Hydrodynamics and Water Quality Report

Northwest Treatment Hub Review of Environmental Factors

Sydney WATER

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Executive summary

The objective of the Hydrodynamic and Water Quality Impact Assessment has been to assess how the upgrades of the Northwest Treatment Hub (NWTH) may impact the hydrodynamics and water quality in their receiving waterways. The waterways assessed are Eastern Creek, Wianamatta-South Creek, Cattai Creek, Second Ponds Creek and the Hawkesbury River. The NWTH consists of the following plants :

- Castle Hill Water Recycling Plant (WRP) which releases treated water to Cattai Creek;
- Rouse Hill Water Recycling Plant (WRP) which releases treated water to Second Ponds Creek, a tributary of Cattai Creek; and
- Riverstone Wastewater Treatment Plant (WWTP) which releases treated water to Eastern Creek, approximately 2.3 km upstream from the confluence with Wianamatta-South Creek.

The assessment has been developed to address the requirements of relevant legislation, policy and guidelines. The assessment has also been undertaken to evaluate performance against the objectives of the upgrades, which include:

- enable compliance with future environmental protection licence (EPL) requirements and maintain the health of local waterways;
- improve reliability, availability, and operability of the treatment processes;
- provide increased capacity to accommodate projected population growth;
- minimise impacts to the surrounding environment and community.

The upgrades include increasing treatment capacity of Rouse Hill and Riverstone WWTP, as well as improving the quality of treated wastewater at all three plants.

The upgrades were assessed against both water quality default guideline values (DGV) and the Hawkesbury-Nepean Framework (EPA, 2019). Modelling was undertaken using Water Quality Response Models (WQRMs) across three specific catchment domains:

- Cattai Creek
- Wianamatta-South Creek
- Hawkesbury-Nepean River.

These domains have varying water quality conditions associated with pressures from urban and industrial development, agricultural practices, land use changes, point source discharges as well as numerous, competing demands for water.

The WQRMs simulate the hydrodynamics and a suite of water quality processes within the receiving waterways. The models were developed using several industry standard software applications and were based on a range of best available datasets including rainfall, land use, topography, channel bathymetry and release data from WWTPs operated by Sydney Water and others. The WQRMs were calibrated and validated against an extensive record of hydrodynamic and water quality monitoring data recorded at various locations along each waterway. The WQRMs performed well across the selected calibration and validation periods and across the range of assessed parameters.

The WQRMs have been developed in line with industry standards and are considered fit for purpose in the application of assessing predicted impacts of the NWTH upgrades. In line with all similar studies, The modelling isconsidered a representative approximation to the real world, with some residual levels of uncertainty. Each model is based on a series of assumptions, and dependent on the accuracy of, and sensitivity to, its input data. The model results should therefore be interpreted as indicative of impacts, responses and trends in the receiving waters and not as absolutes.

Three scenarios were developed to allow simulation of comparative conditions for catchment change such as landuse and population growth as well as the operational changes of the NWTH upgrades. The scenarios were assessed for representative dry and wet climatic years to address the question of how wet and dry conditions affect impacts from the NWTH upgrades.

The scenarios were:

- Baseline scenario: Representing current (circa 2020) conditions
- Background scenario: Representing catchment and waterway conditions expected in 2036 without the inclusion of the NWTH upgrades
- Impact scenario: Representing catchment and waterway conditions expected in 2036 with the inclusion of the NWTH upgrades.

Model results predict the upgrades have a low risk of degrading water quality in the receiving waterways and provide an improvement to water quality and/or ecosystem health for all three catchments assessed. This has been determined from the evaluation of nutrient concentrations (both peak and median annual) and loads in the impact scenario compared to the background and baseline.

For all three catchments, the WQRM results indicate that the environmental impacts downstream of the NWTH treated water release points are predicted to be mostly positive and show improvements from the baseline scenario and/or background scenario for the assessed nutrients and pathogens. This is despite the significant increase in effective population (EP) that will be serviced by the NWTH upgrades.

As a high-level summary, Figure 1 and Figure 2 present an overview of the predicted impacts on key water quality parameters for all three scenarios for both the dry and wet years, respectively. These figures summarise the modelling results for key parameters assessed by the Cattai Creek, South Creek and Hawkesbury Nepean WQRMs, and at several locations downstream of the NWTH discharge locations. The colour coded matrices provide an indication of predicted compliance with waterway objectives, based on the annual median concentrations predicted. Cells shaded in green indicate that DGVs are predicted to be achieved based on the annual median concentration at this location. Cells shaded in red indicate that the annual median concentration is predicted to exceed the DGVs.

For the background and impact scenarios, a trend is also shown as up or down, or unchanged relative to baseline and background scenarios, respectively. The arrows are coloured to indicate worsening (red), improving (green) or unchanged (yellow). In this analysis, a trend was defined as a change in annual medians of greater than five percent.

The Environmental Protection Authority's (EPA) regulatory framework for the Hawkesbury-Nepean (the framework) (EPA, 2019) was established to manage nutrient load inputs in the river system. The Riverstone WWTP is located within Sackville subzone 2 and the Castle Hill and Rouse Hill WRPs are located within Sackville subzone 3, according to the framework. Loads for the NWTH upgrades have been predicted to be below the 2024 – 2028 framework limits for each subzone and therefore comply with the framework.

TN and TP loads for the NWTH upgrades (2036) for Sackville Subzone 3 and 2 are summarized in Table 1 and Table 2, respectively.

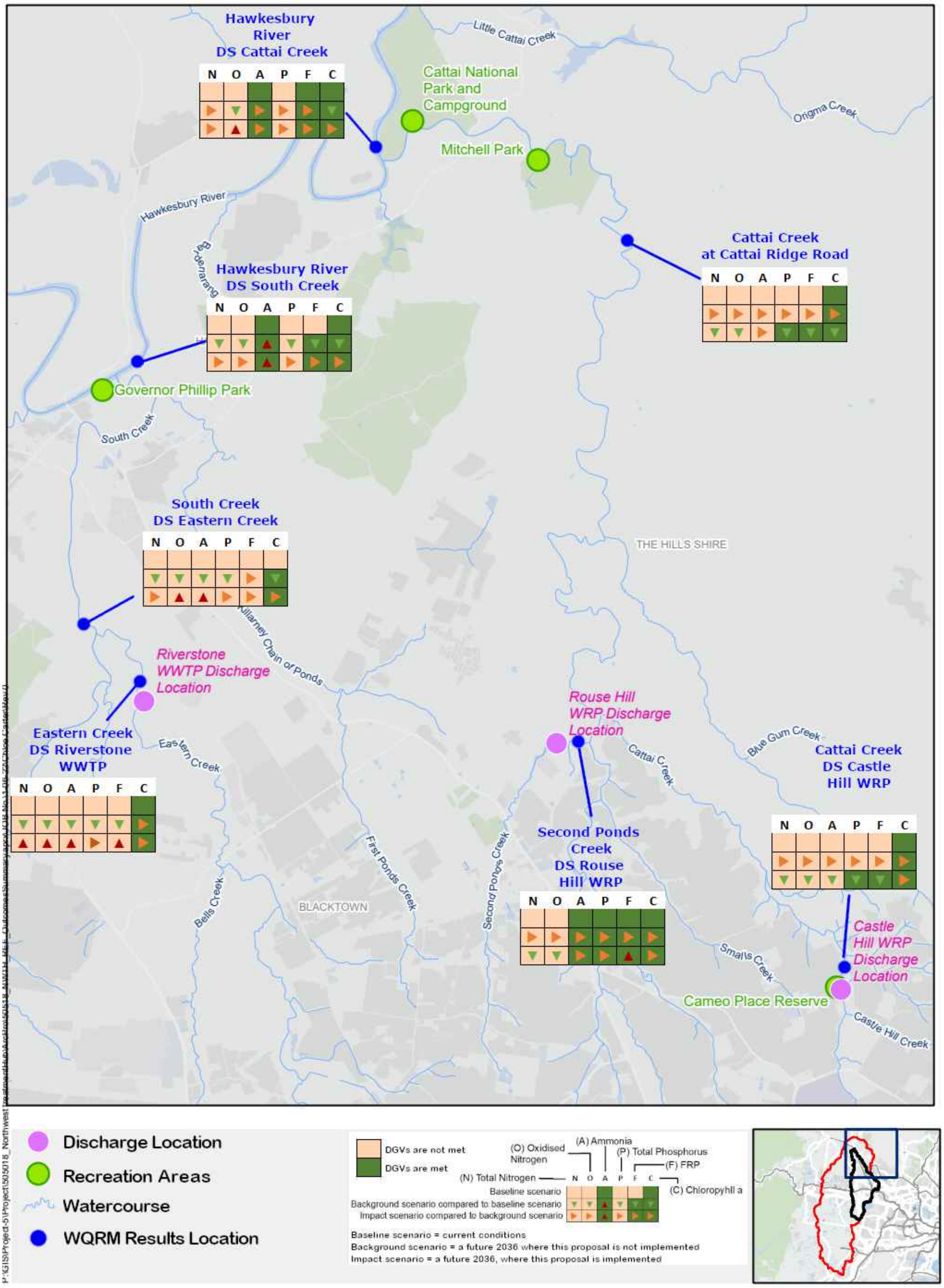

Figure 1 Summary of predicted water quality impacts for the NWTH upgrades in the representative dry year

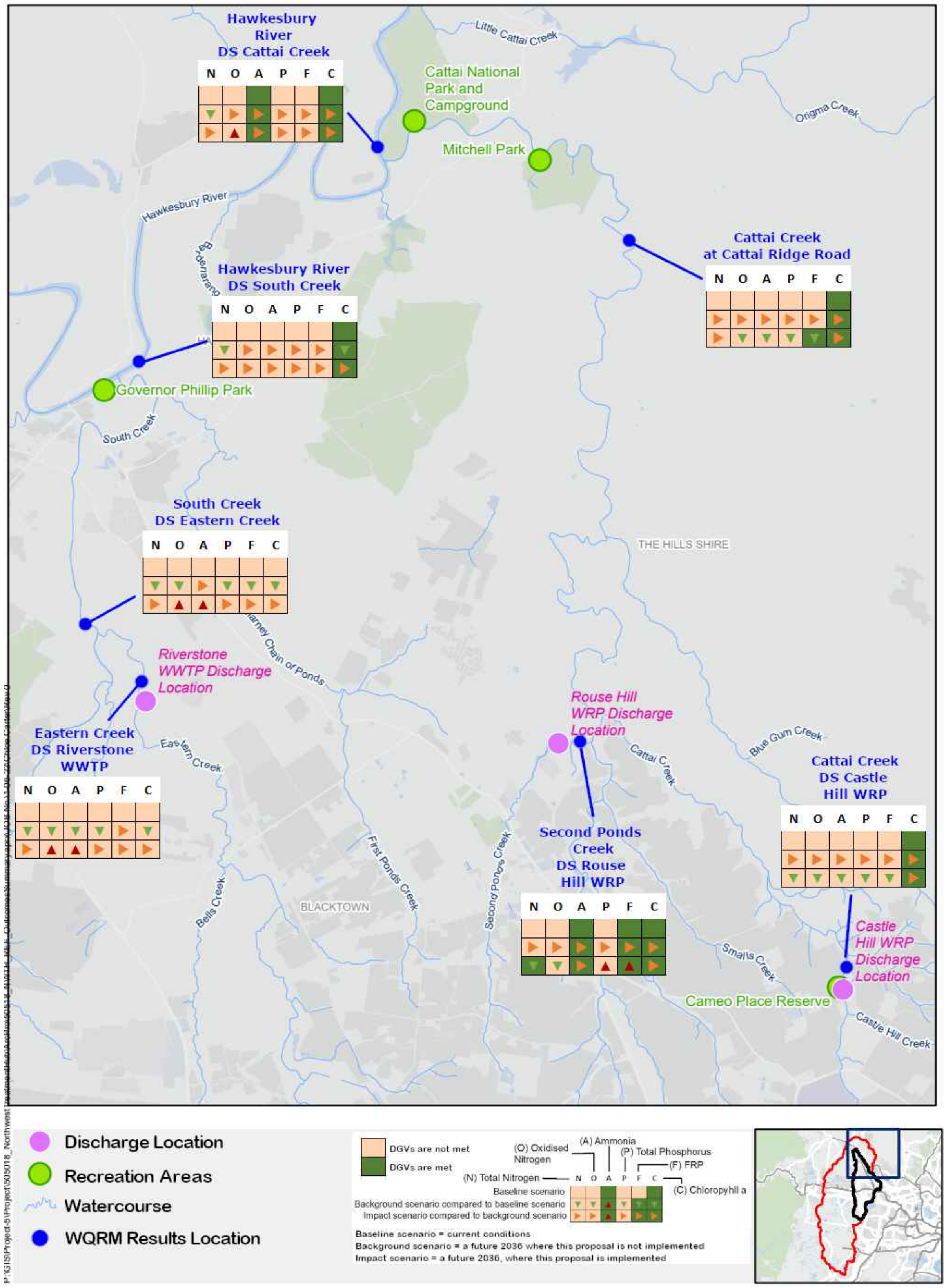

Figure 2 Summary of predicted water quality impacts for the NWTH upgrades in the representative wet year

Table 1 Summary of estimate nutrients loads within Sackville Subzone 3

WRP	2036 - TN (tonnes/year)	2036 -TP (tonnes/yr)
Rouse Hill	18.6	0.1
Castle Hill	30.6	0.8
Total Estimated Load	**49.2**	**0.9**
Subzone Load limit	**82.4**	**1.2**

Table 2 Summary of estimate nutrients loads within Sackville Subzone 2 (Sydney Water plants)

WWTP/WRP	2036 - TN (tonnes/year)	2036 -TP (tonnes/yr)
Riverstone	43.6	0.7
St Marys	37.9	1.0
Quakers Hill	21.6	0.4
AWRC	1.7	0.1
Total Estimated Load	**104.8**	**2.2**
Subzone Load limit	**126.1**	**2.7**

1 Introduction

1.1 Background

This hydrodynamic and water quality assessment has been produced to support and inform the Review of Environmental Factors (REF) for Sydney Water's Northwest Treatment Hub (NWTH) upgrades, required to service population growth in the region. The NWTH consists of the following Sydney Water plants:

- Castle Hill Water Recycling Plant (WRP) with treated water releases to Cattai Creek;
- Rouse Hill Water Recycling Plant (WRP) with treated water releases to Second Ponds Creek, a tributary of Cattai Creek; and
- Riverstone Wastewater Treatment Plant (WWTP) with treated water releases to Eastern Creek, approximately 3 km upstream from the confluence with Wianamatta-South Creek.

The locations of these plants are provided below in Figure 3.

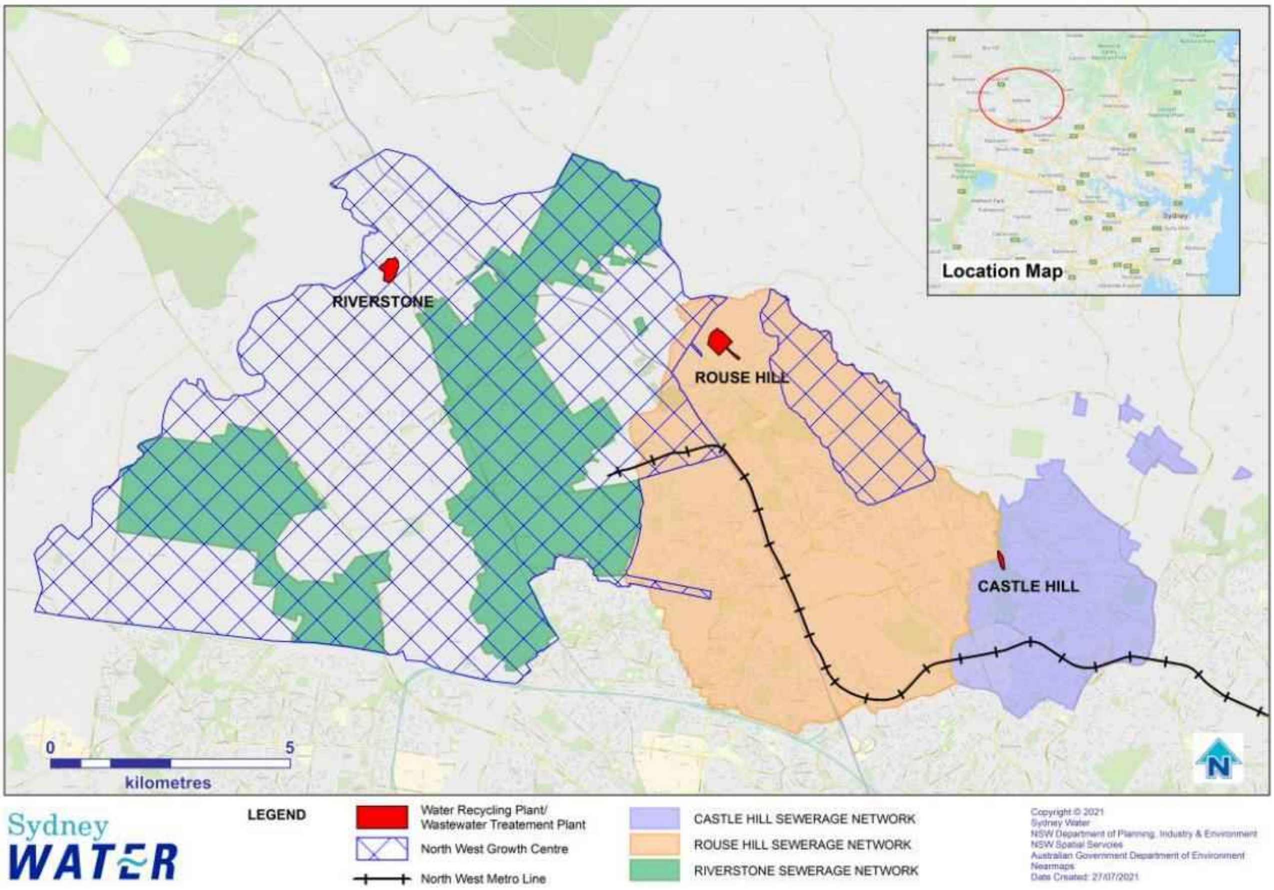

Figure 3 Northwest Treatment Hub plant locations and serviced catchments

This report provides an assessment of how the changes to treated water releases from the NWTH plants may impact the hydrodynamics and water quality in the receiving waters of Eastern Creek, Wianamatta-South Creek, Second Ponds Creek, Cattai Creek and the Hawkesbury River. One future scenario for the 2036 time horizon of these plants has been evaluated with the anticipated changes to the catchment for this scenario also considered. The 2036 assessment combined with an appreciation of the existing conditions allows for evaluation of the potential impacts arising specifically from the upgraded plants.

1.2 Project Description

This study has been undertaken to support capacity upgrades and associated compliance requirements of the NWTH plants. These are detailed in the sections below and collectively referred to within this document as the NWTH upgrades.

1.2.1 Compliance Requirements

Phased upgrades of the NWTH plants are required to ensure compliance with environmental regulatory frameworks and to service the anticipated development of Sydney's North West Growth Area and the Metro Northwest Corridor. In particular, the NSW EPA's Hawkesbury Nepean Nutrient Framework imposes new nutrient load and concentration limits in our Environment Protection Licences (EPLs) effective from July 2024. To achieve these limits, the NWTH will be upgraded for liquid amplification at all three plants and consolidated sludge will be transferred to Riverstone WWTP for centralised processing.

Currently, both Castle Hill WRP and Rouse Hill WRP are operating at treatment capacity and have recorded non-compliances against EPL requirements. Amplifications to Castle Hill and Rouse Hill WRP commenced in 2018 as Phase 1 upgrades. Upgrades at Castle Hill and Rouse Hill WRPs will commence in 2022 to address existing compliance requirements. The 2024 EPL compliance requirements will need to met as demand for wastewater treatment increases.

The capacity upgrades will need to continue to meet compliance requirements. The proposal involves amplifications of the Riverstone WWTP and Castle Hill and Rouse Hill WRPs in response to landuse change and population growth. The proposal objectives are to:

- enable NWTH to meet 2024 EPL requirements;
- enable compliance with future EPL requirements and maintain the health of local waterways;
- improve reliability, options for, and operability of the treatment processes;
- provide increased capacity to accommodate projected population growth;
- minimise impacts to the surrounding environment and community.

1.2.2 Capacity Upgrades

The project involves upgrades to the NWTH and a new sludge transfer system for consolidated biosolids handling at Riverstone WWTP. The proposal will enable Sydney Water to provide wastewater servicing to a growing population in Sydney's northwest to support priority growth areas, improve treatment processes to meet future regulatory requirements and provide a solution that minimises impacts to the community and the environment.

In summary the proposal involves:

- Upgrade Rouse Hill WRP to 40 ML/d ADWF (additional 14 ML/d) capacity including liquid amplification with increased recycled water capacity and improved treated water quality and decommissioning of biosolids handling.
- Upgrade Riverstone WWTP to 30 ML/d ADWF (additional 16 ML/d) capacity including liquid amplification, a new anaerobic digestion, energy recovery facility and flexibility for future food waste co-digestion. The upgrade will be sized to receive sludge from Castle Hill, Rouse Hill and Riverstone wastewater catchments for centralised biosolids treatment and outloading.
- A new sludge transfer system including:
    - a sludge pumping station (SP1224) and associated facilities at Castle Hill WRP
    - a sludge pumping station (SP1223) and associated facilities at Rouse Hill WRP
    - 10.2 km pipeline (~200 mm diameter) between Castle Hill WRP and Rouse Hill WRP dedicated for sludge transfer
    - 6.3 km of pipeline (~315 mm diameter) between Rouse Hill WRP and Riverstone WWTP dedicated for sludge transfer.

1.2.3 Proposed Wastewater Treatment Upgrades and Treated Water Quality

To meet the objectives outlined in Section 1.2, treatment upgrades to the NWTH plants are proposed as outlined in Table 3.

Table 3 Proposed treatment upgrades for NWTH plants

Plant	Proposed Treatment Upgrades
Castle Hill WRP (Compliance Upgrade)	Biological treatment upgrade for improved nitrogen removal Ultra-filtration upgrade for expansion and improvement to tertiary phosphorus removal Ultraviolet (UV) disinfection system upgrade
Rouse Hill WRP	Membrane bioreactor for liquid capacity upgrade and improved nitrogen removal Ultra-filtration upgrade for expansion of tertiary phosphorus removal Recycled water system upgrade Decommissioning of biosolids stabilisation and handling
Riverstone WWTP	Inlet works augmentation Wet weather primary treatment for phosphorus removal Odour treatment upgrade Membrane bioreactor for liquid capacity upgrade Ultra-filtration upgrade for expansion of tertiary phosphorus removal Centralised biosolids treatment and outloading for management of sludge from Castle Hill, Rouse Hill and Riverstone

The modelled changes in treated water quality for current conditions and the NWTH upgrades are provided below in Table 4. The median water quality concentrations presented represent conservative estimates of treatment outcomes. Sydney Water expects nutrient concentrations to be lower than those presented here.

Table 4 Modelled median treated water quality for current and 2036 NWTH plant operations

Water Quality Parameter	Castle Hill WRP		Rouse Hill WRP		Riverstone WWTP	
	Current (2020)	Future (2036)	Current (2020)	Future (2036)	Current (2020)	Future (2036)
Total Nitrogen (TN) (mg/L)	15.76	6.22	7.01	5.04	2.40	3.05
Ammonia (mg/L)	0.10	0.19	0.10	0.20	0.01	0.23
Oxidised Nitrogen (NOx) (mg/L)	14.5	4.98	6.00	3.81	1.37	1.81
Total Phosphorus (TP) (mg/L)	0.11	0.024	0.018	0.021	0.018	0.050
Salinity (g/L)	0.49	0.48	0.46	0.45	0.54	0.54
Dissolved Oxygen (mg/L)	5.9	5.9	5.9	5.9	5.9	5.9
Enterococci (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0
E. coli (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0

The expected future concentrations for Rouse Hill WRP in 2036 are outlined as 5mg/L in the table above, and based on the preliminary estimates during the options study which expected that a TN target equivalent to that at Castle Hill WRP would be suitable for Rouse Hill WRP. Further analysis in the Reference Design stage considering wet weather bypass flows at both Castle Hill and Rouse Hill WRPs and understanding limitations on recycled water use from the Rouse Hill WRP catchment suggests much lower target discharge concentrations in the order of 3.0 to 4.0 mg/L TN will be required at Rouse Hill WRP to continue to meet the H-N framework load caps and limits for Sackville Subzone 3.

The upgraded Rouse Hill WRP system is expected to discharge treated water with a median TN concentration of 3.0 mg/L and median NOx concentration of <2.0mg/L NOx. A 90th percentile concentration for TN of 5.0mg/L and NOx of <4.0mg/L is also expected, with the objective of achieving NOx concentrations of <2.4mg/L if biologically possible in the upgraded system. The modelled values in should therefore be considered conservative in estimating water quality impacts to the creek, given the latest understanding on H-N framework load limit requirements.

Anticipated median treated water quality concentrations at all three NWTH plants for key nutrients after the NWTH upgrades are provided in Table 5.

Table 5 Anticipated median treated water quality concentrations for key nutrients of the NWTH upgrades in 2036

NWTH Plant	TN (mg/L)	TP (mg/L)
Castle Hill WRP	6	0.02
Rouse Hill WRP	6	0.02
Riverstone WWTP	3	0.05

Castle Hill is being upgraded to include sucrose dosing, a sludge age of >18 days under normal operation, and ample return rates for denitrification. Process modelling shows that as an annual median, 5 mg/L of total nitrogen will be achievable, however as the plant is being significantly refurbished, the guarantee provided is 6 mg/L. Process commissioning (forecast for mid-2024) will likely highlight the plant's superior performance to the minimum standard, although this is a biological process and subject to the specifics of wastewater characteristics, including changes to these with change to water usage. An upgrade of Castle Hill in 2028-29 is forecast, and this will be designed with a new process train. The new process train will be all new equipment. Although this will only treat half the flow, this will improve the nitrogen removal potential overall at Castle Hill. The total nitrogen level of 6 mg/L is, therefore, considered a conservative assumption given the potential for operation at a lower level (to be verified with process testing).

Upgrading of the WWTP and WRPs will increase the capacity of the plants and result in increased average dry weather flows (ADWF) as treated water release. The anticipated changes in capacity are outlined in Table 6.

Table 6 Projected ADWF for Northwest Treatment Hub plants by year

NWTH Plant	Projected ADWF Capacity (ML/d)		
	2021 (Current)	2026	2036
Castle Hill WRP[1]	6.9	8.2	10.1
Rouse Hill WRP[2]	28.1	32.1	42.6
Riverstone WWTP[3]	13.1	17.4	27.8

1. Castle Hill Wastewater Treatment Plant Report (Sydney Water, 2021a)
2. Rouse Hill Wastewater Network Capacity Report (Sydney Water, 2021b)
3. Riverstone Wastewater Network Capacity Report (Sydney Water, 2021c)

1.3 Study Objectives

The primary objective of this study is to provide a scientifically robust assessment of the hydrodynamic and water quality changes resulting from the upgrades to the NWTH plants (Section 1.2.3).

The study objective is achieved by answering the following key impact assessment questions regarding the proposed upgrades:

1. How do the hydrodynamics and water quality conditions change downstream of the release points, compared with baseline and background scenarios, due to the NWTH upgrades?
2. How do wet and dry climatic conditions affect the hydrodynamics and water quality of the receiving waterways?

These questions have been selected to support the project objectives identified in Section 1.2.

2 Legislation, Policy and Guidelines

2.1 Legislation and Policy Context

This report has been prepared in support of a Review of Environmental Factors (REF) for the proposed NWTH growth upgrades.

Legislation and Policy relevant to the technical study	Brief description of legislation, salient parts and intent	How legislation/policy is relevant to the study
National Water Quality Management Strategy (NWQMS)	The purpose of the NWQMS is to protect the nation's water resources by maintaining and improving water quality, while supporting dependent aquatic and terrestrial ecosystems, agricultural and urban communities, and industry. The NWQMS therefore provides a nationally consistent approach to water quality management and the provision of information and tools to help water resource managers, planning and management agencies, regulatory agencies and community groups manage and protect water resources. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.	Key outcomes of relevance from the NWQMS include the ANZG (2018) and ANZECC (2000) guidelines. These guidelines are discussed below.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)	Mandated step-by-step guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. Includes stronger emphasis on weight of evidence and desire for inclusion of conceptual models. This 2018 revision of the national water quality guidelines is presented as an online platform, to improve usability and facilitate updates as new information becomes available.	In the absence of site-specific guideline values, the ANZG (2018) provides direction on default guideline values (DGVs) for a range of stressors relevant to different community values, such as aquatic ecosystems, human health, and primary industries. The ANZG (2018) outline required targets and thresholds for relevant water quality indicators in the receiving waterways that are applicable to the project. Development of the waterway objectives for this project have therefore considered these guidelines in conjunction with the ANZECC (2000) and NHMRC (2008) discussed below.

Legislation and Policy relevant to the technical study	Brief description of legislation, salient parts and intent	How legislation/policy is relevant to the study
Guidelines for Managing Risks in Recreational Water (National Health and Medical Research Council, 2008)	These guidelines represent non-mandatory standards designed to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. This includes natural and artificial hazards. They form part of the NWQMS and can be used at a state level as a tool to: • assure the safe management of recreational water environments, so that as many people as possible can benefit from using the water develop legislation and standards appropriate for local conditions and circumstances	These guidelines identify suitable water quality indicators and targets for the assessment of recreational water quality. The standards were consequently included in the development of the project specific waterway objectives presented in Section 2.2.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)	The ANZECC (2000) 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 guidelines provide recommended trigger values (now known as default guideline values) for various levels of protection which have been considered when describing the existing water quality and key indicators of concern.	In addition to the ANZG (2018), the ANZECC (2000) provide detailed guidance on required targets and thresholds for relevant water quality indicators in the receiving waters. These guidelines, along with the ANZG (2018) and NHMRC (2008) documents formed a significant dataset in the development of the waterway objectives for the project.
Using the ANZECC Guidelines and Water Quality Objectives in NSW (DECCW, 2006)	This document was developed to provide additional guidance on the principles behind the ANZECC (2000) guidelines and how to apply these in a NSW context.	Guidance from this booklet provides additional understanding with respect to the current health of the waterways in the vicinity of the project and the ability to support nominated environmental values, particularly the protection of aquatic ecosystems.
NSW Water Quality and River Flow Objectives (DECCW, 2006)	Agreed state-level environmental values and long-term goals for NSW surface waters which stipulate community values and uses, as well as water quality indicators to assess waterway condition.	For the Hawkesbury Nepean catchment, these objectives reference the Healthy Rivers Commission (HRC) as interim environmental objectives. However, the HRC guidelines (referenced below) are now considered superseded by ANZG (2018), ANZECC (2000) and relevant domain specific guidelines.

Legislation and Policy relevant to the technical study	Brief description of legislation, salient parts and intent	How legislation/policy is relevant to the study
Healthy Rivers Commission (HRC, 1998)	The HRC was established in 1995 by the NSW Government to make recommendations on suitable objectives for water quality, flows and other goals central to achieving ecologically sustainable development in a realistic time frame.	The HRC Inquiry established environmental values for the Hawkesbury Nepean catchment, however these have been superseded by the ANZG (2018) and ANZECC (2000) guidelines as part of the National Water Quality Management Strategy (NWQMS), listed previously. The HRC guidelines however provide additional clarification on environmental values that are to be protected.
NSW Water Management Act (2000)	The objects of the Water Management Act are to provide for the sustainable and integrated management of the water sources of the state by protecting, enhancing and restoring water resources.	Consideration of the project against the overarching water management principles promoted under the Water Management Act.
Protection of the Environment Operations Act (1997)	The *Protection of the Environment Operations Act 1997* is the key piece of environment protection legislation administered by the Environment Protection Authority (EPA). The Act enables the Government to set out explicit protection of the environment policies. The EPA also issues environment protection licences to the owners or operators of various industrial premises under the Act. Sydney Water's WWTPs and WRPs all operate under environmental protection licences issued by the EPA.	The constituent concentrations in the treated water releases will need to be compliant with concentrations limits and, consequently, loads as required under the updated EPLs for Riverstone (EPL 1796), Rouse Hill (EPL 4965) and Castle HIll (1725).

Legislation and Policy relevant to the technical study	Brief description of legislation, salient parts and intent	How legislation/policy is relevant to the study
Risk-based framework for considering waterway health outcomes in strategic landuse planning decisions (OEH, 2017)	The Risk Based Framework brings together existing principles and guidelines recommended in the NWQMS, which the federal, state and territory governments have adopted for managing water quality. The purpose of the Risk Based Framework is to: 1) ensure the community's environmental values and uses for our waterways are integrated into strategic landuse planning decisions 2) identify relevant objectives for the waterway that support the community's environmental values and uses, and can be used to set benchmarks for design and best practice 3) identify areas or zones in waterways that require protection 4) identify areas in the catchment where management responses cost-effectively reduce the impacts of landuse activities on our waterways 5) support management of landuse developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.	The development of the project waterway objectives followed the principles of the risk-based framework. The framework was also applied in the development of water quality and flow objectives for South Creek. These objectives have consequently been included alongside ANZG (2018) and ANZECC (2000) guidelines for the assessment of hydrology and water quality in the South Creek catchment.
State Environmental Planning Policy (Biodiversity and Conservation) 2021 Chapter 9 - Hawkesbury-Nepean River (NSW Government, 2022)	The purpose of the State Environmental Planning Policy (Biodiversity and Conservation) 2021 Chapter 9 - Hawkesbury-Nepean River to protect the environment of the Hawkesbury-Nepean River system by ensuring that the impacts of future landuses are considered in a regional context. It covers environmentally sensitive areas, water quality and quantity and development that has the potential to impact on the river environment.	The proposed works are located within the Cattai Creek and South Creek catchments which ultimately drain to the Hawkesbury River. The Local Government Areas (LGAs) of Blacktown and Hawkesbury are identified as two of the 15 LGAs to which Chapter 9 of SEPP (Biodiversity and Conservation) 2021 – Hawkesbury-Nepean River applies and specific planning policies and recommended strategies for consideration in this project are detailed in Clause 6 of this document.

Legislation and Policy relevant to the technical study	Brief description of legislation, salient parts and intent	How legislation/policy is relevant to the study
Regulating nutrients from sewage treatment plants in the Lower Hawkesbury Nepean River catchment (EPA, 2019)	The EPA has developed a regulatory framework to manage nutrient load inputs to the Hawkesbury Nepean River from wastewater treatment plants. The objective is to meet the community's environmental values for the river and provide wastewater treatment plant operators with alternatives to meet those nutrient loads. The framework includes limits on nutrient concentrations, interim caps on nutrient loads and a framework for nutrient trading and offsets.	The framework divides the river system into different zones and proposes separate load limits for Total Nitrogen and Total Phosphorus within each zone. Releases from Riverstone to Eastern Creek are within Sackville subzone 2. Releases from Rouse Hill and Castle Hill to Second Ponds Creek and Cattai Creek, respectively, are within Sackville subzone 3. The framework has been applied to Sydney Water's existing Environment Protection Licences (EPLs). The updated EPLs for 2024 have been adopted for Sackville subzones 2 and 3.
Greater Sydney Water Strategy (DPIE, in development)	The Greater Sydney Water Strategy is currently being developed by DPIE. This 20-year strategy will replace the 2017 Metropolitan Water Plan and reflect the government's objectives and desired outcomes for integrated water cycle management. The government is concerned with water security, enhancing and enabling economic growth, liveability and community wellbeing, environmental sustainability and improvement. The strategy is expected to be finalised in 2021.	Sydney Water has been engaging with DPIE as the strategy develops which has ensured that the project objectives align with the strategy's direction. Sydney Water will continue to work closely with DPIE as the Greater Sydney Water Strategy is developed to ensure alignment of our relevant activities, including this project.

2.2 Waterway Values and Objectives

Table 7 provides a summary of the waterway objectives for the receiving waterways for the NWTH plants' treated water releases. The objectives have been developed for this project, in the context of what was developed as part of the Upper South Creek Advanced Water Recycling Centre's environmental impact statement. They have been developed using the ANZG (2018) and ANZECC (2000) default guideline values based on a waterway typology of slightly disturbed lowland river ecosystems in south-east Australia. Guidelines including *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (OEH, 2017) and *Guidelines for managing water quality in recreational waters* (NHMRC, 2008) have also been used.

Impacts associated with the project will be assessed against these waterway objectives. Table 8 provides relevant toxicant DGVs for Chlorine, Ammonia and Nitrate, where Nitrate is taken to be represented by oxidised nitrogen (NOx) in the modelling undertaken for this report. These constituents were determined as the primary toxicants most relevant to the operation of urban/regional wastewater treatment plants, discharging to freshwater creeks or rivers.

Table 7 Waterway objectives for receiving waterways of the NWTH treated water releases

Values and uses & associated management goals	Indicator	Numerical criteria/metric
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]
	Total phosphorus (TP)	0.025 mg/L[1]
	Oxidised nitrogen (NOx)	0.040 mg/L[1]
	Ammonium (NH_4^+)	0.020 mg/L[1]
	Filterable reactive phosphorus (FRP)	0.020 mg/L[1]
	Chlorophyll *a* (Chl *a*)	0.003 mg/L[1]
	Dissolved oxygen (DO)	85 - 110 % Saturation[1]
	pH	6.5 - 8.0[1]
	Conductivity / Salinity	125 - 2200 µS/cm[1] Equivalent to Salinity of 0.09 -1.5 g/L[1]
	Turbidity	6 - 50 NTU[1] TSS < 40 mg/L[1]
2. Recreation & Aesthetics ***Management Goal:*** ***Maintain or improve water quality for recreational activities such as swimming, boating and fishing.***	Enterococci	Primary contact: 95^{th} percentile for intestinal enterococci/100 mL ≤ 40[2] Secondary contact: 95^{th} percentile for intestinal enterococci/100 mL > 40 and ≤ 200[2]
	Visual clarity and colour	Surface waters should be free from substances that produce undesirable colour, odour, tasting or foaming.[1]

Values and uses & associated management goals	Indicator	Numerical criteria/metric
Management Goal: ***Maintain or improve the 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. 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 Ecosystems
	Human Pathogens	Thermotolerant Coliforms <10 cfu/100 mL[1]
	Cyanobacteria	No overall increase in (cyanobacteria) risk under any scenario, as determined by the length of period with index values consistently above 0.8.

1. *Indicators and metrics adopted from ANZG (2018) and ANZECC (2000) default guideline values (DGVs) are for slightly disturbed lowland river ecosystems in south-east Australia*
2. *Guidelines for managing risks in recreational water (NHMRC, 2008)*

Table 8 Relevant toxicant DGVs

Indicator	Adopted DGV
Total Ammonia as N	0.90* mg/L
Nitrate as N	2.40** / 3.5** mg/L
Total Chlorine (mg/L)	0.003*** / 0.007***

* *DGV for the protection of aquatic ecosystems (95% protection as typically recommended for slightly to moderately disturbed ecosystems) – refer ANZECC (2000) Table 3.4.1 and ANZG (2018)*

** *For Nitrate, the updated ANZG (2018) state that the ANZECC (2000) DGV of 0.7 mg/L was erroneous and recommends the use of the guideline values published in the NIWA report "Updating nitrate toxicity effects on freshwater aquatic species" (2013).*

*** *For Chlorine, the ANZECC (2000)/ANZG (2018) guidelines state a toxicant DGV of 0.003 mg/L for the protection of aquatic ecosystems (95% protection). A more recent Guideline Value (GV) of 0.007 mg/L has been derived for Chlorine in freshwater by Batley et al. (2021).*

3 Assessment Methodology

3.1 Overview

This assessment has adopted a methodology that focuses on the development of Water Quality Response Models (WQRMs) to project the likely hydrodynamic and water quality conditions for the receiving waterways of the NWTH under the changed operational conditions of the three treatment plants.

The WQRMs have two primary functions:

1. To coordinate catchment and discharge inputs (including timing and location) and compute downstream dilution and mixing of this material.
2. To estimate internal transformations that occur whilst substances are 'in transit'.

Three WQRMs have been developed to cover the following geographic domains:

3. Cattai Creek Catchment
4. South Creek Catchment
5. The Hawkesbury River and Nepean River Catchment.

This section outlines the methodology that was adopted in the assessment. The following sequence of tasks was undertaken as part of the assessment methodology:

- data compilation and review
- software selection and model configuration
- model development, calibration and validation
- scenario testing and impact assessment, and
- analysis and interpretation.

Details regarding these tasks are presented in the sub-sections below.

3.2 Data Compilation and Review

An extensive suite of both publicly available and unpublished datasets, and information relevant to the project was compiled and reviewed as part of the assessment. A summary of these tasks is presented below:

The initial phase provided for the development, calibration and validation of the hydrodynamic and water quality models. Descriptions of the underlying datasets included in this development phase are presented in the model calibration report (refer Appendix A). Details provided include the source of the data, its application and where relevant, the resolution and various other key attributes relating to each dataset.

The subsequent phase of data compilation and review tasks primarily focused on information relevant to the characterisation of the existing environment as well as for the development of model scenarios that would be needed in the impact assessment. Key datasets therefore included:

- previous studies relating to hydrodynamic and water quality conditions of the Hawkesbury River, South Creek, Cattai Creek, Eastern Creek and their tributaries
- water quality monitoring data collected within the receiving waterways
- landuse data for the catchments as forecast for the future scenario
- monitoring data from relevant wastewater treatment plants (WWTPs) and water recycling plants (WRPs) located within the catchments including flow rates and water quality relating to the treated water releases
- wet weather overflow data predicted for the future scenario.

3.3 Software Selection

The WQRMs used in this assessment were built on application of the finite volume hydrodynamic modelling software, TUFLOW FV, which was dynamically coupled with the Aquatic Ecodynamics Modelling library, AED2. Further details regarding these software packages as well as other relevant modelling tools are presented below.

3.3.1 TUFLOW FV

The TUFLOW FV (version 2019.01.008 Single Precision Build) hydrodynamic modelling software, developed by BMT Commercial Australia Pty Ltd, was adopted for the WQRM. The software uses a flexible mesh (finite volume) approach to resolve the variations in water level, flow, horizontal salinity distribution and vertical density stratification in response to tides, inflows and surface thermodynamics.

As outlined in the model development and calibration report (Appendix A), the model meshes can consist of a combination of triangular and quadrilateral elements of different sizes. Such mesh structures are well suited to simulating areas of complex riverine and estuarine morphometry. The resolution of the meshes can be easily adapted to accommodate areas of waterway where the hydrodynamics are either considered complex or where there are specific zones of interest.

The model meshes can then be applied as either two dimensional (2D) or three dimensional (3D). Further options exist for the vertical mesh discretisation including sigma or z coordinate systems, or a hybrid of the two, allowing for multiple surface Lagrangian layers to respond to water elevation changes.

The finite volume numerical scheme solves the conservative integral form of the non-linear shallow water equations in addition to the advection and transport of scalar constituents such as salinity and temperature. The timestep, typically in the order of minutes, varies throughout a simulation and is selected by taking into account physical and numerical convergence and stability considerations. The appropriate timestep is calculated by TUFLOW FV such that Courant–Friedrichs–Lewy (CFL) constraints imposed by the flow characteristics are obeyed.

3.3.2 AED2

The AED2 water quality modelling library (libfvaed2 1.0.0 and libaed2 1.3.0), developed by the University of Western Australia (UWA), is coupled with the TUFLOW FV model. The library is organised as a series of independent water quality modules that can be interconnected.

The core conceptualisation of the model is configured to capture the dynamics of oxygen, carbon, nutrients (including inorganic and organic fractions) and primary productivity as presented in Figure 4. Individual phytoplankton groups are simulated with chlorophyll a also included as a primary indicator of phytoplankton abundance and biomass. Other indicators of waterway health (e.g. species habitat, hypoxia or nuisance algal bloom risk) can also be output and summarised. The water quality properties are updated dynamically in response to changes in water conditions brought about by weather and flow events.

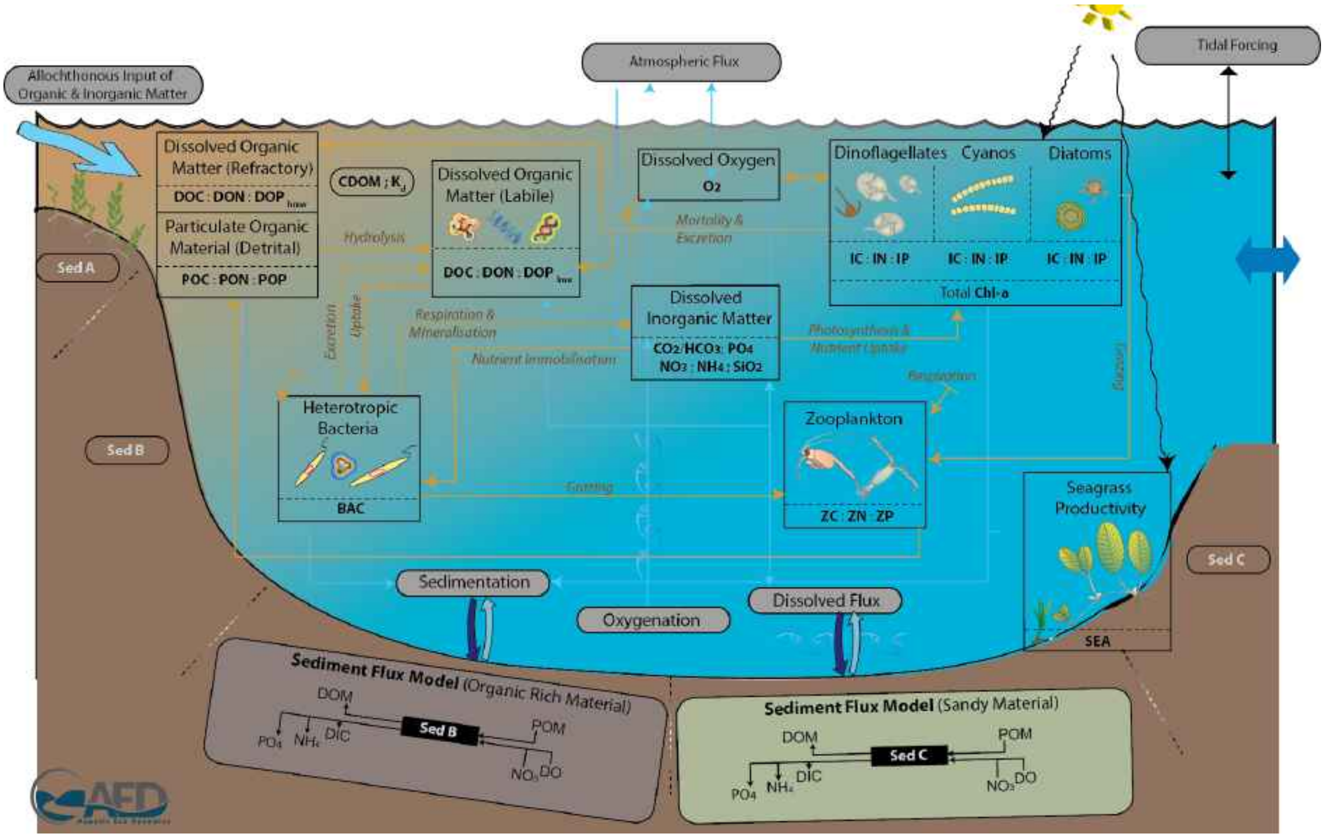

Figure 4 AED2 conceptual model

3.3.3 Other Modelling Tools

TUFLOW FV and AED2 were the primary software packages used to simulate the hydrodynamics and an extended suite of water quality processes within the receiving waterways. However, a number of other modelling tools were also applied in the development of the WQRMs, as well as the impact assessment modelling, as listed below.

- eWater Source models. Catchment processes and inputs were modelled using an integrated river basin water resources modelling software known as Source. The Source catchment models were developed to generate daily timestep data on catchment runoff flows and pollutant export loads for key water quality constituents including nutrients, sediment and pathogens. Scenarios were run using Source for existing and predicted future catchment conditions. Source has been extensively used nationally and internationally to assess changes in runoff and pollutant concentrations and loads resulting from landuse change, of which urbanisation is one example. The catchments mode of Source is intentionally designed for these types of applications that spatially explore changes in catchment characteristics on flows and water quality.

- MOUSE models. MOUSE, short for MOdel for Urban SEwers, is used by Sydney Water for modelling its wastewater network systems. The MOUSE models were used to generate data on wet weather overflows, including spill volumes at each overflow location. Scenarios were run using MOUSE for existing and predicted future network conditions. The timestep for these models can be defined by the user.
- WWTP/WRP models. Daily timestep models were developed within Microsoft Excel to allow the generation of daily timestep timeseries of flow and water quality for each of the treated water releases. Scenarios were run using these spreadsheet models for existing conditions as well as predicted future release conditions. Generally, data from Sydney Water's Effluent Knowledge and Management System (EKAMS) was used as the base dataset with interpolation and modifications to flow rates and water quality applied as required to simulate future conditions, such as population growth, treatment upgrades, network transfers, etc.

3.4 Model Configuration

Figure 5 presents an overview of the interfaces for the various models used in the impact assessment.

In summary:

- Timeseries data from the WWTP/WRP models were incorporated either in the Source catchment model or directly into the WQRM, depending on their location in the catchment. WWTPs and WRPs located in the upper reaches of the catchment, outside of the spatial extent of the TUFLOW FV model waterway mesh, were included in the Source catchment model. However, those with release points located adjacent to or within the TUFLOW FV waterway mesh were included as point sources within the WQRMs.
- Timeseries wet weather overflow data from the MOUSE models were incorporated directly into relevant sub-catchments within the Source catchment models.
- Surface water extractions were represented in the Source catchment model or within the WQRMs depending on their location, following a similar approach to the representation of the WWTP/WRP models.
- Results from the Source catchment models were processed using MATLAB to develop boundary conditions for the WQRMs.

Separate WQRM and Source catchment models were developed for three domains:

- Cattai Creek;
- South Creek (including Eastern Creek); and
- the Hawkesbury Nepean River system.

Upstream, the extents of these models were governed by key catchment features. More specifically, rainfall runoff from several catchments is regulated by dams including the Nepean, Avon, Cordeaux, Cataract, Warragamba and Mangrove Creek dams. The catchments upstream of these dams were therefore not included in the models and the timeseries data on these regulated flows were included directly in the WQRMs.

To allow for integration of the three separate WQRMs, interfaces were developed to allow changes in the flows and water quality originating from South Creek and Cattai Creek to be simulated in the downstream waters of the Hawkesbury Nepean River. The interface was consequently located at the tidal limit of South Creek, Eastern Creek and Cattai Creek with results from the South Creek WQRM and Cattai Creek WQRM scenarios extracted at these locations and formatted as boundary conditions for the Hawkesbury Nepean WQRM.

Downstream, the limit of the Hawkesbury Nepean WQRM is represented as an open ocean boundary that runs from Barrenjoey Head to Box Head. The extents of the WQRM meshes are presented in Figure 5.

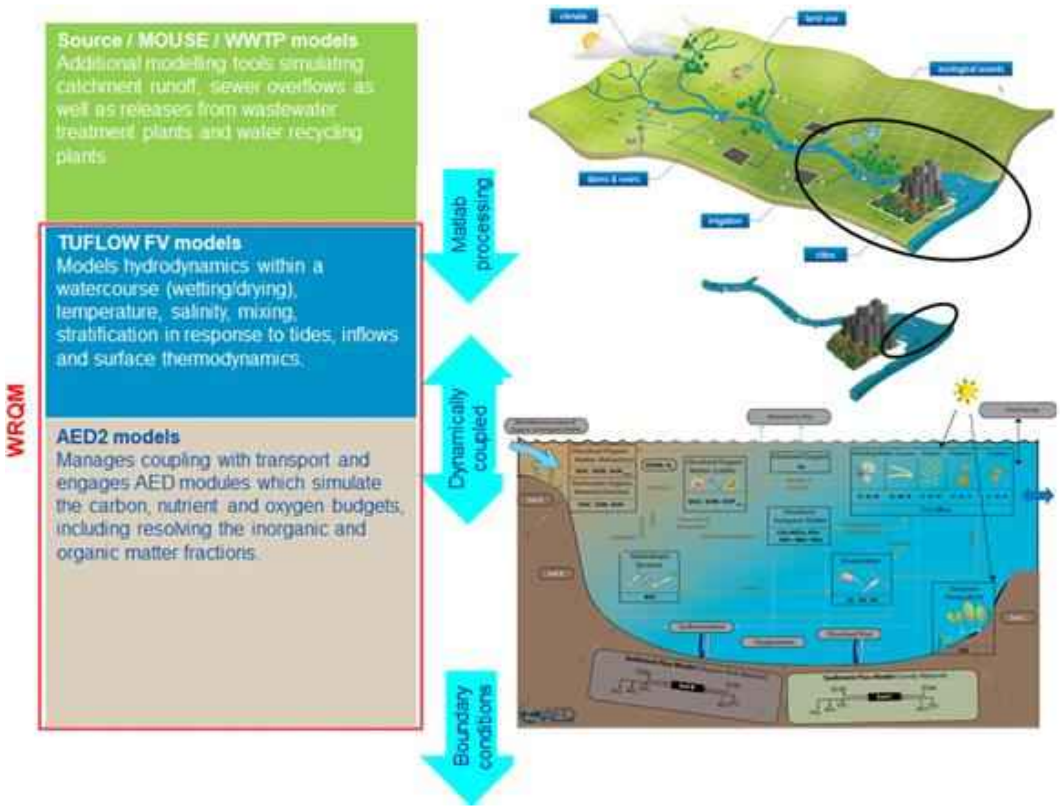

Figure 5 Primary model interfaces (Imagery sources: eWater and University of Western Australia)

Further details regarding the model configurations, extents, datasets and structure are presented in the model calibration report included in Appendix A.

3.5 Hydrodynamic and Water Quality Modelling

3.5.1 Model Development, Calibration and Validation

The WQRMs that have been applied in this assessment to simulate hydrodynamic and water quality impacts, represent the latest upgrades to the Hawkesbury-Nepean modelling developed as part of the Water Quality Modelling of the Hawkesbury Nepean River System (SKM, 2014) and the Upper South Creek Advanced Water Recycling Centre (AWRC) Environmental Impact Statement (EIS) (Sydney Water, 2021d).

In addition to the updating of the boundary conditions for the existing Hawkesbury Nepean WQRM and South Creek WQRM, a new WQRM of Cattai Creek was developed to allow simulation of the upper reaches of Cattai Creek and select tributaries in sufficient detail. Appendix A contains the WQRM calibration report prepared in support of this modelling, and includes further information on the development, calibration and validation of the Cattai Creek WQRM. Appendix B contains the WQRM calibration report prepared for the Hawkesbury Nepean and South Creek WQRMs.

In summary, the model development tasks included:

- updates of various model datasets and model elements for all three WQRM domains,
- development of a new model mesh representing Cattai Creek,
- updates to WWTP/WRP data to represent latest observations and
- extending all boundary condition datasets to cover more recent time periods through to 2020

3.5.1.1 Cattai Creek WQRM

A flexible mesh has been developed stretching over approximately 35 km of Cattai Creek for inclusion in the WQRM. The mesh extends from the confluence with the Hawkesbury River and extends upstream to the Rouse Hill and Castle Hill WRP release points. The mesh was prepared to model the potential hydrodynamic and water quality conditions in the Cattai Creek and HN catchments under the current conditions and upgrades of the WWTPs and WRPs.

The bathymetry of the mesh was primarily digitised using 2017 1m LiDAR data. Recent survey along Second Ponds Creek, just downstream of Rouse Hill WRP, has been added to the mesh bathymetry. Survey has also recently been undertaken between Cattai Ridge Road and the Hawkesbury confluence.

The Cattai Creek WQRM has been developed in a similar fashion to the South Creek and Hawkesbury Nepean models in the AWRC EIS. Figure 6 provides a geographic understanding of the Cattai Creek WQRM domain and the mesh used in developing the WQRM.

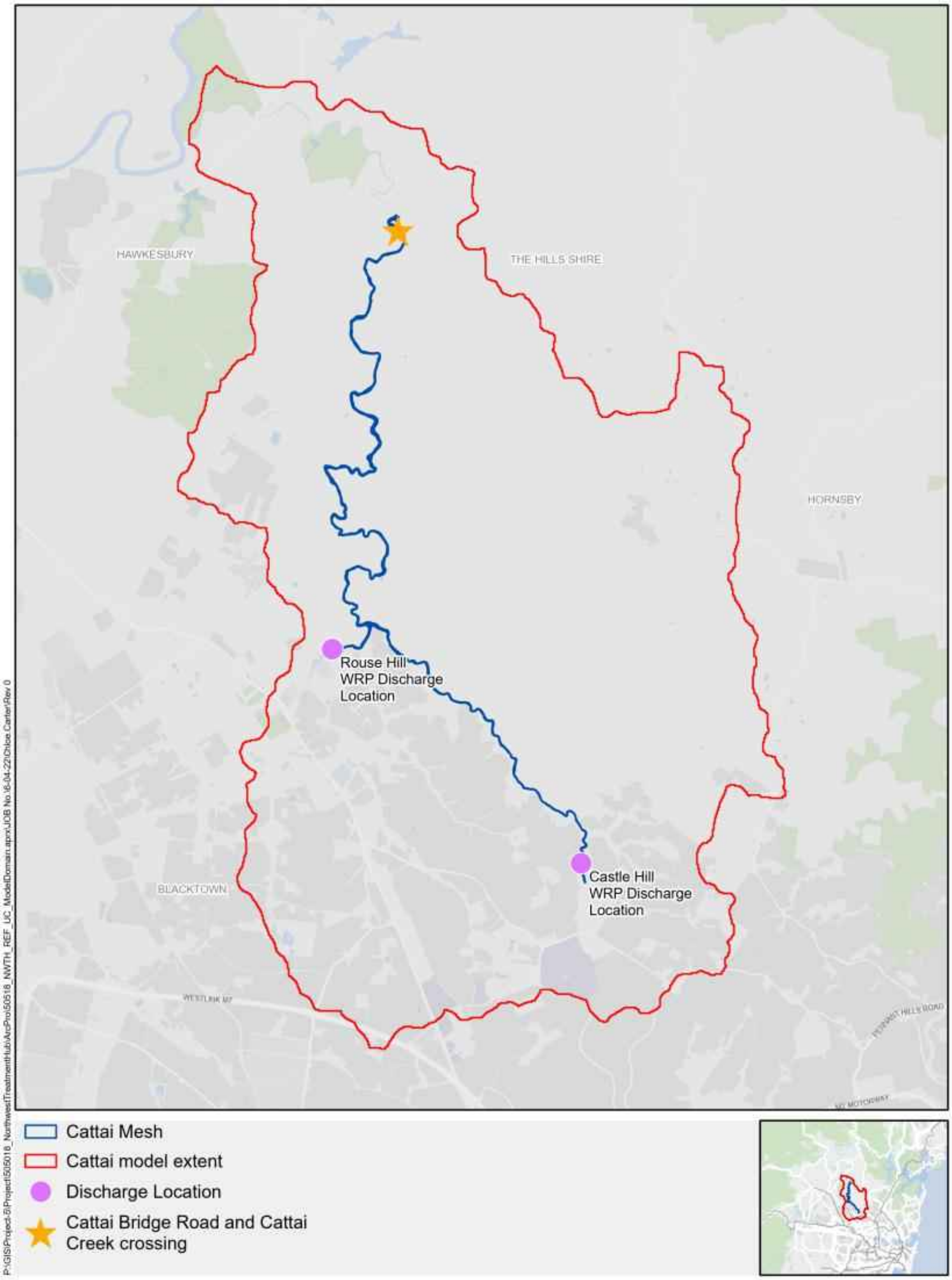

Figure 6 Cattai Creek WQRM domain

3.5.1.2 South Creek WQRM

The South Creek (SC) WQRM was developed as part of the Upper South Creek Advanced Water Recycling Centre (USC AWRC) EIS in order to enable the simulation and assessment of finer scale details of the sub-catchments within the South West and Western Sydney Aerotropolis growth areas. The model includes the Eastern Creek catchment, where Riverstone WWTP plant flows have been updated for this project. A summary diagram of the WQRM domain with the flexible mesh used is provided in Figure 7. Details of the WQRM's development are available in Appendix B.

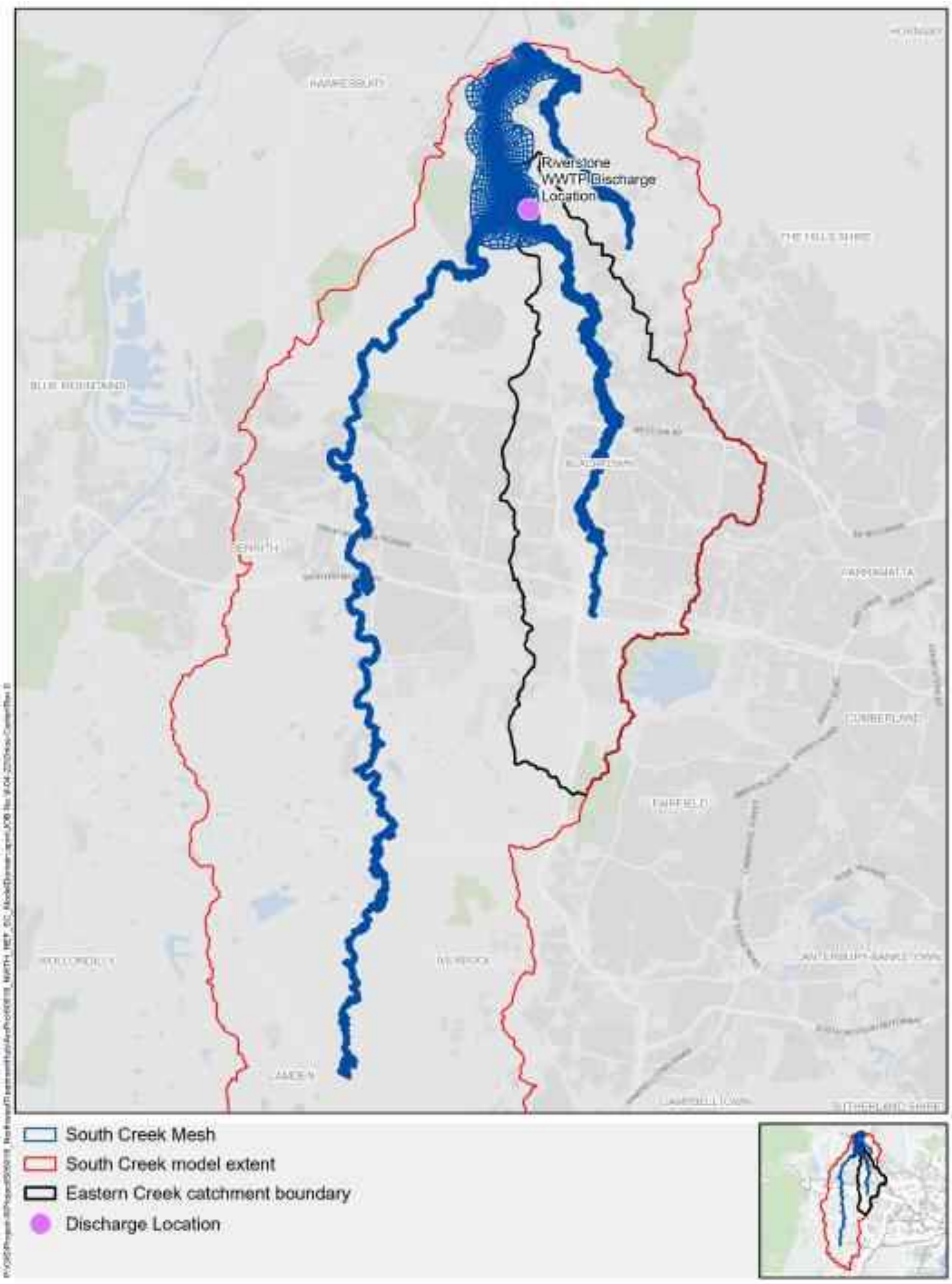

Figure 7 South Creek WQRM domain

3.5.1.3 Hawkesbury Nepean WQRM

The Hawkesbury Nepean (HN) WQRM was developed as part of the USC AWRC EIS, and simulates the movement of water, advection and dispersion of water quality constituents, their interactions in the aquatic environment and their ultimate fate within the Hawkesbury Nepean River system. The WQRM domain itself is defined by a 2D horizontal flexible mesh constrained to the limits of the river and its key tributaries. The flexible mesh consists of a grid of interconnected quadrangular and triangular elements with alignment provided for primary flow paths. The upstream limit of the mesh on the Nepean, Cataract and Warragamba rivers is the same as the Source catchment model and covers the main Hawkesbury Nepean River downstream to the ocean interface. The section of South Creek which is tidally influenced is also included in the mesh.

The mesh used in the USC AWRC EIS has been updated to include the Cattai Creek WQRM mesh in the latest iteration for this assessment. The Hawkesbury Nepean WQRM domain and the treatment plants being updated as part of this project are summarised in Figure 8. Additional details of the Cattai Creek WQRM are previously provided in Figure 6.

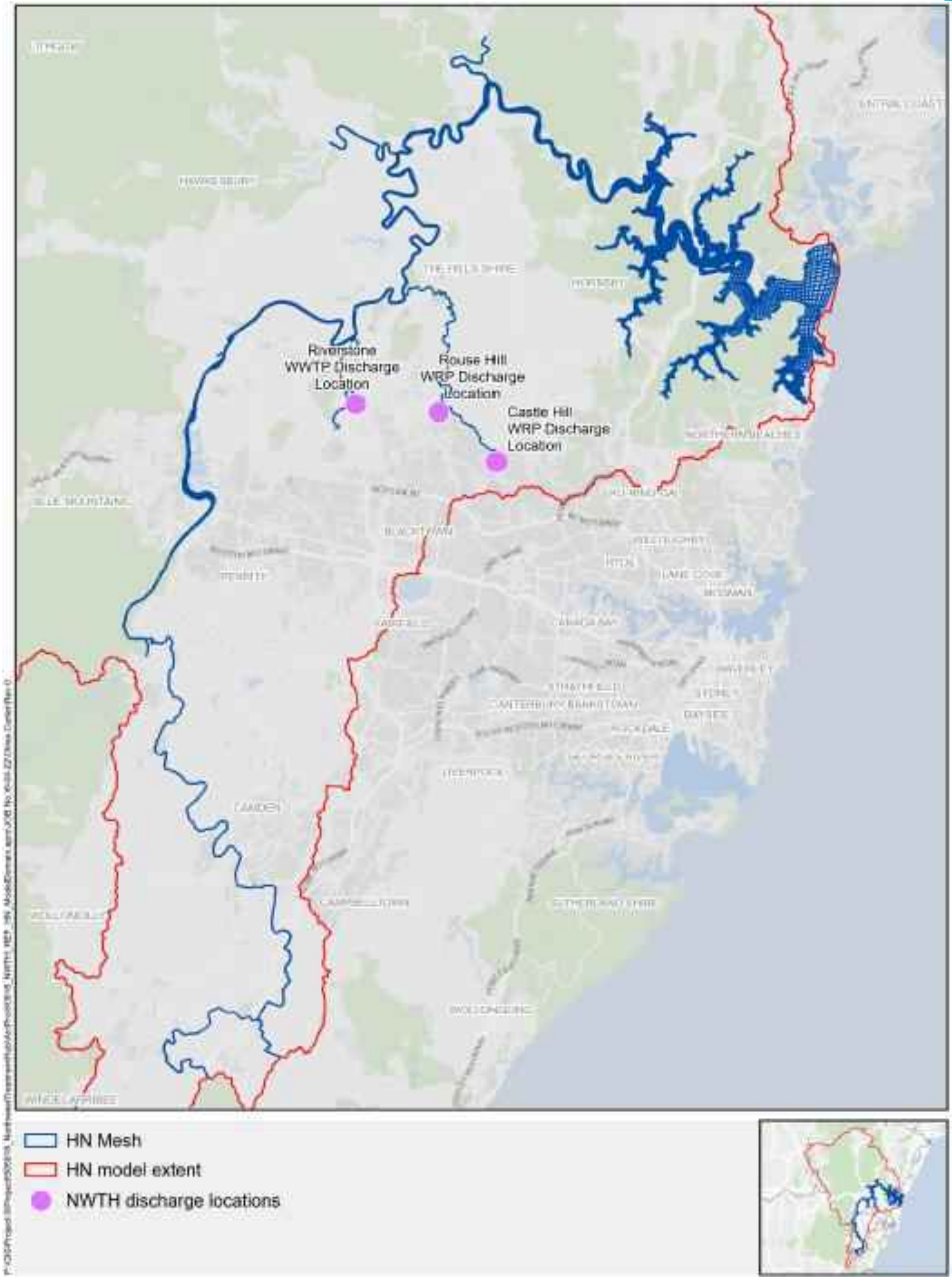

Figure 8 Hawkesbury Nepean WQRM domain

3.5.1.4 Calibration and Validation

The WQRMs were calibrated and validated for the following years based on an assessment of each year's representative climatic conditions and an audit/comprehensive review of available hydrodynamic and water quality monitoring data:

- Calibration: 2017-2018 was selected due to the comprehensive datasets available
- Validation: 2013-2014 and 2014-2015 were selected as representative dry and wet years, respectively, based on a review of climatic data

Calibration and validation of the WQRMs focused on comparing the model predictions against the water quality and hydrodynamic monitoring data. Adjustments were made to model variables until an acceptable fit between predicted and observed data was achieved. The core suite of hydrodynamic and water quality parameters calibrated and validated within the WQRMs included flow, salinity, temperature, dissolved oxygen, suspended solids, nutrients (including inorganic and organic fractions), primary productivity and pathogens.

A range of plotting tools was used for the comparison of model predictions against monitoring data including an innovative zonal analysis approach, which involved data aggregation within predefined zones of the waterways. Transect analysis was also applied to demonstrate the longitudinal variation in different water quality attributes. These plots were integrated over either monthly, seasonal, or annual timeframes, allowing assessment of the large-scale trends along the river or creek, with less emphasis on the high-frequency variability brought about by day-to-day conditions.

The WQRMs performed well across the range of calibration and validation periods and also across the range of parameters that have been assessed. The WQRMs were, therefore, considered to be fit for purpose for use in this assessment.

3.5.2 Scenario Testing Approach

A suite of three scenarios was developed to evaluate the performance of the NWTH plants currently and as a relative contribution to waterway conditions in the future. To achieve this, the anticipated changes in the catchment conditions associated with population growth and stormwater management were evaluated along with the anticipated change to treated water releases from other plants in the Hawkesbury Nepean catchment.

To apply these changes in the models, the boundary conditions were systematically adjusted to represent each of the scenarios. As part of this process, the Source catchment models were used to generate catchment inflow boundaries for the future scenarios and to reflect changes in landuse, WWTP/WRP upgrades, wet weather overflows, extractions and alternative stormwater management strategies.

The WQRMs were then adjusted to represent the remaining scenario elements including the NWTH treated water releases to Cattai Creek and to Eastern Creek.

The potential influence of climatic conditions on the cumulative impacts was also evaluated for each scenario through the adoption of a simulation period that included both representative high (wet) and low (dry) rainfall years.

3.5.3 Scenario Descriptions

Scenarios were assessed for changing conditions across three variables:

- Catchment landuse
- NWTH upgrades
- All other treatment plant flows

These variables were altered to produce three scenarios that allowed for the assessment of current waterway conditions, future contributions to waterway conditions from sources outside of the NWTH plants and future conditions including the NWTH upgrades.

A 2036 time horizon was adopted to represent the future conditions for this assessment as there is currently no spatial landuse estimate for the catchments between 2017 and 2036. The 2036 time horizon has also been used as it represents the time when the NWTH upgrades will be completed for all three plants. Future landuse within the South Creek catchment was also considered to be consistent with the Parklands urban development concept to produce estimates of the relative contribution to water quality and flow from urbanisation. Urbanisation in the Cattai Creek catchment has been represented using the projected landuse without consideration of any water sensitive urban design (WSUD). This decision was made for Cattai Creek due to a lack of information regarding future infrastructure associated with urbanisation in the catchment and the relatively minor amounts of urbanisation expected to 2036.

A series of three modelling scenarios were undertaken to assess the impacts on the water quality of Second Ponds Creek, Cattai Creek, Eastern Creek, South Creek and the Hawkesbury River as a result of proposed upgrades to the NWTH plants, changes in catchment conditions and other plant operations (Section 3.5.3). These scenarios are:

- Baseline scenario: The Baseline scenario represents current (2020 time horizon) catchment inputs and WWTP and WRP operational treated water releases;
- Background scenario: The Background scenario represents future (2036 time horizon) catchment conditions and plant operations that are not part of the NWTH. NWTH plant releases are not upgraded and are instead modelled as the current (2020 time horizon) operations. The Background scenario provides assessment of the impacts on water quality in the waterways due to the changes in catchment conditions and plant operations external to the NWTH between 2020 and 2036 as a result.
- Impact scenario: The Impact scenario represents future conditions for both the catchment and NWTH upgrades at all plants in the WQRM domains. Comparison against the Background scenario therefore allows assessment of impacts on water quality due exclusively to the proposed upgrades to NWTH plants and the consequent change to their treated water releases.

Table 9 provides a matrix of the scenarios assessed and the change in variables expected for each.

Table 9 Scenario descriptions for Northwest Treatment Hub water quality and hydrodynamic modelling

Scenario	Landuse and Catchment Conditions	Representative Period in Time	NWTH Plant Flows	All other Plant Flows
Baseline	2017	2020	2020	2017/20
Background	2036	2036	2020	2036
Impact	2036	2036	2036	2036

3.5.3.1 Scenario Durations and Representative Years

All three scenarios were run over a duration of two years and two months. This simulation duration incorporated the following time periods and climatic conditions:

- 1st May 2013 to 30th June 2013 – a two month 'warm up/conditioning' period to allow the models to adjust to new loading conditions, not included in subsequent analysis
- 1st July 2013 to 30th June 2014 – a representative dry climatic year (~510 mm/year)
- 1st July 2014 to 30th June 2015 – a representative wet climatic year (~1060 mm/year)

Simulation of the two climatic years was undertaken to address the principal question of how do wet and dry conditions affect impacts from the NWTH plant releases. The assessment of impacts on water quality under such different climatic conditions is a standard approach because different catchment influences may become more predominant under wet or dry conditions.

The use of wet and dry years provides for an upper and lower range of impacts that could be expected with any given year existing between these values. The modelling of an average year is therefore expected to fall within these boundaries. If plant operations are shown to fail in achieving the waterway objectives of Section 2.2 for either of these representative climate conditions, it can be expected that the average year will also fail to achieve them. By the same argument, however, if the operation of these plants is shown to achieve the waterway objectives for both typical wet and dry years, the average year can be expected to achieve the waterway objectives.

The two representative climatic years were selected based on decile analysis of rainfall over a 25-year period from 1994 through to 2019. Records from the following meteorological stations were analysed: Penrith, Richmond, South Creek and Annangrove. The median rainfall for this period varied between 710 and 860 mm/year across the four stations. Refer to Figure 9 for a representation of the South Creek rainfall data.

The WQRMs were initialised at the start of the simulation period using initial condition files that provided spatial distribution for each parameter throughout the waterways, derived from the analysis of field monitoring data.

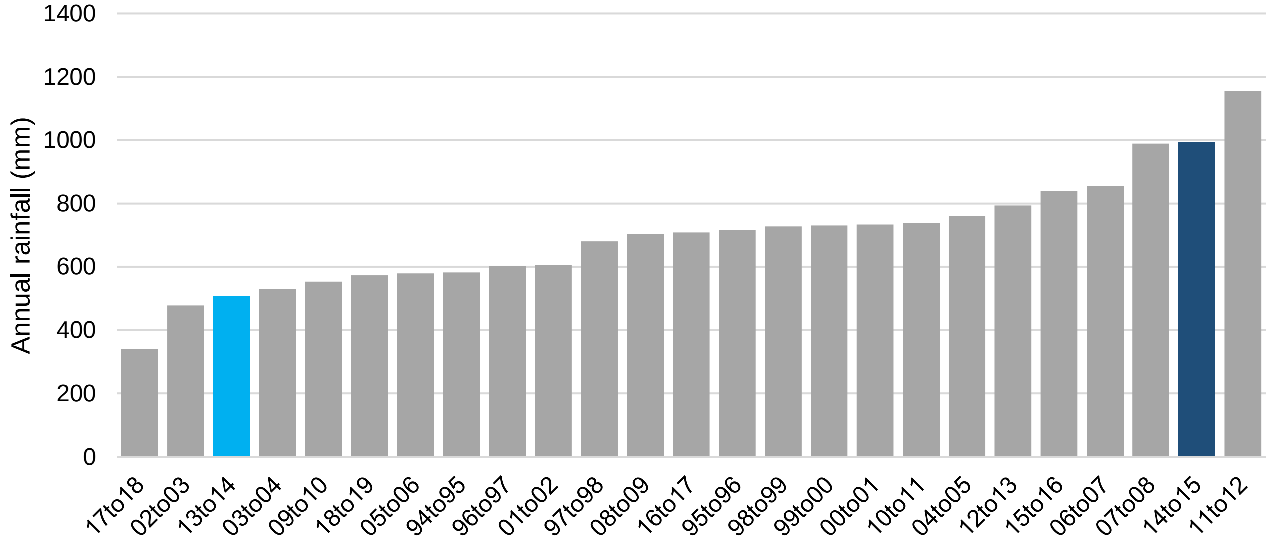

Figure 9 South Creek annual rainfall in increasing annual

3.5.3.2 Scenario Data

3.5.3.2.1 Treatment Performance

The anticipated treatment performance for the NWTH plants has been derived from data sourced using Sydney Water's web-based operational data platform Effluent Knowledge and Management System (EKAMS). This data has then been altered using interpolation and modifications to flow rates and water quality to reflect the plant changes proposed for this project.

The modelled median treated water quality outcomes for NWTH plants under current and future conditions is provided below in Table 10. The median water quality concentrations presented represent conservative estimates of treatment outcomes. Sydney Water expects nutrient concentrations to be lower than those presented here.

Table 10 Median treated water quality assumptions for NWTH plants under current and future conditions.

Water Quality Parameter	Castle Hill WRP		Rouse Hill WRP		Riverstone WWTP	
	Current (2020)	Future (2036)	Current (2020)	Future (2036)	Current (2020)	Future (2036)
Total Nitrogen (TN) (mg/L)	15.76	6.22	7.01	5.04	2.40	3.05
Ammonia (mg/L)	0.10	0.19	0.10	0.20	0.01	0.23
Oxidised Nitrogen (NOx) (mg/L)	14.5	4.98	0.09	3.81	1.37	1.81
Total Phosphorus (TP) (mg/L)	0.11	0.024	0.018	0.021	0.018	0.050
Salinity (g/L)	0.49	0.48	0.46	0.45	0.54	0.54
Dissolved Oxygen (mg/L)	5.9	5.9	5.9	5.9	5.9	5.9
Enterococci (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0
E. coli (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0

3.5.3.2.2 Treated Water Discharge Volumes

Upgrading of the WWTP and WRPs will increase the capacity of the plants, improve quality of treated water and result in increased average dry weather flows (ADWF) as treated water release. The anticipated changes in release flows are outlined in Table 6.

Table 11 Projected ADWF for Northwest Treatment Hub plants by year

NWTH Plant	Projected ADWF Capacity (ML/d)		
	2021 (Current)	2026	2036
Castle Hill WRP[1]	6.9	8.2	10.1
Rouse Hill WRP[2]	28.1	32.1	42.6
Riverstone WWTP[3]	13.1	17.4	27.8

1. Castle Hill Wastewater Treatment Plant Report (Sydney Water, 2021a)
2. Rouse Hill Wastewater Network Capacity Report (Sydney Water, 2021b)
3. Riverstone Wastewater Network Capacity Report (Sydney Water, 2021c)

The change in capacity outlined above has been developed in response to project changes in equivalent population (EP) across the NWTH wastewater treatment network. Across the NWTH servicing catchments, EP is forecasted to increase from 276,000 EP in 2021 to 534,000 EP in 2036, an increase of approximately 195%.

Of the three NWTH plants, the Riverstone WWTP has been identified as the primary treatment facility to service this increase in EP. As such, its EP is expected to increase from 60,000 EP in 2021 to approximately 225,000 EP in 2036, an increase of more than 370%.

The Rouse Hill WRP is also predicted to nearly double its EP between 2021 and 2036, increasing from approximately 147,000 EP to roughly 229,000 EP in that time, an increase of ~155%.

Castle Hill WRP will also experience some growth during this time, with a predicted increase in EP of approximately 28,000 EP, growing from approximately 37,000 EP to an estimated 65,000 EP.

3.5.3.2.3 Additional WWTPs and WRPs Within the WQRM Domains

Throughout the scenarios, the boundary conditions for the other relevant WWTPs and WRPs were developed using spreadsheet models so their flows and treated water quality could be representative of the relevant time horizons (2020 or 2036).

To calculate release volumes, the daily flows from monitoring data were adjusted in line with expected population growth, assumed rates of reuse, network transfers, as well as any forecasted changes in inflow and infiltration to the sewerage system.

Treated water quality concentrations of key contaminants for plants other than the NWTH were adjusted to reflect any planned upgrades that have been agreed to with the EPA as well as the proposed AWRC in Upper South Creek that is currently being reviewed by the EPA. Variability in water quality parameters was also included in line with historical monitoring data or forecasted performance of the WWTPs and WRPs. The location of the treatment plants within the Source and WQRM domains is presented in Figure 10.

Figure 10 Location of WWTPs and WRPs within the Source and WQRM domains

The wider Hawkesbury Nepean catchment contains an additional 17 treatment plants including the AWRC and St Marys Advanced Water Treatment Plant (AWTP). For five of these plants, variations in treatment standards (high and low loading conditions) have been considered, however, the low loading condition has been adopted to provide a conservative estimate of impacts from the NWTH upgrades. This conservative estimate is achieved by comparison to both concentrations and total loads as the relative contributions to each from the NWTH plants are increased. The five plants where low loading has been adopted are Penrith WRP, Picton WRP, West Camden WRP, Wilton WRP and Winmalee WWTP. The assumed treatment standards are also presented in Table 12.

Table 12 Assumed treatment standards for other WWTPs and WRPs for current and future conditions.

Plant Name	Median concentrations			
	TN 2020 (mg/L)	TN 2036 (mg/L)	TP 2020 (mg/L)	TP 2036 (mg/L)
AWRC	N/A	0.35	N/A	0.009
St Marys	3.2	2.5	0.02	0.04
Quakers Hill	5.0	1.6	0.07	0.03
South Windsor[1]	5.8	2.5[3]	0.20	0.04[3]
McGrath Hill[1]	3.6	2.5[3]	1.10	0.04[3]
Penrith	4.5	0.73	0.070	0.014
Winmalee	6.7	2.5[3]	0.14	0.04[3]
Picton	5.0	3.0[3]	0.02	0.05[3]
Wilton	N/A	2.5	N/A	0.05
West Camden	7.8	2.5[3]	0.03	0.03[3]
St Marys AWTP	0.28	0.35	<0.005	0.009
Brooklyn	3.4	3.4	0.03	0.03
Hornsby heights	3.6	4.0	0.04	0.05
North Richmond[2]	6.0	N/A	0.11	N/A
Richmond	6.0	4.0[3]	0.03	0.04[3]
Wallacia	4.0	5.0	0.02	0.05
West Hornsby	4.0	4.0	0.05	0.05

Table notes:

[1] *WWTP operated by Hawkesbury City Council*

[2] *North Richmond WWTP to close with diversion to Richmond WRP*

[3] *Water quality assuming planned upgrade (capacity and/or treatment) to WWTP/WRP*

3.5.3.2.4 Landuse

Landuse layers have previously been developed for two distinct time horizons: 2017 and 2036. These layers represented a key input layer in the Source modelling that was undertaken to simulate the catchment flows and loads for each of the scenarios.

The 2017 landuse layer was generated using base data from NSW Government's Office of Environment and Heritage (OEH). The landuse distribution was then modified and cross checked with Sydney Water Hydra Lot coverage, Google Earth images, land zoning from Local Environmental Plans, and other data layers available from the OEH. Landuse categories applied in this layer included: High Density Urban, Urban, Peri-Urban, Commercial, Industrial, Environmental Living, Cropping, Agriculture, Grazing, Infrastructure/Utilities, Forest, Airport, Mining, Open Space and Developable land.

The 2036 layer was subsequently developed through GIS analysis of the 2017 layer and consolidated growth forecast geospatial data prepared by Sydney Water. For the South Creek catchment additional information was used to inform the 2036 landuse layer including typology metrics data prepared by Cox Architect for Infrastructure NSW (iNSW) and draft information from the Western Sydney Aerotropolis (Initial Precincts) Stormwater and Water Cycle Management Study Interim Report (Sydney Water, 2020a).

Further details on the generation of landuse data and how the data was used within the Source catchment modelling to generate boundary conditions for the WQRMs were provided in the AWRC EIS documentation (Sydney Water, 2021d).

3.5.3.2.5 Extractions

As outlined in the calibration reports for the three WQRM domains (Appendices A and B), extractions for irrigators and other water users have been incorporated into the Source catchment model for all the respective tributaries and from upper sub-catchments. Similar types of extractions from the main water bodies of the Hawkesbury Nepean River and South Creek are incorporated directly within the WQRMs.

For the future scenarios, extractions were adapted for loss of agricultural land as predicted by the respective landuse layers for 2036. In this way, a 20% reduction in agricultural land within a sub-catchment would equate to a 20% reduction in daily irrigation demand at a corresponding extraction point for that catchment in the Hawkesbury Nepean River, Cattai Creek or South Creek.

3.5.3.2.6 Headwaters and Dam Operations

For all scenarios modelled in this assessment, the headwaters of each domain were assumed to be consistent with current conditions to enable a clear assessment of impact from the NWTH plant upgrades. These conditions have been held constant and have not varied.

3.5.4 Analysis and Interpretation

3.5.4.1 Approach

The assessment of the waterway outcomes for the proposed upgrades to the NWTH plant operations consisted of modelling three scenarios across the three WQRM domains:

- A baseline scenario representing the current (2020 horizon) operation of the NWTH plants and catchment conditions;
- A background scenario representing the 2036 catchment conditions and operation of other Sydney Water plants, including the AWRC, releasing treated water to the waterways, but with the current (2020 horizon) operation of the NWTH plants; and
- An impact scenario representing the anticipated 2036 catchment conditions and 2036 operations for all Sydney Water plant treated water releases in the system.

These scenarios have been further described above in Section 3.5.3.

3.5.4.2 Parameters

A range of hydrodynamic and water quality parameters were used to evaluate the anticipated waterway outcomes for the proposed changes to the operations of the NWTH plants. These were selected based on the waterway objectives outlined in Section 2.2

These parameters are listed below:

- Hydrodynamics
- Water level
- Water quality
- Nitrogen (including ammonia, NOx, TN)
- Phosphorus (including filterable reactive phosphorus, TP)
- Chlorophyll *a* (adopted as primary indicator of phytoplankton abundance and biomass)
- Salinity
- Temperature
- Total suspended solids
- Dissolved oxygen saturation
- Pathogens (including enterococci and E. coli)

Chlorophyll *a*, as noted above, has been used as a proxy for phytoplankton abundance and biomass. It is a primary indicator of waterway stress caused by nutrient loading and, therefore, algal blooms. In order to ensure that the risk of algal blooms is sufficiently covered in this assessment, chlorophyll-*a* results are complemented by an assessment of the nutrient loading to confirm that the trends are consistent.

Sydney Water has funded an investigation into algal species composition and statistical analysis of responses through the University of Western Australia (UWA) to better inform risk assessment. The results of this investigation will be used to guide the operation and planning of the NWTH plants and their treated water releases.

Near-field toxicity modelling has not been undertaken for this assessment. Castle Hill WRP does not currently use chlorine dosing in its treatment of wastewater and Rouse Hill WRP will cease chlorine dosing for dry weather treated water releases as part of a switch to a membrane bioreactor system. Riverstone WWTP will continue to use chlorine for disinfection and Sydney Water acknowledges that additional modelling of chlorine may be necessary in the future.

3.5.4.3 Results Format

Results were output for locations upstream of the treated water release locations for each plant and then downstream for the entire extent of each of the WQRM domains.

Three formats were used to evaluate the impacts of the NWTH upgrades:

- Longitudinal profiles of annual median concentrations
- Time series plots of daily concentrations
- Box and whisker plots of daily concentrations

These formats are further discussed and described in the subsections below.

3.5.4.3.1 Longitudinal Profiles

Longitudinal profile plots of the annual median concentrations for the baseline, background and impact scenarios were prepared along the spatial extent of the modelled waterways of each WQRM domain. Where applicable, the longitudinal plots also included the relevant waterway objectives for each parameter (refer to Section 2.2). For the South Creek WQRM domain's profiles, the waterway objectives also included the local values developed by EES/DPIE. Annual median results are the appropriate statistical measure for comparison to the Waterway Objectives guideline values.

Distance markers are included on the x-axis of these profiles along with the locations of key geographic markers, such as tributary confluence points. The longitudinal profiles present the predicted annual median values for the relevant simulated climatic year and were prepared for each of the water quality parameters.

An example longitudinal annual median profile is provided in Figure 11.

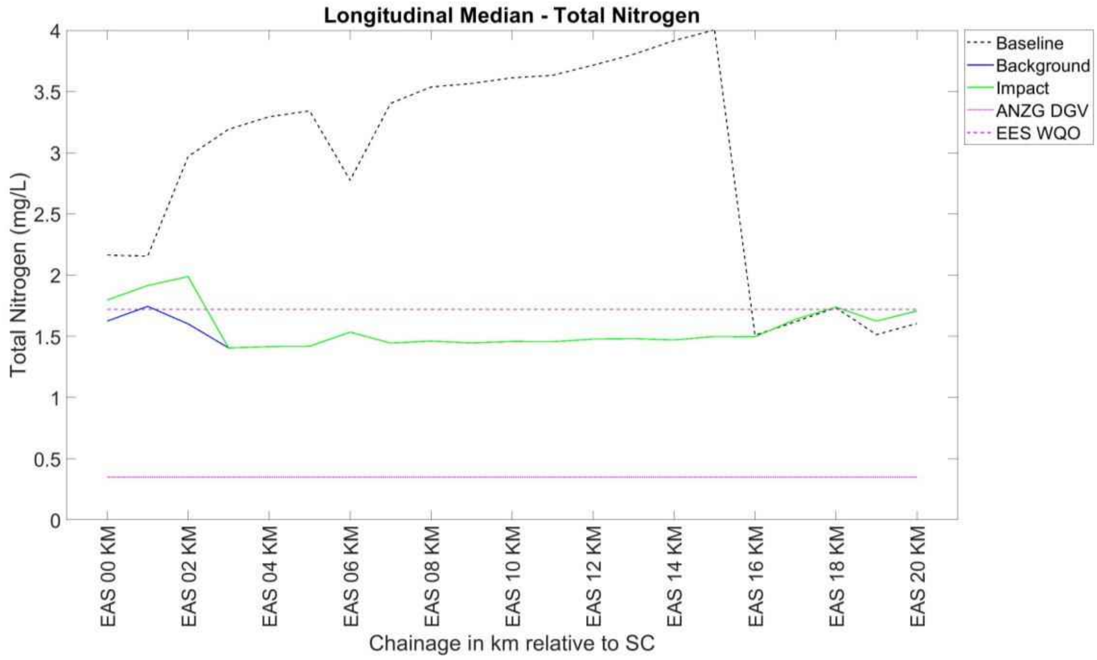

Figure 11 Example longitudinal plot for Eastern Creek

3.5.4.3.2 Timeseries and Box Plots

Timeseries plots showing the baseline, background and impact scenario results were prepared at selected analysis sites along the receiving waterways within each WQRM domain. The dates presented in these plots are representative of 'model dates' and are consistent with the scenario durations and representative climatic years discussed in Section 3.5.1.4.

The analysis sites were selected to provide a representative picture of the impacts as you travel downstream from the proposed release points in the receiving waterways. These sites of interest are presented in Figure 12, Figure 13, Figure 14 and **Error! Reference source not found.** for the Hawkesbury River, Cattai Creek and Eastern and South Creeks, respectively.

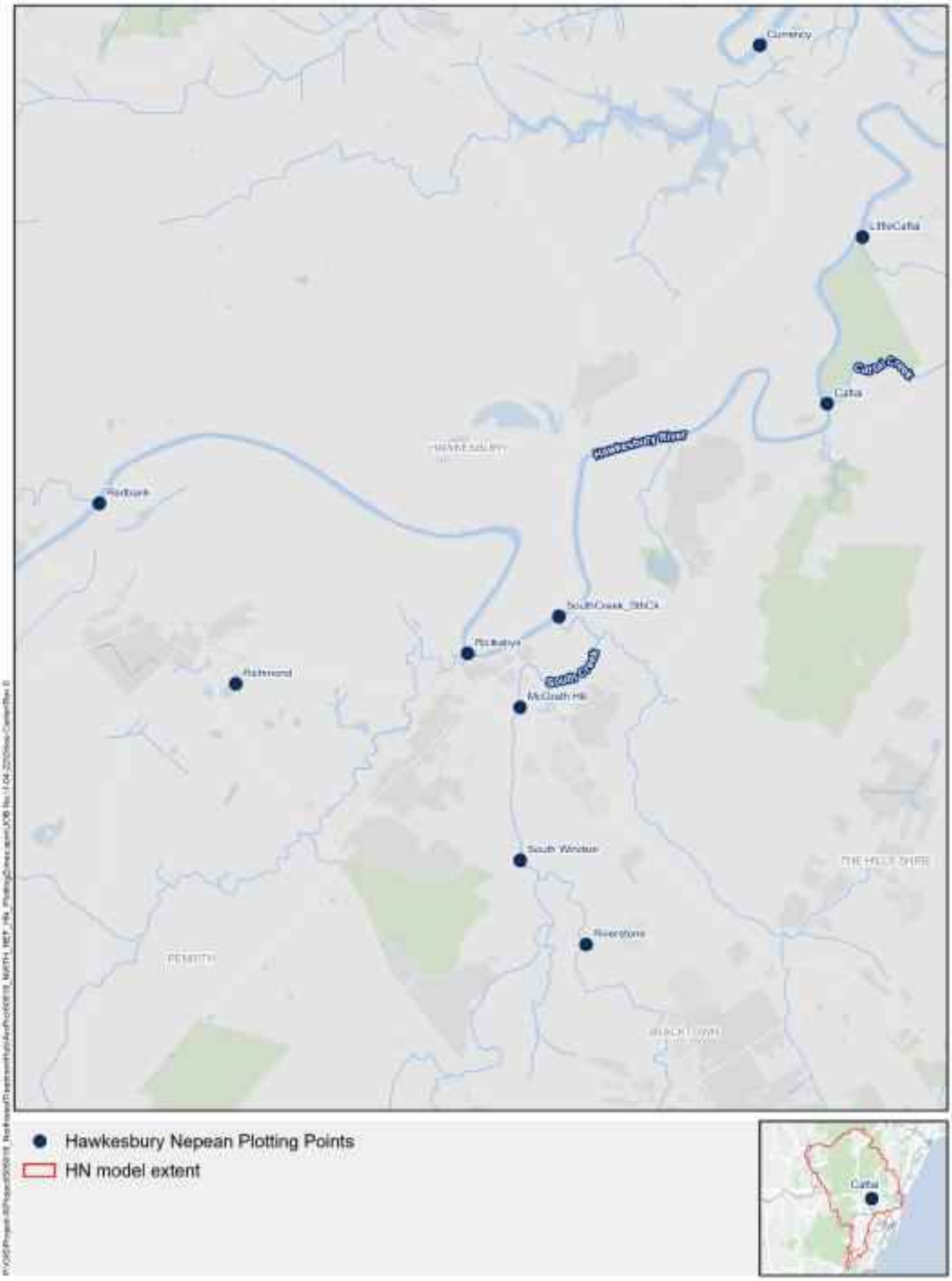

Figure 12 Analysis sites for timeseries and box plot reporting on the Hawkesbury River

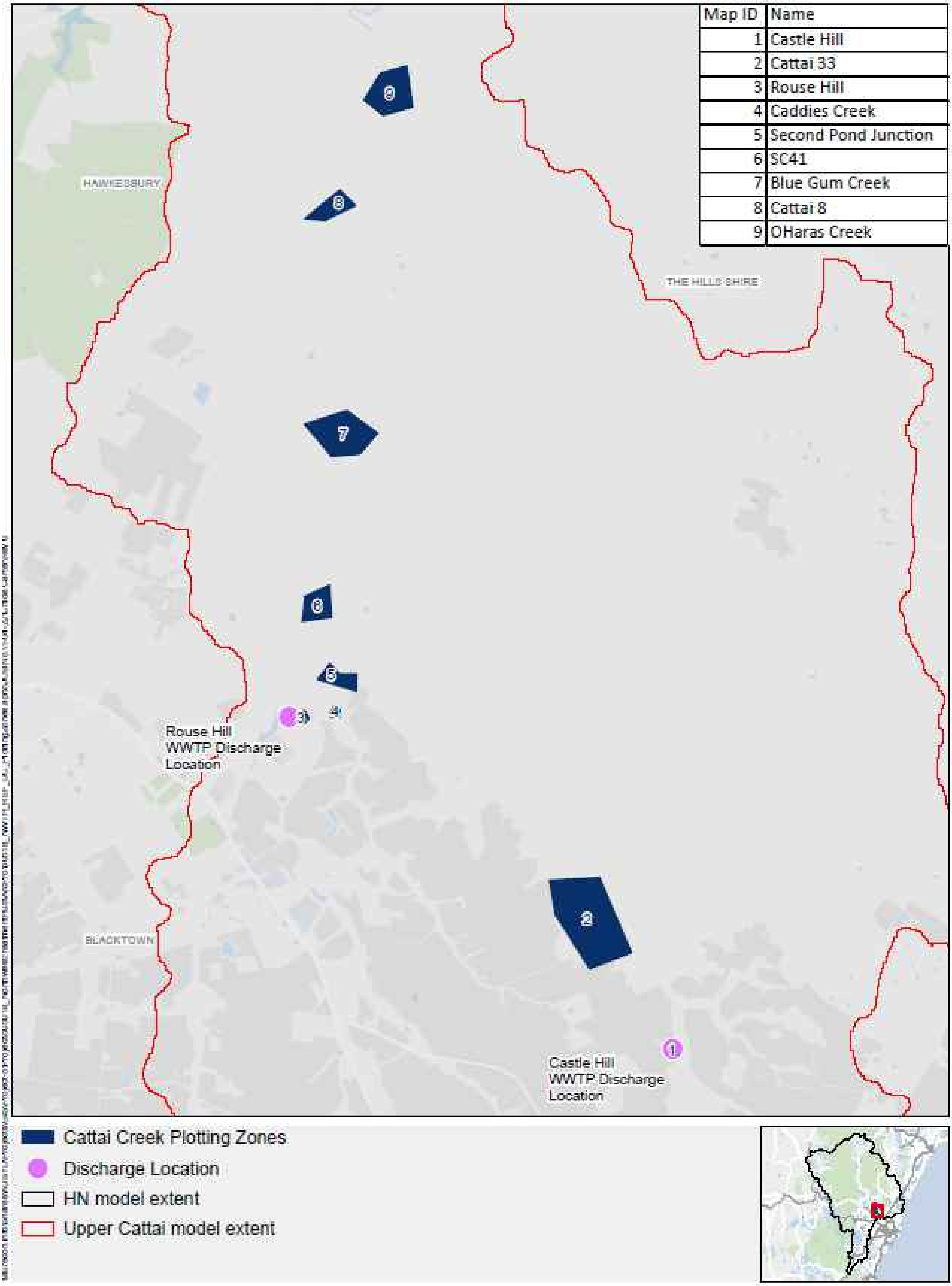

Figure 13 Analysis sites for timeseries and box plot reporting on Cattai Creek

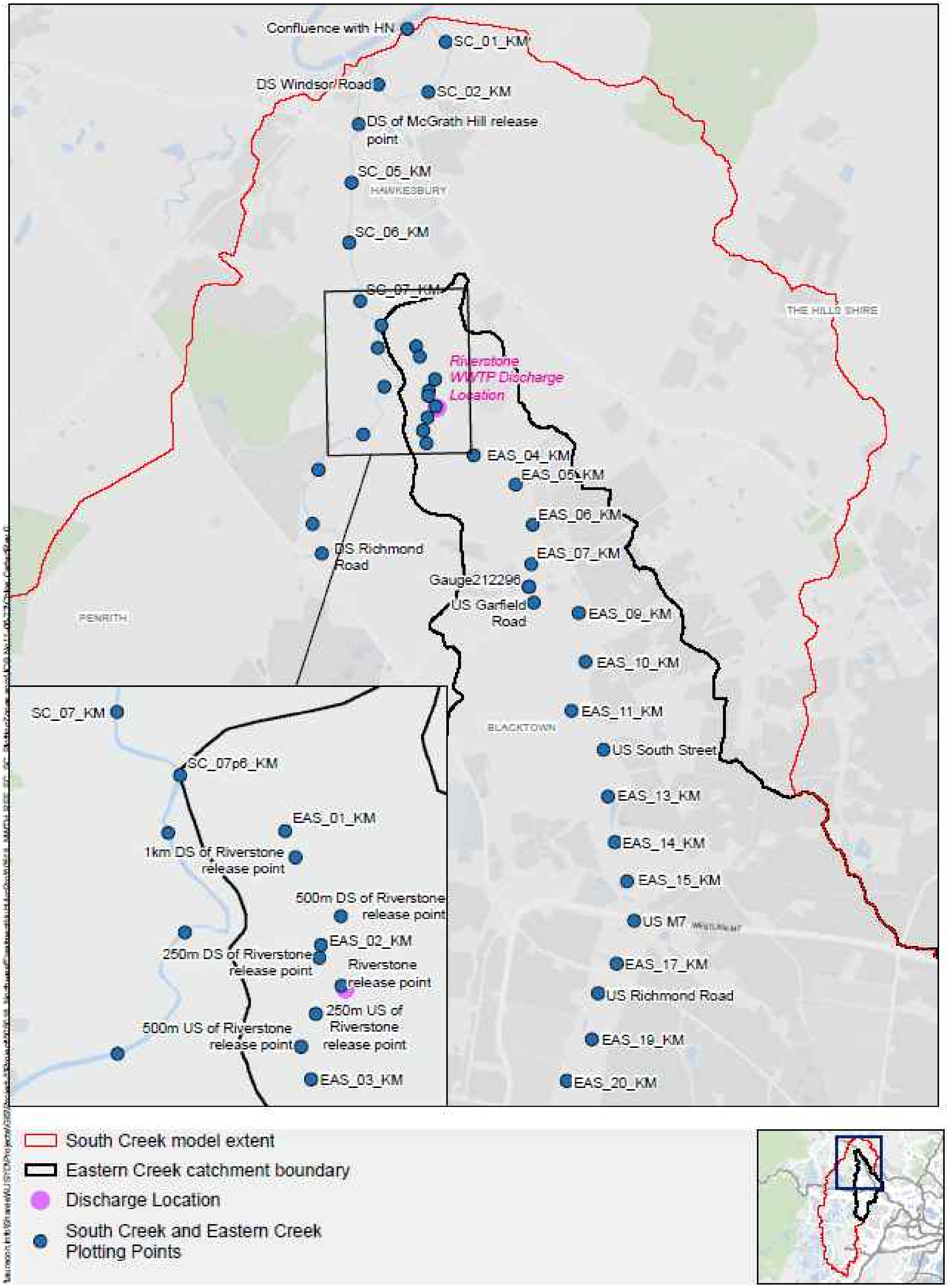

Figure 14 Analysis sites for timeseries and box plot reporting on Eastern and South Creeks

The timeseries data was also converted into box and whisker plots to allow for further evaluation of the impacts and variability of the results. In addition to the results from the different scenario types, both the timeseries and box and whisker plots also included the relevant waterway objectives for each parameter, where applicable.

Examples of the timeseries and box and whisker plots are presented in Figure 15 and Figure 16, respectively.

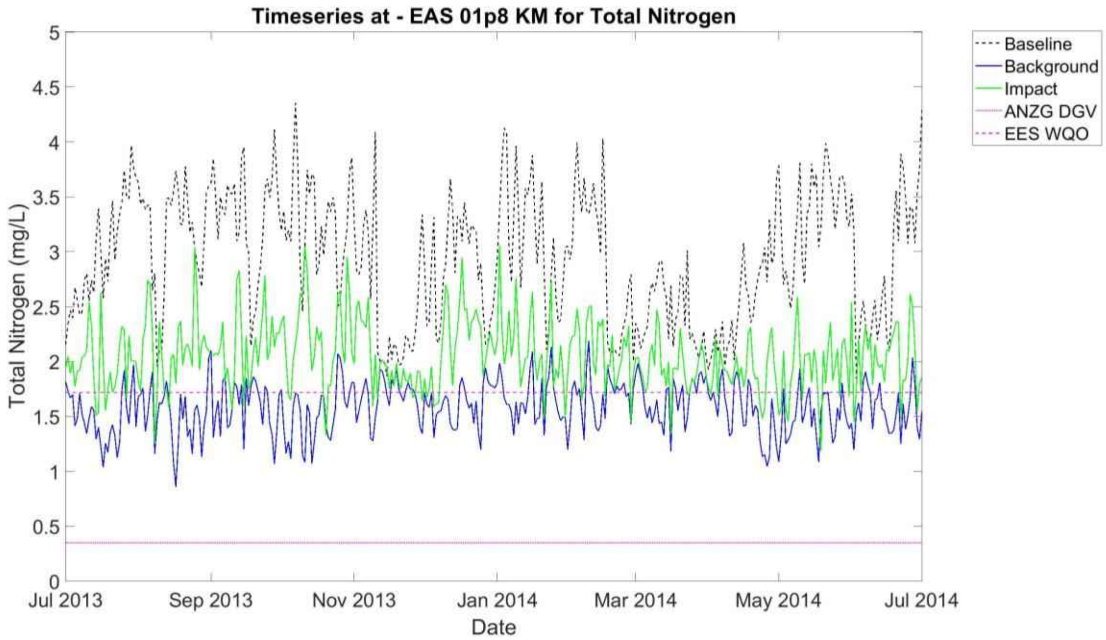

Figure 15 Example timeseries plot for Eastern Creek

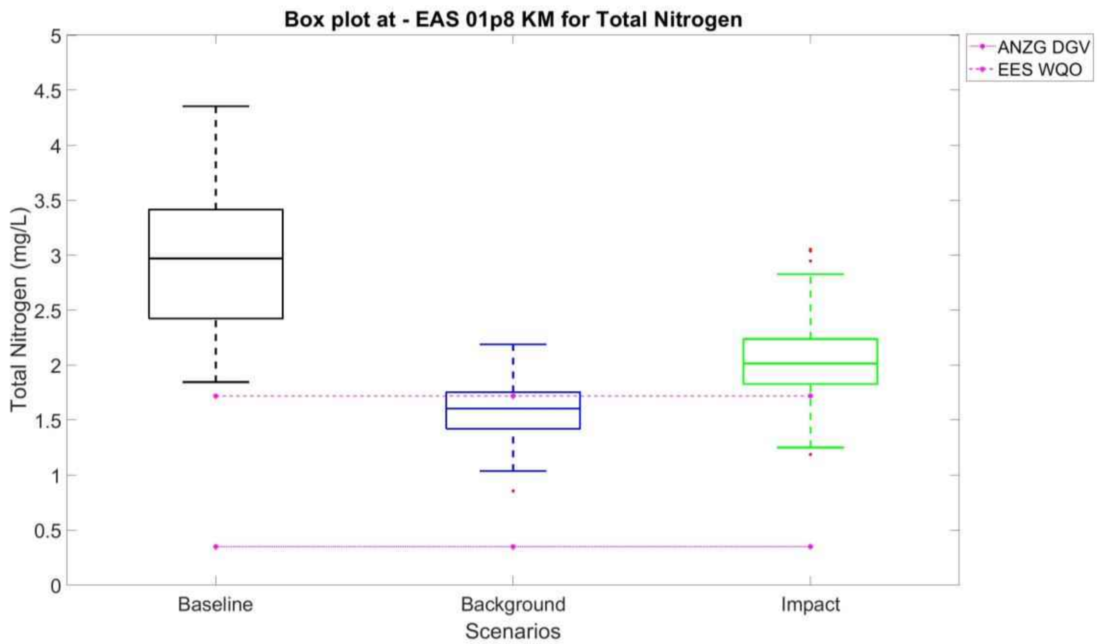

Figure 16 Example box and whisker plot for Eastern Creek

4 Existing Environment

The project includes increased releases of treated water to the receiving waterways of Cattai Creek, Second Ponds Creek, Eastern Creek, South Creek and the Hawkesbury River as a result of upgrades to the NWTH plants.

The following sections present an overview of the existing hydrodynamic and water quality conditions within these receiving waterways. From review of relevant monitoring data and previous studies, descriptions of the catchments, waterways, load estimates and the water quality conditions that currently exist in the water courses are provided.

As outlined in Section 3.1, the assessments of these waterways have been undertaken across three domains:

1. Cattai Creek Catchment
2. South Creek Catchment
3. The Hawkesbury-Nepean River Catchment.

4.1 Data Sources

4.1.1 Previous Studies

The following studies have been included as references to the description of the existing environment:

- Sydney Water Advanced Water Recycling Centre Environmental Impact Statement Hydrodynamic and Water Quality Impact Assessment (Sydney Water, 2021d)
- Sydney Water publications including Sewage Treatment System Impact Monitoring Program (STSIMP) annual data reports, environmental performance annual reports and the interpretative report 2016-17 (Sydney Water, 2018)
- Department of Environment and Climate Change Hawkesbury-Nepean River Environmental Monitoring Program – Final technical report (DECC, 2009a)
- Department of Environment and Climate Change Lower Hawkesbury-Nepean River Nutrient Management Strategy (DECC, 2009b)
- Hornsby Shire Council Waterway Health Review 1995-2017 (HSC, 2019)
- CRC for Irrigation Futures report, Water Management in South Creek Catchment: Current state, issues and challenges (CRC, 2007)
- SKM report, Water Quality Modelling of the Hawkesbury Nepean River System (SKM, 2014)
- Hawkesbury Nepean and South Creek Source Model Calibration (Sydney Water, 2021e)

4.1.2 Monitoring Datasets

The following monitoring datasets and sources were used to characterise the existing environment.

- Sydney Water - routine streamflow/gauge and water quality monitoring data, upstream/downstream water quality monitoring of WWTP/WRP releases as well as wet and dry weather intensive sampling
- DPIE/EES - transect and buoy water quality data
- WaterNSW - routine streamflow/gauge and water quality monitoring data
- Hornsby Shire Council - routine water quality monitoring (sonde and monthly nutrients)

The location of the monitoring sites relevant to these programs within the WQRM domains are presented in Figure 17.

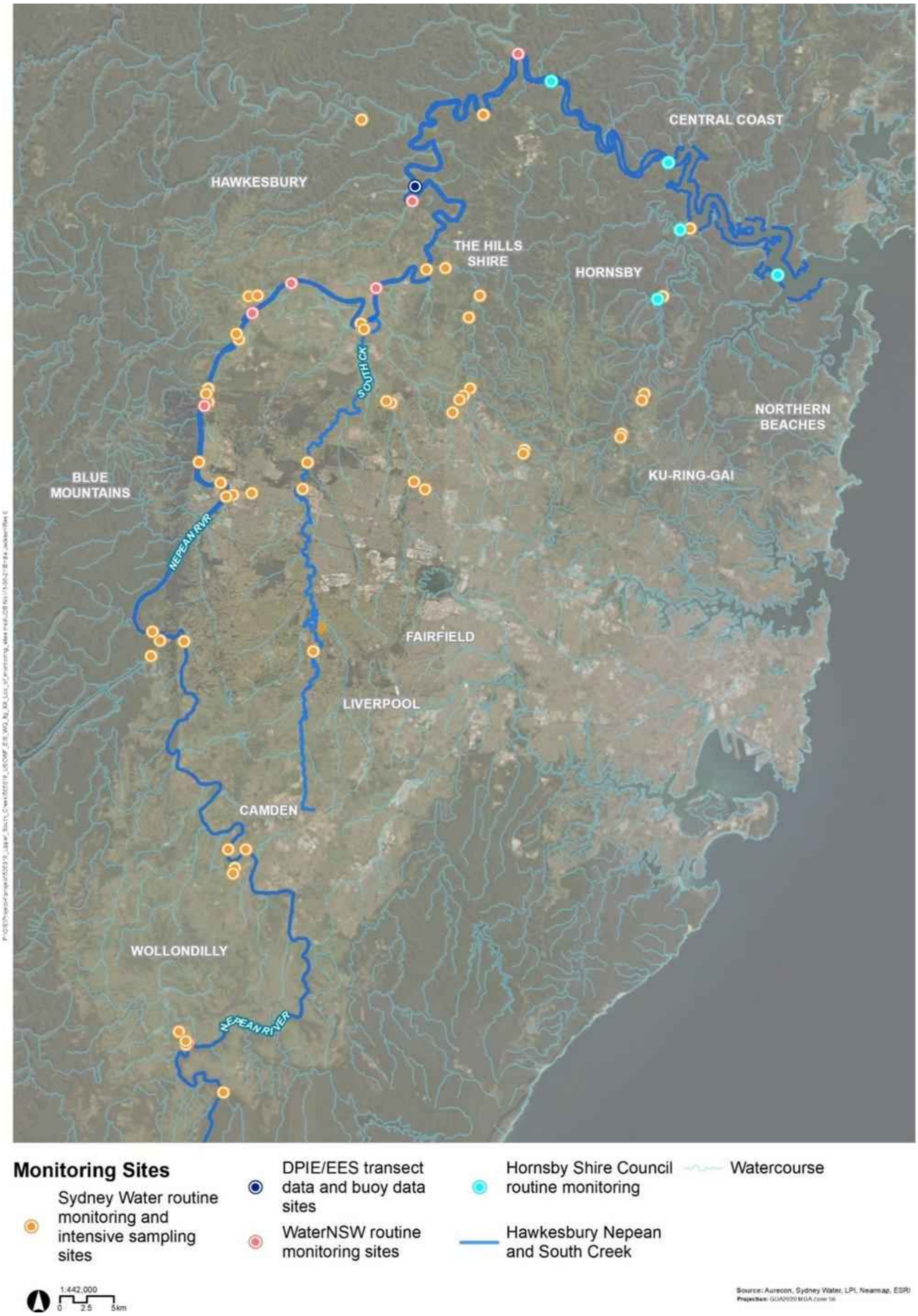

Figure 17 Waterway monitoring site locations

4.2 Cattai Creek and Second Ponds Creek

4.2.1 Catchment Description

The Cattai Creek catchment covers an approximate area of 188 km^2 with its headwaters in Castle Hill and descending to a confluence with the Hawkesbury River in the Cattai National Park.

The creek retains natural drainage characteristics for a large portion of the Hills LGA, including the suburbs of Castle Hill, Glenhaven, Beaumont Hills, Rouse Hill, North Kellyville, Annagrove, Maraylya and Cattai.

The catchment is dominated by urban and peri-urban landuse, with intact forest in the lower reaches. Grazing and agricultural landuses are present in the catchment along with minor amounts of light industrial and high-density commercial landuses. A map of the catchment landuse and relevant waterways for the wider catchment is provided in Figure 18.

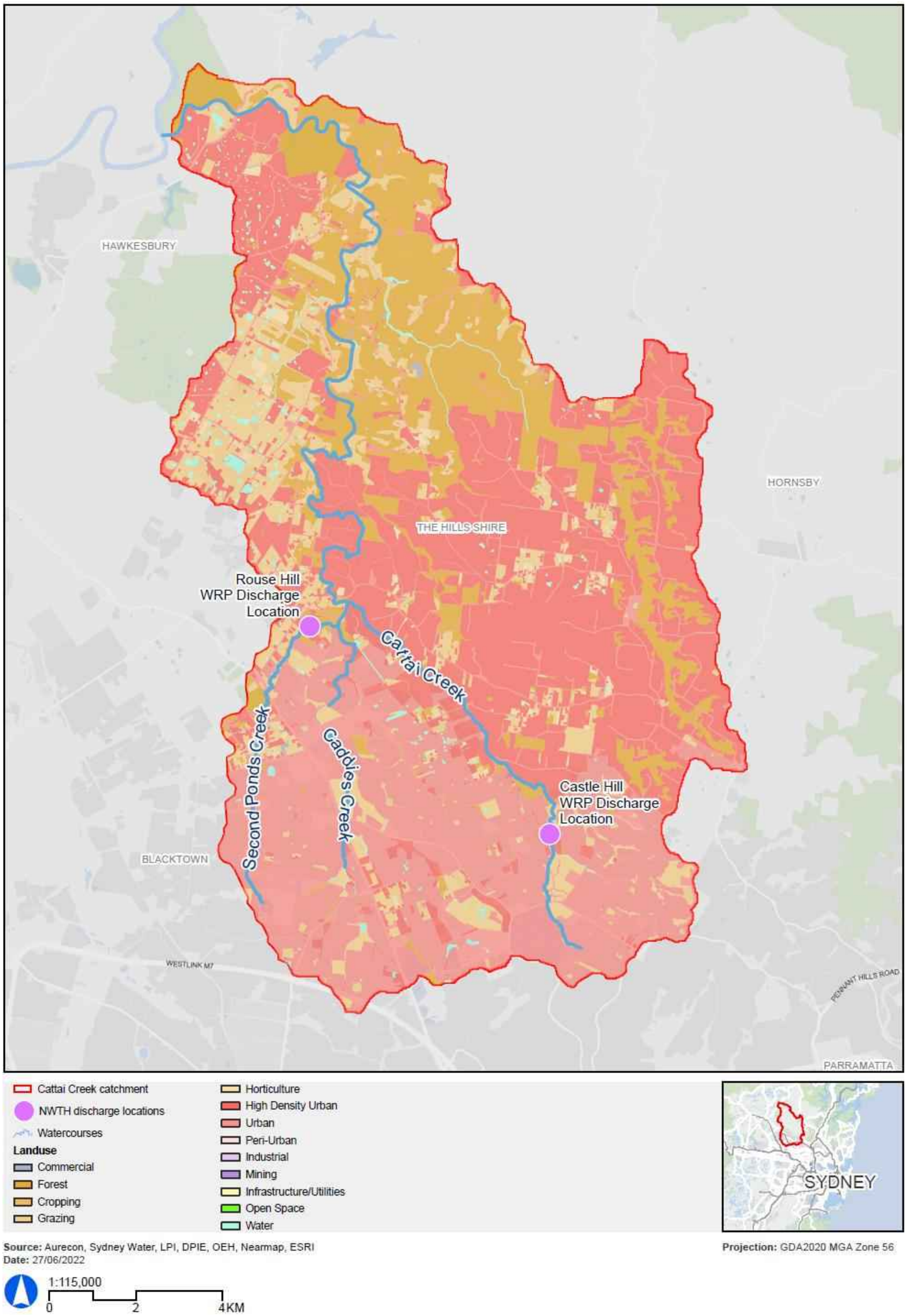

Figure 18 Cattai Creek catchment landuse

Second Ponds Creek catchment covers 11 km² and is a sub-catchment within the greater Cattai Creek catchment. Located within the Blacktown LGA, the catchment has experienced significant development pressures in the 21st century. Despite this, Second Ponds Creek has largely been conserved in response to efforts by developers and the local community to use integrated water management (IWM) for effective stormwater and waterway outcomes (O'dea & Nakkan, 2012). The landuse of the catchment is summarised in Figure 19.

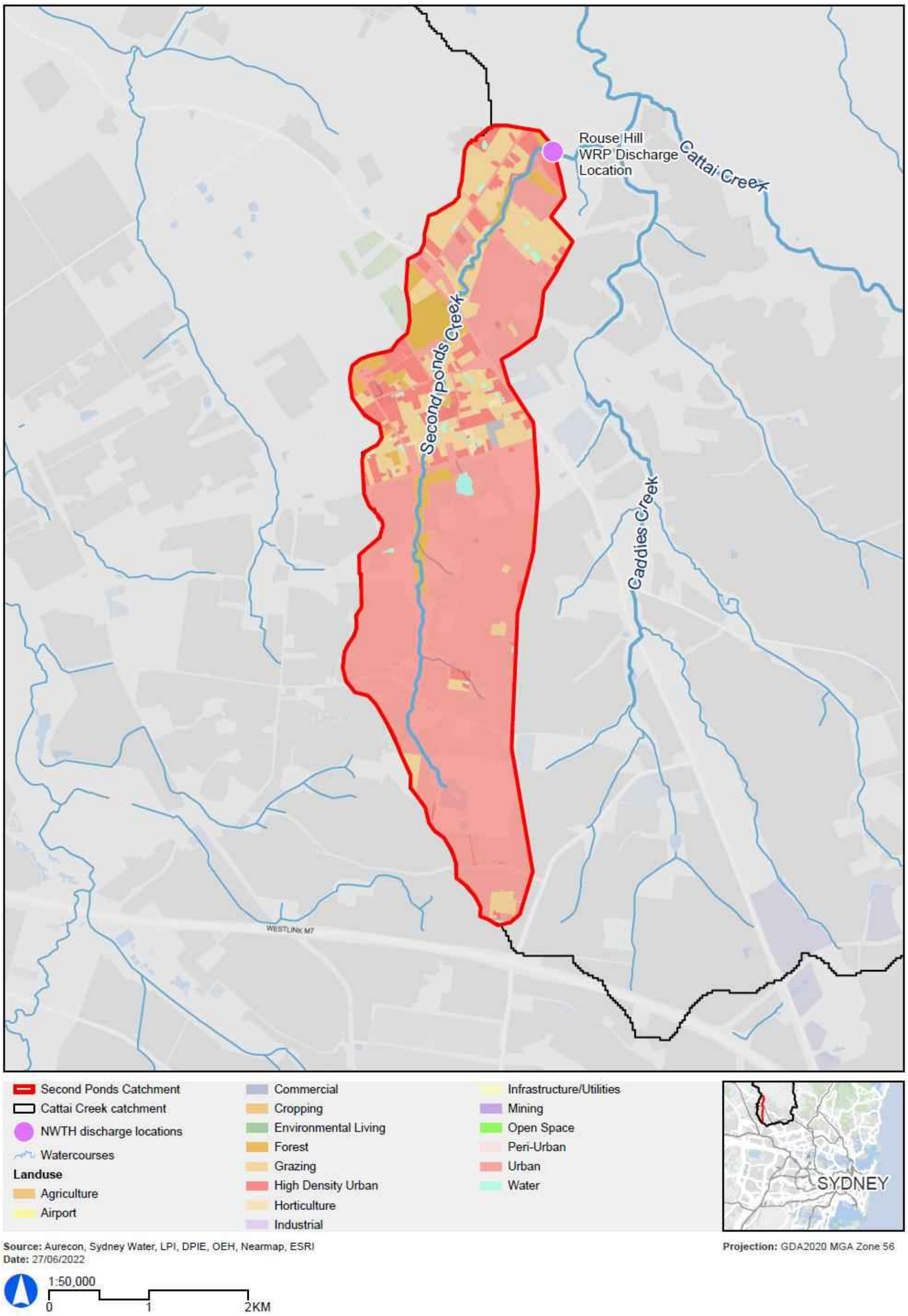

Figure 19 Second Ponds Creek catchment landuse

4.2.2 Waterway Description

Cattai Creek is a meandering creek originating in the hills of Castle Hill, Northwestern Sydney, at an elevation of approximately 80 m AHD before descending to approximately 3 m AHD at the confluence with the Hawkesbury River.

The three main tributaries contributing significant volumes to Cattai Creek are Caddies Creek (of which Second Ponds Creek is a tributary), Blue Gum Creek and O'Hara's Creek. The Second Ponds Creek catchment covers 11 km^2 with the Rouse Hill WWTP discharging 800 m from the downstream end of the catchment into Caddies Creek. Downstream a further 600 m, Caddies Creek discharges into Cattai Creek.

Castle Hill WRP releases treated water into the main stem of Cattai Creek, approximately 8.5 km upstream of where Caddies Creek enters the system.

Cattai Creek has several formal road crossings along its length that vary in form from reinforced concrete box culvert crossings to formal bridges. Aerial imagery suggests that some informal crossings may be present within the creek, but this has not been verified. The creek is tidally influenced for 9 km upstream of its confluence with the Hawkesbury River, in the vicinity of the Cattai Ridge Road bridge (NSW Department of Natural Resources, 2006).

Cattai Creek's riparian vegetation is largely intact in the reaches upstream of the Pitt Town Road Bridge, due in part to the steepness of the creek's banks in this region. Below this, agricultural landuses along the banks of the creek have resulted in the degradation of riparian vegetation until the confluence with the Hawkesbury River. The exception to this lower section of degraded riparian vegetation is Mitchell Park, where approximately 2 km of the creek is well vegetated in the riparian corridor.

Second Ponds Creek originates in Parklea approximately 300 m south of the Parklea Correctional Centre. The creek bisects the large residential estate of "The Ponds", an urban neighbourhood that has been designed and constructed around the waterway (O'dea & Nakkan, 2012). The waterway has thus been treated as an opportunity for amenity and stormwater treatment and abatement. As a result, the riparian corridor of the waterway is in excellent condition.

4.2.3 Pressures and Water Management Issues

The Cattai Creek catchment and Second Ponds Creek are focal points of several community led initiatives and groups such as the Cattai Hills Environmental Network (CHEN) and NSW Landcare and have been recognised as valuable waterways for the communities of The Hills and Blacktown LGAs. Significant land clearing for agriculture, pasture and development has occurred in the catchment since the early 20th century, and, as such, the catchment is heavily altered from its natural state. Figure 18 and Figure 19 provide details of current landuse in the Cattai Creek and Second Ponds Creek catchments, respectively.

Specific water management issues within the catchment include:

- Water quality issues: excess nutrients, algal growth and aquatic weed growth
- Agriculture and grazing pasture: practices involving fertiliser use and riparian clearing for water access as well as increased nutrient loading from cattle and animal husbandry
- Water accounting: the need to meter and more effectively regulate licence holders to account for water extraction
- Point source pollution: increases in pollutant loads from treated wastewater due to population growth. Rouse Hill and Castle Hill WRPs expected to experience growth in catchment populations of 150,000 to 235,000 people and 43,400 to 65,400 people, respectively, between 2020 and 2036.

Development pressures within the catchment are not expected to be on pace with other regions of Wester Sydney, and it is expected that the existing pressures and management issues within the catchment will remain the primary concerns into the 2036 horizon with limited enhancement to pressures from urbanisation and development. A discussion of the anticipated landuse change is provided in Section 3.5.3.2.4.

4.2.4 Load Analysis

Analysis of TN and TP loads has been undertaken to allow comparison of the contributions from various catchment conditions and NWTH plant operations under current conditions for a representative dry year (assuming 2013/14 rainfall) and a representative wet year (assuming 2014/15 rainfall), as explained in Section 3.5.1.4. The load analyses for TN shown in Figure 20 and Figure 21 present the cumulative loads from upstream to downstream for all sources (including Sydney Water's WRPs) in Cattai Creek and Second Ponds Creek, respectively. TP loads are provided in Figure 22 and Figure 23 for Cattai Creek and Second Ponds Creek, respectively.

It can be concluded from the load analysis that the WWTPs and WRPs currently present a major contribution to the total nutrient loads for Cattai Creek, especially during the dry year when the catchment flows are estimated to be relatively low. Under these drier conditions, the WWTPs contributed ~80% of TN load and ~32% of TP load. In the wet year analysis, the WWTP loads reduced to lower relative levels, but the contribution was still sizeable ~60% of the TN load and ~28% of the TP load.

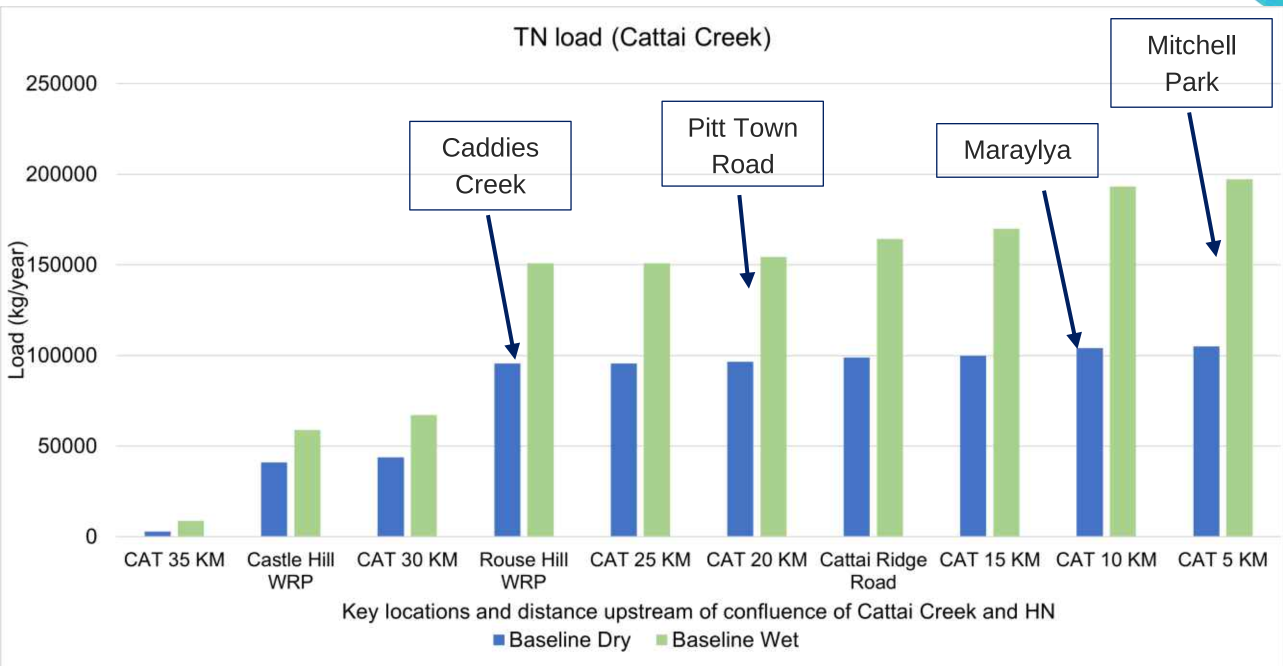

Figure 20 TN loading for Cattai Creek in typical wet and dry years under existing conditions

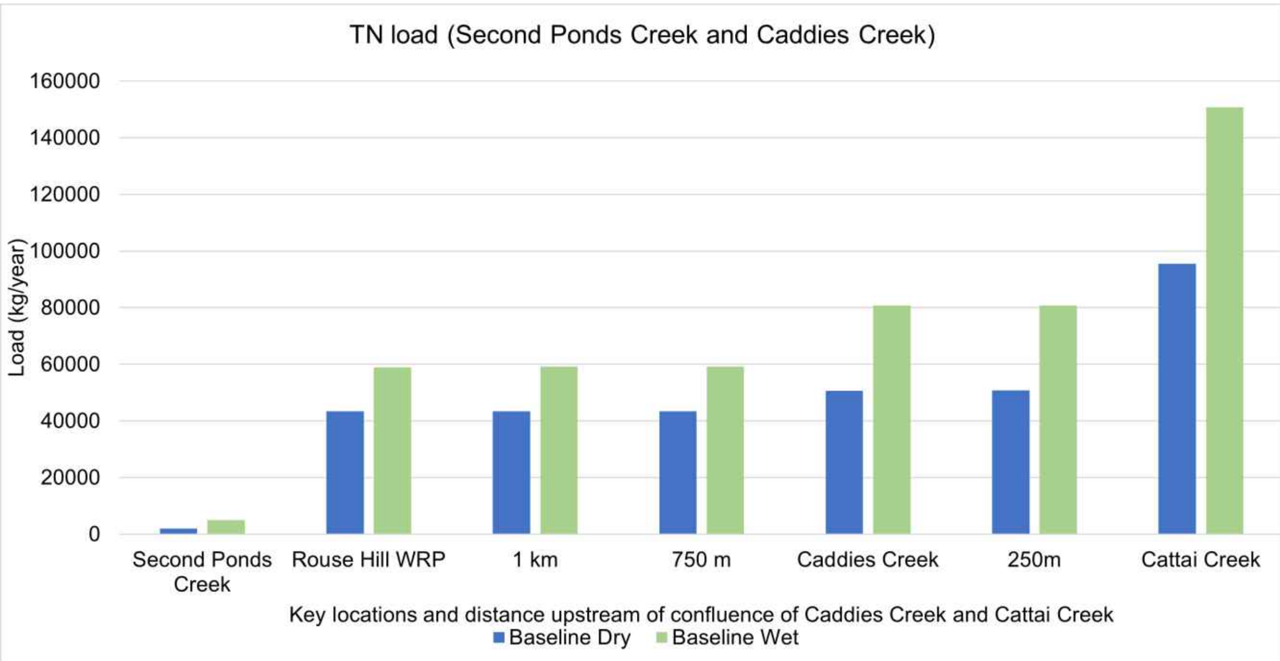

Figure 21 TN loading for Second Ponds Creek in typical wet and dry years under existing conditions

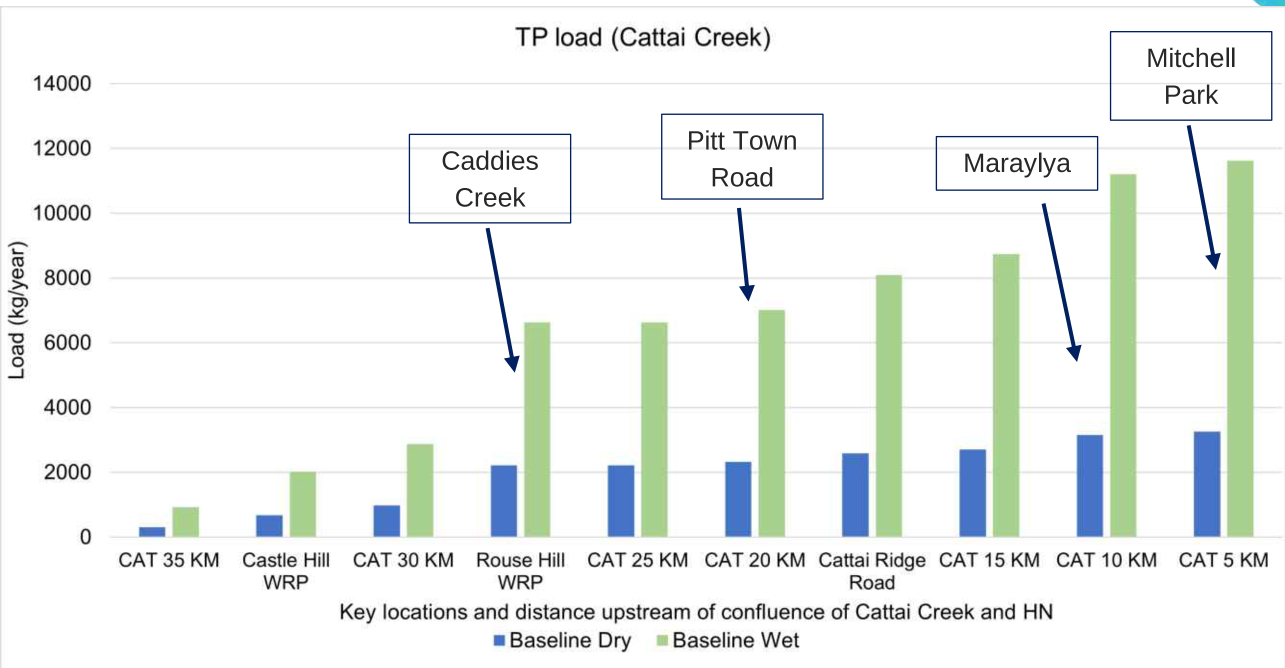

Figure 22 TP loading for Cattai Creek in typical wet and dry years under existing conditions

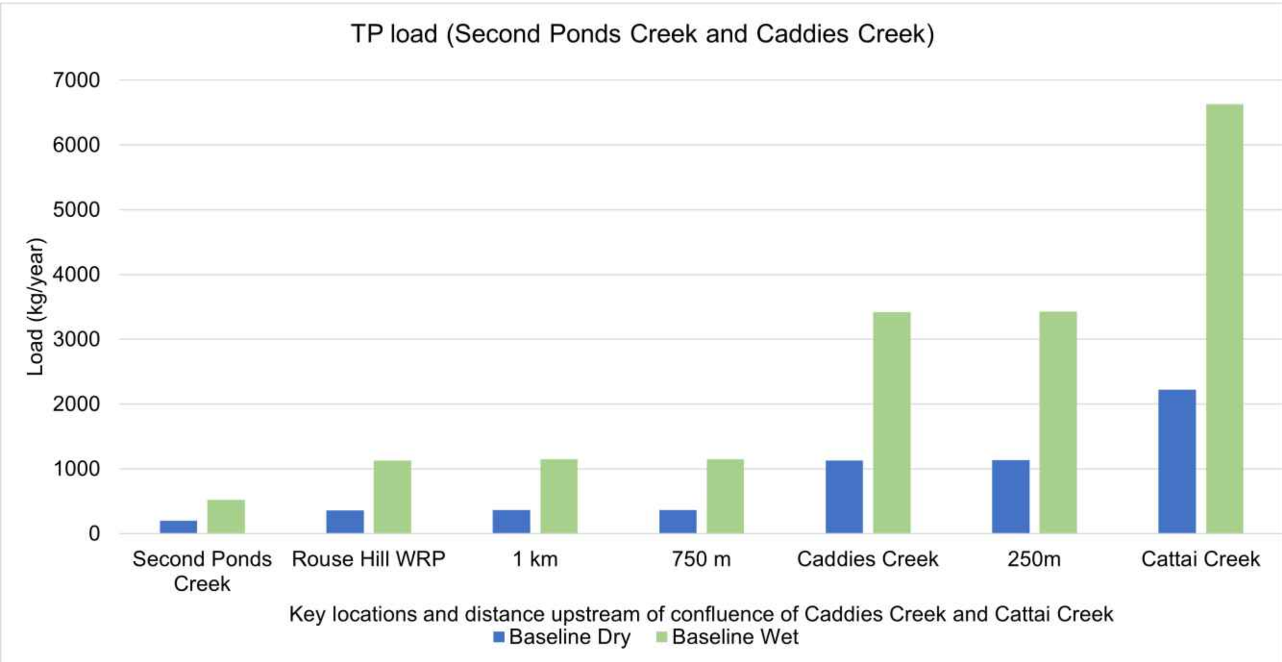

Figure 23 TP loading for Second Ponds Creek in typical wet and dry years under existing conditions

4.2.5 Water Quality

The following sections present the findings of recent studies and analysis into the water quality of Cattai Creek, focusing on the primary water quality processes of concern; nutrients, and algal growth. Of important note is that there is limited monitoring data available within the Cattai Creek catchment.

4.2.5.1 Nutrients

Figure 24 through Figure 26 present concentrations of TN, TP and chlorophyll-*a*, respectively, for Cattai Creek against similar data collected in the 2012/13, 2013/14 and 2014/15 water years for the Hawkesbury-Nepean River and South Creek.

As presented in these figures, data was only available for two sites in the lower reaches of Cattai Creek for the specified study periods. Further upstream, in the reaches of Cattai Creek above Cattai Ridge Road, the availability of water quality data is relatively limited. The sparsity of water quality data has also been recognised as a limitation by The Hills Shire Council who were recently considering establishing a monitoring site within the catchment (L. Vallejo, pers. comm 27/04/2021).

Despite the data limitations, the results provide a valuable insight into the water quality of the creek, indicating the waters are relatively rich in nitrogen. The TN concentrations of Cattai Creek have been reported to be in a similar range to those reported in the lower reaches of South Creek and relatively higher than those in the Hawkesbury-Nepean River immediately downstream of its junction with Cattai Creek by as much as 1.5 mg/L.

In contrast to TN, the TP concentrations are in a similar range to the Hawkesbury River (0.05 mg/L to 0.15 mg/L) in the region of the Cattai Creek junction and relatively lower to those reported in the lower reaches of South Creek by potentially as much as 0.30 mg/L. This suggests that Cattai Creek is a lesser contributor to algal blooms in the Sackville bend region than South Creek.

4.2.5.2 Algae

With respect to chlorophyll-*a* concentrations, the range in Cattai Creek is reportedly similar to the lower reaches of South Creek and lower than the Hawkesbury River in the region of its junction with Cattai Creek by as much as 25 to 40 µg/L in dry year conditions (2013/2014) and as little as 5 to 10 µg/L in wet year conditions (2014/2015). This further supports the suggestion that Cattai Creek is not a principal driver of algal blooms within the Hawkesbury River.

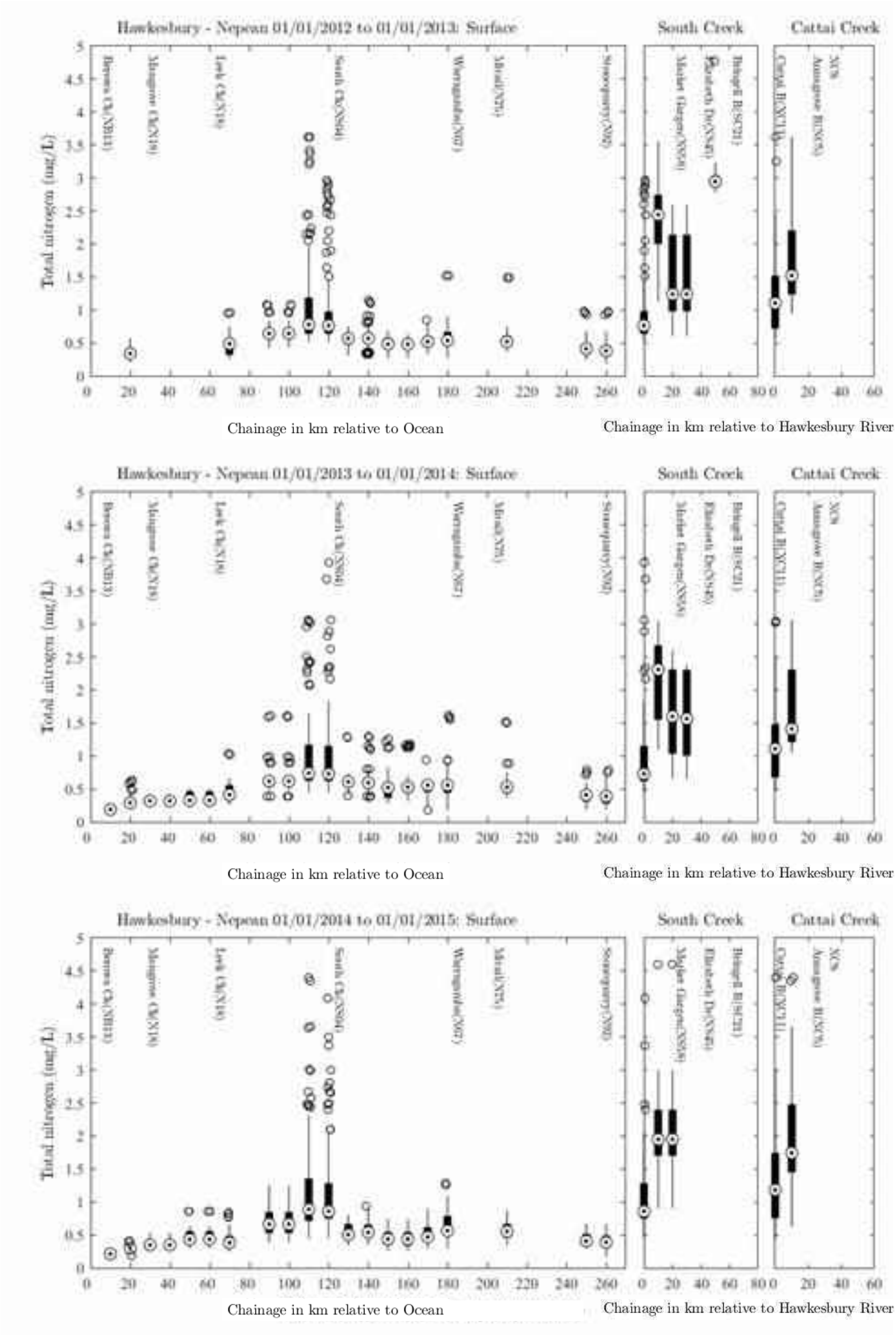

Figure 24 Comparison of annual TN concentration in the Hawkesbury-Nepean River, South Creek and Cattai Creek from 2012 - 2015

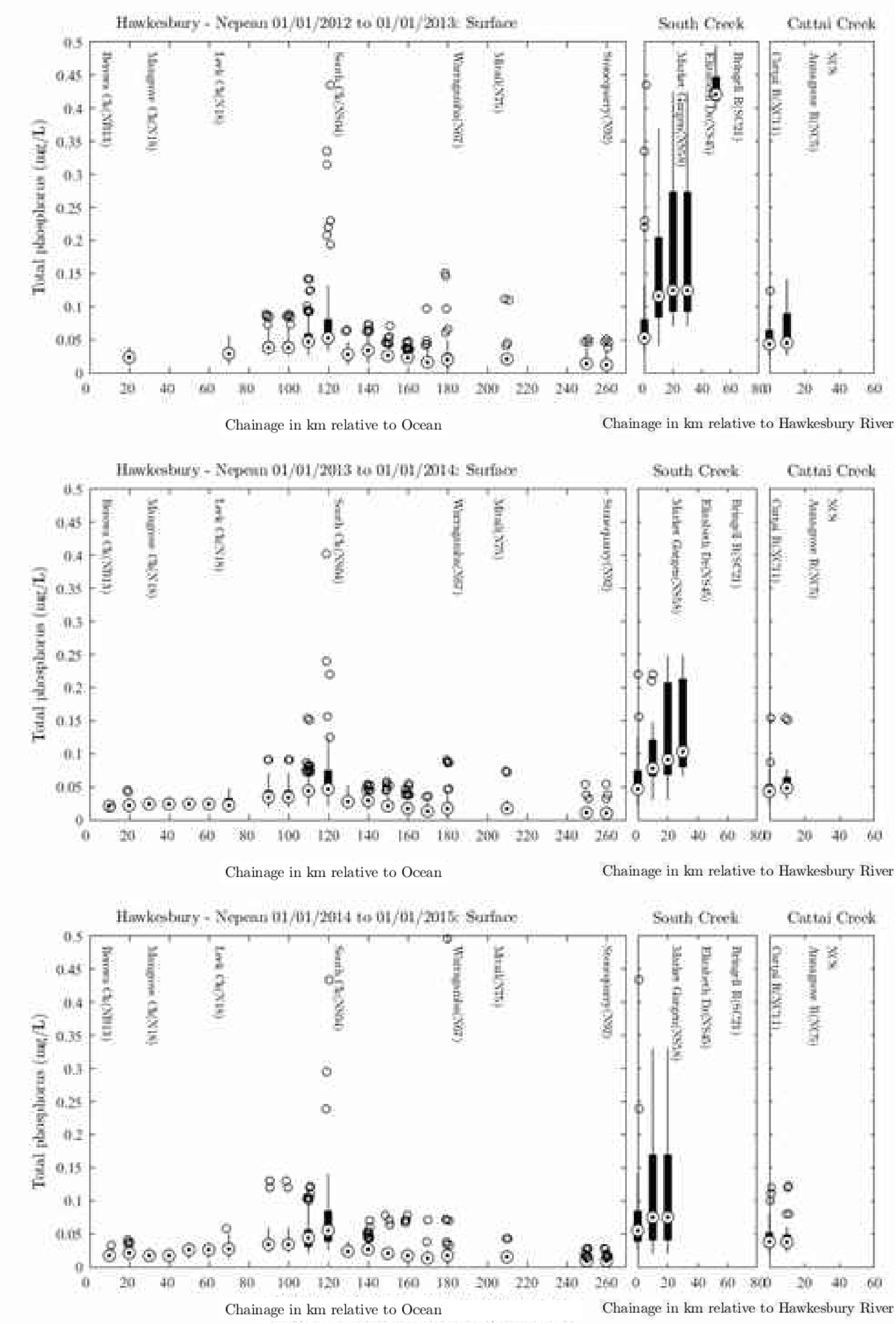

Figure 25 Comparison of annual TP concentrations in the Hawkesbury-Nepean River, South Creek and Cattai Creek from 2012 - 2015

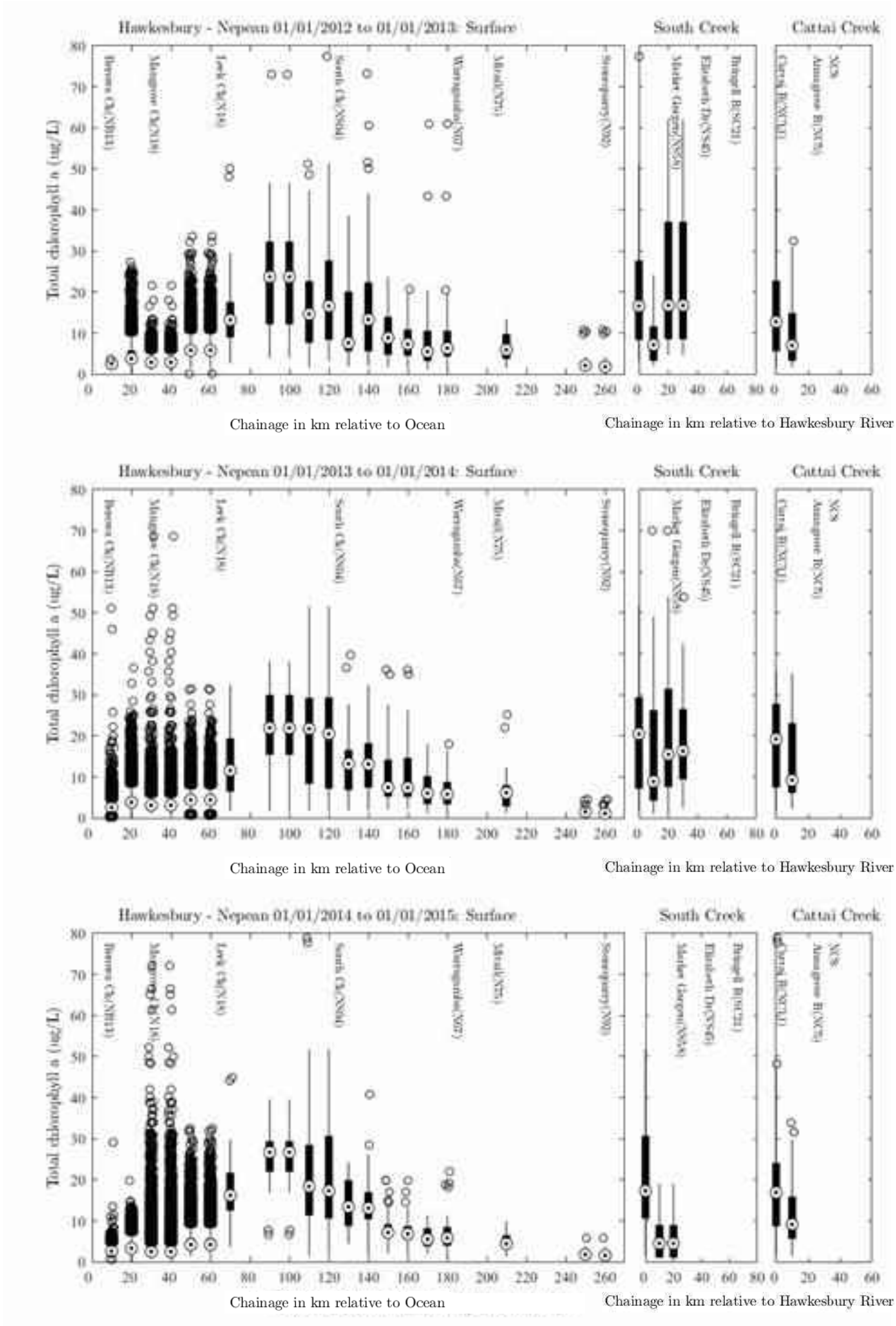

Figure 26 Comparison of annual total chlorophyll-a concentrations in the Hawkesbury-Nepean River, South Creek and Cattai Creek from 2012 - 2015.

4.3 Eastern Creek

4.3.1 Catchment Description

The Eastern Creek catchment covers an area of approximately 118 km² and is slightly more than 1/6 of the South Creek catchment area (628 km²). Landuse within the catchment currently consists of urban areas with a minor amount of the catchment being a combined mix of rural farms and remnant native forest (Sydney Water, 2021d). Catchment landuse conditions are provided in Figure 27.

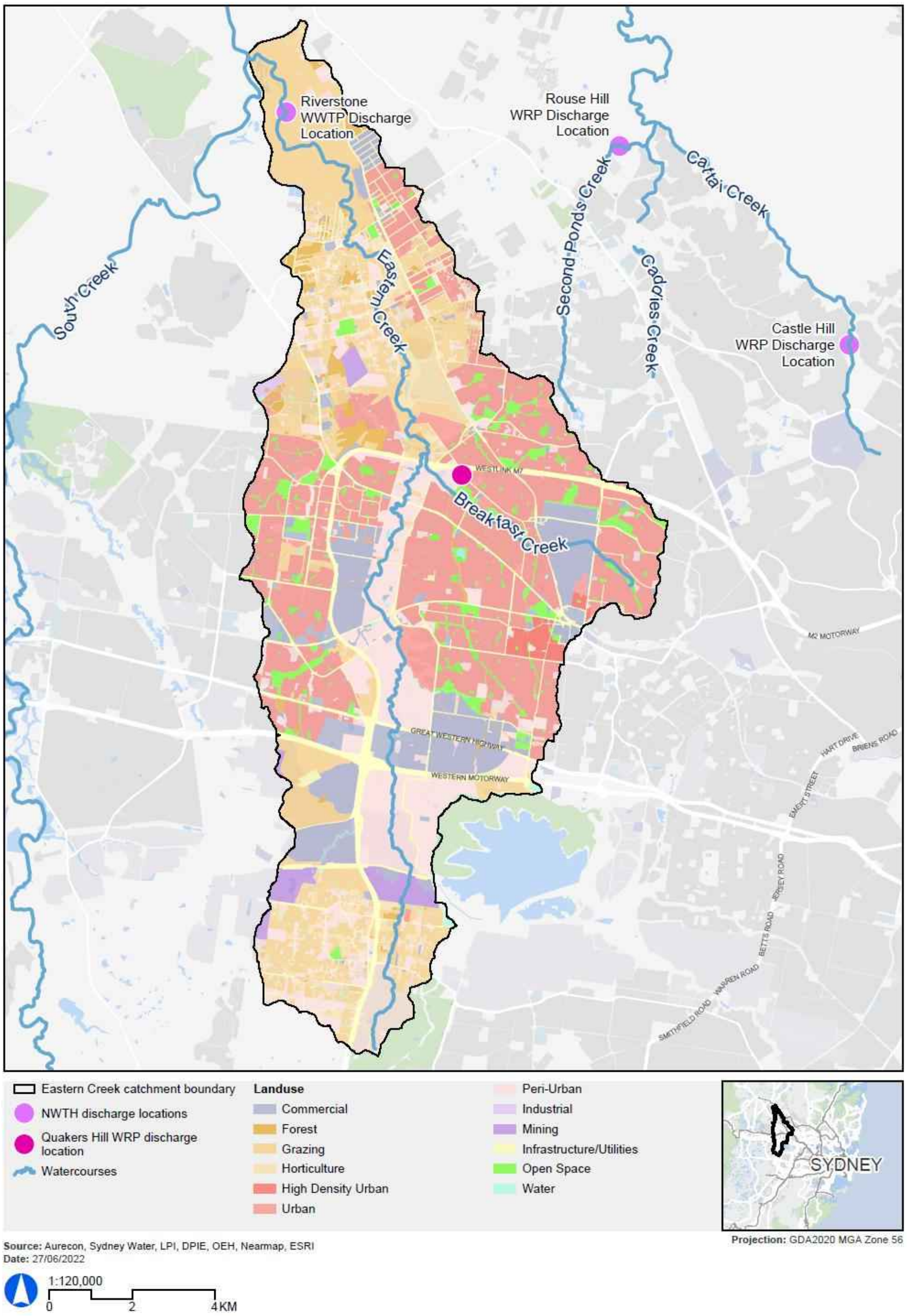

Figure 27 Eastern Creek catchment landuse and waterways

4.3.2 Waterway Description

Eastern Creek is a major tributary of South Creek whose confluence is approximately 11.5 km upstream from the Hawkesbury River. The waterway originates at the base of Sugarloaf Ridge in Horsley Park and flows generally northward for approximately 30 km to Vineyard and its confluence with South Creek. It is named Eastern Creek because it is the largest eastern tributary of South Creek.

In addition to the Riverstone WWTP, the Quaker's Hill WWTP is also located on Eastern Creek and provides treated water releases to the waterway approximately 11km upstream of the Riverstone discharge location.

4.3.3 Pressures and Water Management Issues

Principal pressures and water management challenges for Eastern Creek include intensive urban and industrial development, agricultural practices, landuse change and clearing, as well as numerous, competing demands for water.

Specific water management issues within the catchment include:

- water quality: elevated contaminant levels, excess nutrients, algae and aquatic weed growth
- development: landuse change including growth of urban, commercial and industrial areas
- agriculture: practices that affect downstream waterways including fertiliser use, riparian zone reduction
- increasing demand for water: industry growth as well as extractions for agricultural practices
- water accounting: the need to meter and more effectively regulate licence holders to account for water extraction
- point sources: increases in pollutant loads from treated wastewater due to population growth. This includes the Quakers Hill and Riverstone WWTPs.

As with the wider South Creek catchment, the increasing urbanisation of the Eastern Creek catchment is expected to result in significant changes in landuse and corresponding point and diffuse sources of pollution.

4.3.4 Load Analysis

Analysis of TN and TP loads to Eastern Creek has been undertaken to allow comparison of the contributions from various sub-catchments and treatment plants under current conditions (2020-time horizon). The loads were estimated through analysis of the model boundary conditions derived from Source, as discussed previously in Section 3.5.1.2.

The load analyses presented in the figures below extend from approximately 3 km upstream of Breakfast Creek, down to the confluence with South Creek – a total assessment length of approximately 20 km. Details of the waterways of the catchment are provided in Figure 27. Figure 28 and Figure 29 present the cumulative analysis from upstream to downstream for all loads (including WWTPs).

Figure 28 TN loading for Eastern Creek in typical wet and dry years under existing conditions

Figure 29 TP loading for Eastern Creek in typical wet and dry years under existing conditions

Of note, the Quakers Hill WRP treated water release point is located within Breakfast Creek, approximately 750 m upstream of its confluence with Eastern Creek. From the load analysis graphs, the influence of the Quakers Hill WRP on both TN and TP loads can be observed. With an approximate threefold increase to TN loads attributable to the Quakers Hill WRP and Breakfast Creek in the typical wet year and more than a fourfold increase to TN loads during the typical dry year, it is apparent that the Quakers Hill plant plays a major role as a source of nutrients in Eastern Creek as well as to South Creek and the Hawkesbury River under existing conditions.

The Quakers Hill WRP is currently being upgraded for its treatment processes. These upgrades include new inlet works, the commissioning of a new anaerobic granulated sludge (AGS) bioreactor and the implementation of mechanical primary sedimentation (MPS) screens. In addition to these current upgrades, a diversion of 12.5 ML/d of wastewater to the St Marys AWTP for consolidation of biosolids processing is also proposed.

TP loads are also very strongly correlated to treated water releases at Quakers Hill, however, the magnitude of change is comparatively less for both wet and dry years, with both less than a twofold increase immediately downstream of the release point.

While a component of the loads observed can be attributed to flows originating upstream of the discharge location, this assessment has not been undertaken.

4.3.5 Water Quality

The following sections present the findings of recent studies and analysis into the water quality of Eastern Creek, focusing on the primary water quality processes of concern; nutrients, and algal growth.

4.3.5.1 Nutrients

Two locations have been monitored with respect to Riverstone WWTP’s treated water releases – one upstream, and one downstream of the discharge point. These locations have been monitored for 20 years. Given the recent upgrade of Riverstone WWTP in 2018, results of this monitoring are, however, focused on the most recent period of 2016 to 2022. The monitoring locations are provided below in Figure 30.

Figure 30 Water quality monitoring locations of Eastern Creek for Riverstone WWTP treated water releases

Water quality monitoring datasets for Eastern Creek upstream and downstream of the Riverstone WWTP treated water release point are presented in Figure 31 through Figure 35 below for TN, ammonia, NOx, TP and filterable reactive phosphorous (FRP). These extracts have focused on the period from 2016 to 2021 to capture the latest monitoring data and to represent the Riverstone WWTP upgrade from 2018.

TN monitoring data indicate that nitrogen concentrations in this reach are perpetually above the relevant ANZG DVG (refer Section 2.2), ranging from approximately 0.85mg/L to 6.3mg/L. This is likely due to the upstream influence of both the Riverstone WWTP and the Quakers Hill WWTP.

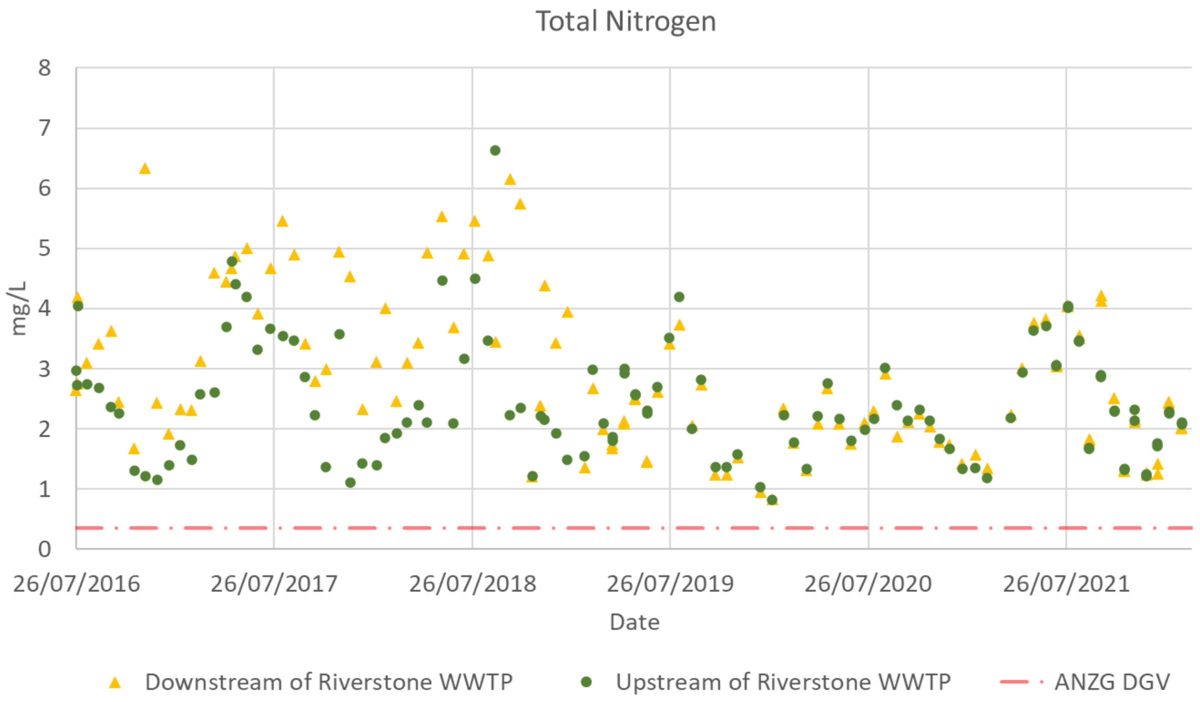

Figure 31 TN monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP release location

Concentrations for ammonia and NOx, the more bioavailable forms of nitrogen, are also observed to be above the ANZG DGVs (refer Section 2.2) for most monitoring events, in the case of ammonia sampling, and for all monitoring events in the case of NOx. From a toxicity perspective, the data presented in Figure 32 indicates Ammonia toxicity is unlikely with values below 0.9 mg/L, generally, despite the concentrations being above the ANZG DGV of 0.020 mg/L. However, there is currently potential for toxicity with NOx as the peaks remain above the toxicant DGV of 2.40 mg/L as demonstrated in Figure 33. Toxicant DGVs are provided in Section 2.2.

It is of important note to identify that nitrogen concentrations of all forms have been seen to generally decline downstream of the Riverstone WWTP after the most recent upgrades to the plant in 2018.

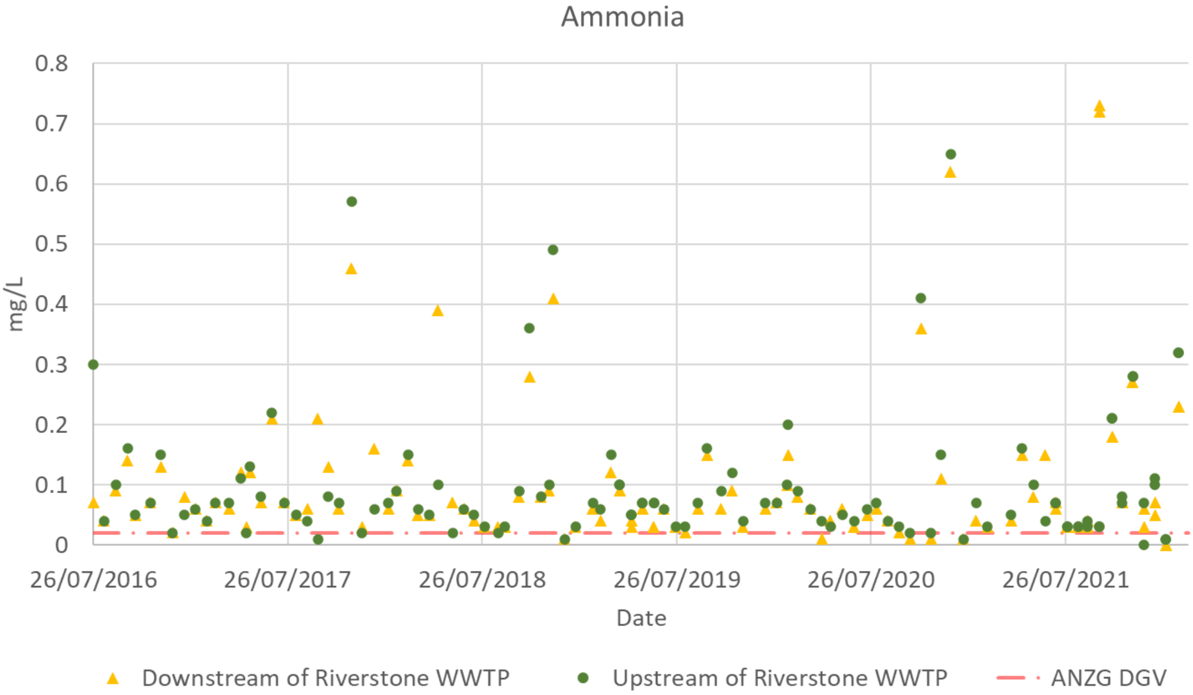

Figure 32 Ammonia monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP release location

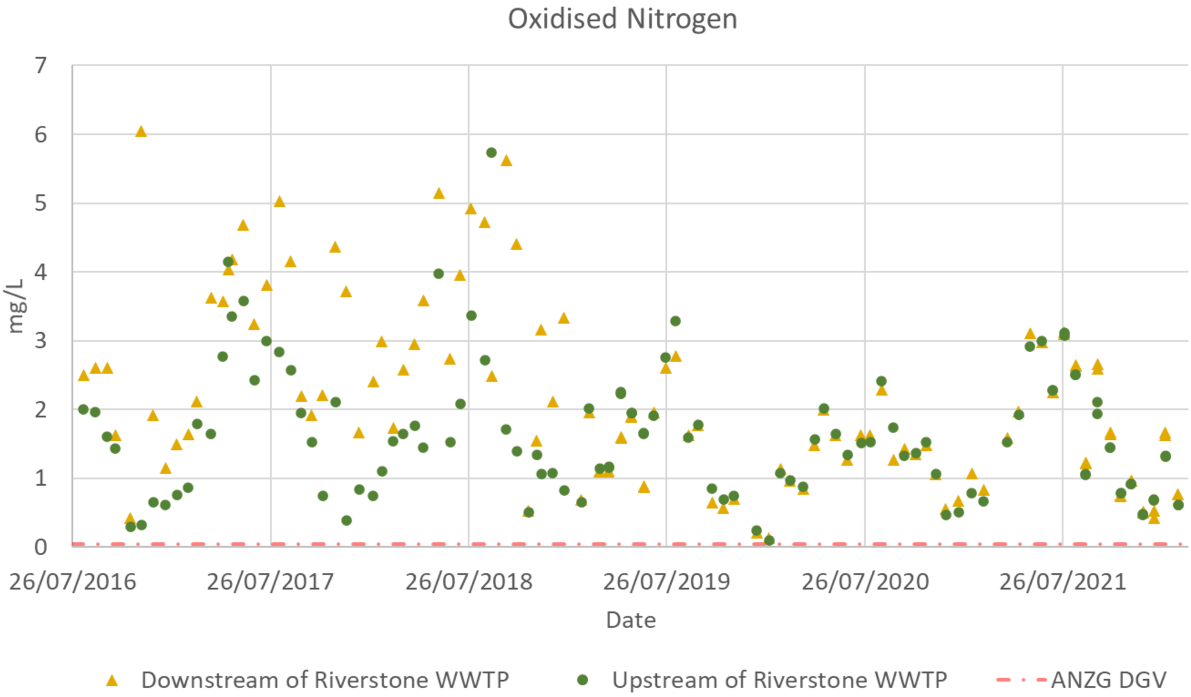

Figure 33 Oxidised Nitrogen monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP release location

TP concentrations downstream of Riverstone, shown in Figure 34, indicate consistent compliance with the ANZG guidelines for all sampling events except one event in 2020. With respect to the more bioavailable forms of phosphorus, FRP concentrations (Figure 35) have been measured at levels above ANZG DGVs for all sampling events both above and below the treated water release location, indicating that FRP concentrations originating upstream dominate the outcomes within the tidal reach.

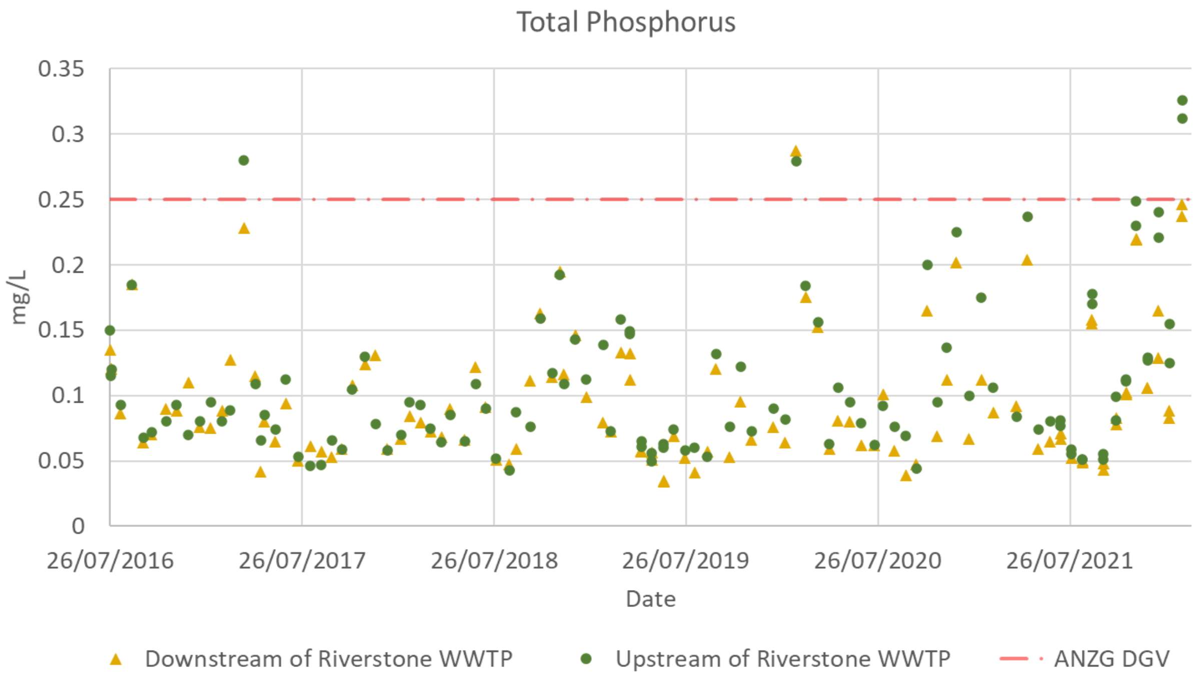

Figure 34 TP monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP release location

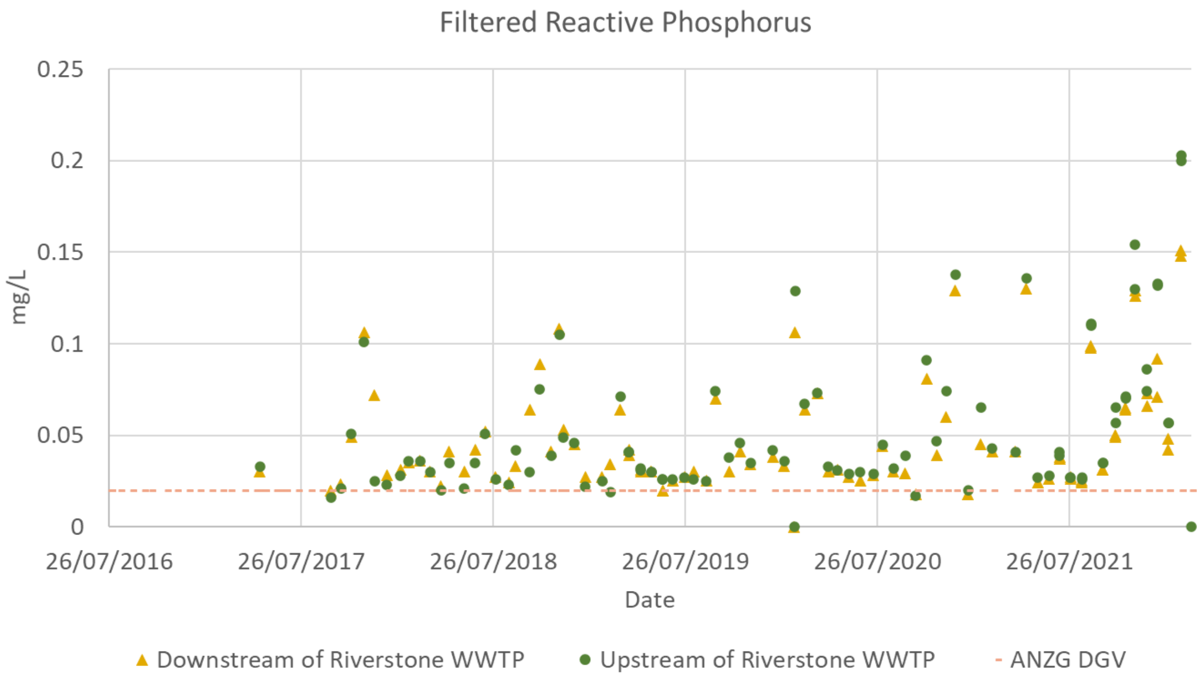

Figure 35 FRP monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP release location

With respect to interpretative analysis from earlier studies, the 2009 technical report by the DECC concluded that long-term median TN levels were strongly linked to areas under the influence of WWTP releases, increasing initially downstream of South Creek and Eastern Creek.

The CRC for Irrigation Futures (2007) undertook an extensive assessment of historical monitoring data in the creek and drew the following conclusions:

- The St Marys, Quakers Hill and Riverstone WWTPs historically contributed significant nutrient loads to the Hawkesbury, downstream of the junction with South Creek. Upgrades to these plants have reduced the levels of nitrogen and phosphorus considerably, although modelling demonstrated that even the highest level of nutrient removal at these facilities would not reduce nutrient levels sufficiently to meet ANZECC (2000) guidelines for a substantial proportion of the time.
- It has been established that diffuse sources such as urban and agricultural runoff have just as great if not greater impact on water quality. Estimates derived after the WWTP upgrades were completed indicate that around 56% of the pollutant load of TN and 64% of TP in the South Creek catchment was contributed by agriculture compared to 27% and 9% from WWTPs (EPA, 2002).
- A more detailed breakdown of the estimated sources of phosphorus in the South Creek catchment indicate that 44% was derived from agricultural runoff, 28% from urban runoff, 18% from unused or cleared land, 9% from WWTPs and 1% from natural runoff (EPA, 2003). As urban development replaces agricultural land in the catchment, urban runoff is likely to become the dominant degrading factor in the future (DEC, 2004).

4.3.5.2 Algae

Higher concentrations in nutrients, and particularly bioavailable species, provide for favourable conditions in algal growth during extended dry weather periods. Figure 36 below presents the timeseries of monitoring data for chlorophyll-*a* in the Eastern Creek tidal reach upstream and downstream of the Riverstone WWTP discharge location.

This monitoring data provides evidence that treated water releases from Riverstone WWTP may have a modest diluting effect on Chlorophyll-*a* concentrations in this reach. When compared to the upstream concentrations, the downstream concentrations are slightly reduced during sampling events, while still non-compliant with the relevant DGV for periods of time.

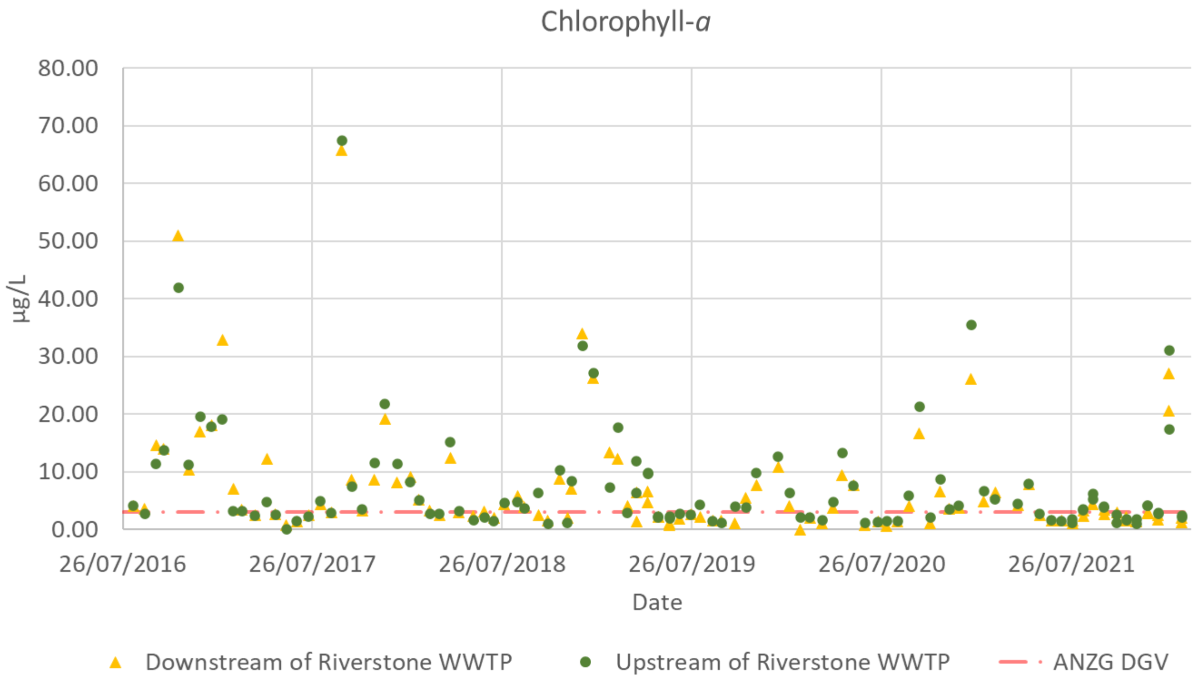

Figure 36 Chlorophyll-*a* monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP discharge location

While the species are unknown, the non-compliance in Chlorophyll-*a* concentrations indicate the potential presence of nuisance algal growth within the tidal reaches.

The Sydney Water STSIMP interpretative report (2018) provided further context with respect to algal growth in the creek. The following key findings were drawn:

- There is relatively limited algal data, however, a significantly increasing trend in the total algal biovolume (254%) was observed over the long-term from 1996 to 2017.
- This in turn has impacts on the water quality of the lower Hawkesbury River, below Windsor. Downstream of the confluence, the quality is comparatively poor with very high levels of nutrients, chlorophyll-*a* and algae.
- Further step trend analysis was undertaken with respect to chlorophyll-*a*, for the periods before and after the WWTP upgrades (including the commissioning of the St Marys AWTP, but predating the upgrade to the Riverstone WWTP in 2018). The findings were as follows:
  - During the period from 2011 to 2017, no significant trends were identified for chlorophyll *a* and/or algae. This is the period prior to the upgrade to Riverstone WWTP in 2018.
  - Despite limitations in data availability, the analysis revealed an increasing trend in total algal biovolume but also a decreasing trend in blue-green algal biovolume prior to the upgrades.

A recent study on the Hawkesbury Nepean River and South Creek found a clear response with reduced chlorophyll-*a* at South Creek with increased flow, irrespective of whether the increased flow was from high quality recycled water or tertiary treated wastewater (Sydney Water, 2015). Consistent with the findings from this report, it is anticipated that chlorophyll-*a* concentrations will be decreased within the Eastern Creek tidal reach and in the downstream receiving waterways of South Creek and the Hawkesbury River as a result of the proposed upgrades to Riverstone WWTP outlined in Section 1.2.3.

4.3.5.3 Other Water Quality Indicators

4.3.5.3.1 Salinity

Monitoring data for the tidal reach of Eastern Creek upstream and downstream of the Riverstone WWTP discharge is presented in Figure 37. Concentrations generally vary between minimum levels of 0.1 g/L up to a maximum of ~0.6 g/L, which is within the acceptable range of the ANZG DGV (Section 2.2). The dataset used has been calculated from conductivity results obtained during sampling and/or monitoring events.

Due to the variability and temporal limitations in the datasets, it is not viable to establish any longer term trends or impacts from the WWTPs.

Also of note, the tidal limit of Eastern Creek is reported as extending upstream of these monitoring locations to a weir approximately 750m upstream (DNR, 2006), indicating that although the river is tidally forced, the water is fresh above the salinity wedge.

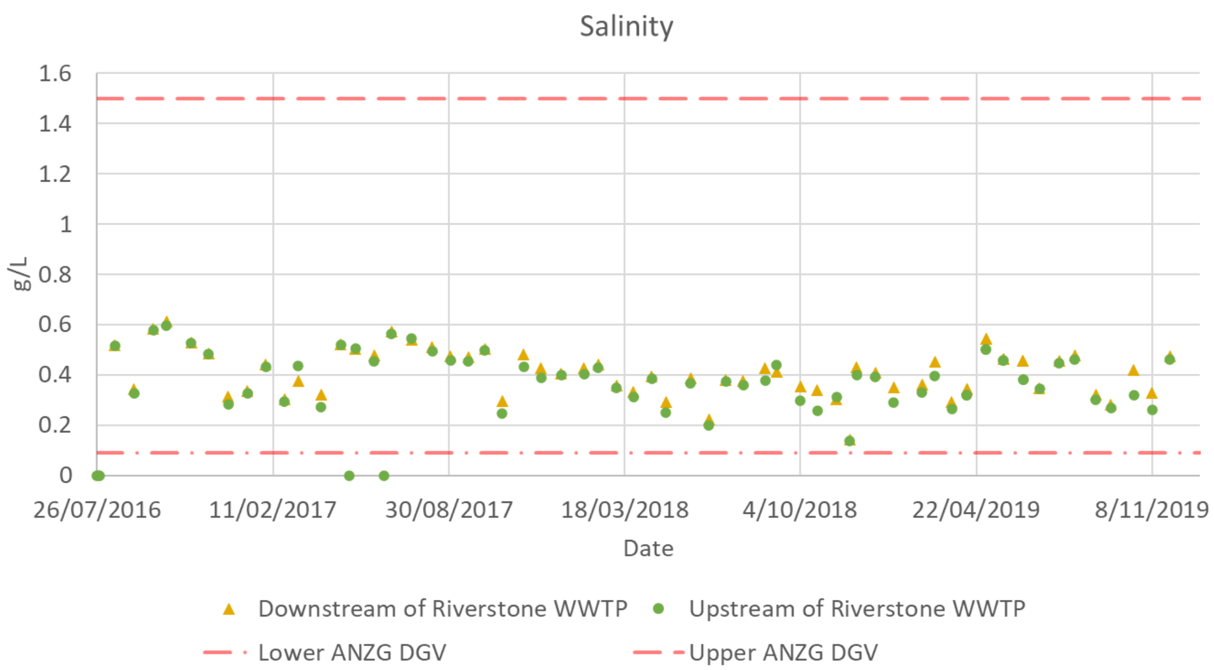

Figure 37 Salinity monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP discharge location

4.3.5.3.2 Total Suspended Solids

Monitoring data for TSS in the tidal reach of Eastern Creek upstream and downstream of the Riverstone WWTP discharge location are presented in Figure 38. The ANZG waterway objective applicable to Eastern Creek is 40 mg/L (Section 2.2).

Concentrations have been observed to be heavily dependent on rainfall and runoff events, ranging from minimum levels of below 5 mg/L up to concentrations of ~100 mg/L above the Riverstone WWTP discharge if sampled during or shortly after wet weather events. It is predicted that TSS concentrations in Eastern Creek will experience improvements as the increased volumes of the Riverstone WWTP releases dilute and therefore reduce TSS concentrations.

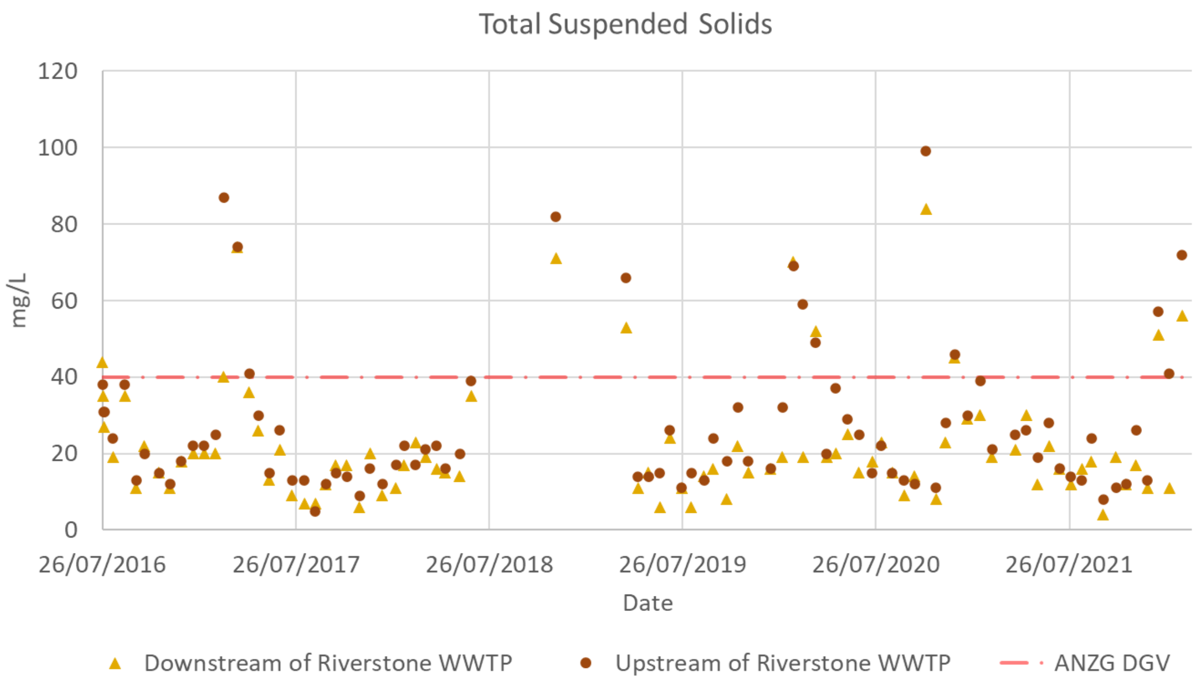

Figure 38 Total Suspended Solids monitoring data for the tidal reach of Eastern Creek in the vicinity of the Riverstone WWTP discharge location

4.4 South Creek

4.4.1 Catchment Description

The South Creek catchment covers an area of 628 km^2, sitting within the lower region of the Cumberland Plain. The creek starts in Narellan, northwest of Campbelltown and then flows generally in a south to north direction through a gently undulating landscape until reaching its confluence with the Hawkesbury River, near Windsor.

From source to mouth, the creek flows through or forms the boundary of many suburbs including Bringelly, Badgerys Creek, Kemps Creek, Orchard Hills, St Marys, Dunheved, Riverstone, Windsor and McGraths Hill.

Landuse within the catchment currently consists of a mix of rural farms, remnant native forest and urban areas (Sydney Water, 2021d). Rural activities include cattle and sheep grazing, market gardening and intensive agriculture such as poultry farming. As part of the development of the Source catchment model, grazing was evaluated to be the dominant landuse of the existing catchment, occupying approximately 39% of the area, while Peri Urban and Urban accounted for approximately 21% and 16% of the region respectively. Landuses for South Creek are presented in Figure 39.

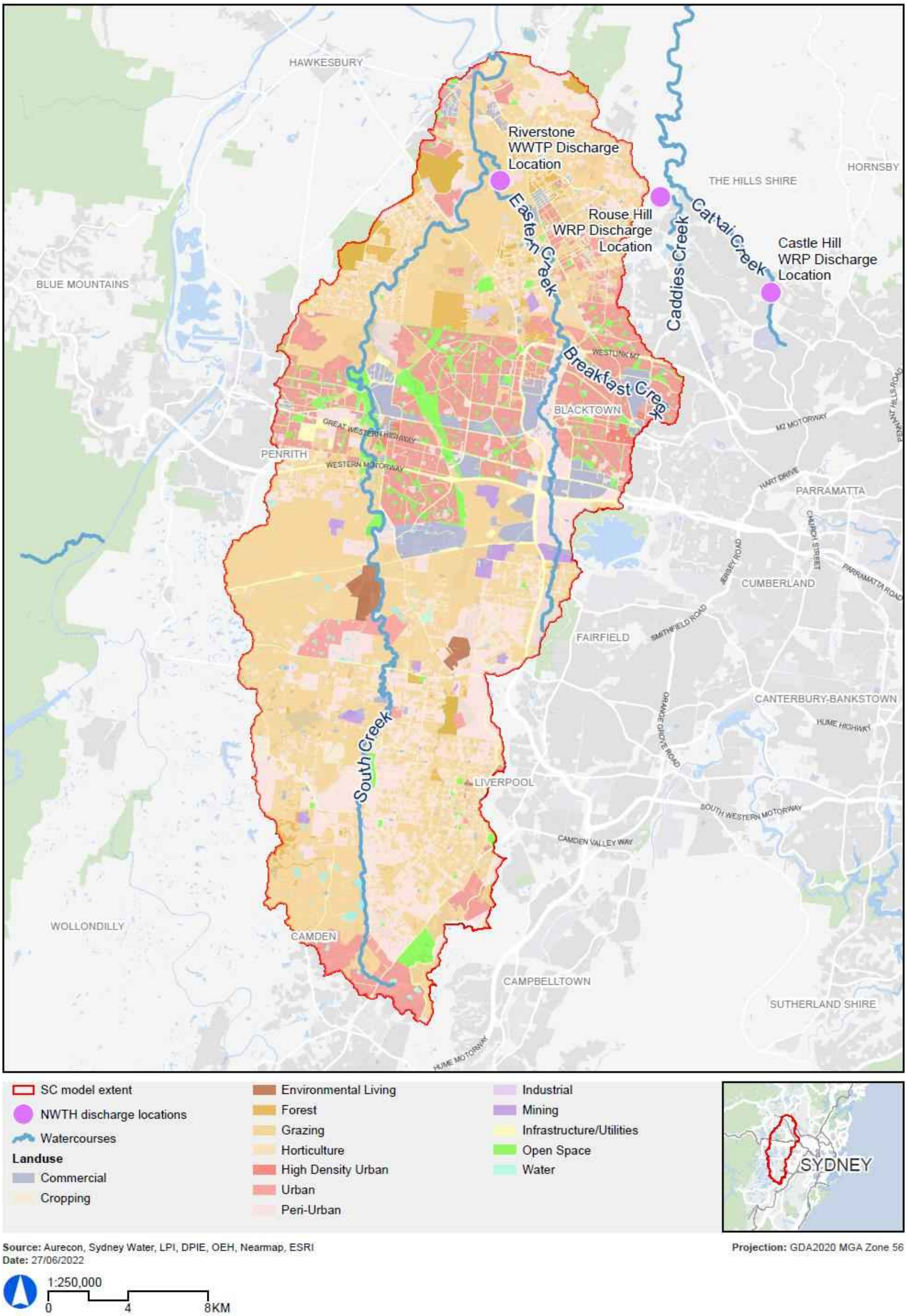

Figure 39 South Creek catchment landuses

4.4.2 Waterway Description

From its origins, the creek descends approximately 94 m over its 70 kms course to the Hawkesbury River. The creek is joined by seventeen major tributaries including Badgerys Creek, Kemps Creek, Ropes Creek, Eastern Creek and McKenzies Creek.

The creek can generally be separated into three waterway types based on its flow regime: ephemeral, perennial and tidal. The ephemeral zone generally extends to the confluence with Kemps Creek, however under extended dry weather conditions, the creek can slow and become segregated into separate pools all the way down to the Dunheved reach. The tidal zone is extends upstream from the Hawkesbury to the Richmond Road Bridge (Department of Natural Resources, 2006), which is approximately 5.7km upstream of South Creek's confluence with Eastern Creek. As such, within this study, the assessment of South Creek has been limited to the tidal reaches of the waterway.

4.4.3 Pressures and Water Management Issues

Principal pressures and water management challenges for South Creek include intensive urban and industrial development, agricultural practices, landuse change and clearing, as well as numerous, competing demands for water.

Specific water management issues within the catchment include:

- water quality: elevated contaminant levels, excess nutrients, algae and aquatic weed growth
- development: landuse change including growth of urban, commercial and industrial areas
- agriculture: practices that affect downstream waterways including fertiliser use, riparian zone reduction
- increasing demand for water: industry growth as well as extractions for agricultural practices
- water accounting: the need to meter and more effectively regulate licence holders to account for water extraction
- point sources: increases in pollutant loads from treated wastewater due to population growth. This includes the existing treatment plants of St Marys, Quakers Hill, Riverstone, South Windsor and McGrath Hill.

In terms of future pressures, the South Creek catchment will see the most significant level of development within the wider Hawkesbury Nepean catchment, with a change from approximately 20% to 80% developed by 2056 (GSC, 2018). The South West and Western Sydney Aerotropolis Growth Areas are primarily located within the South Creek catchment boundary.

The increasing urbanisation of the catchment is expected to result in significant changes in landuse and associated point and diffuse sources of pollution.

4.4.4 Load Analysis

Analysis of TN and TP loads to South Creek has been undertaken to allow comparison of the contributions from various sub-catchments and treatment plants under current conditions (circa 2020). The results of this analysis for TN and TP are provided in the longitudinal plots of Figure 40 and Figure 41, respectively.

As discussed in Section 4.3, the large increase in loads from Eastern Creek is attributable to both the TN and TP loads being released from the Quakers Hill WWTP. Of additional note are the increases in both TN and TP downstream of Ropes Creek, the receiving waterway for treated flows from the St Marys WRP.

Differences in load magnitude between the dry and wet years is also notable, with wet year loads being approximately twice the magnitude of dry year loads.

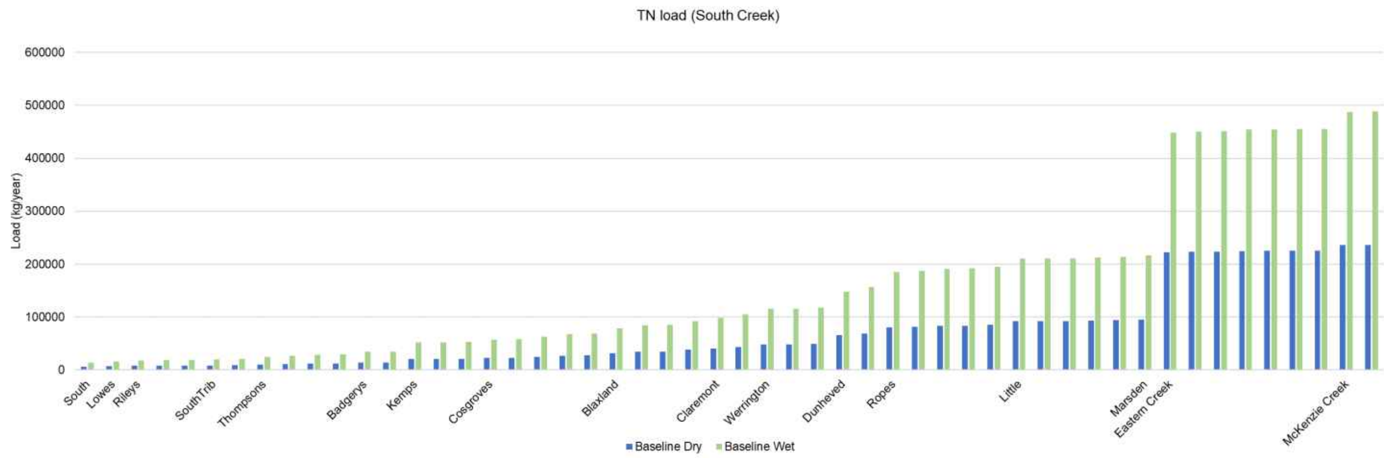

Figure 40 TN cumulative catchment loads for South Creek (wet and dry years)

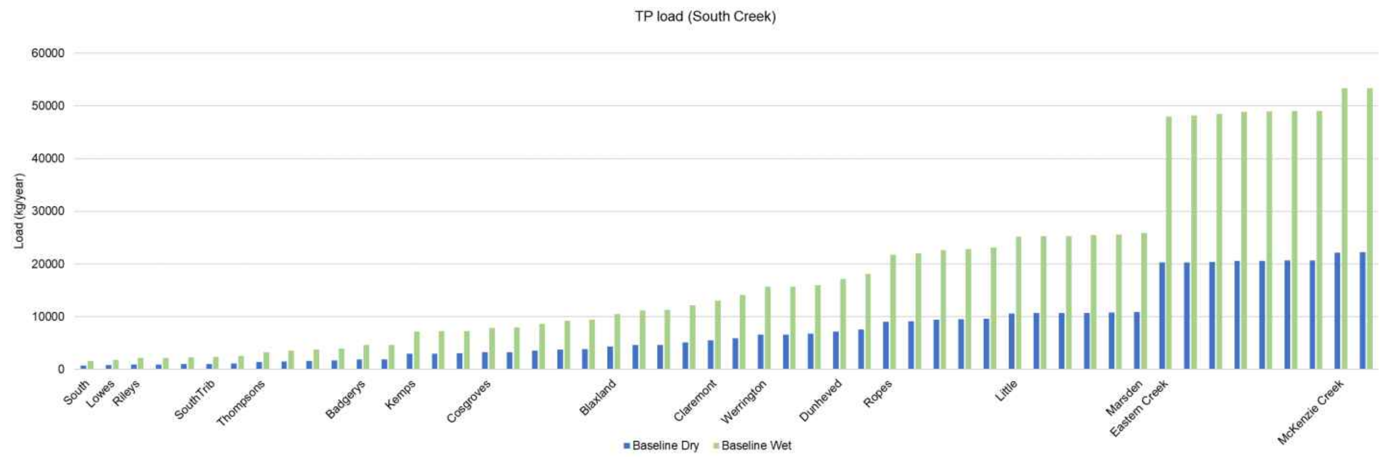

Figure 41 TP cumulative catchment loads for South Creek (wet and dry years)

4.4.5 Water Quality

The following sections present the findings of recent studies and analysis into the water quality of South Creek, focusing on the primary water quality processes of concern; nutrients, and algal growth.

4.4.5.1 Nutrients

Monitoring datasets for South Creek's tidal reaches are presented in Figure 42 through Figure 46 for TN, Ammonia, NOx, TP and phosphate.

The data from the tidal reaches demonstrate a general increase in nutrient concentrations towards the lower sections of the creek, with potential non-compliance with both the EES and the ANZG waterway objectives for TN.

With respect to the more bioavailable forms of nitrogen, concentrations again increase in the tidal section of the creek, often above both sets of waterway objectives when considering annual medians. From a toxicity perspective, the data indicates no potential for toxicity as the peaks remain below the toxicant DGV for Total Ammonia.

For NOx, the data presented includes a significant range of concentrations with peaks up to 3 mg/L. This indicates potential non-compliance with both the EES and ANZG derived waterway objectives on a median basis, and also with respect to the concentration spikes relative to the adopted toxicant DGV of 2.4 mg/L (refer Section 2.2).

With respect to the more bioavailable forms of phosphorus in the tidal reaches, concentrations again are shown to rise and typically lie above the ANZG DGV.

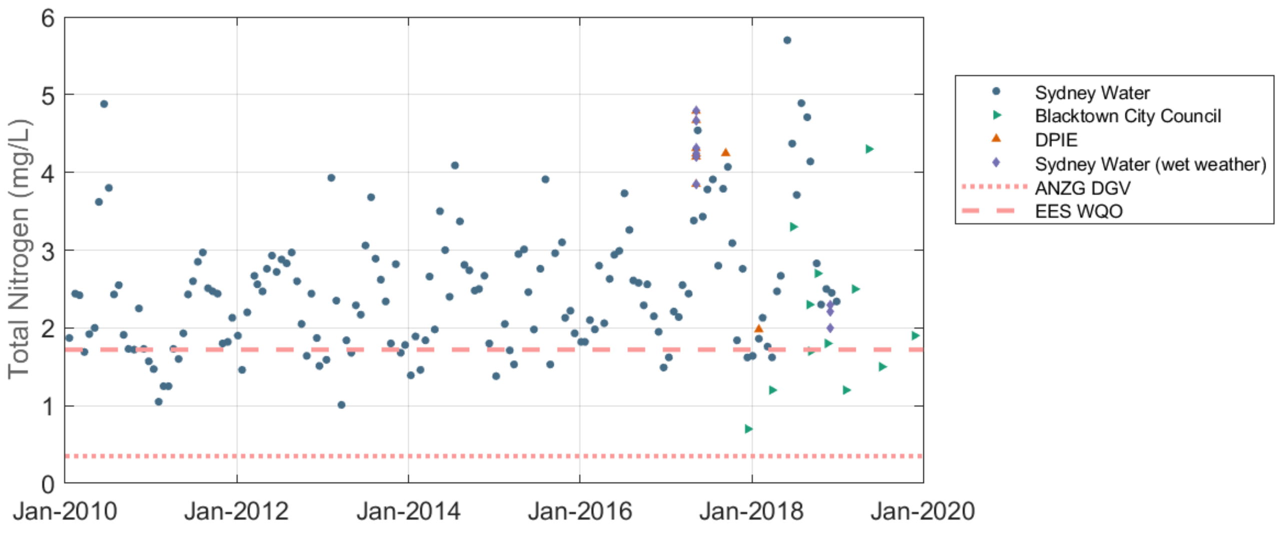

Figure 42 TN monitoring data for tidal reaches of South Creek

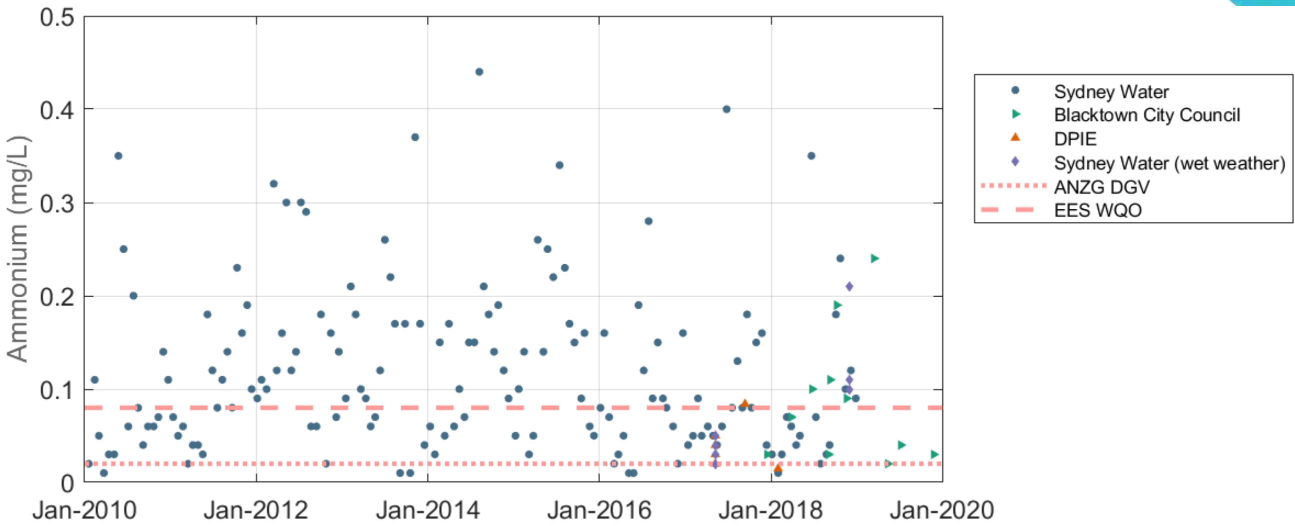

Figure 43 Ammonia monitoring data for tidal reaches of South Creek

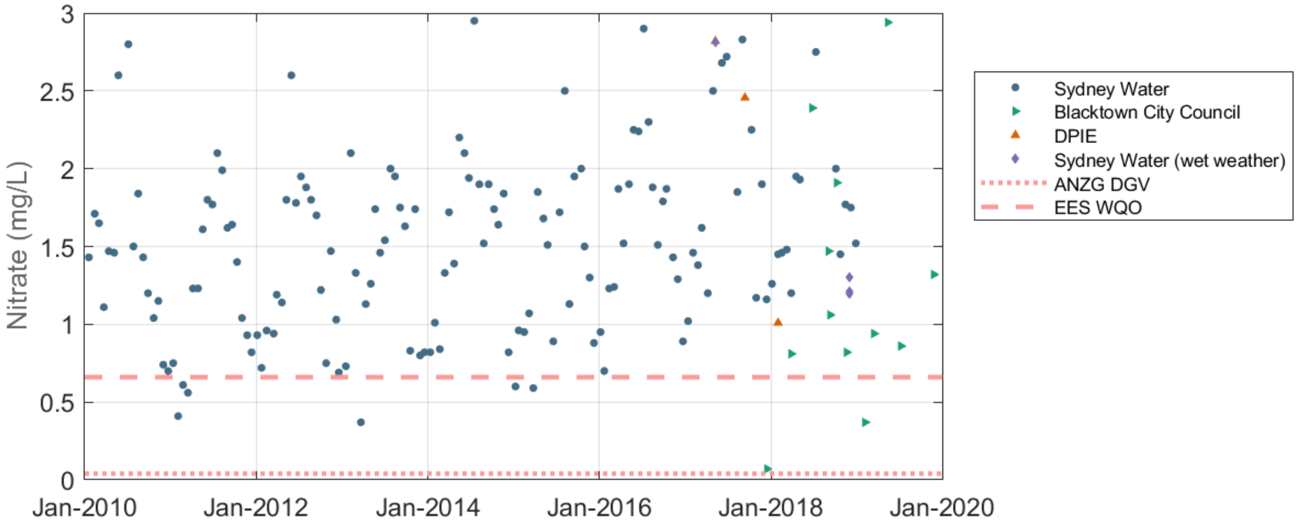

Figure 44 NOx monitoring data for tidal reaches of South Creek

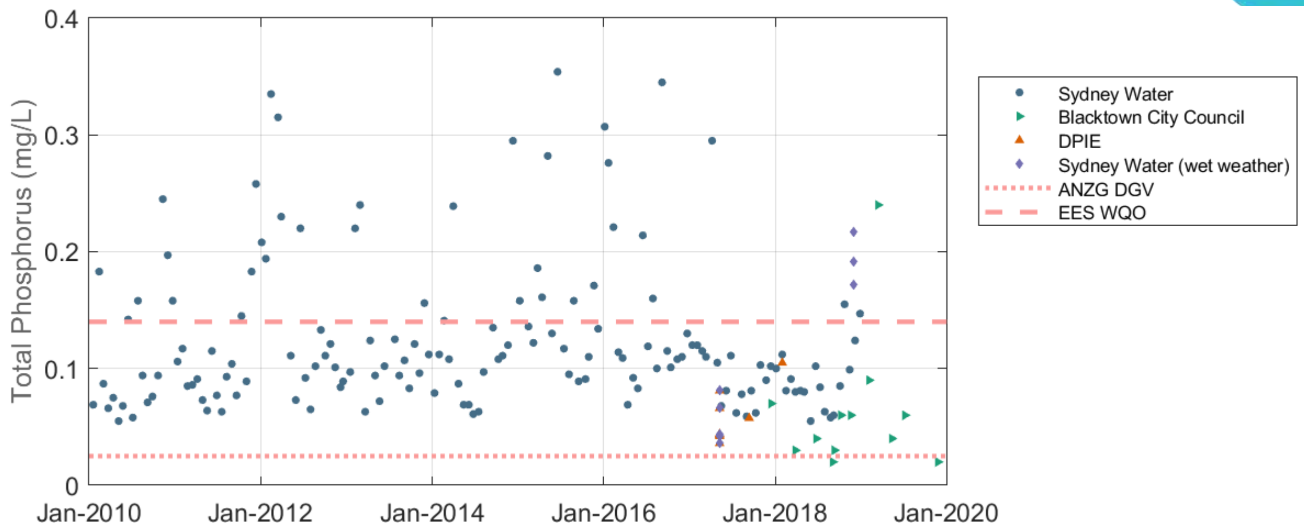

Figure 45 TP monitoring data for tidal reaches of South Creek

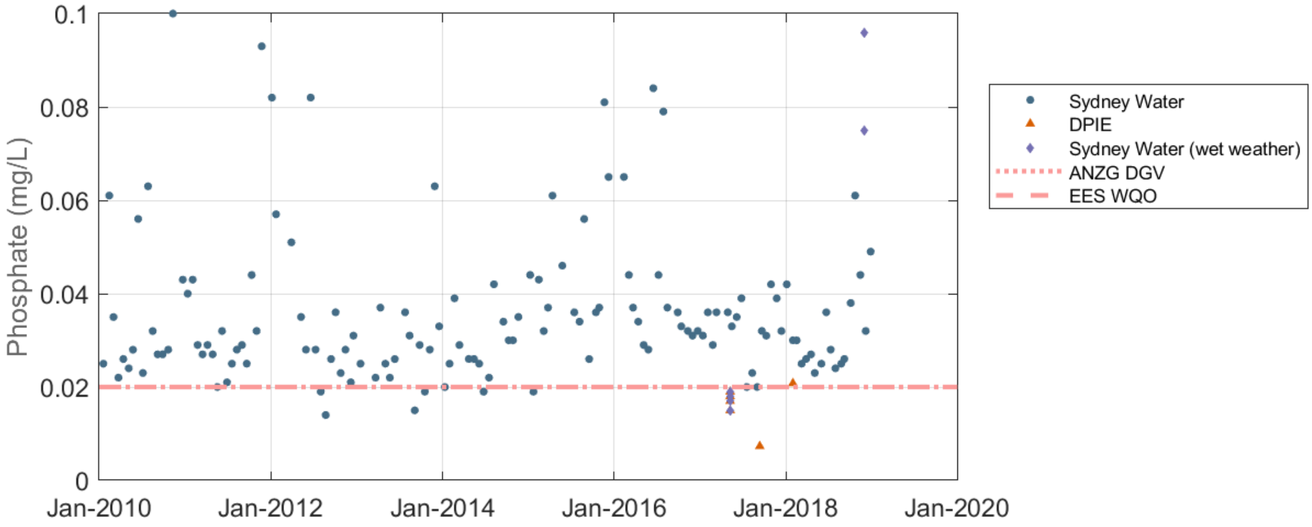

Figure 46 Phosphate monitoring data for tidal reaches of South Creek

The Sydney Water STSIMP interpretative report (2018) provided further context with respect to nutrient loads to the creek and ambient water quality.

The report identified that the population in the South Creek catchment had increased by 45% between 1992 and 2017, but despite this growth, TN and phosphorus loads had significantly reduced by 86% and 92% respectively due to upgrades to the WWTPs/WRPs. Despite these reductions, it was also noted that nutrient loads from treated water releases have trended upwards between 2011 and 2017 due to a combination of population growth (~2.2% per year) and more frequent storm events. With the increasing wastewater inflows requiring treatment, WWTP efficiency was also reduced resulting in increased nutrient concentrations in releases and ultimately in nutrient loads to the creek.

While the analysis contained in this report is focused on the REF for upgrades to the NWTH plants, the upgrade to Riverstone WWTP will occur in tandem with upgrades to the Quakers Hill WWTP to the 2036 time horizon, which should collectively result in significant reductions in nutrient loads to Eastern Creek, the tidal reach of South Creek and the lower Hawkesbury River. The upgrades to Quakers Hill WWTP have been reflected in the Background scenario modelled in the South Creek WQRM for this project.

With respect to impacts from South Creek on the lower Hawkesbury River, the STSIMP interpretative report identified that below Windsor and downstream of the confluence, water quality is comparatively poor with very high levels of nutrients, chlorophyll *a* and algae. Trend analysis performed on flow-adjusted data at the confluence, however, indicated that there have been significant decreases in TN (73%), dissolved inorganic nitrogen (79%), TP (59%), FRP (75%) and turbidity (29%) in the 25 years from 1992 to 2017.

Further investigations were therefore undertaken in the form of step trend analysis, evaluating two different periods before and after the WWTP upgrades at Quakers Hill, St Marys and Riverstone in 2011. This analysis indicated that "*Nutrient concentrations decreased across the board at South Creek (NS04) in the historical period from 1992 to 2011. All four parameters (TN: 80%, dissolved inorganic nitrogen: 85%, TP: 73% and filterable TP: 83%) exhibited significantly decreasing trends during this period between 1992 to 2011. However, no significant trends were found in these parameters for the short-term recent period after completion of upgrade works in 2011.*"

The outcomes of this analysis suggest that catchment interventions are likely required to address this issue.

4.4.5.2 Algae

Timeseries of monitoring data for chlorophyll-*a* in tidal sections of the creek are presented in Figure 47. With increases in algal growth within the tidal reaches, non-compliances with both the EES and ANZG objectives (both being 3 µg/L / 0.003 mg/L) in Section 2.2 can be observed in lower sections of the creek.

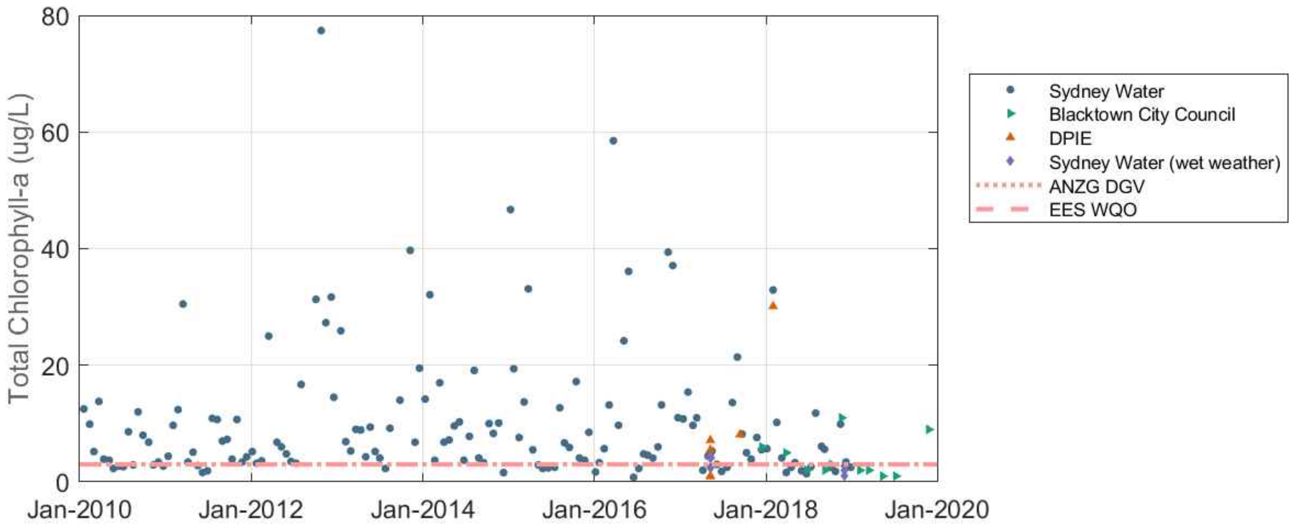

Figure 47 Chlorophyll-*a* monitoring data for tidal reaches of South Creek

The findings of the Sydney Water STSIMP interpretative report (2018) provided in 4.3.5.2 apply to South Creek as well as Eastern Creek. This report outlined a trend of increasing algal biovolume for the system from 1996 to 2017. This existing trend of increasing biovolume was then interpreted to have impacts across the tidal reaches of both creeks as well as the lower Hawkesbury River.

4.4.5.3 Other Water Quality Indicators

4.4.5.3.1 Salinity

Salinity monitoring data for the tidal reaches of South Creek is presented in Figure 48. Concentrations generally vary between minimum levels of 0.1 g/L up to a maximum of ~0.75 g/L, which correlates with the EES derived waterway objective. There are potential signs of seasonal trends, but the variations are likely to be more significantly influenced by rainfall runoff events in the catchment and when the monitoring was undertaken relative to these events.

Due to the variability and temporal limitations in the datasets, it is not viable to establish any longer-term trends.

Also of note, the tidal reaches include monitoring sites near the confluence with the Hawkesbury River, indicating that although the river is tidal, the water is fresh and potentially above the salinity wedge. The tidal limit for South Creek has previously been reported as being located a short distance downstream of the Richmond Road bridge (DNR, 2006).

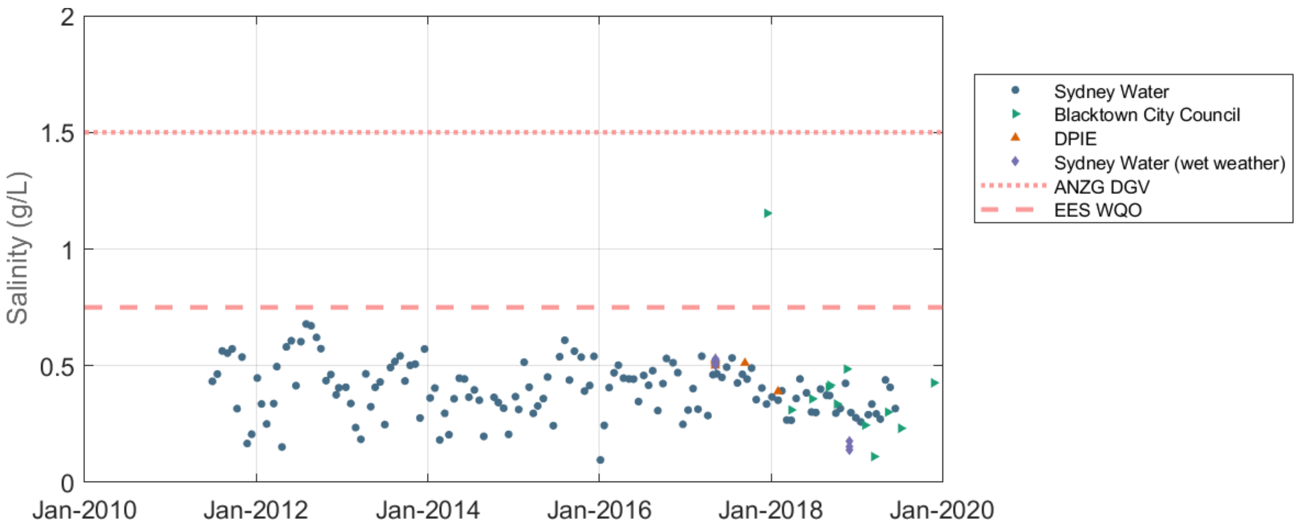

Figure 48 Salinity monitoring data tidal reaches of South Creek

As noted in Section 4.3.5.3.1, salinity in Western Sydney has been recognised as an existing process that has been exacerbated through anthropogenic alteration of the hydrological cycle (Sinclair et al. 2004).

4.4.5.3.2 Total Suspended Solids

Figure 49 presents monitoring data for total suspended solids in the tidal reaches of South Creek. The dataset used is relatively limited within the tidal section of the creek.

Concentrations are expected to be heavily dependent on rainfall and runoff events, ranging from minimum levels of below 5 mg/L up to concentrations of ~100 mg/L, collected during targeted wet weather monitoring.

The EES and ANZG waterway objectives applicable to South Creek are 30 mg/L and 40 mg/L respectively. Insufficient data is available to assess compliance in the tidal reaches of the creek under existing conditions. It is important to note that TSS concentrations are highly sensitive to wet weather due to overland flows entraining soils and other particulates in the water column. As a result, wet weather sampling may result in TSS concentrations that are elevated, skewing the results of the monitoring.

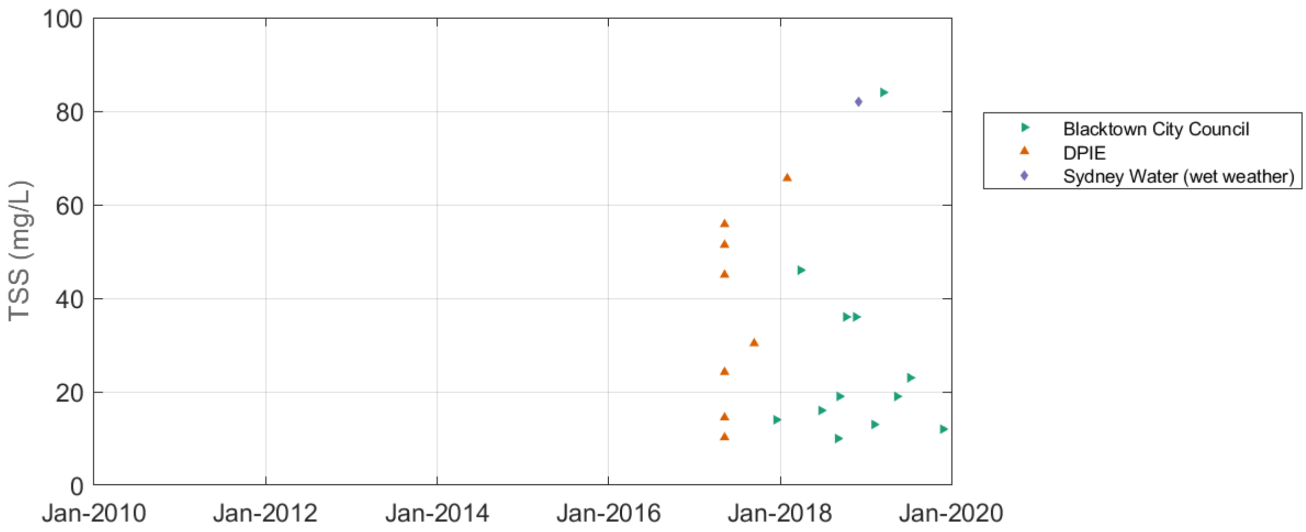

Figure 49 TSS monitoring data for tidal reaches of South Creek

4.5 Hawkesbury River

4.5.1 Catchment Description

In its entirety, the Hawkesbury Nepean catchment represents one of the largest coastal basins in NSW. With an area of approximately 21,400 km², over 70% of the catchment consists of mountainous terrain, with about 10% of flat terrain. A further 10% of the total catchment comprises of undulating plateau type country and is termed the south terrain. The maximum elevation is about 1,290 m above sea level.

Landuse data (circa 2017) indicates that, downstream of the Warragamba Dam, the catchment is predominantly forest (76%), followed by grazing (13%), urban (3%), peri-urban (6%), horticulture (<1%) and cropping (<1%).

Major towns that are located along the river system include Penrith, Gosford, Goulburn, Camden, Lithgow, Richmond, Windsor, Moss Vale, Mittagong and Bowral.

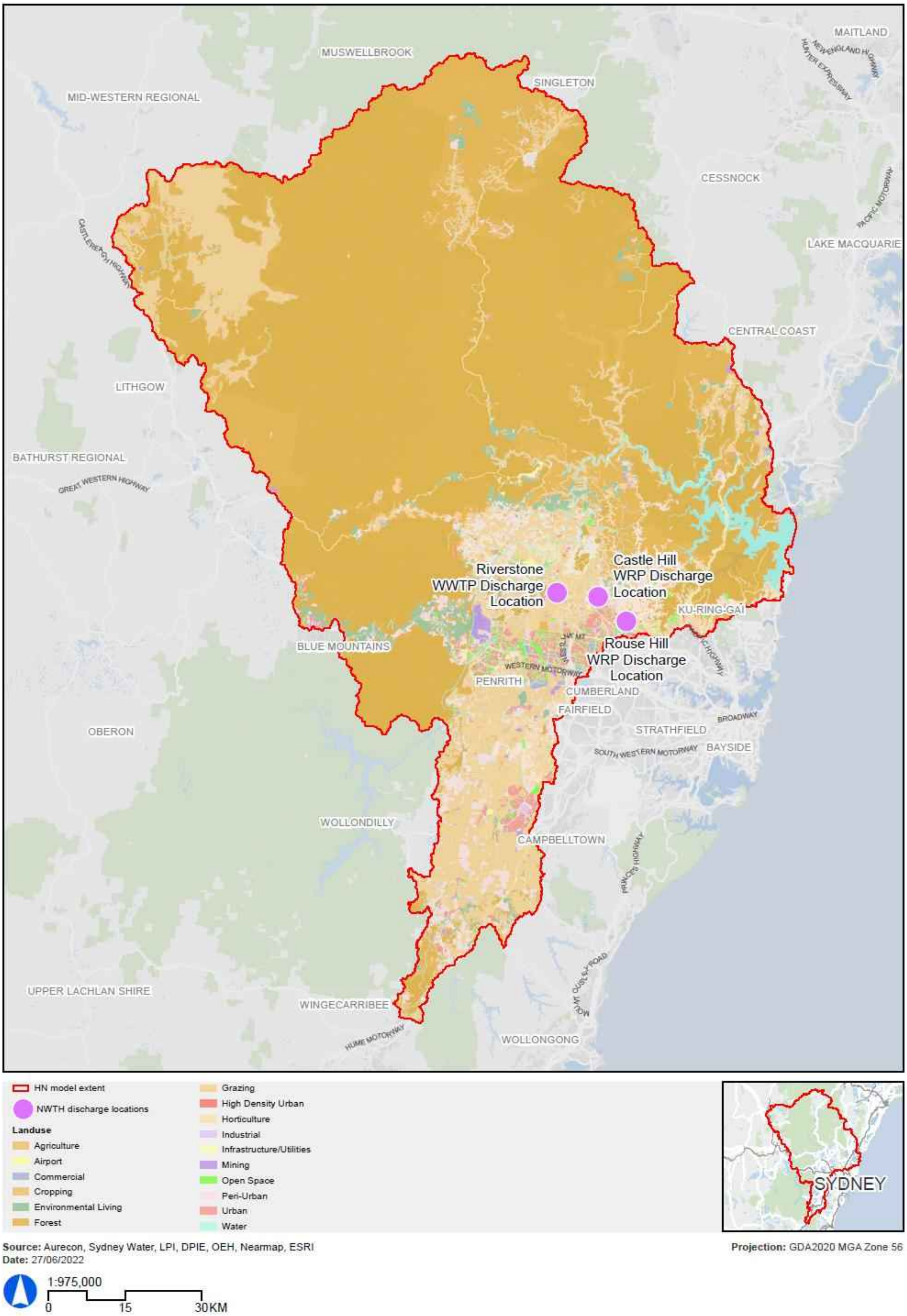

Figure 50 Landuse for the Hawkesbury Nepean catchment

4.5.2 Waterway Description

The main rivers and tributaries include the Nepean, Hawkesbury, Avon, Cataract, Colo, Cordeaux, Coxs, Grose, MacDonald, Wollondilly, Warragamba and Wingecarribee rivers. There are also a significant number of contributing creeks including Berowra, Bundanoon, Cascade, Cattai, Colo, Cowan, Sooley, South and Mooney Mooney creeks.

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

It is this lower 140 km section of the waterway, the lower Hawkesbury River that this assessment is focused on.

4.5.3 Pressures and Water Management Issues

The Hawkesbury Nepean River faces similar challenges that are common to many coastal river systems on the east coast of Australia. Key pressures and water management challenges include intensive urban and industrial development, agricultural practices, landuse change and clearing, significant alteration of the natural river flow, point sources including treated wastewater releases, as well as numerous, competing demands for water.

Specific water management issues within the catchment include:

- water quality: elevated contaminant levels, excess nutrients, algae and weed growth
- development: landuse change including growth of urban, commercial and industrial areas
- agriculture: practices that affect downstream waterways including fertiliser use, riparian zone reduction
- environmental water: sufficient flows and freshes to maintain river health
- increasing demand for water: growing urban population and industry growth as well as extractions for agricultural practices
- water accounting: the need to meter and more effectively regulate licence holders to account for water extraction
- point sources: increases in pollutant loads from treated water due to population growth

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

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

4.5.4 Load Analysis

Analysis of TN and TP loads has been undertaken to allow comparison of the contributions from various sub-catchments and treatment plants under current conditions (circa 2020). The loads were estimated through analysis of the model boundary conditions, discussed previously in Section 4.6 for both the representative wet and dry years.

The load analyses presented in the figures below, extend from upstream of the South Creek confluence at Redbank to upstream of the Colo Creek confluence. Figure 51 and Figure 52 present the cumulative analysis from upstream to downstream for all loads (including WWTPs and WRPs).

From these graphs, the influence of South Creek and Cattai Creek can be observed. To a lesser extent, the influence of some of the larger treatment plants can also be seen. The differences in load magnitude between the dry and wet years is also notable.

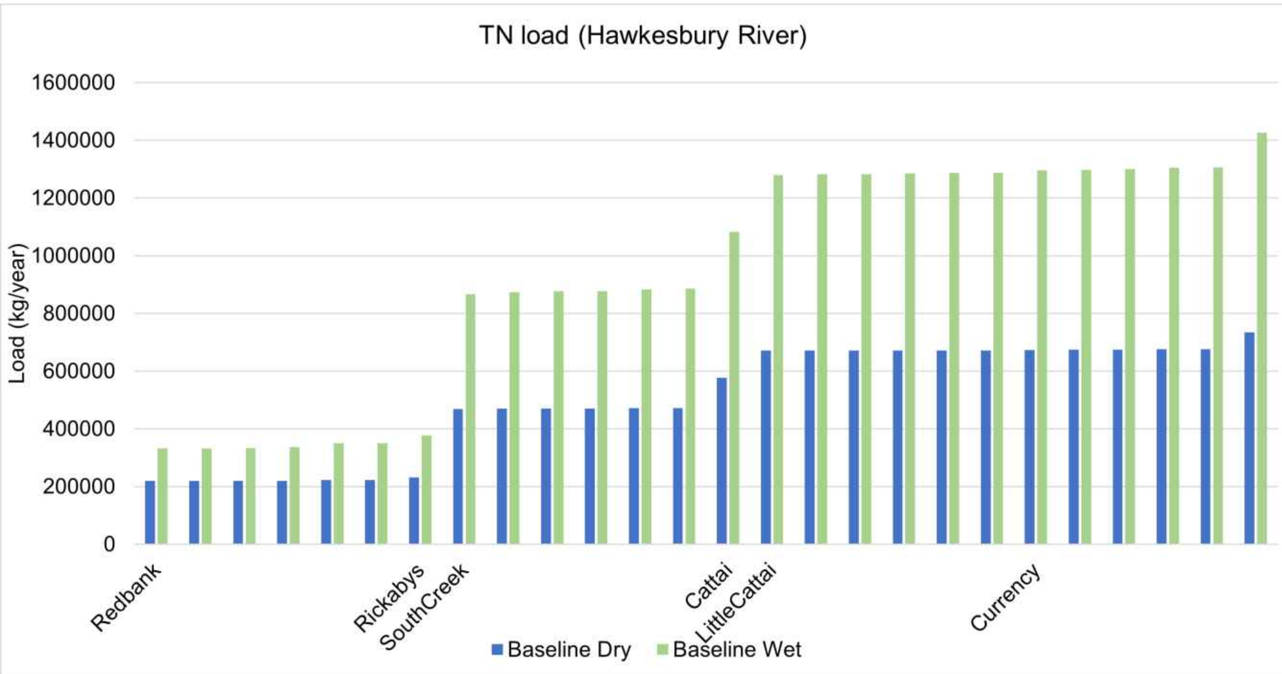

Figure 51 TN cumulative catchment loads for the Hawkesbury Nepean River (wet and dry years)

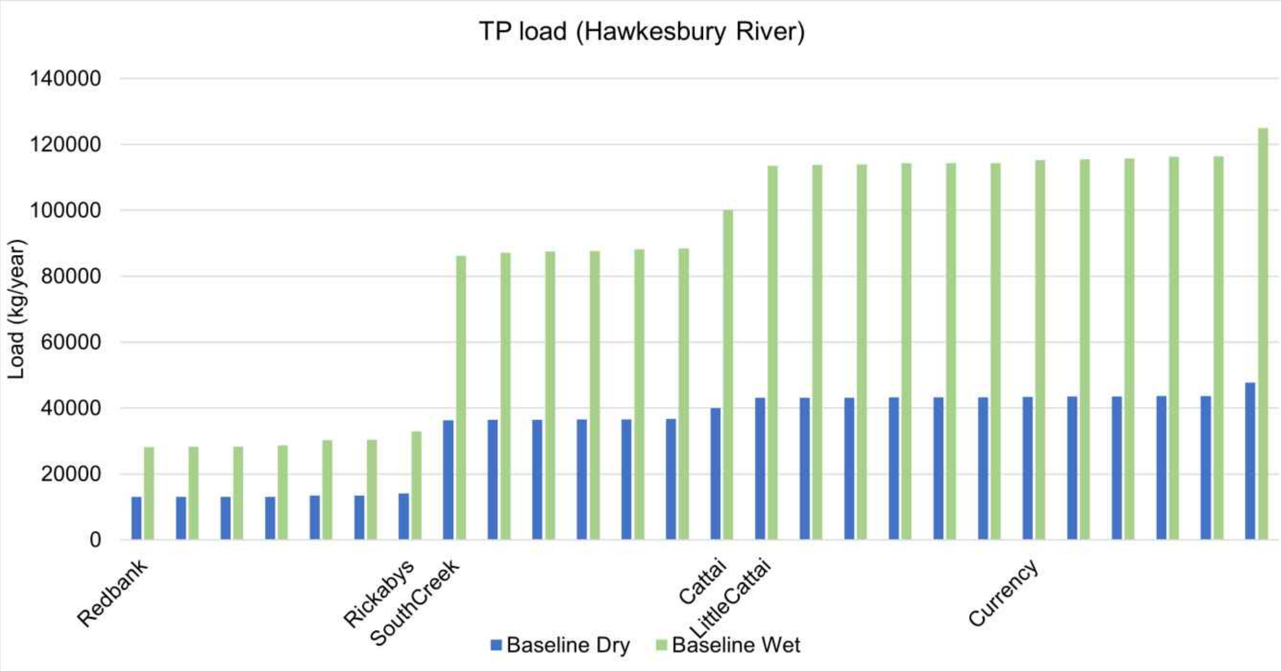

Figure 52 TP cumulative catchment loads for the Hawkesbury Nepean River (wet and dry years)

4.5.5 Water Quality

The following sections present the findings of recent studies and analysis into the water quality of the Hawkesbury River, predominantly focusing on the primary water quality processes of concern, namely nutrients and algal growth.

4.5.5.1 Nutrients

To provide an understanding of how nutrient levels generally vary along the length of the river, and also under different climatic years, the figures below present monitoring data for both TN and TP. The data is displayed in box and whisker format along the river from the mouth (0 km), up to 250 km adopted middle thread distance (AMTD). Figure 53 and Figure 54 present TN for the representative dry and wet years, respectively. Similarly, Figure 59 and Figure 60 present TP for the representative dry and wet years.

In general, nutrient levels increase from the mouth of the Hawkesbury River to a peak near or downstream of 120 km AMTD, at the confluence with South Creek. Concentrations then generally reduce and plateau with distance upstream. This is consistent with the findings of Sections 4.3 and 4.4.

Nitrogen levels in the river upstream of Wisemans Ferry (~50km AMTD) are generally elevated and above the ANZG derived waterway objective of 0.35 mg/L for both the wet and dry years. Similarly, TP concentrations appear consistently above the objective of 0.025 mg/L in the same region from Wisemans Ferry to the South Creek outlet (~120km AMTD). Upstream of the South Creek outlet, TP values are below the DGV, suggesting that the South Creek catchment is a major source of phosphorus for the Hawkesbury River.

With respect to the more bioavailable inorganic forms of nitrogen, ammonia concentrations are generally shown to be compliant, falling below guideline thresholds, except in wetter conditions downstream of the South Creek confluence. Conversely, nitrate levels are generally recorded above the ANZG waterway objective except for the initial 20 km from the estuary mouth. From a toxicity perspective, the data indicates no potential for toxicity as the peaks of ammonia and nitrate remain below the toxicant DGVs discussed in Section 2.2.

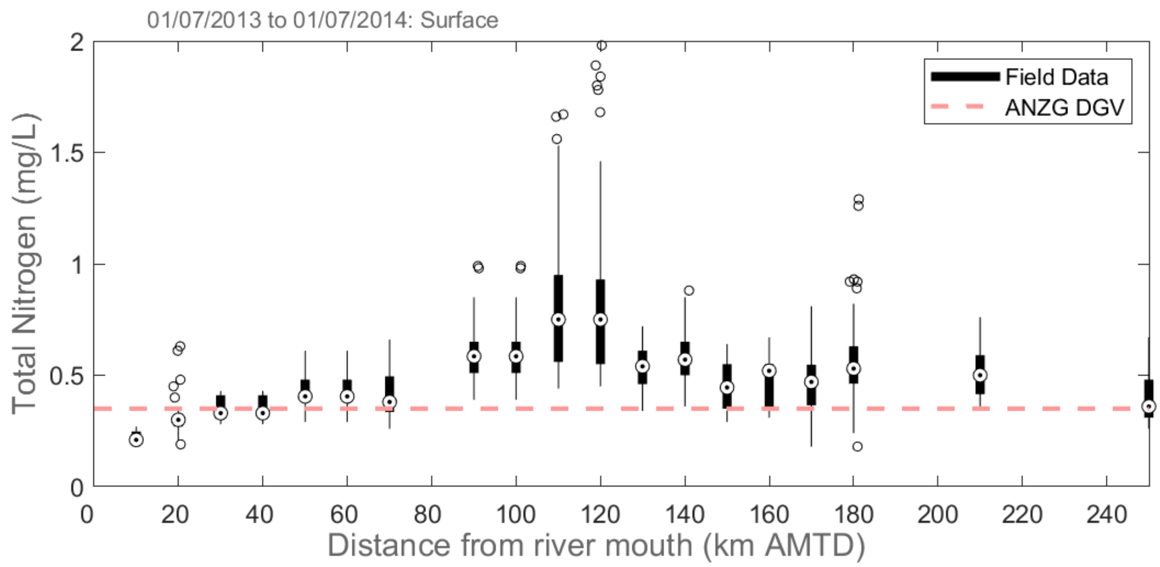

Figure 53 Longitudinal transect plots of TN monitoring data (dry year)

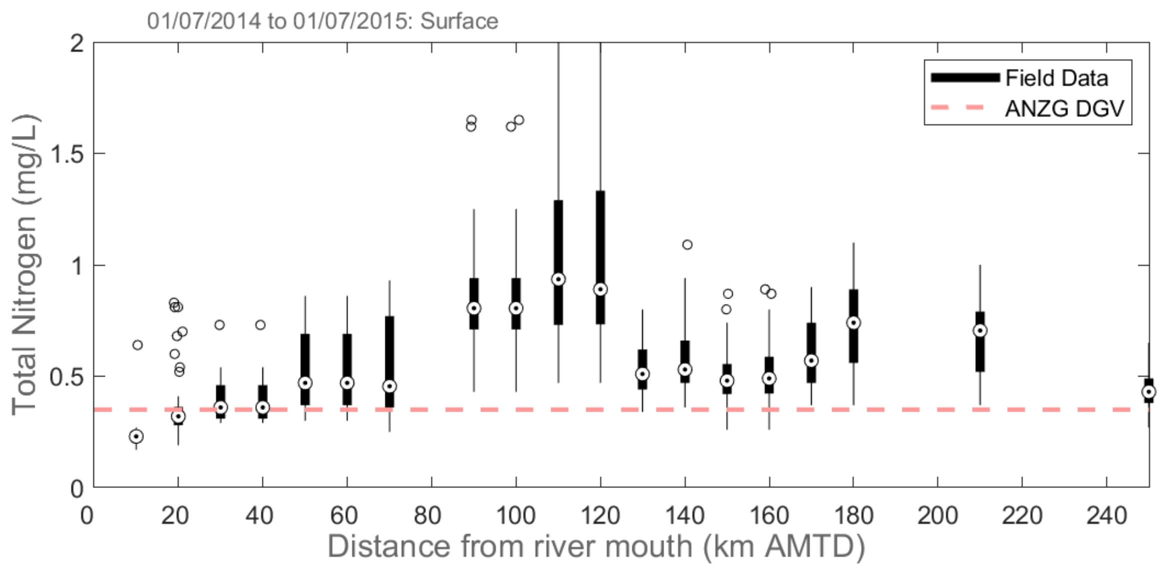

Figure 54 Longitudinal transect plots of TN monitoring data (wet year)

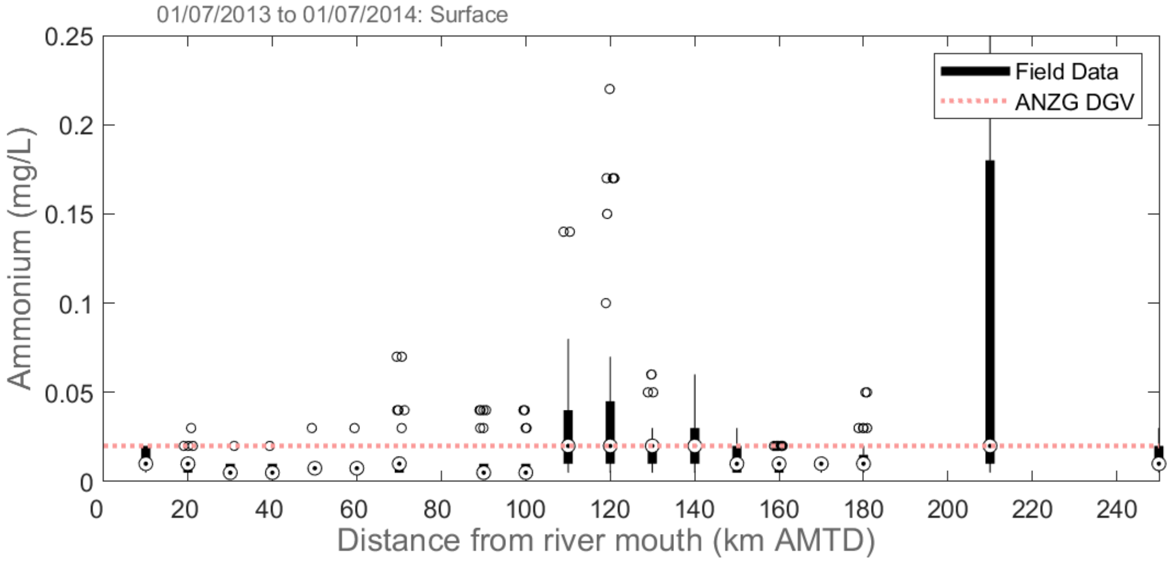

Figure 55 Longitudinal transect plots of Ammonia monitoring data (dry year)

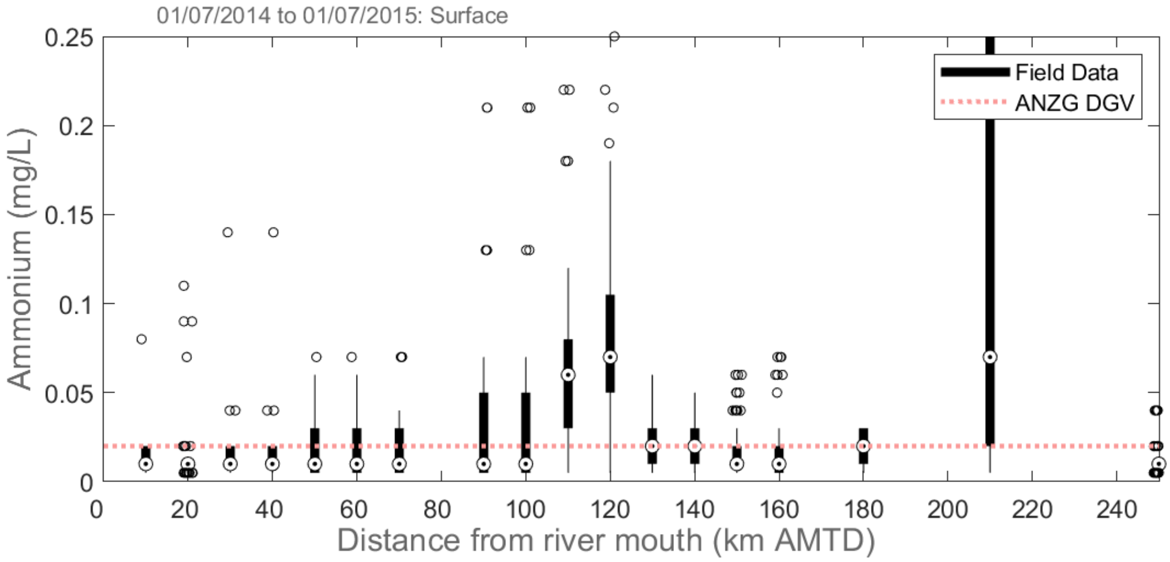

Figure 56 Longitudinal transect plots of Ammonia monitoring data (wet year)

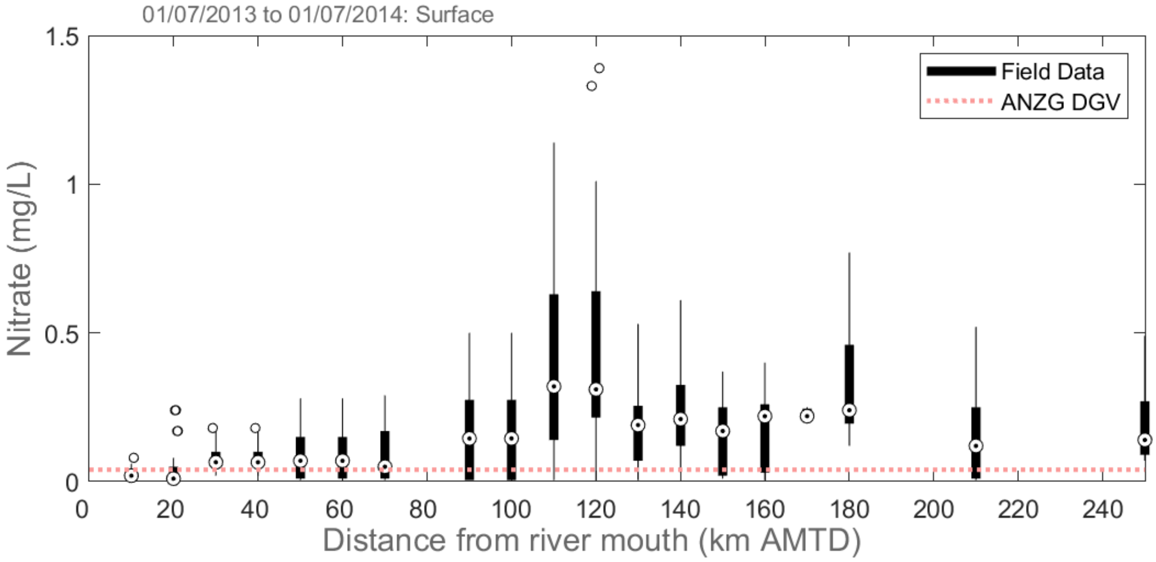

Figure 57 Longitudinal transect plots of Nitrate monitoring data (dry year)

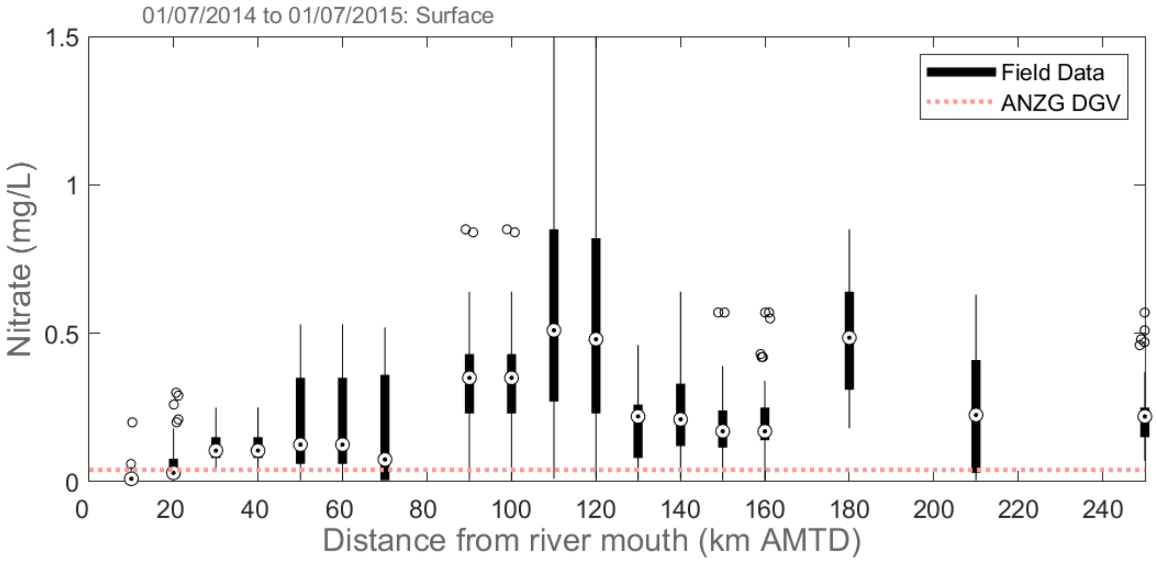

Figure 58 Longitudinal transect plots of Nitrate monitoring data (wet year)

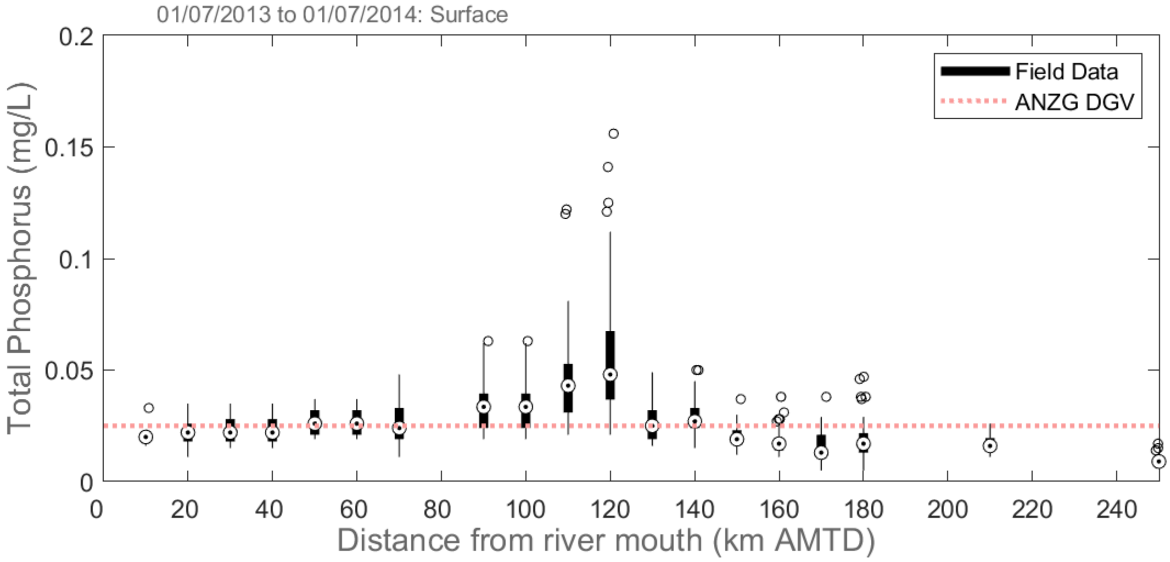

Figure 59 Longitudinal transect plots of TP monitoring data (dry year)

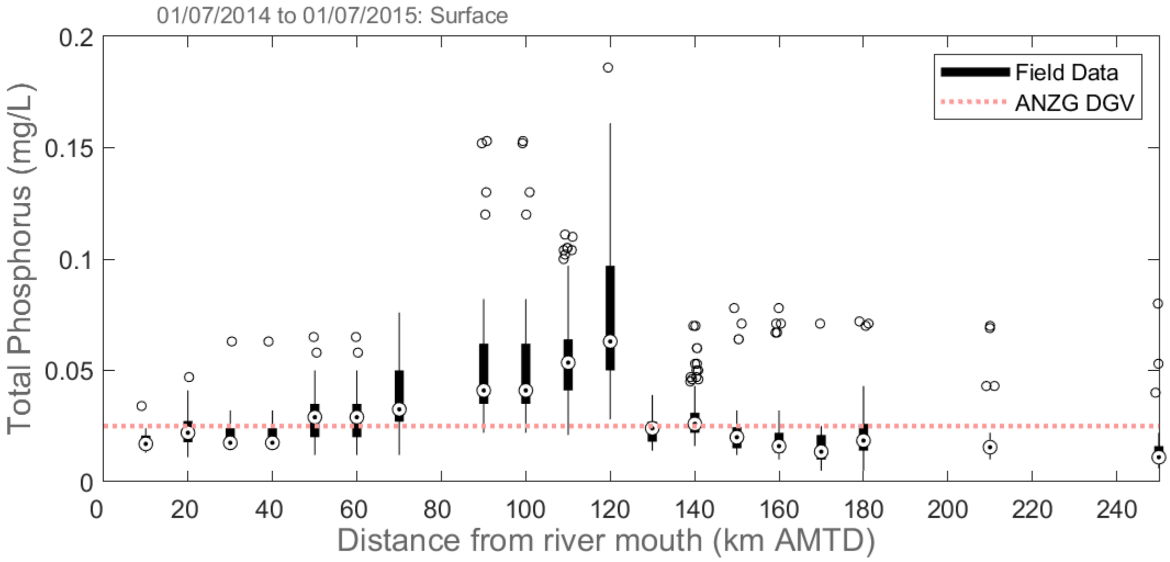

Figure 60 Longitudinal transect plots of TP monitoring data (wet year)

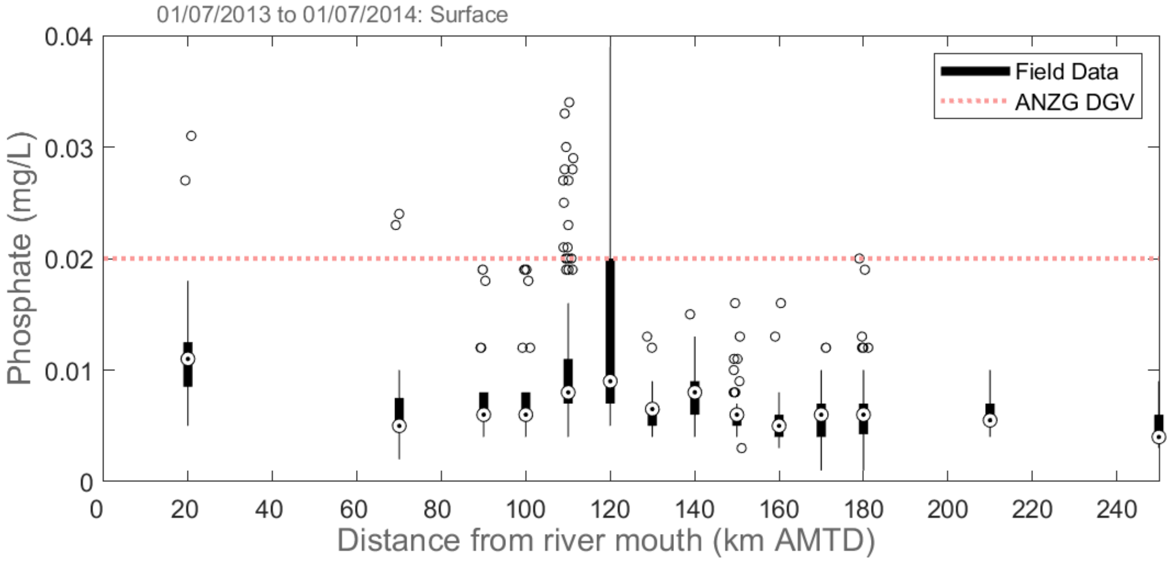

Figure 61 Longitudinal transect plots of Phosphate monitoring data (dry year)

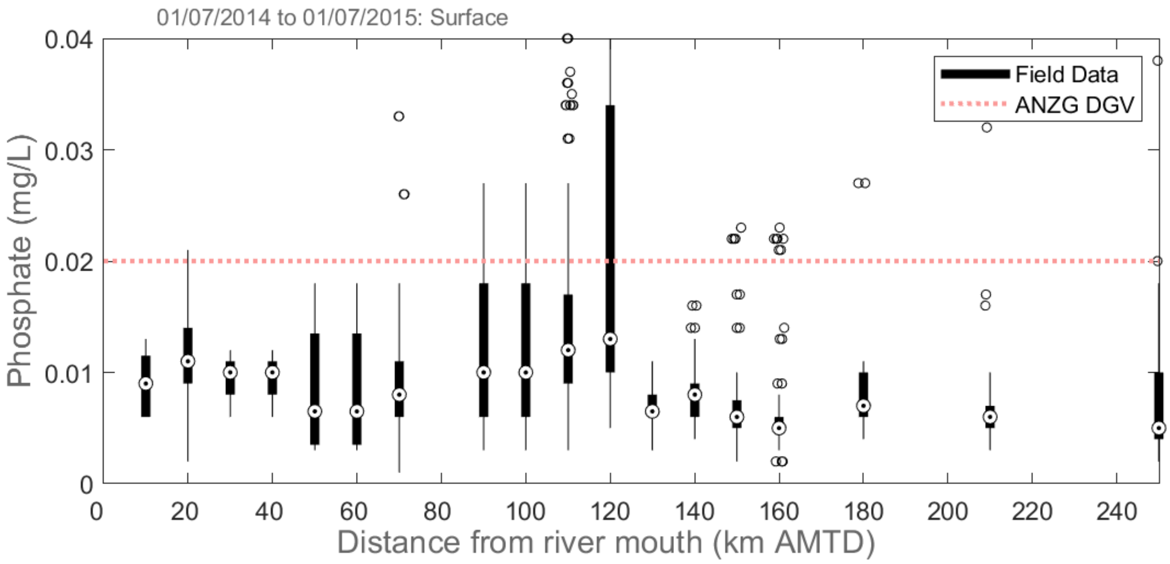

Figure 62 Longitudinal transect plots of Phosphate monitoring data (wet year)

With respect to phosphate, the data indicates compliance with the waterway objective for both climatic years. Peaks in concentrations are again shown downstream of the confluence with South Creek.

Interpretative analysis from the 2009 technical report by DECC (2009a) provided the following conclusions based on analysis of monitoring data:

- Phosphorus levels (both total and filterable) have generally been declining throughout most of the river system, although phosphorus levels downstream of South Creek often remain elevated compared with other sites.
- Long-term median TP levels are considered to be strongly linked to areas under the influence of WWTP releases, particularly between Lapstone Creek and Cattai Creek.
- Nitrogen levels have declined at many sites throughout the river system. Despite this, nitrogen levels often remain well above ANZG (2018) DGVs throughout the river system.
- Long-term median TN levels are also strongly linked to areas under the influence of WWTP releases, with peaks at South and Eastern Creeks.

In the more recent STSIMP interpretative report by Sydney Water (2018), the following findings regarding nutrient loads and waterway conditions were drawn:

- Nutrient loads (both nitrogen and phosphorus) released to the river and its tributaries have considerably decreased over the long-term (1992 to 2017). This decrease was a result of improvements in wastewater treatment processes, as well as decommissioning of older WWTPs.
- Since 2011, however, there has been an increase in the TN load released from the WWTPs. As with South Creek, this increase is thought to be a result of population growth increasing the overall volume of inflow, and thereby reducing the efficiency of nitrogen removal in the treatment process.
- Since 2011, there has been an increase in TN and dissolved inorganic nitrogen concentrations at approximately half the instream monitoring sites, while phosphorus concentrations remained static or decreased. These increases in nitrogen concentrations were primarily observed downstream of South Creek (~120km AMTD) .
- The nutrient loads for total nitrogen and total phosphorus released to the freshwater section of the river from Sydney Water's WWTPs in 2016-2017 amounted to approximately 885 kg/day and 9 kg/day, respectively. This was estimated to be ~ 28% and 2% of the TN and TP loads, respectively, from all agricultural activities.
- The water quality of the river system varied considerably between the upstream and downstream reaches with indications that the modified flow regimes, as well as loading conditions, represent a key influence.
- Generally, the water quality deteriorated with increased distance downstream where the river widens and receives nutrient rich runoff from urbanised catchments and releases from multiple WWTPs. In particular, the water quality of the lower Hawkesbury River and the South Creek confluence was comparatively poorer, with elevated concentrations of nutrients, chlorophyll *a* and algal biomass.

In the Hornsby local government area (LGA), the following range of conclusions have been drawn by the Natural Resources Branch of Hornsby Shire Council (HSC, 2019):

- Estuarine sites in the lower Hawkesbury River are exhibiting impacts from pressures that extend well beyond the Hornsby LGA, particularly with regards to increasing nutrient concentrations. Within the Hawkesbury River estuary, results indicate that TN concentrations are significantly increasing at all of the sampling sites located in the main arm of the river. Significant increases in TP are also of concern at sites located in Milsons Passage and south of Dangar Island.
- Amongst the estuarine sites, elevated nutrient concentrations are of particular concern in Berowra Creek and within the main arm of the river. These elevated levels may lead to an increase in algal blooms and impact on the recreational and commercial use of the estuary.

4.5.5.2 Algae

To demonstrate the range of primary productivity and algal growth, Figure 63 and Figure 64 present longitudinal profiles of monitoring data for chlorophyll *a,* for the representative dry and wet years respectively. While there are the expected seasonal variations in productivity, concentrations generally follow similar patterns to those shown in nutrients, with the most significant growth downstream of South Creek (120 km AMTD) as well as Sackville (80 km AMTD).

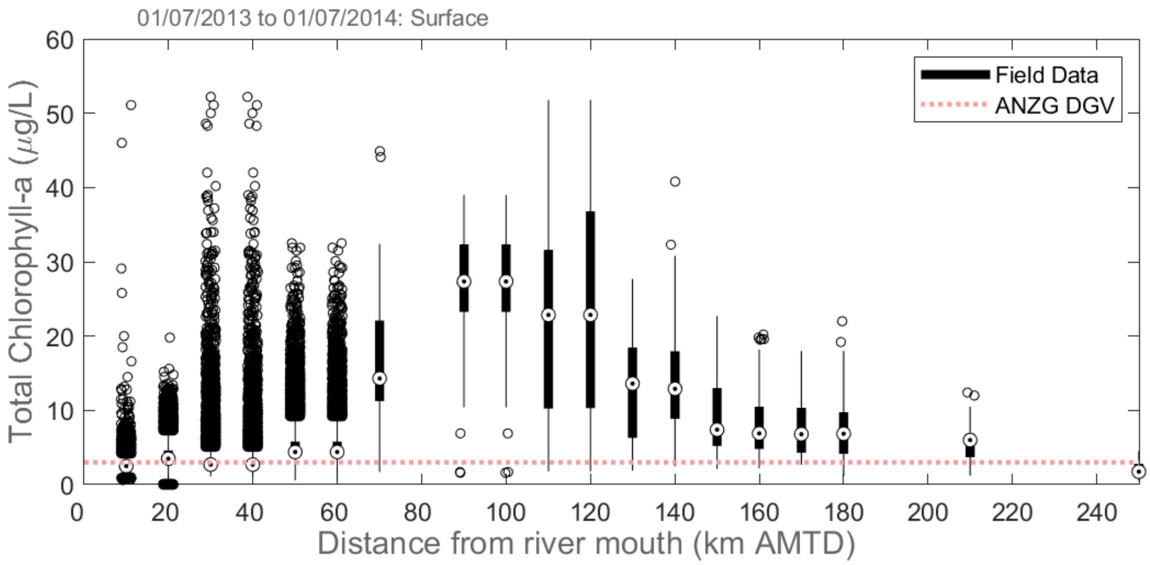

Figure 63 Longitudinal transect plots for Total Chlorophyll *a* (dry year)

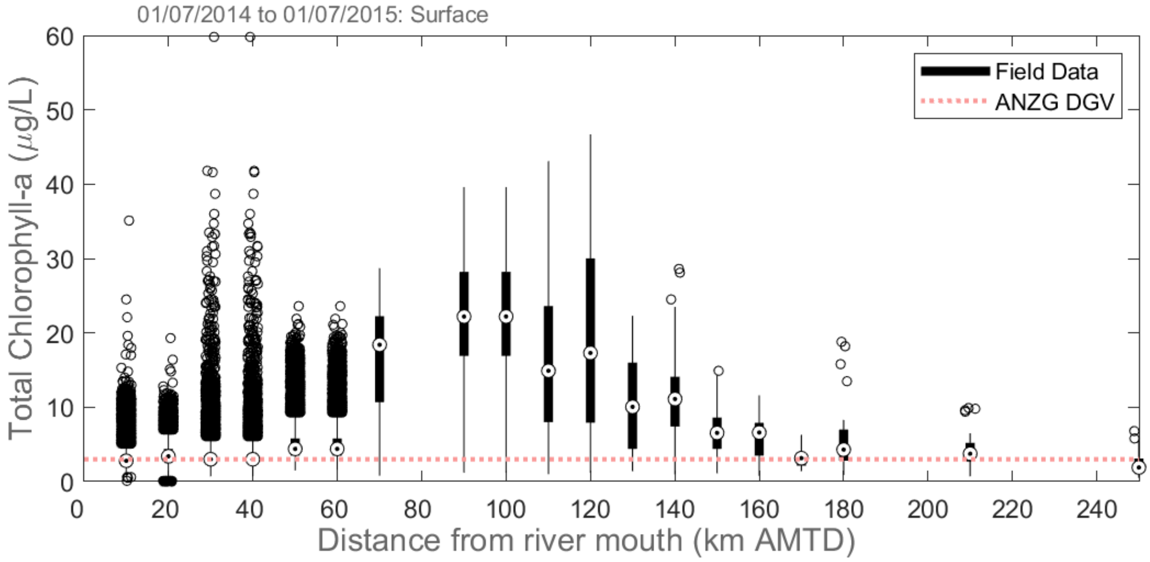

Figure 64 Longitudinal transect plots for Total Chlorophyll *a* (wet year)

Several studies have also documented the presence and impacts of algal blooms as summarised below:

- The STSIMP interpretative report (Sydney Water, 2018) commented that phosphorus was generally considered the key nutrient responsible for potentially toxic blue-green algal blooms in the lower Hawkesbury River.
- The Hawkesbury Nepean River Environmental Monitoring Program technical report (DECC, 2009a) stated that: "*Chlorophyll-a levels have mostly declined or remained stable at most sites. Cyanobacterial cell counts have largely remained stable, although some slight increases are suggested*".
- The technical report also described, however, that many areas in the Hawkesbury-Nepean are stressed, and some areas can be considered eutrophic. Large amounts of water are diverted for water supply and irrigation, and nutrient levels are often high. Outbreaks of algal blooms are therefore common.

4.5.5.3 Other Water Quality Indicators

4.5.5.3.1 Salinity

Figure 65 and Figure 66 present longitudinal profiles of monitoring data for salinity in the representative dry and wet years respectively. The transects show the significant gradient of salinity concentrations as conditions change from oceanic to freshwater. The transition to freshwater occurs around 70 to 80 km inland from the river mouth, but this distance can vary depending on the season. In both years, concentrations are compliant with the ANZG derived freshwater waterway objective upstream of the salinity wedge, located near Wisemans Ferry (~50km AMTD).

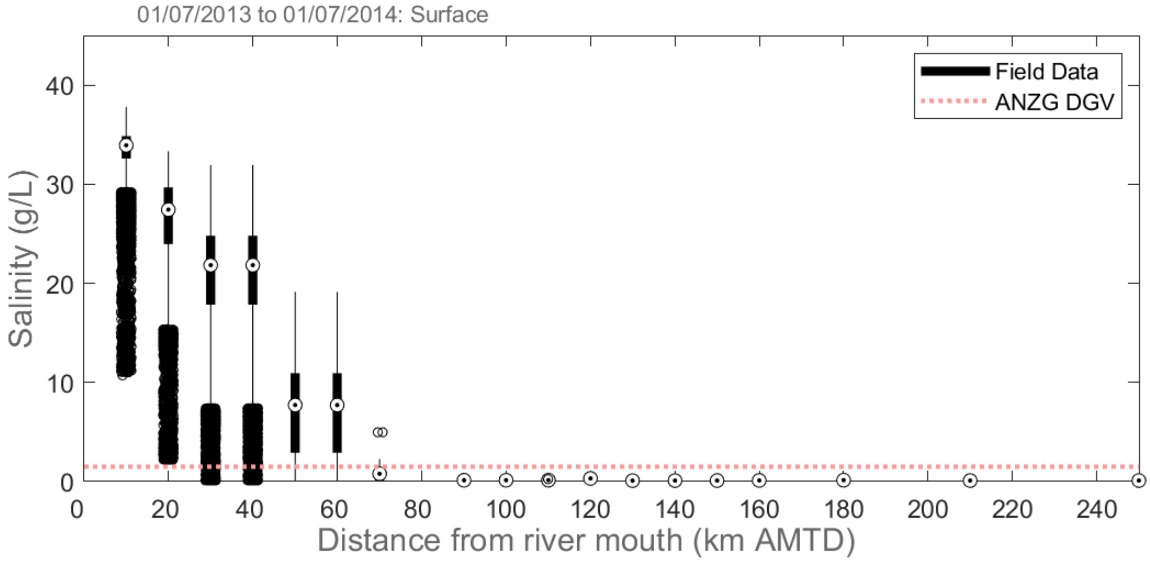

Figure 65 Longitudinal transect plots for Salinity (dry year)

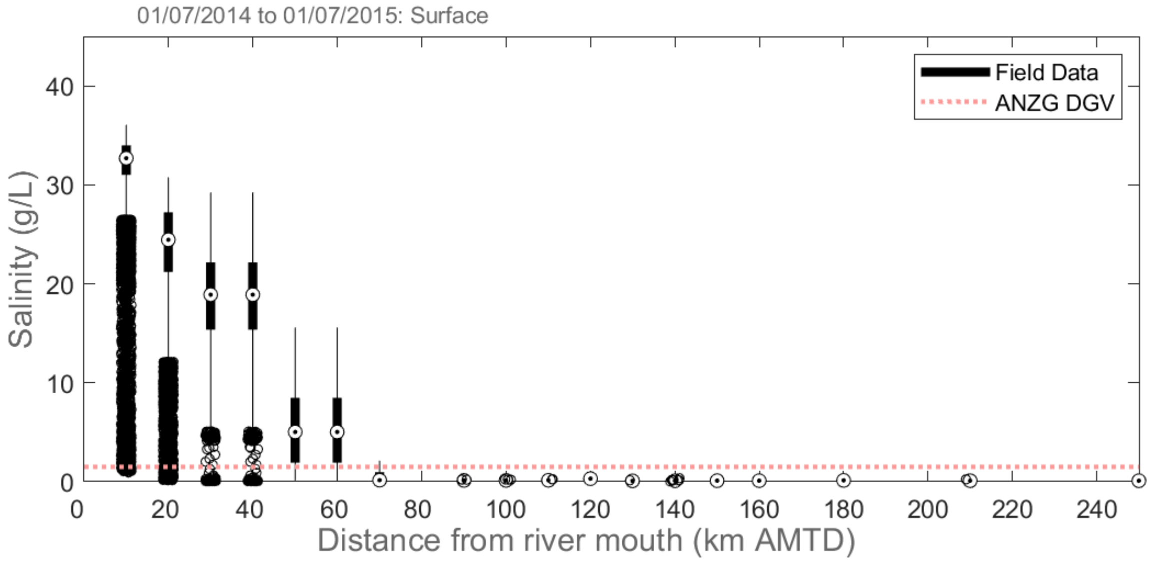

Figure 66 Longitudinal transect plots for Salinity (wet year)

4.5.5.3.2 Total Suspended Solids

Relatively limited datasets were identified with respect to suspended solids in the Hawkesbury Nepean River, particularly for the 2014-15 wet year, with no data downstream of the South Creek outlet in that year. Dry year monitoring indicates compliance against the ANZG derived waterway objective (40 mg/L). This is shown in Figure 67.

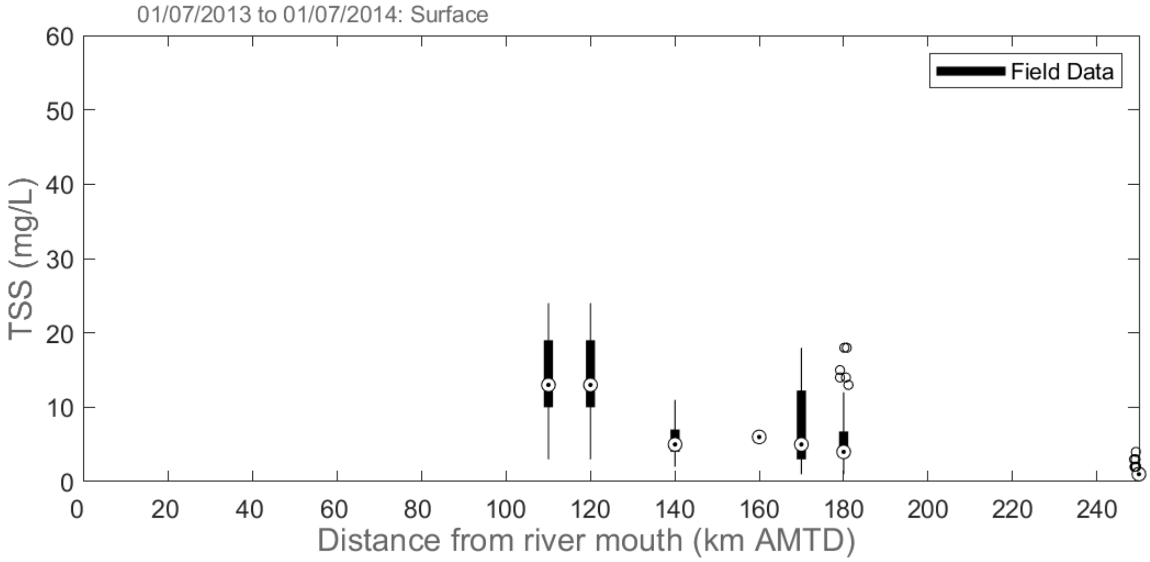

Figure 67 Longitudinal transect plots for TSS (dry year)

5 Impact Assessments

The following sections present the findings of the hydrodynamic and water quality assessments undertaken for in support of the REF. These assessments have been structured to provide assessment of anticipated impacts to the receiving waterways downstream of the NWTH treated water release points.

Within each assessment, the following sub-sections are provided:

- Scenario conditions
- Analysis locations
- Load analysis
- Scenario results
- Interpretation

Further details on the approach are provided in Section 3.5.

5.1 Scenario Conditions

A series of three modelling scenarios were undertaken to assess the impacts on the water quality of Second Ponds Creek, Cattai Creek, Eastern Creek, South Creek and the Hawkesbury River as a result of proposed upgrades to the NWTH plants, changes in catchment conditions and other plant operations (Section 3.5.3).

A summary of catchment input and WWTP discharge conditions in the scenarios is provided in Table 13 below. Details of the assumed changes in catchment input and WWTP releases in current and future conditions have also been included in Section 3.5.3.

Table 13 Summary of catchment and NWTH plant operational conditions by scenario

Scenario	Catchment Conditions and other Treatment Plant Operations	NWTH Plant Operations
Baseline	Current conditions (2020)	Current operations (2020)
Background	Future conditions (2036)	Current operations (2020)
Impact	Future conditions (2036)	Future operations (2036)

Each of the above scenarios were run over two separate climatic rainfall years to allow interpretation of how impacts may vary over the different climatic conditions.

As outlined in Section 3.5.3.1, these years were developed as follows:

- a representative lower rainfall (dry) year (2013/14) condition and
- a representative higher rainfall (wet) year (2014/15) condition.

Simulation of the two climatic years was undertaken to address how impacts from the NWTH plant releases are influenced by wet and dry conditions. The assessment of impacts on water quality under different climatic conditions is commonly undertaken as different catchment influences, such as point and diffuse sources, may become more predominant under wet or dry conditions. Similarly, different release options, such as wet weather or all-weather release strategies, will also have differing levels of influence.

A summary of the projected changes to ADWF capacity for each NWTH plant by year is provided in Table 14.

Table 14 Projected ADWF Capacity for NWTH plants by year

NWTH Plant	Projected ADWF Capacity (ML/d)		
	2021 (Current)	2026	2036
Castle Hill WRP[1]	6.9	8.2	10.1
Rouse Hill WRP[2]	28.1	32.1	42.6
Riverstone WWTP[3]	13.1	17.4	27.8

1. Castle Hill Wastewater Treatment Plant Report (Sydney Water, 2021a)
2. Rouse Hill Wastewater Network Capacity Report (Sydney Water, 2021b)
3. Riverstone Wastewater Network Capacity Report (Sydney Water, 2021c)

A summary of the modelled water quality for the current and future time horizons of 2020 and 2036, respectively, is provided in Table 15.

Table 15 Modelled median treated water quality for current and 2036 NWTH plant operations

Water Quality Parameter	Castle Hill WRP		Rouse Hill WRP		Riverstone WWTP	
	Current (2020)	Future (2036)	Current (2020)	Future (2036)	Current (2020)	Future (2036)
Total Nitrogen (TN) (mg/L)	15.76	6.22	7.01	5.04	2.40	3.05
Ammonia (mg/L)	0.10	0.19	0.10	0.20	0.01	0.23
Oxidised Nitrogen (NOx) (mg/L)	14.5	4.98	6.00	3.81	1.37	1.81
Total Phosphorus (TP) (mg/L)	0.11	0.024	0.018	0.021	0.018	0.050
Salinity (g/L)	0.49	0.48	0.46	0.45	0.54	0.54
Dissolved Oxygen (mg/L)	5.9	5.9	5.9	5.9	5.9	5.9
Enterococci (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0
E. coli (cfu/100mL)	1.0	1.0	1.0	1.0	1.0	1.0

The following formats for primary water quality parameter results have been generated at selected sites within the receiving waterways downstream of the NWTH plants to assist in the assessment of predicted impacts to water quality (as per Section 3.5.4.3):

- Box and whisker plots
- Timeseries plots
- Longitudinal profile

These plots have been generated for all three scenarios and are presented simultaneously at each site. This approach allows for analysis of the impacts from the WWTP releases on their own, in relation to the catchment conditions that are expected for the selected time horizon, and also relative to current conditions. Where pertinent, the relevant water quality objectives and/or DGVs have been provided in the plots for interpretation and impact assessment.

5.2 Scenario Results

A significant level of model output has been generated for the purposes of the hydrodynamic and water quality assessment. This includes the following formats for 11 primary water quality parameters and two hydrodynamic indicators.

- Box and whisker plots
- Timeseries plots
- Longitudinal profile plots

Scenario results have been output and provided in Appendix C.

5.3 Cattai Creek and Second Ponds Creek

5.3.1 Scenario Brief

Limited development upstream of the Rouse Hill and Castle Hill WRPs is expected between the baseline time horizon of 2020 and the background and impact time horizon of 2036. Approximately 20 ha of development is expected to occur upstream of the Rouse Hill WRP, which represents only a 1.8% change in landuse within the catchment area. Upstream of the Castle Hill WRP, catchment land use changes are anticipated to be 6.6 ha for the 2036 time horizon, representing a change of less than 1%. As such, minimal change is anticipated for water quality parameters between the baseline and background scenarios in the upper reaches of the Cattai Creek WQRM. In total, the Cattai Creek catchment is predicted to experience an increase in urban area of 161 ha, representing 0.9%. This urbanisation is further discussed and demonstrated in Section 3.5.3.2.

5.3.2 Analysis Locations

Analyses for Cattai and Second Ponds Creeks have been undertaken at selected sites along the extents of the watercourses, and the location of these sites are presented in Figure 68.

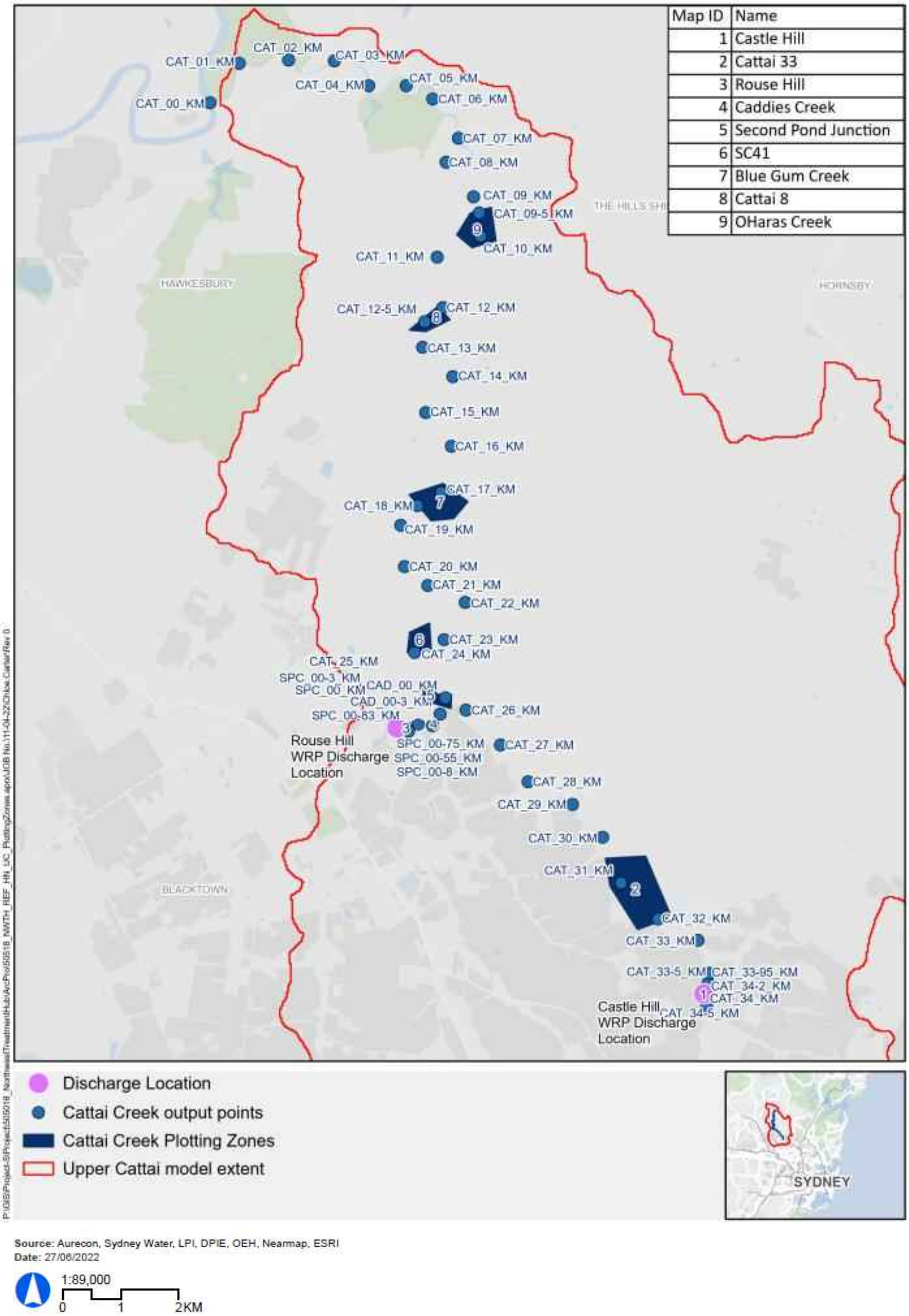

Figure 68 Hawkesbury Nepean and Cattai Creek model domain analysis locations

5.3.3 Load Analysis

An analysis of estimated TN and TP loads to Cattai Creek and Second Ponds Creek has been undertaken for all three scenarios to provide a comparison of the contributions from catchment processes and the NWTH plants. These loads have been generated using the outputs of the Cattai Creek Source model (eWater, 2022) to generate cumulative loads within the waterway from both the WRPs and catchment sources. Predicted nutrient loads have been compared against the Hawkesbury-Nepean nutrient management framework (EPA, 2019) to evaluate the performance of the NWTH upgrades.

The figures presented below are provided for the Cattai Creek and Second Ponds Creek systems. Second Ponds Creek is a tributary of Caddies Creek which is a tributary of Cattai Creek. The figures used in this load analysis seek to simplify the geography of these waterways, to provide a conservative assessment of nutrient loads that is easily interpreted.

Presented from upstream to downstream, Figure 69 through Figure 70 show TN load results in Cattai Creek for the representative dry and wet years, respectively. TN loads for Second Ponds Creek for the representative dry and wet years are provided in Figure 71 and Figure 72, respectively. TP load results for Cattai Creek in the representative dry and wet years are shown in Figure 73 and Figure 74, respectively. TP load results for Second Ponds Creek in the representative dry and wet years are provided in Figure 75 and Figure 76, respectively.

Complementing these figures, median loads and load limits are provided in Table 16.

From the load analyses, the following findings can be drawn:

- The predicted TN and TP loads in the background scenarios are very close to that in the baseline scenarios in both the dry year and wet year, suggesting the land-use change (discussed in Section 5.3.1) in the catchment under future time horizon (2036) has minor impacts on the nutrient loading when compared to the current condition (2020 time horizon).
- From the estimates, the NWTH upgrades at the Rouse Hill WRP are predicted to significantly decrease the total nutrient loads of Caddies Creek and Cattai Creek under all scenarios, despite the TN and TP loads predicted to more than double downstream of the Caddies Creek confluence for the baseline and background scenarios.
    - Under the impact scenario, the median predicted loads for both TN and TP downstream of the Rouse Hill WRP are reduced by more than 60% and 80%, respectively, when compared to those of both baseline and background scenarios within Second Ponds Creek. This is particularly evident in the representative dry year when the catchment inflows are smaller relative to the higher rainfall conditions of the representative wet year. The waterway is therefore more susceptible to nutrient loading from treated water releases.
- Similarly, the predicted influence of the Castle Hill WRP on TN and TP loads to Cattai Creek for all three scenarios is considerable for both dry and wet years when comparing the predicted loads of the region upstream. This is largely attributable to the fact that the headwaters of Cattai Creek above Castle Hill are primarily ephemeral under natural

conditions. Castle Hill WRP releases are continuous, resulting in a complete change in flow regime and associated loading for this portion of the waterway.

- The TN loads in the impact scenario predict large reductions in comparison to the background scenario.
- The magnitude of these reductions is particularly evident in the model results for the representative dry year when the WRPs present a greater contribution to the TN load.
- For the Castle Hill WRP, dry year TN loads in the background scenario are predicted to be nearly identical to those of the baseline at approximately 38 tonnes/year. In the impact scenario, TN loads are predicted to decrease by approximately 13 tonnes/year as part of the NWTH upgrades to approximately 24 tonnes/year.
- For the Rouse Hill WRP, dry year TN loads in the background scenario are predicted to also be nearly identical to those of the baseline at approximately 41 tonnes/year. In the impact scenario, TN loads are predicted to decrease by approximately 23 tonnes/year as part of the NWTH upgrades to be approximately 18.4 tonnes/year.
    - This load reduction is attributable to the compliance upgrades for the 2024 EPLs, where median treated water release TN concentrations have been predicted to reduce from approximately 16 mg/L to 6 mg/L for Castle Hill WRP and from 7 mg/L to 5 mg/L for Rouse Hill WRP. In evaluating the predicted change to concentrations of nitrogen species for both WRPs, NOx has been observed to represent the greatest reductions in bioavailable nitrogen for the impact scenario.
- For Phosphorus also, the improved treatment outcomes associated with the Rouse Hill WRP's upgrades are predicted to more than halve (approximately 1,100 kg/year to 450 kg/year) the TP loads from the plant's treated water releases, resulting in water quality improvements for Second Ponds Creek and Caddies Creek.
- Downstream of the confluence with Caddies Creek, however, the predicted reductions in TN loads from the Rouse Hill WRP treatment upgrades under the impact scenario represent a more minor decrease of 20% relative to the background and baseline scenarios.
    - This is largely due to the increased treatment standards and is despite the increased flows proposed for the NWTH upgrades.
- The TP loads for Cattai Creek are predicted to be similar between the impact and background scenarios in the dry year (Figure 73), however, they are predicted to be slightly increased in the wet year (Figure 74) for the impact scenario.
    - This marginal increase is due to the increase in median TP concentration for treated water releases from Castle Hill from approximately 0.02mg/L to 0.05 mg/L.
- Median combined nutrient loads of both Rouse Hill and Castle Hill WRPs are below the Sackville subzone 3 total limits for both TP and TN specified in the Hawkesbury-Nepean nutrient management framework (EPA, 2019).

- Of particular note is that total TN loads are predicted to be nearly half of the total limit specified by the nutrient management framework.

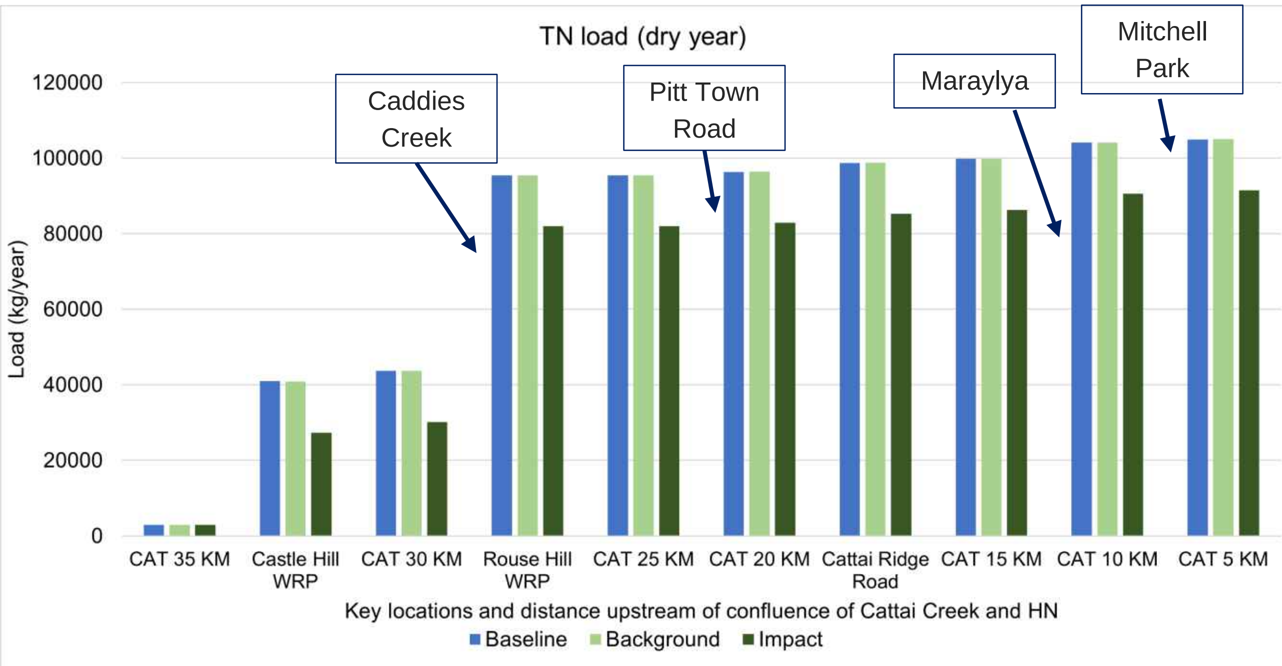

Figure 69 Cumulative TN loads for Cattai Creek assuming a representative dry year

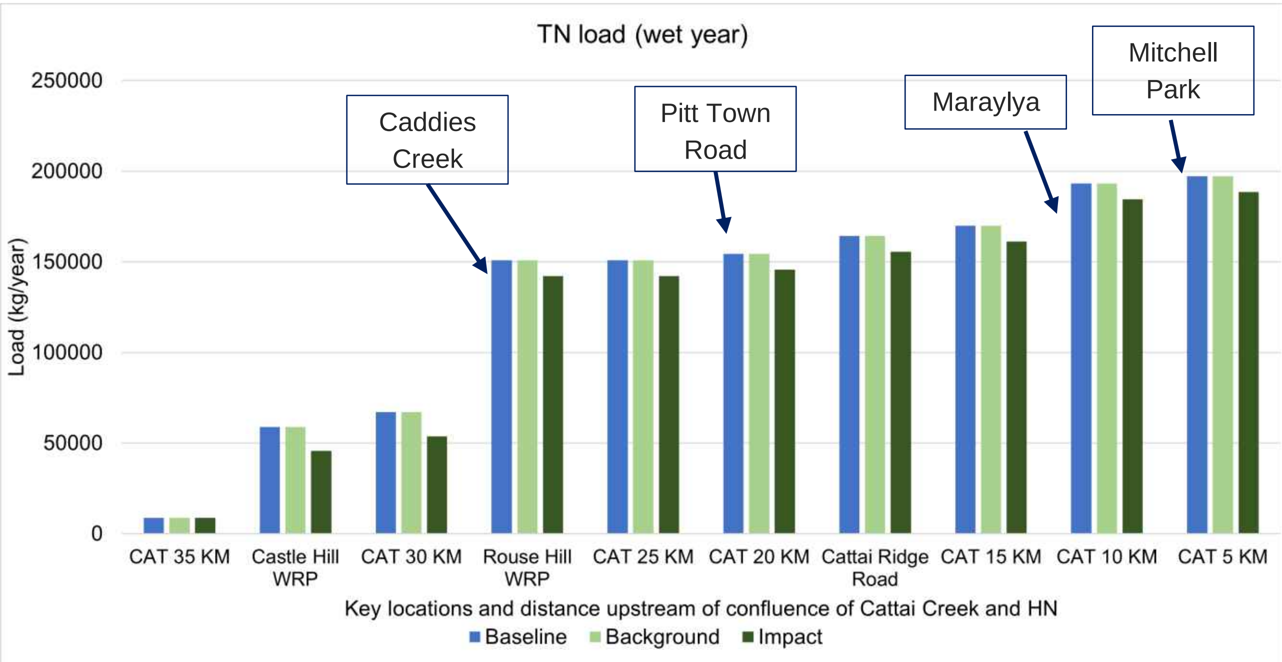

Figure 70 Cumulative TN loads for Cattai Creek assuming a representative wet year

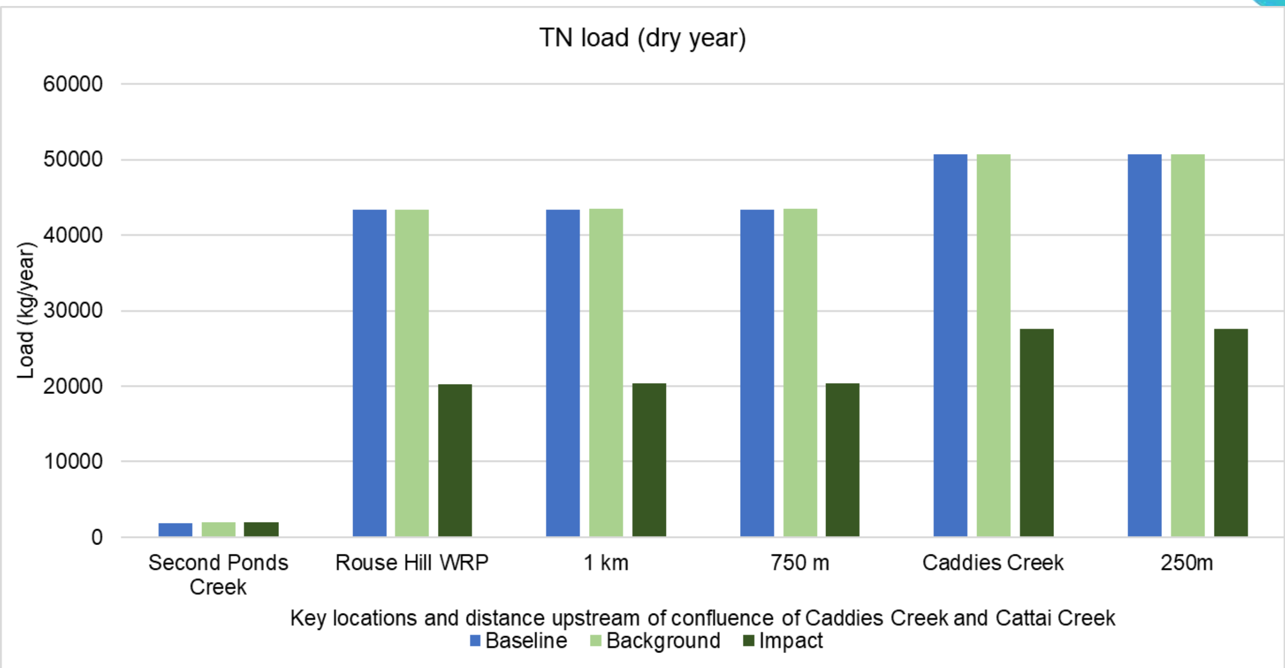

Figure 71 Cumulative TN loads for Second Ponds Creek assuming a representative dry year

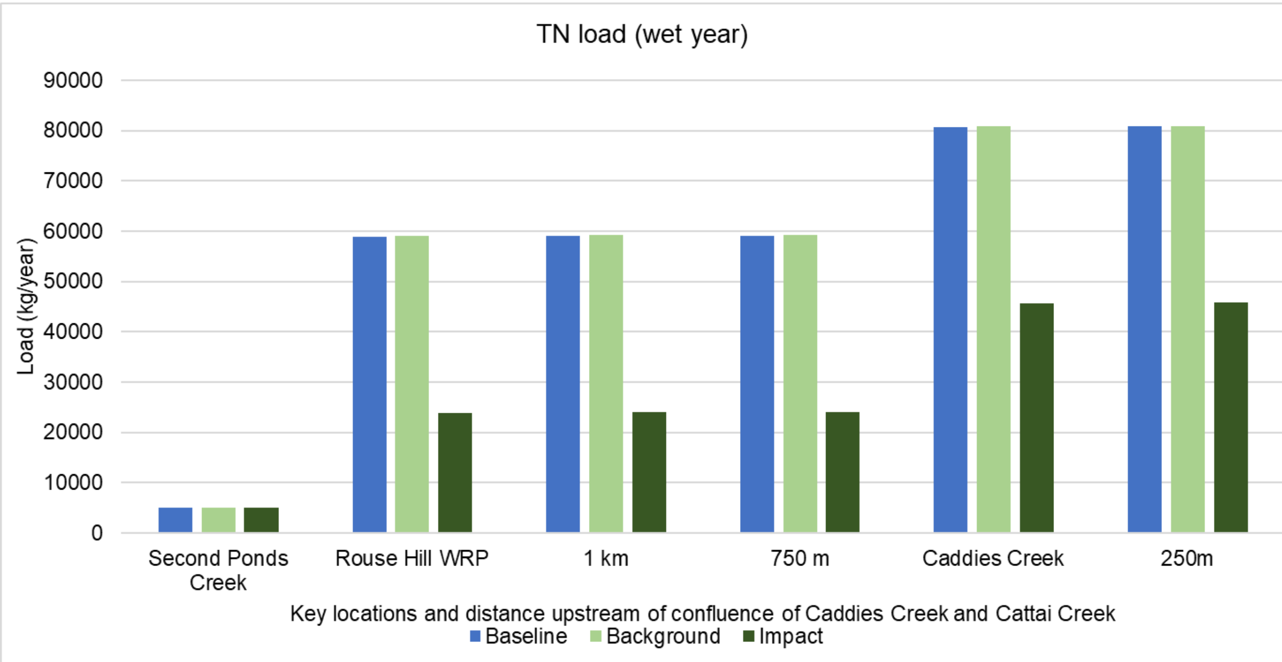

Figure 72 Cumulative TN loads for Second Ponds Creek assuming a representative wet year

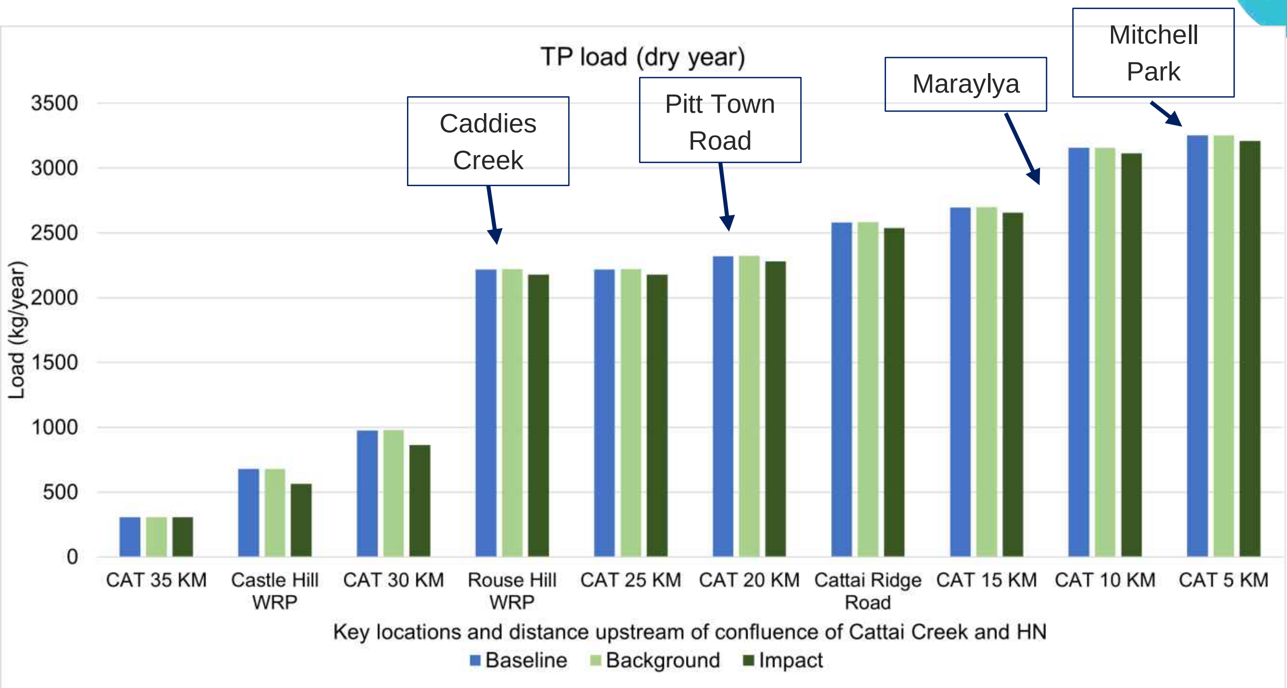

Figure 73 Cumulative TP loads for Cattai Creek assuming a representative dry year

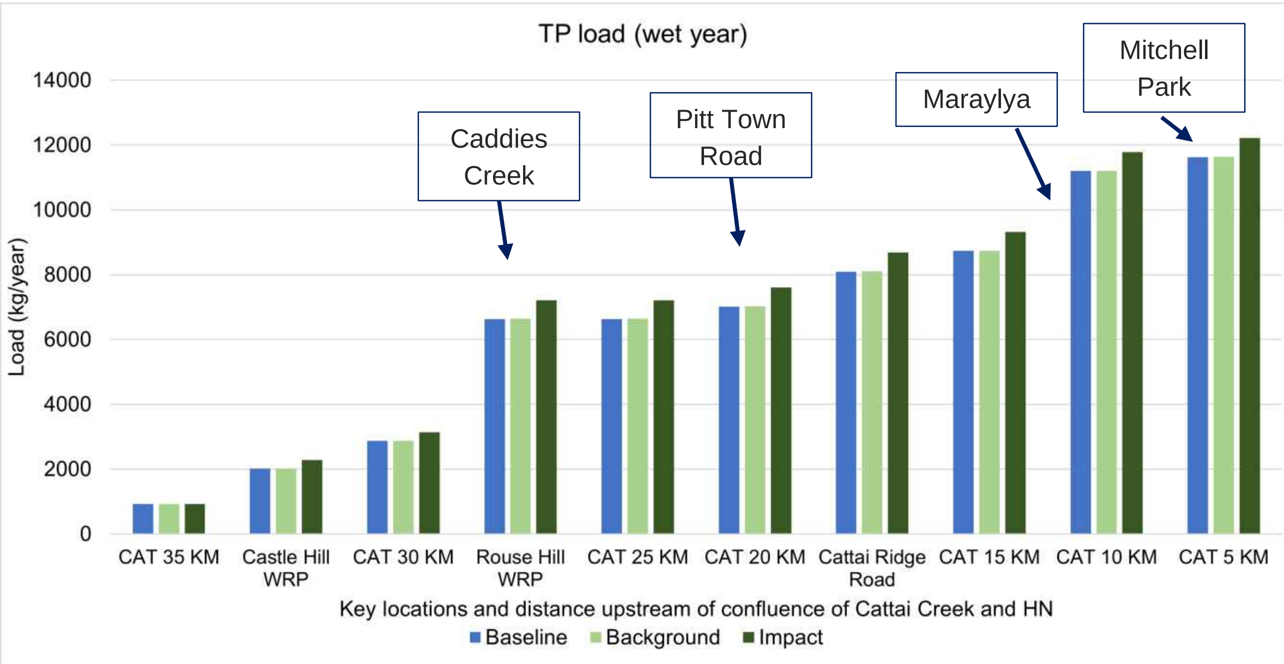

Figure 74 Cumulative TP loads for Cattai Creek assuming a representative wet year

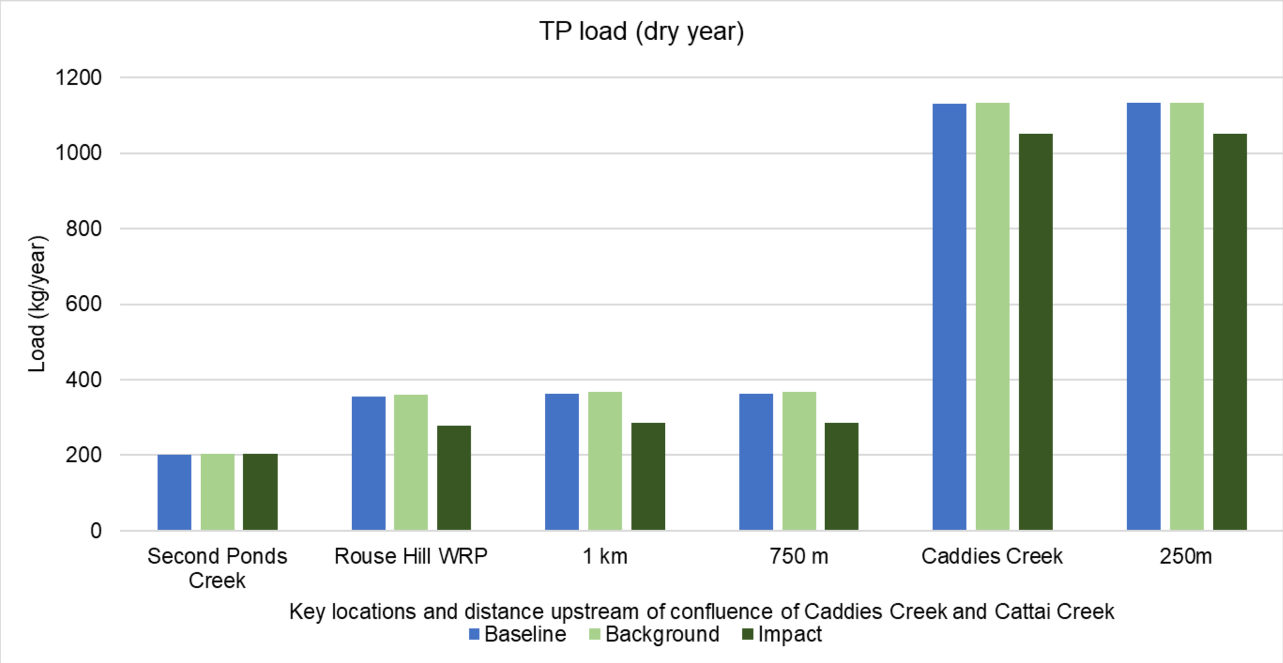

Figure 75 Cumulative TP loads for Second Ponds Creek assuming a representative dry year

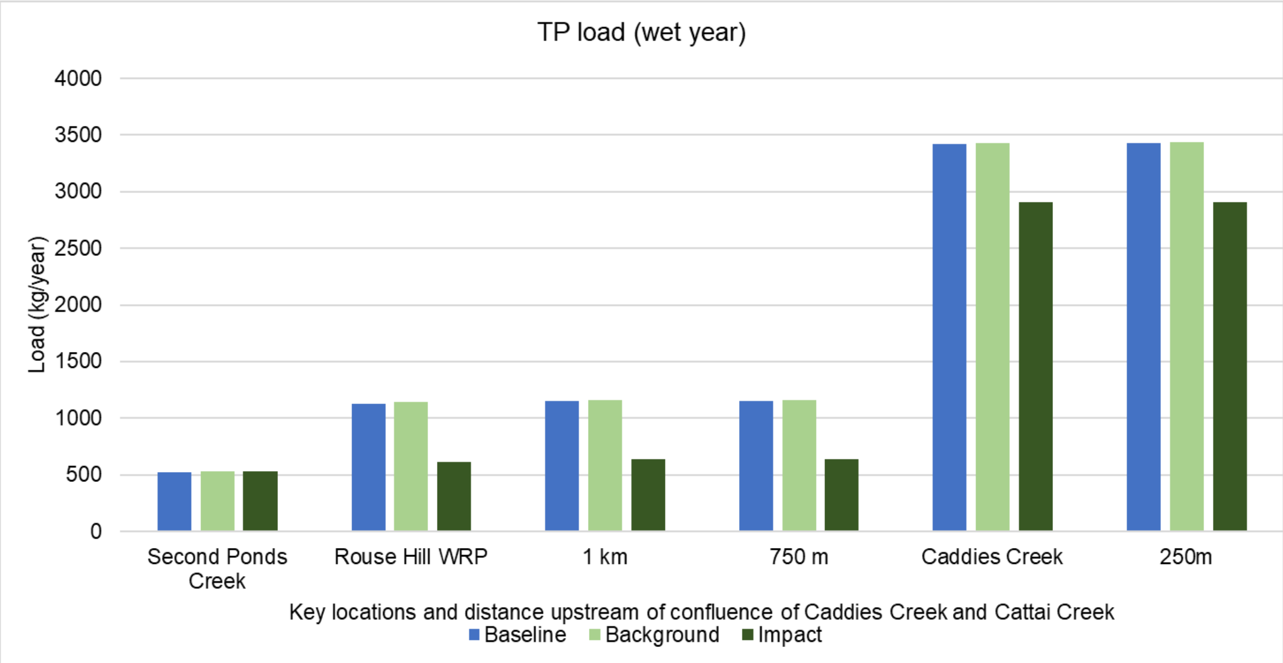

Figure 76 Cumulative TP loads for Second Ponds Creek assuming a representative wet year

Table 16 Nutrient loads NWTH plants and Sackville Zone 3 compliance summary

WRP	2036 - TN (tonnes/year)	2036 -TP (tonnes/yr)
Rouse Hill	18.6	0.1
Castle Hill	30.6	0.8
Total Estimated Load	**49.2**	**0.9**
Subzone Load limit	**82.4**	**1.2**

5.3.4 Interpretation

5.3.4.1 General

The following section summarises the interpreted results from the relative impacts predicted for the impact scenario relative to the background and baseline scenarios. The results therefore allow a comparison with respect to the predicted response of water quality in Cattai Creek and Second Ponds Creek due to changes in the catchment inputs in the background scenario and the relative change to water quality within these waterways due to the NWTH WRP upgrades. The predicted response is then evaluated against the relevant DGVs outlined in Section 2.2. Brief commentary is also provided to relate the predicted changes in nutrient concentrations to the load analyses provided in Section 5.3.3.

- Concentrations for nutrients are predicted to remain almost entirely the same for both Second Ponds Creek and Cattai Creek between the baseline and background scenarios. This is largely due to the limited development that is anticipated to occur within the catchment, as discussed in Section 5.3.1.
- The representative wet year generally predicted lower nitrogen and Enterococci concentrations than the dry year, likely due to the higher flushing arising from elevated catchment flows and the lower residence times associated with those increased flows. This is true for all three scenarios assessed.
- Chlorophyll-*a* concentrations in both the baseline and background scenarios are predicted to be relatively low, suggesting that minimal algal risk exists in the system currently.
- In general, the predicted annual median profiles of TN, TP and Enterococci concentrations are close to or exceed the compliance with the ANZG DGVs for both the background and baseline scenarios.

With implementation of the NWTH upgrades for the Castle Hill and Rouse Hill WRPs (refer Section 5.1.2.1), the predicted residual impacts are considered to improve the long-term ambient water quality and/or ecosystem health, compared to the background scenario.

The following supporting comments are provided with respect to the results from the impact scenarios relative to corresponding background conditions.

- The hydrodynamic conditions for Second Ponds Creek and Cattai Creek are predicted to experience limited change due to the proposed upgrades to the Rouse Hill and Castle Hill WRPs.
- The impact scenario with the WRP discharge based on the 2036 time horizon generally predicted significant decreases in nitrogen and phosphorus concentrations, as well as in concentrations of pathogens and phytoplankton biomass. Differences of other key water quality variables, including TSS and dissolved oxygen, between the impact scenario and background scenario varied across different sites in the creeks, but the differences are generally small when compared to their inter-annual variations.
- The wet year results predicted lower annual median nitrogen concentrations relative to the dry year results in general, most likely as a result of increased stormwater flows in the system providing dilution and increased flushing.
- Despite the significant improvement in water quality in the impact scenario compared to the background scenario, the predicted annual median profiles of TN and TP levels and Enterococci concentrations are still generally close to, or exceeding the compliance DGVs established in Section 2.2. This suggests that the water quality DGVs being met for the system is dependent on the overall catchment loads being addressed.

5.3.4.2 Hydrodynamics

This section provides commentary on the anticipated hydrodynamic impacts to Cattai Creek and Second Ponds Creek from the proposed upgrades to Castle Hill WRP and Rouse Hill WRP. The findings are drawn from analysis of the impact scenario against baseline and background scenarios to provide an estimate of the proportional contribution of impact from treated water releases in comparison to other catchment conditions.

Based on the results of the modelling of Cattai Creek the hydrodynamics immediately below the Castle Hill WRP discharge location are not predicted to be more than marginally impacted upon by the alteration of flows based on the proposed upgrades to the WRP. While the magnitude of ADWF treated water releases from Castle Hill is expected to increase from 6.9 ML/day to 10.1 ML/day, this is predicted to result in minor increases to water level of < 5cm, with those increases being most evident in dry conditions immediately downstream of the WRP treated water release locations (Figure 77). It's predicted that this increase in flow will also encourage flushing of nutrients and improve water quality for the waterway, particularly during dry weather events when conditions may be prone to greater stagnation. The predicted median annual water level of Cattai Creek does not vary by scenario for both dry and wet years, suggesting that the creek is primarily downstream controlled and operating in a low kinetic energy state for the most part.

Water level results for Second Ponds Creek for both dry and wet years show that in the immediate vicinity of the Rouse Hill WRP treated water release location the proposed increase in flows from the WRP will result in less than 10 cm of additional depth within the waterway under dry conditions Figure 78. Given that Rouse Hill WRP is modelled as increasing its treated water discharges (ADWF) from 28.1 ML/day to 42.6 ML/day (an increase of approximately 50%) under the proposed upgrades, this outcome suggests that flow through this section of waterway is hydraulically limited resulting in either a chain of ponds or backwater effect in the system. This is consistent with observations of this reach (EcoLogical, 2021).

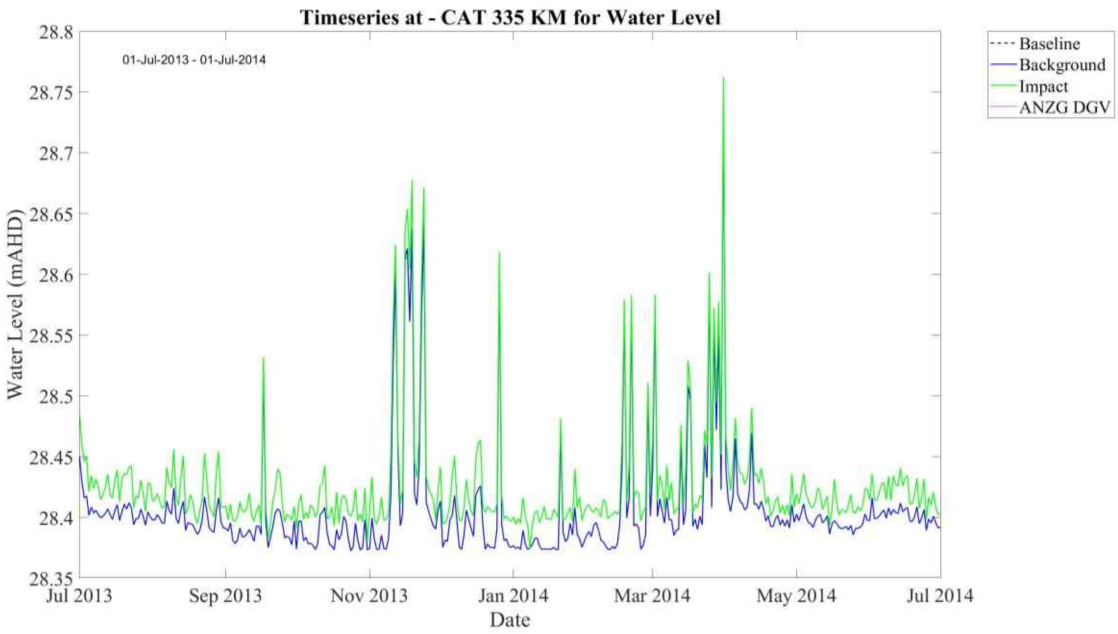

Figure 77 Timeseries of predicted Cattai Creek water level 500m downstream of Castle Hill WRP treated water release location by scenario for typical dry year (2013/2014)

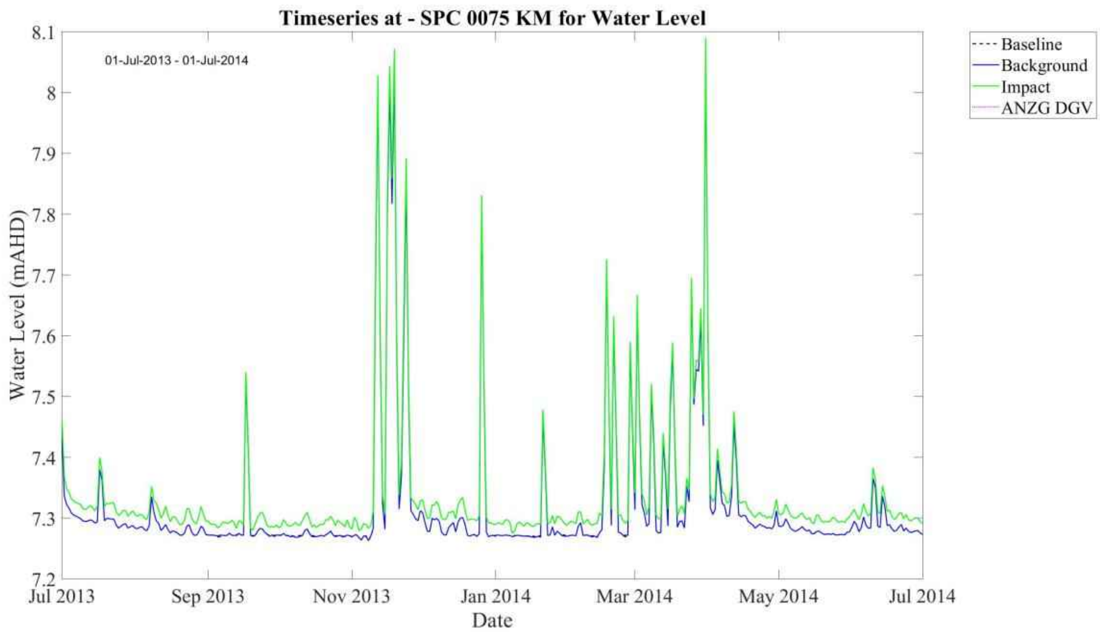

Figure 78 Timeseries of predicted Second Ponds Creek water level 500m downstream of Rouse Hill WRP treated water release location by scenario for typical dry year (2013/2014)

5.3.4.3 Water Quality

5.3.4.3.1 Nutrients

Nitrogen

- For all changes to nitrogen in both Cattai Creek and Second Ponds Creek, the representative dry year represented the least favourable outcomes. For brevity, all figures showing scenario comparisons are for the dry year only as a result.
- The annual median TN concentrations for Cattai Creek and Second Ponds Creek in all three scenarios are predicted to experience a considerable reduction from the background scenario.
  - This decrease is from approximately 15 mg/L in the upstream section of the waterway to less than 5 mg/L for its entire length (Figure 79). Similarly, median TN concentrations within Second Ponds Creek are predicted to experience a decrease of approximately 2 to 2.5 mg/L.
  - Timeseries plots for dry year TN concentrations downstream of Castle Hill WRP and Rouse Hill WRP (Figure 81 and Figure 82, respectively) support this and show dramatic reductions in daily peak concentrations.
- Annual median NOx concentrations for Cattai Creek are predicted to substantially reduce in the upper reaches of the waterway in the impact scenario.
  - This decrease is greatest in the representative dry year with NOx decreasing from approximately 14 mg/L to 3 mg/L due to the improved quality of Castle Hill WRP treated water releases (Figure 83).
  - The median Castle Hill WRP treated water NOx concentrations are expected to decrease by approximately 66% from 14 mg/L to 5 mg/L.
- As the upper reaches of Cattai Creek are ephemeral in the absence of the treated water flows, the concentration of NOx in the treated water releases from Castle Hill can be largely assumed to represent the concentration of NOx within the waterway in the reach immediately downstream of the WRP’s release location for the representative dry year.
  - Timeseries plots for NOx concentrations downstream of the Castle Hill WRP are provided in Figure 81.
- Annual median NOx concentrations within Second Ponds Creek are predicted to decrease by approximately 2 to 3 mg/L for the impact scenario when compared to the background scenario. This is due to the proposed upgrades for Rouse Hill WRP and despite the 155% increase in the WRP’s EP in the impact scenario time horizon (2036).
  - NOx concentrations modelled in the Cattai Creek WQRM have been incorrectly configured for the Rouse Hill WRP at the time of this writing. The baseline and background scenarios have been modelled using erroneous treated water concentrations that are two orders of magnitude smaller than current Sydney Water EKAMS data has identified.

    - Median NOx concentrations of the treated water releases from Rouse Hill are predicted to decrease to 3.8 mg/L from 6.0 mg/L under the impact scenario.
    - The anticipated reductions in NOx concentrations for Second Ponds Creek can be seen in the median annual TN concentrations of the representative dry year provided in Figure 80.
- Annual median NOx concentrations across both waterways are predicted to not meet the ANZG DGV under any scenario, however, they are predicted to be reduced under the impact scenario when compared to the background for both receiving waterways. Upper Cattai Creek above the confluence with Caddies is predicted to experience a greater reduction.
- The annual median Ammonia concentration profiles are presented for Cattai Creek and Second Ponds Creek in Figure 84 and Figure 85, respectively.
    - Ammonia concentrations are predicted to increase for both Castle Hill WRP and Rouse Hill WRP as part of the compliance upgrades evaluated in this project, and modest increases to median Ammonia concentrations can be observed for the lower reaches of Cattai Creek as a result. It should be noted, however, that the Ammonia concentrations used in this modelling are conservative in nature and may be lower than assumed in this assessment.
    - Ammonia concentration time series plots immediately downstream of both WRPs are provided in Figure 86 and Figure 87.
- Median Ammonia concentrations for Second Ponds Creek are predicted to be below ANZG DGVs upstream of Caddies Creek. Ammonia concentrations in the impact scenario are predicted to negligibly decrease from the background scenario, remaining compliant.

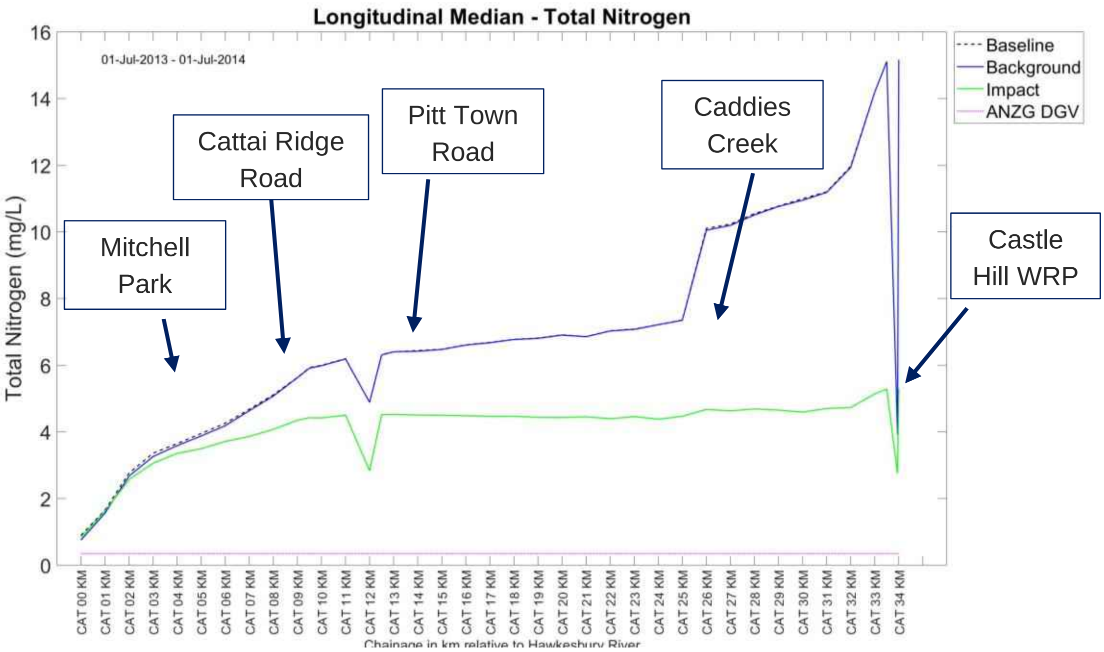

Figure 79 Longitudinal profile of predicted annual median dry year TN concentrations for Cattai Creek

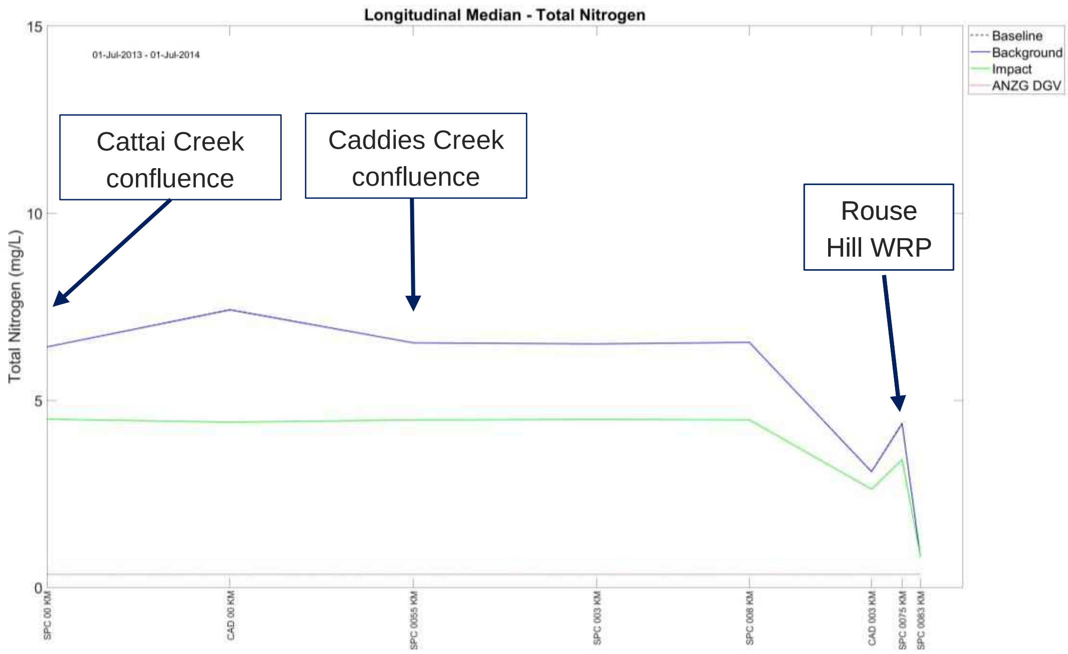

Figure 80 Longitudinal profile of predicted annual median dry year TN concentrations for Second Ponds Creek

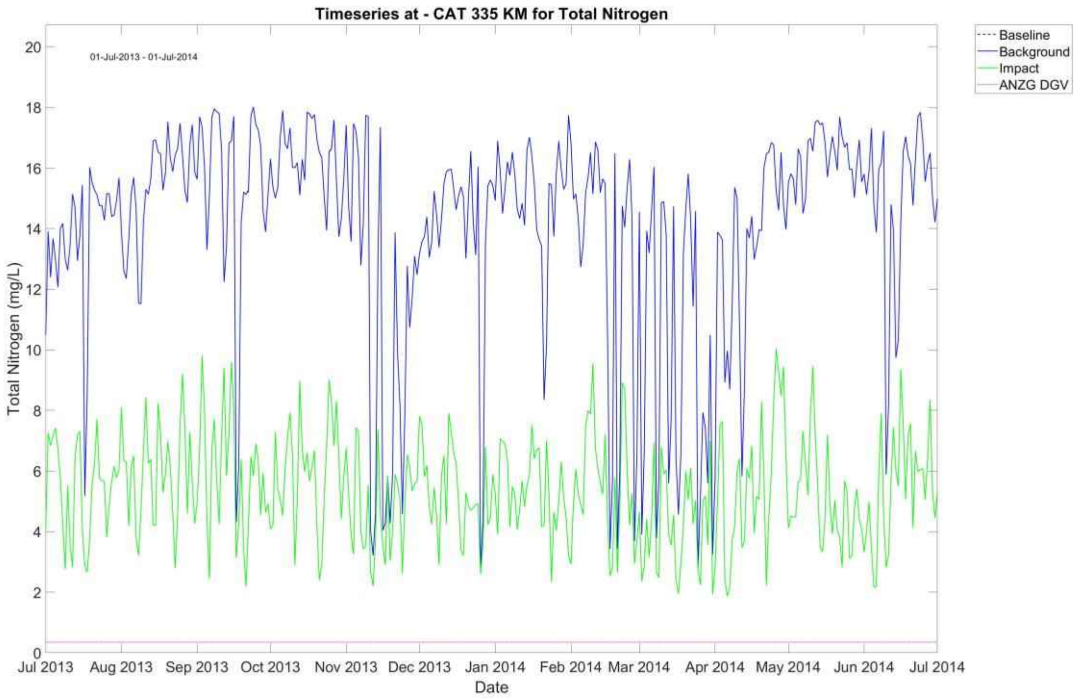

Figure 81 Timeseries of predicted Cattai Creek TN concentrations immediately downstream of Castle Hill WRP by scenario for typical dry year (2013/2014)

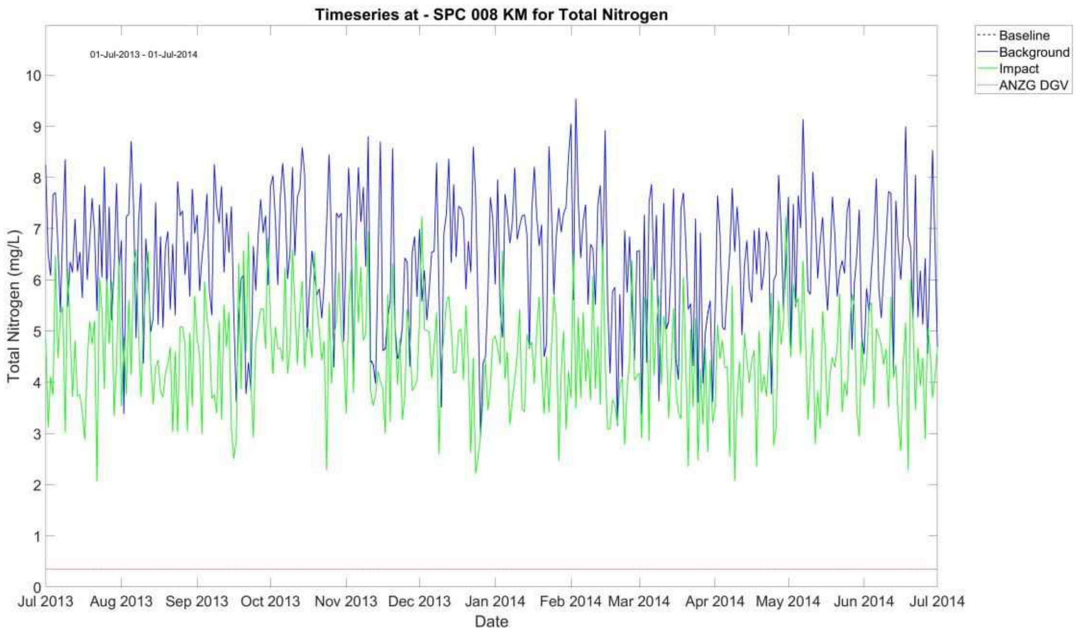

Figure 82 Timeseries of predicted Second Ponds Creek TN concentrations downstream of Rouse Hill WRP by scenario for typical dry year (2013/2014)

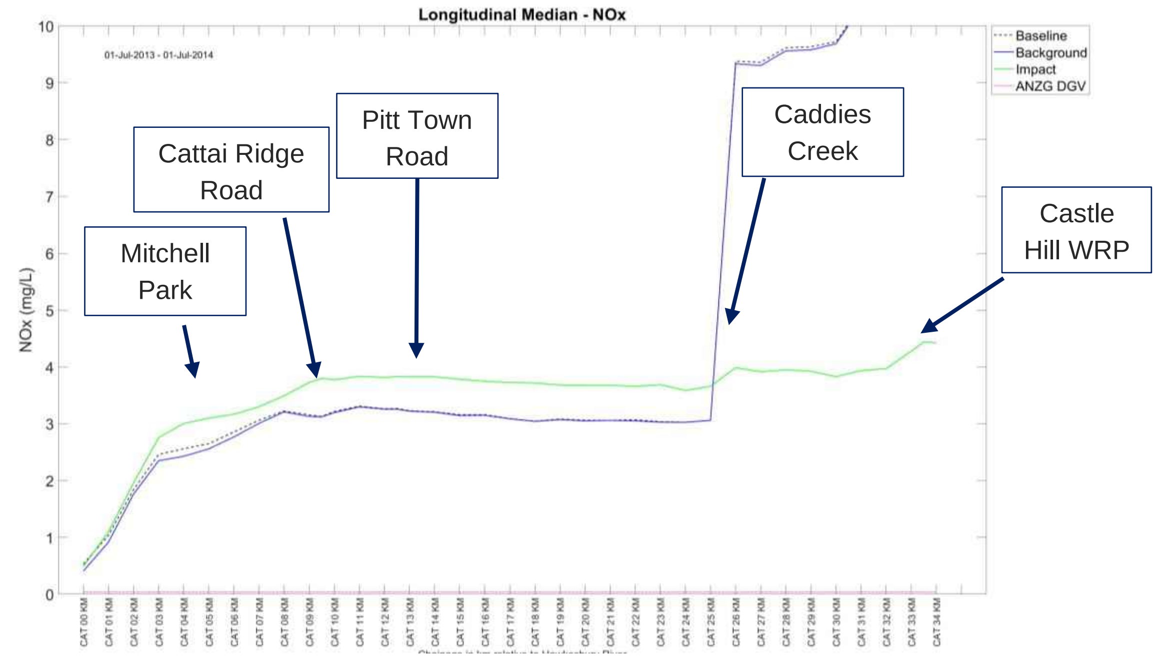

Figure 83 Longitudinal profile of predicted annual median dry year NOx concentrations for Cattai Creek

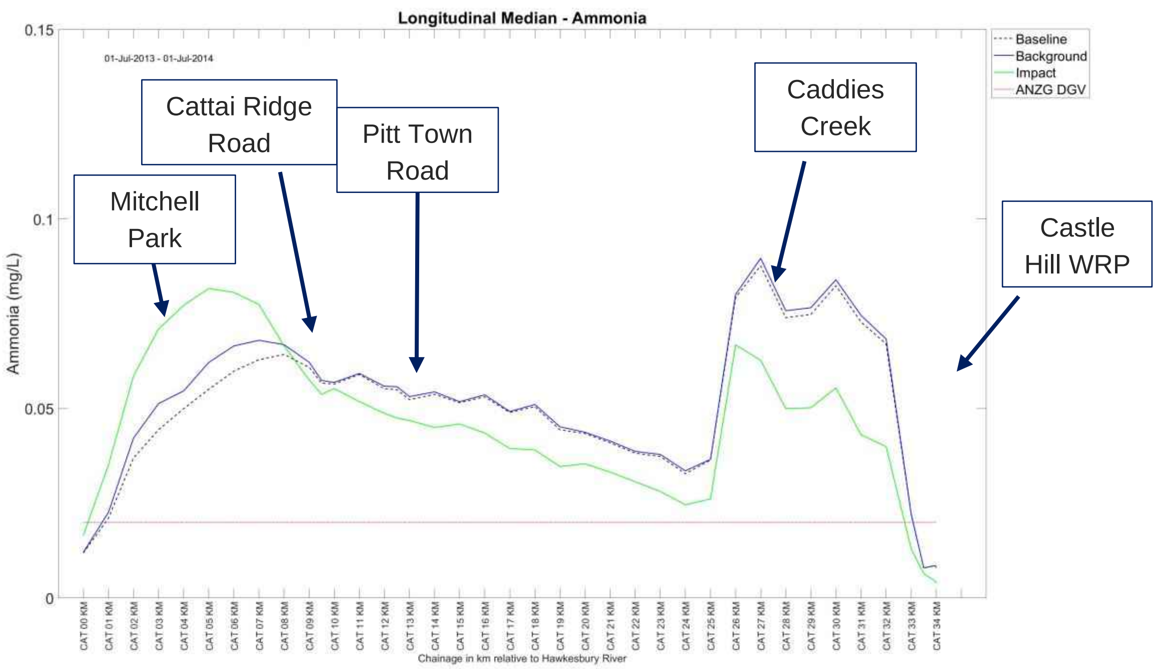

Figure 84 Longitudinal profile of predicted annual median dry year Ammonia concentrations for Cattai Creek

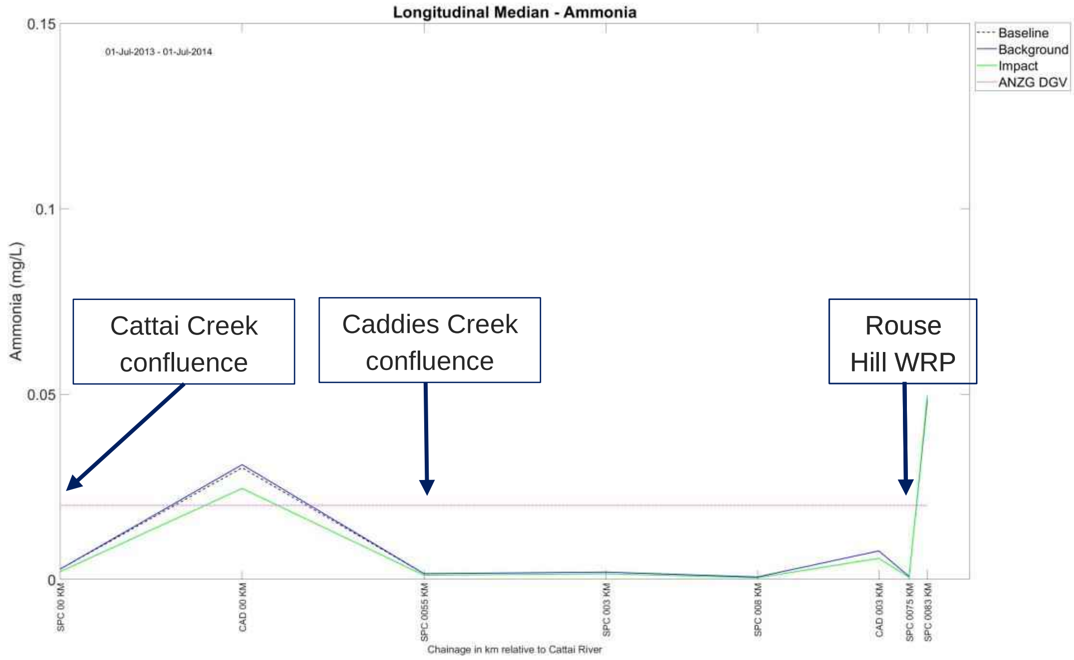

Figure 85 Longitudinal profile of predicted annual median dry year Ammonia concentrations for Second Ponds Creek

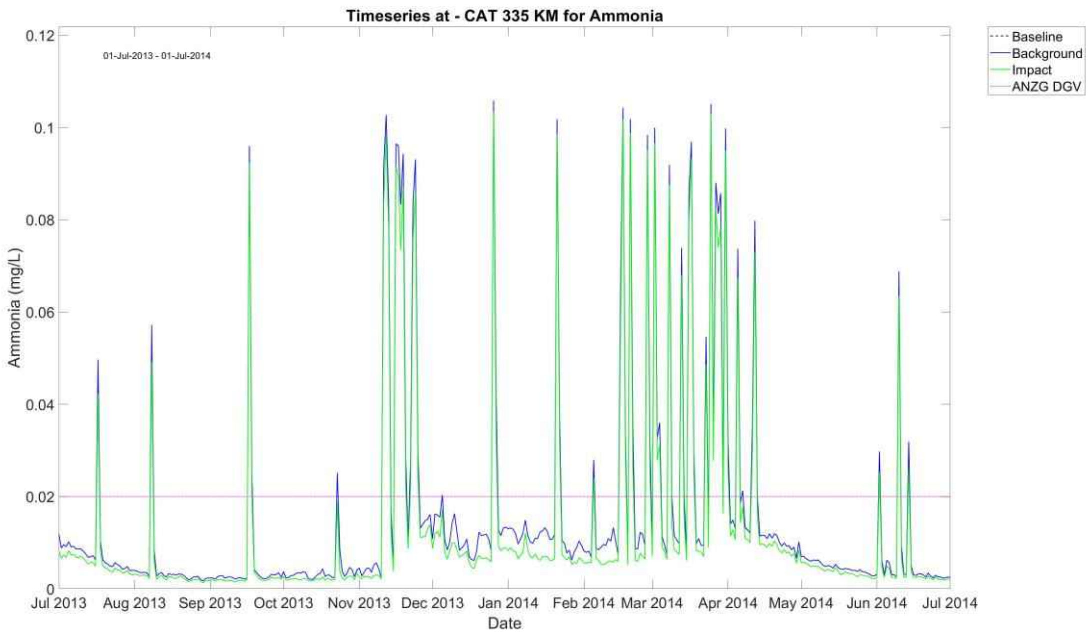

Figure 86 Timeseries of predicted Cattai Creek Ammonia concentrations immediately downstream of Castle Hill WRP by scenario for typical dry year (2013/2014)

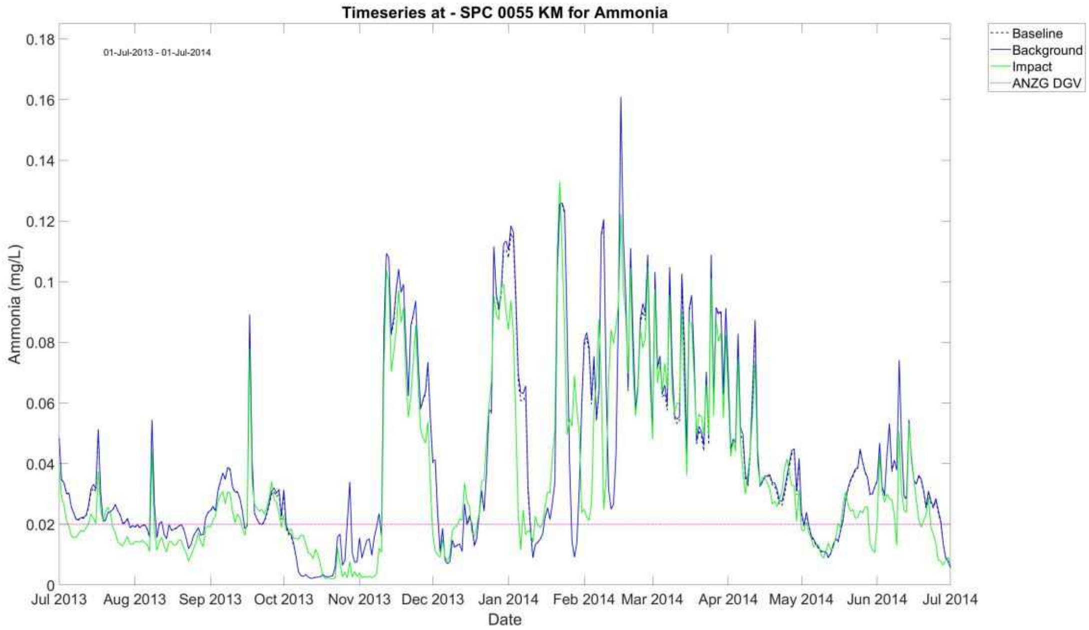

Figure 87 Timeseries of predicted Second Ponds Creek Ammonia concentrations immediately downstream of Rouse Hill WRP by scenario for typical dry year (2013/2014)

Phosphorus

- Annual median TP concentrations for both waterways are predicted to be reduced in the impact scenario when compared with the background scenario, and, as with the nitrogen species, minimal change in median concentration is predicted between the baseline and background scenarios.
- TP concentrations have been predicted to be slightly more elevated under wet conditions, suggesting that the catchment sources have a large influence on waterway water quality. The predicted annual median TP longitudinal plots in the representative wet year for Cattai Creek and Second Ponds Creek are provided in Figure 88 and Figure 89, respectively.
    - Median TP concentrations for Cattai Creek are predicted to be reduced by as much as 0.08 mg/L downstream of the Castle Hill WRP when comparing the results from the background scenario to the impact scenario.
    - Median TP concentrations for Second Ponds Creek in the impact scenario are also predicted to have a very modest decrease in the range of approximately 0.01 mg/L when compared to the background scenario.
- Daily TP concentrations downstream of both Castle Hill and Rouse Hill are predicted to be reduced in the impact scenario when compared to the background scenario.
    - Peak daily TP concentrations, however, are predicted to remain largely the same between the impact and background scenarios, suggesting that a significant source

of TP concentrations is found in catchment runoff. Daily dry year concentrations are, therefore, a better indicator of impacts of treated water releases on water quality.

  - Daily TP concentrations for the representative dry year downstream of Castle Hill WRP and Rouse Hill WRP are provided in Figure 92 and Figure 93, respectively.

- Annual median FRP concentrations for Cattai Creek and Second Ponds Creek are predicted to be nearly identical between the background and baseline scenarios. For both waterways, the impact scenario predicted that median FRP concentrations will be reduced in the impact scenario. This is particularly true for the representative dry year, as with the TP concentrations. The median annual FRP concentrations for both waterways in the dry year are provided in Figure 90 and Figure 91.
  - Dry year annual median FRP concentrations contribute to algal risk as the reduced volumes in the waterway create higher residence times and reduced flushing.
  - Second Ponds Creek is predicted to have median annual FRP concentrations that are compliant with the DGV for the entirety of the assessed waterway. It is also achieved despite the 18% increase in FRP concentration for the Rouse Hill releases as part of the NWTH upgrades. FRP is the bioavailable form of phosphorus and, therefore, of particular importance to waterway ecology and algal blooms. Reductions in FRP are, consequently, excellent indicators of improved water quality.
- While FRP concentrations downstream of the Castle Hill WRP are predicted to decrease considerably under the impact scenario, the peak FRP concentrations remain largely the same as those predicted in the background scenario.
  - FRP concentrations in Second Ponds Creek are predicted to have lower values day to day, but greater peak concentrations during the representative wet year.
  - Operationally, the treated water releases from the Rouse Hill WRP are predicted to provide lower daily FRP concentrations to Second Ponds Creek, but peak concentrations are expected to remain largely the same.
  - From this perspective, the peak FRP concentrations in Second Ponds Creek are almost certainly sourced from catchment runoff.
  - Timeseries plots for FRP concentrations in Cattai Creek and Second Ponds Creek are provided in Figure 94 and Figure 95, respectively.
- Median annual wet year TP concentrations for Cattai Creek and Second Ponds Creek are not predicted to be compliant with the ANZG DGV for any of the three scenarios modelled.
  - Despite this, the upgrades to Rouse Hill and Castle Hill WRPs provide a moderate decrease in median concentrations for the impact scenario when compared to the background.
    - In Cattai Creek upstream of Caddies Creek, this reduction is approximately 0.09 mg/L and approximately 0.01 mg/L for the reaches below.

- Reductions for Second Ponds Creek are greatest in the vicinity of the Rouse Hill WRP treated water release at approximately 0.1 mg/L but < 0.01 mg/L for the remainder of the waterway.

  - This is in response to the increased treated water release volumes and the 77% reduction in TP concentrations from Castle Hill that are expected with these upgrades.

- The median FRP concentrations have been predicted to bring Cattai Creek into compliance with the ANZG DGV for approximately half of the waterway's length in the wet year (and the entire length during the dry year), with the remaining reaches being predicted as only slightly above the DGV.
  - This predicted non-compliance during the wet year is largely attributable to catchment runoff sources contributing additional FRP in wet weather. Additionally, as FRP is a bioavailable form of phosphorus, wet year concentrations are less likely to contribute to algal growth and eutrophication due to increased flushing and reduced residence times in the waterways.

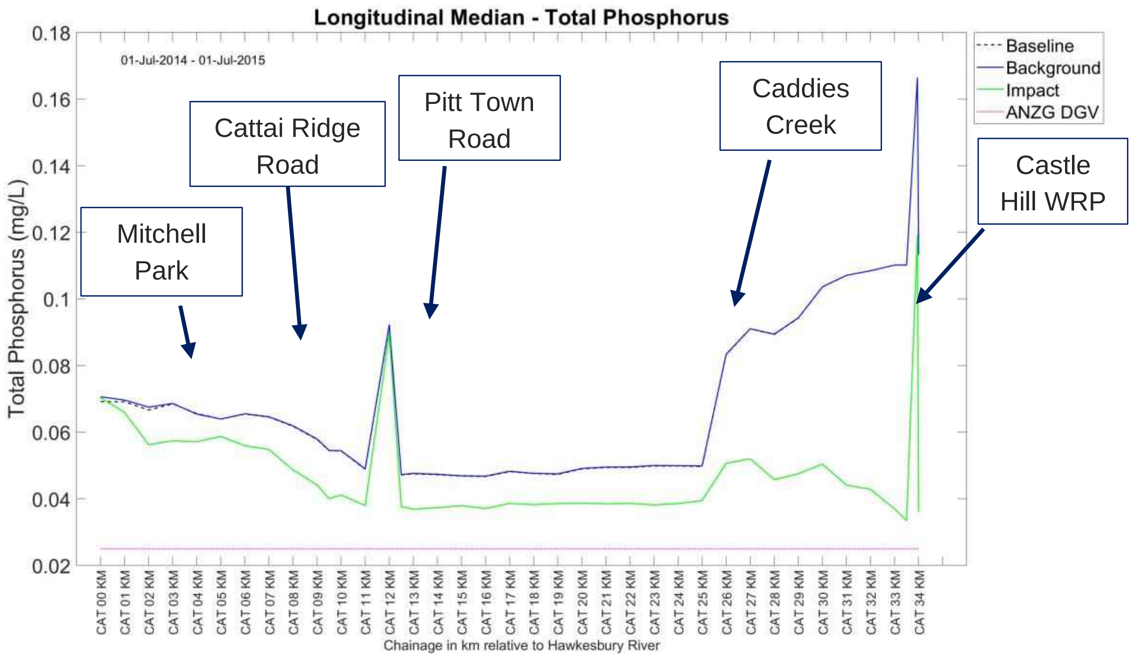

Figure 88 Longitudinal profile of predicted annual median wet year TP concentrations for Cattai Creek

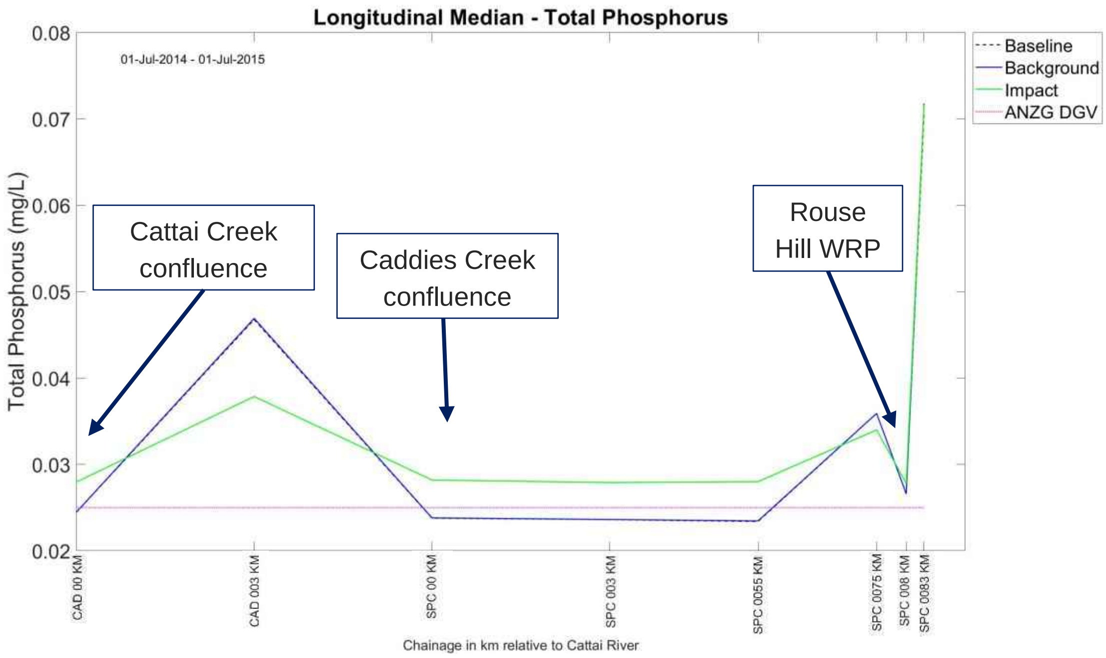

Figure 89 Longitudinal profile of predicted annual median wet year TP concentrations for Second Ponds Creek

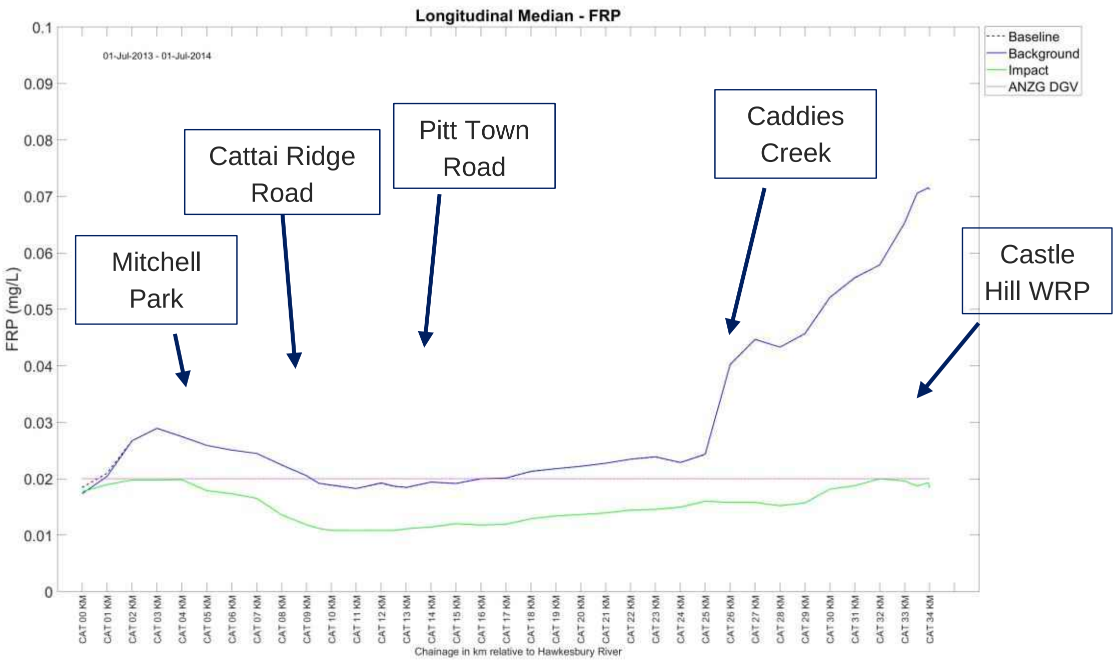

Figure 90 Longitudinal profile of predicted annual median dry year Filterable Reactive Phosphorus concentrations for Cattai Creek

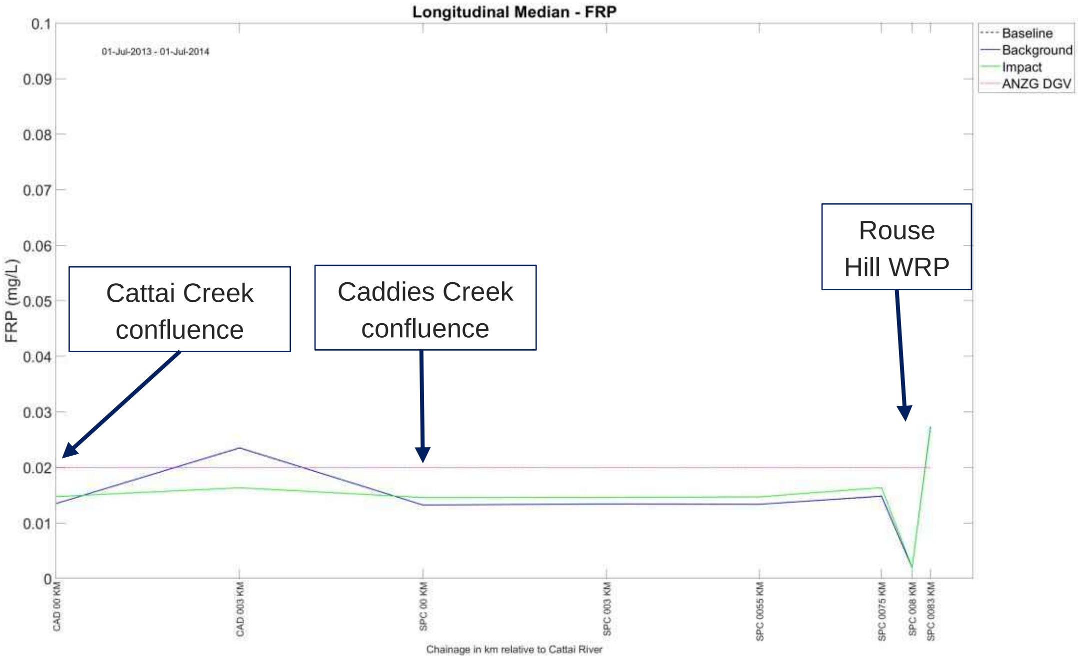

Figure 91 Longitudinal profile of predicted annual median dry year FRP concentrations for Second Ponds Creek

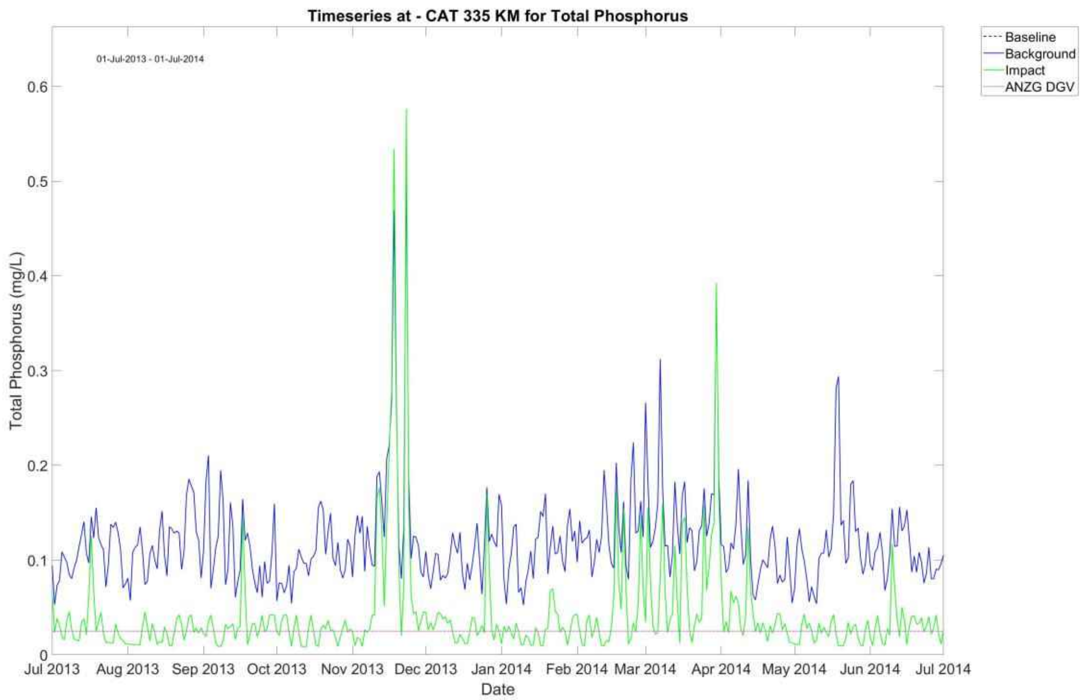

Figure 92 Timeseries of predicted Cattai Creek TP concentrations downstream of the Castle Hill WRP by scenario for typical dry year (2013/2014)

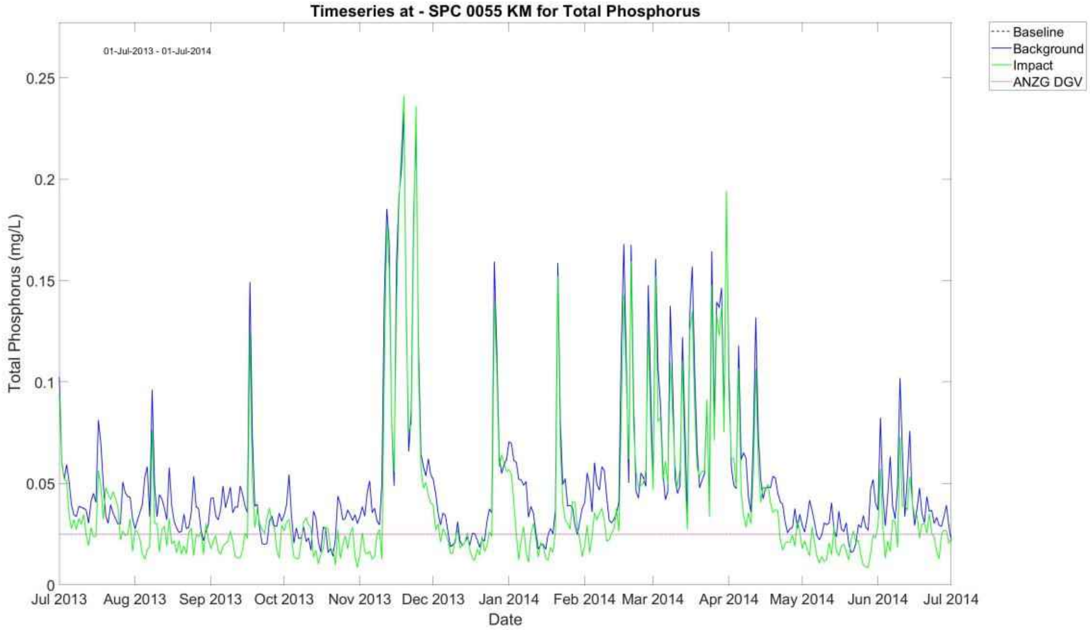

Figure 93 Timeseries of predicted Second Ponds Creek TP concentrations downstream of the Rouse Hill WRP by scenario for typical dry year (2013/2014)

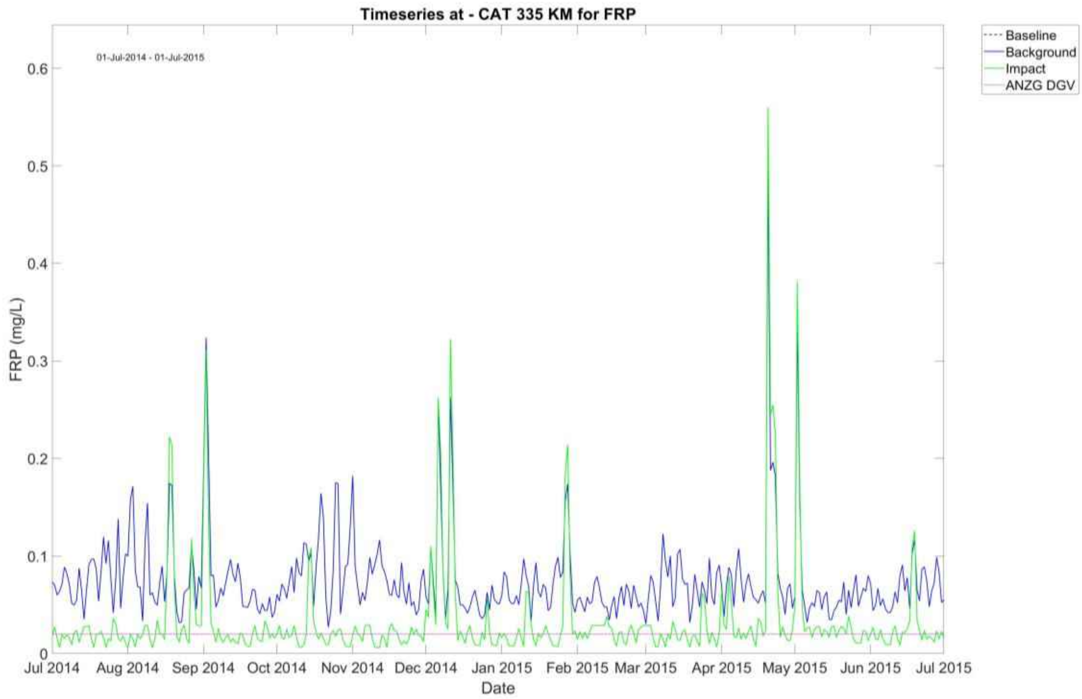

Figure 94 Timeseries of predicted Cattai Creek FRP concentrations downstream of Castle Hill by scenario for typical wet year

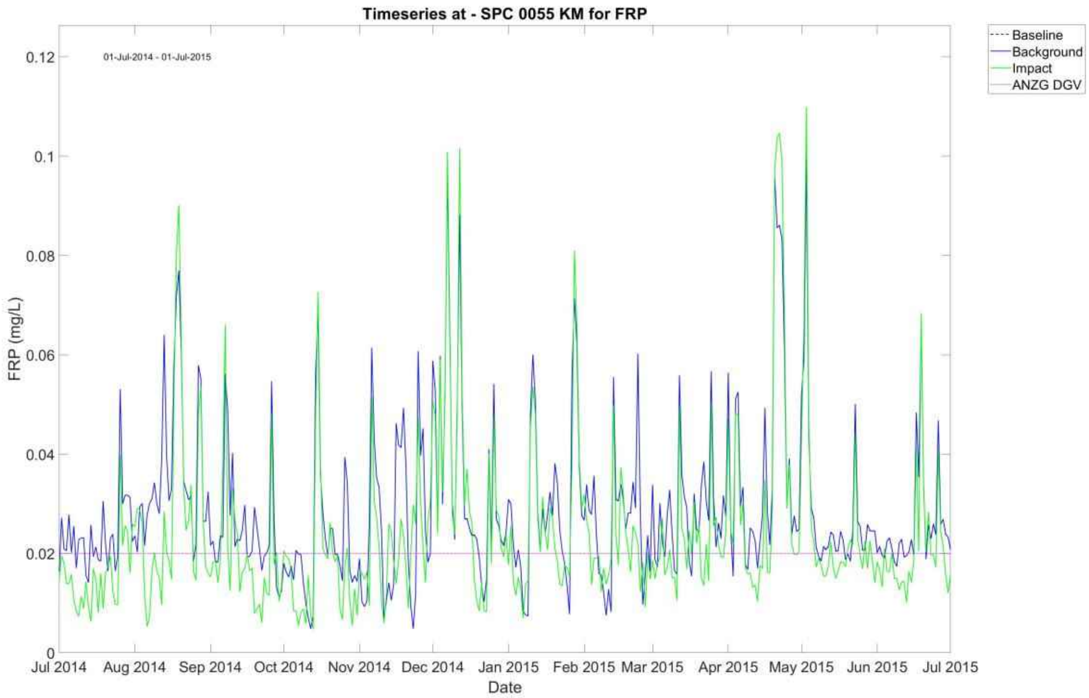

Figure 95 Timeseries of predicted Second Ponds Creek FRP concentrations downstream of Rouse Hill WRP by scenario for typical wet year

5.3.4.3.2 Algae

Chlorophyll-*a*

- The annual median profiles of Chlorophyll-*a* in both the background and baseline scenarios were very similar and generally under the ANZG trigger values along Cattai Creek. This is demonstrated in Figure 96. Chlorophyll-*a* concentrations within Second Ponds Creek were shown to be unaffected by the catchment changes between baseline and background scenarios and equally unaffected by the upgrades to Rouse Hill WRP (Figure 97).
- The predicted Chlorophyll-*a* concentrations in the impact scenario for Cattai Creek are well below that in the background scenario, primarily due to the reductions in the bio-available nutrients of nitrogen and phosphorus between the impact scenario and background scenario.
- For all three scenarios in both the representative wet and dry years, median annual Chlorophyll-*a* concentrations are well below the ANZG DGV, suggesting minimal likelihood of algal blooms downstream of NWTH plants.

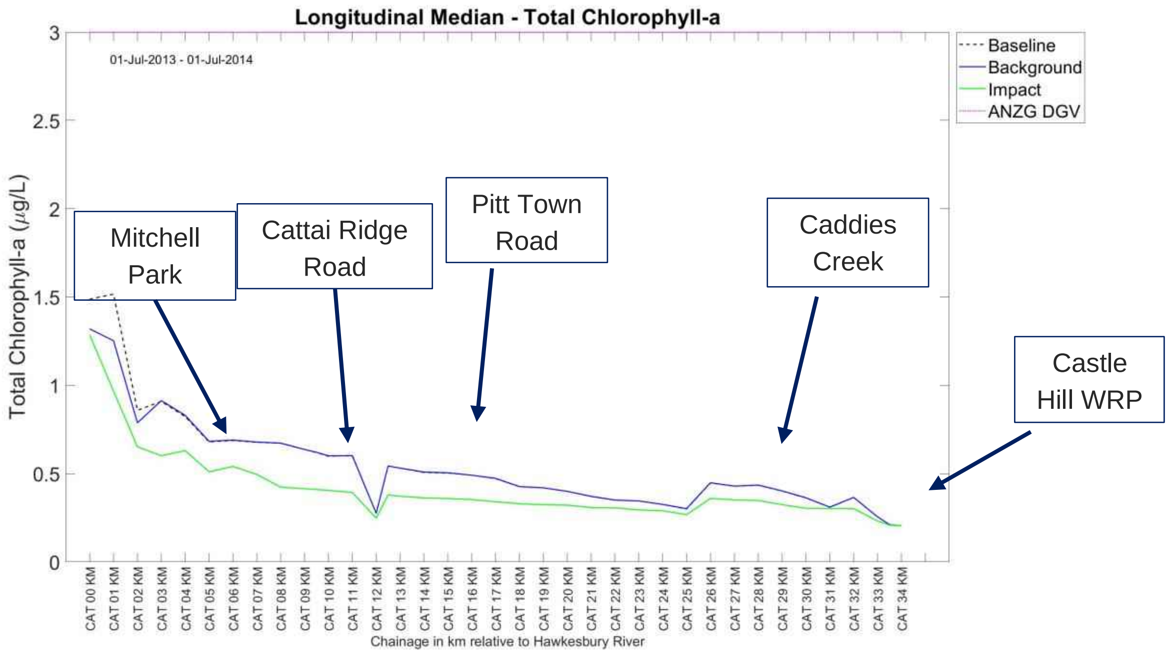

Figure 96 Longitudinal profile of predicted annual median dry year Chlorophyll-*a* concentrations for Cattai Creek

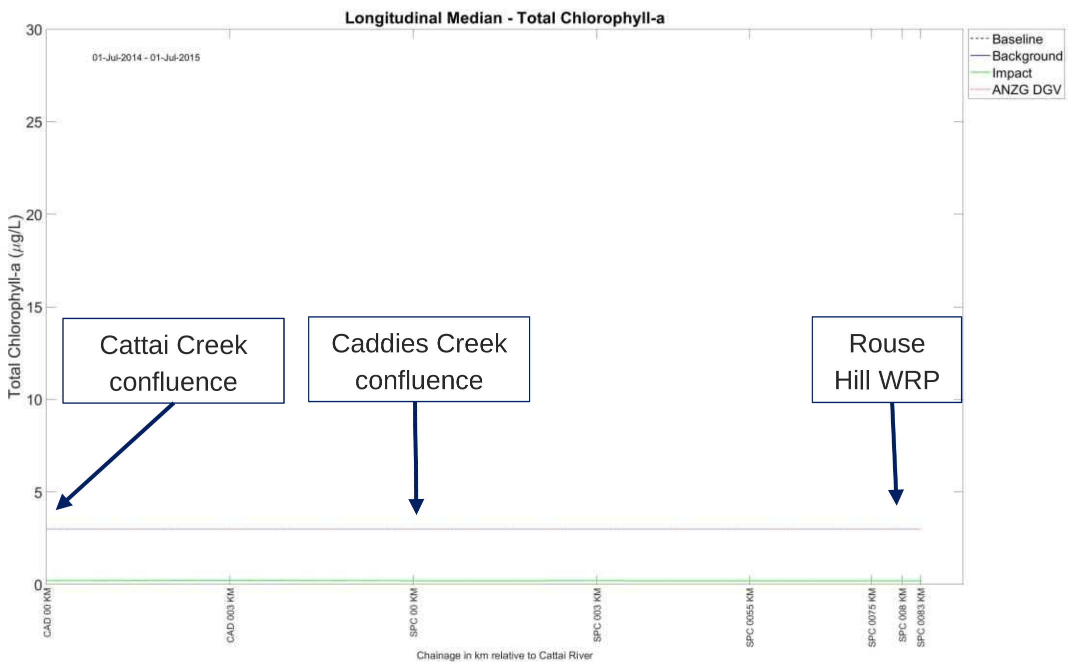

Figure 97 Longitudinal profile of predicted annual median dry year Chlorophyll-*a* concentrations for Second Ponds Creek

5.3.4.4 Other Water Quality Indicators

Salinity

- The predicted salinity concentrations were low in all scenarios (<0.5 g/L) for both Cattai Creek and Second Ponds Creek and the predicted difference in salinity conditions within the creeks was negligible between the dry and wet years and between the impact and background scenarios.

TSS

- The TSS concentrations in all scenarios were predicted to be mostly below the ANZG DGV compliance threshold.
- The predicted TSS concentrations were slightly higher in the impact scenario for Cattai Creek than the background scenario but were mostly below the ANZG compliance.
  - This is potentially due to the increased flows within the system from the treated water releases associated with the WRP upgrades and the resuspension of sediments.
- Second Ponds Creek had predicted TSS concentrations that were largely identical between the impact and background scenarios which is most likely due to the hydraulic nature of the waterway.
- Figure 98 and Figure 99 provide the wet year median TSS concentrations for Cattai Creek and Second Ponds Creek, respectively.

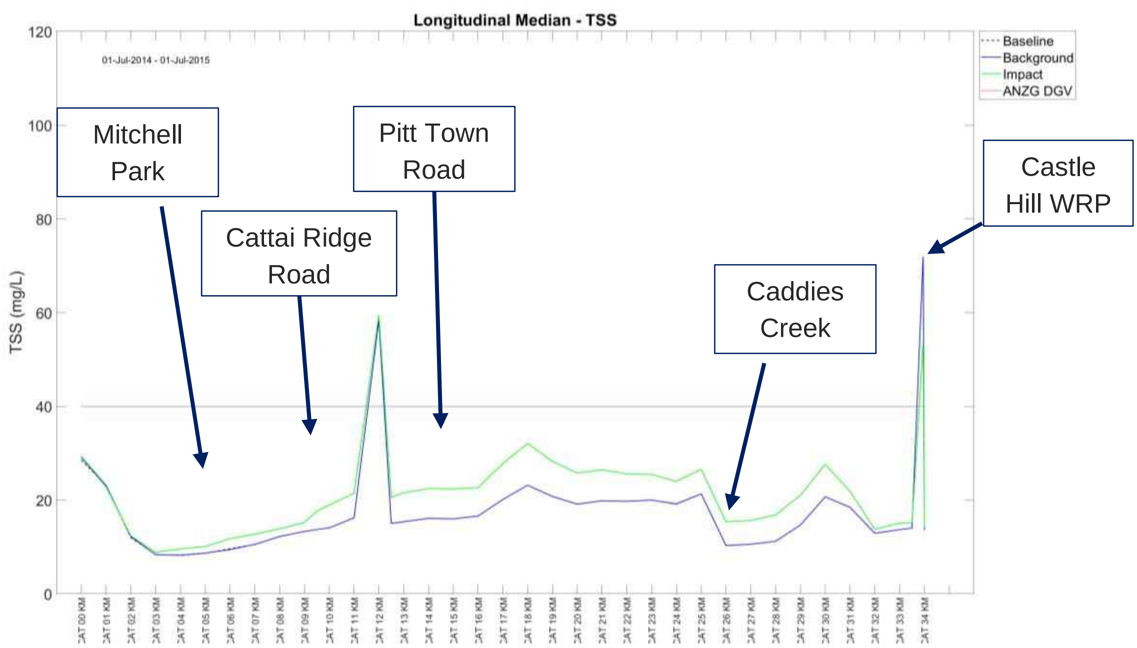

Figure 98 Longitudinal profile of predicted annual median wet year TSS concentrations for Cattai Creek

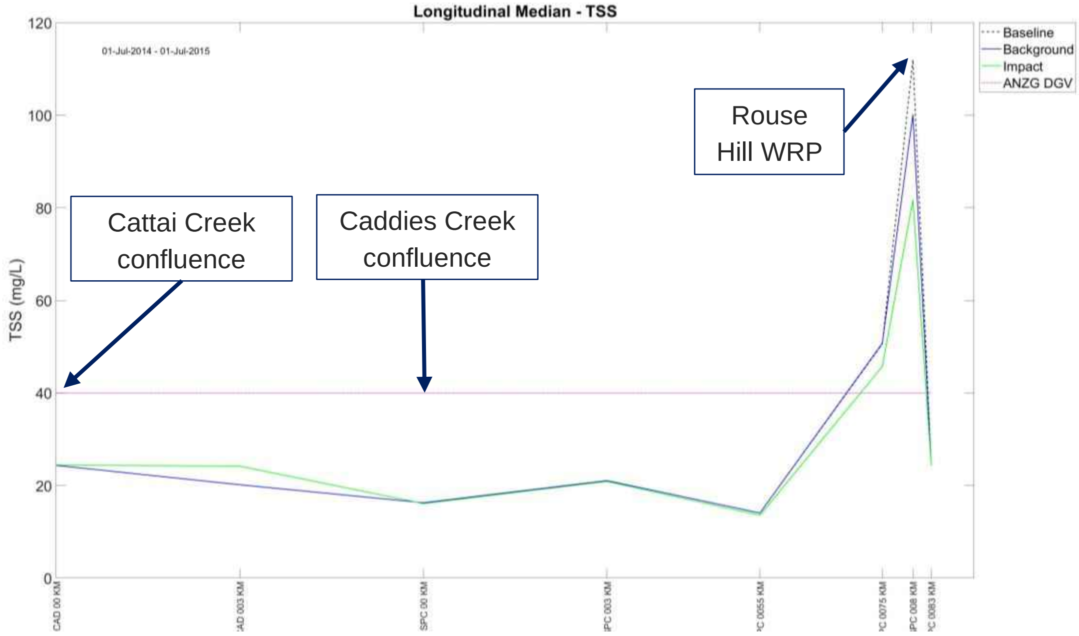

Figure 99 Longitudinal profile of predicted annual median wet year TSS concentrations for Second Ponds Creek

Dissolved Oxygen

- A modest decline of the median annual dissolved oxygen concentration in the region near the Castle Hill WRP discharge (Figure 100) was predicted in both the dry and wet years when comparing the background scenario to the baseline scenario.
    - The predicted annual median concentration decreased to ~4 mg/L while other sites were predicted to be higher than as much as 7 mg/L.
    - Further reductions in dissolved oxygen concentration were predicted in the impact scenario, with the lowest value being approximately 3 mg/L in the reach upstream of the Caddies Creek confluence.
    - When compared with the water levels expected in the waterway for the impact scenario (Section 5.3.4.2), this lack of replenishment in the dissolved oxygen is consistent with the downstream controlled waterway predicted.
- Dissolved oxygen concentrations in Second Ponds Creek were not predicted to increase or decrease in the impact scenario when compared to the background scenario.

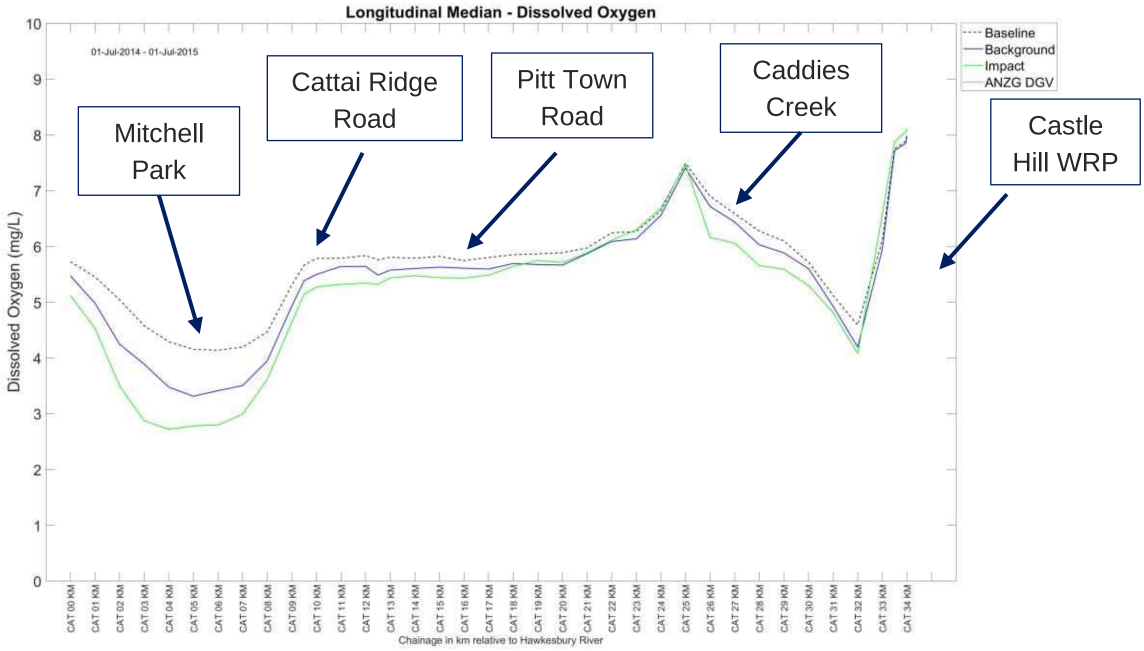

Figure 100 Longitudinal profile of predicted annual median wet year Dissolved Oxygen concentrations for Cattai Creek

Enterococci (analysed as primary pathogenic indicator)

- The predicted annual median profiles of Enterococci showed no difference between the background and baseline scenario for Cattai Creek and Second Ponds Creek, however, the greatest concentrations for these scenarios were predicted in the wet year and in the vicinity of the WRP discharges and waterway sections with known wet weather overflows.
- The median Enterococci concentrations were predicted to be modestly lower in the impact scenario than the background scenario along the creeks, however, this modest reduction for Second Ponds Creek was nearly sufficient to bring the entire waterway into compliance with the NHMRC DGV.
- Peak Enterococci concentrations downstream of both Castle Hill and Rouse Hill are provided in Figure 103 and Figure 104, respectively. For both plants under all scenarios, peak concentrations were no greater than 1000 cfu/100mL, and for both locations, no appreciable increase in peak concentrations were predicted when comparing the impact scenario to the background.
- The annual median Enterococci profile in the wet year for Cattai Creek and Second Ponds Creek are provided in Figure 105 and Figure 106, respectively. Median concentrations for both waterways are similar to those predicted in the dry year, except the magnitude of Enterococci concentration is higher. The highest annual median Enterococci concentration reached 490 cfu/100mL at the upstream in the wet year, compared to ~150 cfu/100mL in the dry year. This increase in Enterococci concentration is potentially due to wet weather overflows in the catchment.

- Similar to the dry year conditions, the Enterococci concentration was modestly reduced in the impact scenario as a result of increased release flows.
- The spatial patterns of the annual median Enterococci profile in the wet year are similar to that in dry year, except the magnitude of Enterococci concentration is higher to the dry year. The highest Enterococci concentration in the impact scenario reached 340 cfu/100mL at the upstream, compared to ~150 cfu/100mL in the dry year.
- The annual median profiles of Enterococci concentration is close or above the NHMRC DGV for the majority of the river reaches in both the dry and wet years. These trends are not notable increased due in the impact scenario, however, a reduction in the median is predicted for both Cattai Creek and Second Ponds Creek when comparing the impact scenario to the background scenario.
  - This reduction in median annual Enterococci concentrations is more than 50% for portions of Cattai Creek and has a magnitude of up to 100 cfu/100mL.

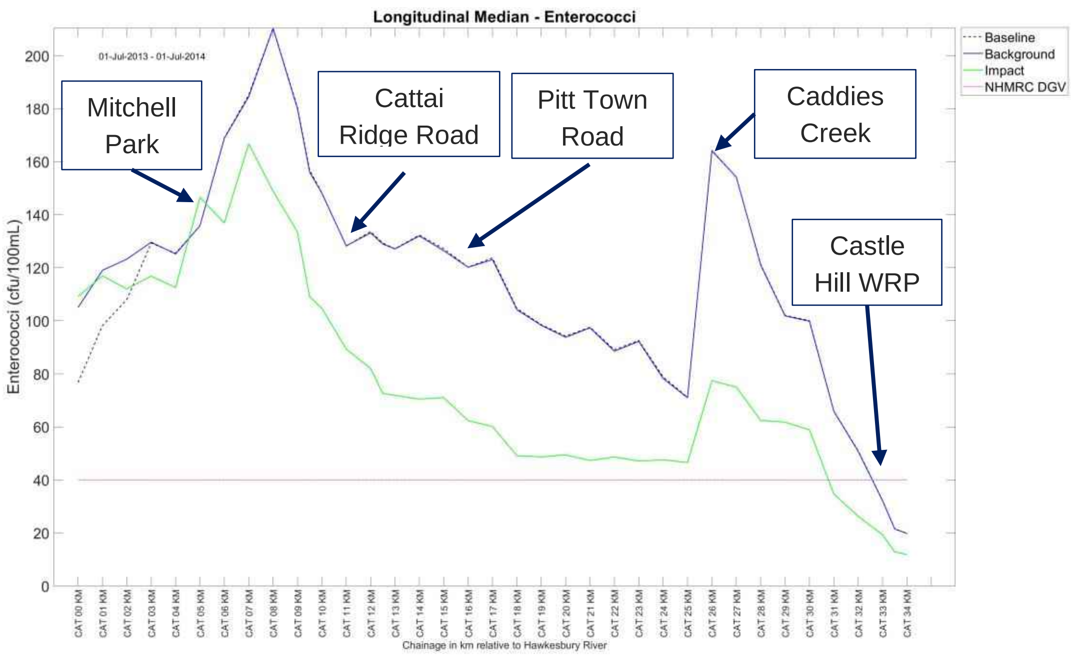

Figure 101 Longitudinal profile of predicted annual median dry year Enterococci concentrations for Cattai Creek

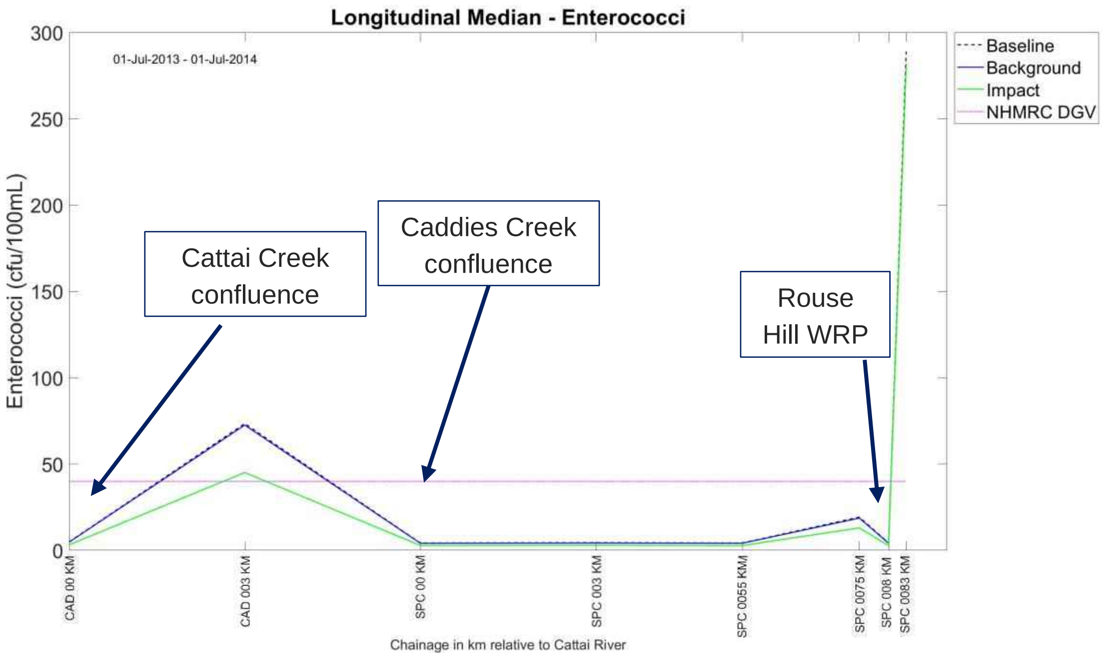

Figure 102 Longitudinal profile of predicted annual median dry year Enterococci concentrations for Second Ponds Creek

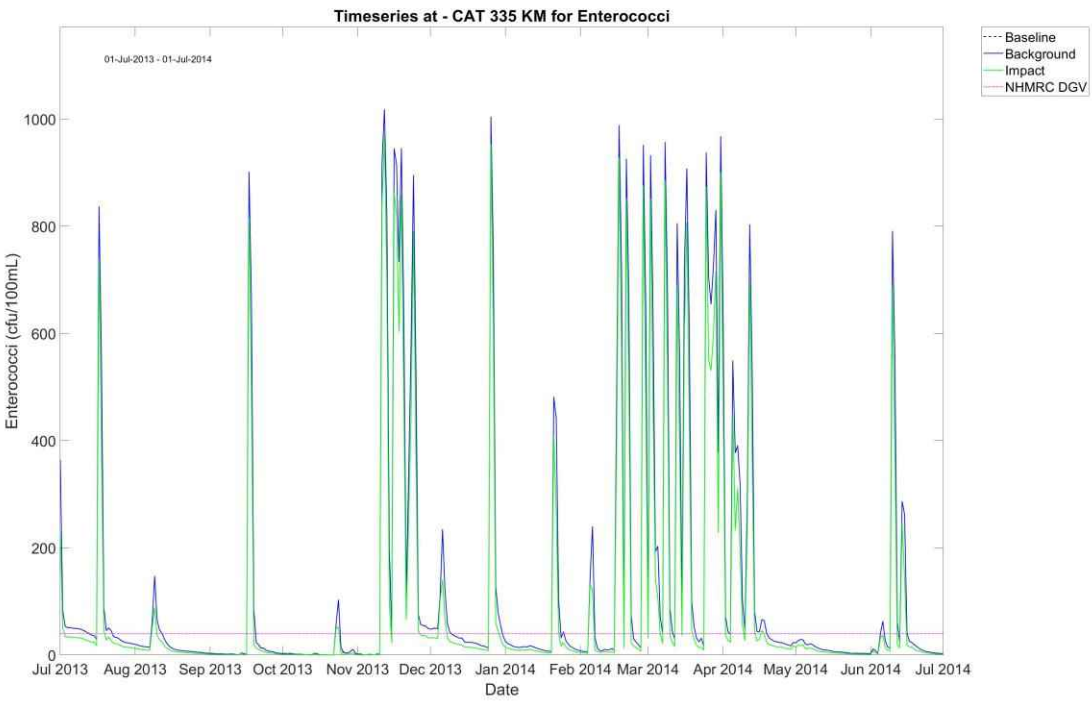

Figure 103 Timeseries of dry year Enterococci concentrations 500m downstream of the Rouse Hill WRP by scenario

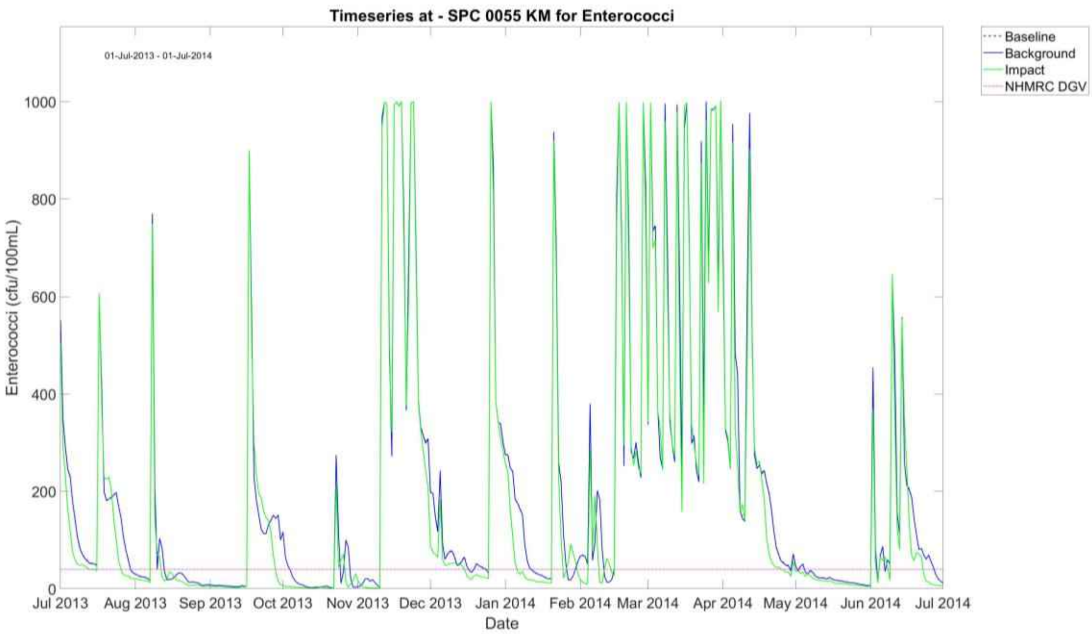

Figure 104 Timeseries of dry year Enterococci concentrations 500m downstream of the Rouse Hill WRP by scenario

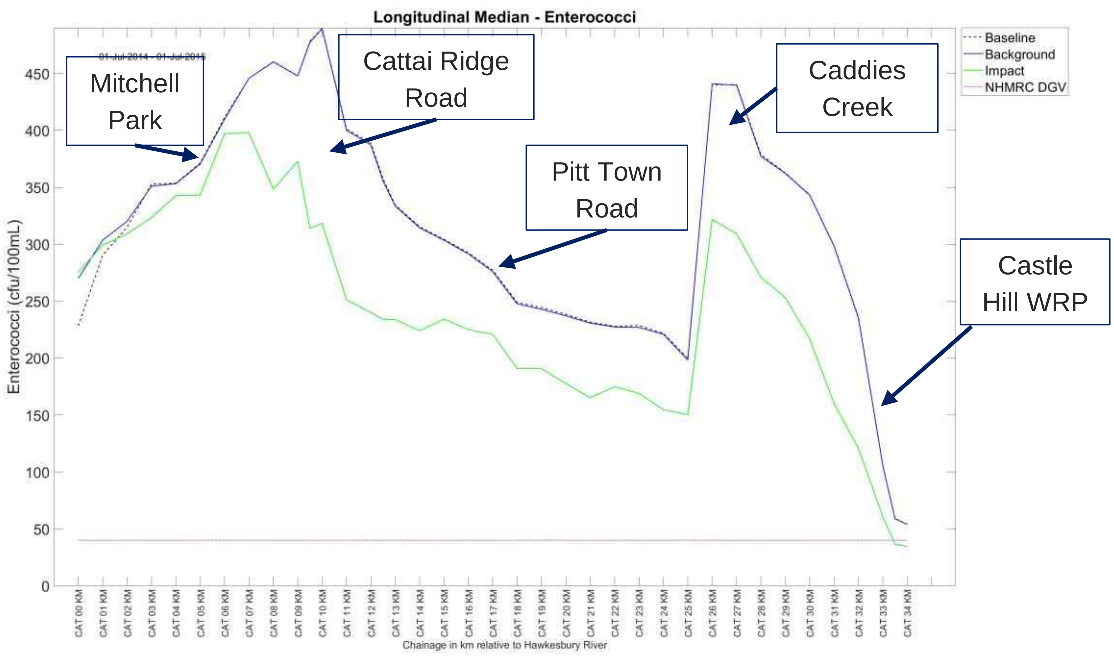

Figure 105 Longitudinal profile of predicted annual median wet year Enterococci concentrations for Cattai Creek

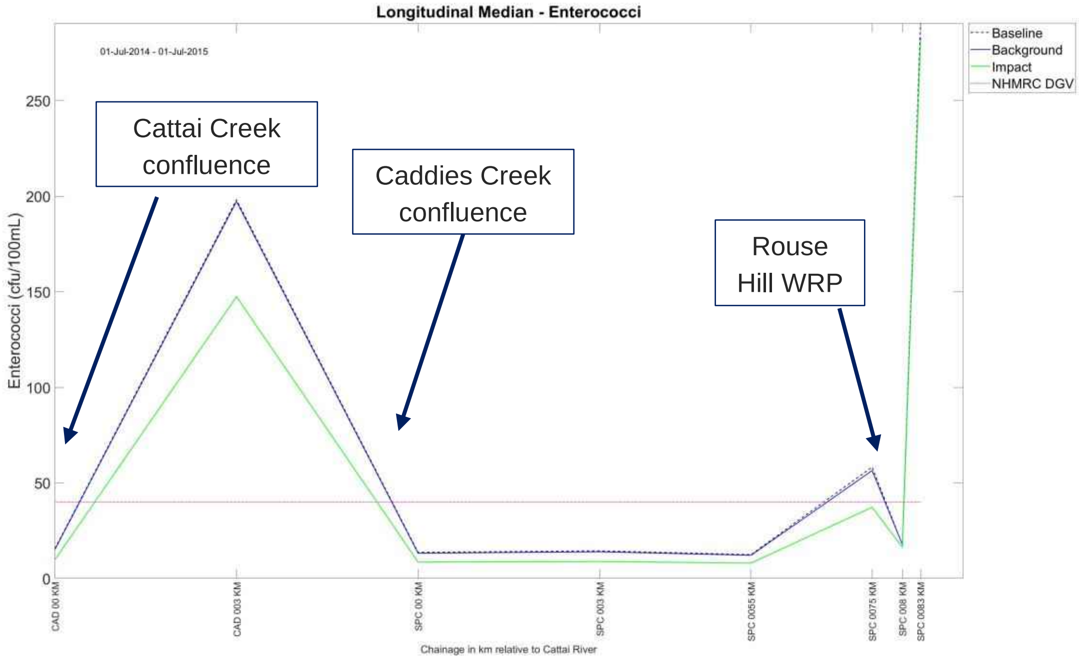

Figure 106 Longitudinal profile of predicted annual median wet year Enterococci concentrations for Cattai Creek

5.4 Eastern Creek and South Creek

5.4.1 Scenario Brief

Development in the Eastern Creek catchment upstream of the Riverstone WWTP is expected to be significant between the baseline time horizon of 2020 and the background and impact time horizon of 2036. In addition to changes in landuse, the Quakers Hill WWTP will be undergoing upgrades in parallel to those of the NWTH to improve treated water release quality. As a consequence, significant change is anticipated for water quality parameters between the baseline and background scenarios for Eastern Creek.

5.4.2 Analysis Locations

Assessment of the conditions of each scenario have been undertaken at select locations over a 20 km length of Eastern Creek upstream from its confluence with South Creek. These locations are shown in Figure 14 and **Error! Reference source not found.**.

Assessment of the conditions of each scenario have been undertaken at select locations over a 20km length of Eastern Creek from its downstream confluence with South Creek. These locations are shown in in Section 5.4.2.

5.4.3 Load Analysis

Analysis of estimated TN and TP loads to Eastern Creek has been undertaken to allow comparison of the contributions from various sub-catchments and treatment plants for baseline, background and impact scenarios as discussed in Section 3.5.3. These loads have been generated using the outputs of the Cattai Creek Source model (eWater, 2022) to generate cumulative loads within the waterway from both the WRPs and catchment sources. Predicted nutrient loads have been compared against the Hawkesbury-Nepean nutrient management framework (EPA, 2019) to evaluate the performance of the NWTH upgrades in meeting the 2024 – 2028 load limits for Sackville subzone 2 (Table 17).

Table 17 Nutrient loads for Sackville subzone 2 compliance summary (Sydney Water plants only)

WWTP/WRP	2036 - TN (tonnes/year)	2036 -TP (tonnes/yr)
Riverstone	43.6	0.7
St Marys	37.9	1.0
Quakers Hill	21.6	0.4
AWRC	1.7	0.1
Total Estimated Load	**104.8**	**2.2**
Subzone Load limit	**126.1**	**2.7**

The NWTH upgrades have been predicted to meet the 2024 - 2028 load limits for both TN and TP of Sackville Subzone 2 outlined by the Hawkesbury-Nepean nutrient management framework (EPA, 2019).

The load analyses presented in the figures below, extend from the confluence with South Creek to upstream of Breakfast Creek, and the Quakers Hill WWTP treated water release location for an approximate length of 20km. Figure 107 and Figure 108 present the cumulative analysis of TN loads from upstream to downstream for all the catchment loads (including all WWTPs and WRPs releasing to the creek). From left to right, each new set of columns/bars represents the cumulative load with the addition of the load from a new boundary in the model.

Figure 109 and Figure 110 present similar outputs for TP loads.

From these graphs, the influence of changing landuse and future development in the Eastern Creek catchment appears to be relatively minor in comparison to the contributions of the Quakers Hill WWTP. The Quakers Hill WWTP is currently undergoing an upgrade to its preliminary, primary and secondary treatment process, including the commission of a new AGS bioreactor and MPS screens. The background scenario of this assessment reflects the treatment outcomes of this upgrade as well as the progressive installation of reverse osmosis treatment from the year 2029 until 2036 to maintain the forecasted load limits for the plant's EPL. In addition to this treatment upgrade, 12.5 ML/day is planned to be transferred to the St Mary's AWTP. The treatment upgrades proposed will seek to maintain a TN concentration in treated water releases of 4.5 mg/L.

The differences in load magnitude between the dry and wet years is also notable.

The contributions of the Riverstone WWTP flows and TN and TP loads to Eastern Creek as part of the planned upgrades proposed in this assessment are estimated to be as follows:

- Treated water flows:
  - Dry year: ~8.2 ML/day (2020) to ~29.3 ML/day (2036) (+250%)
  - Wet year: ~10.0 ML/day (2020) to ~35.4 ML/day (2036) (+250%)
- TN:
  - Dry year: ~6% (2020) to ~31% (2036)
  - Wet year: ~5% (2020) to ~22% (2036)
- TP
  - Dry year: 0.8% (2020) to 6.2% (2036)
  - Wet year: 0.6% (2020) to ~3.9% (2036)

The contributions of the Riverstone WWTP loads to South Creek from Eastern Creek are estimated to be as follows:

- TN:
  - Dry year: ~3.7% (2020) to ~13% (2036)
  - Wet year: ~2.5% (2020) to ~9.4% (2036)
- TP
  - Dry year: 0.4% (2020) to 2.4% (2036)
  - Wet year: ~0.3% (2020) to 1.6% (2036)

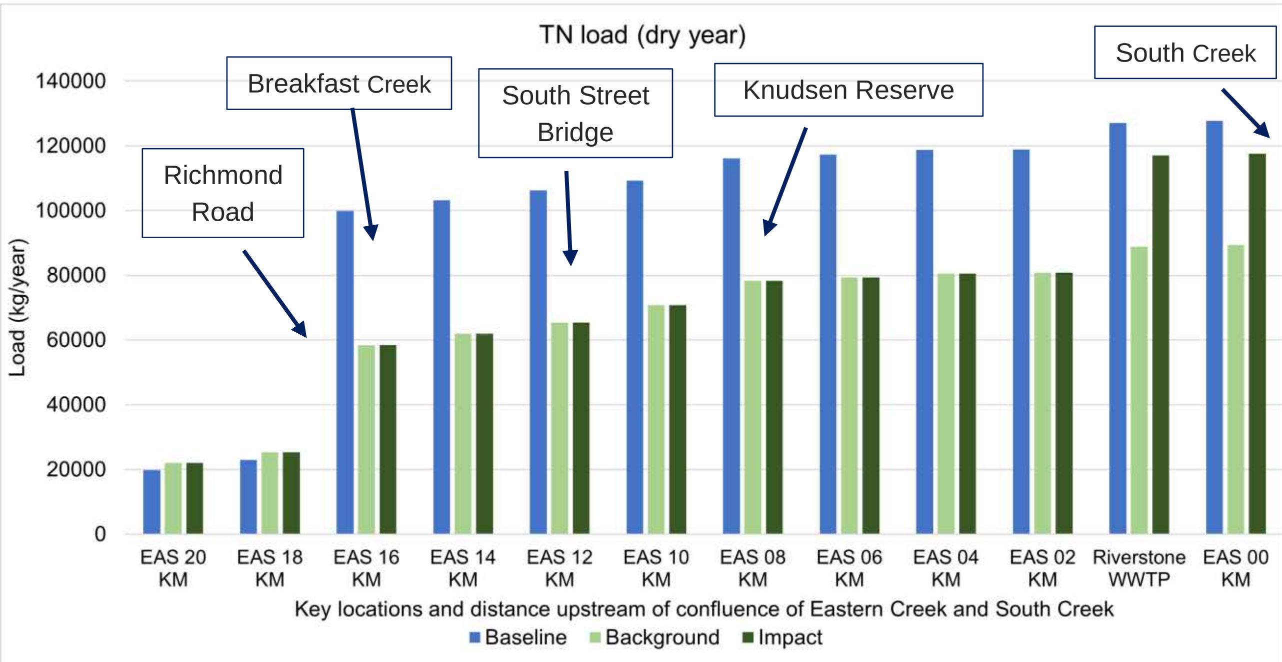

Figure 107 TN cumulative catchment loads for Eastern Creek (dry year)

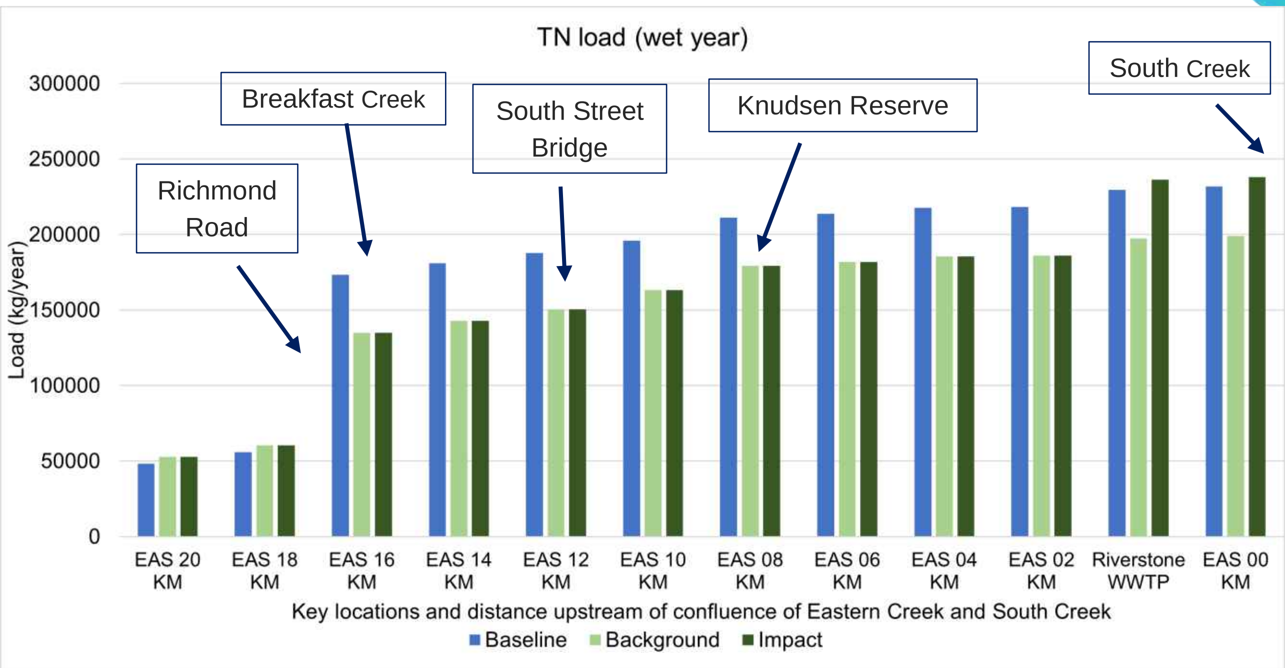

Figure 108 TN cumulative catchment loads for Eastern Creek (wet year)

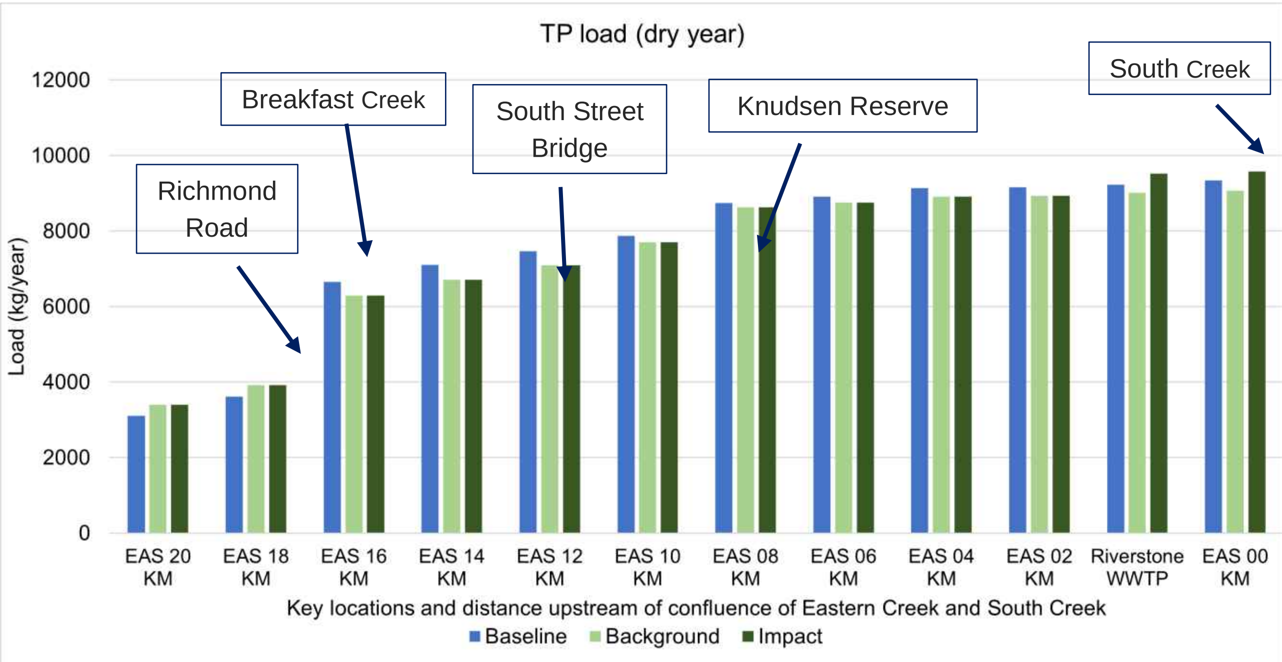

Figure 109 TP cumulative catchment loads for Eastern Creek (dry year)

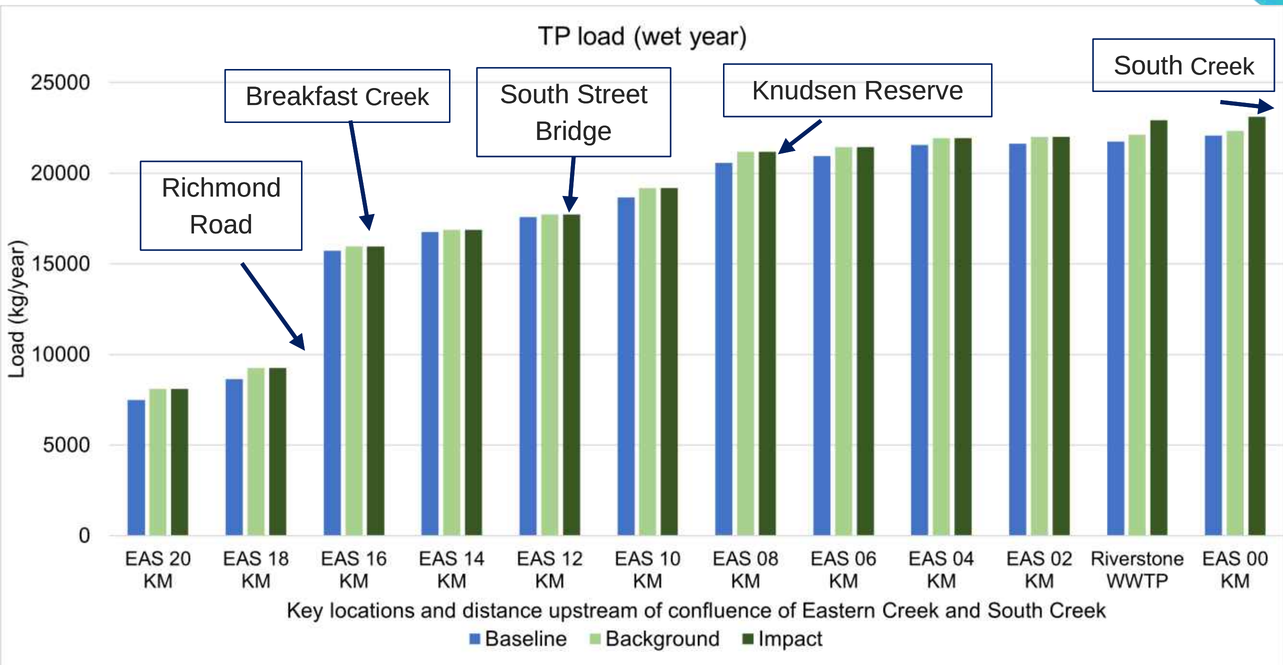

Figure 110 TP cumulative catchment loads for Eastern Creek (wet year)

5.4.4 Interpretation

5.4.4.1 General

The following general conclusions are provided from the assessment of impacts from the proposed Riverstone WWTP's treated water release scenarios on Eastern Creek and South Creek:

- Quakers Hill WWTP has been modelled for its current treatment upgrades in the impact scenario and has also been modelled to use reverse osmosis from 2029 to meet anticipated EPL load and concentration obligations. This upgrade is predicted to reduce TN and TP concentrations in treated water releases from the plant by as much as 90% during peak release concentrations and will also involve the transfer of 12.5 ML/day from Quakers Hill to St Marys AWTP. Because of this, the background and impact scenarios for Eastern Creek generally appear to predict improved water quality for Eastern Creek when compared to baseline conditions.
- Despite the anticipated reductions in nutrient concentrations from Quakers Hill, the predicted concentrations of many analytes from upstream of the Riverstone WWTP do not satisfy the ANZG DGVs specified in Section 2.2. More specifically, this includes Ammonia, TP, FRP and enterococci concentrations.
- Comparatively, the relative increase in concentrations in Eastern Creek, while potentially non-compliant during dry years, represents a significant improvement, holistically, on the water quality of Eastern Creek's tidal reach.
- TN and TP loads to the waterway do not appreciably increase in the impact scenario relative to the background scenario in a manner that would suggest increased eutrophication of Eastern Creek or South Creek. This is despite a 270% increase in EP for

the Riverstone WWTP as part of the NWTH plant upgrades, indicating that the NWTH upgrades represent a significant pathway towards improved water quality in the receiving waterways.

- Enterococci concentrations for both background and impact scenarios were predicted to meet the criteria outlined in Table 7 of Section 2.2. This suggests that pathogen concerns are unlikely to be present for Eastern Creek.
- The effects of the proposed changes in Eastern Creek are minimal in nature for South Creek, and sufficiently benign or even beneficial, that, for the sake of brevity, limited focus is placed on South Creek in this report.

5.4.4.2 Hydrodynamics

This section provides commentary on the anticipated hydrodynamic impacts to Eastern Creek and South Creek from the proposed Riverstone WWTP upgrade. The findings are drawn from analysis of the impact scenario against baseline and background scenarios to provide an estimate of the proportional contribution of impact from treated water releases in comparison to other catchment conditions.

Based on the results of the modelling, the hydrodynamics of Eastern Creek below the Riverstone WWTP discharge location are not predicted to meaningfully impacted upon by the alteration of flows based on the proposed upgrades to the WWTP. While the magnitude of treated releases in the scenarios evaluated is predicted to increase from 13.1 ML/day to 27.8 ML/day, it’s expected that this will encourage flushing of nutrients and improve water quality for the waterway, particularly during dry weather events when conditions may be prone to greater stagnation.

Dry year results shown in Figure 111 predict that acute increases in water level may be experienced of up to ~0.50m. While this increase in water level may result in inundation of riparian veg that was not previously inundated during the representative dry year, the duration of the inundation event is not increased, suggesting that the likely impacts of this increased inundation would be transient. Wet weather water levels (Figure 112) predict greater heights under the new releases for Riverstone WWTP, however, the magnitude of change is more modest than dry year conditions, with an approximate maximum acute increase in water level from baseline to impact of approximately 0.20m.

- Modelling results for South Creek’s tidal reaches downstream of the Eastern Creek confluence for both the representative wet and dry years have predicted negligible increases to peak water levels of < 2cm resulting from the proposed upgrades to the Riverstone WWTP when comparing the background scenario to the impact scenario.
- Changes to the inundation and wetting regime of the riparian corridor of the tidal reach between the background and impact plot are predicted to be nearly imperceptible in both their increased magnitude and transient in nature with respect to the timeline over which they occur.
- No significant increase in erosive forces is expected through this reach on a chronic or acute timescale in either the dry or wet years when comparing the background and impact scenarios.

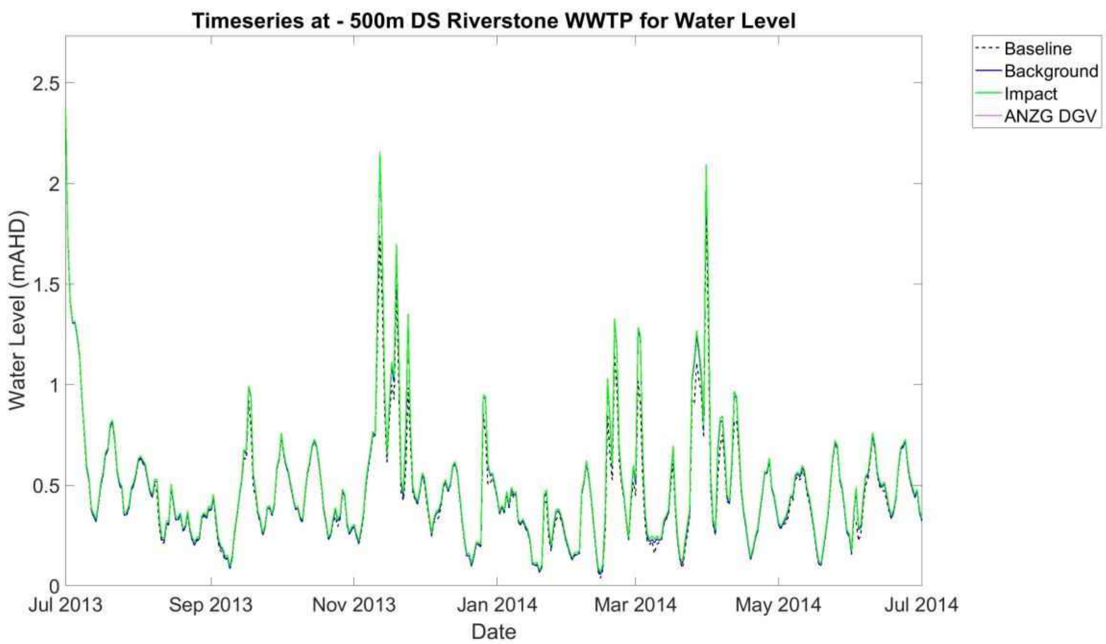

Figure 111 Timeseries of predicted Eastern Creek water level 500m downstream of Riverstone WWTP by scenario for typical dry year (2013/2014)

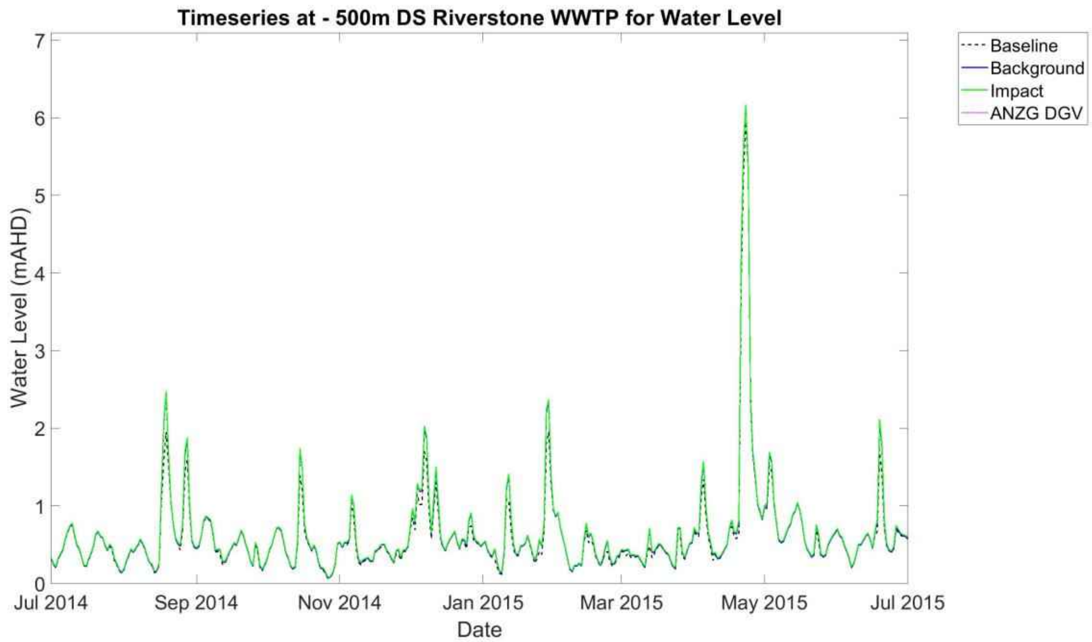

Figure 112 Timeseries of predicted Eastern Creek water level 500m downstream of Riverstone WWTP by scenario for typical wet year (2014/2015)

Additional investigations into the hydrodynamics and hydraulics of the tidal reach of Eastern Creek have been completed as part of the Hydrology and Geomorphology Impact Assessment for the Riverstone WWTP Upgrade (Aurecon, 2022).

5.4.4.3 Water Quality

5.4.4.3.1 Nutrients

Nitrogen

- Median annual TN concentrations for Eastern Creek and South Creek are predicted to experience significant reductions in the background scenario when compared to the baseline scenario for both the wet and dry years.
    - These reductions are primarily attributable to the proposed upgrades to the Quakers Hill WWTP (discussed in Section 5.4.3) and their predicted occurrence is despite the anticipated increase in development of the catchment in the background scenario.
- Median annual TN concentrations in the impact scenario are predicted to experience a minor increase within Eastern Creek and South Creek downstream of the Riverstone WWTP. This is particularly true for the representative dry year, and a longitudinal plot of median TN concentrations for Eastern Creek and South Creek in the dry year is provided in Figure 113.
- Seasonal trends can be seen in the daily predicted TN concentrations for both Eastern Creek and South Creek, and these are provided for the dry year in Figure 114 and Figure 115, respectively.
    - Peak daily TN concentrations for both waterways are predicted to have a modest increase in peak concentrations of approximately 0.4mg/L from background, however, they are approximately an equivalent reduction in concentration from the baseline scenario.
    - Increases in TN concentration from the background scenario are likely in response to the 270% increase in EP for the Riverstone WWTP as part of the NWTH upgrades.
- The median annual concentrations of Ammonia have predicted increases in peak and median concentration for Eastern Creek and South Creek in the impact scenario compared to both the background and baseline. This is particularly true in the dry year, as demonstrated in the longitudinal plot of Figure 116.
    - Peak Ammonia concentration is predicted to increase in the impact scenario by up to 0.5mg/L when compared to the background for both Eastern Creek and South Creek as seen in Figure 117 and Figure 118, respectively.
- Median NOx concentrations under the impact scenario show a relatively small increase in concentration from the background scenario and a modest decrease when compared to the baseline scenario for both Eastern Creek and South Creek. As with Ammonia, this is

particularly true in the dry year and a longitudinal profile of median NOx concentrations for both waterways is provided in Figure 119.

  - Peak NOx concentrations are predicted to increase in the impact scenario by as much as 0.5 mg/L for both Eastern Creek and South Creek as demonstrated in Figure 120 and Figure 121, respectively.

- Less seasonal variation for all nitrogen species is apparent for the wet year than in the dry. This reduced variation is predicted to be due to the increased base flows of the system from both the wet weather conditions in the catchment and the treated water releases as the increased EP for Riverstone WWTP under these upgrades will contribute greater treated water to the waterways.
- The annual median profiles showed the TN, Ammonia and NOx concentrations above the ANZG DGVs for the entire length of the waterways assessed in all three scenarios for both wet and dry years.
  - Despite this, annual median TN and NOx concentrations in the impact scenario show decreases when compared to the baseline scenario.
  - Ammonia concentration results for the impact scenario were shown to have modest increases from the background scenario of 0.02mg/L and 0.025mg/L for the wet and dry years, respectively.

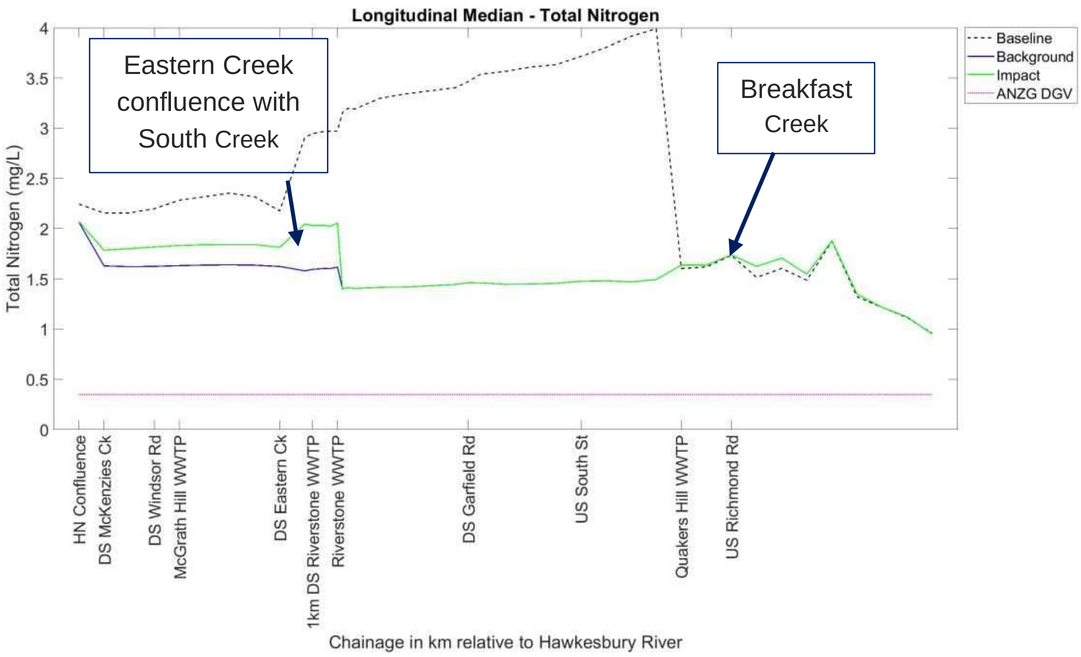

Figure 113 Longitudinal profile of predicted annual median dry year TN concentrations for Eastern Creek and South Creek

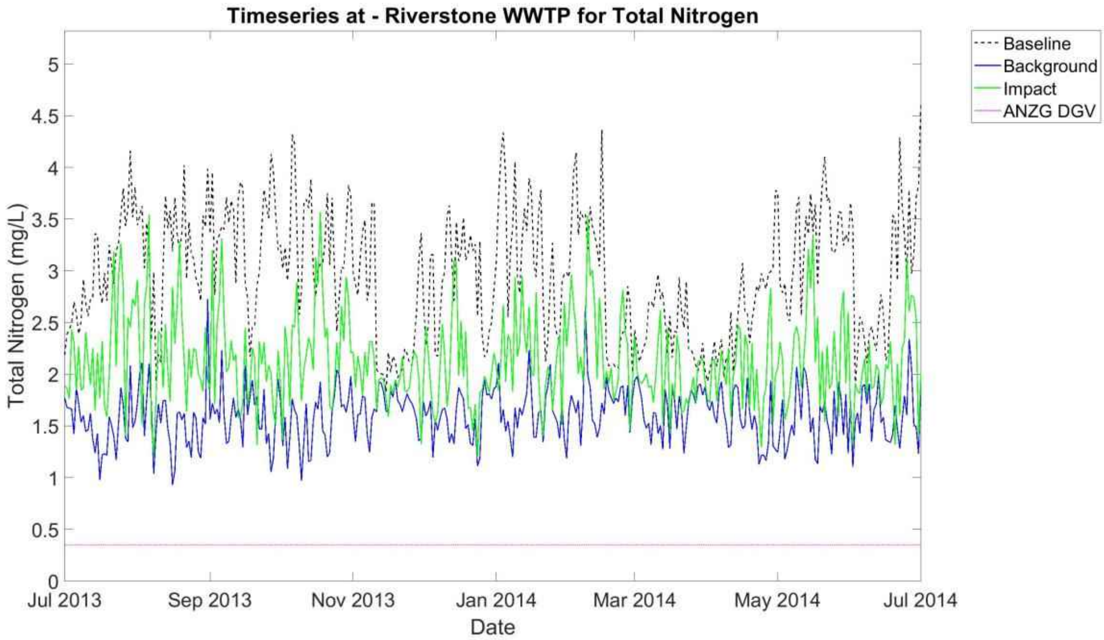

Figure 114 Timeseries of predicted Eastern Creek TN concentrations immediately downstream of Riverstone WWTP by scenario for typical dry year (2013/2014)

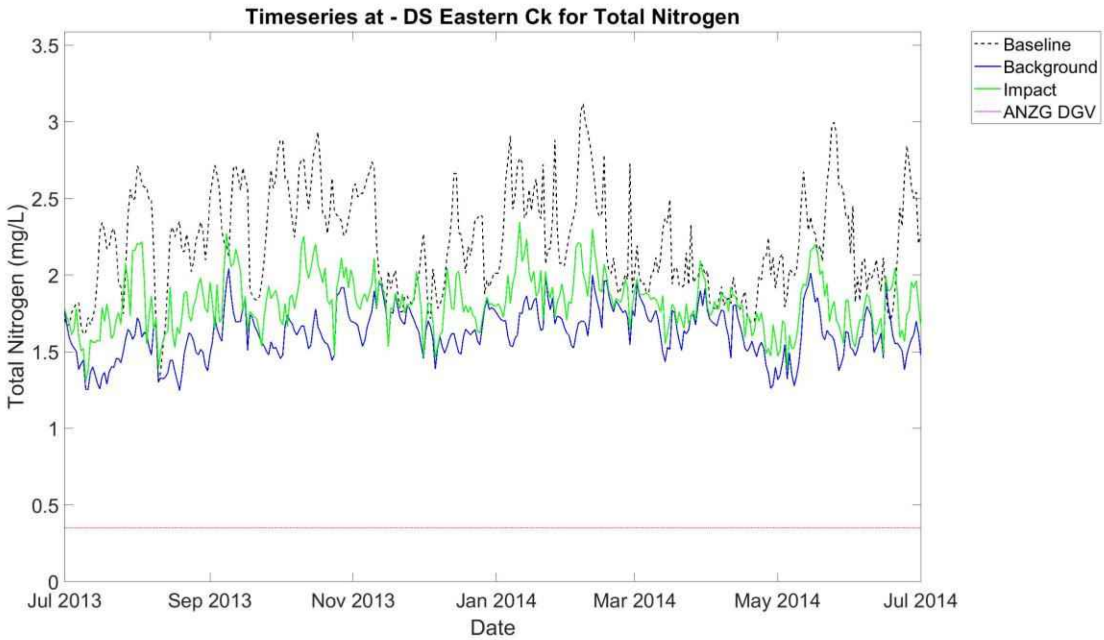

Figure 115 Timeseries of predicted South Creek TN concentrations immediately downstream of Eastern Creek outlet by scenario for typical dry year (2013/2014)

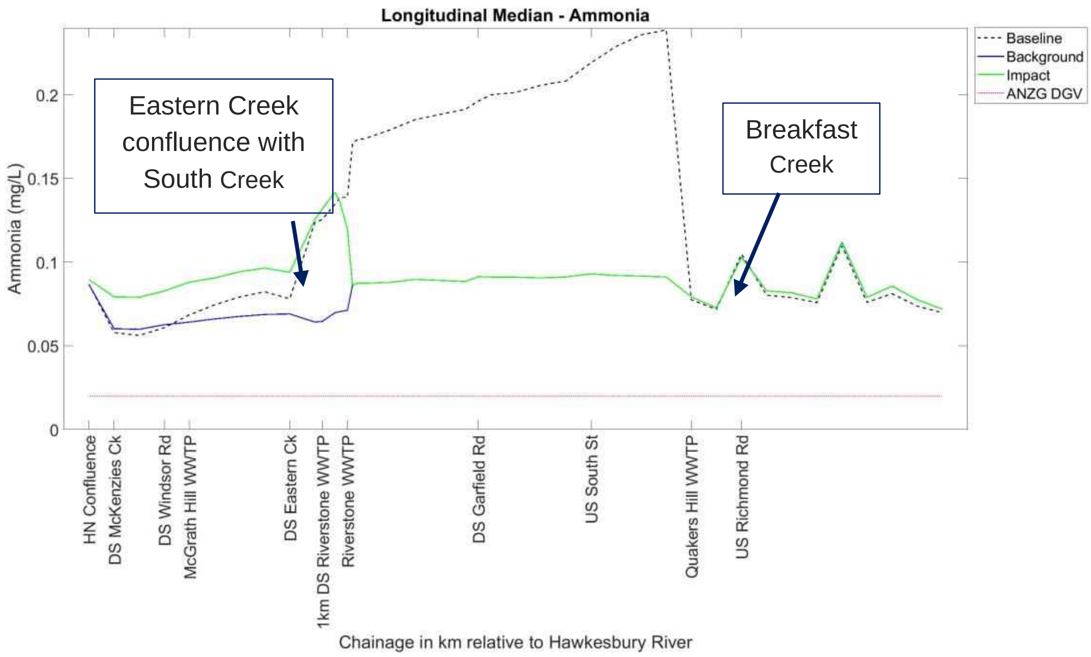

Figure 116 Longitudinal profile of predicted annual median dry year Ammonia concentrations for Eastern Creek and South Creek

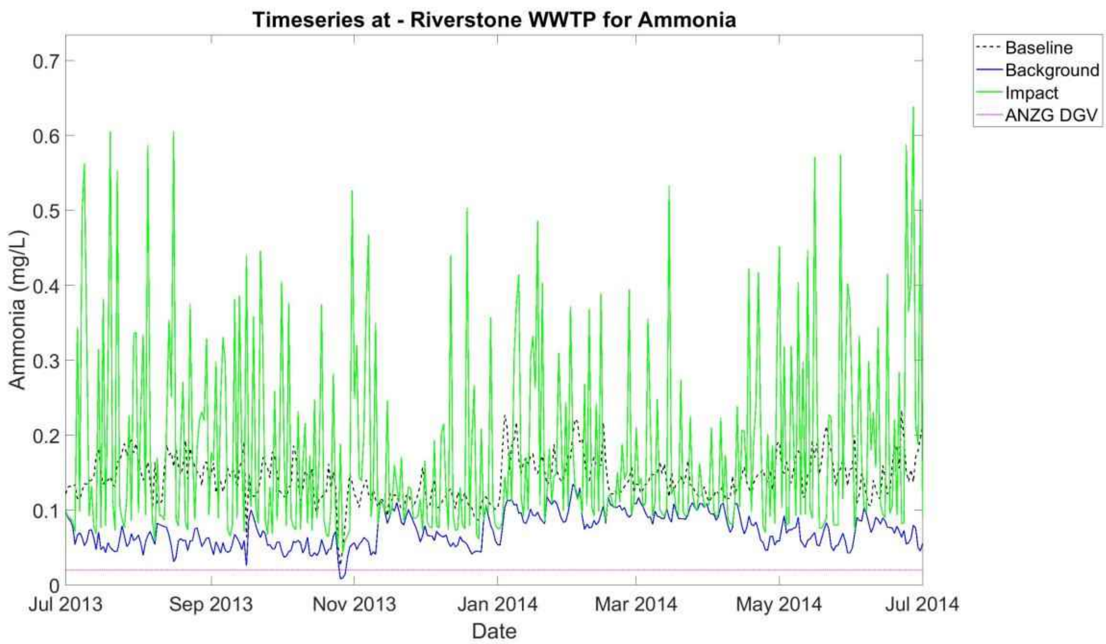

Figure 117 Timeseries of predicted Eastern Creek Total Ammonia concentrations immediately downstream of Riverstone WWTP by scenario for typical dry year (2013/2014)

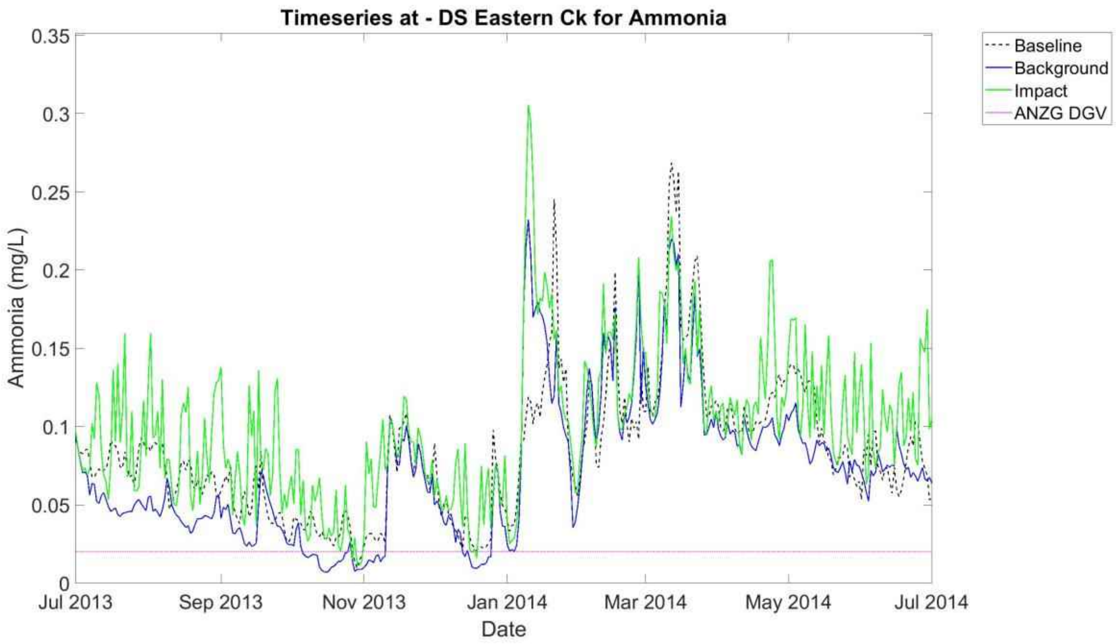

Figure 118 Timeseries of predicted South Creek Total Ammonia concentrations immediately downstream of Eastern Creek outlet by scenario for typical dry year (2013/2014)

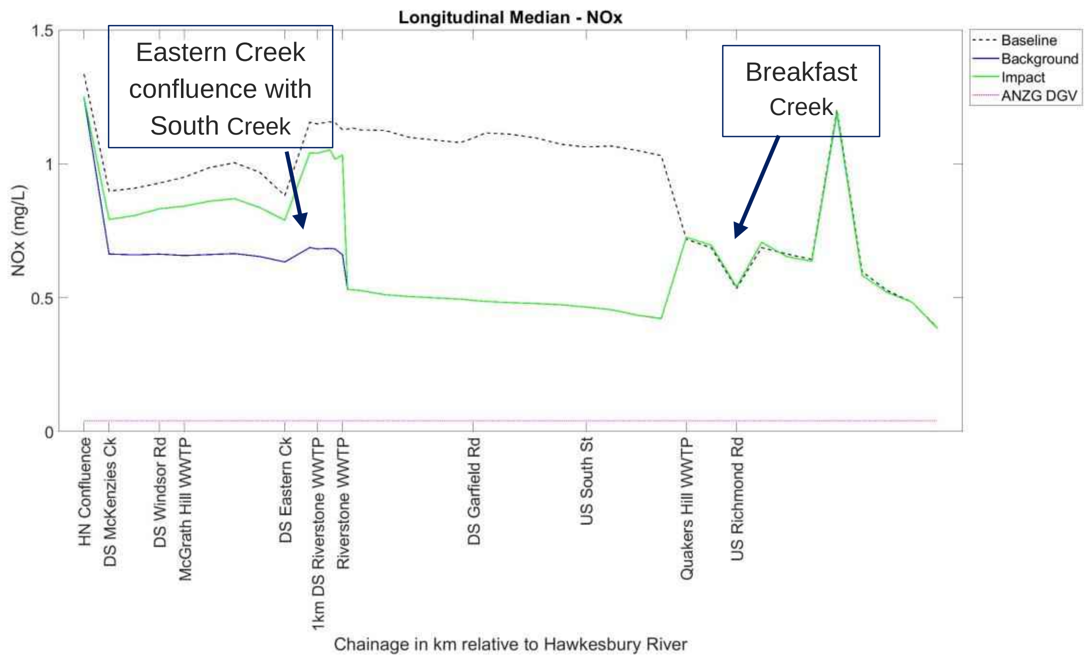

Figure 119 Longitudinal profile of predicted annual median dry year Oxidised Nitrogen concentrations for Eastern Creek and South Creek

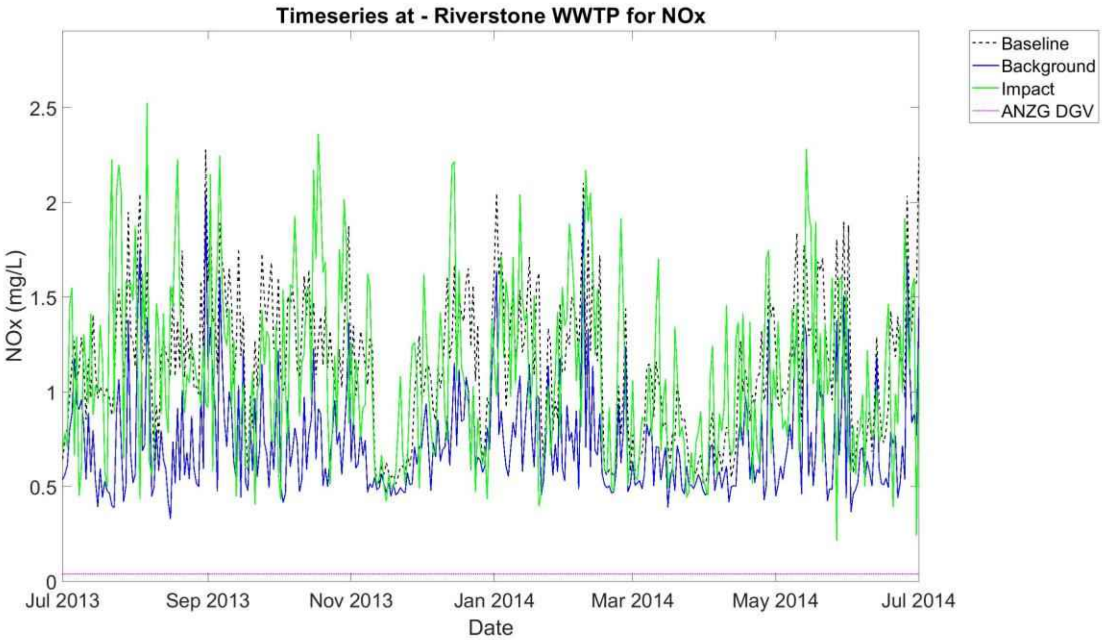

Figure 120 Timeseries of predicted Eastern Creek Oxidised Nitrogen concentrations immediately downstream of Riverstone WWTP by scenario for typical dry year (2013/2014)

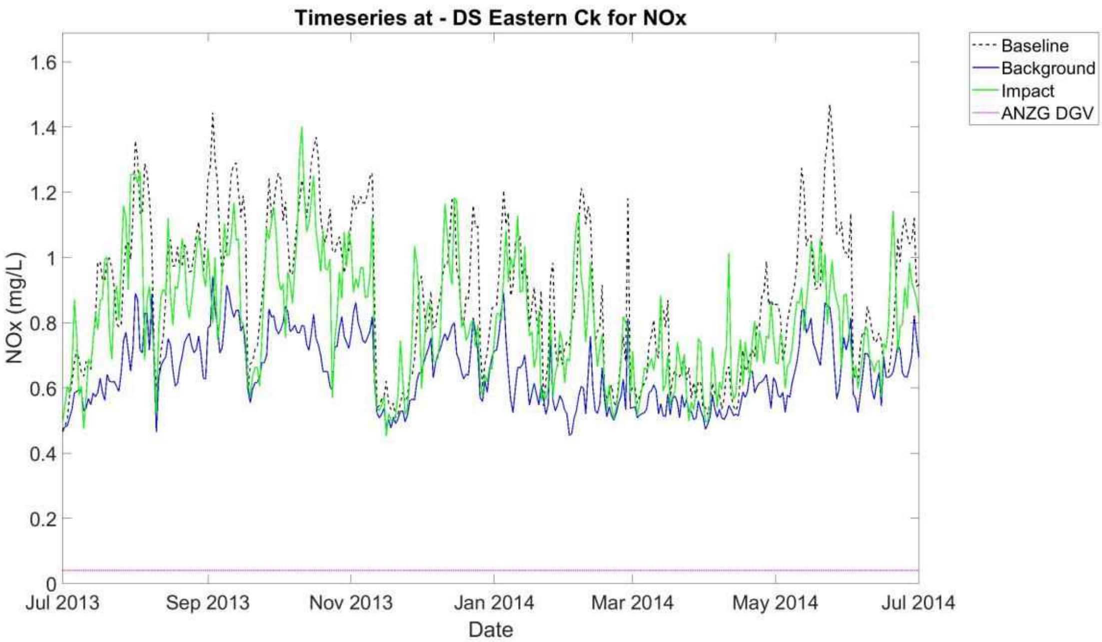

Figure 121 Timeseries of predicted South Creek Oxidised Nitrogen concentrations immediately downstream of Eastern Creek outlet by scenario for typical dry year (2013/2014)

Phosphorus

- Median annual TP concentrations in the background scenario are predicted to experience a large decrease in Eastern Creek and South Creek when compared to the baseline scenario for both wet and dry years.
    - This decrease is predicted as an outcome of the upgrades to Quakers Hill WWTP (as discussed in Section 5.4.3).
- The annual median TP concentrations of the impact scenario were similar in magnitude between the wet year and the dry year, with highest predicted wet year value of approximately 0.28 mg/L found in the region downstream of the Riverstone WWTP, compared to approximately 0.24 mg/L in the dry year of the same area.
- Median annual TP concentrations in the impact scenario are predicted to be marginally decreased when compared to the background scenario.
    - This is particularly true in the wet year, which has greater annual median TP concentrations than the dry, suggesting that a principal component of the TP is sourced from catchment runoff. The impact scenario predicts a decrease in median annual TP concentration of approximately 0.01 mg/L for both Eastern Creek and South Creek downstream of the Riverstone WWTP for the wet year.
    - A longitudinal profile of the median annual TP concentrations in the wet year for Eastern Creek and South Creek downstream of the Riverstone WWTP is provided in Figure 122.
- Peak TP concentrations in the impact scenario were predicted to be largely consistent with those of the background scenario for both Eastern Creek and South Creek, despite the proposed increase to EP for the Riverstone WWTP.
    - Daily TP concentrations are predicted to increase by as much as 0.01 mg/L in Eastern Creek, however, peak concentrations are anticipated to reduce by approximately 0.02 mg/L.
    - Peak TP concentrations in the wet year for Eastern Creek and South Creek downstream of the Riverstone WWTP are provided in Figure 123 and Figure 124.
- Median annual FRP concentrations in the background scenario are predicted to experience significant reductions when compared to the baseline scenario.
    - As with TP concentrations, this is expected to be the result of the Quakers Hill WWTP upgrades (as discussed in Section 5.4.3)
- Median annual FRP concentrations in the impact scenario are predicted to marginally increase when compared to the background scenario.
    - This is particularly true in the wet year when concentrations are predicted to be higher than the dry year due to catchment runoff sources and the wet year median annual FRP concentrations are provided in Figure 125.

- The impact scenario predicts that, immediately downstream of the Riverstone WWTP, Eastern Creek will experience an increase in median annual FRP of approximately 0.01 mg/L in the wet year under the impact scenario when compared to the background.
    - This increased FRP concentration still represents an overall decrease when compared to the baseline scenario and is attributable to the 270% increase in EP to be serviced by the Riverstone WWTP.
    - For the impact scenario, annual median FRP concentration downstream of Riverstone WWTP is below the annual median FRP concentration upstream of Breakfast Creek and the Quakers Hill WWTP, indicating that the NWTH upgrades have a lesser impact to FRP water quality (and, by extension, algal blooms) than runoff sources in the upstream catchment.
- Peak FRP concentrations in the impact scenario were predicted to be slightly elevated downstream of the Riverstone WWTP for both Eastern Creek and South Creek (Figure 126 and Figure 127, respectively).
- The upgrades changed the predicted annual median concentrations in different reaches of the river, but didn't significantly impact the general trends of compliance in either the dry or wet years.
- TP concentrations are not predicted to be compliant with ANZG DGVs for any of the three scenarios in either the dry year or wet years.
    - This is also predicted for the reach of Eastern Creek upstream of Quakers Hill WWTP, indicating that there are catchment sources of TP that bring the water quality out of compliance with the TP DGV.
    - This is also supported by the prediction that median annual TP concentrations are reduced downstream of the Quakers Hill WWTP and Breakfast Creek for both the background and impact scenarios.
- Median annual FRP concentrations are predicted to be compliant only for a very short section of Eastern Creek upstream of the Riverstone WWTP between Breakfast Creek and Garfield Road in the dry year of the background scenario.
    - Median annual FRP concentrations are not expected to be compliant with DGVs for any other portion of the waterways assessed under any of the scenarios or climatic conditions.

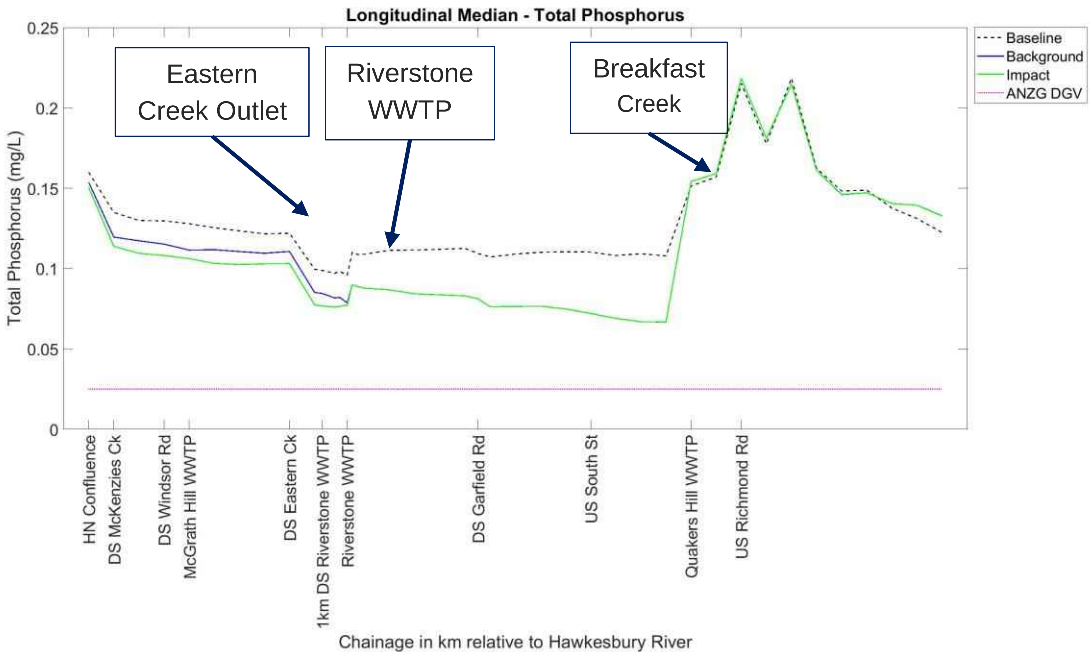

Figure 122 Longitudinal profile of predicted annual median wet year TP concentrations for Eastern Creek and South Creek

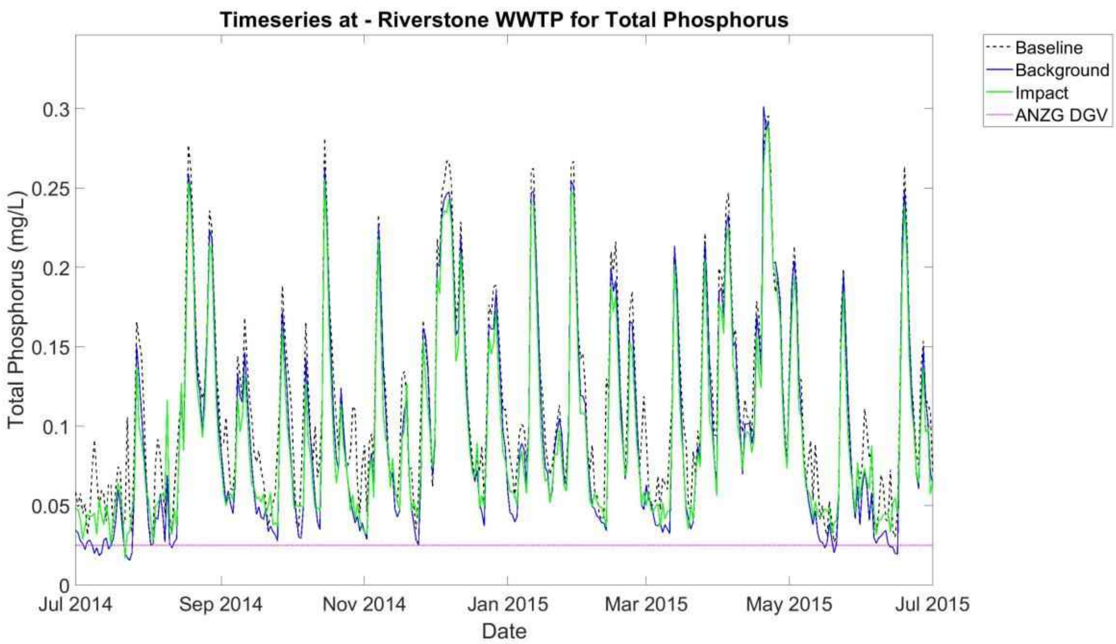

Figure 123 Timeseries of predicted Eastern Creek TP concentrations immediately downstream of Riverstone WWTP by scenario for typical wet year (2014/2015)

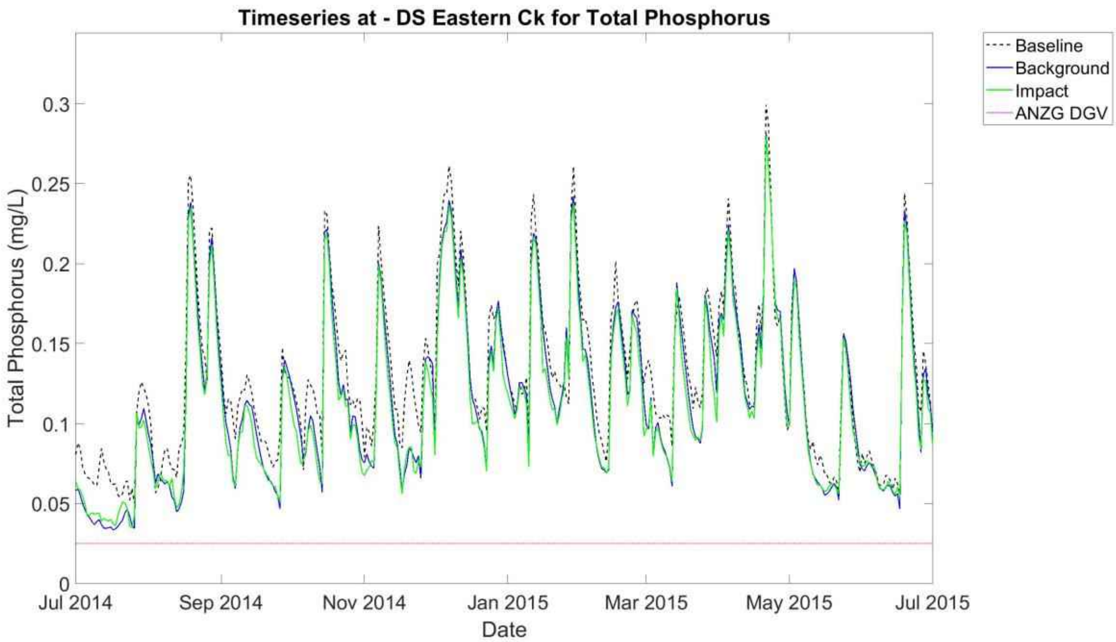

Figure 124 Timeseries of predicted South Creek TP concentrations downstream of Eastern Creek outlet by scenario for typical wet year (2014/2015)

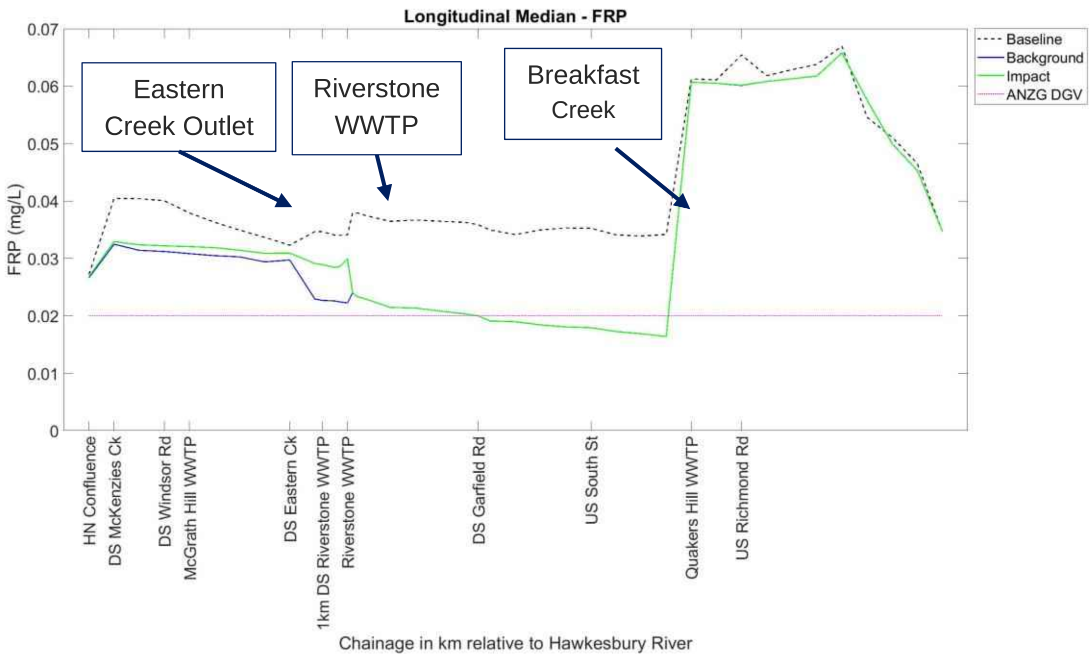

Figure 125 Longitudinal profile of predicted annual median wet year filterable reactive phosphorus concentrations for Eastern Creek and South Creek

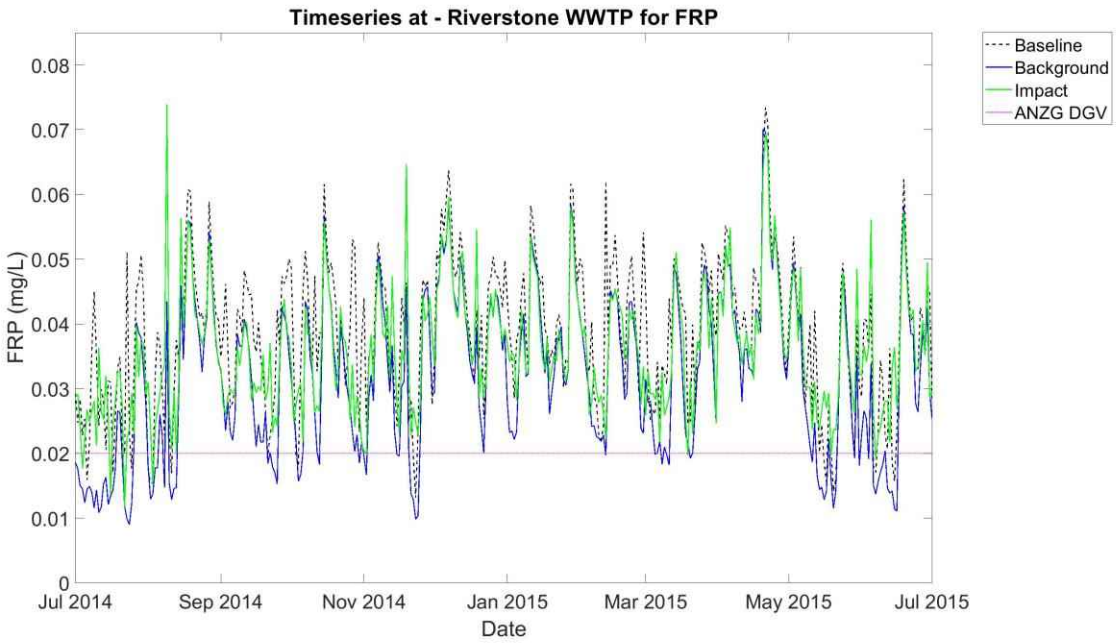

Figure 126 Timeseries of predicted Eastern Creek Filterable Reactive Phosphorus concentrations immediately downstream of Riverstone WWTP by scenario for typical wet year (2014/2015)

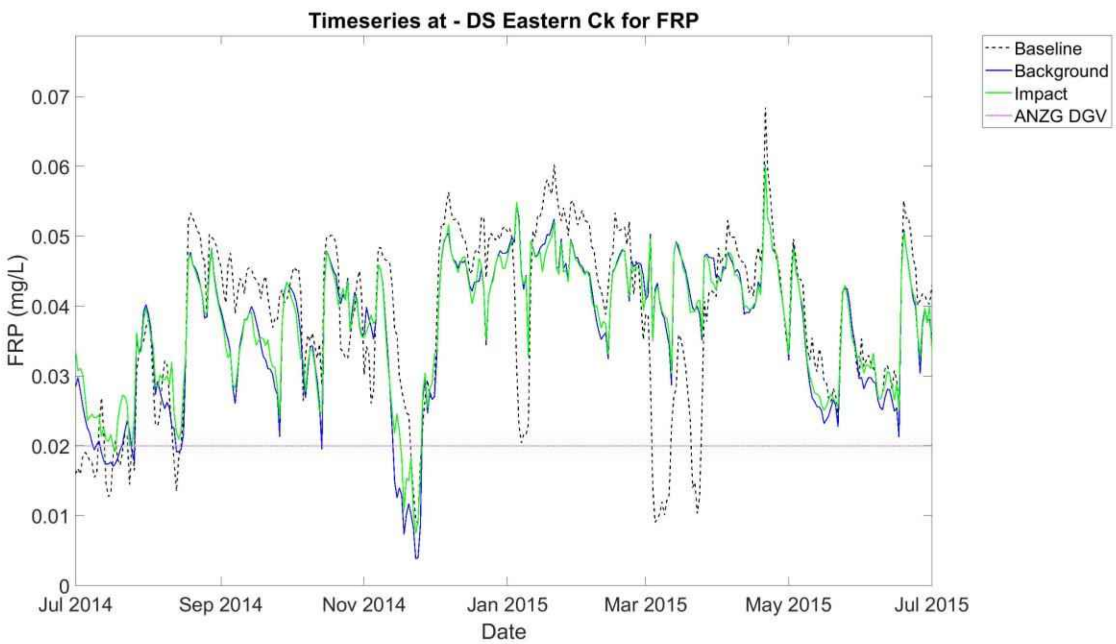

Figure 127 Timeseries of predicted South Creek Filterable Reactive Phosphorus concentrations immediately downstream of Eastern Creek outlet by scenario for typical wet year (2014/2015)

5.4.4.3.2 Algae

Chlorophyll - *a*

- The annual median profiles in both the dry and wet years showed considerably higher Chlorophyll-*a* concentrations in the baseline scenario than both the background and impact scenarios, showing a sharp decrease immediately downstream of the Riverstone WWTP in both of the latter scenarios.
    - The dry year predicted greater median concentrations than the wet year due to the reduced flushing experienced by the waterways in these conditions.
    - The median annual Chlorophyll-*a* concentrations in the dry year are provided in Figure 128.
    - Annual median concentrations of Chlorophyll-*a* in the impact scenario were predicted to decrease by as much as 12 µg/L in South Creek when compared to the baseline.
- The annual median concentrations of Chlorophyll-*a* in both the background and impacts scenarios were under the ANZG DGV along the waterway.
- The Chlorophyll-*a* results predicted for both Eastern Creek and South Creek for all scenarios in both wet and dry years suggest a reduced risk of algal blooms within the waterway. This is likely a product of the reduction in bio-available nitrogen and phosphorus associated with the Quakers Hill and Riverstone WWTP plant upgrades.

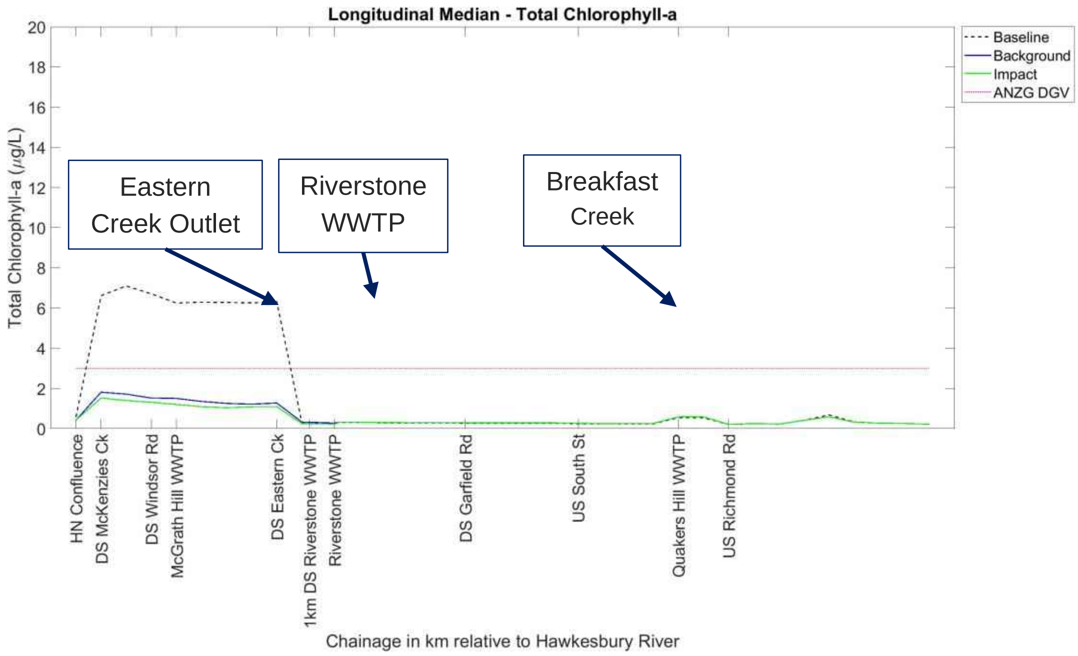

Figure 128 Longitudinal profile of predicted annual median dry year Chlorophyll-*a* concentrations for Eastern Creek and South Creek

5.4.4.3.3 Other Water Quality Indicators

Salinity

- For both wet and dry years in all scenarios, salinity within the tidal reach of Eastern Creek was predicted to experience modest increases from the baseline condition, while remaining below the ANZG DGVs.

TSS

- TSS concentrations are predicted to increase due to the increased urban development within the catchment between the baseline and background scenarios. Conversely, the upgrades to the Riverstone WWTP in the impact scenario are predicted to reduce the concentration of TSS in both Eastern Creek and South Creek due to increased treated water releases and improved treated water quality. Despite this, negligible increases in median TSS concentrations during the dry year due to increased flows from the Riverstone WWTP upgrade were predicted.
- For all three scenarios in both wet and dry years, the median annual TSS concentrations meet the ANZG DGV for the reaches of Eastern Creek and South Creek located downstream of the Riverstone WWTP treated water release location.
- The TSS concentrations in the tidal reach of South Creek are predicted to be improved under the impact scenario for both wet and dry years, showing modest improvements against the baseline and background scenarios for the wet year and slightly greater improvements against the baseline in the dry year.

Oxygen

- Median annual Dissolved Oxygen concentration is predicted to marginally decrease between the background and impact scenarios downstream of the Riverstone WWTP treated water release point for both dry and wet years in Eastern Creek and South Creek. This is anticipated to be caused by minor increases in BOD associated with the upgrades to Riverstone WWTP.

Enterococci (analysed as primary pathogenic indicator)

- The annual median concentrations of Enterococci concentrations in Eastern Creek and South Creek for the impact scenario in both dry and wet years (Figure 129 and Figure 130, respectively) are predicted to be reduced when compared to the background and baseline scenarios downstream of the Riverstone WWTP.
    - This prediction is due to the increased treated water release volumes and disinfection from the Riverstone WWTP.
- The annual median profiles of Enterococci concentrations are predicted to be above the NHMRC guideline values for the entirety of the period analysed for all three scenarios in both wet and dry years.
    - Despite the high Enterococci concentrations, the impact scenario is predicted to reduce peak and median annual concentrations due to the disinfection undertaken

at the Riverstone WWTP and the increased treated water release volumes of the NWTH upgrades.

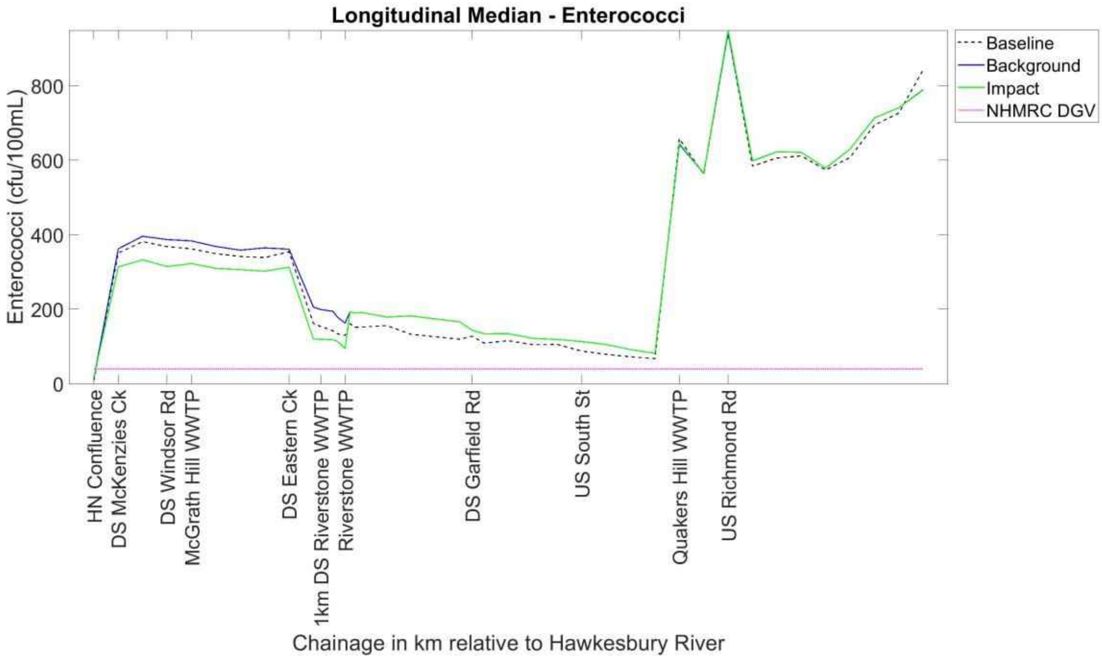

Figure 129 Longitudinal profile of predicted annual median dry year Enterococci concentrations for Eastern Creek and South Creek

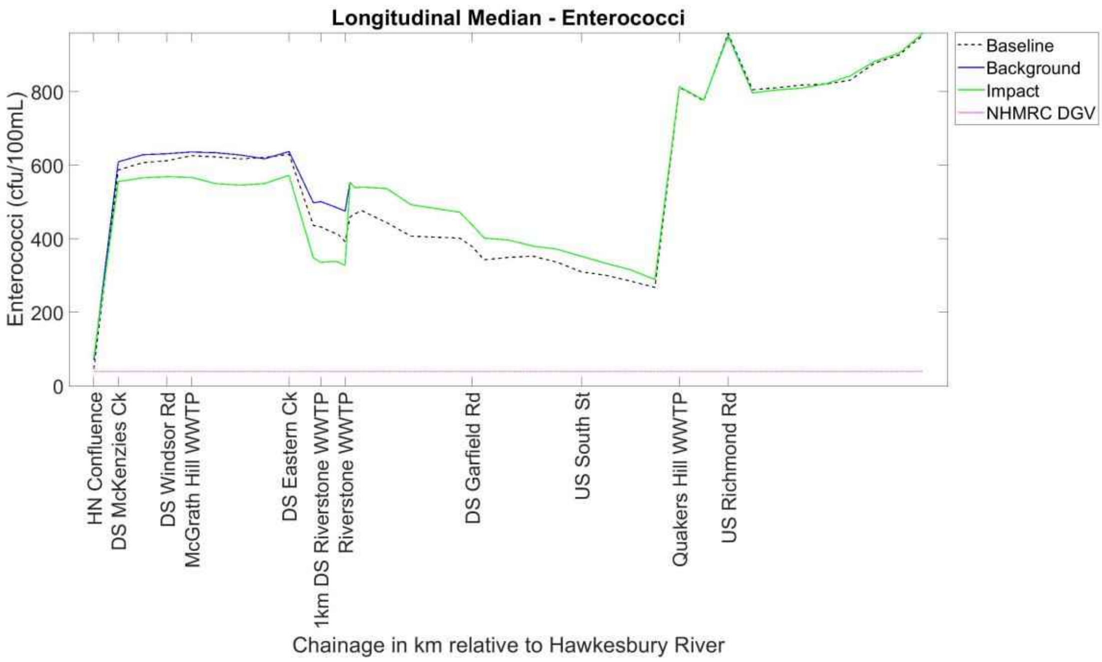

Figure 130 Longitudinal profile of predicted annual median wet year Enterococci concentrations for Eastern Creek and South Creek

5.5 Hawkesbury River

5.5.1 Scenario Brief

Modelling of the Hawkesbury River has utilised the same scenario conditions for both Cattai Creek and Eastern Creek as detailed in Sections 5.3.1 and 5.4.1, respectively. Upstream of its confluence with South Creek, negligible landuse change has been modelled between the baseline and background scenarios. Consequently, changes between these scenarios are only predicted to occur downstream of the confluence with South Creek and are predicted to be proportional to the changes identified for both Eastern and Cattai Creeks.

5.5.2 Analysis Locations

Analyses for the Hawkesbury River have been undertaken at select sites along the waterway's extents. These are detailed in Figure 68 in Section 5.3.2.

5.5.3 Load Analysis

Analysis of estimated TN and TP loads flowing to the Hawkesbury River from the proposed operational upgrades for NWTH has been undertaken to allow comparison of the contributions from various sub-catchments and treatment plants under current conditions, and also for the background and impact scenarios discussed in Section 3.5.3. The loads were estimated through analysis of the model boundary conditions for each scenario, and for both the representative wet and dry years independently.

The load analyses presented in the figures below, extend from Redbank upstream of South Creek confluence to upstream of the Colo Creek confluence. Figure 131 and Figure 132 present the cumulative analysis of TN loads from upstream to downstream for all catchment loads (including WWTPs and WRPs). From left to right, each new set of columns/bars represents the cumulative nutrient load with the addition of a new boundary in the model. Figure 133 and Figure 134 provide equivalent analyses of the TP loads.

From these graphs, the influence of the major tributaries, such as Grose River, South Creek, Cattai Creek, etc can be observed. The differences in load magnitude between the dry and wet years is also notable.

For the impact scenario in both wet and dry years, loads to the Hawkesbury River from the NWTH upgrades predicted to experience negligible change.

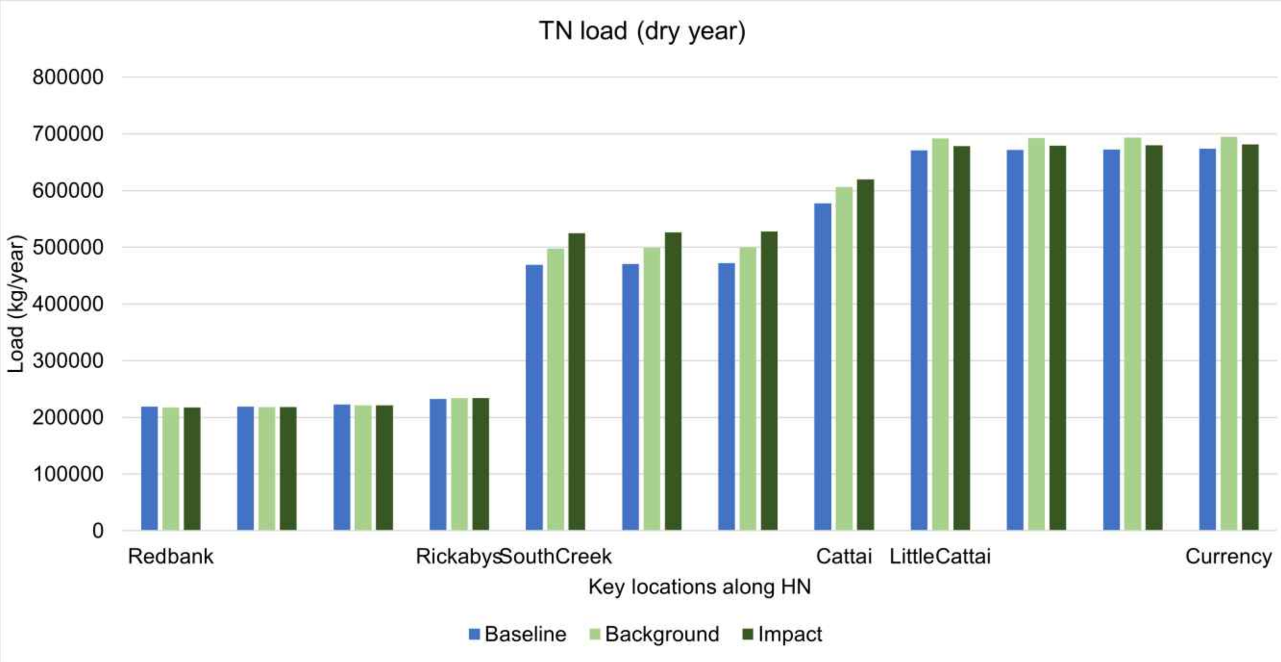

Figure 131 TN cumulative catchment loads for Hawkesbury River (dry year)

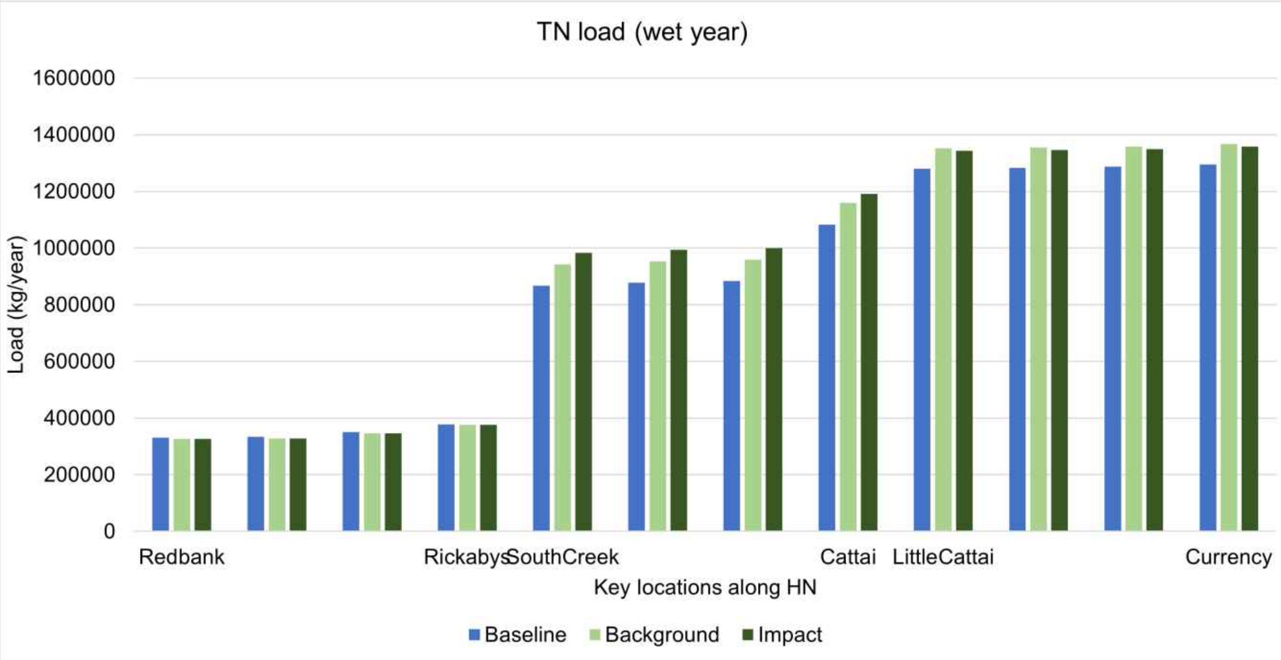

Figure 132 TN cumulative catchment loads for Hawkesbury River (wet year)

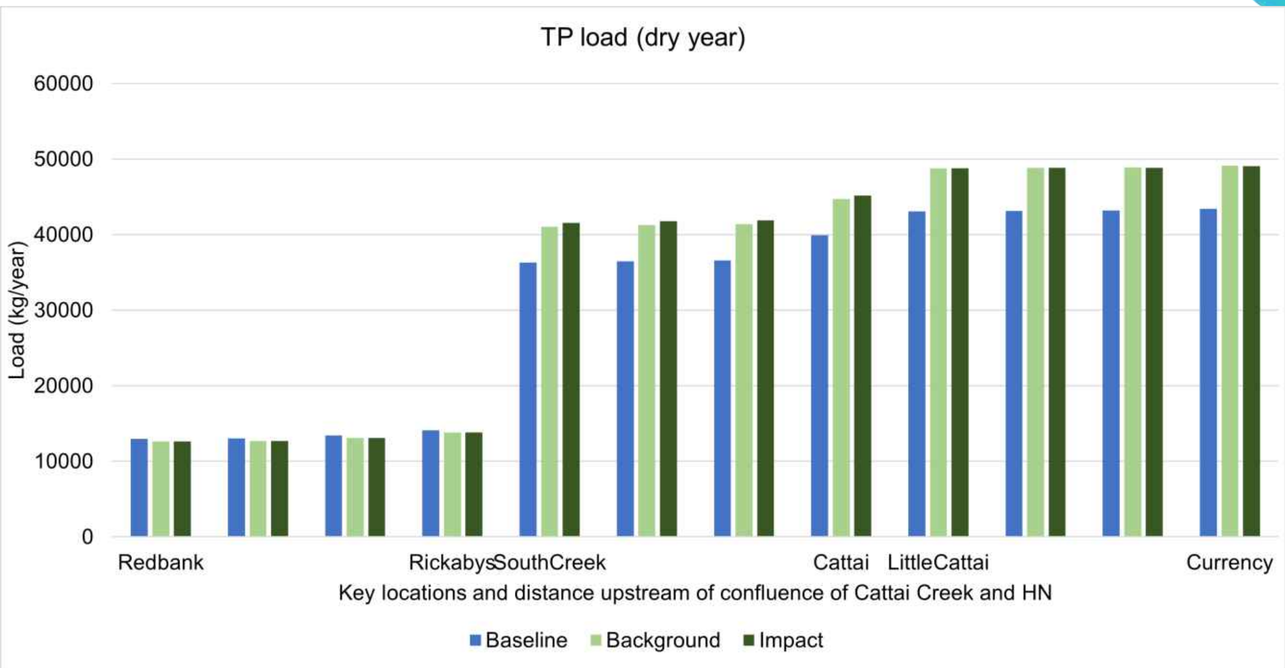

Figure 133 TP cumulative catchment loads for Hawkesbury River (dry year)

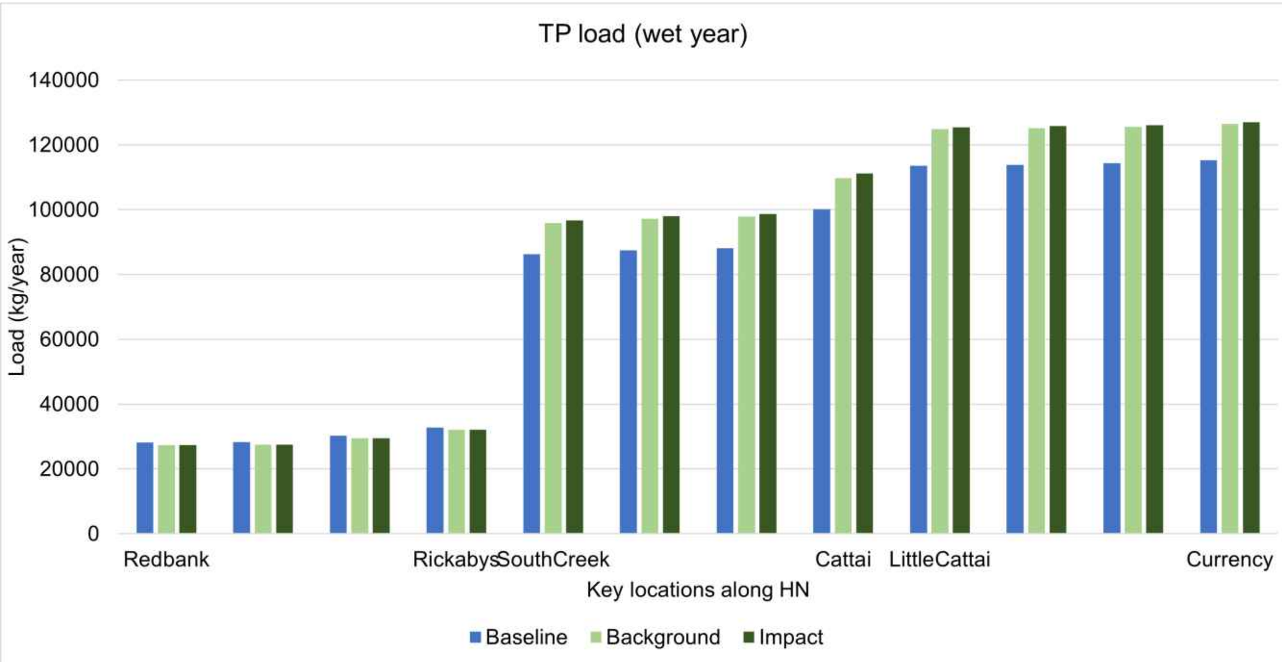

Figure 134 TP cumulative catchment loads for Hawkesbury River (wet year)

5.5.4 Interpretation

5.5.4.1 General

The following general comments are provided with respect to the results for all three scenarios modelled across both the representative wet and dry years.

- Many of the predicted concentrations of the background scenario represent improvements in water quality conditions when compared to the baseline scenario, suggesting that there is a predicted or expected improvement to water quality associated with the parkland development with the Hawkesbury Nepean catchment.
- In many of the modelled water quality parameters, the differences in water quality between the background scenarios and the baseline scenario were predicted to be more significant than the differences between the impact and background scenarios.
  - The difference in the water quality between the impact and background scenarios were observed in a limited section of Hawkesbury River around the South Creek and Cattai Creek confluence (about 14 km upstream to 30 km downstream of Cattai Creek and Hawkesbury River confluence).
  - The water quality at all other sites outside this section was predicted to have almost identical response in both the time series and longitudinal plots of all parameters assessed. Therefore, this chapter provides reporting only for sections of the waterway where impacts were apparent.
- The wet flow years generally showed higher annual median nutrient and Enterococci concentrations than the dry year in both the background and baseline scenarios. Both the background and baseline scenarios presented similar temporal variations in the water quality variables (e.g. same timing of high concentration events), though the magnitudes of variations are different between the scenarios.
- In general, the annual median profiles of TN, TP and Enterococci concentrations are close to or above compliance with their relevant DGVs in the regions from upstream of the South Creek confluence to the vicinity of Wisemans Ferry in both the background and baseline scenarios. In the impact scenario increases or decreases to different forms of nitrogen and phosphorus were predicted in different reaches of the river, though these changes did not result in a predicted alteration of the trend of compliance.
- The impact scenario predicted a slight increase in nitrogen concentrations (TN, NOx, Ammonia) and slight decrease in the DO concentration in the impacted region in both the dry and wet years, compared to the background scenario. Other key water quality variables, including TP, Chlorophyll-*a*, and TSS remained similar between the impact scenario and background scenario. Outside of the identified areas of influence, other reaches showed similar predicted water quality in terms of temporal variations and statistical distributions of all water quality variables.
- The predicted effect to these concentrations is slightly different in wet vs. dry years, with the wet year results indicating higher annual median nutrient and Enterococci concentrations than the dry year results. But the difference on water quality between the wet and dry years is generally consistent and relatively small compared to inter-annual difference that occurs naturally between these hydrological conditions.

Despite the slight differences in the water quality response between both the background and impact scenarios, the annual median profiles of TN and TP levels and Enterococci concentrations are close or above the compliance in the Hawkesbury-Nepean River in both the background and impact scenarios.

With implementation of the treatment and release strategy in the South Creek and Cattai Creek WQRMs, as discussed for the impact scenario in Section 5.1.2.1, the predicted residual impacts from the WWTPs releases are considered to present a low risk of affecting long term ambient water quality and/or ecosystem health in the Hawkesbury River.

5.5.4.2 Water Quality

5.5.4.2.1 Nutrients

Nitrogen

- The annual median TN and NOx concentrations in the background scenarios were generally predicted to be lower than the baseline scenario in the mid-stream of the Nepean River (approximately from Penrith Weir to Sackville Bend), with TN difference of up to ~0.4 mg/L and NOx difference of up to ~0.3 mg/L in the region around the Grose River, indicating the midstream was more notably impacted by the future conditions in the dry year.
    - These changes are attributable to the significant catchment changes within the South Creek catchment as well as the Quakers Hill WWTP upgrades.
- Different to TN and NOx, the Ammonia annual median profiles predicted lower concentration in the region between the South Creek and Cattai Creek confluences in the background scenario than the baseline scenario.
- The annual median TN, NOx and Ammonia concentrations were predicted to be slightly higher in the impact scenario than background scenario at the region from South Creek confluence to downstream of Cattai Creek.
    - This was most evident during the dry year as the system did not benefit from additional flushing of wet weather events as in the wet year.
    - The difference was small (mostly < 0.1 mg/L in the TN concentration) when compared to the annual median TN concentration of about 1.0 mg/L at this region, demonstrating that the influence of the Riverstone WWTP upgrade are dampened by South Creek and the larger flows of the Hawkesbury Nepean system.
    - Annual median TN, NOx and Ammonia concentrations in the dry year are provided in Figure 135, Figure 136 and Figure 137, respectively.
- The annual median profiles showed that TN and NOx concentrations were close to or above the ANZG DGVs in all scenarios. The highest annual median values were found in the region around the Cattai Creek confluence where the TN concentration reached ~1.0 mg/L in both the wet and dry
- The proposed upgrades to treated water discharges of the impact scenario in both the Cattai Creek and South Creek catchments predicted an increase to nitrogen concentrations within the Hawkesbury River downstream of its confluences with both creeks.

- It is of important note, however, that the increased concentrations to nitrogen species in the system are not proportional to the increase in population to be serviced by the NWTH plant. TN is predicted to increase by as much as 10% immediately downstream of Cattai Creek in the impact scenario when compared to the background scenario, and the total EP serviced by all three NWTH plants upstream of this is expected to increase by 112% as part of the upgrades.
- Additionally, while these increases exist in comparison to the background scenario, the predicted results of the impact scenario represent water quality improvements for both the wet and dry year when compared with the baseline scenario.

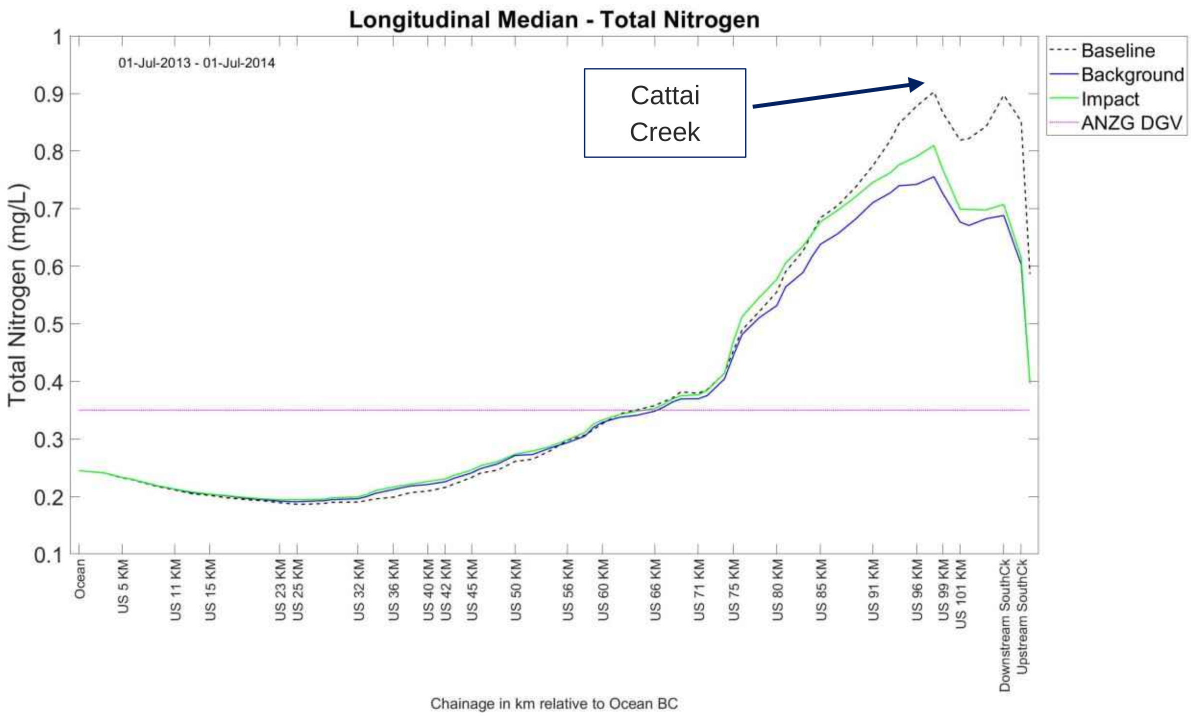

Figure 135 Longitudinal profile of predicted annual median dry year TN concentrations for the Hawkesbury River

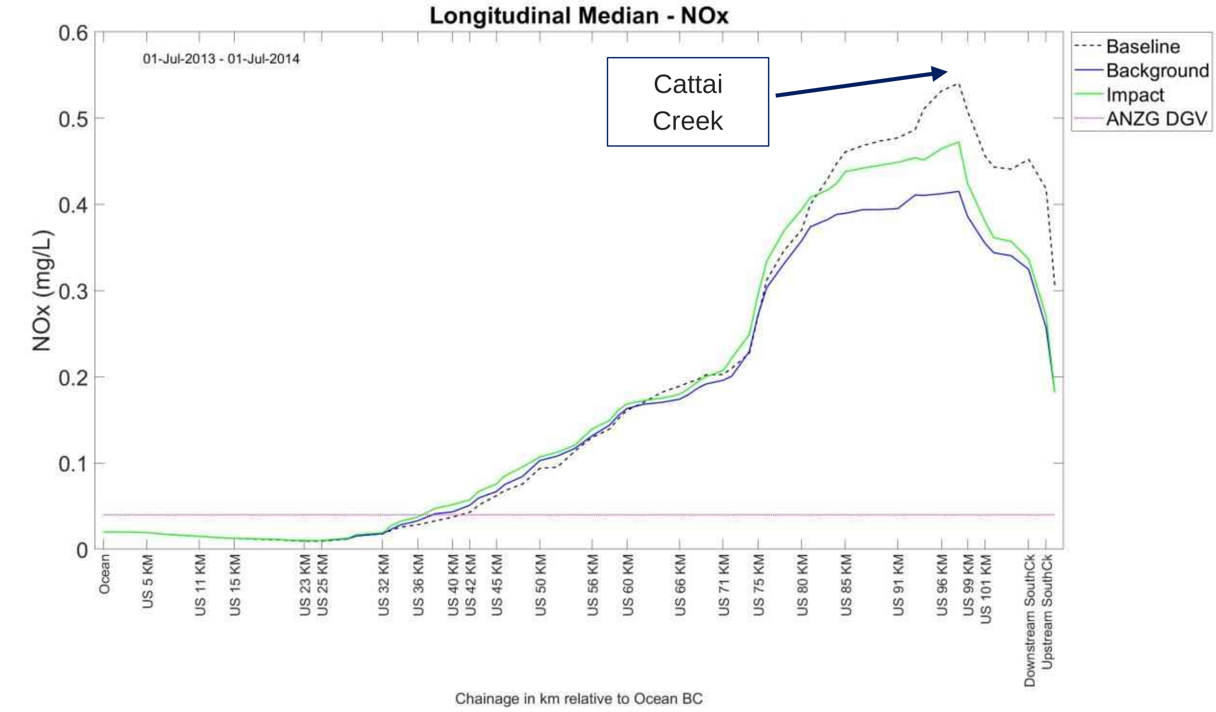

Figure 136 Longitudinal profile of predicted annual median dry year Oxidised Nitrogen concentrations for the Hawkesbury River

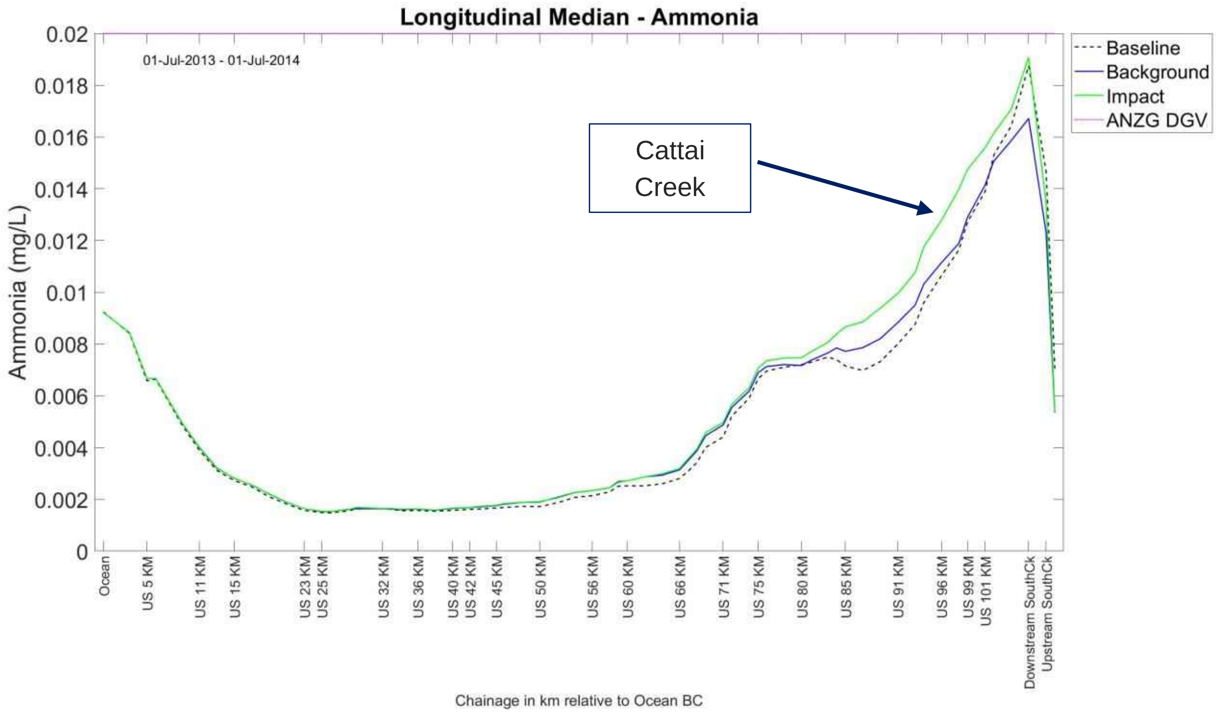

Figure 137 Longitudinal profile of predicted annual median dry year Ammonia concentrations for the Hawkesbury River

Phosphorus

- The annual median phosphorus concentrations were predicted to have marginally lower concentrations in the background scenario than the baseline scenario downstream of the Hawkesbury River's confluence with both South Creek and Cattai Creek.
    - This prediction suggests that catchment contributions external to the NWTH plants are an important driver of phosphorus water quality outcomes.
    - Annual median FRP concentrations between South Creek and Cattai Creek in the background scenario are predicted to be approximately 5 to 10% lower than in the baseline scenario.
- The annual median profiles of phosphorus (TP and FRP) predicted negligible differences in the longitudinal plots between the impact scenario and background scenario, indicating that the future WWTP discharge in South Creek and Cattai Creek are not predicted to meaningfully affect the phosphorus concentrations in the Hawkesbury River.
    - The annual median TP concentrations were generally higher in the wet year compared to the dry year, with highest value of ~0.08 mg/L found in the region downstream of South Creek, compared to ~0.06 mg/L in the dry year of the same area. Annual median wet year TP concentrations are provided in Figure 138.
- The annual median profiles of FRP showed negligible differences between the impact scenario and background scenario. The annual median FRP concentrations in the wet year are provided in Figure 139.
- For both wet and dry years, median annual TP concentrations in the Hawkesbury River have been predicted to exceed the ANZG DGV downstream of the South Creek confluence for all three scenarios. Similarly, median annual FRP concentrations in this region of the waterway have been predicted to exceed the ANZG DGV for both wet and dry years.
- The impact scenario has not been predicted to meaningfully impact on phosphorus concentrations in the Hawkesbury River.
    - For all three scenarios in both wet and dry years, the median annual concentrations of both TP and FRP are predicted to negligibly decrease downstream of the South Creek and Cattai Creek confluences because of the upgrades to the NWTH plants.
    - Comparing the changes to concentrations between baseline and background scenarios, the model results predict that catchment landuse and other phosphorus sources external to the NWTH will have a more meaningful impact to phosphorus water quality outcomes in the Hawkesbury River.
        - This is consistent with the load analyses undertaken for the NWTH upgrades in Sections 5.3.3 and 5.4.3.

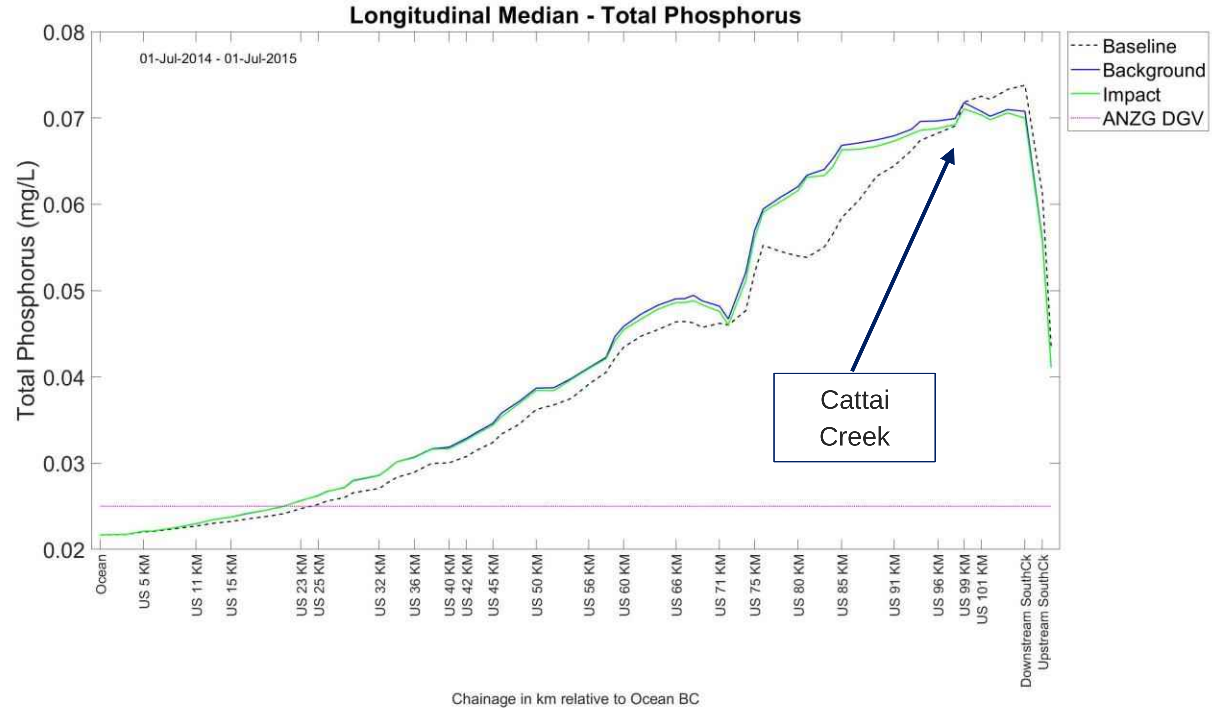

Figure 138 Longitudinal profile of predicted annual median wet year TP concentrations for the Hawkesbury River

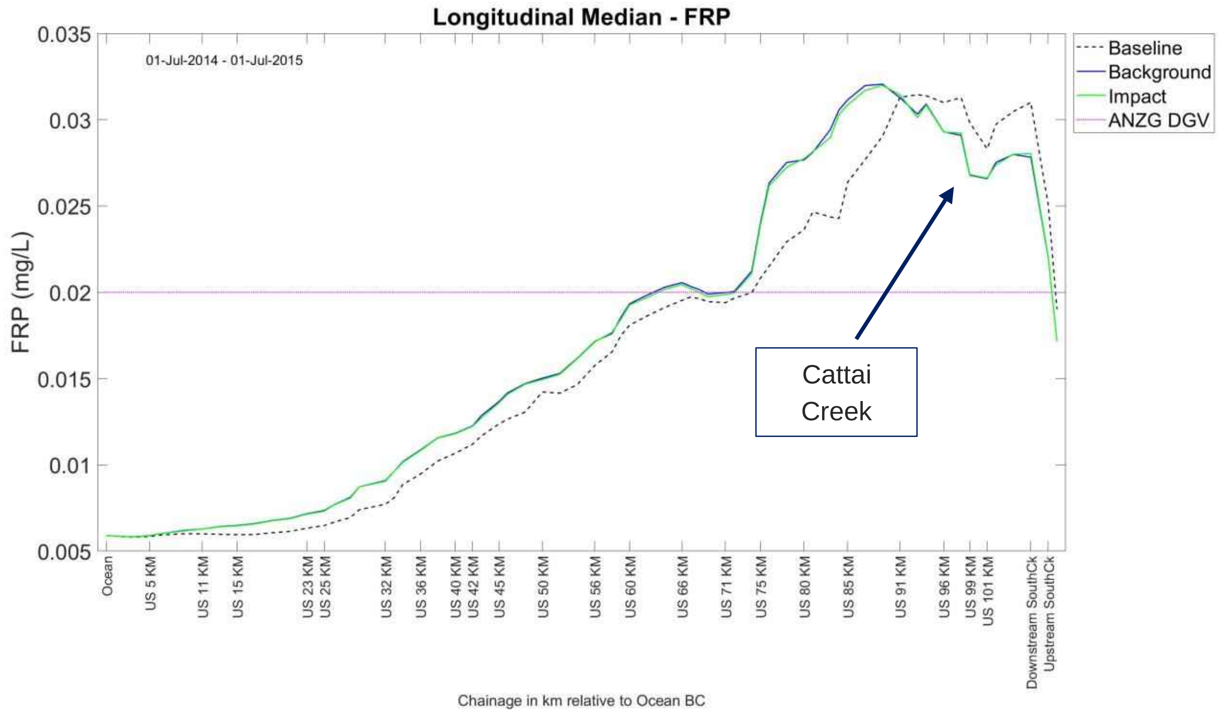

Figure 139 Longitudinal profile of predicted annual median wet year Filterable Reactive Phosphorus concentrations for the Hawkesbury River

5.5.4.2.2 Algae

Chlorophyll - *a*

- The annual median Chlorophyll-*a* concentrations in both the dry and wet years are predicted to be modestly lower in the Hawkesbury River downstream of the South Creek confluence for the background scenario and then furthermore in the impact scenario.

5.5.4.2.3 Other Water Quality Indicators

Salinity

- Median annual salinity concentrations in the Hawkesbury River for the dry and wet years predicted a minor reduction in salinity from the baseline scenario to the background scenario (<2 g/L) in the regions along the river due to more catchment freshwater inputs. A further reduction in salinity is predicted for the impact scenario, as improved salinity outcomes in the NWTH upgrades are accompanied by increased treated water release volumes.

TSS

No notable change in annual median TSS profiles predicted between the impact scenario and background scenario for either dry or wet years.

Oxygen

- A slight decrease in median annual dissolved oxygen in the impact scenario was predicted at the area around the region from South Creek confluence to downstream of Cattai Creek in both the dry and wet years when compared to the background scenario, coincident with the increased nitrogen concentrations in this region.

Enterococci

- Annual median concentrations of Enterococci for the dry year are shown in Figure 140, and predict that Enterococci concentrations will be slightly higher in the impact scenario than the background scenario in areas around South Creek and Cattai Creek confluences, though the differences are very small when compared to their concentration of up to 160 cfu/100mL in this region.
    - Additionally, the increases from the background scenario to the impact scenario are considerably lesser in magnitude than the increase in annual media concentrations from the baseline scenario to the background scenario, indicating that other sources in the catchments are the drivers of pathogen water quality outcomes rather than the NWTH plants.
    - This is largely due to the disinfection practices used by the NWTH plants.
- The annual median Enterococci concentrations in the wet year (Figure 141) are predicted to produce changes between the scenarios that are similar to that of the dry year, however,

the magnitude of Enterococci concentration is predicted to be nearly double that of the dry year.

- The highest wet year Enterococci median concentration reached > 300 cfu/100mL at South Creek, compared to ~160 cfu/100mL in the dry year.
- These magnitude increases are most likely in response to wet weather overflows within the catchment as well as other urban and rural inputs from catchment runoff.

- Similar to the dry year, the impact scenario predicted slight increases in the Enterococci concentration in the region around the South Creek and Cattai Creek confluences, however, the magnitude of change was considerably less than that of the background scenario changes from the baseline.
- The annual median concentrations of Enterococci are predicted to be above the NHMRC DGV for the entirety of the river reach between South Creek and Cattai Creek during the wet and dry years for all three scenarios.
  - This suggests that there is an existing recreational water use risk in the system that, while predicted to be slightly exacerbated by the proposed NWTH upgrades, has significant upstream contributions that cannot be appreciably offset by treatment at the NWTH plants.

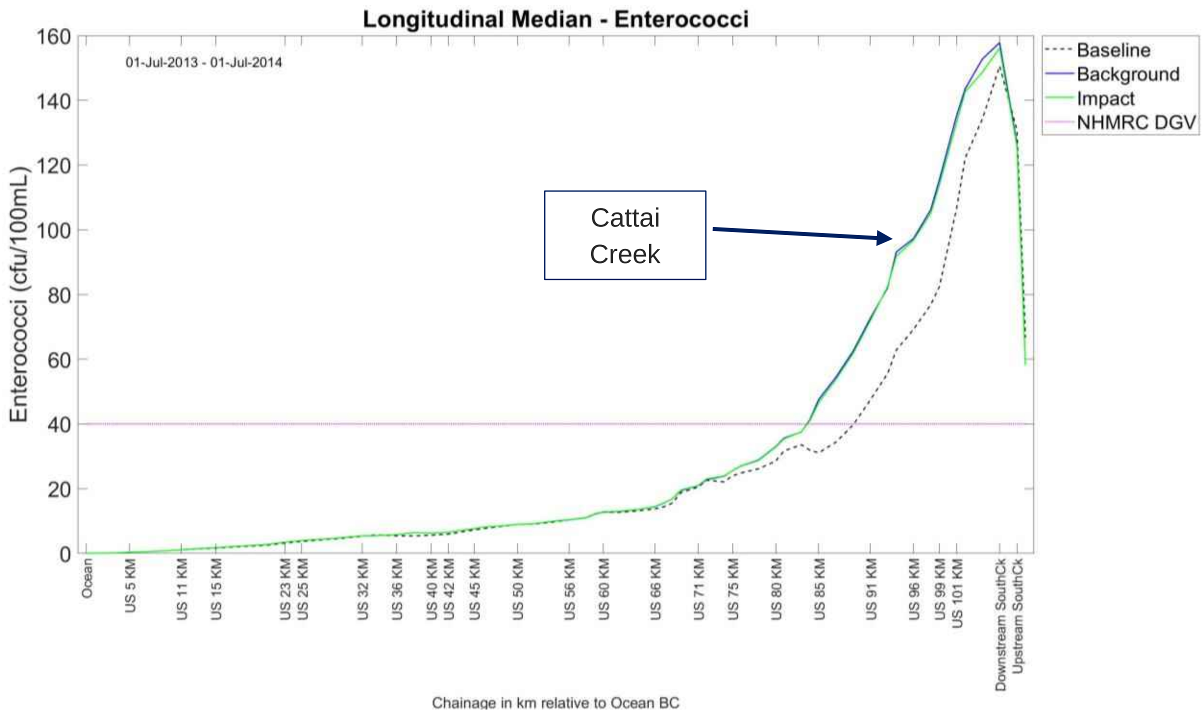

Figure 140 Longitudinal profile of predicted annual median dry year Enterococci concentrations for the Hawesbury River

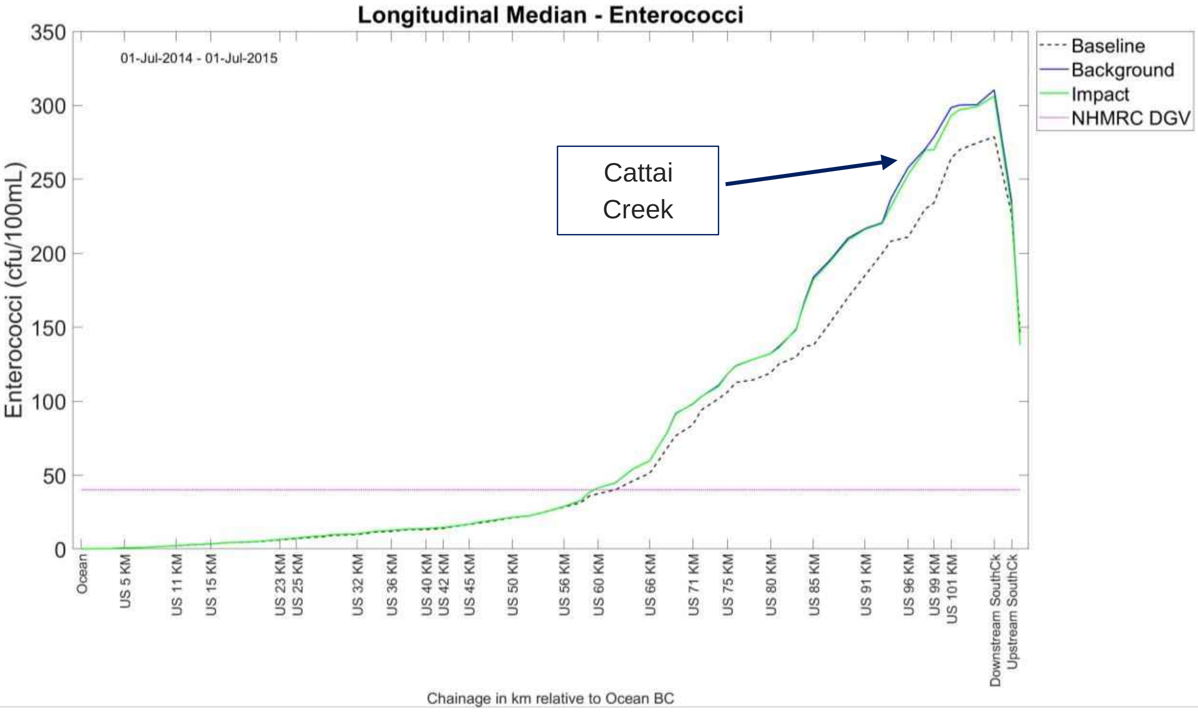

Figure 141 Longitudinal profile of predicted annual median wet year Enterococci concentrations for the Hawkesbury River

6 Conclusions

This report presents the findings of a hydrodynamic and water quality assessment undertaken in support of the REF for the NWTH upgrades. The upgrades include improvements to treatment processes to provide increased water quality in treated water releases as well as increases to treatment capacity.

The primary objective of this study is to provide a scientifically robust assessment of the hydrodynamic and water quality changes that may be realised because of the upgrades.

The study objective is achieved by answering the following key impact assessment questions regarding the proposed upgrades:

1. How do the hydrodynamics and water quality conditions change downstream of the release points, compared with baseline and background scenarios, due to the NWTH upgrades?
2. How do wet and dry climatic conditions affect the hydrodynamics and water quality of the receiving waterways?
3. How are nutrient loads in the receiving waterways altered by the upgrades?

These questions have been selected to evaluate the NWTH upgrades against the project objectives, which are to:

- enable compliance with future EPL requirements and maintain the health of local waterways;
- improve reliability, options for, and operability of the treatment processes;
- provide increased capacity to accommodate projected population growth; and
- minimise impacts to the surrounding environment and community.

The relative success of the upgrades in achieving these objectives was determined against default guideline values (DGV) and the Hawkesbury-Nepean nutrient management framework (EPA, 2019). The report therefore provides analyses pertaining to how the upgrades will potentially impact the hydrodynamics and water quality of the receiving waterways of Eastern Creek, South Creek, Second Ponds Creek, Cattai Creek and the Hawkesbury River.

Also key to the modelling has been the simulation of future conditions in the catchments and the river and creek systems. Background scenarios representative of future time horizons have taken account of changes in land use, population growth, etc. The modelling therefore allows for assessment of cumulative loads on the waterways as well as assessment of the impacts from the NWTH upgrades compared to expected future conditions.

Details regarding the residual impacts on the individual waterways, relative to expected future background conditions, are presented in the summaries below.

6.1 Cattai Creek and Second Ponds Creek

Based on the modelling undertaken, the predicted environmental impacts from the proposed WRP upgrades on Cattai Creek and Second Ponds Creek are generally positive to both water quality and/or ecosystem health.

This determination has been reached due to the reduction in nutrient loads from the NWTH upgrades to the Rouse Hill and Castle Hill WRPs. The Rouse Hill WRP is predicted to have reductions of more than 60% and 80% for TN and TP loads, respectively. This is despite a predicted 10% increase in TP loads from Castle Hill WRP, but is also supported by a predicted decrease of approximately 30% in TN loads from Castle Hill WRP.

The Castle Hill and Rouse Hill WRP loads are predicted to meet the prescribed 2024 - 2028 total load limits for Sackville subzone 3 (EPA, 2019) due to higher level of treatment provided at the Rouse Hill WRP. This predicted decrease in total nutrient loads is also despite the significant increases to EP (155%) for Rouse Hill in the upgrades to 2036.

In addition to the reduced nutrient loads identified above, the following conclusions regarding nutrient concentrations also support the characterisation of the upgrades as being generally positive:

- As a benefit of the reduced TN loads, median and peak TN concentrations for Cattai Creek and Second Ponds Creek are predicted to experience considerable reductions due to the NWTH upgrades.
    - For the impact scenario, when compared to the background scenario, Cattai Creek is predicted to experience reductions in median TN concentrations of up to 10 mg/L upstream of Caddies Creek (reducing from approximately 15 mg/L to 5 mg/L). Similarly, Second Ponds Creek reductions of 2 to 2.5 mg/L (reducing from approximately 7mg/L to 5mg/L) downstream of the Rouse Hill WRP for the same scenario comparison.
    - These reductions are predicted to be primarily as a result of reductions in NOx concentrations, however, the NOx concentrations modelled for the Rouse Hill WRP in the Cattai Creek WQRM were overly conservative and do not reflect the correct values at the time of this writing.
- When compared to the background scenario, Median annual Ammonia concentrations are predicted to increase from 0.1 mg/L to 0.2 mg/L for both Castle Hill WRP and Rouse Hill WRP in the impact scenario, and modest increases to median Ammonia concentrations can be observed for the lower reaches of Cattai Creek as a result.
    - It should be noted, however, that the Ammonia concentrations used in this modelling are conservative in nature and may be lower than assumed in this assessment.
    - Additionally, Ammonia concentrations within Second Ponds Creek are predicted to satisfy the ANZG DGV downstream of the Rouse Hill treated water release location to Caddies Creek.

- Median annual TP concentrations for Cattai Creek downstream of Castle Hill WRP are predicted to decrease by as much as 0.08 mg/L (decreasing from approximately 0.11 mg/L to 0.03 mg/L) in the impact scenario when compared to the background scenario.
- Median Annual TP concentrations for Second Ponds Creek downstream of Rouse Hill WRP are predicted to marginally increase by less than 0.005 mg/L (increasing from approximately 0.018 to 0.021 mg/L) in the impact scenario when compared to the background scenario.
    - This increase is largely attributable to the 155% increase in Rouse Hill's EP anticipated for the impact scenario.
- The median FRP concentrations have been predicted to bring Cattai Creek into compliance with the ANZG DGV for approximately half of the waterway's length in the wet year (and the entire length during the dry year), with the remaining reaches being predicted as only slightly above the DGV. Reductions in the impact scenario for median annual FRP concentrations are predicted to be approximately 0.05 mg/L (decreasing from 0.07 mg/L to 0.02 mg/L) when compared to the background scenario.
    - The predicted non-compliance during the wet year is largely attributable to catchment runoff sources contributing additional FRP in wet weather.
    - Additionally, wet year concentrations are less likely to contribute to algal growth and eutrophication due to increased flushing and reduced residence times in the waterways.
    - FRP is the bioavailable form of phosphorus and, therefore, of particular importance to waterway ecology and algal blooms.
    - Reductions in FRP are, therefore, excellent indicators of improved water quality.
    - Reductions in FRP concentration within Cattai Creek will also benefit the Hawkesbury River and will assist in mitigating algal bloom risks in the vicinity of Sackville Bend.
- Second Ponds Creek is predicted to have median annual FRP concentrations that are compliant with the DGV for the entirety of the assessed waterway. Changes to median annual FRP concentrations within Second Ponds Creek are predicted to be negligible.
    - This is achieved despite the 18% increase in FRP concentration for the Rouse Hill releases as part of the NWTH upgrades.

In addition to the predicted impacts of nutrient conditions in the waterways, the following conclusions were reached:

- The hydrodynamic conditions for Second Ponds Creek and Cattai Creek are predicted to experience limited change due to the proposed upgrades to the Rouse Hill and Castle Hill WRPs, with daily average water levels increasing by 2 to 3 cm for both waterways in the dry year.

- The impact scenario generally predicted large decreases in nitrogen and phosphorus concentrations, as well as in concentrations of pathogens and chlorophyll-*a* biomass.
- Median annual Enterococci concentrations for Cattai Creek are predicted to be reduced by as much as 100 cfu/100mL (reducing from approximately 160 cfu/100mL to 60 cfu/100mL in the representative dry year and from approximately 440 cfu/100mL to 300 cfu/100mL in the wet year) in the impact scenario when compared to the background scenario.
    - Despite the improvement in water quality in the impact scenario compared to the background scenario, the predicted annual median profiles of TN and TP levels and Enterococci concentrations remain close to or exceeding the compliance DGVs established in Section 2.2.
    - This suggests that the water quality DGVs being met for the system is dependent on the overall catchment loads being addressed.
- Differences of other key water quality variables, including TSS and dissolved oxygen, between the impact scenario and background scenario varied across different sites in the creeks, but the differences are generally small when compared to their inter-annual variations.

The conclusions provided above suggest that the NWTH upgrades for the Castle Hill and Rouse Hill WRPs will be viable in achieving the project objectives for waterway health and impact minimisation for the local environment and community while also providing increased capacity and improved treatment processes.

6.2 Eastern Creek and South Creek

Based on the model results, the NWTH upgrades at Riverstone WWTP are considered to have primarily positive impacts on the Eastern Creek and South Creek reaches downstream of the treated water release location. It is generally considered that the totality of changes to the Eastern Creek treated water releases at the Riverstone WWTP as part of the NWTH upgrade will lead to improvements in water quality concentrations and reduced loading of key nutrients, such as nitrogen, producing better outcomes and reduced instances of algal blooms.

The following conclusions are provided to support this determination:

- The Riverstone WWTP has been predicted to increase its EP from approximately 60,000 EP to approximately 225,000 EP by 2036. Despite this, Riverstone is predicted to meet the 2024 - 2028 load limits for both TN and TP with the NWTH upgrades.
- In addition to meeting TN and TP load targets, median annual TN concentrations in the impact scenario are predicted to experience a minor increase within Eastern Creek and South Creek downstream of the Riverstone WWTP when compared to the background scenario. This increase is predicted to be approximately 0.4 mg/L (increasing from approximately 1.6 mg/L to 2 mg/L).

    - This is particularly true for the representative dry year as the increased flushing of catchment flows is not present and residence time in the waterway is increased in dry conditions.
- Median NOx concentrations under the impact scenario show a relatively small increase of approximately 0.4 mg/L (increasing from approximately 0.6 mg/L to 1.0 mg/L immediately downstream of the Riverstone WWTP) in concentration from the background scenario. The impact scenario is also predicted to have a modest decrease in median annual NOx concentrations of approximately 0.2 mg/L (decreasing from 1.2 to 1.0 mg/L immediately downstream of the Riverstone WWTP) when compared to the baseline scenario for both Eastern Creek and South Creek.
- The median annual concentrations of Ammonia have predicted increases in median concentration of as much as 0.07 mg/L (increasing from approximately 0.08 mg/L to 0.15 mg/L immediately downstream of the Riverstone WWTP) for Eastern Creek and South Creek in the impact scenario compared to the background
    - When compared to the baseline scenario, the impact scenario is predicted to have an increased concentration for South Creek, however, only a very modest increase in concentration is expected for Eastern Creek and this increase is considered to be within the margin of error.
- Peak NOx and Ammonia immediately downstream of the Riverstone WWTP are predicted to increase by approximately 0.5 mg/L (from 1 to 1.5 mg/L and 0.1 to 0.6 mg/L, respectively) due to the upgrades when compared to the background scenario.
    - Despite this, the predicted increases in nutrient concentrations are still relative decreases when compared to the baseline conditions and are not in the range of toxicity concentrations as outlined in Section 2.2.
- Median annual TP concentrations in the impact scenario are predicted to be marginally decreased when compared to the background scenario.
    - This is particularly true in the wet year, which has greater annual median TP concentrations than the dry, suggesting that a principal component of the TP is sourced from catchment runoff.
    - The impact scenario predicts a decrease in median annual TP concentration of approximately 0.01 mg/L (decreasing from approximately 0.06 mg/L to 0.05 mg/L) for both Eastern Creek and South Creek downstream of the Riverstone WWTP for the wet year when compared to the background scenario.
- Median annual FRP concentrations in the impact scenario are predicted to marginally increase by approximately < 0.01 mg/L (increasing from approximately 0.023 mg/L to 0.03 mg/L) when compared to the background scenario.
- Due to the tidal influences in the reaches of Eastern Creek and South Creek downstream of where the Riverstone WWTP currently discharges, the anticipated hydrodynamic impacts to the waterways are dampened, resulting in minimal change to peak elevation (< 5 cm) or velocity between baseline, background and impact scenarios.

- Pathogen concentrations in the tidal reach of Eastern Creek have been shown to be modestly improved under the upgraded operations proposed for the Riverstone WWTP.
- Comparatively, the relative increase in concentrations in Eastern Creek, while potentially non-compliant during dry years, represents a significant improvement, holistically, on the water quality of Eastern Creek's tidal reach.
- TN and TP loads to the waterway are not predicted to increase in a manner that would suggest increased eutrophication of Eastern Creek or South Creek. This is despite a 270% increase in EP for the Riverstone WWTP as part of the NWTH plant upgrades, indicating that the NWTH upgrades represent a significant pathway towards improved water quality in the receiving waterways.
- Enterococci concentrations for background and impact scenarios were found to sufficiently meet criteria that pathogen concerns are not considered to be present for Eastern Creek. This is due to the 100% disinfection rate used at Riverstone.

Modelling of the South Creek tidal reach has demonstrated that the proposed upgrades to the Riverstone WWTP will have minor increases to median Ammonia concentrations while simultaneously providing clear improvements to TN, NOx, TP, TRP, Chlorophyll-*a*, TSS, and Enterococci concentrations for both the representative wet and dry years. The toxicity risk of these increased Ammonia concentrations in the tidal reach are sufficiently minor that they are offset by the improvements to the other water quality parameters modelled in this assessment.

Based on the conclusions above, the NWTH upgrades at the Riverstone WWTP are considered to be viable in achieving the project objectives for waterway health and impact minimisation for the local environment and community while also providing increased capacity and improved treatment processes.

6.3 Hawkesbury River

As with the Cattai Creek and South Creek domains, the NWTH upgrades in the South Creek and Cattai Creek catchments together are predicted to provide positive outcomes for the Hawkesbury River. This determination has been made in light of the large increases to treated water releases in the upgrades and the proportionate increase or decrease to water quality that accompanies them.

The following conclusions support this:

- The upgrades are predicted to produce slightly increased concentrations of TN and dissolved forms of nitrogen in the impact scenario when compared to the background scenario for the Hawkesbury River.
    - Despite this, the increases to NOx concentrations represent decreases of up to 0.05 mg/L when compared to the baseline scenario (decreasing from approximately 0.5 mg/L to 0.45 mg/L), suggesting that the Quakers Hill WWTP is a greater contributor to nutrient concentrations and loads in the Hawkesbury than the Riverstone WWTP.

    - When compared to the background scenario, Ammonia concentrations in the impact scenario are predicted to experience an increase of approximately 0.002 mg/L (increasing from approximately 0.016 mg/L to 0.018 mg/L) immediately downstream of South Creek in the representative dry year before being diluted and matching background conditions downstream.
- The impact on the phosphorus, chlorophyll-*a*, and TSS concentrations are predicted to be negligible decreases in the reaches downstream of South Creek and Cattai Creek and did not affect the compliance to the ANZG guidelines.
    - Despite their negligible magnitude, decreases in FRP for the Hawkesbury River are significant benefits in considering the issue of algal blooms in the Sackville Bend.
- The environmental impacts due to changes of the NWTH upgrades are therefore considered to have negligible effects on the water quality and/or ecosystem health at the Hawkesbury River. During wet weather some poor-quality nutrient spikes have a local effect but are quickly offset by beneficial dilution effects between the spike events.

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8 Appendices

Available on request

For more info email multimedia@sydneywater.com.au