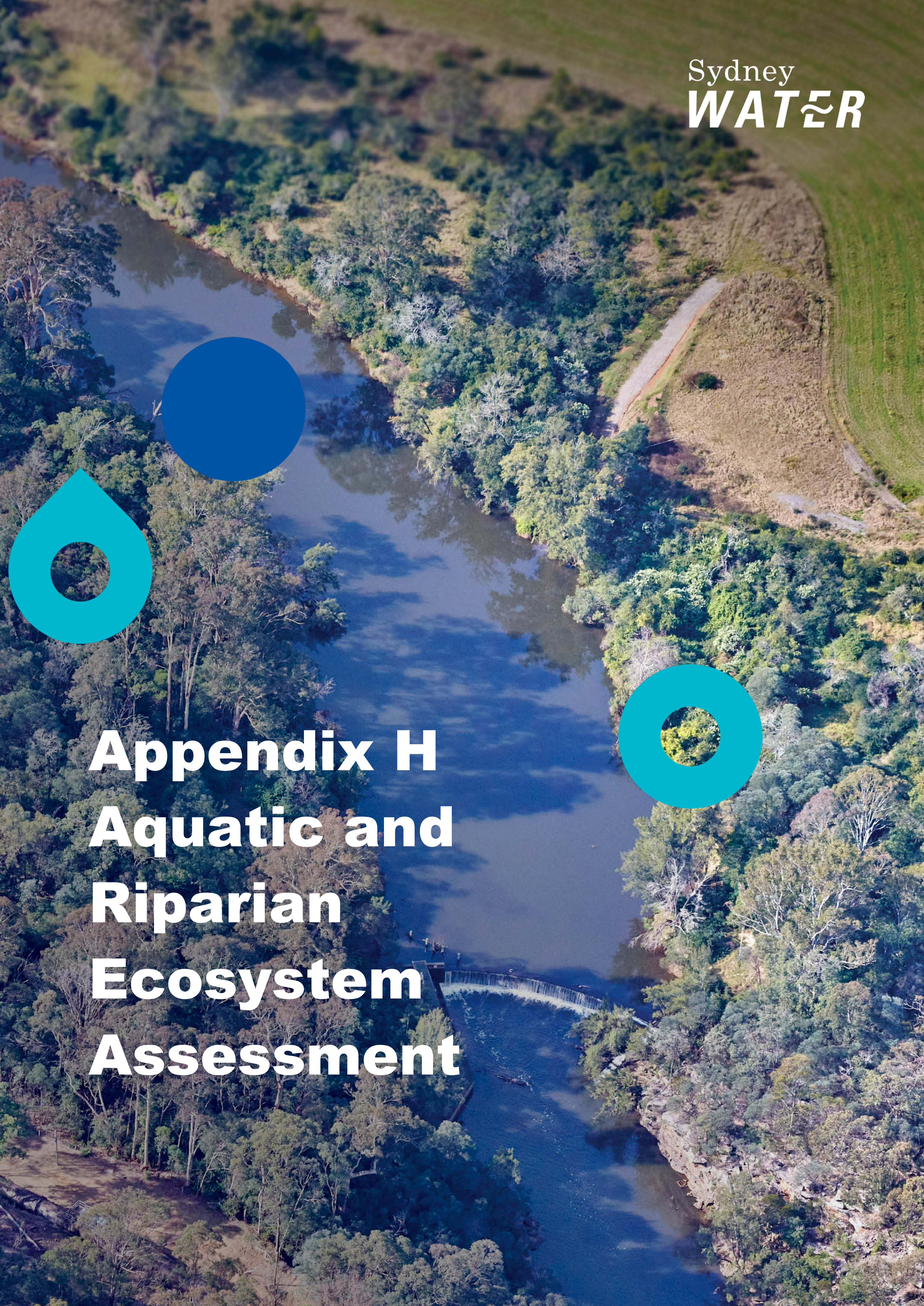

Sydney WATER

Appendix H Aquatic and Riparian Ecosystem Assessment

Aquatic Ecology Impact Assessment

Upper South Creek Advanced Water Recycling Centre

Prepared for: Sydney Water Corporation

September 2021

<table>
<tr><td>PROJECT NUMBER</td><td colspan="4">2020-04</td></tr>
<tr><td>PROJECT NAME</td><td colspan="4">Aquatic Ecology Impact Assessment</td></tr>
<tr><td>PROJECT ADDRESS</td><td colspan="4">Sydney Water Advanced Water Recycling Centre (AWRC)</td></tr>
<tr><td>PREPARED FOR</td><td colspan="4">Sydney Water Corporation</td></tr>
<tr><td>AUTHOR/S</td><td colspan="4">Carl Tippler, Benjamin Green, Bradley Cameron and Rani Carroll</td></tr>
<tr><td rowspan="2">REVIEW</td><td>Technical</td><td colspan="2">QA</td><td>Version</td></tr>
<tr><td>Cathy O’Rourke
Elissa Howie
Rick van Dam
Chris Gippel</td><td colspan="2">Carl Tippler</td><td>FINAL</td></tr>
<tr><td rowspan="2">VERSION</td><td colspan="2">Version</td><td colspan="2">30/09/2021</td></tr>
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Glossary and Abbreviations

ACRONYM	DESCRIPTION
AWRC	Advanced Water Recycling Centre
CEMP	Construction Environmental Management Plan
EPBC Act	Commonwealth Environment Protection and Biodiversity Conservation Act 1999
FM Act	NSW Fisheries Management Act 1994
GBMWHA	Greater Blue Mountains World Heritage Area
IAA	Impact Assessment Area
KFH	Key Fish Habitat
GDE	Groundwater Dependent Ecosystem
LGA	Local Government Area
MNES	Matters of National Environmental Significance
SEARs	Secretary’s Environmental Assessment Requirements
VMP	Vegetation Management Plan
VRZ	Vegetated Riparian Zone
WMA	NSW Water Management Act 2000

Executive Summary

The waterways of the Wianamatta-South Creek and the Nepean River catchments are unique and highly vulnerable natural assets that underpin the future amenity and liveability of the Western Sydney Aerotropolis Growth Area and broader Western Parkland City. The protection, restoration and maintenance of waterways, riparian corridors, and water dependent ecosystems is essential in achieving Sydney Water's cultural, social and biodiversity aspirations.

The Western Sydney Aerotropolis Growth Area and broader Western Parkland City are significant regions of current and future population growth and development in Greater Sydney. Therefore, there is an increasing need for infrastructure to support this growth and Sydney Water proposes to establish the Upper South Creek Advanced Water Recycling Centre (AWRC), to service the forecast population growth and development.

The project includes an AWRC at Kemps Creek which will provide advanced treatment of wastewater by reverse osmosis. It also includes a treated water pipeline to Nepean River, an environmental flows pipeline to Warragamba River and a brine pipeline connecting to the Malabar wastewater system in Lansdowne. Under normal conditions, flows will be released to the Nepean and Warragamba Rivers while in periods of wet weather flows may be released to South Creek. Treated water generated by the AWRC will be suitable for a range of uses including agriculture, industrial and commercial activities, and environmental flows.

The primary objective of this study is to provide a scientifically robust assessment of aquatic and riparian ecosystems and to determine potential impacts on these resulting from construction and operation of the project. This report also recommends measures to prevent and/or minimise any potential environmental impacts.

The key findings of the assessment in relation to construction impacts are:

- The project has the potential to cause erosion that transports sediment to waterways. Settling of fine sediments has the potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering by fine sediments. It can also result in a loss of niche habitats caused by settling of sediment on the creek bed. Loss of invertebrates can also affect higher trophic organisms as fauna such as native fish, wading birds and microbats which are reliant on these for food resources. This risk can be appropriately managed through standard erosion and sediment control measures.
- Impacts at many waterways will be minimised by tunnelling pipelines beneath them. However, riparian vegetation will be removed and creek bed and banks disturbed, where pipelines across waterways will be built by open trenching. These areas can also be disturbed by building release structures to waterways. Many of the waterways in the study area are key fish habitat and these

construction activities also have the potential to block or restrict fish passage if not appropriately managed. This is particularly the case for Australian Bass, which undertake seasonal migrations in late autumn to spawn. Management measures are proposed related to timing of works, construction methodologies and restoration of waterways to minimise these impacts.

- Given the project is State significant infrastructure, many provisions of the *Water Management Act 2000* do not apply. However, mitigation measures are proposed to align with the principles of this legislation and other guidelines for infrastructure in aquatic environments. These include management of vegetated riparian zones (VRZ) on the AWRC site to enhance the condition of South Creek and its aquatic habitat and following guidelines for building structures in waterways.
- The only threatened species expected in the study area is Macquarie Perch. The Warragamba River and parts of the Nepean River are mapped as habitat for the Macquarie Perch and populations have been identified in Glenbrook and Erskine Creek and is protected under the NSW *Fisheries Management Act 1994* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Project construction is not expected to impact this species.

The operational impact assessment has been informed by water quality, hydrodynamic, hydrologic and geomorphology modelling undertaken by other specialists as part of the EIS. Key findings of the assessment in relation to operational impacts are:

- During the operational phase, predicted impacts to aquatic, riparian and groundwater dependent ecosystems are not expected to be significant for the reasons outlined below.
- The modelled impacts to water quality in the Nepean River, Warragamba River and South Creek are predicted to be insignificant with the potential for improvement to occur due to the release of highly treated water to these waterways. In addition, wet weather discharge to South Creek contributes a relatively minor proportion of total flows during wet weather, therefore wet weather releases are not expected to impact the ecology of South Creek.
- In the Nepean River upstream of Wallacia Weir to Bents Basin, modelling predicts moderate water depth changes of up to 18 cm at median flows when the AWRC is operating at 50 ML/day. This is a result of releases to the weir pool. Depth changes are of a lesser magnitude lower downstream. These depth changes all remain within the existing river channel. The exact impact of this depth change is difficult to quantify however localised impacts may occur, and may result in a minor loss of riparian habitats and an equivalent gain in aquatic habitats.
- Some increases in wetted perimeter are predicted to occur in the Nepean River. All these changes are within the existing river channel and represent increased frequency of inundation of in-channel bars (including around Glenbrook Creek), riffles and the base of riverbanks. When considered across

up to 12 m are predicted which has potential to result in some minor changes to riparian communities and an equivalent increase in aquatic habitats which may negatively impact some aquatic taxa and also benefit others.

- Flow velocity modelling suggests no flow driven impacts are expected, including to fish or macroinvertebrates.
- No significant impact to Macquarie Perch or its habitat is predicted to occur as a result of project operation and therefore no offset strategy is required.

The study recommends continuation of Sydney Water's existing monitoring program, with addition of some additional water quality and vegetation monitoring in Nepean River around Glenbrook Creek. This will assist in establishing baseline conditions over an extended period and verifying impacts once the project is operating.

1 Introduction

The South West Growth Centre and Western Sydney Aerotropolis Growth Area are significant regions of current and future population growth and development in Greater Sydney. There is a need to develop infrastructure to support this growth. Sydney Water proposes to establish the Upper South Creek Advanced Water Recycling Centre (AWRC) to service the forecast population growth and development.

The project incorporates key elements that will be developed using a staged approach, including the construction of the AWRC, a treated water pipeline to the Nepean River, an environmental flows pipeline to the Warragamba River, and a pipeline to transport brine from the AWRC to the Malabar wastewater system in Lansdowne (Figure 1).

The proposed AWRC is to be located at Kemps Creek in Western Sydney and will treat wastewater by reverse osmosis. Under normal conditions, flows will be released to the Nepean and Warragamba Rivers while in periods of wet weather flows may be released to South Creek. Treated water generated by the AWRC will be suitable for a range of uses including agriculture, industrial and commercial activities, and environmental flows.

The project is State Significant Infrastructure (SSI), and the required Environmental Impact Statement (EIS) prepared by Sydney Water is guided by the Secretary's Environmental Assessment Requirements (SEARs) issued on 28 January 2021. Consideration of all feasible measures to avoid and minimize impacts to terrestrial and aquatic biodiversity is required.

The project is also in line with the vision of the Greater Sydney Commission's Greater Sydney Region Plan (Greater Sydney Commission, 2018a) and the Western City District Plan (Greater Sydney Commission, 2018b), recognizing the need to provide infrastructure to support the growing population of Greater Sydney and create a sustainable, parkland city.

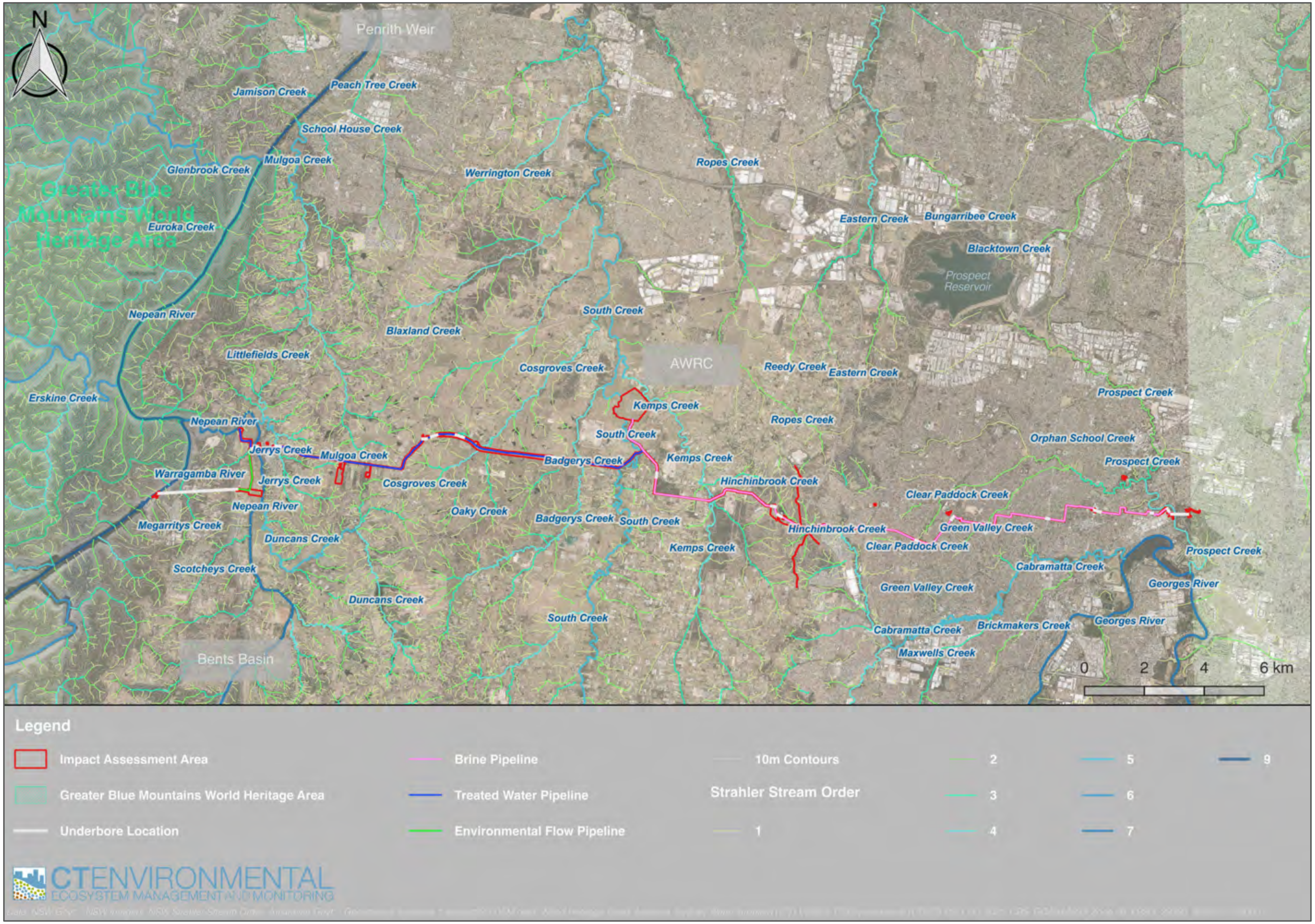

Figure 1 Spatial Extent covered by the Upper South Creek Advanced Water Recycling Centre, associated pipelines and release locations.

2 Study Objectives

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

More specifically, it seeks to respond to the aquatic ecosystem related requirements in the Secretary's Environmental Assessment Requirements (SEARs) and specific Federal and State Agency requirements.

To determine the extent of potential water quality, hydrology and hydraulic driven impacts of the project a series of six concurrent studies have been undertaken.

This assessment sits within the Aquatic and Riparian Ecosystem Assessment component – indicated by the red box below in Figure 2.

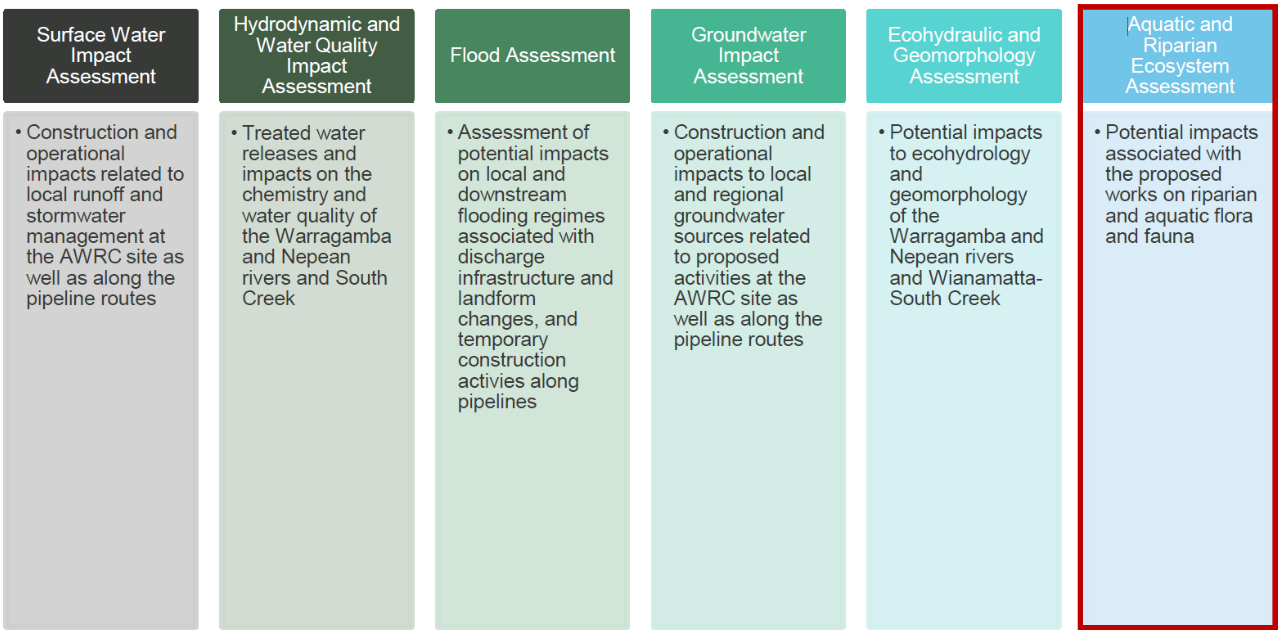

Figure 2 Concurrent studies associated with the Upper South Creek AWRC EIS (taken from Aurecon Arup 2021a).

Table 1 details the requirements outlined by the SEARs that are relevant to the Aquatic Ecology Impact Assessment and the relevant section(s) of this report that presents the results/assessment.

Table 1 Aquatic ecology related SEARs and section of this assessment that addresses requirements.

SEARS	**Requirement**	**Report Section**
General requirements	(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. 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. iv. a description of how any residual impacts will be managed or offset, and the approach and effectiveness of these measures.	Existing environment and potential impacts: 6.1 6.2 6.3 6.4 6.5 6.6 Cumulative impacts: 6.8 Management of residual impacts: 6.1.4 6.2.4 6.3.4 6.3.5 6.4.4.1 6.4.4.2 6.6.4.1 6.6.1.8 6.6.7
Key issues		
Water	1. Describe background conditions for any water resource likely to be affected by the development, including:	SEARs 1(a): 6.1.1 6.1.2 6.2.1 6.2.2 6.3.1 6.3.2 6.4.1 6.4.2 6.5.1 6.5.2 6.6.1 6.6.2 SEARs 1b) and 1c): 5.5 5.5.1 Table 8
	a) existing **surface** and groundwater. b) 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. c) 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.	
Water quality	2. Assess the impacts of the development on water quality, including: a) identification of proposed monitoring of water quality.	8

	3. Assess the impact of the development on hydrology, including: a) effects to downstream **rivers, wetlands,** estuaries, marine waters and floodplain areas. b) effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems. c) 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 6 (bolded items) 6.1 6.2 6.3 6.4 6.5 6.6
Mapping	**4. Map:**	
	a) **rivers, streams, wetlands**, estuaries (as described in s4.2 of the Biodiversity Assessment Method). b) **wetlands** as described in s4.2 of the Biodiversity Assessment Method. c) groundwater dependent ecosystems.	Figures included in Section 6 (Biodiversity Assessment Method not relevant to aquatic ecology)
	6. How the releases will affect the health of the river	6.1 6.2 6.3 6.4 6.5 6.6
	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: b) 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.	6.1.4 7
Biodiversity	10. An assessment of the impacts on groundwater dependent ecosystems.	6.1.2.3 6.1.3.4 6.1.5 6.2.2.3 6.3.2.3 6.4.2.3 6.4.5 6.5.2.3 6.6.2.3 6.6.7
	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).	6.1 6.2 6.3 6.4 6.5 6.6 6.7 6.8 7

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.	6.1 6.2 6.3 6.4 6.5 6.6 6.7
	14. Assessment of impact of changes to inundation behaviour on aquatic ecosystems upstream and downstream from the Water Recycling Centre and associated pipelines.	6.6.4.9 6.6.4.10
	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' b) consideration of NSW DPI threatened species indicative distribution maps for species, populations and ecological communities likely to be present.	15a): 6.7 15b): 6.1.1 6.2.1 6.3.1 6.4.1 6.5.1 6.6.1
	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.	7
	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).	6.2.5 6.3.5 Note that NSW DPI Fisheries Fishway Design Guidelines (2015) are not relevant. Reference has been made to Fairfull and Witheridge (2003).
	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.	6.1.4 6.2.4 6.3.4 6.4.4 6.5.4 6.6.4

	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.	6.1 6.2 6.3 6.4 6.5 6.6
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. e) the impact of the brine pipeline on Kemps Creek, Clear Paddock Creek, Green Valley Creek and Prospect Creek. 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.	6.1 6.2 6.3 6.4 6.5 6.6

The project is considered a controlled action under the *Environment Protection and Biodiversity Conservation* Act 1999 (EPBC Act) and will be assessed under the NSW Bilateral Agreement. As a result, the SEARs also include assessment requirements under the EPBC Act (Table 2).

Table 2 Assessment criteria outlined under the EPBC Act 1999 relevant to the assessment of Matters of Environmental Significance covered by this study.

EPBC 1999	Requirement	Report Section
	2. In the circumstance that a proposal has been determined to be a 'controlled action' requiring full assessment, the decision will identify which MNES protected under the EPBC Act have triggered for assessment. These are called the controlling provisions. Proponents are only required to provide an assessment of protected matters under the controlling provisions that have been triggered. Following is the list of controlling provisions relevant to this assessment: listed threatened species and communities (sections 18 and 18A)	Section 6
General requirements – Impacts		
	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 the relevant impacts (iv) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	Sections 4,5,6
General requirements - Avoidance		
	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	Section 6
	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.	Section 6.7 – Significant residual impacts are not expected
	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.	3,4,6,7 For this aquatic 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. Based on consideration of available information, the proposed action is likely to have a significant impact on the following matters of national environmental significance: Macquarie perch (*Macquaria australasica*) – endangered.	No significant impact to Macquarie Perch predicted as explained in Section 6.7.

	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: 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 6
	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 3 and 5
	description of the relevant impacts of the action having regard to the full national extent of the species or community's range.	Section 6
	description of the specific proposed avoidance and mitigation measures to deal with relevant impacts of the action.	Section 6
	identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account.	No residual impacts expected as explained in sections 6.7.

3 Relevant Legislation, Policy and Guidelines

Table 3 summarises the relevant legislation, policy and guidelines related to the assessment of potential impacts to aquatic ecosystems associated with the construction and operational phases of the project including: the AWRC, treated water pipeline, environmental flows pipeline and brine pipeline.

Table 3 Commonwealth and State Legislation, Policy and Guidelines relevant to this study.

Legislation, Policy and Guidelines	Description	Project Relevance
Federal Legislation		
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	• The EPBC Act enables the Australian 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 Australian Government interests on the protection of matters of national environmental* significance, with the states and territories having responsibility for matters of state and local significance. • The objectives of the EPBC Act are to: • Provide for the protection of the environment, especially matters of national environmental significance conserve Australian biodiversity • Provide a streamlined national environmental assessment and approvals process • Enhance the protection and management of important natural and cultural places • Control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife • Promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources • Recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity • Promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.	The project is a controlled action under the EPBC Act and this study assesses impacts on relevant aquatic Matters of National Environmental Significance (MNES), particularly Macquarie Perch (*Macquaria australasica*).
Matters of National Environmental Significance Significant impact guidelines 1.1	The purpose of these guidelines is to assist any person who proposes to take an action to decide whether or not they should submit a referral to the Australian Government Department of the Environment (the Department) for a decision by the Australian Government Environment Minister (the minister) on whether assessment and approval is required under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	Macquarie Perch (*Macquaria australasica*) is subject to potential impacts by the project. Therefore, a Test of Significance is required under the EPBC Act.
State Legislation		
Water Management Act 2000 (WM Act)	The *Water Management Act 2000* is based on the concept of ecologically sustainable development – development today that will not threaten the ability of future generations to meet their needs. The Act recognises: The fundamental health of our rivers and groundwater systems and associated wetlands, floodplains, estuaries has to be protected The management of water must be integrated with other natural resources such as vegetation, soils and land	Although SSI projects are exempt from regulations associated with Controlled Activities, the principals set out by the Water Management Act 2000 in relation to Controlled Activities have been applied to the project particularly in relation to riparian vegetation management and

	To be properly effective, water management must be a shared responsibility between the government and the community Water management decisions must involve consideration of environmental, social, economic, cultural and heritage aspects Social and economic benefits to the state will result from the sustainable and efficient use of water. The *Act* recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with more secure access to water and greater opportunities to trade water through the separation of water licences from land.	waterway bed and bank disturbance.
Fisheries Management Act 1994 (FM Act)	The FM Act aims 'to conserve, develop and share the fishery resources of the State for the benefit of present and future generations and, in particular to: • Conserve fish stocks and key fish habitats • Conserve threatened species, populations and ecological communities of fish and marine vegetation • Promote ecologically sustainable development, including the conservation of biological diversity • Promote viable commercial fishing and aquaculture industries • Promote quality recreational fishing opportunities, and appropriately share fisheries resources between the users of those resources and provide social and economic benefits for the wider community of New South Wales. To meet these objectives, Part 7 of the FM Act outlines legislative provisions to protect fish habitat and Part 7A outlines provisions to conserve threatened species of fish and marine vegetation and their habitat.	Many of the waterways potentially impacted by the development are considered Key Fish Habitat and species listed as threatened under the Act have potential to be impacted.
7 Part Test of Significance in accordance with the Environmental Planning and Assessment Act 1979 No 203 - Part 1, Section 1.7 (EPA Act)	The purpose of this test is to assist any person who proposes to take an action to decide whether or not the proposed activity will cause significant impact to threatened fish species or their habitats listed under the *NSW Fisheries Management Act* 1994.	A 7 Part Test of Significance has been undertaken to assess the potential of impacts to Macquarie Perch (*Macquaria australasica*) which is listed as threatened under the *NSW Fisheries Management Act* 1994.
State Policy		
Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries 2013)	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 aims to help developers, their consultants and government and non-government organisations to ensure compliance with legislation, policies and guidelines as they relate to fish habitat conservation and management. It can be used to inform land use and natural resource management planning, development planning and assessment processes.	The framework described in this document to determine Key Fish Habitat as applied in this study. Recommendations for management of Key Fish Habitat have been guided by this document.

NSW Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation 2002)	Groundwater Dependent Ecosystems (GDEs) refer to both terrestrial and aquatic ecosystems that require access to groundwater to meet all or some of their water requirements for their ecological processes and ecosystem services. The GDE Policy adopts principles outlined in the NSW State Groundwater Policy Framework Document and provides a framework the management of GDEs in NSW, including: The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.	Potential impacts to terrestrial and aquatic dependent ecosystems have been assessed as part of this study.
Guidelines and Recovery Plans		
National Recovery Plan for the Macquarie Perch (*Macquaria australasica*) (Commonwealth of Australia 2018)	The overarching objective of this recovery plan is to ensure the recovery and ongoing viability of Macquarie perch populations throughout the species' range (including historically translocated populations). The recovery plan sets out six recovery strategies that build toward this overarching objective: • Conserve existing Macquarie perch populations (including historically translocated populations in Cataract Reservoir and the Mongarlowe and Yarra rivers). • Protect and restore Macquarie perch habitat. • Understand and address threats to Macquarie perch populations and habitats. • Establish additional Macquarie perch populations within the species' natural range. • Improve understanding of the biology and ecology of the Macquarie perch and its distribution and abundance. • Increase participation by community groups in Macquarie perch conservation.	This study has assessed impacts the Macquarie Perch (*Macquaria australasica*) under Federal and State assessment frameworks. The recovery plan provides guidance on the ecology, biology, threats and management of the species.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2018 and 2000)	The ANZECC Water Quality Guidelines provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters and list a range of environmental values assigned to that waterbody. The ANZECC Water Quality Guidelines provide recommended trigger values for various levels of protection, which have been considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly to moderately disturbed ecosystems.	Trigger values for potential toxicants have been applied as part of the assessment of water quality driven impacts to aquatic ecosystems of the Warragamba and Nepean Rivers.
Draft Wianamatta-South Creek Waterway Health Objectives (DPIE in review)	The South Creek Waterway Health Objectives provide a framework for conserving water dependent high value ecosystems across South Creek catchment. The objectives provide targets for both water quality and flow management, which have been derived from local reference data.	These objectives have been applied to assess potential impacts driven by water quality and hydrology on aquatic and riparian ecosystems of South Creek catchment.
Guidelines for controlled activities on waterfront land - Riparian corridors (NSW Office of Water 2012)	The overarching objective of the controlled activities provisions of the WM Act is to establish and preserve the integrity of riparian corridors. Ideally, the environmental functions of riparian corridors should be maintained or rehabilitated by applying the following principles: • Identify whether or not there is a watercourse present and determine its order in accordance with the Strahler System • Seek to maintain or rehabilitate a RC/VRZ with fully structured native vegetation • Seek to minimise disturbance and harm to the recommended RC/VRZ	The principals to the management of vegetated riparian zones have been guided by this document, particularly in relation to appropriately sized riparian buffer widths.

	• Minimise the number of creek crossings and provide perimeter road separating development from the RC/VRZ and locate services and infrastructure outside of the RC/VRZ. • Within the RC/VRZ provide multiple service easements and/or utilise road crossings where possible and treat stormwater run-off before discharging into the RC/VRZ.	
NSW Fish Passage Strategy (2019) Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003)	This document aims to minimise impacts on fish passage and general aquatic wildlife by providing practical guidelines to those involved in the planning, design, construction and maintenance of waterway crossings and considers: • Local movement - access food, avoid predators and shelter during daylight. • Daily movement - access habitat, food and shelter, defend territory and avoid predators. • Seasonal movement - breeding cycle in response to rising water levels or temperatures. • Upstream movement - access to new habitats or established spawning areas. • Downstream movement - post-spawning movement, avoid predators. • Lateral movement - access food, breeding cycle and juvenile recruitment to habitat areas.	Guidance from this document has been used to inform appropriate mitigation actions applicable to the crossing of waterways, particularly those considered Key Fish Habitat.
Risk assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water, 2012)	This document aims to minimise impacts on Groundwater Dependent Ecosystems (GDEs) which: • Defines GDE types. • Supports the requirements of the Water Management Act 2000. • Determines the risk of an activity to the ecological value of an aquifer and associated GDEs. • Provides management strategies for aquifers and identified GDEs using the Risk Matrix Approach.	Potential impacts to terrestrial and aquatic dependent ecosystems have been assessed as part of this study.
Threatened biodiversity survey and assessment. Guidelines for developments and activities (2004 working draft) (NSW Government, 2004).	This document provides a framework to guide the assessment of threatened species, populations, ecological communities, or their habitats, including animal and plant species. It aims to assist in the development of surveys through outlining field techniques and considerations, relevant legislation, and the relevant method of impact assessment for threatened biodiversity.	Potential impacts to threatened species and ecosystems have been assessed in accordance with Threatened Biodiversity Survey and Assessment Guidelines.

4 Study Area

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

The AWRC and the associated treated water and brine pipelines are referred to in this study as the ‘project’. An overview of the location of the proposed infrastructure is provided in Figure 1 and a brief outline of associated components is provided below and includes;

- Advanced Water Recycling Centre that includes production of:

  - High quality treated water suitable for a range of uses including recycling and environmental flows
  - Renewable energy
  - Biosolids suitable for beneficial reuse
  - Brine, as a by-product of reverse osmosis treatment
- Treated water pipeline from the Advanced Water Recycling Centre to the Nepean River to release treated water
- Infrastructure from the Advanced Water Recycling Centre to South Creek to release treated water during wet weather
- Pipeline extension from the Nepean River pipeline to the Warragamba River for environmental flow releases
- Brine transfer pipeline from the Advanced Water Recycling Centre to the existing wastewater system

The concept component of the project comprises all the above elements, with the Advanced Water Recycling Centre sized to treat an average dry weather flow of up to 100 ML /day, and to transport and release the equivalent volume through the associated pipelines.

Sydney Water is seeking detailed approval for Stage 1 of the project, which comprises:

- Building and operating the Advanced Water Recycling Centre sized to treat an average dry weather flow of up to 50 ML /day;
- Building all pipelines to their ultimate capacity, but only operating them to transport and release volumes produced by the Stage 1 Advanced Water Recycling Centre.

This assessment focusses mainly on the impacts associated with releases Stage 1 (ADWF of 50ML/day). However, potential impacts associated with future stages have also been considered.

The extent of the Impact Assessment Area (IAA) covered by this study is broad and spans across the Warragamba River, Nepean River, South Creek and Georges River catchments and includes the AWRC site and associated infrastructure.

Each element of the construction and operational phase of the AWRC project poses a different set of potential impacts and therefore to simplify this assessment the spatial extent covered by the IAA has been broken into six discrete study areas (Figure 3). Table 4 provides a breakdown of the study areas derived for this assessment and a summary of the aquatic and riparian factors assessed by this study.

Table 4 Breakdown of study areas and summary of aquatic and riparian ecosystem factors assessed by this study.

STUDY AREA	SITE FEATURES	WATERWAYS ASSESSED	ASSESSMENT
Study Area 1 **AWRC site and downstream receiving waterways**	The AWRC is proposed to be at Kemps Creek (Part Lot 21 DP 258414), within the Penrith Local Government Area (LGA). The proposed site is upstream of the confluence of South Creek and Kemps Creek (close to the point at which they join Badgerys Creek) and covers an area of approximately 80 hectares.	South Creek Kemps Creek	Assessment of potential impacts during the construction phase and wet weather release and stormwater runoff during the operational phase. Impacts to the aquatic and riparian ecosystems will be considered via assessment of water quality and hydrology and stormwater driven pressures on aquatic macroinvertebrate, key fish habitat and riparian vegetation and ground water dependent communities.
Study Area 2 **Brine Pipeline**	A below ground pipeline is proposed to be constructed to transport brine produced from the AWRC site to the Malabar wastewater system located at Lansdowne, approximately 24 km away.	Kemps Creek Unnamed tributary of Kemps Creek Badgerys Creek Prospect Creek Green Valley Creek Clear Paddock Creek Hinchinbrook Creek Unnamed tributary of Hinchinbrook Creek	Assessment of potential impacts during the construction phase which will include assessment of fish passage, key fish habitat and riparian vegetation and ground water dependent communities.
Study Area 3 **Treated Water Pipeline and Environmental Flows Pipeline**	A below ground pipeline is proposed to be constructed to transport treated water from the AWRC to two release locations at Nepean and Warragamba Rivers. This pipeline is proposed to be 2.5 km in length and consist of open trenching and underboring to a depth of approx. 47 m below the surface.	South Creek Unnamed tributary of South Creek Badgerys Creek Unnamed tributary of Badgerys Creek Cosgroves Creek Unnamed tributary of Cosgroves Creek Oaky Creek Mulgoa Creek Jerrys Creek Nepean River Baines Creek Megarritys Creek	Assessment of potential impacts during the construction phase which will include assessment of fish passage, key fish habitat and riparian vegetation and ground water dependent communities.
Study Area 4 **Warragamba River and Warragamba River Release Point**	The release location on Warragamba River is located downstream of the dam wall and upstream of Warragamba Weir. Study Area 4 is mapped as habitat for the Macquarie Perch (*Macquaria australasica),* listed as threatened under both the FM Act and EPBC Act.	Warragamba River	Assessment of potential impacts during the construction phase and operational phase. Impacts to the aquatic and riparian ecosystems will be considered via assessment of water quality and hydrology driven pressures on aquatic macroinvertebrate, key fish habitat and riparian vegetation and ground water dependent communities. 7-part test under the FM Act and Test of Significant Impact under EPBC Act required.

Study Area 5 **Nepean River Release Point and Nepean River Upstream of Wallacia Weir to Bents Basin**	The release location on the Nepean River is located slightly upstream of the Wallacia Weir. The Wallacia Weir pool stretches for approximately 12 km upstream to Bents Basin.	Nepean River	Assessment of potential impacts during the construction phase and the operational phase. Impacts to the aquatic and riparian ecosystems will be considered via assessment of hydrology driven pressures on key fish habitat and riparian vegetation and ground water dependent communities.
Study Area 6 **Nepean River Downstream of Wallacia Weir to Penrith Weir**	This section of the Nepean River extends downstream to the Penrith Weir and incorporates a short steep pool-riffle section down to Norton's Basin where the River then becomes the Penrith Weir pool. Downstream of Warragamba River, Study Area 6 is mapped as habitat for the Macquarie Perch (*Macquaria australasica*), listed as threatened under both the FM Act and EPBC Act.	Nepean River Erskine Creek and Glenbrook Creek confluences with Nepean River	Assessment of potential impacts during the construction phase and the operational phase. Impacts to the aquatic and riparian ecosystems will be considered via assessment of water quality and hydrology driven pressures on key fish habitat and riparian vegetation and ground water dependent communities. 7-part test under the FM Act and Test of Significant Impact under EPBC Act required.

4.1 Project Scope

4.1.1 Study Area 1 – Upper South Creek AWRC and receiving waters

The Advanced Water Recycling Centre will be designed to treat wastewater to a high level using advanced treatment processes, including; inlet works for preliminary treatment, primary, secondary and tertiary treatments, advanced treatment (reverse osmosis), disinfection systems, biosolids handling facilities, cogeneration for heat and energy production, odour control facilities, pumping stations to transfer treated water to the Nepean and Warragamba Rivers, and treated water released to South Creek during wet weather, when inflow capacity is exceeded. The service catchment for this AWRC includes wastewater from households, commercial and industrial activities within the South West Growth Centre and Western Sydney Aerotropolis Growth Area.

The AWRC will produce three types of treated water, including advanced, tertiary treated water and wet weather treated water. During normal dry weather operating conditions, all advanced treated water up to 1.3 x average dry weather flow (ADWF) will be released to Warragamba River and/orNepean River. Beyond 1.3 x AWDF, the AWRC will be operating under wet weather flows scenarios. This includes:

- For flows between 1.3 to 1.7 x AWDF, treated water will be released to Nepean River only via the treated water pipeline. This treated water will be a combination of advanced and tertiary treated water.

- During flows greater than 1.7 x ADWF, advanced treated water will also be released to South Creek via the South Creek release infrastructure. Releases to Nepean River will consist of a blend of tertiary and advanced treated water.
- During flows greater than 3 x ADWF, only tertiary treated water will be released to the Nepean River. Releases to South Creek will include a mixture of advanced and primary treated water (wet weather treated water).

The AWRC is proposed to be constructed in stages, with the goal to eventually service the projected 2056 population. It is projected to treat an average of 100 ML /day; however, the first stage of operation seeks to treat average dry weather flow of up to 50 ML /day.

4.1.2 Study Area 2 – Brine Pipeline

Brine is produced as a by-product of the reverse osmosis process. A below ground pipeline is proposed to be constructed to transport brine produced from the centre to the Malabar wastewater system located at Lansdowne, approximately 24 km away. The pipeline will be 0.6 m in diameter and be comprised of steel, Glass Reinforced Plastic (GRP), Polyethylene and Ductile Iron Cement Line (DICL) pipe materials. The brine pipeline crosses several major waterways including Kemps Creek, Prospect Creek and Green Valley Creek.

The pipeline will be constructed to its ultimate capacity of 100 ML /day and will include underboring and open trench construction. Land use along the proposed route of the brine pipeline is primarily heavily disturbed by existing residential developments, in addition to some areas of rural residential and native vegetation (such as within Western Sydney Parkland), and it is proposed to be located mainly along existing road corridors and developed areas.

4.1.3 Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline

Treated water will be returned to the environment via pipelines. Treated water will be transported from the proposed AWRC to two locations, the Nepean River and the Warragamba River. These routes largely occur within rural residential land uses, with some areas of native vegetation, and follow existing or future infrastructure corridors.

The treated water pipeline will transfer advanced and tertiary treated water to the Nepean River upstream of the Wallacia Weir via a below ground pipeline (16 km) that follows Elizabeth Drive, the Northern Road, Park Road and Silverdale Road.

The environmental flows pipeline diverts from the treated water pipeline at Bents Basin Road, near the intersection with Silverdale Road, Wallacia. The environmental flows pipeline continues south following Bents Basin Road for about 1.4 km before it runs west and is tunnelled for about 2.5 km to end at the release structure at Warragamba River. The total pipeline length is 4.5 km. This pipeline aims to provide environmental flows to the Warragamba River as close as possible to the Warragamba Dam wall, whilst ensuring that structural integrity and river condition is not compromised. Flow splitting valves on the western side of the Nepean River along Silverdale Road will separate the environmental flows from the treated water flows.

The construction of the pipelines will be consistent with their ultimate capacity (100 ML /day), however, transport and release volumes will initially be 50 ML /day. The construction of the pipelines will typically require an impact area of up to 25 m wide along their length, in addition to temporary ancillary facilities (such as construction compounds and access roads). The treated water pipeline will be 1.2 m in diameter and the environmental flows pipeline will be up to one metre in diameter.

4.1.4 Study Area 4 - Warragamba River Release Point and Warragamba River

The release location at Warragamba River is located downstream of the dam wall. Only advanced treated water is proposed to be released into the Warragamba River using energy dissipation structures at the proposed release point. The proposed releases will replace current environmental flows.

4.1.5 Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir to Bents Basin

The Nepean River release location is within the Wallacia Weir pool slightly upstream of the Weir. The Wallacia Weir pool, which stretches for approximately 12 km upstream to Bents Basin, has potential to be impacted by alteration of hydrology as a result of a backwater effect of releases to the weir pool.

4.1.6 Study Area 6 – Nepean River Downstream of Wallacia Weir to Penrith Weir

This section of the Nepean River extends from Wallacia Weir downstream to the Penrith Weir. This section has the potential to be impacted by Nepean River releases. Downstream of the Warragamba River confluence, it also has the potential to be impacted by Warragamba River releases.

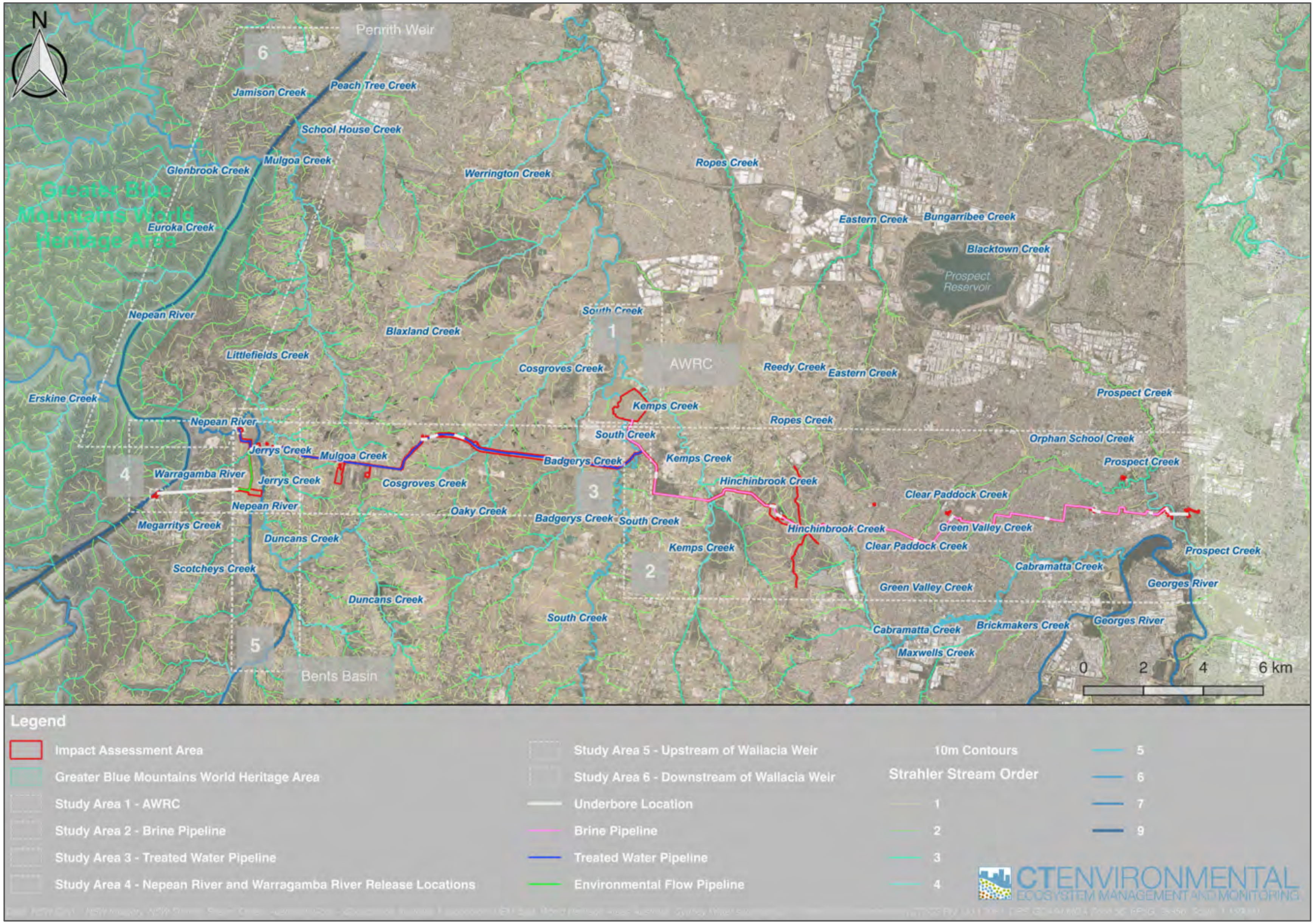

Figure 3 Map showing six (6) discrete study areas across the spatial extent covered by the AWRC and associated infrastructure.

5 Assessment Method

To undertake assessment of potential impacts to aquatic and riparian ecosystems due to the construction and operational phases of the AWRC a combined approach of desktop review of relevant reports, data and spatial data and field assessment was applied. The approach applied to assess current condition and potential impacts to the aquatic and riparian ecosystem within IAA and receiving waters has been guided by the Draft Guidelines for Threatened biodiversity survey and assessment. Guidelines for developments and activities (2004 working draft) (NSW Government, 2004).

As required by the SEARs, the study addresses the project's construction and operational impacts on aquatic and riparian ecosystems. It focuses on direct impacts in the IAA and indirect impacts across the study areas shown in Figure 3.

For this study, direct impacts are considered as those causing direct impacts to the aquatic and riparian ecosystems within the IAA which includes factors such as open trenching of creek bed and banks, clearing of riparian vegetation or removal of submerged woody debris during construction of pipelines and release structures, localised river/creek bed and bank scour due to high velocity release and localised alteration of water quality. The effects of these impacts are centred on (Figure 3) the following:

- Study Area 1 – Adjacent to and downstream of AWRC on South Creek
- Study Area 2 – Brine Pipeline
- Study Area 3 - Treated Water Pipeline
- Study Area 4 – Warragamba River Release Point and Warragamba River
- Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir

Indirect impacts considered by this study include changes in velocity, wetted perimeter, depth and alteration of water quality in areas outside of the IAA, which are centred on (Figure 3) the following:

- Study Area 1 – Adjacent to and downstream of AWRC on South Creek
- Study Area 4 – Warragamba River Release Point and Warragamba River
- Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir
- Study Area 6 – Nepean River Downstream of Wallacia Weir to Penrith Weir

5.1 Current Condition of the Aquatic and Riparian Ecosystem

To understand the current condition of the aquatic and riparian ecosystem across the six study areas a combination of desktop review and field assessment was undertaken. Data reviewed and field survey methods applied are outlined in Sections 5.2 and 5.3.

5.2 Desktop Review

A desktop review of the following resources was undertaken to determine current condition of the aquatic and riparian ecosystem within the IAA and understand constraints and pressures associated with the project. A combination of spatial data, database search, monitoring data and specialist reports were reviewed which include:

- NSW statewide topographic mapping – to determine Strahler stream ordering - (SIX maps, 2021)
- NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a)
- Freshwater threatened species distribution (NSW Department of Primary Industries – Fisheries, Spatial Data Portal 2020b)
- Matters of National Environmental Significance (MNES) – Protected Matters Search Tool (Australian Government, 2021)
- Remnant Vegetation of the western Cumberland subregion, 2013 Update. VIS_ID 4207 (DPIE, 2015)
- Groundwater Dependent Ecosystem Atlas of Australia (BOM, 2021)
- Upper South Creek Advanced Water Recycling Centre – Surface Water Impact Assessment (Aurecon ARUP, 2021a)
- Upper South Creek Advanced Water Recycling Centre – Groundwater Impact Assessment (Aurecon ARUP, 2021b)
- Targeted Survey of Australian Bass and Southern Myotis in South Creek catchment (CTENVIRONMENTAL, 2019)
- Upper South Creek Advanced Water Recycling Centre - Hydrodynamic and Water Quality Impact Assessment (Aurecon ARUP, 2021c)
- Upper South Creek Advanced Water Recycling Centre - Ecohydrology and Geomorphology Impact Assessment (Streamology, 2021)

In addition to the above list, raw water quality, fish, macrophyte and macroinvertebrate survey data from 13 monitoring sites within or in close proximity to IAA were provided by Sydney Water (see Figure 4). Monitoring data supplied by Sydney Water inclusive of location of sites and frequency of monitoring is shown in Table 5. Median values were calculated for all water quality parameters and results compared to the waterway objectives (see section 5.5 for detail). The water quality dataset used for the current study was smaller and focused on a more recent time period than the dataset used for the Hydrodynamic and Water Quality Impact Assessment (Aurecon ARUP 2021c). As such, results of comparisons of median values with relevant water quality objectives may differ to some degree between the two studies.

When no monitoring data from Sydney Water was available effort was made to procure data from other sources. However, this was to no avail, except in the case of fish data, which was complemented by CTENVIRONMENTAL (2019). Note: only raw data was reviewed under the assumption all monitoring was undertaken by Sydney Water using standard methods and NATA accredited laboratory analysis where appropriate.

Table 5 Sydney Water aquatic ecosystem monitoring sites relevant to this project.

Site code	Site description	Significance	Latitude#	Longitude#	Water qualityand algae	Macroinvertebrates	Macrophytes	Fish
NS45	South Creek at ElizabethDrive bridge, u/s of new AWRC	Reference site (upstream of discharges from new AWRC)	-33.87586	150.7678	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear
NS44	South Creek d/s of proposed AWRC at Pluers Farm	Impact from new AWRC discharges (immediately downstream of AWRC)	-33.8545	150.7693	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear
NS450	Kemps Creek @ Elizabeth Dr Bridge u/s confluence with South Creek	Other tributaries joining South Creek downstream of AWRC	-33.88075	150.7987	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	No Record
NS440	Badgerys Creek at ElizabethDrive bridge	As above	-33.87398	150.7547	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	No Record
NS35	South Creek at LuddenhamRoad Bridge	Further downstream of new AWRC and other tributaries	-33.805	150.76647	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear
N642	Warragamba River upstream of Megarritys Creek andWallacia WWTP	Upstream reference site	-33.8761	150.607	Three weekly	STSIMP funded, twice per year (Spring and Autumn)	Autumn and Spring each year	No Record
N642A	Warragamba River downstream of MegarritysCreek, upstream Wallacia WWTP	Impact from new AWRC release via Megarritys Creek	-33.87311	150.61094	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	No Record
N641	Warragamba River at Norton Basin, before the confluencewith the Nepean River	Impact from new AWRCand old Wallacia WWTP	-33.85915	150.61104	Three weekly	STSIMP funded, twice per year (Spring and Autumn)	Autumn and Spring each year	No Record
N67	Nepean River at WallaciaBridge	Upstream reference site	-33.86534	150.63675	STSIMP funded, collect extra analytes	STSIMP, twice peryear (Spring and Autumn)	Autumn and Spring each year	No Record
N66A	Nepean River upstream of proposed discharge point	Upstream reference site	-33.857820	150.633328	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear

Site code	Site description	Significance	Latitude#	Longitude#	Water qualityand algae	Macroinvertebrates	Macrophytes	Fish
N66B	Nepean River downstream of Weir and proposeddischarge point	Impact site, downstream of potential dischargesfrom new AWRC	-33.5141	150.3746	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear
N66	Nepean River upstream of confluence with Warragamba River	Impact site, further downstream of discharges	-33.8618	150.61711	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear
N64	Nepean River downstream of Warragamba River (about 500m)	Impact site, downstreamof Warragamba River and potential discharges from new AWRC	-33.85915	150.606331	Three weekly	Twice per year (Spring and Autumn)	Autumn and Spring each year	Twice peryear

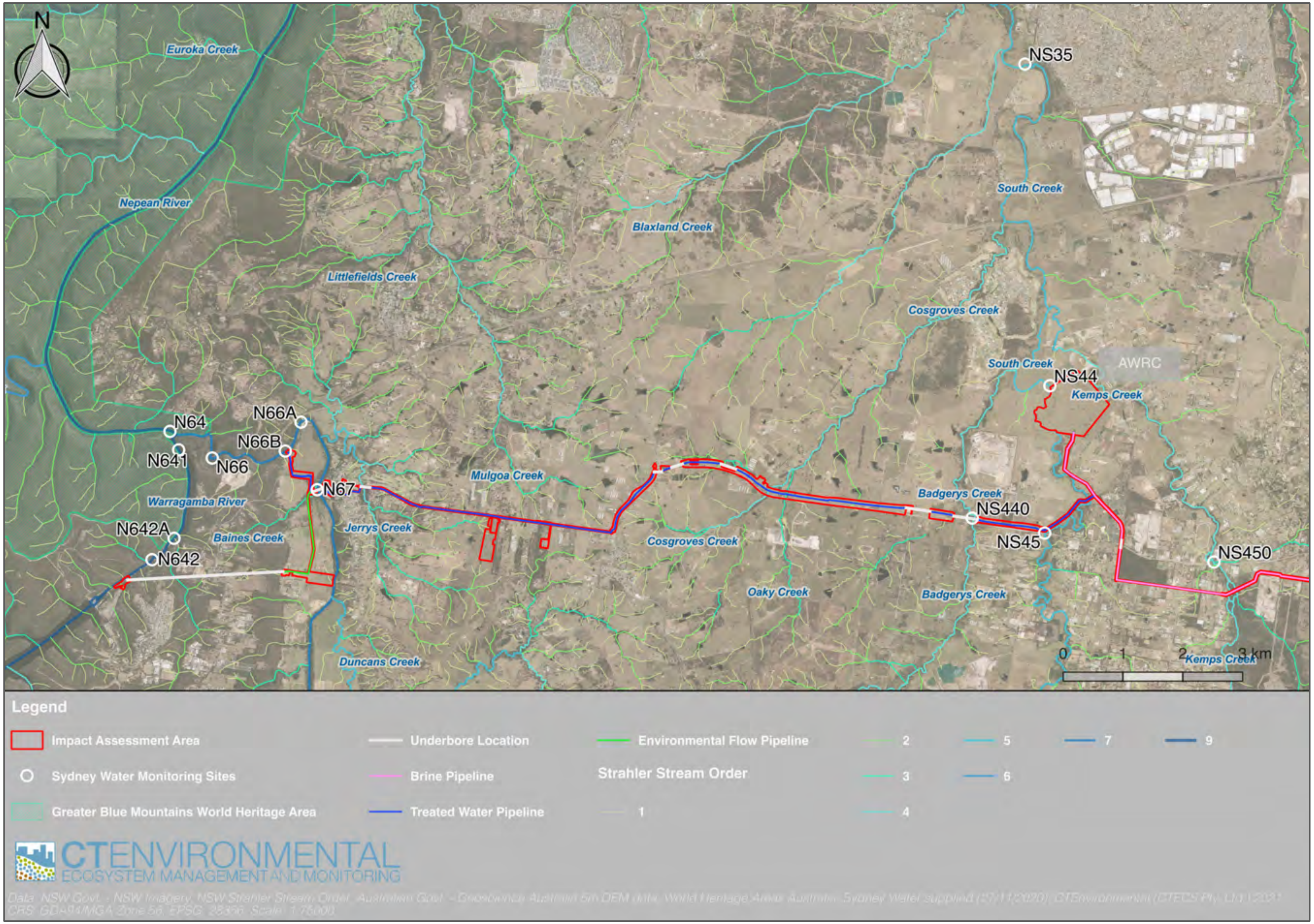

Figure 4 Locations of relevant Sydney Water monitoring sites across the IAA and receiving waters.

5.3 Field Assessment

Field assessment was undertaken to validate the presence of aquatic and riparian ecosystem constraints identified by the desktop review and to provide condition assessments of aquatic and riparian habitats. The methods applied are listed below.

5.3.1 Strahler Stream Order and Waterway Validation

Field validation of potentially impacted waterways was undertaken with the primary objective being to determine if subject waterways fit the criteria of a "river" as defined by the *NSW Water Management* Act 2000 which is:

> *a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved, and*
>
> *b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows, and*
>
> *c) anything declared by the regulations to be a river*

In relation to point (c) of the definition of 'river' in the Dictionary to the Act, the following are declared to be a river as per the Water Management (General) Regulation 2018 (WM Regulation):

> *a) any watercourse, whether perennial or intermittent, comprising an artificial channel that has changed the course of the watercourse*
>
> *b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows.*

Once validated as a "river", mapped Strahler ordering was assigned.

To complement the validation of waterways, top of bank mapping using a TRIMBLE Differential GPS (DGPS) unit was undertaken across the AWRC site (Study Area 1 - Figure 3). This was undertaken to ensure vegetated riparian zones (VRZ) as required by the *NSW Water Management* Act 2000 could be accurately assigned (see Section 6).

The location of top of bank was determined visually by field ecologists with extensive top of bank identification and mapping experience. The validity of this method is an accepted standard approach and was recently applied to develop Western Sydney Aerotropolis (Initial Precincts) Riparian Corridors Assessment (Sydney Water, 2021), which has been reviewed by an expert panel and is now the basis of broad scale waterway planning across the Western Sydney Aerotropolis.

Reliability when defining top of bank was optimised through observation calibration between ecologists at the beginning of each survey day. Further, the surveying ecologists operated in teams to continually cross validate the other members interpretation of top of bank.

5.3.2 Key Fish Habitat

Field verification of waterways mapped as Key Fish Habitat (KFH) in the desktop review was undertaken following the framework outlined in Policy and Guidelines for Fish Habitat Conservation and Management (DPIE Fisheries, 2013), which enabled determination of KFH Type and Class based on the presence of habitat attributes and threatened species.

A total of 61 assessments were undertaken across the IAA (Figure 5).

Assessment criteria for KFH Type and Class (taken from DPIE Fisheries, 2013) are shown in Table 6 and Table 7.

Table 6 Key Fish Habitat Type and associated sensitivity classification scheme.

TYPE 1 - Highly sensitive key fish habitat:

- *Posidonia australis* (strapweed)
- *Zostera, Heterozostera, Halophila and Ruppia* species of seagrass beds >5m^2 in area
- Coastal saltmarsh >5m^2 in area
- Coral communities
- Coastal lakes and lagoons that have a natural opening and closing regime (i.e. are not permanently open or artificially opened or are subject to one off unauthorised openings)
- Marine park, an aquatic reserve or intertidal protected area
- SEPP 14 coastal wetlands, wetlands recognised under international agreements (e.g. Ramsar, JAMBA, CAMBA, ROKAMBA wetlands), wetlands listed in the Directory of Important Wetlands of Australia[2]
- Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants
- Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act
- Mound springs

TYPE 2 – Moderately sensitive key fish habitat:

- *Zostera, Heterozostera, Halophila* and *Ruppia* species of seagrass beds <5m^2 in area
- Mangroves
- Coastal saltmarsh <5m^2 in area
- Marine macroalgae such as *Ecklonia* and *Sargassum* species
- Estuarine and marine rocky reefs
- Coastal lakes and lagoons that are permanently open or subject to artificial opening via agreed management arrangements (e.g. managed in line with an entrance management plan)
- Aquatic habitat within 100 m of a marine park, an aquatic reserve or intertidal protected area
- Stable intertidal sand/mud flats, coastal and estuarine sandy beaches with large populations of in-fauna
- Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in TYPE 1
- Weir pools and dams up to full supply level where the weir or dam is across a natural waterway

TYPE 3 – Minimally sensitive key fish habitat may include:

- Unstable or unvegetated sand or mud substrate, coastal and estuarine sandy beaches with minimal or no in-fauna
- Coastal and freshwater habitats not included in TYPES 1 or 2
- Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation

Notes: For the purposes of these policy and guidelines the following are **not considered key fish habitat**[5]:

- First and second order streams on gaining streams (based on the Strahler method of stream ordering)
- Farm dams on first and second order streams or unmapped gullies
- Agricultural and urban drains
- Urban or other artificial ponds (e.g. evaporation basins, aquaculture ponds)
- Sections of stream that have been concrete-lined or piped (not including a waterway crossing)
- Canal estates

Table 7 Key Fish Habitat Class of waterways for fish passage.

CLASS 1 Major key fish habitat	Marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected fish species or 'critical habitat'.
CLASS 2 Moderate key fish habitat	Non-permanently flowing (intermittent) stream, creek or waterway (generally named) with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. TYPE 1 and 2 habitats present.
CLASS 3 Minimal key fish habitat	Named or unnamed waterway with intermittent flow and sporadic refuge, breeding or feeding areas for aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or other CLASS 1-3 fish habitats.
CLASS 4 Unlikely key fish habitat	Waterway (generally unnamed) with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present).

5.3.3 Threatened Fish Species and Matters of National Environmental Significance

With the exception of Macquarie Perch, the desktop review and field assessment did not identify records or habitat for any other threatened species listed under the NSW *Fisheries Management Act 1994* (FM Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Macquarie Perch is known to inhabit the Warragamba River and the Nepean River between Erskine Creek and Glenbrook Creek. This is within the study area for the project, so the study has been prepared assuming presence of this species. For these reasons, no targeted threatened species surveys were undertaken.

Consultation with DPI Fisheries confirmed this as an acceptable approach, subject to this study confirming the absence of suitable habitat for any other threatened species.

Given the known presence of Macquarie Perch, the study includes a 7 Part Test of Significance for this species under the FM Act and a Commonwealth Test of Significant Impact under the EPBC Act.

5.3.4 Riparian Vegetation and Waterway Channel Condition

To assess the relative condition of riparian vegetation and waterway channels across the study area, the Rapid Riparian Appraisal (RRA) method developed by Findlay et al. (2011) and later refined and localised by Dean and Tippler (2016) was applied.

A total of 61 assessments were undertaken across the IAA (Figure 5).

This method provides a snapshot of the current condition of aquatic and riparian areas and was developed in the Sydney region specifically for visual examination of urban and urbanizing waterways. The RRA method combines qualitative and quantitative assessment of urban stream condition and riparian habitat (on both the left and right bank), incorporating land use, riparian vegetation and weed density, channel features, key fish habitat, and depositional and erosional features. This method produces a rich data set, which can be used to strategically target actions for waterway management.

The RRA method used covers seven main categories, which include site features, riparian vegetation, habitat features, channel features, key fish habitat, deposition and erosion, and liveability and community values.

These categories are then broken down into indices and sub-indices, each receiving a score. Scoring for each feature is based on a scale that ranges from +10 (reflecting excellent condition or a positive impact) to -10 (reflecting degraded condition or a negative impact), with zero indicating a neutral effect (Findlay et al. 2011).

These values are then used to calculate an overall site condition score out of 100, which is grouped into one of seven categories that reflect a gradient of disturbance and riparian condition; 'Excellent' (ranging from 90-100), 'Very Good' (80-<90), 'Good' (70-<80), 'Fair' (60-<70), 'Poor' (50-<60), 'Very Poor' (40-<50), and 'Degraded' (<40) (based on Findlay et al. (2011) and Dean and Tippler (2016)).

'Poor' to 'Degraded' condition is typical of creeks with highly urbanized catchments that have undergone severe channel alteration, are possibly concrete lined, with very restricted or absent vegetated buffer width or riparian vegetation structure. Conversely, 'Excellent' condition indicates a minimally disturbed catchment with intact channel geomorphology, an expansive and complex riparian vegetation community with minimal weeds and unaffected by human induced impacts such as stormwater and sewage.

5.3.5 Groundwater Dependent Ecosystems

To determine if GDEs mapped by the desktop review were present across the IAA, field validation was undertaken whereby the location of mapped GDEs were cross referenced in the field and validated as present or absent.

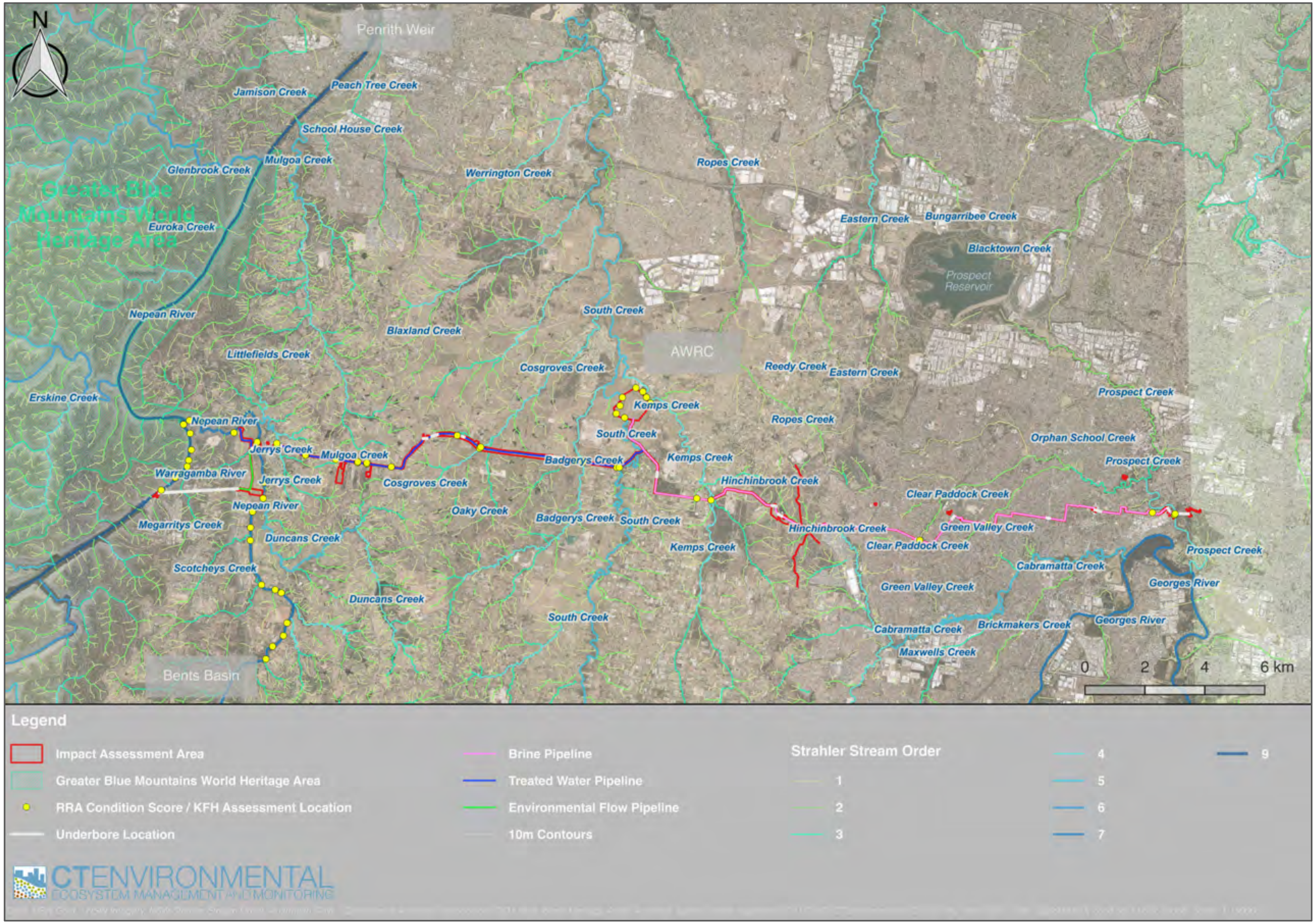

Figure 5 Location of Rapid Riparian and Key Fish Habitat Assessments across the Impact Assessment Area.

5.4 Impact Assessment

To assess the potential for impacts associated with the AWRC on aquatic, riparian and groundwater dependent ecosystems of South Creek, Nepean River, Warragamba River and other minor waterways consideration has been given to potential direct impacts associated with the construction phase of the AWRC, pipelines and outlet structures.

Potential indirect impacts associated with the operational phase of the AWRC have also been considered and include impacts driven by stormwater, including water quality and hydrology, at the AWRC site and hydrology, hydraulic and water quality impacts to South Creek and Warragamba and Nepean Rivers from treated water releases.

Assessment of potential impacts have been determined by review of data and reporting developed by other specialist consultancies working as part of the greater EIS team. Data and reporting presented by the specialist reports were compared to current ecological conditions determined by field survey and spatial review and relevant project waterway objectives).

An assessment of hydrology and hydraulic modeling of the Nepean River was undertaken to identify any potential impacts to aquatic and riparian ecosystems resulting from changes in ecohydraulic metrics under each release scenario. Wetted perimeter, flow velocity and depth data was provided by Streamology (2021) and used to assess the inundation of low-lying riparian vegetation and increases in aquatic habitat availability. The impact of 2036 (Stage 1) and 2056 (Stage 2; where relevant) flow scenarios were assessed against current baseline ecological conditions (as defined for Study Area 5 and 6) and future background ecological conditions (future conditions without AWRC impact).

The Nepean River is uniquely positioned in and adjacent to a World Heritage Area, within State Government land holdings and adjacent to NSW National Parks and Wildlife Service (NPWS) National Park. Thus, it is considered that the ecological condition of aquatic and riparian ecosystems in the assessment reach is not foreseen to change significantly from defined baseline conditions by 2036 or 2056, given consideration of surrounding land holdings and foreseen land use.

In addition, the waterway objectives for the project provide water quality guidelines for the protection of the aquatic ecosystem. These objectives are based on existing Australian and NSW guidelines that have been put in place to ensure future development does not pose significant impact to aquatic systems and as a result preserve the current ecological condition.

As a result, the potential magnitude and severity of future modelled impacts have been compared to the current baseline ecological condition of aquatic and riparian ecosystems in the Nepean and Warragamba Rivers, rather than a future background scenario. This approach is based on the assumption that the baseline condition is also representative of the future background ecological condition of these ecosystems within the Nepean and Warragamba Rivers.

A similar situation exists for South Creek catchment where waterway objectives have been developed based on assessment of current and recent ecological condition. The objectives which include both water quality and hydrological metrics have been set to ensure the current ecological condition is maintained into the future and provides adequate protection against the potential impacts associated with the rapid urbanisation of the catchment.

Therefore, the potential magnitude and severity of future modeled impacts against the current baseline ecological condition of aquatic and riparian ecosystems in South Creek, has been made under the assumption that this is also representative of the future background ecological condition of these ecosystems within the South Creek catchment.

For the purpose of this assessment, baseline ecological conditions act as a suitable and representative measure of future background conditions. The study assesses modelled future impacts such as wetted perimeter change and indicative inundation extent against current baseline ecological conditions as this comparison represents the magnitude of impacts against 2036 and 2056 background conditions. From this, the magnitude and severity of potential impacts to aquatic and riparian ecosystems was determined.

Specialist studies reviewed to assess potential impacts include;

- Upper South Creek Advanced Water Recycling Centre – Surface Water Impact Assessment (Aurecon ARUP 2021a)
- Upper South Creek Advanced Water Recycling Centre – Groundwater Impact Assessment (Aurecon ARUP 2021b)
- Upper South Creek Advanced Water Recycling Centre - Hydrodynamic and Water Quality Impact Assessment (Aurecon ARUP 2021c)
- Upper South Creek Advanced Water Recycling Centre - Ecohydrology and Geomorphology Impact Assessment (Streamology 2021)

To determine potential impacts to threatened species the following documents were reviewed:

- Matters of National Environmental Significance - Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999. (Commonwealth of Australia, 2013)
- Threatened Species Assessment Guidelines: The assessment of significance. (NSW Department of Primary Industries, 2006)
- National Recovery Plan for Macquarie Perch (*Macquaria australasica*). (Commonwealth of Australia, 2018)
- Draft Guidelines for Threatened biodiversity survey and assessment. Guidelines for developments and activities (2004 working draft) (NSW Government, 2004).

- Frameworks for assessment detailed in these documents were followed to determine the significance of impacts and listed Key Threatening Processes.

5.5 Waterway Objectives

Nepean River, Warragamba River and South Creek

Table 8 provides a summary of the waterway objectives for the Nepean and Warragamba Rivers and South Creek. The objectives are specific to this project and were developed in accordance with the Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (OEH, 2017). The numerical criteria are sourced from existing guidelines and objectives. Predicted impacts from the project will be assessed against the waterway objectives.

The Risk-based Framework defines waterway objectives as consisting of:

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

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

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

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

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000 and ANZG, 2018)
- Guidelines for managing risks in recreational water (NHMRC, 2008)
- Australian Drinking Water Guidelines 2011, Version 3.5 Updated August 2018 (NHMRC and NRMMC, 2011)

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

Table 8 Waterway objectives for Nepean and Warragamba Rivers and South Creek.

Values and uses and associated management goals	**Indicator**		**Numerical criteria/metric**	
			Nepean and Warragamba Rivers	**South Creek** *(values in brackets/blue text are DPIE criteria).*
1. Aquatic Ecosystems *Management goal: Protect, maintain and restore the ecological condition of aquatic systems and their riparian zones overtime.*	Total nitrogen (TN)		0.35 mg/L[1]	0.35 mg/L[1] (1.72 mg/L)[2]
	Total phosphorus (TP)		0.025 mg/L[1]	0.025 mg/L[1] (0.14 mg/L)[2]
	NOx		0.040 mg/L[1]	0.040 mg/L[1] (0.66 mg/L)[2]
	Ammonium (NH_4^+)		0.020 mg/L[1]	0.020 mg/L[1] (0.08 mg/L)[2]
	Filterable reactive phosphorus (FRP)		0.020 mg/L[1]	0.020 mg/L[1]
	Chlorophyll-*a* (Chl *a*)		0.003 mg/L[1]	0.003 mg/L[1]
	Dissolved oxygen (DO)		85 - 110 % Saturation[1]	85 - 110 % Saturation[1] (43-75 % Saturation, 8mg/L)[2]
	pH		6.5 - 8.0[1]	6.5 - 8.0[1] (6.2-7.6)[2]
	Conductivity		125-2200 µS/cm[1]	125-2200 µS/cm[1] (1103 µS/cm)[2]
	Toxicants		Refer to EIS, section 8.4	Refer to EIS, section 8.4
	Turbidity		6-50NTU[1]	6-50NTU[1] (50 NTU)[2] (TSS - 37mg/L)[2]
2. Recreation and Aesthetics *Management Goal: Maintain or improve water quality for recreational activities such as swimming, boating and fishing.*	Recreational water quality: Primary Contact	Enterococci	95th percentile for intestinal enterococci/100 mL ≤ 40[3]	
		Cyanobacteria	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	
	Recreational water quality: Secondary Contact	Enterococci	95th percentile for intestinal enterococci/100 mL > 40 and ≤ 200[3]	
		Cyanobacteria	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	
Management Goal: Maintain or improve the	Visual clarity and colour		Surface waters should be free from substances that produce undesirable colour, odour or foaming.[1]	

Values and uses and associated management goals	**Indicator**	**Numerical criteria/metric**	
		Nepean and Warragamba Rivers	**South Creek** *(values in brackets/blue text are DPIE criteria).*
aesthetic qualities of the waterways	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. Primary industries (irrigation and livestock drinking) *Management Goal: Protect the quality of water used for a broad range of irrigation activities 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	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.	
4. Protection of Raw Drinking Water Supplies *Management Goal: Maintain or improve the quality of raw drinking water extracted downstream*	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[4] – Absent Cyanobacteria risk index. Criteria: No overall increase in risk under any scenario.	Not applicable.
	Toxicants	Refer to EIS, section 8.4	Refer to EIS, section 8.4

Table Notes:
1. Indicators and metrics adopted from ANZECC (default trigger 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, November 2020).
3.Guidelines for managing risks in recreational water (NHMRC, 2008)
4. Australian Drinking Water Guidelines 6 V3.5 (NHMRC, NRMMC 2011)

5.5.1 Georges River catchment

A large section of the brine pipeline will be in the Georges River catchment. The environmental values and numerical criteria applicable for lowland rivers in this catchment have been sourced from the NSW Water Quality and River Flow Objectives (NSW DEC, 2006) (Table 9). Note that no releases to waterways within the Georges River are expected during operation and therefore water quality impacts are not assessed. However, water quality may be impacted during the construction period.

Table 9 Waterway objectives for Georges River catchment

Values and uses and associated management goals	Indicator	Numerical criteria/metric
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and riparian zones over the long term.	Total Phosphorus (TP)	0.025 mg/L
	Total Nitrogen (TN)	0.35 mg/L
	Chlorophyll-*a*	0.005 µg/L
	Turbidity	6 - 50 NTU
	Salinity (electrical conductivity)	125 - 2200 µS/cm
	Dissolved Oxygen (DO)	85 - 110% saturation
	pH	6.5 – 8.0
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts
Secondary contact recreation – maintaining or improving water quality of activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	As per the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Nuisance organisms	As per the visual amenity guidelines. Large numbers of midges and aquatic works are undesirable.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable of recreation. Toxic substances should not exceed values provided in the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Visual clarity and colour	As per the visual amenity guidelines.
	Surface films	As per the visual amenity guidelines.
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Turbidity	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).
	Faecal coliforms, enterococci, algae and blue-green algae	As per the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values provided in the Guidelines for managing risks in recreational water (NHMRC, 2008)
	Visual clarity and colour	As per the visual amenity guidelines.

	Temperature	15° - 35°C for prolonged exposure.
	pH	5.0 – 9.0

6 Current Conditions and Impact Assessment

This section details results of the desktop review and field assessment components, which describe the current condition of the aquatic and riparian ecosystems across the six study areas. Potential impacts to these ecosystems associated with the construction and operational phases of the project are assessed.

For the purpose of this assessment results of the desktop review, field assessment and impact assessment are reported by study area.

For clarification, the following terminology is used to describe the severity of environmental impact.

- Improved or improvement - considered 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 the following:
  - Lower ambient concentrations of water quality parameters and/or increased levels of dissolved oxygen.
  - Increased availability of aquatic or riparian habitats and/or aquatic connectivity.
- Insignificant/minor impacts- classified as being recognisable as short term, or temporary, or of limited magnitude in nature and only predicted at a local scale.
- Significant impact - defined as an impact which is important, notable, or of consequence, having regard to its context or intensity as per the EPBC Act 1999.
- Likely or conversely unlikely - used to define the probability of an event occurring. Likely has been defined in the EPBC Act (1999) as "*To be 'likely', it is not necessary for a significant impact to have a greater than 50% chance of happening; it is sufficient if a significant impact on the environment is a real or not remote chance or possibility.*
- Negligible – used to define a very small impact that is unlikely to drive change in conditions.

6.1 Study Area 1 - AWRC site and downstream receiving waterways

6.1.1 Desktop Assessment

6.1.1.1 Strahler stream order, Key Fish Habitat mapping and Threatened Species Distribution

A review of NSW statewide topographic mapping to determine Strahler stream ordering (SIX maps 2021) showed that Kemps and Badgerys Creeks are considered 4^{th} order streams and South Creek to the west of the site, is considered a 6^{th} order stream (Figure 6).

A review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) shows that waterways adjacent to the AWRC site are mapped as Key Fish Habitat (Figure 7).

Waterways within the South Creek catchment are not mapped as habitat for threatened species, there are no threatened species records (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020b), nor was any suitable habitat identified for threatened species, populations and ecological communities listed under Schedule 4, 4A and 5 of the NSW *Fisheries Management Act 1994*.

6.1.1.2 Matters of National Environmental Significance (MNES)

No MNES were mapped as present nor is there potential habitat within the AWRC site, within downstream receiving waters or across the broader South Creek catchment.

6.1.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) showed South Creek is considered an aquatic GDE. No terrestrial GDEs have been 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 (Figure 8).

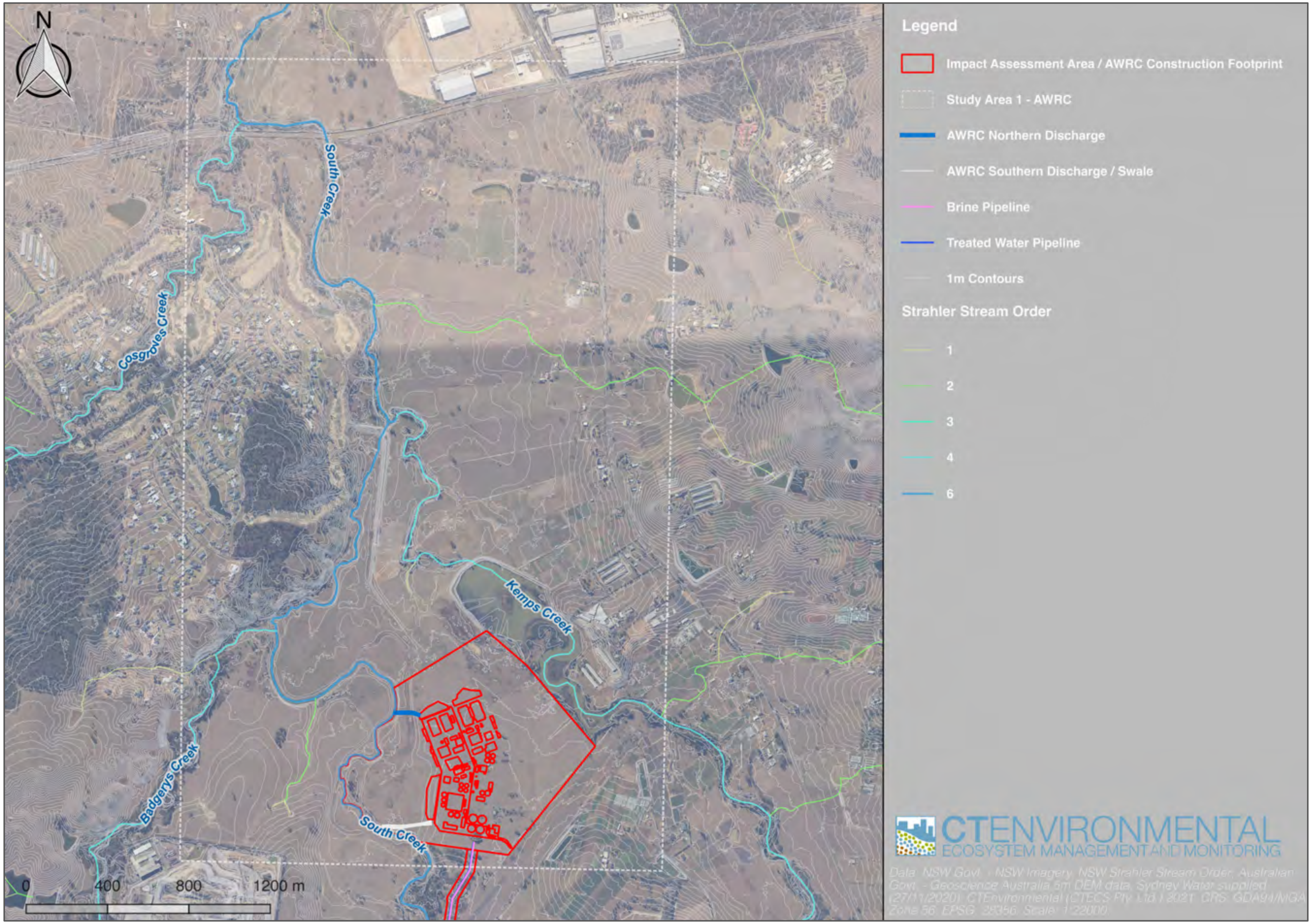

Figure 6 Strahler stream ordering of waterways within and adjacent to the AWRC site.

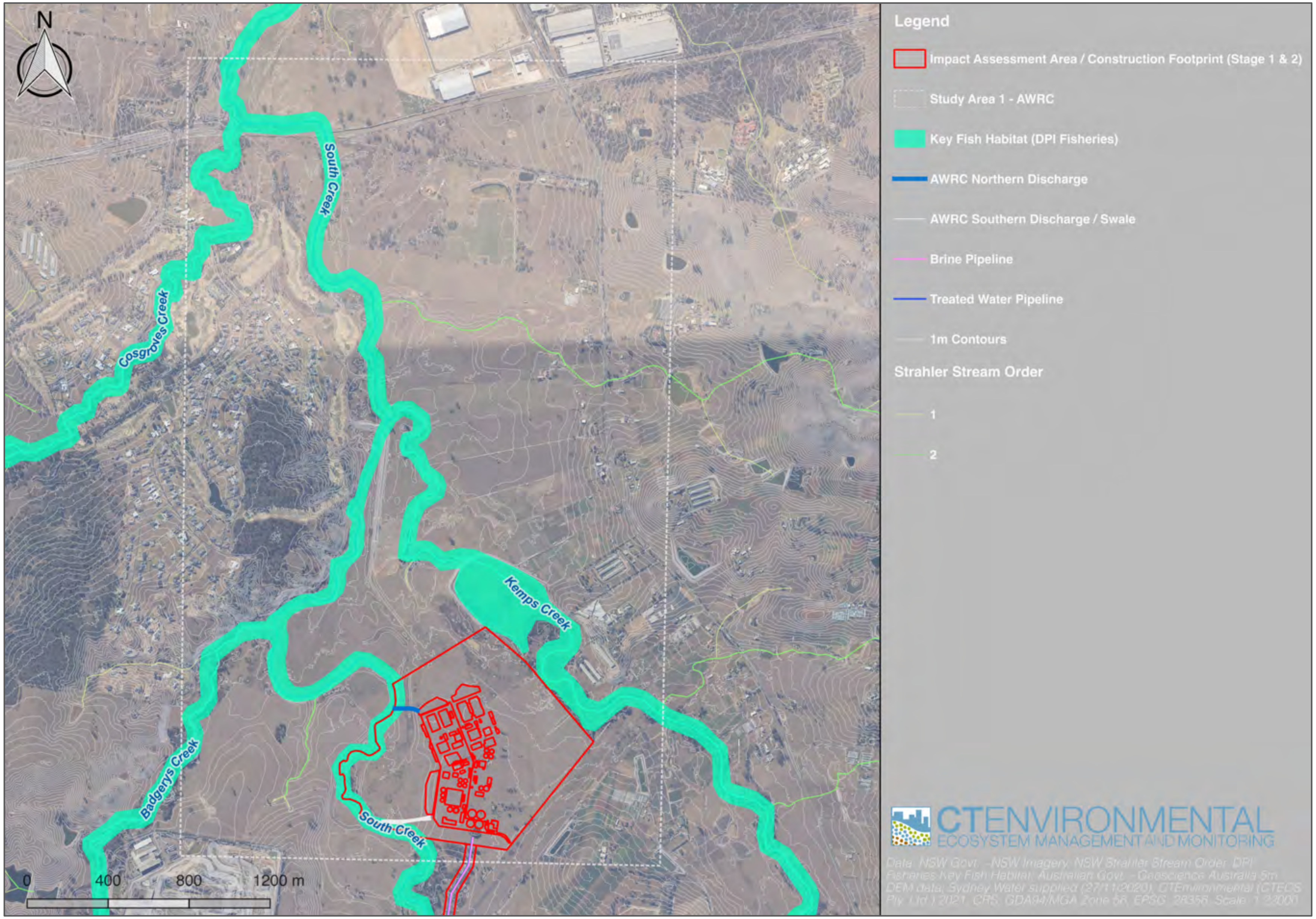

Figure 7 Mapped Key Fish Habitat (DPIE 2007) within and adjacent to the AWRC site.

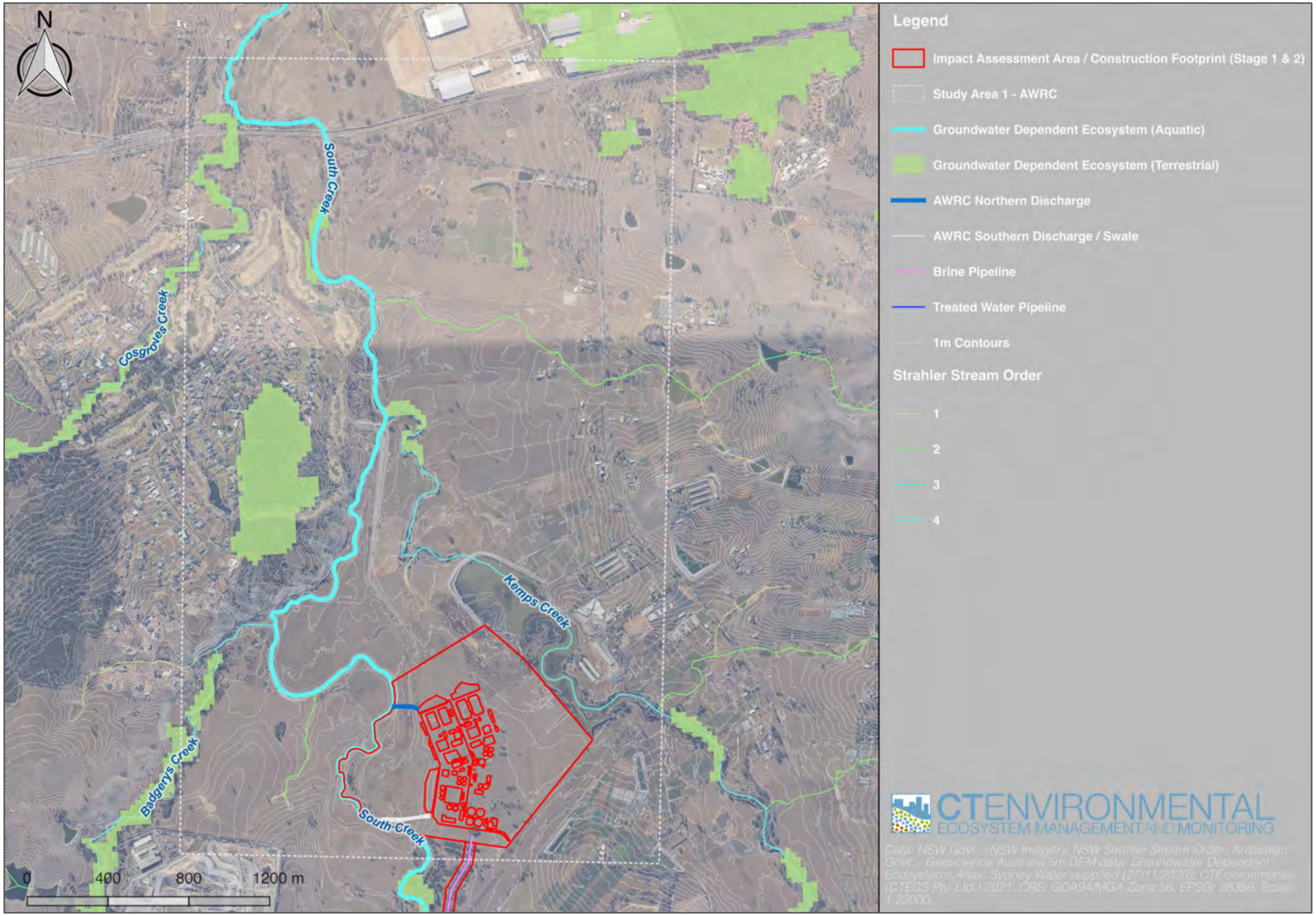

Figure 8 Mapped GDEs (BOM 2021) within and adjacent to the AWRC site.

6.1.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes.

Review of water quality, macroinvertebrate, macrophyte and fish survey monitoring data collected by Sydney Water relevant to the AWRC site and downstream receiving waters shows data has been collected at five sites within close proximity of Study Area 1 (Table 5 and Figure 4).

Results of water quality monitoring from sites listed in In particular, very high concentrations of nutrients were measured at Kemps Creek (NS450).

Table 10 shows median values for many parameters at all sites, with exception of NS440, exceeded the Wianamatta – South Creek Waterway Health Objectives (DPIE 2020). In particular, very high concentrations of nutrients were measured at Kemps Creek (NS450).

Table 10 Median values for water quality parameters monitored by Sydney Water (Jan 2018 – June 2021) within close proximity of Study Area 1. Red text indicate result is outside the Wianamatta – South Creek Waterway Health Objectives.

Site	DO (% Saturation)	EC (µS/cm)	pH	Turbdity (NTU)	TN (mg/L)	TP (mg/l)
NS45 (South Creek)	70.3	1062	7.4	32.5	1.78	0.24
NS44 (South Creek)	86.5	1031	7.5	73	1.5	0.15
NS35 (South Creek)	80.8	928	7.4	63	1.32	0.13
NS450 (Kemps Creek)	71.7	1501	7.5	20.5	3.38	0.704
NS440 (Badgerys Creek)	59.9	1070	7.2	11	1.49	0.195
Wianamatta-South Creek Waterway Health Objectives	43-75	1103	6.2-7.60	37	1.72	0.14

Interpretation of aquatic macroinvertebrate data collected by Sydney Water (Table 11) in waterways proximal to Study Area 1 indicates the aquatic environment is subject to moderate to high level of disturbance. The degradation is evident when the indices of genus richness, EPT% and SIGNAL-SG are examined. Genus richness, EPT% and SIGNAL-SG at all sites are low, indicating a depauperate 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) is comprised of taxa that are pollution tolerant with a lack of pollution sensitive taxa present as shown by relatively low SIGNAL-SG score (4.2) and relatively low EPT% composition (7.9%). For contrast SIGNAL-SG scores of > 6 and EPT% of > 30% are indicative of minimally impacted waterways (Sydney Water 2020).

The macroinvertebrate community of Badgerys Creek (NS440) is comprised of taxa that are pollution tolerant with a lack of pollution sensitive taxa present as shown by relatively low SIGNAL-SG score (4.3) and relatively low EPT% composition (9.8%).

The South Creek sites NS45 and NS44 had similarly low EPT% of 2.8% and 16.4% respectively. This low composition of sensitive taxa was reflected in the low SIGNAL-SG scores of 4.3 and 4.8 respectively.

Table 11 Aquatic macroinvertebrate indices for Sydney Water monitoring in proximity to the AWRC site.

Site	Year Range of data collected	Abundance	Family Richness	%EPT	SIGNAL-SG
NS45 (South Ck)	2006 - 2020	75.5	18.6	2.8	4.3
NS44 (South Ck)	2020	72.0	18.0	16.4	4.8
NS450 (Kemps Ck)	2006 - 2020	66.3	17.6	7.9	4.2
NS440 (Badgerys Ck)	2020	75.3	20.4	9.8	4.3

Review of fish survey results from Sydney Water (2020) and CTENVIRONMENTAL (2019) show 11 species were recorded in waterways in close proximity to Study Area 1. Of these 11 species, three are exotic which include Carp, Gambusia and Goldfish (Table 12).

The capture of Australian Bass (CTENVIRONMENTAL, 2019) in both South Creek and Kemps Creek upstream of the AWRC site indicates periodic connectivity with downstream reaches of South Creek, as this species undertakes annual migration to estuarine habitats to spawn and therefore fish are likely to navigate over obstacles to passage which includes the large weir on South Creek and the Kemps Creek dam (Figure 9). Species dispersal across these obstacles is likely to occur in periods of floodplain inundation.

Table 12 Results of fish survey by Sydney Water (August and December 2020) and CTENVIRONMENTAL (2019) in waterways in proximity to Study Area 1.

Fish (Common Name)	Scientific Name	South Creek NS35	South Creek NS44	South Creek NS45	South and Kemps Creeks CTENVIRONMENTAL (2019)
Australian Bass	*Macquaria novemaculeata*	-	-	-	X
Carp	*Cyprinus carpio*	-	-	-	X
Empire Gudgeon	*Hypseleotris compressa*	X	X	X	-
Firetailed Gudgeon	Hypseleotris galii	-	X	-	-
Flathead Gudgeon	Philypnodon grandiceps	X	-	-	-
Gambusia	Gambusia *holbrooki*	X	X	X	-
Goldfish	*Carassius auratus*	X	X	X	X

Long-finned eel	Anguilla reinhardtii	X	X	X	X
Striped Gudgeon	Gobiomorphus australis	X	-	-	-
Freshwater Mullet	*Pseudomyxus capensis*	X	-	-	-

Twelve species of macrophytes have been recorded in South Creek within Study Area 1, which composed of three exotic species, eight native species and one unconfirmed (Table 13).

Exotic species recorded were *Alternanthera philoxeroides, Eichhornia crassipes* and *Salvinia molesta*, all of which are listed as Weed of National Significance (WoNS). These species are highly dispersive and can form dense mats. The formation of dense mats restricts light penetration and can lead to anaerobic conditions. This in turn can cause the death of other aquatic life and the release of organic matter can trigger a eutrophication event.

The relatively high number of native species indicates that there are reaches of South Creek that provide suitable conditions for native aquatic vegetation. The relatively large number of native species is encouraging for ecosystem function. 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.

Table 13 Macrophytes recorded by Sydney Water at monitoring sites at South and Kemps Creeks (April and October 2020)

Scientific Name	Native / Exotic	South Creek	South Creek	South Creek	Kemps Creek
		NS35	**NS44**	**NS45**	**NS450**
Azolla pinnata	Native		X	X	
Juncus usitatus	Native	X			
Lemna minor	Native	X	X	X	X
Ludwigia peploides	Native		X	X	
Maundia triglochinoides	Native		X		
Persicaria lapathifolia	Native		X		
Phragmites australis	Native				X
Potamogeton crispus	Native		X		
Vallisneria sp	Unconfirmed		X	X	X
Alternanthera philoxeroides	Exotic	X	X	X	X
Eichhornia crassipes	Exotic		X		
Salvinia molesta	Exotic			X	

Figure 9 Location of South Creek Weir and Kemps Creek Dam – Barriers to fish passage.

6.1.2 Field Assessment

6.1.2.1 Waterway Validation

Waterway validation of South Creek and Kemps Creek at the AWRC site shows both creeks fit the definition of a "river", as per *NSW Water Management* Act 2000.

Review of aerial photos of the AWRC site shows an anabranch/oxbow of South Creek is present in the western portion of the site. Field based inspection confirmed this feature as a historical flow path of South Creek which is now separated from South Creek and forms a wetland ecosystem which is likely maintained by rainfall, shallow groundwater and bankfull flows in South Creek (Figure 10 and Figure 11).

Inspection of Kemps Creek and Kemps Creek Dam, both of which are beyond 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 proper below the dam wall (Figure 11).

Figure 10 Historical anabranch of South Creek, now wetland ecosystem on the AWRC site (photo – Jan 2020).

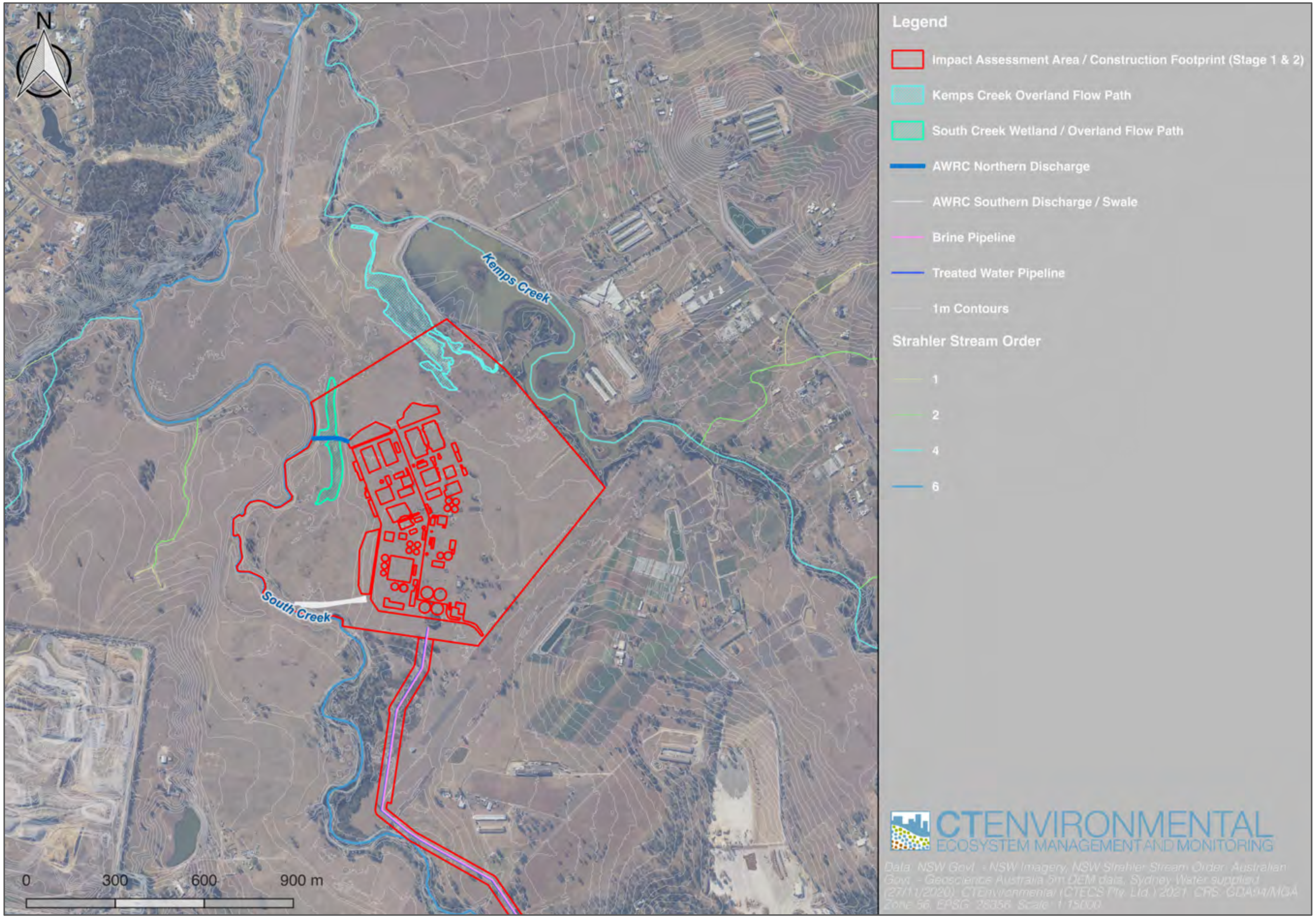

Figure 11 Location of field validated wetland ecosystems observed on the AWRC site.

6.1.2.2 Key Fish Habitat

Field validation of Key Fish Habitat (KFH) Type and Class following the framework outlined by Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) across Study Area 1 included assessment of South Creek and Kemps Creek (inclusive of Kemps Creek Dam).

Results show both South Creek and Kemps Creek are considered Type 1 (highly sensitive key fish habitat) and Class 1 (major key fish habitat) waterways.

While the reaches were classified at Type 1, and Class 1 for KFH, it is highly unlikely that any of the threatened species examined in this study occur in this area.

South Creek was assessed as a Type 1, Class 1 waterway due to the presence of overhanging vegetation, natural bed detritus, snags greater than 300 mm in diameter or 3 m in length, the presence of native aquatic plants and the permanency of water along this reach (Figure 12).

Kemps Creek was assessed as a Type 1, Class 1 waterway due to the presence of overhanging vegetation, natural bed detritus, snags greater than 300 mm in diameter or 3 m in length, the presence of native aquatic plants and the permanency of water along this reach, particularly in and upstream of Kemps Creek Dam (Figure 13).

Figure 14 shows field validated KFH Type for South Creek and Kemps Creek. KFH Type is shown as this is the category on which the recommended width of vegetated riparian zones as per NSW Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) are based.

Figure 12 South Creek at the AWRC site – Type 1, Class 1 Key Fish Habitat.

Figure 13 Kemps Creek adjacent to the AWRC site – Type 1, Class 1 Key Fish Habitat.

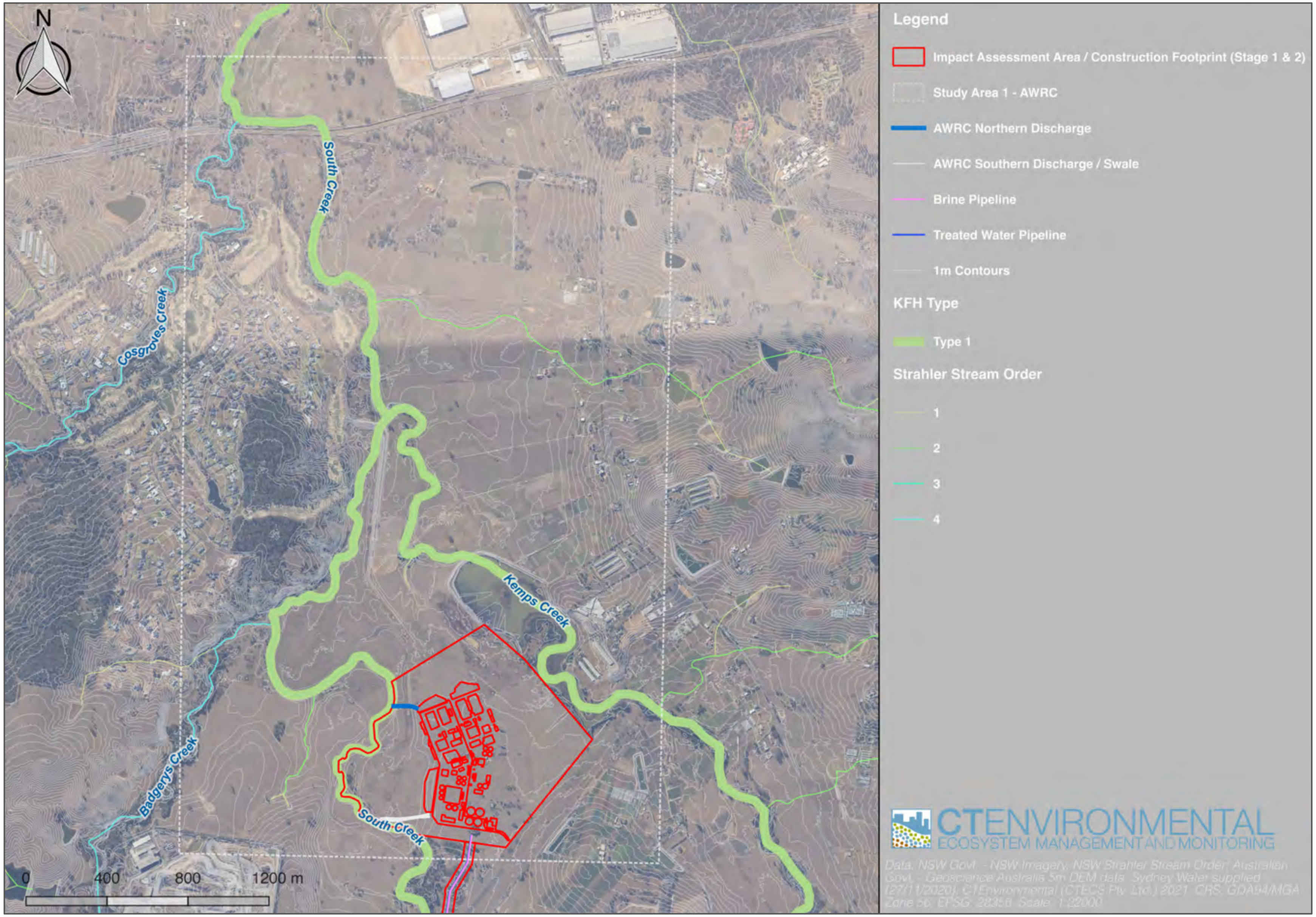

Figure 14 Field validated Type 1 – Study Area 1 – AWRC and receiving waterways.

6.1.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs confirmed no terrestrial GDEs are within the AWRC site boundary and South Creek is highly likely connected to groundwater which is indicated by the permanency of water in this reach of the creek (Figure 15).

Additional confirmation of connectivity to groundwater is shown in the Groundwater Impact Assessment (Aurecon ARUP 2021b), whereby groundwater flows are depicted intercepting South Creek and are likely to also express in the wetland within the AWRC boundary.

No terrestrial GDEs are within the AWRC boundary, however, small patches are mapped in proximity to the AWRC site, which correspond with remnant native vegetation patches (Figure 16).

Figure 15 South Creek looking southeast over the AWRC site (photo – April 2021).

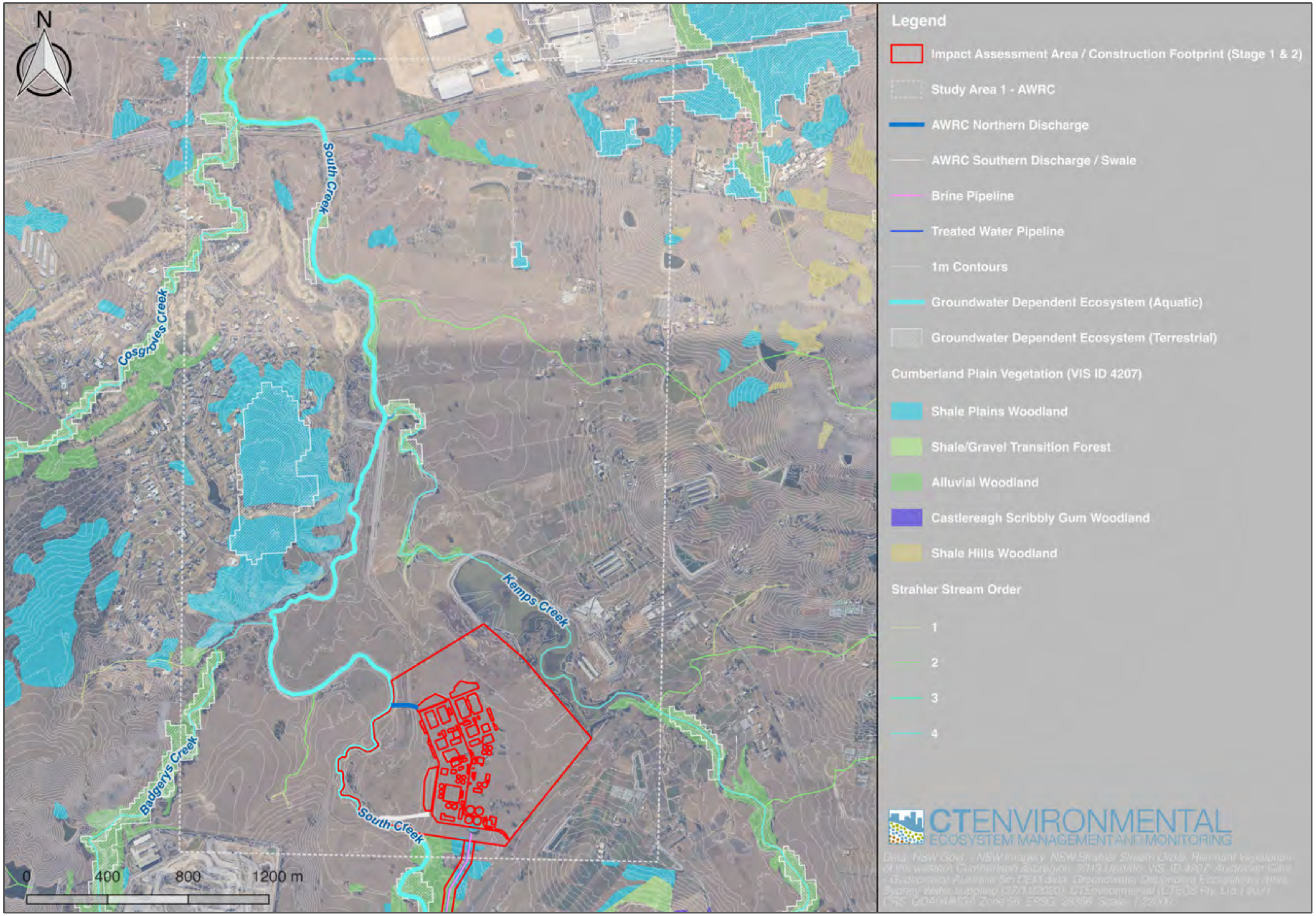

Figure 16 Groundwater dependent ecosystems and remnant native vegetation in proximity to the AWRC site.

6.1.2.4 Riparian Vegetation and Creek Channel Condition

Riparian vegetation and creek channel assessments were undertaken on South Creek and Kemps Creek adjacent to the AWRC site.

Results show the overall condition for the reaches assessed ranged from good to poor (Table 14 and Figure 17). The two sites with the lowest overall score were South Creek-42 (Figure 18) and South Creek-43, indicating poor condition with a score of 64. The site with the highest total score was Kemps Creek-47 (Figure 19), indicative of good condition.

All sites showed signs of erosion, with the greatest impact evident at South Creek-41. All sites assessed had a wide to moderate riparian buffer, with moderate vegetation structural complexity. Weeds were low at all sites, however had a moderate abundance at Kemps Creek-47. There was variability in scores relating to site features, with the lowest scores at South Creek-42 and South Creek-43, and the highest at Kemps Creek-47. Overall, the majority of sites had good aquatic habitat, with Kemps Creek-45 having the lowest aquatic habitat score.

See Appendix A for assessment summary reports.

Table 14 Riparian vegetation and creek channel assessment scores for Study Area 1 - AWRC and Receiving Waters.

Creek Name	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Kemps Creek-44	-3	20	7.1	-6	6.6	0	Fair	65
Kemps Creek-45	-1	16	9.3	-6	11.1	-1	Good	73
Kemps Creek-47	1	16	13.4	-16	15.4	1	Good	75
Kemps Creek-48	-2	20	8	-6	8.7	3	Good	74
South Creek-39	-1	20	2.3	-6	1.6	3	Fair	69
South Creek-41	-8	20	2.3	-6	12.6	3	Fair	69
South Creek-42	-6	20	2	-3	1	3	Poor	64
South Creek-43	-7	20	3.4	-3	1	3	Poor	64

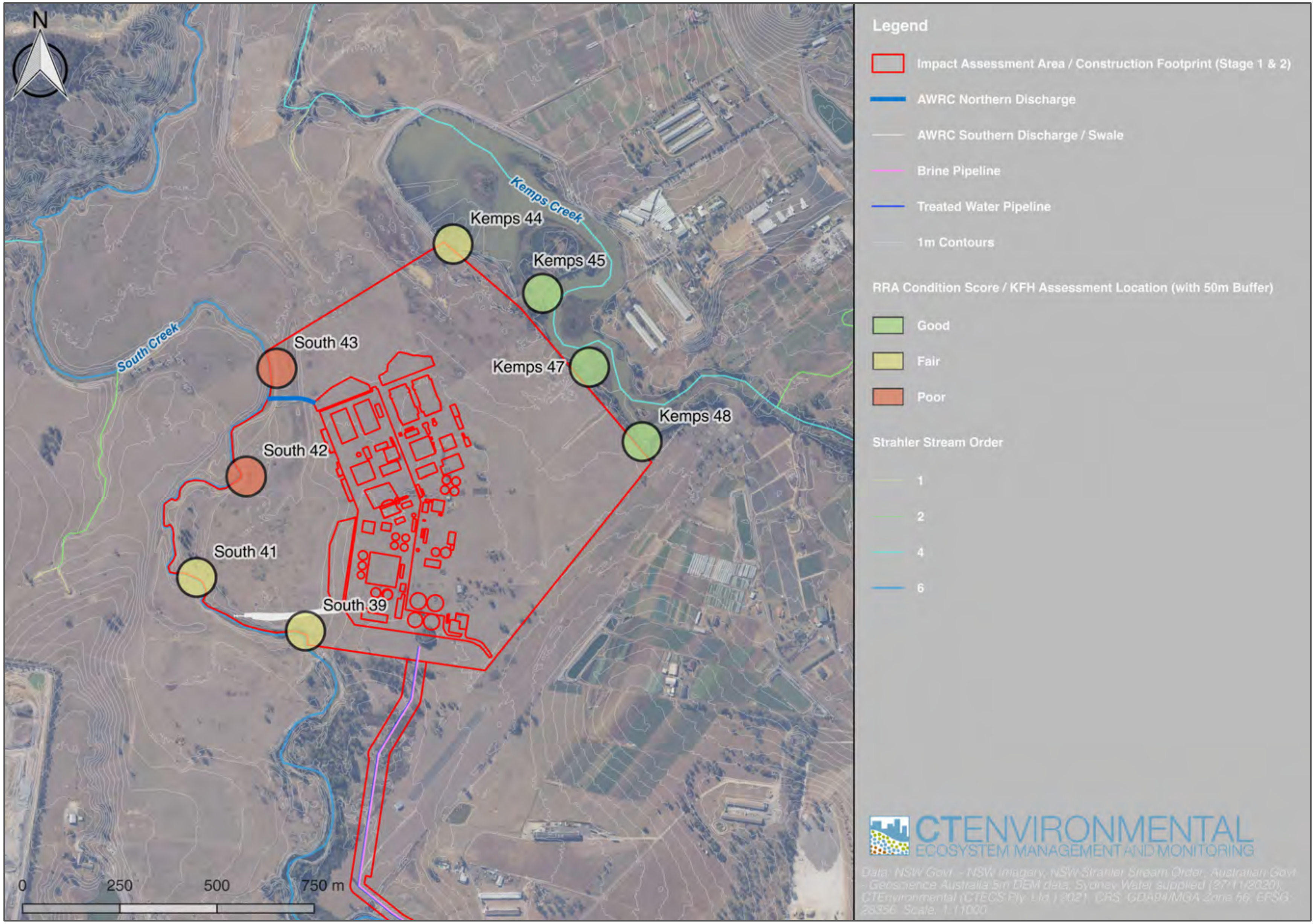

Figure 17 Results of riparian vegetation and creek channel assessment at Study Area 1 – AWRC and Receiving Waterways.

Figure 18 Assessment site South Creek 42 facing upstream. Assessed as “poor” condition.

Figure 19 Assessment site Kemps Creek 47 facing upstream. Assessed as “good” condition.

6.1.3 Assessment of Potential Impacts – Construction Phase

During the construction phase of the AWRC, there is the potential for temporary impacts to water quality in South Creek and the anabranch/wetland ecosystem and to instream fish habitat and passage.

Two waterway release locations will be constructed from the AWRC site. The northern release point will release stormwater runoff from the northern half of the AWRC site and will likely consist of a pipe, headwall and scour protection. The southern release point will release treated water from the AWRC and stormwater runoff from the southern half of the site and will likely consist of a vegetated swale consisting of an earth embankment construction, rip rap (energy dissipation) and scour protection within the creek.

Potential impacts that may impact the aquatic and riparian ecosystem of South Creek during the construction phase of the AWRC are outlined below. Overall, potential impacts to aquatic ecology during construction in Study Area 1 are considered to be minor, and manageable through mitigation measures recommended in section 6.1.6.

6.1.3.1 Degradation of water quality

Activities associated with bulk earthworks including topsoil removal and stockpiling have potential to have significant implications for water quality. This can include increased surface runoff from construction sites, transport of sediment and contaminants such as machinery oil and fluids entering waterways.

There is an increased risk of sedimentation and elevated turbidity due to the stripping of vegetation which exposes topsoil which in wet weather has the potential to be transported to receiving waterways, which in the case of the AWRC is South Creek and Kemps Creek.

Surface water runoff may also contribute to modified hydrology as water is diverted from active areas of the construction site to receiving waterways.

Increased sedimentation of fine particles are typical of alluvial areas across South Creek catchment, have potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering by fine sediments and to loss of niche habitats caused by settling of sediment on the creek bed. Loss of invertebrates can also affect higher trophic organisms as fauna such as native fish, wading birds and microbats are reliant on these for food resources.

6.1.3.2 Erosion

Increased erosion across the AWRC site from bulk earthworks and soil stockpiling is a potentially significant impact associated with the construction phase. Mobile clays typical of the South Creek catchment are easily mobilized if left exposed to surface water run-off and heavy machinery traffic. Key impacts on waterways that are associated with erosion include increased turbidity and mobilisation and sedimentation of coarse sediments which can affect aquatic species as discussed in the degradation of water quality section above.

6.1.3.3 Impeding fish passage

Fish passage is a key factor influencing the survival of many fish species, as it is crucial for breeding, access to food, shelter and habitat. Impeding fish passage can negatively affect fish migration and contribute to local extinctions. 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 has potential to impede the ability of fish to move up and downstream, increase turbidity, reduce light penetration and alter flow, all of which have potential to directly impact native fish population, particularly Australian Bass which undertake seasonal migrations to the Hawkesbury estuary in late autumn/early winter to spawn and then travel back to the upper reaches in late spring/early summer.

6.1.3.4 Riparian vegetation, wetlands and Groundwater Dependent Ecosystems

The AWRC site is currently cleared of native vegetation, including riparian vegetation which, in alluvial soil types in South Creek catchment, are typically considered terrestrial GDE's. The construction of the AWRC will not impact terrestrial GDE's as they are absent from the site. Potential impact may be caused to the aquatic GDE of South Creek as a result of sediment and erosion mismanagement and the associated impacts this can have on aquatic biota. This also applies to the wetland/anabranch system located on the central west boundary of the site.

6.1.4 Assessment of Potential Impacts – AWRC Operational Phase

During the operational phase of the AWRC, there is the potential for residual impacts to the aquatic and riparian ecosystem of South Creek as a result of long term hydrological/hydraulic and water quality driven change. These are outlined below.

6.1.4.1 Predicted changes to hydrology

To determine hydrologically driven impacts to South Creek, results of modelling from Aurecon (2021a), Aurecon Arup (2020c) and Streamology (2021) were reviewed.

Aurecon Arup (2021a) modelled the hydrologic performance of the proposed onsite stormwater management system for the AWRC and these results have been used to assess potential impacts to the aquatic and riparian ecosystem at the proposed release point on South Creek (Figure 20).

Modelling by Aurecon Arup (2020c) and Streamology (2021) 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.

The scenarios were run for a representative dry and wet year and represent the full range of potential operating conditions related to South Creek releases. These results have been applied to assess potential impact to the aquatic and riparian ecosystem of downstream receiving waters of South Creek.

Substantial changes to hydrology within South Creek are expected as a result of future urban development within the upper catchment. 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.

Releases from the AWRC to South Creek are proposed to occur only during wet weather conditions and includes both stormwater and treated water releases which will be limited in their temporal extent and will vary significantly in volume.

Results of modelling indicate that during the representative dry year and assuming a 50 ML/d AWRC capacity (2036), a limited number (~2 events over 3 days) of very minor treated water releases (<0.07 m^3/s or 6 ML /day) are predicted to occur. The releases increase in frequency and volume during the modelled wet year, with ~6 events predicted over 14 days, and with magnitudes of up to 1.5 m^3/s (or 130 ML /day) (Aurecon Arup (2021c)).

For the 100 ML /day capacity AWRC (2056), the number and duration of the events are predicted to be similar to the 50 ML /day scenarios, however the magnitude of releases approximately doubles in line with the capacity of the plant. In a dry year, modelled releases are predicted below 0.15 m^3/s (or 12 ML /day), and during the modelled wet year, the more frequent releases increase in magnitude up to 3 m^3/s (or 260 ML /day) (Aurecon Arup, 2021c).

Modelled wet weather releases (2036 and 2056) from the AWRC account for less than 3% of mean annual releases to South Creek and approximately 1% of flood flows, both of which represent relatively minor proportions (Streamology, 2021).

Figure 20 Approximate location (trees in middle ground) of proposed AWRC stormwater release outlet to South Creek.

Aurecon Arup (2021a) and Streamology (2021) conclude compliance with the Flow Objectives for Wianamatta – South Creek (in draft DPIE 2021), with the exception of the cease to flow threshold. The cease to flow threshold is exceeded under baseline and future background and impact conditions which reflects the on-going rapid urbanisation of the South Creek catchment.

In addition, Streamology (2021) report that 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 background scenario is considered to be negligible. As a result, there is a low risk that benthic communities, primarily macroinvertebrates, will be affected as these taxa live on organic detritus and within coarse sediments and therefore if geomorphic change is negligible, it is likely benthic habitats will remain in-situ during wet weather releases.

6.1.4.2 Predicted Water Quality

As noted above, Aurecon Arup (2021c) undertook water quality modelling for baseline, background and impact scenarios. Near field modelling of toxicants has also been undertaken for 2036 and 2056 conditions. Review of results of water quality modelling for treated water releases was undertaken for parameters that have potential to impact the aquatic and riparian ecosystem which included total and dissolved forms of nitrogen and phosphorus, salinity, chlorophyll-*a*, dissolved oxygen and total suspended solids. These key findings are summarised in more detail below. The results are based on a 2036 representative impact scenario (referred to as SC05). The impact scenario was compared to the equivalent background scenario (SC02) and the baseline scenario (HN00).

As noted above, wet weather releases to South Creek occur infrequently. Release volumes and quality will be different for each wet weather event, and this influences the relative impacts for some of the water quality parameters. 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 still increasing due to the rainfall 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.

- The short-term changes in the majority of these parameters 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 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. Spikes in concentrations are observed during four release events over the wet year.

- 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.

6.1.4.3 Nitrogen

- In modelled 2036 wet years extreme peaks in daily total nitrogen concentrations of up to ~ 0.9 mg/L are apparent up to 250 m below the release point and represent short lived increases on background conditions which decrease with distance downstream and return to background conditions within a day. A similar pattern is modelled for 2056 wet year releases, although the increase more extreme at ~ 1.4 mg/L.
- Dry year modelling shows reductions in total nitrogen in the creek due to the low concentrations in the advanced treated water being released, and the elevated nutrient levels and deteriorated water quality flowing in the creek from the upstream catchment.

6.1.4.4 Phosphorus

- 2036 median total phosphorus concentrations are predicted to remain essentially unmodified under the proposed release scenarios during both wet and dry years.
- A marginal decrease in daily concentrations of total phosphorus of up to ~0.02 mg/L is expected in the 2036 dry year modelling 250 m downstream of the release point. In a wet year total phosphorus and FRP are expected to increase by a maximum ~0.04 mg/L. This impact is expected to be short-lived and return to background conditions within a day of the releases ceasing.

6.1.4.5 Chlorophyll-*a*

- Under the wet and dry year 2036 impact scenario conditions no discernible change in chlorophyll-*a* is predicted, indicating there is no expected modification to primary productivity or algal growth as a result of the AWRC releases.
- In addition to the flushing dynamics, the changes in nutrient loading to the creek assumed in 2036 and 2056 are marginal, with any additional nutrient loads occurring away from sustained dry periods when conditions that favour eutrophication are prominent.
- For 2056 impact scenarios, very minor and short-term reductions in daily chlorophyll-*a* concentrations were predicted downstream of the AWRC following the larger releases, but generally the results indicate there is no expected modification to primary productivity or algal growth. This indicates that

during some of the AWRC release events, dilution is predicted to occur due to the relative differences in concentrations between the creek and the AWRC treated water.

- No modifications to the annual median profiles are predicted compared to the background scenario. Compliance is predicted with both the EES and ANZG derived waterway objectives.

6.1.4.6 Salinity

- For the 2036 impact scenario conditions, minor (<0.05 g/L), infrequent and short-lived reductions in salinity in the creek are predicted immediately downstream to the lower salinity in the AWRC treated water (~0.1 g/L), relative to the assumed salinity in the creek.
- For the 2056 impact scenario, downstream reductions in salinity are predicted to increase up to ~0.07 g/L due to the higher volumes of treated water being released.
- No notable change in annual median profiles were predicted for either the wet or dry year, with compliance predicted against both EES and ANZG waterway objectives throughout the creek.

6.1.4.7 Total Suspended Sediment

- For the 2036 impact scenarios, minor (<15 mg/L), infrequent and short-lived reductions in daily concentrations of suspended solids in the creek are predicted downstream of the releases. This is due to the lower TSS concentrations in the treated water (<15 mg/L) relative to the creek concentrations in wet weather (>80 mg/L).
- On larger events, some evidence is shown that the more significant releases may generate more erosion and/or resuspension and therefore short-lived increases in suspended solids may occur.
- For the 2056 scenarios, the reductions (and increases) are both <20 mg/L relative to background conditions.
- No notable change in annual median profiles were predicted for 2026 and 2056 scenarios or for either plant capacity. The annual median concentrations are predicted to be compliant with both the EES waterway objective (30 mg/L) and ANZG waterway objective (40 mg/L).

6.1.4.8 Dissolved oxygen

- For all impact scenarios, minor beneficial increases (<~1.5 mg/L or ~15%) in daily dissolved oxygen levels were predicted 250 m downstream of the release point as a result of the AWRC wet weather releases. These increases were assumed to be the result of higher concentration in the treated water releases relative to the lower creek concentrations. The increases are short-lived with concentrations returning to background levels within a day of the release event ceasing. While these temporary increases are predicted throughout the downstream creek system to some extent, their magnitudes progressively reduce with distance travelled from the release point.

- For the advanced treatment shutdown scenario, the level of impact remained unchanged relative to the equivalent non-shutdown scenario.
- With respect to compliance, annual median concentrations remain predominantly unmodified with the addition of the AWRC releases. Saturation levels are predicted to be generally compliant with the EES waterway objectives (43% to 75%), but not the ANZG objectives (85% to 110%).

6.1.4.9 Nearfield modelling

The toxicant review for South Creek (Aurecon Arup, 2021c) 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 trigger 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.

Near field modelling undertaken by Aurecon Arup (2021c) 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 focused on periods of extended dry weather.
- Application of ANZG (2018) trigger 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.

6.1.5 Assessment of potential impacts to aquatic, riparian and groundwater dependent ecosystems

Assessment based on the findings of Aurecon ARUP (2021a), Aurecon Arup (2021c) and Streamology (2021) in relation to aquatic and riparian ecosystems is outlined below.

No aquatic species listed as threatened under the FM Act 1994 or EPBC Act 1999 are expected to be impacted by the operational phases of the AWRC in Study Area 1. Review of threatened species mapping and monitoring data show no listed species are expected to occur or have been recorded on site or across the broader the South Creek catchment. Therefore, no impact to threatened species is expected.

South Creek in Study Area 1 is considered Class 1, Type 1 Key Fish Habitat and therefore habitat critical for survival attributes such as submerged woody debris, native macrophytes, gravel beds and hydrology are particularly vulnerable to degradation.

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 (as modelled by Streamology (2021) and Aurecon Arup (2021c). 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.

Review of hydrological and geomorphic assessments (Aurecon, 2021a and Streamology, 2021) suggest wet weather releases from the AWRC contributes a relatively small percentage of flow to South Creek (less than 3%) and all modelled flow metrics, with the exception of cease to flow thresholds, are within acceptable limits specified by the Flow Objectives for Wianamatta South Creek (DPIE, 2021 in review). The Flow Objectives have been developed using a robust data based and field validated process and tipping points have been identified with the primary objective to protect the ecosystem of South Creek.

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.

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.

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 of the EIS for more information). Impacts to aquatic ecology from stormwater runoff are therefore not expected.

Predicted changes to water quality from the treated water releases 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 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 driven impacts, modelling shows small and short-lived reductions are likely for salinity and increases for dissolved oxygen, results which 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 above.

Aurecon (2021b) report that construction of the AWRC will have little effect on groundwater with an estimated 1% drawdown expected. This insignificant change is more than compensated for by stormwater flows to South Creek from the upstream catchment.

Given the results of the modelling, wet weather releases, both in the form of stormwater and treated water, from the AWRC is not expected to drive significant impacts to the aquatic and riparian ecosystem which includes Key Fish Habitat, Groundwater Dependent Ecosystems and riparian vegetation of South Creek at the

AWRC site and in downstream receiving waters as hydrology does not alter to a degree that would change the current ecosystem condition nor does water quality from the site negatively affect South Creek.

It must be noted that AWRC wet weather release contributes a relatively minor percentage of flow to South Creek and stormwater flows from the upstream catchment is the major contributor of flow, particularly during wet weather. As noted above, it is likely that future stormwater flows from upstream, with associated water quality and geomorphic impacts, will contribute to ongoing pressure to the aquatic and riparian ecosystems as land use is rapidly changing due to development of the area which includes the Western Sydney Aerotropolis Precincts, Nancy Bird Airport and ongoing residential development of Oran Park and surrounding suburbs.

Based on the assessment of the potential impacts assessed above, residual impacts to the aquatic ecology of South Creek during the operational phase are considered as assessed as minor.

6.1.6 Recommendations to manage potential impacts

The risk of degradation to the aquatic and riparian ecosystem of South Creek at and downstream of the AWRC site is likely to come from works associated with the construction phase which are primarily attributed to potential impacts related to sediment erosion, an issue also highlighted by Aurecon (2021a).

Chapter 9.2 of the EIS includes management measures to minimise the risk of sediment and erosion driven impacts to the aquatic and riparian ecosystems of South Creek.

During the operational phase, Sydney Water's standard procedures for regular inspections and incident response will minimise the potential for leaks and breaks. Implementation of these will minimize potential sediment and erosion and water quality driven impacts to the aquatic ecosystem.

Riparian vegetation across the AWRC site is dominated by cleared and grazed pasture with one stand of *Casuarina glauca* present at the location of the proposed stormwater outlet. As part of the landscape design for the AWRC, riparian zones will be revegetated (Aurecon ARUP, 2021a). The AWRC is considered State Significant Infrastructure (SSI) and therefore legislative requirements for retention and creation of vegetated riparian zones (VRZ) as per the *NSW Water Management Act* 2000 do not apply, however the principles of this *Act* should be followed (see Appendix B for guidance).

In addition, the Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013) recommend a 50 m VRZ on Type 1 Key Fish Habitat. However, this is a recommendation only and applying the VRZ widths as per the *NSW Water Management Act* 2000 will significantly enhance the riparian ecosystem from its current state.

It is recommended a VRZ of 40 m measured from top of bank should be applied to South Creek and the anabranch/wetland ecosystems within the AWRC site and 30 m VRZ applied to Kemps Creek as per the principles outlined by the "Guideline for Controlled Activities on Waterfront Land" (NSW Office of Water, 2012)(Appendix B) (Figure 21).

Establishment of an appropriately revegetated and managed VRZ will improve on the current condition of the riparian corridor of South Creek and the wetland/anabranch of South Creek. This will result in benefits to both aquatic and terrestrial biodiversity in the form of enhancement of available habitat and food resources.

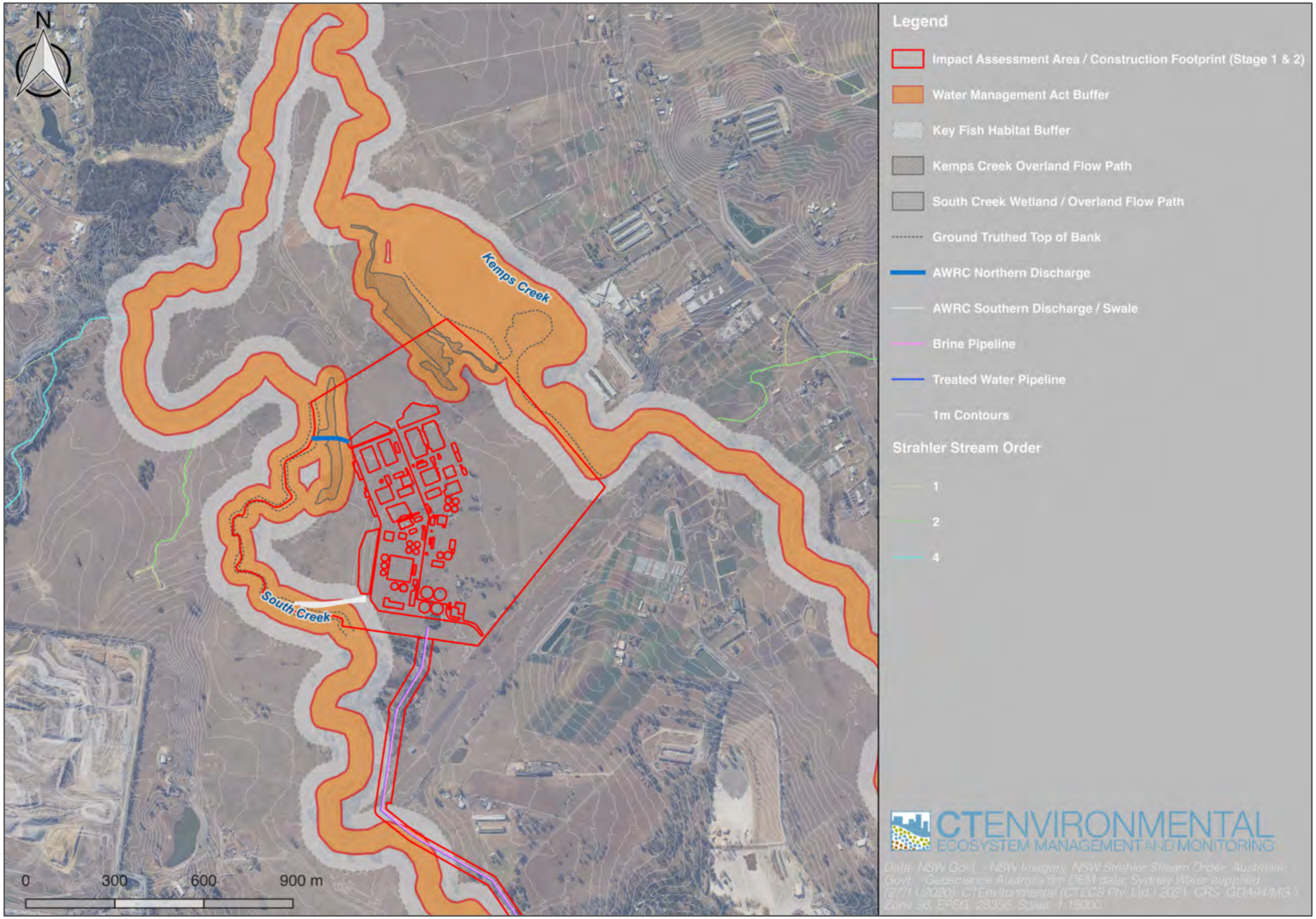

Figure 21 Vegetated Riparian Zone (VRZ) buffers as per *NSW Water Management Act* 2000 for AWRC and adjacent waterways.

To manage riparian vegetation across the Western Sydney Aerotropolis (WSA) Precincts, in which the AWRC site is located, CTENVIRONMENTAL and Sydney Water (in review 2021) developed a Riparian Revegetation Strategy (RRS) which applies the principles of riparian zone management detailed in "Guidelines for Controlled Activities on Waterfront Land" (NSW Office of Water, 2012) and also considers the flood risk of the floodway and floodplain of South Creek. The RRS applies a zoned management approach to guide the broadscale revegetation of riparian and floodplain areas.

It is recommended that revegetation of the AWRC site, which includes areas within the WMA VRZ and adjacent floodplain is undertaken following the guidance of the RRS (CTENVIRONMENTAL and Sydney Water (in review 2021)), which includes a site-specific Vegetation Management Plan (VMP) (which differs from Landscape Architect layouts). The VMP should be ecologically focused and incorporate social/recreation values where and if possible. Guidance on the development of a VMP can be found in "Guidelines for Vegetation Management Plans on Waterfront Land" (NSW Office of Water, 2012) (Appendix C).

Initial layout of the AWRC building footprint shows intrusion of buildings and stormwater infrastructure (Aurecon ARUP, 2021a) into the VRZ of the South Creek anabranch/wetland. Under the principles applied by the WMA, this wetland requires a 40 m buffer measured from the top -of-bank which in this case is the wetland extent. Encroachment is permitted into the VRZ by up to 50% however the "Averaging Rule" must be applied (Figure 22) – see "Guidelines for Controlled Activities on Waterfront Land" (NSW Office of Water, 2012).

It is recommended that if the AWRC building footprint and stormwater infrastructure encroaches the VRZ of the South Creek anabranch/wetland the "Averaging Rule" is applied and an offset for the encroachment is identified in a suitable area of the VRZ (Figure 23, see also Appendix B). Once identified, the offset area should follow the RRS.

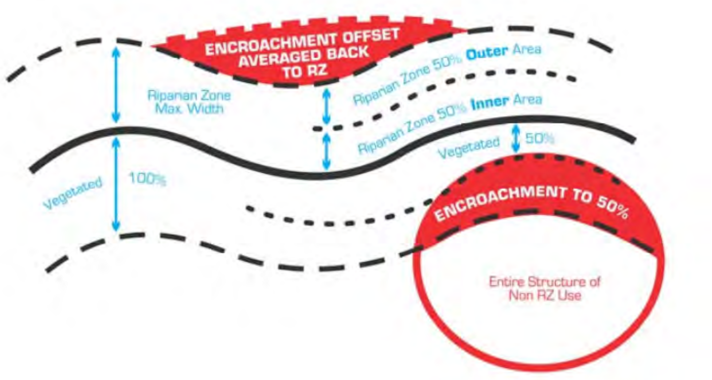

Figure 22: NSW Office of Water, Guidelines for Controlled Activates on Waterfront land VRZ "Averaging Rule" depiction.

Generic guidance to construction of the stormwater outlet pipe/headwall for the AWRC to South Creek has been provided by Aurecon Arup (2021a) however limited guidance to remediation/revegetation has been detailed.

It is recommended construction and remediation/revegetation of riparian areas at both release locations, including South Creek and the South Creek anabranch/wetland is undertaken following the guidance provided by "Guidelines for Outlet Structures on Waterfront Land" (NSW Office of Water, 2012) (see Appendix D).

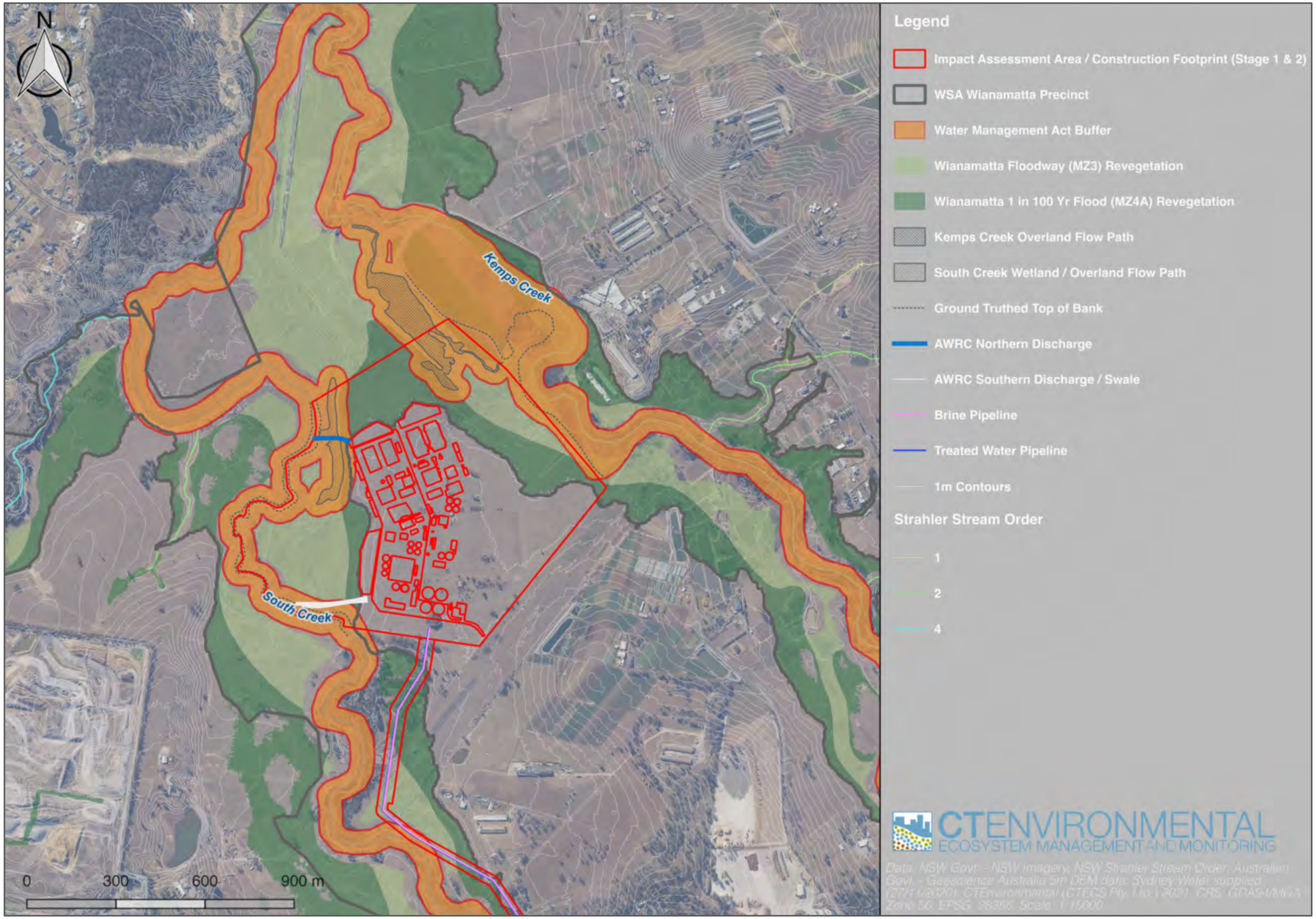

Figure 23 AWRC footprint showing intrusion into South Creek anabranch/wetland VRZ and WMA VRZ and Draft WSA Riparian Revegetation Zone.

6.2 Study Area 2 - Brine Pipeline

6.2.1 Desktop Assessment

6.2.1.1 Strahler stream order, Key Fish Habitat mapping and Threatened Species Distribution

Review of NSW state-wide topographic mapping to determine Strahler stream ordering (SIX maps, 2021) showed that at the point of intersection with the proposed Brine Pipeline, Prospect Creek is > 5th order stream, Kemps Creek and Hinchinbrook Creek are 4th order streams and Green Valley Creek and Clear Paddock Creek are considered 1st order streams (Figure 24).

Review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) of waterways adjacent to the Brine Pipeline show that Prospect Creek, Kemps Creek and Hinchinbrook Creek are the only creeks within Study Area 2 that are mapped as Key Fish Habitat (Figure 25).

Waterways crossed by the brine pipeline are not mapped as habitat for threatened species, there are no threatened species records (NSW Department of Primary Industries –Fisheries Spatial Data Portal, 2020b), nor was any suitable habitat identified for threatened species, populations and ecological communities listed under Schedule 4, 4A and 5 of the NSW Fisheries Management Act 1994.

6.2.1.2 Matters of National Environmental Significance

No MNES were mapped as present across the extent of the brine pipeline route or immediately downstream of waterways crossed. Potential habitat was not identified.

6.2.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) showed no aquatic GDE's are present along the route of the proposed brine pipeline. Terrestrial GDEs have been mapped along the brine pipeline alignment, which are typically bordering waterways, with the largest patch contained within and connected to the Kemps Creek Nature Reserve (Figure 26).

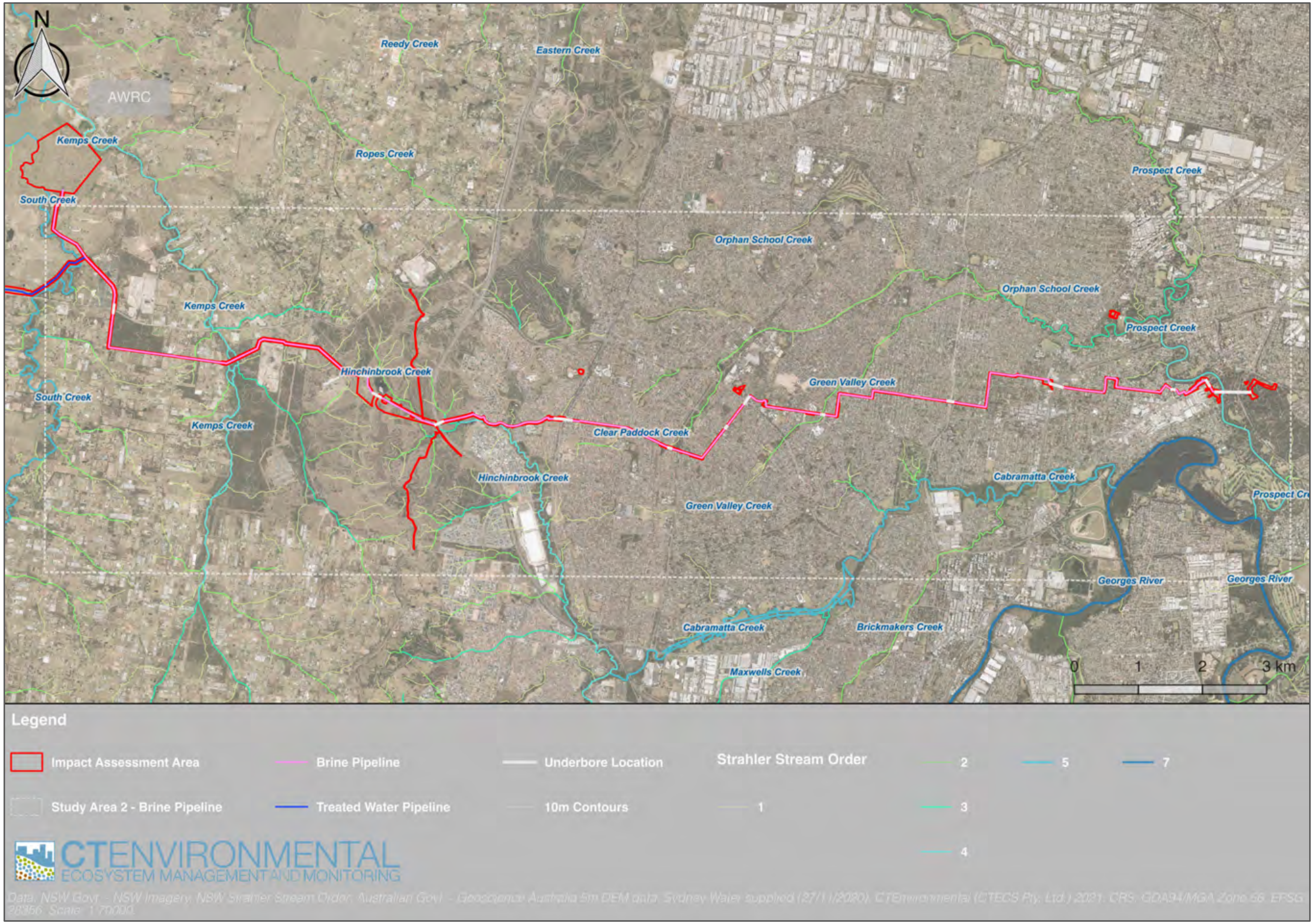

Figure 24 Strahler stream orders of waterways crossed by the proposed brine pipeline.

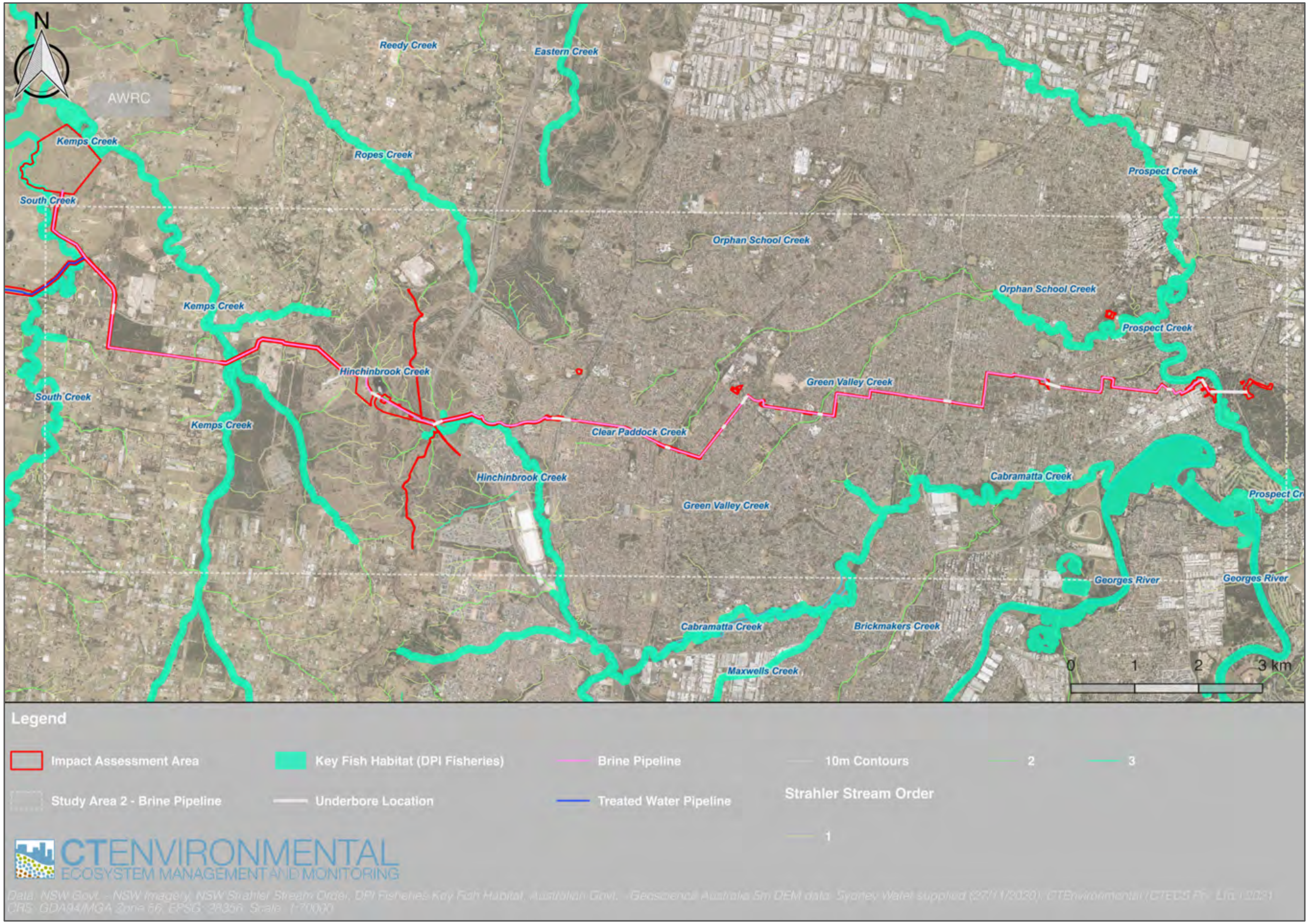

Figure 25 Mapped Key Fish Habitat (DPIE 2007) within proximity of proposed brine pipeline route.

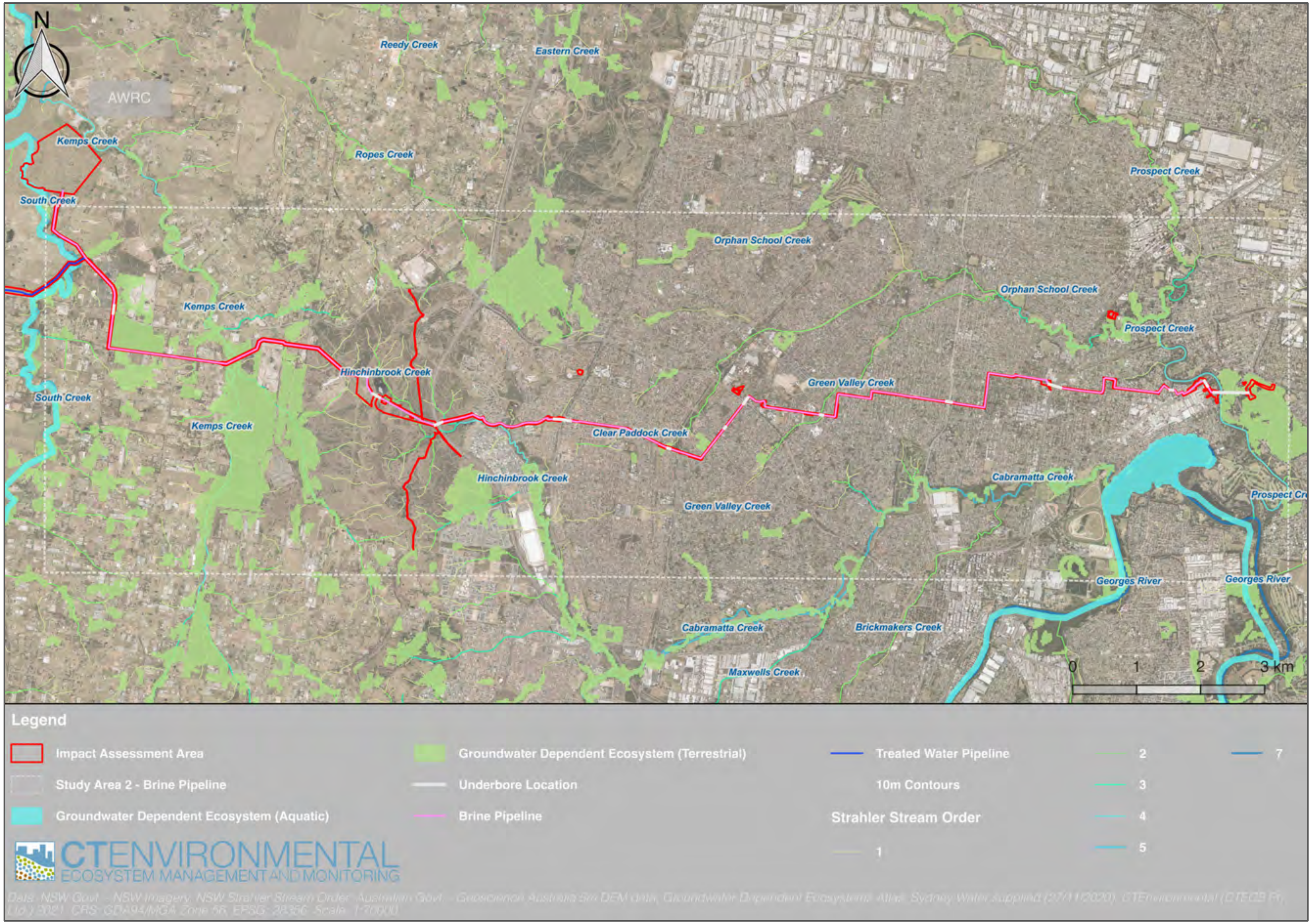

Figure 26 Mapped GDE's (BOM 2021) within and adjacent to the proposed brine pipeline route.

6.2.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes

Review of water quality, aquatic macroinvertebrate, fish survey and macrophyte monitoring data collected by Sydney Water relevant to the brine pipeline route shows only water quality and macroinvertebrate data has been collected at one site on Kemps Creek (NS450) within close proximity of Study Area 2 (Table 5 and Figure 4).

Results of water quality monitoring at Kemps Creek (NS450) shows that median concentrations for electrical conductivity, TN and TP exceeded the Water Quality Objectives for Wianamatta - South Creek (DPIE, 2021 in review) (Table 15). This is typical of waterways with urban, peri-urban and agriculture land use within the catchment.

Table 15 Median values for water quality parameters monitored by Sydney Water within close proximity of Study Area 2 (January 2018 – June 2021). Red text indicates result is outside the Wianamatta – South Creek Waterway Health Objectives.

Site	DO (% Saturation)	EC (μS/cm)	pH	Turbidity (NTU)	TN (mg/L)	TP (mg/l)
NS450	71.7	1501	7.5	20.5	3.38	0.704
Wianamatta - South Creek Waterway Health Objectives	43-75	1103	6.2-7.60	37	1.72	0.14

Results of aquatic macroinvertebrate monitoring undertaken by Sydney Water at NS450 (Kemps Creek) (Figure 4) are indicative of a community that is exposed to regular moderate to high level disturbance events. The degradation is evident when the indices of genus richness, EPT% and SIGNAL-SG are examined.

The macroinvertebrate assemblage recorded at the site was depauperate of a diverse range of taxa and dominated by groups that are known to be disturbance and pollution tolerant. This result is reflected in the by relatively low SIGNAL-SG score (4.2) and low EPT% composition (7.9%) (Table 16). For contrast SIGNAL-SG scores of > 6 and EPT% of > 30% are indicative of minimally impacted waterways (Sydney Water, 2020).

Table 16 Macroinvertebrate indices for NS450 – Kemps Creek.

Site	Abundance	Family Richness	% EPT	SIGNAL-SG
NS450	66.3	17.6	7.9	4.2

Review of fish survey results from CTENVIRONMENTAL (2019) show that Australian Bass were captured in Kemps Creek upstream of the proposed crossing point (Table 17).

The capture of Australian Bass in this area indicates periodic connectivity to downstream reaches of Kemps Creek and into South Creek, as this species undertakes annual migration to estuarine habitats to spawn and therefore fish are likely to navigate over obstacles to passage which includes the large weir on South Creek and the Kemps Creek dam (Figure 9). Species dispersal across these obstacles is likely to occur in periods of high flow and resulting floodplain inundation.

No threatened fish species have been recorded by these surveys.

Table 17 Results of fish survey by CTENVIRONMENTAL (2019) in waterways in Kemps Creek upstream of the proposed brine pipeline crossing point.

Fish (Common Name)	Scientific name	CTENVIRONMENTAL (2019)
Australian Bass	*Macquaria novemaculeata*	X
Carp	*Cyprinus carpio*	X
Goldfish	*Carassius auratus*	X
Long-finned eel	Anguilla reinhardtii	X

Macrophyte survey in Kemps Creek (NS450) shows species diversity was low with four species recorded, one of which was exotic, *Alternanthera philoxeroides* (Table 18).

Table 18 Macrophytes recorded by Sydney Water at Kemps Creek (April and October 2020)

Scientific Name	Native / Exotic	Kemps Creek
Site Code		NS450
Alternanthera philoxeroides	Exotic	X
Lemna minor	Native	X
Phragmites australis	Native	X
Vallisneria sp	Native	X

6.2.2 Field Assessment

6.2.2.1 Waterway Validation

Waterway validation of Kemps Creek, Hinchinbrook Creek, Green Valley Creek, Prospect Creek and Clear Paddock Creek along the brine pipeline alignment shows all creeks fit the definition of a "river" as per *NSW Water Management* Act 2000.

6.2.2.2 Key Fish Habitat

Field validation of Key Fish Habitat (KFH) Type and Class following the framework outlined by Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) across Study Area 2 confirmed that the reach of Clear Paddock Creek is not KFH.

This classification was verified and as a result the reach assessed as Type 3 (minimally sensitive key fish habitat) and Class 3 (minimal key fish habitat). This was due to the ephemeral nature of the creek with sporadic refuge and the lack of native aquatic or wetland vegetation (Figure 27).

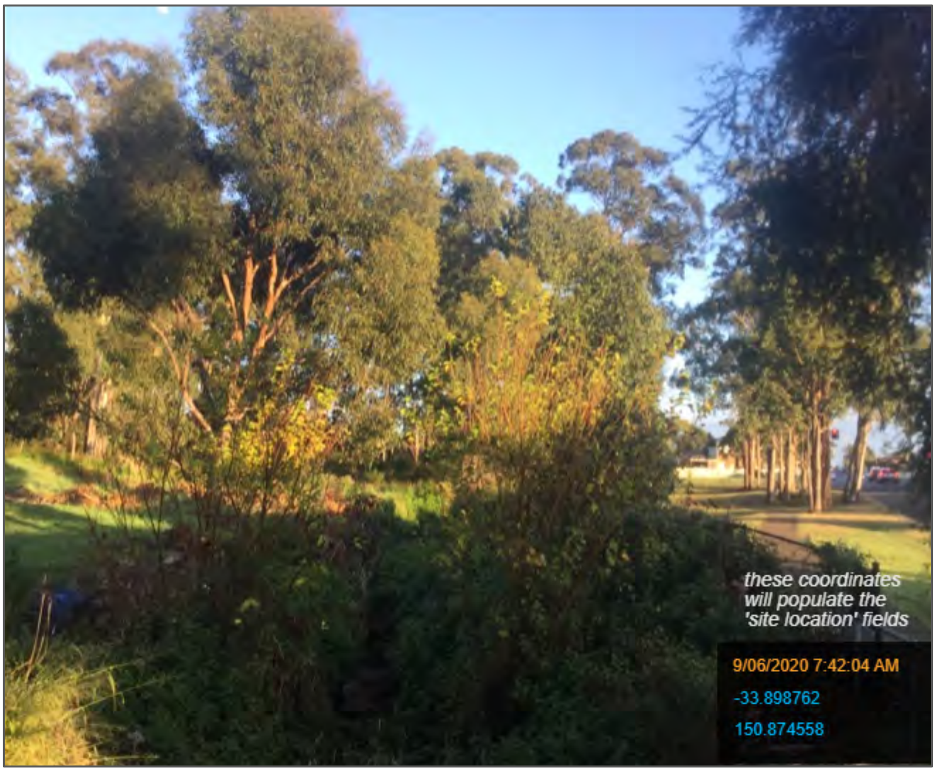

Figure 27 Clear Paddock Creek at the site of the proposed Brine Pipeline alignment.

The reach of Green Valley Creek potentially affected by the Brine Pipeline was not mapped as KFH. This classification was verified, and the reach assessed as Type 3 (minimally sensitive key fish habitat) and Class 4 (unlikely key fish habitat). This was due to the ephemeral nature of the creek, no permanent refuge and the lack of native aquatic or wetland vegetation (Figure 28).

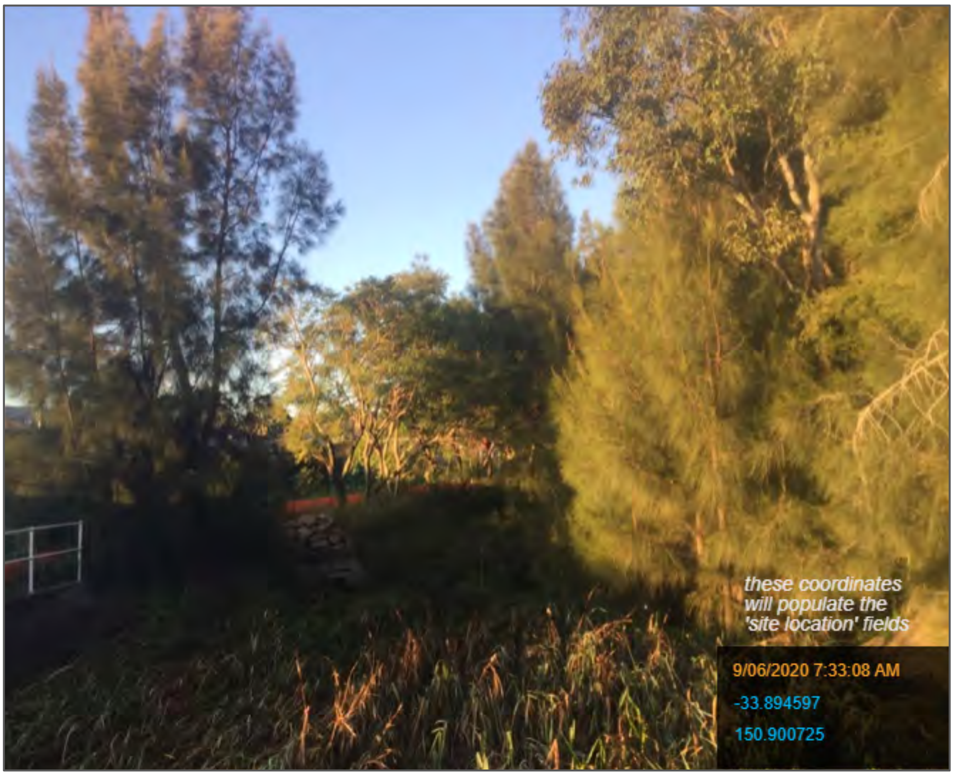

Figure 28 Green Valley Creek at the site of the proposed Brine Pipeline alignment.

The reach of Hinchinbrook Creek potentially affected by the proposed Brine Pipeline was not mapped as KFH. This classification was verified, and the creek reach assessed as Type 3 (minimally sensitive Key Fish Habitat) and Class 3 (minimal Key Fish Habitat). This was due to the ephemeral nature of the creek with sporadic refuge and the lack of native aquatic vegetation or other habitat features such as overhanging vegetation and snags (Figure 29).

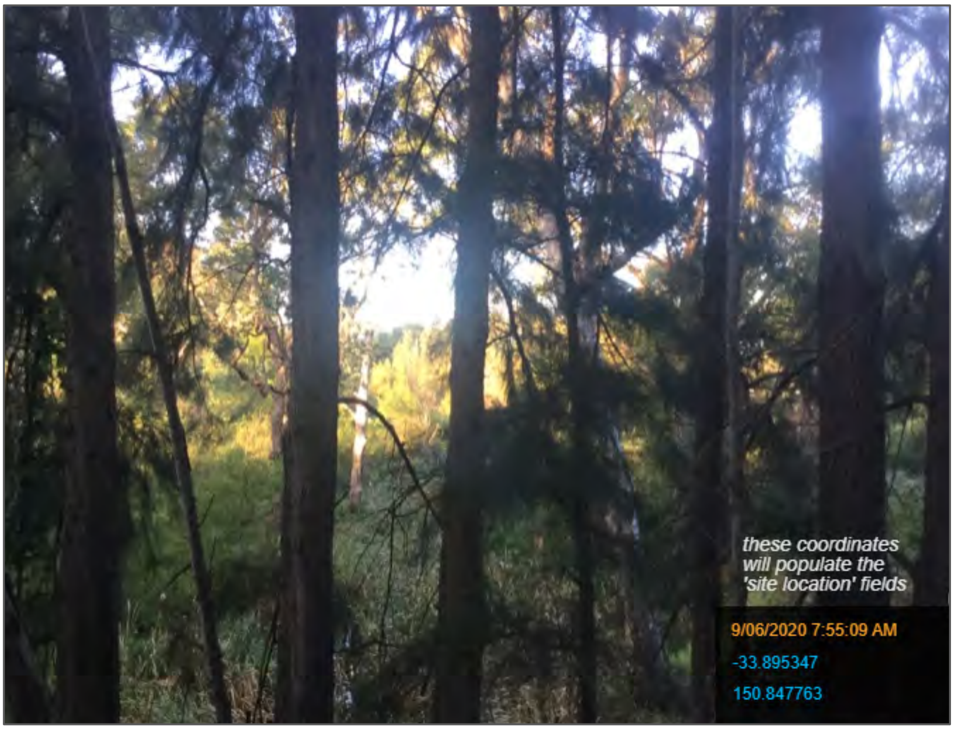

Figure 29 Hinchinbrook Creek at the site of the proposed Brine Pipeline alignment.

The reach of Kemps Creek potentially affected by the proposed Brine Pipeline was mapped as KFH. This classification was verified, and the reach assessed as Type 1 (highly sensitive Key Fish Habitat) and Class 2 (moderate Key Fish Habitat).

This classification was awarded due to the presence of overhanging vegetation, natural bed detritus, snags greater than 300 mm in diameter or 3 m in length and native aquatic plants. This reach of Kemps Creek has an intermittent flow regime with clearly defined bed and bank, which supports permanent pools (Figure 30).

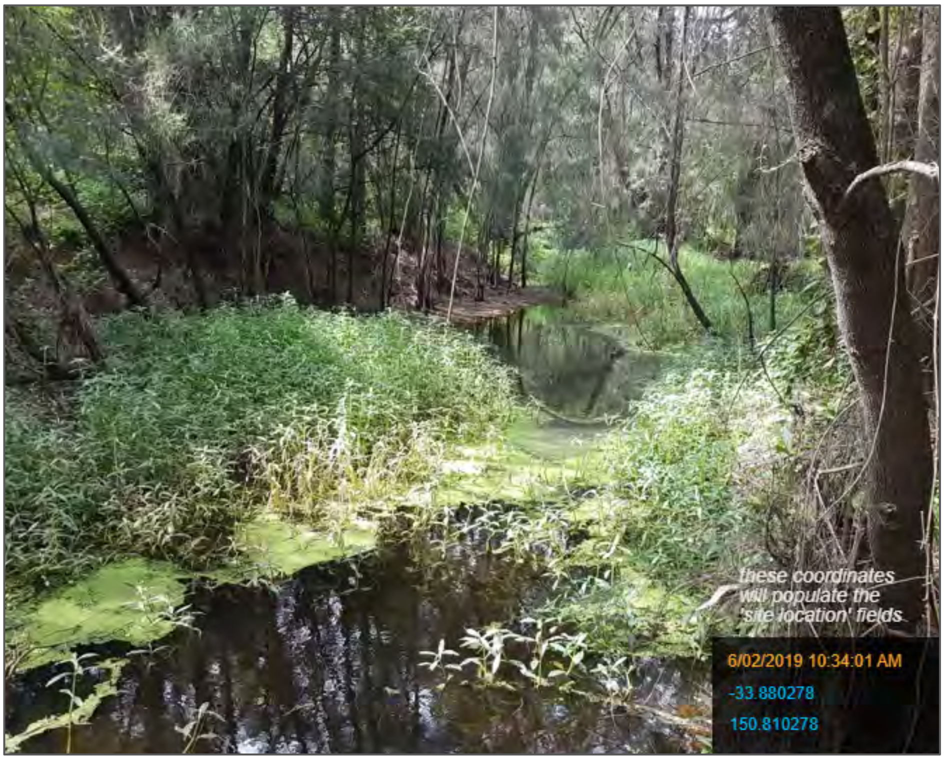

Figure 30 Kemps Creek at the site of the proposed Brine Pipeline alignment.

The section of Prospect Creek potentially affected by the proposed Brine Pipeline alignment is mapped as KFH. Field validation assessed the reach as Type 1 (highly sensitive Key Fish Habitat) and Class 1 (major Key Fish Habitat).

Type 1 (highly sensitive Key Fish Habitat) was awarded due to the presence of overhanging vegetation, natural bed detritus, snags greater than 300 mm in diameter or 3 m in length and native aquatic plants. Class 1 (major Key Fish Habitat) was awarded due to Prospect Creek being a large, permanently flowing body of water (Figure 31).

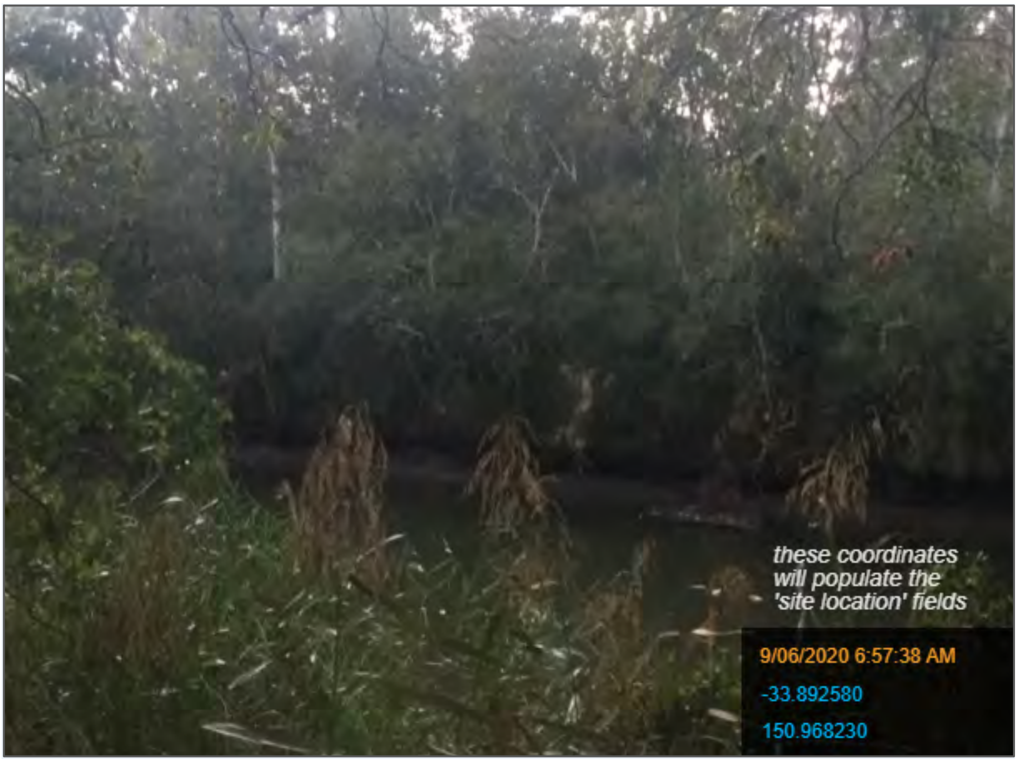

Figure 31 Creek at the site of the proposed Brine Pipeline alignment.

Figure 32 shows results of field validated Key Fish Habitat KFH Type for waterways potentially affected by the Brine Pipeline alignment. KFH Type is shown as this is the category on which the recommended width of vegetated riparian zones as per NSW Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) are based.

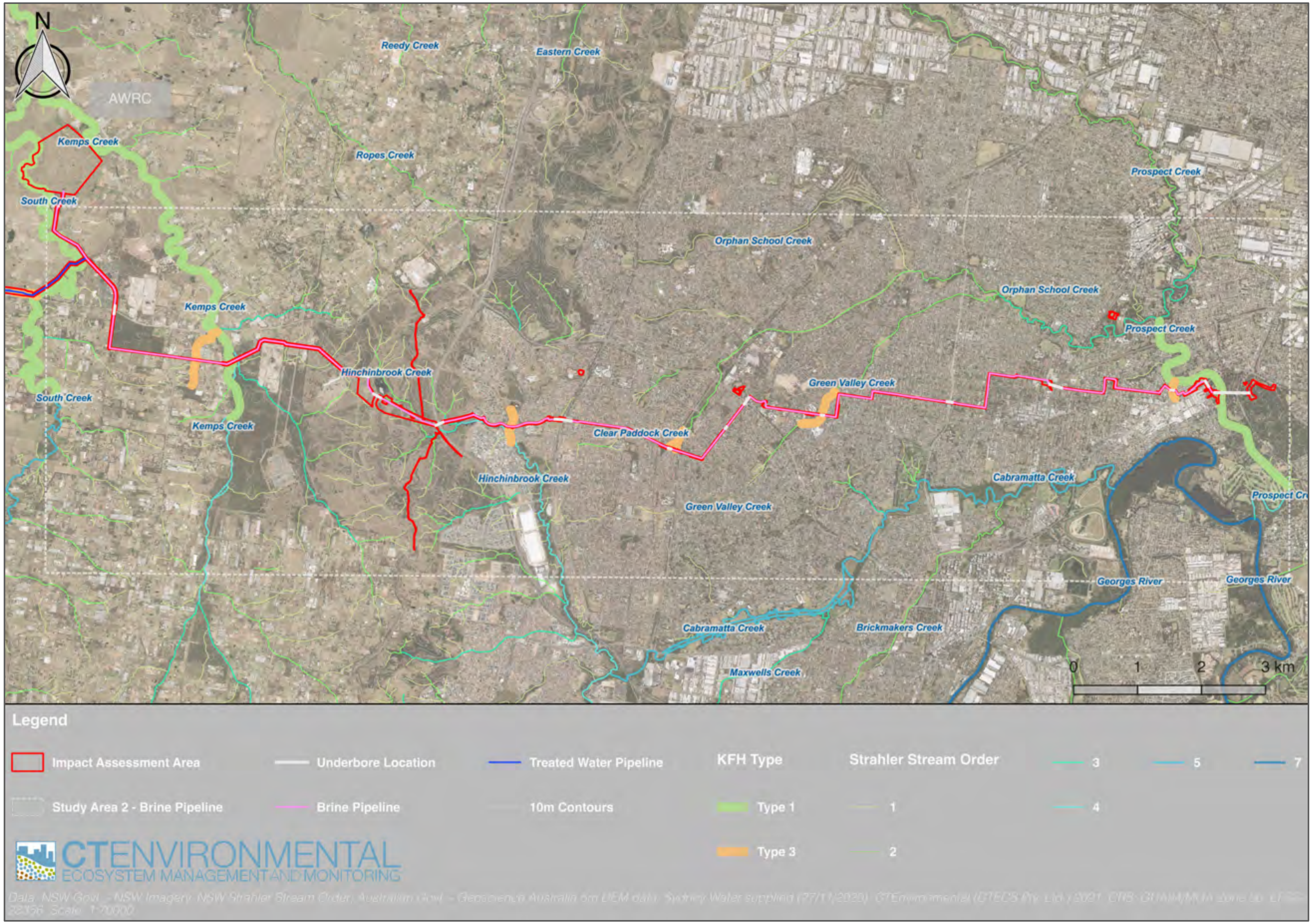

Figure 32 Field validated KFH Type – Study Area 2 – Brine Pipeline.

6.2.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs showed mapped terrestrial GDEs corresponded with the location of remnant native vegetation (Figure 33) (highly disturbed Metropolitan vegetation not mapped).

6.2.2.4 Riparian Vegetation and Creek Channel Condition

Seven assessments of riparian vegetation and creek channel condition were conducted along the proposed Brine Pipeline alignment and results show overall condition of creeks assessed ranged from good to degraded condition (Table 19 and Figure 34).

Two sites with the highest total scores were Prospect Creek-36 and Prospect Creek-37, both of which were assessed as being in good condition. In contrast, the lowest overall score was recorded for Green Valley Creek-32, which was in degraded condition.

Erosion and deposition impacts ranged from low to high, being greatest at Hinchinbrook Creek-38. The riparian buffer was wide at Prospect Creek-36 and Prospect Creek-37 (>40 m), however was restricted at Green Valley Creek-32 and Prospect Creek tributary-34. Vegetation structural complexity ranged from moderate to low across the seven sites. Weeds were prevalent at all sites and were most abundant at Kemps Creek-49. There was variability in scores relating to site features, with the lowest at Green Valley Creek-32 and Prospect Creek tributary-34, and the highest score at Kemps Creek-49. Aquatic habitat scores varied from good at Kemps Creek tributary-12 and Kemps Creek-49, to poor at Green Valley Creek-32 and Prospect Creek tributary-34.

See Appendix A for summary reports.

Table 19 Riparian assessment scores and condition for sites along the proposed Brine Pipeline alignment.

	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Green Valley Creek-32	0	-12	-16.6	-16	-7.4	-4	Very Poor	37
Hinchinbrook Creek-38	-8	12	6.6	-16	5.8	-3	Poor	64
Kemps Creek-Trib-12	-1	12	0	-9	6.6	5	Fair	66
Kemps Creek-49	0	16	11.4	-20	14.2	5	Fair	71
Prospect Creek-37	-3	20	13.7	-6	12.5	3	Good	78
Prospect Creek-36	-3	20	13.7	-6	13.5	4	Good	78
Prospect Creek-Trib-34	-4	-12	-16.6	-16	-7.4	-4	Very Poor	40

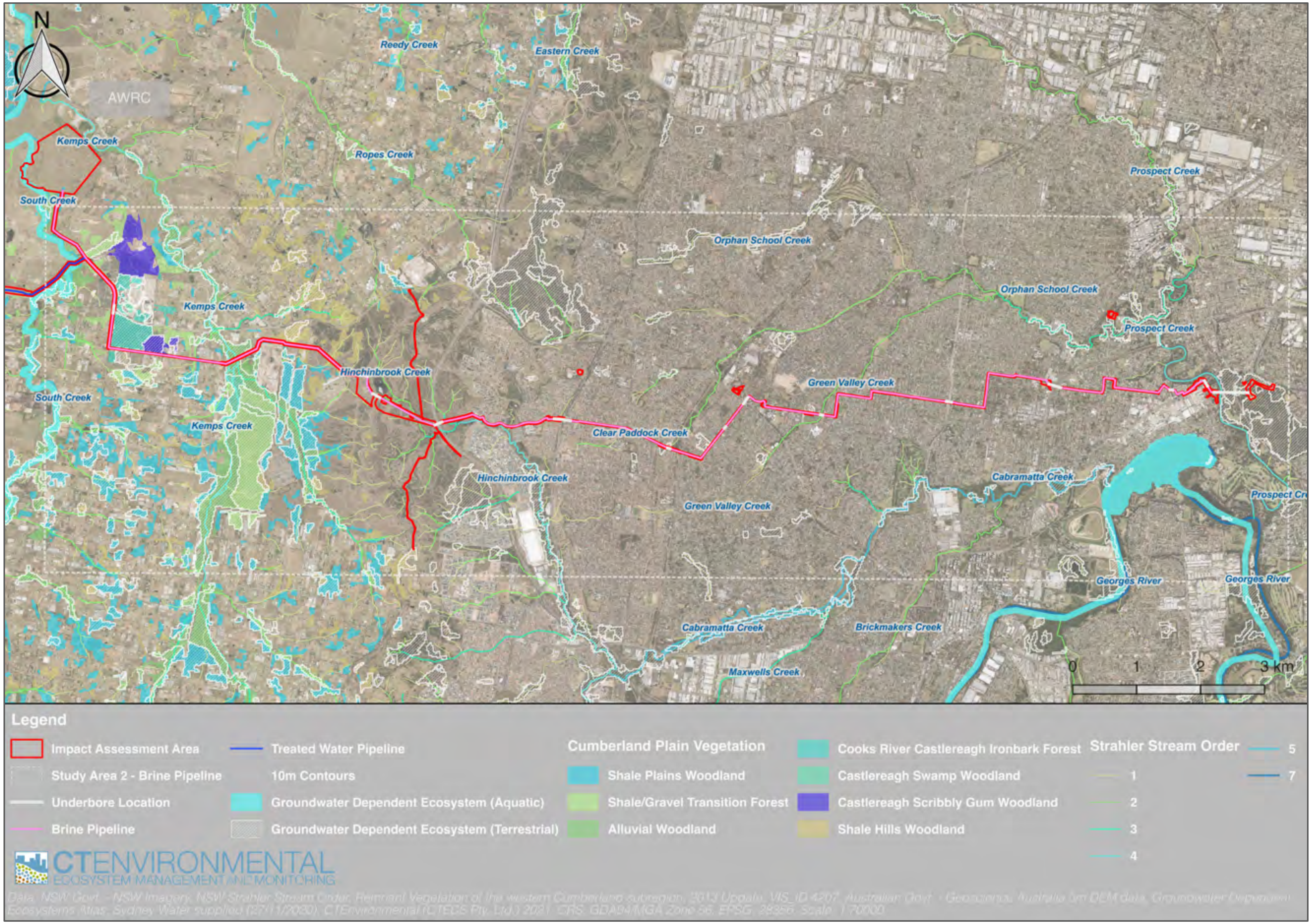

Figure 33 Groundwater Dependent Ecosystems and mapped remnant native vegetation in proximity to the Brine Pipeline alignment (Cumberland Plain vegetation only).

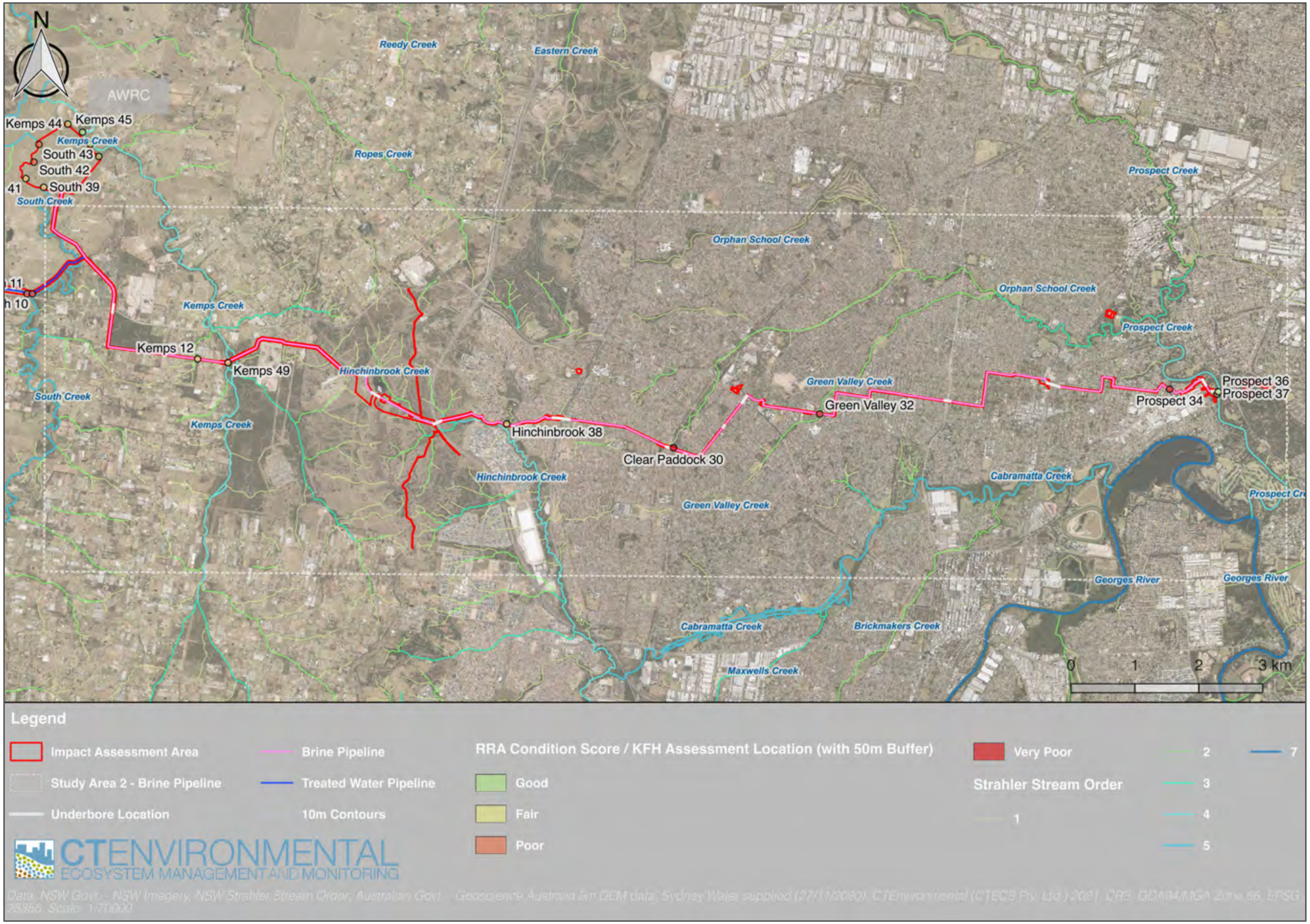

Figure 34 Riparian and creek channel condition scores and assessment site – Study Area 2 – Brine Pipeline.

6.2.3 Assessment of Potential Impacts – Construction Phase

The potential for detrimental impacts on the aquatic and riparian ecosystems would likely occur during the construction phase. It is proposed that underboring is the preferred method for construction for the Brine Pipeline beneath Prospect Creek, Green Valley Creek and Clear Paddock Creek and open trenching will be used to construct the pipeline through Kemps Creek and Hinchinbrook Creek and the unnamed tributaries of both creeks (Aurecon ARUP, 2021a).

A potential impact associated with underbore construction is the unintentional return of drilling fluid to the surface (“frac-outs”). This occurs when the pressures in the drilling fluid exceed the overburden pressure or if preferential pathways (e.g. fault lines, fractures or loose materials) are present.

Frac-outs can result in sedimentation within watercourses, groundwater and surface water quality impacts and harm to ecological communities (particularly in aquatic environments). This would include loss of aquatic biota including macroinvertebrate taxa and native fish.

There is also the low risk that subsidence to creek bed and banks could occur as a result of the underboring process which has potential to alter hydrology and increase erosion and sedimentation, both of which cause deleterious effects to aquatic biota.

A more significant risk to creek ecosystems will occur where the open trenching method is applied which is proposed for Kemps Creek and Hinchinbrook Creek and the unnamed tributaries of both creeks. Construction will require clearing of native vegetation and significant excavation of creek bed and bank. In most cases remnant vegetation along waterways is considered a Groundwater Dependent Ecosystems (Figure 33) and therefore, if removed, will cause significant impact to this community. Removal of native vegetation is addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required.

Open trenching has potential to add significant sediment load to waterways which in turn can cause serious impact to aquatic fauna and flora by way of smothering, in-filling habitat, reducing light penetration, blocking gills of fish and liberating nutrients bound to sediment.

Of particular focus is Kemps Creek which is considered Type 1 Key Fish Habitat and has a known Australian Bass population upstream of the proposed crossing. There is potential for significant, albeit temporary, impacts will occur to creek hydrology and connectivity while open trenching is in progress which in turn has potential to impact native fish.

Temporary bypass of creek waters will occur which will cause localized hydrological impacts, primarily drying of microhabitats which will potentially lead to loss of aquatic species with low mobility. Loss of connectivity is likely to be the most significant impact to the aquatic ecosystem during the 6-8 week period when open trenching will occur. Species such as fish and turtles are vulnerable to loss of creek connectivity, particularly

Australian Bass which undertake migration in late autumn/early winter and late spring/early summer to and from estuary reaches to spawn.

6.2.4 Assessment of Potential Impacts – AWRC Operational Phase

The brine pipeline does not have any overflow points so there will be no releases to the environment from the brine pipeline. If sections of the brine pipeline need to be drained for maintenance, these will be pumped to a tanker and disposed to Sydney Water's wastewater network or a suitable disposal facility. The only potential for releases from the brine pipeline is if it is damaged. Releases to waterways in these circumstances have the potential to cause residual impacts such as scour and erosion to creek bed and banks which has potential to degrade the aquatic ecosystem by increasing turbidity and depositing coarse sediments which may infill deep holes and smother benthic fauna and flora.

Brine releases also have potential to create saline shock to aquatic flora and fauna and trigger acute toxicity to less mobile species and migration of mobile species to areas with less saline waters.

No operational impacts to Groundwater Dependent Ecosystems are expected in the operation phase.

6.2.5 Recommendations to mitigate potential impacts

The risk of degradation to the aquatic and riparian ecosystem of creeks within the Brine Pipeline Alignment associated with underboring is low however these works do pose a risk of “frac-outs”.

It is recommended the steps described in Chapter 9.4 of the EIS are implemented to minimise the risk to aquatic ecology associated with potential frac-outs.

To mitigate potential and actual impacts associated with open trenching, Sydney Water (2021) have developed a comprehensive set of management measures to control the severity of impacts.

It is recommended that the surface water mitigation measures in Chapter 9.2 of the EIS (Sydney Water, 2021) be implemented to minimize potential impacts during the construction phase of the Brine Pipeline.

During the operational phase, Sydney Water's standard procedures for regular inspections and incident response will minimise the potential for leaks and breaks. Implementation of these will minimize potential sediment and erosion and water quality driven impacts to the aquatic ecosystem.

Riparian vegetation (which are also Groundwater Dependent Ecosystems in Kemps Creek) across the Brine Pipeline footprint is a combination of remnant native bushland, cleared areas and highly disturbed patches dominated by exotic species which in areas subject to open trenching will be cleared.

The impacts of clearing native vegetation have been addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required, however revegetation/restoration of native riparian vegetation are considered by this study.

The AWRC and associated infrastructure is considered State Significant Infrastructure (SSI) and therefore legislative requirements for retention and creation of vegetated riparian zones (VRZ) as per the *NSW Water Management Act* 2000 do not apply, however the principles of this *Act* should be followed.

Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013) recommend a VRZ width dependent on the assessed Type of Key Fish Habitat. However, this is a recommendation only and applying the VRZ widths as per the *NSW Water Management Act* 2000 will significantly enhance the riparian ecosystem from its current state.

It is recommended an appropriate VRZ according to stream order (Figure 35) and measured from top of bank should be applied to waterways disturbed by open trenching as per the principles outlined by "Guideline for Controlled Activities on Waterfront Land" (NSW Office of Water, 2012).

Kemps Creek and Prospect Creek are considered Key Fish Habitat and the migratory native fish, Australian Bass have been recorded in Kemps Creek, which is subject to open trenching, and therefore there is a risk that migration of this species is blocked. To mitigate the potential of this, Aurecon ARUP (2021a) recommend a staged coffer dam is constructed to minimize the need to block fish passage during trenching.

It is recommended construction of coffer dams and temporary in-stream structures associated with open trenching is taken from the Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013) which prescribes the following:

- Temporary in-stream structures should avoid spanning the full width of the waterway channel to ensure base flow conditions are maintained down the waterway. If a channel spanning structure is required, measures (e.g. diversion channel) will need to be implemented to ensure that minimum base flow conditions are maintained. Local stream gauges should be consulted to determine appropriate minimum base flows for the prescribed season that temporary works will be installed.

- Temporary in-stream structures should not be constructed from unconsolidated, imported earth fill material. Dispersive material (e.g. clays and sands) used in the construction of temporary in-stream structures should be fully enclosed by geotextile, sheet piling, or similar means to limit erosion and sedimentation within the waterway. If using rock fill, the rock should be clean of fines and of suitable size (≥ 150 mm diameter) to avoid erosion. Use of instream bed material will be evaluated on a case-by-case basis by NSW DPI and will be dependent upon the proponent demonstrating that the project has a net benefit to fish habitat and will not destabilize the waterway channel.

- Temporary in-stream structures should be inserted during low-flow periods, with management plans being submitted to NSW DPI detailing how high flow events will be managed to limit erosion of the structures and associated sedimentation of downstream waterways.

- Dewatering of temporary in-stream structure should adhere to the following guidelines:

- NSW DPI is to be notified 7 days prior to any dewatering activities in order to organize potential fish rescue activities. A separate s.37 permit may be required from NSW DPI to relocate fish.
- Water is to be pumped a minimum of 30 m away from the waterway and should preferentially not re-enter the waterway. If water is to re-enter the waterway, ANZECC water quality guidelines (or Wianamatta - South Creek Water Quality Objectives) need to be adhered to with the proponent being required to submit a detailed water quality monitoring program.

Additionally, it is recommended construction of open trenches, particularly Kemps Creek is avoided between late April and early June so not to disrupt downstream migration of Australian Bass and avoided from late October to late December to enable Bass to return to upper reaches of their preferred creek.

Post construction creek channel rehabilitation should be undertaken in all creeks where open trenching occurs. Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013) and Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) provide high level on rehabilitation of waterways.

It is recommended site specific rehabilitation plans are developed for each waterway subject to open trenching. Each plan should consider enhancing aquatic habitat and restoring the creek to an improved state. Rehabilitation plans should be ecology driven, not landscape design driven, and could be incorporated into the aforementioned Vegetation Management Plan.

Establishment of an appropriately revegetated and managed VRZ will improve on the current condition of the riparian corridors of waterways affected by the construction of the Brine Pipeline. This will result in benefits to both aquatic and terrestrial biodiversity in the form of enhancement of available habitat and food resources.

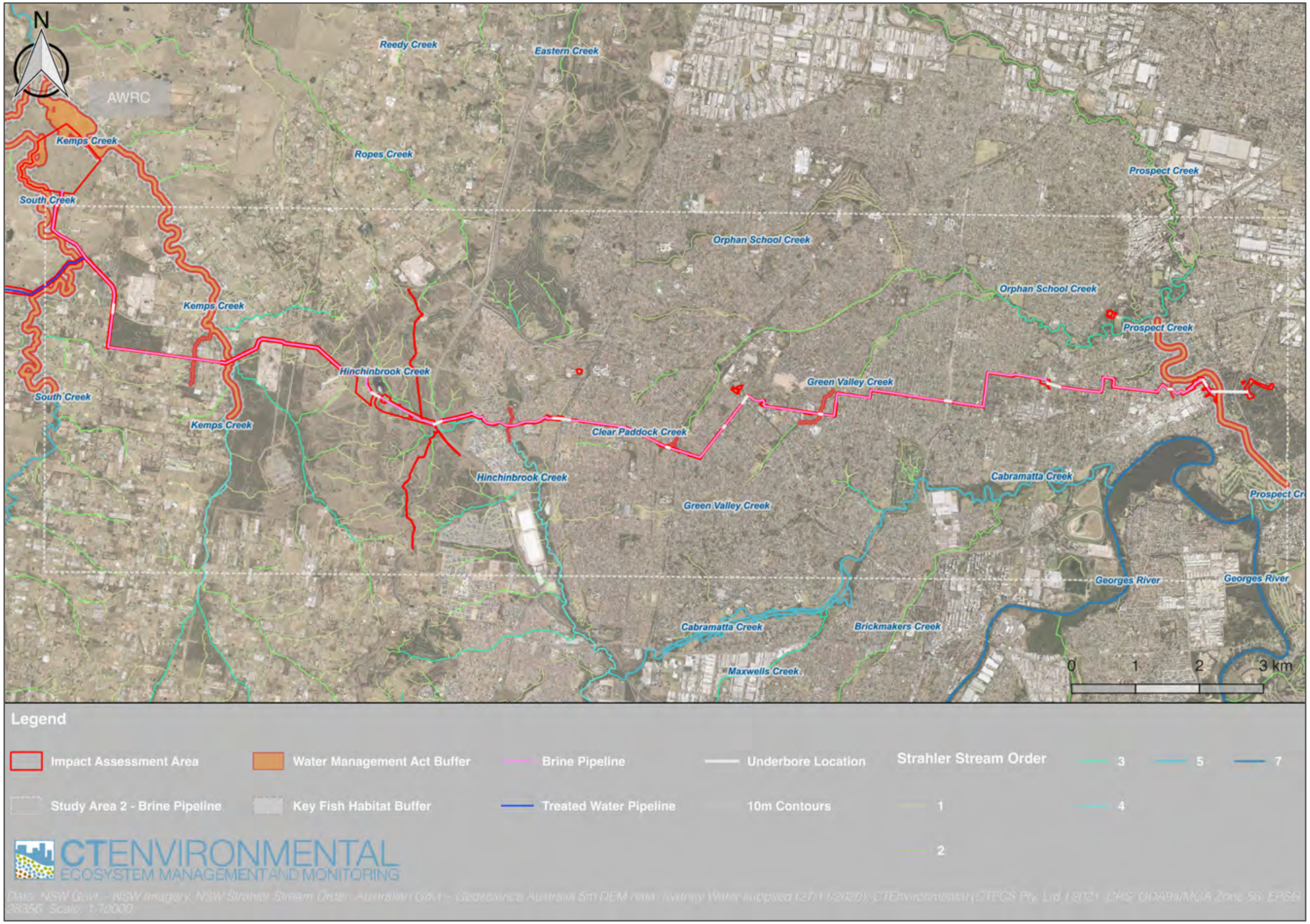

Figure 35 Vegetated Riparian Zones according to stream order as per WMA guidance for Study Area 2.

6.3 Study Area 3 - Treated Water Pipeline and Environmental Flows Pipeline

6.3.1 Desktop Review

6.3.1.1 Strahler stream order, Key Fish Habitat mapping and Threatened Species Distribution

Review of NSW statewide topographic mapping to determine Strahler stream ordering (SIX maps, 2021) showed that at the point of intersection with the treated water and environmental flows pipelines, Nepean River is considered 9th order, South Creek is a 6th order, Badgerys Creek, Cosgroves Creek and Jerry's Creek are 4th order streams, Oaky and Megarritys Creeks 3rd order, Baines Creek 2nd order and tributaries of Mulgoa Creek are 1st order (Figure 36).

Review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) shows that Nepean River, South Creek, Badgerys Creek, Cosgroves Creek, Jerrys Creek, Oaky Creek and Megarritys Creek are mapped as Key Fish Habitat (Figure 37). Baines Creek and tributaries of Mulgoa Creek are not mapped as Key Fish Habitat.

Waterways crossed by the treated water and environmental flows pipeline are not mapped as habitat for threatened species, there are no threatened species records (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020b), nor was any suitable habitat identified for threatened species, populations and ecological communities listed under Schedule 4, 4A and 5 of the NSW Fisheries Management Act 1994.

6.3.1.2 Matters of National Environmental Significance

No matters of MNES were mapped as present within the study area. Potential habitat was not identified.

6.3.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) shows that riparian vegetation of Badgerys Creek, Cosgroves Creek and Jerrys Creek are considered terrestrial GDEs. Additionally, there are patches of terrestrial GDEs adjacent to the treated water pipeline on the southern side of Park Road. Nepean River is considered an aquatic GDE (Figure 38).

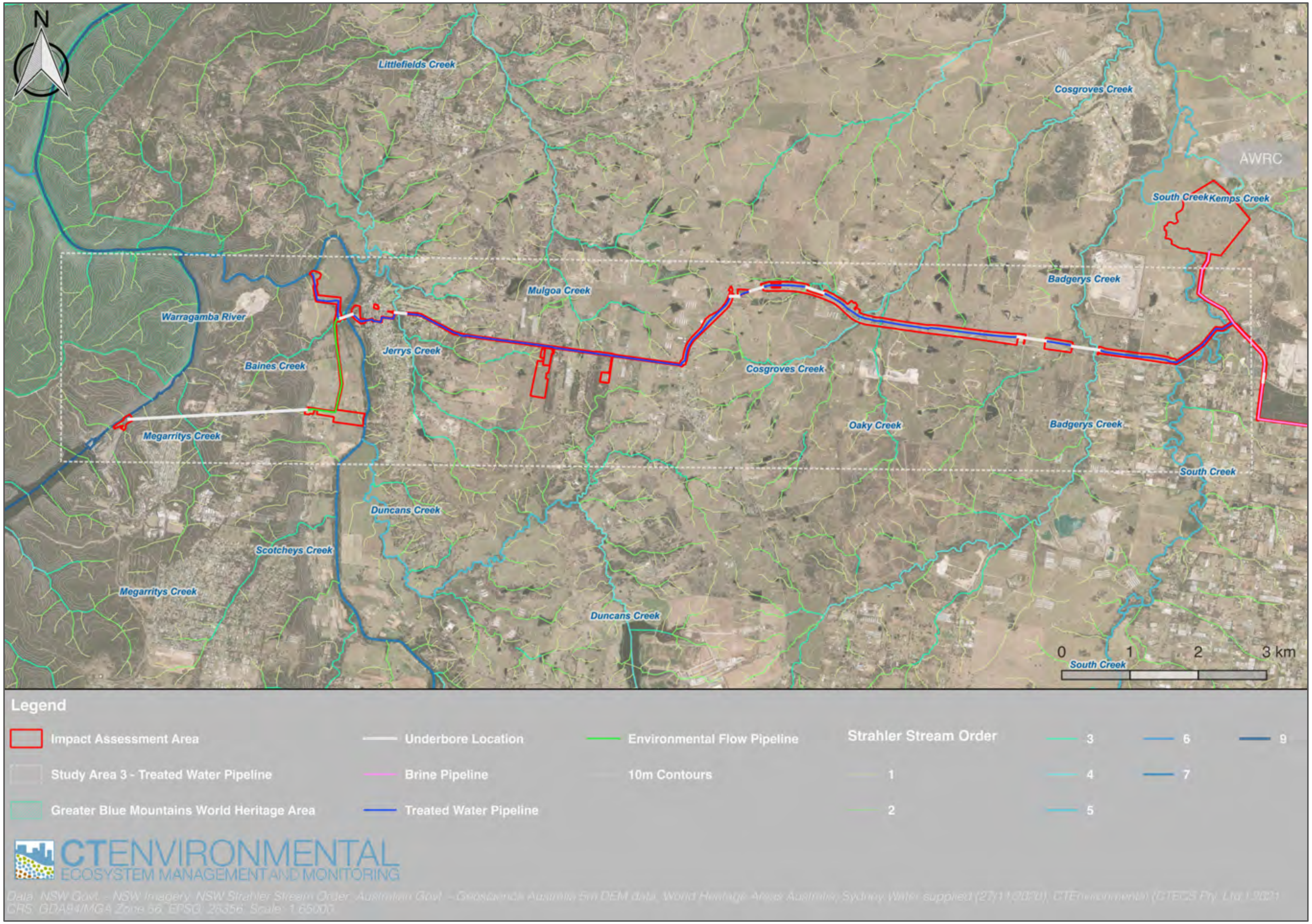

Figure 36 Strahler stream order of waterways within Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

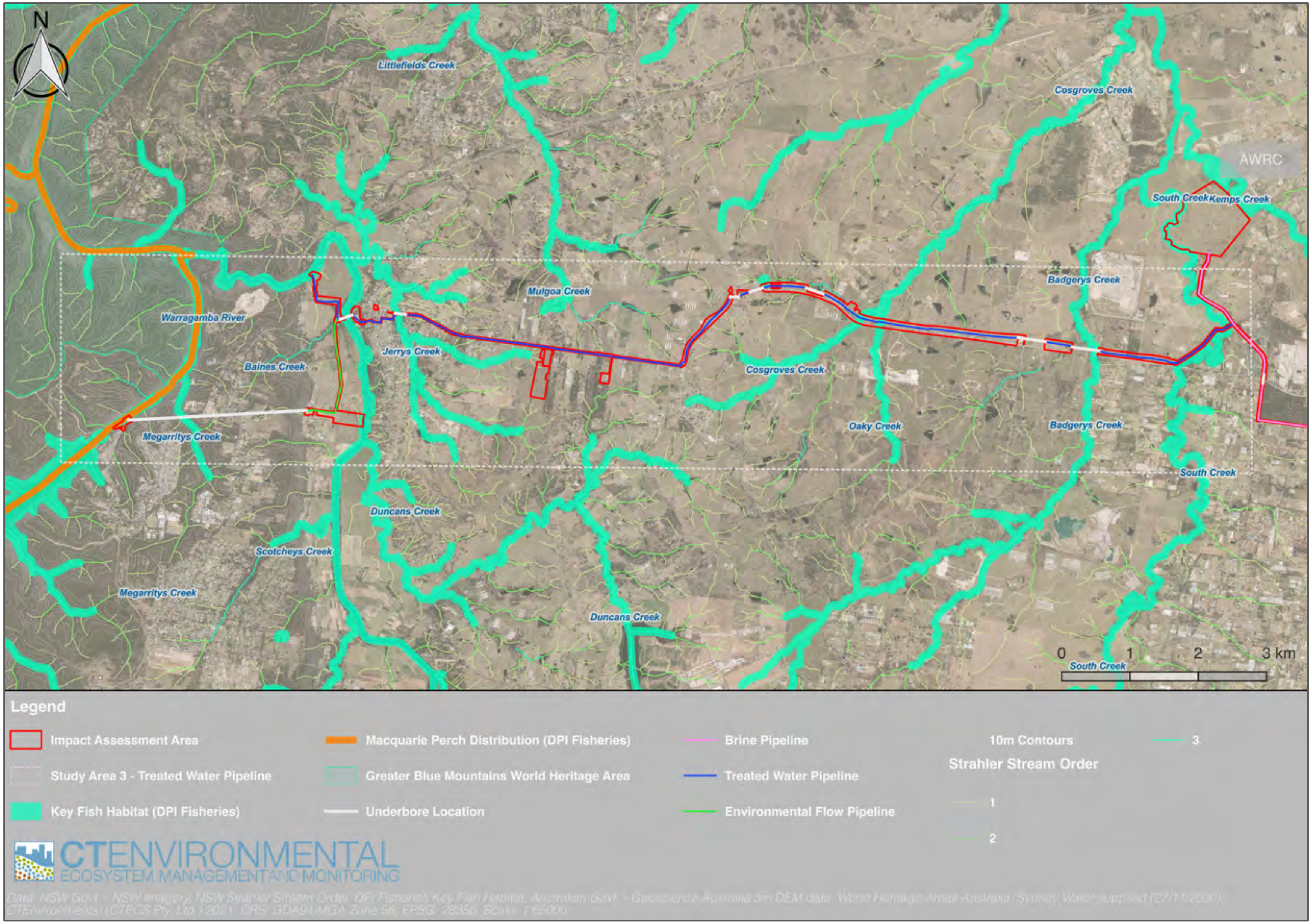

Figure 37 Mapped Key Fish Habitat (DPIE 2007) for Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

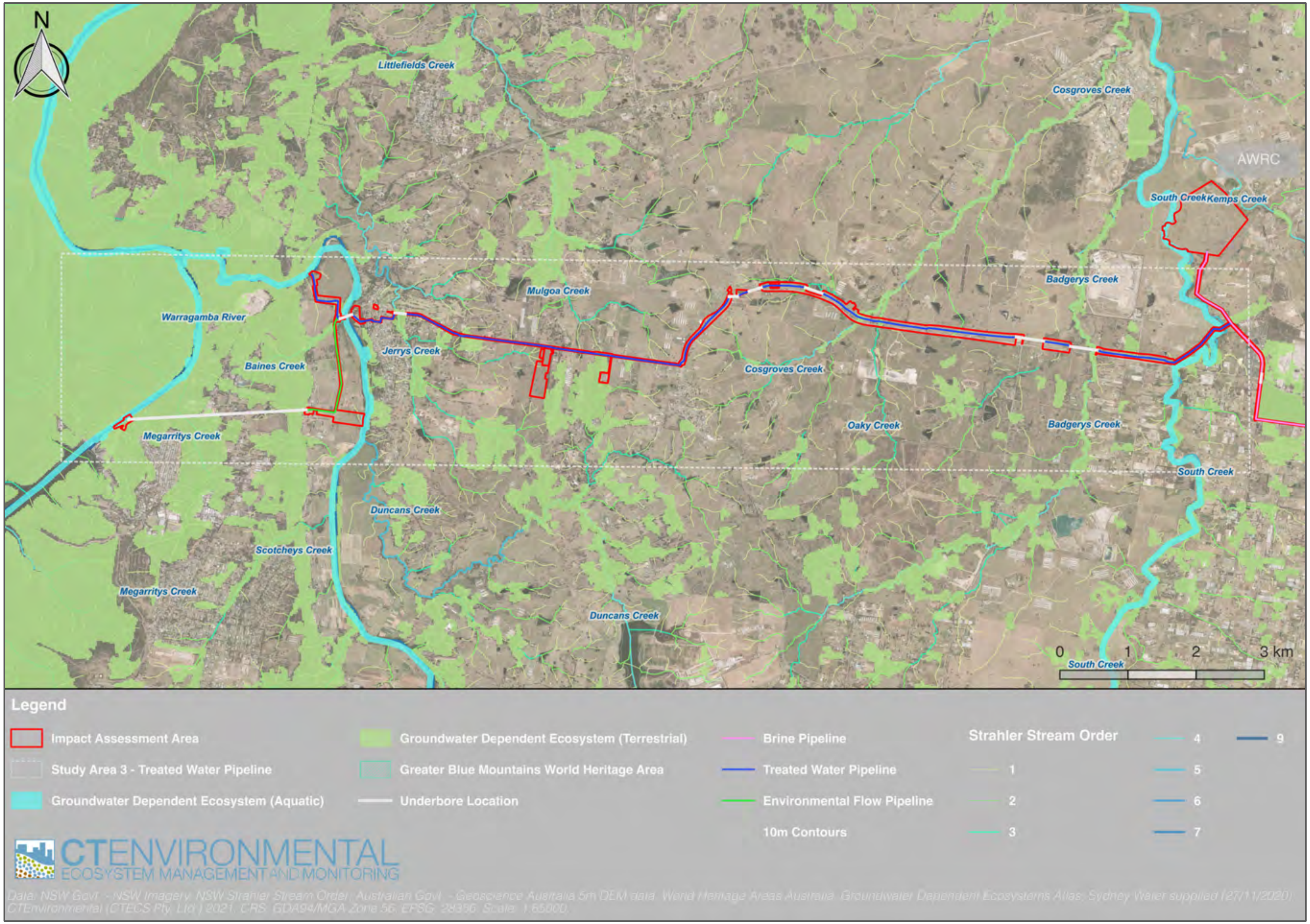

Figure 38 Mapped GDEs within and adjacent to Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

6.3.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes

Review of water quality, aquatic macroinvertebrate, fish survey and macrophyte monitoring data collected by Sydney Water relevant to Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline shows monitoring has been undertaken at South Creek and Badgerys Creek (Table 5 and Figure 4).

Data relevant to the Nepean River is presented in Study Areas 4 and 5 as potential impacts during construction and operation phase are of greater relevance to those areas.

Review of water quality data for South Creek (NS45) showed median concentrations of dissolved oxygen, electrical conductivity, pH and turbidity were compliant with the waterway objectives for Wianamatta – South Creek, while total nitrogen and total phosphorus were not compliant.

Results for Badgerys Creek (NS440) show all parameters with exception of TP were compliant with the Water Quality Objectives for Wianamatta - South Creek (Table 20).

Table 20 Median values for water quality parameters monitored by Sydney Water within close proximity of Study Area 3 (January 2018 to June 2021). Red text indicate result is outside the Waterway Objectives

Site	DO (% Saturation)	EC (mS/cm)	pH	Turbidity (NTU)	TN (mg/L)	TP (mg/l)
NS45 (South Creek)	70.3	1062	7.4	32.5	1.78	0.24
NS440 (Badgerys Creek)	59.9	1070	7.2	11	1.49	0.195
Waterway Objectives for Wianamatta – South Creek	43-75	1103	6.2-7.60	37	1.72	0.14

Results of aquatic macroinvertebrate monitoring at Badgerys Creek are indicative that the waterway is exposed to frequent high-level disturbance events which is evidenced by low EPT% and SIGNAL-SG scores (Table 21). The macroinvertebrate community assemblage recorded at this site was dominated by pollution tolerant taxa and lacked disturbance sensitive taxa, results which reflect compromised water quality and habitat disturbance which are typical of urban, peri urban and agricultural catchments. For contrast SIGNAL-SG scores of > 6 and EPT% of > 30% are indicative of minimally impacted waterways (Sydney Water, 2020).

Table 21 Mean values for macroinvertebrate parameters monitored by Sydney Water within close proximity of Study Area 3.

Site	Year Range of Data Collected	Abundance	Family Richness	%EPT	SIGNAL-SG
NS440	2020	75.3	20.4	9.8	4.3
NS45 (South Ck)	2006-2020	75.5	18.6	2.8	4.3

Results of macrophyte monitoring recorded ten species of macrophytes in Badgerys Creek (NS440) and South Creek (NS45) (Table 22). The three exotic species recorded were *Alternanthera philoxeroides, Cabomba caroliniana and Salvinia molesta.* These species are listed as WoNS and are highly dispersive species that can form dense mats. The formation of dense mats restricts light penetration and can lead to anaerobic conditions. This in turn can cause the death of other aquatic life and the release of organic matter can trigger a eutrophication event.

Table 22 Macrophytes recorded by Sydney Water at Badgerys Creek monitoring site NS440 and NS45 between 2018 and 2020.

Scientific Name	Native / Exotic	South Creek	Badgerys Creek
Site Code		NS45	NS440
Alternanthera philoxeroides	Exotic	x	X
Cabomba caroliniana	Exotic		X
Salvinia molesta	Exotic	x	X
Azolla pinnata	Native	x	X
Lemna minor	Native	x	X
Schoenoplectus mucronatus	Native		X
Persicaria lapathifolia	Native		X
Typha	Native / Exotic		X
Ludwigia peploides	Native	X	
Vallisneria sp	Native	x	

6.3.2 Field Assessment

Field assessment was not undertaken on Baines Creek and Megarrity's Creek. At the time of survey, the proposed pipeline route did not cross Baines Creek therefore assessment was not required. Megarrity's Creek was not surveyed as the proposed pipeline is to be underbored approximately 47 m beneath the creek bed and as a result the risk a surface expression of any impacts is considered unlikely.

However, assessment and mitigation of potential impacts have been considered for these waterways.

6.3.2.1 Waterway Validation

Field validation of waterways subject to potential disturbance in Study Area 3 show that mapped waterways satisfy the definition of a "river" as per *NSW Water Management* Act 2000.

6.3.2.2 Key Fish Habitat

The proposed treated water pipeline to the Nepean River will cross the Nepean River, Badgerys Creek, Cosgroves Creek, Jerrys Creek, Mulgoa Creek, South Creek, Oaky Creek and several unnamed tributaries within Study Area 3 (Figure 43). The 2.5 km long environmental flows pipeline to Warragamba River will cross Baines Creek and Megarritys Creek. Baines Creek will be open trenched, and Megarritys Creek will be underbored at a depth of approx. 47 m.

Field validation of Key Fish Habitat (KFH) Type and Class following the framework outlined by Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) across Study Area 3 included assessment of South Creek and results show South Creek is considered Type 1 (highly sensitive Key Fish Habitat) and Class 1 (major Key Fish Habitat).

This result was due to the presence of overhanging vegetation, natural bed detritus, snags greater than 300 mm in diameter or 3 m in length, the presence of native aquatic plants and the permanency of water along this reach (Figure 39).

Figure 39 South Creek at the AWRC site – Type 1, Class 1 Key Fish Habitat.

The reach of Badgerys Creek subject to potential impact was mapped as KFH and field validated as Type 2 (moderately sensitive Key Fish Habitat) and Class 2 (moderate Key Fish Habitat).

This classification was awarded due to the presence of overhanging vegetation and snags greater than 300 mm in diameter or 3 m in length. This reach of Badgerys has an intermittent flow regime with clearly defined bed and bank, which supports permanent pools (Figure 40).

Figure 40 Badgerys Creek at the site of the proposed Treated Water Pipeline.

The reach of Cosgroves Creek subject to potential disturbance by the Treated Water Pipeline was mapped as KFH and field validated as Type 2 (moderately sensitive Key Fish Habitat) and Class 2 (moderate Key Fish Habitat).

This classification was due to the presence of overhanging vegetation, natural gravel bed and snags greater than 300 mm in diameter or 3 m in length. This reach of Cosgroves Creek has an intermittent flow regime with clearly defined bed and bank, which supports permanent pools (Figure 41).

Figure 41 Cosgroves Creek at the site of the proposed Treated Water Pipeline.

The reach of Jerrys Creek with potential to be affected by the Treated Water Pipeline was not mapped as KFH and field validated as Type 3 (minimally sensitive Key Fish Habitat) and Class 3 (minimal Key Fish Habitat). This was due to the ephemerality of the creek with sparse refugia and the lack of native aquatic vegetation or other habitat features such as overhanging vegetation and snags (Figure 42).

Figure 42 Jerrys Creek at the site of the proposed Treated Water Pipeline.

Mulgoa Creek tributaries with potential to be affected by the Treated Water Pipeline were not mapped as KFH and field validated as Type 3 (minimally sensitive Key Fish Habitat) and Class 4 (unlikely Key Fish Habitat). This was due to the ephemeral nature of the creek, no aquatic refuge and the lack of native aquatic or wetland vegetation.

South Creek tributaries with potential to be affected by the Treated Water Pipeline were not mapped as KFH and field validated as Type 3 (minimally sensitive Key Fish Habitat) and Class 3 (minimal Key Fish Habitat). This was due to the ephemeral nature of the creek with sporadic refuge and the lack of native aquatic vegetation or other habitat features such as overhanging vegetation and snags.

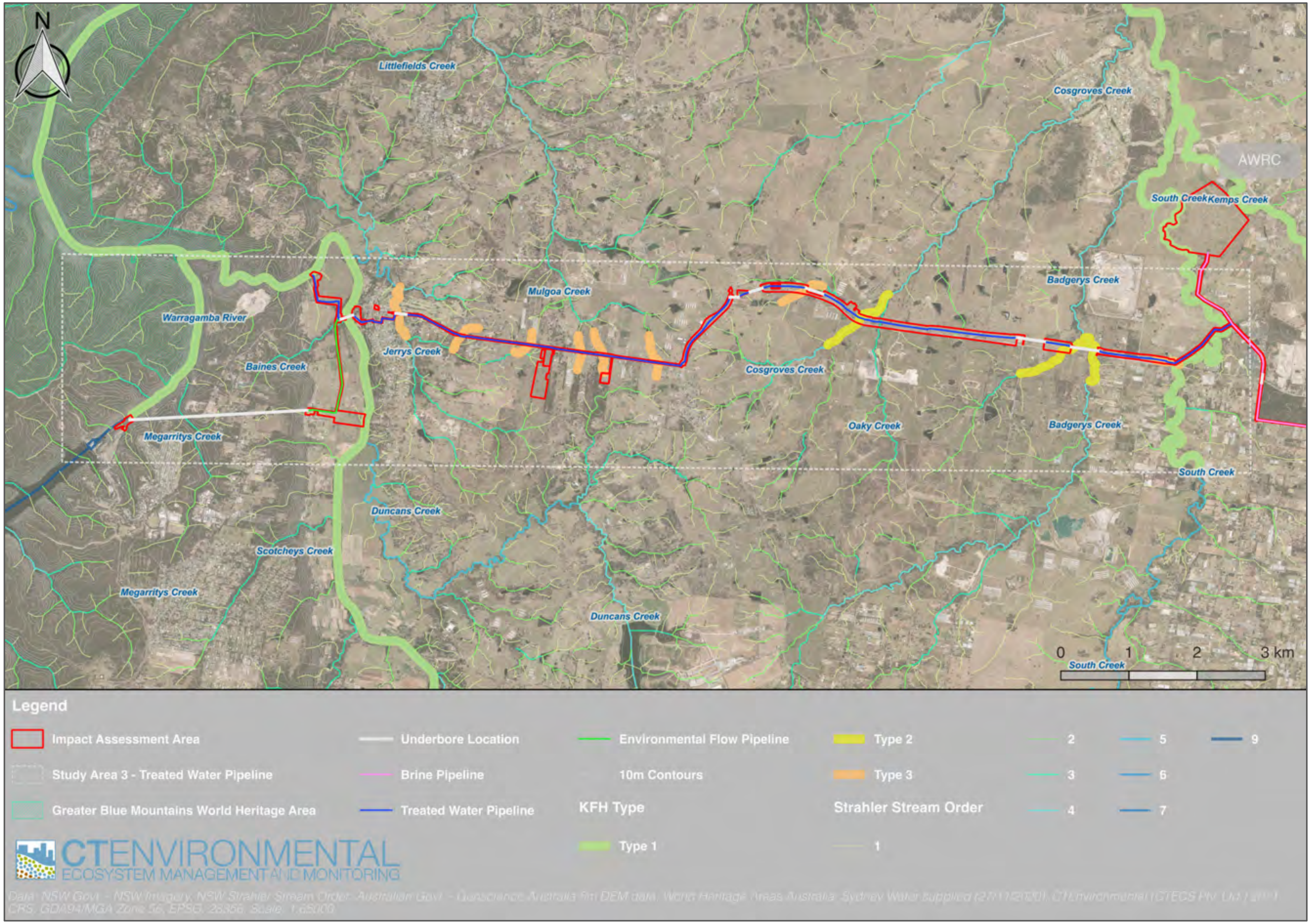

Figure 43 Field validated KFH Type – Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

6.3.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs showed mapped terrestrial GDEs corresponded to the location of remnant native vegetation (Figure 44). Impact assessment regarding native vegetation is detailed in the Biodiversity chapter of the EIS as assessment of impacts under the *Biodiversity Conservation Act 2017* is required.

6.3.2.4 Riparian Vegetation and Creek Channel Condition

Twenty assessments of riparian vegetation and creek channel condition were conducted along the proposed Treated Water Pipeline alignment, with overall condition ranging from good to very poor condition (Table 23 and Figure 45).

The two sites with the highest total scores were Badgerys Creek-7 and Badgerys Creek-8, which were in good condition. The site with the lowest overall score was a tributary of Mulgoa Creek-15, which was in very poor condition. The majority of sites were subject to moderate to high levels erosion and deposition. The width of the riparian buffer varied from wide to restricted and was absent at Jerrys Creek tributaries 22 and 23. Vegetation structural complexity overall was low, with the highest score at Badgerys Creek-7. Weeds were prevalent at all sites, being most abundant at Jerrys Creek-20. There was variability in scores relating to site features, with the lowest score at Mulgoa Creek tributary-16 and the highest at Jerrys Creek tributary-23.

When field surveys were undertaken, neither Baines Creek or Megarrity's Creek were in the IAA. As a result, these creeks were not included in the assessment.

See Appendix A for site summary reports.

Table 23 Riparian assessment scores for sites along the Treated Water Pipeline and Environmental Flows Pipeline.

	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Badgerys Creek-6	-5	12	3	-12	6.8	3	Poor	63
Badgerys Creek-7	-4	20	11.9	-6	13.1	3	Good	75
Badgerys Creek-Trib-8	-3	20	4.4	-9	8.4	6	Good	75
Badgerys Creek-Trib-9	-3	20	4.4	-9	8.4	6	Good	73
Cosgroves Creek-2	-1	12	-0.2	-9	1.6	4	Poor	58
Cosgroves Creek-3	-5	20	-0.2	-9	-0.4	2	Poor	61
Cosgroves Creek-4	-5	20	1.2	-6	4.6	3	Fair	67
Cosgroves Creek-5	-6	20	5.6	-6	6.4	4	Fair	69
Jerrys Creek-Trib-17	-5	12	-2.4	-18	1.2	4	Poor	56
Jerrys Creek-20	-7	6	-2	-26	5.6	-4	Poor	58
Jerrys Creek-21	-9	12	-1.1	-12	3	3	Poor	58

Jerrys Creek-Trib-23	-8	0	4.8	-18	14.4	4	Poor	53
Jerrys Creek-Trib-22	-7	0	5.8	-18	9.9	5	Poor	55
Mulgoa Creek-Trib-13	-5	12	1.8	-18	11.1	4	Fair	63
Mulgoa Creek-Trib-14	-2	12	-2.4	-9	1.2	4	Poor	57
Mulgoa Creek-Trib-15	-6	12	-2.4	-18	-2.8	0	Very Poor	45
Mulgoa Creek-Trib-16	-4	12	0	-18	-5.4	-7	Poor	49
Mulgoa Creek-Trib-26	0	12	-2.4	-9	-2.8	0	Poor	55
South Creek-Trib-11	0	20	2	-9	1	3	Poor	55
South Creek-Trib-10	0	20	4	-9	2.3	-3	Poor	57

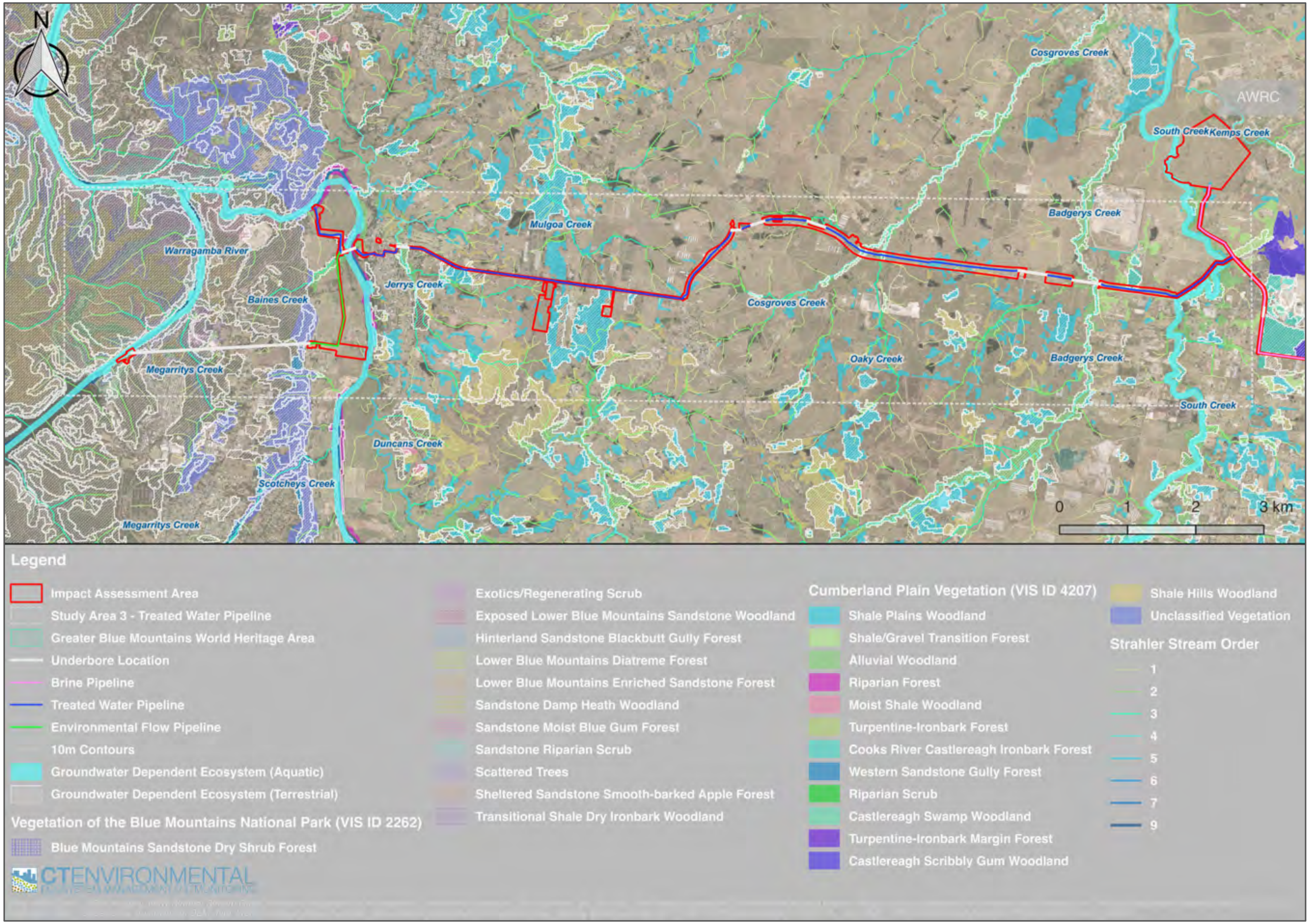

Figure 44 Groundwater Dependent Ecosystems and native vegetation – Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

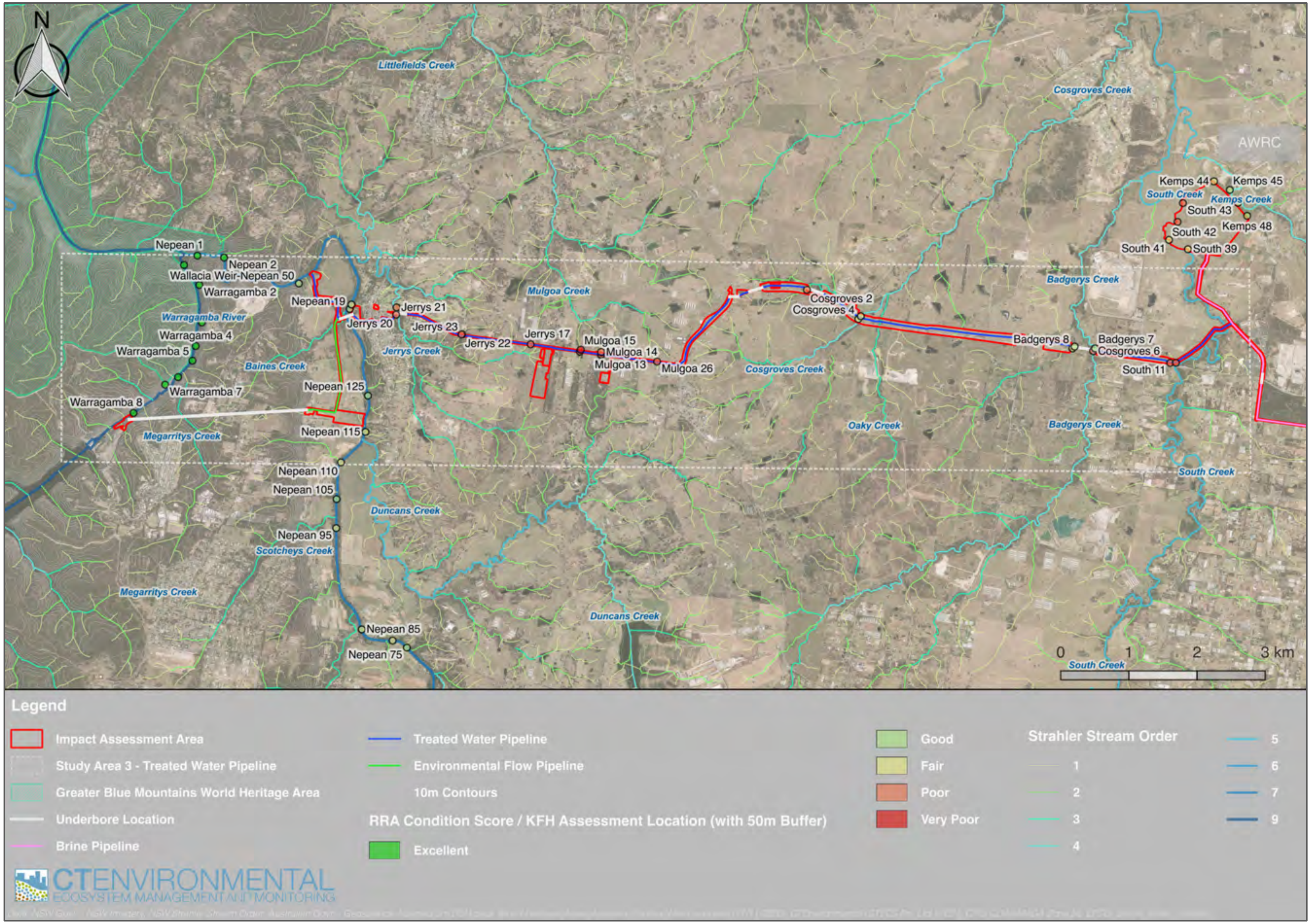

Figure 45 Results of riparian vegetation and creek channel assessment at Study Area 3 – Treated Water Pipeline and Environmental Flows Pipeline.

6.3.3 Assessment of Potential Impacts – Construction Phase

The potential for detrimental impacts to occur to the aquatic and riparian ecosystems would likely occur during the construction phase. It is proposed that underboring is the preferred method for construction for the Treated Water Pipeline beneath all creeks, with exception of South Creek, unnamed tributary of South Creek, unnamed tributary of Cosgroves Creek, and Oaky, Baines and Mulgoa Creek which will be subject to open trenching.

Review of the construction methodology provided by Sydney Water indicates there is low risk to causing significant impacts to waterways that will be underbored, however consideration has been given to spillage or loss of drilling fluid.

A potential impact associated with underbore construction is the unintentional return of drilling fluid to the surface ("frac-outs"). This occurs when the pressures in the drilling fluid exceed the overburden pressure or if preferential pathways (e.g. fault lines, fractures or loose materials) are present.

Frac-outs can result in sedimentation within watercourses, groundwater and surface water quality impacts and harm to ecological communities (particularly in aquatic environments). This would include loss of aquatic biota including macroinvertebrate taxa and native fish.

There is also the low risk that subsidence to creek bed and banks could occur as a result of the underboring process which has potential to alter hydrology and increase erosion and sedimentation, both of which cause deleterious effects to aquatic biota.

A 2.5 km section of the environmental flows pipeline is proposed to be underbored. This section passes beneath Megarritys Creek. No field assessment at Megarritys Creek was undertaken. However, there is very low risk to the ecological condition of the creek as it is proposed to be underbored at a depth of ~47 m.

Aurecon Arup (2021a) assessed the risks associated with frac-outs as low, provided mitigation measures were implemented. For recommendations of suitable mitigation measures see section 6.2.5.

A more significant risk to creek ecosystems will occur where the open trenching method is applied. Construction will require clearing of native vegetation (which are also considered Groundwater Dependent Ecosystems) and significant excavation of creek bed and bank. Construction will require clearing of native vegetation and significant excavation of creek bed and bank. In most cases remnant vegetation along waterways is considered a Groundwater Dependent Ecosystems and therefore, if removed, will cause significant impact to this community. Removal of native vegetation is addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required.

Open trenching has potential to add significant sediment load to waterways which in turn can cause serious impact to aquatic fauna and flora by way of smothering, in-filling habitat, reducing light penetration, blocking gills of fish and liberating nutrients bound to sediment.

Of particular interest is South Creek and the unnamed tributary of Badgerys Creek, both of which are considered Key Fish Habitat and South Creek has known population of Australian Bass upstream of the pipeline crossing. It is recommended that an appropriate construction management plan and vegetation management plan be adopted to ensure no ecological degradation occurs as a result of open trenching through waterways.

It is likely that during construction of the open trenched crossings, significant, albeit temporary, impacts will occur to creek hydrology and connectivity. Temporary bypass of creek waters will occur which will cause localized hydrological impacts, primarily drying of microhabitats which will potentially lead to loss of aquatic species with low mobility. Loss of connectivity is likely to be the most significant impact to the aquatic ecosystem during the 6-8 week period when open trenching will occur. Species such as fish and turtles are vulnerable to loss of creek connectivity, particularly Australian Bass which undertake migration in late autumn/early winter and late spring/early summer to and from estuary reaches to spawn.

6.3.4 Assessment of Potential Impacts – AWRC Operational Phase

The treated water pipeline or the environmental flows pipeline do not have any overflow points so there will be no typical release from the pipeline except at the release structures at Nepean and Warragamba Rivers, discussed in other sections. If sections of the treated water pipeline need to be drained for maintenance, these will be released via scour valves, most likely to local waterways. The only other potential for releases from the treated water pipeline is if it is damaged or leaks and the pipelines are designed to minimise this risk. Releases near waterways in these circumstances have the potential to residual impacts such as cause scour and erosion to creek bed and banks which has potential to degrade the aquatic ecosystem by increasing turbidity and depositing coarse sediments which may infill deep holes and smother benthic fauna and flora.

Releases are unlikely to affect aquatic flora and fauna as the treated water is likely to be of higher quality than that of the receiving waterways.

No operational impacts to Groundwater Dependent Ecosystems are expected in the operation phase.

6.3.5 Recommendations to mitigate potential impacts

The risk of degradation to the aquatic and riparian ecosystem of creeks within the Treated Water Pipeline Alignment associated with underboring is low however these works do pose a risk of “frac-outs”. Mitigation measures to minimise the risk of “frac-outs” can be found in section 6.6.1.

To mitigate potential and actual impacts associated with open trenching, Sydney Water (2021) have developed a comprehensive set of management measures to control the severity of impacts.

It is recommended that the surface water mitigation measures in Chapter 9.2 of the EIS (Sydney Water, 2021) be implemented to minimize potential impacts during the construction phase of the Treated Water Pipelines. During the operational phase, Sydney Water's standard procedures for scour valve releases to waterways from the treated water pipeline will minimise the potential for leaks and breaks. Implementation of these will minimize potential sediment and erosion driven impacts to the aquatic ecosystem.

Riparian vegetation (which are also considered Groundwater Dependent Ecosystems) across the Treated Water Pipeline is a combination of remnant native bushland, cleared areas and highly disturbed patches dominated by exotic species which in areas subject to open trenching will be cleared.

The impacts of clearing native vegetation have been addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required, however revegetation/restoration of native riparian vegetation are considered by this study.

The AWRC and associated infrastructure is considered State Significant Infrastructure (SSI) and therefore legislative requirements for retention and creation of vegetated riparian zones (VRZ) as per the *NSW Water Management Act* 2000 do not apply, however the principles of this *Act* should be followed.

Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013) recommend a VRZ width dependent on the assessed Type of Key Fish Habitat. However, this is a recommendation only and applying the VRZ widths as per the *NSW Water Management Act* 2000 will significantly enhance the riparian ecosystem from its current state.

It is recommended an appropriate VRZ according to stream order (Figure 46) and measured from top of bank should be applied to waterways disturbed by open trenching as per the principles outlined by "Guideline for Controlled Activities on Waterfront Land" (NSW Office of Water, 2012).

South Creek is considered Type 1 KFH and Cosgroves Creek and Badgerys Creek Type 2 KFH. The migratory native fish, Australian Bass have been recorded in South Creek, which is subject to open trenching, and therefore there is a risk that migration of this species is blocked. To mitigate the potential of this, Aurecon ARUP (2021a) recommend a staged coffer dam is constructed to minimize the need to block fish passage during trenching.

It is recommended construction of coffer dams and temporary in-stream structures associated with open trenching is taken from the Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013). Refer to section 6.2.5 for detailed information on effective management of instream works. Additionally, it is recommended construction of open trenches, particularly South Creek is avoided between late April and early June so not to disrupt downstream migration of Australian Bass and avoided from late October to late December to enable Bass to return to upper reaches of their preferred creek.

To reduce residual impacts associated with instream works, post construction creek channel rehabilitation should be undertaken in all creeks where open trenching occurs. Policy and Guidelines for Fish Habitat

Conservation and Management (DPIE, 2013) and Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003) provide high level on rehabilitation of waterways.

It is recommended site specific rehabilitation plans are developed for each waterway subject to open trenching. Each plan should consider enhancing aquatic habitat and restoring the creek to an improved state. Rehabilitation plans should be ecology driven, not landscape design driven, and could be incorporated into the aforementioned Vegetation Management Plan.

Establishment of an appropriately revegetated and managed VRZ will improve on the current condition of the riparian corridors of waterways affected by the construction of the Treated Water Pipeline. This will result in benefits to both aquatic and terrestrial biodiversity in the form of enhancement of available habitat and food resources.

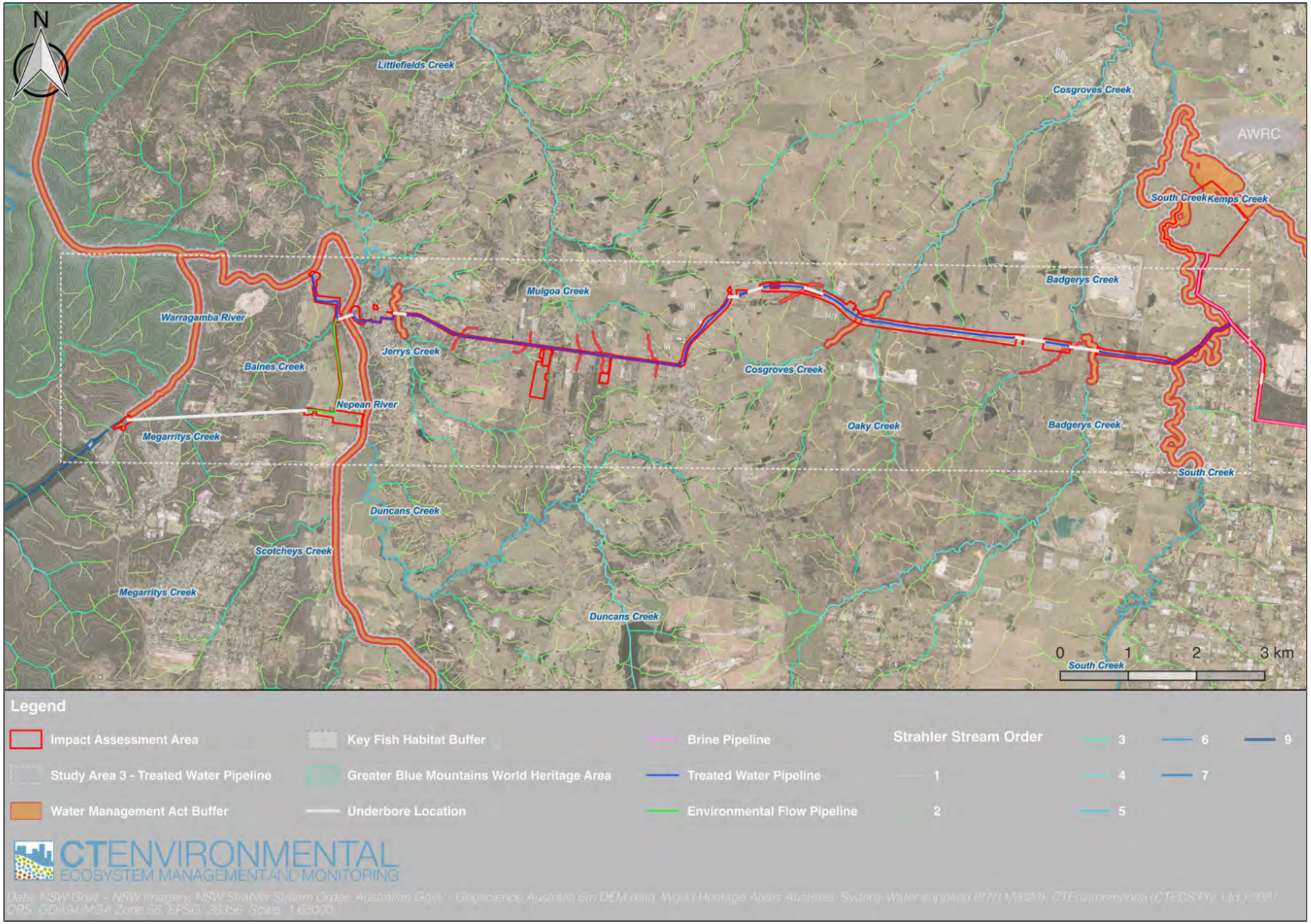

Figure 46 Vegetated Riparian Zones according to stream order as per WMA guidance for Study Area 3.

6.4 Study Area 4 - Warragamba River and Warragamba River Discharge Point

6.4.1 Desktop Review

6.4.1.1 Strahler stream order, Key Fish Habitat mapping and Threatened Species Distribution

Review of NSW statewide topographic mapping to determine Strahler stream ordering (SIX maps, 2021) showed the Warragamba River is considered a 9th order stream (Figure 47).

Review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) and Freshwater Threatened Species Distribution (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020b) shows the Warragamba River is mapped as Key Fish Habitat (Figure 48) and the Warragamba River is considered habitat for the Macquarie Perch (*Macquaria australasica*) which is listed as threatened under the NSW *Fisheries Management Act 1994*. No habitat or records for any other threatened species have been identified.

As a result of Macquarie Perch being potentially present in Study Area 4, this study includes a 7 Part Test of Significance for this species under the FM Act

6.4.1.2 Matters of National Environmental Significance

Review of the Matters of National Environmental Significance (MNES) database shows Macquarie Perch (*Macquaria australasica*) is listed as endangered and the Blue Mountains World Heritage Area is considered a matter of MNES under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC). However, the assessment of potential impacts to the Blue Mountains World Heritage Area is beyond the scope of this report. No habitat or records for any other threatened species have been identified.

As a result of Macquarie Perch being potentially present in Study Area 4, this study includes a Commonwealth Test of Significant Impact under the EPBC Act.

6.4.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) shows the Warragamba River is considered aquatic GDE and terrestrial GDEs are mapped along the banks of the river (Figure 49).

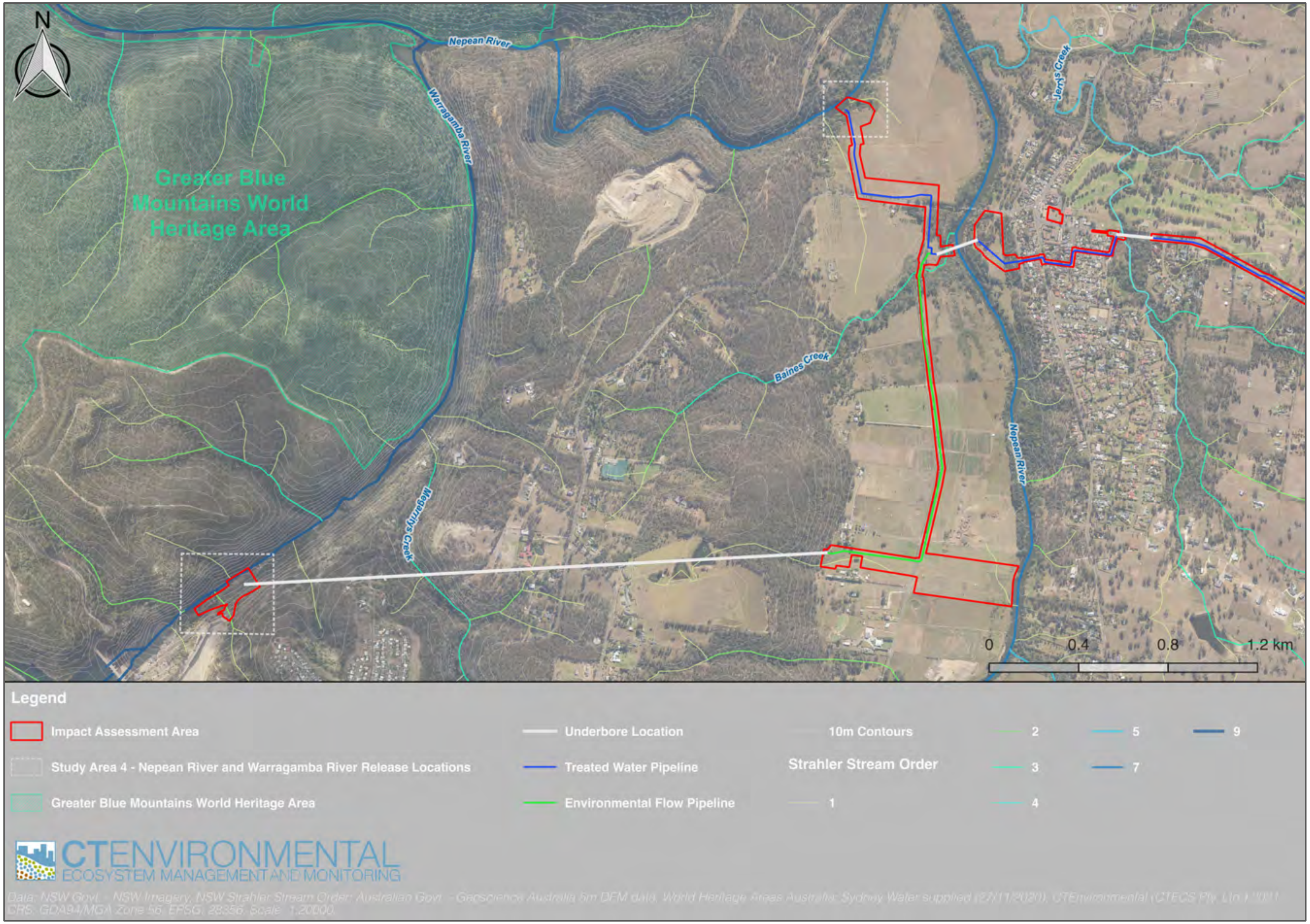

Figure 47 Strahler stream order of waterways within Study Area 4 – Warragamba River and Warragamba River Release Point.

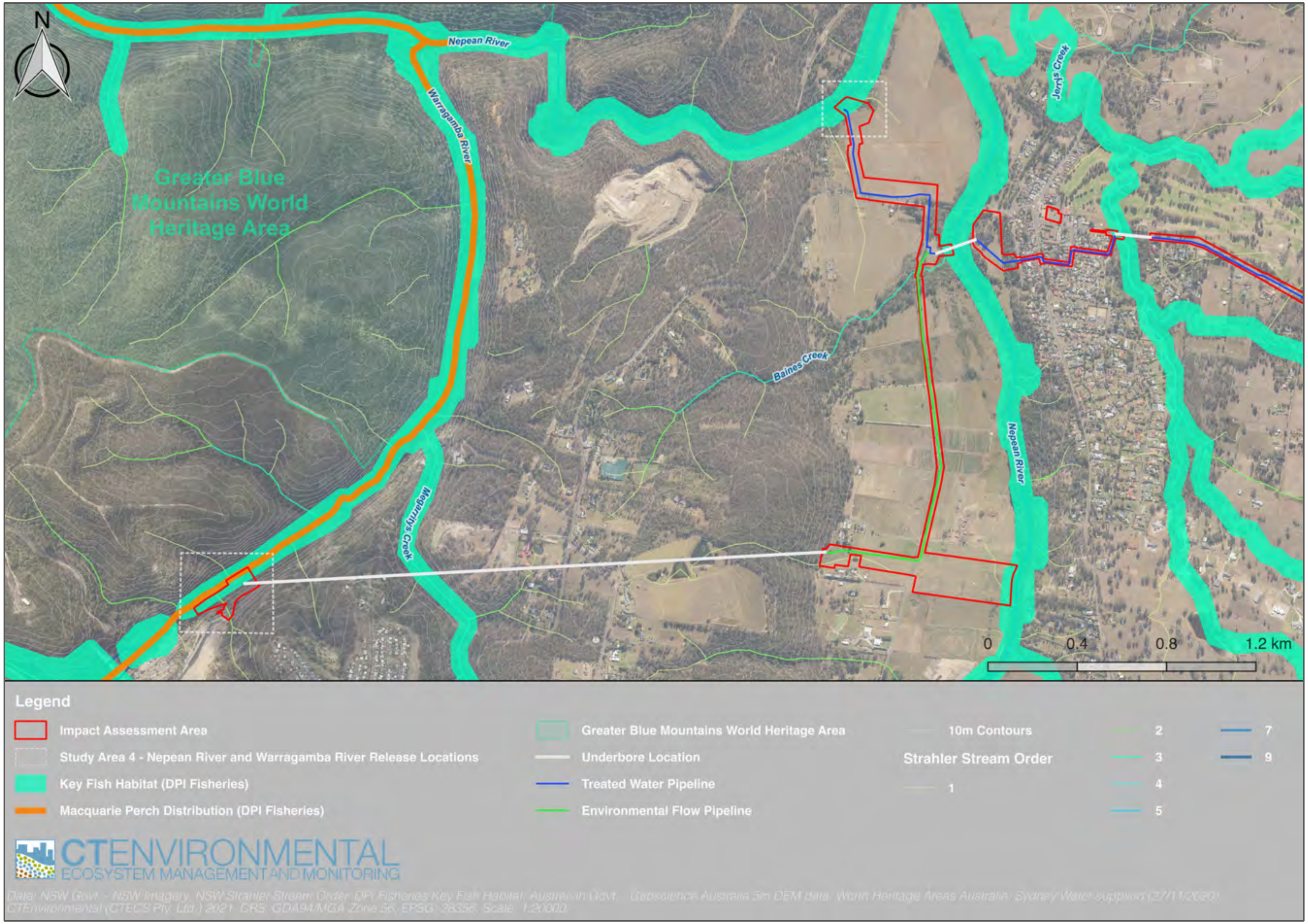

Figure 48 Mapped Key Fish Habitat (DPIE 2007) MNES and Macquarie Perch distribution relative to Study Area 4 – Warragamba River and Warragamba River Release Point.

Figure 49 Mapped GDEs within and adjacent to Study Area 4 – Warragamba River and Warragamba River Release Point.

6.4.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes

Review of water quality, aquatic macroinvertebrate, fish survey and macrophyte monitoring data collected by Sydney Water relevant to Study Area 4 – Warragamba River shows data has been collected at three sites in close proximity to proposed release point (Table 5 and Figure 4).

Results of water quality monitoring from sites in proximity to Study Area 4 shows median values for the majority of parameters at all sites, with the exception of total nitrogen at N642A and N641 and turbidity at N641 and N642, were within the Waterway Objectives for Nepean and Warragamba Rivers (Table 24).

Table 24 Median values for water quality parameters monitored by Sydney Water within close proximity of Study Area 4 (January 2018 to June 2021). Red text indicates result is outside the Waterway Objectives for Nepean and Warragamba Rivers.

Site	DO (% Saturation)	EC (uS/cm)	pH	Turbidity (NTU)	TN (mg/L)	TP (mg/l)
N642	85.2	242	7.0	4.3	0.19	0.01
N642A	98	207	7.5	9.9	0.81	0.01
N641	99.8	245	7.5	3.4	0.44	0.01
Waterway objectives for Nepean and Warragamba Rivers	85 - 110	125 - 2,200	6.5 – 8.0	6 - 50	0.35	0.025

Results of macroinvertebrate monitoring at sites within Warragamba River indicate a moderate level of disturbance is evident which is reflected by a relatively low Family richness and EPT%. 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 the River is subject to releases from Warragamba Dam, it is likely that a combination of altered hydrology and elevated nutrient concentrations influence the macroinvertebrate community (Table 25) and slight alteration from a minimally disturbed waterway is indicated by the SIGNAL-SG scores slightly below 6.0.

Table 25 Mean values for macroinvertebrate indices monitored by Sydney Water within close proximity of Study Area 4.

Site	Year range of data collected	Abundance	Family Richness	%EPT	SIGNAL-SG
N642	2002 - 2020	59.0	17.7	12.2	5.2
N642A	2020	40.0	13.0	7.4	5.1

N641	2002 - 2020	70.6	19.7	17.9	5.2

Results of macrophyte monitoring show five exotic macrophyte species were recorded in the Warragamba River which included *Alternanthera philoxeroides, Egeria densa, Eichhornia crassipes, Hydrilla verticillate* and *Ranunculus sceleratus* (Table 26).

Thirteen native or naturalized species were recorded in the Warragamba River which included Azolla pinnata, Ceratophyllum demersum, Cyperus difformis, Ludwigia peploides, Maundia triglochinoides, Potamogeton crispus, Potamogeton ochreatus, Potamogeton sulcatus, Schoenoplectus mucronatus, *Typha sp., Vallisneria sp. and Persicaria lapathifolia.

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.

Table 26 Macrophytes recorded by Sydney Water at Warragamba River monitoring sites N641, N642 and N642A between 2018 and 2020.

Scientific Name	Native / Exotic	Warragamba River	Warragamba River	Warragamba River
		N641	N642	N642A
Alternanthera philoxeroides	Exotic	X	X	-
Egeria densa	Exotic	-	X	-
Eichhornia crassipes	Exotic	X	-	X
Hydrilla verticillata	Exotic	X	X	-
Ranunculus sceleratus	Exotic	-	X	-
Azolla pinnata	Native	X	-	-
Ceratophyllum demersum	Native	X	-	-
Cyperus difformis	Native	-	X	-
Ludwigia peploides	Native	-	X	X
Maundia triglochinoides	Native	X	-	-
Potamogeton crispus	Native	X	X	X
Potamogeton ochreatus	Native	X	X	X
Potamogeton sulcatus	Native	-	X	-
Schoenoplectus mucronatus	Native	X	X	-
Typha orientalis	Native	-	X	-
Persicaria lapathifolia	Native	-	X	-
****Typha sp.***	*Native/naturalised	-	X	-
Vallisneria sp.	Native	X	X	X

No fish survey data was available for this study area.

6.4.2 Field Assessment

6.4.2.1 Waterway Validation

Waterway validation of Warragamba River in Study Area 4 shows this stretch of the Warragamba River satisfies the definition of a "river" as per *NSW Water Management* Act 2000.

6.4.2.2 Key Fish Habitat

The section of the Warragamba River is mapped as KFH according to the *Fisheries Management Act* 1994 and mapped as habitat of Macquarie Perch (NSW Department of Primary Industries – Fisheries Spatial Data Portal (2020b) and National Recovery Plan for Macquarie Perch (*Macquaria australasica*) Commonwealth of Australia, 2018).

Field validation of the Warragamba River concluded the stretch subject to potential impacts is considered Type 1 (highly sensitive Key Fish Habitat) and Class 1 (major Key Fish Habitat).

Type 1 (highly sensitive Key Fish Habitat) was assessed due to the presence of in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 m in length and native aquatic plants (Figure 50).

Additionally, the assessed reach is classified as Type 1 (highly sensitive Key Fish Habitat) due to the potential presence of the threatened Macquarie Perch. Class 1 (major Key Fish Habitat) was assessed due to the Warragamba River being a large, permanently flowing body of water and potential habitat of threatened Macquarie Perch (Figure 50).

Figure 50 Study Area 4 - Warragamba River Release Point – Type 1, Class 1 Key Fish Habitat.

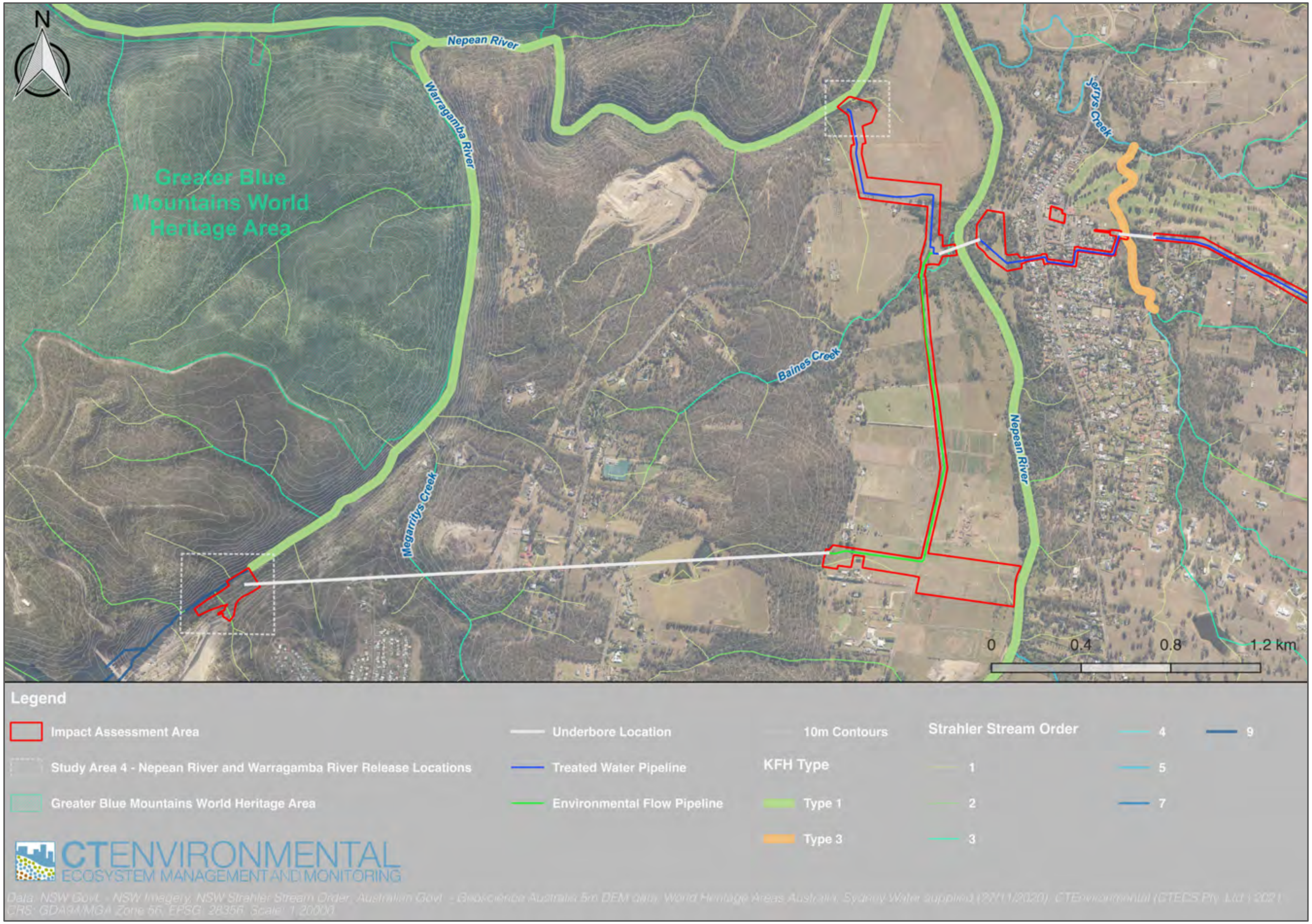

Figure 51 Study Area 4 - Field validated Type 1 Key Fish Habitat.

6.4.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs showed mapped terrestrial GDEs corresponded to the location of mapped native vegetation (Figure 53).

6.4.2.4 Riparian Vegetation and River Channel Condition

Eight assessments of riparian vegetation and creek channel condition were conducted along the Warragamba River, with overall condition at all sites assessed as excellent (Table 27 and Figure 52).

The two sites with the highest total score on the Warragamba River were sites 3 and 5, which were in excellent condition. The site with the lowest overall score was site 6, however the condition was still considered as excellent.

All sites were found to have wide riparian buffer (>40 m) and vegetation structural complexity was high and weed density low. Overall, the majority of sites had good aquatic habitat, however, habitat features were less prevalent at sites 6, 7, and 8.

Table 27 Riparian assessment results for sites at the Warragamba River – Study Area 4.

	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Warragamba River-1	-1	20	20	-6	24	4	Excellent	87
Warragamba River-2	-2	20	20	6	27	7	Excellent	93
Warragamba River-3	-2	20	20	6	27	7	Excellent	94
Warragamba River-4	-2	20	20	6	27	7	Excellent	91
Warragamba River-5	-2	20	20	6	27	7	Excellent	94
Warragamba River-6	-1	20	20	-6	18	-2	Excellent	86
Warragamba River-7	-1	20	20	0	18	-2	Excellent	88
Warragamba River-8	-1	20	20	-6	18	-2	Excellent	89

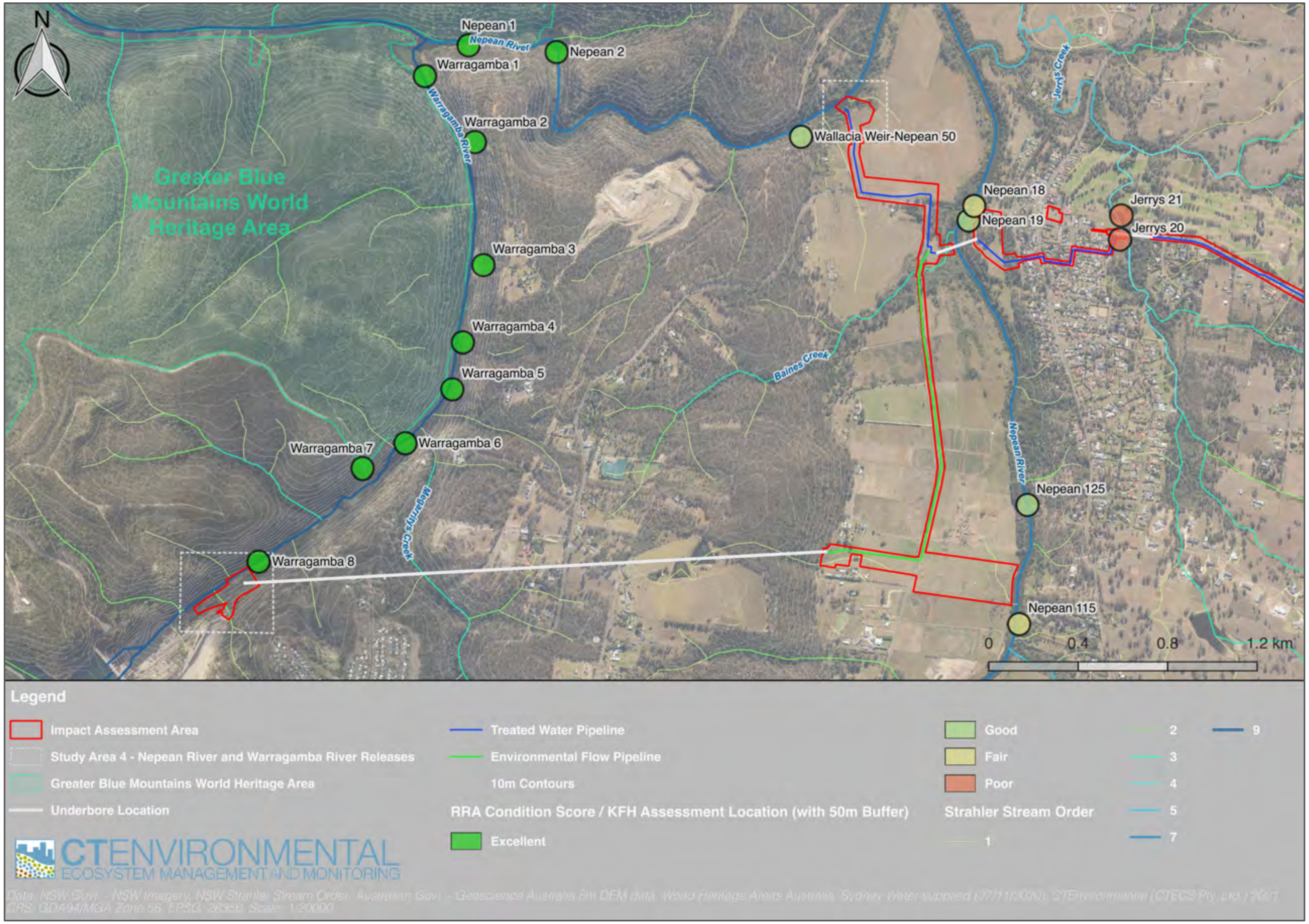

Figure 52 Results of riparian vegetation and creek channel assessment at Study Area 4 – Warragamba River and Release Point.

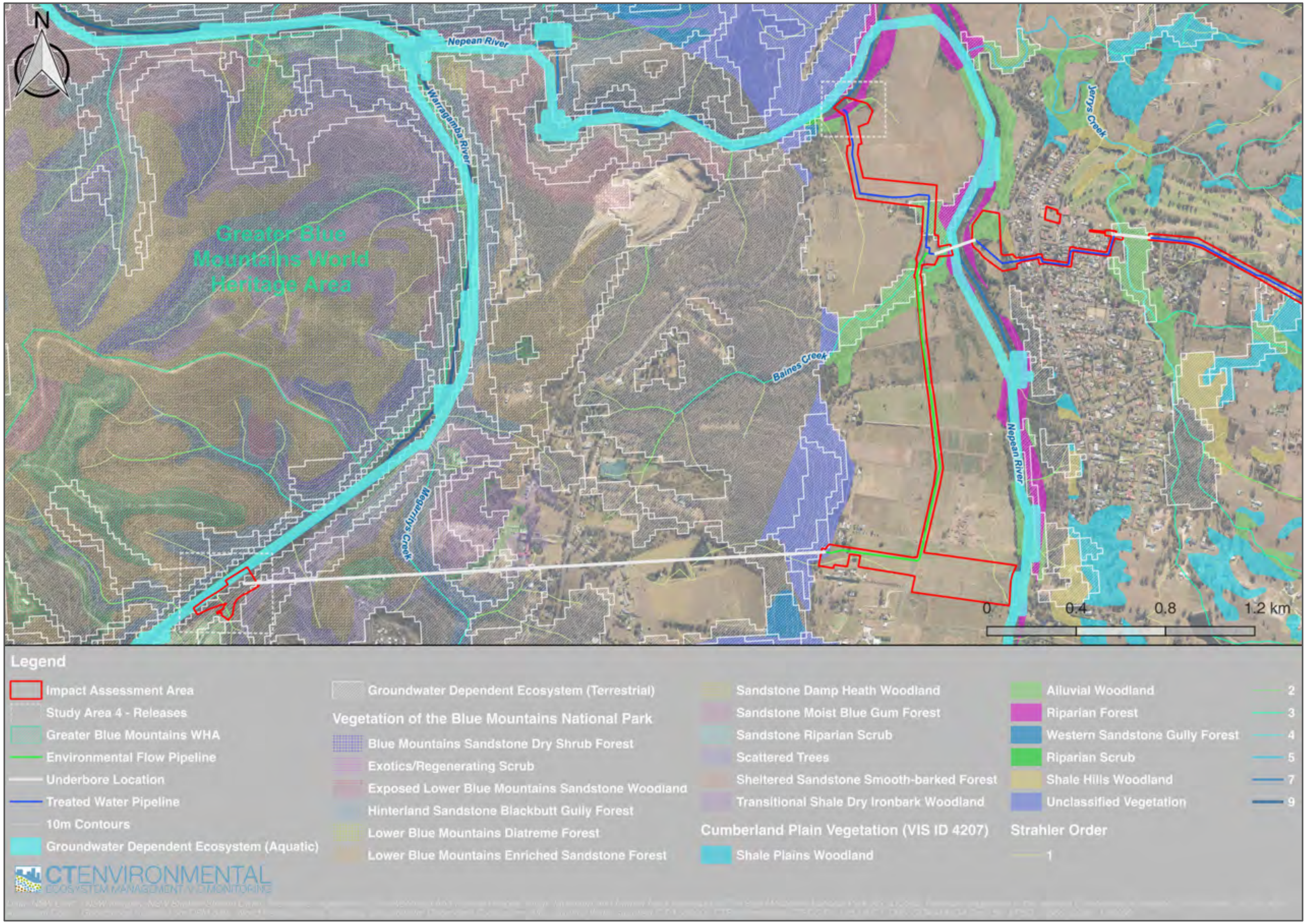

Figure 53 Groundwater dependent ecosystems and remnant native vegetation in proximity to Study Area 4.

6.4.3 Assessment of Potential Impacts – Construction Phase

There is potential for detrimental impacts to occur to the aquatic and riparian ecosystems during the construction phase of the AWRC outlet structure to Warragamba River. The Warragamba River outlet structure is likely to be perched above the waterline and incorporate a rip rap (energy dissipation) and scour structure lining and a release chamber and headwall.

There is a short term and localized risk of debris and sediment falling into the River during bulk earthworks construction which has the potential to disturb the bed and bank of the River, however the risk of significant degradation to the aquatic habitat is low due to the localisation of any impacts.

The construction footprint of the outlet structure will remove native riparian vegetation which is considered as a Terrestrial Groundwater Dependent Ecosystem and the associated impacts have been addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required. Revegetation/restoration of native riparian vegetation are considered by this study.

Underboring and bulk earthworks are the proposed construction methodology for the outlet structure. Draft construction methodology provided by Sydney Water indicates there is low risk to causing significant impacts to waterways through spillage or loss of drilling fluid.

A potential impact associated with underbore construction is the unintentional return of drilling fluid to the surface (“frac-outs”). This occurs when the pressures in the drilling fluid exceed the overburden pressure or if preferential pathways (e.g. fault lines, fractures or loose materials) are present.

Frac-outs can result in sedimentation within watercourses, groundwater and surface water quality impacts and harm to ecological communities (particularly in aquatic environments). This would include loss of aquatic biota including macroinvertebrate taxa and native fish.

There is also the low risk that subsidence to creek bed and banks could occur as a result of the underboring process which has potential to alter hydrology and increase erosion and sedimentation, both of which cause deleterious effects to aquatic biota.

6.4.3.1 Degradation of water quality

Activities associated with earthworks, including underboring and bulk earthworks, associated with construction have potential implications for water quality which can include transport of sediment and contaminants such as machinery oil and fluids entering waterways.

There is an increased risk of sedimentation of coarse sediment and elevated turbidity due to the stripping of vegetation which exposes topsoil which in wet weather has potential to be transported to receiving waterways.

Increased sedimentation of coarse sediment have potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering by sediments and to loss of niche habitats caused by settling of sediment on the creek bed. Loss of invertebrates can also affect higher trophic organisms as fauna such as native fish, wading birds and microbats are reliant on these for food resources.

Additionally, suspension of fine clay and silt has potential to increase turbidity which can lead to a reduction of photosynthesis and/or release nutrients adsorbed to clays which may promote primary productivity and promote algae and aquatic plant growth.

Degradation of water quality has potential to impact the habitat and population of Macquarie Perch which is listed as threatened under both the FM Act 1994 and EPBC Act 1999. An assessment of potential impacts to this species is detailed in Section 6.7.4.

No Terrestrial Groundwater Dependent Ecosystems will be impacted during the construction of the outlet structure as they are absent from the proposed construction footprint.

6.4.4 Assessment of Potential Impacts – AWRC Operational Phase

Operational phase impacts associated with water quality and hydrology have the potential to cause degradation to the Warragamba River and its ecology.

The following sections address potential impacts to the Warragamba River.

6.4.4.1 Predicted Hydrology

Review of the Geomorphic and Ecohydrology study (Streamology, 2021) showed no detailed hydrological or geomorphic assessment was undertaken for the Warragamba River downstream of the AWRC release point given that releases are proposed to partially replace the current e-flow regime and the releases could contribute to identified benefits of those environmental flows.

Therefore, the magnitude of environmental flows are not proposed to change and it is not anticipated that hydrologic and geomorphic impacts will occur as result of the proposed environmental flow release regime. Based on this no hydrologically driven impacts to aquatic or riparian ecosystems are expected. Therefore residual impacts associated with alteration of hydrology in the Warragamba River are not expected.

6.4.4.2 Predicted Water Quality

Warragamba River release scenarios effectively split the flows from the AWRC between release points in the Nepean and Warragamba rivers, with the Warragamba releases effectively replicating the current WaterNSW Warragamba Dam release regime, and only consisting of advanced treated water. In circumstances when advanced treated water from the AWRC is unavailable, releases from the Warragamba Dam would be reinstated to maintain the required level of environmental flows in the river (Aurecon ARUP, 2021c).

Modelling has been used to analyse the likely changes to water quality and hydrodynamics in Warragamba Rivers (Aurecon ARUP, 2021c) and assess potential residual impacts to the aquatic ecosystem. 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.

The scenarios were run for a representative dry and wet year and represent the full range of potential operating conditions related to releases to Warragamba River.

Review of water quality modelling of environmental flow releases to Warragamba River (Aurecon ARUP, 2021c) are discussed below. The results are based on a 2036 representative impact scenario (referred to as HN13), where only advanced treated water us released to Warragamba River up to a maximum of 22ML/day in April to October and 30ML/day in November to March. The remaining releases, including any with tertiary treated water, will be released to Nepean River. The impact scenario was compared to the equivalent background scenario (HN01) and the baseline scenario (HN00).

6.4.4.3 Nitrogen

- Minor changes to total nitrogen were predicted in the Warragamba River downstream of the AWRC release point, although the general magnitude remained similar, or marginally reduced relative to the background conditions. The speciation of the nitrogen downstream of the releases was predicted to be modified with more bioavailable forms (ammonia and oxidised nitrogen) relative to the background conditions.
- Treated water releases from the AWRC were modelled to assist in reducing total nitrogen concentration in the vicinity of the release point, but the annual median concentrations remained above the project waterway objective as per the background scenario.

6.4.4.4 Phosphorus

- Changes to the phosphorus profile are predicted downstream of the AWRC releases in the Warragamba River. An increase in concentration of total phosphorus is predicted along with increased levels of FRP, which is the bioavailable form.

6.4.4.5 Chlorophyll-*a*

- Higher levels of chlorophyll *a* are predicted within Warragamba River, downstream of the AWRC release point compared to both the baseline and background scenarios. 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.

6.4.4.6 Salinity

- Median salinity in the Warragamba River is predicted to be lower as a result of the AWRC releases.

6.4.4.7 Total Suspended Solids

- Suspended sediment concentrations in the Warragamba River are predicted to be reduced as a result of the AWRC releases and remain well below the waterway objectives. This reduction may also contribute to the aforementioned increase in primary productivity in the Warragamba River as a result of less turbid water and increased sunlight penetration.

6.4.4.8 Dissolved Oxygen

- Significant increases in dissolved oxygen were predicted in the Warragamba River with the introduction of the AWRC releases.

6.4.5 Assessment of Potential Impacts to Aquatic, Riparian and Groundwater Dependent Ecosystems

No hydrological or geomorphic driven impacts are expected to occur (Streamology, 2021) and as a result no hydrological driven impacts to the aquatic, riparian or groundwater dependent ecosystems are expected.

Review of water quality modelling for the AWRC release predicts future increases in available nutrient forms i.e. NOx-nitrogen, ammonia and reactive phosphorus which, as per the modelling, is likely to increase the rate of primary productivity as indicated by increased chlorophyll-*a* concentrations. Although there were spikes in Chlorophyll *a* concentration, they were spatially localised and median concentrations remained below the ANZG (2018) default guideline value for Chlorophyll *a* for both dry and wet year (for 2036 scenario). Therefore, the impact from the AWRC releases is predicted to be limited with respect to magnitude and also spatial extent and the modelled response of chlorophyll-*a* suggests AWRC releases would not significantly impact the primary production response beyond the confluence of the Warragamba and Nepean rivers. Given this, direct impact to aquatic flora and fauna within the overall river system, as a result of AWRC releases, is expected to be low and limited in terms of its spatial and temporal extent.

Although the contribution of nutrients by the AWRC is limited, elevated nutrients could be problematic, particularly under extended drier periods when algae concentrations have more potential to increase, consume available nutrients and then begin to decay, stripping away dissolved oxygen from the water column and potentially altering the trophic state of the waterway.

Alteration of the trophic state, particularly if a waterway goes eutrophic 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.

Although this risk has been identified, it is considered as relatively low with the algal blooms predicted to be limited in magnitude and within the reach between the AWRC release point and the confluence with the Nepean River. 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 (Aurecon ARUP, 2021c), the periods of low dissolved oxygen are short lived.

The predicted cyanobacteria risk index indicates only minor differences across the downstream reaches, relative to both the background scenario (Aurecon ARUP, 2021c), though the index has been calculated for a longer reach (down to Penrith Weir) and may miss localised changes. The results predicted no increased risk in the downstream reaches 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 there is likely to be some change to biomass, but no material change in risk.

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 excess algae growth has been described. 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) which may result in an increase of aquatic biodiversity and increase of prey for higher order fauna.

Addition of available nutrients can also promote colonization of weed species in the riparian community, however changes in hydrology are not expected and therefore the risk is considered low.

Alteration of water quality has potential to impact the habitat and population of Macquarie Perch which is listed as threatened under both the FM Act 1994 and EPBC Act 1999. An assessment of potential impacts to this species is detailed in Section 6.7.4.

The Warragamba River has been identified as an aquatic groundwater dependent ecosystem. 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.

6.4.6 Recommendations to mitigate potential impacts

The risk of degradation to the aquatic and riparian ecosystem of Warragamba River is low however some risk is associated with construction and operational phases.

To mitigate potential and actual impacts associated with construction of the release structure, Sydney Water (2021) have developed a comprehensive set of management measures to control the severity impacts.

It is recommended mitigation measures outlined in Chapter 9.2 of the EIS (Sydney Water, 2021) are implemented to minimize potential impacts during the construction phase of the Warragamba River outlet structure. Implementation of these will minimize potential sediment and erosion driven impacts to the aquatic ecosystem.

Riparian vegetation (which are also considered Groundwater Dependent Ecosystems) within the outlet structure footprint is native and the impacts of clearing native vegetation have been addressed in the Biodiversity section of the EIS (Chapter 9.1) as assessment under the *Biodiversity Conservation Act* 2017 is required, however revegetation/restoration of native riparian vegetation are considered by this study.

The AWRC and associated infrastructure is considered State Significant Infrastructure (SSI) and therefore legislative requirements for retention and creation of vegetated riparian zones (VRZ) as per the *NSW Water Management Act* 2000 do not apply, however the principles of this *Act* should be followed.

It is recommended that Vegetation Management Plan (VMP) is developed for the rehabilitation of the release outlet. The VMP should be ecologically focused and incorporate scenic values where and if possible. Guidance on the development of a VMP can be found in "Guidelines for Vegetation Management Plans on Waterfront Land" (NSW Office of Water, 2012).

Warragamba River is considered Type 1 KFH and habitat for Macquarie Perch, listed as threatened under both state and federal legislation. To minimize potential impact to fish habitat, Aurecon ARUP (2021a) recommend a staged coffer dam is constructed to minimize impacts of construction to the waterway.

It is recommended construction of coffer dams and temporary in-stream structures associated with open trenching is taken from the Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013). Refer to section 6.2.5 for detailed information on effective management of instream works.

Generic guidance to construction of the stormwater outlet pipe/headwall for the release structure has been provided by Aurecon ARUP (2021a) however limited guidance to remediation/revegetation has been detailed.

It is recommended construction and remediation/revegetation of riparian areas where the outlet pipe/headwall is to be constructed is undertaken following the guidance provided by "Guidelines for Outlet Structures on Waterfront Land" (NSW Office of Water, 2012) (see Appendix D).

6.5 Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir

6.5.1 Desktop Review

6.5.1.1 Strahler stream order, Aquatic Macroinvertebrates, Key Fish Habitat and Threatened Species Distribution

Review of NSW statewide topographic mapping to determine Strahler stream ordering (SIX maps, 2021) showed the Nepean River upstream of Wallacia Weir is considered a 7th order (Figure 54).

Review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) and Freshwater threatened species distribution (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020b) shows the Nepean River upstream of Wallacia Weir is mapped as Key

Fish Habitat (Figure 55). However, no threatened species or their habitats as per Schedule 4, 4A and 5 of the NSW *Fisheries Management Act 1994* were mapped or recorded in this reach of the River. No potential habitat was identified.

6.5.1.2 Matters of National Environmental Significance

No matters of MNES were mapped as present within the reach of the Nepean River upstream of Wallacia Weir. Potential habitat was not identified.

6.5.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) shows the Nepean River is considered an aquatic GDE and terrestrial GDEs are mapped in scattered areas along the banks of the River however none were mapped at the location of the discharge point (Figure 56).

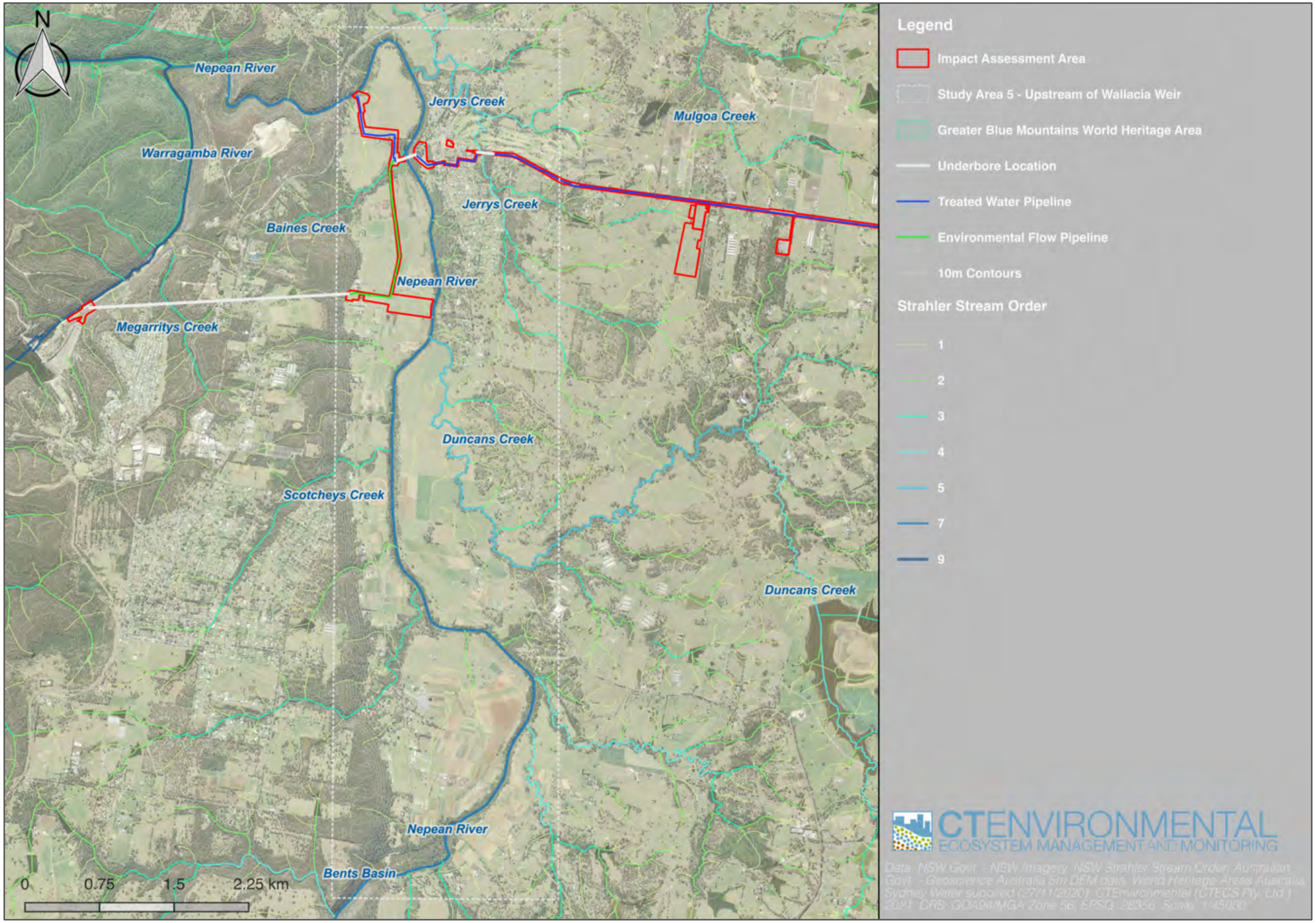

Figure 54 Strahler stream order of waterways within Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir.

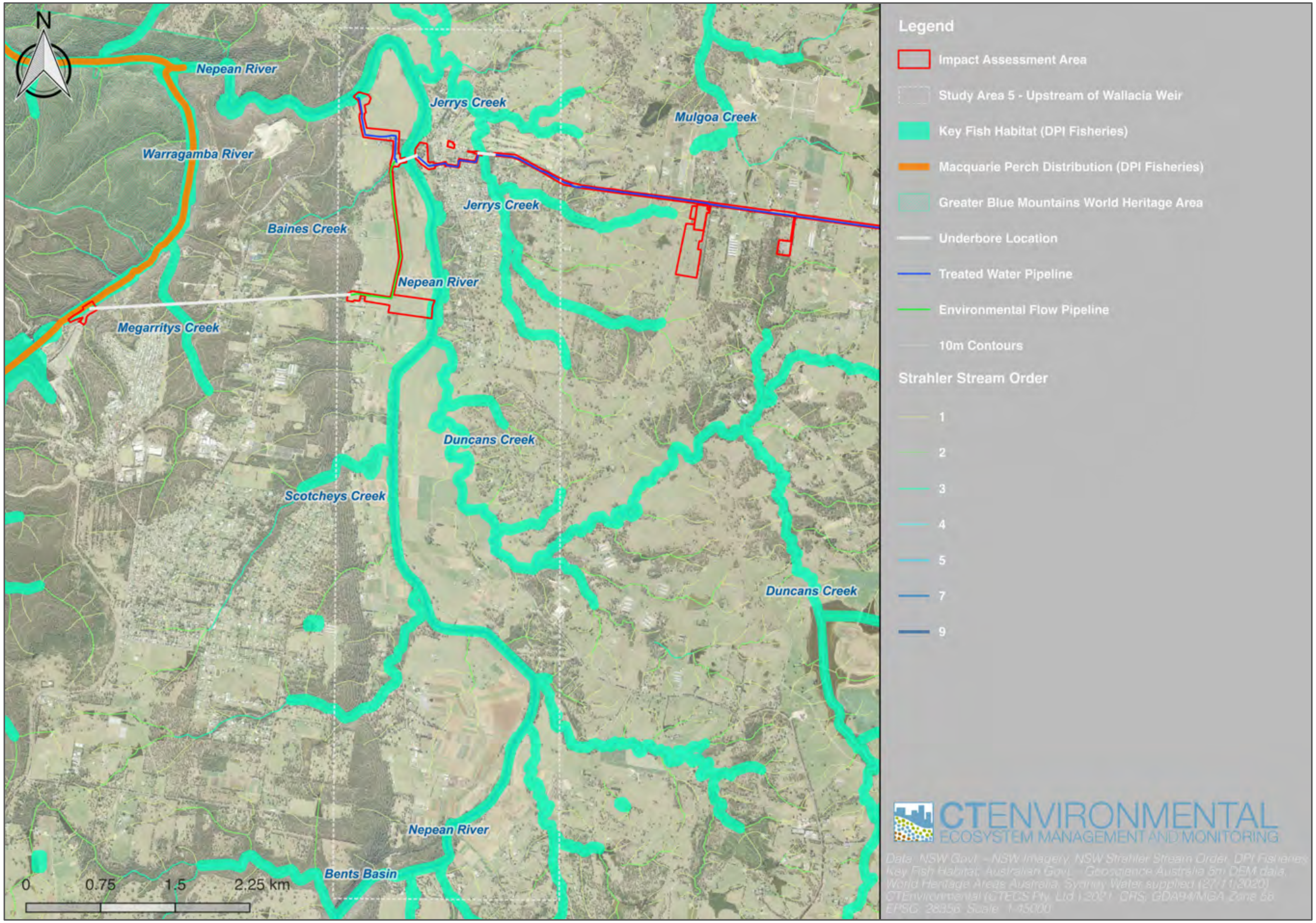

Figure 55 Mapped Key Fish Habitat (DPIE 2007) for Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir.

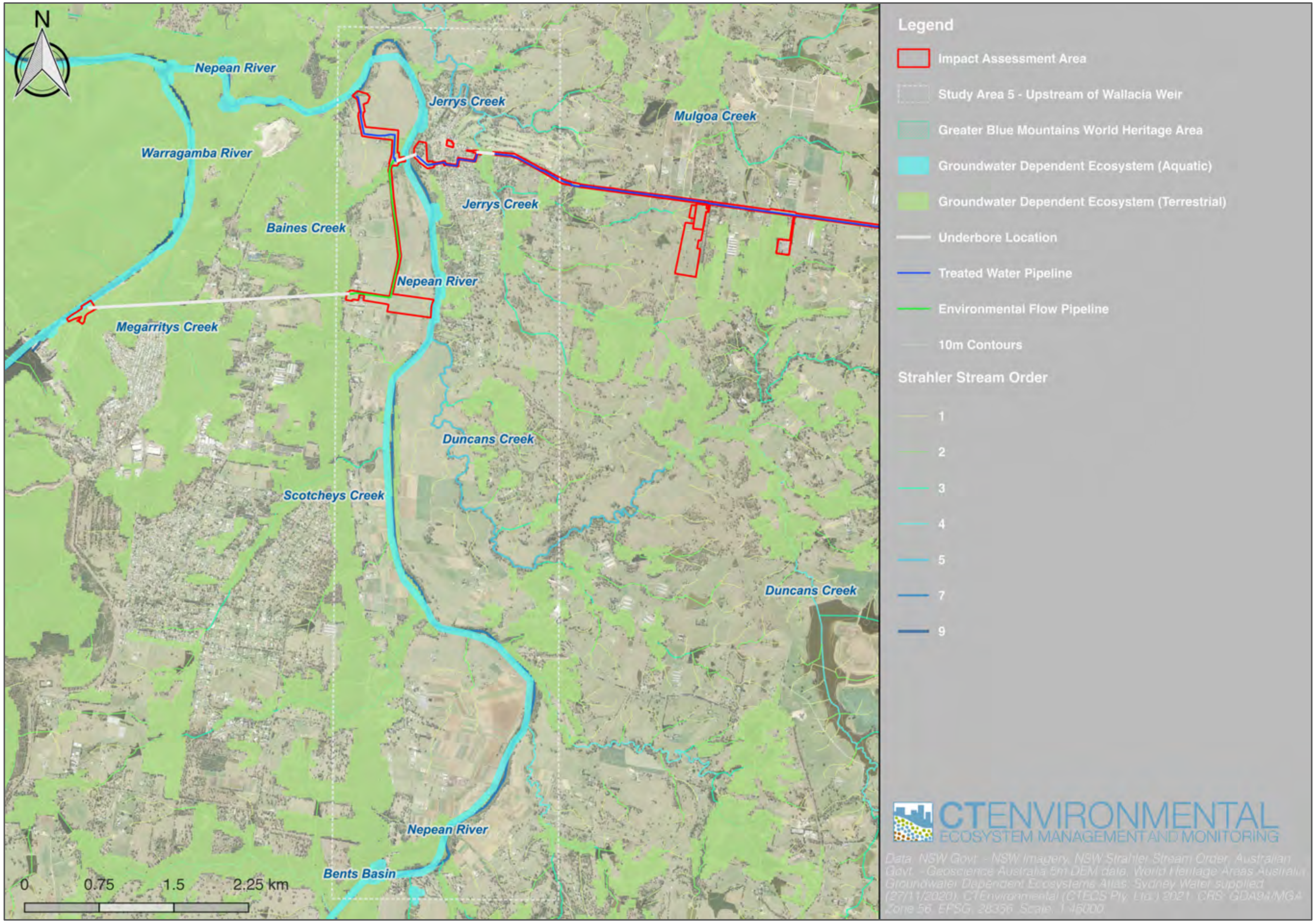

Figure 56 Mapped GDEs within and adjacent to Study Area 5 – Nepean River Release Point and Nepean River Upstream of Wallacia Weir.

6.5.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes

Review of water quality, fish survey, macroinvertebrate and macrophyte monitoring data collected by Sydney Water relevant to Study Area 5 – Nepean River Upstream of Wallacia Weir shows data has been collected at two sites within the lower reach of the weir pool, upstream of the proposed release point.

Results of water quality monitoring from sites in proximity to Study Area 5 shows median values for the majority of parameters at both sites, with the exception of total nitrogen, were within the Waterway Objectives for Nepean and Warragamba Rivers (Table 28).

Table 28 Median values for water quality parameters monitored by Sydney Water within close proximity of Study Area 5 (January 2018 – June 2021). Red font indicates result is outside the Waterway Objectives for Nepean and Warragamba Rivers.

Site	DO (% Saturation)	EC (uS/cm)	pH	Turbidity (NTU)	TN (mg/L)	TP (mg/L)
N67	94.8	365	7.5	7.3	1.00	0.02
N66A	93.9	338	7.4	6.8	1.13	0.023
Waterway Objectives for Nepean and Warragamba Rivers	85 - 110	125 - 2,200	6.5 – 8.0	6 - 50	0.35	0.025

Results of aquatic macroinvertebrate monitoring shows community structure at Nepean River sites (sites N66A and N67) was indicative of a moderate to low level of disturbance. The Nepean River sites had a greater proportion of pollution and disturbance sensitive macroinvertebrate taxa, compared to other study areas, that require water quality and habitat of relatively high quality as indicated by SIGNAL-SG scores of 5.75 and 5.4 respectively and the relatively high percentage of EPT taxa (39% and 25.8%) (Table 29).

Given that this reach of the River is subject to regulation, it is likely that a combination of altered hydrology and elevated nutrient concentrations influence the macroinvertebrate community and slight alteration from a minimally disturbed waterway is indicated by the SIGNAL-SG scores slightly below 6.0.

Table 29 Aquatic macroinvertebrate indices for Nepean River monitoring sites – Study Area 5.

Site	Year Range of Data Collection	Abundance	Family Richness	%EPT	SIGNAL-SG
N66A	2020	66	20.75	39	5.75
N67	2020	82.0	18.9	25.8	5.4

Three macrophyte species were present at study sites N66A and N67 in 2020 (Table 30). The exotic species *Alternanthera philoxeroides and Egeria densa* were recorded, along with one native species, *Vallisneria sp*.

Table 30: Presence / absence Macrophyte data collected from sites N67 and N66A over two sampling events in 2020.

Scientific Name	Native/exotic	N67	N66A
Vallisneria sp	Native	X	-
Alternanthera philoxeroides	Exotic	X	X
Egeria densa	Exotic	X	X

No fish survey was available for this study area.

6.5.2 Field Assessment

6.5.2.1 Waterway Validation

Waterway validation of Nepean River in Study Area 5 shows this stretch satisfies the definition of a “river” as per *NSW Water Management* Act 2000.

Review of aerial photos of Study Area 5 shows the area is a long weir pool that stretches for approximately 12 km upriver from Wallacia Weir to Bents Basin. The River along this reach is confined to the channel by high, steep banks, which contain high flows, restricting the floodplain engagement (Figure 57).

Figure 57 Study Area 5 – Nepean River Upstream of Wallacia Weir. Weir can be seen in foreground.

6.5.2.2 Key Fish Habitat

Field validation of Key Fish Habitat (KFH) Type and Class following the framework outlined by Policy and Guidelines for Fish Habitat Conservation and Management (update 2013) (DPIE Fisheries, 2013) included assessment at 13 sites along the Nepean River in Study Area 5.

Results show this reach of the Nepean River is considered Type 1 (highly sensitive Key Fish Habitat) and Class 1 (major Key Fish Habitat) waterways (Figure 60).

Key Fish Habitat attributes of overhanging vegetation, natural bed detritus, rock overhangs, submerged rocks, gravel beds, large woody debris greater than 300 mm in diameter or 3 m in length and the permanency of water were common within this reach (Figure 58 and Figure 59).

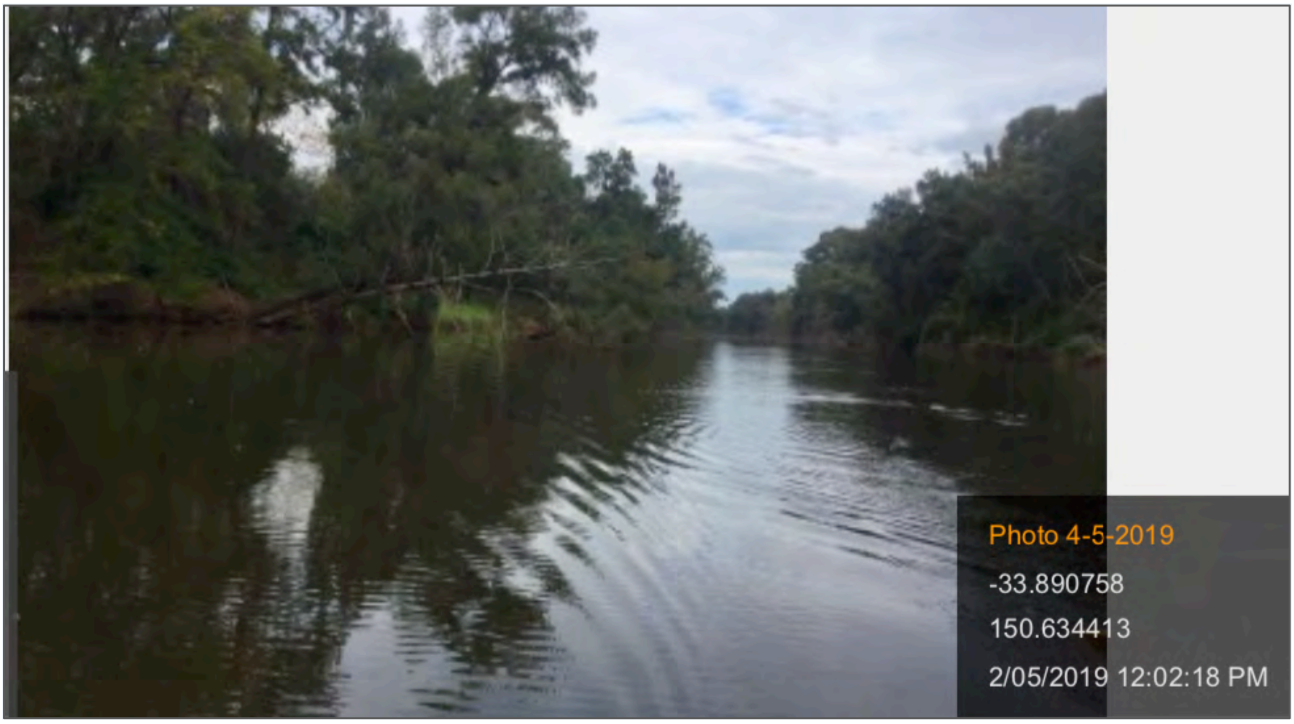

Figure 58 Typical Type 1, Class 1 Key Fish Habitat at Study Site 5 - Nepean River Upstream of Wallacia Weir.

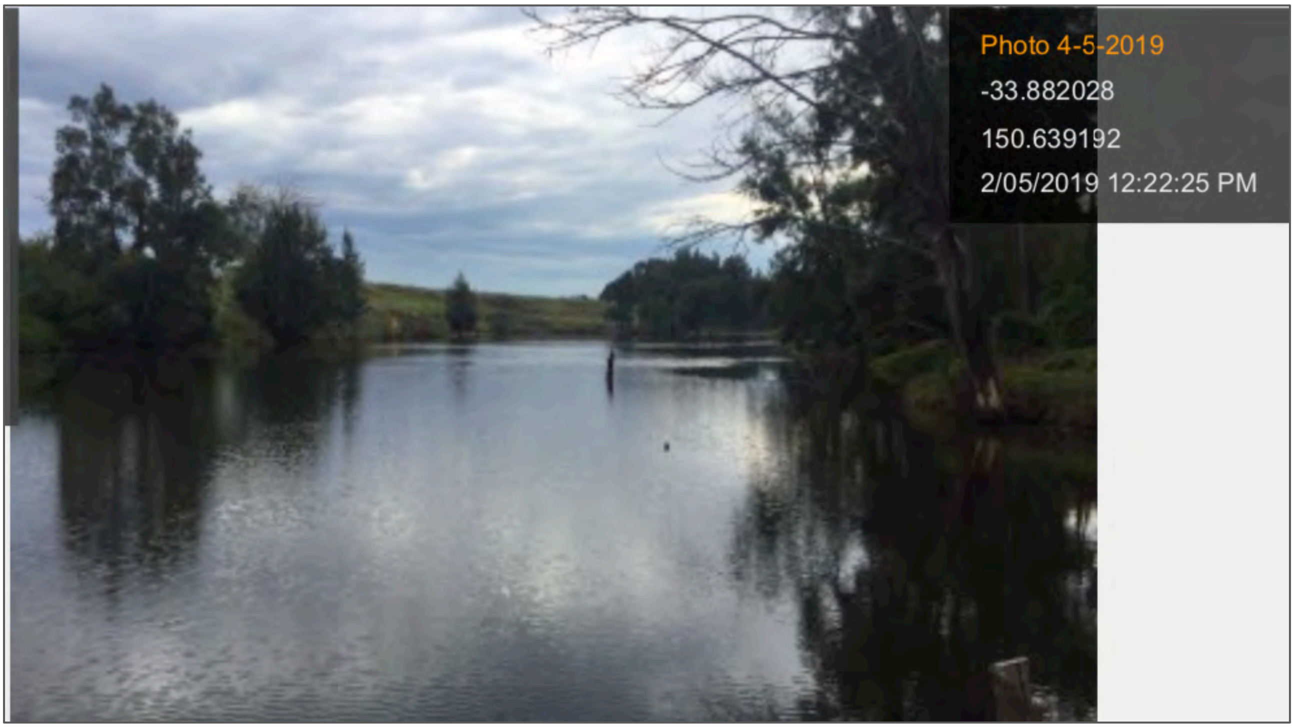

Figure 59 Typical Type 1, Class 1 Key Fish Habitat at Study Site 5 - Nepean River Upstream of Wallacia Weir.

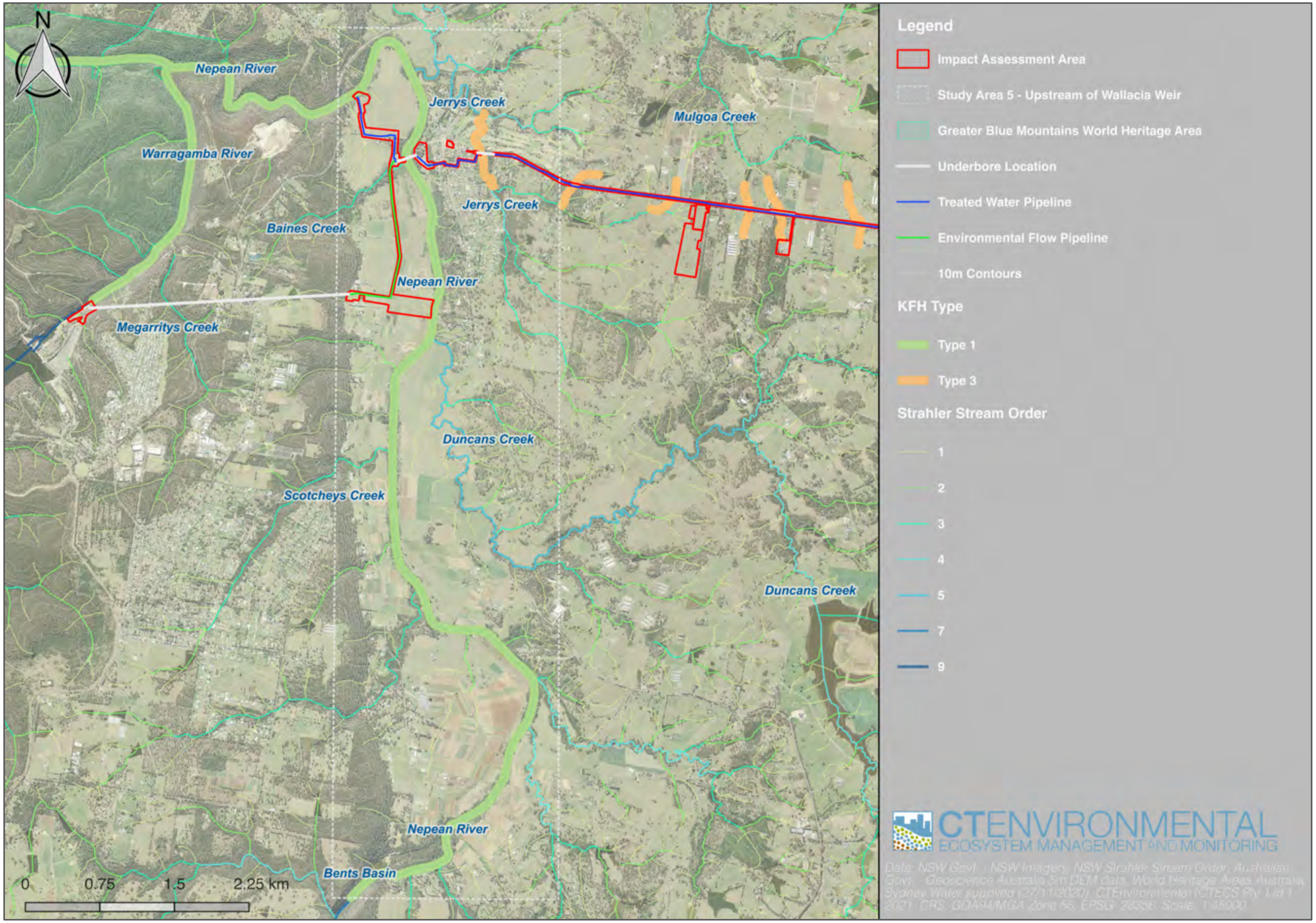

Figure 60 Field validated Type 1, Class 1 KFH – Study Area 5 – Nepean River Release Point and Upstream of Wallacia Weir.

6.5.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs mapped in Study Area 5 validated the presence of terrestrial GDEs which corresponded to the location of remnant native vegetation lining the River's bank (Figure 61). No terrestrial GDE's were present at the release point location.

This reach of the Nepean is considered an aquatic GDE, which is likely as the large catchment, and permanence of water suggests groundwater inflows would occur across the area.

6.5.2.4 Riparian Vegetation and Creek Channel Condition

Seventeen assessments of riparian vegetation and creek channel condition were conducted within Study area 5. Results indicate overall condition ranged from good to fair condition (Table 31 and Figure 62). The two sites with the highest total score on the Nepean River were sites 2 and 50, which were in excellent condition. The site with the lowest overall score was site 95, which was in fair condition. The majority of sites experienced low to moderate erosion and deposition impacts. All sites had a wide riparian buffer (>40 m). Weeds were prevalent at all sites. There was variability in scores relating to site features, with the lowest score at site 95 and highest at sites 1 and 2. Overall, the majority of sites had good aquatic habitat, with site 125 receiving the highest score.

Table 31 Results of riparian and creek channel condition for Study Area 5 – Nepean River Release Point and Upstream of Wallacia Weir.

Site	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Nepean River-18	0	20	7.4	-12	3.4	-1	Fair	71
Nepean River-19	0	20	12.9	-12	17.2	3	Good	79
Nepean River-50	-1	20	18.1	-6	18.9	0	Good	76
Nepean River-55	-6	20	13.8	-20	17.5	3	Good	73
Nepean River-60	-2	20	14.7	-12	17.8	0	Good	78

Nepean River-65	-2	20	12.8	-20	8.2	-3	Fair	70
Nepean River-70	-2	20	10.3	-13	12.2	1	Good	74
Nepean River-75	-4	20	13.2	-13	21.8	4	Good	78
Nepean River-80	0	20	3.2	-13	11.9	4	Fair	71
Nepean River-85	0	20	5.9	-20	11.9	4	Fair	71
Nepean River-90	-3	20	4.4	-9	7.3	6	Fair	71
Nepean River-95	-4	20	3.5	-9	2.3	1	Fair	68
Nepean River-105	-2	20	13.1	-20	18.5	4	Good	75
Nepean River-110	-2	20	4.7	-12	5.3	4	Fair	69
Nepean River-115	-5	20	2.3	-9	7.5	4	Fair	69
Nepean River-125	-2	20	15.3	-20	21.5	7	Good	76

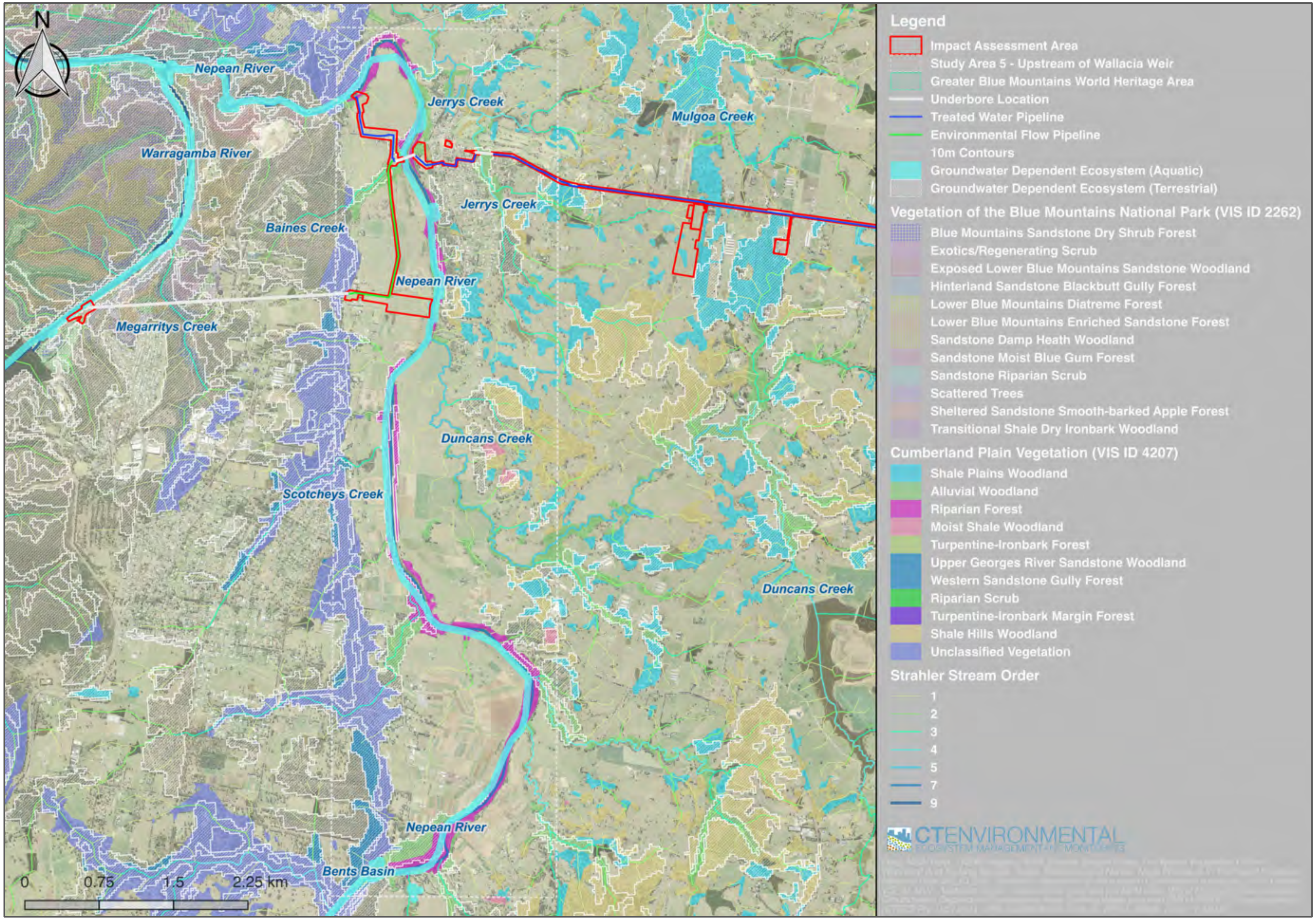

Figure 61 Groundwater dependent ecosystems and remnant native vegetation in Study Area 5.

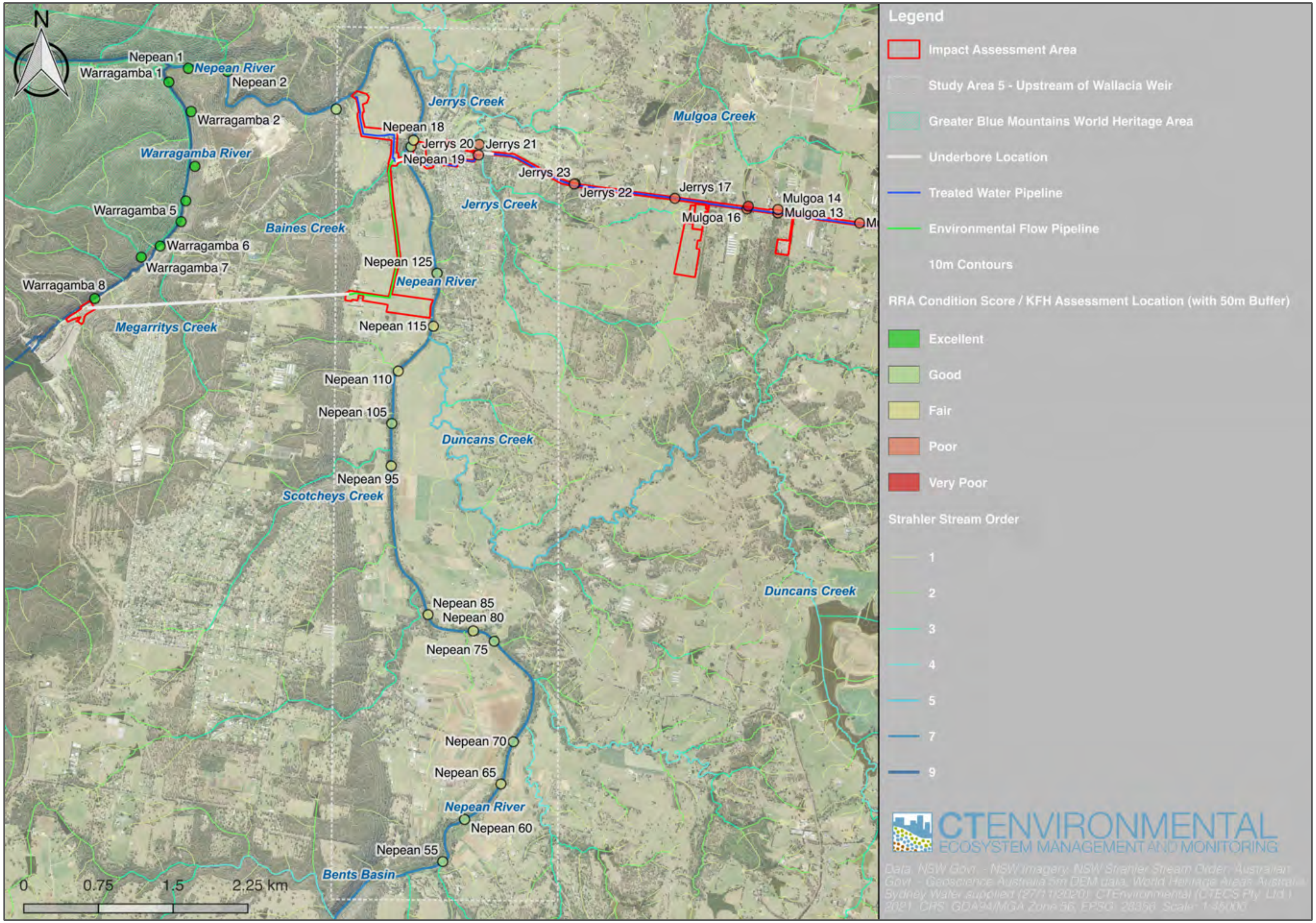

Figure 62 Results of riparian vegetation and creek channel assessment at Study Area 5 – Upstream of Wallacia Weir.

6.5.3 Assessment of Potential Impacts – Construction Phase

There is potential for detrimental impacts to occur to the aquatic and riparian ecosystems during the construction phase of the AWRC outlet structure on the Nepean River in the Wallacia Weir Pool. The outlet structure is proposed to release above the water level of the Wallacia Weir Pool and include a scour structure lining and a release chamber and headwall.

There is a short term and localized risk of debris and sediment falling into the River during bulk earthworks construction which will disturb the bed and bank of the River. The construction of the outlet structure will result in the direct loss of a small area of River bed and bank.

The construction footprint of the outlet structure may require removal of native riparian vegetation and the associated impacts have been addressed in the Biodiversity section of the EIS as assessment under the *Biodiversity Conservation Act* 2017 is required, however revegetation/restoration of native riparian vegetation are considered by this study.

6.5.3.1 Degradation of water quality

Activities associated with construction, including bulk earthworks and excavation of the Riverbed and bank has potential implications for water quality which can include disturbance and suspension of fine sediment and addition of contaminants such as machinery oil and fluids entering waterways.

There is also an increased risk of sedimentation of coarse sediment and elevated turbidity due to the stripping of riparian vegetation which exposes topsoil which in wet weather has potential to be transported to receiving waterways.

Increased sedimentation of coarse sediment and suspension of fine silts and clays in a low energy environment like the Wallacia Weir Pool have potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering by sediments and to loss of niche habitats caused by settling of sediment on the creek bed. Loss of invertebrates can also affect higher trophic organisms as fauna such as native fish, wading birds and microbats are reliant on these for food resources.

Additionally, suspension of fine clay and silt has potential to increase turbidity which can lead to a reduction of photosynthesis and/or release nutrients adsorbed to clays which may promote primary productivity and promote algae and aquatic plant growth.

6.5.3.2 Riparian vegetation and Key Fish Habitat

During construction of the outlet structure riparian vegetation will be removed and excavation of the River bed and bank will occur. This will have a direct, albeit very localized, impact however degradation of native riparian vegetation and installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams are considered as Key Threatening Processes under the FM Act 1994 (see section 6.7.3).

The combination of riparian vegetation removal and bed and bank disturbance has potential to impact habitat used by both native and aquatic fauna.

6.5.4 Assessment of Potential Impacts – AWRC Operational Phase

Potential impacts associated with the operational phase to Study Areas 5 and 6 are similar and therefore these are detailed together in Section 6.6.4.

6.5.5 Recommendations to mitigate potential impacts during construction phase

The risk of degradation to the aquatic and riparian ecosystem of the Wallacia Weir Pool during the construction phase is low and although impacts have been identified, they are expected to be short term and remediation should improve on current condition.

To mitigate potential and actual impacts associated with construction of outlet structures, Sydney Water (2021) have developed a comprehensive set of management measures to control the severity impacts.

It is recommended mitigation measures outlined in Chapter 9.2 of the EIS (Sydney Water, 2021) are implemented to minimize potential impacts during the construction phase of the Nepean River outlet structure. Implementation of these will minimize potential sediment and erosion driven impacts to the aquatic ecosystem.

Riparian vegetation (which are also considered Groundwater Dependent Ecosystems) within the outlet structure footprint is native and the impacts of clearing native vegetation have been addressed in the Biodiversity section of the EIS (Chapter 9.1) as assessment under the *Biodiversity Conservation Act* 2017 is required, however revegetation/restoration of native riparian vegetation are considered by this study.

The AWRC and associated infrastructure is considered State Significant Infrastructure (SSI) and therefore legislative requirements for retention and creation of vegetated riparian zones (VRZ) as per the *NSW Water Management Act* 2000 do not apply, however the principles of this *Act* should be followed.

It is recommended that Vegetation Management Plan (VMP) is developed for the rehabilitation of the release outlet. The VMP should be ecologically focused and incorporate scenic values where and if possible. Guidance on the development of a VMP can be found in "Guidelines for Vegetation Management Plans on Waterfront Land" (NSW Office of Water, 2012).

The Wallacia Weir Pool is considered Type 1 KFH. To minimize potential impact to fish habitat, Aurecon ARUP (2021a) recommend a staged coffer dam is constructed to minimize impacts of construction to the waterway.

It is recommended construction of coffer dams and temporary in-stream structures associated with open trenching is taken from the Policy and Guidelines for Fish Habitat Conservation and Management (DPIE, 2013). Refer to section 6.2.5 for detailed information on effective management of instream works.

Generic guidance to construction of the stormwater outlet pipe/headwall for the release structure has been provided by Aurecon ARUP (2021a) however limited guidance to remediation/revegetation has been detailed.

It is recommended construction and remediation/revegetation of riparian areas where the outlet pipe/headwall is to be constructed is undertaken following the guidance provided by “Guidelines for Outlet Structures on Waterfront Land” (NSW Office of Water, 2012) (see Appendix D).

In addition, consideration should be given to improving Key Fish Habitat in the Wallacia Weir Pool. This could include addition of submerged large woody debris or large boulders in areas that do not pose a risk to infrastructure or recreational users and would enhance habitat for native aquatic fauna.

6.6 Study Area 6 – Nepean River Downstream of Wallacia Weir

6.6.1 Desktop Review

6.6.1.1 Strahler stream order, Key Fish Habitat mapping and Threatened Species Distribution

Review of NSW statewide topographic mapping to determine Strahler stream ordering (SIX maps, 2021) showed the Nepean River is considered a 9th order stream (Figure 63).

Review of NSW Key Fish Habitat Mapping (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020a) and Freshwater Threatened Species Distribution (NSW Department of Primary Industries – Fisheries Spatial Data Portal, 2020b) shows the Nepean River is mapped as Key Fish Habitat (Figure 64).

The section of the Nepean River is mapped as habitat for the Macquarie Perch (*Macquaria australasica*) (Figure 64) which is listed as threatened under the NSW Fisheries Management Act 1994. No habitat or records for any other threatened species have been identified.

As a result of Macquarie Perch being potentially present in Study Area 6, the study includes a 7 Part Test of Significance for this species under the FM Act.

6.6.1.2 Matters of National Environmental Significance

Review of the Matters of National Environmental Significance (MNES) database shows Macquarie Perch (*Macquaria australasica*) is considered a matter of MNES and listed as endangered under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC). No habitat or records for any other threatened species have been identified.

As a result of Macquarie Perch being potentially present in Study Area 5, the study includes a Commonwealth Test of Significant Impact under the EPBC Act. The Blue Mountains World Heritage is also considered a Matter of National Environmental Significance and forms the east and west bank of the Nepean River along a stretch of the study area (Figure 65). Assessment of impacts to the World Heritage Area are outside the scope of this study.

6.6.1.3 Groundwater Dependent Ecosystems

Review of the Atlas of Groundwater Dependent Ecosystems (BOM, 2021) shows the Nepean River is considered an aquatic GDE and terrestrial GDEs are mapped along the banks of the river (Figure 65).

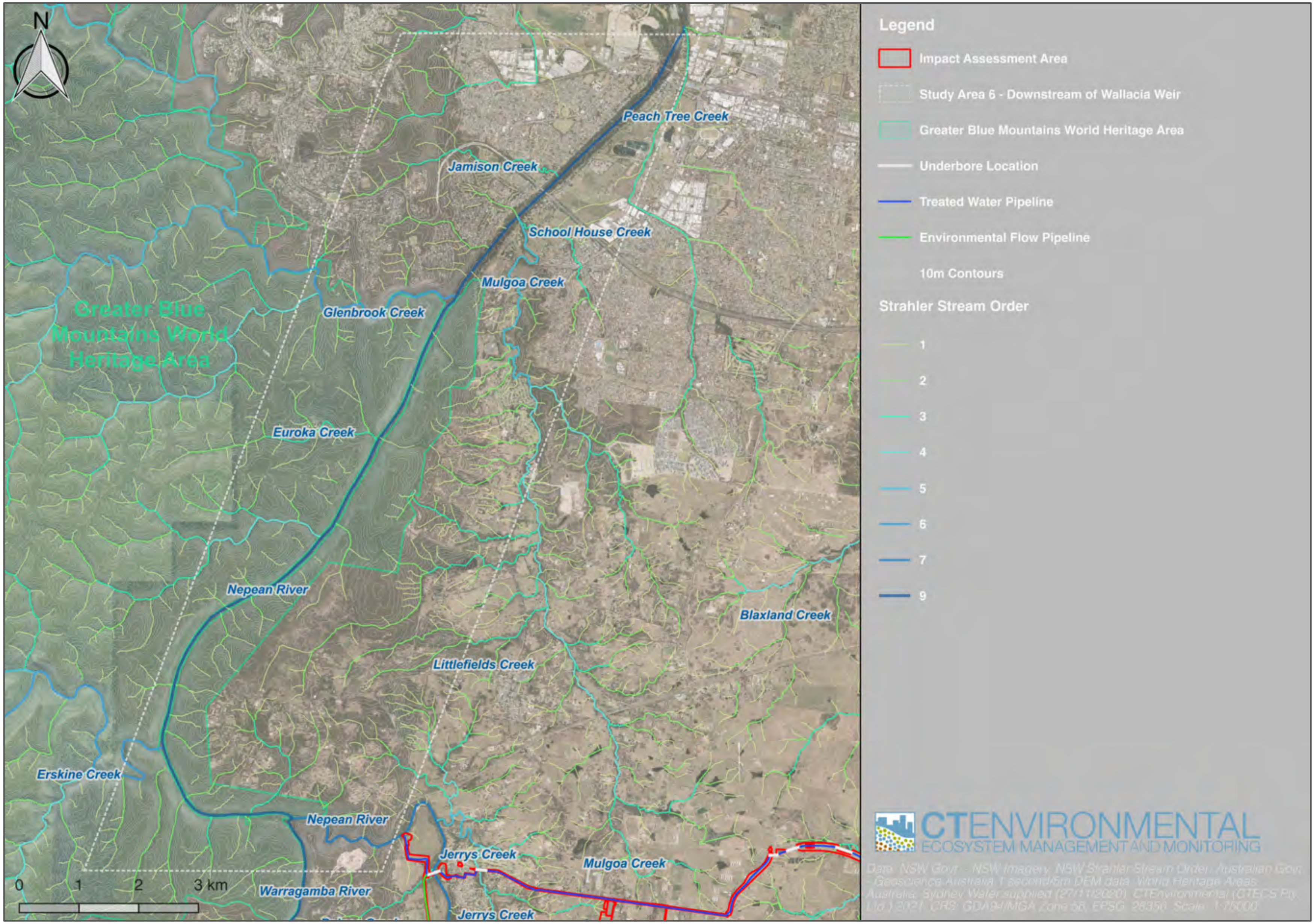

Figure 63 Strahler stream order of waterways within Study Area 6 – Nepean River Downstream of Wallacia Weir.

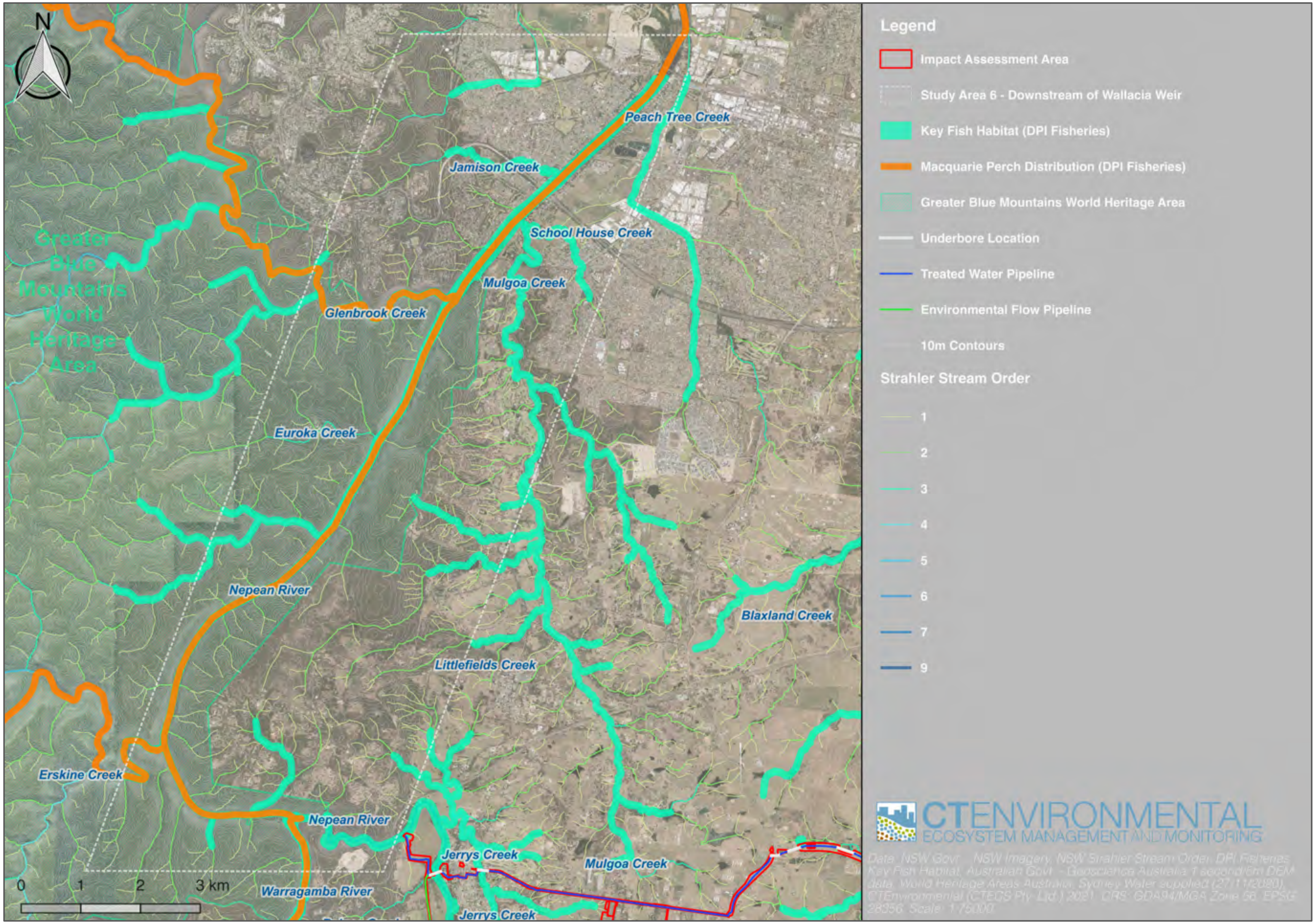

Figure 64 Mapped Key Fish Habitat (DPIE 2007) for Study Area 6 – Nepean River Downstream of Wallacia Weir.

Figure 65 Mapped GDEs within and adjacent to Study Area 6 – Nepean River Downstream of Wallacia Weir.

6.6.1.4 Water Quality, Aquatic Macroinvertebrates, Fish and Macrophytes

Review of water quality, aquatic macroinvertebrate, fish survey and macrophyte monitoring data collected by Sydney Water relevant to Study Area 6 – Downstream of Wallacia Weir shows data has been collected at four sites downstream of the proposed discharge point. N66, N66B and N64 are all located upstream of Warragamba River, while N57 is located near Penrith Weir (Table 5 and Figure 4).

Results of water quality monitoring from sites in proximity to Study Area 6 shows median values for the majority of parameters at all sites, with the exception of total nitrogen both sites, were within the Waterway Objectives for Nepean and Nepean Rivers (Table 32).

Table 32 Median values for water quality parameters monitored by Sydney Water within close proximity of Study Area 6 (January 2018 – June 2021). Red text indicate result is outside the Waterway Objectives for Nepean and Nepean Rivers.

Site	DO (% Saturation)	EC (uS/cm)	pH	Turbidity (NTU)	TN (mg/L)	TP (mg/L)
N57	96	301	7.5	3.6	0.66	0.014
N64	98.3	305	7.6	5.8	1.03	0.016
N66B	98	327	7.5	8.1	1.13	0.024
N66	99	332	7.5	6.4	1.09	0.02
Waterway Objectives for Nepean and Warragamba Rivers	85 - 110	125 - 2,200	6.5 – 8.0	6 - 50	0.35	0.025

The macroinvertebrate community structure in reaches of the Nepean River within Study Area 6 indicates a slight level of disturbance is evident. Family richness and EPT% are relatively low, indicating a reduction of biodiversity (Table 33). The macroinvertebrate community of Nepean River comprises of taxa that range from pollution tolerant to pollutant sensitive and shows signs of slight impairment which is reflected by SIGNAL - SG scores of less than six.

Table 33 Mean values for macroinvertebrate indices monitored by Sydney Water within Study Area 6.

Site	Year Range of Data Collected	Abundance	Family Richness	%EPT	SIGNAL--SG
N57	2000 - 2020	83.2	18.9	33.8	5.6
N64	2020	49.3	17.0	37.2	5.9
N66B	2020	64	17.25	31	5.6
N66	2020	65.13	19.75	42.75	5.9

Ten macrophyte species were recorded in the Nepean River downstream of Wallacia Weir which included four exotic species and six native species (Table 34).

Table 34 Macrophytes recorded by Sydney Water at Nepean River monitoring sites N64, N66 and N66B between 2018 and 2020.

Scientific Name	Native / Exotic	Nepean River	Nepean River	Nepean River
Site Code		N64	N66	N66B
Alternanthera philoxeroides	Exotic	-	X	X
Egeria densa	Exotic	-	-	X
Eichhornia crassipes	Exotic	X	X	-
Hydrilla verticillata	Exotic	-	X	-
Ludwigia peploides	Native	X	-	-
Maundia triglochinoides	Native	-	X	-
Potamogeton crispus	Native	X	X	-
Potamogeton ochreatus	Native	X	X	X
Potamogeton sulcatus	Native	-	X	-
Vallisneria sp	Native	-	X	-

6.6.2 Field Assessment

Field assessments within this study area were undertaken downstream from Wallacia Weir to the junction of the Warragamba River and from the proposed release point on the Warragamba River to the junction with the Nepean River. No further assessment was undertaken downstream from the junction of the Nepean and Warragamba Rivers.

6.6.2.1 Waterway Validation

Waterway validation of Nepean River in Study Area 6 shows this stretch satisfies the definition of a “river” as per *NSW Water Management* Act 2000.

6.6.2.2 Key Fish Habitat

The section of the Nepean River is mapped as KFH according to the Fisheries Management Act 1994. This reach of river is also mapped as habitat critical for survival for Macquarie Perch. Field validation of this reach classified the River as Type 1 (highly sensitive Key Fish Habitat) and Class 1 (major Key Fish Habitat) (Figure 66).

Type 1 (highly sensitive Key Fish Habitat) was awarded due to the presence of in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 m in length and native aquatic plants. Additionally, the reach was classed as Type 1 (highly sensitive Key Fish Habitat) due to the expected presence of the Macquarie Perch.

Class 1 (major Key Fish Habitat) was awarded due to the Nepean River being a large, permanently flowing body of water and expected habitat of Macquarie Perch.

6.6.2.3 Groundwater Dependent Ecosystems

Field validation of GDEs showed mapped terrestrial GDEs corresponded to the location of native vegetation within riparian areas of the Nepean River (Figure 67).

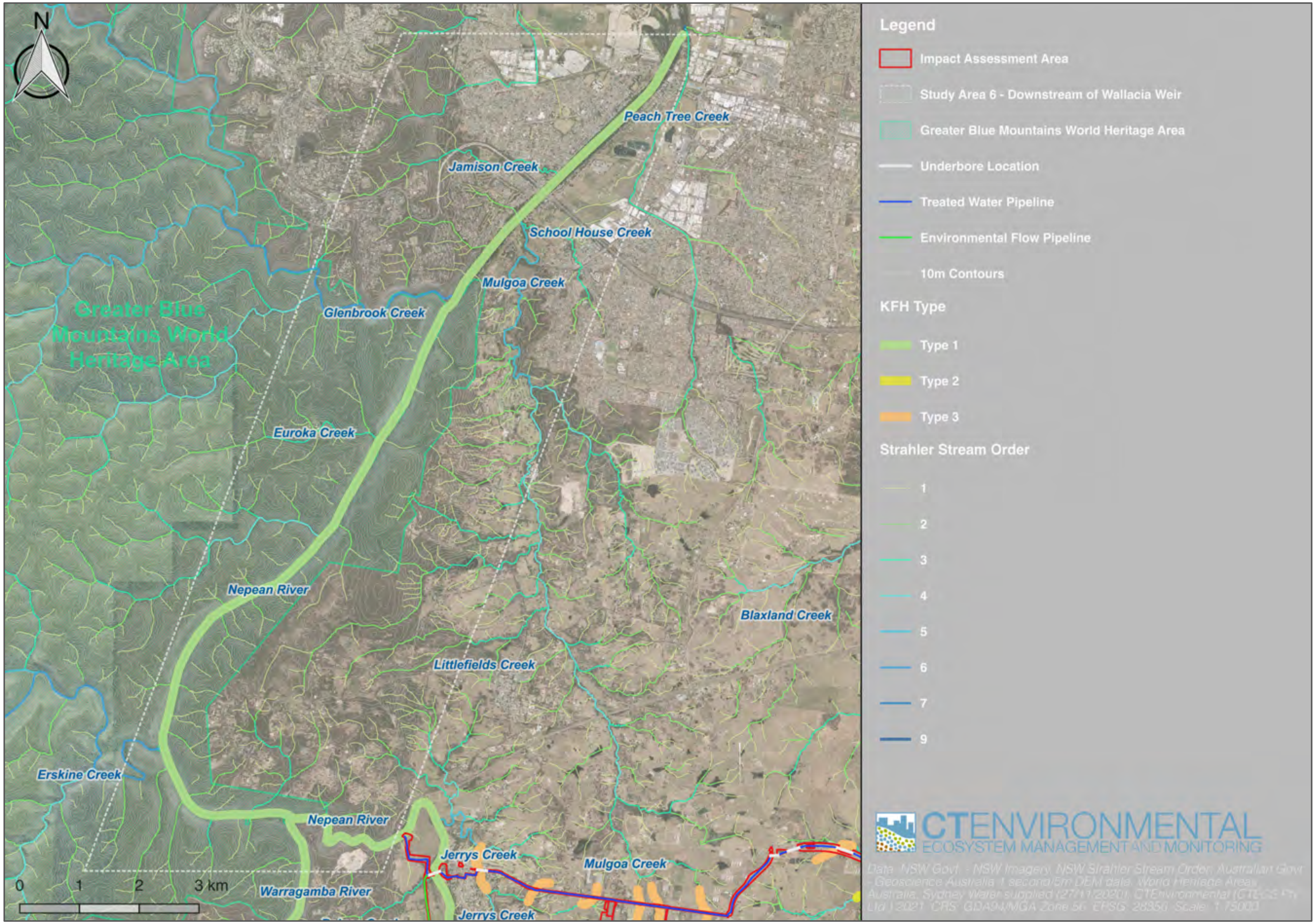

Figure 66 Study Area 6 - Downstream of Wallacia Weir – Type 1, Class 1 Key Fish Habitat.

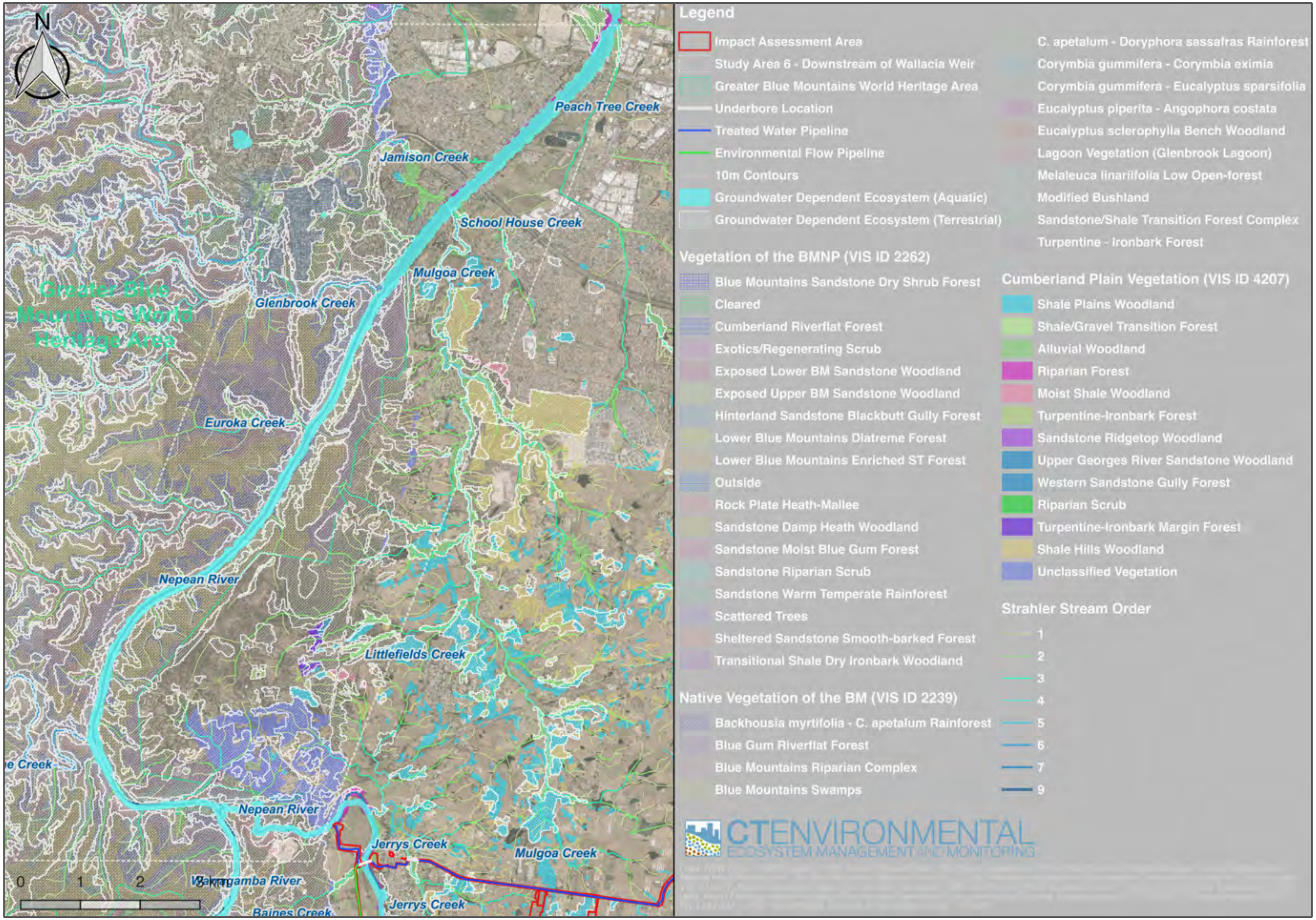

Figure 67 Groundwater dependent ecosystems and remnant native vegetation in Study Area 6.

6.6.2.4 Riparian Vegetation and River Channel Condition

Three assessments of riparian vegetation and creek channel condition assessments were conducted along the Nepean River within Study Area 6 and overall condition ranged from excellent to good condition (Table 35 and Figure 68).

The two sites with the highest total score on the Nepean River were sites 1 and 2, with overall scores of 90, which represent excellent condition. The other site, Nepean 50, had an overall score of 76%, which indicates good condition. The main influencer of the high RRA overall condition scores was the large extent of native bushland bordering the section of the waterway. All sites had excellent to good aquatic habitat and site features. The factor influencing the relatively lower score at Nepean River 50 was the presence of weed species, albeit at low abundance. There were minimal negative erosional features present at each site.

Table 35 Riparian vegetation and creek channel assessment results for the Nepean River – Study Area 6.

	Deposition and Erosion	Riparian Buffer	Vegetation Structure	Weeds	Site Features	Aquatic Habitat	Condition	Total Score (%)
Nepean River-1	-1	20	20	0	24	4	Excellent	90
Nepean River-2	-1	20	20	0	24	4	Excellent	90
Nepean River-50	-1	20	18.1	-6	18.9	0	Good	76

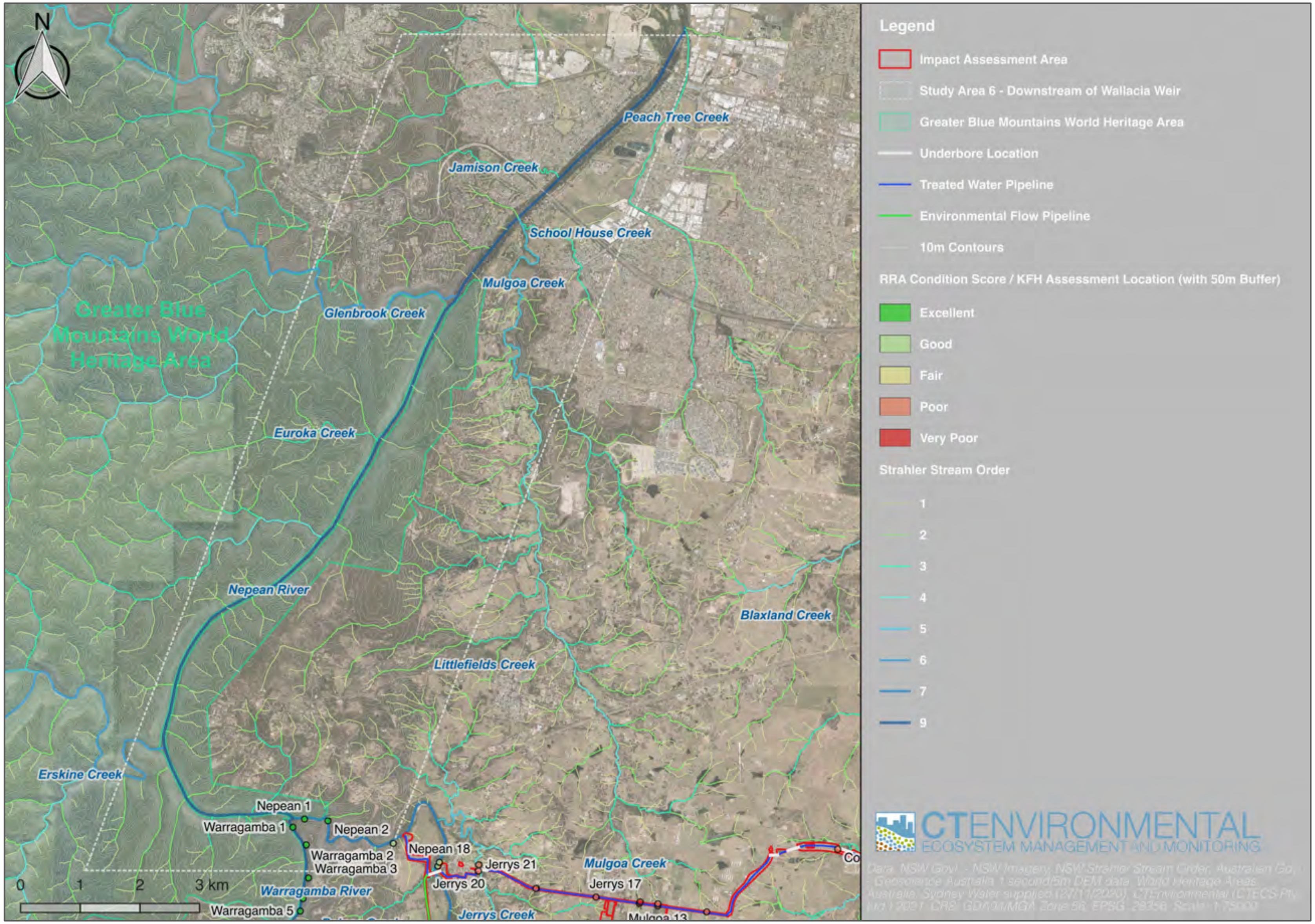

Figure 68 Results of riparian vegetation and creek channel condition across Study Area 6 – Downstream of Wallacia Weir.

6.6.3 Assessment of Potential Impacts – Construction Phase

Study Area 6 will not be directly impacted by construction phase impacts as no construction will occur within the study area. There is potential for indirect impacts to occur as a result of the construction of outlet structures in the Warragamba and Nepean Rivers which have been identified in Sections 6.4.3 and 6.5.3.

6.6.4 Assessment of Potential Impacts – AWRC Operational Phase

Assessment of potential water quality and hydrological driven impacts for Study Areas 5 and 6 have been combined in the following sections as potential impacts apply to the entire reach of the Nepean River subject to assessment by this study.

6.6.4.1 Predicted Water Quality

Modelling has been used to analyse the likely changes to water quality and hydrodynamics and assess potential residual impacts to the aquatic and riparian ecosystems of the Nepean River (Aurecon ARUP, 2021c). 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.

The scenarios were run for a representative dry and wet year and represent the full range of potential operating conditions related to Nepean River releases.

Near field modelling of toxicants has also been undertaken for 2036 and 2056 conditions.

Review of water quality modelling for AWRC releases (under the 2036 scenario) was undertaken to determine potential water quality driven impacts in the Nepean River upstream of Wallacia Weir to Bents Basin (Study Area 5) and downstream of Wallacia Weir to Penrith Weir (Study Area 6).

Results indicate significant change to water quality in the Nepean River upstream of Wallacia Weir is not apparent.

However, change to water quality in the Nepean River below the Weir (Study Area 6) is expected. These key findings are summarised in more detail below. For the 2036 impact scenarios, water quality changes generally extended about 15 km from Wallacia Weir. 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 impact scenario was compared to the equivalent background scenario (HN01) and the baseline scenario (HN00) (Aurecon ARUP 2021c).

6.6.4.2 Nitrogen

- In dry years, annual median total nitrogen concentrations were predicted to be comparatively lower than the background scenario in the reaches immediately downstream of the Nepean River release point. For the 2036 impact scenario (HN05), reductions in median concentrations were predicted in the range ~0.02 to ~0.03 mg/L. These reductions are due to increased dilution of the river water with the lower concentrations of the advanced treated water from the AWRC releases.

- Whilst the total nitrogen concentrations are predicted to be lower, the dissolved inorganic forms of nitrogen (ammonia and oxidised nitrogen) were predicted to be marginally higher than the background scenario in the vicinity of the AWRC release point, reflecting the composition of the treated water. Despite the marginal increases in ammonia and oxidised nitrogen, peaks in daily concentrations remained well below known toxicity levels.
- During the modelled wet year, the total nitrogen concentrations were generally predicted to be lower than the background scenario (HN01) downstream of Wallacia Weir, with median concentrations ~0.06 mg/L lower than background conditions for the simulated 2036 conditions (HN05). However periodic spikes of higher nitrogen concentrations were also predicted, associated with the episodic release of tertiary treated water from the AWRC. During the wet year, increases in concentrations were predicted up to ~0.7 mg/L higher than background conditions, with the introduction of the AWRC releases. These increases are however relatively short-lived, with concentrations returning quickly to levels equivalent, or lower, than background conditions within a few days.
- Due to the composition of the treated water releases, similar trends were also predicted for ammonia and oxidised nitrogen with temporary spikes in concentrations correlating with the release of tertiary treated water. Despite the temporary increases in the more bioavailable forms of nitrogen, peaks in daily concentrations remained well below the toxicant guideline values.

6.6.4.3 Phosphorus

- In a dry year, median phosphorus concentrations in the reaches of the Nepean River are expected to be marginally lower (<0.005 mg/L of total phosphorus and FRP on average in 2036) than background conditions.
- Downstream of Wallacia Weir, daily concentrations of total phosphorus and FRP are predicted to be generally lower than background conditions but with the periodic and relatively short-lived spikes correlating with the introduction of tertiary treated water into the AWRC releases.
- For total phosphorus, predicted median concentrations are reduced by ~0.005 mg/L at this location, but with periodic increases in daily concentrations up to 0.06 mg/L. These increases were predicted to return quickly to levels equivalent, or typically lower, than background conditions within a few days.

- In a wet year annual median phosphorus concentration is similar to that of the dry year, except the concentrations are incrementally higher than that in the dry year due to the elevated loading from the catchment. With introduction of the AWRC releases (circa 2036), reductions in annual median values were predicted up to 0.01 mg/L downstream of the Wallacia Weir releases.

Periodic spikes of higher nutrient concentrations are predicted, associated with the episodic release of tertiary treated water from the AWRC. With the introduction of the tertiary treated water, increases in daily concentrations of up to ~0.27 mg/L (total phosphorus) and 0.19 mg/L (FRP) were predicted, relative to background conditions.

- Immediately downstream of the confluence with the Warragamba River, these spikes in concentrations were modelled to reduce in magnitude with maximum predicted increases of 0.13 mg/L in total phosphorus, and 0.09 mg/L in FRP.
- Modelled spikes correlate with releases from the AWRC when there are higher proportions (up to 100%) of tertiary treated water being released into the Wallacia Weir pool. On average however, the total phosphorus and FRP concentrations were predicted to be generally lower than background conditions, and the spikes were short-lived with concentrations returning to background conditions, or below, within a day or two of the wet weather events.

6.6.4.4 Chlorophyll-*a*

- Change in modelled chlorophyll-*a* concentration between the impact and background scenarios is marginal when looking at the annual median profiles along the river. The predicted annual median profiles also showed concentrations lower than the relevant waterway objective from the upstream reach of the Nepean River down to well below Penrith Weir. The level of compliance with the waterway objectives was predicted to remain unmodified with the introduction of the AWRC releases.
- Elevated chlorophyll-*a*, above the waterway objective were however often observed in time periods when the inflow rates were low and the river was less well flushed and tended to increase during dry periods and would exceed the waterway objective quickly in these times. This risk was however not significantly changed in the impact scenario, relative to the background conditions.
- Peaks of chlorophyll-*a* appear to occur as a delayed response to available nutrient spikes.

6.6.4.5 Salinity

- Minor reductions (<0.05 g/L) in salinity were predicted with the introduction of the AWRC releases relative to the background conditions. These reductions were most evident in the regions around, and downstream of, the release point and due to the lower salinities in the treated water relative to the ambient river salinity.

- No significant differences in annual median profiles, or compliance with waterway objectives, were predicted for either the dry or wet years.

6.6.4.6 Dissolved Oxygen

- Notable improvements in dissolved oxygen were modelled with the introduction of the AWRC around and downstream of the AWRC releases, where oxygen sags (difference below saturation) were reduced in both the dry and wet years. Further downstream, sites showed similar responses to background conditions in terms of temporal variations of dissolved oxygen.
- The potential to improve compliance with the waterway objective is predicted with the introduction of the AWRC treated water releases to the River.

6.6.4.7 2056 Modelled Water Quality

In Nepean River, the impacts are generally predicted to be greater for the 2056 releases, with greater reductions in annual median concentrations for some parameters (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.

6.6.4.8 Nearfield modelling

During wet weather conditions, when inflows to the AWRC are greater than 1.3 x ADWF, releases to the Nepean River will include tertiary treated water, which introduces the risk of potential toxicity to aquatic organisms, including metals such as aluminium, copper, zinc and manganese.

CORMIX models were developed by Aurecon Arup (2021c) in line with industry standards to assess near field impacts, such as the potential for toxicity, in the immediate vicinity of the proposed AWRC release points. For the Nepean River upstream of Wallacia Weir, these models considered the potential toxicity of metals, including aluminium, copper, zinc and manganese.

The findings from the CORMIX modelling for the Nepean River (upstream of Wallacia Weir) suggests that dilution of wastewater in Nepean River receiving water associated with AWRC influent rates three times greater than the ADWF will be insufficient to maintain concentrations of these key metals below relevant guideline values all the time.

However, these are predicted to be infrequent and in line with severe wet weather events (for example two to three times per year, but frequencies may actually vary between zero and six events per year (Aurecon ARUP, 2021c)), and exceedances are often short-lived and therefore the risk of residual impacts to aquatic biota is considered low.

6.6.4.9 Hydrology and Hydraulics

An assessment of hydrology and hydraulic modelling of the Nepean River was undertaken to identify any potential impacts to aquatic and riparian ecosystems resulting from changes in ecohydraulic metrics under each release scenario. Wetted perimeter, flow velocity and depth data was provided by Streamology (2021) and used to assess the inundation of low-lying riparian vegetation and increases in aquatic habitat availability.

The impact of 2036 (Stage 1) and 2056 (Stage 2; where relevant) flow scenarios were assessed against current baseline ecological conditions (as defined for Study Area 5 and 6) and future background ecological conditions (future conditions without AWRC impact).

The section of the Nepean River with greatest potential for influence from the AWRC is uniquely positioned in and adjacent to a World Heritage Area, within State Government land holdings and adjacent to NSW National Parks and Wildlife Service (NPWS) National Park. Thus, it is considered that the ecological condition of aquatic and riparian ecosystems in the assessment reach is not foreseen to change significantly from defined baseline conditions by 2036 or 2056, given consideration of surrounding land holdings and foreseen land use.

In addition, the waterway objectives for the project provide water quality guidelines for the protection of the aquatic ecosystem. These objectives are based on existing Australian and NSW guidelines that have been put in place to ensure future development does not pose significant impact to aquatic systems and as a result preserve the current ecological condition.

As a result, the potential magnitude and severity of future modelled impacts have been compared to the current baseline ecological condition of aquatic and riparian ecosystems in the Nepean River, rather than a future background scenario. This approach is based on the assumption that this is also representative of the future background ecological condition of these ecosystems within this River.

For the purpose of this assessment, baseline ecological conditions act as a suitable and representative measure of future background conditions. The study assesses modelled future impacts such as wetted perimeter change and indicative inundation extent against current baseline ecological conditions as this comparison represents the magnitude of impacts against 2036 and 2056 background conditions. From this, the magnitude and severity of potential impacts to aquatic and riparian ecosystems was determined.

An assessment of hydrological and hydraulic-driven impacts to the aquatic and riparian environments of the Nepean River was undertaken (Streamology 2021) to assess the extent and magnitude of any hydraulic changes associated with future releases from the AWRC.

Included in this work was an assessment of changes in wetted perimeter, maximum channel depth and flow velocity under pre-determined flow scenarios which have been used to evaluate potential ecological impacts associated with increased flows in the Nepean River.

Approximately 30 km of the Nepean River was modelled and for assessment this has been divided into three (3) discrete Assessment Zones (Figure 69) which include:

- Assessment Zone 1: Warragamba River Confluence to Penrith Weir
- Assessment Zone 2: Wallacia Weir to Warragamba River Confluence
- Assessment Zone 3: Bents Basin to Wallacia Weir

The impacts of increased flows on the aquatic and riparian ecology of the Nepean River have been assessed for each of the abovementioned zones individually, and for the entirety of the study reach. Due to the spatial extent of the study area, further ad-hoc detailed analysis has been conducted for specific features of the system where required.

All assessment has been based on reporting and raw data presented in and developed for the Ecohydrology and Geomorphology Impact Assessment (Streamology 2021).

The Ecohydrology and Geomorphology Impact Assessment (Streamology 2021) has considered the influence of the current and proposed environmental flow releases into the Warragamba River on the hydrologic metrics of the Nepean River. Results of this study reported that there would be "negligible influence due to the small magnitude of the environmental flow releases (maximum of 30 ML/d) and the constrained low flow connection between the rivers at the junction". Further, it was reported that any influences on conditions in the Nepean River downstream of the junction were further reduced by the operation of Penrith Weir.

Impacts to the aquatic and riparian ecology of the Nepean River have been assessed for both the modelled 2036 and median and ninetieth-percentile flow scenarios (hereafter referred to as 90th percentile flows). An assessment of 90th percentile flows was conducted to account for any ecological impact in the Nepean River that may arise during low flow conditions as a result of AWRC releases. Under 90th percentile flow conditions in the Nepean River, AWRC releases comprise the greatest proportion of flow relative to total flow, and thus have been considered further in this assessment.

Table 36 provides an overview of flows that informed the impact assessment.

Table 35 Nepean River flow scenarios selected to inform the aquatic ecology impact assessment.

Flow Type	Baseline	+50 ML /day	+100 ML /day
Median Flow	229ML /day	279ML /day	329ML /day
90th Percentile	55ML /day	105ML /day	155ML /day
***Closest modelled flow for 90th Percentile conditions**	50ML /day	114ML /day	149ML /day

The closest modelled flows for 90th percentile conditions of 50 ML /day, 114 ML /day and 149 ML /day were used in this assessment.

6.6.4.10 Wetted Perimeter Analysis

One of the primary methods of impact assessment was to determine whether an increase and/or decrease of aquatic habitat availability under future flow scenarios for both median (baseline, +50 ML /day and +100 ML /day scenarios) and 90th percentile (baseline, +50 ML /day and +100 ML /day scenarios) flows were apparent. To do this, a review of modelled wetted perimeter data was undertaken. Wetted perimeter relates to the area of the waterway channel that is touched by water. It does not accurately represent the area of inundation.

The percentage change in wetted perimeter extent (i.e. aquatic habitat availability) under the prescribed flow scenarios was calculated for each Assessment Zone and for the entire study reach. This metric was used to gain an understanding of any potential change in aquatic and riparian habitats across the assessment area, to gauge the magnitude of change (relative to baseline flows) and to identify any potential beneficial impacts to habitats in the Nepean River.

This approach was in line with Streamology's (2021) assessment of ecohydraulic metrics (i.e. wetted perimeter, depth and velocity), which focused on how the metrics vary between baseline flow scenarios and the Stage 1 (50 ML /day) impact flows. This assessment also represents an analysis against future background ecological conditions (future conditions without AWRC impact) within the reach (refer to Methods Section for definition). Conditions and ecological impacts relating to +100 ML /day scenarios were also considered to provide a high level understanding of potential 2056 conditions and magnitude of potential change.

Calculations related to modelled changes in wetted perimeter were undertaken using spatial and spreadsheet data provided by Streamology (2021). Data was extracted for cross sections of interest, which were areas identified by Streamology (2021) where significant changes were predicted, and changes in area of wetted perimeter calculated.

6.6.4.11 Flow Velocity

Maximum flow velocities under median and 90th percentile flows (baseline, +50 ML /day and +100 ML /day scenarios) at specific cross-sections of the Nepean River were provided by Streamology (2021) to inform assessment of any potential velocity-driven impacts to aquatic fauna, including macroinvertebrates, and other aquatic fauna, such as the threatened Macquarie Perch (*Macquaria australasica*). Where relevant and/or available, macroinvertebrate flow-tolerance/mobilization threshold values were interrogated considering modelled velocities at notable features (cross-sections) along the Nepean River.

6.6.4.12 Aquatic Ecology

Potential hydraulic-driven impacts to aquatic flora (macrophytes) and fauna were considered using a combination of the abovementioned model results for the Nepean River, field survey data and available scientific literature. Flow tolerances and defined ecological thresholds for aquatic fauna have been assessed, particularly those pertaining to the mobilization of macroinvertebrates, some of which constitute prey of the threatened Macquarie Perch (*Macquaria australasica*).

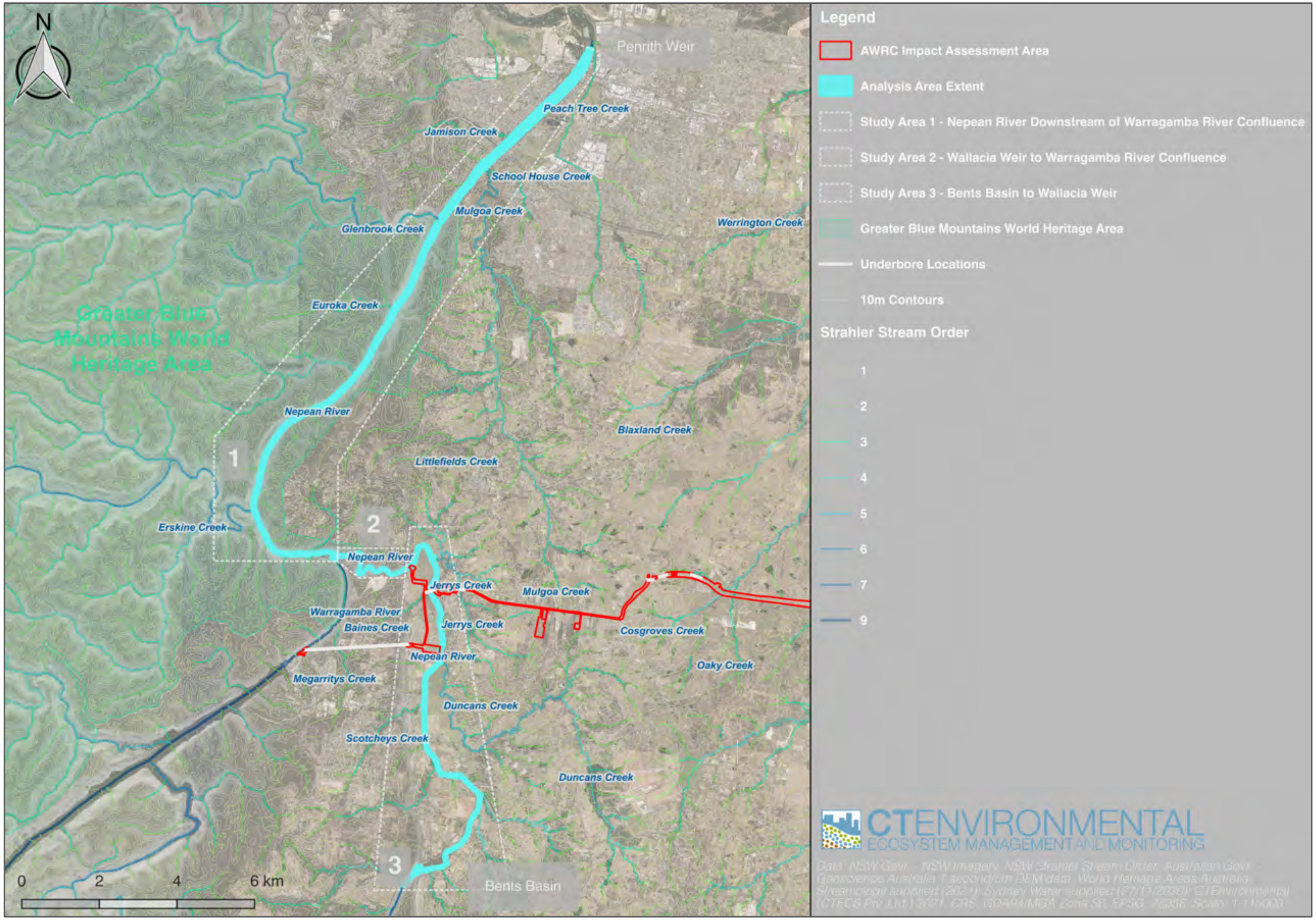

Figure 69 Overview of Assessment Zones (1-3). Light blue depicts the extent of the assessment.

6.6.5 Wetted Perimeter Analysis – Total Study Reach

The wetted perimeter assessment was calculated for the Nepean River for both median and 90th percentile flows (baseline, +50 ML /day and +100 ML /day scenarios). Table 36 displays the results from this assessment.

The percentage change of wetted perimeter polygons between baseline and future modelled flow scenarios was calculated to determine the magnitude of change across the entire subject area and the extent to which aquatic habitat would be lost and/or gained under certain flow conditions (Table 36).

The difference in wetted perimeter extent under each flow condition for the entire assessment area is presented below, along with the percentage change (i.e. percentage increase and/or decrease of wetted perimeter relative to baseline flows).

As reported by Streamology (2021), a spatial assessment of wetted perimeter showed isolated increases at several locations along the study reach. Where these changes exist, they are confined to the bounds of the existing/defined channel and it should be noted that under all modelled flow conditions the flows remain within the channel and so changes in wetted perimeter do not engage the floodplain or cause additional overbank flow.

Note that no field validation to assess the potential magnitude of localized impacts was undertaken as part of this study. Assessment of potential impacts are based on desktop analysis only.

Table 36 Wetted perimeter extents for flow scenarios across the modelled extent of the Nepean River (* closest modelled equivalent flow), area differences and percent change from baseline flows.

Scenario	Flow (ML /day)	Wetted Perimeter Extent (m^2)	Wetted Perimeter Extent (Km^2)	Wetted Perimeter Extent Area Difference (m^2)	Wetted Perimeter Area Difference (Km^2)	Percent Change from baseline flow
Baseline 90%ile Flow (low flow)	50*	2363681.2	2.4	-	-	-
Baseline 90%ile Flow + 50 ML /day	114*	2392889.9	2.34	29208.7	0.03	**1.2**
Baseline 90%ile Flow + 100 ML /day	149*	2400248.4	2.4	36567.2	0.04	**1.5**
Baseline Median Flow	229	2398204.2	2.4	-	-	-
Baseline Median Flow + 50 ML /day	279	2424059.5	2.4	25855.3	0.03	**1.1**
Baseline Median Flow + 100 ML /day	329	2436321.2	2.4	38117.1	0.04	**1.6**

An assessment of 90th percentile flow wetted perimeter extent across the entire assessment area showed a 1.2 percent increase under the +50 ML /day flow was predicted. A 1.5 percent increase was predicted under the +100 ML /day flow.

For reference, a 0.31 percent increase is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

An assessment of median flow wetted perimeter extent across the entire assessment showed that a 1.1 percent increase of under the +50 ML /day flow was predicted. A 1.6 percent increase is predicted under the +100 ML /day flow.

For reference, a 0.51 percent increase is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

The assessment of wetted perimeter extent for the entire study reach under the selected flow scenarios provides a coarse indication of the magnitude of potential increased inundation that may occur in the Nepean River between Bents Basin and Penrith Weir as a result of AWRC releases.

The percentage change from baseline flows across all flow scenario comparisons, for both 90th percentile and median flows is a maximum of 1.6 percent increase in wetted perimeter extent, across the entire study reach.

When considered across the broad spatial context, the modelled increases shown in Table 36 are likely to result in negligible impacts to riparian vegetation and aquatic ecosystems which is highlighted by the maximum increase in the area of wetted perimeter of only 3.8 Hectares.

There may be some localized additional inundation of in-channel vegetation and a small upward shift of the aquatic ecosystem within the river channel (refer to Depth Assessment). However, due to limitations of the hydrological modeling developed for this area (Appendix E), it is difficult to predict with high accuracy the extent and magnitude of any localised impacts across the approximate 30 km stretch of the River subject to potential change.

It must be considered that the hydrology, geomorphology and ecology differ along this spatial gradient and cannot be expressed in this result with enough definition to determine location or area specific impacts to aquatic and riparian ecology.

In the broader context an increase in wetted perimeter may equate to an increase in aquatic habitat, but in turn impact riparian habitats as more frequent inundation may occur, having the potential to cause in-channel die back of vegetation due to over saturation of root zones or drive a highly-localised change in riparian community structure to one that preferences wetter conditions.

These potential impacted areas are examined in the following sections at smaller spatial scales in Assessment Zones 1 – 3, with an understanding of the model limitations (Appendix E) and constraints that this poses on identifying areas of impact and quantifying the magnitude of these impacts, where they may exist.

The wetted perimeter percentage change assessment conducted for Assessment Zones 1 – 3 provides greater definition and has been used to inform inferences made by this assessment. Further, individual assessments have also been completed at specific cross sections within Assessment Zones 1 – 3 to provide a finer level of detail, as required.

6.6.5.1 Assessment Zone 1 – Warragamba River Confluence to Penrith Weir

Assessment of wetted perimeter change was conducted for both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenario) flows within Zone 1 (Figure 70). The percentage change between modelled flow scenarios was calculated to determine the magnitude of wetted perimeter change across Assessment Zone 1 and the extent to which aquatic habitat would be gained under certain flow conditions (Table 38).

Assessment of the 90th percentile flow wetted perimeter extent across Assessment Zone 1 showed a 0.77 percent increase was predicted under the +50 ML /day flow. A 0.85 percent increase was predicted under the +100 ML /day flow.

For reference, a 0.076 percent increase is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

An assessment of median flow wetted perimeter extent across Assessment Zone 1 showed that a 0.35 percent increase under the +50 ML /day flow was predicted. A 0.69 percent increase was predicted under the +100 ML /day flow.

For reference, a 0.34 percent increase of available aquatic habitat is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

An assessment of wetted perimeter extent across Assessment Zone 1 under each flow scenario provides insight into the magnitude of potential inundation impact that is predicted between the Warragamba River Confluence and Penrith Weir (commonly referred to as “Penrith Weir Pool”).

The percentage change from baseline flows across all flow scenarios, for both 90th percentile and median flows, was modelled at a maximum 0.85% increase in wetted perimeter across Assessment Zone 1. It is considered that an increase in wetted perimeter in the order of <1 percent (which is indicative of a change in inundation extent), which equates to a maximum area of 1.5 Hectares of change, will result in negligible broad scale impacts to riparian vegetation and aquatic ecosystems.

When considered across the broader spatial context, the modelled increases shown in Table 37 are likely to result in negligible impacts to riparian vegetation and aquatic ecosystems. There may be some localized additional inundation of in-channel vegetation and a small upward shift of the aquatic ecosystem within the river channel (refer to Depth Assessment). However, due to limitations of the hydrological modeling developed for this area (Appendix E), it is difficult to predict with high accuracy the extent and magnitude of any localised impacts.

A notable area of a predicted localised impact is at the confluence of the Nepean River and Glenbrook Creek. Streamology (2021), offered commentary on the potential of the inundation impact within this area which states that “due to the confined nature of the channel, the flows remain in-channel and there is no overbank flow occurring because of the release (Stage 1 +50 ML /day)”, further noting that the, “large in-channel bar [at the confluence]… is slightly more inundated under the AWRC release conditions”.

The Glenbrook Creek – Nepean River Confluence is the most prone feature to wetted perimeter change (as an indicator of inundation) in this management zone and was considered by Streamology (2021) to be subject to minor impacts. Given this, it is considered that other areas up and downstream of this location would only experience an equal and/or lesser wetted perimeter change, thus illustrating that the overall impact on riparian ecosystems in this assessment zone is considered to be low.

Similarly, an increase in wetted perimeter in the order of <1 percent for all assessed flow scenarios suggests there may be a slight upward shift of the aquatic ecosystem within the river channel within this zone due to a potential increase in inundation extent. However, based on the hydraulic modelling, the magnitude of this increase is considered negligible (as described above) and therefore the impact on aquatic and riparian ecosystems is also considered negligible as native vegetation is generally elevated slightly above the waterline and regular inundation is unlikely as the Penrith Weir essentially controls the level of the weir pool which also regulates fluctuations in water depth.

The modelled minor and arguably imperceptible upward shift of the aquatic ecosystem as a result of potential localised inundation within the river channel in this zone is considered to provide a beneficial increase to aquatic refuge and habitat and is not considered to adversely impact habitat of aquatic fauna and macrophytes that exhibit preference for shallow/edge habitats.

It must be noted that wetted perimeter change does not exclusively refer to changes to the area of bank inundated, rather it incorporates the entire area of the channel touched by the water. As a result, the area riparian vegetation and/or shallow aquatic habitats are a proportion of the total area of wetter perimeter and are therefore smaller than the area total.

Table 37 Assessment Zone 1 wetted perimeter extent areas (* closest modelled equivalent flow), differences and percent change from baseline flow.

Scenario	Flow (ML /day)	Wetted Perimeter Extent (m^2)	Wetted Perimeter Extent (Km^2)	Wetted Perimeter Area Difference (m^2)	Wetted Perimeter Area Difference (Km^2)	Percent Change from Baseline flows
Baseline 90%ile Flow	50*	1822111.5	1.8	-	-	-
Baseline 90%ile Flow + 50 ML /day	114*	1836128.2	1.8	14016.8	0.01	**0.77**
Baseline 90%ile Flow + 100 ML /day	149*	1837517.7	1.8	15406.3	0.02	**0.85**
Baseline Median Flow	229	1838821.3	1.8	-	-	-
Baseline Median Flow + 50 ML /day	279	1845193.1	1.8	6371.8	0.01	**0.35**
Baseline Median Flow + 100 ML /day	329	1851471.7	1.9	12650.4	0.01	**0.69**

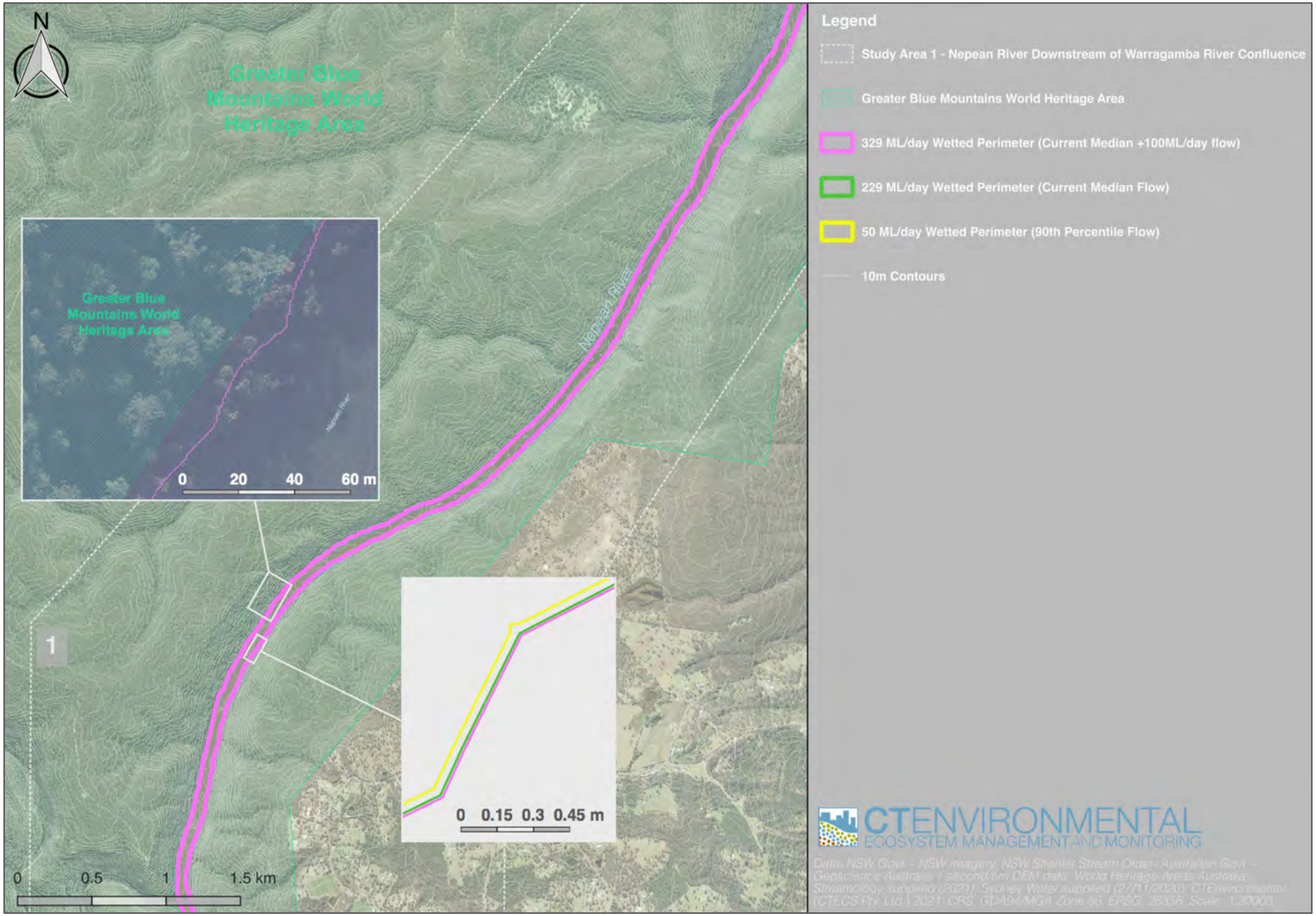

Figure 70 A subsection of Assessment Zone 1.

6.6.5.2 Assessment Zone 2 – Wallacia Weir to Warragamba River Confluence

A wetted perimeter extent assessment was undertaken for the Nepean River between Wallacia Weir and Warragamba River confluence for both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenarios) flow within Assessment Zone 2 (Figure 71).

The percentage change between modelled flow scenarios was calculated to determine the magnitude of wetted perimeter extent change across Assessment Zone 2 and the extent to which aquatic habitat may change under certain flow conditions. The difference in wetted perimeter extent under each flow condition is presented below (Table 38).

Table 38 Assessment Zone 2 wetted perimeter extent areas (* closest modelled equivalent flow), difference and percent change from baseline flow.

Scenario	Flow (ML /day)	Wetted Perimeter Extent (m^2)	Wetted Perimeter Extent (Km^2)	Wetted Perimeter Extent Area Difference (m^2)	Wetted Perimeter Extent Area Difference (Km^2)	Percent Change from Baseline flows
Baseline 90%ile Flow	50*	53343.4	0.05	-	-	-
Baseline 90%ile Flow + 50 ML /day	114*	59230.9	0.06	5887.5	0.01	**11**
Baseline 90%ile Flow + 100 ML /day	149*	61724	0.06	8380.6	0.01	**16**
Baseline Median Flow	229	65225	0.07	-	-	-
Baseline Median Flow + 50 ML /day	279	67348.6	0.07	2123.6	0.002	**3.3**
Baseline Median Flow + 100 ML /day	329	70074.5	0.07	4849.4	0.01	**7.4**

An assessment of 90th percentile flow wetted perimeter extent across Assessment Zone 2 predicts an 11 percent increase under the +50 ML /day flow. A 16 percent increase is predicted under the +100 ML /day flow.

For reference, a 4.2 percent increase is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

An assessment of median flow wetted perimeter extent across Assessment Zone 2 showed a 3.3 percent increase is predicted under the +50 ML /day flow. A 7.4 percent increase is predicted under the +100 ML /day flow.

For reference, a 4 percent increase of available aquatic habitat is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

Assessment of wetted perimeter extent change across Assessment Zone 2 under the prescribed flow scenarios provides insight into the magnitude of potential inundation impact between Wallacia Weir and the Warragamba River Confluence.

This section of the Nepean River, unlike Assessment Zones 1 and 3 flows through a meandering sandstone gorge, with steep bedrock exposed banks, large boulder chokes and pools on prominent river bends i.e. Norton's Basin. As such, the Nepean River in this section is narrower and more confined to boulder-laden and bedrock flow paths than the wide, deep weir pools of Penrith Weir Pool (Assessment Zone 1) and Wallacia Weir Pool (Assessment Zone 3).

The percentage change from baseline median flows was in the magnitude of up to 3.3 percent (+50 ML /day) and 7.4 percent (+100 ML /day) increase in wetted perimeter extent across the assessment zone.

It is considered that an increase in wetted perimeter in the order of 3.3 percent (+50 ML /day), which provides a coarse indication of inundation extent, has some potential for localised inundation of low-lying riparian habitats which may cause vegetation dieback of species that cannot tolerate prolonged periods of inundation or sustained root zone saturation. This may trigger a direct loss of riparian vegetation or a change in the vegetation community to one with higher tolerance to inundation or saturated root zones.

Note that this effect is only likely to occur to scatted vegetation growing near the current waterline. This area is steep, and the majority of vegetation is located above the bedrock dominated channel and boulder strewn banks.

Additionally there is potential positive impacts to the aquatic ecosystem associated with a possible upward shift of the aquatic ecosystem within the river channel (refer to Depth Assessment).

Results of modelling shown in Table 38 predict a maximum increase in wetted perimeter of 0.8 Hectares of River is expected across the area and although very localised impacts may occur, the potential for broader scale impact to the riparian and aquatic ecosystem is this assessment area is considered negligible due to the dominant geomorphology within this area which includes steep bedrock bed and banks and patchy in-channel riparian vegetation which predominantly grows higher up the bank above the current waterline.

However, given the coarseness of the modelled data across the zone and multiple anomalies identified within the Norton's Basin complex (Appendix E), this result should be treated with caution and may represent a potential over-expression of wetted perimeter percent change.

Further data ground-truthing would be required to refine the model to remove anomalies that are likely resulting in an over-expression of wetted perimeter (Appendix E) and thus, the magnitude of impacts associated with this metric.

Similarly, an increase in wetted perimeter percent change in the order of up to 3.3 percent (+50 ML /day) and 7.4 percent (+100 ML /day) suggests a potential upward shift of the aquatic ecosystem may occur within this zone which has potential to increase aquatic habitat by displacing riparian habitats. This has potential to expand aquatic habitats along the margins of the river and provide benefits to taxa that rely on edge habitats and shallow areas such as benthic macroinvertebrates and species that prey on this group such as Australian Bass.

Again, for reasons mentioned above, this result should be treated with caution. Identifying and accurately defining the magnitude and locations of these increases is not possible given limitations associated with model coarseness. However, based on the modelling results (described above), the magnitude of the predicted increase across the broader assessment area scale is unlikely to drive significant impact on the aquatic and riparian ecosystems and therefore the risk of impact is considered negligible.

It must be noted that wetted perimeter change does not exclusively refer to changes to the area of bank inundated, rather it incorporates the entire area of the channel touched by the water. As a result, the area riparian vegetation and/or shallow aquatic habitats are a proportion of the total area of wetter perimeter and are therefore smaller than the area total.

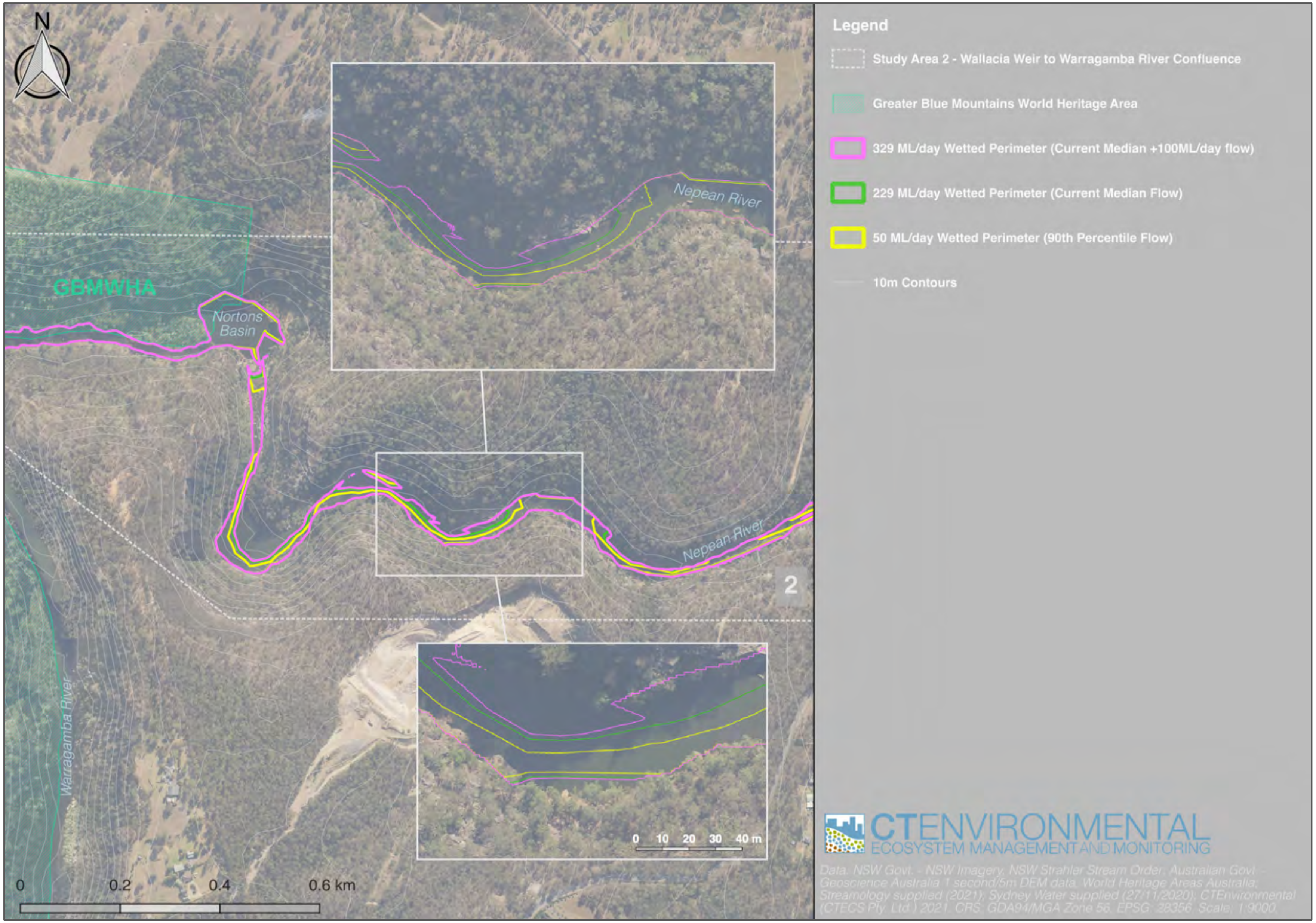

Figure 71 A subsection of Assessment Zone 2. Norton’s Basin is observed image left.

6.6.5.3 Assessment Zone 3 – Bents Basin to Wallacia Weir

Assessment of wetted perimeter extent was conducted for the Nepean River for both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenario) flows within Assessment Zone 3 (Figure 72). The following (Table 39) displays the results from this assessment.

The percentage change between modelled flow scenarios was calculated to determine the magnitude of wetted perimeter change across Assessment Zone 3 and the extent to which aquatic habitat may change under certain flow conditions. The difference in wetted perimeter extent under each flow condition is presented below, along with the percentage change.

An assessment of 90th percentile flow wetted perimeter extent across Assessment Zone 3 predicted a 1.9 percent increase under the +50 ML /day flow. A 2.6 percent increase is predicted under the +100 ML /day flow. These proportional increases equate to a respective 0.9 hectare and 1.3 hectare increase in wetted perimeter.

For reference, a 0.70 percent increase of available aquatic habitat is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

An assessment of median flow wetted perimeter extent across Assessment Zone 3 showed a 3.5 percent increase was predicted under the +50 ML /day flow. A 4.2 percent increase was predicted under the +100 ML /day flow. Which equates to a respective 1.7 hectare and 2.0 hectare increase in wetted perimeter.

For reference, a 0.64 percent increase of available aquatic habitat is predicted under the +100 ML /day flows relative to +50 ML /day flows (note: not a baseline flow comparison – for reference only).

The assessment of wetted perimeter extent across Assessment Zone 3 under current and proposed future flow scenarios provides a coarse indication of the magnitude of potential inundation impact between Bents Basin and Wallacia Weir (commonly referred to as the “Wallacia Weir Pool”).

The percentage change from baseline flows for all flow scenarios, for both 90th percentile and median flows, shows a maximum of 4.2 percent increase in wetted perimeter extent across the entire assessment zone.

It is considered that an increase in wetted perimeter (which provides a coarse indication of inundation extent) in the order of 3.5 percent (+50 ML /day), or 1.7 Hectares, has some potential for localised inundation of low-lying riparian habitats which may cause vegetation dieback of species that cannot tolerate prolonged periods of inundation or sustained root zone saturation. This may trigger a direct loss of riparian vegetation or a change in the vegetation community to one with higher tolerance to inundation or saturated root zones. Additionally, this modelled increase may drive an upward shift of the aquatic ecosystem within the river channel which may provide benefit to some aquatic taxa, but impact others (refer to Depth Assessment).

Given the coarseness of the modelled data across the zone, it is not possible to quantify the magnitude of this change with greater definition than <3.5 percent indicative inundation extent increase. Further data ground-truthing would be required to refine and define the magnitude and locations of impacts in this zone beyond the current assessment. In any case, the modelled outputs suggest the magnitude of the predicted increase in wetted perimeter, which equates to < 2 Hectares of change, is unlikely to drive significant change across the broader assessment reach and therefore the potential impact on riparian vegetation is considered low.

This result compliments the results of the Depth Assessment and reflects the findings of Streamology (2021) who commented on the increased wetted perimeter and inundation of a flood plain flow re-entry point to a, “slightly higher level” which represents a very localised impact. Streamology further notes, that [even under median +100 ML /day flows], “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”.

Similarly, an increase in wetted perimeter in the order of 3.5 percent (median +50 ML /day) or < 2 hectares suggests that there may be a slight upward shift of the aquatic ecosystem in the river channel within this zone. A small, upward shift of the aquatic ecosystem within the river channel in this zone has potential to expand aquatic habitats along the margins of the River and provide benefits to taxa that rely on edge habitats and shallow areas such as benthic macroinvertebrates and species that prey on this group such as Australian Bass.

Based on the modelled results (described above), the magnitude of the increase in wetted perimeter is considered to be small given the low percentage of change predicted, and therefore the impact on aquatic and riparian ecosystems is considered low. It must be noted that wetted perimeter change does not exclusively refer to changes to the area of bank inundated, rather it incorporates the entire area of the channel touched by the water. As a result, the area riparian vegetation and/or shallow aquatic habitats are a proportion of the total area of wetter perimeter and are therefore smaller than the area total.

Table 39 Assessment Zone 3 wetted perimeter extent areas (* closest modelled equivalent flow), difference and percent change from baseline flow

Scenario	Flow (ML /day)	Wetted Perimeter Extent (m^2)	Wetted Perimeter Extent (Km^2)	Wetted Perimeter Area Difference (M^2)	Wetted Perimeter Extent Area Difference (Km^2)	Percent Change from Baseline flow
Baseline 90%ile Flow	50*	488156.6	0.5	-	-	-
Baseline 90%ile Flow + 50 ML /day	114*	497467.9	0.5	9311.4	0.01	**1.9**
Baseline 90%ile Flow + 100 ML /day	149*	500942.9	0.5	12786.3	0.01	**2.6**
Baseline Median Flow	229	494093.3	0.5	-	-	-
Baseline Median Flow + 50 ML /day	279	511453.8	0.5	17360.5	0.02	**3.5**
Baseline Median Flow + 100 ML /day	329	514707.2	0.5	20613.9	0.02	**4.2**

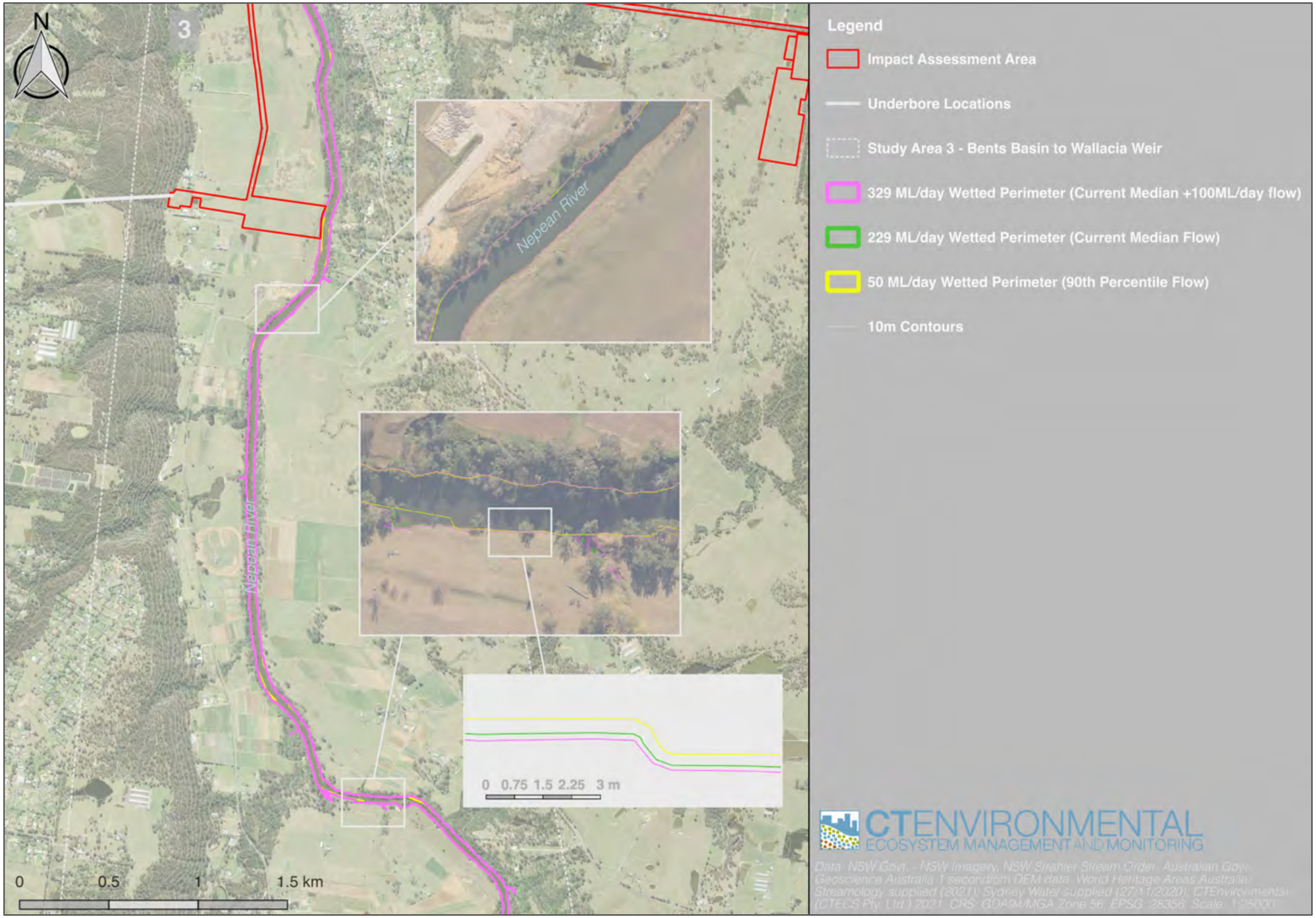

Figure 72 A subsection of Assessment Zone 3. Insert at the bottom of the image displays the minor differences in wetted perimeter extents between flows at this location.

6.6.6 Flow Velocity and Depth at Key Cross Sections on the Nepean River

Model output data provided by Streamology (2021) for maximum flow velocity and depth at cross-sections along the Nepean River from Bents Basin to Penrith Weir was used to identify any potential hydraulic-driven impacts to aquatic and riparian ecology. Ten (10) key locations (Figure 74) were selected as follows (listed north to south) for further assessment:

- Penrith Weir
- Nepean Bridge
- Glenbrook Creek-Nepean River confluence
- Erskine Creek-Nepean River Confluence
- Warragamba River-Nepean River Confluence
- Norton's Basin
- Wallacia Weir
- Wallacia Bridge
- Nepean River at Scotcheys Creek
- Bents Basin

The above cross-sections were chosen based on their spatial distribution within the model and for their potential to experience notable changes to metrics assessed. Several recommendations have been made regarding where greater model definition could be developed.

6.6.6.1 Velocity-Driven Impacts to Aquatic Ecology

Changes to flow velocity have the potential to significantly alter assemblages of aquatic macroinvertebrates in streams and rivers, which comprise a substantial proportion of the diet of fish and other aquatic fauna species, and create barriers to fish movement, including the threatened Macquarie Perch (*Macquaria australasica*).

A consideration of localised, velocity-driven hydraulic changes and their potential to impact aquatic and riparian ecology was, therefore, an instrumental part of this assessment.

Where relevant and/or available, macroinvertebrate flow-tolerance/mobilization threshold values were interrogated considering modelled maximum velocities at notable features (cross-sections) along the Nepean River (Table 41). Maximum flow velocities for both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenarios) flows were assessed at key cross sections for any increases in flow velocity that would have the potential to exceed aquatic macroinvertebrate mobilization or hydraulic habitat thresholds, thus resulting in a potential change to macroinvertebrate community assemblage and potentially impacting higher trophic relations.

In addition to determining potential impacts on aquatic macroinvertebrates, this is critical in determining impacts (if any) to the threatened Macquarie Perch, which has been mapped by NSW DPI Fisheries to potentially utilize habitat within the Nepean River, Glenbrook Creek and Erskine Creek.

Hydraulic modelling was conducted by Streamology using best-available data. Data presented in this assessment has been extracted from notable and representative cross-sections generated as part of the modelling.

6.6.6.2 Aquatic Macroinvertebrate Mobilization Velocity Thresholds

Extensive literature review was undertaken to determine critical flow related thresholds for selected macroinvertebrate taxa present or potentially present in the study area. Due to the scarcity of literature on this topic, specifically the determination of maximum flow velocities that macroinvertebrates can withstand before being mobilised, a field based trial was conducted by CTENVIRONMENTAL (unpublished data) to supplement the literature values. For details on the field-based study see Appendix F.

In the absence of available scientific literature defining macroinvertebrate mobilisation velocity thresholds, the literature review focused on identifying available values for optimal macroinvertebrate flow tolerances/thresholds, which then allowed the results of the CTENVIRONMENTAL (unpublished data) experiment to be situated and validated within a value range applicable to each taxa.

Research into optimal flow thresholds undertaken by Gore (1977), Collier (1993), Gore (2001), Thirion (2016) and Theodoropoulos (2017) was consulted and where relevant, optimal threshold values were extracted to supplement the values of the field experiment. Values derived by Thirion (2016) and Collier (1993) were situated against the experimental results (Appendix F).

Values developed by Gore (1977), Gore (2001) and Theodoropoulos (2017), which were used as a reference by this study, are presented graphically below in Figure 73 and exemplify the range of reference values available in the literature. Where taxa (such as *Isostictidae* (*Coenagrionidae* and *Megapodagrionidae*)) were not assessed by the experiment or values were not available in the literature, this was highlighted and a velocity threshold value was assigned based on values of like taxa.

Defined optimal threshold values in the literature varied. For example, an assessment of optimal flow velocity for EPT varied between the work of Gore (2001; 0.22 m/s) and Theodoropoulos (2017; 0.425 m/s), highlighting the indicative range of optimal values for which the CTENVIRONMENTAL (unpublished data) experimental mobilisation value for the EPT grouping was situated against. The CTENVIRONMENTAL (unpublished data) values supplemented those available in the literature for taxa common or with the potential to occur in the Nepean River and were generally situated within the defined range of values available in the literature. Application of these thresholds then facilitated a more detailed assessment of ecological impacts associated with flow velocity and depth at key cross sections along the Nepean River.

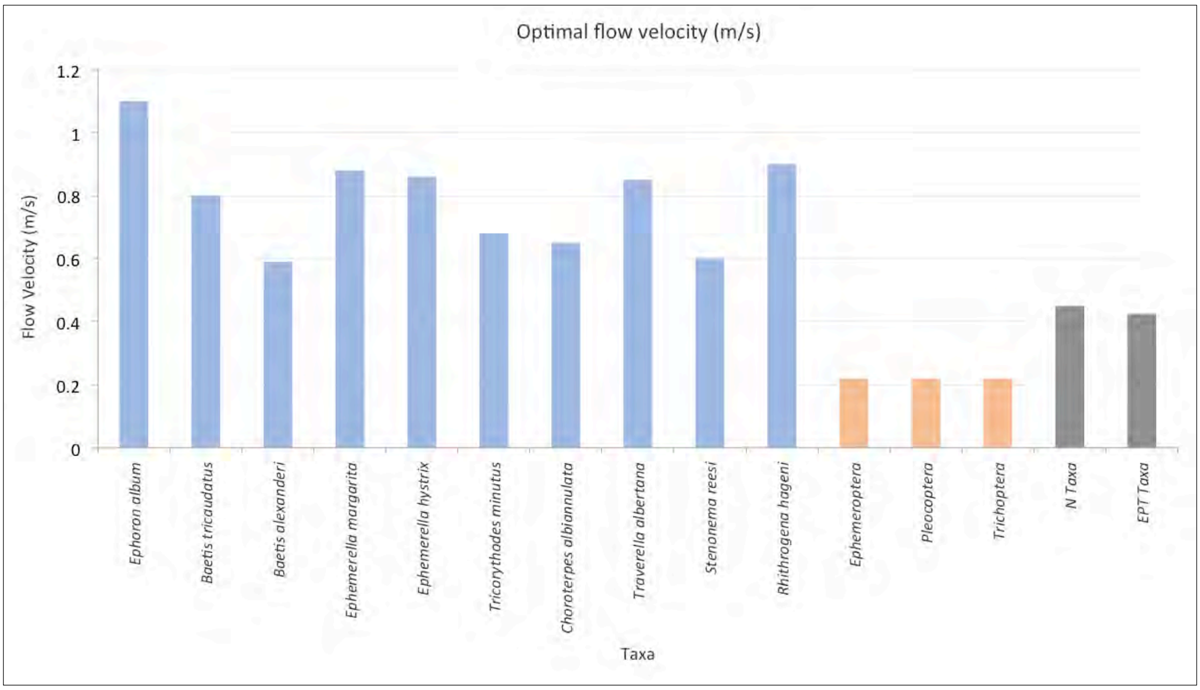

Figure 73 Optimal flow velocities (m/s) of selected macroinvertebrate taxa/groups used to situate the results of the CTENVIRONMENTAL field experiment. Values derived from: Gore (1997, Blue), Gore (2001, Orange) and Theodoropoulos (2017, Grey).

Aquatic macroinvertebrate mobilization velocity thresholds were interrogated to provide insight into whether any future changes in flow velocity in the Nepean River could potentially impact upon aquatic macroinvertebrate individuals and/or community assemblages. Available scientific literature informed this ecological threshold assessment (Table 40).

Table 40 Aquatic macroinvertebrate mobilisation velocity thresholds for Families common and/or with potential to occur in the Nepean River (Range: 0.10 m/s – 2.90 m/s).

Aquatic Macroinvertebrate Taxa	Mean Mobilization Velocity (m/s)	Reference
Dytiscidae	0.10	Thirion 2016 (optimal flow)
Veliidae	0.10	Thirion 2016 (optimal flow)
Lymnaeidae	0.10	Thirion 2016 (optimal flow)
Leptoceridae	0.25	CTENVIRONMENTAL Unpublished data
Corixidae / Micronectidae	0.30	CTENVIRONMENTAL Unpublished data
Caenidae	0.30	Thirion 2016 (optimal flow)
Isostictidae (Coenagrionidae and Megapodagrionidae)	0.32	CTENVIRONMENTAL Unpublished data
Gomphidae	0.40	CTENVIRONMENTAL Unpublished data
Aeshnidae	0.45	CTENVIRONMENTAL Unpublished data
Gyrinidae	0.52	CTENVIRONMENTAL Unpublished data
Leptophlebiidae	0.54	CTENVIRONMENTAL Unpublished data
Elmidae	0.60	Thirion 2016 (optimal flow)
Hydraenidae	0.60	Thirion 2016 (optimal flow)
Unionicolidae (Acarina)	0.60	Thirion 2016 (optimal flow)
Limnesiidae (Acarina)	0.60	Thirion 2016 (optimal flow)
Ceratopogonidae	0.60	Thirion 2016 (optimal flow)
Hydrodromidae (Acari)	0.60	Thirion 2016 (optimal flow)
Atyidae	0.62	CTENVIRONMENTAL Unpublished data
Hydrophilidae	0.90	Thirio n2016 (optimal flow)
Chironomidae	0.95	Collier 1993 (optimal flow)
Baetidae	0.96	CTENVIRONMENTAL Unpublished data
Physidae	1.50	CTENVIRONMENTAL Unpublished data
Simuliidae	2.90	CTENVIRONMENTAL Unpublished data
Ephemeroptera	0.59 – 1.1*, *0.09 - 0.35^*	*Gore 1977 (optimal flow), ^Gore 2001 (optimal flow)
Pleocoptera	*0.09 - 0.35^*	^Gore 2001 (optimal flow)
Trichoptera	*0.09 - 0.35^*	^Gore 2001 (optimal flow)
EPT Taxa	0.25 - 0.60	Theodoropoulos 2017 (optimal flow)

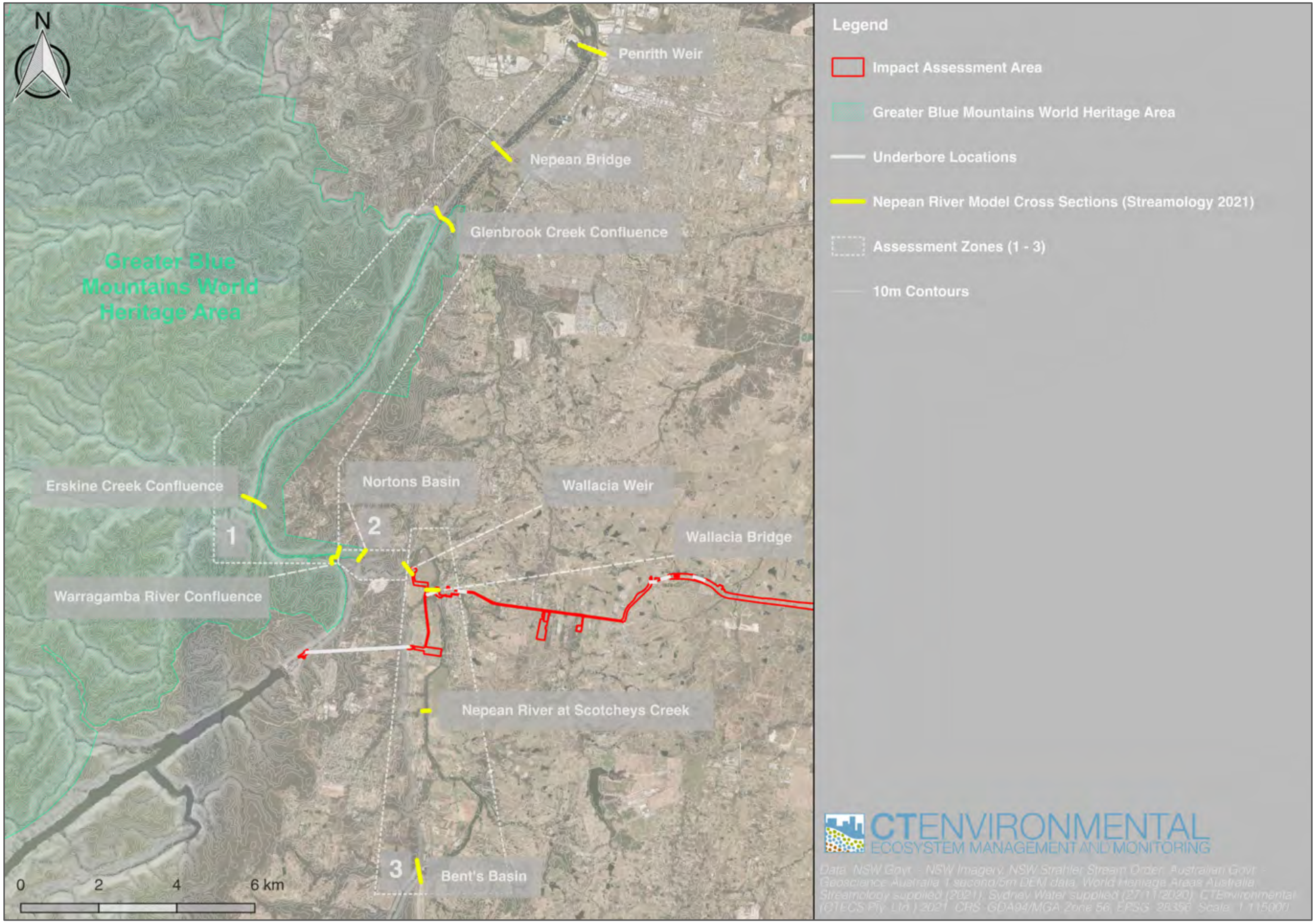

Figure 74 Location of cross sections assessed on the Nepean River from Bents Basin to Penrith Weir.

Table 41 Velocity data from Streamology (2021) HEC-RAS modelling at 10 cross-sections on the Nepean River. Red shading represents a value that lies within the range of macroinvertebrate mobilisation velocity thresholds for Families common and/or with potential to occur in the Nepean River (* Note discussion regarding model output data in Flow Velocity Assessment below).

		90th Percentile	90th Percentile + approx. 50ML /day	90th Percentile + approx. 100ML /day	Median Flow	Median + 50ML /day	Median + 100ML /day				
Location	**Chain Identification Number (Streamology Model Reference)**	**50ML /day (m/s)**	**114ML /day (m/s)**	**149ML /day (m/s)**	**229ML /day (m/s)**	**279ML /day (m/s)**	**329ML /day (m/s)**	**Difference between 50ML /day and 114ML /day (m/s)**	**Difference between 50ML /day and 149ML /day (m/s)**	**Difference between 229ML /day and 279ML /day (m/s)**	**Difference between 229ML /day and 329ML /day (m/s)**
Penrith Weir	4665.58	0.02	0.03	0.04	0.05	0.06	0.07	0.01	0.02	0.01	0.02
Nepean Bridge	8252.58	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
Glenbrook Creek Confluence	10540.97	0.53	0.84	0.82	0.61	0.52	0.48	0.31*	0.29*	-0.09	-0.13*
Erskine Creek Confluence	19550.57	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01
Confluence w/ Warragamba	22636.82	0.05	0.09	0.11	0.15	0.18	0.20	0.04	0.06	0.03	0.05
Norton's Basin	23267.02	0.01	0.01	0.02	0.03	0.03	0.03	0.00	0.01	0.00	0.00
Wallacia Weir	25161.07	0.01	0.01	0.02	0.02	0.02	0.03	0.00	0.01	0.00	0.01
Wallacia Bridge	27162.71	0.01	0.01	0.01	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Nepean River at Scotcheys Creek	30500.22	0.01	0.01	0.01	0.02	0.02	0.02	0.00	0.00	0.00	0.00
Bents Basin	36414.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.6.6.3 Flow Velocity Assessment

An assessment of maximum flow velocity at ten key cross-sections on the Nepean River (Figure 74 and Table 41) showed that modelled velocity-driven changes (if any) between both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenarios) flows at Penrith Weir, Nepean Bridge, Erskine Creek Confluence, Confluence with Warragamba River, Norton's Basin, Wallacia Weir, Wallacia Bridge, Nepean River at Scotcheys Creek and Bents Basin will have a negligible impact on aquatic and riparian ecology.

Cross sections located at the Nepean Bridge, Erskine Creek Confluence, Norton's Basin, Wallacia Weir, Wallacia Bridge, Nepean River at Scotcheys Creek and Bents Basin are modelled to experience flow velocity changes (if any), across both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenarios) flows, ranging from 0.00 m/s (no change) to 0.01 m/s (negligible change). A change in the order of 0.01 m/s is considered to have a negligible impact on aquatic macroinvertebrates, as it is out of the range of flow velocities considered to pose an impact to individual mobilization. Further, a velocity change in the order of 0.01 m/s is considered to have a negligible impact on macrophytes, aquatic fauna and the riparian zone at these locations.

Cross sections located at Penrith Weir and the confluence with the Warragamba River are modelled to have flow velocity changes across both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenario) flows ranging from 0.01 m/s (negligible change) to 0.06 m/s (negligible change). A change in the order of 0.06 m/s is considered to have a negligible impact on aquatic macroinvertebrates, as it is out of the range of flow velocities considered to pose an impact to individual mobilization. Further, a velocity change in the order of 0.06 m/s is considered to have a negligible impact on macrophytes, aquatic fauna and the riparian zone at these locations.

Flow velocity modelling provided by Streamology (2021) for the cross-section located at the Glenbrook Creek-Nepean River confluence indicates that there will be reductions in flow velocity up to 0.1 m/s under the median flow scenarios and increases in flow velocity greater than 0.3 m/s under the 90th percentile flow scenarios. This stretch of the River has been modelled as a higher velocity reach with flows typically higher than 0.50 m/s. Therefore, this result will not drive velocity impacts as velocities at this reach are typically above the reported flow thresholds of macroinvertebrate taxa.

However, these are noteworthy results when considered within the broader context of the model result and are most likely an isolated product of the coarseness/resolution of the hydraulic model output and spatial anomaly identified at this cross-section.

For this reason, the model output for these cross sections is viewed with caution and may not be representative of the flow velocities that will be experienced under all flow scenarios. Regardless it is considered that flow velocity changes at this location will be within the range that is considered to have a negligible or low impact on aquatic macroinvertebrates, and as such, flow velocity is not considered to pose an impact to individual mobilization. Further, a negligible or low velocity change at this cross-section is not considered to significantly impact macrophytes, aquatic fauna and the riparian zone.

6.6.6.4 Depth Assessment

An assessment of changes in depth (maximum channel depth) at key cross sections along the Nepean River under both median and 90th percentile (baseline, +50 ML /day and +100 ML /day scenario) flows was conducted to support an understanding of the spatial extent of wetted perimeter and potential changes (i.e. increases and/or decreases) of aquatic habitat availability at key locations. This data is summarized in Table 42.

A consideration of depth change against the median flow baseline was instrumental to further understanding any changes associated with Stage 1 releases (+50 ML /day). There were negligible modelled depth changes in between, and inclusive of, the Norton's Basin and Penrith Weir cross-sections for both the Stage 1 (+50 ML /day) and Stage 2 (+100 ML /day) releases against median flow.

Depth changes in this reach under both these scenarios were modelled in the magnitude of 3 cm – 7 cm. A change of this magnitude is likely to have a negligible impact upon aquatic and riparian ecosystems.

There were slightly larger increases in depth in between, and inclusive of, the Wallacia Weir and Bent's Basin cross-sections. Depth changes in this reach under both modelled median flow scenarios were in the magnitude of 18 cm and 35 cm under the median +50 ML /day and median +100 ML /day scenario respectively. As reported by Streamology (2021), this is a result of the operation and control of the Wallacia Weir and any physical changes to habitat conditions, such as depth, will likely be in the range of imperceptible.

However the depth increases of 18 – 35 cm indicate a potential for increases in the depth of the weir pool which may drive an increase in habitat for aquatic fauna species that exhibit a preference for the deep pools of this reach such as Australian Bass that use deep pools as refuge in the hotter summer months.

In contrast, this increase may influence taxa dependent on shallow habitats. For example, the optimal depth of benthic macroinvertebrate taxa diversity richness has been reported to range from 0.2 – 0.7 m (Gore 1977 and Theodoropoulas 2001) and therefore a change in depth of the likes reported may result in refuges becoming too deep and beyond the ideal depth range for macroinvertebrate taxa. In turn, a depth change may lead to a reduction in available macroinvertebrate food resources and impact higher trophic level taxa such as fish, turtles, waterbirds and microbats.

Although a shift of the aquatic ecosystem inline with the median +50 ML /day depth may occur, it is not foreseen that this shift will adversely impact aquatic and riparian ecosystems as impacts are likely to be very localised.

Similarly, increase associated with the Stage 1 release may result in slight, and localised, inundation of bank vegetation (refer wetted perimeter assessment for further assessment) however, it is considered that a depth increase of this magnitude will have a low impact on riparian and macrophyte communities as the depth of the weir pool is ultimately controlled by the height of the weir.

Depth change associated with 90th percentile flows was also considered to further understand any changes associated with Stage 1 releases (+50 ML /day). There were negligible depth changes under the 90th percentile flow (+50 ML /day) scenario in between, and inclusive of, the Warragamba River Confluence and Penrith Weir cross-sections.

Depth changes in this reach under this scenario were in the magnitude of 6 cm – 9 cm. A change of this magnitude will have a negligible/low impact upon aquatic and riparian ecosystems (refer to wetted perimeter assessment for further detail).

Similarly, there were negligible/low, albeit slightly larger, changes in depth in between, and inclusive of, the Norton's Basin and Bent's Basin cross-sections under this scenario. Depth changes in this reach were in the magnitude of 10 cm (Norton's Basin cross-section) – 34 cm (Bent's Basin cross-section).

It is considered that a depth increase of this magnitude will have a negligible/low impact on riparian and macrophyte communities (inline with the wetted perimeter assessment), and provide for a beneficial, however, likely imperceptible, increase in aquatic habitat availability for fauna inhabiting this reach under 90th percentile low flow conditions.

Further, a depth change associated with 90th percentile flows (+100 ML /day) was also considered. Under this flow scenario, depth changes of 10 cm were modelled at Penrith Weir and Nepean Bridge cross-sections; a depth change of 9 cm was modelled at the Glenbrook Creek Confluence and changes in the magnitude of 12 cm – 13 cm were modelled at the Erskine Creek Confluence, Confluence with the Warragamba River and the Norton's Basin cross-section.

An increase of 50 cm was modelled at the Wallacia Weir, Wallacia Bridge and Nepean River at Schotcheys Creek cross-sections. Similarly, an increase of 49 cm was modelled at the Bent's Basin cross-section. It is critical to note that these changes represent an increase in depth under 2056 operating conditions and from an existing low (baseline) 90th percentile flow.

As discussed in relation to Wallacia Weir Pool a similar impact may occur where, this increase may influence taxa that have sensitivities to depth. For example, the optimal depth of benthic macroinvertebrate taxa diversity richness has been reported to range from 0.2 – 0.7 m (Gore 1977 and Theodoropoulas 2001) and therefore a change in depth of the likes reported may results in refuges becoming too deep and beyond the idea depth range for macroinvertebrate taxa. In turn, a depth change may lead to a reduction in available macroinvertebrate food resources and impact higher trophic level taxa such as fish, turtles, waterbirds and microbats.

Any increase described is located entirely within the channel and is likely to be imperceptible. It is considered that depth increases of this magnitude will have a negligible impact on riparian communities (inline with the wetted perimeter assessment), as the increase will be entirely located within the channel and only result in an increase of in-channel wetting frequency, not the inundation of new areas or riparian vegetation. This will provide for a minor increase in aquatic habitat availability for aquatic fauna during low flow conditions and thus is seen to provide for a beneficial impact to the aquatic ecosystem.

Overall, a consideration of both median and 90th percentile flow scenarios revealed that the introduction of AWRC releases would contribute to an increase in maximum channel depth within reaches of the Nepean River (particularly upstream of Wallacia Weir). Such increases, under all proposed release scenarios, are considered to have a negligible/low impact upon aquatic and riparian ecosystems, indeed providing for an increase in aquatic habitat availability under 90th percentile flows, which may drive beneficial change to the aquatic ecosystem during low flow conditions. Increases under Stage 1 (median + 50 ML /day) releases upstream of Wallacia Weir may result in a low impact to riparian vegetation. A slight upwards shift in the aquatic ecosystem is also predicted inline with Stage 1 release depths, however, it is not foreseen that this shift will adversely impact aquatic riparian ecosystems in this reach, indeed providing for a minor increase in aquatic habitat availability for aquatic fauna inhabiting the pools of the reach. The impact of the Stage 1 release scenario on the aquatic ecosystem is therefore also considered to be low. This result is complementary to the result of the wetted perimeter analysis for this reach. Streamology and CTENVIRONMNTAL have provided recommendations for monitoring, where relevant.

Table 42 Depth data from Streamology HEC-RAS modelling at 10 cross-sections on the Nepean River (LOR >10 cm; shaded).

		90th Percentile	90th Percentile + approx. 50 ML /day	90th Percentile + approx. 100 ML /day	Median Flow	Median + 50 ML /day	Median + 100 ML /day				
Location	Chain Identification Number (Streamology Model Reference)	50 ML /day (m)	114 ML /day (m)	149 ML /day (m)	229 ML /day (m)	279 ML /day (m)	329 ML /day (m)	Difference between 50 ML /day and 114 ML /day (m)	Difference between 50 ML /day and 149 ML /day (m)	Difference between 229 ML /day and 279 ML /day (m)	Difference between 229 ML /day and 329 ML /day (m)
Penrith Weir	4665.58	0.84	0.91	0.94	1.00	1.04	1.06	0.07	0.10	0.04	0.06
Nepean Bridge	8252.58	4.94	5.01	5.04	5.10	5.14	5.17	0.07	0.10	0.04	0.07
Glenbrook Creek Confluence	10540.97	0.64	0.70	0.73	0.80	0.84	0.87	0.06*	0.09*	0.04*	0.07*
Erskine Creek Confluence	19550.57	4.29	4.37	4.41	4.46	4.49	4.52	0.08	0.12	0.03	0.06
Confluence w/ Warragamba	22636.82	0.67	0.76	0.80	0.87	0.90	0.93	0.09	0.13	0.03	0.06
Norton's Basin	23267.02	1.24	1.34	1.37	1.44	1.48	1.51	0.10	0.13	0.04	0.07
Wallacia Weir	25161.07	1.68	2.02	2.18	2.49	2.67	2.84	0.34	0.50	0.18	0.35
Wallacia Bridge	27162.71	2.39	2.73	2.89	3.20	3.38	3.55	0.34	0.50	0.18	0.35
Nepean River at Scotcheys Creek	30500.22	2.29	2.63	2.79	3.11	3.28	3.46	0.34	0.50	0.17	0.35
Bent's Basin	36414.42	13.66	14.00	14.15	14.47	14.65	14.82	0.34	0.49	0.18	0.35

* Glenbrook Creek-Nepean River confluence: Refer to Model Limitations section for further insight.

6.6.7 Summary of Assessment of Potential Impacts – Operational Phase

Review of water quality modelling for the AWRC releases predicts no change to quality of water upstream of Wallacia Weir Pool and therefore no water quality driven impacts are expected.

The quality of released water has potential to improve water quality of the Nepean River downstream of Wallacia Weir and therefore provide potential improvement.

Modelling has predicted improvement in many water quality parameters, including total nitrogen, total phosphorus, filterable reactive phosphorus, chlorophyll-*a*, dissolved oxygen, salinity and total suspended solids. However, increases to oxidised nitrogen and ammonia are predicted. Short term increases in nutrients are predicted in wet weather when tertiary treated water is released.

Elevated available nutrients are likely associated with modelled spikes in chlorophyll-*a.* This is indicative of a primary production response however it must be noted the risk of increased chlorophyll-*a* was not significantly changed in the impact scenario, relative to the background conditions. Therefore, releases from the AWRC are not expected to significantly impact the primary production response in the River which can cause alteration of the trophic state, particularly if a waterway goes eutrophic which 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.

Although this risk has been identified it is considered as low probability and may only occur when nutrient availability, climatic and flow conditions are optimal and as modelling of dissolved oxygen shows (Aurecon ARUP, 2021c) periods of potential anoxia (an additional indicator of an altered trophic state) are short lived.

An increase of available nutrients (ammonia and oxidized nitrogen) 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 excess algae growth has been described. 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.

CORMIX modelling suggests that primary mixing zone criteria cannot be achieved for the majority of the metals during the relevant severe wet weather release events, however, potential toxicity and environmental harm arising from these releases is considered to be low (Aurecon ARUP, 2021c) and therefore potential of residual impacts to aquatic taxa, including Macquarie Perch as low as potential toxicity events are predicted to be linked with conditions of significantly elevated flow within the Nepean River, residence times are expected to be low.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) and the updated Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) provide detailed guidance on required targets and thresholds for relevant water quality indicators in freshwater systems (ANZECC and ARMCANZ 2000; 2018).

However, toxicity guidelines are based on short-term lethal doses and no applicable long-term toxicity-based guidance values are available under the ANZG (2018) and ANZECC (2000). Therefore, there is uncertainty as to the long-term infrequent cumulative exposure impacts of metal concentrations for freshwater invertebrate taxa and the wider ecological community. This is of particular concern within areas of pooled water where metals are more likely to accumulate in sediment and organic material, such as along the Nepean River upstream of Wallacia Weir.

Modelling suggests increased depth changes of up to 50 cm may be apparent in the Nepean River at Wallacia Bridge, Scotchys Creek and Bents Basin under the 90th percentile flows and therefore thus reflects a change in the frequency depth variation. The exact impact of this depth change is difficult to quantify however there is a likelihood that localized impacts may occur which may result in the loss of riparian habitats and conversely a gain in aquatic habitats.

Additionally, changes in wetted perimeter are modelled to occur. When considered across the extent of the study area the change is not considered significant.

Again, it is difficult to quantify the magnitude of impacts to the locations subject to such change however there is a high likelihood that impacts will occur to riparian communities, such as complete loss or increased inundation. In turn, increased wetted perimeters has the potential to increase aquatic habitats and benefit aquatic species.

However, three sections will see change in wetted perimeter of between 5 and 11 m. One affected area is the bar at the entrance of Glenbrook Creek, which 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 associated inundation extent could be seen as beneficial to aquatic fauna, as an increase in aquatic habitat availability will result from proposed increased flow.

Flow velocity modelling provided by Streamology (2021) for the cross-section located at the Glenbrook Creek-Nepean River confluence indicates that there will be reductions in flow velocity up to 0.1 m/s under the median flow scenarios and increases in flow velocity greater than 0.3 m/s under the 90th percentile flow scenarios. However, no velocity driven ecological impacts are expected and no impacts to fish passage or aquatic connectivity are predicted.

Potential impact to Macquarie Perch and their habitats in this reach have been considered in Section 6.7.4.

The Nepean River has been identified as an aquatic groundwater dependent ecosystem. 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.

6.6.8 Recommendations to mitigate potential impacts

Based on findings of CORMIX modelling, actions to mitigate the risks of toxicity for the Nepean River could include modifications to the reference design for the release infrastructure, such as the provision of a submerged piped release located within the Wallacia Weir Pool to assist in increasing initial mixing and dilution in the vicinity of the release point. This may further reduce the risk of attachment of the plume to riverbanks (Aurecon ARUP, 2021c).

It is difficult to mitigate the potential effects described above as the impacts described, particularly those driven by wetted perimeter change are localized and subject to limitations of the modelling. To determine if any impacts do occur, ecological monitoring is recommended.

6.7 Threatened Aquatic Species and Communities

To determine the potential impacts to species listed as threatened under the FM Act 1994 and EPBC Act 1999 a broad scale desktop survey was undertaken. Sources included NSW Fisheries Threatened Species Distribution Mapping and Matters of Environmental Significance search tool.

Results show 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 and the catchment is not considered habitat for any species listed under this Act.

The Nepean River is mapped as habitat critical for survival for the Macquarie Perch (*Macquaria australasica*) from downstream of the confluence with Warragamba River to Lynch Creek, downstream of Penrith Weir. This species is also known to inhabit Erskine Creek and Glenbrook Creek and the two populations are genetically similar, therefore dispersal between creeks via the Nepean River occurs. The Warragamba River is also mapped as habitat for this species (Figure 75).

The Macquarie Perch is listed as endangered under the FM Act 1994 and EPBC Act 1999.

The Adams Emerald Dragonfly (*Archaeophya adamsi*) and Sydney Hawk Dragonfly (*Austrocordulia leonardi*), both listed under the FM Act, are found in the Sydney basin (Figure 76).

The sections of the Warragamba and Nepean Rivers subject to potential impacts of the AWRC are not considered as habitat for these Dragonfly species and therefore these species are not considered as potentially present.

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

6.7.1 Assessment of impacts to Macquarie Perch

Due to the known distribution of Macquarie Perch within the Nepean River, particularly the population of Erskine Creek and Glenbrook Creek and recognition of the Warragamba River as potential habitat , assessment of the potential impacts to the fish and its habitat is required.

Activities associated with the construction and operational phases of the AWRC which may pose a threat to the species are considered.

The species is listed as threatened under the FM Act 1994 and EPBC Act 1999 and therefore a 7 Part Test of Significance has been undertaken as per the FM Act 1994 and a Significant Impact Assessment has been undertaken as per the EPBC Act 1999.

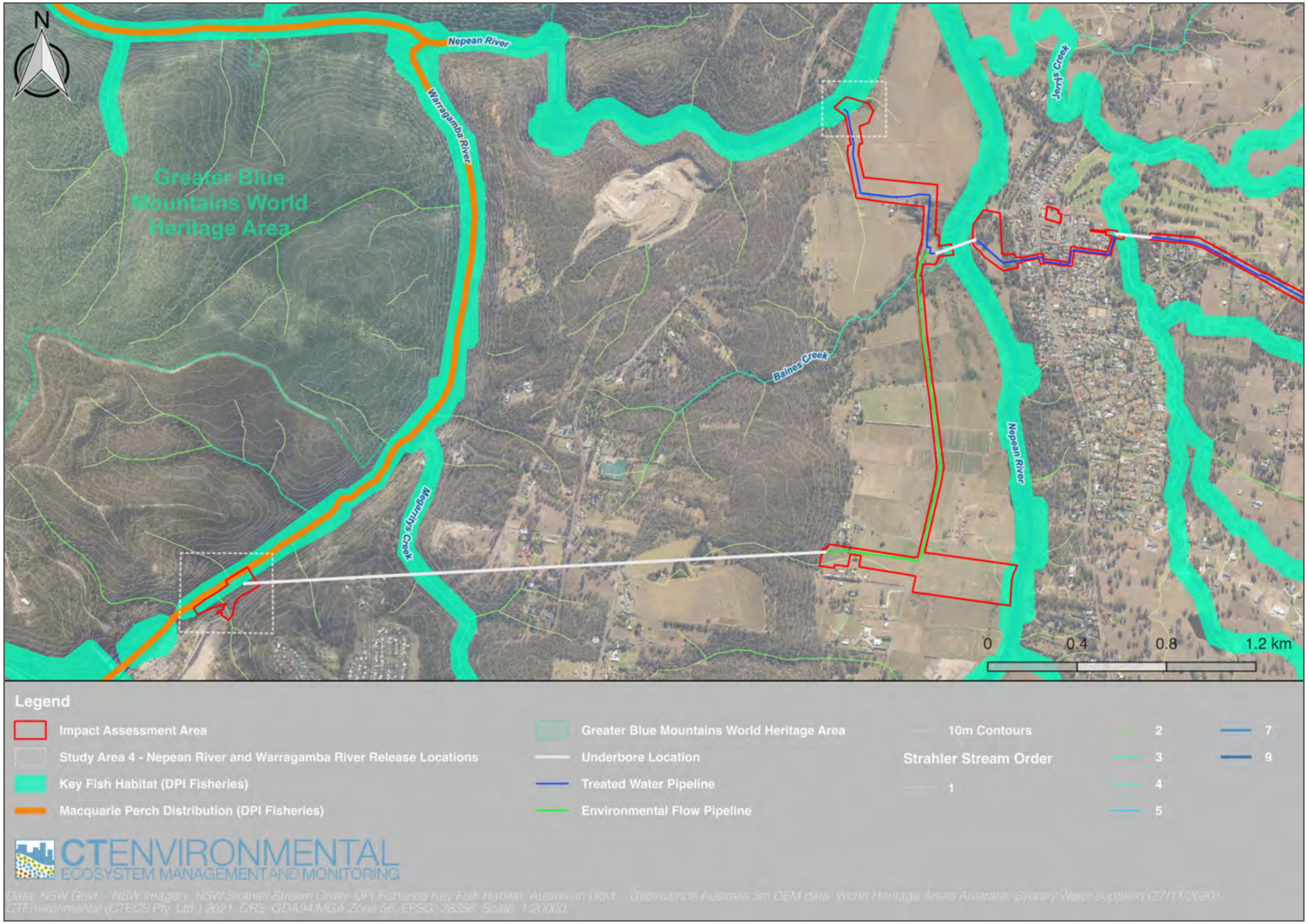

Figure 75 Macquarie Perch distribution within assessment area.

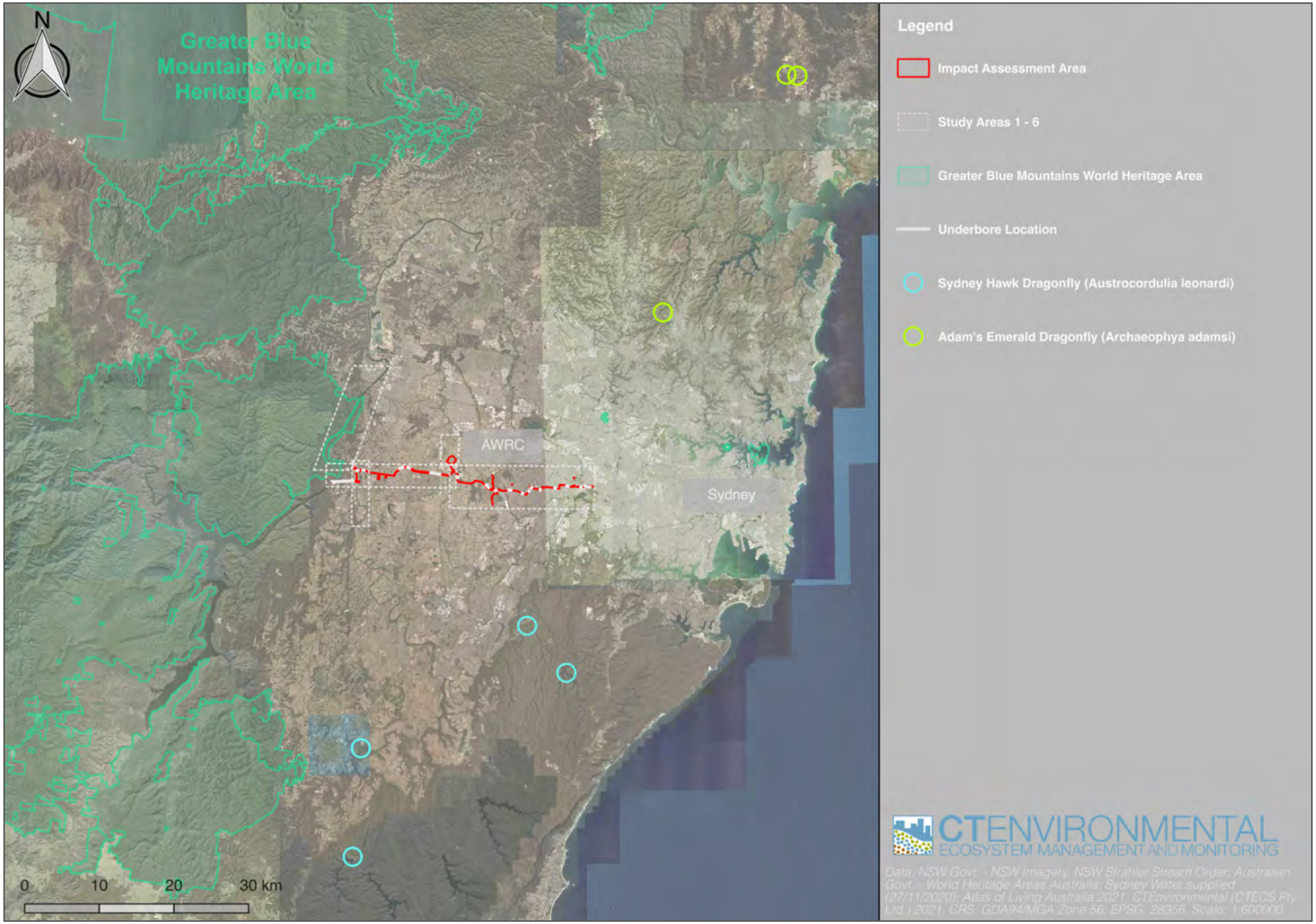

Figure 76 Known populations of Sydney Hawk Dragonfly and Adam's Emerald Dragonfly across the greater Sydney Basin.

6.7.2 Critical Requirements of Macquarie Perch (*Macquaria australasica*)

The Warragamba River and the Nepean River downstream from the junction of the Warragamba River are mapped as habitat critical for survival for the Macquarie Perch. The following sections detail the critical requirements of Macquarie Perch.

6.7.2.1 Conservation Significance

- Listed as Endangered under the NSW Fisheries Management Act 1994 (Commonwealth of Australia, 2018).
- Listed as Endangered under the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999, with associated recovery plan completed in 2018 (Commonwealth of Australia, 2018).
- Listed as Endangered on the International Union for the Conservation of Nature (IUCN) Red List.

6.7.2.2 Refuge habitat

- Adults found in cool, clear water in both rivers and lakes (and reservoirs), especially upper reaches of rivers and tributaries (i.e. 400 m to 700 m above sea level), where natural flow and temperature regimes persist and riparian vegetation is intact (Lintermans et al. 2019).
- Preferred microhabitat is slow-flowing, deep and rocky pools with lots of cover including aquatic macrophytes, large boulders, debris and overhanging banks (Lintermans et al. 2019).
- Juveniles often at the head and tails of pools (depth 0.2 m – 1.0 m) in associated with boulders, cobbles or large wood (Broadhurst et al. 2012).
- Small schools of larvae at mid to upper water column (< 1 m depth), along steep rock faces, in deep sections of pools (> 1.5 m depth) and in low or no-flow areas (Broadhurst et al. 2012).
- Newly hatched larvae shelter amongst pebbles (Broadhurst et al. 2012).

6.7.2.3 Spawning habitat

- Those fish living in lakes migrate to tributaries to spawn (fish living in streams may not need to migrate) (Tonkin et al. 2018).
- Spawning occurs in spring or summer (i.e. October to December, when water temperature reaches between 14°C and 18°C) (NSW DPI 2016).
- Spawning occurs in shallow upland streams and rivers (Cadwallader and Rogan, 1977).

- Ability to swim against flow varies with the body size of fish and temperature: mean sprint swimming speed is >80 cm s^{-1} for adults at 22°C, but <20 cm s^{-1} for juveniles at 10°C (Starrs et al. 2011).
- Riffles: spawning occurs at the lower end of pools and eggs settle amongst downstream cobbles and gravel on the bed of riffles, or spawning directly to riffles (NSW DPI, 2016).

6.7.2.4 Food

- Generalist predators (Cadwallader and Rogan, 1977).
- Benthic feeding, with only a small amount of food captured at the water surface (Cadwallader and Rogan, 1977).
- Primary food items include nymph/adult stages of flies and mosquito (Diptera, particularly Chironomidae), caddisflies (Trichoptera), mayflies (Ephemeroptera); secondary food includes stoneflies (Plecoptera), dragonflies and damselflies (Odonata), bugs (Hemiptera), beetles (Coleoptera), Crustacea (from microcrustaceans to Decapoda), gastropod snails (Mollusca) and small fish (NSW DPI, 2016).
- Dietary diversity and size of prey increase with age (e.g. dietary shift from microcrustaceans to dipterans to decapods) (Cadwallader and Rogan, 1977).

6.7.2.5 Threats

- Urban expansion and water pollution has the potential to affect all aspects of the life history of the Macquarie Perch. Of particular concern are endocrine disrupting chemicals such as pesticides, sewage effluent and plasticisers (NSW DPI, 2016).
- In-stream habitat modification or destruction, e.g. removal of rocks or large wood (Lintermans et al. 2019).
- Clearing of riparian vegetation (Lintermans et al. 2019).
- Suspended sediment reducing water quality, damaging gills, hindering primary productivity, submergent macrophytes, food and habitat availability for fish (Cadwallader, 1981).
- Siltation/sedimentation, including that after bushfires and hazard reduction burns (blankets suitable spawning substrate and alters composition of benthic prey) (Lintermans et al. 2019).
- Habitat fragmentation – lost connectivity between populations and habitats required through life cycle (Lintermans et al. 2019). Fast-flowing water through culvert pipes may be just as impassable as a vertical weir.

- River damming and regulation (flood spawning habitat and inhibit migration, plus reduce water temperatures below impoundments) (Lintermans et al. 2019).
- Altered flow regimes: most studies related to reductions in flow, reduced frequency and magnitude of natural flooding and associated reduced habitat quality, loss of spawning cues and reduced opportunities for dispersal and migration (Tonkin et al. 2018).
- Introduced trout and other exotic fish (predation and competition, plus the diseases such as Epizootic Haematopoietic Necrosis Virus (EHNV), largely spread by Redfin Perch and Rainbow Trout) (Cadwallader, 1981).
- Illegal fishing (Cadwallader, 1981).
- Episodic disturbance from drought (Lintermans et al. 2019).

6.7.2.6 General suggested management actions

- Determine local population sizes, habitats and ecological requirements (Commonwealth of Australia, 2018).
- Develop local recovery plan to conserve existing populations (Commonwealth of Australia, 2018).
- Improved education, including signage to increase awareness of protected status and improve participation by community groups in Macquarie Perch conservation (Commonwealth of Australia, 2018).
- Prevent hydrological alteration (Commonwealth of Australia, 2018).
- Restore native riparian vegetation (Commonwealth of Australia, 2018).
- Protect and restore Macquarie Perch habitat, e.g. resnagging (Commonwealth of Australia, 2018).
- Eradicate pest fish (Commonwealth of Australia, 2018).

6.7.2.7 Possible impacts of altered hydrology

- Large flows could reduce access to preferred refuge habitat, which have considerably lower flow velocities than the mainstream, and flush larvae and juveniles downstream (Starrs et al. 2011).

- Changes in flow prompt adult migration during the spawning season (Tonkin et al. 2018), so altered flow regimes could influence movement, distribution and spawning (spawning season from October to December; Koster and Crook, 2017).
- Large flow events negatively affect recruitment during the egg and larval period of the lifecycle, possibly owing to scour of eggs or displacement of larvae, siltation of eggs, loss of critical nursery habitat and/or high turbidity and velocity hindering foraging (Tonkin et al. 2018).
- Large flushing flows could reduce the quality and availability of preferred habitat, such as slow-flowing deep pools and/or large wood (Koster and Crook, 2017).
- Large flushing flows could reduce the quality and availability of preferred food.
- Sedimentation and other water quality degradation, owing to higher peak flows transporting pollutants, lack of smaller flushing flows and low baseflows facilitating accumulation of pollutants in pools (Koster and Crook, 2017).

6.7.3 Potential Impacts and Key Threatening Processes

This study has shown that potential impacts on Study Area 4 and the lower portion of Study Area 6 that may affect Macquarie Perch and their habitat include;

1. Alteration of aquatic habitat via increased wetted perimeter and depth
2. Increase in sediment and erosion and associated loss or degradation of habitat
3. Spills of chemicals associated with construction equipment
4. Alteration of water quality due to release to the Nepean and Warragamba Rivers
5. Removal or loss of riparian vegetation

Key Threatening Processes as listed under the FM Act 1994 include:

- Degradation of native riparian vegetation along New South Wales water courses
- Hook and line fishing in areas important for the survival of threatened fish species
- Human-caused climate change
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams
- Introduction of fish to waters within a river catchment outside their natural range

- Introduction of non-indigenous fish and marine vegetation to the coastal waters of New South Wales
- Removal of large woody debris from New South Wales rivers and streams
- The current shark meshing program in New South Wales waters

It is considered that the potential impacts listed above are consistent with the Key Threatening Processes of:

- Degradation of native riparian vegetation along New South Wales water courses
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams

Assessment of these impacts are detailed in the following sections.

6.7.4 Assessment of Impacts to Macquarie Perch

The following sections include assessments of significance for Macquarie Perch under the FM Act and EPBC Act.

6.7.4.1 7 Part Test in Accordance with Section 221ZV of the *Fisheries Management Act 1994*

The following factors must be taken into account in making a determination under this section:

a) in the case of a threatened species, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.

Correspondence with DPI Fisheries has confirmed populations of Macquarie Perch are present in Erskine Creek and Glenbrook Creek, both of which confluence with the Nepean River in the Penrith Weir Pool reach. These populations are not considered genetically distinct and therefore migration between these creeks via the Nepean River occurs.

As a result of the presence of this known population this assessment is focused on the spatial extent between the confluences of Erskine Creek and Glenbrook Creek with the Nepean River and also Warragamba River as it is mapped as habitat for the species.

It is considered unlikely that proposed discharge of treated water from the AWRC to the Nepean River will have a detrimental effect on the Macquarie Perch. Water Quality modelling of future discharge shows that median concentrations of bioavailable and non-bioavailable forms of nitrogen will not change significantly from background conditions at and downstream of the Erskine Creek confluence.

Modelling predicts improvement to median concentrations of bioavailable and non-bioavailable forms of phosphorous 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 in no indicative of an algal bloom response and concentrations remain the below the waterway health objective guideline of 3 µg/L.

Modelled outcomes for future levels of salinity, dissolved oxygen and total suspended solids show very marginal, if any, change will occur at and downstream of Erskine Creek confluence.

As a result of this assessment water quality is not predicted to change significantly at and downstream of the Erskine Creek confluence and therefore water quality driven impacts are not expected to affect the population of Macquarie Perch.

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

For detailed results on water quality modelling see Aurecon-ARUP (2021) Upper South Creek Advanced Water Recycling Centre – Hydrodynamic and Water Quality Impact Assessment.

Future modelled hydrological change relating to the proposed wastewater discharge indicates a potential ~3 cm change in depth of the Penrith Weir Pool and between 0 – 11 m change in wetted perimeter.

Increases in depth of 3 cm and increase in wetted perimeter are not likely to negatively impact the lifecycle of the Macquarie Perch but rather provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

11 m of change in wetted perimeter is predicted at the Glenbrook Creek confluence which is likely to cause partial inundation of the vegetated bar at the creek mouth. This may cause die back of the vegetation of the bar which may result in an increase of submerged woody debris which is a favored habitat of the species. In addition, an increase in wetted perimeter may provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

Modelled changes in velocity are non-significant in the Penrith Weir Pool as the weir forms a significant flow control and maintains low velocity flows in the upstream weir pool.

No hydrological change to the Warragamba River is expected and therefore no impact is expected.

For detailed results on hydrological modelling see Streamology (2021) Upper South Creek Advanced Water Recycling Centre – Ecohydrology and Geomorphology Impact Assessment.

(b) in the case of an endangered population, whether the proposed development or activity is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction,

Not applicable. This consideration refers to an endangered population. This assessment of significance relates to the endangered species, the Macquarie Perch (*Macquaria australasica*) only.

(c) in the case of an endangered ecological community or critically endangered ecological community, whether the proposed development or activity:

(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or

Not applicable. This consideration refers to an endangered or critically endangered ecological community. This assessment of significance relates to the endangered species, the Macquarie Perch (*Macquaria australasica*) only.

(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,

Not applicable. This consideration refers to an endangered or critically endangered ecological community. This assessment of significance relates to the endangered species, the Macquarie Perch (*Macquaria australasica*) only.

(d) in relation to the habitat of a threatened species, population or ecological community:

(i) the extent to which habitat is likely to be removed or modified as a result of the proposed development or activity, and

Hydrological modelling of the Penrith Weir Pool shows potential habitat modification. The modelled increase in ~3 cm of depth and change of 0-11 m in wetted perimeter in the vicinity of the Erskine Creek and Glenbrook Creek confluences is likely to increase habitat for the Macquarie Perch and also increase habitat for invertebrate prey species. This is expected to have a minor positive benefit, however, the geographical extent of this expected change cannot be quantified due to the modelling limitations.

(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed development or activity, and

Hydrological modelling of the Penrith Weir Pool indicates no fragmentation or isolation of habitat will occur. The modelled increase in ~3 cm of depth and change of 0-11 m in wetted perimeter in the vicinity of the Erskine Creek and Glenbrook Creek confluences is likely to reduce fragmentation of habitat and increase habitat for the Macquarie Perch and also increase habitat for invertebrate prey species. Therefore, potential habitat fragmentation is considered as unlikely.

(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the threatened species, population or ecological community in the locality,

No habitat will be removed, isolated or fragmented and potential modification of the vegetation on the creek mouth bar may provide benefits to the Macquarie Perch – see section d(i)

Future modelled hydrological change relating to the proposed wastewater discharge indicates a potential ~3 cm change in depth of the Penrith Weir Pool and between 0 – 11 m change in wetted perimeter. 11 m of change in wetted perimeter is predicted at the Glenbrook Creek confluence.

Increases in depth of 3 cm and increase in wetted perimeter are likely provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

(e) whether the proposed development or activity is likely to have an adverse effect on any critical habitat (either directly or indirectly).

No critical habitat for Macquarie Perch (*Macquaria australasica*) is present in the study area.

(f) whether the proposed development or activity is consistent with a Priorities Action Statement.

The Priorities Action Statement - Actions for Macquarie Perch, outlines a range of recovery actions for Macquarie Perch. These relate to:

- Collating existing information
- Community education
- Compliance activities
- Natural resource management planning
- Habitat rehabilitation
- Pest eradication
- Research
- Stocking and translocation
- Survey and mapping

The project is consistent with the Priorities Action Statement either because the actions are the responsibility of other parts of government and the project will not impact on them being achieved, or the project can contribute to them as outlined below:

- Implement relevant State policies and programs (e.g. the NSW Diffuse Source Water Pollution Strategy) in an effort to reduce water pollution (particularly chemical pollution from agricultural pesticides) impacts on Macquarie Perch habitats in NSW. Chapter 2 and Chapter 8 of the EIS describe how the project aligns with State policies and programs for water management, including how it has been designed to comply with the EPA's Hawkesbury Nepean Nutrient Framework, to minimise water pollution.
- Allocate and manage environmental water flows in regulated rivers to restore natural seasonal flow patterns, and to reduce the impact of cold water downstream of dams. Although it is not Sydney Water's responsibility to allocate and manage environmental flows, as outlined in Chapter 3 of the EIS, the project has the potential to replace some environmental flows from Warragamba Dam under current and potential future environmental flows regimes.
- Collect data on the presence/absence of Macquarie Perch during incidental surveys. The project has completed some fish surveys and proposes to continue these as outlined in Chapter 8. Any Macquarie Perch identified in these surveys would be recorded.

(g) whether the proposed development constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

It is considered that the potential impacts listed above are consistent with the Key Threatening Processes of:

- Degradation of native riparian vegetation along New South Wales water courses
- Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams

The Nepean River system is a controlled system with numerous major weirs and dams throughout the catchment and therefore the key threatening process of alteration of the natural flow regimes of rivers and streams is already imposed on the River ecosystem.

The discharge of treated water from the AWRC, by definition, is also considered an alteration of flow against current conditions however as discussed in previous sections modelled velocities are not expected cause impact to the Macquarie Perch and modelled depth and wetted perimeter change are likely to increase habitat, albeit marginally, and not impede passage between passage between Erskine Creek and Glenbrook Creek.

Potential change to riparian vegetation due to changes in wetted perimeter is considered a key threatening process, however this impact is likely to be minimal across the study area and has potential to provide benefits increasing of large woody debris to the system.

Based on the assessment provided above, it is concluded that Macquarie perch is unlikely to be significantly impacted by the project.

6.7.5 Test of Significant Impact as per Environment Protection and Biodiversity Conservation Act 1999

An action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will result in one or more of the following:

a) Lead to a long-term decrease in the size of a population

Correspondence with DPI Fisheries has confirmed populations of Macquarie Perch are present in Erskine Creek and Glenbrook Creek, both of which confluence with the Nepean River in the Penrith Weir Pool reach. These populations are not considered genetically distinct and therefore migration between these creeks via the Nepean River occurs.

As a result of the presence of this known population this assessment is focused on the spatial extent between the confluences of Erskine Creek and Glenbrook Creek with the Nepean River and also Warragamba River as it is mapped as habitat for the species.

It is considered unlikely that proposed discharge of treated water from the AWRC to the Nepean River will have a detrimental effect on the Macquarie Perch. Water Quality modelling of future discharge shows that median concentrations of bioavailable and non-bioavailable forms of nitrogen will not change significantly from background conditions at and downstream of the Erskine Creek confluence.

Modelling predicts improvement to median concentrations of bioavailable and non-bioavailable forms of phosphorous 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 in no indicative of an algal bloom response and concentrations remain the below the waterway health objective guideline of 3 µg/L.

Modelled outcomes for future levels of salinity, dissolved oxygen and total suspended solids show very marginal, if any, change will occur at and downstream of Erskine Creek confluence.

As a result of this assessment water quality is not predicted to change significantly at and downstream of the Erskine Creek confluence and therefore water quality driven impacts are not expected to affect the population of Macquarie Perch.

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

For detailed results on water quality modelling see Aurecon-ARUP (2021) Upper South Creek Advanced Water Recycling Centre – Hydrodynamic and Water Quality Impact Assessment.

Future modelled hydrological change relating to the proposed wastewater discharge indicates a potential ~3 cm change in depth of the Penrith Weir Pool and between 0 – 11 m change in wetted perimeter.

Increases in depth of 3 cm and increase in wetted perimeter are not likely to negatively impact the lifecycle of the Macquarie Perch but rather provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

11 m of change in wetted perimeter is predicted at the Glenbrook Creek confluence which is likely to cause inundation of the vegetated bar at the creek mouth. This may cause die back of the vegetation of the bar which may result in an increase of submerged woody debris which is a favored habitat of the species. In addition, an increase in wetted perimeter may provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

Modelled changes in velocity are non-significant in the Penrith Weir Pool as the weir forms a significant flow control and maintains low velocity flows in the upstream weir pool.

No hydrological change to the Warragamba River is expected and therefore no impact is expected.

For detailed results on hydrological modelling see Streamology (2021) Upper South Creek Advanced Water Recycling Centre – Ecohydrology and Geomorphology Impact Assessment.

b) Reduce the area of occupancy of the species

No

As discussed above, there is insignificant impact to water quality, migration and other habitat needs of the species. Accordingly, this will not influence the area of occupancy of the Macquarie Perch.

c) Fragment an existing important population into two or more populations

No

Hydrological modelling of a key stream reach in Penrith Weir Pool indicates no fragmentation or isolation of habitat will occur. The modelled increase in ~3 cm of depth and change of 0-11 m in wetted perimeter in the vicinity of the Erskine Creek and Glenbrook Creek confluences is likely to reduce fragmentation of habitat and increase habitat for the Macquarie Perch and also increase habitat for invertebrate prey species.

d) Adversely affect habitat critical to the survival of a species

No

No habitat will be removed, isolated or fragmented and modification will provide benefits to the Macquarie Perch.

Discharge from the AWRC is unlikely to adversely impact habitat critical for survival.

Marginal change in flow velocity (~0.01 m/s) in and around the Nepean River at the confluence of Erskine Creek and Glenbrook Creek is predicted and a result weir pool conditions will remain unchanged and as a result no adverse impact to habitat is expected.

Future modelled hydrological change relating to the proposed wastewater discharge indicates a potential ~3 cm change in depth of the Penrith Weir Pool and between 0 – 11 m change in wetted perimeter. 11 m of change in wetted perimeter is predicted at the Glenbrook Creek confluence. Further investigation of this change is being undertaken to determine whether the result is an anomaly in the modelling or true on the ground.

At any rate increases in depth of 3 cm and increase in wetted perimeter are likely provide potential benefits to passage between Erskine and Glenbrook Creek, enhancing the ongoing connection of individuals to ensure a viable breeding population persists.

No change in hydrology is expected in Warragamba River and therefore impacts are unlikely.

e) Disrupt the breeding cycle of a population

This species is unlikely to use the Penrith Weir Pool or Warragamba River to breed as spawning occurs in shallow gravel races at the head of fast flowing rock bars at the end of deep pools, habitats that are not present in the study reaches. For this reason, the project is unlikely to impact the breeding cycle of a population.

f) Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

No.

No habitat will be modified, destroyed, removed or in a way that adversely affects the Macquarie Perch. Potential partial inundation of the bar at the mouth of Glenbrook has potential to cause die back of vegetation which may provide a supply of woody debris to the River which is a favoured habitat resource of the species. Therefore, there is potential for enhancement of habitat.

g) Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat

No.

The proposed activities are unlikely to adversely alter the water quality, habitat or hydraulic characteristics of the Nepean and Warragamba Rivers in a way that would allow the establishment or increase of any invasive species populations.

h) Introduce disease that may cause the species to decline, or

No.

The proposed activities are unlikely to adversely alter the water quality, habitat or hydraulic characteristics of the Nepean and Warragamba Rivers in a way that would allow the introduction or increase in a disease that may cause the species to decline.

i) Interfere with the recovery of the species

No.

The proposed activities are unlikely to adversely alter the water quality, habitat or hydraulic characteristics of the Nepean and Warragamba Rivers in a way that would detrimentally affect the Macquarie Perch populations. Further, the increase in habitat through the increase in inundation extent may enhance the recovery of Macquarie Perch.

The National Recovery Plan for Macquarie Perch (Commonwealth of Australia, 2018) has been established to 'ensure the recovery and ongoing viability of Macquarie perch populations throughout the species' range'. It identifies a range of actions to:

- protect populations from competition, predation, recreational fishing and disease
- restore populations by translocations
- enhance habitat and provide appropriate flow regimes downstream of water storages
- research spawning, life cycle competition, predation, disease, parasites and best practice habitat restoration
- improve captive breeding techniques and undertake a conservation stocking program
- implement long term monitoring programs
- raise community awareness about the conservation status of Macquarie Perch and educate private landholders and land managers responsible for land adjacent to relevant waterways.

As with the NSW Priorities Action Statement, many of these actions are the responsibility of others to implement, and the project would not interfere with any of these actions. It can also potentially contribute to some of these actions including by providing high quality treated water to partially replace environmental flows from Warragamba Dam.

Based on the assessment provided above, it is concluded that Macquarie Perch is unlikely to be significantly impacted by the project, and as such offsetting in accordance with the EPBC Act Environmental Offsets Policy (CoA 2012) and the EPBC Act is not required.

6.8 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.

When considered in isolation, any identified project impacts may be considered minor. These minor impacts may, however, be compounded, when the cumulative impacts of the proposed urban growth on waterways. As such, impacts to the aquatic and riparian ecology, identified and listed below, need to be considered in terms of cumulative impacts. The waterway health objectives for South Creek and Nepean-Warragamba Rivers provide guidelines and trigger values to mitigate the cumulative impacts of development. Where all development provides surface water management measures to achieve or work towards the surface water objectives, then there will be an acceptable impact on waterways and downstream infrastructure.

The major projects currently being proposed within close proximity to the study areas are outlined below.

6.8.1 Western Sydney Airport

The proposed Western Sydney Airport site will be located approximately 3.2 km south-west of the AWRC site, south of Elizabeth Drive. The site is primarily drained by Badgerys Creek and Cosgroves Creek. Construction at the Western Sydney Airport site has already commenced. Any elevated pollutant concentration, inclusive of sediment will be transported downstream by Badgerys Creek and discharge to South Creek downstream of the AWRC site and potentially impact aquatic and riparian ecology. Any increase in stormwater pollution originating from the AWRC site or the waterways being crossed downstream of the airport site will add to these impacts.

6.8.2 M12 Motorway

The proposed M12 Motorway will run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 km and would be opened to traffic prior to opening of the Western Sydney Airport. The AWRC site itself is located within the extents of the M12 surface and hydrology study area. The discharge pipelines will follow a similar alignment to the M12 along portions of their routes. Erosion and sedimentation are expected during construction of the M12 Motorway, with sediment basins located to best capture runoff before it enters the waterway. Whilst increased runoff is expected to occur during operation of the project, the associated pollutants transported in runoff are expected to decrease with the implementation of appropriate water quality controls identified in the EIS (RMS, 2019). Therefore, it is expected that there would be minor cumulative water quality and hydrological impacts (and subsequently aquatic ecology impacts) associated with the construction and operation of the Project and the M12 Motorway.

6.8.3 Aerotropolis initial precincts

The Western Sydney Planning Partnership (WSPP) has identified several precincts as priority precincts which will be targeted for rezoning in late 2020. These precincts all directly border the Western Sydney Airport site, they include: the Aerotropolis Core, Badgerys Creek, Northern Gateway, Agribusiness and adjoining areas of Wianamatta-South Creek. These precincts are primarily located within the South Creek catchment as the discharge pipelines will transect several of them. An integrated water management plan targeting these precincts is currently being developed. The purpose of the plan is to identify measures and control mechanisms to ensure sustainable water management practices are established and consequently mitigate the cumulative impacts to waterways (including aquatic ecology) that the rapid urbanization may lead to.

6.8.4 Sydney Metro – Western Sydney Airport

The proposed new railway will link St Marys to the new airport and the Western Sydney Aerotropolis (Aurecon ARUP, 2021a). The Project footprint is primarily located within the South Creek catchment (or its tributaries). The scoping document reiterates the degraded water quality within the area and references a water management system associated with the Western Sydney International Stage 1 which is expected to effectively mitigate potential flooding, water quality and aquatic ecology impacts.

6.8.5 The Northern Road Upgrade – Glenmore Road to Bringelly

The Project will upgrade around 35 km of The Northern Road between The Old Northern Road at Narellan and Jamison Road at South Penrith. The project will see The Northern Road upgraded to a minimum four-lane divided road, and up to an eight-lane divided road with dedicated bus lanes. The treated effluent pipeline will run alongside the Northern Road for a stretch of approximately 1.4 km. Construction works within this area could likely overlap. The road upgrades will likely result in increased local impervious areas, subsequently leading to higher peak runoff rates. As the pipeline is expected to be below ground in this section, there are limited impacts expected post-construction and thus cumulative impacts to waterways should be negligible.

6.8.6 Warragamba Dam Raising

Warragamba Dam Raising is a project to provide temporary storage capacity for large inflow events into Lake Burragorang to facilitate downstream flood mitigation and includes infrastructure to enable environmental flows. Cumulative impacts are expected to be minimal as the dam is located upstream of the e-flows discharge location, and the raising is aimed at storing major flood events rather than retaining more water on a regular basis.

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

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

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

7 Conclusion

The AWRC Aquatic Ecology Impact Assessment report has determined the current ecological condition of streams and waterways in the vicinity of the AWRC and the project's potential impacts on them. The potential impacts are not expected to be significant and are summarized below.

The key findings of the assessment in relation to construction impacts are:

- The project has the potential to cause erosion that transport sediment to waterways. Settling of fine sediments has the potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering by fine sediments. It can also result in a loss of niche habitats caused by settling of sediment on the creek bed. Loss of invertebrates can also affect higher trophic fauna such as native fish, wading birds and microbats which are reliant on these for food resources. This risk can be appropriately managed through standard erosion and sediment control measures.
- Impacts at many waterways will be minimised by tunnelling pipelines beneath them. However, riparian vegetation will be removed, and creek bed and banks disturbed, where pipelines across waterways will be constructed by open trenching. These areas can also be disturbed by building release structures to waterways. Many of the waterways in the study area are considered Key Fish Habitat and these construction activities have the potential to block or restrict fish passage if not appropriately managed. This is particularly the case for Australian Bass, which undertake seasonal migrations in late autumn to spawn. Management measures are proposed related to timing of works, construction methodologies and restoration of waterways to minimise these impacts.
- Given the project is State Significant Infrastructure, many provisions of the *Water Management Act 2000* do not apply. However, mitigation measures are proposed to align with the principles of this legislation and other guidelines for infrastructure in aquatic environments. These include management of vegetated riparian zones (VRZ) on the AWRC site to enhance the condition of South Creek and its aquatic habitat and following guidelines for building structures in waterways.
- The only threatened species expected in the study area is Macquarie Perch. This species is known to be present in Warragamba River and parts of Nepean River and is protected under the NSW *Fisheries Management Act 1994* and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Project construction is not expected to impact this species and therefore no Offset Strategy as per the NSW *Fisheries Management Act 1994* is required.

The operational impact assessment has been informed by water quality, hydrodynamic and geomorphology modelling undertaken by other specialists as part of the EIS. Key findings of the assessment in relation to operational impacts are:

- During the operational phase, predicted impacts to aquatic, riparian and groundwater dependent ecosystems are not expected to be significant for the reasons outlined below:
- The modelled impacts to water quality are predicted to be insignificant with the potential for improvement due to the release of highly treated water to both South Creek and Nepean and Warragamba Rivers.
- Upstream of Wallacia Weir to Bents Basin, 2036 modelling predicts moderate water depth changes of up to 18 cm under median flows when the AWRC is operating at 50 ML/day. This is a result of the releases discharging to the Wallacia Weir pool which provides a flow control and regulates fluctuations in depth. With a constant discharge to the Weir Pool, depth fluctuations will be reduced, and a median depth change will occur. Depth changes are lower downstream of the Wier. The exact impact of this depth change is difficult to quantify however localised impacts may occur.

  Changes in depth may may drive an increase in habitat for aquatic fauna species that exhibit a preference for the deep weir pool such as Australian Bass that use deep pools as refuge in the hotter summer months.

  In contrast, this increase may impact taxa dependent on shallow habitats of < 50 cm and therefore a change in depth may result in refuges becoming too deep and beyond the ideal depth range for macroinvertebrate taxa and may lead to a reduction in available macroinvertebrate food resources and impact higher trophic level taxa such as fish, turtles, waterbirds and microbats.
- Some increases in wetted perimeter are predicted to occur in the Nepean River which are indicative of potential changes in inundation extent. All these changes are within the existing river channel and represent an increased frequency of inundation of in-channel bars (including around Glenbrook Creek), riffles and the base of riverbanks.

  When considered across the extent of the approximate 30 km of the Nepean River subject to potential hydrological change, a <2 percent change in wetted perimeter is expected, which has the potential to impact (albeit marginal) riparian vegetation and aquatic ecosystems due to minor potential inundation of in-channel vegetation and an upward shift of the aquatic ecosystem within the river channel. However, at this broad assessment scale, localised impacts cannot be quantified.

  Smaller scale reach assessments indicate a small percentage of change (<5%) in wetted perimeter is apparent which includes very localised changes of up to 12 m. This has potential to result in some change to riparian communities driven by increased inundation of riparian habitats which may cause vegetation dieback of species that cannot tolerate prolonged periods of inundation or sustained root zone saturation. This may trigger a direct loss of riparian vegetation or a change in the vegetation community to one with higher tolerance to inundation or saturated root zones.

Similarly, an increase in wetted perimeter percent may result in a potential upward shift of the aquatic ecosystem which has potential to increase aquatic habitat by displacing riparian habitats. This has potential to expand aquatic habitats along the margins of the River and provide benefits to taxa that rely on edge habitats and shallow areas such as benthic macroinvertebrates and species that prey on this group such as Australian Bass.

However, given the coarseness and limitations of the modelled data and multiple anomalies identified (see Appendix E), these results should be treated with caution and may represent a potential over-expression of wetted perimeter percent change.

As a result, it is not possible to accurately quantify the potential magnitude of impacts associated with wetted perimeter increase on riparian and aquatic ecosystems, particularly at the very localised scale where the larger potential impacts may occur.

Further data ground-truthing would be required to refine the model to remove anomalies that are resulting in an over-expression of wetted perimeter and thus, the magnitude of impacts associated with this metric.

However, based on the current modelled results with consideration of the dominant geomorphology (i.e. steep sided rock lined banks, bedrock lines channels, riparian vegetation slightly elevated above the water line) it is considered that the current modelled impact to aquatic and riparian ecosystems is low and any impacts are likely to be very localised and of relatively small scale.

- Flow velocity modelling suggests no flow driven impacts are expected, including to fish or macroinvertebrates.
- No significant impact to Macquarie Perch or its habitat is predicted to occur as a result of project operation and therefore no offset strategy is required.

The study recommends continuation of Sydney Water's existing monitoring program, with addition of some additional water quality and vegetation monitoring in Nepean River around Glenbrook Creek. This will assist in establishing baseline conditions over an extended period and verifying impacts once the project is operating.

8 Recommendations

Recommendations for mitigation of impacts as a result of the construction and operational phases of the AWRC have been made specific to Study Areas 1 – 6.

However, an overarching recommendation to modify the existing monitoring program is suggested and consideration given to include:

Inclusion of benthic diatom modelling and calculation of associated biotic indices, particularly Trophic Diatom Index (TDI) which will provide understanding of primary production level response to alteration of water quality. Benthic diatoms are less susceptible to hydrological change when compared to aquatic macroinvertebrates and chlorophyll-*a* and will provide an additional and reliable tool to assess ecosystem response.

Additional monitoring points should be included in the Penrith Weir pool approximately 100m upstream of the Glenbrook Creek junction for water quality and biological parameters. Sampling should commence prior to the construction phase and extend throughout the post-commissioning phase. Inclusion of additional points will enable a longitudinal assessment of potential change driven by AWRC releases and enable Sydney Water to investigate potential sources of algae or problematic macrophyte growth in the Penrith Weir Pool.

Regular fish survey is included in the monitoring program which will assist with assessing upper trophic level change as a result of AWTP releases to the Nepean River and South Creek.

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10 Appendix A: Summary reports for Rapid Riparian Appraisals (RRAs)

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 9:32 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

73 % good

17.5
20
13.75
-20
3
-6

Nepean-55

notes

The site is in good condition, with a raw score of 28.25 (73%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 50% bushland, 50% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 25% forest/woodland, 25% derived exotic shrubland, 50% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African boxthorn, Balloon vine , Narrow leaved privet .

upstream

Photo 4-5-2019 9.51.51 am.jpg
-33.930503
150.638870
2/05/2019 10:05:37 AM

downstream

Photo 4-5-2019 9.52.16 am.jpg
-33.930480
150.638870
2/05/2019 10:05:41 AM

extraction	water
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	17.5
Site Features Total	17.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	3
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	severe >30% bank
knick point	absent
bank erosion	absent
Erosion Total	-6
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	13.75
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	13.75

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 10:02 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

78 % good

17.8 | 20 | 22.7 | -12 | 4 | -2

Nepean-60

stream order 5+

notes

The site is in good condition, with a raw score of 42.5 (78%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 80% bushland, 20% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 90% forest/woodland, 10% weed/exotic, approximately. Right bank vegetation structure is 80% under-scrubbed forest/woodland, 10% weed/exotic, 10% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Privet , Tobacco .

upstream

Photo 4-5-2019 9.54.08 am.jpg
-33.926758
150.641358
2/05/2019 10:13:10 AM

downstream

Photo 4-5-2019 9.54.41 am.jpg
-33.926737
150.641358
2/05/2019 10:13:14 AM

extraction	absent
excavation	absent
litter	
sewer	
stormwater	
odour	
turbidity	
Land Use Subtotal	17.8
Site Features Total	17.8
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	14.7
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	22.7

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 10:12 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

70 %	good
8.2	
20	
12.8	
-20	
2	
-2	

Nepean-65

notes

The site is in fair condition, with a raw score of 21 (70%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 60% bushland, 40% pasture, approximately. Right bank land use is 60% bushland, 40% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 60% forest/woodland, 40% pasture grassland, approximately. Right bank vegetation structure is 60% forest/woodland, 40% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Privet .

upstream

Photo 4-5-2019 9.56.16 am.jpg
-33.923613
150.645338
2/05/2019 10:20:27 AM

downstream

Photo 4-5-2019 9.56.47 am.jpg
-33.923588
150.645370
2/05/2019 10:20:31 AM

extraction	water
excavation	present
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	8.2
Site Features Total	8.2
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	low 1-3
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	2
benches	absent
islands	absent
channel bars	no restriction
Deposition Total	1
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	12.8
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	12.8

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 10:25 am | assessor CTENVIRONMENTAL
weather sunny | reach type permanent | flow medium

74 %

12.2 | 20 | 17.25 | -13 | 4 | -2

good

Nepean-70

stream order 5+

notes The site is in good condition, with a raw score of 31.45 (74%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse Within the 50 metre assessment radius, left bank land use is 70% bushland, 30% pasture, approximately. Right bank land use is 50% bushland, 50% pasture, approximately. This is included in the site features score.

vegetation Within the 50 metre assessment radius, left bank vegetation structure is 30% forest/woodland, 30% under-scrubbed forest/woodland, 40% pasture grassland, approximately. Right bank vegetation structure is 25% under-scrubbed forest/woodland, 25% forest/woodland, 50% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds Weed species observed at the site include Prickly pears - Opuntias, Privet .

upstream

Photo 4-5-2019 9.57.41 am.jpg
-33.919808
150.646820
2/05/2019 10:25:37 AM

downstream

Photo 4-5-2019 9.58.06 am.jpg
-33.919778
150.646820
2/05/2019 10:25:41 AM

extraction	water
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	12.2
Site Features Total	12.2
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	10.25
weed density left bank	severe over 70%
weed density right bank	light up to 40%
Weeds Subtotal	-13
Vegetation Total	17.25

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 10:40 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

78 %

21.8 | 20 | 20.2 | -13 | 3 | -4

good

Nepean-75

stream order 5+

notes

The site is in good condition, with a raw score of 41 (78%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 80% bushland, 20% pasture, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 80% forest/woodland, 20% pasture grassland, approximately. Right bank vegetation structure is 50% forest/woodland, 50% weed/exotic, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Privet .

upstream

Photo 4-5-2019 9.59.07 am.jpg
-33.910595
150.644897
2/05/2019 11:20:50 AM

downstream

Photo 4-5-2019 9.59.31 am.jpg
-33.910637
150.644988
2/05/2019 11:20:41 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	21.8
Site Features Total	21.8
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	3
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	13.2
weed density left bank	light up to 40%
weed density right bank	severe over 70%
Weeds Subtotal	-13
Vegetation Total	20.2

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 10:58 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

71 % good

11.9
20
10.2
-13
2
0

Nepean-80

stream order 5+

notes

The site is in fair condition, with a raw score of 24.1 (71%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 100% pasture, approximately. Right bank land use is 90% bushland, 10% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 60% weed/exotic, 30% under-scrubbed forest/woodland, 10% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 4-5-2019 10.05.06 am.jpg
-33.909672
150.642822
2/05/2019 11:24:38 AM

downstream

Photo 4-5-2019 10.06.39 am.jpg
-33.909655
150.642762
2/05/2019 11:24:45 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	11.9
Site Features Total	11.9
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	low 1-3
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	2
benches	present unconstricted
islands	present
channel bars	absent
Deposition Total	2
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	3.2
weed density left bank	light up to 40%
weed density right bank	severe over 70%
Weeds Subtotal	-13
Vegetation Total	10.2

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 11:07 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

71 %	11.9	good
	20	
	5.9	
	-20	
	5	
	0	

Nepean-85

stream order 5+

notes

The site is in fair condition, with a raw score of 22.8 (71%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 80% pasture, approximately. Right bank land use is 70% bushland, 30% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% forest/woodland, 80% pasture grassland, approximately. Right bank vegetation structure is 40% under-scrubbed forest/woodland, 30% weed/exotic, 30% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Fireweed, Privet .

upstream

downstream

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	11.9
Site Features Total	11.9
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	5
benches	absent
islands	present
channel bars	no restriction
Deposition Total	2
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	5.9
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	5.9

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 11:30 am | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

71 % good

7.3 | 20 | 15.4 | -9 | 4 | -3

Nepean-90

stream order 5+

notes

The site is in fair condition, with a raw score of 23.7 (71%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 30% bushland, 70% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% forest/woodland, 10% under-scrubbed forest/woodland, 70% pasture grassland, approximately. Right bank vegetation structure is 100% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Privet .

upstream

Photo 4-5-2019 10.09.52 am.jpg
-33.903637
150.635025
2/05/2019 11:41:15 AM

downstream

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	7.3
Site Features Total	7.3
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	4.4
weed density left bank	moderate 40-70%
weed density right bank	light up to 40%
Weeds Subtotal	-9
Vegetation Total	15.4

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 12:23 pm | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

68 % fair

2.3
20
14.45
-9
3
-4

Nepean-95

notes

The site is in fair condition, with a raw score of 15.75 (68%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 10% bushland, 90% pasture, approximately. Right bank land use is 20% bushland, 80% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 90% pasture grassland, 5% under-scrubbed forest/woodland, 5% weed/exotic, approximately. Right bank vegetation structure is 80% pasture grassland, 20% under-scrubbed forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Privet , Willows.

upstream

Photo 4-5-2019 10.15.39 am.jpg
-33.894630
150.634262
2/05/2019 11:56:30 AM

downstream

Photo 4-5-2019 10.16.01 am.jpg
-33.894600
150.634247
2/05/2019 11:56:33 AM

extraction	water
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	2.3
Site Features Total	2.3
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	3
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	3.45
weed density left bank	moderate 40-70%
weed density right bank	light up to 40%
Weeds Subtotal	-9
Vegetation Total	14.45

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 1:45 pm | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

75 % good

18.5
20
13.1
-20
4
-2

Nepean-105

stream order 5+

notes

The site is in good condition, with a raw score of 33.6 (75%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 50% bushland, 50% pasture, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 50% forest/woodland, 50% pasture grassland, approximately. Right bank vegetation structure is 70% forest/woodland, 30% exotic landscaped, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Bridal creeper, Fireweed, Privet .

upstream

Photo 4-5-2019 10.17.14 am.jpg
-33.890758
150.634413
2/05/2019 12:02:18 PM

downstream

Photo 4-5-2019 10.17.38 am.jpg
-33.890747
150.634413
2/05/2019 12:02:22 PM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	18.5
Site Features Total	18.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	natural > 500 mm
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	no restriction
Deposition Total	1
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	13.1
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	13.1

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 2:33 pm | assessor CTENVIRONMENTAL
weather sunny | reach type permanent | flow medium

69 % fair

5.3 | 20 | 12.7 | -12 | 4 | -2

Nepean-110

stream order 5+

notes

The site is in fair condition, with a raw score of 20 (69%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 30% bushland, 70% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 30% forest/woodland, 70% pasture grassland, approximately. Right bank vegetation structure is 100% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Cestrum, Privet .

upstream

Photo 4-5-2019 10.19.57 am.jpg
-33.886013
150.635222
2/05/2019 12:09:45 PM

downstream

Photo 4-5-2019 10.20.15 am.jpg
-33.885995
150.635253
2/05/2019 12:09:49 PM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	5.3
Site Features Total	5.3
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	4.7
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	12.7

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 3:00 pm | assessor CTENVIRONMENTAL
weather sunny | reach type permanent | flow medium

69 %

7.5 | 20 | 13.3 | -9 | 4 | -5

fair

Nepean-115

stream order 5+

notes

The site is in fair condition, with a raw score of 19.8 (69%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 50% bushland, 50% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 40% forest/woodland, 30% pasture grassland, 30% absent/concrete/earth, approximately. Right bank vegetation structure is 100% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine , Castor plant, Privet .

upstream

Photo 4-5-2019 10.22.43 am.jpg
-33.882030
150.639192
2/05/2019 12:22:21 PM

downstream

Photo 4-5-2019 10.23.19 am.jpg
-33.882028
150.639192
2/05/2019 12:22:25 PM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	7.5
Site Features Total	7.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	minor restriction
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	2.3
weed density left bank	moderate 40-70%
weed density right bank	light up to 40%
Weeds Subtotal	-9
Vegetation Total	13.3

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 2 May 2019 | time 3:55 pm | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow medium

76 % good

21.5
20
15.3
-20
2
-2

Nepean-125

stream order 5+

notes

The site is in good condition, with a raw score of 36.8 (76%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 70% bushland, 30% pasture, approximately. Right bank land use is 80% bushland, 20% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 70% forest/woodland, 30% pasture grassland, approximately. Right bank vegetation structure is 80% forest/woodland, 20% weed/exotic, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Bridal creeper, Lantana , Morning Glory , Privet .

upstream

Photo 4-5-2019 10.24.06 am.jpg
-33.877262
150.639738
2/05/2019 12:46:18 PM

downstream

Photo 4-5-2019 10.24.28 am.jpg
-33.877220
150.639725
2/05/2019 12:46:25 PM

extraction	absent
excavation	absent
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	21.5
Site Features Total	21.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	low 1-3
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	2
benches	
islands	
channel bars	
Deposition Total	
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	15.3
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	15.3

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Cosgroves Creek

type Regular | date 4 Jun 2020 | time 3:13:07 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow low

58 % poor

1.6
12
5.8
-6
-14
-1

Cosgroves-2

stream order 4

notes

The site is in poor condition, with a raw score of -7.6 (58%) overall. The bed type is natural bed (invert) - Nv. The bank type is grass - G.

landuse

Within the 50 metre assessment radius, left bank land use is 90% pasture, 10% road, approximately. Right bank land use is 90% pasture, 10% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 90% pasture grassland, 10% absent/concrete/earth, approximately. Right bank vegetation structure is 90% pasture grassland, 10% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet , Willow.

upstream

Photo 4-6-2020 3.18.41 pm.jpg
-33.864522
150.709733
4/06/2020 9:00:55 AM

downstream

Photo 4-6-2020 3.19.12 pm.jpg
-33.864533
150.709717
4/06/2020 9:00:58 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	1.6
Site Features Total	1.6
channel shape	grass-lined
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	not visible
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 3; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-14
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	
knick point	absent
bank erosion	absent
Erosion Total	-1
riparian corridor WMAct	80
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-.2
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	5.8

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Nepean River

type Regular | date 5 Jun 2020 | time 9:06 am | assessor CTENVIRONMENTAL
weather sunny | reach type permanent | flow medium

79 % good

17.2	
20	
20.9	
-12	
6	
0	

Nepean-19

stream order 5+

notes

The site is in good condition, with a raw score of 44.1 (79%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 80% bushland, 20% park, approximately. Right bank land use is 80% bushland, 10% park, 10% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 40% forest/woodland, 40% under-scrubbed forest/woodland, 20% mown grass/park, approximately. Right bank vegetation structure is 40% forest/woodland, 40% under-scrubbed forest/woodland, 10% mown grass/park, 10% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African olive, Balloon vine , Lantana, Narrow leaved privet .

upstream

Photo 5-6-2020 10.07.27 am.jpg
-33.865692
150.637222
5/06/2020 10:05:11 AM

downstream

Photo 5-6-2020 10.07.48 am.jpg
-33.865697
150.637208
5/06/2020 10:05:08 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	17.2
Site Features Total	17.2
channel shape	simple
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	6
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	12.9
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	20.9

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 5 Jun 2020 | time 10:37:02 am | assessor Ben Green

weather sunny | reach type permanent | flow medium

71 % good

3.4
20
15.4
-12
6
0

Nepean-18

stream order 5+

notes

The site is in fair condition, with a raw score of 24.8 (71%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 40% bushland, 60% pasture, approximately. Right bank land use is 40% bushland, 60% park, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 20% forest/woodland, 60% pasture grassland, approximately. Right bank vegetation structure is 40% under-scrubbed forest/woodland, 60% mown grass/park, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African olive, Balloon vine , Narrow leaved privet .

upstream

Photo 5-6-2020 10.37.50 am.jpg
-33.865138
150.637358
5/06/2020 10:34:53 AM

downstream

Photo 5-6-2020 10.38.20 am.jpg
-33.865120
150.637497
5/06/2020 10:34:35 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	present
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	3.4
Site Features Total	3.4
channel shape	simple
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	6
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	7.4
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	15.4

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Hinchinbrook Creek

type Regular date 10 Jun 2020 time 8:17:53 am assessor Ben Green
weather overcast reach type ephemeral flow low

64 %	fair
5.8	
12	
12.6	
-6	
-3	
-8	

Hinchinbrook-38

stream order 4

notes

The site is in fair condition, with a raw score of 7.4 (64%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 60% bushland, 20% park, 20% road, approximately. Right bank land use is 60% bushland, 20% park, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 30% forest/woodland, 30% mature native revegetation, 20% mown grass/park, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 30% forest/woodland, 30% mature native revegetation, 20% mown grass/park, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African olive, Narrow leaved privet .

upstream

Photo 11-6-2020 8.21.42 am.jpg
-33.895347
150.847763
9/06/2020 7:55:09 AM

downstream

Photo 11-6-2020 8.22.02 am.jpg
-33.895067
150.847717
9/06/2020 7:54:25 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	present
odour	normal/none
turbidity	medium
Land Use Subtotal	5.8
Site Features Total	5.8
channel shape	simple
pool riffle sequence	absent
meanders	confined no
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 3; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-3
benches	moderate restriction
islands	absent
channel bars	minor restriction
Deposition Total	-3
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	headcut
Erosion Total	-5
riparian corridor WMAct	80
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	6.6
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	12.6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Clear Paddock Creek

type Regular | date 10 Jun 2020 | time 8:40:30 am | assessor Ben Green

weather overcast | reach type ephemeral | flow low

46 % very poor

-4.4 | 0 | -19.6 | -12 | -8 | -7

Clear-30

notes The site is in very poor condition, with a raw score of -39 (46%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

stream order 1

landuse Within the 50 metre assessment radius, left bank land use is 20% bushland, 20% park, 60% peri-urban mixed use, approximately. Right bank land use is 40% bushland, 60% peri-urban mixed use, approximately. This is included in the site features score.

vegetation Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 20% mown grass/park, 60% absent/concrete/earth, approximately. Right bank vegetation structure is 40% under-scrubbed forest/woodland, 60% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds Weed species observed at the site include Castor , Narrow leaved privet , Trad.

upstream

Photo 15-6-2020 1.47.43 pm.jpg
-33.898762
150.874558
9/06/2020 7:42:04 AM

downstream

Photo 11-6-2020 8.44.12 am.jpg
-33.898950
150.875870
9/06/2020 7:43:55 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	present
stormwater	present
odour	normal/none
turbidity	low
Land Use Subtotal	-4.4
Site Features Total	-4.4
channel shape	simple
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	low <30%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 3; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-8
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	moderate 10-30%
knick point	absent
bank erosion	headcut
Erosion Total	-6
riparian corridor WMAct	20
riparian buffer width left	10-20m
riparian buffer width right	10-20m
Riparian Vegetation Subtotal	0
Vegetation Structure Subtotal	-7.6
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-19.6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

South Creek

type Regular | date 12 Jun 2020 | time 8:25:36 am | assessor Ben Green

weather overcast | reach type permanent | flow medium

69 %

fair

1.55 | 20 | 16.3 | -6 | 1 | -1

South-39

stream order 5+

notes

The site is in fair condition, with a raw score of 17.85 (69%) overall. The bed type is natural bed (invert) - Nv. The bank type is grass - G.

landuse

Within the 50 metre assessment radius, left bank land use is 100% pasture, approximately. Right bank land use is 5% bushland, 95% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 95% pasture grassland, 5% under-scrubbed forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry, Fireweed, Solanum spp..

upstream

Photo 12-6-2020 8.49.48 am.jpg
-33.860237
150.770247
12/06/2020 8:48:55 AM

downstream

Photo 12-6-2020 8.50.06 am.jpg
-33.860242
150.770263
12/06/2020 8:49 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	1.55
Site Features Total	1.55
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	moderate 4-10
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	not visible
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	1
benches	present unconstricted
islands	absent
channel bars	absent
Deposition Total	1
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	2.3
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	16.3

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

South Creek

type Regular | date 12 Jun 2020 | time 9:10:27 am | assessor CTENVIRONMENTAL

weather overcast | reach type permanent | flow medium

69 % fair

12.55 | 20 | 16.3 | -6 | -1 | -8

South-41

stream order 5+

notes

The site is in fair condition, with a raw score of 19.85 (69%) overall. The bed type is natural bed (invert) - Nv. The bank type is grass - G.

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 5% bushland, 95% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 5% under-scrubbed forest/woodland, 95% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry, Fireweed, Solanum spp., Thistle.

upstream

Photo 12-6-2020 9.11.07 am.jpg
-33.858947
150.767272
12/06/2020 9:10:01 AM

downstream

Photo 12-6-2020 9.11.19 am.jpg
-33.858947
150.767272
12/06/2020 9:10:04 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	12.55
Site Features Total	12.55
channel shape	straighened/deepened
pool riffle sequence	present
meanders	unconfined yes
large woody debris	moderate 4-10
woody debris size	> 3 metres length
overhanging vegetation	absent
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	-1
benches	major restriction
islands	present
channel bars	minor restriction
Deposition Total	-4
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	absent
knick point	absent
bank erosion	gully/rill
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	2.3
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	16.3

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
South Creek

type Regular | date 12 Jun 2020 | time 9:23:49 am | assessor CTENVIRONMENTAL
weather overcast | reach type permanent | flow medium

64 %	1	fair
	20	
	19	
	-3	
	-8	
	-6	

South-42

notes

The site is in poor condition, with a raw score of 6 (64%) overall. The bed type is natural bed (invert) - Nv. The bank type is grass - G.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 100% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry, Fireweed , Solanum spp..

upstream

Photo 12-6-2020 9.24.54 am.jpg
-33.856555
150.768692
12/06/2020 9:22:58 AM

downstream

Photo 12-6-2020 9.25.06 am.jpg
-33.856633
150.768708
12/06/2020 9:23:14 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	1
Site Features Total	1
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	-8
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	gully/rill
Erosion Total	-6
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	2
weed density left bank	sparse less than 5%
weed density right bank	light up to 40%
Weeds Subtotal	-3
Vegetation Total	19

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

South Creek

type Regular | date 12 Jun 2020 | time 9:39:56 am | assessor CTENVIRONMENTAL

weather overcast | reach type permanent | flow medium

64 %

fair

1 | 20 | 20.4 | -3 | -8 | -7

South-43

stream order 5+

notes

The site is in poor condition, with a raw score of 6.4 (64%) overall. The bed type is natural bed (invert) - Nv. The bank type is grass - G.

landuse

Within the 50 metre assessment radius, left bank land use is 100% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 80% pasture grassland, 20% waterway/wetland/swamp, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Fireweed, Solanum spp..

upstream

Photo 12-6-2020 9.40.54 am.jpg
-33.854145
150.769622
12/06/2020 9:40:13 AM

downstream

Photo 12-6-2020 9.41.04 am.jpg
-33.854145
150.769622
12/06/2020 9:40:17 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	1
Site Features Total	1
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	-8
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	absent
knick point	absent
bank erosion	gully/rill
Erosion Total	-6
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	3.4
weed density left bank	sparse less than 5%
weed density right bank	light up to 40%
Weeds Subtotal	-3
Vegetation Total	20.4

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Kemps Creek

type Regular | date 12 Jun 2020 | time 10:11:52 am | assessor CTENVIRONMENTAL
weather overcast | reach type permanent | flow medium

65 % fair

6.6
20
21.1
-6
-15
-3

Kemps-44

stream order 4

notes

The site is in fair condition, with a raw score of 9.7 (65%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 60% bushland, 40% pasture, approximately. Right bank land use is 20% bushland, 70% pasture, 10% market gardens, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% forest/woodland, 40% waterway/wetland/swamp, 10% weed/exotic, 30% pasture grassland, approximately. Right bank vegetation structure is 20% under-scrubbed forest/woodland, 70% pasture grassland, 10% urban yards, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry, Fireweed, Narrow leaved privet .

upstream

Photo 12-6-2020 10.12.34 am.jpg
-33.851325
150.774612
12/06/2020 10:09:18 AM

downstream

Photo 12-6-2020 10.13.15 am.jpg
-33.851350
150.774597
12/06/2020 10:09:27 AM

extraction	water
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	6.6
Site Features Total	6.6
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	-15
benches	absent
islands	present
channel bars	absent
Deposition Total	1
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	7.1
weed density left bank	moderate 40-70%
weed density right bank	not visible
Weeds Subtotal	-6
Vegetation Total	21.1

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Kemps Creek

type Regular date 12 Jun 2020 time 10:30:39 am assessor CTENVIRONMENTAL
weather overcast reach type permanent flow medium

73 %	11.1	good
	16	
	19.3	
	-6	
	0	
	-1	

Kemps-45

notes

The site is in good condition, with a raw score of 29.4 (73%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

stream order 4

landuse

Within the 50 metre assessment radius, left bank land use is 80% bushland, 20% pasture, approximately. Right bank land use is 50% bushland, 30% pasture, 20% peri-urban mixed use, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 40% forest/woodland, 10% weed/exotic, 20% pasture grassland, 30% derived native grassland, approximately. Right bank vegetation structure is 30% forest/woodland, 30% pasture grassland, 20% urban yards, 20% waterway/wetland/swamp, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine, Blackberry, Purpletop verbena, Thistle.

upstream

Photo 12-6-2020 10.32.01 am.jpg
-33.852538
150.777053
12/06/2020 10:29:50 AM

downstream

Photo 12-6-2020 10.32.18 am.jpg
-33.852538
150.777053
12/06/2020 10:29:54 AM

extraction	water
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	11.1
Site Features Total	11.1
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	0
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	-1
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	16
Vegetation Structure Subtotal	9.3
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	19.3

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Kemps Creek

type Regular | date 12 Jun 2020 | time 10:51:41 am | assessor CTENVIRONMENTAL
weather overcast | reach type permanent | flow medium

75 % good

15.4
16
16.4
-13
0
1

Kemps-47

notes

The site is in good condition, with a raw score of 32.8 (75%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

stream order 4

landuse

Within the 50 metre assessment radius, left bank land use is 90% bushland, 10% pasture, approximately. Right bank land use is 60% bushland, 30% pasture, 10% peri-urban mixed use, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 50% forest/woodland, 10% pasture grassland, 10% derived exotic shrubland, 10% weed/exotic, 20% waterway/wetland/swamp, approximately. Right bank vegetation structure is 60% forest/woodland, 10% mown grass/park, 30% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Balloon vine, Blackberry, Narrow leaved privet , Patty's Lucerne , Tacoma stands.

upstream

Photo 12-6-2020 10.52.17 am.jpg
-33.854275
150.778288
12/06/2020 10:51:07 AM

downstream

Photo 12-6-2020 10.52.40 am.jpg
-33.854275
150.778305
12/06/2020 10:51:12 AM

extraction	absent
excavation	absent
litter	high 20-50
sewer	absent
stormwater	absent
odour	normal/none
turbidity	high
Land Use Subtotal	15.4
Site Features Total	15.4
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	0
benches	absent
islands	absent
channel bars	no restriction
Deposition Total	1
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	16
Vegetation Structure Subtotal	13.4
weed density left bank	severe over 70%
weed density right bank	light up to 40%
Weeds Subtotal	-13
Vegetation Total	16.4

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Kemps Creek

type Regular date 12 Jun 2020 time 11:10:10 am assessor CTENVIRONMENTAL

weather overcast reach type permanent flow medium

74 %	good
8.7	
20	
21.95	
-6	
2	
-2	

Kemps-48

stream order 4

notes

The site is in good condition, with a raw score of 30.65 (74%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 30% bushland, 70% pasture, approximately. Right bank land use is 40% bushland, 60% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 25% forest/woodland, 70% pasture grassland, 5% derived exotic shrubland, approximately. Right bank vegetation structure is 40% forest/woodland, 60% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet.

upstream

Photo 12-6-2020 11.10.20 am.jpg
-33.856030
150.779725
12/06/2020 11:09:46 AM

downstream

Photo 12-6-2020 11.10.35 am.jpg
-33.856030
150.779725
12/06/2020 11:09:50 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	8.7
Site Features Total	8.7
channel shape	widened/infilled
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	high >10
woody debris size	> 3 metres length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	2
benches	absent
islands	present
channel bars	absent
Deposition Total	1
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	7.95
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	21.95

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Jerrys Creek

type Regular | date 11 Jun 2020 | time 10:16:37 am | assessor Ben Green
weather sunny | reach type permanent | flow medium

58 %	poor
5.6	
6	
-12	
-16	
4	
-7	

Jerrys-20

notes
The site is in poor condition, with a raw score of -9.4 (58%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

stream order
4

landuse
Within the 50 metre assessment radius, left bank land use is 40% bushland, 30% residential, 30% road, approximately. Right bank land use is 80% bushland, 20% road, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 20% forest/woodland, 20% weed/exotic, 60% absent/concrete/earth, approximately. Right bank vegetation structure is 40% forest/woodland, 40% weed/exotic, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include African olive, Black willow, Broad leaved privet , Narrow leaved privet , Salvinia.

upstream

Photo 15-6-2020 10.25.41 am.jpg
-33.866588
150.644500
5/06/2020 10:52:18 AM

downstream

Photo 15-6-2020 10.26.04 am.jpg
-33.866600
150.644500
5/06/2020 10:52:30 AM

extraction	absent
excavation	absent
litter	high 20-50
sewer	absent
stormwater	present
odour	normal/none
turbidity	medium
Land Use Subtotal	5.6
Site Features Total	5.6
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 3 metres length
overhanging vegetation	mod <30>60%
natural bed detritus	absent
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 3; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	gully/rill
Erosion Total	-7
riparian corridor WMAct	80
riparian buffer width left	10-20m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	6
Vegetation Structure Subtotal	-2
weed density left bank	severe over 70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-16
Vegetation Total	-12

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Jerrys Creek

type Regular date 10 Jun 2020 time 10:36:25 am assessor Ben Green

weather sunny reach type permanent flow low

58 %

3
12
-1.1
-12
0
-9

poor

Jerrys-21

stream order 4

notes

The site is in poor condition, with a raw score of -7.1 (58%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 60% park, 20% road, approximately. Right bank land use is 40% bushland, 30% park, 30% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 10% forest/woodland, 10% weed/exotic, 60% mown grass/park, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 20% forest/woodland, 20% weed/exotic, 30% mown grass/park, 30% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet .

upstream

downstream

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	3
Site Features Total	3
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	high >60%
natural bed detritus	absent
natural gravel bed	present
natural rock in-stream	natural > 500 mm
native macrophyte	absent
mapped Key Fish Habitat	no / Class 3 / Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	0
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	from incision
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	gully/rill
Erosion Total	-9
riparian corridor WMAct	80
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-1.1
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-1.1

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Jerrys Creek

type Regular | date 15 Jun 2020 | time 10:50:57 am | assessor Ben Green
weather sunny | reach type ephemeral | flow none

53 %

14.4 | 0 | -7.2 | -12 | -21 | -8

poor

Jerrys-Trib-23

stream order 1

notes
The site is in poor condition, with a raw score of -21.8 (53%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse
Within the 50 metre assessment radius, left bank land use is 60% bushland, 20% pasture, 20% road, approximately. Right bank land use is 60% bushland, 20% pasture, 20% road, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 60% under-scrubbed forest/woodland, 20% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 60% under-scrubbed forest/woodland, 20% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include African olive, Narrow leaved privet .

upstream

Photo 15-6-2020 10.53.55 am.jpg
-33.869372
150.654787
5/06/2020 11:07:12 AM

downstream

Photo 15-6-2020 10.54.20 am.jpg
-33.869400
150.654938
5/06/2020 11:07:43 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	14.4
Site Features Total	14.4
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	confined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	mod <30>60%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-21
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	severe >30% bank
knick point	absent
bank erosion	gully/rill
Erosion Total	-8
riparian corridor WMAct	20
riparian buffer width left	10-20m
riparian buffer width right	10-20m
Riparian Vegetation Subtotal	0
Vegetation Structure Subtotal	4.8
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-7.2

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Jerrys Creek

type Regular | date 5 Jun 2020 | time 11:05:35 am | assessor Ben Green

weather sunny | reach type ephemeral | flow low

55 %	poor
	9.9
	0
	-6.2
	-12
	-12
	-7

Jerrys-Trib-22

stream order 2

notes

The site is in poor condition, with a raw score of -15.3 (55%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 40% bushland, 40% pasture, 20% road, approximately. Right bank land use is 30% bushland, 50% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 30% forest/woodland, 30% derived exotic shrubland, 20% derived native shrubland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 30% forest/woodland, 20% derived native shrubland, 30% derived exotic shrubland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry, Narrow leaved privet .

upstream

Photo 15-6-2020 11.07.33 am.jpg
-33.869475
150.654847
5/06/2020 11:09:49 AM

downstream

Photo 15-6-2020 11.07.51 am.jpg
-33.869433
150.654830
5/06/2020 11:08:32 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	9.9
Site Features Total	9.9
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	mod <30>60%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-12
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	gully/rill
Erosion Total	-7
riparian corridor WMAct	40
riparian buffer width left	10-20m
riparian buffer width right	10-20m
Riparian Vegetation Subtotal	0
Vegetation Structure Subtotal	5.8
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-6.2

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Mulgoa Creek

type Regular | date 6 Jun 2020 | time 12:42:09 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow none

55 % poor

-2.8 | 12 | 3.6 | -6 | -17 | 0

Mulgoa-unnamed trib-26

stream order 1

notes

The site is in poor condition, with a raw score of -16.2 (55%) overall. The bed type is grass invert - Gv. The bank type is grass - G.

landuse

Within the 50 metre assessment radius, left bank land use is 80% pasture, 20% road, approximately. Right bank land use is 80% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Castor plant .

upstream

Photo 15-6-2020 11.39.57 am.jpg
-33.873713
150.685745
5/06/2020 11:16:27 AM

downstream

Photo 15-6-2020 11.40.19 am.jpg
-33.873562
150.685700
5/06/2020 11:16:46 AM

extraction	absent
excavation	present
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	-2.8
Site Features Total	-2.8
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-17
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-2.4
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	3.6

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Prospect Creek

type Regular | date 6 Jun 2020 | time 6:55 am | assessor Ben Green
weather sunny | reach type tidal | flow incoming

78 % good
12.5 | 20 | 27.7 | -6 | 4 | -3

Prospect-37

stream order 5+

notes
The site is in good condition, with a raw score of 41.2 (78%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 30% bushland, 70% park, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 30% forest/woodland, 70% mown grass/park, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include Balloon vine .

upstream

Photo 15-6-2020 11.52.21 am.jpg
-33.892887
150.968003
9/06/2020 6:56:11 AM

downstream

Photo 15-6-2020 11.52.39 am.jpg
-33.892875
150.967987
9/06/2020 6:55:51 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	12.5
Site Features Total	12.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	13.7
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	27.7

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Prospect Creek

type Regular | date 6 Jun 2020 | time 12:42:33 pm | assessor Ben Green

weather sunny | reach type tidal | flow incoming

78 % good

13.5
20
27.7
-6
3
-3

Prospect-36

stream order 5+

notes

The site is in good condition, with a raw score of 41.2 (78%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 30% bushland, 70% park, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 30% forest/woodland, 70% mown grass/park, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet .

upstream

Photo 15-6-2020 12.25.42 pm.jpg
-33.892580
150.968230
9/06/2020 6:57:38 AM

downstream

Photo 15-6-2020 12.26.10 pm.jpg
-33.892555
150.968230
9/06/2020 6:57:30 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	13.5
Site Features Total	13.5
channel shape	simple
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	not visible
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	present
mapped Key Fish Habitat	yes / Class 1 / Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	3
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	13.7
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	27.7

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Prospect Creek

type Regular date 7 Jun 2020 time 1:24:35 pm assessor Ben Green
weather sunny reach type ephemeral flow low

40 %

-7.4
-12
-34.6
-6
-8
-4

very poor

Prospect-unnamed trib-34

stream order 1

notes

The site is in very poor condition, with a raw score of -54 (40%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 10% bushland, 90% residential, approximately. Right bank land use is 10% bushland, 90% residential, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 10% under-scrubbed forest/woodland, 90% absent/concrete/earth, approximately. Right bank vegetation structure is 10% under-scrubbed forest/woodland, 90% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet .

upstream

Photo 15-6-2020 1.27.20 pm.jpg
-33.892162
150.959992
9/06/2020 7:07:02 AM

downstream

Photo 15-6-2020 1.28.06 pm.jpg
-33.892055
150.960037
9/06/2020 7:07:12 AM

extraction	absent
excavation	absent
litter	high 20-50
sewer	absent
stormwater	present
odour	normal/none
turbidity	medium
Land Use Subtotal	-7.4
Site Features Total	-7.4
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined no
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-8
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	20
riparian buffer width left	0-10m
riparian buffer width right	0-10m
Riparian Vegetation Subtotal	-12
Vegetation Structure Subtotal	-16.6
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	-34.6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Green Valley Creek

type Regular | date 9 Jun 2020 | time 7:43 am | assessor Ben Green

weather sunny | reach type ephemeral | flow low

37 % degraded

-7.4 | -12 | -34.6 | -6 | -18 | 0

Green-32

stream order 1

notes

The site is in very poor condition, with a raw score of -60 (37%) overall. The bed type is concrete invert - Cv. The bank type is concrete trapezoidal wall- Ctrap.

landuse

Within the 50 metre assessment radius, left bank land use is 10% bushland, 90% residential, approximately. Right bank land use is 10% bushland, 90% residential, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 10% under-scrubbed forest/woodland, 90% absent/concrete/earth, approximately. Right bank vegetation structure is 10% under-scrubbed forest/woodland, 90% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Trad.

upstream

Photo 15-6-2020 1.37.22 pm.jpg
-33.894597
150.900725
9/06/2020 7:33:08 AM

downstream

Photo 15-6-2020 1.37.50 pm.jpg
-33.894580
150.900742
9/06/2020 7:33:20 AM

extraction	absent
excavation	absent
litter	high 20-50
sewer	absent
stormwater	present
odour	normal/none
turbidity	medium
Land Use Subtotal	-7.4
Site Features Total	-7.4
channel shape	concrete/block-lined
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	low <30%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-18
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	20
riparian buffer width left	0-10m
riparian buffer width right	0-10m
Riparian Vegetation Subtotal	-12
Vegetation Structure Subtotal	-16.6
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	-34.6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Kemps Creek

type Regular | date 5 Jun 2020 | time 2:10:21 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow none

66 %

fair

6.6
12
6
-6
1
-1

Kemps-unnamed trib-12

stream order 1

notes

The site is in fair condition, with a raw score of 12.6 (66%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 60% pasture, 20% road, approximately. Right bank land use is 20% bushland, 60% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 20% under-scrubbed forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet .

upstream

Photo 15-6-2020 2.13.11 pm.jpg
-33.884955
150.795670
4/06/2020 11:07:44 AM

downstream

Photo 15-6-2020 2.13.36 pm.jpg
-33.884933
150.795700
4/06/2020 11:07:55 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	6.6
Site Features Total	6.6
channel shape	complex
pool riffle sequence	absent
meanders	unconfined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	1
benches	absent
islands	absent
channel bars	minor restriction
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	0
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Kemps Creek

type Regular | date 6 Feb 2019 | time 1:46:06 pm | assessor CTENVIRONMENTAL

weather sunny | reach type permanent | flow none

71 %	good
14.2	
16	
7.4	
-20	
2	
0	

Kemps-49

stream order 4

notes

The site is in fair condition, with a raw score of 23.6 (71%) overall. The bed type is natural bed clay - Nvc. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 40% commercial, 40% market gardens, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 80% weed/exotic, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 11-2-2019 2.02.40 pm.jpg
-33.880278
150.810278
6/02/2019 10:34:01 AM

downstream

Photo 11-2-2019 2.03.19 pm.jpg
-33.885555
150.800833
6/02/2019 10:34:05 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	14.2
Site Features Total	14.2
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	low 1-3
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	high >60%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 2; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	2
benches	present unconstricted
islands	absent
channel bars	no restriction
Deposition Total	2
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	absent
knick point	root-supported
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	20-40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	16
Vegetation Structure Subtotal	11.4
weed density left bank	severe over 70%
weed density right bank	severe over 70%
Weeds Subtotal	-20
Vegetation Total	7.4

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Cosgroves Creek

type Regular | date 4 Jun 2020 | time 9:50 am | assessor Ben Green
weather sunny | reach type ephemeral | flow low

67 %	fair
4.6	
20	
15.2	
-6	
0	
-5	

Cosgroves-4

stream order 4

notes

The site is in fair condition, with a raw score of 14.8 (67%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 60% pasture, 20% road, approximately. Right bank land use is 20% bushland, 60% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 20% forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Trad.

upstream

Photo 15-6-2020 2.52.38 pm.jpg
-33.868558
150.717728
4/06/2020 9:41:23 AM

downstream

Photo 15-6-2020 2.53.04 pm.jpg
-33.868553
150.717728
4/06/2020 9:41:29 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	4.6
Site Features Total	4.6
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 3 metres length
overhanging vegetation	high >60%
natural bed detritus	absent
natural gravel bed	not visible
natural rock in-stream	not visible
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 3; Type 2
KFH riparian buffer zone	50 metres
Aquatic Habitat Total	0
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	severe >30% bank
bank slumps	moderate 10-30%
knick point	absent
bank erosion	absent
Erosion Total	-5
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	1.2
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	15.2

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Badgerys Creek

type Regular | date 4 Jun 2020 | time 8:12 am | assessor Ben Green

weather sunny | reach type ephemeral | flow medium

75 %

13.1 | 20 | 25.9 | -6 | 0 | -4

good

Badgerys-7

stream order 4

notes

The site is in good condition, with a raw score of 35 (75%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 90% bushland, 10% pasture, approximately. Right bank land use is 20% bushland, 80% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 90% forest/woodland, 10% pasture grassland, approximately. Right bank vegetation structure is 80% pasture grassland, 20% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African boxthorn, Green cestrum.

upstream

Photo 15-6-2020 3.46.28 pm.jpg
-33.873142
150.755128
4/06/2020 10:17:44 AM

downstream

Photo 15-6-2020 3.47.02 pm.jpg
-33.873142
150.755142
4/06/2020 10:17:48 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	13.1
Site Features Total	13.1
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	yes; Class 2; Type 2
KFH riparian buffer zone	50 metres
Aquatic Habitat Total	0
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	moderate 10-30%
knick point	root-supported
bank erosion	absent
Erosion Total	-4
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	11.9
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	25.9

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Badgerys Creek

type Regular | date 6 Jun 2020 | time 12:45:46 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow low

75 % good

8.4	
20	
18.4	
-6	
9	
-3	

Badgerys-unnamed trib-8

stream order 3

notes

The site is in good condition, with a raw score of 32.8 (75%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 80% pasture, approximately. Right bank land use is 20% bushland, 80% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 80% pasture grassland, approximately. Right bank vegetation structure is 20% under-scrubbed forest/woodland, 80% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Green cestrum.

upstream

Photo 16-6-2020 12.48.34 pm.jpg
-33.873088
150.751617
4/06/2020 10:28:19 AM

downstream

Photo 16-6-2020 12.49.28 pm.jpg
-33.873088
150.751617
4/06/2020 10:28:23 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	8.4
Site Features Total	8.4
channel shape	simple
pool riffle sequence	present
meanders	unconfined yes
large woody debris	low 1-3
woody debris size	> 3 metres length
overhanging vegetation	high >60%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 3; Type 2
KFH riparian buffer zone	50 metres
Aquatic Habitat Total	9
benches	absent
islands	absent
channel bars	minor restriction
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	60
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	4.4
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	18.4

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Badgerys Creek

type Regular | date 4 Jun 2020 | time 11:55 am | assessor Ben Green
weather sunny | reach type ephemeral | flow low

73 %	good
8.4	
20	
18.4	
-6	
5	
-3	

Badgerys-unnamed trib-9

stream order 3

notes
The site is in good condition, with a raw score of 28.8 (73%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 20% bushland, 80% pasture, approximately. Right bank land use is 20% bushland, 80% pasture, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 80% pasture grassland, approximately. Right bank vegetation structure is 20% under-scrubbed forest/woodland, 80% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include Green cestrum.

upstream

Photo 16-6-2020 12.56.50 pm.jpg
-33.872842
150.751983
4/06/2020 10:32:03 AM

downstream

Photo 16-6-2020 12.57.19 pm.jpg
-33.872845
150.751970
4/06/2020 10:31:57 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	8.4
Site Features Total	8.4
channel shape	simple
pool riffle sequence	present
meanders	unconfined yes
large woody debris	absent
woody debris size	> 300 mm dia
overhanging vegetation	high >60%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	present
mapped Key Fish Habitat	yes; Class 3; Type 2
KFH riparian buffer zone	50 metres
Aquatic Habitat Total	5
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	60
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	4.4
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	18.4

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

South Creek

type Regular | date 6 Jun 2020 | time 1:05:38 pm | assessor Ben Green
weather sunny | reach type ephemeral | flow low

55 % poor

1 | 20 | 16 | -6 | -32 | 0

South-unnamed trib-11

stream order 1

notes

The site is in poor condition, with a raw score of -15 (55%) overall. The bed type is natural bed mud - Nvm. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 100% pasture, approximately. Right bank land use is 100% pasture, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% pasture grassland, approximately. Right bank vegetation structure is 100% pasture grassland, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include African boxthorn.

upstream

Photo 16-6-2020 1.06.50 pm.jpg
-33.875245
150.767058
4/06/2020 10:47:27 AM

downstream

Photo 16-6-2020 1.07.15 pm.jpg
-33.875247
150.767045
4/06/2020 10:47:33 AM

extraction	absent
excavation	present
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	1
Site Features Total	1
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 3; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-32
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	20
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	2
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	16

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

South Creek

type Regular date 4 Jun 2020 time 10:40 am assessor Ben Green

weather sunny reach type ephemeral flow low

57 %	poor
2.3	
20	
18	
-6	
-32	
0	

South-unnamed trib-10

stream order 2

notes

The site is in poor condition, with a raw score of -11.7 (57%) overall. The bed type is natural bed clay - Nvc. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 30% bushland, 70% pasture, approximately. Right bank land use is 40% bushland, 40% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 30% under-scrubbed forest/woodland, 70% pasture grassland, approximately. Right bank vegetation structure is 40% under-scrubbed forest/woodland, 40% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Green cestrum .

upstream

Photo 16-6-2020 1.39.06 pm.jpg
-33.875253
150.767988
4/06/2020 10:45:16 AM

downstream

Photo 16-6-2020 1.39.55 pm.jpg
-33.875247
150.767958
4/06/2020 10:45:05 AM

extraction	water
excavation	present
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	2.3
Site Features Total	2.3
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	confined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no / Class 3 / Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-32
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	40
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	4
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	18

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Mulgoa Creek

type Regular | date 4 Jun 2020 | time 2:18:53 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow none

63 % fair

11.1
12
1.8
-12
-3
-5

Mulgoa-unnamed trib-13

stream order 1

notes

The site is in poor condition, with a raw score of 4.9 (63%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 50% bushland, 30% pasture, 20% road, approximately. Right bank land use is 40% bushland, 40% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 30% under-scrubbed forest/woodland, 50% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 40% under-scrubbed forest/woodland, 40% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Narrow leaved privet , Trad.

upstream

downstream

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	11.1
Site Features Total	11.1
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	unconfined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-3
benches	minor restriction
islands	absent
channel bars	moderate restriction
Deposition Total	-3
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	1.8
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	1.8

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Mulgoa Creek

type Regular | date 4 Jun 2020 | time 2:31:21 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow none

57 % poor

1.2 | 12 | 3.6 | -6 | -14 | -2

Mulgoa-unnamed trib-14

stream order 1

notes

The site is in poor condition, with a raw score of -11.2 (57%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 80% pasture, 20% road, approximately. Right bank land use is 80% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry.

upstream

Photo 16-6-2020 2.32.44 pm.jpg
-33.872187
150.676895
4/06/2020 11:44:29 AM

downstream

Photo 16-6-2020 2.33.19 pm.jpg
-33.872167
150.676880
4/06/2020 11:44:25 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	1.2
Site Features Total	1.2
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	unconfined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-14
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-2.4
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	3.6

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Mulgoa Creek

type Regular | date 4 Jun 2020 | time 2:42:39 pm | assessor Ben Green

weather sunny | reach type ephemeral | flow none

49 %

-5.4 | 12 | 0 | -12 | -21 | -4

very poor

Mulgoa-unnamed trib-16

stream order 1

notes

The site is in poor condition, with a raw score of -30.4 (49%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 60% pasture, 20% road, approximately. Right bank land use is 20% bushland, 60% pasture, 20% road, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 20% under-scrubbed forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 20% under-scrubbed forest/woodland, 60% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

Weed species observed at the site include Blackberry.

upstream

Photo 16-6-2020 2.45.25 pm.jpg
-33.872047
150.673508
4/06/2020 11:49:43 AM

downstream

Photo 16-6-2020 2.45.57 pm.jpg
-33.872047
150.673508
4/06/2020 11:49:33 AM

extraction	water
excavation	present
litter	med 6-20
sewer	absent
stormwater	absent
odour	sewage
turbidity	high
Land Use Subtotal	-5.4
Site Features Total	-5.4
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	confined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	mod <30>60%
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-21
benches	absent
islands	absent
channel bars	moderate restriction
Deposition Total	-2
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	0
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	0

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Mulgoa Creek

type Regular | date 4 Jun 2020 | time 2:53:19 pm | assessor Ben Green
weather sunny | reach type ephemeral | flow low

45 % very poor
-2.8 | 12 | -2.4 | -12 | -29 | -6

Mulgoa-unnamed trib-15

stream order 1

notes
The site is in very poor condition, with a raw score of -40.2 (45%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse
Within the 50 metre assessment radius, left bank land use is 80% pasture, 20% road, approximately. Right bank land use is 80% pasture, 20% road, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include Blackberry.

upstream

Photo 16-6-2020 2.55.08 pm.jpg
-33.872280
150.675125
4/06/2020 11:51:18 AM

downstream

Photo 16-6-2020 2.55.41 pm.jpg
-33.871803
150.673662
4/06/2020 11:51:44 AM

extraction	water
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	-2.8
Site Features Total	-2.8
channel shape	dam/divert/pipe
pool riffle sequence	absent
meanders	unconfined no
large woody debris	absent
woody debris size	absent
overhanging vegetation	absent
natural bed detritus	absent
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-29
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	gully/rill
Erosion Total	-6
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-2.4
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-2.4

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Jerrys Creek

type Regular | date 4 Jun 2020 | time 1:04 pm | assessor Ben Green
weather sunny | reach type ephemeral | flow none

56 %	poor
1.2	
12	
-2.4	
-12	
-7	
-5	

Jerrys-unnamed trib-17

stream order 1

notes
The site is in poor condition, with a raw score of -13.2 (56%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural earth - Ne.

landuse
Within the 50 metre assessment radius, left bank land use is 80% pasture, 20% road, approximately. Right bank land use is 80% pasture, 20% road, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. Right bank vegetation structure is 80% pasture grassland, 20% absent/concrete/earth, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 16-6-2020 3.04.27 pm.jpg
-33.870963
150.665725
4/06/2020 12:05:26 PM

downstream

Photo 16-6-2020 3.06.13 pm.jpg
-33.870945
150.665725
4/06/2020 12:05:23 PM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	no flow
Land Use Subtotal	1.2
Site Features Total	1.2
channel shape	straighened/deepened
pool riffle sequence	absent
meanders	confined yes
large woody debris	absent
woody debris size	absent
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	absent
natural rock in-stream	absent
native macrophyte	absent
mapped Key Fish Habitat	no; Class 4; Type 3
KFH riparian buffer zone	10-50 metres
Aquatic Habitat Total	-7
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	absent
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	gully/rill
Erosion Total	-5
riparian corridor WMAct	20
riparian buffer width left	20-40m
riparian buffer width right	20-40m
Riparian Vegetation Subtotal	12
Vegetation Structure Subtotal	-2.4
weed density left bank	moderate 40-70%
weed density right bank	moderate 40-70%
Weeds Subtotal	-12
Vegetation Total	-2.4

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Nepean River

type Regular | date 24 Jun 2020 | time 3:00:42 pm | assessor Ben Green
weather sunny | reach type permanent | flow medium

76 % good

18.9 | 20 | 32.1 | -6 | -14 | -1

Nepean-50

stream order 5+

notes
The site is in good condition, with a raw score of 36 (76%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 90% bushland, 10% pasture, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 80% forest/woodland, 10% weed/exotic, 10% pasture grassland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds
Weed species observed at the site include Lantana , Mother of millions , Narrow leaved privet , Tobacco .

upstream

Photo 25-6-2020 6.24.16 am.jpg
-33.861053
150.631487
24/06/2020 2:59:45 PM

downstream

Photo 25-6-2020 6.24.45 am.jpg
-33.862153
150.629197
24/06/2020 2:14:35 PM

extraction	water
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	18.9
Site Features Total	18.9
channel shape	dam/divert/pipe
pool riffle sequence	present
meanders	confined yes
large woody debris	high >10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	-14
benches	present unconstricted
islands	absent
channel bars	absent
Deposition Total	1
bedrock/clay exposure	natural
undercutting	minor <10% bank
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-2
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	18.1
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	32.1

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Warragamba River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

87 % very good
24 | 20 | 34 | -6 | 8 | -1

Warragamba-1

notes
The site is in excellent condition, with a raw score of 65 (87%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

stream order 5+

landuse
Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.08.29 pm.jpg
-33.859330
150.611113
23/07/2020 8:19:37 AM

downstream

Photo 18-5-2021 1.09.03 pm.jpg
-33.859355
150.611083
23/07/2020 8:19:30 AM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	24
Site Features Total	24
channel shape	complex
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	8
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	34

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Warragamba River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

93 %

27 | 20 | 46 | 6 | 8 | -2

excellent

Warragamba-2

stream order 5+

notes

The site is in excellent condition, with a raw score of 79 (93%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.10.27 pm.jpg
-33.862070
150.613280
23/07/2020 8:38:19 AM

downstream

Photo 18-5-2021 1.11.08 pm.jpg
-33.862063
150.613433
23/07/2020 8:38:08 AM

extraction	absent
excavation	absent
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	27
Site Features Total	27
channel shape	complex
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	8
benches	moderate restriction
islands	absent
channel bars	absent
Deposition Total	-2
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	absent
Weeds Subtotal	6
Vegetation Total	46

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Warragamba River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

94 %

27
20
46
6
10
-2

excellent

Warragamba-3

notes

The site is in excellent condition, with a raw score of 81 (94%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.12.50 pm.jpg
-33.867037
150.613587
23/07/2020 9:02:57 AM

downstream

Photo 18-5-2021 1.13.21 pm.jpg
-33.867042
150.613708
23/07/2020 9:02:45 AM

extraction	absent
excavation	absent
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	27
Site Features Total	27
channel shape	complex
pool riffle sequence	present
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	10
benches	moderate restriction
islands	absent
channel bars	absent
Deposition Total	-2
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	absent
Weeds Subtotal	6
Vegetation Total	46

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Warragamba River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

91 %	excellent
Site Features	27
Riparian Vegetation	20
Vegetation	46
Weeds	6
Aquatic Habitat	4
Deposition	-2

Warragamba-4

notes

The site is in excellent condition, with a raw score of 75 (91%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

stream order: 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.14.20 pm.jpg
-33.870147
150.612305
23/07/2020 9:35:03 AM

downstream

Photo 18-5-2021 1.15.10 pm.jpg
-33.870153
150.612625
23/07/2020 9:34:59 AM

extraction	absent
excavation	absent
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	27
Site Features Total	27
channel shape	complex
pool riffle sequence	present
meanders	confined no
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	moderate restriction
islands	absent
channel bars	absent
Deposition Total	-2
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	absent
Weeds Subtotal	6
Vegetation Total	46

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Warragamba River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green

weather sunny | reach type permanent | flow low

94 %

27
20
46
6
10
-2

excellent

Warragamba-5

stream order 5+

notes

The site is in excellent condition, with a raw score of 81 (94%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.20.48 pm.jpg
-33.872047
150.612137
23/07/2020 9:50:09 AM

downstream

Photo 18-5-2021 1.21.28 pm.jpg
-33.872033
150.612062
23/07/2020 9:50:13 AM

extraction	absent
excavation	absent
litter	absent
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	27
Site Features Total	27
channel shape	complex
pool riffle sequence	present
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	10
benches	moderate restriction
islands	absent
channel bars	absent
Deposition Total	-2
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	absent
Weeds Subtotal	6
Vegetation Total	46

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Warragamba River
type Regular date 23 Jul 2020 time 9:37:10 am assessor Ben Green
weather sunny reach type permanent flow low

86 % very good
18 | 20 | 34 | -6 | 10 | -1

Warragamba-6

stream order 5+

notes
The site is in excellent condition, with a raw score of 61 (86%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.22.30 pm.jpg
-33.873645
150.610520
23/07/2020 10:09:31 AM

downstream

Photo 18-5-2021 1.22.50 pm.jpg
-33.874175
150.609725
23/07/2020 10:19:37 AM

extraction	absent
excavation	absent
litter	absent
sewer	present
stormwater	absent
odour	sewage
turbidity	high
Land Use Subtotal	18
Site Features Total	18
channel shape	complex
pool riffle sequence	present
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	10
benches	moderate restriction
islands	present
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	sparse less than 5%
weed density right bank	moderate 40-70%
Weeds Subtotal	-6
Vegetation Total	34

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Warragamba River

type Regular date 23 Jul 2020 time 9:37:10 am assessor Ben Green
weather sunny reach type permanent flow low

88 % very good

18
20
40
0
10
-1

Warragamba-7

notes

The site is in excellent condition, with a raw score of 67 (88%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.23.51 pm.jpg
-33.875512
150.608672
23/07/2020 10:38:10 AM

downstream

Photo 18-5-2021 1.24.21 pm.jpg
-33.875142
150.607637
23/07/2020 10:38:07 AM

extraction	absent
excavation	absent
litter	absent
sewer	present
stormwater	absent
odour	sewage
turbidity	high
Land Use Subtotal	18
Site Features Total	18
channel shape	complex
pool riffle sequence	present
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	present
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	10
benches	moderate restriction
islands	present
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	light up to 40%
Weeds Subtotal	0
Vegetation Total	40

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water
Warragamba River

type Regular date 23 Jul 2020 time 9:37:10 am assessor Ben Green
weather sunny reach type permanent flow low

89 %	
18	very good
20	
40	
0	
11	
-1	

Warragamba-8

stream order 5+

notes
The site is in excellent condition, with a raw score of 68 (89%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 1.25.20 pm.jpg
-33.878855
150.602692
23/07/2020 11:34:27 AM

downstream

Photo 18-5-2021 1.25.44 pm.jpg
-33.878803
150.602508
23/07/2020 11:33:37 AM

extraction	absent
excavation	absent
litter	absent
sewer	present
stormwater	absent
odour	sewage
turbidity	high
Land Use Subtotal	18
Site Features Total	18
channel shape	complex
pool riffle sequence	present
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	mod <30>60%
natural bed detritus	present
natural gravel bed	present
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes / Class 1 / Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	11
benches	moderate restriction
islands	present
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	absent
weed density right bank	light up to 40%
Weeds Subtotal	0
Vegetation Total	40

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Nepean River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

90 %

24 | 20 | 40 | 0 | 8 | -1

excellent

Nepean-1

notes

The site is in excellent condition, with a raw score of 71 (90%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 12.50.25 pm.jpg
-33.858150
150.613237
23/07/2020 2:12:10 PM

downstream

Photo 18-5-2021 12.50.59 pm.jpg
-33.858150
150.613237
23/07/2020 2:12:07 PM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	24
Site Features Total	24
channel shape	complex
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	8
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	light up to 40%
weed density right bank	absent
Weeds Subtotal	0
Vegetation Total	40

RAPID RIPARIAN SITE ASSESSMENT
Sydney Water

Nepean River

type Regular | date 23 Jul 2020 | time 9:37:10 am | assessor Ben Green
weather sunny | reach type permanent | flow low

90 %

24
20
40
0
8
-1

excellent

Nepean-2

stream order 5+

notes
The site is in excellent condition, with a raw score of 71 (90%) overall. The bed type is natural bedrock. The bank type is natural vegetation - Nveg.

landuse
Within the 50 metre assessment radius, left bank land use is 100% bushland, approximately. Right bank land use is 100% bushland, approximately. This is included in the site features score.

vegetation
Within the 50 metre assessment radius, left bank vegetation structure is 100% forest/woodland, approximately. Right bank vegetation structure is 100% forest/woodland, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 18-5-2021 12.46.53 pm.jpg
-33.858330
150.617370
23/07/2020 2:23:40 PM

downstream

Photo 18-5-2021 12.47.14 pm.jpg
-33.858505
150.617478
23/07/2020 2:23:46 PM

extraction	absent
excavation	absent
litter	low 1-5
sewer	absent
stormwater	absent
odour	normal/none
turbidity	medium
Land Use Subtotal	24
Site Features Total	24
channel shape	complex
pool riffle sequence	absent
meanders	confined yes
large woody debris	moderate 4-10
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	8
benches	minor restriction
islands	absent
channel bars	absent
Deposition Total	-1
bedrock/clay exposure	natural
undercutting	absent
bank slumps	absent
knick point	absent
bank erosion	absent
Erosion Total	0
riparian corridor WMAct	80
riparian buffer width left	over 40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	20
Vegetation Structure Subtotal	20
weed density left bank	light up to 40%
weed density right bank	absent
Weeds Subtotal	0
Vegetation Total	40

RAPID RIPARIAN SITE ASSESSMENT

Sydney Water

Nepean River

type Regular | date 24 Aug 2021 | time 9:54:22 am | assessor Ben Green

weather sunny | reach type permanent | flow medium

69 %

fair

4.2
16
14.2
-6
4
-3

Nepean

notes

The site is in fair condition, with a raw score of 19.4 (69%) overall. The bed type is natural bed (invert) - Nv. The bank type is natural vegetation - Nveg.

stream order 5+

landuse

Within the 50 metre assessment radius, left bank land use is 20% bushland, 80% pasture, approximately. Right bank land use is 20% bushland, 80% park, approximately. This is included in the site features score.

vegetation

Within the 50 metre assessment radius, left bank vegetation structure is 10% forest/woodland, 10% derived exotic shrubland, 80% mown grass/park, approximately. Right bank vegetation structure is 10% forest/woodland, 10% derived exotic shrubland, 80% mown grass/park, approximately. This is reflected in the vegetation structure subtotal.

weeds

upstream

Photo 24-8-2021 9.58.56 am.jpg
-33.760703
150.665405
15/05/2019 2:27:25 PM

downstream

Photo 24-8-2021 9.59.54 am.jpg
-33.754692
150.673417
17/10/2019 11:43:20 AM

extraction	absent
excavation	absent
litter	med 6-20
sewer	absent
stormwater	absent
odour	normal/none
turbidity	low
Land Use Subtotal	4.2
Site Features Total	4.2
channel shape	complex
pool riffle sequence	absent
meanders	unconfined no
large woody debris	low 1-3
woody debris size	> 300 mm dia and 3 m length
overhanging vegetation	low <30%
natural bed detritus	present
natural gravel bed	not visible
natural rock in-stream	natural > 500 mm
native macrophyte	present
mapped Key Fish Habitat	yes; Class 1; Type 1
KFH riparian buffer zone	100 metres
Aquatic Habitat Total	4
benches	absent
islands	absent
channel bars	absent
Deposition Total	0
bedrock/clay exposure	natural
undercutting	moderate 10-30%
bank slumps	minor <10% bank
knick point	absent
bank erosion	absent
Erosion Total	-3
riparian corridor WMAct	80
riparian buffer width left	20-40m
riparian buffer width right	over 40m
Riparian Vegetation Subtotal	16
Vegetation Structure Subtotal	4.2
weed density left bank	light up to 40%
weed density right bank	light up to 40%
Weeds Subtotal	-6
Vegetation Total	14.2

11 Appendix B: Controlled Activities on Waterfront Land – Guidelines for riparian corridors on waterfront land (NSW Office of Water, 2012

Department of Primary Industries
Office of Water

CONTROLLED ACTIVITIES ON WATERFRONT LAND

Guidelines for riparian corridors on waterfront land

Controlled activities carried out in, on or under waterfront land are regulated by the *Water Management Act 2000* (WM Act). The NSW Office of Water administers the WM Act and is required to assess the impact of any proposed controlled activity to ensure that no more than minimal harm will be done to waterfront land as a consequence of carrying out the controlled activity.

Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary.

This means that a controlled activity approval must be obtained from the Office of Water before commencing the controlled activity.

What is a riparian corridor?

A riparian corridor (RC) forms a transition zone between the land, also known as the terrestrial environment, and the river or watercourse or aquatic environment. Riparian corridors perform a range of important environmental functions such as:

- providing bed and bank stability and reducing bank and channel erosion
- protecting water quality by trapping sediment, nutrients and other contaminants
- providing diversity of habitat for terrestrial, riparian and aquatic plants (flora) and animals (fauna)
- providing connectivity between wildlife habitats
- conveying flood flows and controlling the direction of flood flows
- providing an interface or buffer between developments and waterways
- providing passive recreational uses.

The protection, restoration or rehabilitation of vegetated riparian corridors is important for maintaining or improving the shape, stability (or geomorphic form) and ecological functions of a watercourse.

Changes to controlled activities within riparian corridors

On 1 July 2012 new rules commenced regarding controlled activities within riparian corridors. The new rules amend the riparian corridor widths that apply to watercourses, providing more flexibility in how riparian corridors can be used and making it easier for applicants to determine the Office of Water controlled activity approval requirements. Key aspects of the changes include:

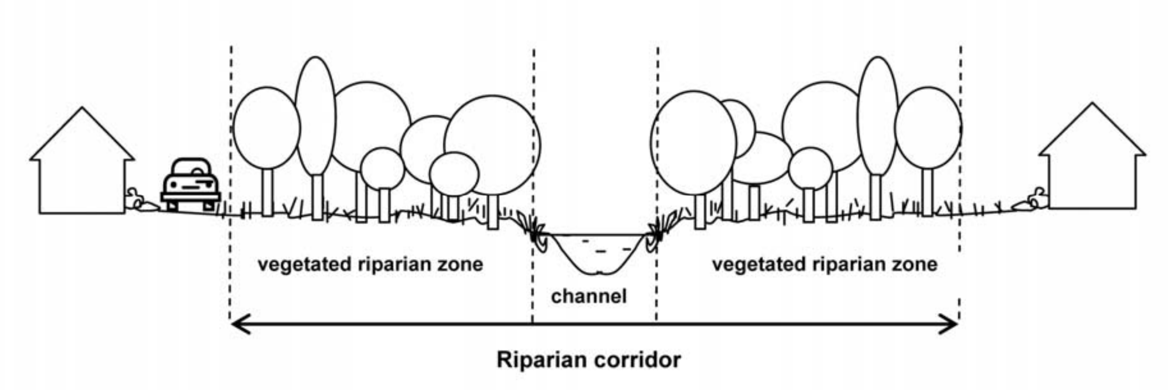
- Provision of greater flexibility in the allowable uses and works permitted within riparian corridors.
- The core riparian zone and vegetated buffer have been combined into a single vegetated riparian zone (VRZ).
- The width of the VRZ within the riparian corridor has been pre-determined and standardised for first, second, third and fourth order and greater watercourses.
- Where suitable, applicants may undertake non-riparian corridor works or development within the outer 50 per cent of a VRZ, as long as they offset this activity by connecting an equivalent area to the RC within the development site.
- A new ‘riparian corridors matrix’ enables applicants to determine what activities can be considered in riparian corridors.

These changes will simplify the controlled activities application and assessment process, provide greater flexibility, help make more land available for housing, support floodplain, stormwater and bush fire management, and allow riparian corridors to be used for public amenity whilst continuing to deliver environmental outcomes required under the WM Act.

The riparian corridor consists of:

- the channel which comprises the bed and banks of the watercourse (to the highest bank) and
- the vegetated riparian zone (VRZ) adjoining the channel.

Figure 1. The riparian corridor



Riparian corridor widths

The Officer of Water recommends a VRZ width based on watercourse order as classified under the Strahler System of ordering watercourses and using current 1:25 000 topographic maps (see Figure 2 and Table 1). The width of the VRZ should be measured from the top of the highest bank on both sides of the watercourse.

Figure 2. The Strahler System

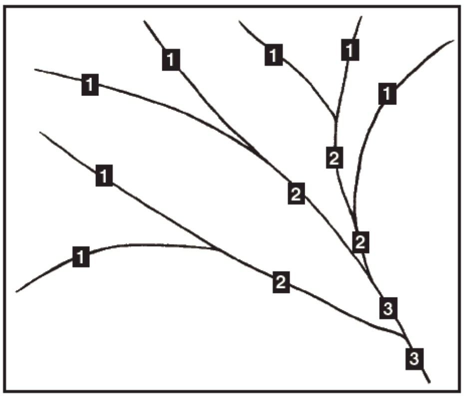


Table 1. Recommended riparian corridor (RC) widths

Watercourse type	**VRZ width** (each side of watercourse)	**Total RC width**
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

Note: where a watercourse does not exhibit the features of a defined channel with bed and banks, the Office of Water may determine that the watercourse is not waterfront land for the purposes of the WM Act

Objectives for riparian corridor management

The overarching objective of the controlled activities provisions of the WM Act is to establish and preserve the integrity of riparian corridors.

Ideally the environmental functions of riparian corridors should be maintained or rehabilitated by applying the following principles:

- Identify whether or not there is a watercourse present and determine its order in accordance with the Strahler System.
- If a watercourse is present, define the RC/VRZ on a map in accordance with Table 1.
- Seek to maintain or rehabilitate a RC/VRZ with fully structured native vegetation in accordance with Table 1.
- Seek to minimise disturbance and harm to the recommended RC/VRZ.
- Minimise the number of creek crossings and provide perimeter road separating development from the RC/VRZ.
- Locate services and infrastructure outside of the RC/VRZ. Within the RC/VRZ provide multiple service easements and/or utilise road crossings where possible.
- Treat stormwater run-off before discharging into the RC/VRZ.

The Office of Water however, does allow for a range of works and activities on waterfront land and in riparian corridors to better meet the needs of the community, so long as they cause minimal harm as outlined in the riparian corridor matrix below.

Riparian corridor matrix

The riparian corridor matrix enables applicants to identify certain works and activities that can occur on waterfront land and in riparian corridors. Applicants should note that the matrix relates to controlled activity approvals under the WM Act only. They are still required to comply with other relevant government legislation, such as threatened species, flood planning levels and fisheries guidelines.

Table 2. Riparian corridor matrix

Stream order	**Vegetated Riparian Zone (VRZ)**	**RC off-setting for non RC uses**	**Cycleways and paths**	**Detention basins**		**Stormwater outlet structures and essential services**	**Stream realignment**	**Road crossings**		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1^{st}	10m	•	•	•	•	•	•	•		
2^{nd}	20m	•	•	•	•	•		•		
3^{rd}	30m	•	•	•		•			•	•
4^{th} +	40m	•	•	•		•			•	•

Key

Stream order: The watercourse order as classified under the Strahler System based on 1:25,000, 1:50,000 or 1:100,000 topographic maps whichever is the smallest scale available. A full list is provided at Part 2, Schedule 2 of the Water Management (General) Regulation 2011.

Vegetated riparian zone (VRZ): The required width of the VRZ measured from the top of the high bank on each side of the watercourse.

Riparian corridor (RC) off-setting for non RC uses: Non-riparian uses, such as Asset Protection Zones are allowed within the outer 50 per cent of the VRZ, so long as offsets are provided in accordance with the averaging rule as seen in Figure 3.

Cycleways and paths: Cycleways or paths no wider than four metres total disturbance footprint can be built in the outer 50 per cent of the VRZ.

Detention basins: Detention basins can be built in the outer 50 per cent of the VRZ or online where indicated. Refer to the Office of Water's *Controlled activities. Guidelines for outlet structures* and *Controlled activities. Guidelines for instream works*. Online basins must:

- be dry and vegetated
- be for temporary flood detention only with no permanent water holding
- have an equivalent VRZ for the corresponding watercourse order
- not be used for water quality treatment purposes.

Stormwater outlet structures and essential services: Stormwater outlets or essential services are allowed in the RC. Works for essential services on a fourth order or greater stream are to be undertaken by directional drilling or tied to existing crossings. Refer to the Office of Water's *Controlled activities. Guidelines for laying pipes and cables in watercourses* and *Controlled activities. Guidelines for outlet structures.*

Stream realignment: Indicates that a watercourse may be realigned. Refer to the Office of Water's *Controlled activities. Guidelines for instream works.*

Road crossings: Indicates permitted road crossing methods. Refer to the Office of Water's *Controlled activities. Guidelines for watercourse crossings* and NSW DPI policy and guidelines for fish friendly waterway crossings for Class 1 and 2 waterways.

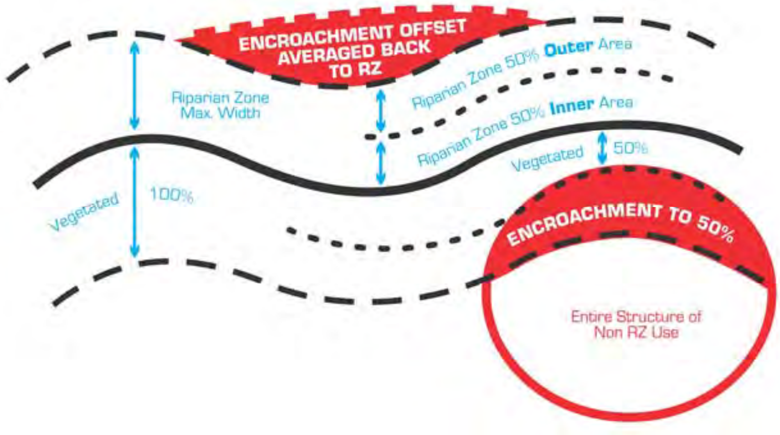
What is the averaging rule?

Non riparian corridor works and activities can be authorised within the outer riparian corridor, so long as the average width of the vegetated riparian zone can be achieved over the length of the watercourse within the development site. That is, where appropriate 50 per cent of the outer vegetated riparian zone width may be used for non-riparian uses including asset protection zones, recreational areas, roads, development lots and infrastructure. However, an equivalent area connected to the riparian corridor must be offset on the site (see Figure 3) and the inner 50 per cent of the vegetated riparian zone must be fully protected and vegetated with native endemic riparian plant species.

Bridges, cycleways, paths, stormwater oulets and other essential services do not need to be offset, but must comply with the requirements set out in the riparian corridor matrix (Table 2) and other relevant Office of Water controlled activities guidelines. Offline detention basins do not need to be offset so long as there is an equivalent VRZ for the corresponding watercourse and they are built in compliance with the Office of Water's *Controlled activities: Guidelines for watercourse crossings* and *Controlled activities: Guidelines for in-stream works*. If a proposed basin will not have an equivalent VRZ for the corresponding watercourse, it may still be built in the outer 50 per cent of the VRZ but must be offset.

The averaging rule should generally be applied to cleared waterfront land. Development proposals involving waterfront lands that contain existing native vegetation should seek to preserve that riparian vegetation in accordance with the minimum riparian corridor requirements outlined in Table 1.

Figure 3. Averaging rule



Applications for controlled activity approvals

Applications for controlled activities approvals should be informed by the riparian corridor matrix shown in Table 2 and prepared using the *Application for a Controlled Activity Approval for works on waterfront land* form and the *Guideline for completing an application for a Controlled Activity Approval*.

Other controlled activity guidelines are available on the Office of Water website and outline relevant considerations for applicants when proposing activities and works on waterfront lands.

Streamlined assessment

Where applications are presented in accordance with the riparian corridor matrix (Table 2) and other Office of Water controlled activity guidelines, they will be assessed under a streamlined process. This may decrease the amount of time it takes the Office of Water to make a determination, saving applicants time and money.

Applications that do not conform to the matrix and/or relevant Office of Water controlled activity guidelines will continue to be subject to merit assessment to ensure that the proposals meet the requirements of the WM Act. All applications will still need to demonstrate that minimal harm will occur to waterfront land before a controlled activity approval will be issued.

Where do I go for additional information?

Find out more about controlled activities at the Office of Water website www.water.nsw.gov.au.

Contact us

Contact a water regulatory officer as listed on the Office of Water website www.water.nsw.gov.au, free call the licensing information on 1800 353 104 or email information@water.nsw.gov.au.

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12 Appendix C: Controlled Activities on Waterfront Land – Guidelines for vegetation management plans on waterfront land (NSW Office of Water, 2012)

CONTROLLED ACTIVITIES ON WATERFRONT LAND

Guidelines for vegetation management plans on waterfront land

Controlled activities carried out in, on or under waterfront land are regulated by the *Water Management Act 2000* (WM Act). The NSW Office of Water administers the WM Act and is required to assess the impact of any proposed controlled activity to ensure that no more than minimal harm will be done to waterfront land.

Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary.

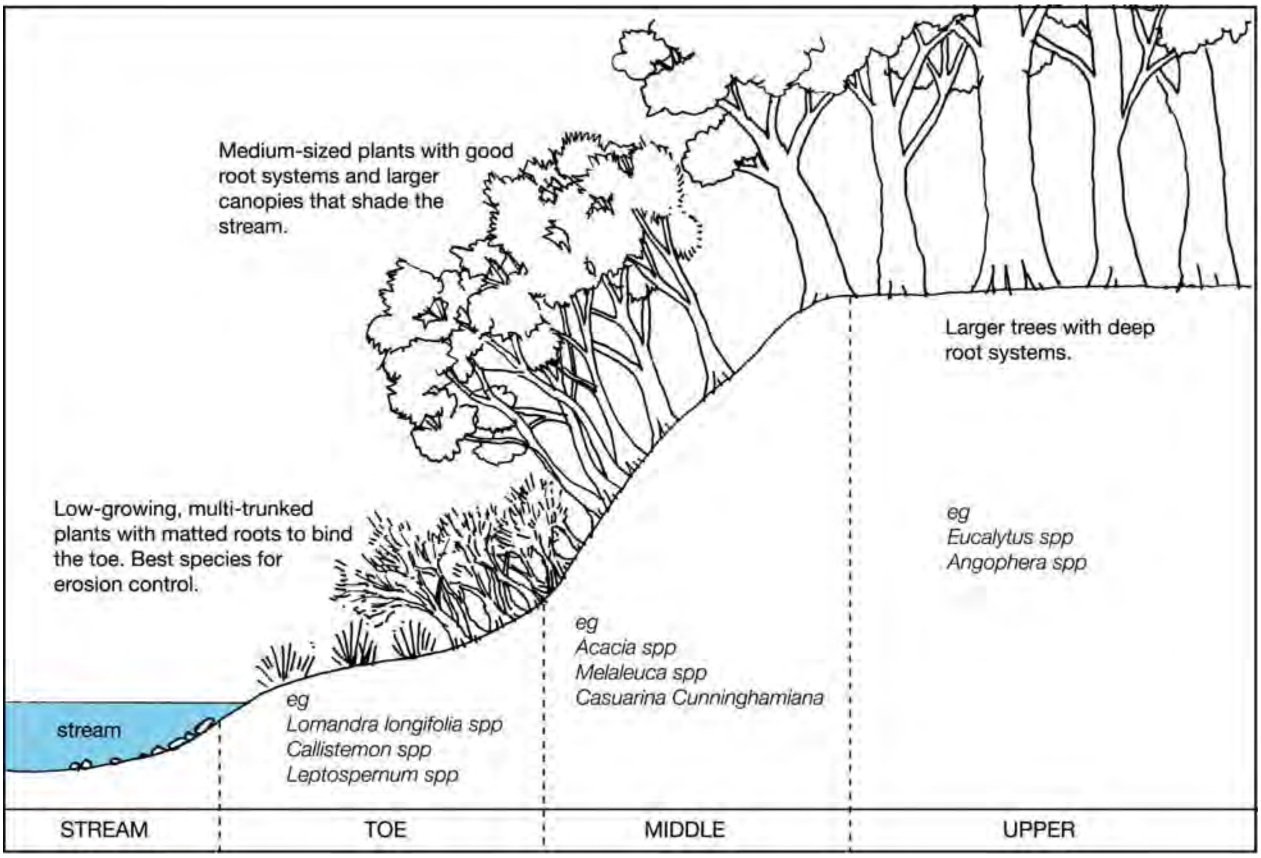
This means that a controlled activity approval must be obtained from the NSW Office of Water before commencing the controlled activity.

Why is a vegetation plan required?

When a proposed controlled activity disturbs or substantially modifies the riparian corridor, its restoration or rehabilitation will be a requirement of the controlled activity approval. A vegetation management plan (VMP) details how the restoration or rehabilitation will be carried out.

The main objective of a VMP is to provide a stable watercourse and riparian corridor which will emulate local native vegetation communities.

Figure 1. Typical riparian cross section - Adapted from Rivercare: Guidelines for Ecological Sustainable Management of Rivers and Riparian Vegetation: Raine, A.W & Gardiner, J.N, (1995), Land and Water Resources Research and Development Corporation, Canberra.



How should a vegetation management plan be prepared?

A VMP should be prepared by a suitably qualified person and should clearly address the following criteria.

- An appropriate width for the riparian corridor should be identified by consulting either the development consent, the relevant environmental planning instrument or the NSW Office of Water guidelines for riparian corridors. The VMP should consider the full width of the riparian corridor and its functions including accommodating fully structured native vegetation.
- Maps or diagrams which clearly identify the riparian corridor; the existing vegetation; the vegetation to be retained; the vegetation to be cleared; the footprint of construction activities; and areas of proposed revegetation etc. should be prepared.
- The location of the bed and banks or foreshore of waterfront land and the footprint of the riparian corridor should be clearly identified. Vegetated riparian zones must be indicated.
- Photographs of the site should be supplied and photo points should be identified. To assist with future monitoring and reporting requirements, the photo points should be identified by GPS coordinates or by survey. This is particularly important for large scale earthworks or extractive industries.
- Measures for controlling long term access and encroachments (bollards, fences, etc.) into the riparian corridor should be identified.
- Vegetation species composition, planting layout and densities should be identified. The required mix of plant species relates to the actual community to be emulated and the size of the area or areas to be rehabilitated but mature vegetation communities are generally well structured, comprising trees, shrubs and groundcovers species. Planting densities should achieve quick vegetative cover and root mass to maximise bed and bank stability along the subject watercourse.
- Costs associated with high density planting will be recovered through reduced maintenance costs for weeding or replacement planting in the maintenance period specified in the controlled activity approval (CAA).
- Seed or plant sources should be identified. Where possible, native plants and seed sources of local provenance should be used.
- Exotic vegetation should be avoided. The use of exotic species for temporary soil stabilisation is permitted provided they are sterile, non-invasive and easily eradicated when permanent vegetation is established.
- Details of the planting program, rehabilitation methods and staging should be provided. Techniques such as hydro-seeding, direct seeding, brush matting or assisted natural regeneration may be considered.
- Maintenance requirements should extend for a minimum of two years after the completion of works or until such time as a minimum 80 per cent survival rate of each species planted and a maximum 5 per cent weed cover for the treated riparian corridor controlled activity is achieved.
- Project tasks should be defined and described, including a schedule detailing the sequence and duration of works necessary for the implementation of the VMP.
- Costings for the implementation of all components and stages of the work including materials, labour, watering, maintenance which includes plant replacement, monitoring and reporting should be prepared.
- Processes for monitoring and review, including a method of performance evaluation should be identified. This should include replacing plant losses, addressing deficiencies, problems, climatic conditions and successful completion of works.
- Regular reporting on the implementation and status of works covering progress, success or failures and completion should be provided. The number and duration of reporting periods will be identified in the CAA. Works as executed plans and reports detailing how the components of the VMP have been implemented will be required prior to the release of any security held by the NSW Office of Water.
- Security such as bank guarantees may be required before a controlled activity involving the implementation of a VMP is commenced. The amount of security is usually based on the costings provided.

Where do I go for additional information?

Find out more about controlled activities at the Office of Water website www.water.nsw.gov.au.

Contact us

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13 Appendix D: Controlled Activities on Waterfront Land – Guidelines for outlet structures on waterfront land (NSW Office of Water, 2012)

Department of Primary Industries
Office of Water

CONTROLLED ACTIVITIES ON WATERFRONT LAND

Guidelines for outlet structures on waterfront land

These guidelines relate to the design of stormwater outlets and spillways from infrastructure including roads, buildings, constructed basins/wetlands, swales or other drainage works into a watercourse or waterfront land.

Outlet structures on waterfront land are a controlled activity under the *Water Management Act 2000* (WM Act).The NSW Office of Water administers the WM Act and is required to assess the impact of any proposed controlled activity to ensure that no more than minimal harm will be done to waterfront land as a consequence of carrying out the controlled activity.

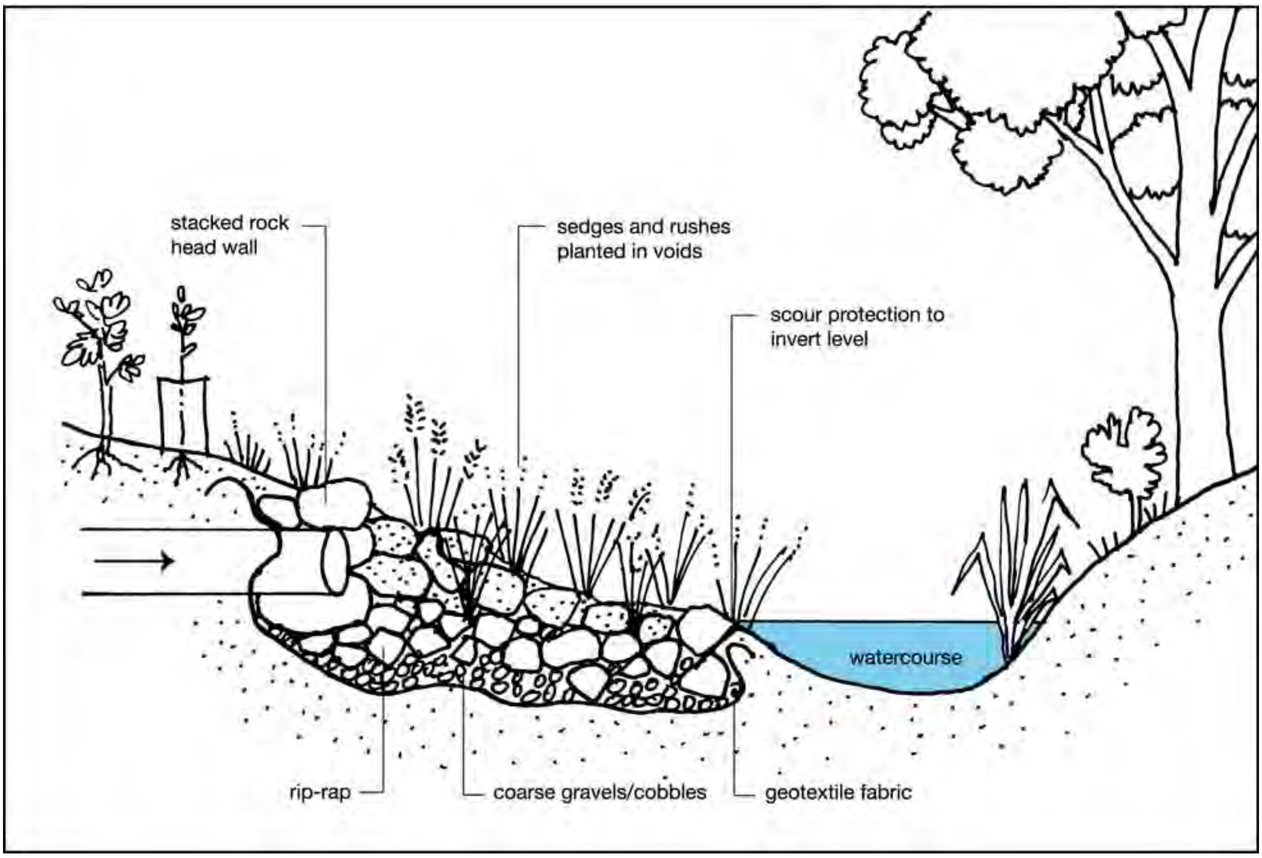
Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary.

This means a controlled activity approval must be obtained from the NSW Office of Water before commencing the controlled activity.

What are the aims and objectives for outlet structures?

The design and construction of stormwater outlets should aim to be natural, yet provide a stable transition from a constructed drainage system to a natural flow regime as seen in Figure 1.

Figure 1. Natural outlet structure.



The design and construction footprint and extent of disturbance within the riparian corridor should be minimised even allowing for the intended discharge function to be achieved. Refer to the NSW Office of Water guidelines for riparian corridors.

All ancillary drainage infrastructure, such as oil or grease interceptors, sediment and litter traps, constructed wetland, detention basins or any works requiring on-going access or maintenance should be located outside the riparian corridor or in accordance with the NSW Office of Water guidelines for riparian corridors.

Water run-off from the site should be of appropriate quality and quantity before being discharged into a riparian corridor or watercourse.

Appropriate rehabilitation of disturbed areas following the installation of outlet structures should adequately restore the integrity of the riparian corridor.

What should be considered in the design and construction of outlet structures?

The design and construction of outlet structures should consider, but not be limited to, the following:

- Define the infrastructure route and identify the specific point of discharge. Where possible select a route along an existing cleared or disturbed area that avoids trees, preferably beyond their drip line.
- Choose a stable section of the stream for the discharge point, preferably mid-way between bends. Alternatively, incorporate outlet discharge points into disturbed/eroded areas which are to be stabilised or rehabilitated.
- Minimise construction footprint and proposed extent of disturbance to soil and vegetation within the watercourse or waterfront land.
- Demonstrate that changes to the hydrology of the receiving watercourse have been assessed and there is no detrimental impact on discharge volumes and channel velocities. Discharge velocities and flow rates should mimic natural flows and not initiate erosion.
- Discharge from an outlet should not cause bed or bank instability.
- Protect the bed of the watercourse below the outlet if not bedrock, or if bed scour is likely. Consider bank material and outlet jet effect and protect the opposite streambank if required.
- Point outlet structure and direct discharge downstream.
- The outlet should not protrude beyond the streambank but tie in with the adjoining bank alignment.
- Calculate tractive stresses generated from outlet discharges and from bank full discharges to determine appropriate rock size requirements for the structure.
- Rock rip-rap is the preferred material to provide a natural outlet. Rip-rap should extend for the full extent of the design scour apron and adjoining flanks/streambank. Rip-rap must be appropriately keyed in to withstand the velocities of runoff or discharge from the site and cut-off trenches should be provided where necessary.
- Rip-rap should consist of durable, angular run-of-quarry rock placed over a bedding layer of angular cobbles over geotextile. Where possible, incorporate vegetation such as sedges and rushes into scour management as Figure 1 for further stability.
- Grade scour apron to bed level of the watercourse or just below any permanent water created by any stable feature such as a rock bar within the watercourse.
- Stabilise and rehabilitate all disturbed areas including topsoiling, revegetation and regeneration, mulching, weed control and maintenance.

What information should be submitted for assessment?

When seeking approval to outlet structures across a watercourse or waterfront land, the NSW Office of Water will rely on the above information to undertake its assessment and to determine if the activity should be approved. All works and activities within watercourses should be designed by suitably qualified persons.

The following additional information may also be required:

- Detailed design drawings which include a surveyed plan, cross sections across the watercourse and a long section of the watercourse showing proposed works relative to existing and proposed bed and bank profiles and water levels. The cross section is to extend to the landward limit of the identified riparian corridor. All plans must include a scale bar.
- Detailed plans should include a location plan, plan view, elevation view and cross section of the proposed outlet structure.
- Detailed plans of any permanent bed and bank stabilisation works for scour protection.
- Sediment and erosion control plan.
- Detailed report of pre and post construction hydraulic, hydrologic and geomorphic conditions.
- Photographs of the site should be supplied. To assist with future monitoring and reporting, all photo points should be identified by GPS coordinates or by survey, particularly for large scale earthworks or extractive industries.
- A vegetation management plan prepared in accordance with the NSW Office of Water guidelines for vegetation management plans.
- A site management plan incorporating a works schedule, sequence and duration of works, contingencies such as in case of flooding, erosion and sediment controls and proposed monitoring and reporting periods.
- Costing of all works including materials and labour and stages of works including outlet structure installation and rehabilitation.
- Copies of other relevant approvals, for example development consent.

Will a maintenance period be necessary?

Applicants may need to allow for a minimum maintenance period of two years after practical completion of each stage or until the site is stable. The maintenance period will depend on the scope, size and level of risk. Engineering certification may be required at the end of the maintenance period. Maintenance until stable includes sediment and erosion control; the replacement of any works, vegetation or areas damaged or destroyed by flows and flooding or vandalism; and any other requirements necessary to ensure a naturalised stable watercourse system is functioning by the end of the maintenance period.

Will a security deposit be required?

Applicants should note that if the likelihood of significant impact on the watercourse or waterfront land is identified, security (as bank guarantees) may be required before the controlled activity is commenced. The amount of security is usually based on the costings provided.

Where do I go for additional information?

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Contact us

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14 Appendix E: Limitations of hydrological modelling – Nepean River wetted perimeter

Model Limitations

An assessment of potential impacts to the aquatic and riparian environment was informed by wetted perimeter extent modelling detailed in the *Ecohydrology and Geomorphology Impact Assessment* (Streamology, 2021). Given the spatial extent of the area subject to assessment, wetted perimeter analysis under each flow scenario was conducted via bulk calculation under the assumption that the provided data was correct and consistent with that used by Streamology in all related modelling and analysis.

It is acknowledged that data anomalies may be inherent when modelling wetted perimeter in complex terrain (i.e. Norton's Basin gorge complex), over large spatial scales and across multiple flow scenarios. Review of wetted perimeter spatial data identified potential anomalies in the model outputs at several locations, including upstream of Norton's Basin (sees Figures 75-78) and at the Glenbrook Creek-Nepean River confluence (see Figure 77). Both these locations have been identified as important reaches by this assessment as they are highlighted as reaches most affected by potential increases in wetted perimeter.

Wetted perimeter extent data anomalies at these important reaches have been reviewed and assessed as having the potential to result in an over-expression of aquatic habitat gain (i.e. increase in wetted perimeter extent) during analysis, under both baseline Median +50 ML /day and baseline Median +100 ML /day scenarios. As reported by Streamology (2021), the magnitude of change is also similarly expressed under 90th percentile +50 ML /day and 90th percentile +100 ML /day scenarios.

It is considered that the magnitude and consequence of this over-expression relative to the scale of wetted perimeter analysis conducted from Bents Basin to Penrith Weir is negligible, and in no way detracts or under-represents the impact of wetted perimeter from increased flow events. Wetted perimeter calculations presented by this assessment for both baseline median and 90th percentile flow scenarios would therefore be considered conservative.

Examples of these isolated anomalies are displayed with accompanying commentary where relevant (Figures 1-5). All effort has been taken to draw upon a range of relevant ecohydraulic metrics and field survey data to inform inferences and mitigations proposed by this assessment.

Figure 77 Identified anomaly at the Glenbrook Creek-Nepean River confluence. Cross section 10540.97 dissects the baseline Median and baseline Median +50ML /day wetted perimeter polygons, resulting in an over-expression of wetted perimeter extent within the wetted channel (approximately adjacent to the western bank).

Wetted Perimeter

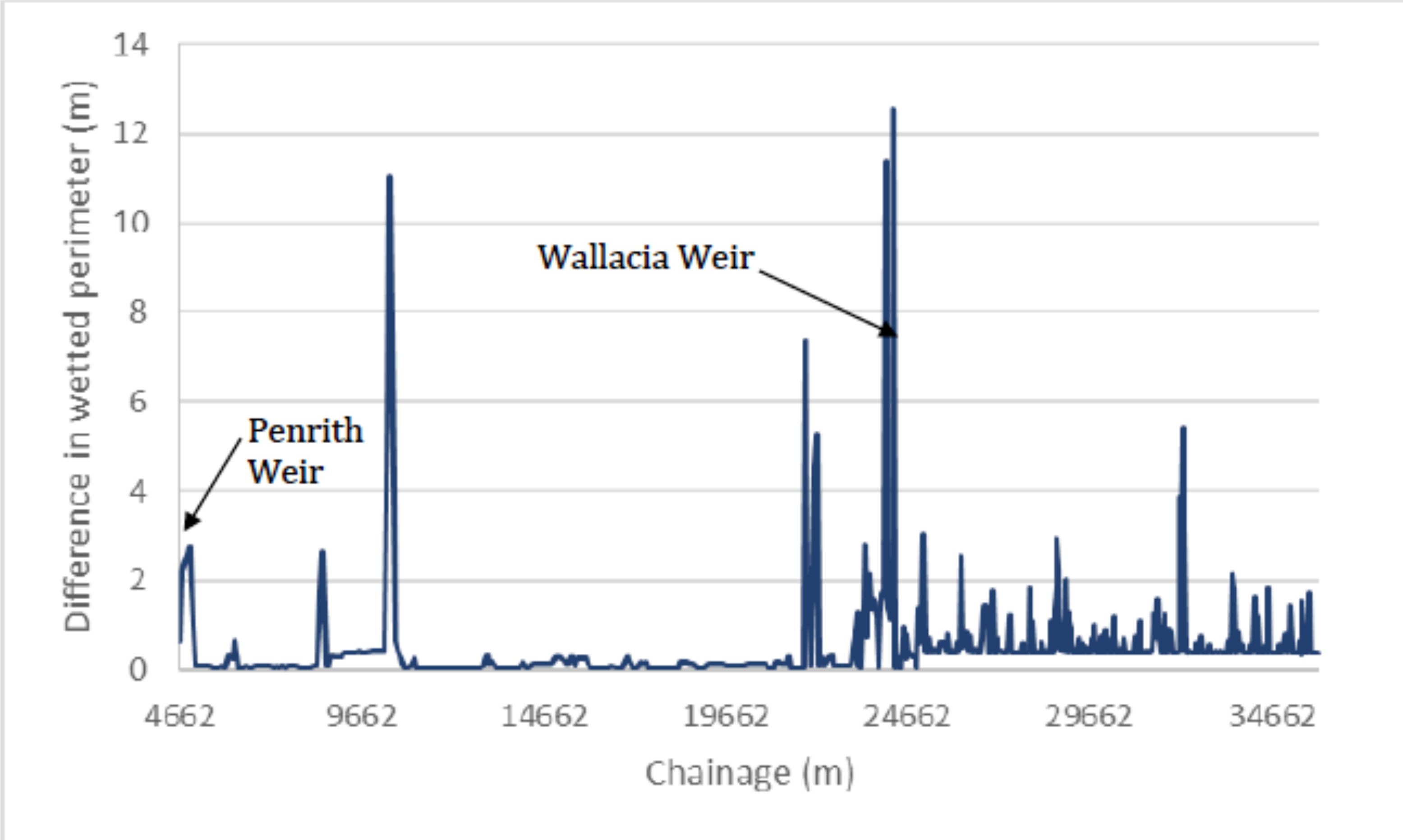

Figure 21 Difference in wetted perimeter between baseline conditions and scenario with the 50 ML/d release from the AWRC along the Nepean River between Bent's Basin (chainage 36,000) and Penrith Weir (chainage 4662m).

Figure 78 Depiction of the difference in Wetted Perimeter between baseline Median (baseline) and the baseline Median +50ML /day flow scenario along the entire assessment area (Streamology 2021). The three largest spikes are observed L to R at Glenbrook Creek and upstream of Norton's Basin in the gorge complex (labelled Wallacia Weir above).

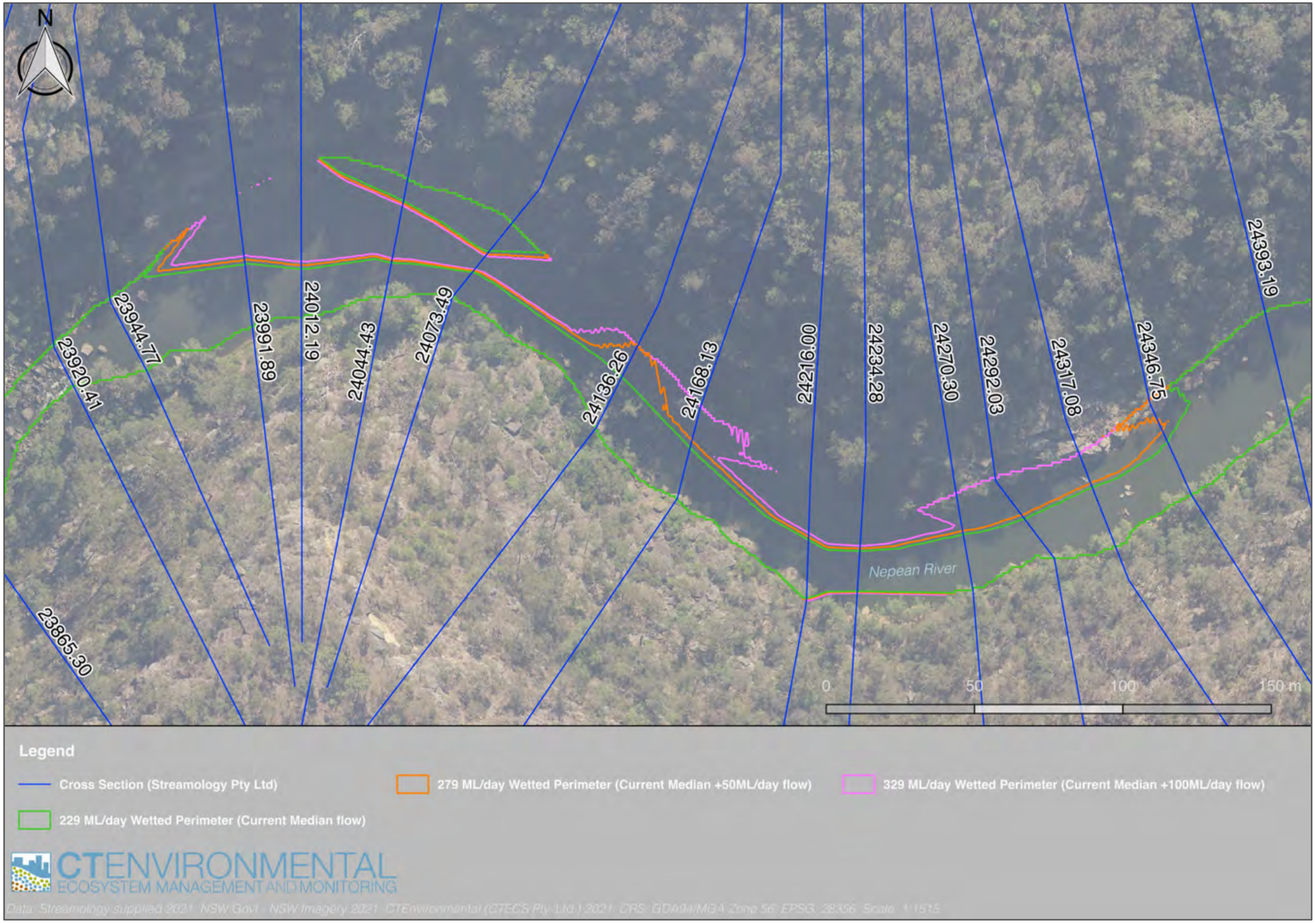

Figure 79 Potential anomalies (selected examples discussed only) within the gorge complex upstream of Norton's Basin at cross section 24136.26 and 24346.75.

Figure 80 Close up of cross section 24136.26 (selected example discussed only) dissecting baseline Median, baseline Median +50ML /day and baseline Median +100ML /day wetted perimeter extents.

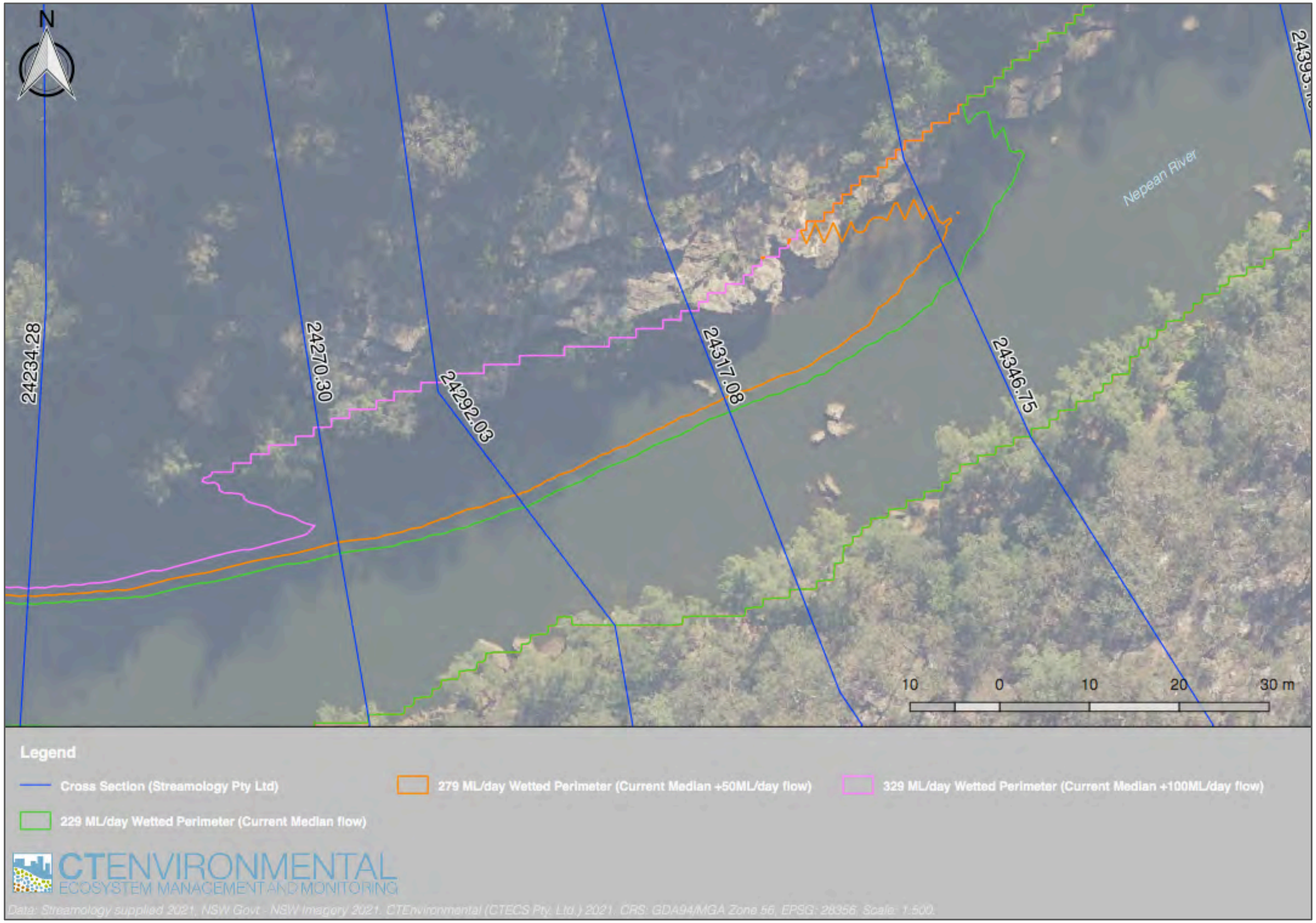

Figure 81 Close up of cross section 24346.75 (selected example discussed only) dissecting baseline Median, baseline Median +50ML /day and baseline Median +100ML /day wetted perimeter extent.

Appendix F: Determination of aquatic macroinvertebrate mobilisation velocity thresholds

Determination of Aquatic Macroinvertebrate Mobilization Velocity Thresholds

Due to the scarcity of literature on this topic, specifically the determination of maximum flow velocities that macroinvertebrates can withstand before being washed away an experiment was conducted by CTENVIRONMENTAL to determine these values. A brief outline of the method is provided below.

Location and Study Site

The experiment was conducted on 1 April 2021 on a semi-rural private property in Sun Valley, NSW, Australia within a 100 m section of Valley Heights Creek. The catchment comprises primarily of natural vegetation and modified semi-rural/residential land, with some lots occupied by recreational livestock. Valley Heights Creek is a Strahler third order stream that flows into Fitzgeralds Creek, a fourth order stream approximately 1.3 km downstream.

Field Method & Sampling

Pre-Experiment Survey: A pre-experiment aquatic macroinvertebrate survey was conducted to investigate the abundance and diversity taxa present in the stream. The stream was deemed to have sufficient aquatic macroinvertebrate abundance and diversity and provided for the safe installation of the in-stream experiment. Flow conditions on the day were considered normal (<0.1 metres/second) and no rainfall or natural increases in stream flow velocity was observed during the experiment.

Flume Installation: A 2000 mm (L) by 70 mm (W) by 100 mm (H) metal flume was erected on bedrock in situ within the stream and positioned parallel to the bank and in-line with the downstream flow. The flume channel comprised of an 800 mm long open top 'observation area' to allow for visual observation of aquatic macroinvertebrate mobilization. The flume was submerged until approximately 20 mm of the observation area rail was exposed above the water surface. Upon installation, natural downstream flow was allowed to travel down the flume channel unless blocked with baffles at the head and end of the observation area. Plastic baffles were used to block natural flow (<0.1 metres/second) from interfering with the observation area during the insertion of substrates and aquatic macroinvertebrates. The insertion of baffles allowed aquatic macroinvertebrates to establish in static flow conditions.

An in-stream, actively pumped flume installation was chosen as it ensured; 1) the time between aquatic macroinvertebrate sampling, picking and insertion into the flume was minimized; 2) aquatic physiochemical parameters were comparable between sampling sites and within the flume channel; and 3) a constant flow velocity across the cross section of the flume head and within the channel could be maintained.

Flow Control: An agricultural pump was used to extract water from a large pool downstream of the flume installation, which was then pumped upstream to the head of the flume and discharged at varying velocities as required. Flow velocity within the flume was controlled manually by positioning the pumped flow outlet at varying distances away from the flume head. All experimental runs commenced with the flow outlet positioned at a distance of 1 m from the head of the flume channel. This distance was reduced to increase flow velocity within the flume with respect to observed aquatic macroinvertebrate mobilization.

Measuring Flow: A Global Water digital handheld water velocity meter was positioned at the head of the observation area to measure flow velocity within the flume. Readings were taken in metres/second (m/s) and recorded at the point at which macroinvertebrate/s were mobilized from sediment/gravel or bare metal substrate within the flume. Measurements were recorded on site at the conclusion of testing each subject taxa. In cases where the sediment/gravel substrate was mobilized before the aquatic macroinvertebrate/s, the results were not included in subsequent analysis.

Macroinvertebrates: Macroinvertebrates were sampled from a 100 m section of stream from a variety of habitats. A total of 72 individuals from 12 families of 8 orders were subject to mobilization testing in the flume. Observations of the following taxa were made; 1) Order: Odonata, Family: *Aeshnidae* (n = 4), *Coenagrionidae* (n = 5), *Gomphidae* (n = 4) and *Megapodagrionidae* (n = 4); 2) Order: Decapoda, Family: *Atyidae* (n = 6); 3) Order: Ephemeroptera, Family: *Baetidae* (n = 7) and *Leptophlebiidae* (n = 8); 4) Order: Hemiptera, Family: *Corixidae* (n = 5); 5) Order: Coleoptera, Family: *Gyrinidae* (n = 6); 6) Order: Trichoptera, Family: *Leptoceridae* (n = 12); 7) Order: Gastropoda, Family: *Physidae* (n = 5); 8) Order: Diptera, Family: *Simuliidae* (n = 6). The minimum number of individuals per family subject to flume testing was n = 4.

Sample processing on-site was stopped when a substantial number of individual taxa were collected allowing immediate processing within the flume. The holding time of macroinvertebrates was minimized where possible to reduce any stress placed on the organisms. Where an individual required confirmation of identification, an on-site light microscope was used for microscopic examination to the taxonomic level of family.

Flume Operation: The insertion of plastic baffles to prevent downstream and backflow interface with the observation area preceded the insertion of a sediment/gravel substrate that resembled that of the adjacent streambed. Once the substrate settled, the subject taxa was introduced into the static observation area and allowed to establish. The baffles were then removed and an increase from natural flow velocity (<0.1 metres/second) was gradually introduced, and taxa mobilization points monitored. To accurately observe the mobilization point of individuals within the flume, a maximum of n = 5 individuals was observed per test. The gravel substrate was observed to be mobilized at 1.5 m/s, which caused some individuals to be washed away with the substrate. Families that were observed to be impacted by this, including *Baetidae*, *Physidae* and *Simuliidae*, were re-tested using new individuals which were allowed to settle on the metal substrate. Only the data from the re-evaluation was included for analysis. This was done to ensure maximum flow velocity was determined for each taxa, removing the effect of benthos mobilization. The determined values for mean macroinvertebrate mobilization have been incorporated into Table 44.