Upper South Creek Advanced Water Recycling Centre

Environmental Impact Statement

Volume 3 Impact Assessment

September 2021

7 Impact assessment approach

This chapter outlines Sydney Water's general approach to assessing impacts across Chapters 8-13.

Chapters 8-13 of this EIS present an assessment of the project's impacts on:

- key waterway impacts (Chapter 8)
- physical and biological environment impacts (Chapter 9)
- heritage impacts (Chapter 10)
- social and amenity impacts (Chapter 11)
- sustainability and resource management impacts (Chapter 12) and
- impacts on adjacent infrastructure (Chapter 13).

The intention of this chapter is to explain Sydney Water's reasoning on a range of assessment matters and include methodology information that would otherwise be duplicated across all chapters.

7.1 Addressing SEARs

Each impact assessment chapter includes a table listing the SEARs covered in that chapter. In addition, each impact assessment chapter also addresses the general SEARs outlined in Table 7-1 below. Appendix A presents a summary of all SEARs and where they are addressed in the EIS.

Table 7-1 General SEARs addressed in impact assessment chapters

SEARs
General Requirements
(b) (v) (iv) ….including an assessment of the cumulative impacts on the environment
(g) an assessment of the likely impacts of the project on the biophysical and socio-economic environment, focusing on the specific issues identified below and any other significant issues identified, including: i. a description of the existing environment likely to be affected by the project using relevant and adequate data. ii. an assessment of the potential impacts of the project, including any cumulative impacts, and taking into consideration relevant guidelines, policies, plans and industry codes of practice.

SEARs
iv. a description of how any residual impacts will be managed or offset, and the approach and effectiveness of these measures.

Where specialist reports have been prepared to inform a chapter, these are included as appendices, and the chapter provides a summary of that report.

DPIE has also provided Sydney Water with letters from government agencies and councils that informed their preparation of the SEARs. Sydney Water has reviewed these letters and addressed the matters raised throughout the impact assessment chapters where possible.

7.2 Impact area

Chapter 4 describes the area to be impacted by the project (impact area), and a wider area (impact assessment area) in which Sydney Water is seeking flexibility to locate project infrastructure. The impact area and impact assessment area are also shown in Figure 4-16 and Figure 4-17. Where the impact primarily results from the project's physical footprint, the impact area described in Chapter 4 has been used to assess project impacts (for example, terrestrial biodiversity and heritage). However, for some aspects, the impact area is not defined by a physical boundary but by where the impacts may be experienced (for example, sensitive receivers for noise and air quality and downstream environments for water quality). The impact area is therefore different for each environmental or social aspect as described in each chapter.

7.3 Project staging

The impact assessment chapters focus on the impacts of Stage 1 of the project. Although future project stages will require another EIS to address construction and operational impacts, Sydney Water has included a brief assessment of operational impacts where the AWRC is operating at 100 ML/day. This is to demonstrate acceptability of the long-term impacts of the project. However, Sydney Water has not assessed construction impacts of future stages given those impacts will be short-term and focused around the AWRC site.

7.4 Cumulative impacts

As outlined in section 2.13, other major projects and urban development in the vicinity of the project means there is potential for cumulative impacts with the project. Where there is adequate public information available about environmental impacts and timing for these projects, and there is likely to be an overlap in construction or operational impacts with the project, Sydney Water has assessed cumulative impacts in the impact assessment chapters. For some aspects, cumulative impacts are also inherently part of the methodology (for example in water models which make assumptions about stormwater inputs across catchments).

7.5 Impact assessment and management measures

For each environmental aspect, Sydney Water and its specialist consultants completed a level of assessment commensurate with the project's potential impacts. For many aspects, guidelines exist about how to assess the level and significance of impact, which means the approach to this is slightly different for each aspect. In addition, each assessment specifies the source of information used and its date. Information is primarily from studies done as part of the project or from other reputable government or consultant sources. The information used is therefore considered reliable with any key uncertainties or limitations documented in the methodology sections of the impact assessment chapters.

The assessment included assessing whether the identified impacts could be avoided or minimised as summarised in sections 3.3 and 3.4. Where impacts could not be avoided, Sydney Water has identified environmental management measures to manage these residual impacts to acceptable levels. Specialist consultants have developed these measures based on a range of factors including previous experience and best practice from guidelines or industry standards. The proposed measures therefore represent Sydney Water's best understanding of the most effective way to manage residual impacts.

As described in Chapter 14, the management measures will form part of the Construction Environmental Management Plan (CEMP) and operational environmental management systems. These plans and systems provide a framework to verify implementation and effectiveness of the management measures through actions such as inspections, auditing, monitoring and continual improvement.

Given the management measures have been identified in a series of specialist reports, in some instances different reports have similar management measures. Sydney Water has captured the intent of the measures in each report to develop a consolidated list of management measures. These are listed in each impact assessment section and compiled into one list in Chapter 15. Sydney Water intends to use the consolidated list in Chapter 15 as the agreed management measures for the project, to minimise duplication or inconsistency and ensure clarity for future compliance reporting.

8 Key waterway impacts

This chapter assesses the project's key waterway impacts, including impacts to hydrodynamics, water quality and ecohydrology during operation and geomorphology and aquatic ecology during construction and operation.

This chapter describes the existing waterways near the project and the potential impacts on water quality, hydrodynamics, geomorphology and aquatic ecology during construction and operation. It provides an overview of the key findings of the following reports:

- Hydrodynamics and Water Quality Impact Assessment (Aurecon Arup, 2021a) included in Appendix F.
- Ecohydrology and Geomorphology Impact Assessment (Streamology, 2021) included in Appendix G.
- Aquatic Ecology Impact Assessment (CT Environmental, 2021) included in Appendix H.

Other water-related assessments are covered in Chapter 9, including impacts to surface water, flooding and groundwater during construction and operation. Table 8-1 provides an overview of all the water-related assessments for the project, their scope and where in the EIS they are addressed.

Table 8-1 Summary of water-related assessments

Study	Scope	Project phase	EIS section
Hydrodynamics and water quality impact assessment	Hydrodynamics relates to the motion of water within the creeks and rivers, including how flows, velocities and water depths may be affected by structures, boundaries or changes in surrounding catchments. Assesses how the AWRC treated water releases during operation impact the hydrodynamics and water quality in the receiving waters of South Creek and the Hawkesbury Nepean River.	Operation (construction impacts to water quality covered by surface water impact assessment)	Chapter 8 Appendix F

Study	Scope	Project phase	EIS section
Ecohydrology and geomorphology impact assessment	Ecohydrology links flow patterns in a waterway to aquatic flora and fauna responses. Geomorphology is the study of landforms and analysis of how processes (such as running water) can shape and change landforms. Assesses how AWRC releases will impact the ecohydrology and geomorphology of the Hawkesbury Nepean River and South Creek. Also assesses impacts to the geomorphic attributes of waterways from the construction of pipelines and release structures.	Construction and operation	Chapter 8 Appendix G
Aquatic ecology impact assessment	Assesses potential impacts to the aquatic ecology of the Hawkesbury Nepean River and South Creek from AWRC treated water releases during operation. Assesses impacts to aquatic ecology from the construction of pipelines and release structures.	Construction and operation	Chapter 8 Appendix H
Surface water impact assessment	Assesses construction and operational impacts related to local runoff and stormwater management at the AWRC site and along the pipeline routes.	Construction and operation	Section 9.2 Appendix K
Flooding	Assesses whether the release structures will change the flow carrying capacity in the channel or floodway. The study also assesses how treated water releases may contribute to increased flows to the waterways.	Construction and operation	Section 9.3 Appendix L
Groundwater	Assesses construction and operational impacts to local and regional groundwater sources from proposed activities at the AWRC site as well as along the pipeline routes.	Construction and operation	Section 9.4 Appendix M

Waterways impact summary

The project is located in the Hawkesbury Nepean River catchment (including the South Creek sub-catchment) and the Georges River catchment. The waterways in these catchments have all been subject to historical impacts associated with urban and agricultural land use, including elevated nutrient levels and altered hydrology due to in-stream weirs and dams.

The main project impacts during construction are direct impacts on waterways (where construction activities are required for pipeline crossings and release structures) and indirect impacts from potential erosion and sedimentation. The activities can potentially affect water quality, geomorphology and aquatic ecology. These construction impacts are not expected to be significant and can be effectively mitigated through standard management measures for erosion and sediment control and other measures such as careful management and timing of waterway crossings in accordance with DPI Fisheries guidelines. Some waterways will be crossed using tunnelling methods which will minimise impacts.

During operation, the main potential for impacts to waterways is from treated water releases to South Creek and Nepean and Warragamba rivers. These releases have the potential to impact on water quality, geomorphology and aquatic ecology as a result of altered water quality and flow regimes.

For all waterways, the assessments indicate that the main future changes to waterways result from increased surface flows and pollutant loads from urban development and that treated water releases from the project represent a marginal additional impact. This is partly a result of the high-quality advanced treated water produced by the AWRC and, for South Creek in particular, that the treated water releases represent a small proportion of total flows.

Sydney Water has developed waterway objectives for the project, with management goals relating to aquatic ecology, recreation and aesthetics, primary industries (irrigation and livestock drinking) and drinking water. Overall, the project is predicted to achieve the management goals and, in some cases, potentially lead to improvements in the condition of the waterway. The project is not expected to have any negative impacts on Sydney’s drinking water catchment.

The only threatened species potentially impacted by the project is the Macquarie Perch, which is protected under the *Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A Seven-part Test of Significance has been undertaken in accordance with the FM Act and an Assessment of Significant Impact has also been undertaken in accordance with the EPBC Act. The results of these assessments indicated that the project’s impacts on this species are not considered significant, given impacts on its habitat and food sources in Nepean and Warragamba rivers will be minor.

South Creek

In South Creek, treated water (either advanced treated water or a blend of advanced treated water and primary treated water) will be released infrequently and only during wet weather, with no releases during dry weather. Water quality impacts are predicted to be infrequent and short-lived with concentrations returning to background levels within a day of the releases ceasing, with impacts generally minor and/or not identifiable downstream of Kemps Creek.

As a result of the proposed release strategy, the treatment of releases from the AWRC also has the potential to dilute and improve some aspects of water quality within the creek during smaller events.

The potential for toxicity impacts is low given the infrequent nature and short duration of the releases. The treated water releases will result in a minor increase (less than 3%) in mean annual flows in South Creek resulting in limited additional geomorphological change to the creek. Treated water releases align with the NSW Government's flow objectives for South Creek. The exception is the cease to flow metrics, where modelling shows they are unlikely to be achieved both with and without AWRC releases given the urbanisation of the catchment.

The aquatic ecology of South Creek is currently in a degraded state. The water quality and hydrological changes induced by the AWRC are not expected to further impact the system given that the releases will be infrequent, short-term and treated to minimise the risk of environmental harm.

Nepean River

In Nepean River, treated water releases (either advanced treated water or a blend of advanced and tertiary treated water) are expected to typically improve water quality for some indicators (such as total nitrogen, total phosphorus, salinity, dissolved oxygen and enterococci) with slight increases in bioavailable forms of nitrogen. During infrequent wet weather events, elevated nutrient concentrations are predicted downstream of the releases due to the higher proportion of tertiary treated water in the releases. These 'spikes' result in localised and short-lived downstream impacts on water quality. Nutrient concentrations are predicted to drop quickly to levels lower than the background scenario within a few days as a result of dilution.

Hydraulic and geomorphic impacts are expected to be minor. Moderate increases in water surface elevation (averaging about 18 cm) are expected upstream of the Wallacia Weir, however increases are well within the channel extents and will not result in flooding or engagement of floodplain areas. Downstream of the weir, increases to water surface elevation are minor. Changes to velocity and shear stress are generally minor, with one area showing a localised increase through a steep riffled section.

The impacts on aquatic ecology are expected to be minor given the generally beneficial impacts or minor impacts associated with water quality and geomorphology. The potential for toxicity impacts is also assessed to be low given the infrequency and short duration of the tertiary treated water releases. There is potential for the small increases in bioavailable nitrogen to contribute to enhanced algal growth, but this is considered a low risk given the overall positive impacts on water quality. The increases in wetted perimeter may provide a small benefit to in-stream aquatic ecology by increasing habitat and an equivalent minor reduction in riparian habitat.

Warragamba River

Similar to Nepean River, treated water releases (of advanced treated water only) are expected to result in water quality improvements in relation to total nitrogen, salinity, total suspended solids, enterococci and dissolved oxygen, with an increase in bioavailable forms of nitrogen and phosphorus. Higher levels of chlorophyll *a* are predicted which increases the risk of localised algal growth in Warragamba River. This change is not observed downstream of the confluence with Nepean River.

The project can contribute to potential geomorphic benefits identified for variable environmental flows including mobilisation of in-channel sediment, an increase in wetted perimeter and a better defined, active low flow channel.

Aquatic ecology impacts are considered similar to those related to water quality in Nepean River. The increased risk of algal growth is not expected to alter the trophic state of the river, meaning any potential impacts would be minor.

Sydney Water will implement a baseline and post-commissioning monitoring program to help understand impacts of the project once it is operational. This will have water quality, aquatic ecology and geomorphic components.

8.1 Relevant Secretary's Environmental Assessment Requirements

Table 8-2 shows the Secretary's Environmental Assessment Requirements (SEARs) relevant to key waterway impacts and where in this section they are addressed.

Table 8-2 Project SEARs relating to key waterway impacts

SEARs	EIS section where requirement addressed
Water 1. Describe background conditions for any water resource likely to be affected by the development, including: a) existing surface and groundwater	Section 8.5 discusses the existing surface water likely to be impacted by treated water releases.
b) hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	Section 8.5 discusses the existing hydrology, including at release locations. The project does not have an intake location.
c) Water Quality Objectives (as endorsed by the NSW Government (www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Section 8.2.1 and 8.4 (incorporated into the waterway objectives).

SEARs	EIS section where requirement addressed
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.	Section 8.2.1 and 8.4 (incorporated into the waterway objectives).
e) Consideration of the Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions.	Section 8.2.1 and 8.4
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 wastewater management during and after construction.	Section 8.5 provides a comparison of existing surface water quality to waterway objectives. Sections 8.2.3 and 8.7 discuss operational impacts on waterway objectives (surface water), incorporating mitigating effects of proposed wastewater management during operation.
b) identification of proposed monitoring of water quality.	Section 8.11 identifies proposed baseline and operational water quality monitoring.
c) if the proposal will achieve a neutral or beneficial effect (NorBE) on water quality within the declared Sydney Drinking Water Catchment (SDWC).	Section 8.7.1
3. Assess the impact of the development on hydrology, including:	
b) effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas.	Section 8.7 discusses hydrological impacts to rivers from treated water releases during operation. . Hawkesbury Nepean estuary not predicted to be impacted. Hydrological impacts to wetlands not anticipated. Section 8.7.1 assesses potential impacts to marine waters from brine releases to Malabar wastewater network and compliance with Malabar EPL.
c) effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	Section 8.6.2 and 8.7.3

SEARs	EIS section where requirement addressed
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).	Section 8.7.1 discusses nutrients loads. Section 8.7.2 assesses hydrological and hydraulic changes. Section 8.7.3 discusses impacts to aquatic connectivity, access to habitat for spawning and refuge.
e) changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	Section 8.7.4.
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.	Section 8.2.3, 8.7.1 and 8.7.2 discuss wastewater management and effects on volumes and flow rates in waterways during operation.
g) identification of proposed monitoring of hydrological attributes.	Section 8.11 outlines monitoring of geomorphological impacts from releases.
4. Map: a) rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method).	Figure 8-6 – South Creek catchment Figure 8-11 – Hawkesbury Nepean River catchment Figure 8-18 – Georges River catchment
b) wetlands as described in s4.2 of the Biodiversity Assessment Method.	Figure 8-8 – wetlands at AWRC site
d) groundwater dependent ecosystems.	Figure 8-9 – South Creek sub-catchment Figure 8-16 – Hawkesbury Nepean catchment Figure 8-18 – Georges River catchment

SEARs	EIS section where requirement addressed
e) proposed intake and discharge locations.	No intake locations during operation. Figure 8-5 and Figure 8-7 show South Creek release points. Figure 8-12 and Figure 8-13 show Nepean River release area. Figure 8-14 shows Warragamba River release area.
5. Demonstrate that the project is consistent with the Environment Protection Authority's (EPA) framework for regulating nutrient discharges in effluent from STPs discharging to the lower Hawkesbury Nepean River (EPA 2019) including:	Section 8.7.1
a) obtain prior agreement from the EPA on the approach and study design where site specific studies are proposed to tailor the guideline values to reflect local conditions.	Section 8.4 discusses the project waterway objectives and selection of indicators and guideline values. Site specific guideline values were not developed for the project.
b) specify the location of discharge points, including but not limited to Nepean River, Warragamba River and South Creek release location(s) for dry and wet weather justifying why the location was selected over other potential discharge points, including discussion of waterway characteristics at each point (eg depth, salinity, hydrodynamics) and consideration of the relative water quality risks.	Section 8.5 discusses the location of discharge points and discussion of waterway characteristics. Section 8.7.1 provides consideration of the water quality risks associated with the releases. Section 3.4 provides further detail about the options selection process for the release locations.
6. Provide a detailed analysis of discharges into Warragamba River including e-flow needs going back 20 years. This analysis needs to consider:	Appendix C provides a detailed analysis of the history of discharges into Warragamba River.
a) whether the discharge at Nepean River is adequate for replacement or supplementing e-flows	Section 8.7.5
b) how the discharge will affect the health of the river	Section 8.7
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: 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.	Chapter 6 outlines consultation with DPIE. Section 8.7 discusses potential impacts on the quantity and quality of surface water along South Creek and implications of wet weather

SEARs	EIS section where requirement addressed
	flows (dry weather releases to South Creek not proposed).
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.	Section 8.7.2 assesses the impact to South Creek flows from treated water releases.
Biodiversity 10. An assessment of the impacts on groundwater dependent ecosystems.	Section 8.6.2 and 8.7.3
12. An assessment of the direct and indirect impacts of the project on aquatic ecology, including key fish habitat and threatened species of fish, populations and ecological communities listed under the Fisheries Management Act 1994 (FM Act) and any downstream or upstream impacts, including cumulative aquatic ecological impacts within the catchment (considering existing or proposed developments that may impact aquatic ecology in the catchment).	Section 8.6.2, 8.7.3 and 8.9.3
Aquatic and Riparian Biodiversity and Ecology 13. Assessment of aquatic, riverine and riparian biodiversity and ecology that addresses all direct, indirect, and prescribed impacts of the project on Key Fish Habitat and associated flora and fauna, riparian zones, threatened species, populations, and communities for the construction and operation of the asset. The assessment must comply with requirements outlined in the Policy and Guidelines for Fish Habitat Conservation and Management (2013) and the FM Act (namely the aquatic habitat protection and threatened species conservation provisions in Parts 7 and 7A of the Act, respectively) and must be prepared in consultation with, and have regard to the requirements of DPI Fisheries.	Section 8.6.2 discusses construction impacts and section 8.7.3 discusses operational impacts. Chapter 6 outlines consultation including with DPI Fisheries
14. Assessment of impact of changes to inundation behaviour on aquatic ecosystems upstream and downstream from the Water Recycling Centre and associated pipelines.	Section 8.7.3
15. An assessment of likely significant impacts on listed threatened species, populations or ecological communities, in accordance with Part 7A of the Fisheries Management Act, 1994, including: a) assessment of the impacts according to the ‘Seven-Part Test”	Sections 8.6.2, 8.7.3 and Appendix H

SEARs	EIS section where requirement addressed
b) consideration of NSW DPI threatened species indicative distribution maps for species, populations and ecological communities likely to be present.	Section 8.5
16. Development of an Aquatic Biodiversity Offsets Strategy that is consistent with the Policy and Guidelines for Fish Habitat Conservation and Management (2013) and the NSW Biodiversity Offsets Policy for Major Projects that addresses direct, indirect, and prescribed impacts of the project during construction and operation, focusing on protecting and improving the biodiversity and conservation of aquatic environments and associated riparian zones in the medium to long-term. The strategy must be prepared in consultation with, and have regard to, the requirements of DPI Fisheries.	Section 8.6.2 and 8.7.3 provide consideration of whether this is needed. An aquatic biodiversity offsets strategy is not proposed, given that impacts to aquatic ecology are predicted to be minor and can be adequately managed by management measures includd in Section 8.10.
17. Description of the type and extent of any dredging or reclamation activities within 'water land' as defined under the FM Act. This assessment must be prepared in consultation with, and have regard to the requirements of DPI Fisheries.	Section 8.6.2 assesses construction impacts.
18. Development of suitable fish passage mitigation strategies (including potential offsets) to the satisfaction of NSW DPI Fisheries that align with the NSW DPI Fisheries Fishway Design Guidelines (2015) and the Policy and Guidelines for Fish Habitat Conservation and Management (2013).	Section 8.10
19. A description and assessment of how the project will be managed over the full range of operating conditions, and how this relates to aquatic biodiversity mitigation and offsetting strategies.	Sections 4.5 and 4.6 describe how the project will be operated. Section 8.7.3 describes aquatic biodiversity impacts and the conclusion that an aquatic biodiversity offset strategy is not required. Section 8.10 describes mitigation measures.
Flooding 31. Modelling must consider and document: j) impacts to South Creek under all scenarios, specifically where South Creek and the Warragamba Pipelines intersect.	Section 8.7.2 for impacts to the Warrgamba pipeline from treated water releases.
l) assessment of the hydrological flows into South Creek from both wet and potential dry weather flows, including consideration of the effects on downstream receiving environments, specifically the Warragamba Pipelines infrastructure (footings etc).	Section 8.7.2

SEARs	EIS section where requirement addressed
32. The EIS must assess the impacts on the proposed development on flood behaviour, including: g) whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses.	Section 8.7.2 assesses erosion, siltation and stability of riverbanks and watercourses. Section 8.6.2 and 8.7.3 assesses impacts to riparian vegetation during construction and operation.
Public safety 53. Outline how the proposal has considered WaterNSW's 'Guidelines for Development Adjacent to the Upper Canal and Warragamba Pipelines' and include all practical measures to prevent damage to WaterNSW water supply infrastructure from construction or operation of the project.	Section 13.2.3 Section 8.7.2 provides as assessment of impacts to WaterNSW infrastructure from treated water releases not waterways where WaterNSW infrastructure is located.
Crown Lands 65. An assessment of project impacts on Crown Land Waterways, including:	
d) the impact of the treated water pipeline on South Creek, Badgerys Creek, Oaky Creek, Cosgroves Creek, Nepean River, Megaritys Creek.	Section 8.6
e) the impact of the brine pipeline on Kemps Creek, Clear Paddock Creek, Green Valley Creek and Prospect Creek.	Section 8.6
f) An assessment of the potential impacts of released 'treated water' flows on stream banks and riparian areas within the downstream creek systems, including South Creek.	Sections 8.7.2 and 8.7.3.
Attachment 1 9. The EIS must include an assessment of the relevant impacts of the action on the matters protected by the controlling provisions, including: i. a description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short term and long term relevant impacts; ii. a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible; iii. analysis of the significance of relevant impacts; and iv. any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	Sections 8.6 and 8.7

SEARs	EIS section where requirement addressed
10. For each of the relevant matters protected that are likely to be significantly impacted by the action, the EIS must provide information on proposed avoidance and mitigation measures to manage the relevant impacts of the action including: i. a description, and an assessment of the expected or predicted effectiveness of the mitigation measures; ii. any statutory policy basis for the mitigation measures; iii. the cost of the mitigation measures; iv. an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing; v. the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.	Sections 8.6 and 8.7 The cost of mitigation measures is not known at this stage and is therefore not included. Chapter 14 describes the overall environmental management approach for the project.
11. Where a significant residual adverse impact to a relevant protected matter is considered likely, the EIS must provide information on the proposed offset strategy, including discussion of the conservation benefit associated with the proposed offset strategy.	Significant residual impacts are not expected as outlined in sections 8.6 and 8.7.
12. For each of the relevant matters likely to be impacted by the action the EIS must provide reference to, and consideration of, relevant Commonwealth guidelines and policy statements including any: i. conservation advice or recovery plan for the species or community, ii. relevant threat abatement plan for a process that threatens the species or community iii. wildlife conservation plan for the species iv. management plan for Ramsar wetland v. management plan for a World Heritage property or National Heritage place; vi. Marine Bioregional Plan; vii. any strategic assessment.	Sections 8.6 and 8.7 For the waterways related assessment, only items i, ii and iii are of relevance.
14. The EIS must identify each EPBC Act listed threatened species and community and migratory species likely to be impacted by the action. For any species and communities that are likely to be impacted, the proponent must provide a description of the nature, quantum and consequences of the impacts. For species and communities potentially located in the project area or in the vicinity that are not likely to be impacted, provide evidence why they are not likely to be impacted.	Sections 8.5, 8.6 and 8.7

SEARs	EIS section where requirement addressed
15. For each of the EPBC Act listed threatened species and communities and migratory species likely to be impacted by the action the EIS must provide a separate:	
a. description of the habitat (including identification and mapping of suitable breeding habitat, suitable foraging habitat, important populations and habitat critical for survival), with consideration of, and reference to, any relevant Commonwealth guidelines and policy statements including listing advice, conservation advice and recovery plans;	Section 8.5
b. details of the scope, timing and methodology for studies or surveys used and how they are consistent with (or justification for divergence from) published Australian Government guidelines and policy statements;	Section 8.2.3
c. description of the relevant impacts of the action having regard to the full national extent of the species or community's range; and	Sections 8.6 and 8.7
d. description of the specific proposed avoidance and mitigation measures to deal with relevant impacts of the action;	Section 8.10
e. identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account;	Sections 8.6 and 8.7
f. a description of any offsets proposed to address residual adverse significant impacts and how these offsets will be established.	Significant residual impacts are not expected as outlined in sections 8.6 and 8.7, therefore no offsets are proposed.
g. details of how the current published NSW Biodiversity Assessment Method (BAM) has been applied in accordance with the objects of the EPBC Act to offset significant residual adverse impacts; and	Not applicable as BAM only applies to terrestrial biodiversity.
h. details of the offset package to compensate for significant residual impacts including details of the credit profiles required to offset the action in accordance with the FBA and/or mapping and descriptions of the extent and condition of the relevant habitat and/or threatened communities occurring on proposed offset sites;	Significant residual impacts are not expected as outlined in sections 8.6 and 8.7, therefore no offsets are proposed.
16. Any significant residual impacts not addressed by the BAM may need to be addressed in accordance with the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offset Policy.	Significant residual impacts are not expected as outlined in sections 8.6 and 8.7, therefore no offsets are proposed.

8.2 Methodology and assumptions

The assessment of key waterway impacts included:

- development of waterway objectives and assessment of project impacts against them
- implementation of a baseline water quality and aquatic ecology monitoring program
- specialist studies, including:
  - an assessment of operational impacts to hydrodynamics and water quality (construction impacts to surface water are covered separately in section 9.2)
  - an assessment of operational impacts to ecohydrology and geomorphology and construction impacts to geomorphology
  - an assessment of construction and operational impacts on aquatic ecology.
- assessment of compliance with the Hawkesbury Nepean Nutrient Framework (Environment Protection Authority, 2019a) and the Southern Suburbs Sewage Treatment System Environment Protection Licence No. 372 including Malabar STP (Malabar EPL)
- peer review of specialist assessments and this chapter by independent reviewers.

These steps are outlined in more detail below.

8.2.1 Development of waterway objectives

Sydney Water developed specific waterway objectives for the project, against which project impacts were assessed.

Waterway objectives are defined by the Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (OEH, 2017) (Risk-based Framework) as consisting of:

- the 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.

To meet the requirements of SEARs, the waterway objectives incorporated:

- NSW Government endorsed Water Quality Objectives (SEARs 1a) (DECCW, 2006)
- indicators and trigger values/criteria in accordance with ANZECC/ARMCANZ (2000) and ANZG (2018) and other local criteria (SEARs 1b)
- guidance within the Risk-based Framework (SEARs 1c).

Sydney Water followed the steps outlined in Step 1 of the Risk-based Framework to develop the waterway objectives. ANZG (2018) was also used to assist in defining terminology and developing management goals. The main steps in the development of waterway objectives were:

- identification of community values and uses
- development of management goals

- identification of key risks
- selection of relevant indicators and guideline values from existing guidelines.

These steps and key outcomes are explained in more detail in section 8.4, along with a summary of how potential impacts to the waterway objectives were assessed.

8.2.2 Baseline monitoring program

A baseline monitoring program (Sydney Water, 2020a) for the project commenced in March 2020 and is still underway. It involves monitoring of surface water quality, macroinvertebrates, macrophytes and fish at the locations shown in Figure 8-1. Sampling sites are located upstream and downstream of the project's release points to South Creek and Nepean and Warragamba rivers. There are also sites located on Kemps and Badgerys Creek upstream of their confluence with South Creek.

At each site, water quality sampling is undertaken every three weeks and sampling for macroinvertebrates and macrophytes is undertaken each autumn and spring. Fish sampling occurs at seven of the sites twice per year (NS45, NS44, NS35, NS66A, NS66B, N66, N64). The baseline monitoring program will continue for a minimum of three years. Results from the baseline monitoring program assisted in characterising the existing environment.

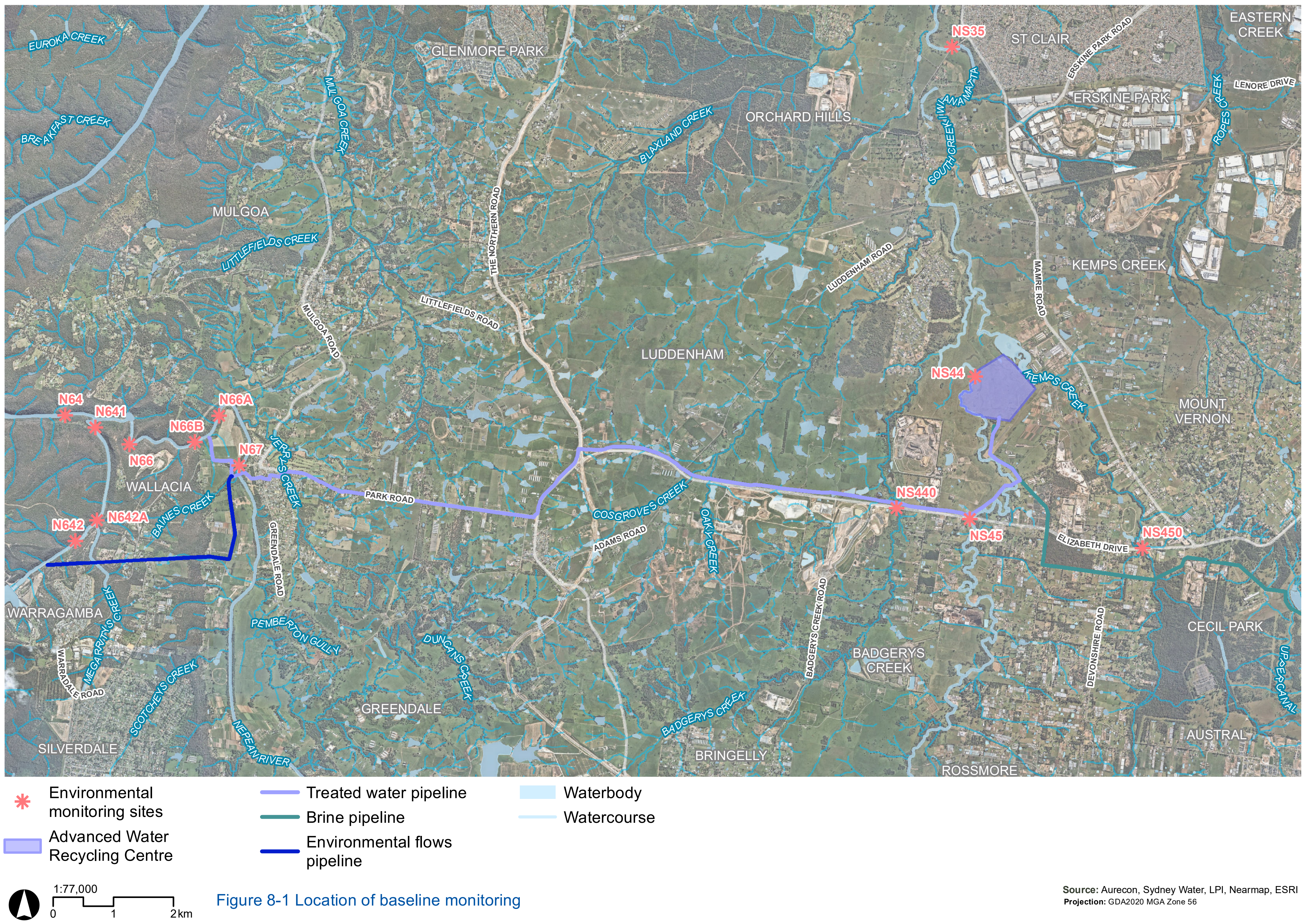


Figure 8-1 Location of baseline monitoring

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

8.2.3 Specialist assessments

The key waterway specialist assessments are highly interdependent and have therefore been considered together in this chapter. A collaborative approach was taken in developing methodologies, model scenarios and sharing results. The following sections outline the specific methodology and assumptions for each study.

Various terms are used in the assessments to describe the potential impacts. An overview of these terms and their definitions is provided below, with additional detail provided in Appendix F, G and H:

- Improved water quality: classified as changes in ambient conditions that support the protection or enhancement of applicable environmental values and objectives. In the context of this assessment, this may relate to maintenance/achievement of one or more of the following effects:
  - Lower ambient concentrations of nutrients.
  - Lower ambient concentrations of pathogens. Increased
  - ambient levels of dissolved oxygen.
  - Lower potential risk of algal blooms and cyanobacteria.
  - Increased compliance with relevant waterway objectives.
- Insignificant/minor impacts: impacts are classified as being recognisable as short term, or temporary, or of limited magnitude in nature and only predicted at a local scale.
- Low, medium or high potential risk: based on the interpretation of both predicted consequences and the likelihood of an event occurring.

Hydrodynamics and Water Quality Impact Assessment

The hydrodynamics and water quality impact assessment considered how the releases of treated water from the AWRC may impact the hydrodynamics and water quality in the receiving waters of South Creek and the Hawkesbury Nepean River during its operation. Stage 1 and future stages of the AWRC were evaluated along with cumulative impacts of other expected changes in the surrounding catchments. Construction impacts to surface water (including stormwater runoff and management) are covered separately in section 9.2.

To meet the objectives of the assessment, hydrodynamic and water quality modelling software was used to simulate the existing and future waterway conditions and predict potential impacts from the AWRC releases.

Two Water Quality Response Models (WQRMs) were upgraded specifically for use in the assessment to allow simulation of the relevant hydrodynamic and water quality processes in the Hawkesbury Nepean River and South Creek. The ongoing development of these WQRMs has been a long standing focus of the inter-agency Hawkesbury Nepean Science Working Group. Each model has been built on the application of the finite volume hydrodynamic modelling software, Two-dimensional Unsteady FLOW (TUFLOW FV), which was dynamically coupled with the Aquatic Ecodynamics Modelling Library (AED2). Other models were also developed to provide the required inputs and boundary conditions to the WQRMs, including Source, Model for Urban Sewers (MOUSE) and wastewater treatment plant (WWTP) and water recycling plant (WRP) models.

CORMIX modelling software was also used to assess more localised near field impacts at the release locations.

Figure 8-2 presents an overview of the various models used in the impact assessment and the interfaces between them.

The spatial extent of the models is shown in Figure 8-3.

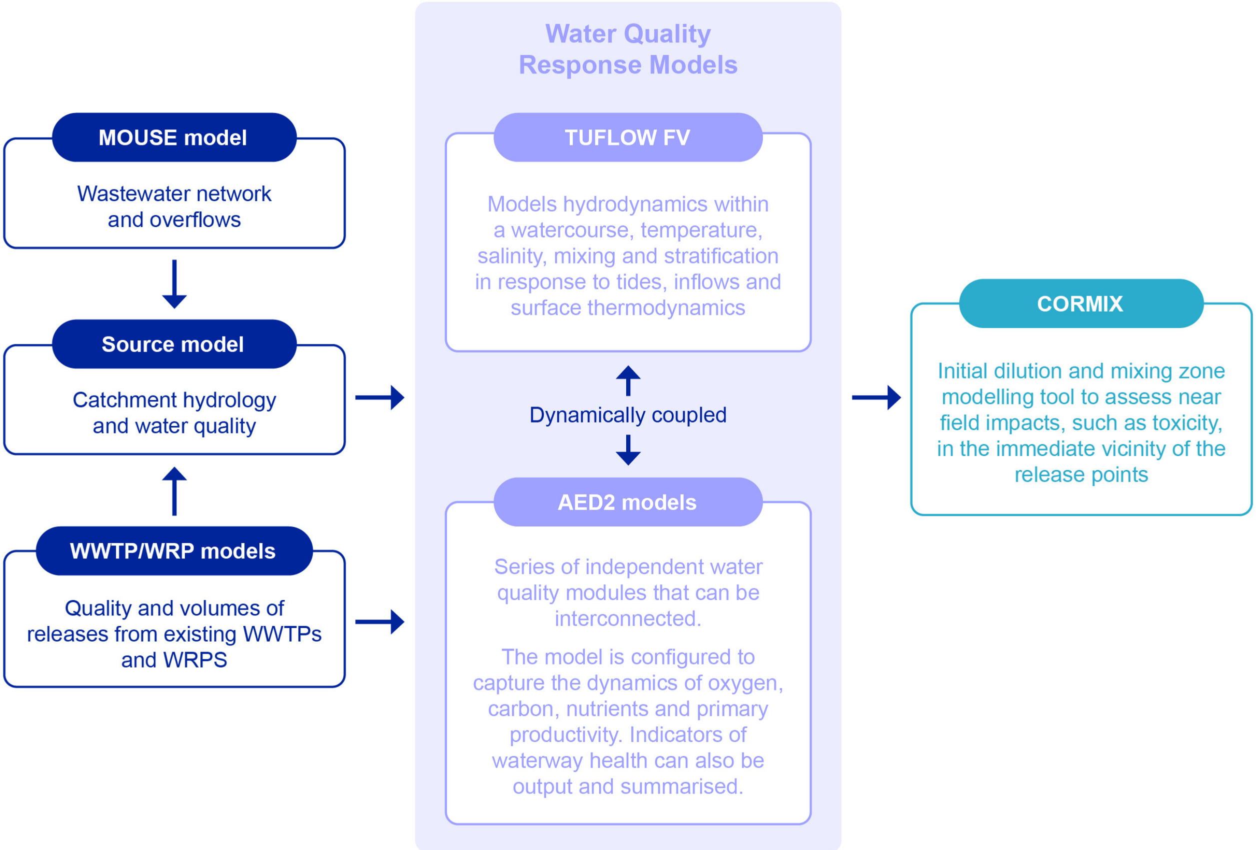


Figure 8-2 Overview of hydrodynamic and water quality models

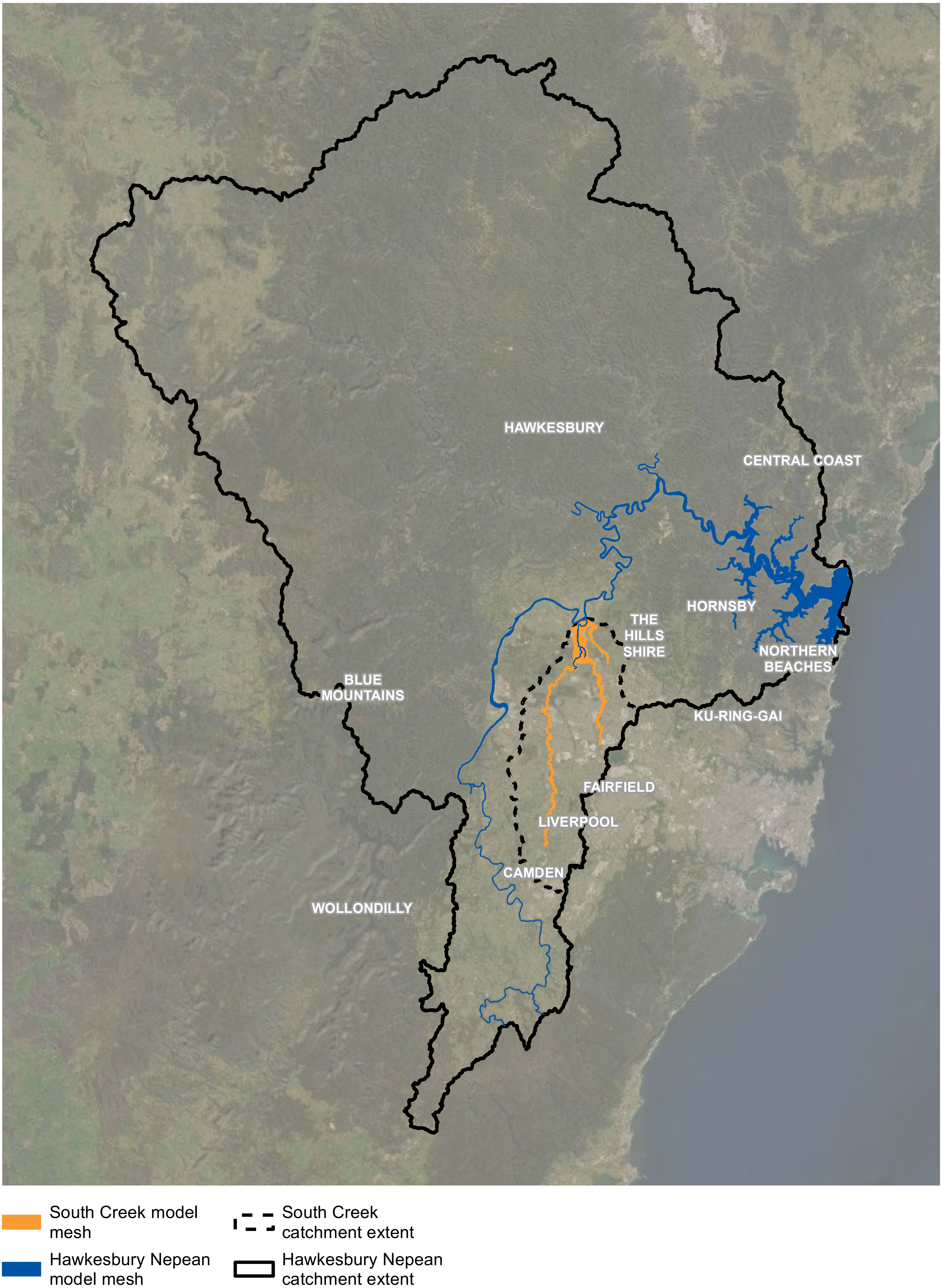


Figure 8-3 Spatial extent of models

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Development and application of the water quality response models (WQRMs)

Development and application of the WQRMs was divided into two key phases.

The first phase involved model development, calibration and validation of WQRMs. Calibration and validation of the two WQRMs focused on comparing the model predictions against the water quality and hydrological monitoring data. The WQRMs were independently reviewed by the University of New South Wales Water Research Laboratory.

The second phase involved compiling input data to characterise the existing and future environment, including land use, waterway extractions, and releases from other WWTPs, WRPs and emergency relief structures. Model scenarios were developed to simulate future conditions, then run and analysed.

Three different types of scenarios were developed to incorporate a range of catchment conditions and releases that could be expected during the operational life of the AWRC, including:

- baseline scenarios to represent current (circa 2020) conditions
- background scenarios to simulate catchment and waterway conditions expected in 2036 and 2056 without the introduction of AWRC releases. Variations included:
  - two stormwater management strategies, described as parkland and business as usual (BaU). The parkland strategy is consistent with the Western Parkland City stormwater strategy. The BaU approach is consistent with existing stormwater management practices within the Greater Sydney region
  - different levels of treatment at other WWTPs and WRPs releasing into the Hawkesbury Nepean catchment, described as low and high loading. In low loading conditions, it was assumed that many of the treatment plants had been upgraded to reduce nutrient loads. High loading represents the assumption that treatment plants have not been substantially upgraded, and inflows from treatment plants have increased nutrient loads. The high loading variation remains within the limits of the Hawkesbury Nepean Nutrient Framework (EPA, 2019a).
- impact scenarios to allow targeted evaluation of any potential impacts from the treated water releases from the AWRC. Each impact scenario corresponded to a background scenario but with the addition of AWRC releases. Releases were varied to capture:
  - average dry weather flow (ADWF) of 50 ML/day (2036) and 100 ML/day (2056)
  - scenarios with and without releases to Warragamba River
  - scenarios where the advanced water treatment system is turned off temporarily due to potential capacity issues in the Malabar wastewater collection network.

The impact scenarios incorporate wastewater management measures that have been included into the design to minimise impacts on waterways. A key element of these measures is the implementation of the AWRC treatment and release strategy which allows for advanced levels of treatment for the majority of releases to mitigate impacts on water quality and the transfer of flows to Nepean River during dry weather to avoid impacts on South Creek.

All the scenarios were run for a representative dry and wet year to understand the range of potential impacts under different climatic conditions.

The scenarios assumed the AWRC is operating at full capacity i.e. 50 ML/d in 2036 and 100 ML/d in 2056, with no allowance for beneficial reuse. Prior to reaching these operating levels, the extent of the impacts on the receiving water, whether they be beneficial or detrimental, are likely to be proportionally reduced.

The assessment of potential impacts involved comparing results for the baseline, background and impact scenarios for the following hydrologic/hydrodynamic and water quality indicators:

- Hydrology/hydrodynamics:
  - Flow.
  - Water level.
- Water quality:
  - Nitrogen (including ammonia, oxidised nitrogen, total nitrogen).
  - Phosphorus (including filterable reactive phosphorus, total phosphorus).
  - Chlorophyll a (adopted as primary indicator of phytoplankton abundance and algal biomass).
  - Salinity.
  - Temperature.
  - Total suspended solids.
  - Dissolved oxygen (including concentration and saturation).
  - Pathogens (including enterococci and E. coli).
  - Cyanobacteria risk.

Water quality results for baseline, background and impact scenarios were also compared to the relevant waterway objectives. Results for annual median concentrations have been compared to the guideline values in accordance with ANZG (2018).

The hydrodynamic outputs from the WQRMs were subsequently used to inform the ecohydrology and geomorphology assessment. The results and analysis are therefore included as part of that study.

Toxicant review

The toxicants typically found in wastewater include inorganic chemicals, metals/metalloids, pesticides, residual disinfectants and pharmaceuticals (DES, 2021). The risk of toxicity from these contaminants can initially be undertaken through analysis of the maximum end-of-pipe concentrations and comparison to toxicant trigger values in section 3.4 of the ANZECC/ARMCANZ (2000) guidelines, or the ANZG (2018) toxicant default guideline values. For the purposes of this assessment, this analysis was undertaken for a suite of toxicants using monitoring datasets from wastewater treatment plants that have similar treatment processes as those proposed at the AWRC (refer to Appendix B of Appendix F). The toxicants that were identified as presenting a potential risk of toxicity in the receiving waters (that is, where estimated concentrations exceeded trigger/guideline values) were:

- Wet weather releases to South Creek: ammonia and chlorine.
- Tertiary treated releases to Nepean River: aluminium, copper, manganese and zinc.

No toxicants of concern were identified as potentially occurring within the advanced treated water.

Near field and toxicity modelling

Results from the toxicant review identified that the potential for near field impacts is higher during the more significant wet weather events, when flows to the AWRC exceed 3 x ADWF. Under these conditions, the releases to Nepean River will include higher proportions of tertiary treated water. Similarly, the releases to South Creek will include elevated proportions of primary treated water mixed with the advanced treated water. Both release streams therefore potentially include higher levels of contaminants that could pose a risk of toxicity to the waters and associated biota in the immediate vicinity of the release points. CORMIX modelling was undertaken to examine near field dilution of the release plume and to assess any potential for toxicity in near field waters.

The modelling and impact assessments included:

- analysis of the outcomes from the toxicant review and proposed release conditions, including the quantity and quality of the treated water releases. The 95th percentile concentrations of toxicants were used in the assessment in accordance with ANZG (2018)
- analysis of the characteristics and hydrodynamics of the waterways in the immediate vicinity of the release points at the time of the releases. Ambient conditions were derived from bathymetry and topographic data, background water quality concentrations and flow rates from the WQRM
- evaluation of the dilution requirements for each toxicant
- near field modelling of the initial dilution and mixing processes for the releases with consideration of a representative range of release conditions and corresponding ambient conditions. Modelling was undertaken for South Creek and Nepean River for both Stage 1 (2036) and the ultimate future stage (2056)
- assessment of the size and configuration of mixing zones in line with the ANZG (2018) and ANZECC/ARMCANZ (2000) technical guidelines. Mixing zones are defined as the areas of the receiving waterways where waterway objectives are not met. Consistent with the ANZECC/ARMCANZ (2000) guidelines, the assessments were restricted to soluble, non-bioaccumulatory toxicants.

There are no specific technical guidelines and assessment criteria relating to regulatory mixing zones in NSW. Therefore, the primary considerations presented in the Queensland Government Technical Guideline (DES, 2021) were adopted in the modelling assessments which are considered to follow the principles and procedures presented in the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines.

Specifically, the following lateral and longitudinal dimensions of the mixing zones and potential interaction with banks and shorelines were used as the principal criteria to determine whether the mixing zones were consistent with the principles of the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines:

- The maximum lateral dimension should be the lesser of 50 m diameter or 30% of the waterway width.
- The maximum longitudinal dimension should be the lesser of 300 m or three stream widths.

Neutral or beneficial effect assessment

The proposed location of the environmental flows pipeline and release structure are within the declared Sydney Drinking Water Catchment (SDWC). The release is located downstream of Warragamba Dam, so will not impact on the drinking water storage. However, SEARs 2c requires an assessment of the impacts on water quality including 'if the proposal will achieve a neutral or beneficial effect (NorBE) on water quality within the declared Sydney Drinking Water Catchment (SDWC).'

The NorBE guidelines (WaterNSW, 2021) state that a neutral or beneficial effect on water quality is satisfied if the development:

- has no identifiable potential impact on water quality, or
- will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or
- will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

As impacts cannot be contained or transferred, as outlined in the second and third dot points above, the NorBE assessment involved a review of water quality impacts from the AWRC release. The WQRM for Warragamba River does not include this section of the river, therefore the NorBE assessment involved a review of existing water quality in the upper section of Warragamba River and a comparison with proposed AWRC releases to Warragamba River.

Assumptions and limitations

Table 8-3 provides a list of assumptions and limitations for the key components of the Hydrodynamic and Water Quality Impact Assessment.

Table 8-3 Assumptions and limitations of the hydrodynamic and water quality impact assessment

	Assumptions and limitations
WQRMs	The hydrodynamic and water quality modelling was undertaken in line with accepted industry standard practices and the WQRMs were independently reviewed for the purposes of this EIS. The WQRM models are considered fit for purpose in their application for the impact assessment undertaken for the AWRC EIS. However, in line with all similar impact assessment studies, the modelling undertaken for the EIS is a representative approximation to the real world and not without accepted levels of uncertainty. Each model is based on a series of assumptions, and also dependent on the accuracy of its input data. This means that the results for the various model scenarios do not represent absolute values that can be achieved and instead provide a basis to consider relative differences. In addition to the above, an underprediction of flows in the Nepean River at Wallacia Weir was identified during analysis of the WQRM scenarios. Modelled baseline and background flows were lower than historical flow volume data at Wallacia Weir during lower flows. Sensitivity analysis was undertaken to establish the influence of this issue with respect to the water quality impacts predicted by the WQRM. The results from the analysis indicated that the WQRM results for the impact scenarios could be considered as conservative and potentially over predicting the impacts of the AWRC releases. Section 6.1.2.6 of Appendix F discusses this in more detail.
CORMIX	CORMIX software is internationally recognised as a leading and proven hydrodynamic modelling software package. However, the developers, MixZon Inc. advise users regarding its accuracy and limitations, and that it should not be considered as exact science. MixZon Inc. provide guidance that extensive comparison with field and laboratory data has shown that CORMIX predictions on dilutions and concentrations (with associated plume geometries) are reliable for most cases and are accurate to within about ± 50% (standard deviation).

Ecohydrology and geomorphology impact assessment

The primary focus of the ecohydrology and geomorphology assessment is on the impacts related to the operational releases from the AWRC. Other components of the study included an assessment of potential impacts to WaterNSW infrastructure downstream of the release points and potential impacts on geomorphology from construction in waterways.

In this chapter, the term geomorphology is used to generally describe geomorphological processes and/or forms. Similarly, the terms hydrology and ecology are used to describe hydrological and ecological attributes of a waterway.

The main steps involved in the assessment included a desktop and field review, identification of assessment metrics, hydrologic and hydraulic modelling and interpretation and impact assessment. Additional information about the key steps is provided below.

Hydrological and hydraulic modelling

Hydrological models focus on catchment runoff and stream flow volumes and are developed to understand the flow volumes of water in a waterway. Hydrological modelling for the project involved:

- an analysis of available flow gauge data for South Creek and Nepean River. Flow gauges are installed within the waterways and measure flow volumes (and sometimes water depth)
- an analysis of scenario modelling outputs from the WQRMs.

Hydraulic modelling involves taking catchment flows from the hydrological models to simulate flow conditions at a structure or location. The industry standard modelling package HEC-RAS was used for this purpose. A one-dimensional model was created for the broader Nepean River from Bents Basin to downstream of Penrith Weir. The one-dimensional model was used to simulate the flow conditions in Nepean River based on the gauged flow information. From these simulations, the following hydraulic conditions were extracted for every model cross-section:

- Water surface elevation – the surface of the water in metres (using Australian Height Datum or AHD) along the waterway. Depth changes between scenarios can be interpreted from this metric.
- Wetted perimeter – the length of the cross-sectional area that is ‘wet’, meaning in contact with the flow. This is used to calculate changes in inundation.
- Velocity – the speed of water in a given direction.
- Shear stress - a measure of the force of friction from the flow acting on the bed of the waterway. Bed load movement and sediment transport are a function of the shear stress.

Two-dimensional hydraulic models were set up in selected locations to provide greater spatial resolution of the flow velocities and shear stress within the model extent. These two-dimensional models were set up at the following locations:

- Nepean River, downstream of Wallacia Weir to just downstream of Warragamba River confluence. This site was chosen as it consists of a steep section with prominent riffles, runs and pools that have the potential to be subject to higher levels of inundation with smaller changes in depth.
- A section of Nepean River running through the Blue Mountains World Heritage Area. This site was chosen because of its location within the heritage area and because it is on an outside bend.

Scenarios for the hydraulic models were based on the current flow regime of Nepean River. A series of flow increments were selected to provide a representative range of flows in Nepean River at the treated water release location. Table 8-4 summarises these two-dimensional model scenarios in Nepean River.

Table 8-4 Summary of hydraulic scenarios in Nepean River (downstream of release point)

Scenario	10th percentile flow (ML/day)	50th percentile flow (median) (ML/day)	90th percentile flow (ML/day)
Baseline (based on gauged flows 2010 – 2021)	782	229	78
+ 50 ML/day release	832	279	128
+100 ML/day release	882	329	178

Hydraulic modelling using HEC-RAS was not undertaken for the South Creek wet weather releases for the section of waterway immediately downstream of the AWRC. Given the larger catchment changes and small and infrequent contribution of the AWRC releases to South Creek, there was more value in focusing on the analysis of hydrologic scenarios.

Assessment metrics

The NSW Department of Planning, Industry and Environment (DPIE) have drafted performance criteria for ambient stream flows and requirements of waterways and water dependent ecosystems in the Western Sydney Aerotropolis (Western Sydney Planning Partnership, 2020b). These objectives are provided in Table 8-5.

Table 8-5 Wianamatta – South Creek waterway health (flow) objectives (Western Sydney Planning Partnership, 2020b)

Flow variable	Description[1]	Unit	Performance Criteria	
			1st-2nd Order Streams	≥ 3rd Order Streams
Median Daily Flow Volume	Volumetric flow rate (runoff) per unit area (catchment response to rainfall).	L/ha	71.8 ± 22.0	1096.0 ± 157.3
Mean Daily Flow Volume	Volumetric flow rate (runoff) per unit area (catchment response to rainfall).	L/ha	2351.1 ± 604.6	5542.2 ± 320.9
High Spell ≥ 90th Percentile Flow Volume	High spell flow days have been defined in the objectives as the top ten percent of days with the highest flows.	L/ha	2048.4 ± 739.2	10,091.7 ± 769.7
High Spell – Frequency High Spell – Average duration	Number of high spell events (flow conditions defined above) that occur in a year. Number of days during which a high spell event occurs in a year.	Number/yr Days/yr	6.9 ± 0.4 6.1 ± 0.4	19.2 ± 1.0 2.2 ± 0.2
Freshes ≥ 75th and ≤ 90th Percentile Flow Volume	Freshes are defined as the days when the flow exceeds the 75th percentile flow rate (or the top 25% of flows) but excludes the high spell flow conditions (>90th percentile values). These flows are more than the median flows but less than high flows.	L/ha	327.1 to 2048.4	2642.9 to 10091.7
Freshes – Frequency Freshes – Average Duration	Number of freshes events (flow conditions as defined above) that occur each year. Average number of days in a year during which freshes event occur.	Number/yr Days/yr	4.0 ± 0.9 38.2 ± 5.8	24.6 ± 0.7 2.5 ± 0.1

Flow variable	Description[1]	Unit	Performance Criteria	
			1st-2nd Order Streams	≥ 3rd Order Streams
Cease to Flow	The proportion of time per year that zero flows occur in the waterway.	Proportion of time/yr	0.34 ± 0.04	0.03 ± 0.00
Cease to Flow – Duration	Number of days per year that zero flows occur in a year.	Days/yr	36.8 ± 6	6 ± 1.1

Notes on table:

1. Description not provided in objectives but included to explain Sydney Water's interpretation.

The ecohydrology and geomorphology assessment considered the impact of wet weather releases to South Creek against these objectives. The impact of stormwater runoff from the AWRC site is considered in section 9.2.

In addition to these objectives, project specific hydrologic and ecohydraulic metrics were developed.

Hydrologic metrics can be used to demonstrate changes in the hydrologic regime for different scenarios from which geomorphic responses can be inferred. The Urban Stream Flow Impact Assessment (USIA) method (Vietz et al, 2018, Kermode et al, 2020), developed for the Western Sydney region, was adopted for this assessment. Hydrologic metrics assessed included flow dynamics, frequency and duration of zero flows and freshes and bed erosion threshold. These metrics are similar to those described in the flow objectives in Table 8-5 but with a greater focus on geomorphic indicators such as zero flows.

Ecohydraulic modelling relies on hydraulic modelling and metrics that describe characteristics of flow. The four hydraulic metrics focused on in this study included water surface elevation, wetted perimeter, velocity and bed shear stress.

All metrics described above relate to both geomorphology and aquatic and riparian ecology. Metrics were used to show the changes between the baseline, background and impact scenarios to allow potential impacts to be assessed.

WaterNSW infrastructure assessment

In response to WaterNSW feedback, Streamology completed an independent assessment of risks to the integrity and security of WaterNSW lands, assets and infrastructure that may result from the treated water releases, and the proposed measures to mitigate against those risks, including consideration of:

- the effect the project will have on Warragamba Pipeline footings and other WaterNSW infrastructure, through potential changed flow regimes and flood impacts
- potential direct or indirect increases of erosion or sediment deposition in the Warragamba pipeline corridors and at the treated water release locations.

WaterNSW infrastructure downstream of the treated water releases was assessed, including Warragamba Weir, Wallacia Weir, Penrith Weir and Warragamba Pipeline crossings of South Creek and Nepean River.

The main steps included:

- data collation and review
- collection of new aerial drone photography (due to COVID-19 restrictions limiting in-person inspections)
- geomorphic analysis of each site
- flow regime analysis

- comparison of the current and future geomorphic and flow conditions. This included the impacts of flooding and changes in flood conditions as well as more frequent flow conditions. The hydraulic models developed for Nepean River were used for this assessment. A new two-dimensional model of South Creek at the Warragamba Pipeline crossing location was also developed to assist with the assessment
- assessment of the risks related to flooding, erosion and scour at each location and implications for the integrity of the various structures.

Assessment of impacts

Construction impacts on geomorphology were assessed by reviewing the design, construction methodology and geomorphic sensitivity of impacted waterways. This included where pipelines across waterways will be constructed by trenching and construction of the release structures at South Creek, Nepean River and Warragamba River.

Operational impacts were assessed using the outputs from the hydrologic and hydraulic modelling. A risk-based approach was applied to assess the impacts. The risk matrix is provided in Appendix G.

Assumptions and limitations

Appendix G includes a detailed list of assumptions and limitations which are summarised below:

- The hydraulic scenarios are based on analysis of gauged flow data in Nepean River covering the period 2010 to 2021, due to significant changes in the flow regime of Nepean River since 2010.
- The hydrologic scenario data from the WQRM was assumed to be accurate. The hydrologic data is a primary input that greatly influences the modelled results on which the impact assessment is based. As explained in Table 8-3, a discrepancy was identified between the flow gauge data in Nepean River and the outputs of the modelled scenarios. For this reason, assessment in Nepean River focused on the relative difference between the scenario modelling results rather than the absolute values. An assumption was made that the discrepancy in the hydrologic scenario data was consistent across all the scenarios.
- Models are only as useful as their accuracy dictates. The hydraulic models have undergone initial verification based on available field observations. Given the significant hydraulic control Wallacia Weir and Penrith Weir provide within this system, the model setup focused on accurately representing water levels at these locations. The model is considered fit for purpose for low and median flows. However, it is less likely to be accurate under higher or flood flow conditions (less than 10th percentile flows) due to the increased engagement of floodplain areas and the lack of detail of floodplain storage in the model.
- The hydraulic modelling is based on bathymetric and topographic data and it is assumed that these datasets are representative of the channel topography (both above and below water level).

- The calibre of the bed material determines the threshold of flow required to mobilise bed sediments. Detailed bed sediment data was not available for Nepean River and bed sediment characteristics were based on visual inspection from a boat. For South Creek, bed sediments were digitally assessed during field inspections by Streamology staff.
- There are no specific geomorphic likelihood or consequence definition that are widely agreed for risk assessment purposes and such assessments typically involve a significant level of expert interpretation. The risk assessment detailed in Appendix G and summarised in section 8.7.2 was based on the technical expertise of the senior staff within Streamology and was not tested with a broader expert group. However relevant literature, data, and field work were also used to inform these expert opinions.

Aquatic ecology impact assessment

The purpose of the aquatic ecology impact assessment was to consider potential impacts on the surrounding aquatic ecosystems, which incorporates both instream, riparian, wetland and floodplain habitats, for reaches of South Creek, Nepean River, Warragamba River and numerous smaller waterways across the study area.

The main steps involved in the assessment included desktop review, field assessment, an assessment of construction and operational impacts and development of management measures to mitigate impacts. Additional information about the key steps is provided below.

The study area for the aquatic ecology assessment included:

- the impact assessment area (IAA), as defined in section 4.9.2
- waterways crossed by the pipelines, including immediately upstream and downstream
- waterways adjacent to the AWRC site, including South and Kemps Creek
- waterways impacted by treated water releases, including:
  - South Creek, adjacent to the AWRC site downstream to Cosgrove Creek Nepean
  - River, from Bents Basin to Penrith Weir
  - Warragamba River from the release point to the confluence with Nepean River.

The study area extents for South Creek, Nepean River and Warragamba River were based on the extent of potential impacts identified in the hydrodynamic and water quality impact assessment and ecohydrology and geomorphology impact assessment.

Desktop review

A desktop review of the following resources was undertaken for the study area to determine current condition of the aquatic ecology of the impact assessment area, as well as the downstream waterways of South Creek, Nepean River and Warragamba River:

- NSW topographic mapping to determine Strahler stream ordering (SIX maps, 2021). Stream order is used to describe the hierarchy of streams from the top to bottom of a catchment. The Strahler system is adopted in the Water Management (General) Regulations 2018.

- NSW Key Fish Habitat Mapping (NSW DPI 2020a).
- Freshwater threatened species distribution (NSW DPI 2020b).
- Matters of National Environmental Significance (MNES) – Protected Matters Search Tool (DoE, 2021).
- Remnant Vegetation of the western Cumberland subregion, 2013 update (DPIE, 2013a).
- Groundwater Dependent Ecosystem Atlas of Australia (BOM, 2021).
- Water quality, fish, macrophyte and macroinvertebrate survey data (Sydney Water, 2021).
- Targeted survey of Australian Bass and Southern Myotis in South Creek catchment (CTEnvironmental, 2018).
- Other specialist studies completed for the EIS for surface water, groundwater, hydrodynamics and water quality, and ecohydrology and geomorphology.
- Literature review of available scientific literature relating to flow tolerances for aquatic flora and fauna and defined ecological thresholds for aquatic fauna, particularly those relating to the mobilisation of macroinvertebrates, some of which constitute prey of the threatened Macquarie Perch (*Macquaria australasica*).

Field assessment

The field assessment involved:

- waterway validation, including identifying if a waterway met the definition of a river under the *Water Management Act 2000* (WM Act)
- verification of key fish habitat, following the framework outlined in Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPI, 2013a). Key fish habitat type and class was determined based on the presence of habitat attributes and threatened species. A total of 61 assessments were completed across the impact assessment area
- identification of habitat associated with threatened species under the *Fisheries Management Act 1994* (FM Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- validation of mapped Groundwater Dependent Ecosystems identified in the desktop review
- assessment of the condition of riparian vegetation and waterway channels across the study area using the Rapid Riparian Appraisal (RRA) method. This method provides a snapshot of the current condition of aquatic and riparian areas. The RRA method:
  - combines qualitative and quantitative assessment of urban stream condition and riparian habitat
  - covers seven main categories including site features, riparian vegetation, habitat features, channel features, key fish habitat, deposition/erosion and liveability/community values

- breaks these seven categories down into indices and sub-indices, each receiving a score. These values are used to calculate an overall site condition score which is rated using seven grades from degraded to excellent (based on Findlay et al. (2011) and Dean and Tippler (2016). ‘Poor’ to ‘Degraded’ condition is typical of creeks with highly urbanised catchments that have severe channel alteration, with limited vegetated buffer width or riparian vegetation structure. ‘Excellent’ condition indicates a minimally disturbed catchment with intact channel geomorphology, a complex riparian vegetation community with minimal weeds. These waterways are generally unaffected by human-induced impacts such as stormwater and wastewater.

Assessment of impacts

The assessment phase included consideration of potential impacts during construction and operation.

The construction impact assessment considered direct and indirect impacts on aquatic, riparian and aquatic groundwater dependent ecosystems from construction of the AWRC, pipelines (particularly at waterway crossings) and the release structures. This included an assessment of impacts to key fish habitat and associated flora and fauna, riparian zones, threatened species, populations, and communities. The type and extent of dredging and reclamation activities within ‘water land’ as defined under the FM Act was also assessed.

Potential impacts associated with the operational phase of the AWRC have also been considered and include impacts associated with the treated water releases to South Creek and Nepean and Warragamba rivers and stormwater from the AWRC site.

Assessment of potential impacts has been determined by review of data and reporting from other specialist studies prepared for this EIS. Specialist studies reviewed included the Surface Water Impact Assessment (Appendix K), the Groundwater Impact Assessment (Appendix M), the Hydrodynamic and Water Quality Assessment (Appendix F) and the Ecohydrology and Geomorphology Impact Assessment (Appendix G). Data and reporting presented by the specialist reports were compared to current ecological conditions determined by field survey and spatial analysis and relevant waterway objectives. Assessment of the potential for impacts and the magnitude of impacts was then determined. In relation to the treated water releases, this involved:

- review of water quality results for baseline, background and impact scenarios and consideration of impacts to aquatic ecology
- review of hydrological changes for the baseline, background and impact scenarios
- review of the hydraulic changes for Nepean River for the median and 90th percentile flows and Stage 1 (50 ML/day) and ultimate (100 ML/day), including:
  - changes to water surface level
  - increases to wetted perimeter. Wetted perimeter extents were uses as a proxy to estimate changes in inundation

– changes to flow velocity and consideration of localised velocity driven hydraulic changes and an assessment of the potential impact to aquatic flora and fauna and riparian ecology. Changes in velocity were compared to macroinvertebrate flow tolerance and mobilisation thresholds at cross sections within Nepean River.

The outcomes of the above steps were used to inform the overall impact on aquatic ecology and riparian vegetation. They also informed assessments required for the threatened Macquarie Perch including:

- an Assessment of Significance (or 7-part test), undertaken in accordance with the requirements of the *Fisheries Management Act 1994*
- an Assessment of Significance, undertaken in accordance with the requirements of the *Environment Protection and Biodiversity Conservation Act 1999.*

Assumptions and limitations

Field survey was limited to waterways within the IAA footprint and those impacted by treated water releases. The reach of Kemps Creek adjacent to the AWRC site was also surveyed given the potential for indirect impacts during construction. Waterways along the tunnelled section of the environmental flows pipeline (including Megarritys Creek) were not assessed due to the depth of the pipeline in this section (about 47 m) and the low potential for impact. Field assessment was not undertaken for Baines Creek as, at the time of survey, the proposed pipeline route did not cross the creek. This was considered acceptable, given that impacts will be limited to construction and standard mitigation measures apply.

Rapid Riparian Assessments were undertaken at intervals along rivers and creeks which have potential to be impacted by the construction and/or operational phases of the AWRC. A 50 m radius from a selected point in the creek was assessed and an overall condition assigned to that reach. It was then assumed that the area surveyed was representative of the impacted section of waterway (see Findlay et al 2011).

The impact assessment was based on the modelling outputs from other studies mentioned above and was assumed reliable for the purposes of the aquatic ecology study. The results are therefore subject to the same assumptions and limitations listed for the hydrodynamics and water quality and ecohydrology and geomorphology impact assessments.

In the absence of inundation extent modelling, wetted perimeter extents from the hydraulic modelling were used as a proxy to determine the potential extent of impact on aquatic and riparian habitats. Wetted perimeter change provides a broad indication of the potential change in inundation extent, however it is noted the relationship between the two is not exact. Therefore, assessment of the wetted perimeter provides an indication that an impact has potential to occur, however the certainty around the impact is low.

The percentage change in wetted perimeter extent was used to gain an understanding of potential inundation across the impacted area. Calculations were undertaken using spatial and spreadsheet data provided by Streamology (2021). The data on which the wetted perimeter is built was coarse and therefore data anomalies may be inherent when modelling wetted perimeter in complex terrain (for example Norton's Basin gorge complex), over large spatial scales and across multiple flow scenarios.

Review of modelled wetted perimeter spatial data identified potential anomalies in the model outputs at several locations, including upstream of Norton's Basin and at the Glenbrook Creek-Nepean River confluence. These potential anomalies were reviewed by CT Environmental and assessed as having the potential to result in an over-expression of aquatic habitat gain (that is, increase in wetted perimeter extent) during analysis. The magnitude and consequence of this over-expression, relative to the scale of wetted perimeter analysis conducted from Bents Basin to Penrith Weir, is considered conservative.

There is limited scientific literature available on mobilisation thresholds and depth preferences of macroinvertebrates and where it is available it is largely focused on American and European taxa. This literature was used as the foundation on which to base the assessment of hydrological impacts and was complemented by a field-based trial undertaken separately by CT Environmental to determine mobilisation thresholds of macroinvertebrate taxa native to the Nepean River system.

8.2.4 Compliance with Hawkesbury Nepean Nutrient Framework and Malabar EPL

The treated water releases must comply with the requirements in 'Regulating nutrients from sewage treatment plants in the Lower Hawkesbury Nepean River catchment' (EPA, 2019a), referred to as the Hawkesbury Nepean Nutrient Framework. The brine releases must not impact on Sydney Water's compliance with the Malabar EPL. The assessment of compliance involved:

- a review of pollutant concentration and load limits in the Hawkesbury Nepean Nutrient Framework and Malabar EPL
- a review of existing loads in the Malabar system and the relevant zones in the Hawkesbury Nepean Framework (Yarramundi Zone 2 and Sackville Zone 2)
- a review of predicted concentrations of nutrients in the AWRC release streams
- predicting future pollutant loads, including accounting for:
  - planned treatment plant upgrades
  - growth forecasts
  - loads in the treated water and brine produced by the AWRC
- comparing predicted pollutant concentrations and loads with regulatory requirements.

8.2.5 Peer review

Two independent experts were selected to provide independent and specialist peer review and input focused on environmental impacts from the release of treated water to South Creek and Nepean and Warragamba rivers.

The experts were selected based on their expertise in the areas of water quality, hydrodynamics, geomorphology and aquatic ecology. The two experts are:

- Dr Chris Gippel: Specialist expertise in applied fluvial geomorphology, environmental hydraulics and hydrology, especially as applied to environmental flows, river health assessment and environmental impact of developments, and stream design and rehabilitation
- Dr Rick van Dam: specialist aquatic ecosystem and water quality specialist. Leading contributor to the 2000 and 2018 Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Broadly, the scope of the independent expert role included:

- review of background information, including:
  - site inspection
  - review of specialist methodology and assessment approach
- input to the development of waterway objectives
- review of specialist reports and relevant EIS chapters
- preparation of a peer review report (Appendix I).

8.3 Legislation and guidelines

8.3.1 Relevant legislation

Protection of the Environment Operations Act

The *Protection of the Environment Operations Act 1997* (POEO Act) establishes the NSW environmental regulatory framework and includes licensing requirements for certain activities.

Under section 48 of the POEO Act, a licence is required for a scheduled activity. Clause 36 of Schedule 1, states that sewage treatment with a capacity that exceeds 2,500 persons equivalent or 750 kilolitres per day is a scheduled activity. The project meets the definition of a scheduled activity and will require an environment protection licence (EPL), as it will have an initial operating capacity of up to 50 ML/day.

Under section 47 a licence is required for a scheduled development activity, which is defined as ‘work at any premises at which scheduled activities are not carried on that is designed to enable scheduled activities to be carried on at the premises’. Construction of the project meets this definition, as it will enable scheduled activities to be carried out.

Under section 5.24(1)(e) of the EP&A Act, an EPL cannot be refused if it is necessary for carrying out approved State significant infrastructure and is to be substantially consistent with the approval under Division 5.2 of the EP&A Act.

The project includes the release of brine into the Malabar wastewater collection network. This network operates under EPL 372. The EPL includes load and concentration limits for several pollutants. An assessment of the impacts on annual loads and concentrations from the addition of brine from the AWRC is included in section 8.7.1.

Water Management Act and water sharing plans

The objects of the *Water Management Act 2000* (WM Act) 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. Water sharing plans are the main tool within the WM Act for managing water sources. They define the rules for sharing water within a particular water source. The following water sharing plans are applicable to the project:

- Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Source 2011 (within the Hawkesbury and Lower Nepean Rivers Water Source).
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (within the 'Sydney Basin Central' groundwater source).

Section 5.23(1) of the EP&A Act states that the following approvals are not required for approved State significant infrastructure:

- Water use approval under section 89 of the WM Act.
- Water management work approval under section 90 of the WM Act.
- Activity approval (other than an aquifer interference approval) under section 91 of the WM Act (including controlled activities).

Tunnelling for the environmental flows pipeline may require a one-off extraction of water from Nepean River for drilling fluid, given the closest drinking water connection is in Wallacia. The exact location will not be identified until the construction phase, but it would likely be around Wallacia. If so, a Water Access Licence under section 56 of the WM Act will be required.

The need for an aquifer interference approval and water access licence for groundwater is discussed in section 9.4.

Fisheries Management Act

The *Fisheries Management Act 1994* (FM Act) aims 'to conserve, develop and share the fishery resources of the State for the benefit of present and future generations'.

Part 7 of the FM Act outlines legislative provisions to protect aquatic habitat. Of relevance to the project are the requirements relating to dredging and reclamation and impacts to fish passage.

Section 5.23(1) of the EP&A Act states that the following permits under the FM Act are not required for approved State significant infrastructure:

- Section 201 for carrying out dredging or reclamation works.

- Section 205 for harming marine vegetation.
- Section 219 to block fish passage.

Notification to the Minister if dredging or reclamation is required under section 199 of the FM Act. A description of proposed dredging works is included in section 8.7.3.

Part 7A outlines provisions to conserve threatened species of fish and marine vegetation and their habitat. The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW waters. Declared critical habitats are listed in a register kept by the Minister of Primary Industries.

Potential impacts to these species, populations, communities, processes and habitats from the project have been considered and assessed as part of the aquatic ecology impact assessment (refer to section 8.7.3). Where impacts are likely, an assessment of significance (or 7-part test) under section 220ZZ(2A) is required.

Environment Protection and Biodiversity Conservation Act

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) enables the Commonwealth Government to join with the states and territories in providing a truly national scheme of environment and heritage protection and biodiversity conservation. The EPBC Act focuses Commonwealth Government interests on the protection of matters of national environmental significance (MNES), with the states and territories having responsibility for matters of state and local significance.

The project is a controlled action under the EPBC Act, which means impacts on various MNES must be assessed in the EIS. MNES relevant to the project include nationally threatened species and ecological communities, migratory species and world heritage places. This chapter considers impacts to aquatic threatened species protected by the EPBC Act, in particular the Macquarie Perch and includes an assessment of significance.

State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011

The State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 (Drinking Water SEPP), has three main aims which are to:

- provide for healthy water catchments that will deliver high quality water and permit development that is compatible with that goal
- ensure that consent authorities only allow proposed developments that have a neutral or beneficial effect on water quality
- support water quality objectives in the Sydney drinking water catchment.

The Drinking Water SEPP defines the Sydney drinking water catchment on the Sydney Drinking Water Catchment (SDWC) Map as shown in Figure 8-4. The environmental flows release structure and part of the environmental flows pipeline is within the map boundary, despite being downstream of Warragamba Dam and its catchment. As required by SEARs 2(c), an assessment of whether the project will achieve a neutral or beneficial effect (NorBE) on water quality within the declared SDWC is therefore required. This is further discussed in section 8.7.1. The assessment considered the ‘Neutral or Beneficial Effect on Water Quality Assessment Guideline’ (WaterNSW, 2021).

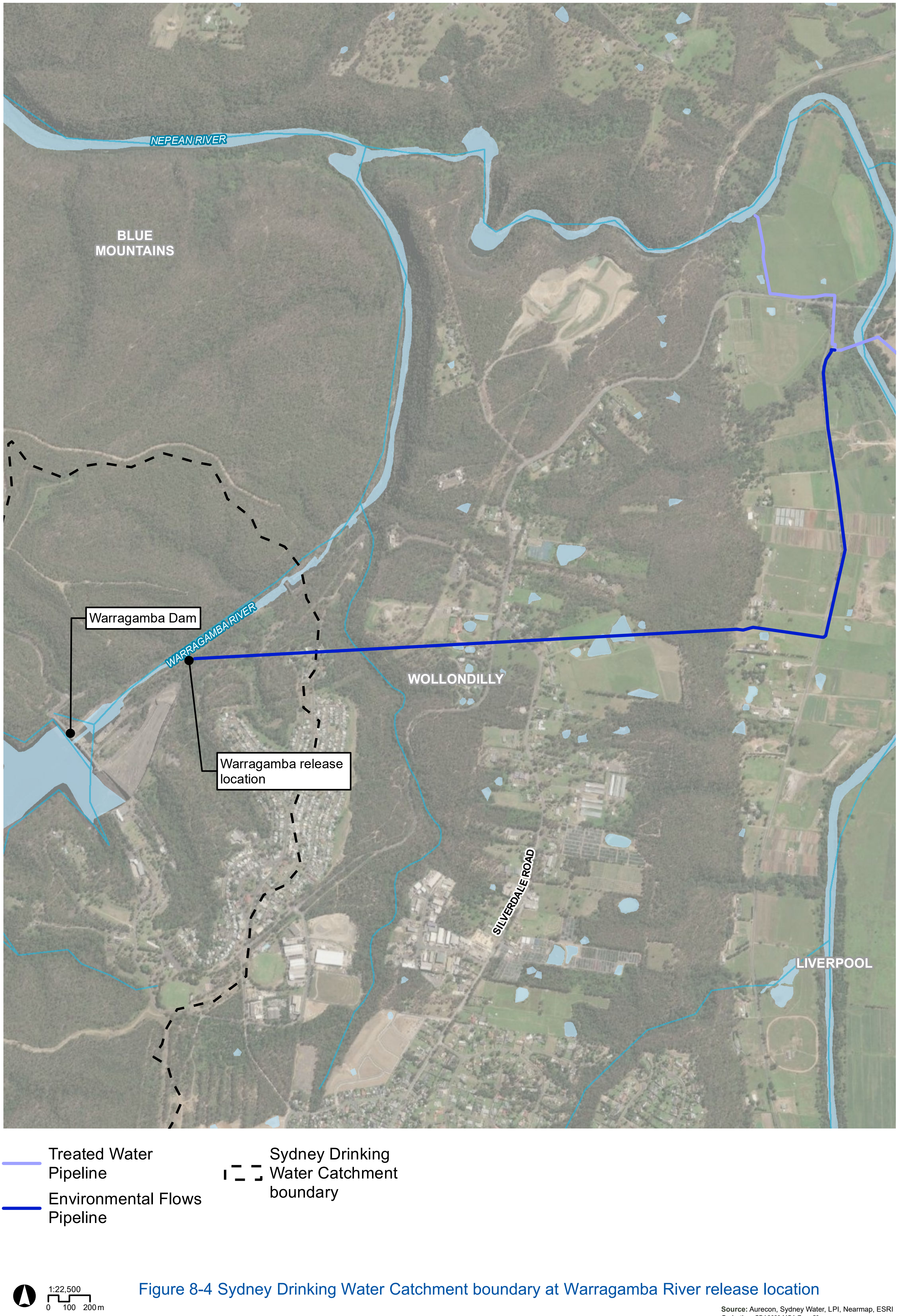


Figure 8-4 Sydney Drinking Water Catchment boundary at Warragamba River release location

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) (SREP 20) 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 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 Nepean River and South Creek catchments which ultimately drain to the Hawkesbury Nepean River. The Local Government Areas (LGAs) of Penrith, Liverpool, Wollondilly and Fairfield are identified as four of the 15 LGAs to which the SREP 20 applies. Specific planning policies and recommended strategies for consideration in this project are detailed in Clause 6 of SREP 20. Section 5.2.2 includes a consideration of how the project aligns with SREP 20.

Greater Metropolitan Regional Environmental Plan No. 2 – Georges River catchment

Two key aims from this planning instrument are to maintain and improve the water quality and river flows of the Georges River and its tributaries and to protect and enhance the environmental quality of the catchment for the benefit of all users.

Part of the brine pipeline is located in the area covered by the Greater Metropolitan Regional Environmental Plan No. 2. General and specific planning principles for consideration in this project are detailed in clauses 8 and 9. Section 5.2.2 includes a consideration of how the project aligns with this plan.

8.3.2 Guidelines

NSW Water Quality and River Flow Objectives (DECCW, 2006) and Healthy Rivers Commission

The NSW Water Quality Objectives (WQOs) are the agreed environmental values and long-term goals for NSW surface waters. In NSW, these represent the community's environmental values for waterways expressed for each catchment. They include a range of water quality indicators to help assess whether the current condition of a waterway supports those values and uses.

When the NSW Water Quality and River Flow objectives were approved by the NSW Government (September 1999) the Healthy Rivers Commission (HRC) had substantially completed the public inquiry for the Hawkesbury Nepean catchment (DECCW, 2006). In March 2001, the NSW Government issued a Statement of Joint Intent for the Hawkesbury Nepean River System which endorsed the values and water quality objectives identified in the Final Reports of the Healthy Rivers Commission Independent Inquiry (released August 1998 and April 1999).

The environmental values were identified by region. The project has the potential to impact the regions listed in Table 8-6. Sydney Water reviewed the values identified by the HRC and incorporated relevant values into the project waterway objectives. The indicators and values recommended by the HRC have since been superseded by the ANZECC/ARMCANZ (2000) and ANZG (2018) guidelines.

Table 8-6 Summary of values identified by the Healthy Rivers Commission

Land use	Values
Predominantly forested	Aquatic ecosystems, swimming, boating, visual, drinking water
Mixed use rural	Aquatic ecosystems, swimming, boating, visual, irrigation water supply, homestead water supply, drinking water
Predominantly urban	Aquatic ecosystems, boating, visual, irrigation and swimming

Source: Figures in section 7 of HRC (1998).

Water quality guidelines

There are several water quality guidelines relevant to the project, which form part of the National Water Quality Management Strategy. The strategy and relevant guidelines are summarised in Table 8-7, along with how Sydney Water has applied them to the project.

Table 8-7 Summary of water quality guidelines and application to the project

Guideline	Summary
National Water Quality Management Strategy (NWQMS)	The purpose of the NWQMS is to protect the nation’s water resources by maintaining and improving water quality, while supporting dependent aquatic and terrestrial ecosystems, agricultural and urban communities, and industry. Channels for delivery of the NWQMS include: • policy that enables effective water quality management for the delivery of fit for purpose water that supports community values • process (framework) for the development and implementation of management plans. These plans focus on the reduction of pollution released into coastal pollution hotspots and other aquatic ecosystems • guidelines that are developed using best available scientific evidence, providing benchmarks and targets for managing water quality across a range of risk profiles and uses. The guidelines outlined below sit under the NWQMS. An explanation of how they have been applied to the project is provided for each specific guideline.

Guideline	Summary
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).	The objective of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality is to provide authoritative guidance on the management of water quality in Australia and New Zealand. It includes guidance on setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources. The development of waterway objectives was guided by ANZG (2018), including in the identification of community values and uses and the development of management goals. In the absence of site-specific guideline values, the ANZG (2018) provides direction on default guideline values for a range of stressors relevant to different community values, such as aquatic ecosystems, human health, and primary industries. For the most part, ANZG (2018) supersedes the ANZECC/ARMCANZ (2000) guidelines. For many guideline values, reference is made to ANZECC/ARMCANZ (2000).
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000).	The ANZECC/ARMCANZ Water Quality Guidelines provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters. The guidelines recognise a range of environmental values and include water quality guidelines to protect and manage the values. In addition to the ANZG (2018), the ANZECC/ARMCANZ (2000) guidelines provide detailed guidance on required targets and thresholds for relevant water quality indicators in the receiving waters. Many of the indicators and guideline values adopted in the waterway objectives have been taken from ANZECC/ARMCANZ (2000), including those for aquatic ecology, aesthetics and primary industries.
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, including threats related to the discharge of wastewater. Recreational indicators and guideline values adopted in the waterway objectives have been taken from NHMRC (2008).
Australian Drinking Water Guidelines 6, Version 3.5 (National Health and Medical Research Council 2011 updated 2018)	The Australian Drinking Water Guidelines (ADWG) are intended to provide a framework for good management of drinking water supplies. The guidelines are not mandatory standards. However, they provide a basis for determining the quality of water to be supplied to consumers in all parts of Australia. Some of the drinking water indicators and guideline values adopted in the waterway objectives have been taken from ADWG.

Risk-based framework for considering waterway health outcomes in strategic land use planning decisions (NSW OEH, 2017)

The Risk-based Framework brings together existing principles and guidelines recommended in the NWQMS.

The purpose of the Risk-based Framework is to:

- ensure the community's environmental values and uses of 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 waterways
- support management of land use developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.

The framework has been considered during the development of the project waterways objectives, in the following way:

- The definition of waterway objectives for the project has been adopted from the framework.
- Sydney Water followed the steps outlined in Step 1 of the framework to develop the waterway objectives.

Further information is provided in sections 8.2.1 and 8.4.1.

Hawkesbury Nepean Nutrient Framework

The EPA has developed a regulatory framework to manage nutrient load inputs to the Hawkesbury Nepean River from wastewater treatment plants (Environment Protection Authority, 2019a). The objective is to meet the community's environmental values for the river and provide wastewater treatment plant operators with alternatives to meet those nutrient loads. The framework has been applied to Sydney Water's existing Environment Protection Licences and will be applied to the project's Environment Protection Licence. It includes limits on nutrient concentrations, interim caps on nutrient loads and a framework for nutrient trading and offsets.

The framework divides the river system into different zones and proposes separate load limits for total nitrogen and total phosphorus within each zone. The project's treated water releases to Nepean and Warragamba rivers are in Yarramundi subzone 2. The project's wet weather releases to South Creek are in Sackville subzone 2.

Policy and guidelines for fish habitat conservation and management (update 2013) (DPI, 2013a)

This document outlines policies and guidelines aimed at maintaining and enhancing fish habitat for the benefit of native fish species, including threatened species, in marine, estuarine and freshwater environments.

The document provides a framework for the assessment of key fish habitat. This framework has been used to confirm the location and type of key fish habitat throughout the impact assessment area (refer to section 8.5 for identification of key fish habitat). Recommendations for management of Key Fish Habitat have also been guided by this document.

Guidelines for controlled activities on waterfront land (DPI, 2012)

A controlled activity approval is not required for this project, however Sydney Water has considered the 'Guidelines for controlled activities on waterfront land' (DPI, 2012) in the impact assessment.

The overarching objective of the controlled activities provisions of the WM Act is to establish and preserve the integrity of riparian corridors. The guidelines include a set of principles to apply to maintain and rehabilitate the environmental functions of riparian corridors. These principles have been addressed in the Aquatic Ecology Impact Assessment in section 8.6.2.

8.4 Waterway objectives

As outlined in section 8.2.1, Sydney Water developed specific waterway objectives for the project. The waterway objectives consist of the community's environmental values and uses of the waterway, and indicators and corresponding numerical criteria (guideline values) to assess whether the waterway will support a particular environmental value or use.

This section outlines how the waterway objectives were developed. The waterway objectives themselves are also presented, along with a summary of how achievement of the objectives has been assessed.

8.4.1 Development of waterway objectives for Nepean and Warragamba rivers and South Creek

The main steps in the development of waterway objectives were:

- identification of community values and uses
- development of management goals
- identification of key risks
- selection of relevant indicators and guideline values from existing guidelines.

Values and uses

ANZG (2018) defines a community value as 'a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors'.

Sydney Water reviewed several sources of information to develop representative values for the project, including:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG (2018) and ANZECC/ARMCANZ (2000))
- interim WQOs as endorsed by NSW Government - work by the Healthy Rivers Commission (HRC,1998)
- 'Using the ANZECC Guidelines and Water Quality Objectives in NSW' (DEC, 2006).

Section 8.5 includes a detailed description of the waterways, including community values and uses. Values adopted for the waterway objectives include:

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

This is a representative list of values and is not intended to be a comprehensive set of all values and uses for the waterways. These values were adopted because they represent the broader range of values and uses that may be impacted by the project. They also have well established indicators and guideline values that can be used to assess project impacts.

Management goals

ANZG (2018) defines a management goal as ‘a measure or statement used to assess whether community values for water quality are being attained or maintained. The management goal should reflect the desired level of protection and provide precise and detailed descriptions of which aspects of the community values are to be protected.’

Sydney Water developed management goals for each value, including:

- Aquatic ecology: Protect, maintain and restore the ecological condition of aquatic systems and their riparian zones overtime.
- Recreation and aesthetics: Maintain or improve water quality for recreational activities such as swimming, boating and fishing. Maintain or improve the aesthetic qualities of the waterways.
- Primary industries (irrigation and livestock drinking): Protect the quality of water used for a broad range of irrigation activities and livestock drinking.
- Drinking water: Maintain or improve the quality of raw drinking water extracted downstream.

These management goals represent a high level of protection for the waterways. The next steps of identifying key risks, indicators and guideline values assist in defining how achievement of these goals can be measured.

Key risks

Sydney Water identified key water quality risks to each community value from the release of treated water to assist in the selection of appropriate indicators and guideline values. They include:

- Aquatic ecology:
  - Potential for high levels of nutrients to lead to eutrophication and excessive growth of algae and aquatic plants.
  - Potential for toxicants to impact aquatic ecology.
- Recreation and aesthetics:

  - Potential for pathogens and cyanobacteria, eutrophication, surface scums, oil and grease, objectionable matter and changed visual clarity of waters.
- Primary industries (irrigation and livestock drinking):
  - Potential for microbial contamination, cyanobacteria and other contaminants.
- Drinking water:
  - Potential for pathogens, cyanobacteria and toxicants.

Indicators and guideline values

The Risk-based Framework (NSW OEH, 2017) recommends that selected indicators should have a direct relationship to the risks and impacts posed by the activity and be at the appropriate scale to manage those risks and impacts. This has been considered in the selection process.

Sydney Water has taken indicators and guideline values from the guidelines listed below. This list also identifies what values and uses are applicable to this guideline.

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000 and ANZG 2018) – primarily relevant to aquatic ecology, aesthetics and primary industries.
- Guidelines for managing risks in recreational water (NHMRC, 2008) – relevant to recreational use of water.
- Australian Drinking Water Guidelines 2011, Version 3.5 Updated August 2018 (NHMRC, NRMMC, 2011) – relevant to drinking water.

Sydney Water has adopted default guideline values for Nepean and Warragamba rivers and has not developed site-specific guideline values. For South Creek, the Department of Planning, Industry and Environment has developed draft water quality and flow objectives as part of the precinct planning work for the Western Sydney Aerotropolis Growth Area (WSAGA) (Western Sydney Planning Partnership, 2020b). These draft objectives include performance criteria that Sydney Water has included in the objectives for South Creek.

Consultation

The waterway objectives were developed in consultation with internal and external stakeholders and the Sydney Water expert panel. The draft objectives were presented at a Waterways Workshop held in December 2020 with a range of attendees across NSW Government agencies and local Councils.

Feedback during the workshop was positive. Generally, feedback related to the overall waterways assessment and no changes to waterway objectives were proposed. Chapter 6 lists the attendees at this workshop and the key issues raised.

8.4.2 Waterway objectives for Nepean and Warragamba rivers and South Creek

Table 8-8 summarises the waterway objectives for Nepean and Warragamba rivers and South Creek.

Lines of evidence (information sources) have been used to inform the assessment and understand how (or if) the project is likely to change current performance of the waterways against the guideline values. Lines of evidence for each indicator are listed in Table 8-8 and include:

- Level of treatment: this relates to the AWRC reference design and the expected performance of the treatment processes.
- Monitoring data: water quality monitoring data from treated water streams at other treatment plants that have similar types of treatment to what is proposed at the AWRC, as described in section 8.2.3.
- Water Quality Response Models (WQRMs): water quality results from the water quality and hydrodynamic models, as described further in sections 8.2.3 and 8.7.1.
- CORMIX models: water quality results from near field and toxicity modelling. This was undertaken for toxicants that may exceed ANZECC/ARMCANZ (2000) or ADWG (2018) guideline values as explained in more detail in sections 8.2.3 and 8.7.1.

The waterway objectives have been used as a benchmark to understand the existing condition of the waterways and as a way of estimating predicted impacts on water quality. Other impacts outside of the indicators and guideline values included in the waterway objectives have been assessed by the waterway studies, including those related to flow changes. These assessments also seek to demonstrate alignment with the values and management goals within the waterway objectives. Assessment against the waterway objectives is covered throughout the operational impacts assessment section (section 8.7) with an overall summary provided in section 8.7.4.

Table 8-8 Waterway objectives for Nepean and Warragamba rivers and South Creek

Values and uses	Indicator	Guideline values: Nepean & Warragamba rivers	Guideline values: South Creek *(values in brackets are DPIE criteria)*	Lines of evidence: Level of treatment	Lines of evidence: Monitoring data	Lines of evidence: WQRMs	Lines of evidence: CORMIX model
1. Aquatic Ecosystems	Total nitrogen (TN)	0.35 mg/L[1]	0.35 mg/L[1] (1.72 mg/L)[2]	✓	✓	✓	
	Oxidised nitrogen (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]	✓	✓	✓	
	Total phosphorus (TP)	0.025 mg/L[1]	0.025 mg/L[1] (0.14 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 (D O)	85 - 110 % Saturation[1]	85 - 110 % Saturation[1] (43-75 % Saturation)[2]	✓	✓	✓	
	pH	6.5 - 8.0[1]	6.5 - 8.0[1] (6.2-7.6)[2]	✓	✓		
	Conductivity / Salinity[7]	125-2200 µS/cm[1] Equivalent to salinity of 0.085-1.5g/L[1,8]	125-2200 µS/cm[1] Equivalent to salinity of 0.09 - 1.5g/L[1,8] (1103 µS/cm[2] Equivalent to salinity of 0.75g/L[8]).	✓	✓	✓	

Values and uses	Indicator	Guideline values: Nepean & Warragamba rivers		Guideline values: South Creek *(values in brackets are DPIE criteria)*		Lines of evidence: Level of treatment	Lines of evidence: Monitoring data	Lines of evidence: WQRMs	Lines of evidence: CORMIX model
	Toxicants[3]	Total ammonia as N	0.90 mg/L[10]	Total ammonia as N	0.90 mg/L[10]	✓	✓		✓[5]
		Nitrate as N	2.4 mg/L[11]	Nitrate as N	2.4 mg/L[11]				
		Total chlorine	0.003 mg/L[10]	Total chlorine	0.003 mg/L[10]				
		Aluminium	0.055 mg/L[10]						
		Copper	0.0014 mg/L[10]						
		Zinc	0.008 mg/L[10]						
		Manganese	0.100 mg/L[12]						
	Turbidity / Total suspended Solids (TSS)[7]	6-50NTU[1] TSS<40mg/L[1,9]		6-50NTU[1] TSS<40mg/L[1,9] (50 NTU[2] TSS - 37mg/L)[2]		✓	✓	✓	
2. Recreation & Aesthetics	Enterococci	Primary contact: 95th percentile for intestinal enterococci/100 mL ≤ 40[4] Secondary contact: 95th percentile for intestinal enterococci/100 mL > 40 and ≤ 200[4]				✓	✓	✓	
	Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.				✓	✓	✓	
	Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour or foaming.[1]				✓			

Values and uses	Indicator	Guideline values: Nepean & Warragamba rivers	Guideline values: South Creek *(values in brackets are DPIE criteria)*	Lines of evidence: Level of treatment	Lines of evidence: Monitoring data	Lines of evidence: WQRMs	Lines of evidence: CORMIX model
	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						
	Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL[1] *E. Coli* used as representative indicator.		✓	✓	✓	
	Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.		✓	✓	✓	
4. Drinking water	As per Water Quality metrics, under Aquatic Ecology		Not applicable to South Creek.				
	Microorganisms	*E. Coli* < 1cfu/100mL Enterococci <1cfu/100mL		✓	✓	✓	
		Viruses, protozoa and helminths[3,6] - Absent		✓	✓		
		Cyanobacteria risk index. Criteria: No overall increase in risk under any scenario.		✓	✓	✓	
	Toxicants	Refer to toxicants listed in aquatic ecology above.		✓	✓		✓

Notes on table:

1. Indicators and metrics adopted from ANZG (2018) and ANZECC/ARMCANZ (2000) default guideline values are for slightly disturbed lowland river ecosystems in south-east Australia.
2. These metrics are performance criteria presented in the Draft Aerotropolis Precinct Plan (Western Sydney Planning Partnership, 2020b). As these metrics are still in draft, DPIE and ANZECC/ARMCANZ (2000) guideline values have both been used in the impact assessment.
3. Refer to section 8.2.3 and Appendix F for more information on how these indicators were identified and assessed.
4. Guidelines for managing risks in recreational water (NHMRC 2008).
5. CORMIX modelling undertaken for toxicants where concentrations may be above guideline values (refer section 8.7.1 for further information).
6. Australian Drinking Water Guidelines 6 V3.6 (NHMRC 2011).
7. Salinity and total suspended solids have been adopted as alternative indicators to conductivity and turbidity respectively as they can be modelled in the WQRMs.
8. The guideline value for conductivity was converted to salinity using the approach recommended in section 8.2.1.4 in the ANZECC/ARMCANZ (2000) guidelines.
9. Adopted from Table 4.4.2 Physico-chemical stressor guidelines for the protection of aquaculture species – ANZECC/ARMCANZ (2000).
10. Default guideline value for the protection of aquatic ecosystems (95% protection as typically recommended for slightly to moderately disturbed ecosystems) – refer ANZECC/ARMCANZ (2000) Table 3.4.1 and ANZG (2018).
11. For nitrate, the updated ANZG (2018) state that the ANZECC/ARMCANZ (2000) DGV of 0.7 mg/L was erroneous and recommends the use of the guideline values published in NIWA (2013).
12. ANZECC/ARMCANZ (2000) Table 5.2.3.

8.4.3 Waterway objectives for the Georges River catchment

A large section of the brine pipeline will be in the Georges River catchment. The environmental values, indicators and guideline values applicable for lowland rivers in this catchment have been sourced from the *NSW Water Quality and River Flow Objectives* (DECCW, 2006) and are shown in Table 8-9.

Table 8-9 Waterway objectives for the Georges River catchment

Values, uses and associated management goals	Indicator	Guideline values
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and riparian zones over the long term.	Total phosphorus	0.025 mg/
	Total nitrogen	0.35 mg/
	Chlorophyll *a*	0.005 µg/
	Turbidity	6 - 50 NTU
	Salinity (electrical conductivity)	125 - 2200 µS/cm
	Dissolved Oxygen	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%.
	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.

Values, uses and associated management goals	Indicator	Guideline values
	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 (about 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

8.5 Existing environment

The project is located in the Hawkesbury Nepean and Georges River catchments. This includes the:

- AWRC and sections of the treated water and brine pipeline in the South Creek sub-catchment of the Hawkesbury Nepean catchment
- treated water and environmental flows pipelines in the Hawkesbury Nepean catchment
- brine pipeline partly in the Georges River catchment.

Each pipeline crosses several different waterways within each of these catchments. During operation, treated water will be released to South Creek within the South Creek sub-catchment and Warragamba and Nepean rivers within the Hawkesbury Nepean catchment.

The following sections describe the existing environment in the South Creek sub-catchment, Hawkesbury Nepean catchment and Georges River catchment. The focus of this section is on the existing water quality, hydrology, geomorphology, aquatic ecology and community and economic uses of the South Creek and Hawkesbury Nepean catchments. These features underpin the operational impact assessment of treated water releases in Section 8.7. There are no operational releases to waterways in the Georges River catchment so the focus for this section is limited to aquatic ecology and geomorphology. More details about the existing environment can be found in the relevant specialist reports, specifically Appendix F, G and H.

8.5.1 South Creek catchment

The South Creek sub-catchment covers an area of 628 km^2, sitting within the lower region of the Cumberland Plain. South Creek is a major waterway in the Hawkesbury-Nepean catchment as shown on Figure 8-6. The creek starts its journey in Narellan, north west of Campbelltown and then flows generally in a south to north direction through a gently undulating landscape until reaching its confluence with the Hawkesbury River, near Windsor.

From its origins, South Creek descends about 94 m over its 70 km course to the Hawkesbury River. The creek is joined by seventeen major tributaries including Badgerys Creek, Kemps Creek, Ropes Creek, Eastern Creek and McKenzies Creek. The creek flows through or forms the boundary of many suburbs including Bringelly, Badgerys Creek, Kemps Creek, Orchard Hills, St Marys, Dunheved, Riverstone, Windsor and McGraths Hill. The waterways within this catchment that are relevant to the project include:

- South Creek
- Kemps Creek
- Badgerys Creek
- Cosgroves Creek
- Oaky Creek.

South, Badgerys, Cosgroves and Oaky creeks are crossed by the treated water pipeline. Kemps Creek is crossed by the brine pipeline. South Creek will also receive treated water releases from the AWRC during wet weather.

A review of NSW statewide topographic mapping to determine Strahler stream ordering showed that Kemps, Badgerys, Cosgroves and Oaky creeks are fourth order streams and South Creek (to the west of the AWRC site) is a sixth order stream (CTEnvironmental, 2021).

The AWRC is located adjacent to South Creek, upstream of the confluences with Badgerys Creek and Kemps Creek. Figure 8-5 and Figure 8-7 show the location of the AWRC relative to South Creek as well as the treated water and stormwater release locations.

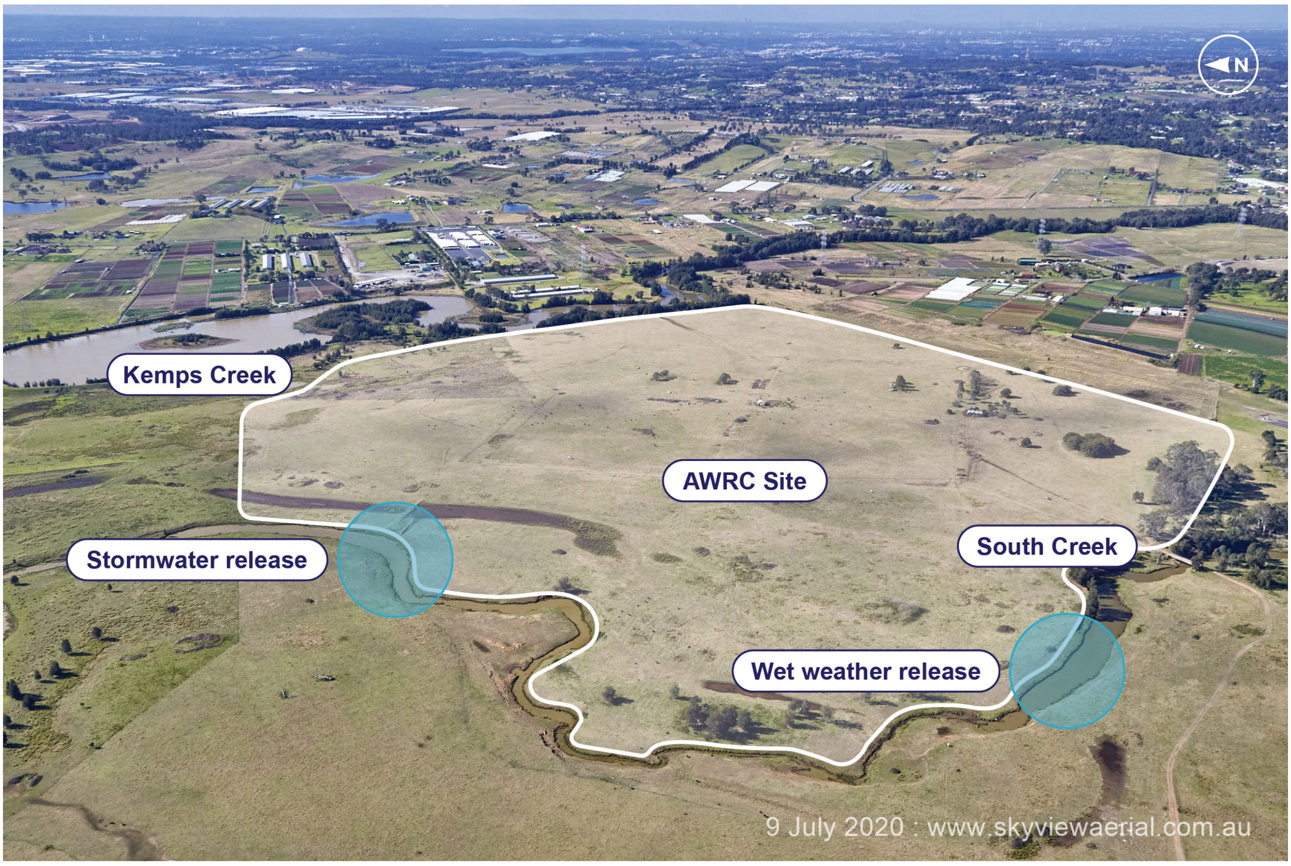
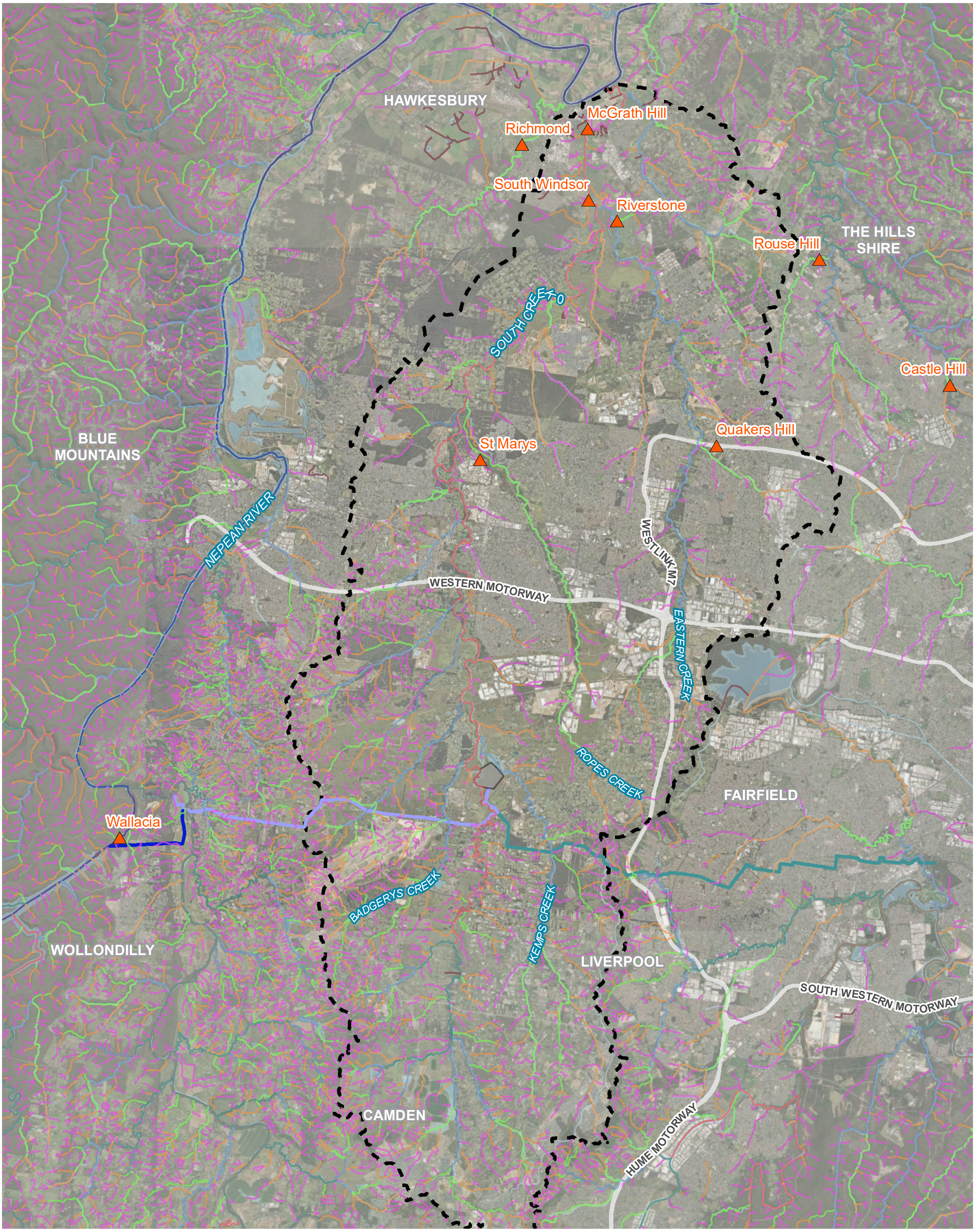


Figure 8-5 Aerial view of release locations at South Creek



Advanced Water Recycling Centre
Treated water pipeline
Brine pipeline
Environmental flows pipeline
Existing waste water treatment plants and water recycling plants

Strahler Stream Order

0
1
2
3
4
5
6
7
9
Watercourse
Waterbody

1:213,000
0 2.5 5km

Figure 8-6 South Creek catchment

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

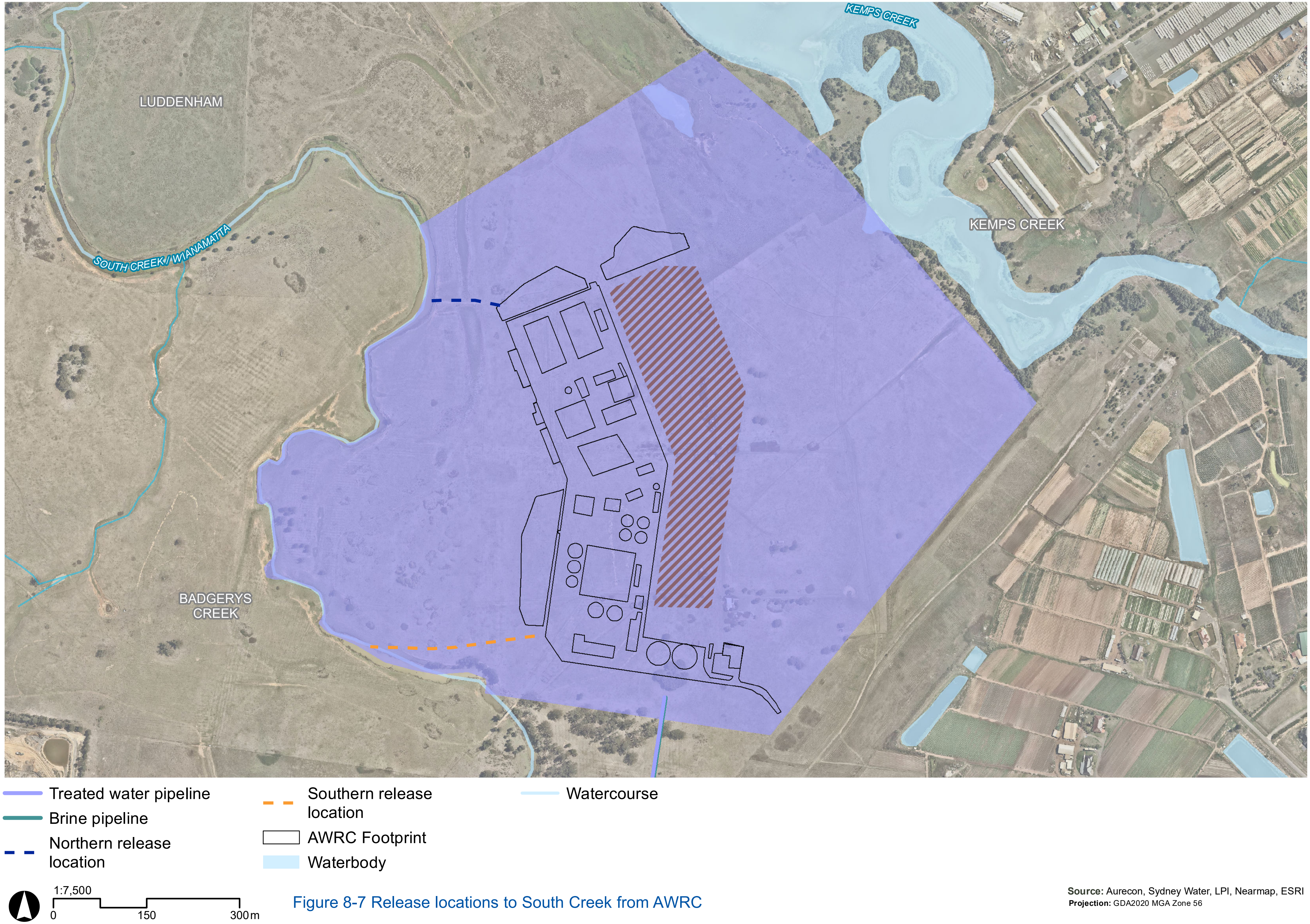


Figure 8-7 Release locations to South Creek from AWRC

Water quality

Bligh Tanner (2015) summarised the current condition of South Creek and noted that agricultural, urban and industrial activity have caused detrimental impacts to riparian and aquatic ecosystems including:

- fragmentation and loss of native riparian vegetation communities
- accelerated creek bed and bank erosion
- colonisation of invasive plant and animal species
- alteration and loss of aquatic habitats
- loss of sensitive aquatic macroinvertebrate species
- degraded water quality.

Sydney Water operates three WWTPs and WRPs in the South Creek sub-catchment at St Marys, Riverstone and Quakers Hill. Hawkesbury Council also operates two WWTPs in the South Creek catchment, including McGraths Hill and South Windsor.

Table 8-10 summarises water quality data collected at South Creek catchment monitoring sites. Figure 8-1 shows the locations of these monitoring sites. In accordance with ANZG (2018), South Creek can be considered a highly disturbed ecosystem as evidenced by elevated physical, chemical and microbial stressors. In particular, elevated concentrations of total nitrogen, oxidised nitrogen, total phosphorus and chlorophyll *a* throughout the catchment combined with generally low levels of dissolved oxygen and elevated enterococci densities reflect the cumulative impacts of urban, peri-urban and agricultural landuses within the catchment. As can be seen in Table 8-10 the highest concentration of nutrients was measured at NS450 in Kemps Creek likely indicating the cumulative impacts from upstream landuses. It is also noteworthy that elevated nutrient and chlorophyll *a* concentrations combined with low dissolved oxygen percentage saturation and elevated microbial indicators were also measured at NS45 upstream of the proposed AWRC.

Table 8-10 Summary of data from South Creek monitoring sites

Indicator		TN	TP	NOx	NH4	Chl a	DO	pH	Conductivity	Turbidity	Enterococci
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**%Sat**		**uS/cm**	**NTU**	**cfu/100ML**
ANZECC/ ARMCANZ (2000)		**0.35**	**0.025**	**0.04**	**0.02**	**0.003**	**85-110**	**6.5-8**	**125-2200**	**6-50**	**Primary <40, Secondary 41-200**
DPIE (2020)		**1.72**	**0.14**	**0.66**	**0.08**	**n/a**	**43-75**	**6.2-7.6**	**1103**	**50**	**n/a**
NS45	South Creek, upstream AWRC	1.78 (22)	0.241 (23)	0.88 (23)	0.05 (23)	0.018 (23)	70.3 (23)	7.4 (23)	1062 (23)	32.5 (22)	6960 (22)
NS44	South Creek, downstream, of AWRC	1.50 (22)	0.151 (22)	0.47 (22)	0.03 (22)	0.024 (22)	86.5 (22)	7.5 (22)	1031 (22)	73.0 (21)	809 (22)
NS450	Kemps Creek	3.38 (23)	0.704 (23)	2.38 (23)	0.03 (23)	0.008 (23)	71.7 (23)	7.5 (23)	1501 (23)	20.5 (22)	7700 (22)
NS440	Badgerys Creek	1.49 (23)	0.195 (23)	0.15 (23)	0.05 (23)	0.006 (23)	59.9 (23)	7.2 (23)	1070 (23)	11.0 (22)	6180 (22)
NS35	South Creek downstream, of Kemps Creek and Badgerys Creek	1.32 (23)	0.131 (23)	0.38 (23)	0.05 (23)	0.010 (23)	80.8 (23)	7.4 (23)	928 (23)	63.0 (22)	4790 (22)

Notes on table:

1. Guideline values taken from waterway objectives
2. All monitoring results are presented as medians, except for enterococci which is the 95th percentile.
3. Data covers period from January 2018 – June 2021
4. Values in brackets are sample numbers
5. Numbers in blue are below or equal to guideline values, and numbers in green are above guideline values. DPIE performance criteria adopted for comparison where available, otherwise ANZECC/ARMCANZ (2000) guideline values adopted.
6. For enterococci, numbers in red are above both secondary and primary guideline values.

In the future, the South Creek sub-catchment will see the most significant level of development within the wider Hawkesbury Nepean catchment. The South West and Western Sydney Aerotropolis Growth Areas are primarily located within the South Creek catchment boundary.

Hydrology

The hydrology of the South Creek sub-catchment has been significantly altered due to a decrease in pervious surfaces through land clearance and urbanisation.

South Creek can generally be separated into three waterway types: ephemeral, non-ephemeral and tidal. Upstream of the AWRC site and downstream to the confluence with Kemps Creek, South Creek is ephemeral. Under extended dry weather conditions, the creek can slow and become segregated into separate pools all the way down to around Dunheved Creek. The tidal influence extends up to near Richmond Road, about 14 km from the confluence with the Hawkesbury River.

No detailed bathymetry or topographic data was available for South Creek. The WQRM for South Creek, which uses LiDAR data, estimates that median water depth at the proposed release locations is about 0.8 m.

Table 8-11 summarises median flows at stream flow gauges located upstream and downstream of the AWRC. At the Elizabeth Drive gauge, there are very low to no flows for a significant proportion of the time (that is flows are less than 0.01 ML/day about 46% of the time). Further downstream at the Great Western Highway site, flows less than 0.01 ML/day occur less frequently, about 16% of the time.

Table 8-11 Median flows at existing stream flow gauges near AWRC

Gauge number	Location	Median flow
212320	South Creek at Elizabeth Drive, 1.7 km upstream of AWRC	0.26 ML/day
212048	South Creek at the Great Western Highway, 14.3 km downstream of the AWRC	7.6 ML/day

A search of the NSW Water Register indicated that there nine water access licences with a total share component of 313 ML/yr (under the category of unregulated river) (WaterNSW, 2021a). Of agricultural water users in the catchment, market gardens, dairy and pastures use the largest water volumes (Rae, 2007).

Geomorphology

South Creek at and downstream of the proposed AWRC site is a laterally unconfined waterway in a valley setting with a cohesive and continuous floodplain. It has a low sinuosity (that is, bends are sparse, low wavelength or low amplitude) and is characterised by fine grained bed materials varying between uncemented coarse matrix and cemented fines.

Bank composition through this section of South Creek consists of fines with limited coarse materials and marginally dispersive conditions. There are several informal obstructions throughout this section of creek that have preserved remnant chain of ponds function through weir pool effects. However, the original physical form of chain of ponds in this region was lost long ago.

South Creek in this region is characterised by several large billabongs and observable anabranches, with an example visible near the stormwater release on Figure 8-5. These are a result of the low gradient of the system. South Creek has meandering bends with steep outside banks and shallow inside banks.

The condition of South Creek is poor based on the high extent and severity of erosion, and the poor quality of riparian vegetation both of which affect bank stability and character. However, the South Creek channel also maintains various important geomorphic features such as fine-grained benches and gravel bars.

Table 8-12 summarises the river styles and geomorphic sensitivity for South Creek and other affected waterways in the sub-catchment. The river styles framework characterises geomorphic river styles, their behaviour, condition and recovery potential (sensitivity).

Table 8-12 River styles and geomorphic sensitivity of other waterways crossed by the pipelines (DPIE, 2021c)

Waterway	River style	Geomorphic sensitivity
South Creek	Meandering, fine grained	High
Kemps Creek	Low sinuosity, fine grained	Moderate
Badgerys Creek	Low sinuosity, fine grained	Moderate
Cosgroves Creek	Low sinuosity, fine grained	Moderate
Oaky Creek	Low sinuosity, fine grained	Moderate

Aquatic and riparian ecosystems

The results from the aquatic ecology desktop and field work confirmed that waterways within the South Creek catchment are generally in a degraded state. None of the potentially impacted waterways within the catchment are classified as habitat for any threatened species or their habitats protected under the *Fisheries Management Act 1994*. Likewise, no MNES were mapped as present under the EPBC Act.

Field based inspection of the anabranch on the AWRC site near the stormwater release confirmed this feature as a historical flow path of South Creek. It is now separated from South Creek and forms a wetland ecosystem which is likely maintained by rainfall, shallow groundwater and high flow conditions in South Creek (shown on Figure 8-8).

Macroinvertebrates

Interpretation of aquatic macroinvertebrate data collected by Sydney Water (2021a) in South Creek as part of the baseline monitoring program indicates the aquatic environment is subject to moderate to high levels of disturbance. Family richness, EPT% (total number of distinct taxa within the Trichoptera, Ephemeroptera and Plecoptera groups) and SIGNAL-SG (Stream Invertebrate Grade Number Average Level where 'S' indicates Sydney and 'G' indicates identification to the genus taxonomic level), at NS44 and NS45 are low. This indicates a lack of macroinvertebrate biodiversity which is likely driven by hydrological, habitat and water quality degradation typical of the modified landscape of the upper South Creek catchment.

The macroinvertebrate community of Kemps Creek (NS450) comprises taxa that are pollution tolerant with a lack of pollution sensitive taxa present as shown by relatively low EPT% composition and SIGNAL-SG score.

Fish

In terms of fish habitat classification, South Creek is a Type 1 (highly sensitive key fish habitat) and Class 1 (major key fish habitat) waterway as shown in Figure 8-8. Kemps Creek is a Type 1 (highly sensitive key fish habitat) and Class 2 (moderate key fish habitat) waterway.

Review of fish survey results from Sydney Water (2021a) shows eight species recorded in South Creek. Of these eight species, two are exotic, Gambusia and Goldfish. Table 8-13 summarises the species and numbers of fish that were identified in two fish surveys undertaken by Sydney Water in 2020.

Fish survey by CTEnvironmental (2018) identified Australian Bass, Carp, Goldfish and Long-Finned Eel in South and Kemps Creeks upstream of the AWRC site. The capture of Australian Bass in this area indicates periodic connectivity to downstream reaches of South Creek, as this species undertakes annual migration to estuarine habitats to spawn. Fish are likely to navigate over downstream obstacles during periods of floodplain inundation.

Table 8-13 Fish survey results for South Creek

Fish (Common Name)	NS35		NS44		NS45	
	Aug-20	Dec-20	Aug-20	Dec-20	Aug-20	Dec-20
Empire Gudgeon	1	6	1	2		10
Firetailed Gudgeon				2		
Flathead Gudgeon		2				
Gambusia Aff	2	12	14	166	6	292
Goldfish		1	1	1		6
Long-finned eel	17	12		3	8	
Striped Gudgeon	4	14				

Fish (Common Name)	NS35		NS44		NS45	
	Aug-20	Dec-20	Aug-20	Dec-20	Aug-20	Dec-20
Freshwater Mullet	1					

Macrophytes

Thirteen species of macrophytes have been recorded at monitoring sites within the South Creek catchment, included five exotic species and eight native species.

Native macrophytes play an important role in the functioning of aquatic ecosystems. They provide habitat for other aquatic life, contribute to nutrient cycling, reduce erosion, increase dissolved oxygen levels, capture atmospheric carbon dioxide and act as a food source. The relatively high number of native species indicates that there are waterways within the catchment that provide suitable conditions for native aquatic vegetation.

The surveys recorded macrophytes listed as weeds of national significance, including *Alternanthera philoxeroides* (Alligator Weed), *Eichhornia crassipes* (Water Hyacinth) and *Salvinia molesta*. These species are highly dispersive and can form dense mats. The formation of dense mats restricts light penetration and can lead to anerobic conditions. This in turn can cause the death of other aquatic life and the discharge of organic matter can trigger a eutrophication event.

Table 8-14 Summary of macrophytes recorded within South Creek catchment (April and October, 2020)

Scientific Name	Native/exotic	NS45	NS35	NS44	NS450 (Kemps Ck)	NS440 (Badgerys Ck)
Azolla pinnata	Native	X		X		X
Juncus usitatus	Native		X			
Lemna minor	Native	X	X	X	X	X
Ludwigia peploides	Native	X		X		
Maundia triglochinoides	Native			X		
Persicaria lapathifolia	Native			X		X
Phragmites australis	Native				X	

Scientific Name	Native/exotic	NS45	NS35	NS44	NS450 (Kemps Ck)	NS440 (Badgerys Ck)
Potamogeton crispus	Native			X		
Typha	Not confirmed					X
Vallisneria sp	Not confirmed	X		X	X	
Alternanthera philoxeroides	Exotic	X	X	X	X	X
Eichhornia crassipes	Exotic			X		
Salvinia molesta	Exotic	X				

Riparian vegetation and creek channel condition

CTEnvironmental (2021) completed 20 riparian vegetation and creek channel assessments within the South Creek sub-catchment.

Six assessments were completed along South Creek at the locations identified in Figure 8-8. Four sites were located adjacent to the AWRC site and two further upstream at the treated water pipeline crossing. Results show the overall condition of these sites ranges from poor to fair. The sites all show signs of erosion. All sites have a wide to moderate riparian buffer, with moderate vegetation structural complexity. Weeds are low at all sites. Overall, most of the sites have good aquatic habitat.

Riparian vegetation and creek channel assessments were completed at six locations along Kemps Creek, four to the north east of the AWRC site and two further upstream at the brine pipeline crossing. Results show the overall condition at these sites ranges from fair to good. Inspection of Kemps Creek and Kemps Creek Dam, to the east of the AWRC boundary, shows an overflow channel extends from the southern end of the main body of the dam into the AWRC site, where it forms wetland habitat before joining Kemps Creek below the dam wall (shown on Figure 8-8).

Other sites were also assessed within the South Creek catchment, including sites at Badgerys and Cosgroves Creeks. Table 8-15 provides a summary of the aquatic features of the main waterways in the South Creek catchment.

Table 8-15 Summary of aquatic features of other waterways within South Creek catchment

Waterway	Location	Strahler Stream Order (at pipeline crossing)	KFH Status	Riparian vegetation and creek channel condition
South Creek	AWRC and treated water pipeline	6	Type 1 – Highly sensitive key fish habitat Class 1 (major key fish habitat)	Poor to fair
Badgerys Creek	Treated water pipeline	4	Type 2 – Moderately sensitive key fish habitat Class 2 – Moderate key fish habitat	Fair to good
Cosgroves Creek	Treated water pipeline	4	Type 2 – Moderately sensitive key fish habitat Class 2 – Moderate key fish habitat	Poor to fair
South Creek tributaries	Treated water pipeline	1-2	Type 3 – Minimally sensitive key fish habitat Class 3 – Minimal key fish habitat	Poor
Kemps Creek	Brine pipeline	4	Type 1 – Highly sensitive key fish habitat Class 2 – Moderate key fish habitat	Fair to good
Oaky Creek	Treated water pipeline	3	Mapped as key fish habitat however type and class not confirmed during site investigations.	Not assessed

Groundwater dependent ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (GDE) (BOM, 2021) shows South Creek is considered an aquatic GDE. No terrestrial GDEs are mapped within the AWRC site. However, small patches of terrestrial GDEs, which correspond to remnant patches of native vegetation, are mapped within 500 m of the AWRC boundary. These are shown on Figure 8-9.

Field validation of GDEs confirmed no terrestrial GDEs are within the AWRC site boundary and that it is highly likely South Creek is connected to groundwater as indicated by the permanency of water in this reach of the creek.

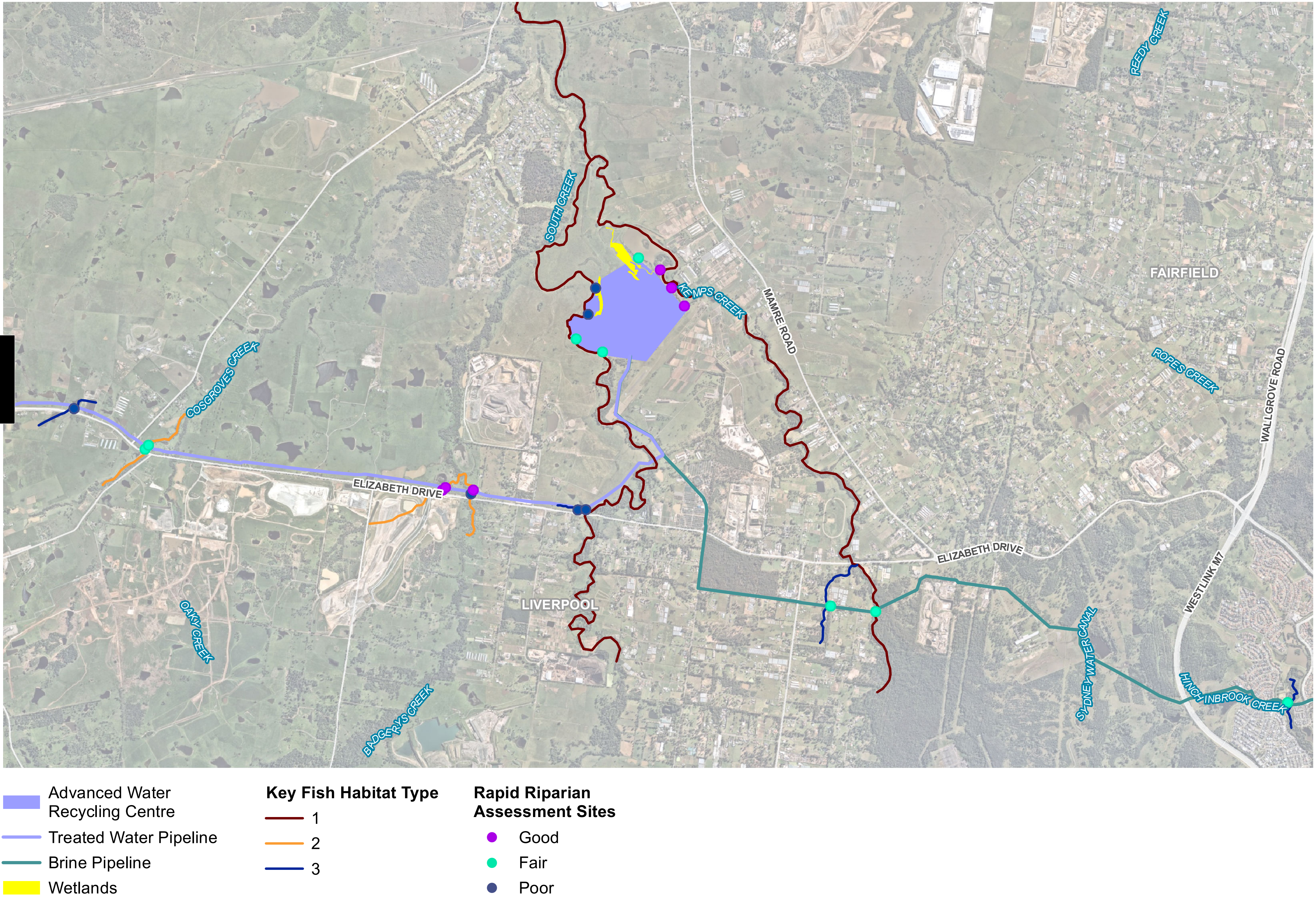
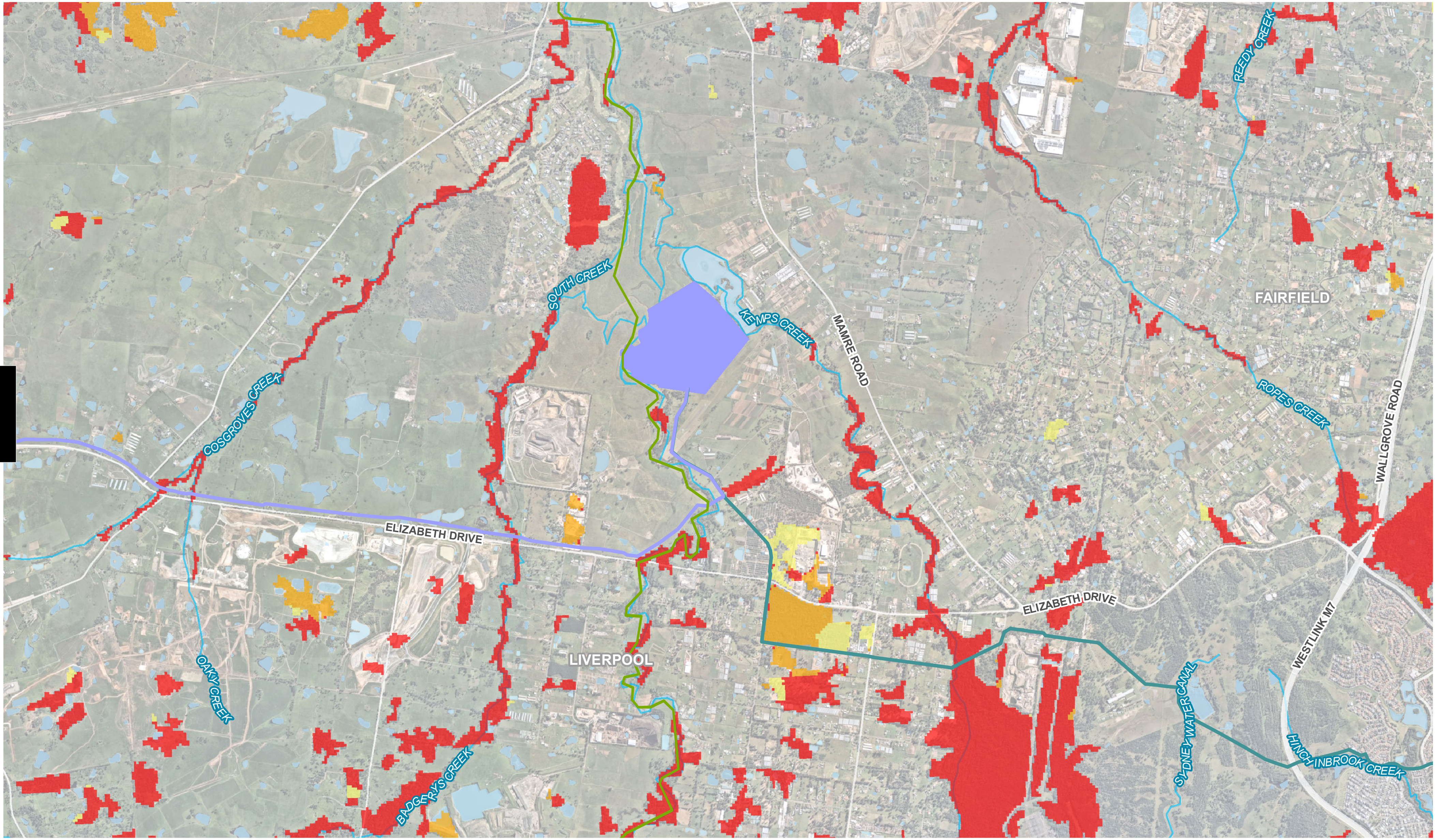


Figure 8-8 Aquatic ecology features of South Creek

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56



Advanced Water Recycling Centre
Treated Water Pipeline
Brine Pipeline

GDE Terrestrial
High potential
Moderate Potential
Low Potential

GDE Aquatic
High potential

1:50,000
0 0.5 1km

Figure 8-9 Aquatic ecology features of South Creek

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Community and economic uses

Land use within the catchment currently consists of a mix of rural farms, remnant native forest and urban areas (Alluvium, 2019).

Recreation

South Creek is popular for fishing and water activities, casual outdoor activities and bird and bat watching (Tippler et al. 2016). Bass fishing is particularly popular in South Creek with several clubs and associations using the waterway, including the Bass Sydney Fishing Club and the South Creek Bass Club.

Within the South Creek catchment, 34 active community groups or community activities with an environmental focus were identified in CT Environmental (2016). Of these, 28 have a Cumberland Plain Woodland focus, three are bird watching groups, two are fishing groups and one is a council organised bat watching group.

Figure 8-10 shows recreational areas located adjacent to South Creek downstream of the AWRC including:

- Samuel Marsden Reserve, Orchard Hills
- The Kingsway
- Penrith BMX club
- St Marys Tennis Court Clubhouse
- St Marys Community and Road Education Scheme (CARES)
- Nepean Bowhunters Club
- Penrith City Archers
- Dunheved Golf Club
- Wianamatta Regional Park
- Governor Phillip Park at the confluence with the Hawkesbury River.

Agriculture

Rural activities in the catchment include cattle and sheep grazing, market gardening, greenhouse and horticultural crops and pastures and intensive agriculture such as poultry farming. The extent of agriculture within the catchment is shown in Figure 8-10.

Figure 8-10 Land use and recreational sites along South Creek

8.5.2 Hawkesbury Nepean catchment

The Hawkesbury Nepean catchment, shown on Figure 8-11, represents one of the largest coastal basins in NSW. The catchment covers about 21,400 km^2 and is a major source of drinking water for Sydney, the Blue Mountains and the Illawarra (Sydney Water, 2018).

The headwaters of Nepean River rise near Robertson, about 100 km south of Sydney before flowing north through an unpopulated catchment area and later past the town of Camden and the city of Penrith. Near Wallacia it is joined by the dammed Warragamba River. North of Penrith, near Yarramundi, at its confluence with the Grose River, Nepean River becomes the Hawkesbury River. It then continues on a meandering course for about 140 km, combining with the significant tributaries of South Creek, Cattai Creek, Colo Creek and MacDonald River before reaching the ocean between Barrenjoey and Box Head.

The project's treated water release to Nepean River is located upstream of Wallacia Weir, about 2.5 km upstream of Warragamba River confluence as shown on Figure 8-12. Figure 8-13 shows an aerial view of Wallacia Weir and the approximate location of the release.

Figure 8-14 shows the treated water release location to Warragamba River. Downstream of Warragamba Dam, Warragamba River runs for about 3.3 km before flowing into Nepean River. The surrounding catchment includes the Blue Mountains World Heritage Area to the west and Warragamba township and rural-residential properties to the east.

The Blue Mountains World Heritage Area is located along the east and west bank of Nepean River from around Nortons Basin to Glenbrook Creek. This area is classified as a MNES under the EPBC Act.

In addition to Nepean and Warragamba rivers, other waterways relevant to the project in this catchment include:

- Mulgoa Creek
- Jerrys Creek
- Baines Creek
- Megarritys Creek.

Mulgoa and Jerrys creeks are crossed by the treated water pipeline. Baines and Megarritys creeks are crossed by the environmental flows pipeline.

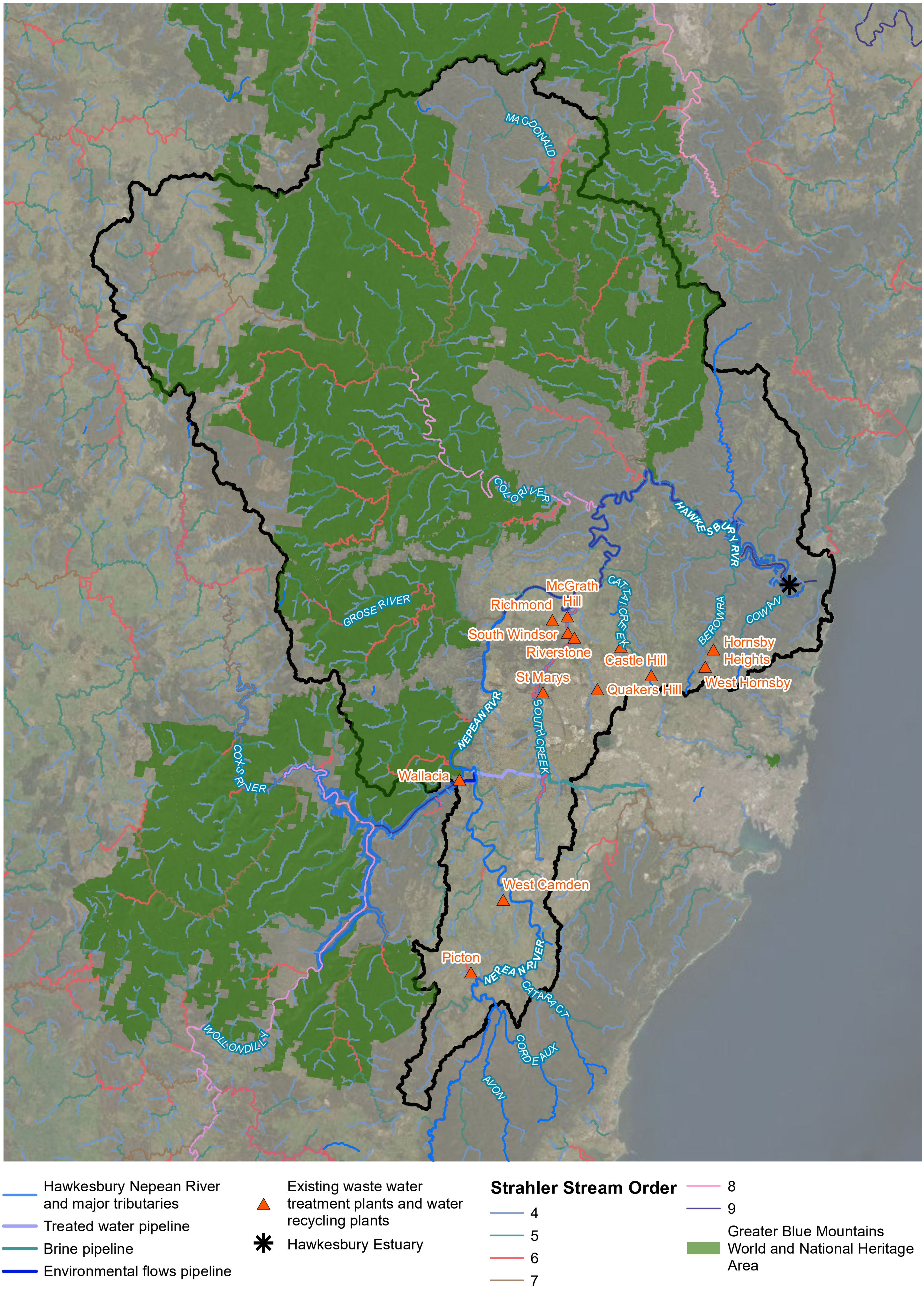


Figure 8-11 Hawkesbury Nepean River catchment

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Figure 8-12 Nepean River treated water release location

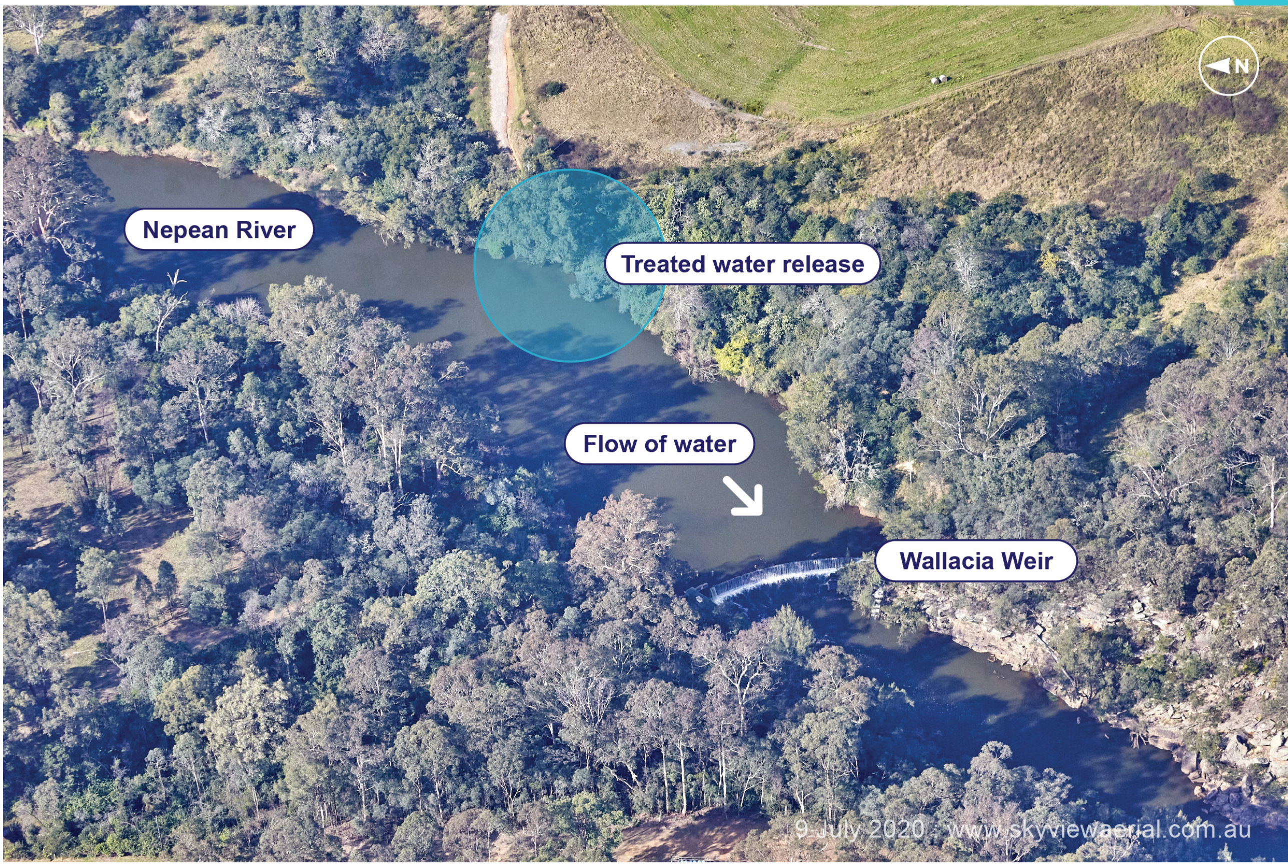


Figure 8-13 Aerial view of Wallacia Weir looking upstream

Environmental flows pipeline

Environmental flows release structure

Waterbody

Watercourse

1:6,000

0 25 50m

Figure 8-14 Warragamba River treated water release location

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI

Projection: GDA2020 MGA Zone 56

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Water quality

The Hawkesbury Nepean River faces challenges common to many coastal river systems on the east coast of Australia. Key pressures and water management challenges include intensive urban and industrial development, agricultural practices, land use change and clearing, significant alteration of the natural river flow, point sources including treated wastewater releases, as well as numerous, competing demands for water. These stressors have impacted water quality through elevated contaminant levels, excess nutrients, algae and weed growth.

Sydney Water operates 15 WWTPs and WRPs in the Hawkesbury Nepean River catchment from West Camden to Brooklyn. These are shown on Figure 8-11.

Table 8-16 summarises water quality data collected as part of Sydney Water's baseline monitoring program in Nepean and Warragamba rivers. The location of the monitoring sites is shown in Figure 8-1.

In accordance with ANZG (2018), Nepean River is considered a slightly-to-moderately disturbed ecosystem. Elevated concentrations of total nitrogen, oxidised nitrogen and chlorophyll *a* are evidenced at all sites while low levels of total phosphorus and well oxygenated waters generally low in turbidity are also typical of the river system. The slightly elevated enterococci densities measured at N67, N66A and N66B possibly reflect associated landuses and/or wet weather events when elevated microbial indicators are typical.

Similarly, Warragamba River is considered a slightly-to-moderately disturbed ecosystem as evidenced by slightly elevated total and oxidised nitrogen concentrations, low total phosphorus, ammonium and chlorophyll-*a* concentrations coupled with well oxygenated waters low in turbidity and enterococci densities. This water quality profile is generally typical of forested catchments with low to no urban and agricultural sources of pollution.

At Megarritys Creek, WaterNSW releases between 22-30 ML/day from the Warragamba Pipeline. Megarritys Creek flows into Warragamba River. The releases include 5 ML/day to dilute Wallacia WWTP discharges. An additional 17 ML/day of water is released between April to October, increasing to 25 ML/day between November and March to effectively replace water extracted for Sydney Water's North Richmond Water Filtration Plant (WFP). These releases are specified in the Water Sharing Plan for the Greater Metropolitan Region.

The reach downstream of Megarritys Creek is a backwater of the Penrith Weir pool and is characterised by long residence times, estimated at about 180 days (DPI, 2014a). Wallacia WWTP releases 0.8 ML/day about 150 m downstream of Megarritys Creek. This section has abundant aquatic weeds which almost block part of the channel during summer months. There are records of visual discolouration (greenish colour) however the cause of this is unknown (DPI, 2014a).

Table 8-16 Summary of data from Nepean and Warragamba rivers monitoring sites (Sydney Water 2021)

Indicator		TN	TP	NOx	NH4	Chl *a*	DO	pH	Conductivity	Turbidity	Enterococci
Units		mg/L	mg/L	mg/L	mg/L	mg/L	%Sat		uS/cm	NTU	cfu/100 ML
ANZECC/ARMCANZ (2000)		0.35	0.025	0.04	0.02	0.003	85-110	6.5-8	125-2200	6-50	Primary <40, Secondary 41-200
N67	Nepean River at Wallacia Bridge	1.00 (120)	0.020 (120)	0.66 (120)	0.01 (120)	0.007 (120)	94.8 (61)	7.5 (61)	365 (61)	7.3 (61)	508 (22)
N66A	Nepean River upstream of proposed AWRC release	1.13 (18)	0.023 (18)	0.68 (18)	0.02 (18)	0.006 (17)	93.9 (18)	7.4 (18)	338 (18)	6.8 (17)	752 (18)
NS66B	Nepean River downstream of Wallacia Weir and release	1.13 (18)	0.024 (18)	0.67 (18)	0.02 (18)	0.006 (18)	98.1 (18)	7.5 (18)	327 (18)	8.1 (17)	798 (18)
N66	Nepean River upstream of confluence with Warragamba River	1.09 (22)	0.022 (22)	0.74 (22)	0.02 (22)	0.004 (22)	99.3 (22)	7.5 (22)	332 (22)	6.4 (22)	167 (22)
N64	Nepean River downstream of Warragamba River	1.03 (17)	0.016 (17)	0.66 (17)	0.02 (17)	0.003 (17)	98.3 (17)	7.6 (17)	305 (17)	5.8 (17)	111 (17)
N57	Penrith Weir	0.66 (119)	0.014 (119)	0.35 (119)	0.01 (119)	0.005 (119)	96.0 (60)	7.5 (60)	301 (60)	3.6 (60)	Not available

Indicator		TN	TP	NOx	NH4	Chl *a*	DO	pH	Conductivity	Turbidity	Enterococci
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**%Sat**		**uS/cm**	**NTU**	**cfu/100 ML**
ANZECC/ARMCANZ (2000)		**0.35**	**0.025**	**0.04**	**0.02**	**0.003**	**85-110**	**6.5-8**	**125-2200**	**6-50**	**Primary <40, Secondary 41-200**
N642	Warragamba River upstream of Megarritys Creek	0.19 (39)	0.009 (39)	0.04 (39)	0.01 (39)	0.002 (39)	85.2 (39)	7.00 (39)	242 (39)	4.3 (39)	72 (38)
N642A	Warragamba River downstream of Megarritys Creek and upstream of Wallacia WWTP	0.81 (17)	0.013 (17)	0.45 (17)	0.01 (17)	0.002 (17)	98.0 (17)	7.53 (17)	207 (17)	9.9 (16)	530 (17)
N641	Warragamba River downstream of Wallacia WWTP	0.44 (45)	0.009 (45)	0.17 (45)	0.01 (45)	0.001 (45)	99.8 (45)	7.54 (45)	245 (45)	3.4 (45)	73 (45)

Notes on table:

1. Guideline values taken from waterway objectives
2. All monitoring results are presented as medians, except for enterococci which is the 95th percentile.
3. Data covers period from January 2018 – June 2021
4. Values in brackets are sample numbers
5. Numbers in blue are below or equal to guideline values, and numbers in green are above guideline values
6. For enterococci, numbers in orange meet secondary contact guideline values and numbers in red are above both secondary and primary guideline values.

In terms of future pressures, continued and significant urban growth in the catchment and other parts of Sydney is expected to place increasing demand on the river's resources. It is planned that a large proportion of Sydney's urban growth will occur in the South West and Western Sydney Aerotropolis growth areas, which are primarily located within the catchment of South Creek, although some of this urban growth will extend into other parts of the overall Hawkesbury Nepean catchment.

The increasing urbanisation of the catchment is expected to not only result in a significant increase in demand for drinking water but will also potentially result in changes in land use and point and diffuse sources of pollution.

Hydrology

Key elements that drive the motion of water in the Hawkesbury Nepean river system include the tidal cycle from the Tasman Sea, freshwater inflows from surrounding catchments, releases from dams and weirs as well as climatic conditions such as wind.

Flows within the Hawkesbury Nepean river system have been heavily modified. The upper Nepean River is controlled by major drinking water storages including the Warragamba, Nepean, Avon, Cataract and Cordeaux dams. The Broughtons Pass and Pheasants Nest water supply diversion weirs located near Wilton and Appin also form major retention structures on the Cataract and Nepean rivers. Flows have been further reduced by a series of weirs between Menangle and Wallacia. To counteract the presence of the weirs and dams, as well as the significant levels of water demand, daily variable environmental flows from the Upper Nepean dams and water supply weirs were introduced in July 2010.

The proposed treated water release location at Nepean River is located about 120 m upstream of Wallacia Weir and about 2.5 km upstream of the confluence with Warragamba River. Flows in Nepean River downstream of the release are influenced by Wallacia Weir, Warragamba River inflows and Penrith Weir. Water depths from the release location to Wallacia Weir vary between about two to five metres. Downstream of the confluence of Warragamba River and Nepean River, water levels are influenced by the Penrith Weir pool. Downstream of Penrith Weir, Sydney Water releases up to 50 ML/day of advanced treated water into Boundary Creek from the St Marys Advanced Water Treatment Plant as part of the Replacement Flows project.

From Warragamba Dam to Megarritys Creek, Warragamba River is a series of discontinuous pools. Water pools upstream of Warragamba Weir, located about 1.2 km downstream of Warragamba Dam. The proposed release location is located upstream of Warragamba Weir. This reach rarely receives inflows and appears to be dominated by iron-rich groundwater inflow (DPI, 2014a). Current inflows to this reach are a combination of flood flows that spill from the dam, groundwater and dam seepage, local catchment runoff and water releases from the Dam. Warragamba Dam filled and spilled for the first time in 14 years in March 2012. The most recent dam spill event occurred in March 2021. This flood event has been estimated as a 10% to 5% Annual Exceedance Probability (AEP) event (NSW Government, 2021).

At Warragamba Weir, water depth is estimated to be about 0.4 m at median flow. Downstream of the Warragamba Weir, median water depth is estimated to be about 4 m.

Downstream of Megarritys Creek, Warragamba River is dominated by WaterNSW releases to Megarritys Creek (outlined above).

Table 8-17 summarises median flows at stream flow gauges located at Wallacia Weir, Penrith Weir and Warragamba Weir.

Table 8-17 Median flows in Nepean and Warragamba rivers at existing stream flow gauges near release locations

Gauge number	Location	Description of flows
212202	Nepean River at Wallacia	Median flow of about 229 ML/day since June 2010 when environmental flows from the upper Nepean scheme were introduced. Prior to this, median flows were about 10 ML/day. Low to no flow conditions (less than 10 ML/day) only occur a small proportion of the time (about 5%).
21220	Nepean River at Penrith	Minimum flow of about 50 ML/day. Median flow is about 275 ML/day.
212241	Warragamba River at Warragamba Weir	There has been a significant reduction in flows in Warragamba River downstream of the dam since the early 1990's. About 22% of the time flows are less than 5 ML/day.

Water extractions

In addition to drinking water supply, there is also an extensive network of extractions from the river and its tributaries to supply water for the region's significant agricultural production.

Water is extracted from the Hawkesbury Nepean River for:

- irrigation for agricultural businesses including pasture, cereals, turf, lucerne, vegetables and fruit
- land use (farming, housing and other commercial activities)
- town and industrial water supply.

The major utilities that extract water from the Hawkesbury-Nepean are WaterNSW and Sydney Water. WaterNSW extracts water for water supply. Sydney Water currently extracts water from the Hawkesbury River at North Richmond for drinking water supply purposes. Table 8-18 provides a breakdown of the current water access licences in the Hawkesbury and Lower Nepean Rivers.

Table 8-18 Summary of water access licences and water usage in the Hawkesbury and Lower Nepean Rivers (WaterNSW, 2021a)

Water access licence category	Number of water access licences	Total share component (ML/yr)
Domestic and stock	165	1,113
Unregulated river	1,379	112,402

Water access licence category	Number of water access licences	Total share component (ML/yr)
Local water utility	1	1,293
Major utility (Sydney Water and WaterNSW)	2	26,075

Geomorphology

The geomorphic character of Nepean River varies across five distinct reaches. Table 8-19 summarises the geomorphology of Nepean River upstream and downstream of the release location. River Styles are geomorphic descriptions of waterways used to assist in identifying a waterway's sensitivity to change and ability to recover from disturbance (DPIE, 2021c).

Table 8-19 Summary of geomorphology of Nepean and Warragamba rivers

Reach	River Style[1]	Geomorphic sensitivity[1]	Description
Upstream of Wallacia Weir	Alluvial, low sinuosity, gravel	Moderate	The Nepean River upstream of Wallacia Weir is alluvial with low sinuosity and is less bedrock-controlled than sections downstream. It is backwater controlled, with a low hydraulic gradient which means it is slow flowing. The river bed is likely to consist of sand and gravel.
Wallacia Weir to Norton's Basin	Gorge	Low	The section from Wallacia Weir to Norton's Basin is characterised with a sequence of pool and riffle features and is significantly steeper, which greatly increases hydraulic diversity. It is bedrock controlled with a gravel, cobble and boulder bed.
Norton's Basin to upstream margin of backwater from Penrith Weir	Planform controlled, low sinuosity, gravel	Moderate	This section is bedrock controlled. The river bed is likely to consist of gravel, cobble and boulders.
Penrith Weir backwater	Water storage – dam or pool	Low	This section is backwater controlled, with a low hydraulic gradient and low to moderate sinuosity. It is bedrock controlled. The river bed is likely to consist of gravel, cobble and boulders. The river is in a degraded condition downstream of Glenbrook Creek due to gravel extraction.
Warragamba River	Gorge	Low	The Warragamba River downstream of Warragamba Dam is bedrock controlled with a cobble bed and moderate sinuosity.

Table notes:

1. NSW River Styles Database (DPIE 2021c)

The river styles and geomorphic sensitivity for other waterways crossed by the pipelines is summarised in Table 8-20.

Table 8-20 River styles and geomorphic sensitivity of other waterways crossed by the pipelines (DPIE 2021c)

Waterway	River style	Geomorphic sensitivity
Mulgoa Creek	Valley fill, fine grained	High
Jerrys Creek	Low sinuosity, fined grained	Moderate
Baines Creek	Low sinuosity, fined grained	Moderate
Megarritys Creek	Gorge	Low

Aquatic and riparian ecosystems

The results from the aquatic ecology desktop and field work confirmed the overall condition of Nepean River upstream of Wallacia Weir as good to fair condition, and downstream of Wallacia Weir from fair to excellent. Nepean River at both locations is considered key fish habitat. Field assessments identified wide riparian buffers, presence of weeds and good aquatic habitat, and minor to moderate erosion and deposition impacts.

The results from the aquatic and riparian desktop and field work confirmed the overall condition of Warragamba River as excellent. The river is considered key fish habitat. Riparian vegetation was greater than 40 m wide, with good structural complexity and low weed density. Aquatic habitat is in good condition.

Both Nepean and Warragamba rivers are mapped as critical habitat for the threatened Macquarie Perch (*Macquaria australasica*). This species is discussed in more detail below.

Figure 8-15 shows the aquatic ecology features of waterways in the Hawkesbury Nepean catchment.

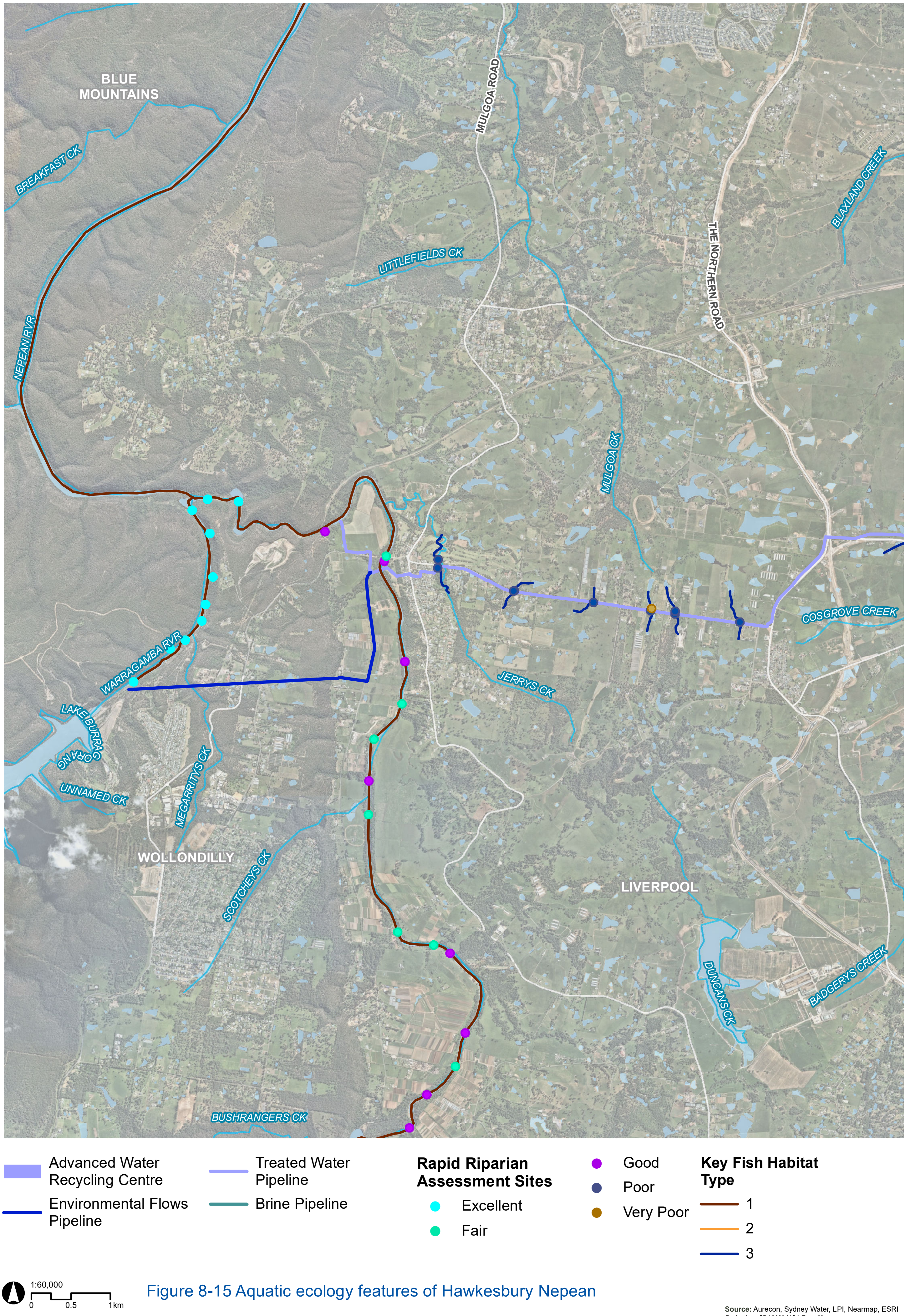


Figure 8-15 Aquatic ecology features of Hawkesbury Nepean

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Macroinvertebrates

The macroinvertebrate community structure in Nepean River indicates a moderate to low level of disturbance upstream of Wallacia Weir and a moderate level of disturbance downstream of the weir. Family richness and EPT% are relatively low, indicating a reduction of biodiversity. The macroinvertebrate community of Nepean River comprises taxa that range from pollution tolerant to pollutant sensitive. The macroinvertebrate data indicates that a combination of human factors (most likely reduced water quality from pollution and disturbance) are adversely affecting the macroinvertebrate community.

Results of macroinvertebrate monitoring in Warragamba River indicate a moderate level of disturbance due to a relatively low family richness and EPT%. The macroinvertebrate community structure of Warragamba River includes a range of taxa with varying tolerance to disturbance and alteration of water quality. Given that this reach of Warragamba River is currently subject to releases from Warragamba Dam, it is likely that a combination of altered hydrology and potentially temperature driven effects influence the macroinvertebrate community.

Threatened species

Three threatened aquatic species listed under the FM Act or EPBC Act were identified in a broad scale desktop review and include:

- Macquarie Perch (*Macquaria australasica*) – listed under FM Act and EPBC Act
- Adams Emerald Dragonfly (*Archaeophya adamsi*) – listed under FM Act
- Sydney Hawk Dragonfly (*Austrocordulia leonardi*) - listed under FM Act.

The Warragamba River and Nepean River (from downstream of the confluence with Warragamba River to Lynch Creek, downstream of Penrith Weir) are mapped as critical habitat for the Macquarie Perch. The Commonwealth referral decision under the EPBC Act identified the Macquarie Perch as a species for which there is potential for the project to have a significant impact. This chapter and Appendix H therefore provide further assessment of the project's potential impacts on Macquarie Perch.

Although the Adams Emerald Dragonfly and Sydney Hawk Dragonfly are found in the Sydney basin, the sections of Warragamba and Nepean Rivers subject to potential impacts of the project are not considered as habitat and therefore these species are not expected to be present.

The Adams Emerald Dragonfly is known at only four sites across the Sydney basin, none of which are near the study area. The Sydney Hawk Dragonfly is known at three locations. The closest is in Nepean River at Maldon Weir which is well upstream of the study area and will not be impacted by the project.

Accordingly, no further assessment of the Adams Emerald Dragonfly or Sydney Hawk Dragonfly is required.

Fish

The Nepean and Warragamba rivers are both classified as Type 1 (highly sensitive key fish habitat) and Class 1 (major key fish habitat).

Table 8-21 summarises the fish survey results from four monitoring locations undertaken by Sydney Water in 2020 in Nepean River (note fish surveys have not occurred in 2021 due to COVID restrictions and weather). Eleven species were identified, two of which are exotic species including Gambusia and Goldfish. As noted above, the Nepean and Warragamba Rivers are mapped as critical habitat for the threatened Macquarie Perch. The Macquarie Perch was not recorded during the surveys. A known population exists in Erskine and Glenbrook Creeks, which join the Nepean River downstream of the Warragamba River confluence (CT Environmental, 2021).

Table 8-21 Fish survey results for Nepean River

Fish (Common Name)	N64		N66	N66B		N67	
	Aug-20	Dec-20	Dec-20	Aug-20	Dec-20	Aug-20	Dec-20
Australian Bass	1	2	1				
Empire Gudgeon			1	1	1	4	1
Flathead Gudgeon				1		2	
Freshwater Mullet	20	7					
Striped Gudgeon					3	1	1
Gambusia				12	9	31	21
Goldfish		1					
Long-finned eel		1	16		7	2	
Nepean Herring		8					
Smelt	2		5		1		
Coxs Gudgeon			18		65		4

Macrophytes

Nine species of macrophytes were recorded at Nepean River monitoring sites as part of Sydney Water's baseline monitoring program. This includes five native species, three exotic species and one unconfirmed. Of the exotic species, one weed of national significance, *Alternanthera philoxeroides* (Alligator Weed), was identified. *Egeria densa* was also identified at 4 out of 5 monitoring sites. This species is highly invasive and has spread throughout many of the freshwater reaches of the river system. It is typically found in areas of lower flow. It can alter its environment by changing nutrient availability, reducing turbidity by trapping sediment, reduces velocity through its dense growth and alters light availability (DPI, 2014a).

Sixteen species of macrophytes were recorded at Warragamba River monitoring sites, included eight native species, six exotic species and two unconfirmed. Of the exotic species, three weeds of national significance were identified, including *Alternanthera philoxeroides* (Alligator Weed), *Cabomba caroliniana* and *Salvinia molesta.*

Table 8-22 Summary of macrophytes recorded within Nepean and Warragamba rivers (April and October, 2020)

		Nepean River					Warragamba River		
Scientific Name	**Native/exotic**	**N67**	**N66A**	**N66B**	**N66**	**N64**	**N642**	**N642A**	**N641**
Cyperus difformis	Native						X		
Ludwigia peploides	Native					X		X	
Maundia triglochinoides	Native				X				X
Persicaria lapathifolia	Native						X		
Potamogeton crispus	Native				X	X		X	X
Potamogeton ochreatus	Native			X	X	X	X		X
Potamogeton sulcatus	Native				X		X	X	
Schoenoplectus mucronatus	Native						X		X
Typha	Not confirmed						X		
Vallisneria sp	Not confirmed	X		X	X	X	X	X	X
Alternanthera philoxeroides	Exotic	X	X	X	X		X		X
Cabomba caroliniana	Exotic						X		
Ceratophyllum demersum	Exotic								X

Scientific Name	Native/exotic	Nepean River					Warragamba River		
		N67	N66A	N66B	N66	N64	N642	N642A	N641
Elodea candensis	Exotic				X		X		X
Egeria densa	Exotic	X	X	X		X		X	X
Salvinia molesta	Exotic								X

Riparian vegetation and creek channel condition

Sixteen assessments of riparian vegetation and creek channel condition were conducted in Nepean River upstream of Wallacia Weir. Results indicate overall condition ranges from fair to good. Most sites have minor to moderate erosion and deposition impacts. All sites have a wide riparian buffer (greater than 40 m) and weeds are prevalent at all sites. Overall, most sites have good aquatic habitat.

Three assessments of riparian vegetation and creek channel condition were conducted along Nepean River between Wallacia Weir and Penrith Weir. The overall condition ranges from fair to excellent. All sites have excellent to good aquatic habitat and site features. There are minimal signs of erosion at each site.

Eight assessments of riparian vegetation and creek channel condition were conducted along Warragamba River, with overall condition at all sites assessed as excellent. All sites have a wide riparian buffer (greater than 40 m), high vegetation structural complexity and low weed density. Overall, most of the sites have good aquatic habitat, however, habitat features were less prevalent at sites upstream of Megarritys Creek.

Other sites were also assessed within the Hawkesbury Nepean catchment, including sites at Jerrys Creek and Mulgoa Creek. Table 8-23 provides a summary of the aquatic features of the main waterways in the Hawkesbury Nepean catchment.

Table 8-23 Summary of aquatic features of other waterways within Hawkesbury Nepean catchment

Waterway	Location	Strahler Stream Order (at pipeline crossing or release location)	KFH Status	Riparian vegetation and creek channel condition
Nepean River	Treated water pipeline and release location	7	Type 1 – Highly sensitive key fish habitat Class 1 - Major key fish habitat	Upstream of Wallacia Weir – fair to good Downstream of Wallacia Weir – good to excellent
Warragamba River	Release location	9	Type 1 – Highly sensitive key fish habitat Class 1 - Major key fish habitat	Excellent
Jerrys Creek	Treated water pipeline	4	Type 3 – Minimally sensitive key fish habitat Class 3 – Minimal key fish habitat	Poor
Baines Creek	Environmental flows pipeline	3	Not mapped as key fish habitat	Not assessed
Megarritys Creek	Environmental flows pipeline	3	Mapped as key fish habitat	Not assessed
Mulgoa Creek	Treated water pipeline	1	Type 3 – Minimally sensitive key fish habitat Class 4 – Unlikely key fish habitat	Very poor to fair

Groundwater dependent ecosystems

A review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) shows Nepean and Warragamba rivers are considered aquatic GDEs. Terrestrial GDEs are mapped along the banks of the rivers. Field validation of GDEs showed mapped terrestrial GDEs corresponded to the location of native vegetation within riparian areas of the rivers.

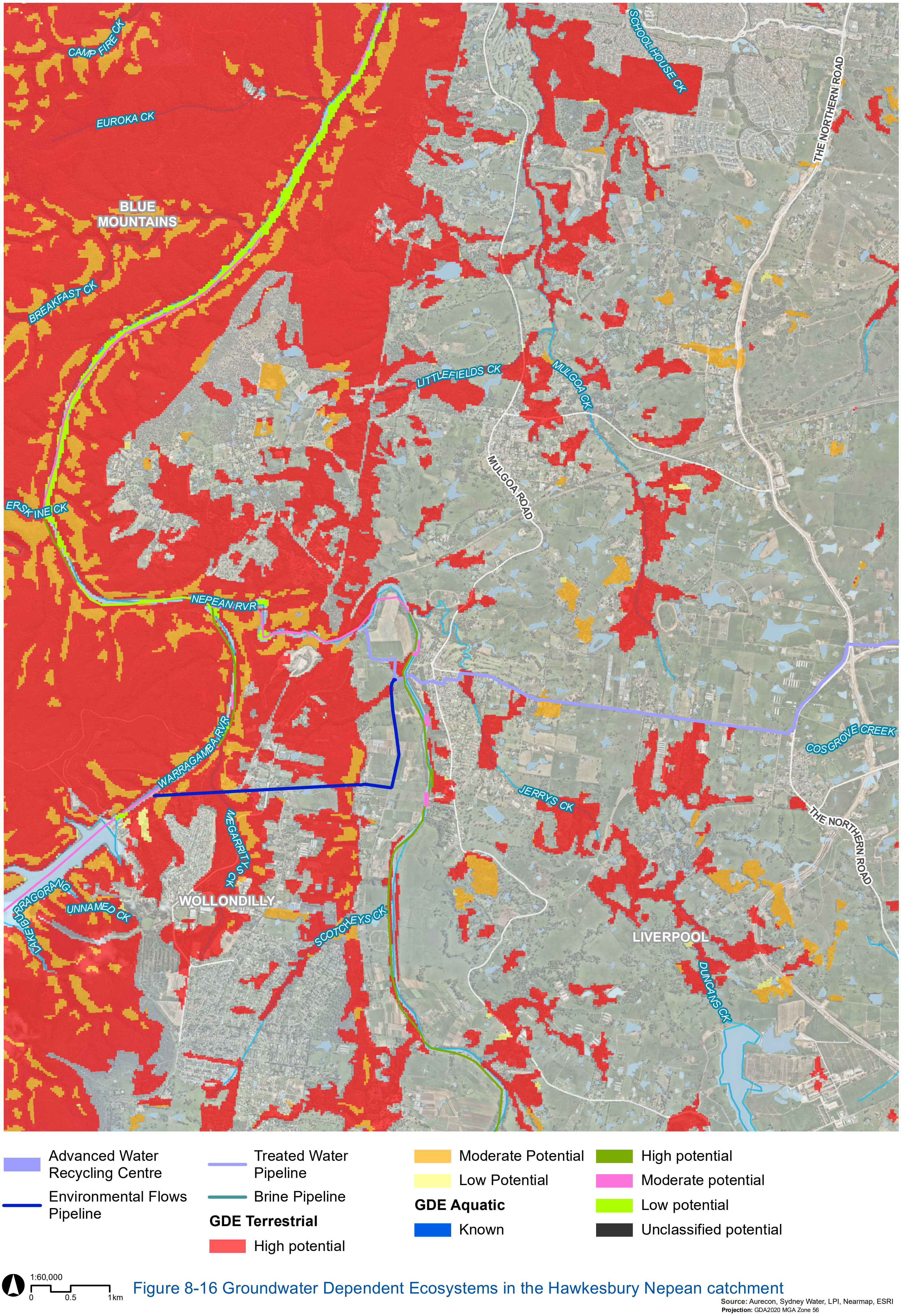


Figure 8-16 Groundwater Dependent Ecosystems in the Hawkesbury Nepean catchment

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Community and economic uses

The Hawkesbury Nepean River is an important economic and environmental asset and a diverse waterway in terms of its usage. It is a significant recreational destination for many Sydney households, particularly for activities like picnicking, boating, walking and fishing. The river and estuary support industries including agriculture, commercial fishing and aquaculture and tourism, as well as being a significant source of drinking water for Sydney, the Illawarra and Blue Mountains.

Recreation

The Hawkesbury Nepean River is an important recreational resource for the local population and for tourists. As well as providing opportunities for water-based activities, many of the main river stretches have retained their scenic qualities, which attract visitors who come to enjoy the natural surroundings. Key recreational areas are shown on Figure 8-17 and described in Table 8-24.

Table 8-24 Recreation areas along Nepean River

River reach	Description of reach and recreation activities
Upstream of Wallacia Weir	Recreational facilities and areas include Blaxlands Crossing reserve, Wallacia Caravan Park and Wallacia Golf Course at Wallacia. Further upstream is Bents Basin State Conservation Area, a popular camping and swimming location.
Wallacia Weir to Warragamba River confluence	Includes rapids navigable by canoe. Norton's Basin is a large calm pool surrounded by rocky cliffs and is a popular swimming area.
Nepean gorge – Warragamba River and Nepean River confluence to Euroka Creek	The gorge is bounded by scenic cliffs and there are large exposed and submerged rocks in this area which makes navigation by some craft difficult. Euroka Creek runs through the Blue Mountains World Heritage Area and joins Nepean around Nepean Gorge. There are walking tracks alongside the creek and camping is available within the National Park at Euroka Clearing.
Downstream of Glenbrook Creek to Castlereagh	From this point onwards the river becomes wide and deep and there are high levels of public access. Tench Reserve lies on the eastern bank of Nepean River at Regentville. The reserve has a boat ramp on the north side of the bridge. The Nepean Belle paddle steamer also operates from the Tench Reserve, taking passengers on trips through the scenic Nepean Gorge. To the north of Tench Reserve is Cables Wake Park and Aqua Park. The stretch of Nepean River between Tench Reserve and Victoria Bridge at Penrith is used heavily for rowing. The Nepean Rowing Club is located north of Victoria Bridge on the eastern bank. There are parks on either side of the river around Victoria Bridge, including Regatta Park and River Road Reserve on the western bank and Weir Reserve on the eastern side.
Castlereagh to Yarramundi	Further north into Castlereagh, the river passes alongside the Yellow Rock Reserve and Yellow Rock Recreation Reserve. Further north, around Lynch Creek, is the Lynch Creek Reserve, located on the western bank of Nepean.

River reach	Description of reach and recreation activities
Yarramundi	Yarramundi Reserve lies to the west of Agnes Banks and Yarramundi Lagoon and provides local and regional recreation opportunities such as fishing, canoeing, swimming, nature-based study, bird watching, educational activities, walking, mountain-bike riding, jogging, dog walking and horse riding.
Downstream of Grose River (Hawkesbury River)	The upper reaches of the Hawkesbury River are dominated by water skiing and wakeboarding, particularly in the vicinity of Wisemans Ferry. This section of the river and its tributaries, such as the Colo River, are also popular for canoeing and other forms of non-powered craft activities. In the lower reaches of the river, recreational activities include power boating, recreational fishing, water skiing and wakeboarding, personal watercraft usage, house boating, rowing, sailing, kayaking, canoeing and swimming.

Agriculture

The Hawkesbury Nepean River supports a $259 million agriculture industry (DPIE, 2020b), including considerable irrigation for lucerne, fodder, pasture, nurseries, turf, vegetables, orchards, cereals, cut flowers and drinking water supplies for stock. Further information about water extractions for agricultural purposes is provided above in Table 8-18.

Aquaculture and commercial fishing

Aquaculture and commercial fishing is significant in the Hawkesbury Estuary (commencing at Wisemans Ferry, about 120 km downstream from Nepean River release). The main commercial fisheries in operation are the Estuary General Fishery, the Estuary Prawn Trawl Fishery and the Lobster Fishery. Oyster farming also occurs within the estuary with oyster leases existing downstream from the confluence with Mangrove Creek (DPI, 2020c), located about 150 km downstream from Nepean River release.

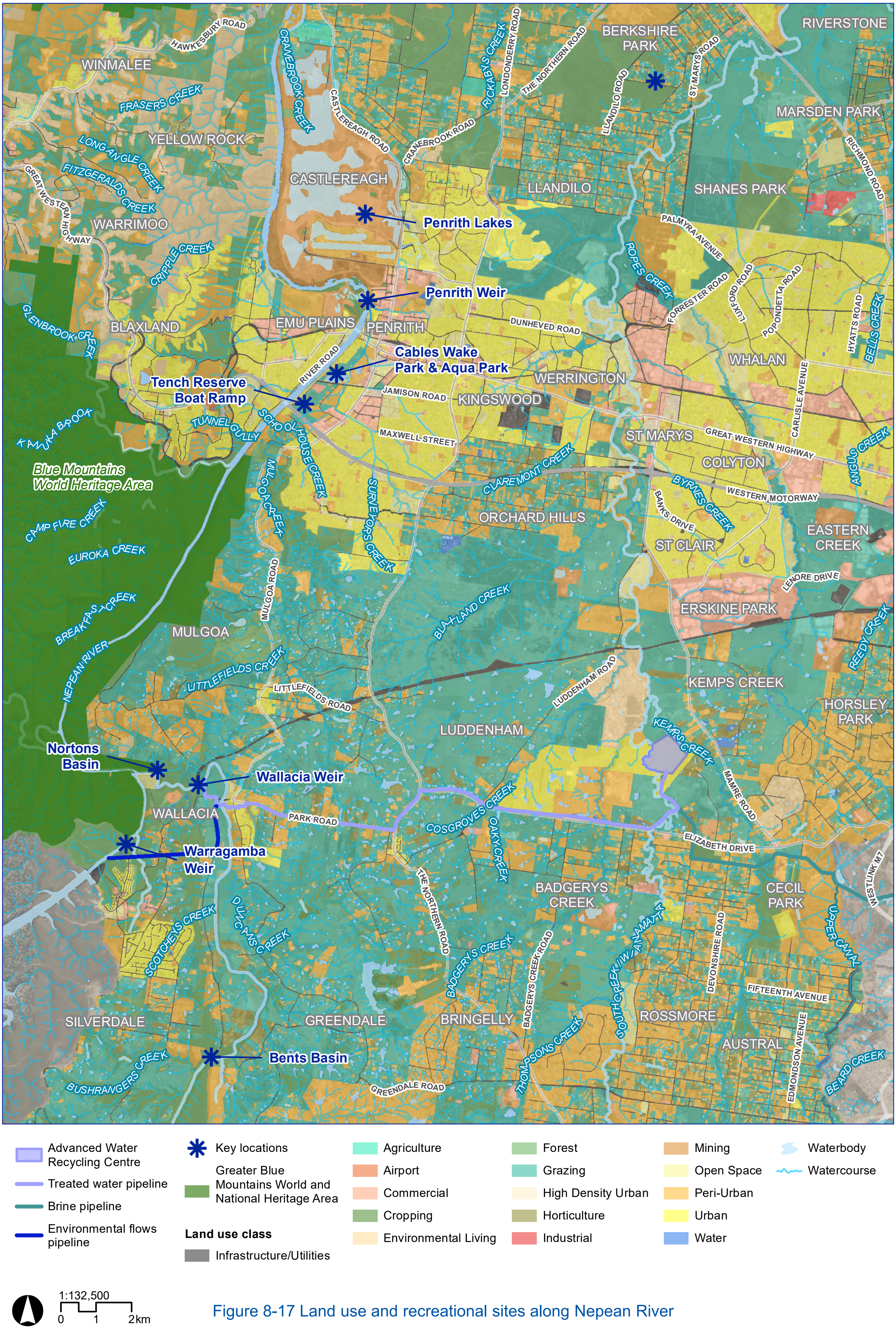


Figure 8-17 Land use and recreational sites along Nepean River

8.5.3 Georges River catchment

Table 8-25 lists the waterways crossed by the brine pipeline in the Georges River catchment.

Generally, the condition of aquatic ecology and riparian vegetation of these waterways is disturbed and impacted by surrounding land uses. No threatened species or their habitats as per Schedule 4, 4A and 5 of the FM Act are mapped in the area. Likewise, no MNES under the EPBC Act are mapped as present across the extent of the brine pipeline alignment or immediately downstream of waterways crossed.

Terrestrial GDEs are mapped along the brine pipeline alignment, generally at locations bordering waterways. This was verified during field investigations.

Figure 8-18 shows the relevant aquatic ecology features for waterways in the Georges River catchment. It also includes the river style and geomorphic conditions of the waterways.

Table 8-25 Summary of aquatic features at brine pipeline waterway crossings

Waterway	Strahler Stream Order (at pipeline crossing)	KFH Status	Riparian vegetation and creek channel condition	River style[1]	Geomorphic sensitivity[1]
Prospect Creek	5	Type 1 – Highly sensitive key fish habitat Class 1 – Major key fish habitat	Very poor to good	Low sinuosity, fined grained.	Moderate
Hinchinbrook Creek	4	Type 3 – Minimally sensitive key fish habitat Class 3 – Minimal key fish habitat	Poor	Low sinuosity, fined grained.	Moderate
Green Valley Creek	1	Type 3 – Minimally sensitive key fish habitat Class 3 – Minimal key fish habitat	Very poor	Low sinuosity, fined grained.	Moderate
Clear Paddock Creek	1	Type 3 – Minimally sensitive key fish habitat Class 3 – Minimal key fish habitat	Poor	Not mapped by DPIE	Not mapped by DPIE

Table notes:

1. NSW River Styles Database (DPIE 2021)

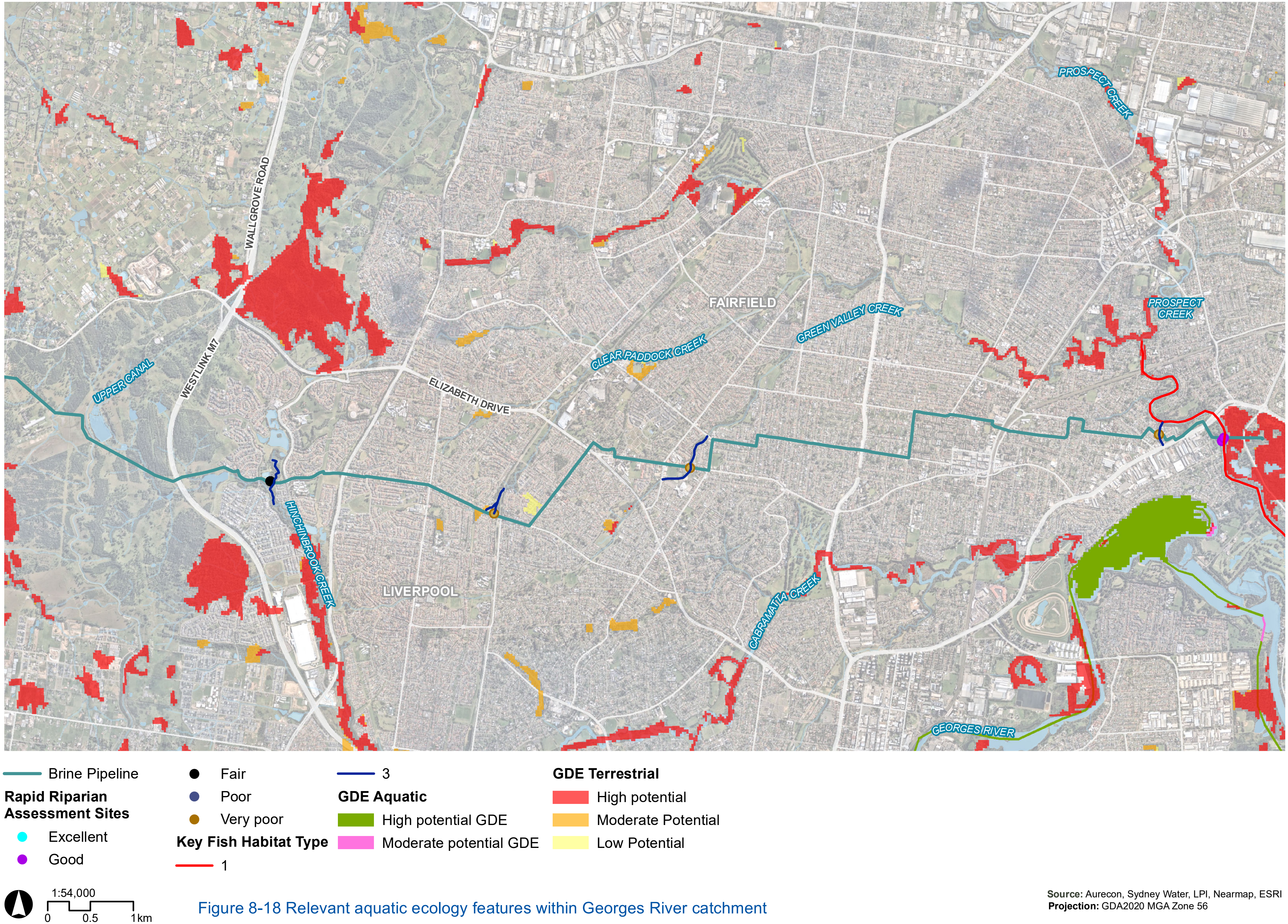


Figure 8-18 Relevant aquatic ecology features within Georges River catchment

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

8.6 Construction impact assessment

The project will require construction within waterways. This includes trenched and tunnelled pipeline crossings, and the construction of the environmental flows and treated water release structures. This has the potential to impact the geomorphology and aquatic ecology of waterways. Impacts associated with water quality are covered in section 9.2.

Table 8-26 lists the waterways that will be crossed by the project pipelines and the proposed construction methodology at each waterway. Chapter 4 provides a detailed explanation of the trenching and tunnelling construction methodologies and Figure 4-17 shows the location of the different construction methodologies.

Table 8-26 Waterway crossings for project pipelines

Waterway	Location	Construction method
South Creek	Treated water pipeline	Trenching
Badgerys Creek	Treated water pipeline	Tunnelling
Oaky Creek	Treated water pipeline	Trenching
Cosgroves Creek	Treated water pipeline	Trenching
Mulgoa Creek	Treated water pipeline	Trenching
Jerrys Creek	Treated water pipeline	Tunnelling
Nepean River	Treated water pipeline	Tunnelling
Baines Creek	Environmental flows pipeline	Trenching
Megarritys Creek	Environmental flows pipeline	Tunnelling
Kemps Creek	Brine pipeline	Trenching
Prospect Creek	Brine pipeline	Tunnelling
Hinchinbrook Creek	Brine pipeline	Trenching
Green Valley Creek	Brine pipeline	Tunnelling
Clear Paddock Creek	Brine pipeline	Tunnelling

8.6.1 Geomorphology

Pipeline crossings

The construction of pipelines across waterways has the potential to result in short-term and long-term impacts to the geomorphic attributes of waterways. This is particularly important for South Creek and Mulgoa Creek which have high geomorphic sensitivity and are both proposed to have trenched pipeline crossings. Waterways with a moderate and low geomorphic sensitivity are less likely to have geomorphic impacts from pipeline construction.

Both trenched and tunnelling construction methodologies have the potential to impact on the geomorphology of the waterways. Potential impacts include:

- impacts to bank stability and erosion of exposed soils, as a result of vegetation clearing and excavation activities. This can lead to changes in sediment concentrations, particularly for South Creek, which has dispersive soils
- changes in channel morphology and hydraulic conditions as a result of the placement of material or structures in waterways
- resuspension of sediment from dredging and excavation activities
- bank and/or bed erosion and changes in substrate composition and sediment concentrations as a result of changes in timing, duration and frequency of flow.

Impacts mainly occur from the disturbance of sediment from excavation and vegetation clearing. This can result in the mobilisation and dispersion of sediment in the waterways, resulting in erosion and deposition. The dispersion of sediments at the construction site can result in downstream smothering and accumulation, changing the morphology of the downstream environment. Dispersive soils are known to be present in South Creek. Dispersion of soils results in release of very fine grained material that does not settle or accumulate and may find its way to the estuary.

Erosion and sediment dispersal are more likely to occur at trenched pipeline crossings then tunnelled pipeline crossings. If construction areas within and adjacent to waterway pipeline crossings are not adequately restored and stabilised, there is potential for ongoing impacts from sediment run-off and slumping. This is more likely to occur where trenching and vegetation clearing is required. However, impacts will mainly be restricted to the construction period for each crossing, which is about 6-8 weeks in duration. Impacted waterways will be restored and stabilised to minimise the potential for erosion while vegetation is re-establishing.

Pipeline construction can also impact the flow of water through the construction area. This can occur from water extraction for tunnelling construction, diversions during trenched construction, as well as the placement of machinery and environmental controls within the waterways. Changed flow conditions can result in alteration of some geomorphic attributes of the waterway, as well as changes to hydraulic conditions and suspended sediment concentrations.

Tunnelled pipeline construction under waterways can result in slumping of the streambed. This can change the geomorphic profile of the waterway and is more likely to occur in unconsolidated soil types or where soil cracking can occur.

Impacts associated with both trenchless and trenching operations for pipeline crossings can be mitigated with a range of standard measures, included in section 8.10. Provided these are implemented, the risk to geomorphology from construction of the pipelines is predicted to be minor.

Release structures

The project will require the construction of release structures at South Creek, Nepean River and Warragamba River that will release treated water into the environment during operation of the project. Chapter 4 provides further details on how the release structures will be constructed.

The release structures will be set back from each waterway to minimise inundation during operation and for safer construction. Potential impacts during construction include erosion and sedimentation as a result of excavation and vegetation removal. Potential impacts are likely to be similar to that of trenched pipeline crossings of waterways.

During the construction of these release structures, silt curtains and temporary coffer dams will be installed to segregate the construction zone from the low flow zones of the waterways and minimise the generation of sediment.

The expected duration of the cofferdam construction activities 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 will have a minor impact on turbidity and sediment loads in the waterway. The likelihood of a release will be further mitigated through scheduling the construction of these structures during seasons when bank full discharges are less likely.

Potential impacts are not expected to be significant and can be adequately managed through the implementation of management measures outlined in section 8.10. On-site geomorphic inspections are required prior to construction to plan how construction will minimise geomorphic impacts, including through understanding:

- hydraulic conditions that may impinge on the site at a range of flows (particularly elevated flows)
- location of knickpoints (a steep region along a river profile)
- implications of large wood debris interacting with the site
- surface flows (floodplain runoff) that may influence/impede construction
- bank stability immediately upstream and downstream of the structure, and the influence of construction barriers on this
- bed stability, including the impact this has on base support for structures or construction equipment, or the geomorphic impacts that might occur.

8.6.2 Aquatic ecology

The construction activities with potential to impact geomorphology also have the potential to impact aquatic ecology. Construction associated with open trenching and tunnelling for the pipelines and construction of the release structures at Nepean River, Warragamba River and South Creek will include clearing of riparian vegetation, bulk earthworks and excavation of waterway bed and banks, spoil movement and stockpiling and temporary complete or partial blockage or bypass of waterways.

Open trenching of waterway crossings

Impacts to aquatic ecology are more likely to occur in waterways subject to open trenching which include South Creek, Oaky Creek, Cosgroves Creek, Mulgoa Creek, Baines Creek, Kemps Creek and Hinchinbrook Creek (identified in Table 8-26) as associated works create a higher level of disturbance than tunnelling.

With the exception of Baines Creek, the creeks listed above are considered key fish habitat. Open trenching will require removal of riparian vegetation, potential removal of large woody debris and temporary blockage of creek channels and flow diversion. These actions are considered as Key Threatening Processes described by the FM Act and include:

- degradation of native riparian vegetation along New South Wales watercourses
- installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams
- removal of large woody debris from New South Wales rivers and streams.

Increased erosion from trenched pipeline crossings of waterways or runoff from construction sites can reduce water quality and modify aquatic habitats by transporting sediment and other contaminants into waterways. This can result in impacts to aquatic flora and fauna, including smothering, in-filling habitat from settling of sediment, reducing light penetration by increasing the turbidity of the water, fine sediment blocking gills of fish and mobilising nutrients bound to sediment which has potential to shift the trophic state of the waterway.

Benthic macroinvertebrates are particularly vulnerable to impacts related to erosion and sedimentation. This taxa group contribute significant food resources to many non-aquatic fauna such as wading birds and microbats and therefore degradation of macroinvertebrate communities has potential to affect species higher up the food chain.

Impacts associated with erosion and sedimentation can be effectively managed by standard mitigation practices. Impacts are expected to be minor and short term only.

Trenched pipeline construction will require temporary bypass of waterways around the construction site. This can impact aquatic ecology through drying of aquatic habitat, which will potentially lead to loss of aquatic species with low mobility. Loss of connectivity between upstream and downstream areas of waterway crossings can impact species such as fish and turtles which rely on the waterway for movement, particularly Australian Bass which undertake migration in late autumn/early winter and late spring/early summer to and from estuary reaches to spawn. This can be managed by timing works outside of these periods.

Tunnelling of waterway crossings

Tunnelling construction has the potential to cause frac-outs, resulting in a loss of drilling fluid from the bore into waterways. This fluid can impact aquatic ecology through reduced water quality from contaminants, as well as increased erosion and sedimentation.

Construction of release structures

Construction of the proposed stormwater and wet weather release points to South Creek will require disturbance to the creek bed and bank which is considered Type 1, Class 1 Key Fish Habitat. Construction of these outlet structures may impede the ability of fish to move up and downstream, increase turbidity, reduce light penetration and alter flow. This may result in impacts to native fish population, including Australian Bass.

The construction of the release structure at Nepean River may require a coffer dam to create a dry working area. This will partially block the flow of water in Nepean River, and temporarily reduce the width of waterway at the works location, however fish passage will be maintained throughout construction and the works are not considered to pose a significant threat to native fish species.

The Warragamba River release structure is located above the waterline. There is a short term and localised risk of debris and sediment falling into the river during construction which has the potential to disturb the bed and bank of the river. The risk of significant degradation to the aquatic habitat is low due to the localisation of any impacts.

Impacts on ‘water land’

The FM Act defines ‘water land’ as land submerged by water, whether permanently or intermittently. Excavation and dredging in ‘water land’ will be required where trenched construction is proposed for waterway crossings (refer to Table 8-26) and at the release locations at South Creek, Nepean River and Warragamba Rivers. Chapter 4 provides information about the extent of the impact areas where these works are required. No reclamation work will be required, and all waterways will be restored following completion of construction.

Groundwater dependent ecosystems

As outlined in section 9.4, there are potential minor and short-term impacts to groundwater dependent ecosystems during pipeline construction. This is primarily from drawdown of groundwater that enters excavations. Groundwater drawdown for pipeline construction is likely to be minor and return to normal levels within several days.

There are no terrestrial groundwater dependent ecosystems within the AWRC site. However temporary groundwater drawdown during AWRC construction is expected and may decrease baseflows to South Creek, which is considered an aquatic groundwater dependent ecosystem, by about 6% during the first 18 months of construction before returning to normal. This impact is considered minor.

Impacts to threatened species

A section of Nepean and Warragamba rivers is mapped as critical habitat for the endangered Macquarie Perch. A known population exists in Erskine and Glenbrook Creeks.

The treated water pipeline will be tunnelled beneath Nepean River and the treated water release structure will be constructed on the banks of Nepean River. Macquarie Perch habitat distribution mapping indicates this reach of Nepean River is outside of the current range of the species.

The environmental flows release structure is on Warragamba River, which is mapped habitat for Macquarie Perch. As outlined in the assessments of significance in Appendix H, significant impacts on Macquarie Perch are unlikely during construction given works are outside the main channel of the river and mitigation measures (such as coffer dams and silt curtains) are proposed to ensure impacts on water quality and fish passage are minimal.

Summary

Overall impacts to aquatic ecology are expected to be minor. No significant impacts are expected to Macquarie Perch or their habitat as a result of construction activities.

Principle 1 of the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014) states that impacts must first be avoided and unavoidable impacts minimised through mitigation measures. Only then should offsets be considered. Given that impacts have been avoided where possible (for example tunnelling) and direct and indirect impacts can be effectively minimised through the management measures outlined in section 8.10, an aquatic ecology biodiversity offset strategy is not proposed for construction impacts.

8.6.3 Waterway objectives

Potential impacts to waterway objectives during construction are summarised in Table 8-27. The results from the geomorphology, aquatic ecology and surface water impact assessments (section 9.2) predict that that potential impacts during construction can be effectively managed by standard mitigation measures. Impacts to the waterway objectives will be short term and minor.

Table 8-27 Potential impacts to waterway objectives during construction

Values and uses	Potential impacts during construction
Aquatic ecology	Directly from construction within waterways, including impacts on aquatic connectivity. Indirectly through erosion and sedimentation of waterways.
Recreation and aesthetics	Impacts to access during construction. Visual impacts due to waterway disturbance and removal of riparian vegetation. Indirect visual impacts from erosion and sedimentation.
Primary industries (Irrigation and livestock drinking)	Impacts not expected.
Drinking water (Nepean River only)	Given the distance between the release locations and drinking water extraction (over 42 km), impacts are not expected.

8.7 Operational impact assessment

8.7.1 Water quality and hydrodynamics

The release of treated water has the potential to impact both the water quality and hydrodynamics of the receiving waterway. Depending on the level of treatment, treated water can contain elevated levels of nutrients (including nitrogen and phosphorus) and other contaminants that can degrade aquatic ecosystems in the short and long term. Releases of additional water can also alter the hydrodynamics of a waterway, by altering flow patterns, volumes and water depths. Impacts to hydrodynamics are also covered in more detail in the ecohydrology and geomorphology assessment in section 8.7.2.

Modelling has been used to analyse the likely changes to water quality and hydrodynamics in South Creek and Nepean and Warragamba Rivers. As discussed in section 8.2.3, the modelling involved the assessment of:

- a baseline scenario that represents current conditions (2020)
- background scenarios that represent potential future conditions in 2036 and 2056
- impact scenarios that represent potential future conditions and AWRC releases in 2036 and 2056.

Near field modelling of toxicants has also been undertaken for 2036 and 2056 conditions in South Creek and Nepean River.

This section provides an overview of the 2036 modelling results and predicted changes to water quality in South Creek and Nepean and Warragamba rivers, which represents Stage 1 of the project operating at 50 ML/day. It includes:

- a summary of the predicted changes to water quality that occur in the future background scenarios, compared to baseline
- a summary of the predicted changes to water quality that occur as a result of the AWRC releases. Results for both the dry and wet year are considered
- a comparison of the modelling results for baseline, background and impact scenarios to the relevant waterway objectives
- a summary of potential impacts to all waterway objectives from the AWRC releases for each waterway.

The 2056 modelling results are covered in section 8.8 (impact on future stages).

This section summarises general findings from the modelling based on representative scenarios. Appendix F includes a more comprehensive analysis of the scenarios, including graphs and numerical outputs.

Although this section discusses 'predicted' impacts, the results discussed here are based on modelling that simulates complex systems and has been developed using a range of input assumptions and historical data (as outlined in section 8.2.3). This means that impact scenarios showing AWRC releases need to be compared with baseline and background scenarios produced by the model, to consider relative differences associated with the releases. The impact scenarios do not represent absolute values that can be achieved, but rather an indication of the relative change in quality. For this reason, the discussion in this section focuses on the patterns of differences between the various modelled scenarios.

Sydney Water has modelled a range of scenarios to test different assumptions and the sensitivity of the results to those assumptions, however the modelling remains a tool for providing an indication of the scale of impacts and does not represent conditions that should be licensed in an Environment Protection Licence (EPL). The pre- and post-commissioning monitoring program proposed by Sydney Water in section 8.11 is a critical part of demonstrating actual changes in water quality due to AWRC releases.

South Creek

AWRC releases to South Creek will occur in wet weather only and will consist of advanced and primary treated water. Flow volumes and quality will vary as follows, depending on inflows to the AWRC:

- During dry weather and mild wet weather conditions (<1.7 x ADWF), no releases to South Creek will occur.
- During moderate wet conditions (1.7 to 3 x ADWF), releases of advanced treated water to South Creek will occur.
- During severe wet conditions (>3 x ADWF), releases to South Creek will consist of advanced treated water (maximum of 1.3 x ADWF) and primary treated water.

Key findings from the assessment are:

- Changes in water quality from urban development in the catchment are predicted to be greater than changes relating to AWRC releases.
- Predicted impacts from the releases vary depending on the scale of the wet weather event. Impacts are greater in more severe wet weather events when the proportion of primary treated water is increased.
- All impacts are predicted to be short lived, with concentrations returning to background levels within a day. Changes are either minor or not identifiable downstream of Kemps Creek.
- Overall, there is no predicted impact to the waterway objectives from the AWRC releases (based on annual median concentrations).

- The near field modelling predicts that the primary mixing zone criteria cannot be achieved during severe wet weather release events for ammonia and total chlorine. However, the potential for toxicity and environmental harm arising from these releases is considered low due to the infrequency of the events and typically short duration.

These key findings are summarised in more detail below. The results are based on a representative impact scenario (referred to as SC05). This 2036 scenario includes AWRC releases and assumes a comprehensive parkland stormwater management approach. The impact scenario is compared to the equivalent background scenario (SC02) and the baseline scenario (SC00). These scenarios are summarised in Table 8-28. General commentary is also provided on other scenario variations in Table 8-29.

Table 8-28 Summary of representative scenarios for South Creek

Scenario	Year	Land use and stormwater management	AWRC flows
Baseline (SC00)	2020	Current land use and stormwater management	None
Background (SC02)	2036	2036 land use and parkland stormwater management	None
Impact (SC05)	2036	2036 land use and parkland stormwater management	ADWF – 50 ML/day

Predicted future changes in water quality (without AWRC releases)

Future background scenarios show the flow regime of South Creek will be substantially modified in terms of both base flows and storm event peaks compared to the baseline scenario. This is due to the more impervious surfaces associated with growth areas. Under these modified conditions, the modelling predicts lower concentrations in some indicators in parts of the upper and middle reaches of the creek (for example total phosphorus and chlorophyll *a*). This is due to higher flows and increased connectivity throughout the creek, even during extended dry periods. The conditions for algal blooms are also predicted to become less prevalent.

Predicted water quality improvements, including reductions in total and inorganic nutrients, are also expected in the lower sections of the Creek as a result of planned upgrades to Quakers Hill, McGraths Hill and South Windsor WWTPs. The releases from St Marys WRP result in an increase in nutrients due to population growth and increased inflows.

The annual trends in key indicators (including nitrogen, oxidised nitrogen, ammonia, total phosphorus, filterable reactive phosphorus and chlorophyll *a*) are shown at key locations for the wet and dry year in Table 8-30 below.

Predicted changes due to AWRC releases

Potential impacts from the AWRC releases were assessed by comparing the impact scenarios to the background scenarios.

Wet weather releases to South Creek occur infrequently. For the 2036 scenarios, two events over three days are forecast in a dry year. During the wet year, more frequent releases of greater magnitude are forecast (about six events over 14 days).

Release volumes and quality will be different for each wet weather event and this influences the relative impacts for some of the water quality indicators. This is illustrated by the difference in predicted impacts in a dry year compared to a wet year.

In the modelled dry year, releases are forecast to occur during wet weather events up to 3 x ADWF. During these events the proportion of advanced treated water will be significant (up to 100%) and releases can dilute poorer quality ambient water in South Creek. The largest changes are seen from the release point to the confluence with Badgerys Creek, with the magnitude of changes progressively reducing downstream. Predicted changes during these release events are summarised below:

- Negligible changes are predicted in nutrient concentrations (ammonia, oxidised nitrogen, total nitrogen, filterable reactive phosphorus and total phosphorus). The modelling suggests concentrations in the creek will generally be lower due to the dilution from the releases.
- Minor beneficial increases in daily dissolved oxygen levels are predicted immediately downstream of the release. The magnitude of improvement progressively reduces with distance travelled downstream from the release point.
- Minor reductions are predicted in salinity and total suspended solids concentrations immediately downstream due to the lower salinity and total suspended solids concentrations in the advanced treated water relative to ambient water in South Creek.
- Similarly, temporary reductions in the densities of enterococci are predicted as a result of the releases.
- No discernible change in chlorophyll *a* and the risk of cyanobacteria is predicted. This is likely the result of releases occurring during wet weather when there is rapid flushing of the creek rather than during sustained dry periods when conditions that favour algal growth are more prominent.
- There is the potential for releases from the AWRC to commence while creek flows are relatively low and/or still increasing due to the rainfall runoff in the upper catchment. This can lead to short-lived periods where there is less dilution in the creek and higher proportions of AWRC release relative to the overall creek flows. This risk may be a result of the daily time steps used in the Source model and AWRC modelling. This potential impact will be further investigated during detailed design. If necessary and where feasible, opportunities to minimise releases while flows are still increasing in South Creek will be investigated.
- The short-term changes in the majority of these indicators are predicted to be either minor or not identifiable downstream of Kemps Creek.

In a wet year, the nature of the predicted impacts varies considerably due to different levels of treatment associated with the AWRC releases during wet weather events. During smaller wet weather events (less than 3 x ADWF), when the proportion of advanced treated water is high or 100%, results are very similar to those summarised above for the dry year. In other more severe wet weather circumstances (greater than 3 x ADWF), when primary treated water is introduced, concentrations of nutrients in the creek are predicted to increase temporarily.

Predicted changes during the larger wet weather events are summarised below:

- Spikes in the concentrations of nutrients are predicted during larger releases. Figure 8-19 shows the results for total nitrogen. Spikes in concentrations are observed during four release events over the wet year (circled).
- Releases may generate more erosion and/or resuspension, resulting in increased total suspended solids.
- Minor reductions are predicted in salinity immediately downstream of the release due to the lower salinity in the AWRC treated water relative to South Creek.
- Minor beneficial increases in daily dissolved oxygen levels are predicted 250 m downstream of the release point.
- Increases in daily enterococci densities are predicted during the more severe wet weather events due to the higher densities present in the primary treated water.
- No discernible change in chlorophyll *a* and overall cyanobacteria risk is predicted.
- The impacts during these larger events are again predicted to be short lived with concentrations returning to background conditions within a day of releases ceasing.

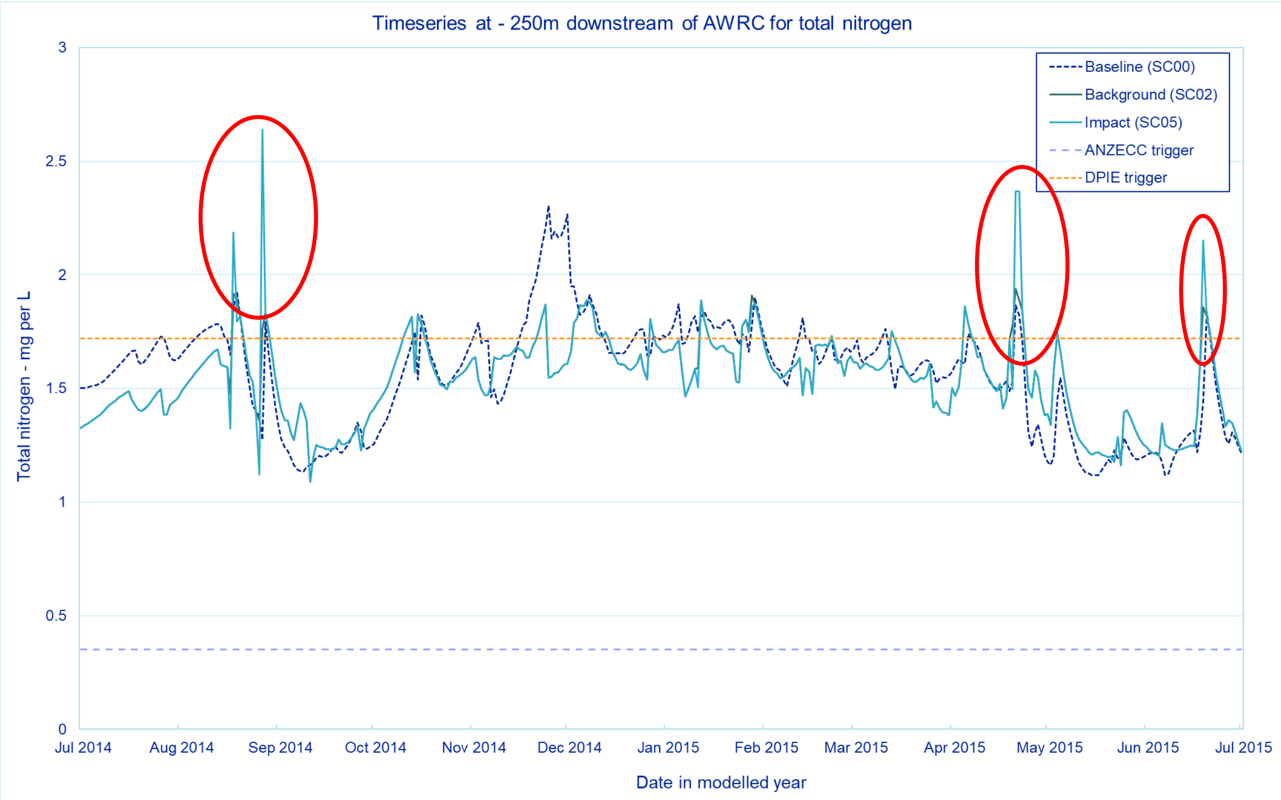


Figure 8-19 Changes in daily concentrations of total nitrogen 250m downstream of the AWRC release (wet year)

The modelling results also include an estimate of increases in nutrient loads. AWRC releases are estimated to account for about 0.002% of the total nitrogen load for the South Creek catchment in a dry year, increasing to about 0.6% in a wet year. Similarly, the AWRC is expected to account for less than 0.001% of the total phosphorus load in a dry year and up to 0.3% in a wet year.

Table 8-29 provides an overview of the key differences between scenarios and the relative changes to water quality.

Table 8-29 Differences between scenario variations

Scenario variation	Description
Stormwater management approach in catchment	The business as usual approach to stormwater management results in more flow in South Creek, including higher peak flows, due to an assumed increase in impervious area compared to the parkland approach. While of similar magnitude, the AWRC impacts for the parkland scenarios are marginally greater than the scenarios that represent the BaU stormwater management strategy. This is because the AWRC releases represent a slightly higher proportion of overall flows in the parkland scenario, where creek flows are lower.
AWRC advanced treatment shut down	Potential shut downs of the advanced treatment (reverse osmosis) process due to capacity issues within the Malabar wastewater collection network are predicted to be very infrequent with only one occurrence in the representative wet year. No

Scenario variation	Description
	events are predicted in the dry year. The relative impacts are predicted to be insignificant.

Near field and toxicity assessments

The toxicant review for South Creek (included as Appendix B in the Hydrodynamic and Water Quality Impact Assessment (Appendix F)) focused on total ammonia, nitrate, free chlorine and total chlorine. The quality of wet weather treated releases is highly variable, so these toxicants were chosen as they are considered the most relevant to the operation of an urban wastewater treatment plant that discharges to freshwater or tidal environments. The analysis predicted that guideline values for ammonia and total chlorine will be exceeded during severe wet weather events. The near field modelling was therefore undertaken for ammonia and total chlorine.

The near field modelling predicts that the primary mixing zone criteria for ammonia and total chlorine cannot be achieved for the relevant severe wet weather release events. However, the potential for toxicity and environmental harm arising from these releases is considered low due to the factors listed below:

- The events are very infrequent. On average the more severe events (>3 x ADWF) are predicted to occur two to three times per year but frequencies may vary between zero and six events per year.
- The release events are typically short lived with durations ranging from less than one day to intermittently over three days.
- The releases correlate with conditions of significant flow within the creek and corresponding low residence times.
- Mixing zones are generally only considered in terms of management of continuous releases of treated wastewater, where releases may present a risk of harm to fish migration or harm to sedentary species.
- Mixing zone modelling is generally focussed on periods of extended dry weather.
- Application of ANZG (2018) guideline values in the near field impact assessments could be considered as very conservative as the default guideline values are applicable to long term exposure situations. Therefore, these guideline values are deemed more relevant to exposure durations of greater than three days. No applicable shorter-term toxicity-based guidance values are available under the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines.

Alternative release structures may improve mixing and dilution of releases in the waterways. Consideration of opportunities to improve mixing and dilution of releases (for example investigating options for submerging release structures) will be considered during detailed design and is included as a management measures in section 8.10. The feasibility of alternative options would need to be assessed against a number of key considerations such as engineering requirements, operations and maintenance risk, geomorphology and energy dissipation requirements.

Waterway objectives for South Creek

Table 8-30 summarises results for key indicators covered by the WQRM at several locations downstream of the AWRC site for the baseline, background and impact scenarios for the dry and wet year. The location of these sites is shown in Figure 8-20. The table provides an indication of predicted compliance with waterway objectives, based on the modelled results for one set of baseline, background and impact scenarios (SN00, SC02 and SC05). Cells shaded in grey indicate that waterway objectives are predicted to be achieved based on the annual median concentration at this location. Cells shaded in pink indicate that the annual median concentration is predicted to exceed the waterway objectives. As noted earlier, the results do not represent absolute values that can be achieved and do not guarantee that waterway objectives will or will not be achieved. They provide an indication of change as a result of the releases and as a result of cumulative impacts from the surrounding catchment.

For the background and impact scenarios, a trend is also shown as up or down relative to baseline and background scenarios respectively. A trend was defined as a change in annual medians greater than five percent. If blank, any change is predicted to be less than 5%. Changes less than this are considered negligible or marginal.

Table 8-30 shows that for the impact scenario no changes are predicted to the annual medians, indicating that the releases to South Creek are unlikely to impact the waterway objectives.

Table 8-30 Summary of water quality trends for key indicators and comparison to waterway objectives at South Creek

Location	Distance downstream	Scenario	Dry year: Total nitrogen[1]	Dry year: Oxidised nitrogen[1]	Dry year: Ammonia[1]	Dry year: Total phosphorus[1]	Dry year: Filterable reactive phosphorus[2]	Dry year: Chlorophyll *a*[2]	Wet year: Total nitrogen[1]	Wet year: Oxidised nitrogen[1]	Wet year: Ammonia[1]	Wet year: Total phosphorus[1]	Wet year: Filterable reactive phosphorus[2]	Wet year: Chlorophyll *a*[2]
250 m downstream of AWRC	250 m	Baseline												
		Background			▲	▼	▲	▼		▼	▲			▼
		Impact												
Kemps Creek	5 km	Baseline												
		Background			▲	▼	▲	▼			▲			▼
		Impact												
Blaxland Creek	12 km	Baseline												
		Background			▲		▲	▼	▲		▲	▲	▲	▼
		Impact												
Dunheved Creek	24 km	Baseline												
		Background		▼	▲	▼	▼	▼	▼			▼	▼	▼
		Impact												
Richmond Road	34 km	Baseline												

Location	Distance downstream	Scenario	Dry year						Wet year					
			Total nitrogen[1]	Oxidised nitrogen[1]	Ammonia[1]	Total phosphorus[1]	Filterable reactive phosphorus[2]	Chlorophyll *a*[2]	Total nitrogen[1]	Oxidised nitrogen[1]	Ammonia[1]	Total phosphorus[1]	Filterable reactive phosphorus[2]	Chlorophyll *a*[2]
		Background	▲		▲	▼		▼			▲	▼		▼
		Impact												

Above waterway objectives

Below waterway objectives

▲ Increasing trend (>5%)

▼ Decreasing trend (>5%)

Notes on table

1. DPIE criteria applied (Western Sydney Planning Partnership, 2020b).
2. ANZG (2018) and ANZECC/ARMCANZ (2000) guideline values applied.
3. DPIE criteria applied where available, otherwise ANZG (2018) and ANZECC/ARMCANZ (2000) guideline values applied.

Advanced Water Recycling Centre

Treated water pipeline

Brine pipeline

Analysis Points - South Creek

1:100,000
0 1 2 km

Figure 8-20 South Creek analysis sites

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Table 8-31 summarises predicted changes to all indicators included in the waterway objectives for South Creek. The table brings together results from the WQRM and near field modelling as well as other lines of evidence including expected treatment performance.

Overall, impacts to the water quality of South Creek from the AWRC releases are predicted to be minor and impacts to the waterway objectives are unlikely. The model results indicate that the impacts on water quality in South Creek from the AWRC releases are considered to present a low risk of affecting long term ambient water quality and/or ecosystem health. Management and monitoring measures are included in sections 8.10 and 8.11.

Table 8-31 Overview of predicted changes to waterway objectives for all indicators at South Creek due to AWRC releases (2036, wet and dry year)

Indicator	**Guideline values** *(values in brackets/blue text are DPIE criteria).*	Predicted changes resulting from AWRC releases
1. Aquatic Ecosystems		
Total nitrogen (TN)	0.35 mg/L (1.72 mg/L)	Negligible changes to annual medians compared to background scenarios. Short term reductions or spikes in concentration predicted depending on severity of wet weather event.
Oxidised nitrogen (NOx)	0.040 mg/L (0.66 mg/L)	
Ammonium (NH_4^+)	0.020 mg/L (0.08 mg/L)	
Total phosphorus (TP)	0.025 mg/L (0.14 mg/L)	
Filterable reactive phosphorus (FRP)	0.020 mg/L	
Chlorophyll *a* (Chl *a*)	0.003 mg/L	No change predicted.
Dissolved oxygen (DO)	85 - 110 % Saturation (43-75 % Saturation)	Negligible changes to annual medians compared to background scenarios. Short term beneficial increases in daily concentration predicted downstream during releases.
pH	6.5 - 8.0 (6.2-7.6)	Design indicates that a pH of 7 is achievable for all release streams. No impact on pH predicted.
Conductivity / Salinity[7]	125-2200 µS/cm Equivalent to salinity of 0.09 - 1.5g/L (1103 µS/cm Equivalent to salinity of 0.75g/L).	Negligible changes to annual medians compared to background scenarios. Minor reductions in daily concentrations predicted downstream during releases.

Indicator	Guideline values *(values in brackets/blue text are DPIE criteria).*	Predicted changes resulting from AWRC releases
Toxicants	Total ammonia – 0.9 mg/L Total chlorine – 0.003 mg/L	Conservative mixing zone criteria not met however the potential for toxicity and environmental harm is considered low due to infrequency of events and short-term nature.
Turbidity / Total suspended solids (TSS)[7]	6-50NTU TSS<40mg/L (50 NTU TSS - 37mg/L)	Negligible changes to annual medians compared to background scenarios. Short term reductions or spikes in concentration observed depending on severity of wet weather event. Larger events may generate more erosion, increasing total suspended solids.
2. Recreation and Aesthetics		
Enterococci	Primary contact: 95^{th} percentile for intestinal enterococci/100 mL ≤ 40 Secondary contact: 95^{th} percentile for intestinal enterococci/100 mL > 40 and ≤ 200	Negligible changes compared to background scenarios. Short term reductions or spikes in concentration observed depending on severity of wet weather event.
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	No overall increase in cyanobacteria risk index predicted.
Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour or foaming.	All release streams are free from substances that produce undesirable colour, odour or foaming. Maximum total suspended solids concentration of 35 mg/L during severe wet weather.
Surface films and debris	Surface waters should be free from floating debris, oil, grease and other objectionable matter	All release streams are free from floating debris, oil, grease and other objectionable matter.
Nuisance organisms	Surface waters should be free from undesirable aquatic life, such as algal blooms, or dense growths of attached plants or insects[1].	No overall increase in nuisance organisms is predicted.

Indicator	Guideline values *(values in brackets/blue text are DPIE criteria).*	Predicted changes resulting from AWRC releases
3. Primary industries (irrigation and livestock drinking)		
Water quality	As per water quality metrics under Aquatic Ecology.	Refer above.
Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL *E. Coli* used as representative indicator.	Negligible changes to annual medians compared to background scenarios. Short term reductions or spikes in concentration predicted depending on severity of wet weather event.
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	No overall increase in cyanobacteria risk index predicted.

Nepean River

AWRC releases to Nepean River will vary according to weather conditions with indicative flow volumes and quality depending on inflows to the AWRC outlined below:

- During dry weather and partial wet weather (<1.3 x ADWF), releases will consist only of advanced treated water. Releases may be diverted to Warragamba River, if the environmental flows pipeline is constructed.
- During wet weather conditions (1.3 to 3 x ADWF), releases to Nepean River will consist of a blend of advanced and tertiary treated water.
- During severe wet weather conditions (>3 x ADWF), releases to Nepean River consist only of tertiary treated water, with a maximum flow of 1.7 x ADWF.

Key findings from the assessment are:

- Similar to South Creek, changes in water quality from urban development in the catchment are predicted to be greater than changes relating to AWRC releases.
- Modelling predicts that the AWRC releases to Nepean River will improve water quality for some indicators when compared to the background scenario. The environmental impacts from the treated water releases in the reaches immediately downstream of the release point are predicted to be predominantly positive.
- Further downstream of the initial footprint (~15 km), the impacts are predicted to be either insignificant, or minor with no negative effects on river water quality and/or ecosystem health.

- With respect to relevant project waterway objectives, analysis of the impacts on annual median concentrations indicate that overall AWRC releases have the potential to maintain or improve achievement of these objectives.
- During infrequent severe wet weather events (>3 x ADWF), higher concentrations of nutrients are predicted due to the higher proportion of tertiary treated water in the releases. These ‘spikes’ result in localised downstream impacts on water quality but are short-lived. Nutrient concentrations are predicted to drop quickly to levels lower than the background scenario within a few days.
- The near field modelling predicts that the primary mixing zone criteria cannot be achieved during severe wet weather release events for aluminium, copper, manganese and zinc. However, the potential for toxicity and environmental harm arising from these releases is considered low due to the infrequency of the events and typically short duration.

These key findings are summarised in more detail below. The results are based on a 2036 representative impact scenario (referred to as HN05), where all dry weather flows are released to Nepean River. The results also incorporate the previously discussed releases to South Creek, which only occur in wet weather. This scenario assumes that releases from other treatment plants are operating under a low loading approach, which represents the case that some of the treatment plants have been upgraded to reduce nutrient loads. The impact scenario was compared to the equivalent background scenario (HN01) and the baseline scenario (HN00). These scenarios are summarised in Table 8-32. General commentary is also provided on other scenario variations in Table 8-33.

Table 8-32 Summary of representative scenarios for Nepean River

Scenario	Land use and stormwater management	Releases from other treatment plants	AWRC flows
Baseline (HN00)	Current land use	2020 volumes and qualities	None
Background (HN01)	2036 land use	Forecast 2036 volumes Low loading conditions	None
Impact (HN05)	2036 land use	Forecast 2036 volumes Low loading conditions	ADWF – 50 ML/day All dry weather releases to Nepean River. No releases to Warragamba River Wet weather releases to South Creek

Predicted future changes in water quality (without AWRC releases)

In Nepean River, river flows are predicted to change due to the increase in impermeable surfaces and higher releases from existing WWTPs/WRPs resulting from urban development and associated population growth. These changes are also predicted to result in a marginal shift in the salinity wedge downstream of Sackville Bend, with freshwater conditions moving further downstream relative to baseline (circa 2020) conditions.

The predicted changes in flow regime and nutrient loads indicate a potentially complex impact on water quality and subsequently the biogeochemical environment in the Hawkesbury Nepean River system. This complexity is increased by the presence of the weirs and how releases from these structures vary with changing flow dynamics.

The wet year generally showed higher annual median nutrient and enterococci concentrations than in the dry year in both the background and baseline scenarios due to increases in diffuse and point source inputs. In general, the annual median concentrations of total nitrogen, total phosphorus and enterococci are predicted to be close to, or above the waterway objectives to about Wisemans Ferry, in both the background and baseline scenarios.

The influence of the existing WWTPs/WRPs can also be seen in the background scenarios with reductions in total and inorganic nutrients in several reaches. In particular, the effects of the planned upgrades to the Winmalee WWTP and Penrith WRP, and the decommissioning of the North Richmond WWTP, are seen in the results for the future scenarios.

The annual trends in key indicators (including nitrogen, oxidised nitrogen, ammonia, total phosphorus, filterable reactive phosphorus and chlorophyll *a*) are shown at key locations for the wet and dry year in Table 8-34.

Predicted changes due to AWRC releases

Impacts from the AWRC releases were predicted by comparing the impact scenarios to the background scenarios.

Similar to South Creek, impacts are presented for the representative dry and wet years. For the 2036 impact scenarios, water quality changes generally extended about 15 km from Wallacia Weir, and about 20 km from the South Creek confluence. Predicted changes during the representative dry year include:

- Annual median total nitrogen concentrations are predicted to be comparatively lower in the reaches immediately downstream of the AWRC release point, and also in the reaches between South Creek to Cattai Creek. These reductions are due to increased dilution of the river water with the lower concentrations of the advanced treated water from the AWRC releases.

Marginal increases in ammonia and oxidised nitrogen concentrations are predicted downstream of the release point, reflecting the composition of the treated water. Despite these increases, peaks in daily concentrations remain well below the toxicant values for ammonia and nitrate included in the waterway objectives. The predicted changes are shown in Figure 8-21 to Figure 8-24.

- Figure 8-21 shows that for scenario HN05, annual medians for ammonia are generally predicted to be below the ANZECC/ARMCANZ (2000) physical and chemical stressor guideline value for ammonia, with a very slight exceedence between the release point and Warragamba River. Ammonia and oxidised nitrogen have the potential to stimulate growth of algae and aquatic plants. This potential impact is covered further in the aquatic ecology assessment (section 8.7.3).
- The annual median concentrations of phosphorus (total phosphorus and filterable reactive phosphorus) showed results similar to total nitrogen, again due to the dilution effect of the AWRC treated water that generally reduced median concentrations downstream of the releases.
- Periodic and relatively short-lived spikes of total phosphorus and filterable reactive phosphorus are predicted during wet weather events when tertiary treated water is released. These increases are predicted to return quickly to levels equivalent to, or typically lower, than background conditions within a few days.
- Other sites, away from the immediate downstream footprints of Wallacia Weir and the South Creek confluence, generally correlated with the results for the background scenarios.
- Reduction in annual median values of chlorophyll *a* are predicted from the release point to downstream of Warragamba River. However, the overall difference between the impact and background scenarios is marginal when looking at the annual median concentrations along the length of the river. Elevated chlorophyll *a* concentrations are predicted during dry periods across all scenarios, although the timing of algal blooms is predicted to be slightly different between the impact and background scenarios due to the changes in the flow regimes and biogeochemical environment. In the reaches downstream of the AWRC release, elevated chlorophyll *a* concentrations are generally predicted later in the impact scenario than in the background scenario presumably due to the different flow regimes inherent in the two scenarios.
- Reductions in median and daily salinity, total suspended solids concentrations and enterococci densities and notable improvements in dissolved oxygen are predicted downstream of the AWRC release. Lower enterococci densities are also predicted near, and downstream of the South Creek confluence presumably due to dilution.
- The cyanobacteria risk index indicates minor changes but no increased risk relative to the background scenarios. Slightly warmer temperature near the AWRC release in winter can increase risk slightly at this time, but in summer when blooms are more likely, the AWRC also has a cooling effect on the river water. Along with small changes to water clarity and nutrient availability there is likely to be some change to biomass, but no material change in risk is predicted.

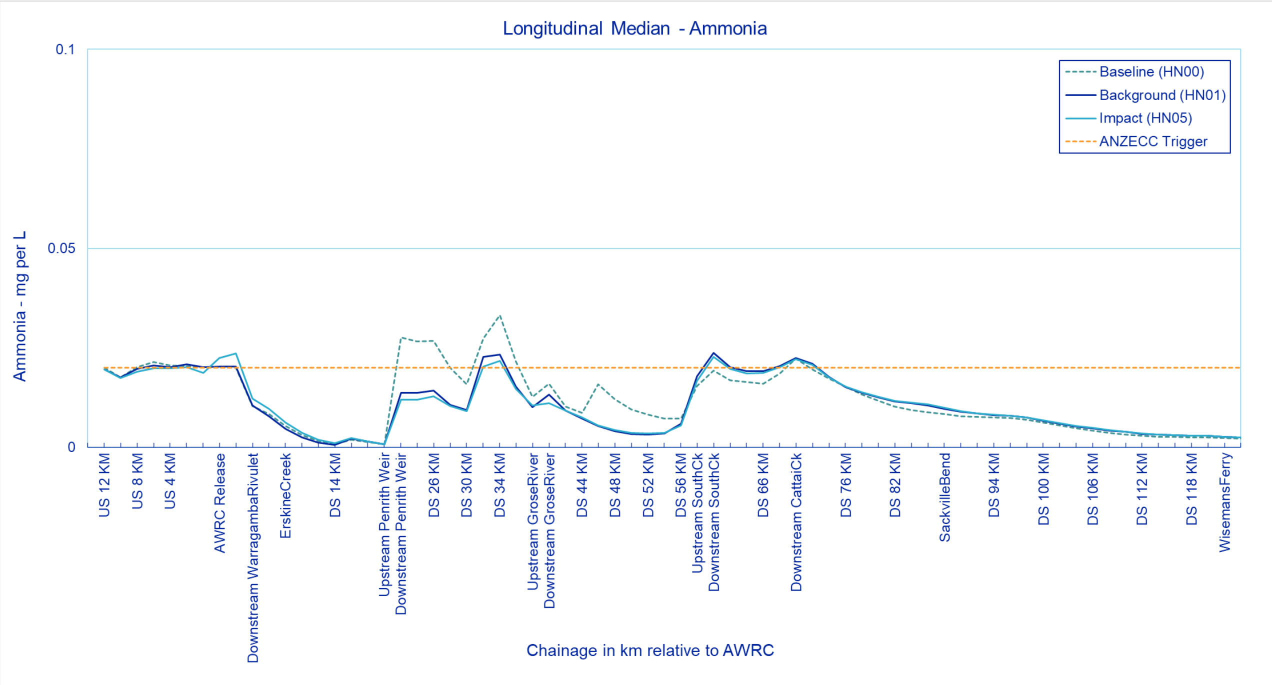


Figure 8-21 Longitudinal profile of predicted annual median ammonia concentrations (2036 releases/dry year)

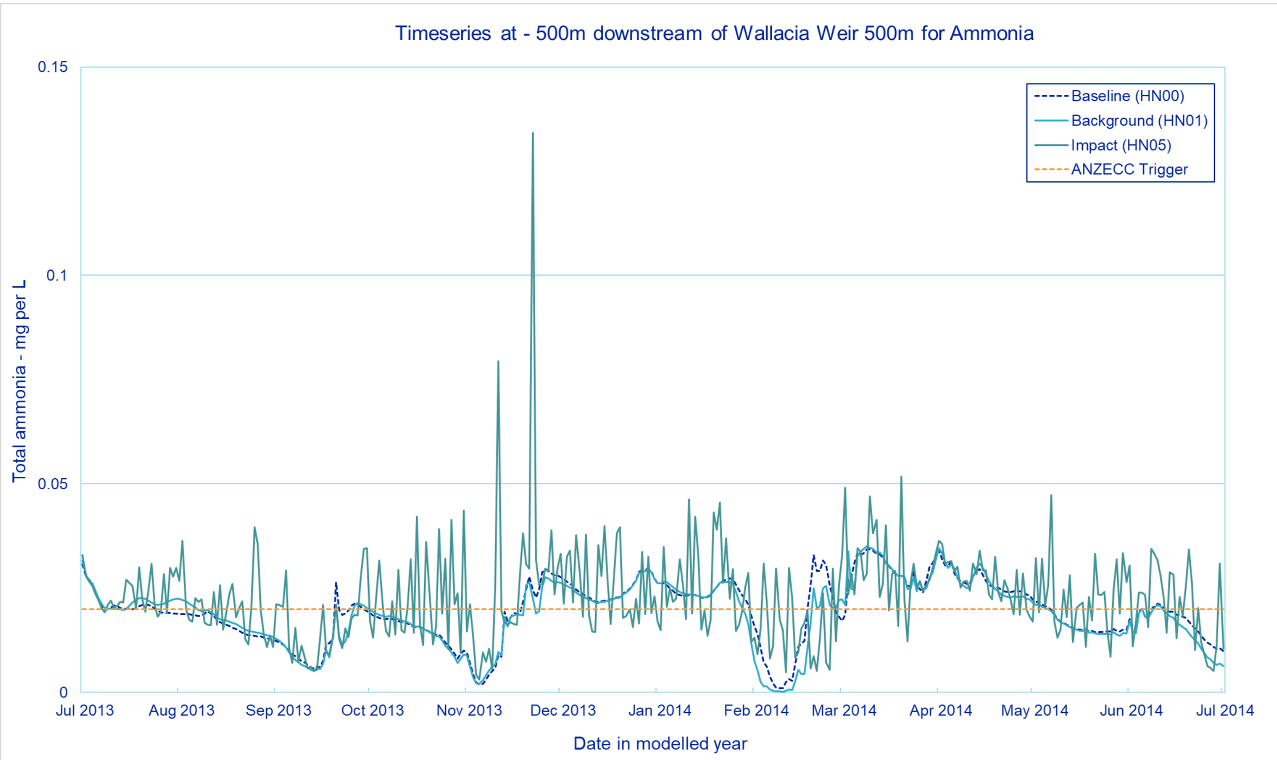


Figure 8-22 Timeseries of predicted ammonia concentrations 500 m downstream of Wallacia Weir (2036 releases/dry year)

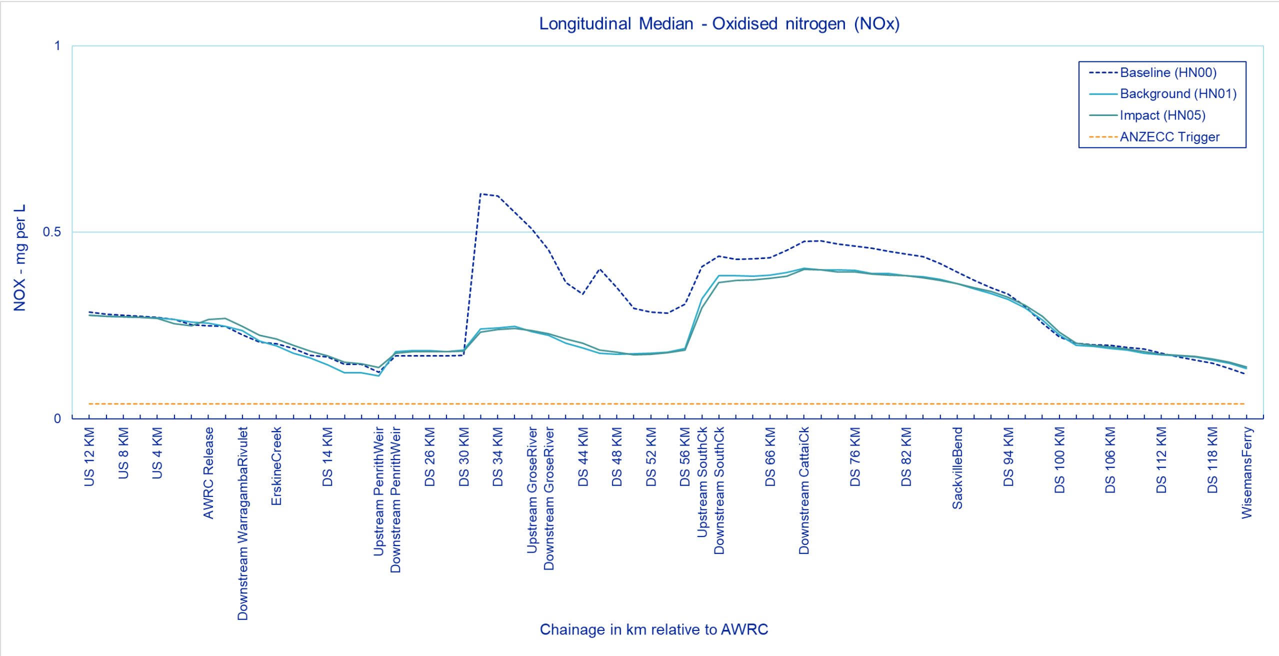


Figure 8-23 Longitudinal profile of predicted annual median oxidised nitrogen concentrations (2036 releases/dry year)

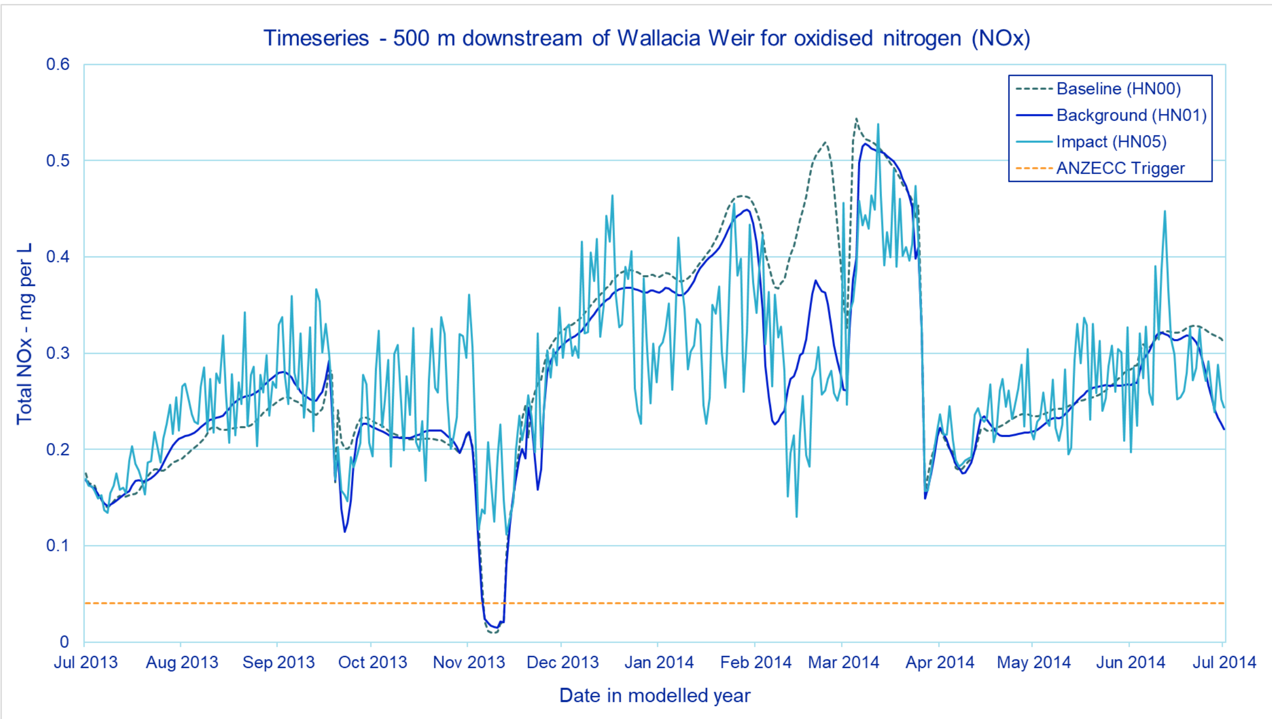


Figure 8-24 Timeseries of predicted oxidised nitrogen concentrations 500 m downstream of Wallacia Weir (2036 releases/dry year)

During the modelled wet year, there are more events where tertiary treated water is released. Key findings include:

- The results for nutrients are predicted to be similar to those in the dry year, although the annual median concentrations are incrementally higher due to the cumulative increase in catchment loads.
- Periodic spikes of higher concentrations of nitrogen, ammonia, oxidised nitrogen, total phosphorus and filterable reactive phosphorus are also predicted, associated with the release of tertiary treated water from the AWRC during wet weather. These increases are relatively short-lived, with concentrations returning quickly to levels equivalent to, or lower than background conditions within a few days. The time series for total nitrogen 500 m downstream of Wallacia Weir is shown as an example in Figure 8-25. Spikes can be seen during tertiary treated releases but for most of the time total nitrogen concentrations are lower in the impact scenario (HN05) than in the background scenario (HN01).
- Results for chlorophyll *a*, salinity, total suspended solids, enterococci, dissolved oxygen and cyanobacteria risk are generally similar to the dry year.

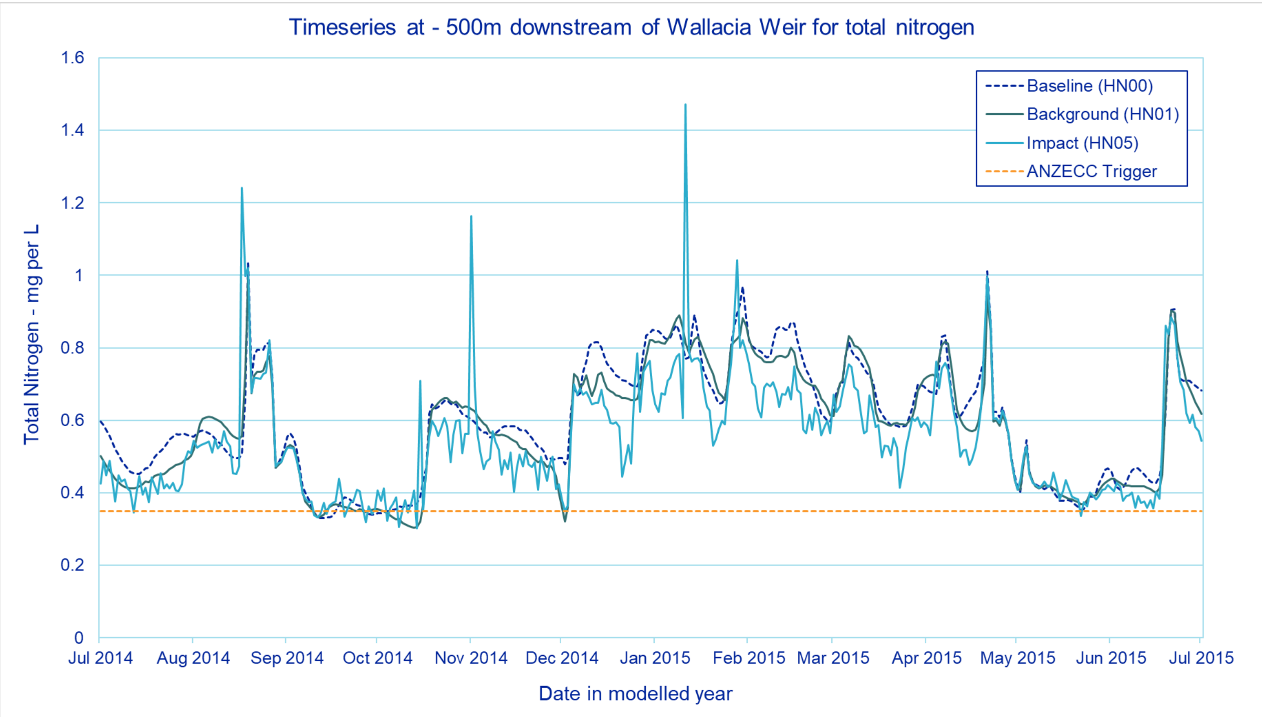


Figure 8-25 Timeseries of predicted total nitrogen concentrations 500 m downstream of Wallacia Weir (2036 releases/wet year)

The modelling results also include an estimate of increases in nutrient loads for Nepean and Warragamba rivers as well as South Creek. AWRC releases are estimated to account for about 0.9% of the total nitrogen load for the Hawkesbury Nepean River in a dry year and about 0.8% in a wet year. Similarly, the AWRC releases accounted for about 0.6% of the total phosphorus load in a dry year and about 1% in a wet year.

Table 8-33 provides an overview of the key differences between scenarios and the relative changes to water quality.

Table 8-33 Differences between scenario variations for Nepean River

Scenario variation	Description
High loading	Minor increases in total nitrogen and total phosphorus are predicted in the higher loading background scenarios compared to the low loading background scenarios with the largest increases occurring in the upper reaches of the river, upstream of Penrith Weir. No notable differences in salinity, total suspended solids and dissolved oxygen are predicted between the low and high loading background scenarios. The relative changes between the impact and background scenario for the high loading conditions are similar to the low loading results.
AWRC advanced treatment shut down	There is only one event in the wet year where a shutdown of the advanced treatment process is predicted. No events are predicted in the dry year. The consequences to Nepean River releases include changes to daily release volumes and water quality. The relative impacts from this event are predicted to be negligible.
Flows split between Nepean River and Warragamba River	The altered flow regime results in reduced water levels in the Wallacia Weir pool relative to those predicted for Nepean release scenarios. Consequently, during Stage 1, flows are significantly reduced downstream of Wallacia Weir under this scenario. The water quality differences predicted in Nepean River when releases are diverted to Warragamba River are relatively small.

Near field and toxicity assessment

The desktop review of potential toxicants in advanced and tertiary treated water identified that there is potential for concentrations of aluminium, copper, zinc and manganese to exceed the guideline values when tertiary treated water is released. The full review is included as Appendix B in the Hydrodynamic and Water Quality Impact Assessment (Appendix F).

Near field modelling was therefore undertaken for aluminium, copper, zinc and manganese in Nepean River. The near field modelling predicts that the primary mixing zone criteria for these toxicants cannot be achieved for the relevant severe wet weather release events. However, the potential for toxicity and environmental harm arising from these releases is considered low due to the same factors outlined earlier in the near field and toxicity assessment for South Creek. Alternative release structures will be considered during detailed design to improve mixing and dilution.

Waterway objectives for Nepean River

Table 8-34 summarises results for key indicators covered by the WQRM at several locations downstream of the AWRC release for the baseline, background and impact scenarios for the dry and wet years. The location of these sites is shown in Figure 8-26. The table provides an indication of predicted compliance with waterway objectives, based on the modelled results for one set of baseline, background and impact scenarios (HN00, HN01 and HN05). These scenarios assume all flows are released to Nepean River and that flows are not diverted to Warragamba River. Cells shaded in grey indicate that waterway objectives are predicted to be achieved based on the annual median concentrations at this location. Cells shaded in pink indicate that the annual median concentrations are predicted to exceed the waterway objectives. As noted earlier, the results do not represent absolute values that can be achieved and do not guarantee that waterway objectives will or will not be achieved, but rather provide an indication of change resulting from the releases.

For the background and impact scenarios, the trend is also shown as up or down relative to baseline and background scenarios respectively. A trend was defined as a change in annual median greater than 5%. If blank, any change is predicted to be less than 5%. Changes less than this are considered negligible or marginal.

Table 8-34 Summary of water quality trends for key indicators and comparison to waterway objectives at Nepean River

Location	Distance downstream	Scenario	Dry year						Wet year					
			Total nitrogen	Oxidised nitrogen	Ammonia	Total phosphorus	FRP	Chlorophyll *a*	Total nitrogen	Oxidised nitrogen	Ammonia	Total phosphorus	FRP	Chlorophyll *a*
500 m downstream of release	500 m	Baseline												
		Background				▼	▼	▲		▼		▼	▼	▲
		Impact	▼		▲	▼	▼	▼	▼	▼	▲	▼	▼	▼
Warragamba River confluence	4 km	Baseline												
		Background				▼	▼	▲				▼	▼	▲
		Impact		▲	▲	▼	▼	▼	▼		▲	▼	▼	▼
14 km downstream	14 km	Baseline												
		Background	▼	▼	▼	▼	▼	▲	▼		▼	▼	▼	▲
		Impact	▲	▲	▲	▼	▼	▼		▲	▲			
Downstream of Penrith Weir	22 km	Baseline												
		Background	▲	▲	▼	▼	▼	▼		▲	▼	▼	▼	
		Impact			▼			▼			▼			▲
Yarramundi	40 km	Baseline												
		Background	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▲
		Impact			▼		▼	▼		▼			▼	▲
Cattai Creek	70 km	Baseline												
		Background	▼	▼		▲		▼	▼	▼	▲			▼

Location	Distance downstream	Scenario	Dry year						Wet year					
			Total nitrogen	Oxidised nitrogen	Ammonia	Total phosphorus	FRP	Chlorophyll *a*	Total nitrogen	Oxidised nitrogen	Ammonia	Total phosphorus	FRP	Chlorophyll *a*
		Impact						▲						
Sackville Bend	88 km	Baseline												
		Background		▼	▲	▲		▼	▼	▼	▲	▲	▲	▼
		Impact						▼						

Above waterway objectives | Below waterway objectives | ▲ Increasing trend (>5%) | ▼ Decreasing trend (>5%)

Notes on table:

1. ANZG (2018) and ANZECC/ARMCANZ (2000) guideline values applied for all indicators

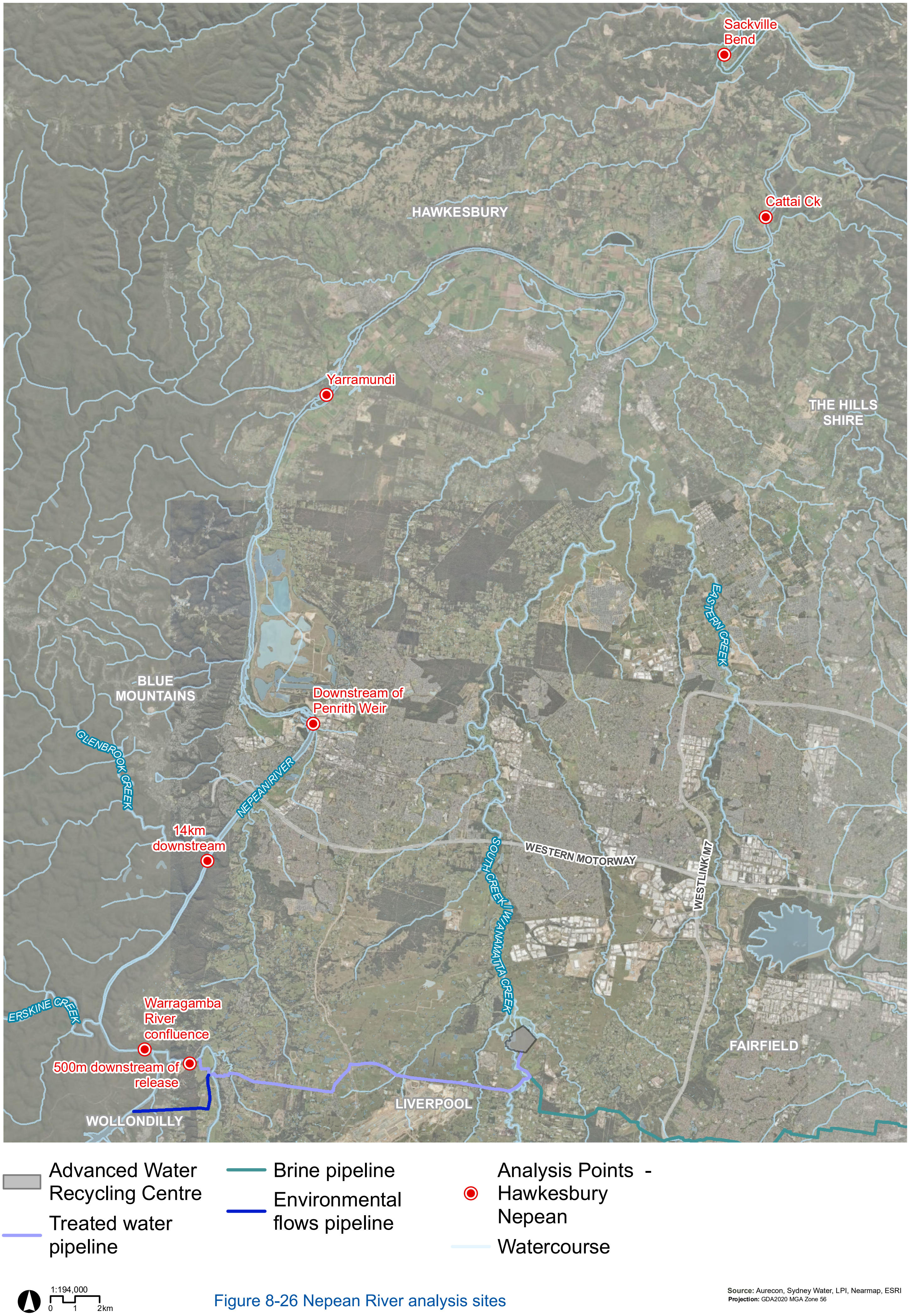


Figure 8-26 Nepean River analysis sites

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Table 8-35 summarises predicted changes to all indicators included in the waterway objectives for Nepean River. Generally, the WQRM predicted that the changes in water quality will extend to about 15 km downstream of the release. The table brings together results from the WQRM and near field modelling as well as other lines of evidence including expected treatment performance.

Overall, impacts to the water quality of Nepean River from the AWRC releases are predicted to be minor and impacts to the waterway objectives are unlikely. Management and monitoring measures are included in sections 8.10 and 8.11.

Table 8-35 Overview of predicted changes to waterway objectives at Nepean River due to AWRC releases

Indicator	**Guideline values**		**Predicted changes resulting from AWRC releases**
1. Aquatic Ecosystems			
Total nitrogen (TN)	0.35 mg/L		Reductions in annual medians downstream of Nepean River release point and South Creek confluence. Short term spikes in concentrations predicted in severe wet weather events.
Oxidised nitrogen (NOx) Ammonium (NH_4^+)	0.040 mg/L 0.020 mg/L		Marginal increases in annual medians. Short term spikes in concentrations predicted in severe wet weather events.
Total phosphorus (TP) Filterable reactive phosphorus (FRP)	0.025 mg/L 0.020 mg/L		Reductions in annual medians. Short term spikes in concentrations predicted in severe wet weather events.
Chlorophyll *a* (Chl *a*)	0.003 mg/L		Reduction in annual medians predicted to just downstream of Warragamba River.
Dissolved oxygen (DO)	85 - 110 % Saturation		Beneficial increases in annual medians.
pH	6.5 - 8.0		Design indicates that a pH of about 7 is achievable for all release streams.
Conductivity / Salinity	125-2200 µS/cm Equivalent to salinity of 0.09 - 1.5g/L		Reductions in annual medians.
Toxicants	Aluminium Copper Zinc	0.055 mg/L 0.0014 mg/L 0.008 mg/L	Conservative mixing zone criteria not met, however the potential for toxicity and

Indicator	Guideline values	Predicted changes resulting from AWRC releases
	Manganese 0.100 mg/L	environmental harm is considered low due to infrequency of events and short term nature.
Turbidity / Total suspended Solids (TSS)	6-50NTU TSS<40mg/L	Reductions in annual medians.
2. Recreation and Aesthetics		
Enterococci	Primary contact: 95th percentile for intestinal enterococci/100 mL ≤ 40 Secondary contact: 95th percentile for intestinal enterococci/100 mL > 40 and ≤ 200	Reductions in enterococci densities.
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	No overall increase in cyanobacteria risk index predicted.
Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour or foaming.	All release streams are free from substances that produce undesirable colour, odour or foaming.
Surface films and debris	Surface waters should be free from floating debris, oil, grease and other objectionable matter	All release streams are free from floating debris, oil, grease and other objectionable matter.
Nuisance organisms	Surface waters should be free from undesirable aquatic life, such as algal blooms, or dense growths of attached plants or insects.	No overall increase in nuisance organisms is predicted.
3. Primary industries (irrigation and livestock drinking)		
Water quality	As per water quality metrics under Aquatic Ecology.	Refer above.
Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL *E. Coli* used as representative indicator.	No increase in human pathogens due to reverse osmosis treatment train and disinfection.

Indicator	Guideline values	Predicted changes resulting from AWRC releases
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	No overall increase in cyanobacteria risk index predicted.
4. Drinking water		
As per Water Quality metrics, under Aquatic Ecology		
Microorganisms	*E. Coli* < 1cfu/100mL Enterococci <1cfu/100mL	Reductions in enterococci and *E. Coli* densities.
	Viruses, protozoa and helminths - Absent	Not present in advanced or tertiary treated water.
	Cyanobacteria risk index. Criteria: No overall increase in risk under any scenario.	No overall increase in cyanobacteria risk index predicted.
Toxicants	Aluminium Zinc Copper Manganese	Conservative mixing zone criteria not met however the potential for toxicity and environmental harm is considered low due to infrequency of events and short-term nature.

Warragamba River

The Metropolitan Water Plan for Sydney (Department of Industry, Skills and Regional Development, 2017) recommended the release of environmental flows from Warragamba Dam. Currently, releases from Warragamba Dam are for the purposes of diluting flows from Wallacia WWTP and drinking water extraction for the Richmond WFP. The Plan recommends a new variable flow regime and further work to refine this is currently underway by DPIE.

Model scenarios were considered with and without releases to Warragamba River. This section presents the findings for scenarios with releases to Warragamba River. For modelling purposes, the AWRC releases to Warragamba River effectively replicate the current seasonal variations of the existing WaterNSW release regime from Warragamba Dam. The only exception is when there is limited or no availability of advanced treated water from the AWRC, at which times no flows can be provided from the AWRC. Under these infrequent circumstances, the modelling has assumed releases from Warragamba Dam will be reinstated to maintain the required level of flows in the river. A variable release environmental flow regime was not considered, given that it is yet to be finalised by DPIE.

Table 8-36 summarises the representative scenarios used to assess impacts to Warragamba River. The results are based on a 2036 representative impact scenario (referred to as HN13), where only advanced treated water is released to Warragamba River up to a maximum of 22 ML/day in April to October and 30 ML/day in November to March. The remaining releases, including any with tertiary treated water, will be released to Nepean River. The impact scenario (HN13) was compared to the equivalent background scenario (HN01) and the baseline scenario (HN00). The predicted changes in impacts to Nepean River under this scenario are discussed above in Table 8-33.

Scenario variations, including low and high loading and the AWRC advanced treatment shut down did not have any impact on Warragamba River results, so have not been assessed here.

Table 8-36 Summary of representative scenarios for Warragamba River

Scenario	Land use and stormwater management	Releases from other treatment plants	AWRC flows
Baseline (HN00)	Current land use.	2020 volumes and qualities.	None.
Background (HN01)	2036 land use.	Forecast 2036 volumes. Low loading conditions.	None.
Impact (HN13)	2036 land use.	Forecast 2036 volumes. Low loading conditions.	ADWF – 50 ML/day. Advanced treated water only to Warragamba River (maximum 30 ML/day in November to March and 22 ML/day in April to October). Remaining and/or tertiary releases to Nepean River. Wet weather releases to South Creek.

Predicted future changes in water quality (without AWRC releases)

Water quality in Warragamba River is heavily influenced by dam releases and the discharge from the Wallacia WWTP. Similar to Nepean River, forecast population growth in the catchment is predicted to result in changes to water quality. Under 2036 conditions, the modelling identified that the most significant impacts on water quality in Warragamba River related to nutrients and pathogens. Concentrations were predicted to increase measurably across all indicators relevant to these two water quality groups, principally as a result of increases in concentrations and loads from the Wallacia WWTP.

Predicted changes due to AWRC releases

Key findings for Warragamba River included (in both the wet and dry year):

- Marginal reductions in total nitrogen are predicted in Warragamba River downstream of the AWRC release point. However similar to the results for Nepean River, increases in concentrations of bioavailable forms of nitrogen, including oxidised nitrogen and ammonia, are predicted.
- Increases in concentrations of total phosphorus are predicted along with increased levels of filterable reactive phosphorus due to the introduction of the advanced treated water.
- Higher levels of chlorophyll *a* are predicted within Warragamba River, downstream of the AWRC release point compared to both the baseline and background scenarios (refer to Figure 8-27). While not major blooms, they are considered to be the result of increased, and more inorganic forms of nutrients, particularly bioavailable phosphorus and to a lesser extent nitrogen. The lower levels of suspended sediment may also contribute to the predicted increase in chlorophyll *a*. These increases in primary productivity are limited to Warragamba River.
- Reductions in median and daily concentrations of salinity and total suspended solids and enterococci densities were also predicted alongside notable improvements in dissolved oxygen downstream of the release point as a result of the AWRC releases.
- The model predicted localised increases in algal growth within Warragamba River. However, the cyanobacteria risk index results indicated no increased risk in the downstream reaches of Nepean River based on the conditions that are considered conducive to growth of cyanobacteria. Slightly warmer temperature near the AWRC releases in winter can increase risk slightly at this time, but in summer when blooms are likely, the AWRC also has a cooling effect on the river water. Along with small changes to water clarity and nutrient availability, it was concluded that there is likely to be some change to biomass, but no material change in risk.

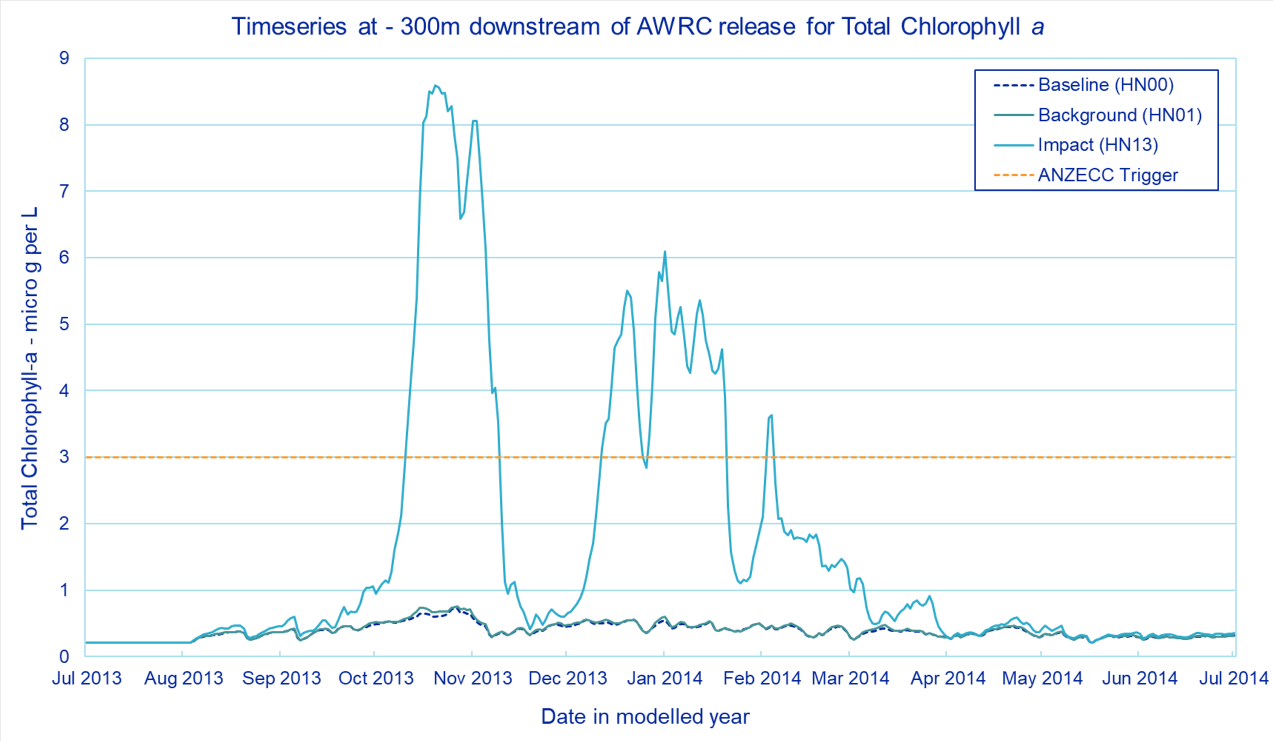


Figure 8-27 Timeseries of predicted chlorophyll *a* concentrations downstream of the AWRC Warragamba release point (dry year)

Waterway objectives for Warragamba River

Table 8-37 summarises results for key indicators covered by the WQRM downstream of Warragamba River release for the baseline, background and impact scenarios for the dry and wet years. The location of the analysis site for comparison is shown in Figure 8-28. The table provides an indication of predicted compliance with waterway objectives, based on the modelled results for one set of baseline, background and impact scenarios (HN00, HN01 and HN13). Cells shaded in grey indicate that waterway objectives are predicted to be achieved based on the annual median concentration at this location. Cells shaded in pink indicate that the annual median concentration is predicted exceed the waterway objectives.

For the background and impact scenarios, the trend is also shown as up or down relative to baseline and background scenarios respectively. A trend was defined as a change in annual medians greater than 5%. If blank, any change is predicted to be less than 5%. Changes less than this were considered negligible or marginal.

Table 8-37 Summary of water quality trends for key indicators and comparison to waterway objectives at Warragamba River

Location	Scenario	Dry year: Total nitrogen	Dry year: Oxidised nitrogen	Dry year: Ammonia	Dry year: Total phosphorus	Dry year: FRP	Dry year: Chlorophyll *a*	Wet year: Total nitrogen	Wet year: Oxidised nitrogen	Wet year: Ammonia	Wet year: Total phosphorus	Wet year: Filterable Reactive Phosphorus	Wet year: Chlorophyll *a*
300m downstream of release	Baseline												
	Background	▲	▲	▲	▲	▲		▲	▲	▲	▲	▲	
	Impact		▲	▲	▲	▲	▲		▲	▲	▲	▲	▲

Above waterway objectives   Below waterway objectives   ▲ Increasing trend (>5%)   ▼ Decreasing trend (>5%)

Notes on table
1. ANZG (2018) and ANZECC/ARMCANZ (2000) guideline values applied for all indicators

Treated water pipeline

Environmental flows pipeline

Watercourse

Analysis Points - Hawkesbury Nepean

1:47,038

0 0.5 1 km

Figure 8-28 Warragamba River analysis site

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI

Projection: GDA2020 MGA Zone 56

Table 8-38 summarises predicted changes to all indicators included in the waterway objectives for Warragamba River. The table brings together results from the WQRM and near field modelling as well as other lines of evidence including expected treatment performance.

Overall, impacts to the water quality of Warragamba River from the AWRC releases are predicted to be minor and impacts to the waterway objectives are unlikely. Management and monitoring measures are included in sections 8.10 and 8.11.

Table 8-38 Overview of predicted changes to waterway objectives at Warragamba River due to AWRC releases

Indicator	Guideline values	Predicted changes resulting from AWRC releases to Warragamba River
1. Aquatic Ecosystems		
Total nitrogen (TN)	0.35 mg/L	Reductions in annual medians predicted downstream of release to confluence with Nepean River.
Oxidised nitrogen (NOx)	0.040 mg/L	Increase in annual medians predicted downstream of release to confluence with Nepean River.
Ammonium (NH_4^+)	0.020 mg/L	
Total phosphorus (TP)	0.025 mg/L	
Filterable reactive phosphorus (FRP)	0.020 mg/L	
Chlorophyll *a* (Chl *a*)	0.003 mg/L	
Dissolved oxygen (DO)	85 - 110 % Saturation	Beneficial increases in annual medians predicted downstream of release to confluence with Nepean River.
pH	6.5 - 8.0	Design indicates that a pH of about 7 is achievable for all release streams.
Conductivity / Salinity	125-2200 µS/cm Equivalent to salinity of 0.09 - 1.5g/L	Reductions in annual medians predicted downstream of release to confluence with Nepean River.
Toxicants	N/A	Not applicable to advanced treated water.
Turbidity / Total suspended Solids (TSS)[7]	6-50NTU TSS<40mg/L	Reductions in annual medians predicted downstream of release to confluence with Nepean River.

Indicator	Guideline values	Predicted changes resulting from AWRC releases to Warragamba River
2. Recreation and aesthetics		
Enterococci	Primary contact: 95th percentile for intestinal enterococci/100 mL ≤ 40 Secondary contact: 95th percentile for intestinal enterococci/100 mL > 40 and ≤ 200	Reductions in enterococci densities predicted downstream of release to confluence with Nepean River.
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	Potential for increase in risk within Warragamba River. No overall increase in cyanobacteria risk index predicted downstream in Nepean River.
Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour or foaming.	All release streams are free from substances that produce undesirable colour, odour or foaming.
Surface films and debris	Surface waters should be free from floating debris, oil, grease and other objectionable matter	All release streams are free from floating debris, oil, grease and other objectionable matter.
Nuisance organisms	Surface waters should be free from undesirable aquatic life, such as algal blooms, or dense growths of attached plants or insects.	No overall increase in nuisance organisms is predicted.
3. Primary industries (irrigation and livestock drinking)		
Water quality	As per water quality metrics under Aquatic Ecology.	Refer above.
Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL *E. Coli* used as representative indicator.	No increase in human pathogens due to reverse osmosis treatment train and disinfection.
Cyanobacteria risk index	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	Potential for increase in risk within Warragamba River. No overall increase in cyanobacteria risk index predicted downstream in Nepean River.
4. Drinking water		
As per Water Quality metrics, under Aquatic Ecology		

Indicator	Guideline values	Predicted changes resulting from AWRC releases to Warragamba River
Microorganisms	*E. Coli* < 1cfu/100mL Enterococci <1cfu/100mL	Absent in advanced treated water.
	Viruses, protozoa and helminths: Absent	Absent in advanced treated water.
	Cyanobacteria risk index. Criteria: No overall increase in risk under any scenario.	Potential for increase in risk within Warragamba River. No overall increase in cyanobacteria risk index predicted downstream in Nepean River.
Toxicants	N/A	Not applicable to advanced treated water.

Neutral or Beneficial Effect (NorBE)

The Sydney Drinking Water Catchment (SDWC) extends to Warragamba Weir, which is about 1.2 km downstream of Warragamba Dam wall. While there are no extractions for drinking water or for other purposes within this reach, it does officially lie within the SDWC boundary.

The impacts on this reach have not been assessed using the WQRM as the model boundary starts downstream of the weir and does not extend to the dam wall. Therefore, analysis of the potential impacts from the operation of the proposed environmental flow releases has been undertaken through analysis of monitoring data and an assessment of the expected change in water quality that may result from the introduction of the AWRC releases.

The Warragamba environmental flows options assessment (DPI, 2014a) presented a summary of the characteristics and water quality conditions for sub-reach 19a, which extends from the dam wall to Megarritys Creek.

Sub-reach 19a generally receives very limited inflows from the surrounding catchments but infrequently can also receive major flows in the event of Warragamba Dam spilling. Flushing of this reach, particularly upstream of the weir, is therefore limited due to the presence of Warragamba Dam, particularly during dry weather.

The DPI report referred to historic data at Warragamba weir monitoring site (N642) collected during the 1980s that indicated occasional algal blooms. Other measures of water quality were generally acceptable at that time although elevated levels of nitrogen were observed (median total nitrogen level of 0.85 mg/L and a median oxidised nitrogen level of 0.43 mg/L).

The report also states that more recent data suggests that conductivity and levels of total and oxidised nitrogen have decreased, potentially due to the closure of the old Warragamba WWTP. However, other than during spill events from Warragamba Dam there remains limited flow in this section, derived primarily from the small catchments draining to this section of the river and seepage from Warragamba Dam wall. High levels of iron bacteria have been noted in this reach, indicating iron-rich groundwater intrusions.

Analysis of monitoring data from 2018 at site N642 indicates more recent increases in total nitrogen, oxidised nitrogen, total phosphorus and chlorophyll *a*.

Introduction of a consistent source of advanced treated water at the head of this poorly flushed reach is considered beneficial to the river's water quality. Due to the nature and limited extent of the reach (1.2 km length and 10 to 50 m width), it is expected that the water quality will generally correlate with that of the treated water being released. As a result of the release rates, the introduced flow regime is also expected to improve water quality conditions by improving flushing times. Impacts from groundwater and/or seepage from the dam wall are also likely to be mitigated due to the significant inflows and reduced residence times.

Based on these assumptions, it is predicted that there will be a beneficial effect on water quality within this section of the river within the SWDC. If the environmental flows pipeline is not built and no treated water flows are released to Warragamba River, the project will have no impact on the SDWC.

Compliance with Hawkesbury Nepean Nutrient Framework

The Hawkesbury Nepean Nutrient Framework includes limits on nutrient concentrations and caps on nutrient loads.

The Framework includes three options for the management of wastewater flows in the Upper South Creek Catchment. The project best represents Option 2, which involves no discharge to South Creek, but some to Nepean River. Load limits are provided for Option 2, however no concentration limits are specified.

Table 8-39 and Table 8-40 summarise future nutrient loads for the AWRC and Sydney Water's existing WWTPs and WRPs within Yarramundi subzone 2 and Sackville subzone 2. The estimates include future growth predictions and planned upgrades at treatment plants. Total predicted TN and TP loads for 2036 and 2056 are below the framework load limits for each subzone. The additional loads from the AWRC releases are therefore consistent with the EPA's framework.

Table 8-39 Estimated total nitrogen (TN) loads within Yarramundi Subzone 2

WWTP	2036 -TN (kg/yr)	2056 – TN (kg/yr)	2036 -TP (kg/yr)	2056 -TP (kg/yr)
Penrith	11,749	6,765	199	203
Wallacia	2,563	2,675	26	26
Winmalee	19,090	20,267	489	518
St Marys AWTP	5,810	5,856	84	84
AWRC	8,538	17,172	383	1,673
Total Estimated Load	**47,749**	**52,735**	**1,180**	**2,504**
Load limit[1]	**55,300**	**55,300**	**3,450**	**3,450**

Table 8-40 Estimated total nitrogen (TN) loads within Sackville Subzone 2

WWTP	2036 -TN (kg/yr)	2056 – TN (kg/yr)	2036 -TP (kg/yr)	2056 -TP (kg/yr)
St Marys	37,911	50,793	991	1,283
Riverstone	33,344	37,991	759	641
Quakers Hill	21,613	7,517	350	165
AWRC	1,686	3,362	105	211
Total Estimated Load	**94,554**	**99,664**	**2,205**	**2,301**
Load limit[1, 2]	**126,100**	**126,100**	**2,710**	**2,710**

Notes on Table 8-39 and Table 8-40

1. Load limits taken from Table 7, Regulating nutrients from sewage treatment plants in the Lower Hawkesbury Nepean River catchment (EPA, 2019a).
2. Load limit for Sackville excludes loads from McGraths Hill and South Windsor (non-Sydney Water facilities).

Compliance with Malabar EPL

Transfer of brine to the Malabar wastewater system has the potential to impact EPL pollutant load and concentration limits. Load projections have been completed for Malabar WWTP and the AWRC to understand the impact of brine transfer for Stage 1 and future stages. Table 8-41 summarises the forecast loads at Malabar WWTP for 2036 and 2056, compared to current EPL load limits. Oil and grease is not expected in the brine, so has not been included in Table 8-41.

The transfer of brine to the Malabar system is expected to have minimal impact on the annual loads discharged at Malabar WWTP. Compliance with load limits is predicted until at least 2056.

Table 8-41 Forecast loads at Malabar WWTP compared to EPL limits

Pollutant	Load Limit[1] (kg/yr)	2036		2056	
		Malabar load (kg/yr)	Malabar load including brine (kg/yr)	Malabar load (kg/yr)	Malabar load including brine (kg/yr)
Total nitrogen	**13,231,250**	10,457,673	10,508,955	11,592,081	11,694,646
Total phosphorus	**2,646,250**	1,454,433	1,472,501	1,638,148	1,674,283
Total suspended solids	**47,632,500**	31,463,141	31,481,391	34,341,646	34,378,146
Cadmium	**301**	67	73	74	85
Chromium	**10,804**	1,697	1,841	1,863	2,150

Pollutant	Load Limit[1] (kg/yr)	2036 Malabar load (kg/yr)	2036 Malabar load including brine (kg/yr)	2056 Malabar load (kg/yr)	2056 Malabar load including brine (kg/yr)
Copper	**43,610**	20,408	22,136	22,405	25,859
Lead	**5,615**	861	946	934	1,091
Mercury	**103**	8	8	8	10
Selenium	**3,969**	136	147	149	172
Zinc	**59,761**	24,042	26,077	26,394	30,464

1. Taken from EPL 372, June 2021.

Similarly, there is no risk to Malabar concentration limits with the addition of the brine. There is no hydrogen sulfide and biological oxygen demand expected in the brine.

Predicted concentrations of total suspended solids and aluminium in the brine will be less than the current Malabar influent concentration, so AWRC will effectively dilute other inflows.

Table 8-42 Comparison of pollutant concentration of brine and Malabar influent

Indicator	Unit	Brine concentration	Malabar Influent concentration (median 2020/21)
Aluminium	ug/L	425.0	1245.5
Total suspended solids	mg/L	8.3	355

8.7.2 Ecohydrology and geomorphology

The release of treated water has the potential to impact on the ecohydrology (including hydrology and hydraulics) of the receiving waterways. Flow volumes in the waterways will increase and potentially impact on geomorphic attributes, aquatic ecology and riparian vegetation.

Modelling has been used to analyse the potential changes to ecohydrology. This has involved the assessment of:

- hydrologic outputs from the WQRM models for South Creek and Nepean River for baseline, background and impact scenarios for 2036 and 2056
- hydraulic modelling results for Nepean River, including:
  - baseline flows – based on flow gauge data
  - baseline plus AWRC Stage 1 releases of 50 ML/day

- baseline plus AWRC ultimate release of 100 ML/day.

This section provides an overview of the 2036 modelling results. For the hydraulic scenarios, the median flows are presented. This section includes:

- a summary of the predicted changes to hydrology that occur in the future background scenarios, compared to baseline
- a summary of the predicted changes to hydrology and hydraulics that occur as a result of the AWRC releases
- an assessment of potential impacts to the geomorphology of South Creek and Nepean River.

As outlined in the previous section, the results are based on modelling that simulates complex systems and has been developed using a range of assumptions and historical data. The results do not represent absolute values that can be achieved, but rather an indication of the relative change expected.

The 2056 modelling results are covered in section 8.8 (impact on future stages).

South Creek

AWRC releases to South Creek will occur in wet weather only. Key findings from the ecohydrology and geomorphic assessment include:

- Significant hydrological changes are predicted to occur as a result of urban growth and land use changes in the catchment.
- The stormwater management strategy has a large impact on hydrology, with peak flows reduced under the parkland management approach.
- Impacts from AWRC releases are relatively minor, with only small increases to the hydrologic metrics.

These findings are discussed in more detail below. Results for representative baseline, background and impacts scenarios are provided. The representative scenarios are the same as those presented in section 8.7.1 for the water quality results.

Predicted future changes in ecohydrology and geomorphology (without AWRC releases)

The hydrologic modelling results predict that changes to land use within the South Creek catchment represent the dominant change to hydrology. Currently, during sustained dry weather, isolated, stagnant water pools develop in South Creek that do not flow and join until there is a pulse of inflows from the upstream catchments. During the future background scenario conditions, the flow regime is significantly modified in terms of both base flows and event peaks, due to more impermeable surfaces associated with urban areas.

Representative results for a baseline, background and impact scenario are presented in Table 8-43. Table 8-43 shows the combined results for the representative dry and wet year. Comparison of the specific metrics in Table 8-43 shows that there is a significant change in flow conditions between baseline and background scenarios.

Land use change is likely to significantly increase flows in South Creek which will result in potentially increased mobilisation of bank and bed sediments and erosion due to the dispersive nature of the soils in this catchment. Bank erosion may result in channel widening.

Other than change in land use, the most significant model variable that influences the hydrologic metrics is the stormwater management approach. A parkland stormwater management strategy will result in increased infiltration, transpiration and water recycling. The application of this strategy is likely to reduce the peak flows compared to a business as usual approach. It will also lead to a significant reduction in the percentage of time erosion is likely to occur.

Predicted future changes due to AWRC releases

Limited change in hydrology is predicted as a result of the AWRC releases. Comparison of the specific metrics in Table 8-43 shows that the impact scenario results are similar to the background scenario.

The effect of wet weather releases from the AWRC is a minor increase (less than 3%) in mean annual flows which will result in limited additional morphological change in the creek. Similarly, negligible changes to the other metrics are predicted, as shown by the small changes between the background and impact scenarios in Table 8-43.

At a location 250 m downstream, releases are predicted to account for about 10% of the total flow at the start of the more severe wet weather events, reducing to less than 0.5% as the creek flows increase. Further downstream near Blaxland Creek (about 12 km downstream of the releases), the predicted contributions are reduced to less than 4% of the total creek flow at the start of these larger wet weather events, reducing to less than 0.4% as the creek flows increase. The relative contribution from the AWRC treated water releases then generally declines as flows within the creek increase. During the wet weather release events (around 2036), the average contribution of the AWRC releases downstream of the release point, lies between 4% and 7% of the total creek flows. The percentage contribution can however also account for up to 40% to 50% when the creek flows are relatively low, and the AWRC releases commence. Further downstream (about 12 km) near Blaxland Creek, the releases on average account for about 2%, up to a maximum of about 10% of the total creek flow.

Table 8-43 Hydrologic flow metric results for South Creek – 2 km downstream of the AWRC

Flow metrics	Baseline (SC00)	Background Scenario (SC02)	Impact Scenario (SC05)
Maximum (ML/day)	1,827	3,012	3,129
Minimum (ML/day)	0.05	0.24	0.25
Mean (ML/day)	28	66	67
Mean Annual Flow Volume (ML)	10,113	23,925	24,300
Median (ML/day)	2	7	7
St. Dev (ML/day)	112	210	217
Average zero flow duration (days)	0	0	0

Flow metrics	Baseline (SC00)	Background Scenario (SC02)	Impact Scenario (SC05)
Percentage of time with zero flow	9	3	3
Number of Fresh Events per year (> 3 x Median Flow)	23.5	24.5	24.5
Percentage of time over fresh event	33.5	32.5	32.5
Average fresh duration (hours)	125	175	182
Percentage of time bank/matrix mobilisation threshold exceeded	0.8	3.6	3.7
Percentage of time bed mobilisation threshold exceeded	0.4	1.4	1.4

Table 8-44 compares baseline, background and impact scenarios to DPIE flow objectives performance criteria (Western Sydney Planning Partnership, 2020b). The flow objectives are presented in units of ML/day rather than L/ha to allow for specific comparison to the AWRC site data. This has been done by calculating the South Creek catchment area upstream of the release.

The results show that baseline, background and impact scenarios do not exceed the flow performance criteria except for the cease to flow threshold. The cease to flow threshold is exceeded under baseline and background conditions (shown in red) which reflects the on-going rapid urbanisation of the South Creek catchment. Cease to flow exceedance improves under some of the background and impact scenarios due to a reduction in runoff from some urban sources. This change is also noted in the duration of cease to flow events, which reduce significantly under all the scenarios modelled. The flow objectives for freshes were not compared in the current assessment due to differences in the definition of ‘fresh’ used. However, based on the results for freshes presented in Table 8-43 there is again little difference in results between background and impact scenarios for these metrics.

Table 8-44 Comparison of flow objectives performance criteria to baseline and future scenario results for key metrics

Metric	Performance criteria (DPIE, 2020)	Baseline (SC00)	Background (SC01 – SC04)	Wet weather releases from AWRC (SC05-SC08)
Median daily flow (ML/day)	67.95 ± 9.75	2.0	6-7	7.0
Mean daily flow (ML/day)	643.61 ± 67	28.0	66-99	67.0
Mean annual flow volume (ML)	125,503	10,114	23,925 – 36,234	24,302 – 36,986

Metric	Performance criteria (DPIE, 2020)	Baseline (SC00)	Background (SC01 – SC04)	Wet weather releases from AWRC (SC05-SC08)
Cease to flow (proportion of time/year)	0.03 ± 0.007 (11 days ± 2.5)	0.09	0.03 – 0.09	0.03 – 0.09
Cease to flow – Duration (days/year)	6 ± 1.1	0.1	0.1 – 0.2	0.1 – 1.9

There is limited change in the overall geomorphic risk as a result of the AWRC releases, with a medium risk determined for both the background and impact scenarios. South Creek downstream of the AWRC is considered a moderately sensitive waterway and there is again a medium risk of geomorphic change under both background and impact scenarios. The hydrologic analysis suggests that the additional impact of the AWRC releases on the geomorphic condition of South Creek compared to baseline or background scenario is likely to be negligible.

AWRC release structures

The project's reference design proposes the southern release point as a swale, comprising earth embankment and rip rap, including an energy dissipation structure (scour control) at the outlet to the creek. This is the main release location. The northern release point is only catering for surface water from the northern half of the site.

The peak wet weather flow rate from the main release location is expected to be 2.5 m^3/s. The wet weather flows are less than or about 1% of the South Creek flood flow rates and therefore the individual impacts of the releases are deemed to be minimal.

The release flows must be considered relative to catchment land use changes in flows. As identified above, increased stream flows in South Creek from stormwater runoff are likely due to urban development and catchment changes. This will increase bank and bed erosion and these aspects should be considered during detailed design of the release structure.

Given the geomorphic sensitivity of South Creek the design must avoid unnecessary disturbance of the soils and limit removal of existing vegetation. The presence of dispersive soils will be considered during detailed design, as any increases in flow or saturation will lead to erosion by dispersion. This will limit the potential for surface soil erosion and additional sediment discharges to South Creek. The detailed design process will also include consideration of riparian planting and natural bank stabilisation measures.

Nepean River

AWRC releases to Nepean River will be ongoing and will occur in dry and wet weather. Key findings from the ecohydrology and geomorphic assessment include:

- Only small changes to hydrology are predicted as a result of future urban growth and land use changes in the catchment.
- The releases will result in a more consistent flow regime downstream of Wallacia Weir.
- The AWRC releases are predicted to result in moderate increases in water surface elevation upstream of the Wallacia Weir, however increases are well within the channel extents and will not result in flooding or engagement of floodplain areas. Downstream of the weir, increases to water surface elevation are minor.
- Changes to velocity and shear stress are generally minor, with one area showing a localised increase through a steep riffled section.
- Overall, predicted hydraulic and geomorphic impacts are considered minor.

These findings are discussed in more detail below.

Results for the same representative baseline, background and impact scenarios as those presented in section 8.7.1 are presented for the hydrologic results. For the ecohydraulic modelling, results presented represent the impacts of the 50 ML/day release compared to baseline median flows.

Predicted future changes in ecohydrology and geomorphology (without AWRC releases)

The impact of future changes in land use are predicted to be less for Nepean River compared to South Creek. The hydrologic modelling results demonstrate:

- negligible changes in mean annual flows
- an increase in median flows
- negligible increase in the duration of time flows are above ‘fresh’ levels
- no increase in flows above bed erosion levels.

Predicted changes due to AWRC releases

The results in this section are divided into the results from the hydrologic modelling, ecohydraulic modelling and geomorphic assessment.

The hydrologic modelling results predicts that downstream of the releases there will be increases to minimum flows, mean annual flow volume and median flows as a result of the AWRC releases. The introduction of AWRC releases into the Wallacia Weir pool will increase water levels and provide for a more consistent flow regime in Nepean River, downstream of the weir.

The increases in river flow are also predicted further downstream but the contribution of the AWRC gradually declines due to the contributions from tributaries. During an extended dry period, the increases are predicted to represent about 37% of the background flows at Penrith and 12% at Yarramundi.

The ecohydraulic modelling shows that the hydraulic conditions in the river, particularly for non-flood flow conditions, are controlled by the various weirs and structures present. Of specific relevance is Wallacia Weir, located immediately downstream of the release location and Penrith Weir, located a further 20 kilometres downstream.

Table 8-45 summarises results from the ecohydraulic modelling (water surface level, wetted perimeter, velocity and sheer stress) and the predicted impacts and risks. The results represent the impacts of the 50 ML/day release compared to baseline median flows. Low flow and high flow results are included in Appendix G. The results are consistent across the median, low and high flow regimes.

Many of the results presented in this table are inputs to other studies including aquatic ecology, terrestrial ecology and world heritage studies. These impacts are discussed in sections 8.7.3, 9.1 and 10.3.

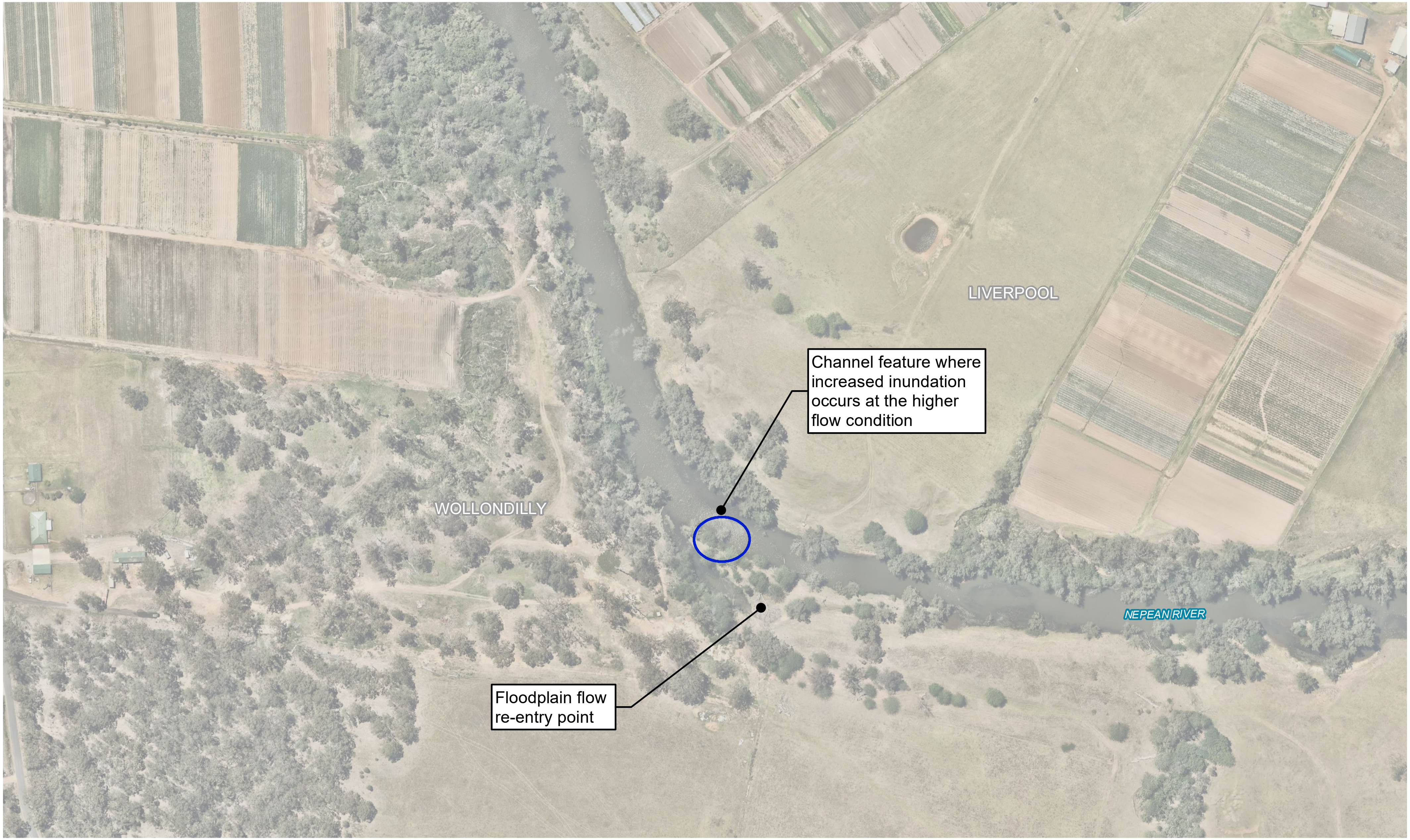
Table 8-45 Summary of predicted ecohydraulic and geomorphic impacts in Nepean River

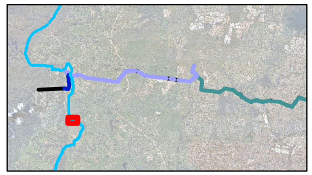
Reach	Modelling results and predicted impacts
Upstream of Wallacia Weir	The release of treated water to Nepean River is predicted to result in an increase in the water level upstream of Wallacia Weir. This increase is an average of about 18 cm and extends for about 12 km upstream of Wallacia Weir (up to Bents Basin). This water surface elevation change will be well within the existing channel extents and will not result in flooding or engagement of floodplain areas. Wetted perimeter changes occur where the increase in water surface elevation engages more of the channel area, such as in-channel bars or benches. For this section of Nepean River, wetted perimeter increases are generally predicted to be less than 2 m, with the largest increase occurring at a location where there appears to be a floodplain flow re-entry point as shown in Figure 8-29. This is creating a small backwater area which is connected to the main channel. With the slightly higher flow conditions with the AWRC release it is predicted more of the backwater becomes engaged and hence the wetted perimeter increases. The increase in water surface level and wetted perimeter will influence hydraulic habitat dependent on shallow depths. It will also increase the inundation of bank vegetation The impact on aquatic ecology and riparian vegetation is discussed further in sections 8.7.3 and 9.1. Differences in velocity and shear stress upstream of the weir are negligible. Given the negligible changes in velocity and shear stress, the geomorphic implications will be confined to the potential for increased erosion due to loss of vegetation, and potential for erosion (specifically notching) higher on the bank face. The overall risk is rated as low.
Wallacia Weir to Warragamba River	Predicted changes in water surface elevation downstream of the weir are minor, with an average increase of less than 3 cm and a maximum increase of about 5 cm in some localised channel sections. Generally, the predicted changes in wetted perimeter are minor (less than 2 m), however there are two locations, shown in Figure 8-30, where increases are larger (10 to 12 m). This may occur where a slight increase in surface water elevation may inundate a bench or engage a wider cross-section which is reflected in larger changes in wetted perimeter.

Reach	Modelling results and predicted impacts
	On average, a minor increase in velocity of around 0.05 m/s is predicted in this reach, with a maximum increase of 0.24 m/s through a steep riffle section immediately upstream of Norton's Basin, shown in Figure 8-30. Similarly, the modelling predicts an increase in shear stress of around 20 N/m2 in the steep riffle section, however the bedrock-controlled nature of the channel limits any impacts. Generally, increases in shear stress in this section were less than 2 N/m2. Given the small changes in the hydraulic metrics and the bedrock-controlled nature of the channel and banks the geomorphic implications are low. The overall risk is rated as low.
Warragamba River confluence to Penrith Weir	Changes in water surface elevation are minor, with an average increase of about 3 cm. Similarly, the changes in wetted perimeter are generally minor (less than 1 m), however there are four locations where increases are larger, including an increase of up to 11m at the confluence with Glenbrook Creek where an in-channel bar has been deposited at the creek mouth, as shown in Figure 8-31). The impact on aquatic ecology and riparian vegetation in this section is discussed further in section 8.7.3 and 9.1. The modelling predicts negligible changes in velocity and shear stress in this reach. Given the small changes in the hydraulic metrics and the planform-controlled nature of the channel and banks the geomorphic implications are minor. The overall risk is rated as low.

Overall, the predicted hydraulic and geomorphic impact is predicted to be minor based on the predicted changes in water surface elevation, wetted perimeter, velocity and shear stress.

The ecohydraulic conditions are in the range of imperceptible with regard to physical changes in habitat conditions such as depths and velocities. Given the minor impact to geomorphic conditions along Nepean River as a result of the treated water releases at Wallacia Weir no additional mitigation measures are recommended except for on-going monitoring of bank stability and change upstream of Wallacia Weir. Should the monitoring indicate an increase in erosion along this reach then modification of flows releases, or further bank stabilisation measures will be considered.





1:3,500
0 25 50 m

Figure 8-29 Locations of floodplain re-entry point where the modelled wetted perimeter increases as a result of the AWRC

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

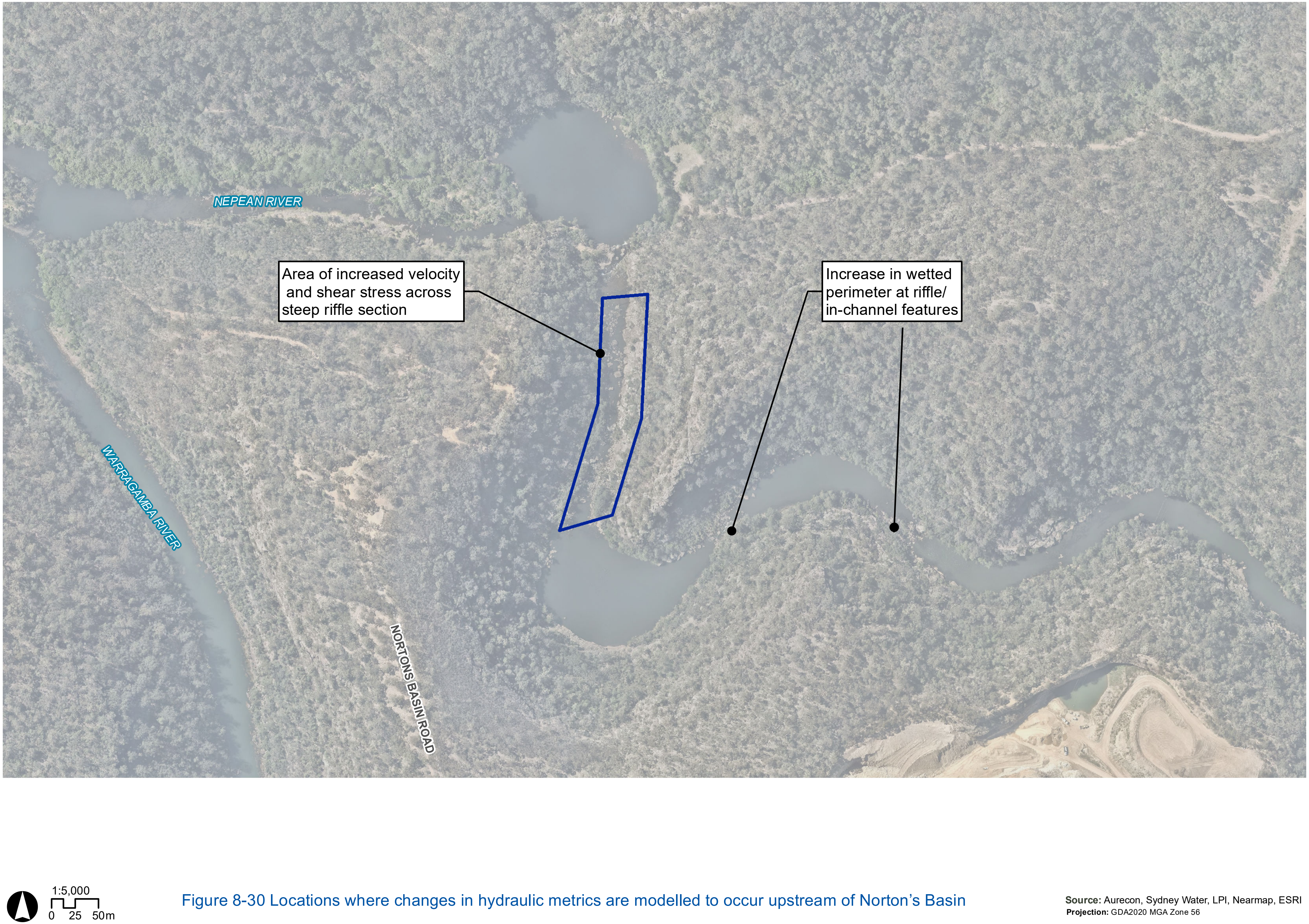


Figure 8-30 Locations where changes in hydraulic metrics are modelled to occur upstream of Norton's Basin

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

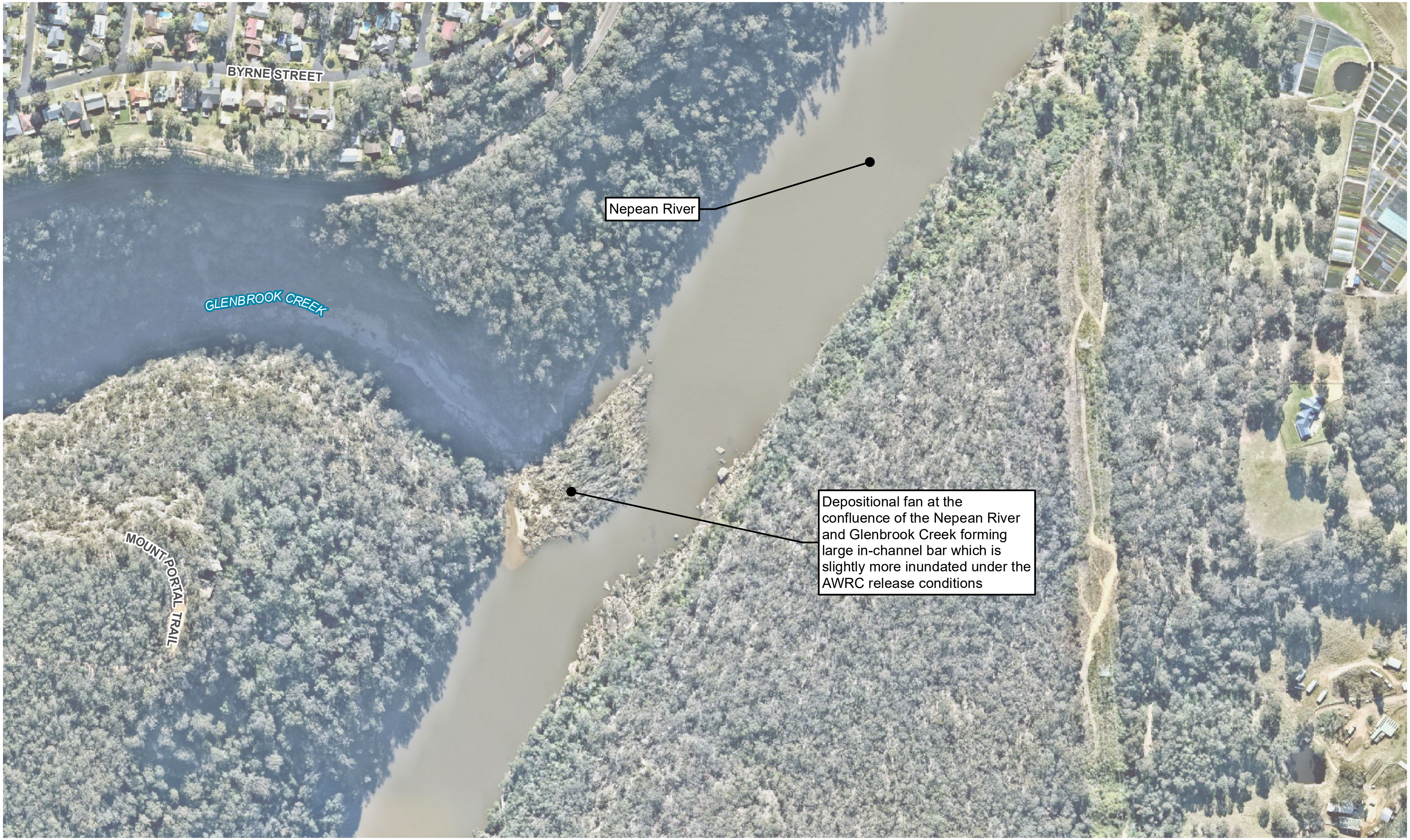


Figure 8-31 Locations of large in-channel bar at the confluence of Glenbrook Creek and the Nepean River

Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI
Projection: GDA2020 MGA Zone 56

Nepean River release structure

The configuration of the release structure upstream of Wallacia Weir will not alter the cross-sectional area or flow conveyance capacity of Nepean River in a significant way. This structure will be partly recessed into the channel wall and will not protrude into the river in such a way that will alter conveyance in the vicinity of the structure or downstream. As such, it will not result in channel constriction or alter flow conditions which could contribute to erosion.

The release flow rates are very small (about 0.5 m^3/s to 3 m^3/s in dry and wet weather conditions respectively) compared to the magnitude of Nepean River flood flows at this location and the flows are impounded by Wallacia Weir which effectively minimises flow velocities.

Provided mitigation measures included in section 8.10 are implemented, impact to geomorphology at and immediately downstream of the release is predicted to be minor.

Warragamba River

The Metropolitan Water Plan for Sydney (Department of Industry, Skills and Regional Development, 2017) recommends the release of environmental flows from Warragamba Dam. Currently, releases from Warragamba Dam are for the purposes of diluting flows from Wallacia WWTP and for drinking water extraction at the Richmond WFP. The Plan recommends a new variable flow regime and further work to refine this is currently underway by the Department of Planning, Industry and Environment (DPIE).

DPI (2014a) noted that this section of Warragamba River, between the Dam and the current release point at Megarritys Creek, will benefit directly from the commencement of variable environmental flows. The anticipated benefits include:

- an improvement in water quality
- mobilisation of in-channel sediment
- an increase in wetted perimeter and a better defined, active low flow channel
- improved water quality through a more natural temperature regime, decrease in nutrients and metals, and increased turnover of pools.

For modelling purposes, a variable release environmental flow regime was not considered, given that it is yet to be finalised by DPIE. The WQRM model therefore assumed that the AWRC releases to Warragamba River effectively replicate the current seasonal variations of the existing WaterNSW release regime from Warragamba Dam. Therefore, no changes in hydrologic metrics in Warragamba River were observed. The key difference was that the release point is further upstream.

Sydney Water has identified treated water releases in this location as an opportunity to support the NSW Government's position on environmental flows and partly replace some releases from Warragamba Dam which saves water for drinking water supplies. As noted in section 3.5, discussions are ongoing with DPIE about whether similar benefits can be achieved by releasing treated water only to Nepean River and not building the environmental flows pipeline. If they proceed, Sydney Water's releases to Warragamba River would align with the current or future regime approved by DPIE. Any future impacts associated with a variable environmental flow regime would be assessed as part of the broader NSW Government decision-making process.

As a result, the ecohydraulic and geomorphology impact assessment did not assess potential impacts associated with the releases in detail. In replacing some environmental flows from Warragamba Dam, the releases would contribute to the benefits identified above. Therefore, it is not anticipated that there will be any negative geomorphological impacts associated with the proposed environmental flow release.

Warragamba River release structure

The primary impacts with the proposed design for release to Warragamba River are associated with the difference in elevation from the release outlet to the river.

Due to the steepness of the hill beneath the outlet, some higher velocities may be experienced resulting in the erosion of the bank and or bed of the river. The release structure design includes rock gabions and riprap to dissipate flows and minimise the potential for erosion. Streamology (2021) recommended that the erosion control extend sufficiently into the river. The existing substrate in the vicinity of the outlet needs to be confirmed prior to construction to determine the likelihood of erosion as well as the scale of time over which erosion can be expected to occur. If non-cohesive substrate or easily eroded substrate is identified, instream works may be required for protection of the riverbed.

The design proposed directly releases flows into the existing riparian area of Warragamba River. The detailed design process will include consideration of riparian planting and natural bank stabilisation measures.

Channel migration and impacts of this on fixed infrastructure are of little concern in this location as this section of river is bedrock controlled and is unlikely to undergo significant changes.

Provided mitigation measures included in section 8.10 are implemented, impact to geomorphology at and immediately downstream of the release is predicted to be minor.

Pipeline waterway crossing impacts

The pipeline infrastructure will primarily be below ground so potential impacts at waterway crossing locations are expected to be minimal during operation. The potential operational phase impacts will be associated with maintenance activities and system malfunctions, such as leaks or bursts. The impacts are expected to be temporary and local in nature.

The influence of geomorphic change of channels on pipeline crossings and infrastructure can include channel migration moving beyond/around these fixed points particularly in alluvial sections of waterways, as a result of processes unrelated to the project. As part of detailed design, the influence of these geomorphic changes should be considered in terms of potential channel change impacting the longevity of infrastructure.

WaterNSW infrastructure

Overall, the results showed that all WaterNSW assets on Nepean River and Warragamba River are considered to be at low risk from flooding or erosion impacts under current conditions and also with the addition of AWRC treated water releases.

The WaterNSW Warragamba pipeline crossing on South Creek is considered to be at medium risk from flood impacts from current conditions. The risk is also considered medium for non-flood impacts associated with erosion or deposition. The risk ratings are unchanged with the addition of AWRC releases.

This is discussed in more detail in section 13.2 and Appendix G.

8.7.3 Aquatic ecology

The release of treated water to waterways has the potential to impact on aquatic ecology in the following ways:

- Water quality changes can result in conditions favouring the growth of algae and aquatic plants. Excessive algae growth and subsequent decay that occurs when algae consumes available nutrients and dies, can deplete oxygen levels in the waterway and trigger eutrophic conditions which has potential to impact aquatic fauna vulnerable to low oxygen conditions.
- Elevated levels of contaminants can have acute or chronic impacts on aquatic flora and fauna.
- Changes to the flow patterns and depth (due to change in flow volume) may impact aquatic connectivity and access to habitat.
- Increases to water surface levels can increase aquatic habitat and as a result inundate riparian vegetation.
- Increases in velocity can mobilise sediments, organic matter, macroinvertebrates and macrophytes and create barriers to juvenile fish passage.

The aquatic ecology impact assessment draws heavily on the results of the water quality and hydrodynamic, and ecohydrology and geomorphology assessments to assess these potential impacts.

Results for the representative baseline, background and impact scenarios (including potential releases to Warragamba River) have been considered in the assessment. For the hydraulic results, the median and 90th percentile flow conditions have been considered. The results from the surface water assessment have also been considered. Together this represents the full range of potential operating conditions for the AWRC.

The results presented here are for the 2036 scenario. Future impacts are considered in section 8.8.3.

The need for an offset strategy has also been considered in relation to the predicted impacts, in accordance with the requirements in SEARs 16.

South Creek

South Creek is considered Class 1: Type 1 Key Fish Habitat and therefore critical habitat attributes including submerged woody debris, native macrophytes, gravel beds and permanency are particularly vulnerable to degradation from changes hydrology.

South Creek catchment is not considered habitat for threatened species or endangered populations listed under the *Fisheries Management Act 1994* and there are no records for threatened aquatic species.

Likewise, no aquatic MNES listed under the EPBC Act were mapped within the AWRC site or in downstream receiving waters.

Predicted future changes in aquatic ecology (without AWRC releases)

As described in the previous sections, substantial changes to water quality and hydrology within South Creek are expected as a result of future urban development within the upper catchment, as represented by the background scenario. These predicted changes have the potential to have the following impacts on aquatic ecology:

- Predicted hydrological changes are likely to result in additional wetting of riparian zones which can exacerbate weed issues.
- The frequency of high velocity flows is likely to increase, which will alter habitat and hydrology and potentially impact aquatic macroinvertebrate populations. This may have a subsequent impact on native fish populations due to a reduction of favourable prey species.
- The predicted increase in bioavailable nutrients (ammonia, oxidised nitrogen and filterable reactive phosphorus) can increase primary productivity. Excessive algae growth and subsequent decay that occurs when algae consumes available nutrients and dies, can deplete oxygen levels in the waterway. This can trigger eutrophic conditions which has potential to impact aquatic fauna vulnerable to low oxygen conditions.
- The alteration of hydrology which includes more frequent flows may benefit fish passage by providing assistance to overcome barriers posed by obstacles such as Kemps Creek Dam and South Creek Weir, both of which are in close proximity to the AWRC. This is particularly relevant to the migratory Australian Bass.

Predicted changes to aquatic ecology due to AWRC releases and stormwater runoff

Impacts on water quality, hydrology and geomorphology directly attributed to AWRC releases are predicted to be minor relative to future changes resulting from urban development in the upper South Creek catchment.

Predicted changes to water quality are limited to short term reductions or increases in concentrations depending on the severity of the wet weather event. Predicted spikes in concentrations are particularly evident for total nitrogen, ammonia, filterable reactive phosphorus and total suspended solids during severe wet weather events and represent a short-term reduction in water quality. The concentration spikes predicted for ammonia are not at levels toxic to aquatic biota and are not expected to cause impacts.

The aquatic ecosystem of South Creek is significantly altered due to a history of land use change and therefore aquatic taxa have tolerance to water quality degradation and alteration of hydrology. Given this and the infrequent and short-term nature of the wet weather releases, significant impacts on aquatic ecology are not expected.

With respect to salinity and dissolved oxygen impacts, modelling shows small and short-lived reductions are likely for salinity and increases for dissolved oxygen. These results could be considered as beneficial to the aquatic ecosystem, albeit on a very localised and temporary basis.

Near field modelling predicts that the primary mixing zone criteria for ammonia and total chlorine cannot be achieved for the relevant severe wet weather release events. In high concentrations, ammonia and total chlorine can have toxic impacts on aquatic ecology. However, the potential for harm to aquatic ecology is considered low as a result of the same factors identified in section 8.7.1.

Treated water releases from the AWRC will alter the hydrology in South Creek during release events. Potential impacts from the AWRC releases are infrequent and of short duration. Timing of releases generally coincides with higher wet weather flows in the creek and therefore the relative contribution is small. Wet weather releases from the AWRC contribute a relatively small percentage of flow to South Creek (less than 3%) and with the exception of cease to flow, modelled flow metrics are within acceptable limits specified by the draft flow objectives. Impacts to aquatic ecology due to hydrological changes associated with the AWRC treated water releases are not expected. Fish passage and connectivity are not predicted to be impacted by the additional flows.

Streamology (2021) reported a medium risk of geomorphic change in South Creek, however the contribution from wet weather releases from the AWRC is negligible and therefore not expected to contribute significantly to degradation of potential bed and bank aquatic habitat.

Once built, the AWRC will increase the extent of impervious surfaces on the site and potentially lead to increased runoff and pollutant loads to South Creek. Water sensitive urban design (WSUD) measures will be implemented to manage additional runoff and pollutant loads.

These measures will ensure that draft NSW Government water quality and flow objectives for South Creek and Penrith Council pollution reduction targets are met and maintain peak flows from the AWRC site at pre-development levels (refer to section 9.2 for more information). Impacts to aquatic ecology from stormwater runoff are therefore not expected.

Additionally, the development of a vegetation management plan (VMP) is recommended which will guide revegetation of the riparian and wetland areas within the AWRC site. Ultimately the establishment of native vegetation in these areas will improve the aquatic and terrestrial ecology in and adjacent to the site.

The South Creek catchment is not considered habitat for aquatic species listed under the FM Act or EPBC Act and therefore no further tests of significance are required.

Groundwater Dependent Ecosystems

The groundwater impact assessment (section 9.4) predicts that construction of the AWRC will have little ongoing effect on groundwater with an estimated 1% drawdown expected. This insignificant change is more than compensated for by future predicted stormwater flows to South Creek from the upstream catchment. Impacts on groundwater dependent ecosystems are not expected.

Summary of impacts to aquatic ecology in South Creek

The hydrology of South Creek is not predicted to be altered to a degree that will significantly affect ecosystem condition nor is water quality expected to be negatively altered as a direct result of the AWRC. The infrequent nature of wet weather releases means that any pressure to key fish habitat, aquatic flora and fauna and riparian vegetation would be of short duration and unlikely to drive impacts.

During smaller wet weather events, impacts may be positive due to improvements in water quality predicted from the release of advanced treated water. During more severe events, when the water quality of the releases is poorer, there is potential for minor water quality driven impacts to aquatic biota. However, any potential impacts are short lived and not considered to cause significant long-term impacts.

South Creek catchment is not considered habitat for aquatic species listed under the FM Act or EPBC Act and therefore no further tests of significance are required.

In accordance with Principle 1 of the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014), the development of an aquatic biodiversity offsets strategy is not considered necessary, given that:

- impacts have been avoided by releasing treated water during wet weather only
- impacts have been minimised by releasing advanced treated water to South Creek during wet weather.

Nepean and Warragamba rivers

Both Nepean and Warragamba rivers are considered Class 1: Type 1 Key Fish Habitat. The condition of aquatic ecology and riparian vegetation in these waterways is generally good, with some signs of stress from surrounding land uses.

Nepean River is mapped as critical habitat for the Macquarie Perch (*Macquaria australasica*) from downstream of the confluence with Warragamba River to Lynch Creek, downstream of Penrith Weir. This species is known to inhabit Erskine Creek and Glenbrook Creek and the two populations are genetically similar, therefore dispersal between creeks via Nepean River occurs.

The Warragamba River is also mapped as habitat for this species. The Macquarie Perch is listed as endangered under the FM Act and EPBC Act.

Predicted future changes in aquatic ecology (without AWRC releases)

The degree of change associated with future land use development in Nepean and Warragamba catchments is less than the changes forecast in South Creek. However urban growth, particularly in the Camden and Wollondilly LGAs is likely to increase stormwater runoff to Nepean River. In addition, existing WRPs at Picton and West Camden will continue to discharge to the river. These pressures combined with agricultural uses will potentially result in an increase in point and diffuse sources of pollution.

Modelling of nutrient concentrations in reaches of Nepean River upstream of Wallacia Weir show total nitrogen and total phosphorus are predicted to increase in both and wet dry years. This may cause nutrient driven impacts to weir pool ecosystems such as nutrient build up, particularly in dry years. This may drive changes in the trophic state and lead to eutrophication and/or problematic macrophyte growth, which have potential to degrade aquatic systems.

Predicted changes to aquatic ecology due to AWRC releases

Table 8-46 summarises the impacts identified by the water quality and hydrodynamics and ecohydrology and geomorphic assessments from the AWRC releases and summarises the resulting impacts to aquatic ecology.

Table 8-46 Summary of potential impacts from AWRC releases to aquatic ecology in Nepean and Warragamba rivers

Section of river	Summary of impacts identified by other studies of relevance to aquatic ecology	Potential impacts to aquatic ecology
Upstream of treated water release	• No predicted changes to water quality. • Predicted increase in water surface elevation and wetted perimeter. • Negligible changes to velocity and shear stress.	The predicted increase in water surface elevation and wetted perimeter correspond to a median increase in the inundation of about 3.5%. This increase is expected to have a negligible impact on riparian flora and macrophytes and provide for a beneficial impact to aquatic fauna as a result of an increase in aquatic habitat availability.
Downstream of treated water release to Warragamba River	• Improvement in many water quality indicators predicted, including total nitrogen, total phosphorus, filterable reactive phosphorus, chlorophyll *a*, dissolved oxygen, salinity and total suspended solids. • Increases are predicted to oxidised nitrogen and ammonia. • Short term increases in nutrients predicted in wet weather when tertiary treated water is released. • Minor changes in water surface elevation. • Minor changes in wetted perimeter, except for two locations where increases are more significant (Figure 8-30). • Minor increases in velocity and shear stress through steep riffle section (Figure 8-30).	The marginal increase in bioavailable nutrients (oxidised nitrogen and ammonia) has a potential to promote algae and aquatic plant growth in this reach. However, the probability of this is considered low due to the high velocity nature of flows in this gorge section of the river. If an algal or plant response does occur, it is likely it would happen at times of very low flow when pool environments are poorly flushed and weather conditions are suitable. In the event this occurs there is potential to impact the aquatic ecosystem by changing the trophic status. If a waterway becomes eutrophic, it can cause detrimental impacts to the aquatic ecosystem as a result of oxygen depletion which fish and many macroinvertebrate species with preference to oxygenated waters are dependent on. However, this effect may also provide opportunity for species that rely on macrophytes as habitat such as Odonata (dragonflies and damselflies) and juvenile fish (such as Australian Bass and Macquarie Perch) which may result in an increase of aquatic biodiversity and increase of prey for higher order fauna. Given the overall improvement in water quality, the risk of negative impacts is considered to be low and any occurrence would be short lived and occur when flows are very low. The predicted increase in water surface elevation and wetted perimeter correspond to a median increase in wetted perimeter of about 3.3%. Although

Section of river	Summary of impacts identified by other studies of relevance to aquatic ecology	Potential impacts to aquatic ecology
		considered minor, two sections will see change in wetted perimeter of between 11 and 13 m. There is expected to be inundation of areas currently not frequently inundated and a possibility of a loss or change in riparian flora not adapted to temporary partial or complete inundation. However, any increase in wetted perimeter and associated inundation extent could be seen as beneficial to aquatic fauna, as an increase in aquatic habitat availability will result from proposed increased flow. The minor increases in velocity and shear stress are not expected to result in the mobilisation of sediment or macroinvertebrates in an already high velocity mobile environment. No impacts to fish passage or aquatic connectivity are predicted. This section of the river is mapped as critical habitat for the Macquarie Perch (*Macquaria australasica*). The Macquarie Perch is listed as endangered under the FM Act and EPBC Act. An assessment of impacts is provided in a separate section below this table.
Warragamba River to Penrith Weir	• Water quality impacts are similar to those described above for the reach between Wallacia Weir and Warragamba River, though the magnitude of change reduces slightly due to the introduction of flows from Warragamba River. • Minor changes in water surface elevation. • Minor changes in wetted perimeter, except for four locations where increases are more significant	Impacts from changes to water quality are predicted to be similar to the reach between Wallacia Weir and Warragamba River. Changes to water surface elevation and wetted perimeter correspond to an increase in inundation extent of less than 1% which is predicted to have a negligible impact on riparian flora and macrophytes and provide for a beneficial impact to aquatic fauna as a small increase in aquatic habitat availability will result from future proposed flow scenarios. However, there are four locations where increases in wetted perimeter are larger, included including an increase of up to 11 m at the confluence with Glenbrook Creek. This area is is considered Macquarie Perch habitat. There is expected to be inundation of areas currently not frequently inundated and a possibility of a loss or change in riparian flora not adapted to temporary partial or complete inundation may occur. However, any increase in wetted perimeter and

Section of river	Summary of impacts identified by other studies of relevance to aquatic ecology	Potential impacts to aquatic ecology
	(Figure 8-31), including at the confluence of Glenbrook Creek. • Minor increases in velocity and sheer stress.	associated inundation extent could be seen as beneficial to aquatic fauna, as an increase in aquatic habitat availability will result from proposed increased flow. Velocity modelling provided by Streamology (2021) shows minimal change to velocity in this reach and no velocity driven impacts are expected. No impacts to fish passage or aquatic connectivity are predicted. This section of the river, particularly the reach between Erskine and Glenbrook Creeks, is has a known population of Macquarie Perch (*Macquaria australasica*). An assessment of potential impacts is provided in a separate section below this table.
Warragamba River	• Marginal reductions in total nitrogen. Reductions in salinity, total suspended solids and dissolved oxygen concentrations and enterococci densities. • Increases to oxidised nitrogen, ammonia, total phosphorus, filterable reactive phosphorus. • Localised increases in algal growth predicted. • No impacts to hydrology or hydraulics, as the modelling assumed that the current release regime would be adopted.	Releases to Warragamba River will replace current or proposed future environmental flows and therefore no alteration to hydrology is expected and therefore no hydrological driven impacts are expected. Marginal reductions in some water quality indicators are expected when compared to background conditions which may provide benefit to the aquatic system (albeit very small amount). Predicted increases in available nutrient forms (oxidised nitrogen, ammonia and filterable reactive phosphorus) is likely to increase the rate of primary productivity as indicated by predicted increased chlorophyll-a concentrations. However, the impact from the AWRC releases is limited with respect to magnitude and also spatial extent with impacts predicted to not extend beyond the confluence of the Warragamba and Nepean rivers. The risk is also predicted to be limited to the summer months when nutrient availability, climatic and flow conditions are optimal and as modelling of dissolved oxygen shows, the periods of low dissolved oxygen are short lived. In addition, increase of available nutrients may promote aquatic plant growth which has potential, if excessive growth occurs, to impact the aquatic ecosystem by way of changing the trophic status in the same way as excess algae growth. However, this effect may also provide opportunity for species that rely on

Section of river	Summary of impacts identified by other studies of relevance to aquatic ecology	Potential impacts to aquatic ecology
		macrophytes as habitat such as Odonata (dragonflies and damselflies) and juvenile fish (such as Australian Bass) which may result in an increase of aquatic biodiversity and increase of prey for higher order fauna. Addition of available nutrients can also promote colonisation of weed species in the riparian community, however changes in hydrology are not expected and therefore the risk is considered low. No impacts to fish passage or aquatic connectivity are predicted. This reach of Warragamba River is mapped as critical habitat for the Macquarie Perch (*Macquaria australasica*). An assessment of potential impacts is provided in a separate section below this table.

Potential impacts to Macquarie Perch

The Warragamba River and Nepean River (from downstream of the confluence with Warragamba River to Lynch Creek, downstream of Penrith Weir) are mapped as critical habitat for the Macquarie Perch. Correspondence with DPI Fisheries confirmed that populations of Macquarie Perch are present in Erskine Creek and Glenbrook Creek, both of which join Nepean River in the Penrith Weir pool. These populations are not considered genetically distinct and therefore migration between these creeks via Nepean River occurs.

As a result, a Seven-part Test of Significance has been undertaken in accordance with the FM Act and an Assessment of Significant Impact has also been undertaken in accordance with the EPBC Act. The complete assessments are included in Appendix H, with results summarised below.

As a result of the presence of this known population and mapped critical habitat, the assessments focused on the spatial extent between the confluences of Erskine Creek and Glenbrook Creek within Nepean River and the stretch of Warragamba downstream of the dam wall.

It is considered unlikely that the proposed release of treated water from the AWRC to Nepean River and Warragamba River will have a detrimental effect on the Macquarie Perch.

Water quality modelling predicts that median concentrations of bioavailable and non-bioavailable forms of nitrogen will not change significantly from current conditions at and downstream of Erskine Creek confluence.

A slight increase to the median concentration of chlorophyll *a* is predicted at and downstream of Erskine Creek confluence however this is considered an insignificant increase and is not indicative of an algal bloom response with concentrations predicted to remain below the waterway objectives of 3 µg/L.

Similar results are expected for the Warragamba River with AWRC discharge not contributing to significant alteration of water quality when compared to background conditions.

Therefore water quality driven impacts are not expected to affect the population of Macquarie Perch.

The release of treated water from the AWRC will modify the current flow regime in Nepean River and result in changes to water surface level and wetted perimeter, particularly at the bar at the mouth of Glenbrook Creek where inundation of the vegetation on the bar is likely.

The modelled increase in wetted perimeter and depth is not considered a significant impact to the species as this has potential to maintain connectivity between the Erskine and Glenbrook Creeks by providing additional depth and area passage. Additionally, inundation of the vegetated bar at the mouth of Glenbrook Creek may cause die back of trees on the bar which may fall into the creek or River and add submerged woody debris which is considered as an important habitat resource of the species.

No significant change in velocity of Penrith Weir pool is expected therefore no velocity related impacts are expected to affect the Macquarie Perch or its aquatic invertebrate prey.

No hydrological change is expected in Warragamba River as AWRC flows are proposed to replace the current environmental flows. Therefore no hydrological driven impacts to the species in Warragamba River are expected.

Both the Seven Part Test and Significant Impact Assessment concluded that a significant impact on Macquarie Perch is not expected.

Groundwater dependent ecosystems

Both Nepean and Warragamba rivers have been identified as aquatic groundwater dependent ecosystems. The groundwater impact assessment has not predicted any operational impacts to groundwater in this area. Therefore, no impacts, in addition to those discussed above, are expected.

Summary of predicted impacts to aquatic ecology in Nepean and Warragamba rivers

Overall, the impact to aquatic ecology in Nepean and Warragamba rivers is considered minor for the following reasons:

- Overall the water quality impacts are positive in Nepean River. Concentration spikes in wet weather are of short duration and unlikely to have short term toxic impacts or longer term on aquatic ecology.
- Localised water quality impacts in Warragamba River are predicted, with a minor increase in the risk of algal growth (cyanobacteria risk index) in Warragamba River. However, blooms are unlikely and not predicted downstream of the confluence with Nepean River. It is not expected that these levels will pose a risk to altering the trophic state of the River and drive eutrophication. Along with small changes to water clarity and nutrient availability there is likely to be some change to biomass, but no material change in risk. Therefore the risk to aquatic ecology is low.
- Changes in flows are likely to lead to localised increases in wetted perimeter and inundation. There is potential for very localised losses of riparian vegetation or a shift to a community which favours wetter conditions in these areas. In contrast, an increase in wetted perimeter can drive a positive benefit in increasing habitat for aquatic fauna.
- There may be changes to the vegetated bar at the mouth of the Glenbrook Creek due to an increase in wetted perimeter which has potential to cause die back of the vegetation community.
- A significant impact to the threatened Macquarie Perch is not expected.

In accordance with Principle 1 of the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014), the development of an aquatic biodiversity offsets strategy is not considered necessary, given that:

- there will be a small increase in aquatic habitat
- impacts have been avoided and minimised by releasing advanced treated during dry weather and tertiary treated water during wet weather.

The need for offsets for impacts to riparian zones is considered in section 9.1.

8.7.4 Impact on waterway objectives

Table 8-47 provides an assessment of the project's contribution to the achievement of the waterway objectives during operation. A summary is provided for each waterway. The assessment combines the results of impact assessments for water quality and hydrodynamics (including the numerical assessment against indicators), ecohydrology and geomorphology and aquatic ecology. Overall, the project is predicted to achieve the management goals set for the project and in some cases potentially lead to improvements.

Table 8-47 Assessment of project contribution to waterway objectives

Values and uses and management goal	Assessment
Aquatic ecology Protect, maintain and restore the ecological condition of aquatic systems and their riparian zones overtime.	**South Creek** • Short term benefits predicted when AWRC releases are dominated by advanced treated water (smaller wet weather impacts). • Short term negative impacts for some indicators predicted during severe wet weather impacts. • Predicted toxicant exceedances not expected to impact aquatic ecology. • No change predicted to annual median concentrations. • Minor impacts to ecohydraulics and geomorphology. • Minimal impacts to aquatic ecology. • Impacts are infrequent and short term. Given the above, the project is predicted to **protect and maintain** the ecological condition of aquatic systems and their riparian zones over time. **Nepean River** • Improvement in many water quality indicators predicted downstream of the AWRC release, including total nitrogen, total phosphorus, filterable reactive phosphorus, chlorophyll *a*, dissolved oxygen, salinity and total suspended solids. • Increases are predicted to oxidised nitrogen and ammonia. • Short term increases in nutrients predicted in wet weather when tertiary treated water is released. • Predicted toxicant exceedances not expected to impact aquatic ecology. • Moderate increase in water surface levels predicted upstream of Wallacia Weir to Bents Basin. Minor changes predicted downstream. • Minor changes in wetted perimeter predicted upstream and downstream of AWRC release, with some localised larger increases. • Generally negligible to minor increases in velocity and sheer stress through steep riffle section. • Impacts to aquatic ecology and riparian habitats predicted to be minor. Given the above, the project is predicted to **protect and maintain** the ecological condition of aquatic systems and their riparian zones over time.

Values and uses and management goal	Assessment
	Warragamba River • Marginal reductions in total nitrogen. Reductions in salinity, total suspended solids and dissolved oxygen concentrations and enterococci densities. • Increases to oxidised nitrogen, ammonia, total phosphorus, filterable reactive phosphorus, chlorophyll *a*. • Localised increases in algal growth predicted. • No impacts to hydrology or hydraulics, as the modelling assumed that the current release regime would be adopted. • Impacts upstream of Warragamba Weir are expected to be beneficial as outlined in the NorBE assessment. • Impacts to aquatic ecology and riparian habitats predicted to be minor. While some minor impacts are expected, on balance the project is predicted to **protect and maintain** the ecological condition of aquatic systems and their riparian zones over time.
Recreation and aesthetics Maintain or improve water quality for recreational activities such as swimming, boating and fishing. Maintain or improve the aesthetic qualities of the waterways.	**South Creek** • Negligible changes to annual medians of enterococci compared to background scenarios. • Short term reductions observed during small wet weather events when releases are dominated by advanced treated water. • Short term peaks predicted during severe wet weather event when releases are dominated by primary releases. During these severe events, South Creek is highly unlikely to be used for recreational purposes. • AWRC releases are not expected to result in aesthetic impacts. The project is predicted to **maintain** water quality for recreational activities and maintain the aesthetic qualities of the waterways. **Nepean River** • Reductions in enterococci densities are predicted to about 14 km downstream in both dry and wet weather. • AWRC releases are not expected to result in aesthetic impacts. The project is predicted to **improve** water quality for recreational activities and maintain the aesthetic qualities of the waterways. **Warragamba River** • Reductions in enterococci densities predicted downstream of release to confluence with Nepean River. • AWRC releases are not expected to result in aesthetic impacts. The project is predicted to **improve** water quality for recreational activities and maintain the aesthetic qualities of the waterways.

Values and uses and management goal	Assessment
Primary industries (irrigation and livestock drinking) Protect the quality of water used for a broad range of irrigation activities and livestock drinking.	The indicators for this metric adopt the water quality indicators and guideline values under aquatic ecology, as well as human pathogens and cyanobacteria risk index. The results for human pathogens and cyanobacteria are added here. **South Creek** • Negligible changes to annual medians of *E. Coli* compared to background scenarios. • Short term reductions observed during small wet weather events when releases are dominated by advanced treated water. • Short term peaks predicted during severe wet weather event when releases are dominated by primary releases. Events are infrequent and of short duration. Extraction for primary industry during these periods unlikely, given that they would likely coincide with rain. • No overall predicted increase in cyanobacteria risk index. The project is predicted to **protect** the quality of water used for a broad range of irrigation activities and livestock drinking. The availability of water for primary industry purposes will not be impacted. **Nepean River** • Reduction to annual medians of *E. Coli* compared to background scenarios. • No overall predicted increase in cyanobacteria risk index. The project is predicted to **protect and improve** the quality of water used for a broad range of irrigation activities and livestock drinking. The releases may also contribute to increased availability of water within the river that is available for extraction. **Warragamba River** Not applicable. No extractions for primary industries in this section of Warragamba River.
Drinking water Maintain or improve the quality of raw drinking water extracted downstream.	**South Creek** Not applicable to South Creek as water is not extracted for drinking purposes. **Nepean River** • Reduction to annual medians of enterococci and *E. Coli* compared to background scenarios. • Viruses, protozoa and helminths absent in advanced treated water. • No overall predicted increase in cyanobacteria risk index. The project is predicted to **improve** the quality of raw drinking water extracted downstream. The availability of water for drinking water purposes will not be impacted. **Warragamba River**

Values and uses and management goal	Assessment
	Not applicable as water is not extracted from Warragamba River for drinking purposes.

8.7.5 Adequacy of Nepean River flows to replace or supplement environmental flows

There is an opportunity for treated water releases to Nepean River or Warragamba River to be considered as a replacement or supplement for the environmental flows currently being released from Warragamba Dam or to support a future environmental flows regime.

The quality of the advanced treated water is high and, with the exception of ammonia and oxidised nitrogen, is similar to what is currently being released from the dam. As identified in the previous section, waterway objectives are predicted to be achieved and on the whole the releases provide for water quality improvements in Nepean River.The replacement or supplement of environmental flows could reduce the amount of drinking water released from the dam for environmental flows.

Sydney Water understands that the key purpose and benefits of a future environmental flows regime from Warragamba Dam are to support the health of the main channel of Nepean River. Given the high quality of treated water, Sydney Water considers that treated water releases to Nepean River can provide a substantial contribution to these benefits, without building the environmental flows pipeline to Warragamba River. The project will not produce enough treated water to entirely replace the proposed future environmental flows regime from Warragamba Dam. This means that additional releases from Warragamba Dam would still be required and these can support the health of Warragamba River if the environmental flows pipeline is not built. If the project releases treated water only to Nepean River, this also avoids the environmental impacts and costs involved in building the environmental flows pipeline to Warragamba River.

8.8 Impact of future stages

This section provides a brief summary of impacts associated with the 2056 scenario where the AWRC is assumed to be operating at 100 ML/day and all treated water is released to waterways. This is a worst-case scenario, as it is likely that some of the treated water will be reused locally (for example as recycled water for residents, businesses, industry or irrigation) rather than being released to waterways. Appendices F, G and H provide more detailed analysis of these scenarios. In addition, these impacts would be assessed in more detail as part of EISs for future project stages.

8.8.1 Water quality and hydrodynamics

The water quality and hydrodynamic assessment included modelling of 2036 (Stage 1) and 2056 (future stages) scenarios.

In South Creek, the impacts are generally predicted to be greater for the 2056 releases, assuming a plant capacity of 100 ML/day, relative to those predicted under the 2036 scenarios, assuming a plant capacity of 50 ML/day. However, despite the release of larger volumes of treated water, there remains a demonstrable low risk of affecting long term ambient water quality in South Creek. The extent of impacts downstream also remained largely unaffected. In general, the impacts are again predicted to be either minor or not identifiable downstream of Kemps Creek for most of the indicators modelled. Where there are impacts predicted further downstream, the influence of Dunheved Creek and releases from St Marys WWTP generally mask the impacts from the AWRC.

In Nepean River, again the impacts are generally predicted to be greater for the 2056 releases, with greater reductions in annual median concentrations for some indicators (total nitrogen, total phosphorus, FRP, salinity, enterococci) and increases to others (oxidised nitrogen and ammonia). Higher spikes in nutrient concentrations are also predicted during wet weather events when tertiary treated water is released. Overall, the AWRC releases under the assumed 2056 conditions continued to demonstrate a relative improvement in water quality in downstream reaches of Nepean River, relative to the background conditions.

With respect to the extents of the influence from the AWRC releases, the footprints increased marginally downstream of Wallacia Weir and the South Creek confluence. Based on analysis of predicted annual median concentrations, the extent of water quality changes downstream of the weir increased to about 20 km under 2056 conditions relative to about 15 km under 2036 conditions. Similarly, the extent of water quality changes downstream of the South Creek confluence increased to about 30 km under 2056 conditions relative to about 20 km under 2036 conditions.

For Warragamba River, impacts are predicted to be similar to the 2036 scenario. This is because the same strategy for Warragamba releases was adopted for both scenarios. This applies to geomorphic and aquatic impacts as well.

Analysis of the near field impacts indicates that the potential for higher dilutions to be realised in the near field is generally lower under 2056 conditions relative to the 2036 conditions. This applies to both South Creek and Nepean River and is considered to be a result of the higher volumes being released from the open channel (South Creek) and headwall structure (Wallacia Weir). Consequently, the dilution and mixing zone requirements for some toxicants remain unachievable with the current release configuration.

8.8.2 Ecohydrology and geomorphology

Results for the ultimate AWRC release (100 ML/day) are very similar to Stage 1 (50 ML/day).

For South Creek, the same trends and relative results, as predicted for Stage 1, are predicted for the ultimate release.

In Nepean River, the most significant difference is the further increase of about 35 cm in water levels upstream of Wallacia Weir. The additional increase in water surface elevation from the higher AWRC release may result in the potential for additional impacts on bank erosion in the reach upstream of Wallacia Weir. The flow conditions inclusive of the AWRC release are still well within the existing channel capacity and do not engage with the floodplain or result in overbank flows. The consequence of this increase in water surface elevation is still considered to be moderate and therefore the risk remains low. This may require additional mitigation measures to be investigated, such as targeted bank protection. These changes will be identified through the on-going monitoring program.

8.8.3 Aquatic ecology

For South Creek, the ultimate release of 100 ML/day is predicted to also have a minimal impact on aquatic ecology, given the continued infrequency of events and low risk of impact on ambient water quality.

For Nepean River, the following additional impacts are associated with the ultimate release of 100 ML/day:

- Overall, the water quality impacts are positive in Nepean River. Higher concentration spikes are predicted, however these are of short duration and unlikely to have short or longer term toxic impacts on aquatic ecology.
- The additional flows are likely to increase inundation and there may be small losses of riparian vegetation in these areas.
- The additional flows do not result in significant changes in velocity, so any permanent changes in macroinvertebrate community assemblages will be minor.

8.9 Cumulative impacts

The assessment of cumulative impacts was built into the methodology of the key waterway assessments through the consideration of background scenarios. The background scenarios accounted for urban growth, land use changes and forecast increases in population as well as predicted changes at existing treatment plants. The impact scenarios included these background changes as well as changes related to the AWRC releases, enabling cumulative impacts to be assessed.

In addition, potential cumulative impacts to geomorphology and aquatic ecology, have been assessed with consideration to the high number of major projects also being constructed or proposed in the region, including:

- Western Sydney Airport
- M12 Motorway
- Western Sydney Aerotropolis Growth Area initial precincts
- Sydney Metro – Western Sydney Airport
- The Northern Road Upgrade – Glenmore Road to Bringelly
- Warragamba Dam Raising.

8.9.1 Hydrodynamics and water quality

The background scenarios assessed in the hydrodynamic and water quality modelling include land use changes and forecast population growth. The impact scenarios consider these changes in addition to the background changes. Therefore, the impacts predicted in section 8.7.1 are considered cumulative impacts.

8.9.2 Ecohydraulics and geomorphology

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

Major projects must be 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 AWRC is not expected to generate significant hydrological/hydraulic or geomorphic impacts during construction or operation, the project is predicted to have a minor contribution to any cumulative hydrological and geomorphic impacts from other projects.

8.9.3 Aquatic ecology

As outlined above, there are a number of other major projects in the area that are in the planning or construction phases. There is potential that this project could contribute to impacts to waterways and aquatic ecology during construction. However, provided the mitigation measures are implemented, construction impacts on aquatic ecology will be minor.

The cumulative impacts associated with the releases on aquatic ecology has been assessed as part of the modelling work, as outlined above. The project is expected to have a minor cumulative impact on aquatic ecology.

8.10 Management measures

Table 8-48 outlines proposed measures to manage ecohydraulic and geomorphology, aquatic ecology, water quality and hydrodynamic impacts from the project.

Table 8-48 Ecohydraulic, geomorphology, aquatic ecology, water quality and hydrodynamic management measures

ID	Potential impact	Management measure	Timing
WW01	Impacts on geomorphology from construction in waterways (general)	Design and implement construction methodologies for works in waterways to appropriately manage site-specific geomorphic conditions in each waterway (for example dispersive soils in South Creek), seeking inputs from a qualified geomorphologist where needed.	Detailed design During construction
WW02	Instream works temporarily change the flow of water resulting in erosion and changes to hydraulic conditions and the geomorphology of a waterway	• Minimise the duration of instream works and where practical, conduct instream work during periods of low flow. • Minimise the 'wet area' impacted during the installation of trenched crossings.	During construction
WW03	Use of equipment and machinery in waterways reduces bank and bed stability and leads to resuspension of sediment	Whenever possible: • operate equipment on land or from a floating barge to minimise disturbance to the banks and bed of the water body • use temporary crossing structures or other practices to cross watercourses with steep and/or highly erodible banks and beds. • limit machinery fording of the watercourse to a one-time event (ie over and back).	During construction
WW04	Clearing of riparian vegetation and excavation activities within and adjacent to waterways causes erosion and sedimentation of waterways, impacting downstream geomorphology	Isolate works in waterways using booms, silt curtains or similar to contain suspended sediment.	During construction

ID	Potential impact	Management measure	Timing
WW05	Construction in waterways reduces bed and bank stability and geomorphology of channel is altered by gradient change (slumping)	Undertake the following measures: • Store materials excavated from the trench above the top of bank until the materials can be backfilled into the trench. The top 10 to 50 cm of channel substrate should be stored separately and replaced during backfilling, where practical or material of the same quality should be used. • Restore bed and banks of the watercourse or water body to their original contour and gradient; if the original gradient cannot be restored due to instability, a stable gradient should be restored. Consider principles in relevant policy and guidelines including Fish Habitat Conservation and Management (DPI, 2013a) and Why do fish need to cross the road? (Fairfull and Witheridge, 2003).	During construction
WW06	Construction in waterways reduces bed and bank stability	When using an isolated construction method such as a coffer dam, do not remove the isolation method until all works, including backfilling, contouring and stabilisation have taken place.	During construction
WW07	Construction in waterways reduces bank stability	If replacement rock reinforcement or armouring is required to stabilise eroding or exposed areas, ensure that appropriately sized, clean rock is used; and that rock is installed at a similar slope to maintain a uniform bank and natural stream alignment.	Detailed design During construction
WW08	Geomorphology and aquatic ecology impacts of trenchless construction on waterways, including frac-outs and streambed slumping	Determine failure-threshold criteria to indicate when a trenchless crossing method has failed, and construction works will be stopped. Examples of failure-threshold criteria may include: • an in-water frac-out that cannot be contained or mitigated • streambed slumping • schedule delays resulting from unexpected equipment failure or weather.	Detailed design During construction

ID	Potential impact	Management measure	Timing
WW09	Geomorphology impacts of trenchless construction on waterways (general)	Implement the following measures to minimise the risk of impacts to geomorphology: • Design the alignment of the crossing to an appropriate depth below the watercourse to minimise the risk of an inadvertent release and scouring of the stream bed to the depth of the pipe • Determine an alternative crossing method (eg contingency crossing plan) in the event the trenchless crossing method is not successful.	Detailed design During construction
WW10	Tunnelling of waterways reduces bank stability and cause erosion and sedimentation	Locate the entry and exit points back from the channel, beyond the top of bank to allow containment of any sediment or other substances above the top of bank. Restore entry and exit points to pre-construction conditions.	During construction
WW11	Removal of riparian vegetation reduces bank stability at Warragamba River release	Consider riparian planting and natural bank stabilisation measures in the detailed design phase.	Detailed design
WW12	Release of treated water causes erosion of the bank or bed of Warragamba River	Ensure that the erosion control extends sufficiently into the river. Confirm the existing substrate prior to construction to determine the likelihood of erosion as well as the scale of time over which erosion can be expected to occur. If non-cohesive substrate or easily eroded substrate is identified, instream works may be required for protection of the riverbed.	Detailed design
WW13	Impacts to bank stability from construction and operation of release structures	Implement subsurface drainage controls, where appropriate, to maintain groundwater and surface water interactions and to maintain the stability of any reclaimed land. The type and location of subsurface drainage controls should be determined through onsite investigation with considerations for: subsurface flow potential, erodibility of backfill materials, and degree of slope.	Detailed design During construction

ID	Potential impact	Management measure	Timing
WW14	Impacts to aquatic ecology and fish passage	Design and install coffer dams and temporary in-stream structures associated with open trenching in accordance with the Policy and Guidelines for Fish Habitat Conservation and Management (DPI 2013a).	Detailed design During construction
WW15	Aquatic ecology impacts of trenched construction on waterways from flow modification and erosion and sedimentation	Temporary in-stream structures should be installed during low-flow periods, and measures established in the CEMP about how high flow events will be managed to limit erosion of the structures and associated sedimentation of downstream waterways.	Detailed design During construction
WW16	Aquatic ecology impacts of trenched construction on waterways, including impacts to fish and water quality	For dewatering of temporary in-stream structures: • notify NSW DPI seven days prior to any dewatering activities in order to organise potential fish rescue activities. A separate s.37 permit may be required from NSW DPI to relocate fish. • pump water a minimum of 30 m away from the waterway so it preferentially does not re-enter the waterway. If water is to re-enter the waterway, the waterway objectives need to be adhered to.	During construction
WW17	Impacts on fish migration	Where practical, open trenching of waterways, particularly Kemps Creek and South Creek are to be avoided between late April and early June, and late October to late December, to minimise disruption of downstream and upstream Australian Bass migration.	During construction
WW18	Disturbance to vegetated riparian zone at AWRC site	Establish a vegetated riparian zone (VRZ) on the AWRC site (40 m from South Creek and wetland areas and 30 m from Kemps Creek) and apply an offset where operational areas of the AWRC encroach on this, in accordance with the principles of Guideline for Controlled Activities on Waterfront Land (NSW Office of Water, 2012).	Post construction

ID	Potential impact	Management measure	Timing
WW19	Aquatic ecology impacts of outlet structures (South Creek, Nepean River, Warragamba River)	Design release structures considering the principles in Guidelines for Outlet Structures on Waterfront Land (NSW Office of Water, 2012).	During detailed design
WW20	Mixing of waterway releases	Consider opportunities, where practical, to improve mixing and dilution of releases (for example investigating options for submerging release structures). The feasibility/acceptance of alternative options would need to be assessed against a number of key considerations including (but not limited to) engineering requirements, operations and maintenance risk, geomorphology and energy dissipation requirements.	During detailed design
WW21	Impacts on South Creek from wet weather releases during low flows	Investigate whether there are any scenarios where treated water releases to South Creek could occur when creek flows are low and still increasing in response to rainfall. If necessary and where feasible, identify opportunities to minimise releases while flows are still increasing in South Creek.	Detailed design
	Geomorphology impacts of building release structures	This impact appropriately managed by other measures in this 'Waterways' section of the table, including WW01-7.	Detailed design During construction
	Erosion and sedimentation of waterways	This impact appropriately managed by surface water management measures in section 9.2.	Prior to construction During construction
	Spoil transport from stockpiles into waterways	This impact appropriately managed by surface water management measures in section 9.2.	During construction

ID	Potential impact	Management measure	Timing
	Geomorphology and aquatic ecology impacts of trenchless construction on waterways associated with groundwater interaction	This impact appropriately managed by groundwater management measures in section 9.4.	Detailed design

8.11 Waterways monitoring

Table 8-49 outlines the waterways monitoring proposed to monitor the project's potential impacts. Specific details of the monitoring will be included in the appropriate operational monitoring plan or where applicable the project's EPL or Sydney Water's Sewage Treatment System Impact Monitoring Program (STSIMP).

Table 8-49 Project waterways monitoring

	Monitoring	Monitoring requirement	Timing
Baseline and post-commissioning water quality and aquatic ecology monitoring of waterways			
WW22	Baseline water quality and ecology monitoring program	Continue baseline monitoring program outlined in section 8.2.2 until project starts operating. Complete a report documenting results and analysis at completion of monitoring program. Monitoring results from construction or commissioning phases to be analysed separately to avoid skewing baseline results.	Prior to construction During construction
WW23	Post-commissioning water quality and aquatic ecology monitoring program	Continue water quality, macrophyte and fish surveys outlined in section 8.2.2 for two years post-commissioning. Complete a report documenting results and analysis at completion of monitoring program.	During operation
WW24	Penrith Weir pool and monitoring of water quality and biological indicators	Include an additional monitoring point to the programs outlined in WW22 and WW23 at the Penrith Weir pool (at the bar at the mouth of Glenbrook Creek). Inclusion of this additional point will fill a gap in the current monitoring program and enable a longitudinal assessment of potential change driven by AWRC releases and enable Sydney Water to investigate any ecological changes that occur in the Penrith Weir pool and in particular the Glenbrook Creek bar.	Prior to construction During construction During operation
Monitoring of flow related impacts in waterways			
WW25	Bank erosion and condition monitoring on Nepean River upstream of Wallacia Weir to Bents Basin	Develop and implement a baseline and impact monitoring program of bed and banks prior to the commencement of operational releases. The monitoring program design and reporting will be by a qualified geomorphologist.	During construction During operation

Monitoring	Monitoring requirement	Timing
	The baseline monitoring will include an analysis of historical aerial photos to understand historical and potential future geomorphological changes. Following commencement of releases, the monitoring should be undertaken at six monthly intervals for the first two years. After this, monitoring should be undertaken after three, four, six, eight and ten years. Monitoring should also be undertaken following three flood events greater than 20% Annual Exceedance Probability (AEP) (1 in 5 year flood). The monitoring will include a report documenting the results and analysis, including identifying changes that can be attributed to the treated water releases. Monitoring will include appropriate methods to establish potential impacts from the project including consideration of the following approaches: • for the riverbed – cross sectional survey. The cross section must be made accurately to a fixed point, with redundancy to cope with disturbance (intentional or otherwise). • for riverbanks – riverbank fixed photo-points at strategic locations, cross section surveys at strategic locations, drone-monitoring baseline survey (topographic and imagery data) for some representative sections of each reach. It is recommended that the baseline survey include a detailed visual inspection by an experienced geomorphologist of the reach between Bents Basin and Wallacia Weir to identify priority site locations for future monitoring.	

	Monitoring	Monitoring requirement	Timing
WW26	Bank erosion and condition monitoring at each release structure	Undertake baseline and impact monitoring of the structure condition and bank conditions for at least 100m upstream and downstream of each release structure location. The inspections should be undertaken at six monthly intervals for a minimum of 2 years with further review at this time to determine the need for any on-going monitoring. Monitoring methods described in WW25 can be adopted. Should any erosion or sedimentation issues associated with the releases be identified a risk assessment should be completed. This may identify the need for specific remediation measures. Field survey of any erosion sites should be added to the six-monthly monitoring program.	During operation
WW27	Pipeline crossing of waterways	Undertake baseline monitoring at each crossing location. Following construction, undertake impact monitoring of the waterway bed and bank conditions, at the open trench crossing locations. The inspections should be undertaken at six monthly intervals, or after an event of about 1 in 20 year ARI, for a minimum of two years with further review at this time to determine the need for any on-going monitoring. The monitoring should include inspection of the waterway bed and bank conditions at the crossing location and for at least 100 m upstream and downstream. Should any erosion or sedimentation issues associated with the releases be identified a risk assessment should be completed. This may identify the need for specific remediation measures. Field survey of any erosion sites should be added to the six-monthly monitoring program.	During operation

	Monitoring	Monitoring requirement	Timing
WW28	Bank and erosion monitoring on South Creek at the Warragamba pipeline crossing	Undertake baseline and impact monitoring of bed and bank condition along the channel 500 m upstream and downstream of the Warragamba pipeline crossing. The monitoring is to be consistent with WW25 and will seek to identify any geomorphological changes that can be attributed to the releases. Surveys can be undertaken by visual inspection. If impacts observed, further inspection by topographic survey or imagery analysis will be completed. Monitoring is recommended to be undertaken for two years following bed and bank stabilisation works are undertaken by the responsible agency.	During operation
WW29	Changes to wetted perimeter near Glenbrook Creek	Include monitoring of vegetation extent and species composition at the bar at the mouth of Glenbrook Creek as part of the monitoring programs outlined in WW23. A baseline survey is also required prior to works commencing.	Prior to construction During construction During operation
Long term monitoring of release streams and ambient water quality			
WW30	Monitoring of treated water releases - general	Analysis of water quality in the final release stream(s) is to be undertaken consistent with the monitoring requirements of the EPL for St Marys AWTP and Penrith WRP. Monitoring locations will be selected to allow for monitoring of representative samples from the AWRC release streams and will account for any mixing of different treated water streams. Daily monitoring of release volumes is to be undertaken using a calibrated flow meter. Monitoring and reporting requirements will be finalised with the EPA during the EPL application process.	During operation

	Monitoring	Monitoring requirement	Timing
WW31	South Creek treated water release monitoring	Monitoring of the water quality of the wet weather release stream will take place when releases to South Creek commence and the release occurs for longer than two hours. Monitoring indicators, sampling locations and reporting requirements would be in accordance with an EPL issued by the EPA. Hourly monitoring of the release volumes should also be undertaken during a release event, using a suitable calibrated flow meter. All indicators are to be analysed by a NATA accredited laboratory.	During operation
WW32	South Creek ambient water quality monitoring	Monitoring of the water quality of the receiving waters of South Creek is to be undertaken daily when releases occur to South Creek that are longer than two hours in duration. Two monitoring locations are to be sampled, one upstream and one downstream of the release location. The upstream site will act as a background site with the downstream site used to determine the level of impacts from the releases. Monitoring indicators, sampling locations and reporting requirements would be in accordance with an EPL issued by the EPA. As this sampling will be weather dependent, trigger rainfall conditions that are expected to initiate releases to South Creek are to be identified. Procedures will be developed that allow for early notification of expected rainfall events that may exceed the modelled trigger conditions to allow for timely sampling to be undertaken in accordance with planned releases. All indicators are to be analyses by a NATA accredited laboratory.	During operation
WW33	Nepean River and Warragamba River treated water release monitoring	Monitoring of the water quality of the wet weather release stream will take place when releases to Nepean River and Warragamba River commence and the release occurs for longer than two hours. Monitoring indicators, sampling locations and reporting requirements would be in accordance with an EPL issued by the EPA. Hourly monitoring of the release volumes should also be undertaken during a release event, using a suitable calibrated flow meter. All indicators are to be analysed by a NATA accredited laboratory.	During operation

	Monitoring	Monitoring requirement	Timing
WW34	Nepean River and Warragamba River ambient water monitoring	Monitoring of the water quality of the receiving waters of Nepean River and Warragamba is to be undertaken at a frequency consistent with the current STSIMP. Two monitoring locations are to be sampled, one upstream and one downstream of each release location. The upstream site will act as a background site with the downstream site used to determine the level of impacts from the releases. Monitoring indicators, procedures and reporting requirements are to be consistent with the STSIMP. All indicators are to be analysed by a NATA accredited laboratory.	During operation

8.12 Peer review

As outlined in section 8.2.5, two independent experts, Dr Chris Gippel and Dr Rick van Dam, were selected to provide independent and specialist peer review of the key waterway assessments. Their input focused on environmental impacts from the release of treated water to South Creek and Nepean and Warragamba rivers.

Appendix I provides a summary of the findings from their review.