
	Total phosphorus (TP)	0.025 mg/L[1]	0.025 mg/L[1] (0.14 mg/L)[2]
	TP Loads	Yarramundi Subzone 2 - 3,450 kg/yr[3]	Sackville Zone 2 - 2,720 kg/yr[3,4]
	NOx	0.040 mg/L[1]	0.040 mg/L[1] (0.66 mg/L)[2]
	Ammonium (NH_4^+)	0.020 mg/L[1]	0.020 mg/L[1] (0.08 mg/L)[2]
	Filterable reactive phosphorus (FRP)	0.020 mg/L[1]	0.020 mg/L[1]
	Chlorophyll *a* (Chl *a*)	0.003 mg/L[1]	0.003 mg/L[1]
	Dissolved oxygen (DO)	85 - 110 % Saturation[1]	85 - 110 % Saturation[1] (43-75 % Saturation, 8 mg/L)[2]
	pH	6.5 - 8.0[1]	6.5 - 8.0[1] (6.2-7.6)[2]
	Conductivity	125-2200 μS/cm[1]	125-2200 μS/cm[1] (1103 μS/cm)[2]
	Toxicants	Refer to ANZECC guidelines	Refer to ANZECC guidelines
	Turbidity	6-50NTU[1]	6-50NTU[1] (50 NTU)[2] (TSS – 37 mg/L)[2]
2. Recreation & Aesthetics *Management Goal:* *Maintain or improve water quality for*	Recreational water quality: Primary Contact	Enterococci	95th percentile for intestinal enterococci/100 mL ≤ 40[5]

Values and uses & associated management goals	Indicator	Numerical criteria/metric	
		Nepean & Warragamba Rivers	Wianamatta-South Creek (values in brackets/blue text are DPIE criteria)
recreational activities such as swimming, boating and fishing.		Cyanobacteria	< 5000 cells/mL *M. aeruginosa* or biovolume equivalent of > 0.04 to <0.4 mm^3/L for the combined total of all cyanobacteria (Categories A & B)[5]
	Recreational water quality: Secondary Contact	Enterococci	95^{th} percentile for intestinal enterococci/100 mL > 40 and ≤ 200[5]
		Cyanobacteria	≥ 5000 to <50,000 cells/ mL *M. aeruginosa* or biovolume equivalent of ≥ 0.4to <4 mm^3/L for the combined total of all cyanobacteria (Category C)[5]
Management Goal: *Maintain or improve the aesthetic qualities of the waterways*	Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour, tasting or foaming.[1]	
	Surface films and debris	Surface waters should be free from floating debris, oil, grease and other objectionable matter[1]	
	Nuisance organisms	Surface waters should be free from undesirable aquatic life, such as algal blooms, or dense growths of attached plants or insects[1].	
3. Irrigation and livestock drinking	As per Water Quality metrics, under Aquatic Ecology		
Management Goal: *Protect the quality of water used for a broad range of irrigation activities and livestock drinking*	Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL[1]	
	Cyanobacteria	< 11,500 cells/mL Microcystis, <2.3 μ g/L microcystins[1]	
4. Protection of Raw Drinking Water Supplies	As per Water Quality metrics, under Aquatic Ecology		Not applicable to South Creek.

Values and uses & associated management goals	Indicator	Numerical criteria/metric	
		Nepean & Warragamba Rivers	Wianamatta-South Creek (values in brackets/blue text are DPIE criteria)
Management Goal: Maintain or improve the quality of raw drinking water extracted downstream	Microbial Water Quality – bacteria, viruses, protozoa & helminths; Cyanobacteria and their Toxins; Disinfection by-products – particularly NDMA; Pesticides; Pharmaceuticals; Endocrine Disruptors; Radioactive Materials;	Primarily bacteria and cyanobacteria[6]	Not applicable.

Table Notes:

1. Indicators and metrics adopted from ANZECC (default trigger values) are for slightly disturbed lowland river ecosystems in south-east Australia (ANZECC 2000 and ANZG 2018)
2. These metrics are performance criteria presented in the Draft Aerotropolis Precinct Plan (Western Sydney Planning Partnership, November 2020)
3. Load limits taken from Table 7, Regulating nutrients from sewage treatment plants in the Lower Hawkesbury Nepean River catchment (EPA, 2019)
4. Limits adopted exclude loads from McGraths Hill and South Windsor (non-Sydney Water facilities)
5. Guidelines for managing risks in recreational water (NHMRC 2008)
6. Australian Drinking Water Guidelines 6 V3.5 (NHMRC, NRMMC 2011)

Wianamatta-South Creek flow objectives

The NSW Department of Planning, Industry and Environment (DPIE) have drafted numerical objectives to preserve the hydrologic condition of Wianamatta-South Creek (and its tributaries) to inform the planning of the Western Parkland City. The criteria were developed to support the vision for Wianamatta-South Creek (and its tributaries): *"To become a cool green corridor through the Western Parkland City and be the core element of liveability and amenity for the residents. This vision relies on urban planners to explicitly keep water in the landscape by integrating waterways into the design of the city and residential neighbourhoods, and for the waterways to be healthy so they can provide the essential* services and functions expected of a cool green corridor."

Flows objectives for waterways and water dependent ecosystems (WDEs) have been developed by DPIE through the application of the Risk Based Framework and provide a numerical values that define the desired hydrologic regime for Wianamatta-South Creek (listed in **Table 2-3**)

Table 2-3 Draft Wianamatta-South Creek waterway health (flow) criteria

Flow Variable	Unit	Performance Criteria	
		1-2 Order Streams	≥ 3rd Order Streams
Median Daily Flow Volume	L/ha/d	71.8 ± 22.0	1,095.0 ± 157.3
Mean Daily Flow Volume	L/ha/d	2,351.1 ± 604.6	5,542.2 ± 320.9
High Spell ≥ 90th Percentile Flow Volume	L/ha/d	2,048.4 ± 739.2	10,091.7 ± 769.7
High Spell - Frequency High Spell - Average Duration	number/y days/y	6.9 ± 0.4 6.1 ± 0.4	19.2 ± 1.0 2.2 ± 0.2
Freshes ≥ 75th and ≤ 90th Percentile Flow Volume	L/ha/d	327.1 to 2048.4	2,642.9 to 10,091.7
Freshes - Frequency Freshes - Average Duration	number/y days/y	4.0 ± 0.9 38.2 ± 5.8	24.6 ± 0.7 2.5 ± 0.1
Cease to Flow	proportion of time/y	0.34 ± 0.04	0.03 ± 0.007
Cease to Flow – Duration	days/y	36.8 ± 6	6 ± 1.1

2.2.2 Georges River catchment

A large section of the brine pipeline would be in the Georges River catchment. The environmental values and numerical criteria applicable for lowland rivers in this catchment have been sourced from the NSW Water Quality and River Flow Objectives (NSW DEC, 2006).

Table 2-4 Waterway objectives for Georges River catchment

Values and uses & associated management goals	Indicator	Numerical criteria/metric
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and riparian zones over the long term	Total Phosphorus (TP)	0.025 mg/L
	Total Nitrogen (TN)	0.35 mg/L
	Chlorophyll-a	0.005 µg/L
	Turbidity	6 - 50 NTU
	Salinity (electrical conductivity)	125 - 2200 µS/cm
	Dissolved Oxygen (DO)	85 - 110% saturation
	pH	6.5 – 8.0
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.

Values and uses & associated management goals	Indicator	Numerical criteria/metric
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts
Secondary contact recreation – maintaining or improving water quality of activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	As per the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Nuisance organisms	As per the visual amenity guidelines. Large numbers of midges and aquatic works are undesirable.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable of recreation. Toxic substances should not exceed values provided in the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Visual clarity and colour	As per the visual amenity guidelines.
	Surface films	As per the visual amenity guidelines.
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Turbidity	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).
	Faecal coliforms, enterococci, algae and blue-green algae	As per the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values provided in the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Visual clarity and colour	As per the visual amenity guidelines.
	Temperature	15° - 35°C for prolonged exposure.
	pH	5.0 – 9.0

2.3 Drainage and water sensitive urban design policy and guidelines

At the time of preparing this EIS, the Western Sydney Planning Partnership Office was writing a new set of Development Control Plans (DCPs) for the Western Sydney Aerotropolis precincts. Once finalised, these DCPs may compliment or completely replace Penrith Council's existing stormwater drainage DCPs that apply to the AWRC site. It is recognised that until those new Western Sydney Aerotropolis DCPs are adopted, the Project reference design must accommodate both sets of DCPs.

In addition to the waterway health objectives outlined above, existing stormwater management design criteria summarised in **Table 2-5** have been applied to development of the Project reference design to ensure that the site can be developed in accordance with Penrith Council's drainage standards.

Table 2-5 WSUD related policy and guidelines

Policy/Guideline	Relevant Criteria
Penrith Council Drainage Specifications (Nov 2016)	Though not directly applicable, these specifications have been applied as guidance during the drainage design process. • On Site Detention (OSD) sized to contain 1% Annual Exceedance Probability (AEP) event volume • Council does not allow a reduction in OSD storage volumes based on inclusion of rainwater tanks and other WSUD measures • The outlet control for the OSD system shall be above the 1% AEP flood level at the discharge point • Maximum depths for above ground storage – Landscaped areas: 600 mm – Industrial open basins: 1,200 mm • Where landscaped areas are to be used, the required volume shall be increased to accommodate any potential mature planting within the basin – 15% additional for design storage volume >25 m^3 • Batter slopes in landscaped areas shall be generally 1:6 (V:H) • Any proposed infiltration systems as part of WSUD must be lined as direct stormwater infiltration to ground is not permitted due to the soils in the Penrith LGA being predominantly impermeable, saline and / or sodic clays • Water Sensitive Urban Design measures shall be provided as required by Council's Development Control Plan and Water Sensitive Urban Design Policy
Penrith Council DCP (2014)	• New industrial developments greater than 2,500 m^2 site area must submit a WSUD Strategy (report dealing with measures to be implemented as part of the development) with a Development Application • The stated council approval requirements for WSUD systems are not to be construed as limiting, in any way, Council's right to impose differing conditions when approving development proposals or limiting the discretion of Council's nominated representative to vary any necessary requirements in respect of a particular development or Council project, having regard to potential site restrictions and best practice.

Policy/Guideline	Relevant Criteria
	• Required stormwater pollution load reductions: – 90% reduction in the post development mean annual load total gross pollutant (greater than 5 mm); – 85% reduction in the post development mean annual load of Total Suspended Solids (TSS); – 60% reduction in the post development mean annual load of Total Phosphorus (TP); – 45% reduction in the post development mean annual load of Total Nitrogen (TN); – 90% free oils and grease with no visible discharge. • Any changes to the flow rate and flow duration within the receiving watercourses as a result of the development shall be limited as far as practicable. • The post development duration of stream forming flows shall be no greater than 3.5 times the pre-developed duration of stream forming flows.
Penrith Council's WSUD Technical Guidelines (June 2015)	• Discussion with Council is encouraged at an early stage of a development proposal to agree on a general design approach before a detailed WSUD Strategy is prepared • Establish a stormwater quality (MUSIC) model for the proposed development to predict expected stormwater pollutant loads generated from development and to develop a strategy to achieve the stormwater quality targets. • When determining Stream Erosion Index (SEI) Council requires the use of the methodology in the Draft NSW MUSIC Modelling Guide (Aug 2010) that is adapted from Blackham and Wettenhall (2010) • WSUD measures should be positioned outside the mainstream flooding extents.
On-site stormwater detention guide (Sydney Water, 2014)	• An OSD system must be able to store the run-off caused by a storm event up to 100-year ARI for the site • The development's internal drainage network is to be designed to convey the 20-year ARI storm event. While the earthworks platforms and road corridors are to be designed to convey storm events up to the 100-year ARI storm event to the OSD storages.
Stormwater Retention and Detention for WSUD (Sydney Water, June 2019)	• The guidelines use two measures of runoff volumes from impervious surfaces. A percentage of these must be retained on site by appropriately designed and sized stormwater retention systems. – The Mean Annual Runoff Volume (MARV) is the average volume of runoff from impervious surfaces over the course of the year. – The Flood Event Runoff Volume (FERV) is the volume of runoff from impervious surfaces during a flood causing burst of rainfall. • The new metrics bridge the gap between existing practice and more effective waterway protection and rehabilitation. The protection of waterway ecosystems requires the following: – Minimising changes to hydrology including the frequency and magnitude of flows – Minimising increases in pollutant and nutrient loads • Catchment managers may also elect to take advantage of more recent technologies such as smart tanks with telemetry and controls. For example, the

Policy/Guideline	Relevant Criteria
	prior emptying of retention storages in the day or days ahead of a forecast severe weather event.
Green and Cool Streetscapes (Sydney Water, Sept 2019)	• WSUD requires collaboration with a range of disciplines for successful implementation (landscape design, planning, catchment management, engineering, architecture, urban ecology and water servicing). These facilities should preferably be integrated into the social and amenity fabric of the development and not just viewed as an add-on. • Includes promotion of: – Low Flow Bypass Pits - developed to make it easier for stormwater engineers to devise green integrated WSUD road solutions in preference to end-of-pipe gross pollutant traps. – Vegetated Roadside Swales – Streetscape raingardens

3 SEARs

The Project is State Significant Infrastructure (SSI) and the Secretary of the Department of Planning, Industry and Environment has issued project specific environmental assessment requirements (SEARs). These SEARS provide the technical requirements for the impact assessment of each potential key issue, including the desired performance outcome, requirement and current guidelines.

The approach in addressing surface water related matters within the SEARs is summarised in **Table 3-1**.

Table 3-1 Scope of work to address project SEARs

Requirement	Scope of work undertaken to address	Section
1. Describe background conditions for any water resource likely to be affected by the development, including:		
a) existing surface and groundwater.	The surface water study describes the existing hydrological environment and features including catchments, sub catchments, creeks and watercourses. Stream orders are mapped and discussed. Groundwater conditions are described in the *Groundwater Impact Assessment* report.	Sections 1.1, 5.4 and 5.5
b) hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	**Intakes** The surface water study describes stormwater runoff from the Project and its retention (including stormwater harvesting) to contribute towards waterway health (flow) objectives associated. No other surface water sources are taken in by the Project. The primary potential groundwater take associated with the Project only relates to the temporary operations expected during construction to dewater excavations. The assessment of the associated impacts is provided in the *Groundwater Impact Assessment* report. **Discharges** Stormwater discharges (i.e. excess leaving the WSUD treatment train) from the Project reference design have been modelled and assessed against flow discharge regimes. The surface water study describes stormwater releases and operational releases from the AWRC associated with South Creek. The *Hydrodynamic and Water Quality Impact Assessment* and the *Ecohydraulic and Geomorphology Impact Assessment* reports address releases of treated wastewater to Wianamatta-South Creek, Warragamba and Nepean Rivers.	Sections 5.4, 5.5 and 7.1

Requirement	Scope of work undertaken to address	Section
c) Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Applicable WQO's and NSW Government issued relevant ambient performance water criteria are stated. WQO's related to groundwater are provided in the *Groundwater Impact Assessment* report.	Section 1.1
d) indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Applicable WQO's and NSW Government issued relevant ambient performance water criteria are stated.	Section 1.1
e) Consideration of the Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions.	The Risk-based Framework has been considered in this surface water study by adopting existing waterway health (flow and quality) objectives developed by DPIE for Wianamatta-South Creek in October 2020. These objectives are understood to incorporate the existing waterway values and represent the level of hydrologic and water quality protection required to preserve the waterway values. The stormwater management approach for the reference design and WSUD measures have been designed to achieve the objectives.	Section 4.5.1
2. Assess the impacts of the development on water quality, including:		
a) The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and	Available water quality data for the streams traversing the study area (South Creek and the watercourses along the pipeline alignments) have been collated and compared to the waterway objectives for Warragamba and Nepean Rivers and South Creek and the Georges River WQOs. The analysis indicates several WQO's are not currently being met within most streams in the study area and the data indicates nutrient concentrations above and DO levels below the stated trigger levels for the baseline conditions. Stormwater runoff quality during the construction and completed Project phase (AWRC and pipelines) entering Wianamatta-South Creek and the local creeks along the pipeline have been predicted using qualitative analyses (for pipelines) and using MUSIC modelling (for the AWRC reference design).	Sections 5.5, 7.1 and 7.2

Requirement	Scope of work undertaken to address	Section
wastewater management during and after construction.	The expected quality of the stormwater discharges (i.e. excess leaving the WSUD treatment train) have been assessed against WQOs and demonstration provided on how the WSUD mitigation measures of the reference design would contribute to the WQOs being achieved over time. The *Hydrodynamic and Water Quality Impact Assessment* report assesses the impacts of the discharge of the highly treated water to the receiving waters against the waterway objectives. Groundwater impacts are described in the *Groundwater Impact Assessment* report.	
b) identification of proposed monitoring of water quality.	The current water quality monitoring programme has been described as well as proposed future monitoring during the Project construction and operation phases.	Sections 5.5 and 9
c) if the proposal will achieve a neutral or beneficial effect (NorBE) on water quality within the declared Sydney Drinking Water Catchment (SDWC).	One of the discharge locations for the highly treated water would be at the Warragamba River downstream of the Warragamba Dam wall but within the area of Operations for WaterNSW. The potential associated impacts have been assessed and are documented in the *Hydrodynamic and Water Quality Impact Assessment* report.	
3. Assess the impact of the development on hydrology, including:		
a) water balance including quantity, quality and source.	The highly treated water would be discharged to the Nepean River, South Creek and potentially the Warragamba River and potential associated impacts have been assessed and are documented in the *Hydrodynamic and Water Quality Impact Assessment* report. Stormwater (eWater MUSIC) models have been used to inform the stormwater balance for runoff generated from the Project reference design. Two water-take / discharge activities have been assessed: • Potential for dewatering requirements during construction (assessment provided in the *Groundwater Impact Assessment* report) • Stormwater discharge off-site: location, estimated volumes and frequencies have been estimated by developing relevant local MUSIC and XP-RAFTS models. Both an operations water balance as well as an environmental water balance for the AWRC site have been provided.	Section 7.1.2
b) effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas.	The surface water study assesses the impact of the reference design on stormwater runoff. Changes in runoff from the AWRC site post-development have been	Sections 7.1.2.2, 7.1.2.3 and 7.2

Requirement	Scope of work undertaken to address	Section
c) effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems. d) impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches). e) changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	modelled using stormwater models and results assessed against waterway health (quality and flow) objectives. Stormwater impacts on waterways that may be impacted during the construction of the pipelines have been qualitatively assessed. Impacts of treated water releases have been documented in the *Aquatic Ecology and Riparian Ecosystem Impact Assessment, Ecohydraulic and Geomorphology Impact Assessment* and the *Hydrodynamic and Water Quality Assessment*. The stormwater management approach for the AWRC site adopts the Wianamatta-South Creek waterway health objectives (flow) as flow-based targets. By achieving the flow targets, the management of stormwater on the AWRC site contributes to the existing flow conditions being preserved in waterways and having an acceptable impact of existing hydrology and water availability. It is therefore unlikely that the site would affect environmental water availability or access to water. The *Flood Impact Assessment* assesses impacts on the downstream environment from a flood flow perspective.	
f) mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	The sediment and erosion controls associated with the construction phase, have been qualitatively assessed against the industry standard design criteria contained in the Blue Book. Changes in runoff from the AWRC reference design, during the operational phases, have been modelled using industry standard software (eWater MUSIC) and results assessed against waterway health (quality and flow) objectives. Assessment of the mitigation measures associated with the wastewater management and discharge have been documented in the *Aquatic Ecology and Riparian Ecosystem Impact Assessment, Hydrodynamic and Water Quality Impact Assessment* and *Ecohydraulic and Geomorphology Impact Assessment*.	Sections 7.1, 7.1.2.2 and 7.1.2.3
g) identification of proposed monitoring of hydrological attributes.	The proposed monitoring during the Project construction and operation phases has been included where relevant to stormwater discharges. Other monitoring recommendations would align with the programmes proposed in the other water studies.	Section 9
4. Map:		
a) rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method)	Mapping of rivers and streams have been included in this report. Wetlands have been mapped in the *Aquatic Ecology and Riparian Ecosystem Impact Assessment* report.	Section 5.4.1

Requirement	Scope of work undertaken to address	Section
b) wetlands as described in s4.2 of the Biodiversity Assessment Method	Wetlands have been mapped in the *Aquatic Ecology Impact Assessment* report.	
c) groundwater	Groundwater has been mapped in the *Groundwater Impact Assessment* report.	
d) groundwater dependent ecosystems (GDE)	GDE's have been mapped in the *Groundwater Impact Assessment* and the *Aquatic Ecology Impact Assessment* reports.	
e) proposed intake and discharge locations	Stormwater discharge locations have been indicated.	Figure 7-3
7. Consult/coordinate with the Department of Planning, Industry and Environment (and Planning Partnership Office) in respect to environmental impacts on the South Creek catchment and the Wianamatta South Creek program. This includes:		
a) integrating with a blue-green infrastructure delivery strategy to enhance and protect the South Creek catchment.	The proposed WSUD measures incorporated in the surface water impact assessment align with the blue-green strategy.	Section 7.1.2.2
b) address the potential for dry weather releases and consider the amount of treated water to be released into South Creek.	Provided in the *Ecohydraulic and Geomorphology Impact Assessment* and *Hydrodynamic and Water Quality Impact Assessment* reports	
c) assess the potential impacts on the quantity and quality of surface and groundwater resources along South Creek, including the implications of dry and wet weather flows from the Project.	Potential impacts associated with site-runoff on the quantity and quality of surface water resources along South Creek have been assessed. Groundwater impacts are assessed in the *Groundwater Impact Assessment* report. Dry and wet weather highly treated water discharges have been assessed in the *Hydrodynamic and Water Quality Impact Assessment, Aquatic Ecology Impact Assessment* and *Ecohydraulic and Geomorphology Impact Assessment* reports.	Section 8
d) details about how the Project will be designed, operated and maintained to ensure post-development flows do not exceed pre-development flows into and through the Pipelines Corridor and additional surface and groundwater entering the Pipelines Corridor must be prevented.	Discharge volumes have been assessed and mitigation measures proposed to ensure post-development peak flows do not exceed pre-development peak flows. The impacts on the local flooding regime have been documented in the *Flood Impact Assessment* report. The *Hydrodynamic and Water Quality Impact Assessment* and *Ecohydraulic and Geomorphology Impact Assessment* reports also review these impacts.	Section 7.1.2.3

4 Assessment methodology

4.1 Overview

The steps and tasks listed in **Table 4-1** were carried out as part of the surface water assessment. It should be noted that where pipelines did not result in significant permanent change in land use, then a qualitative assessment is provided.

Table 4-1 Key steps and tasks carried out during the development of the impact assessment

Nr	Key Steps	Sub tasks	Project component	
			AWRC Site	Pipelines
1	Desktop review of available information and data collation		X	X
2	Site walkover and inspection		X	Not completed due to Covid related restrictions. Refer to Section 4.3 for approach and method
3	Define existing environment	Review & description	X	X
		Modelling	XPRAFTS	Qualitative only
4	Expected changes (construction & operation)	Modelling	XPRAFTS & MUSIC	Qualitative only
		Qualitative	X (where appropriate)	X
5	Assess against WQO's		X	Qualitative only
6	Mitigation measures (construction & operation)	Modelling	XPRAFTS & MUSIC	Qualitative only
		Qualitative	X (where appropriate)	X
7	Assess against WQO's		X	Qualitative only
8	Write-up of impact assessment findings and outcomes		X	X

The approach used to complete each of these tasks is detailed below.

4.2 Desktop review

Multiple sources of publicly available information, relevant to the local and regional surface water conditions were identified, and data from these sources were collated and reviewed as part of this report, to inform the identification and assessment of the following hydrological characteristics:

- Local and regional climatic conditions
- Stream flows
- Surface water quality, including potential sources of surface water contamination

- Topography.

Several investigations and reports containing information on surface water, hydrology and water quality have been undertaken in the study area. A summary of the previous investigations and reports from which hydrological characteristics have been derived is provided in **Table 4-2** below.

Table 4-2 Summary of previous investigations and reports

Document Title	Author	Date Published
South Creek Source Model Calibration	Alluvium	2019
Objectives and targets for managing the natural blue grid and stormwater in the Aerotropolis	DPIE EES	2020
M12 Motorway Environmental Impact Statement – Appendix M Surface water quality and hydrology assessment	RMS	2019
Western Sydney Airport Environmental Impact Statement – Appendix L1 Surface water hydrology and geomorphology	GHD	2015
Western Sydney Airport Environmental Impact Statement – Appendix L2 Surface water quality	GHD	2015
Environmental field survey of Commonwealth land at Badgerys Creek	SMEC	2014
Second Airport EIS	PPK	1999
Baseline monitoring data from the ongoing Project program, as detailed in the *Hydrodynamic and Water Quality Impact Assessment* report.	Sydney Water	2018-2020 (dataset)
STSIMP Interpretive report 2016-17 (Trends in WWTP nutrient loads and water quality of the Hawkesbury-Nepean River)	Sydney Water	2018

4.3 Site inspection

A walkover of the proposed AWRC site was conducted on the 20th of April 2020. The visit focused on visual inspection of the site including the condition and geomorphology of South Creek and Kemps Creek, topography, soil and flood plain.

Topographical findings of the field investigations are described in **Section 5.3**. The field observations relating to hydrology were used mainly in the consideration of appropriate discharge points from the proposed stormwater management facilities.

Additional site visits to inspect the pipeline watercourse crossing locations were planned for April 2020, however due to the restrictions put in place as a result of the COVID pandemic, these did not take place. These inspections were deemed not critical to the understanding and assessment of the Project, as sufficient understanding of the systems could be drawn from the available desktop information and aerial imagery.

4.4 Reference design

A Project reference design was prepared which includes consideration of how surface water would be managed during construction and operation including:

- Earthworks designs to locate the AWRC development and evacuation routes outside of the flood planning extents and demonstrating that land use is suitable for flood hazard

- Conceptual design of sedimentation basins, stormwater detention basins and water sensitive urban design elements and demonstration of performance using industry standard methods
- Sizing and locating suitable positions for pipeline crossings, stormwater outlets and channels on waterfront land.

4.5 Impact assessment

4.5.1 Approach

Quantitative and qualitative methods were adopted to assess the potential impacts pre- and post-mitigation attributable to the activities and the physical changes proposed by the Project reference design.

Proposed activities associated with the Project construction and operation have been reviewed to identify those activities with the potential to lead to a disturbance or a change of the local and/or regional hydrology and water quality. These activities are indicated in **Section 6.1** for the construction phase and **Section 6.2** for the operational phase of the Project.

The impact assessment covers the activities and changes brought about by the Stage 1 development, however where models were developed to inform infrastructure sizing the full developed footprint was also assessed to ensure consideration and inclusion (where suited) of the long-term requirements.

Pipelines

The pipeline infrastructure would primarily be below ground and result in no significant change of land use. Potential impacts to the surface water resources associated with the pipelines are expected to be minimal and primarily associated with the construction phase.

Potential impacts associated with the construction and operation of the effluent pipelines have been qualitatively assessed.

AWRC Site

Significant above ground / surface changes are expected to occur during the construction phase of the AWRC site, these changes would mostly remain in place during the operational phase as well. Given these expected changes a mix of quantitative and qualitative assessments have been conducted to inform the impact assessment.

Low flows: Draft numerical low flow objectives and targets have been established for the Wianamatta-South Creek catchment by DPIE EES through the Risk-based framework (Dela-Cruz et al, 2017) process. The numerical criteria established by these objectives serve as low-flow discharge targets for the stormwater management response in the Project reference design. By achieving the low flow discharge targets, there is a low risk of stormwater discharges from the Project contributing to unacceptable impacts in the local waterways downstream of the AWRC.

Peak stormwater discharge: A risk-based approach has also been followed in the development of the flood management response. The Project reference design seeks to ensure no increase in downstream peak flows for a range of events between the 50% and 1% annual exceedance probability storm events. Stormwater and flood flow management measures for the reference design have been developed that achieve or contribute towards these objectives being achieved by ensuring stormwater detention can be provided as necessary.

Hydrologic, hydraulic and earthworks models of the AWRC site were developed to quantify the potential impacts as well as assess the effectiveness of proposed stormwater management and mitigation measures.

Models used to inform the assessment include:

- Hydrology: XP-RAFTS
- Hydraulics: DRAINS
- Water Quality: MUSIC
- Terrain and earthworks: Civil3D

As the AWRC would be constructed in stages, modelling and assessment contemplates a Stage 1 and ultimate footprint.

The methodologies adopted for the modelling analyses, which were used to inform the assessment, are described in **Section 4.5.3**.

4.5.2 Impact significance

The significance of any potential project impact on the local surface water resources has been determined by considering the sensitivity of the environment related to the assessed criteria as well as the magnitude of the expected change. The resultant matrix of significance is shown in **Table 4-3**.

Table 4-3 Matrix of significance

Magnitude of Impact	Sensitivity of Environmental Values		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The *Sensitivity of Environmental Values* evaluation is influenced by the following criteria:

- Condition of the environmental value, i.e. how far is it understood to have already been changed from its original natural form or state?
- How unique or rare is the condition or value or it's dependant ecological receptors?
- How sensitive are the dependant receptors to changes?

The *Magnitude of Impact* evaluation is influence by the following criteria:

- If a qualitative assessment has been conducted, how do the results compare to the relevant WQOs
- For quantitative assessments the following is considered
- Expected duration of impact: Temporary vs. long-lasting/permanent
- Expected extent of impact: Local vs. regional/widespread
- Estimated degree of change from pre-development conditions

4.5.3 Modelling methodologies

For the post development scenario, the modelling assessed the ultimate footprint with the AWRC sized to 100 ML/day. This is because operational stormwater management facilities, including detention basins and drainage, would need to be constructed to accommodate future stages of the AWRC. These measures can be delivered in stages or may be constructed in total during Stage 1. If the full extent of the reference design measures are delivered during Stage 1, they would be slightly oversized and would provide a higher level of protection than required at that time’

Low flow metrics (MUSIC)

A volumetric balance and low flow assessment of the Project reference design provides a detailed understanding of the change in stormwater runoff volumes, flows and pollutant loads associated. Changes are assessed in the context of WQOs (flow and quality). Water balance modelling includes land use and rainfall inputs, evaporation, evapotranspiration, stormflow runoff and baseflow. A detailed balance and flow assessment has been developed using industry standard software (eWater MUSIC) to demonstrate the net impact on the existing environment when incorporating the various WSUD elements and management measures. The methodology, inputs, assumptions, and results are further detailed in **Appendix A**.

Peak storm discharge assessment (XPRAFTS)

An XP-RAFTS hydrological model of the AWRC Project reference design site was developed to compare pre- and post-development peak runoff rates and volumes associated with frequent and rare storm events. The pervious and impervious areas and general drainage slopes for each catchment were inputted to the model as sub-catchments. The hydrologic modelling was guided by Australian Rainfall and Runoff 2019 (ARR 2019) rainfall data and methods and incorporated the modelling of 10 representative storms for 14 varying storm durations (25 min to 30 hours). The storm durations resulting in the highest simulated median peaks were then identified as the critical duration events for each of the discharge locations. The highest median peak flow was thus identified for both pre- and post-development and compared. These steps were repeated to assess discharge resulting from storm events with annual exceedance probabilities (AEPs) of 50%, 5% and 1%.

The hydrologic modelling was used to assess the risk of site changes increasing local peak flows contributing to increased flood flows affecting downstream development and infrastructure.

Hydraulic models were developed in DRAINS to inform the stage-discharge relationships for the various discharge conduit sizes considered. Detailed methodology, inputs, assumptions, and results are further detailed in **Appendix B**.

Sizing of stormwater quality and low flow management measures (MUSIC)

A MUSIC model was developed to estimate pollutant loads generated from the AWRC site under existing and proposed development conditions. This platform was chosen as it can estimate the quantity and quality of stormwater runoff generated by the Project reference design conditions, and to determine the effectiveness of the proposed mitigation measures. The details of the MUSIC modelling are provided in **Appendix A**.

5 Existing environment

5.1 Climate

5.1.1 Historical records

The Bureau of Meteorology database was used to identify weather observation stations close to the study area. The identified stations were further assessed to determine the most representative set of records. The results are summarised in **Table 5-1**.

Table 5-1 Local rainfall gauges metadata

Gauge ID	Location	Distance (km)	Elevation (m)	Years active	Percent complete	MAP*
067066	Erskine Park Reservoir	5.9	85	Jul 2013 – Mar 2020 [7 yr]	99%	649
067108	Badgerys Creek AWS	6.2	81	Nov 1995 – Mar 2020 [25 yr]	93%	706
067119	Horsley Park Equestrian Centre AWS	7.6	100	Oct 1997 – Mar 2020 [23 yr]	97%	748
067114	Abbotsbury (Fairfield)	8.0	75	Dec 2000 – Mar 2020 [20 yr]	94%	700
067084	Orchard Hills Treatment Works	8.6	93	Dec 1970 – Jan 2020 [50 yr]	97%	780
067019	Prospect Reservoir	13.3	61	Jan 1887 – Mar 2020 [133yr]	99%	874
***Mean Annual Precipitation (MAP) is calculated over the years with complete datasets**						

The following primary factors were used to assess the data records:

- Completeness of rainfall record
- Distance from the AWRC site
- Record length

Considering the above factors, the Badgerys Creek AWS and Orchard Hills Treatment Works stations were analysed further. Comparing only the period with overlapping data (and excluding months with any missing data), the MAP for the two sites were calculated as 698 mm and 714 mm, respectively, over this period. As the two gauges show correlated measures on a monthly and annual basis, the Orchard Hills station's data record was selected as the representative record, given the longer and more complete dataset.

Representative evaporation data was sourced from the SILO (Scientific Information for Land Owners) database (SILO, 2020). The metadata associated with the stations closest to site is summarised in **Table 5-2**. Based on similar considerations mentioned above, the Orchard Hills dataset was considered most appropriate and used to characterise the expected evaporation rates for the Project site to inform water balance and irrigation demand modelling.

Table 5-2 Details of gauges with available evaporation data close to study area

Gauge ID	Location	Elevation (m)	Data availability	MAE[1] (mm)
67068	Badgerys Creek McMasters F.stn	65	Jan 1970 – Apr 2020	1,475
67108	Badgerys Creek AWS	81	Jan 2010 – Apr 2020	1,493
67084	Orchard Hills Treatment Works	93	Jan 1970 – Apr 2020	1,459

The annual total rainfall and evaporation values over the 1971 to 2019 monitoring period (excluding the years with prolonged periods of missing data) are shown in **Figure 5-1**. Review of the historical data associated with this station reveals a variable annual rainfall rate. Wetter years, i.e. 1978 and 1990, may experience rainfall in excess of 1,200 mm and drier years record less than 500 mm. The pan evaporation data fluctuates between 1,200 mm and 1,900 mm with an increasing trend observed in the total annual evaporation since 2012.

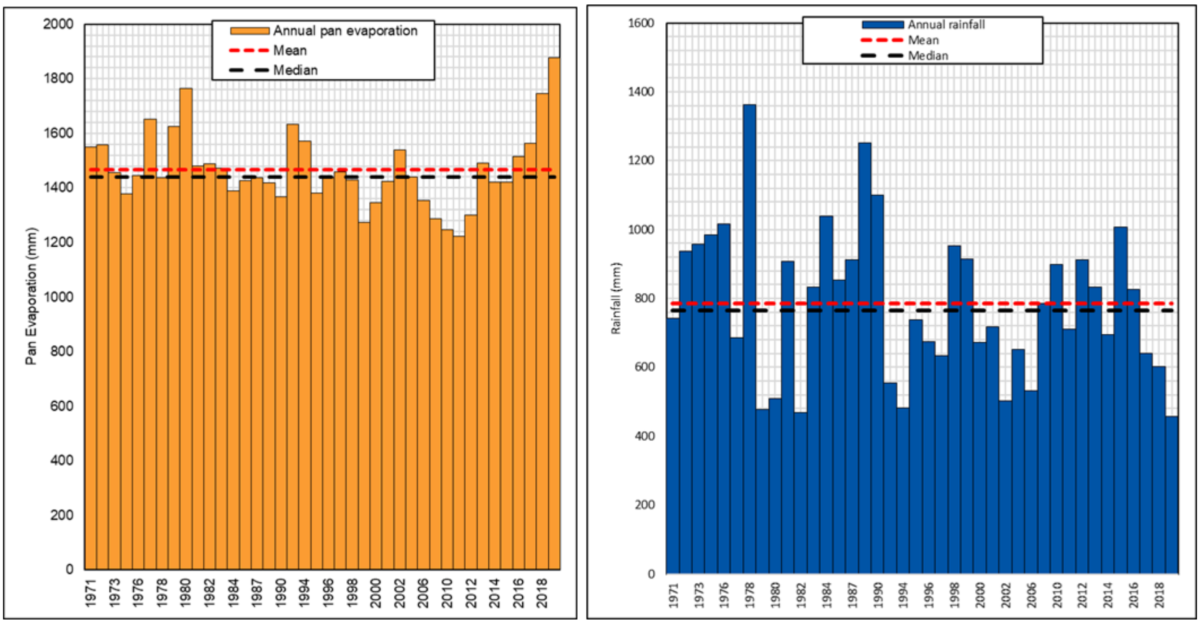


Figure 5-1 Average annual evaporation and rainfall measured - Orchard Hills station (1971-2019)

To better visualize the distribution of the rainfall and evaporation data for each calendar month, a box and whisker and plot chart was developed (**Figure 5-2)**. This monthly breakdown, data suggests generally “wet season” from November to May” and “dry season” from June to October. **Figure 5-2** also indicates that in all the months the average evaporation exceeds the average rainfall with December having the highest evaporation rate.

[1] *MAE: Mean Annual Pan Evaporation; Selected site in bold*

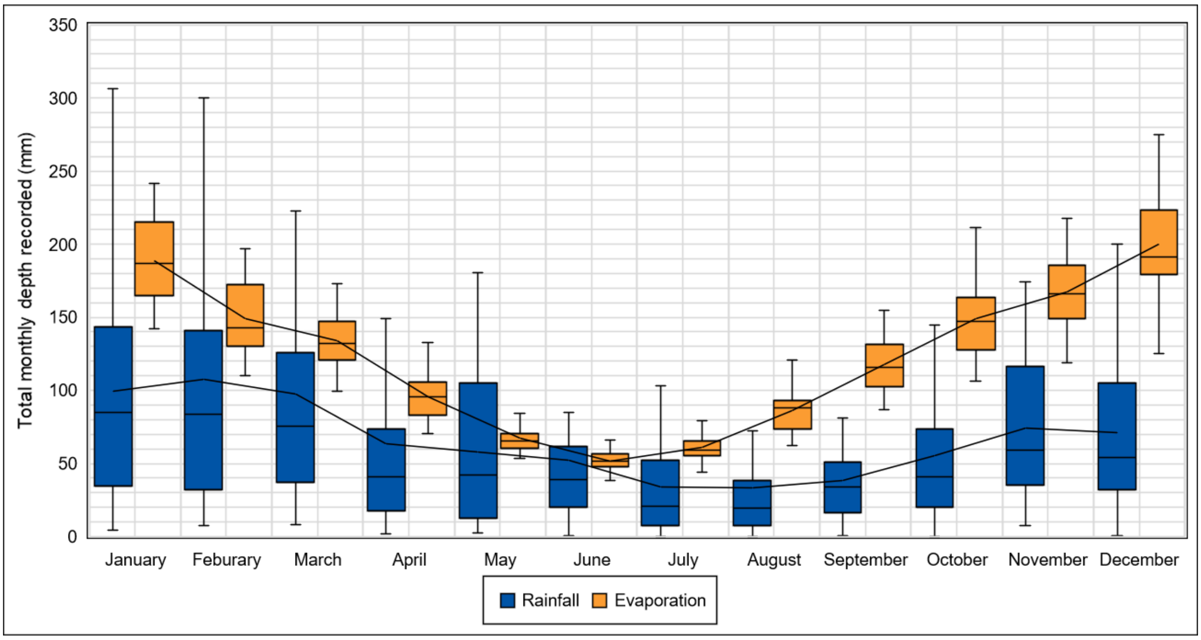


Figure 5-2 Range of total monthly rainfall and evaporation (1971-2019)

Notes: Whiskers show 10th and 90th percentiles. Boxes depict median values, upper and lower quartiles. Trend lines reflect monthly averages.

Design rainfall depths were obtained from the Bureau of Meteorology website for the AWRC site location (BOM, 2020). The storm depths associated with various AEP's for the 1-hour and the 24-hour duration events are indicated in **Table 5-3**.

Table 5-3 Daily Rainfall depths associated with different AEP storm events

Annual Exceedance Probability (AEP)	1-Hr Rainfall depth (mm)	24-Hr Rainfall depth (mm)
0.5%	76.5	249
1%	70.1	229
2%	62.0	203
5%	51.9	169
10%	44.4	144
20%	37.0	119
50%	26.5	85.0

As temperature data, and its inherent variance, is not as critical as rainfall and evaporation to the local hydrological modelling, the record length at the Badgery's Creek station (067108) was deemed sufficient. Analysis of the these records, presented in **Figure 5-3,** indicates a temperate climate with warm to hot summers (average maximum temperatures around 30°C) and cooler winter periods with average maximum temperatures below 20°C and minimum temperatures averaging around 5°C.

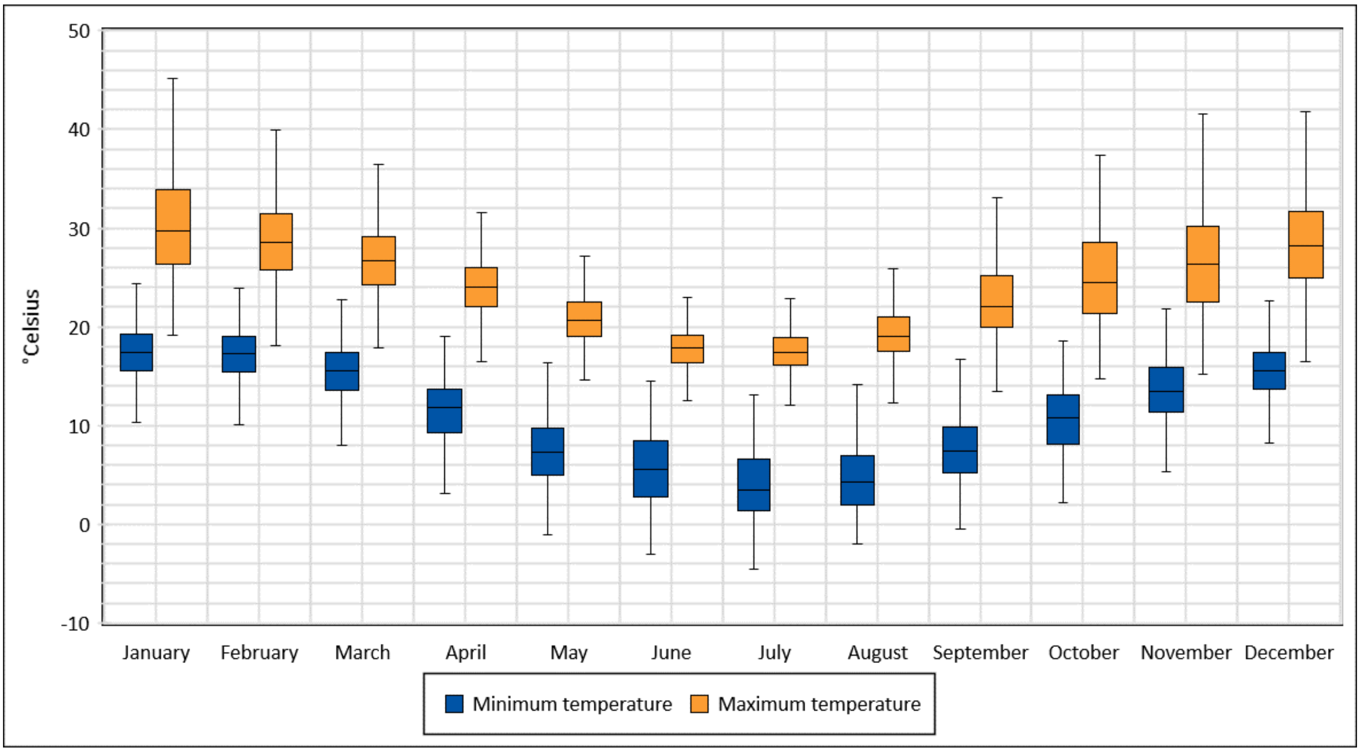


Figure 5-3 Monthly maximum and minimum temperature ranges (1996-2019)

Notes: Whiskers show 10th and 90th percentiles. Boxes depict median values, upper and lower quartiles.

5.1.2 Climate change

Consideration of potential climate change is a crucial factor in assessing the future water resources, as it has the potential to influence the general environmental water balance as well as groundwater availability, soil and water salinity and water quality. The NSW Office of Environment and Heritage (OEH) has published several documents detailing the expected effects of climate change on water resources. Study results documented in a 2015 report, "*Climate change impacts on surface runoff and recharge to groundwater*" (OEH, 2015), have been used to assess expected local climatic changes.

There are two models of climate data in use in Australia which are applicable to this study area. The national model, CSIRO, and a local model, the NSW and ACT Regional Climate Model (NARCliM). The CSIRO data is not as granular as NARCliM, which uses downscaled regional climate models (RCM's) derived from IPCC's Global Climate Models (GCM) to project their findings across three time periods.

Utilising NARCliM, the OEH study predicted near future (2020-2039) and far future (2060-2079) changes to rainfall, runoff and recharge to groundwater. **Table 5-4** presents a summary of the statistical analysis for Metropolitan Sydney.

Table 5-4 Percent changes to multi-model mean annual rainfall, surface runoff and recharge

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Metropolitan Sydney	0.4	4.0	-5.0	8.1	17.6	12.5

The results of this model for the Hawkesbury catchment are presented in **Table 5-5**. In summary, the study predicted that changes in near future, were likely to be a reduction in the rainfall and recharge to the groundwater and increase in the surface runoff, while in far future, the model predicted an increase in all three parameters (rainfall, surface runoff and recharge to the groundwater).

Table 5-5 Percentage change in rainfall, runoff and groundwater recharge for the Hawkesbury catchment

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Hawkesbury Nepean Catchment	-0.1	0.9	-9.3	6.1	13.4	5.6

Understanding of the physical processes that cause extreme rainfall, coupled with modelled projections, indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected. The publication does not provide details regarding changes to flood-producing rainfall events other than to confirm that changes to rainfall intensity are predicted.

The ”*Practical Consideration of Climate Change”* (NSW Government Department of Environment and Climate Change, 2007) publication references modelling carried out by the CSIRO in 2007 for the NSW Government to assess the impacts of climate change on rainfall intensities. The results showed a trend of increased rainfall intensities for the 40-year ARI one-day rainfall event across New South Wales (**Table 5-6**).

Table 5-6 CSIRO indicative change in rainfall and evaporation one-day total (CSIRO, 2007)

Location	40 Year 1-day rainfall total projected change 2030	40 Year 1-day rainfall total projected change 2070	Evaporation projected change 2030	Evaporation projected change 2070
Sydney Metropolitan	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
Hawkesbury Nepean	-3% to +12%	-7% to +10%	+1% to +8%	+2% to +24%
New South Wales Average	-2% to +15%	-1% to +15%	+1% to +12%	+3% to +38%

These expected rainfall and evaporation changes largely support the predictions presented in **Table 5-5**, as higher intensity storms will result in higher runoff volumes, whereas the increased evaporation rates will likely lead to reduced recharge, as suggested in the near future results.

Temperature projections for Eastern Australia indicate higher average temperatures for the near future (2030) with the daily average expected to rise between 0.5 and 1.4°C above the average value recorded between 1986 and 2005. By late in the century (2090), for a high emission scenario (RCP8.5) the Projected range of warming is 2.8 to 5.0 °C. Under an intermediate scenario (RCP4.5) the Projected warming is 1.3 to 2.6 °C. (OEH, 2014).

5.2 Land use

The AWRC site as well as a large portion of the pipeline alignments are located within the Kemps Creek Precinct of the Western Sydney Aerotropolis growth area, which is currently undergoing rezoning on a regional scale. Future changes are expected to change the bulk of the rural and primary production zoned areas to commercial and industrial land uses.

The AWRC itself represents a change in land use from the current rural zoning. Following construction of the pipelines, land use within the pipeline corridors would be unchanged.

5.3 Topography

Available LiDAR data with 1-m resolution was used to define the physiographic context of the Project. The AWRC site is located within a regional alluvial plain associated with the South Creek and Kemps Creek watercourses (**Figure 5-4**). The topography in the area is predominately flat, with a gentle slope towards the north as indicated by the surface elevation data presented in **Figure 5-5** . Elevations across the centre of the site generally range between 35 and 40 mAHD.

Figure 5-4 Flat topography of the AWRC site (South Western corner of site looking North East)

The treated water pipeline (**Figure 5-6**) follows gently sloping topographies, with elevations generally ranging from 30 m to 90 mAHD, from the low-lying areas around the South Creek/Kemps Creek (35 – 40 mAHD) through to the Nepean River valley (35 mAHD), traversing a small ridge in the vicinity of The Northern Road, Luddenham (90 mAHD).

The brine pipeline alignment, shown in **Figure 5-7**, heading out east from the AWRC site at 40 mAHD elevation, follows gently sloping topographies, rising from 40 mAHD, rising to reaching a high point at Cecil Hills (80 mAHD) before sloping down again towards Prospect Creek and the Georges River in Fairfield at 10 mAHD.

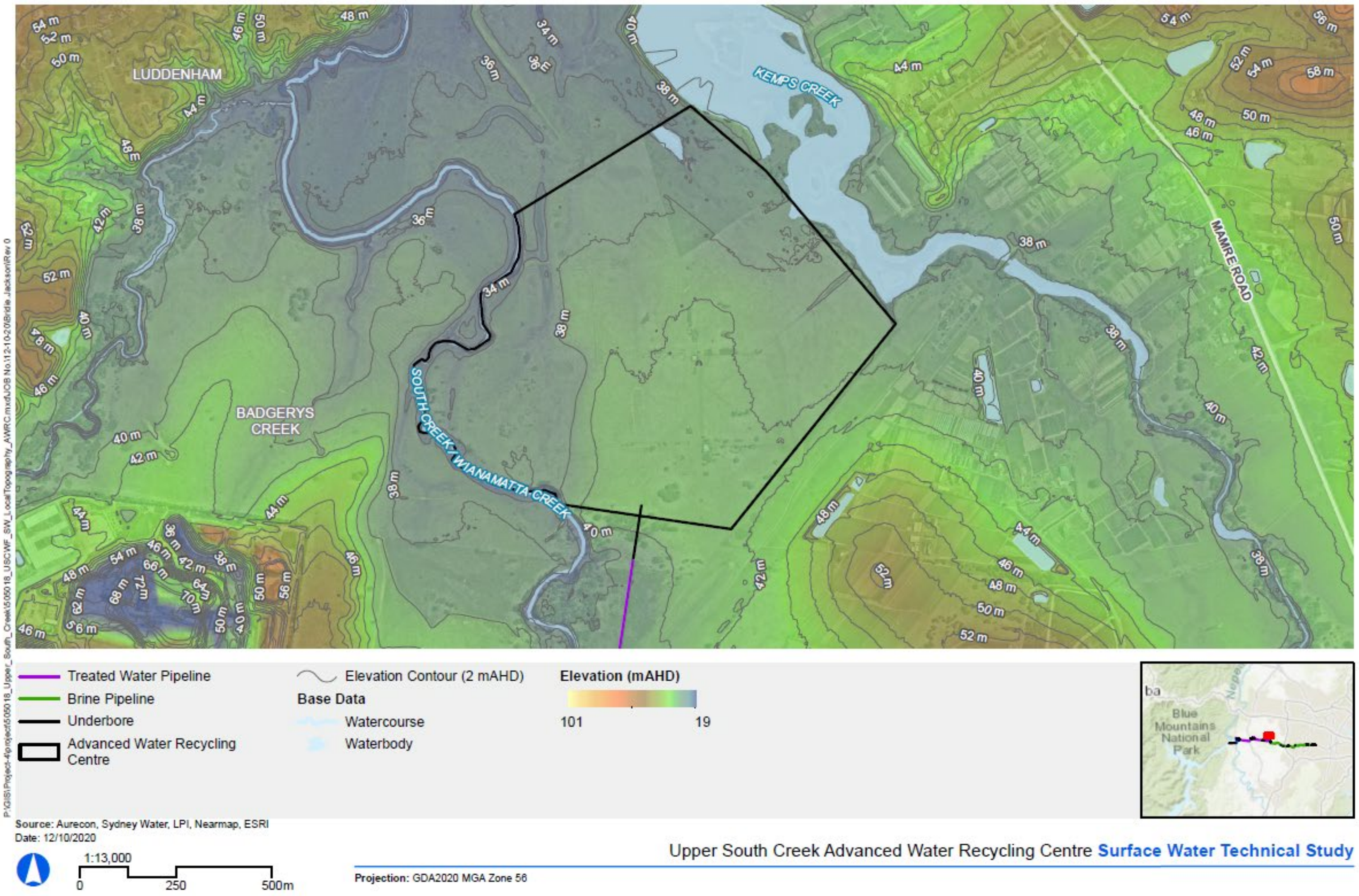


Figure 5-5 Topography AWRC site

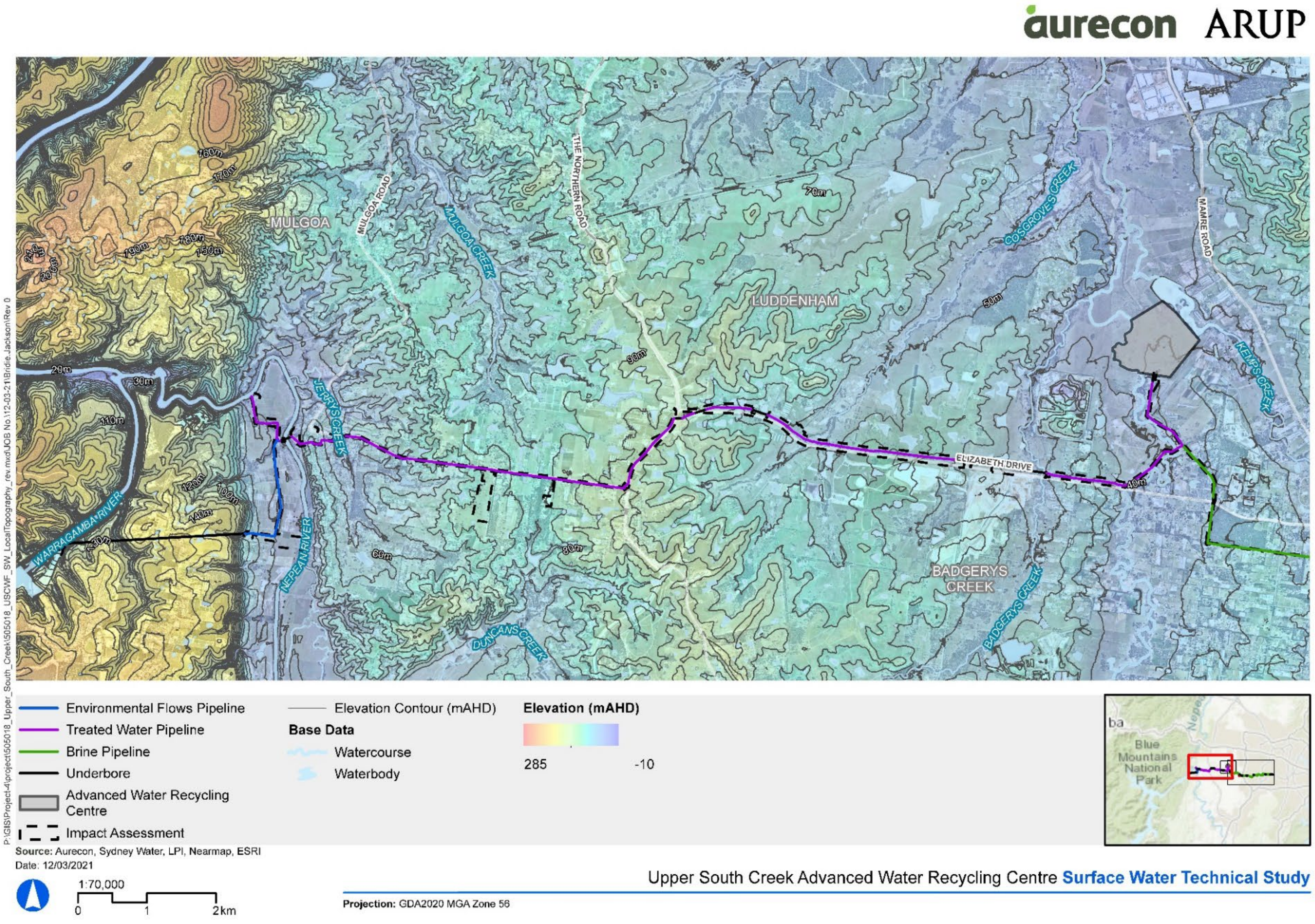


Figure 5-6 Topography – Treated water and Environmental flows pipelines

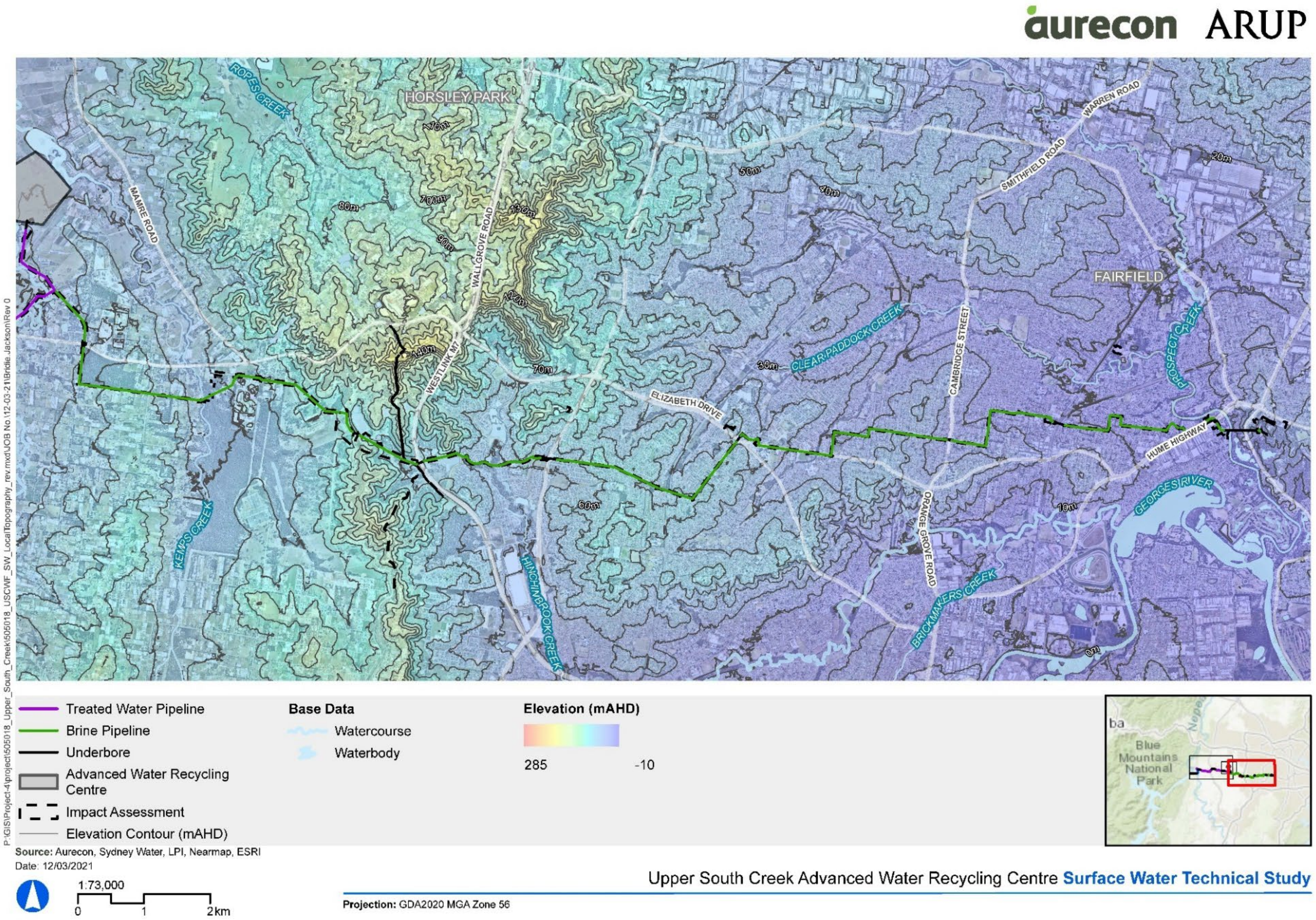


Figure 5-7 Topography - Brine pipeline

The environmental flows pipeline continues south along a plateau adjacent to the Nepean River valley before turning west towards the Warragamba River. Shortly after this direction change, the pipeline route encounters a fairly steep ridge with the surface elevation increasing from 61 m to 153 m within a distance of 300 m (slope of 31%). At this point the proposed construction methodology is a tunnelled section cutting into the east side of the ridge line at 66 m and exiting on the west side of the ridge line at an elevation of 34 m close to the Warragamba River for release The complete elevation profile for the pipeline along its 4.5 km length, is presented in **Figure 5-8**.

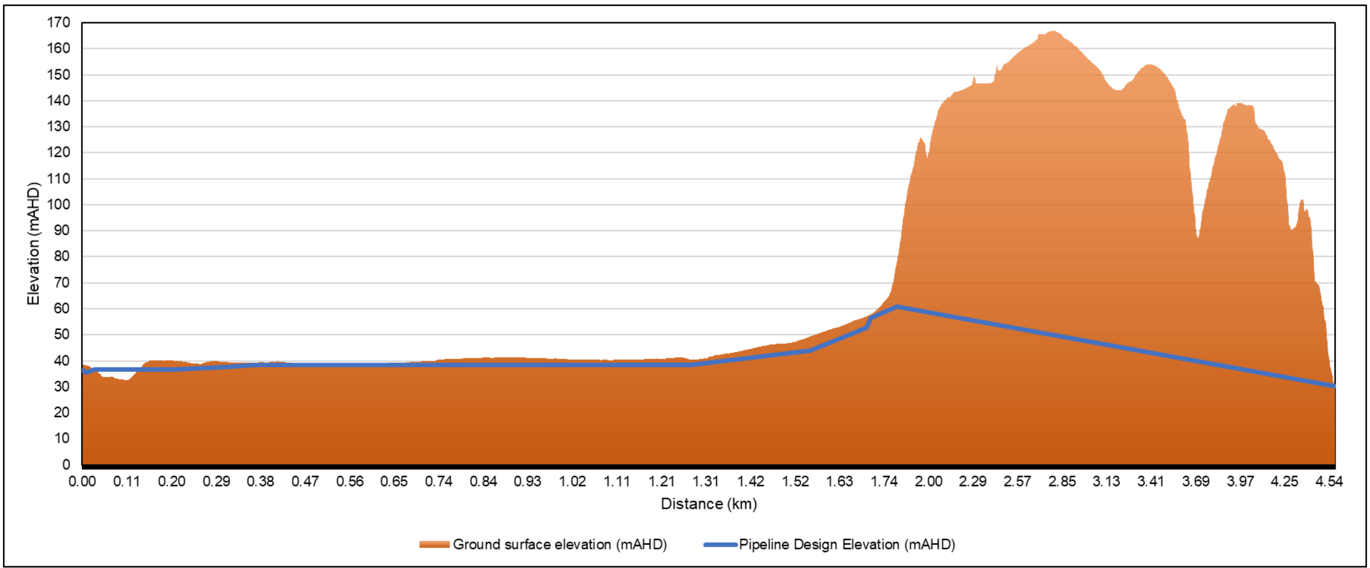


Figure 5-8 Elevation profile along the environmental flows pipeline

Within the local surrounding area, the landscapes are typified by a mixture of urbanised areas associated with current residential and commercial developments, and open areas of grasslands and low rolling hills.

5.4 Hydrology

The hydrological characteristics of the watercourses adjacent to the AWRC site, and their catchments, are described below. Most of the watercourses traversing the pipeline have intermittent flows throughout the year, in drier periods the creek beds maybe completely dry. Generally, the higher the stream order the more representative of the higher flows that can be expected at that point in the watercourse. A detailed review of hydrology for water courses traversing the pipeline has not been undertaken because ongoing impacts during the operational phase are not expected. The hydrology of the Nepean and Warragamba Rivers is discussed in the Flood Assessment chapter.

5.4.1 Catchment descriptions (for AWRC and alignments)

The AWRC site and most of the pipeline alignments are in the Wianamatta-South Creek and Hawkesbury-Nepean catchment.

The Hawkesbury-Nepean catchment provides drinking water, agricultural and fisheries produce, recreational opportunities and tourism resources for the metropolitan area of Sydney and is one of the largest coastal basins in NSW with an area of 21,400 km^2 (NSW DPI, 2017). Over its 470 km length, it originates from the headwaters of the Nepean River in Goulburn before joining the Hawkesbury River in the west of Sydney and draining to Broken Bay, a semi–mature tide-dominated drowned valley estuary and large inlet of the Tasman Sea located about 50 kms north of Sydney central business district. The approximate saline limit is at Wisemans Ferry, but the tidal limit is 85 km further upstream at Yarramundi.

The Georges River, which has a catchment area of approximately 960 km^2, is one of the most highly urbanised catchments in Australia. It flows approximately 100 km from the headwaters on the Illawarra escarpment and Appin down to the river mouth at Botany Bay. The water is fresh above Liverpool Weir and is tidal and saltier below the weir down to Botany Bay.

The majority of the Project lies within the Lower Nepean River Management Zone of the Hawkesbury-Nepean Catchment. A significant proportion of the Hawkesbury-Nepean Catchment is protected in national parks and water catchment reserves; however, the centre and associated pipelines lie primarily within the South Creek sub-catchment which has been extensively modified and disturbed as a result of urbanisation and associated land clearing. The hydrology of the South Creek catchment has been significantly altered due to a decrease in pervious surfaces which has in turn altered the geomorphological regime and ecological habitat features of the watercourses. The Hawkesbury River is the ultimate downstream receiving environment and is located about 29 km from the AWRC at the closest point.

AWRC – Wianamatta-South Creek

Wianamatta-South Creek is a significant tributary of the Hawkesbury River. South Creek was renamed Wianamatta Creek on the 28 March 2003 by the Geographical Names Board of NSW. It was renamed after the Wianamatta Aboriginal Tribe local to Windsor but the name "South Creek" wasn't dropped on the basis of the name was a long standing name and should not be lost in historical context (Enacademic, 2020).

The watercourse originates around Oran Park, flowing generally north, where it is joined by other tributaries such as Badgerys Creek and Kemps Creek before reaching its confluence with the Hawkesbury River, near Windsor. The creek descends 94 m over its 70 km course. Several farm dams and minor waterbodies exist within the Project area.

The South Creek sub-catchment covers around 620 km^2. The confluence of Kemps Creek and Badgerys Creek into South Creek is about three kilometres north of Elizabeth Drive. The South Creek catchment upstream of the confluence with Badgerys's Creek covers an area of approximately 96 km^2, the extent of which is shown in **Figure 5-9.**

The channel width and flow velocity varies significantly within the stretch of the creek directly adjacent to the AWRC site as indicated in photos provided in **Figure 5-10** taken along the river banks, looking downstream.

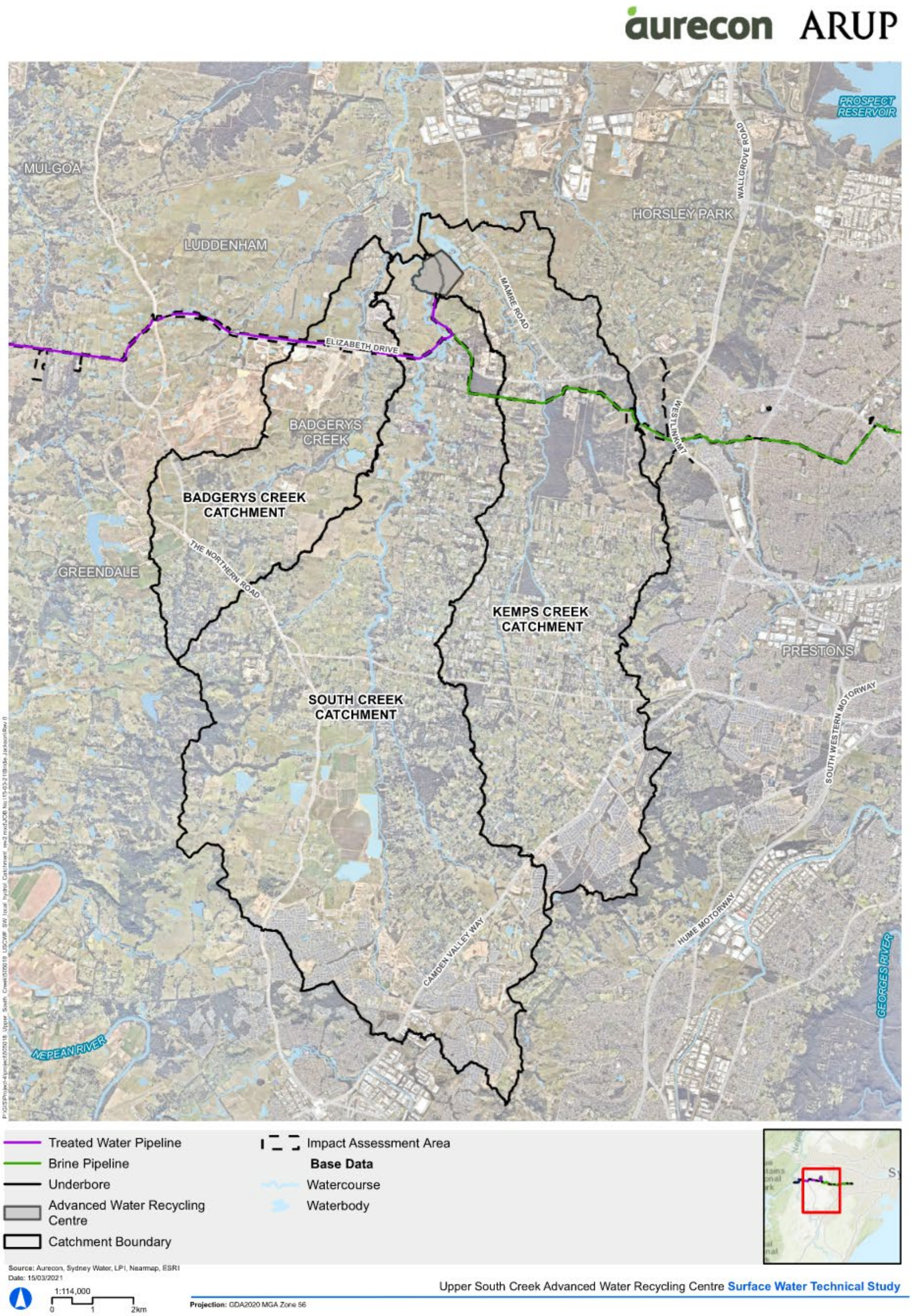


Figure 5-9 Upstream contributing catchments

Figure 5-10 South Creek adjacent to AWRC site (photos taken looking downstream)

AWRC - Kemps Creek

Kemps Creek is a tributary of South Creek and is a fourth order stream in the vicinity of the AWRC site. The creeks source is approximately 2 km east of Catherine Fields and it flows for about 17 km through the suburbs of Rossmore, Bringelly, Austral and Kemps Creek before discharging to South Creek just north of the AWRC site. The creek flows through a predominately semi-rural setting, although urbanisation has increased in recent years (Liverpool City Council, 2003).

Kemps Creek catchment has been known to experience flooding problems likely due to limited hydraulic capacity in the creek channels, filling activities on the floodplain and inadequate hydraulic capacity at culverts and bridges (Liverpool City Council, 2003). As a result of this, extensive earthworks have been undertaken in the catchment to control water including construction of dams to provide storage, construction of channels or banks to divert flow of water and widening the creek channel to reduce flood levels as well as the frequency and extent of inundation (Liverpool City Council, 2003). Land use within the Kemps Creek sub-catchment largely includes agriculture (grazing, market gardens, poultry), residential, commercial and extractive industries. Kemps Creek has a catchment area of approximately 59 km^2, the extent of which is shown in **Figure 5-9.**

Watercourses traversed by the discharge pipelines

The Warragamba River, Nepean River, Georges River, and numerous tributary streams are within the study area. To describe the hierarchy of the streams within the study area, the Strahler order system is used. This method is the preferred method used in the Water Management Regulation 2018 (NSW Government, 2018). Hydro line spatial data, a dataset of mapped watercourses and waterbodies in NSW, is used and streams are sequentially numbered from the top of the catchment to the bottom (NSW Department of industry, 2020). While Sydney Water is exempt from riparian lands legislation, the Strahler system is an indicator of catchment size, regional significance and potentially hazardous construction conditions.

The result of the Strahler order analysis for the streams directly adjacent to the AWRC as well as those traversed by the pipelines, is summarised in **Table 5-7** and the results indicated graphically in **Figure 5-11** through **Figure 5-16** . Watercourses with a Strahler order of 2 and higher are listed, as well as the sections traversing existing farm dams (T5 & T9). It should be noted that where the Brine pipeline crosses Clear Paddock Creek (between B4 and B5), the waterway has a Strahler order of 1. The associated prescribed riparian corridor width for each watercourse is shown, following the latest guidance from DPIE (DPI, 2018).

Table 5-7 Strahler order analysis of water crossings and creeks bordering ARWC site

ID	Location name	Strahler Order	Riparian corridor width*	Catchment
AWRC site – Local watercourses				
A1	South Creek (West of AWRC site)	6	40 m	Hawkesbury-Nepean
A2	Kemps Creek (East of AWRC site)	4	40 m	
Treated Water Pipeline – Water crossings				
T1	South Creek	6	40 m	Hawkesbury-Nepean
T2	Unnamed tributary to South Creek	2	20 m	
T3	Badgerys Creek	4	40 m	
T4	Unnamed tributary to Badgery's Creek	3	30 m	
T5	Farm dams u/s of Badgerys Creek tributary	1	10 m	
T6	Unnamed tributary to Cosgroves Creek	2	20 m	
T7	Oaky Creek	3	30 m	
T8	Cosgroves Creek	4	40 m	
T9	Farm dam & unnamed tributary to Cosgroves Creek	2	20 m	
T10	Jerrys Creek	4	40 m	
T11	Nepean river	7	40 m	
T12	Baines Creek	3	30 m	
Environmental Flows Pipeline – Water crossings				
E1	Baines Creek	3	30 m	Hawkesbury-Nepean
E2	Megarritys Creek	3	30 m	

ID	Location name	Strahler Order	Riparian corridor width*	Catchment
Brine Discharge Main – Water crossings				
B1	Unnamed tributary to Kemps Creek	2	20 m	Hawkesbury-Nepean
B2	Kemps Creek	4	40 m	
B3	Hinchinbrook Creek	2	20 m	Georges River
B4	Unnamed tributary to Hinchinbrook Creek	3	30 m	
B5	Green Valley Creek	2	20 m	
B6	Prospect Creek	4	40 m	

* On either side of the waterway

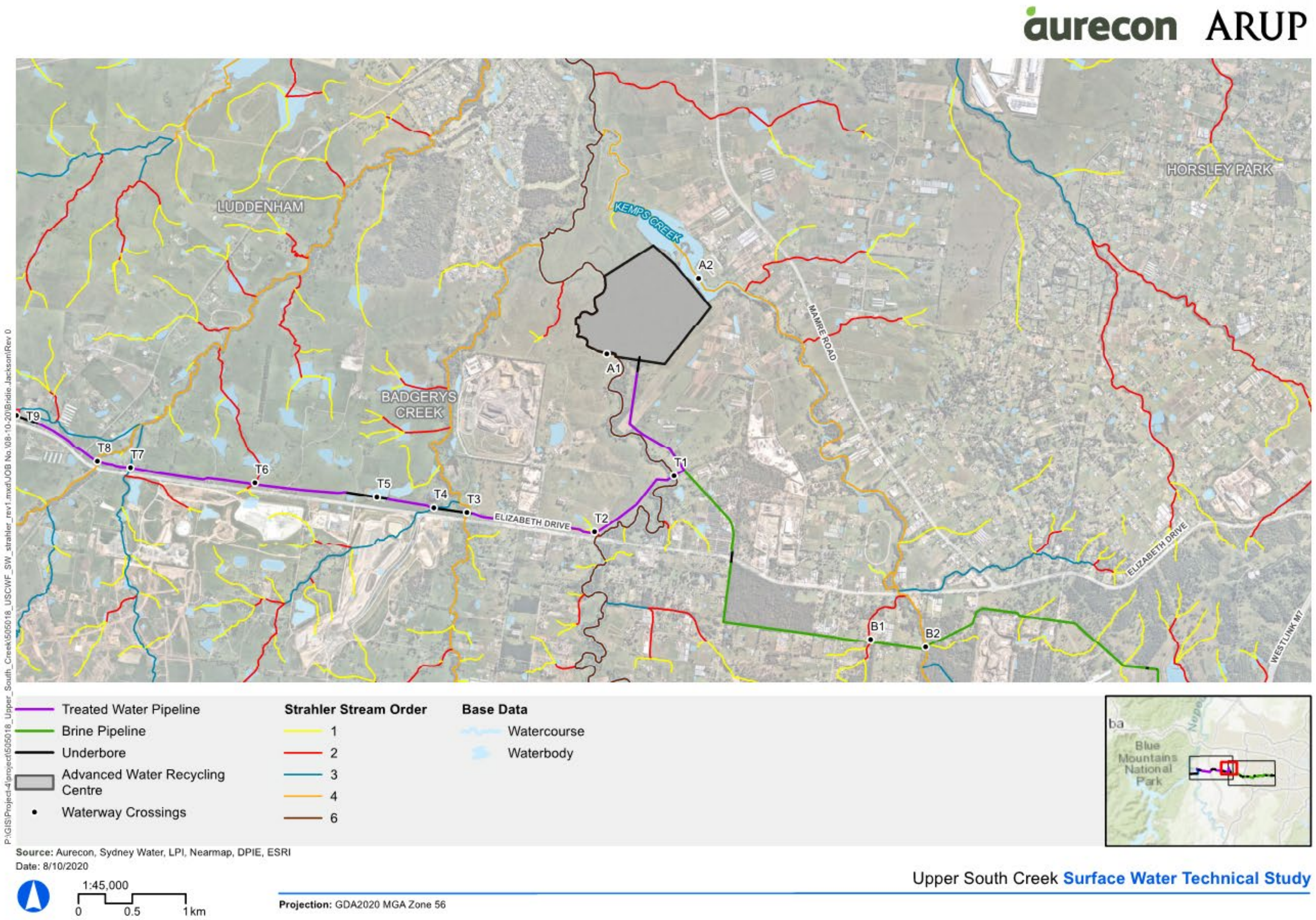


Figure 5-11 Strahler stream order - AWRC site

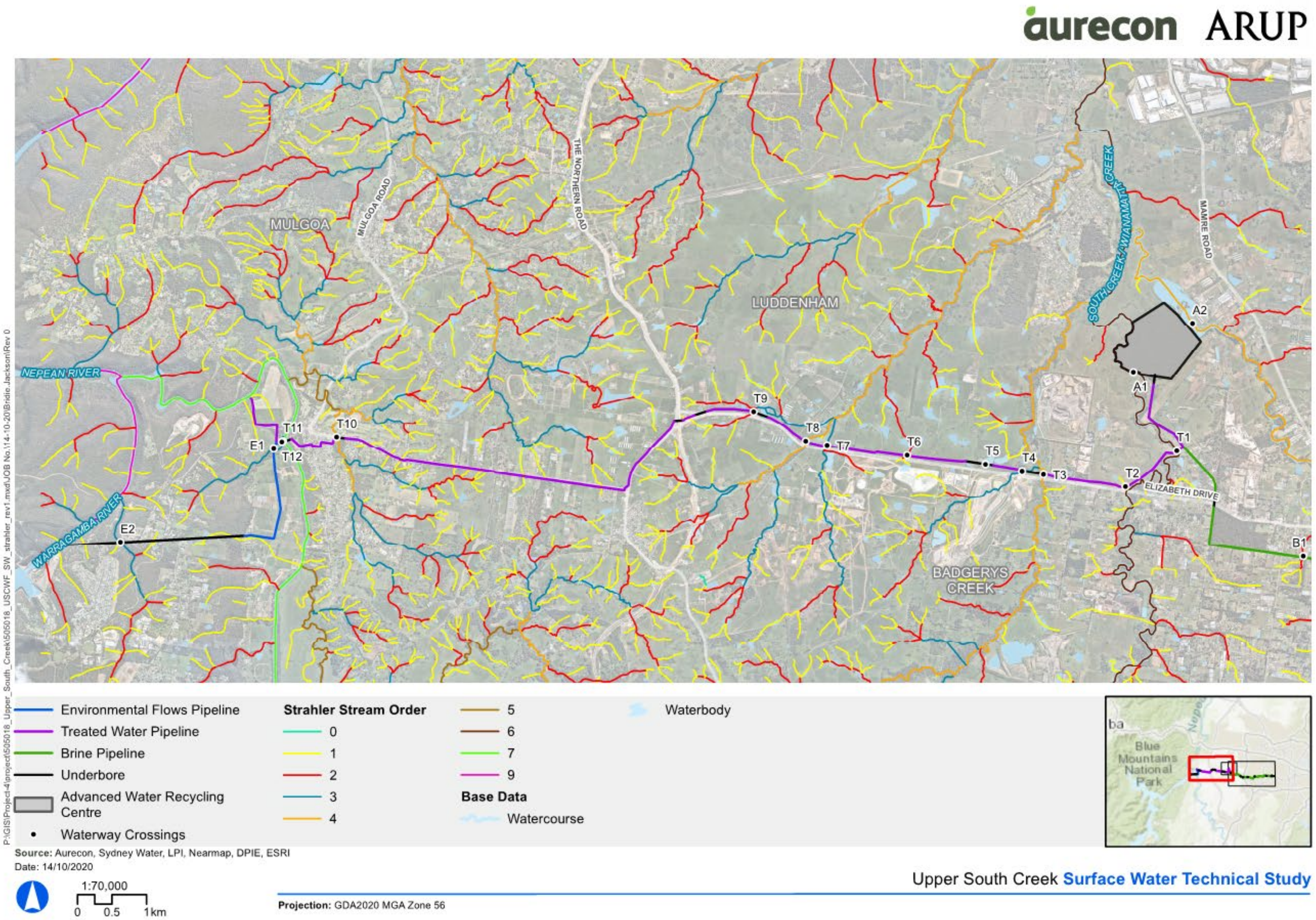


Figure 5-12 Strahler stream order – Treated water and Environmental flows pipelines

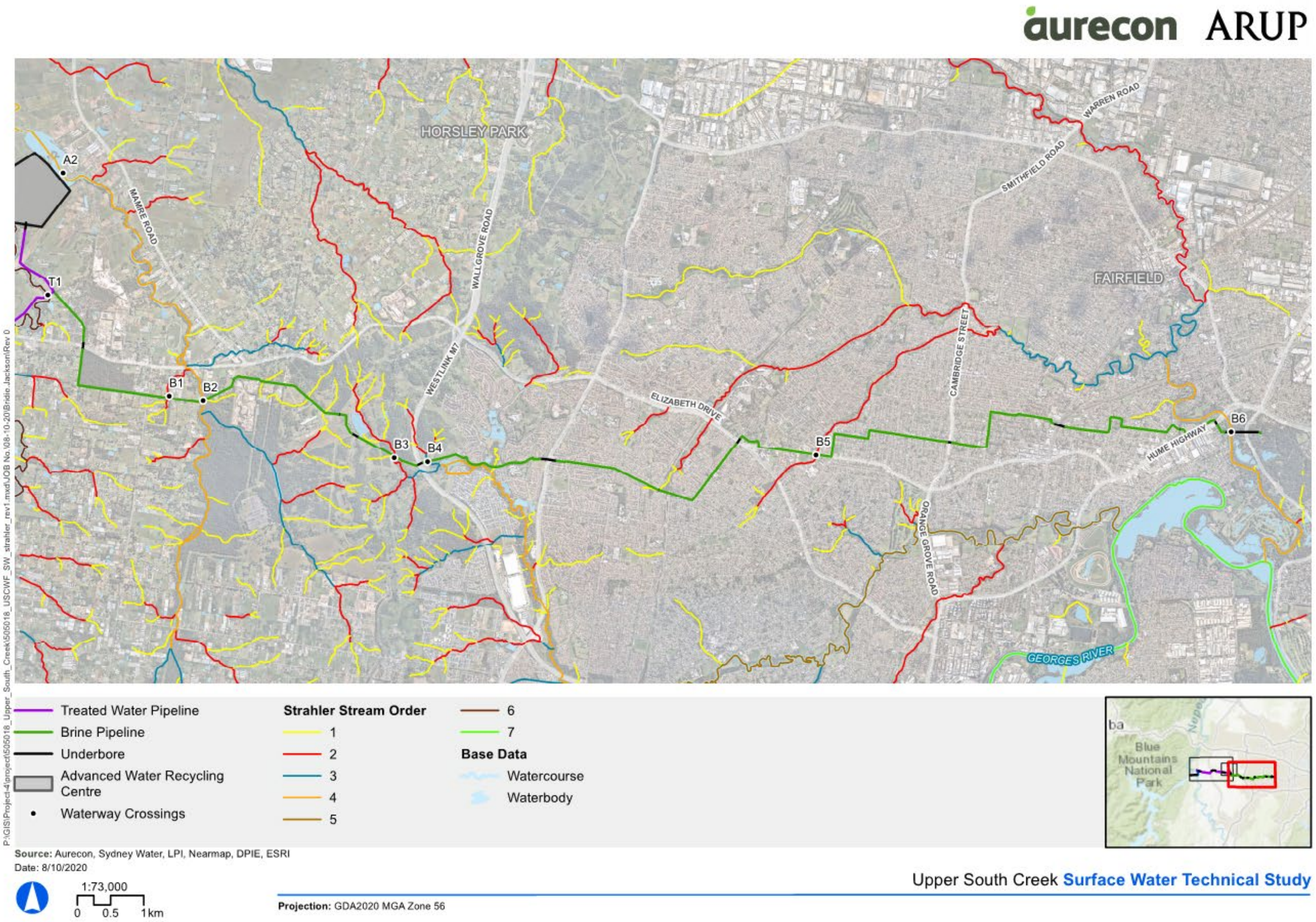


Figure 5-13 Strahler stream order – Brine pipeline

5.4.2 Stream flow

Monitoring

There are multiple stream flow gauges located within the Wianamatta-South Creek catchment. The site falls between two gauges:

- Gauge 21320 is located approximately 1.7 km upstream of the site, near the Elizabeth Drive crossing
- Gauge 212048 is located approximately 14.3km downstream of the site, near the Great Western Highway crossing

Table 5-8 Stream flow gauge

Gauge Number	Location	Waterway	Monitoring Start Date
212320	South Creek at Elizabeth Drive	South Creek	01/06/1970
212048	South Creek at Great Western Highway	South Creek	25/02/1986

The Elizabeth Drive gauge data (median flow of 0.1 ML/d or 0.001 m^3/s) records lower flow magnitudes than the recorded flows further downstream of the site, given the confluence with several tributaries within this reach. The graph also indicates a large portion of the time with very low to no flows in South Creek where it passes the site (approximately 35% of the time with <0.001ML/d). These very low flow conditions are significantly less likely 16 km further downstream at the second gauge.

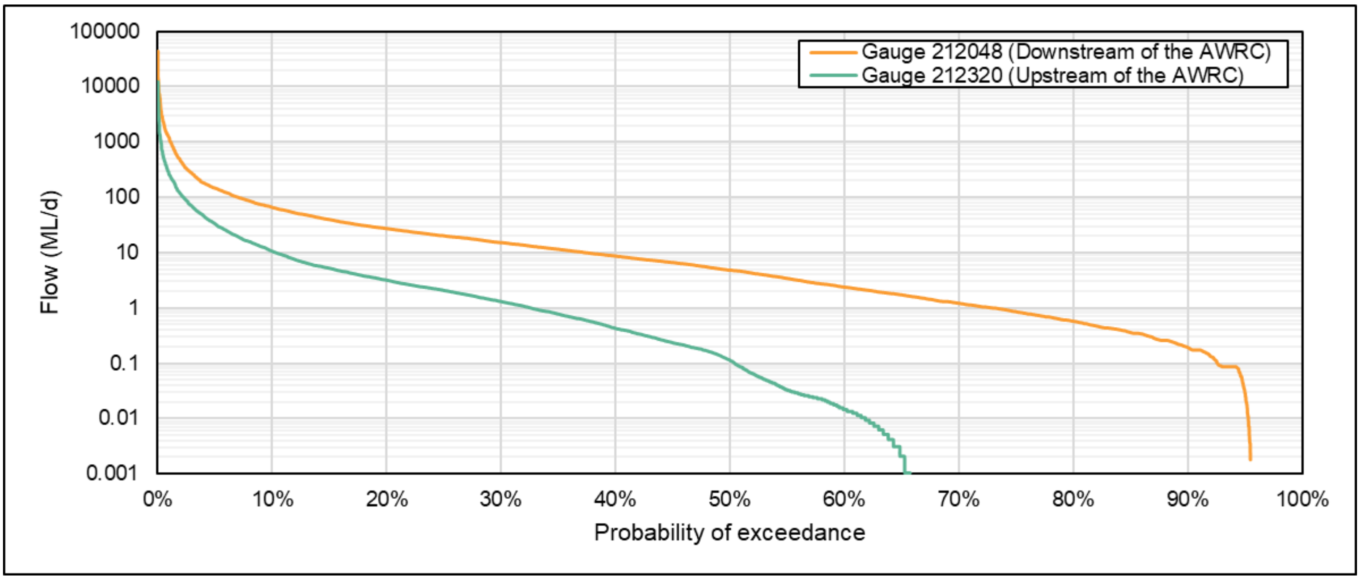


Figure 5-14 Comparison of the flow duration curves for gauge 212048 and 212320

Modelling

Due to the lack of streamflow gauges on smaller waterways within the study areas, including Kemps Creek, the results of the eWater Source hydrological model, developed by Sydney Water (2019) has also been considered when describing the local hydrology. This model represents the entire South Creek catchment as 195 sub catchments and simulates rainfall and runoff processes at an hourly time step over the period of 1994 to 2017 inclusively. The model calibration provides an insight into the relative contribution of runoff and baseflow from upper and lower tributaries. The simulated discharges for both South Creek upstream of the Badgerys Creek confluence, as well as Kemps Creek upstream of South Creek, have been used to approximate the baseline hydrology of the catchment at points of interest in this study; in particular adjacent to the AWRC site and in the vicinity of pipeline trenches. The locations of the 212320 gauge as well as the Source model simulated discharge points used within this study are indicated in **Figure 5-15**.

Baseline hydrology

Flow duration curves have been developed for the three locations using a combination of calibrated hydrologic modelling and flow gauge data. While time series plots provide an overview of the flow behaviour, flow duration curves provide a more concise summary of the flow variance and the percentage of time a certain flow is equalled or exceeded for a specified location in the catchment. The results for three assessed datasets are presented in **Figure 5-16.**

Box and whisker plots have been created for South Creek (gauged and simulated) and Kemps Creek (simulated) to show the distribution of flows across different months of the year (**Figure 5-17**). Whiskers show 10^{th} and 90^{th} percentiles and boxes depict median values, upper and lower quartiles. This data is important to understand flow variability.

These graphs can provide guidance to the targeted scheduling of works during the construction phase of the pipeline, particularly when planning the trenching works through South Creek and Kemps Creek (refer to **Section 7.2**). The recorded gauge data should be considered when describing existing conditions, however the simulated model results can be applied when planning the construction at the watercourse crossings, given the more conservative flowrates (i.e. higher probabilities of higher flowrates).

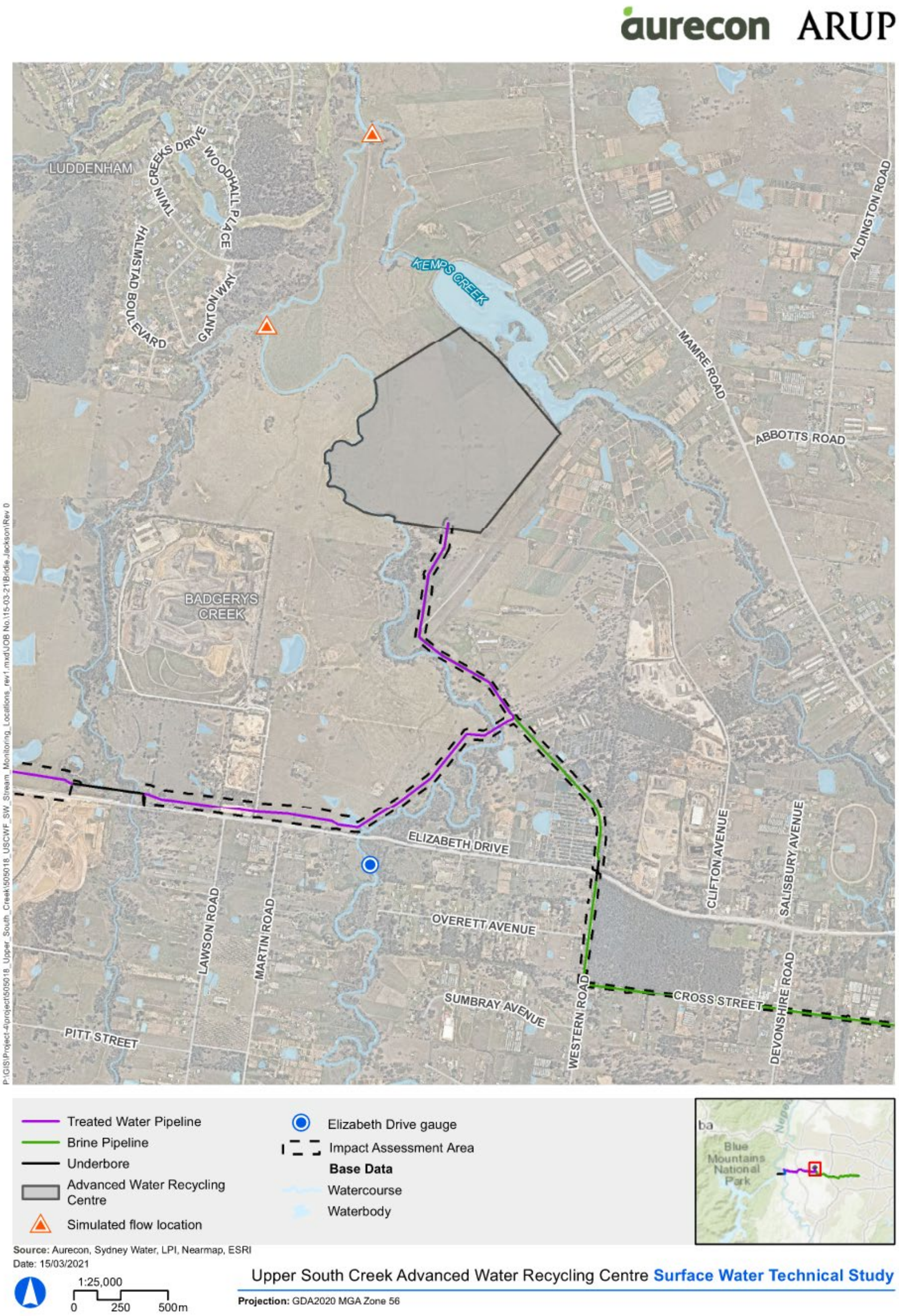


Figure 5-15 Location of available stream monitoring data

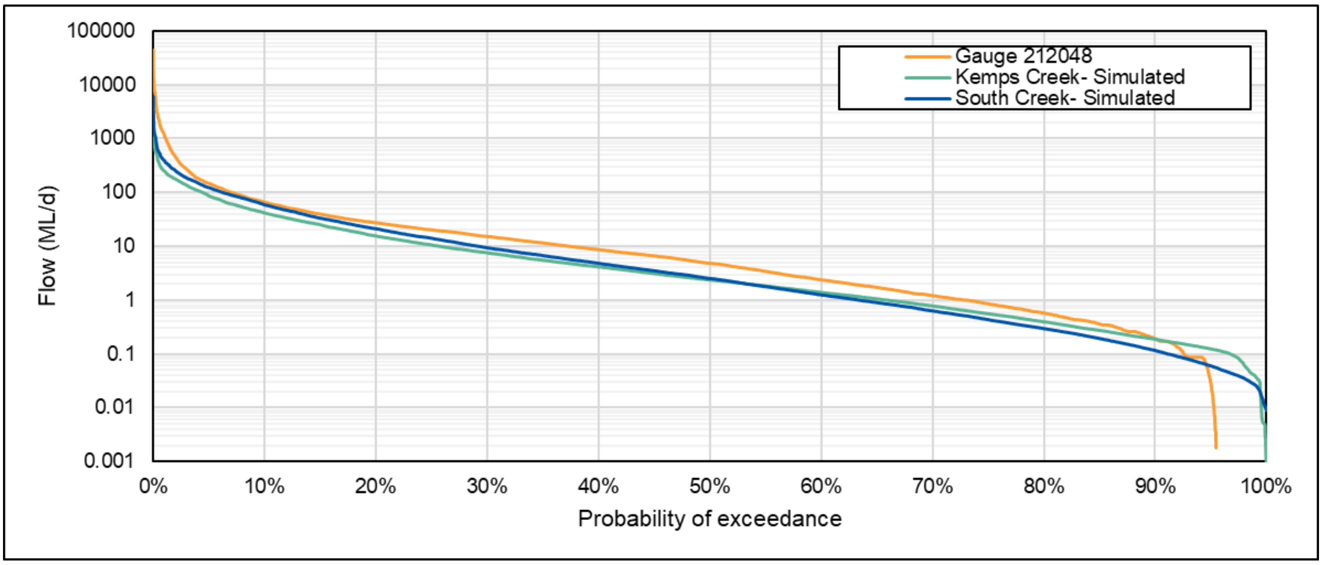


Figure 5-16 Flow duration curves (Oct 1993 – Dec 2017)

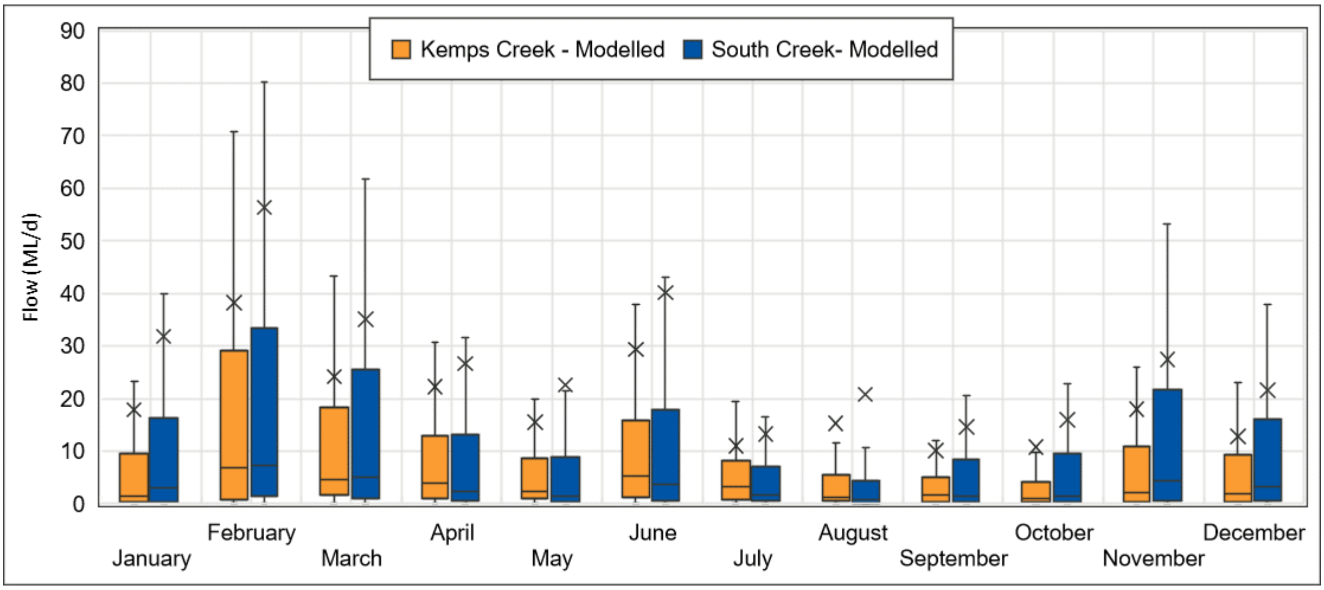


Figure 5-17 Flow distribution across different calendar months for South Creek and Kemps Creek

5.4.3 Site drainage

LiDAR data with 1 m resolution has been used to define the elevation profile and infer drainage lines within the proposed AWRC site. The existing topography indicates a minor ridge line dividing the South Creek and Kemps Creek catchments as indicated in **Figure 5-18**.

The infrastructure footprint indicated in the reference design is primarily be located west of this divide. Runoff from this area naturally drains towards *Drainage Line 1*, where it ponds within a billabong and any excess spills over to South Creek via the connecting spillway channel (see **Figure 5-19** and **Figure 5-20**). Runoff generated east of the ridge naturally flows towards *Drainage Line 2* and discharges to Kemps Creek upstream of the farm dam.

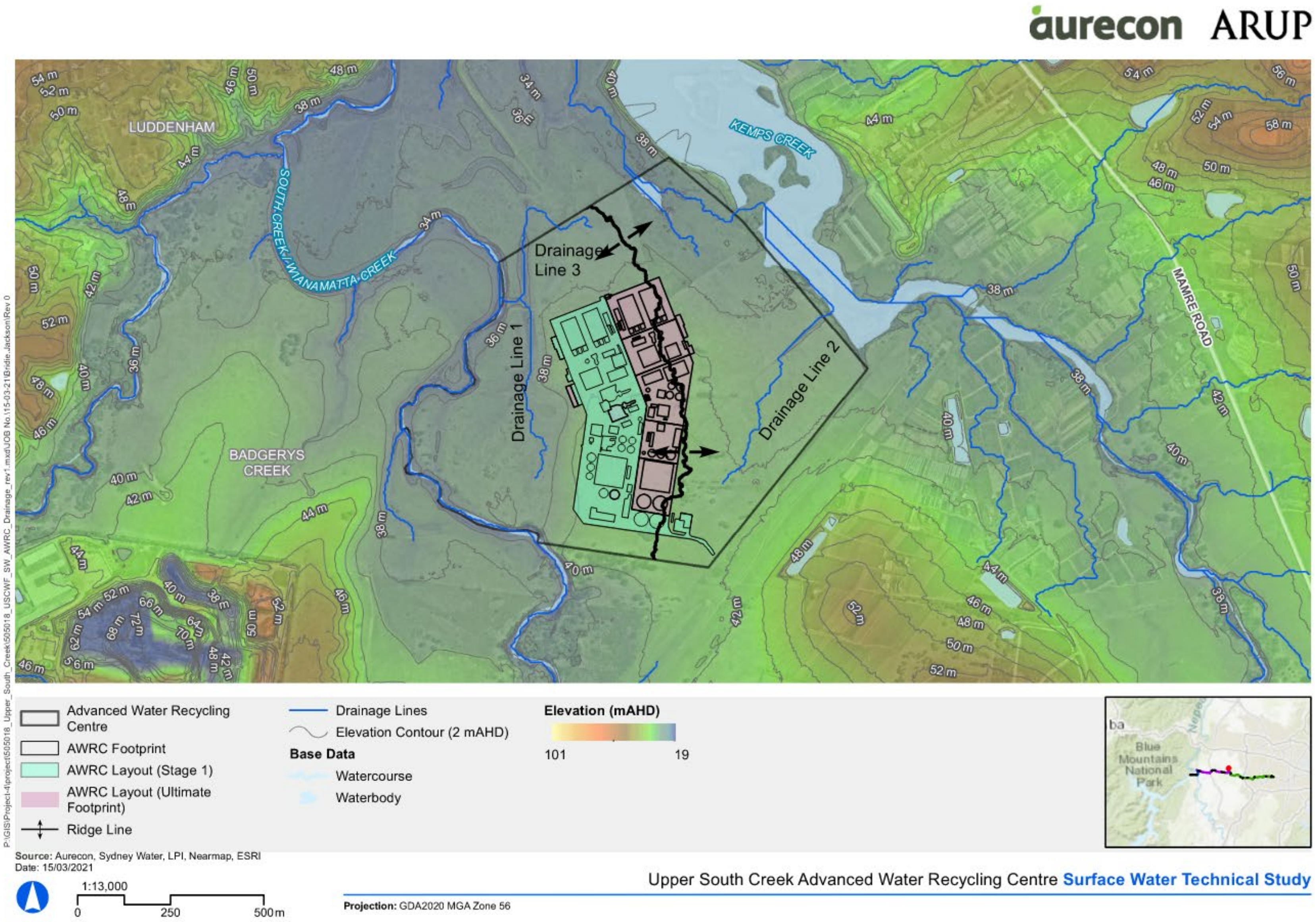


Figure 5-18 Site drainage

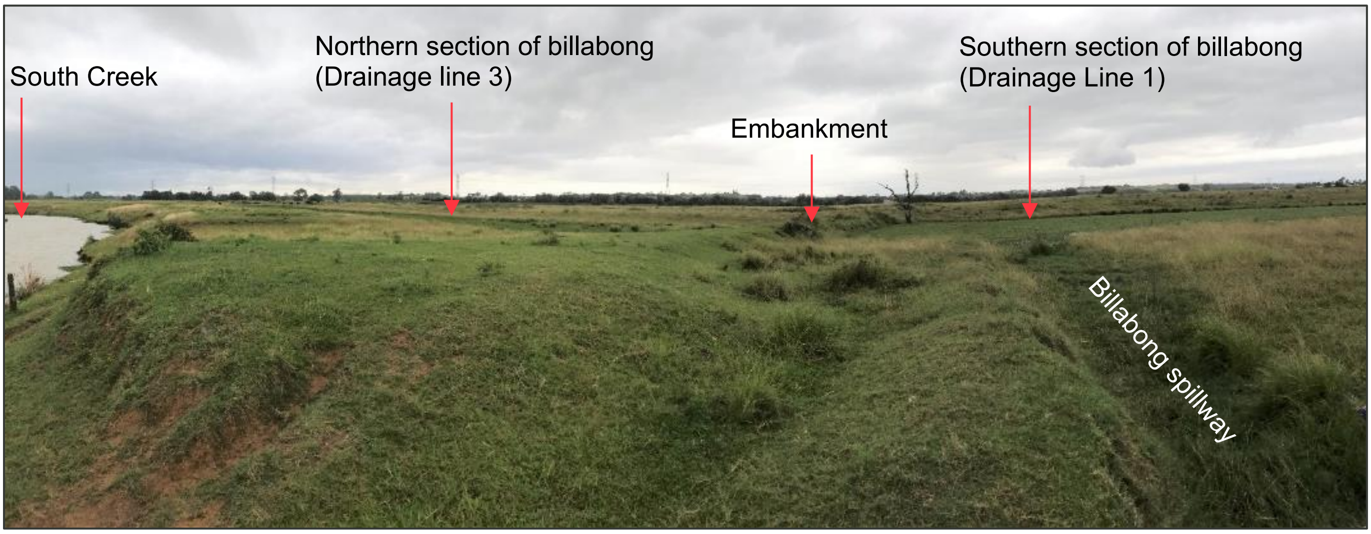


Figure 5-19 Drainage lines 1 and 3 with dividing embankment (Photo taken looking NW)

Figure 5-20 Billabong spillway connecting drainage line 1 to South Creek

5.5 Water quality

5.5.1 Baseline monitoring program

A baseline monitoring program has been established by Sydney Water with the aim of collecting baseline (pre-) and post-commissioning data to assess any changes in the aquatic environment resulting from the operation of the Upper South Creek AWRC. This program is further detailed in the *Hydrodynamic and Water Quality Impact Assessment* report.

The locations currently being sampled are indicated in **Figure 5-21** and detailed in **Table 5-9**. Water samples are being collected at these sites on a three-weekly basis. Sampling at some of the sites started as long ago as January 2018 and data was available up until September 2020 at the time of this study.

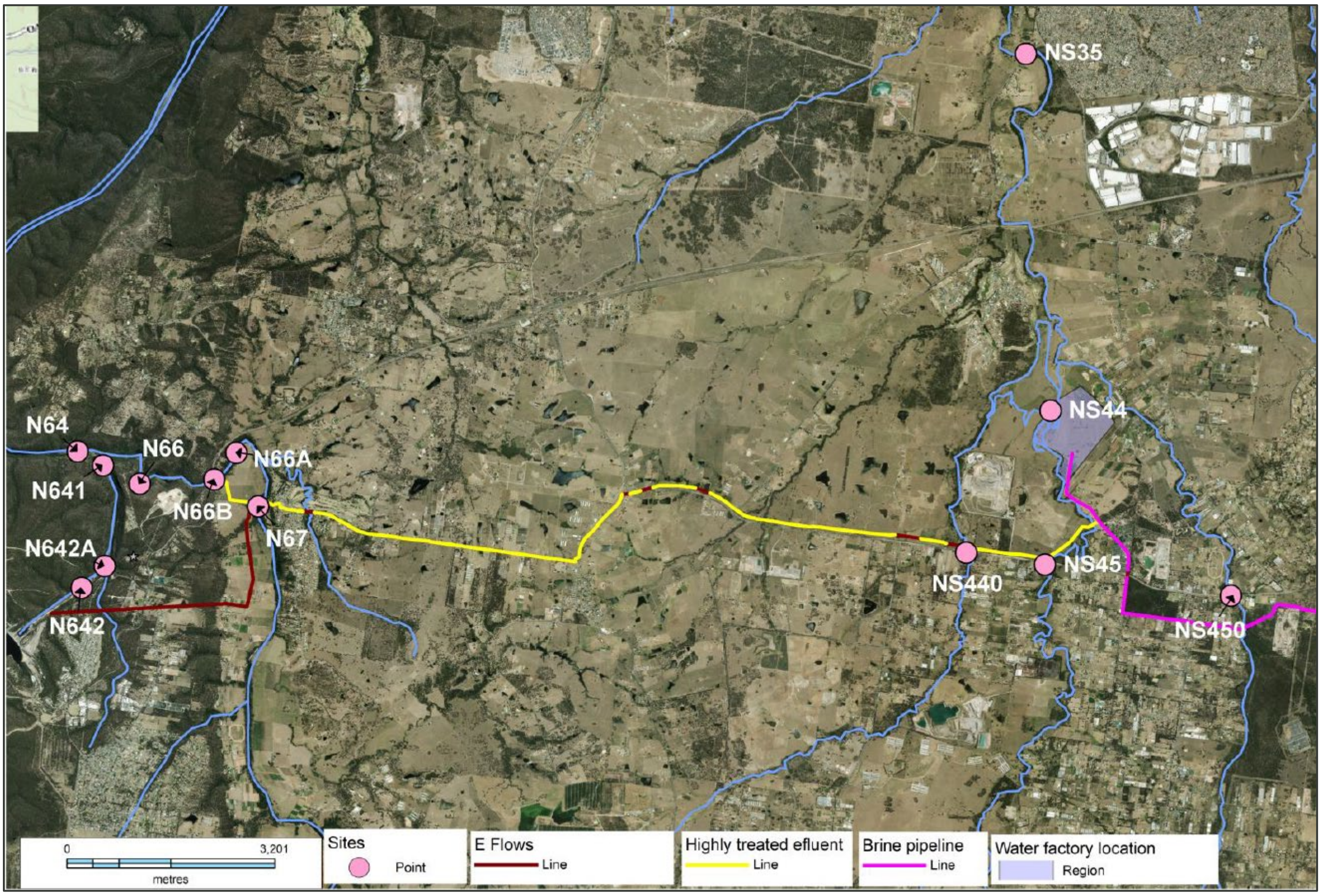


Figure 5-21 Map showing all monitoring sites of current AWRC monitoring program

Table 5-9 Baseline monitoring program site descriptions

Stream name	Site code	Site description	Significance	Monitoring start date
South Creek	NS45	At Elizabeth Drive bridge, u/s of new AWRC	Reference site (upstream of discharges from new AWRC)	March 2020 (& single 2018 sample)
	NS44	Downstream of proposed AWRC at Pluers Farm	Impact from new AWRC discharges (immediately downstream of AWRC)	March 2020
	NS35	At Luddenham Road Bridge	Further downstream of new AWRC & other tributaries	March 2020 (& single 2018 sample)
Kemps Creek	NS450	At Elizabeth Drive Bridge, u/s confluence with South Creek	Other tributaries joining South Creek downstream of AWRC	March 2020 (& single 2018 sample)
Badgerys's Creek	NS440	At Elizabeth Drive Bridge, u/s confluence with South Creek	Other tributaries joining South Creek downstream of AWRC	March 2020 (& single 2018 sample)
Nepean River	N67	At Wallacia Bridge	Upstream reference site	Jan 2018

Stream name	Site code	Site description	Significance	Monitoring start date
	N66A	Upstream of proposed discharge point	Upstream reference site	June 2020
	N66B	Downstream of Weir and proposed discharge point	Impact site, downstream of potential discharges from new AWRC	June 2020
	N66	Upstream of confluence with Warragamba River	Impact site, further downstream of discharges	March 2020
	N64	Downstream of Warragamba River (about 500m)	Impact site, downstream of Warragamba River & potential discharges from new AWRC	March 2020
Warragamba River	N642	Upstream of Megarritys Creek & Wallacia WWTP	Upstream reference site	March 2018
	N642A	Downstream of Megarritys Creek, upstream Wallacia WWTP	Impact from new AWRC release via Megarritys Creek	March 2020
	N641	At Norton Basin, before the confluence with the Nepean River	Impact from new AWRC & old Wallacia WWT	March 2018

The water quality data available to date was analysed and the median and 95th percentile results are presented in **Table 5-10** and **Table 5-11** respectively and compared to the Project waterway objectives presented in **Section 1.1**. Further discussion on these results is provided in **Section 5.5.3**.

Table 5-10 Monitoring program water quality data (Median values)

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TN (mg/l)	TP (mg/l)
South Creek						
NS45 (upstream)	73	1023	7.4	41	1.67	0.21
NS44 (immediately downstream)	88	931	7.5	82	1.69	0.18
NS35 (further downstream)	80	928	7.5	68	1.73	0.14
Kemps Creek						
NS450 (upstream)	77	1,341	7.5	24	2.27	0.61
Badgery's Creek						
NS440 (upstream)	60	904	7.2	11	1.48	0.16
Relevant performance criteria**	***43 - 75***	***1,103***	***6.2 - 7.6***	***50***	***1.72***	***0.14***
Nepean River						
N67 (upstream 1)	94	379	7.5	7.2	0.98	0.02
N66A (upstream 2)	97	347	7.5	6.2	nd	nd
N66B (downstream)	98	348	7.6	6.2	nd	nd
N66 (further downstream)	99	328	7.6	6.8	1.33	0.02
N64 (d/s Warragamba)	96	336	7.6	6.0	1.27	0.02

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TN (mg/l)	TP (mg/l)
Warragamba River						
N642 (upstream)	86	245	7.0	4.9	0.18	0.01
N642A (downstream)	98	208	7.5	7.2	0.66	0.01
N641 (further downstream)	100	248	7.5	2.8	0.41	0.01
ANZECC default trigger value*	***85 - 110***	***125 - 2,200***	***6.5 – 8.0***	***6 - 50***	***0.35***	***0.025***
Cell colouring: Red indicates value outside the guideline value range; Green indicates all measured values within the guideline value range; Grey indicates no data (nd) or no guideline value *Represents laboratory reporting limit **Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020) ***Guideline values for lowland rivers in south-east Australia with slightly disturbed ecosystems (ANZG, 2018)						

Table 5-11 Monitoring program water quality data (95th percentile values)

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TN (mg/l)	TP (mg/l)
South Creek						
NS45 (upstream)	98	1,268	7.6	130	2.58	0.36
NS44 (immediately downstream)	119	1,203	8.2	131	2.31	0.29
NS35 (further downstream)	91	1,171	7.6	225	2.53	0.24
Kemps Creek						
NS450 (upstream)	94	2,660	7.7	114	6.99	0.85
Badgery's Creek						
NS440 (upstream)	72	1,086	7.3	54	2.49	0.29
Relevant performance criteria*	***43 - 75***	***1,103***	***6.2 - 7.6***	***50***	***1.72***	***0.14***
Nepean River						
N67 (upstream 1)	110	492	8.1	13	1.91	0.05
N66A (upstream 2)	99	450	7.7	14	nd	nd
N66B (downstream)	100	448	7.7	13	nd	nd
N66 (further downstream)	102	449	7.8	11	1.75	0.04
N64 (d/s Warragamba)	108	420	7.6	12	1.57	0.03
Warragamba River						
N642 (upstream)	109	317	7.5	12	0.69	0.01
N642A (downstream)	108	226	7.7	13	0.90	0.01
N641 (further downstream)	113	296	7.9	15	0.80	0.02
ANZECC default trigger value*	***85 - 110***	***125 - 2,200***	***6.5 – 8.0***	***6 - 50***	***0.35***	***0.025***
Cell colouring: Red indicates value outside the guideline value range; Green indicates all measured values within the guideline value range; Grey indicates no data (nd) *Represents laboratory reporting limit ** Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020)***Guideline values for lowland rivers in south-east Australia with slightly disturbed ecosystems (ANZG, 2018)						

5.5.2 Supplemental water quality data

Supplemental water quality data was obtained from several technical studies, including the M12 Motorway EIS (RMS, 2019), the Western Sydney Airport EIS (GHD, 2015), the Badgerys Creek Environmental Survey (SMEC, 2014) as well as the Second Sydney Airport study (PPK, 1997). The streams with available water quality data, along with their respective data sources, are indicated in **Figure 5-22** and additional information for each monitoring location is provided in **Table 5-12**. Also provided are the relevant guidelines values for comparative purposes.

The existing water quality for the three major creeks in close proximity to the AWRC site (Badgerys, Kemps and South Creek) are summarised in **Table 5-13**. The water quality data available for the streams which would be traversed by the proposed effluent pipelines is summarised in **Table 5-14**. The reported water quality data are presented along with the corresponding ANZG guideline trigger values for “slightly disturbed or modified ecosystems in NSW lowland rivers” as discussed in **Section 1.1**.

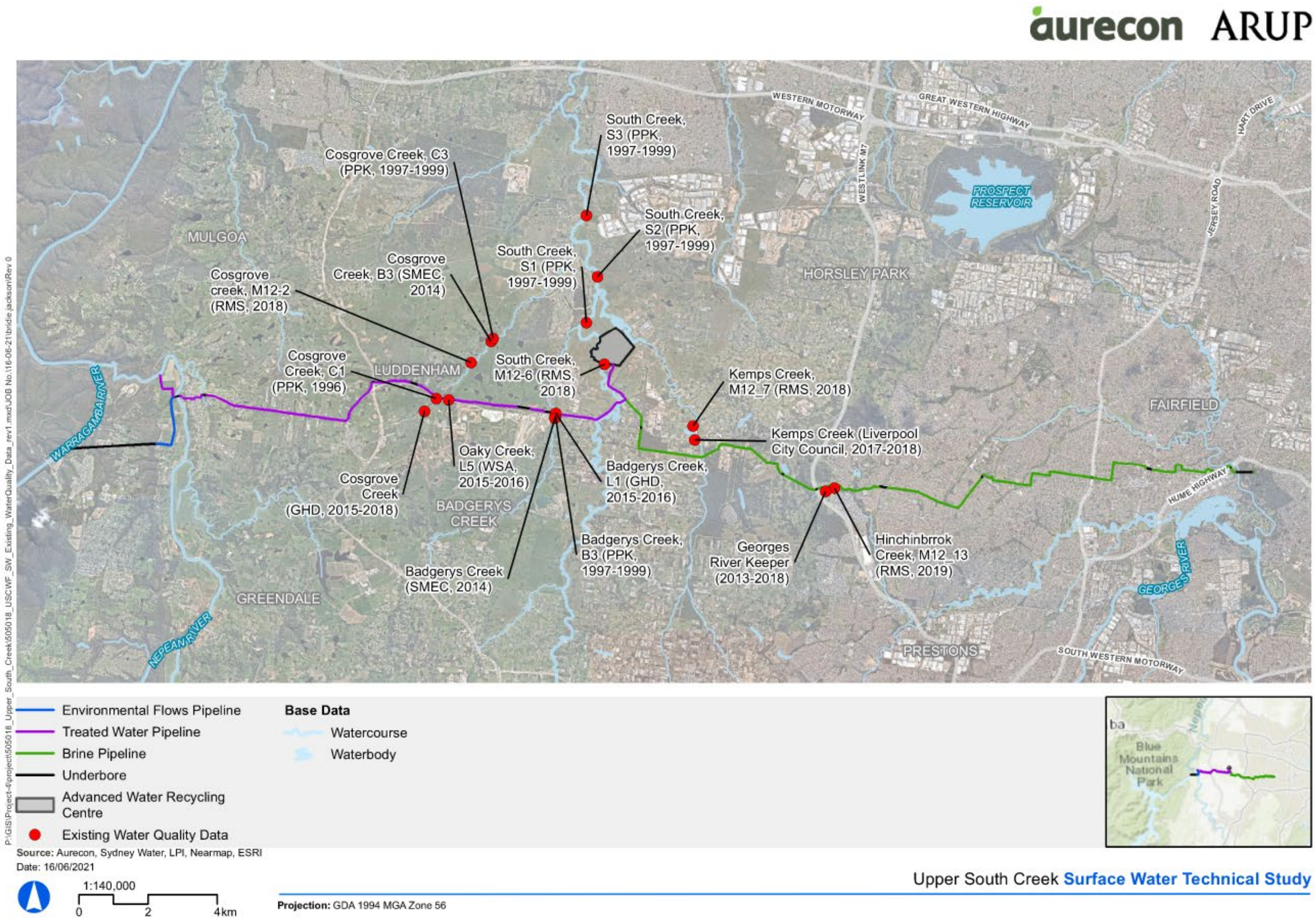


Figure 5-22 Available water quality data sampling locations

Table 5-12 Sources of available water quality monitoring data for local watercourses

Stream name	Previous studies[2]	Location Description
South Creek	M12 Highway EIS (RMS, 2018) (M12-6)	Directly upstream of the AWRC site
	Second Airport EIS (PPK, 1997-1999) (S1)	3 km downstream of AWRC site
	Second Airport EIS (PPK, 1997-1999) (S2)	1.5 km downstream of the AWRC site
Badgerys Creek	Badgerys Creek Environmental Field Survey (SMEC, 2014) (B3)	In close proximity to the treated water pipeline alignment
	WSA EIS (GHD, 2015-2018) (L1) - Average monthly data	In close proximity to the treated water pipeline alignment
	Second Airport EIS (PPK, 1997-1999) (B3)	In close proximity to the treated water pipeline alignment
Oaky Creek	WSA EIS (GHD, 2015-2016) (L5) - Average monthly data	In close proximity to the treated water pipeline alignment
Cosgrove Creek	Second Airport EIS (PPK, 1997-1999) (C2)	2.5 km downstream of the treated water pipeline alignment
	Second Airport EIS (PPK, 1997-1999) (C1)	In close proximity to the treated water pipeline alignment
	M12 Highway EIS (RMS, 2018) (M12-2)	1.5 km downstream of the treated water pipeline alignment
Kemps Creek	Liverpool City Council (2017-2018)	500 m downstream of the brine pipeline alignment
	M12 Highway EIS (RMS, 2018) (M12-7)	800 m downstream of the brine pipeline alignment
Hinchinbrook Creek	M12 Highway EIS (RMS, 2019) (M12-13)	500 m downstream of the brine pipeline alignment
	Georges River Keeper (2013-2018)	2 km downstream of the brine pipeline alignment

Table 5-13 Available water quality data for the streams adjacent to the AWRC site

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
South Creek							
M12 Highway EIS (RMS, 2018) (M12-6)	80	2,640	8.5	14.3	16	1.40	<0.05*
Second Airport EIS (PPK, 1997-1999) (S1)	83 - 105	nd	7.0 - 7.2	15 - 65	9 - 56	0.49 - 1.60	0.01 - 0.14
Second Airport EIS (PPK, 1997-1999) (S2)	60 - 87	nd	6.8 - 6.9	7 - 82	5 - 19	0.44 - 1.50	0.01 - 0.11
Second Airport EIS (PPK, 1997-1999) (S3)	39 - 79	nd	6.9 - 7.4	12 - 40	4 - 14	0.8 - 1.50	0.05 - 0.50

[2] Date ranges in 'Location' column refer to the sampling year(s)

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
Kemps Creek							
Liverpool City Council (2017-2018)	31	1,889	7.7	11	nd	4.5	0.75
M12 Highway EIS (RMS, 2018) (M12-7)	36	1,500	7.3	12	10	6.6	0.60
Relevant performance criteria*	***43 - 75***	***1,103***	***6.2 - 7.6***	***50***	***37***	***1.72***	***0.14***

Cell colouring: Red indicates measured values outside the guideline value range; Orange indicates some measured values outside the guideline value range; Green indicates all measured values within the guideline value range; Grey indicates no data (nd)
*Represents laboratory reporting limit
**Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020)

Table 5-14 Existing water quality data for the streams that intersect with project pipelines

Location	DO (% satn)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
Badgerys Creek							
WSA (GHD, 2015-2018) – Median water quality results	47	2,372	7.4	24	14	1.70	0.19
Badgerys Creek Environmental Field Survey (SMEC, 2014) (B3)	nd	nd	nd	11	16	2.60	0.50
Second Airport EIS (PPK, 1997-1999) (B3)	13 - 107	nd	6.7 - 7.2	5 - 46	9 - 24	0.12 - 2.30	0.26 - 0.47
Cosgrove Creek							
M12 Highway EIS (RMS, 2018) (M12-2)	63	3,510	8.0	19	16	2.30	<0.05*
Second Airport EIS (PPK, 1997-1999) (C3)	2 - 65	nd	6.7 - 7.4	3 - 16	5 - 12	1.23 - 1.70	0.02 - 0.07
Second Airport EIS (PPK, 1996) (C1)	25	nd	6.7	2.9	5	nd	<0.02
Oaky Creek							
WSA (GHD, 2015-2016) (L5) - Average monthly data	54	2,370	nd	28	8	2.40	0.10
Relevant performance criteria*	***43 - 75***	***1,103***	***6.2 - 7.6***	***50***	***37***	***1.72***	***0.14***
Hinchinbrook Creek							
M12 Highway EIS (RMS, 2019) (M12-13)	77	850	9.3	21	29	1.80	0.20
Georges River Keeper (2013-2018)	32	610	7.1	13	nd	0.59	0.04
Georges River WQO's	***85 - 110***	***125 - 2,200***	***6.5 – 8.0***	***6 - 50***	***n/a***	***0.35***	***0.025***

Cell colouring: Red indicates measured values outside the guideline value range; Orange indicates some measured values outside the guideline value range; Green indicates all measured values within the guideline value range; Grey indicates no data (nd) or no guideline value
*Represents laboratory reporting limit
**Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020)

5.5.3 Results discussion

South Creek

The results collected as part of the current monitoring program (**Table 5-10** and **Table 5-11**) indicate in comparison to the adopted guideline values:

- Localised exceedances of DO, turbidity, TN and TP (median values)
- 95th Percentile values indicate exceedances have been observed throughout, across all indicators and sites, except pH values at NS45 and NS35 that have maintained acceptable levels throughout the monitoring period assessed

The historical data collected to inform the Second Sydney Airport study (1997-1999) (**Table 5-13**) indicated significantly lower nutrient concentrations and marginally lower pH values.

Kemps Creek

The water sampled in Kemps Creek recently indicates a similar profile to the South Creek water, with even further elevated nutrient concentrations, however slightly lower turbidity observed. The available historic samples (**Table 5-13**) support this observation, but also indicate lower DO values at the time, while still exceeding the current relevant performance criteria.

Badgerys Creek

Badgerys Creek results indicate a significant closer alignment to the set performance criteria compared to Wianamatta-South Creek and Kemps Creek. The only exceedance observed when considering the median values is a slight exceedance in TP. The 95th percentile values indicate turbidity and nutrient level exceedances. This indicates a relatively fluctuating profile not too far from the relevant criteria.

Badgerys Creek was also sampled previously as part of the WSA EIS, as well as an independent SMEC study (2014). The two sampling locations are in close proximity to each other (**Figure 5-22**).

The analysis results (**Table 5-14**) indicated, in comparison to the set performance criteria:

- DO levels had large variation with low values (13 and 47%) compared to the lower limit but also a high value (107%) which exceeds the upper limit
- Nutrient concentrations were generally elevated

A visual inspection of Badgerys Creek in April 2020, at the Elizabeth Drive crossing, indicated an algal bloom had occurred (**Figure 5-23**) within the stagnant water observed within the creek drainage line which could be indicative of the large variation in DO levels noted at this location.

Figure 5-23 Badgerys Creek near Elizabeth drive (photo date: 20/04/2020)

Cosgrove Creek

A single water quality sample was collected as part of the investigations undertaken to inform the M12 EIS technical report in June 2018. The sample was collected a short distance downstream of the proposed watercourse crossing. The analysis results (**Table 5-14**) indicated in comparison to the adopted performance criteria:

- Exceedances of EC, pH and TN
- DO, Turbidity, TSS and TP achieving the set criteria

Additionally, as part of the Second Sydney Airport study (1996-1999), two locations were monitored which were located at the crossing location as well as a short distance downstream. The analysis results (**Table 5-14**) indicated in comparison to the adopted guideline values:

- DO around the acceptable range, with some low values
- pH, Turbidity, TSS and nutrients were below the stated criteria

Oaky Creek

Oaky Creek was also sampled as part of the Western Sydney Airport EIS, at the approximate location where the watercourse is intended to be crossed by the treated water pipeline (**Figure 5-22**). Monitoring covered a period between 2015 and 2016 with monthly samples being collected.

The average monthly results (**Table 5-14**) indicated, in comparison to the adopted performance criteria:

- Acceptable DO, Turbidity, TSS and TP values
- Significant exceedance of EC
- Elevated TN concentrations

Nepean River

Previous assessments have indicated that the nutrient concentrations in the Nepean River significantly decreased between 1992 and 2017 (13% to 72% decrease) (Sydney Water, 2018), along with decreasing trends in conductivity. The 2016-2017 data indicates concentrations of the assessed indicators below or within the guidelines values upper limits and ranges (Sydney Water, 2018), indicating relatively good quality water within the system.

The recent results available for the Nepean River (**Table 5-10** and **Table 5-11**) show median values all within the acceptable ranges, except for TN, which is elevated throughout the reach monitored. The 95th percentile values also mostly meet the required criteria, however the upper limit TP values observed all exceed the adopted trigger value. The water quality profile throughout the reach is relatively stable, with only conductivity clearly showing a slight decreasing trend as one progresses downstream.

Warragamba River

Similar to the Nepean River results the Warragamba River's median values mostly fall within the acceptable ranges, except for TN, which is slightly elevated in the downstream sections and Turbidity which was measured below the adopted trigger value range. The 95th percentile values also mostly meet the required criteria, however the upper limit TN values observed all exceed the adopted trigger value. The water quality profile throughout the reach is relatively stable, with only pH showing a slight increasing trend as one progress downstream.

Georges River

No water quality datasets were sourced for the Georges River. Instead, the Georges River Report Cards for periods 2016 - 2017 and 2017 2018 (Georges Riverkeeper, 2017 and 2018) has been used to provide a snapshot of river health and gain an understanding of water quality trends.

- Water quality was rated Fair (on a scale Excellent-Good-Fair-Poor) in 2016 – 2017 at Lieutenant Cantello Reserve, approximately 2 km downstream from the Prospect Creek confluence. Water quality in the Lower Georges River is fairly typical of conditions in urbanised catchments and is compounded by minimal tidal flushing unable to counter the inputs of pollutants from stormwater runoff.
- Water quality was rated Good in 2017 – 2018 at Lieutenant Cantello Reserve, approximately 2 km downstream from the Prospect Creek confluence. This result may not be a true reflection on overall long-term water quality, as a drought and low rainfall led to reduced stormwater inflows. This in-turn led to lower chlorophyll-*a* and turbidity levels.

Prospect Creek

No water quality datasets were sourced for the Prospect Creek. Instead, the Georges River Report Cards for periods 2016 - 2017 and 2017 2018 (Georges Riverkeeper, 2017 and 2018) has been used to provide a snapshot of river health and gain an understanding of water quality trends.

Water quality in the lower Prospect Creek was rated Fair (on a scale Excellent-Good-Fair-Poor) for both 2016 – 2017 and 2017 – 2018. Prospect Creek lies in a catchment with extensive urban and industrial development and 'poor' riparian vegetation. Large stormwater loadings are generated in this catchment and these transfer pollutants contained in the stormwater rapidly into the creek. This results in low diversities of macroinvertebrates with predominately pollution tolerant species present.

Summary

The results collated for all the creeks located in the study area indicate general poor water quality with low DO and elevated EC and nutrient concentrations on account of endemic saline soils and agricultural land use within the catchment. The levels of pH and turbidity were generally within the guideline ranges, with some exceedances of upper limit turbidity presumably during low flow algal bloom events or rainfall events with high suspended matter captured from storm runoff. The temporal representativeness of these data has not been evaluated and it has not been established if they represent a full range of hydrological conditions (i.e. zero, low, intermediate and high flow events).

Water quality in the Warragamba and Nepean Rivers is generally good, with the median and 95th percentile values for most criteria within the acceptable ranges. Exceedances associated with nutrient levels are more common, however it should be noted that the numerical criteria applied within these rivers are significantly lower than those applied for the Wianamatta-South Creek catchment.

By exception, the recent water quality monitoring results for the local creeks indicate either regular (driving median values, **Table 5-10**) or periodic (driving 95th percentile values, **Table 5-11**) exceedances of the Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020) across all indicators.

Low order ephemeral creeks in this area often form disconnected ‘chain-of-ponds’ which do not flow for a large proportion of time (circa one-third of the time, **Figure 5-16**). Low frequency-high magnitude rainfall events trigger flow due to initiation of overland flow pathways in the sub-catchments to the channels. These tend to occur in a short-wet season between November and March (**Figure 5-17**). Furthermore, there is a sampling bias towards easy to access sampling locations at bridge crossings where pools are over-widened to improve flood flow conveyance – even when these pools contain water, the majority of the creek channel may be dry and the resulting stagnation and evaporation processes have the potential to significantly alter water chemistry.

6 Project activities

6.1 Construction phase

AWRC Site

The key construction phase activities for the proposed AWRC site include the following:

- Clearing of vegetation and mulching at the proposed treatment plant site
- Demolition of existing house, if not repurposed during construction and operation
- Bulk earthworks. Detailed approach to this has not been finalised but a typical methodology would involve:
  - Grubbing
  - Removal and stockpiling of 200-300 mm of topsoil for re-use later (following chemical and geotechnical testing for suitability). An area of approximately 115,000 m^2 would need to be stripped equating to a topsoil volume around 34,500 m^3
  - Geotech investigation identified the underlying 200 mm of material below the topsoil is unsuitable for construction and is to be removed and disposed offsite
  - Cut and fill to bench levels with import of quality engineered fill as required and removal of any excess / poor quality material if it cannot be re-used on site elsewhere for landscaping purposes
  - Fill in layers of up to about 300 mm, which is compacted before the next layer is added. The fill depth on this site would generally increase from southeast to northwest up to a depth of about 2.5 m
  - Targeted dewatering of surficial local aquifer systems to required depths (refer to impacts assessed in the *Groundwater Impact Assessment* report)
- Excavation for construction of below surface infrastructure
- Installation of subfloor drainage, foundations and underground infrastructure
- Installation of aboveground civil works, mechanical and electrical plant and equipment
- General landscaping, planting out of WSUD elements and installation of stormwater harvesting and irrigation equipment
- Commissioning and testing

Water would be used during construction for a range of purposes including excavation, dust suppression, drilling, hydrostatic testing, materials preparation and use, and amenities for the construction workforce. Construction areas and access tracks would be watered to supress dust, with the frequency of watering dependent on wind and rainfall conditions. During construction, water would likely be sourced offsite from suitable mains reticulation so multiple tankers would be required.

Pipelines

Key construction phase activities associated with the installation of the discharge pipelines would include the following:

- Establishment of construction depots

- Progressive clearing of vegetation along the routes
  - Stormwater management (e.g. installation of appropriate erosion and sediment controls)
  - Grubbing
  - Removal and stockpiling of 200-300 mm of topsoil (typical) for re-use later (following chemical and geotechnical testing for suitability)
  - Targeted dewatering of surficial local aquifer systems (refer to the *Groundwater Impact Assessment* report)
- Excavation for construction of below surface infrastructure including
  - Temporary pipe jacking works
  - Open trench excavation, including open trenches in creek lines
  - Discharge outlets at waterway
- Installation of foundations, pipelines and underground infrastructure
- Installation of aboveground civil (access roads, discharge headwalls), mechanical and electrical plant and equipment
- Commissioning and testing

6.2 Operational phase

AWRC Site

The primary activities that could lead to surface water impacts associated with the operational phase of the Project all relate to site stormwater management practices as well as the potential discharge of incoming wastewater to the local environment.

The key operational phase activities for the proposed AWRC site include the following:

- Receipt and treatment of wastewater from the SWGA and WSAGA catchments
- Receipt, handling, storage and use of chemicals for water treatment and generation of potential contaminants
- Transfer of highly treated water, primarily to the Nepean River, and potentially as recycled water reuse and as overflows to South Creek during wet periods
- Power generation from installed photovoltaic systems
- Operation and maintenance of plant and stormwater infrastructure

Pipelines

During standard operating conditions limited activities would be conducted directly relating to the operation of the pipelines. However, maintenance activities or breakdowns could result in impacts to the local surface water environment. Key activities associated with these conditions are:

- Intentional scouring of pipes during maintenance operations
- Hydrostatic testing
- Pipe leaks/bursts
- Operation and maintenance of pipeline outlet structures that discharge to waterways

7 Proposed surface water management

Surface water management activities have been incorporated into the Project reference design for the AWRC site.

Other elements of the Project reference design, including pipelines and pipeline construction depot sites did not require significant consideration of surface water management beyond flood preparedness and sediment and erosion control.

The following sections describe the surface water management approach for each of the following aspects of the Project:

- AWRC site
  - Construction phase
  - Stormwater management
  - Operations water supply and disposal
  - Operational phase
  - Operations water balance
  - Environmental water balance and stormwater discharge quality
  - Peak stormwater discharge assessment
- Pipelines
  - Construction phase
  - Operations water supply and disposal
  - Watercourse crossings
  - Operational phase
- Other key considerations
  - Photovoltaic installation
  - Climate change
  - Wet weather discharge to South Creek
  - Critical state infrastructure – Warragamba Pipelines

7.1 AWRC Site

7.1.1 Construction phase

Stormwater management

During the construction phase, disturbed soil and stockpiles exposed to rainfall and runoff would contribute elevated levels of suspended solids in runoff. It is possible that the entire stage footprint would be disturbed earth and stormwater management basins would be required for sediment management.

During this time, flow patterns from the site would not be significantly altered due to the flat nature of the existing site (0.4 to 0.6%) and proposed reference design grades (0.8%). Impacts to flood flows downstream would not be significant during the bulk earthworks phase and flood detention would not be required until hard surfaces are established.

Construction of the AWRC represents the largest risk of sediment pollution to neighbouring waterways. To ensure suspended solids concentrations are reduced to acceptable levels it is expected that stormwater management basins would be utilised as sedimentation basins to capture and contain runoff and facilitate sediment removal. The areas associated with the proposed future on-site detention (OSD) basins (see **Section 7.1.2.3**), provides a suitable area away from waterways and flooding for this effect. The capacity to function as sediment basins was confirmed in accordance with the Soils and Construction Guide Volume 1, 4th Edition for managing urban stormwater by the NSW government (Landcom, 2004).

Given the site characteristics, the basin types selected for management of sediment laden stormwater runoff during the construction phase are earthen wet basins to be able to cater for type D and Type F soils. For basin sizing the disturbed area has been split into two sub catchments of approximately 5.0 and 5.6 ha respectively, each with the low points as potential basin sites at the periphery of the area of disturbance. The calculations indicated required storage volumes of 670 m^3 and 750 m^3 for the north and south basins respectively. This is significantly less than the current proposed OSD volumes (2,900 m^3 and 5,700 m^3) and thus the initial use of these areas for sedimentation purposes is expected to be adequate.

Construction of the photovoltaic cells, site compounds and landscaping work outside of the catchments mentioned above present a lesser risk of sediment pollution given the smaller extent of ground disturbance. Sediment controls would be installed as necessary and in accordance with the Soils and Construction Guide.

Water supply and disposal

During the construction phase, water for bulk earthworks would be provided from a combination of harvested stormwater runoff and potable water.

It is proposed that within the construction impact zone, temporary basins would be constructed, and existing on-site dams would be repurposed, to catch any runoff for reuse in the bulk earthworks.

Mains water supply would be connected to the AWRC site before construction to top up harvested stormwater. The re-use of local runoff is expected to reduce the external demand significantly.

Wastewater services would likely be provided via portable ablutions block as sewer won't be connected.

7.1.2 Operational phase

Operations water balance treatment process

The treatment plant design flows are summarised below:

- Estimated average wastewater inflows: 50 ML/d under stage 1 and potentially increasing to 100 ML/d in the future
- Estimated average treated wastewater discharge: 43.7 ML/d
- Estimated average brine discharge: 7.8 ML/d
- Additional detail on effluent volumes, effluent quality and discharge locations is provided in

General operations

Water requirements during the operational phase of the Project are expected to be limited to potable use and general site washdown requirements for a small number of employed workers. The estimated full time equivalent of staff on site would be 15 people. At an average demand rate of 200 L/d and an equivalent persons (EP) conversion factor of 0.2 EP/job. The general daily potable water demand is thus expected to be in the range of 600 L/d (or 0.0006 ML/d). The wastewater generated is expected to be around 480 L/d (based on a return efficiency of 80%) and would be directed straight to the headworks. Supply for washdown water would be prioritised from the local rainwater harvesting tanks.

Water balance summary:

- Estimated potable demand: 600 L/d
- Estimated wastewater discharge: 480 L/d

The strategy for local water supply would be developed during the detailed design phase of the Project and in consultation with the relevant Sydney Water representatives.

Environmental water balance and stormwater discharge quality

After construction, surface water management elements would be in place to achieve the draft WQOs (flow and health) for Wianamatta-South Creek established by DPIE EES in October 2020.

The WQOs are understood to maintain acceptable hydrologic conditions within downstream waterways as well as contribute towards water quality objectives in waterways. By discharging stormwater in ways that closely match these numerical criteria the impact of stormwater discharges on the local waterways is acceptable.

The stormwater management approach for the Project reference design is summarised below in Table 7-1. The elements in the treatment train have been iteratively sized to achieve the WQOs set by DPIE EES, as well as the pollutant load reduction targets and stream erosion controls set by the Penrith City Council.

These measures are considered to demonstrate adequate mitigation of the potential impacts of increased imperviousness and surface water hydrologic impacts. These mitigations are proposed as part of the reference design but the final design of the ARWC may adopt a different mix of surface water management elements.

Table 7-1 Indicative stormwater pollution mitigation and low flow management measures

Indicative WSUD measures in reference design	Description
First flush capture	To manage the risk of spills and chemical leaks during handling and transport, a first flush capture system would intercept the first 10 mm of rainfall from the roads and hardstand areas around the AWRC site. This first 10 mm of rainfall would typically wash most of the oil, grease and residual chemicals from these hardstand areas. First flush capture tanks would be installed in stages to reflect the potential expansion of the AWRC site from stage 1 to the ultimate capacity. The reference design locates tanks at low points that coincide with the On-site Stormwater Detention Basins. The first flush capture system pumps stormwater to the head of the AWRC treatment train where it would undergo the same treatment process as the wastewater entering the site via the rising mains. The reference design proposes a pump rate that would empty the tank storages in 3 days. Stormwater runoff that exceeds the first flush capture would be diverted to the subsequent WSUD elements.
Passively irrigated street trees	Regularly spaced biofiltration rain gardens and passively irrigated street tree pits provide an opportunity to reduce stormwater volumes and provide local microclimate benefits as well as contributing to visual impact of the AWRC site.
Gross pollutant traps (GPT)	Gross pollutant traps would be installed directly upstream of the discharge points to the three detention basins providing pre-screening of stormwater prior to filtration.
Bioretention basins	The bioretention basins are located within the OSD and excess water would overflow into the detention system. Bioretention basins may be lined to reduce the risk of a perched groundwater table forming.
Pond / wetland	A constructed pond or wetland provides a means of slowly releasing stormwater over many days to the creek in a way that contributes to the baseline hydrologic discharges. The same flow controls cannot be achieved with bioretention basins. While underground detention tanks may provide a similar outcome, wetlands provide the added benefit of replicating the evaporative function of existing farm dams which are a significant feature in the rural hydrologic landscape of the Wianamatta-South Creek catchment. The wetland seeks to mimic the storage, evaporation and slow release of surface runoff.
Rainwater tank and stormwater harvesting	Stormwater harvesting tanks provide an effective means of reducing stormwater volumes in this circumstance, due to the extent of the site and parklands proposed adjacent to the site. Low numbers of staff on the AWRC site mean that there is a low water demand associated with internal non-potable water uses. Excluding street scape areas within the treatment plant, the adjacent park provides up to 16 ha of land to irrigate and a potential water demand of 40 to 80 ML/yr. While potentially at odds with the availability of free, high-quality recycled water; a stormwater harvesting strategy demonstrates the principles of stormwater volume reduction and provide an opportunity for developing a pilot scale demonstration project. Tank configuration would ideally be below ground concrete tanks that are formed on site. Consideration of groundwater levels would be important.
Grassed swales	Vegetated and grass lined swales would be used to collect and dissipate stormwater runoff photovoltaic cells during low flow events. Swales would convey high flows to local waterways.

Stormwater balance and flows

A pre- and post-development water balance for the site accounts for the components of water cycle (including exfiltration and evapotranspiration) that are managed through the Project reference design stormwater management approach. The summary of the key components of the catchment water balance under the pre- and post-development conditions is provided in **Figure 7-1** and **Table 7-2**.

Table 7-2 Water Balance for the pre-development, Stage 1 and ultimate footprint conditions with mitigation

Summary variable	Units	Base line (Pre-development)	Stage 1 with Mitigation (WSUD)	Ultimate Development with Mitigation (WSUD)
Rain in	ML/yr	161.8	161.8	161.8
Evaporation loss		141.5	126.5	91.2
Infiltration loss / baseflow		5.9	1.3	1.5
First flush tank		-	7.8	12.7
Stormwater harvesting		-	5	10.9
Runoff		14.4	21.1	45.5
Potable water in		-	2.2	2.2
Wastewater generated (on-site)*		0.21	1.8	1.8

* Excludes treated wastewater

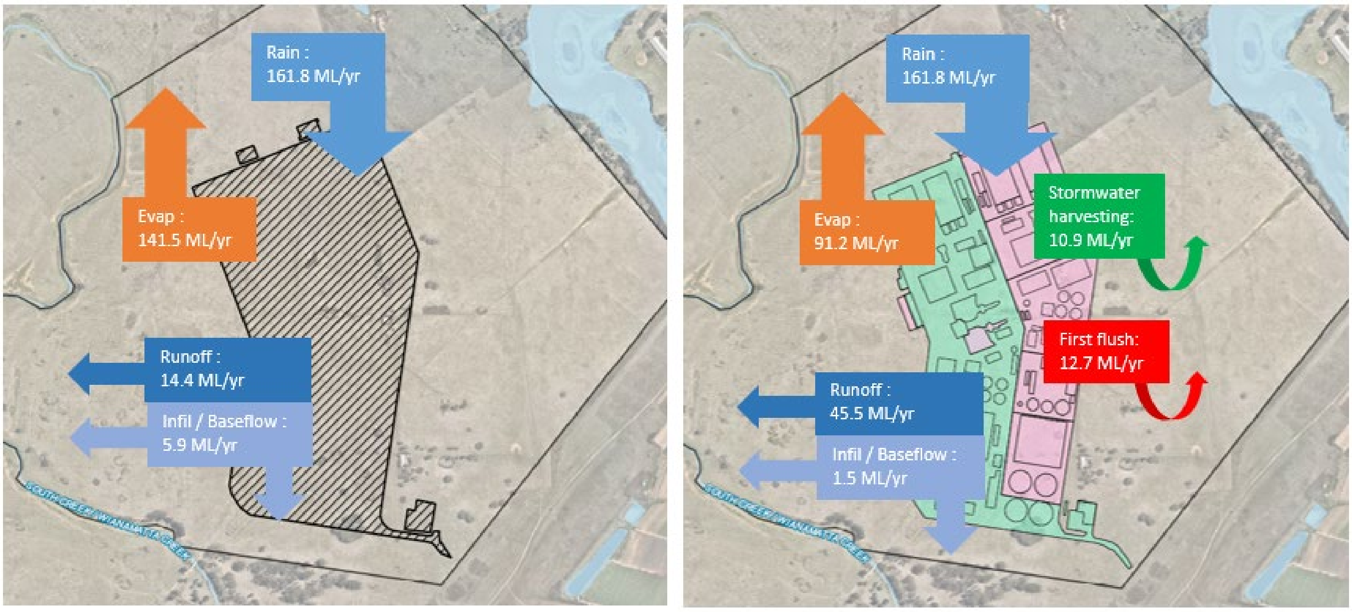


Figure 7-1 Water balance schematic pre-development (left) and ultimate future footprint (right) with mitigation

As detailed in **Appendix A**, a hydrologic performance of the reference design was provided by eWater MUSIC modelling over the period of 1993 to 2018. Models were run at an hourly time step and results exported as continuous hydrographs. The results were analysed to produce flow metrics for comparison against the objectives. The target flow metrics, as indicated in **Section 11** (**Table 2-3**), were converted to volumetric flow rates for the ultimate site footprint area (22.27 ha) and the resultant upper and lower limit values are shown along with the modelled results in **Table 7-3**. The table provides a comparison commentary on the effectiveness of the stormwater management measures to work towards waterway health (flow) objectives under ultimate development conditions. Where flow metrics sit between the ideal and 'limit of change', it is considered that the flow metrics contribute towards acceptable hydrologic conditions in the downstream waterway.

By achieving the waterway health objectives for the ultimate development, the waterway health objectives would also be met for Stage 1.

Table 7-3 Surface water management performance against WQO (flow) numerical criteria (Ultimate footprint)

Flow Objectives	Existing Condition (Objective for 1st & 2nd Order Waterways)	WSUD Performance for Reference Design	Tipping Point (3rd Order and greater Waterways)	Commentary on compliance
	Ideal	Modelled Performance of Mitigation	Upper Limit of Change	
Mean Runoff Volume (L/d) (ML/yr)	38,895 24.0	**124,657** **45.5**	130,571 47.7	Acceptable - remains between Exiting Condition and Tipping Point
High Spell (L/d) ≥ 90th Percentile Daily Flow Volume	29,156	**43,200**	241,883	Acceptable - remains between Exiting Condition and Tipping Point
High Spell - Frequency (number/y)	6.5	**8.3**	20	Acceptable - remains between Exiting Condition and Tipping Point
High Spell - Average Duration (days/y)	6.5	**3.8**	1.57	Acceptable - remains between Exiting Condition and Tipping Point
Freshes (L/d) ≥ 75th and ≤ 90th Percentile Daily Flow Volume	7,285	**34,560**	224,742	Acceptable - remains between Exiting Condition and Tipping Point
Freshes - Frequency (number/y)	3.1	**10.1**	25.3	Acceptable - remains between Exiting Condition and Tipping Point
Freshes - Average Duration (days/y)	44	**14.1**	2.4	Acceptable - remains between Exiting Condition and Tipping Point

Flow Objectives	Existing Condition (Objective for 1st & 2nd Order Waterways)	WSUD Performance for Reference Design	Tipping Point (3rd Order and greater Waterways)	Commentary on compliance
	Ideal	Modelled Performance of Mitigation	Upper Limit of Change	
Cease to Flow (proportion of time/y)	38%	**52%**	2.3%	Acceptable – While outside the range, this is still considered to be acceptable at the site outlet since the delivery of low flows via the wetland would contribute to groundwater top up within the local creeks, and in turn contributing to the local and regional water table that provides base flows downstream.

Note that the table above does not explicitly addresses wet weather sewer overflows from the AWRC. These issues are assessed in the *Ecohydraulic and Geomorphology Impact Assessment* report.

Stormwater pollution load reductions

The average annual stormwater pollutant loads discharged to the waterways from the Project reference design are presented in **Table 7-4** for generic pollutants; TSS, TP, TN and gross pollutants. The stormwater pollution load reduction would be achieved by the implementation of the WSUD measures as part of the Project reference design. The results indicate that all the target reduction values specified in the Penrith Council DCP (PCC, 2020) can be achieved.

Table 7-4 Stormwater pollution load reduction performance

Parameter	Ultimate design + no WSUD measures	Ultimate design with mitigation (WSUD)	Load reduction (%)	Penrith Council load reduction target (%)	Penrith Council Target Met
TSS (kg/yr)	13,200	1,510	88.6	85	Yes
TP (kg/yr)	25.5	7.06	72.3	60	Yes
TN (kg/yr)	185	54.3	70.7	45	Yes
Gross Pollutants (kg/yr)	2,210	0	100	90	Yes

Stream erosion index

The Stream Erosion Index for the reference design was calculated by determining the volume of discharges under rural and post development conditions that exceed:

- half the 2-year ARI flow (0.15 m^3/s) as shown in **Table 7-5** which is critical for medium clays
- a quarter of the 2-year ARI flow (0.075 m^3/s) as shown in **Table 7-6** which is critical for sandy clays

Table 7-5 Stream Erosion Index Results (*AWRC_7102020.sqz*) for medium heavy clays

Parameter	Volume Exceeding $Q_2/2$	Stream Erosion Index	Penrith Council target	Penrith Council Target Met
Reference design	9.4	1.4	SEI < 3.5	Yes
Pre-development / Rural	6.7			

Table 7-6 Stream Erosion Index Results (*AWRC_7102020.sqz*) for silty clays

Parameter	Volume Exceeding $Q_2/4$	Stream Erosion Index	Penrith Council target	Penrith Council Target Met
Reference design	14.8	1.6	SEI < 3.5	Yes
Pre-development / Rural	9.5			

Results demonstrate that the reference design achieves the stream erosion index specified in the Penrith Council DCP (PCC, 2020).

Stormwater pollution concentrations

The probability of exceedance of different concentration of TSS, TP and TN for the ultimate developed footprint of the proposed site discharge is presented in **Figure 7-2**. The MUSIC modelling results represent long term discharges of stormwater to the waterways and are associated with storm events. The WQOs for Wianamatta South Creek are also presented to enable comparison.

The results show that the concentrations of TSS and TN are predominantly (>90% of the time) below the ambient water quality objective for Wianamatta-South Creek (as indicated in **Section 2.2.1**). The TP concentrations are below water quality objectives more than 80% of the time. This shows that storm flows may exceed the ambient objectives but overall contribute to waterways achieving the WQO. A detailed description of the assessment and the full set of results are provided in **Appendix A**.

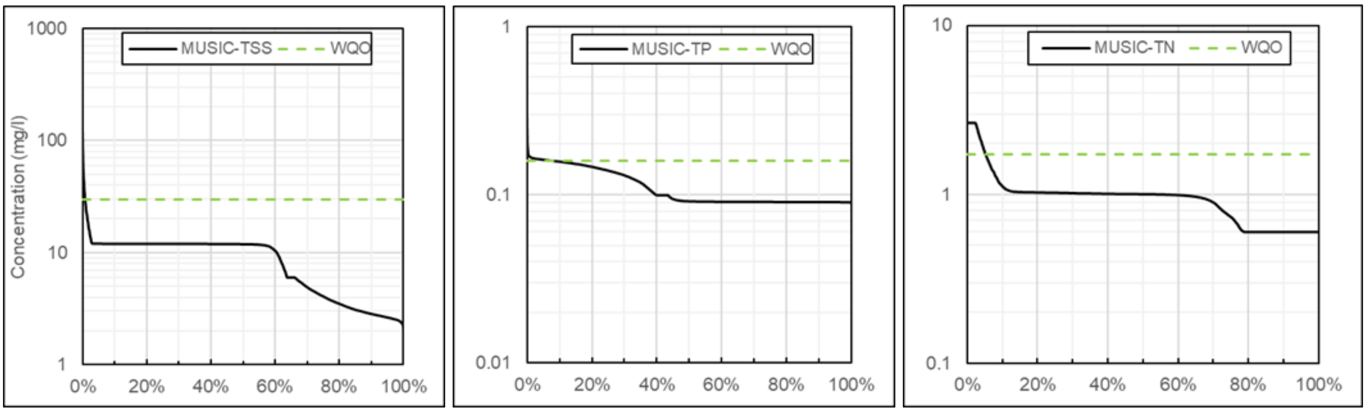


Figure 7-2 Simulated probability of exceedance of TSS, TP and TN – Ultimate footprint with mitigation

Flexibility of approach

It should be noted that there are various permutations of the stormwater treatment train that could be altered to achieve the same WQOs outcomes. The Project reference design provides flexibility to scale elements of the treatment train by up or down, which may offset the need for other elements.

Peak stormwater discharge assessment

The stormwater drainage network in the Project reference design has been sized to accommodate both Stage 1 and the ultimate future expansion of the ARWC. The most efficient earthworks design for the Project divides the Project site into two catchments draining north and west as shown in **Figure 7-3**.

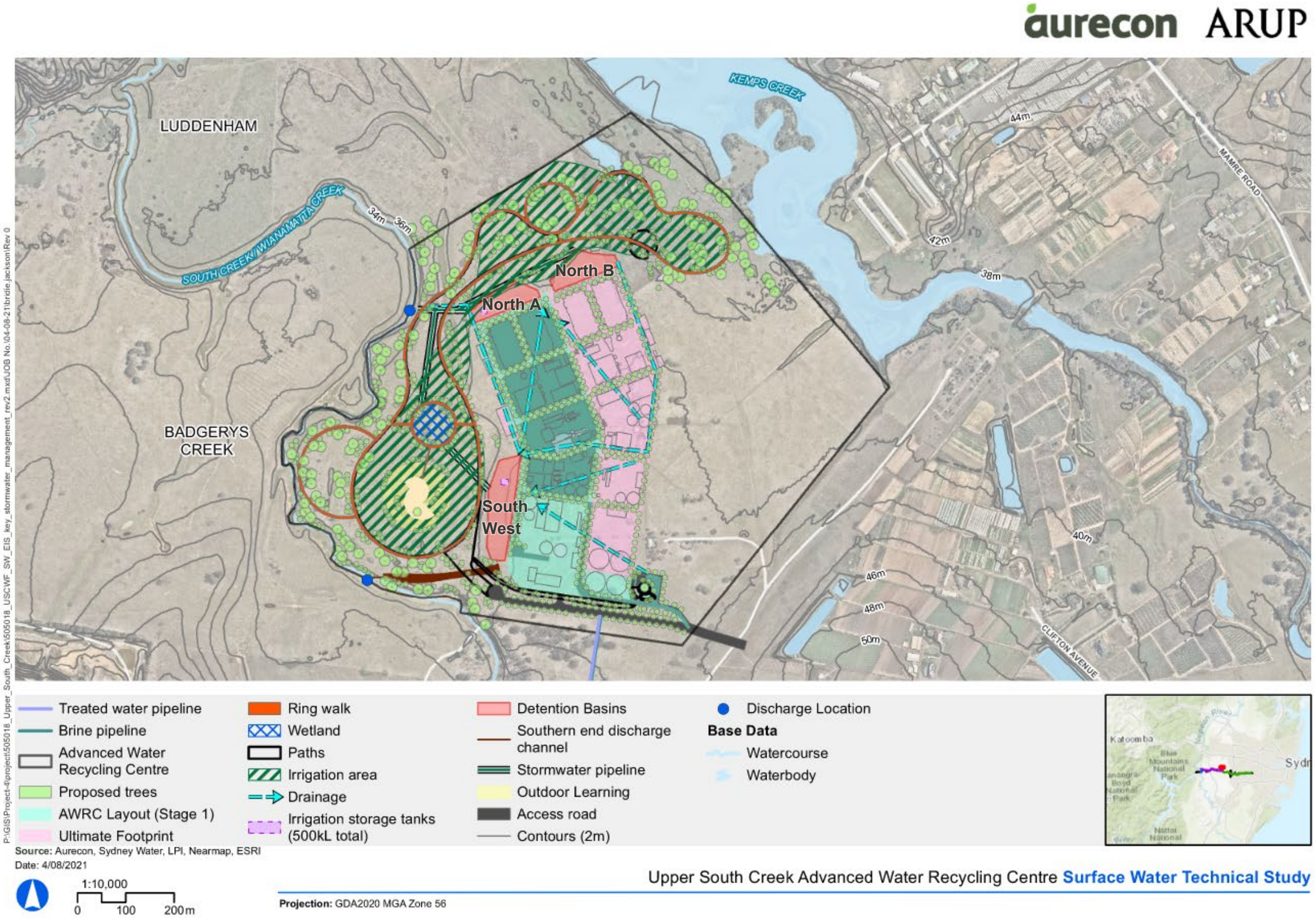


Figure 7-3 Stormwater quality and flow management mitigation features

During future stages of the Project the additional AWRC footprint would increase the catchment areas draining to the proposed On-site Stormwater Detention basins. The reference design accommodates the ultimate developed footprint and ensures sufficient allowance for on-site detention requirements for that ultimate stage.

OSD basin configurations for Stage 1 and ultimate AWRC have been designed using terrain and hydrologic modelling software. Areas and slopes as well as the applied hydrological parameters (roughness, initial and continuing losses) within the models are provided in **Table 7-7**.

Table 7-7 Land cover for ultimate footprint and adopted hydrologic parameters

Parameter	Unit	North A	North B	South-West	Rationale/Data source
Total Area	ha	5.88	6.49	9.90	Site civil design
Impervious portion	%	54	49	63	Site civil design
Slope (Pre-development)	%	0.6	0.65	0.44	Natural drainage slope measured using DEM data
Slope (Post-development)	%	0.5			Site civil design
Manning's n (Pre-development)		0.03			Natural short length grass (conservative)
Manning's n pervious areas (Post-development)		0.028			Cut short length grass (conservative)
Initial loss (Pervious)	mm	37.1			2015 Updated South Creek Flood Study
Continuing loss (Pervious)	mm/hr	0.94			2015 Updated South Creek Flood Study
Initial loss (Impervious)	mm	1			ARR 2019
Continuing loss (Impervious)	mm/hr	0			ARR 2019

Earthworks calculations for the three proposed basins determined the following available flood detention storage volumes can be provided adjacent to the site and outside of the 1% AEP flood extent:

- North A: 2,933 m^3
- North B: 3,525 m^3
- South-West: 5,732 m^3

Modelled performance of pre- and post-development peak flows as well as maximum volumes contained in storage for all three basins, for frequent (50% AEP), less frequent (5% AEP) and rare (1% AEP) storm events are provided in **Table 7-8**.

Table 7-8 OSD performance (2019 ARR)

AEP	Parameter	Unit	North A	North B	South-West
50%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.130	0.144	0.194

AEP	Parameter	Unit	North A	North B	South-West
	Peak Discharge Rate (Post-development)[1]	m^3/s	0.097	0.130	0.155
	Maximum water level in OSD	m	0.38	0.29	0.42
	Maximum volume in OSD	m^3	566	580	1,322
5%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.327	0.366	0.477
	Peak Discharge Rate (Post-development)[1]	m^3/s	0.286	0.266	0.427
	Maximum water level in OSD	m	0.67	0.56	0.73
	Maximum volume in OSD	m^3	1,243	1,251	2,840
1%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.582	0.649	0.811
	Peak Discharge Rate (Post-development)[1]	m^3/s	0.386	0.552	0.570
	Maximum water level in OSD	m	0.921	0.725	0.961
	Maximum volume in OSD	m^3	1,979	1,766	4,180

[1] Peak discharge rate refers to the maximum median flowrate simulated across all storm durations

The range of storms modelled demonstrates that the reference design accommodates sufficient OSD to maintain existing peak flow rates for a range of events up to and including the 1% AEP and function under an elevated tailwater caused by flooding in the Wianamatta-South Creek.

OSD outlets have been sized to ensure the maximum release rates would be less than the pre-development peak runoff rates from this area while still maintaining safe water depths within the basins (less than 1.2m).

A detailed description of the assessment and the full set of results are provided in **Appendix B**.

Flexibility of approach

The approach above addresses the Penrith Council requirement that OSD may prevent worsening of downstream flooding by ensuring no increase in peak flood flows after development. It is understood that the Aerotropolis Precinct Planning will prescribe requirements for flood detention in the Kemps Creek precinct, which will include the AWRC site. At that time, the Project reference design should be revisited. For instance, if the precinct planning determines that 1% AEP flood detention is not required on the AWRC site, but 50% AEP flood detention is required, then the basins may be modified to remove this component of flood storage.

While it is not yet known whether development within the Kemps Creek Precinct of the Aerotropolis will require flood detention basins, the provision of the basins in the reference design ensures that the site design can accommodate this significant requirement.

7.2 Pipelines and discharge structures

7.2.1 Construction phase

Operations water supply and disposal

During the construction phase water would be required when conducting bulk earthworks. Additional high-water demand activities associated with the concrete batching plants may be needed.

The water source and wastewater discharge arrangements would be location dependant. Where possible the local mains water and sewer systems would be utilised.

Watercourse and in-stream works

Different construction methods are proposed along the pipeline routes to overcome various environmental constraints. **Table 7-9** summarises the proposed method for each waterway crossing (with a Strahler order 2 and higher) along the alignments. It should be noted that where the Brine pipeline crosses Clear Paddock Creek (between B4 and B5), the waterway has a Strahler order of 1.

In general, pipelines would be constructed across watercourses using temporary open trenching methods. Deeper waterway crossings would be constructed using trenchless methods where it is necessary to pass below existing infrastructure or to mitigate potential impacts associated open trenching within waterways.

Trenched crossings are generally shallower, with less probability of sub-surface related impacts such as disruption of surface water and groundwater connectivity.

The impacts are primarily expected to be temporary and local in nature and are listed and rated in Table 8-1 and Table 8-3.

Table 7-9 Proposed construction methodology for crossing watercourses

ID	Watercourse	Riparian corridor width*	Pipe OD (mm)	Reference design construction method**
Treated Water Discharge Main				
T1	South Creek	40 m	1283	Trenched
T2	Unnamed tributary to South Creek	20 m	1283	Trenched
T3	Badgerys Creek	40 m	1283	Trenchless – Micro Tunnel (DN 1500)
T4	Unnamed tributary to Badgerys's Creek	30 m	1283	Trenchless – Micro Tunnel (DN 1500)
T5	Farm dams u/s of Badgerys Creek tributary	10 m	1283	Trenchless – Micro Tunnel (DN 1500)
T6	Unnamed tributary to Cosgroves Creek	20 m	1283	Trenched
T7	Oaky Creek	30 m	1283	Trenched
T8	Cosgrove Creek	40 m	1283	Trenched

ID	Watercourse	Riparian corridor width*	Pipe OD (mm)	Reference design construction method**
T9	Farm dam & unnamed trib to Cosgroves Creek	20 m	1283	Trenchless – Micro Tunnel (DN 1500)
T10	Jerrys Creek	40 m	1283	Trenchless – Micro Tunnel (DN 1500)
T11	Nepean river	40 m	1283	Trenchless – Micro Tunnel (DN 1500)
T12	Baines Creek	30 m	1283	Trenchless – Micro Tunnel (DN 1500)
Environmental Flows Pipeline				
E1	Baines Creek	30 m	1016	Trenched
E2	Megarritys Creek	30 m	711	Trenchless – Horizontal Directional Drilling (HDD
Brine Discharge Main				
B1	Unnamed tributary to Kemps Creek	20 m	560	Trenched
B2	Kemps Creek	40 m	560	Trenched
B3	Hinchinbrook Creek	20 m	560	Trenched
B4	Unnamed tributary to Hinchinbrook Creek	30 m	560	Trenched
B5	Green Valley Creek	20 m	560	DN 700 Jacking Pipe
B6	Prospect Creek	40 m	560	Conventional or bi-directional HDD

* On either side of the waterway

** Pipe diameter and encasing pipe may be subject to change in detailed design

Construction of the proposed discharge structures at Nepean River, South Creek and Warragamba River sites would include the installation of silt curtains and temporary cofferdams to segregate earthworks from river flows. This is indicatively shown in **Figure 7-4**.

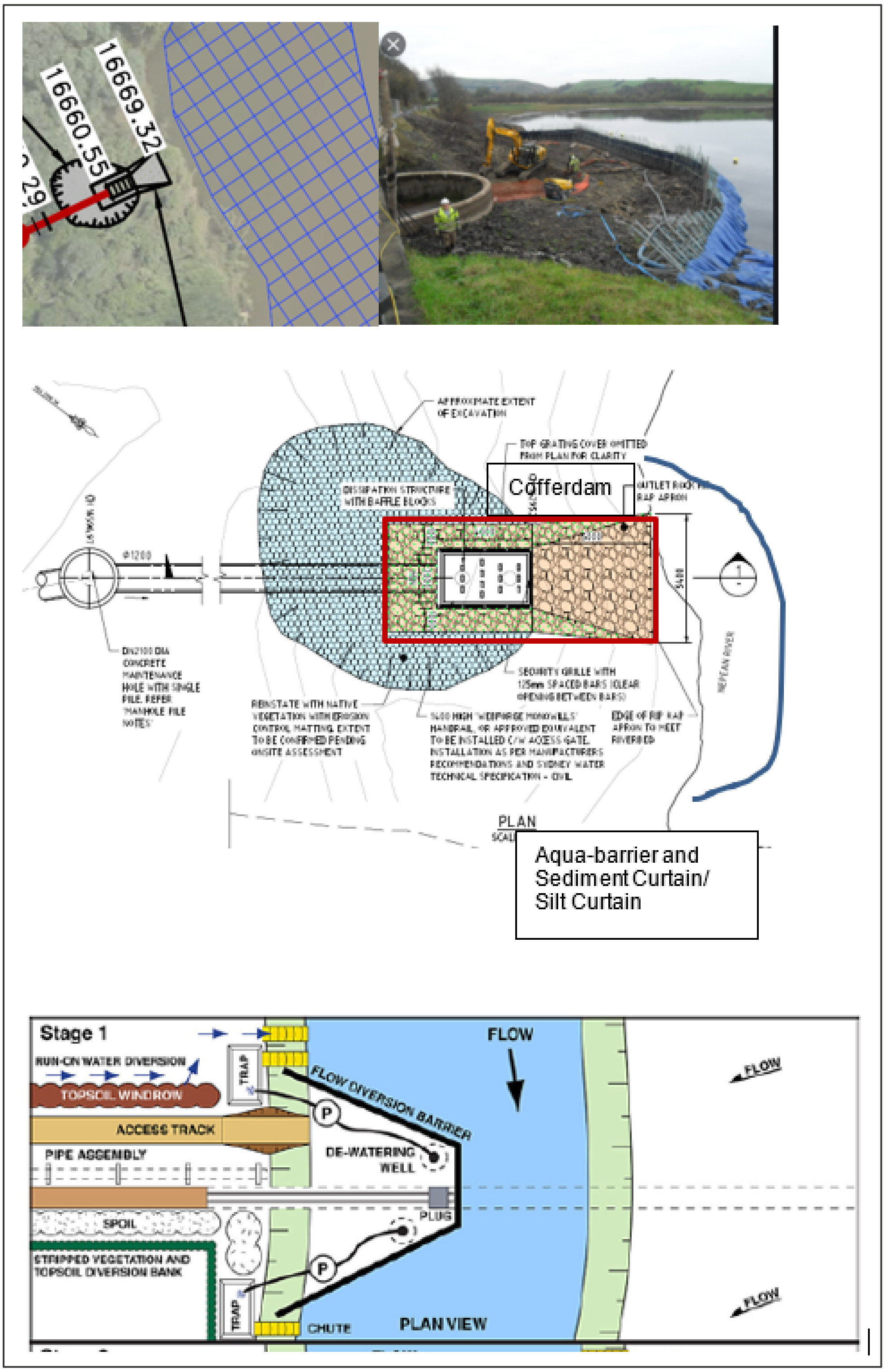


Figure 7-4 Indicative diagrams of construction activities for the pipeline discharge structures

The expected duration of the cofferdam construction activity is six months. During dry weather, impacts of the construction activities are expected to be negligible. Overtopping of the coffer dams would occur during bank full discharge in the waterway, which has the potential to generate additional sediment loads to the waterway. Considering the small footprint of the works area within the cofferdams, the volume of sediment released would have a minor impact on turbidity and silt loads in the waterway. The likelihood of a release would be further mitigated through scheduling the construction of these structures during seasons when bank full discharges are less likely.

7.2.2 Operational phase

The pipeline infrastructure would primarily be below ground and thus potential impacts to the surface water resources associated with the pipelines are expected to be minimal and primarily associated with the construction phase. The potential operational phase impacts would be associated with maintenance activities and system malfunctions, such as leaks or bursts. The impacts are expected to be temporary and local in nature and are listed and rated in

Table 8-2 and **Table 8-4**.

7.3 Other key considerations

Warragamba River discharge location

The e-flow pipeline outlet would discharge to the reach of the Warragamba River that is downstream of the Warragamba Dam wall and outside of the drinking water catchment.

Discharge infrastructure would include a new sealed access road from Core Pare Rd, hardstand areas for trucks and maintenance associated with the pipeline outlet structure and headwall.

The works would occur within the steep and rocky terrain of the Warragamba River valley. Construction works would require temporary sediment fences and barriers, and erosion controls to prevent discharge of any eroded material from excavation within the valley sides.

Alterations to surface water conditions from the completed road and headwall structure present a relatively small increase in stormwater runoff from the existing rocky valley which has a relatively highly imperviousness due to the presence of rock and very steep terrain. Stormwater quality impacts at the site would therefore be low as stormwater runoff from the discharge infrastructure and road are not substantially different to the current stormwater being generated from the existing rocky valley.

There is no water use associated with discharge structure operation.

Discharges of treated wastewater associated with the e-flow pipeline are detailed within the *Ecohydraulic and Geomorphology Impact Assessment* report.

Photovoltaic installation

The proposed PV facility presents a small change to the existing landform and low risk of altered surface water impacts.

Minimal earthworks are required, and appropriate drainage features would be constructed along any access roads (such as vegetated swales) to minimise the risks of stormwater and pollutants leaving the site. Except for access roads, and areas around the onsite substation, the site should be revegetated with grass cover. Despite the presence of photovoltaic cells, the effective increase in imperviousness would be low. Water quality impacts at the site would therefore be low and are not considered substantially different to the current potential water quality impacts occurring from revegetated, stable land.

Water use volumes during operation of the PV site would be minimal. Water may be required occasionally for panel cleaning. Panel cleaning may be required in dry conditions. Water sourcing from the on-site storage tanks would be prioritised, in cases of prolonged drought water would be trucked to site as required.

Salinity risks associated with irrigation

The Low Flow and Stormwater Study (**Appendix A**) proposes harvesting stormwater from the AWRC site for irrigation application of the adjacent regional park as a means of contributing to the regional Waterway Health (flow) targets. The irrigation rate proposed would strike a balance between retaining stormwater in the catchment, providing for a quality regional park, and preventing salinification of groundwater by avoiding excessive infiltration of water into soils.

Proposed landscape planting across the adjacent regional park would comprise a mix of turf and native species giving a high-quality landscape character. The proposed irrigation rate (4.5 ML/Ha/yr) makes up the local rainfall deficit or shortfall between rainfall (approximately 700 mm/yr) and potential evapotranspiration (approximately 1,200 mm/yr). Through controlled irrigation, which avoids watering saturated soils and areas of no vegetation cover, the risk of increased groundwater recharge beneath the park and irrigated zones would be low.

Soil salinity mapping of the study area and supplementary soil salinity testing as part of the Soils and Contamination Technical Study, indicate that soil across the AWRC site exhibit non saline properties near surface. In several instances the sampling indicates a vertical salinity profile of saline to moderately saline soils within the 1 to 3m below ground depths and this salinity profile is expected to increase at depth within nearing the water table.

The proposed controlled irrigation rate on low saline soils is therefore considered to have a combined low risk of salinity impacts on soils and underlying groundwater table.

Climate change considerations

Local climate change projections based on the NARCliM published results have been provided in **Section 5.1.2**. Given the Project timeline the near future projections (2020-2039) have been considered. Projected near future rainfall and runoff changes are less than 1% for the Hawkesbury Nepean Catchment. These changes are insignificant compared to the uncertainty in stable climate modelling and standard seasonal variation. The recharge rate is projected to decrease by around 9%. Urbanisation of the surrounding catchment is expected to have a far larger impact on the reduction in recharge.

Any consideration of modelling the future systems under these conditions and then considering appropriate mitigation measures would be obscured as no clear baseline could be set, and the Project cannot be held accountable to mitigate changes brought about by climate change. The Project would endeavour to mitigate any impacts which could further reduce the current natural recharge rate.

Wet weather discharges to South Creek

Discharges to Wianamatta-South Creek from the ARWC associated with wet weather overflows are considered within the *Ecohydraulic and Geomorphology Impact Assessment* report.

WaterNSW Pipelines

The WaterNSW Pipelines cross the Wianamatta-South Creek floodplain as an elevated structure with footings constructed within areas subject to frequent inundation. Concern has been raised over the long-term stability of the channel and surrounding floodplain in the context of increased stormwater runoff resulting from the cumulative development of the upstream catchment.

Mitigation measures included into the Project reference design work towards the protection of the pipelines under a cumulative development scenario through the following:

- Preserving the peak flow discharge from the site under the critical 50% and 1% AEP storm events to ensure no increase in the magnitude of erosive forces
- Limiting the volume of stormwater discharged from the AWRC and therefore limiting the duration of potentially erosive forces imparted on the creek channels
- Preserving frequent low flows discharged from the AWRC as far as is practicable to achieve the Wianamatta South Creek water quality objectives (flow) which have been specified to limit erosion in the downstream waterway

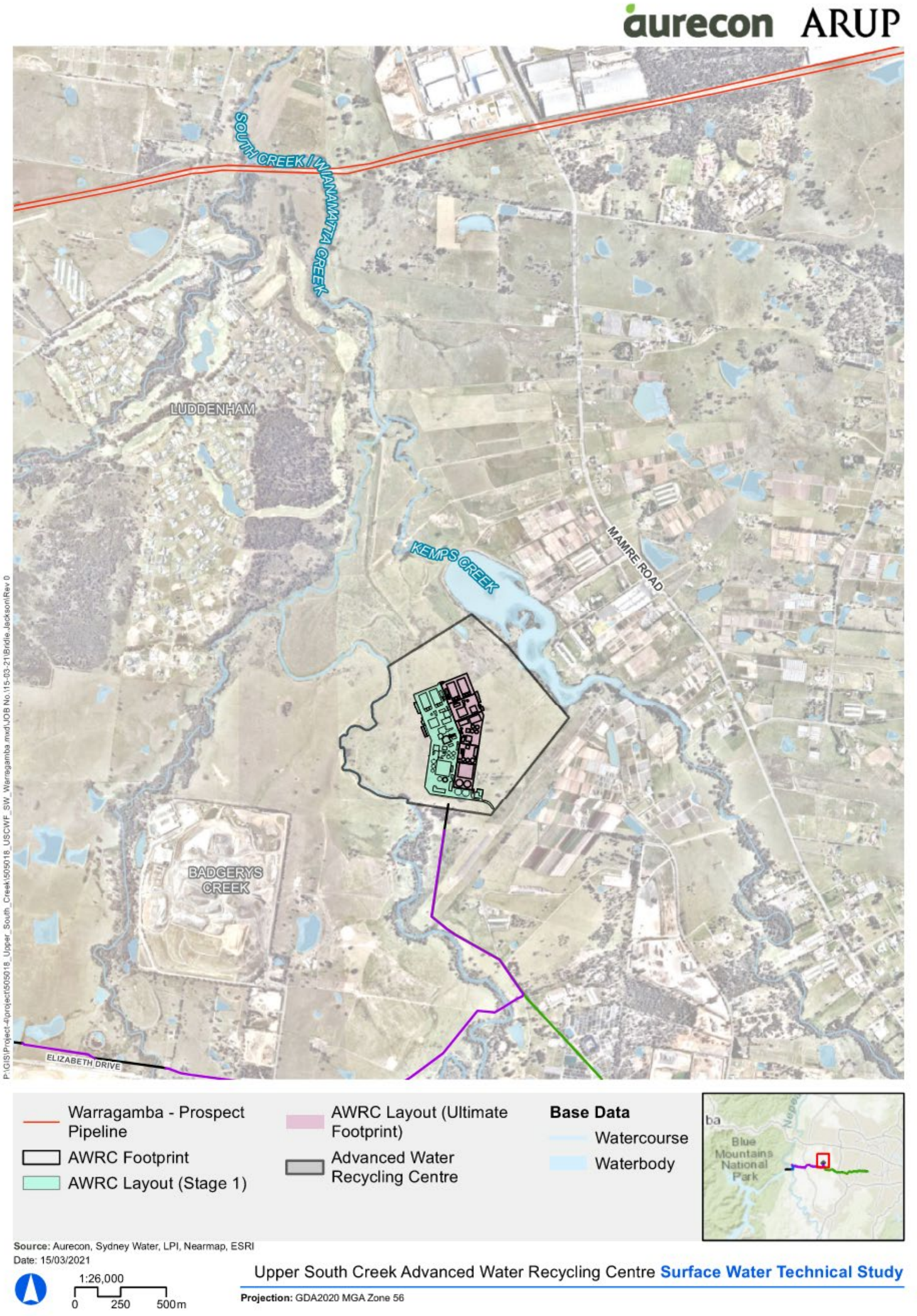


Figure 7-5 Relative location of the AWRC site to the Warragamba to Prospect pipelines

8 Impact assessment

8.1 Identified impacts

Surface water impacts associated with the proposed project have been identified and an assessment undertaken in accordance with the Project SEARs. Understanding potential impacts that may occur during the construction and operational phases will lead to more informed mitigation measures to minimise and / or contain these impacts on site. This section was developed and applied to inform the Project's reference design and ensure appropriate mitigation measures have been considered.

The following sections respond to the SEARs (**Section 1.3**) while providing an overview of potential construction and operational phase impacts for the AWRC site and pipeline alignments including pipeline discharge structures. The potential impacts have been assessed with consideration of the relevant components of the reference design, through an iterative design process.

The significance of any potential project impact on the local surface water resources has been determined by considering the sensitivity of the environment related to the assessed criteria as well as the magnitude of the expected change, as described in **Section 4.5.2**.

Due to historic significant land use changes within the catchments, the watercourses have likely already been altered from their natural state. These land use changes have likely led to higher peak flowrates, lower baseflow rates and increased nutrients and dissolved solids (linked to high conductivity) in the runoff being discharged from the area. Thus, the current conditions are already partially altered.

The potential impacts associated with the construction phase activities of the Project are identified and assessed in **Table 8-1,** any additional impacts potentially arising during the operational phase are indicated in

Table 8-2**.**

Where impacts are moderate and high, mitigation measures are required, and the residual impacts are assessed below in **Section 8.2**.

Table 8-1 Impact assessment outcomes and significance of stormwater runoff during construction phase

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C1	AWRC site, pipeline corridors and access roads: • Clearance of vegetation, earthworks, and stockpiling	• Discharges of sediment-laden stormwater from stockpiled sites and cleared areas to receiving waterways resulting in sedimentation within adjoining watercourses	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary) Sediment management procedures are required to prevent generation of downstream impacts (see **Section 7.1.1)** of sediment be provided as a mitigation measure to collect stormwater runoff for reuse.
C2	AWRC site, pipeline corridors and access roads: • Clearance of vegetation, earthworks, and stockpiling	• Increased loading of nutrients (dissolved and particulate-bound) from exposed surfaces and stockpiled materials into adjacent watercourses from site runoff. This process has the potential to simulate the growth of nuisance plants, algae and cyanobacteria • Tannin leachate from clearing and mulching discharging to near site drainage pathways resulting in eutrophication, reduced water pH and visual aesthetic issues	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary) Local watercourses currently have high nutrient concentrations and any impacts would be temporary during the construction phase
C3	AWRC site and pipelines: • Disturbance and/or demolition of existing structures	• Waste materials such as concrete, plasterboard, timber, asbestos and contaminated soil spreading via surface run-off to near site drainage pathways	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary) The contamination assessment indicates the presence of waste materials currently on the site. If these materials were to find their way to the local watercourses, this could negatively affect the water quality in the area and downstream.

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C4	AWRC site and pipelines: • Excavation, dewatering and installation of underground infrastructure and discharge structures	• Runoff or unintended dewatering and discharge of contaminated water from excavations or stockpiles which include contaminated soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary) Acid sulphate soils have not been mapped within this area. Stockpile runoff would be managed on site (see **Section 7.1.1** and **C5** below**).**
C5	AWRC site: • Sediment discharges during construction and discharges from the sediment basin or basin dewatering activities	• Discharges from sediment basins or any required dewatering activities (where water quality is proven acceptable for discharge, see *Groundwater Impact Assessment* report) may mobilise sediments increase the turbidity of the receiving waters	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local) Sediment basins (see **Section 7.1.1)** would be provided as a mitigation measure, any potential turbidity impacts from the discharges are expected to be localised
C6	Pipelines: • Construction of pipelines and pipeline discharge structures within waterways	• River flow events overtopping cofferdams, sending water into the construction works site of pipeline discharge structures that mobilise sediments and increase the turbidity of the receiving waters	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local) Potential turbidity impacts would be localised, rare and associated with high flow events when background levels of sediment in receiving waters would be elevated
C7	AWRC site, pipelines and access roads: • Compaction, concreting and installation of impervious surfaces and pavements	• Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely)

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C8	AWRC site, pipelines and access roads: • Compaction, concreting and installation of impervious surfaces and pavements	• Changes in volumes and rates of flow to the receiving creeks • Worsening flood conditions (flow rates) downstream of the site	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local) Stormwater discharge from the AWRC site would have no impact on the peak flow rates in adjacent waterways (See **Appendix B**) Limited surface compaction and concreting at pipeline discharge structures would have an unmeasurable and insignificant impact on peak flows in adjacent waterways during construction.
C9	AWRC site: • Compaction, concreting and installation of impervious surfaces and pavements	• Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site	Significance: Low (Pipeline access road at Warragamba discharge) Sensitivity of environmental values: High (significant infrastructure) Magnitude of impact: Low (limited change) Stormwater discharge from the AWRC site would have no impact on the peak flow rates in adjacent waterways (See **Appendix B**) During construction, the stormwater management controls cap the volumes of stormwater entering creeks to double that of existing conditions which is as far as is practicable. The increase in volume is associated with more intense rain events and floods. During intense rain events, the volume of runoff would increase but the peak flow would not increase as flow controls prescribed in the DCP ensure no increase in peak discharge from development in 50% to 1% Annual Exceedance Probability events.

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C10	AWRC site and pipelines: Leaks/spills: Spills of chemicals, heavy metals, oils, and petroleum hydrocarbons during the use and operation of machinery • Storage, transport, use and handling of chemicals	• Potential to introduce surface contaminants to surface water runoff and impact the quality of surrounding surface waters through stormwater discharge and plant wash down routines • Acute impacts to ecosystems receiving surface water run-off; in particular, the discharge location to South Creek • Leakage from construction worker ablution and toilet facilities or wastewater collection points with subsequent runoff into receiving watercourses	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) Chemicals used during construction and operation would likely be handled and stored on site, any significant volumes of these chemicals entering the local water environment would lead to local ecological degradation
C11	AWRC site: • Water demand and sourcing	• Impact on regional and and/or local water resources	Significance: Negligible Sensitivity of environmental values: Low (external sourcing) Magnitude of impact: Low (no expected change) See **Section 7.1.1**
C12	Pipelines: • Trenching / Direct disturbance of watercourse bed and / or banks	• Temporary obstruction and interference with normal drainage channels and subsequent ponding or damming of water upstream	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) With the exception of South Creek, all of the watercourses to be crossed using trenching methods have been historically subjected to periods of ponding close to the crossing location during the dry season. Any impacts are expected to be temporary in nature.

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C13		• Obstruction of surface drainage from the contributory sub-catchments leading to unnatural dried channels downstream, if conducting works during periods when surface flow would usually be occurring	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) Unnatural dry channel beds can lead to temporary disturbances of local ecology
C14		• Increases in sedimentation directly upstream from in-channel works as a result of ponding and associated decreases in flow velocity	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) TSS concentrations in the watercourses are currently at acceptable levels, increased sedimentation however would be very localised and temporary.
C15		• Removal of riparian vegetation and topsoil during construction causing risk of erosion during subsequent revegetation and establishment	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) The erosion of exposed banks can further deteriorate over time if not managed, this can lead to ongoing erosion and deposition of sediments into the watercourses
C16		• Deterioration in visual water quality due to trapping of coarse litter upstream from crossings	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) Coarse litter being transported via the waterways would only temporarily accumulate, as is the case for the current ponding systems during the dry season

Item Nr	Project location/Activity	Potential Impact	Impact significance without mitigation
C17	Pipelines: • HDD and micro tunnelling	• Fluid loss during any HDD required for installation of the pipelines (uncontrolled release of drilling fluid escaping from the borehole through fissures or weakness in the substrate resulting in increased sedimentation and turbidity in watercourses) • Discharge of contaminated hydrostatic test water	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) Any significant volumes of these chemicals entering the local water environment may lead to local ecological degradation or destruction, albeit temporary
C18	Pipelines: • Horizonal directional drilling under a watercourse	• Disruption of surface water and groundwater connectivity	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) Any disruption in connectivity would be very localized

Table 8-2 Impact assessment outcomes and significance of stormwater runoff during operational phase

Item ID	Project location/Activity	Potential Impact	Impact significance without mitigation
O1	AWRC site discharge location to South Creek: • Increased imperviousness across the site associated with compaction, concreting and installation of pavements	• Increased stormwater runoff from buildings, roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen) to Wianamatta South Creek	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate Risk of surface water pollution without proper containment and spill management measures to capture and treat first flush (10 mm) of rainfall across the AWRC site which is likely to contain hydrocarbons, chemicals, dissolved and particulate-bound nutrients. Risk of surface water pollution without appropriate reductions in nutrients and sediment loads from paved surfaces. The detailed approach is presented in **Section 7.1.2.2**. Results indicate that stormwater discharge works towards achieving water quality objectives by discharging at concentrations below the ambient water quality targets for up to 90% of the time.
O2		• Increased stormwater runoff from buildings, roads and exposed surfaces contributing to altered low flows and baseflow to Wianamatta-South Creek	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (low change but would contribute to cumulative impacts from development of the upper catchment). Significant change in hydrologic characteristics of runoff from the AWRC without stormwater retention and detention to manage stormwater flows entering adjacent waterways with potential to contribute to waterway health decline as development of the catchment progresses (See **Section 7.1.2.2**).
O3		• Worsening of existing flood conditions (flow rates) downstream of the AWRC site • Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (low change but would contribute to cumulative impacts from development of the upper catchment). Stormwater discharge from the AWRC site would have the potential to impact on the peak flow rates in adjacent waterways (See **Section 7.1.2.3**).

Item ID	Project location/Activity	Potential Impact	Impact significance without mitigation
O4	Discharge structure and access roads Warragamba and Nepean Rivers: • Increased imperviousness associated with discharge structures, compaction, concreting and installation of pavements	• Increased stormwater runoff from access roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen) to Warragamba and Nepean Rivers	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (minimal change) Small incremental increase in runoff volumes and nitrogen and phosphorous loads associated with the relatively minor increases in impervious areas within the Warragamba Valley catchment. Low traffic movements on access roads presents low risk of sediment pollutants being generated
O5	AWRC discharge location to South Creek: • Moving and storing untreated and partially treated wastewater throughout the plant	• Spilling or discharging untreated or partially treated wastewater to the local watercourses	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) Any spills or accidental discharges would be temporary in nature but could contribute to pathogens in waterways
O6	Treated water pipeline in Wianamatta-South Creek • Pipe leaks or bursts	• Incidental discharge of highly treated water to waterways which could increase turbidity, lead to local scouring, impact the local and downstream geomorphology	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) Local discharges would be temporary and the water quality acceptable for discharge
O7	Treated water pipeline in Wianamatta-South Creek • Uncontained pipe scouring during maintenance periods	• Discharge of highly treated water to waterways during maintenance which could cause local scouring	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change) During pipe cleaning activities (e.g. flushing, swabbing & scouring) water may be discharged from the Treated and Environmental Flows pipelines. This water would be of high quality and unlikely to cause significant impacts. Procedures, as prescribed in Sydney Water's Discharge Protocols Standard Operating Procedure (WPIMS5021), would be followed ensuring potential localised impacts are managed and mitigated.

Item ID	Project location/Activity	Potential Impact	Impact significance without mitigation
O8	Brine pipeline: • Pipe leaks or bursts	• Incidental discharges from the brine pipeline could temporarily impact water quality in freshwater creeks and cause local scouring of creek	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary, local, unlikely to occur) Sydney Water designs its pipelines to a high standard to minimise the risk of leaks. Sydney Water's standard procedures include regular inspections and incident response procedures would also manage this potential risk and impact.
O9	Brine pipeline: • Scouring of pipes and discharge to waterways	• Discharge of brine water to waterways during maintenance which could temporarily impact water quality and cause local scouring	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary, local, likely to be required) Scouring of the pipelines would be required periodically. If the brine is directly discharged to the environment there would likely be localised impacts to the local waterways.
O10	AWRC site and pipelines: • Spills of chemicals, heavy metals, oils, and petroleum hydrocarbons during the use and operation of machinery • Storage, transport, use and handling of chemicals	• Potential to introduce surface contaminants to surface water runoff and impact the quality of surrounding surface waters through stormwater discharge and plant wash down routines	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (temporary and local) Chemicals used during construction and operation would likely be handled and stored on site, any significant volumes of these chemicals entering the local water environment would lead to local ecological degradation
O11	AWRC site discharge location to South Creek: • Discharge of wastewater and stormwater associated with wet weather overflows	• Changes in surface flow rates associated with wastewater discharges to waterways during high flow bypasses, plant shut down and wet weather discharges • Increase in flood flows due to wastewater discharges associated with high flow bypasses, plant shut down and wet weather discharges	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (moderate cumulative impact) Excess flows relate to stormwater being conveyed via the sewage system and as such would not add to the total volume being discharged to the environment when considering the entire catchment. Peak wet weather discharges represent a relatively small increase in peak flow.

Item ID	Project location/Activity	Potential Impact	Impact significance without mitigation
		• Increased erosion risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site	Being conveyed via the pipe network may lead to the water volumes arriving at the proposed discharge location a little sooner than via the natural watercourses. The expected maximum volumes are significantly smaller than the total storm peak discharge volumes expected to be conveyed within Wianamatta-South Creek during these major wet events.
O12	Photovoltaic cells on AWRC site: • Installation of photovoltaic cells	• Worsening of existing flood conditions (flow rates) downstream of the site • Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site • Increased stormwater runoff from access roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen)	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (minimal change) Small incremental increase in runoff volumes and nitrogen and phosphorous loads associated with photovoltaic cells. The relatively minor increases in effective imperviousness of the photovoltaic cells and associated grassed swales would mitigate runoff impacts on Wianamatta-South Creek and Kemps Creek. No measurable increase in peak runoff volumes.
O13	• AWRC site: Harvesting of stormwater and irrigation application of adjacent regional park	• Increased groundwater recharge leading to raising of saline aquifer water levels • Mobilisation of inherent soil salinity and increased load discharged to local water resources	Significance: Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (local) Local aquifers are highly saline and over irrigation could lead to localised salinity impacts over the irrigation area.

8.2 Mitigation of residual impacts

A summary of the identified potential impacts, with a significance rating other than low, along with their proposed mitigation measures and resultant impact significance are provided for the construction phase activities and are listed in **Table 8-3**. Any additional impacts associated only with the operational phase are indicated with their proposed mitigation measured in **Table 8-4**.

Table 8-3 Potential project specific mitigation measures (Construction phase)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
C1	AWRC site, pipeline corridors and access roads: • Clearance of vegetation, earthworks and stockpiling	• Discharges of sediment-laden stormwater from stockpiled sites and cleared areas to receiving waterways • Tannin leachate from clearing and mulching discharging to near site drainage pathways resulting in eutrophication, reduced water pH and visual aesthetic issues	• A Soil and Water Management Plan (SWMP) would be prepared as part of the CEMP and implemented throughout construction. It would include, but not be limited to: – Erosion and Sediment Control Plan – Stormwater management strategy – Dewatering Procedure – Acid Sulphate Soil Management Plan (where applicable) – Soil Salinity management strategy • Schedule construction works to avoid wet seasons and heavy rainfall, where possible. • Stormwater management features, including drains, swales and detention basins would be constructed progressively to manage potential flow increases. Where required, temporary drainage would need to be installed to manage on-site surface water. • Locate stockpiles of cleared vegetation away from waterways and within appropriately bunded areas. • Develop and implement of an erosion and sediment control plan in accordance with Managing Urban Stormwater: Soils and Construction which may include: – Installation of silt fences, sediment traps, contour berms and energy dissipaters	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
			– Appropriately designed and operated sedimentation basins – Resealing or revegetating surfaces as soon as applicable – Locating stockpiles, sediment basins, bunds and vehicle wash-downs away from drainage lines – Using geofabric on stockpiles throughout the course of construction – Establishing dirty water drains to direct site runoff to a sediment retention basin – Reuse captured stormwater for dust suppression to limit the volume of stormwater leaving the construction site • Eliminate ponding and erosion by restoring natural landforms to the pre-works condition where possible. • Stop work during heavy rainfall or in waterlogged conditions when there is a risk of sediment loss off site. • See Section 7.1	
C2	AWRC site, pipeline corridors and access roads: • Clearance of vegetation, earthworks, and stockpiling	• Increased loading of nutrients (dissolved and particulate-bound) from exposed surfaces and stockpiled materials into adjacent watercourses from site runoff. This process has the potential to simulate the growth of nuisance plants, algae and cyanobacteria • Tannin leachate from clearing and mulching discharging to near site	• Manage nutrients in runoff by reuse captured stormwater for dust suppression to limit the volume of stormwater leaving the construction site.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
		drainage pathways resulting in eutrophication, reduced water pH and visual aesthetic issues		
C3	AWRC site and pipelines: • Disturbance and/or demolition of existing infrastructure	• Waste materials such as concrete, plasterboard, timber, asbestos and contaminated soil spreading via surface run-off to near site drainage pathways	• Implement an erosion and sediment control plan in accordance with *Managing Urban Stormwater: Soils and Construction*. • Excavate and stockpile any contaminated soils within appropriately bunded areas • Locate contaminated waste material stockpiles away from drainage lines • Any waste material generated to be accurately classed and transported for offsite disposal at an appropriately licenced facility where necessary.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C4	AWRC site and pipelines: • Excavation, dewatering and installation of underground infrastructure and discharge structures	• Runoff or unintended dewatering of contaminated water from excavations or stockpiles which include contaminated or acid sulphate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	Stockpile runoff would be managed on site (see **Section 7.1.1 and C5 below).** Develop and implement an approach to manage extracted groundwater and/or contaminated runoff via one or a combination of these methods: • **Discharge to a receiving surface water body** such as creek, river, stream etc. An Environment Protection Licence (EPL) would be required under the Protection of the Environment Operations Act (1997). To support the application for an EPL, a discharge impact assessment would be required to demonstrate the discharge will not have significant deleterious impacts to the receiving water body. The EPL would stipulate the volume of water that could be discharged and the water quality discharge criteria (outlined in the *Groundwater Impact Assessment* report). Depending on extracted groundwater quality, temporary	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
			storage and treatment may be required to meet the applicable water quality criteria, prior to discharge. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in the *Groundwater Impact Assessment* report. • **Discharge to stormwater collection system.** This would require a similar level of assessment to discharging to receiving surface water body as described above. • **Discharge to sewer via a Trade Waste Agreement (TWA)** with the wastewater system operator. Discharge to sewer is to be conducted in accordance with the TWA, which may require temporary storage and treatment of the water prior to discharge. • **Land based application or reinjection / irrigation.** Feasibility of this option is dependent upon soil properties (infiltration rates, salinity etc.) at the reinjection / irrigation area. Generally precluded as a discharge option in areas with low permeability soils and salinity issues. However, for incidental or small volumes of extracted groundwater, this option could be considered provided the groundwater quality is suitable and other approval mechanisms are in place. Stability of nearby trenches / excavations and surrounding underground structures must be considered. • **Offsite disposal**. Extracted groundwater would be trucked offsite and treated and/or disposed of at a licensed wastewater treatment plant.	
C5	AWRC site: • Sediment discharges during construction and	• Discharges from sediment basins or any other required may mobilise sediments and	• Develop and implement an erosion and sediment control plan which would include: – Sediment basin sizing and location and maintenance regime	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
	discharges from the sediment basin or basin dewatering activities	increase the turbidity of the receiving waters	– Procedure for flocculating dirty water and water quality testing requirements – Procedure for dewatering and designated discharge point/s – Monitoring and inspection requirements • Discharge water in accordance with *Managing Urban Stormwater: Soils and Construction* guidance, including erosion controls, discharge rate, dichlorination, monitoring. Re-use potable / groundwater water where possible. • See Section 7.1.1	Magnitude of impact: Low (unlikely to occur)
C6	Pipelines: • Sediment discharges during construction of pipeline and pipeline discharge structures within waterways	• River flow events overtopping cofferdams, sending water into the construction works site of pipeline discharge structures that mobilise sediments and increase the turbidity of the receiving waters	Impact significance low without mitigation: • Potential turbidity impacts would be localised, rare and associated with high flow events when background levels of sediment in receiving waters would be elevated	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C7	AWRC site, pipelines and access roads: • Compaction, concreting and installation of impervious surfaces and pavements	• Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts	Impact significance low without mitigation: • Any impacts would be localised and temporary in nature	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C8	AWRC site, pipelines and access roads:	• Changes in volumes and rates of flow to the receiving creeks	• Different stormwater management and retention devices have been proposed and sized so discharges to waterways contribute to regional water quality objectives for	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
	• Compaction, concreting and installation of impervious surfaces and pavements	• Worsening flood conditions (flow rates) downstream of the site	Wianamatta-South Creek. Detailed approach is presented in **Appendix A.** • On-site stormwater detention system has been proposed and assessed to ensure post-development peak flows do not exceed pre-development peak flows. Detailed approach is presented in **Appendix B**.	Magnitude of impact: Low (unlikely to occur)
C9	AWRC site: • Compaction, concreting and installation of impervious surfaces and pavements	• Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing	• Develop and implement an erosion and sediment control plan which would include harvesting runoff from construction works and the transition of sedimentation basins to permanent WSUD elements after practical completion of the AWRC facility	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C10	AWRC site and pipelines: Leaks/spills: Spills of chemicals, heavy metals, oils, and petroleum hydrocarbons during the use and operation of machinery • Storage, transport, use and handling of chemicals	• Potential to introduce surface contaminants to surface water runoff and impact the quality of surrounding surface waters through stormwater discharge and plant wash down routines • Acute impacts to ecosystems receiving surface water run-off; in particular, the discharge location to South Creek • Leakage from construction worker ablution and toilet facilities or wastewater	• Prepare and implement site specific Environmental Management Plans • Groundwater quality samples from the piezometers should be collected during the recommended field investigations to determine the required engineering controls. • Incorporate the proposed first flush system, which would incorporate trickle release back into the treatment plant • Develop a spill response procedure • Spill kits to be maintained in appropriate locations in accordance with Australian Standards, including where required inside machinery and vehicles. • Conduct refuelling, fuel decanting and vehicle maintenance in compounds where possible. If field refuelling is necessary, designate an area away from waterways and drainage lines with functioning spill kits close by. • All vehicles, plant and equipment to be checked regularly for fuel tank and line leaks or failures	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
		collection points with subsequent runoff into receiving watercourses	• Bunds and sumps should be regularly inspected, and capacity maintained by regular draining and disposal • Contractors must complete pre-mobilisation and post-demobilisation soil sampling on compound sites to confirm no residual impacts.	
C11	AWRC site: • Water demand and sourcing	• Impact on regional and and/or local water resources	• Strategy for water supply to be developed during detailed design and in consultation with Sydney Water • It is envisaged that within the construction impact zone, temporary basins would be constructed, and existing on-site dams would be repurposed, to catch any runoff for reuse in the bulk earthworks. See Section 7.2.2	Significance: Negligible Sensitivity of environmental values: Low (external sourcing) Magnitude of impact: Low (no expected change)
C12	Pipelines: • Trenching / Direct disturbance of watercourse bed and / or banks	• Temporary obstruction and interference with normal drainage channels and subsequent ponding or damming of water upstream	• For in-stream works: – analyse usual discharge patterns to schedule works at appropriate times – keep materials, plant, equipment and stockpiles outside of drainage lines and flood risk • Incorporate contingency measures to ensure any significant discharge via the channel can safely be diverted around the works zone	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C13		• Obstruction of surface drainage from the contributory sub-catchments leading to unnatural dried channels downstream, if conducting works during periods when surface flow would usually be occurring		Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C14		• Increases in sedimentation directly upstream from in-channel works as a result		Significance: Low Sensitivity of environmental values: Moderate (existing local impacts)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
		of ponding and associated decreases in flow velocity		Magnitude of impact: Low (unlikely to occur)
C15		• Removal of riparian vegetation and topsoil during construction causing risk of erosion during subsequent revegetation and establishment	• Minimise removal riparian vegetation and top soil • Recreate pre-construction bed and bank conditions once pipeline is installed • Develop and implement of an erosion and sediment control plan in accordance with Managing Urban Stormwater: Soils and Construction. which may include: – Resealing or revegetating surfaces as soon as applicable – Using geofabric on exposed surfaces • Apply long term channel stabilisation methods	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, unlikely to occur)
C16		• Deterioration in visual water quality due to trapping of coarse litter upstream from crossings	Impact significance low without mitigation: • Coarse litter being transported via the waterways would only temporarily accumulate, as is the case for the current ponding systems during the dry season	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
C17	Pipelines: • HDD and micro tunnelling	• Fluid loss during any drilling required for installation of the pipelines (uncontrolled release of drilling fluid escaping from the borehole through fissures or weakness in the substrate resulting in increased sedimentation and turbidity in watercourses)	• Prepare Drilling Fluid Management plan to avoid impacts, including: – contain and monitor drilling fluids at entry/exit points – identify and manage frac-outs • re-use and/or dispose of drilling fluids appropriately	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
		• Discharge of contaminated hydrostatic test water		
C18	Pipelines: • Horizonal directional drilling under a watercourse	• Disruption of surface water and groundwater connectivity	Impact significance low without mitigation: • Any disruption in connectivity would be very localized	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change)

Table 8-4 Potential project specific mitigation measures (Operational phase)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
O1	AWRC site discharge location to South Creek: • Increased imperviousness across the site associated with compaction, concreting and installation of pavements	• Increased stormwater runoff from buildings, roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen) to Wianamatta-South Creek	• A range of stormwater management and retention devices would be included to manage stormwater in a way that contributes to regional water quality objectives (water quality) for Wianamatta-South Creek. • The detailed approach is presented in **Section 7.1.2.2**. Results indicate that stormwater discharge works towards achieving water quality objectives by discharging at concentrations below the ambient water quality targets for up to 90% of the time.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
O2		• Increased stormwater runoff from buildings, roads and exposed surfaces contributing to altered low flows and baseflow to Wianamatta-South Creek	• A range of stormwater retention and detention elements would be included in the stormwater drainage network to – Limit the volume of stormwater discharged from the AWRC and therefore limiting the duration of potentially erosive forces imparted on the creek channels – Preserve frequent flows discharged from the AWRC as far as is practicable to achieve the Wianamatta South Creek water quality objectives (flow) which have been specified to limit erosion in the downstream waterway • Demonstration of an approach is presented in **Section 7.1.2.2**	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
O3		• Worsening of existing flood conditions (flow rates downstream of the ARWC site • Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site	• On-site stormwater detention basins may be incorporated into the site design. A demonstration of how OSD can support reference design is provided which shows pre-development peak flows can be preserved if required by the Western Sydney Aerotropolis Development Control Plans. Detailed modelling is presented in **Appendix B**. • Protection measures included into the Project reference design work towards the protection of the pipelines under a cumulative development scenario through the following:	Significance: Low Sensitivity of environmental values: Moderate (significant infrastructure) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
			– Preserving the peak flow discharge from the site under the critical 50% and 1% AEP storm events to ensure no increase in the magnitude of erosive forces – Limiting the volume of stormwater discharged from the AWRC and therefore limiting the duration of potentially erosive forces imparted on the creek channels • Preserving frequent low flows discharged from the AWRC as far as is practicable to achieve the Wianamatta South Creek water quality objectives (flow) which have been specified to limit erosion in the downstream waterway	
O4	Discharge structure and access roads Warragamba and Nepean Rivers: • Increased imperviousness associated with discharge structures, compaction, concreting and installation of pavements	• Increased stormwater runoff from access roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen) to Warragamba and Nepean Rivers	Impact significance low without mitigation: Small incremental increase in runoff volumes and nitrogen and phosphorous loads associated with the relatively minor increases in impervious areas within the Warragamba Valley catchment. Low traffic movements on access roads presents low risk of sediment pollutants being generated	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (minimal change)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
O5	AWRC discharge location to South Creek: • Moving and storing untreated and partially treated wastewater throughout the plant	• Spilling or discharging untreated or partially treated wastewater to the local watercourses	• Regular maintenance checks • Implement a spill response plan and plant shutdown plan	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
O6	Treated water pipeline in Wianamatta-South Creek • Pipe leaks or bursts	• Incidental discharge of highly treated water to waterways which could increase turbidity, lead to local scouring, impact the local and downstream geomorphology	Impact significance low without mitigation: Local discharges would be temporary and the water quality acceptable for discharge Sydney Water designs its pipelines to a high standard to minimise the risk of leaks. Sydney Water's standard procedures include regular inspections and incident response procedures would also manage this potential risk and impact.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change)
O7	Treated water pipeline in Wianamatta-South Creek • Uncontained pipe scouring during maintenance periods	• Discharge of highly treated water to waterways during maintenance which could increase turbidity, lead to local scouring, impact the local and downstream geomorphology	Impact significance low without mitigation: During pipe cleaning activities (e.g. flushing, swabbing & scouring) water may be discharged from the Treated and Environmental Flows pipelines. This water would be of high quality and unlikely to cause significant impacts. Procedures, as prescribed in Sydney Water's Discharge Protocols Standard Operating Procedure (WPIMS5021), would be followed ensuring potential localised impacts are managed and mitigated.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary and local, minimal change)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
O8	Brine pipeline: • Pipe leaks or bursts	• Incidental discharges from the brine pipeline could impact water quality in freshwater creeks	Impact significance low without mitigation: Sydney Water designs its pipelines to a high standard to minimise the risk of leaks. Sydney Water's standard procedures include regular inspections and incident response procedures would also manage this potential risk and impact.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (temporary, local, unlikely to occur)
O9	Brine pipeline: • Scouring of pipes	• Discharge of brine water to waterways during maintenance which could impact water quality, increase turbidity, lead to local scouring, impact the local and downstream geomorphology	• Any brine discharged during scouring activities on the brine pipeline would be collected and disposed of at an appropriate facility	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)
O10	AWRC site and pipelines: Leaks/spills: Spills of chemicals, heavy metals, oils, and petroleum hydrocarbons during the use and operation of machinery • Storage, transport, use and handling of chemicals	• Potential to introduce surface contaminants to surface water runoff and impact the quality of surrounding surface waters through stormwater discharge and plant wash down routines	• Prepare an Incident Management Plan (IMP) outlining actions and responsibilities during: – predicted/onset of heavy rain during works – spills – unexpected finds (e.g. heritage and contamination) – other potential incidents relevant to the scope of works. – All site personnel must be inducted into the IMP. – Immediately notify the Project Manager, Community Relations Representative (Delivery Management) and Environmental Representative (Delivery Management) of any complaints. • To ensure compliance with legislative requirements for incident management (e.g. Protection of the Environment Operations Act 1997), Sydney Water's employees and contractors would follow SWEMS0009. Attach SWEMS0009 to the CEMP. Chemicals used during AWRC operation would	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
			be handled and stored within a bunded area and with a first flush capture system in place to capture and treat first flush (10 mm) of rainfall across the AWRC site which is likely to contain hydrocarbons, chemicals, dissolved and particulate-bound nutrients. • A Spill Response Procedure would be developed including: – Training and PPE – Precautionary measures for handling and storage of chemicals and fuels – Spill response protocols (control, contain, clean up) – Contaminated soils to be disposed of appropriately – All spills to be reported – Spill kits to be restocked following use – Spill kits to be maintained in appropriate locations in accordance with Australian Standards, including where required inside machinery and vehicles. – All vehicles, plant and equipment to be checked regularly for fuel tank and line leaks or failures • The first flush facilities, bunds and sumps should be regularly inspected, and capacity maintained by regular draining and disposal	
O11	AWRC site discharge location to South Creek: • Discharge of wastewater and stormwater associated with wet weather overflows	• Changes in surface flow rates associated with wastewater discharges to waterways during high flow bypasses, plant shut down and wet weather discharges • Increase in flood flows due to wastewater discharges associated with high flow	Impact significance low without mitigation: Excess flows relate to stormwater being conveyed via the sewage system and as such would not add to the total volume being discharged to the environment when considering the entire catchment. Being conveyed via the pipe network may lead to the water volumes arriving at the proposed discharge location a little sooner than via the natural watercourses.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (moderate cumulative impact)

Item Nr	Project location/Activity	Potential Impact	Mitigation measure	Impact significance following mitigation
		bypasses, plant shut down and wet weather discharges • Increased erosion risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site	The expected maximum volumes are significantly smaller than the total storm peak discharge volumes expected to be conveyed within Wianamatta-South Creek during these major wet events.	
O12	Photovoltaic cells on AWRC site: • Installation of photovoltaic cells	• Worsening of existing flood conditions (flow rates) downstream of the site • Increased risk to the WaterNSW Pipeline (known as the Warragamba Pipeline) crossing South Creek approximately 2.7 km downstream of the site • Increased stormwater runoff from access roads and exposed surfaces generating increased loading of total suspended solids and nutrients (phosphorous and nitrogen)	Impact significance low without mitigation: Small incremental increase in runoff volumes and nitrogen and phosphorous loads associated with photovoltaic cells. The relatively minor increases in effective imperviousness of the photovoltaic cells and associated grassed swales would mitigate runoff impacts on Wianamatta-South Creek and Kemps Creek. No measurable increase in peak runoff volumes.	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (minimal change)
O13	• AWRC site: Harvesting of stormwater and irrigation application of adjacent regional park	• Increased groundwater recharge leading to localised raising of aquifer water levels • Mobilisation of inherent soil salinity and increased load discharged to local water resources	• Controlling the irrigation rate to ensure the landscape water balance deficit is replenished and no significant change deep drainage occurs	Significance: Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (minimal change)

8.3 Cumulative impacts

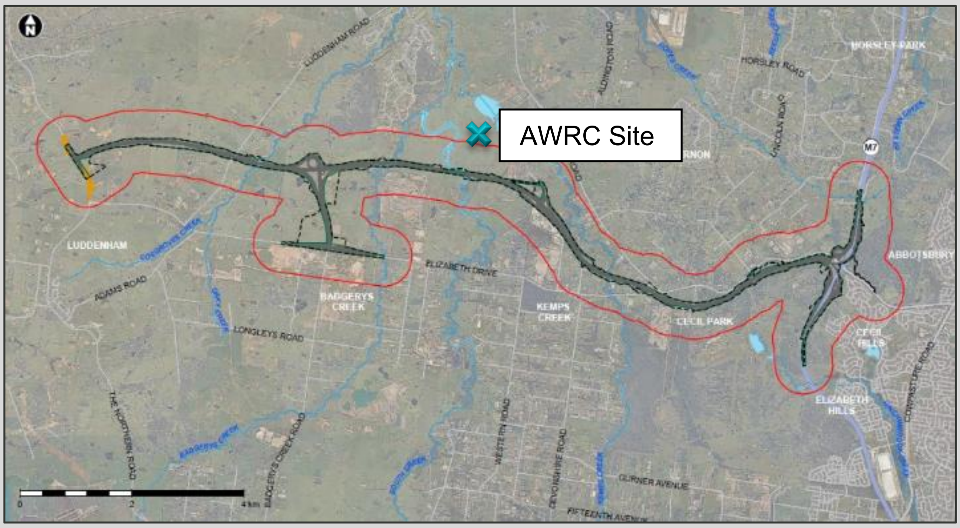
The Western Sydney Aerotropolis is being rezoned as a major growth and urban centre. This growth is the primary driver for the development of the AWRC project.

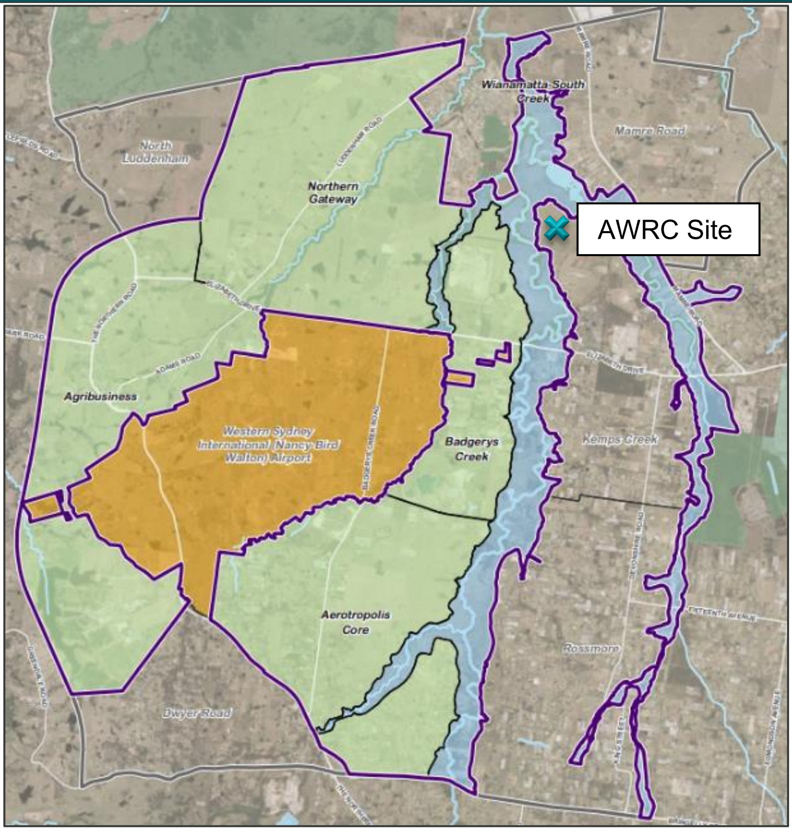
When considered in isolation, any identified project impacts may be considered minor. These minor impacts may, however, be compounded, when the cumulative impacts of the proposed urban growth on waterways. As such, the surface water quality and hydrology impacts identified and listed in **Section 8.1** and **8.2** need to be considered in terms of cumulative impacts. The waterway health objectives and flood management objectives adopted for the reference design address the cumulative impacts of development. Where all development provides surface water management measures to achieve or work towards the surface water objectives, then there will be an acceptable impact on waterways and downstream infrastructure.

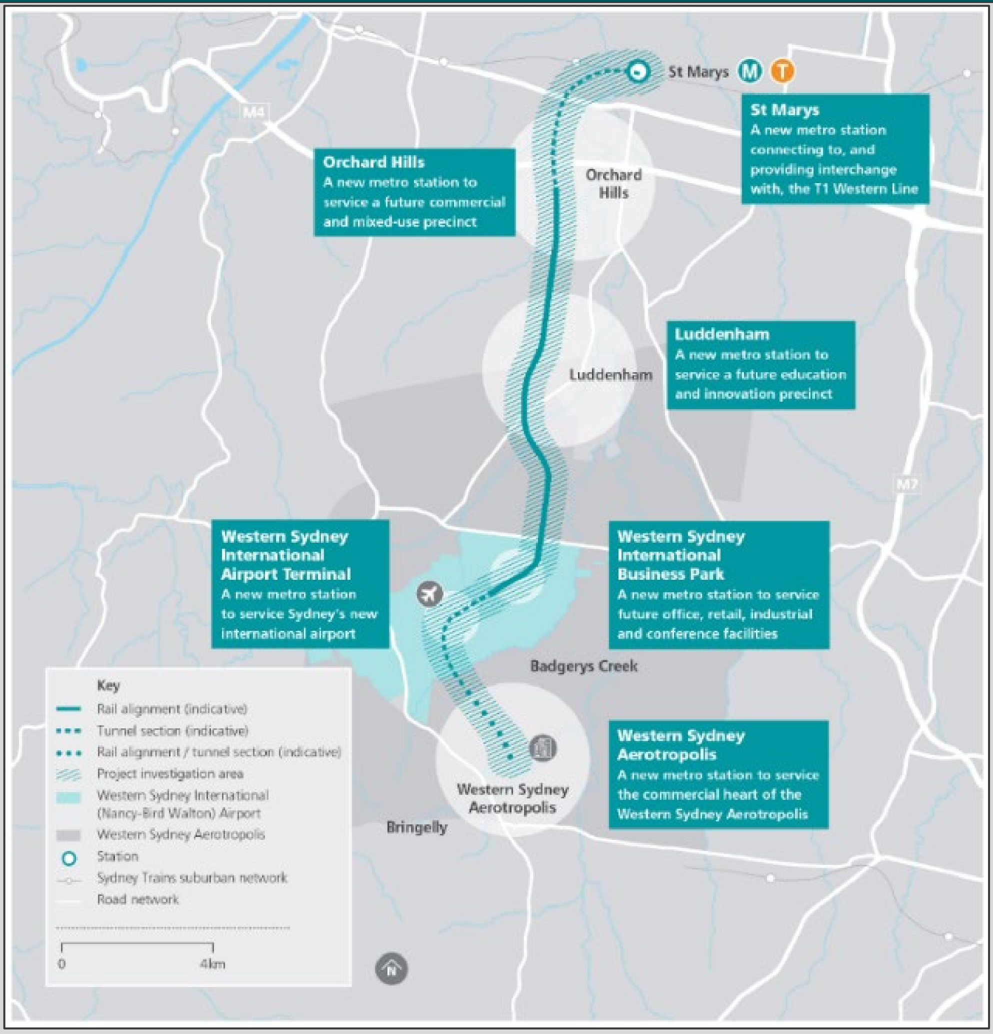
The major projects currently being proposed within close proximity to the study areas are indicated in **Table 8-5**.

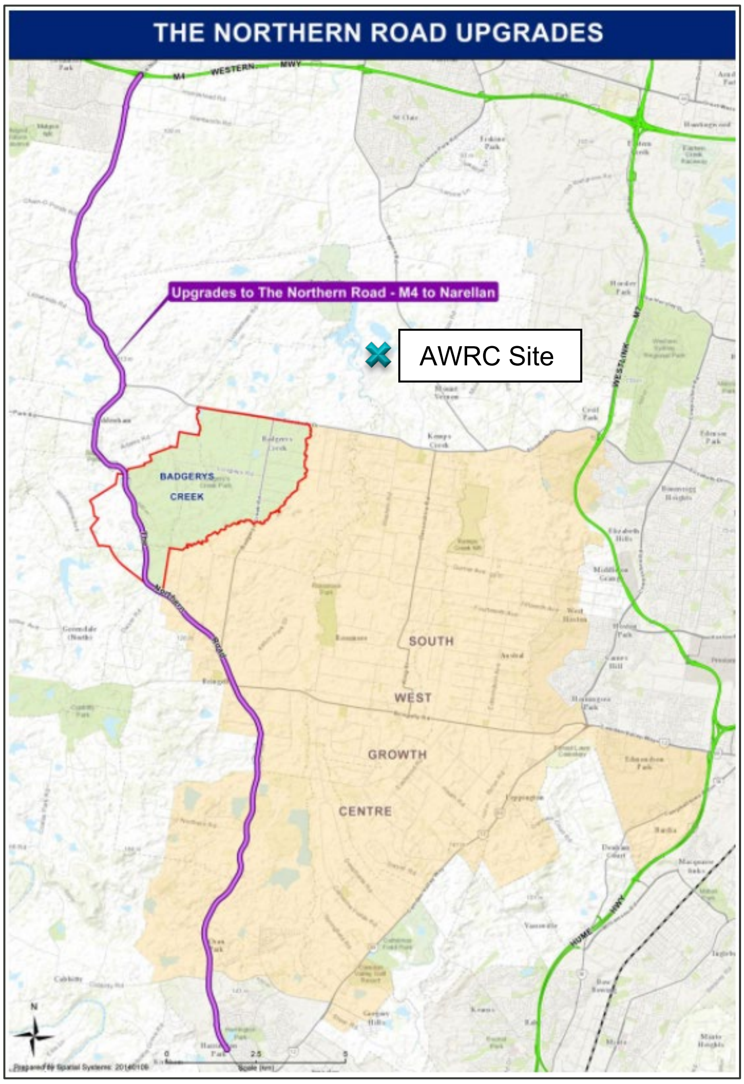
Table 8-5 Proposed major projects in close proximity to AWRC study areas

Project	Project description, relation to current proposed AWRC project and expected residual impacts
Western Sydney Airport	The proposed Western Sydney Airport site will be located approximately 3.2 km south-west of the AWRC site, south of Elizabeth Drive. The site is primarily drained by Badgerys Creek and Cosgroves Creek. Construction at the Western Sydney Airport site has already commenced. The Western Sydney Airport EIS surface water quality assessment (GHD, 2016) and surface water hydrology and geomorphology assessment (GHD, 2016b) concluded that: • With the implementation of a SWMP and CEMP construction is unlikely to have a significant impact on downstream water quality and that any potential impacts are likely to be localised and short term • Upon completion of construction, water quality discharged from the airport site to the downstream waterways is expected to improve compared to existing conditions for TSS, TN and TP • The proposed detention basin strategy would be effective at limiting the downstream impacts such that any increases in flood level would not worsen flooding to surrounding roads and dwellings, and the risks to changes in creek geomorphology would be low • Minor changes in water level is predicted immediately downstream of the airport site • There would be an increase in impervious surfaces and therefore increased pollutants (suspended and dissolved solids, nutrients, gross pollutants, heavy metals and total petroleum hydrocarbons) and litter entering downstream waterways Any elevated pollutant concentration transported downstream by Badgerys Creek will discharge to South Creek downstream of the AWRC site. Any increase in stormwater pollution originating from the AWRC site or the waterways being crossed downstream of the airport site will add to these impacts.

Project	Project description, relation to current proposed AWRC project and expected residual impacts
M12 Motorway	The proposed M12 Motorway will run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 kilometres and would be opened to traffic prior to opening of the Western Sydney Airport. The AWRC site itself is located within the extents of the M12 surface and hydrology study area. The discharge pipelines will follow a similar alignment to the M12 along portions of their routes.  Erosion and sedimentation is expected during construction of the M12 Motorway, with sediment basins located to best capture runoff before it enters the waterway. Whilst increased runoff is expected to occur during operation of the Project the associated pollutants transported in runoff are expected to decrease with the implementation of appropriate water quality controls identified in the EIS (RMS, 2019). Therefore, it is expected that there would be minor cumulative water quality and hydrological impacts associated with the construction and operation of the Project and the M12 Motorway.
Aerotropolis initial precincts	The Western Sydney Planning Partnership (WSPP) has identified several precincts as priority precincts which will be targeted for rezoning in late 2020. These precincts all directly border the Western Sydney Airport site, they include: the Aerotropolis Core, Badgerys Creek, Northern Gateway, Agribusiness and adjoining areas of Wianamatta-South Creek as indicated below. These precincts are primarily located within the South Creek catchment as the discharge pipelines will transect several of them.

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 An integrated water management plan targeting these precincts is currently being developed. The purpose of the plan is to identify measures and control mechanisms to ensure sustainable water management practices are established and consequently mitigate the cumulative hydrological and geomorphological impacts that the rapid urbanisation may lead to.
Sydney Metro – Western Sydney Airport	The proposed new railway will link St Marys to the new airport and the Western Sydney Aerotropolis, alignment indicated below (Sydney Metro, 2020a).

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 The Project footprint is primarily located within the South Creek catchment (or its tributaries). The scoping document reiterates the degraded water quality within the area and references a water management system associated with the Western Sydney International Stage 1 which is expected to effectively mitigate potential flooding and water quality impacts. The EIS (Sydney Metro, 2020b) was published in October 2020, indicating that the potential impacts from the operation of the project may further degrade the water quality if not properly managed, as well as the potential for minor but localised changes to the catchment and watercourse health. Several mitigation measures, such as the incorporation of operational detention basins (designed to Penrith Council requirements), and WSUD features at stations to treat stormwater runoff, will be incorporated to mitigate impacts and achieve the stated project performance outcomes.
The Northern Road Upgrade – Glenmore Road to Bringelly	The Project will upgrade around 35 kilometres of The Northern Road between The Old Northern Road at Narellan and Jamison Road at South Penrith. The Project will see The Northern Road upgraded to a minimum four-lane divided road, and up to an eight-lane divided road with dedicated bus lanes. The treated water pipeline will run alongside the Northern Road for a stretch of approximately 1.4 km. Construction works within this area could likely overlap. The road upgrades will likely result in increased local impervious areas, subsequently

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	leading to higher peak runoff rates. As the pipeline is expected to be below ground in this section, there are limited impacts expected post-construction and thus cumulative impacts should be negligible. 
Warragamba Dam Raising	Warragamba Dam Raising is a project to provide temporary storage capacity for large inflow events into Lake Burragorang to facilitate downstream flood mitigation and includes infrastructure to enable environmental flows. The EIS for this project is still being developed and thus potential impacts have not been assessed and published as yet. Cumulative impacts are expected to be minimal as the dam is located upstream of the environmental flows discharge location, and the raising is aimed at storing major flood events rather than retaining more water on a regular basis. The potential changes in flow regime which will likely result from the Warragamba wall raising may have broader implications for how the AWRC will need to be operated (specifically in relation to the discharge regime to the Warragamba River. These considerations are addressed in the *Ecohydraulic and Geomorphology Impact Assessment* report.

These proposed major projects, along with the general expected future urban development in the area, have the potential to increase flood impacts, alter current watercourse geomorphology and exacerbate any impacts arising from the construction and operation of the AWRC and the discharge pipelines.

Generally major projects are designed and delivered in accordance with current environmental legislation and incorporate sufficient control measures to mitigate associated impacts. Given the widespread expected urbanisation of the local environment, which would also include numerous small-scale developments, the cumulative impacts from these smaller developments could become a more likely source of cumulative impacts.

As the Project is not expected to generate significant water quality or hydrological impacts during construction or operation, if the proposed mitigation measures are incorporated, the Project would have a minor contribution to any foreseen cumulative surface water quality and hydrological impacts associated with the Project and other identified projects in the vicinity.

9 Monitoring requirements

The application of a water quality monitoring program is important in ensuring construction and operational phase mitigation measures are effective, and contamination (untreated wastewater, fuels, chemicals, gross pollutants) levels within the whole drainage system and discharge locations do not exceed the appropriate trigger values.

Monitoring should incorporate pre-construction monitoring of water quality parameters to form a baseline dataset to which the construction and operational monitoring trigger values could be compared against.

As indicated in **Section 5.5.1** a baseline monitoring program has been established by Sydney Water with the aim of collecting baseline (pre-) and post-commissioning data to assess any changes in the aquatic environment resulting from the operation of the Upper South Creek AWRC.

Supplementary pre-construction baseline monitoring data could be considered at the three identified AWRC site drainage lines. The monitoring would be undertaken after periods of increased rainfall (i.e. >40mm in a 24-hr period).

Construction phase monitoring would be undertaken by the contractor and include all discharges of potentially sediment laden stormwater at the three identified site drainage lines as well as additional stormwater control facilities (e.g. sediment retention ponds) that drain directly to South or Kemps Creek or other waterways along the pipelines and discharge structures. The contractor is also responsible for regular inspection, monitoring and maintenance of erosion and sediment control structures (e.g. sediment fences) would be undertaken in accordance with the Blue Book and other Erosion and Sediment Control Plan guidance. In addition, the contractor would be responsible for inspections immediately prior to and following rainfall events and rectifications made as required.

10 Conclusion

The AWRC site and the majority of the effluent pipeline alignments are located in the Wianamatta-South Creek and Hawkesbury-Nepean catchments which have been extensively modified because of historical rural land uses.

An assessment of existing water quality data associated with the watercourses within the study area (including South Creek, Badgerys Creek, Oaky Creek, Cosgroves Creek, Kemps Creek and Hinchinbrook Creek) found that they exhibit poor water quality with elevated nutrient levels and low dissolved oxygen. Most of these watercourses currently do not meet the determined WQOs. Despite this, the Wianamatta-South Creek catchment retains pockets of remnant vegetation and habitats with high ecological value. The Wianamatta-South Creek and Hawkesbury Nepean Rivers also hold significant value for the community.

A section of the brine pipeline enters into the Georges River catchment which is also highly modified but also retains regionally significant waterway habitats.

Construction and operation of the proposed AWRC site and associated pipelines has the potential to impact the local surface water resources through:

- Discharge of sediment-laden stormwater to receiving waterways resulting in sedimentation within near site watercourses and habitat degradation
- Scouring and elevated bank erosion rates of the natural waterways as a result of increased volume / rate of channelised discharges to the environment
- Temporary obstruction and interference with normal drainage channels and subsequent ponding or damming of water upstream of watercourse crossing locations
- Increased loading of dissolved nutrients (nitrate / nitrite and phosphate) and particulate-bound nutrients (nitrogen and phosphorus) from exposed surfaces and stockpiled materials into adjacent watercourses from site runoff.
- Leaks / spills of chemicals, heavy metals, oils, and petroleum hydrocarbons during the use and operation of the machinery, resulting in acute impacts to the ecosystem receiving runoff
- Destruction of riparian vegetation and bank damage, leading to sediment loss into the adjacent channel
- Changes in peak runoff rates from the developed site area subsequently leading to risk of property damage (including critical state infrastructure, the Warragamba pipelines) or risk to human health and livelihoods

To minimise impacts to surface water quality and hydrology a range of measures would be implemented during the detailed design, construction and operational phases of the Project including:

- Acid Sulphate Soil Management Plan
- Dewatering Procedure
- Erosion and Sediment Control Plan
- Soil and Water Management Plan
- Soil Salinity Management

Expected residual impacts to the local waterways and alignment with the stated Waterway Objectives:

- Warragamba & Nepean Rivers: During construction the residual impacts would be minimal and stormwater management at the discharge locations and along the pipeline routes would be conducted in accordance with the *Managing Urban Stormwater, Soils and Construction* guidelines (the "Blue Book"). Operational impacts are associated with stormwater runoff from infrequently used, and short lengths of access roads as well as headwall structures. Stormwater impacts are negligible. Impacts from the discharge of treated water are addressed in the *Aquatic Ecology and Riparian Ecosystem Impact Assessment*, *Ecohydraulic and Geomorphology Impact Assessment* and the *Hydrodynamic and Water Quality Assessment*.
  - Wianamatta-South Creek and tributaries: During construction the residual impacts would be minimal and stormwater management at the AWRC site and along the pipeline routes would be conducted in accordance with the *Managing Urban Stormwater, Soils and Construction* guidelines (the "Blue Book"). As the pipelines would be underground, any residual operational impacts are expected to be negligible. The proposed WSUD measures would mitigate changes to low flow, peak flow and water quality at the AWRC site during the operational phase. Detailed modelling and assessment of the proposed management measures and infrastructure have indicated:
    - Council Stormwater Pollution Load reduction targets are achieved, and the stream erosion index is maintained below 3.5. The stormwater management approach performs significantly better than required by Council targets.
    - Stormwater pollution concentrations up to the 85%ile event are maintained below the waterway health (quality) objectives for ambient conditions and therefore contribute to these objectives being met over time. Recent monitoring data indicates water quality objectives are exceeded on a regular basis and thus the nett impact would likely be positive.
    - Waterway health (flow) objectives are maintained between the 'existing condition' and 'tipping point' for all numerical waterway flow objectives except for the cease to flow target. The discharge pattern is expected to contribute to local recharge of groundwater via the local channel which would have the effect of contributing to base flow and the 'cease to flow' target in downstream waterways.
    - The reference design demonstrates that sufficient OSD storage and control of flood discharges can be provided to ensure post-development peak flowrates do not exceed pre-development flowrates.
  - Georges River and tributaries: During construction the residual impacts would be minimal and stormwater management along the pipeline routes would be conducted in accordance with the *Managing Urban Stormwater, Soils and Construction* guidelines (the "Blue Book"). As the pipelines would be underground, any residual operational impacts are expected to be negligible.

Overall, with the implementation of the proposed mitigation measures included in the reference design, the Project is expected to have acceptable impacts on existing water quality and environmental values during both the construction and operation phases.

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Appendix A

Low Flow and Water Quality Modelling Report

August 2021

Upper South Creek Advanced Water Recycling Centre

Low Flow and Water Quality Assessment
FINAL rev2

Contents

Figures

Tables

1 Introduction

1.1 Study Background

Sydney Water is planning to build and operate new wastewater infrastructure to service the South West and Western Sydney Aerotropolis Growth Areas. The proposed development will include a wastewater treatment plant in Western Sydney, known as the Upper South Creek Advanced Water Recycling Centre (AWRC).

This report provides an assessment of low flows; stormwater runoff quality and flow rates resulting from frequent storm events up to and including the notional worst storm in six months. To inform the reference design, this report has undertaken a MUSIC - Model for Urban Stormwater Improvement Conceptualisation - modelling to test and size water sensitive urban design elements (WSUD).

The conventional approach required by Council is to achieve stormwater pollution reduction targets and stream erosion be treated at a single location at the end of the stormwater network rather than before it enters the stormwater network. However, this report approach is to also incorporation of at-source runoff control measures and stormwater reuse principles as a means to achieving South Creek waterway health objectives (flow and volume)

Models were developed to quantify stormwater runoff volumes, rates and quality from the AWRC site and estimating residual pollutant loads and runoff characteristics generated under existing and proposed development conditions. This allows for the testing of proposed WSUD mitigation measures and assessment against waterway health flow and water quality objectives established by the Department of Planning, Infrastructure and Environment for the Wianamatta-South Creek catchment.

The process for this MUSIC modelling assessment is outlined in below:

- Data gathering and meteorological template set up
- Catchment delineation and land use input
- Defining baseline hydrology
- Defining post development hydrology
- Model refinement using USIA metrics
- Impact assessment.

1.2 Study Objectives

The objective of this study is to inform the development of a reference design and complete an impact assessment of the proposed stormwater management features relative to surface water management objectives.

Water sensitive urban design approaches have been sized to achieve:

- Penrith City Council’s current stormwater development control plan targets for storm flows and stormwater pollution loads
- Wildlife Attraction Guidelines
- Wianamatta-South Creek waterway health water quality objectives
- Wianamatta-South Creek water stream flow objectives.

The draft layout plan is shown in **Figure 1-1** and includes the indicative layout of various WSUD measures.

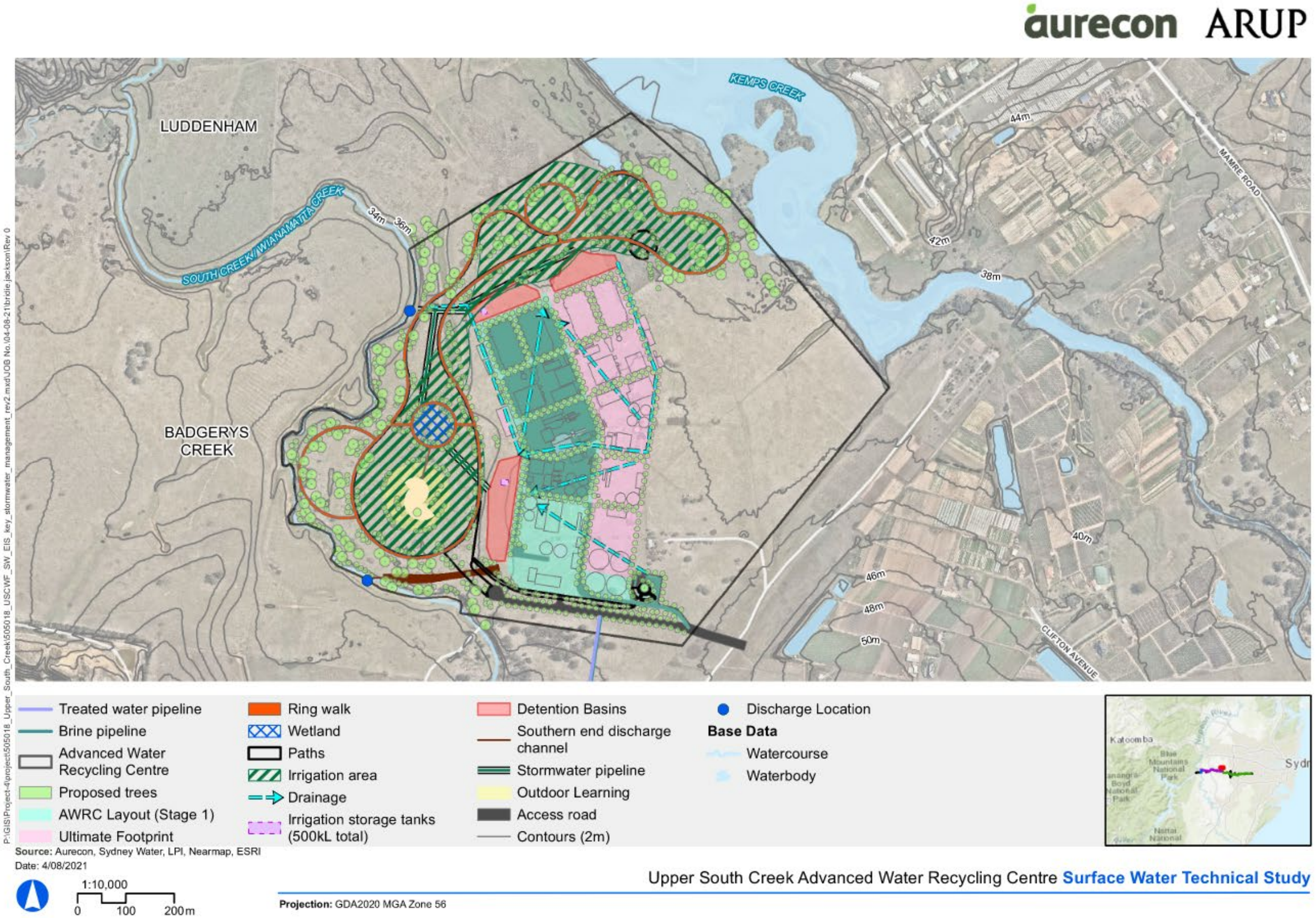


Figure 1-1 Site overview

2 Design Standards and Approach

2.1 Penrith City Council

2.1.1 Flood Flows

Peak stormwater flows for the management of storm flows contributing to flooding is described in **Appendix B** of this study.

2.1.2 Stormwater Pollution Load and Erosion Risk Reduction

Prior to being discharged into the local receiving waterway (South Creek), Penrith City Council requires the stormwater treatment targets specified in **Table 2-1** to be met. It is proposed to demonstrate compliance with these metrics, but it is also expected that lower stormwater pollution loads will be discharged to local waterways.

Table 2-1 Internal Stormwater Runoff Requirements

Authority	Reduction in the post development mean annual pollutant load and flow					
	Gross pollutants	Total Suspended solids	Total Phosphorus	Total Nitrogen	Free oils and Grease	Stream Erosion Index
Penrith Council	90%	85%	60%	45%	90% (no visible discharge)	SEI < 3.5

2.2 DPIE Waterway Health Objectives

The Department of Planning Infrastructure and Environment (DPIE) has applied the 'Risk-based Framework for considering waterway health outcomes in strategic land use planning decisions' to developing flow and water quality objectives that protect and improve Wianamatta-South Creek. These objectives were developed in October 2020 and have been incorporated into the Aerotropolis planning.

2.2.1 Flow Objectives

DPIE has used the relationship between stream flows and habitat indicators to establish several flow objectives that are critical for the protection or restoration of waterway health, ecology and biodiversity.

Flows from drainage areas with mixed land uses were considered the (tipping) point at which health, ecology and biodiversity of water dependent ecosystems declined. The flow characteristics for these waterways have been established as the waterway flow objectives for performance outcomes on third order waterways and greater. This includes the reach of Wianamatta-South Creek that is adjacent to the AWRC.

Table 2-2 Waterway Health (Flow) Requirements established by DPIE for the Western Sydney Planning Partnership Office

Flow Objectives	Baseline Hydrology (1st and 2nd Order Waterways)	Upper Limit of Changed Hydrology (3rd Order Waterways and Greater)
Median Daily Flow Volume (L/ha)	71.8 ± 22.0	1095.0 ± 157.3
Mean Daily Flow Volume (L/ha) Mean Annual Runoff Volume (ML/Ha/yr)	2351.1 ± 604.6 (0.9 ML/Ha/yr)	5542.2 ± 320.9 2.0 ML/Ha/yr
High Spell (L/ha) ≥ 90th Percentile Daily Flow Volume	2048.4 ± 739.2	10,091.7 ± 769.7
High Spell - Frequency (number/y) High Spell - Average Duration (days/y)	6.9 ± 0.4 6.1 ± 0.4	19.2 ± 1.0 2.2 ± 0.2
Freshes (L/ha) ≥ 75th and ≤ 90th Percentile Daily Flow Volume	327.1 to 2048.4	2642.9 to 10091.7
Freshes - Frequency (number/y) Freshes - Average Duration (days/y)	4.0 ± 0.9 38.2 ± 5.8	24.6 ± 0.7 2.5 ± 0.1
Cease to Flow (proportion of time/y)	0.34 ± 0.04	0.03 ± 0.007

Stormwater management on AWRC site must contribute towards the stream flow objectives by limiting stormwater flows from the site in accordance with the right most column of Table 1-2 above.

The following sections provides an overview of each of these metrics.

2.2.2 Water Quality Objectives

Water quality objectives have been established by DPIE to achieve the vision for the Western Parkland City by applying the Risk Based Framework. The criteria were determined from a reference site within the Little Creek Tributary. Dissolved fractions of nitrogen and phosphorus (DIN, DIP) are recommended rather than totals (TN, TP).

Table 2-3 Wianamatta-South Creek water quality objectives: Ambient water quality

Water Quality Variable	Unit	Performance Criteria
*Total Nitrogen (TN)	mg/L	1.72
Dissolved Inorganic Nitrogen (DIN)	mg/L	0.41
Ammonia (NH_3-N)	mg/L	0.08
Oxidised Nitrogen (NO_x)	mg/L	0.66
*Total Phosphorus (TP)	mg/L	0.14
Dissolved Inorganic Phosphorus (DIP)	mg/L	0.03

Water Quality Variable	Unit	Performance Criteria
Turbidity (NTU)		50
Total Suspended Solids (TSS)	mg/L	30
Conductivity	µS/cm	1103
pH		6.2 – 7.6
Dissolved Oxygen (DO)	%SAT	43-75
Dissolved Oxygen (DO)	mg/L	8

* when showing compliance towards TN and TP through industry models, the DIN and DIP performance criteria should be instead to recognise that stormwater discharges of nutrients are mostly in dissolved form

2.2.3 Western Sydney Aerotropolis Wildlife Management

The site lies within close proximity to the Western Sydney Airport as shown in **Figure 2-1**. The Western Sydney Aerotropolis Wildlife Management Report identifies potential wildlife attraction risks and mitigation measures for stormwater management measures (Avisure, 2020). The summary of identified risks and suggested mitigation measures for proposed WSUD is summarised in **Table 2-4.** The guidance provided in this report may be applied to site design.

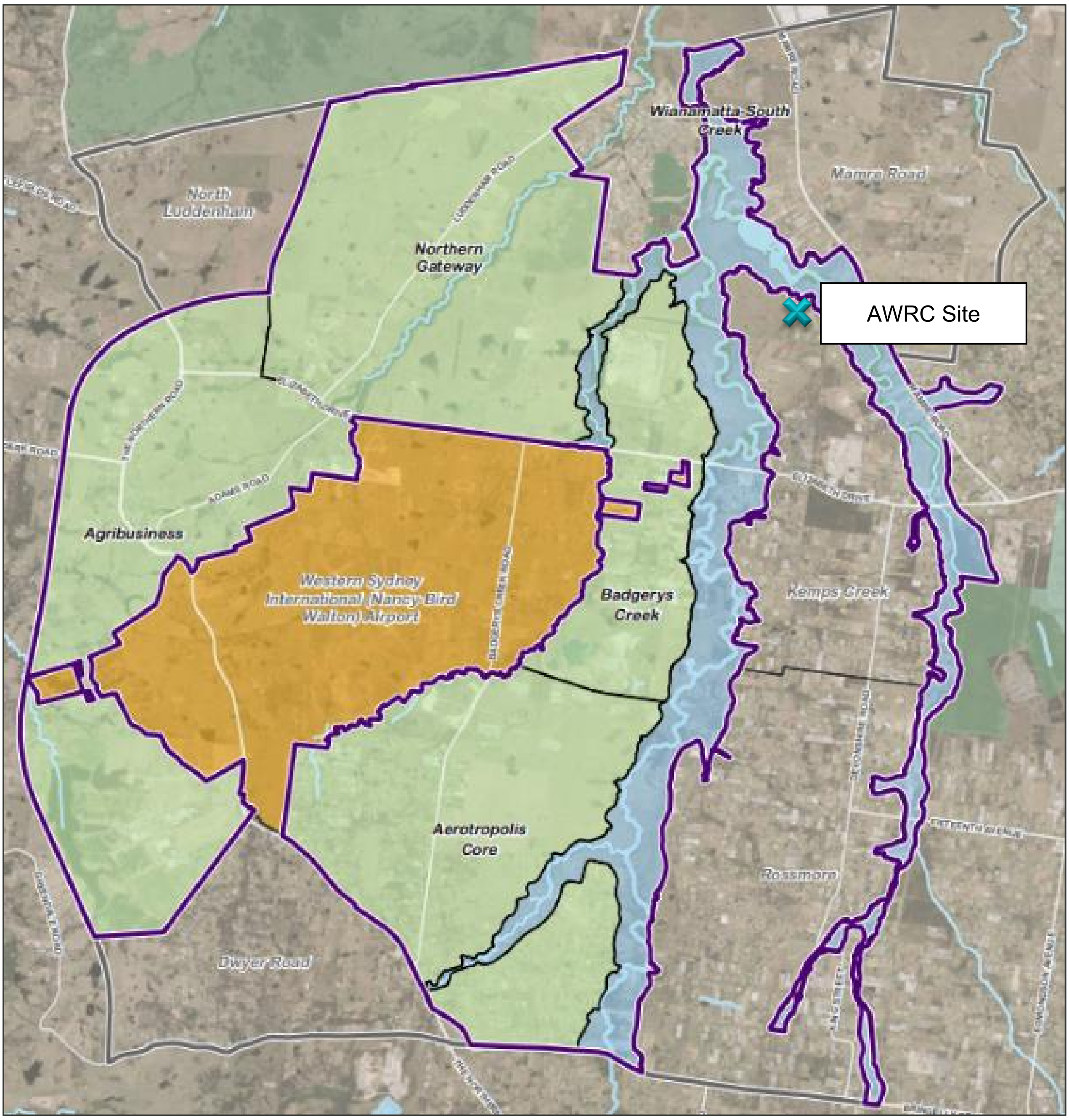


Figure 2-1 Aerotropolis precincts and Western Sydney Airport location

Table 2-4 Proposed WSUD risks to wildlife attraction and mitigation measures (Avisure, 2020)

WSUD measure	Risk	Mitigation measure
Detention basin and biofiltration	Detention basins can attract significant numbers of wildlife	• Detention areas will hold water temporarily and fully drain within 24-48 hours • Biofiltration basins will contain 300mm to 600mm high vegetation
Biofiltration street trees	offer feeding, sheltering, roosting, and nesting opportunities	• Will hold water on the surface temporarily and fully drain within 24-48 hours • Maximum mature height of any tree: 10m • No more than 5 trees planted in any one group

WSUD measure	Risk	Mitigation measure
	Shrubs and trees that produce nectar, berries, fruit or seeds will attract birds and flying foxes.	• Minimum interval between tree groups is ideally 12.5m to achieve stormwater management. Low shrubs should be substituted where this cannot be achieved. • Trees may be staggered to improve spacing
Wetlands	Artificial wetlands can attract significant numbers of wildlife	• Water depth between 0.5m and 1.18m is less likely to attract hazardous flocking bird such as pelicans, swans, and cormorants; or upending ducks such as Pacific Black Ducks; or wading birds such as ibis and egrets • Wetland would be in the floodplain adjacent to existing water bodies and farm dams in the riparian corridor • Bank slopes approaching the wetland should not exceed 4V:1H. • Vertical sandstone blocks will form the wetland edge to a depth of 0.5m in permanent water • Open water zones should be limited to 100m^2 in surface area. Dense planning of macrophytes can break up open water into those zones • Total water surface area is 5,000m^2
Irrigated lands and grassed lined basins		• Stormwater and recycled water will be applied to landscape areas • Bank slopes for landscape zones, earthworks, detention areas and stormwater drains will not exceed 4V:1H to facilitate mowing • Dense zones of native sedges and grasses will be provided within steeper swale channels
Discharge channels		• Grassed bank slopes in stormwater drains will not exceed 4V:1H to facilitate mowing • Dense zones of native sedges and grasses will be provided within steeper channels

3 Low Flow Hydrologic Model Development

This section details the methodologies and assumptions adopted for low flow modelling that was undertaken to inform the reference design measures that would achieve the waterway health (flow and quality) objectives for Wianamatta-South Creek.

3.1 MUSIC Modelling

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a decision support tool for stormwater management. It helps with the planning and conceptual design of stormwater management systems. The software represents an accumulation of the best available knowledge and research on urban stormwater management in Australia. MUSIC is the preferred modelling tool for the assessment of water sensitive urban design strategies across Australia. It estimates stormwater flows and stormwater pollution generation and simulates the performance of single or multiple stormwater treatment measures that are typically connected in series to improve overall treatment performance. MUSIC estimates this performance over a continuous historical period rather than for discrete storm events. By simulating the performance of stormwater treatment measures, MUSIC is typically applied to evaluate whether a proposed treatment system conceptually would achieve stormwater flow and water quality targets (BMT WBM, 2015).

3.2 Rainfall and Evaporation Inputs

The Penrith City Council and the associated meteorological template from the *MUSIC link* configuration was used to demonstrate compliance against Council's stormwater pollution reduction targets. The rainfall and evaporation data include a record from 1999-2008, over which the mean annual rainfall is 691 mm and the mean annual evapotranspiration is 1158 mm (**Figure 3-1**).

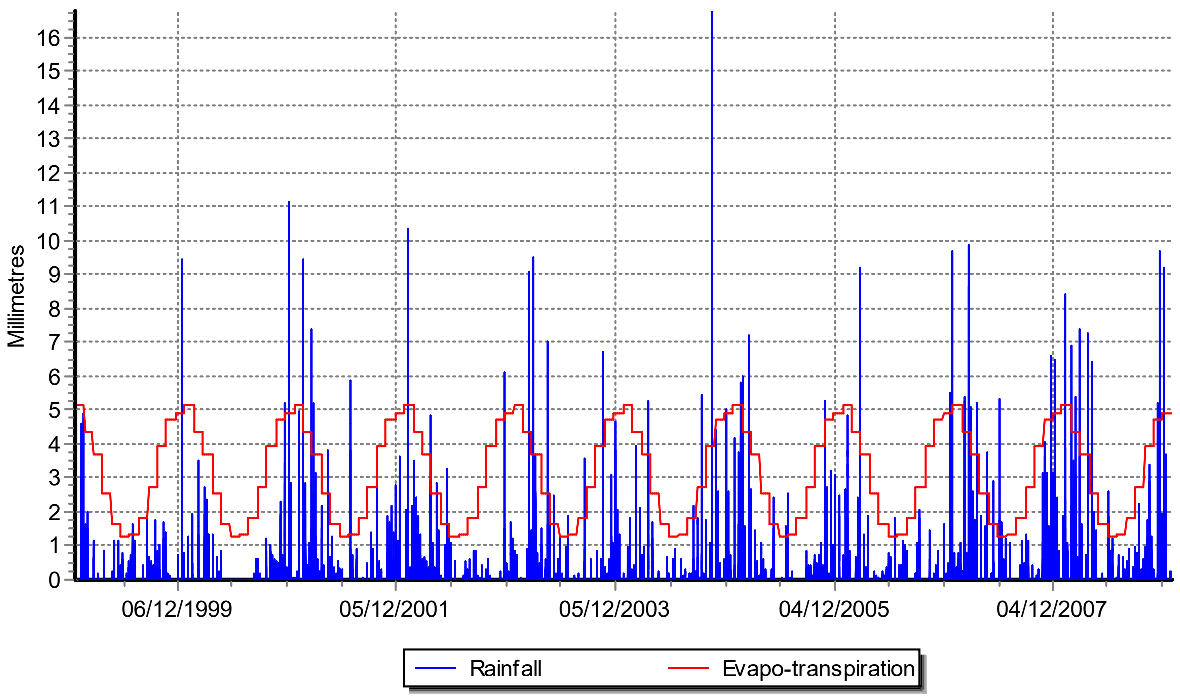


Figure 3-1 Rainfall and evapotranspiration time series incorporated into the MUSIC model

A second hydrologic time series was selected to refer to a longer period of stormwater modelling to demonstrate compliance against DPIE's waterway health objectives. The alternative meteorological rainfall and evaporation data includes a record from 1993-2017, over which the mean annual rainfall is 739 mm and the mean annual evapotranspiration is 1266 mm.

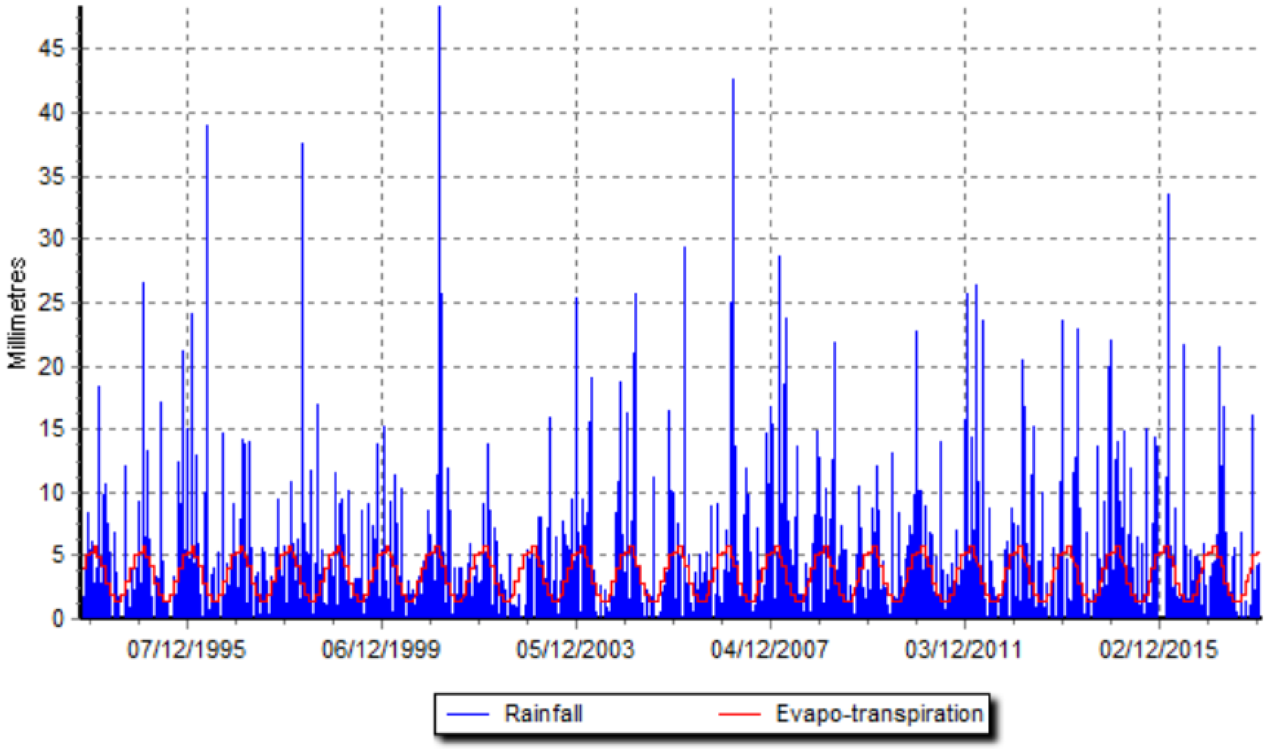


Figure 3-2 Rainfall and evapotranspiration time series incorporated into the MUSIC model

3.3 Catchment inputs

The reference design splits the site into two separate catchments, one draining north-west (North catchment) and the other directly west (South catchment), both into the Wianamatta-South Creek. The land use breakdown associated with these catchments for the Stage 1 and future stages of the development are indicated in **Table 3-1**. Total imperviousness rates have been adopted.

Stormwater quality parameters for each land use and the rainfall-runoff parameters for the AWRC site are adopted in MUSIC modelling are summarised in **Table** 3-2 and **Table 3-3**.

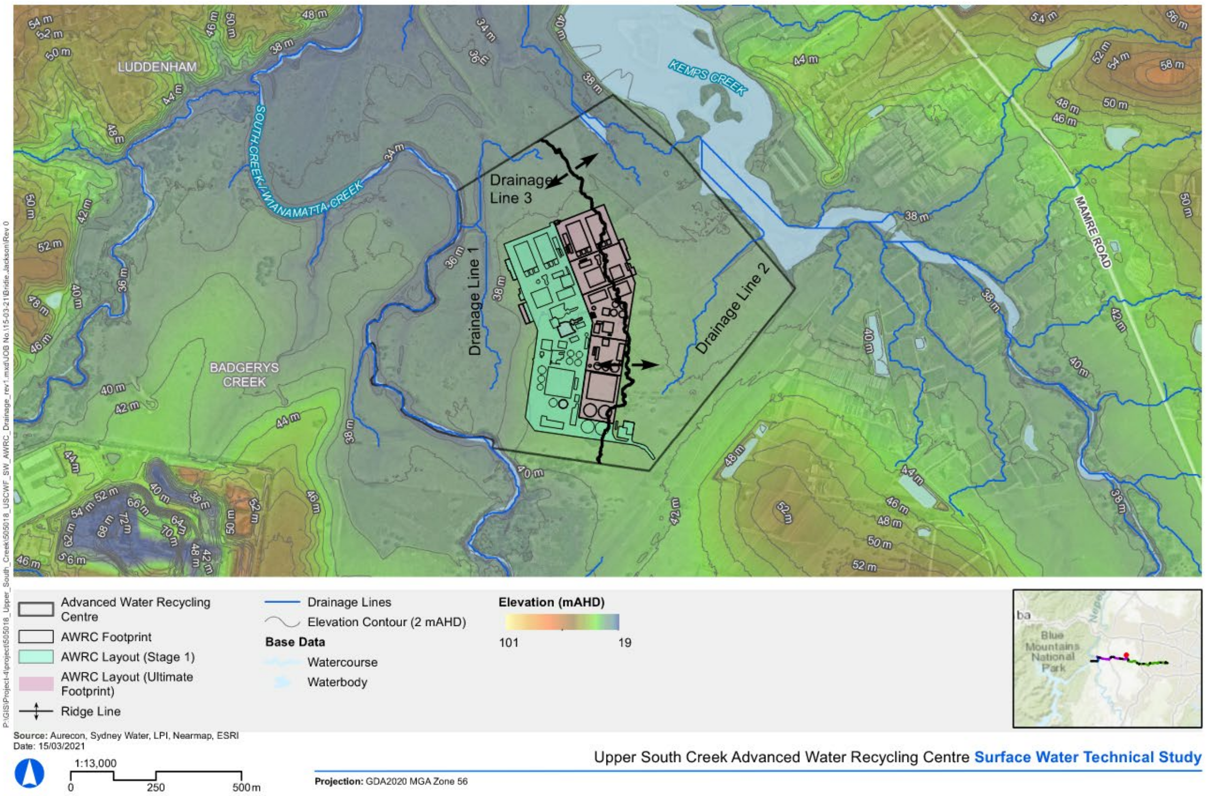


Figure 3-3 AWRC site current drainage showing Stage 1 and Ultimate Footprint

Table 3-1 Land use breakdown for the stage 1 and future stages of the AWRC site

Surface Area	North (ha)	South (ha)	Total (ha)
Stage 1 (50ML plant capacity)			
Total Area	5.88	6.63	12.51
Impervious Area	3.20 (54%)	4.185 (63%)	7.387 (59%)
Roads	1.036	1.113	2.149
Hardstand	0.84	1.067	1.908
Covered structure	1.326	2.005	3.331
Future Stages (100ML plant capacity)			
Total Area	6.49	3.27	9.76
Impervious Area	3.18ha (49%)	2.05ha (63%)	4.532 (54%)
Roads	0.835	0.435	1.27
Hardstand	1.001	0.494	1.495
Covered structure	1.341	1.124	1.341
Ultimate footprint			
Total Area	12.373	9.898	22.27

Surface Area	North (ha)	South (ha)	Total (ha)
Impervious Area	6.380 (52%)	6.237 (63%)	12.617 (57%)
Roads	1.871	1.548	3.419
Hardstand	1.842	1.561	3.402
Covered structure	2.667	3.128	5.795

Table 3-2 Stormwater quality parameters adopted for each land use (Source: MUSIC-link)

Land-use category		Log10 TSS (mg/L)		Log10 TP (mg/L)		Log10 TN (mg/L)	
		Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow
Road Areas	Mean Std Dev	2.43 0.32	---* ---*	-0.30 0.25	---* ---*	0.34 0.19	---* ---*
Roof Areas	Mean Std Dev	1.30 0.32	---* ---*	-0.89 0.25	---* ---*	0.30 0.19	---* ---*
Other (General urban, Residential, Industrial Commercial)	Mean Std Dev	2.15 0.32	1.20 0.17	-0.60 0.25	-0.85 0.19	0.30 0.19	0.11 0.12
*Base flows are only generated from pervious areas and are not applicable to the impervious surfaces							

Table 3-3 Adopted rainfall-runoff Parameters (Source: MUSIC-link)

Parameters	Value
Impervious area	
Rainfall Threshold (mm/day)	1.4
Pervious area properties	
Soil storage capacity (mm)	105
Initial storage capacity (% of capacity)	30
Field capacity (mm)	70
Infiltration Capacity Coefficient - a	150
Infiltration Capacity Exponent - b	3.5
Groundwater properties	
Initial Depth (mm)	10
Daily Recharge Rate	25
Daily baseflow Rate (%)	10
Daily Deep Seepage Rate (%)	0

3.4 Treatment measures

The various stormwater management and WSUD measures proposed as part of the reference design are modelled in eWater MUSIC software. This section gives a short overview of each measure and discusses the assumptions, parameters and values input to the model.

3.4.1 First Flush tanks

The initial runoff generated during storm events contains the highest concentration of pollutants and sediments. Capturing this runoff, makes a substantial contribution to ensuring the discharge from site meets all water quality trigger values and the impacts with regards to in-stream water qualities are mostly mitigated. The purpose of the first flush system is to capture this initial runoff and pump it to the wastewater treatment plant for the same treatment process as the wastewater entering the site via the trunk sewer mains.

Currently the proposed first flush systems have been sized to capture the first 10mm of runoff from the hardstand and road areas for the 100ML/day AWRC. Adopted parameters in the modelling of the first flush tanks are summarised in **Table 3-4**.

Table 3-4 Parameters adopted for the design of the first flush tank

Parameter	North	South	Total
Hardstand and road catchment area (ha)	3.71	3.11	3.42
First Flush Volume (m^3)	371	311	348
Drawdown / empty rate	3 days	3 days	3 days
Modelled tank extraction rate in MUSIC (kL/d)	123	103	116

3.4.2 Bioretention Basin

Bioretention basins are typically large vegetated sand filters to manage stormwater quality at the sub-catchment scale. The bioretention basins are a cost-effective method of achieving Council DCP. Biofiltration provides a combination of physical and biological transformation of stormwater pollutants by passing stormwater through 500m to 800mm of vertical sandy-loam filtration media under gravity. This provides a significant design constraint due to the required level change needed to drive the stormwater system.

Biofiltration also provides a means of pre-treating stormwater before collecting water in harvesting tanks or open water bodies. This step reduces nutrients and sediments and is an important step in algal risk management and low maintenance harvesting assets.

Bioretention basins are proposed at the outlet of the stormwater drainage network and within the proposed detention basins.

Figure 3-4, below, is a schematic of end-of-pipe biofiltration systems. The adopted parameters in the modelling of the end of pipe biofiltration is summarised in **Table 3-5**.

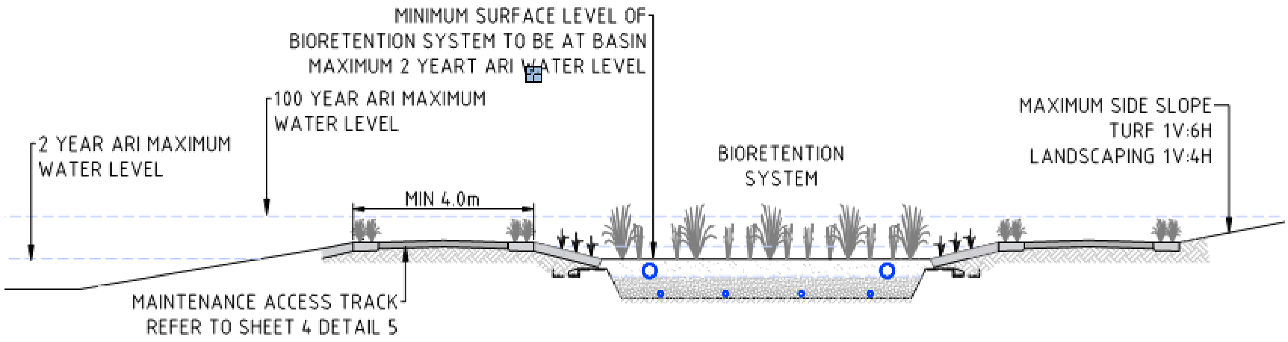


Figure 3-4 Schematic illustration of end of pipe biofiltration system (Source : Blacktown City Council)

Table 3-5 Adopted parameters for the bio retention for ultimate plant footprint

	Parameter	North	South	Description
Inlet properties	Low flow By-pass (m^3/s)	0	0	
	High Flow By-pass (m^3/s)	0.05	0.05	3-month ARI flow
Storage properties	Extended Detention Depth (m)	0.3	0.3	MUSIC-link 0.1-0.3
	Surface area (m^2)	600	850	Area 1.5% of the catchment draining to the treatment node-Concept design
	Extended detention volume (m^3)	180	255	
Filter and media properties	Filter area (m^2)	600	850	
	Unlined Filter media perimeter (m)	14	14	
	Saturated Hydraulic conductivity (mm/h)	125	125	MUSIC-link
	Filter Depth (m)	0.5	0.5	MUSIC-link 0.5-0.8
	TN content of filter Media (mg/kg)	800	800	MUSIC-link
	orthophosphate content of filter media (mg/kg)	40	40	MUSIC-link
Infiltration properties	Exfiltration Rate (mm/hr)	0.0	0.0	Biofiltration lined to avoid salinity risk
Outlet properties	Overflow weir width (m)	2	2	
	Underdrain present?	Y	Y	
	Submerged Zone with Carbon present?	N	N	
Advanced properties	PET scaling factor	2.1	2.1	
	Weir coefficient	1.7	1.7	
	Porosity of filter media	0.35	0.35	
	Porosity of submerged zone	0.35	0.35	

Parameter	North	South	Description
Saturated zone = 400mm to ensure water for plants during dry spells Maintenance provisions = 15m maximum width to allow an excavator to reach all areas Access provisions = 3m wide vehicle track on all sides			

3.4.3 Pond

Farm dams are a significant feature in the existing hydrologic landscape of the South Creek catchment that play a significant role in the storage, evaporation, infiltration of surface runoff. Retention of water bodies in the landscape is a low cost and low-tech way of preserving hydrologic conditions.

Pond and wetlands provide a means of slowly releasing stormwater over many days to match the baseline hydrologic discharges, namely the receding limb of stormwater hydrographs. The same cannot be achieved with bioretention basins. The adopted parameters to model the open water is presented in **Table 3-6**.

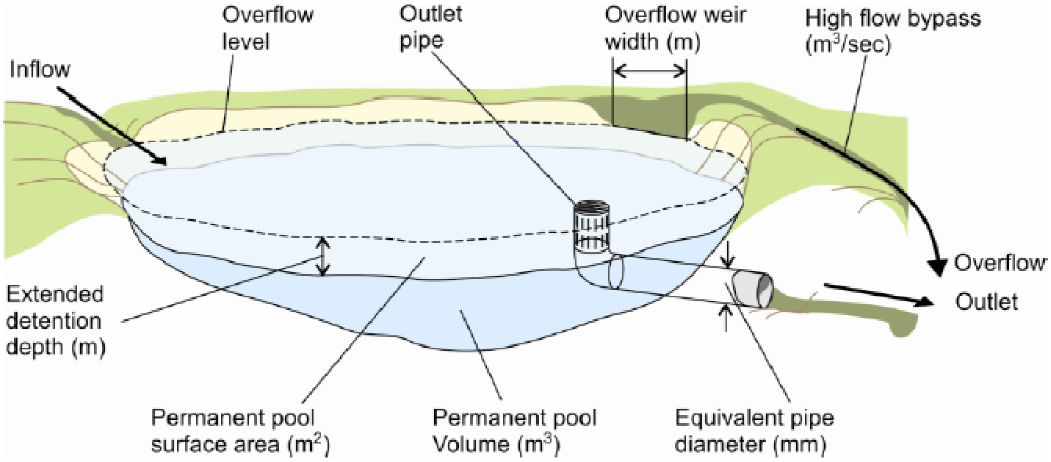


Figure 3-5 Schematic view of pond

Table 3-6 Adopted parameters for the design of the pond

Parameter		Value	Description
Inlet properties	Low flow By-pass (m^3/s)	0	
	High Flow By-pass (m^3/s)	0.05	
Storage properties	Surface area (m^2)	5000	
	Extended Detention Depth (m)	0.3	MUSIC-link (0.25-1)
	Permanent pool volume (m^3)	5000	Penrith technical guideline: (1-2) m permanent pool depth multiply by surface area
	Initial volume	0	
	Exfiltration rate (mm/hr)	0	
	Evaporative loss as % of PET	75	MUSIC-link
Outlet properties	Equivalent pipe diameter	37	Notional detention time = 10 days
	Overflow weir width	1	
Reuse	max Drawdown height (m)	1	

Parameter			Value	Description
	Annual demand	Demand(kL/day)	-	
		Distribution	-	
Advanced properties	Orifice discharge coefficient		0.6	MUSIC-link
	Equivalent residence time (days)		10	
	Event background concentration for Nitrogen		0.7	Recommended lower bound in MUSIC Manual, Appendix G
	Effective residence time (days)		20	
	Weir coefficient		1.7	MUSIC-link
Note: Parameters within the MUSIC model assume that stormwater is pre-treated to remove coarse sediment upstream of the pond, therefore ponds should never be designed without pre-treatment (such as a swale or sedimentation basin).				

3.4.4 Streetscape Biofiltration Tree Pits

Regularly spaced biofiltration street tree pits provide an opportunity to reduce stormwater volumes and provide local microclimate benefits as well as contributing to visual impact of the AWRC site (Cooperative Research Centre for Water Sensitive Cities, 2020).

While the trees provide multiple benefits, the location of the trees and extent of root zones must be carefully considered to avoid impacts on site movements, operations and services. It is possible to substitute street trees for lower shrubs with some reduction in water evaporation.

Water usage rates quoted for street trees are significantly higher than shrubs due to their leaf area, however typical values show that the potential water losses through street trees (18kL/tree/yr) are the equivalent of irrigating park and gardens (2.5 to 4.5 ML/Ha/yr).

New guidance provided by the CRC for Water Sensitive Cities *Guideline for passively irrigated landscapes* recommends that street trees be provided with a self-watered tree pits that accept flows onto their surface and discharge excess flows that pass vertically through the soil profile from their base (as per bioretention systems). Schematics are provided below (Cooperative Research Centre for Water Sensitive Cities, 2020).

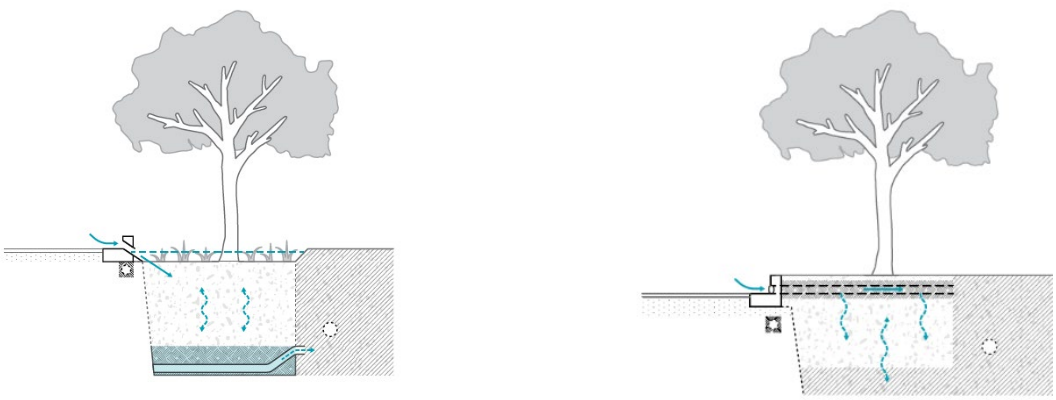


Figure 3-6 Schematic illustration of at-source passive irrigation street tree system (Cooperative Research Centre for Water Sensitive Cities, 2020)

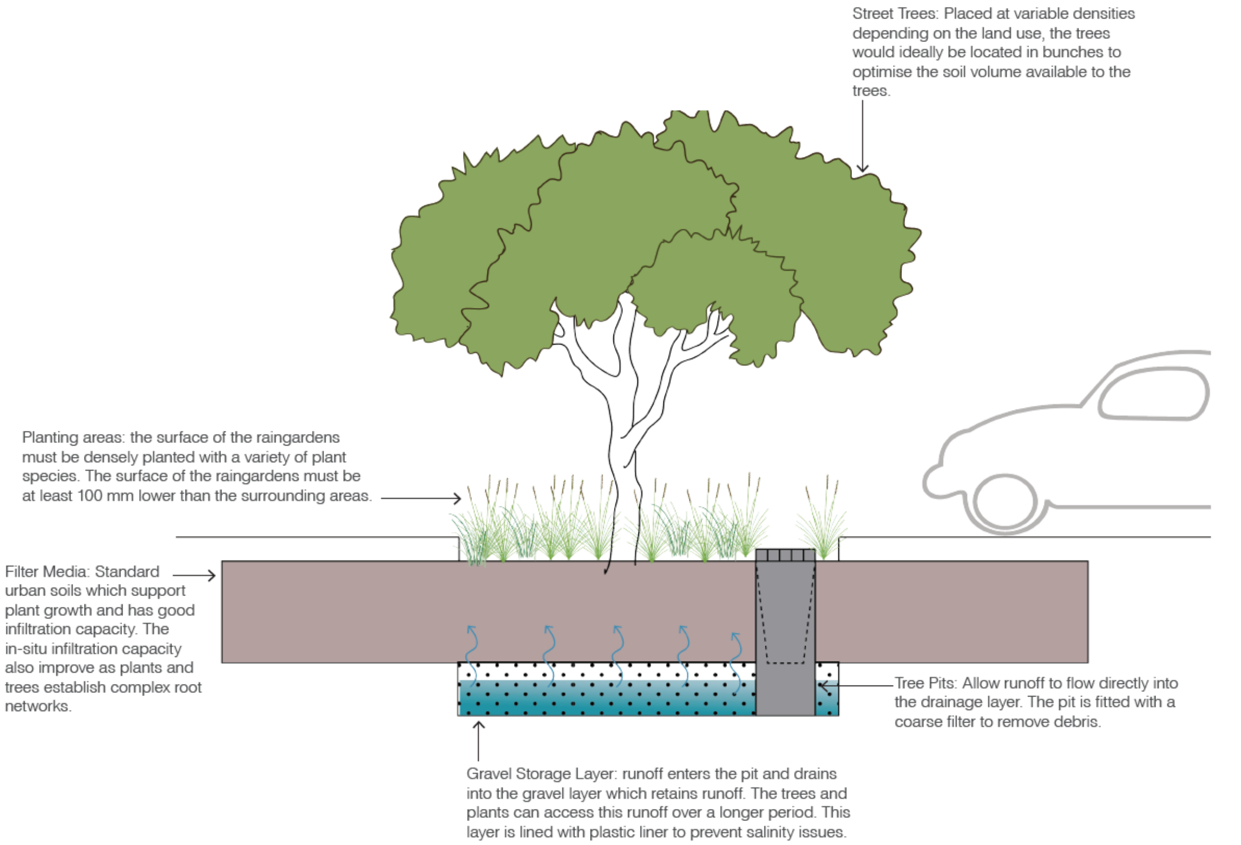


Figure 3-7 Schematic illustration of at-source passive irrigation street tree system (Cooperative Research Centre for Water Sensitive Cities, 2020)

Table 3-7 Adopted parameters for design of street trees

Parameters		North Trees	South Trees	Description
Inlet properties	Low flow By-pass (m^3/s)	0	0	No low flow bypass
	High Flow By-pass (m^3/s)	1	1	3-month ARI
Storage properties	Extended Detention Depth (m)	0.1	0.1	MUSIC-link, 0.1-0.3
	Surface area (m^2)	600	720	Based on $4m^2$ surface area per tree
Filter and media properties	Filter area (m^2)	600	720	Same as surface area
	Unlined Filter media perimeter (m)	0	0	Lined base to prevent saline groundwater impacts
	Saturated Hydraulic conductivity (mm/h)	125	125	MUSIC-link, 100-125
	Filter Depth (m)	0.5	0.5	MUSIC-link, 0.5-0.8, Max to allow for the root grow
	TN content of filter Media (mg/kg)	800	800	MUSIC-link
	orthophosphate content of filter media (mg/kg)	40	40	MUSIC-link
Infiltration properties	Exfiltration Rate (mm/hr)	0.0	0.0	Lined base to prevent saline groundwater impacts
Outlet properties	Overflow weir width (m)	1000	1000	

Parameters		North Trees	South Trees	Description
	PET scaling factor	2.1	2.1	MUSIC-link
	Weir coefficient	1.7	1.7	MUSIC-link
	Porosity of filter media	0.35	0.35	Conservative low rate adopted for improved soil for tree health
	Porosity of submerged zone	0.35	0.35	Reservoir for tree roots during dry spells
	Horizontal flow coefficient	3	3	Default adopted
Underdrain and submerged zone present with 0.3 m depth				

3.5 Stormwater Harvesting

Stormwater harvesting tanks can be provided as an effective means of reducing stormwater volumes in this circumstance due to the extent of the site and parklands proposed adjacent to the site. Low numbers of staff on the AWRC site mean that there is a low water demand associated with internal non-potable water uses. Excluding street scape areas within the treatment plant, the adjacent park provides up to 16 Ha of land to irrigate and a potential water demand of 40 to 80 ML/yr.

While potentially at odds with the availability of free, high-quality recycled water; a stormwater harvesting strategy demonstrates the principles of stormwater volume reduction and provide an opportunity for developing a pilot scale demonstration project. Tank configuration would ideally be below ground concrete tanks that are formed on site. Consideration of groundwater levels will be important in the location and depth of storage tanks to design around buoyancy issues.

Over irrigation of surrounding parkland areas and streets must be avoided to prevent saturation of soils and over infiltration to the groundwater. The adopted parameters are summarised in **Table 3-8.**

Table 3-8 Adopted parameters for the rainwater harvesting tank

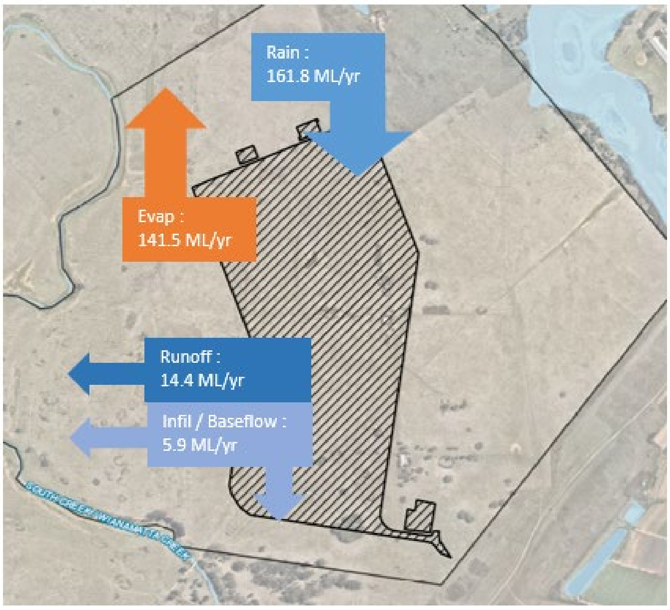
	Parameters	North Trees	Description
Inlet properties	Low flow By-pass (m3/s)	0	
	High Flow By-pass (m3/s)	100	
Tank properties	Volume below overflow pipe (kL)	500	
	Depth above overflow (m)	0.2	
	Surface Area (m^2)	5	
	Initial Volume (kL)	10	
Outlet properties	Overflow Pipe Diameter (mm)	50	
Annual Demand Rate	Irrigation demand (ML/yr)	108	24 Ha of parkland irrigated at 4.5 ML/ha/yr- adopted from land capability study

4 Results and Discussion

The following provides a demonstration that flow management objectives are achievable through a range of WSUD approaches.

4.1 Mean Annual Runoff Volume Reductions

The AWRC treatment train proposed for the reference design was modelled using a continuous simulation (eWater MUSIC) to demonstrate the hydrologic water balance. The model predicts the volumes of stormwater (or MARV reductions) as summarised below. Multiple scenarios have been tested to compare different wetland and pond size the results are summarised in the Sensitivity Analysis section of this report. A summary of the changes in the stormwater balance are presented in **Figure 4-1**.



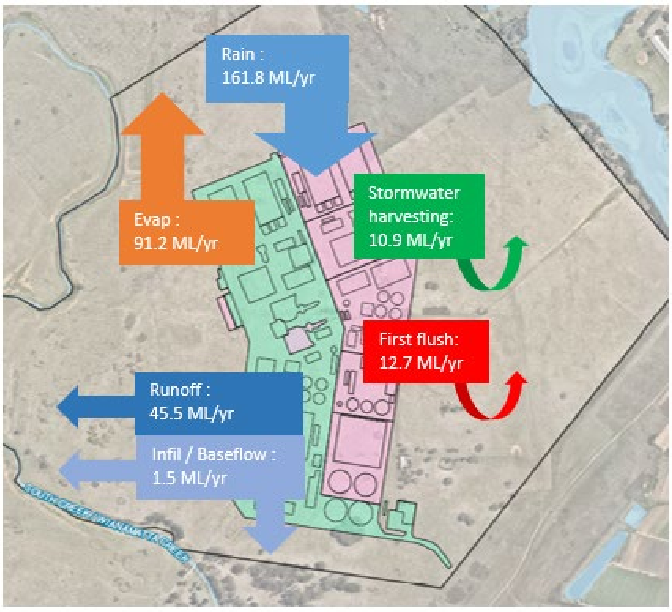


Figure 4-1 Pre and post development (Stage 1 + Future stages) stormwater balance

Table 4-1 Effectiveness of proposed stormwater management elements on MARV

WSUD Element	Adopted size for Stage 1 and Ultimate	Mean Annual Runoff Volume Reduction (ML/yr)	Description
First flush tank	North: 371 m^3 South: 311 m^3	-9.9	Collect the first 10mm of the rainfall from the hardstands. Pump it back to the head of AWRC to be treated like incoming influent
Street trees	North: 600 m^2 South: 720 m^2	-3.0 -3.4	North catchment:150 (number of trees) x 4 m^2 (active area where stormwater is applied) South catchment:180 (number of trees) x 4 m^2 (active area where stormwater is applied)
Bio retention	North: 600 m^2 South: 850 m^2	-1.3 -1.9	Recommended reference design surface areas

WSUD Element	Adopted size for Stage 1 and Ultimate	Mean Annual Runoff Volume Reduction (ML/yr)	Description
Pond / wetland	Surface area: 0.5 ha Detention time: 20 days	-4.6	No additional stormwater harvesting, or extractions adopted
Stormwater harvesting for irrigation	Volume: 500 kL	-11	Includes 16 Ha irrigation network that provides 10% of water demand with remainder being supplied by recycled water from the Treatment Plant
Total MARV Reduction (ML/yr)		-35.1	
MARV reduction		45%	AWRC runoff from ultimate footprint MARV 83.9 ML/yr 22.87 Ha of site @ 57% imperviousness
Residual MARV(ML/yr)		45.5	Achieves target for 3rd order waterways and greater

4.2 Waterway Health (Flow) Objectives

DPIE have drafted waterway health objectives based on relationships between stream flows and a range of habitat indicators including condition of vegetation, erosion of waterways, complexity of in-stream habitats for fish and macroinvertebrates.

Flows from predominantly rural drainage areas were classified as ‘current condition’ represent ideal stream flow objectives.

Flows from waterway areas with mixed land uses were considered the tipping point at which health, ecology and biodiversity of water dependent ecosystems declined.

Based on DPIE’s recommendations, the use of:

- ‘Current’ flow objectives provide performance outcomes for sensitive ecosystems and
- ‘Tipping point’ flow objectives provide performance outcomes for ≥ 3rdorder streams

It is therefore appropriate if stormwater objectives lie between these two sets of objectives with the ‘tipping point’ representing the upper limit of hydrologic modification.

Hydrologic performance of the reference design is provided by eWater MUSIC modelling over the period of 1993 to 2018. Models were run at an hourly time step and results exported as a continuous hydrograph which is provided in Figure 4-2.

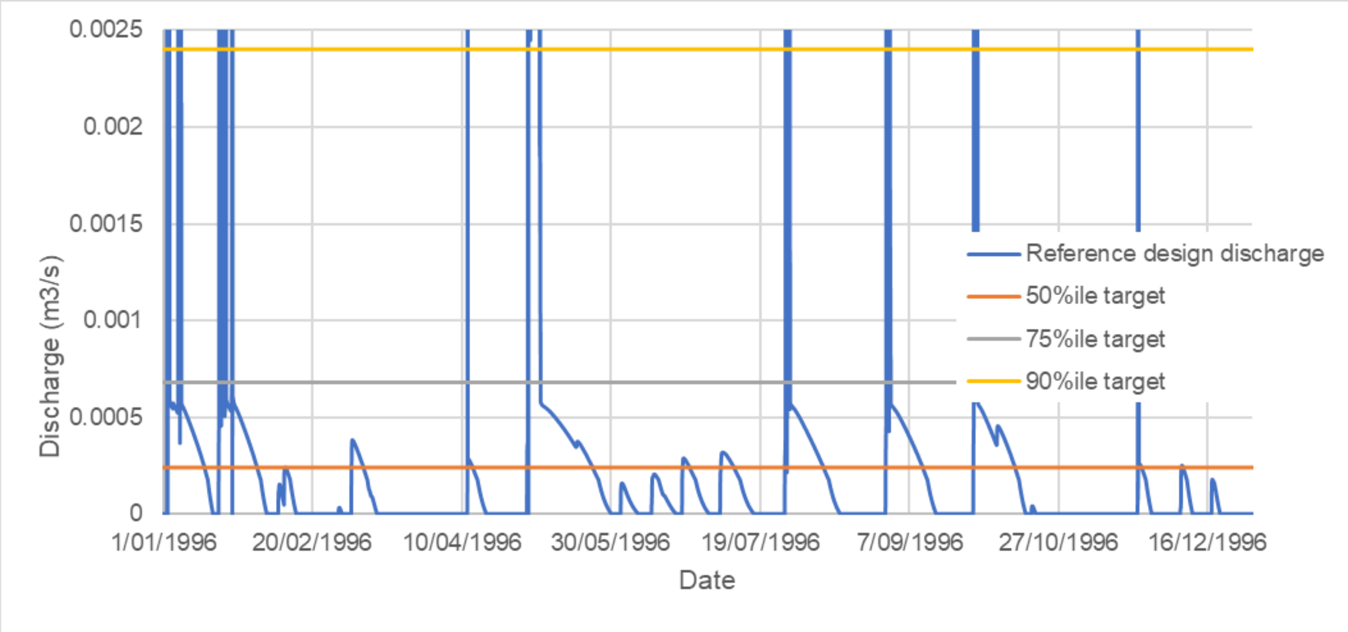


Figure 4-2 Hydrograph discharge to waterways from the reference design and flow criteria

The results were analyzed to produce flow metrics for comparison against the objectives shown in **Table 4-2**. The table below provides a comparison commentary on the effectiveness of the stormwater management measures to work towards waterway health (flow) objectives.

Table 4-2 Effectiveness of proposed stormwater management elements on flow duration curve (AWRC_7102020.sqz)

Flow Objectives for Ultimate Development (22.27 Ha)	Current Condition (Objective for 1st & 2nd Order Waterways) Ideal	WSUD Performance for Reference Design Modelled Performance	Tipping Point (3rd Order and greater Waterways) Upper Limit of Change	Commentary on compliance
Mean Daily Flow Volume (L/d)	38,895	124,657	130,570	Acceptable – mean annual runoff volume does not exceeded the waterway objective for Wianamatta-South Creek
Mean Annual Runoff Volume (ML/yr)	24.0	45.5	47.7	
High Spell (m^3/s) ≥ 90th Percentile Daily Flow Volume	0.0003	0.0005	0.0028	Acceptable – remains below tipping point
High Spell - Frequency (number/y)	6.5	8.3	20	Acceptable – remains below tipping point
High Spell - Average Duration (days/y)	5.7	3.8	2.4	Acceptable – remains below tipping point

Flow Objectives for Ultimate Development (22.27 Ha)	Current Condition (Objective for 1st & 2nd Order Waterways)	WSUD Performance for Reference Design	Tipping Point (3rd Order and greater Waterways)	Commentary on compliance
	Ideal	Modelled Performance	Upper Limit of Change	
Freshes (m^3/s) ≥ 75th and ≤ 90th Percentile Daily Flow Volume	0.0001	0.0004	0.0026	Acceptable – remains below tipping point
Freshes - Average Duration (days/y)	32.4	14.1	2.4	Acceptable – between existing conditions and tipping point
Freshes - Frequency (number/y)	3.1	10.1	25.3	Acceptable – between existing conditions and tipping point
Cease to Flow (proportion of time/y)	38%	52%	2%	Acceptable – Exceeds acceptable range at the site outlet but delivery of low flows via wetland will ensure groundwater top up within the creeks will contribute to the local and regional water table that provides zero flows.

As demonstrated in the table above, the stormwater management approach for the reference site design contributes to achieving the regional waterway objectives by discharging at rates that do not exceed the ‘tipping point values’ for all metrics except the cease to flow objective.

The cease to flow objective shows the proportion of zero flows achieved by the site WSUD approach is (52%) which is longer in duration than current conditions in the waterway. This is due to the contribution of prolonged flows of expressed groundwater in the waterway, and the short and flashy nature of discharges off the site. The reference design uses wetlands that detain and slowly release stormwater over a long period to allow trickles of flow to slowly enter South Creek and interact naturally with the underlying groundwater table. In this way the approach does contribute to the objective being achieved, however it is not possible to demonstrate this through the models.

Alternatively, to achieve the zero-flow objective, treated stormwater could discharge to groundwater directly from the base of unlined biofiltration basins or via a ‘soak’ in the floodplain, however this is not recommended at this time due to concerns around salinity impacts in the floodplain. Therefore, despite the cease to flow objective not being achieved at the wetland outlet or site boundary, the approach of discharging stormwater slowly over many days will contribute to the objective being achieved in the regional waterways.

The results above demonstrate that the WSUD approach will achieve the Wianamatta-South Creek Waterway Health (flow) objectives and contribute to the Wianamatta-South Creek Waterway Health (flow) objectives being achieved under ultimate development in the catchment. It is also feasible that a different arrangement or configuration could be delivered that would also achieve the objectives.

4.3 Stream Erosion Index

Applying a partial series assessment to MUSIC model time series (1995-2018) shows that the 2-year ARI flow rate off the equivalent rural lands to the reference design (22.75 Ha) is approximately 0.30 m^3/s.

The Stream Erosion Index for the reference design was calculated by determining the volume of discharges under rural and post development conditions that exceed:

- half the 2-year ARI flow (0.15 m3/s) as shown in **Table 4-3** which is critical for medium clays
- a quarter of the 2-year ARI flow (0.075 m3/s) as shown in **Table 4-4** which is critical for sandy clays

Table 4-3 Stream Erosion Index Results (*AWRC_7102020.sqz*) for medium heavy clays with mitigation

Parameter	Volume Exceeding $Q_2/2$	Stream Erosion Index	Penrith Council target	Penrith Council Target Met

Table 4-4 Stream Erosion Index Results (*AWRC_7102020.sqz*) for silty clays with mitigation

Parameter	Volume Exceeding $Q_2/4$	Stream Erosion Index	Penrith Council target	Penrith Council Target Met

Results demonstrate that by achieving the Wianamatta-South Creek waterway health (flow) objectives Council's Stream Erosion Index is also achieved. It is feasible that a different arrangement or configuration of WSUD elements could be delivered that would achieve the same outcomes.

4.4 Stormwater Pollution Load Reduction

MUSIC model results showing the stormwater pollution reductions delivered by the reference design stormwater treatment train are summarised in **Table 4-5**. This demonstrates that the reduction targets set by the Penrith City Council satisfied and are exceeded.

Table 4-5 Load reduction of the proposed stormwater management measures (*AWRC_7102020.sqz*) with mitigation

Parameter	Ultimate design	Ultimate design with mitigation (WSUD)	Load reduction (%)	Penrith Council load reduction target (%)	Penrith Council Target Met
TSS (kg/yr)	13200	1510	88.6	85	Yes
TP (kg/yr)	25.5	7.06	72.3	60	Yes
TN (kg/yr)	185	54.3	70.7	45	Yes

Parameter	Ultimate design	Ultimate design with mitigation (WSUD)	Load reduction (%)	Penrith Council load reduction target (%)	Penrith Council Target Met
Gross Pollutants (kg/yr)	2210	0	100	90	Yes

The stormwater pollution load reductions achieved by the reference design exceed Council's requirements and approach the ideal stormwater management targets. The reference design will contribute significantly less stormwater pollutant loads that approach ideal stormwater management targets.

4.5 Stormwater Pollution Concentrations

The probability of exceedance of generic stormwater pollutant concentration from the reference design is presented in **Table 4-6** and **Figure 4-3,** respectively. The MUSIC modelling results are presented together with the existing water quality objectives for the Wianamatta-South Creek to enable comparison.

The results show that the concentrations of TSS and TN are predominantly (>90% of the time) below the ambient water quality objective for South Creek. The TP concentrations are below water quality objectives 85% of the time. This shows that storm flows may exceed the ambient objectives less than 10% of the time but overall will contribute to waterways achieving the Wianamatta South Creek WQOs.

Table 4-6 Total Phosphorous and Total Nitrogen concentrations with mitigation compared to Wianamatta-South Creek Water Quality Objectives (AWRC_7102020.sqz)

	Total Suspended Solids		Total phosphorus		Total Nitrogen	
	Receiving Water Objective	90th Percentile Discharge	Receiving Water Objective	85th Percentile Discharge	Receiving Water Objective	90th Percentile Discharge
Concentration (mg/L)	30	11.95	0.14 TP 0.03 DIP	0.14	1.72 TN 0.41 DIN	1.12

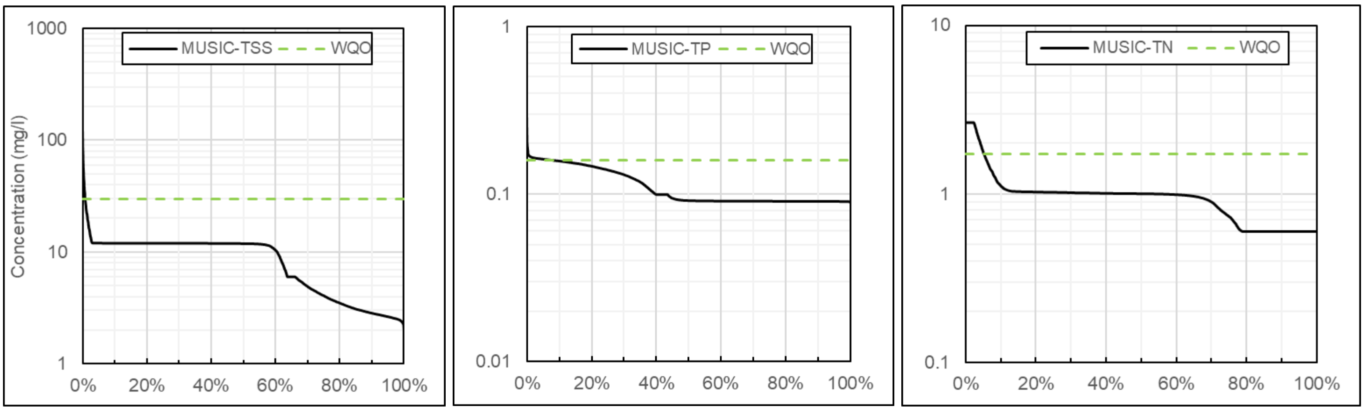


Figure 4-3 Simulated probability of exceedance of TSS, TP and TN leaving WSUD measures under ultimate

4.6 Strategic Impact Assessment

A strategic impact assessment provides a measure of the cost effectiveness of each of the measures proposed in the site treatment train for the ultimate development condition of the site. The costs of construction and maintenance have been considered against the effectiveness of each of the stormwater management measures in terms of its effectiveness to remove stormwater volumes from the waterway, which is the most difficult element to achieve. Costs for each element are not provided in this report, but the effectiveness of each measure is described below as well as the feasibility of scaling up each element in the treatment train. This assessment shows where there is some capacity to make the treatment train work harder or make up for a shortfall should some elements of the treatment train be changed in the future to overcome site constraints

1. First Flush Tanks – most cost-effective approach to removing stormwater due to the availability of header works and discharge pipelines that move water out of the catchment to the Hawkesbury Nepean discharge site. It would be cost effective to scale up this element of the treatment train by collecting more water from the site.
2. Stormwater Harvesting Tanks – when located at the end of the treatment train, stormwater harvesting for irrigation of the adjacent park provides the second most cost-effective way of removing stormwater. Stormwater harvesting cannot be cost effectively scaled up and it is unlikely that additional loads of stormwater can be removed through additional irrigation. Where a higher rate of irrigation is proposed, it should be accompanied by a detailed irrigation and salinity risk assessment.
3. Constructed wetland / open water – Wetlands are required for their ability to slowly release stormwater slowly and contribute to cease to flow objectives for waterways. Wetlands are relatively more effective at removing stormwater from the site. Wetlands can be scaled up to remove additional stormwater volumes.
4. Biofiltration street trees – these elements are expensive due to the volume of soil that a healthy street tree may require. However, it is a relatively low-cost exercise to convert a healthy street tree into a stormwater treatment element. When including the total cost of the street tree, these are at the lower end of cost effectiveness in removing stormwater however this overlooks all the other benefits that justify their inclusion in the site street scape. Street trees are optimal at 15m centres but cannot be cost effectively scaled up beyond this.
5. Biofiltration – Similar to biofiltration street trees, these elements are a costly means of removing stormwater volumes but are more effective as stormwater pollutant control devices. They cannot be scaled up.
6. Rainwater tanks – While not explored here as part of the current AWRC reference design, the site presents insufficient demand for non-potable water to be effective but may present a suitable alternative to end of pipe stormwater tanks if unfavourable ground conditions prevent the establishment of stormwater harvesting tanks.

5 Climate Sensitivity

Climate change has the potential to alter rainfall and evapotranspiration rates and alter the effectiveness of the treatment train to achieve stormwater pollution reductions and contribute to waterway health objectives.

5.1 Changes to Rainfall

The NSW Office of Environment and Heritage (OEH) has published several documents detailing the expected effects of climate change on water resources. Study results documented in a 2015 report, "*Climate change impacts on surface runoff and recharge to groundwater*" (OEH, 2015), have been used to assess expected local climatic changes.

Utilising NARCliM, the OEH study predicted near future (2020-2039) and far future (2060-2079) changes to rainfall, runoff and recharge to for the Hawkesbury catchment are presented in **Table 5-1**. In summary, the study predicted that changes in near future, were likely to be a reduction in the rainfall and recharge to the groundwater and increase in the surface runoff, while in far future, the model predicted an increase in all three parameters (rainfall, surface runoff and recharge to the groundwater).

Table 5-1 Percentage change in rainfall, runoff and groundwater recharge for the Hawkesbury catchment

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Hawkesbury Nepean Catchment	-0.1	0.9	-9.3	6.1	13.4	5.6

5.2 Changes to Runoff Patterns

The stormwater runoff response to the 6.1% increase in rainfall due to climate change is difficult to quantity due to the lack of detail on how the rainfall intensity will change.

Rainfall variations have been included into the modelled time series by adopting 24 years of rainfall. This provides for a rigorous basis for determining the long-term performance of the stormwater infrastructure through a range of wet and dry years.

To assess the sensitivity of increasing rainfall, performance of the treatment train is compared using two rainfall data (6-minute time step) with average total rainfall depths as follows:

- 691 mm rainfall (Penrith Council's preferred data set via MUSICLink)
- 857 mm rainfall (Liverpool Council's preferred data set via MUSICLink)

The assessment shows that a 25% increase in rainfall may result in:

- Slightly higher runoff rates which would proportionately increase the flow targets
- Slightly lower stormwater pollution load reductions (expressed as a % of source loads) but still compliance with Council stormwater pollution reduction targets
- 90%ile concentrations are less than water quality objectives for all pollutants

Stormwater quality performance under an increased rainfall intensity resulting in an 25% increase in rainfall will result in similar water quality outcomes and will still comply with Council targets and WQOs. It is likely that the treatment train will result in similar performance outcomes under predicted near (-1%) and far future (+6%) rainfall changes. It is likely that flow objectives will be achieved for near future climate scenarios but unlikely that flow objectives would be met if rainfall increases by 25%.

6 Conclusions

This report presents an assessment of the surface water management, explicitly the runoff and stormwater pollution loads resulting from frequent rainfall events across the AWRC reference design under ultimate development. The demonstration shows that flow management objectives are achievable however, detailed design may present a different suite of measures that achieve the same outcomes.

Objectives

The low flow regime of the Wianamatta-South Creek catchment is defined by the waterway health (flow and quality) objectives established by DPIE EES in October 2020. These objectives provide numerical criteria for stormwater and wastewater discharges to the waterway. It is understood that by achieving these objectives, the reference design will preserve the community values, ecology and waterway stability (erosion) of downstream waterways under ultimate development in the catchment.

These objectives also provide ambient water quality objectives which also have been applied as numerical objectives for stormwater quality management.

Penrith Council has also established stormwater pollution reduction targets as well as a stream erosion index for new development. These controls are demonstrated above to be less stringent than the new numerical waterway health objectives for Wianamatta-South Creek.

Demonstration

MUSIC modelling has been undertaken using a continuous simulation at an hourly time series (1993 to 2018) to design a water sensitive urban design approach for the reference design of the ultimate development state.

The WSUD approach incorporates a mix of:

- first flush stormwater capture
- stormwater pollution capture and filtration through green infrastructure
- passive irrigation, evapotranspiration and evaporation.
- stormwater harvesting and reuse irrigation.

Performance of the stormwater management approach has been assessed against all objectives outlined above.

MUSIC modelling shows that council stormwater pollution Load reduction targets are achieved, and the stream erosion index is maintained below 3.5. The stormwater management approach performs significantly better than required by Council targets.

Stormwater pollution concentrations up to the 85%ile event are maintained below the waterway health (quality) objectives for ambient conditions.

Waterway health (flow) objectives are maintained between the ‘existing condition’ and ‘tipping point’ for all numerical waterway flow objectives except for the cease to flow target.

The cease to flow objective shows the proportion of zero flows achieved by the site is longer in duration than current conditions. The reference design uses wetlands that detain and slowly release stormwater over a long period to allow trickles of flow to slowly enter Wianamatta-South Creek and interact naturally with the underlying groundwater table. In this way the approach does not satisfy the numerical criteria at the discharge point but does contribute to the objective being achieved.

By achieving the numerical criteria for High Spell flows and Freshes, then it follows that the development reduces erosion risk on downstream development and infrastructure as well as downstream habitat channels and in stream vegetation.

The results above demonstrate that the WSUD approach will contribute to protecting and restoring Wianamatta South Creek by achieve the Wianamatta-South Creek Waterway Health (flow and water quality) objectives and contribute to those objectives being achieved under ultimate development in the catchment. It is also feasible that the final AWRC design may present a different WSUD treatment train arrangement that would also achieve the objectives as outlined above by undertaking a similar modelling exercise.

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Appendix B

AWRC Peak Stormwater Discharge Assessment

August 2021

Upper South Creek Advanced Water Recycling Centre

AWRC Site Peak Stormwater Discharge Assessment

Final rev1

aurecon ARUP

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Figures

Tables

1 Introduction

1.1 Project background

The purpose of the Sydney Water Upper South Creek Advanced Water Recycling Centre (AWRC) project is to design, construct and operate new wastewater infrastructure to service the proposed growth areas in Western Sydney. The AWRC will be located on an 80 ha site in the Kemps Creek precinct, upstream of the confluence of Kemps Creek and South Creek at the northern end of Clifton Avenue along the corridor of the proposed M12 Motorway. This site is approximately 4 km north-east of the Badgerys Creek Western Sydney Airport Precinct.

The key features/elements of the project are displayed in **Figure 1-1**.

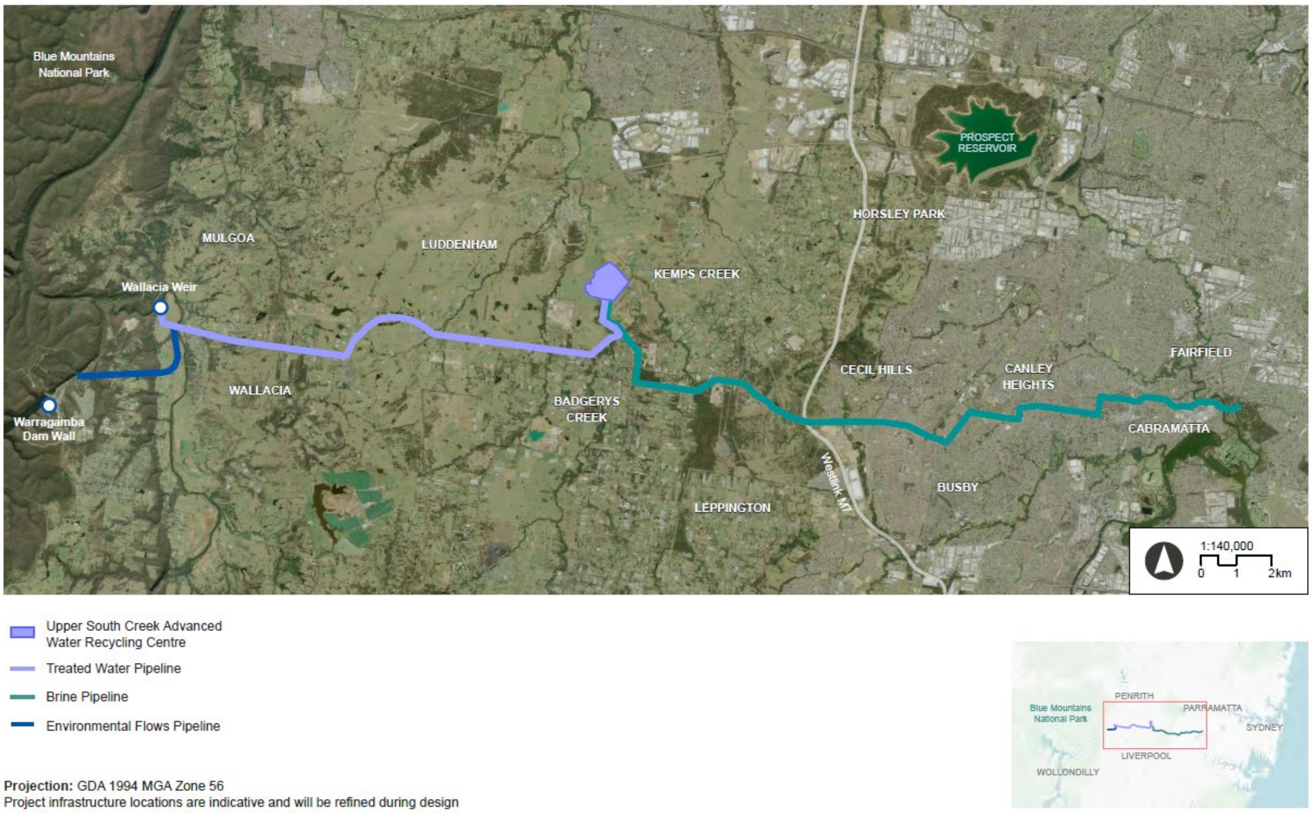

Figure 1-1 USC AWRC Project Overview

The pipeline infrastructure will primarily be below ground and thus potential impacts to the surface water resources associated with the pipelines are expected to be minimal with negligible permanent impact on local stormwater runoff regimes. Surficial changes at the AWRC site, such as the addition of impervious surfaces, will likely lead to changes in the stormwater runoff patterns from this site.

1.2 Purpose of assessment

The assessment documented in this report was conducted to demonstrate the adequacy of the proposed peak AWRC site stormwater discharge management approach, and that it:

- Adheres to the current Penrith City Council specifications. (Though not directly applicable, these specifications have been applied as guidance)

- Minimises development impacts related to local and regional flood impacts from increased peak runoff rates

To assess the change in peak discharge from the site and ensure the impacts are sufficiently mitigated the pre- and post-development systems were simulated for storms associated with three (3) annual exceedance probabilities (AEPs): 50%, 5% and 1%.

A separate *Flood Impact Assessment* has been conducted to assess the general impacts of the site development and surficial changes on the local and regional flood levels.

2 Site description

2.1 Site layout

The new Upper South Creek Advanced Water Recycling Centre (AWRC) will be located in the Kemps Creek precinct (Penrith local government area). The project will be located on an 80ha site as shown in **Figure 2-1**.

The AWRC will produce high quality treated water suitable for a range of uses including recycling and environmental flows. The plant is being designed to treat average dry weather flows of 50 ML/day with the potential to extend during future stages to enable treatment of flows up to 100 ML/day. Treated water will be released to the Nepean River, South Creek and the Warragamba River.

The full footprint of the plant (Stage 1 & 2) is expected to cover an area less than 15ha.

2.2 Site drainage

The on-site drainage system included in the reference design has been designed with the potential future expansion in mind. Two catchment areas will be associated with the first stage of the project (green area indicated in **Figure 2-1**). The northern half of the site will drain north to proposed OSD "North A"; the southern section of the site will drain west to proposed OSD "South".

During future stages of the project the additional plant footprint will be developed (pink area indicated in **Figure 2-1**). The northern half of this area will drain north independently from the Stage 1 drainage system to proposed OSD "North B". The drainage network covering the southern half will also direct flows west and tie into the existing Stage 1 network discharging to OSD "South".

The footprint areas as well as expected impervious coverage for each of these drainage areas for both stages of the project are provided in **Table 2-1**.

This assessment assumes the worst-case scenario, i.e. the fully developed footprint, to ensure sufficient allowance has been made to address the final on-site detention requirements.

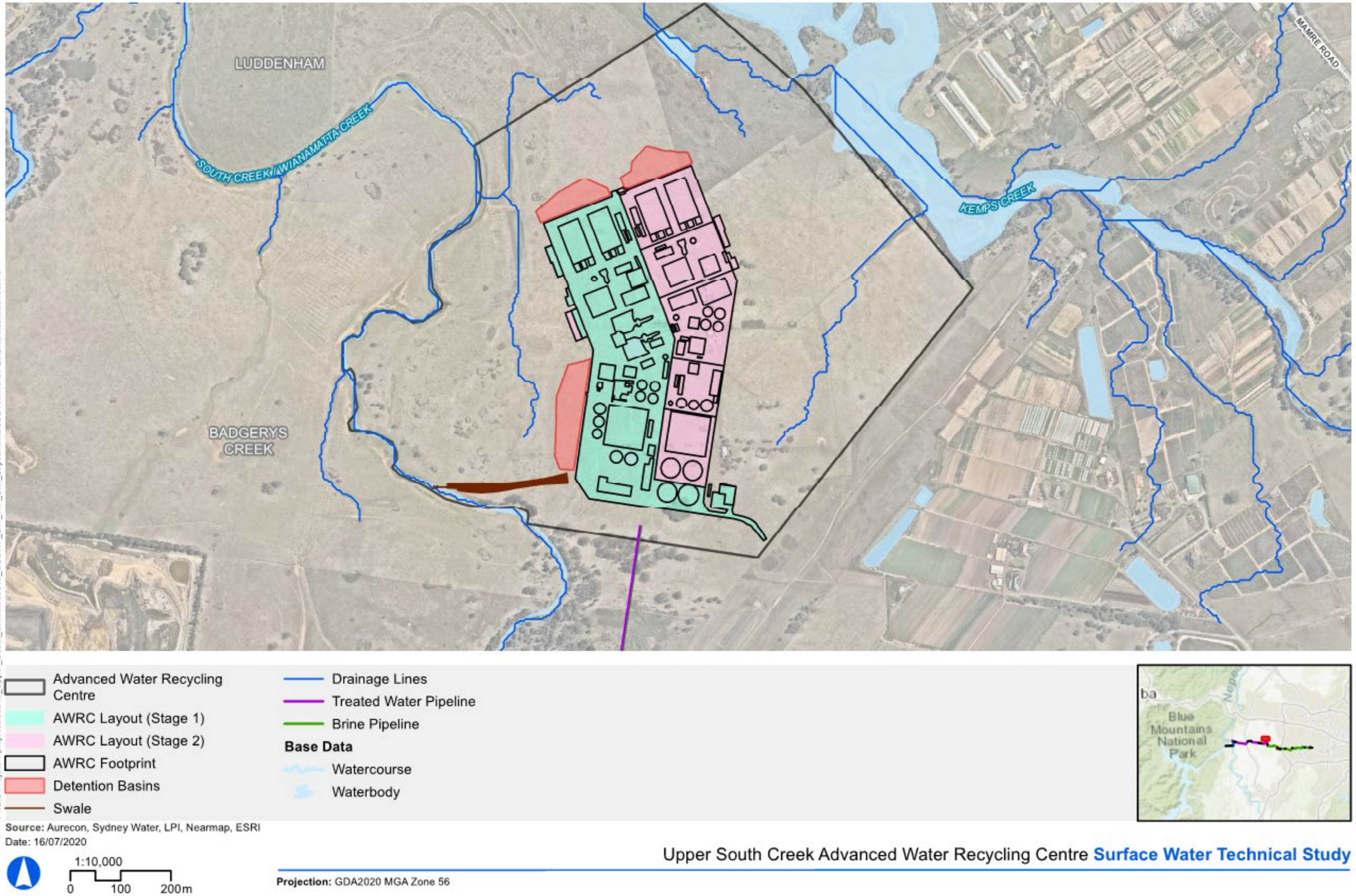

Figure 2-1 Site layout

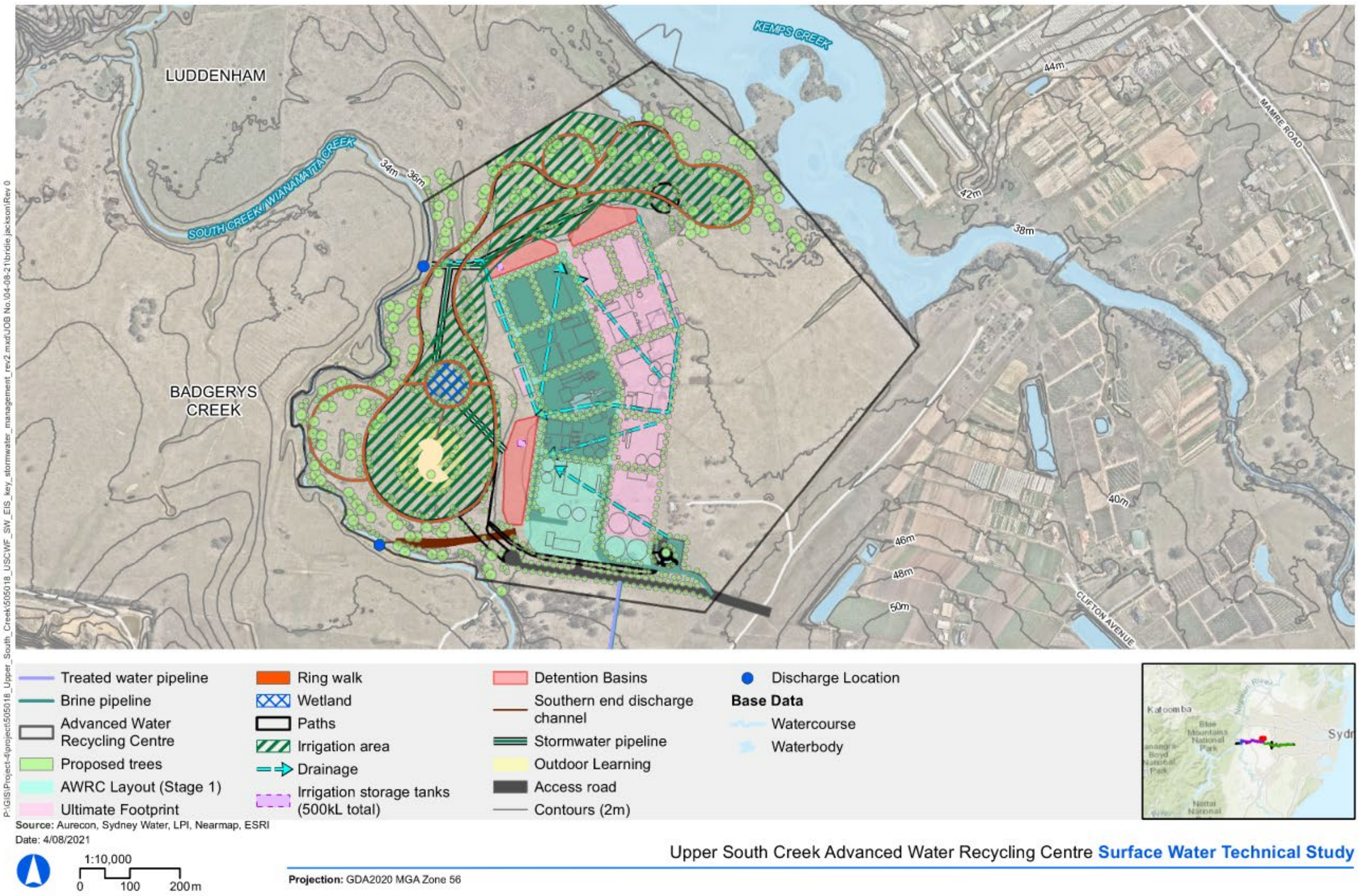

Figure 2-2 Stormwater management

Table 2-1 Land cover for stage 1 and ultimate footprint development

Surface Area	North A	North B	South	Total
Stage 1				
Total Area	5.88	n/a	6.63	12.51
Impervious Area	3.20	n/a	4.19	7.39
Impervious %	54%	n/a	63%	59%
Ultimate footprint				
Total Area	5.88	6.49	9.90	22.27
Impervious Area	3.20	3.18	6.24	12.62
Impervious %	54%	49%	63%	57%

3 Drainage design guidelines

The Penrith City Council *Stormwater Drainage Guidelines for Building Developments* (2018) includes the following relevant design requirements for any on-site stormwater detention (OSD) developed within their jurisdiction:

- OSD's should be sized to contain all flood events up to and including the 1% AEP event volume
- Council does not allow a reduction in OSD storage volumes based on inclusion of rainwater tanks and other WSUD measures
- The outlet control for the OSD system shall be above the 1% AEP flood level at the discharge point
- Maximum depths for above ground storage
  - Landscaped areas: 600 mm
  - Industrial open basins: 1,200 mm
- Where landscaped areas are to be used, the required volume shall be increased to accommodate any potential mature planting within the basin – 15% additional for design storage volume >25m^3
- Batter slopes in landscaped areas shall be generally 1(V):6(H)

4 Methodology

The Penrith City Council DCP states that adequate stormwater systems shall be designed and constructed to ensure that, for all rainwater events up to and including the 5% AEP (for pit and pipe systems) and 1% AEP even (for other infrastructure, i.e. OSDs), new developments and redevelopments do not increase stormwater peak flows in any downstream areas.

In the context of development within the Aerotropolis, the contribution of the site to cumulative impacts from development on surrounding lands can only be specified by catchment wide flood mitigation controls, which are currently still being developed.

Where it is demonstrated that there is no change in peak flood flow or timing of peak flow from the developed site, it is reasonably assumed that the site does not contribute to increased peak flood flows in the downstream system and does not increase flood depths.

An XP-RAFTS model of the AWRC site area was developed to compare pre- and post-development peak stormwater runoff rates and volumes and assess the potential for local and regional flood impacts.

The pervious and impervious areas and general drainage slopes for each catchment (as detailed in **Section 5.1.2**) were input into the model as sub-catchments draining towards the proposed on-site detention basins.

The hydrologic modelling was undertaken in accordance with Australian Rainfall and Runoff 2019 (ARR, 2019) rainfall data and methods. It incorporated the modelling of ten representative storms for 14 varying storm durations (25 min to 30 hours). The storm durations resulting in the highest simulated median peak discharge values were then identified as the critical duration events for each of the discharge locations. The highest median peak flow was thus identified for both pre- and post-development and compared. These steps were repeated to assess discharge resulting from storm events with Annual Exceedance Probabilities (AEPs) of 50%, 5% and 1%.

The hydrologic modelling was used to assess the need for flood detention storage volumes as well as the need for and performance of discharge controls to ensure storm events up to the 1% Annual Exceedance Probability (1% AEP) could be contained and the peak discharge rates associated with the three storm frequencies (1%, 5% and 50%) analysed would not exceed the simulated pre-development peak flow rates at the site boundary.

Hydraulic models were developed to inform the stage-discharge relationships for the various discharge conduit sizes considered.

Subsequent to assessing and sizing the discharge conduits using the ARR 2019 methodology the system was also evaluated using the Australian Rainfall and Runoff 1987 (Institution of Engineers Australia, 1987) methodology. The pre-and post-development peak discharge rates for the various catchments were compared for the single representative storm events associated with each of the three assessed AEPs.

5 Modelling inputs and assumptions

5.1 Design rainfall

5.1.1 ARR 2019

The Australian Rainfall and Runoff (ARR) 2019 guideline requires the use of ten temporal patterns for each design Annual Exceedance Probability (AEP) and storm duration combination. The representative storms for the AWRC site location were sourced from the ARR Data Hub (https://data.arr-software.org/, accessed 22 April 2020) and used in combination with six pre-burst timesteps to generate the rainfall simulated within the model.

Without prior knowledge of the critical storm duration, as well as understanding that it is likely to change post-development, 14 storm durations were simulated ranging from 25 minutes in length to 30 hours. The simulated rainfall for all ten representative storm sets for all 14 selected durations representative of 1% AEP events is shown in **Figure 5-1**. Each line represents a single storm duration event. An example of a single representative storm is also provided in **Figure 5-2**.

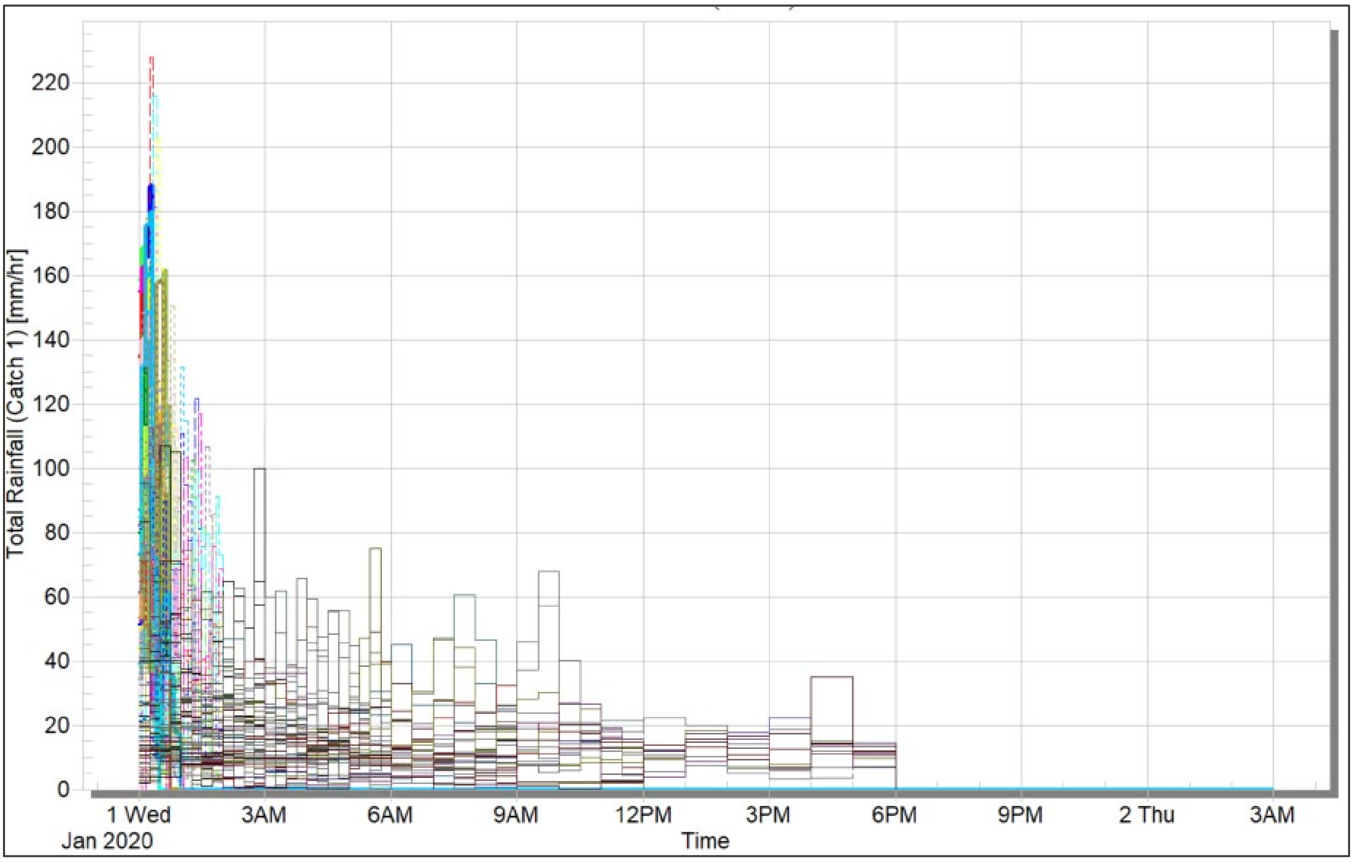

Figure 5-1 Simulated rainfall (1% AEP events)

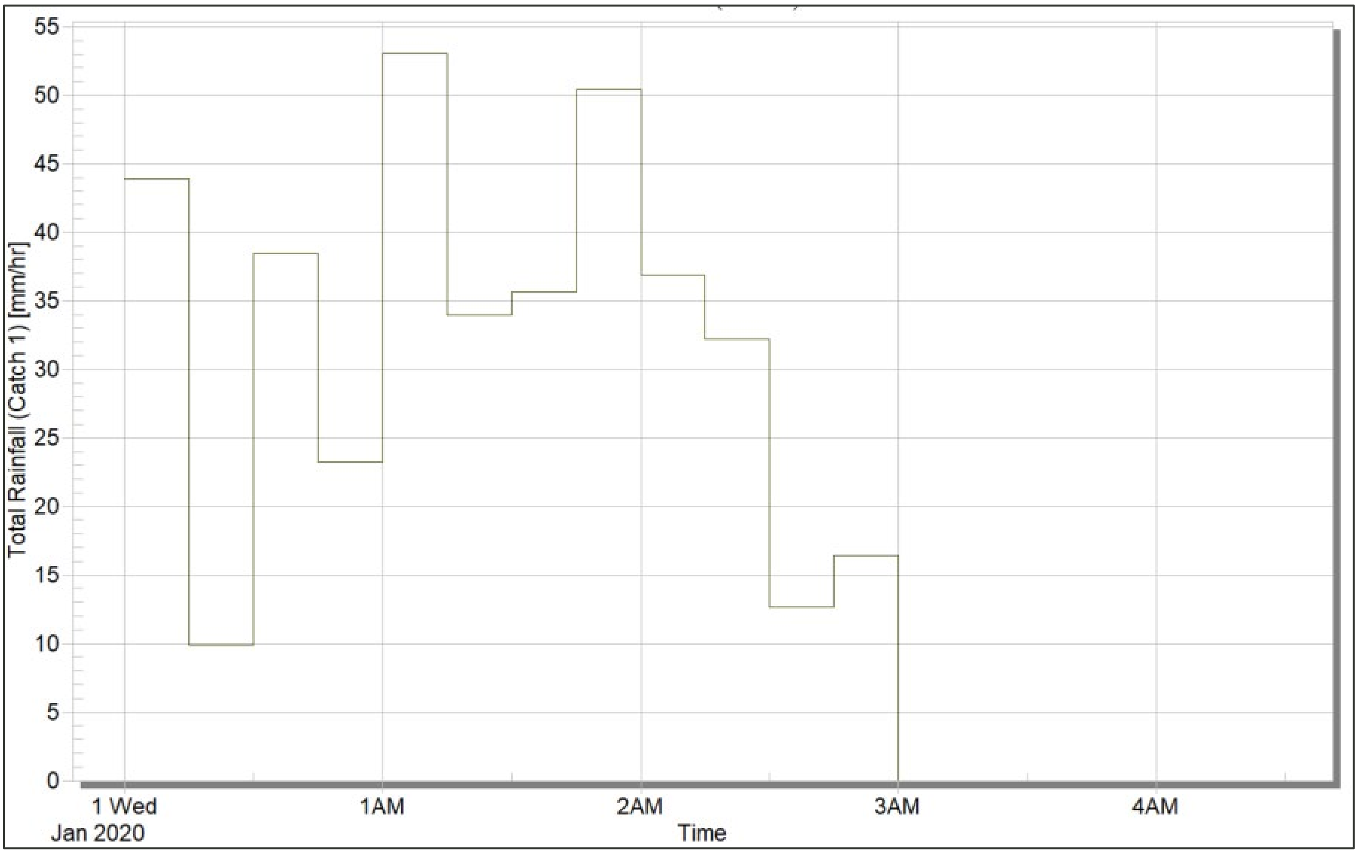

Figure 5-2 Representative single storm event (1% AEP, 3-hour duration, storm number 9)

5.1.2 ARR 1987

The system was also assessed using the 1987 ARR methodology, to ensure compliance under both the established as well as the recently published 2019 methodology. Representative IFD data was sourced from the BOM website (**Figure 5-3**) and input to the XPRAFTS model. The remainder of the simulation model was kept unchanged from the 2019 setup.

RAINFALL INTENSITY IN mm/h FOR VARIOUS DURATIONS AND RETURN PERIODS

RETURN PERIOD (YEARS)

DURATION	1	2	5	10	20	50	100
5 mins	75.9	98.0	127.	144.	166.	195.	218.
6 mins	71.0	91.7	119.	135.	156.	183.	204.
10 mins	58.1	75.0	97.0	110.	127.	149.	166.
20 mins	42.4	54.6	70.5	79.7	91.9	108.	120.
30 mins	34.4	44.3	57.1	64.6	74.5	87.5	97.3
1 hour	23.2	30.0	38.6	43.7	50.4	59.1	65.8
2 hours	15.3	19.7	25.4	28.7	33.1	38.8	43.1
3 hours	11.9	15.3	19.7	22.3	25.6	30.0	33.4
6 hours	7.72	9.94	12.8	14.4	16.6	19.4	21.6
12 hours	4.99	6.44	8.29	9.37	10.8	12.7	14.1
24 hours	3.19	4.13	5.40	6.15	7.13	8.43	9.42
48 hours	1.97	2.57	3.44	3.97	4.65	5.55	6.26
72 hours	1.45	1.90	2.57	2.98	3.51	4.22	4.77

(Raw data: 30.07, 6.45, 1.90, 59.04, 12.59, 4.21,skew= 0.010)
HYDROMETEOROLOGICAL ADVISORY SERVICE
(C) AUSTRALIAN GOVERNMENT, BUREAU OF METEOROLOGY
* ENSURE THE COORDINATES ARE THOSE REQUIRED SINCE DATA IS BASED ON THESE AND NOT LOCATION NAME.

Figure 5-3 BOM 1987 IFD dataset for AWRC site location

All storm events between 30 min and 12 hours in duration were then simulated for the 50%, 5% and 1% AEPs. The simulated rainfall for all selected durations representative of all three AEP events is shown in **Figure 5-4**. An example of a single representative storm is also provided in **Figure 8-3**.

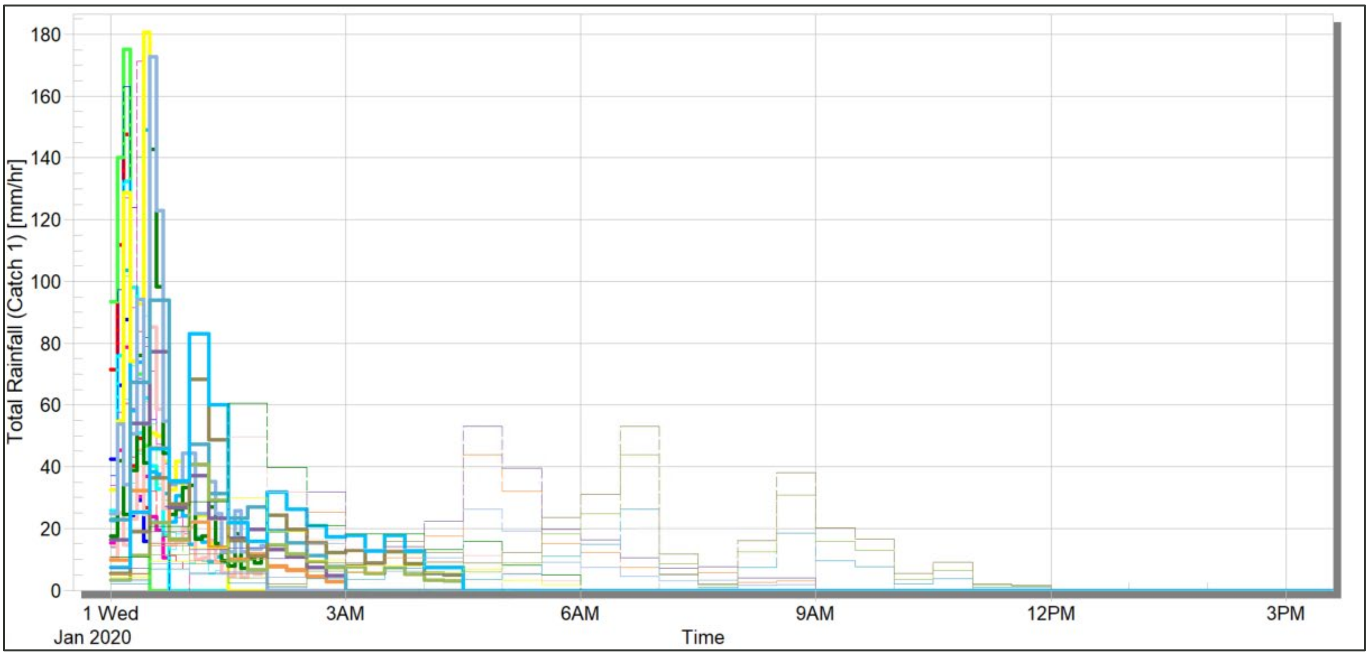

Figure 5-4 Simulated rainfall (All AEP events)

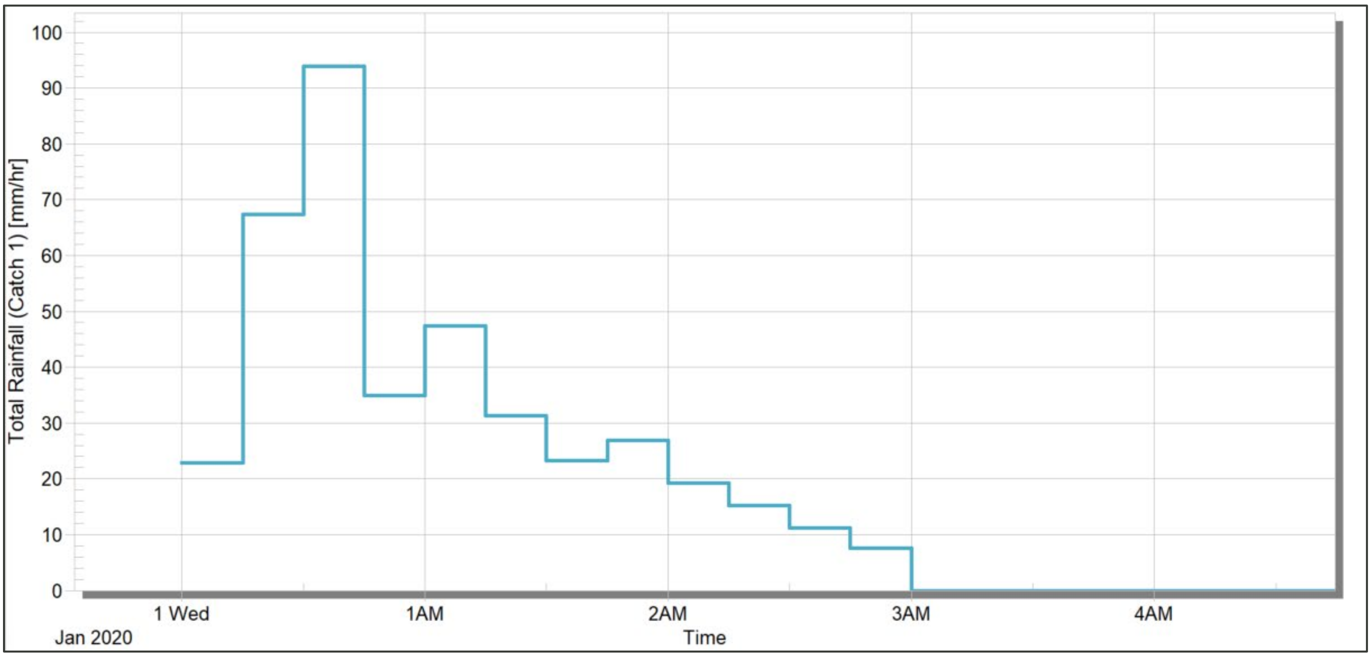

Figure 5-5 Representative single storm event (1% AEP, 3-hour duration)

5.2 Catchment characteristics

The catchment areas and slopes as well as the applied hydrological parameters (roughness, initial and continuing losses) used within the modelling are provided in **Table 5-1**.

The latest guidance on the ARR 2019 data hub provides NSW specific recommendations for rainfall losses to be used in flood investigations. This approach was developed by the NSW Office of Environment and Heritage (OEH) in response to under-estimation of flows being experienced when using standard ARR2019 design event methods with default data from ARR data hub. The OEH guideline adopts a hierarchical approach to loss and pre-burst estimation. The proposed hierarchy prioritises the use of calibration losses for the catchment, if available. Calibrated losses are available for the South Creek catchment from the 2015 Updated South Creek Flood Study (WorleyParsons, 2015), and these values were used within the simulation modelling.

Table 5-1 Land cover for stage 1 and ultimate footprint development

Parameter	Unit	North A	North B	South	Rationale/Data source
Total Area	ha	5.88	6.49	9.90	Site civil design
Impervious portion	%	54	49	63	Site civil design
Slope (Pre-development)	%	0.6	0.65	0.44	Natural drainage slope measured using DEM data
Slope (Post-development)	%	0.5			Site civil design
Manning's n (Pre-development)		0.03			Natural short length grass (conservative)
Manning's n pervious areas (Post-development)		0.028			Cut short length grass (conservative)
Initial loss (Pervious)	mm	37.1			2015 Updated South Creek Flood Study
Continuing loss (Pervious)	mm/hr	0.94			2015 Updated South Creek Flood Study
Initial loss (Impervious)	mm	1			
Continuing loss (Impervious)	mm/hr	0			

6 Pre-development conditions

6.1 North A catchment

Ten (10) representative storms for 14 varying storm durations (25 min to 30 hours) with a 50% AEP were simulated. Only storms with durations of 3 hours or more resulted in runoff being generated. The discharge hydrographs associated with the simulated storm events are shown in **Figure 6-1**.

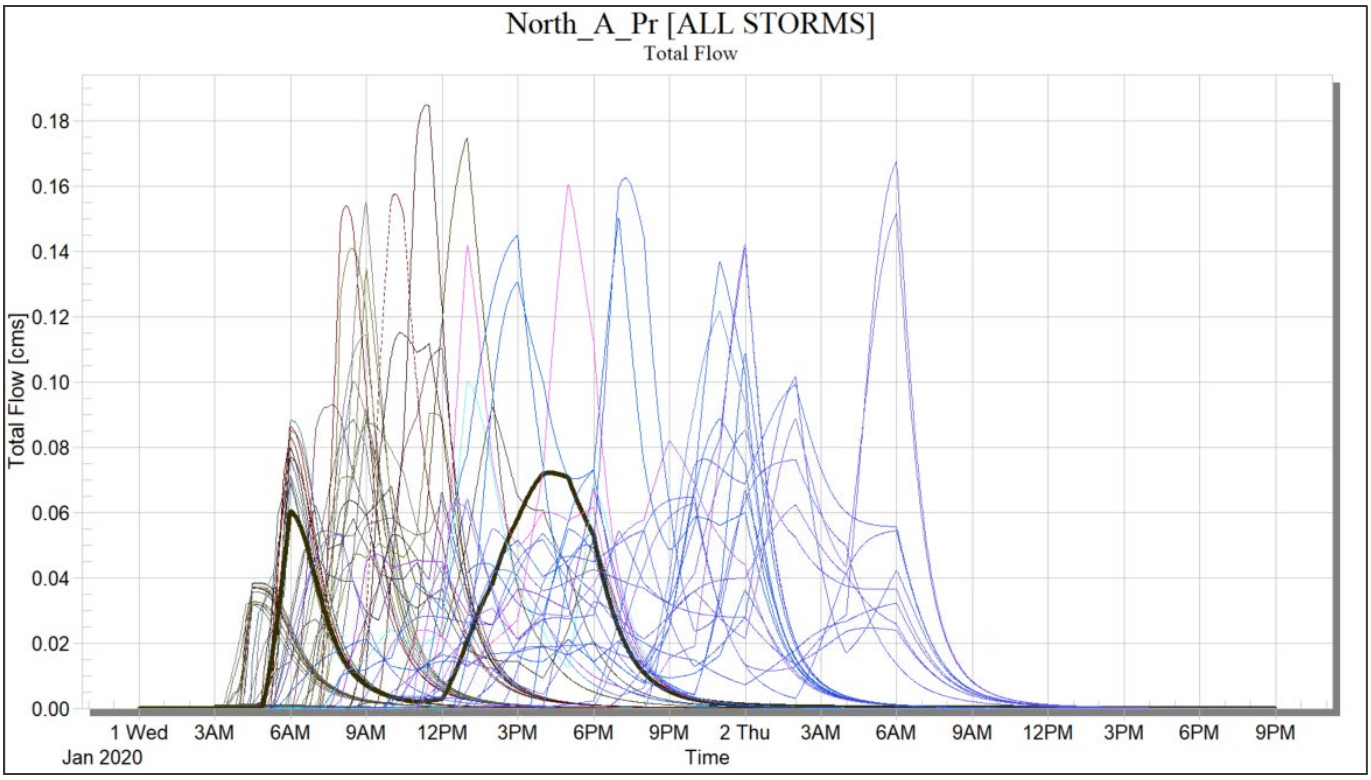

Figure 6-1 Discharge from the North A catchment associated with representative 50% AEP storms

The median peak flow simulated for each duration ensemble (or group of representative storms with the same duration) is presented in **Table 6-1**.

Table 6-1 50% AEP Ensemble storm results (North A)

Duration	Median peak discharge rate (m^3/s)	Median storm
25 min	0	ECS_50pct_25min_1
30 min	0	ECS_50pct_30min_1
45 min	0	ECS_50pct_45min_1
1 hr	0	ECS_50pct_1hr_1
1.5 hr	0	ECS_50pct_1_5hr_1
2 hr	0	ECS_50pct_2hr_1
3 hr	0.001	ECS_50pct_3hr_1
4.5 hr	0.037	ECS_50pct_4_5hr_1

Duration	Median peak discharge rate (m^3/s)	Median storm
6 hr	0.079	ECS_50pct_6hr_8
9 hr	0.104	ECS_50pct_9hr_5
12 hr	0.095	ECS_50pct_12hr_3
18 hr	0.116	ECS_50pct_18hr_10
24 hr	0.130	ECS_50pct_24hr_8
30 hr	0.081	ECS_50pct_30hr_7

The results indicate that the critical storm duration under the set conditions for this catchment is the 24-hr storm, as this results in the highest peak flows. The representative storms for this duration result in a median peak runoff rate of 0.130 m^3/s. This represents the upper limit of the pre-development storm flowrates and post-development peak flow rates should be equal or less than this.

Similar methodologies were followed to determine the critical storm durations as well as the associated median peak runoff rates for the 5% and 1% AEP storm ensembles. These are:

- 5% AEP Median peak discharge rate: 0.327 m^3/s (Storm: ECS_5pct_3hr_6)
- 1% AEP Median peak discharge rate: 0.582 m^3/s (Storm: ECS_1pct_2hr_7)

6.2 North B catchment

Ten (10) representative storms for 14 varying storm durations (25 min to 30 hours) with a 50% AEP were simulated. Only storms with durations of 3 hours or more resulted in runoff being discharged. The discharge hydrographs associated with the simulated storm events are shown in **Figure 6-2**.

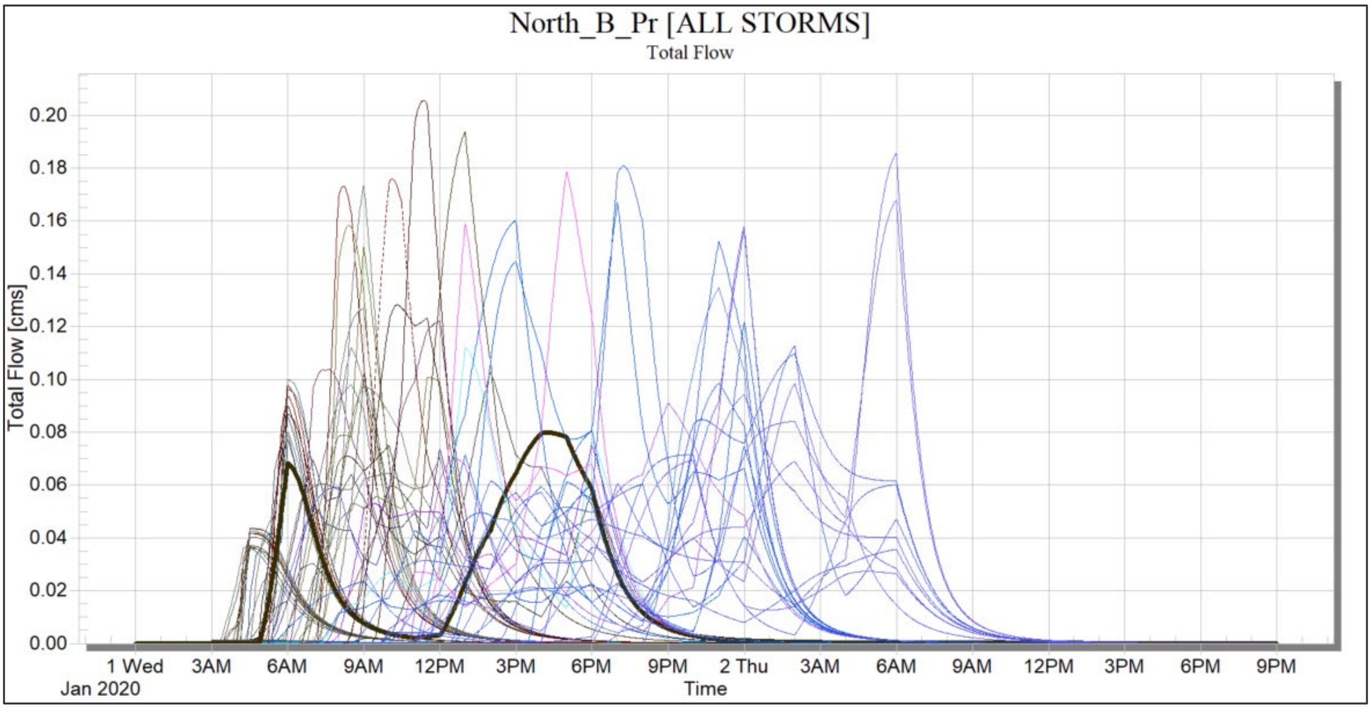

Figure 6-2 Discharge from the North B catchment associated with representative 50% AEP storms

The median peak flow simulated for each duration ensemble is presented in **Table 6-2**.

Table 6-2 50% AEP Ensemble storm results (North B)

Duration	Median peak discharge rate (m^3/s)	Median storm
25 min	0	ECS_50pct_25min_1
30 min	0	ECS_50pct_30min_1
45 min	0	ECS_50pct_45min_1
1 hr	0	ECS_50pct_1hr_1
1.5 hr	0	ECS_50pct_1_5hr_1
2 hr	0	ECS_50pct_2hr_1
3 hr	0.001	ECS_50pct_3hr_1
4.5 hr	0.041	ECS_50pct_4_5hr_1
6 hr	0.089	ECS_50pct_6hr_8
9 hr	0.116	ECS_50pct_9hr_5
12 hr	0.107	ECS_50pct_12hr_3
18 hr	0.129	ECS_50pct_18hr_10
24 hr	0.144	ECS_50pct_24hr_8
30 hr	0.089	ECS_50pct_30hr_7

The results indicate that the critical storm duration under the set conditions for this catchment is the 24-hr storm, as this results in the highest peak flows. The representative storms for this duration result in a median peak runoff rate of 0.144 m^3/s. This represents the upper limit of the pre-development storm flowrates and post-development peak flow rates should be equal or less than this.

Similar methodologies were followed to determine the critical storm durations as well as the associated median peak runoff rates for the 5% and 1% AEP storm ensembles. These are:

- 5% AEP Median peak discharge rate: 0.37 m^3/s (Storm: ECS_5pct_3hr_6)
- 1% AEP Median peak discharge rate: 0.65 m^3/s (Storm: ECS_1pct_2hr_7)

6.3 South catchment

Ten (10) representative storms for 14 varying storm durations (25 min to 30 hours) with a 50% AEP were simulated. Only storms with durations of 3 hours or more resulted in runoff being discharged. The discharge hydrographs associated with the simulated storm events are shown in **Figure 6-3**.

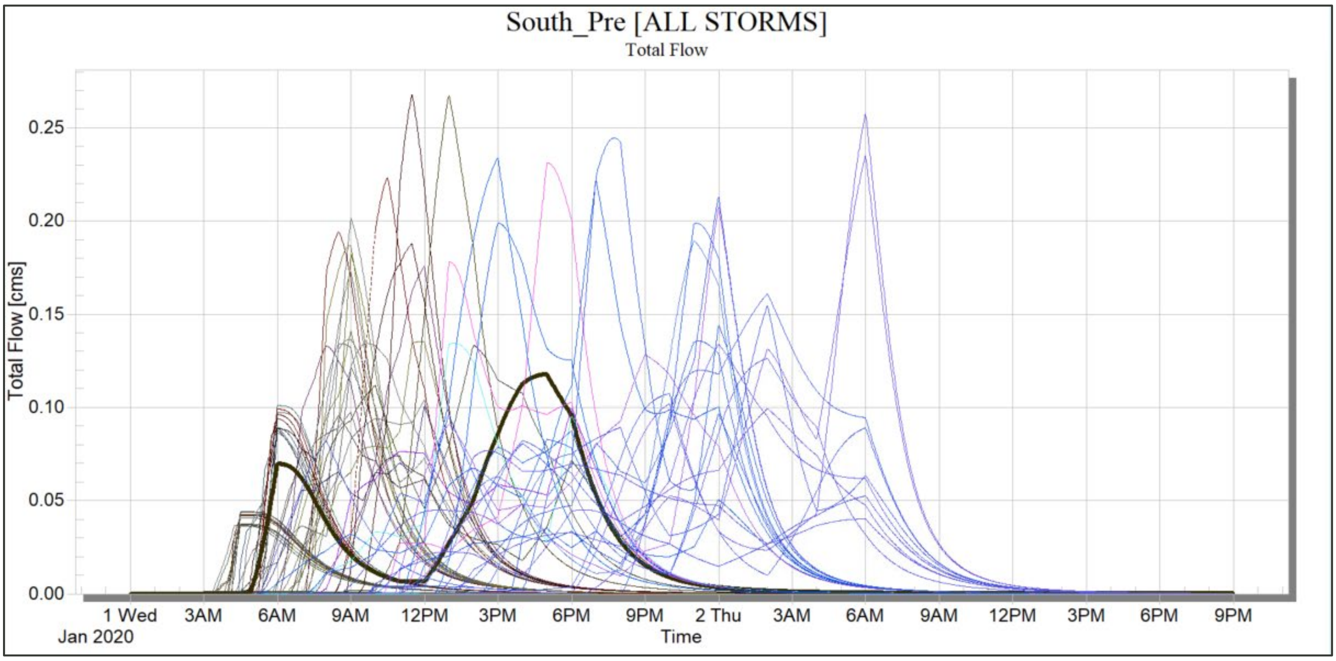

Figure 6-3 Discharge from the South catchment associated with representative 50% AEP storms

The median peak flow simulated for each duration ensemble is presented in **Table 6-3**.

Table 6-3 50% AEP Ensemble storm results (South)

Duration	Median peak discharge rate (m^3/s)	Median storm
25 min	0	ECS_50pct_25min_1
30 min	0	ECS_50pct_30min_1
45 min	0	ECS_50pct_45min_1
1 hr	0	ECS_50pct_1hr_1
1.5 hr	0	ECS_50pct_1_5hr_1
2 hr	0	ECS_50pct_2hr_1
3 hr	0.001	ECS_50pct_3hr_1
4.5 hr	0.042	ECS_50pct_4_5hr_3
6 hr	0.092	ECS_50pct_6hr_8
9 hr	0.157	ECS_50pct_9hr_5
12 hr	0.136	ECS_50pct_12hr_3
18 hr	0.156	ECS_50pct_18hr_8
24 hr	**0.194**	**ECS_50pct_24hr_8**
30 hr	0.130	ECS_50pct_30hr_7

The results indicate that the critical storm duration under the set conditions for this catchment is the 24-hr storm resulting in a median peak runoff rate of 0.194 m^3/s.

Similar methodologies were followed to determine the critical storm durations as well as the associated median peak runoff rates for the 5% and 1% AEP storm ensembles. These are:

- 5% AEP Median peak discharge rate: 0.48 m^3/s (Storm: ECS_5pct_6hr_8)
- 1% AEP Median peak discharge rate: 0.81 m^3/s (Storm: ECS_1pct_3hr_9)

7 Post-development conditions

To represent the post-development conditions with no mitigation measures included, the catchment nodes were adjusted to reflect the new pervious and impervious fractions along with the adjusted drainage slopes. The simulation outcomes with respect to pre- and post-development peak flows for each AEP assessed (with storm durations 10 min to 3 hours) are provided in **Table 7-1**.

Table 7-1 System simulation results summary (ARR 2019)

AEP	Parameter	Unit	North A	North B	South
50%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.130	0.144	0.194
	Peak Discharge Rate (Unmitigated post-development)[1]	m^3/s	0.710	0.704	1.357
5%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.327	0.366	0.477
	Peak Discharge Rate (Unmitigated post-development)[1]	m^3/s	1.487	1.474	2.887
1%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.582	0.649	0.811
	Peak Discharge Rate (Unmitigated post-development)[1]	m^3/s	2.073	2.055	4.007

[1] Peak discharge rate refers to the maximum median flowrate simulated across all storm durations

These results show that under all scenarios simulated the post-development peak flows significantly exceeded the pre-development peak flows, increasing by a factor between 2 and 6. The pre- versus post-development discharge hydrographs for the 1% AEP storm events for all three catchments are presented in **Figure 7-1**, **Figure 7-2** and **Figure 7-3**, indicating a significant shift in the time to peak as well as the actual maximum flow rates expected.

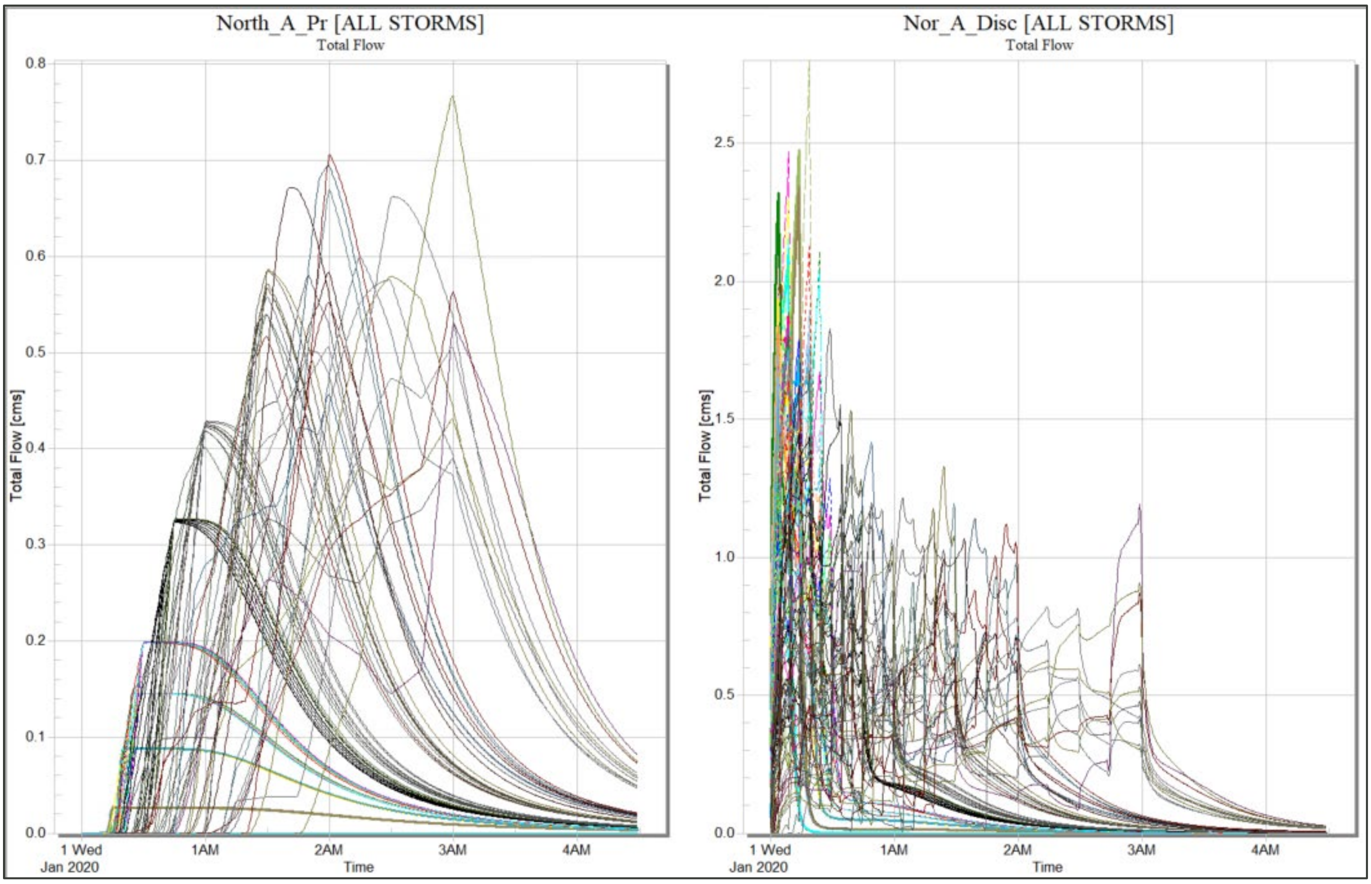

Figure 7-1 North A simulated discharge pre- and post-development (1% AEP, unmitigated)

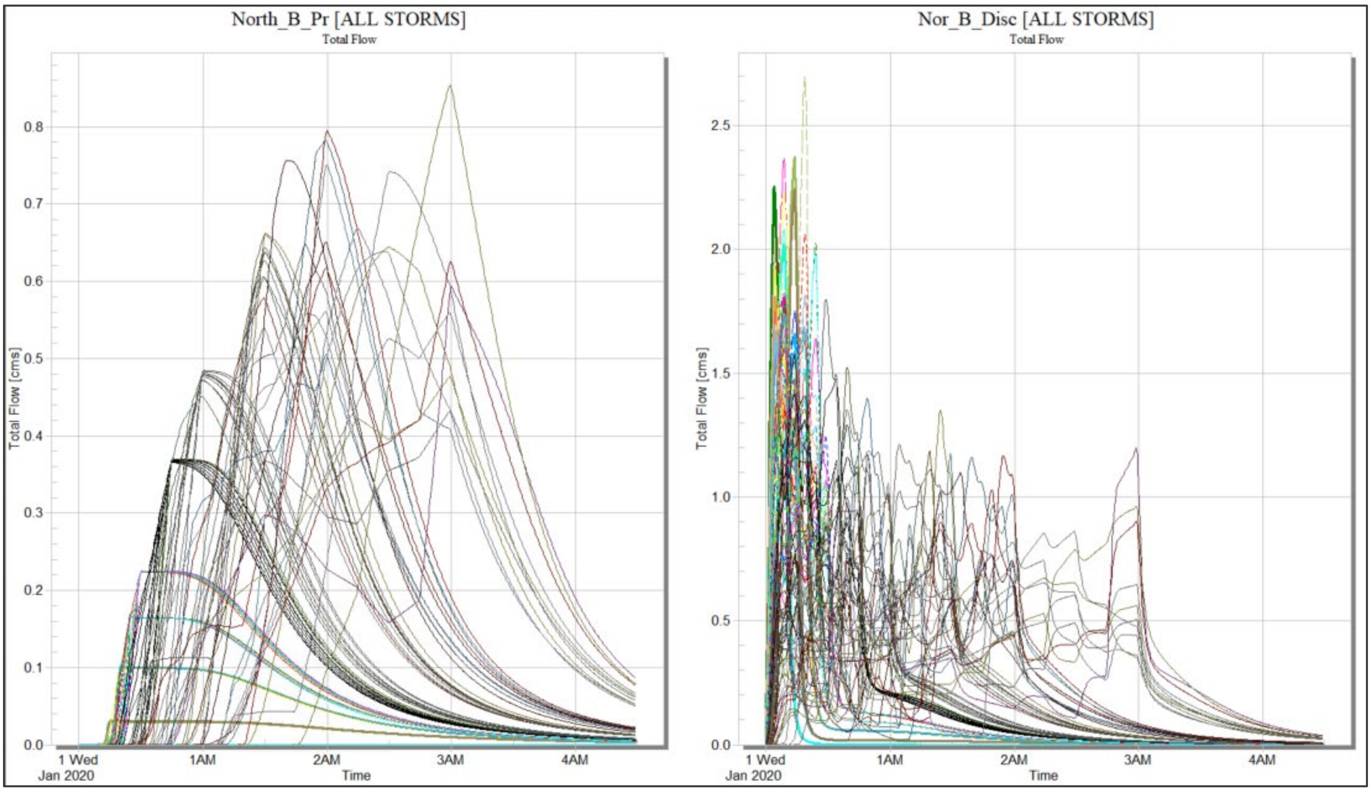

Figure 7-2 North B simulated discharge pre- and post-development (1% AEP, unmitigated)

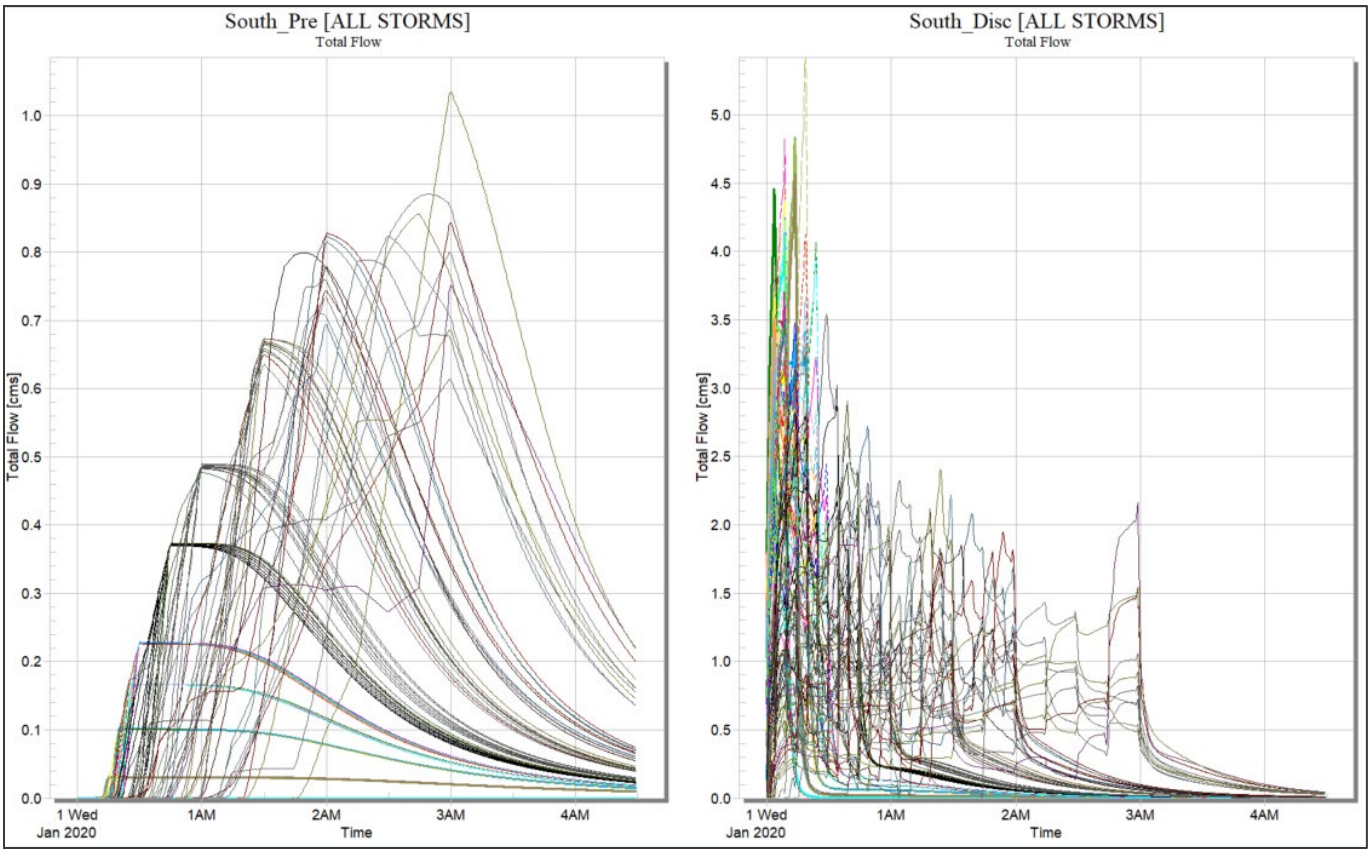

Figure 7-3 South simulated discharge pre- and post-development (1% AEP, unmitigated)

8 Peak discharge management

8.1 Detention basin design

The results in **Section 6** indicate significant increases in unmitigated post-development peak stormwater discharge rates, and thus not meeting the stated council specifications. The incorporation of several on-site detention (OSD) basins has been proposed as a mitigation measure to ensure runoff volumes are detained on site before being released, and thus lower the peak flowrates.

Three OSD basins have been included in the reference design, two on the northern edge of the site (North A and North B basins) and one located west of the site receiving runoff from the southern section (South basin). The proposed OSD footprints are indicated in **Figure 8-1** and **Figure 8-2**, also showing site earthworks platform (0.2 m contours).

The stage-storage relationships associated with the three proposed basins have been determined and are provided in **Figure 8-3**. Council specifications limit the depth of the industrial basins to 1.2 m, which results in the following available active storage volumes associated with each of the three reference OSDs:

- North A: 2,933 m^3
- North B: 3,525 m^3
- South: 5,732 m^3

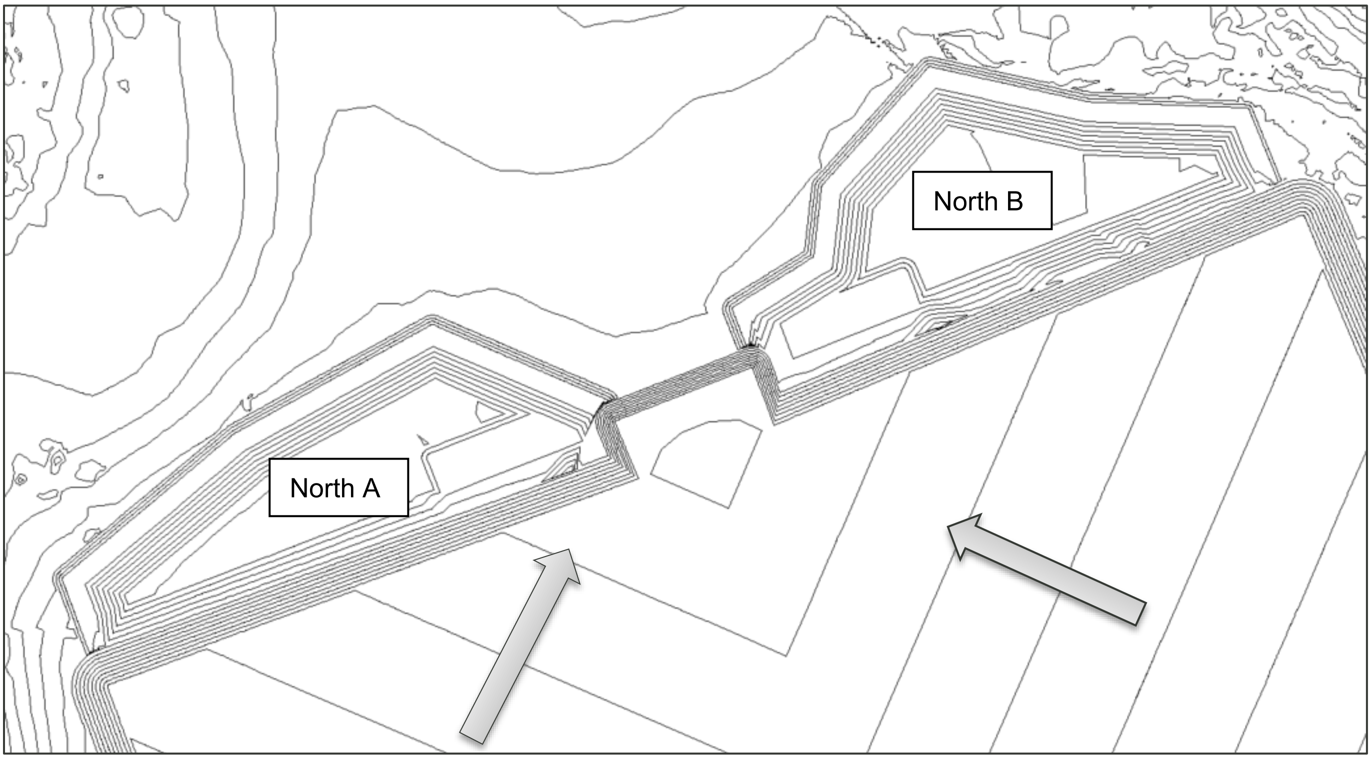

Figure 8-1 Surface elevation profile of Northern OSDs (0.2 m contour intervals)

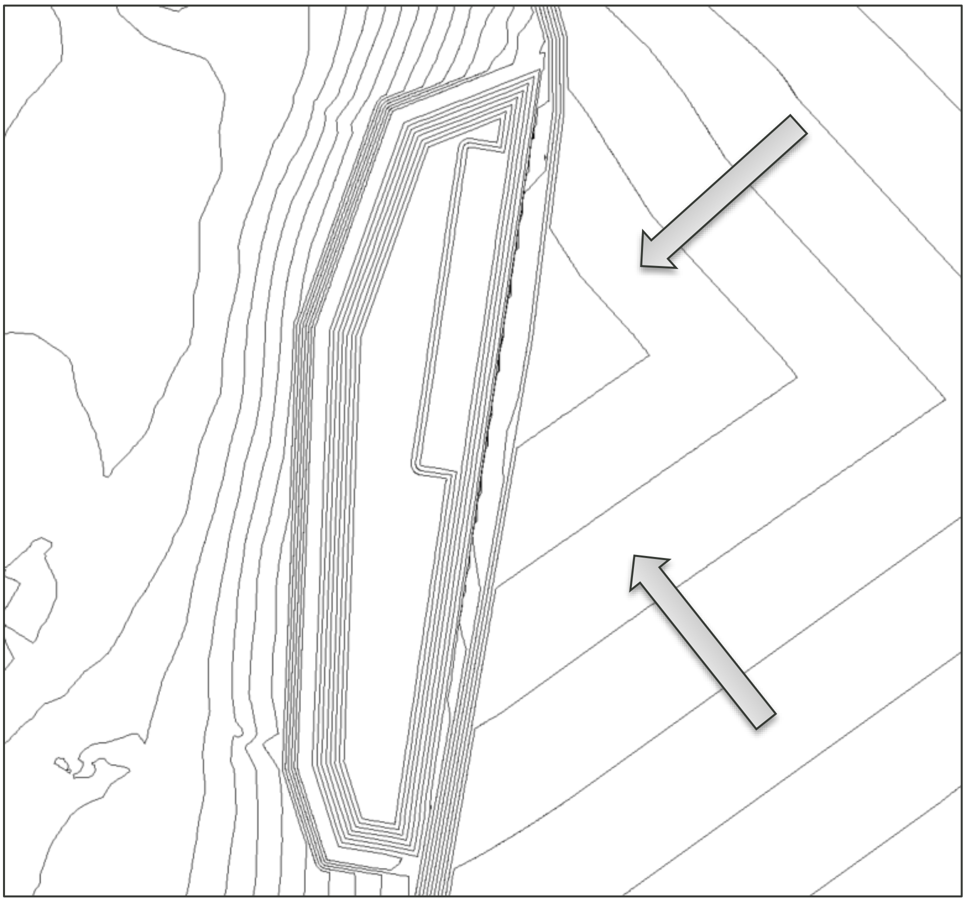

Figure 8-2 Surface elevation profile of South OSD (0.2 m contour intervals)

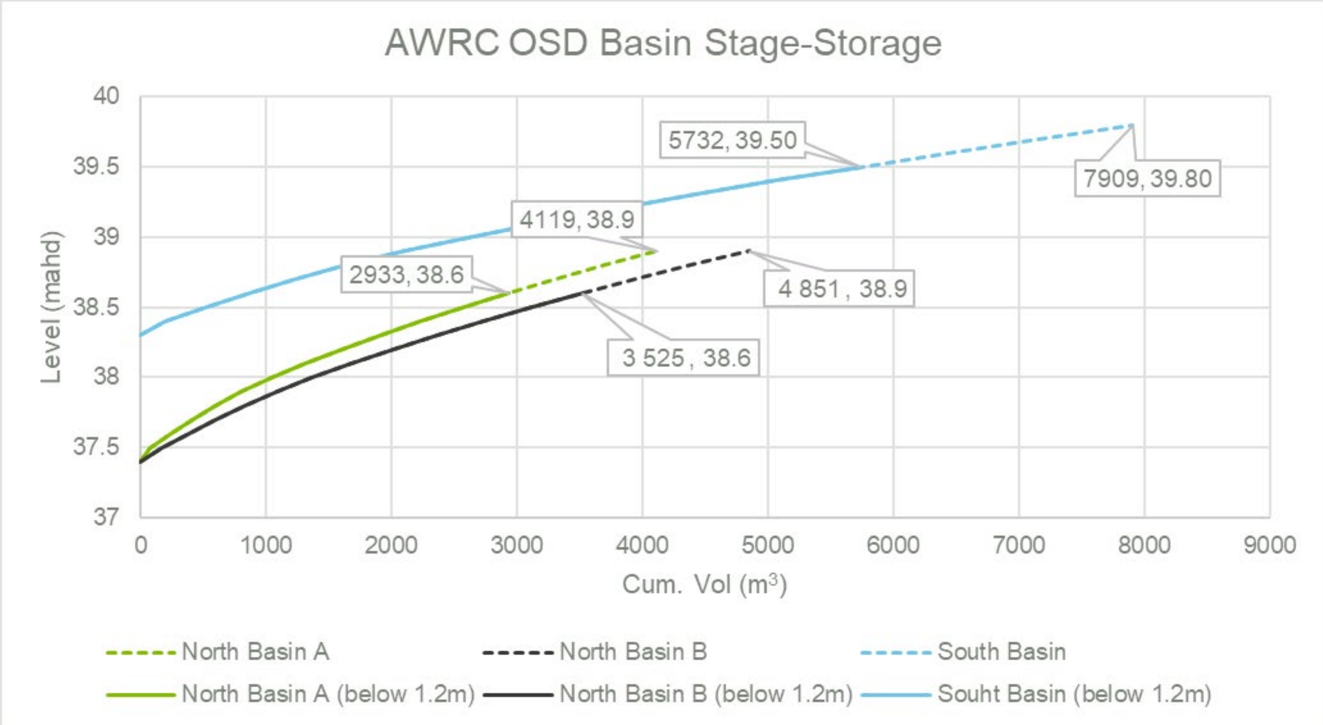

Figure 8-3 Reference design OSDs – Stage-storage relationships

To ensure the post-development peak discharge rates do not exceed the pre-development rates under varying conditions, a multi-outlet system may be required. Such a system will result in stepped variations in the stage-discharge relationship. A conceptual sketch of a multi-outlet system is provided in **Figure 8-4**.

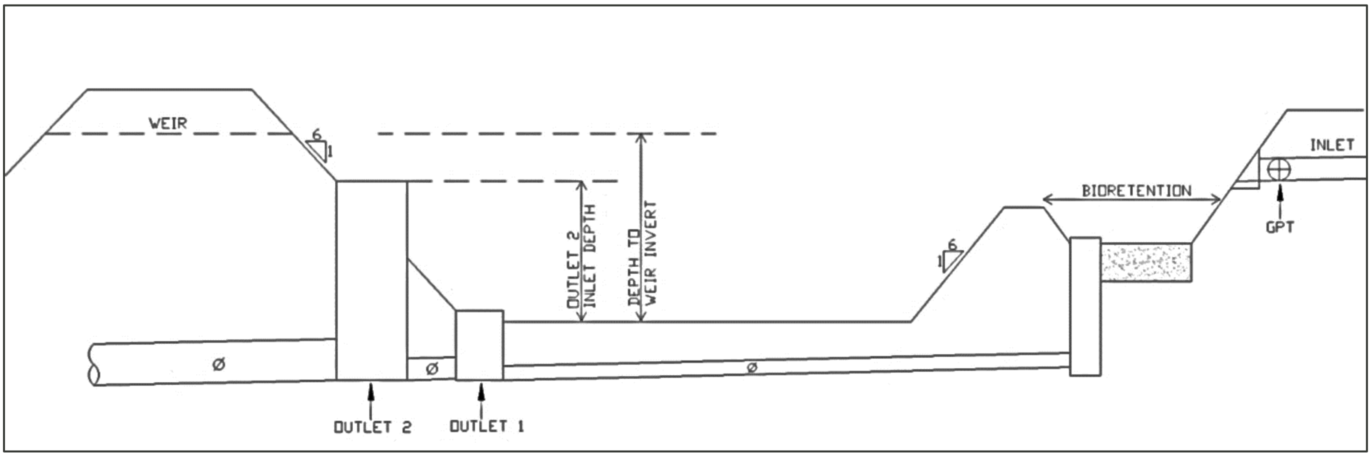

Figure 8-4 Conceptual OSD sketch with proposed discharge arrangement

The stage-discharge relationships for various combinations of outlet diameters were then developed to use as an input to the XPRAFTS system modelling and determine if a feasible combination would result in sufficiently controlling the discharge subjected to the 1%, 5% and 50% AEP storm ensembles. An example of such a relationship is provided in **Figure 8-5**. As the water level in the basin rises the discharge rate is controlled by the following features:

1. Outlet 1 diameter
2. Outlet 2 “inlet weir” overflow rate
3. Outlet 2 diameter

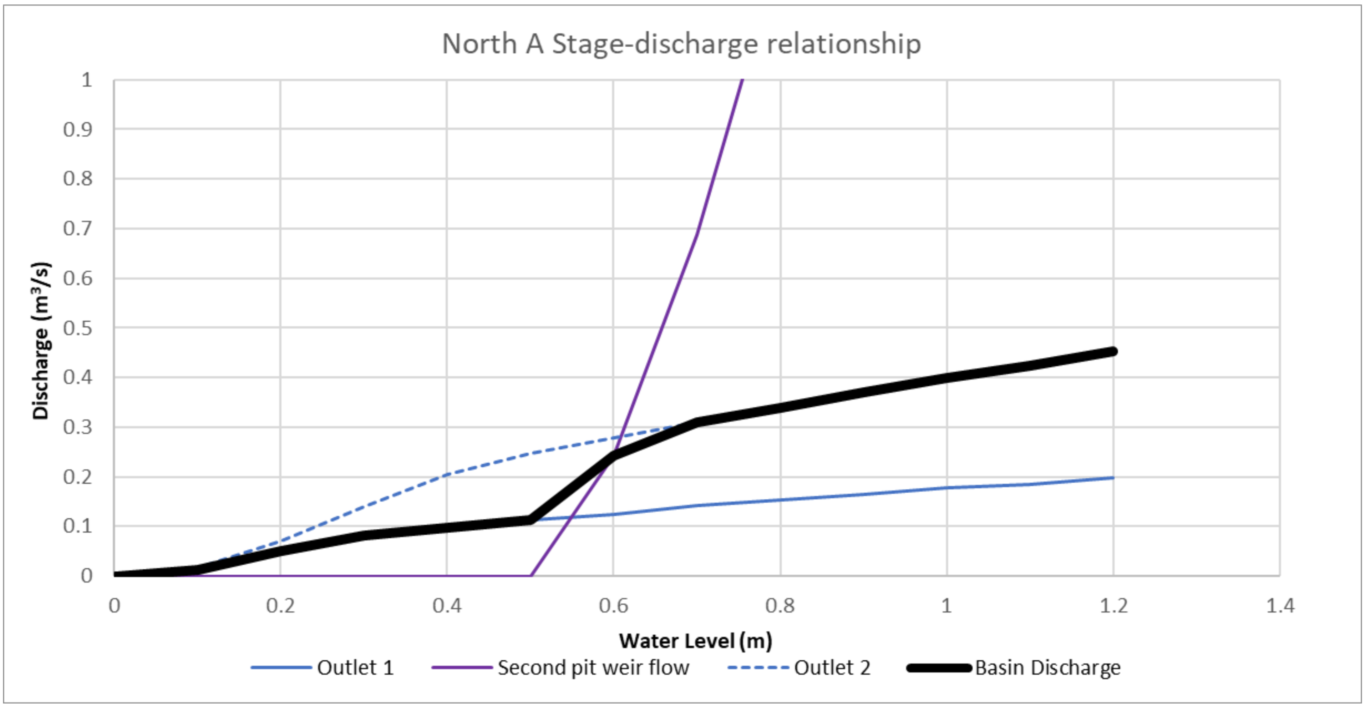

Figure 8-5 Example stage-discharge relationship (North A)

A set of outlet diameters and invert levels were determined for each OSD which would result in acceptable discharge rates across all simulated conditions, these are provided in **Section 8.2**.

8.2 Discharge assessment

To represent the post-development conditions and system the catchment nodes were adjusted to reflect the new pervious and impervious fractions along with the adjusted drainage slopes. Detention basins were added and sized according to the reference design geometrics (**Section 8.1**) and various iterations of outlet pipe sizes and levels were tested to assess the feasibility of the current reference design.

A feasible set of infrastructure sizing and locations was identified, and these specifications are provided in **Table 8-1**. The simulation outcomes with respect to pre and post-development peak flows as well as maximum volumes contained in storage for all three basins and for each AEP assessed are provided in **Table 8-2**. These results show that under all conditions simulated the post-development peak flows do not exceed the pre-development peak flows. The simulated water levels in the basins never rise above 1 m, thus achieving the council maximum depth criteria.

Table 8-1 Feasible multi-outlet system design specifications

Parameter	Unit	North A	North B	South
Outlet 1 diameter	mm	300	450	375
Outlet 2 diameter	mm	450	600	525
Outlet 2 inlet depth	m	0.5	0.5	0.5
Depth to weir invert	m	0.9	0.9	0.9
Weir width	m	2	2	2

Table 8-2 System simulation results summary (ARR 2019)

AEP	Parameter	Unit	North A	North B	South
50%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.130	0.144	0.194
	Peak Discharge Rate (Mitigated post-development)[1]	m^3/s	0.097	0.130	0.155
	Max water level in OSD	m	0.38	0.29	0.42
	Max vol in OSD	m^3	566	580	1,322
5%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.327	0.366	0.477
	Peak Discharge Rate (Mitigated post-development)[1]	m^3/s	0.286	0.266	0.427
	Max water level in OSD	m	0.67	0.56	0.73
	Max vol in OSD	m^3	1,243	1,251	2,840
1%	Peak Discharge Rate (Pre-development)[1]	m^3/s	0.582	0.649	0.811
	Peak Discharge Rate (Mitigated post-development)[1]	m^3/s	0.386	0.552	0.570
	Max water level in OSD	m	0.921	0.725	0.961
	Max vol in OSD	m^3	1,979	1,766	4,180

[1] Peak discharge rate refers to the maximum median flowrate simulated across all storm durations

Hydrographs and associated simulated data for each basin and for all post-development critical storm events are provided in **Figure 8-6** through **Figure 8-14**. The upper timeseries data sets (blue and red lines) indicated the total and excess rainfall, the middle hydrographs represent the basin water level and volume in storage over time and the bottom set indicates the runoff flowrates entering the OSD with the red dashed line (“Total Flow”) along with the outflow rates, thin pink line (“Channel and Pipe (ds)”).

Comparative graphs for the 1% critical storm events for each basin are provided in **Figure 8-15** through **Figure 8-17**. These graphs indicate smaller peak flows post-development as well as little change in the actual timing of the peak flow occurring.

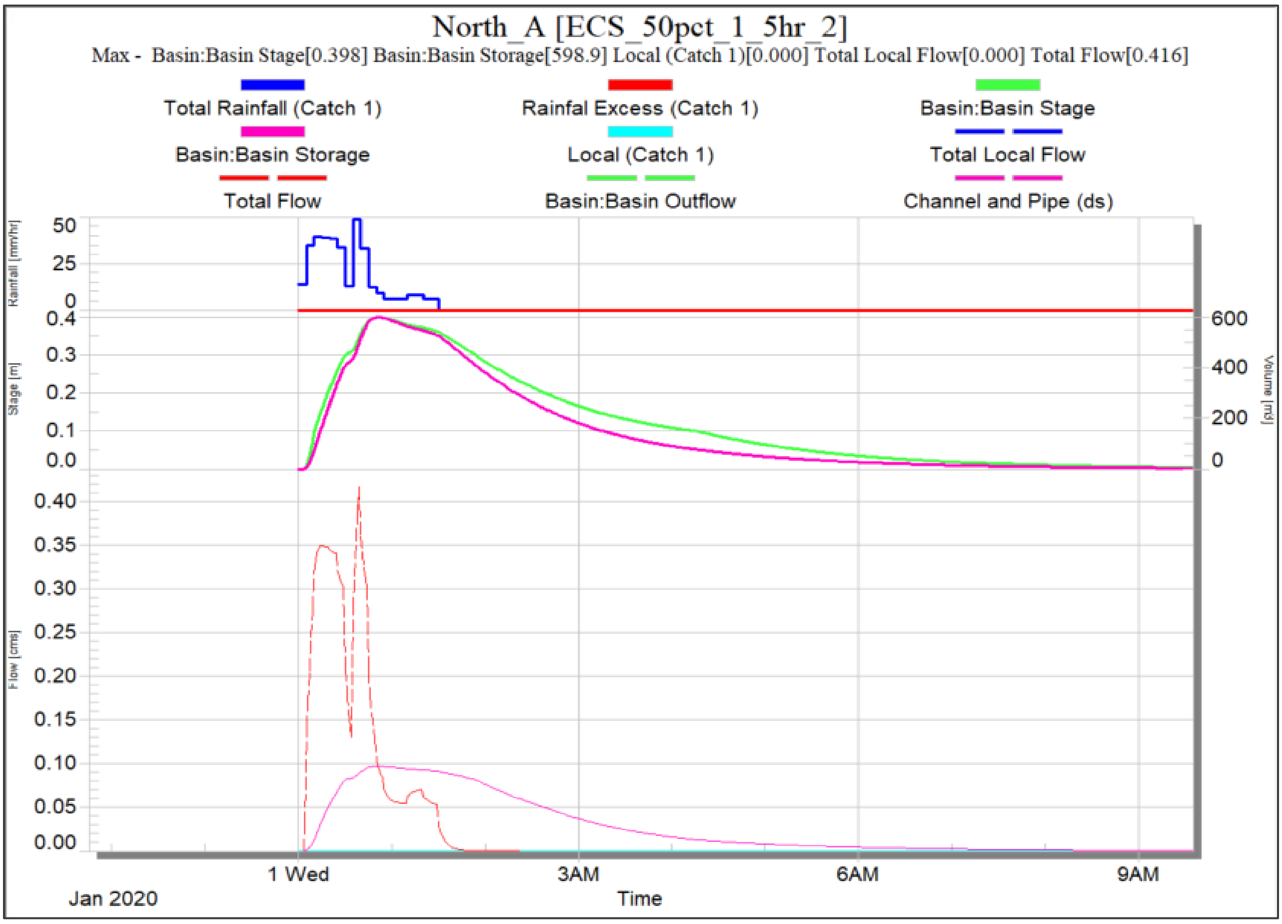

Figure 8-6 North A OSD simulation results for critical storm (50% AEP)

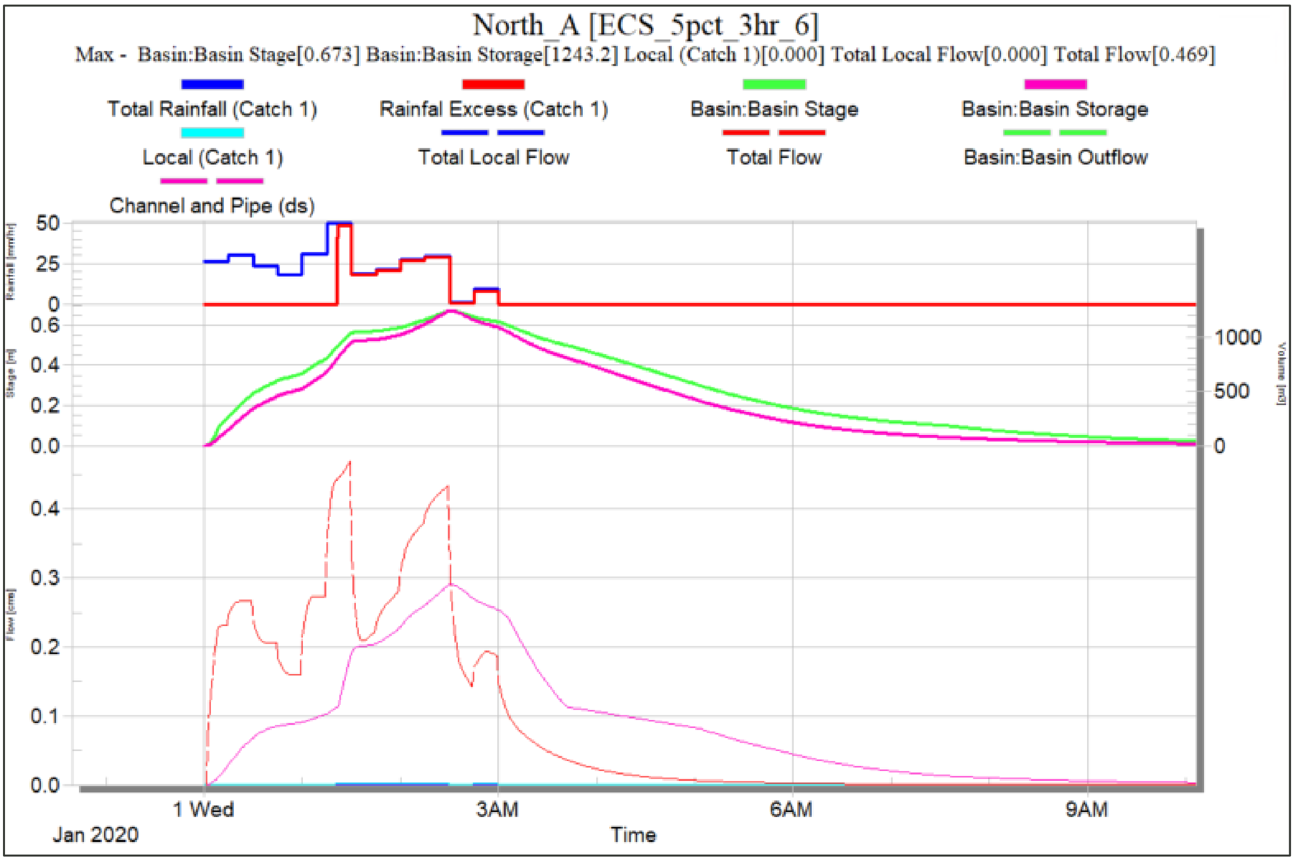

Figure 8-7 North A OSD simulation results for critical storm (5% AEP)

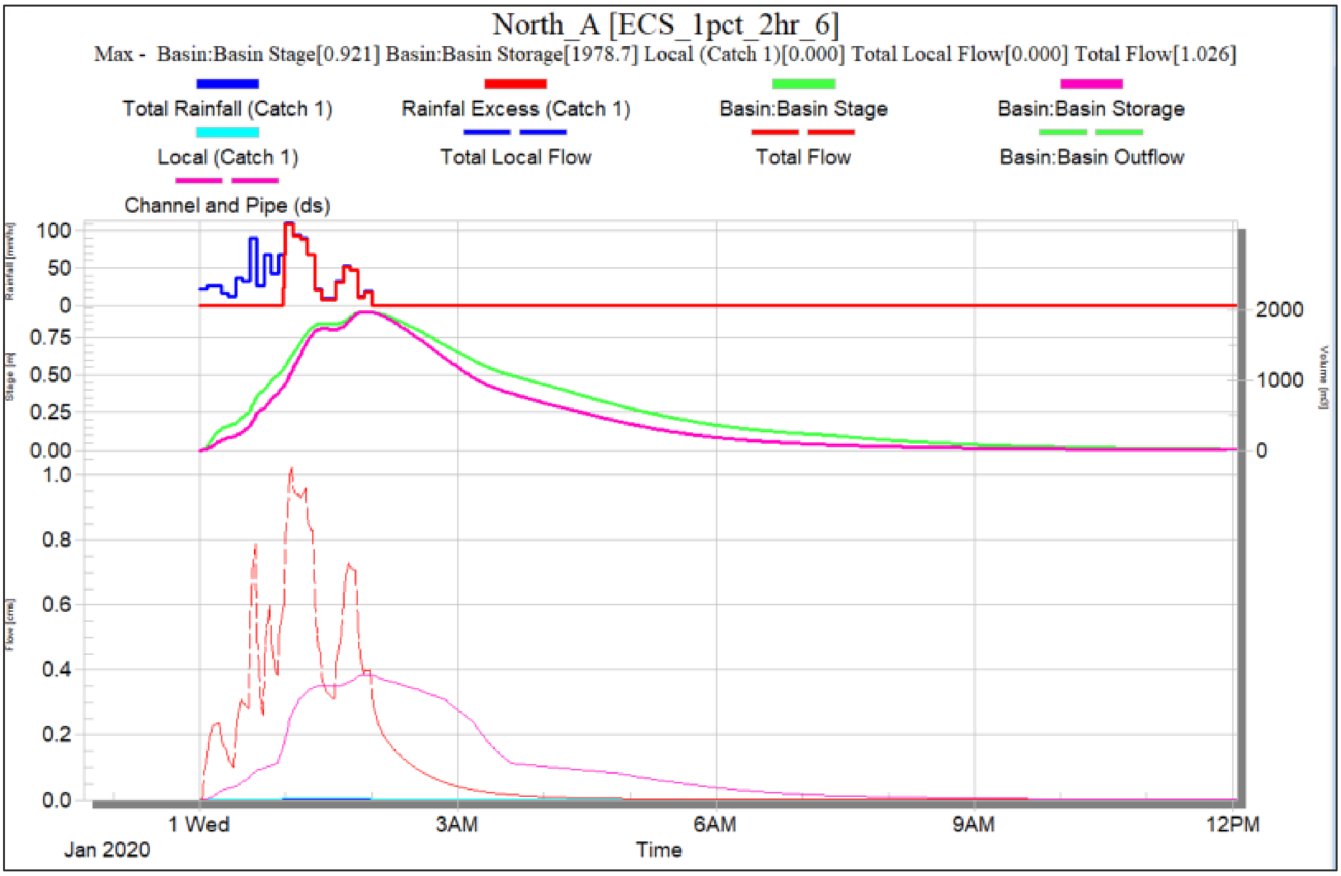

Figure 8-8 North A OSD simulation results for critical storm (1% AEP)

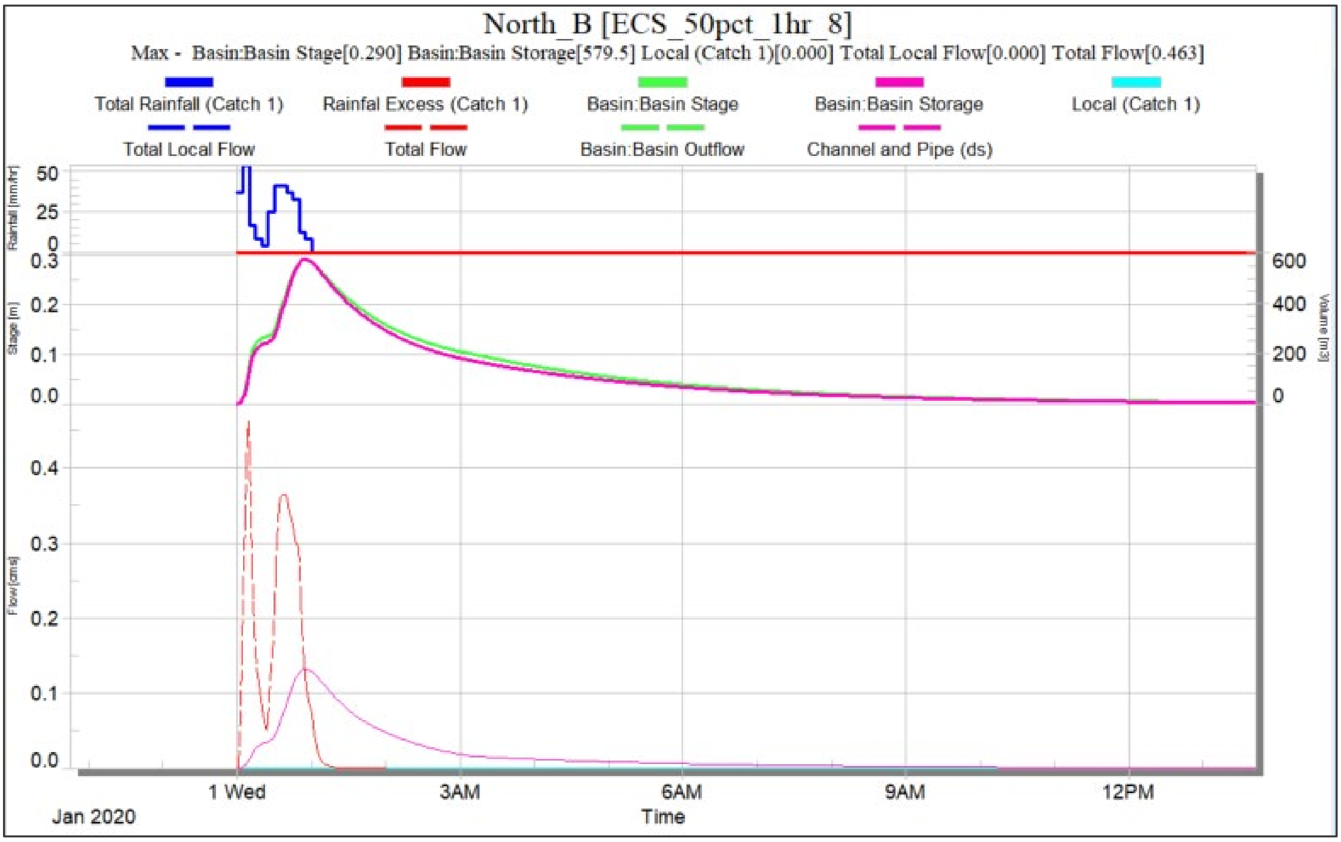

Figure 8-9 North B OSD simulation results for critical storm (50% AEP)

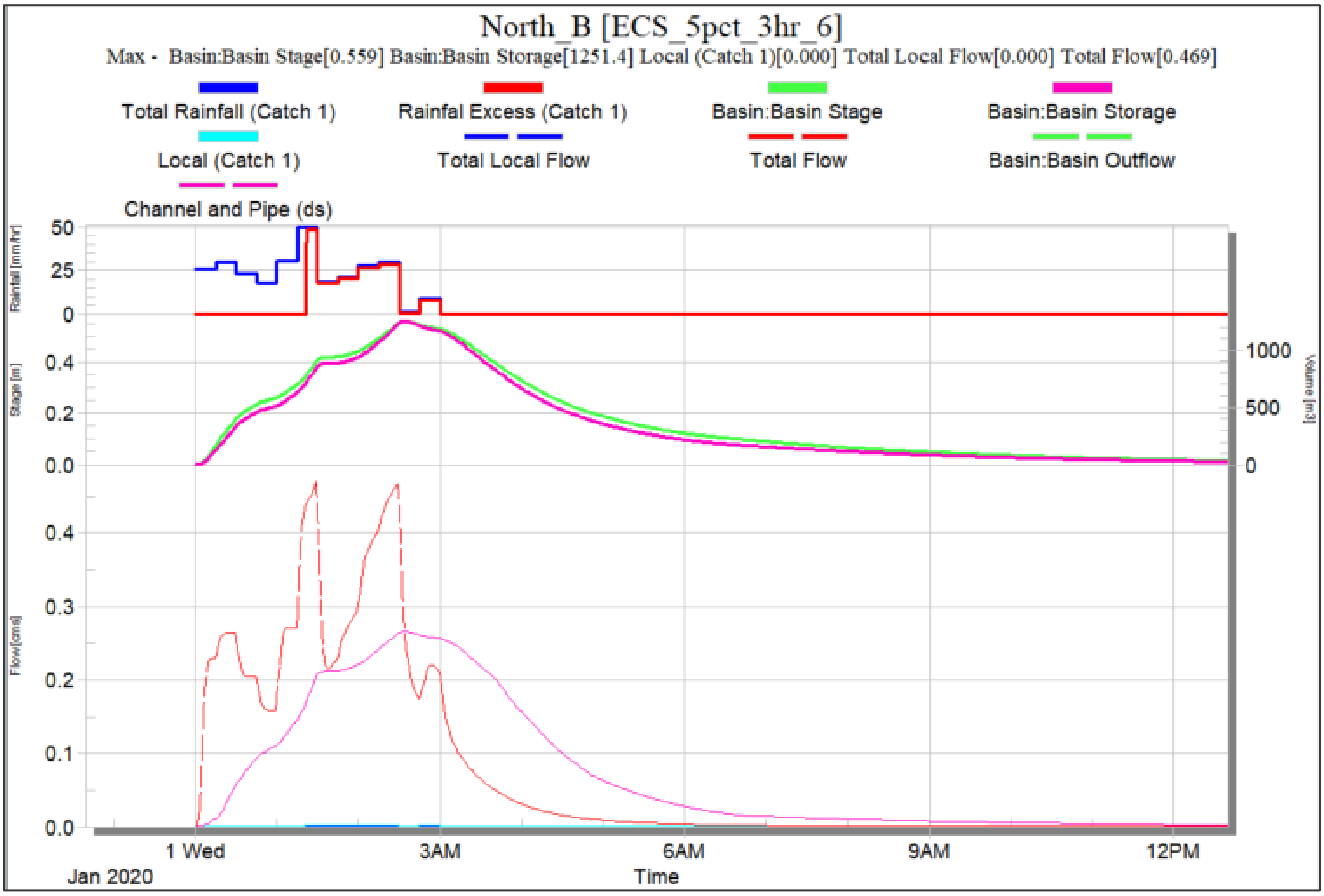

Figure 8-10 North B OSD simulation results for critical storm (5% AEP)

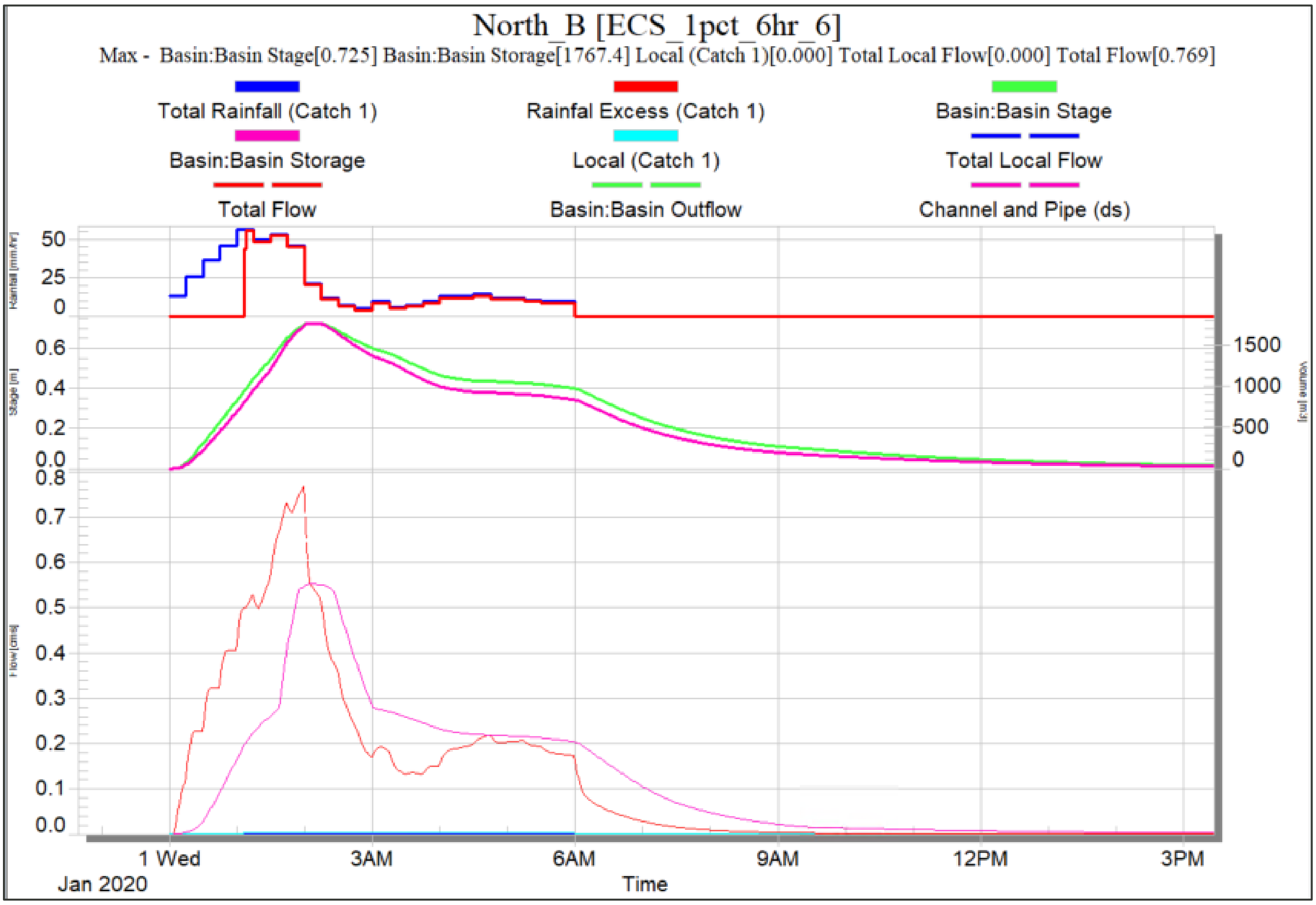

Figure 8-11 North B OSD simulation results for critical storm (1% AEP)

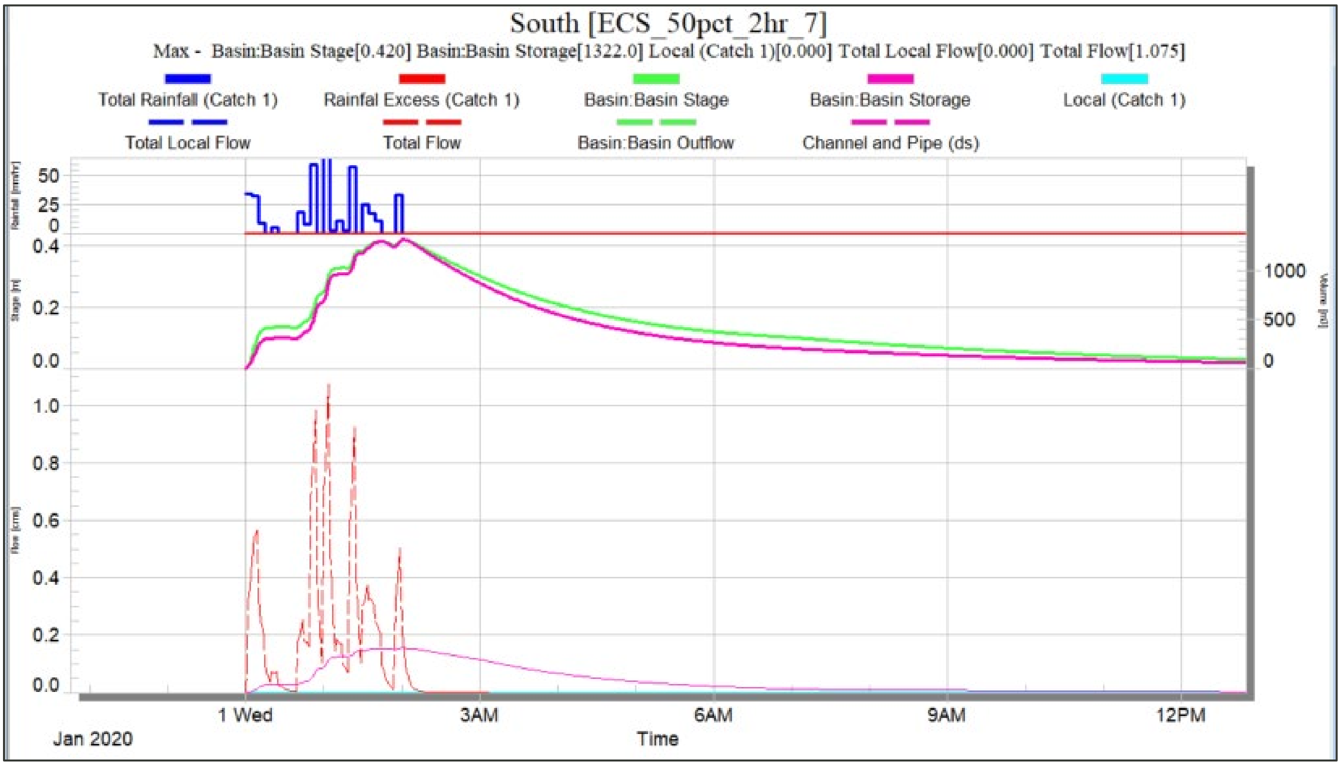

Figure 8-12 South OSD simulation results for critical storm (50% AEP)

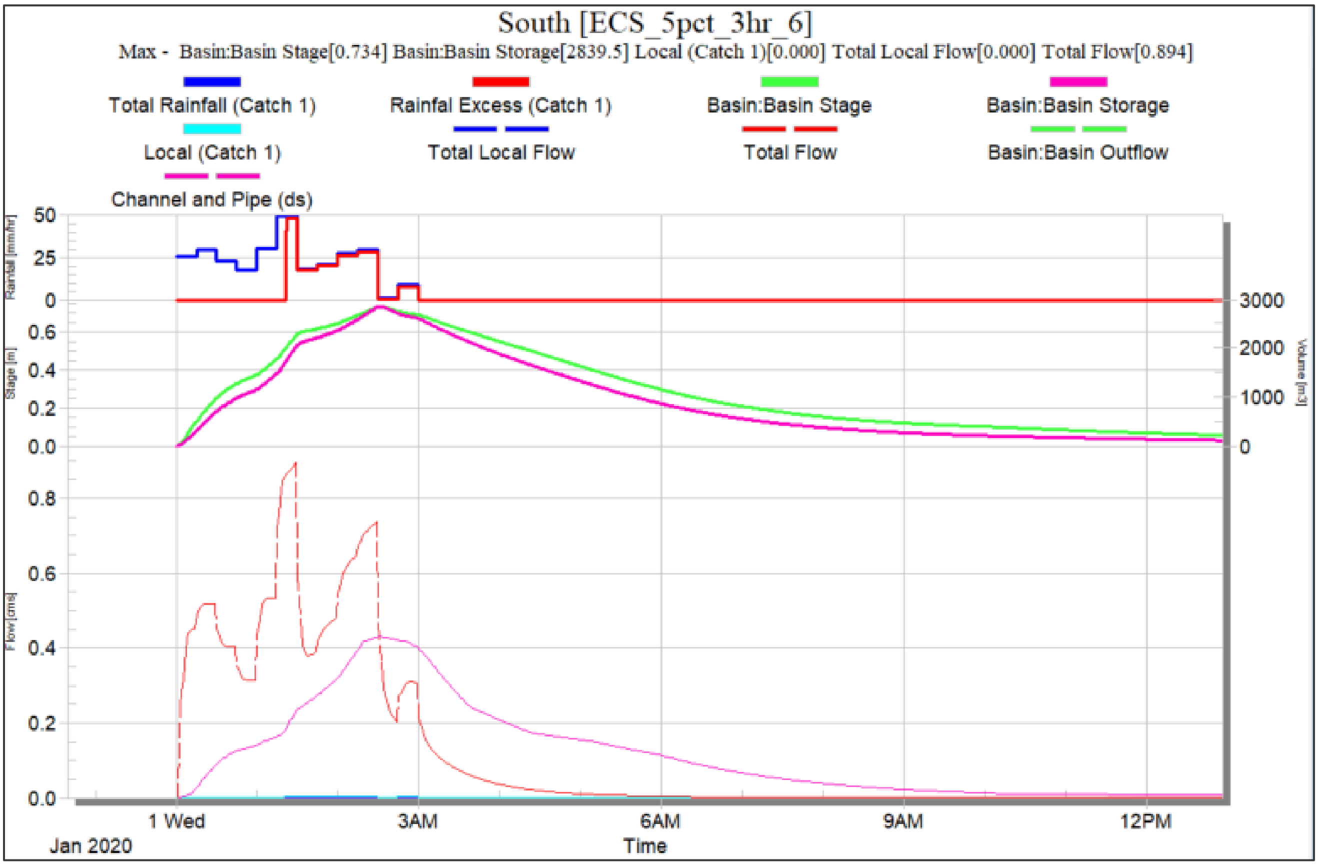

Figure 8-13 South OSD simulation results for critical storm (5% AEP)

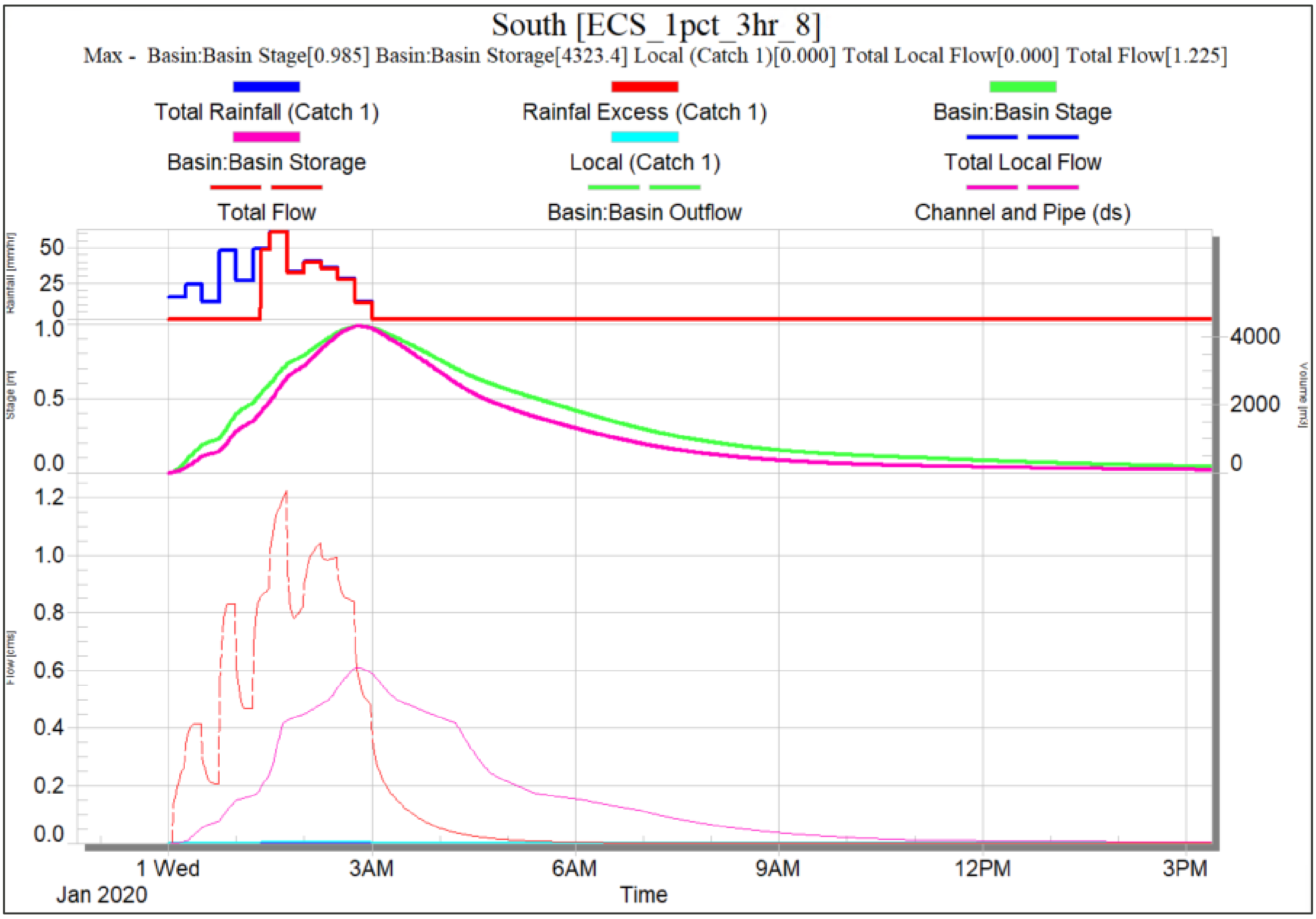

Figure 8-14 South OSD simulation results for critical storm (1% AEP)

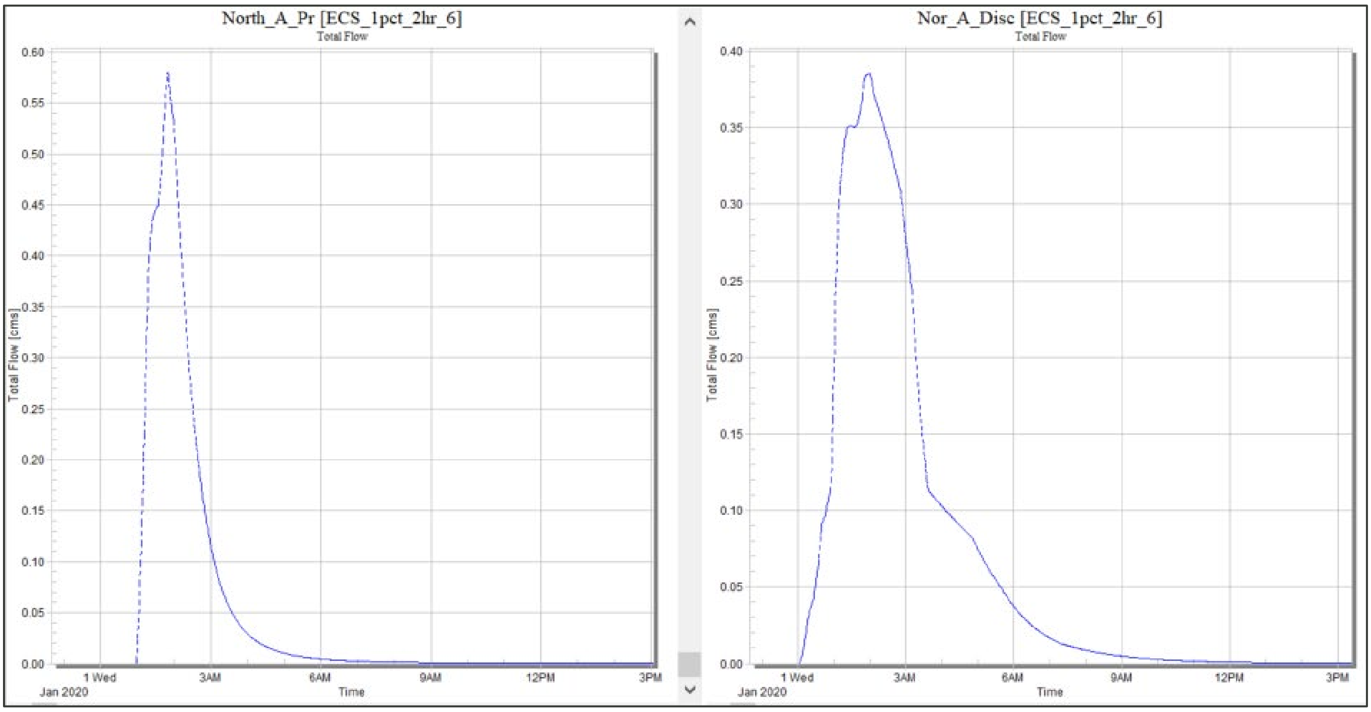

Figure 8-15 Post-development critical storm discharge comparison to pre-development (North A: 1% AEP)

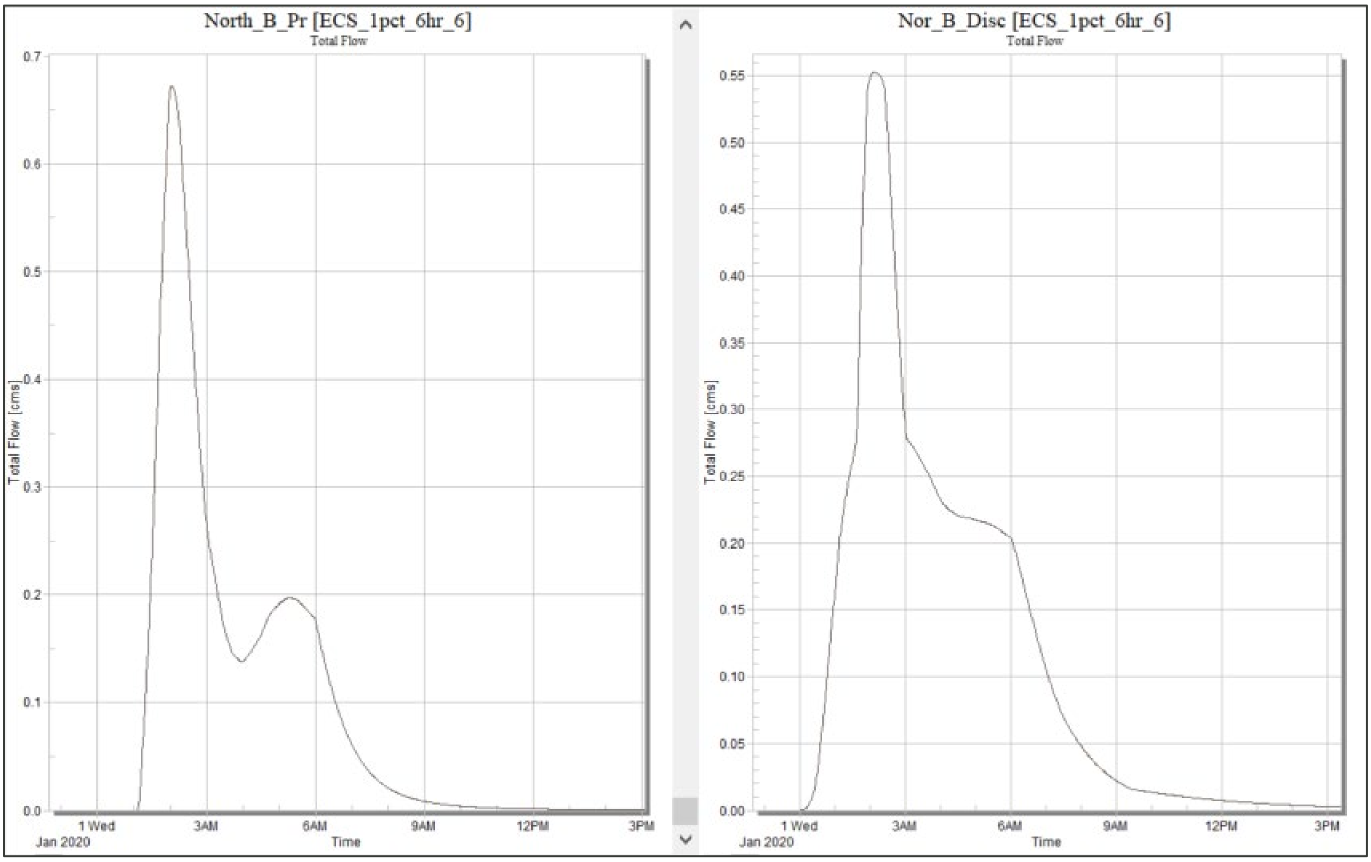

Figure 8-16 Post-development critical storm discharge comparison to pre-development (North B: 1% AEP)

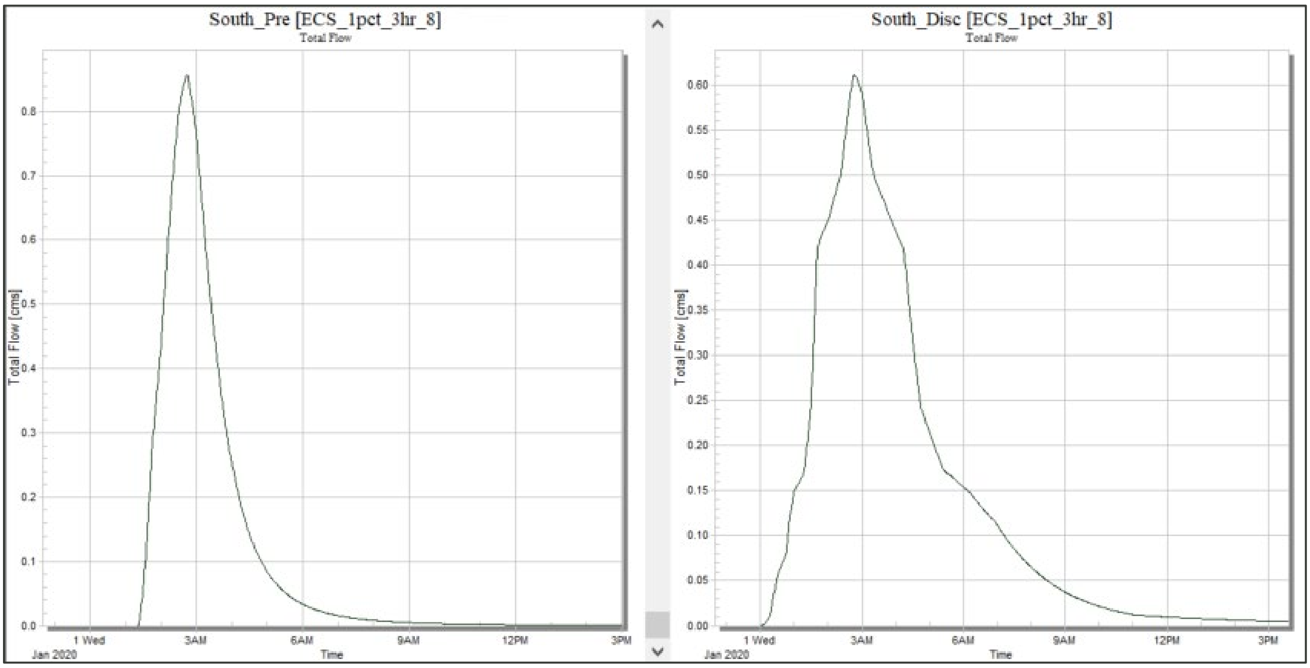

Figure 8-17 Post-development critical storm discharge comparison to pre-development (South: 1% AEP)

9 Comparison to 1987 ARR

The system was also tested using the 1987 ARR methodology, to ensure compliance under both the established as well as the recently published 2019 methodology. The resultant pre- and post-development discharge hydrographs are shown in **Figure 9-1, Figure 9-2** and **Figure 9-3** for the North A, North B and South OSD respectively.

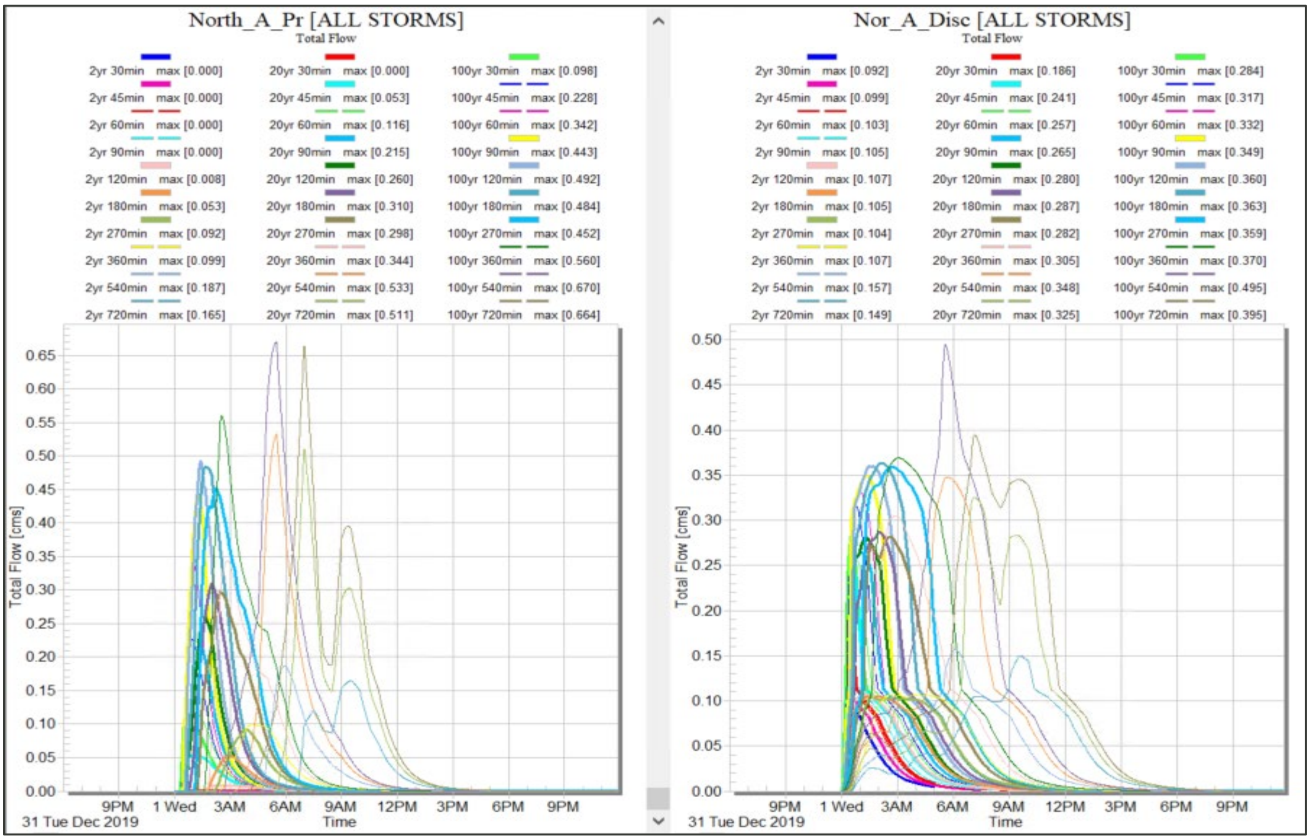

Figure 9-1 North A simulated discharge pre- and post-development

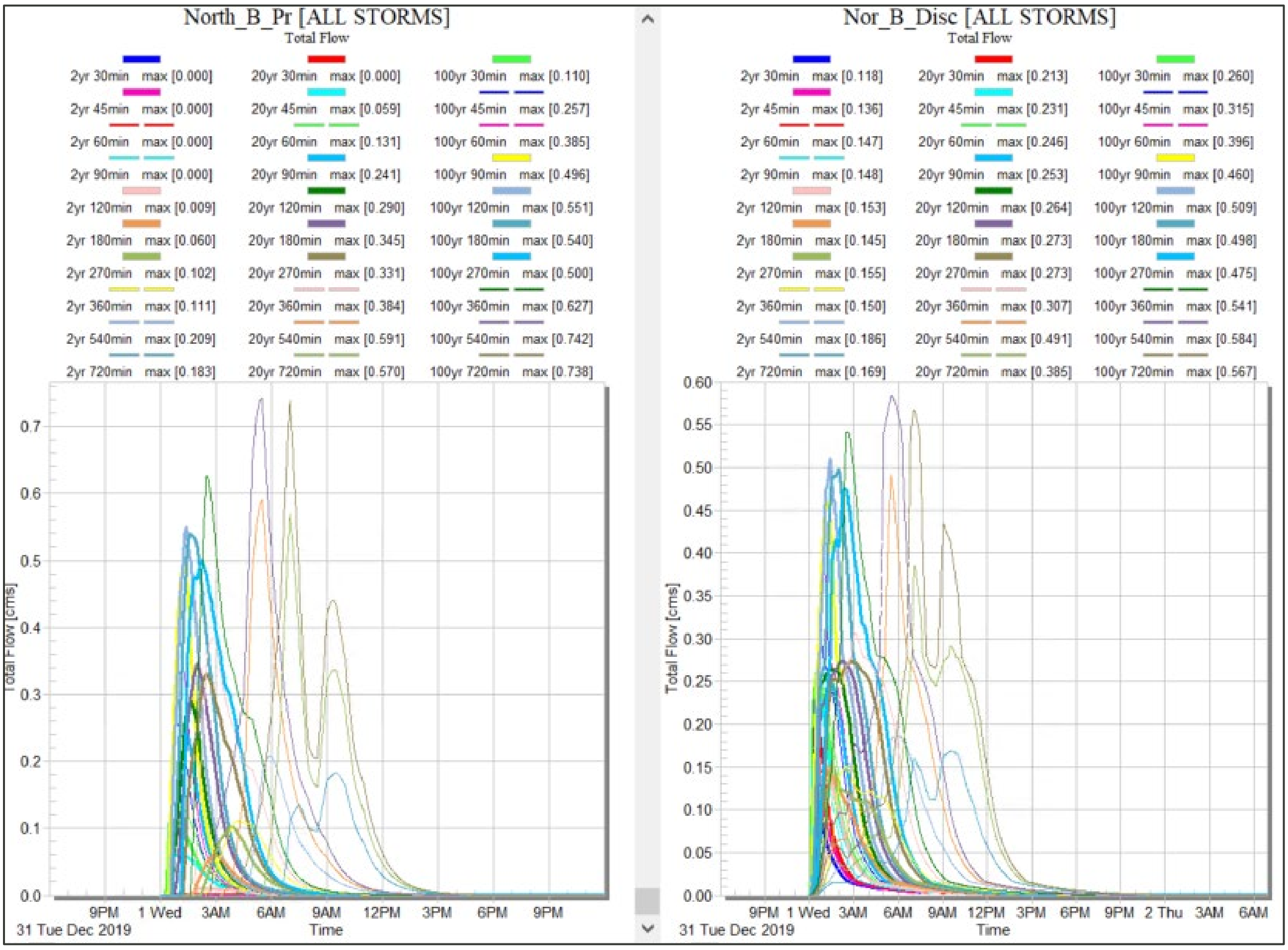

Figure 9-2 North B simulated discharge pre- and post-development

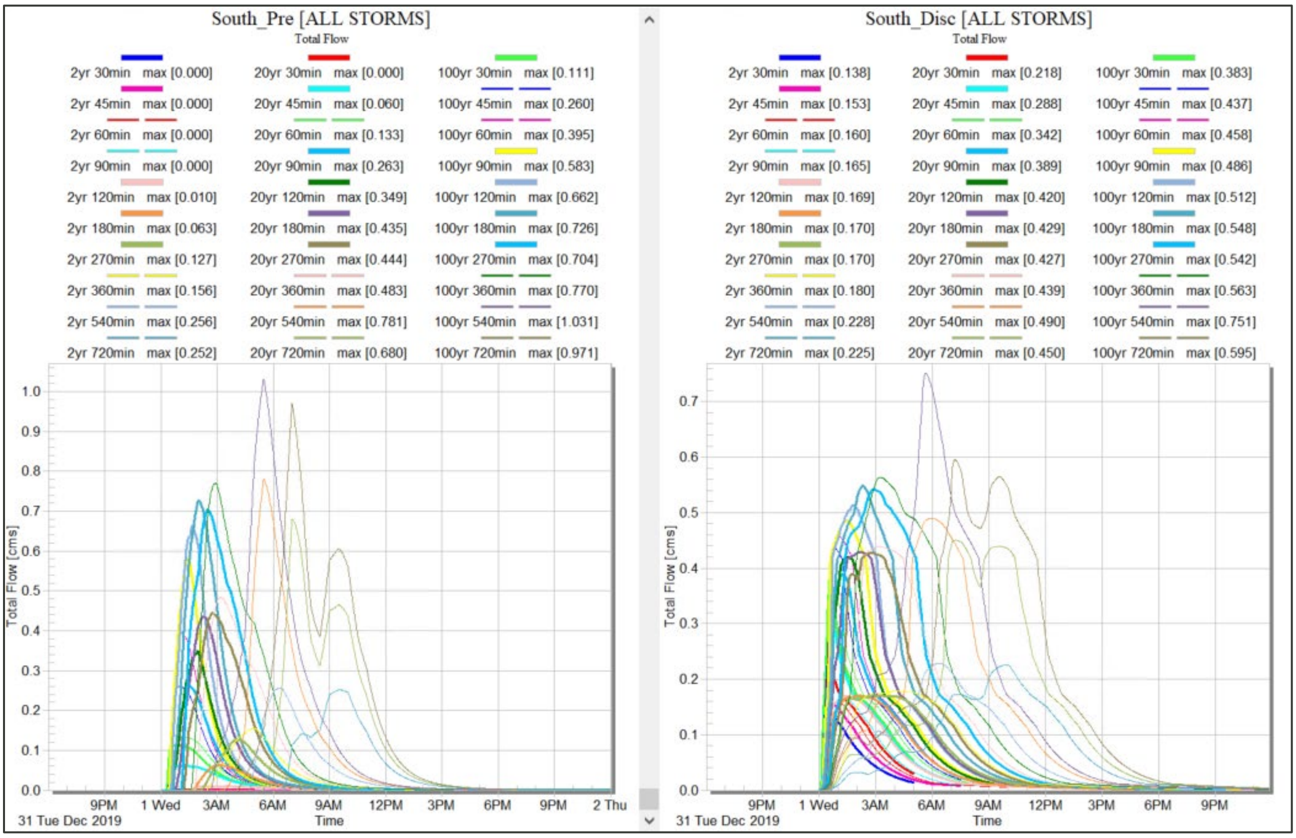

Figure 9-3 South simulated discharge pre- and post-development

A summary of the simulated peak flows and maximum water volumes stored is provided in **Table 9-1**.

Table 9-1 System simulation results summary (1987 ARR)

AEP	Parameter	Unit	North A	North B	South
50%	Peak Discharge Rate (Pre-development)	m^3/s	0.187	0.209	0.256
	Peak Discharge Rate (Mitigated post-development)	m^3/s	0.157	0.186	0.228
	Max water level in OSD	m	0.53	0.37	0.58
	Max vol in OSD	m^3	888	771	2,012
5%	Peak Discharge Rate (Pre-development)	m^3/s	0.533	0.591	0.781
	Peak Discharge Rate (Mitigated post-development)	m^3/s	0.348	0.491	0.490
	Max water level in OSD	m	0.83	0.68	0.89
	Max vol in OSD	m^3	1,694	1,625	3,731
1%	Peak Discharge Rate (Pre-development)	m^3/s	0.670	0.742	1.031
	Peak Discharge Rate (Mitigated post-development)	m^3/s	0.495	0.584	0.751
	Max water level in OSD	m	0.99	0.79	1.05
	Max vol in OSD	m^3	2,214	1,984	4,742

The results of the 1987 ARR analysis indicate slightly higher discharge rates and water levels within the detention basins compared to those simulated when applying the 2019 ARR methodology (**Table 8-2**). These results however also indicate the sufficiency of the current OSD and outlet conduit designs in ensuring the post-development peak flows do not exceed the pre-development peaks. The simulated water levels within the basins all remain below 1.2 m (the council upper limit for industrial basins).

10 Conclusion

The proposed OSD's as detailed in the reference design are sufficient to detain runoff volumes associated with storms up to the 1 % AEP. Discharge conduits can be sized to ensure the maximum release rates will be less than the pre-development peak runoff rates from this area.

11 References

- ARR (2019) Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia
- Institution of Engineers, Australia (1987) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987, Barton, ACT
- PCC (2018) *Penrith City Council Stormwater Drainage Guidelines for Building Developments*, Policy Number 002, Amended: May 2018
- WorleyParsons (2015) *Updated South Creek Flood Study*, Issue No. 4, 30 January 2015