Greater Parramatta and Olympic Peninsula Water Cycle Management

Hydrodynamics and Water Quality Impact Assessment

Sydney WATER

sydneywater.com.au

December 2025

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Sydney Water respectfully acknowledges the Traditional Custodians of the land and waters on which we work, live and learn. We pay respect to Elders past and present.

Sydney Water recognises the physical and cultural connection of local Aboriginal communities to waters and the land.

Executive summary

Background

Sydney Water is proposing to build and operate a new water resource recovery facility (WRRF) at Camellia-Rosehill. The new WRRF is required to provide additional wastewater capacity to support growth in the Greater Parramatta and Olympic Peninsula (GPOP) corridor, as well as more broadly across other growth areas in Greater Sydney.

The project is State Significant Infrastructure and Sydney Water is preparing an Environmental Impact Statement (EIS) to support an application to the Minister for Planning and Public Spaces.

The EIS is seeking approval for a WRRF operational capacity of 70 megalitres per day (ML/d). The WRRF has been designed to allow flexibility for future expansion for greater treatment capacities up to about 150 ML/d. The WRRF would incorporate reverse osmosis (RO) treatment to produce advanced treated water to minimise impacts on Parramatta River.

The primary objective of this report is to provide a scientifically robust assessment of the hydrodynamic and water quality impacts from the operation of the WRRF, with a capacity of 70 ML/d. This report has been prepared to support the EIS for the project and addresses the Secretary's Environmental Assessment Requirements (SEARs) relevant to hydrodynamics and water quality in the receiving waters of the Parramatta River.

This project builds on an existing pipeline of investment contributed by Sydney Water to improve the waterway health and recreational outcomes of the Parramatta River. As long-standing members of the Parramatta River Catchment Group, Sydney Water has collaborated to deliver on the mission of making the river swimmable again. Sydney Water's recent Our Water, Our Voice stakeholder engagement program also identified that maintaining clean and healthy waterways and water recreation areas is the third highest priority for customers, right after providing safe drinking water and affordable bills.

Assessment methodology

The proposed WRRF will release treated water to the Parramatta River at Meadowbank. Project specific waterway objectives have been developed which include numerical criteria sourced from existing guidelines and policies. Predicted impacts from the operation of the WRRF were assessed against these waterway objectives using numerical outputs from a new Water Quality Response Model (WQRM). The WQRM simulates the hydrodynamics and an extensive suite of water quality processes within the receiving waters of the river.

The GPOP WQRM was developed for the Parramatta River and its major tributaries using a number of software applications, including MIKE 3 Flow Model Flexible Mesh, MIKE Mud Transport, and MIKE Ecolab modules. The WQRM was interfaced with other modelling tools to allow representation of catchment runoff, sewer overflows and the releases from the WRRF. The WQRM was calibrated and validated against an extensive record of hydrodynamic and water quality monitoring data collected at various locations, frequencies and durations in the estuary and across Sydney Harbour. The WQRM was verified to perform well across the selected calibration and validation periods and also across the range of parameters that

have been assessed, including salinity, nutrients, total suspended solids, dissolved oxygen, chlorophyll *a,* and enterococci. Following calibration, the WQRM informed the development of CORMIX models which were used to assess near field impacts, such as toxicity, in the immediate vicinity of the proposed release points.

The WQRM and CORMIX models have been developed in line with industry standards and are considered fit for purpose in the application of assessing predicted impacts of the Camellia-Rosehill WRRF. In line with all similar studies, the modelling should however be considered as a representative approximation to the real world and not without accepted levels of uncertainty. It should therefore be understood that each model is based on a series of assumptions, and also 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.

A suite of scenarios was developed to allow simulation of a range of conditions that could be expected during the operation of the WRRF. This included expected releases of treated water from the WRRF as well as expected changes in other catchment conditions such as overflows, population growth and impacts of climate change.

The following scenarios were run over an extensive simulation period incorporating representative dry, average, and wet rainfall years so as to address the question of how different climatic conditions affect impacts from operation of the WRRF:

- **Baseline scenario (Sc1)**: represents current (circa 2024/25) conditions.
- **Background scenarios (Sc2 and Sc2cc):** simulate catchment and waterway conditions expected in future years (circa 2056) without the inclusion of the treated water releases from the WRRF. Sc2 represents the background conditions without climate change, whilst Sc2cc also incorporates climate change using Representative Concentration Pathway 4.5 (RCP 4.5).
- **Impact scenarios (Sc3 and Sc3cc):** represent the potential catchment and waterway conditions in future years (2056) with the inclusion of the Camellia-Rosehill WRRF. Sc3 simulates the impacts under current climate conditions, whilst Sc3cc incorporates climate change with application of RCP 4.5 assumptions.

With respect to the operation of the WRRF, the following details are noted:

- At an average dry weather flow (ADWF) of 70 ML/d, the following conditions were modelled:
  - Release of 63 ML/d of advanced treated (RO quality) water to the river from a submerged multiport diffuser in the vicinity of John Whitton Bridge near Meadowbank
  - Episodic release of 70 ML/d of tertiary treated (membrane bioreactor (MBR) quality) water to the river to represent infrequent events when the RO treatment process may go offline
  - Modifications to sewer overflows within the North Head network.

Key assumptions regarding the modelling of the WRRF's operation also included:

- The impact scenarios assume the WRRF is operating at full capacity, i.e. 70 ML/d in 2056. Prior to reaching these operating levels, the extent of the impacts on the receiving waters, and whether they are beneficial or detrimental, are likely to be proportionally reduced.
- Similarly, the scenarios assume no allowance for beneficial reuse. Therefore, the full volume of treated water generated by the WRRF is released to the river and no percentage is supplied for recycling purposes.

Impact assessment

The model results indicate the impacts on water quality in the estuary to be predominantly positive. Predicted improvements generally consisted of lower concentrations of nutrients, chlorophyll *a* and pathogens, as well as minor elevations in concentrations of dissolved oxygen. These improvements in ambient water quality in turn demonstrated the potential for improved protection of relevant waterway objectives, as well as a potential reduction in the risk of algal blooms.

Potential risks for short-term deterioration of water quality were predicted subsequent to the offline events when releases of higher nutrient content water (tertiary treated) occurred. While the modelling adopted a worst-case scenario in relation to the timing of these events (i.e. consecutive releases during periods of low rainfall and limited estuarine flushing), the effects of these infrequent short-term releases are expected to be assimilated relatively rapidly within the river.

Due to the freshwater nature of the treated water, salinities in the river are predicted to reduce in the vicinity of the releases and also across a more extended region of the river and harbour. More specifically, reductions in annual medians of up to 3 Practical Salinity Units (PSU) were predicted in nearby river reaches, while instantaneous/short-term impacts generally were estimated to be between 5 and 6 PSU. The magnitude of these reductions decreased with distance, with reductions of approximately 0.5 PSU predicted between 6 to 10 km downstream of the release point. These changes in salinity were predicted for both variations of the impact scenarios but with slightly higher reductions predicted under the non-climate change scenario.

In addition to the estuary wide assessment relating to hydrodynamics and water quality, impacts from the operation of the WRRF were also evaluated with respect to nominated sites that represent specific environmental sensitivities. These included aquatic ecology, recreational swimming sites and also locations referenced in the SEARs. From these assessments, the impacts from the operation of the WRRF were found to be consistent with the findings of the broader hydrodynamic and water quality assessment.

As a high-level summary, Figures E1 to E4 present an overview of the predicted impacts on key water quality parameters from the operation of the WRRF. The figures summarise the modelling results for key parameters simulated by the GPOP WQRM under representative average rainfall year conditions, and at several locations in the upper estuary, both upstream and downstream of the proposed releases. Maps have been prepared for the aquatic ecology site, SEARS reference sites and river centreline locations, both with and without climate change (Figures E1 and E2) and for the swim sites, both with and without climate change (Figure E3 and E4).

The colour coded matrices within the maps provide an indication of predicted protection of waterway objectives, where relevant, based on the annual median model results for the baseline, background and impact scenarios. Cells shaded in green indicate that waterway objectives are predicted to be achieved based on the annual median concentration at this location. Cells shaded in pale pink indicate that the annual median concentration is predicted to exceed the waterway objectives. For the background and impact scenarios, a trend is also shown as up or down, or unchanged relative to baseline and background scenarios respectively. In this analysis, a trend was defined as a change in annual medians of greater than five percent.

As noted previously, these results should not be interpreted as absolute values that can be achieved and do not guarantee that waterway objectives will or will not be achieved, but rather provide an indication of improved protection of relevant waterway objectives as a result of the releases, and also as a result of cumulative impacts from the surrounding catchment.

In relation to the analysis of recreational swimming sites in the river (Figure E3 and E4), the results indicate that the operation of the WRRF presents a potentially beneficial effect regarding pathogenic levels in the river with spikes in wet weather concentrations generally predicted to reduce at each site analysed across all the rainfall years simulated.

Near field impact assessments were also undertaken with respect to the potential for toxicity and environmental harm in the immediate vicinity of the river releases. Modelling and analysis determined the risk from toxicants in the release water to be low, and no regulatory mixing zones are proposed.

Monitoring and mitigation measures

A comprehensive monitoring program is proposed for the post-commissioning operational phase of the WRRF to monitor treated water quality and potential impacts on the ambient water quality of the Parramatta River. Additional recommendations are also provided in relation to ongoing reviews of the monitoring program and the datasets generated by the program.

With respect to mitigation, potential water quality impacts to the Parramatta River are primarily addressed through the implementation of the project specific treatment and release strategy. This strategy incorporates advanced treatment processes at the WRRF and a diffuser to generate initial mixing and dilution of the treated water releases.

Further improvements in water quality within the river are also anticipated due to the operation of the WRRF providing additional mitigation of sewer overflows across the catchments of the upper estuary.

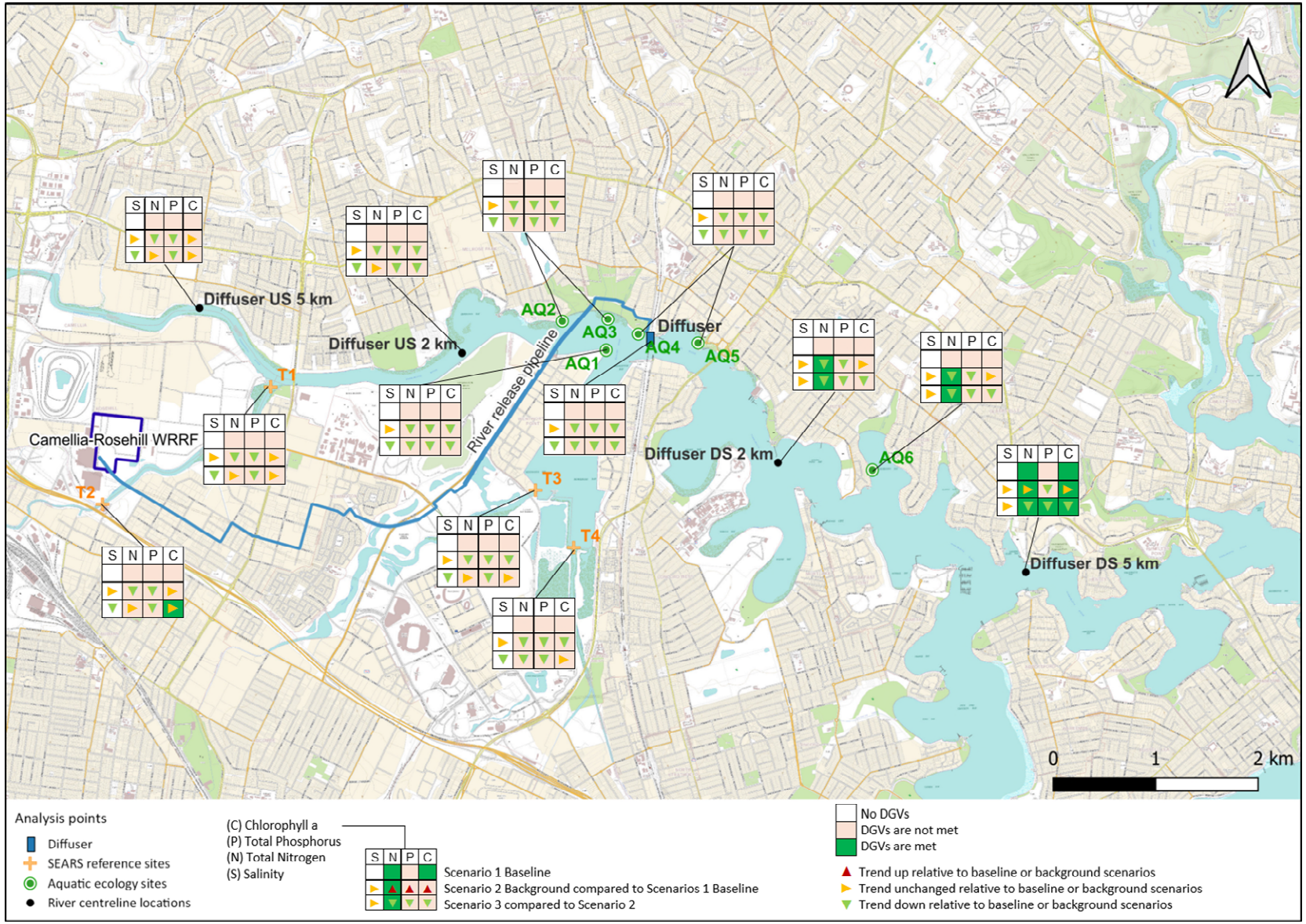

Figure E1 Summary of predicted water quality impacts for operation of the WRRF - average rainfall year without climate change

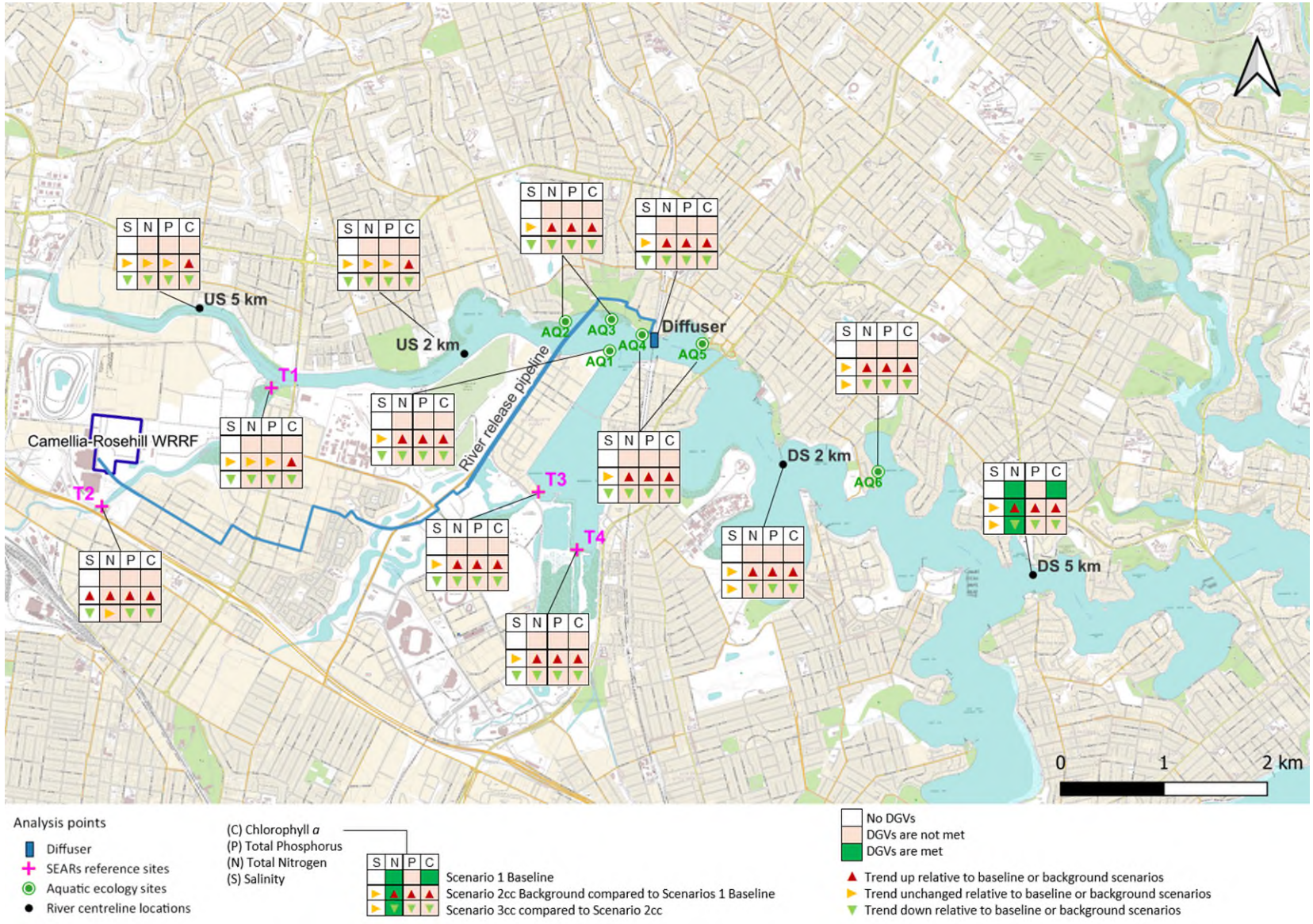

Figure E2 Summary of predicted water quality impacts for operation of the WRRF - average rainfall year with climate change

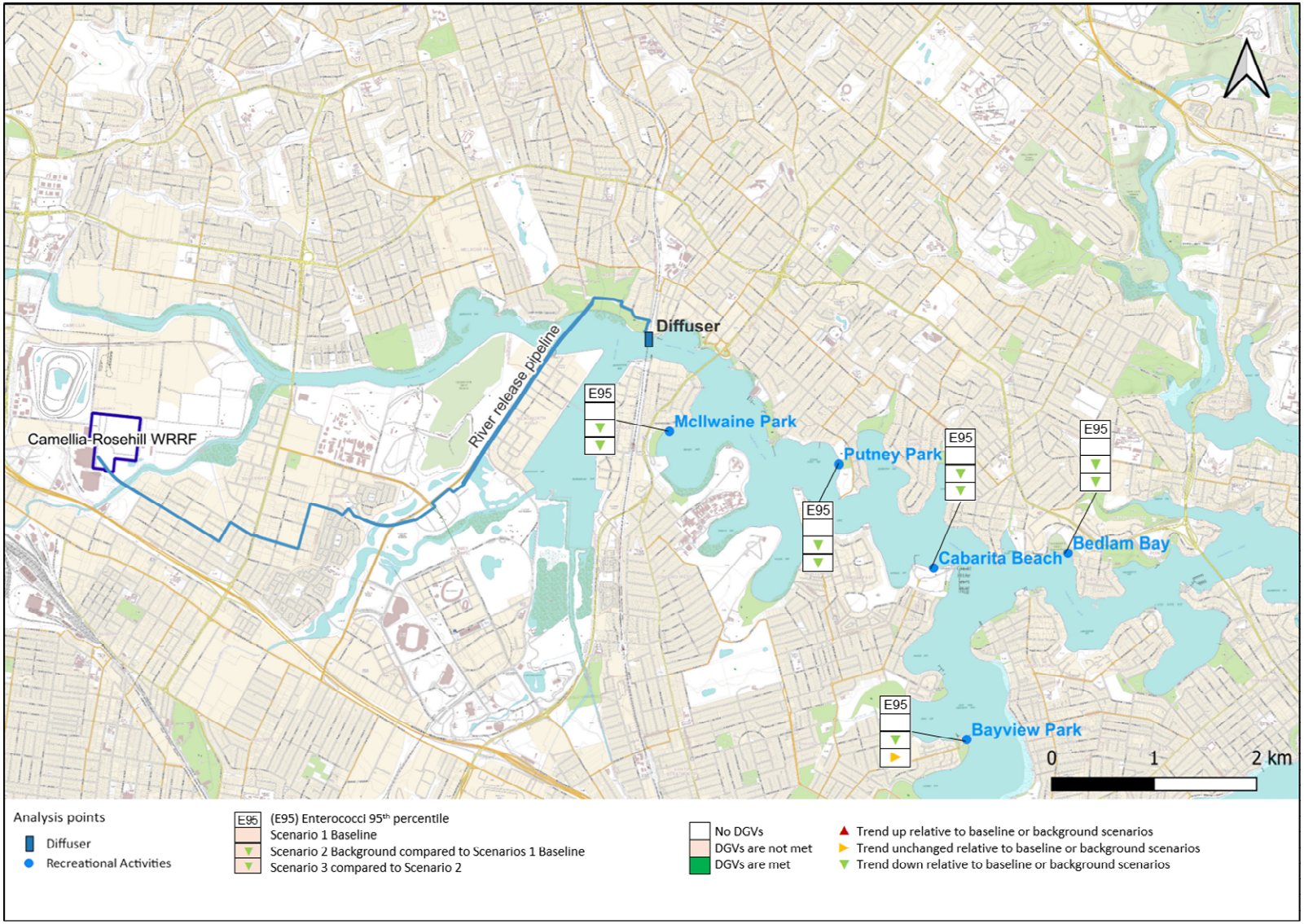

Figure E3 Summary of predicted water quality impacts for operation of the WRRF at swim / recreational sites - average rainfall year without climate change

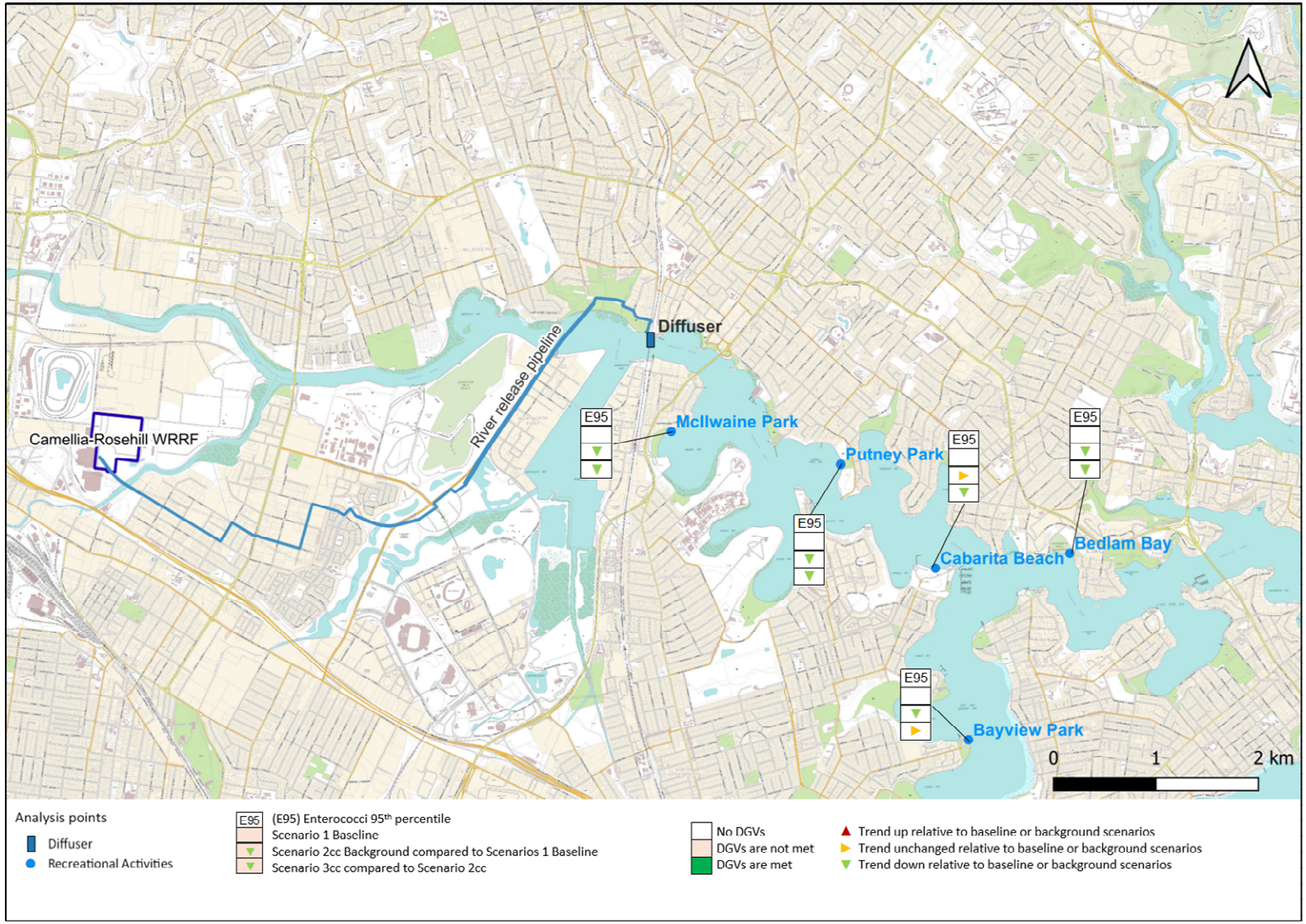

Figure E4 Summary of predicted water quality impacts for operation of the WRRF at swim / recreational sites - average rainfall year with climate change

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Change history

Version	Status	Issue Date	Endorsed by	Approved by	Brief description of change and consultation
1	Draft	31/07/2025	JB	BS	Draft for internal Sydney Water review
2	Final	12/12/2025	VK	BS	Final

Glossary and abbreviations

Term	Abbreviation	Definition
Australian Height Datum	AHD	The official national vertical datum for Australia, established in 1971. It serves as a reference for measuring elevation.
Advanced treated water	-	Wastewater treatment process which involves using reverse osmosis membrane technology to produce highly treated recycled water.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)	ANZG	Guidelines (2018 online version) to provide a framework and supporting guidance for the management, assessment and monitoring of water quality for natural and semi-natural water resources in Australia and New Zealand.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)	ANZECC/ARMCA NZ	Guidelines (2000 version) to provide a framework and supporting guidance for the management, assessment and monitoring of water quality for natural and semi-natural water resources in Australia and New Zealand.
Average Dry Weather Flow	ADWF	Average Dry Weather Flow consists of average daily wastewater flows. ADWF is the average flow that occurs on a daily basis with no evident reaction to rainfall.
Advanced Water Treatment Plant	AWTP	A wastewater treatment plant that uses membrane technology to produce highly treated advanced tertiary water.
Average year	-	A representative average climatic year. Selected as 2016/17 in this study.
Background scenario	-	Represents catchment and waterway conditions expected in future years.
Baseline scenario	-	Represents current (circa 2024/25) waterway and catchment conditions including land use, wet weather overflows, etc.
Brine	-	Brine is a by-product of the reverse osmosis technology applied in the WRRF treatment process.
Brine pipeline	-	A pipeline to transport brine from the WRRF to the NSOOS for treatment and offshore discharge at North Head WRRF.
Business as Usual	BaU	The execution of standard functional operations. Also indicative of no change of approach in terms of future management or policy.
Climate change	cc	Climate change
Colony-forming unit	cfu	Unit used in microbiology to estimate the number of viable bacteria or fungal cells in a sample.

Term	Abbreviation	Definition
Courant–Friedrichs–Lewy	CFL	A condition in numerical equation solving which states that a time step larger than a computable quantity should not be taken.
CORMIX	-	Numerical software for the analysis of near field mixing of wastewater in watercourses.
Default guideline values	DGV	Default water quality guideline values in line with the ANZG (2018) guidelines. Previously referred to as trigger values in the ANZECC (2000) guidelines.
Department of Environment and Climate Change	DECC	Former department in the NSW government with responsibility for protecting and caring for the environment and developing and coordinating programs to address the impacts of climate change.
Department of Climate Change, Energy, the Environment and Water	DCCEEW	DCCEEW is a NSW government department responsible for protecting the state's environment and heritage.
Department of Planning, Housing and Infrastructure	DPHI	DPHI is a NSW government department responsible for effective and sustainable planning, and the development of industry to support growth in NSW.
Dissolved Oxygen	DO	The oxygen level present in water, expressed as either percentage saturation, or as a concentration.
Dry year	-	A representative dry climatic year. Selected as 2017/18 in this study.
Effluent Knowledge and Management System	EKAMS	Sydney Water web-based system for accessing operational data and licencing reports.
Environment Protection Authority	EPA	The EPA is the primary environmental regulator for NSW with a mandate to reduce pollution and waste, protect human health, and prevent degradation of the environment.
Environment Protection Licence	EPL	Licences to the owners or operators of various industrial premises under the *Protection of the Environment Operations Act 1997.* Licence conditions relate to pollution prevention and monitoring, and cleaner production through recycling, reuse and implementation of best practice.
Environmental Impact Statement	EIS	An Environmental Impact Statement is a publicly available document that provides information on a project, including its environmental impacts and mitigation measures.
Environmental values	EVs	ANZG (2018) defines a community/environmental value as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors.

Term	Abbreviation	Definition
		In the ANZG (2018) guidelines, the following values are recognised: aquatic ecosystems, cultural and spiritual values, drinking water, industrial water, primary industries, recreational water and aesthetics.
Flexible mesh	FM	Flexible mesh
Filterable reactive phosphorus	FRP	Filterable reactive phosphorus
Global Climate Model	GCM	GCMs are sophisticated numerical models that simulate the interactions between the atmosphere, oceans, land surface, and ice.
Geographical Information System	GIS	A framework for gathering, managing, and analysing spatial data.
Grams per litre	g/L	Unit for measuring a concentration as a quantity in a volume of liquid.
Greater Parramatta and Olympic Peninsula	GPOP	Refers to the area within the Greater Parramatta and Olympic Peninsula.
Impact scenario	-	Represents catchment and waterway conditions expected in future years including the releases of treated water from the WRRF.
Improved water quality	-	Improved water quality is classified as changes in ambient conditions that support the protection or enhancement of applicable environmental values and waterway objectives. In the context of this assessment, this may relate to maintenance/achievement of one or more of the following effects: • Lower ambient concentrations of nutrients. • Lower ambient concentrations of pathogens. • Increased ambient levels of dissolved oxygen. • Lower potential risk of algal blooms and cyanobacteria. • Increased compliance with relevant waterway objectives.
Insignificant/Negligible/minor impacts		Impacts are classified as being recognisable as short term, or temporary, or of limited magnitude in nature and only predicted at a local scale
Kilograms	kg	Unit for measuring weight.
Kilometre	km	Unit for measuring length.
Kilometre squared	km^2	Unit for measuring area.

Term	Abbreviation	Definition
Local Government Area	LGA	Local Government Area.
Lower estuary		For the purposes of the hydrodynamic and water quality assessment, the lower estuary extends from the route of the Mortlake Ferry downstream to the estuary's junction with Sydney Harbour, as marked by a line between Clarkes Point, Woolwich and Yurulbin Point, Birchgrove.
MATLAB	-	Software program used for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly.
Membrane bioreactor	MBR	Advanced wastewater treatment technologies that combine biological treatment with membrane filtration.
Megalitres	ML	Unit for measuring volume.
Megalitres per day	ML/d	Unit for measuring volumetric rate of flow.
Micro Siemens per centimetre	µS/cm	Unit for measurement of electrical conductivity.
Milligrams per litre	mg/L	Unit for measuring a concentration as a quantity in a volume of liquid.
Millimetres	mm	Unit for measuring length.
Model for Urban Sewers	MOUSE	Numerical modelling software that models collection system for urban wastewater and stormwater.
Most probable number	MPN	Unit for measuring faecal coliforms and enterococci.
Mud transport	MT	Mud transport.
The Model for Urban Stormwater Improvement Conceptualisation	MUSIC	A software tool that simulates the behaviour of stormwater in urban catchments and helps to understand the performance of stormwater quality treatment systems.
The NSW and Australian Regional Climate Modelling	NARCliM	The NARCliM project brings together trusted science and broad expertise to deliver world-recognised regional climate projections for NSW and its regions.
National Association of Testing Authorities	NATA	The NATA is Australia's leading accreditation body. It provides accreditation services to organisations involved in testing, inspection, and calibration, ensuring they comply with relevant national and international standards.
National Water Quality Management Strategy	NWQMS	Australian wide strategy for water quality management and the provision of information and tools to help water resource managers, planning and management agencies,

Term	Abbreviation	Definition
		regulatory agencies and community groups manage and protect water resources.
Negligible/minor impacts	-	In the context of this assessment, these impacts are classified as being recognisable as short-term, or temporary, or of limited magnitude in nature and only predicted at a local scale.
Nephelometric Turbidity Unit	NTU	Unit for measuring turbidity.
Nitrogen oxides	NOx	Refers to nitrogen oxides, primarily nitric oxide and nitrogen dioxide.
Northern Suburbs Ocean Outfall Sewer	NSOOS	The NSOOS is a critical sewer built between 1916 and 1933, servicing areas from Blacktown through Parramatta, Lane Cove, North Sydney to North Head. The North Head WRRF provides primary treatment of flows from the NSOOS, with the treated flows discharged into the ocean 3.6 km offshore at seabed level, via the deep-water ocean outfall.
Office of Environment and Heritage	OEH	The NSW OEH is a former division of the Government of New South Wales between April 2011 and July 2019. The NSW OEH was responsible for the care and protection of the environment and heritage, which includes the natural environment, Aboriginal country, culture and heritage, and built heritage in New South Wales.
Protection of the Environment Operations Act 1997	POEO Act	The POEO Act 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.
Potential Evapotranspiration	PET	Evaporation from an extended surface of a short green crop that fully shades the ground, has negligible resistance to water flow, and is consistently well supplied with water.
Potential of hydrogen	pH	A logarithmic scale used to specify the acidity or basicity of aqueous solutions.
Project	-	The construction and operation of the Camellia-Rosehill WRRF, pipelines and all ancillary infrastructure.
Practical Salinity Units	PSU	A unit of measurement for salinity which indicates the total amount of dissolved salts in water.
Representative Concentration Pathway	RCP	RCPs are prescribed pathways for greenhouse gas and aerosol concentrations, together with land use change, that are consistent with a set of broad climate outcome used by the climate modelling community.
Regional Climate Model	RGM	A RCM is a sophisticated tool used to simulate climate conditions at a specific geographic area, allowing for

Term	Abbreviation	Definition
		higher resolution and accuracy compared to global climate models.
Reverse Osmosis	RO	A wastewater treatment technology where a solution is forced under pressure through a semi-permeable membrane separating pure water from dissolved salts.
Secretary's Environmental Assessment Requirements	SEARs	These are issued by the Secretary of the NSW DPHI for projects declared by the Minister of Planning as State Significant Infrastructure. These SEARs provide the technical requirements for the impact assessment.
State Environmental Planning Policy	SEPP	SEPPs are regulations that govern land use and development across a state, ensuring that environmental considerations are integrated into planning decisions.
Sydney Institute of Marine Science	SIMS	Research institute focused on marine science in Sydney.
Source	-	Numerical modelling software for the analysis of catchment processes including water quantity, quality and environmental management.
State Significant Infrastructure	SSI	State Significant Infrastructure (SSI) refers to major infrastructure projects that are considered to have state-level importance due to their scale, economic value, or potential environmental and social impacts.
Sewage Treatment System	STS	Sewage treatment system
Sydney Water Aquatic Monitoring	SWAM	The Sydney Water Aquatic Monitoring program began in July 2023. The program helps to identify long-term trends in water quality and waterway health, monitor performance and understand how wastewater interacts with the environment.
Tertiary treated	-	Wastewater treatment process which consists of three stages to treat wastewater prior to reuse applications or release to the environment. The stages commonly include filtration, biological and chemical processes as well as disinfection.
Total Nitrogen	TN	Total nitrogen
Total Organic Carbon	TOC	Total organic carbon
Total Phosphorus	TP	Total phosphorus
Total Suspended Solids	TSS	Total suspended solids

Term	Abbreviation	Definition
Toxicant	-	A chemical or physical agent that can cause adverse effects in aquatic organisms when present in the environment at sufficient concentrations.
Upper estuary		For the purposes of the hydrodynamic and water quality assessment, the upper estuary extends from Charles Street Weir to the route of the Mortlake Ferry.
Urban Growth Intelligence	UGI	Sydney Water produces growth forecast data based on intelligence received from the development industry. This is mapped spatially and stored in a centralised MapInfo 'UGI' layer.
Water Resource Recovery Facility	WRRF	A facility in which a series of treatment processes (e.g. physical, chemical and biological) are used to treat wastewater and convert it into a form that can be recycled or returned to the environment.
Wastewater	-	The used water from baths, showers and washing machines ('greywater') and toilets ('blackwater') and enters into the wastewater reticulation system.
Waterway objectives	-	The waterway objectives are specific to this project but draw heavily on the NSW Water Quality and River Flow Objectives of the Sydney Harbour and Parramatta River (DCCEEW, 2006). The numerical criteria are sourced from DCCEEW (2006) and existing guidelines relating to relevant waterway values such as aquatic ecosystems, visual amenity, primary and secondary recreation and aquatic foods.
Water Quality Objectives	WQO	Water Quality Objectives are parameter-based goals for water quality management. They effectively define what the water quality should be to protect the environmental values for a waterway.
Water Quality Response Model	WQRM	Combination of numerical models used to simulate hydrodynamic and water quality responses in receiving waterways.
Wet weather overflows	-	During heavy rainfall the wastewater system can be impacted due to inflow and infiltration into the wastewater collection system. The system can become overloaded and wastewater can 'overflow' from pipes and other wastewater network structures.
Wet year	-	A representative wet climatic year. Selected as 2021/22 in this study.
Year	yr	Year

1. Introduction

1.1 Project overview

Sydney Water is proposing to build and operate a new water resource recovery facility (WRRF) at Camellia-Rosehill. The new WRRF is required to provide needed additional wastewater capacity to support growth across the northern suburbs of Sydney, and in the Greater Parramatta and Olympic Peninsula (GPOP) growth corridor. The WRRF and associated infrastructure together form the GPOP Water Cycle Management project (the project).

The additional growth would place pressure on the existing northern suburbs wastewater network, which includes the Northern Suburbs Ocean Outfall Sewer (NSOOS) and the North Head WRRF. These critical assets provide wastewater services to around 1.7 million people, and with current growth projections would reach capacity by 2031.

The project has been designed to be efficient, sustainable, and cost effective for the community, as well as resilient and adaptable for future water uses.

The project is needed to provide a water cycle management solution for the GPOP growth corridor that is efficient and cost effective for the community, and one which is sustainable, resilient and adaptable to future water uses. The project also provides a future opportunity to develop a rainfall independent water supply and deliver a more sustainable wastewater system.

The main elements of the project include:

- a new WRRF at Camellia-Rosehill to treat wastewater to produce advanced treated water
- upgrades to the existing pumping station at Camellia
- a new wastewater transfer pipeline from Camellia pumping station to the WRRF
- a new and repurposed brine pipeline to transfer brine from the WRRF to the NSOOS
- a new river release pipeline to transfer advanced treated water from the WRRF to a release structure in Parramatta River at Meadowbank.

The project is State significant infrastructure and Sydney Water is preparing an Environmental Impact Statement (EIS) to support an application to the Minister for Planning and Public Spaces.

1.2 Project description

An overview of the location of the proposed infrastructure is presented in Figure 1-2. Further details regarding the project are provided below.

1.2.1 Camellia-Rosehill WRRF

The proposed WRRF will have capacity to treat 70 megalitres of wastewater per day (ML/d) and will produce advanced treated water to minimise impacts on Parramatta River. In addition to the advanced treated water, the reverse osmosis (RO) treatment process within the WRRF will generate brine as a by-product.

The main components of the WRRF include:

- inlet works

- primary, secondary and tertiary wastewater treatment process units
- advanced treatment processes involving reverse osmosis
- disinfection systems
- biosolids handling facilities
- odour control facilities.

The WRRF would require a range of process infrastructure such as tanks, bioreactors and digestors. The operation of the WRRF would also require ancillary facilities such as an administration building and associated car park, chemical storage and stormwater infrastructure.

1.2.2 Transfer pipeline

The transfer pipeline is about 2.2 kilometres (km) in length and would transfer wastewater from the Camellia pumping station to the WRRF.

1.2.3 River release pipeline

The proposed river release pipeline is approximately 7.6 km long commencing at the WRRF and then traversing through the suburbs of Silverwater, Newington, Sydney Olympic Park and Meadowbank. The river release pipeline would discharge advanced treated water into the Parramatta River near John Whitton Bridge at Meadowbank.

Above ground infrastructure is limited to concrete bridge-style aerial crossings over minor waterways in Meadowbank Park, and an approximately 8 m high barometric loop located in Memorial Park.

The pipeline would release advanced treated water into Parramatta River via a river release structure, which would have the capacity to release up to about 63 ML of treated water per day. In the rare event that the advanced treatment process equipment is undergoing maintenance or is not at specification, tertiary treated water would be discharged instead. It is expected this may occur for 2 days, around twice a year.

The proposed river release structure involves eight smaller pipelines that extend out underneath the sandstone sea wall and along the riverbed of the Parramatta River. These pipelines vary in length and connect to the multiport diffuser that would release water upstream between the first and third piers of the John Whitton Bridge. Figure 1-1 presents an extract from the reference design for the river release structure.

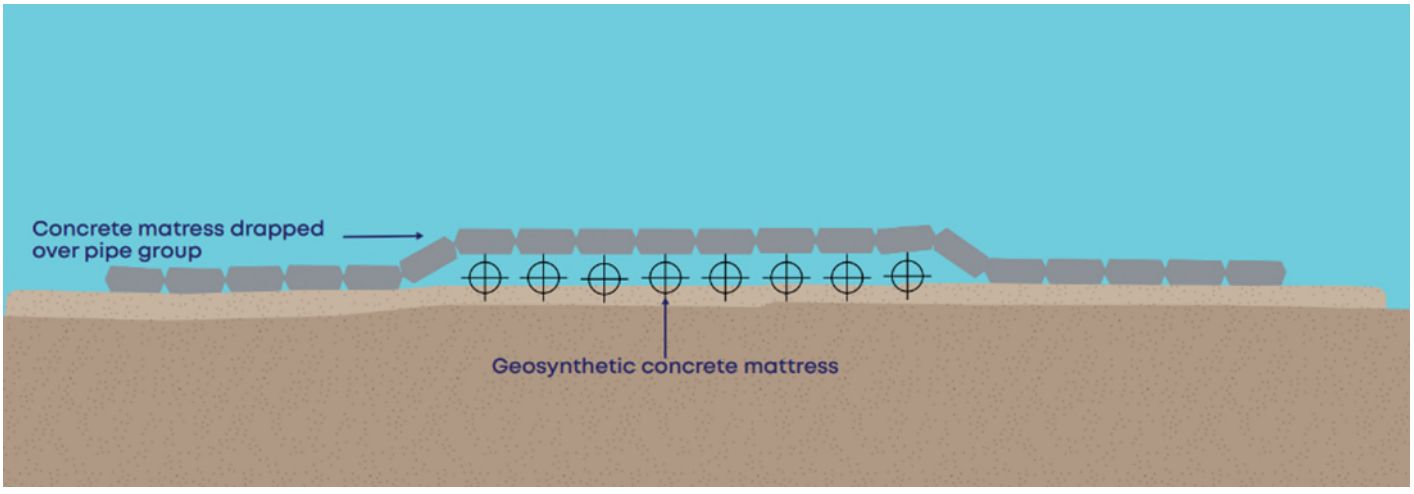

Figure 1-1 Configuration of the river release structure

1.2.4 Brine pipeline

The brine pipeline is approximately 5.2 km in length and would transfer brine from the WRRF to the NSOOS for treatment and offshore discharge at North Head WRRF. A new pipeline would be constructed between the WRRF and Camellia pumping station. From this location, the project would reline an existing pipeline between Camellia and the NSOOS.

1.2.5 Camellia pumping station upgrades

The existing Camellia pumping station would be upgraded to divert wastewater to the WRRF. Upgrades would include the installation of new pumps to deliver wastewater flows to the new WRRF, while remaining pumps would pump excess existing flows from the catchment and the brine produced by the WRRF to the NSOOS via existing pressure mains. New connections would be installed to divert the wastewater into the transfer pipeline. The existing site sheds would be replaced with a new electrical switchroom, transformers and high voltage cabling along the eastern boundary of the site.

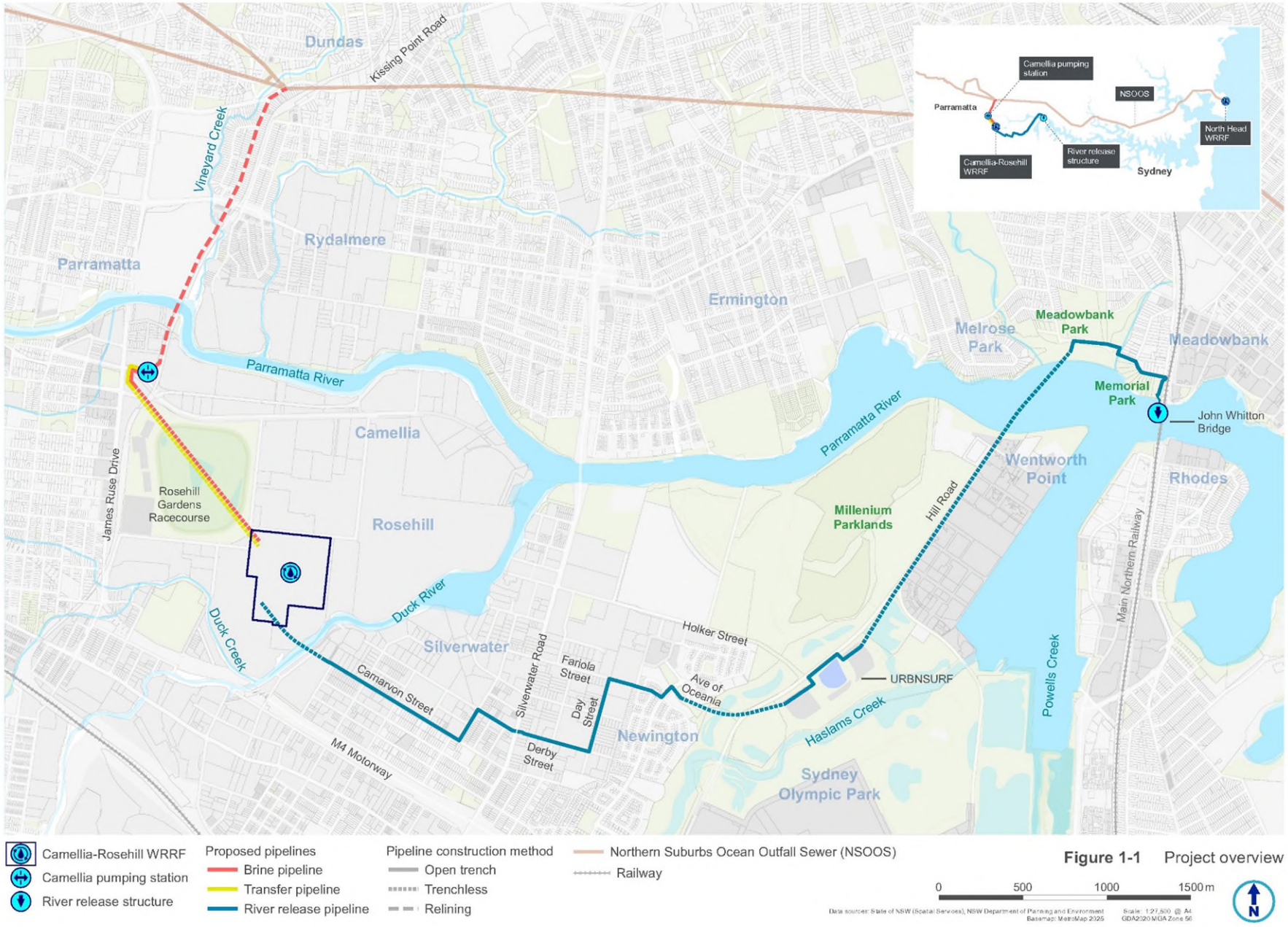

Figure 1-1 Project overview

Figure 1-2 Location of proposed infrastructure

1.3 Study objectives

The primary objective of this report is to provide a scientifically robust assessment of the hydrodynamic and water quality impacts that may arise from the treated water releases. This report has been prepared to support the EIS for the project and addresses the Secretary's Environmental Assessment Requirements (SEARs) relating to hydrodynamic and receiving water quality.

In addition to this standalone report, the results and interpretation from the assessment are to be provided to other specialist studies relating to the potential hydrodynamic and water quality impacts. These studies and an overview of the extent of their associated considerations are presented in Figure 1-3.

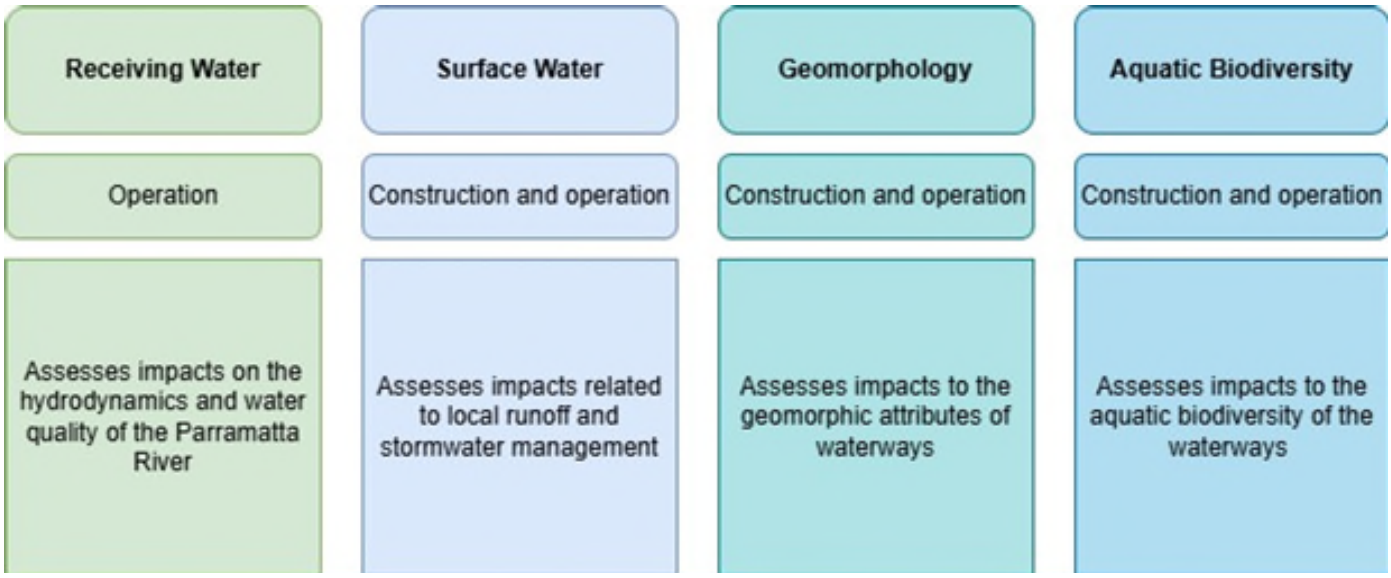

Figure 1-3 Key waterway assessments

1.4 Report structure

The following structure has been adopted for this report:

- Section 1: Introduction
- Section 2: Legislation and policy context (applicable national, state and local legislative requirements)
- Section 3: Relevant SEARs (specific clauses relevant to the hydrodynamic and water quality assessment)
- Section 4: Assessment methodology (including details on the software applied, modelling approach, analytical methods, assumptions and limitations)
- Section 5: Existing environment (description of the receiving waterway)
- Section 6: Impact assessments (evaluation of impacts of relevant release scenarios covering a range of climatic conditions, operational conditions, etc.)
- Section 7: Mitigation and monitoring measures
- Section 8: Summary and conclusions

2. Legislation and policy context

2.1 Legislation, policy and guidelines

Table 2-1 summarises the current legislative requirements, policies and guidelines that are considered most relevant to the hydrodynamic and water quality elements of the project.

Table 2-1 Legislation, policy and guidelines

Legislation, policy and guidelines	Requirement	Relevance to the project
Water Management Act 2000	The objects of the *Water Management Act 2000* 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 Act.
Protection of the Environment Operations Act 1997 (POEO Act)	The POEO Act 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 (EPLs) to the owners or operators of various industrial premises under the Act. Sydney Water's WRRFs all operate under EPLs issued by the EPA.	Sydney Water intends to vary the existing EPL 378 to include operation of the Camellia-Rosehill WRRF and a new release point to Parramatta River. Such a licence will specify environmental performance requirements, such as the likely impact of the activity on the environment including the receiving waterways.

Legislation, policy and guidelines	Requirement	Relevance to the project
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.	Key outcomes of relevance from the NWQMS include the overarching strategic principles of the strategy as well as the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines. These guidelines are discussed below.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)	The guideline provides step-by-step guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. This guideline is presented as an online platform, to improve usability and facilitate updates as new information becomes available.	The guidelines provide direction on default guideline values (DGVs) for a range of stressors relevant to different environmental values, such as aquatic ecosystems, drinking water, industrial water, recreational water and aesthetics and primary industries. The guidelines 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 those of ANZECC/ARMCANZ (2000), DCCEEW (2006) and NHMRC (2008) discussed below.

Legislation, policy and guidelines	Requirement	Relevance to the project
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)	The 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 DGVs) 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), these guidelines provide detailed guidance on required targets and thresholds for relevant water quality indicators in the receiving waters. These guidelines, along with the ANZG (2018), DCCEEW (2006) and NHMRC (2008) documents, formed a significant dataset in the development of the waterway objectives for the project.
Greater Sydney Water Strategy (Department of Planning and Environment, 2022)	The NSW Government has developed the Greater Sydney Water Strategy, which charts a direction for delivering sustainable and resilient water services to Greater Sydney for the next 20 to 40 years, servicing a growing Greater Sydney, including the Illawarra and Blue Mountains, and safeguarding our city even in times of prolonged drought and extreme weather events. The strategy sets out priorities and actions for the delivery of water, wastewater, recycled water and stormwater services into the future to support a sustainable, liveable and productive Greater Sydney.	The project is consistent with priorities under the strategy by providing a solution that enables adaptability on future water needs. The project would manage wastewater locally and ensure water quality objectives are maintained or improved.
NSW Water Strategy (Department of Planning, Industry and Environment, 2021)	The NSW Government has developed the 20-year, state-wide strategy to improve the security, reliability and quality of the state's water resources over the coming decades. The strategy addresses key challenges and opportunities for water management and service delivery across the state and set the strategic direction for the NSW water sector over the long-term.	By providing necessary wastewater infrastructure, the project would be supporting economic growth and contributing to the resilience and liveability of the GPOP area.

Legislation, policy and guidelines	Requirement	Relevance to the project
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 included in the development of the project specific waterway objectives presented in Section 2.2.
Using the ANZECC/ARMCANZ Guidelines and Water Quality Objectives in NSW (Department of Environment and Conservation NSW, 2006)	This document was developed to provide additional guidance on the principles behind the ANZECC/ARMCANZ (2000) guidelines and how to apply these in NSW context.	Guidance from this document 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 (Department of Climate Change, Energy, the Environment and Water, 2006)	These objectives provide an 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. Current uses and environmental values for the Sydney Harbour and Parramatta River system include maintaining healthy ecosystems, recreation (including swimming, boating, fishing and aesthetics) and commercial activities (such as commercial shipping and tourism). There is very limited extraction of fresh water, or reuse of stormwater (as is occurring at the Olympic site at Homebush Bay and adjacent village, usually for irrigation of golf courses or parks).	The water quality and river flow objectives of the Sydney Harbour and Parramatta River catchment are adopted for the project, as detailed in Section 2.2.

Legislation, policy and guidelines	Requirement	Relevance to the project
Risk-based framework for considering waterway health outcomes in strategic land use planning decisions (Office of Environment and Heritage and EPA, 2017)	This 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 framework is to: • ensure the community's environmental values and uses for our waterways are integrated into strategic land use planning decisions • identify relevant objectives for the waterway that support the community's environmental values and uses, and can be used to set benchmarks for design and best practice • identify areas or zones in waterways that require protection • identify areas in the catchment where management responses cost-effectively reduce the impacts of land use activities on our waterways • support management of land use developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.	The development of the project waterway objectives has followed the principles of the risk-based framework.
Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA, 2022)	This document lists the sampling and analysis methods to be used to test for the presence or concentration of matter in water and the volume, depth and flow of water or wastewater, when complying with statutory requirements.	The application of these methods is prescribed as one of the relevant environmental planning instruments, policies, guidelines and plans within the project specific SEARs.

Legislation, policy and guidelines	Requirement	Relevance to the project
DUBA, BUDU, BARRA – Ten Steps to a Living River – The Parramatta River Masterplan (Parramatta River Catchment Group, 2018)	The masterplan aims to improve waterway health and establishes the actions required to achieve a swimmable Parramatta River by 2025. The project would be compatible with the Parramatta River Masterplan.	The project would be compatible with the Parramatta River Masterplan.
Cumulative Impact Assessment Guidelines for State Significant Projects (DPIE, 2022)	The purpose of this guideline is to set clear expectations and requirements for assessing project-level cumulative impacts related to State significant projects.	The WQRM accounts for cumulative impacts through the inclusion of climate change, current and predicted land use and catchment conditions and the WRRF releases.

2.2 Waterway values and objectives

The NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) is updating the NSW Water Quality Objectives (WQOs) across all coastal catchments in NSW to ensure they reflect current community values and uses of waterways. The revised WQOs are yet to be released. Sydney Water has therefore adopted the current WQOs (DCCEEW, 2006).

The project will discharge advanced treated water to the Parramatta River near the John Whitton Bridge at Meadowbank. The NSW WQOs for the upper estuary of the Sydney Harbour and Parramatta River catchment apply (DCCEEW, 2006). The NSW WQOs specify protection of the following environmental values for the upper estuary of Sydney Harbour:

- Aquatic ecosystems
- Visual amenity
- Secondary contact recreation
- Primary contact recreation
- Aquatic foods.

Table 2-2 includes the relevant indicators for these environmental values and the associated guideline values and criteria. The management goals and numerical criteria for each of these values and uses have been informed by the following guidelines:

- NSW Water Quality and River Flow Objectives of the Sydney Harbour and Parramatta River (DCCEEW, 2006)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000 and ANZG, 2018)
- Guidelines for managing risks in recreational water (NHMRC, 2008).

The WQOs will be used as a benchmark to understand the existing condition of the waterway and to assist in evaluation of predicted impacts on water quality.

Table 2-2 Waterway objectives

Environmental value and management goal	Indicator	Numerical criteria (trigger values)
Aquatic ecosystems *Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term*	Total phosphorus	0.03 mg/L[1]
	Total nitrogen	0.3 mg/L[1]
	Chlorophyll *a*	0.004 mg/L[1]
	Turbidity	0.5 – 10 NTU[1]
	Salinity (electrical conductivity)	No value included for estuaries[1]
	Dissolved oxygen	80 - 110% Saturation[1]
	pH	7 - 8.5[1]
	Temperature	Reference data preferred.

Environmental value and management goal	Indicator	Numerical criteria (trigger values)	
		Default trigger value: • > 80%ile • < 20%ile[2]	
	Oxidised nitrogen (NOx)	0.015 mg/L[3]	
	Ammonium (NH_4^+)	0.015 mg/L[3]	
	Filterable reactive phosphorus (FRP)	0.005 mg/L[3]	
	Chemical contaminants or toxicants	Total ammonia as N	0.91 mg/L[4]
		Nitrate as N	2.6 mg/L[4,5]
		Aluminium	37 µg/L[4]
		Cadmium	0.7 µg/L[8]
		Copper	1.3 µg/L[4]
		Cobalt	6.1 µg/L[6]
		Manganese	300 µg/L[7]
		Mercury (inorganic)	0.1 µg/L[8]
		Iron	540 µg/L[4]
		Zinc	8 µg/L[4]
		Total Chlorine	0.0072 mg/L[10]
	Biological assessment indicators	Macroinvertebrates – Signal-SG *The NSW WQOs do not specify a particular method, but notes that recognised protocols using algae, macrophytes, macroinvertebrates and fish populations may be used. Sydney Water typically monitors aquatic ecosystem health via Signal-SG.*	
Visual amenity *Aesthetic qualities of waters*	Visual clarity and colour[1]	• Natural visual clarity should not be reduced by more than 20%. • Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. • The natural reflectance of the water should not be changed by more than 50%.	
	Surface films and debris[1]	• Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. • Waters should be free from floating debris and litter.	

Environmental value and management goal	Indicator	Numerical criteria (trigger values)
	Nuisance organisms[1]	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.
Primary Contact Recreation *Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed*	Turbidity[1]	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).
	Faecal coliforms[1]	N/A – values are included in NSW WQOs, but current practice is to monitor for enterococci as representative indicator.
	Enterococci[9]	95th percentile for intestinal enterococci/100mL ≤ 40
	Protozoans[1]	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note, it is not necessary to analyse water for these pathogens unless temperature is greater than 24°C).
	Algae & blue-green algae[1]	< 15 000 cells/mL
	Nuisance organisms[1]	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
	pH[1]	5.0 – 9.0
	Temperature[1]	5°-35°C for prolonged exposure
	Chemical contaminants[1]	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in Tables 5.2.3 and 5.2.4 of the ANZECC/ARMCANZ (2000) guidelines. *Note that concentrations in Tables 5.2.3 and 5.2.4 were reviewed as part of the toxicant review. The most conservative value was adopted (refer values under Aquatic Ecosystems).*
	Visual clarity and colour[1]	Use visual amenity guidelines
	Surface films[1]	Use visual amenity guidelines
Secondary Contact Recreation *Maintaining or improving water quality for activities such as boating and wading, where there*	Faecal coliforms[1]	Median bacterial content in fresh and marine waters of < 1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).

Environmental value and management goal	Indicator	Numerical criteria (trigger values)
is a low probability of water being swallowed	Enterococci[9]	95th percentile for intestinal enterococci/100 mL > 40 and ≤ 200
	Algae & blue-green algae[1]	< 15 000 cells/mL
	Nuisance organisms[1]	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
	Chemical contaminants[1]	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in Tables 5.2.3 and 5.2.4 of the ANZECC/ARMCANZ (2000) guidelines.
	Visual clarity and colour[1]	Use visual amenity guidelines
	Surface films[1]	Use visual amenity guidelines
Aquatic foods (cooked) *Refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.*	Algae & blue-green algae[1]	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.
	Faecal coliforms[1]	Guideline in water for shellfish: • The median faecal coliform concentration should not exceed 14 MPN/100 mL; with no more than 10% of the samples exceeding 43 MPN/100 mL. Standard in edible tissue: • Fish destined for human consumption should not exceed a limit of 2.3 MPN *E Coli* /g of flesh with a standard plate count of 100,000 organisms /g.
	Toxicants (as applied to aquaculture activities) [1]	Metals: • Copper: less than 5 µg/L. • Mercury: less than 1 µg/L. • Zinc: less than 5 µg/L. *Given that no aquaculture activities are present downstream of the discharge, toxicant values for aquatic ecology will be adopted.* Organochlorines: • Chlordane: less than 0.004 µg/L (saltwater production) • Polychlorinated Biphenyls (PCBs): less than 2 µg/L.

Environmental value and management goal	Indicator	Numerical criteria (trigger values)
	Physico-chemical indicators (as applied to aquaculture activities) [1]	Suspended solids: less than 40 µg/L (freshwater) Temperature: less than 2°C change over one hour.

Table notes:

1. *Indicators and metrics for estuaries adopted from NSW WQOs (for Parramatta River and Sydney Harbour Catchment) (DCCEEW 2006)*
2. *Table 3.3.1 ANZECC/ARMCANZ (2000)*
3. *Numerical criteria adopted from Table 3.3.2 ANZECC/ARMCANZ (2000) default trigger values for slightly disturbed estuarine ecosystems in south-east Australia*
4. *Numerical criteria adopted from ANZG (2018) DGV for 95% species protection - marine ecosystem values adopted where available. Otherwise freshwater value adopted.*
5. *Value assumes moderately hard water.*
6. *Based on personal communication with G. Batley.*
7. *Numerical criteria adopted from Draft Toxicant default guideline values for aquatic ecosystem protection: Manganese in marine water (ANZG 2025). Confirmed based on personal communication with G. Batley. DGV for 95% species protection adopted.*
8. *Numerical criteria adopted from ANZG (2018) for marine ecosystems– 99% species protection*
9. *Numerical criteria adopted from recent guidelines from Guidelines for managing risks in recreational water (NHMRC, 2008) rather than NSW WQOs.*
10. *For Total Chlorine, the concentration stated represents the proposed default guideline value for Total Chlorine in slightly to moderately disturbed marine systems (Batley & Simpson, 2020).*

3. Relevant SEARs

The SEARs that are directly relevant to the hydrodynamic and water quality assessment have been identified and are presented in Table 3-1. Table 3-1 also provides guidance in relation to which section of the report addresses each requirement.

Table 3-1 Project SEARs relevant to the hydrodynamic and water quality impact assessment

Key Issue	Relevant SEARs	Report section where addressed
1. Environmental Impact Assessment Process	1. The Environmental Impact Statement (the EIS) must be prepared in accordance with Part 8 of the Environmental Planning and Assessment Regulation 2021 (the EP&A Regulation). 2. The EIS must be prepared having regard to the Department's State Significant Infrastructure Guidelines and State Significant Project Technical Guidelines (together, the Guidelines), as relevant. 5. The onus is on the Proponent to ensure legislative requirements relevant to the project are met.	All sections
3. Assessment and Mitigation of Key Issues and Impacts	1. The level of assessment of likely impacts must be proportionate to the significance of, or degree of impact on, the issue, within the context of the project location and the surrounding environment. The level of assessment must be commensurate to the degree of impact and sufficient to ensure that the Department and other government agencies are able to understand and assess impacts.	Section 6
3. Assessment and Mitigation of Key Issues and Impacts	2. For each key issue, the EIS must include a detailed summary of the results of the assessment of the potential impacts of the project undertaken in detailed studies, including: a) the condition of the existing environment b) a summary of the key findings of the detailed technical studies in the appendices of the EIS, using suitable cross-referencing to specific sections and subsections to reduce repetition between the main body of the EIS and technical studies c) description of the scale and nature of the predicted impacts, including any cumulative impacts, and whether these impacts will comply with the relevant statutory requirements,	EIS Chapter 7

Key Issue	Relevant SEARs	Report section where addressed
	standards, performance measures, and goals and criteria set out in relevant guidelines and policies d) demonstrated ability to avoid, mitigate or offset the impacts of the project having regards to: i. mitigation measures incorporated into the design of the project (e.g., changes to the project area, project layout and design, key uses and activities carried out on site, timing) ii. other mitigation measures that will be implemented iii. any negotiated agreements or offsets proposed to address residual impacts of the project following mitigation. e) detailed reasons justifying any predicted exceedances of relevant standards, performance measures, and goals and criteria set out in relevant guidelines and policies f) identification of key uncertainties associated with the assessment and what action will be taken to address these uncertainties g) highlight any key linkages between the assessment of different matters or likely cumulative impacts of the project.	
19. Water – Hydrology	2. Map the following estuaries: a) rivers, streams, estuaries, and wetlands (as described in section 3.1.3 of the BAM) d) proposed discharge locations.	Sections 1.2, 4.5 and 5.3
19. Water – Hydrology	3. A description of works / activities that may intercept, interfere, extract, use divert or receive surface water and groundwater on a temporary or permanent basis during construction and operation.	Sections 1.2 and 4.5.4.2 Groundwater related impacts are assessed separately in the Groundwater Impact Assessment.

Key Issue	Relevant SEARs	Report section where addressed
19. Water – Hydrology	6. Surface and groundwater hydrology impacts (both quality and source) of the construction and operation of the project and any ancillary facilities (both built elements and discharges) in accordance with the current guidelines, including: a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge b) effects to upstream and downstream rivers, wetlands, estuaries, marine waters, floodplain areas and water-dependent fauna and flora (including groundwater dependent ecosystems) f) methods for minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems.	Section 6 Groundwater related impacts are assessed separately in the Groundwater Impact Assessment. Aquatic ecology impacts are assessed separately in the Aquatic Ecology Impact Assessment.
20. Water – Quality	1. Water Quality (surface and groundwater) impacts on waterways potentially impacted by the project, including but not limited to the Parramatta River, Homebush Bay and Haslams Creek, including:	
20. Water – Quality	a) existing background levels	Sections 5 and 6
20. Water – Quality	b) details on the ambient NSW Water Quality Objectives (NSW WQOs) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values	Section 2.2
20. Water – Quality	c) identification and estimation of the quality and quantity of pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment	Sections 4.5.4.2, 6.1 and 6.2

Key Issue	Relevant SEARs	Report section where addressed
20. Water – Quality	d) results of water quality modelling and analysis including descriptions under the full range of operating scenarios, including average or typical through to worst-case for any proposed discharge point, including but not limited to the full range of weather conditions, bypasses, and 'off-spec' effluent scenarios	Section 6
20. Water – Quality	e) outline impacts from the proposal on existing sewage infrastructure including any potential impacts on dry weather and wet weather overflows from the existing reticulation network and any impacts on North Head Water Resource Recovery Facility concentrations and loads discharged and hydraulic and treatment capacity	Sections 4.5.4.2, 4.5.4.3 and 6
20. Water – Quality	f) details on the rainfall event that the water quality protection measures will be designed to cope with	Sections 4.5.4.2 and 6
20. Water – Quality	g) the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Section 6
20. Water – Quality	h) details on how construction and operation of the project will, to the extent that the project can influence, ensure that: i. where the NSW WQOs for receiving waters are currently being met they will continue to be protected ii. where the NSW WQOs are not currently being met activities will work toward their achievement over time iii. the objectives of making the Paramatta River swimmable can be met iv. migration of contamination is considered and how it will be managed and minimised.	Sections 6, 7 and 8
20. Water – Quality	i) justification for, if required, why the WQOs cannot be maintained or achieved over time	Sections 6, 7 and 8
20. Water – Quality	j) demonstration that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented. This also	Sections 6, 7 and 8

Key Issue	Relevant SEARs	Report section where addressed
	includes consideration and management of frac out from the temporary loss of drilling fluids and inappropriate storage of chemicals and fuels	Details on frac out and chemical and fuels storage are provided in the Groundwater Impact Assessment.
20. Water – Quality	k) Identification of sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments	Sections 5.4, 6.3 and 7
20. Water – Quality	l) proposed water quality monitoring programs, including monitoring locations, monitoring frequency and the parameters that will be monitored pre-construction, during construction and during operation, including justification for these.	Section 7.2 Note: this report only covers the operational monitoring program.

4. Assessment methodology

4.1 Overview

This section outlines the methodology that was adopted in the assessment to adequately address the SEARs as well as other relevant, previously discussed, technical and legislative requirements. As a high-level overview, the following sequence of tasks was undertaken as part of the assessment methodology:

- data compilation and review
- software selection and configuration of model framework
- model development, calibration and validation
- scenario modelling and impact assessments
- analysis and interpretation of scenario modelling results.

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

4.2 Data compilation and review

An extensive suite of publicly available datasets, datasets from external organisations and data captured as part of the project were compiled and reviewed as part of the assessment. A summary of the relevant phases and tasks is presented below.

The initial phase provided for the development, calibration and validation of the Water Quality Response Model (WQRM). Descriptions of the underlying datasets included in this development phase are presented in the GPOP Water Quality Response Model Calibration Report (Sydney Water, 2025b) included in Appendix A. Details provided include the source of the data, their 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 focussed 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 Parramatta River, its tributaries and Sydney Harbour
- water quality monitoring data collected within the receiving waterway
- land use data for the contributing catchments
- monitoring data from relevant wastewater pumping stations (i.e., Camelia pumping station) located within the catchment including flow rates and water quality monitoring data
- water quality monitoring data from other similar Sydney Water WRRFs (e.g., St Marys AWTP) on which to base performance assumptions on for the proposed release
- wet weather overflow data predicted for future conditions
- meteorological and climate change datasets associated with climate change modelling approach.

4.3 Software selection

The GPOP WQRM is primarily built on application of the finite volume hydrodynamic modelling software, MIKE 3 Flow Model Flexible Mesh (FM), which is then coupled with the MIKE Mud Transport (MT) and MIKE Ecolab modules, to simulate sediment transport and water quality processes respectively. Further details relating to these modelling software packages are presented below and in the GPOP WQRM Calibration Report (refer Appendix A).

4.3.1 MIKE 3 Flow Model FM

The MIKE 3 Flow Model FM is a modelling system based on a flexible mesh approach, developed by DHI Water and Environment, for applications within oceanographic, coastal and estuarine environments.

The hydrodynamic module is based on the numerical solution of the three-dimensional (3D) incompressible Reynolds averaged Navier-Stokes equations invoking the assumptions of Boussinesq. Both the full 3D Navier-Stokes equations and the 3D shallow water equations can be applied, with the latter invoking the hydrostatic pressure assumption. Thus, the model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. In the horizontal domain both Cartesian and spherical coordinates can be used. The free surface is taken into account using a Sigma coordinate transformation approach.

The spatial discretisation of the governing equations in conserved form is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the model domain into non-overlapping elements/cells. In the horizontal plane an unstructured grid is used while in the vertical domain a structured discretisation is applied. The elements can be prisms or bricks whose horizontal faces are triangles and quadrilateral elements, respectively.

4.3.2 MIKE Mud Transport

The MIKE Mud Transport (MT) module provides the ability to simulate the transport of fine-grained sediments, particularly mud, in estuarine, coastal and marine environments. The software presents the capacity to analyse the transport of sediment particles with a range of different characteristics. Application therefore allows for assessment of impacts of suspended solids and siltation for marine, brackish, and freshwater projects.

The MT module can simulate sediment dynamics influenced by waves, currents, tides, and sediment characteristics. Typical applications include management of dredging operations, for turbidity reduction, or ensuring environmental compliance. Importantly for the GPOP WQRM, the results from the MT models are used as a key input to the Ecolab models, thereby presenting a temporally and spatially varying database for total suspended solids (TSS).

4.3.3 MIKE Ecolab

The MIKE Ecolab module is a customisable numerical modelling tool that can be applied to allow simulation of a suite of water quality processes including eutrophication, nutrient dynamics, pathogens, heavy metals, etc. Pre-defined or project specific templates can be applied to describe dissolved substances, particulate matter of dead or living material, living biological organisms and other components. The modules are

generally developed to describe chemical, biological, ecological processes and interactions as well as the physical process of sedimentation of components. Coupled with the MIKE 3 FM software and results from MT simulations, the water quality properties are updated dynamically in response to changes in water conditions brought about by weather and flow events.

Of relevance to this study, the conceptualisation of the EU2 eutrophication template has been configured to capture the dynamics of oxygen, carbon, nutrients (including inorganic and organic fractions) and primary productivity as presented in Figure 4-1. Modifications were also made to the EU2 template to allow inclusion of Enterococci as a primary constituent due to the use of the river for swimming and other recreational activities. The primary variables included in the GPOP WQRM simulations are described in further detail in the GPOP WQRM Calibration Report (refer Appendix A).

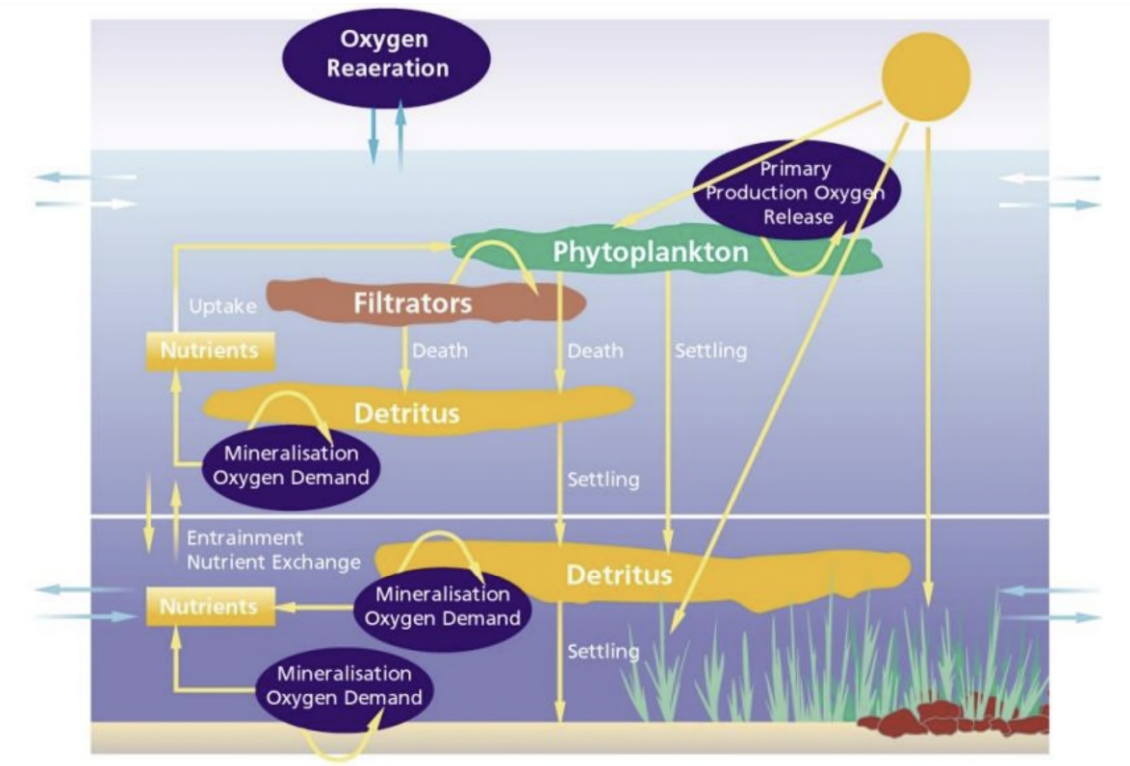

Figure 4-1 Conceptual diagram illustrating the key variables and processes of the MIKE Ecolab eutrophication template (Source: DHI Water and Environment)

4.3.4 CORMIX

The CORMIX software (version 12.0GT) is a US EPA supported mixing zone model and decision support system, commonly used for environmental impact assessments of treated wastewater releases. The software consists of a series of algorithms for the analysis of near field mixing of wastewater in receiving waterways, with an emphasis on steady-state analysis for the prediction of plume geometry and dilution characteristics.

The CORMIX models developed for the EIS used boundary condition data from the WQRM as well as relevant monitoring data to define the initial dilution and mixing characteristics within the Parramatta River. The models were then applied to assess near field impacts, such as toxicity, in the immediate vicinity of the river releases.

4.3.5 Boundary condition models

A range of other modelling software packages were also applied to provide the hydrodynamic and water quality boundary conditions that were required in the development of the GPOP WQRM. The structure and purpose of these models are summarised as follows:

4.3.5.1 Source catchment models

Hydrological modelling of the contributing catchments was undertaken through application of the eWater Source software. A suite of four Source models was developed to encompass the following catchment areas: Upper Parramatta River, Upper Lane Cove River, Upper Duck River and the remaining smaller catchments draining to the Sydney Harbour estuary (including Vineyard Creek). The Source catchment models were developed to generate sub-daily (hourly) time step data on catchment runoff flows and pollutant export concentrations for key water quality constituents including nutrients, sediment and pathogens. The Source models were applied to run scenarios representative of existing and predicted future catchment conditions.

4.3.5.2 Upper Parramatta River model

To provide representative boundary conditions of flow and water quality for water overtopping the Charles Street Weir, modelling of the Upper Parramatta River was undertaken through application of a standalone hydrodynamic and water quality model developed in the MIKE 21 FM, MT and Ecolab software modules. The Upper Parramatta River model was developed in a similar structure, and with the same underlying datasets and parameterisation as the GPOP WQRM, the model mesh extending upstream of Charles Street Weir encompassing the weir pool storage, up to the confluence of Toongabbie Creek and Darling Mills Creek.

4.3.5.3 Wastewater network models

Sydney Water has developed wastewater network models with application of the Model for Urban Sewers (MOUSE) software package, developed by DHI Water and Environment. As part of the MIKE URBAN software platform, MOUSE allows for simulation of collection systems for urban wastewater and stormwater. It is commonly used to assess the network capacity of wastewater networks, associated bottlenecks, analysing sewer overflows, as well as evaluating water quality and sediment conditions.

Scenarios were run using MOUSE models for North Head, Malabar and Bondi systems for both existing and predicted future network conditions to generate a time series of wet weather overflow data. To characterise the water quality of the overflows, a dilution-based approach was developed. This approach involved application of an algorithm that calculated a dilution factor based on antecedent rainfall for the sub-catchment in which each overflow was located, and then calculated a release concentration for each water quality parameter based on the predicted contribution of raw sewage and stormwater.

4.3.5.4 Camellia-Rosehill WRRF model

A daily time step model was developed within Microsoft Excel to allow for the generation of daily timestep time series of flow and water quality for the proposed releases from the Camellia-Rosehill WRRF. The spreadsheet model was used to generate predicted future release conditions with representation of variations in flow and each water quality constituent. Further information regarding the release conditions is provided in Section 4.5.4.2.

4.4 Model configuration and interfaces

Figure 4-2 presents a high-level overview of how the aforementioned boundary condition models were interfaced with the WQRM. More specifically, the following interfaces were applied:

- Results from the Source catchment models were processed to develop the catchment inflow boundary conditions for the WQRM.
- Results from the Upper Parramatta River model were processed to develop flow and water quality boundary conditions for the WQRM immediately downstream of the Charles Street Weir.
- Overflow results from the MOUSE models were incorporated directly into the WQRM or indirectly via the Source models depending on the location of each overflow relative to the model mesh.
- Outputs from the WRRF model were incorporated directly into the WQRM across a distribution of cells representative of the proposed diffuser location.

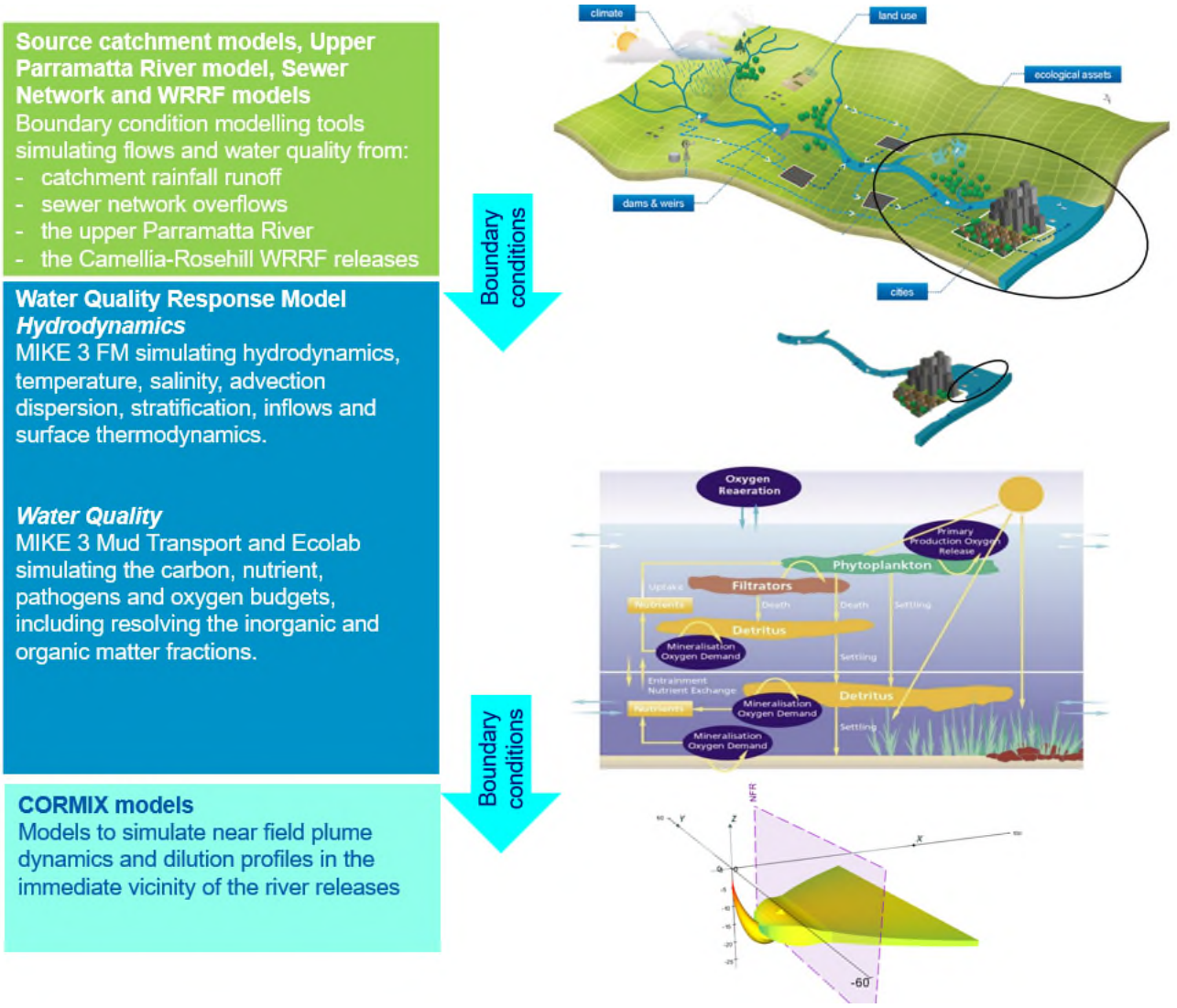

Figure 4-2 Primary model interfaces (Source: eWater and DHI Water and Environment)

4.5 Hydrodynamic and water quality modelling

4.5.1 Model development, calibration and validation

Sydney Water has previously developed hydrodynamic and water quality models of the Parramatta River and Sydney Harbour as part of the Wet Weather Overflow Abatement project (Sydney Water, 2018). The resulting integrated modelling system incorporated hydrodynamic and biogeochemical processes to allow evaluation of relevant environmental impacts originating from the catchment and more specifically the wet weather overflows.

More recently, the models were updated as part of the Parramatta River Flows Feasibility Study (Sydney Water, 2022). The updates to the model included modifications to the software, transition to a 3D model domain, revision of the boundary conditions and the calibration and validation periods.

As part of the GPOP EIS, further upgrades of the WQRM were undertaken, which incorporated refinements that were considered necessary to evaluate the hydrodynamic and water quality impacts from the operation of the proposed WRRF. The upgrade included further software updates, expansion of the model domain as well as revision of key boundary conditions and the data used to calibrate and validate the model's performance. The revised geographical extent of the WQRM mesh and domain is presented in Figure 4-3. The domain encompasses the tidal limits of the Parramatta River and Sydney Harbour, inclusive of coastal waters offshore of the Sydney Heads.

The GPOP WQRM has been calibrated and validated against a diverse suite of data collected over the period of 2012 to 2024. The final datasets processed for comparison with the model results included data from the following sources: Sydney Water, DCCEEW, Sydney Institute of Marine Science and the Port Authority of NSW. Collectively, these datasets have provided useful insights into the hydrodynamics and water quality within the Parramatta River and Sydney Harbour.

Calibration and validation of the WQRM has focussed on comparing the model predictions against the water quality and hydrodynamic monitoring data. Hydrodynamically, the model was calibrated and validated against both water elevation and flow transect data. With respect to water quality, the core suite of parameters calibrated within the model has included salinity, temperature, dissolved oxygen, suspended sediment, nutrients (including inorganic and organic fractions), primary productivity and pathogens. For the majority of these parameters, the model was calibrated for the years 2012-13 and validated for 2021-24.

Through visual and statistical analysis, the model has been demonstrated to perform well across the range of simulation periods and also across the range of parameters that have been assessed. Sensitivity analysis has also been undertaken to evaluate how the model responds to modification in external forcings. The sensitivity analysis highlighted that catchment nutrient loads are a significant driver of water quality in the Parramatta River despite its tidal influences. It also indicates that the middle and upper reaches may be more sensitive to external loading changes, while the lower estuarine regions are more dominated by tidal flushing and are subject to lower residence times.

As a result of the upgrade and the corresponding calibration and validation, the models in their current format are considered to be a significant enhancement on their previous iteration and have been independently reviewed by the University of New South Wales (UNSW) Water Research Laboratory (WRL). The review by the UNSW WRL stated the following:

The numerical models and 3D modelling approach are commensurate with industry best practice. The overall calibration and verification are sound and the modelling suitable for assessment of hydrodynamic and water quality scenarios associated with the Greater Parramatta and Olympic Peninsula (GPOP) discharges.

The models are consequently considered to represent a robust modelling platform for application in the GPOP EIS.

Further details relating to the development, calibration and validation of the WQRM are in the GPOP WQRM Calibration Report (Appendix A).

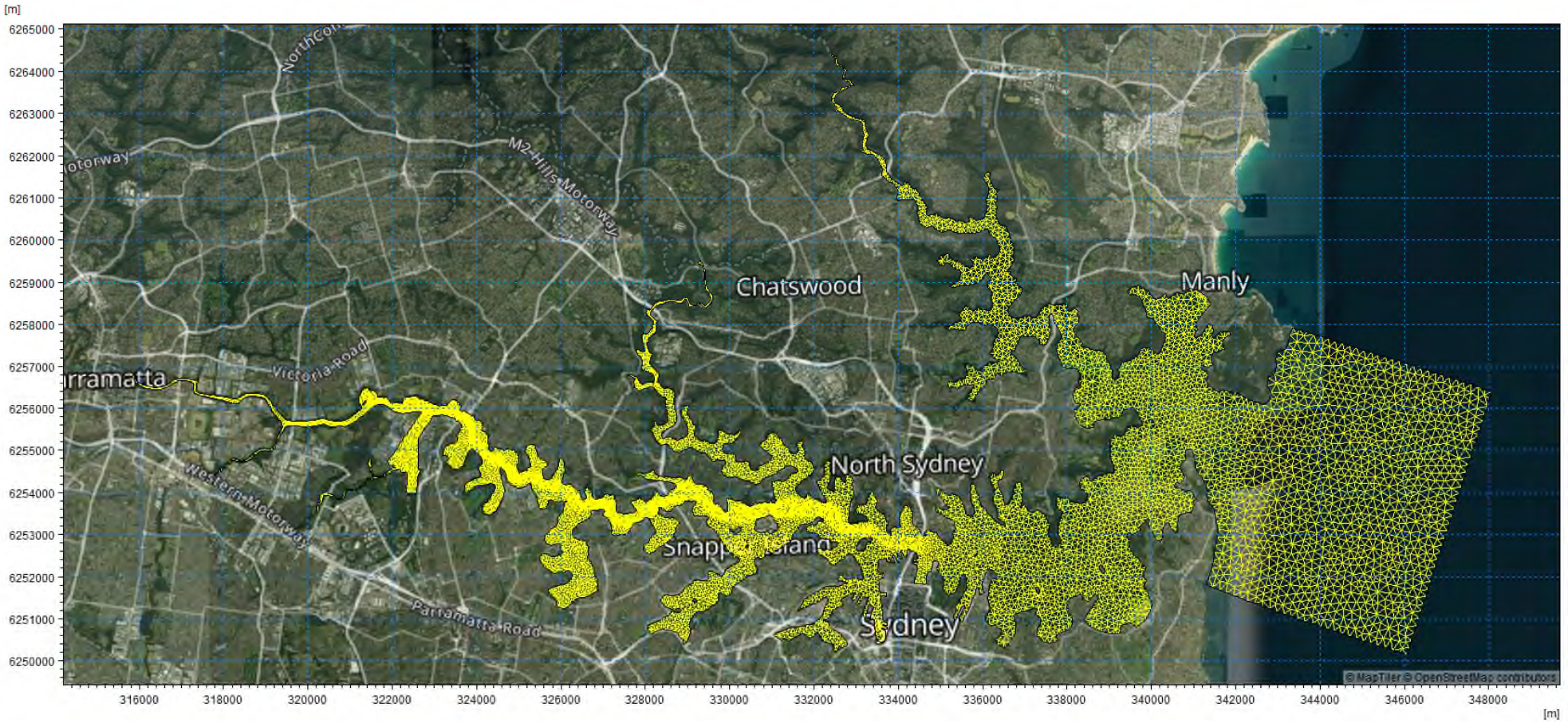

Figure 4-3 WQRM model domain and mesh

4.5.2 Scenario modelling approach

A suite of scenarios was developed to allow simulation of a range of conditions that could be expected during the operational life of the Camellia-Rosehill WRRF. Therefore, in addition to the introduction of releases of treated water from the WRRF on their own, expected changes in other catchment conditions such as climate change and sewer overflows, were also incorporated into the scenarios. Through consideration and simulation of these other expected changes in the catchment conditions, the cumulative impacts in the receiving waters for the selected future time horizon could be assessed.

To apply these changes in the models, the boundary conditions were systematically adjusted so as to represent the relevant settings for each of the scenarios. As part of this process, the Source catchment models were used to generate catchment inflow boundary conditions for the future scenarios and to reflect changes in wet weather overflows and climate conditions. The WQRM was also adjusted to represent the remaining scenario elements including wet weather overflows, climate change, and the WRRF treated water releases to Parramatta River.

Further details regarding the application of the scenario conditions and any relevant assumptions are presented below in Section 4.5.3.

4.5.3 Scenario descriptions

In addition to scenarios that simulated the operational phase of the Camellia-Rosehill WRRF, the suite of scenarios also included baseline and background simulations that were used for comparative purposes and allowed for targeted assessment of the impacts from the WRRF on its own. The types of scenarios are described in the following sections.

4.5.3.1 Baseline scenario

The baseline scenario (Sc1) represents current conditions (circa 2024/25). The land use applied in these scenarios was representative of the year 2017. It was considered appropriate to use this dataset to represent current conditions as a review of aerial photographs showed negligible changes in land use over the period from 2017 to 2024. All other inputs, e.g. rainfall, wet weather overflows, etc. were representative of current catchment conditions.

4.5.3.2 Background scenarios

The background scenarios (Sc2 and Sc2cc) simulate catchment and waterway conditions expected in future years (circa 2056) and include updated wet weather overflows based on source control works planned by Sydney Water but without the operation of the Camellia-Rosehill WRRF. Sc2 represents the background conditions without climate change, whilst Sc2cc incorporates climate change based on Representative Concentration Pathway 4.5 (RCP 4.5) (refer Section 4.5.4.1). The 2056 planning horizon was selected as this corresponds with when the daily Average Dry Weather Flow (ADWF) volume of the Camellia-Rosehill WRRF is expected to reach 70 ML/d.

4.5.3.3 Impact scenarios

The impact scenarios (Sc3 and Sc3cc) represent the potential catchment and waterway conditions in future years (circa 2056) with the inclusion of discharges from the Camellia-Rosehill WRRF. Associated changes to the sewer overflows that are predicted from the operation of the WRRF are also incorporated into the

impact scenarios. Sc3 represents the background conditions without climate change, whilst Sc3cc incorporates climate change using RCP 4.5. Further details regarding operation of the WRRF are provided in Section 4.5.4.2, including simulation of offline events relating to the RO treatment process.

4.5.3.4 Scenario comparisons

For the analysis of the scenario results, the results from the impact scenarios are plotted against a corresponding background scenario as well as the baseline scenario.

Importantly, to allow assessment of the impacts from the operation of the Camellia-Rosehill WRRF on its own, the background scenario selected in any comparison represents the same catchment conditions as that of the impact scenario, except for the operation of the WRRF.

Therefore, the following results are collated and presented separately:

- Climate change scenarios: Sc3cc (impact), Sc2cc (background) and Sc1 (baseline)
- Non-climate change scenarios: Sc3 (impact), Sc2 (background) and Sc1 (baseline)

4.5.3.5 Scenario duration and representative climatic conditions

Precipitation data sourced from the Bureau of Meteorology were used to determine representative model simulation years.

Based on decile analysis of rainfall over a 20-year period from 2003 through to 2023 (refer to Figure 4-4), three rainfall years were selected as the scenario simulation periods, with the intention of representing a range of climatic conditions. From this analysis, the following three rainfall years were selected:

- Representative average rainfall year - modelled between 1 July 2016 – 30 June 2017 (~1,110 mm/year)
- Representative dry rainfall year - modelled between 1 July 2017 – 30 June 2018 (~630 mm/year)
- Representative wet rainfall year - modelled between 1 July 2021 – 30 June 2022 (~1,905 mm/year)

Simulation of the three climatic years was undertaken to address the principal question of how different climatic conditions may affect the impacts from operation of the WRRF. The assessment of impacts on water quality under such different climatic conditions is commonly undertaken in an EIS as different catchment influences, such as point and diffuse sources, may become more predominant under wet or dry conditions. Similarly, different types of releases, such as wet weather overflows, may also have differing levels of influence.

The three climate periods were run back-to-back with a restart file being written at the end of each simulation period and the succeeding scenario simulation reading these in as initial conditions.

This extended level of simulation duration further addresses the SEARS item 20 d) which includes the following requirements: *results of water quality modelling and analysis including descriptions under the full range of operating scenarios, including average or typical through to worst-case for any proposed discharge point, including but not limited to the full range of weather conditions, bypasses, and 'off-spec' effluent scenarios.*

In addition to the three aforementioned simulation periods, a four-month warm-up period (March 2016 to June 2016) was also run, preceding the representative average rainfall year.

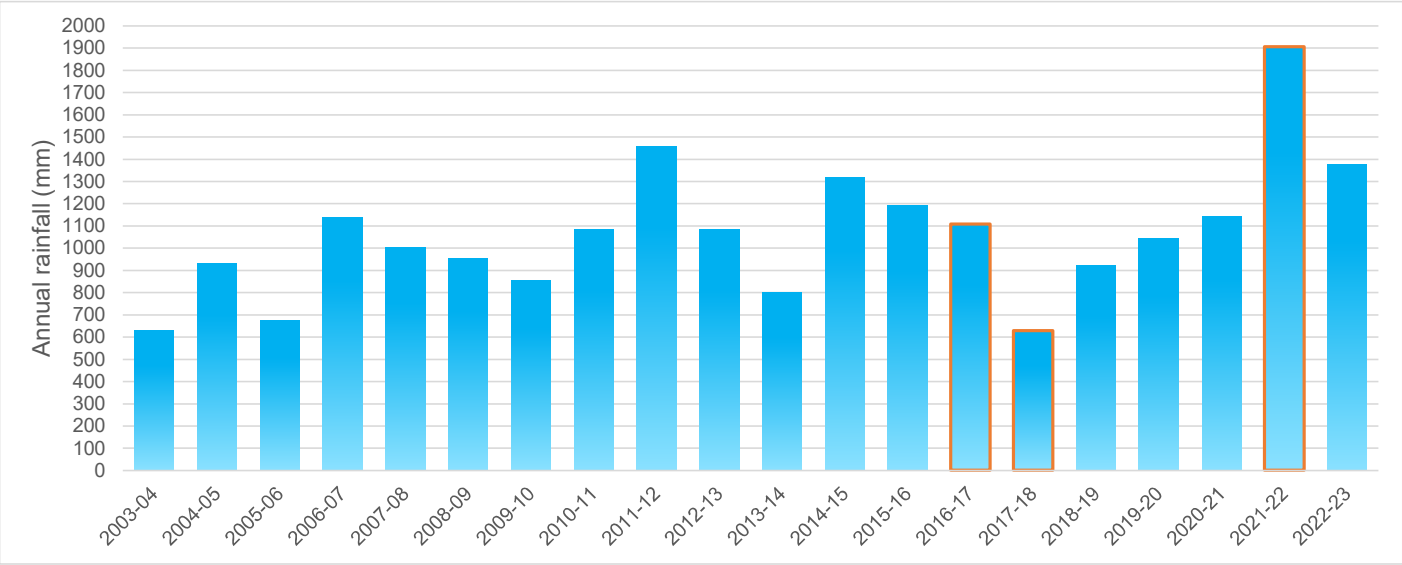

Figure 4-4 Local annual rainfall data. Orange outlines display the selected average, dry and wet years

4.5.4 Scenario datasets

Table 4-1 provides a summary of the model components for each scenario with the following sections outlining the methodology and input data used to develop the scenario datasets.

Table 4-1 Overview of model components for each scenario

Model component	Baseline Sc1	Background Sc2	Background with climate change (RCP 4.5) Sc2cc	Impacts of WRRF Sc3	Impacts of WRRF with climate change (RCP 4.5) Sc3cc
Camellia-Rosehill WRRF river releases	Not applicable	Not applicable	Not applicable	70 ML/d ADWF 63 ML/d of continuous river release of RO quality water (assuming a brine return of 10%) into Parramatta River RO off-line events assumed to occur for 48 hours, twice per year (consecutive months) during dry periods. Modelled as releases of 70 ML/d of membrane bioreactor (MBR) quality water. 7 ML/d brine flow (transferred to NSOOS for discharge at North Head WRRF)	
Wet weather overflows	MOUSE (Model for Urban Sewers) network models wet weather overflows data (2024), including spill volumes at each overflow location based on current climate condition data.	MOUSE network models wet weather overflows data based on predicted 2056 future network conditions simulated with current climate condition data.	MOUSE network models wet weather overflows data based on predicted 2056 future network conditions simulated with climate change rainfall and potential evapotranspiration (PET) data (RCP 4.5).	Same as Sc2, with exception of North Head STS MOUSE network model which includes changes in overflows associated with sewer mining to Camellia-Rosehill WRRF.	Same as Sc2cc, with exception of North Head STS MOUSE network model which includes changes in overflows associated with sewer mining to Camellia-Rosehill WRRF.
Catchment rainfall runoff	Based on 2017 land use, current catchment condition wet weather overflows as outlined above and simulated using current climate condition data.	Based on 2017 land use, wet weather overflows data as outlined above and simulated using current climate condition data.	Based on 2017 land use data, wet weather overflows data as outlined above and simulated using climate change rainfall and PET data (RCP 4.5).	Based on 2017 land use data, wet weather overflows data as outlined above and simulated using current climate condition data.	Based on 2017 land use data, wet weather overflows data as outlined above and simulated using climate change rainfall and PET data (RCP 4.5).

4.5.4.1 Climate change approach

Sydney Water's strategic position on climate change adaptation is to plan and invest prudently to ensure the business can maintain service levels by managing the climate risk. To achieve this strategic position, Sydney Water aims to:

- Prepare the business to be resilient to plausible futures by adapting to RCP 4.5 as a standard requirement (representing the most likely climate future based on current global pledges).
- Demonstrate adaptive pathways to RCP 8.5 and incorporate changes now if it is prudent to do so based on risk, impact, cost, and required future adaptive capacity.

A comparison of predictions between RCP 4.5 and RCP 8.5 at the 2056 planning horizon indicated that there was a minimal difference in predictions. Consequently, RCP 4.5 was selected for the purpose of assessing the impact of climate change.

The NSW and Australian Regional Climate Modelling (NARCliM) project brings together trusted science and broad expertise to deliver world-recognised regional climate projections for NSW and its regions. These projections describe plausible future climates, based on the latest available emissions scenarios, to help users understand and plan for an uncertain future. NARCliM data and technical information can be accessed through the NSW Climate Data Portal.

At the time of commencing the climate change assessment, the most recent set of projections (NARCliM 2.0) was not available to Sydney Water as a final product and the decision was made in consultation with DCCEEW to use NARCliM 1.5 (released in 2021) for the climate change analysis.

A range of model components were adjusted to represent climate change conditions, including precipitation, potential evapotranspiration (PET) rate, offshore water elevation levels and temperature. The adjustments made to these key components are discussed in the sections below.

Precipitation

The statistical characteristics from the NARCliM 1.5 precipitation data were extracted from the NARCliM data portal and used to generate a future (2056) precipitation time series that represents climate change under a medium impact scenario. This time series was generated at virtual rainfall stations in the catchment, which are located at the centroid of each sub-catchment represented in the Source catchment model.

The methodology for generating the future climate change precipitation data was based on the approach by Lam and Liu (2024) and is summarised in Figure 4-5. It involves approximation by adjusting the original virtual rainfall time series based on statistical characteristics. The six datasets from Global Climate Model (GCM) and corresponding Regional Climate Model (RCM) combinations that are outlined within Table 4-2 were used to extract the statistical characteristics from the NARCliM 1.5 data.

The 'Bias corrected precipitation' data datasets were downloaded from the NSW Climate Data Portal in NetCDFs format for each year from 1994 - 2071. The datasets have a seasonal frequency, meaning that each data point represents the average rainfall for each season of that year. Each data point represents 10 km-spaced grid points located in South-East Australia. The data process procedure was undertaken in the coding language MATLAB.

The detailed climate change approach for precipitation can be found in the GPOP EIS climate change assessment memo (refer to Appendix B).

Table 4-2 GCM and RCM combinations

GCM	RCM	
	R1	R2
Driving GCM CSIRO BOM ACCESS 1.0	✓	✓
GCM CCCma CanESMM2	✓	✓
GCM CSIRO BOM ACCESS1.3	✓	✓

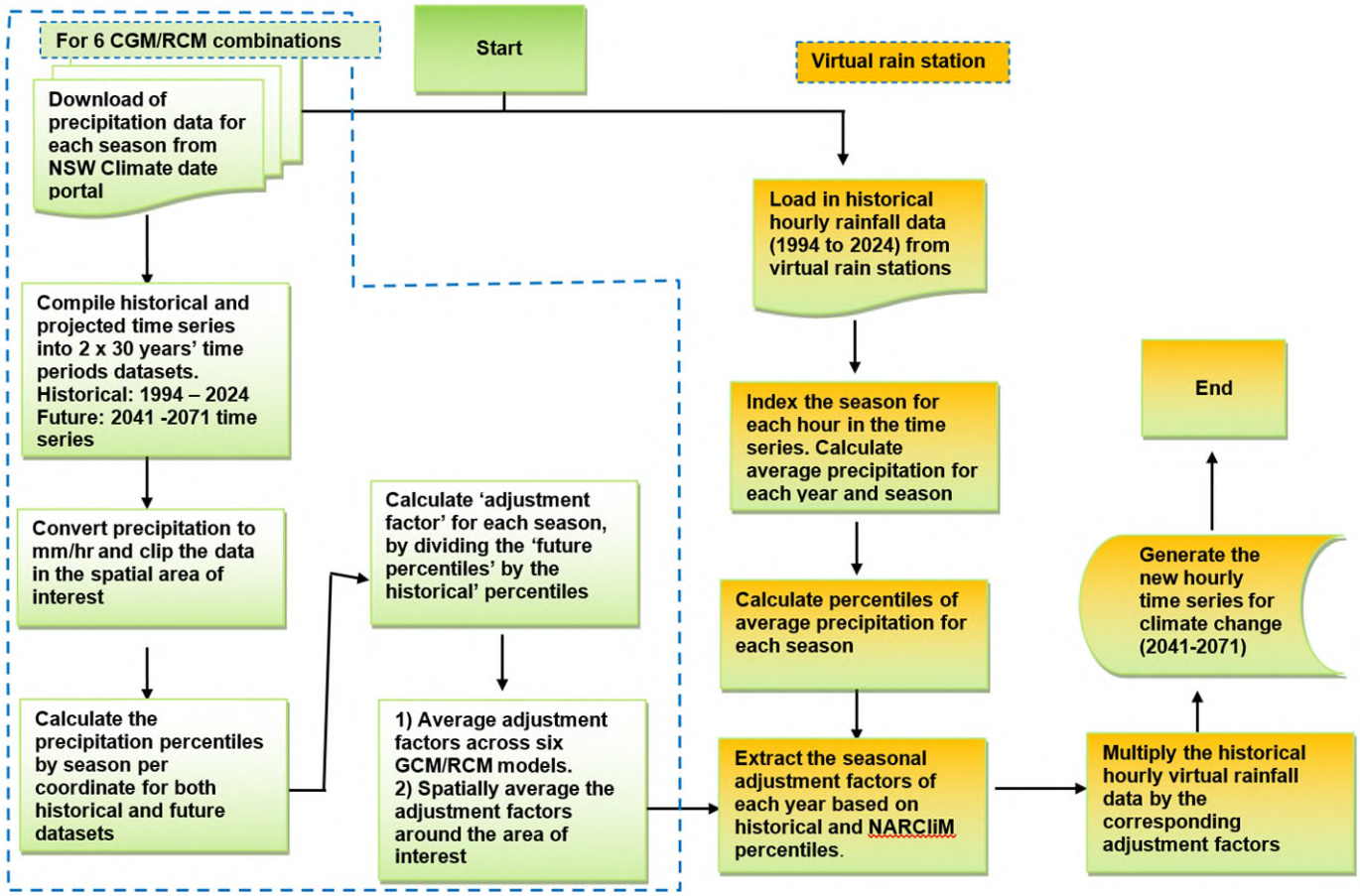

Figure 4-5 Precipitation climate change approach

Potential Evapotranspiration (PET)

The methodology for generating the future climate change PET data was also based on the approach by Lam and Liu (2024) and is summarised in Figure 4-6. PET data are not available from the NARCliM 1.5 datasets. Therefore, PET was estimated based on relevant variables that are available within NARCliM 1.5. PET is affected by a number of key factors, mainly temperature, wind and radiation. Temperature was adopted as the key factor, with the other factors possessing a co-relationship with temperature. As the effect of PET on WQRM performance is minor, an approximate relationship between the PET and change in

temperature due to climate change was considered adequate to account for the effect of climate change on PET. On this basis, PET has been estimated in line with the equation below.

$$PET_{future} = PET_{current} + \frac{12.711}{24 \times No.of\ days\ in\ a\ month} \times \Delta T\ at\ each\ time\ step \qquad \text{Equation (1)}$$

where ΔT is the change in average mean daily temperature. The average mean daily temperature has been estimated for the existing time series data period (2010-2024) and the future time series data period (2049-2063), centring at 2056.

The six datasets from the Global Climate Model (GCM) and corresponding Regional Climate Model (RCM) combinations contained in Table 4-2 were used to extract the statistical characteristics from the NARCliM 1.5 data. The detailed climate change approach for PET can be found in the GPOP EIS climate change assessment memo (refer to Appendix B).

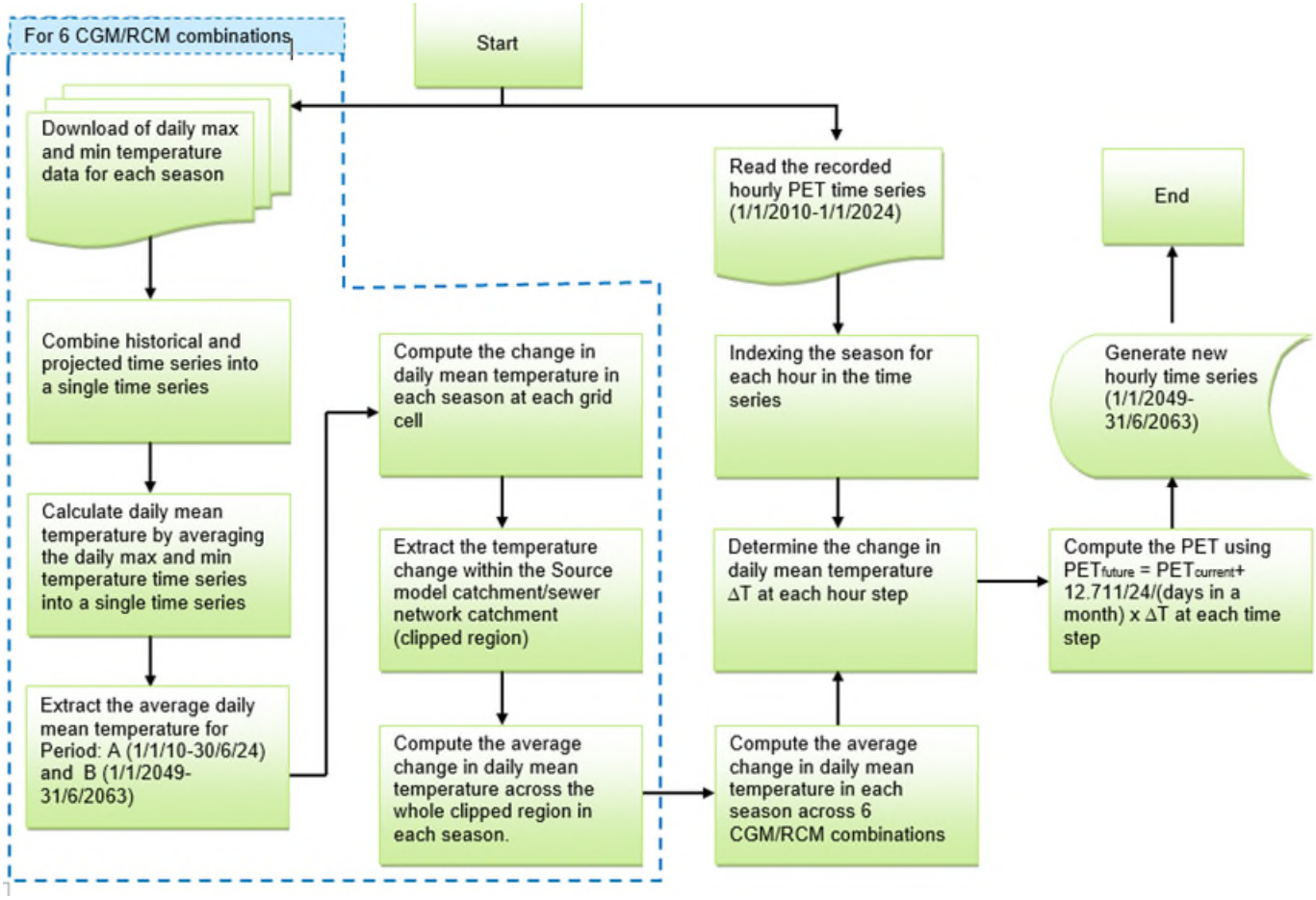

Figure 4-6 PET climate change approach

Tidal boundary levels

The tidal signal for the Fort Denison tide gauge was adjusted relative to 2023/24 by 0.16 m so as to represent forecasted sea level rise for the 2056 planning horizon. The increase in tide levels is based on interpolation between forecasts assuming RCP 4.5.

In addition to this adjustment, analysis was undertaken to verify if there were additional areas which should be included in the model domain to account for tidal inundation under climate change conditions. From this analysis, it was determined that the extents of predicted inundation were generally very limited. It was

further assumed that intervention measures would be applied to retain the existing shoreline boundary. Based on these findings, no additional areas were included within the model mesh.

Temperature

Table 4-3 lists the temperature parameters which were adjusted in the WQRM in line with NARCliM 1.5, RCP 4.5 datasets.

Table 4-3 Climate change temperature parameters

Season	Air Temp °C	Sea Temp °C	Catchment inflow temperature °C	Relative humidity % Change from existing)
Summer	1.02	1.10	1.10	1.00%
Autumn	0.82	1.11	1.11	0.70%
Winter	0.93	1.10	1.10	-0.90%
Spring	1.25	1.13	1.13	1.60%

In addition to the above adjustments, an increase in solar radiation of ~0.6% was applied (CoastAdapt, 2024).

With respect to the data presented in

Table 4-3, determination of the potential changes in the temperature of catchment inflows was considered challenging given the complexity of flows from pipes, channels, creeks, etc. However, as outlined in the data, ambient air temperatures are predicted to increase by a similar magnitude to those prescribed for the sea, therefore the same level of increases were applied to the catchment inflows as per sea temperature.

4.5.4.2 Camellia-Rosehill WRRF and river releases

The following sections outline the flow and water quality assumptions adopted to represent the releases from the Camellia-Rosehill WRRF for each of the modelled scenarios detailed in Section 4.5.3 and for the simulation periods outlined in Section 4.5.3.5. Based on these assumptions, continuous daily flow and concentration time series for analytes of interest were developed for the modelled simulation periods.

Proposed Camellia-Rosehill WRRF staging and time horizons

The Camellia-Rosehill WRRF would likely be delivered in several stages as a response to capacity constraints in the NSOOS and growth in the servicing area, as detailed in Table 4-4. The timing of future upgrades at the Camellia-Rosehill WRRF would align with population growth forecasts and changes in the servicing area.

For the purpose of this assessment, modelling scenarios are based on a single stage ultimate flow, i.e., a WRRF capacity of 70 ML/d.

Table 4-4 Proposed Camellia-Rosehill WRRF staging

Stage	Description
Current project	The operational capacity of this initial stage of the Camellia-Rosehill WRRF is 70 ML/d. The project includes: • Build and operation of the WRRF to treat up to 70 ML/d • Construction of river release and brine pipelines to cater for volumes generated by the WRRF operating at up to 150 ML/d (but only operating them to transport and release volumes associated with the WRRF operating at 70 ML/d capacity) • Construction and operation of transfer pipelines to cater for up to 70 ML/d flow at the WRRF
Future stages	The WRRF has been designed to allow flexibility to expand for greater treatment capabilities along with GPOP growth projections, and for upgrades in the future to support water recycling for drinking, and potentially, a recycled water network. Given the river release and brine pipelines will be built to their ultimate capacity as part of the current project, future stages may only require the transfer pipeline and the process units of the Camellia-Rosehill WRRF to be expanded in response to increased servicing demand. Current growth projections suggest the ultimate capacity of the Camellia-Rosehill WRRF could be 100-150 ML/d. The timing and size of these stages will be established over time to align with growth in the area and changing treatment technology. The Camellia-Rosehill WRRF has been designed to produce advanced treated water with space allowed for additional water treatment components (ultraviolet, ultrafiltration, and advanced oxidation) to be adaptable to a circular economy future.

Proposed treatment and release streams

The WRRF will treat wastewater transferred from the existing Camelia pumping station and operate 24 hours a day, 7 days a week.

The outflow will generally follow the inflow to the RO treatment plant. Generally, the inflow to the RO plant will operate at a constant rate, such that a constant source of advanced treated water will be produced by the RO plant. There will be a storage tank connected to the RO treatment plant such that the pump can adjust its speed and operation based on the adopted pump control. Some flow interruptions can be expected, but generally a constant outflow can be assumed for modelling for 24 hours per day.

The Camellia-Rosehill WRRF would primarily produce advanced treated water, which would be discharged to the Parramatta River. In the rare event that the advanced treatment process equipment is offline (planned or unplanned outage/maintenance), tertiary treated water would be released instead. The RO treatment plant has been assumed to operate with approximately 99% reliability for river release performance, based on the RO outage risk assessment undertaken.

RO offline events have been represented in the treated water time series as two 48-hour offline events per year, occurring during consecutive dry months. This is considered achievable for a river release application. RO offline events have been assumed to occur during dry rainfall periods as the likely reason for an unplanned RO shutdown would be a build-up of pressure due to membrane fouling not being adequately under control. The reasons for membrane fouling include abnormal sulfate, calcium, or temperature, which are likely to occur during dry weather, representing the worst-case impact.

During normal operation, all advanced treated water would be released to the Parramatta River. Brine is a highly concentrated solution of salt and is a by-product of the reverse osmosis technology applied in the WRRF treatment process, and will be transferred to Sydney Water's NSOOS and treated at and ultimately discharged via North Head WRRF.

Brine is typically produced at a rate of 10-20% of the treatment flows. To ensure a conservative approach has been undertaken, 10% brine production has been used for calculation of advanced treated water to Parramatta River for the purpose of assessing the greatest impact of releases on the receiving waterway. Conversely, for the purpose of asset sizing for brine transfer infrastructure, 20% brine production to return to the NSOOS is assumed.

The proposed release streams and associated levels of treatment that are currently being considered for the Camellia-Rosehill WRRF are summarised below in Table 4-5. A high-level schematic diagram of Camellia-Rosehill WRRF treatment and release system is presented in Figure 4-7.

Flow estimates for the simulation periods are presented as time series in Figure 4-8. The daily flow estimates presented in Figure 4-8 align with the proposed release conditions presented in Table 4-5. The spikes in the discharge in Figure 4-8 represent the RO offline releases (MBR quality), assumed to occur during dry rainfall periods.

Table 4-5 Camellia-Rosehill WRRF release conditions

Release type	Flow (ML/d)	Release volume (ML/y)	Treatment	Release location	Justification
River release	63	~22,743	Reverse osmosis (RO)	Parramatta River	Continuous river release, 24 hours per day, (729 L/s), except when RO plant is offline.
RO-offline releases	70	~280	Membrane bioreactor (MBR)	Parramatta River	Constant discharge occurring during RO-offline events. RO treatment plant is assumed to operate with approximately 99% reliability for river release performance, based on an RO outage risk assessment undertaken. This has been represented as two 48-hour offline events per year, conservatively assumed to occur during consecutive dry months. Refer to Figure 4-8 for assumed timing of offline events.
Brine[1]	7	-	Treated at North Head WRRF	Transferred to the NSOOS	Assuming RO recovery of 90%

Table notes:

[1]Advanced treated water process also produce brine as a by-product, resulting in around 10-20% less treated water production. Tertiary treatment only does not produce brine, resulting in release of maximum volume of tertiary treated water.

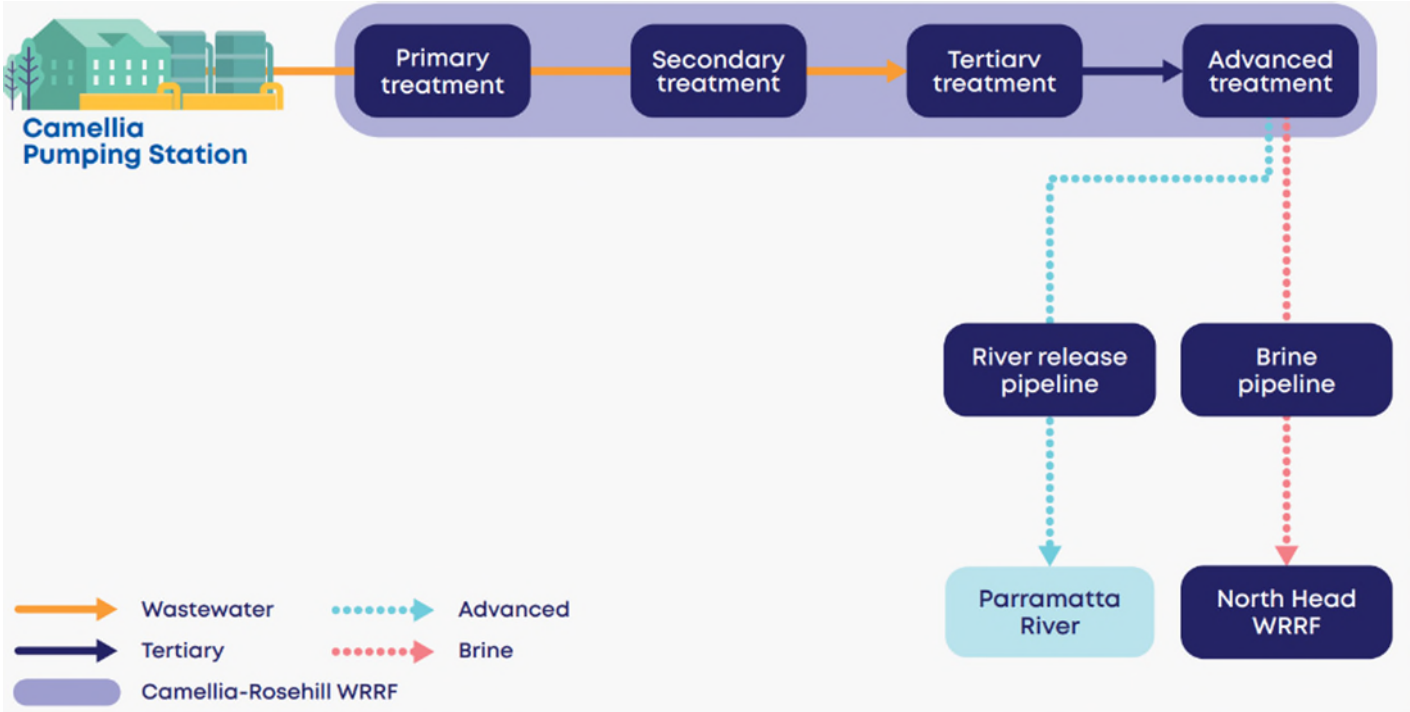

Figure 4-7 Schematic diagram of Camellia-Rosehill WRRF treatment and release system

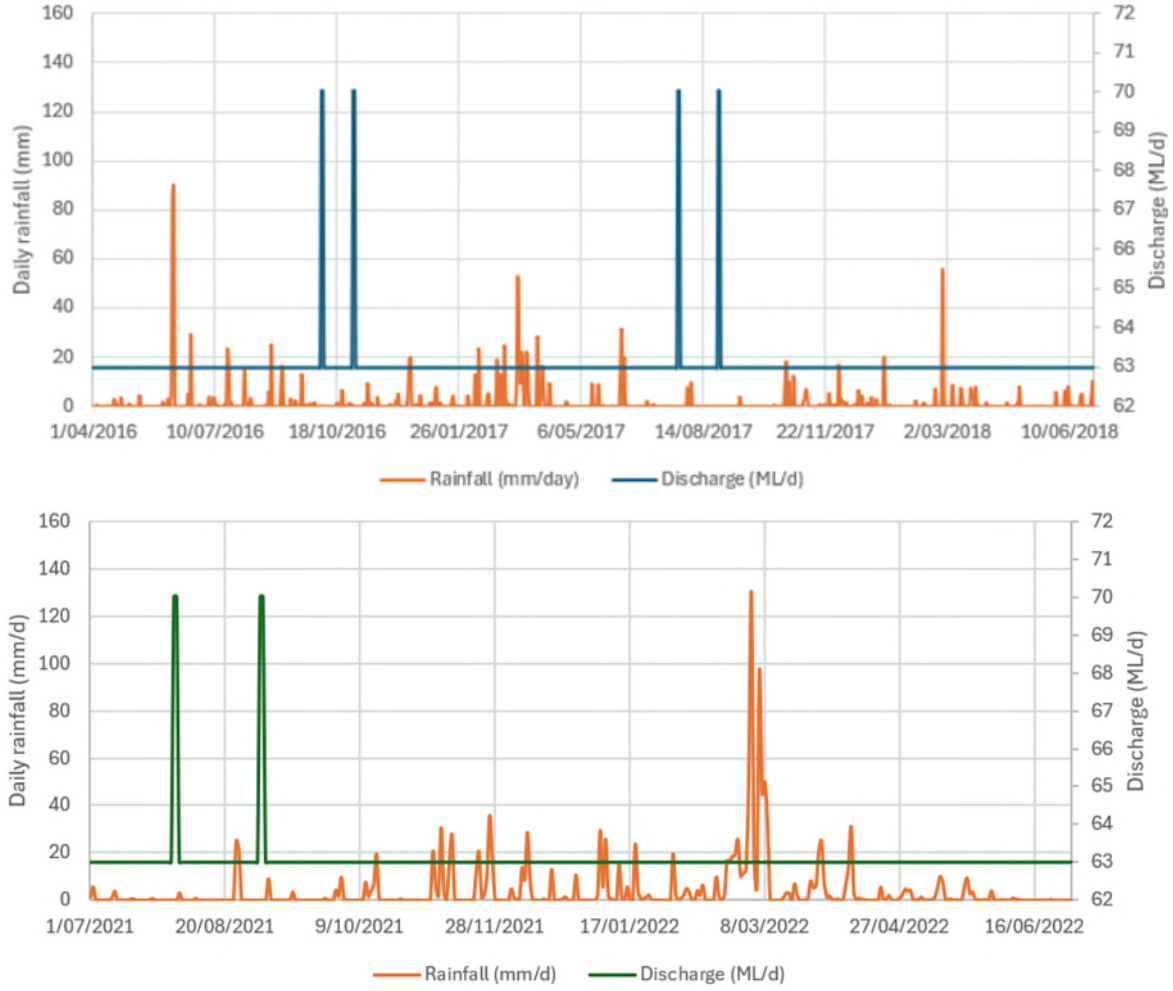

Figure 4-8 Daily discharge for dry-average (1/4/16 – 30/6/18) and wet (1/7/21 – 30/6/22) simulation periods. Rainfall data sourced from SILO Long Paddock patched point grid data (latitude of -33.75, longitude of 150.75).

Treated water quality

The anticipated treatment performance of the WRRF was derived from various sources including:

- Monitoring data from similar treatment plants operated by Sydney Water, e.g., St Marys AWTP
- Camellia-Rosehill WRRF Reference Design Report
- Parramatta River Feasibility Study (Sydney Water, 2023a)
- Advice from Jacobs Group Pty Ltd. (Jacobs) (provided on 9th April 2025)

The median water quality concentrations assumed for the release streams to the Parramatta River are presented in Table 4-6.

While Table 4-6 presents the median expected concentrations for the release streams, it was acknowledged that there would be variability in the treatment processes and consequently the concentration of the river releases over time. To provide a representation of the expected daily variability, modifications to the boundary condition time series for the river releases were made to allow for expected ranges in each water quality parameter.

Table 4-6 Indicative concentrations of water quality under different treatment levels

Parameter	Units	Median concentrations	
		Advanced treated water (RO)	Tertiary treated water (MBR)
Flow	ML/d	63	70
TOC	mg/L	0.5	10
TN	mg/L	0.35	3
Org N	mg/L	0.1	1.2
Ammonia	mg/L	0.03	0.2
NOx	mg/L	0.22	2.5
Nitrate	mg/L	0.1	2.5
TP	mg/L	0.009	1
Inorganic P	mg/L	<0.002	0.002
FRP	mg/L	0.006	0.66
Org P	mg/L	0.003	0.338
DO	mg/L	6	5.9
Enterococci	cfu/100ml	0	0
TSS[1]	mg/L	4	1
Salinity	PSU	0.08	0.75
Temperature	(°C)	23.20	23.20

Table notes:

[1]TSS concentration is higher in advanced treated water than tertiary treated water due to the addition of lime for pH stabilisation following RO treatment.

4.5.4.3 Wet weather overflows

Overflows from the wastewater networks are considered as significant point sources of untreated wastewater within the Parramatta River and Sydney Harbour. Overflows of this nature generally occur during wet weather events when the wastewater collection and transfer systems reach capacity.

Wet weather overflows are modelled by Sydney Water using the MOUSE platform, with updates to the models undertaken annually with calibration against available field data. The MOUSE software has been applied in the development of Sydney Water's Sewage Treatment Systems (STS) models. The results from these models provided a 15-minute interval time series of sewer overflows at various overflow points within the sub-catchments flowing to the Parramatta River and wider Sydney Harbour. Overflow time series results were extracted from the Bondi, Malabar and North Head wastewater systems as the project domain falls across all these network domains.

Different versions of these STS models are available for current catchment conditions (circa 2024) and future scenario catchment conditions based on a 2056 population equivalent. The future scenario models incorporate source control measures planned by Sydney Water up to 2030. Sydney Water will continue to

improve the performance of wet weather overflows beyond 2030, however, the location of these source control measures beyond 2030 is currently unknown and therefore cannot be modelled.

For the baseline scenario, the current catchment condition models were updated to include rainfall and PET data for the average, dry and wet years outlined in Section 4.5.3.5 and simulated to generate a time series of flows at each overflow location.

For both background scenarios, the network models representing a 2056 population equivalent were updated to include the rainfall and PET data for the average, dry and wet years for both current climate conditions and including RCP 4.5 climate change predictions. The models were simulated to generate separate time series outputs of flows at each overflow location for background (with and without climate change).

The operation of the Camellia-Rosehill WRRF impacts on the overflows within the North Head STS model only, with the WRRF mining flows from this system. Therefore, for the impact scenarios, only the North Head STS model was simulated to reflect the mining of flows. The model was simulated both with and without climate change, to generate a time series of flows at each overflow location in this system.

A comparison of the release volumes from the overflows for the different scenarios is provided in Appendix C with a sample of the results from the North Head STS model presented for a representative average rainfall year in Figure 4-9 below. The maps show the impact of the various scenarios at release structures which discharge the largest volumes and demonstrate the impact of the planned network upgrades and the Camellia-Rosehill WRRF on release volumes to the receiving waterways.

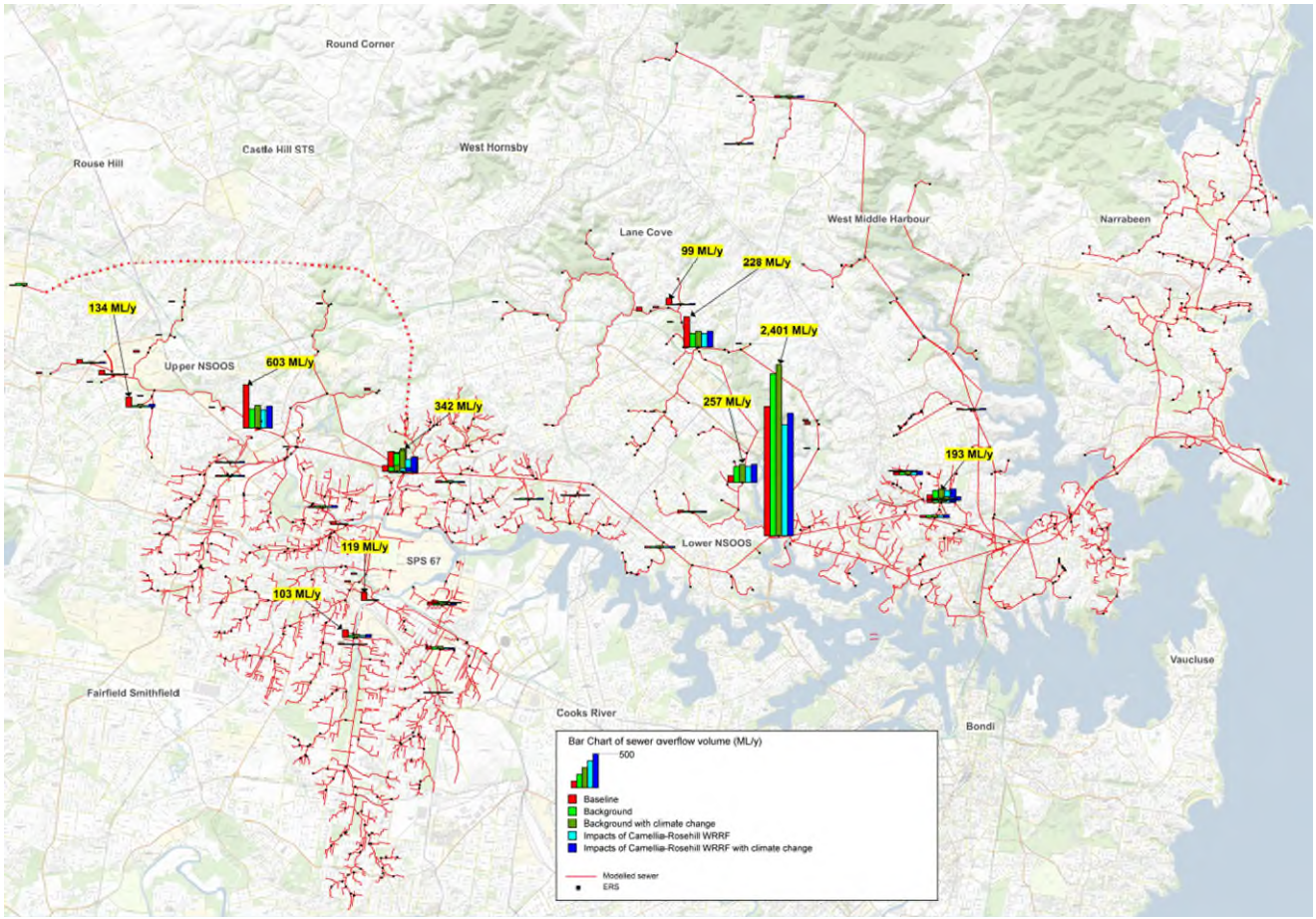

Figure 4-9 Overflow volumes for the scenarios in an average rainfall year from North Head STS model

To characterise the water quality of the overflows, the dilution-based approach referred to in Section 4.3.5.3 was used. The overflows were then included as boundary conditions in either the GPOP WQRM or the Source catchment model, depending on their geographic location. More specifically, if an overflow point was located in a sub-catchment immediately adjacent to the WQRM model mesh, the overflow was incorporated as a direct input to the WQRM. However, if the overflow was located in a sub-catchment not immediately adjacent to the model mesh, then the overflow was incorporated into the relevant Source model.

4.5.4.4 Catchment rainfall runoff

The calibrated versions of the Source catchment models were used as a basis to generate catchment rainfall runoff flow and contaminant load time series inputs to the WQRM for all five scenarios. The updates to the models varied across the scenarios and included changes to wet weather overflows and changes to rainfall and PET to represent climate change predictions as summarised in Table 4-1. An assessment of the potential impact of stormwater quality treatment systems on rainfall runoff and contaminant loads under a 2056 planning horizon was also undertaken.

As the majority of the catchment is already urbanised, the assessment of stormwater quality treatment systems focussed on identified growth areas within the catchment with data on these growth areas sourced from Sydney Water Urban Growth Intelligence (UGI) data and the State Environmental Planning Policy (SEPP) online repository. The Model for Urban Stormwater Improvement Conceptualisation (MUSIC), a software tool that simulates the behaviour of stormwater in urban catchments and helps to understand the performance of stormwater quality treatment systems, was used to complete the assessment.

The MUSIC model was set up for the growth areas with both existing land use and land use representing the expected development in 2056. It was assumed that the new developments within these growth areas will comprise of infill and urban renewal. Assumptions pertaining to the imperviousness, event mean concentration and dry weather concentration of contaminants within the MUSIC model were based on adopted parameters for the Source catchment model.

As a first step, the model was tested with land use changes only to determine the impact of these land use changes on nutrient loads. The need to represent water quality treatment systems within the MUSIC models and subsequently, the Source catchment models, was only considered where the change in nutrient loads (kg/yr) under the future development scenario compared to the existing conditions was considered large, i.e., greater than 5%.

The model was simulated for the average, dry and wet years outlined in Section 4.5.3.5 and the model results compared between existing and future scenario conditions. The model results indicated that for the wet, average and dry years, the difference between TN and TP loads (kg/yr) is less than 1% across all three climatic years. Based on these results, it was decided that there was no need to develop a future 2056 land use layer or to represent water quality treatment systems within the Source catchment model.

4.5.5 Scenario analysis and interpretation

4.5.5.1 Approach

The assessment of impacts consistently involved comparison of results from the following scenario types:

- a baseline scenario representing current (circa 2024/25) catchment conditions, without river releases from the Camellia-Rosehill WRRF

- a background scenario representing 2056 catchment conditions but without the river releases from the Camellia-Rosehill WRRF
- an impact scenario representing 2056 catchment conditions with river releases from the Camellia-Rosehill WRRF.

In addition to the comparative analysis against baseline and background conditions, relevant waterway objectives were also included in the plotting of the results. As discussed in Section 2.2, these objectives include guideline values from a range of relevant guidelines, including ANZG (2018), ANZECC/ARMCANZ (2000), NHMRC (2008), etc.

4.5.5.2 Parameters

The impacts were assessed for a range of hydrodynamic and water quality parameters necessary to assess the relevant waterway objectives (refer Section 2.2) and address the SEARs requirements (refer Section 3). These parameters are listed below:

- Hydrodynamics
  - Flow and velocity
  - Water level
- Water quality
  - Salinity
  - Temperature
  - Nitrogen (including ammonia, oxidised nitrogen, total nitrogen)
  - Phosphorus (including filterable reactive phosphorus, total phosphorus)
  - Chlorophyll *a* (adopted as a primary indicator of phytoplankton abundance and biomass)
  - Total suspended solids
  - Dissolved oxygen
  - Enterococci (adopted as a primary indicator of pathogens).

Near field impacts relating to toxicants and contaminants of concern that may pose a risk of non-trivial harm to human health and the environment were assessed separately as part of a near field impact assessment. The models and the assessment approach adopted in this assessment are described in Section 4.6.

4.5.5.3 Formats

The impacts from the operation of the WRRF were assessed from upstream of the releases to the full downstream spatial extent of the WQRMs using three different formats.

- Bar charts of annual nutrient loads
- Longitudinal profiles (or bar charts) of annual median and 80th percentile concentrations
- Time series plots of hourly concentrations

Load analysis

Analysis of nutrient and pathogen loads has been undertaken to allow a comparison of the contributions from catchment runoff, wet weather overflows and the WRRF river releases across all the scenarios. The loads were estimated through analysis of the model boundary conditions for each scenario, and for all three representative rainfall years independently. The load analyses were completed for the catchment area that

extends from the uppermost boundary of the Parramatta River catchment, downstream to Cockatoo Island. A sample load analysis plot is presented in Figure 4-10.

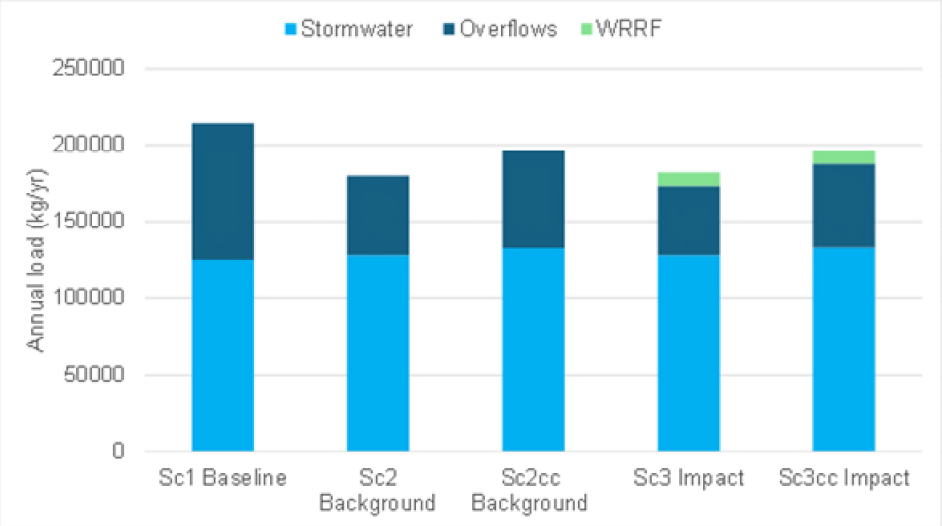

Figure 4-10 Example load analysis plot for total nitrogen

Longitudinal profiles

Longitudinal profile plots of annual median concentrations and 80th percentile concentrations for the baseline, background and impact scenarios were prepared along the spatial extent of the modelled waterways from Charles Street Weir (chainage 0 km) to the heads of Sydney Harbour (chainage 33 km). The concentrations in these profiles are representative of a mid-water column depth (i.e. the model results were extracted from the central vertical layer within the model domain).

Where applicable, the longitudinal plots also included the relevant waterway objectives (i.e. DGV) for each parameter. The waterway objectives are of particular relevance to the annual median results as they represent the appropriate statistical measure for comparison to these guideline values.

Kilometre markers with a distance relative to the upstream limit of the WQRM at Charles Street Weir are included on the x-axis of these profiles along with the location of the release point at John Whitton Bridge (chainage 8.4 km). The longitudinal profiles present the predicted annual median values for the relevant simulated rainfall year and were prepared for each of the aforementioned water quality parameters.

A sample longitudinal annual median plot is presented in Figure 4-11.

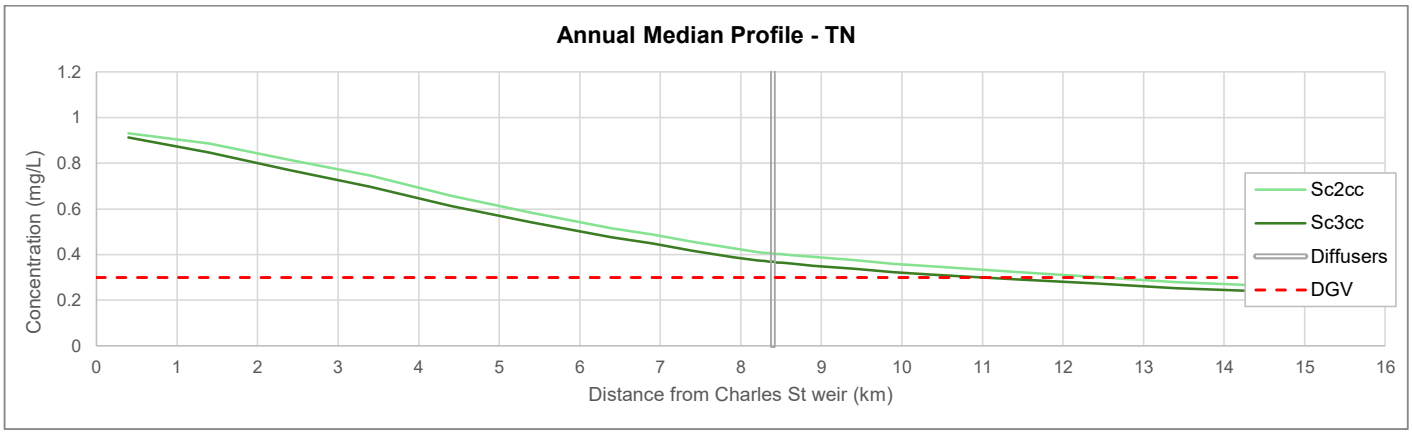

Figure 4-11 Example longitudinal annual median profile plot

Bar charts

For the analysis of sites representing sensitive environments (refer Section 5.4), bar charts of annual median concentrations and 80th percentile concentrations for the baseline, background and impact scenarios were prepared.

A sample annual 80th percentile bar chart is presented in Figure 4-12.

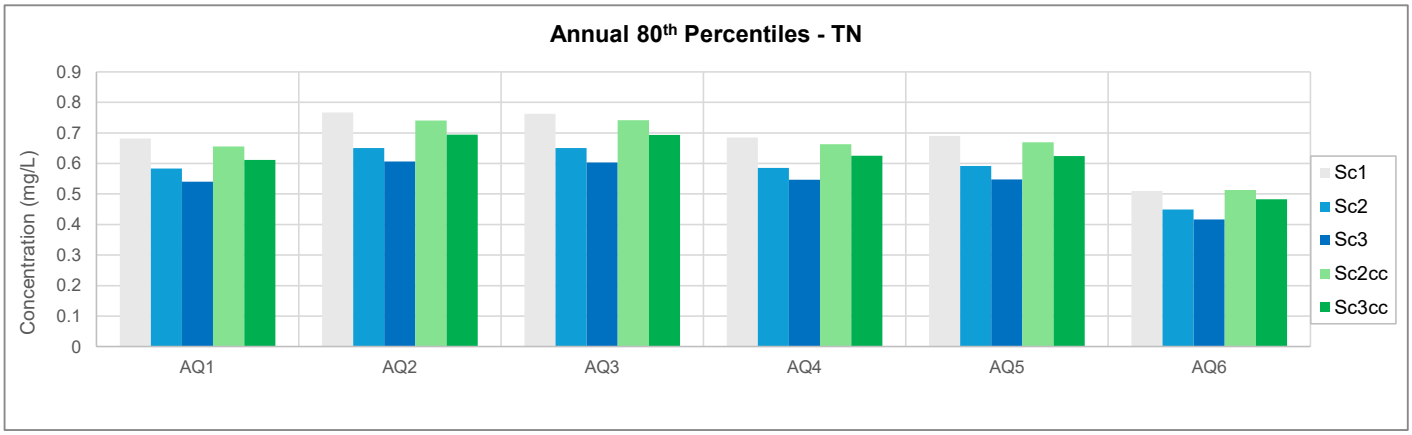

Figure 4-12 Example annual 80th percentile bar chart

Time series plots

Time series plots showing the baseline, background and impact scenario results were prepared at selected analysis sites in the receiving waterways. 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 4.5.3.5. The concentrations in these plots are again representative of a mid-water column depth, with the exception of the analysis for recreational activities, where the plots were representative of the higher water column.

The time series data also included the relevant waterway objectives for each parameter, where applicable. An example time series plot is presented in Figure 4-13.

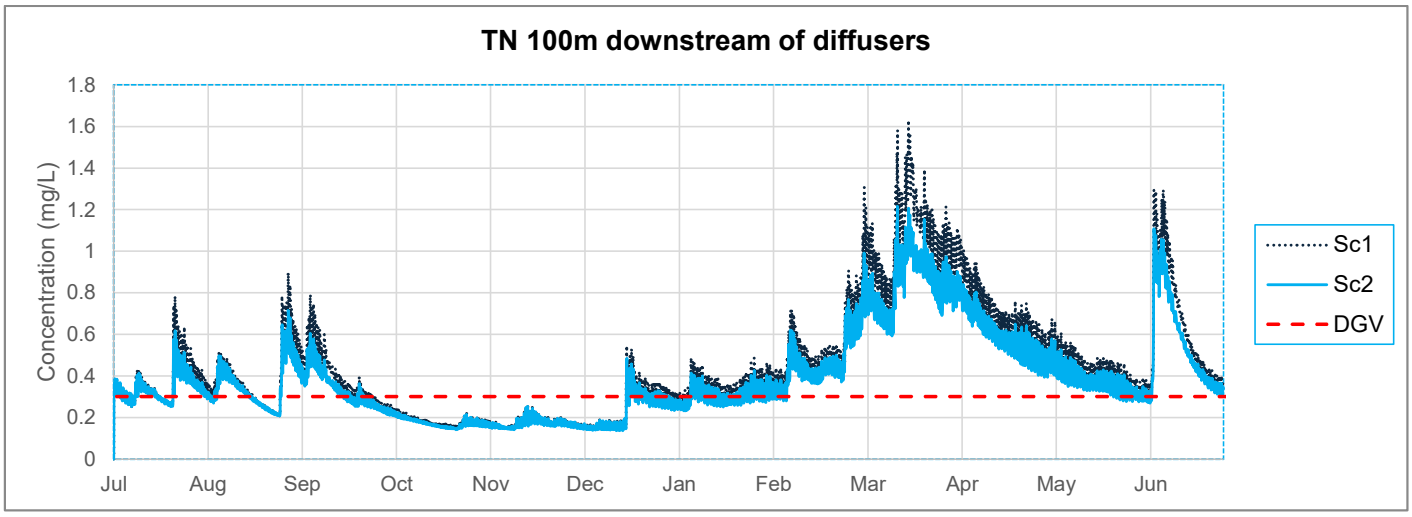

Figure 4-13 Example time series plots

The analysis sites were selected to provide a representative picture of the impacts upstream and downstream of the proposed release point and at the sensitive environments discussed in Section 5.4.

4.6 Near field and toxicity modelling

4.6.1 Scenario testing approach

The near field modelling and impact assessment followed the stepped approach outlined below:

- analysis of proposed release conditions to determine contaminants of concern that may present a risk of toxicity or environmental harm
- analysis of the characteristics and hydrodynamics of the waterway in the immediate vicinity of the release point
- evaluation of the dilution requirements for each contaminant of concern based on the expected release concentrations, background ambient conditions and the relevant guideline values
- near field modelling of the initial dilution and mixing processes with consideration of the expected range of release rates and ambient flow conditions
- assessment of the size and configuration of mixing zones, if required, in line with the ANZG (2018) and ANZECC/ARMCANZ (2000) technical guidelines
- in line with the NSW Guide to Licensing (DECC, 2009), appropriate measures are to be made to consult with the EPA as soon as possible, if a mixing zone is to be proposed.

Consistent with Appendix 1 of Volume 2 of the ANZECC/ARMCANZ (2000) guidelines, the mixing zone and near field assessments have been restricted to soluble, non-bioaccumulatory contaminants.

4.6.2 Model development

With an emphasis on the steady-state simulation of plume geometries and initial dilution characteristics, the CORMIX software applied in the near field impact assessments consists of a series of algorithms for characterisation, analysis and prediction of near field mixing. To inform the application of these algorithms, a suite of datasets was acquired so the GPOP river releases could be simulated realistically in the near field.

The datasets included the following fundamental groups:

- Release conditions including configuration of the proposed release infrastructure, release depth, release rates, treated water density and contaminant concentrations.
- Ambient conditions of the receiving waters including details of bathymetry, ambient flow rates, background contaminant concentrations and ambient density.

A summary of these datasets is provided below with further details regarding the scenario conditions and assumptions included in Section 6.2.1.

4.6.2.1 Release conditions

The release conditions were derived from analysis of the WQRM scenario boundary conditions. Additional characterisation of the release conditions was undertaken through analysis of relevant monitoring data as well as the reference design drawings of the release infrastructure.

With respect to release quantity, the expected release rates were determined from analysis of the boundary conditions as assumed in the WQRM scenarios. These release rates ranged from 63 to 70 ML/d dependent on the operational status of the WRRF (refer Sections 4.5.4.2 and Table 4-7).

With respect to release water quality, as an initial step to determine the likely presence and potential concentrations of contaminants of concern in the release streams, analysis was undertaken of treated water quality data collected over the period 2011-24, at the following Sydney Water facilities:

- advanced treated water quality data from the St Marys AWTP
- tertiary treated water quality data from the Penrith, St Marys and Rouse Hill WRRFs.

These facilities incorporate similar treatment processes as those proposed for the Camellia-Rosehill WRRF. The 50th and 90th percentile values from the monitoring data were then compared to values estimated for the reference design and adjusted as applicable, including adding factors of safety to allow for variations in influent quality.

For the purposes of this assessment, analysis of 90th percentiles was undertaken. Consequently, if the 90th percentile for any parameter was determined to exceed the relevant toxicant DGV, it was considered as a potential contaminant of concern (i.e. non-trivial).

From this analysis, two contaminants of concern were identified for the advanced treated water, and due to the lower level of treatment, an additional four were identified for the tertiary treated water.

The potential contaminants of concern for each release stream are listed below:

- Advanced treated water
  - Total Chlorine
  - Copper
- Tertiary treated water
  - Total Chlorine
  - Nitrate
  - Aluminium
  - Copper
  - Mercury
  - Zinc

The concentrations derived from the analysis are presented in Sections 4.6.3 and 6.2.3.

4.6.2.2 Ambient conditions

The ambient conditions assumed for the Parramatta River were derived as follows:

- Bathymetric data in the vicinity of the proposed release points was acquired from survey data collected by Sydney Water in 2024 using multibeam echo sounders.
- Flow rates in the vicinity of the diffuser were determined from analysis of the WQRM model results. Velocities and flows were extracted from locations representative of the proposed release points. The ranges of these flows are presented in Sections 4.6.3 and 6.2.1.
- Background concentrations for the selected contaminants of concern were determined from median analysis of the baseline monitoring data. Data from surface samples at John Whitton Bridge from September 2024 to July 2025 was used for the analysis. The adopted background concentrations are presented in Sections 4.6.3 and 6.2.3.

4.6.3 Scenario descriptions

A suite of scenario conditions was developed to allow simulation of a range of releases that could present a risk of toxicity or environmental harm to the waters in the immediate vicinity of the river releases. The scenario conditions tested in the near field modelling were therefore defined based on the expected ranges of these potentially harmful release conditions, as well as the ambient hydrodynamic conditions expected in the receiving waterways.

These ranges were determined through the aforementioned analysis of the WQRM scenario conditions, monitoring data and the reference design for the treatment plant and diffuser. Table 4-7 and Table 4-8 present a summary of the scenario release and ambient tidal flow conditions.

With respect to water quality of the releases and the receiving waters, representative values for the relevant toxicants are presented in Table 4-9 and Table 4-10 for the advanced and tertiary treated water releases respectively.

Table 4-7 Near field scenario – release flow conditions (circa 2056)

Release scenario	Release flow (m^3/s)
Advanced treated water	0.729
Tertiary treated water	0.810

Table 4-8 Near field scenario – ambient flow conditions

Tidal scenario	Ambient velocity (m/s)
Slack tide (5^{th} percentile)	0.024
Median tide (50^{th} percentile)	0.125
Peak tide (95^{th} percentile)	0.243

Table 4-9 Near field scenarios - water quality conditions (advanced treated water)

Contaminant	Toxicant DGV	Treated water quality[1]	Background water quality[2]
Total Chlorine (mg/L)	0.0072	0.01	0
Copper (µg/L)	1.3	1.4	1.6

Table 4-10 Near field scenarios - water quality conditions (tertiary treated water)

Contaminant	Toxicant DGV	Treated water quality[1]	Background water quality[2]
Nitrate (µg/L)	2.6	4	0.01
Total Chlorine (µg/L)	0.0072	0.01	0
Aluminium (µg/L)	37	285	12
Copper (µg/L)	1.3	12	1.6
Mercury (µg/L)	0.1	0.2	0.01
Zinc (µg/L)	8	66.5	6

Table notes

1. *Values for metals are estimated filtered values based on monitoring data from other treatment plants and reference design.*
2. *Median data from surface samples taken from sampling point adjacent John Whitton Bridge (PRMB02_3333 Sept 2024 to July 2025). Values for metals are filtered values.*

4.6.4 Analysis and interpretation

4.6.4.1 Approach

As outlined above in Section 4.6.1, the near field assessments followed a stepped approach including comparison of the modelling results for initial dilution and mixing against the dilution requirements for each contaminant of concern. From this analysis, the size and configuration of any applicable mixing zone could be evaluated.

The following sections outline the format of the analysis and also the regulatory criteria relevant to mixing zones as presented in ANZG (2018) and ANZECC/ARMCANZ (2000).

4.6.4.2 Formats

Dilution requirements

The dilution requirements have been presented in tabular format for each contaminant of concern. These dilution factors were determined from the assumed maximum (90th percentile) treated water concentrations, the assumed background ambient concentrations and the relevant toxicant DGV. These dilution factors effectively represent the level of dilution required in the vicinity of the release point to reach each toxicant

DGV. The factors therefore represent the level of dilution required at the boundary of a regulatory mixing zone.

The equation used to calculate these factors is presented below:

$$Dilution\ Factor = \frac{(C_{WRRF} - C_{Back})}{(C_{DGV} - C_{Back})}$$

Where:

C_{WRRF} is the concentration of the treated water releases

C_{DGV} is the relevant Default Guideline Value

C_{Back} is the ambient background concentration

Dilution profiles

Dilution profiles generated from the CORMIX modelling were plotted against distance downstream of the release points. An example of these profiles is presented in Figure 4-14.

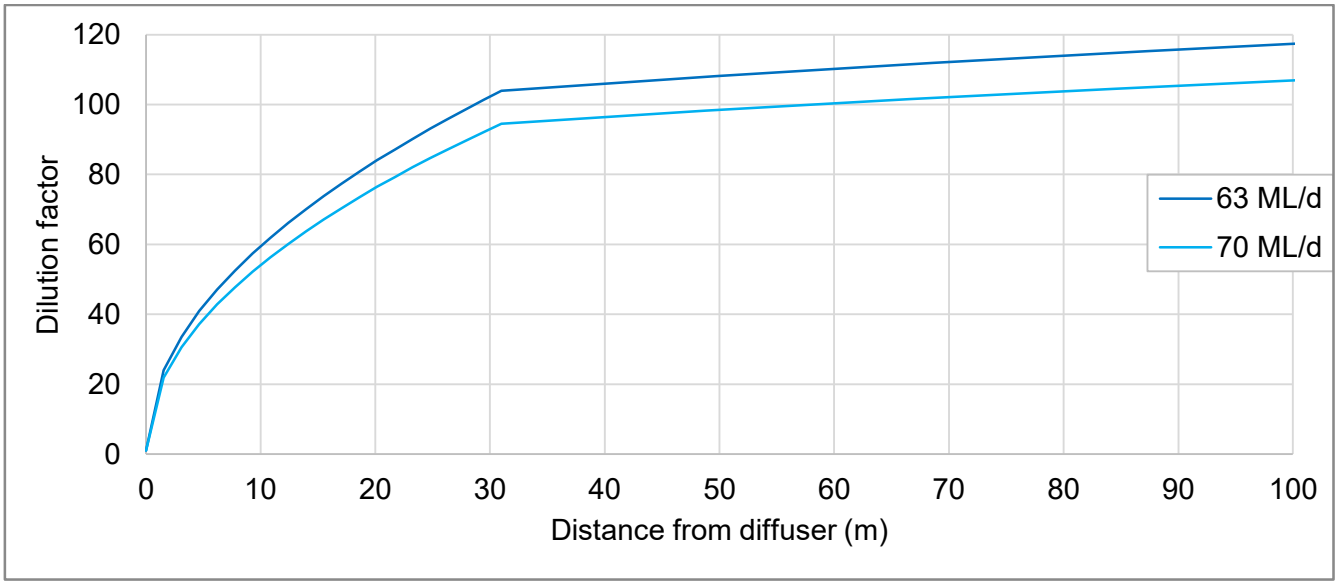

Figure 4-14 Example dilution profile

Mixing zone and plume analysis

Where applicable, the predicted size and configuration of the relevant mixing zones have been presented in tabular format. These results represent the predicted dimensions of a mixing zone where sufficient dilution has been realised to achieve concentrations on the zone boundary equal to the applicable toxicant DGV.

4.6.4.3 Mixing zone criteria

In the absence of NSW specific technical guidelines and assessment criteria relating to regulatory mixing zones, the assessment criteria adopted for this study has followed the principles and procedures presented in the ANZECC/ARMCANZ (2000) water quality guidelines, specifically Appendix 1 of Volume 2 which acts as a key information source regarding mixing zones.

From the guidelines, mixing zones are defined as: "*An explicitly defined area around an effluent discharge where effluent concentrations may exceed guideline values and therefore result in certain environmental values not being protected*."

For the purposes of this assessment, mixing zones have therefore been determined as the areas of the receiving waterways where the relevant toxicant DGVs are exceeded. In line with the analysis approach presented in section 7.4.4.2 of the ANZECC/ARMCANZ (2000) guidelines, the 90th percentile treated water concentrations of the toxicants are assumed. Adoption of this percentile allows for removal of outliers in the monitoring data and provides for a reasonable representation of the maximum levels expected in the release streams.

In the absence of NSW specific technical guidelines and assessment criteria relating to regulatory mixing zones, primary considerations as presented in the Queensland Government Technical Guideline (DETSI, 2024) have been adopted in the modelling assessments. These guidelines are considered to follow the principles and procedures presented in the ANZECC/ARMCANZ (2000) water quality guidelines.

Specifically, the following lateral and longitudinal dimensions of the mixing zones and potential interaction with banks and shorelines have been used as the principal three criteria. This is to determine whether the zones may be consistent or not with the principles of the ANZG (2018)/ANZECC/ARMCANZ (2000) guidelines:

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

4.7 Assumptions and limitations

Hydrodynamic and water quality modelling has been undertaken in line with accepted industry standard practices and the WQRM has been independently reviewed for the purposes of this EIS. With recognition of the findings documented in Sections 4 and 5 of the calibration report (refer Appendix A), the WQRM model is considered fit for purpose in its application for the impact assessment undertaken for the GPOP EIS.

However, in line with all similar impact assessment studies, the modelling undertaken for the EIS should be considered as a representative approximation to the real world and not without accepted levels of uncertainty. It should therefore be understood that each model is based on a series of assumptions, and also dependent on the accuracy of its input data. The model results should therefore be interpreted as indicative of impacts, responses and trends in the receiving waters and not absolutes.

Periodic briefings were held with DCCEEW and EPA throughout the project to provide updates on the model development and results. These sessions allowed for feedback at key stages of the assessment. In addition, the briefings facilitated discussions on key matters, including the use of NARCliM 1.5 for the climate change analysis, as explained in Section 4.5.4.1.

Further discussion regarding the levels of uncertainty and model limitations are presented in Sections 4 and 5 of the GPOP WQRM Calibration Report (Sydney Water, 2025b) (refer Appendix A). Sensitivity analysis relating to the boundary conditions has also been undertaken as part of the calibration process.

With respect to CORMIX, while the software is internationally recognised as a leading and proven modelling software, the aforementioned caveats also apply. The developers, MixZon Inc. also advise users regarding its accuracy and limitations, and that it should not be considered as exact science. Further guidance is also provided in relation to extensive comparisons that have been undertaken in relation to field and laboratory data.

5. Existing environment

The following sections provide an overview of the characteristics of the Parramatta River catchment and the estuary, including information on hydrodynamics and existing water quality conditions.

5.1 Data sources

5.1.1 Previous studies

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

- Parramatta River Estuary Data Compilation and Review Study (Cardno, 2008)
- Parramatta River Estuary Processes Study (AECOM, 2010)
- Sydney Harbour Estuary Processes Study (NSW LLS, 2018)
- Wet Weather Overflow Abatement project Sydney Harbour Model Calibration Report (Sydney Water, 2018)
- Parramatta River Masterplan Water Quality Modelling (Sydney Water, 2019)
- Parramatta River Releases Water Quality Modelling Assessment (Sydney Water, 2022)
- GPOP WQRM Calibration Report (Sydney Water, 2025b)
- Source models for the Parramatta River and Sydney Harbour Catchment (HARC, 2025).

5.1.2 Monitoring datasets

An extensive suite of monitoring datasets was compiled as part of the model development phase of this assessment. These datasets are described in detail in the GPOP WQRM Calibration Report (Sydney Water, 2025b) (refer to Appendix A). From this more extensive list, the following datasets were used to characterise existing water quality conditions within the estuary:

- Sydney Institute of Marine Science (SIMS) monitoring data (2012 to 2014)
- Sydney Water GPOP baseline monitoring data (2024 to 2025)
- Sydney Water Riverwatch monitoring data (2020 to 2025).

5.2 Catchment description

The Parramatta River catchment covers an area of 252 km^2, extending from Blacktown Creek in the west to its confluence with the Lane Cove River in the east. The main sub-catchments include: the Upper Parramatta River (upstream of Charles Street Weir), Vineyard Creek, Duck River, Homebush Bay, Iron Cove Bay, Hen and Chicken Bay and the Ponds Subiaco Creek system. The remaining sub-catchments comprise of smaller bays, creeks, and foreshore land draining to the river (AECOM, 2010).

The principal topographic features of the lower Parramatta River estuary catchment are the low relief landscape along the river foreshores (less than 10 m AHD in some areas), higher elevated areas along the ridgeline in the Baulkham Hills LGA (up to 120 m AHD) and the steeper slopes to the north of the Parramatta River (Cardno, 2008).

The main geological groups underlying the study area are Ashfield Shale, Bringelly Shale and Hawkesbury Sandstone. The prevalent soil landscape in the catchment is the Blacktown landscape, with Luddenham and Glenorie representing the next most prevalent soil landscapes. Fluvial soils are also generally found along the line of the valley and river margins (Cardno, 2008).

While generally considered to be highly urbanised, the catchment consists of numerous land uses including residential, commercial, environmental protection, education, industrial, open space and recreation (Cardno, 2008).

5.3 Waterway description

5.3.1 Bathymetry

The Parramatta River estuary is a drowned river valley, consisting of a varying bathymetry including shallow embayments and deeper sections located within the main river channel. These deeper sections are presented as a series of “deep holes” with typical depths of below 20 m AHD and up to a depth of 46 m AHD (Birch et al., 2021, 2022). In comparison, the embayments along the southern shore are much shallower, generally below 5 m AHD. Also apparent are areas above AHD that are exposed over some portions of the tidal cycle. These areas are located primarily in Homebush Bay but may also be seen at the upstream margins of some of the other embayments.

Over the past two centuries there have also been extensive modifications to the estuary bed, including both dredging and reclamation works (Cardno, 2008).

5.3.2 Hydrodynamics

The Parramatta River is the largest river entering Port Jackson. The river is tidal to the Charles Street Weir in Parramatta, some 19 km upstream of the commencement of the river at Balmain, or approximately 30 km from Sydney Heads (Cardno, 2008).

In addition to the system bathymetry, the creek and estuary systems are controlled by three major forcing mechanisms: ocean tides, freshwater inflows and wind- and wave-driven flows. Within the estuary, a maximum tidal range of 2.1 m (Hatje, 2003) is experienced. Less dominant forcing factors that operate on a local and global scale include density-driven flows, global changes in meteorological conditions and sea level rise.

Flood control, transport and water supply systems associated with the early settlement of the area have greatly altered the flow of the Parramatta River. Dredging for ferry access has also changed the natural channels of the river, altering the flow conditions. The Charles Street Weir is also the artificially imposed limit of tidal influences on the main arm of the river.

Under low rainfall conditions, the estuary is vertically well mixed. During such dry periods, residence times increase with a maximum of 225 days estimated in the uppermost parts of the estuary (Das et al., 2006). The embayments along the southern shore are likely to be among the most poorly flushed areas. Conversely, the system may become stratified during high precipitation events of over 50 mm/day (Birch and Rochford, 2010; Lee, et al., 2011).

5.3.3 Industrial impacts

The estuary and its catchment have also been exposed to persistent stress over the last two centuries due to historical and current anthropogenic impacts. Consequently, the river's embankments and sediments are contaminated with a range of heavy metals and chemicals. Historically, industrial development has impacted upon the southern side of the harbour and river substantially more than the northern side (Birch et al., 2015, AECOM, 2010).

Contaminated sediments in the river resulted in a complete fishing ban in Homebush Bay (due to dioxin contamination) and a commercial fishing ban throughout Sydney Harbour and its tributaries, including the Parramatta River in 2006 (Birch et al., 2007). Considerable research has been conducted, and continues, in relation to contaminated sediments within the study area (Birch and Taylor, 1999, Birch and Taylor, 2000, McCready et al., 2004; 2006). Elevated concentrations of heavy metals, organochlorine compounds and polycyclic aromatic hydrocarbons have been recorded in surficial sediments of Port Jackson, including the study area. Concentrations of all three classes of contaminant are highest in the upper reaches of embayments and tributaries, especially those on the southern shores of the estuary (AECOM, 2010). Sediment sampling has been undertaken for the project to understand the sediment characteristics at the river release structure (Birch and Batley, 2025).

5.3.4 Water quality

5.3.4.1 Overview

In general, estuary water quality processes are dominated by catchment inputs (including point sources and diffuse sources), oceanic inputs and in-estuary processes (Lee and Birch, 2012). The latter includes biological interactions and interactions with sediments and the atmosphere, generally strongly affected by climate and hydrodynamic processes.

The Parramatta River Estuary Data Compilation and Review Study (Cardno, 2006) identified that the water quality within the estuary was poor with only limited areas of the Parramatta River estuary considered suitable for secondary contact. Anthropogenic activities have resulted in elevated levels of nutrients and gross pollutants entering the estuary. Sediment contamination due to urbanisation and industrialisation of the catchment has also had an impact on water quality within the estuary. Extensive alteration of the estuarine foreshore has limited tidal flushing in some areas, further reducing the water quality.

The Parramatta River Estuary Processes Study (AECOM, 2010) also concludes that water quality continues to be a major environmental issue due to its highly urbanised catchment.

In 2014, the Parramatta River Catchment Group (PRCG) launched the *Our Living River* initiative with the mission to make Parramatta River swimmable again by 2025. The Parramatta River Masterplan (PRCG 2018) details the steps required to make the river swimmable. This includes projects aimed at improving water quality in the river, such as reducing runoff, improving overflows and habitat creation and enhancement. There are currently six swimming sites established within the catchment.

Further analysis of existing estuarine water quality is presented in the sections below.

5.3.4.2 Existing water quality conditions

The following sections present results and interpretation from the SIMS and Sydney Water monitoring programs.

Monitoring programs and sites

The location of the sampling sites for the monitoring programs listed previously in Section 5.1.2 are presented in Figure 5-1 and Figure 5-2 below. With respect to the Sydney Water baseline monitoring program, it is noted that six sites are currently monitored on a weekly basis, however the analysis has been limited to sites PJ01A, PRWP and PRRH as these represent longer term datasets collected since March 2024.

As a general rule, analysis of the SIMS datasets provides for an estuary wide description of the water quality parameters, with the Sydney Water datasets providing more recent data at sites within the immediate study area.

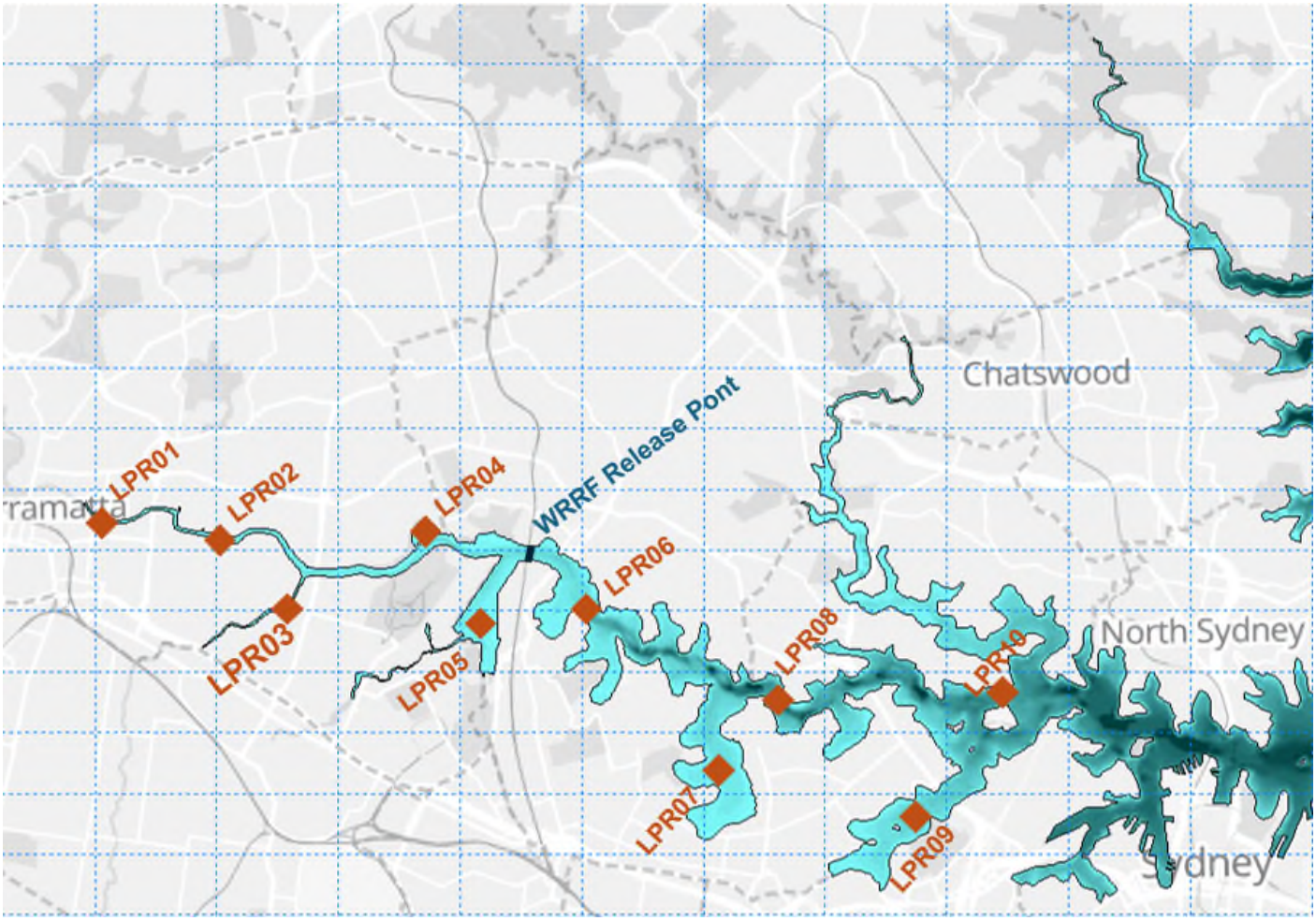

Figure 5-1 Locations of the SIMS monitoring sites

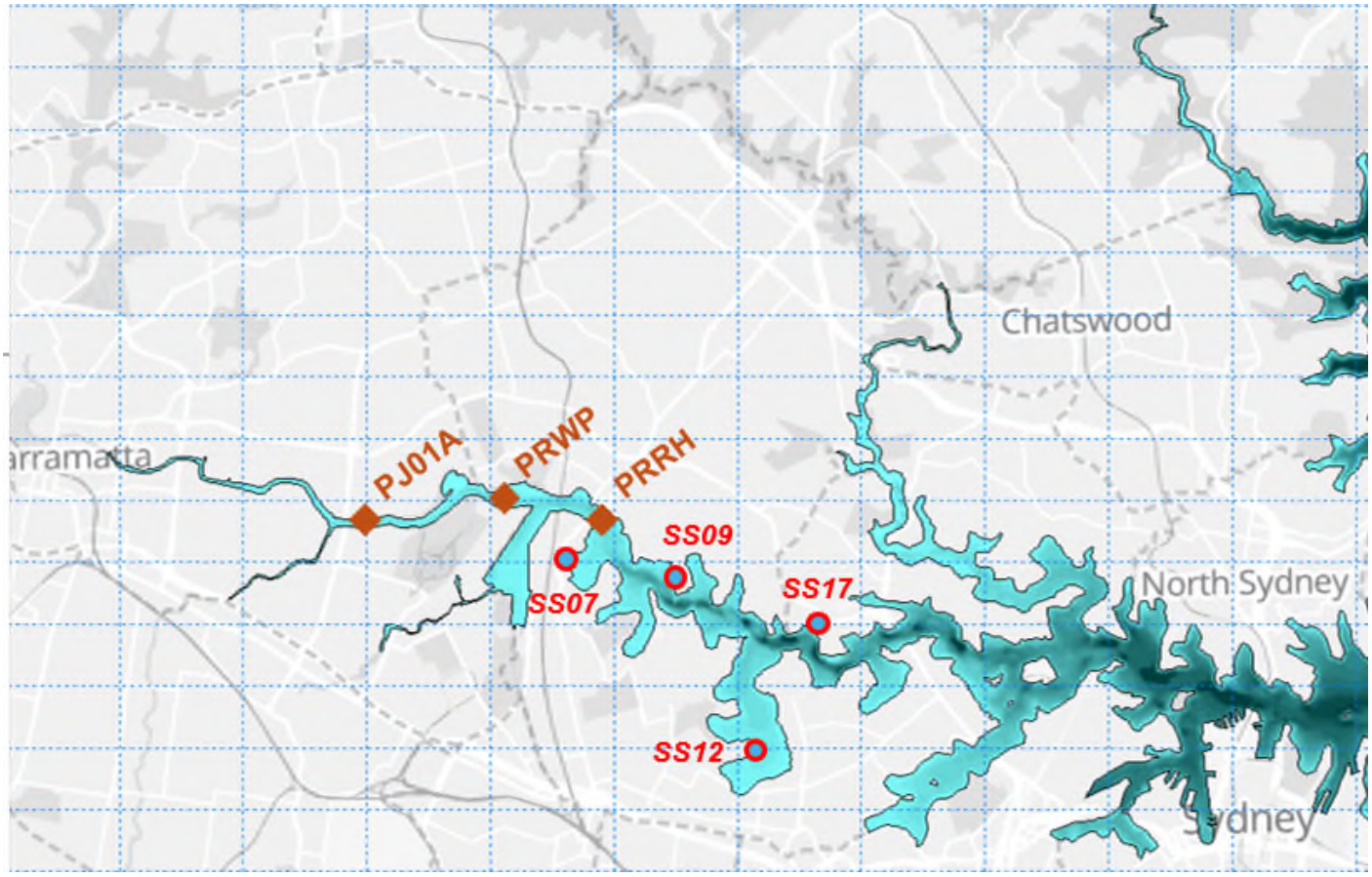

Figure 5-2 Locations of the Sydney Water monitoring sites

Salinity

Figure 5-3 presents the percentile analysis of the SIMS monitoring data. Similar analysis of salinity data from the Sydney Water programs was not undertaken.

From the data presented in this figure and within the GPOP WQRM Calibration Report (Sydney Water, 2025b), the following comments were drawn:

- The extensive range of concentrations presented in the upper estuarine sites are indicative of the influence of rainfall and increased catchment flows.
- The effects of stratification can clearly be seen in the multi-depth and depth profiling data presented in the model calibration report. Similarly, relatively rapid salinity recovery is observed in the data following the cessation of the freshwater inflows.
- Median salinities vary between ~17 to ~34 Practical Salinity Units (PSU) at sites upstream and downstream of the proposed river releases.

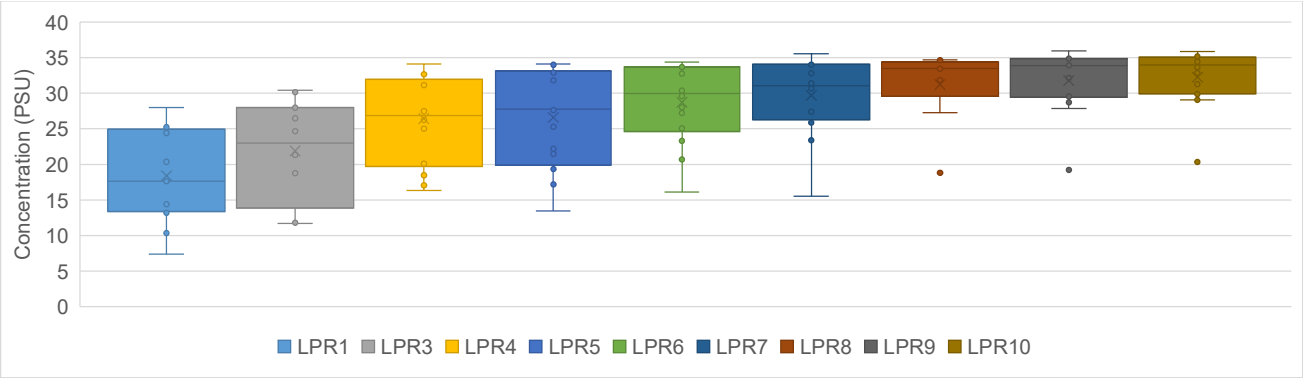

Figure 5-3 Salinity box plot analysis – SIMS data (2012 to 2014)

Nitrogen

Figure 5-4 and Figure 5-5 present the percentile analysis of total nitrogen for the SIMS and Sydney Water monitoring datasets respectively. Figure 5-6 and Figure 5-7 present the percentile analysis of the Sydney Water baseline monitoring data for ammonium and oxidised nitrogen respectively.

From the data presented, the following conclusions were drawn:

- Nitrogen consistently increases with distance travelled upstream. This is expected to be predominantly due to reduced rates of flushing within the upper reaches of the estuary and the higher influence from catchment inputs. From the SIMS data, median concentrations of total nitrogen range from 0.87 mg/L (LPR1) to 0.19 mg/L (LPR10).
- The effects of rainfall and increased catchment loads are evident in the analysis presented in the model calibration report with significantly lower concentrations recorded during lower rainfall periods. During wetter periods, surface concentrations were elevated but the concentrations in the lower water column remain relatively unchanged.
- Concentrations of total nitrogen have the potential to exceed the ANZG DGV of 0.3 mg/L in the upper estuary, however the median values indicate the potential to fall below the DGV in the vicinity, and downstream of site LPR6, which is located downstream of the proposed river release point. Sydney Water's data also demonstrate the potential for concentrations to exceed the ANZG DGV in the more immediate GPOP study area.
- Similarly, the Sydney Water data also indicate that ambient concentrations of ammonium and oxidised nitrogen generally exceed the common DGV of 0.015 mg/L. This may be due to a combination of influences including higher inorganic loads from stormwater and sewer overflows.

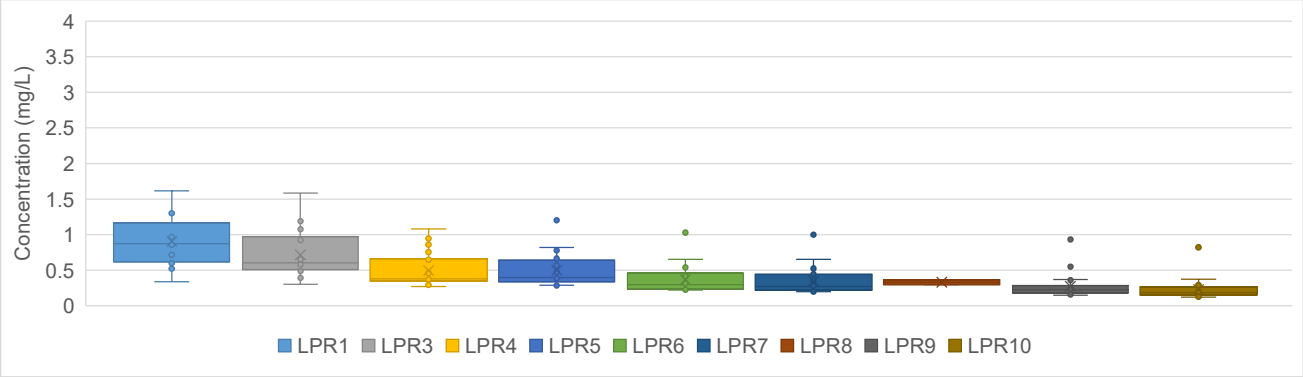

Figure 5-4 Total Nitrogen box plot analysis – SIMS data (2012 to 2014)

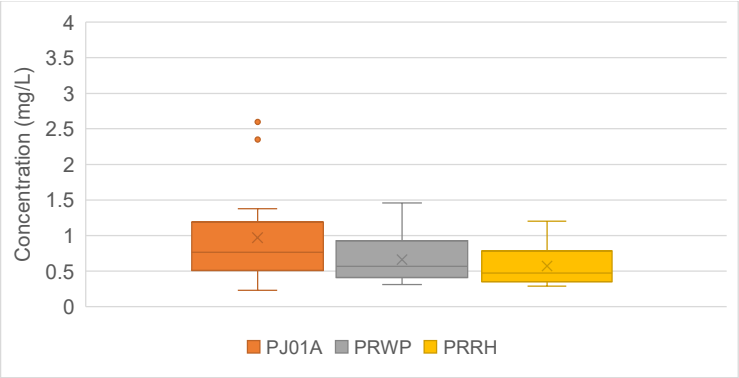

Figure 5-5 Total Nitrogen box plot analysis – Sydney Water baseline data (2024 to 2025)

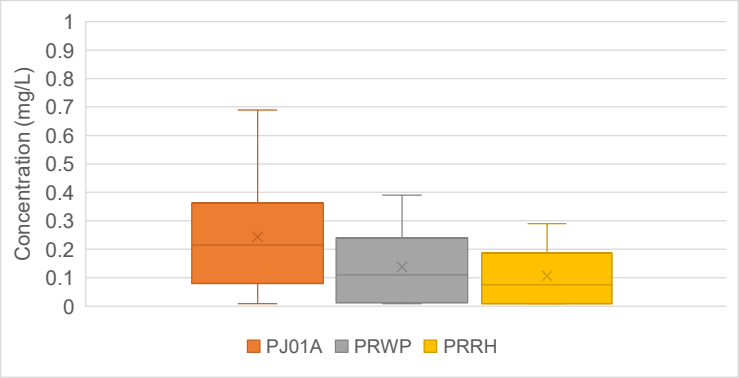

Figure 5-6 Ammonium box plot analysis – Sydney Water baseline data (2024 to 2025)

Figure 5-7 Oxidised Nitrogen box plot analysis – Sydney Water baseline data (2024 to 2025)

Phosphorus

Figure 5-8 and Figure 5-9 present the box plot analysis of total phosphorus for the SIMS and Sydney Water monitoring datasets respectively, while Figure 5-10 presents the box plot analysis of the Sydney Water monitoring data for inorganic phosphorus.

From the data presented, the following conclusions were drawn:

- Phosphorus consistently increases with distance upstream in a similar manner to nitrogen. This is again expected to be predominantly due to reduced rates of flushing within the upper reaches of the estuary and the higher influence from catchment inputs. From the SIMS data, median concentrations of total nitrogen range from 0.09 mg/L (LPR1) to 0.03 mg/L (LPR10).

- The effects of rainfall and increased catchment loads were also evident. During wetter periods, surface concentrations were elevated but the concentrations in the lower water column remained relatively unchanged.
- Concentrations of total phosphorus exceed the DGV of 0.03 mg/L in the upper estuary. Similarly, concentrations of inorganic phosphorus exceed the DGV of 0.005 mg/L. This may be due to a combination of influences including higher inorganic loads from stormwater, sewer overflows and sediment fluxes.

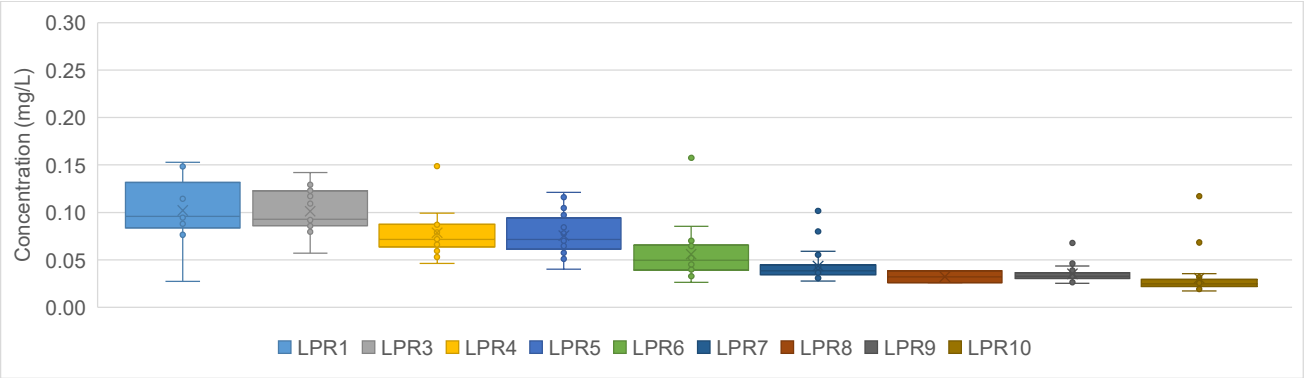

Figure 5-8 Total Phosphorus box plot analysis – SIMS data (2012 to 2014)

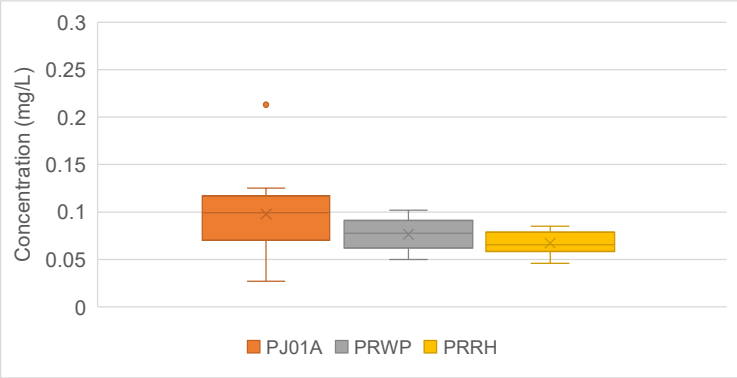

Figure 5-9 Total Phosphorus box plot analysis – Sydney Water baseline data (2024 to 2025)

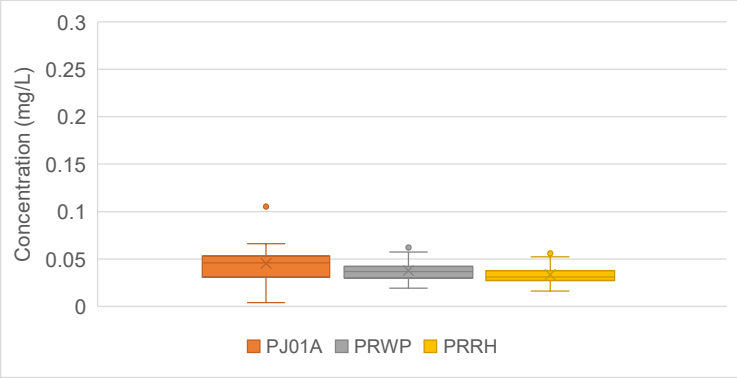

Figure 5-10 Inorganic Phosphorus box plot analysis – Sydney Water baseline data (2024 to 2025)

Chlorophyll *a*

Figure 5-11 and Figure 5-12 present the box plot analysis of chlorophyll *a* for the SIMS and Sydney Water monitoring datasets respectively.

From the data presented, the following findings are drawn:

- In line with the nutrient analysis, concentrations of chlorophyll *a* present a tendency to increase with distance travelled upstream, however the data does also indicate the highest percentiles occurring at site LPR4.
- Spikes are identifiable in the periods following increased rainfall and associated elevations in nutrient concentrations.
- Concentrations exceed the DGV of 0.004 mg/L in the upper and middle estuary.

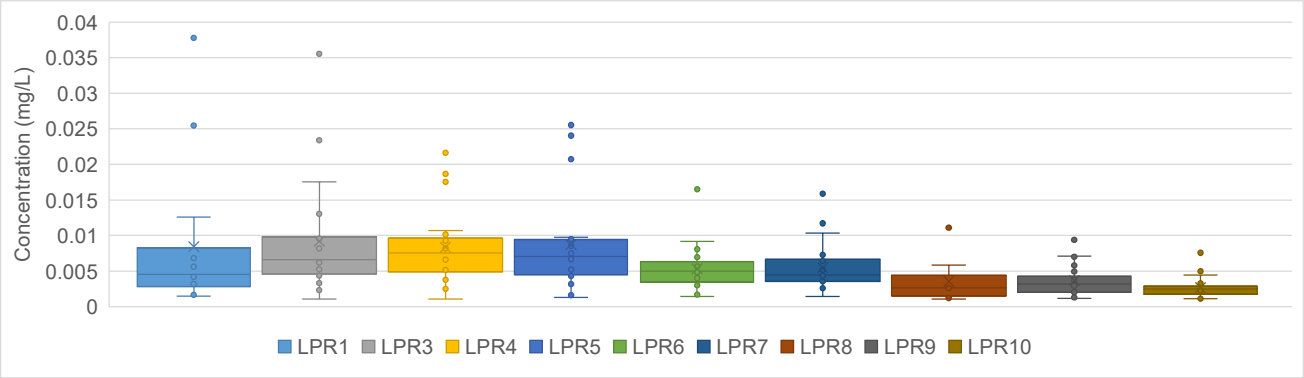

Figure 5-11 Chlorophyll *a* box plot analysis – SIMS data (2012 to 2014)

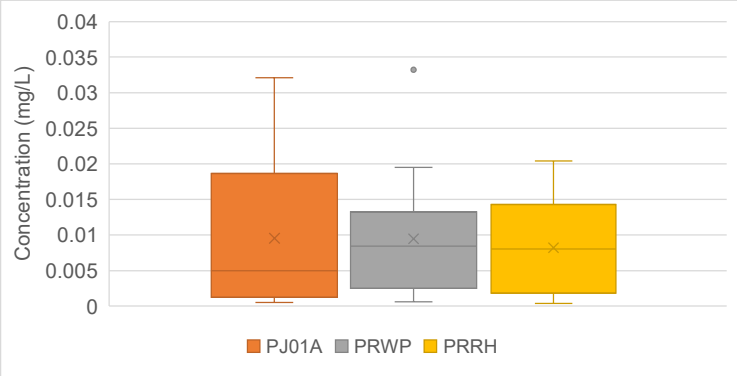

Figure 5-12 Chlorophyll *a* box plot analysis – Sydney Water baseline data (2024 to 2025)

Enterococci

Figure 5-13 and Figure 5-14 present the box plot analysis of enterococci for the Sydney Water Riverwatch and GPOP baseline monitoring datasets respectively.

From the data presented, the following findings are drawn:

- Significant spikes are evident in both datasets, corresponding to rain events. The elevated concentrations arising from both catchment runoff and sewer overflows.
- Under the majority of events, concentrations exceed the 95th percentile objectives for both primary and secondary recreation i.e. 40 and 200 cfu/100 mL.

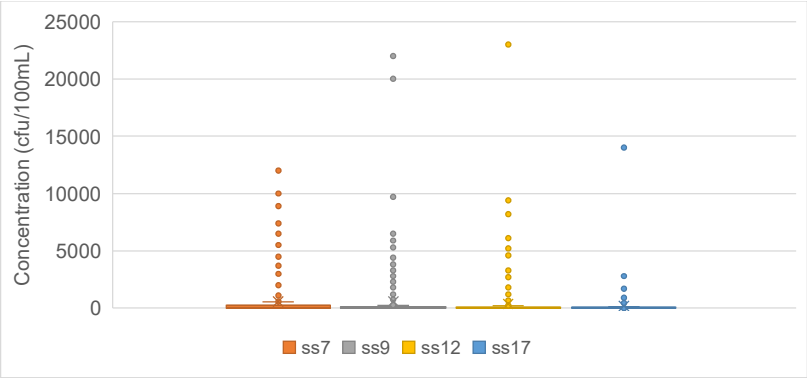

Figure 5-13 Enterococci percentile analysis – Sydney Water Riverwatch data (2020 to 2025)

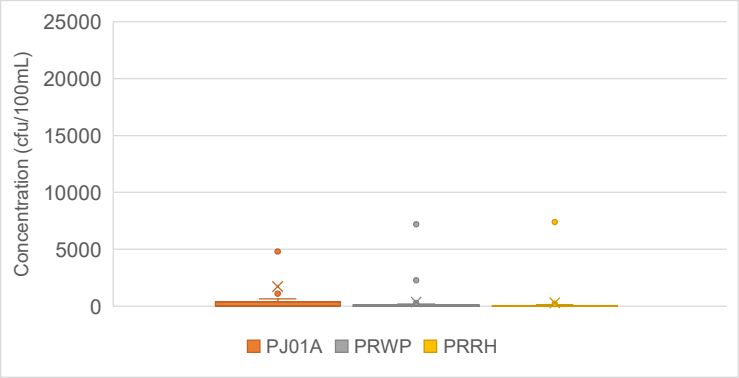

Figure 5-14 Enterococci percentile analysis – Sydney Water baseline data (2024 to 2025)

5.4 Sensitive environments

5.4.1 Aquatic ecology

The upper reaches of the Parramatta River estuary supports a variety of important habitats, including artificial and modified habitats along with diverse intertidal and subtidal habitats. This includes:

- Mangroves, along the Parramatta River foreshore, at the following locations:
  - Meadowbank Park, west of John Whitton Bridge
  - Anderson Park, east of John Whitton Bridge
  - Sydney Olympic Park suburb, particularly at Bicentennial Park and Newington Nature Reserve
  - Duck River
  - lower reaches of Vineyard Creek.
- Small patches of saltmarsh at Wentworth Point, Melrose Park, Duck River, Bicentennial Park and Olympic Park Waterbird Refuge, Newington Nature Reserve.
- Natural rocky reefs, at a range of locations, supporting macroalgal communities.
- Artificial habitats, including seawalls, wharfs and other infrastructure.
- Intertidal and subtidal soft sediment habitats.

To allow for analysis of impacts on aquatic ecology, a selection of six key habitats sites has been selected as part of this assessment. These sites of interest are presented in Figure 5-15.

Further information about these sites, and additional interpretation of results is included in the Aquatic Ecology Impact Assessment for the project (Stantec 2025).

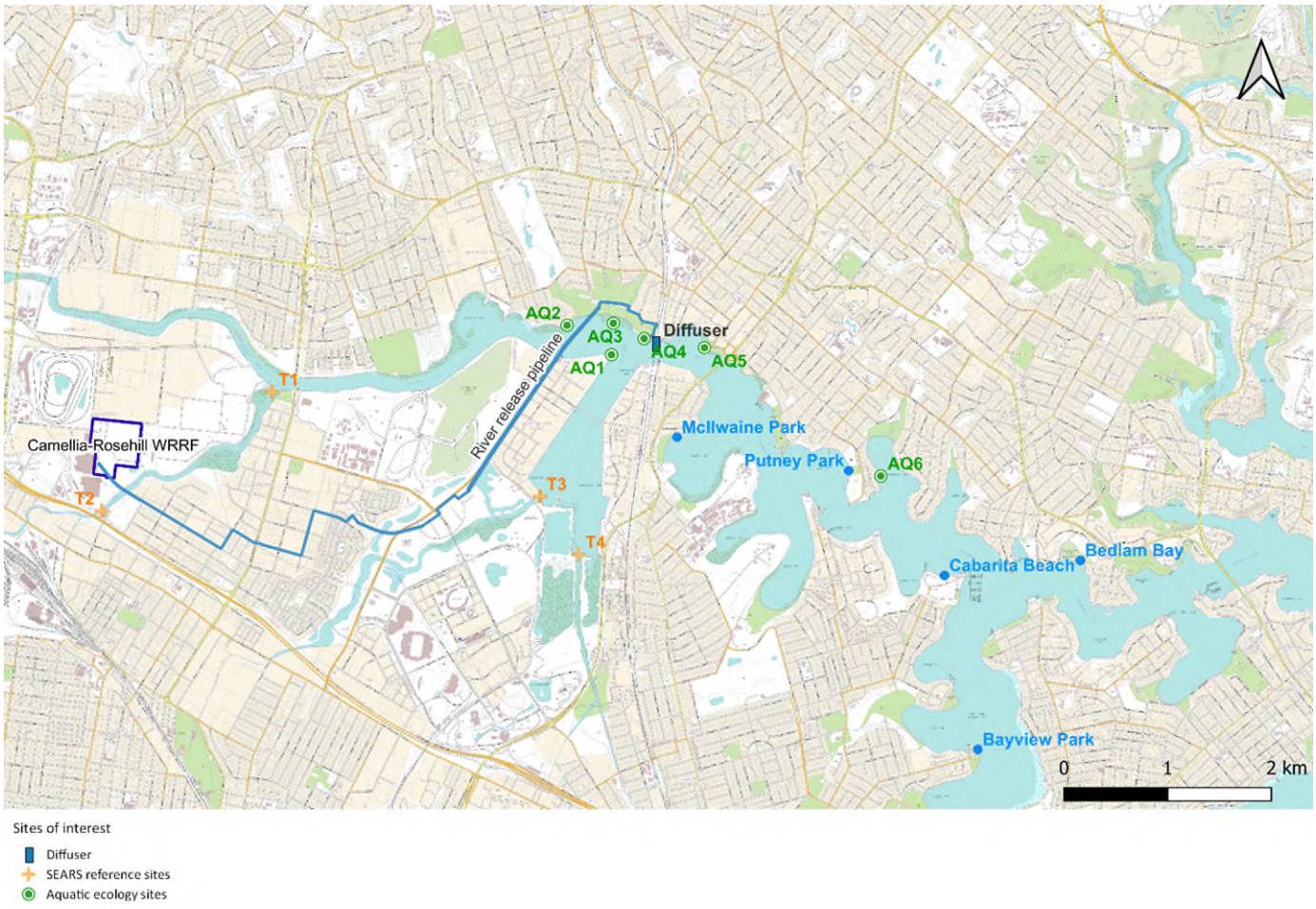

Figure 5-15 Sites of interest – sensitive environments

5.4.2 SEARs reference sites

As documented in Section 3, selected locations within the estuary are discussed in the SEARs e.g. Homebush Bay and Haslams Creek. To allow for analysis of these sites, the following locations have been selected as part of this assessment:

- Duck River
- Duck Creek (confluence with Duck River)
- Haslams Creek (Homebush Bay)
- Powells Creek (Homebush Bay)

These sites of interest are presented in Figure 5-15.

5.4.3 Recreational activities

The Parramatta River estuary is an important recreational waterway, particularly for the western suburbs of Sydney. Designated areas are used for power boating, sailing and other activities. The river has a long historical association with rowing, evidenced by a number of active, long-term sailing and yachting clubs.

There is an increasing amount of waterfront land becoming accessible to the public through the development of walkways and cycleways in foreshore parks and reserves. However, a large proportion of the foreshore is still in the hands of industry and individuals as private residences. There are also regular ferry services along the Parramatta River to Circular Quay with a number of wharves at various points along the river.

As outlined in the SEARs, making the Paramatta River swimmable is a key objective in relation to future management of the estuary. To provide for analysis relating to water quality and more specifically risks to human health from primary and secondary recreational activities, the following sites were selected as part of this assessment:

- Putney Beach (active swim site)
- Bayview Park (active swim site)
- McIlwaine Park (recreational site)
- Bedlam Bay (active swim site)
- Cabarita Park Beach (active swim site)
- Dawn Fraser Baths *(Note this site in Balmain included as a representative lower estuarine location).*

It should be noted that McIlwaine Park is not a planned swim site in the Parramatta River Masterplan (PRCG, 2018). However, this site is opened to the community for recreational uses. Given the site is in the vicinity of the river release structure, it was selected to assess the potential water quality impacts.

Figure 5-15 presents the locations of the sites within the upper estuary, noting the Dawn Fraser Baths site is located in the lower estuary and is therefore not presented.

6. Impact assessments

6.1 Hydrodynamic and water quality assessment

The following sections present the findings of the hydrodynamic and water quality assessment. The assessment has been structured as follows:

- Scenario conditions
- Load analysis
- Scenario results
- Interpretation - background scenarios
- Interpretation - impact scenarios.

Further details on the modelling and assessment approach are provided in Section 4.5.

6.1.1 Scenario conditions

As discussed in Section 4.5.3, the results from each impact scenario are plotted against a corresponding background scenario as well as the baseline scenario. This approach allows for analysis of the impacts from the operation of the WRRF on its own, in relation to the catchment conditions that are expected for the circa 2056 time horizon, and also relative to current conditions.

Table 6-1 presents a summary of the key conditions relating to the scenarios. Further details relating to these impact scenarios, and also the relevant background and baseline scenarios, can be found in Section 4.5.3.

Table 6-1 Summary of GPOP scenario conditions

Scenario	Time horizon	Release volume [WRRF ADWF] (ML/d)	Climate change	Relevant background scenario
Sc1	2025	NA	Not included	NA
Sc2	2056	0	Not included	NA
Sc2cc	2056	0	Included	NA
Sc3	2056	63 [70]	Not included	Sc2
Sc3cc	2056	63 [70]	Included	Sc2cc

6.1.2 Load analysis

Analysis of estimated total nitrogen, total phosphorus and enterococci loads has been undertaken to allow comparison of the contributions from catchment runoff, wet weather overflows and the WRRF river releases across all the scenario types discussed in Section 4.5.3, as well as across the range of rainfall years.

The loads were estimated through analysis of the model boundary conditions for each scenario, and for all three representative rainfall years independently.

The load analyses presented in the figures below, are representative of the catchment area that extends from the uppermost boundary of the Parramatta River catchment, downstream to Cockatoo Island. Figure 6-1 to Figure 6-3 present the cumulative analysis of annual total nitrogen loads for the average, lower and higher rainfall years respectively.

Similarly, Figure 6-4 to Figure 6-6 present similar outputs for total phosphorus annual loads. Finally, Figure 6-7 to Figure 6-9 present the load analyses for enterococci.

From this analysis, interpretation can be provided in terms of the contributions of the releases from the WRRF, relative to total catchment load. Changes in predicted overflow loads arising from the operation of the Camellia-Rosehill WRRF can also be evaluated.

Similarly, from comparison of both the overflow and stormwater contributions, the following effects can be assessed:

- the influence of climate change on both stormwater and overflow loads
- the influence of source controls that are planned to occur between the baseline (circa 2024/25) and background (circa 2056) time horizons.

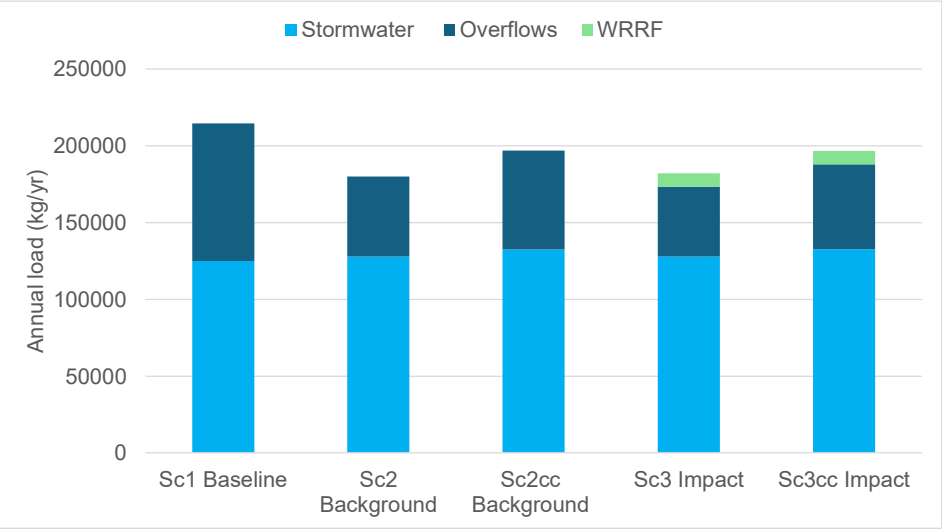

Figure 6-1 Estimated annual loads for total nitrogen (average rainfall year)

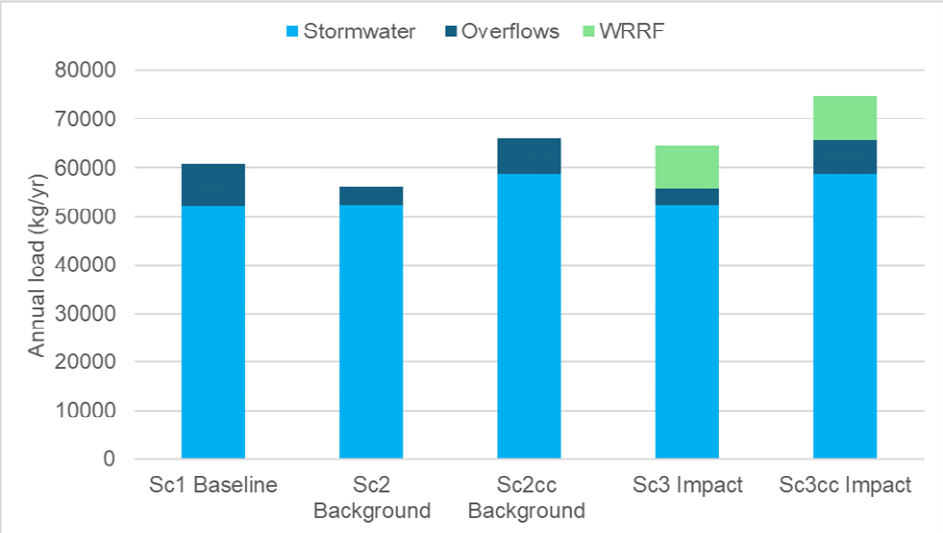

Figure 6-2 Estimated annual loads for total nitrogen (lower rainfall year)

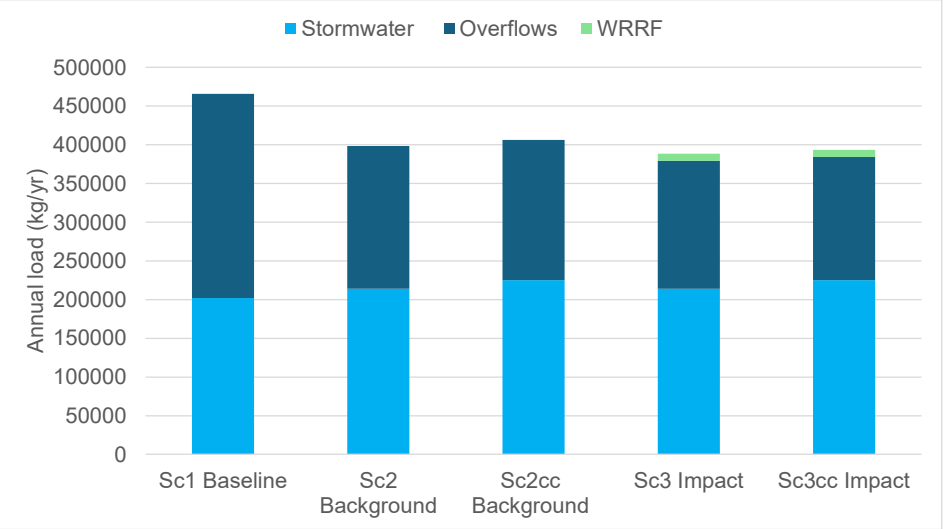

Figure 6-3 Estimated annual loads for total nitrogen (higher rainfall year)

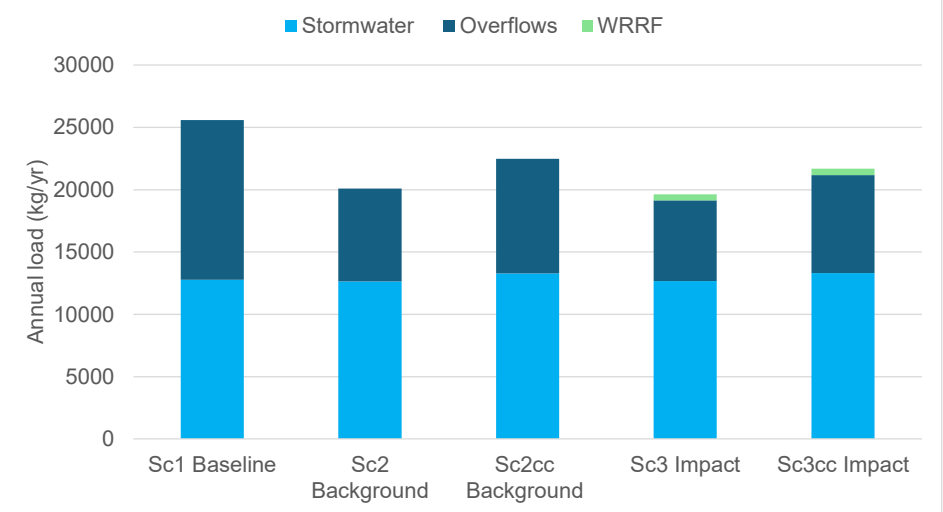

Figure 6-4 Estimated annual loads for total phosphorus (average rainfall year)

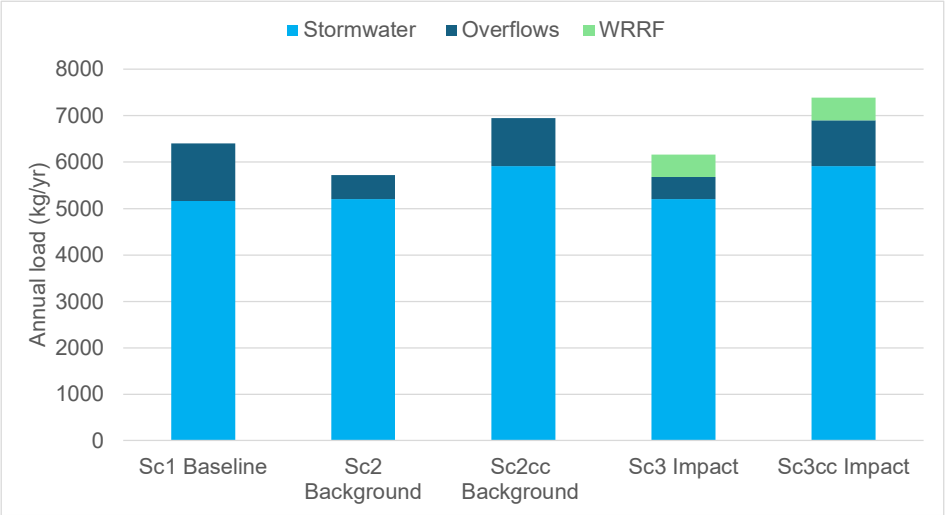

Figure 6-5 Estimated annual loads for total phosphorus (lower rainfall year)

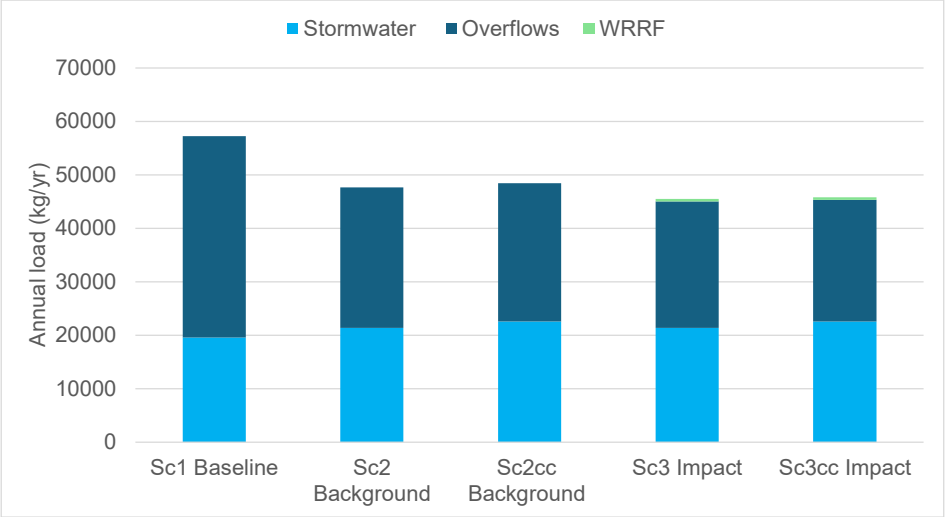

Figure 6-6 Estimated annual loads for total phosphorus (higher rainfall year)

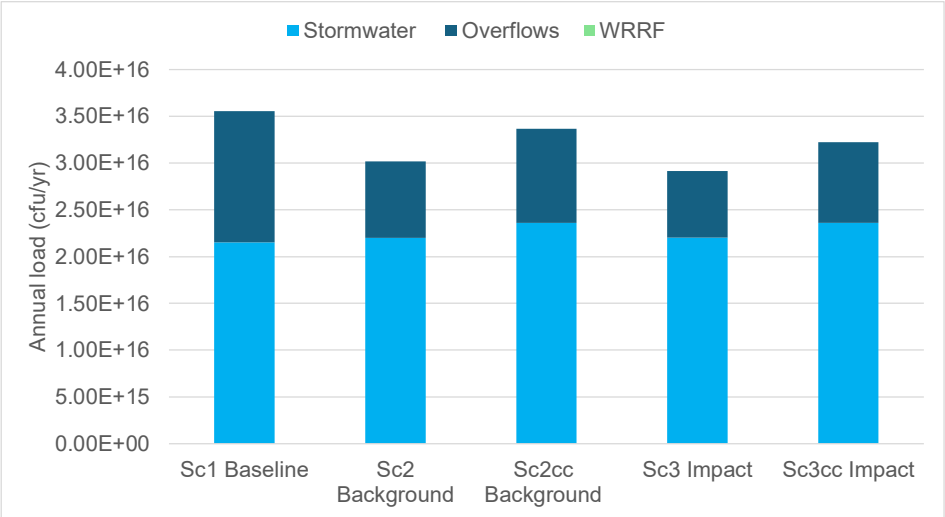

Figure 6-7 Estimated annual loads for enterococci (average rainfall year)

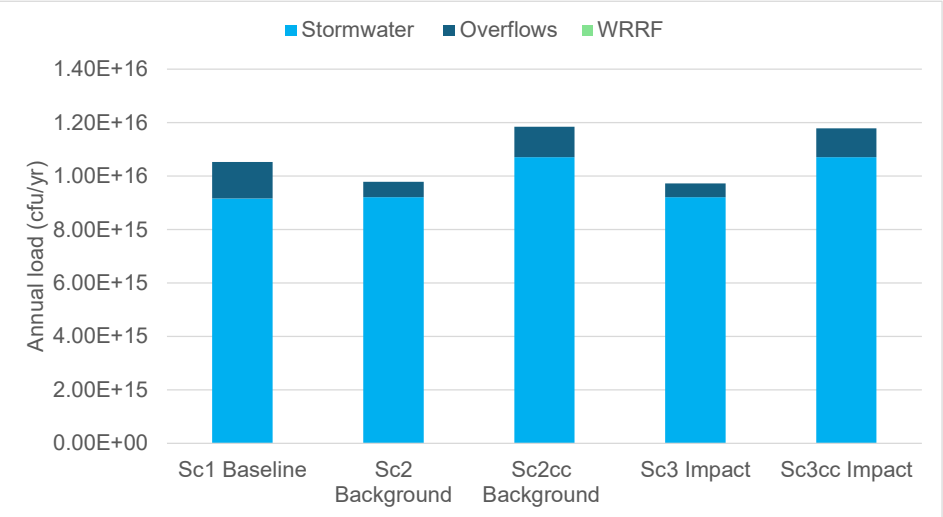

Figure 6-8 Estimated annual loads for enterococci (lower rainfall year)

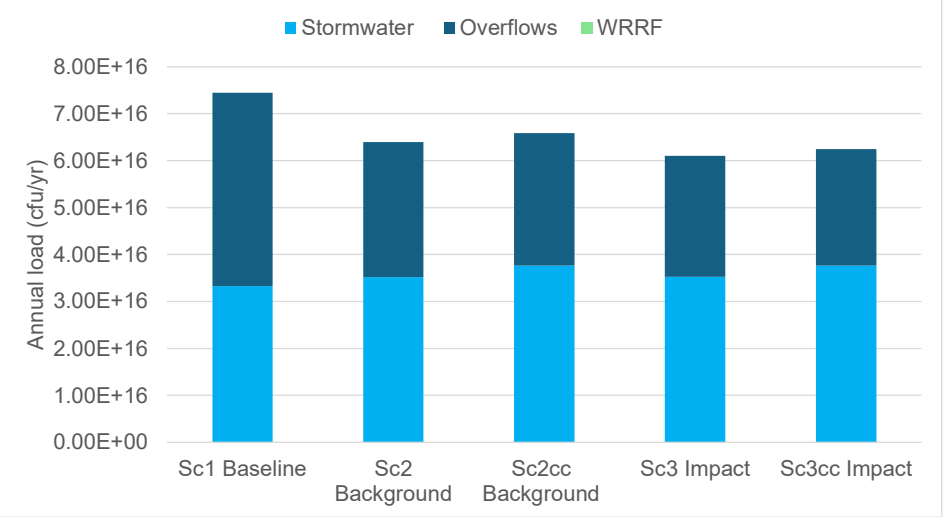

Figure 6-9 Estimated annual loads for enterococci (higher rainfall year)

6.1.3 Scenario results

Additional model output has been generated for the purposes of the hydrodynamic and water quality assessment. In addition to analysis of hydrodynamic indicators including water elevation, velocity and flow, the outputs include the following formats for each of the primary water quality parameters.

- Longitudinal profiles (or bar charts) of annual median and 80th percentile concentrations
- Time series plots of hourly concentrations

With respect to the longitudinal profiles, these were plotted with the x-axis representing chainages from the Charles Street Weir. The location of the proposed diffuser at a distance of 8.4 km is also plotted.

With respect to the bar charts of annual median and 80th percentile concentrations, these graphs were plotted for the sites representing sensitive environments (refer Section 5.4).

With respect to the time series plots, the results have been presented at primary sites of interest for each of the respective rainfall years. These sites include locations within 1 km of the river releases, identified

locations of aquatic ecological interest, locations referenced in the SEARs as well as recreational swimming / recreational sites.

As discussed in Section 4.5.3, the results from each impact scenario are plotted against a comparative background scenario as well as the baseline scenario. This approach allows for analysis of the impacts from operation of the WRRF on its own, in relation to the catchment conditions that are expected for the circa 2056 time horizon, and also relative to current conditions. Further details regarding the formats used to present the results, and the location of the analysis sites, are discussed in Sections 4.5.5 and 5.4.

For brevity, a selection of relevant scenario results has been included in the following sections to aid interpretation. A full set of results is also included in Appendix D for reference.

6.1.4 Interpretation – background scenarios

The following interpretation is provided with respect to the results from the background scenarios (circa 2056 conditions) relative to the baseline scenario (circa 2024/25 conditions).

6.1.4.1 Load analysis

With respect to the analysis of annual loads, the following findings are drawn:

- For total nitrogen, depending on the rainfall year analysed, total loads are predicted to decrease by between 8% and 15% due to the planned source controls that were adopted in the modelling of the sewer overflows. The changes in load are however more variable if climate change conditions are adopted. Due to modifications in the rainfall over the catchment, reductions of ~13% are predicted under the higher rainfall year and an increase of 8% under the lower rainfall conditions.
- Similar patterns are seen for total phosphorus, with total loads predicted to decrease by between 10 and 20% depending on the rainfall year. This is again due to the source controls that planned by Sydney Water and which were incorporated into the modelling of the sewer overflows. The changes in load are again more variable if climate change conditions are adopted with reductions of 15% predicted under the higher rainfall year and an increase of 10% under lower rainfall conditions.
- With respect to enterococci, reductions in total load of up to 15% are predicted if no climate change was assumed. However, if climate change adjustments were included in the modelling, changes varied considerably dependent on the rainfall year considered in the analysis. In a higher rainfall year, the load was estimated to be 12% lower than the baseline. Conversely, in a lower rainfall year, the load was estimated to be 12% higher than that of the baseline scenario.

6.1.4.2 Hydrodynamics

As a consequence of the assumed rise in sea level, increases of approximately ~0.16 m are predicted under the climate change background scenario conditions relative to the baseline as well as the Sc2 background scenario results.

From percentile analysis of mid-channel velocities within 500 m of the proposed release point, the following comments are provided:

- Due to the increase in tidal prism, median and 95th percentile velocities are predicted to reduce by approximately 4% to 7% under the influence of climate change.
- Modification to the lower percentiles of tidal velocity were slightly more significant with reductions of up to 10% predicted within the Meadowbank reach.

6.1.4.3 Salinity

Under the climate change scenario, relatively minor variations in salinity are predicted. These variations are expected to be a product of changes in inflows to the estuary that occur due to modification of rainfall in association with altered flushing due to sea level rise. From the time series results extracted in the vicinity of the John Whitton Bridge, salinity levels are predicted to both increase and decrease throughout the year potentially dependent on seasonal trends and also the intensity of rainfall events (refer Figure 6-10).

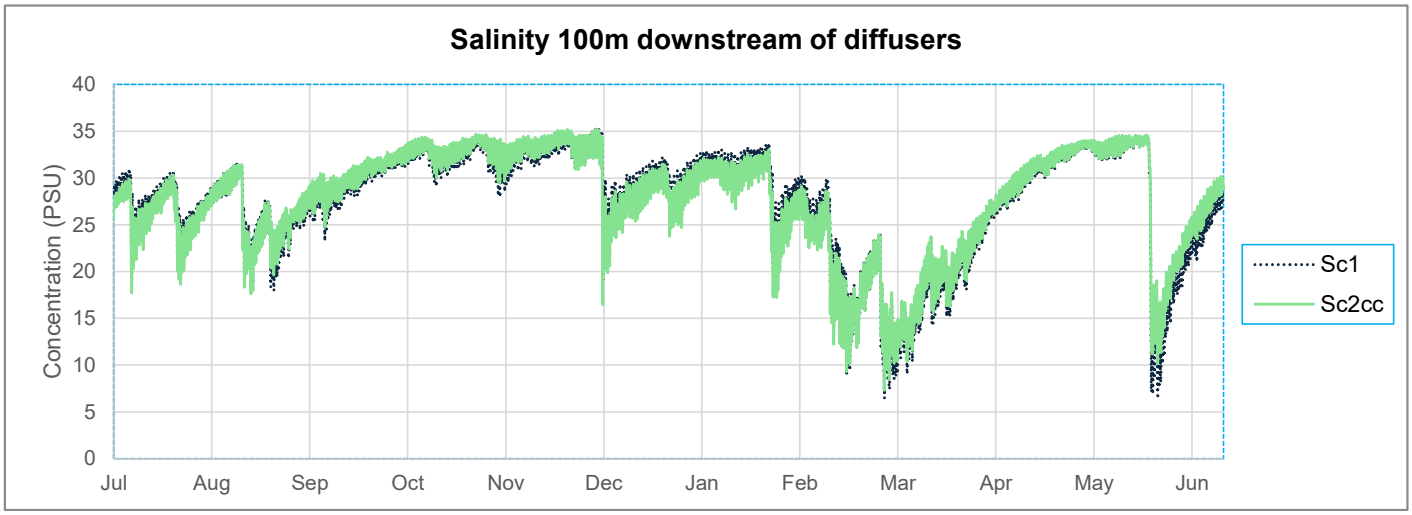

Figure 6-10 Predicted time series concentrations of salinity in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2cc (average rainfall year)

From analysis of the annual median profiles however there is a tendency for salinities to increase in the uppermost 6 to 7 km of the river and with a potential to reduce in the mid and lower estuary (refer Figure 6-11). The increases in the upper estuary are potentially due to modifications in the flow regime within the Upper Parramatta River which in turn affects the volumes of water overtopping the Charles Street Weir.

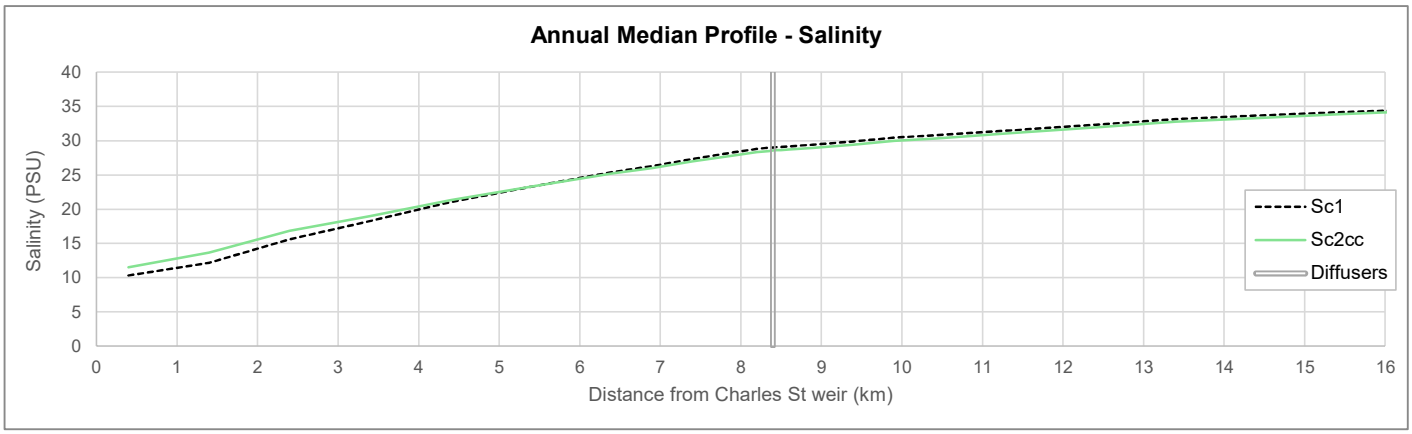

Figure 6-11 Predicted annual median salinity concentrations – scenarios Sc1 and Sc2cc (average rainfall year)

With respect to the non-climate change background scenario, due to only minimal changes to overflow conditions, negligible changes were predicted between the background and baseline scenarios.

6.1.4.4 Temperature

In line with the assumptions applied to simulate climate change, temperatures within the estuary are predicted to increase by ~1^{o}C throughout the year, with slight variations depending on the season.

Similarly, in line with assumptions adopted in the non-climate change scenario, changes in temperature are predicted to be negligible.

6.1.4.5 Nitrogen

With respect to the non-climate change background scenario Sc2, reductions in total nitrogen are predicted relative to the baseline conditions. These reductions are due to the planned source controls assumed in the wastewater networks that provide for mitigation of the wet weather overflows. This is demonstrated by the greater reductions being predicted during and post wet weather events (refer Figure 6-12).

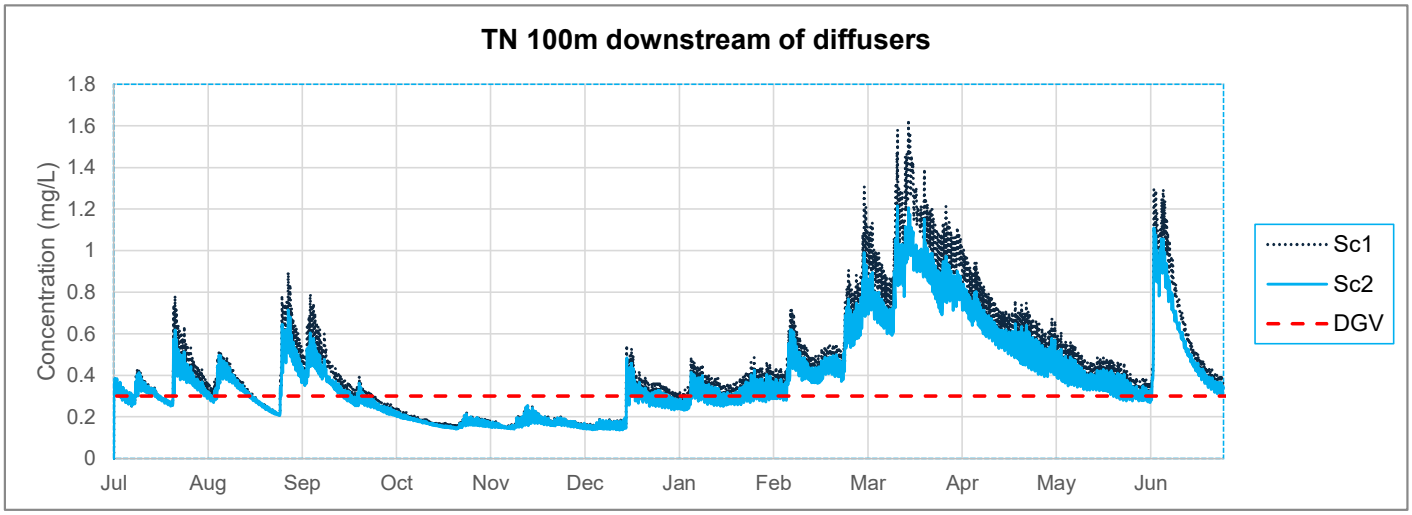

Figure 6-12 Predicted time series concentrations of TN in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2 (average rainfall year)

For the background scenario that included climate change conditions, the pattern is more complex. While reductions from the planned source controls are still predicted, further modifications in ambient concentrations were observed due to the adjustments in key model forcings including rainfall, sea level rise, etc. These modifications therefore included periods of both increases and reductions in total nitrogen within the immediate study area (refer Figure 6-13).

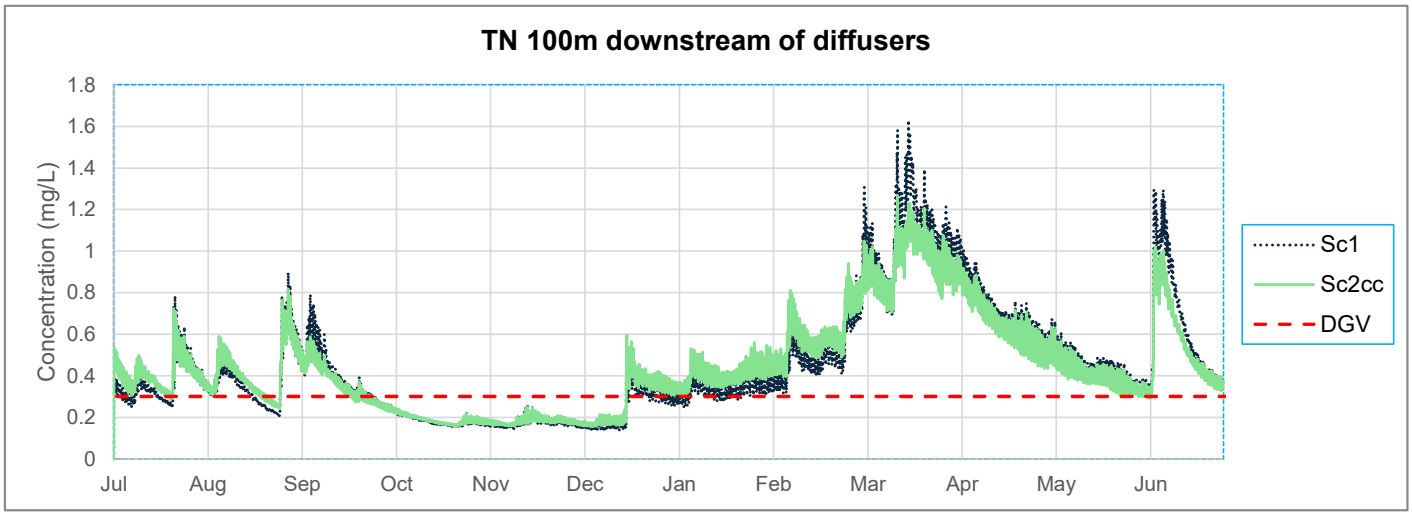

Figure 6-13 Predicted time series concentrations of TN in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2cc (average rainfall year)

Similar trends were typically predicted for the inorganic fractions of nitrogen with the effects of the planned source controls evident and presenting more substantial reductions, particularly under the climate change scenario Sc2cc.

6.1.4.6 Phosphorus

Similar to the pattern shown for total nitrogen, due to the planned source controls assumed in the wastewater network, reductions in total phosphorus are predicted for background scenario Sc2 relative to the baseline conditions (refer Figure 6-14).

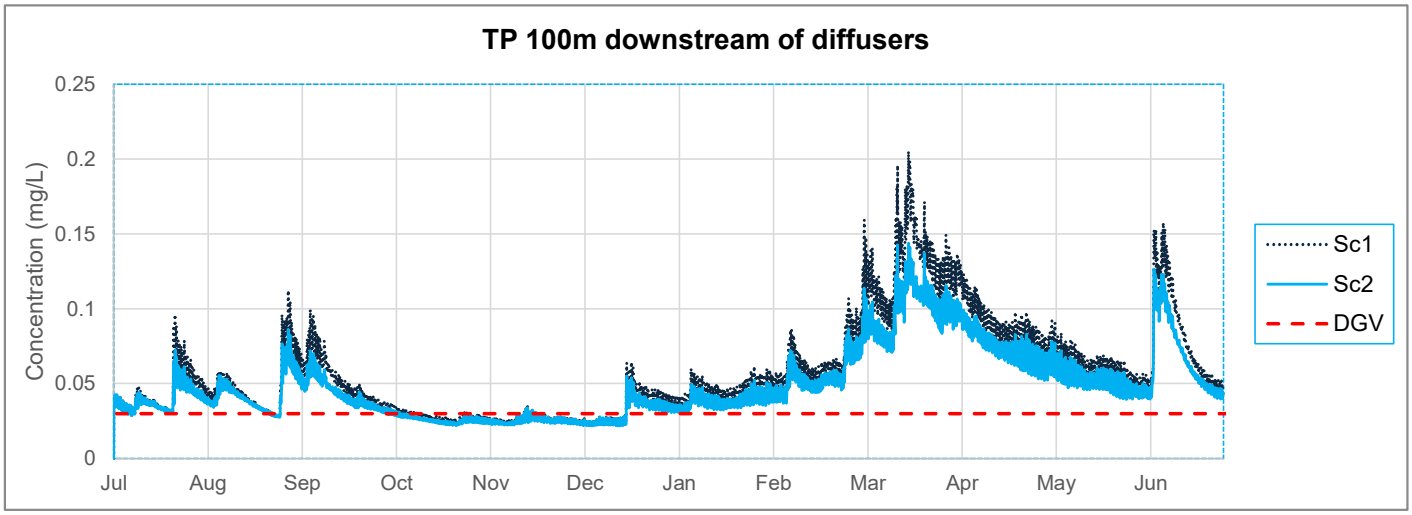

Figure 6-14 Predicted time series concentrations of TP in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2 (average rainfall year)

Under climate change conditions, the pattern again presented a more complex pattern with reductions from the planned source controls as well as modifications due to adjustments in key model forcings including catchment inflows, sea level rise, etc. These modifications again generated periods of both increases and reductions in concentrations within the immediate study area (refer Figure 6-15).

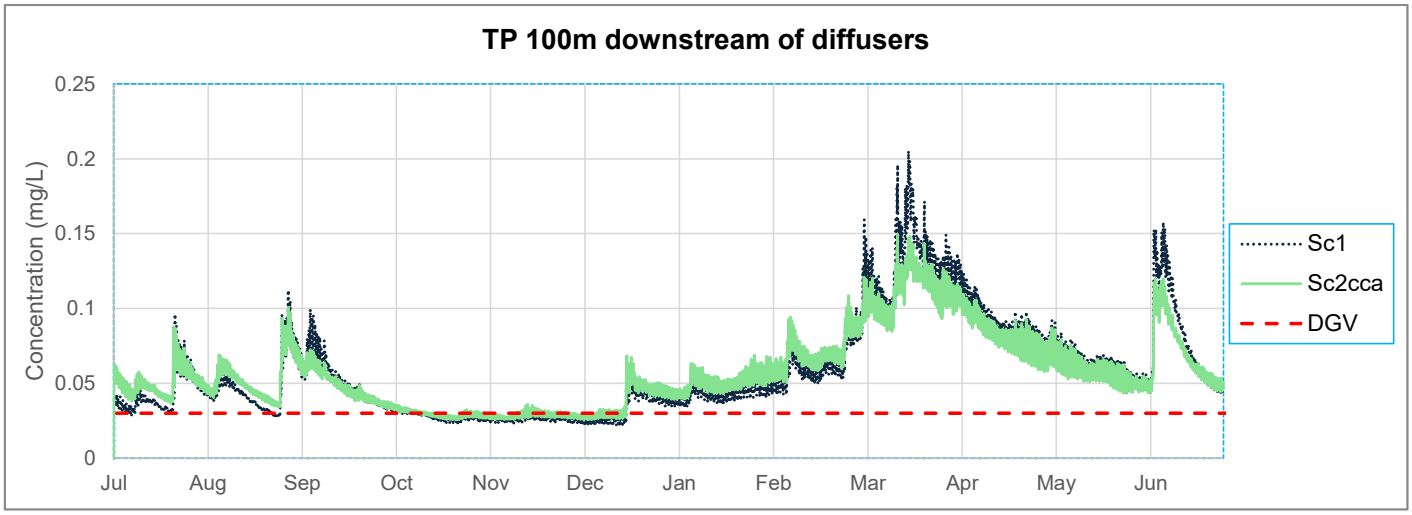

Figure 6-15 Predicted time series concentrations of TP in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2cc (average rainfall year)

6.1.4.7 Total suspended solids

With respect to Total Suspended Solids, under the climate change version of the scenarios, minor increases in annual median concentrations of up to 3 mg/L are predicted, particularly in the reaches immediately downstream of the Charles Street Weir (refer Figure 6-16). These increases were considered to be a product of the modifications in rainfall and runoff and constituent export as modelled by the Source catchment model.

In comparison, negligible changes were predicted under the non-climate change scenario conditions.

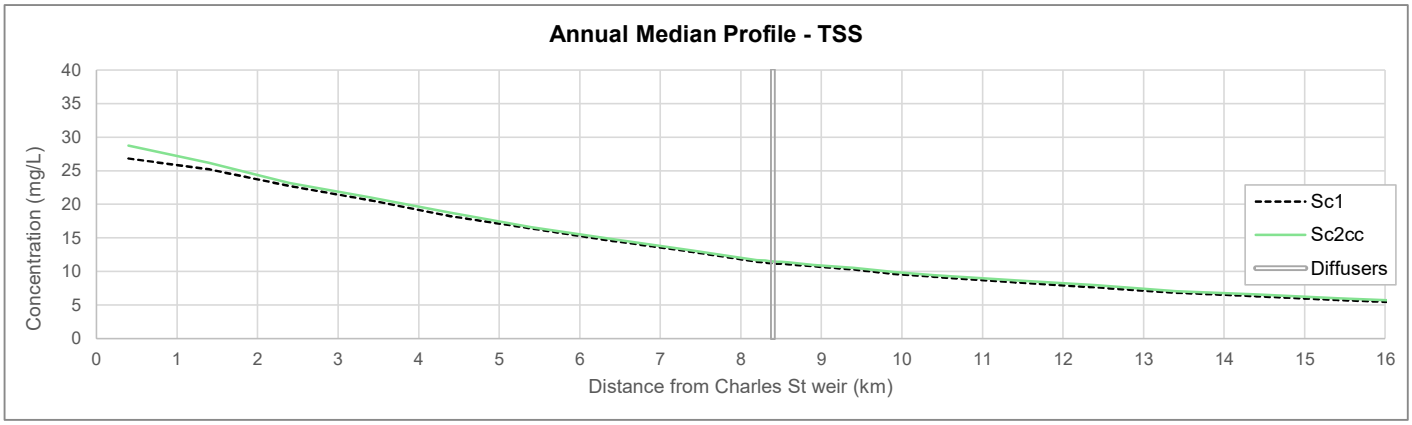

Figure 6-16 Predicted annual median TSS concentrations – scenarios Sc1 and Sc2cc (higher rainfall year)

6.1.4.8 Chlorophyll *a*

Generally, there were relatively limited changes in the predicted levels of chlorophyll *a* relative to baseline conditions, however minor reductions were seen in the Sc2 model results due to the planned source controls.

With adoption of the climate change conditions, some additional variability was observed with limited increases in median concentrations during the average and lower rainfall years, while reductions were predicted for the higher rainfall year.

Figure 6-17 and Figure 6-18 present the annual median profiles for non-climate change and climate change scenario variations. Similarly, Figure 6-19 and Figure 6-20 present time series for the two variations respectively.

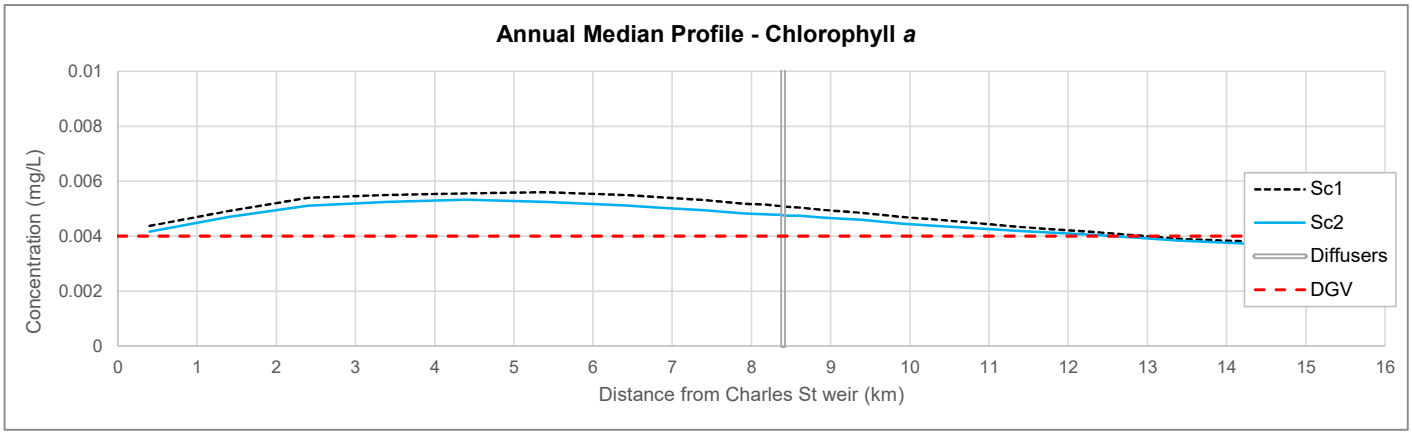

Figure 6-17 Predicted annual median chlorophyll *a* concentrations – scenarios Sc1 and Sc2 (average rainfall year)

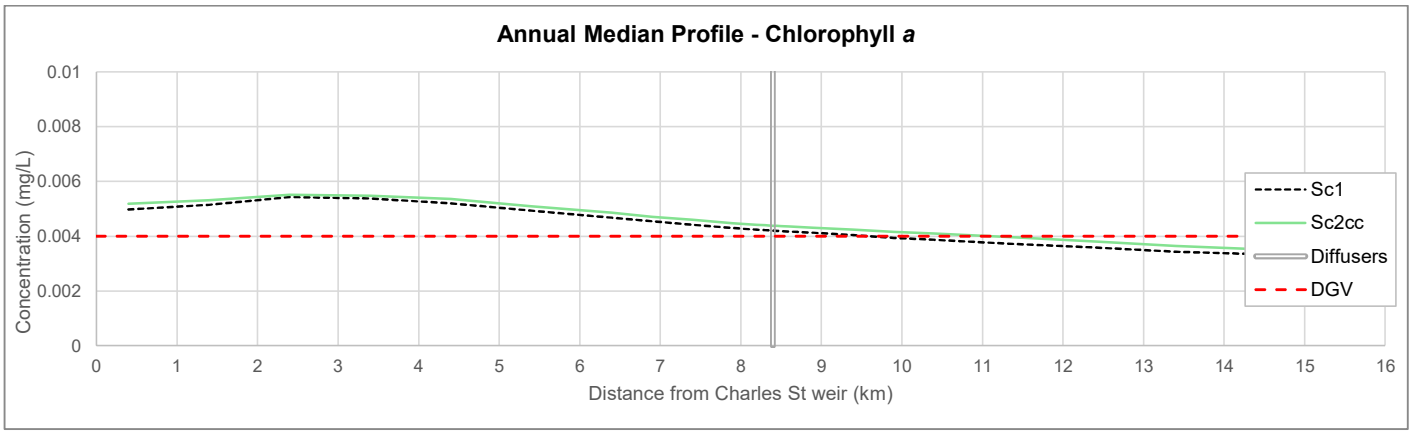

Figure 6-18 Predicted annual median chlorophyll *a* concentrations – scenarios Sc1 and Sc2cc (lower rainfall year)

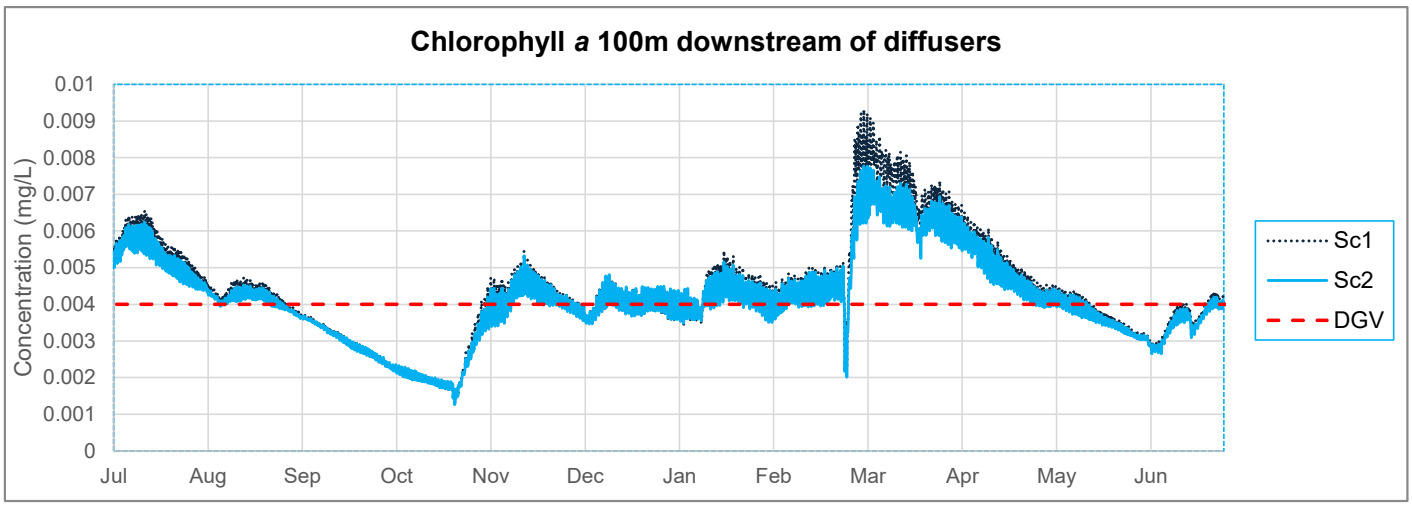

Figure 6-19 Predicted time series concentrations of chlorophyll *a* in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2 (lower rainfall year)

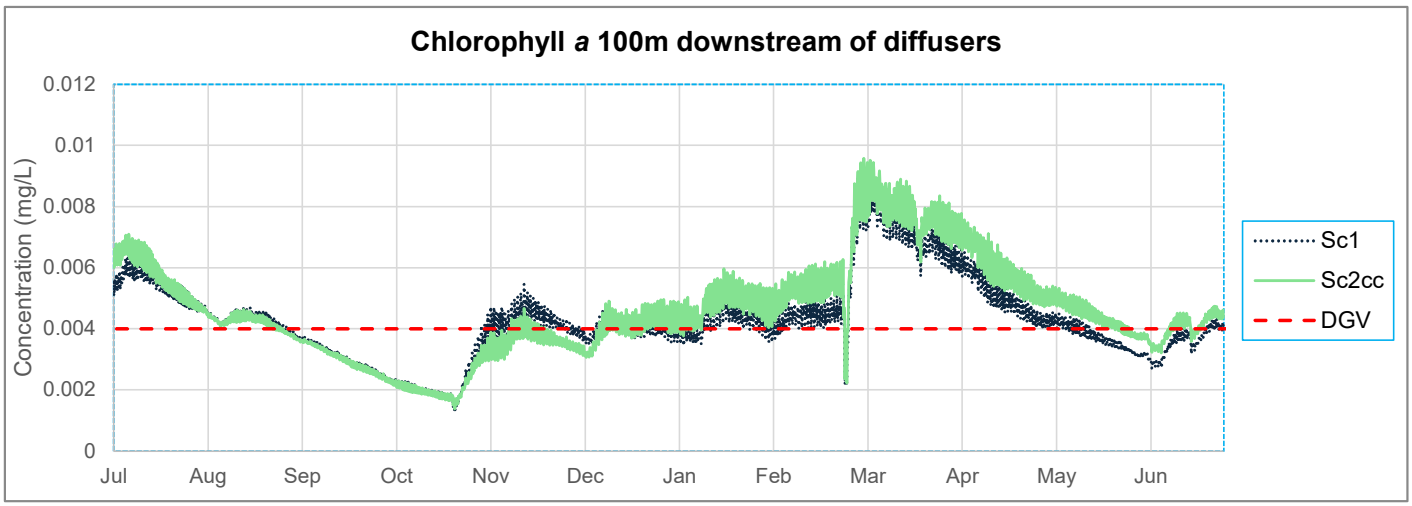

Figure 6-20 Predicted time series concentrations of chlorophyll *a* in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2cc (lower rainfall year)

6.1.4.9 Dissolved oxygen

Comparison of the modelling results for the background and baseline scenarios indicate changes in dissolved oxygen would be limited due to both the effects of climate change and the source controls that are planned by Sydney Water to mitigate wet weather overflows.

Figure 6-21 and Figure 6-22 presents the annual median and time series results for the climate scenario Sc2cc relative to the baseline scenario Sc1.

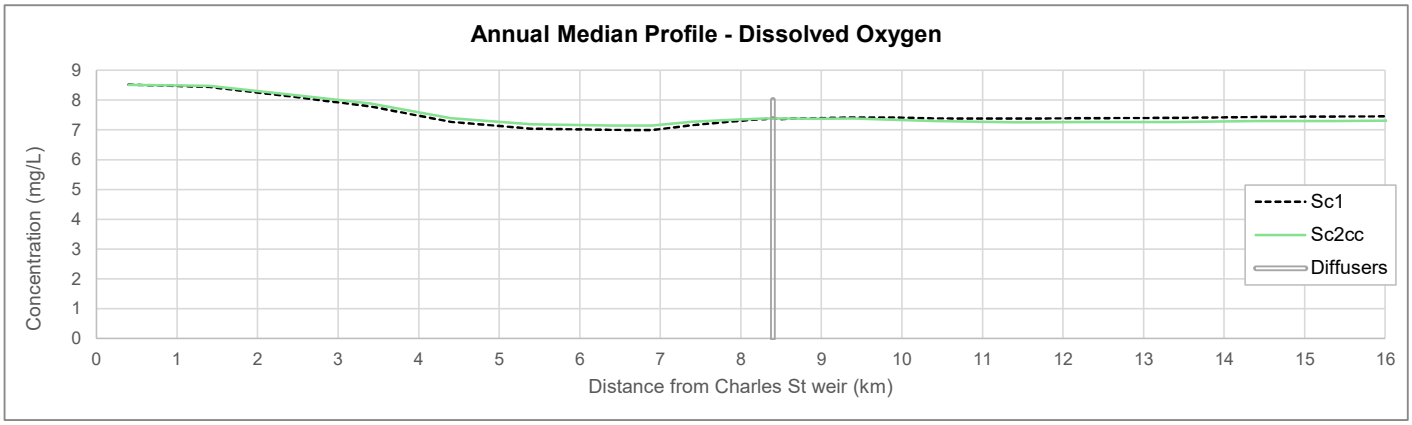

Figure 6-21 Predicted annual median Dissolved Oxygen concentrations – scenarios Sc1 and Sc2cc (average rainfall year)

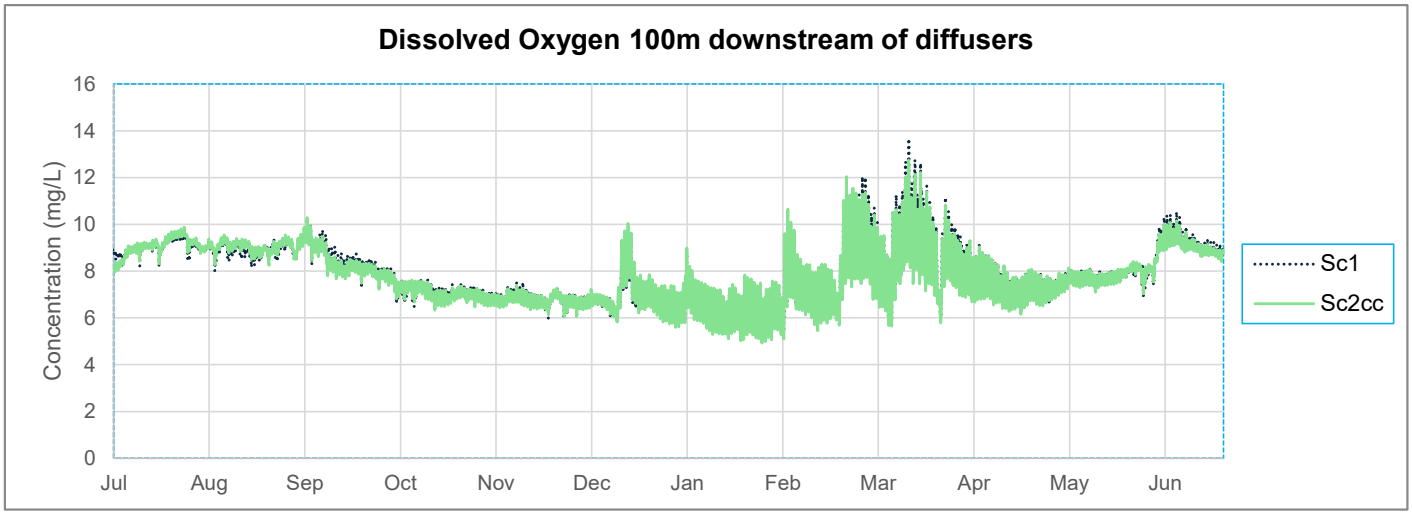

Figure 6-22 Predicted time series concentrations of Dissolved Oxygen in the vicinity of the John Whitton Bridge – scenarios Sc1 and Sc2cc (average rainfall year)

6.1.4.10 Enterococci

Due to the planned source controls, the background scenarios are predicted to reduce wet weather spikes in enterococci relative to the baseline conditions (refer to Figure 6-23). Further modifications are predicted due to the simulation of climate change, but the source controls represent the primary modifications relative to the baseline scenario.

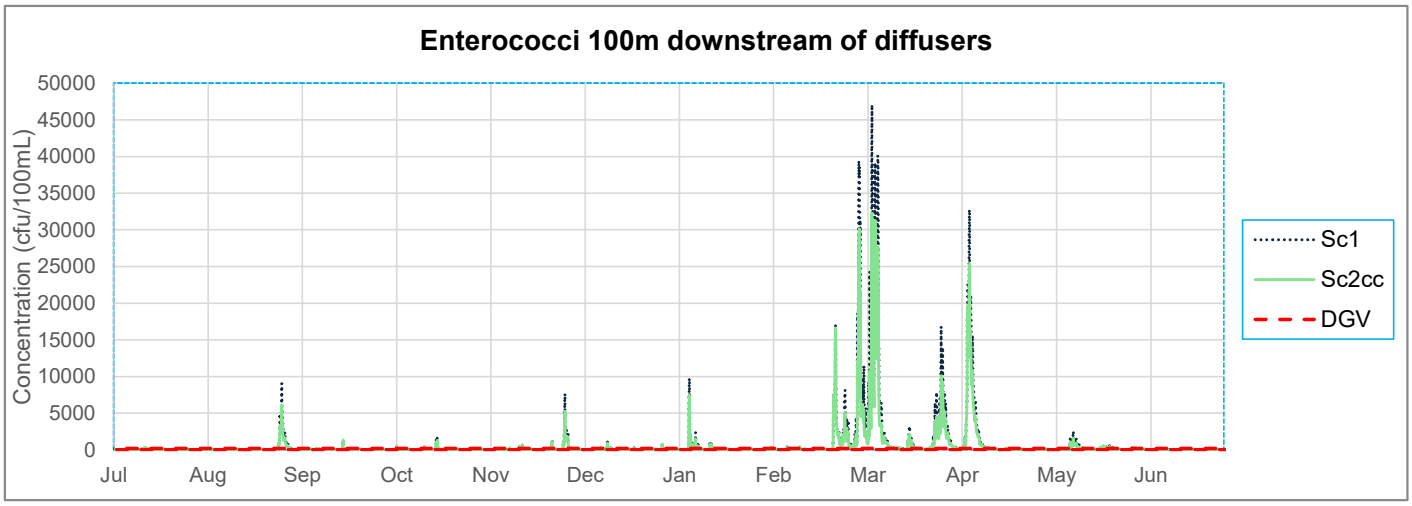

Figure 6-23 Predicted time series concentrations of Enterococci in the vicinity of the John Whitton bridge – scenarios Sc1 and Sc2cc (higher rainfall year)

6.1.5 Interpretation – impact scenarios

The following interpretation is provided with respect to the results from the impact scenarios (circa 2056 conditions with operation of the WRRF) relative to the background scenarios (circa 2056 conditions).

While two versions of the background and impact scenarios have been simulated as part of this assessment (with and without climate change), generally the same trends and patterns were predicted in both versions of the scenarios. The following interpretation has therefore primarily focussed on the scenarios that included adjustments for climate change, with discussion added where notable differences were observed between the two variants.

6.1.5.1 Load analysis

With respect to the analysis of annual loads, the following findings are drawn with respect to load contributions from the river releases. It is noted that the below estimates assume climate change conditions and also include allowance for the offline events and therefore include contingency for the release of tertiary treated water for four days per year.

- For total nitrogen, the estimated contribution of the river releases relative to total load in the estuary varies from ~2% under the higher rainfall year conditions and up to ~12% for the lower rainfall year.
- Similarly, for total phosphorus, the estimated contribution of the river releases relative to total load in the estuary varies from 1% under the higher rainfall year conditions and up to 7% for a lower rainfall year.
- As the river releases are assumed to include no pathogenic load, the estimated contributions to enterococci load are zero across all the rainfall years.

With respect to predicted reductions in sewer overflows, the following findings are also drawn:

- Reductions in load of up to 14% were estimated for all the parameters under the average rainfall year conditions.
- Similar results were observed for the higher rainfall year; however, the reductions were less (~5%) under the lower rainfall conditions if climate change conditions were assumed in the modelling.

6.1.5.2 Hydrodynamics

From comparison of the results from the impact scenarios relative to their corresponding background conditions, the following conclusions were drawn:

- Negligible changes in water levels were predicted as a result of the river releases being introduced.
- Median mid-channel velocities upstream of the river releases were predicted to reduce by up to 5%, while velocities downstream were predicted to increase by a similar percentage.
- Lower (5th percentile) velocity magnitudes in the immediate 50 m of the diffuser were predicted to increase by 150% to over 200%. Beyond this distance, upstream velocities were again predicted to reduce and downstream velocities to increase.
- Relative to the 5th and 50th percentiles, higher velocity magnitudes remained relatively unchanged as a result of the river releases.
- From comparison of cross channel flows 200 m upstream of the diffuser, the releases are predicted to incur a net upstream residual in terms of the predicted flows i.e. over the course of several tidal cycles, the cumulative flow upstream increases. A median change of 0.1 m^3/s directed upstream was predicted relative to the background conditions.
- Conversely, from comparison of cross channel flows 200 m downstream of the diffuser, the releases are predicted to incur a net downstream residual. A higher median change of 0.6 m^3/s directed downstream was predicted relative to the corresponding background conditions.

6.1.5.3 Salinity

Salinity levels are predicted to reduce slightly as a result of the operation of the WRRF and the release of freshwater near the John Whitton Bridge. These reductions were predicted for both variations of the impact scenarios but with slightly higher reductions predicted under the non-climate change scenario. Reductions against the background scenario results were also predicted to be higher under lower rainfall conditions. This is due to the increased influence of the river releases, as well as the prevailing higher salinity conditions that occur in the absence of substantial freshwater inflows from the catchment and the Upper Parramatta River.

Under the non-climate change scenarios, annual median concentrations were predicted to reduce within a range of ~2.9 PSU (lower rainfall year – refer to Figure 6-24) to ~2.3 PSU (average rainfall year) to ~1.7 PSU (higher rainfall year) with the most sizable reductions occurring within approximately 2 km of the release point. Marginally higher reductions were predicted for the annual 80th percentile profiles.

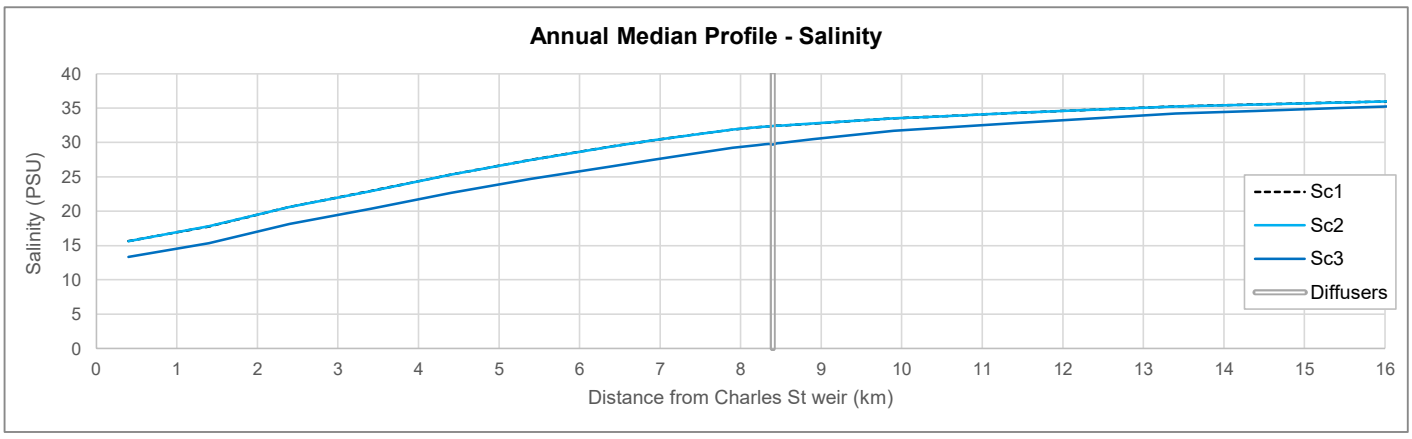

Figure 6-24 Predicted annual median salinity concentrations – scenarios Sc1, Sc2 and Sc3 (lower rainfall year)

Under the climate change scenarios, the impacts were marginally lower with annual median concentrations predicted to reduce within a range of ~2.7 PSU (lower rainfall year – refer to Figure 6-25) to ~1.8 PSU (average rainfall year) to ~1.7 PSU (higher rainfall year). Marginally higher reductions were again predicted for the 80th percentile profiles.

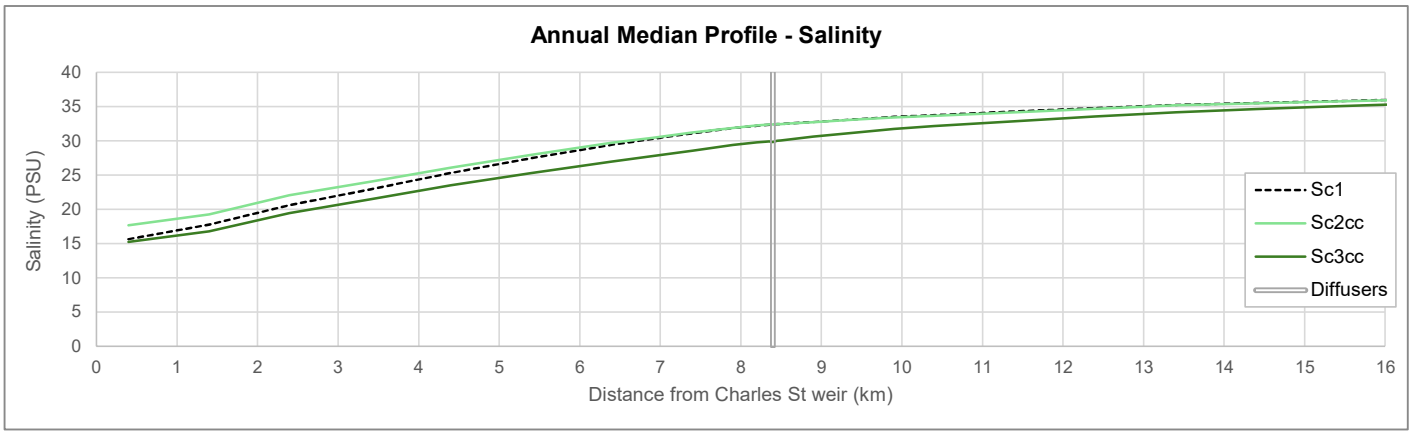

Figure 6-25 Predicted annual median salinity concentrations – scenarios Sc1, Sc2cc and Sc3cc (lower rainfall year)

In terms of instantaneous/short-term impacts on salinity in the vicinity of the river releases, peak reductions generally were predicted to be between 5 and 6 PSU but up to 7 PSU under more extended dry periods (refer to Figure 6-26). The magnitude of these shorter-term reductions decrease quickly with distance with peak reductions generally predicted to be ~3 PSU at a distance of 1 km from the diffuser (refer to Figure 6-27).

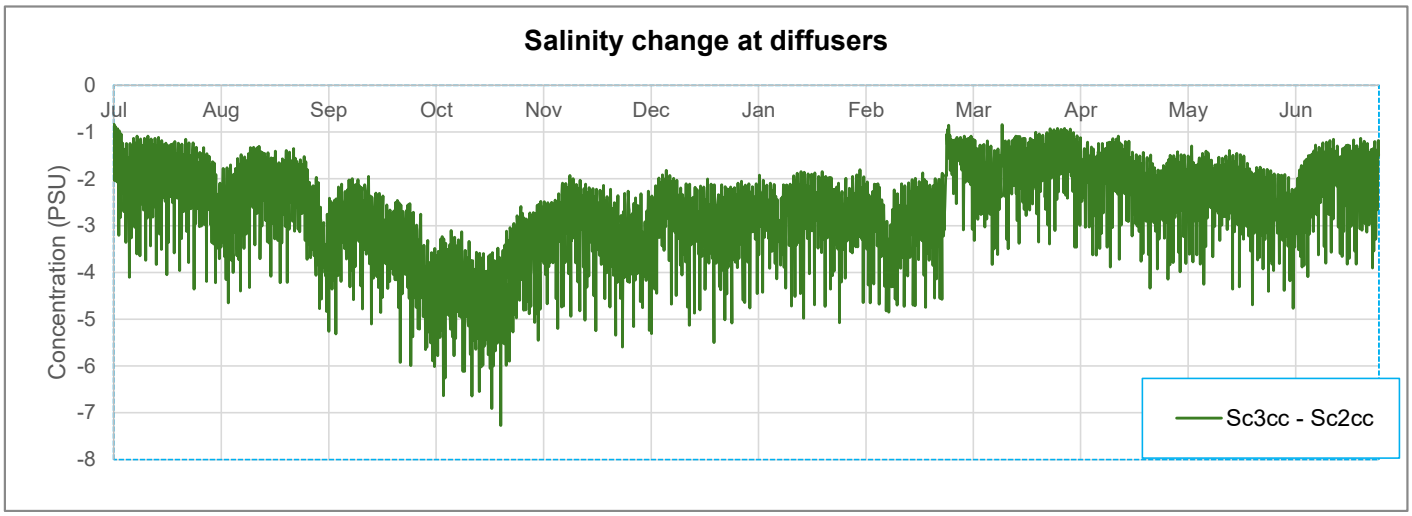

Figure 6-26 Predicted change in time series concentrations of salinity in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (lower rainfall year)

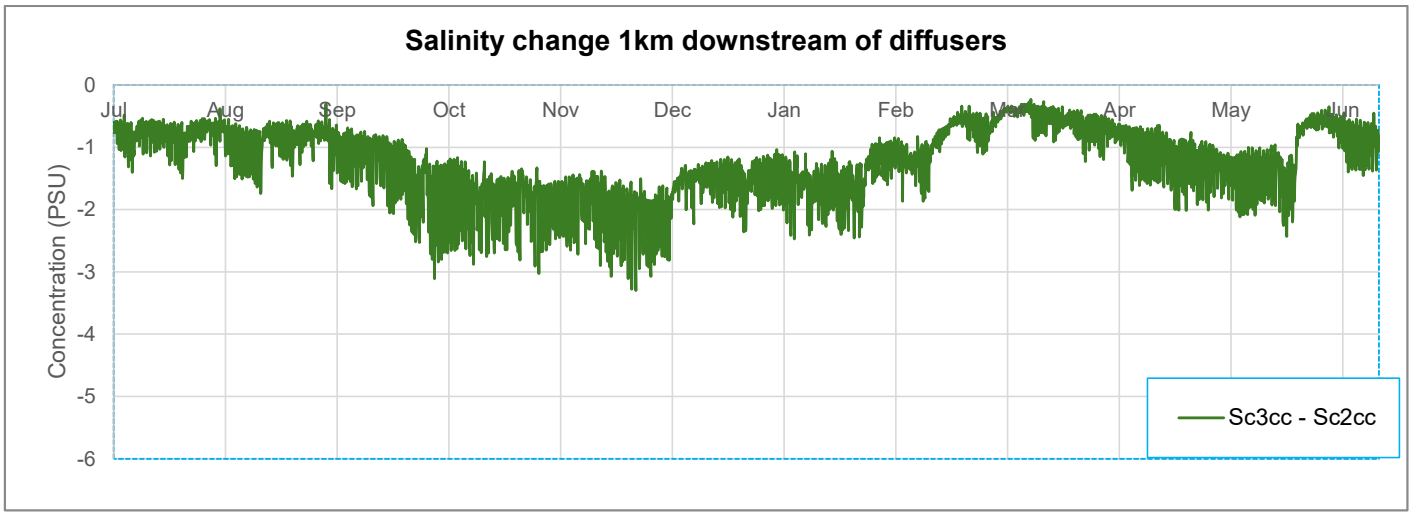

Figure 6-27 Predicted change in time series concentrations of salinity 1 km downstream of the diffuser – scenario Sc3cc relative to Sc2cc (average rainfall year)

While the more substantial impacts were predicted in the river reaches near the John Whitton Bridge, reductions in salinity were observed to lesser extents across the wider estuary and within Sydney Harbour. Dependent on the rainfall year and assumptions relating to climate change, reductions in annual median salinity of up to 0.5 PSU were predicted between 14 to 18 km downstream of the Charles Street Weir, noting the diffuser is located at a chainage of 8.4 km (refer Figure 6-28 and Figure 6-29).

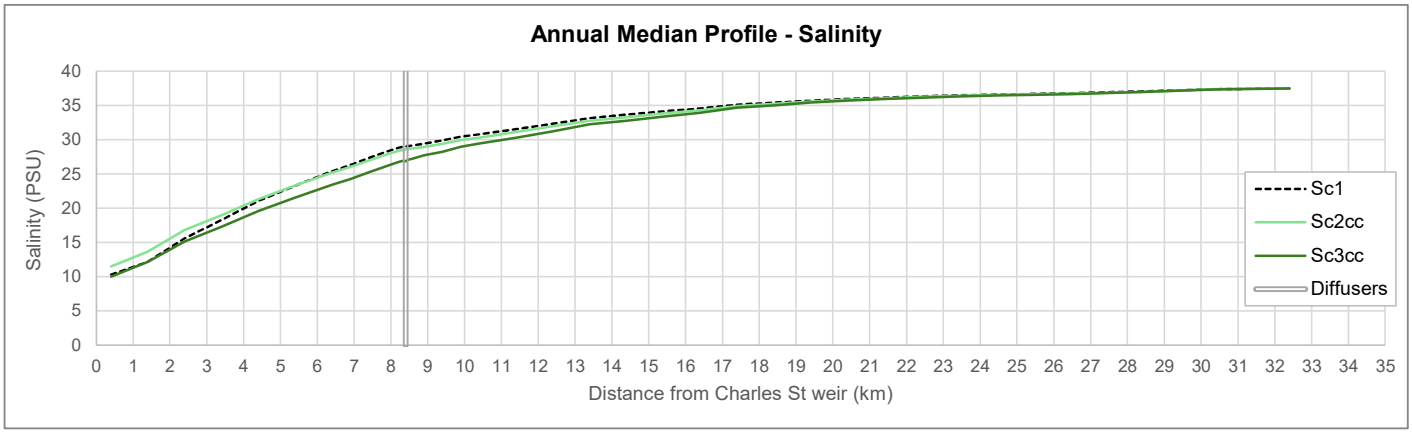

Figure 6-28 Predicted annual median salinity concentrations – scenarios Sc1, Sc2cc and Sc3cc (average rainfall year)

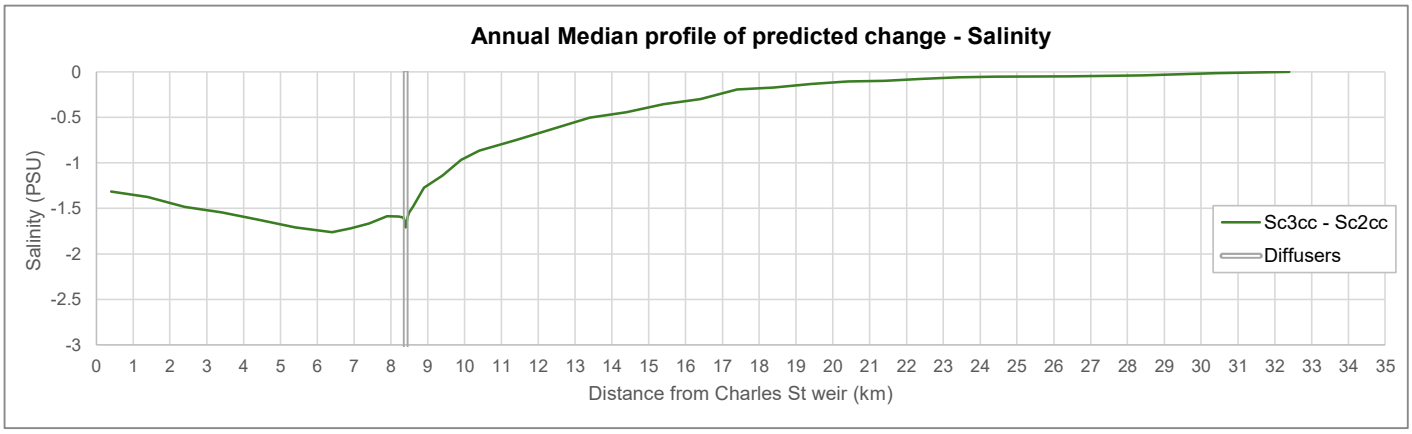

Figure 6-29 Predicted annual median of changes in salinity concentrations – scenario Sc3cc relative to Sc2cc (average rainfall year)

While the results presented above (and in Appendix D) are representative of predicted salinity levels at a mid-water column depth, it is expected that under extended low rainfall conditions, the water column would generally be well mixed both upstream and downstream of the release point. The well mixed nature of the water column being generated as a product of the diffuser design (refer Sections 6.2.1 and 6.2.2 for details) as well as the prevailing tidal velocities, which are elevated due to the relatively shallow and constricted nature of the river near the John Whitton Bridge. The risk of stratification or pooling of freshwater at the water surface as a product of the project is therefore expected to be low.

6.1.5.4 Temperature

Temperatures were generally predicted to increase due to the river releases with peak elevations in annual medians of ~0.1ºC if climate change was not simulated. These elevations reducing to ~0.05ºC if climate change was simulated (refer to Figure 6-30).

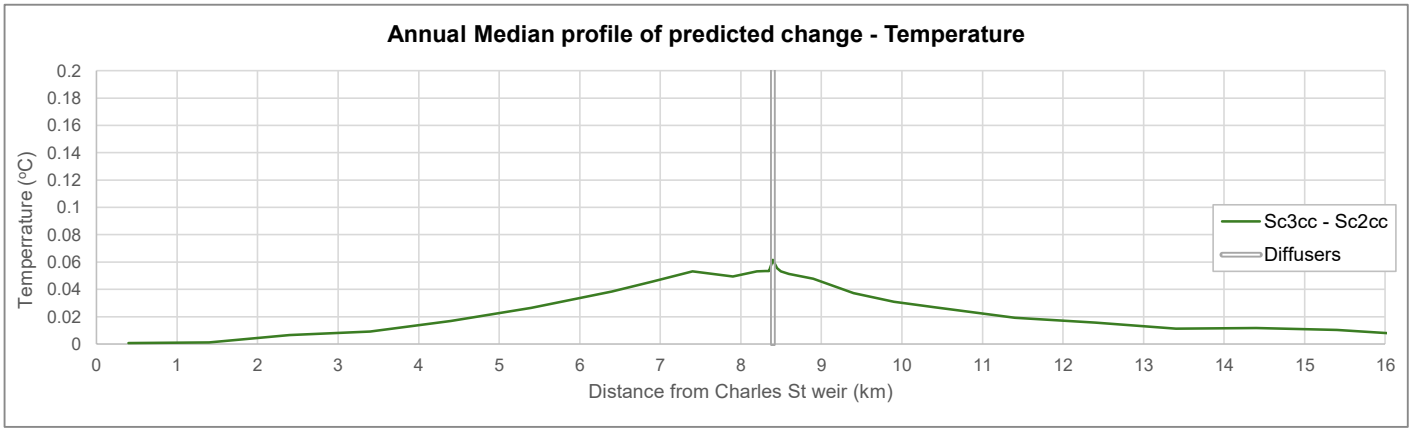

Figure 6-30 Predicted annual median of changes in temperature – scenario Sc3cc relative to Sc2cc (average rainfall year)

A seasonal pattern was observed with more substantial increases in temperature observed during the cooler months and some potential for minor cooling in the summer months.

In terms of shorter-term variations, changes of up to ±0.5ºC were generally predicted in the vicinity of the releases but with some more short period peaks predicted closer to ~1ºC (refer to Figure 6-31).

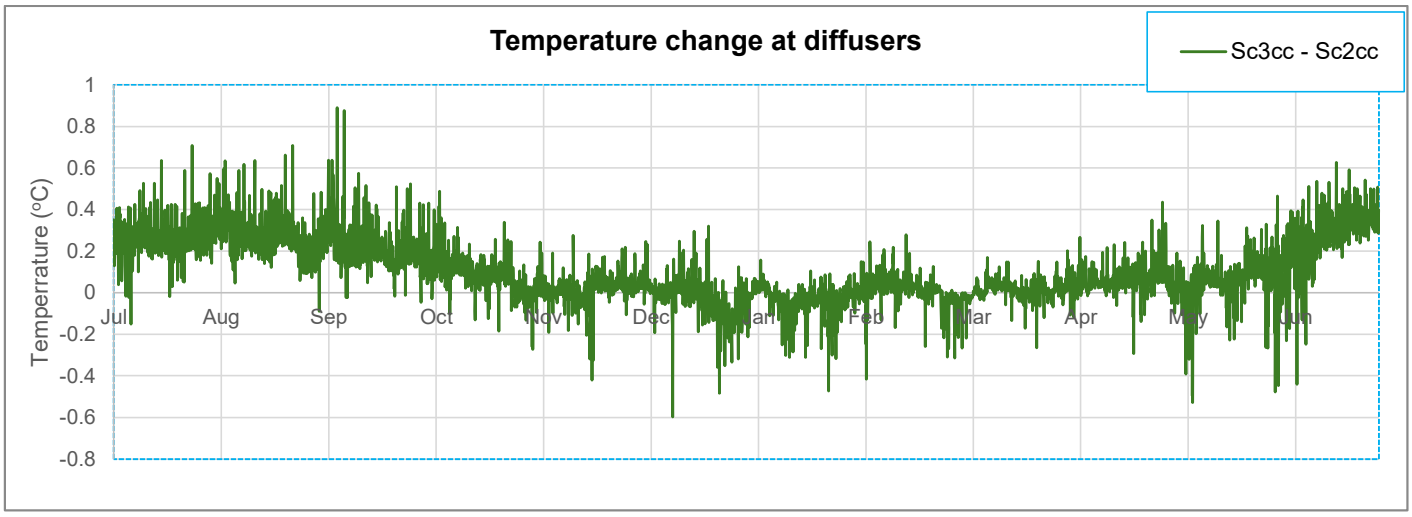

Figure 6-31 Predicted change in time series of temperature in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.1.5.5 Nitrogen

Concentrations of total nitrogen in the river were generally reduced as a result of the WRRF operation. These reductions were generated as a product of the low nutrient releases as well as the corresponding mitigation of wet weather overflows. Of note, the effects of the offline events were easily identified but generally short lived with the exception of the events that occurred within the lower rainfall year when the reduced levels of flushing prolonged their impact.

Annual median concentrations were predicted to reduce by up to ~0.04 mg/L in the higher rainfall years but with the potential for minor increases in lower rainfall years due to the prolonged impact of the offline events. Annual 80th percentile concentrations were predicted to reduce more substantially, by up to ~0.25 mg/L under the higher rainfall year conditions.

Due to the reductions in annual medians shown in the results, the predicted protection of relevant ANZG DGV is also increased for all the rainfall years simulated. The predicted extent of the estuary where annual median concentrations fall below the relevant guideline value increases.

Figure 6-32 and Figure 6-33 present the predicted annual medians and annual medians of changes in concentrations under the average rainfall simulations. Figure 6-34 presents the corresponding time series for the average rainfall year and finally Figure 6-35 and Figure 6-36 present the change in predicted time series concentrations for the average year and lower rainfall year. Figure 6-35 and Figure 6-36 allow for an understanding of the predicted responses to the offline events and the duration of the impacts following these events.

Generally, both variations of the impact scenarios (Sc3 and Sc3cc) predicted similar patterns of response to the river releases and overflow mitigations, however larger reductions were predicted if climate change conditions were adopted.

With respect to the inorganic fractions, increases in ammonia and oxidised nitrogen were predicted in the scenario simulations, particularly for oxidised nitrogen due to the higher percentage of content within the releases of advanced treated water. Increases in annual medians of ammonia and oxidised nitrogen range up to 0.0005 mg/L and 0.003 mg/L respectively under the lower rainfall year.

From analysis of the time series results, the predicted effects of the river releases (including the offline events) as well as the mitigation of the overflows can be clearly observed. Figure 6-37 presents the wet year time series results for ammonia and provides an understanding of the potential reductions due to the overflow mitigations that were predicted to be prevalent from February to April 2022. Figure 6-38 presents time series results for oxidised nitrogen for the same period. In addition to the overflow mitigation effect, the results for oxidised nitrogen also clearly show the predicted impacts for the offline events (in August and September) as well as increases due to the release of advanced treated water.

With respect to the inorganic fractions of nitrogen, it is also noted in the GPOP WQRM Calibration Report (Sydney Water, 2025b) that the model has the potential to under-predict ambient concentrations, particularly for oxidised nitrogen. The results from the impact assessments may therefore be treated as conservative.

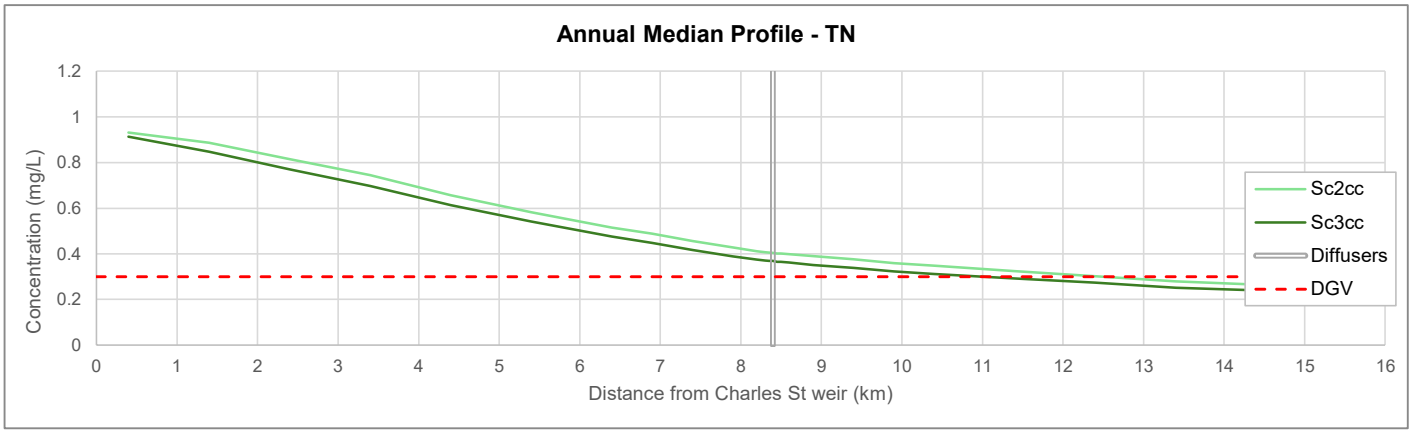

Figure 6-32 Predicted annual median TN concentrations – scenario Sc3cc and Sc2cc (average rainfall year)

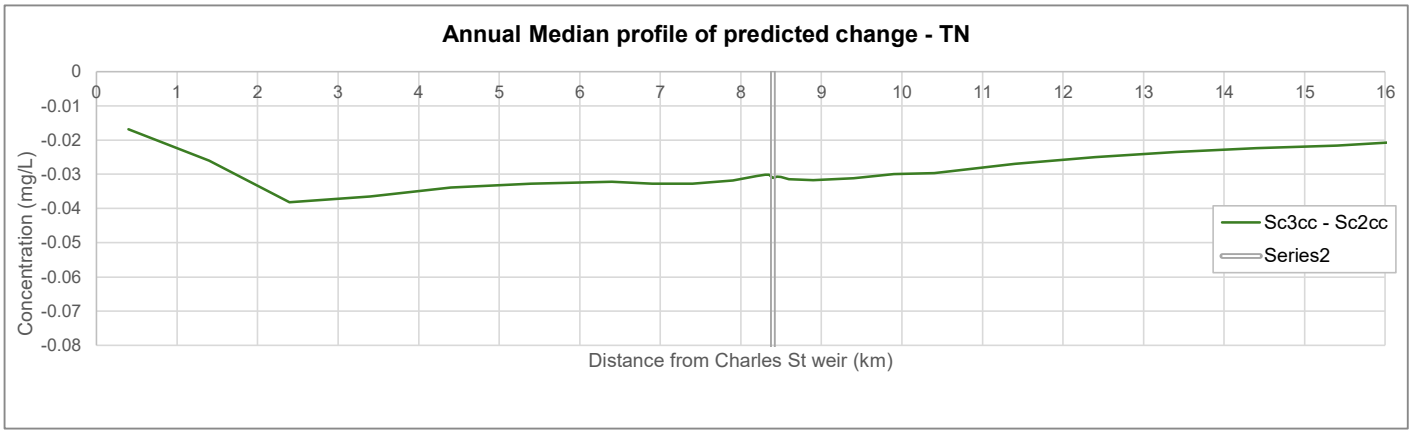

Figure 6-33 Predicted annual median of changes in TN concentrations – scenario Sc3cc relative to Sc2cc (average rainfall year)

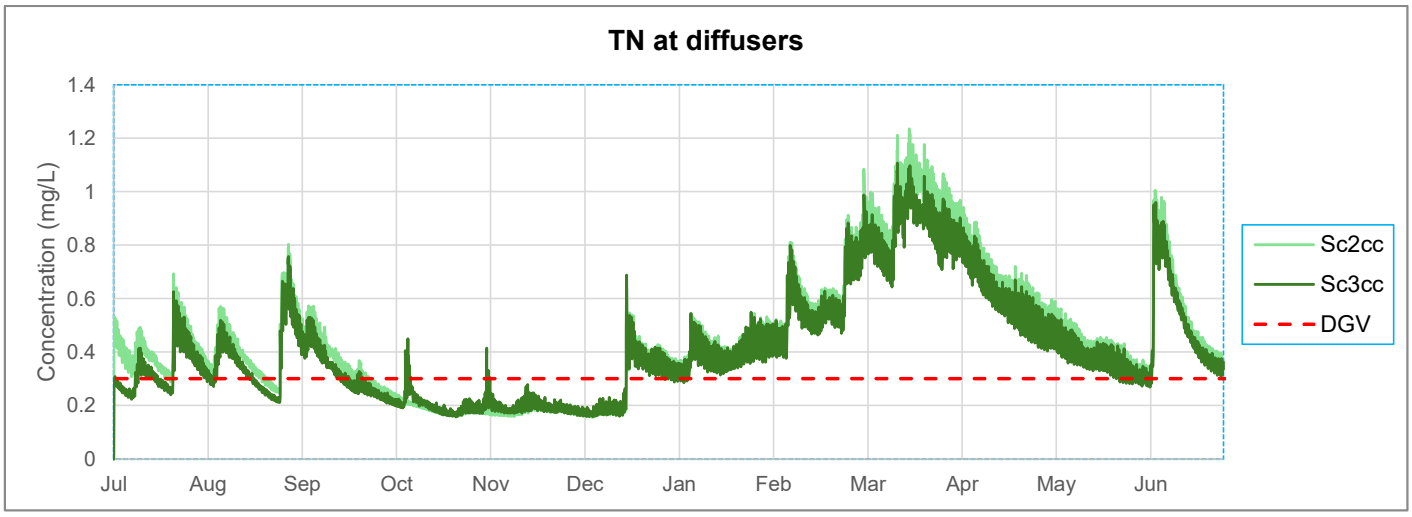

Figure 6-34 Predicted time series of TN concentrations in the vicinity of the diffuser – scenario Sc3cc and Sc2cc (average rainfall year)

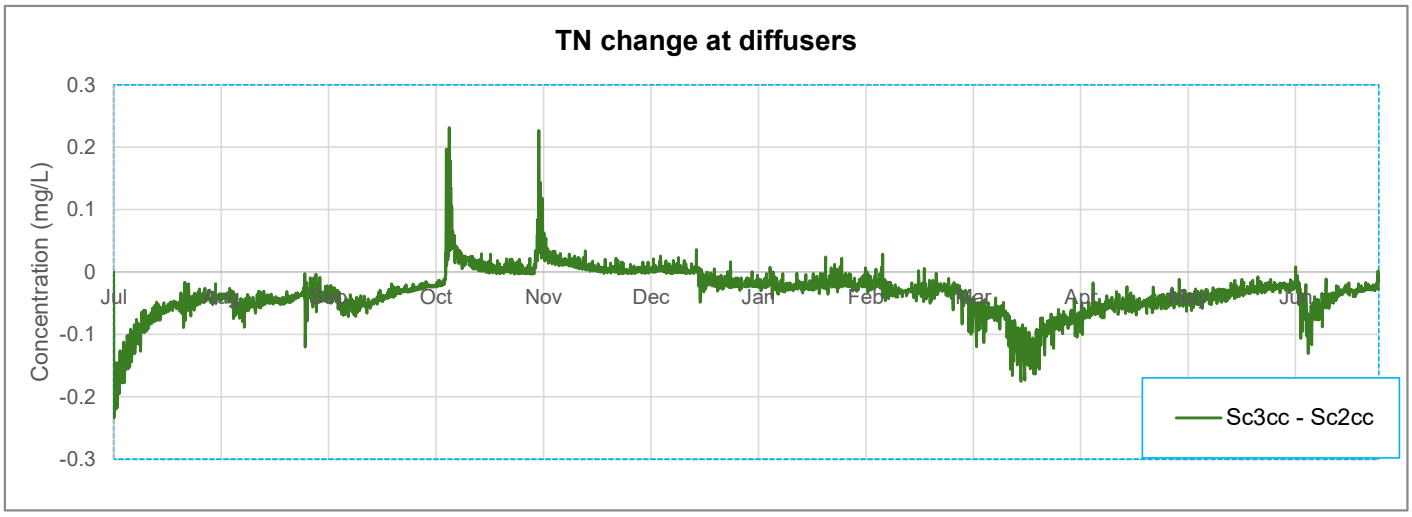

Figure 6-35 Predicted change in time series of TN concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (average rainfall year)

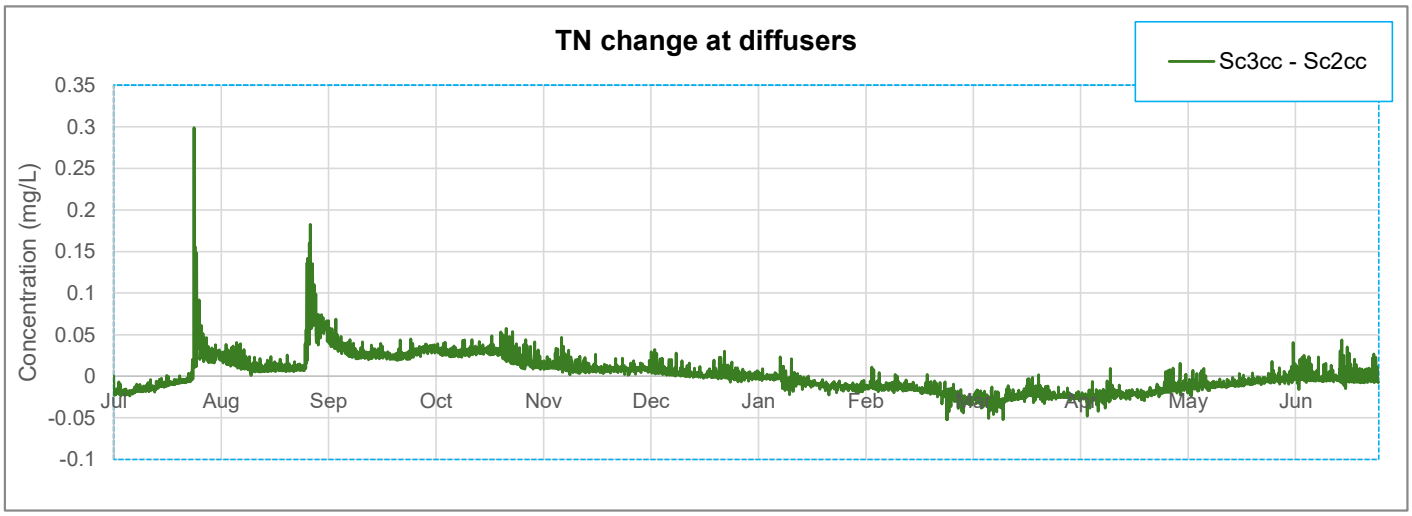

Figure 6-36 Predicted change in time series of TN concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (lower rainfall year)

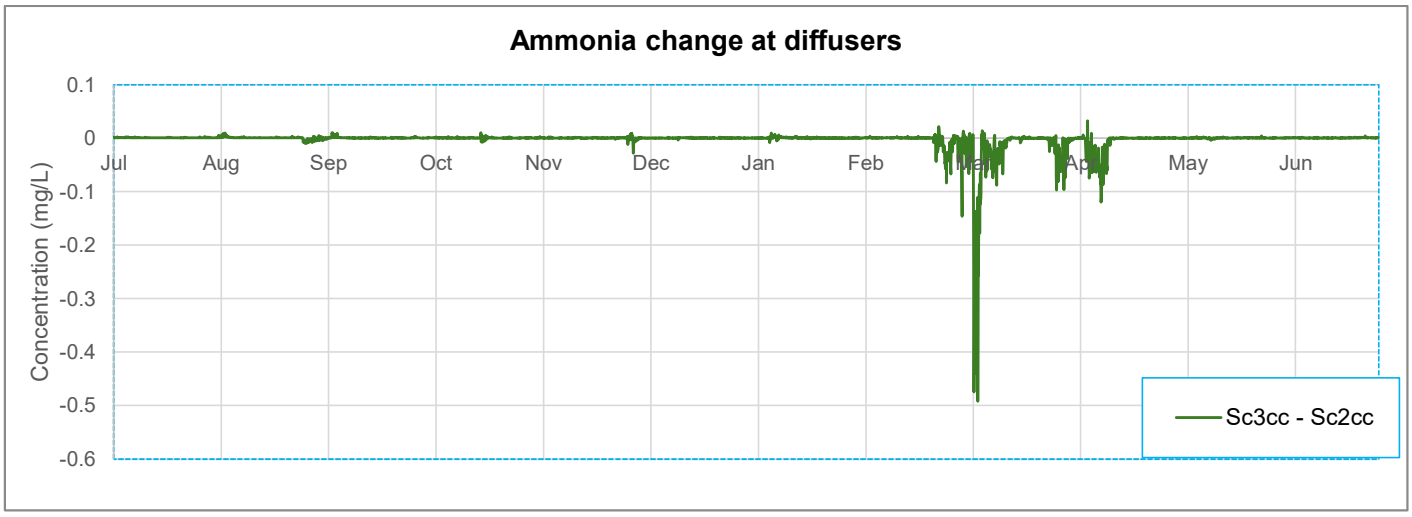

Figure 6-37 Predicted change in time series of ammonia concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (higher rainfall year)

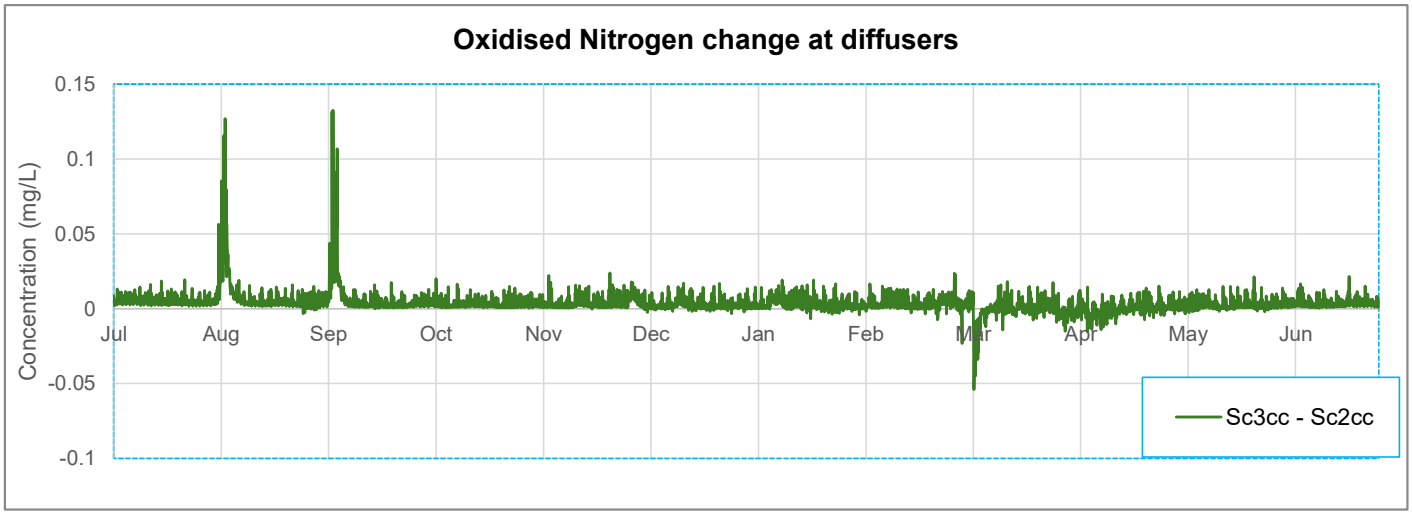

Figure 6-38 Predicted change in time series of oxidised nitrogen concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.1.5.6 Phosphorus

Similar trends were observed in the phosphorus scenario results as those presented for total nitrogen, however the reductions were predicted to be proportionally higher due to the lower concentrations assumed in the releases of advanced treated water. Also, as a result of the low release concentrations, reductions were also predicted for inorganic phosphorus. In addition to the beneficial effects generated as a product of the river releases, mitigation of overflows from the wastewater network also contributed to the overall reductions.

The effects of the offline events are again easily identified but the impacts are predicted to be shorter than those predicted for nitrogen.

Figure 6-39 presents the annual median concentrations for the lower rainfall year with Figure 6-40 and Figure 6-41 respectively presenting corresponding time series concentrations and the change in predicted time series concentrations. These latter two figures allow for an understanding of the predicted responses to the advanced treated water and wet weather overflow mitigation, as well as the offline events and the duration of the impacts following these events.

Due to the reductions in annual medians shown in the results, predicted protection of relevant ANZG DGV increases. The predicted extent of the estuary where annual median concentrations fall below the relevant guideline value may increase.

With respect to the inorganic fractions, the same trends were observed. Figure 6-42 presents the average year annual median concentrations with Figure 6-43 and Figure 6-44 presenting the corresponding time series results and the predicted change in time series concentrations respectively.

Annual medians of inorganic phosphorus were predicted to decrease by up to ~0.0025 mg/L and while these reductions are considered beneficial, increased protection of relevant DGVs was not predicted for any of the rainfall years simulated.

Again, both variations of the impact scenarios (Sc3 and Sc3cc) predicted similar patterns of response to the river releases and overflow mitigations, however larger reductions were predicted if climate change conditions were adopted.

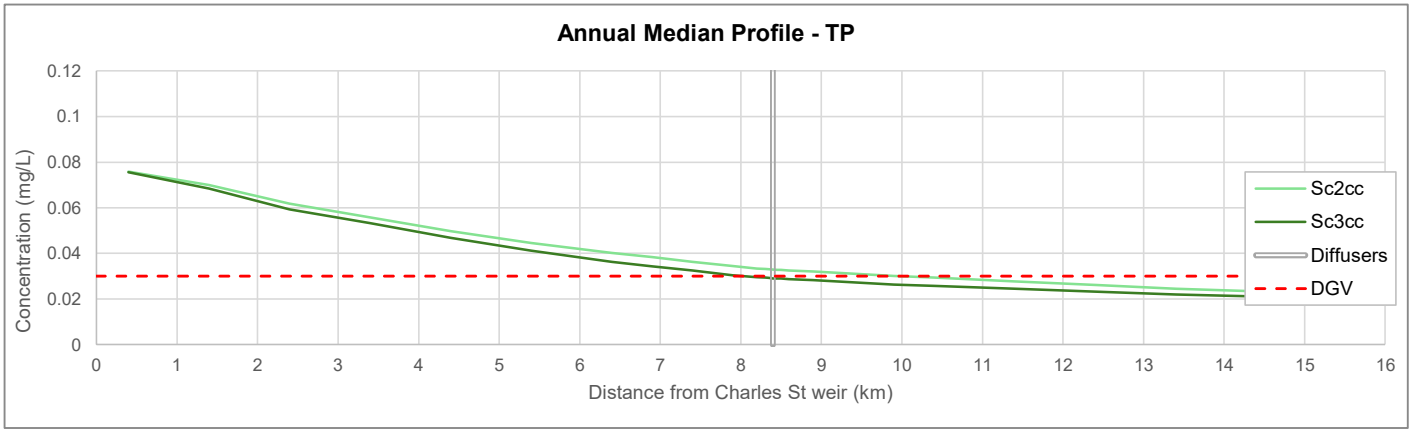

Figure 6-39 Predicted annual median TP concentrations – scenario Sc3cc and Sc2cc (lower rainfall year)

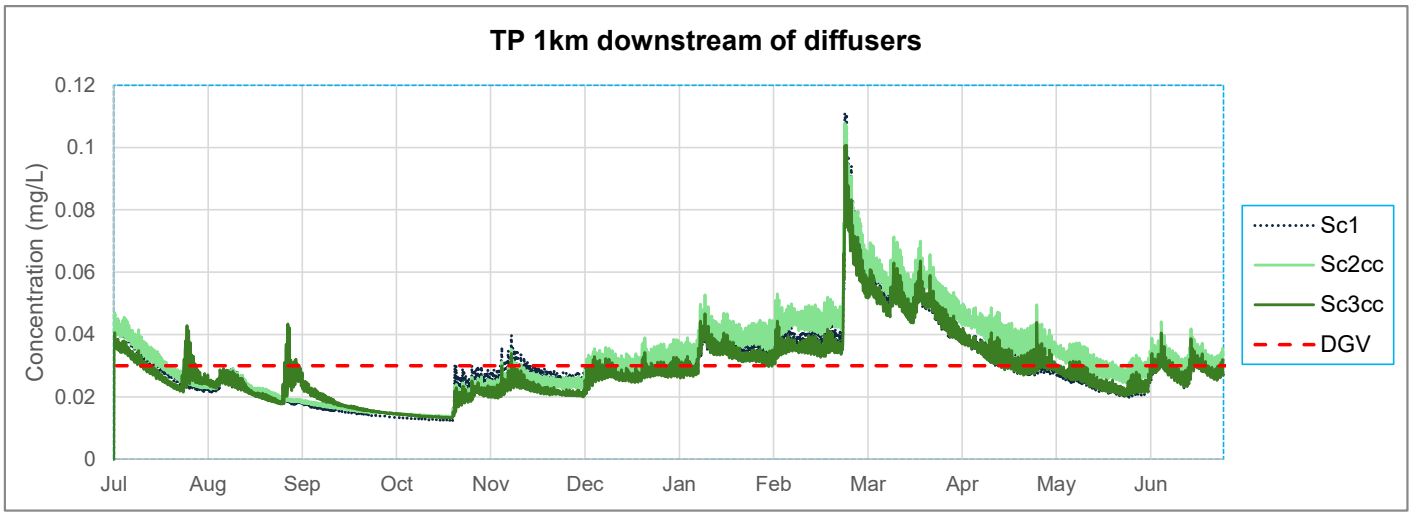

Figure 6-40 Predicted time series of TP concentrations 1 km downstream of the diffuser – scenarios Sc3cc and Sc2cc (lower rainfall year)

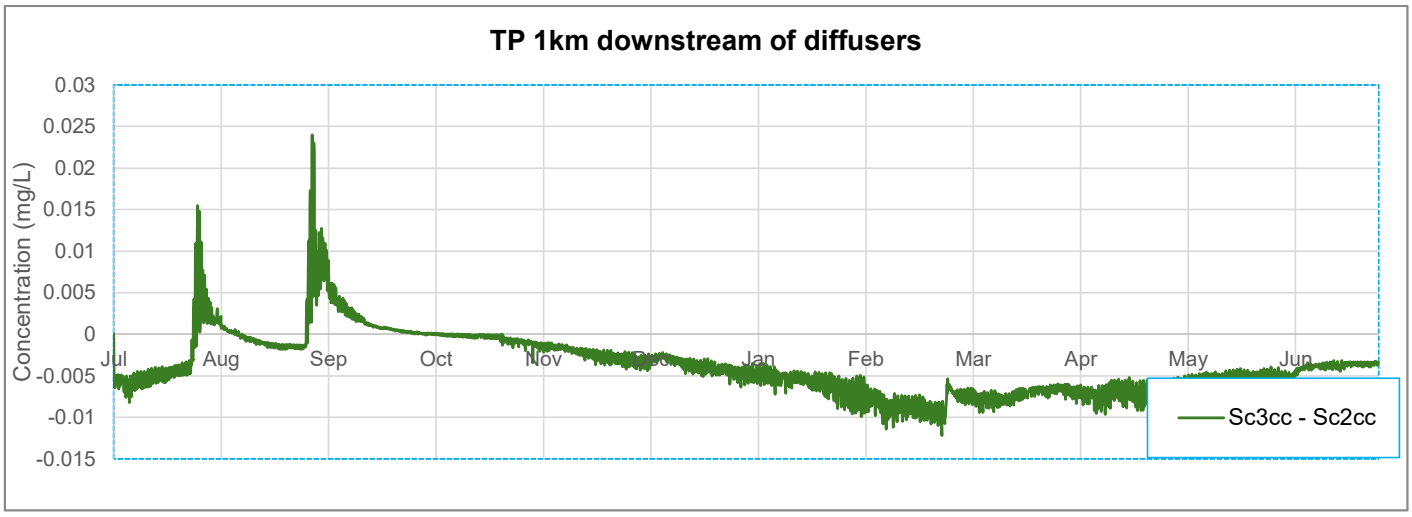

Figure 6-41 Predicted change in time series of TP concentrations 1km downstream of the diffuser – scenario Sc3cc relative to Sc2cc (lower rainfall year)

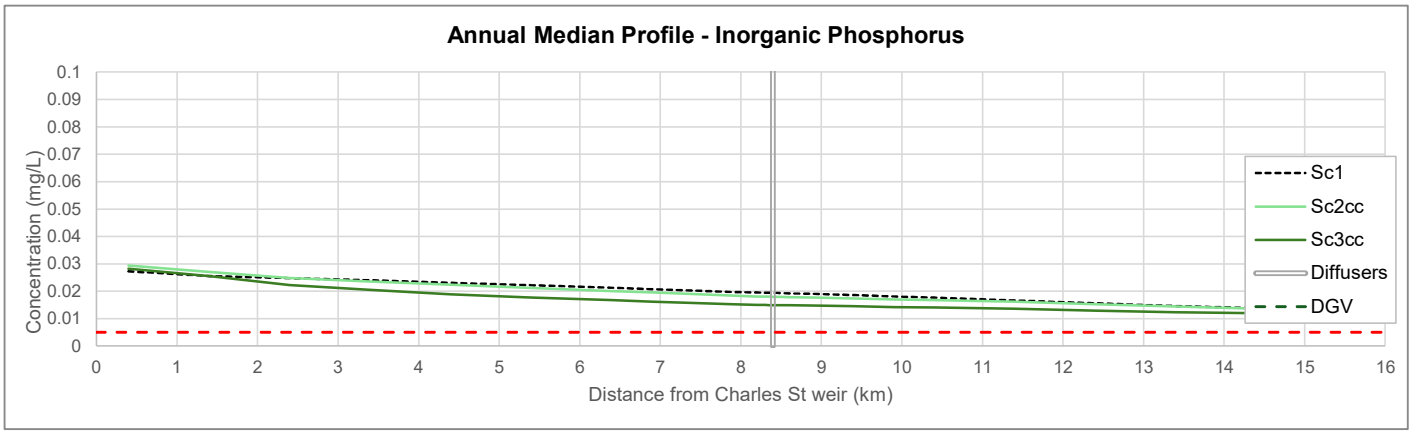

Figure 6-42 Predicted annual median Inorganic Phosphorus concentrations – scenario Sc3cc and Sc2cc (average rainfall year)

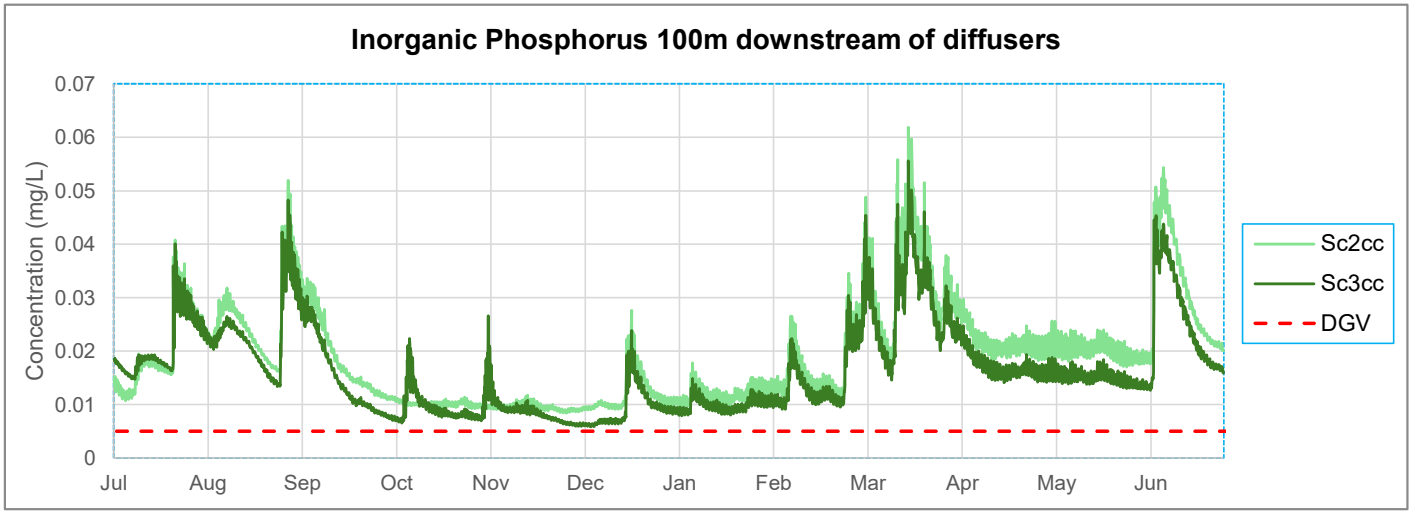

Figure 6-43 Predicted time series of Inorganic Phosphorus concentrations 100 m downstream of the diffuser – scenarios Sc3cc and Sc2cc (average rainfall year)

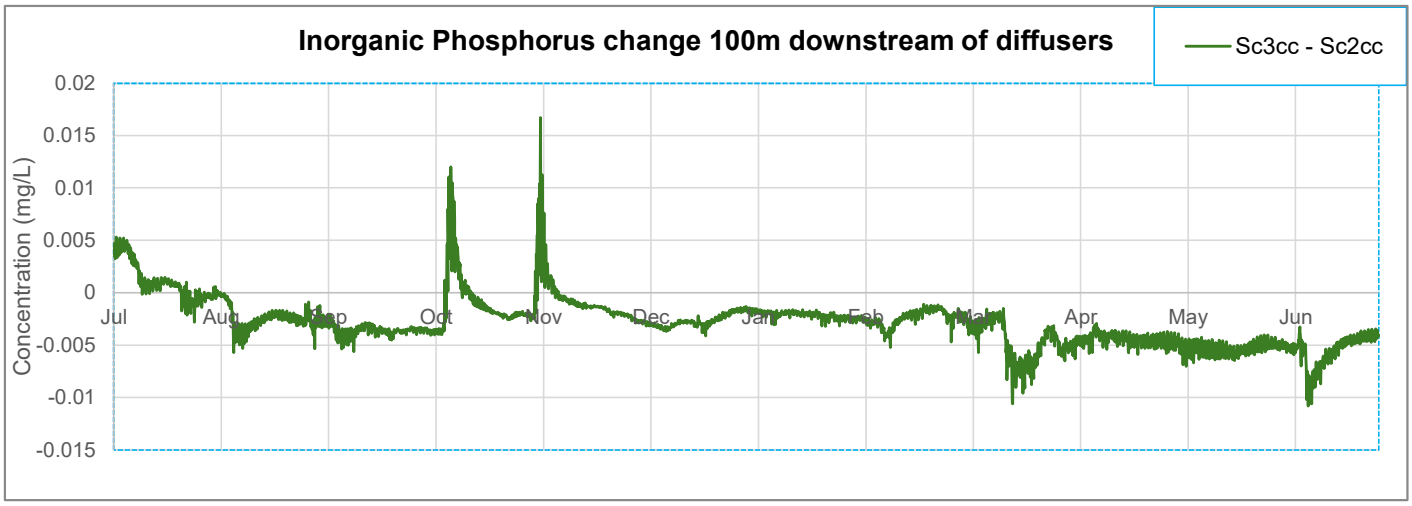

Figure 6-44 Predicted change in time series of Inorganic Phosphorus concentrations 100 m downstream of the diffuser – scenario Sc3cc relative to Sc2cc (average rainfall year)

6.1.5.7 Total suspended solids

With respect to total suspended solids, only limited reductions in concentrations were predicted as a result of the WRRF operation. Under both variations of the scenarios, predicted annual median concentrations generally varied by less than 0.5 mg/L (refer Figure 6-45).

On a temporal basis, short-term modifications were predicted (refer Figure 6-46 and Figure 6-47) but these were generally limited (< 2 mg/L) and considered primarily to be a product of changes in the wet weather overflow conditions.

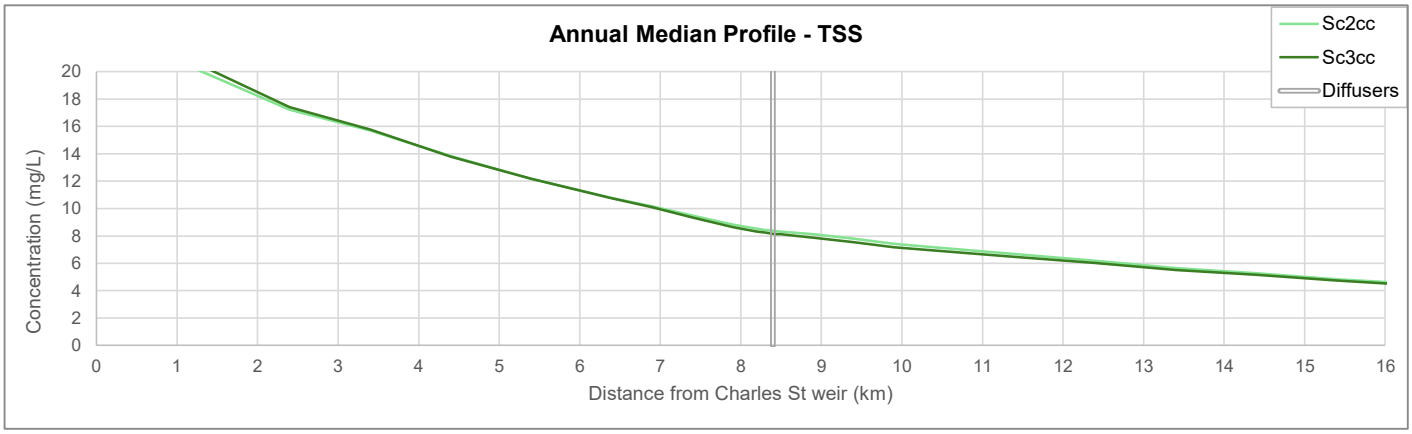

Figure 6-45 Predicted annual median TSS concentrations – scenario Sc3cc and Sc2cc (average rainfall year)

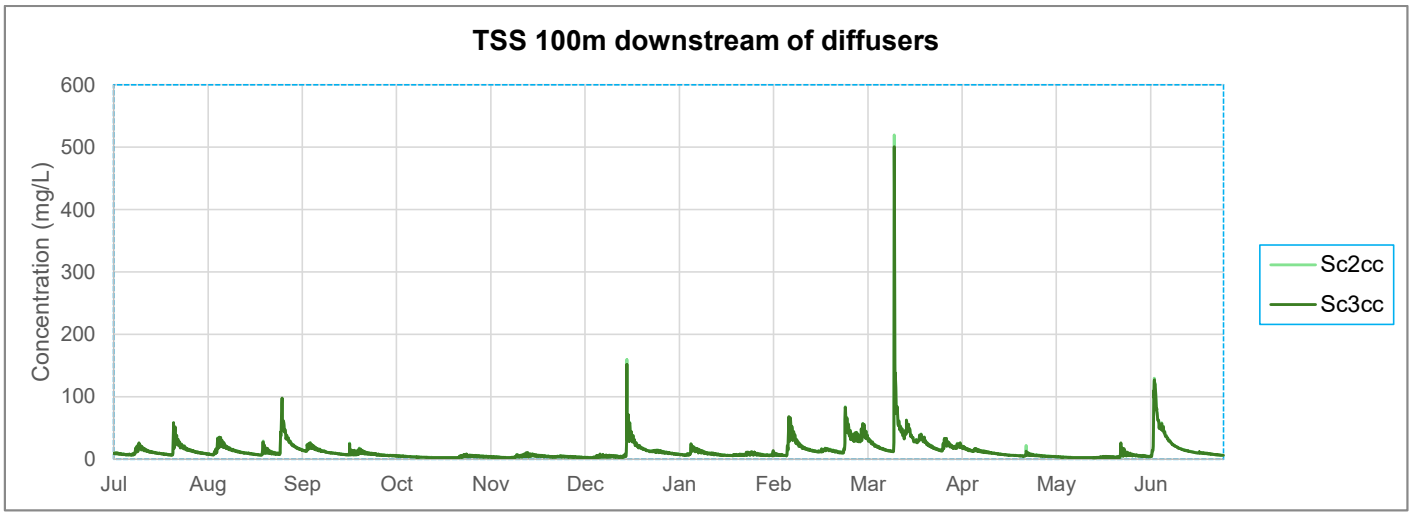

Figure 6-46 Predicted time series of TSS concentrations 100 m downstream of the diffuser – scenarios Sc3cc and Sc2cc (average rainfall year)

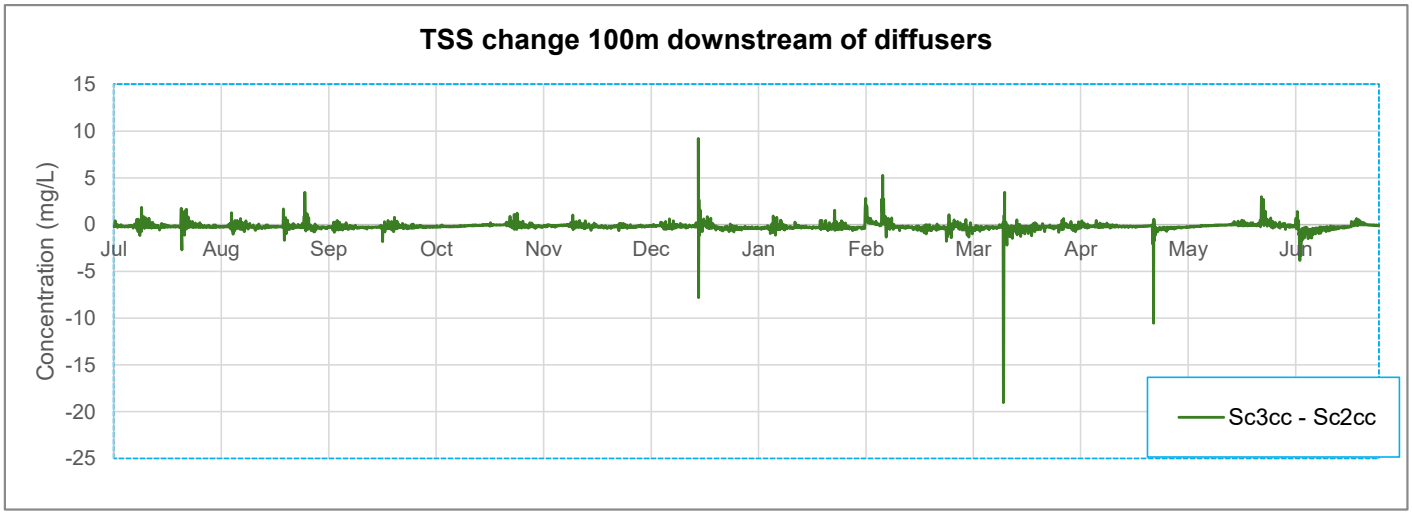

Figure 6-47 Predicted change in time series of TSS concentrations 100 m downstream of the diffuser – scenario Sc3cc relative to Sc2cc (average rainfall year)

6.1.5.8 Chlorophyll *a*

The modelling results indicated the potential for overall reductions in chlorophyll *a* across all the rainfall years simulated, thereby indicating a potential decrease in algal biomass within the estuary (refer Figure 6-48 and Figure 6-49). These reductions occurred because of mitigation in overflow nutrient loads as well as the introduction of the releases of the advanced treated water with low nutrient content. Periods of higher chlorophyll *a* were predicted subsequent to the offline events when higher nutrient loads were introduced from the tertiary treated water, particularly during the lower rainfall year where minor increases of up to 0.0005 mg/L (0.5 µg/L) were predicted for approximately two months after the events (Figure 6-50). This was considered to be the worst-case scenario with the offline events timed during extended dry periods during the low rainfall year. Under both the average and higher rainfall years, while the offline events were still timed to occur during the drier periods, the effects of the offline events were predicted to decrease in magnitude and the duration of their impact (refer Figure 6-51).

On an annual median concentration basis, the reductions were predicted to be marginally higher under climate change conditions. Conversely, there was potential for the effects of the offline events to be higher under the non-climate change scenario Sc3.

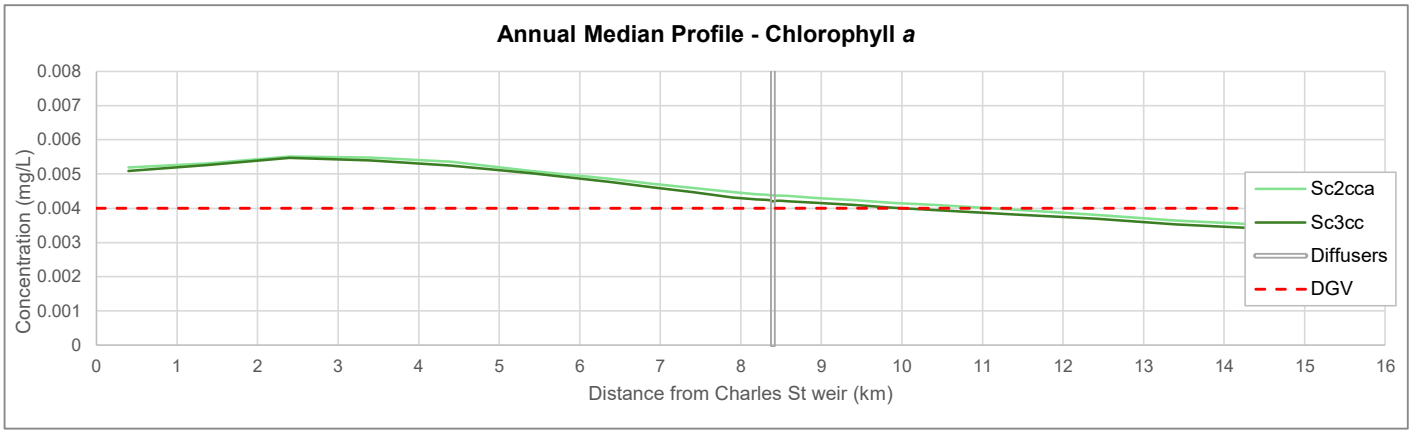

Figure 6-48 Predicted annual median Chlorophyll *a* concentrations – scenario Sc3cc and Sc2cc (lower rainfall year)

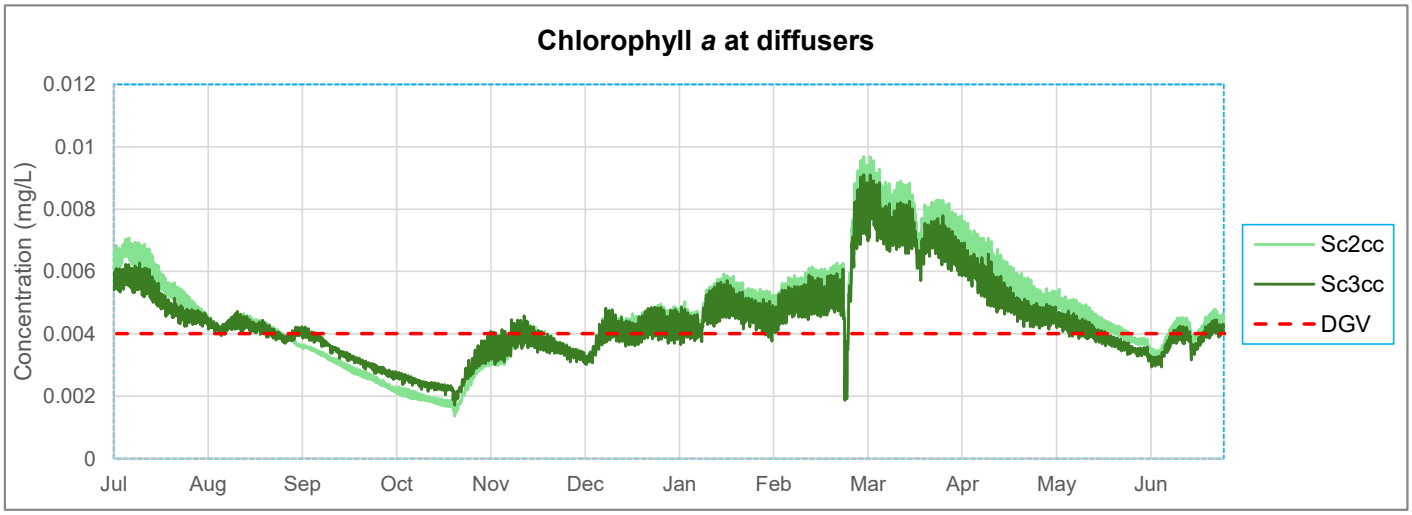

Figure 6-49 Predicted time series of Chlorophyll *a* concentrations in the vicinity of the diffuser – scenarios Sc3cc and Sc2cc (lower rainfall year)

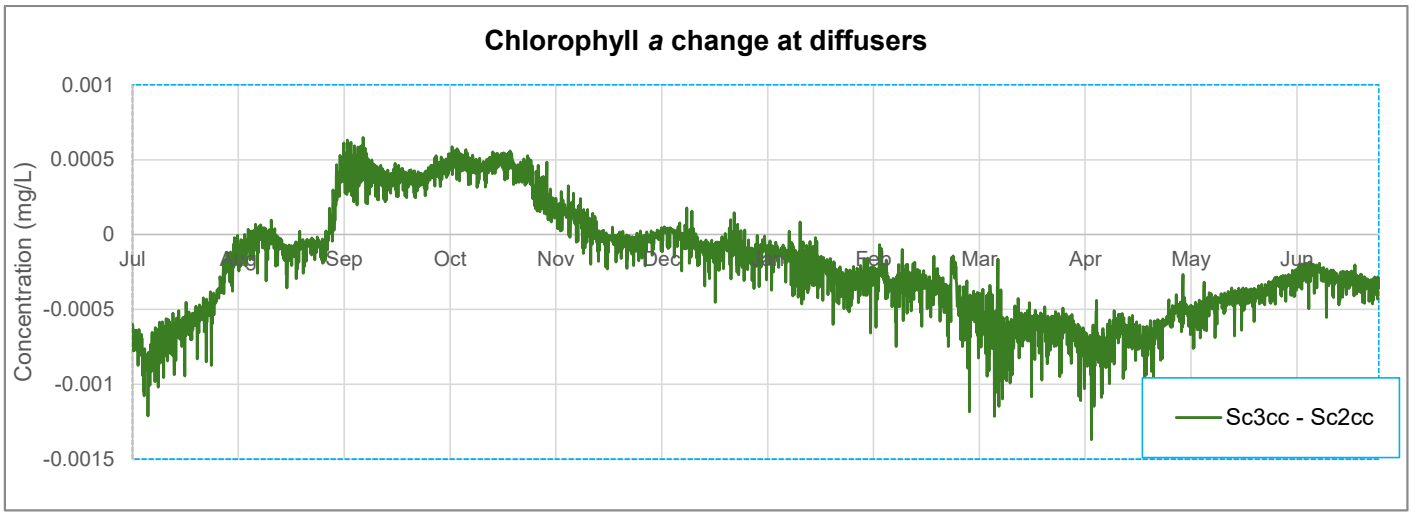

Figure 6-50 Predicted change in time series of Chlorophyll *a* concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (lower rainfall year)

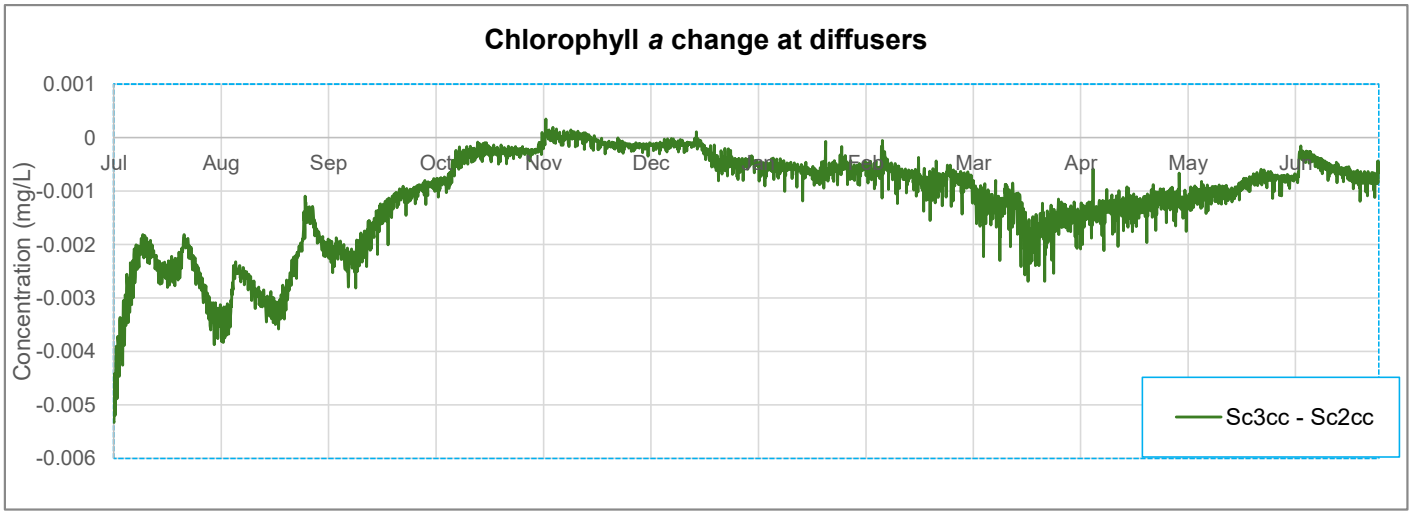

Figure 6-51 Predicted change in time series of Chlorophyll *a* concentrations in the vicinity of the diffuser – scenario Sc3cc relative to Sc2cc (average rainfall year)

6.1.5.9 Dissolved oxygen

Limited increases in dissolved oxygen concentrations are predicted as a result of the operation of the WRRF. From the annual median results, dissolved oxygen levels are predicted to increase up to 0.1 to 0.15 mg/L in the upper estuary (refer Figure 6-52). The time series results also indicate the potential for increases as a result of the river releases and to a lesser degree from the mitigation of overflows (refer Figure 6-53 and Figure 6-54). These variations generally fell within ±0.4 mg/L of the background concentrations.

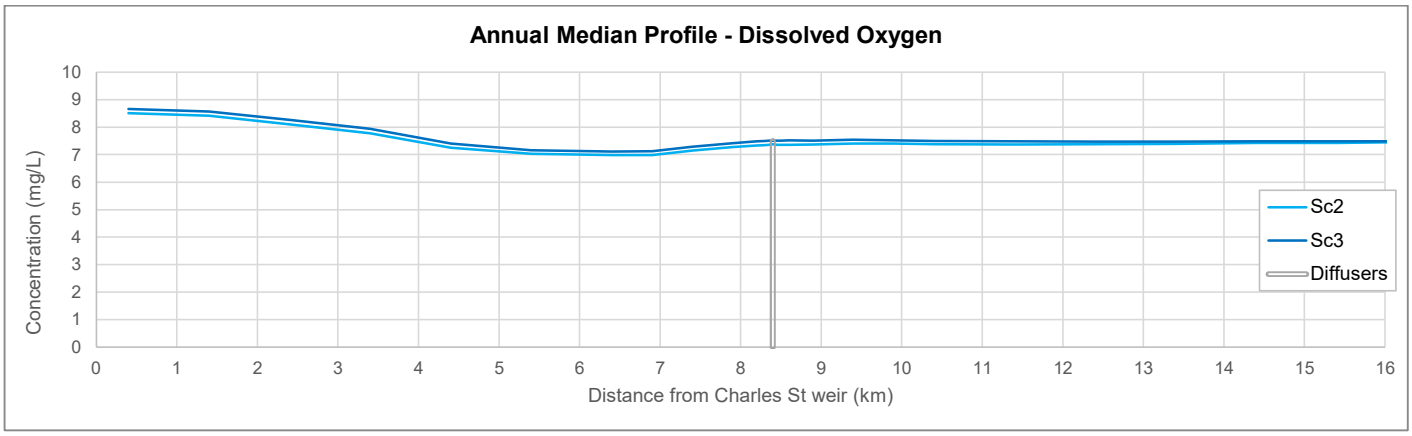

Figure 6-52 Predicted annual median Dissolved Oxygen concentrations – scenario Sc3cc and Sc2cc (lower rainfall year)

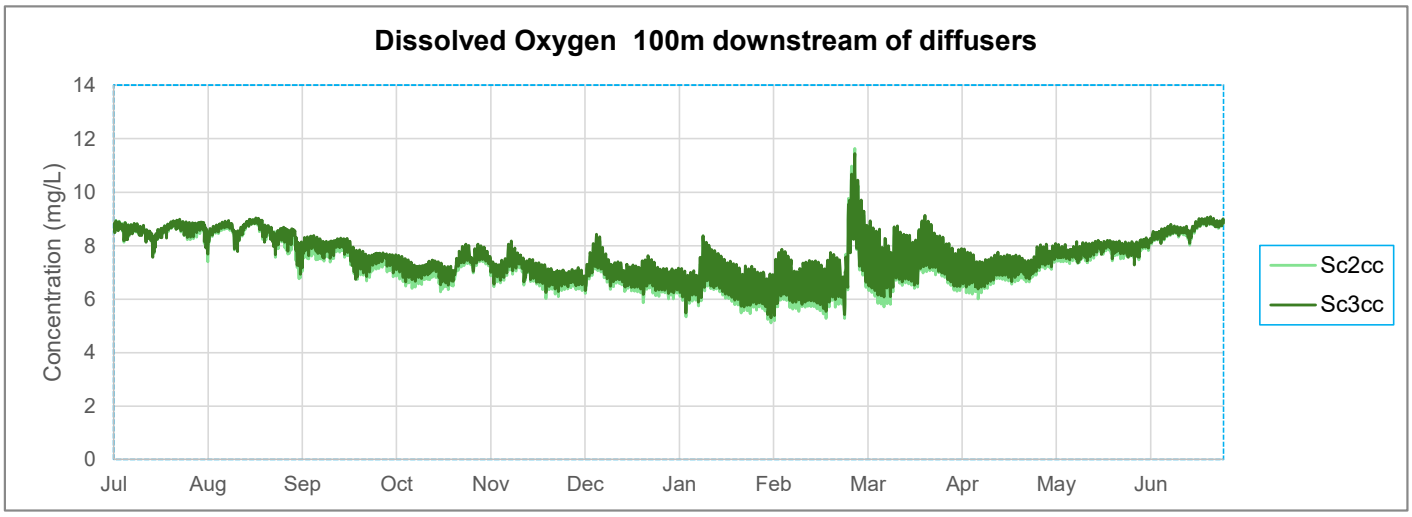

Figure 6-53 Predicted time series of Dissolved Oxygen concentrations 100 m downstream of the diffuser – scenarios Sc3cc and Sc2cc (lower rainfall year)

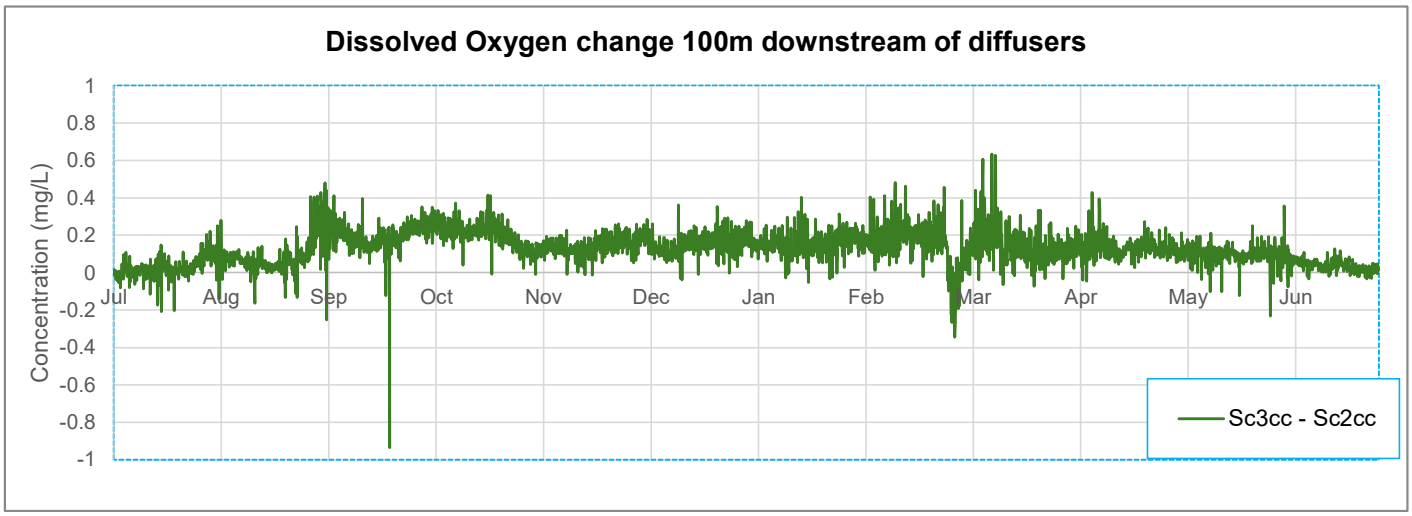

Figure 6-54 Predicted change in time series of Dissolved Oxygen concentrations 100 m downstream of the diffuser – scenario Sc3cc relative to Sc2cc (lower rainfall year)

6.1.5.10 Enterococci

While the operation of the WRRF assumes a continuous release of treated water with zero pathogenic content, the primary impact from its operation is predicted from the associated mitigation of wet weather overflows. Reductions of up to 10,000 cfu/100 mL in wet weather concentrations are predicted at some sites in the upper estuary during the higher rainfall year (refer Figure 6-55, Figure 6-56 and Figure 6-57).

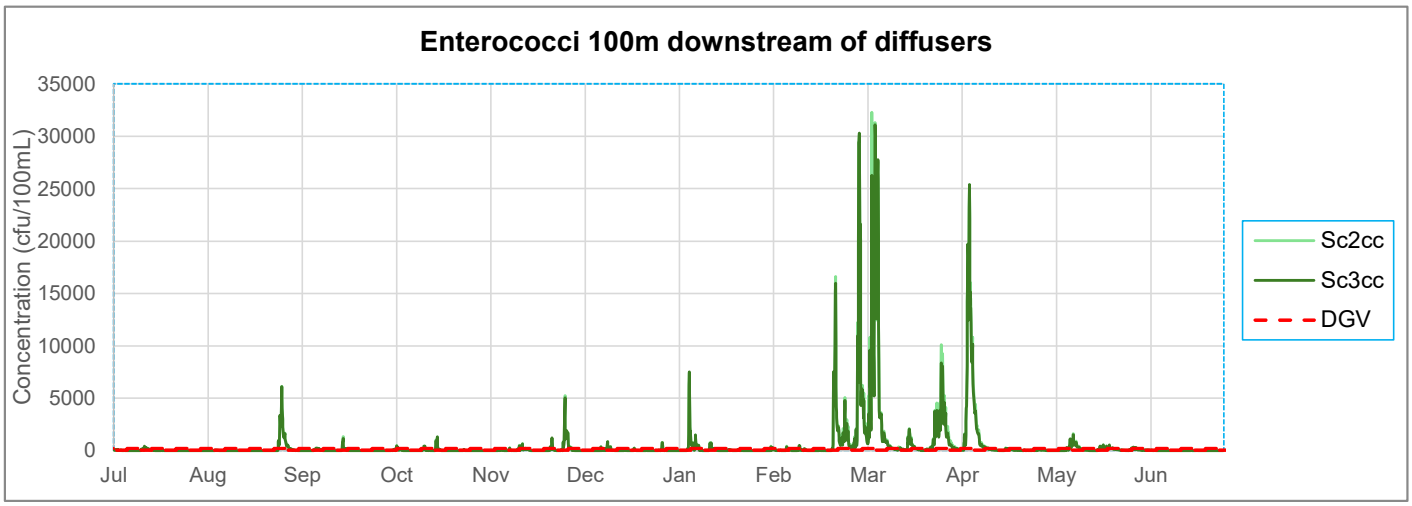

Figure 6-55 Predicted time series of Enterococci concentrations 100 m downstream of the diffuser – scenarios Sc3cc and Sc2cc (higher rainfall year)

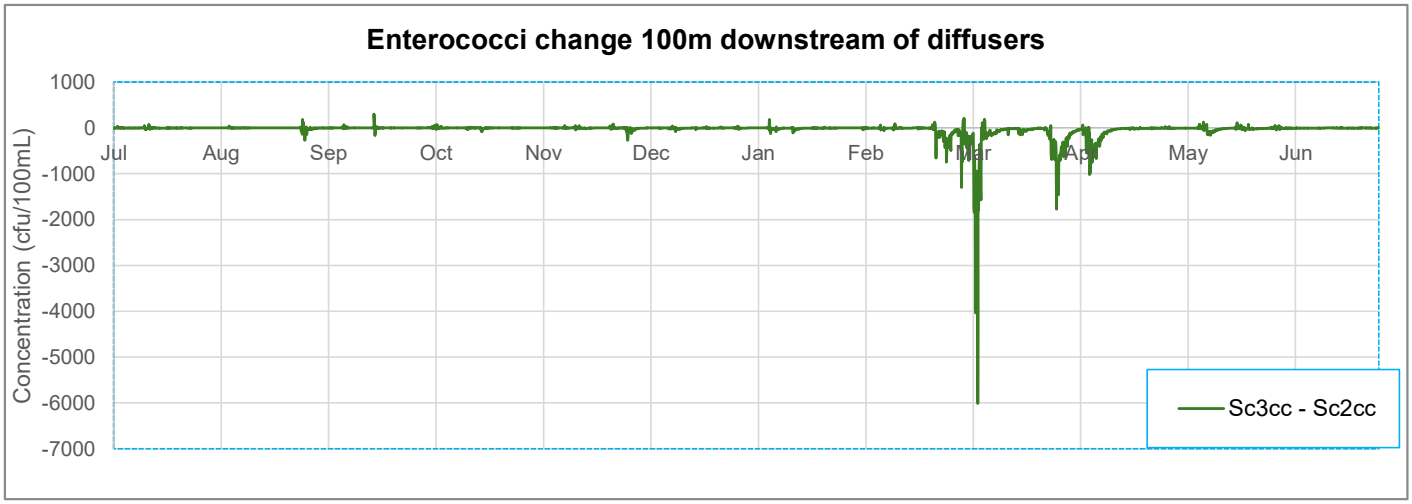

Figure 6-56 Predicted change in time series of Enterococci concentrations 100 m downstream of the diffuser – scenario Sc3cc relative to Sc2cc (higher rainfall year)

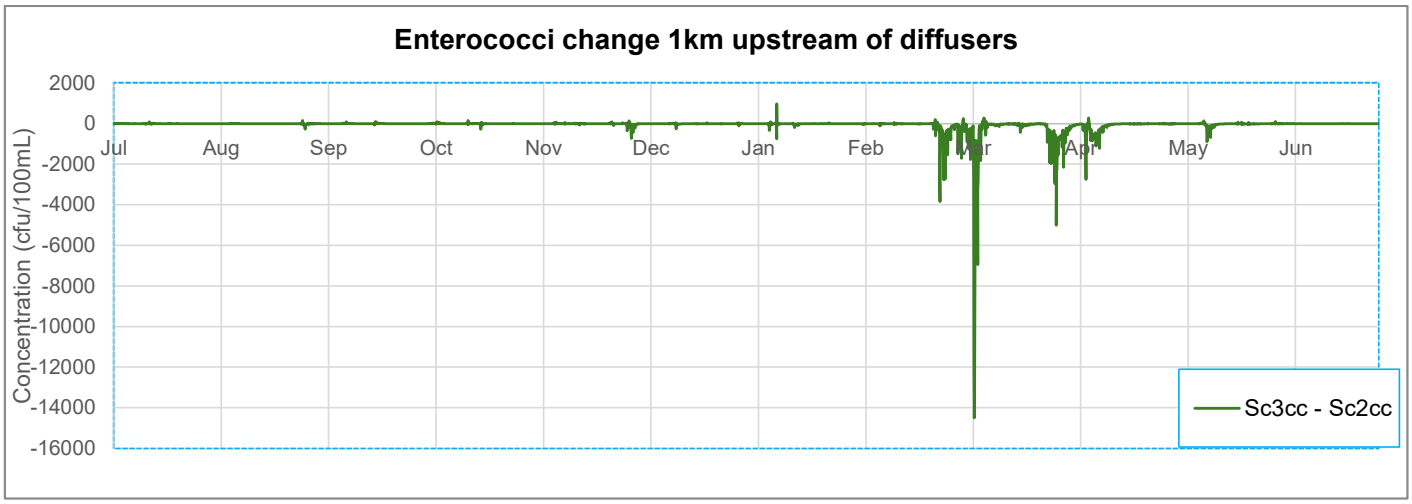

Figure 6-57 Predicted change in time series of Enterococci concentrations 1 km upstream of the diffuser – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.2 Near field and toxicity assessment

6.2.1 Scenario conditions

6.2.1.1 Release conditions

Release infrastructure

The proposed release infrastructure for the river releases consists of a submerged multi-port diffuser located at Meadowbank, ~15 m upstream of the piers of the John Whitton Bridge. The diffuser consists of 24 ports originating from eight DN315 pipes that are to be laid on a grout mattress positioned on the riverbed. A concrete mattress then covers the eight pipes to provide protection and anchoring.

Each port is angled at 30° to the horizontal, comprises of a duckbill valve and faces downstream towards the bridge. In line with the reference design, the ports have been assumed to be DN225 with an internal diameter of 182.9 mm. For the purposes of the near field modelling, the ports sizes have however been modified to represent installation of the duckbill valves, which have assumed settings for a CLA-VAL model DBF/DBO series.

The diffuser ports are located between the first and third piers of the bridge to maximise the depth of the releases and to distribute the flows within the central portion of the river. The ports are therefore distributed across ~62 m of riverbed, however a break in the port distribution is provided upstream of the second pier to reduce the potential for impacts on the pier structure or with respect to water quality and dilution of the releases.

Figure 6-58 presents an extract from the reference design for the river release structure.

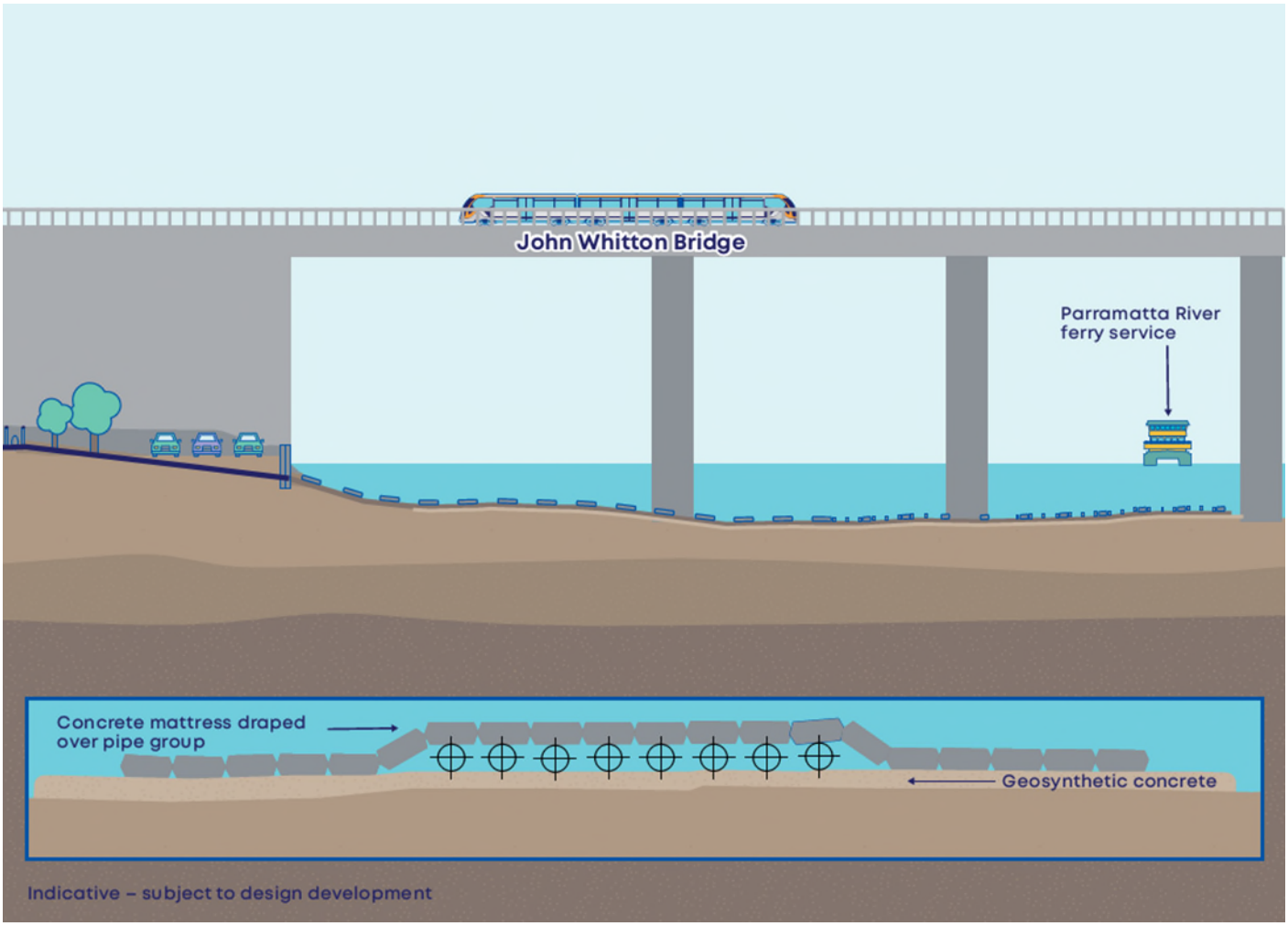

Figure 6-58 Configuration of the river release structure

Release volumes

In line with the scenario descriptions presented in Sections 4.6 and 6.1, the following release rates were assumed in the near field assessment:

- Advanced treated water (normal operation) – 63 ML/d (0.729 m^3/s)
- Tertiary treated water (offline events) – 70 ML/d (0.810 m^3/s)

Further details regarding derivation of the release conditions are presented in Section 4.6.2.1.

6.2.1.2 Ambient conditions

The bathymetry in the vicinity of the diffuser is variable with deeper sections found downstream and extending between the central bridge spans. However, a bed elevation of -5 m AHD is typically encountered along the alignment of the diffuser.

The ambient currents are predominantly driven by the semi-diurnal tides. Velocities and flows vary across each tidal cycle and across the range of tidal amplitudes experienced in the estuary. For the purposes of the near field assessment, the following representative tidal velocities were adopted:

- Peak tide (95^{th} percentile) - 0.243 m/s
- Median tide (50^{th} percentile) - 0.125 m/s

- Slack tide (5th percentile) - 0.024 m/s.

Further details regarding derivation of the ambient conditions are presented in Section 4.6.2.2.

6.2.2 Dilution profiles

The predicted dilution profiles for the two release conditions and the range of tidal velocities are presented in the figures below. More specifically, Figure 6-59, Figure 6-60 and Figure 6-61 present the dilution profiles for the aforementioned peak, median and slack water tidal conditions.

The following commentary is provided in relation to these profiles:

- Under the peak tidal conditions, the near field region extends to ~30 m downstream of the diffuser, prior to a transition to more ambient-driven mixing processes. Within the near field region, mixing is driven by both the momentum and buoyancy of the releases. More specifically, the near field behaviour is influenced by the positive buoyancy of the releases as well as the near-vertical orientation of the ports.
- Within the near field region, it is also predicted that the plume becomes vertically well mixed across the water column.
- Under the median tidal conditions, the near field region is predicted to extend to a similar distance (~30 m) but with markedly reduced dilution potential due to the lower ambient flows.
- Further reductions in dilution are predicted under slack water conditions, however a dilution factor of ~25 is still predicted prior to a transition to more ambient mixing.

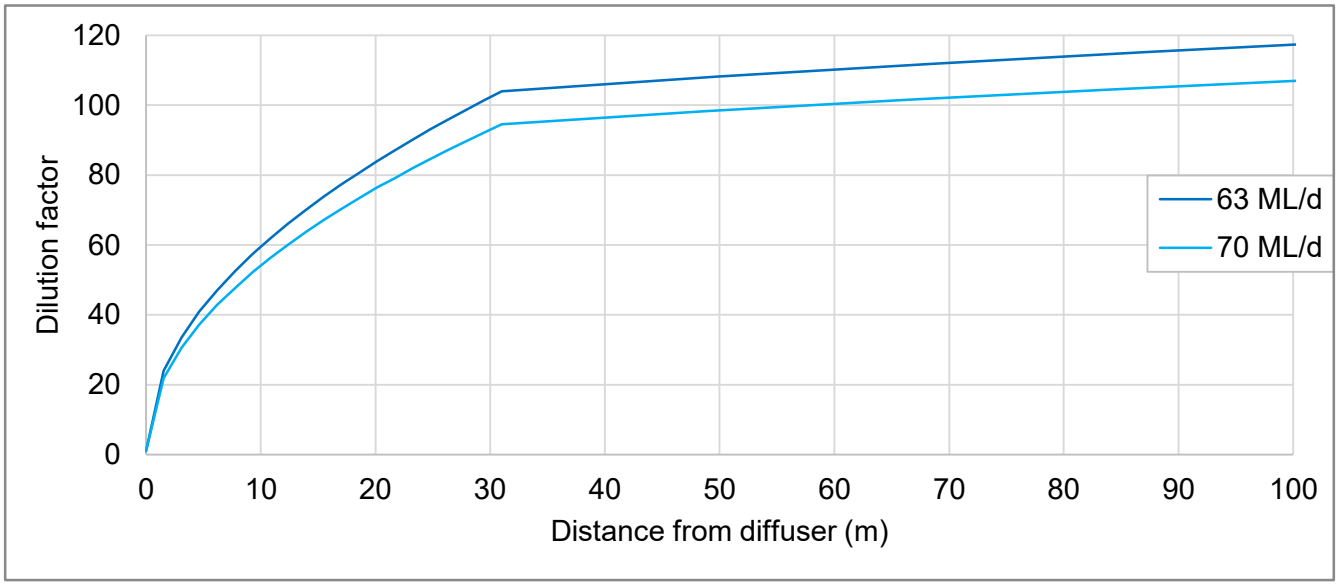

Figure 6-59 Predicted dilution profiles for representative peak tidal flows (95th percentile velocity)

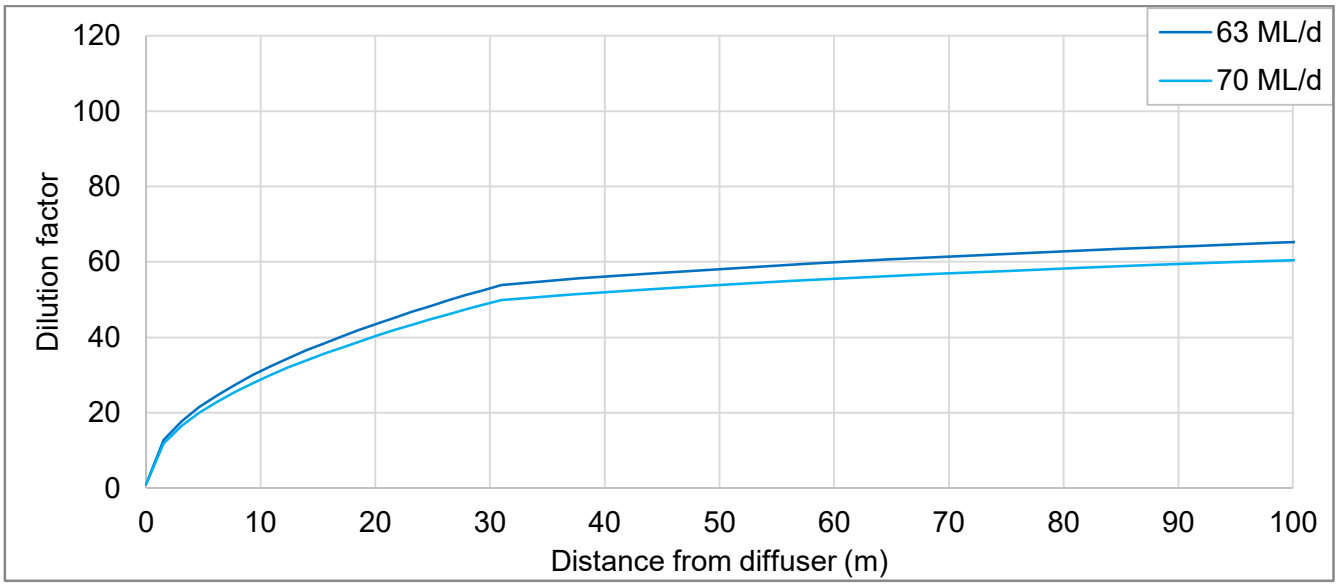

Figure 6-60 Predicted dilution profiles for representative median tidal flows (50th percentile velocity)

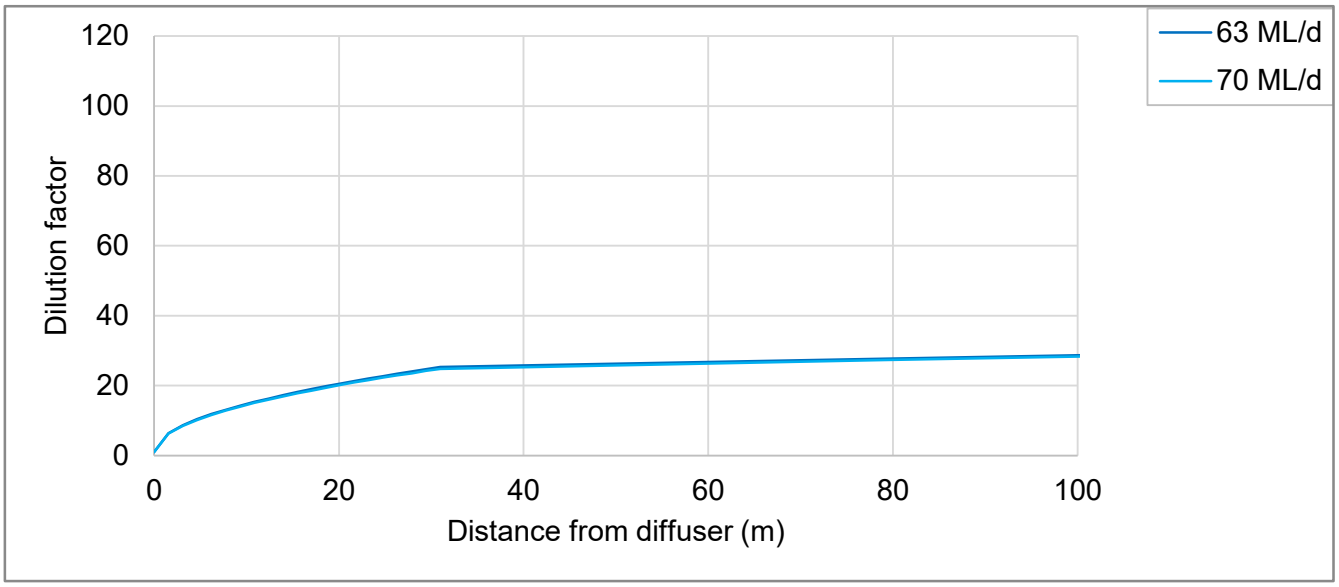

Figure 6-61 Predicted dilution profiles for representative slack water tidal flows (5th percentile velocity)

6.2.3 Toxicity and mixing zone analysis

6.2.3.1 Dilution requirements

The dilution requirements are presented below for each contaminant of concern identified in Section 4.6.3. More specifically, Table 6-2 and Table 6-3 present the dilution requirements for the advanced and tertiary treated water respectively.

These dilution factors were determined from the assumed maximum treated water concentrations, available background ambient concentration data and the relevant toxicant DGVs. The equation used to calculate these dilution factors is included in Section 4.6.3.

The dilution factors effectively represent the level of dilution required in the vicinity of the release point to reach each of the DGVs. These factors therefore represent the level of dilution required at the boundary of a mixing zone.

From this analysis, the following comments and conclusions are drawn:

- For the advanced treated water:
  - With respect to total chlorine, a dilution factor of ~1.5 is required.
  - For copper, it is noted that median levels from the baseline monitoring indicate the toxicant DGVs are exceeded in the study area.
- For the tertiary treated water:
  - For nitrate, total chlorine, aluminium, mercury and zinc, dilution requirements range up to a maximum of ~30.
  - For copper, it is again noted that median levels from the baseline monitoring indicate the toxicant DGVs are exceeded in the study area.

Table 6-2 Dilution requirements – advanced treated water

Contaminant	Toxicant DGV	Treated water quality	Background water quality	Dilution requirement
Total Chlorine (mg/L)	0.0072	0.01	0	1.4
Copper (µg/L)	1.3	1.4	1.6	NA

Table notes

NA – analysis inhibited due to the background ambient concentration exceeding respective toxicant DGV (refer Section 6.2.3.2)

Table 6-3 Dilution requirements – tertiary treated water

Contaminant	Toxicity DGV	Treated water quality	Background water quality	Dilution requirement
Nitrate (µg/L)	2.6	4	0.01	1.5
Total Chlorine (µg/L)	0.0072	0.01	0	1.4
Aluminium (µg/L)	37	285	12	10.9
Copper (µg/L)	1.3	12	1.6	NA
Mercury (µg/L)	0.1	0.2	0.01	2.1
Zinc (µg/L)	8	70	13.5	30.3

NA – analysis inhibited due to the background ambient concentration exceeding respective toxicant DGV (refer Section 6.2.3.2)

6.2.3.2 Mixing zone analysis

Advanced treated water

For the releases of advanced treated water, Table 6-4 presents the dimensions of the predicted mixing zones for each contaminant of concern and across all three tidal conditions.

The modelling results indicate that the dilution requirements presented in Table 6-2 are achieved in the immediate vicinity of the diffuser ports. Even under the conservative slack tidal conditions, the dilution requirements are predicted to be exceeded within the first metre of the diffuser ports. The mixing zone longitudinal dimension criteria discussed in Section 4.6.4.3 is therefore achieved for total chlorine.

With respect to the lateral dimension criteria discussed in Section 4.6.4.3, the plume widths are predicted to exceed the 50 m criteria, however they are compliant with the 30% of the waterway width criteria. A width of 220 m was conservatively assumed for the river in the vicinity of the releases.

For copper, the analysis of the modelling results against the mixing zone requirements is inhibited due to the assumed background ambient conditions exceeding the respective toxicant DGVs.

Table 6-4 Predicted mixing zone dimensions – advanced treated water

Contaminant	Mixing zone dimensions – length (m) x width (m)		
	Peak tidal flows	Median tidal flows	Slack water tidal flows
Total Chlorine	1 x 62	1 x 62	1 x 62
Copper	NA	NA	NA

Tertiary treated water

For the releases of advanced treated water, Table 6-5 presents the dimensions of the predicted mixing zones for each contaminant of concern and across all three tidal conditions.

The modelling results indicate that the dilution requirements presented in Table 6-3 are generally achieved within close proximity to the diffuser ports. Under the peak and mid tidal conditions simulated, the dilution requirements are achieved within ~12 m. Under the more conservative slack tidal conditions, the dilution requirements are predicted to be achieved within ~6 m of the diffuser ports, with the exception of zinc which is achieved at a predicted distance of ~140 m. The mixing zone longitudinal dimension criteria discussed in Section 4.6.4.3 is therefore achieved for nitrate, total chlorine, aluminium, mercury and zinc.

With respect to the lateral dimension criteria discussed in Section 4.6.4.3, the plume widths are predicted to exceed the 50 m criteria, however they are generally compliant with the 30% of the waterway width criteria. The one exception being zinc, which exceeds the criteria under the slack water tidal condition. For this analysis, a width of 220 m was conservatively assumed for the river in the vicinity of the releases.

For copper, the analysis of mixing zone requirements is again inhibited due to the assumed background ambient conditions exceeding the respective toxicant DGVs. Under these conditions, the assumed maximum (90th percentile) concentrations of the river releases and the median concentrations of the baseline monitoring data are both estimated to exceed the relevant toxicant DGV.

Table 6-5 Predicted mixing zone dimensions – tertiary treated water

Contaminant	Mixing zone dimensions – length (m) x width (m)		
	Peak tidal flows	Median tidal flows	Slack water tidal flows
Nitrate	1 x 62	1 x 62	1 x 62
Total Chlorine	1 x 62	1 x 62	1 x 62
Aluminium	1 x 62	2 x 62	6 x 62
Cadmium	1 x 62	1 x 62	1 x 62
Cobalt	1 x 62	1 x 62	1 x 62
Copper	NA	NA	NA
Mercury	1 x 62	1 x 62	1 x 62
Zinc	3 x 62	12 x 62	140 x 130

6.2.4 Interpretation – near field dilution and mixing zone requirements

From the analysis of near field modelling results, the following conclusions are drawn:

- Initial mixing and dilution in the near field is predicted to be relatively high under all the tidal conditions simulated. The initial mixing zone generally extended approximately 30 m downstream of the diffuser ports, prior to a transition to more ambient mixing processes. The near field mixing is promoted by the momentum and exit velocities of the treated water released from the diffuser ports, as well as by the positive buoyancy of the treated water relative to the denser saline receiving waters.
- With the exception of the more extreme and transient low tide slack-water conditions, near field dilutions are predicted to be compliant with the criteria presented in the Australian Guidelines for Effluent Management (NWQMS, 1997). Under the low tide slack-water conditions, it is conservatively estimated that the criterion of 50:1 is predicted to be achieved within approximately 750 m distance from the diffuser.

From the analysis of the dilution requirements, the following comments are provided:

- To mitigate the risk of toxicity, the dilution requirements for a suite of contaminants was estimated from analysis of expected release concentrations, background conditions and applicable toxicant DGVs. The suite of contaminants was determined through comparisons of concentrations proposed in the river releases against relevant DGVs to determine contaminants that may pose a risk of non-trivial harm to the environment.
- From this analysis, a dilution requirement of approximately 1.5 was identified for total chlorine for the releases of the advanced treated water.
- For the tertiary treated water, dilution requirements ranged up to a maximum of ~30 for the following contaminants: nitrate, total chlorine, aluminium, mercury and zinc.
- For copper, it is noted that median levels from the baseline monitoring indicate the toxicant DGVs are marginally exceeded in the receiving waters of the Parramatta River near the proposed releases. It is however expected that improvements in water quality will occur due to the continuous release of

advanced treated water from the WRRF. Consequently, background/ambient concentrations may potentially reduce.

From the analysis of mixing zone requirements, the following findings were drawn:

- During the release of advanced treated water, the risk of toxicity is predicted to be mitigated in the immediate vicinity of the diffuser ports. Even under the conservative slack tidal conditions, the dilution requirements are predicted to be exceeded within the first metre of the ports. The plume widths are predicted to be less than 30% of the waterway width.
- During the offline events with short-term release of tertiary treated water, the risk of toxicity is again generally predicted to be mitigated within close proximity to the diffuser ports. Under the peak and mid tidal conditions simulated, the dilution requirements are achieved within ~12 m. Under the more conservative slack tidal conditions, the dilution requirements are similarly predicted to be achieved within 10 m of the diffuser ports, with the exception of zinc which is achieved at a predicted distance of ~140 m. The plume widths are again predicted to be generally lower than 30% of the waterway width.
- For copper, the analysis of mixing zone requirements for both the advanced and tertiary treated water is inhibited due to the assumed background ambient conditions exceeding the respective toxicant DGVs.

6.3 Supplementary assessments

6.3.1 Water quality at aquatic ecology sites

The following sections present a summary of the changes in water quality that are predicted as a result of the operation of the WRRF. The sites included in this analysis are presented in Figure 5-15.

For brevity, a selection of relevant scenario results has been included in these sections to aid interpretation. A full set of results is also included in Appendix D for reference.

6.3.1.1 Salinity

Figure 6-62 presents the annual medians for the lower rainfall year. In line with the discussion presented in Section 6.1.5.3, reductions at all the aquatic ecology sites are predicted due to the influence of the low salinity river releases. On a median basis for the more extreme lower rainfall year, reductions of between 2.3 and 2.8 PSU are predicted at the sites in the vicinity of Meadowbank and Wentworth Point (sites AQ1 to AQ5), while a reduction of up to ~1.7 PSU is predicted at the more distant site in Morrison Bay (AQ6), which is approximately 3 km downstream from the release point.

With respect to variations in the hourly time series results, the modelling indicates that peak changes in salinity are generally in the order of 3 to 4 PSU at the sites closer (< 1 km) to the river releases but with potential for up to 5 or 6 PSU under extended dry periods.

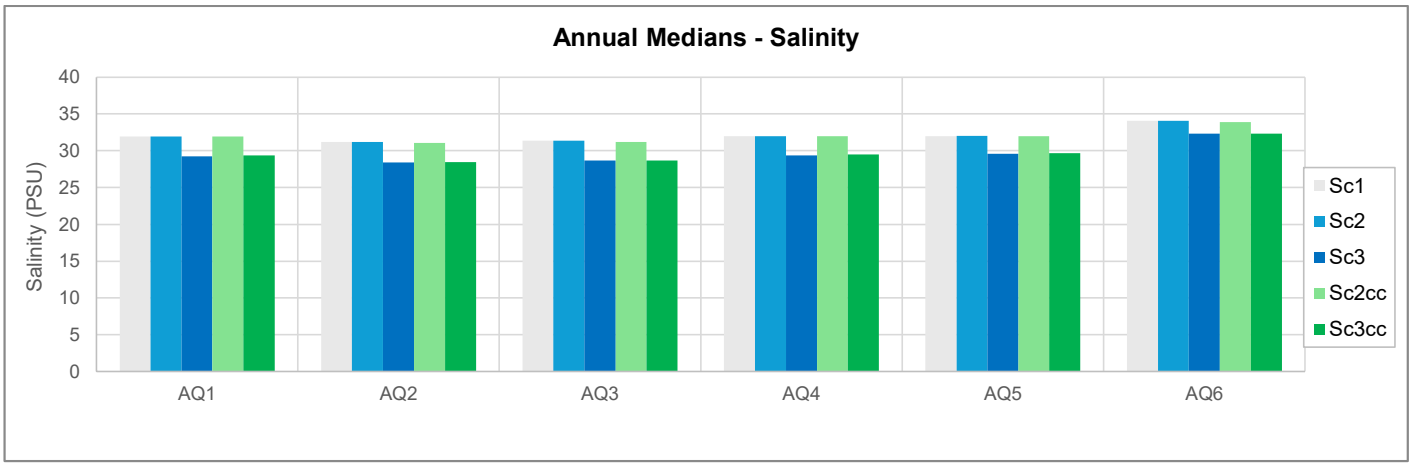

Figure 6-62 Predicted annual median salinity concentrations – aquatic ecology sites (lower rainfall year)

6.3.1.2 Temperature

Consistent with the findings in Section 6.1.5, impacts on temperature were generally predicted to be relatively limited (refer to Figure 6-63 and Figure 6-64). The greatest changes were predicted during the lower rainfall year, however changes in annual median temperature were still predicted to be in the order of 0.1°C or less if climate change conditions were assumed.

With respect to variations in the hourly time series results, the modelling indicates that peak changes were generally in the order ±0.5ºC at the sites closer to the river releases (AQ1 to AQ5) and lower at the Morrison Bay site (AQ6). Also consistent with previous findings, a seasonal pattern was observed with more substantial increases in temperature observed during the cooler months and some potential for minor cooling in the summer months.

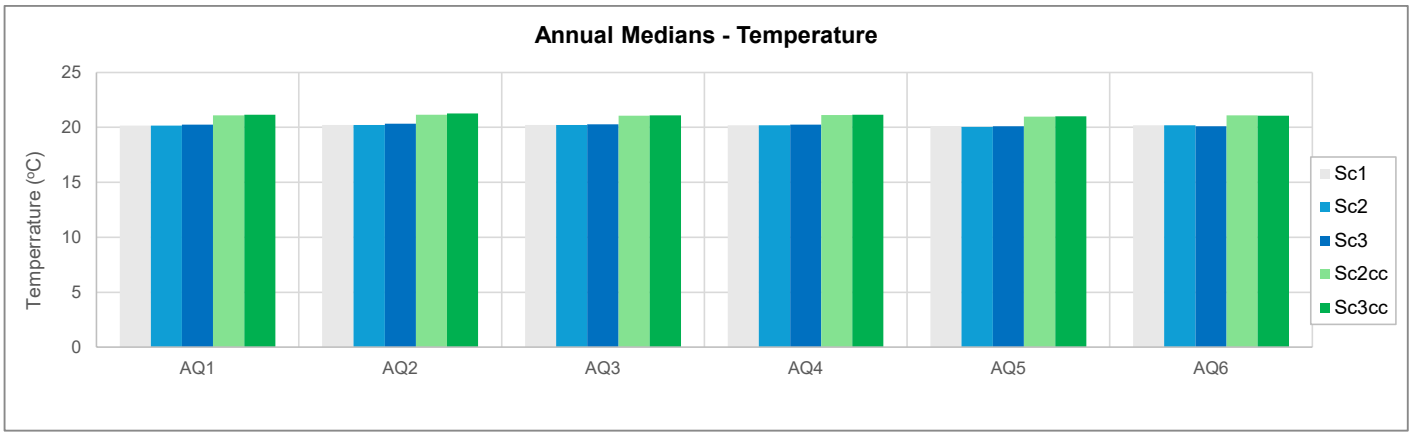

Figure 6-63 Predicted annual median temperatures – aquatic ecology sites (lower rainfall year)

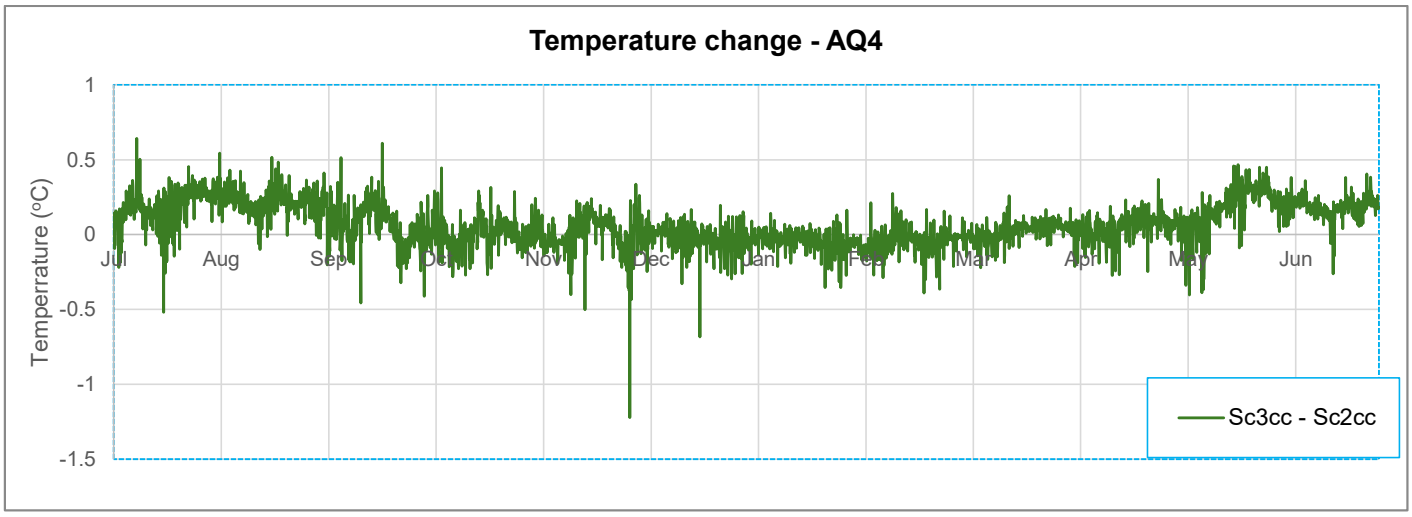

Figure 6-64 Predicted change in time series of at aquatic ecology site AQ4 – scenario Sc3cc relative to Sc2cc (lower rainfall year)

6.3.1.3 Nitrogen

Figure 6-65 presents the annual median concentrations at the aquatic ecology sites for the average rainfall year. In line with the findings presented in Section 6.1.4.5, these results verify the predicted influence of the WRRF in reducing total nitrogen levels in the estuary through the release of the low nutrient content river releases as well as through mitigation of the wet weather overflows. For the average year, reductions in annual medians are predicted in the order of 0.02 to 0.04 mg/L throughout the investigation area depending on whether climate change is simulated.

The reductions are more substantial under the wet weather year simulation, in the order of 0.05 mg/L due to the abatement of higher overflows (refer Figure 6-66 and Figure 6-67). Conversely, the impacts are reduced in the lower rainfall year as a result of the longer-term effects of the offline events (refer to Figure 6-68). The magnitude and longevity of impacts of the offline events are predicted to vary across the range of years simulated and whether climate change is included in the scenarios but generally the effects are predicted to extend for a period of weeks up to a duration of two months.

With respect to the inorganic fractions, in line with the discussion in Section 6.1.5.5, potential for increases in ammonia and oxidised nitrogen were predicted in the scenario simulations, particularly for oxidised nitrogen due to the higher percentage of content within the releases of advanced treated water. Refer to Figure 6-69 and Figure 6-70. With respect to these inorganic species, it is also noted that the model has the potential to under predict ambient concentrations, particularly for oxidised nitrogen. The results from the impact assessments may therefore be treated as conservative.

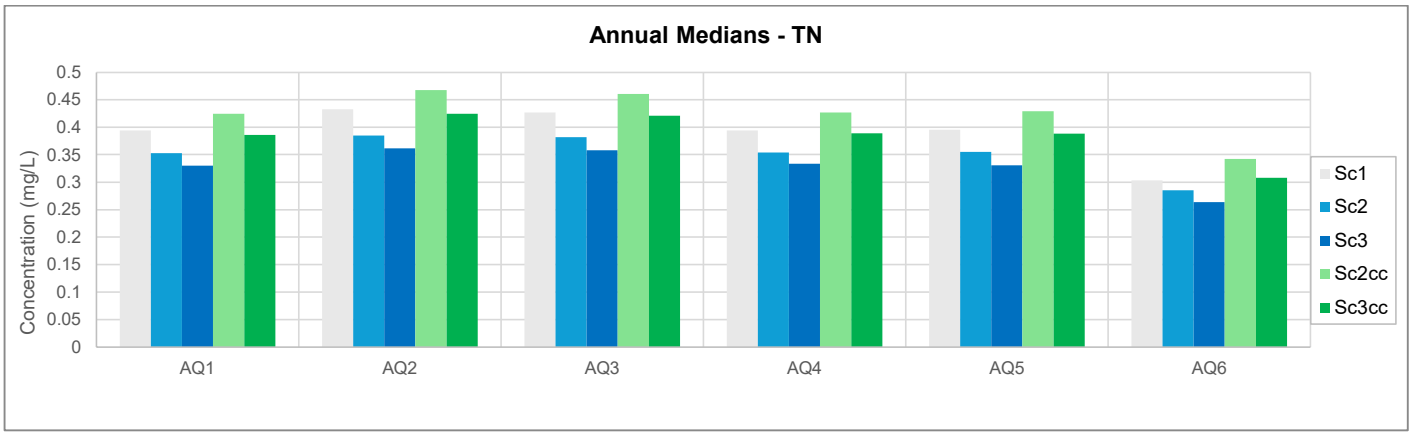

Figure 6-65 Predicted annual median TN concentrations – aquatic ecology sites (average rainfall year)

Figure 6-66 Predicted time series of TN concentrations at aquatic ecology Site AQ6 (Morrison Bay) – scenario Sc1, Sc2cc and Sc3cc (higher rainfall year)

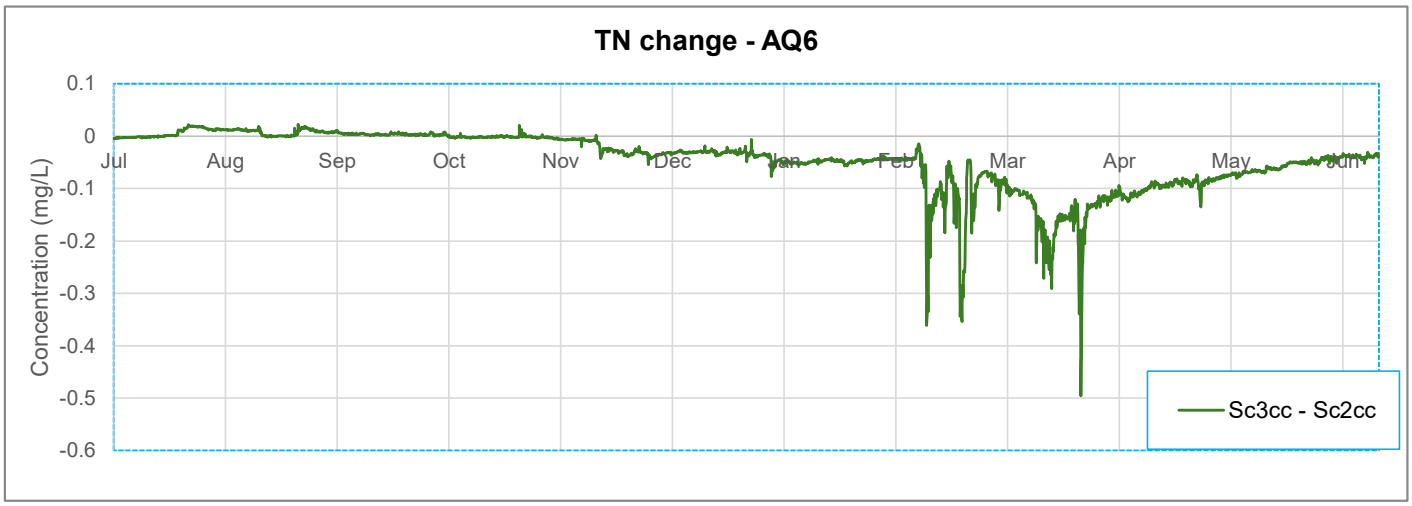

Figure 6-67 Predicted change in time series of TN concentrations aquatic ecology Site AQ6 (Morrison Bay) – scenario Sc3cc relative to Sc2cc (higher rainfall year)

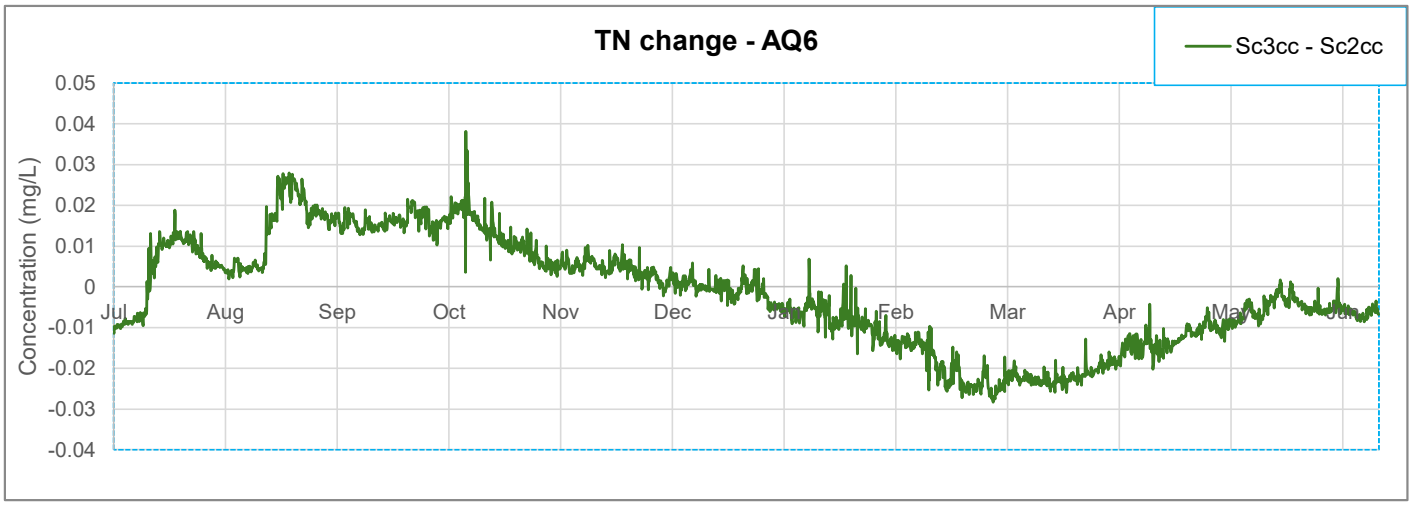

Figure 6-68 Predicted change in time series of TN concentrations aquatic ecology Site AQ6 (Morrison Bay) – scenario Sc3cc relative to Sc2cc (lower rainfall year)

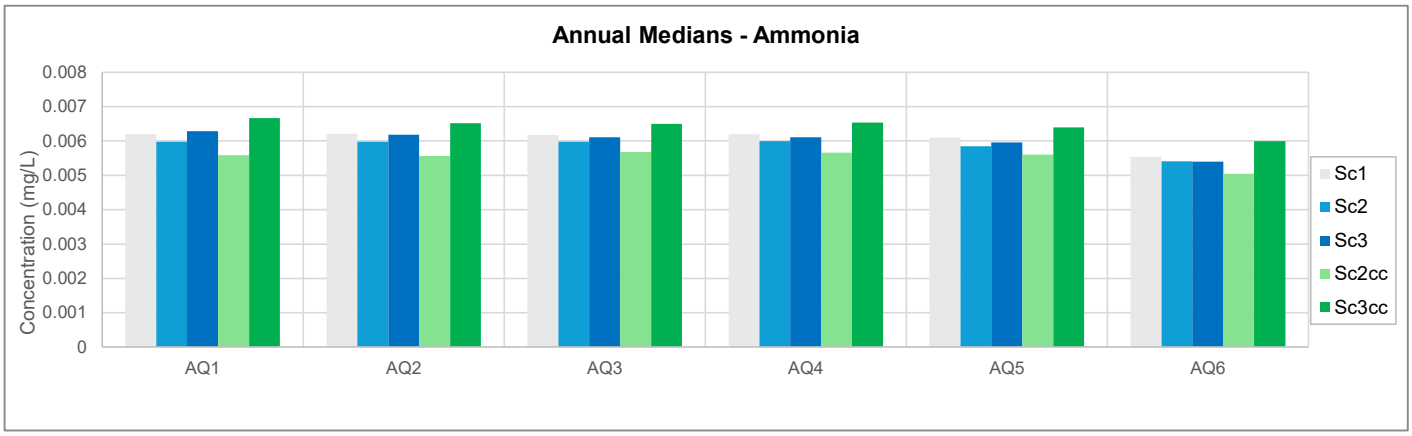

Figure 6-69 Predicted annual median Ammonia concentrations – aquatic ecology sites (average rainfall year)

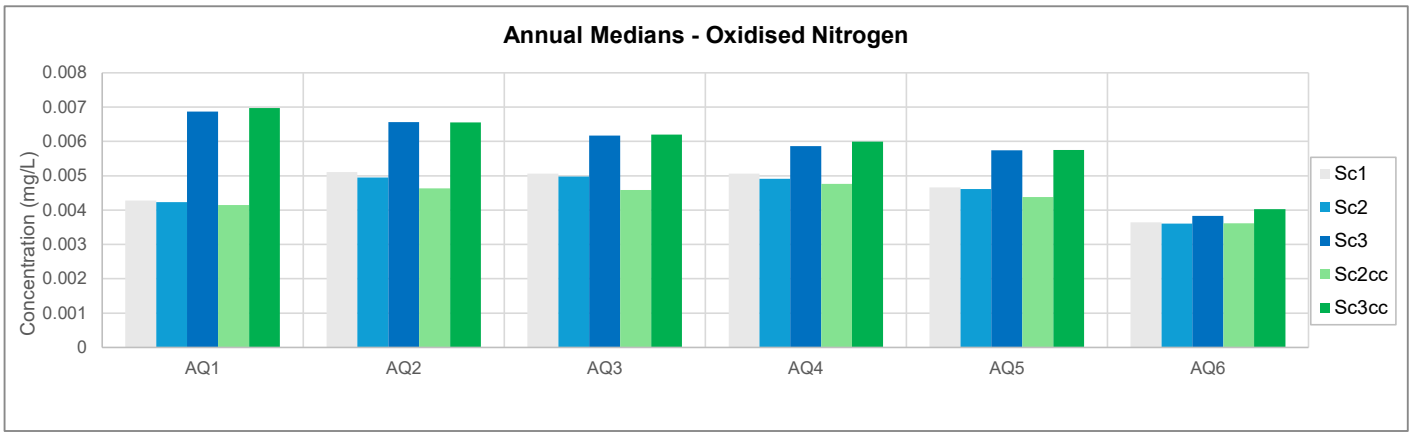

Figure 6-70 Predicted annual median Oxidised Nitrogen concentrations – aquatic ecology sites (average rainfall year)

6.3.1.4 Phosphorus

Similar trends were observed in the phosphorus scenario results as for those presented for total nitrogen, however the reductions were predicted to be proportionally higher due to the lower concentrations assumed in the releases of advanced treated water. Reductions were also predicted for inorganic phosphorus. In

addition to the beneficial effects generated as a product of the river releases, mitigation of overflows from the wastewater network also contributed to the overall reductions.

The effects of the offline events are again easily identified, but the impacts are predicted to be shorter than those predicted for nitrogen.

Figure 6-71 presents the annual median concentrations for the higher rainfall year with Figure 6-72 and Figure 6-73 respectively presenting the corresponding time series concentrations and the change in predicted time series concentrations at Wentworth Point (AQ1). These latter two figures allow for an understanding of the predicted responses to the advanced treated water and wet weather overflow mitigation, as well as the offline events and the duration of the impacts following these events.

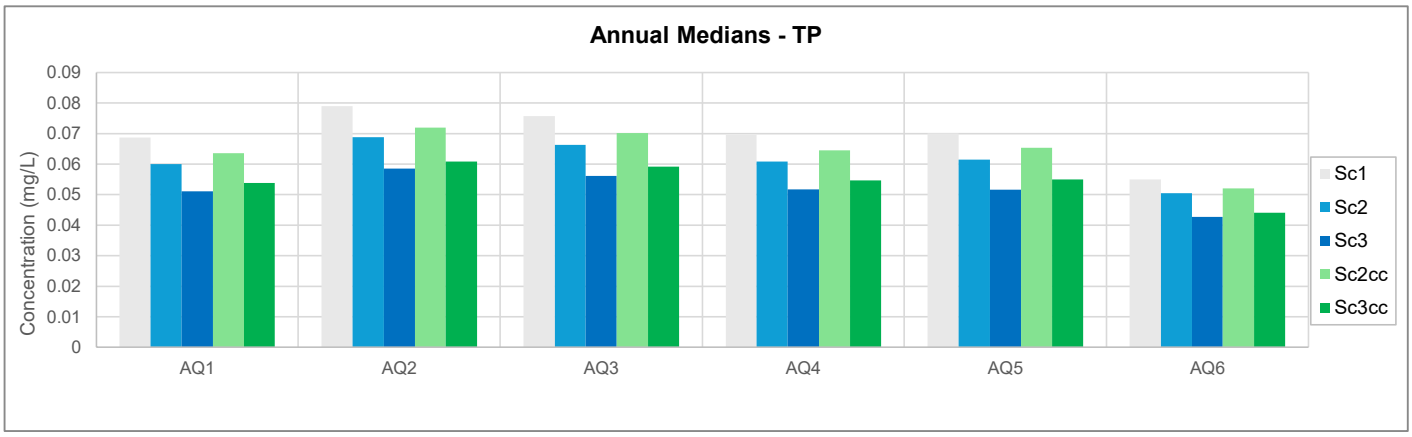

Figure 6-71 Predicted annual median TP concentrations – aquatic ecology sites (higher rainfall year)

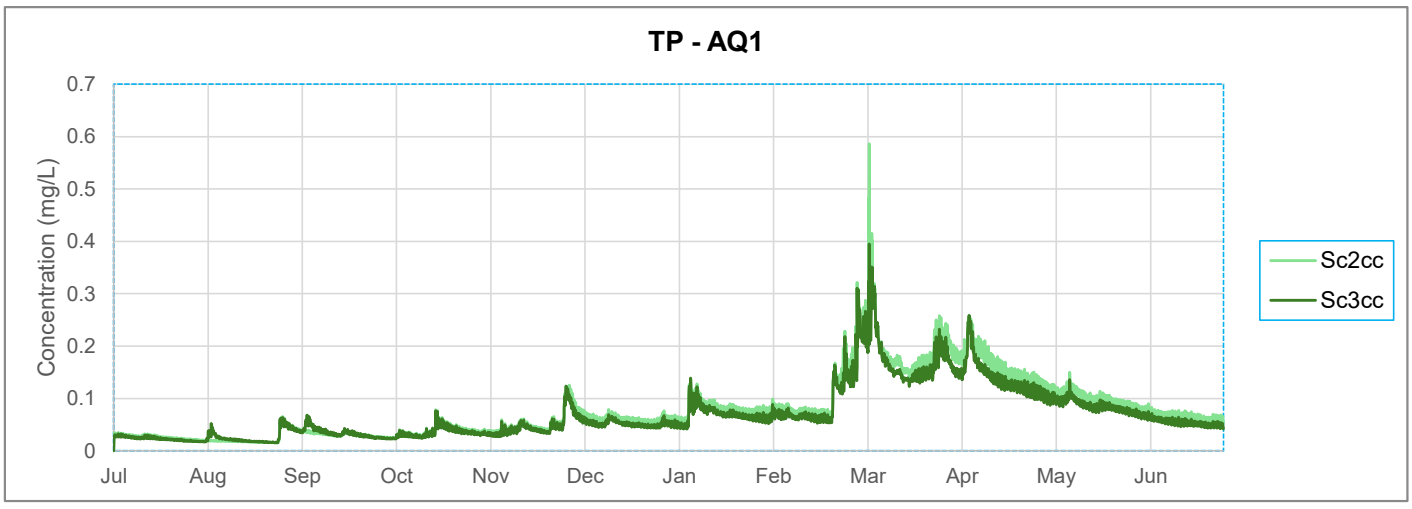

Figure 6-72 Predicted time series of TP concentrations at aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc and Sc2cc (higher rainfall year)

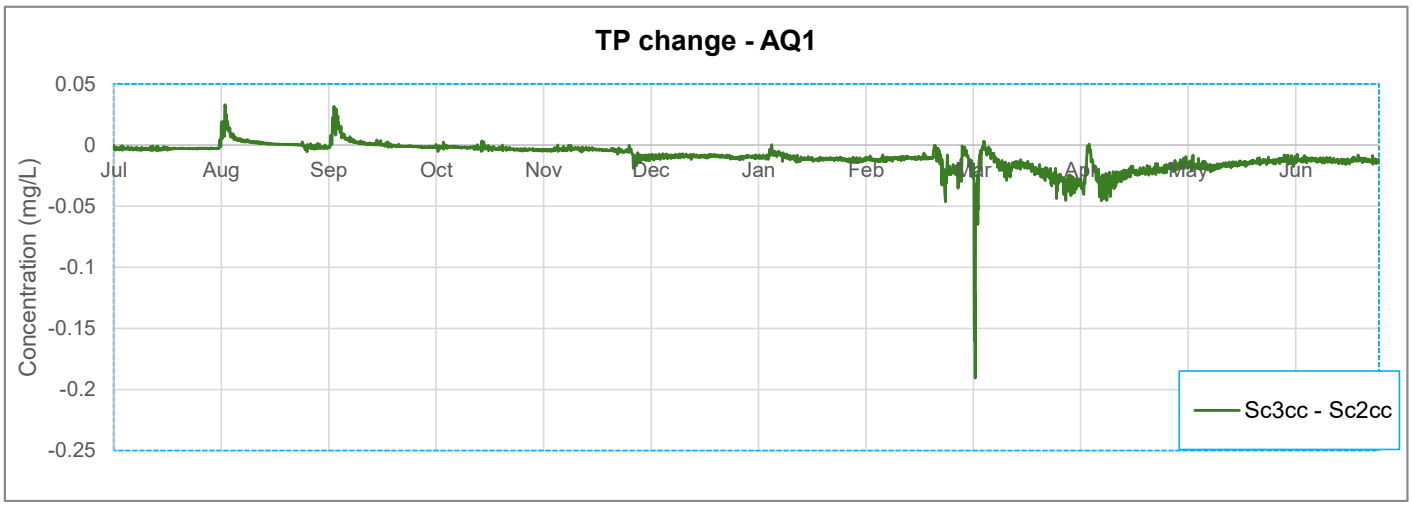

Figure 6-73 Predicted change in time series of TP concentrations aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.3.1.5 Total suspended solids

Reductions were predicted in the ambient concentrations of TSS due to the WRRF operation. At the selected aquatic ecology sites, reductions in annual medians of up to 0.5 mg/L were predicted (refer Figure 6-74).

On a temporal basis, short-term modifications of less than 5 mg/L were generally predicted and considered primarily to be driven by changes in the wet weather overflow conditions (refer Figure 6-75).

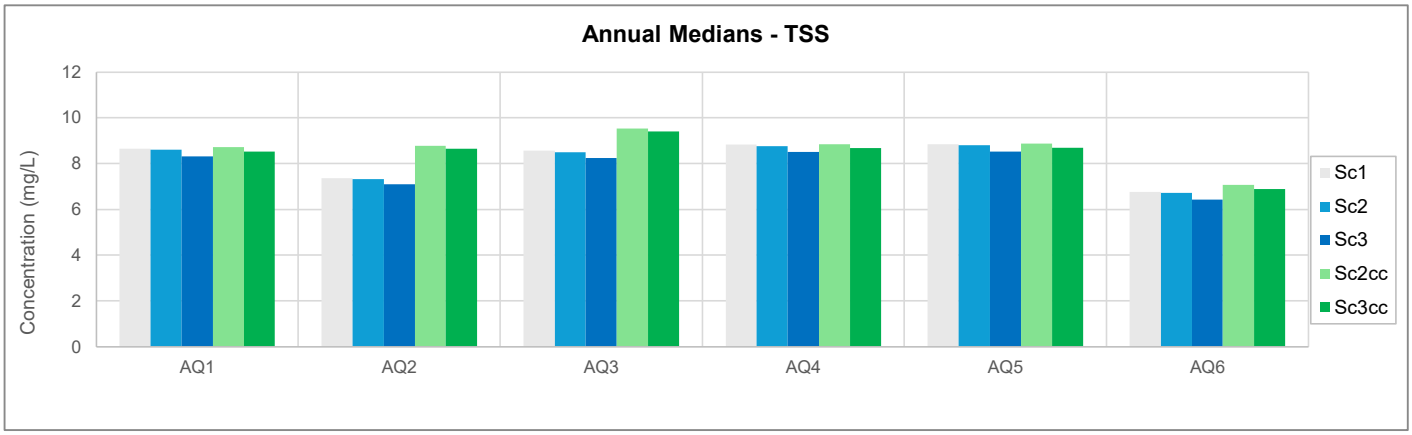

Figure 6-74 Predicted annual median TSS concentrations – aquatic ecology sites (average rainfall year)

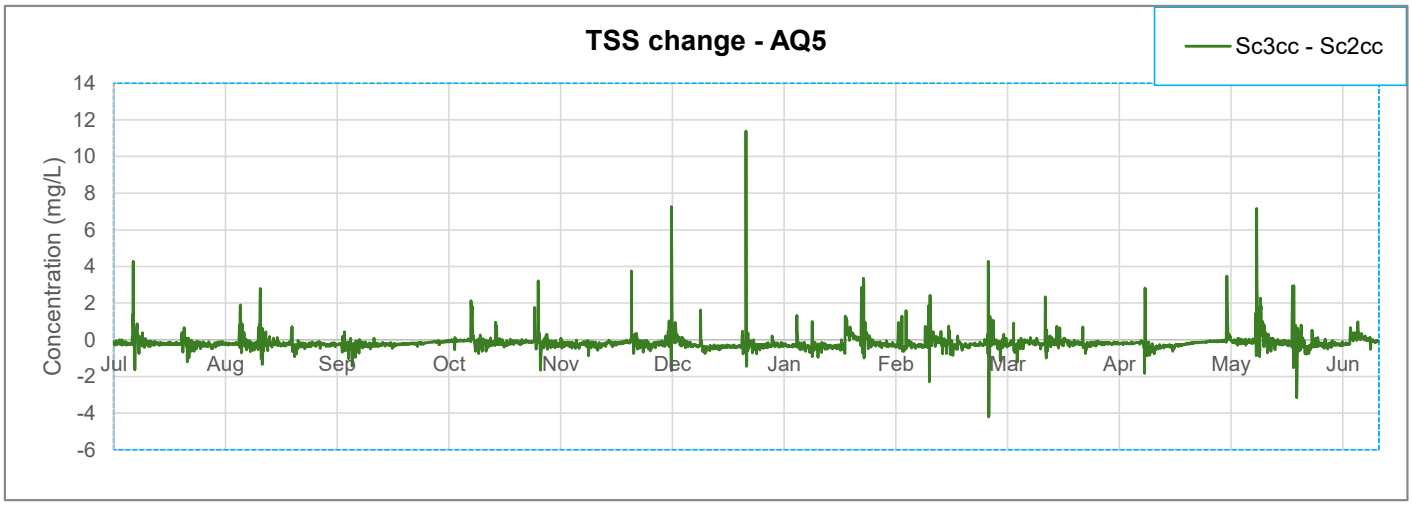

Figure 6-75 Predicted change in time series of TSS concentrations aquatic ecology Site AQ5 – scenario Sc3cc relative to Sc2cc (average rainfall year)

6.3.1.6 Chlorophyll *a*

Consistent with Section 6.1.5.8, the modelling results indicated the potential for overall reductions in chlorophyll *a* across all the rainfall years simulated and at all the aquatic ecology sites analysed. These reductions thereby indicating a potential decrease in algal biomass and risk of blooms within the estuary (refer Figure 6-76). These reductions were generated as a result of reductions in overflow nutrient loads as well as the introduction of the releases of the advanced treated water with low nutrient content.

The potential for periods of higher chlorophyll *a* concentrations were however predicted after the offline events when higher nutrient loads were introduced from the tertiary treated water being released. Particularly during the lower rainfall year, elevated concentrations were predicted for approximately two months after the events (Figure 6-77). This was however considered to be the worst-case scenario with the offline events timed during extended dry periods during the low rainfall year. Under both the average and higher rainfall years, while the offline events were still timed to occur during the drier periods, the effects of the offline events were predicted to decrease in magnitude and the longevity of their impact (refer Figure 6-78).

On an annual median concentration basis, the reductions were predicted to be marginally higher under the climate change conditions simulated. Conversely, there was potential for the effects of the offline events to be higher under the non-climate change scenario Sc3.

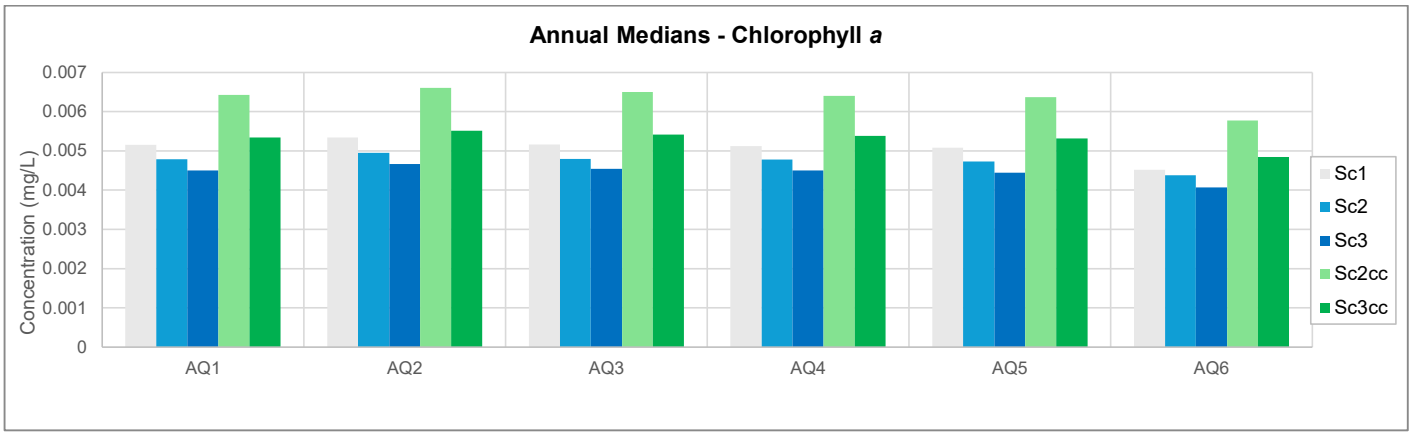

Figure 6-76 Predicted annual median Chlorophyll *a* concentrations – aquatic ecology sites (average rainfall year)

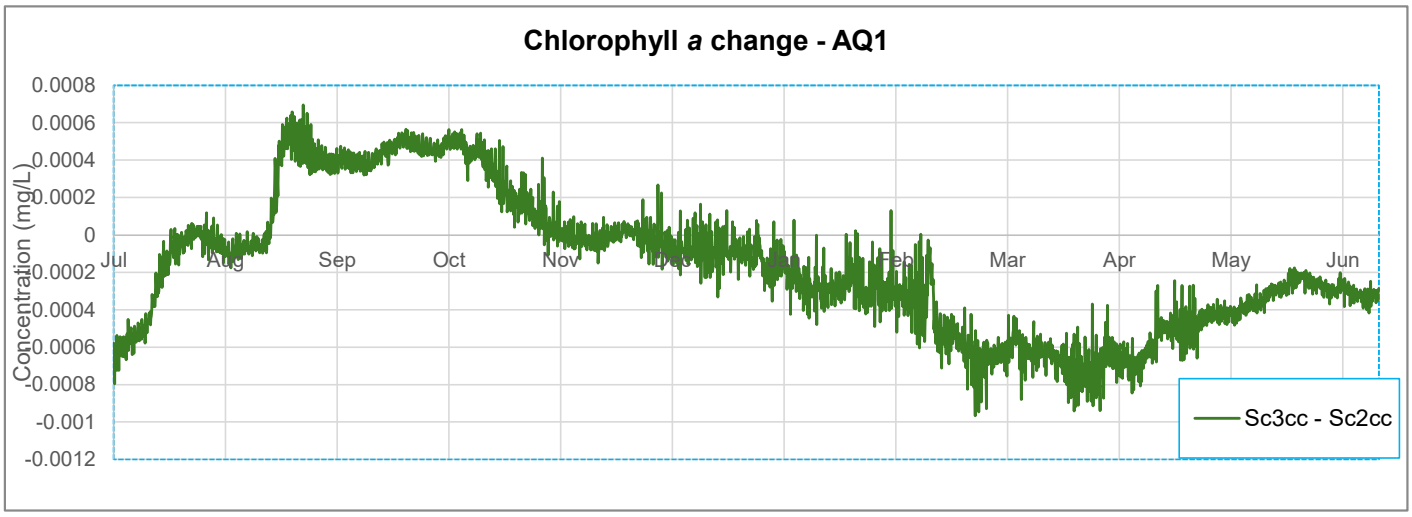

Figure 6-77 Predicted change in time series of Chlorophyll *a* concentrations aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc relative to Sc2cc (lower rainfall year)

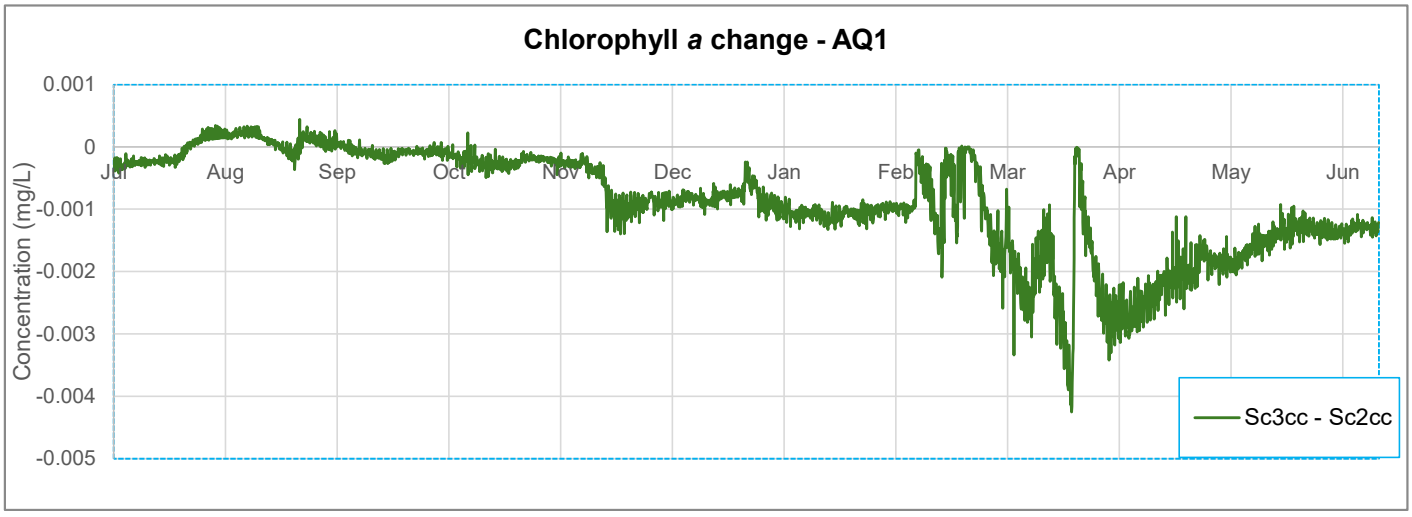

Figure 6-78 Predicted change in time series of Chlorophyll *a* concentrations aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.3.1.7 Dissolved oxygen

Limited increases were predicted at the aquatic ecology sites as a result of the WRRF operation. From the annual median results, dissolved oxygen levels were predicted to increase up to 0.1 to 0.2 mg/L in the upper estuary (refer Figure 6-79). The time series results also indicate the potential for elevations as a result of the river releases and to a lesser degree from the mitigation of overflows (refer Figure 6-80 and Figure 6-81). These variations generally falling within ±0.4 mg/L of the background concentrations.

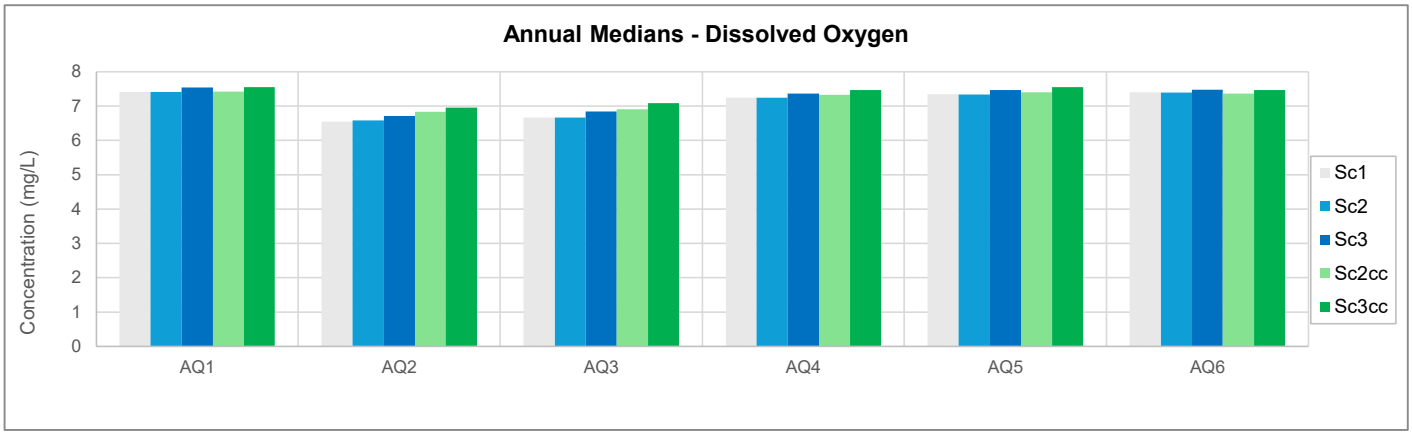

Figure 6-79 Predicted annual median Dissolved Oxygen concentrations – aquatic ecology sites (lower rainfall year)

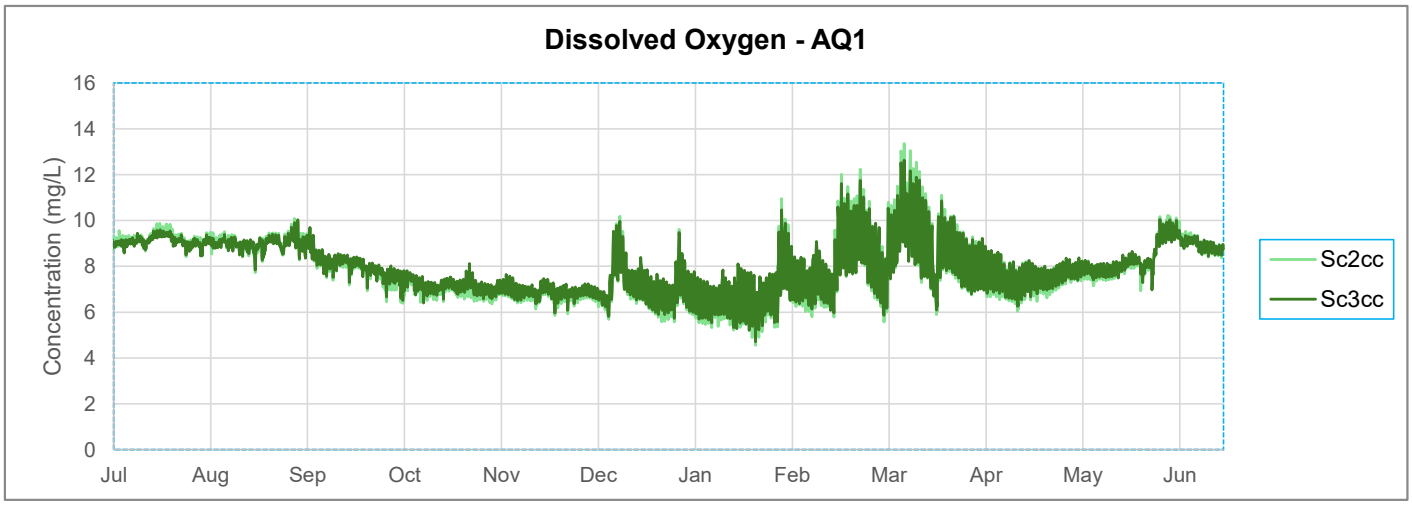

Figure 6-80 Predicted time series of Dissolved Oxygen concentrations at aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc and Sc2cc (average rainfall year)

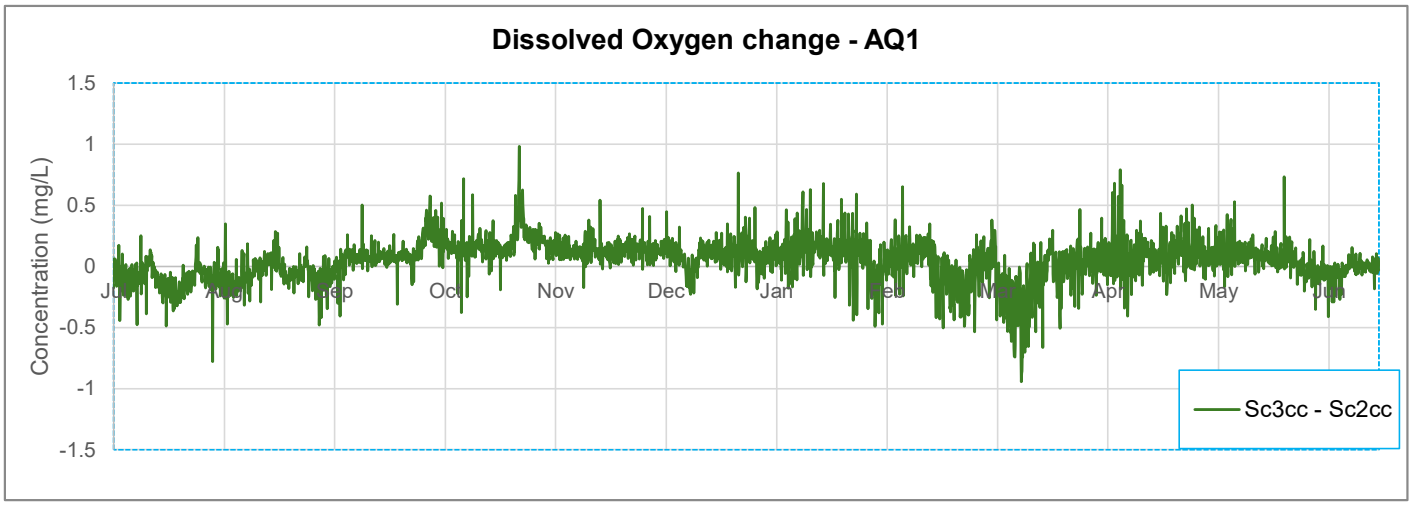

Figure 6-81 Predicted change in time series of Dissolved Oxygen concentrations aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc relative to Sc2cc (average rainfall year)

6.3.1.8 Enterococci

Reductions in enterococci are predicted at the aquatic ecology sites due to the mitigation of wet weather overflows and the continuous release of treated water with zero pathogenic content.

Figure 6-82 presents the predicted annual medians for the average rainfall year with Figure 6-83 and Figure 6-84 presenting the time series and change in time series concentrations for the site AQ1 located at Wentworth Point. The latter two figures indicate the potential for a decrease in pathogen spikes during wet weather. Reductions of up to 10,000 cfu/100 mL in wet weather concentrations are predicted at some of the aquatic ecology sites.

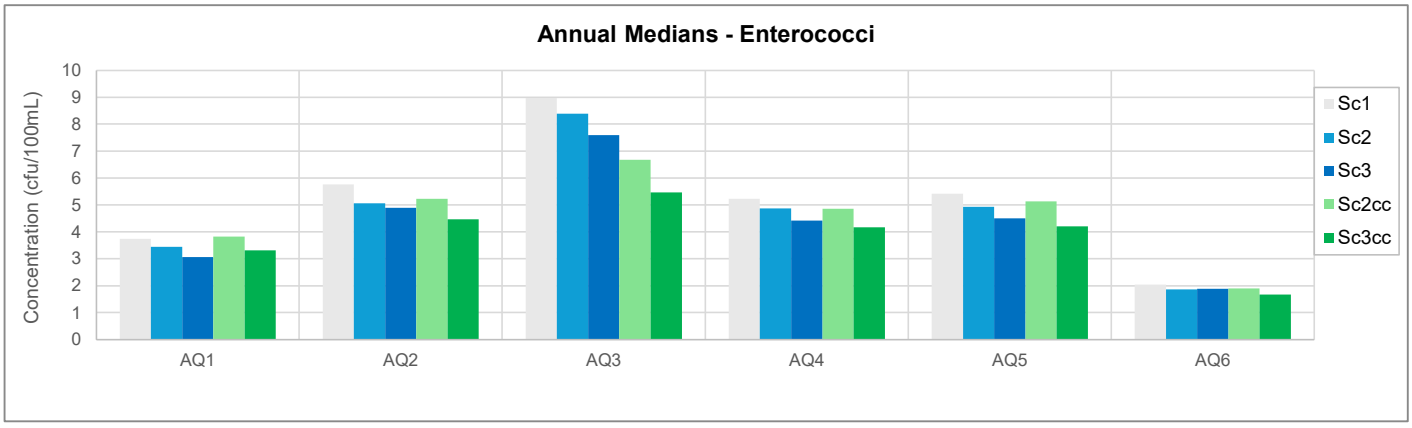

Figure 6-82 Predicted annual median Enterococci concentrations – aquatic ecology sites (average rainfall year)

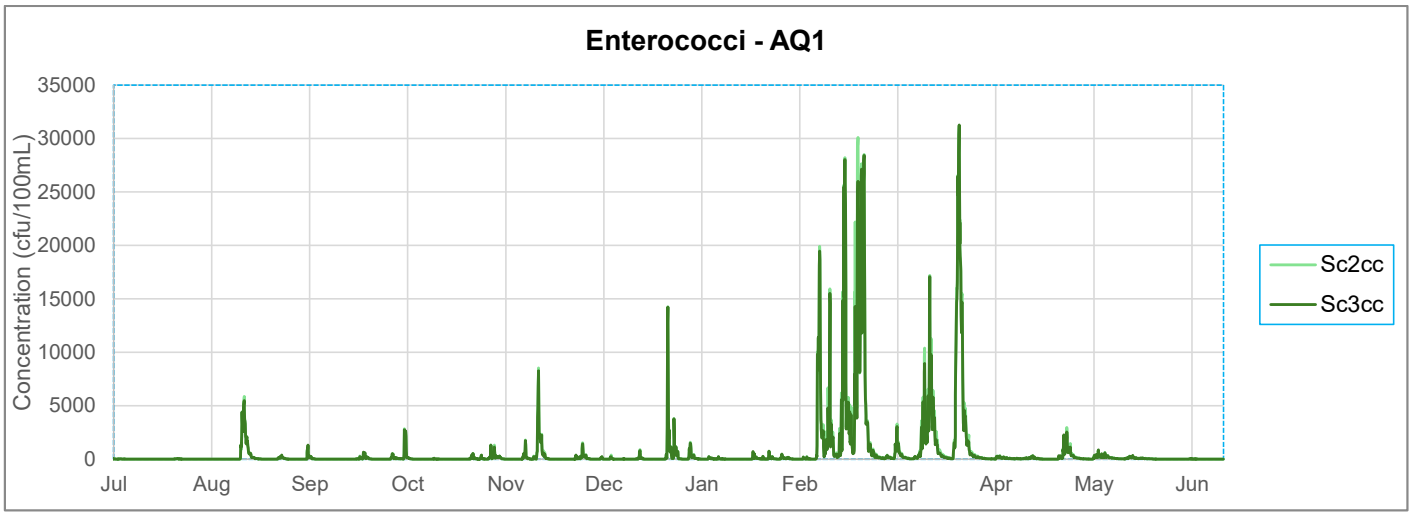

Figure 6-83 Predicted time series of Enterococci concentrations at aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc and Sc2cc (higher rainfall year)

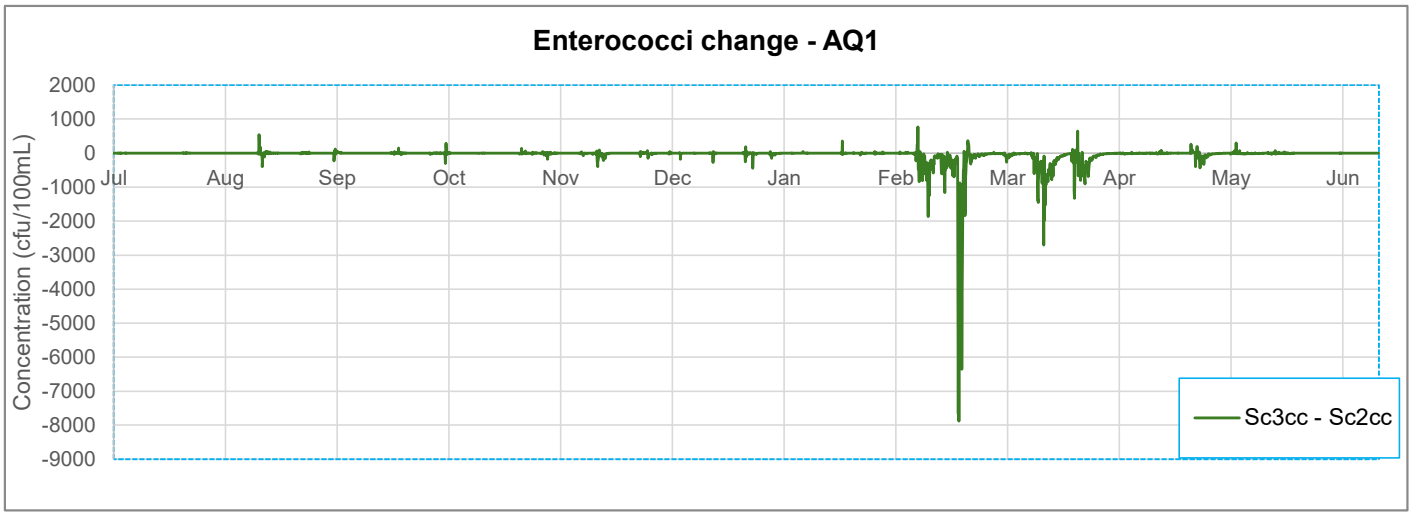

Figure 6-84 Predicted change in time series of Enterococci concentrations aquatic ecology Site AQ1 (Wentworth Point) – scenario Sc3cc relative to Sc2cc (higher rainfall year)

6.3.2 Water quality at SEARs reference sites

The following sections present a summary of the changes in water quality that are predicted as a result of the operation of the WRRF. The sites included in this analysis are presented in Figure 5-15.

For brevity, a selection of relevant scenario results has been included in these sections to aid interpretation. A full set of results is also included in Appendix D for reference.

6.3.2.1 Salinity

Figure 6-85 presents the annual medians for the lower rainfall year. In line with the discussion presented in Sections 6.1.5.3 and 6.3.1.1, reductions at all the reference sites are predicted. On a median basis for the lower rainfall year, reductions of between 2 and 3 PSU are predicted at the sites, with more substantial changes predicted for Haslams Creek (T3) and Powells Creek (T4) and the least impact predicted at the more distant Duck Creek site (T2), which is approximately 6 km upstream of the release point.

With respect to the variations in the hourly time series results, the modelling indicates that peak changes in salinity are generally in the order of 3 to 4 PSU but with potential for up 5 or 6 PSU under extended dry periods.

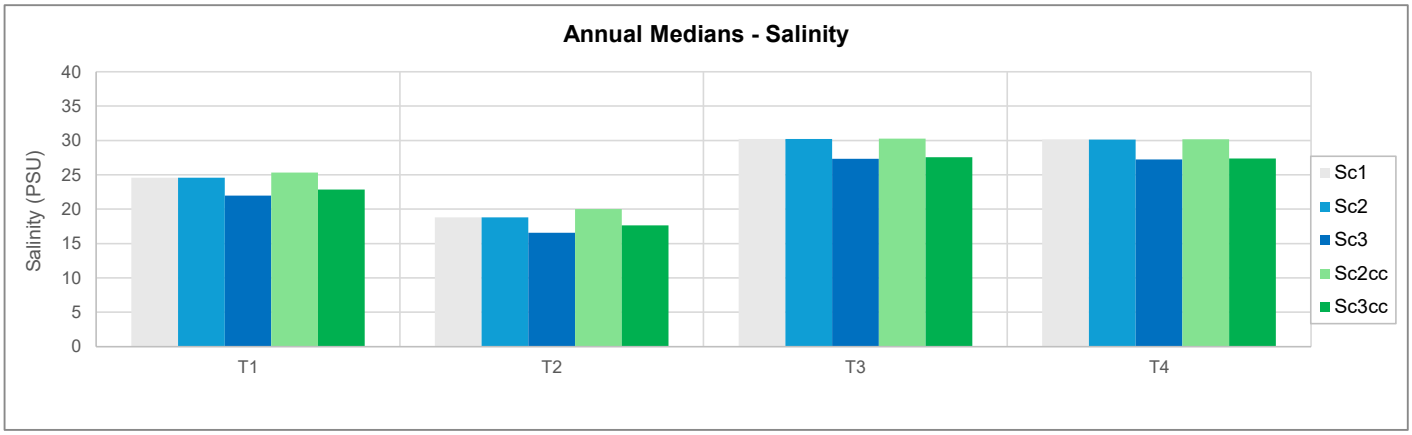

Figure 6-85 Predicted annual median salinity concentrations – SEARs sites (lower rainfall year)

6.3.2.2 Temperature

In line with previous analysis, limited levels of temperature change are predicted at the reference sites (refer Figure 6-86). On a median basis for the lower rainfall year, changes of less than ±0.05°C are predicted at all of the sites.

The modelling indicates that short-term variations may be in the range of ±0.4°C. A seasonal pattern is again observed with more substantial increases in temperature observed during the cooler months and some potential for minor cooling in the summer months.

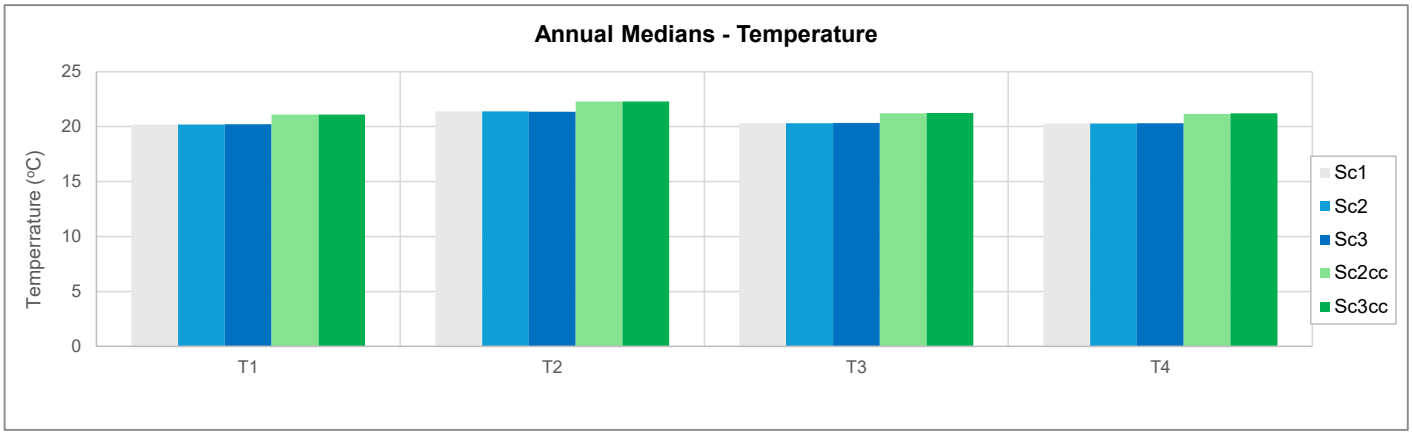

Figure 6-86 Predicted annual median temperatures – SEARs sites (lower rainfall year)

6.3.2.3 Nitrogen

In accordance with the results and findings presented in Sections 6.1.5.5 and 6.3.1.3, annual median concentrations of total nitrogen are predicted to reduce at all the SEARs sites (refer Figure 6-87). For Haslams Creek and Powells Creek, reductions in annual medians of up to 0.05 mg/L are predicted. Within Duck River, reductions of 0.04 mg/L are also predicted.

Aligning with previous discussion, the effects of the WRRF are beneficial during normal operation, however the effects of the offline events, while relatively limited, can extend over a period of weeks to months in the upper estuary.

With respect to the inorganic fractions, in line with previous analysis (refer Sections 6.1.5.5 and 6.3.1.3), increases in ammonia and oxidised nitrogen were predicted in the scenario simulations due to the higher proportion of these species within the releases of advanced treated water (refer Figure 6-88 and Figure 6-89).

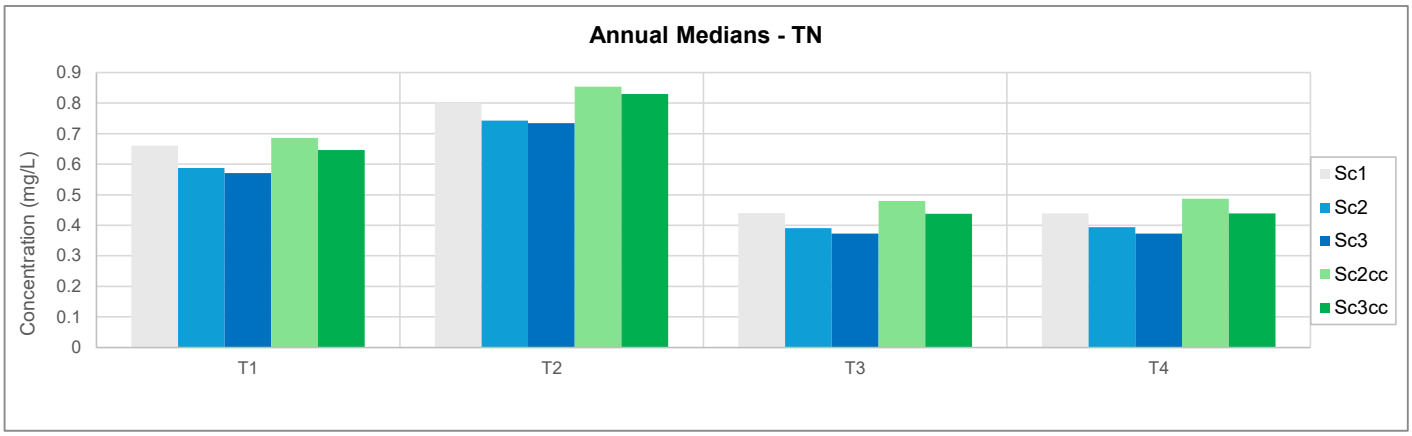

Figure 6-87 Predicted annual median TN concentrations – SEARs sites (average rainfall year)

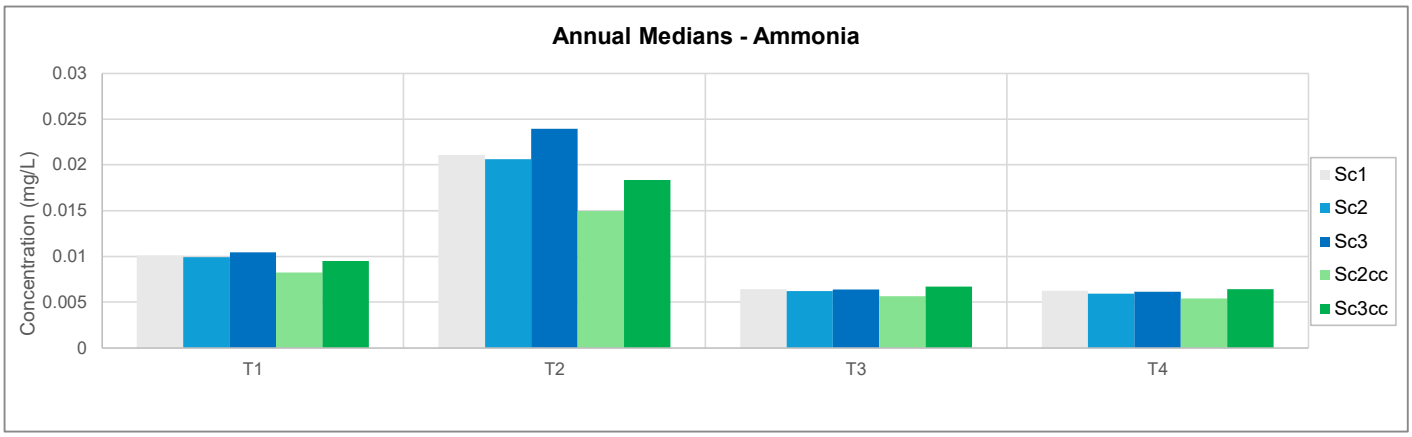

Figure 6-88 Predicted annual median Ammonia concentrations – SEARs sites (average rainfall year)

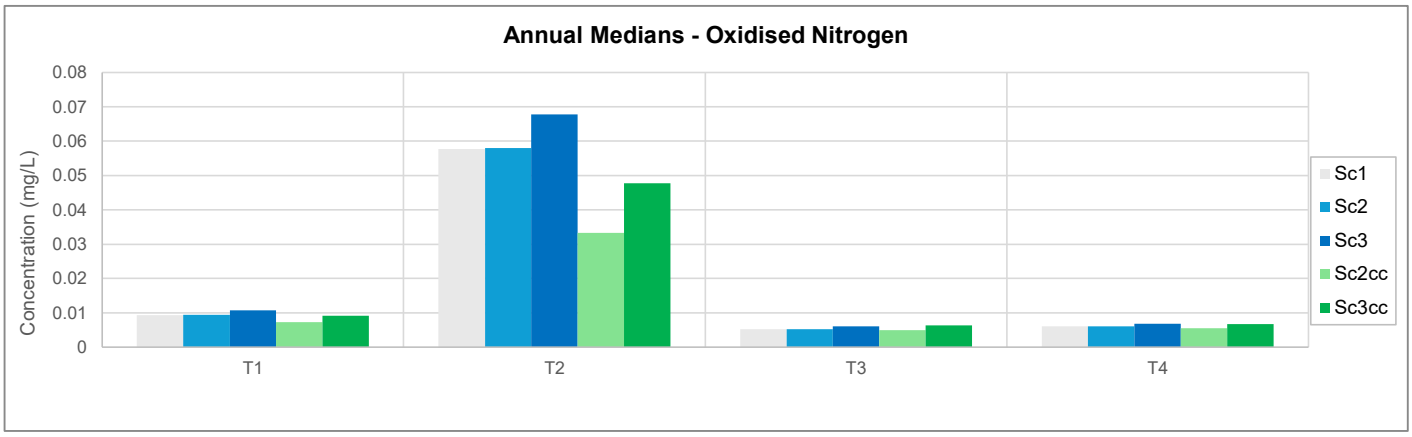

Figure 6-89 Predicted annual median Oxidised Nitrogen concentrations – SEARs sites (average rainfall year)

6.3.2.4 Phosphorus

Consistent with the findings in Sections 6.1.4.6 and 6.3.1.4, reductions in phosphorus are predicted at all the SEARs reference sites due to the operation of the WRRF (refer Figure 6-90). With the exception of the offline events, the river releases in association with mitigation of the wet weather overflows provide for beneficial impacts in both total and inorganic phosphorus.

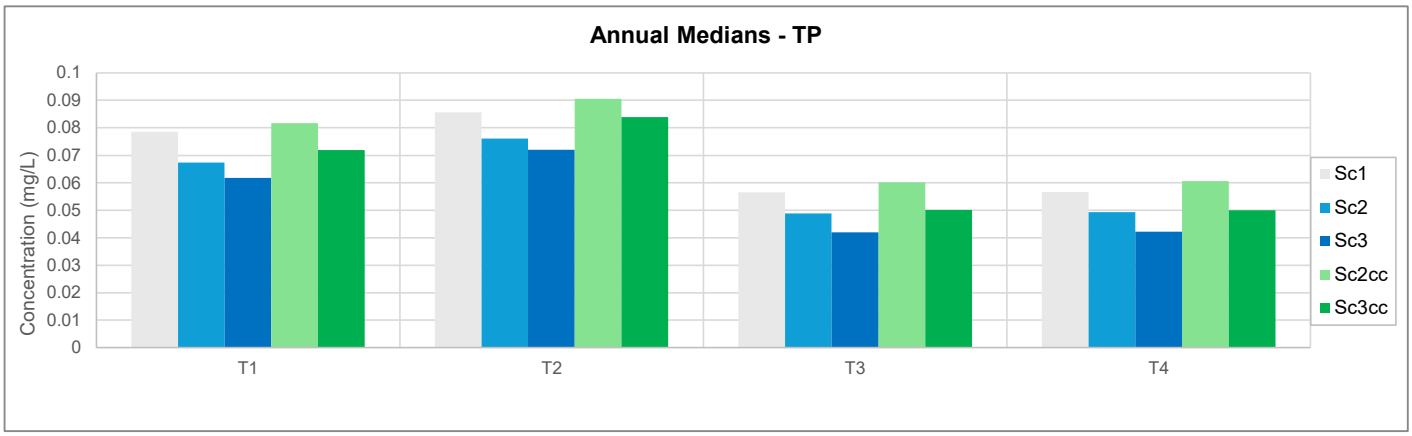

Figure 6-90 Predicted annual median TP concentrations – SEARs sites (average rainfall year)

6.3.2.5 Total suspended solids

Figure 6-91 presents the annual median concentrations for TSS assuming the average rainfall year conditions. Minor reductions are predicted in the ambient concentrations of TSS at the majority of the sites due to the WRRF operation. The reductions in annual medians were predicted to be up to 0.4 mg/L for Haslams and Powells Creeks and below 0.1 mg/L in Duck River.

On a temporal basis, short-term modifications of less than 5 mg/L were generally predicted.

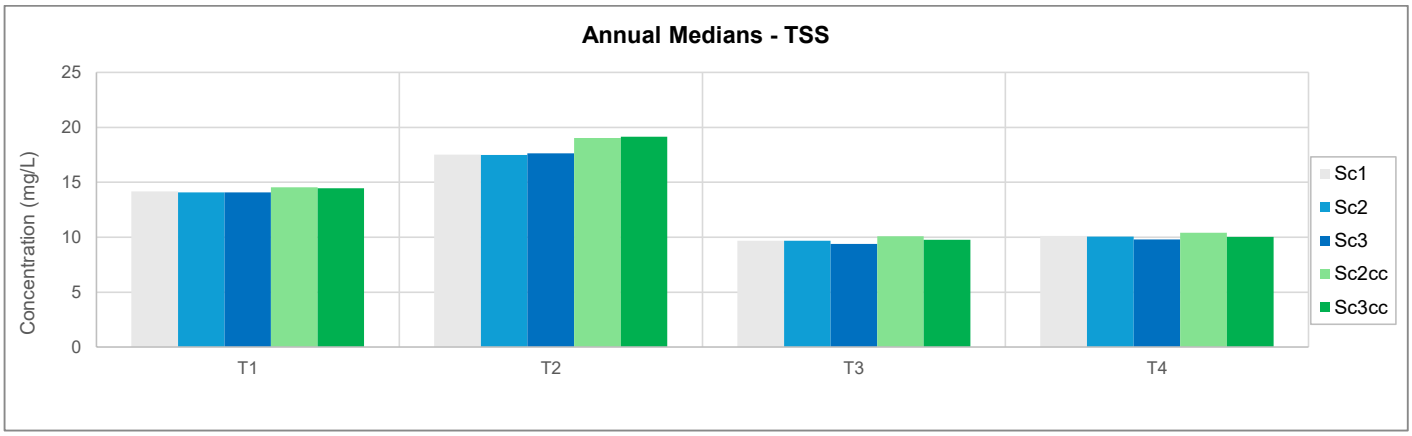

Figure 6-91 Predicted annual median TSS concentrations – SEARs sites (average rainfall year)

6.3.2.6 Chlorophyll *a*

In line with the analysis presented previously in Sections 6.1.5.8 and 6.3.1.6, overall reductions in chlorophyll *a* are predicted across all the rainfall years and at all the SEARs sites analysed (refer to Figure 6-92). These reductions thereby indicating a potential decrease in algal biomass and blooms within the estuary.

Also consistent with the previous analysis, periods of higher chlorophyll *a* were however predicted at the reference sites subsequent to the offline events when higher nutrient loads were introduced over two-day durations. This again is particularly evident during the lower rainfall year.

As per previous discussion, reductions from the WRRF operations were again predicted to be marginally higher under the climate change conditions simulated. Conversely, there was potential for the effects of the offline events to be higher under the non-climate change scenario Sc3.

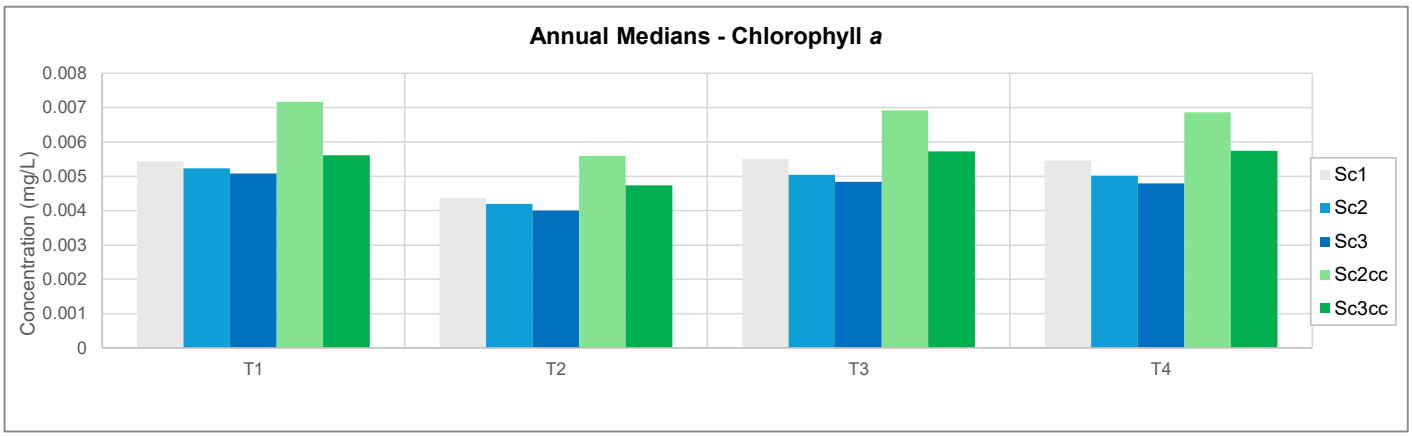

Figure 6-92 Predicted annual median Chlorophyll *a* concentrations – SEARs sites (average rainfall year)

6.3.2.7 Dissolved oxygen

Aligning with previous analysis (Sections 6.1.5.9 and 6.3.1.7), increases in dissolved oxygen were predicted at the SEARs sites as a result of the WRRF operation. From the annual median results, dissolved oxygen levels were predicted to increase up to 0.2 mg/L at the Haslams Creek and Powells Creek sites and up to 0.15 mg/L in Duck River (refer Figure 6-93). The time series results also indicate the potential for elevations as a result of the river releases and to a lesser degree from the mitigation of overflows. These variations predominantly fell within ±0.5 mg/L of the background concentrations.

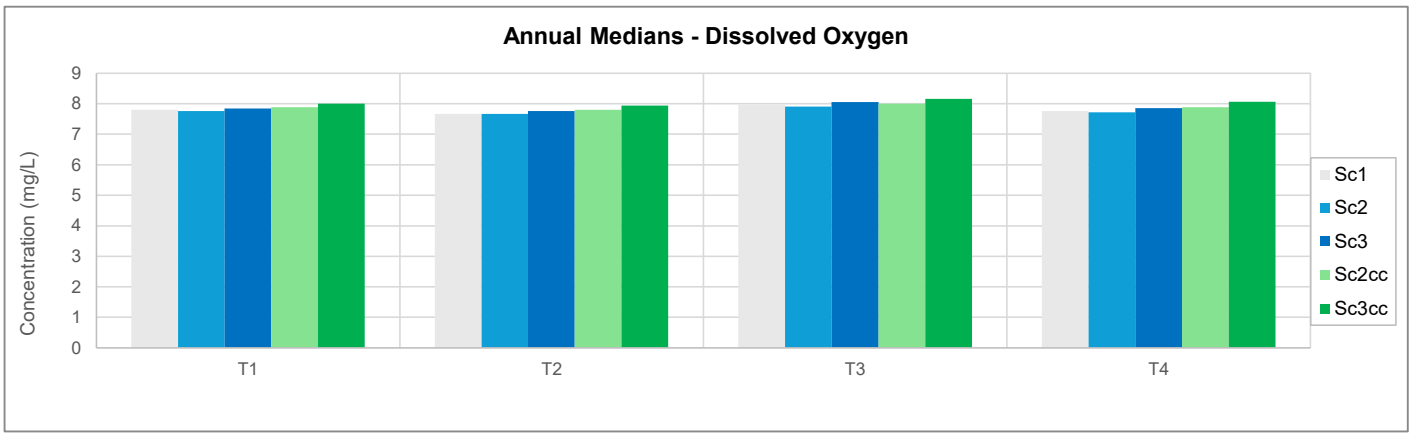

Figure 6-93 Predicted annual median Dissolved Oxygen concentrations – SEARs sites (average rainfall year)

6.3.2.8 Enterococci

Reductions in enterococci are predicted at the SEARs sites due to mitigation of wet weather overflows and the continuous release of treated water with zero pathogenic content.

Figure 6-94 presents the predicted annual 95th percentiles for the average rainfall year. These results indicate negligible changes at most of the reference sites other than site T1 which is located in the lower

reaches of the Duck River. The predicted reduction in concentrations at site T1 indicates the potential for a higher influence in the upper estuary relative to the tributaries and embayments to the south, this influence likely due to the proximity of wet weather overflows that are mitigated by the operation of the WRRF.

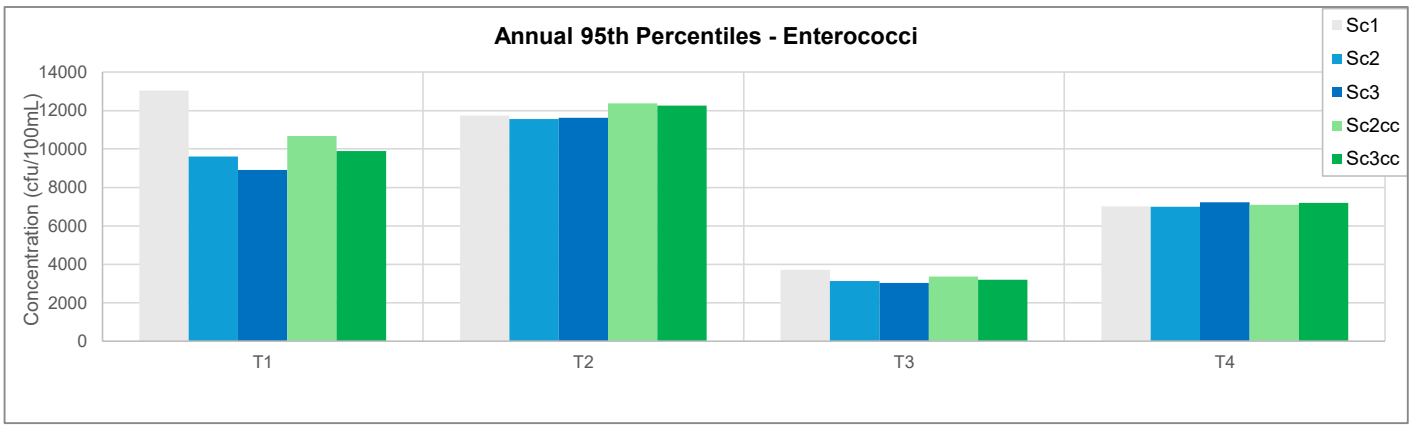

Figure 6-94 Predicted annual 95th percentile Enterococci concentrations – SEARs sites (average rainfall year)

6.3.3 Water quality at recreational activity sites

The assessment of recreational activities has focussed on the impacts on enterococci levels as a primary pathogenic indicator and a measure by which risks to human health can be analysed in terms of both primary and secondary recreational activities.

The sites selected in the assessment include both existing or proposed swimming / recreational sites located downstream of the proposed river release structure. Further details relating to these sites are presented in Section 5.4. While these sites represent key recreational locations, it is acknowledged that primary and secondary recreational activities occur throughout the estuary. Therefore, the broader analysis and interpretation presented in Section 6.1.5.10 is also directly applicable and can be referred in relation to primary and secondary recreation and with respect to corresponding risks to human health.

This modelling approach incorporated datasets beyond the RiverWatch program including simulated worst-case scenarios of wastewater overflows and system failures. The graphs below show modelled and simulated data intended for the EIS. The data shown in these graphs does not reflect actual conditions or real risk at swim sites. More information on water quality conditions at swim sites in the Parramatta River can be found on the Urban Plunge website.

Figure 6-95, Figure 6-96 and Figure 6-97 present the corresponding 95th percentile concentrations predicted for the average, lower and higher rainfall years respectfully. Finally, Figure 6-98 and Figure 6-99 present the time series and change in time series concentrations at the Putney Beach site. The latter two figures indicate the potential for a decrease in pathogen spikes during wet weather (refer red outlines).

The modelling results therefore indicate that the operation of the WRRF presents a potentially beneficial effect regarding pathogenic levels at the swimming sites. Spikes in wet weather concentrations are generally predicted to reduce at each site analysed and across all the rainfall years simulated due to the mitigation of wastewater network overflows. In terms of recreational activities, the influence from the WRRF operation may therefore assist reducing the risk to human health and/or extend safe swimming conditions.

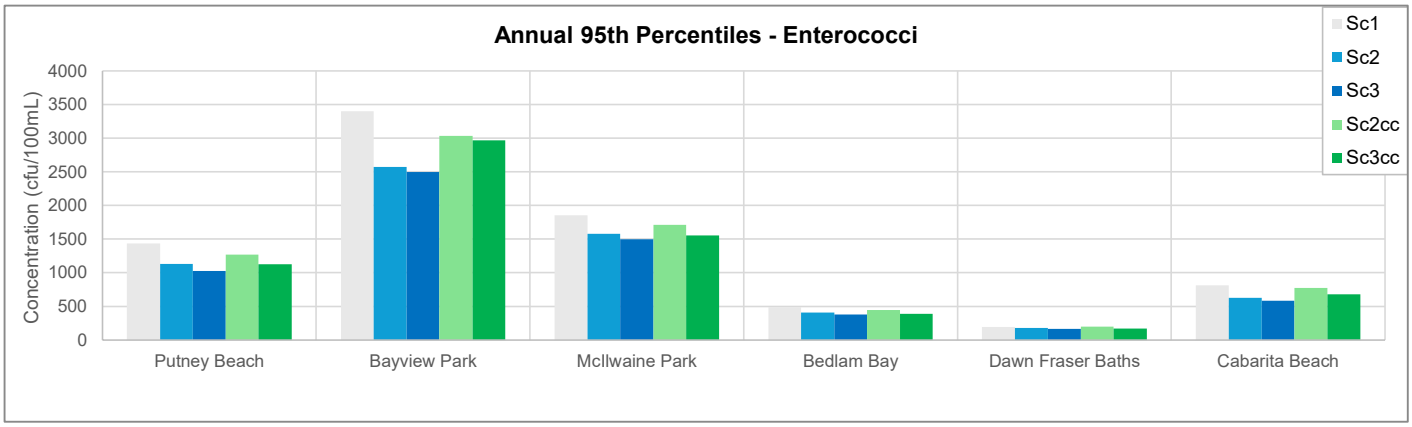

Figure 6-95 Predicted annual 95th percentile Enterococci concentrations – recreational sites (average rainfall year)

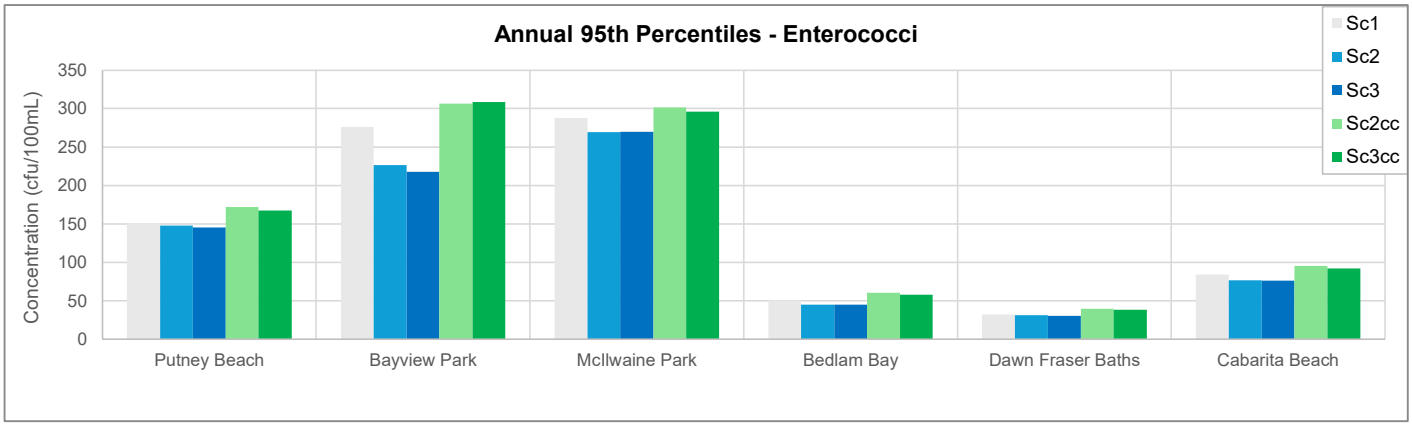

Figure 6-96 Predicted annual 95th percentile Enterococci concentrations – recreational sites (lower rainfall year)

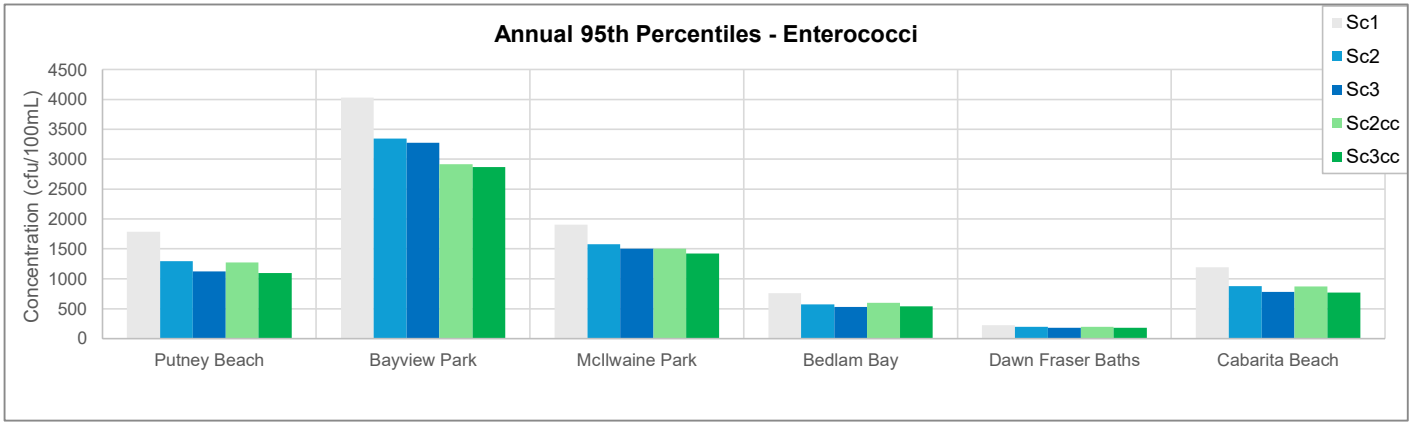

Figure 6-97 Predicted annual 95th percentile Enterococci concentrations – recreational sites (higher rainfall year)

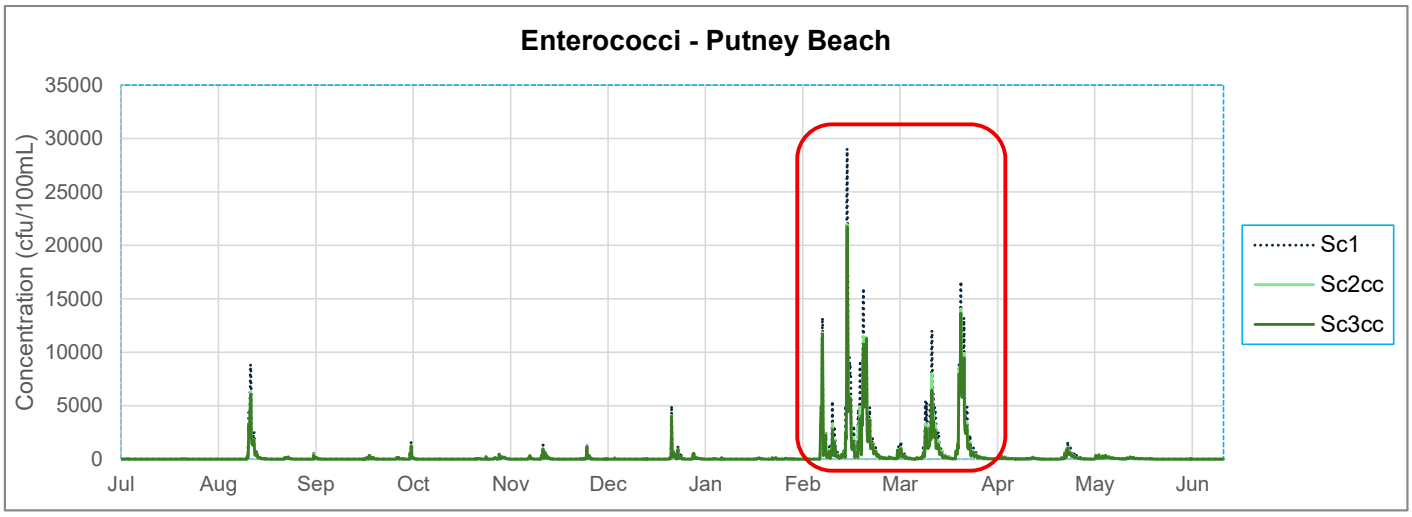

Figure 6-98 Predicted time series of Enterococci concentrations at Putney Beach – scenarios Sc1, Sc2cc and Sc3cc (higher rainfall year)

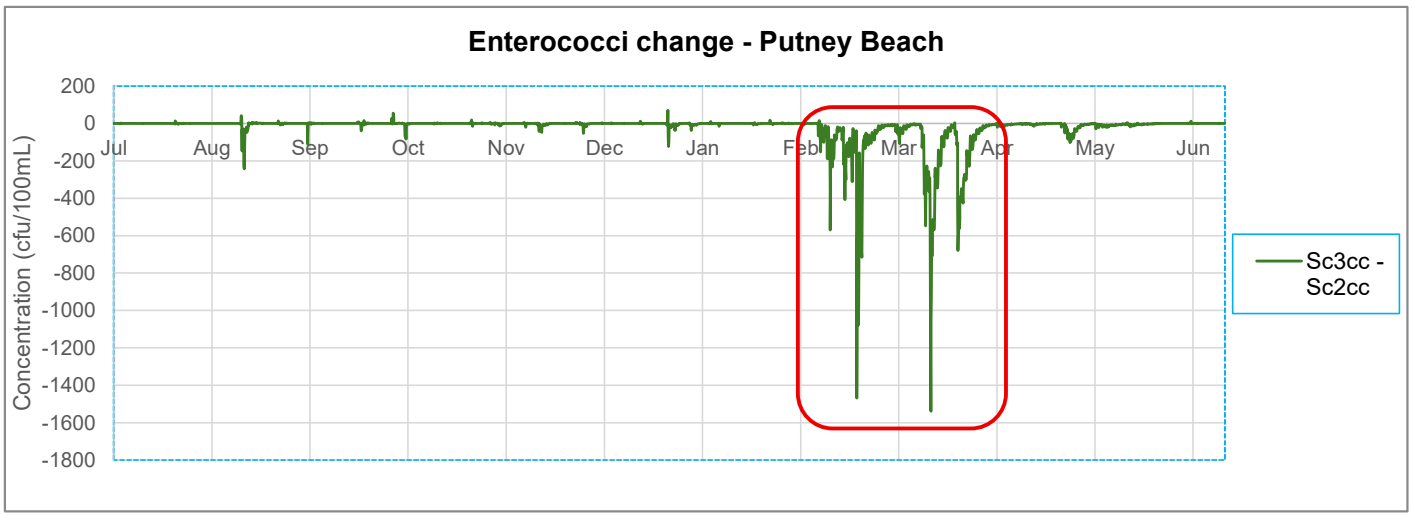

Figure 6-99 Predicted change in time series of Enterococci concentrations at Putney Beach – scenario Sc3cc relative to Sc2cc (higher rainfall year)

7. Mitigation and monitoring measures

7.1 Mitigations measures

7.1.1 Proposed treatment and release strategy

The primary form of mitigation and management of environmental impacts on the receiving waters is through the implementation of the proposed treatment and release strategy. As outlined below, and in more detail in Section 4.5.4.2, the proposed strategy allows for the release of advanced treated water from a multi-port diffuser that will be located on the riverbed within the Meadowbank reach of the estuary.

Under standard operating conditions, only advanced treated water will be released to the river. The high level of RO treatment generates a release stream with low levels of nutrients and other contaminants. The release of the advanced treated water has been demonstrated in the modelling to generally result in improvements in water quality in the immediate vicinity of the releases as well as further afield in the estuary.

The modelling has also demonstrated that implementation of a diffuser in line with the reference design will generate significant levels of mixing and dilution within 30 m of the ports. Under typical tidal conditions, the proposed design is predicted to generate initial dilutions that exceed the minimum criteria stated in the Australian Guidelines for Effluent Management (NWQMS 1997).

7.1.2 Mitigation of sewer overflows

From network modelling, substantial reductions in sewer overflows have been predicted due to the operation of the Camellia-Rosehill WRRF. These reductions relate to both the volumes and contaminant loads released to the river.

As outlined in Section 6.1.5.1, reductions in nutrient and pathogen loads of up to 14% were estimated under the representative average rainfall year conditions. Similar results were presented for the higher rainfall year. Reductions are also expected under drier conditions however understandably these changes were predicted to be of lesser degree (5 to 10%).

7.1.3 Additional mitigation recommendations

7.1.3.1 Minimisation of offline events

As outlined in Section 4.5.4.2, offline events have been represented in the modelling as two 48-hour offline events per year when the RO systems are shutdown, and the tertiary treated feedwater is released to the river. The impacts of these events on water quality in the river include periods of elevated levels of nutrients and chlorophyll *a* during and subsequent to their cessation.

While it is understood that these events may be generally unavoidable due to incidents of membrane fouling, etc, it is recommended that all precautions are taken to reduce the frequency of these incidents, particularly during extended low rainfall periods when flushing in the river is limited.

7.1.3.2 Review of salinity reductions

The modelling has also indicated the potential for ambient salinity concentrations to reduce within the estuary. It is recommended that salinity conditions are reviewed regularly as part of the proposed ambient water quality monitoring program (refer Section 7.2.2).

7.1.3.3 Review of inorganic nutrient concentrations

The modelling has also indicated the potential for increases in the inorganic fractions of nitrogen, i.e. ammonia and nitrate. Due to the model's potential to under predict ambient concentrations of these parameters, the assessment has commented that this analysis may be conservative. Due to the uncertainty in the modelling of these fractions it is recommended that ongoing reviews of the monitoring data are undertaken to evaluate any potential increases in inorganic nitrogen in the river.

7.1.3.4 Review of release temperatures

The water quality assessment has indicated the potential for the river releases to increase temperatures within the river (increase in annual medians up to ~0.1^{o}C). This predicted influence may be driven by the adoption of data from the St Marys AWTP and may therefore not consider the travel time and effects on water temperature within the 7.6 km river release pipeline. It is recommended that release temperatures are reviewed regularly as part of the proposed water quality monitoring program.

7.2 Monitoring requirements

Monitoring of the treated water releases, and also within the receiving waterway, are key to confirming the potential for impacts on ambient water quality from operation of the WRRF. More specifically, the monitoring will allow for the following:

- Monitoring of treated water for assessment of the performance of the WRRF over a range of operating conditions
- Monitoring in the Parramatta River for evaluation of impacts on the receiving waterway relative to baseline conditions.

The following sections present recommended details of the monitoring programs for the post-commissioning and operational phase of the WRRF.

All monitoring is to follow Sydney Water's standard sampling and laboratory procedures and also align with the Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA, 2022). The application of these EPA (2022) methods is prescribed within the project-specific SEARs.

7.2.1 Treated water

The monitoring activities for treated water are recommended before its release to Parramatta River as shown in Table 7-1.

Table 7-1 Treated water monitoring

Monitoring plan	Requirements
Frequency	Monitor release volumes daily with a calibrated flow meter, including during offline events/ incidents where tertiary treated water is released. Monitor water quality every 6 days, or daily if tertiary releases occur.

Monitoring plan	Requirements
Location	Monitor at suitable locations within the WRRF that are representative of the final release streams, including for flow metering.
Analysis and reporting	Water quality analysis is to be completed by Sydney Water's Laboratory Services, or an alternative NATA accredited laboratory. Sydney Water will submit an Annual Return as required by the EPL. The Annual Return will report on pollutants listed in the EPL.

7.2.2 Ambient monitoring

The ambient water quality monitoring at Parramatta River is recommended as shown in Table 7-2.

Table 7-2 Ambient water quality monitoring

Monitoring plan	Requirements
Frequency	Monitor river quality every three weeks. This is consistent with the Sydney Water Aquatic Monitoring (SWAM) program.
Location	Collect samples at one location upstream and one location downstream of the release. The location of these two monitoring sites will be finalised in consultation with the EPA. All water samples to be collected from the surface or within a depth of 0.5 metres of the surface.
Analysis and reporting	Analysis is to include duplicate samples. Field-based parameters (such as temperature, dissolved oxygen, pH, conductivity, turbidity) to be recorded for one of the samples. Field observations such as visual indications of pollution, odour and any other important general comments to be noted at each site. Report on parameters appropriate to the release stream and the receiving environment. Analysis is to be completed by Sydney Water's Laboratory Services laboratories, or an alternative NATA accredited laboratory. Reporting protocols to be finalised in consultation with the EPA.

8. Summary and conclusions

This report presents the findings of a hydrodynamic and water quality impact assessment that has been developed to support and inform the EIS for the GPOP Water Cycle Management project. The report consequently provides analysis of how the hydrodynamics and water quality in the receiving waters of the Parramatta River may potentially be impacted.

The assessment has evaluated the operational phase of the WRRF (circa 2056) along with cumulative impacts of other expected changes in climatic and catchment conditions. Key assumptions regarding the modelling of the WRRF's operation include:

- The scenarios assume the WRRF is operating at full capacity, i.e. 70 ML/d ADWF in 2056. Prior to reaching these operating levels, the extent of the impacts on the receiving water are likely to be proportionally reduced.
- Similarly, the scenarios assume no allowance for beneficial reuse. Therefore, the entire volume of treated water generated by the WRRF is released to the waterway and no percentage is supplied for recycling purposes.

The modelling has assumed the adoption of a treatment and release strategy specifically developed to reduce impacts on the river. The strategy allows for the release of advanced treated water to the waters of the Parramatta River, with consideration of the sensitivities and characteristics of this waterway. The adoption of the treatment and release strategy forms a key mitigation measure for the avoidance of environmental harm from the operation of the WRRF.

In addition to the proposed release strategy, further improvements in water quality within the river are also anticipated due to the additional mitigation of sewer overflows within the upper estuary, as generated by the operation of the WRRF.

Further to these mitigation measures, extensive monitoring has also been proposed with respect to the release streams and within the receiving waters.

Also, key to the modelling has been the simulation of future conditions in the catchments and within the estuary. Background scenarios representative of the circa 2056 time horizon have taken account of changes in population growth, etc. The effects of climate change have also been evaluated through simulation of this future time horizon, with and without changes in catchment and waterway conditions as predicted under RCP 4.5. The modelling therefore allows for assessment of cumulative effects on the waterway as well as assessment of the impacts from the operation of the WRRF relative to expected future conditions.

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

8.1 Hydrodynamic and water quality impacts

The impacts on hydrodynamics and water quality arising from the operation of the WRRF were predicted to be predominantly positive. While the influence of the releases was predicted to be higher in the reaches of the upper estuary, beneficial effects on water quality also extended to the mid and lower estuarine region and beyond into Sydney Harbour.

The positive nature of these impacts is principally a result of the high quality of the treated water being released and the proposed design of the release infrastructure. In addition to the river releases, further improvements in water quality are also predicted due to additional mitigation of sewer overflows within the upper estuary.

To aid interpretation, the impacts of the river releases have been compared against baseline conditions (circa 2024/25) and corresponding background conditions (circa 2056) as well as against the relevant waterway objectives. The analysis therefore allowed for an understanding of the cumulative impacts from future conditions (with and without the predicted influence of climate change) as well as residual impacts from just the operation of the WRRF.

A summary of the key findings of the assessment is presented below, noting that the impact assessment presented in Section 6.1 also provides additional analysis relating to selected aquatic ecology sites, locations referenced in the SEARs as well as for specific recreational activity sites.

- Based on the modelling undertaken, the operation of the WRRF provided for many improvements in the water quality of the Parramatta River. As discussed in more detail below, these improvements in river water quality generally consisted of lower concentrations of nutrients, pathogens and algal biomass, and higher levels of dissolved oxygen.
- Analysis of total estuarine loads was undertaken with consideration of the advanced treated water releases and inclusive of episodic offline events. From this analysis, the estimated contribution of the releases from the WRRF relative to total nitrogen load ranged from ~2% to ~12% dependent on the year simulated. For total phosphorus, the estimated percentage contribution was lower than for nitrogen, up to an estimated maximum of ~7%. Finally, the contribution to enterococci load was estimated to be zero due to the river releases including no pathogenic content.
- The load analysis also provided an indication of the expected reductions in sewer overflows arising from the operation of the WRRF. Reductions in load of up to 14% were estimated for all the parameters analysed under the average rainfall year conditions. Similar results were presented for the higher rainfall year, reducing to between 5% and 10% under the lower rainfall conditions.
- With respect to potential impacts on hydrodynamics, negligible changes to water level were predicted as a result of the river releases being introduced. Modifications to ambient flows and velocities were however predicted upstream and downstream of the releases. Relative to the background conditions, a net upstream residual of 0.1 m^3/s was predicted upstream of the release point. Conversely, a net downstream residual of 0.6 m^3/s was predicted downstream of the diffuser.
- Salinity is predicted to reduce due to the release of freshwater near the John Whitton Bridge. These reductions were predicted for both variations of the impact scenarios but with slightly higher reductions predicted under the non-climate change scenario. Reductions in annual medians of up to 3 PSU were predicted, while variations in the time series analysis were generally predicted to be between 5 and 6 PSU. While these larger impacts were predicted in the river reaches near the releases, reductions in salinity were observed to lesser extents across the wider estuary and within Sydney Harbour.
- Due to the low nutrient content of the releases and the associated mitigation of sewer overflows, concentrations of nitrogen and phosphorus in the river generally were predicted to decrease. The exceptions being impacts from the offline events, as well as the potential for minor increases in the inorganic fractions of nitrogen. The effects of the offline events varied in terms of duration and magnitude dependent on the rainfall year and levels of flushing prevalent in the river. Despite these exceptions, the modelling indicated the potential to increase levels of compliance within the estuary for key indicators against relevant guideline values.
- With respect to Total Suspended Solids, only limited reductions in ambient conditions were predicted as a result of the WRRF operation with annual median concentrations modified by less than 0.5 mg/L and shorter-term variations below 2 mg/L.

- As a product of predicted reductions in nutrients, the modelling indicated the potential for overall reductions in chlorophyll *a* across all the rainfall years simulated, thereby indicating a potential decrease in algal biomass within the estuary. These reductions were generated as a result of mitigation in overflow nutrient loads as well as the introduction of the releases of the advanced treated water with low nutrient content. The only exception to this was during offline events when higher nutrient loads were introduced from the tertiary treated water. While relatively limited in terms of magnitude (~0.5 µg/L), elevations in chlorophyll *a* were predicted for periods of weeks up to two months following these events.
- Limited elevations in dissolved oxygen concentrations were predicted as a result of the operation of the WRRF with annual median results predicted to increase by up to 0.1 to 0.15 mg/L in the upper estuary.
- With respect to pathogens, reductions in enterococci of up to 10,000 cfu/100 mL in wet weather concentrations were predicted at some sites in the upper estuary. These reductions are directly attributed to the mitigation of wet weather overflows associated with the operation of the WRRF.
- Extending this analysis to the swimming sites in the river, the results indicate that the operation of the WRRF presents a potentially beneficial effect regarding pathogenic levels. Spikes in wet weather concentrations are generally predicted to reduce at each site analysed and across all the rainfall years simulated.

8.2 Near field impacts

A summary of the key findings from the near field impact assessment is presented below:

- Initial dilution within the near field region of the diffuser is predicted to be relatively high under all the tidal conditions simulated. The initial mixing zone generally extended approximately 30 m downstream of the diffuser ports, prior to a transition to more ambient mixing processes. The near field dilutions were predicted to be compliant with the criteria presented in the Australian Guidelines for Effluent Management (NWQMS, 1997) across the tidal conditions analysed with the exception of the more extreme and transient low tide slack-water scenario.
- To determine the risk of toxicity or environmental harm, dilution requirements for a suite of contaminants were estimated from analysis of expected release concentrations, background conditions and applicable toxicant DGVs. From the analysis, a dilution requirement of approximately 1.5 was identified for total chlorine for the releases of the advanced treated water.
- For the tertiary treated water, dilution requirements ranged up to a maximum of ~30 for the following contaminants: nitrate, total chlorine, aluminium, mercury and zinc
- Based on this analysis and the results of the near field modelling, the following findings were drawn with respect to mixing zone requirements:
  - During the release of advanced treated water, the risk of toxicity is predicted to be mitigated in the immediate vicinity of the diffuser ports. Even under the conservative slack tidal conditions, the dilution requirements are predicted to be exceeded within the first metre of the ports. The plume widths are predicted to be less than 30% of the waterway width.
  - During the offline events with short-term release of tertiary treated water, the risk of toxicity is again generally predicted to be mitigated within close proximity to the diffuser ports. Under the peak and mid tidal conditions simulated, the dilution requirements are achieved within ~12 m. Under the more conservative slack tidal conditions, the dilution requirements are similarly predicted to be achieved within 10 m of the diffuser ports, with exception of zinc which is achieved at a predicted distance of ~140 m.
  - For copper, the analysis of mixing zone requirements for both the advanced and tertiary treated water releases is inhibited due to the assumed background ambient conditions exceeding the respective toxicant DGVs.

8.3 Mitigation and monitoring measures

The project specific treatment and release strategy forms the key mitigation measure for the avoidance of environmental harm from the releases.

In addition to the proposed release strategy, further improvements in water quality within the river are also anticipated due to the additional mitigation of sewer overflows within the upper estuary, as generated by the operation of the WRRF.

Section 7 presents recommendations regarding monitoring of the releases as well as ambient monitoring at sites upstream and downstream of the proposed release points. Further recommendations are also provided with respect to release conditions and how the releases could be managed to further reduce the risk of environmental harm in the river.

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Appendix A. GPOP Water Quality Response Model Calibration Report

GPOP Water Quality Response Model Calibration Report

December 2025

Sydney WATER

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Change history

Version	Status	Issue Date	Endorsed by	Approved by	Brief description of change and consultation
1	Draft	3/07/2025	JB	BS	Draft for internal and external review
2	Final Draft	29/08/2025	VK	BS	Final draft issue
3	Final	15/12/2025	VK	BS	Final incorporating Independent Reviewer feedback

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1 Introduction

1.1 Background

1.1.1 The Greater Parramatta and Olympic Peninsula Water Cycle Management project

Sydney Water is proposing to build and operate a new water resource recovery facility (WRRF) at Camellia-Rosehill with associated infrastructure to provide wastewater services to the Greater Parramatta and Olympic Peninsula (GPOP) growth area (the project).

As a key growth area in Sydney, the population in GPOP is projected to double in size by 2056. An increase of residents and businesses in the area will generate substantial volumes of wastewater requiring treatment. This growth would place pressure on Sydney Water's existing wastewater network which includes the Northern Suburbs Ocean Outfall Sewer (NSOOS). The NSOOS is a critical sewer main which transfers wastewater from a large catchment area to North Head WRRF for treatment. With current growth projections the NSOOS would reach capacity by 2031-32.

The project is needed to provide a water cycle management solution for the GPOP growth corridor that is efficient and cost effective for the community. The proposal avoids duplication of the NSOOS and provides a wastewater solution which is sustainable, resilient and adaptable.

The main elements of the project include:

- a new WRRF at Camellia-Rosehill to treat wastewater from the GPOP area to produce advanced treated water
- upgrade to the existing pumping station at Camellia (SP0067) to enable wastewater to be directed to the new WRRF and brine to be discharged into the existing wastewater system
- a new wastewater transfer pipeline from SP0067 to the WRRF
- a new brine pipeline from the WRRF to SP0067 and repurpose an existing pipeline to transfer brine from SP0067 to the NSOOS
- installation of a river release pipeline to transfer high quality treated water from the WRRF to a release structure in Parramatta River near John Whitton Bridge

The project has been classified as State Significant Infrastructure and Sydney Water is preparing an Environmental Impact Statement (EIS) to support an application to the Minister for Planning and Public Spaces.

1.1.2 The GPOP Water Quality Response Model

Sydney Water previously developed hydrodynamic and water quality models of the Parramatta River and Sydney Harbour as part of the Wet Weather Overflow Abatement project (Sydney Water, 2018). The resulting integrated modelling system incorporated hydrodynamic and biogeochemical processes to allow evaluation of relevant environmental impacts originating from the catchment and more specifically the wet weather overflows. Since their initial development, the

models have provided valuable insights on the efficacy of various management strategies through its application on a range of projects.

More recently, the models were updated as part of the Parramatta River Flows Feasibility Study (Sydney Water, 2022). The updates to the model included modifications to the software, transition to a three-dimensional model domain, revision of the calibration and validation periods as well as the model data used as inputs and for calibration of the model.

In response to recommendations from the feasibility study, further model development has been undertaken to ensure the model's fitness for purpose in its application for the GPOP EIS. The product of this most recent model development is the GPOP Water Quality Response Model (WQRM) that is discussed in detail in this report.

A fundamental focus of the recent model development phase has been to ensure the modelling system has the capacity to realistically evaluate hydrodynamic and water quality impacts from the following potential release scenarios:

- Continuous release of 63 ML/d of advanced treated (reverse osmosis quality) water from the new WRRF to be released in the vicinity of John Whitton bridge
- Temporary short-term releases of 70 ML/d of MBR secondary treated feedwater that may also be released in the vicinity of John Whitton bridge
- Potential modifications to wet weather overflows from the sewerage network as a result of the operation of the new WRRF

1.2 Study objectives

The primary objectives of the model development and calibration component of this project are listed below:

- Development, calibration, and validation of a new hydrodynamic and receiving water quality model of the Parramatta River estuary and Sydney Harbour.
- Provision of the aforementioned model that is considered fit for purpose in its application and delivery for the hydrodynamic and water quality impact assessment which is being prepared as part of the GPOP EIS.

1.3 Report structure

To allow for ease of understanding of the model development and associated calibration/validation tasks, the report has been structured in the following format:

- Modelling framework
- Model structure and datasets
- Calibration and validation
- Conclusions

2 Modelling framework

2.1 Conceptual model

As part of an initial model development phase and in alignment with directives from the NSW Environment Protection Authority (EPA) and the Department of Climate Change, Energy, the Environment and Water (DCCEEW), a conceptual model of the Parramatta River estuary was developed. The focus of this model was to ensure key processes had been considered for inclusion in the numerical modelling.

The model was developed as a series of Microsoft PowerPoint slides addressing the following key elements:

- initial considerations
- NSW Water Quality Objectives including major concerns raised in consultation
- System/environmental values
- system pressures of relevance
- system conceptual model – hydrodynamics and salinity dynamics
- system conceptual model – water quality
- system conceptual model – nutrient dynamics

Figure 2-1 presents an extract from the conceptual model with respect to nutrient dynamics assuming a mixed water column. The full set of slides are presented in Appendix A.

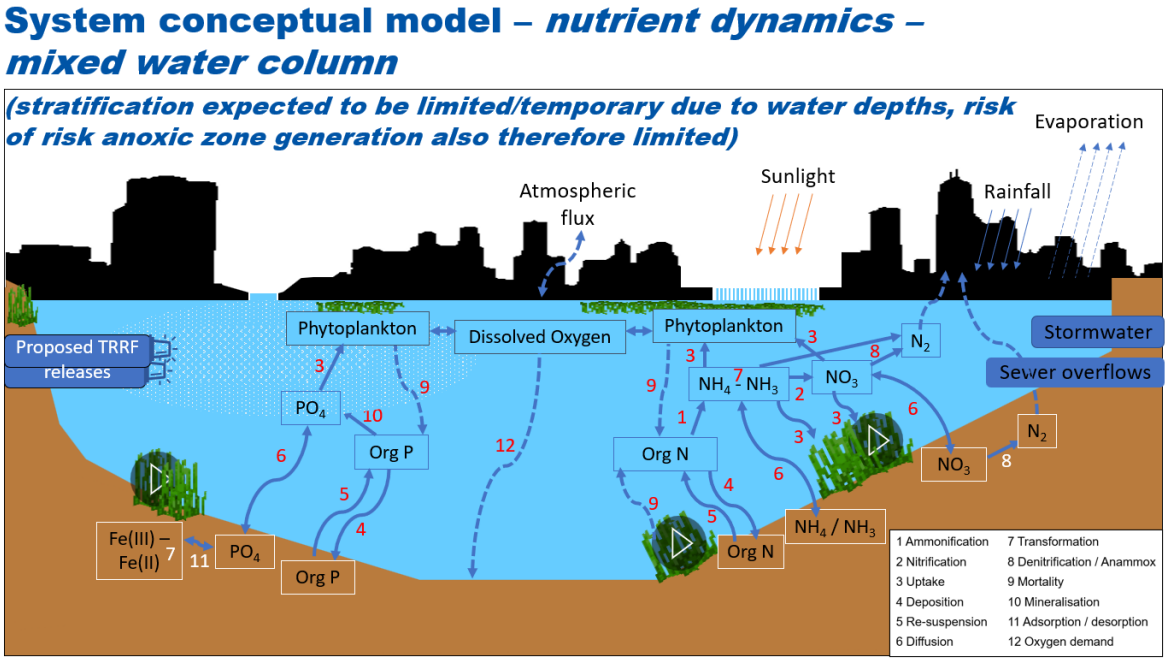


Figure 2-1 Extract from the Conceptual Model – Nutrient dynamics in a mixed water column

2.2 Water Quality Response Model

The Greater Parramatta and Olympic Peninsula (GPOP) Water Quality Response Model (WQRM) is primarily built on application of the finite volume hydrodynamic modelling software, MIKE 3 Flow Model Flexible Mesh (FM), which is then coupled with the MIKE Mud Transport (MT) and MIKE Ecolab modules, to simulate sediment transport and water quality processes respectively. Further details relating to these modelling software packages are presented below.

2.2.1 MIKE 3 FM

The MIKE 3 Flow Model FM is a modelling system based on a flexible mesh approach, developed by DHI Water and Environment, for applications within oceanographic, coastal and estuarine environments.

The hydrodynamic module is based on the numerical solution of the three-dimensional (3D) incompressible Reynolds averaged Navier-Stokes equations invoking the assumptions of Boussinesq. Both the full 3D Navier-Stokes equations and the 3D shallow water equations can be applied, with the latter invoking the hydrostatic pressure assumption. Thus, the model consists of continuity, momentum, temperature, salinity and density equations and is closed by a turbulent closure scheme. In the horizontal domain both Cartesian and spherical coordinates can be used. The free surface is taken into account using a Sigma coordinate transformation approach.

The spatial discretisation of the governing equations in conserved form is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the continuum into non-overlapping elements/cells. In the horizontal plane an unstructured grid is used while in the vertical domain a structured discretisation is applied. The elements can be prisms or bricks whose horizontal faces are triangles and quadrilateral elements, respectively.

For the time integration, a semi-implicit approach is used where the horizontal terms are treated explicitly, and the vertical terms are treated implicitly. The interface convective fluxes are calculated using an approximate Riemann solver. This shock-capturing scheme enables robust and stable simulation of flows involving shocks or discontinuities such as hydraulic jumps.

For further details of the MIKE 3 FM software and its configuration, readers are referred to the documentation in Appendix B as well as the following link: https://manuals.mikepoweredbydhi.help/latest/MIKE_3.htm.

2.2.2 MIKE Mud Transport

The MIKE Mud Transport (MT) module provides the ability to simulate the transport of fine-grained sediments, particularly mud, in estuarine, coastal and marine environments. The software presents the capacity to analyse the transport of sediment particles with a range of different characteristics. Application therefore allows for assessment of impacts of suspended solids and siltation for marine, brackish, and freshwater projects.

The MT module can simulate sediment dynamics influenced by waves, currents, tides, and sediment characteristics. Typical applications include management of dredging operations, for turbidity reduction, or ensuring environmental compliance.

Importantly for the GPOP modelling, the results from the MT models are used as a key input to the Ecolab models, thereby presenting a temporally and spatially varying database for Total Suspended Solids (TSS) that in turn is used to derive light availability and inform light dependent processes in the Ecolab models.

For further details of the MT module, readers are referred to the documentation in Appendix B as well as the following link: https://manuals.mikepoweredbydhi.help/latest/MIKE_3.htm.

2.2.3 MIKE Ecolab

The MIKE Ecolab module is a customisable numerical modelling tool that can be applied to allow simulation of a suite of water quality processes including: eutrophication, nutrient dynamics, pathogens, heavy metals, etc. Pre-defined or project specific templates can be applied to describe dissolved substances, particulate matter of dead or living material, living biological organisms and other components. The modules are generally developed to describe chemical, biological, ecological processes and interactions as well as the physical process of sedimentation of components.

Of relevance to this study, the conceptualisation of the EU2 eutrophication template has been configured to capture the dynamics of oxygen, carbon, nutrients (including inorganic and organic fractions) and primary productivity as presented in Figure 2-2. Modifications were also made to the EU2 template to allow inclusion of Enterococci as a primary constituent. It therefore includes the core elements of the conceptual model discussed in Section 2.1. The primary variables included in the GPOP WQRM simulations are described in further detail in Appendix B.

The module also allows indicators of waterway health (e.g. hypoxia or nuisance algal bloom risk) to be output and summarised over the simulated domain. A large number of derived variables are also available for inclusion e.g. primary production, total nitrogen and phosphorus, sediment oxygen demand and Secchi disc depth. The water quality properties are updated dynamically in response to changes in water conditions brought about by weather and flow events.

For further details of the Ecolab software and its configuration, readers are referred to the documentation in Appendix B as well as the following link.
https://manuals.mikepoweredbydhi.help/latest/MIKE_3.htm

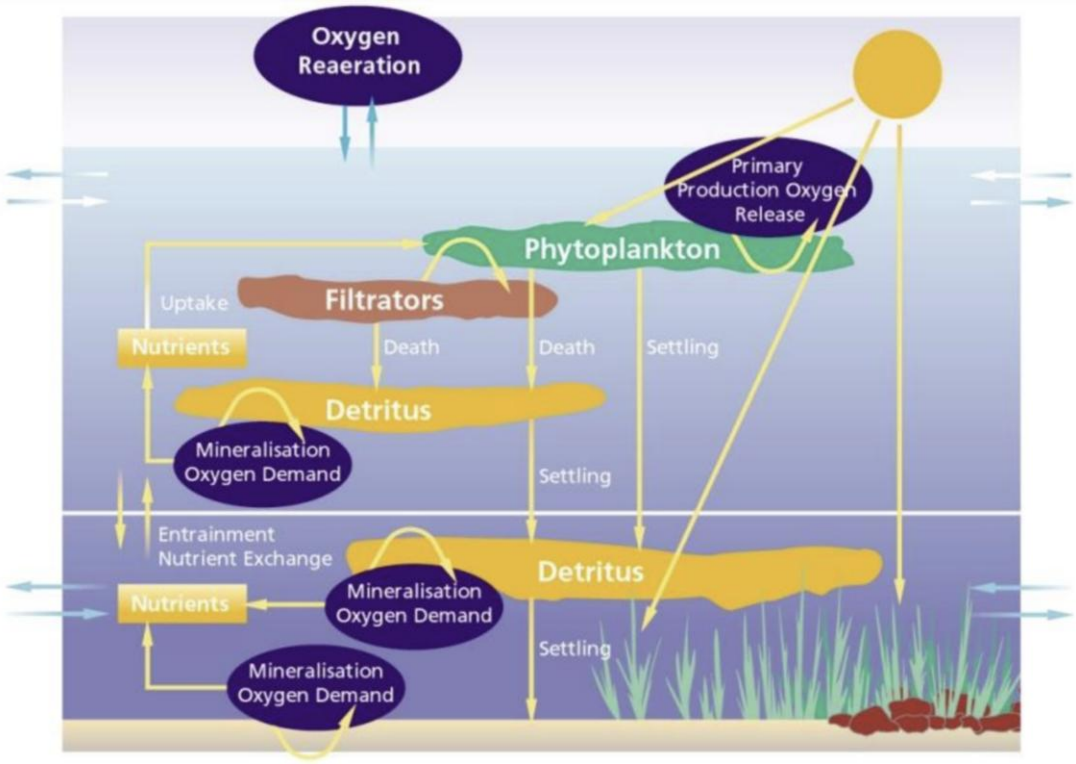


Figure 2-2 Conceptual diagram illustrating the key variables and processes of the MIKE Ecolab eutrophication template (Source: DHI Water and Environment)

2.3 Boundary condition models

A range of other modelling software packages were also applied to provide the hydrodynamic and water quality boundary conditions that were required in the development of the GPOP WQRM. The structure and purpose of these models are discussed briefly in the sections below. Analysis relating to the sensitivity of the WQRM to these models is also presented in Section 4.2.4.

2.3.1 Source Catchment models

Hydrological modelling of the contributing catchments was undertaken through application of the eWater Source software. A range of rainfall runoff models are available within the Source software. For the purposes of this project the runoff model selected for application in the GPOP model catchments was Simhyd, which was applied on a sub-daily (hourly) time step.

A suite of four Source models were developed to encompass the following catchment areas: Upper Parramatta River, Upper Lane Cove River, Upper Duck River and the remaining smaller catchments draining to the Sydney Harbour Estuary (including Vineyard Creek.

To provide constituent export results for use in the WQRM, a dry weather concentration (DWC) and event mean concentration (EMC) approach was adopted in the Source software. This approach provided for the generation of results for a set of key water quality parameters including Nitrogen species, Phosphorus species, Total Suspended Solids and Enterococci.

Further details of the rainfall runoff and constituent export modelling are provided in the *Source models for the Parramatta River and Sydney Harbour Catchment calibration report* (HARC, 2025). This report is presented in Appendix C. Additional information regarding how the results from the catchment model were incorporated into the GPOP WQRM is presented in Section 3.6.1.

2.3.2 Upper Parramatta River model

To provide representative boundary conditions of flow and water quality for water overtopping the Charles Street Weir, modelling of the Upper Parramatta River (UPR) was undertaken through application of a standalone hydrodynamic and water quality model developed in the MIKE 21 FM, MT and Ecolab software modules.

The UPR model was developed in a similar structure, and with the same underlying datasets and parameterisation as the GPOP WQRM, the model mesh extending upstream of Charles Street Weir encompassing the weir pool storage, up to the confluence of Toongabbie Creek and Darling Mills Creek.

Further details regarding the Upper Parramatta River model and how the model results were incorporated into the GPOP WQRM are presented in Section 3.6.2.

2.3.3 Sewer network models

Sydney Water has developed sewer network models with application of the Model for Urban Sewers (MOUSE) software package, developed by DHI Water and Environment. As part of the MIKE URBAN software platform, MOUSE allows for simulation of collection systems for urban wastewater and stormwater. It is commonly used to assess the network capacity of sewerage networks, associated bottlenecks, analysing sewer overflows, as well as evaluating water quality and sediment conditions.

To allow for representative routing of overflows in the contributing catchments, results for the overflows from these models were incorporated into the GPOP WQRM, or the Source catchment models, depending on their geographic location.

To characterise the water quality of the overflows a dilution-based approach was developed. This approach involved application of an algorithm that calculated a dilution factor based on antecedent rainfall for the sub-catchment in which each overflow was located, and then calculated a release concentration for each water quality parameter based on the predicted contribution of raw sewage and stormwater.

Further details relating to these models, their outputs and how they were incorporated into the catchment model and GPOP WQRM are presented in Section 3.6.3.

2.4 Model interfaces

Figure 2-3 presents a high-level overview of how the boundary condition models were interfaced with the WQRM. More specifically, the following interfaces were applied:

- Results from the Source models were processed to develop the catchment inflow boundary conditions for the WQRM.

- Results from the UPR model were processed to develop flow and water quality boundary conditions for the WQRM immediately downstream of the Charles Street weir.
- Overflow results from the MOUSE models were incorporated directly into the WQRM or indirectly via the Source models depending on the location relative to the model mesh.

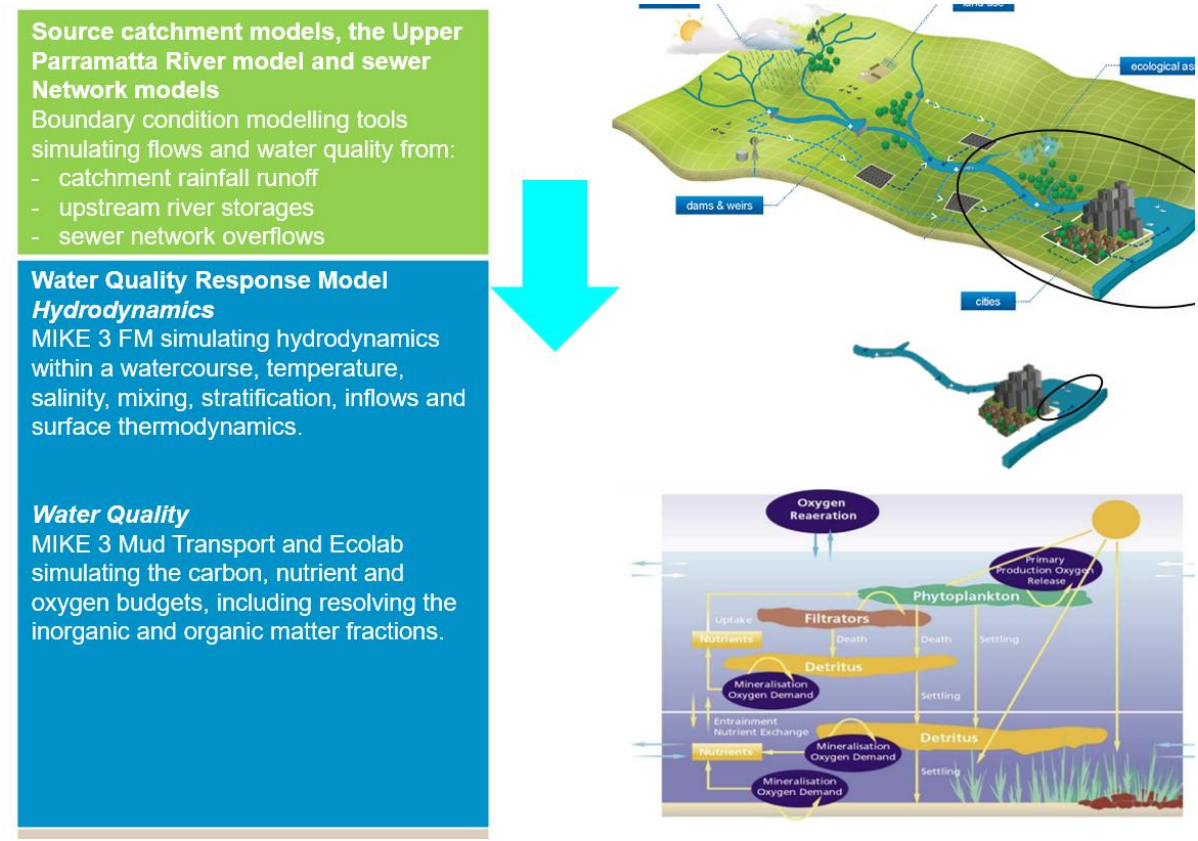


Figure 2-3 Primary model interfaces (Source: eWater and DHI Water and Environment)

3 Model structure and datasets

3.1 Model domain and mesh

The geographical extent of the WQRM is presented in Figure 3-1. The domain encompasses the tidal limits of the Parramatta River estuary and Sydney Harbour, inclusive of coastal waters offshore of the Sydney Heads. The following major tributaries and embayments were also included: the Lane Cove River, Duck River, Haslams Creek, Homebush Bay, Hen and Chicken Bay, Iron Cove and Middle Harbour.

Tidal limits for the study area were extracted from data presented in the Manly Hydraulics Laboratory report "Survey of Tidal Limits and Mangrove Limits in NSW estuaries" (MHL, 2006). Other tributaries, while not explicitly included in the model domain e.g. Vineyard Creek, were represented through application of catchment inflows as discussed in Sections 2.3.1 and 3.6.1.

The WQRM domain itself is defined by a two dimensional horizontal flexible mesh principally constrained to the shoreline limits of the river and its tributaries. The flexible mesh consists of a grid of interconnected quadrangular and triangular elements with alignment of the quadrilateral elements provided for primary flow paths, generally located within the main river and creek channels.

The resolution of the WQRM is ultimately based upon the granularity of its mesh. The greater the number of elements covering a given area of the channel, the finer the resolution of the mesh and vice-versa. Higher resolution is typically required in sections of the estuary where the hydrodynamic or water quality processes are complex or where there is a specific area of interest, for example, a section where there is a steep gradient in the river bed, or where releases from treatment plants need to be evaluated. In the case of the GPOP WQRM, a higher resolution of mesh elements has been provided for in the main channel of the river as well as where potential releases from the new WRRF are to be simulated and assessed in terms of their environmental impact.

The finalised model mesh incorporates 14,251 nodes and 23,148 elements. Lateral dimensions of the mesh ranged from ~20 m in the estuarine channels to ~200 m in the coastal waters.

While the 2D horizontal mesh has been developed in alignment with the above approach, the WQRM mesh is also configured in 3D, adopting the Sigma configuration of vertical layering. This type of 3D configuration allows for layering of specified number of cells along the depth dimension throughout the mesh. The configuration can adopt either equally spaced layers or user specified fractions of the total water column for each layer e.g., 0.1, 0.2, etc.

The GPOP WQRM included a total of six equidistant Sigma layers during the calibration runs. Sensitivity testing regarding the number of Sigma layers was undertaken to assess the potential benefit of increasing the number of vertical layers. It was concluded from this sensitivity analysis that adoption of the six layer configuration adequately represented variations in the water column in the river reaches of interest. A model mesh with six equi-distant Sigma layers was consequently adopted in the final model setup.

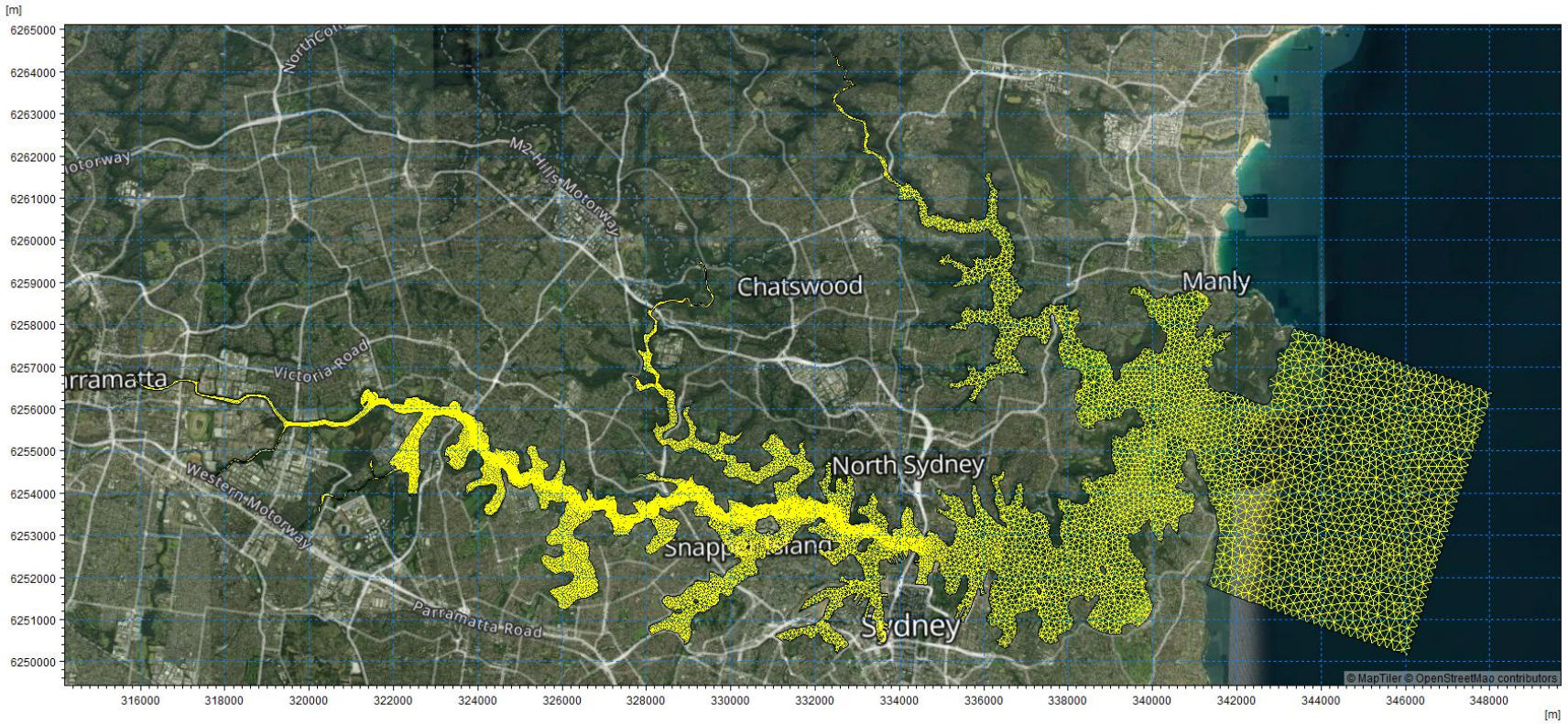


Figure 3-1 WQRM model domain and mesh

3.2 Time step

The GPOP WQRM employs an adaptive time step scheme. Through implementation of this scheme, the time step is allowed to vary throughout a simulation period and is selected by taking into account physical and numerical convergence and stability considerations.

A variable time step interval is applied in the hydrodynamic calculations, determined so that the Courant-Friedrichs-Lewy (CFL) number is less than the critical CFL number in all computational nodes. To provide further control, limits can be specified by the user in terms of a minimum time step and a maximum time step. For the GPOP WQRM, the limits were set at 0.01 and 120 seconds respectively, with the maximum CFL set at 0.9.

In addition to the above settings, a user defined 'overall discrete time step' is specified to determine the frequency for which output can be obtained from the different modules and to synchronise their interfacing. All time steps within the simulation for all the applied modules are synchronised to this overall discrete time step as described below:

- the time step for the hydrodynamic calculations was synchronised at the time step for the advection/dispersion calculations.
- the time step applied in the Ecolab and MT modules used to update the process descriptions was set as a multiple relative to the overall time step.

For the GPOP WQRM, the overall discrete time step was set to two minutes.

Relative to the WQRM, the boundary condition models adopted marginally higher time step or export intervals as detailed below:

- the Source catchment models used an hourly time step, exporting results on every time step
- the MOUSE sewer overflow models exported results at 15-minute intervals
- the UPR model exported results at an hourly frequency

Adoption of these sub-hourly, or hourly, datasets for the boundary conditions removed many challenges commonly encountered when using daily time step models in the calibration of similar hydrodynamic and receiving water quality models.

3.3 Material types and bed roughness

Each cell in the WQRM mesh was assigned a material type. This material type specification was used for:

- assigning a bed roughness coefficient which is a representation of the bed resistance at that point in the river, typically converted from Manning's n coefficients.
- assigning other coefficients in the Ecolab water quality module which guide, for example, sediment oxygen demand or nutrient fluxes.

Figure 3-2 presents the distribution of the respective bed roughness heights.

3.4 Bathymetric data

Bathymetric data registers the shape of the river channel in the vertical dimension and assigns bed elevation to the cells of the mesh. The data is generally processed as either a Digital Elevation Model (DEM) layer, or in x, y, z coordinates, before it is used to assign elevations to the mesh.

For the GPOP WQRM, data from the following sources were acquired:

- Sydney Water
- The Port Authority of NSW
- The NSW Government Office of Environment and Heritage

These datasets were combined using GIS to ensure equivalent datums were applied throughout the model domain and, where datasets overlapped, higher resolution and more recently acquired surveys were prioritised. The resulting bathymetry adopted for the GPOP mesh is presented in Figure 3-3, with elevations shown relative to Australian Height Datum (AHD).

3.5 Wetting and drying

The approach for treatment of the moving boundaries (wetting and drying) problem is based on the work by Zhao et al. (1994) and Sleigh et al. (1998). When the depths are small the problem is reformulated and only when the depths are very small the elements/cells are removed from the calculation. The reformulation is made by setting the momentum fluxes to zero and only taking the mass fluxes into consideration.

The depth in each element/cell is monitored and the elements are classed as dry, partially dry or wet. Also, the element faces are monitored to identify wetted boundaries.

For the purposes of the WQRM the following values were adopted: drying depth h_{dry} = 0.005 m and wetting depth h_{wet} = 0.1 m.

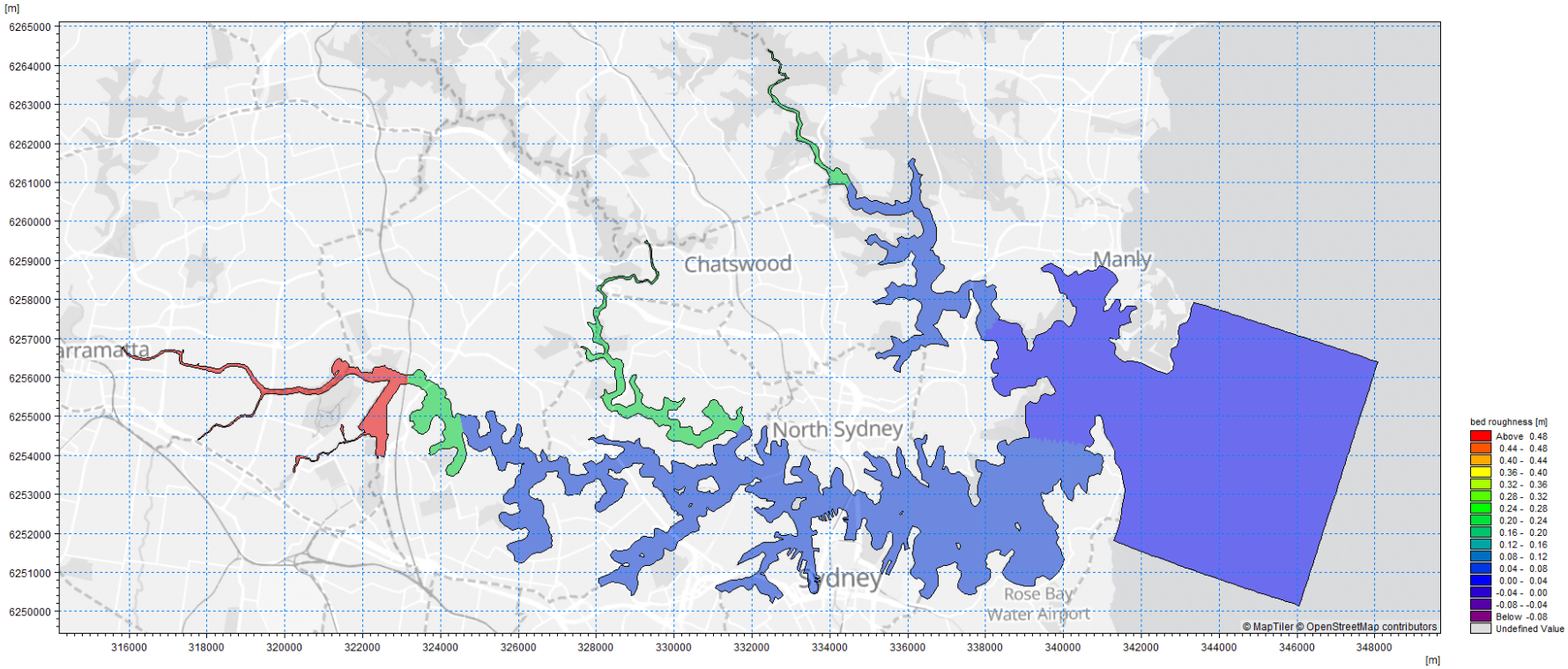


Figure 3-2 Distribution of material types and bed roughness zones

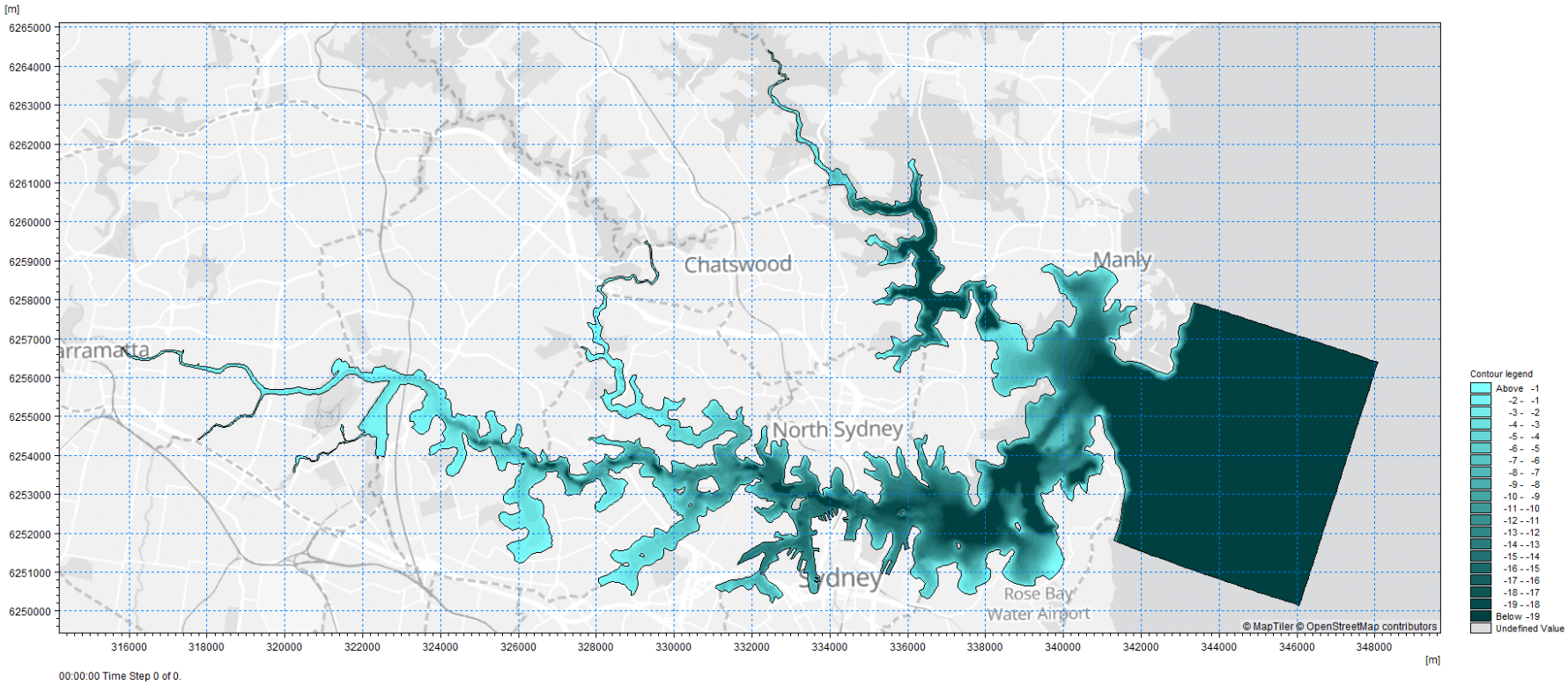


Figure 3-3 Bathymetry of the GPOP WQRM

3.6 Boundary conditions

Boundary conditions are the external inputs to a numerical model that drive the hydrodynamic and water quality processes. These can include inputs from the ocean, the catchment and from the atmosphere. The following sections provide an overview of each of the boundary condition types applied in the GPOP WQRM.

3.6.1 Catchment inflows

Catchment inflows to the GPOP WQRM were derived from the results of the Source catchment models for the Upper Parramatta River, Upper Lane Cove River, Upper Duck River and the remaining smaller catchments draining to the wider Sydney Harbour estuary. Details relating to the configuration, development and calibration of these models are presented in Appendix C.

Post-processing of the Source model results was undertaken to develop boundary conditions in the correct format for input to the WQRM. Analysis using GIS was undertaken to 'link' each catchment result to a relevant location within the WQRM mesh.

Dependent on their locations the processed results from the Source models were configured as either "headwater" boundary conditions or "element inflow" locations within the model mesh. A total of 225 boundary conditions within the WQRM mesh were developed, 21 of these representing headwater boundary conditions, and 204 representing element inflow locations within the model mesh. Figure 3-4 presents the location of these catchment inflow boundaries.

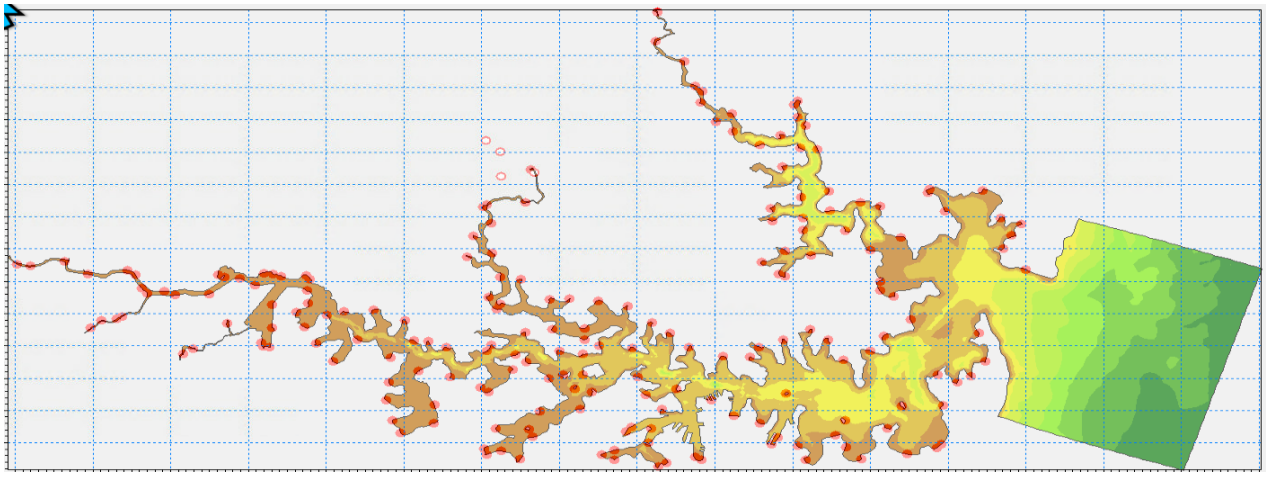


Figure 3-4 Location of the catchment inflow boundaries

The constituent export function adopted within the Source models generated outputs for the following parameters: Total Nitrogen, Ammonia, Oxidised Nitrogen, Organic Nitrogen, Total Phosphorus, Phosphate, Organic Phosphorus, Total Suspended Solids and Enterococci.

Table 3-1 describes how the inputs for the WQRM inflow boundary conditions were developed, noting that speciation factors for nutrients were originally sourced from Fletcher et al. (2004) and recent Sydney Water studies, and then modified during model calibration. Further details regarding the development and calibration of the constituent export function are presented in Appendix C.

Table 3-1 Catchment model to WQRM conversion details

Parameter	Unit	Conversion factor	Methodology/Comments
Date	dd/mm/yyyy hh:mm	N/A	The catchment model generated results at an hourly interval.
Flow	m^3/s	÷ 86.4	Conversion required as results from the Source models were provided in ML/d
Salinity	g/L	<1 g/L	Set to constant in line with monitoring data.
Temperature	^oC	N/A	Time series derived from monitoring data
Total Suspended Solids (TSS)	mg/L	= TSS mg/L	No conversion required from the Source model results
Ammonia (NH)		= 0.05*TN	Estimated as 5% of TN from the Source model results. Percentage derived from SW and additional NSW datasets.
Oxidised Nitrogen (NOx)	mg/L	= 0.4*TN	Estimated as 40% of TN from the Source model results. Percentage derived from SW and additional NSW datasets.
Organic/Detritus Nitrogen (DN)	mg/L	= 0.55*TN	Estimated as 55% of TN from the Source model results. Percentage derived from SW and additional NSW datasets.
Inorganic Phosphorus (IP)	mg/L	= 0.35*TP	Estimated as 35% of TP from the Source model results. Percentage derived from SW and additional NSW datasets.
Organic/Detritus Phosphorus (DP)	mg/L	= 0.65*TP	Estimated as 65% of TP from the Source model results. Percentage derived from SW and additional NSW datasets.
Organic/Detritus Carbon (DC)	mg/L	= 5*DN	Estimated as a factor of Organic/Detritus Nitrogen
Phytoplankton **Chlorophyll *a*** **Zooplankton**	mg/L mg/L mg/L	= 0 mg/L = 0 mg/L = 0 mg/L	Set to zero as assumed to be negligible in stormwater
Enterococci	Cfu/100mL	= ENT	No conversion required from the Source model results.

3.6.2 Upper Parramatta River inflows

As outlined in Section 3.6.1, the majority of the headwater boundary conditions were derived from results from the Source catchment models. A key exception to this rule was the upstream boundary of the Parramatta River at Charles Street Weir.

To allow simulation of the water quality processes that may occur in the storage areas upstream of the weir, a separate WQRM for a freshwater section of the Upper Parramatta River (UPR) was developed. The model was developed with a similar structure as the estuarine GPOP WQRM, but with adoption of an EU1 Ecolab template and application of the 2D MIKE 21 FM software as opposed to the 3D MIKE 3 FM software.

The model mesh for the UPR model extended from the Charles Street Weir up to the confluence of Toongabbie Creek and Darling Mills Creek, encompassing 13 inflows from upstream and surrounding catchments. Bathymetric data from historical Sydney Water survey datasets were interpolated to the model mesh. The model domain and mesh are presented in Figure 3-5.

In the absence of long term datasets collected at Charles Street weir, calibration of the model's hydrology was undertaken against flow data at Marsden Street weir, this data being derived from water elevation data and a ratings curve. The Marsden Street weir is located ~700m upstream of the Charles Street weir.

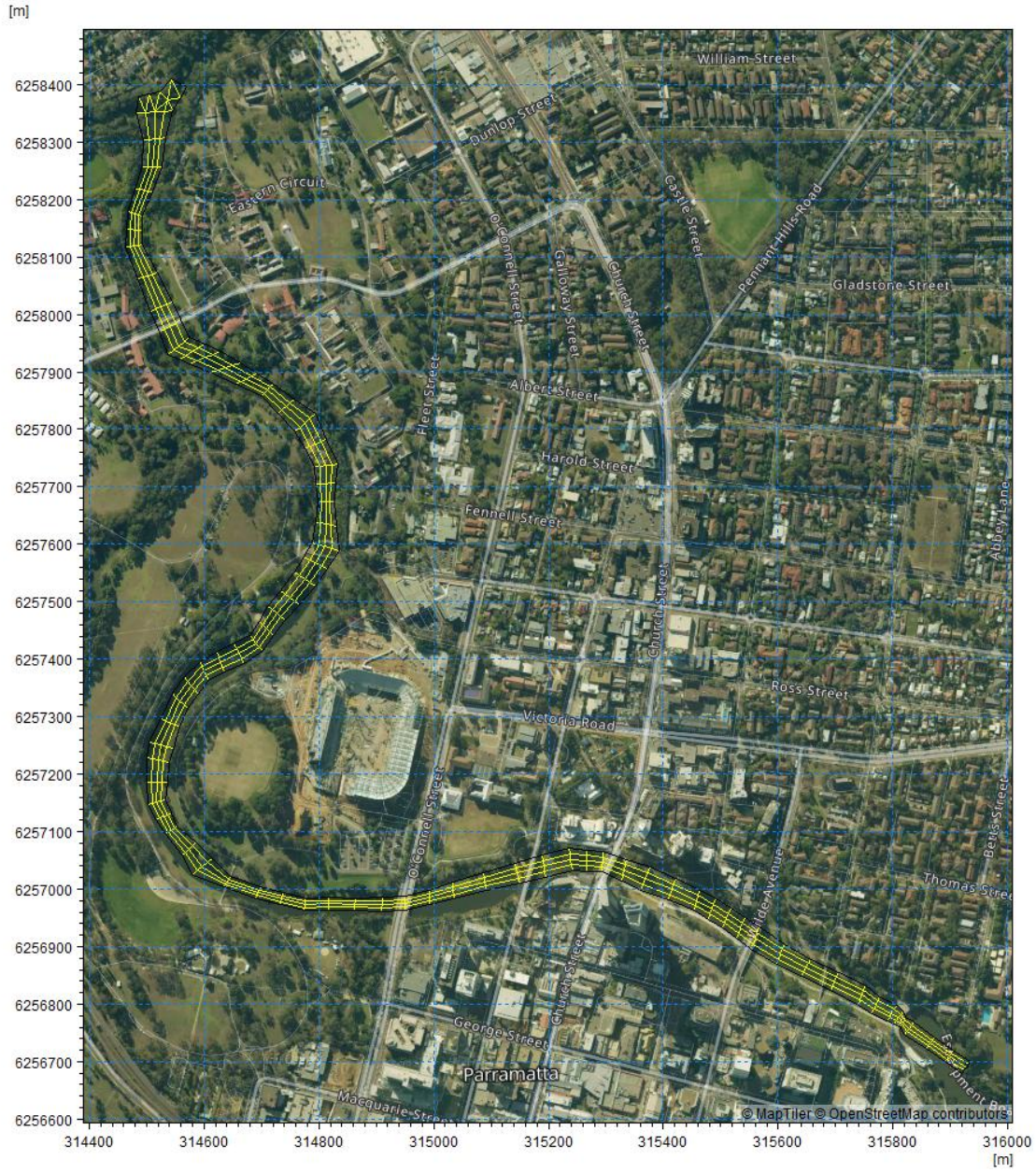


Figure 3-5 Upper Parramatta River model domain and mesh

3.6.3 Sewer overflows

Overflows from the sewer system have previously been considered as significant point sources of untreated wastewater within the Parramatta River and Sydney Harbour. Overflows of this nature generally occur during wet weather events when the sewer collection and transfer systems reach capacity. As discussed in Section 2.3.3, sewer overflows are modelled by Sydney Water using the MOUSE platform, with updates to the models undertaken annually with calibration against available field data.

The MOUSE software has been applied in the development of Sydney Water's Sewage Treatment Systems (STS) models and its Sewerage Catchment Area Management Plan (SCAMP) models. The STS models primarily simulate the trunk network while the SCAMP models simulate both trunk

and reticulation network assets. The results from these models provided a 15-minute interval timeseries of sewer overflows at various overflow points within the sub-catchments flowing to the Parramatta River estuary and wider Sydney Harbour. Overflow timeseries results were extracted from the Bondi, Malabar and North Head wastewater systems as the project domain falls across all these network domains.

To allow for representative routing of overflows in the contributing catchments, results for the overflows from these models were incorporated into the GPOP WQRM, or the Source catchment models, depending on their geographic location. More specifically, if an overflow point was located in a sub-catchment immediately adjacent to the WQRM mesh, the overflow was incorporated as a direct input to the WQRM. However, if the overflow was located in a sub-catchment not immediately adjacent to the model mesh, then the overflow was incorporated into the relevant Source model.

To limit the number of overflow points within the WQRM, selected overflows were grouped/ aggregated on a sub-catchment basis if it was identified that more than one overflow would have the same or a similar release location within the river/harbour. For the GPOP modelling, the overflows were accumulated to allow for 126 element inflow points within the WQRM. The locations of these boundaries are presented in Figure 3-6.

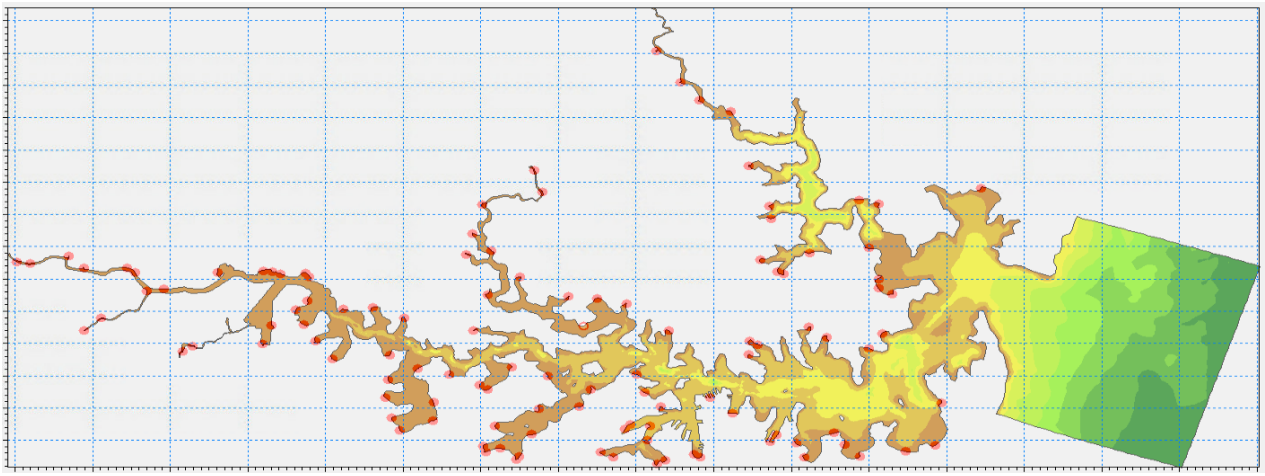


Figure 3-6 Location of the sewer overflow boundaries

To characterise the water quality of all the overflows, a dilution-based approach was developed to improve the representation of sewer overflows within the GPOP WQRM (refer Appendix E). This approach replaced the previous relatively simplistic methodology of attributing a single concentration value for pollutants such as nutrients, suspended sediments, etc.

The dilution-based approach involved application of an algorithm that calculated a dilution factor based on antecedent rainfall for the sub-catchment in which each overflow was located, and then calculated a release concentration based on the predicted contribution of raw sewage and stormwater. The approach was applied for suspended sediment and nutrient species.

More specifically, the following stepped approach was applied:

- Acquisition and analysis of hourly time series rainfall data for each sub-catchment that included a sewer overflow.

- Calculation of cumulative antecedent rainfall (CAR). Provisionally the length of time adopted for the CAR was selected as 24 hours, however this could be lengthened or shortened based on further investigations and determination of a relationship between dilution factors and temporal extent of preceding rainfall.
- Calculation of a dilution factor (DF) based on the following rules, which were provisionally developed to encompass expected dilution factors from inflow and infiltration in the sewerage networks:
    - If CAR <5, zero DF was applied
    - If CAR >5 and <120, a linear relationship from 0 to 6 for the DF was applied
    - If CAR>120, a DF of 6 was applied
- Calculation of the water quality concentration for parameter X for each time step with application of the above dilution factor and the relevant concentrations for raw sewage and stormwater EMC (event mean concentration) for urban land use, as presented in the equation below.

$$C_{Overflow} = (1 \times C_{Sewage} + DF \times C_{Stormwater}) / (1 + DF)$$

where $C_{Overflow}$ represents the calculated concentration of the overflow

C_{Sewage} represents the cell for assumed concentration of sewage

$C_{Stormwater}$ represents the cell for assumed concentration of stormwater

DF represents the cell for the Dilution Factor (DF)

Table 3-2 presents the applied concentrations for C_{Sewage} and $C_{Stormwater}$.

Table 3-2 Applied overflow and stormwater concentrations

Parameter	$C_{Overflow}$ concentration (mg/L)	$C_{Stormwater}$ concentration (mg/L)
Total Nitrogen	63	1.0
Total Phosphorus	9	0.1
Total Suspended Solids	320	140

Table notes

- *The raw sewage concentrations were derived from analysis of influent monitoring data (collected under dry weather conditions) from Sydney Water's WWTPs and WRPs.*
- *The Stormwater EMC was derived from the proposed parameterisation of urbanised land use for the GPOP Source models.*

Appendix E presents further information in relation to the development of the dilution based approach, as well as initial comparisons regarding its performance against water quality monitoring data collected within Sydney Water's sewer networks.

3.6.4 Offshore boundary conditions

As presented in Figure 3-1, the model mesh extends beyond the heads of Sydney Harbour into the Tasman Sea. The offshore hydrodynamic boundary was driven by a 20 minute frequency water elevation timeseries which was derived from higher frequency datasets collected at the Fort Denison and Camp Cove tidal gauges.

Water quality for the offshore boundary was specified as the median of monitoring data collected in the vicinity of the heads by Sydney Water and the NSW DCCEEW (refer Table 3-3).

Table 3-3 Offshore water quality boundary conditions

Parameter	Value
Salinity	37 g/L
Total Suspended Solids (TSS)	1 mg/L
Ammonia	0.002 mg/L
Oxidised Nitrogen (IN)	0.018 mg/L
Organic/Detritus Nitrogen (DN)	0.1 mg/L
Inorganic Phosphorus (IP)	0.007 mg/L
Organic/Detritus Phosphorus (DP)	0.005 mg/L
Organic/Detritus Carbon (DC)	0.5 mg/L
Chlorophyll *a* (Chl *a*)	0.001 mg/L
Enterococci (ENT)	1 cfu/100 mL

3.6.5 Weir structures

With the exception of the Charles Street weir, no other weirs or control structures were included in the WQRM. Weirs were identified as the tidal limits of other tributaries e.g. the Upper Lane Cove river, but these were considered to have minor effects on the hydrodynamics and water quality processes to be considered in the GPOP WQRM.

3.7 Meteorological data

The WQRM required input data for the following meteorological parameters:

- Wind speed and direction
- Air temperature
- Relative humidity
- Solar radiation
- Precipitation (*deemed optional due to negligible influence on the estuarine hydrodynamics*)
- Evaporation (*deemed optional due to negligible influence on the estuarine hydrodynamics*)

Based on data availability over the calibration and validation time periods, data for the above meteorological parameters were sourced from Bureau of Meteorology stations including Sydney Olympic Park (station 066212), Riverview Observatory (station 066131) and Sydney Airport (station 066037).

3.8 Initial conditions

Initial conditions for the WQRM were derived from the calibration data discussed below in Section 3.9. The model was then run for a minimum warm up period of eight weeks to allow for conditioning against the boundary condition loading. Further checks were undertaken to review water quality at each site and whether concentrations had reached what could be described as baseline conditions.

3.9 Calibration and validation data

3.9.1 Hydrodynamic data

The data used for hydrodynamic calibration comprised of the following:

- Acoustic Doppler Current Profiler (ADCP) monitoring data collected by Sydney Water in 2013 and 2014. These transect surveys were undertaken at the following locations:
  - Transect C3 Greenwich – Birchgrove
  - Transect C5 Drummoyne - Huntley's Point
  - Transect C7 Cabarita – Gladesville
  - Transect C8 Rhodes - Meadowbank (Ryde bridge)
  - Transect C9 North head - South head
  - Transect C10 Middle head - South head
- Water elevation monitoring data collected by the Port Authority of NSW in 2013 and 2014 at Fort Denison.

The data used for hydrodynamic validation included the following:

- ADCP monitoring data on behalf of Sydney Water in 2021 at the following locations:
  - Transect V1 Bedlam Point
  - Transect V2 Pulpit Point
- ADCP monitoring data on behalf of Sydney Water in 2024 at the following locations:
  - Transect V3 Wentworth Point
  - Transect V4 John Whitton Bridge
- Water elevation monitoring data collected by the Port Authority of NSW in 2024 at Fort Denison.

The locations of the ADCP calibration and validation transects are presented in Figure 3-7 and Figure 3-8 respectively.

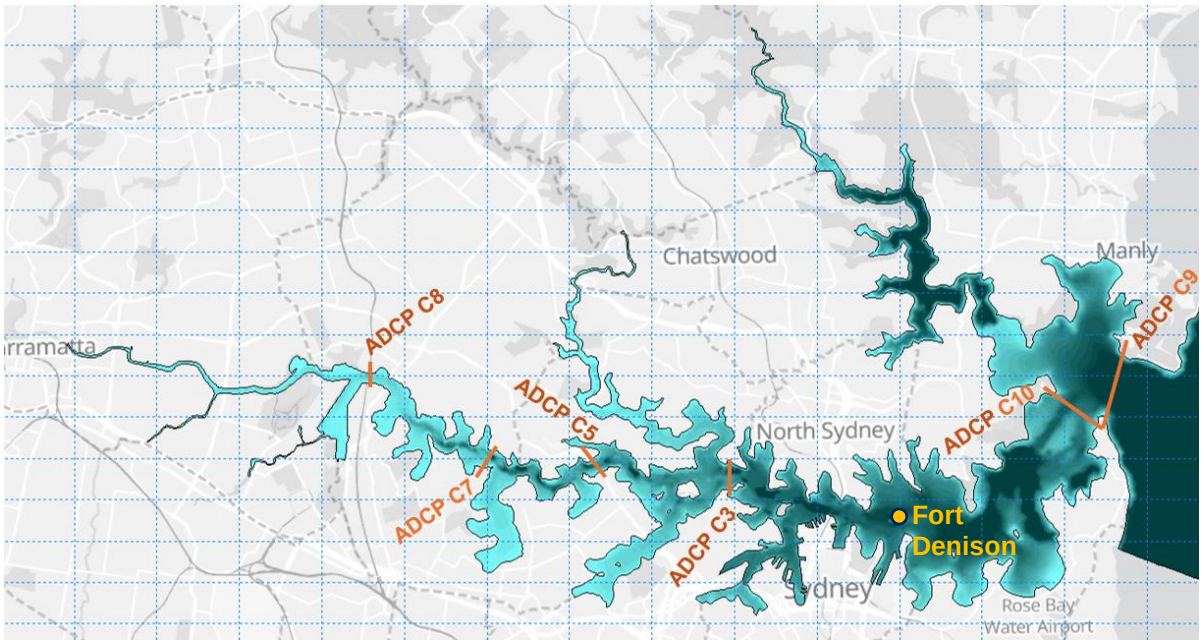


Figure 3-7 Location of the hydrodynamic calibration transects and Fort Denison tide gauge

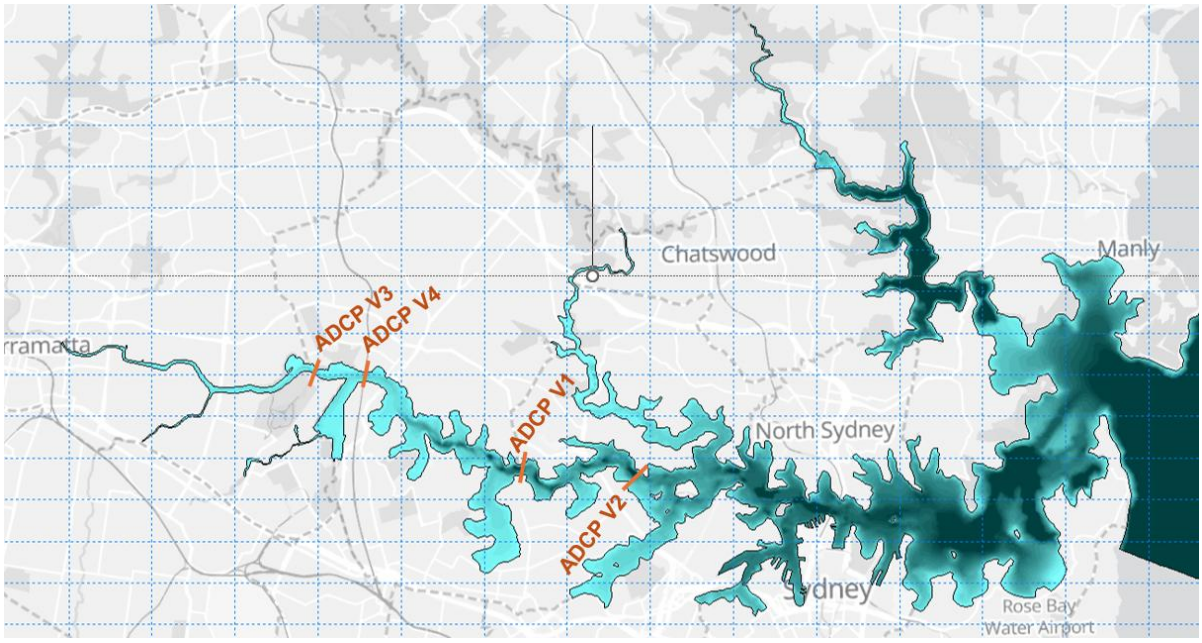


Figure 3-8 Location of the hydrodynamic validation transects

With respect to all the ADCP transect surveys, the following two versions of the flow data are included (where available) in the calibration and validation comparisons:

- ADCP measured – this dataset represents the raw measured data with no correction for surface or bottom ADCP measurement effects, or for areas near the bank that could not be included due to shallow water or other constraints.

- ADCP processed – this dataset represents modification of the measured data to address the above-mentioned surface, bottom and shoreline effects i.e., estimates of additional flow have been added to compensate for these constraints.

The difference in the two datasets vary based on location and tide, however both sets have been included to present possible minimum and maximum bounds of bank-to-bank flow.

3.9.2 Water quality data

A review of available data within the Parramatta River and Sydney Harbour was undertaken to determine availability of datasets that could be used in the calibration and validation assessment process. This included discussions with the Sydney Institute of Marine Science (SIMS), Greater Sydney Local Land Services (GSLLS), Southern Cross University (SCU) and NSW DCCEEW.

Findings from this review indicated a relatively limited extent of water quality data was available within the model domain, with no long term/continuous monitoring programs in operation.

To address these limitations, Sydney Water implemented additional data collection programs during 2024. These included programs undertaken by Sydney Water's field survey teams as well as external contractors.

The final datasets processed for comparison with the model results are summarised in Table 3-4.

The locations of the water quality calibration and validation sampling sites are presented in Figure 3-9, Figure 3-10 and Figure 3-11.

Table 3-4 Summary of the data sources used for the model calibration and validation assessment

Agency	Application	Description	Date Range
SIMS	Calibration	Weekly monitoring (surface and bottom samples), including CTD depth profiling Sites LPR 01,03,04,05,06,07,09	Oct 2012 to Dec 2012
SIMS	Calibration	Monthly monitoring (surface only), including CTD depth profiling Sites LPR 01,03,04,05,07,09	Jan 2013 to Dec 2013
Sydney Water (River watch)	Calibration	Variable frequency (surface only) Sites SS 7, 9, 12, 17	Jan 2021 to Dec 2023
DCCEEW	Validation	Variable frequency including 12 sampling events over 24 months (surface only) Sites Z 1, 5, 6, 7, 8, 10, 13, 14, 17, 20	Dec 2021 to Dec 2023
Sydney Water	Validation	Weekly monitoring (surface, middle and bottom samples) Sites PJ01A, PRWP, PRRH	Mar 2024 to Jun 2024

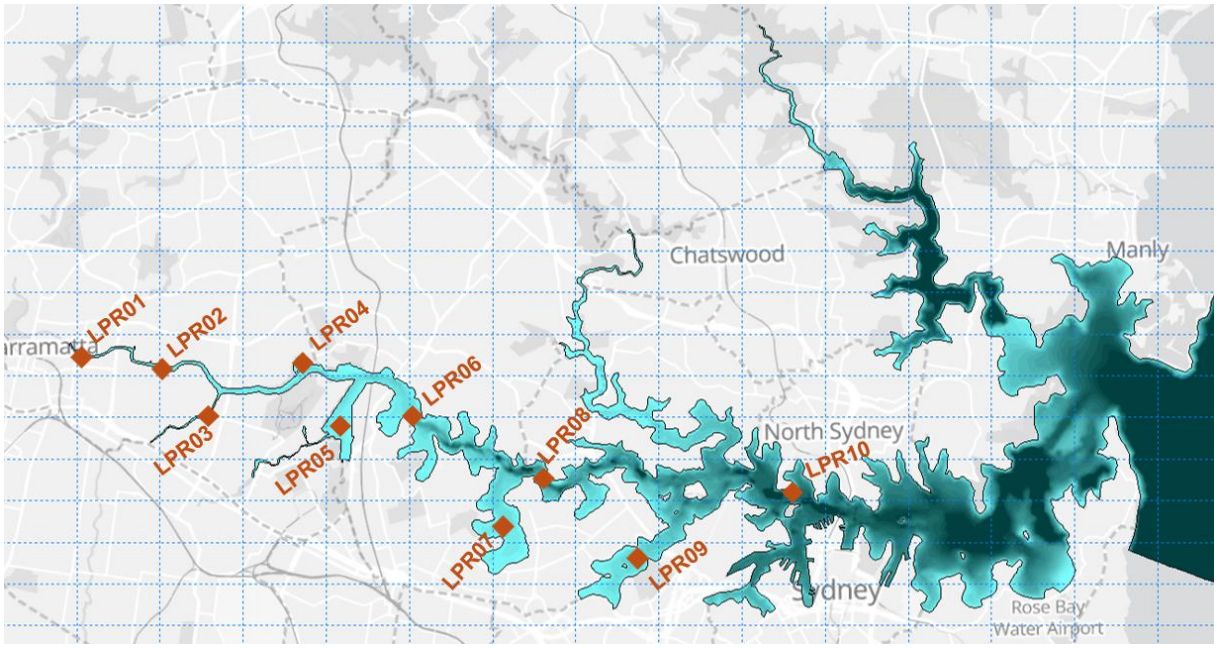


Figure 3-9 Location of water quality calibration sites

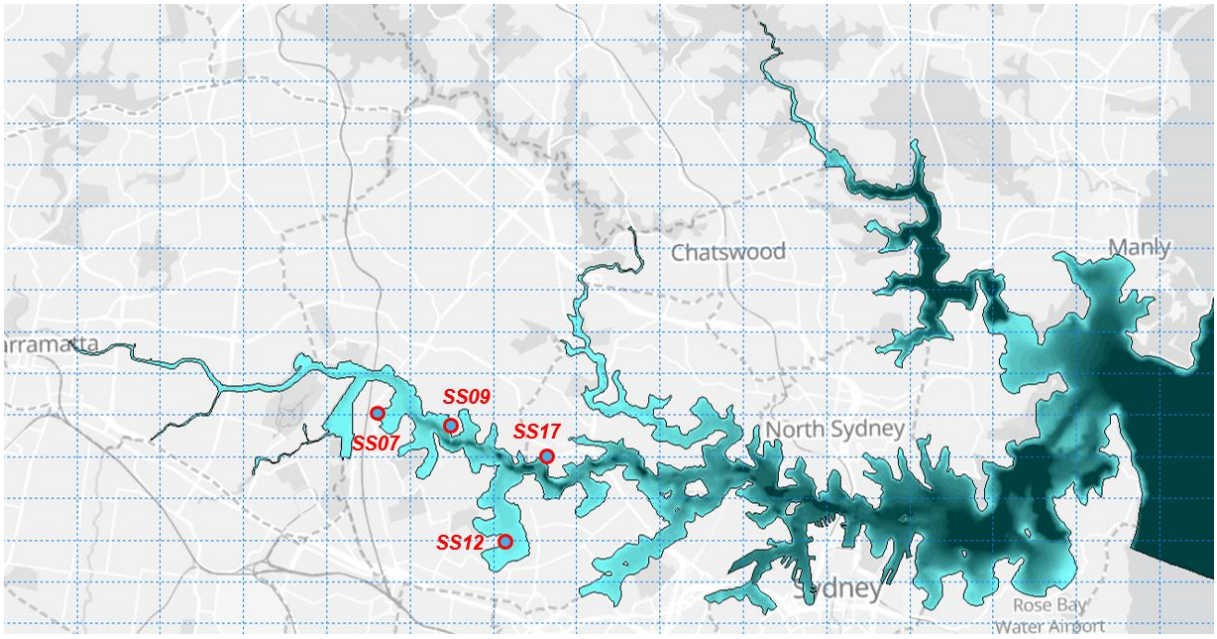


Figure 3-10 Location of water quality calibration swim sites

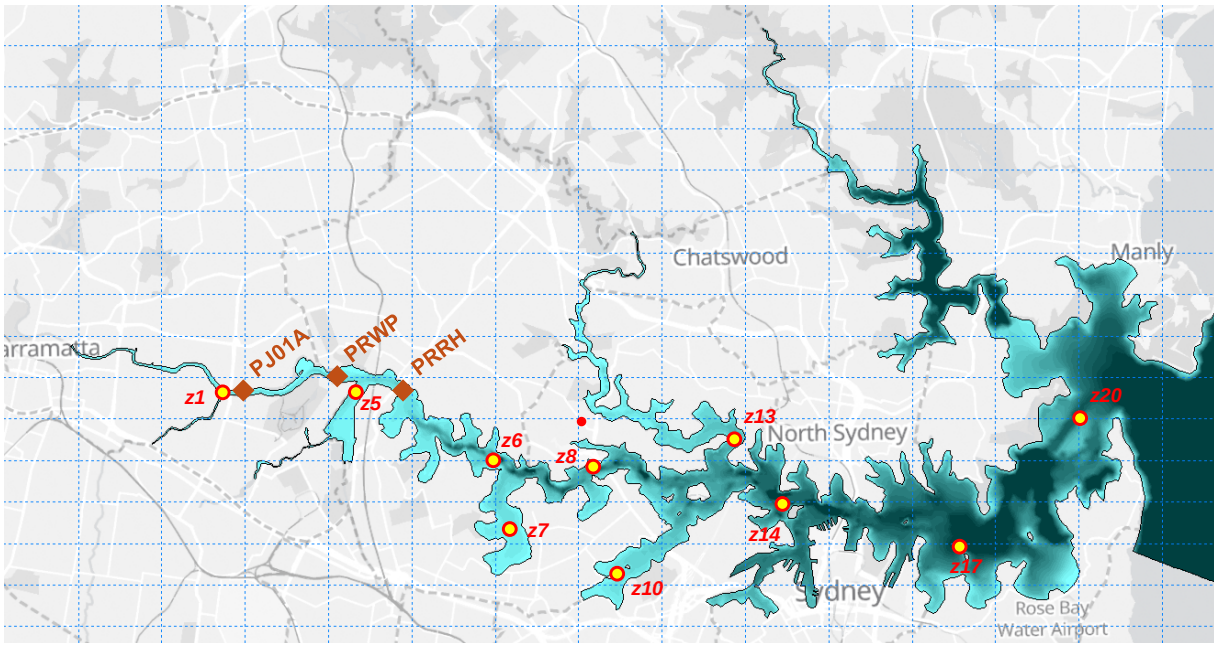


Figure 3-11 Location of water quality validation sites

3.10 Assumptions and limitations

The development of the GPOP hydrodynamic and water quality model has been undertaken in line with accepted industry standard practices. Following calibration and validation, the WQRM has been determined to be fit for purpose in its application for the GPOP EIS and the related hydrodynamic and water quality impact assessment.

However, in line with all similar model development exercises, the modelling undertaken for this study should be considered as a representative approximation to the real world and not without accepted levels of uncertainty. It should therefore be understood that the models are based on a series of assumptions, and also dependent on the accuracy of its input data. The model results should therefore be interpreted as indicative of natural processes, responses and trends in the receiving waters and not absolutes.

4 Calibration and Validation

4.1 Approach

4.1.1 Overview and assessment approach

4.1.1.1 Hydrodynamics

To allow for assessment of the WQRM's hydrodynamic performance, visual and statistical comparisons were made between the model results and datasets from relevant monitoring programs that collected flow and water elevation data.

For the ADCP transects, visual assessment of the model results focussed on how they compared in terms of phasing of the tidal cycle and also the magnitude of flows measured throughout the survey periods. Statistical analysis was then also undertaken to further assess the model's performance with the results of this analysis presented in Section 4.2.3.

Similarly, for the water elevations, visual and statistical analysis focussed on tidal phasing and amplitudes across a range of spring and neap conditions.

Importantly, equal emphasis was placed on the comparisons undertaken against the calibration and validation datasets. If concerns or distinct anomalies were observed in either exercise, model settings were reviewed and remodelled across both periods.

4.1.1.2 Water quality

With respect to water quality, the WQRM was initially run over the calibration period using model settings derived from previous modelling of the Parramatta River estuary and Sydney Harbour, and then manually calibrated with modification of the Ecolab settings as required. Validation was then undertaken against independent sets of monitoring data so as to confirm how well the model was able to simulate water quality conditions within the river.

It is again noted that while the initial assessment of the model's performance was undertaken for the calibration period, equal emphasis was again placed on both the calibration and validation exercises. Therefore, if concerns or distinct anomalies were observed in either calibration and validation exercises, the model settings were reviewed, remodelled and reanalysed until it was deemed performance could not be significantly improved with the current model setup.

For both calibration and validation exercises, the model's performance was evaluated for a suite of key water quality parameters, through visual assessment of the model results against the available monitoring data discussed in Section 3.8. The visual assessment included both comparison of time series point data as well as percentiles, through application of box and whisker plots. Key aspects within this evaluation were the model's capacity to respond to dry and wet periods and also seasonal trends.

Statistical analysis of the model's performance has also been included in Section 4.2.3 to assist in determining the model's performance.

Sensitivity analysis was also included with modification of concentrations applied in the Source catchment models and subsequent evaluation of how these modifications affected water quality within the river in terms of nutrients and algal growth. Results and discussion relating to this analysis are included in Section 4.2.4.

4.1.2 Calibration and validation periods

4.1.2.1 Hydrodynamics

The hydrodynamic performance of the WQRM was evaluated for the periods when ADCP data was available. As discussed in Section 3.8, this included:

- December 2013, March 2014, August 2014 (calibration - ADCP and water elevation data)
- September 2021 (validation – ADCP data)
- May, October and November 2024 (validation - ADCP and water elevation data)

4.1.2.2 Water quality

Water quality calibration was undertaken over the period October 2012 to December 2013. This duration incorporated the following two SIMS monitoring programs:

- Weekly monitoring (Oct to Dec 2012) – a representative lower rainfall period
- Monthly monitoring (Jan to Dec 2013) – a combination of higher and lower rainfall periods

Validation was undertaken over the periods January 2022 to December 2023 and March to June 2024. These simulations incorporated the following monitoring programs:

- Variable frequency monitoring by DCCEEW
- Variable frequency monitoring by Sydney Water (Riverwatch)

Validation was also undertaken over the period March to June 2024. These simulations incorporated the following monitoring program:

- Weekly baseline monitoring by Sydney Water

4.1.3 Adopted formulations

4.1.3.1 Hydrodynamic formulation

The model adopted a Smagorinsky formulation in the horizontal and a two-equation turbulence model in the vertical with scaled eddy viscosity formulation adopted for dispersion in both the horizontal and vertical. Further details relating to configuration of the hydrodynamic module are presented in Appendix B1.

4.1.3.2 Sediment transport formulation

The WQRM adopted the mud transport module for simulation of suspended solids. Further details regarding the formulation and constants applied in this module are presented in Appendix B2.

4.1.3.3 Water quality formulation

The WQRM adopted the Eutrophication 2 template for simulation of nutrient processing and algal growth. Further details regarding the formulation and constants applied in this template are presented in Appendix B3.

4.2 Results and discussion

All model results are presented within subsections of Appendix D. A link to the appropriate section of the Appendix is provided for each variable in Table 4-1.

The sub-sections presented below provide a brief summary of the key points to note for each parameter, inclusive of findings from both calibration and validation analyses.

Table 4-1 Summary table with links to files with model comparison plots

Parameter	Calibration	Validation
Water elevation	AppendixD1_1	Appendix D1_2
Flow	AppendixD1_1	Appendix D1_2
Salinity	Appendix D2_1	Appendix D2_2
Temperature	Appendix D3_1	Appendix D3_2
Total Suspended Solids	Appendix D4_1	-
Total Nitrogen	Appendix D5_1	Appendix D5_2 Appendix D5_3
Total Phosphorus	Appendix D6_1	Appendix D6_2 Appendix D6_3
Ammonia	Appendix D7_1	Appendix D7_2 Appendix D7_3
Oxidised Nitrogen	Appendix D8_1	Appendix D8_2 Appendix D8_3
Inorganic Phosphorus	Appendix D9_1	Appendix D9_2 Appendix D9_3
Dissolved Oxygen	Appendix D10_1	Appendix D10_2
Chlorophyll *a*	Appendix D11_1	Appendix D11_2 Appendix D11_3
Enterococci	Appendix D12_1	Appendix D12_2

The following nomenclature applies for all the time series plots presented in Appendix D.

3Dt - WQRM surface layer

3Db - WQRM bottom layer

SIMS#t - SIMS surface sample

SIMS#b - SIMS bottom sample

DPs - SIMS depth profile

DPE data – DPE/DCCEEW surface sample

SW data – Sydney Water sample

4.2.1 Hydrodynamics

4.2.1.1 Water elevation

From comparison of the model results against the water elevation data, the WQRM is observed to reproduce the tidal phasing and amplitudes accurately at Fort Denison, both during the calibration and validation periods.

The model's performance is also verified through the statistical analysis of the calibration period with values for R^2, NSE and the index of agreement (d) all presented to be above 0.98.

4.2.1.2 Flow (ADCP transects)

From comparison of the model results against the ADCP transect data, the WQRM is observed to generally reproduce the amplitude and phasing of the tidal flows well at each transect site, both during the calibration and validation periods. More specifically, the predicted bank-to-bank flows generally fall between the two versions of the ADCP data discussed in Section 3.9.1. This indicates that the volumetric interchange within the main river channel is being captured realistically by the model throughout the river and under a range of tidal conditions.

From the statistical analysis, values for R^2 and index d were determined to be above the relevant criteria for satisfactory fit at all the transect surveys. Values for NSE were also determined to achieve the relevant criteria with the exception of the Wentworth and John Whitton bridge surveys.

The following points were also noted:

- The potential for irregularities in the predicted tidal signal is shown in some of the timeseries data. This is considered to be a product of the estuarine hydrodynamics as well as minor fluctuations in the tidal boundary conditions that forces the offshore boundary, this tidal boundary condition being derived from high frequency water elevation data collected at Camp Cove and Fort Denison (refer Section 3.5.4).
- The correlation of predicted flows against the ADCP data in the upper estuary was lower, particularly during periods of lower tidal amplitude. The correlation at the John Whitton transect site was also affected by variances in the ADCP flow data created by the presence of the bridge piers.

It is recommended that for future upgrades to the model, that a review of the bed roughness parameterisation is undertaken, particularly with respect to the higher values currently attributed to the upper estuary. Reducing the existing values or undertaking a sensitivity assessment may assist in mitigating the irregularities that are seen in the results of some of the upper estuarine sites.

Further reviews are also recommended in relation to the water elevation conditions applied at the offshore boundary. More specifically analysis is recommended as to whether the existing time series could be modified further to provide a smoother tidal signal, or if a harmonic derived signal may generate improved results.

4.2.1.3 Summary

From the results of both the calibration and validation exercises, it is concluded that the model is resolving the hydrodynamic processes well throughout the Parramatta River estuary. While minor anomalies are noted in the upper estuary under lower tidal ranges, the hydrodynamic model is considered to provide a suitably robust base module for simulation of the advection dispersion and water quality processes discussed below.

Recommendations are presented in Section 4.2.1.2 in relation to future model development and opportunities to improve the model's performance in the upper estuary.

4.2.2 Water quality

The ability of the WQRM to reproduce ambient water quality within the Parramatta River estuary was assessed over both calibration and validation periods (refer Section 4.1.2). Details regarding the calibration and validation for the suite of key parameters, including discussion on any discrepancies, are presented under the following sub-headings.

Details regarding the water quality monitoring datasets applied in this assessment are presented in Section 3.8.2.

4.2.2.1 Salinity

4.2.2.1.1 Calibration period

The results for the calibration period are presented in Appendix D2_1. This data includes all depth profiling measurements undertaken during the SIMS data collection programs. Across all the sites analysed, the model results generally show a very robust correlation across the range of climatic conditions, including periods of significant rainfall and freshwater inflows as well as drier durations where the estuary becomes predominantly saline.

The model is observed to simulate the responses to the freshwater flows, including the magnitude of stratification. Similarly, the model is observed to simulate the salinity recovery well following these events, although it is noted the model may not adequately simulate the speed of salinity recovery on occasions. This is partially attributed to the model's sensitivity to the Charles Street weir boundary condition. In the absence of monitoring data at this weir, uncertainty exists in relation to both base flows and event flows.

Away from the wetter periods, the model is shown to be accurately reproducing the salinity conditions throughout the model domain, including the well mixed/unstratified nature of the estuary presented in the monitoring data. It is therefore considered that the significant range of salinities that are encountered across the lower, middle, and higher estuarine sites is being realistically captured by the WQRM.

Within the embayments, similar discussion points are also noted with the salinity at sites within Duck River and Homebush Bay (LPR03 and 05 respectively) being very well predicted by the model with marginal underprediction of the salinity recovery after major inflow events. Similar comments apply to the sites in Hen and Chicken Bay (LPR07) and Iron Cove (LPR09) but with a minor potential to underpredict the degree of stratification seen following the more extreme freshwater inflow events.

From the statistical analysis, values for R^2, NME and the index of agreement (d) were determined to be above the relevant criteria for satisfactory fit for sites LPR4, 5 and 6. These SIMS sites lie in the vicinity of the immediate EIS study area.

4.2.2.1.2 Validation period

Model results plotted against the salinity data collected at the DCCEEW sites are presented in Appendix D2_2. Across this broader range of monitoring locations, the WQRM demonstrates a good correlation of the background (dry weather) salinity conditions as well as the response to rainfall events.

From the statistical analysis, values for R^2, NME and index d were determined to be above the relevant criteria for satisfactory fit at sites z1 and z5, which are both located in the upper estuary and in the vicinity of the EIS study area. Values for the downstream site z6 were however below the criteria.

4.2.2.1.3 Summary

The results of both calibration and validation exercises demonstrate a robust correlation between the WQRM and the multiple monitoring datasets assessed. The model results are shown to reproduce the salinity conditions across the model domain during dry conditions and also successfully reproduces responses to large and small rainfall events. These responses include significant stratification with salinity values in the upper water column prone to decrease extensively as a result of the freshwater inflows from the catchments and major tributaries. Similarly, the model successfully simulates the subsequent salt intrusion following these wet weather events.

Based on these comparisons, it is considered that there is a high degree of confidence that the model is resolving the hydrodynamics, plus the advection and dispersion processes of the river system sufficiently for application in the scenario testing for GPOP EIS.

4.2.2.2 Temperature

4.2.2.2.1 Calibration period

The calibration results against the 2012-13 SIMS data are presented in Figures D3_1. The model is observed to successfully reproduce the seasonal trend with only a minor potential to underpredict temperatures at certain sites in the lower estuary during the winter and spring months.

Seasonal trends are also well captured in the embayments but with potential to again underpredict temperatures during winter and spring months, potentially due to the model not adequately simulating heat exchange processes sufficiently in these shallower waters.

4.2.2.2.2 Validation period

Results from the DCCEEW monitoring program are plotted against the WQRM results in Figures D3_2. While seasonal trends are well simulated in the upper estuarine sites, lower levels of correlation are presented for the downstream datasets, again principally in the winter and spring periods. These variances are considered to be a product of application of generic temperature timeseries data that is attributed to the inflows and offshore boundary.

4.2.2.2.3 Summary

The WQRM is shown to capture short and long term variations in temperature within the upper estuary with a tendency to underpredict conditions in the cooler months at sites downstream and within the embayments.

Overall, the model's ability to replicate temperature is considered to be sufficient across the calibration and validation periods, and concluded to be appropriate for the project's requirements.

4.2.2.3 Total suspended solids

4.2.2.3.1 Calibration period

Relative to the other analysed parameters, there is comparatively limited data for Total Suspended Solids available across the SIMS monitoring programs. In light of the WQRM simulating one particle type/size in the MT module, the model simulates the range and responses in concentrations very well in terms of wet weather and dry periods within the river as well as resuspension processes that may become prevalent in the shallow embayments to the south.

4.2.2.3.2 Validation period

No additional monitoring datasets were identified to allow validation with the DCCEEW and Sydney Water monitoring programs relying on collection of turbidity and not Total Suspended Solids.

4.2.2.3.3 Summary

The WQRM is observed to replicate the magnitudes, ranges, and temporal patterns of suspended solids well throughout the estuary. While simulation of multiple particle classes may assist in future modelling, the performance of the WQRM is considered appropriate for the purposes of the GPOP EIS project.

4.2.2.4 Nitrogen

4.2.2.4.1 Calibration period

The model results for Total Nitrogen are presented against the SIMS data in Figures D4_1. The period includes periods of rainfall as well as extended dry periods. The spikes in concentration generated by the wet weather inflows from stormwater and sewer overflows are well captured in terms of magnitude, timing and duration. Similarly, during 'baseline' conditions, when the river is driven predominately by tidal forces, concentrations are also well produced in both the river channel and the embayments.

From the statistical analysis, values for R^2, NME and the index of agreement were determined to be above the relevant criteria for satisfactory fit at sites LPR4, 5 and 6, which all lie in the vicinity of the immediate EIS study area.

The WQRM exhibits the potential to underestimate concentrations of the inorganic fractions, particularly for Oxidised Nitrogen. This is considered to be a product of the speciation of Total Nitrogen in the boundary conditions and the potential variability in this speciation that is not captured across dry and wetter periods. Despite this potential, the WQRM simulates the temporal and spatial variations of wet weather spikes and lower dry period conditions relatively well.

4.2.2.4.2 Validation period

With respect to the data collected by DCCEW in 2022/23, the model predicts the Total Nitrogen concentrations well spatially and temporally, however correlations are improved for the upper estuarine sites.

The model similarly performs well against the Sydney Water data collected in 2024 with the potential to overestimate concentrations during some drier periods.

Values for R^2 and the index of agreement were calculated to be above the relevant criteria for satisfactory fit at DCCEEW sites z1, z5, z6, z8 and also for Sydney Water sites PJ01A, PRRH and PRWP.

With respect to the inorganic fractions, the WQRM replicates the DCCEEW monitoring data well but generally underpredicts the concentrations for Ammonia and Oxidised Nitrogen across the Sydney Water program.

4.2.2.4.3 Summary

Overall, the model's ability to replicate Nitrogen dynamics in the river across a range of climatic conditions is considered to be robust. The correlation against the field data for Total Nitrogen is particularly high. This includes replicating ambient concentration during drier periods as well as responses to wet weather inflow events in terms of magnitude, timing, and duration of the resulting elevated concentrations.

With respect to the inorganic fractions, there is potential for the WQRM to underpredict concentrations particularly for Oxidised Nitrogen. This is attributed to the representation of how nitrogen speciation may vary during different climatic periods including simulation of network overflows. Interpretation of the EIS scenario results will therefore require consideration of this potential for underprediction of Oxidised Nitrogen, and to a lesser degree, Ammonia.

4.2.2.5 Phosphorus

4.2.2.5.1 Calibration period

Many similarities are observed in the simulation of Phosphorus as seen in the results discussed previously for Nitrogen. The model captures the responses to wet weather as well as during the drier durations within the 2012-13 calibration period but with a potential to underestimate Total and Inorganic Phosphorus at several sites.

Based on the statistical analysis, the adopted statistical criterion is achieved for the index of agreement at sites LPR 4 and 6 in the main river channel.

4.2.2.5.2 Validation period

With respect to the DCCEEW and Sydney Water datasets, the WQRM performs generally well for both Total and Inorganic Phosphorus, however in line with the calibration results, similar trends are exhibited i.e. the potential for under prediction of concentrations across several sites is again observed.

Values for R^2 and the index of agreement are generally estimated to be above the relevant criteria for satisfactory fit against both the DCCEEW and Sydney Water monitoring data including DCCEEW sites z1, z5, z6, z8 and for Sydney Water sites PJ01A, PRRH and PRWP.

4.2.2.5.3 Summary

While the potential to underestimate is noted, the model's ability to replicate both Total Phosphorus and Inorganic Phosphorus across a range of climatic conditions is considered to be relatively robust. As per previous analysis for Nitrogen, this includes replicating ambient concentration during drier periods as well as responses to wet weather inflow events in terms of magnitude, timing and duration of the resulting elevated concentrations.

4.2.2.6 Primary productivity

4.2.2.6.1 Calibration period

The WQRM currently includes simulation of two primary algal groups: diatoms and green algae. With this configuration, the model is observed to simulate the seasonal patterns, magnitudes, blooms and die off exceptionally well across all the monitoring sites analysed.

The percentile analysis also indicating the model is capturing the geographical variations observed within the estuary.

4.2.2.6.2 Validation period

Similar to the model calibration comments, the WQRM is seen to predict Chlorophyll *a* concentrations well at the DCCEEW and Sydney Water sites. While some of the short-term higher values are not predicted, the magnitudes and temporal patterns are very well captured at all the sites analysed.

4.2.2.6.3 Summary

As with all similar modelling exercises, the accurate simulation of phytoplankton dynamics can be one of the most challenging. Many aspects need to be reviewed to allow for representative characterisation of algal growth and die-off. This extends to inclusion of a representative suite of algal groups, representative parameterisation of growth and die-off for each species, light availability, as well as potential competition between different species or groups.

The WQRM in its current state is observed to simulate the temporal and spatial patterns extremely well across the range of sampling locations and climatic conditions simulated.

4.2.2.7 Dissolved oxygen

4.2.2.7.1 Calibration period

During the model development phase, instability issues were identified specifically in the simulation of dissolved oxygen. From consultation with the software developers this was attributed to the adoption of the sigma layer configuration and simulation of layers with limited thickness. With modification of the Ecolab template these instabilities were mitigated but not completely removed. Despite these issues, the WQRM predicts the seasonal trends in the SIMS data at the majority of the sites as well as some shorter term variations that are presented in the monitoring data.

4.2.2.7.2 Validation period

Relative to the calibration period, the WQRM replicates the seasonal and shorter-term trends exceptionally well across the two years of DCCEEW data. Some instabilities are still presented in the model results, however good correlation is demonstrated at all the sites analysed.

4.2.2.7.3 Summary

Despite instabilities presented by the Ecolab template, the WQRM demonstrates good correlation to the monitoring datasets in terms of seasonal and shorter term trends of dissolved oxygen.

4.2.2.8 Enterococci

4.2.2.8.1 Calibration period

From comparison of the percentiles and the timeseries presented on logarithmic and non-logarithmic axes, the model is observed to replicate the wet weather spikes and die-off patterns of the Riverwatch data at all four sites very well.

4.2.2.8.2 Validation period

Similarly, from review of all comparison plot formats, the WQRM is observed to replicate the spikes and die-off patterns of the Sydney Water data at all three sites.

4.2.2.8.3 Summary

From both the calibration and validation periods, the WQRM is observed to simulate the wet weather and dry weather behaviour of Enterococci as a primary pathogenic indicator.

4.2.3 Statistical analysis

4.2.3.1 Approach

The objective of this analysis was to provide corroboration of the performance of the WQRM using standard statistical techniques. In addition to providing support to the more visual assessments, the analysis presents the opportunity to provide further comment regarding the performance of the model across the range of water quality parameters, including identification of areas for further improvement and ongoing calibration efforts.

The statistical analysis has focused on a range of indicators including flow, water elevation, Salinity, Total Nitrogen, Total Phosphorus, Chlorophyll *a* and Enterococci. With respect to the

water quality parameters, the analysis has also focused on monitoring locations in the more immediate GPOP study area within the upper/mid estuary and where sufficient data points (>10) were present. The analysis was also generally restricted to surface samples.

The statistical metrics that have been applied include the following:

- Mean Error / Bias
- Mean Absolute Error
- Root Mean Square Error
- Std. dev of Residuals
- Coefficient of Determination (R^2)
- Nash-Sutcliffe coefficient (E)
- Index of Agreement (d)

The last three represent non-dimensional metrics where criteria were applied to determine whether the value could be considered satisfactory or non-satisfactory. Derived from Moriasi et al (2007) and DHI (2024), the following criteria for satisfactory fit, were adopted:

Hydrodynamics

- Coefficient of Determination (R^2) > 0.6
- Nash-Sutcliffe coefficient (E) > 0.5
- Index of Agreement (d) > 0.75

Water quality

- Coefficient of Determination (R^2) > 0.3
- Nash-Sutcliffe coefficient (E) > 0
- Index of Agreement (d) > 0.5

4.2.3.2 Results

The results from the statistical analysis are presented in the tables below. Discussion regarding the interpretation of the non-dimensional criteria is included in Sections 4.2.1 and 4.2.2.

4.2.3.2.1 Water elevation (calibration)

Indicator		Fort Denison 12/13	Fort Denison 3/14	Fort Denison 8/14
Mean Error / Bias	[m]	0.004	0.001	-0.001
Mean Absolute Error	[m]	0.052	0.041	0.014
Root Mean Square Error	[m]	0.064	0.052	0.018
Std. dev of Residuals	[m]	0.064	0.052	0.018
Coefficient of Determination (R2)	[-]	0.988	0.992	0.998
Nash-Sutcliffe coefficient (E)	[-]	0.984	0.991	0.997
Index of Agreement (d)	[-]	0.996	0.998	0.999

4.2.3.2.2 Flow (calibration)

Indicator		Transect 10 03/14	Transect 10 08/14	Transect 9 03/14	Transect 8 08/14	Transect 7 08/14	Transect 5 08/14	Transect 3 08/14	Transect 3 12/13
Mean Error / Bias	[m^3/s]	-5.1	35.7	-4.0	-0.4	12.6	-61.8	-35.8	33.2
Mean Absolute Error	[m^3/s]	257.7	229.7	361.2	21.0	48.3	67.5	73.8	101.8
Root Mean Square Error	[m^3/s]	323.1	275.6	408.4	28.5	59.7	75.2	123.3	114.7
Std. dev of Residuals	[m^3/s]	323.1	273.2	408.4	28.5	58.3	42.8	118.0	109.8
Coefficient of Determination (R2)	[-]	0.987	0.983	0.990	0.935	0.935	0.985	0.968	0.999
Nash-Sutcliffe coefficient (E)	[-]	0.986	0.976	0.987	0.924	0.926	0.954	0.961	0.995
Index of Agreement (d)	[-]	0.997	0.994	0.997	0.978	0.979	0.988	0.991	0.999

4.2.3.2.3 Flow (validation)

Indicator		Bedlam (N) 09/21	Bedlam (S) 09/21	Pulpit (N) 09/21	Pulpit (S) 09/21	Wentworth (S) 05/24	Wentworth (N) 05/24	J Whitton (S) 10/24	J Whitton (N) 11/24
Mean Error / Bias	[m^3/s]	59.4	16.6	57.2	93.4	-15.4	-22.5	-25.0	22.2
Mean Absolute Error	[m^3/s]	118.0	113.8	64.0	148.7	32.8	22.5	40.1	60.3
Root Mean Square Error	[m^3/s]	135.1	157.2	77.6	220.8	36.9	26.5	47.9	72.0
Std. dev of Residuals	[m^3/s]	121.3	156.3	52.4	200.1	33.5	14.1	40.9	68.5
Coefficient of Determination (R2)	[-]	0.927	0.954	0.976	0.902	0.786	0.777	0.871	0.718
Nash-Sutcliffe coefficient (E)	[-]	0.856	0.932	0.937	0.873	0.464	-0.065	0.287	0.494
Index of Agreement (d)	[-]	0.953	0.980	0.985	0.969	0.901	0.794	0.892	0.900

4.2.3.2.4 Water quality (calibration)

		Salinity			Total Nitrogen			Total Phosphorus			Chlorophyll a			Enterococci		
Indicator		**LPR4**	**LPR5**	**LPR6**	**LPR4**	**LPR5**	**LPR6**	**LPR4**	**LPR5**	**LPR6**	**LPR4**	**LPR5**	**LPR6**	**LPR4**	**LPR5**	**LPR6**
Mean Error / Bias	[psu]	2.2408	1.2676	0.1664	-0.0773	-0.022	-0.0285	-0.0002	0.0008	-0.0096	0.002	0.0011	-0.0007	ID	ID	ID
Mean Absolute Error	[psu]	2.7514	1.7056	1.4941	0.1882	0.1526	0.1337	0.0358	0.0291	0.0243	0.0029	0.005	0.0034	ID	ID	ID
Root Mean Square Error	[psu]	3.5606	2.3218	1.8644	0.2396	0.2034	0.1867	0.0446	0.0347	0.028	0.0051	0.0072	0.0046	ID	ID	ID
Std. dev of Residuals	[psu]	2.767	1.9452	1.8569	0.2268	0.2022	0.1845	0.0446	0.0347	0.0263	0.0048	0.0072	0.0045	ID	ID	ID
Coefficient of Determination (R2)	[-]	0.8971	0.9211	0.8904	0.5982	0.5183	0.4799	0.0881	0.0453	0.249	0.405	0.1979	0.0591	ID	ID	ID
Nash-Sutcliffe coefficient (E)	[-]	0.7869	0.8876	0.8876	0.5424	0.4972	0.4598	-0.07	-0.0299	0.1355	0.3013	0.1707	-0.3421	ID	ID	ID
Index of Agreement (d)	[-]	0.9333	0.9702	0.9707	0.829	0.8424	0.8113	0.5484	0.4792	0.6169	0.7571	0.5823	0.4575	ID	ID	ID

4.2.3.2.5 Water quality validation (DCCEEW/Riverwatch)

		Salinity				Total Nitrogen				Total Phosphorus				Chlorophyll a				Enterococci			
Indicator		**z1**	**z5**	**z6**	**z8**	**z1**	**z5**	**z6**	**z8**	**z1**	**z5**	**z6**	**z8**	**z1**	**z5**	**z6**	**z8**	**z1**	**z5**	**z6**	**z8**
Mean Error / Bias	[psu]	3.935	1.783	-2.741	-0.77	-0.186	-0.154	-0.132	-0.126	-0.008	-0.007	-0.008	-0.011	0.005	0.002	4E-04	-0.001	-1E-04	1E-04	3E-04	-2E-04
Mean Absolute Error	[psu]	4.538	2.424	3.988	1.268	0.225	0.187	0.155	0.135	0.035	0.024	0.02	0.017	0.007	0.005	0.003	0.002	7E-04	5E-04	5E-04	4E-04
Root Mean Square Error	[psu]	5.367	2.912	9.947	1.868	0.261	0.236	0.196	0.17	0.041	0.03	0.023	0.02	0.009	0.006	0.004	0.003	0.003	0.002	0.002	0.001
Std. dev of Residuals	[psu]	3.65	2.303	9.562	1.702	0.182	0.179	0.145	0.114	0.04	0.029	0.022	0.017	0.008	0.006	0.004	0.002	0.003	0.002	0.002	0.001
Coefficient of Determination (R2)	[-]	0.802	0.913	0.011	0.937	0.796	0.607	0.552	0.411	0.304	0.359	0.316	0.241	0.344	0.137	0.282	0.28	0.497	0.435	0.332	0.163
Nash-Sutcliffe coefficient (E)	[-]	0.401	0.857	-0.165	0.898	0.05	-0.528	-1.669	-4.992	-0.286	-5E-04	-0.757	-3.926	0.009	-0.118	0.17	-0.74	-0.581	0.432	0.216	-0.222
Index of Agreement (d)	[-]	0.879	0.964	0.404	0.969	0.847	0.778	0.693	0.504	0.728	0.761	0.708	0.564	0.597	0.594	0.723	0.658	0.759	0.747	0.44	0.575

4.2.3.2.6 Water quality validation (Sydney Water)

		Salinity			Total Nitrogen			Total Phosphorus			Chlorophyll a			Enterococci		
TN		PJ01A	PRWP	PRRH	PJ01A	PRWP	PRRH	PJ01A	PRWP	PRRH	PJ01A	PRWP	PRRH	PJ01A	PRWP	PRRH
Mean Error / Bias	[mg/l]	ID	ID	ID	-0.1247	-0.1645	-0.165	-0.016	-0.0136	-0.0132	-0.0009	-0.0004	-0.0009	0.00108	-0.00028	-0.00004
Mean Absolute Error	[mg/l]	ID	ID	ID	0.4354	0.2347	0.1957	0.0265	0.0228	0.0153	0.005	0.0038	0.003	0.00282	0.00054	0.00056
Root Mean Square Error	[mg/l]	ID	ID	ID	0.5401	0.3054	0.2545	0.0332	0.0283	0.0208	0.0068	0.0064	0.0036	0.00742	0.00110	0.00120
Std. dev of Residuals	[mg/l]	ID	ID	ID	0.5255	0.2573	0.1938	0.0291	0.0248	0.016	0.0068	0.0063	0.0035	0.00734	0.00107	0.00120
Coefficient of Determination (R2)	[-]	ID	ID	ID	0.3793	0.3869	0.4473	0.5714	0.1879	0.4971	0.5187	0.4573	0.8133	0.618	0.648	0.6093
Nash-Sutcliffe coefficient (E)	[-]	ID	ID	ID	-1.6889	-0.685	-0.7776	0.4338	-0.092	0.1031	0.2769	-1.1171	-0.4395	-2.8934	0.5204	-0.2683
Index of Agreement (d)	[-]	ID	ID	ID	0.6967	0.7265	0.7329	0.8227	0.545	0.6327	0.8311	0.7132	0.8325	0.686	0.8838	0.8124

Green/red shading – achieves/does not achieve criteria for satisfactory fit (refer Section 4.2.3.1)

ID – Insufficient data

4.2.4 Sensitivity analysis

4.2.4.1 Approach

The primary objective of the sensitivity analysis was to evaluate the response of key water quality indicators, to changes in external loading conditions. In line with this objective, an “effects-based” assessment approach was adopted to evaluate responses in water quality indicators from a change in boundary condition loading, thereby developing an understanding of how changes in loads could be expected to affect water quality in the receiving waterways.

For the purposes of this analysis, responses to the external loading of nitrogen and phosphorus from the catchments was evaluated. More specifically modifications to the DWC and EMC Source model settings were applied across the model domain.

As an initial step, a review was undertaken with respect to the DWC and EMC settings used in the Source model calibration and then extended to analysis of the range of concentrations that are commonly found in literature and those applied in similar Sydney Water modelling studies.

From this review, an alternative suite of DWC and EMC settings was selected for the key parameters including Total Nitrogen and Total Phosphorus. Table 4-2 presents the constituent export concentrations applied in the sensitivity analysis.

Table 4-2 Summary table of DWC and EMC settings applied in the sensitivity analysis

		TN		TP	
Parameter		**EMC**	**DWC**	**EMC**	**DWC**
Calibration	Urban	1.00	0.70	0.10	0.04
	Green space	0.70	0.30	0.05	0.02
Sensitivity	Urban	1.85	0.90	0.26	0.09
	Green space	0.90	0.51	0.10	0.03

Following determination of these concentration settings, simulations were undertaken in the GPOP Source models using the modified EMC and DWC settings. The results from these simulations were then post processed to provide boundary conditions for input to the GPOP WQRM.

4.2.4.2 Results and discussion

Evaluating the results from the sensitivity scenario was undertaken by comparing changes in relevant water quality parameters against the reference calibration conditions.

The results of the sensitivity analysis are presented in both graphical and tabular formats. The graphical formats (refer Figures 4-1 to 4-6) include box and whisker plots of model results for the two scenarios with data presented at the SIMS monitoring sites (refer Section 3.8.2).

The results are also presented as tables (refer Tables 4-3 to 4-8) with the scenario results compared using statistical analysis (5^{th} percentile, median, and 95^{th} percentile) at the same SIMS sites.

From the analysis, the following comments are drawn:

- The sensitivity of the ambient concentrations increases with distance upstream, with site LPR1 in the upper estuary predicted to be most sensitive and LPR9 in the lower estuary to be least sensitive. This is considered to be a product of a combination of the following: the relative levels of tidal flushing and respective residence time, the dimensions of the waterway and the proximity and concentration of the catchment loads.
- Total Phosphorus in the river is predicted to change more significantly than the other parameters analysed with increases in medians ranging from ~50% in the lower estuary and up to ~140% in the upper reaches. These increases are generated by the EMC and DWC settings being raised by 160% and 125% respectively for “urban” land uses.
- Total Nitrogen in the river is also predicted to change substantially with increases in medians ranging from ~25% in the lower estuary and up to ~75% in the upper reaches. These increases are generated by the EMC and DWC settings being raised by 85% and 30% respectively for the dominant “urban” land uses.
- Results for Chlorophyll *a* demonstrate the responses in algal growth that could be expected from elevations in nutrient load to the river. Increases in medians ranging from ~20% up to ~50% are predicted. More significant increases (35% to 100%) are predicted in the 95th percentiles indicating the model’s simulation of more significant peaks in algal growth.

In summary, the sensitivity analysis has highlighted that catchment nutrient loads are a significant driver of water quality in the Parramatta River despite its tidal influences. It also indicates that the middle and upper reaches may be more sensitive to external loading changes, while the lower estuarine regions are more dominated by tidal flushing and are subject to lower residence times.

The analysis has provided an indication of how the WQRM is responsive to changes in external nutrient loading. This responsiveness has been demonstrated in the sensitivity of ambient nutrient concentrations within the river and also with respect to algal growth. While the sensitivity analysis has primarily assessed changes in diffuse catchment loads, it is expected to be similarly responsive to modification in more bioavailable and inorganic point source loading conditions. Such modifications are those likely to be expected in impact assessments such as the GPOP EIS.

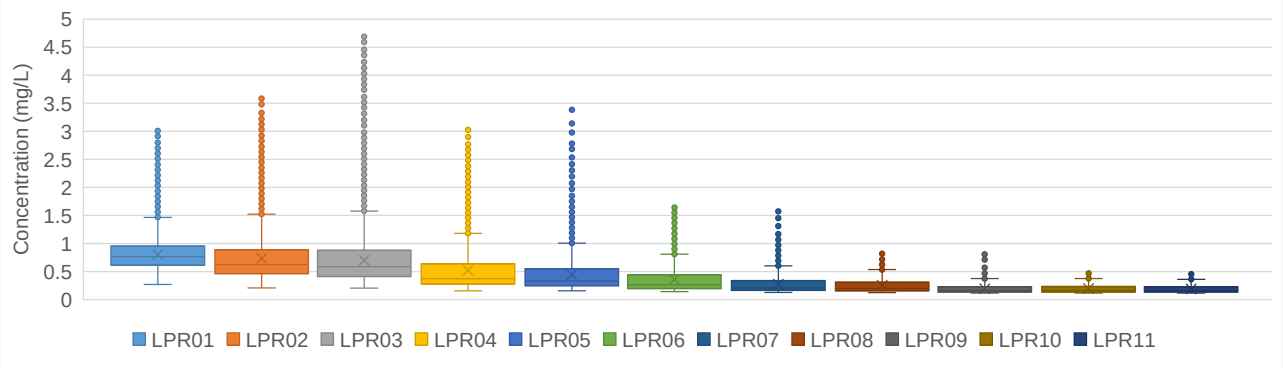


Figure 4-1 Percentile analysis of TN (calibration settings)

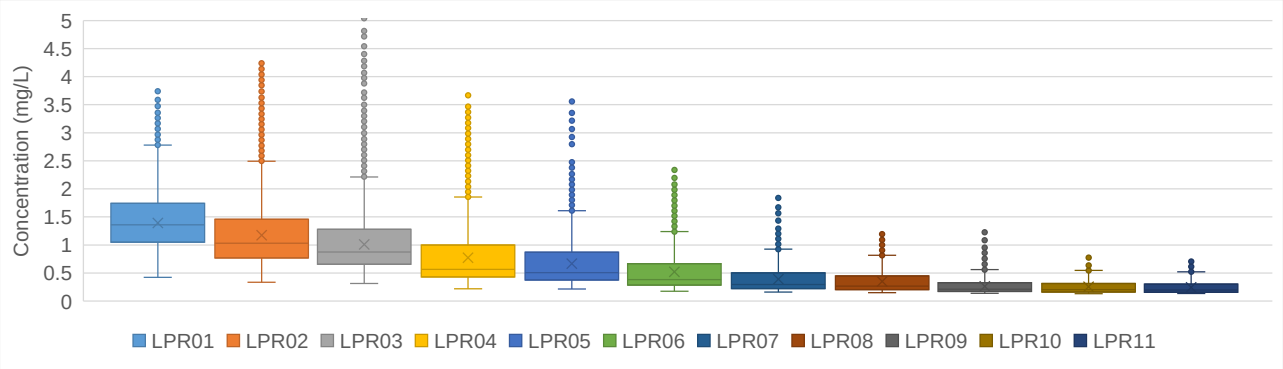


Figure 4-2 Percentile analysis of TN (sensitivity settings)

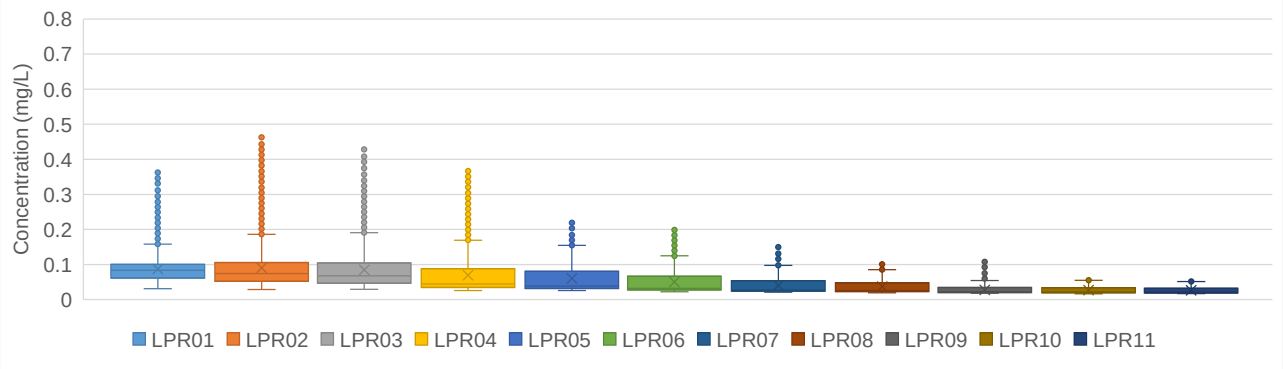


Figure 4-3 Percentile analysis of TP (calibration settings)

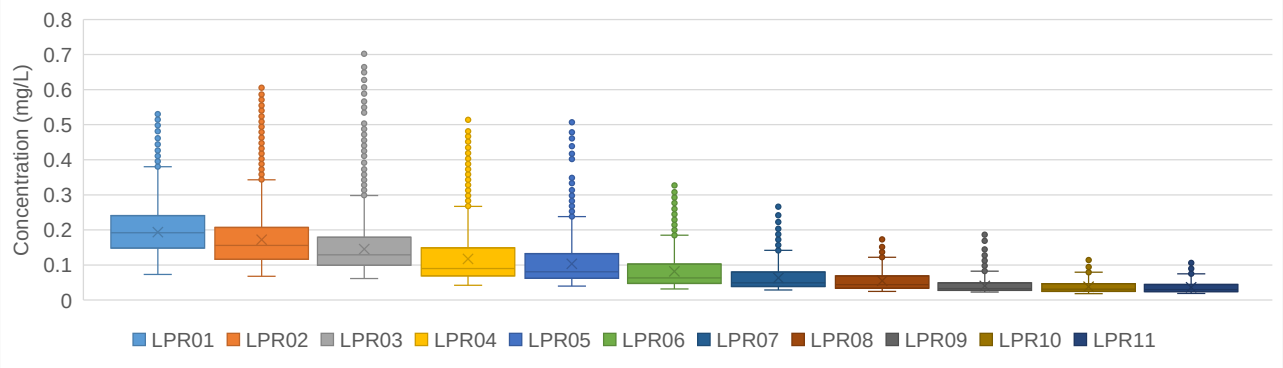


Figure 4-4 Percentile analysis of TP (sensitivity settings)

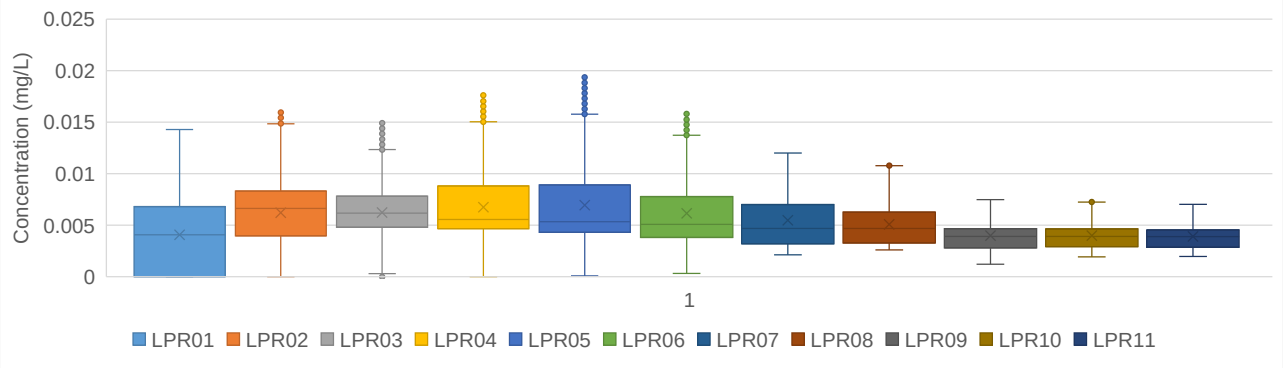


Figure 4-5 Percentile analysis of Chlorophyll *a* (calibration settings)

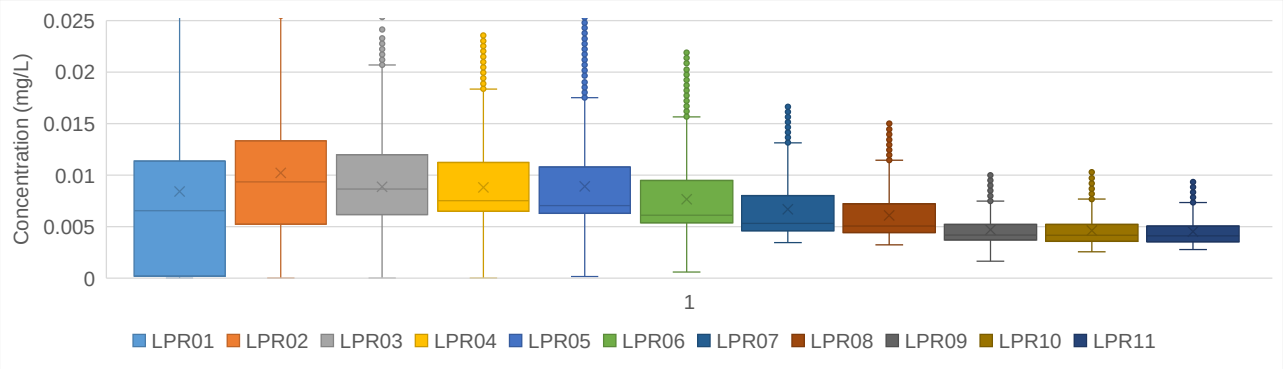


Figure 4-6 Percentile analysis of Chlorophyll *a* (sensitivity settings)

Table 4-3 Percentile analysis of TN (calibration settings)

Percentile	LPR01	LPR02	LPR03	LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.374	0.269	0.257	0.198	0.192	0.165	0.142	0.139	0.125
50th median	0.754	0.608	0.565	0.363	0.327	0.259	0.212	0.203	0.167
95th	1.175	1.415	1.554	1.290	1.097	0.861	0.637	0.553	0.365

Table 4-4 Percentile analysis of TN (sensitivity settings)

Percentile	LPR01	LPR02	LPR03		LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.598	0.414	0.349	0.245	0.231	0.210	0.180	0.174	0.155	0.598
50th median	1.326	0.990	0.828	0.540	0.472	0.362	0.276	0.259	0.211	1.326
95th	2.026	2.102	1.818	1.766	1.535	1.215	0.899	0.773	0.524	2.026

Table 4-5 Percentile analysis of TP (calibration settings)

Percentile	LPR01	LPR02	LPR03	LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.040	0.036	0.034	0.029	0.029	0.026	0.023	0.021	0.018
50th median	0.077	0.069	0.066	0.047	0.043	0.034	0.029	0.027	0.022
95th	0.125	0.172	0.188	0.159	0.137	0.107	0.081	0.069	0.045

Table 4-6 Percentile analysis of TP (sensitivity settings)

Percentile	LPR01	LPR02	LPR03	LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.084	0.074	0.060	0.038	0.035	0.033	0.030	0.028	0.024
50th median	0.188	0.150	0.124	0.086	0.076	0.060	0.048	0.042	0.032
95th	0.276	0.300	0.241	0.257	0.224	0.179	0.137	0.115	0.078

Table 4-7 Percentile analysis of Chlorophyll *a* (calibration settings)

Percentile	LPR01	LPR02	LPR03	LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.0000	0.0000	0.0000	0.0019	0.0030	0.0031	0.0030	0.0030	0.0025
50th median	0.0042	0.0058	0.0056	0.0052	0.0051	0.0047	0.0043	0.0041	0.0035
95th	0.0093	0.0113	0.0112	0.0117	0.0120	0.0107	0.0095	0.0082	0.0056

Table 4-8 Percentile analysis of Chlorophyll *a* (sensitivity settings)

Percentile	LPR01	LPR02	LPR03	LPR04	LPR05	LPR06	LPR07	LPR08	LPR09
5th	0.0000	0.0000	0.0000	0.0027	0.0036	0.0037	0.0039	0.0036	0.0031
50th median	0.0063	0.0091	0.0085	0.0073	0.0069	0.0060	0.0052	0.0050	0.0042
95th	0.0186	0.0205	0.0174	0.0171	0.0172	0.0151	0.0134	0.0113	0.0077

4.3 Independent review

As part of Sydney Water's quality assurance requirements, an independent technical review of the model's development and calibration was undertaken by the University of New South Wales (UNSW) Water Research Laboratory (WRL}. The review by the UNSW WRL is included in Appendix F. The following conclusions are presented in the review's findings:

The numerical models and 3D modelling approach are commensurate with industry best practice. The overall calibration and verification are sound and the modelling suitable for assessment of hydrodynamic and water quality scenarios associated with the Greater Parramatta and Olympic Peninsula (GPOP) discharges.

5 Conclusions

5.1 Model development and application

Sydney Water has previously developed hydrodynamic and water quality models of the Parramatta River and Sydney Harbour as part of the Wet Weather Overflow Abatement project (Sydney Water, 2018). The resulting integrated modelling system incorporated hydrodynamic and biogeochemical processes to allow evaluation of relevant environmental impacts originating from the catchment and more specifically the wet weather overflows. Since their initial development, the models have provided valuable insights on the efficacy of various management strategies through its application on a range of projects.

More recently, the models were updated as part of the Parramatta River Flows Feasibility Study (Sydney Water, 2022). The updates to the model included modifications to the software, transition to a three-dimensional model domain, revision of the calibration and validation periods as well as the model data used as inputs and to calibrate and validate the model.

This report documents the delivery of the most recent upgrade of the WQRM, which also incorporated refinements that were considered necessary to evaluate the hydrodynamic and water quality impacts from the operation of a new water resource recovery facility. A fundamental focus of the upgrade has therefore been to ensure the modelling system has the capacity to realistically evaluate environmental impacts from a range of potential operational scenarios.

The upgrade has included further software updates, expansion of the model domain as well as revision of key boundary conditions and the data used to calibrate and validate the model's performance.

5.2 Model calibration and validation

The GPOP WQRM has been calibrated and validated against a diverse suite of data collected over the period of 2012 to 2024. The final datasets processed for comparison with the model results served to collate data from the following sources: Sydney Water, DCCEEW, Sydney Institute of Marine Science and the Port Authority of NSW. Collectively, these datasets have provided useful insights into the hydrodynamics and water quality within the Parramatta River estuary and the wider Sydney Harbour area.

Hydrodynamically, the model was calibrated and validated against both water elevation and flow transect data. With respect to water quality, the core suite of parameters calibrated within the model has included salinity, temperature, dissolved oxygen, suspended sediment, nutrients (including inorganic and organic fractions), primary productivity and pathogens.

For the majority of these parameters, the model was calibrated for the year 2012-13, and then independently validated in the years 2022-24.

Through visual and statistical analysis, the model has been demonstrated to perform well across the range of simulation periods and also across the range of parameters that have been assessed.

Sensitivity analysis has also been undertaken to evaluate how the model responds to modification in external boundary conditions.

An independent review of model structure and calibration results, undertaken by the University of New South Wales, concluded that the models and 3D modelling approach were commensurate with industry best practice, and were considered suitable for assessment of hydrodynamic and water quality scenarios associated with the GPOP project..

As a result of the upgrade and the corresponding calibration and validation, the models in their current format are considered to be a significant enhancement on their previous iteration and represent a robust modelling platform for application in relevant hydrodynamic and water quality studies, including the GPOP EIS.

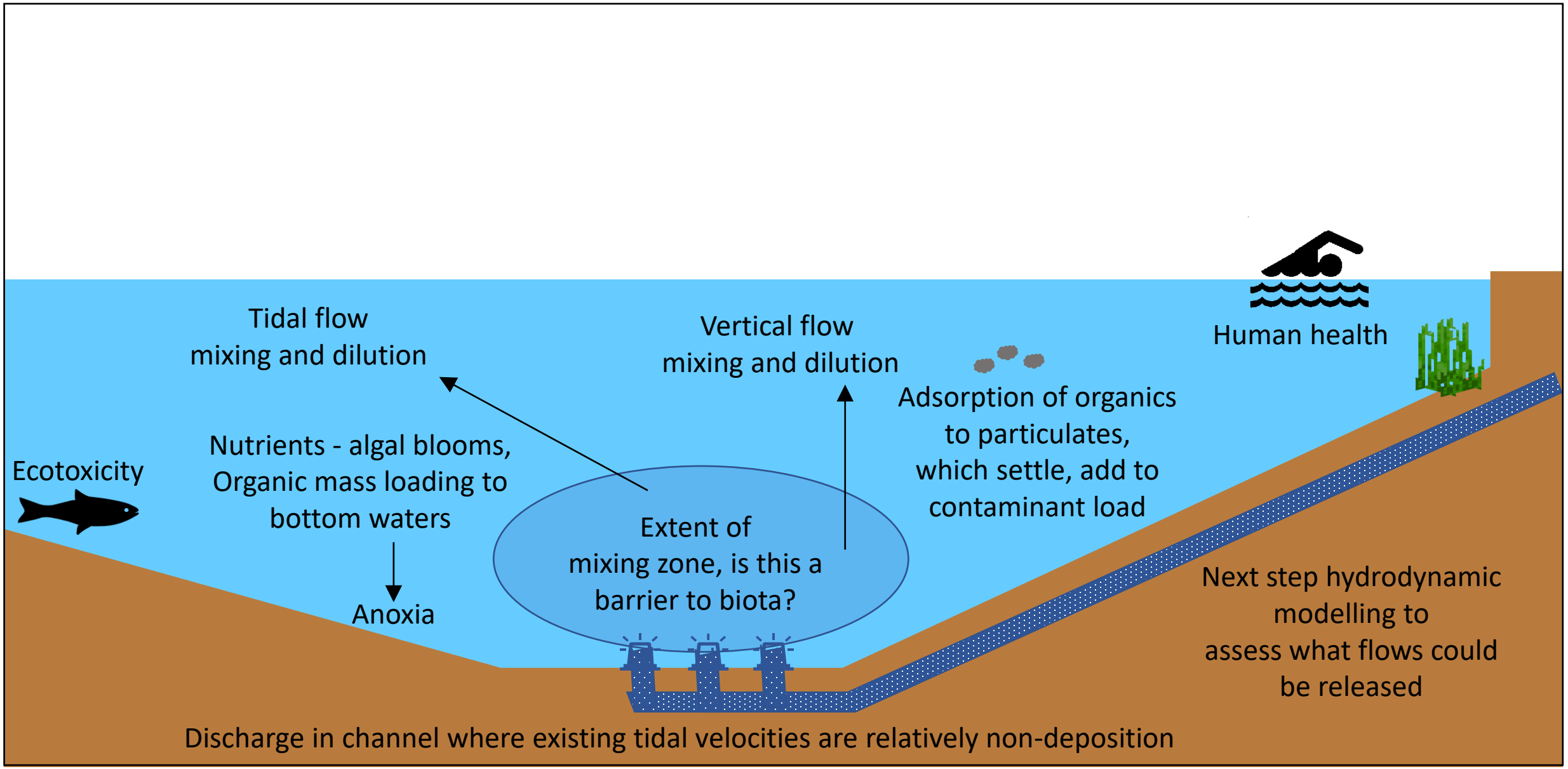
Appendix A Conceptual model

GPOP River Releases Conceptual Model

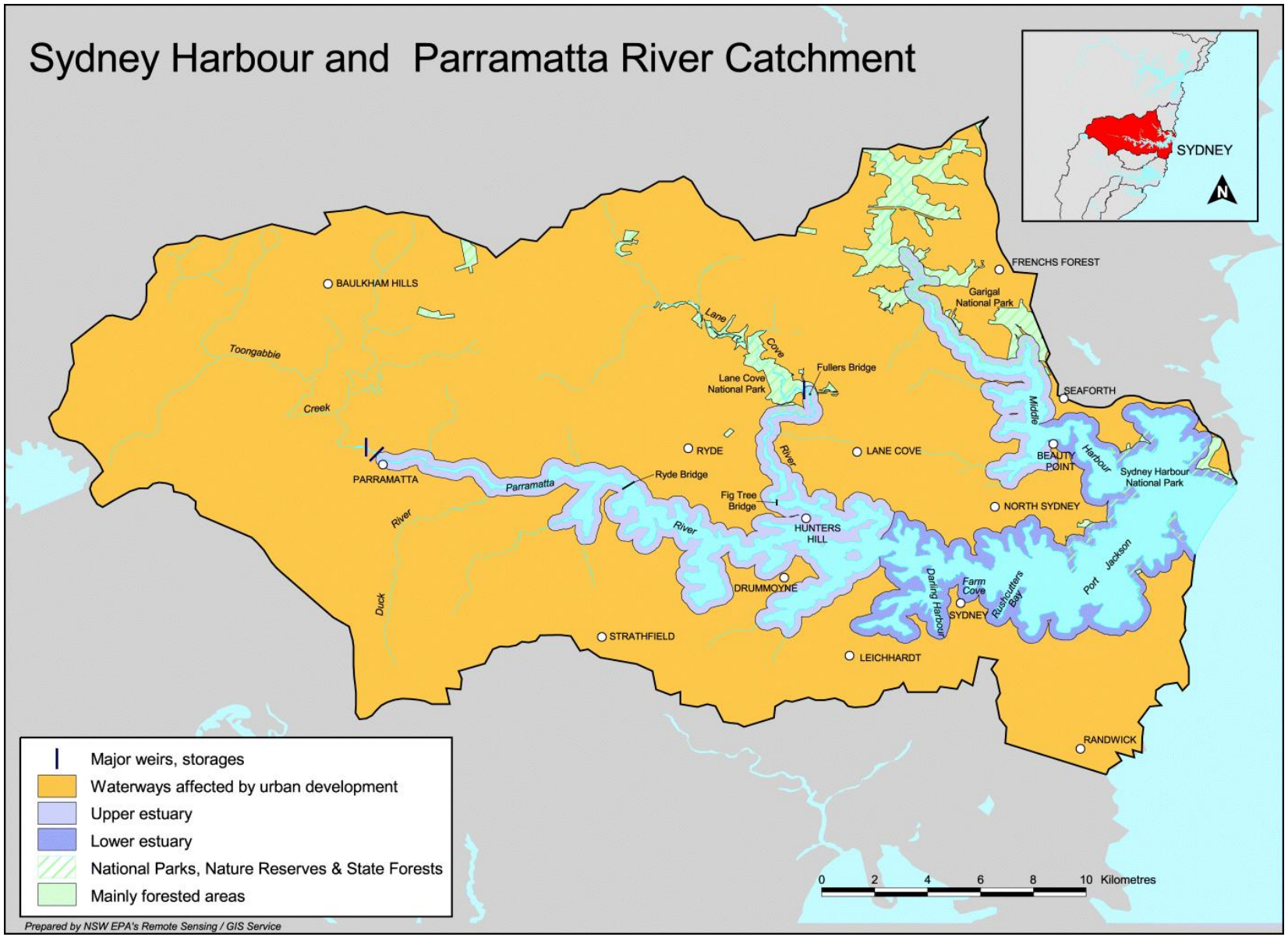
March 2024

Sydney WATER

Initial considerations as workshopped for Phase 1



NSW Water Quality Objectives – Sydney Harbour and Parramatta River
(NSW Environment and Heritage, 2006)



Water Quality Objectives

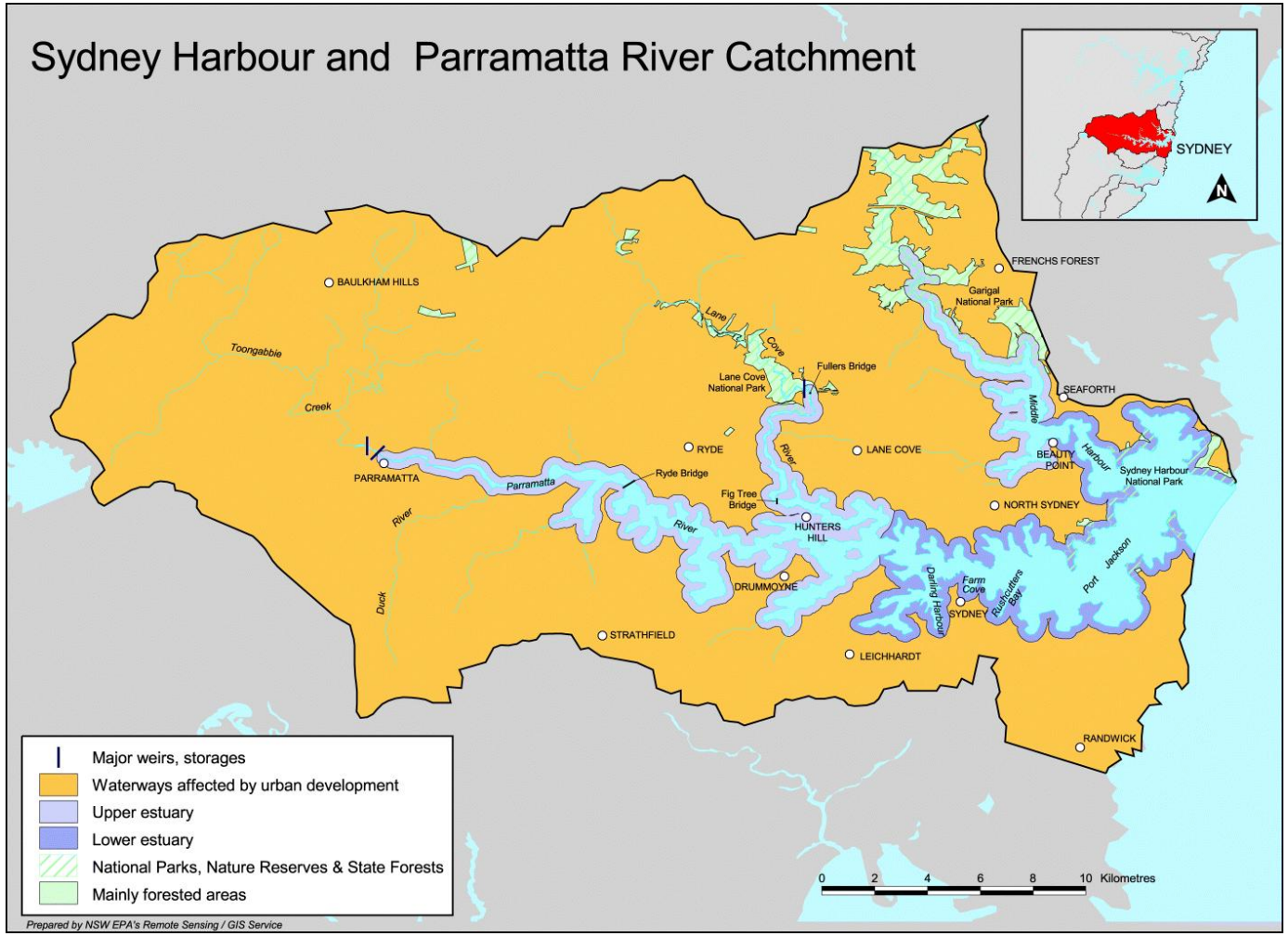
Protection of :

- Aquatic ecosystems
- Visual amenity
- Secondary contact recreation
- Primary contact recreation, in the longer term, 1(

River Flow Objectives

- Protect pools in dry times
- Protect natural low flows
- Maintain wetland and floodplain inundation
- Mimic natural drying in temporary waterways
- Maintain natural flow variability
- Maintain natural rates of change in water levels
- Minimise effects of weirs and other structures

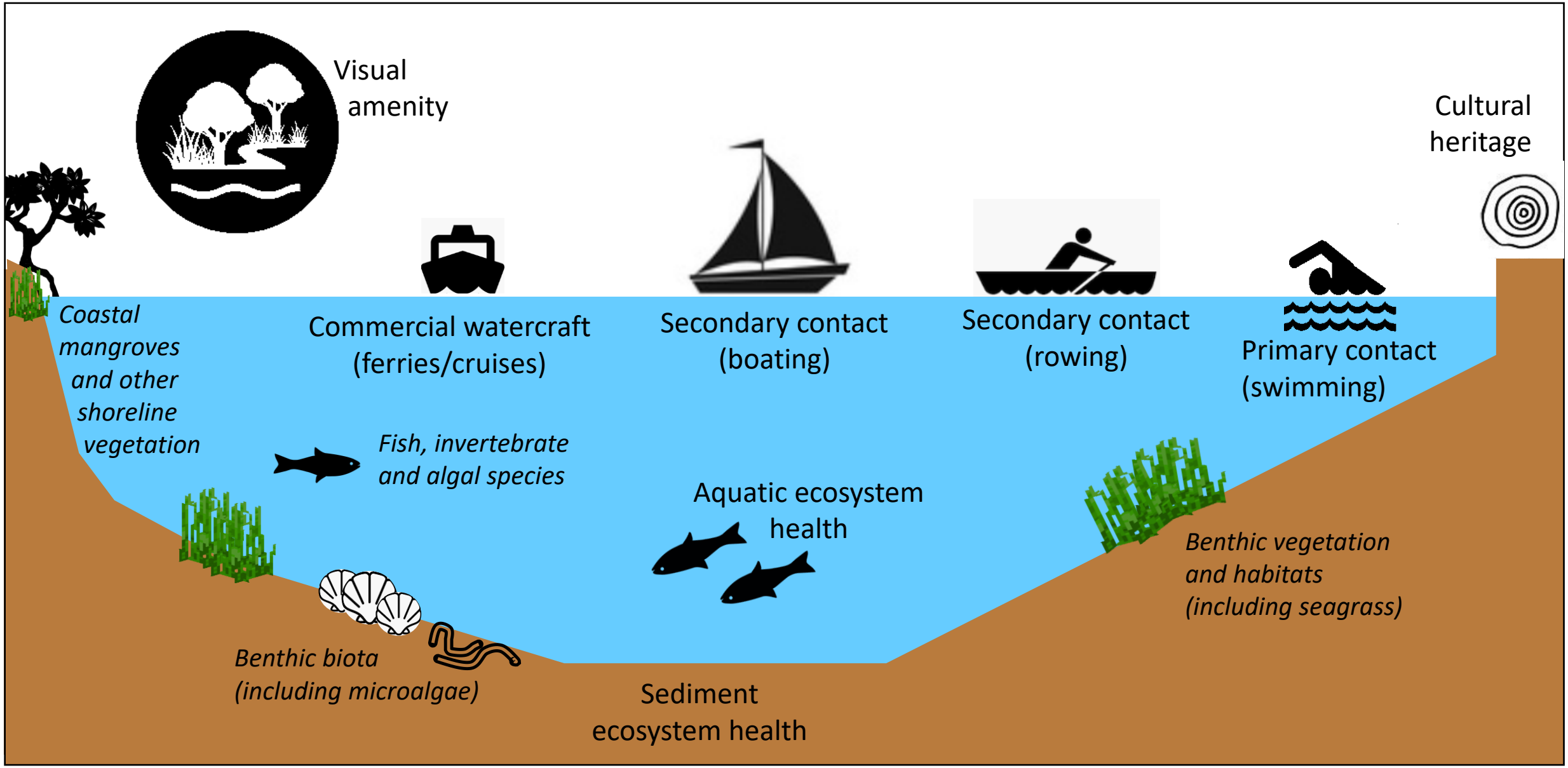
NSW Water Quality Objectives – Sydney Harbour and Parramatta River
(NSW Environment and Heritage, 2006)



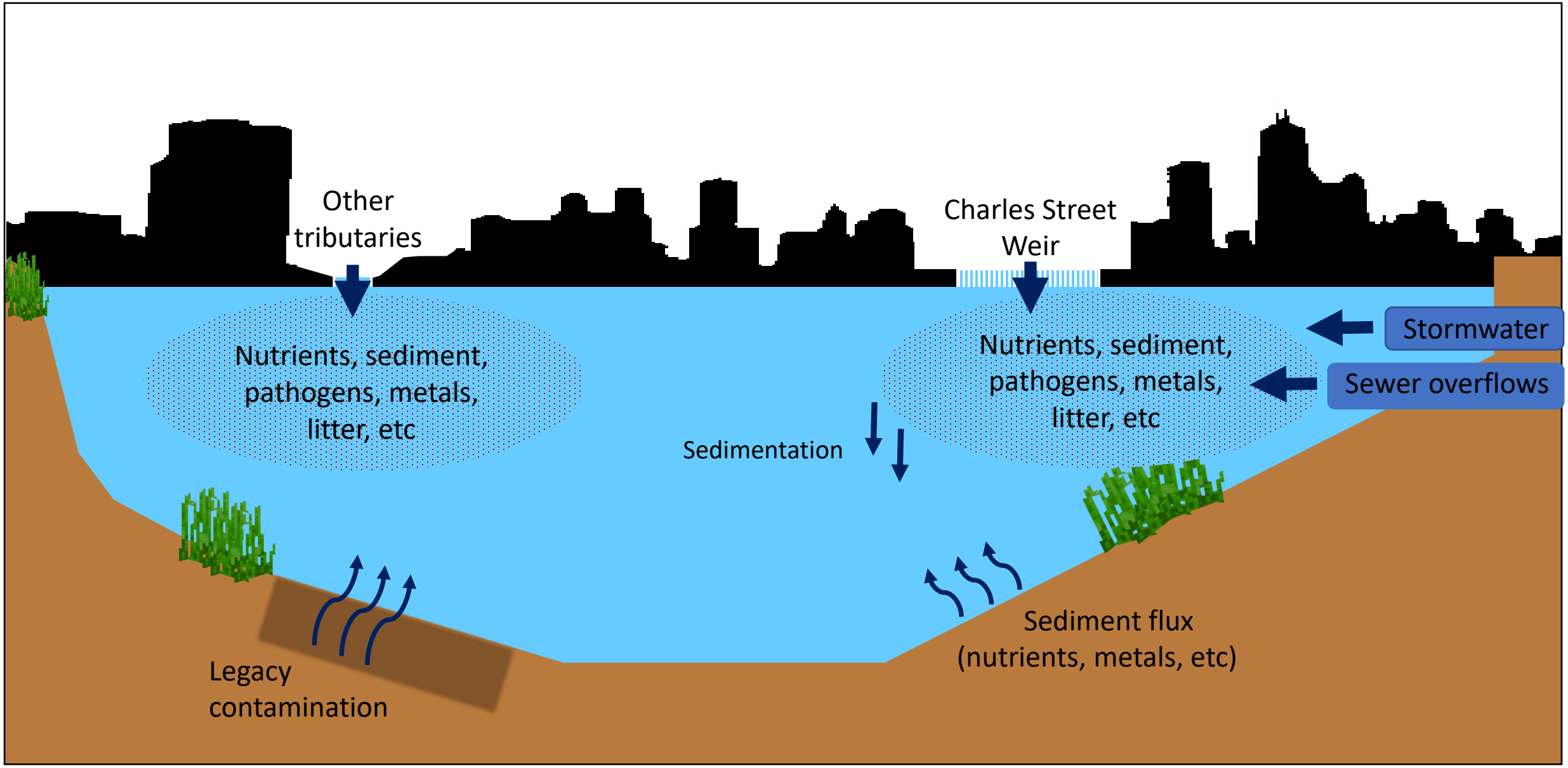
Major issues identified

- Management of stormwater pollution
- Impacts from development
- Legacy sediment contamination
- Impacts of in-stream structures
- Protection of natural values
- Management of sewerage overflows and leachate
- Impacts of boating including discharges from private vessels
- Impacts from shipping including bilge pumping

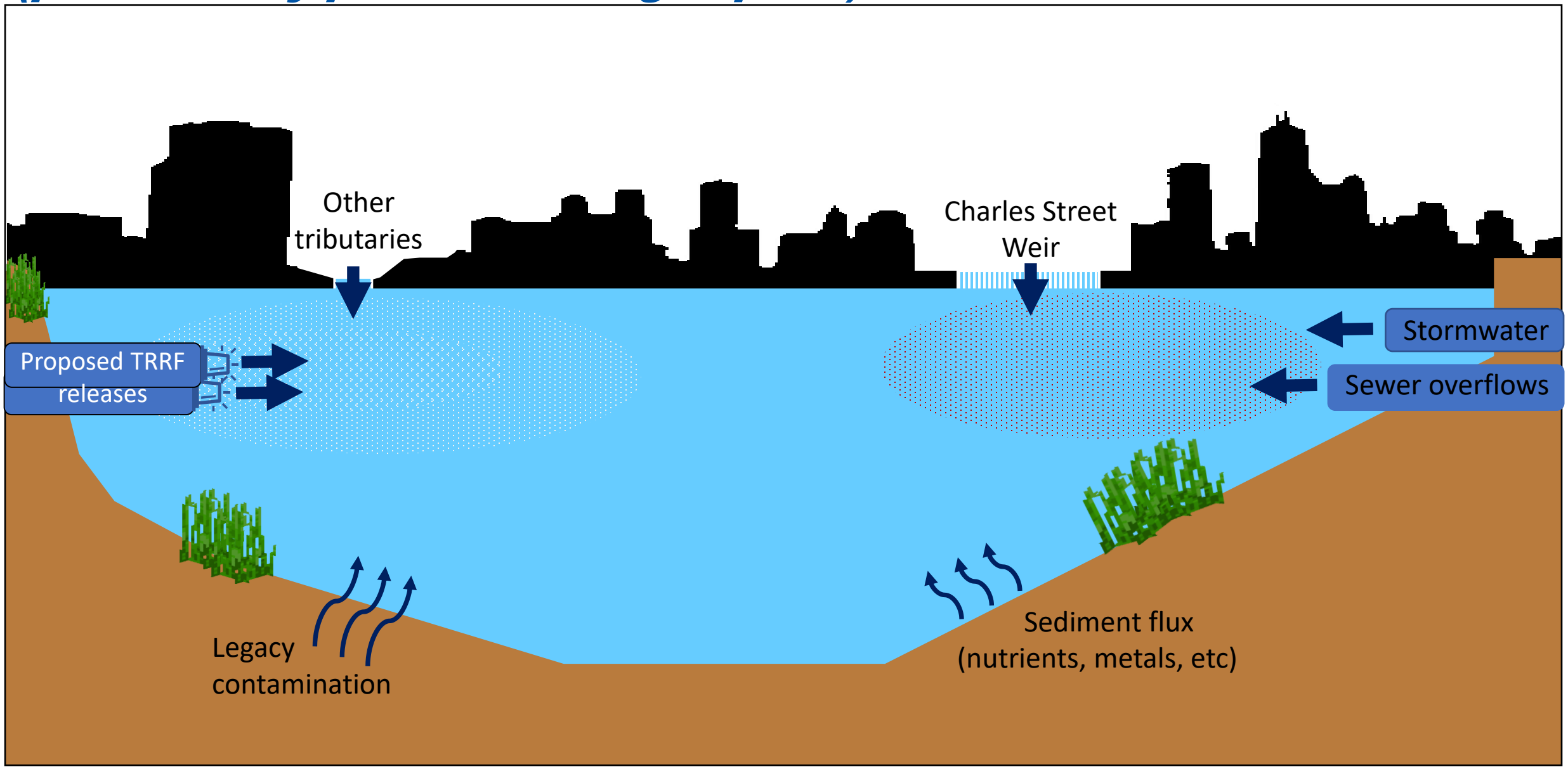
Summary of system/environmental values



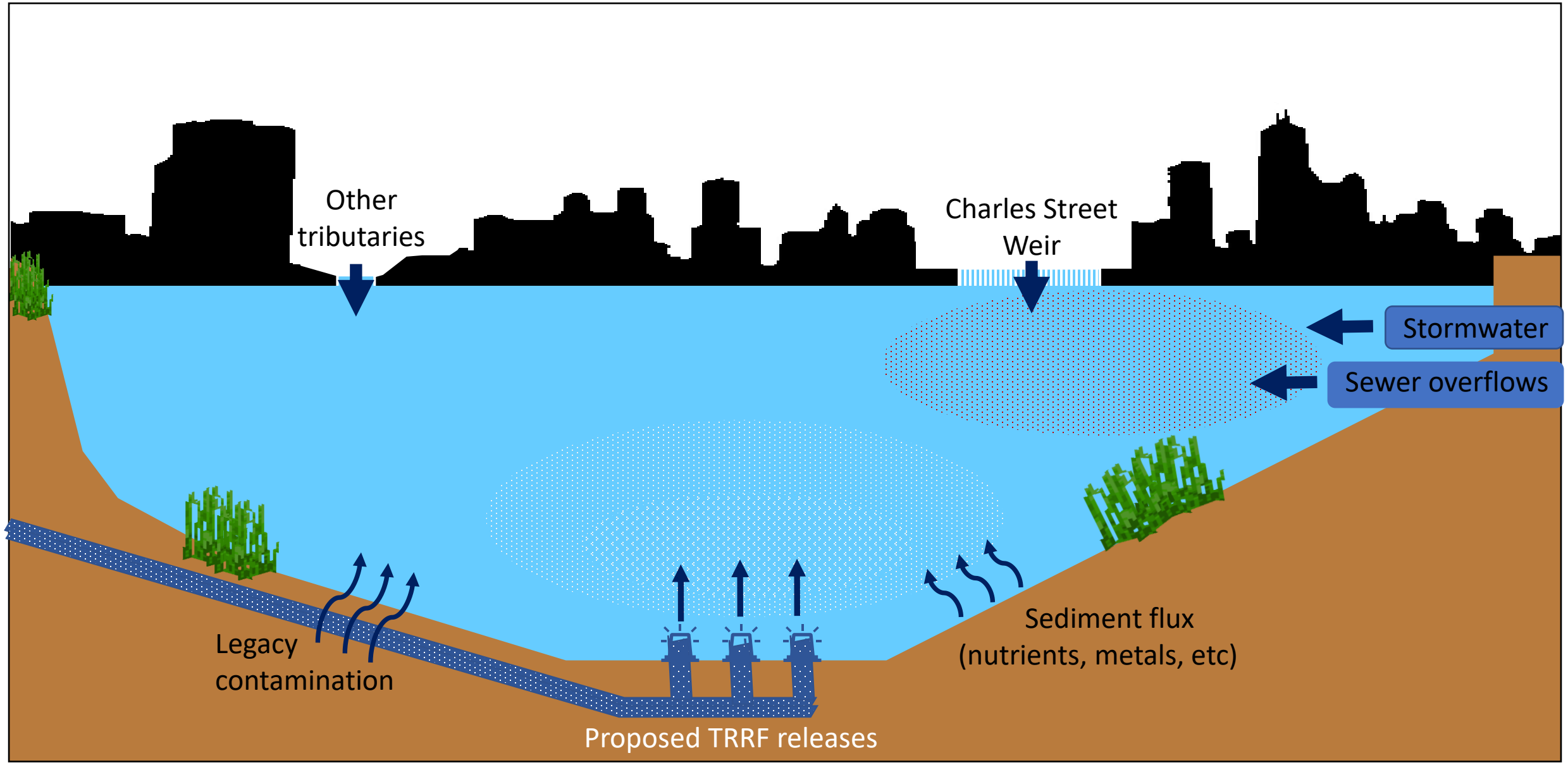
System pressures of relevance – *existing*



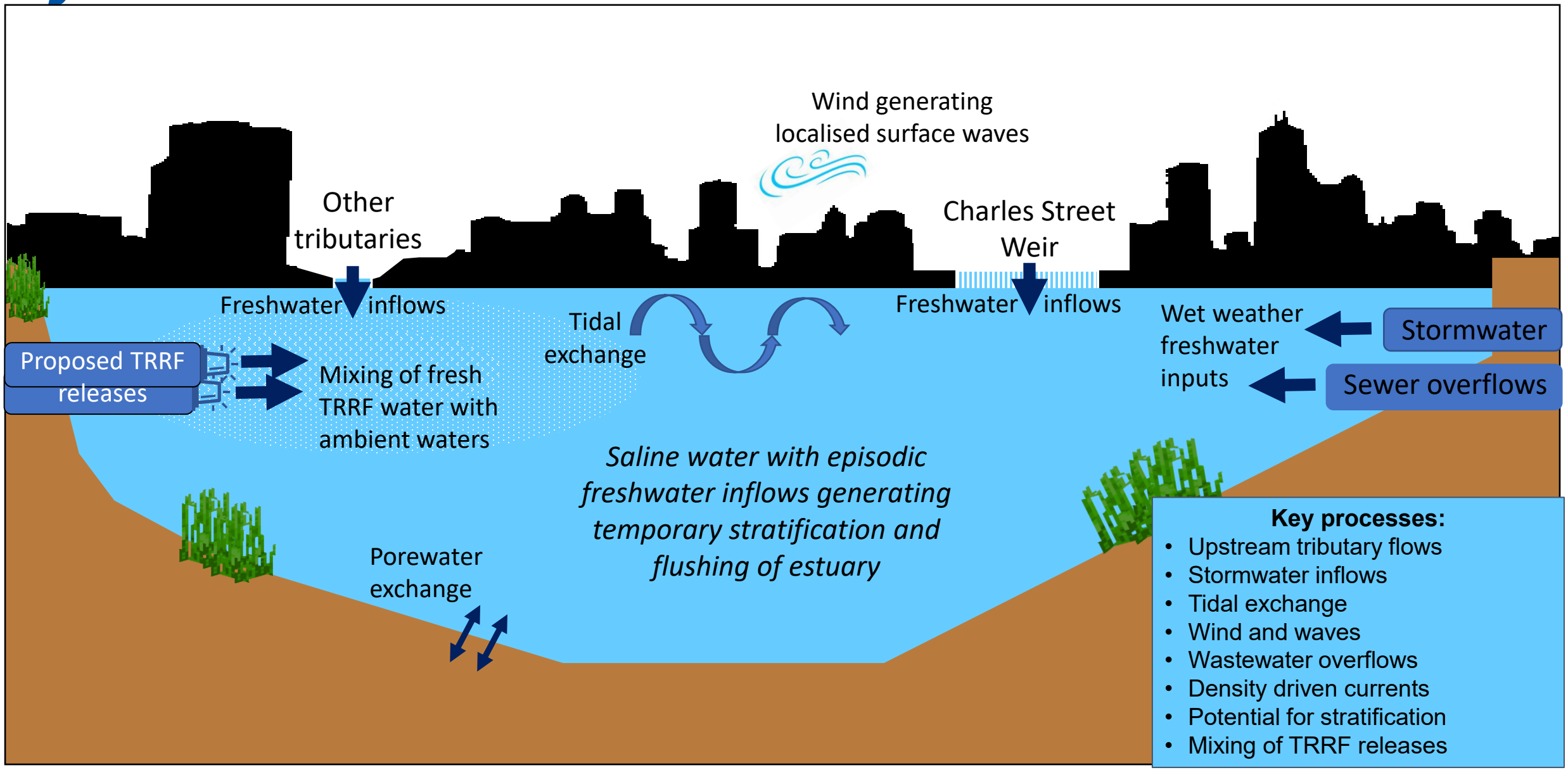
System pressures of relevance – *bank mounted option*
(provisionally preferred design option)



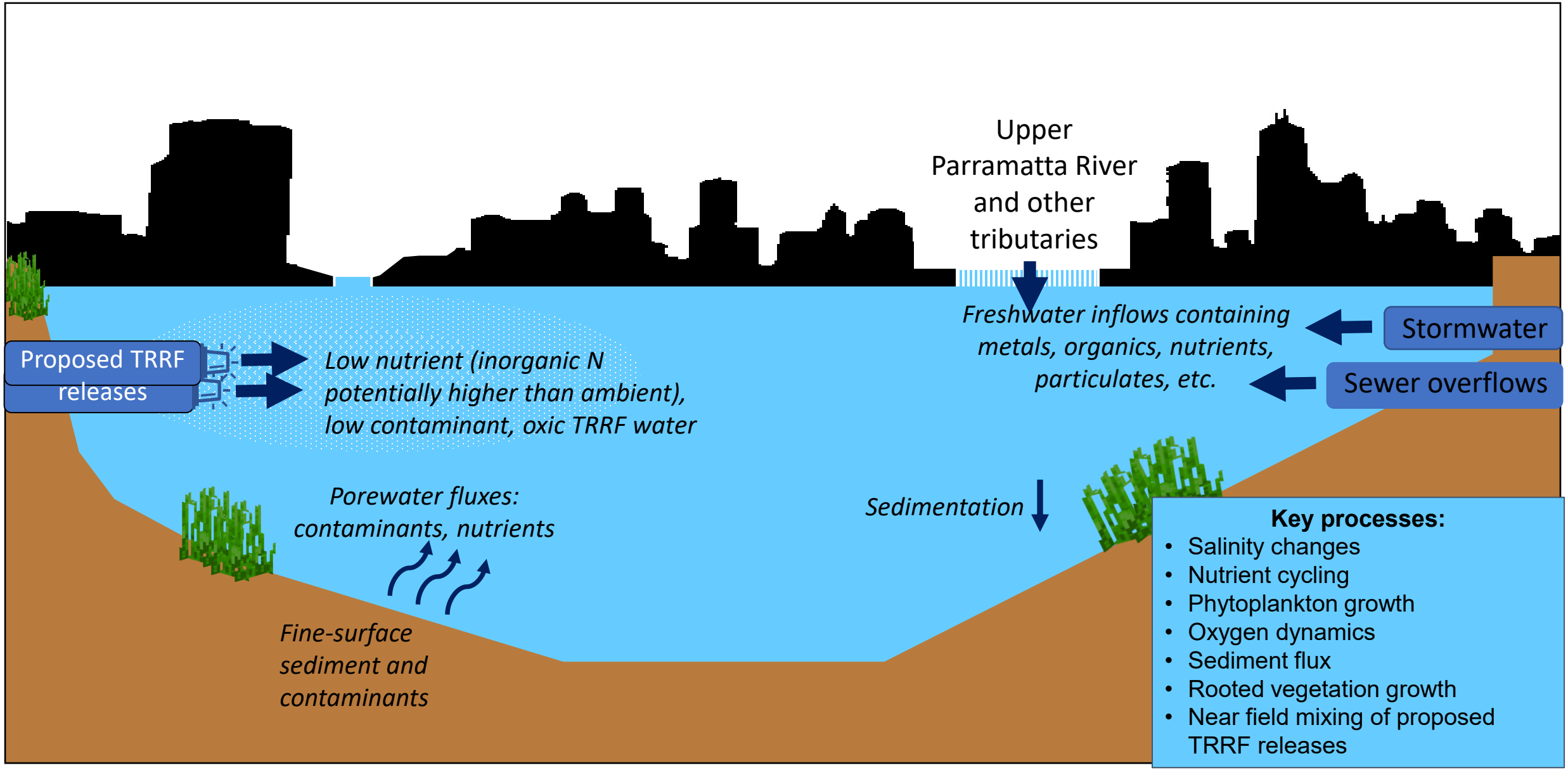
System pressures of relevance – *bed mounted option*
(secondary design option)



System conceptual model – *hydrodynamics and salinity dynamics*

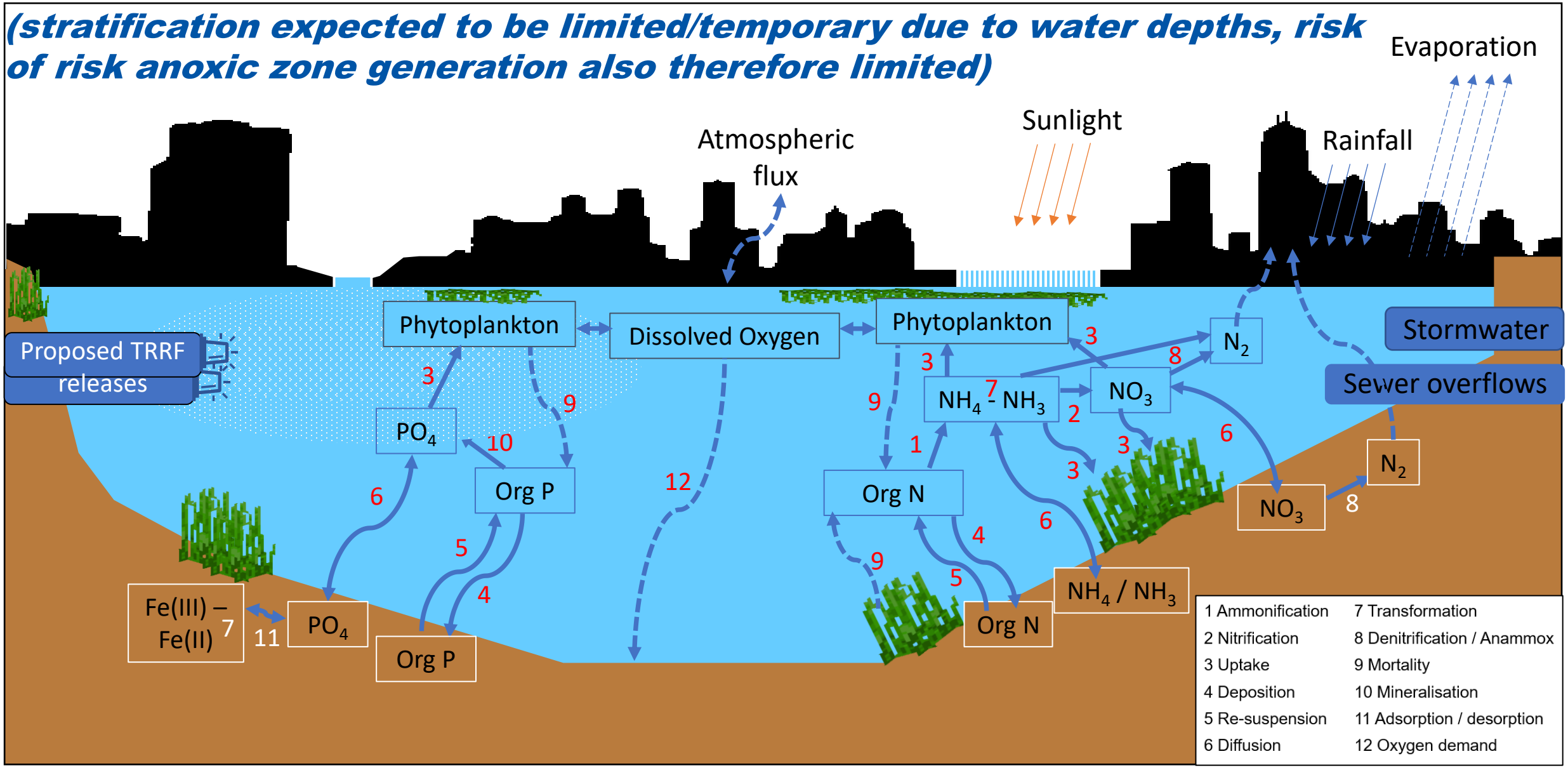


System conceptual model – *water quality*



System conceptual model – *nutrient dynamics – mixed water column*

(stratification expected to be limited/temporary due to water depths, risk of risk anoxic zone generation also therefore limited)



Additional considerations for analysis (Prof. Bill Maher, 2021)

- Oxic and anoxic conditions – These conditions will have the potential to influence nutrient sequestration processes between the sediment and water column.
- Carbon flux – Additional assessment of carbon flux into the water column from the proposed TRRF releases to be reviewed as this could be a potential driver of anoxia.
- Benthic microalgae – Sequestration by benthic microalgae will depend on water depth and availability of light.
- Low and high flow conditions – Assessment of the effects on hydrodynamics and stratification, nutrient and oxygen dynamics, and also near field to be undertaken under a range of flow conditions.
- Contemporary chemicals of concern – Consideration of newer chemicals of concern should be given so as to alleviate future concerns.

Sydney WATER

Appendix B MIKE HD, Ecolab and Sand Transport Template Descriptions

Appendix B1 Hydrodynamic formulation

Hydrodynamic model configuration

The model adopted a Smagorinsky formulation in the horizontal (with a coefficient of 0.25) and a two-equation turbulence model in the vertical.

The turbulence model was based on a standard k-ε model, with a buoyancy extension. This model uses transport equations for the turbulent kinetic energy (TKE), k, and the dissipation of TKE, e, to describe the turbulence. Four empirical constants were specified for the standard k-ε model: c1e, c2e, c3e (related to the equation for the dissipation of TKE) with the Prandtl number applied in the buoyancy production term. Cmy was also included as an empirical constant used in the expression for determination of the eddy viscosity. The following values were adopted for c1e, c2e, c3e, Prandtl and Cmy: 1.44, 1.92, 0, 0.9, 0.09.

A scaled eddy viscosity formulation was adopted in both the horizontal and vertical. Scaling factors of 1.0 and 0.01 respectively were specified in the final calibration phase.

Salinity was simulated through application of the temperature/salinity module and specification of baroclinic density. The module sets up additional transport equations for temperature and salinity and provides feed-back to the hydrodynamic equations through buoyancy forcing induced by density gradients.

Appendix B2 Ecolab template description

Water quality model configuration

A modified Ecolab template was applied to simulate the water quality dynamics in the Parramatta River estuary and the extended Sydney Harbour model domain. More specifically, the MIKE Ecolab Eutrophication Model 2 template was adopted to describe the nutrient cycling, phytoplankton and zooplankton growth, growth and distribution of rooted vegetation and macroalgae in addition to simulating oxygen conditions. Modifications were made to the template to allow inclusion of Enterococci as a primary state variable.

The model results therefore describe concentrations of phytoplankton, chlorophyll *a*, zooplankton, organic matter, organic and inorganic nutrients, oxygen, enterococci and area-based biomass of benthic vegetation over time. In addition, a number of derived variables are also stored including: primary production, total nitrogen, total phosphorus, sediment oxygen demand and Secchi disc depth.

The Eutrophication Model 2 is integrated with the advection-dispersion module which describes the physical transport processes at each grid-point within the model domain. Other data requirements include concentrations at the model boundaries, flow and concentrations of all relevant pollution sources, water temperature and irradiance.

Comprehensive descriptions of the science and algorithms are presented in the following MIKE documentation and have therefore not been repeated here:

https://manuals.mikepoweredbydhi.help/latest/MIKE_3.htm.

The parameter settings adopted in the final calibration simulation are summarised below.

Description	Value	Units
General parameter: Reference temperature for temperature dependencies	20	deg.C
Phytoplankton parameter: Growth rate phytoplankton C	1.17	/d
Phytoplankton parameter: Phytoplankton settling rate <2m	0.05	/d
Phytoplankton parameter: Phytoplankton settling velocity >2m	0.1	meter/day
Phytoplankton parameter: Coagulation induced settling at high phytoplankton concentrations	0.02	(mg/)^-2*day^-1
Phytoplankton parameter: 1st order death rate for phytoplankton	0.0125	/d
Phytoplankton parameter: Temperature dependency growth rate green algae	1.12	dimensionless
Phytoplankton parameter: Coefficient for min. chlorophyll-a production	0.02	micro Einstein/m2/s
Phytoplankton parameter: Coefficient for max. chlorophyll-a production	1	dimensionless
Phytoplankton parameter: Min. intracellular concentration of nitrogen	0.07	g N/g C
Phytoplankton parameter: Max. intracellular concentration of nitrogen	0.18	g N/g C
Phytoplankton parameter: Min. intracellular concentration of phosphorous	0.002	g P/g C
Phytoplankton parameter: Shape factor for sigmoide nitrate uptake function	0.01	dimensionless
Phytoplankton parameter: Max. intracellular concentration of phosphorous	0.01	g P/g C
Phytoplankton parameter: Half-saturation constant for NH4 uptake	0.3	mg N/l
Phytoplankton parameter: Half-saturation constant for NO3 uptake	0.3	mg N/l
Phytoplankton parameter: Half-saturation concentration for phosphorus	0.1	g P/g C
Phytoplankton parameter: Maximum N uptake phytoplankton	0.3	g N/g C/d
Phytoplankton parameter: P uptake under limiting conditions	0.02	mg P/l
Phytoplankton parameter: Half-saturation constant for P uptake	0.1	g P/g C
Phytoplankton parameter: Fraction of nutrients released at phytoplankton death	0.3	dimensionless
Phytoplankton parameter: Specification for nutrient saturation	0.001	dimensionless
Phytoplankton parameter: Light saturation intensity at reference temperature	15	micro Einstein/m2/s
Phytoplankton parameter: Temperature dependency for light saturation intensity	1.04	dimensionless
Phytoplankton parameter: Algae respiration rate	0.06	per day
Phytoplankton parameter: Gradient coefficient for light dependency curve	0.012	(micro Einstein/m2/s)^-1
Phytoplankton parameter: Coefficient for nitrate dark uptake by phytoplankton	0.6	dimensionless
Zooplankton parameter: Max. grazing rate	2	/d
Zooplankton parameter: Zooplankton death rate 1st order	0.1	/d
Zooplankton parameter: Zooplankton death rate 2nd order	12	/d
Zooplankton parameter: Grazing threshold	0.02	mg/l
Zooplankton parameter: Half-saturation for Zooplankton grazing PC	0.5	mg/l
Zooplankton parameter: Temperature dependency for max. grazing rate	1.1	dimensionless
Zooplankton parameter: N to C ratio in zooplankton	0.07	g N/g C

Zooplankton parameter: P to C ratio in zooplankton	0.002	g P/g C
Zooplankton parameter: Respiration due to specific dynamic action	0.3	dimensionless
Zooplankton parameter: Basal metabolism for zooplankton	0.04	1/d
Zooplankton parameter: Assimilation factor	0.28	Dimensionless
Detritus parameter: Detritus C mineralisation rate	0.1	/d
Detritus parameter: Detritus C settling rate <2m	0.2	/d
Detritus parameter: Detritus C settling velocity >2m	0.05	meter/day
Detritus parameter: Temperature dependency for C mineralisation	1.08	dimensionless
Detritus parameter: Proportional factor for release of N from mineralisation	1	dimensionless
Detritus parameter: Proportional factor for release of P from mineralisation	1	dimensionless
Oxygen parameter: Half-saturation concentration for processes dependent on oxygen	2	mg/l
Oxygen parameter: Dependency coefficient for processes dependent on oxygen	1	dimensionless
Oxygen parameter: Production/consumption relative to carbon	3.5	g DO/g C
Extinction parameter: Light extinction constant phytoplankton	30	m2/g Chl-a
Extinction parameter: Light extinction background constant	0.35	m2
Extinction parameter: Light extinction detritus C	0.1	m2/g detritus C
Extinction parameter: Light extinction constant macroalgae	0.02	m2/g macroalgae C
Extinction parameter: Light extinction constant suspended solids	0.07	m2/g SS
Macroalgae parameter: Sloughing rate reference temperature	0.02	/d
Macroalgae parameter: Production rate at reference temperature	0.27	/d
Macroalgae parameter: Respiration rate at reference temperature	0	/d
Macroalgae parameter: Threshold values for self-shading	20	g C/m2
Macroalgae parameter: Temperature dependency sloughing rate	1.03	dimensionless
Macroalgae parameter: Temperature dependency production rate	1.05	dimensionless
Macroalgae physiological parameter: N to C ratio	0.137	g N/g C
Macroalgae physiological parameter: P to C ratio	0.016	g P/g C
Macroalgae physiological parameter: Half-saturation concentration for N uptake	0.3	mg/l
Macroalgae physiological parameter: Half-saturation concentration for P uptake	0.1	mg/l
Macroalgae physiological parameter: Light saturation intensity at reference temperature	20	micro Einstein/m2/s
Macroalgae physiological parameter: Temperature dependency for light saturation and photoinhibition	1.04	dimensionless
Sediment parameter: Proportional factor for sediment respiration	1	dimensionless
Sediment parameter: Proportional factor for N release from sediment	1	dimensionless
Sediment parameter: Proportional factor for P release from sediment	1	dimensionless
Sediment ecosystem parameter: Temperature dependency sediment N release	1.1	dimensionless
Sediment ecosystem parameter: Temperature dependency sediment P release	1.08	dimensionless
Sediment ecosystem parameter: N-release under anoxic conditions	0.05	g N/m2/day
Sediment ecosystem parameter: P-release under anoxic conditions	0.01	g P/m2/day
Sediment ecosystem parameter: Temperature dependency sediment respiration	1.07	dimensionless
Sediment parameter: Diffusion (vertical transport) of NO3 and NH4 between sediment and water	0.002	m2/d
Sediment parameter: Max. de-nitrification in sediment at reference temperature	0.2	mg N/l/d
Sediment parameter: Constant 1, DO penetration into sediment	0.00124	m
Sediment parameter: Constant 2, DO penetration into sediment	0.000403	m4/g O2
Sediment parameter: Constant 3, DO penetration into sediment	0.000473	m3*d/g O2
Sediment parameter: Half saturation conc. DO, NH4 or NO3 release from sediment	2	

Inorganic N parameter: Specific nitrification rate pelagic water at reference temperature	0.05	1/d
Inorganic N parameter: Teta value, nitrification	1.04	
Inorganic N parameter: Half-saturation conc. NH4 for nitrification	0.02	mg/l
Inorganic N parameter: Exponent for DO in sqdo	1	
Inorganic N parameter: Max. DO conc. for de-nitrification in water	1	mg O2/l
Inorganic N parameter: Maximum de-nitrification rate water	0.06	mg N/l/d
Inorganic N parameter: Half-saturation conc, NO3, for de-nitrification	0.2	mg N/l
Inorganic N parameter: Half-saturation conc. for DC de-nitrification in water	0.5	mg C/l
Inorganic N parameter: Half-saturation conc. DO for de-nitrification	0.5	mg O2/l
Inorganic N parameter: g O2 used to oxidise 1 g NH4 to 1 g NO3 (stoichiometry)	4.3	g O/g NH4-N
KfEntm, Enterococci decay relative to E.coli decay, dark reaction	0	undefined
KfEntd, Enteroccoci decay relative to E.coli decay, light reaction	0.5	undefined
at, Temperature dependency, dark reaction	0.0582	1/deg.C/d
Kmo, Initial coliform decay rate, dark reaction	0.19824	/d
bt, Temperature dependency, light reaction	0.003192	m2/W.day.degree C
Sm, Reference salinity	34.5	PSU
a, Correction for salinity	1.54	dimensionless
Klo, Initial coliform decay rate, light reaction	0.050976	m2/W.day

Appendix B3 Mud Transport module description

Module Description

The MIKE Mud Transport (ST) module provides the ability to simulate cohesive and non-cohesive sediment transport processes within coastal and estuarine environments. In addition to sediment transport, the module enables assessment of erosion and sedimentation impacts through the calculating the transport of non-cohesive and cohesive sediments from both currents and waves. The module therefore has the capacity to couple with both the MIKE hydrodynamic and wave analysis modules.

This integration allows for effective prediction of sediment dynamics within coastal and estuarine domains. Importantly, results of suspended sediment concentrations from the MT module can then also be applied as an input to the Ecolab module allowing for interactions between suspended sediment in the water column and relevant water quality processes e.g., algal growth. Morphological changes to the bathymetry are however not integrated into the WQRM. The bathymetry therefore remains unmodified throughout simulations.

For further details of the MT module, readers are to the documentation in Appendix B as well as the following link. https://manuals.mikepoweredbydhi.help/latest/MIKE_3.htm

Structure and parameterisation

Due to limitations in the extent of sediment data and monitoring data, the module was applied with one cohesive particle fraction and zero non-cohesive fractions.

Default settings were applied with the exception of the following parameterisation of sediment properties:

- Settling velocity coefficient: 0.5 (dimensionless)
- Deposition critical shear stress: 0.1 N/m^2
- Erosion critical shear stress: 0.12 N/m^2
-

Appendix C Source model development and calibration report

Source models for the Parramatta River and Sydney Harbour Catchment

Report

Version 1

23 July 2025

Document status

Client	Sydney Water
Project	Source models for the Parramatta River and Sydney Harbour Catchment
Report title	Report
Version	Version 1
Authors	Phillip Jordan and Nassim Khosravi
Project manager	Phillip Jordan
File name	SWC00008_Source models for the Parramatta River and Sydney Harbour Catchment_Report_v1.docx
Project number	SWC00008

Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	02/10/2024	Russell Beatty	Russell Beatty	Sydney Water project team	Draft covering flow calibration only, prior to water quality modelling
Draft B	22/10/2024	NA	NA	Sydney Water project team	Updated draft addressing first round of comments on flow calibration draft A
Draft C	13/11/2024	Russell Beatty	Russell Beatty	Sydney Water project team	Water quality modelling and verification to monitored data added
Draft D	05/12/2024	Russell Beatty	Russell Beatty	Sydney Water project team	Extension of input data and running of models to 30 June 2024. Response to comments and updating of water quality parametrisation in response to comments on Draft C.
Draft E	06/06/2025	Phillip Jordan	Russell Beatty	Sydney Water project team	Addition of scenario runs. Updating of water quality parameters to produce consistency with water quality response in MIKE model for Harbour.
Version 1	23/07/2025	Phillip Jordan	Russell Beatty	Sydney Water project team	Address comments on Draft E report. Update all water quality verification plots and tables to be consistent with adopted parameters (adopted to fit receiving water model), instead of water quality monitoring data at sites in the catchment.

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Executive Summary

A catchment flow and water quality model was developed for the catchments that drain to Sydney Harbour in the eWater Source software. It runs on an hourly time step, covering the period between 1 July 2011 and 30 June 2024.

The Source model simulates catchment runoff using hourly time-step SimHyd models, with flows then routed between subcatchments using non-linear storage flow routing. Modelled time series of hourly sewer overflows were also incorporated into the Source model. Rainfall runoff and flow routing parameters were calibrated to gauge streamflow at 7 gauges across the study area. The calibration of the Source model to hourly gauged flows was very good at the 3 gauges that had the longest and most reliable records (in Toongabbie Creek, the Parramatta River and Upper Lane Cove River), with all producing Nash Sutcliffe Efficiency (NSE) values from hourly data greater than 0.8 and NSE values from daily data greater than 0.87. Calibration performance at the other 4 gauges was more variable but gauge records at these sites were typically only a few years and the rating of gauged level to flow at these sites was less accurate. The model generally produced a very good match to gauged flow for the total volumes of runoff for the 13 water years that were simulated.

The total area upstream of the calibration gauges is 188.6 km², which represents 39% of the total land area represented in the Source models. Only one streamflow gauge, 213219: Toongabbie Creek at Briens Road, has complete data for the entire model calibration period and the area upstream of that gauge is 68.9 km² or 14% of the study area. The other gauges have valid data for no more than half of the calibration period. The consequence of the generally high degree of urbanisation and limited streamflow gauging is that the purpose and role that calibration of rainfall runoff models to gauged flows should take in this study area is different to how it would be applied in most other catchments. The approach that adopted for this study relied upon a combination of calibration to the few gauges in the study area and on parameters of rainfall runoff models that are typically adopted in urban environments and identified from calibrations in neighbouring basins. A representative set of parameters from calibrated regions was calculated by weighting the parameter values from gauged parts of the model, which were then applied to the ungauged residual regions of all models that are downstream of all gauges.

The Source model was used to model constituent concentrations and loads for seven water quality parameters: Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), Enterococci, Oxidised Nitrogen (NOx, the combined concentrations of Nitrate, NO_3^- and Nitrite, NO_2^-), Ammonium (NH_4^+) and Ortho Phosphate (PO_4^{3-}). The Source model was used to generate water quality concentrations from catchment runoff and diluted stormwater overflows. Concentrations in catchment runoff of all water quality parameters were modelled using Event Mean Concentration Dry Weather Concentration (EMCDWC) models, with the EMC and DWC parameters varying by constituent and Functional Unit (FU). EMC and DWC parameter values adopted for constituents and FUs were informed by relevant literature (BMT WBM, 2015; Sydney Water, 2024) and comparisons with monitoring data in the study area. Constituent inputs from sewer overflows were modelled using the same method as was adopted in the Georges River Source model. Concentrations in raw sewage were taken as the median values of monitored inflows from a nearby Sewerage Treatment Plant. The magnitude of stormwater dilution varies with antecedent rainfall in the period prior to the stormwater overflow. The dilution factor is a function of the cumulative 24-hour antecedent rainfall (CAR).

The Source model produced generally very poor matches to Event Mean Concentrations of water quality parameters that were obtained from auto-samplers during events. Mean values of Event Mean Concentrations of monitored Total Nitrogen and Nitrogen species, Total Phosphorus and Ortho Phosphate, Total Suspended Solids were consistently lower than the corresponding event concentrations produced by the Source models. This was a consequence of adopting water quality parameters in the Source models to be consistent with parameters adopted in Source models in neighbouring catchments and to produce improved matches between modelled and monitored water quality concentrations in the receiving water model for Sydney Harbour. This could be a consequence of water quality monitoring data being limited to sites that were mainly in the upper part of each of the catchments, with limited water quality monitoring available at sites that were downstream of catchments with more densely developed upstream landuse.

The Source model was used to generate flow and load timeseries inputs to the MIKE model of Sydney Harbour for five scenarios:

- Baseline
- 2056 Background
- 2056 Background with climate change
- 2056 Impact
- 2056 Impact with climate change

Sydney Water supplied all the necessary inputs, including modified projections of climate data for the climate change scenarios and modified time series of sewer overflows for the five scenarios. The simulation of all five source models spanned from July 2015 to June 2022 (inclusive).

1. Introduction

The purpose of this project was to develop and calibrate flow and water quality models for the catchments that contribute flow to the waterways of the Paramatta River and Sydney Harbour. These models were developed in the eWater Source modelling software, version 5.40 (eWater, 2024a). The models generate flow and pollutants export boundary conditions for a Water Quality Response Model (WQRM), which will be developed in the MIKE 3 coast and marine water modelling software. The MIKE 3 model outputs will be used to inform an Environmental Impact Statement (EIS) relating to Sydney Water stormwater and wastewater management assets located in the Parramatta River estuary.

Four Source models were produced, for the catchments of the: Upper Parramatta River, Upper Lane Cover River, Upper Duck River and the remaining smaller catchments draining to the Sydney Harbour Estuary (including Vineyard Creek). These catchments are shown in Figure 1-1, along with the Sydney Harbour receiving waters.

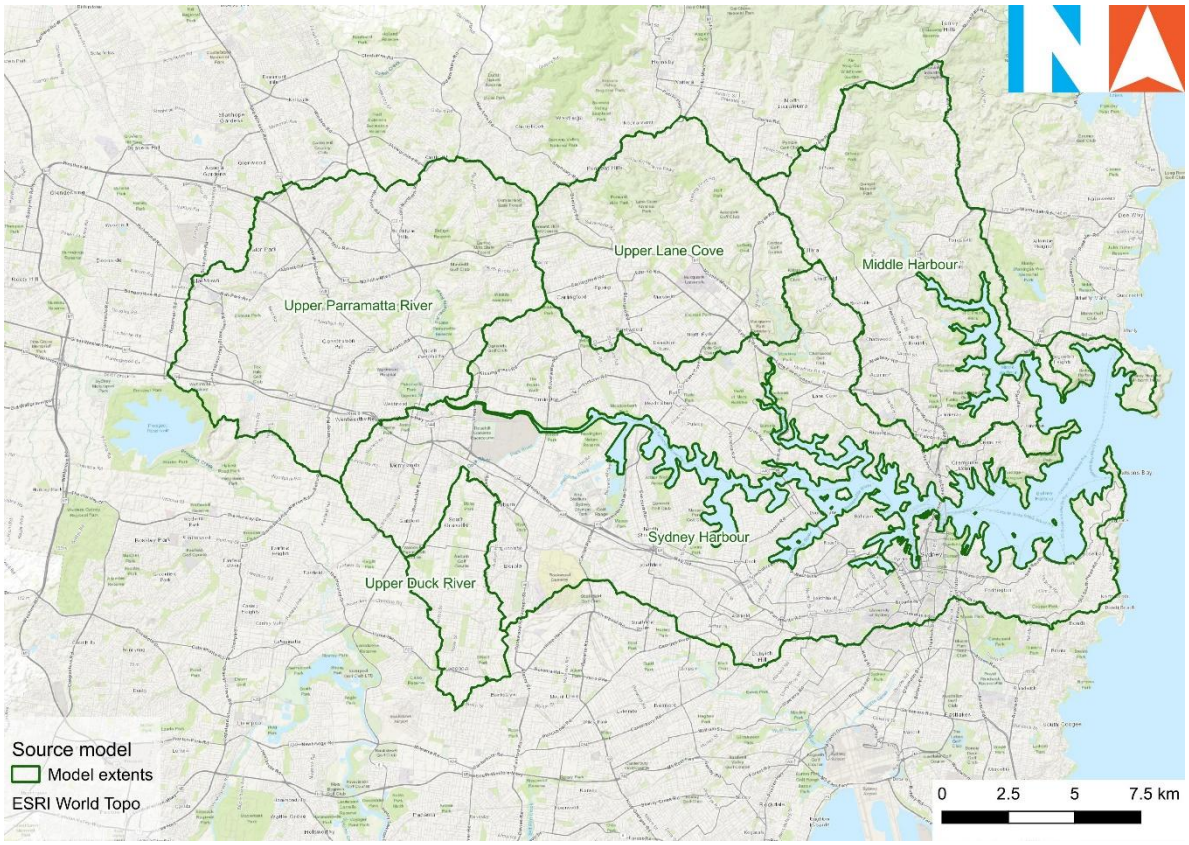

Figure 1-1 Study area map showing boundaries of the Source model extents

2. Source model structure

2.1 Spatial data

The coordinate system adopted for this project was Geocentric Datum of Australia 2020 (GDA 2020), Zone 56 and all the inputs for Source modelling were reprojected to this coordinate system.

The Digital Elevation Model (DEM) for this model was downloaded from the ELVIS cloud-based elevation and bathymetry database as a TIFF file, sourced from the DEM 5-Metre Grid of Australia derived from LiDAR (Intergovernmental Committee on Surveying and Mapping, 2024: https://elevation.fsdf.org.au/).

A Python script was prepared by burning in the initial hydro lines provided, to trace the stream network from each of the pour points and headwater nodes and down to the catchment outlet, by following the flow direction grid determined from the lowest adjacent grid cell to one of the four sides or four corners of each grid cell (referred to as the eight direction, or D8 flow direction grid, see Lindsay, 2023).

2.2 Model structure

Source allows for the explicit modelling of spatial variations in inputs and key processes. It models catchments and river systems as a series of nodes interconnected with links. The sequence of nodes and links forms a model network. The nodes in the models include the following:

- Confluence nodes:
  - Flow and constituent generated from each sub-catchment
  - Confluence between two streams
- Gauge nodes
  - Locations where streamflow gauging or water quality monitoring data is available (for calibration and/or comparison with modelled outputs)
- Inflow nodes
  - Point sources to add flows specifically from treated and untreated overflow discharges

The links are defined based on the main tributaries and streams. The models use both storage routing and straight-through routing for these links. Storage routing allows for flow lagging and attenuation between upstream and downstream nodes in the freshwater tributaries. Straight-through links are used in the models to connect both overflow inflow nodes and catchments adjacent to estuary coastal shorelines, where the tide influences flow directions. Figure 2-1 shows the Source model for the study area, noting the extent of the 715 model subcatchments and the link network connecting those subcatchments.

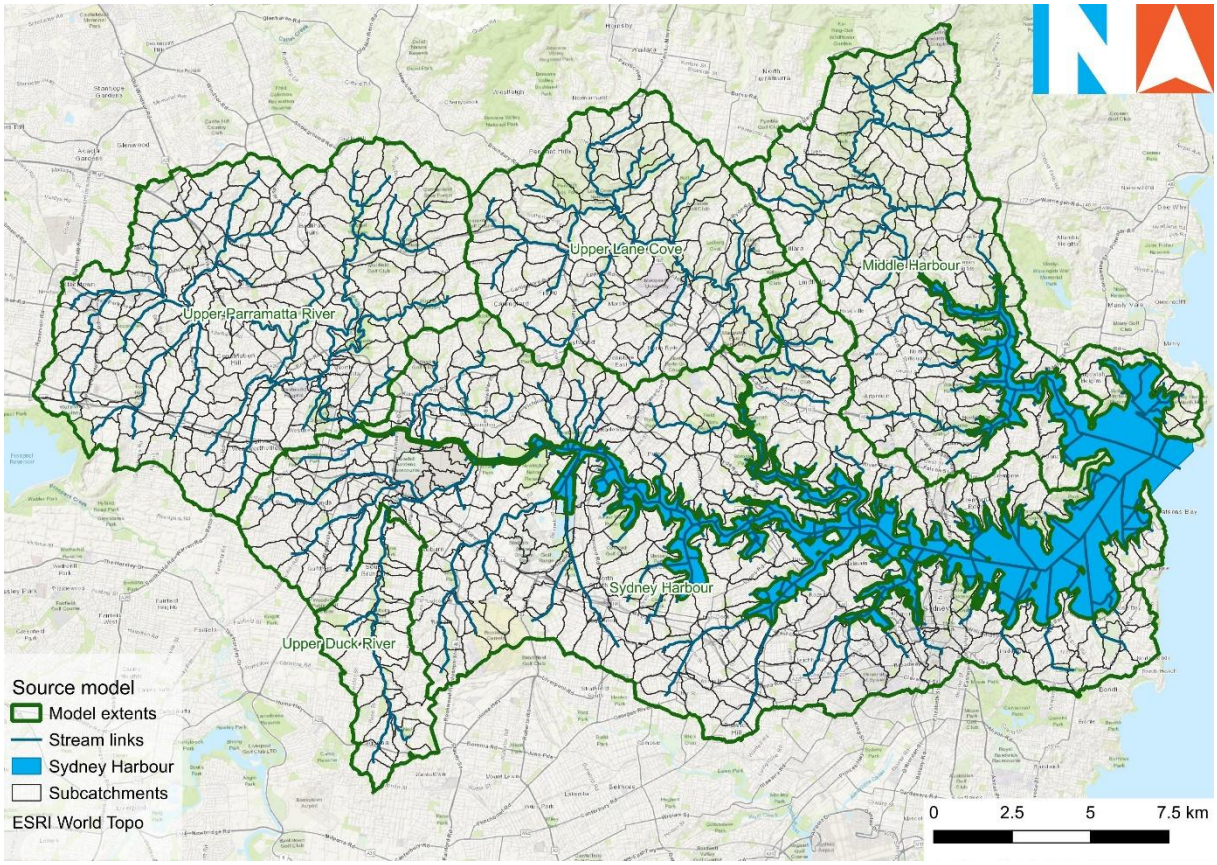

Figure 2-1 Source model subcatchments and link network

2.3 Land use and functional units

The land use layer used in this project was updated in 2018-2019 for ecological response modelling. The data sources for this modelling included Sydney Water's 2019 Hydra land parcel data, local environment plan zones, Nearmap, and NSW land use data from the NSW Department of Planning and Environment.

For this model, land use data named “SH_Land_Use_Final” was provided by Sydney Water and utilised. A map of this data is shown in Figure 2-2. The nine land use categories from the initial data provided, were grouped into six parameter sets as seen in Table 2-1. Note that these six land use categories were also adopted as the Functional Units (FU’s) in the Source rainfall-runoff modelling.

Total areas of each functional unit by Source model are shown in Table 2-2. The proportion of each Source model area covered by each functional unit are provided in Table 2-3. The proportion of rural landuse across each of the models is similar, varying between 42% (in Middle Harbour) and 51% (Upper Parramatta). Bush and parkland areas make up a larger proportion of the Middle Harbour (35%) and Upper Lane Cove (27%) Source models than the remaining three models (all ~16%). The Source models represent runoff and constituent generation within each subarea of each of the models, so spatial variations in runoff and constituent generation are carried forward by the Source models into the inflow time series that are generated for input to the MIKE models.

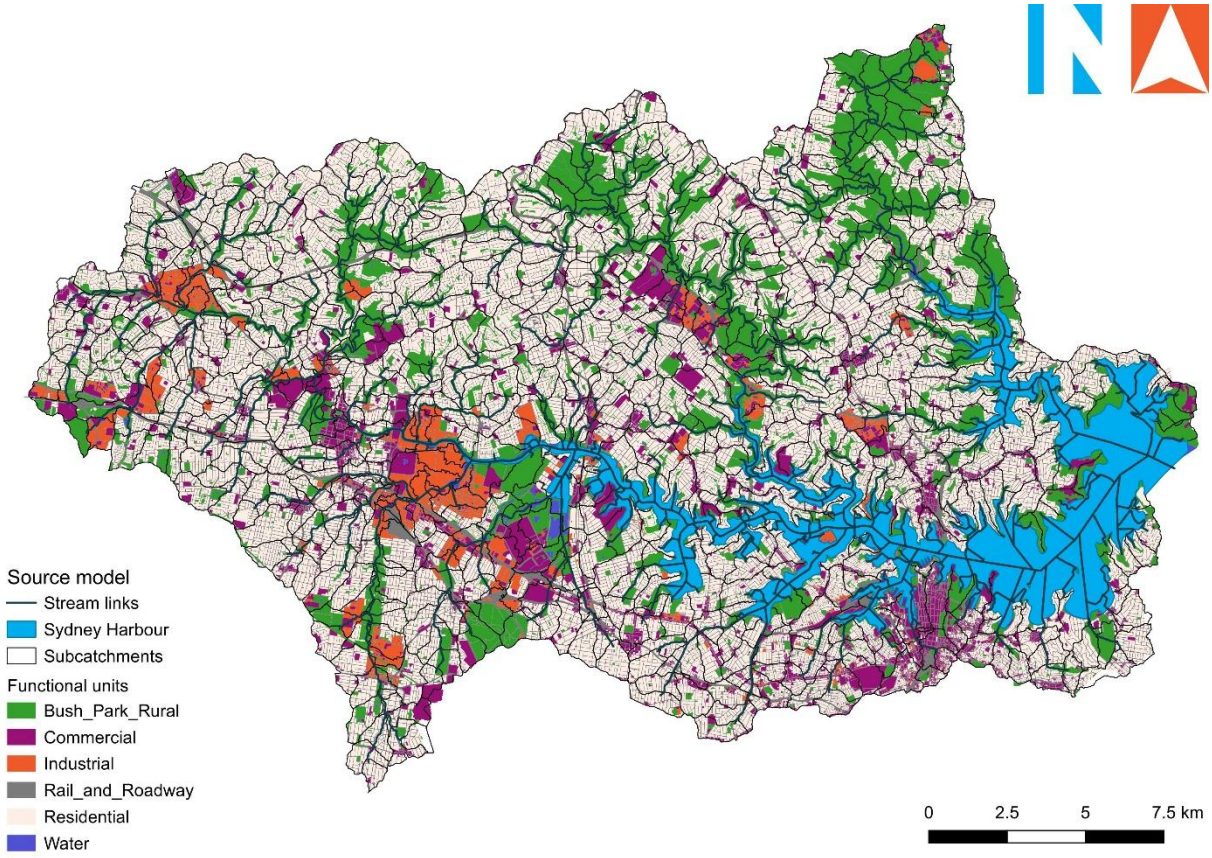

Figure 2-2 Landuses and functional units across the study area, overlaid with Source model subcatchments and link network

Table 2-1 Assignment of functional units (land use categories) in Source model

Functional unit (i.e. land use category)	Land use grouping in Source
Railway Roadway	Rail_and_Roadway
Bushland Parkland Rural	Bush_Park_Rural
Industrial	Industrial
Commercial	Commercial
Residential	Residential
Water	Water

Table 2-2 Total area of functional unit in each Source model

Land use grouping in Source	Area by Source model (km²)					Total area in all models (km²)
	Upper Lane Cove River	Middle Harbour	Upper Parramatta River	Upper Duck River	Sydney Harbour	
Rail_and_Roadway	11.06	12.82	21.68	4.14	45.89	95.59
Bush_Park_Rural	17.57	27.71	17.27	3.02	33.10	98.68
Industrial	0.68	1.34	5.15	1.71	10.55	19.44
Commercial	4.71	3.62	8.26	1.35	24.92	42.87
Residential	31.63	33.21	54.79	9.12	93.03	221.76
Water	0.33	0.84	0.66	0.06	3.10	4.99
Total	65.99	79.55	107.82	19.41	210.59	483.34

Table 2-3 Proportion of each Source model area represented by functional units

Land use grouping in Source	Upper Lane Cove River	Middle Harbour	Upper Parramatta River	Upper Duck River	Sydney Harbour	All Models
Rail_and_Roadway	16.8%	16.1%	20.1%	21.3%	21.8%	19.8%
Bush_Park_Rural	26.6%	34.8%	16.0%	15.6%	15.7%	20.4%
Industrial	1.0%	1.7%	4.8%	8.8%	5.0%	4.0%
Commercial	7.1%	4.6%	7.7%	6.9%	11.8%	8.9%
Residential	47.9%	41.7%	50.8%	47.0%	44.2%	45.9%
Water	0.5%	1.1%	0.6%	0.3%	1.5%	1.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

3. Input data

3.1 Rainfall

Hourly rainfall data was provided by Sydney Water for the study area. Hourly rainfall depths were spatially interpolated to the centroid location of each of the 715 subcatchments from hourly rainfall data recorded at gauges around the study area. Figure 3-1 shows the locations of the 72 hourly rainfall gauges that were used in the interpolation process. The spatial interpolation process created a weighted average hourly rainfall, at the centroid of each of the subcatchments, using inverse-distance weighting of the hourly rainfall from the five nearest rainfall gauges that recorded valid data in each hour of the model run period.

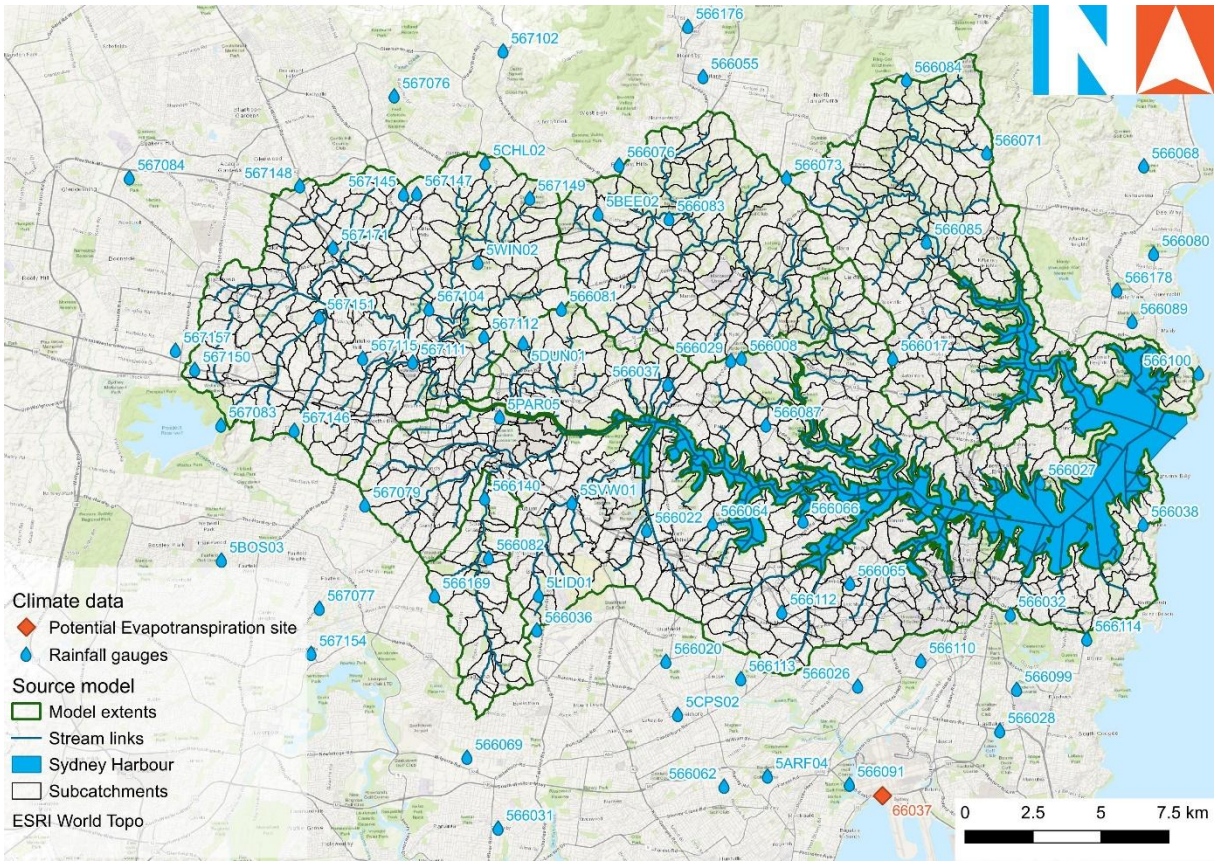

Figure 3-1 Map of locations of rainfall gauge sites and potential evapotranspiration (PET) site used for deriving climate inputs to the Source models

3.2 Potential Evapotranspiration

Morton's Wet Areal Potential Evapotranspiration (PET) is recommended as being suitable for rainfall runoff modelling in Australia (McMahon *et al.*, 2013). The study area is sufficiently small that PET data obtained at a single climate data station was appropriate for representing PET in the rainfall runoff models across the entire study area.

Daily PET time series were obtained at Bureau of Meteorology site number 66037, Sydney Airport Meteorological Office. The location of the PET gauge is shown in Figure 3-1. The daily PET data was obtained from the SILO Long Paddock website, using the Morton's Daily Wet Areal PET algorithm, for the period between 1 January 2010 and 30 June 2024 (Queensland Department of Environment and

Science, 2020; Queensland Government, 2025). Checks were undertaken to confirm that there was no trend in PET with air temperature, across the 2010 to 2024 period (see Figure 3-2, which shows that there is a straight line with constant slope between cumulative temperature and cumulative PET). Figure 3-3 shows the daily Morton's Wet Areal PET data for the site.

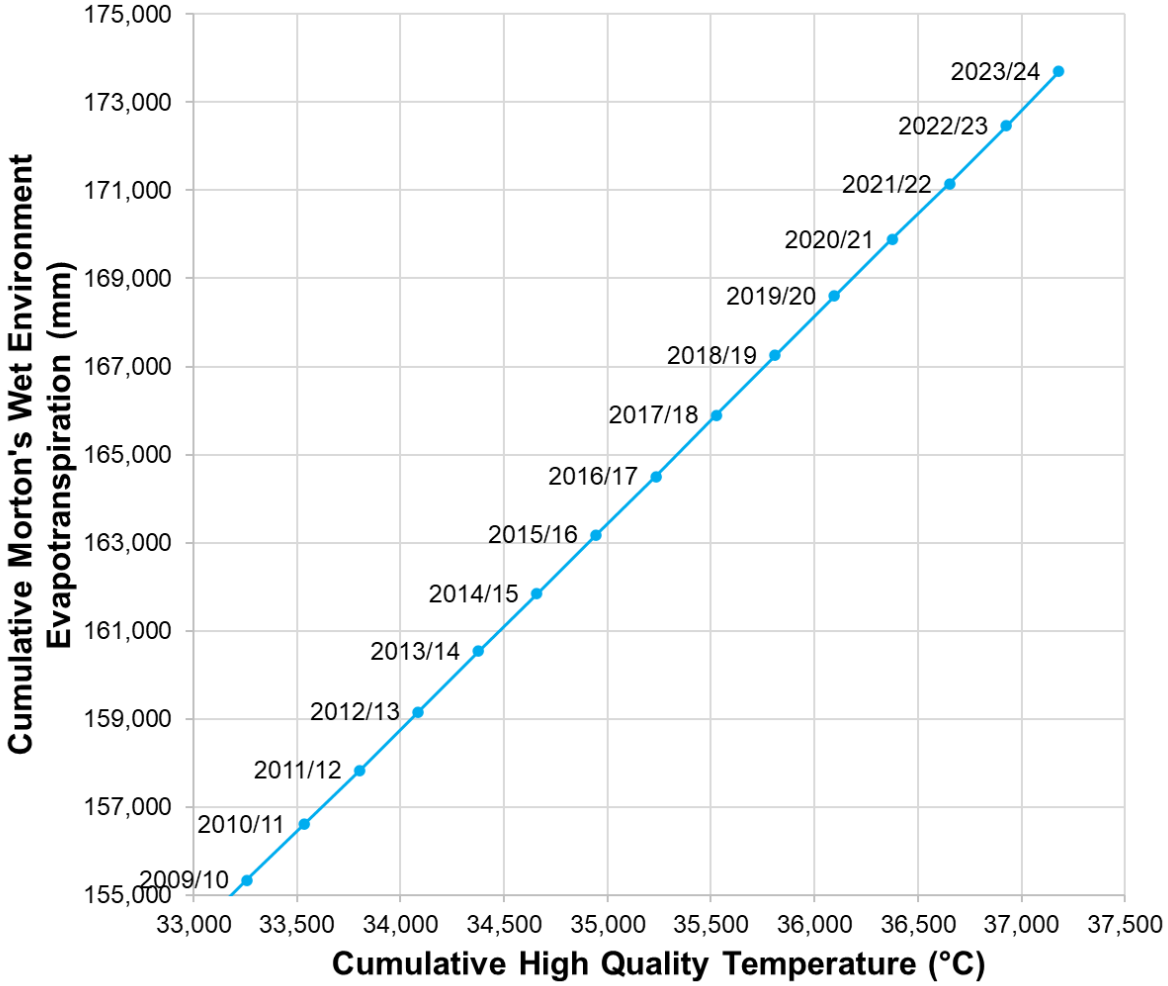

Figure 3-2 Double-mass curve of cumulative daily temperature and cumulative Morton's Wet Environment Potential Evapotranspiration for 2009/10 to 2023/24 water years

The Source model runs on an hourly time step. The daily PET data was disaggregated to an hourly time step, by calculating the hourly pattern of incoming net solar radiation within each day. The data was disaggregated for the entire model run period (2011 to 2024), with Figure 3-4 showing a portion of the disaggregated hourly data for the period between August and November 2011.

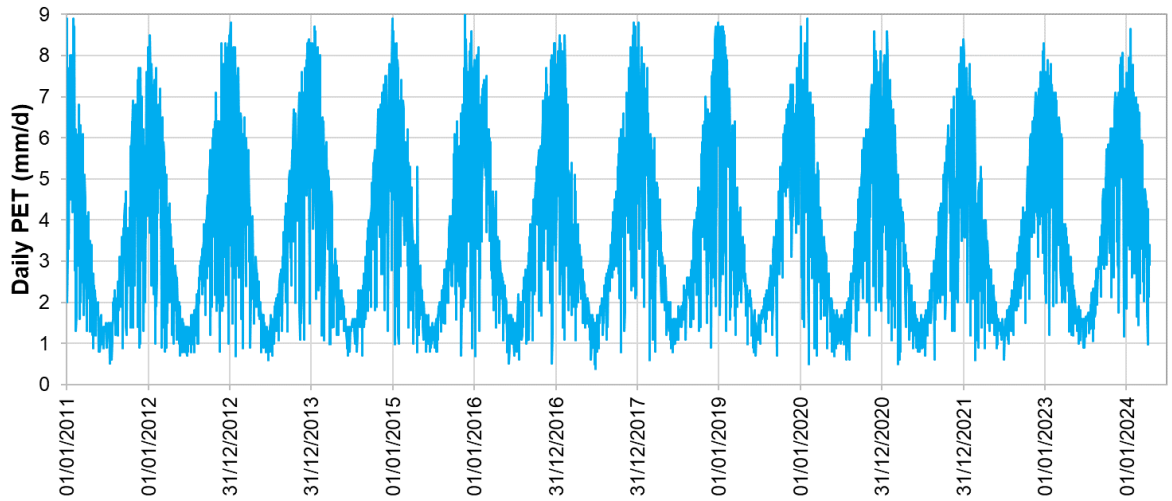

Figure 3-3 Daily Morton's Wet Areal Potential Evapotranspiration (PET) data for 2011 to 2024

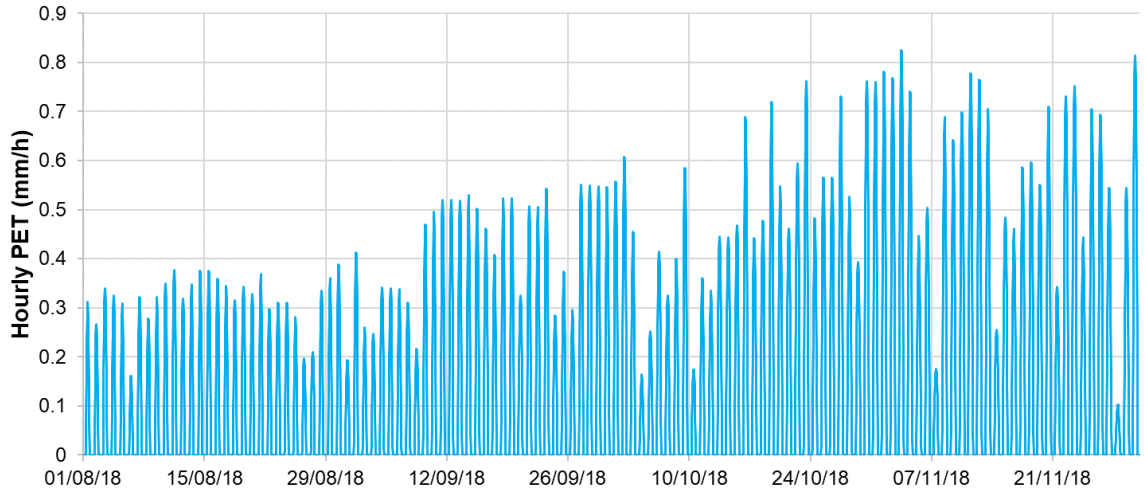

Figure 3-4 Hourly Morton's Wet Areal Potential Evapotranspiration (PET) data

3.3 Sewer overflows

Hourly time series of sewer overflow volumes were supplied by Sydney Water, for the period between 1 July 2011 and 30 June 2024. Sewer overflows were provided as an aggregate total for 191 Source model subcatchments. Sewer overflows were calculated by Sydney Water using hydraulic models of sewer networks in the North Head, Malabar and Bondi systems. The locations of the sewer overflow inputs to the Source models are shown in Figure 3-5. It should be noted that there were additional sewer overflows that were applied directly into the MIKE receiving water model, which were not in the Source model and are not shown on Figure 3-5.

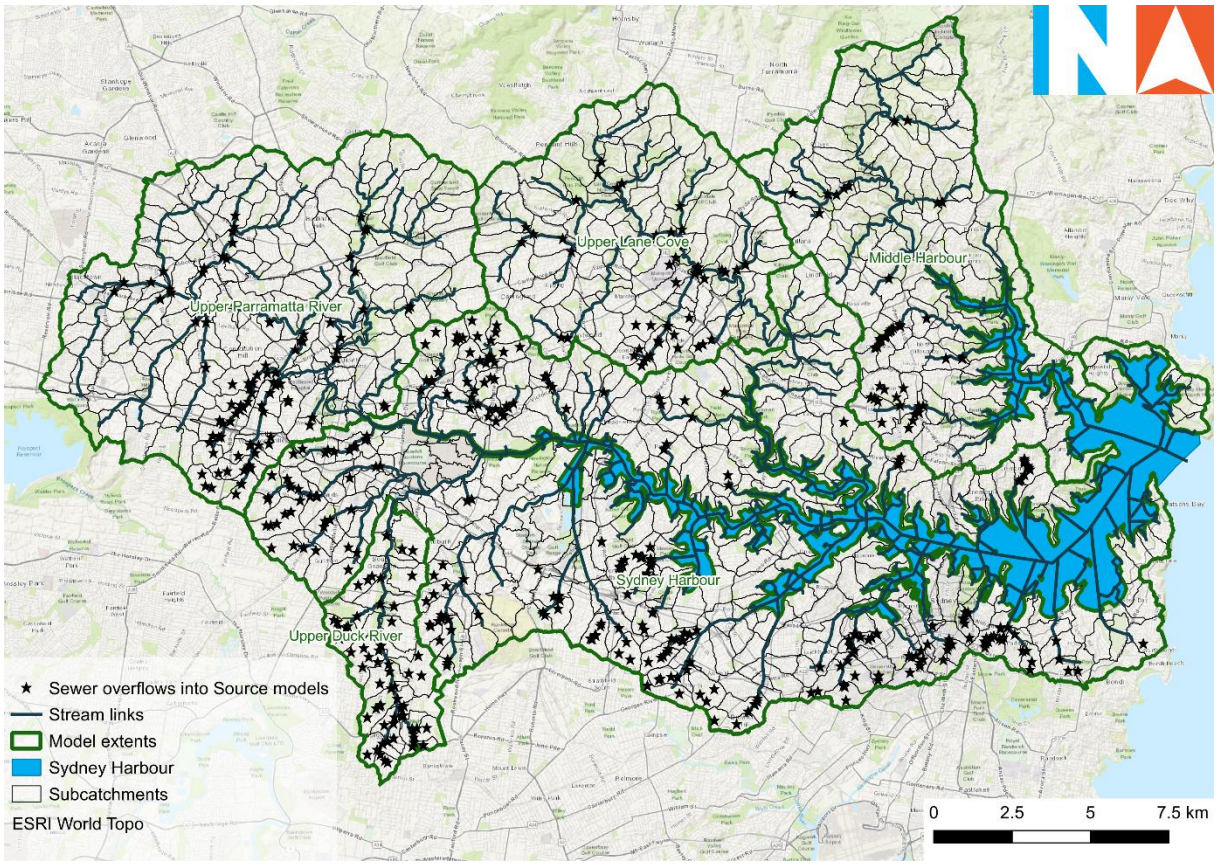

Figure 3-5 Study area map showing sewer overflow inputs to the Source model (noting that there were additional direct sewer overflow inputs to the MIKE receiving water model)

Total volumes for each water year total volumes of all sewer overflows that were input to the Source model are shown in Figure 3-6.

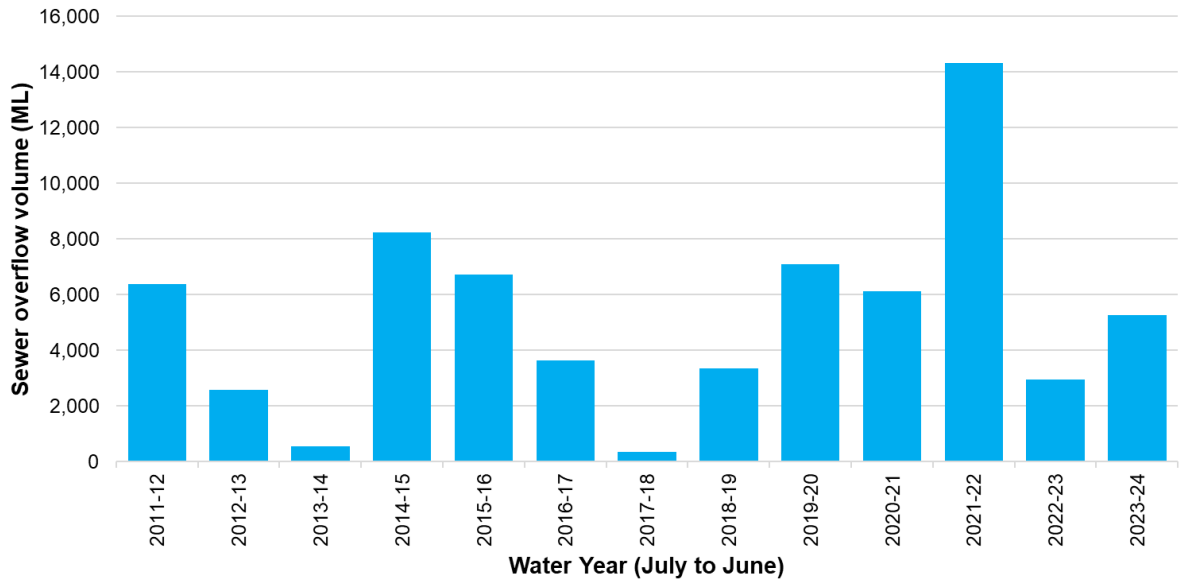

Figure 3-6 Total volume of modelled sewer overflow by water year that were input to the Source model

3.4 Gauged streamflow

Water level and flow data was obtained at several gauges in the study area. For gauges where only water level data were provided, a rating table was supplied that was used to convert gauged water levels to flow rates. Figure 3-7 shows the locations of streamflow gauging stations across the study area.

The streamflow gauging stations in the study area and the period of available record at each gauge is listed in Table 3-1. There is relatively limited streamflow gauging across the study area. The nature of the study area is that there are many smaller streams, which drain directly to the Harbour. Water levels at the lower end of streams draining to the harbour are tidally influenced, which makes them unsuitable for estimation of flows using simple water level to flow relationships.

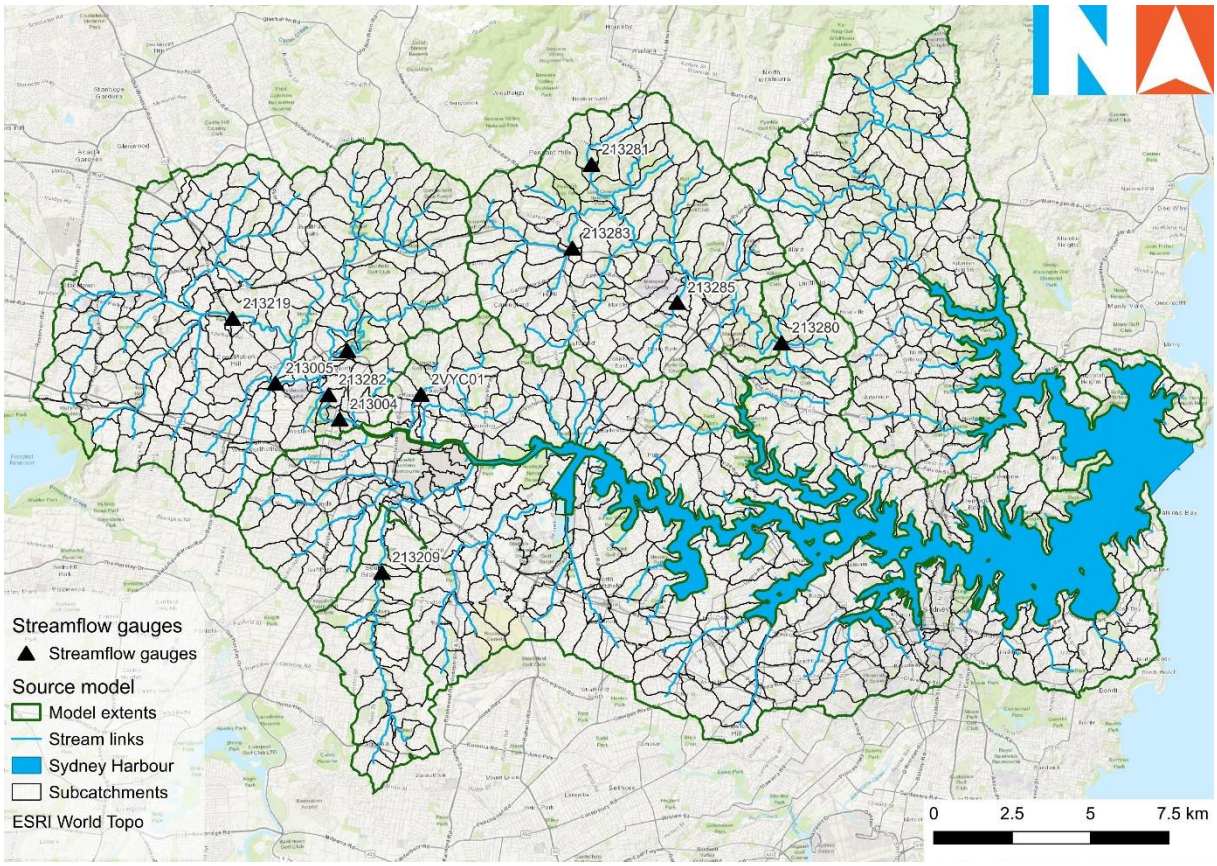

Figure 3-7 Location of streamflow gauges in the study area[1]

[1] The unlabeled gauge site is Lake Parramatta Dam but storage effects at the dam made it difficult to reliably convert recorded water levels at the gauge site to inflow rates to the Dam. This gauge would have added little additional data, as there were already 4 streamflow gauges in the Upper Parramatta River catchment that were used for Source model calibration.

Gauged water level and flow data was obtained for gauge 213005 (Toongabbie Creek at Briens Road) from the WaterNSW water monitoring data portal website. Hydrographers regularly rate the flows at the 213005 gauge and progressively update the rating of water levels to flows at this site (see Figure 3-8).

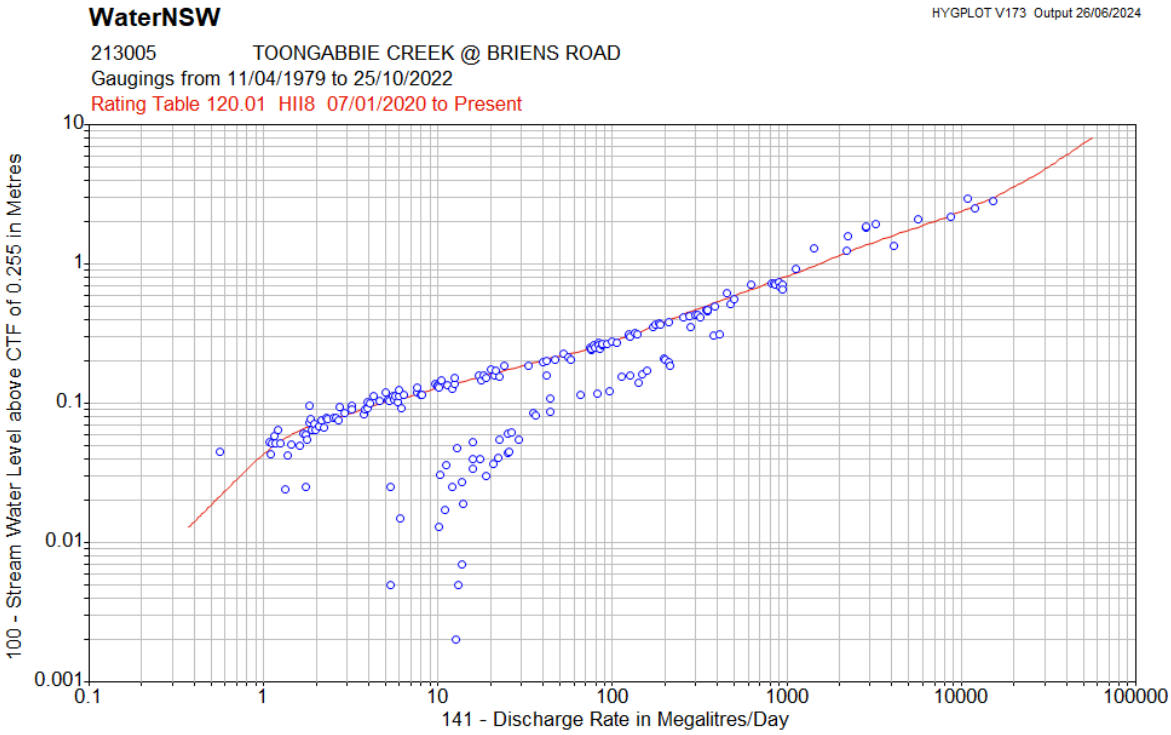

Figure 3-8 Rated flows and current rating table for gauge 213005 Toongabbie Creek at Briens Road (from WaterNSW water monitoring data portal)

The flows at the 213005 gauge are therefore reliable across the entire period of record and full range of flows, from low flows to flood events. By comparison, the rating information at all other sites in the study area is considerably poorer in quality. Whilst these other gauges could generally record flows during moderate to high flow events (greater than about 200 ML/d) with some level of reliability, they were often poor at accurately capturing low flows. Visual inspection of the flow hydrographs at other gauges showed transitions from one flow rate to another, which were inconsistent with the flow hydrographs recorded at the 213005 gauge, which was a few km away and in the same catchment. These inconsistencies were most likely caused by errors in recording of the water levels at the other gauge or changes in the rating of the gauge over time, which were not well represented by the single rating table for the site supplied by either Sydney Water or the BoM (for an example, see Figure 3-9).

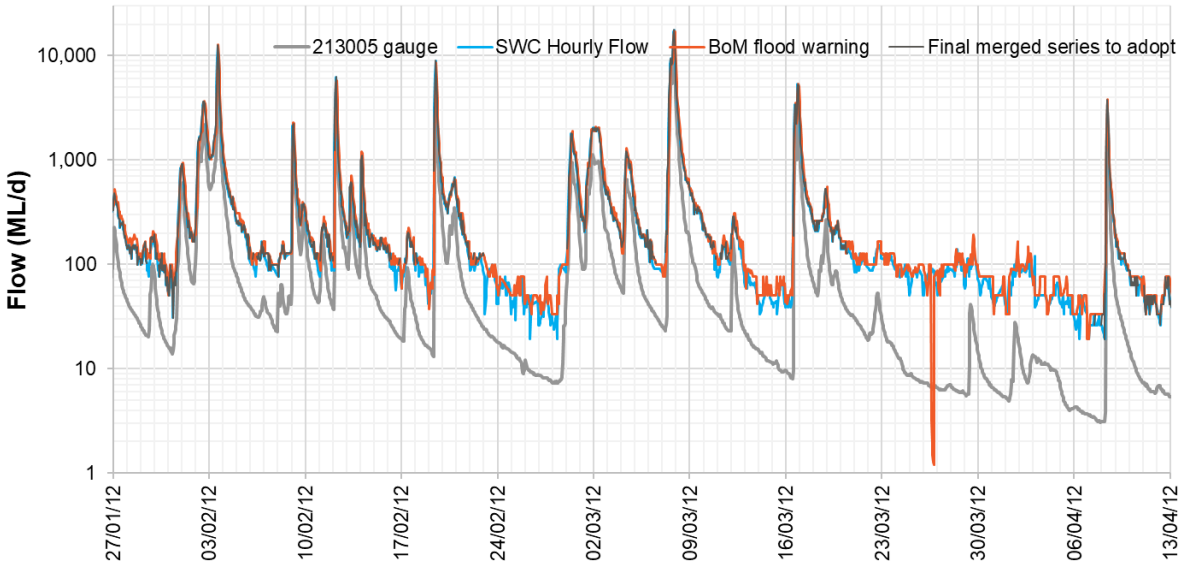

Figure 3-9 Comparison of gauged flows at 213004 (Parramatta River at Marsden Street Weir) and 213005 (Toongabbie Creek at Briens Road), showing periods that were removed from the 213004 data series for model calibration, due to spikes in recorded levels and inconsistencies in rated flows between the two sites

There were two gauges where data was supplied, for different periods, from Sydney Water and the Bureau of Meteorology (BoM) flood warning gauge network. A merging and quality assurance process was undertaken at these two gauges (213004 and 213219), which is detailed in Appendix A. At all other sites, water level and rated flow data was supplied from a single data supplier. Periods of gauge data without valid water level data or where the derived flow data had obvious high or low flow spikes or inconsistent ratings were removed from the time series that were used for calibration of Source model flows and representation of model flow performance statistics.

The final list of gauges utilised for calibration are detailed in Table 3-1.

Table 3-1 Streamflow gauges

Number	Name	Start date	End date	Years of valid data
2VYC01	Vineyard Ck @ Kissing Point Rd	10/09/2013	18/09/2014	1
213209	Duck River @ Mackay Road South Granville	10/03/2011	17/10/2022	6
213280	Lane Cove River @ Lane Cove Weir	8/07/2013	9/08/2022	6.2
213281	Lane Cove River @ Fox Valley	1/09/2013	13/03/2014	0.5
213283	Devlins Creek @ Epping	5/09/2013	13/03/2014	0.5
213285	Shrimptons Creek @ Alma Road	6/09/2013	13/03/2014	0.5
213005	Toongabbie Creek @ Briens Road	1/01/2011	30/06/2024	13.5
213219	Toongabbee Creek @ Johnstons Bridge (Upper Parramatta River Catchment Trust)	05/08/2011	02/06/2023	7.2
213282	Parramatta River @ Cumberland Hospital	19/12/2012	09/01/2015	2.1
213004	Parramatta River @ Parramatta Hospital (former Department of Water Resources) or Parramatta River @ Marsden Street Weir	24/10/2012	31/12/2023	7.6
	Lake Parramatta Dam	1/04/2013	14/08/2013	0.4

3.5 Water quality monitoring

Water quality monitoring data was provided at the sites shown in Figure 3-10.

Three Sydney Water monitoring sites were located in the Upper Lane Cove River catchment. Water quality sampling was undertaken at these sites for several events that occurred between May 2013 and August 2014. There were 5 Sydney Water sites in the Upper Parramatta River catchment and one on Vineyard Creek. The auto-sampling sites are listed in Table 3-2, noting the number of events and the total number of water quality samples taken at each site. The dates of events at each site, number of samples of each constituent in each event at each site and monitored event mean concentrations are provided for all these sites in Appendix D. Although monitoring data was provided for the site on Vineyard Creek, the data provided had the date of sampling but not the time. Since times of sampling were not provided, it was not possible to use this data for calculating event loads or for comparison against Source modelling results.

There were 4 Parramatta Council operated water quality monitoring sites on the Parramatta River, in the reach near the Parramatta Central Business District, as listed in Table 3-3. All these sites had sampling at weekly intervals during the period of monitoring. There were also 4 Parramatta Council operated water quality monitoring sites in Lake Parramatta Dam, which are listed in Table 3-4.

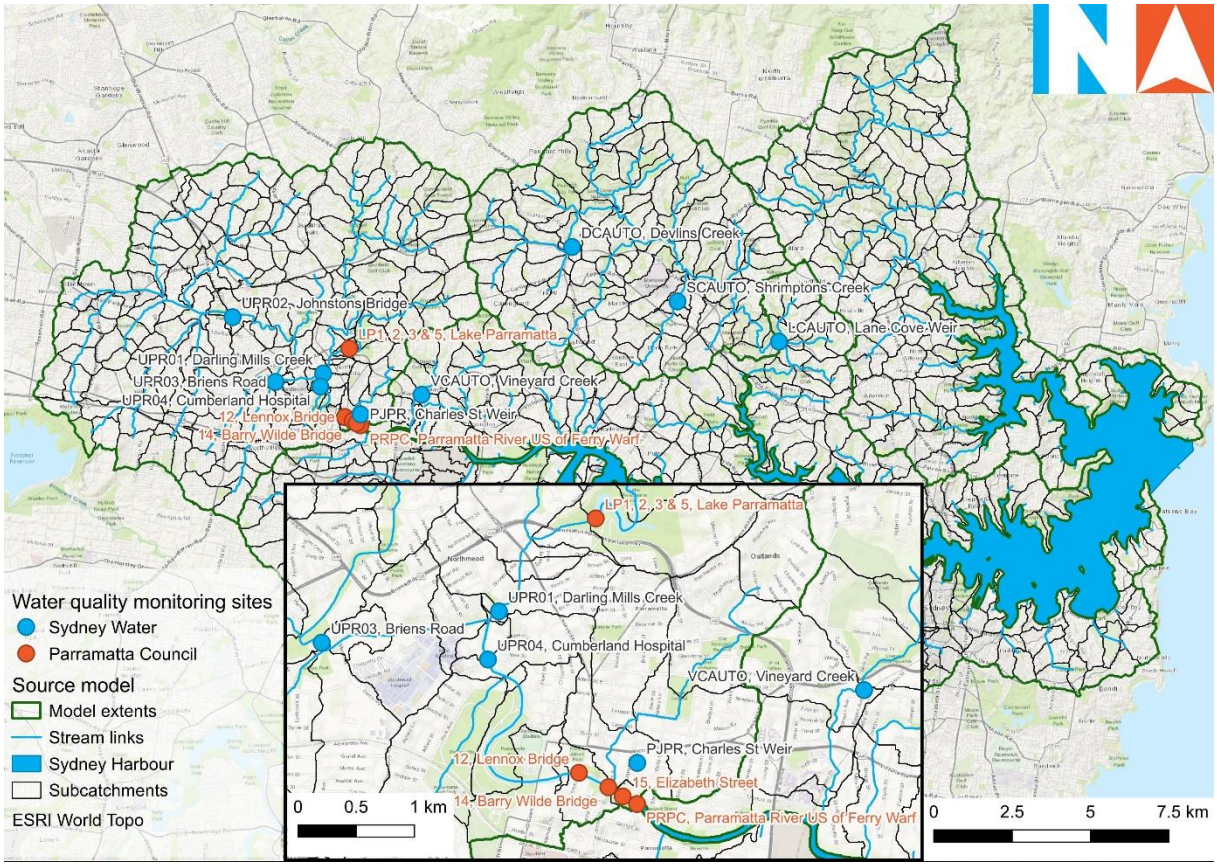

Figure 3-10 Location of water quality monitoring sites in the study area

Table 3-2 Sydney Water operated auto-sampler sites for water quality monitoring

Water quality site code	Site name	Gauge number or Source node	Number of monitored events	Total volume of monitored events (ML)	Number of samples across all events
LCAUTO	Lane Cove National Park Weir	213280	6	8,442	128
DCAUTO	Devlins Creek	213283	7	1,423	152
SCAUTO	Shrimptons Creek	213285	6	936	81
UPR03	Briens Road	213005	2	2,367	49
UPR01	Darling Mills Creek	HW_02	2	1,710	52
UPR04	Cumberland Hospital	UPR04	3	6,391	58
VCAUTO	Vineyard Creek	2VYCO1	5*	NA*	74*

* Water quality monitoring data for Vineyard Creek (VCAUTO) had dates supplied but no times associated with samples. It was therefore not possible to use any of the monitoring data from this site to assess Event Mean Concentrations or to verify the Source model

Table 3-3 Weekly water quality monitoring sites in Parramatta River near Central Business District

Site Name	Relevant constituents sampled	Number of TSS samples
Lennox Bridge	TSS	12
Barry Wilde Bridge	TSS	12
Elizabeth Street Footbridge	TSS	12
PRPC	TSS	34

Table 3-4 Intermittent water quality monitoring sites at Lake Parramatta Dam

Water quality side code	Relevant constituents sampled	Number of samples of each constituent
LP1	TN, TP	61
LP2	TN, TP	20
LP3	TN, TP	61
LP5	TN, TP	61

3.6 Output reporting locations

The Source model was used to generate hourly time series of inputs to MIKE models of Sydney Harbour. Outputs from the Source models were produced at 23 headwater nodes (blue diamonds with labels starting “HW_”, in Figure 3-11) and 215 subcatchment outflow nodes (orange dots in Figure 3-11). Hourly time series outputs at each node were provided in 238 individual files, labelled starting with HW_ for the headwater nodes and PP_ for the subcatchment outflow nodes.

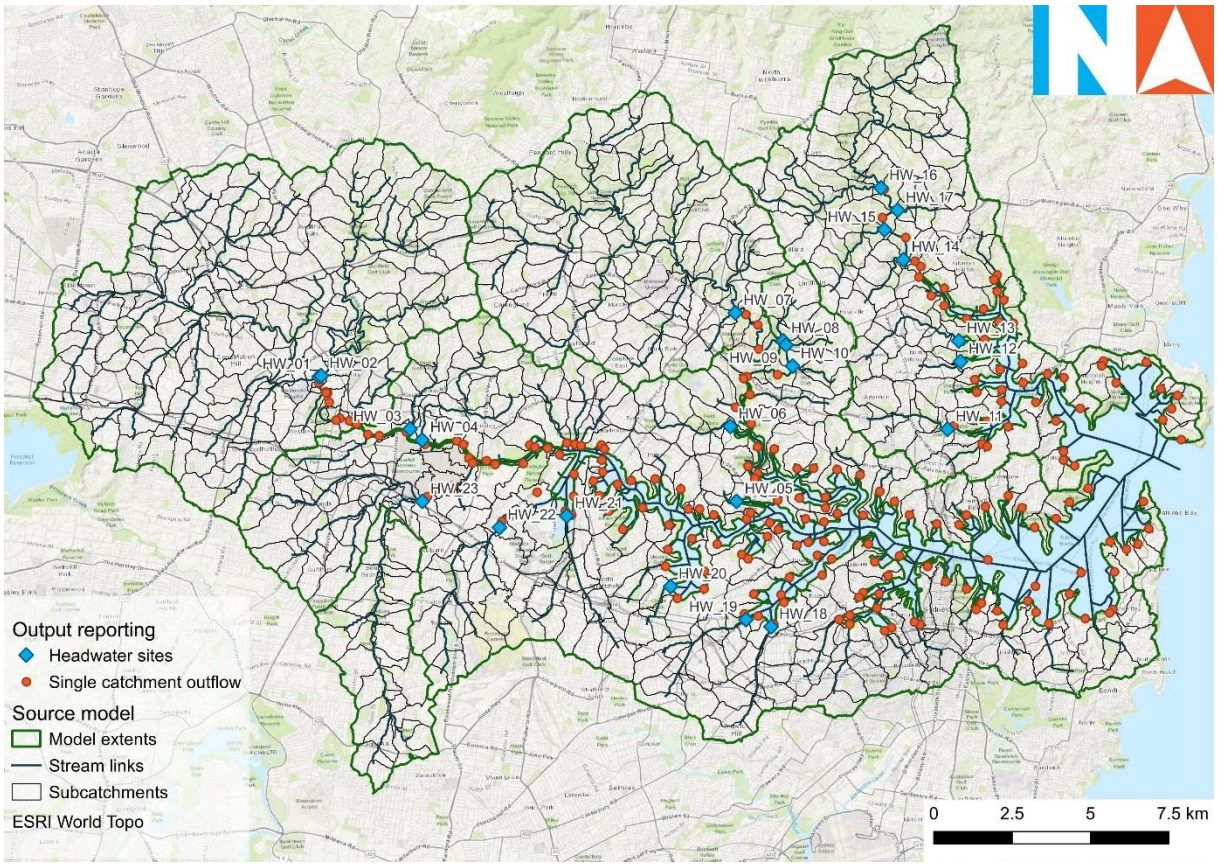

Figure 3-11 Study area map showing locations of outputs from the Source models to MIKE receiving water model

4. Rainfall runoff modelling

4.1 Hourly SimHyd model structure

All rainfall runoff models are conceptual models that represent the catchment hydrological response to rainfall as a series of mathematical relations. They estimate catchment runoff from climate input datasets. The Source modelling platform applies rainfall-runoff modelling at the functional unit scale but aggregates runoff output at the sub-catchment scale.

Rainfall runoff modelling for all FUs in the model was undertaken using the SimHyd rainfall runoff model, which were run on a 1 hour time step. The default implementation of SimHyd in Source now permits running on a 1 hour time step, so plugins to Source were not required to run the hourly SimHyd model. The SimHyd model is a simple lumped conceptual rainfall-runoff model commonly used in Australia. The SimHyd model also provides the ability to apply a physical representation of pervious areas, which can be used to capture changes in land use from non-urban (green space) to urban. Figure 4-1 illustrates the conceptual diagram of the SIMHYD model (eWater 2022).

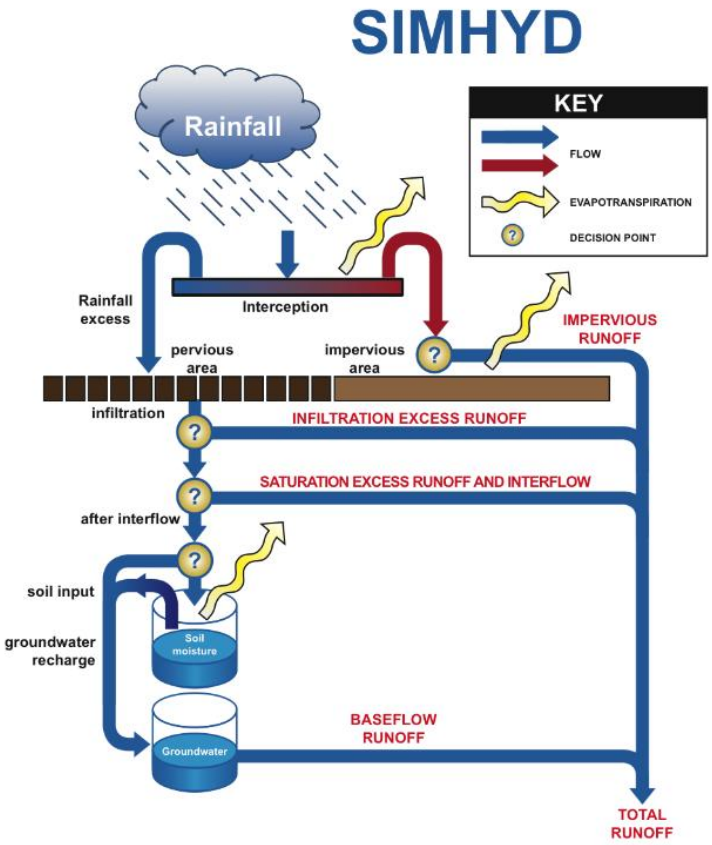

Figure 4-1 Conceptual diagram of the SIMHYD model

4.2 Fixed parameter values and feasible parameter ranges

The SIMHYD model has nine parameters, with typical ranges listed in Table 4-1. The first seven parameters listed in the Table control the runoff response from the pervious portion of the FU, the eight parameter controls the runoff response from the impervious area and the Impervious Fraction

specifies the proportion of the FU that is pervious or impervious. Typical parameter ranges were informed by the Source Scientific Reference Guide (eWater, 2024b) and previous experience in applying the SimHyd model in Australian catchments.

The study area has a high proportion of urban area. For many parts of the study area, a large proportion of the runoff will be generated from the impervious proportion of urbanised land uses. The influence of the Rainfall Interception Storage Capacity parameter on runoff is weak, particularly in urbanised areas. Since it had very little influence on the rainfall runoff response, the Rainfall Interception Store Capacity was set to a fixed value of 2.5 mm.

Table 4-1 SimHyd rainfall runoff model parameters and typical ranges

Parameter	Units	Typical minimum value	Typical maximum value
Rainfall Interception Store Capacity	mm	0	5
Soil Moisture Store Capacity	mm	20	600
Infiltration Shape	None	1	10
Infiltration Coefficient	None	50	500
Interflow Coefficient	None	0.1	0.9
Recharge Coefficient	None	0.1	0.95
Baseflow Coefficient	None	0.00001	0.01
Impervious Threshold	mm	0	2 mm/d or 0.5mm/h *
Impervious Fraction	None	0%	100%

* Note: Impervious threshold is time-step dependent. Whist impervious threshold values for urban land uses in a daily time-step model would typically be around 1 mm/d, lower impervious threshold values are likely in an hourly time-step model, as depression storage in urban areas would fully or partially fill in the first hour of a rainfall event and the rainfall required to create runoff from impervious areas in subsequent hours of the day would normally be minimal.

The pervious fraction has been derived based on guidance provided in the NSW MUSIC Modelling Guideline (BMT WBM, 2015) and *Australian Rainfall and Runoff* (ARR) (Ball *et al.*, 2019; Hill and Thomson, 2019). The guidance highlights that the impervious area response in the catchment models should be represented by the effective impervious area (EIA), which is a fraction of the total impervious area (EIA factor). EIA contributes to surface runoff observed at the outlet during hours when hourly rainfall exceeds the rainfall threshold. Table 4-2 lists the recommended typical EIA factors for residential, commercial, and industrial areas according to the guideline. Based on adjustments from the EIA factors, the final pervious fractions in the Source models are provided in Table 4-5. The adopted total impervious area fractions, which include impervious areas that are not connected to drainage, are shown on the bottom row of Table 4-5. For residential land uses, the total impervious area is 2/3 of the total area but as only 60% of that impervious area contributes to direct surface runoff, the effective impervious fraction is 40.2%. The total impervious area fractions for commercial and industrial properties are larger than for residential properties, at 89% and 94.2% respectively. With the EIA to Total Impervious Area (TIA) factors adopted, the effective impervious fractions were 71.2% and 84.8% for commercial and industrial land uses. Roads and railways were assumed to have effective and total impervious fractions of 100% but the impervious threshold adopted for the roads and railway FU were larger than for all other FUs in the model (see Table 4-5), to allow for the effects on runoff generation of railway ballast, gap-graded road pavement and small portions of pervious areas within road and railway reserves, such as median strips.

Table 4-2 Typical Effective Impervious Areas Proportions for MUSIC Models in NSW

Land use or FU	Effective Impervious Area factor
Commercial	0.8
Industrial	0.9
Residential	0.6

Table 4-3 Total pervious and impervious fractions and effective impervious area fractions

Model and gauge region	Bush, parkland and rural	Residential	Commercial	Industrial	Road and railway
Pervious Fraction	97.0%	59.8%	28.8%	15.2%	0.0%
Effective Impervious Fraction	3.0%	40.2%	71.2%	84.8%	100.0%
EIA/TIA ratio	60.0%	60.0%	80.0%	90.0%	100.0%
Total Impervious Area Fraction	5.0%	67.0%	89.0%	94.2%	100.0%

The Impervious Threshold parameter sets the volume in each 1 hour time-step of the model that is lost to depression storage in impervious areas. In simulations that calculate impervious area runoff at a daily time step, such as the SURM model used in MUSIC, an Impervious Threshold of 1 mm is adopted for most urban land uses or 1.5 mm for roads. However, impervious threshold is time-step dependent. Lower impervious threshold values are likely in an hourly time-step model, as depression storage in urban areas would fully or partially fill in the first hour of a rainfall event and the rainfall required to create runoff from impervious areas in subsequent hours of the day would normally be minimal. Simulations for the study area with typical rainfall input (and with all other parameters the same), found that simulations run at hourly time-step with an Impervious Threshold parameter 1/5 of the Impervious Threshold parameter value for a daily time-step model produced the same long-term average volume of impervious area runoff. Therefore, 0.3 mm/h was adopted as the Impervious Threshold parameter value for the Road and Railway FU (i.e. 1.5 mm/d x 0.2 = 0.3 mm/h) and 0.2 mm/h was adopted as the Impervious Threshold parameter value for all other FUs (i.e. 1.0 mm/d x 0.2 = 0.2 mm/h). Subsequent calibration of the models to gauged flows (see Section 4.4) confirmed that this produced reasonable volumes and timing of runoff generated from impervious areas in the model. If larger Impervious Threshold parameter values had been adopted, it would have been difficult to simulate sufficient runoff to match the volume and timing of the gauged flows.

4.3 Storage routing links and parameters

Storage routing links have several parameters that control attenuation and routing of flows and water quality:

- K, which was calibrated to streamflow gauging data (see Section 4.4)
- m, which was set to a fixed value of 0.8, typically used for rainfall runoff routing of flood events
- Inflow bias, which was set to 0, typically used in catchment models for flood events
- Initial flow, which was set to 0.1 ML/d but only influences the first few hours of each model run and can then be ignored

- Average regulated flow rate, which was set to 0.1 ML/d but has no impact in the study area as there are no regulated flow releases from dams.[2]
- Number of divisions, which was set to 1, as this is only relevant to marker routing of water quality parameters in much longer river reaches (e.g. the Murray River) than this study.

4.4 Calibration method

After setting three parameters to fixed values for each FU, the remaining 6 parameters (Soil Moisture Store Capacity, Infiltration Shape, Infiltration Coefficient, Interflow Coefficient, Recharge Coefficient and Baseflow Coefficient) were set by calibrating the Source model to gauged streamflow. Joint calibration was undertaken of the rainfall runoff parameters and the K parameter of the storage routing links in the model. Calibration runs therefore undertook joint calibration of up to 7 parameters (six SimHyd parameters and the link routing K parameter) in each run.

All calibration model runs commenced on 1 July 2011, which as the start of the period of rainfall data supplied by Sydney Water. Split-sampling was not implemented during calibration (see Callout Box 1).

An iterative calibration process was implemented, whereby:

1. Automated calibration was performed, using the Flow Calibration Analysis tool in Source. Initial calibration was undertaken to optimise against gauged flows using the Standard Deviation of Error and Bias (SDEB), Nash Sutcliffe Efficiency (NSE) of hourly flows, NSE with log-bias penalty, or NSE and hourly flow duration curve objective functions.
2. Hourly flow hydrographs from the Source model were examined, which identified that flows in the first 35 days of the model runs were likely influenced by the unknown initial conditions in the internal stores of the SimHyd and routing models. The end of the warm-up period was therefore defined as 4 August 2011, or 35 days after the start of the simulation.
3. Hourly flow hydrographs from the Source model and gauge were plotted and compared. Inspection of the hydrographs was used to identify periods when gauged flows were likely to be unreliable for calibration of the Source models and to compare the rate of baseflow recession between gauged and modelled flows. The Baseflow Coefficient parameter was fixed for subsequent rounds of calibration to match the rate of recession against gauged flows, as identified from periods when gauged flows appeared to be sufficiently reliable.
4. Comparison statistics were calculated using the hourly, daily, monthly and water year (July to June) totals from modelled and gauged flows:
    - Hourly flow statistics were calculated using all hours with valid gauged flow between the end of the warm-up period (4 August 2011) and the end of the gauged flow data.

[2] Source can model unregulated catchments (like those in this study area) or regulated catchments and systems. In regulated systems, Source needs a basis to estimate the travel time between a dam that needs to release water and user that wants to take water from the dam. Since the travel time is a function of the flow rate (higher flow rates typically travel faster), Source needs to know the typical flow rate in regulated reaches to estimate the travel time. Source calculates this for all reaches in the model, whether they are regulated or not. If the regulated flow rate entered is 0, the travel time cannot be computed (it will be infinite) and Source will flag an error on every time step of the model run. To avoid Source creating millions of pointless errors on every model run, a regulated flow rate was provided even though it is not used in this model as the entire system is unregulated.

- Daily flow statistics were calculated using all calendar days (midnight to midnight) that had at least 90% (or 22 out of 24 hours) of valid hours of gauged flow data, between 4 August 2011 and the end of the model run.
- Monthly flow statistics were calculated using all months that had at least 80% of valid hours of gauged flow data, between 4 August 2011 and the end of the model run.
- Water year or Financial Year flow statistics were calculated using all months in years starting on 1 July and ending on 30 June that had at least 50% of valid hours of gauged flow data.
- It should be noted that the statistical comparison tools in the Source Results Manager and Calibration Tool will return slightly different statistics to those calculated and reported (see Callout Box 2).

5. Targeted calibration runs were undertaken, optimising the Soil Moisture Store Capacity parameter only, reduce the bias in the total volume of modelled to gauged runoff for the entire run period (see Callout Box 3).
6. Previous calibration run(s) were used to refine the feasible ranges of each parameter. Targeted calibration runs were undertaken on the remaining parameters (other than SMSC, Baseflow Coefficient, Pervious Fraction and Impervious Threshold), optimising to SDEB, NSE and the flow duration curve.
7. Steps 3 and 4 were repeated: examination of hourly gauged and modelled flow hydrographs and calculations of statistics.
8. Steps 5 to 7 were repeated until it was apparent that acceptable calibrations had been achieved at each of the flow gauges, given the limitations in the quality of the streamflow gauging data (see Callout Box 4).
9. A representative set of parameters from calibrated regions was calculated by weighting the parameter values from gauged parts of the model, which were then applied to the ungauged residual regions of all models that are downstream of all gauges (see Callout Box 4).
   Table 4-4 shows the weighting factors that were used to apply the adopted parameters from each calibration gauge to derive representative parameter values for the ungauged parts of the study area. Weightings were informed by the period of record at each gauge, total catchment area upstream and area between one gauging station and the next (interstation area).

Table 4-4 Periods of record of valid gauge data and adopted weighting factors for multi-site calibration

Gauge	Number of years of valid data			Interstation area (km²)	Total upstream area (km²)	Adopted Weight
	Hourly	Daily*	Monthly#			
213219: Toongabbie Creek @ Johnstons Bridge	7.234	7.055	6.333	50.1	50.1	8
213005: Toongabbie Creek @ Briens Road	12.609	12.282	12.500	18.8	68.9	25
213282: Parramatta River @ Cumberland Hospital	2.050	1.979	2.000	34.3	103.2	5
213004: Parramatta River @ Marsden St Weir	7.621	7.392	6.750	1.0	104.3	15
213280: Lane Cove River @ National Park Weir	5.187	5.008	4.583	66.0	66.0	30
213209: Duck River @ Mackay Road	5.295	5.147	5.167	15.6	15.6	15
2VYC01: Vineyard Creek @ Kissing Point Road	0.567	0.504	0.167	2.8	2.8	2
Total	39.512	30.522	28.167	188.6	188.6	100
213281: Lane Cove River @ Fox Valley	0.321	0.318	0.333			0
213283: Devlins Creek @ Epping	0.311	0.309	0.333			0
213285: Shrimptons Creek @ Alma Road	0.194	0.156	0.000			0

Notes:
* Valid days of gauge data required at least 90% of hours in the calendar day (midnight to midnight) to have valid gauged flow
# Valid months of gauge data required at least 80% of the hours in the month to have valid gauged flow

Figure 4-2 shows the locations of the streamflow gauges in the study area and the zones that were used for calibrating and applying rainfall runoff model parameters. The model calibration process set the parameters that were used for all subcatchments upstream of each streamflow gauge. The subcatchments that were shaded pink in Figure 4-2 were downstream of all streamflow gauges and it was not possible to calibrate rainfall runoff model parameters to gauged flow data for those subcatchments. Rainfall runoff model parameters were applied to these ungauged residual areas, as discussed in Callout Box 4. The total area upstream of the calibration gauges is 188.6 km², which represents 39% of the total land area represented in the Source models.

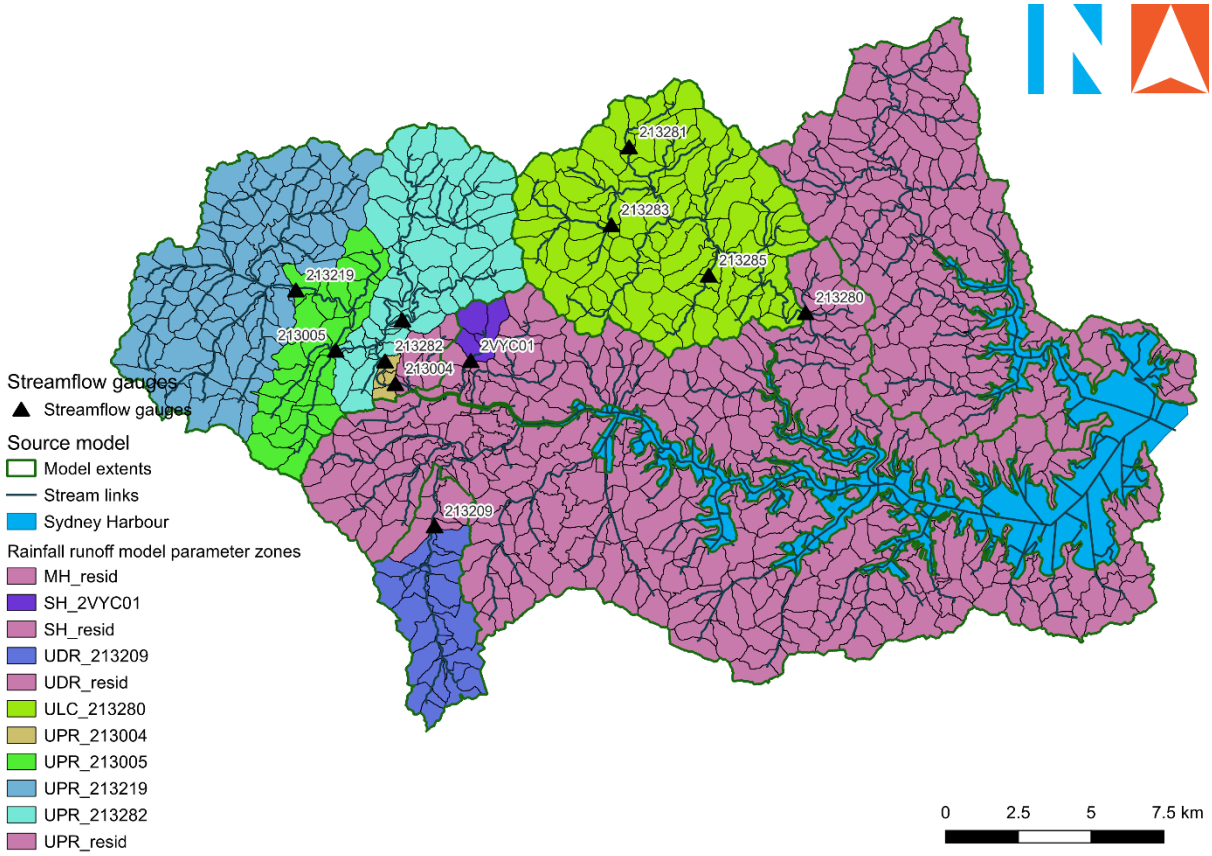

Figure 4-2 Rainfall runoff model parameter zones

Callout Box 1: Lack of justification for split-sample calibration of rainfall runoff models

Recent literature has demonstrated that split sample calibration delivers no benefit, in terms of improved modelling outcomes, instead of using the entire period of available streamflow data for model calibration, with no independent validation period (Shen et al., 2022). This is particularly the case when the number of streamflow gauges and period of record is relatively limited. Rainfall runoff model calibration was therefore undertaken using the entire period of record for parameter calibration. This was also in keeping with the example approach for Georges River, which used the full 12 years of available data for calibration.

Post-calibration, verification statistics for individual water years were calculated that represented dry, average and wet weather condition years. This again was in keeping with the Source modelling for the Georges River.

Callout Box 2: Slight differences in comparison statistics between reported and calculated by eWater Source Results Manager or Calibration Tool

Statistical comparison tools in the Source Results Manager and Calibration Tool will return slightly different statistics to those calculated and reported, as those tools only use days, months and water years with 100% valid data for comparison. Statistical calculations from spreadsheets, which are provided in this report, use all hours of data; all days of data with at least 22 hours of valid gauged flow; all months with at least 80% of hours with valid gauged flow and all water years / Financial Years with at least 50% of hours with valid gauged flow.

Note that annual volumes reported are only for the overlapping period of valid hours in each water year. The modelled total volume in each water year will normally be larger, as the model will simulate volume for all hours.

Callout Box 3: Influence of SimHyd parameters on bias in total runoff volume

Only 3 parameters have a material impact on the total volume of runoff generated: the Pervious Fraction, Impervious Threshold and Soil Moisture Store Capacity. Since the Pervious Fraction and Impervious Threshold parameters were fixed for each FU type (see Section 4.2), it was only the Soil Moisture Store Capacity parameter that could be used to materially influence the bias in total runoff volume.

Callout Box 4: Coverage of streamflow gauging data in study area and influence on rainfall-runoff model parameterisation

The study area is mostly urbanised but with pockets of open space and forested park and riparian areas distributed throughout the urban area. There are larger areas of forest in the upper parts of the Lane Cove River, Middle Harbour Creek and Darling Mills Creek catchments. However, even in these areas, the streamflow recorded at any downstream gauge would have contributions of a significant proportion of urbanised catchment area.

The total area upstream of the calibration gauges is 188.6 km², which represents 39% of the total land area represented in the Source models. Only one streamflow gauge, 213219: Toongabbie Creek at Briens Road, has complete data for the entire model calibration period and the area upstream of that gauge is 68.9 km² or 14% of the study area. The other gauges have valid data for no more than half of the calibration period.

The consequence of the generally high degree of urbanisation and limited streamflow gauging is that the purpose and role that calibration of rainfall runoff models to gauged flows should take in this study area is different to how it would be applied in most other catchments. The approach that adopted for this study relied upon a combination of calibration to the few gauges in the study area and on parameters of rainfall runoff models that are typically adopted in urban environments and identified from calibrations in neighbouring basins.

There was less than ½ a year of valid gauge flow data at three gauges on tributaries of the Upper Lane Cove River (213281, 213283 and 213285) (see Table 3-1). Since there was more than 5 years of valid flow data downstream of these gauges at the 213280 gauge on the Lane Cove River at the National Park Weir, calibration of the Lane Cove River catchment was only undertaken using the data at 213280.

4.5 Adopted parameter values

The adopted values of parameters for the SimHyd models, by gauge zone and FU, are shown in Table 4-5 and Table 4-6. Adopted parameters of the link storage routing models are listed in Table 4-7. Parameter values for the residual areas of all models downstream of gauges, shown in the last row of each table, were calculated from the weighted average of the parameter values from the calibration zones with weighting factors adopted from Table 4-4.

Table 4-5 SimHyd rainfall runoff model parameter values for impervious areas, by parameter zone and Functional Unit

Model and gauge region	Impervious Threshold (mm)		Impervious Fraction				
	Road and railway	All other FUs	Road and railway	Bush, parkland and rural	Residential	Commercial	Industrial
SH: US 2VYC01	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
UDR: US 213209	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
ULC: US 213280	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
UPR: US 213219	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
UPR: US 213005	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
UPR: US 213282	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
UPR: US 213004	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%
All models: residual areas downstream of gauges	0.20	0.30	0.0%	97.0%	59.8%	28.8%	15.2%

Table 4-6 SimHyd rainfall runoff model parameter values for pervious areas, by parameter zone for all Functional Units

Model and gauge region	Rainfall Interception Store Capacity (mm)	Soil Moisture Store Capacity (mm)	Infiltration Shape	Infiltration Coeff.	Interflow Coeff.	Recharge Coeff.	Baseflow Coeff.
SH: US 2VYC01	2.50	20.00	6.00	331.08	0.4210	0.7253	0.0043
UDR: US 213209	2.50	30.00	6.00	50.00	0.9000	0.5000	0.0068
ULC: US 213280	2.50	30.00	6.00	75.35	0.4000	0.7000	0.0057
UPR: US 213219	2.50	71.00	5.54	100.00	0.0500	0.9800	0.0040
UPR: US 213005	2.50	71.00	5.54	100.00	0.0500	0.9800	0.0040
UPR: US 213282	2.50	20.00	5.54	100.00	0.0500	0.9800	0.0050
UPR: US 213004	2.50	20.00	5.54	100.00	0.0500	0.9800	0.0050
All models: residual areas downstream of gauges	2.50	41.33	5.76	89.73	0.2899	0.8189	0.0051

Table 4-7 Link routing parameters by parameter zone

Model and gauge region	Routing constant, k	Routing exponent, m	Inflow bias, x	Number of divisions
SH: US 2VYC01	9658	0.8	0	1
UDR: US 213209	1690	0.8	0	1
ULC: US 213280	1508	0.8	0	1
UPR: US 213219	1800	0.8	0	1
UPR: US 213005	1800	0.8	0	1
UPR: US 213282	1729	0.8	0	1
UPR: US 213004	1729	0.8	0	1
All models: residual areas downstream of gauges	1679	0.8	0	1

4.6 Model performance

Table 4-8 summarises the performance of the calibrated Source model at each of the streamflow gauges in the study area.

The monthly values of Nash Sutcliffe Efficiency (NSE) at all gauges, except for 213219 (Parramatta River at Cumberland Hospital) were all greater than 0.75 and therefore would be rated as “Very Good” against the Moriasi et al. (2007) criteria. The monthly NSE for at gauge 213219 was on the borderline between Satisfactory and Good, rated against the Moriasi et al. (2007) criteria.

The hourly and daily NSE values at the gauges with the longest and most reliable records in the Upper Lane Cove and Parramatta River catchments (213005, 213280, 213004 and 213282) were all near to or exceeded 0.8. This is excellent performance at a daily and hourly time scale for rainfall runoff model calibration. The hourly and daily NSE values at the other gauges were lower but the periods of record and quality of gauged flows at these other gauges (213219, 213209 and 2VYC01) were all poorer than the other gauges used for calibration in this study (refer to Section 3.4)

There was virtually no bias between the modelled and gauged flows for 213280: Upper Lane Cove River at National Park Weir. The bias for the gauge on the Duck River (213209) was also less than 10% and so both gauges would achieve a Very Good rating for bias against the Moriasi et al. (2007) criteria.

Due to inconsistency in the gauged flows between the gauges in the Upper Parramatta River catchment, it was impossible to achieve an unbiased rainfall runoff model calibration simultaneously at all four gauges. The weighted average of the mean bias at the four gauges (213004, 213005, 213219 and 213282, using the weighting factors from Table 4-4) was within less than 0.1%. This was a compromise between over-estimation of the model against gauged flows at 213005 and 213282 (by +4% and +20% respectively) and under-estimation at 213004 and 213219 (by –4% and –11% respectively).

Table 4-8 Summary of model performance at calibration gauges for whole period of valid flow record

Gauge number	Period of record (years)	Mean daily flow (ML/d)		Mean Bias	Nash Sutcliffe Efficiency		
		Gauged	Modelled		Hourly	Daily	Monthly
213004	7.6	170.0	163.5	-3.8%	0.834	0.879	0.825
213005	12.6	79.0	82.1	3.8%	0.806	0.901	0.901
213219	7.2	82.9	73.9	-10.9%	0.245	0.297	0.644
213282	2.1	92.9	112.1	20.6%	0.780	0.863	0.880
213280	5.2	130.8	130.7	-0.1%	0.809	0.873	0.865
213209	5.3	27.3	24.9	-8.8%	0.447	0.619	0.810
2VYC01	0.6	5.3	3.9	-27.1%	0.478	0.615	Insufficient data

Table 4-9 summarises the performance of the model at gauge 213005: Toongabbie Creek at Briens Road by water year. This was the only gauge that had valid gauged flow data for the entire calibration period (2011-12 to 2023-24). In addition, this was the only gauge with a reliable rating that had been updated regularly by hydrographic staff over the calibration period. Summary tables of statistics by water year for the other gauges, with shorter periods of valid flow data, are provided in Appendix B.

Figure 4-3 compares the water year totals of gauged and modelled flow for the calibration period at the four gauges in the Upper Parramatta River catchment. The calibration of the Source model represents a compromise between over-estimating flow volumes in drier years against under-estimating flow volumes in the wettest year. The 2021-22 water year at gauge 213004 (Marsden Street Weir) is a notable outlier, with the model under-predicting the gauged flow. However, there was a much closer match at the other gauges for the same water year, including the 213005 gauge, which has more reliable rated and gauged flows than 213004. It was not possible to further improve the calibration at 213004 for the wettest year (2021-22) without making the overall calibration worse at the other gauges in the Upper Parramatta River catchment. The SimHyd model over-estimates flow in the wettest year because regular runoff from impervious areas keeps pervious areas and depression storage wetter than would be simulated by the SimHyd model. Conversely, the SimHyd model under-estimates flow in the driest years because rainfall occurs more infrequently and water evaporates from depression storages of impervious areas more than would be simulated by the SimHyd model. Over-coming these issues would require creation of a modified SimHyd model with different code that would allow for more sophisticated representation of runoff generation across the pervious and impervious areas of each FU.

Table 4-9 shows that the hourly NSE was greater than 0.68 at gauge 213005 in every water year except the driest year of 2017-18. This was an excellent performance overall, as it is difficult to for an hourly rainfall runoff model to achieve an NSE of 0.7 or more. The monthly NSE was 0.90 and the mean bias was +3.7%, which were both excellent when compared to the Moriasi et al. (2007) criteria.

Table 4-9 Model performance at calibration gauge 213005: Toongabbie Creek at Briens Road by water year

Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	9%	40,834	34,042	-17%	-17%	0.686
2012-13	0%	16,605	21,438	29%	-3%	0.753
2013-14	0%	10,636	14,826	39%	3%	0.745
2014-15	0%	39,283	42,878	9%	5%	0.837
2015-16	0%	30,759	33,410	9%	6%	0.887
2016-17	0%	27,027	29,913	11%	7%	0.776
2017-18	0%	6,531	11,230	72%	9%	0.299
2018-19	0%	21,111	26,587	26%	11%	0.781
2019-20	5%	27,611	30,234	9%	11%	0.872
2020-21	0%	37,112	36,253	-2%	9%	0.822
2021-22	0%	59,333	48,453	-18%	4%	0.738
2022-23	0%	34,545	31,939	-8%	3%	0.757
2023-24	25%	12,654	16,675	32%	4%	0.778

Note: * modelled flow volume for concurrent period with valid gauged flow

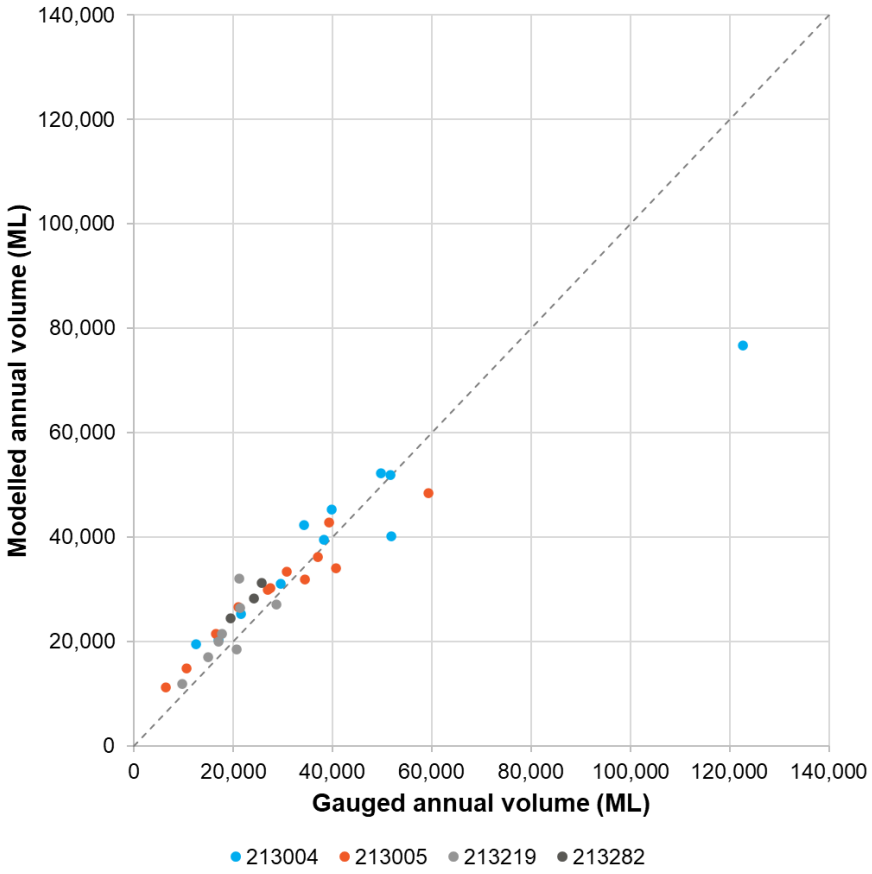

Figure 4-3 Comparison of gauged versus modelled flow for the four gauges in the Parramatta River catchment by water year (July to June)

The figures on the following pages (Figure 4-4 to Figure 4-15) demonstrate the performance of the calibrated rainfall runoff model at the three gauges with the longest period of gauging data in the study area: 213004 (Marsden Street Weir), 213005 (Toongabbie Creek at Briens Road) and 213280 (Upper Lane Cove River at National Park Weir).

The models reproduce the timing and magnitude of flows during the driest years of the simulation period, as demonstrated by Figure 4-4 and Figure 4-8 (for 2017-18 at the gauges in the Parramatta River catchment) and Figure 4-12 (for 2013-14 at the gauge in the Lane Cove River catchment). The rates of baseflow recession are reasonably well matched by the Source model, albeit that the gauged flows are most likely not well rated for lower flow rates, below about 10 ML/d.

The flow duration curves show that the calibrated Source models produce a good match to the hourly distribution of flow rates monitored by the gauges, across most of the range of flows, as shown in Figure 4-5, Figure 4-9 and Figure 4-13. The Source models underpredict the lowest flows, below about 2 ML/d at each gauge, although rating and gauging of these low flows is subject to considerable uncertainty. In urban areas, irrigation water applied to private back yards, public parks, gardens and sporting fields can also artificially supplement baseflows during dry periods and this is not explicitly represented by the Source model.

The Source models produce a good representation of high flow events. Modelled and gauged flow hydrographs for the February 2020 and February 2022 flood events are provided at each of the three gauges in Figure 4-6, Figure 4-7, Figure 4-10, Figure 4-11, Figure 4-14 and Figure 4-15. The shape and timing of the flows produced by the model are generally good. The models under-predict peak flow for these flood events. This could be because the rainfall representation across the catchment from the gauges did not capture the highest intensity of rainfall during these flood events. It could also be a consequence of pervious areas of catchments during wet periods being wetter in reality than represented by the model, due to runoff from impervious areas in urban areas, as discussed on the previous page.

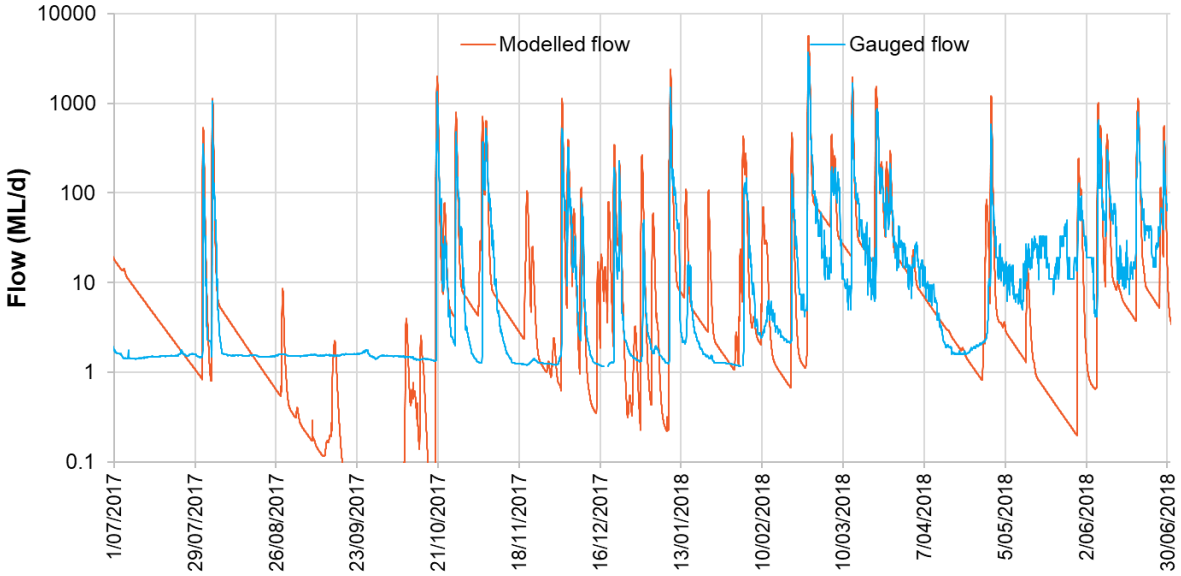

Figure 4-4 Hourly flow hydrograph (log scale) for gauge 213004: Parramatta River at Marsden St Weir for 2017-18 water year (dry year)

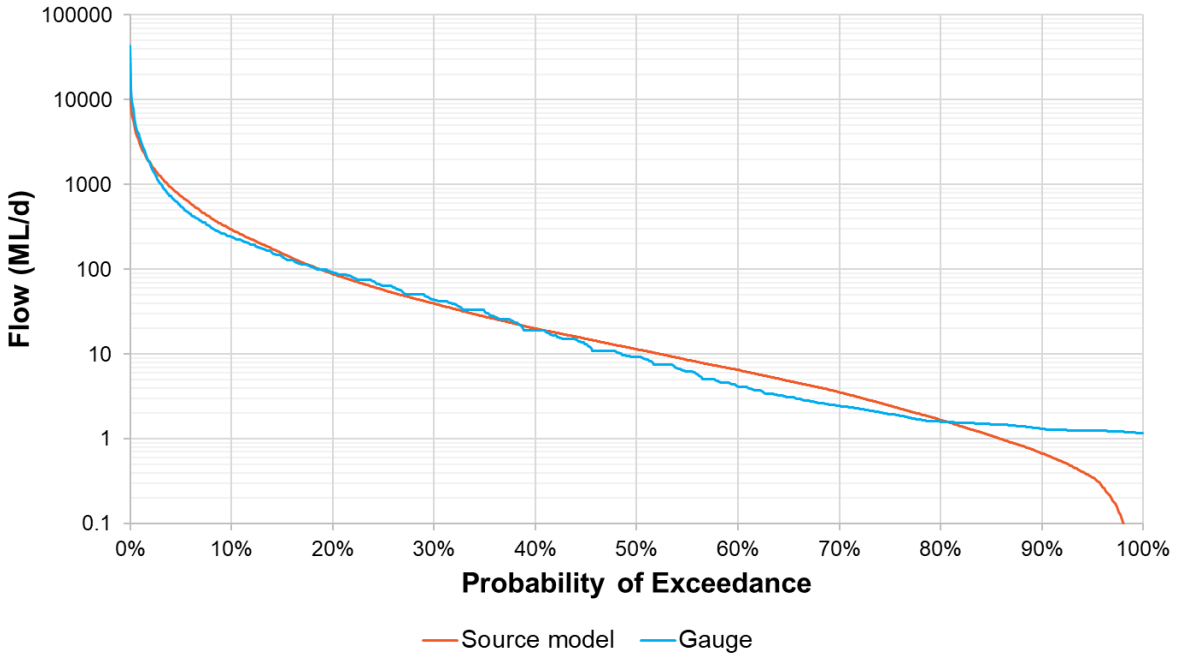

Figure 4-5 Hourly flow duration curve (log scale) for gauge 213004: Parramatta River at Marsden St Weir

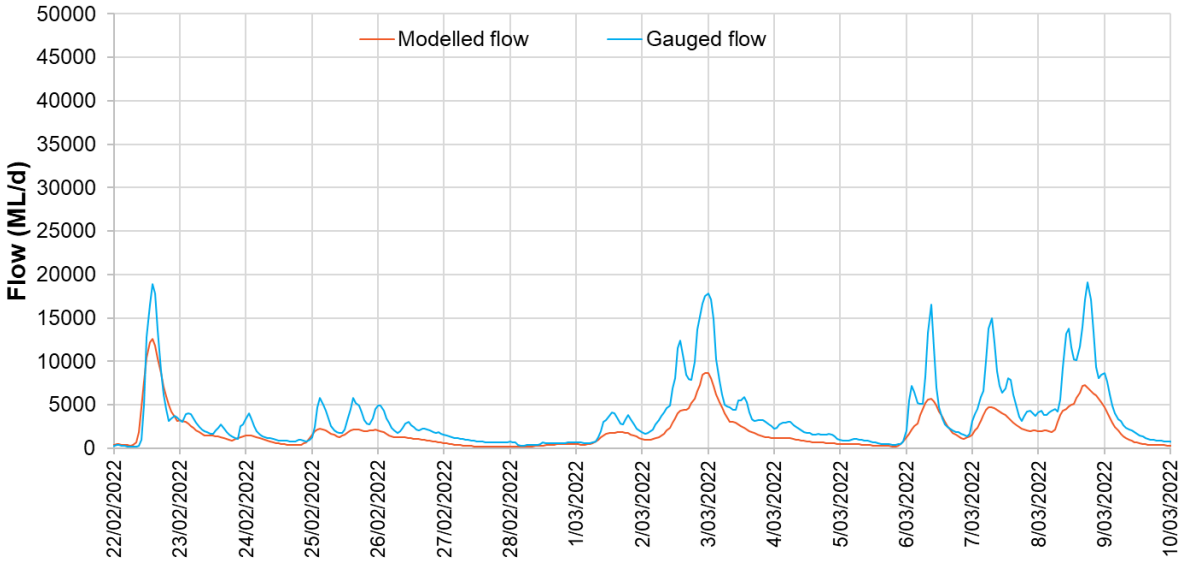

Figure 4-6 Hourly flow hydrograph (linear scale) for gauge 213004: Parramatta River at Marsden St Weir for February 2022 runoff event

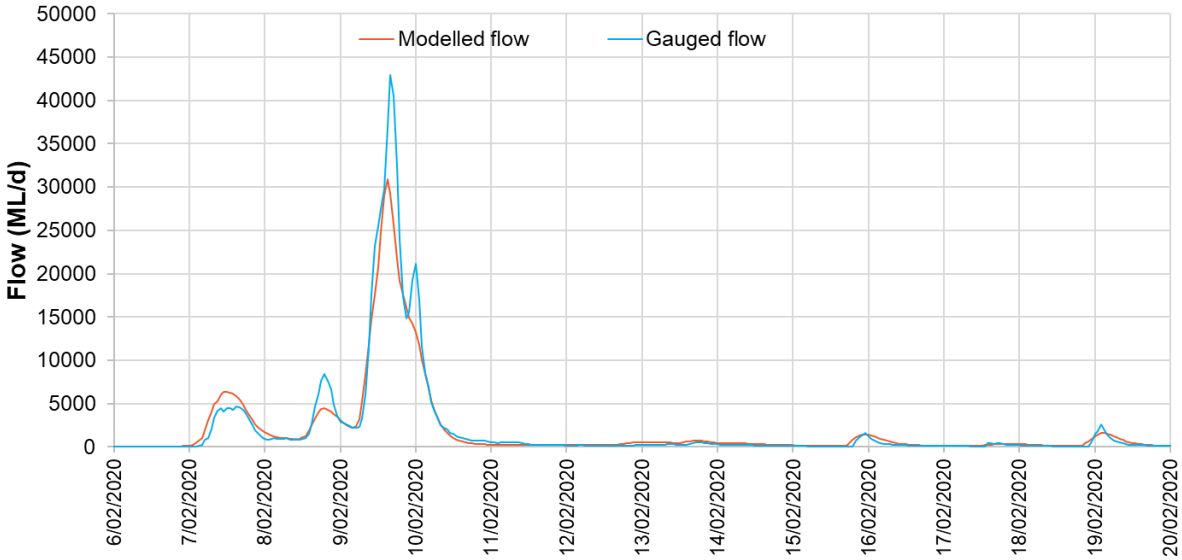

Figure 4-7 Hourly flow hydrograph (linear scale) for gauge 213004: Parramatta River at Marsden St Weir for February 2020 runoff event

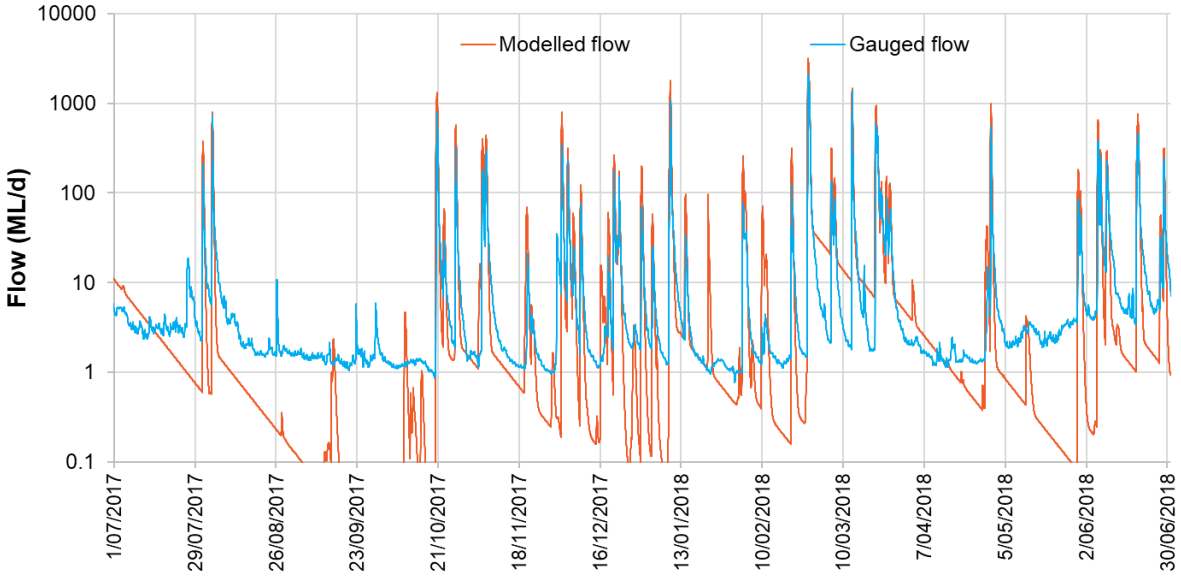

Figure 4-8 Hourly flow hydrograph (log scale) for gauge 213005: Toongabbie Creek at Briens Road for 2017-18 water year (dry year)

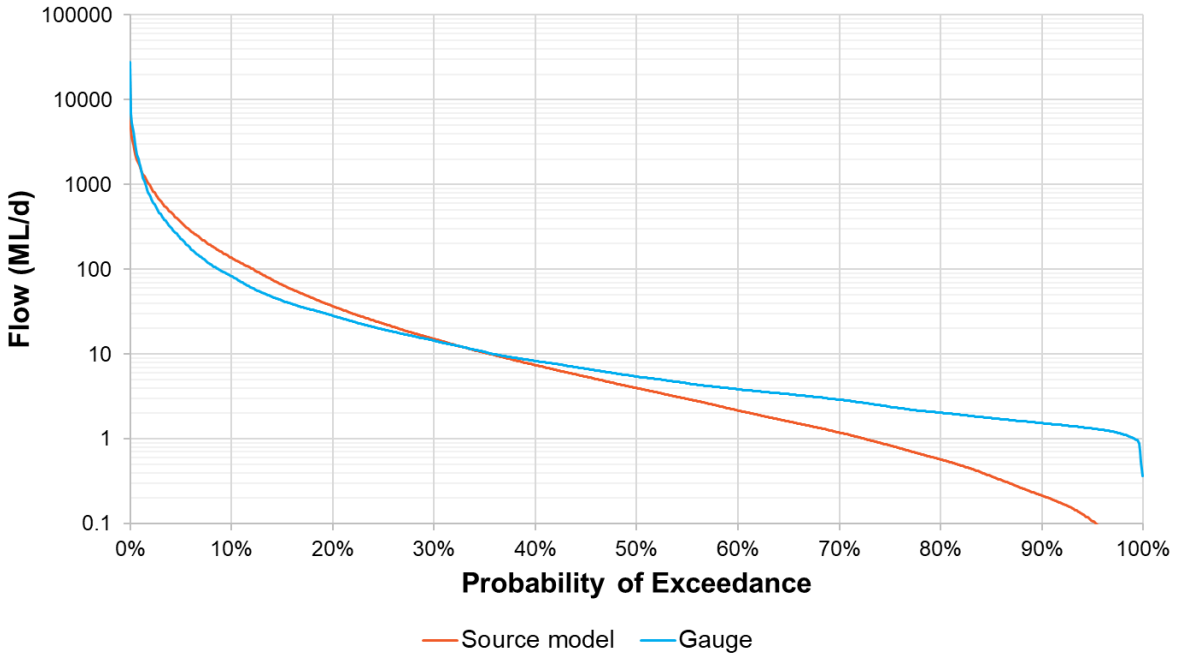

Figure 4-9 Hourly flow duration curve (log scale) for gauge 213005: Toongabbie Creek at Briens Road

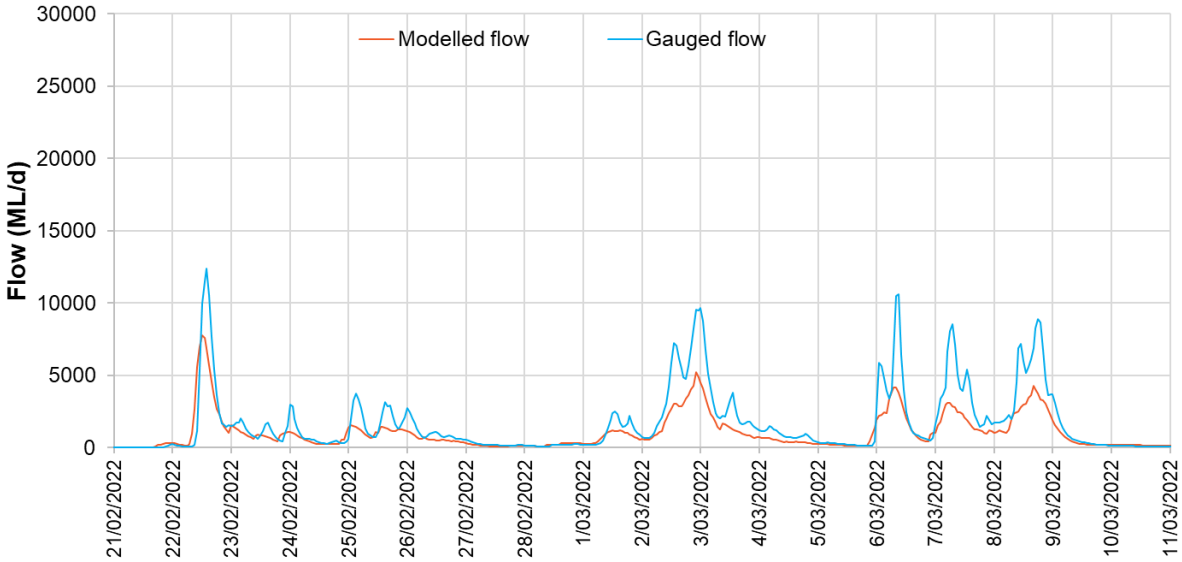

Figure 4-10 Hourly flow hydrograph (linear scale) for gauge 213005: Toongabbie Creek at Briens Road for February 2022 runoff event

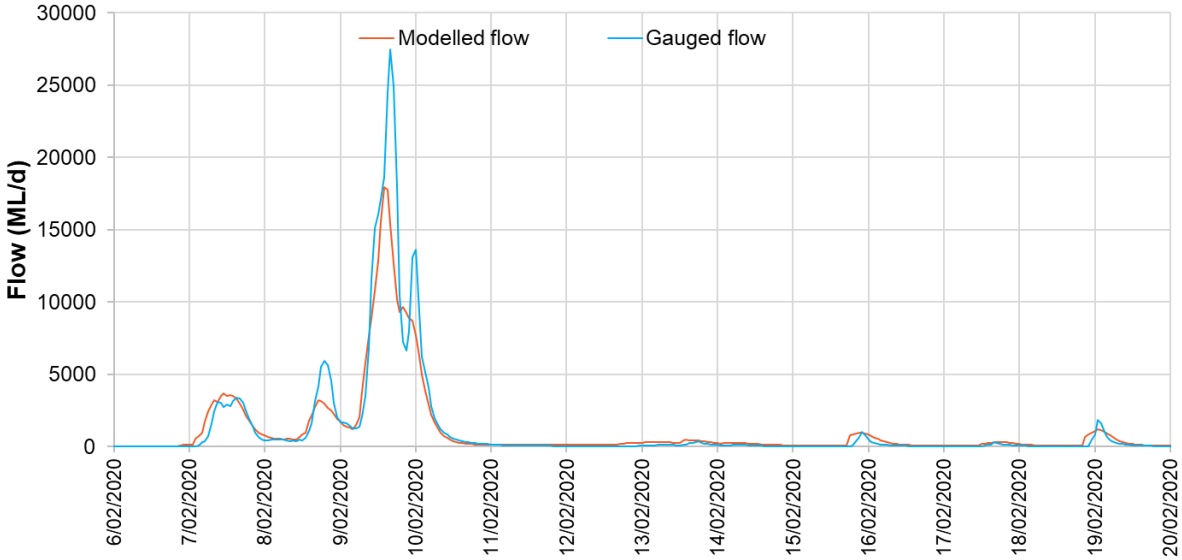

Figure 4-11 Hourly flow hydrograph (linear scale) for gauge 213005: Toongabbie Creek at Briens Road for February 2020 runoff event

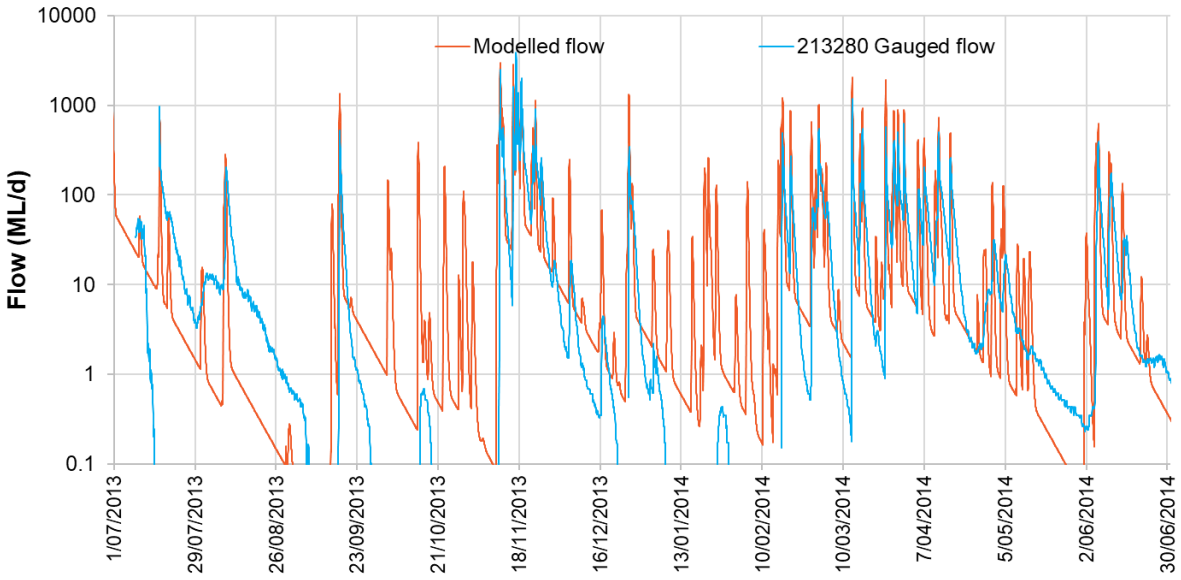

Figure 4-12 Hourly flow hydrograph (log scale) for gauge 213280: Upper Lane Cove River at National Park Weir for 2013-14 water year (moderately dry year, driest year with some gauge flow data)

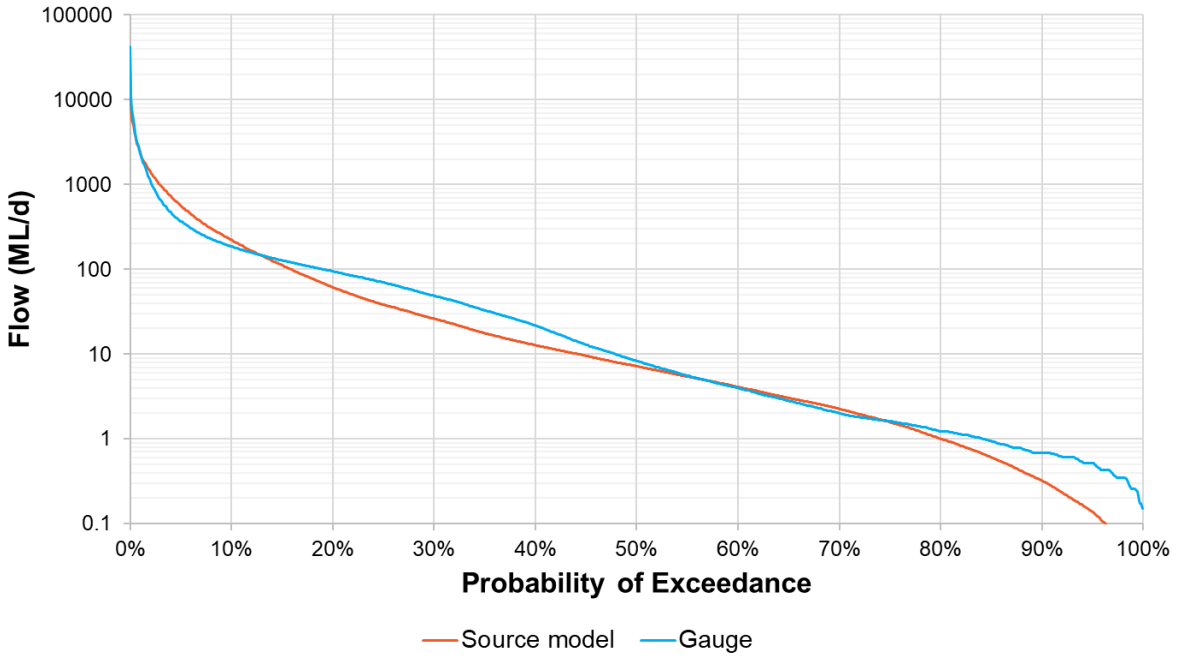

Figure 4-13 Hourly flow duration curve (log scale) for gauge 213280: Upper Lane Cove River at National Park Weir

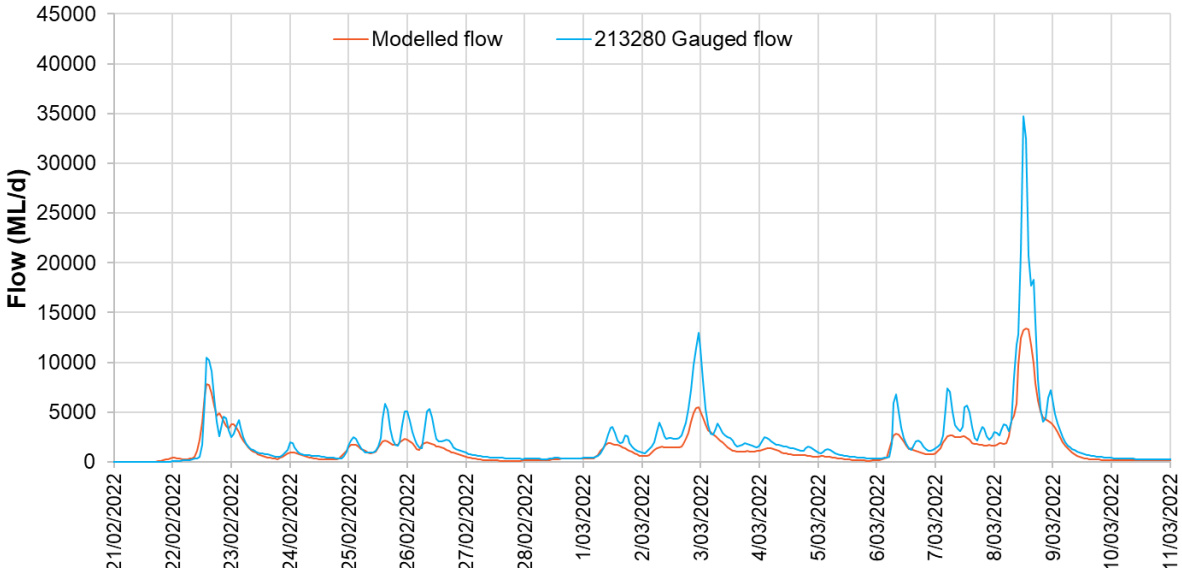

Figure 4-14 Hourly flow hydrograph (linear scale) for gauge 213280: Upper Lane Cove River at National Park Weir for February 2022 runoff event

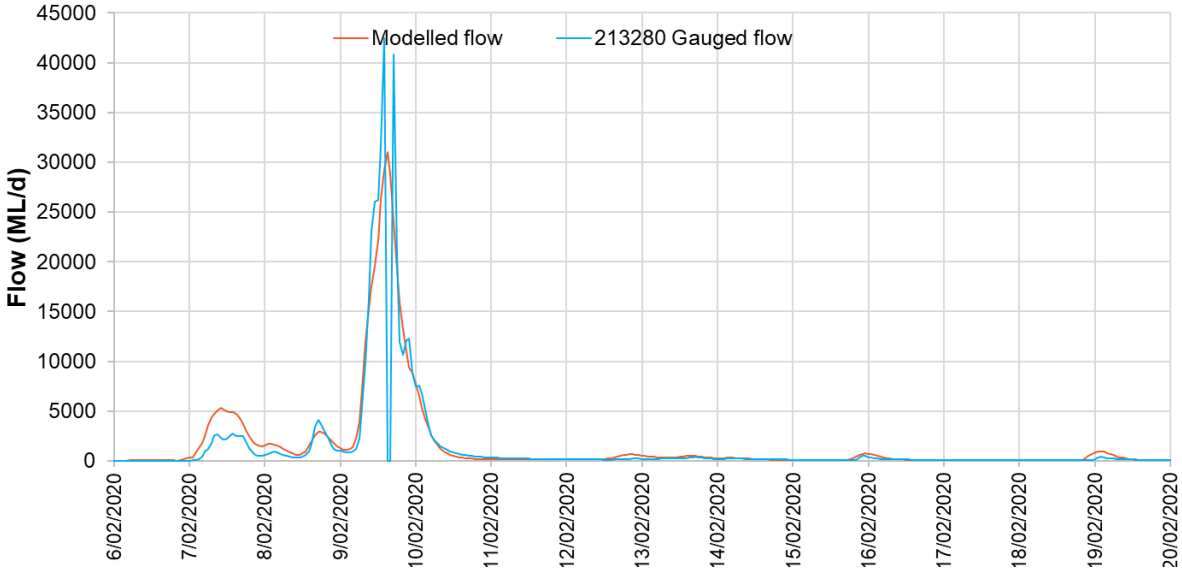

Figure 4-15 Hourly flow hydrograph (linear scale) for gauge 213280: Upper Lane Cove River at National Park Weir for February 2020 runoff event

The mean annual runoff was calculated for the entire model run period (July 2011 to June 2024) for each output reporting location (see Section 3.6 and Figure 3-11). For each of the 238 model output locations (from the Source to MIKE models) the mean annual flow was calculated, and this was then divided by the total upstream catchment area to return the mean annual runoff. The mean annual runoff was then mapped back to each subcatchment upstream of each of the 238 model output locations, as a quality assurance check on the flow time series produced by the Source model.

Figure 4-16 shows the spatial variation in mean annual runoff across the study area. Low values of mean annual runoff (indicated by “hot” or “redder” colours in Figure 4-16) were associated with single catchment outflows from parts of the model where there was a high proportion of bushland, parkland rural and other open space. Mean annual runoff from these areas was typically between 300 and

400 mm/year or less than ~40% of mean annual rainfall. The highest values of mean annual runoff (indicated by “cold” or “bluer” colours in Figure 4-16) were associated with single catchment outflows from parts of the model with high proportions of commercial, industrial and road and railway landuses – all of which have high impervious fractions and therefore generate runoff greater than ~90% of mean annual rainfall. Intermediate values of mean annual runoff were found for outputs that had a mixture of landuses and/or a high proportion of residential landuse and hence had a mixture of pervious and impervious surfaces.

Figure 4-17 shows the same information but this time presented as the mean annual runoff at each of the 238 inflow locations to the model, with the size of the circles varying according to the mean annual runoff (total volume generated per unit of catchment area) at each inflow location to the MIKE model. Figure 4-18 shows that the overall mean annual inflow is strongly dependent on the catchment area draining to each inflow location, with the largest contributions coming from the HW (headwater) input nodes draining from the Upper Parramatta River, Upper Lane Cove River, Duck River, Darling Mills Creek and Middle Harbour and Rocky Creek and many, much smaller contributions, from the 233 other inflow nodes.

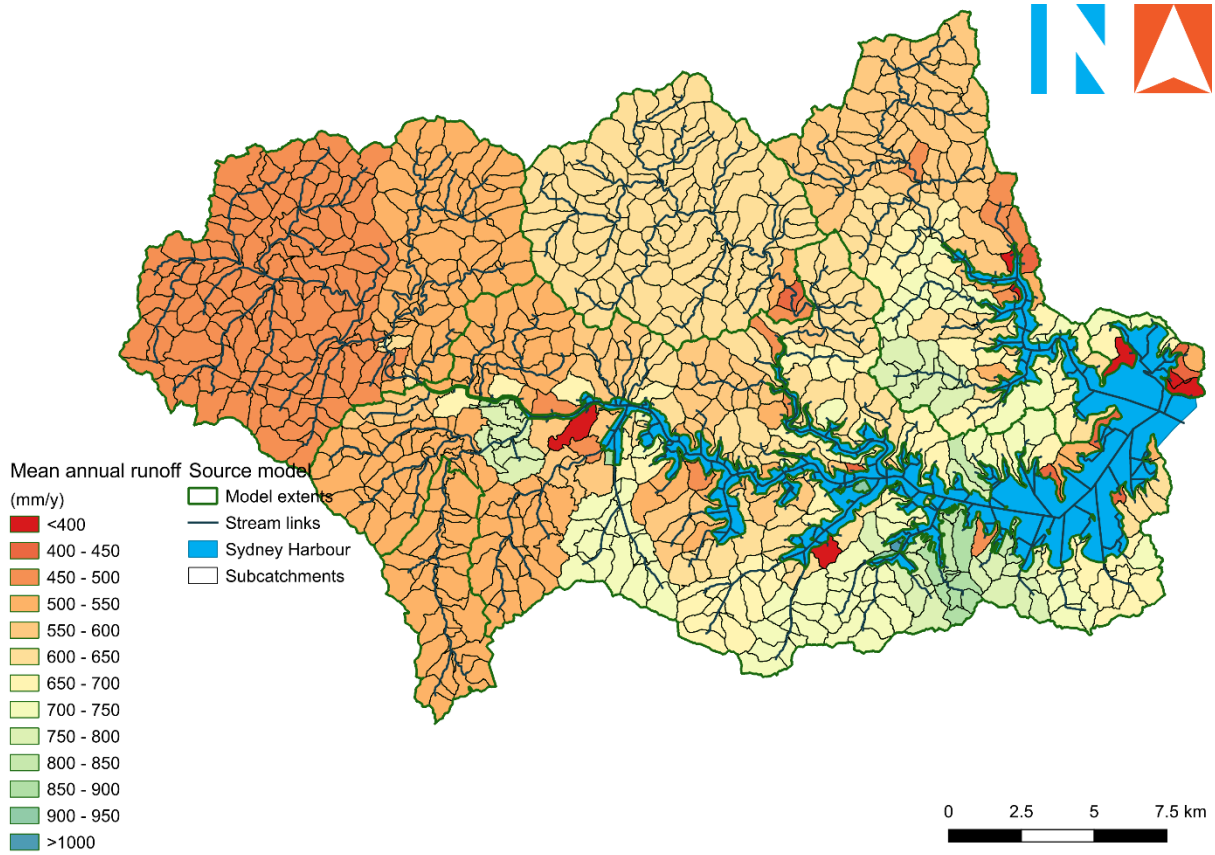

Figure 4-16 Mean annual runoff (2011 to 2024) by output reporting location, shaded by subcatchment

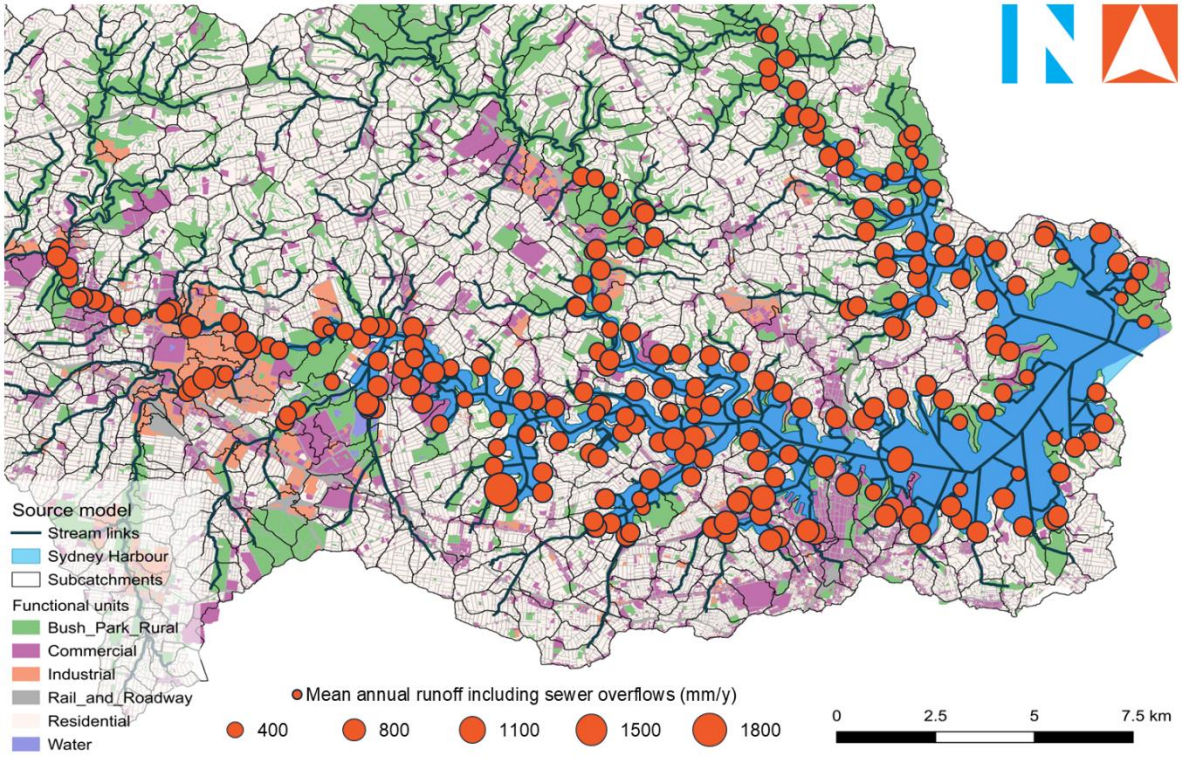

Figure 4-17 Mean annual runoff (2011 to 2024) by output reporting location

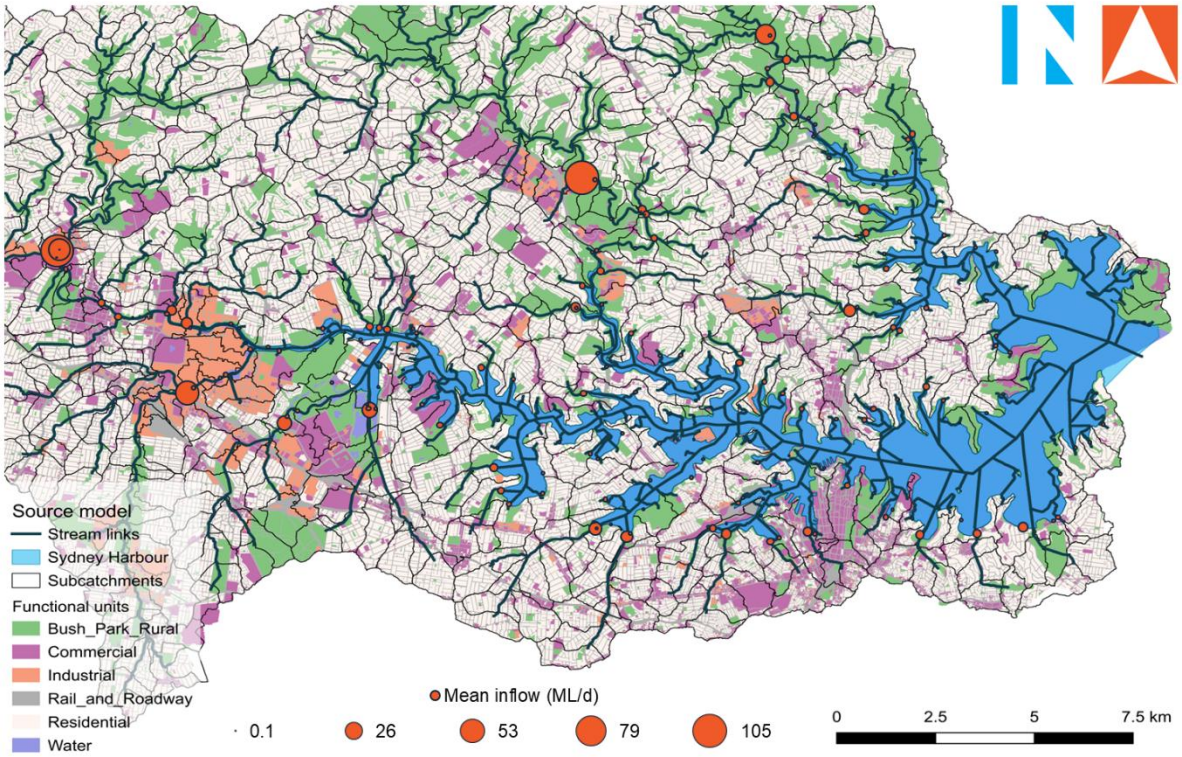

Figure 4-18 Mean annual inflow (2011 to 2024) by output reporting location

5. Water quality modelling

The Source model represents two sources of constituents for modelling water quality:

- Generation of constituent loads associated with runoff from FUs (see Section 5.1)
- Generation of constituents loads from sewer overflows (see Section 5.2)

Source model performance in modelling water quality was assessed by comparing concentration outputs for constituents from the model to water quality monitoring data at several monitoring sites (see Section 3.5).

5.1 Constituent generation from functional unit runoff

Almost all water quality modelling studies applying Source separate the area of interest into Functional Units (FU), model the generation of constituents from each of those FUs in each subcatchment and route the flows and constituent loads through the stream network (represented by nodes and links in the Source model). Source allows different algorithms and different parameter values to be applied for each combination of constituent and FU in each subcatchment of the Source model.

Most water quality modelling studies applying Source have applied an Event Mean Concentration Dry Weather Concentration (EMCDWC) model, with the EMC and DWC parameters varying by constituent and FU. The generation equation in the EMCDWC model is given by:

$$L_c = DWC_c . Q_{b,t} + EMC_c . Q_{s,t}$$

Where:
L_c is the load of constituent c
DWC_c and EMC_c are the dry weather and event mean concentrations of constituent c
$Q_{b,t}$ and $Q_{s,t}$ are the baseflow and surface components of flow generated from the FU in the subcatchment for hourly time step, t of the model run.

Source automatically calculates the baseflow and surface runoff components of generated runoff from each FU for each timestep of the model run.

5.2 Constituent inputs to sewer overflows

Constituent inputs from sewer overflows were modelled using the same method as was adopted in the Georges River Source model (Sydney Water, 2024). Adopted concentrations of TN, TP and TSS, before dilution in sewage, are shown in Table 5-1. These were the median values of monitored inflows from a nearby Sewerage Treatment Plant (Glenfield Sewerage Treatment Plant).

The sewer overflow water quality concentrations are diluted by stormwater. The magnitude of stormwater dilution varies with antecedent rainfall in the period prior to the stormwater overflow. The dilution factor is a function of the cumulative 24-hour antecedent rainfall (CAR). The overflow concentrations are assigned to raw sewage concentrations when the rainfall in the preceding 24 hours is less than 5 mm. When the cumulative 24-hour antecedent rainfall exceeds 120mm, the overflow concentrations are 1/6 of typical raw concentration and a linear dilution factor (between 0-6) is applied according to rainfall depth in the preceding 24 hours, when the rainfall was between 5-120 mm, as shown in the formulas below.

$$DF = \begin{cases} 0, & \text{when CAR} \leq 5 \\ \frac{6}{115}(CAR - 5), & \text{when 5<CAR<120} \\ 6, & when\ CAR \geq 120 \end{cases}$$

$$C = \frac{C_{OF} + DF \times C_{stormwater}}{1 + DF}$$

where C is the estimated overflow concentration, C_{OF} is the raw sewerage concentration, $C_{stormwater}$ is the stormwater concentration.

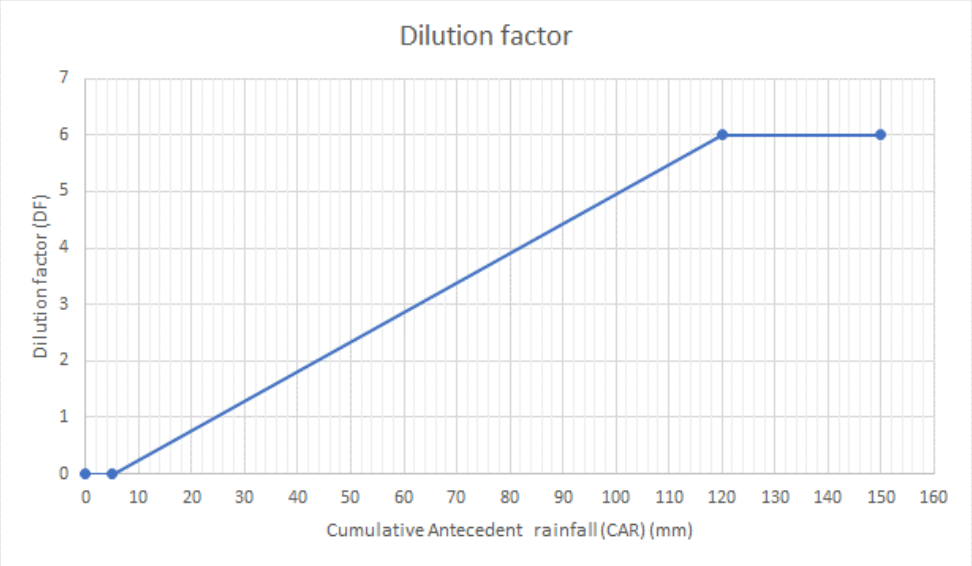

Figure 5-1 Relationship between dilution factor and antecedent rainfall depth

Table 5-1 lists the water quality concentration assumptions for raw sewerage and stormwater. The raw sewage water quality assumptions were consistent with the values adopted for raw sewage in the Georges catchment (Sydney Water, 2024). The stormwater concentrations were consistent with the EMC values adopted for the urban functional units in the Source model (see Table 5-4).

Table 5-1 Concentrations of constituents in raw sewage and stormwater

Constituent	Raw sewage concentration (mg/L)	Stormwater concentration (mg/L)
TN	63	1.85
TP	9	0.26
TSS	320	140
Ent	1,000,000	20,000
NOx	0.1	0.74
NH_4^+	46	0.0925
PO_4^{3-}	6	0.091

5.3 Water quality parameterisation approach

EMC and DWC parameter values adopted for constituents and FUs were informed by relevant literature (BMT WBM, 2015; Sydney Water, 2024), concentrations adopted in neighbouring catchments and comparisons with monitoring data in the study area.

Water quality monitoring data in the catchments are limited to sites that cover a relatively small proportion of the overall study area (about 1/3 of the total area draining to Sydney Harbour) and were somewhat limited in frequency. It was important that the water quality response within the MIKE model of Sydney Harbour was consistent with monitoring data collected in the Harbour. Therefore, the EMC and DWC parameters adopted for model scenario runs were selected to produce water quality responses within the Harbour, even if different parameter values would produce an improved verification to the water quality monitoring data collected within the catchment.

The EMC and DWC values adopted for TSS in this study area were the same as those adopted for the Georges River Source model (Sydney Water, 2024) (see Table 5-2 and Table 5-3). The EMC values adopted for TSS were similar to the mid-point (mode) of the EMC distribution from the NSW MUSIC modelling guidelines (BMT WBM, 2015). DWC values adopted for TSS were slightly lower than the modal value from the NSW MUSIC modelling guidelines but would still be well within the typical range in this area.

The EMC values adopted for TN and TP in this study were close to the mid-point values from the NSW MUSIC modelling guidelines (see Table 5-2 and Table 5-3). DWC values adopted for TN and TP in this study sat between the values adopted in the Georges River model and the mid-point values from the NSW MUSIC modelling guidelines (see Table 5-2 and Table 5-3).

EMC and DWC values for Enterococci EMC were informed by an analysis of pathogen concentrations undertaken by Alluvium (2020) (see Table 5-2 and Table 5-3).

Table 5-2 Event Mean Concentrations adopted for each landuse in the Source model, compared to event monitoring data in the Upper Parramatta, Upper Lane Cove and Vineyard Creek catchments, adopted EMC in the Georges River Source model (Sydney Water, 2024) and the NSW MUSIC modelling guidelines (BMT WBM, 2015)

Constituent	Landuse / FU	EMC in Georges River Source model	Mode of EMC distribution from NSW MUSIC guidelines	Median monitored EMC	Adopted EMC in Source model
Total Suspended Solids (TSS)	Residential, Commercial and Industrial	140 mg/L	141 mg/L	19 mg/L	140 mg/L
	Forest / Bushland	40 mg/L	40 mg/L		40 mg/L
Total Nitrogen (TN)	Residential, Commercial and Industrial	0.75 mg/L	2.0 mg/L	1.03 mg/L	1.85 mg/L
	Forest / Bushland	0.7 mg/L	0.9 mg/L		0.9 mg/L
Total Phosphorus (TP)	Residential, Commercial and Industrial	0.08 mg/L	0.25 mg/L	0.10 mg/L	0.26 mg/L
	Forest / Bushland	0.05 mg/L	0.08 mg/L		0.09 mg/L
Enterococci	Residential, Commercial and Industrial	Not modelled	No guidance	3,300 cfu/100 mL	20,000 cfu/100 mL
	Forest / Bushland	Not modelled	No guidance		4,000 cfu/100 mL

Table 5-3 Dry Weather Concentrations adopted for each landuse in the Source model, compared to weekly monitoring data in the Upper Parramatta catchment, adopted DWC in the Georges River Source model (Sydney Water, 2024) and the NSW MUSIC modelling guidelines (BMT WBM, 2015)

Constituent	Landuse / FU	DWC in Georges River Source model	Mode of DWC distribution from NSW MUSIC guidelines	Median monitored DWC	Adopted DWC in Source model
Total Suspended Solids (TSS)	Residential, Commercial and Industrial	4 mg/L	16 mg/L	13 mg/L	4 mg/L
	Forest / Bushland	2 mg/L	6 mg/L		2 mg/L
Total Nitrogen (TN)	Residential, Commercial and Industrial	0.41 mg/L	1.3 mg/L	0.7 mg/L	0.9 mg/L
	Forest / Bushland	0.3 mg/L	0.3 mg/L		0.51 mg/L
Total Phosphorus (TP)	Residential, Commercial and Industrial	0.04 mg/L	0.14 mg/L	0.04 mg/L	0.1 mg/L
	Forest / Bushland	0.02 mg/L	0.06 mg/L		0.03 mg/L
Enterococci	Residential, Commercial and Industrial	Not modelled	No guidance	No data	4,000 cfu/100 mL
	Forest / Bushland	Not modelled	No guidance		200 cfu/100 mL

Table 5-4 summarises the EMC and DWC parameters adopted for each constituent and FU in the study area for all of the scenario runs. Monitoring data was analysed to establish that typically in stormwater runoff:

- NOx was 40% of TN
- NH_4^+ was 5% of TN and
- PO_4^{3-} was 35% of TP.

These proportions were used to calculate the EMC and DWC values for NOx, NH_4^+ and TP (see Table 5-4).

Table 5-4 Summary of adopted water quality generation parameters in Source model by constituent and FU adopted for scenario runs

Constituent	Residential, Commercial Industrial, Rail and Roadway FUs		Bushland, Parkland and Rural FU		Water	
	EMC	DWC	EMC	DWC	EMC	DWC
Total Suspended Solids (TSS)	140 mg/L	4 mg/L	40 mg/L	2 mg/L	0	0
Total Nitrogen (TN)	1.85 mg/L	0.9 mg/L	0.9 mg/L	0.51 mg/L	0	0
Oxidised Nitrogen (NOx)	0.74 mg/L	0.36 mg/L	0.36 mg/L	0.204 mg/L	0	0
Ammonium (NH_4^+)	0.0925 mg/L	0.045 mg/L	0.045 mg/L	0.0255 mg/L	0	0
Total Phosphorus (TP)	0.26 mg/L	0.09 mg/L	0.1 mg/L	0.03 mg/L	0	0
Ortho Phosphate (PO_4^{3-})	0.091 mg/L	0.0315 mg/L	0.035 mg/L	0.0105 mg/L	0	0
Enterococci	20,000 cfu/100 mL	4,000 cfu/100 mL	4,000 cfu/100 mL	200 cfu/100 mL	0	0

5.4 Water quality verification to monitoring data in the catchment

Performance of the Source model in modelling water quality outcomes was assessed by comparing Source model results to monitored concentrations of constituents at sampling sites. Water quality monitoring data is much more limited in number of observations at each site than streamflow data, so a formal calibration optimisation was not undertaken for water quality. Instead, parameter values were chosen for the Source model and the resulting modelled constituent concentration at each monitoring site were compared to monitoring data.

5.4.1 Time series comparisons for events

Time series plots were prepared of monitored and modelled concentration for each of the monitored events at the auto-sampled sites operated by Sydney Water. These plots for every monitored event are included in Appendix C. For example, plots of Nitrogen, Phosphorus and Total Suspended Solids concentrations for the August 2014 monitored event for the Lane Cove River at Lane Cove National Park Weir (gauge 213280) are provided in Figure 5-2, Figure 5-3 and Figure 5-4 respectively. For this event, Figure 5-2 shows that the Source model predicted the peak concentration of TN but the Nitrogen concentrations peaked about 2 days earlier than was indicated by the monitoring data. The maximum NH_4^+ concentration was reasonably consistent with the monitoring data but occurred earlier in the event, rather than near the peak, whilst the peak NOx concentration from the model under-predicted the peak monitored NOx concentration for this event.

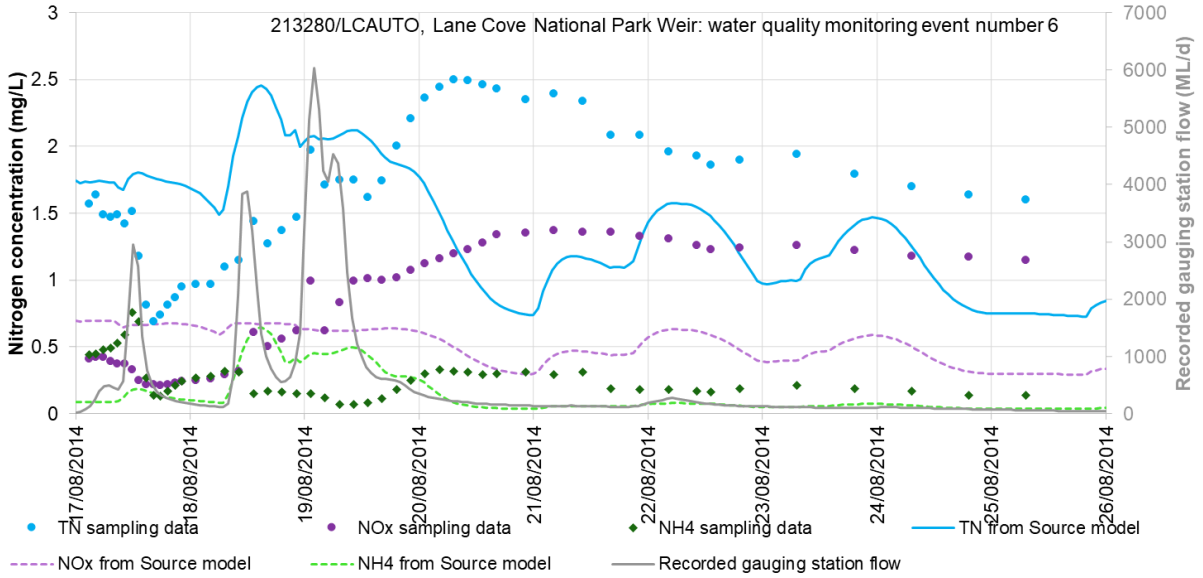

Figure 5-2 Time series of Total Nitrogen and Nitrogen species concentrations from Source model and monitoring data at gauge 213280, Lane Cove River at National Park Weir, for the 17 to 26 August 2014 flow event

Figure 5-3 shows that the Source model over-predicts the concentrations of TP and Ortho Phosphate for this event.

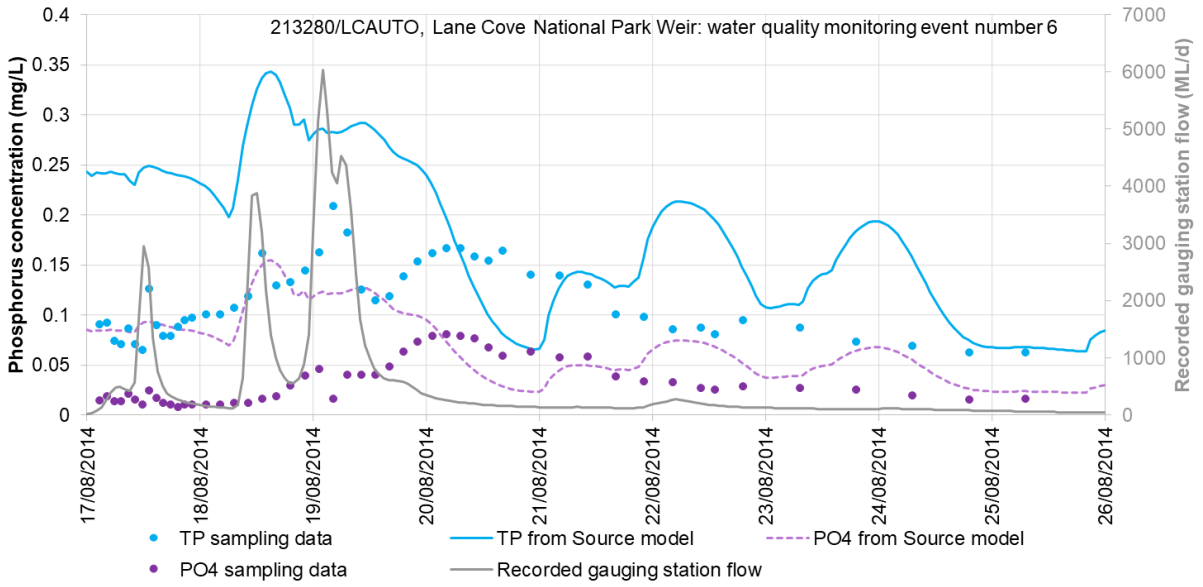

Figure 5-3 Time series of Total Phosphorus and Ortho Phosphate concentrations from Source model and monitoring data at gauge 213280, Lane Cove River at National Park Weir, for the 17 to 26 August 2014 flow event

Figure 5-4 shows that the Source model also over-predicts the concentration of TSS compared to the sampling data across the whole event.

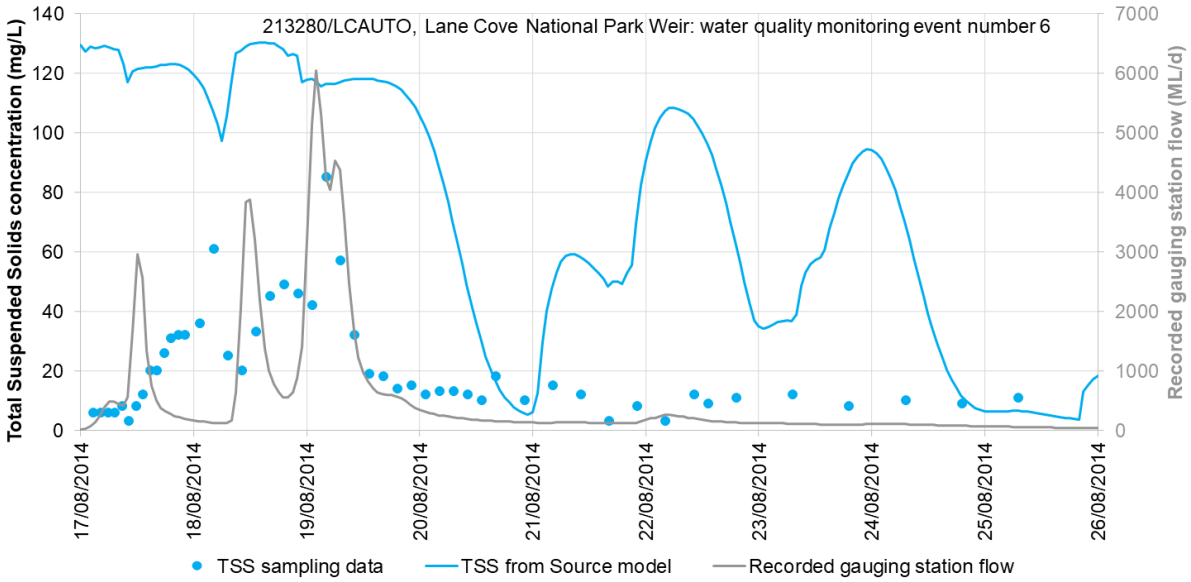

Figure 5-4 Time series of TSS from Source model and monitoring data at gauge 213280, Lane Cove River at National Park Weir, for the 17 to 26 August 2014 flow event

Water quality modelling performance varies from event to event and across the different constituents included in the models, as shown by the time series plots in Appendix C. Box-plots of constituent concentration distributions were prepared to provide a more wholistic assessment of model performance across monitored events, which is provided in the remainder of this chapter.

5.4.2 Distributions of event loads

Monitoring data was compared to modelled results, as follows:

- The Sydney Water-operated sampling sites employed auto-samplers, to capture multiple water quality samples at relatively closely spaced intervals across the flow hydrograph of an event. The data from these sites was therefore useful for assessing event concentration of constituents.
- By contrast, the Parramatta Council-operated sampling sites collected data at generally at weekly intervals. As sampling occurred at weekly intervals and the time of monitoring was not always noted (just the date), the monitoring data could not be used to provide a reliable indication of event concentrations but was useful for assessing the range concentrations across a range of flow conditions, including dry weather.

At the Sydney Water operated auto-sampling sites, the EMC was calculated for each event in three different ways:

- EMC of monitored events at sample times only (shown in grey on the box and whisker plots)

$$EMC_{Monitored\ at\ sample\ times,i,c} = \frac{\sum_{j=1}^{j=N_{i,c}} (c_{Sampled,i,j} Q_{i,j})}{\sum_{j=1}^{j=N_{i,c}} Q_{i,j}}$$

  Where:
  $Q_{i,j}$ is the gauged flow (if valid gauging data is available), or modelled flow (if valid gauging data is not available) for the same hour as the sample j in event i
  $c_{Sampled,i,j}$ is the monitored concentration for constituent c from sample j in event i
  $N_{i,c}$ is the number of samples of constituent c in event i

- EMC of monitored events interpolated in time across the event hydrograph (shown in blue on the box and whisker plots)

$$EMC_{Monitored\ and\ interplolated\ across\ event,i,c} = \frac{\sum_{t=1}^{t=D_i} (c_{Sampled,i,t} Q_{i,t})}{\sum_{j=1}^{j=D_i} Q_{i,t}}$$

  Where:
  $Q_{i,t}$ is the gauged flow (if valid gauging data is available), or modelled flow (if valid gauging data is not available) in hour t of event i
  $c_{Sampled,i,t}$ is the concentration for constituent c that is linearly interpolated in time to hour t of event i between the sampled concentrations (1 to j) of event i
  D_i is the duration in hours of event i

- Source modelled EMC (shown in orange on the box and whisker plots)

$$EMC_{Source\ Model,i,c} = \frac{\sum_{t=1}^{t=D_i} (c_{Modelled,i,t} Q_{i,t})}{\sum_{j=1}^{j=D_i} Q_{i,t}}$$

Where $c_{Modelled,i,t}$ is the concentration for constituent c from the Source model for hour t of event i

5.4.3 Total Suspended Solids

Figure 5-5 Box plots of Total Suspended Solids concentration from monitored events compared to Source model results shows that the mean concentration of TSS across monitored events from the Source model are about a factor of 3 larger than the TSS from the monitoring data. This was a consequence of selecting TSS concentrations in the Source model to be consistent with TSS concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

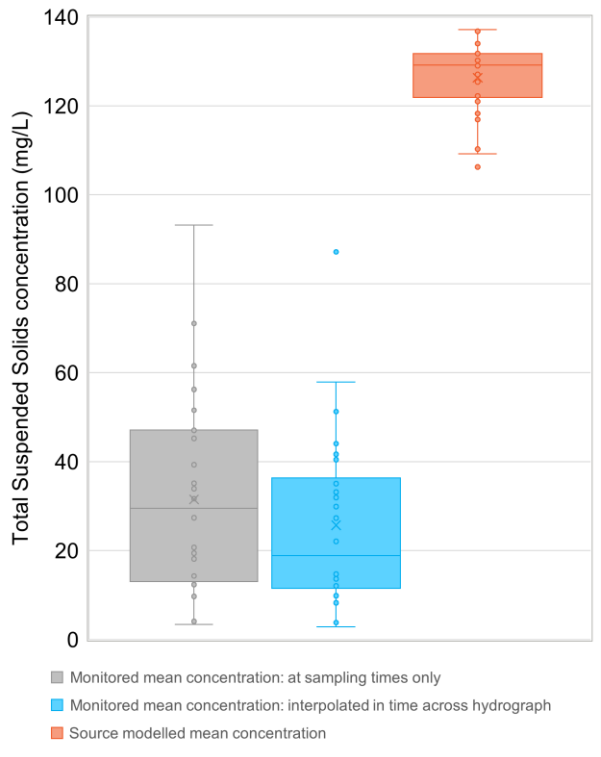

Figure 5-5 Box plots of Total Suspended Solids concentration from monitored events compared to Source model results

There were four monitoring sites in the Parramatta River near the Parramatta CBD, where regular monitoring was undertaken, generally at weekly intervals. The period of sampling varied at each site, with sampling undertaken across December 2011 to June 2012, December 2012 to January 2013 and July to August 2013. There were almost 3 times as many samples of TSS taken at PRPC as at any of the other three sites in this reach. Figure 5-6 shows that the Source model is over-predicting concentrations of TSS during events by around a factor of 3, when compared to the monitoring data at these sites. Concentrations produced by the Source model during dry weather conditions are more similar to the TSS monitoring data at these sites.

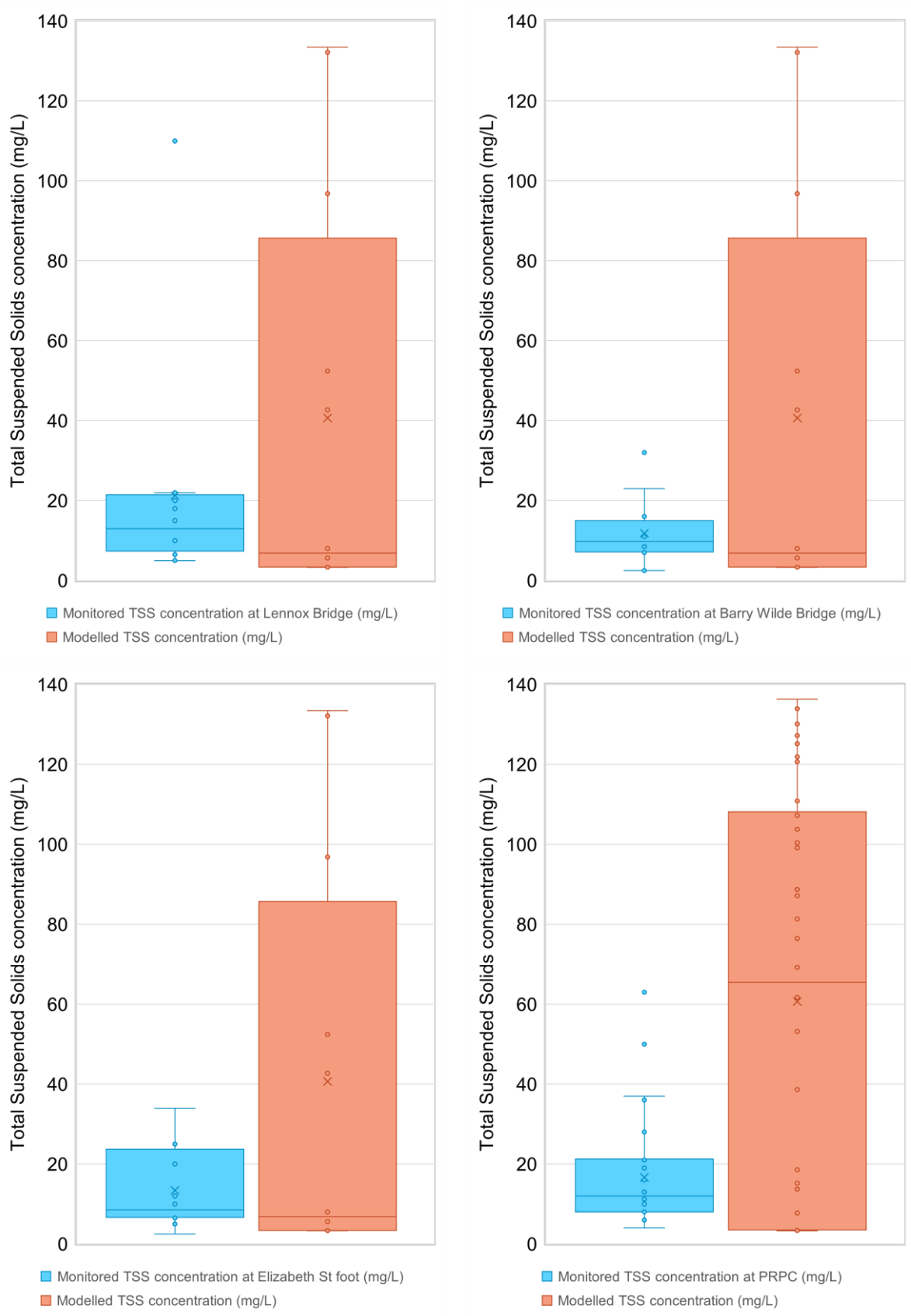

Figure 5-6 Monitored and modelled Total Suspended Solids concentrations at sites on the Parramatta River near the Parramatta Central Business District: Lennox Bridge (top left), Barry Wilde Bridge (top right), Elizabeth Street Footbridge (bottom left) and PRPC (bottom right)

5.4.4 Enterococci

Figure 5-7 shows that the mean concentrations of Enterococci across monitored events from the Source model are around 5 times the monitored concentrations of Enterococci across those same events. This was a consequence of selecting Enterococci concentrations in the Source model to be consistent with Enterococci concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

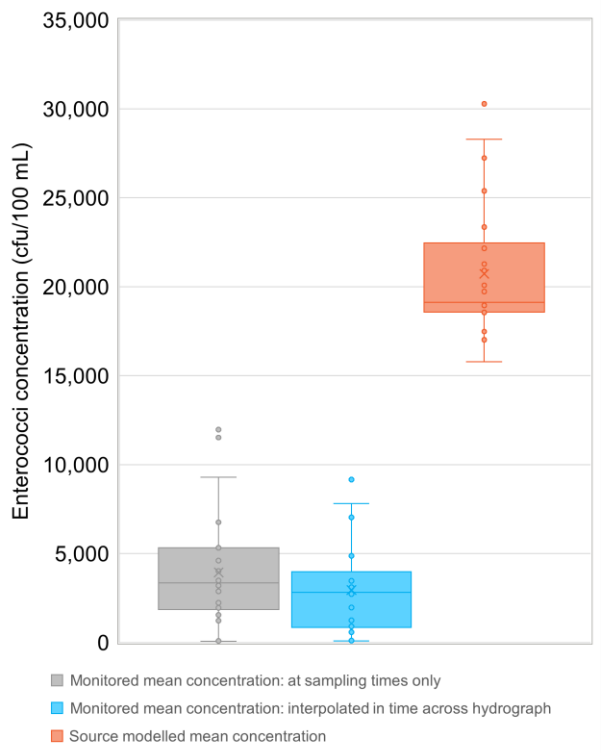

Figure 5-7 Box plots of Enterococci concentration from monitored events compared to Source model results

5.4.5 Nitrogen

Figure 5-8 shows that the Source model was over-predicting the TN concentration across events, when compared to the monitoring data The mean TN concentration from the Source model was approximately double the mean TN concentration derived from the monitoring data, for the same set of events. This was a consequence of selecting TN concentrations in the Source model to be consistent with TN concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

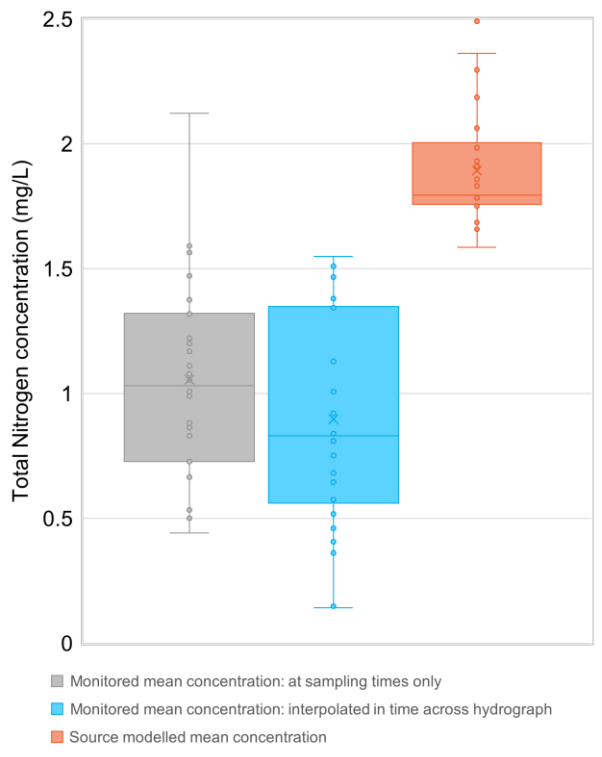

Figure 5-8 Box plots of Total Nitrogen concentration from monitored events compared to Source model results

Figure 5-10 shows that the mean ratio of modelled Ammonium to TN was close to the mean ratio of Ammonium to TN from the monitoring data. Figure 5-9 shows that the mean and median values of Ammonium concentration were over-predicted by the Source model because the Source model also over-predicted the concentrations of TN. This was a consequence of selecting TN concentrations in the Source model to be consistent with TN concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

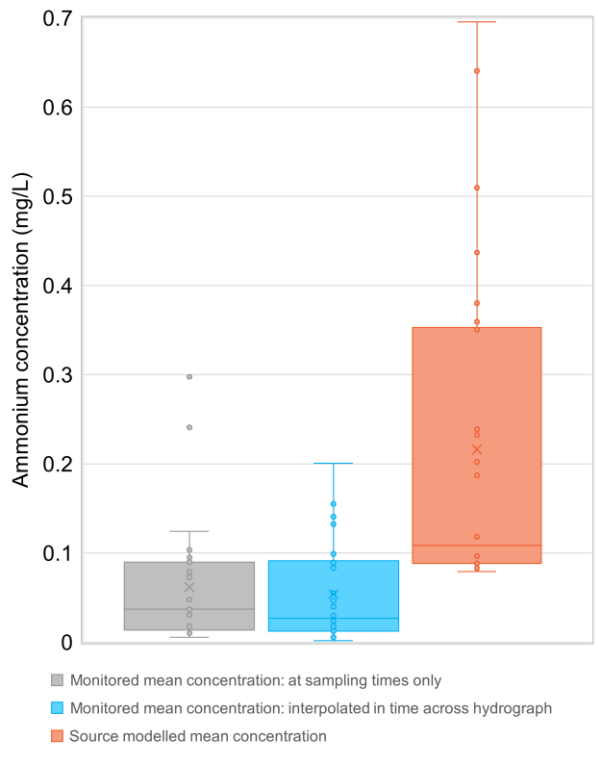

Figure 5-9 Box plots of Ammonium concentration from monitored events compared to Source model results

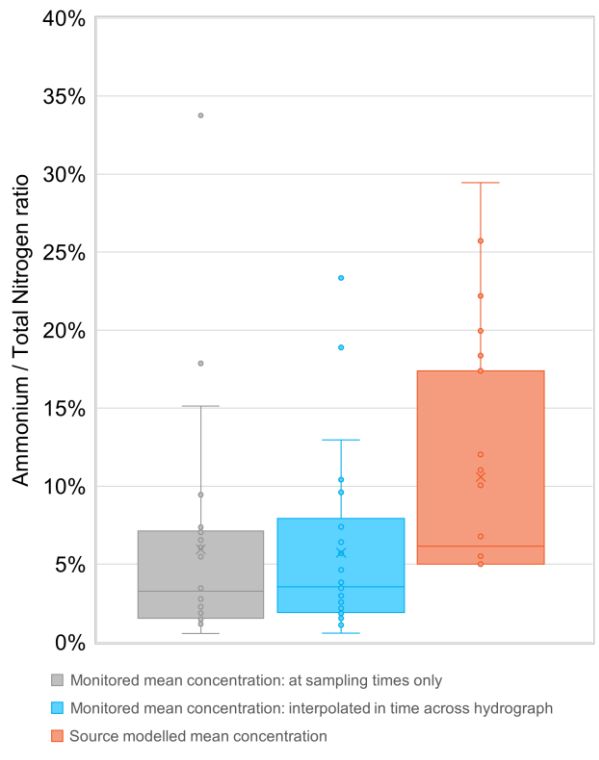

Figure 5-10 Box plots of Ammonium to Total Nitrogen ratio from monitored events compared to Source model results

Figure 5-12 shows that the mean ratio of modelled NOx to TN was close to the mean ratio of NOx to TN from the monitoring data. There was considerably less variation in the Source model results for NOx to TN ratio, since a constant value was assumed for NOx EMC generation for all events. Figure 5-11 shows that the mean and median values of NOx concentration were over-predicted by the Source model because the Source model also over-predicted the concentrations of TN. This was a consequence of selecting TN concentrations in the Source model to be consistent with TN concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

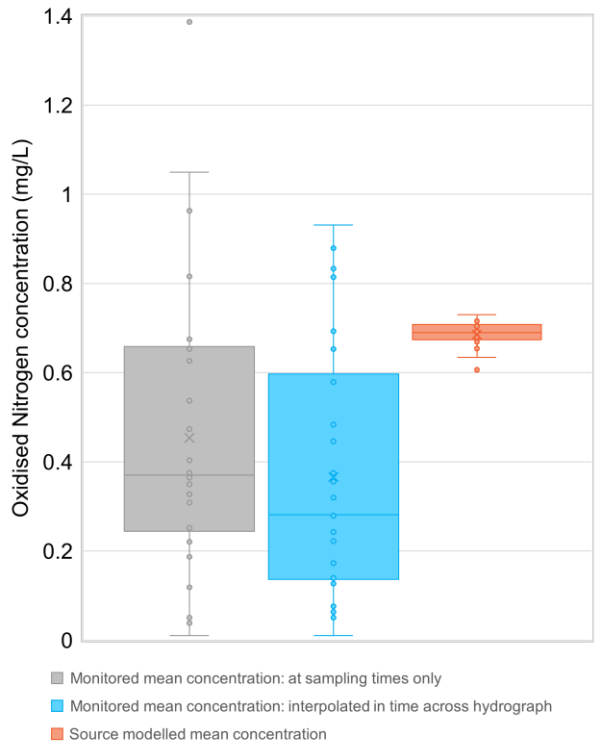

Figure 5-11 Box plots of Oxidised Nitrogen concentration from monitored events compared to Source model results

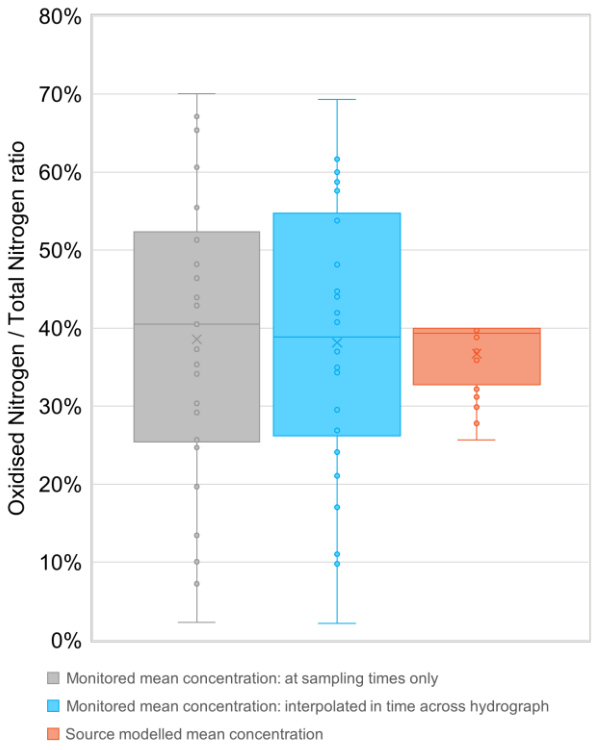

Figure 5-12 Box plots of Oxidised Nitrogen to Total Nitrogen ratio from monitored events compared to Source model results

Parramatta Council took intermittent samples of water quality at four sites in Lake Parramatta Dam (LP1, LP2, LP3 and LP5) over the period between December 2014 and February 2017. There were 61 samples of TN taken across this period at each of sites LP1, LP3 and LP5 and 20 samples of TN at site LP2. The gaps between samples varied considerably, with the shortest gaps being around 2 days and the longest gap extending to just over a month. Figure 5-13 shows that the modelled TN concentrations at all sites were larger than the monitored concentrations at Parramatta Dam, with no overlap in the interquartile ranges of modelled to monitored TN at any of the sites. This was a consequence of selecting TN EMC values in the Source model to match monitoring data in the receiving water model, rather than to match monitoring data in the catchment.

There was no analysis data provided of the Nitrogen speciation at the Lake Parramatta monitoring sites.

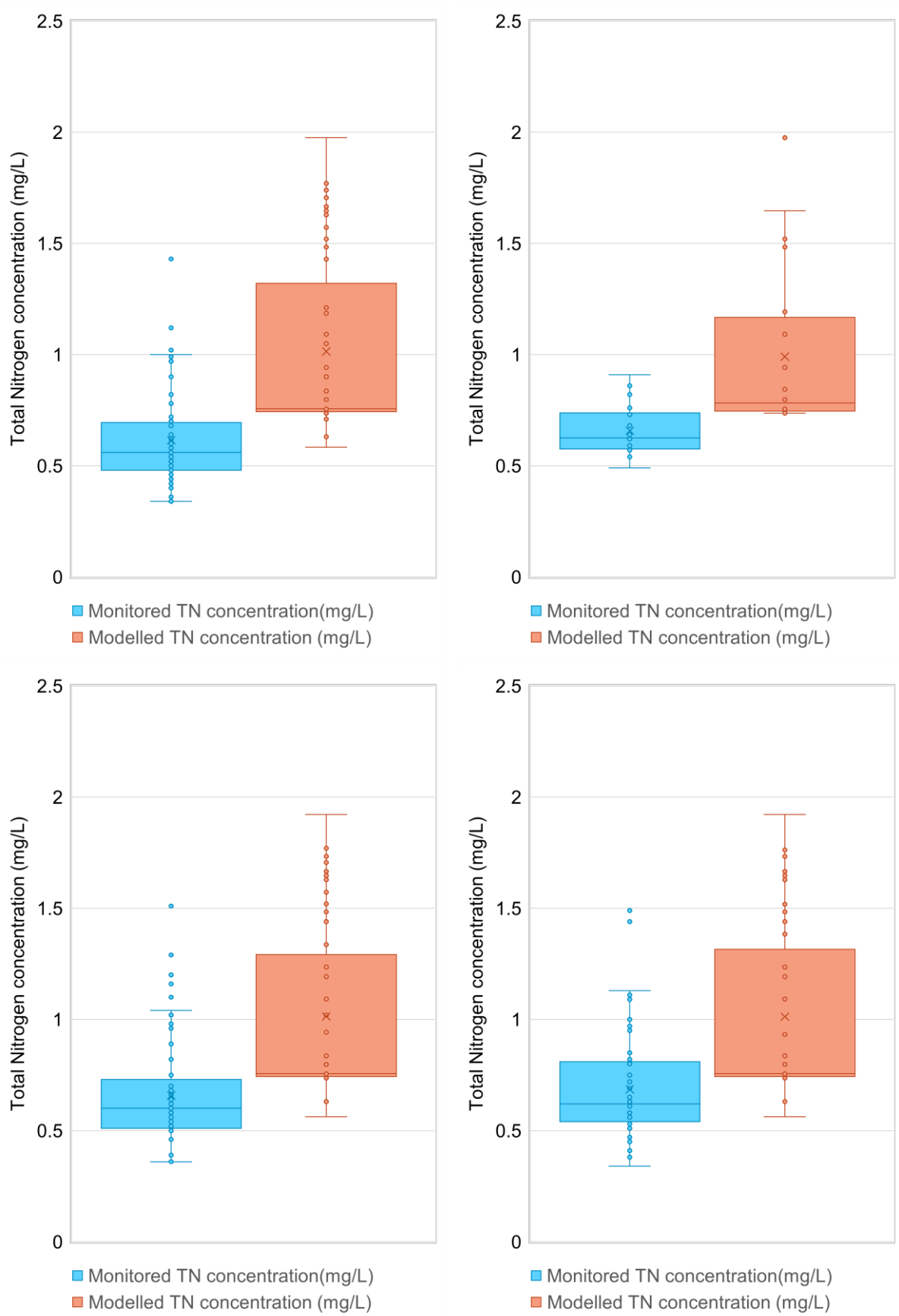

Figure 5-13 Monitored and modelled Total Nitrogen concentrations at Lake Parramatta sites: LP1 (top left), LP2 (top right), LP3 (bottom left) and LP5 (bottom right)

5.4.6 Phosphorus

Figure 5-14 shows that the modelled concentrations of TP produced by the Source model were on average about 2.5 times the monitored concentrations of TP at the event monitoring sites. This was a consequence of selecting TP concentrations in the Source model to be consistent with TP concentrations used in other models and to match monitoring data in the Sydney Harbour receiving water model.

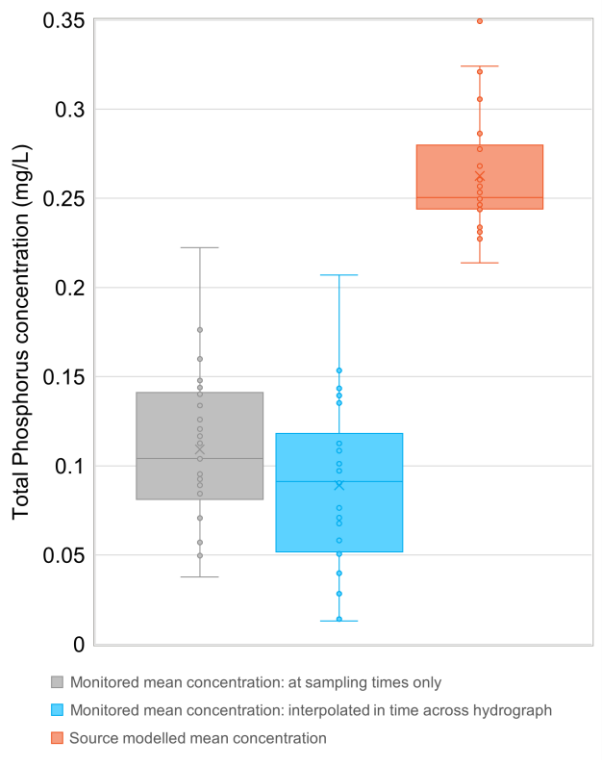

Figure 5-14 Box plots of Total Phosphorus concentration from monitored events compared to Source model results

Figure 5-16 shows that the mean ratio of modelled Ortho Phosphate to TP about 15% greater than the mean ratio of Ortho Phosphate to TP from the monitoring data. There was considerably less variation in the Source model results for Ortho Phosphate to TP ratio, since a constant value was assumed for Ortho Phosphate EMC generation for all events. Figure 5-11 shows that the mean and median values of Ortho Phosphate concentration were about four time the Ortho Phosphate concentrations from the event monitoring data. This was a consequence of selecting TP concentrations and Ortho Phosphate to TP ratios that were consistent with the parameters selected in other models and to match water quality monitoring data in the receiving water model, rather than to match monitoring data in the catchment.

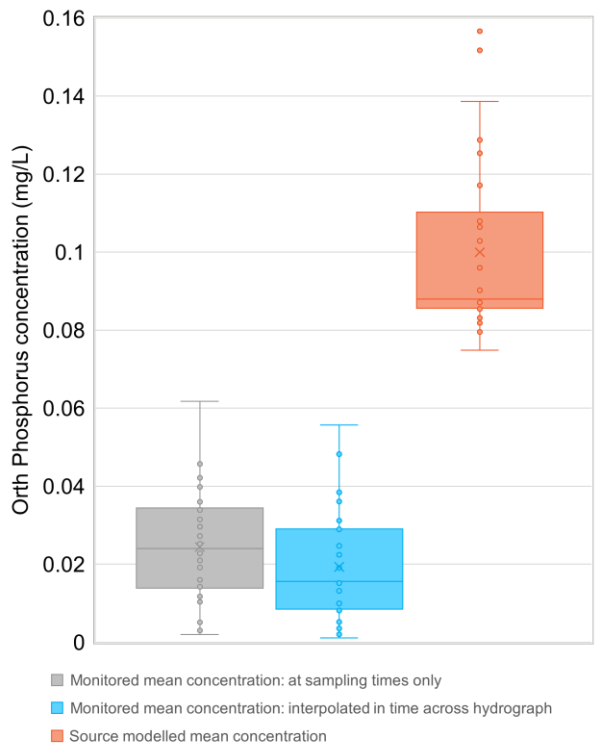

Figure 5-15 Box plots of Ortho Phosphate concentration from monitored events compared to Source model results

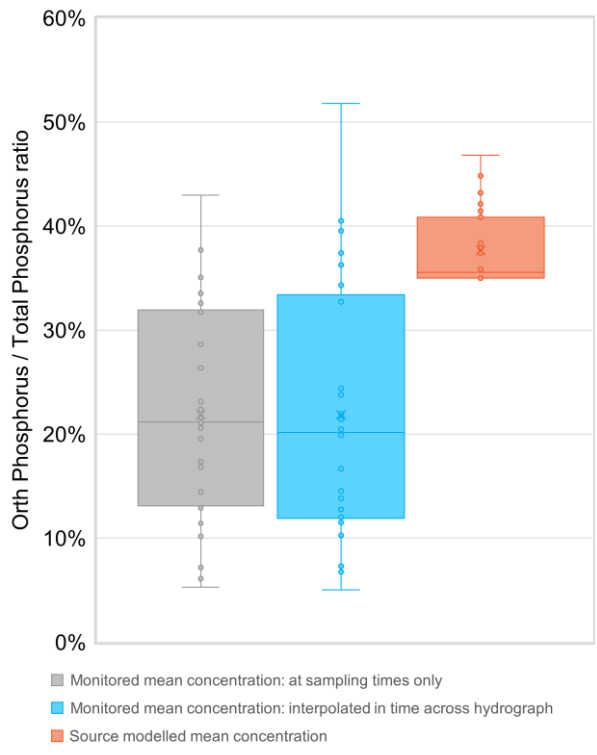

Figure 5-16 Box plots of Ortho Phosphate to Total Phosphorus ratio from monitored events compared to Source model results

In their intermittent sampling of water quality at the four sites in Lake Parramatta Dam over the period between December 2014 and February 2017 Parramatta Council took 61 samples of TP at each of sites LP1, LP3 and LP5 and 20 samples of TP at site LP2. The gaps between samples varied considerably, with the shortest gaps being around 2 days and the longest gap extending to just over a month. Figure 5-17 shows that that the modelled TP concentrations at all sites were larger than the monitored concentrations at Parramatta Dam, with no overlap in the interquartile ranges of modelled to monitored TP at any of the sites. This was a consequence of selecting TP EMC values in the Source model to match monitoring data in the receiving water model, rather than to match monitoring data in the catchment.

There was no analysis data provided of the Ortho Phosphate component of TP at the Lake Parramatta monitoring sites.

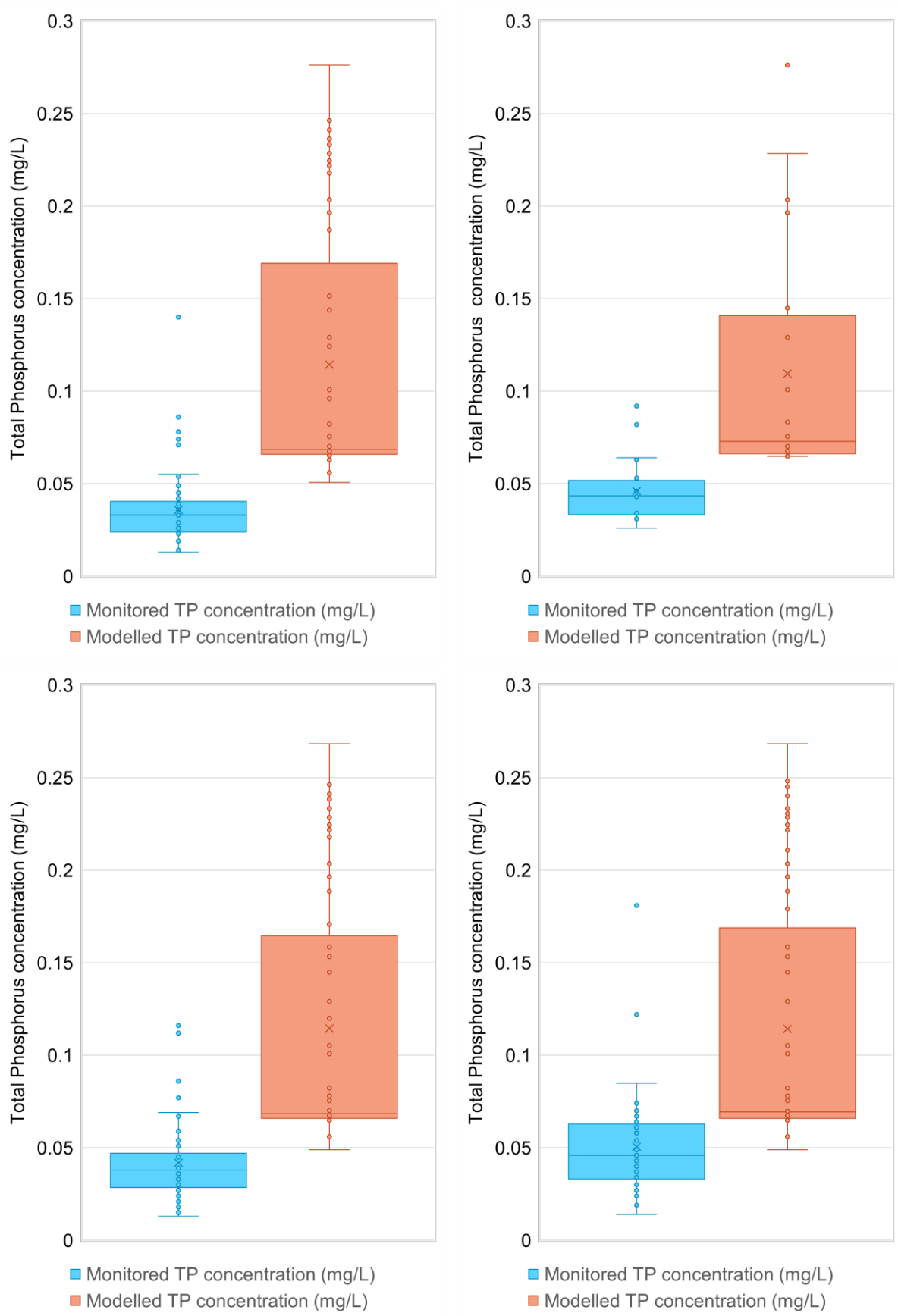

Figure 5-17 Monitored and modelled TP concentrations at Lake Parramatta sites: LP1 (top left), LP2 (top right), LP3 (bottom left) and LP5 (bottom right)

5.5 Spatial distribution of generated loads and concentrations

The Source model was used to generate hourly time series of inputs to MIKE models of Sydney Harbour at 238 locations (see Section 3.6). As discussed in Section 4.6, the mean annual inflow volume at each inflow node was strongly dependent on the upstream catchment area draining to each node, with the largest contributions of inflow provided by the largest catchments (see Figure 4-18). Patterns of mean annual runoff were consistent with the expected hydrological response, with the largest mean annual runoff per unit catchment area contributed by highly urbanised catchments.

A similar approach was used to check the concentrations and loads of constituents generated at each inflow location. For each constituent, maps were prepared of the flow-weighted mean concentration at each inflow location and the mean annual load of constituent per unit of upstream catchment area. For brevity, a few representative maps are shown and discussed in this section. Figure 5-18, Figure 5-19, Figure 5-20 and Figure 5-21 show mean concentrations of TSS, TN, TP and Enterococci respectively. Higher modelled concentrations were produced at inflow nodes that had a higher proportion of urban landuse upstream and/or a large contribution of inflow from sewer overflows relative to stormwater runoff. Conversely, lower modelled concentrations were produced at inflow nodes that were mainly bush or parkland catchments, with no sewer overflow contribution. The maps of mean concentrations and load per unit area of each constituent were used to diagnose and remove errors in the Source model (such as minor errors in input rainfall timeseries), which were then fixed before producing the final time series of flows and loads at each of the 238 input locations.

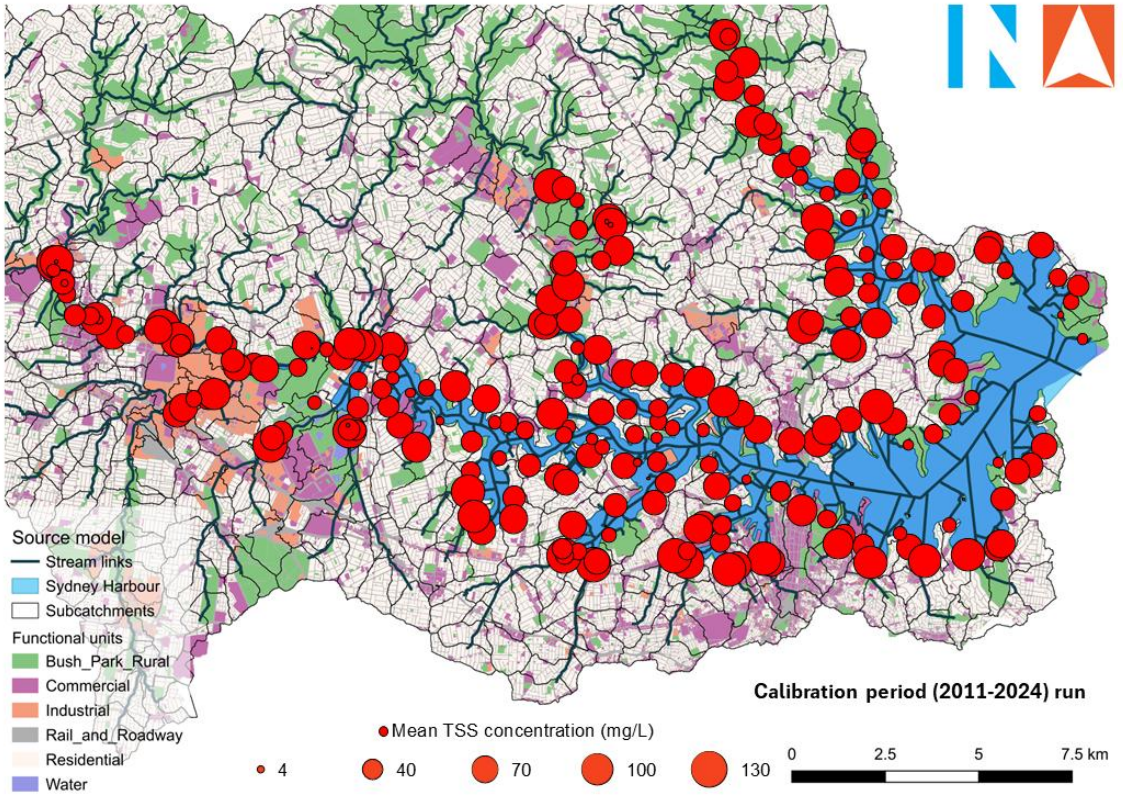

Figure 5-18 Mean TSS concentration for inflow locations

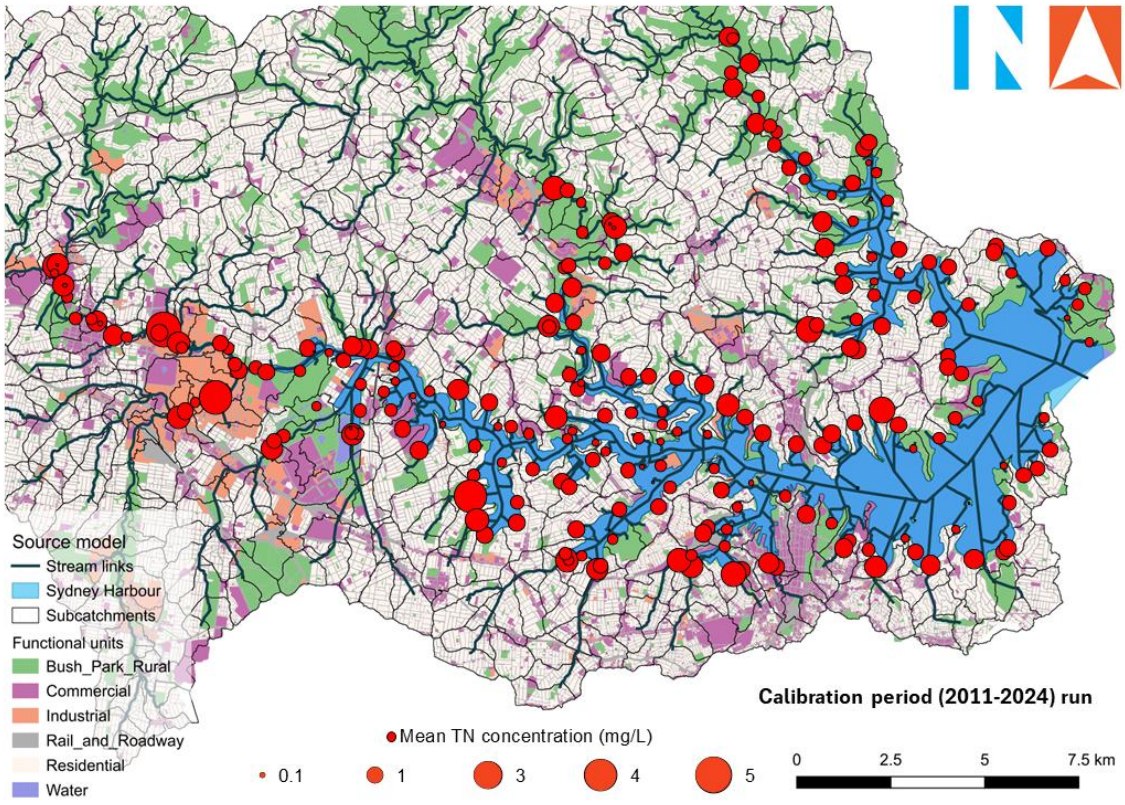

Figure 5-19 Mean TN concentration for inflow locations

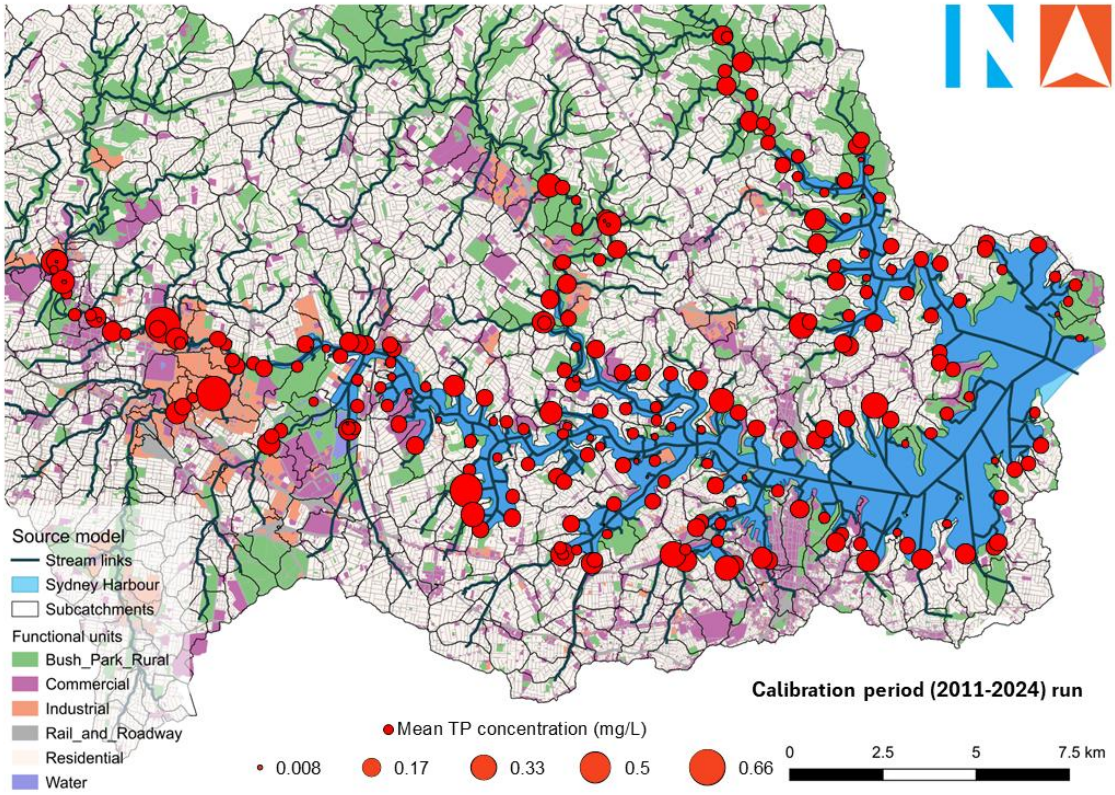

Figure 5-20 Mean TP concentration for inflow locations

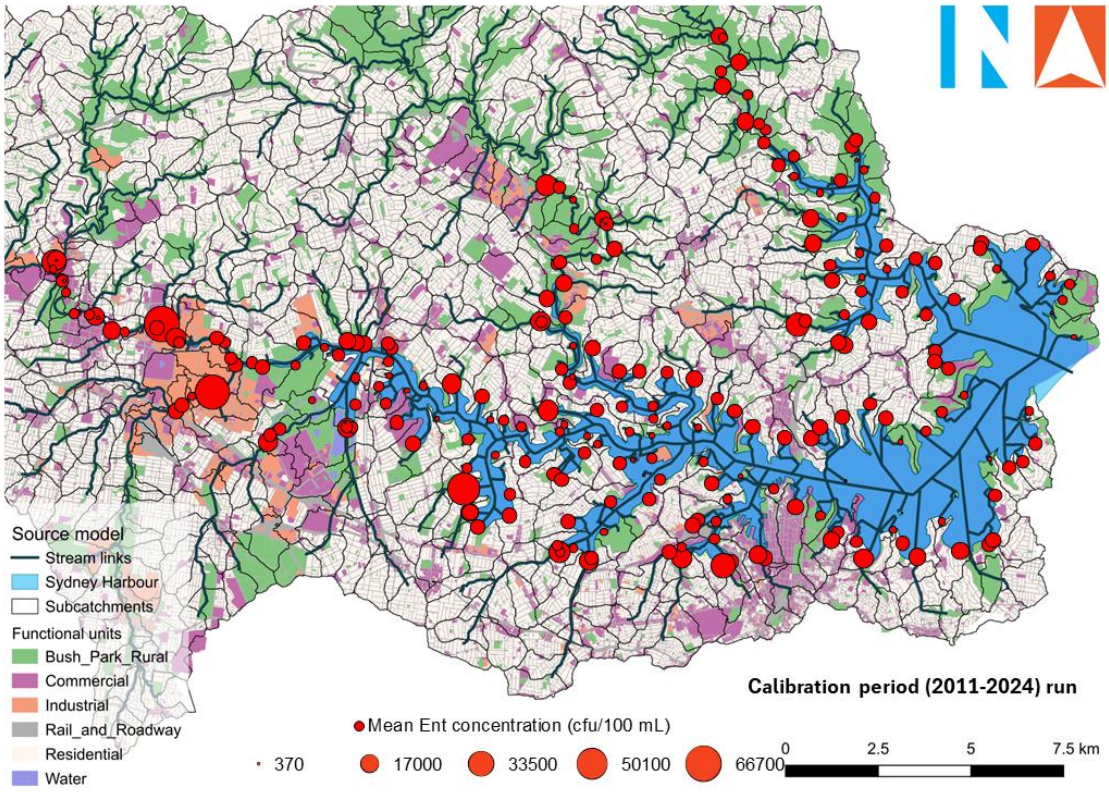

Figure 5-21 Mean Enterococci concentration for inflow locations

6. Scenario models

The Source model was used to generate flow and load timeseries inputs to the MIKE model of Sydney Harbour for five scenarios:

- Baseline
- 2056 Background
- 2056 Background with climate change
- 2056 Impact
- 2056 Impact with climate change

Sydney Water supplied all the necessary inputs, including modified projections of climate data for the climate change scenarios and modified time series of sewer overflows for the five scenarios. The simulation of all five source models spanned from July 2015 to June 2022 (inclusive).

6.1 Baseline scenario

The Baseline scenario represents the current state of the water quality system without any specific climate change impacts included. For this scenario, only sewer overflows data updated with climate change factors are considered. This scenario provides a reference point to compare how water quality conditions might change under different climate change scenarios.

Maps of mean concentrations generated for each of the inflow points to the MIKE models are provided in Appendix F.

6.2 Scenario 2056 background

In the 2056 Background scenario, the focus is on projecting the future state of water quality in 2056 based on background trends and factors, excluding direct climate change impacts. Like the Baseline scenario, only sewer overflows data updated with climate change factors are utilised.

6.3 Scenario 2056 background with climate change

The 2056 Background with climate change scenario combines the projected conditions of the 2056 Background scenario with the additional impacts of climate change. For this scenario, inputs include processed overflows, future climate change rainfall data, dilution factors based on climate-changed rainfall, and climate change-adjusted Potential Evapotranspiration (PET) provided by Sydney Water.

6.4 Scenario 2056 impact

The 2056 Impact scenario focuses on specific environmental impacts that are expected to occur by 2056, excluding direct climate change effects. Like the Baseline and 2056 Background scenarios, only sewer overflows data updated with climate change factors are used for this scenario.

6.5 Scenario 2056 impact with climate change

In the 2056 Impact with Climate Change scenario, the projected impacts of climate change are integrated with the specific environmental impacts outlined in the 2056 Impact scenario. Inputs for this scenario include processed overflows, future climate change rainfall data, dilution factors based on climate-changed rainfall, and climate change-adjusted PET provided by Sydney Water.

7. Conclusions

A catchment flow and water quality model was developed for the catchments that drain to Sydney Harbour. The model was developed in the eWater Source software. It runs on an hourly time step, covering the period between 1 July 2011 and 30 June 2024.

The Source model simulates catchment runoff using hourly time-step SimHyd models, with flows then routed between subcatchments using non-linear storage flow routing. Modelled time series of hourly sewer overflows were also incorporated into the Source model. Rainfall runoff and flow routing parameters were calibrated to gauge streamflow at 7 gauges across the study area. The calibration of the Source model to hourly gauged flows was very good at the 3 gauges that had the longest and most reliable records (in Toongabbie Creek, the Parramatta River and Upper Lane Cove River), with all producing Nash Sutcliffe Efficiency (NSE) values from hourly data greater than 0.8 and NSE values from daily data greater than 0.87. Calibration performance at the other 4 gauges was more variable but gauge records at these sites were typically only a few years and the rating of gauged level to flow at these sites was less accurate.

The model generally produced a very good match to gauged flow for the total volumes of runoff for the 13 water years that were simulated. It was noted that the SimHyd model over-estimates flow in the wettest year because regular runoff from impervious areas keeps pervious areas and depression storage wetter than would be simulated by the SimHyd model. Conversely, the SimHyd model under-estimates flow in the driest years because rainfall occurs less frequently, and water evaporates from depression storages of impervious areas more than would be simulated by the SimHyd model. Also, in dry periods irrigation water is applied to private gardens and public parks, gardens and sporting fields, which artificially supplements baseflow and therefore adds to the total gauged volume of flow, but irrigation application is not explicitly represented in the SimHyd model.

Overcoming these relatively small differences in total water year modelled volume would require changes to the structure of the rainfall runoff model applied in Source, which could be implemented via a custom rainfall-runoff model plugin in Source. Whist this is something that could be considered for future implementations of Source models in urban areas, further work research and development and testing against more accurate and reliable gauging data in urban catchments would be required before such a change would be recommended.

The Source model produced generally very poor matches to Event Mean Concentrations of water quality parameters that were obtained from auto-samplers during events. Mean values of Event Mean Concentrations of monitored Total Nitrogen and Nitrogen species, Total Phosphorus and Ortho Phosphate, Total Suspended Solids were consistently lower than the corresponding event concentrations produced by the Source models. This was a consequence of adopting water quality parameters in the Source models to be consistent with parameters adopted in Source models in neighbouring catchments and to produce improved matches between modelled and monitored water quality concentrations in the receiving water model for Sydney Harbour. This could be a consequence of water quality monitoring data being limited to sites that were mainly in the upper part of each of the catchments, with limited water quality monitoring available at sites that were downstream of catchments with more densely developed upstream landuse.

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Appendix A Streamflow data merging and quality assurance checks

A.1 213004: Parramatta River at Marsden Street Weir

Two sources of streamflow data were available at gauging station 213004: Parramatta River at Marsden Street Weir:

- Data supplied by Sydney Water for gauge number 213004, which started on 06/02/1979 and ended on 08/04/2013.
- Data supplied by the Bureau of Meteorology for flood warning gauge number 567107, which started on 27/07/2009 and ended on 06/05/2024.

The Sydney Water supplied data was on an irregular time step and constituted water levels (in m AHD) and flow (in both m³/s and ML/d).

The BoM flood warning gauge was supplied as irregular data and constituted water level data only. The BoM also supplied a rating table for converting gauged water levels to flow rates at the gauge.

The process for creating a single merged gauge flow data set at the gauge was:

1. Sydney Water flow data was regularised to a 1 hour time step by:
    a. Averaging the flow rates from all data points within each hour, where at least one data point was available
    b. For short periods of missing data (less than 6 hours) between the hourly averaged data, flows were interpolating by taking the logarithm of the flow rates (in ML/d) at either end of the gap, linearly interpolating the log-flow across the gap with time and then converting back from log-flow to flow in ML/d
2. Bureau of Meteorology data was converted from Universal Time Coordinate (UTC) time zone data to local Sydney time, including the application of daylight saving during relevant periods (i.e. +11 hours during daylight saving and +10 hours during non-daylight saving) (Bureau of Meteorology, 2024).
3. Bureau of Meteorology water level data was regularised to a 1 hour time step by:
    a. Averaging the water levels from all data points within each hour, where at least one data point was available
    b. For short periods of missing data (less than 6 hours) between the hourly averaged data, water levels were linearly interpolated across the gap with time
4. Regularised and infilled Bureau of Meteorology water levels were used to calculate flow rates by applying the rating table supplied by the BoM.
5. A merged data set from Sydney Water and the BoM was created by using Sydney Water hourly data when valid data was available (after interpolation) and otherwise using BoM hourly data when available (after interpolation).
6. The merged data set of hourly flow hydrographs was plotted on a log-flow axis (in ML/d) with time and then compared to the flow hydrograph at gauge 213005: Toongabbie Creek at Briens Road. Data at 213005 gauge was more reliable, particularly for lower flow rates, as this gauge is maintained by WaterNSW hydrographers as part of the NSW Government statewide flow monitoring network. Hydrographers regularly measure ratings at the 213005 gauge and use

these ratings to update the rating table and gauged flows at the gauge. By contrast, ratings are not regularly updated at the 213004 gauge by Sydney Water or the BoM and the flows at the 213004 gauge are less reliable, particularly for lower flow rates. Visual inspection of the hourly flow hydrographs from the 213005 and 213004 gauges revealed artefacts in the 213004 gauged data, including:

a. Spurious “spikes” of low flow at 213004, which were unrelated to actual changes in flow in the catchment (see Figure_Apx A-1)
b. Spurious "spikes” of very high flow and water level at 213004, which were unrelated to actual flow events in the catchment (see Figure_Apx A-2 and Figure_Apx A-3)
c. Obvious shifts or transitions in low flows from one near constant level to another at 213004, which were inconsistent with the gauged flows at 213005. These were most likely due to inappropriate rating tables for lower flows at 213004, as the BoM focusses on flood flows at this site rather than accurate rating of low flows (see Figure_Apx A-1, Figure_Apx A-2 and Figure_Apx A-3).

7. Manual comparison of the 213004 against the 213005 hourly flow hydrographs was undertaken to define periods when the 213004 data was sufficiently reliable and consistent with 213005 to make it useful for calibration of catchment model flows.

A.2 213219: Toongabbie Creek at Johnsons Bridge

Two sources of streamflow data were available at gauging station 213219: Toongabbie Creek at Johnsons Bridge:

- Data supplied by Sydney Water for gauge number 213282, which started on 31/01/2013 and ended on 06/08/2013.
- Data supplied by the Bureau of Meteorology for flood warning gauge number 567058, which started on 26/11/2005 and ended on 06/06/2023.

The Sydney Water supplied data was on an irregular time step and constituted water levels (in m AHD) and flow (in both m³/s and ML/d). Sydney Water also supplied a rating table for converting gauged water levels to flow rates at the gauge.

The BoM flood warning gauge was supplied as irregular data and constituted water level data only. No rating table for the BoM gauge data was supplied.

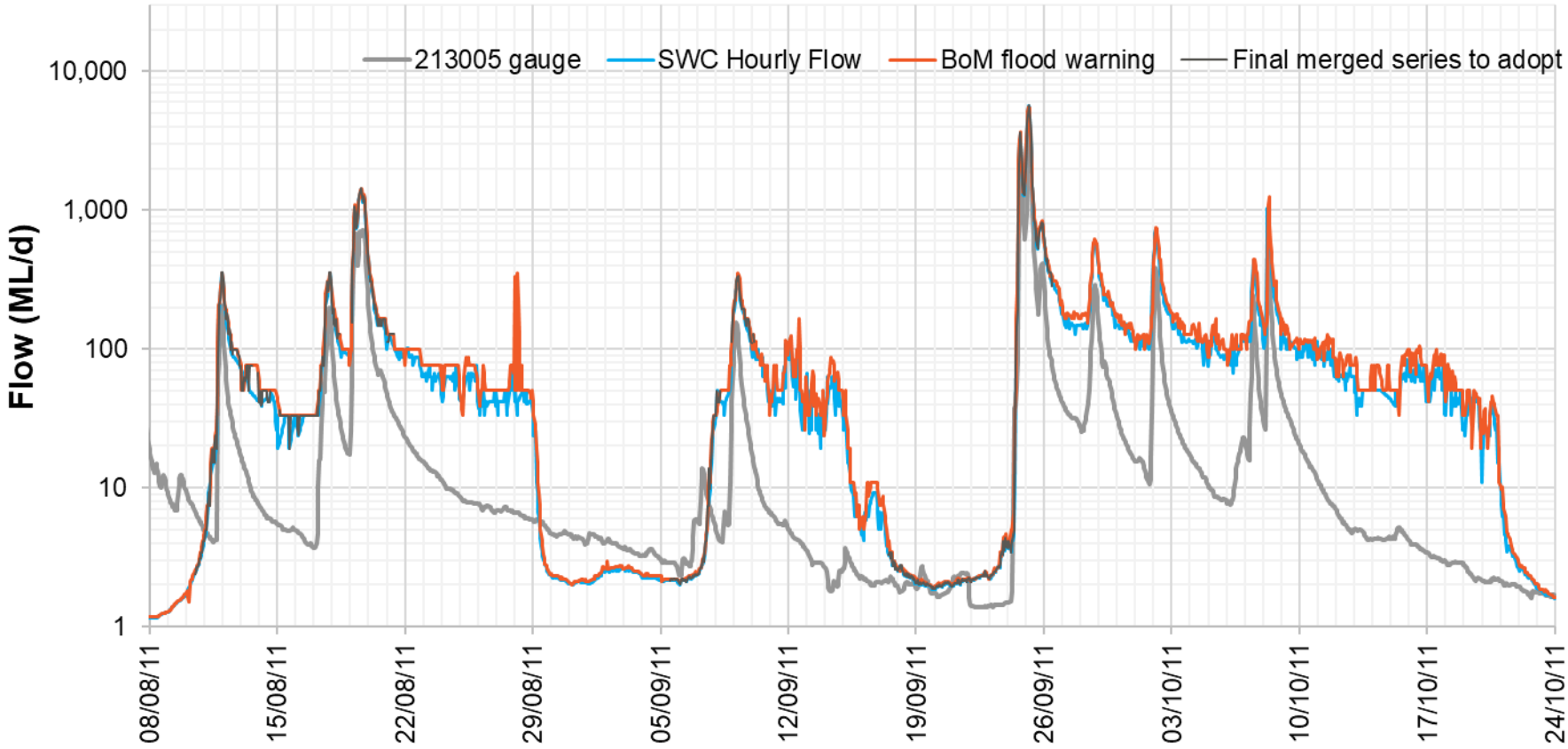
The process for creating a single merged gauge flow data set at the gauge was:

1. Sydney Water water level data was regularised to a 1 hour time step by:
    a. Averaging the water levels from all data points within each hour, where at least one data point was available
    b. For short periods of missing data (less than 6 hours) between the hourly averaged data, water levels were linearly interpolated across the gap with time
2. Bureau of Meteorology data was converted from Universal Time Coordinate (UTC) time zone data to local Sydney time, including the application of daylight saving during relevant periods (i.e. +11 hours during daylight saving and +10 hours during non-daylight saving) (Bureau of Meteorology, 2024).
3. Bureau of Meteorology water level data was regularised to a 1 hour time step by:
    a. Averaging the water levels from all data points within each hour, where at least one data point was available
    b. For short periods of missing data (less than 6 hours) between the hourly averaged data, water levels were linearly interpolated across the gap with time
4. For hours that had water level data recorded at both the Sydney Water and BoM gauges, a regression relationship was derived between Sydney Water and BoM levels. The fitted regression relationship was $H_{SWC\ 213219} = 1.00659\ H_{BoM\ 567058} + 0.025$ ($R^2 = 0.986$) (see Figure_Apx A-4).
5. For hours that only had water level recorded at the BoM gauge but not the Sydney Water gauge, the equation derived from the previous step was used to convert water levels at the BoM gauge to equivalent water levels to the Sydney Water gauge 213219 (see Figure_Apx A-4).
6. Regularised and infilled hourly water levels from both gauges were used to calculate flow rates by applying the rating table supplied by Sydney Water.
7. A merged data set from Sydney Water and the BoM was created by using Sydney Water hourly data when valid data was available (after interpolation) and otherwise using BoM hourly data when available (after interpolation).
8. The merged data set of hourly flow hydrographs was plotted on a log-flow axis (in ML/d) with time and then compared to the flow hydrograph at gauge 213005: Toongabbie Creek at Briens

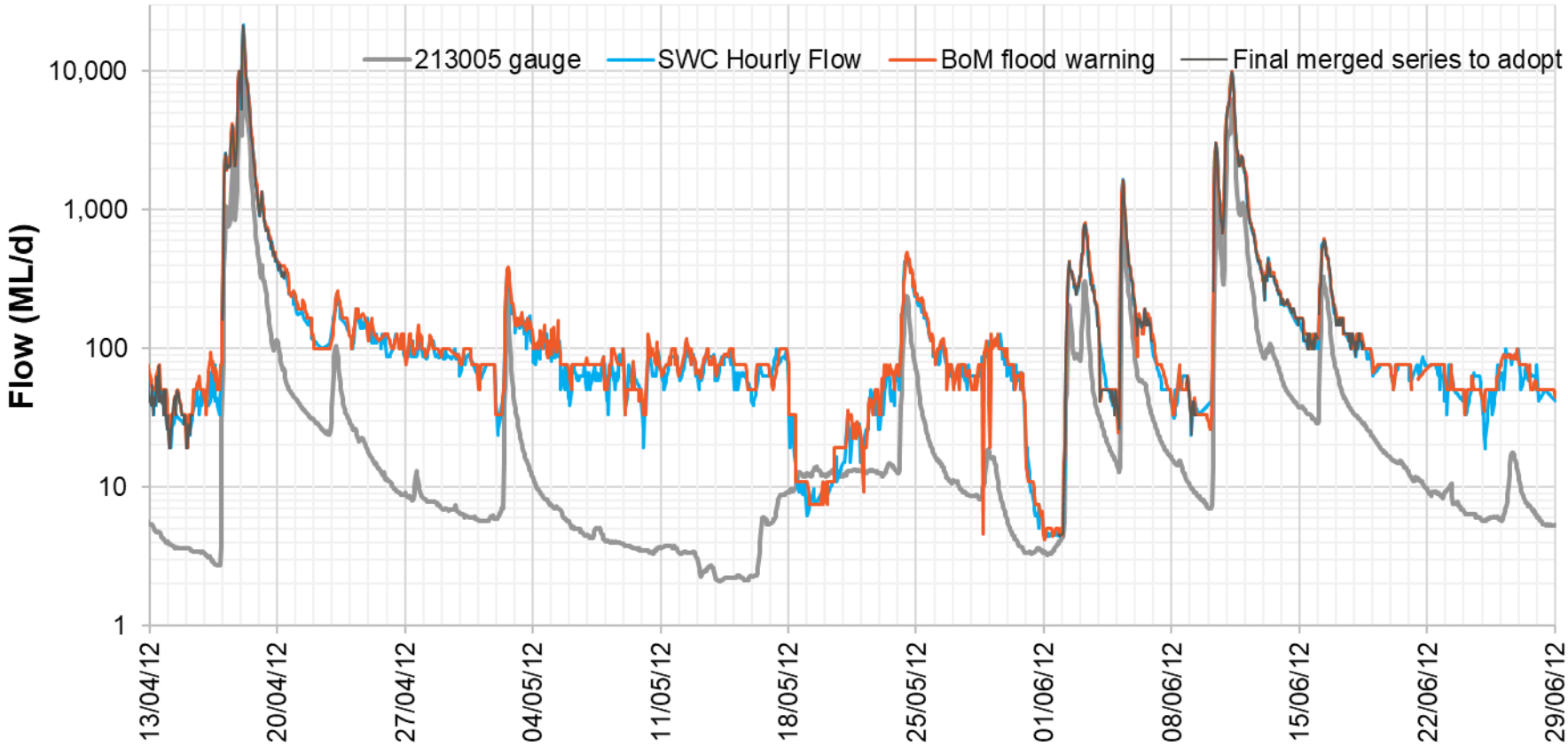
Road. Data at 213005 gauge was more reliable, particularly for lower flow rates, as this gauge is maintained by WaterNSW hydrographers as part of the NSW Government statewide flow monitoring network. Hydrographers regularly measure ratings at the 213005 gauge and use these ratings to update the rating table and gauged flows at the gauge. By contrast, ratings are not regularly updated at the 213219 gauge by Sydney Water or the BoM and the flows at the 213219 gauge are less reliable, particularly for lower flow rates. Visual inspection of the hourly flow hydrographs from the 213005 and 213219 gauges revealed artefacts in the 213219 gauged data, including:

a. Spurious “spikes” of low flow at 213219, which were unrelated to actual changes in flow in the catchment (see Figure_Apx A-6)
b. Spurious "spikes” of very high flow and water level at 213219, which were unrelated to actual flow events in the catchment (see Figure_Apx A-5)
c. Obvious shifts or transitions in low flows from one near constant level to another at 213219, which were inconsistent with the gauged flows at 213005. These were most likely due to inappropriate rating tables for lower flows at 213219, as the BoM focusses on flood flows at this site rather than accurate rating of low flows catchment (see Figure_Apx A-5).

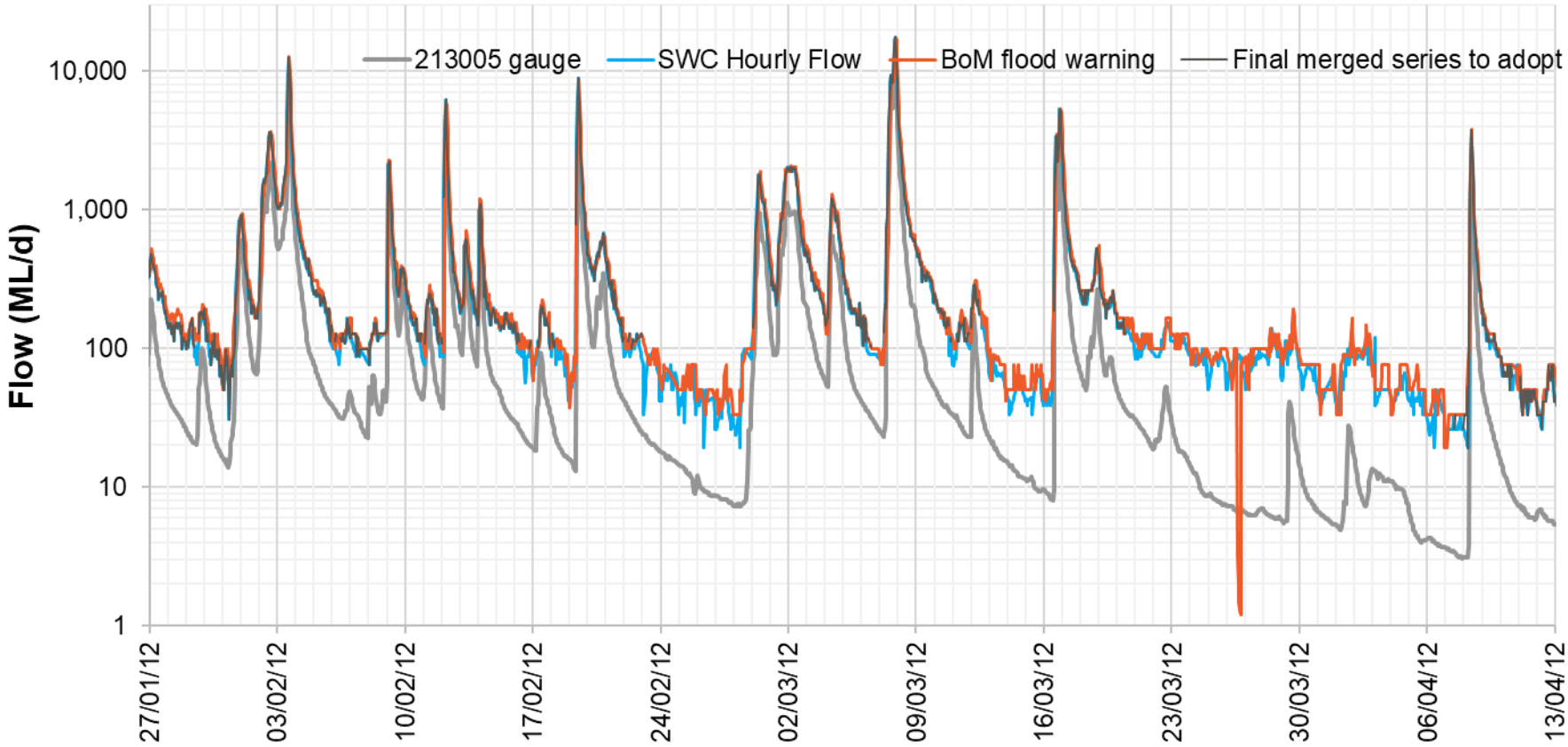
9. Manual comparison of the 213219 against the 213005 hourly flow hydrographs was undertaken to define periods when the 213219 data was sufficiently reliable and consistent with 213219 to make it useful for calibration of catchment model flows.



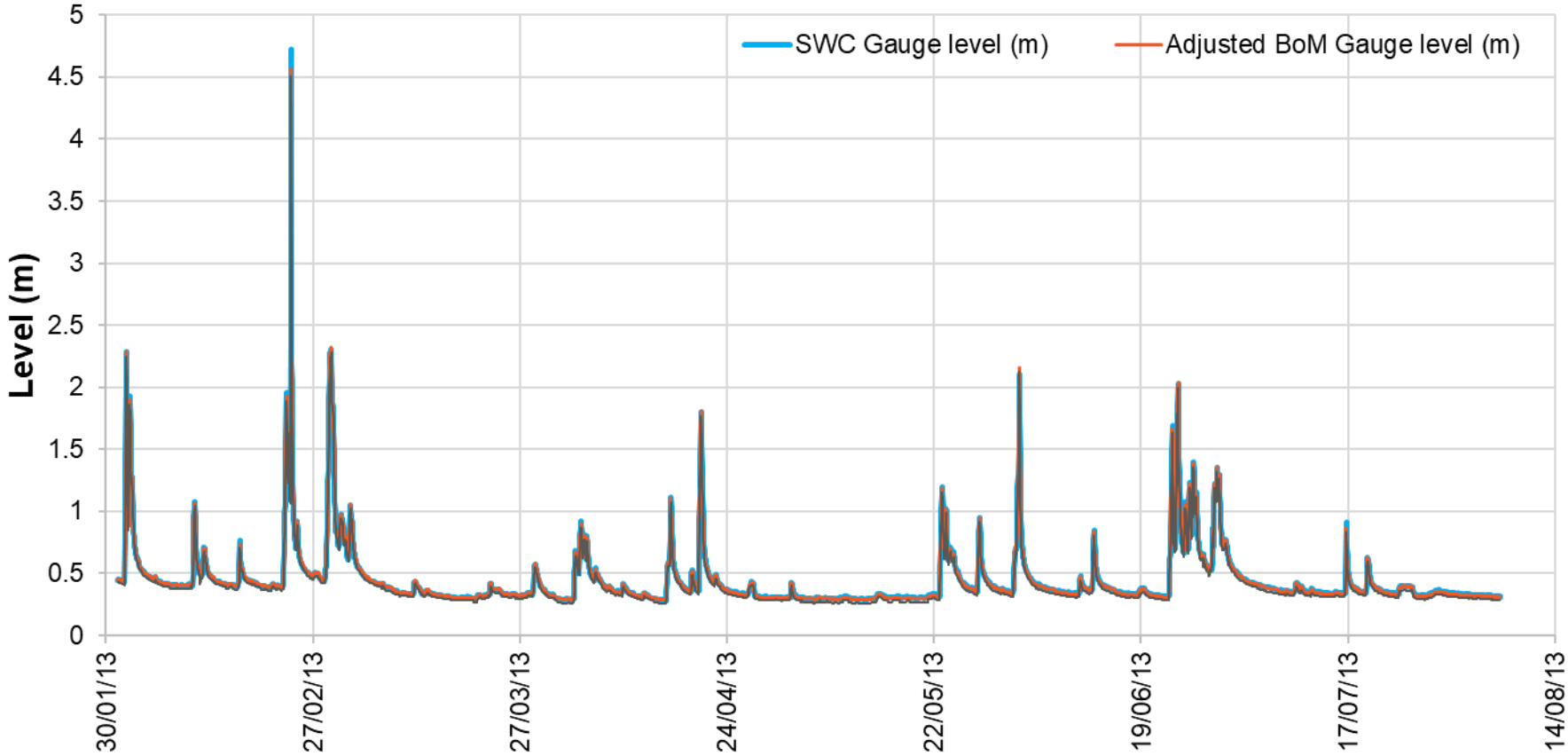
Figure_Apx A-1 213004 Marsden Street Weir v 213005 Toongabbie Creek gauges, showing an example of a period showing high flow spikes in the BoM flood warning gauge data, which were clearly inconsistent with the other gauge on Toongabbie Creek. Periods of high flow spikes were removed from the 213004 gauge data used for Source model calibration.



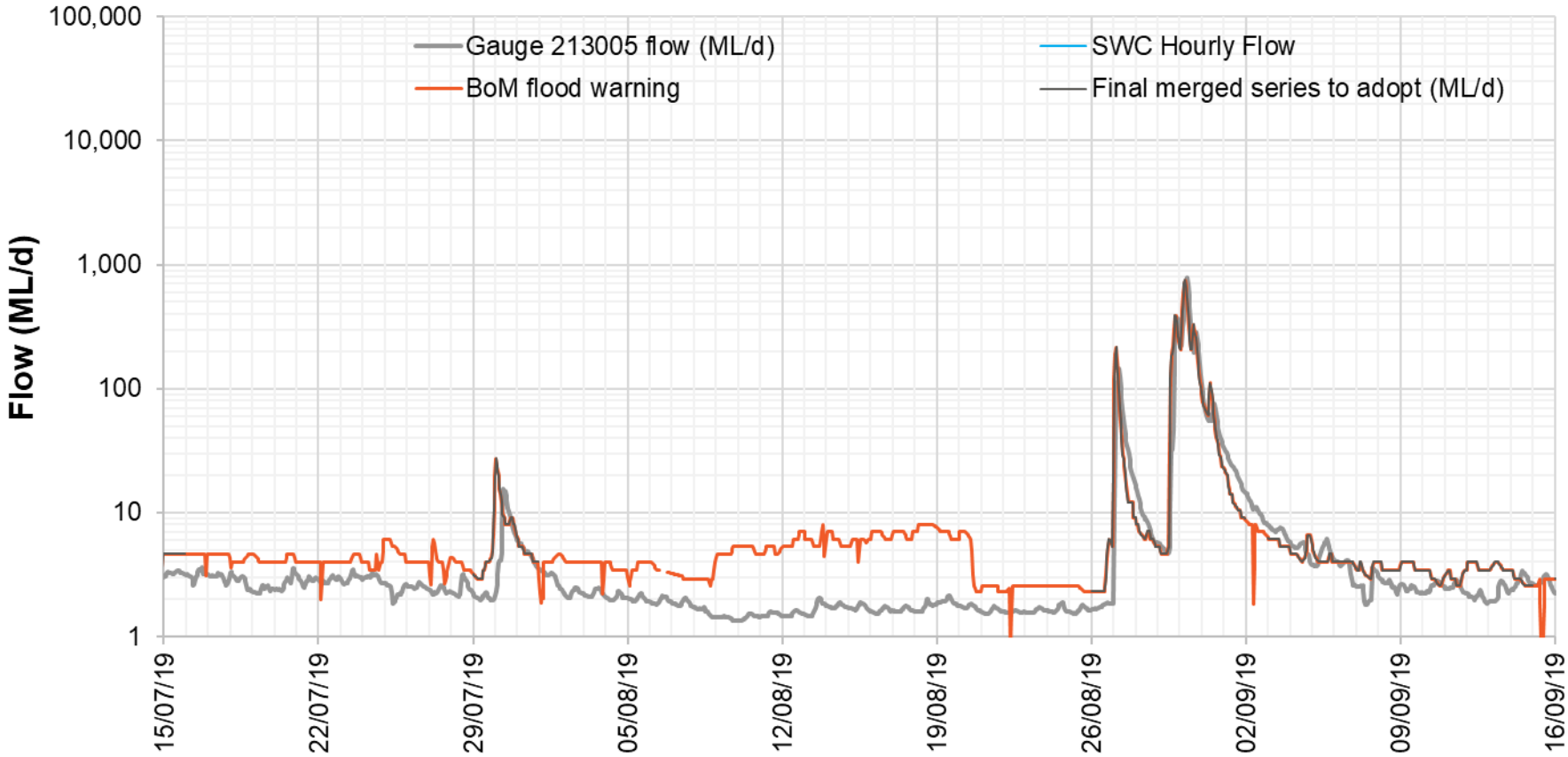
Figure_Apx A-2 213004 Marsden Street Weir v 213005 Toongabbie Creek gauges, showing a period when the rating table at 213004 (shown by the orange line as BoM flood warning) was spuriously high, likely due to an inappropriate rating table for this period and therefore inconsistent with flows at the 213005 gauge, which has a much more reliable rating



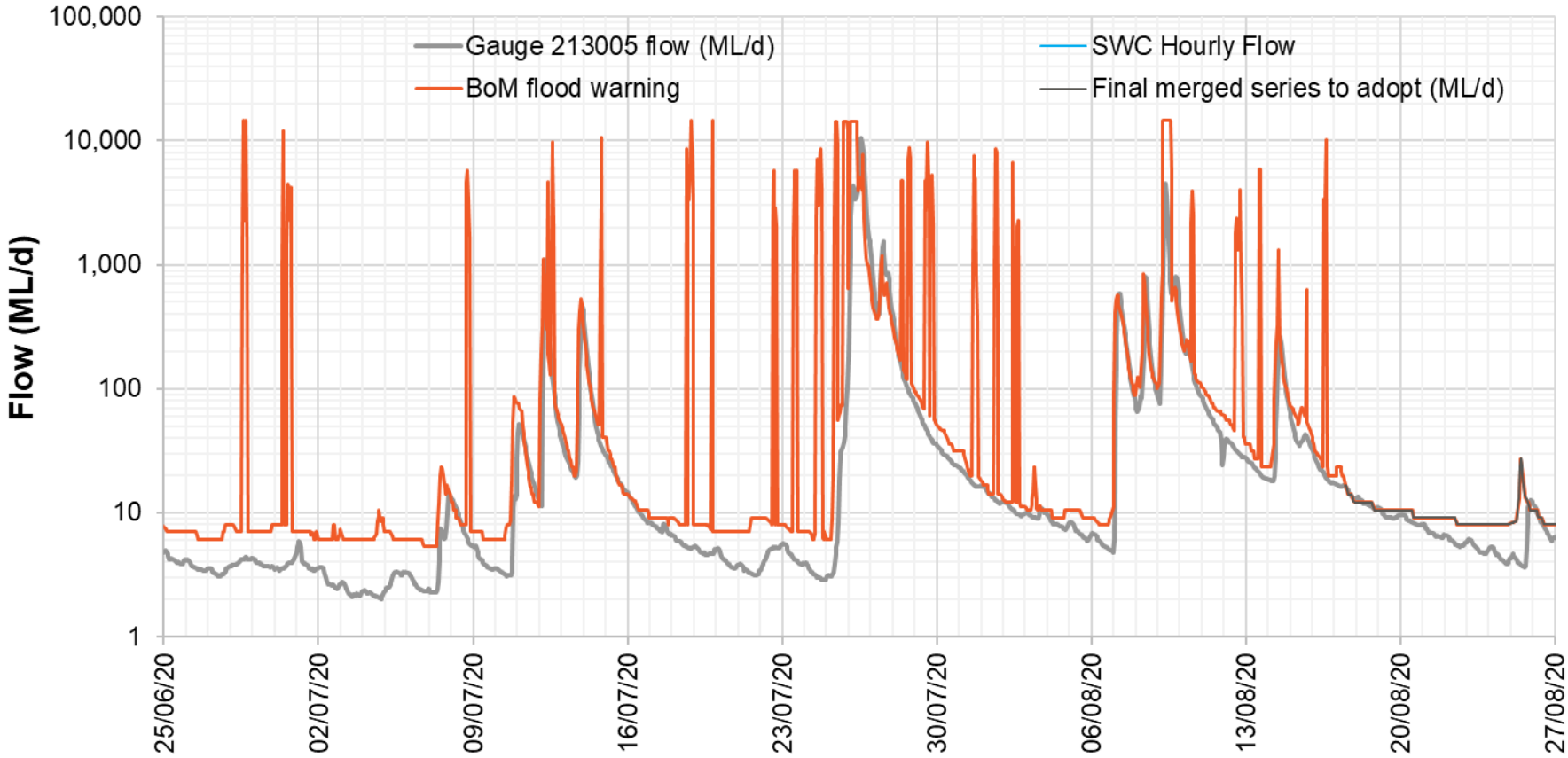
Figure_Apx A-3 213004 Marsden Street Weir v 213005 Toongabbie Creek gauges, showing a period when the rating table at 213004 (shown by the orange line as BoM flood warning) was spuriously high, likely due to an inappropriate rating table for this period and therefore inconsistent with flows at the 213005 gauge, which has a much more reliable rating



Figure_Apx A-4 213219 Toongabbie Creek at Johnsons Bridge: comparison of gauge height levels from Sydney Water supplied and BoM flood warning gauge for period of overlapping record at both gauges (January to August 2013)



Figure_Apx A-5 213219 Toongabbie Creek at Johnsons Bridge: example of period showing low flow spikes in the BoM flood warning gauge data and instability in the rating of low flows at the BoM gauge, which were clearly inconsistent with the other gauge on Toongabbie Creek. Periods of low flow spikes and inconsistent flows were removed from the 213219 gauge data used for Source model calibration.



Figure_Apx A-6 213219 Toongabbie Creek at Johnsons Bridge: example of period showing high flow spikes in the BoM flood warning gauge data, which were clearly inconsistent with the other gauge on Toongabbie Creek. Periods of high flow spikes were removed from the 213219 gauge data used for Source model calibration.

Appendix B Summary of rainfall runoff model performance by water year

Table Apx B-1 Model performance at gauge 213004: Parramatta River at Marsden Weir by water year

Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	100%					
2012-13	45%	21,606	25,241	17%	17%	0.816
2013-14	48%	17,056	20,313	19%	18%	0.796
2014-15	39%	51,704	52,085	1%	8%	0.885
2015-16	37%	29,554	30,990	5%	7%	0.851
2016-17	33%	38,290	39,521	3%	6%	0.849
2017-18	1%	12,523	19,490	56%	10%	0.389
2018-19	27%	39,923	45,336	14%	11%	0.814
2019-20	24%	49,845	52,181	5%	9%	0.926
2020-21	57%	51,960	40,320	-22%	4%	0.839
2021-22	33%	122,598	76,801	-37%	-8%	0.714
2022-23	30%	34,368	42,338	23%	-5%	0.777
2023-24	65%				-4%	

Note: * modelled flow volume for concurrent period with valid gauged flow

Table Apx B-2 Model performance at gauge 213282 Parramatta River at Cumberland Hospital by water year

Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	100%					
2012-13	47%	25,795	31,236	21%	21%	0.737
2013-14	0%	19,563	24,441	25%	23%	0.734
2014-15	47%	24,253	28,288	17%	21%	0.828
2015-16	100%				17%	
2016-17	100%				17%	
2017-18	100%				17%	
2018-19	100%				17%	
2019-20	100%				17%	
2020-21	100%				17%	
2021-22	100%				17%	
2022-23	100%				17%	
2023-24	100%				17%	

Table Apx B-3 Model performance at gauge 213219: Toongabbie Creek at Johnsons Bridge by water year

Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	15%	28,727	27,007	-6%	-6%	0.684
2012-13	21%	15,063	17,041	13%	1%	0.481
2013-14	0%	9,743	11,873	22%	4%	0.494
2014-15	10%	21,303	32,113	51%	18%	-1.868
2015-16	2%	21,373	26,457	24%	19%	0.544
2016-17	24%	20,797	18,409	-11%	14%	0.122
2017-18	90%				13%	
2018-19	32%	17,137	19,993	17%	14%	0.713
2019-20	37%	17,768	21,526	21%	15%	0.586
2020-21	48%	65,599	19,246	-71%	-11%	0.227
2021-22	100%				-11%	
2022-23	99%				-11%	
2023-24	100%				-11%	

Table Apx B-4 Model performance at gauge 213280: Upper Lane Cove River at National Park Weir by water year

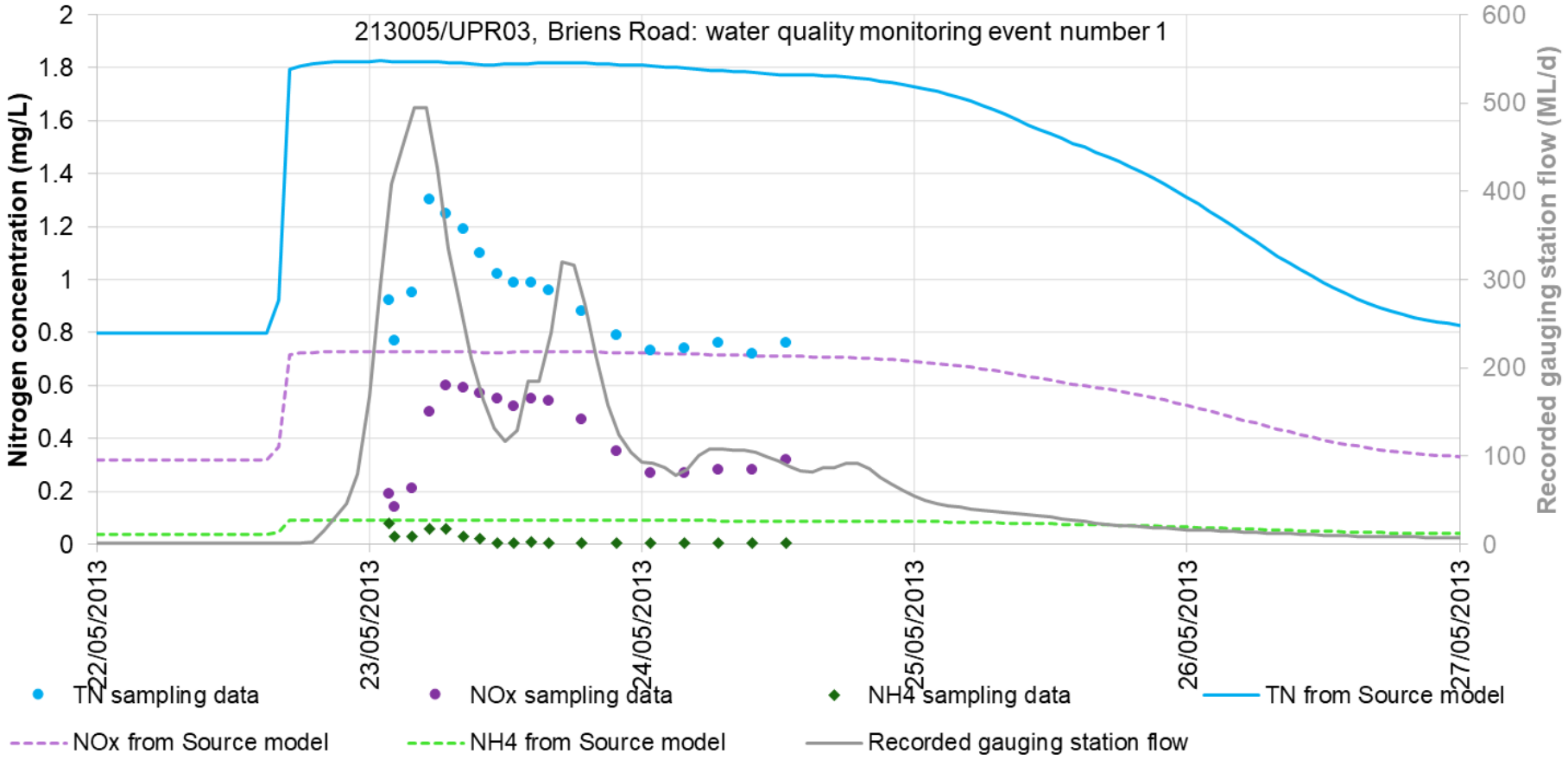
Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	100%					
2012-13	100%					
2013-14	27%	12,237	17,083	40%	40%	0.211
2014-15	50%	13,635	19,055	40%	40%	0.688
2015-16	100%				40%	
2016-17	100%				40%	
2017-18	70%				50%	
2018-19	14%	26,039	35,755	37%	44%	0.716
2019-20	20%	35,918	41,701	16%	33%	0.894
2020-21	5%	42,301	44,533	5%	25%	0.912
2021-22	1%	91,294	66,323	-27%	4%	0.751
2022-23	94%				0%	
2023-24	100%				0%	

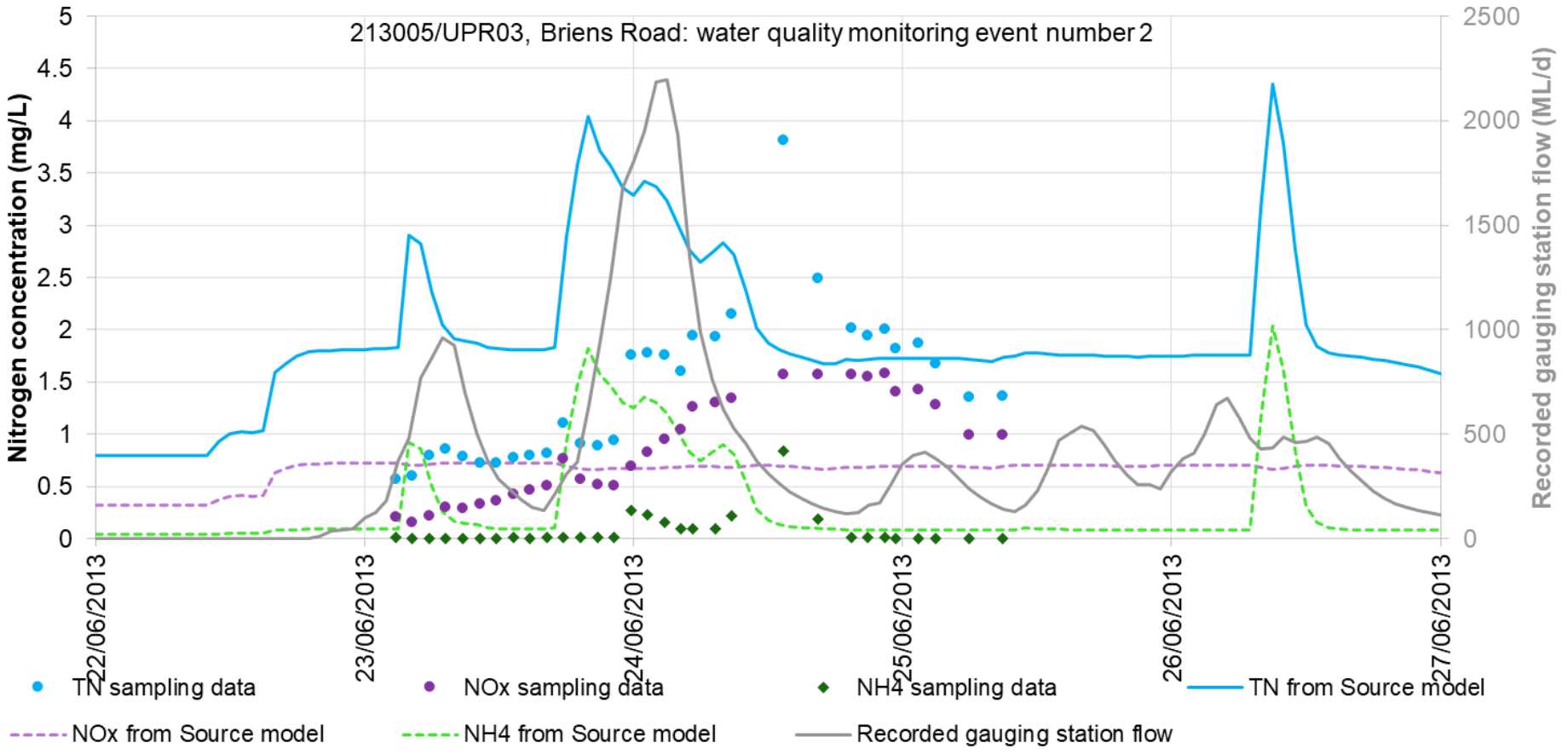
Table Apx B-5 Model performance at gauge 213209: Duck River at Mackay Road by water year

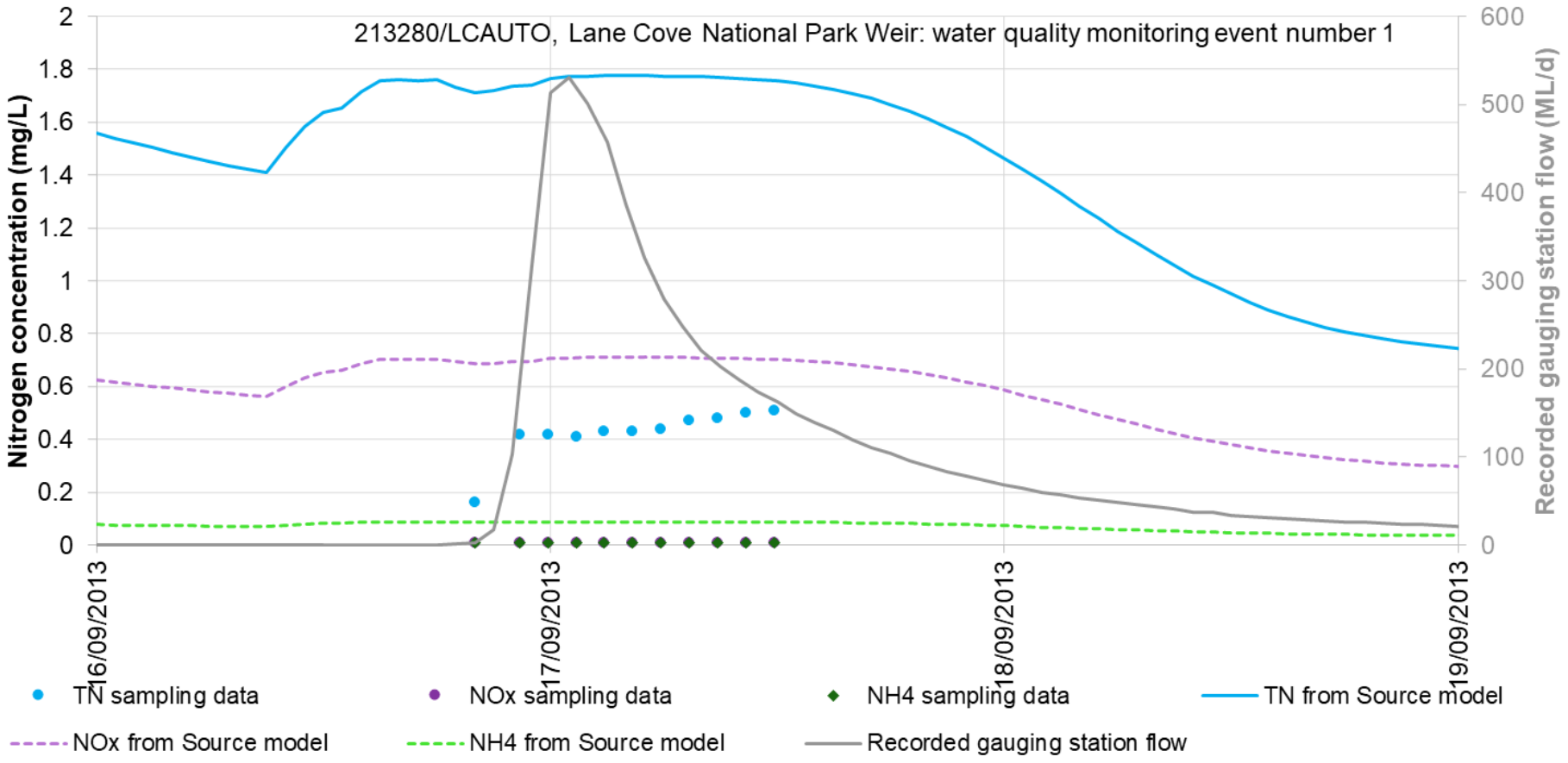
Water year (July to June)	Proportion of missing data (%)	Annual flow volume (ML)		Annual Bias	Cumulative Bias	Nash Sutcliffe Efficiency Hourly
		Gauged	Modelled*			
2011-12	51%	2,307	3,849	67%	67%	0.620
2012-13	100%				67%	
2013-14	100%				67%	
2014-15	100%				67%	
2015-16	100%				67%	
2016-17	100%				67%	
2017-18	18%	2,053	2,860	39%	54%	0.131
2018-19	1%	9,827	6,439	-34%	-7%	0.055
2019-20	5%	10,430	8,924	-14%	-10%	0.635
2020-21	0%	10,259	9,626	-6%	-9%	0.715
2021-22	13%	16,456	14,955	-9%	-9%	0.548
2022-23	100%					
2023-24	100%					

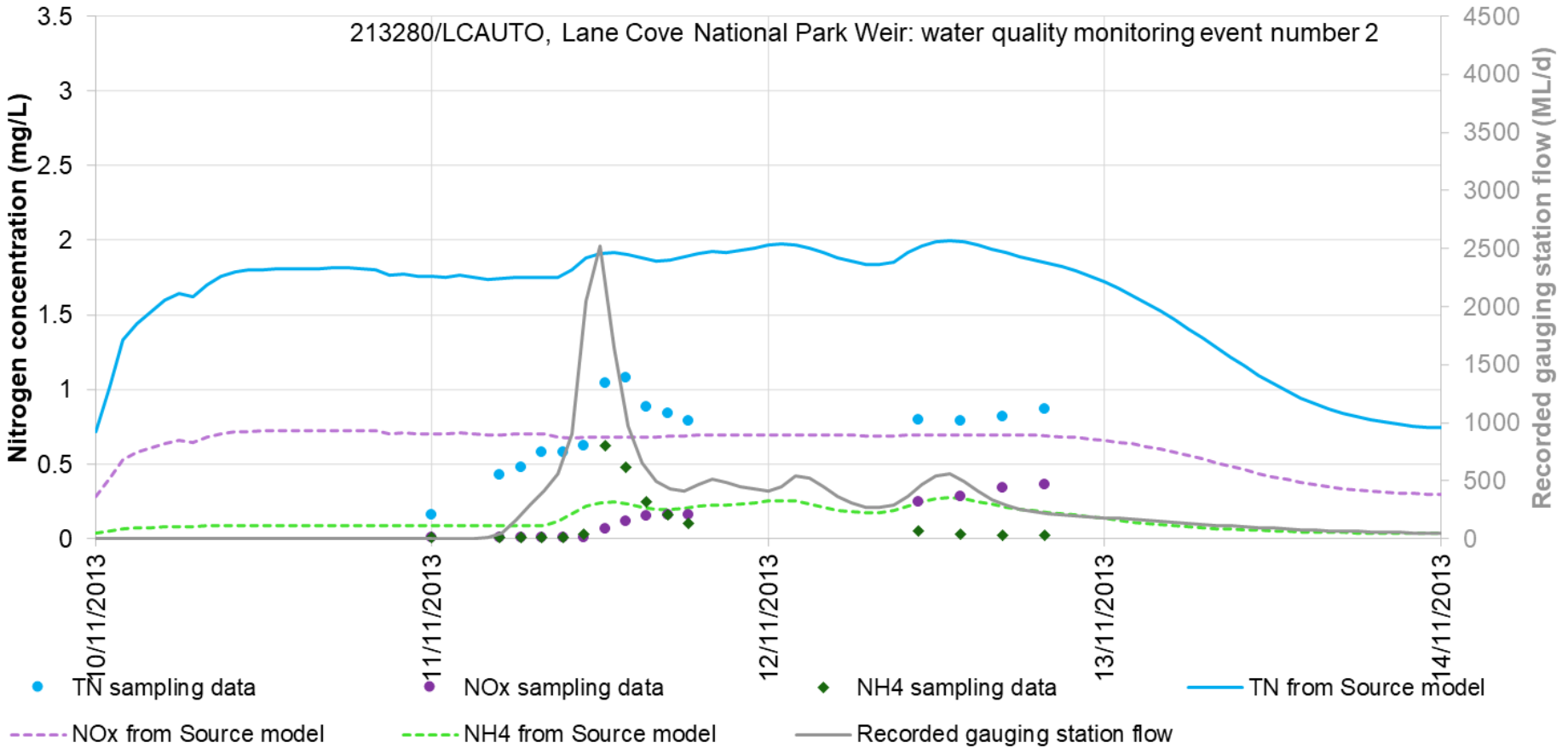
Appendix C Water quality comparison plots for monitored events

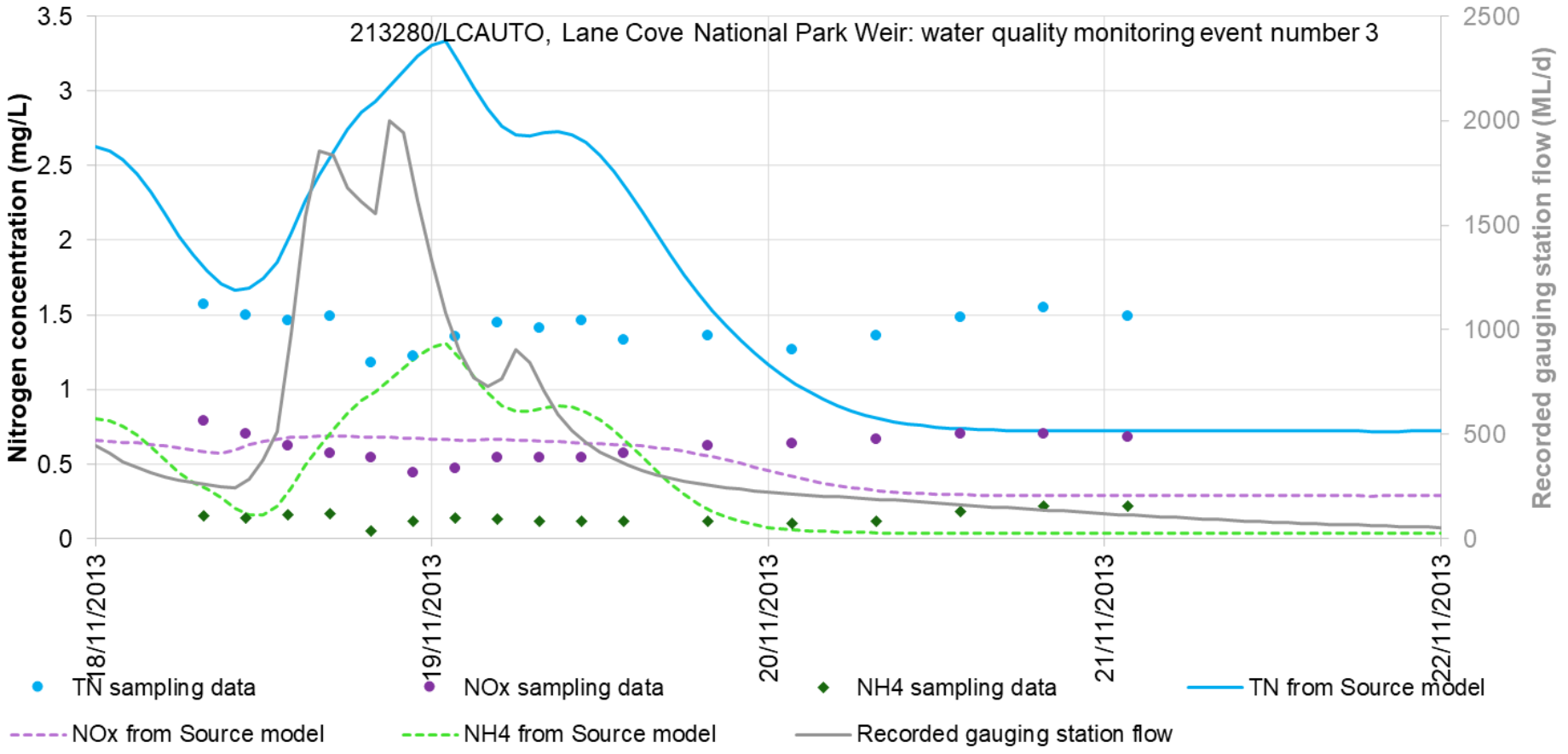
C.1 Total Nitrogen and Nitrogen species comparison plots for monitored events

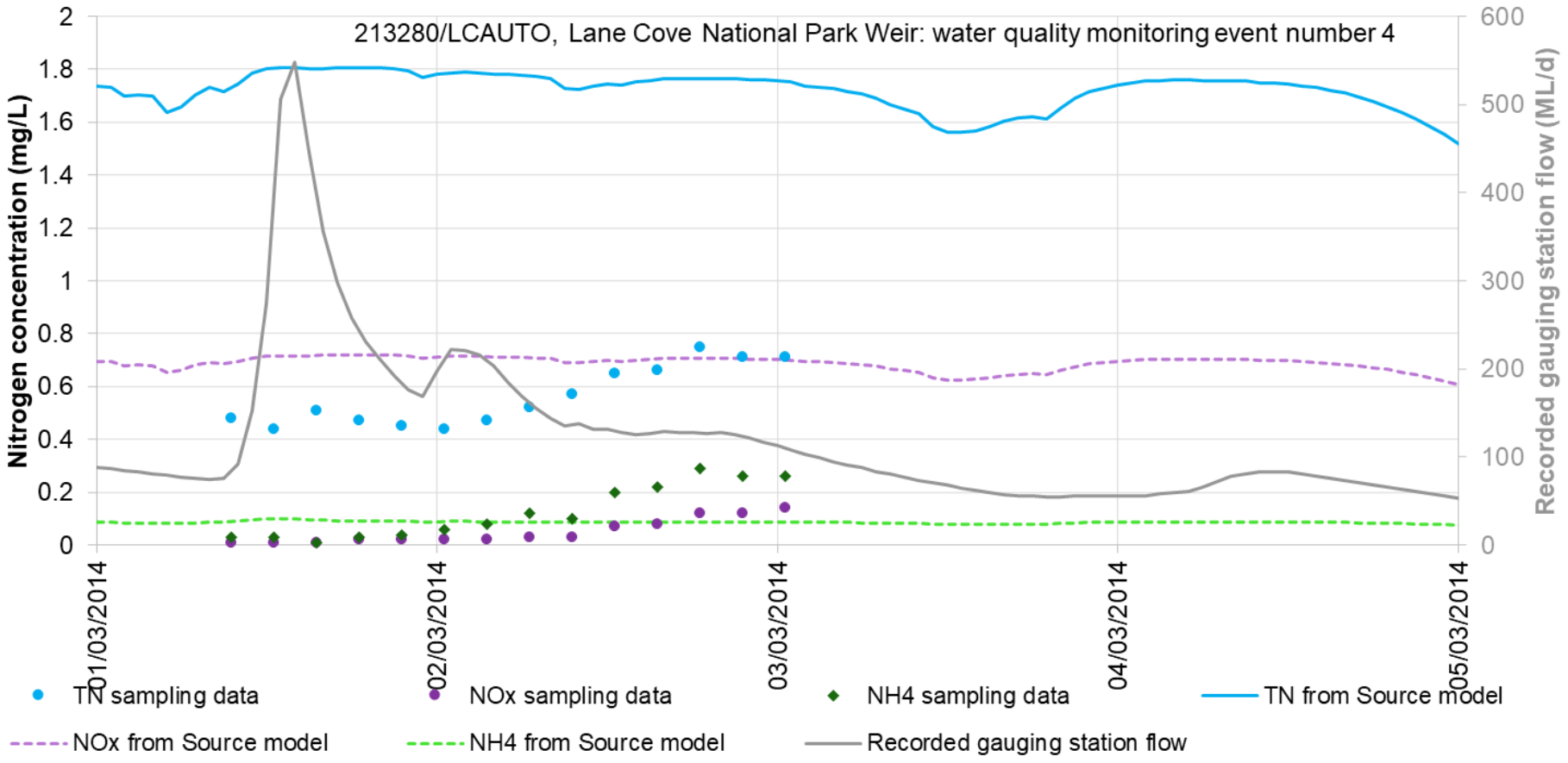


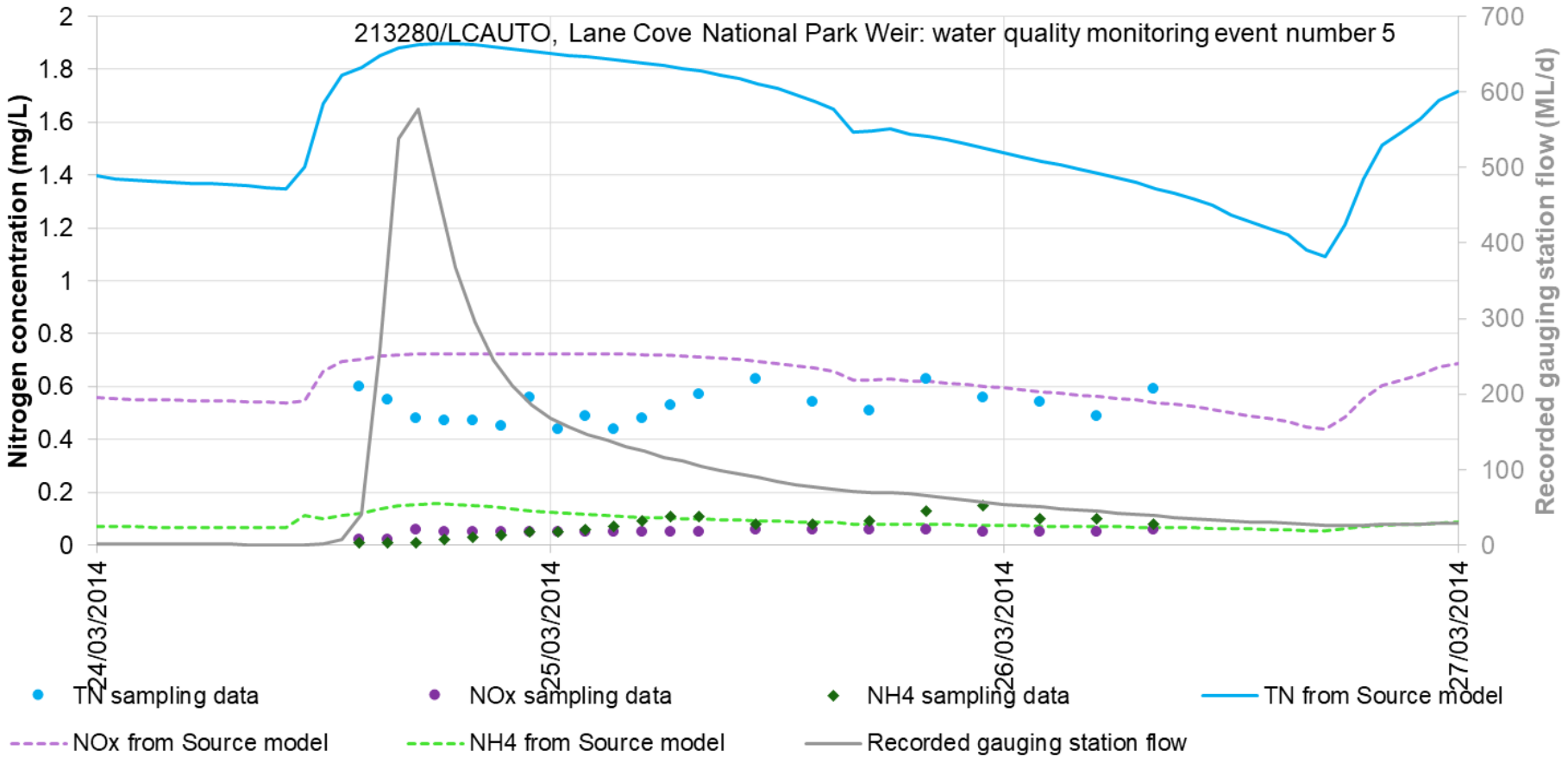

213005/UPR03, Briens Road: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

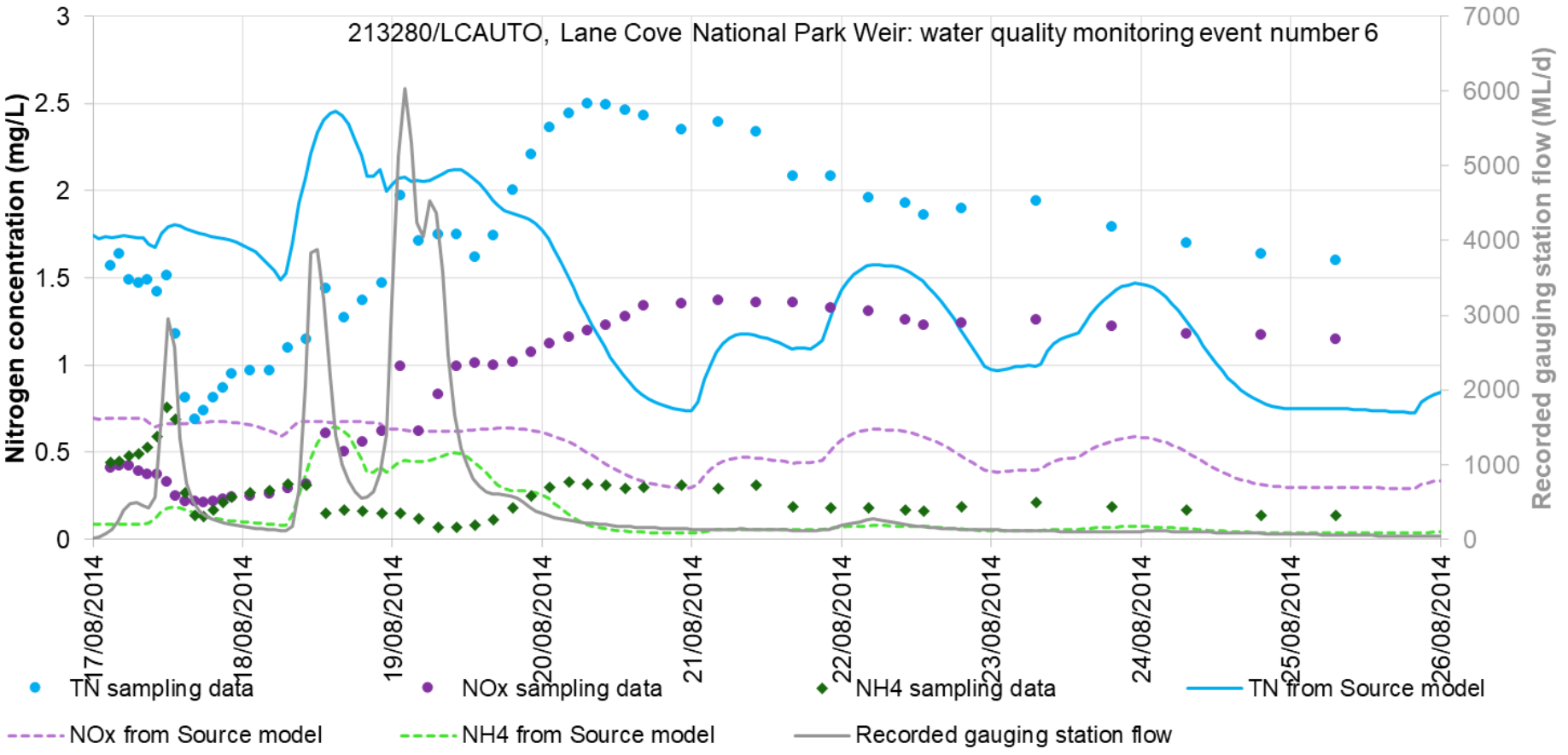

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 1
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
600
500
400
300
200
100
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

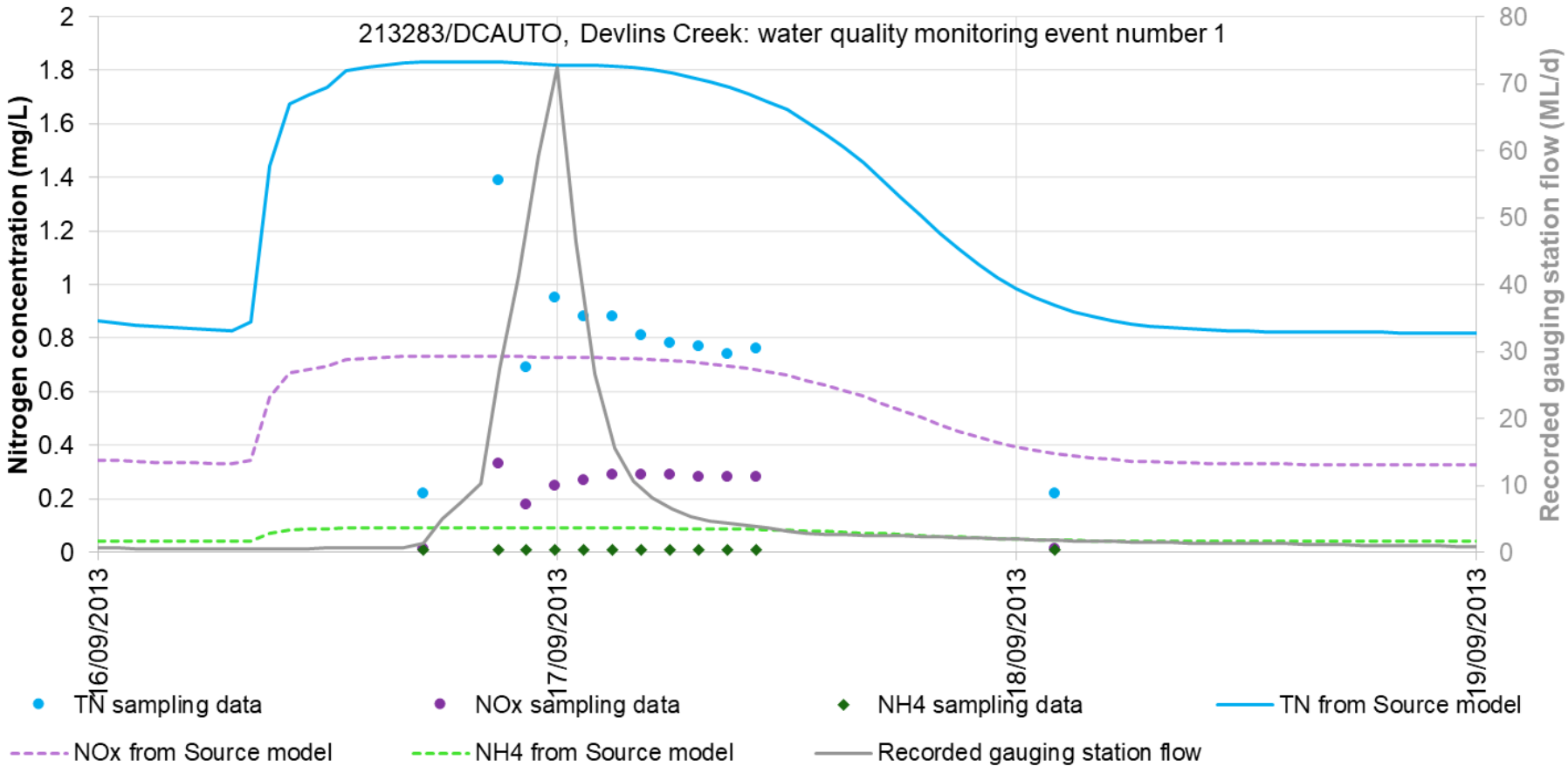

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
3.5
3
2.5
2
1.5
1
0.5
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

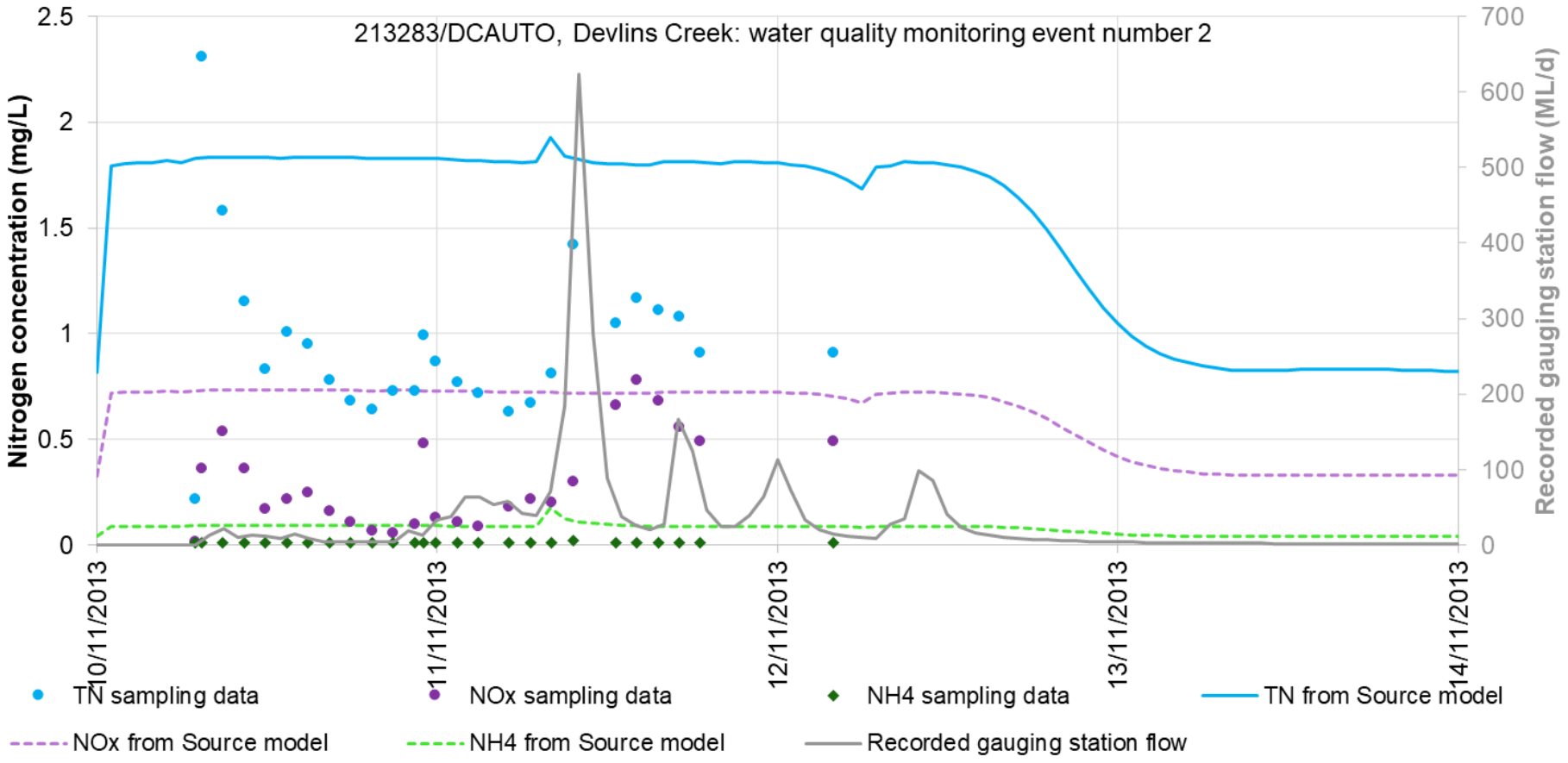

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 3
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
3.5
3
2.5
2
1.5
1
0.5
0
2500
2000
1500
1000
500
0
18/11/2013
19/11/2013
20/11/2013
21/11/2013
22/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

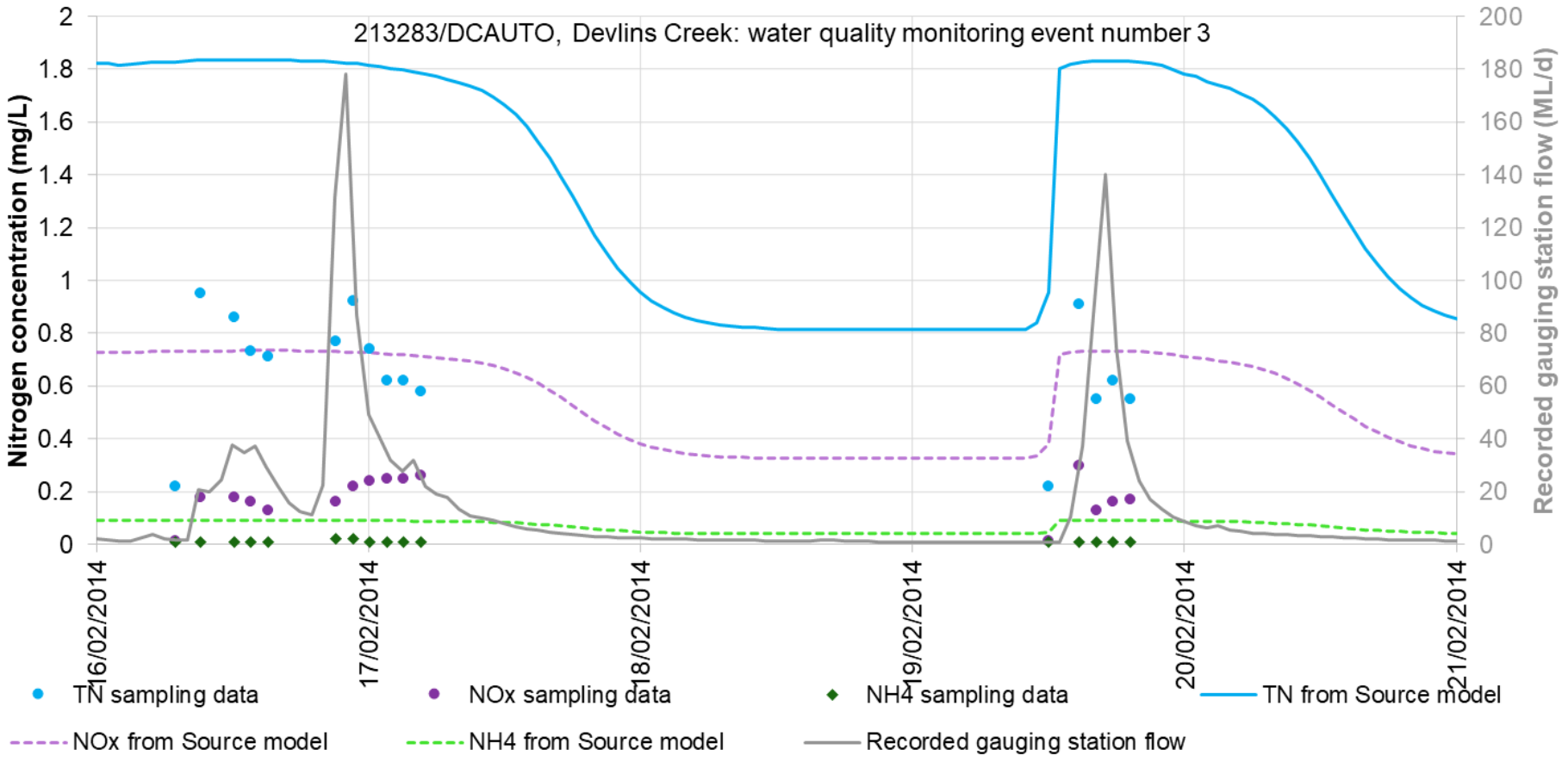

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 4
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
600
500
400
300
200
100
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

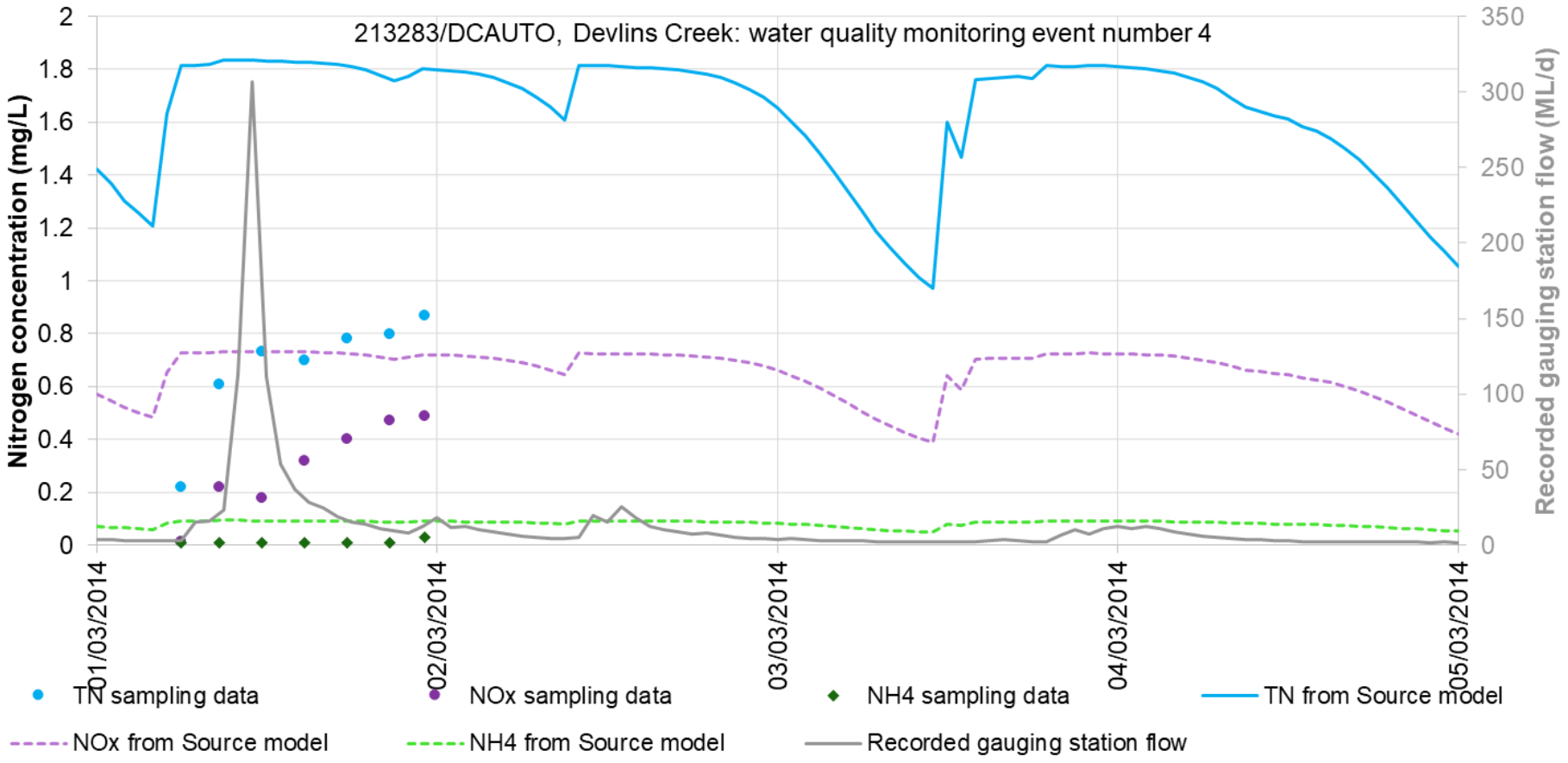

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 5
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

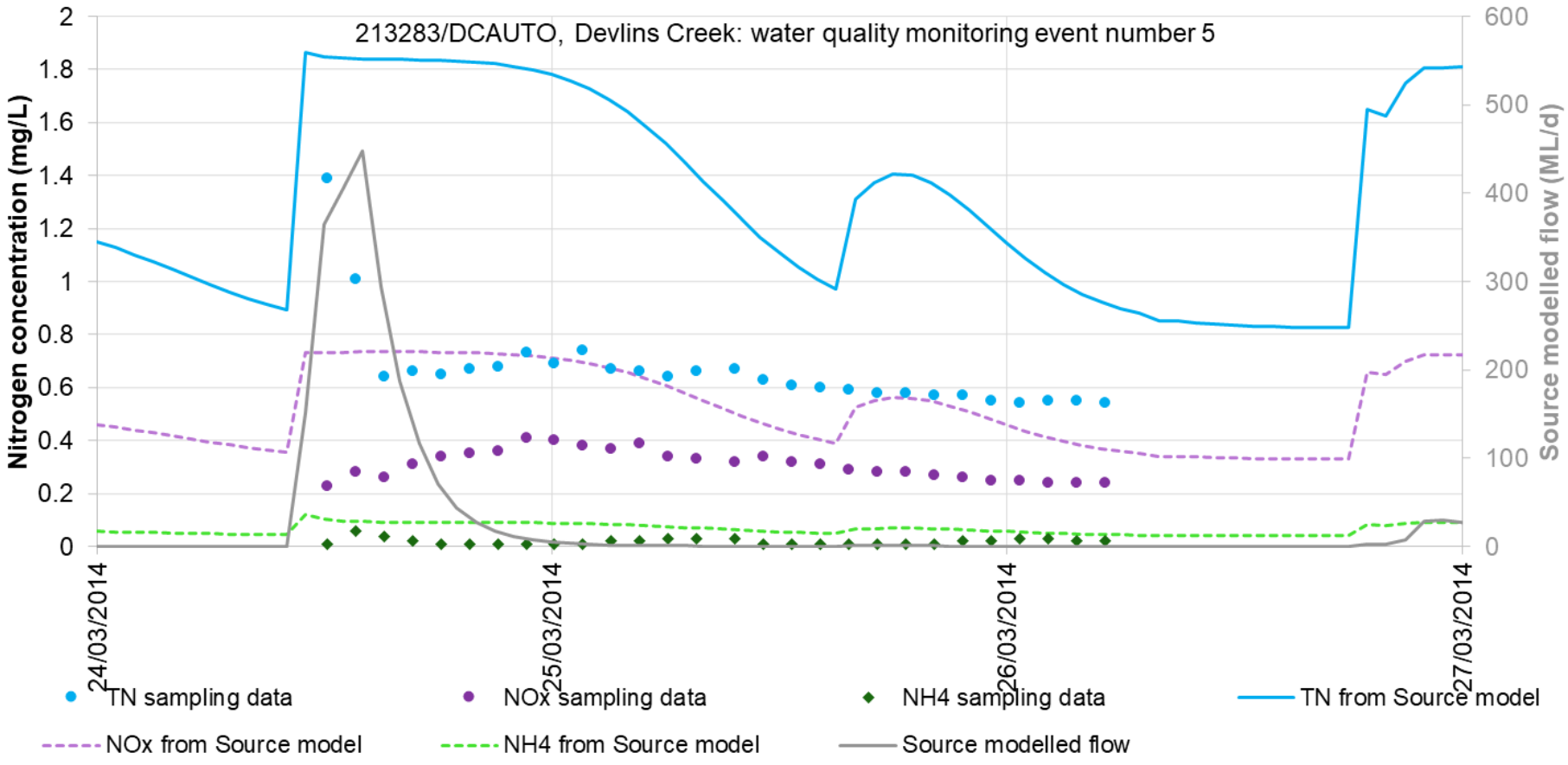

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 6
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
0
0.5
1
1.5
2
2.5
3
0
1000
2000
3000
4000
5000
6000
7000
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

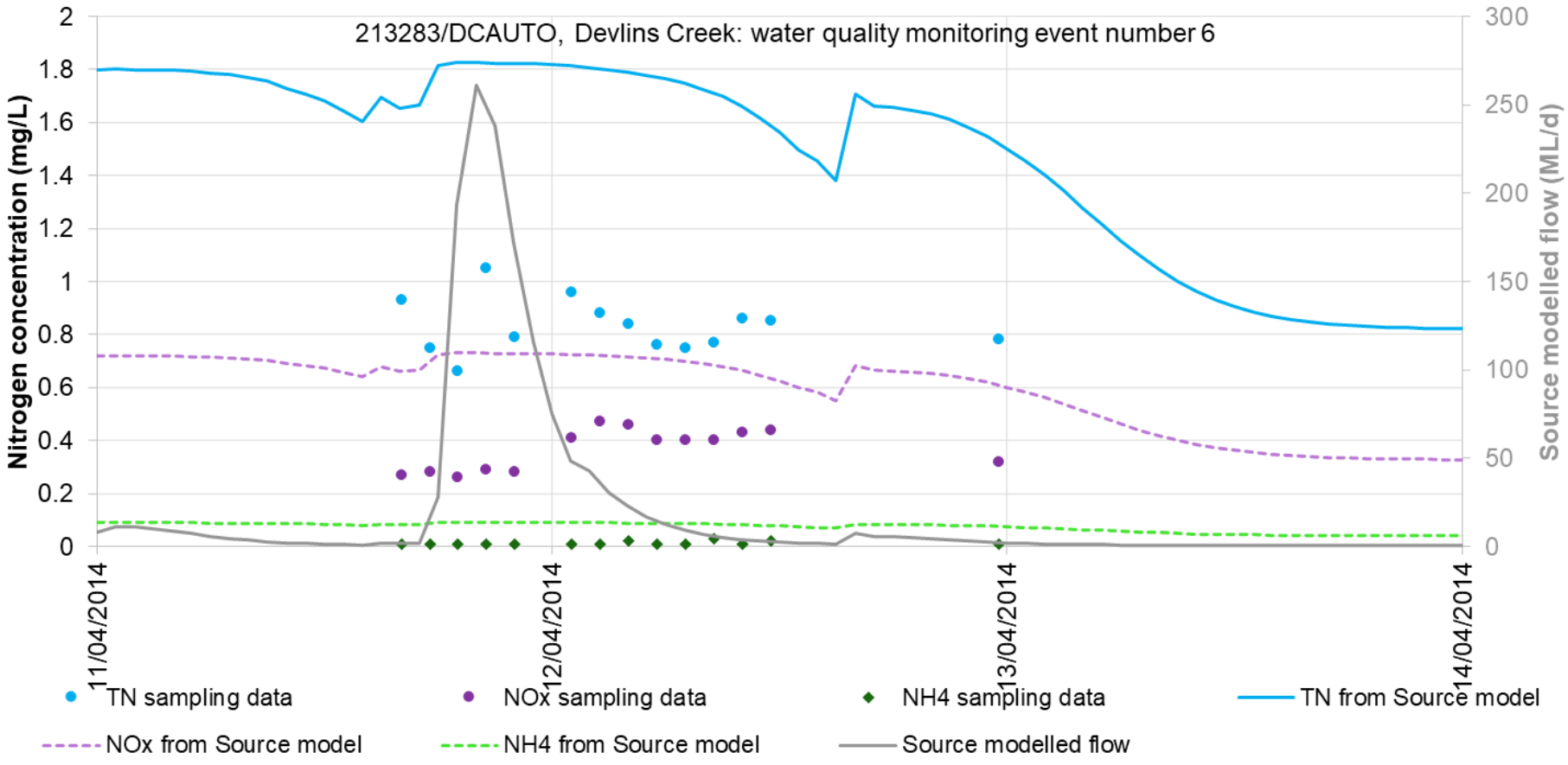

213283/DCAUTO, Devlins Creek: water quality monitoring event number 1
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
80
70
60
50
40
30
20
10
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

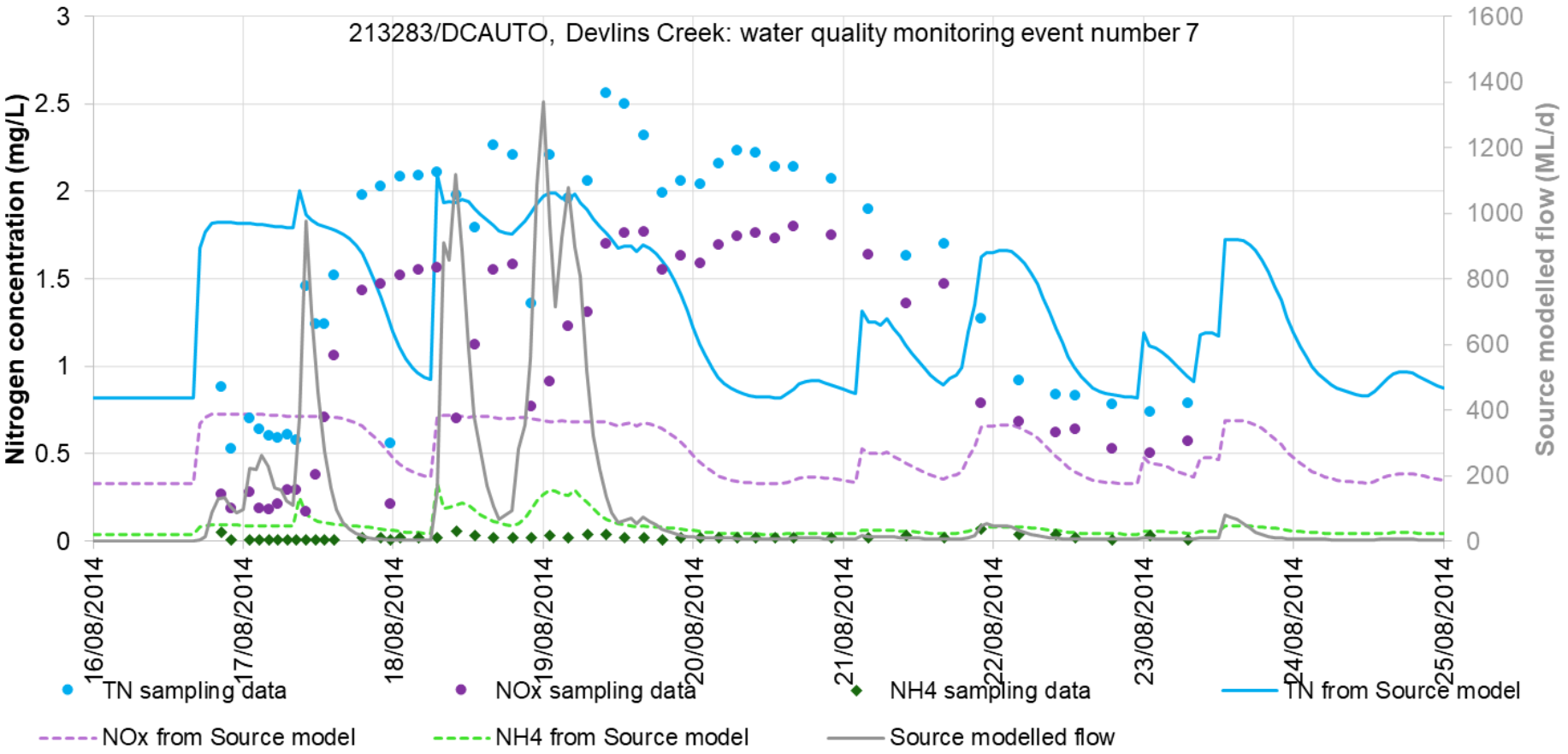

213283/DCAUTO, Devlins Creek: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2.5
2
1.5
1
0.5
0
700
600
500
400
300
200
100
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

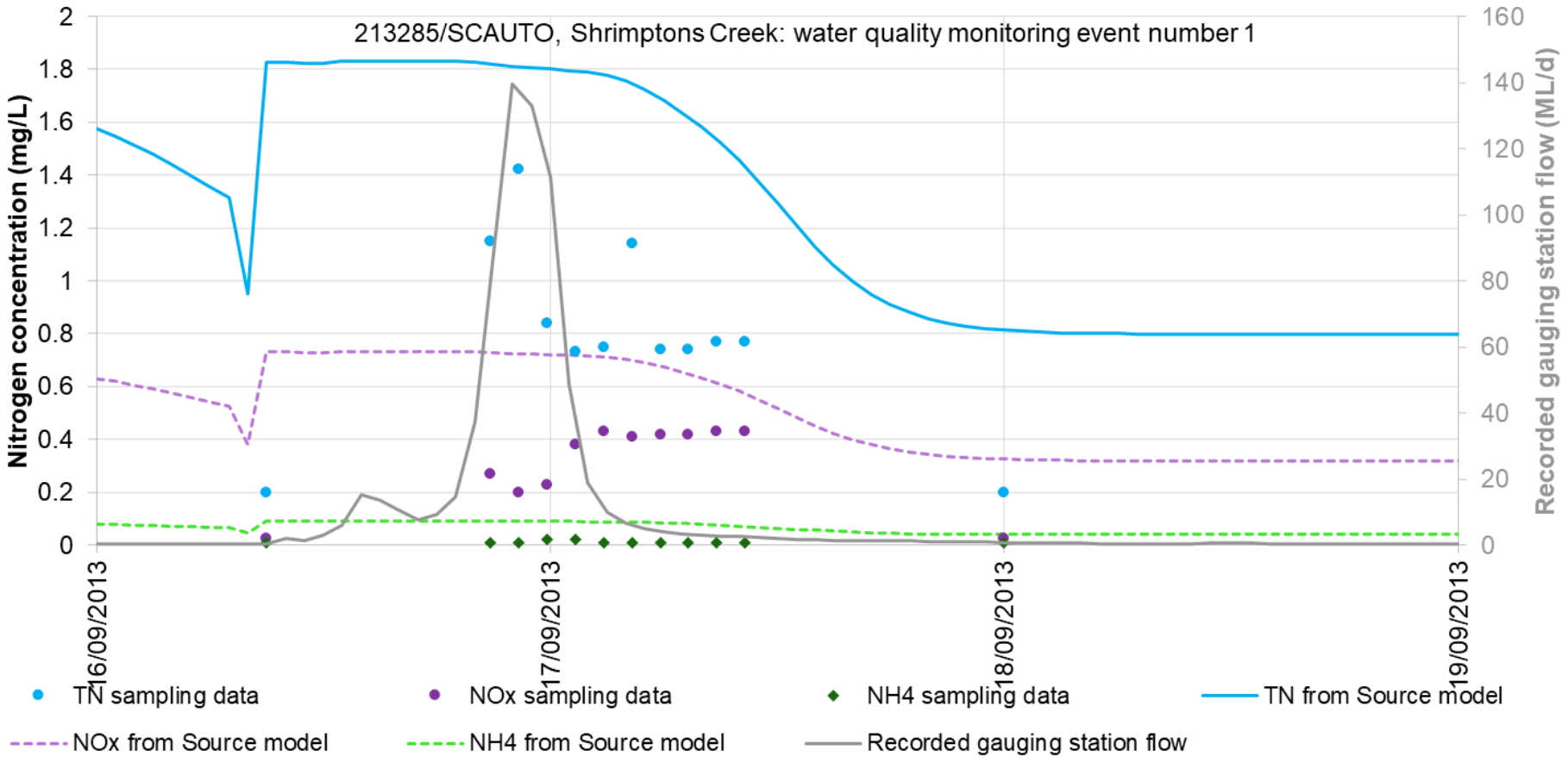

213283/DCAUTO, Devlins Creek: water quality monitoring event number 3
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
200
180
160
140
120
100
80
60
40
20
0
16/02/2014
17/02/2014
18/02/2014
19/02/2014
20/02/2014
21/02/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

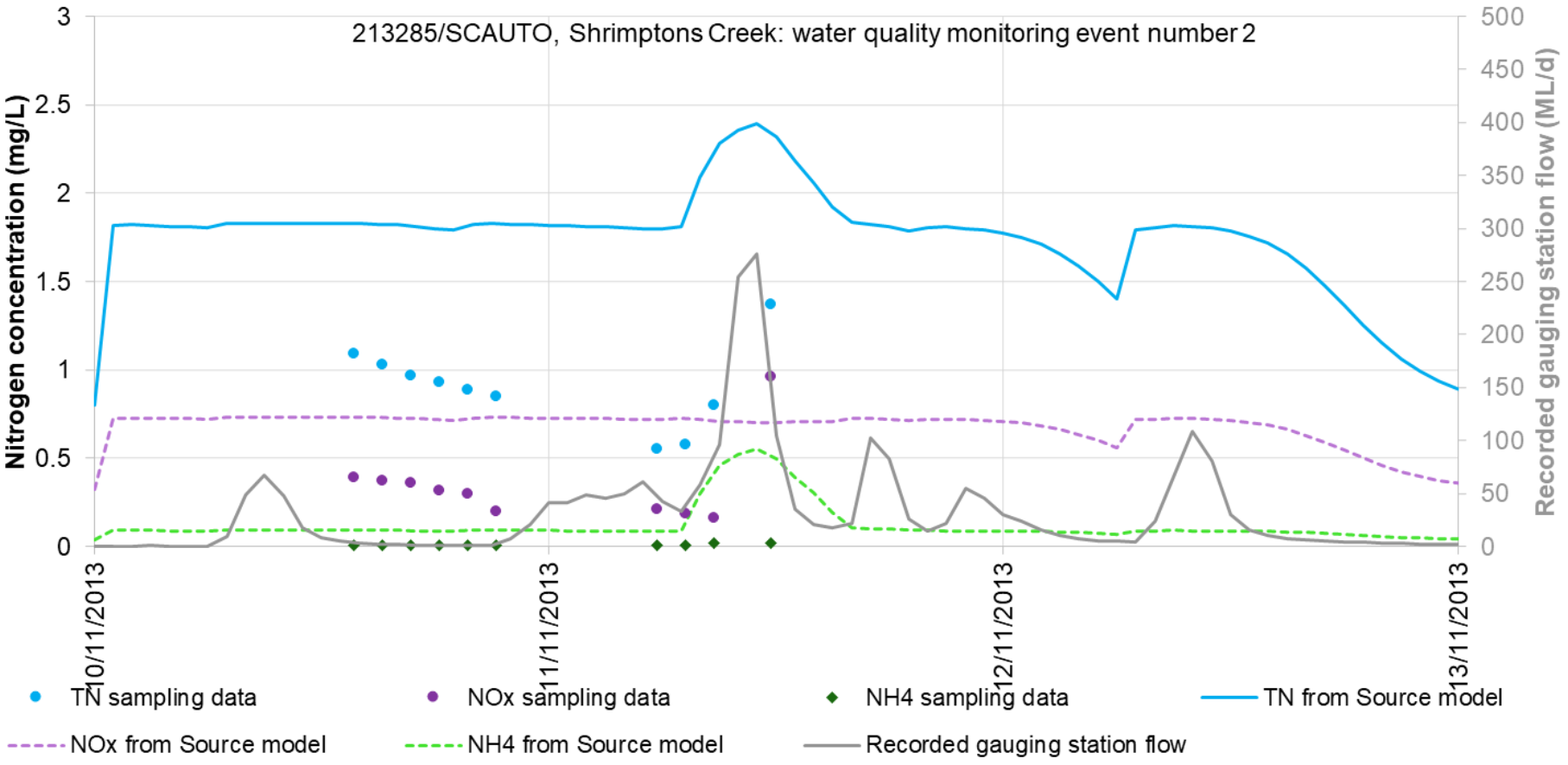

213283/DCAUTO, Devlins Creek: water quality monitoring event number 4
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
350
300
250
200
150
100
50
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

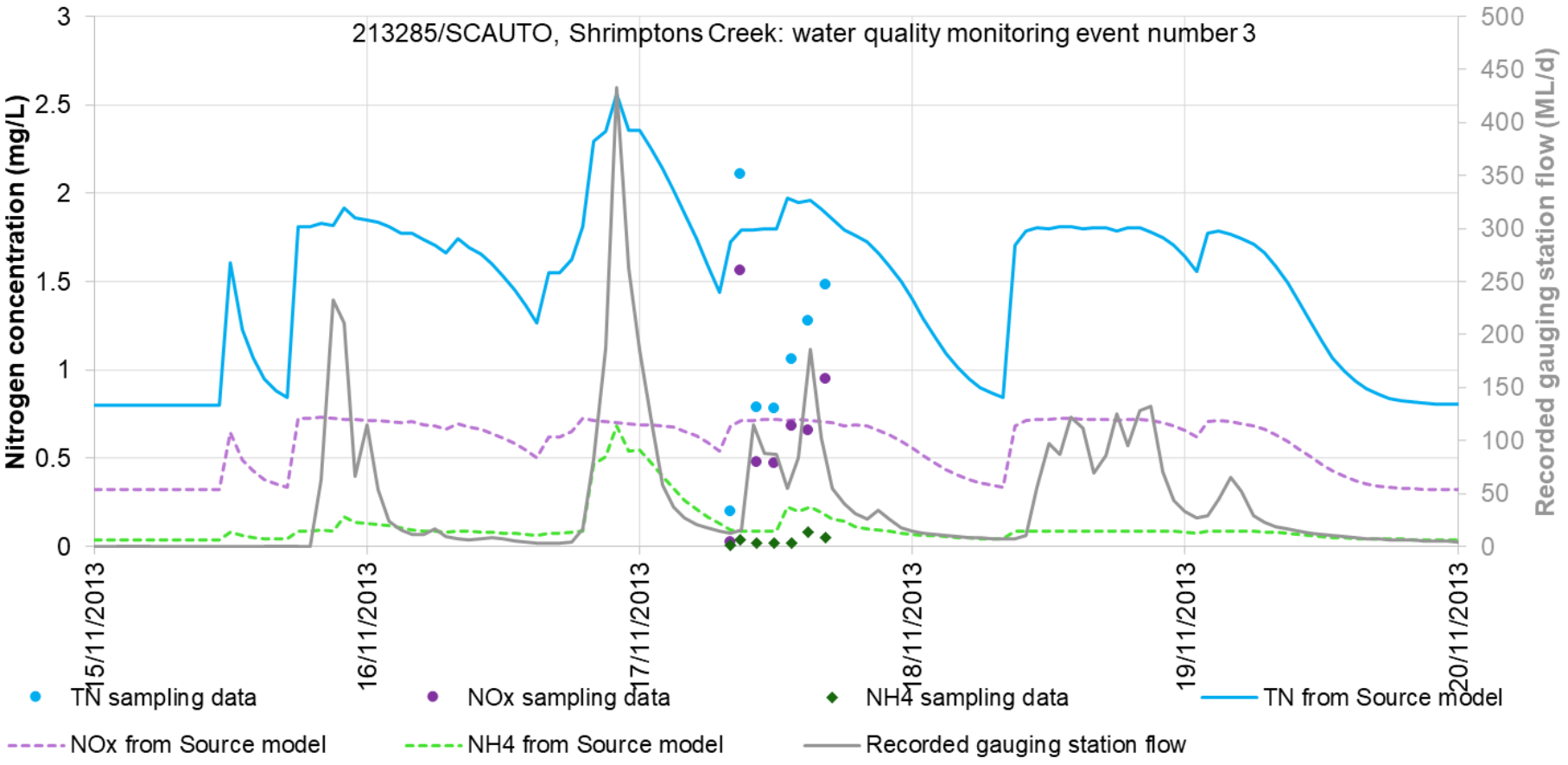

213283/DCAUTO, Devlins Creek: water quality monitoring event number 5
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

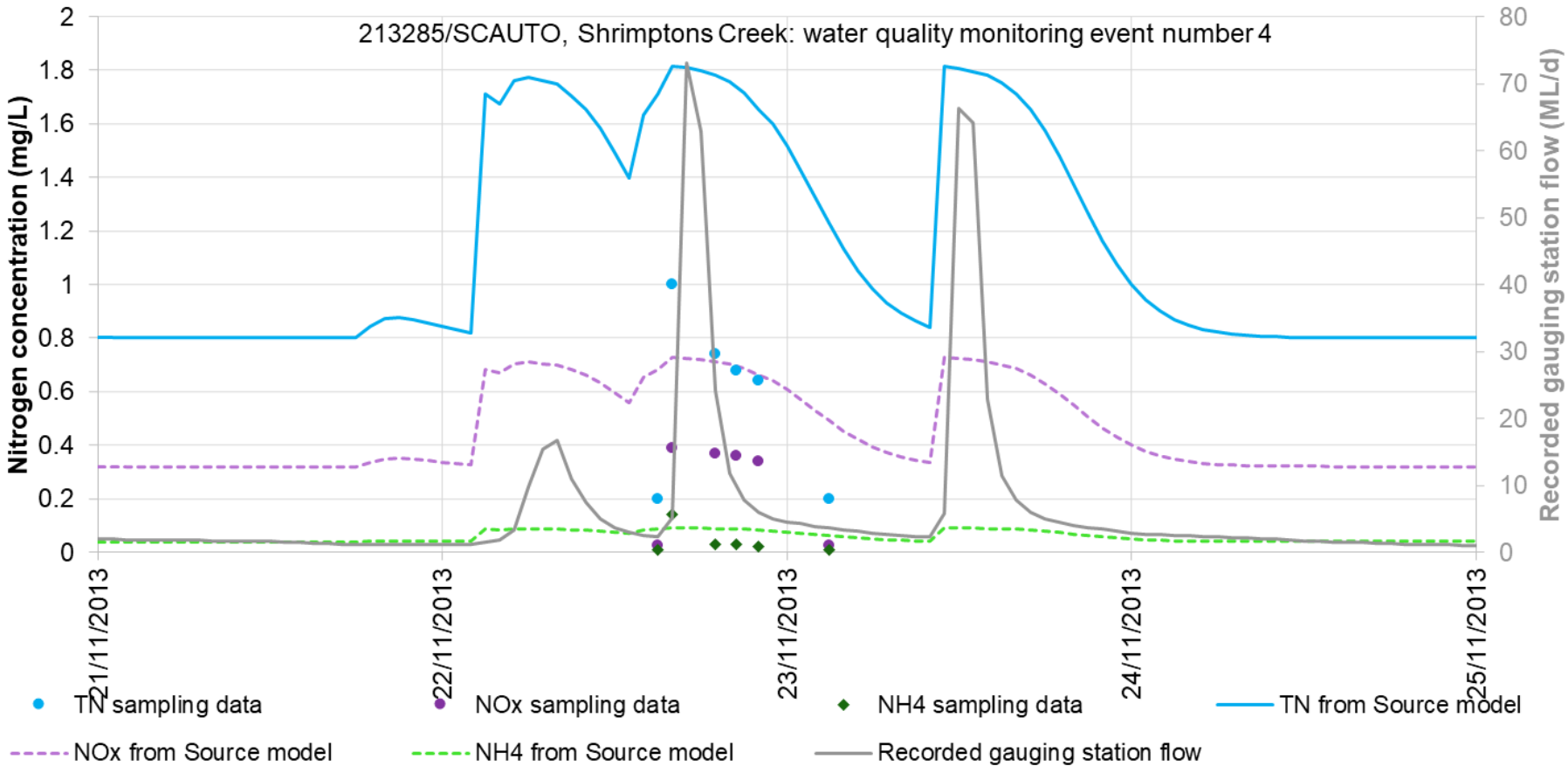

213283/DCAUTO, Devlins Creek: water quality monitoring event number 6
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
300
250
200
150
100
50
0
11/04/2014
12/04/2014
13/04/2014
14/04/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

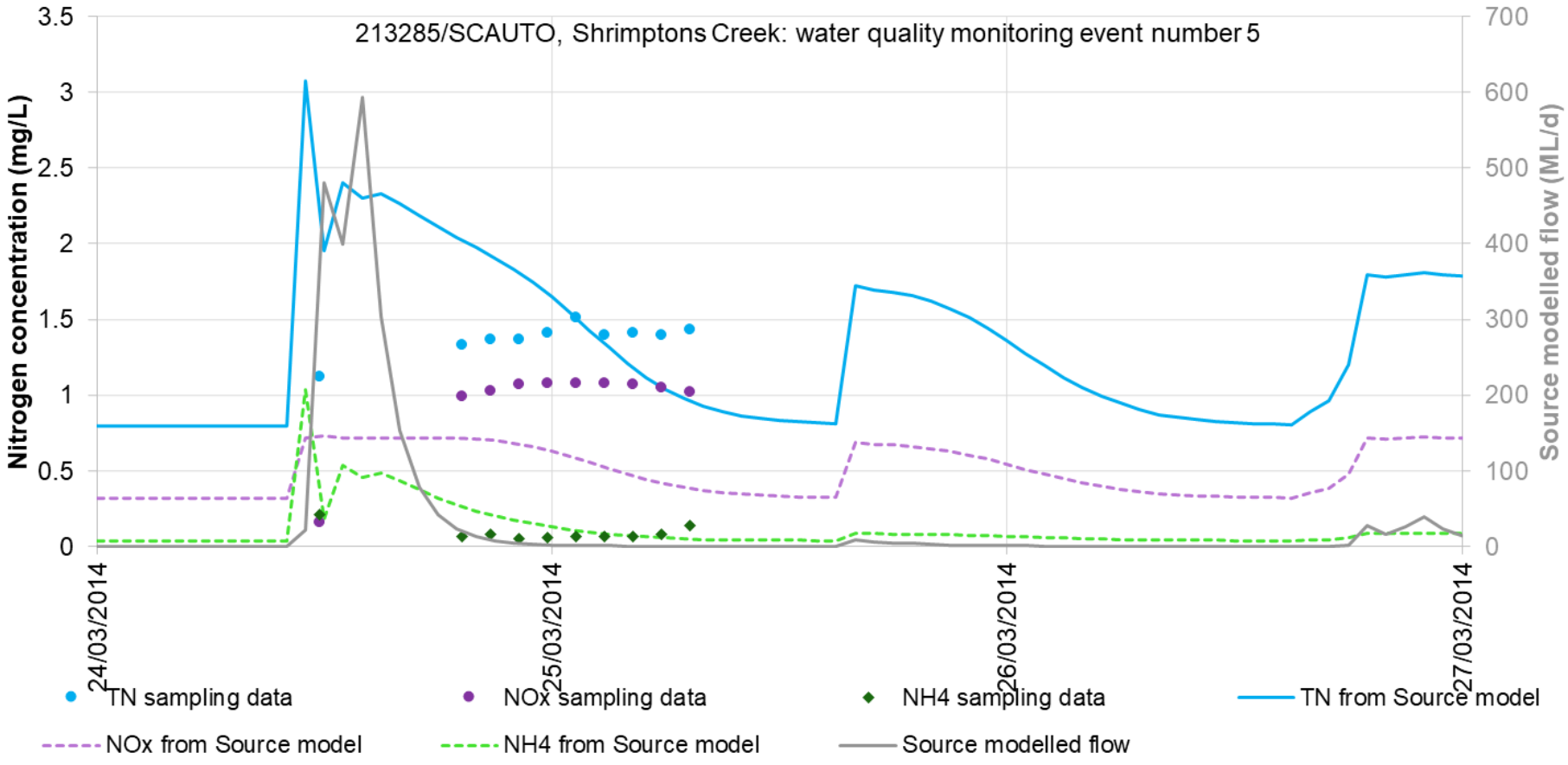

213283/DCAUTO, Devlins Creek: water quality monitoring event number 7
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
3
2.5
2
1.5
1
0.5
0
1600
1400
1200
1000
800
600
400
200
0
16/08/2014
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

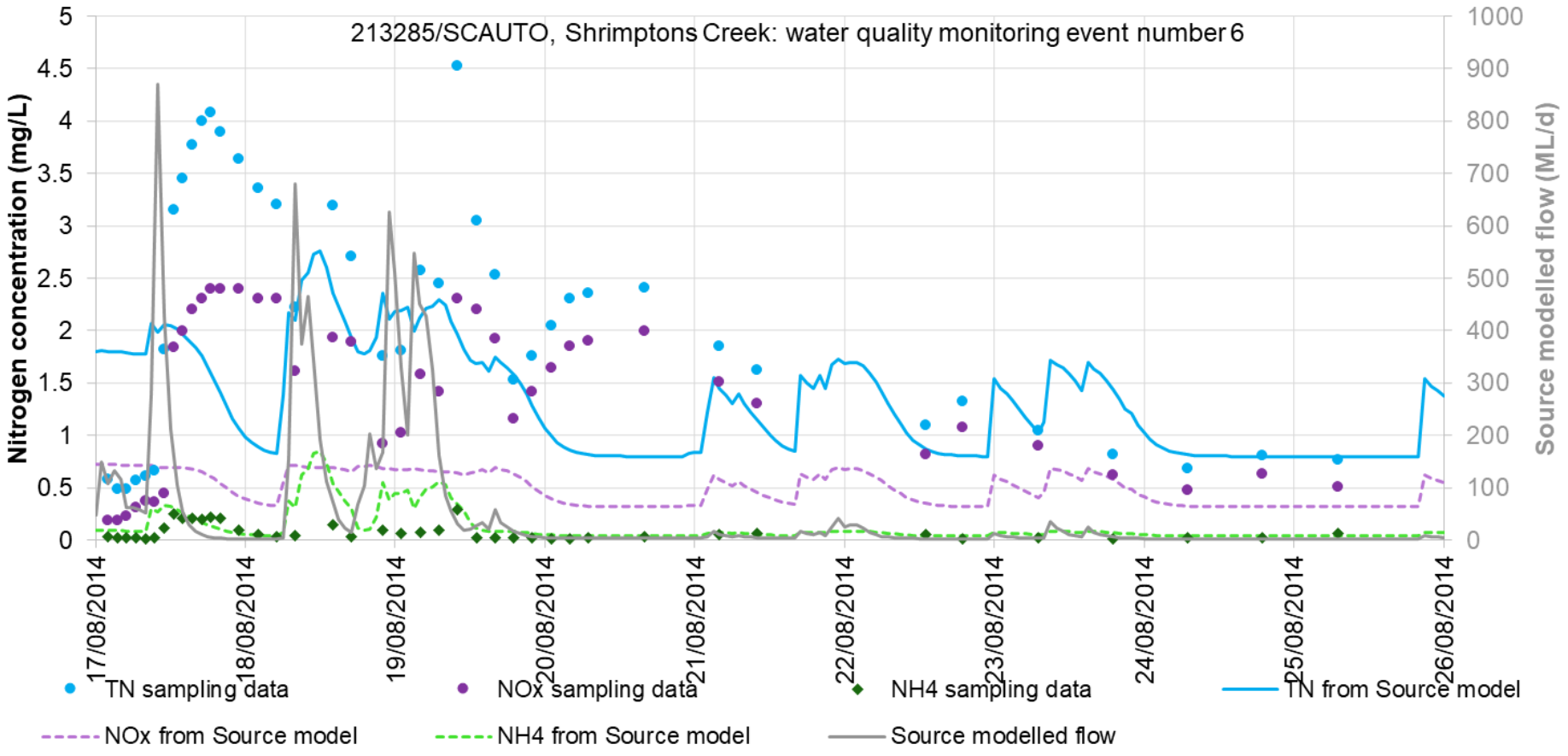

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 1
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
160
140
120
100
80
60
40
20
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

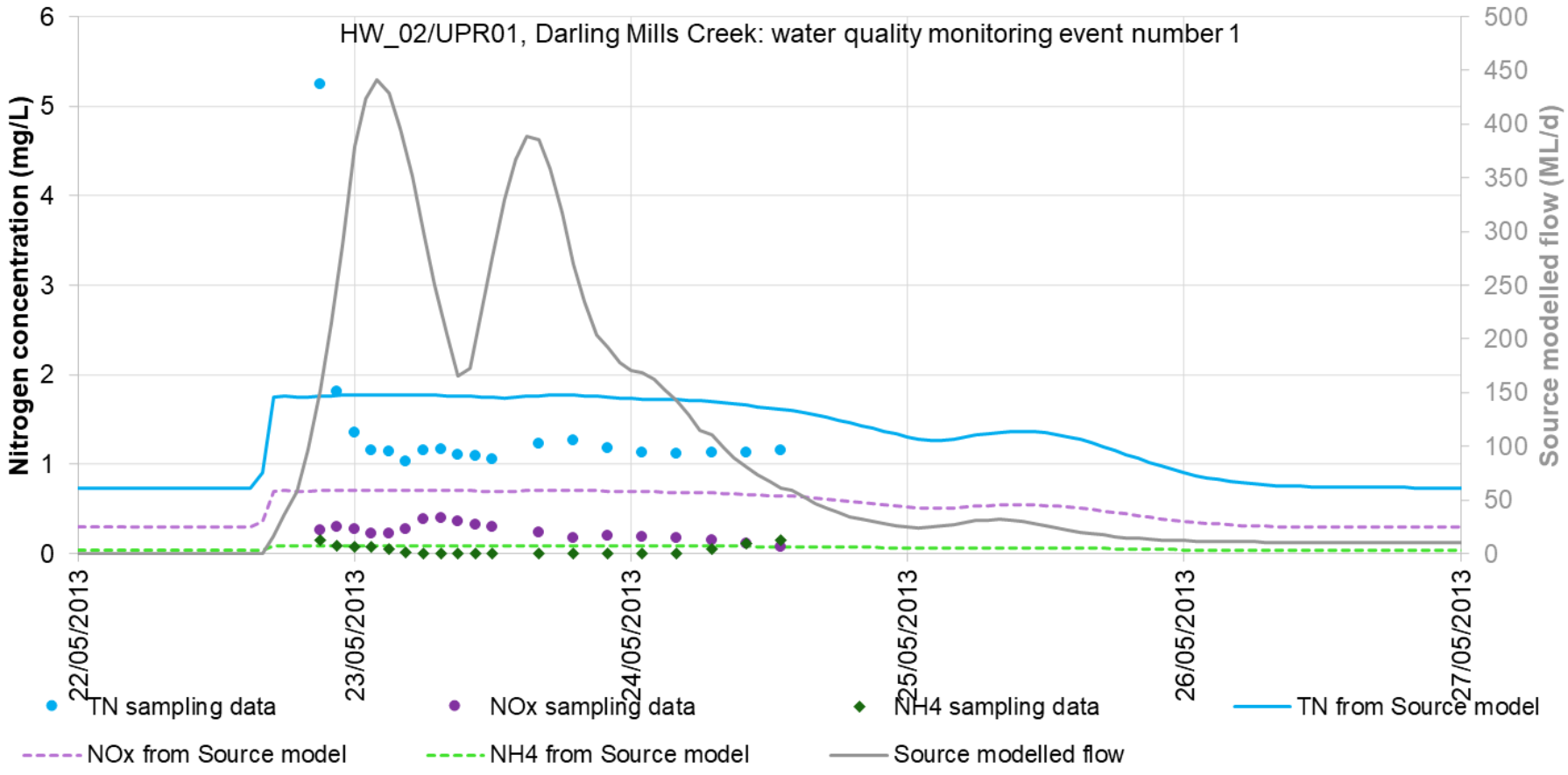

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
3
2.5
2
1.5
1
0.5
0
500
450
400
350
300
250
200
150
100
50
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

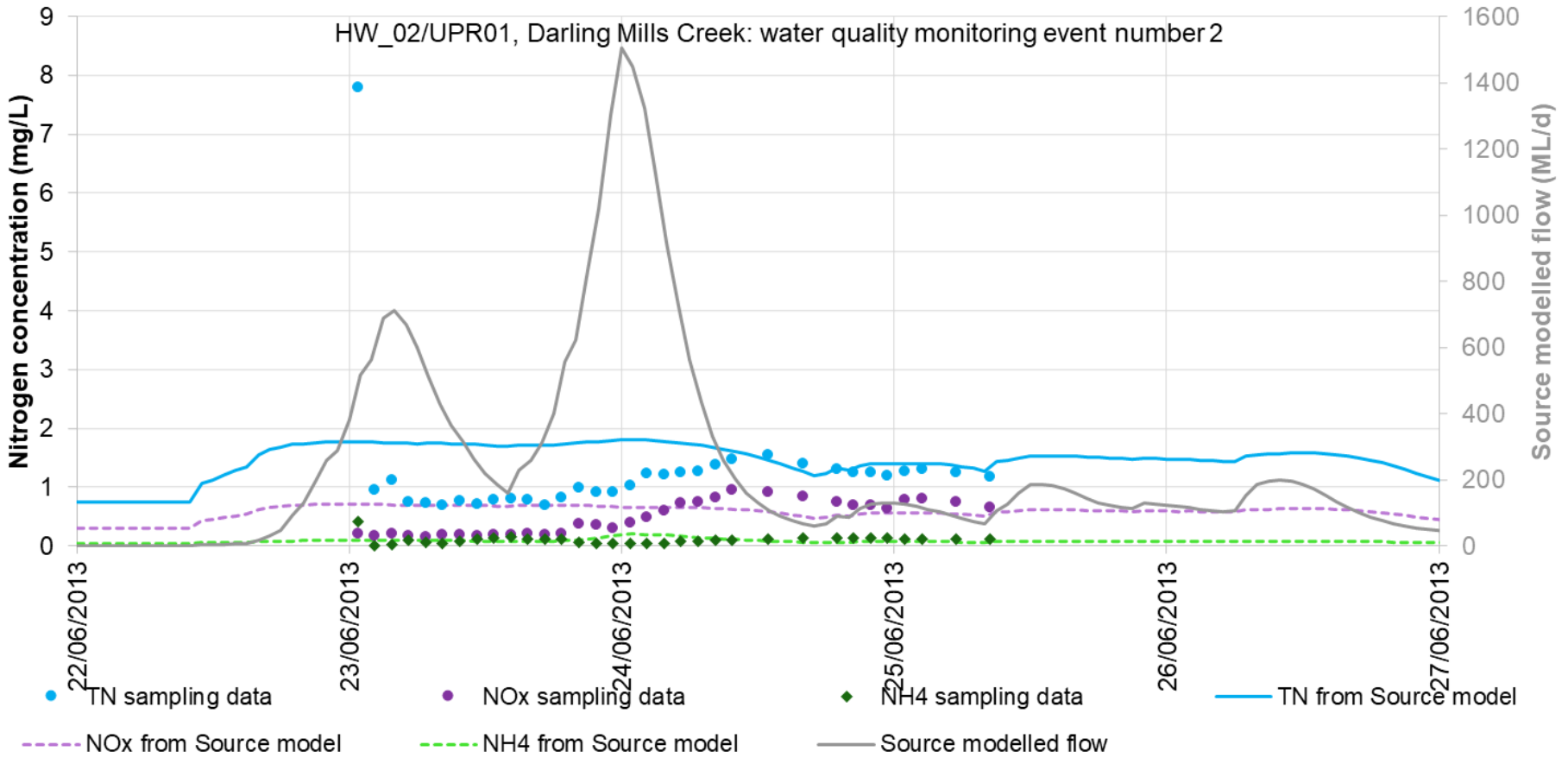

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 3
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
3
2.5
2
1.5
1
0.5
0
500
450
400
350
300
250
200
150
100
50
0
15/11/2013
16/11/2013
17/11/2013
18/11/2013
19/11/2013
20/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

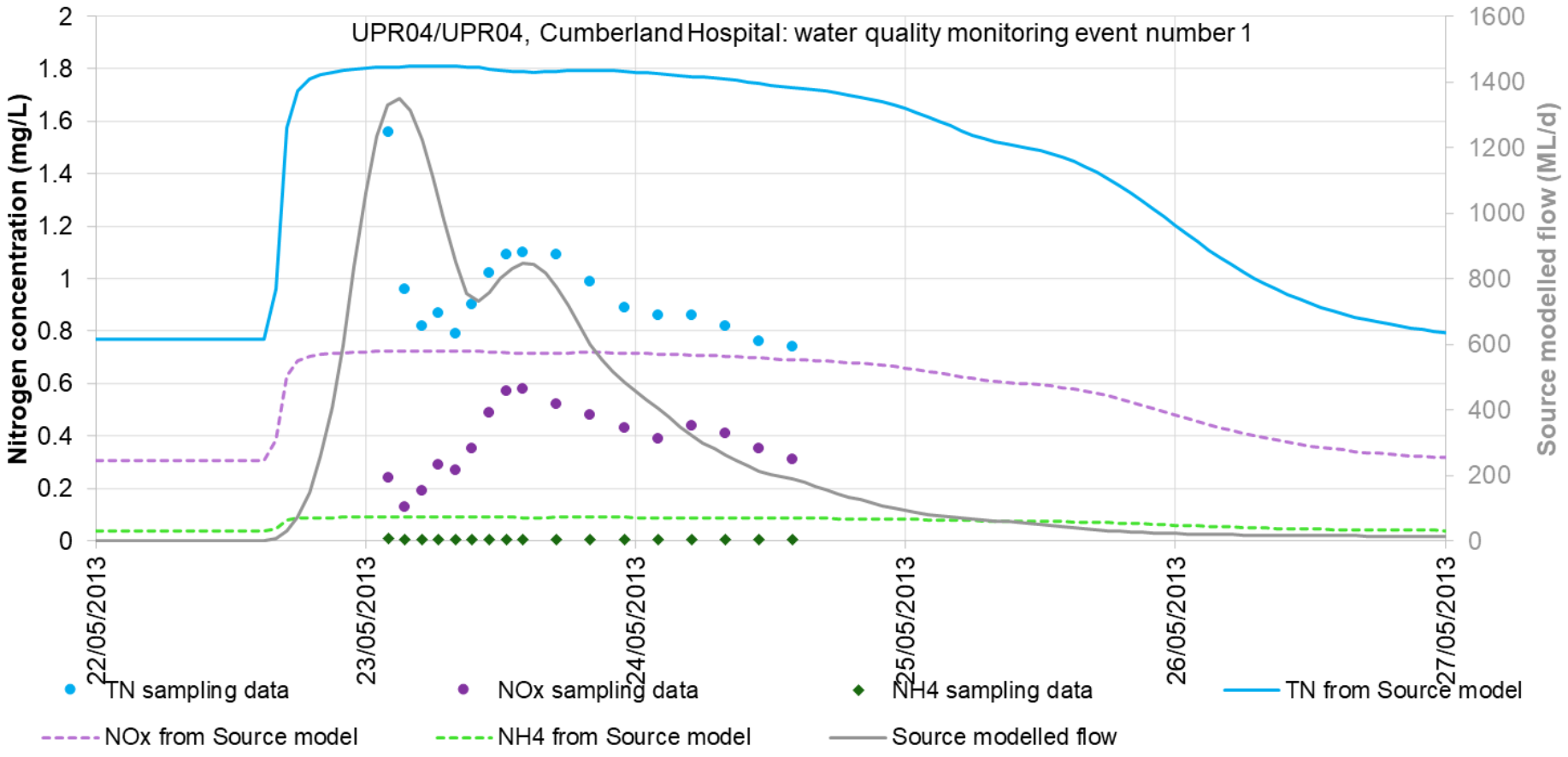

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 4
Nitrogen concentration (mg/L)
Recorded gauging station flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
80
70
60
50
40
30
20
10
0
21/11/2013
22/11/2013
23/11/2013
24/11/2013
25/11/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Recorded gauging station flow

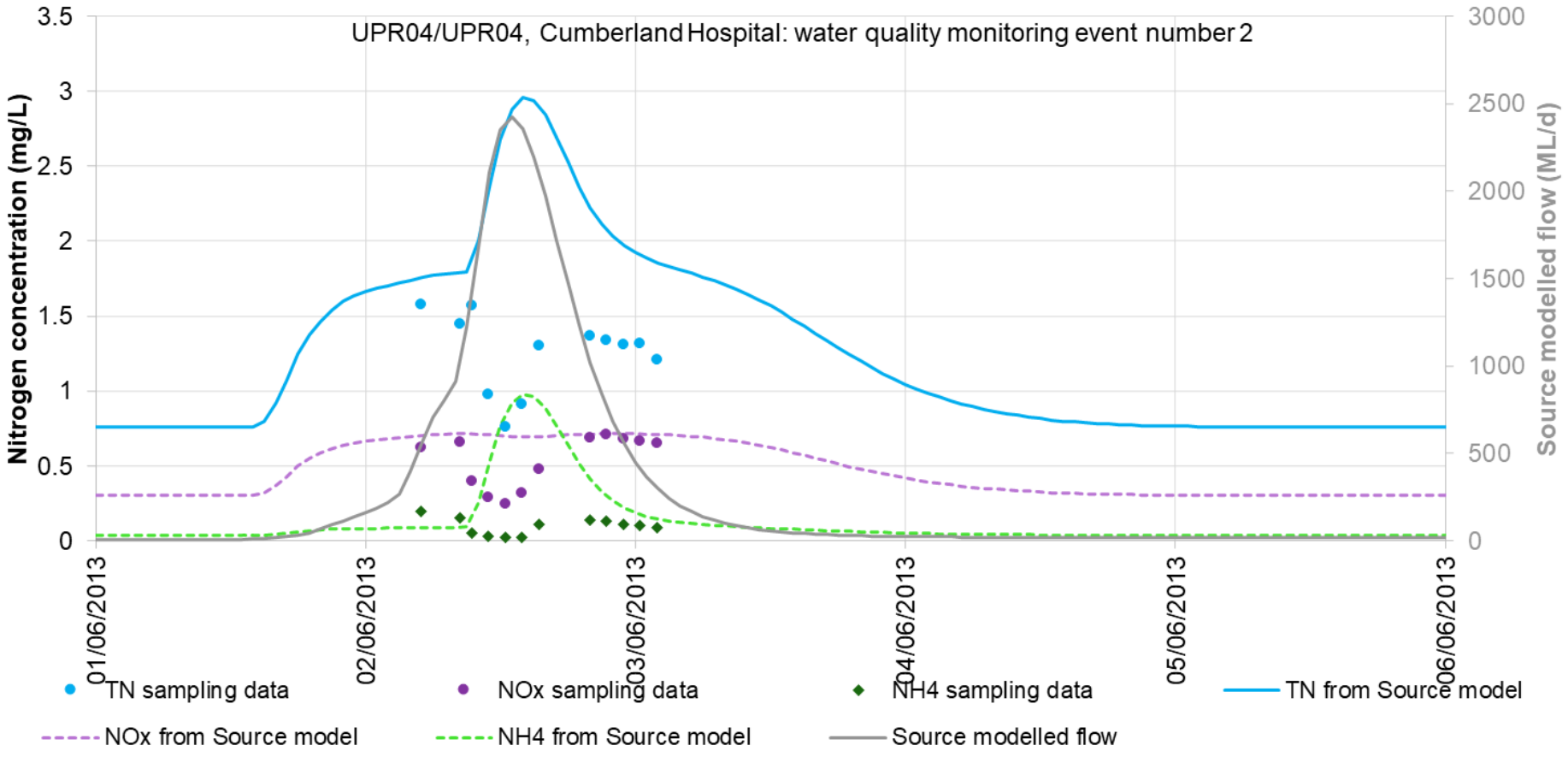

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 5
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
3.5
3
2.5
2
1.5
1
0.5
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

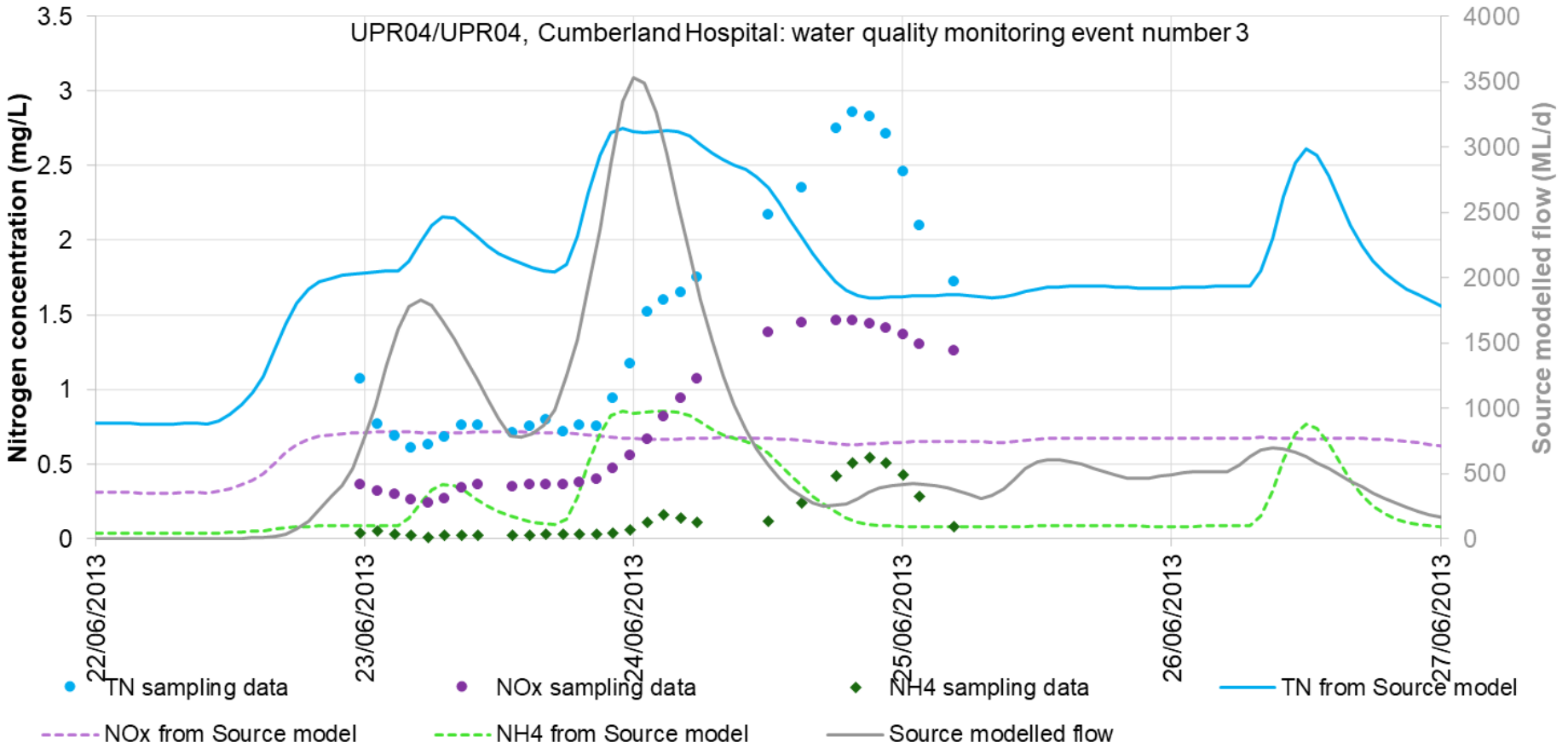

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 6
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
100
200
300
400
500
600
700
800
900
1000
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow


HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 1
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
500
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

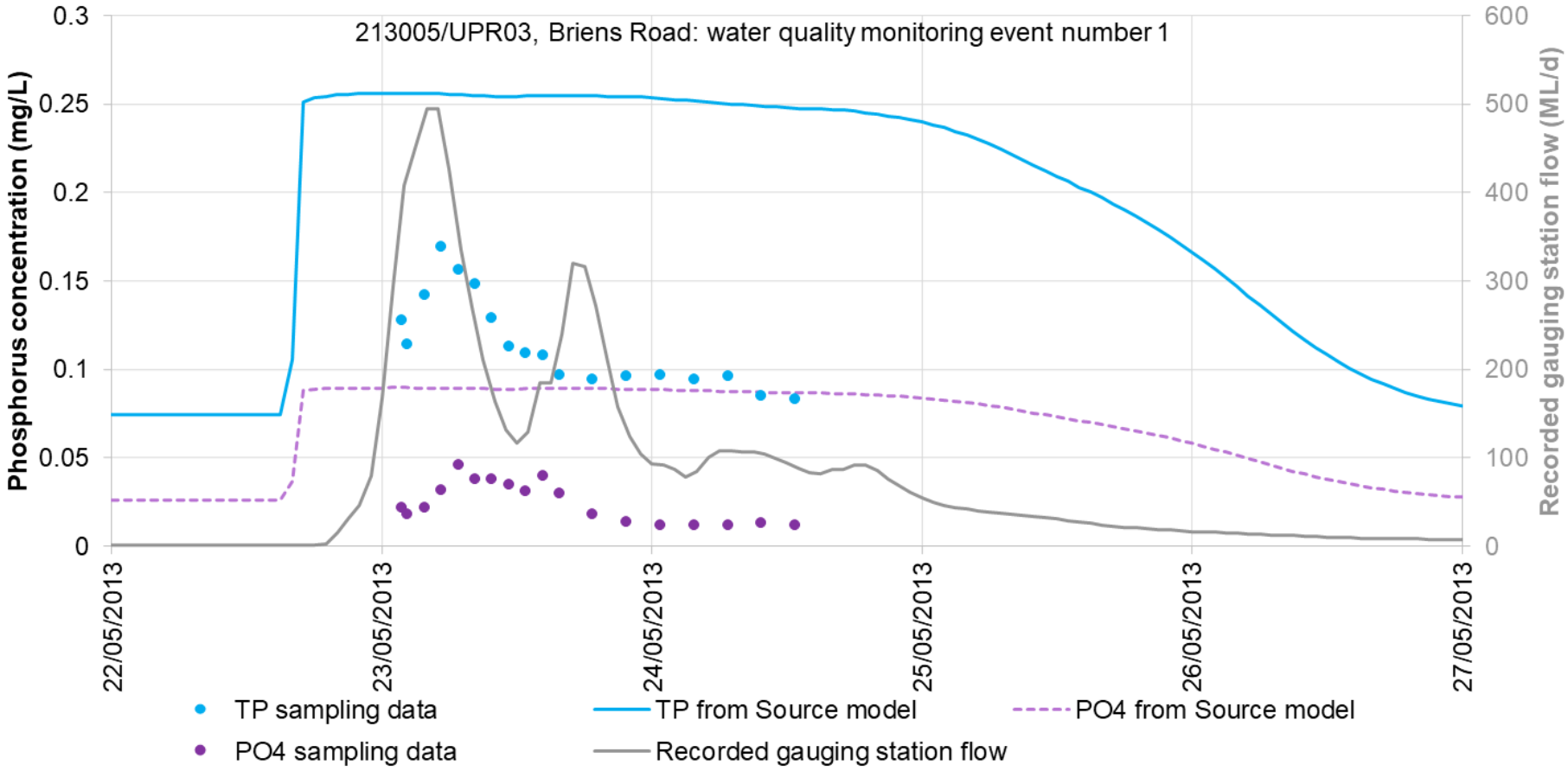

HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
0
1
2
3
4
5
6
7
8
9
0
200
400
600
800
1000
1200
1400
1600
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

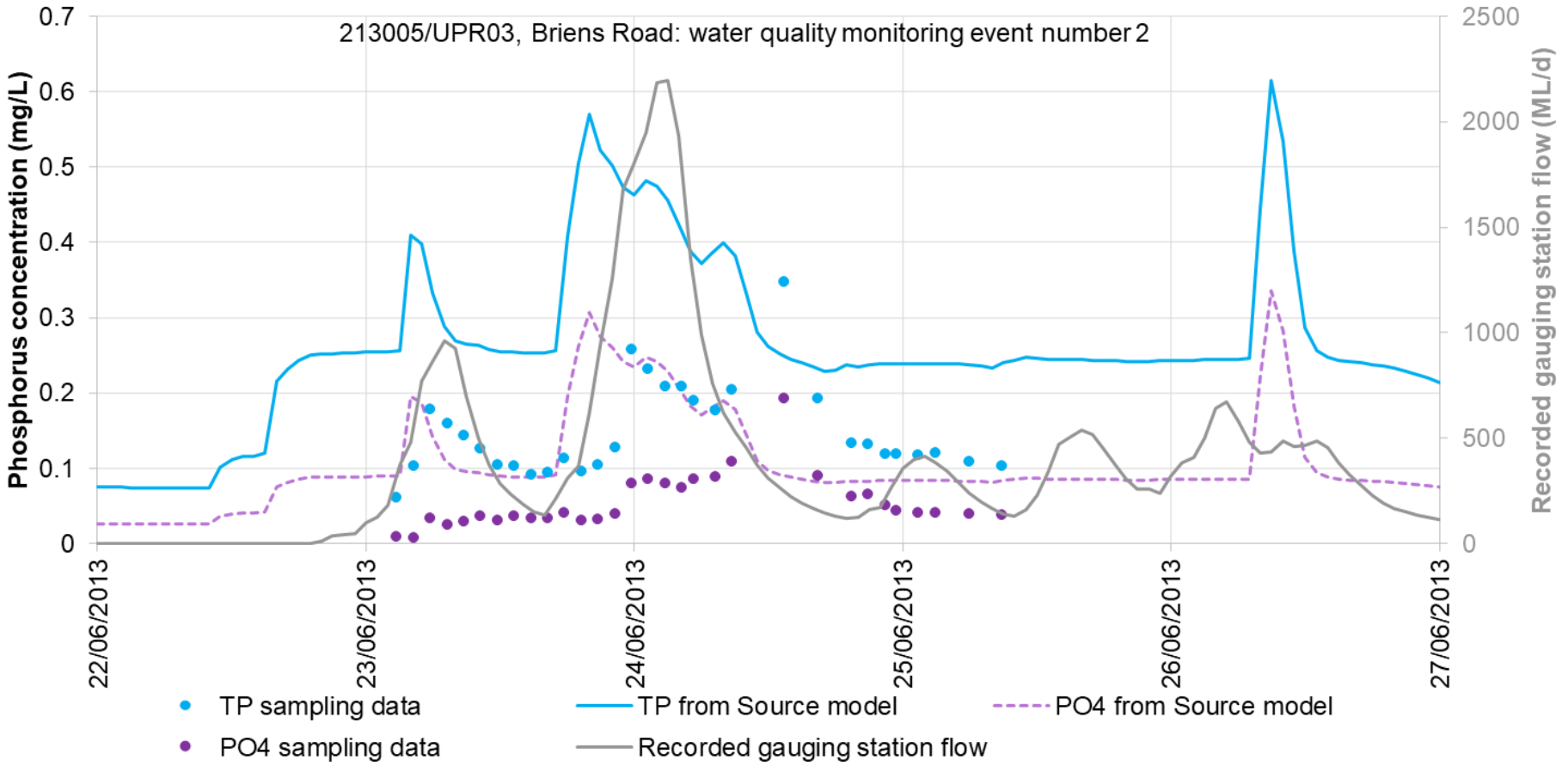

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 1
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1600
1400
1200
1000
800
600
400
200
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

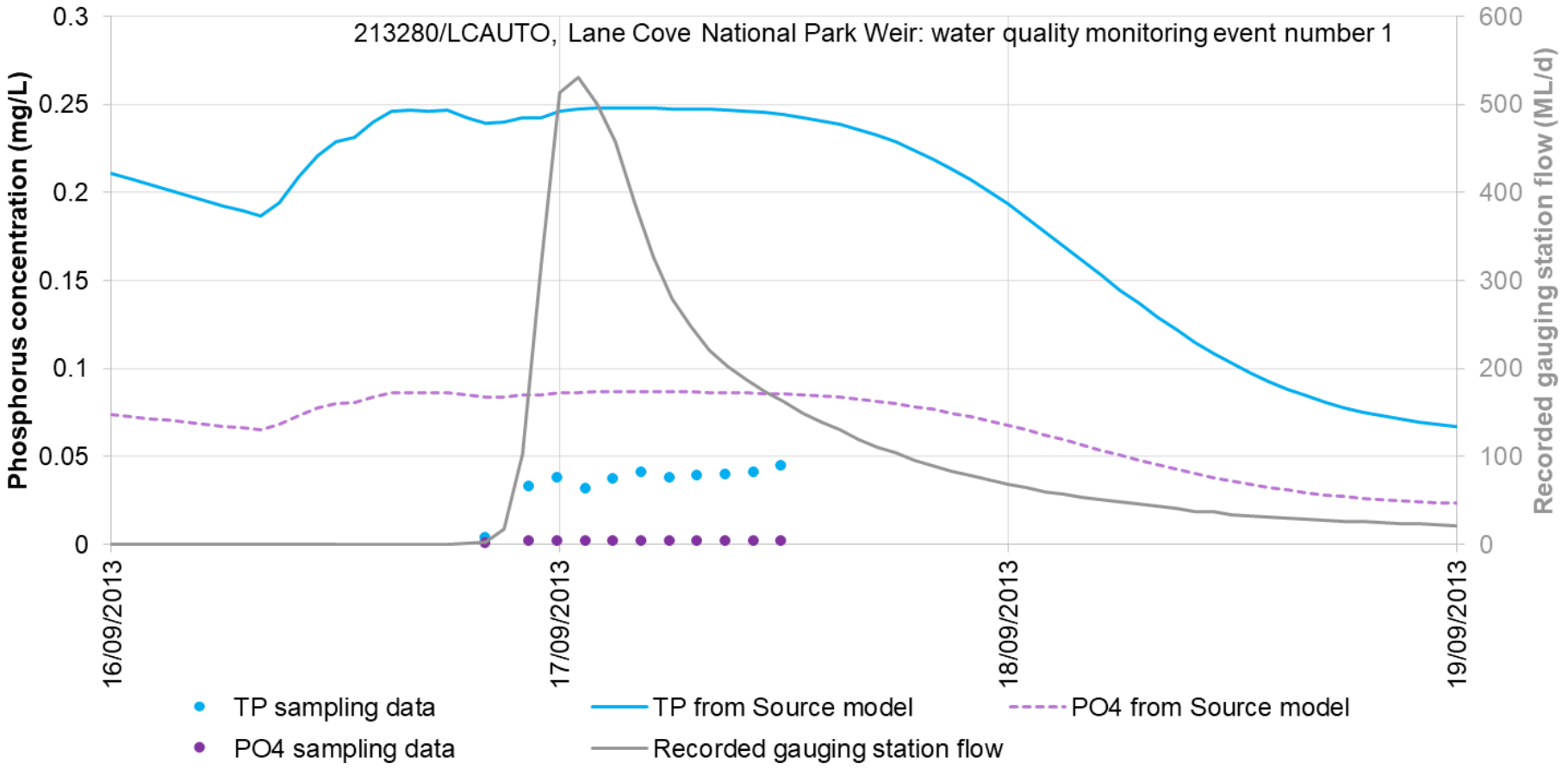

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 2
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
3.5
3
2.5
2
1.5
1
0.5
0
3000
2500
2000
1500
1000
500
0
01/06/2013
02/06/2013
03/06/2013
04/06/2013
05/06/2013
06/06/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

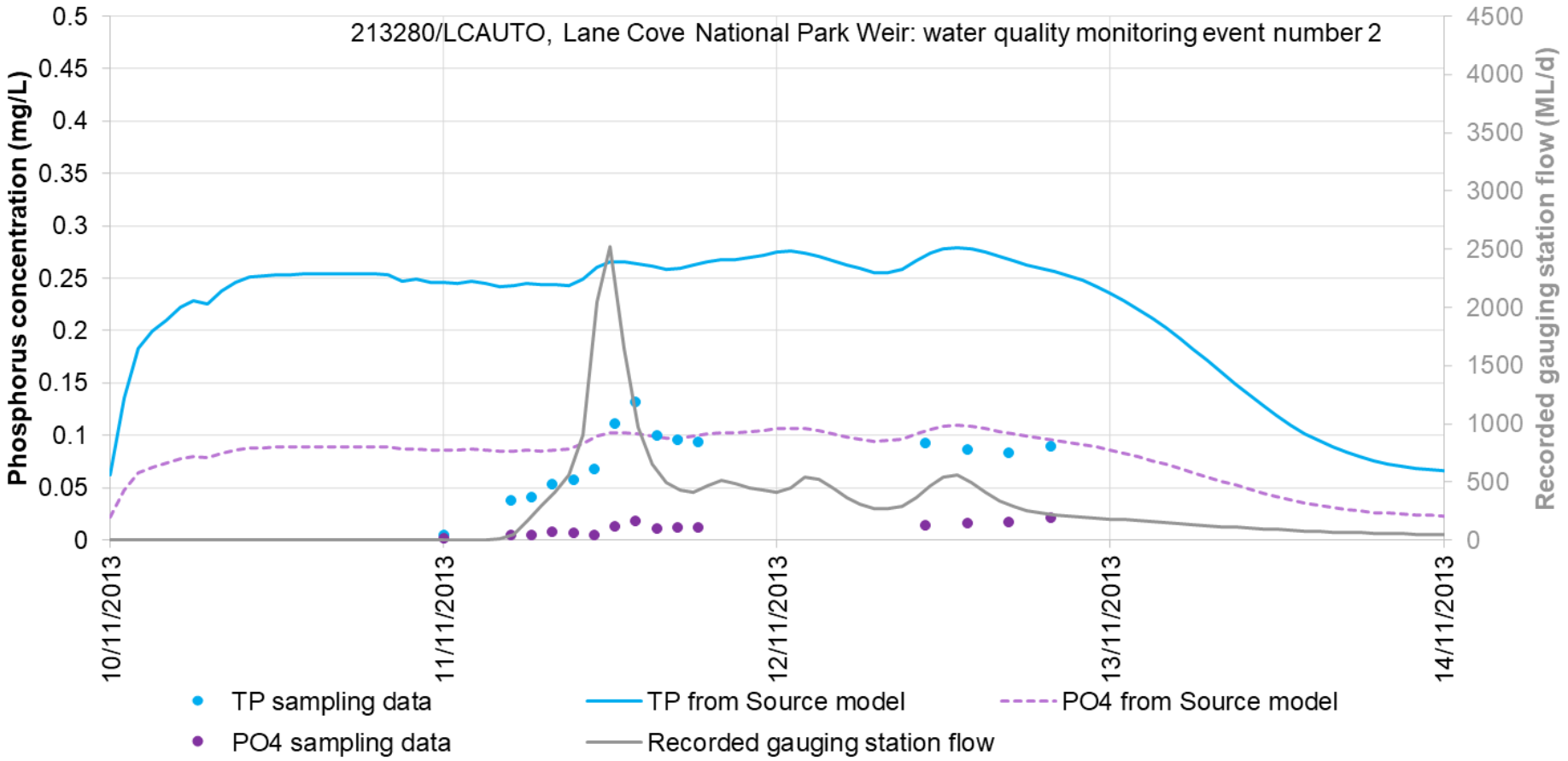

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 3
Nitrogen concentration (mg/L)
Source modelled flow (ML/d)
3.5
3
2.5
2
1.5
1
0.5
0
4000
3500
3000
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TN sampling data
NOx sampling data
NH4 sampling data
TN from Source model
NOx from Source model
NH4 from Source model
Source modelled flow

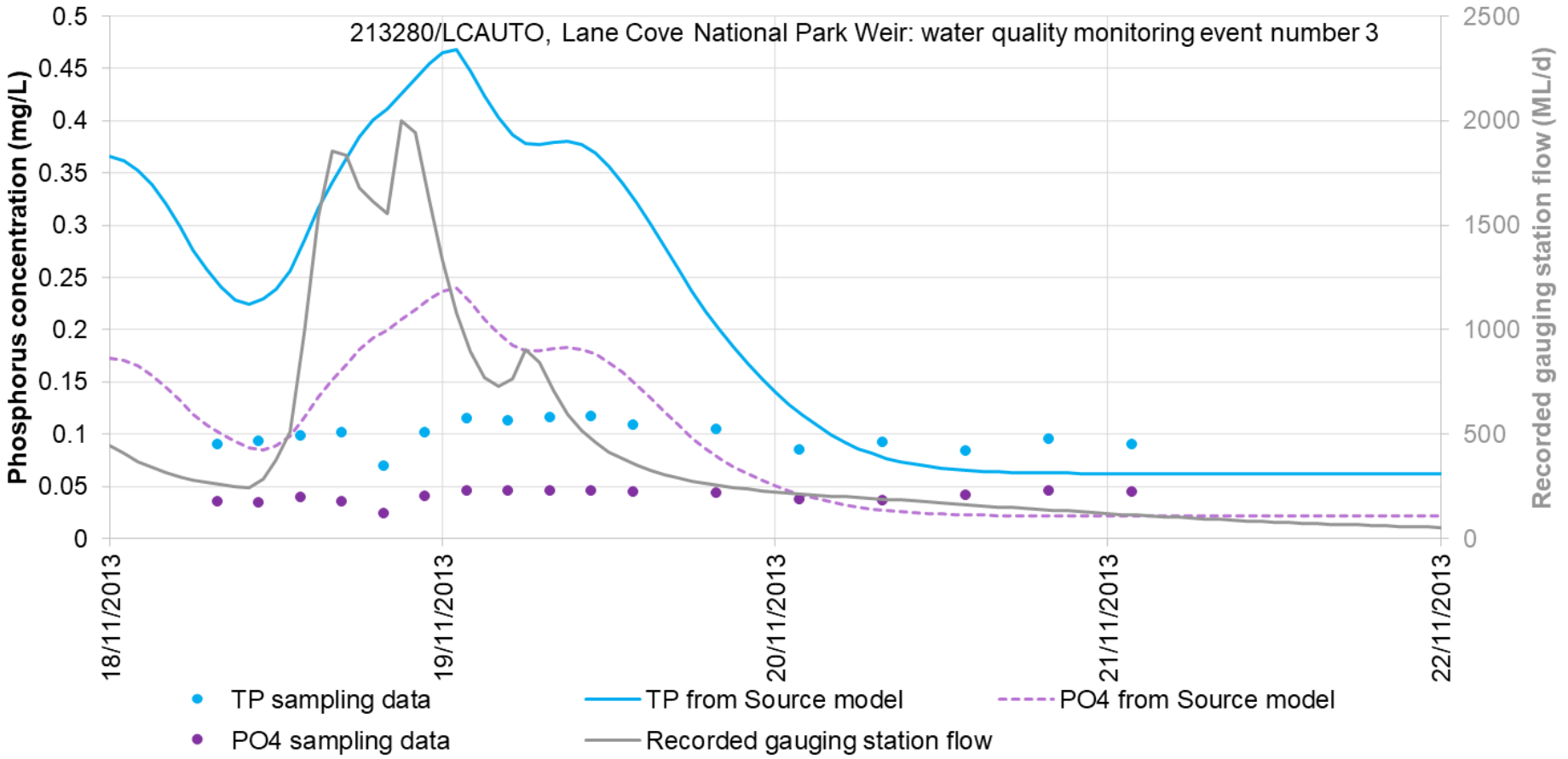
C.2 Total Phosphorus and Ortho Phosphate comparison plots for monitored events

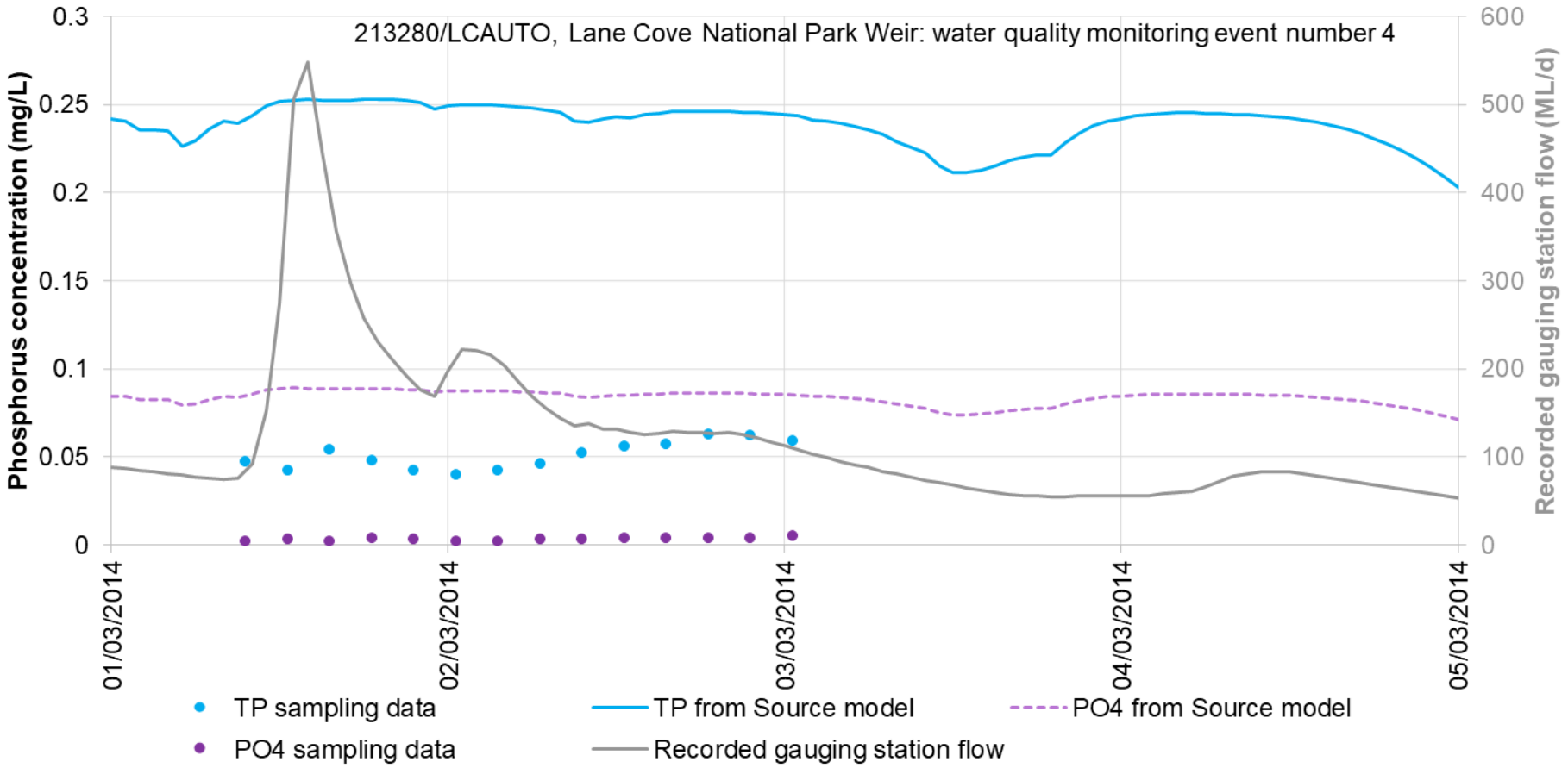


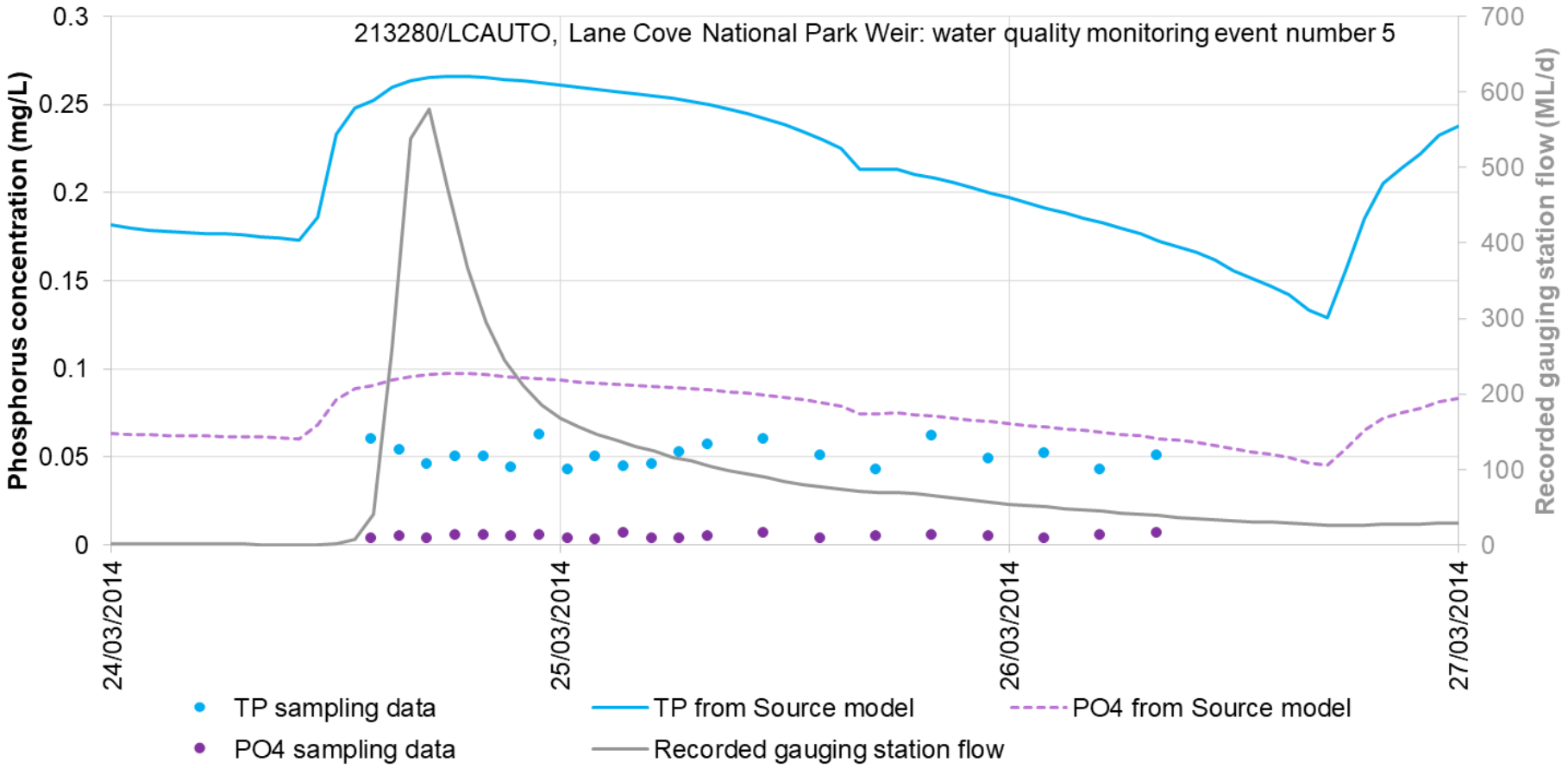

213005/UPR03, Briens Road: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

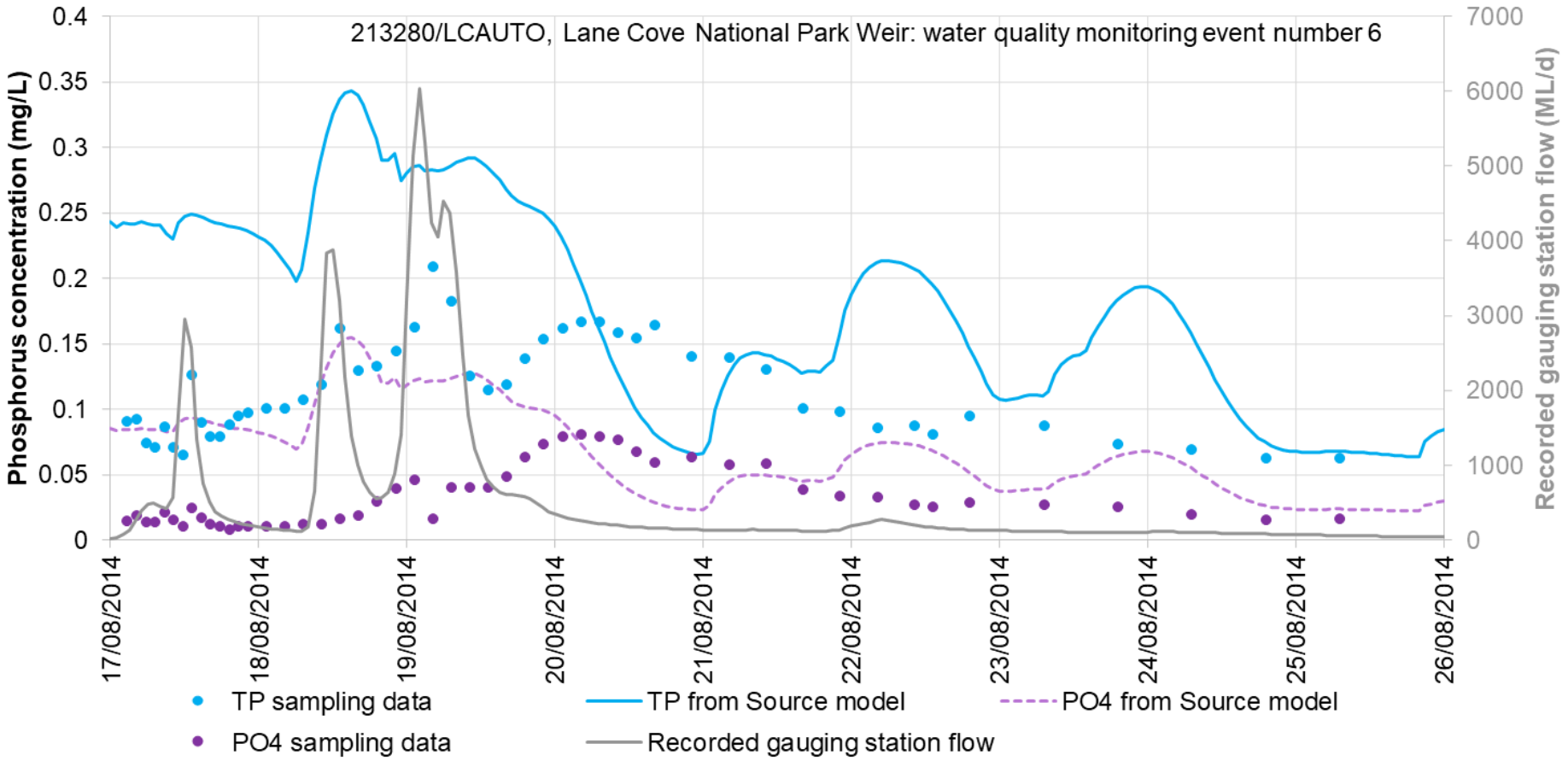

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 1
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
600
500
400
300
200
100
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

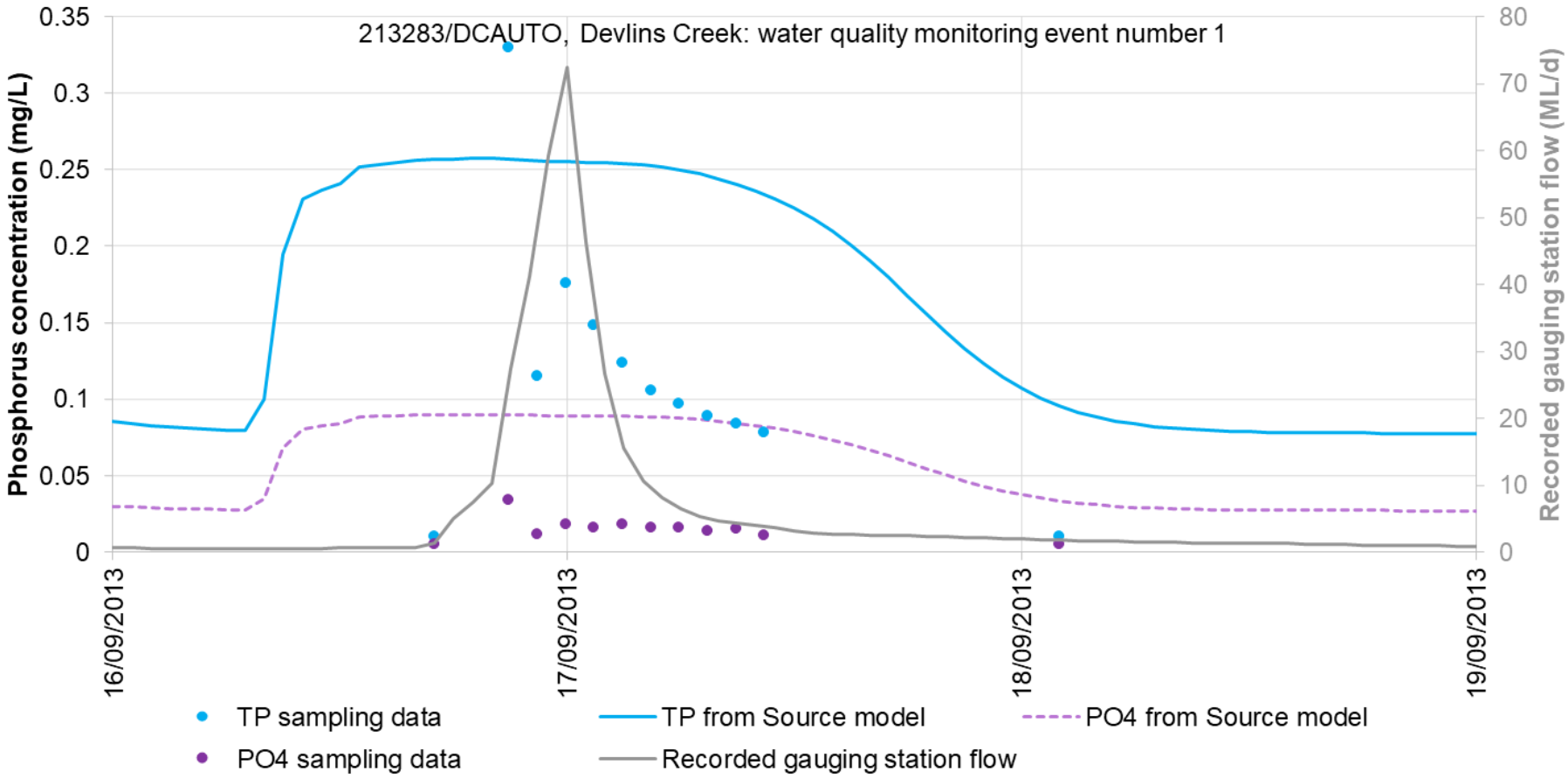

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

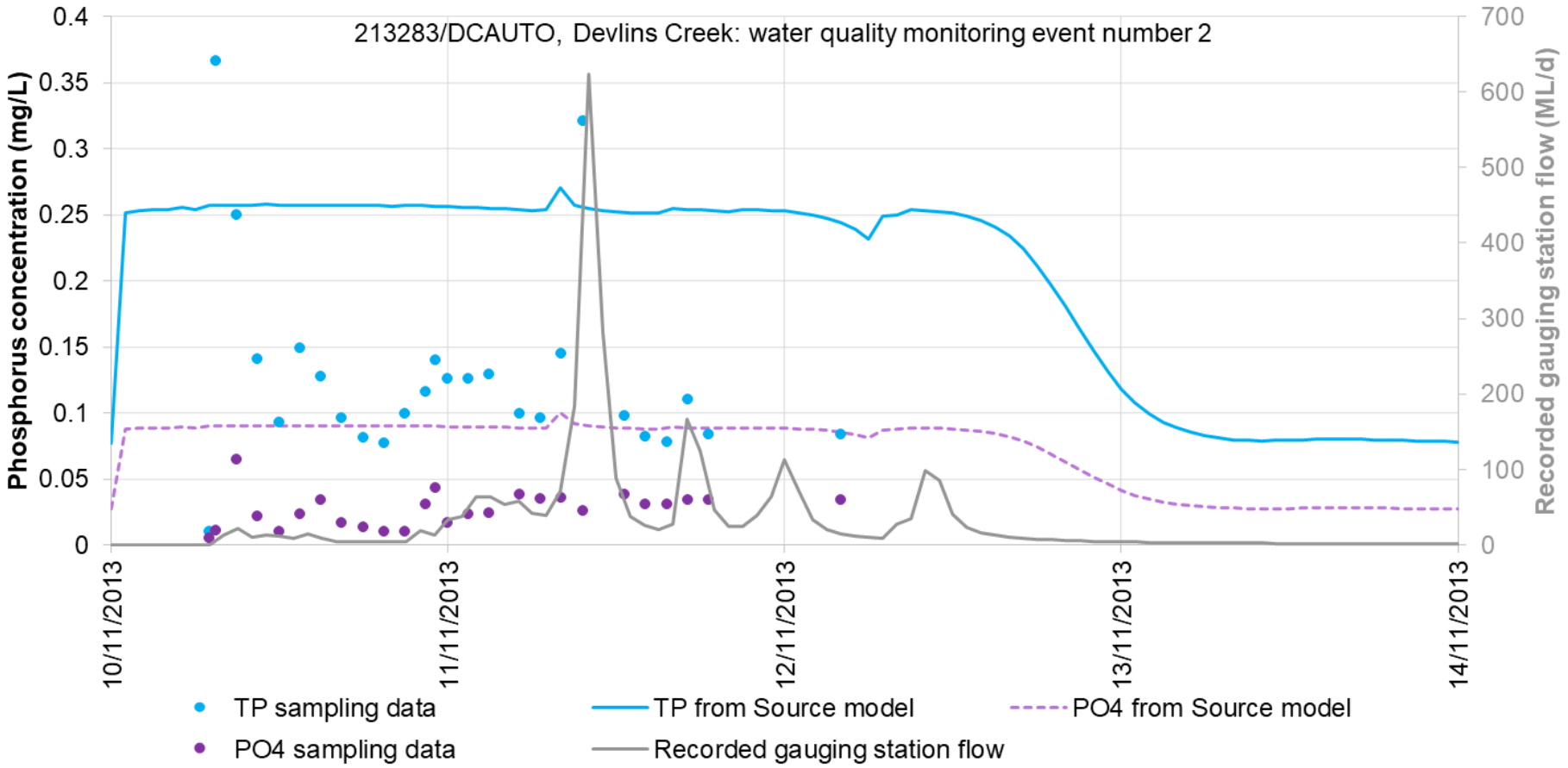

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 3
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2500
2000
1500
1000
500
0
18/11/2013
19/11/2013
20/11/2013
21/11/2013
22/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

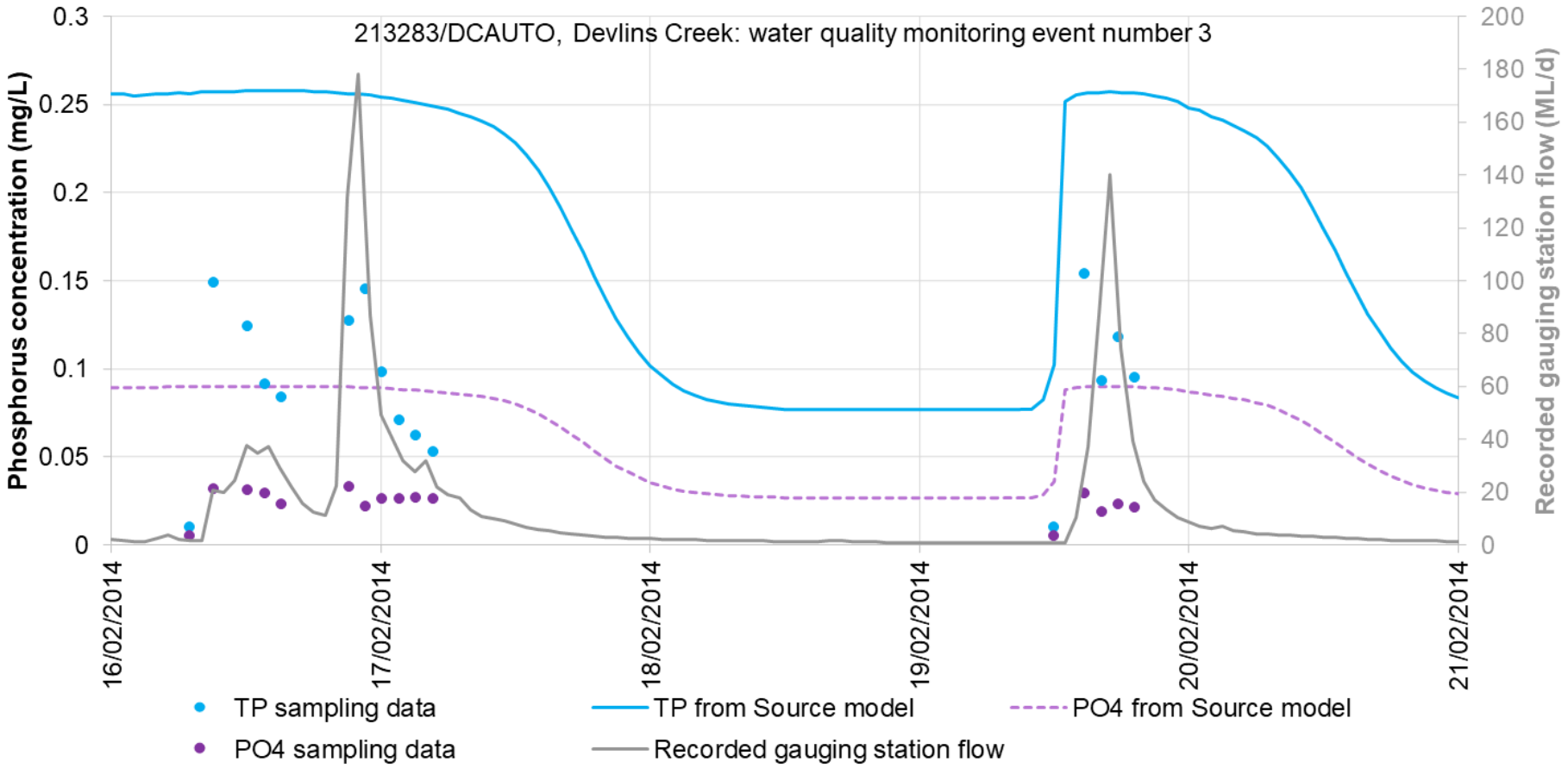

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 4
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
600
500
400
300
200
100
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

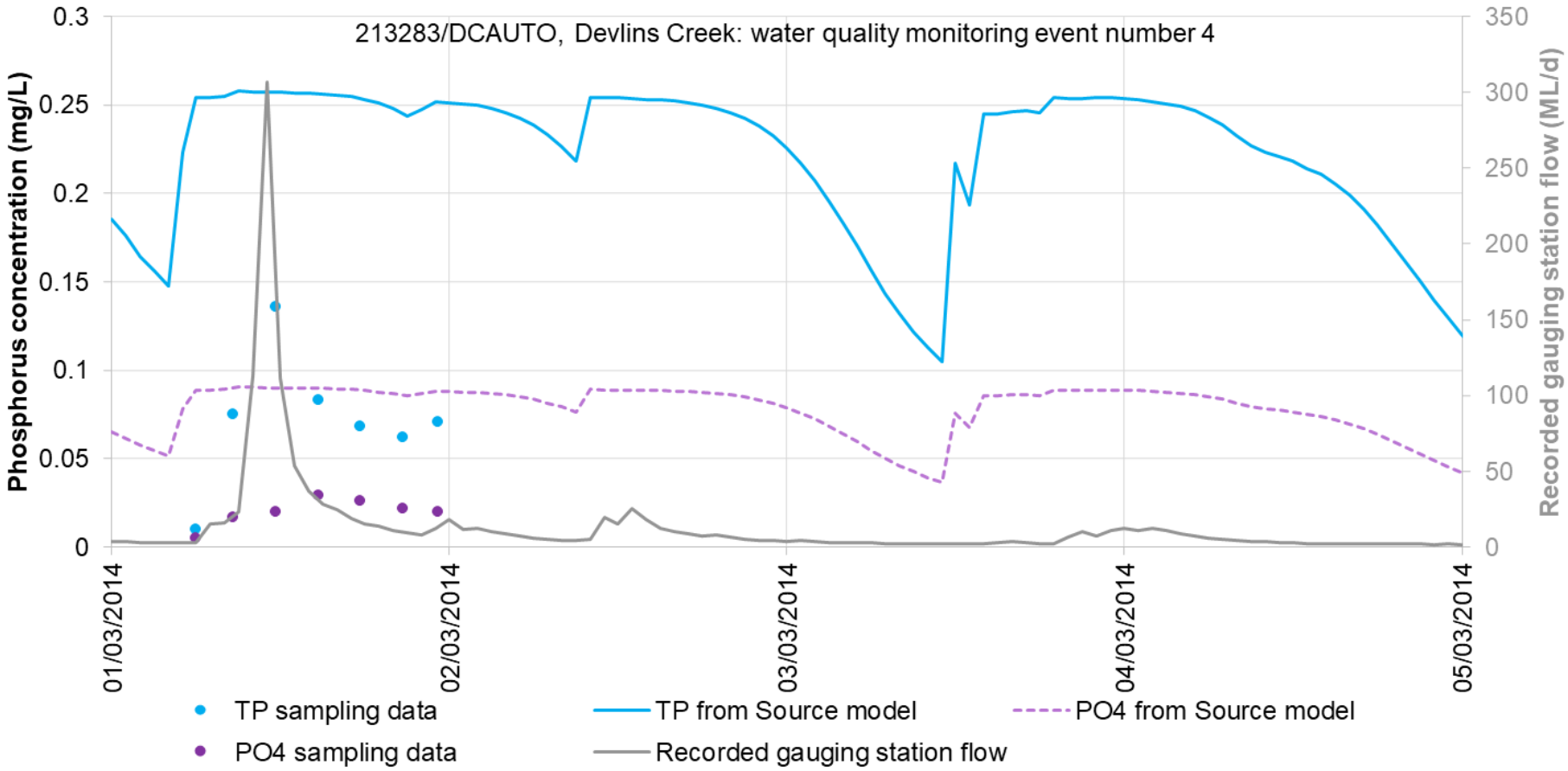

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 5
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

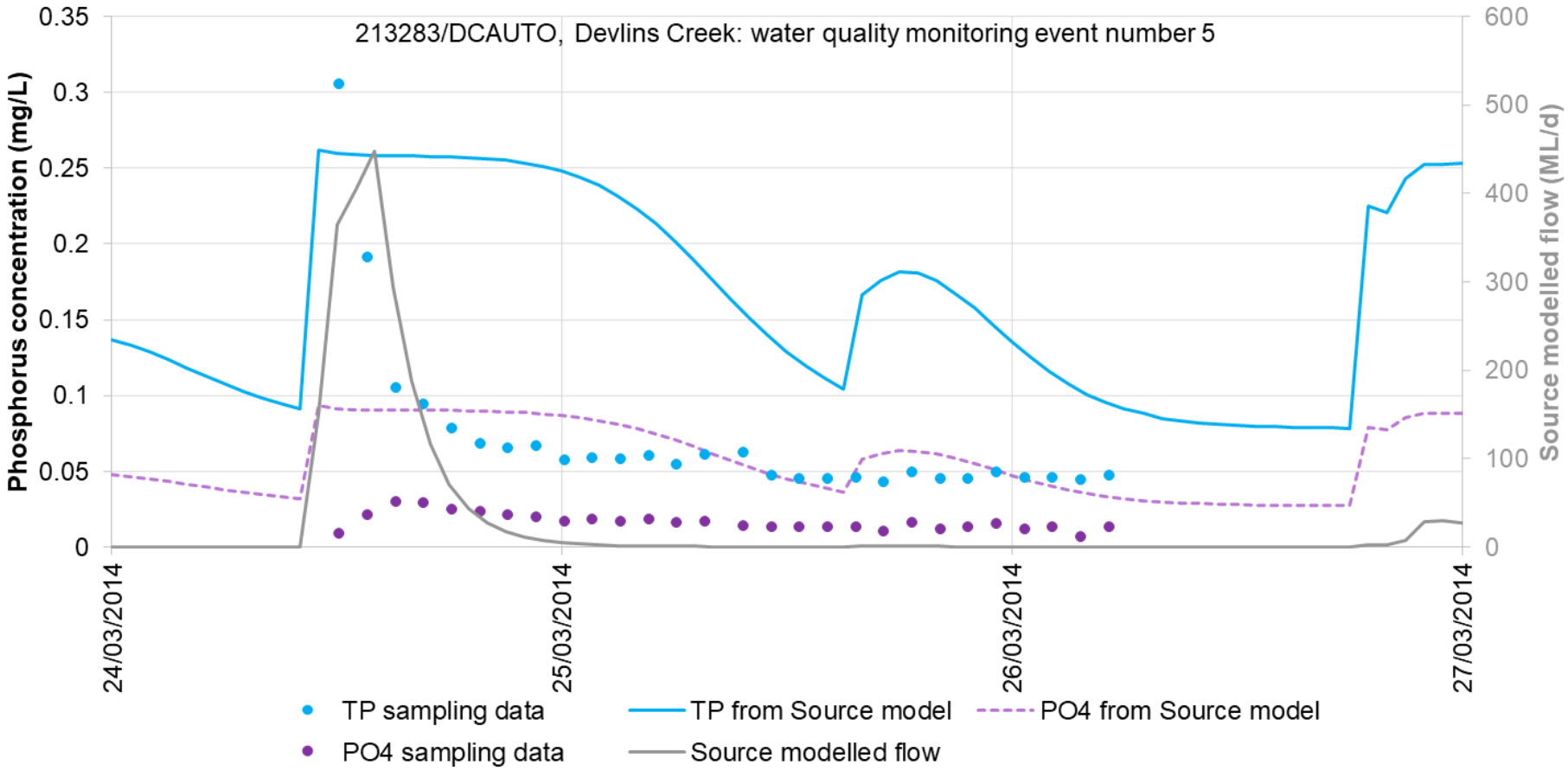

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 6
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7000
6000
5000
4000
3000
2000
1000
0
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Recorded gauging station flow

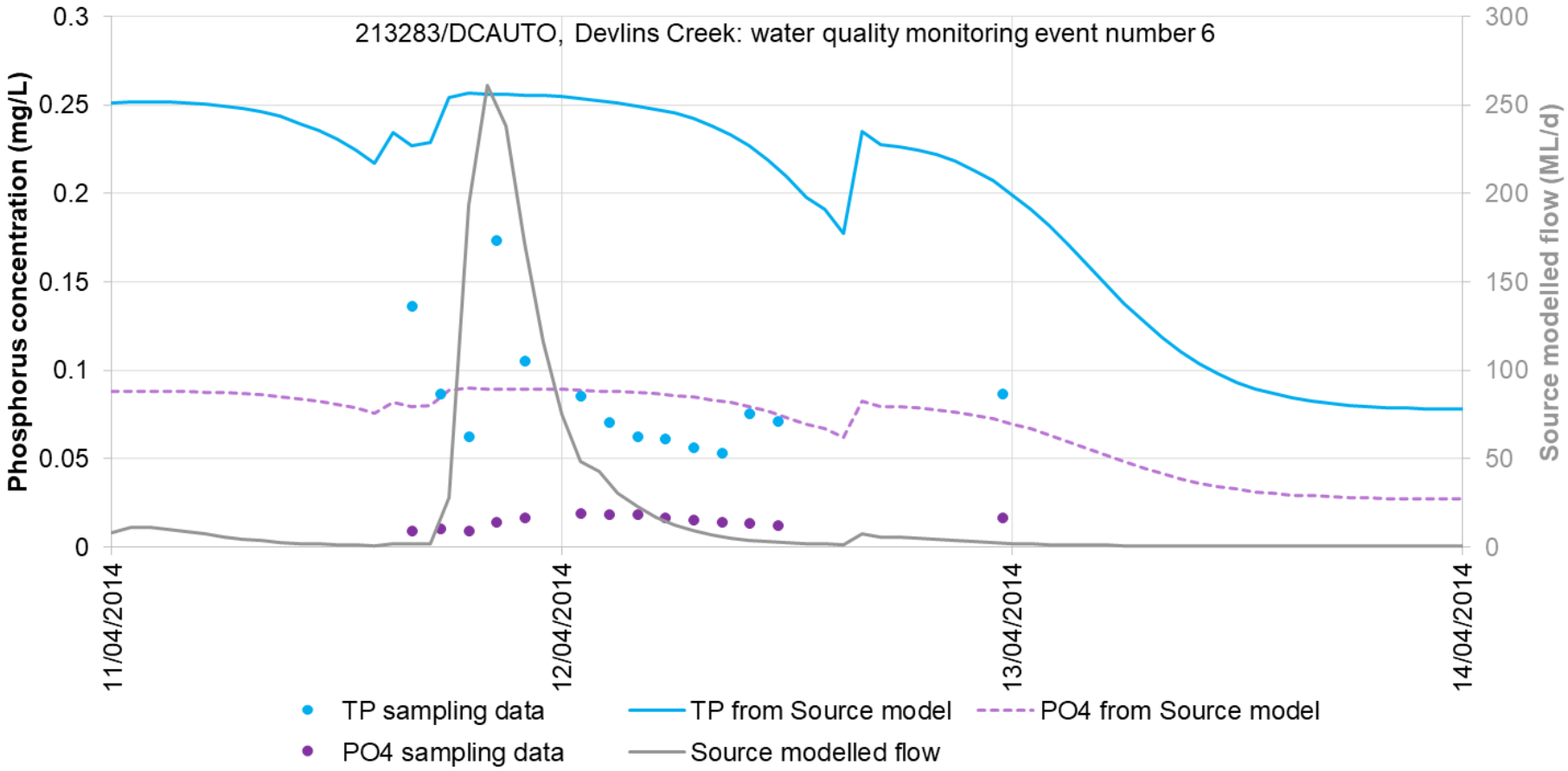

213283/DCAUTO, Devlins Creek: water quality monitoring event number 1
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
80
70
60
50
40
30
20
10
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

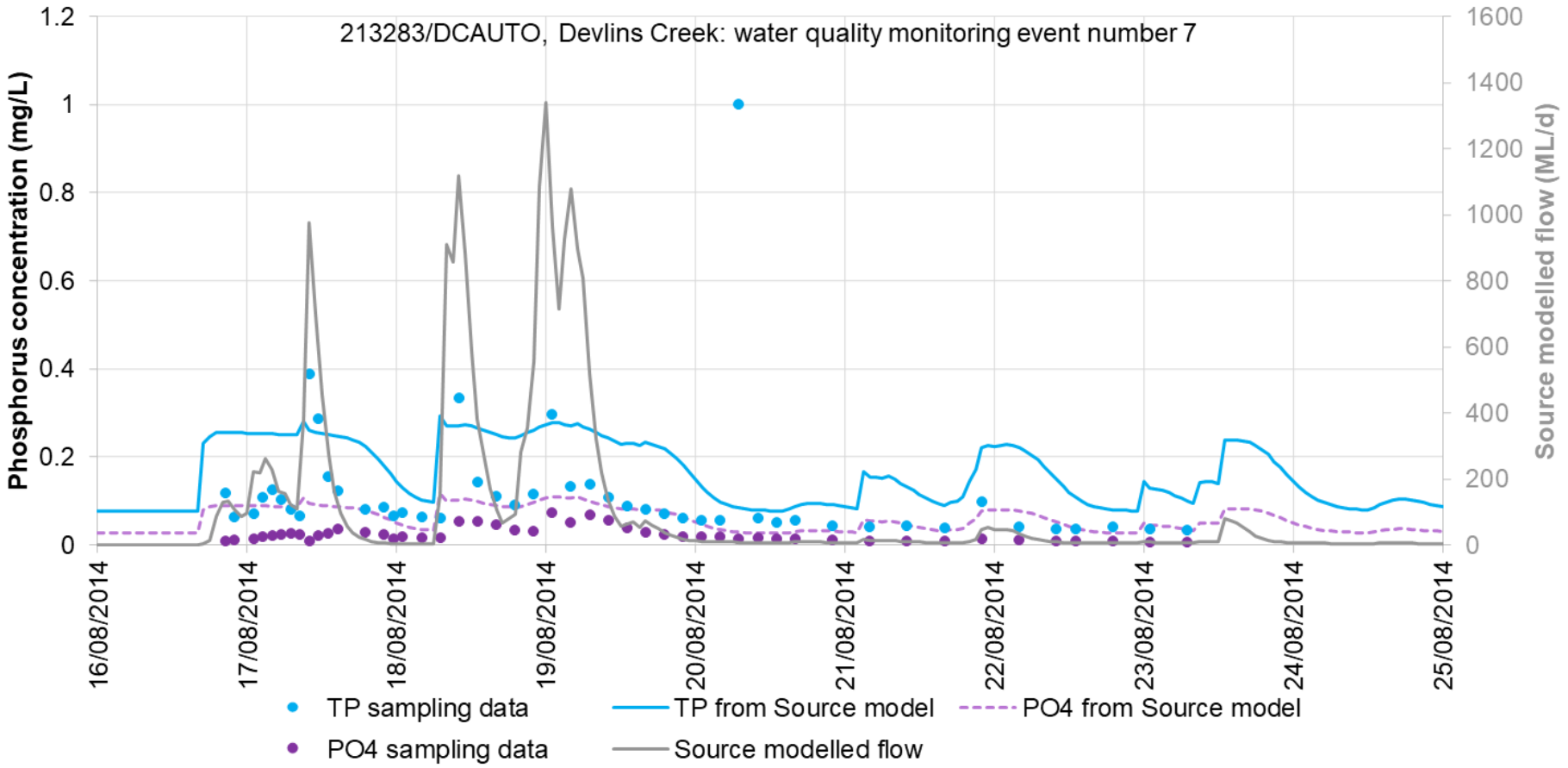

213283/DCAUTO, Devlins Creek: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
700
600
500
400
300
200
100
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

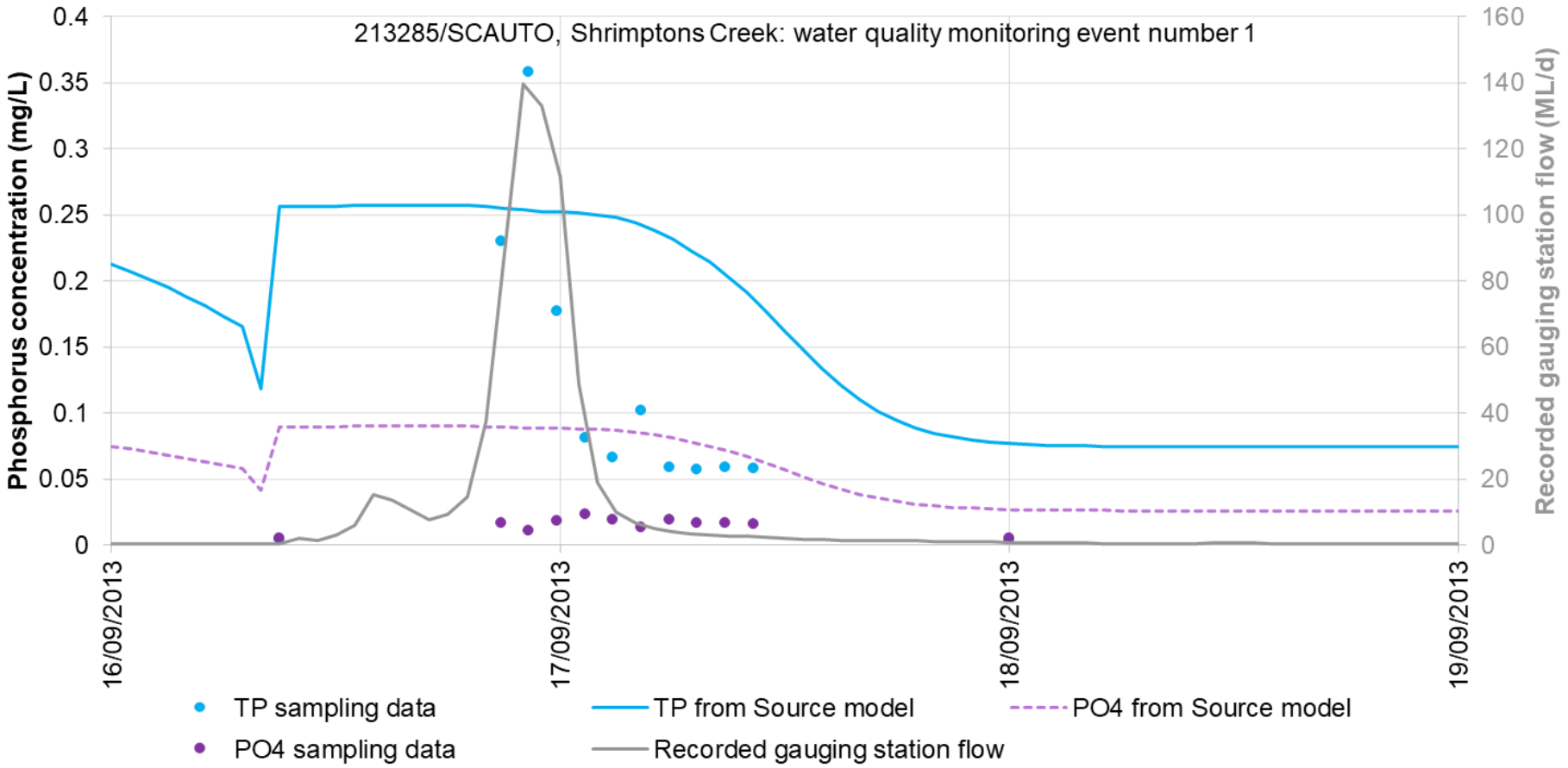

213283/DCAUTO, Devlins Creek: water quality monitoring event number 3
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
200
180
160
140
120
100
80
60
40
20
0
16/02/2014
17/02/2014
18/02/2014
19/02/2014
20/02/2014
21/02/2014
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

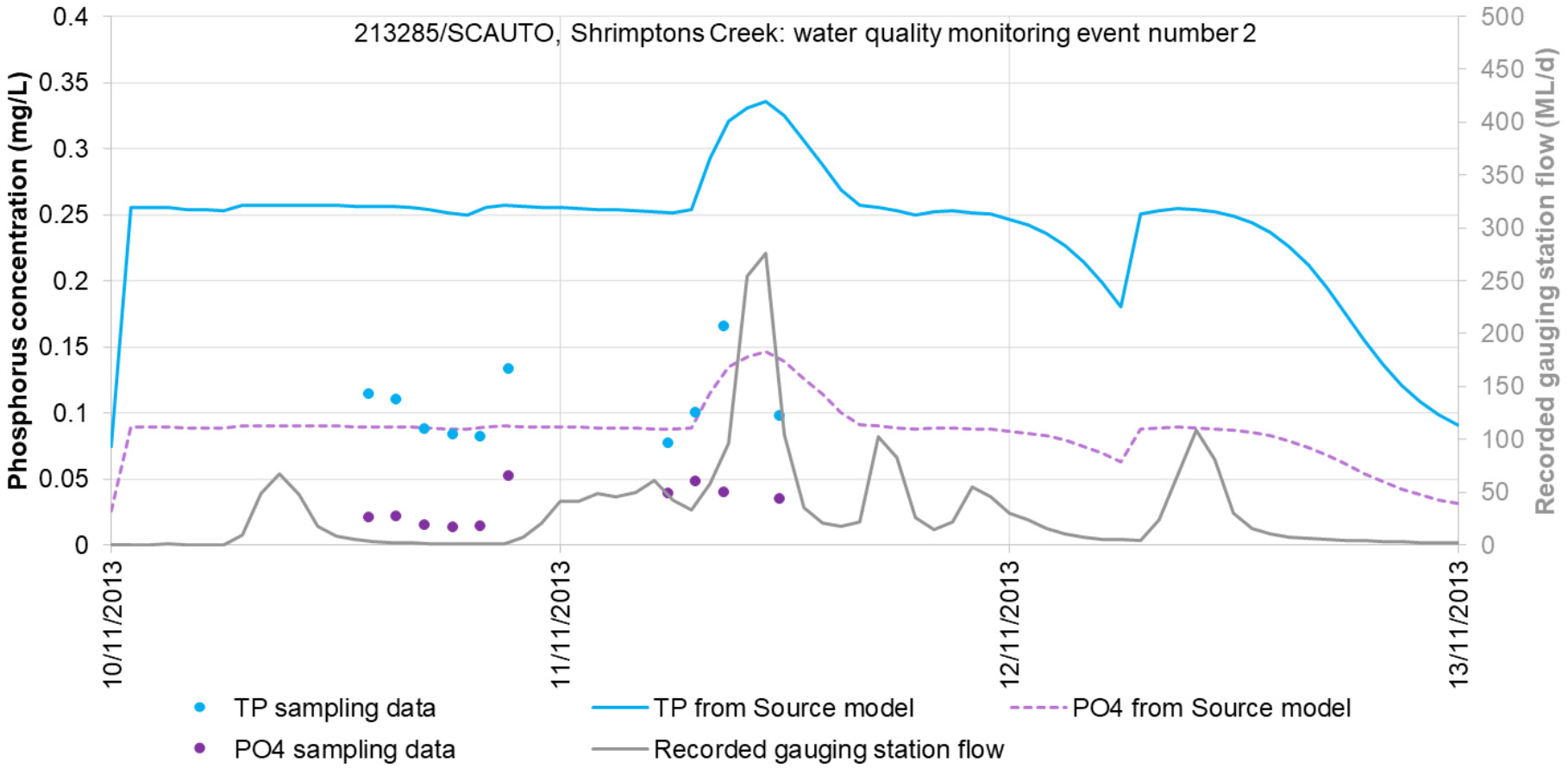

213283/DCAUTO, Devlins Creek: water quality monitoring event number 4
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
350
300
250
200
150
100
50
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

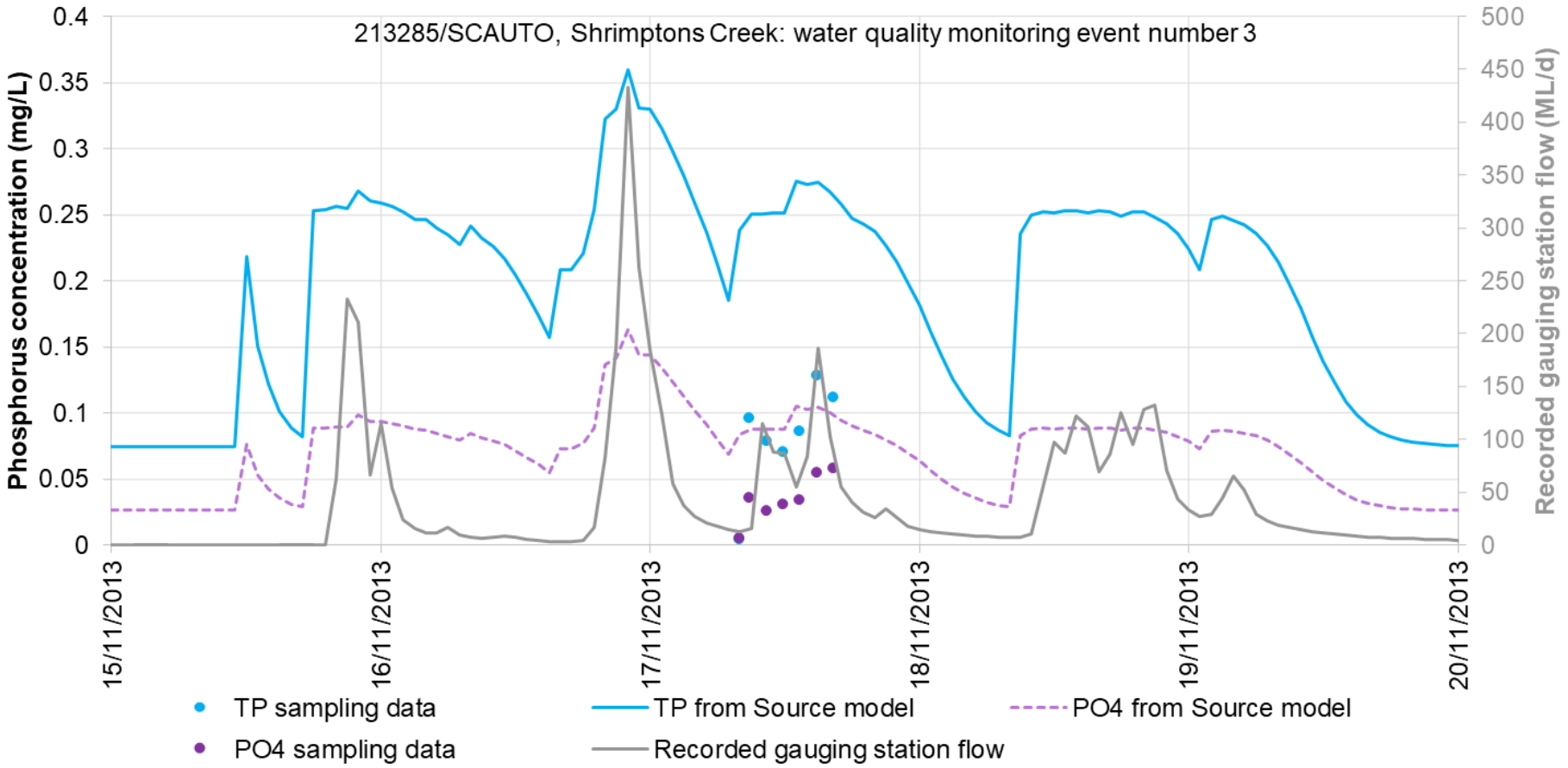

213283/DCAUTO, Devlins Creek: water quality monitoring event number 5
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TP sampling data
PO4 sampling data
TP from Source model
Source modelled flow
PO4 from Source model

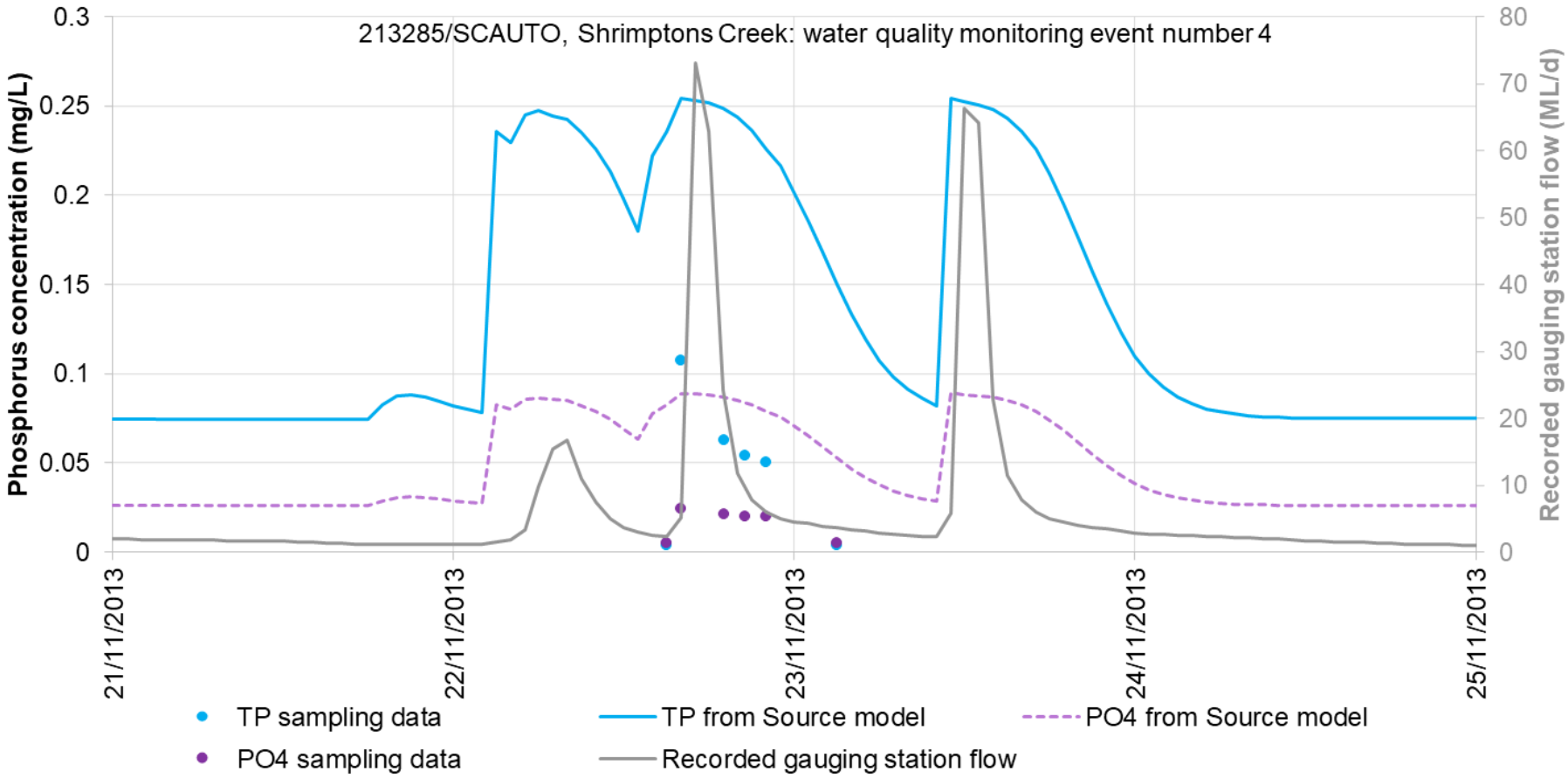

213283/DCAUTO, Devlins Creek: water quality monitoring event number 6
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
300
250
200
150
100
50
0
11/04/2014
12/04/2014
13/04/2014
14/04/2014
TP sampling data
PO4 sampling data
TP from Source model
Source modelled flow
PO4 from Source model

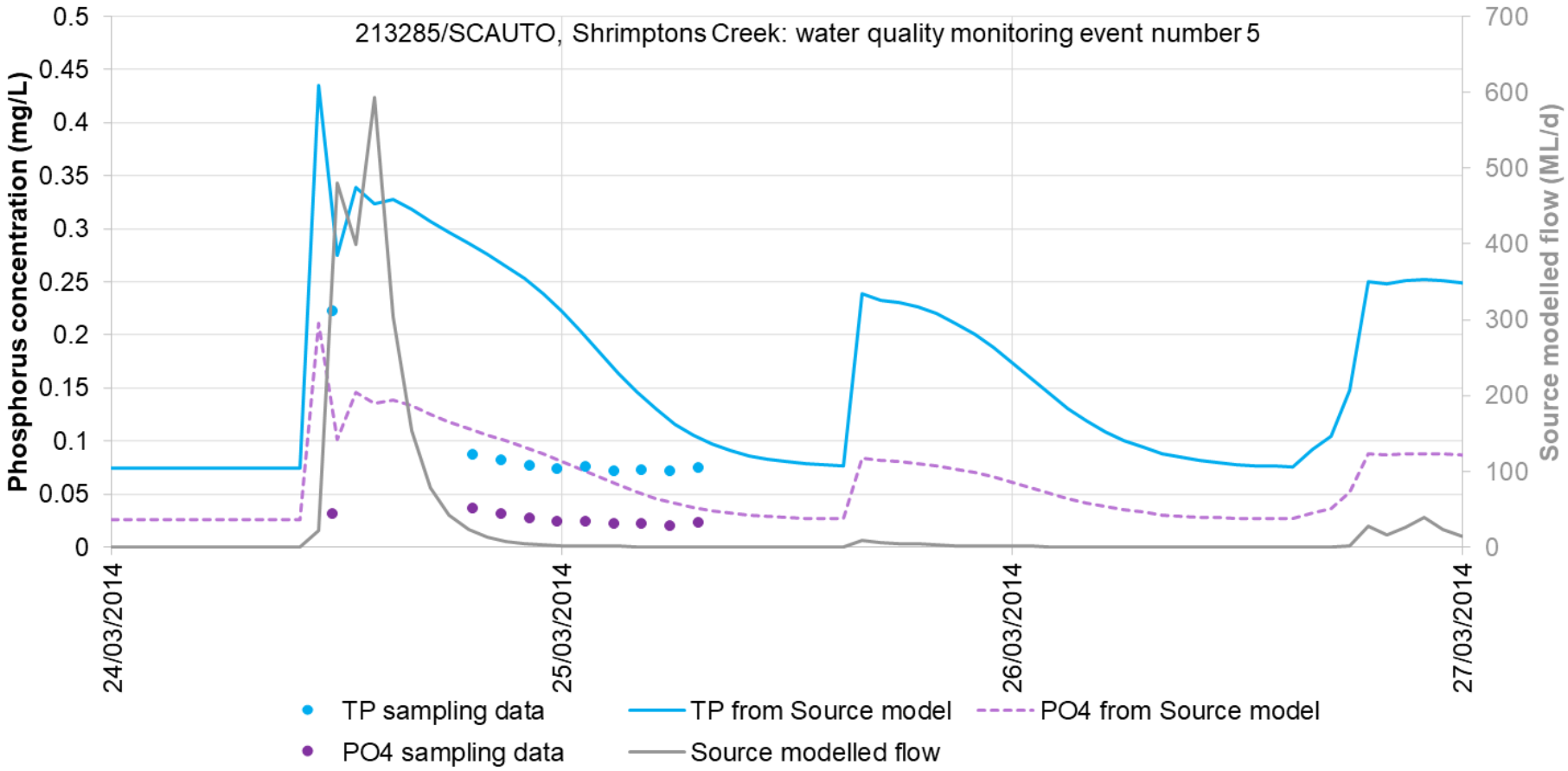

213283/DCAUTO, Devlins Creek: water quality monitoring event number 7
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
1.2
1
0.8
0.6
0.4
0.2
0
1600
1400
1200
1000
800
600
400
200
0
16/08/2014
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Source modelled flow

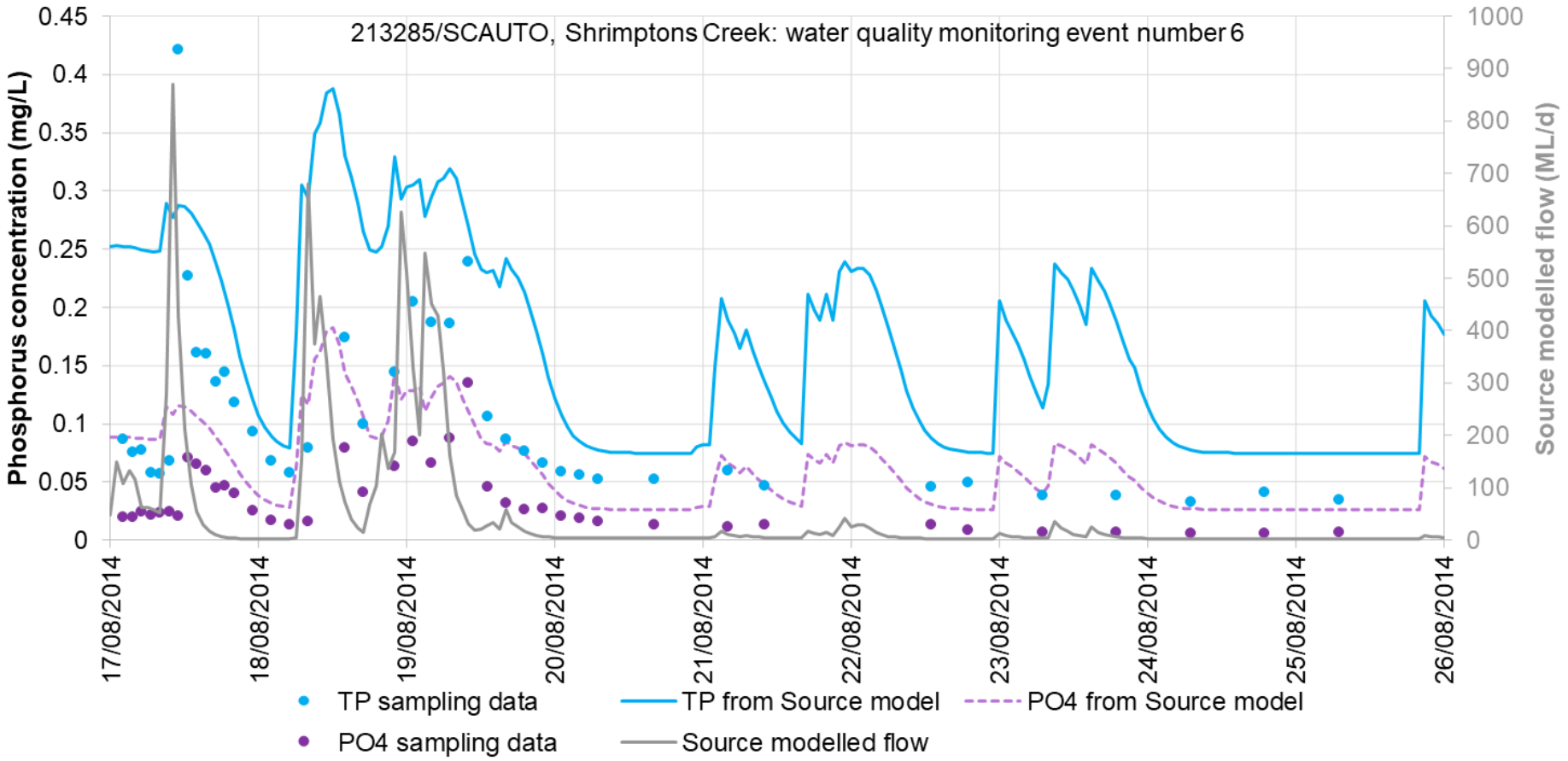

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 1
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
160
140
120
100
80
60
40
20
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

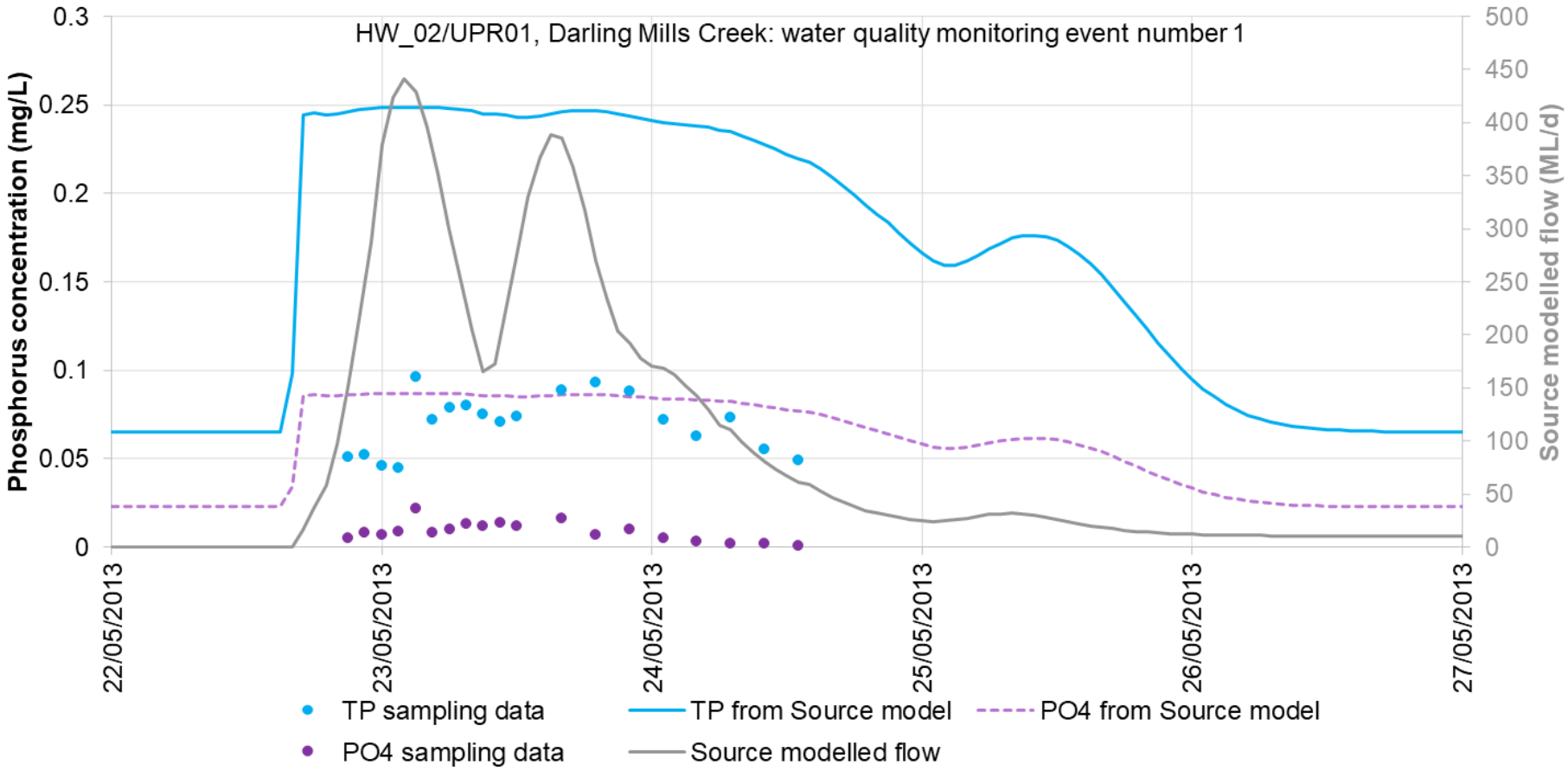

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
500
450
400
350
300
250
200
150
100
50
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

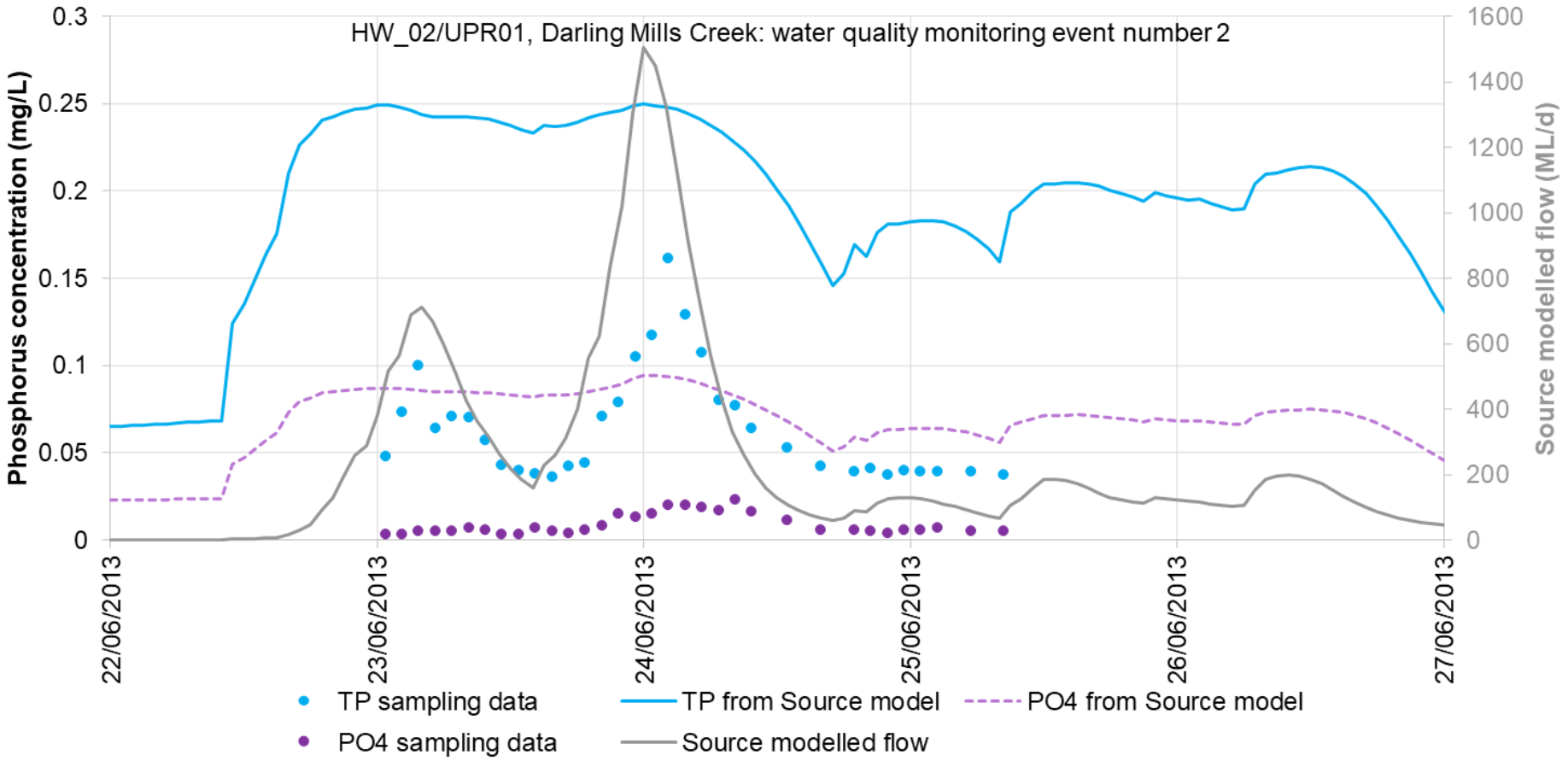

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 3
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
500
450
400
350
300
250
200
150
100
50
0
15/11/2013
16/11/2013
17/11/2013
18/11/2013
19/11/2013
20/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

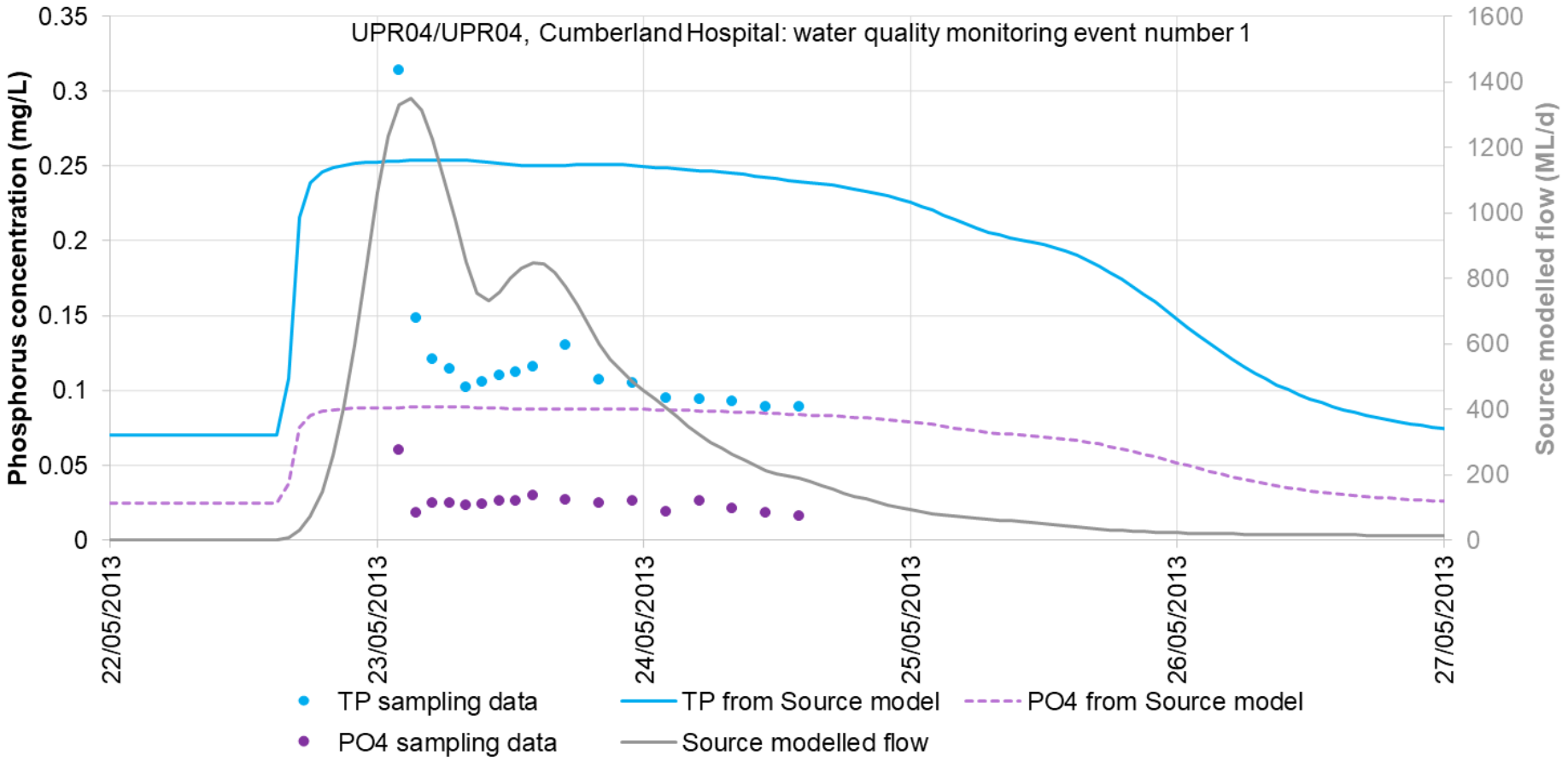

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 4
Phosphorus concentration (mg/L)
Recorded gauging station flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
80
70
60
50
40
30
20
10
0
21/11/2013
22/11/2013
23/11/2013
24/11/2013
25/11/2013
TP sampling data
PO4 sampling data
TP from Source model
Recorded gauging station flow
PO4 from Source model

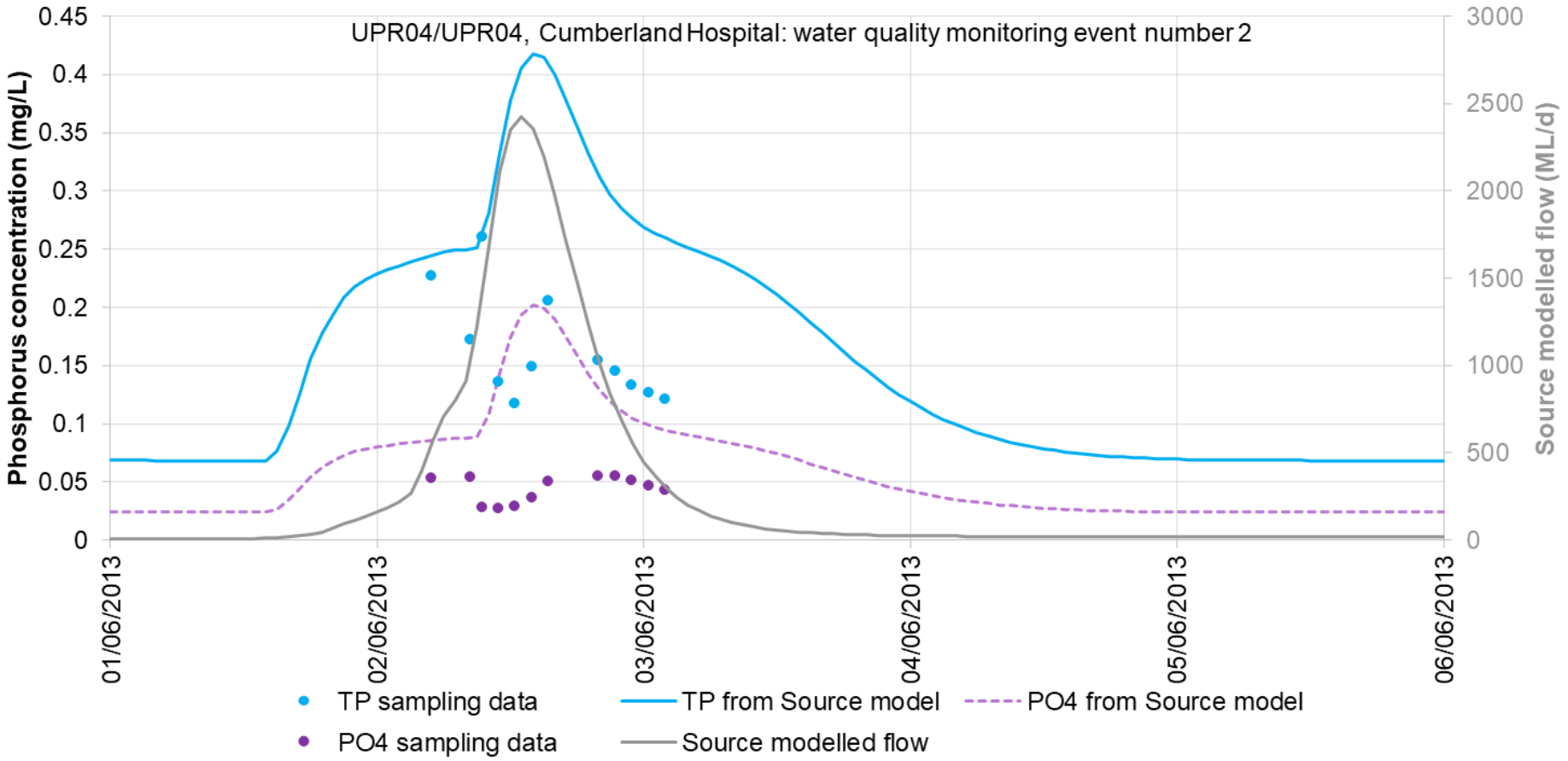

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 5
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TP sampling data
PO4 sampling data
TP from Source model
Source modelled flow
PO4 from Source model

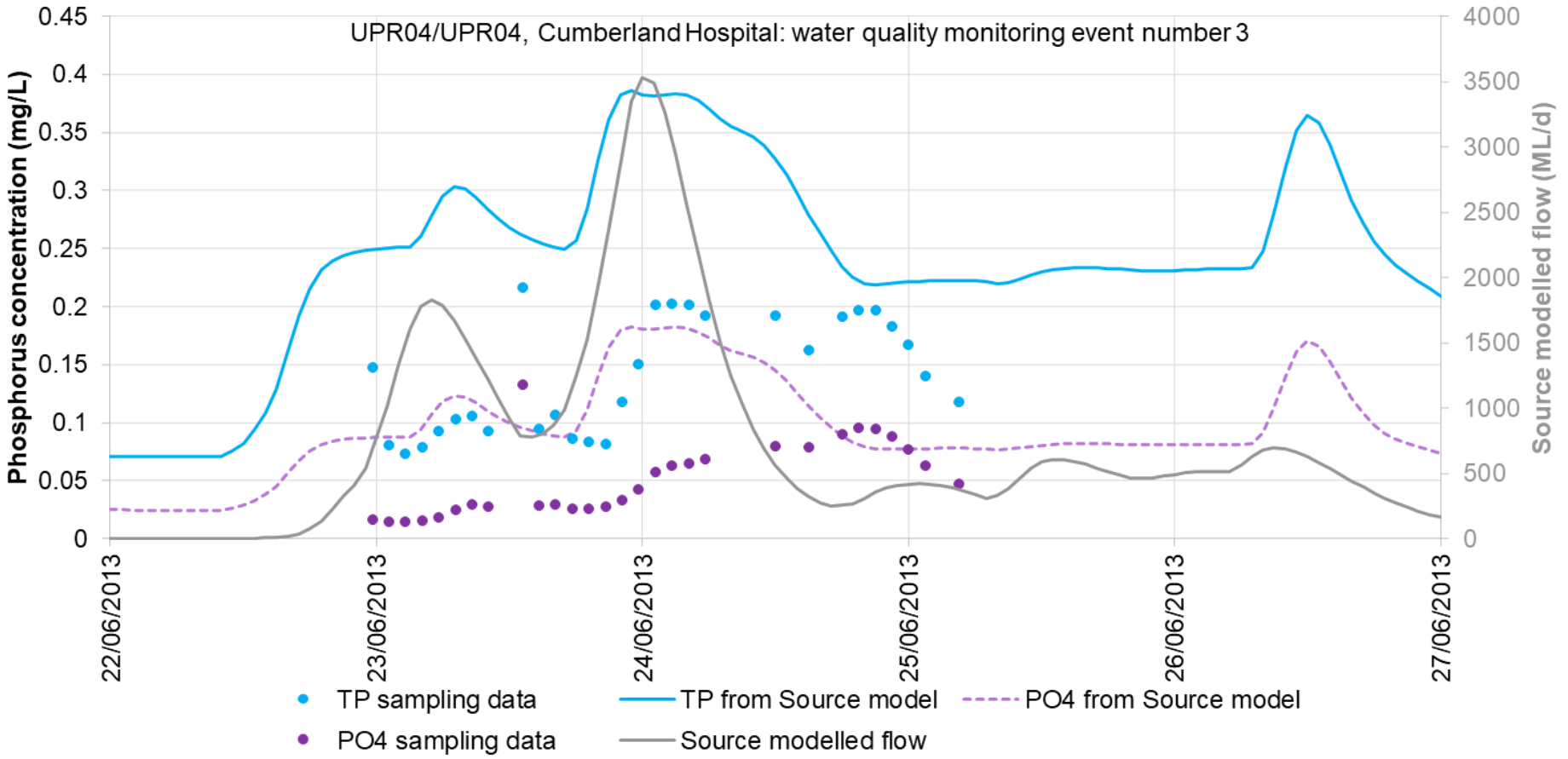

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 6
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1000
900
800
700
600
500
400
300
200
100
0
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Source modelled flow


HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 1
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
500
450
400
350
300
250
200
150
100
50
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TP sampling data
PO4 sampling data
TP from Source model
Source modelled flow
PO4 from Source model

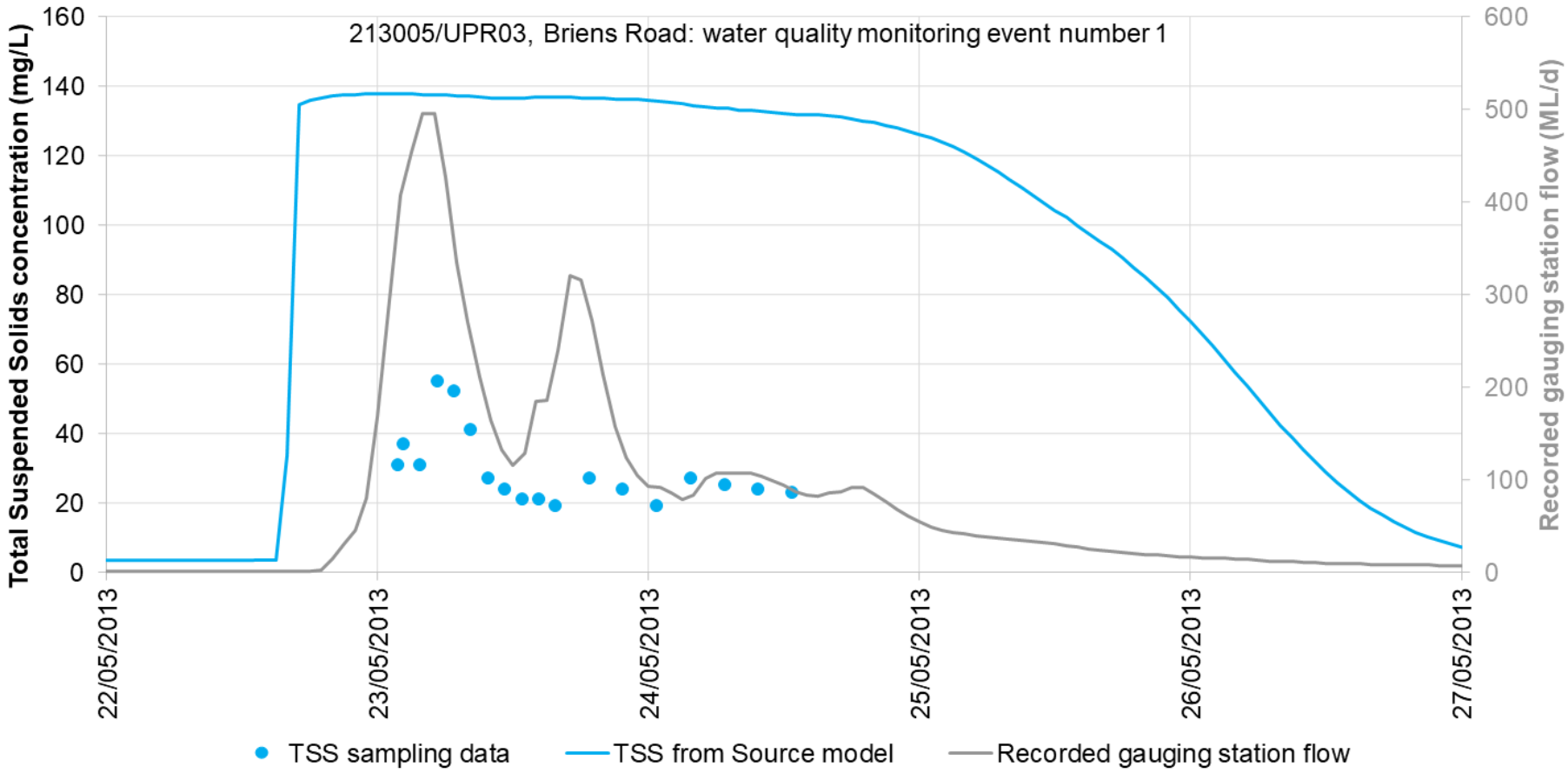

HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.3
0.25
0.2
0.15
0.1
0.05
0
1600
1400
1200
1000
800
600
400
200
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Source modelled flow

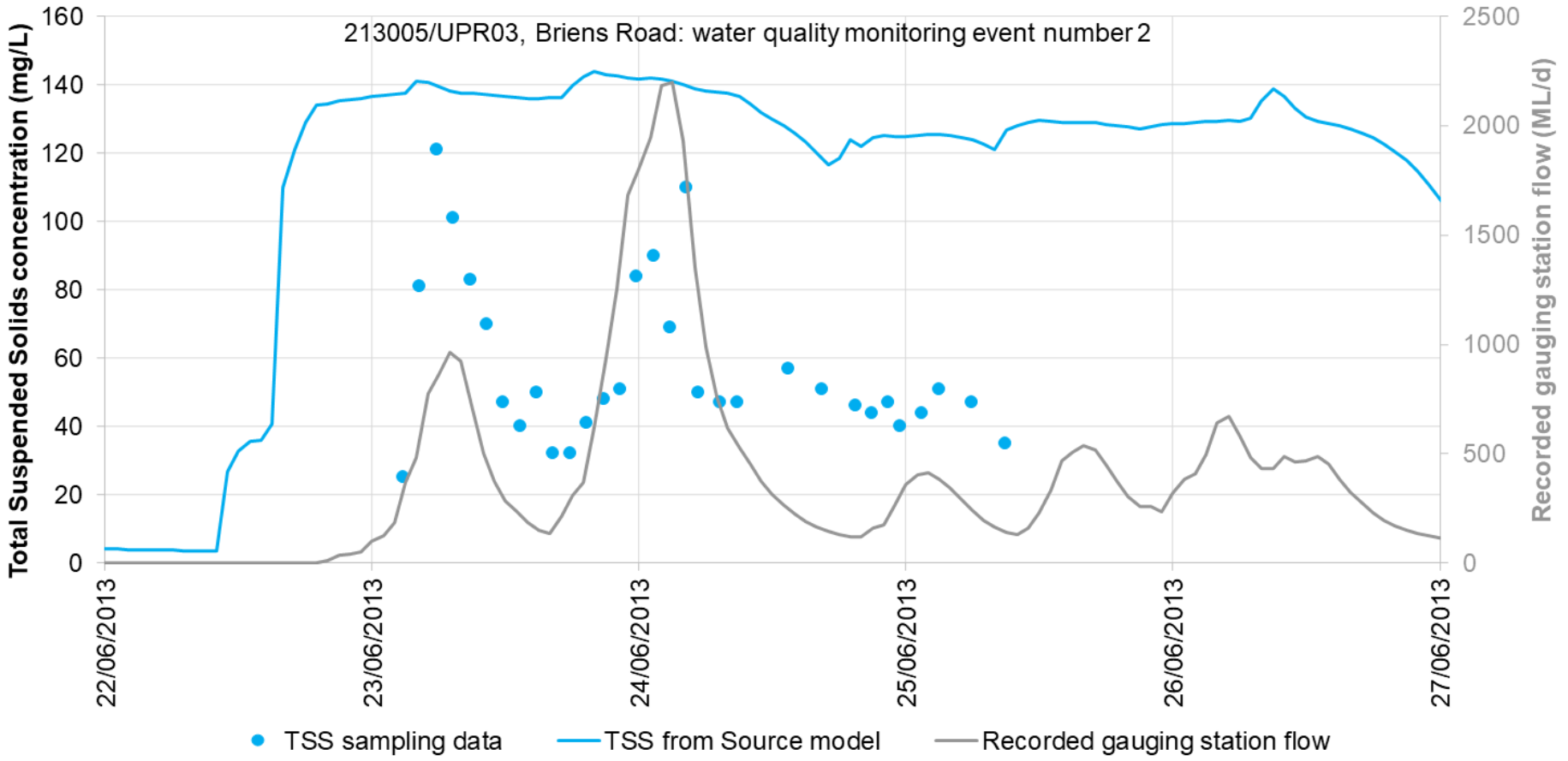

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 1
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1600
1400
1200
1000
800
600
400
200
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Source modelled flow

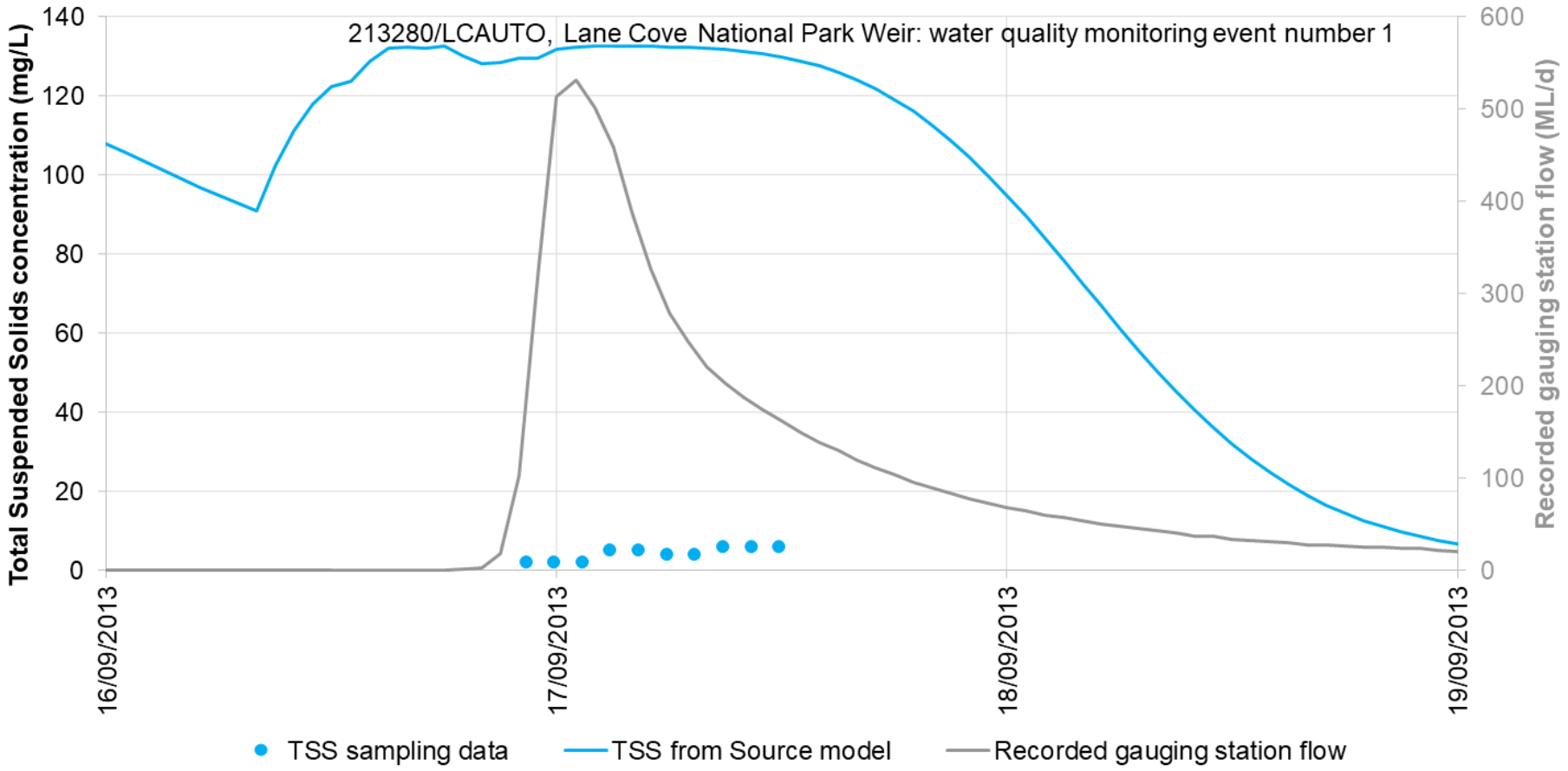

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 2
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3000
2500
2000
1500
1000
500
0
01/06/2013
02/06/2013
03/06/2013
04/06/2013
05/06/2013
06/06/2013
TP sampling data
TP from Source model
PO4 from Source model
PO4 sampling data
Source modelled flow

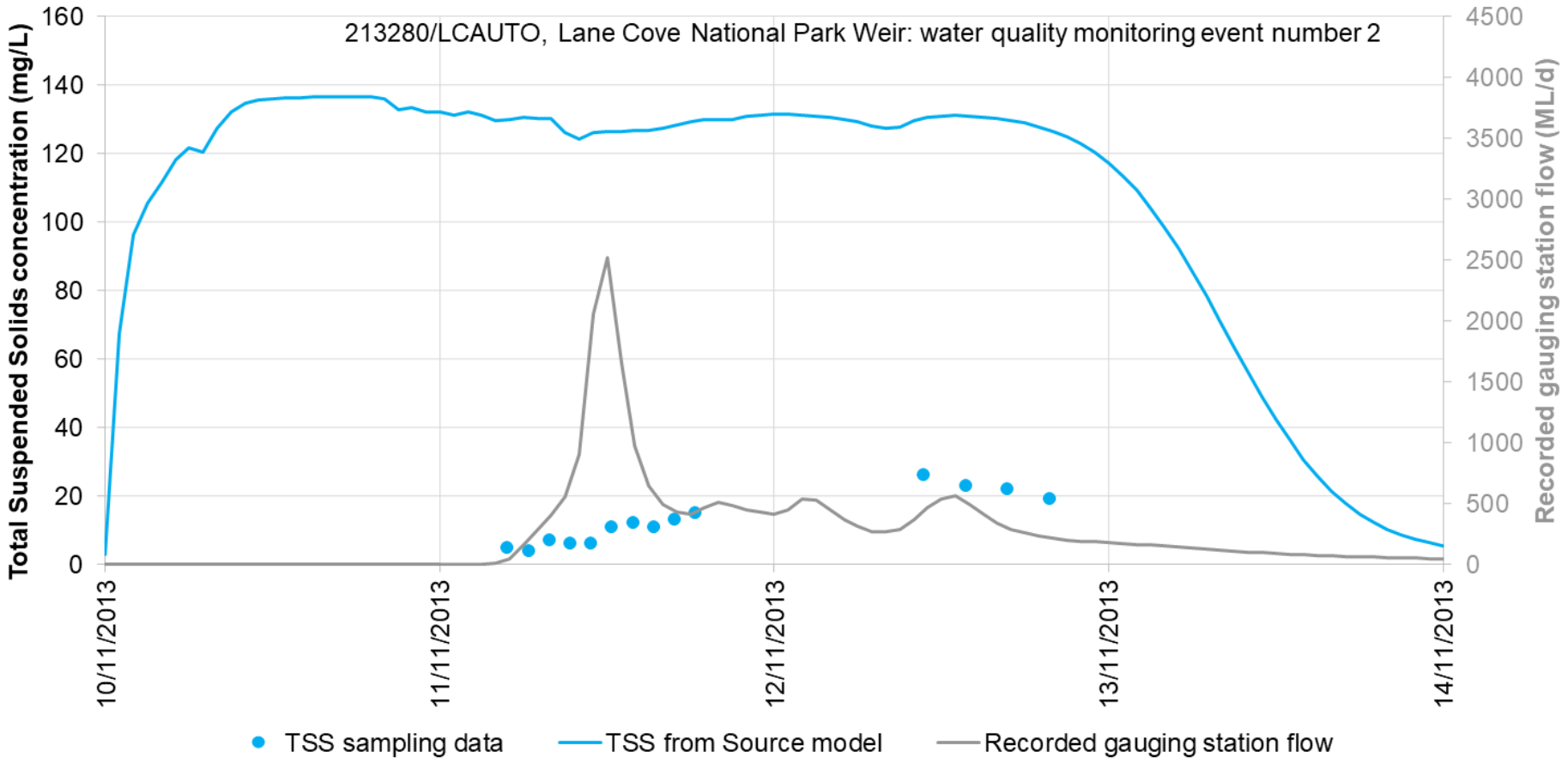

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 3
Phosphorus concentration (mg/L)
Source modelled flow (ML/d)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
4000
3500
3000
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TP sampling data
PO4 sampling data
TP from Source model
PO4 from Source model
Source modelled flow

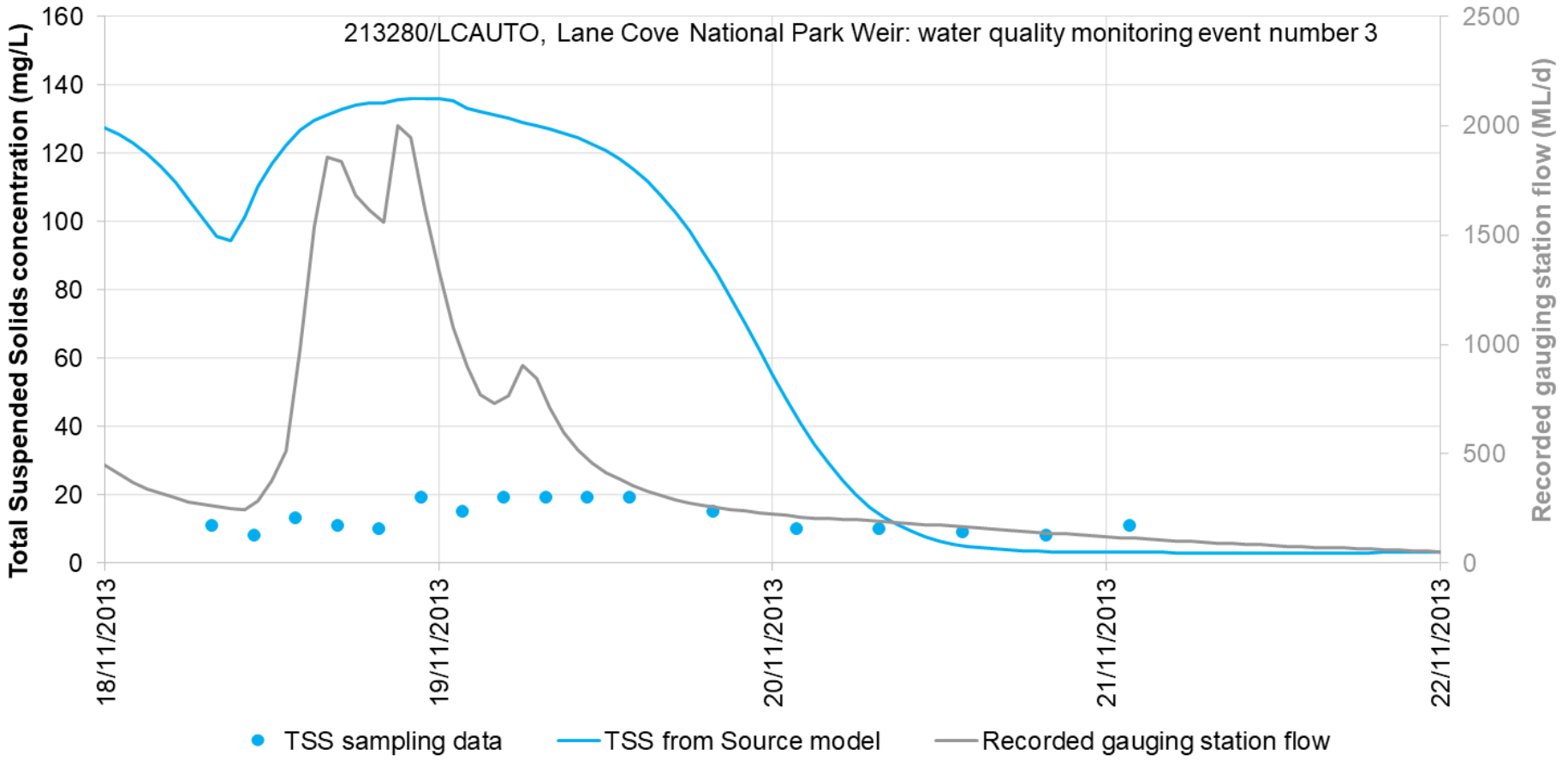
C.3 Total Suspended Solids comparison plots for monitored events

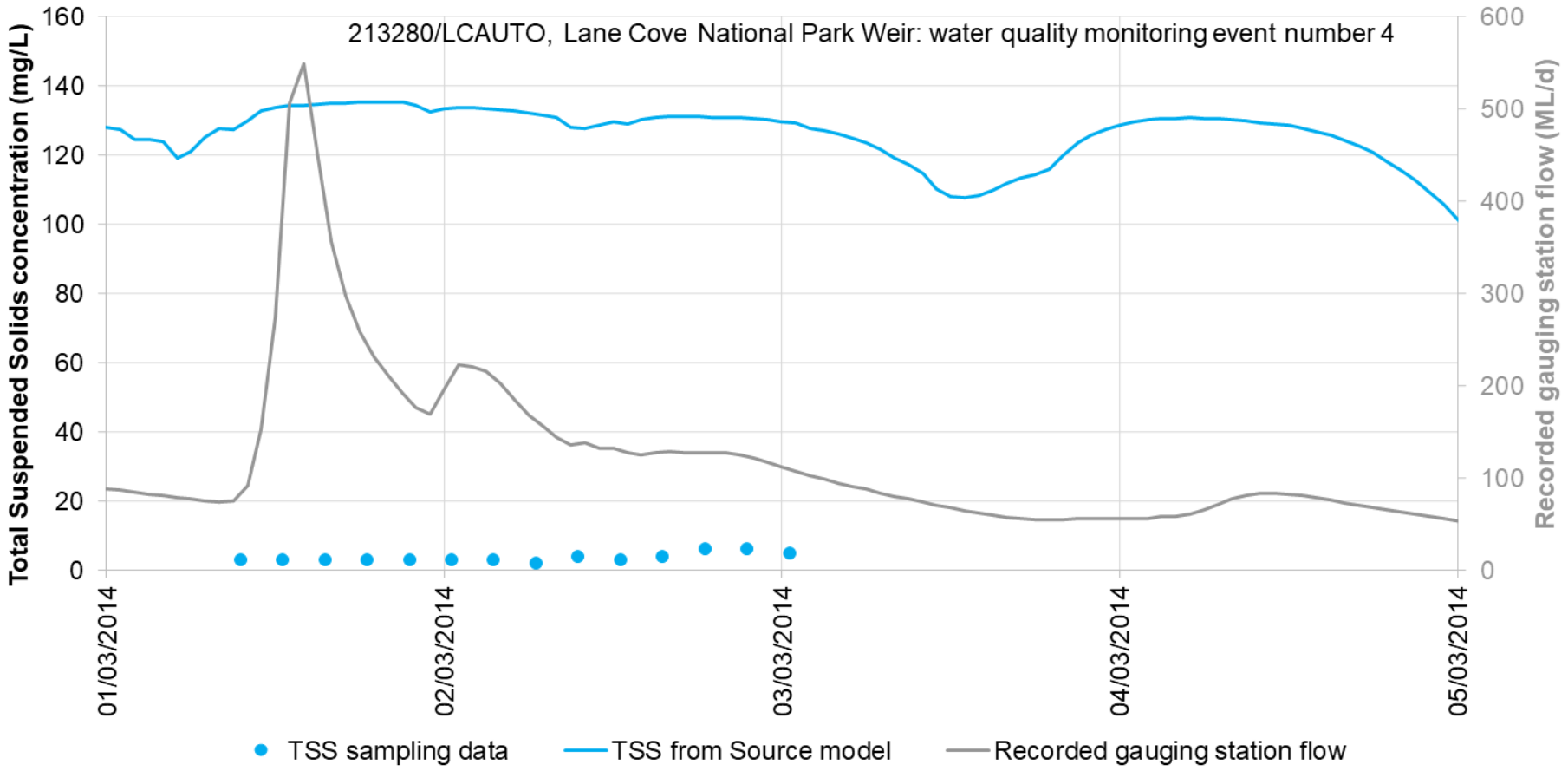


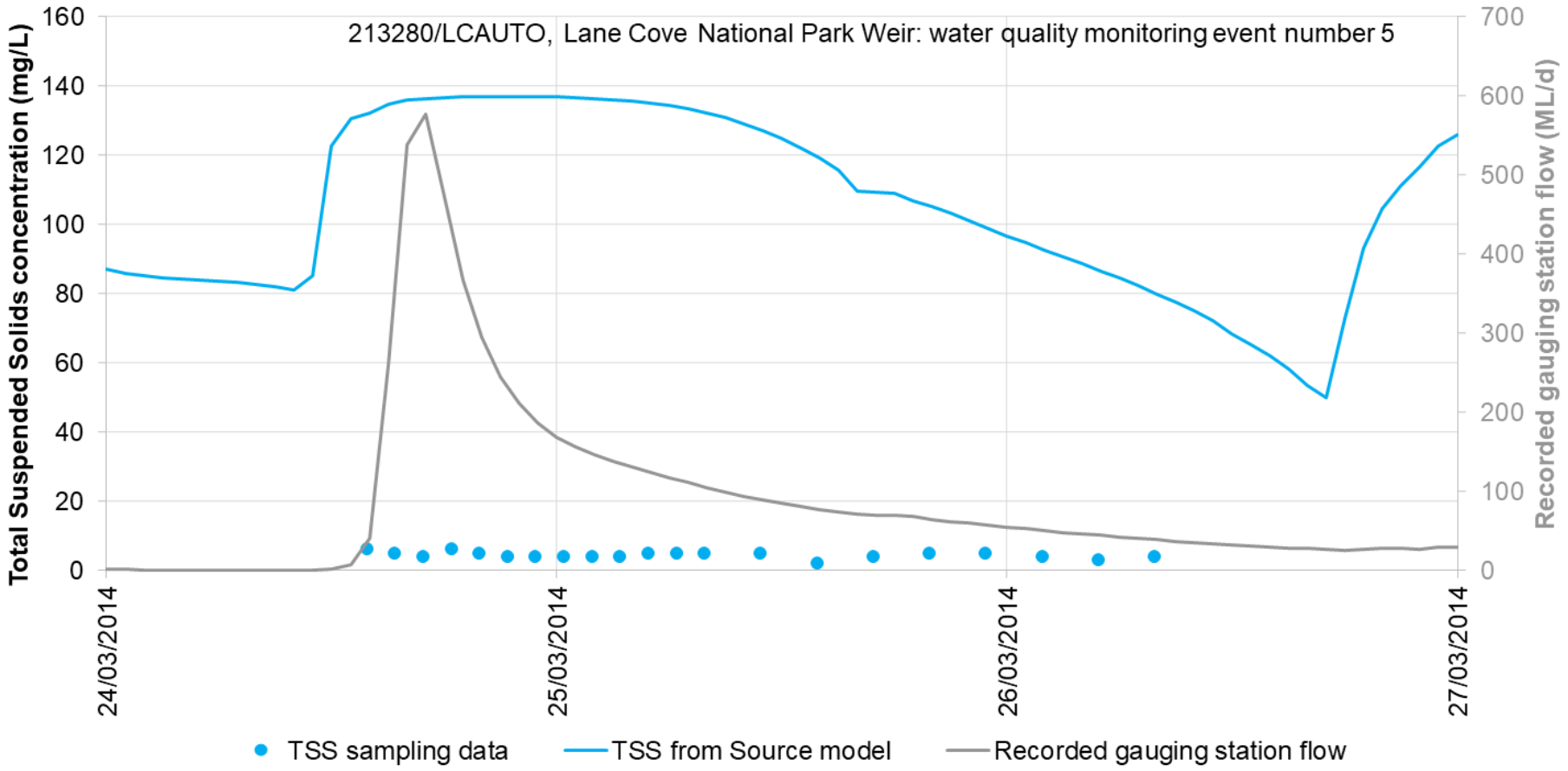

213005/UPR03, Briens Road: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

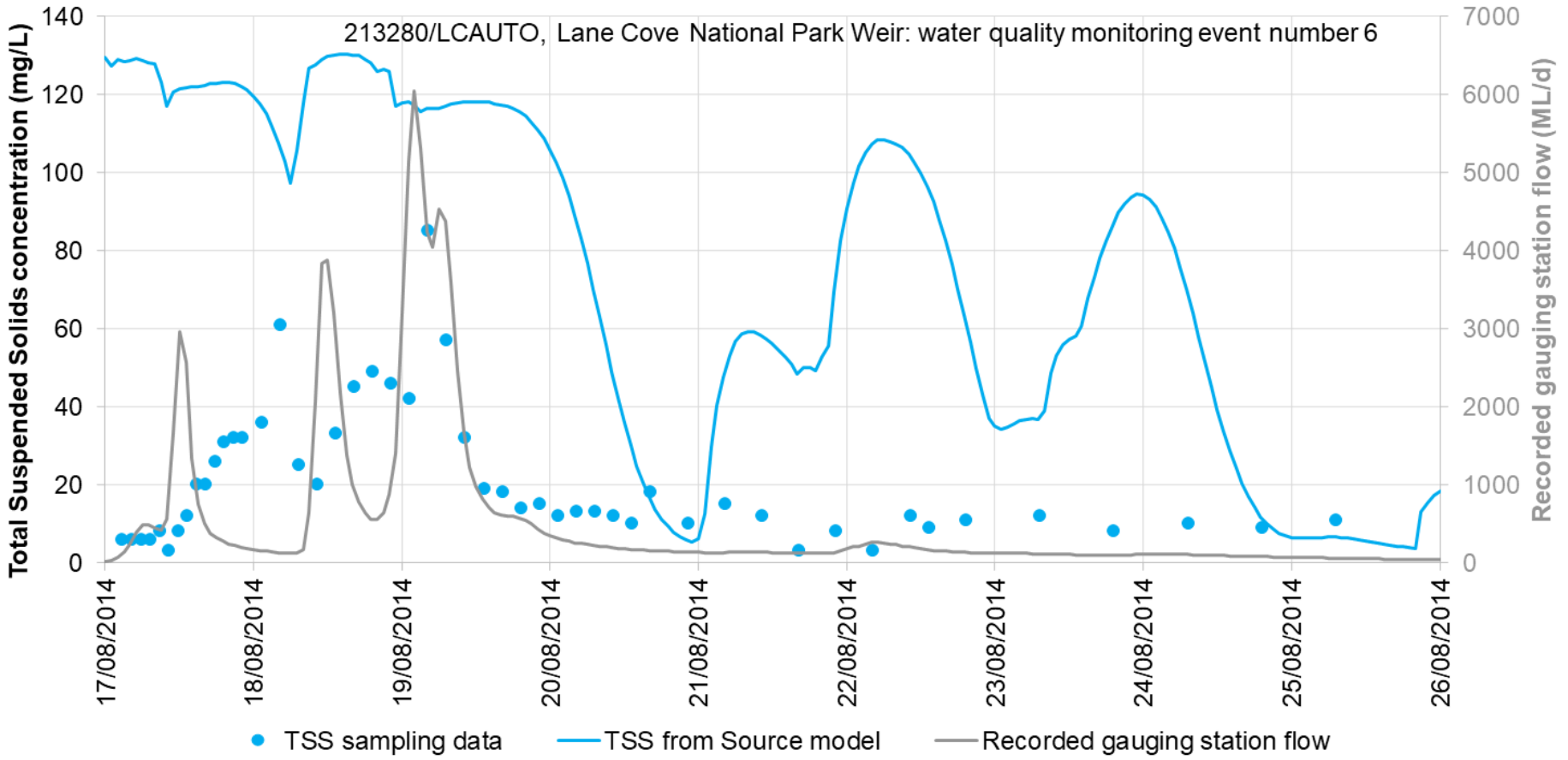

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 1
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
140
120
100
80
60
40
20
0
600
500
400
300
200
100
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

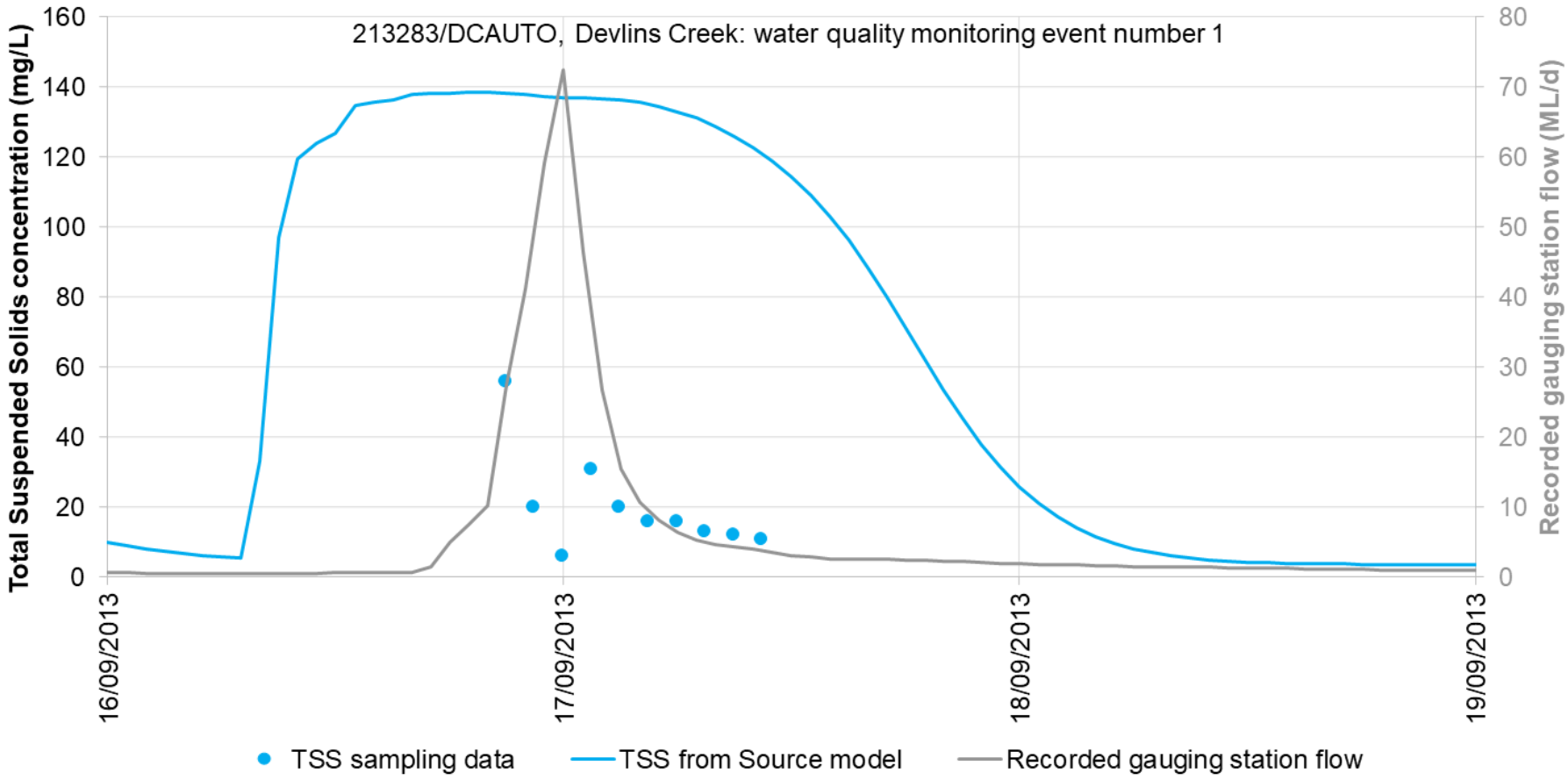

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

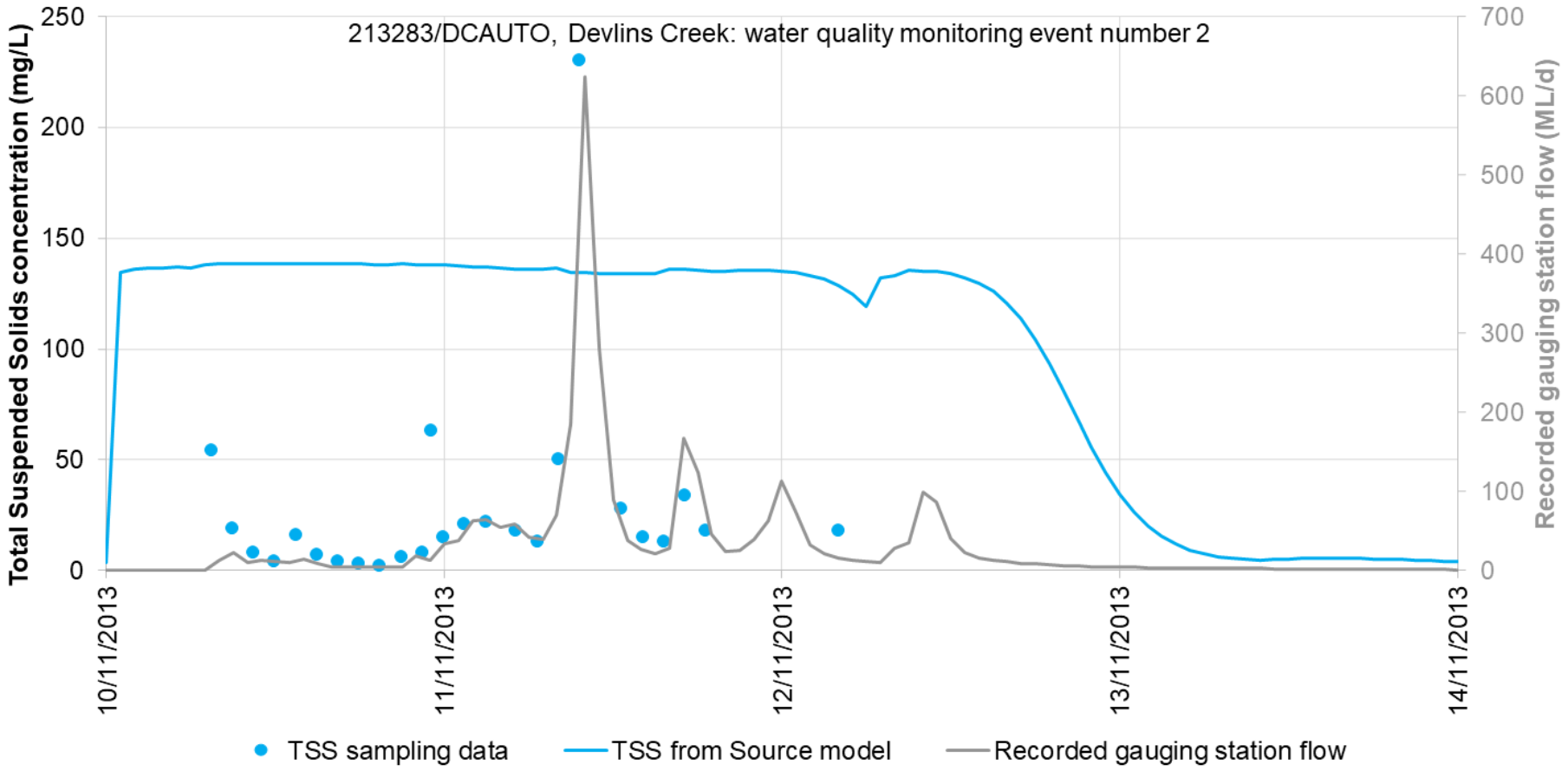

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 3
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
2500
2000
1500
1000
500
0
18/11/2013
19/11/2013
20/11/2013
21/11/2013
22/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

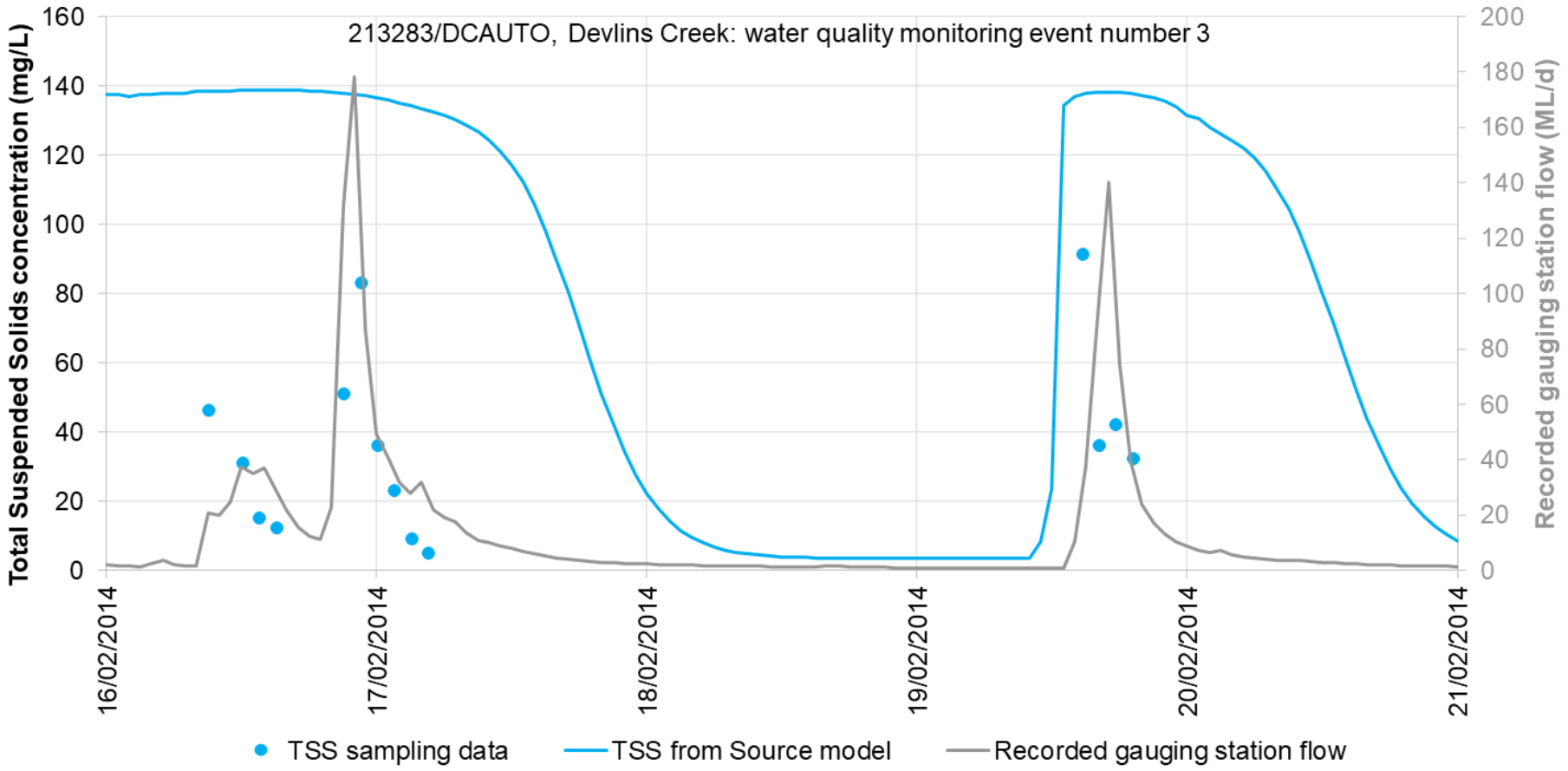

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 4
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
600
500
400
300
200
100
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TSS sampling data
TSS from Source model
Recorded gauging station flow

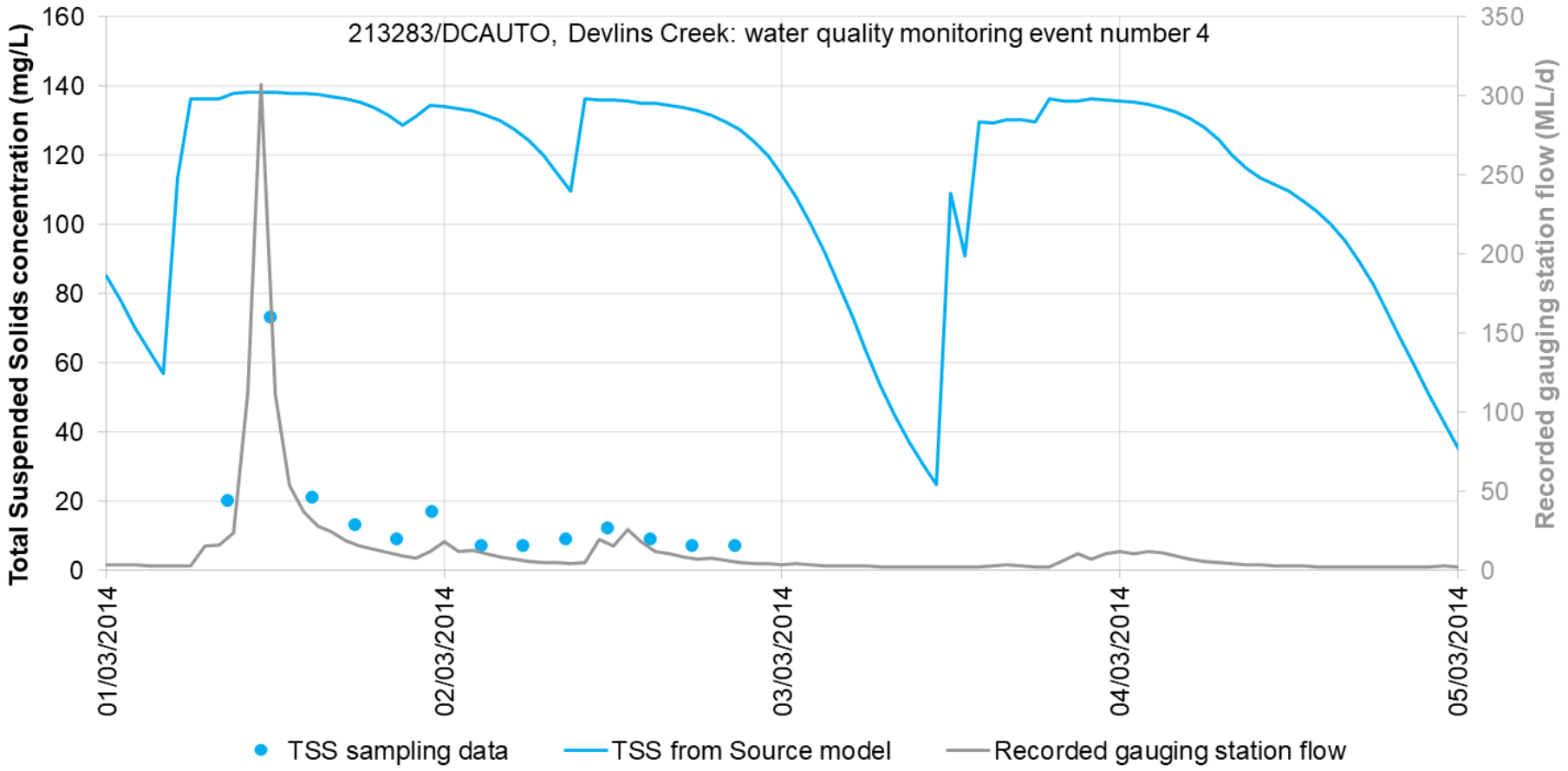

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 5
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TSS sampling data
TSS from Source model
Recorded gauging station flow

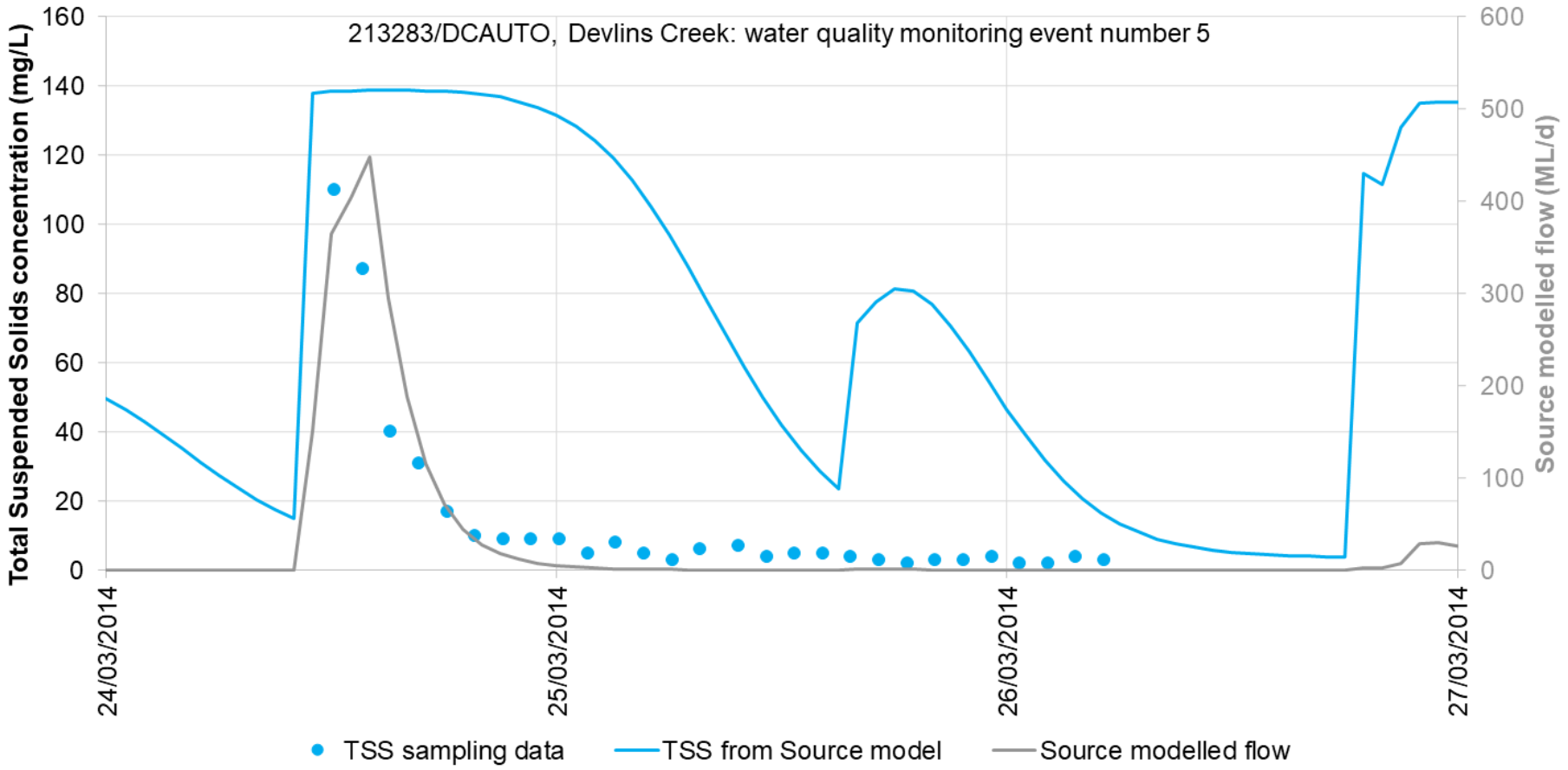

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 6
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
0
20
40
60
80
100
120
140
0
1000
2000
3000
4000
5000
6000
7000
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TSS sampling data
TSS from Source model
Recorded gauging station flow

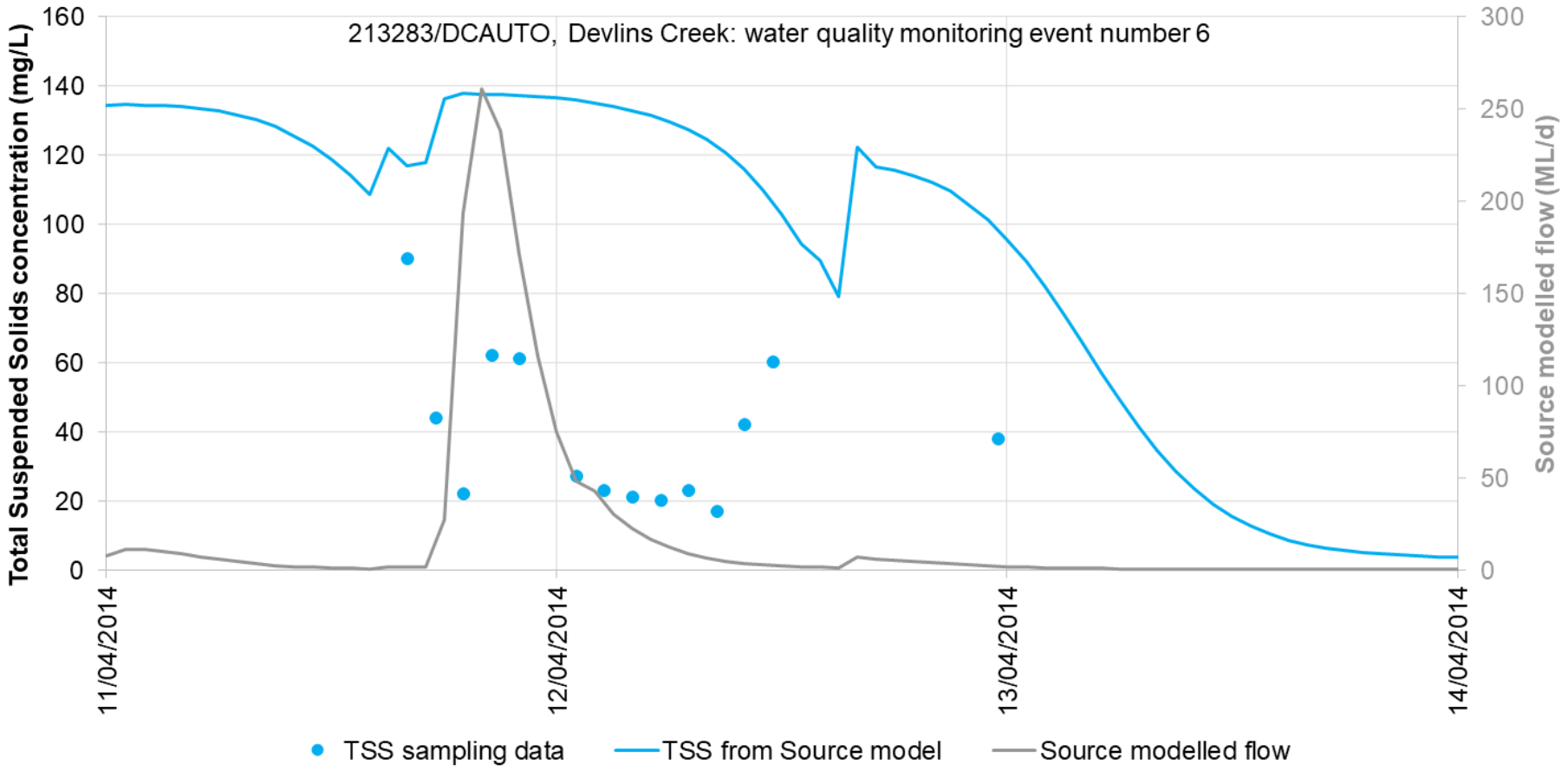

213283/DCAUTO, Devlins Creek: water quality monitoring event number 1
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
80
70
60
50
40
30
20
10
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

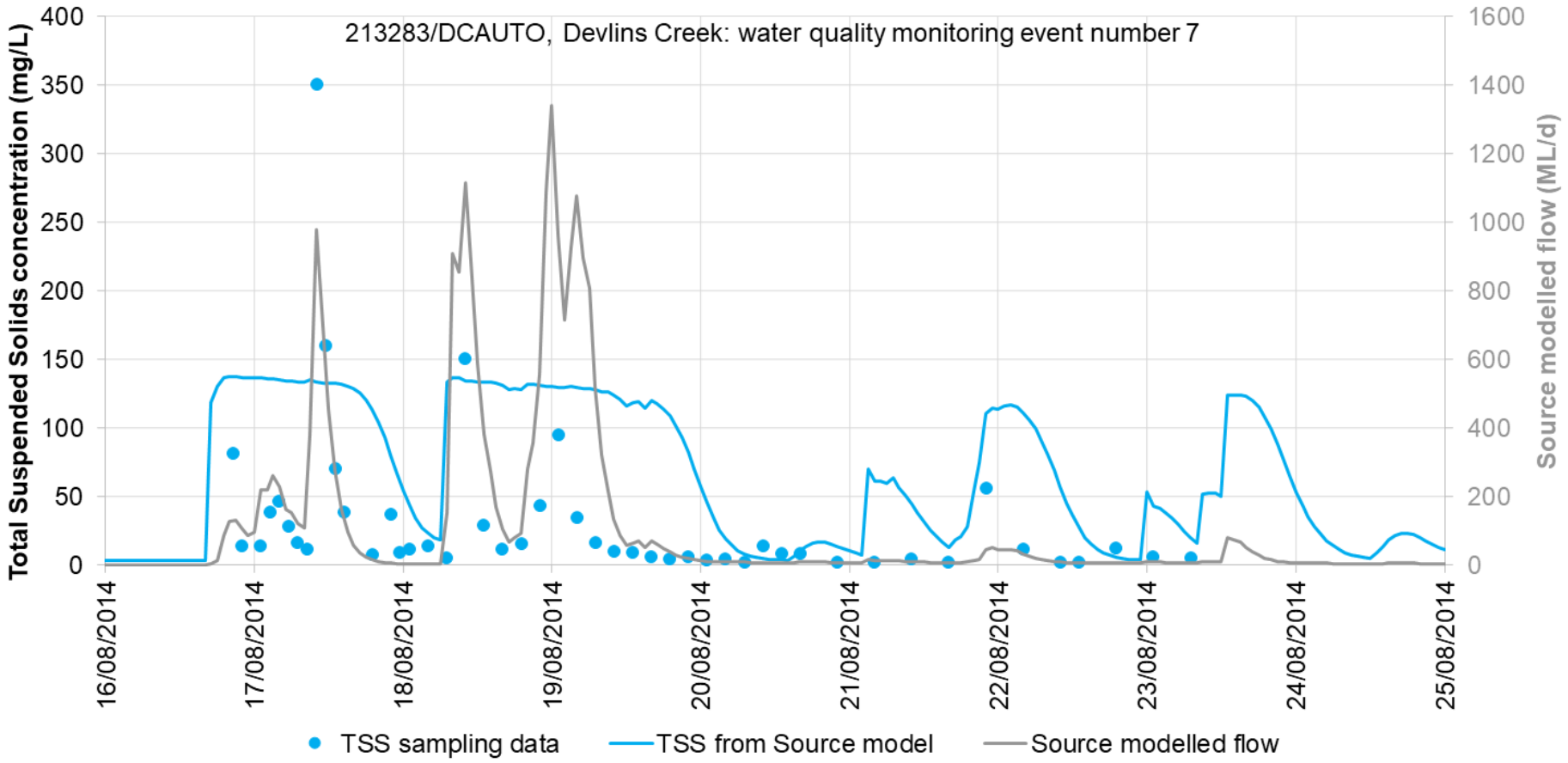

213283/DCAUTO, Devlins Creek: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
250
200
150
100
50
0
700
600
500
400
300
200
100
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

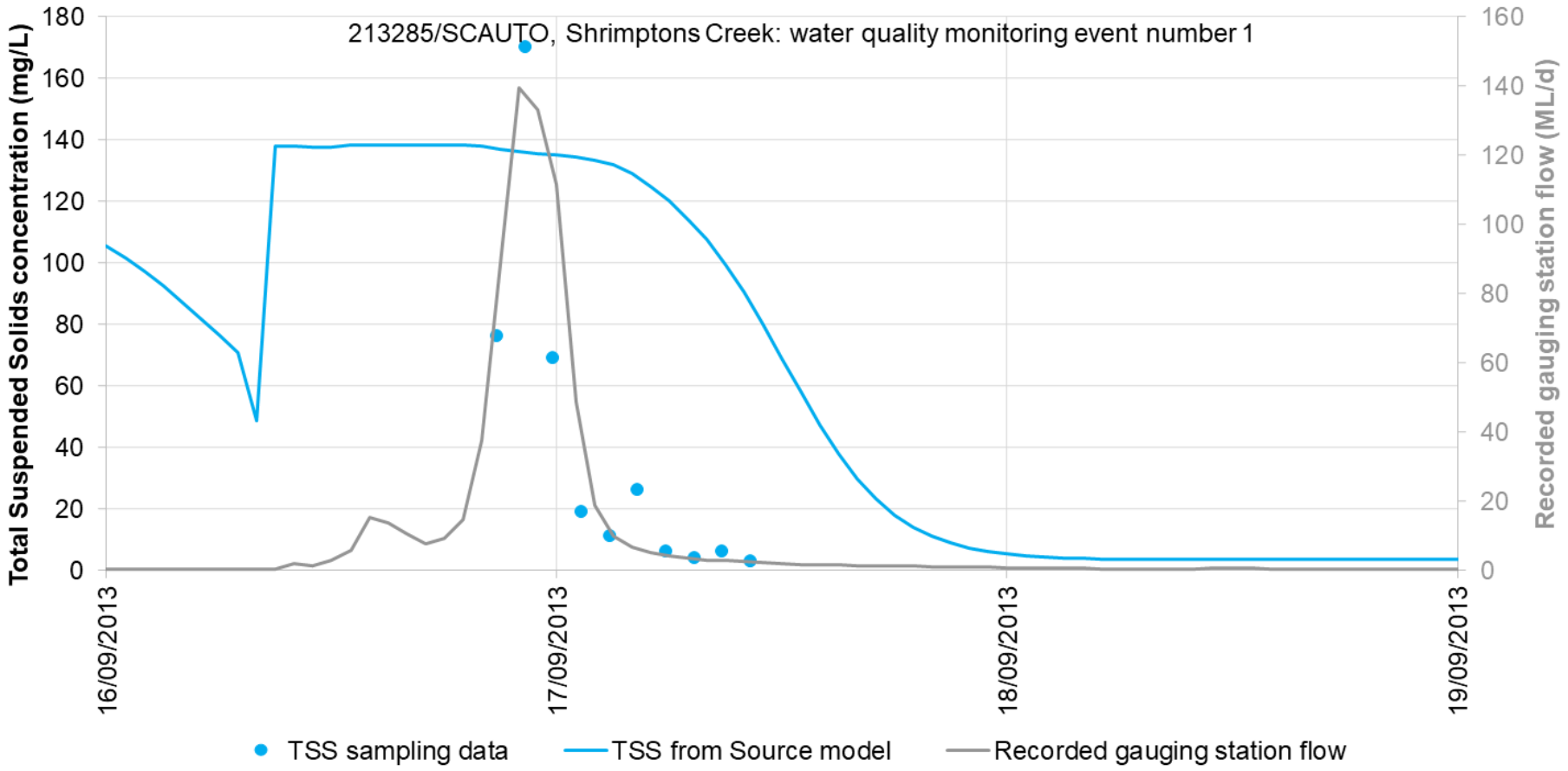

213283/DCAUTO, Devlins Creek: water quality monitoring event number 3
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
0
20
40
60
80
100
120
140
160
180
200
16/02/2014
17/02/2014
18/02/2014
19/02/2014
20/02/2014
21/02/2014
TSS sampling data
TSS from Source model
Recorded gauging station flow

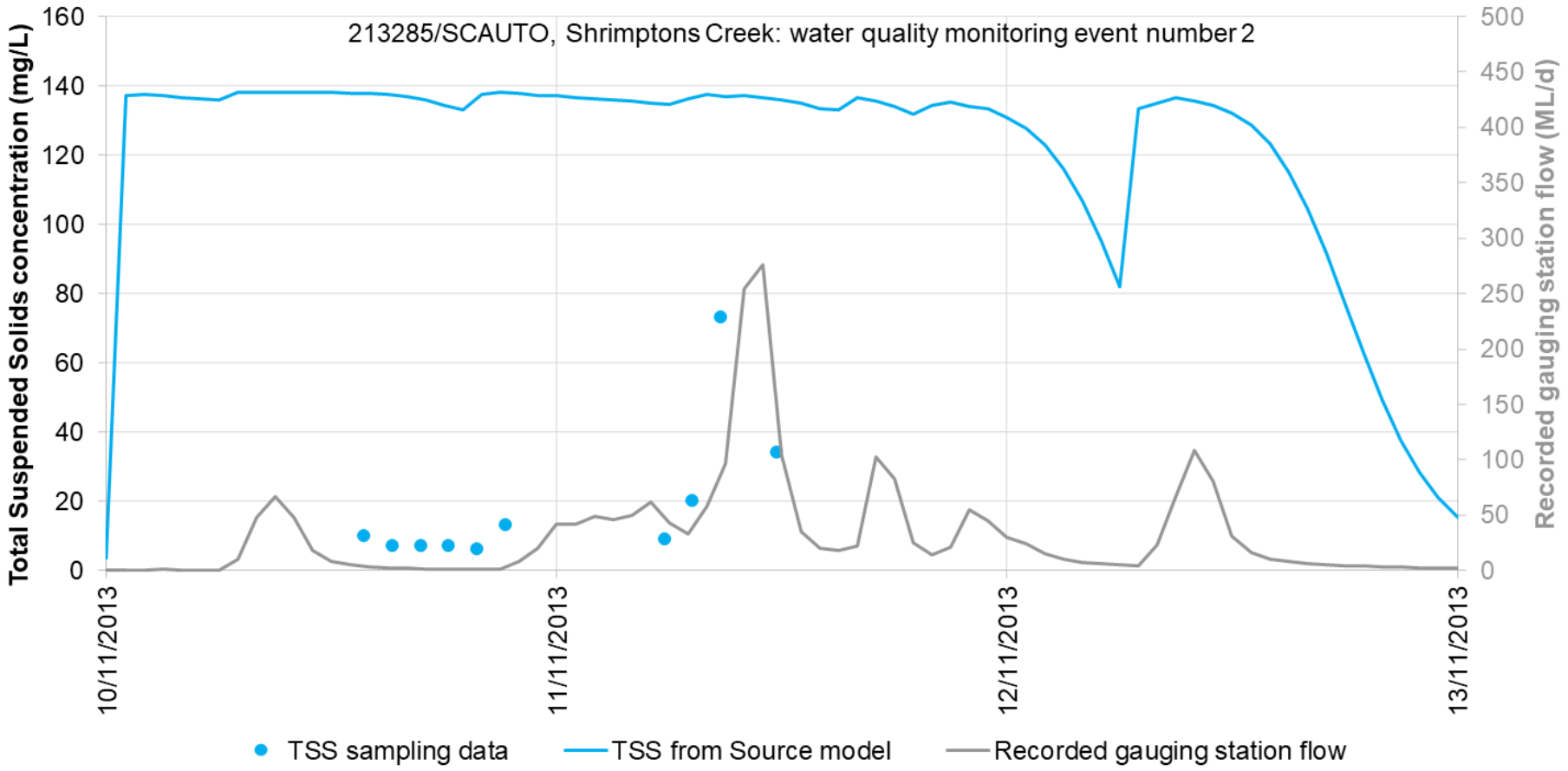

213283/DCAUTO, Devlins Creek: water quality monitoring event number 4
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250
300
350
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
TSS sampling data
TSS from Source model
Recorded gauging station flow

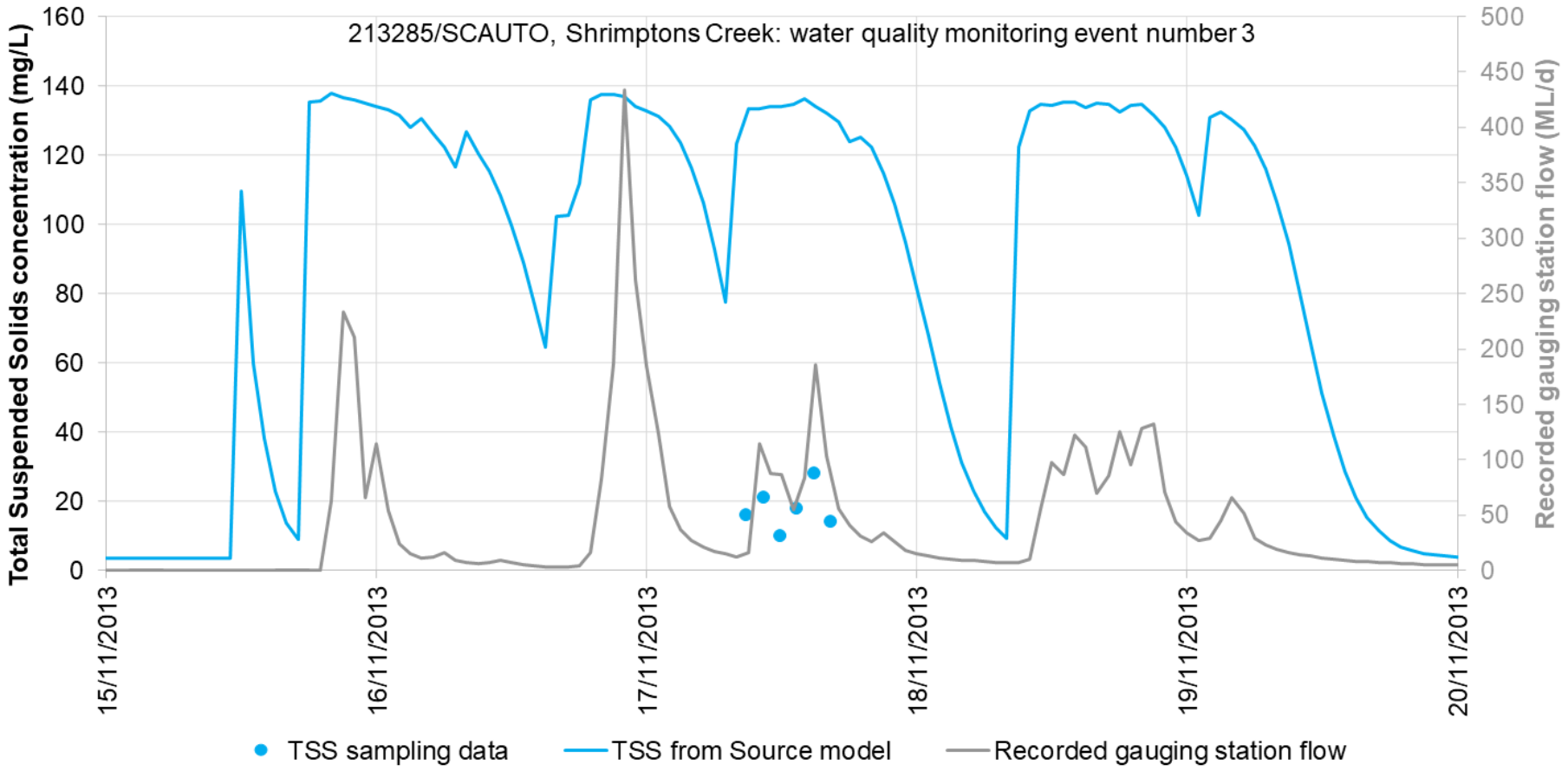

213283/DCAUTO, Devlins Creek: water quality monitoring event number 5
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
160
140
120
100
80
60
40
20
0
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TSS sampling data
TSS from Source model
Source modelled flow

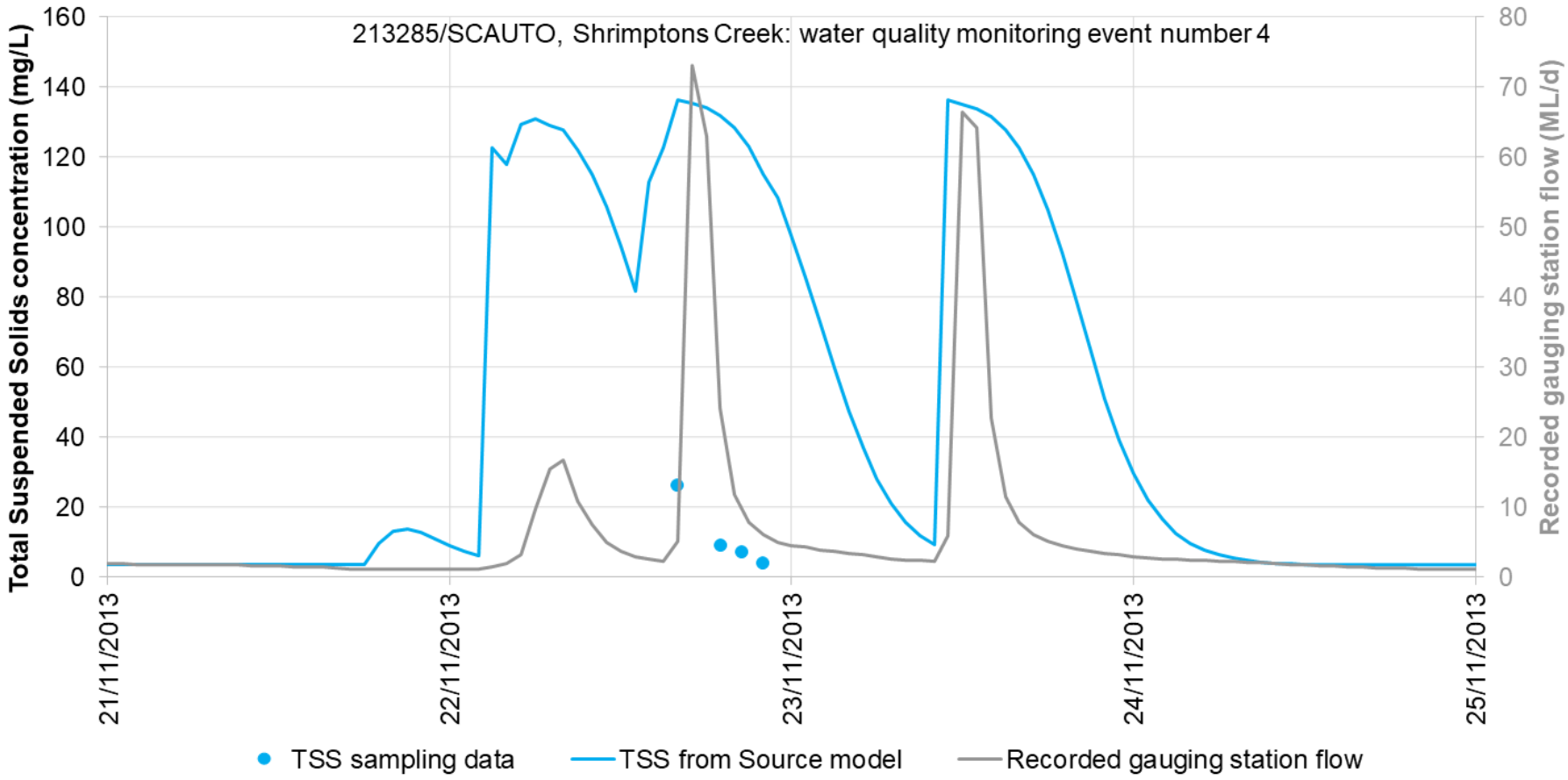

213283/DCAUTO, Devlins Creek: water quality monitoring event number 6
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
160
140
120
100
80
60
40
20
0
300
250
200
150
100
50
0
11/04/2014
12/04/2014
13/04/2014
14/04/2014
TSS sampling data
TSS from Source model
Source modelled flow

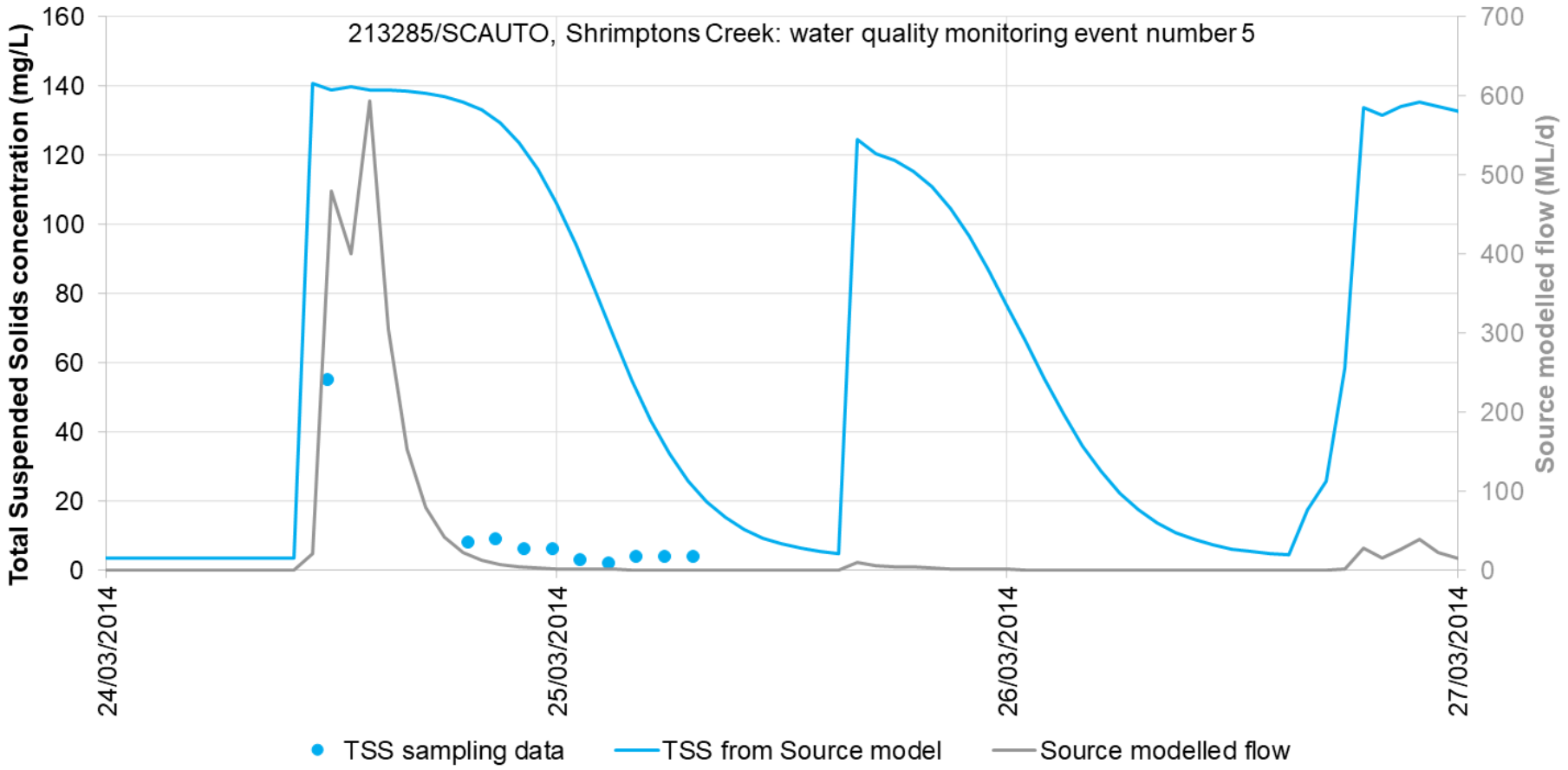

213283/DCAUTO, Devlins Creek: water quality monitoring event number 7
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
400
350
300
250
200
150
100
50
0
1600
1400
1200
1000
800
600
400
200
0
16/08/2014
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
TSS sampling data
TSS from Source model
Source modelled flow

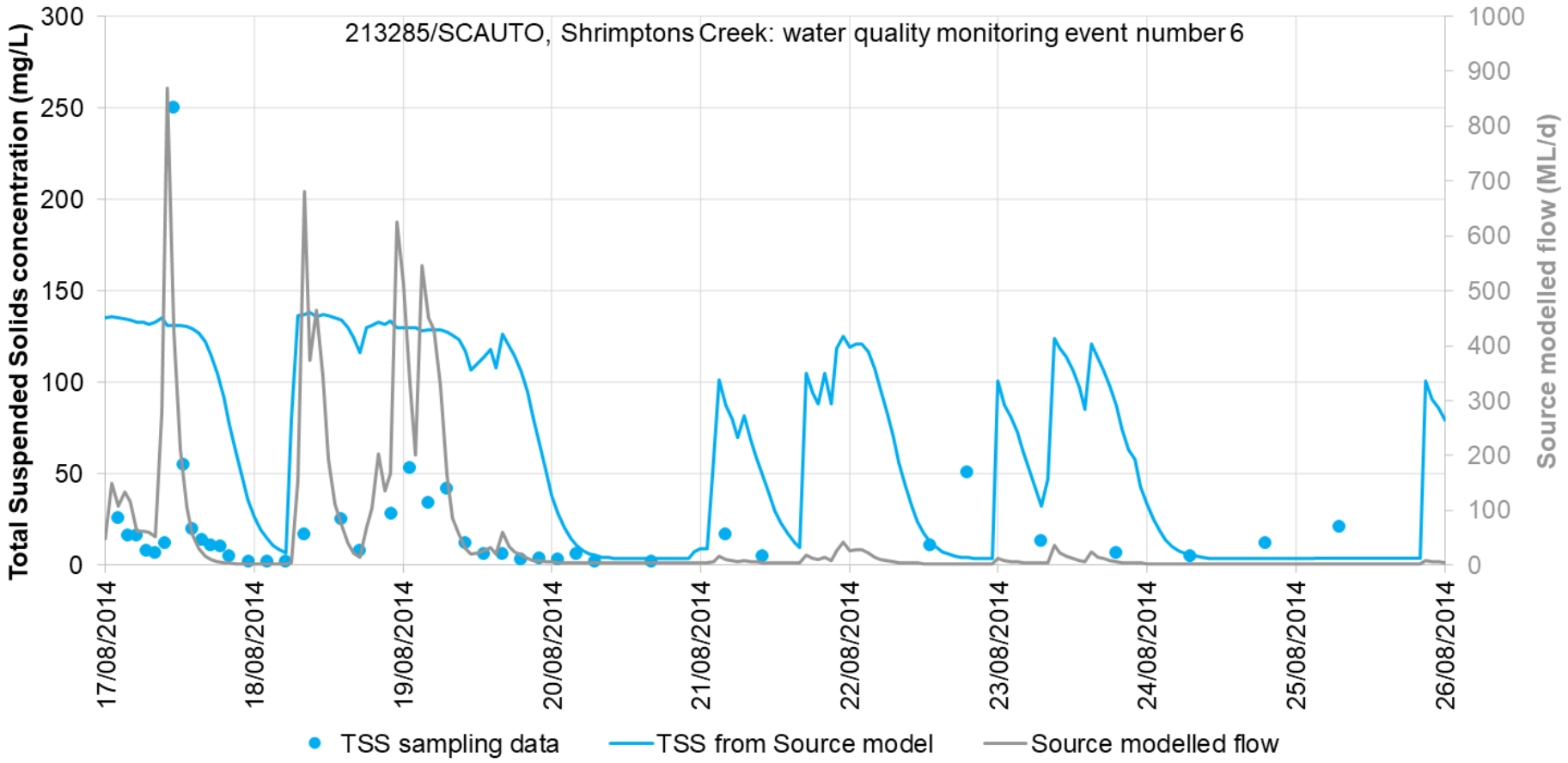

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 1
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
180
160
140
120
100
80
60
40
20
0
160
140
120
100
80
60
40
20
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

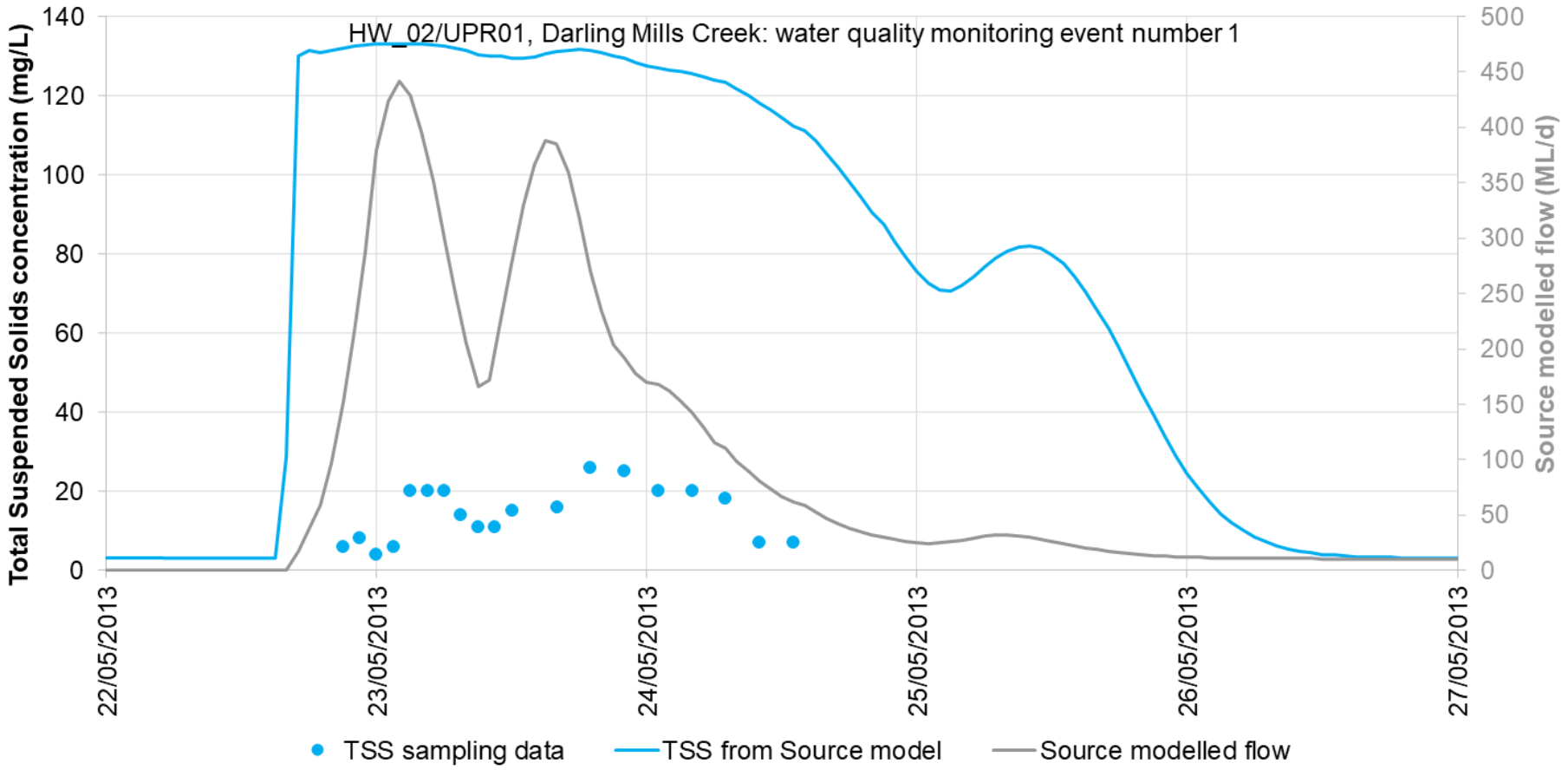

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
500
450
400
350
300
250
200
150
100
50
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

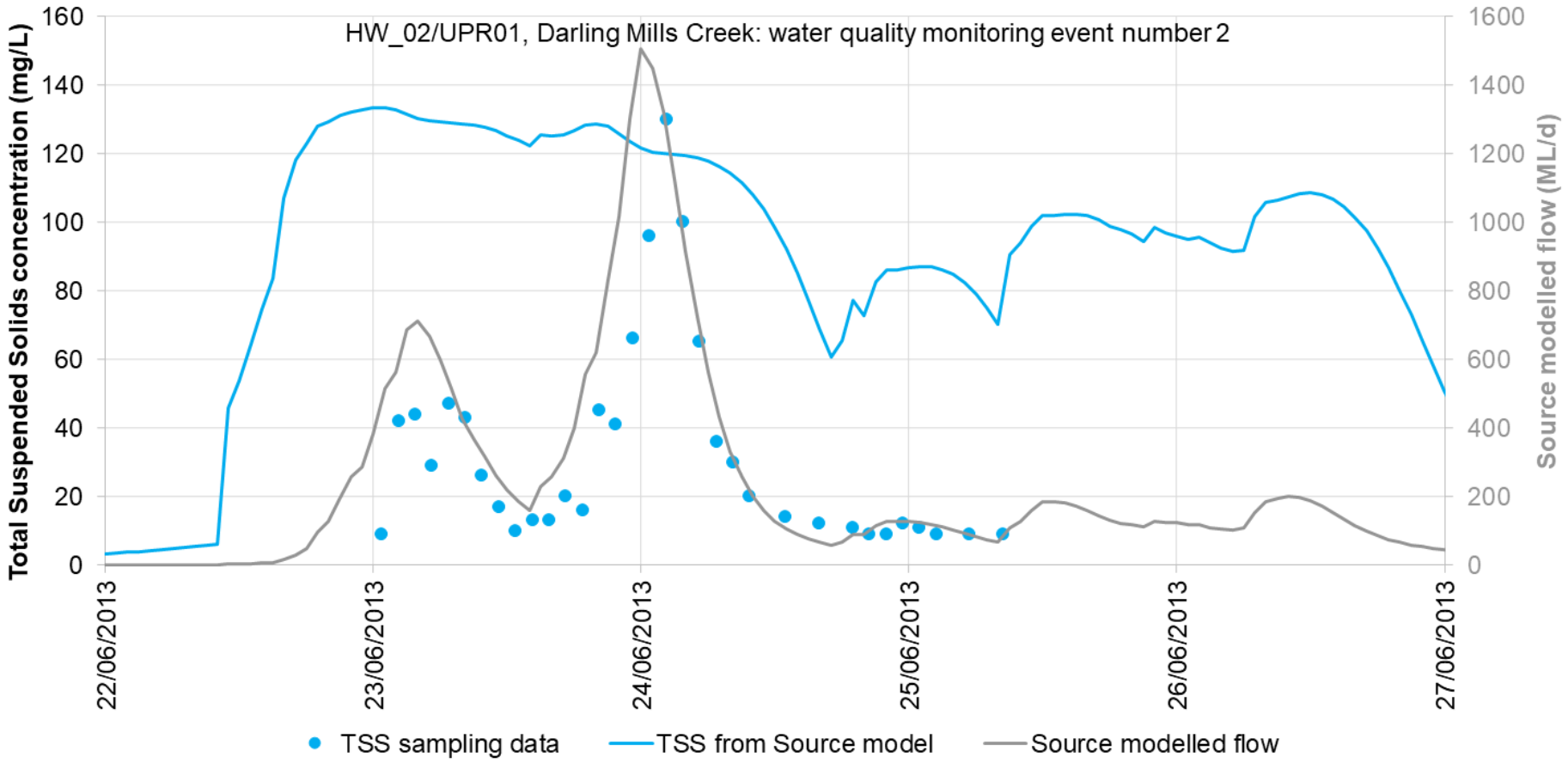

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 3
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
500
450
400
350
300
250
200
150
100
50
0
15/11/2013
16/11/2013
17/11/2013
18/11/2013
19/11/2013
20/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

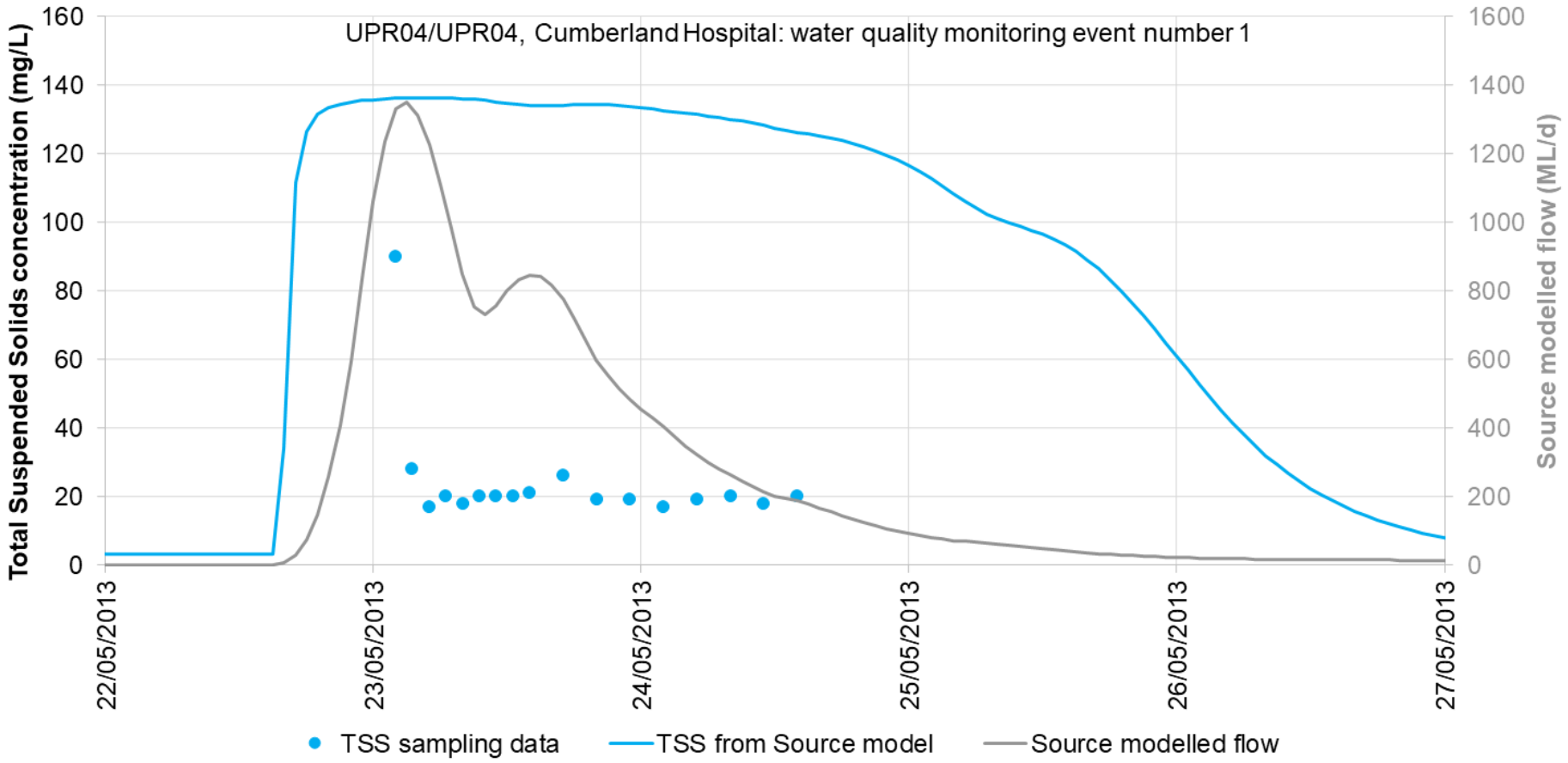

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 4
Total Suspended Solids concentration (mg/L)
Recorded gauging station flow (ML/d)
160
140
120
100
80
60
40
20
0
80
70
60
50
40
30
20
10
0
21/11/2013
22/11/2013
23/11/2013
24/11/2013
25/11/2013
TSS sampling data
TSS from Source model
Recorded gauging station flow

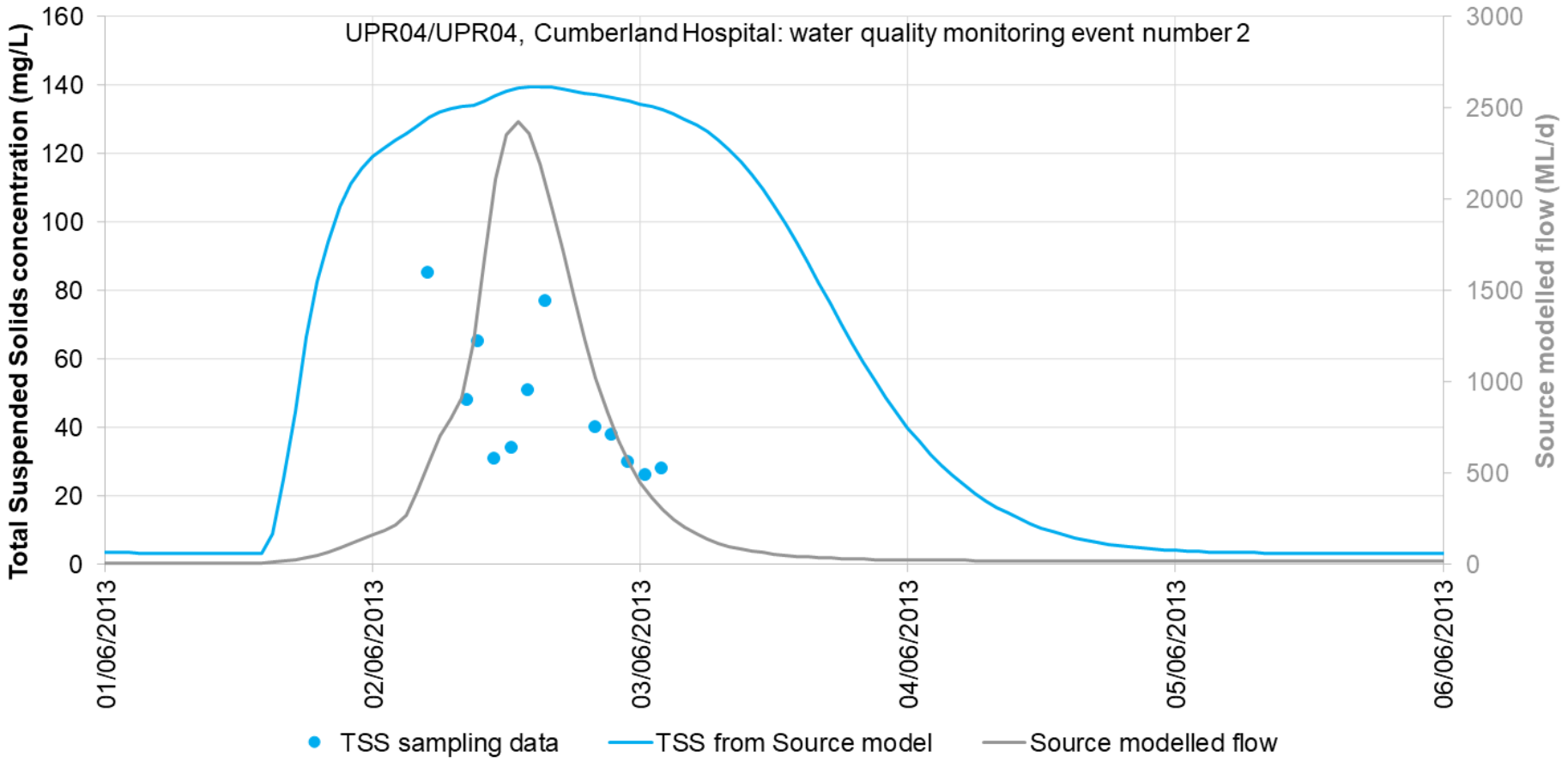

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 5
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
160
140
120
100
80
60
40
20
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
TSS sampling data
TSS from Source model
Source modelled flow

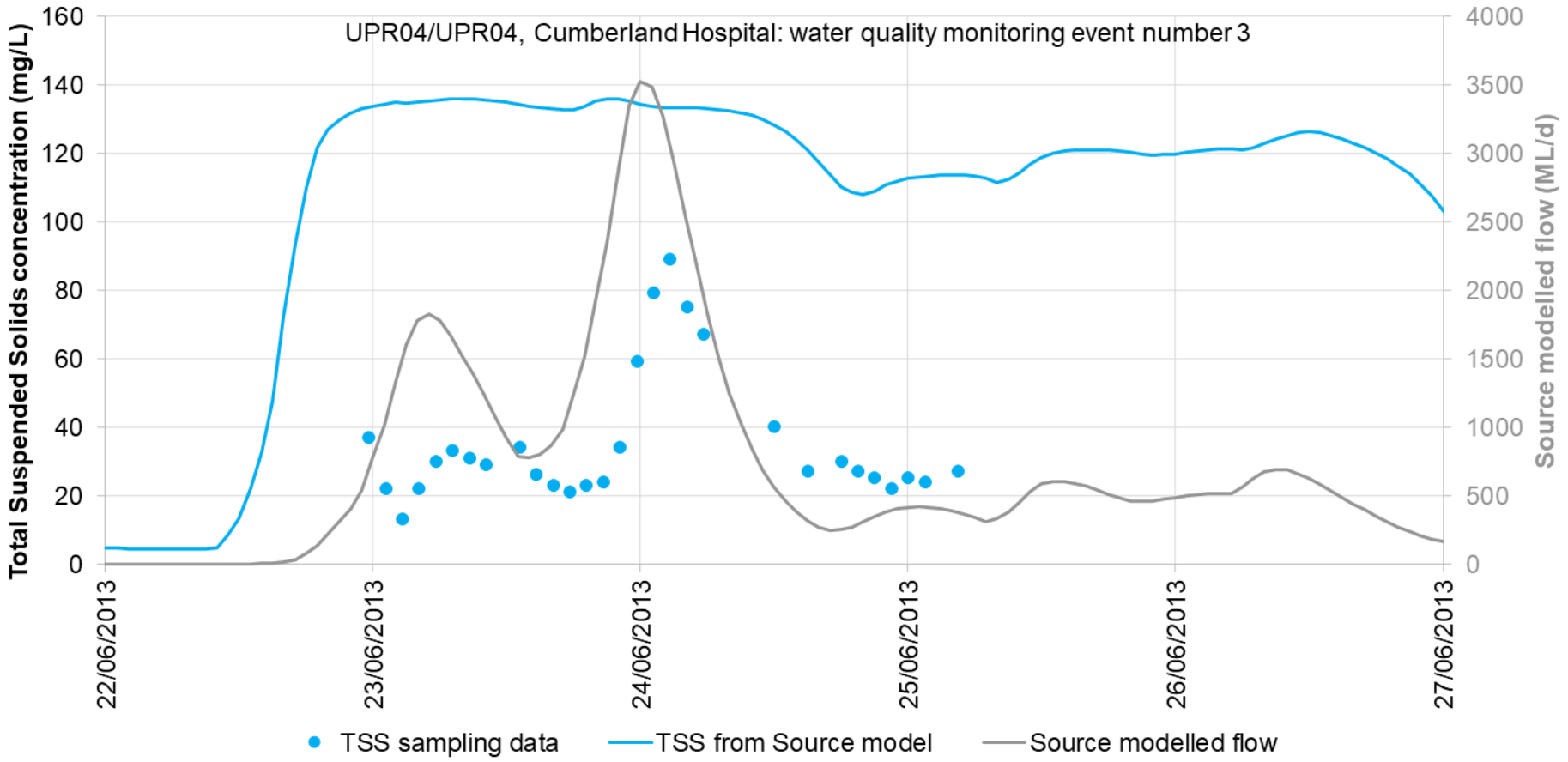

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 6
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
300
250
200
150
100
50
0
1000
900
800
700
600
500
400
300
200
100
0
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
TSS sampling data
TSS from Source model
Source modelled flow


HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 1
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
450
500
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TSS sampling data
TSS from Source model
Source modelled flow

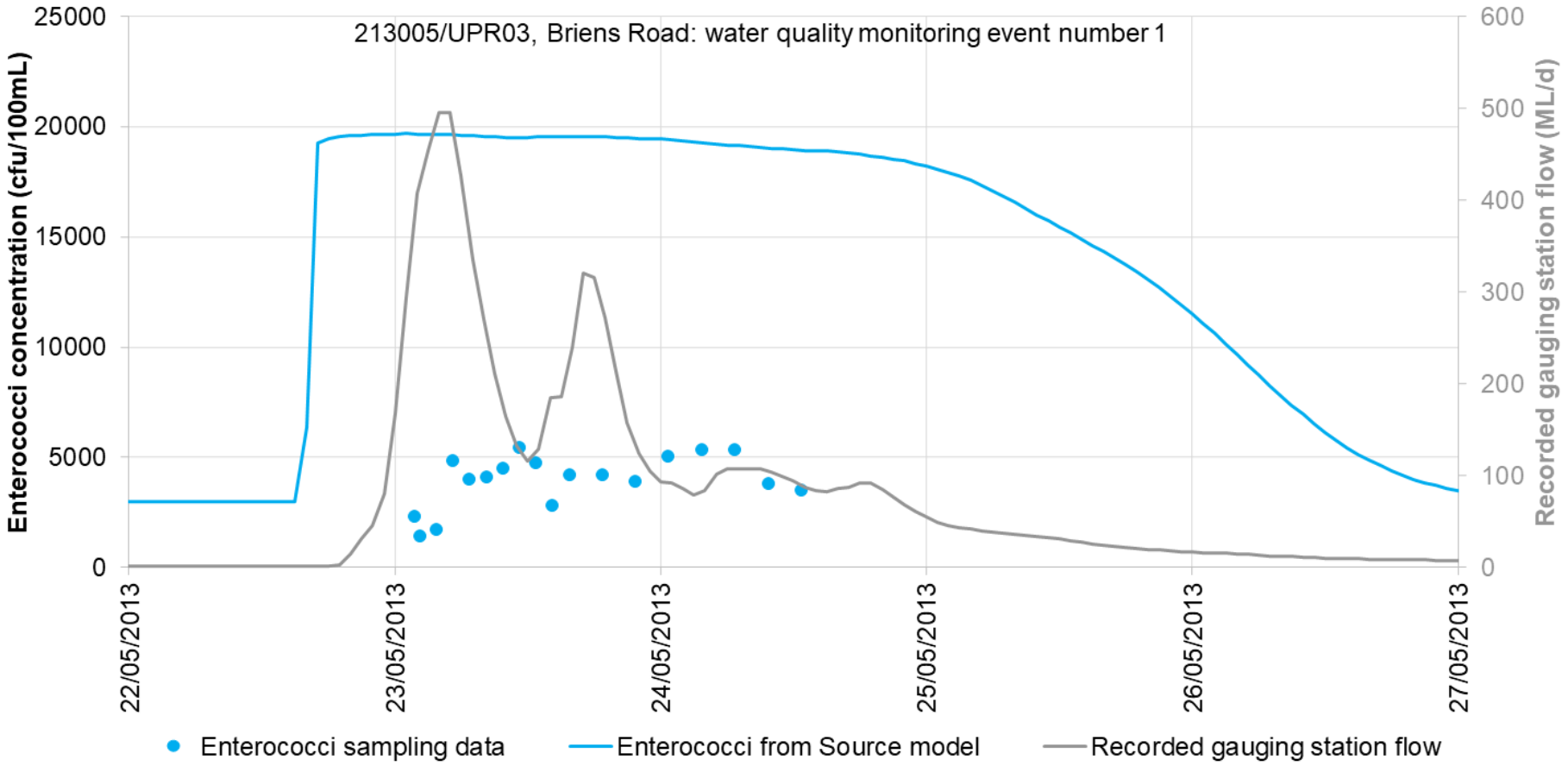

HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
0
20
40
60
80
100
120
140
160
0
200
400
600
800
1000
1200
1400
1600
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TSS sampling data
TSS from Source model
Source modelled flow

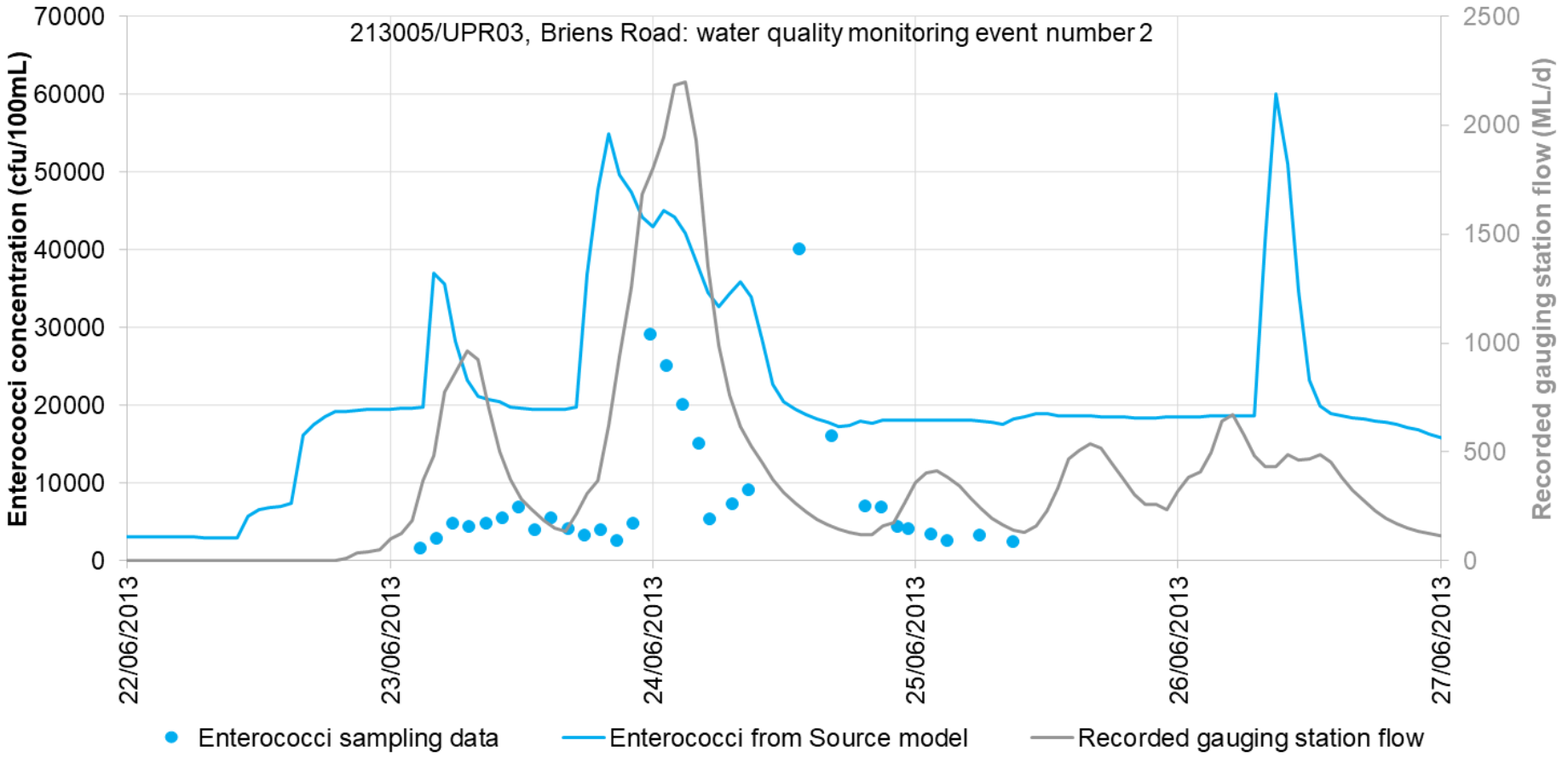

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 1
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
0
20
40
60
80
100
120
140
160
0
200
400
600
800
1000
1200
1400
1600
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
TSS sampling data
TSS from Source model
Source modelled flow

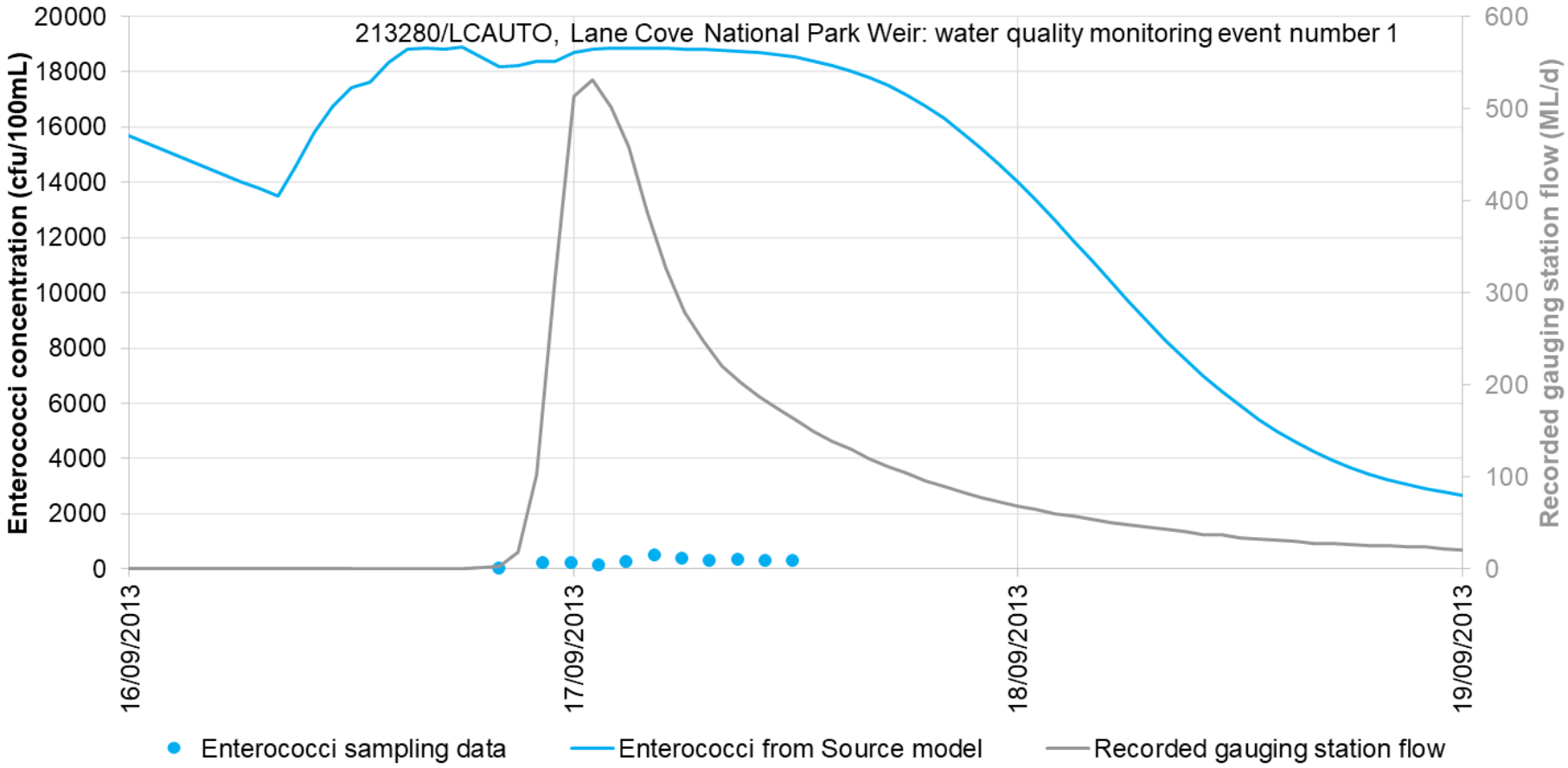

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 2
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
160
140
120
100
80
60
40
20
0
3000
2500
2000
1500
1000
500
0
01/06/2013
02/06/2013
03/06/2013
04/06/2013
05/06/2013
06/06/2013
TSS sampling data
TSS from Source model
Source modelled flow

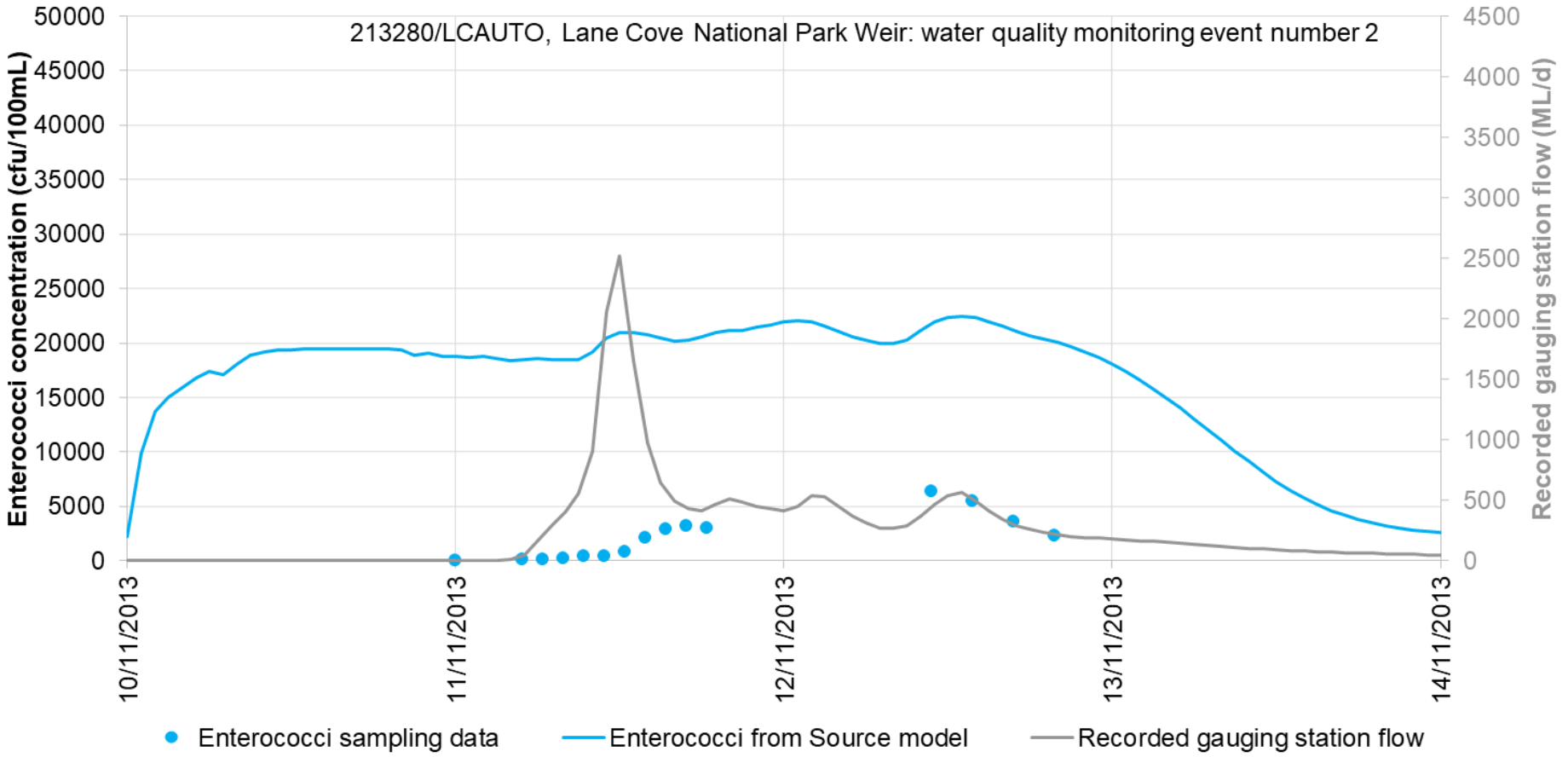

UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 3
Total Suspended Solids concentration (mg/L)
Source modelled flow (ML/d)
0
20
40
60
80
100
120
140
160
0
500
1000
1500
2000
2500
3000
3500
4000
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
TSS sampling data
TSS from Source model
Source modelled flow

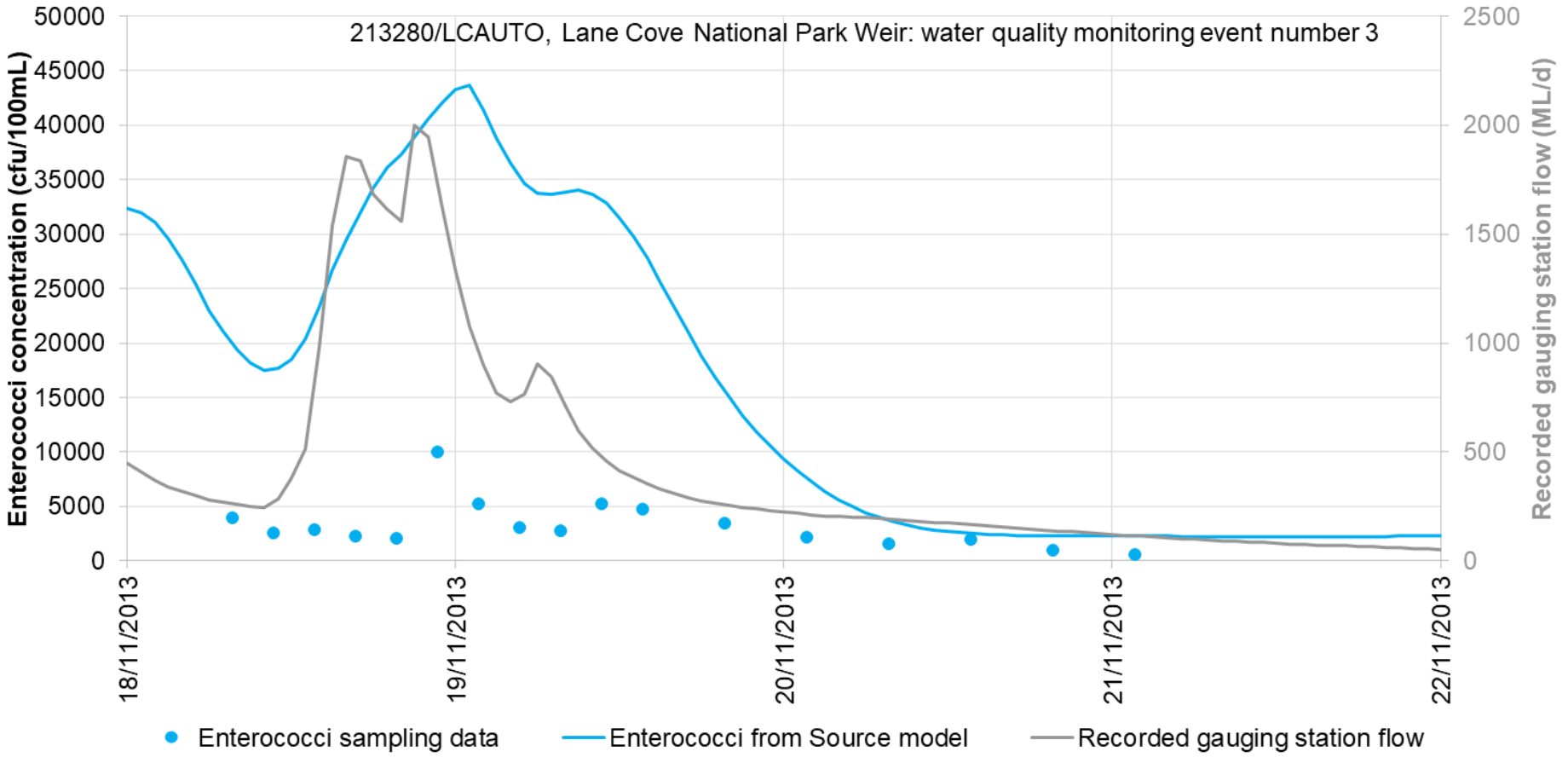
C.4 Enterococci comparison plots for monitored events

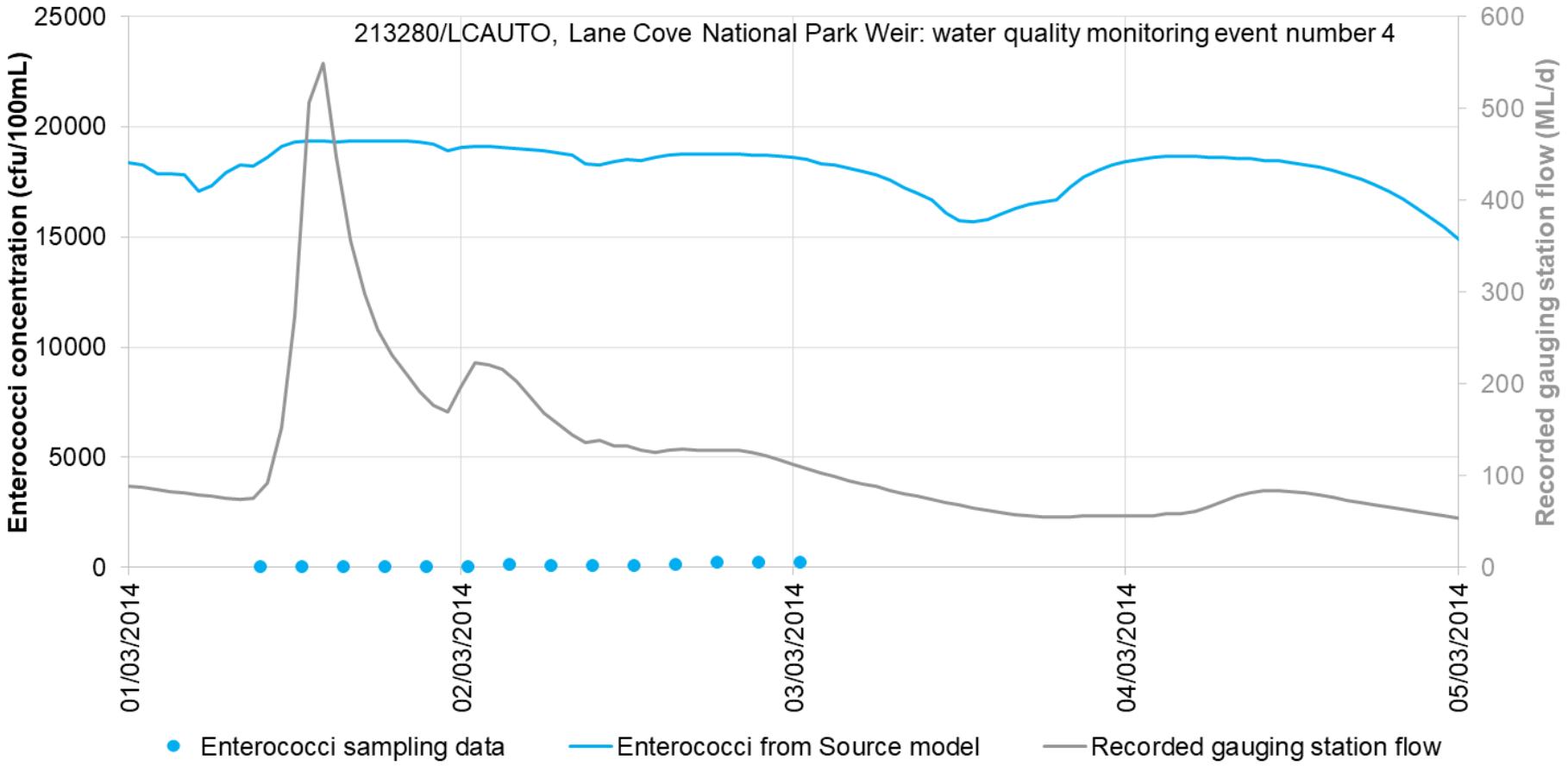

213005/UPR03, Briens Road: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
600
500
400
300
200
100
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

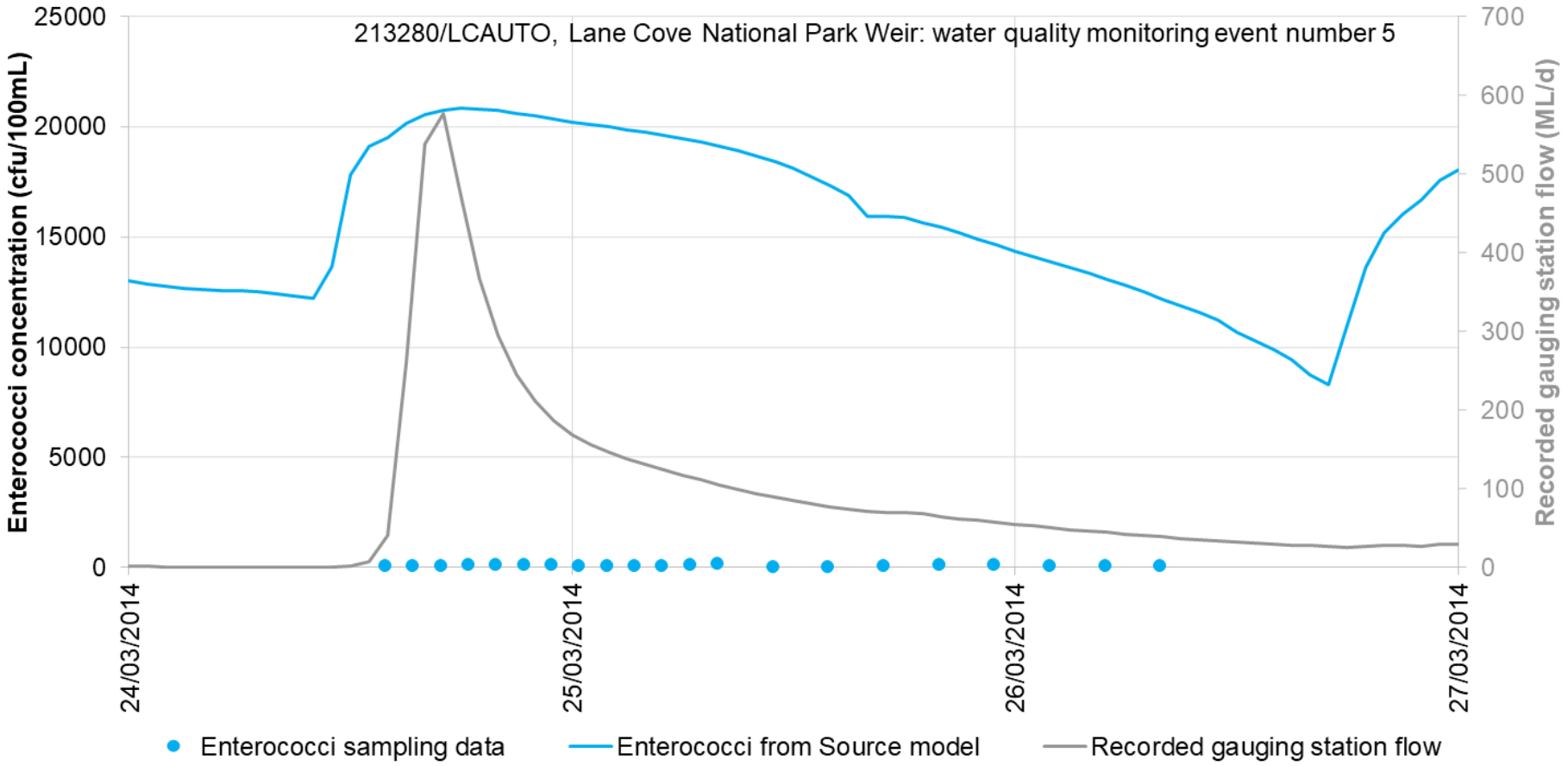

213005/UPR03, Briens Road: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
70000
60000
50000
40000
30000
20000
10000
0
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

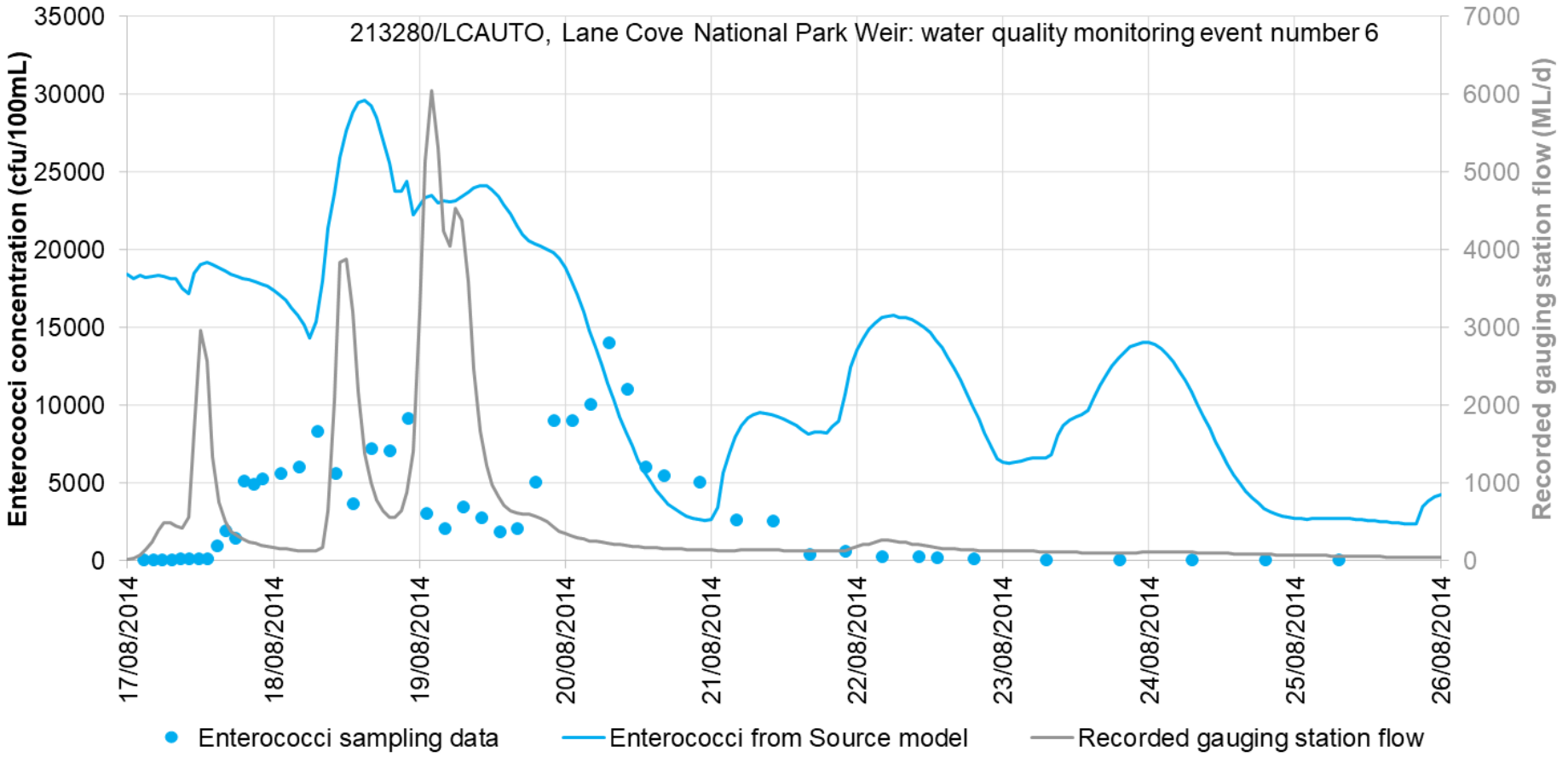

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
600
500
400
300
200
100
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

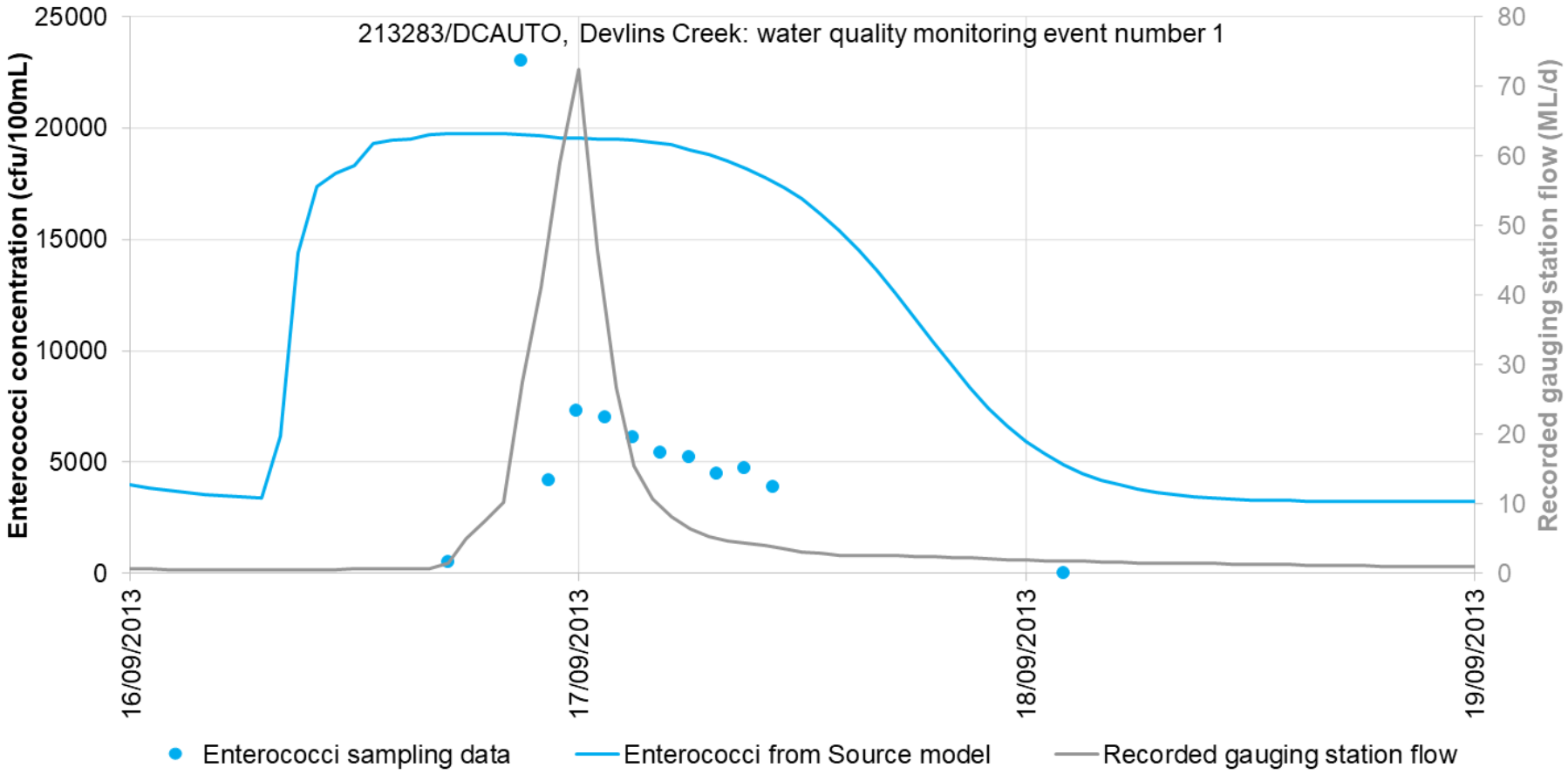

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

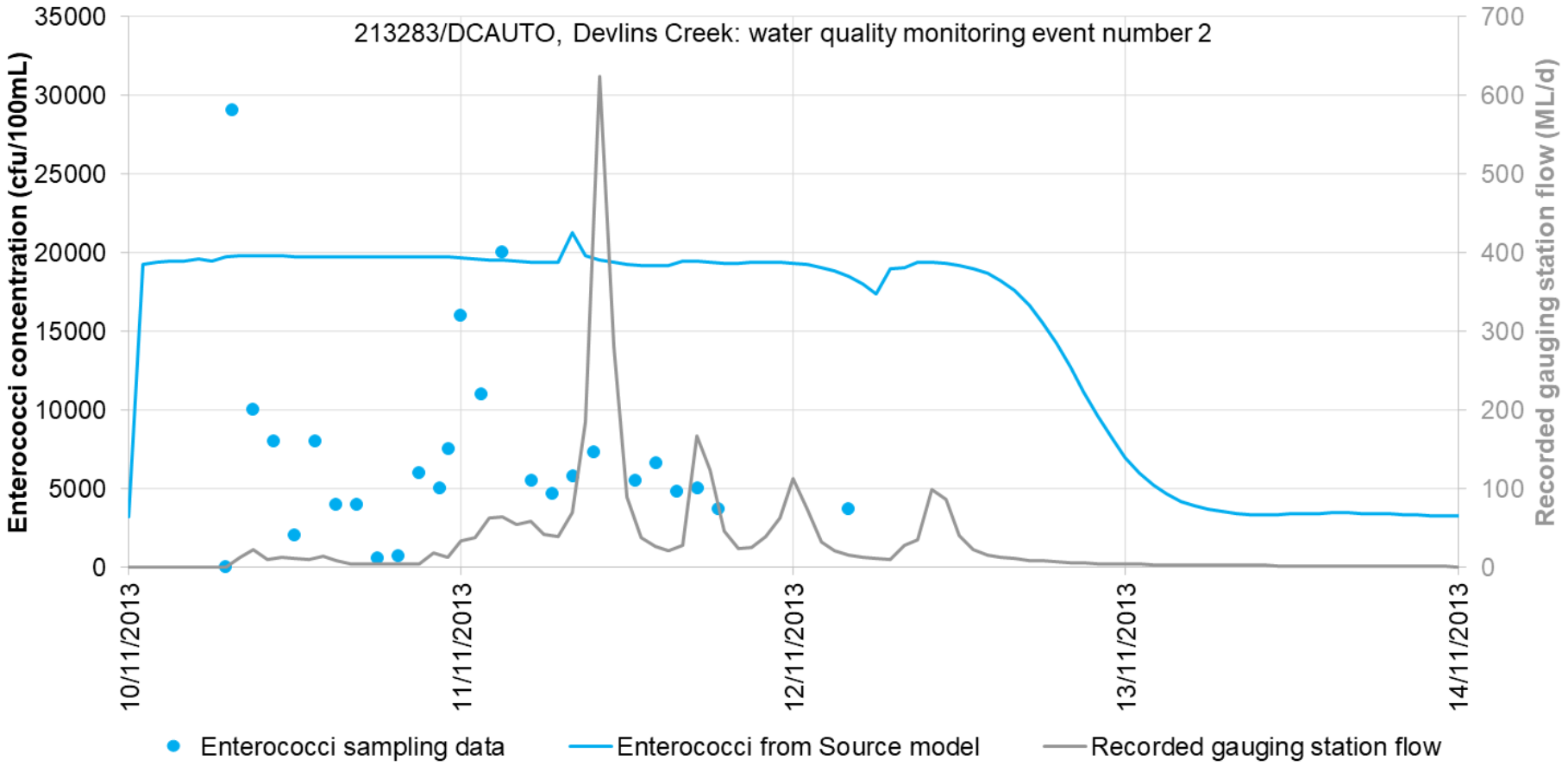

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 3
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2500
2000
1500
1000
500
0
18/11/2013
19/11/2013
20/11/2013
21/11/2013
22/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

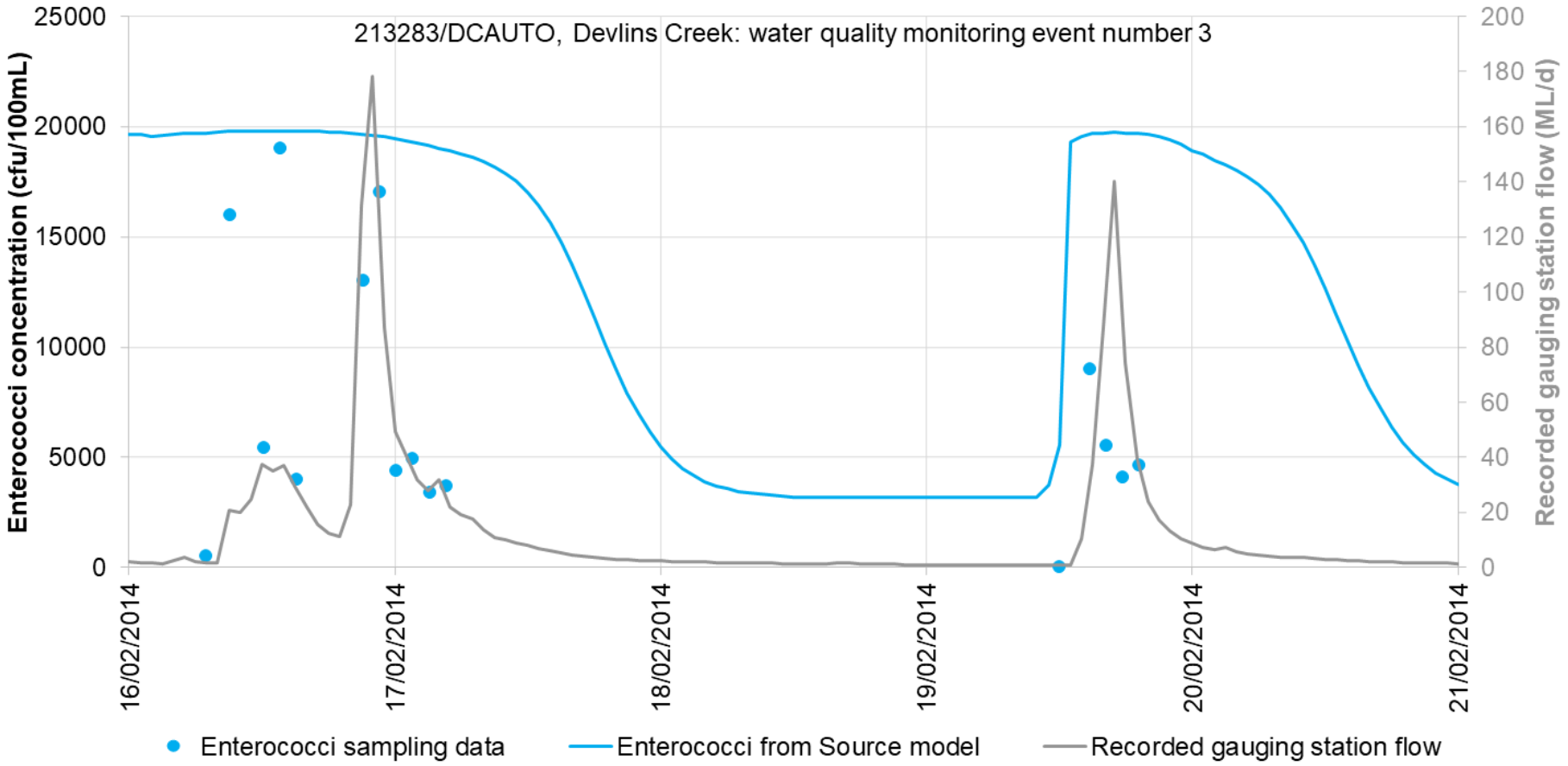

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 4
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
600
500
400
300
200
100
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

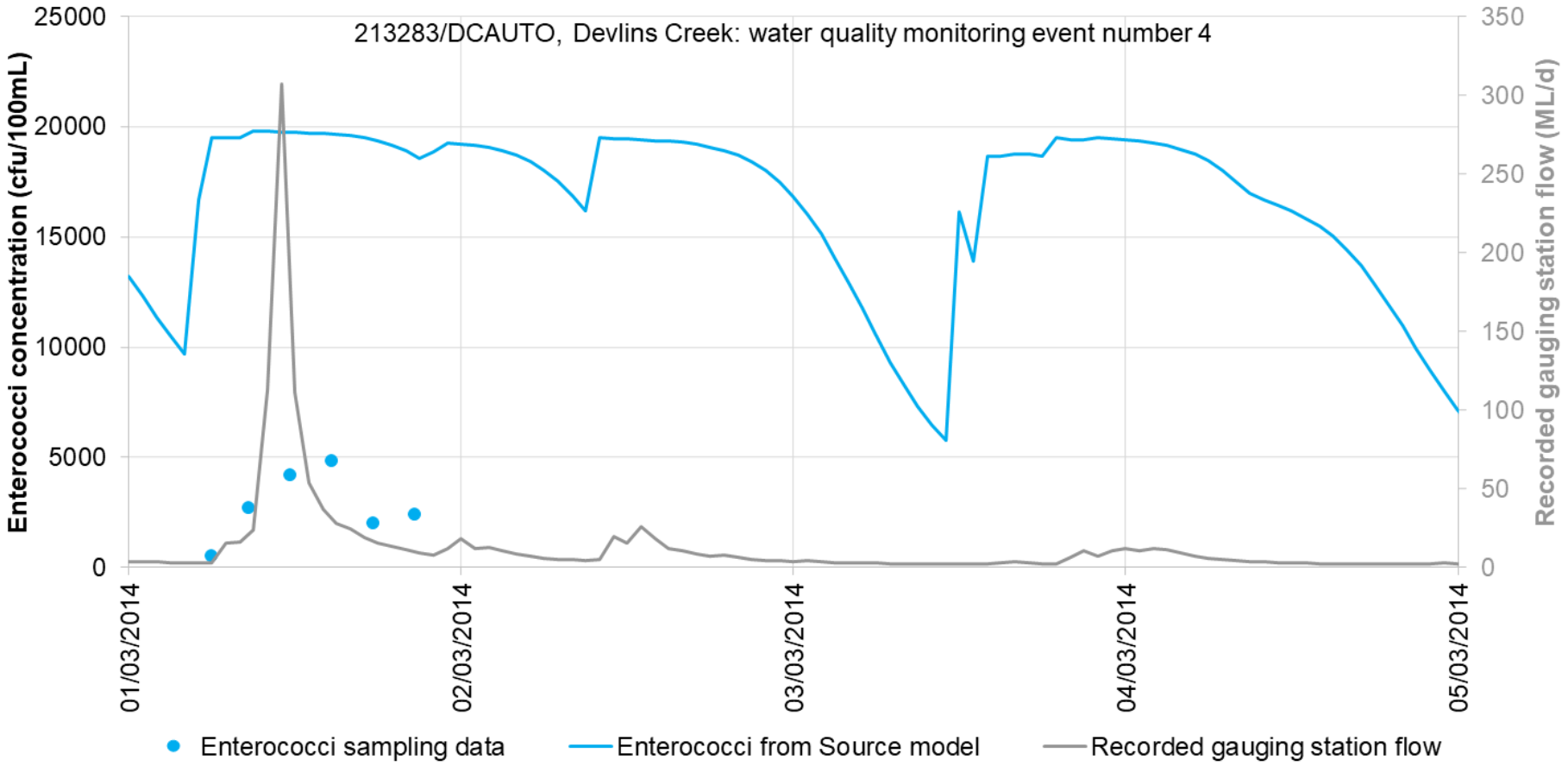

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 5
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

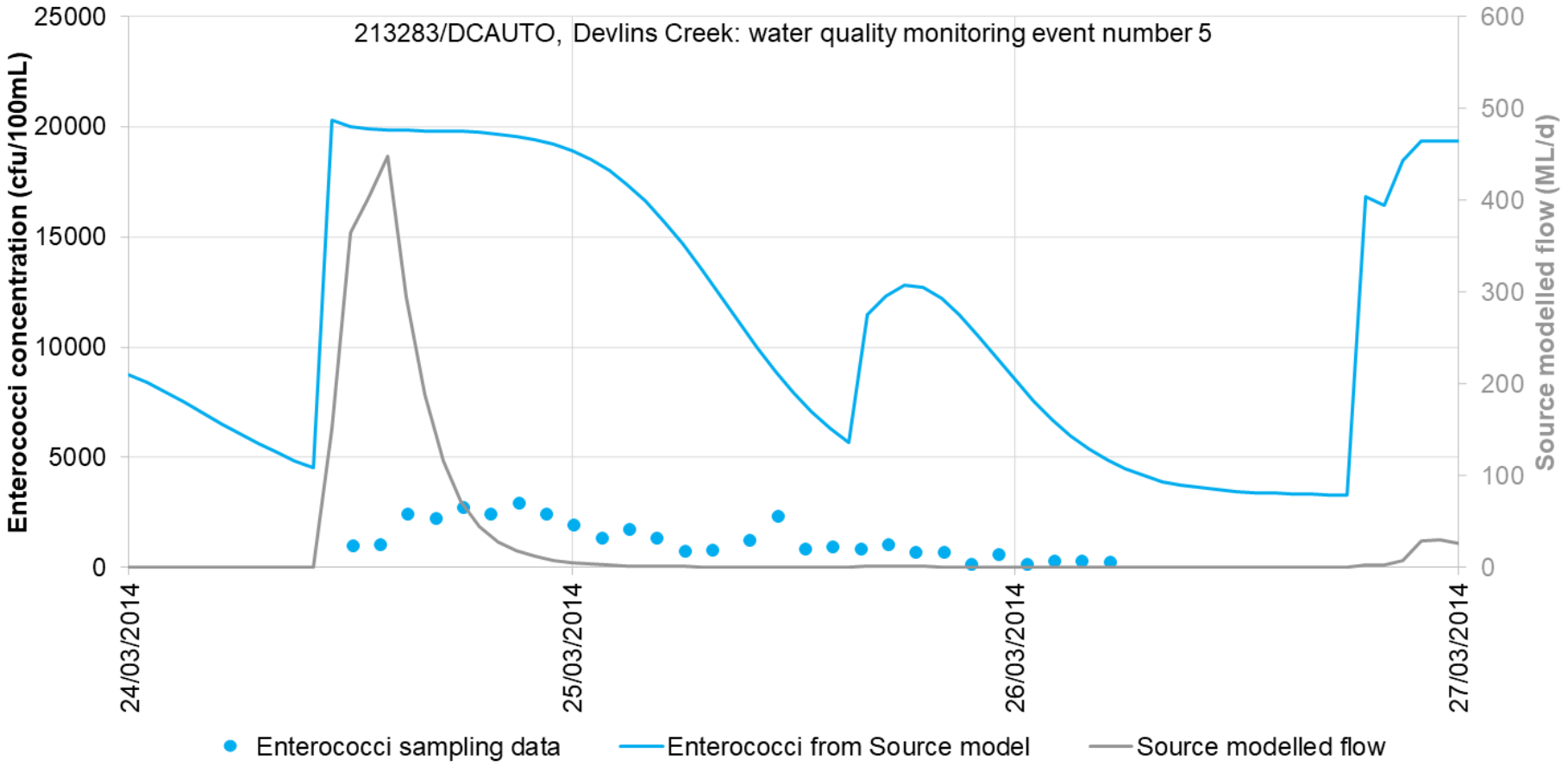

213280/LCAUTO, Lane Cove National Park Weir: water quality monitoring event number 6
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
35000
30000
25000
20000
15000
10000
5000
0
7000
6000
5000
4000
3000
2000
1000
0
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

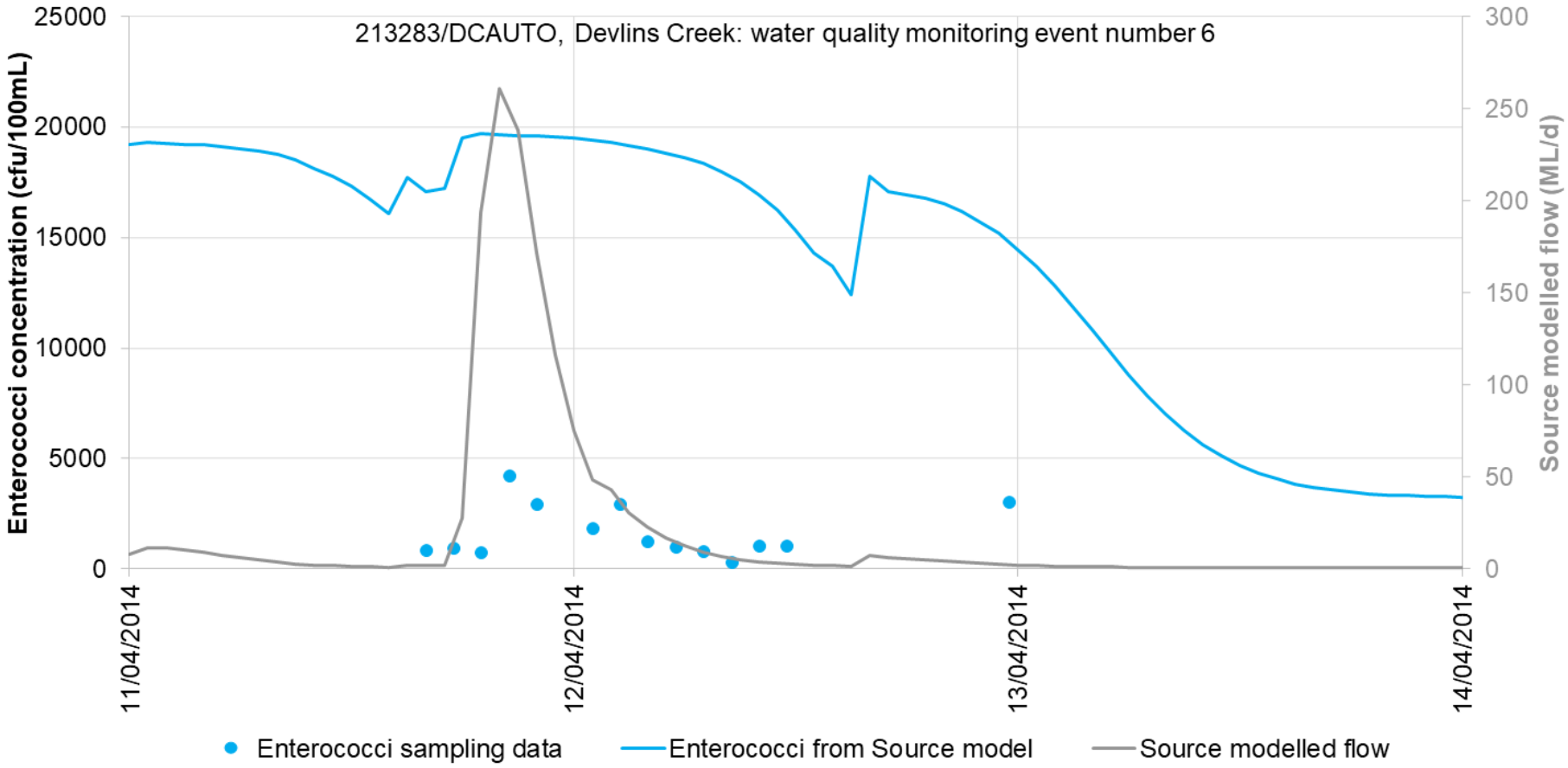

213283/DCAUTO, Devlins Creek: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
80
70
60
50
40
30
20
10
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

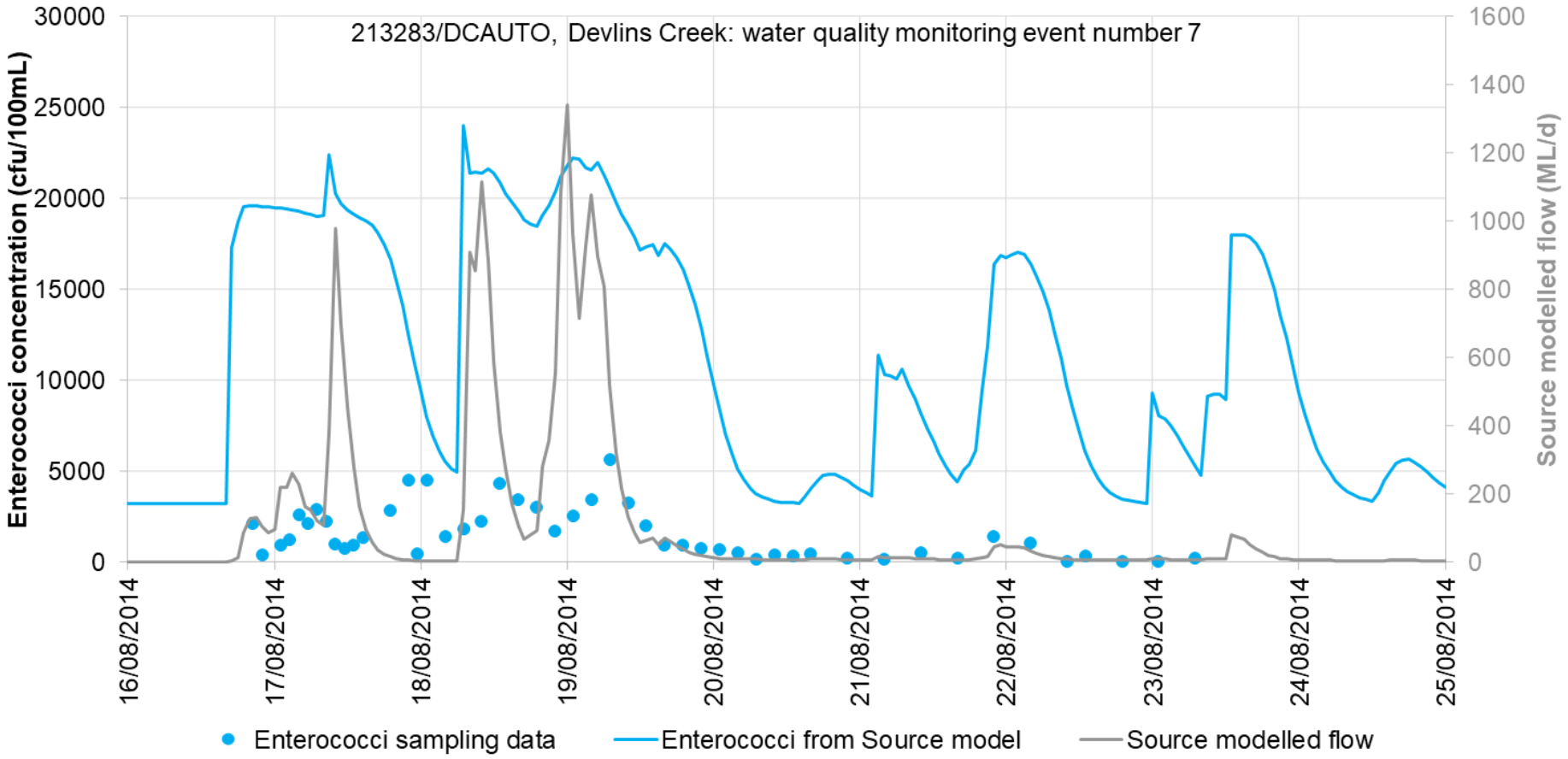

213283/DCAUTO, Devlins Creek: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
35000
30000
25000
20000
15000
10000
5000
0
700
600
500
400
300
200
100
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
14/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

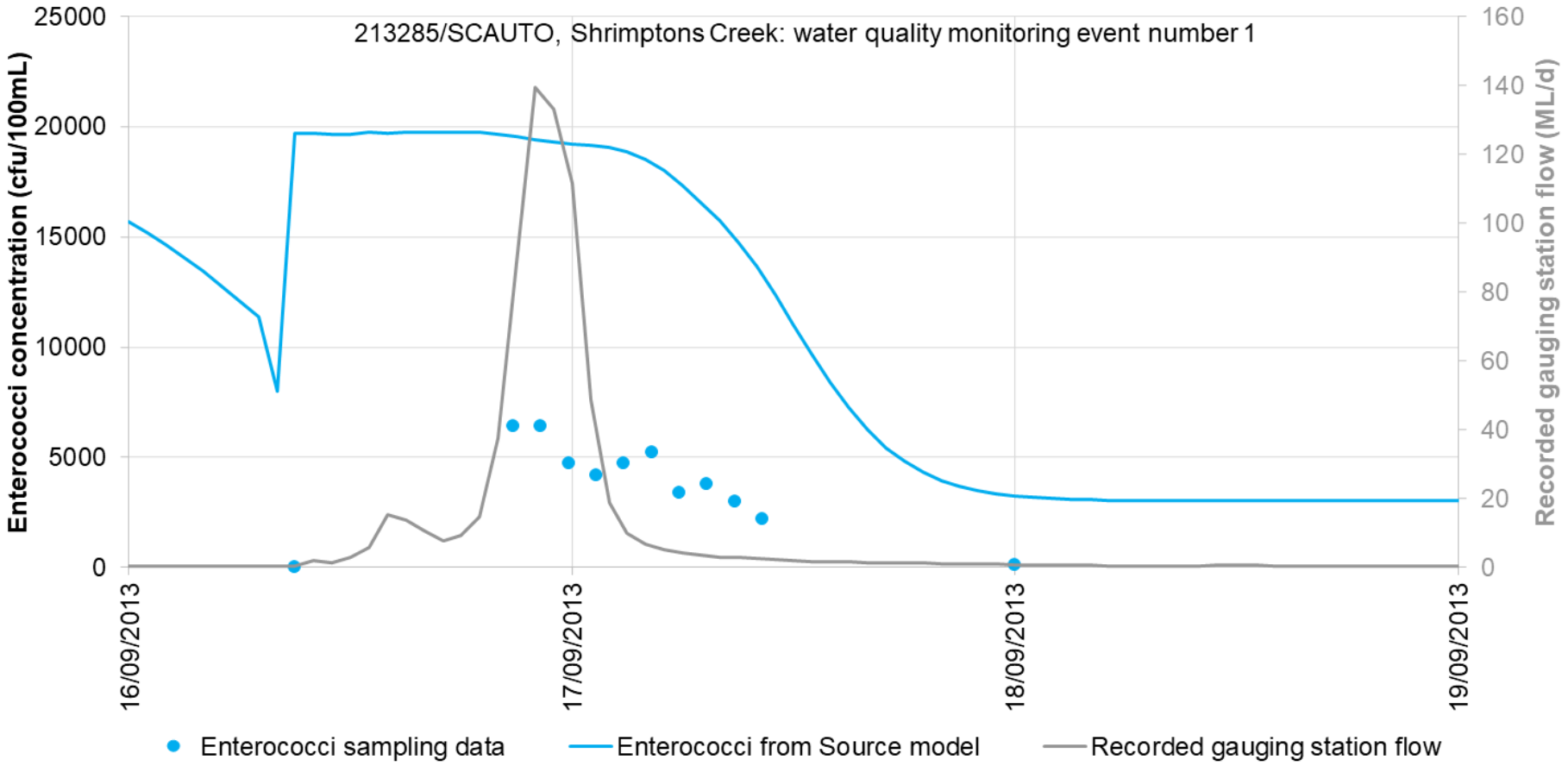

213283/DCAUTO, Devlins Creek: water quality monitoring event number 3
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
200
180
160
140
120
100
80
60
40
20
0
16/02/2014
17/02/2014
18/02/2014
19/02/2014
20/02/2014
21/02/2014
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

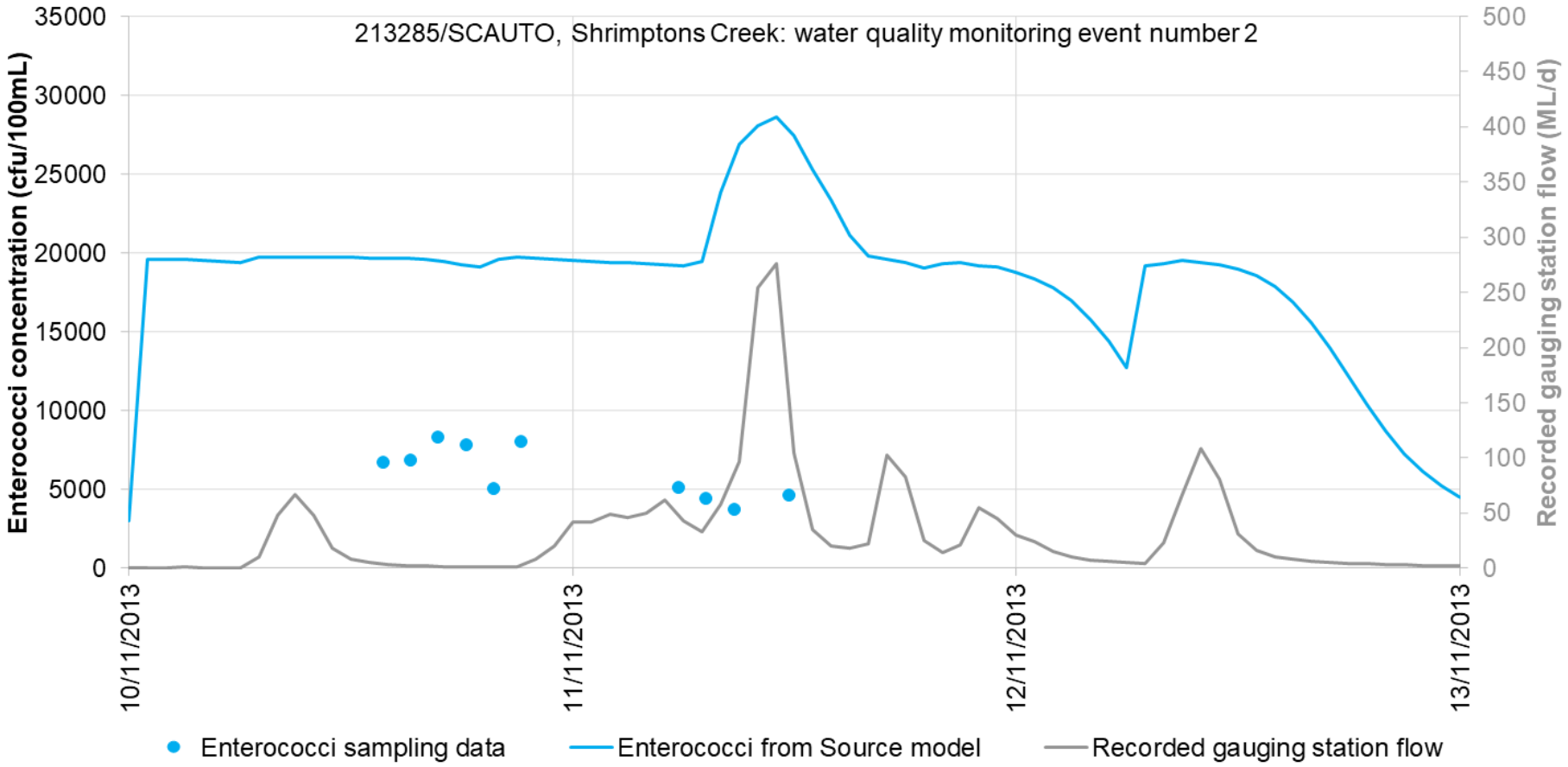

213283/DCAUTO, Devlins Creek: water quality monitoring event number 4
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
350
300
250
200
150
100
50
0
01/03/2014
02/03/2014
03/03/2014
04/03/2014
05/03/2014
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

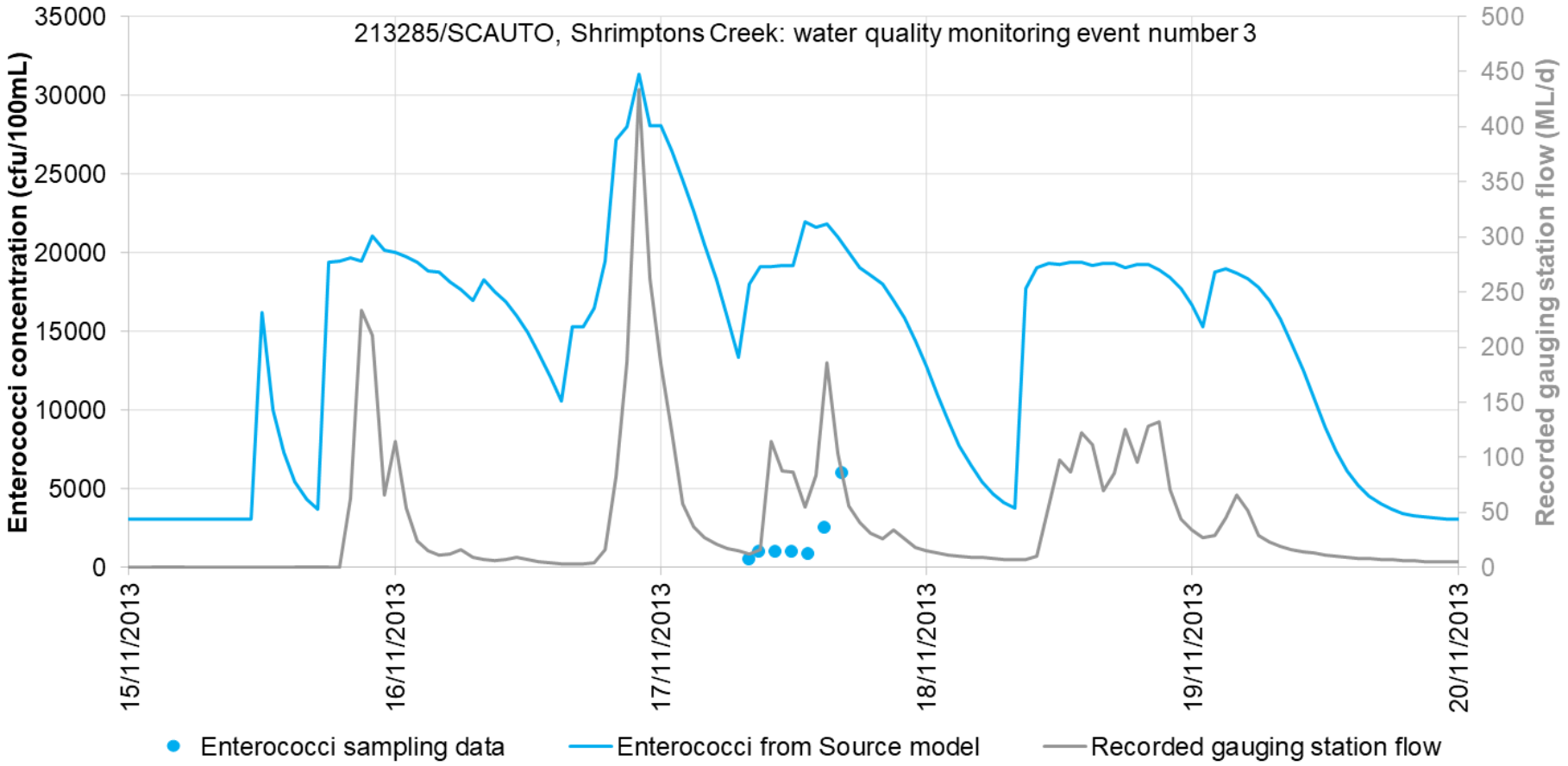

213283/DCAUTO, Devlins Creek: water quality monitoring event number 5
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
25000
20000
15000
10000
5000
0
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
Enterococci sampling data
Enterococci from Source model
Source modelled flow

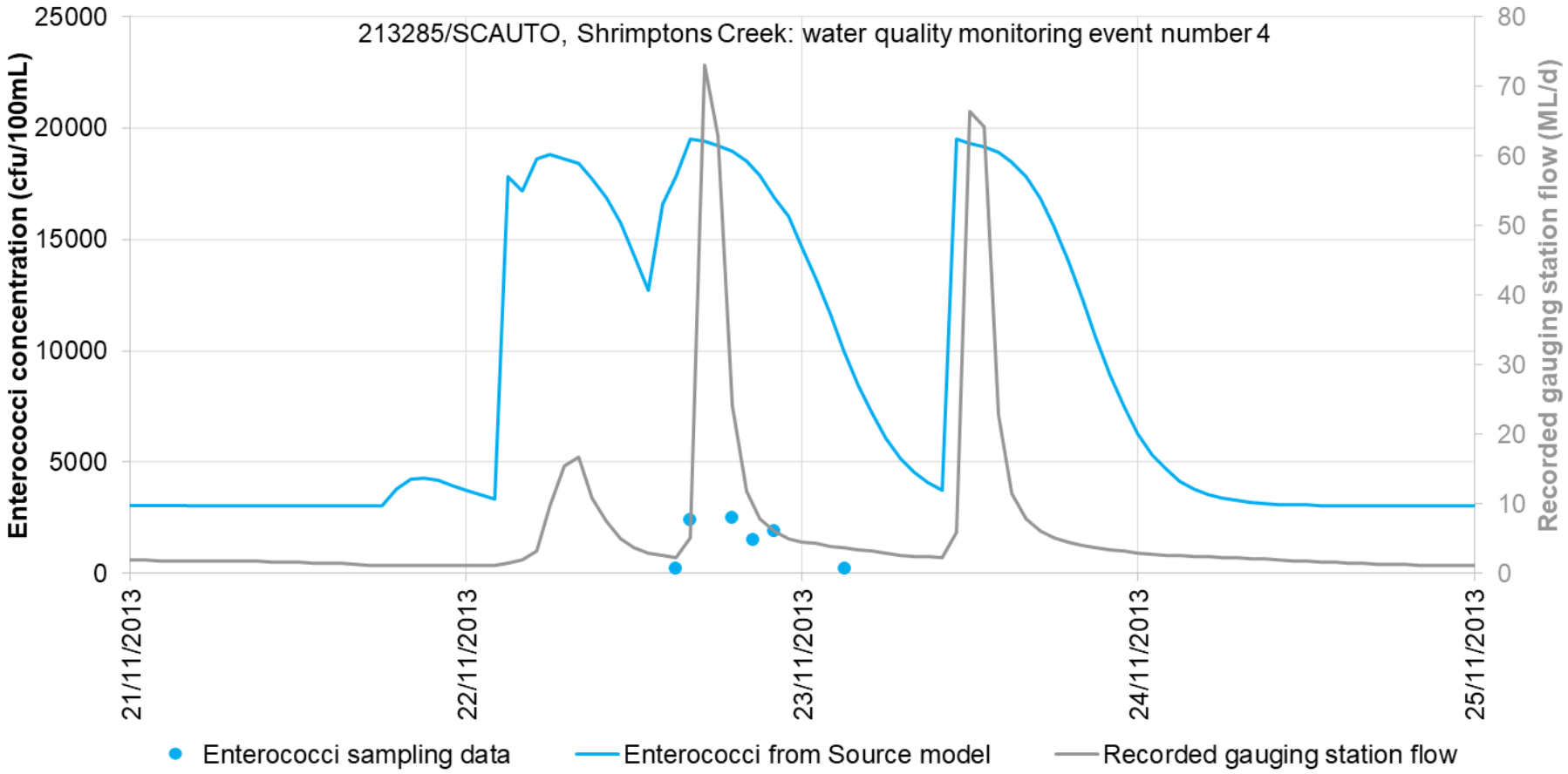

213283/DCAUTO, Devlins Creek: water quality monitoring event number 6
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
25000
20000
15000
10000
5000
0
300
250
200
150
100
50
0
11/04/2014
12/04/2014
13/04/2014
14/04/2014
Enterococci sampling data
Enterococci from Source model
Source modelled flow

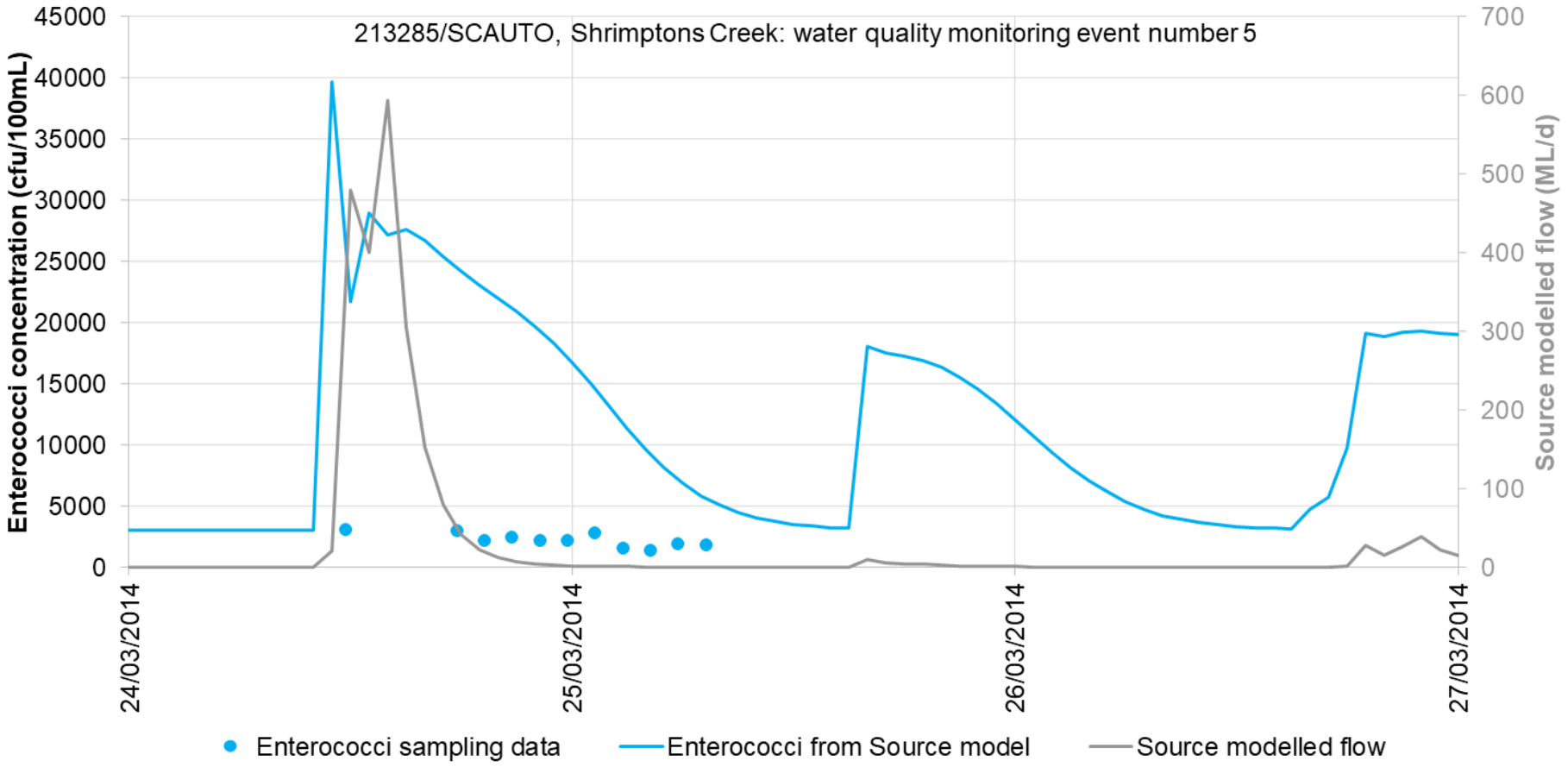

213283/DCAUTO, Devlins Creek: water quality monitoring event number 7
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
30000
25000
20000
15000
10000
5000
0
1600
1400
1200
1000
800
600
400
200
0
16/08/2014
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
Enterococci sampling data
Enterococci from Source model
Source modelled flow

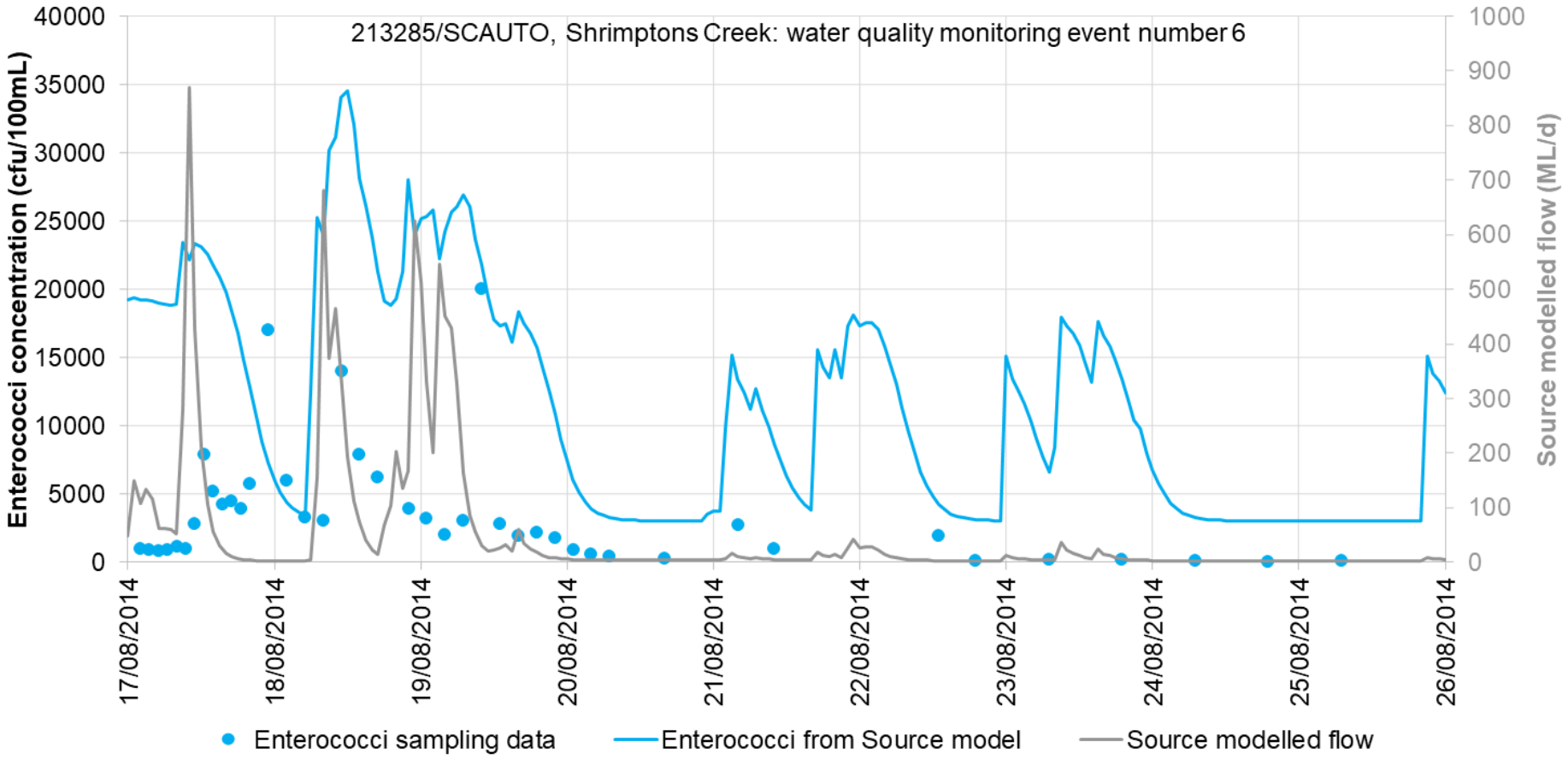

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
160
140
120
100
80
60
40
20
0
16/09/2013
17/09/2013
18/09/2013
19/09/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

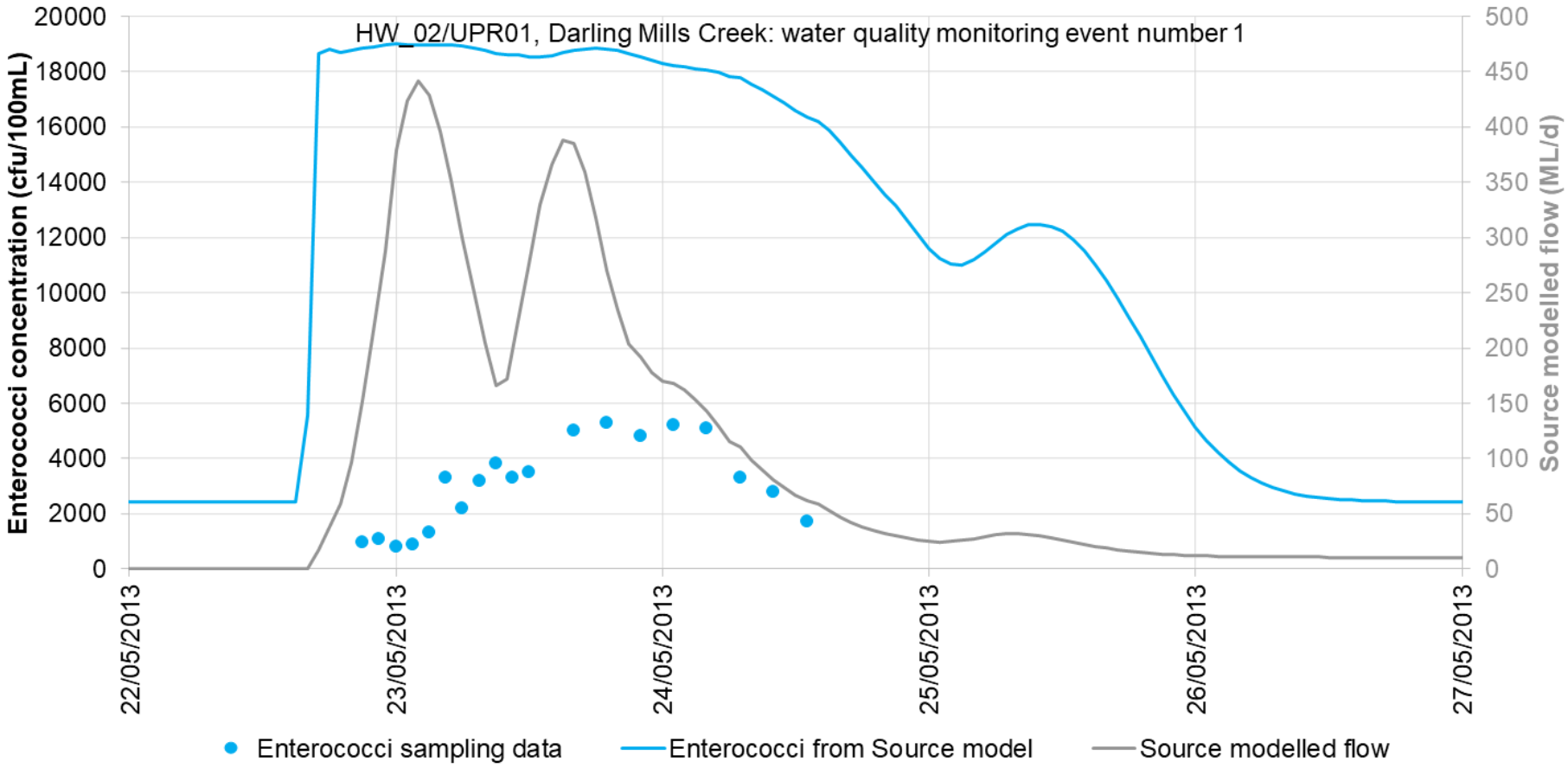

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
35000
30000
25000
20000
15000
10000
5000
0
500
450
400
350
300
250
200
150
100
50
0
10/11/2013
11/11/2013
12/11/2013
13/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

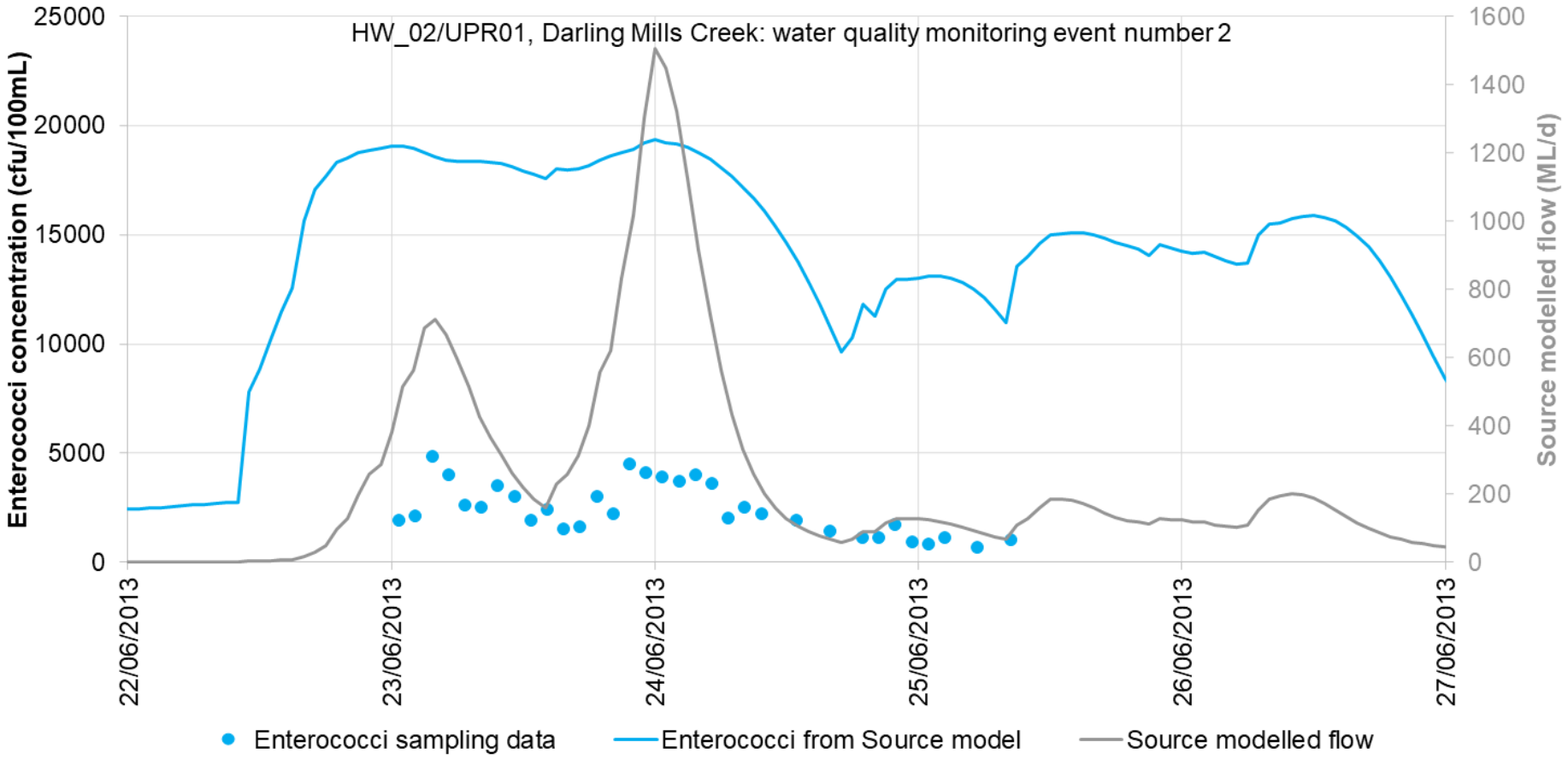

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 3
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
35000
30000
25000
20000
15000
10000
5000
0
500
450
400
350
300
250
200
150
100
50
0
15/11/2013
16/11/2013
17/11/2013
18/11/2013
19/11/2013
20/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

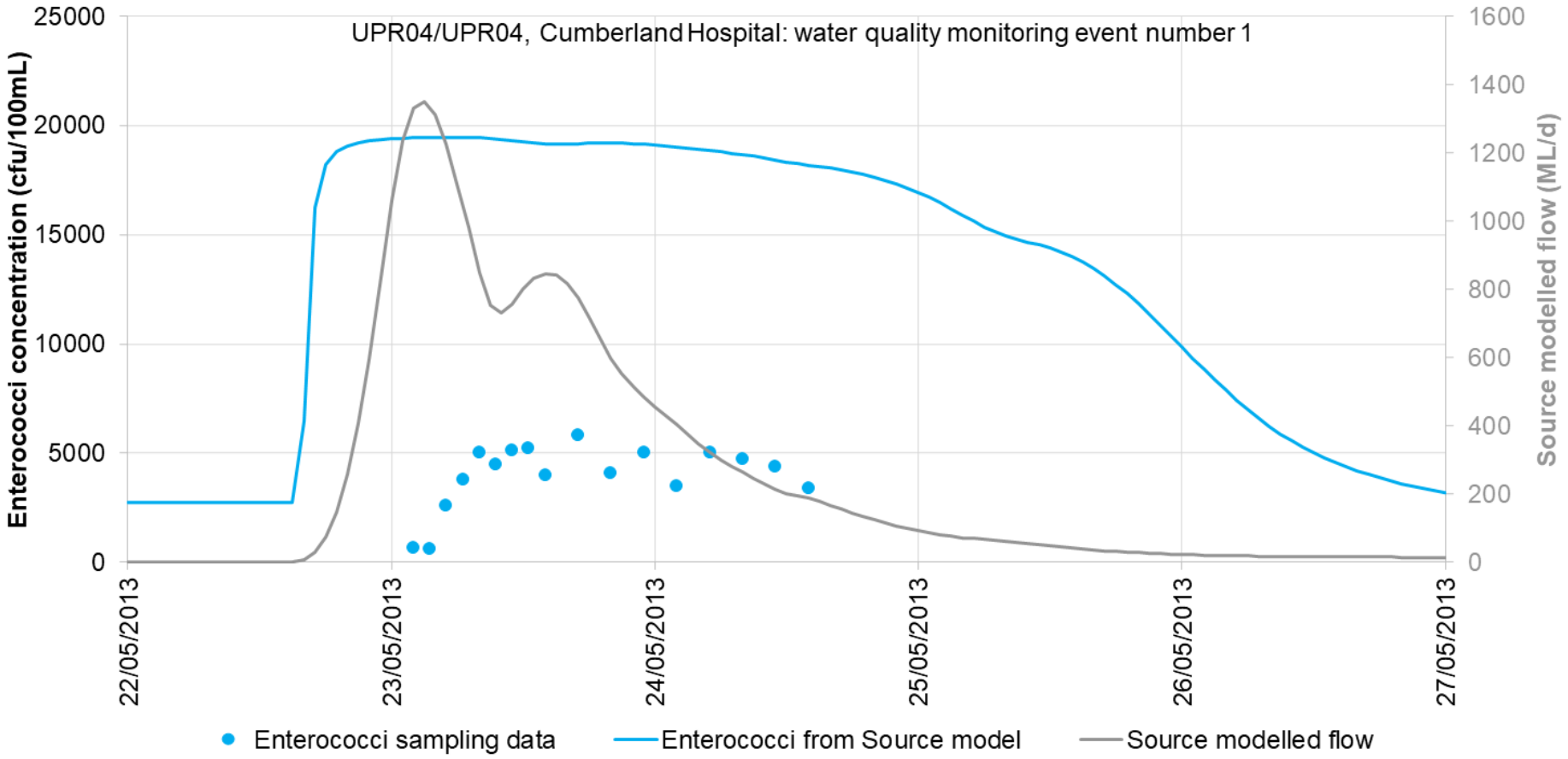

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 4
Enterococci concentration (cfu/100mL)
Recorded gauging station flow (ML/d)
25000
20000
15000
10000
5000
0
80
70
60
50
40
30
20
10
0
21/11/2013
22/11/2013
23/11/2013
24/11/2013
25/11/2013
Enterococci sampling data
Enterococci from Source model
Recorded gauging station flow

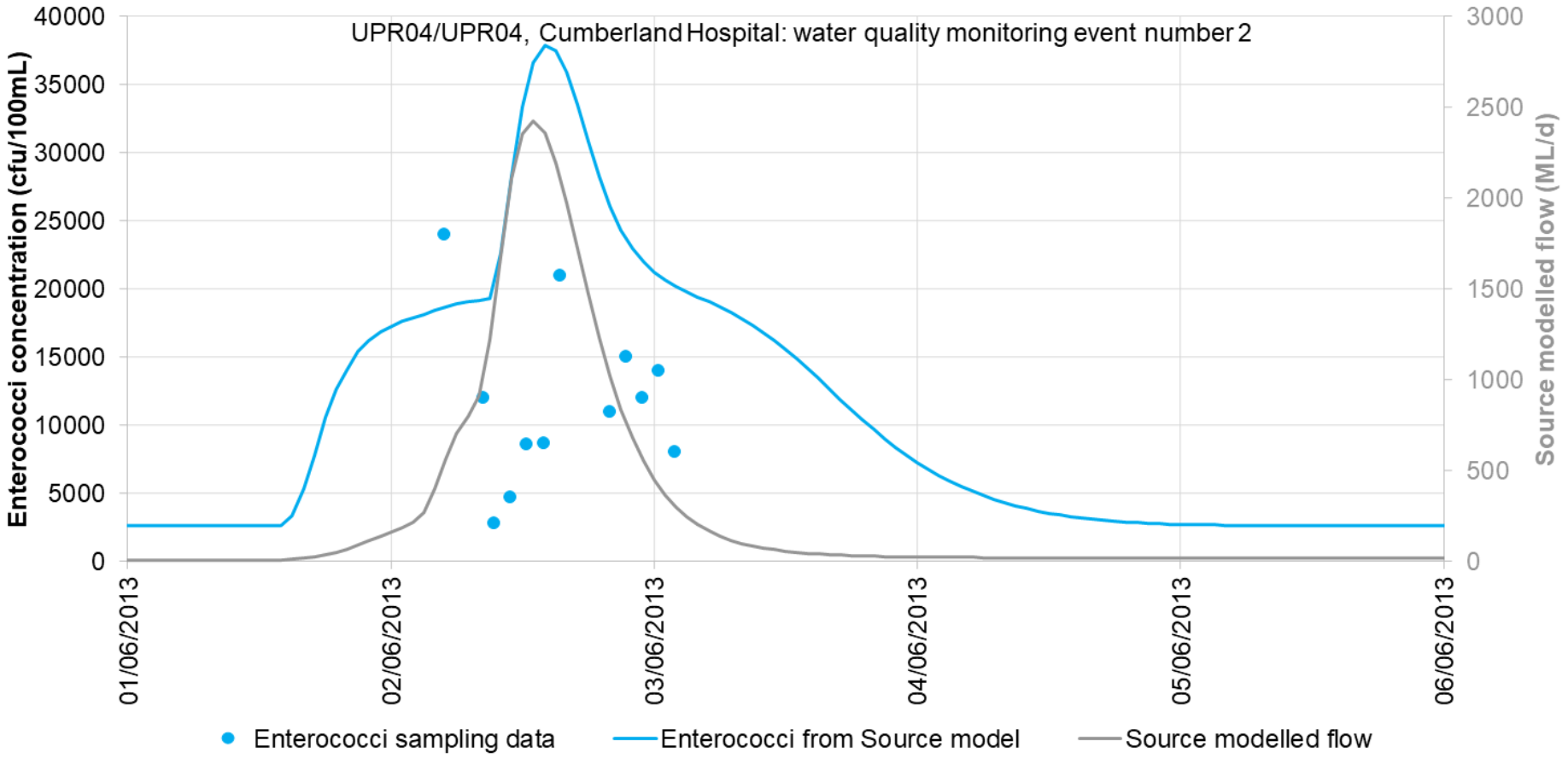

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 5
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
700
600
500
400
300
200
100
0
24/03/2014
25/03/2014
26/03/2014
27/03/2014
Enterococci sampling data
Enterococci from Source model
Source modelled flow

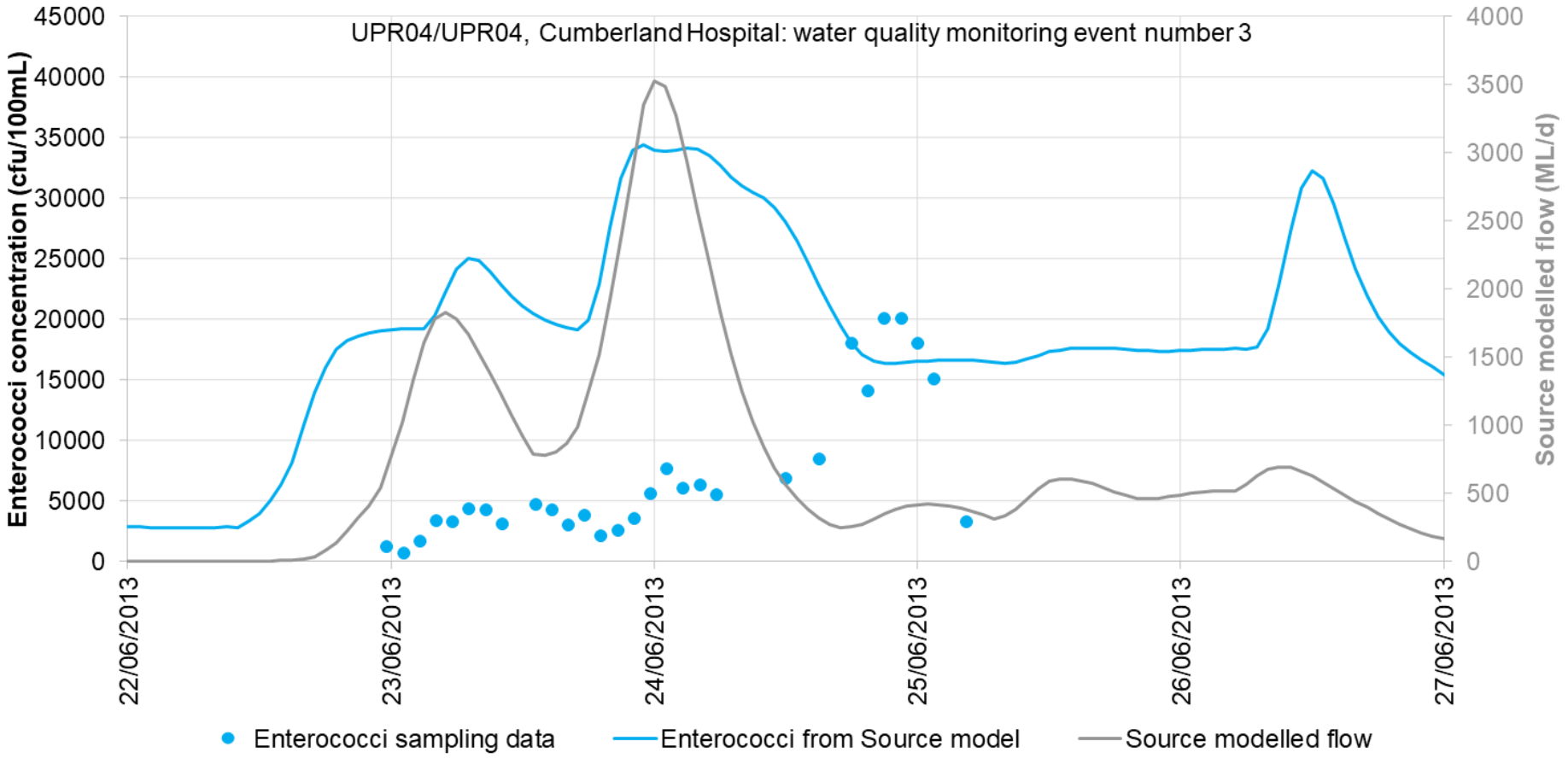

213285/SCAUTO, Shrimptons Creek: water quality monitoring event number 6
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
40000
35000
30000
25000
20000
15000
10000
5000
0
1000
900
800
700
600
500
400
300
200
100
0
17/08/2014
18/08/2014
19/08/2014
20/08/2014
21/08/2014
22/08/2014
23/08/2014
24/08/2014
25/08/2014
26/08/2014
Enterococci sampling data
Enterococci from Source model
Source modelled flow


HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
500
450
400
350
300
250
200
150
100
50
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
Enterococci sampling data
Enterococci from Source model
Source modelled flow


HW_02/UPR01, Darling Mills Creek: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
25000
20000
15000
10000
5000
0
1600
1400
1200
1000
800
600
400
200
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
Enterococci sampling data
Enterococci from Source model
Source modelled flow


UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 1
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
25000
20000
15000
10000
5000
0
1600
1400
1200
1000
800
600
400
200
0
22/05/2013
23/05/2013
24/05/2013
25/05/2013
26/05/2013
27/05/2013
Enterococci sampling data
Enterococci from Source model
Source modelled flow


UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 2
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
40000
35000
30000
25000
20000
15000
10000
5000
0
3000
2500
2000
1500
1000
500
0
01/06/2013
02/06/2013
03/06/2013
04/06/2013
05/06/2013
06/06/2013
Enterococci sampling data
Enterococci from Source model
Source modelled flow


UPR04/UPR04, Cumberland Hospital: water quality monitoring event number 3
Enterococci concentration (cfu/100mL)
Source modelled flow (ML/d)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
4000
3500
3000
2500
2000
1500
1000
500
0
22/06/2013
23/06/2013
24/06/2013
25/06/2013
26/06/2013
27/06/2013
Enterococci sampling data
Enterococci from Source model
Source modelled flow

Appendix D Tables of water quality comparisons for monitored events

Table Apx D-1 Monitored and Source modelled concentrations of Total Suspended Solids for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Suspended Solids concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	10	4.0	4.5	118.3
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	14	12.4	15.4	122.2
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	13.2	13.6	109.2
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	3.4	3.8	129.3
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	4.6	4.5	125.4
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	35.1	35.0	110.3
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	10	19.4	22.1	121.0
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	25	61.6	2.8	131.8
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	14	45.2	40.4	129.0
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	13	51.6	33.1	131.7
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	14.3	27.3	137.2
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	39.3	51.3	134.0
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	31.7	8.3	127.1
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	10	93.2	87.2	130.2
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	33.9	33.3	134.3
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	6	18.1	15.7	127.7
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	4	9.7	12.1	106.3
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	10.1	15.7	136.8

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Suspended Solids concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	20.7	9.8	126.2
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	34.2	29.9	130.6
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	71.1	57.9	134.8
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	14.8	14.7	123.1
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	56.2	44.0	116.9
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	27.4	31.9	131.1
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	47.5	12.7	130.3
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	47.0	41.6	129.5
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	30.8*	Not calculated	138.5
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	48.8*	Not calculated	159.9
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	70.6*	Not calculated	124.1
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	258.4*	Not calculated	146.8
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	42	57.1*	Not calculated	139.0

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

Table Apx D-2 Monitored and Source modelled concentrations of Total Phosphorus for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Phosphorus concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	0.038	0.040	0.227
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	0.097	0.090	0.253
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	0.095	0.097	0.324
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	0.050	0.052	0.244
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	0.050	0.051	0.244
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	0.140	0.135	0.260
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	0.145	0.139	0.234
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	0.148	0.013	0.250
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	0.113	0.101	0.245
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	7	0.121	0.092	0.249
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	0.071	0.104	0.257
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	0.084	0.068	0.251
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	0.117	0.014	0.258
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	0.222	0.207	0.246
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	0.104	0.109	0.278
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	0.093	0.060	0.268
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	0.057	0.028	0.214
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	0.091	0.108	0.307
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	0.104	0.058	0.286
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	0.126	0.113	0.246

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Phosphorus concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	0.176	0.154	0.349
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	0.072	0.071	0.234
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	0.089	0.076	0.231
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	0.134	0.143	0.246
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	0.160	0.052	0.321
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	0.144	0.140	0.306
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	0.135*	Not calculated	0.584
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	1.012*	Not calculated	1.757
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	0.263*	Not calculated	0.237
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	0.539*	Not calculated	0.842
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	40	0.422*	Not calculated	0.861

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

Table Apx D-3 Monitored and Source modelled concentrations of Ortho Phosphate for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Ortho Phosphate concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	0.002	0.002	0.080
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	0.013	0.013	0.096
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	0.036	0.038	0.152
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	0.003	0.003	0.085
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	0.005	0.005	0.087
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	0.030	0.029	0.108
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	0.017	0.016	0.082
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	0.031	0.005	0.088
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	0.025	0.025	0.086
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	7	0.021	0.020	0.087
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	0.016	0.014	0.090
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	0.014	0.008	0.088
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	0.023	0.001	0.096
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	0.016	0.015	0.086
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	0.037	0.036	0.106
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	0.040	0.031	0.103
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	0.019	0.011	0.075
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	0.026	0.026	0.125
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	0.034	0.019	0.117
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	0.027	0.022	0.086

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Ortho Phosphate concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	0.062	0.056	0.157
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	0.010	0.009	0.082
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	0.012	0.010	0.083
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	0.028	0.029	0.086
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	0.042	0.009	0.139
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	0.046	0.048	0.129
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	0.029*	Not calculated	0.320
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	0.254*	Not calculated	1.122
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	0.021*	Not calculated	0.083
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	0.037*	Not calculated	0.495
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	40	0.101*	Not calculated	0.521

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

Table Apx D-4 Monitored and Source modelled concentrations of Total Nitrogen for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Nitrogen concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	0.44	0.46	1.66
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	0.88	0.82	1.83
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	1.32	1.38	2.36
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	0.53	0.57	1.75
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	0.50	0.52	1.76
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	1.59	1.55	1.91
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	0.86	0.81	1.70
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	1.01	0.14	1.79
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	0.73	0.68	1.76
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	7	0.73	0.75	1.78
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	0.67	0.75	1.83
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	0.83	0.64	1.80
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	1.56	0.15	1.86
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	1.05	1.01	1.77
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	1.11	1.13	1.98
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	1.08	0.84	1.93
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	0.68	0.41	1.59
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	1.38	1.35	2.19

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Total Nitrogen concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	2.12	1.34	2.06
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	1.00	0.92	1.77
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	1.47	1.47	2.49
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	1.33	1.35	1.70
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	1.20	1.51	1.69
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	0.99	1.02	1.77
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	1.17	0.36	2.30
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	1.22	1.39	2.19
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	1.14*	Not calculated	4.15
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	6.71*	Not calculated	12.39
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	1.53*	Not calculated	1.72
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	2.45*	Not calculated	5.95
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	40	4.13*	Not calculated	6.13

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

Table Apx D-5 Monitored and Source modelled concentrations of Oxidised Nirogen for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Oxidised Nitrogen concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	0.01	0.01	0.66
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	0.12	0.17	0.67
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	0.54	0.58	0.61
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	0.04	0.06	0.70
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	0.05	0.05	0.69
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	0.68	0.69	0.61
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	0.25	0.22	0.68
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	0.38	0.08	0.71
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	0.19	0.18	0.70
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	7	0.22	0.32	0.71
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	0.31	0.28	0.73
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	0.37	0.28	0.72
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	1.05	0.07	0.69
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	0.26	0.24	0.71
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	0.68	0.65	0.71
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	0.65	0.48	0.69
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	0.33	0.14	0.63
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	0.96	0.83	0.72
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	1.39	0.93	0.68
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	0.40	0.37	0.71

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Oxidised Nitrogen concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	0.82	0.88	0.69
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	0.26	0.23	0.68
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	0.41	0.45	0.65
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	0.35	0.36	0.71
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	0.47	0.13	0.69
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	0.63	0.81	0.68
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	0.55*	Not calculated	0.64
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	1.1*	Not calculated	0.47
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	0.43*	Not calculated	0.68
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	0.74*	Not calculated	0.60
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	40	1.65*	Not calculated	0.50

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

Table Apx D-6 Monitored and Source modelled concentrations of Ammonium for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Ammonium concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	0.010	0.010	0.083
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	0.298	0.155	0.202
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	0.124	0.132	0.696
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	0.095	0.134	0.089
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	0.048	0.055	0.119
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	0.241	0.201	0.351
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	0.010	0.010	0.085
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	0.012	0.002	0.099
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	0.014	0.013	0.088
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	7	0.011	0.017	0.090
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	0.019	0.018	0.096
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	0.013	0.012	0.090
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	0.022	0.006	0.187
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	0.015	0.013	0.088
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	0.018	0.017	0.239
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	0.038	0.031	0.232
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	0.037	0.030	0.079
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	10	0.090	0.141	0.380
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	41	0.073	0.040	0.359
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	0.030	0.024	0.088

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Ammonium concentration (mg/L)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	0.104	0.083	0.641
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	0.037	0.047	0.085
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	0.073	0.099	0.118
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	0.005	0.006	0.088
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	0.079	0.017	0.510
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	0.090	0.089	0.437
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	0.033*	Not calculated	1.951
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	2.37*	Not calculated	8.274
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	0.036*	Not calculated	0.091
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	0.355*	Not calculated	3.333
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	40	0.855*	Not calculated	3.634

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

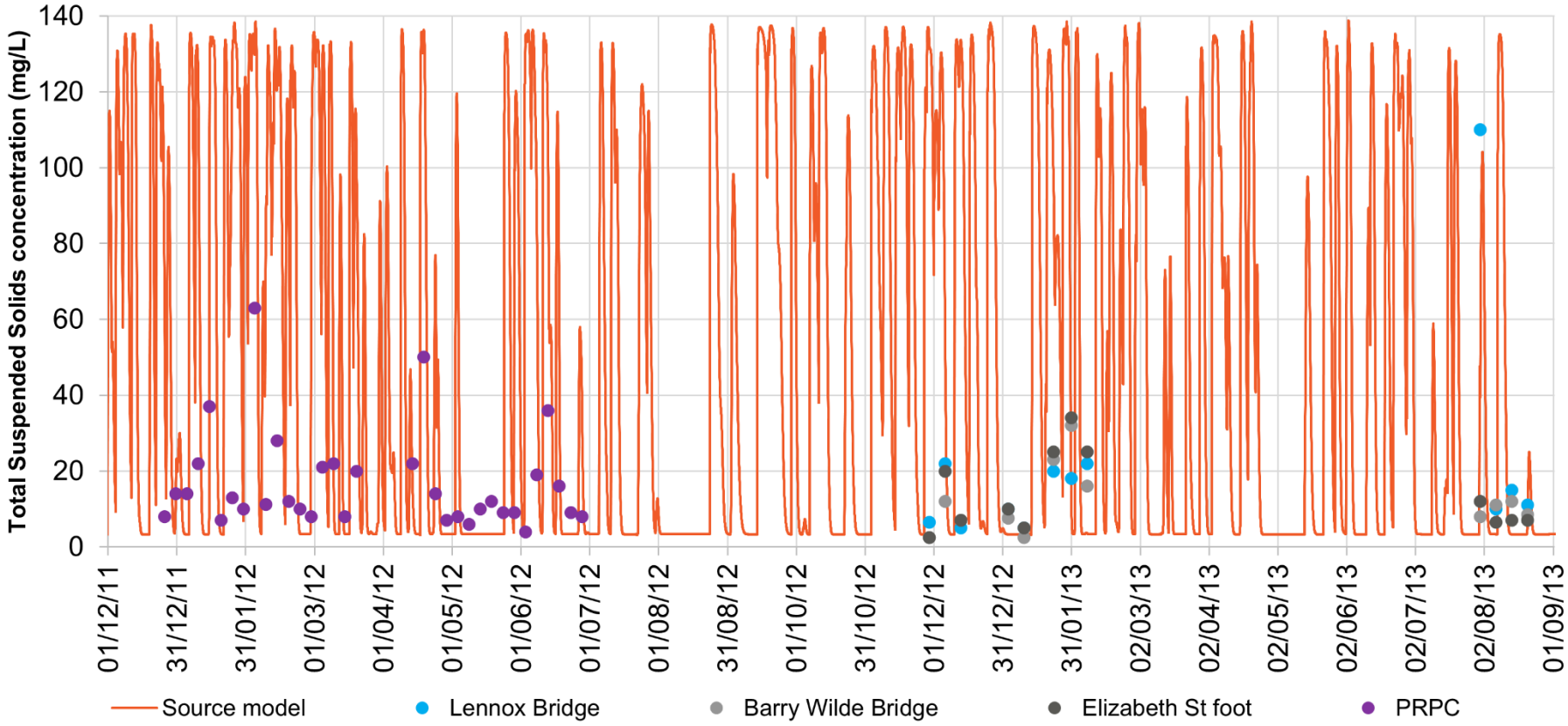
Table Apx D-7 Monitored and Source modelled concentrations of Enterococci for events with multiple water quality

WQ Site code	Site Name	Gauge	Event number	Start date	End date	Event Flow Volume (ML)	Number of samples	Enterococci concentration (cfu/100mL)		
								Monitored mean concentration: at sampling times only	Monitored mean concentration: interpolated in time across hydrograph	Source modelled mean concentration
LCAUTO	Lane Cove National Park Weir	213280	1	16/09/2013	19/09/2013	281	11	277	278	17,016
LCAUTO	Lane Cove National Park Weir	213280	2	10/11/2013	14/11/2013	1,041	15	1,973	2,752	19,792
LCAUTO	Lane Cove National Park Weir	213280	3	18/11/2013	22/11/2013	1,692	19	3,729	3,692	28,292
LCAUTO	Lane Cove National Park Weir	213280	4	01/03/2014	05/03/2014	491	14	69	108	18,552
LCAUTO	Lane Cove National Park Weir	213280	5	24/03/2014	27/03/2014	266	21	85	79	18,708
LCAUTO	Lane Cove National Park Weir	213280	6	17/08/2014	26/08/2014	4,671	50	3,075	3,257	20,906
DCAUTO	Devlins Creek	213283	1	16/09/2013	19/09/2013	18	12	6,784	7,039	17,585
DCAUTO	Devlins Creek	213283	2	10/11/2013	14/11/2013	131	26	6,756	574	19,067
DCAUTO	Devlins Creek	213283	3	16/02/2014	21/02/2014	68	16	9,299	7,805	18,579
DCAUTO	Devlins Creek	213283	4	01/03/2014	05/03/2014	54	6	4,012	3,172	18,956
DCAUTO	Devlins Creek	213283	5	24/03/2014	27/03/2014	94	28	1,230	940	19,727
DCAUTO	Devlins Creek	213283	6	11/04/2014	14/04/2014	60	14	1,601	691	19,188
DCAUTO	Devlins Creek	213283	7	16/08/2014	25/08/2014	979	48	1,541	218	20,082
SCAUTO	Shrimptons Creek	213285	1	16/09/2013	19/09/2013	31	12	5,334	5,080	18,667
SCAUTO	Shrimptons Creek	213285	2	10/11/2013	13/11/2013	97	10	4,605	4,902	22,166
SCAUTO	Shrimptons Creek	213285	3	15/11/2013	20/11/2013	213	7	2,324	2,897	21,278
SCAUTO	Shrimptons Creek	213285	4	21/11/2013	25/11/2013	25	6	1,940	905	15,774
SCAUTO	Shrimptons Creek	213285	5	24/03/2014	27/03/2014	97	11	2,227	2,184	25,392
SCAUTO	Shrimptons Creek	213285	6	17/08/2014	26/08/2014	456	42	3,488	1,967	23,349
UPR03	Briens Road	213005	1	22/05/2013	27/05/2013	401	18	3,594	3,658	18,777

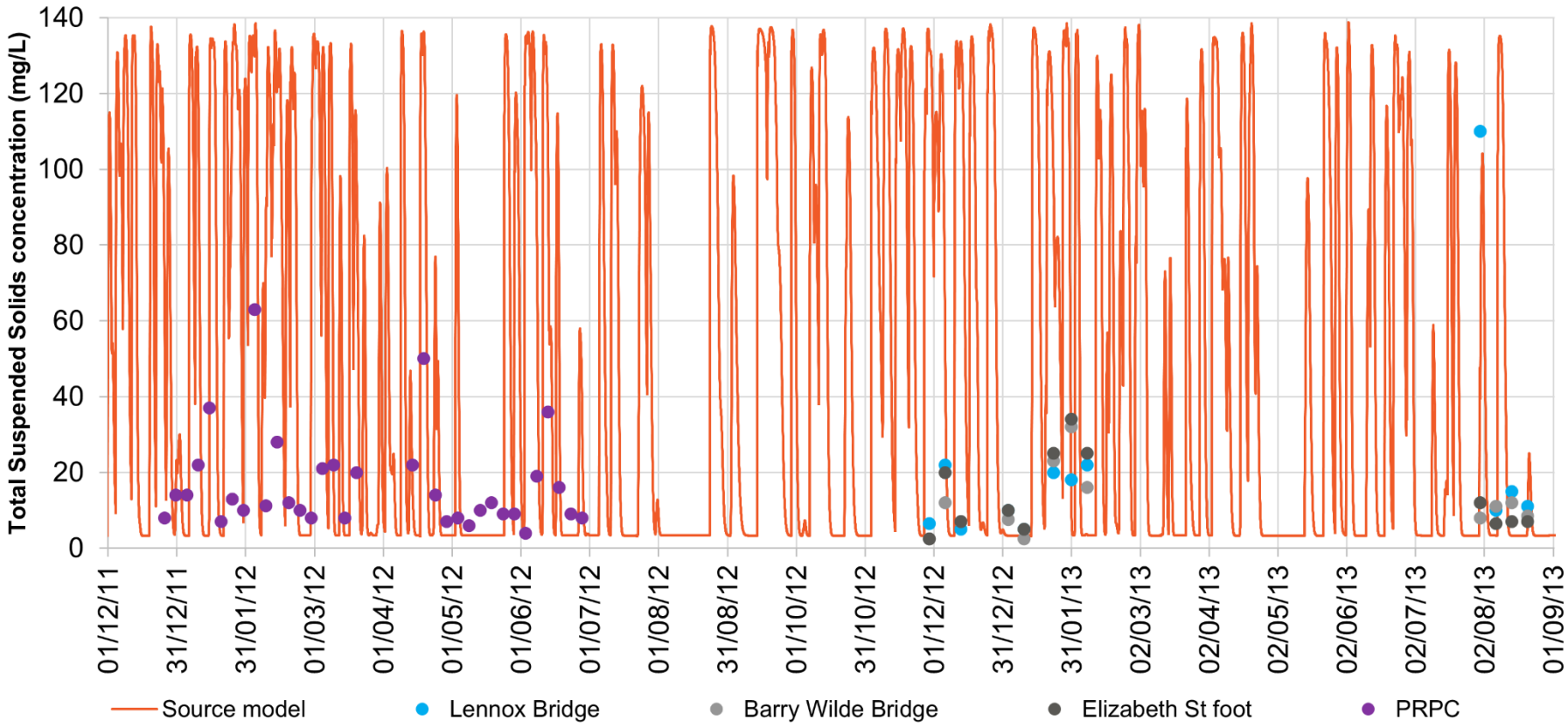
UPR03	Briens Road	213005	2	22/06/2013	27/06/2013	1,966	31	11,968	9,156	30,289
UPR01	Darling Mills Creek	HW_02	1	22/05/2013	27/05/2013	455	19	2,876	3,098	17,721
UPR01	Darling Mills Creek	HW_02	2	22/06/2013	27/06/2013	1,222	33	3,203	2,727	17,480
UPR04	Cumberland Hospital	UPR04	1	22/05/2013	27/05/2013	1,284	17	3,587	3,466	18,795
UPR04	Cumberland Hospital	UPR04	2	01/06/2013	06/06/2013	1,351	12	11,521	1,240	27,237
UPR04	Cumberland Hospital	UPR04	3	22/06/2013	27/06/2013	3,721	29	5,330	4,864	25,511
VCAUTO	Vineyard Creek	2VYC01	1	10/11/2013	13/11/2013	93	9	5,089*	Not calculated	56,627
VCAUTO	Vineyard Creek	2VYC01	2	18/11/2013	21/11/2013	57	5	91,080*	Not calculated	188,370
VCAUTO	Vineyard Creek	2VYC01	3	22/11/2013	26/11/2013	37	6	6,790*	Not calculated	17,992
VCAUTO	Vineyard Creek	2VYC01	4	24/03/2014	27/03/2014	57	14	5,482*	Not calculated	85,490
VCAUTO	Vineyard Creek	2VYC01	5	17/08/2014	21/08/2014	292	42	14,380*	Not calculated	87,963

* Times were not provided for samples at VCAUTO site. Mean monitored concentrations are a straight average of monitored values at samples for the event, not a flow-weighted mean concentration (as was calculated at the other monitoring sites).

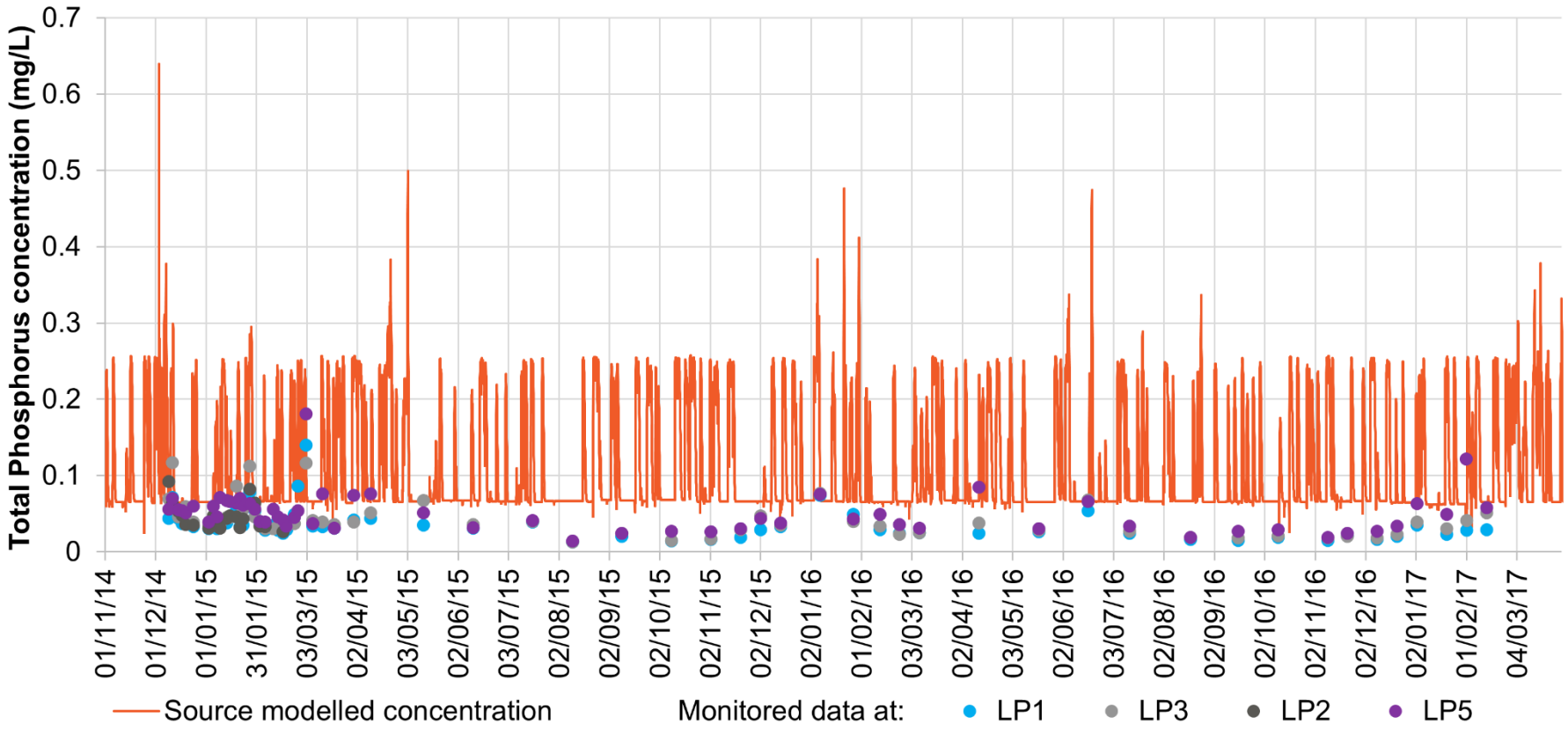
Appendix E Water quality time series comparison plots at intermittent monitoring sites



Figure_Apx E-1 Monitored and modelled Total Suspended Solids concentrations at sites on Parramatta River near the Parramatta CBD

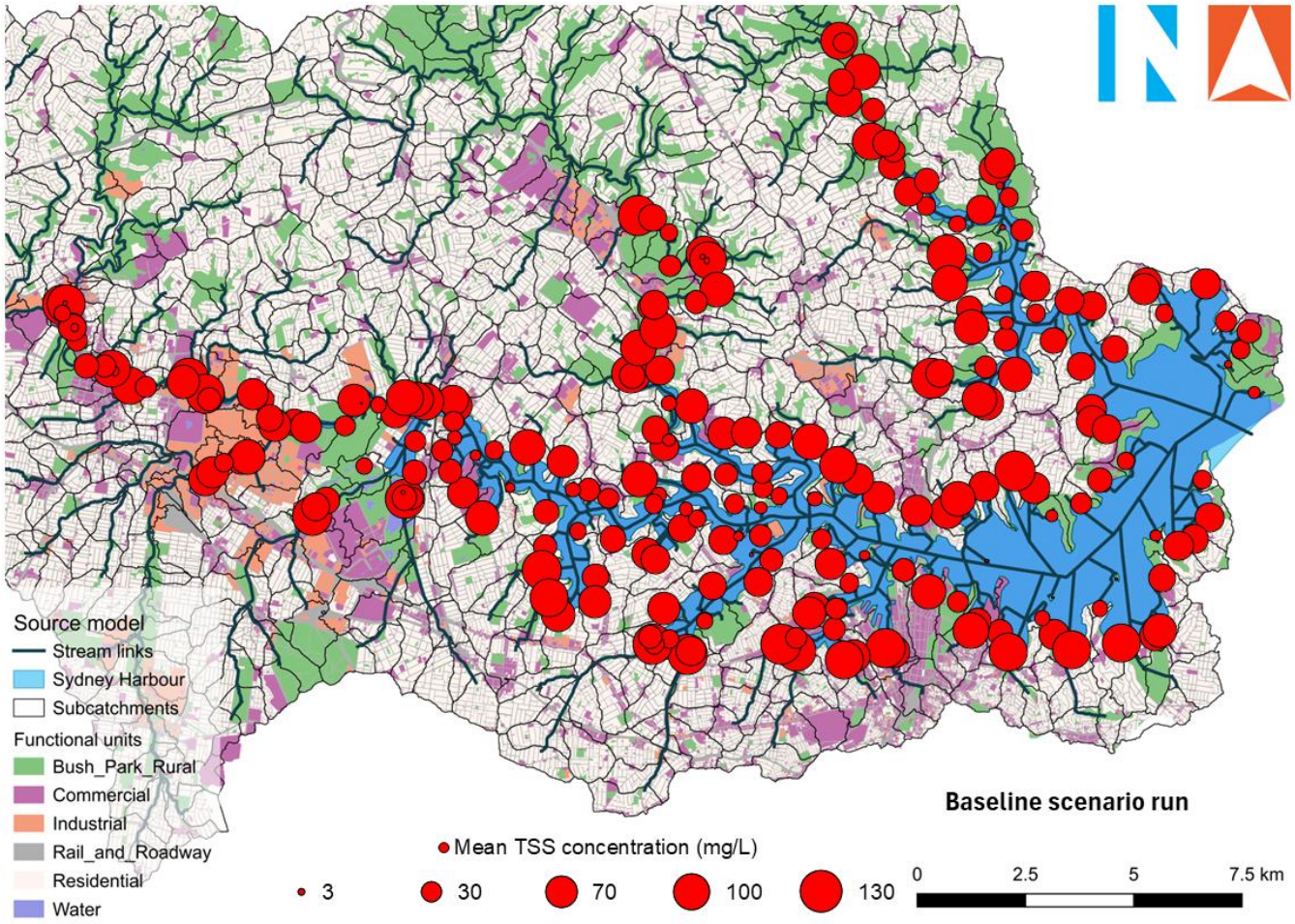


Figure_Apx E-2 Monitored and modelled Total Nitrogen concentrations at Lake Parramatta Dam sites

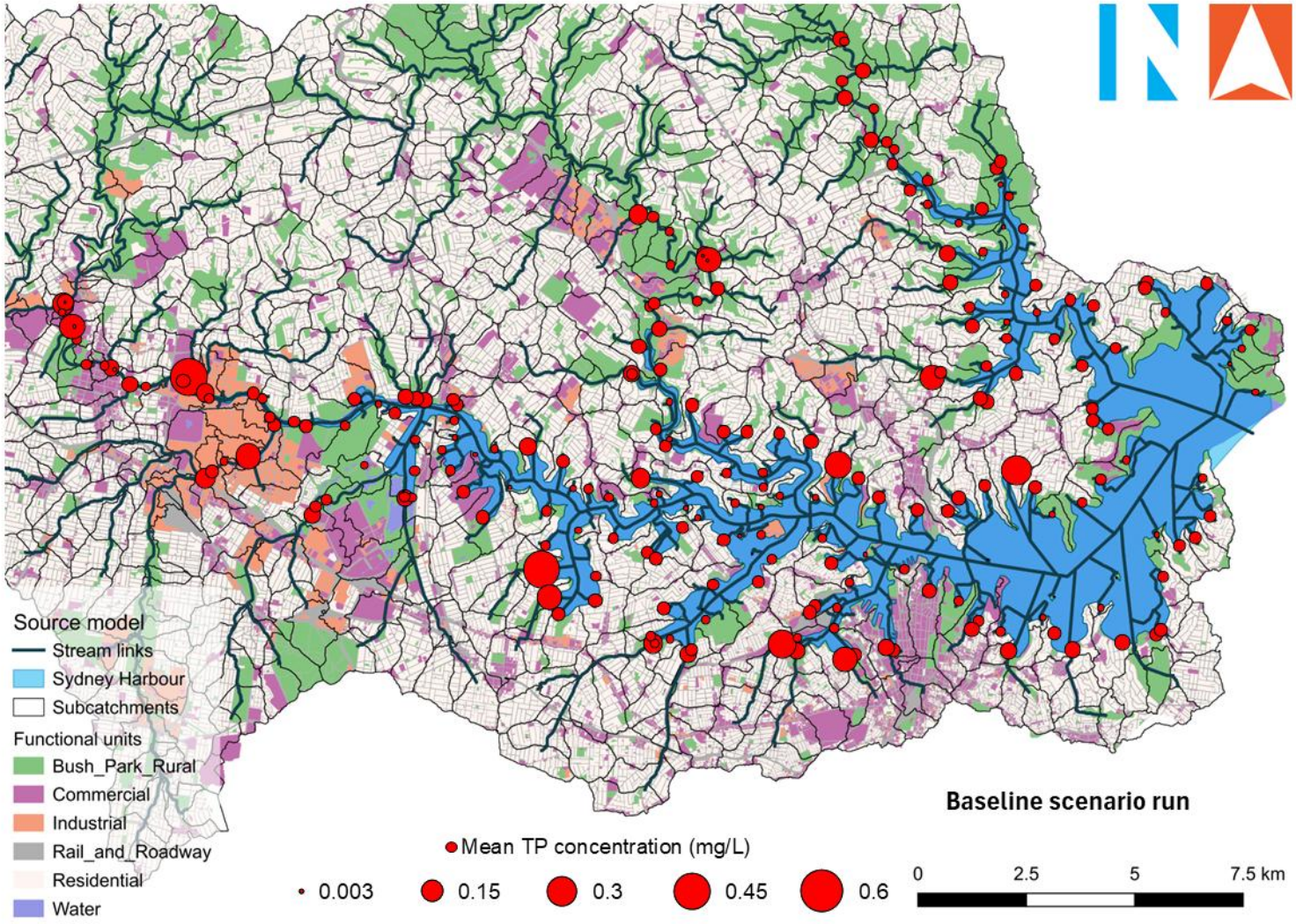


Figure_Apx E-3 Monitored and modelled Total Phosphorus concentrations at Lake Parramatta Dam sites

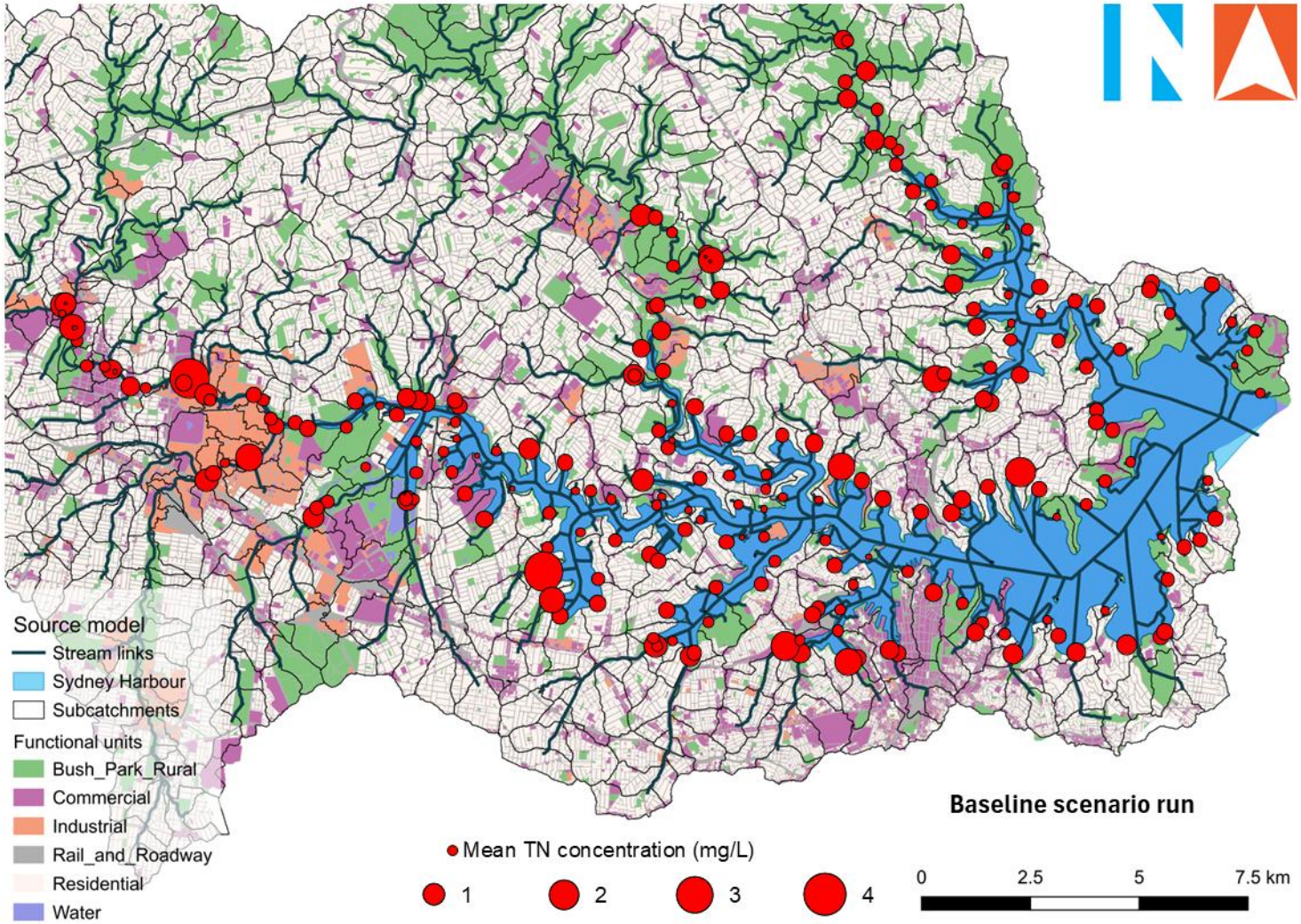
Appendix F Maps of mean annual flow and load for baseline scenario



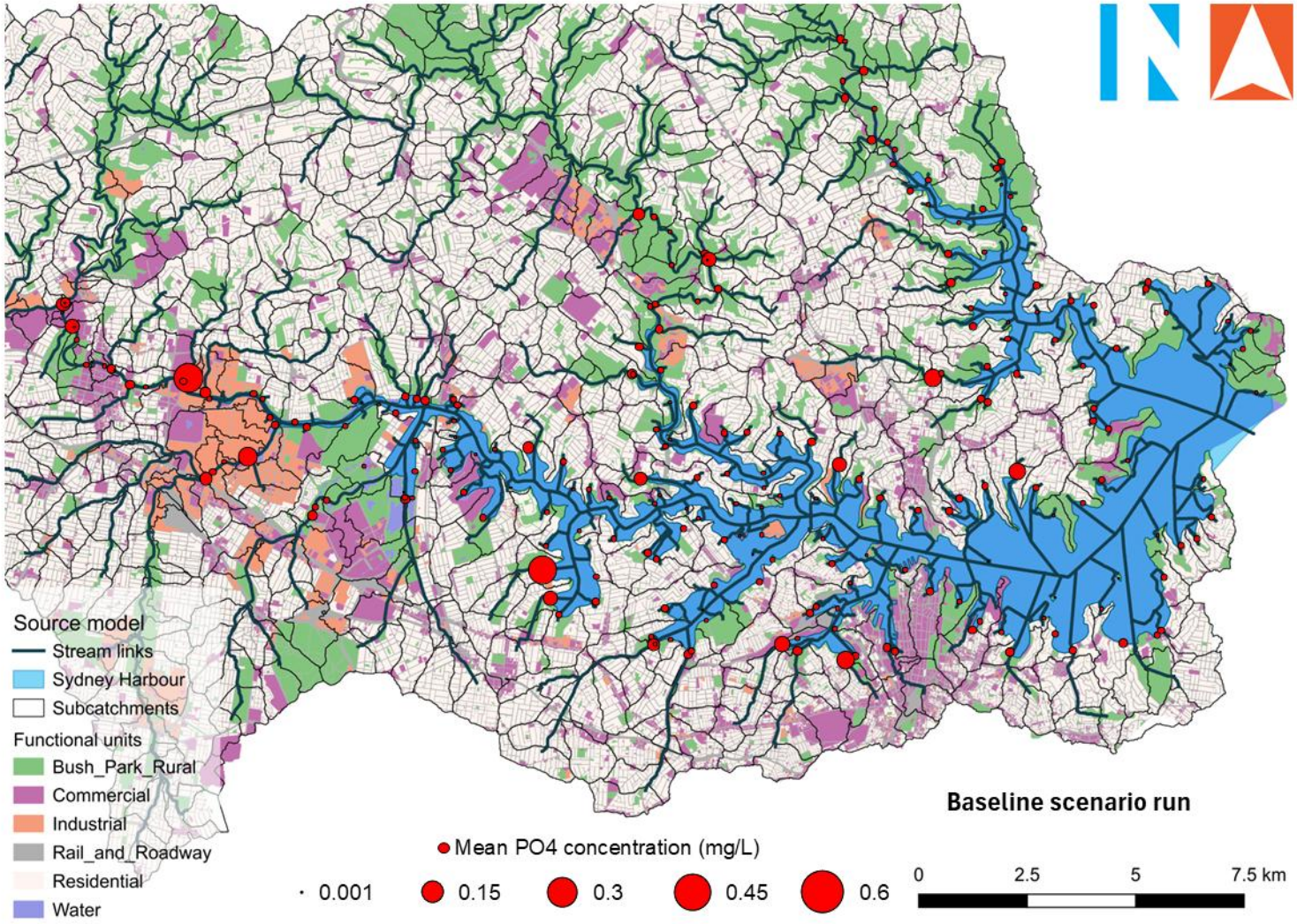
Figure_Apx F-1: Mean TSS concentration at inflow locations for baseline scenario



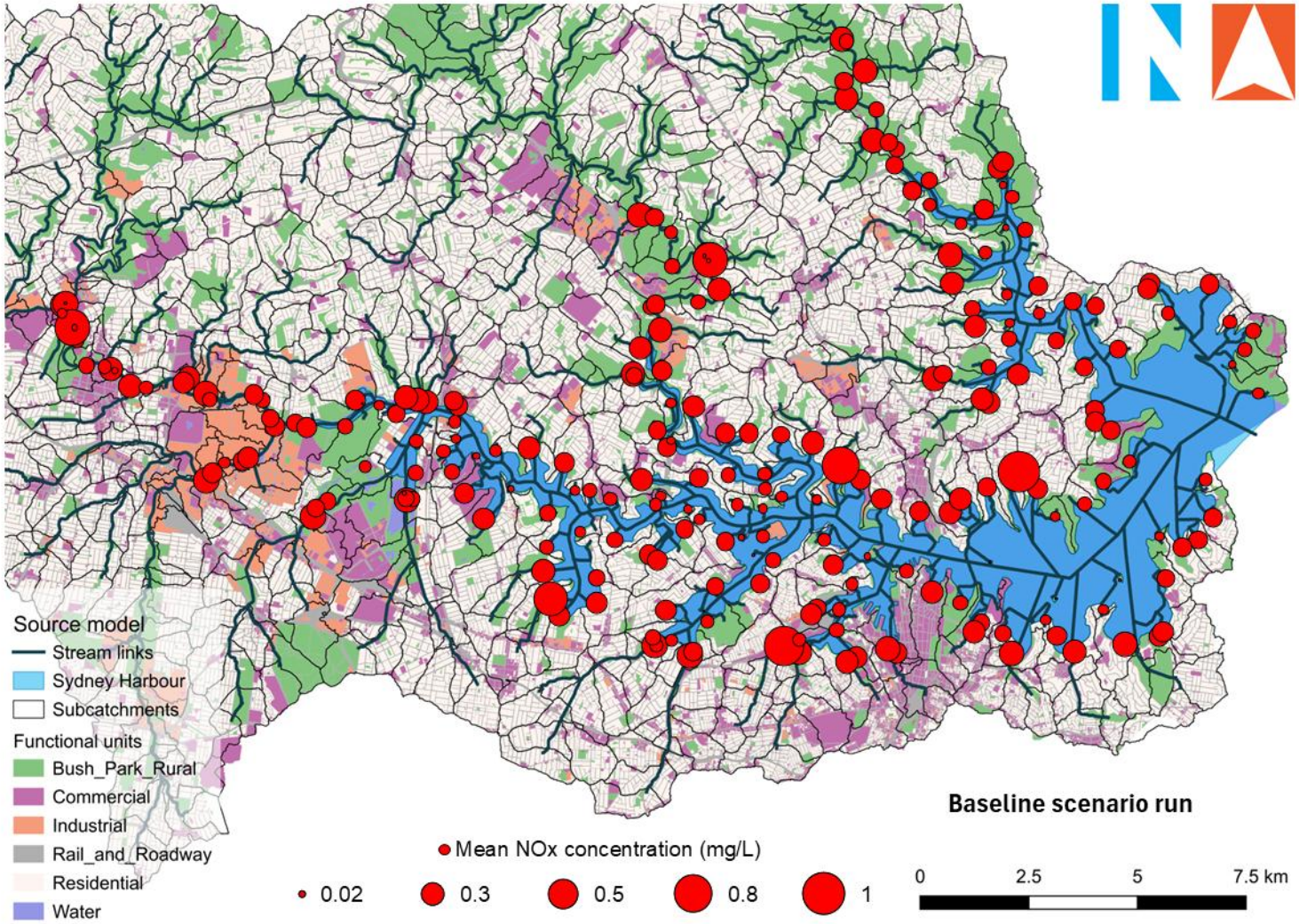
Figure_Apx F-2: Mean TP concentration at inflow locations for baseline scenario



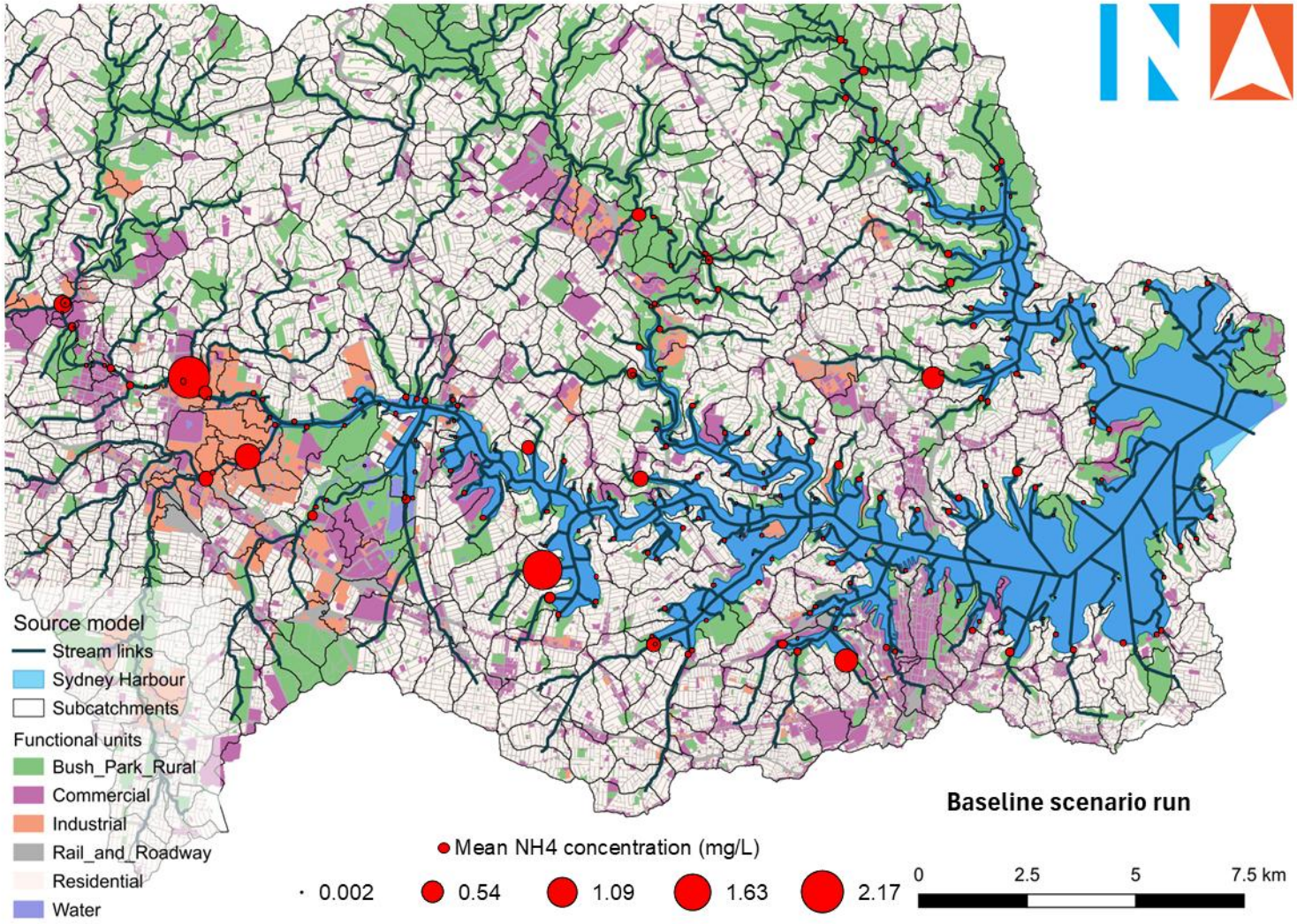
Figure_Apx F-3: Mean TN concentration at inflow locations for baseline scenario



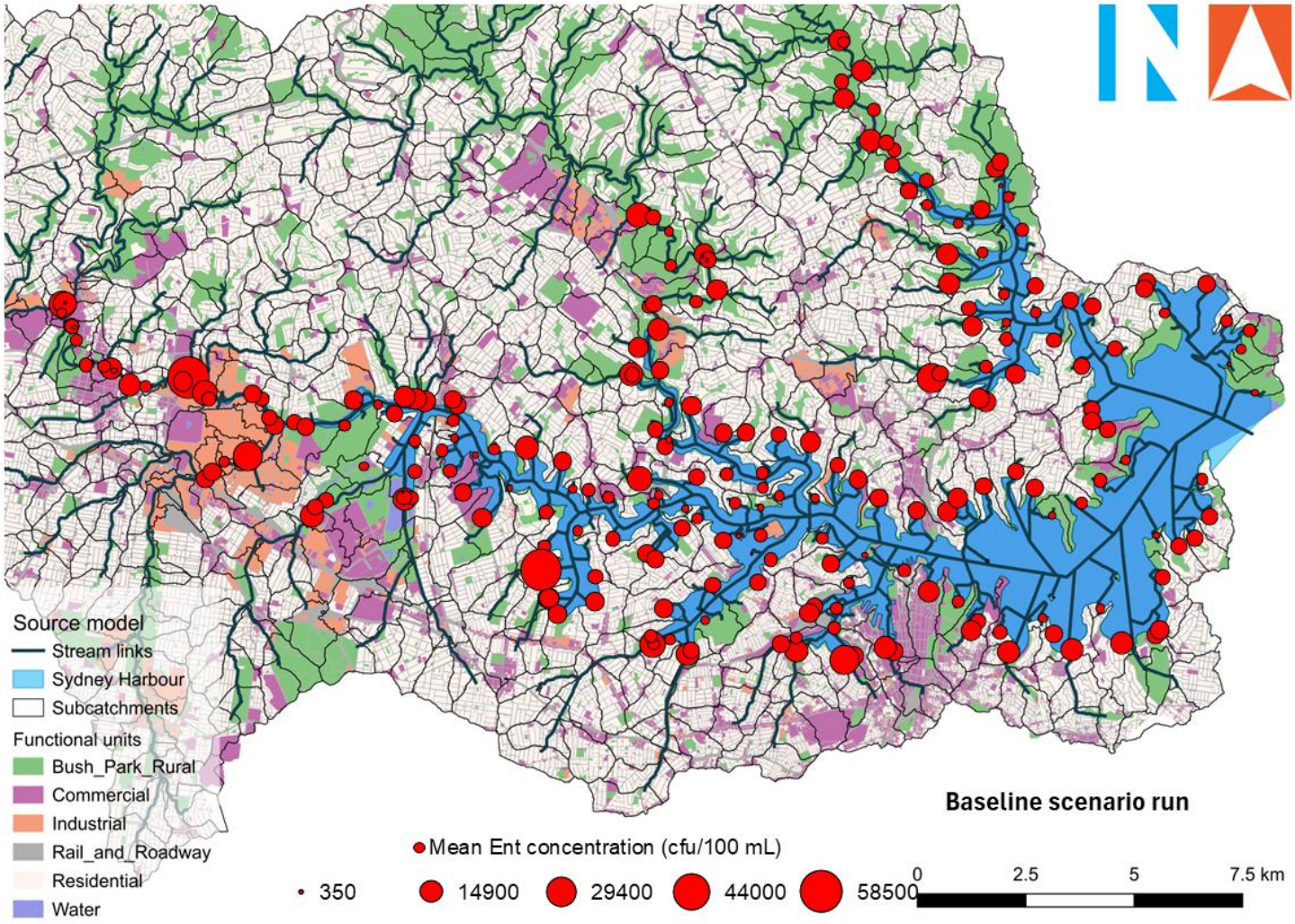
Figure_Apx F-4: Mean PO_4^{3-} concentration at inflow locations for baseline scenario



Figure_Apx F-5: Mean NOx concentration at inflow locations for baseline scenario



Figure_Apx F-6: Mean NH_4^+ concentration at inflow locations for baseline scenario



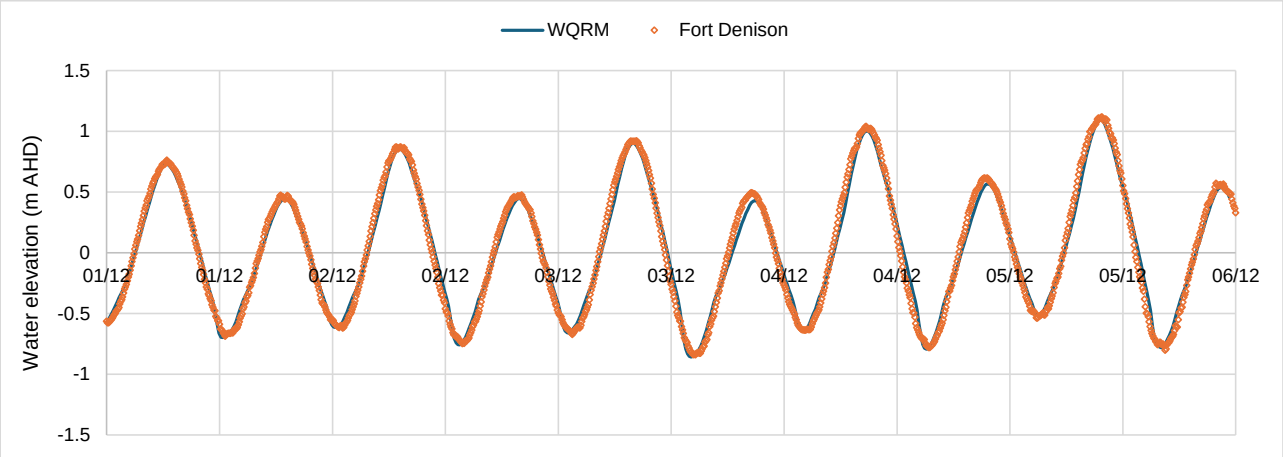
Figure_Apx F-7: Mean Ent concentration at inflow locations for baseline scenario

Appendix D Calibration Results

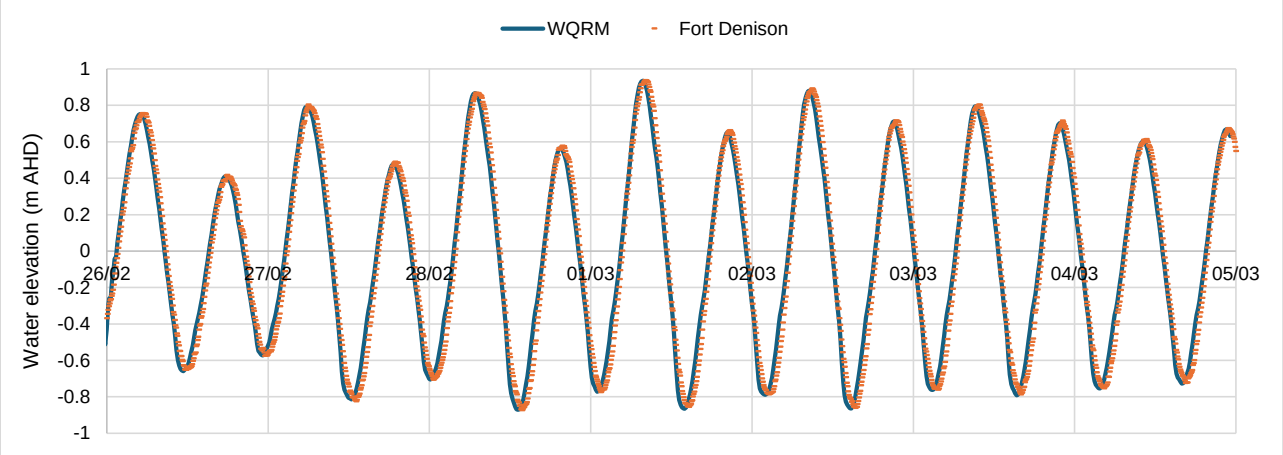
Appendix D1 Hydrodynamics

Appendix D1_1 – Hydrodynamic calibration (PA and SW data)

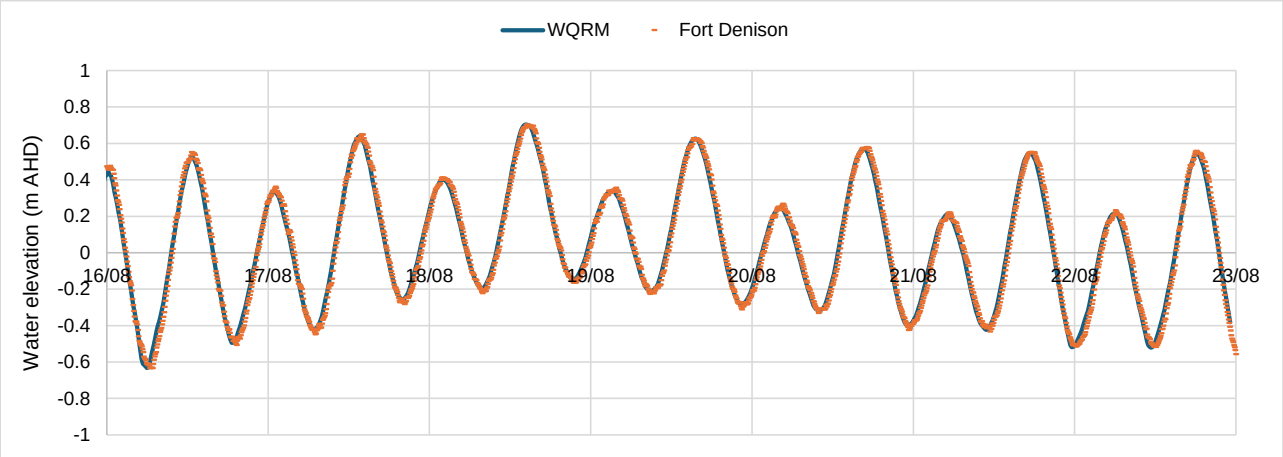
Water elevation data – Fort Denison (December 2013)



Water elevation data – Fort Denison (March 2014)



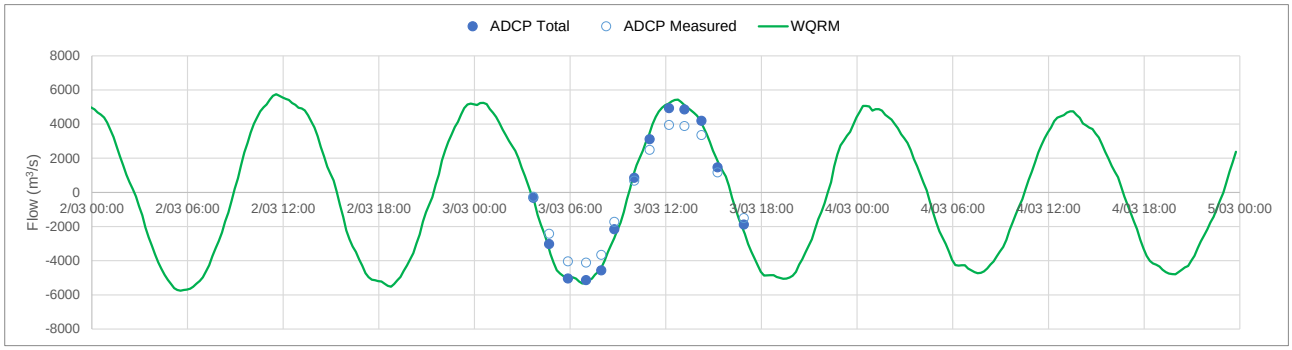
Water elevation data – Fort Denison (August 2014)



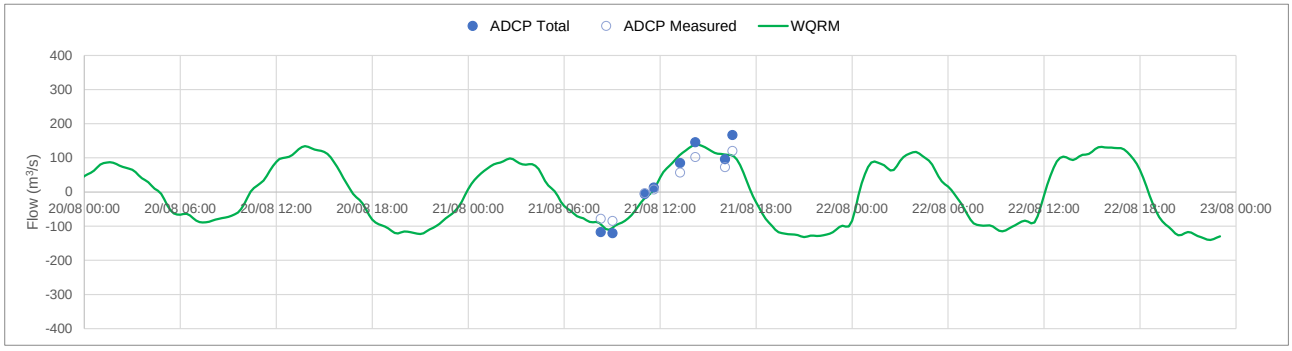
ADCP transect data – Transect C10 Middle head - South head (March 2014)

ADCP transect data – Transect C10 Middle head - South head (August 2014)

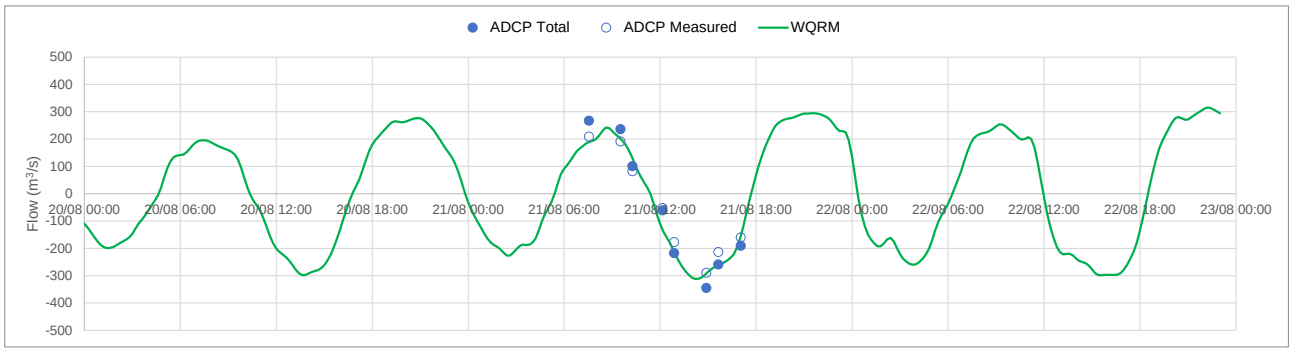
ADCP transect data – Transect C9 North head - South head (March 2014)



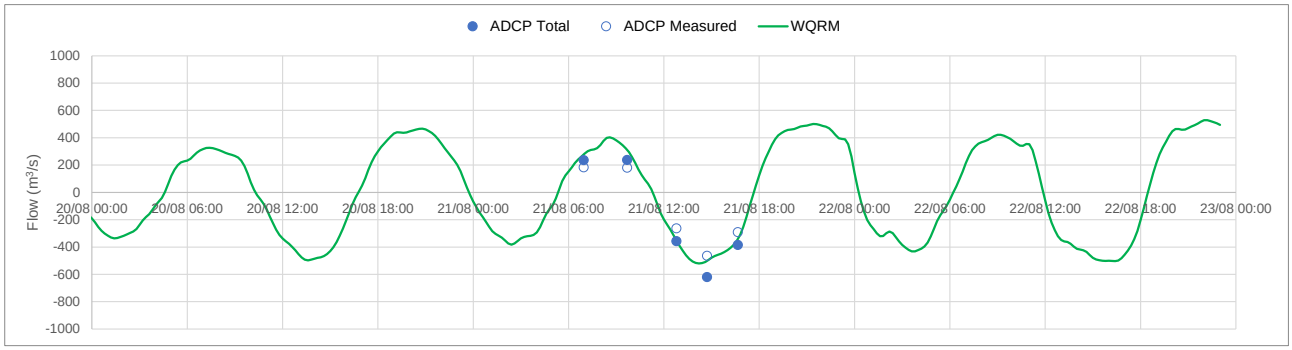
ADCP transect data – Transect C8 Rhodes - Meadowbank (Ryde bridge) (August 2014)



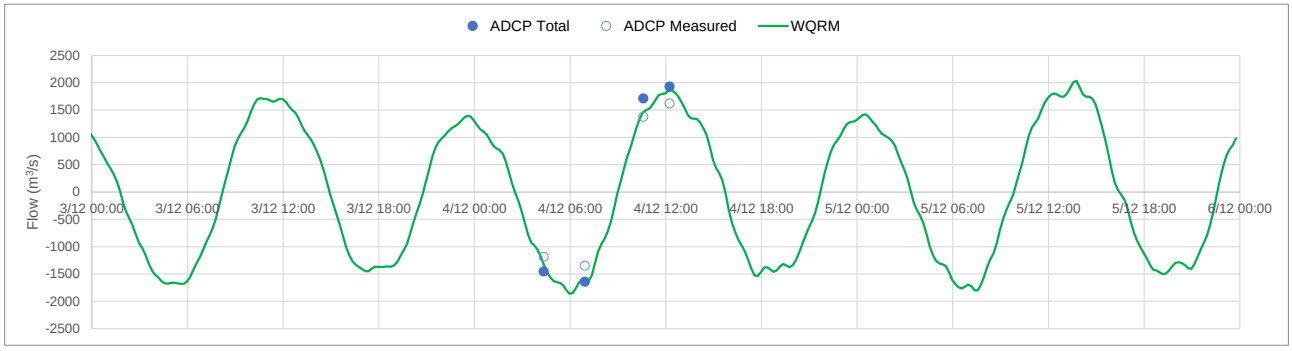
ADCP transect data – Transect C7 Cabarita – Gladesville (August 2014)



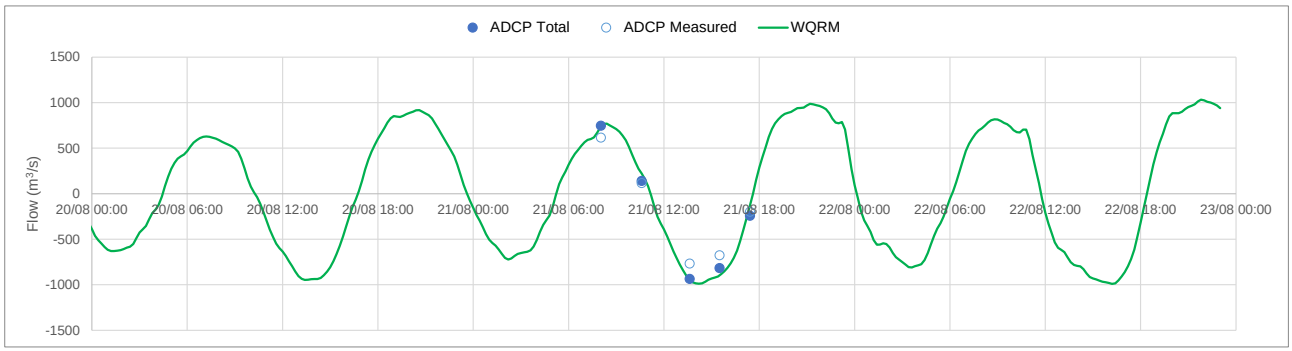
ADCP transect data – Transect C5 Drummoyne - Huntley's Point (August 2014)



ADCP transect data – Transect C3 Greenwich – Birchgrove (December 2013)

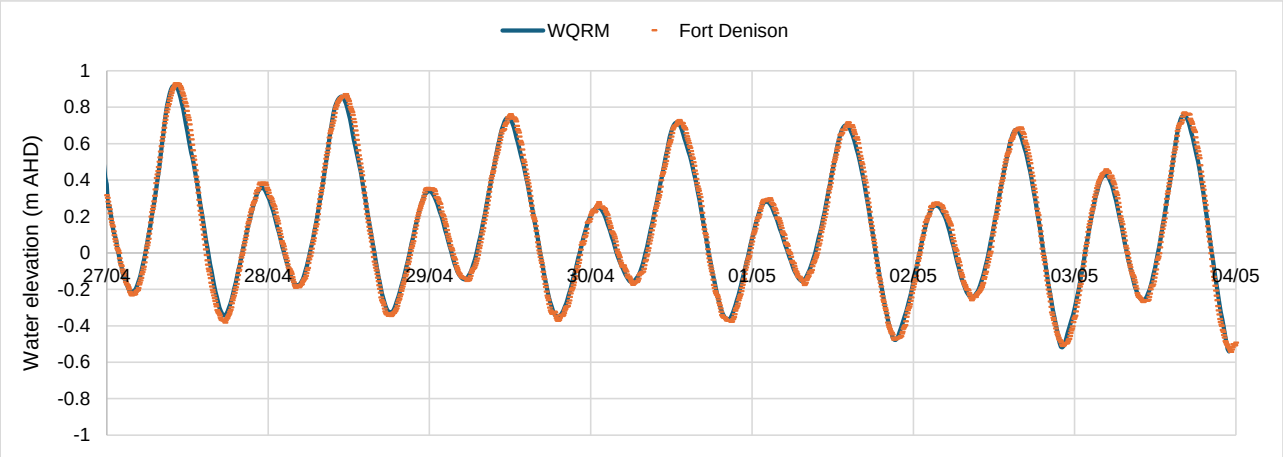


ADCP transect data – Transect C3 Greenwich – Birchgrove (August 2014)

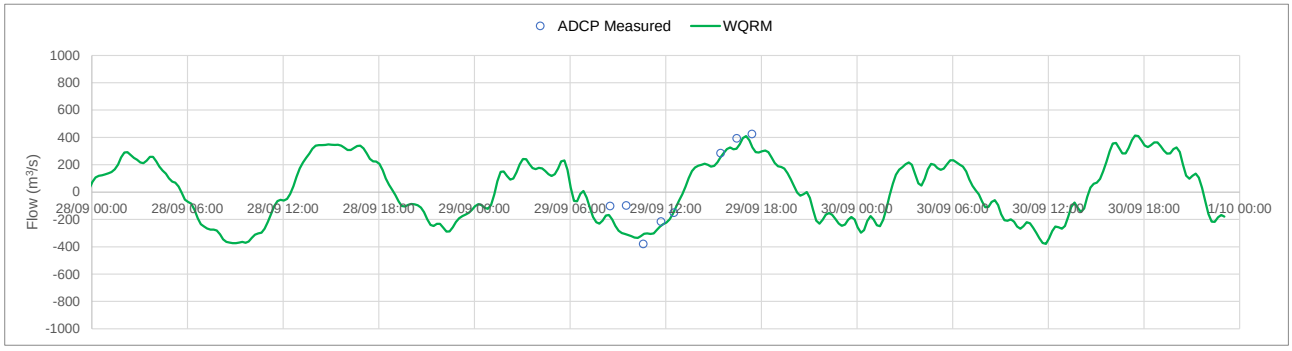


Appendix D1_2 – Hydrodynamic validation (PA and SW data

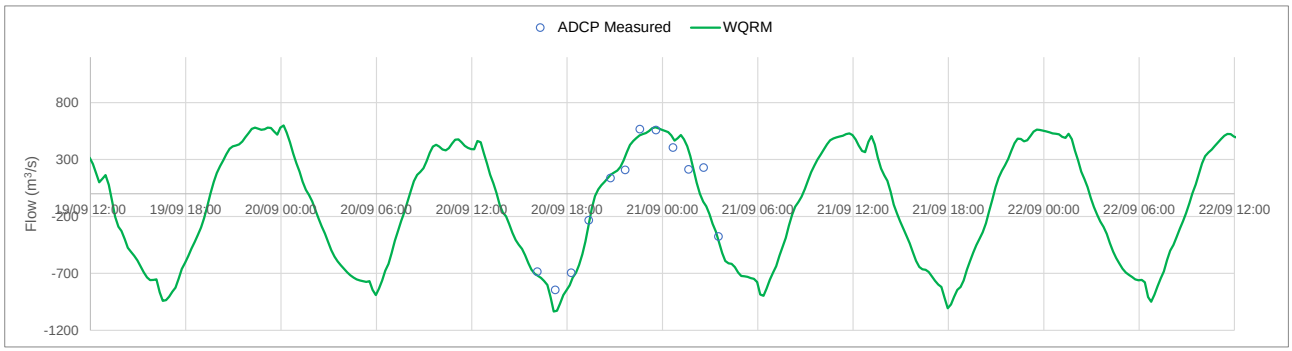
Water elevation data – Fort Denison (May 2024)



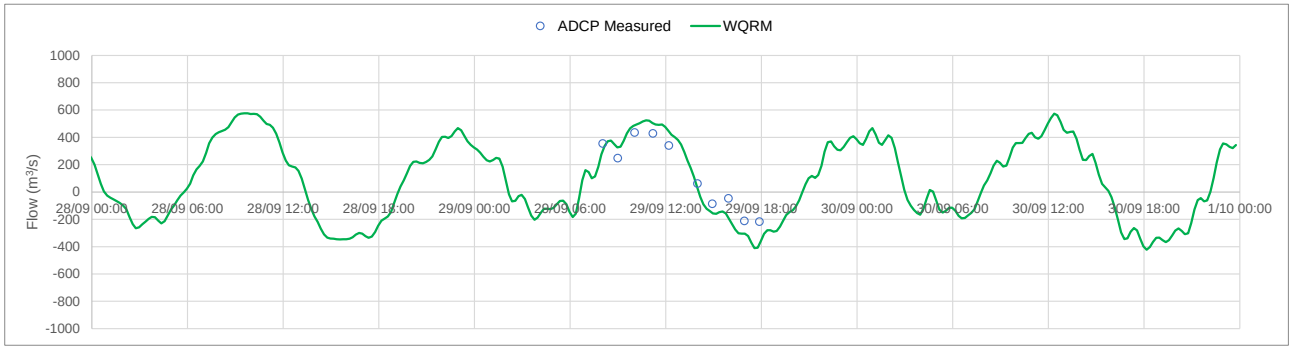
ADCP transect data – V1 Bedlam Point (September 2021 – Neaps)



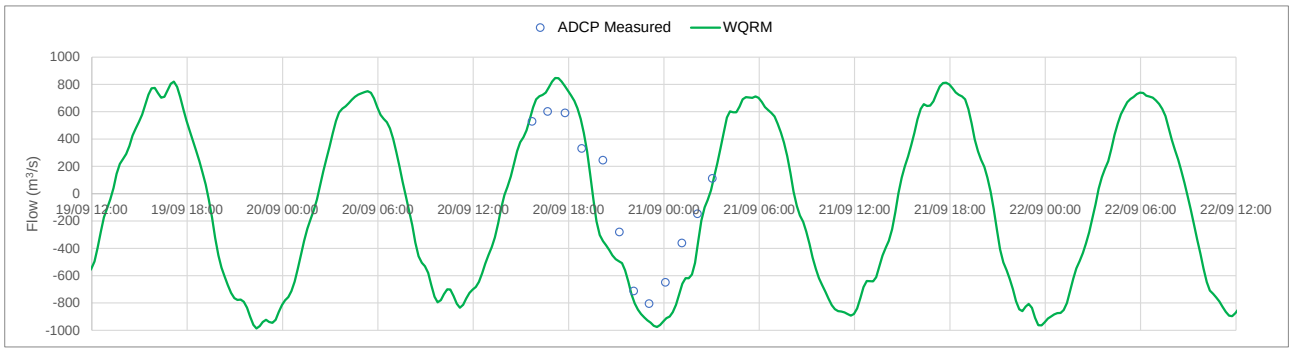
ADCP transect data – V1 Bedlam Point (September 2021 – Springs)



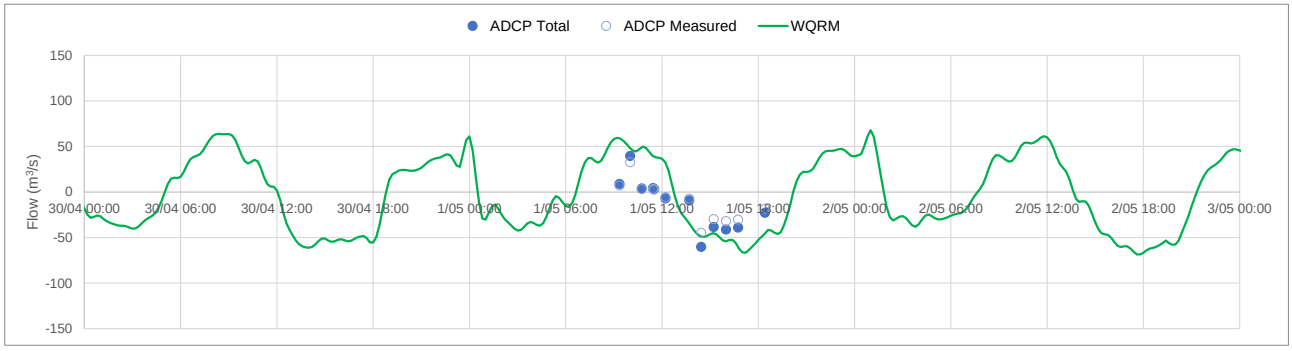
ADCP transect data – V2 Pulpit Point (September 2021 – Neaps)



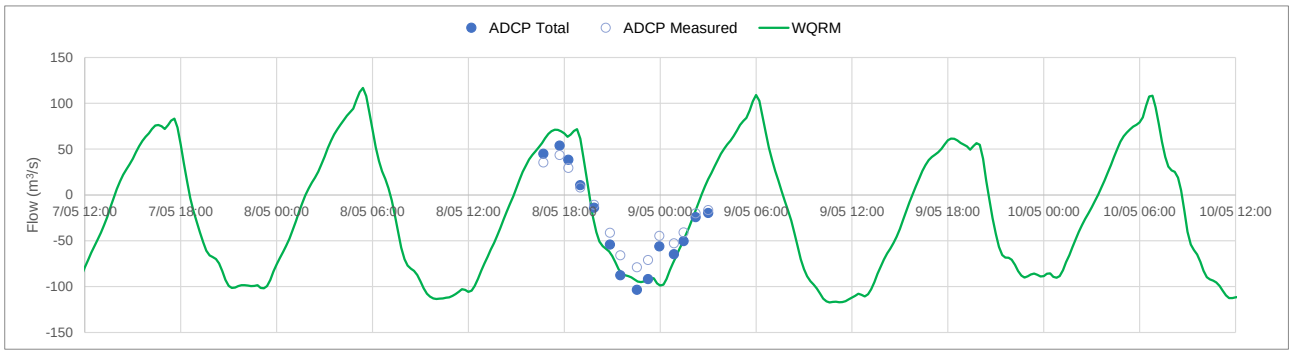
ADCP transect data – V2 Pulpit Point (September 2021 – Springs)



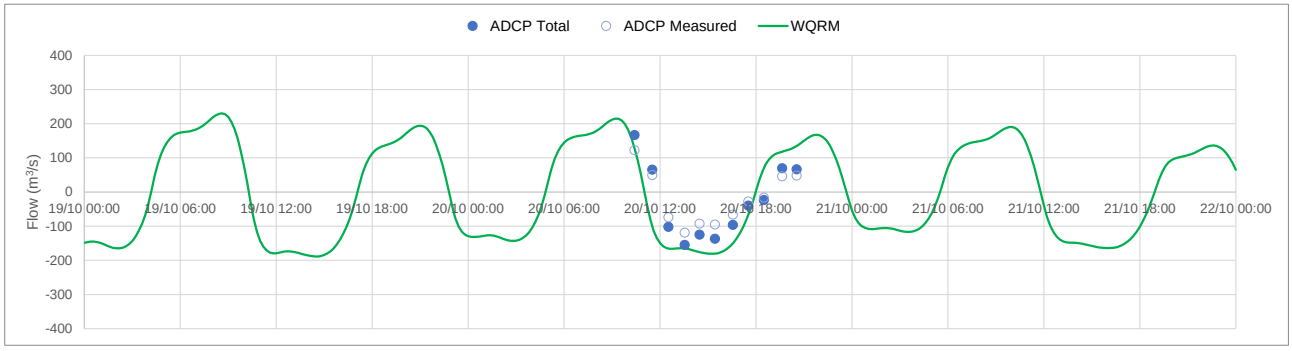
ADCP transect data – V3 Wentworth Point (May 2024 – Neaps)



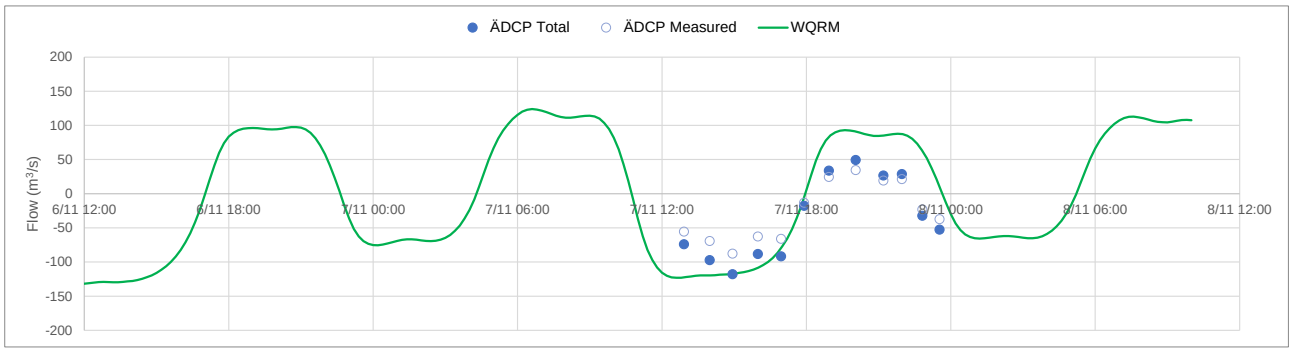
ADCP transect data – V3 Wentworth Point (May 2024 – Springs)



ADCP transect data – V4 John Whitton Bridge (October 2024 – Springs)

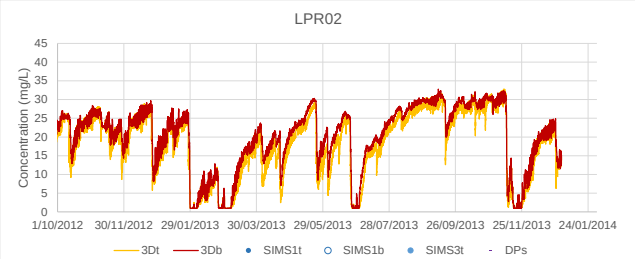


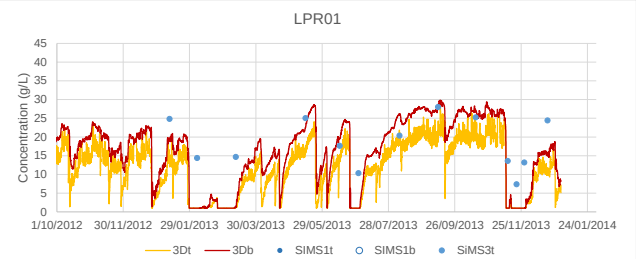
ADCP transect data – V4 John Whitton Bridge (November 2024 – Neaps)

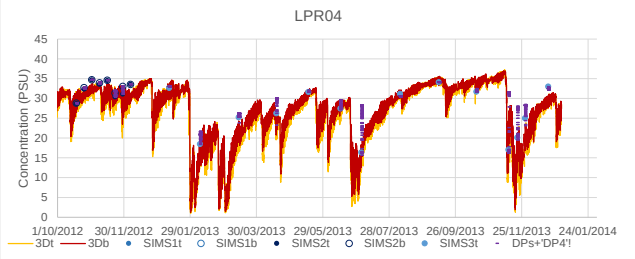


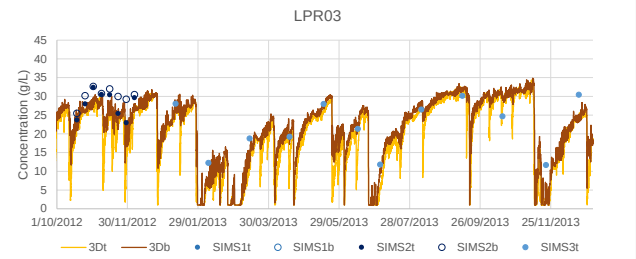
Appendix D2 Salinity

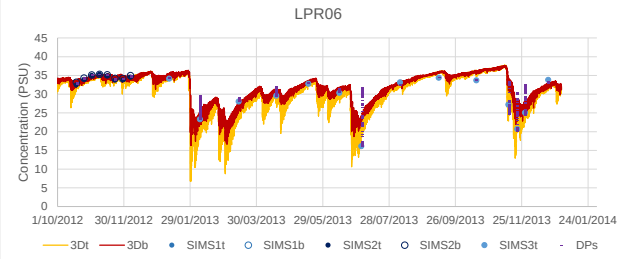
Appendix D2_1 – Salinity calibration (SIMS data 2012-13)

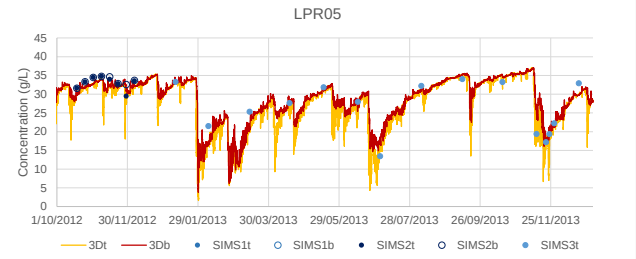

LPR02
Concentration (mg/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS3t DPs

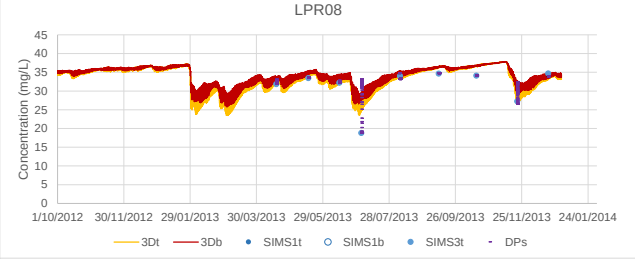

LPR01
Concentration (g/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SiMS3t

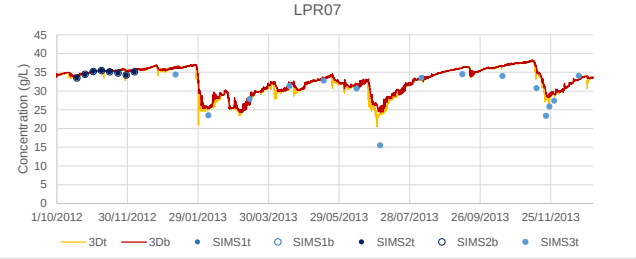

LPR04
Concentration (PSU)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t DPs+'DP4'!

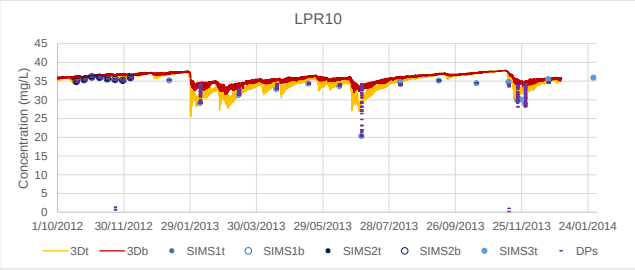

LPR03
Concentration (g/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

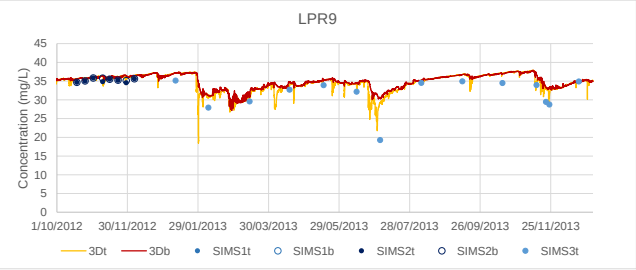

LPR06
Concentration (PSU)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t DPs

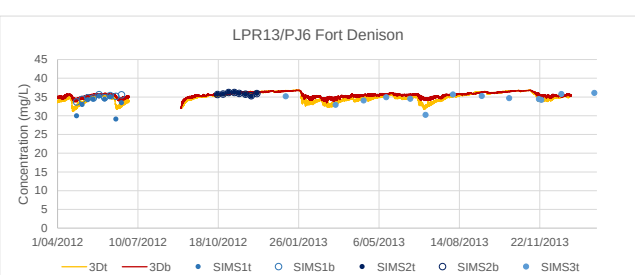

LPR05
Concentration (g/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

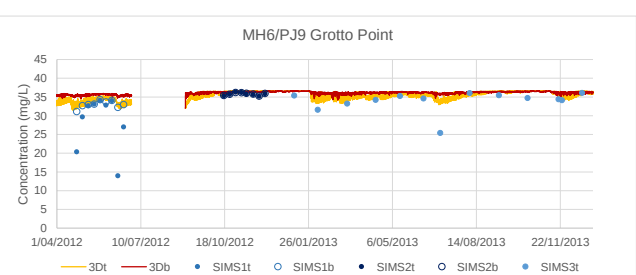

LPR08
Concentration (mg/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS3t DPs


LPR07
Concentration (g/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

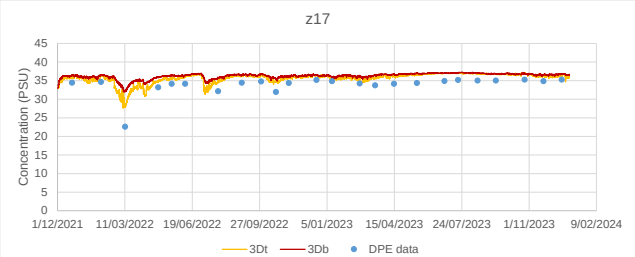

LPR10
Concentration (mg/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t DPs

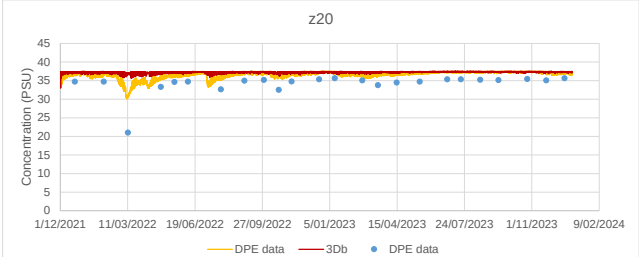

LPR9
Concentration (mg/L)
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

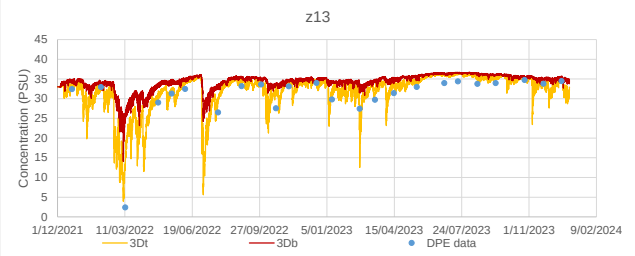

LPR13/PJ6 Fort Denison
Concentration (mg/L)
1/04/2012 10/07/2012 18/10/2012 26/01/2013 6/05/2013 14/08/2013 22/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

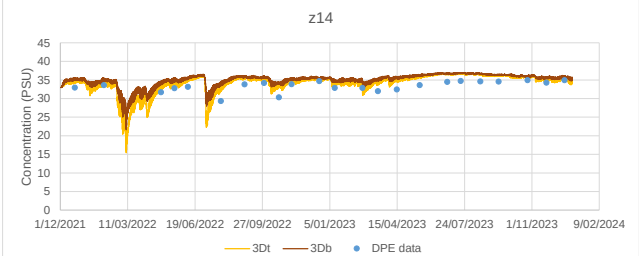

MH6/PJ9 Grotto Point
Concentration (mg/L)
1/04/2012 10/07/2012 18/10/2012 26/01/2013 6/05/2013 14/08/2013 22/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

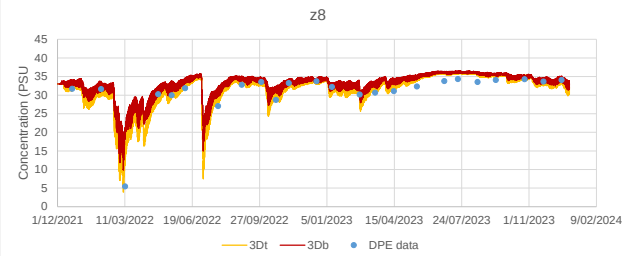
Appendix D2_2 – Salinity validation (DCCEEW data 2022-23)


z17
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z20
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
DPE data
3Db
DPE data


z13
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z14
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z8
Concentration (PSU)
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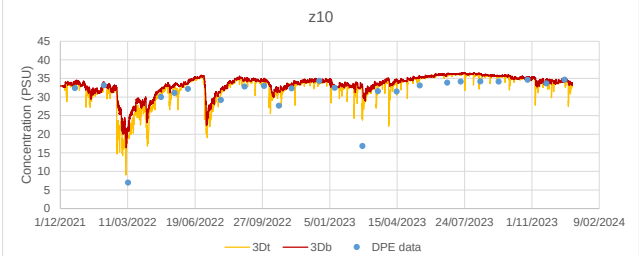
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z10
Concentration (PSU)
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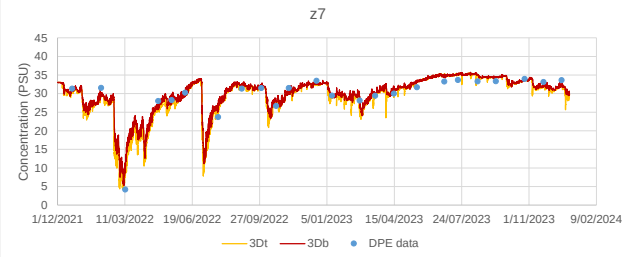
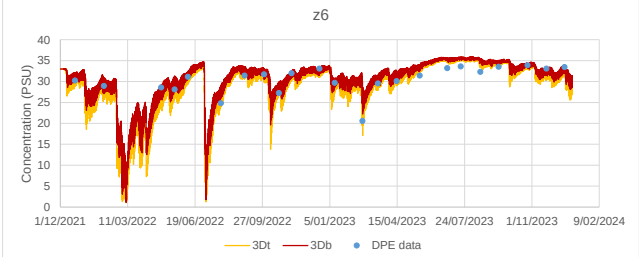
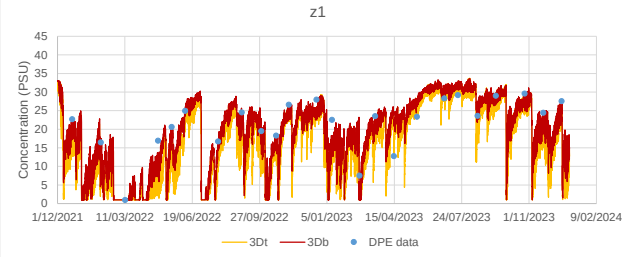
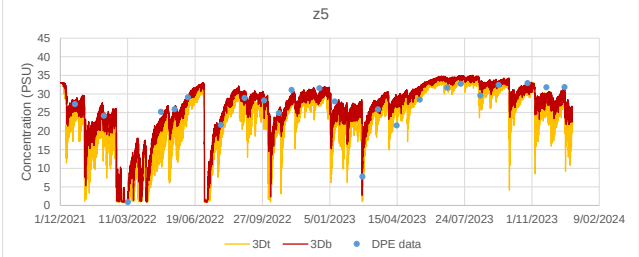
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z7
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z6
Concentration (PSU)
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z1
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

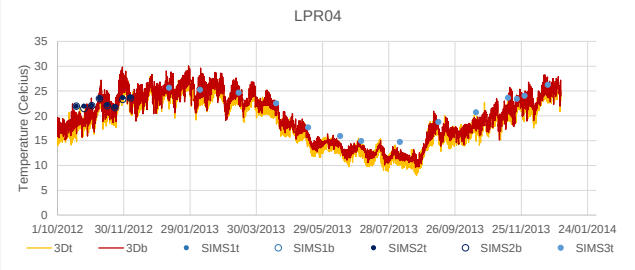

z5
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

Appendix D3 Temperature

Appendix D3_1 – Temperature calibration (SIMS data 2012-13)

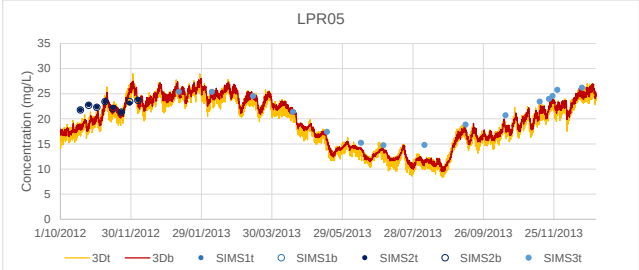
LPR02
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS3t

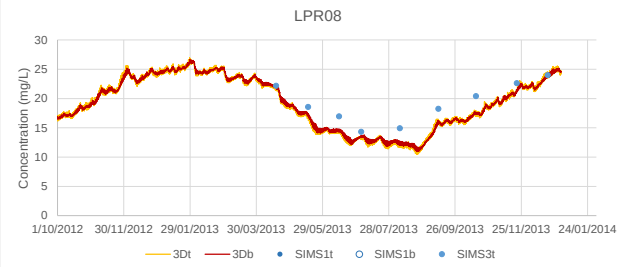
LPR01
Concentration (mg/L)
0 5 10 15 20 25 30 35
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SiMS3t


LPR04
Temperature (Celcius)
0 5 10 15 20 25 30 35
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

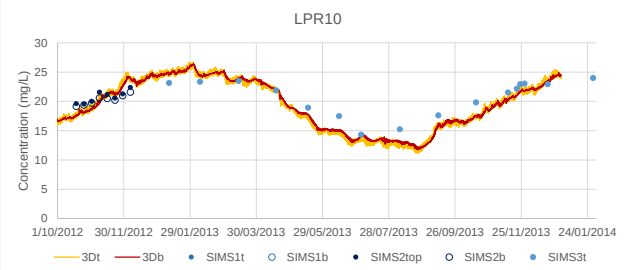
LPR03
Concentration (mg/L)
0 5 10 15 20 25 30 35
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

LPR06
Temperature (Celcius)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t


LPR05
Concentration (mg/L)
0 5 10 15 20 25 30 35
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

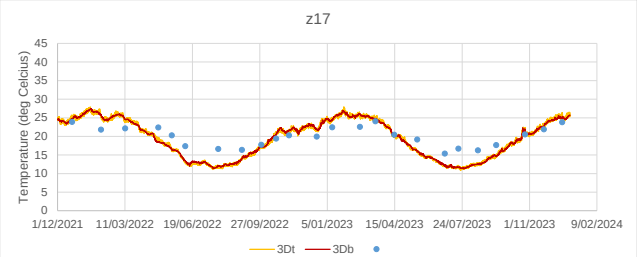

LPR08
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS3t

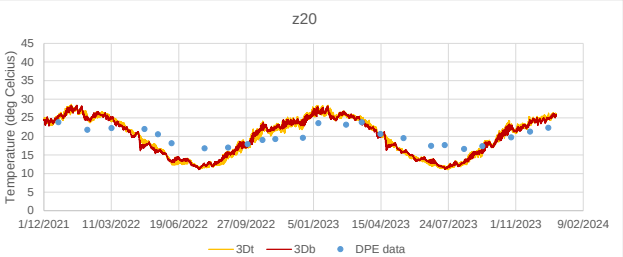
LPR07
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

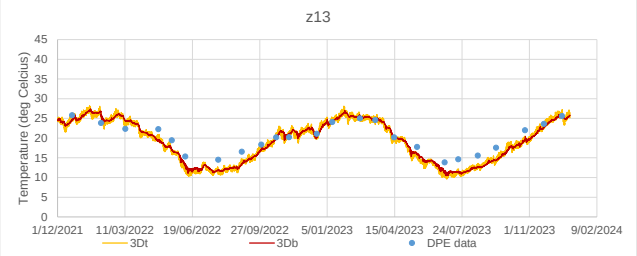

LPR10
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013 24/01/2014
3Dt 3Db SIMS1t SIMS1b SIMS2top SIMS2b SIMS3t

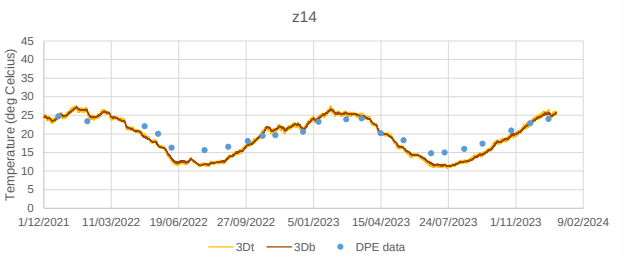
LPR9
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 30/11/2012 29/01/2013 30/03/2013 29/05/2013 28/07/2013 26/09/2013 25/11/2013
3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

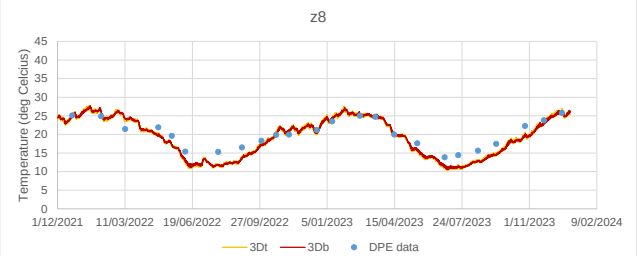
Appendix D3_2 – Temperature validation (DCCEEW data 2022-23)

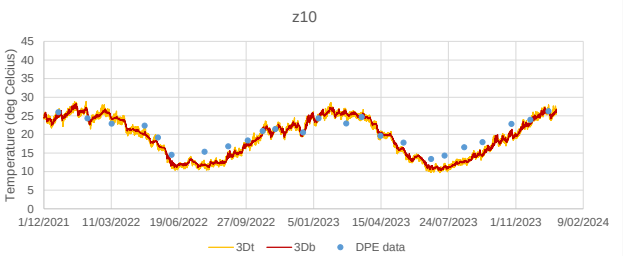

z17
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db

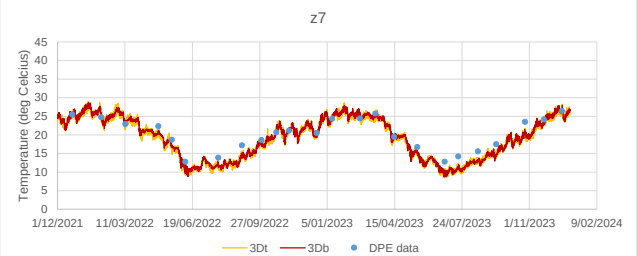

z20
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

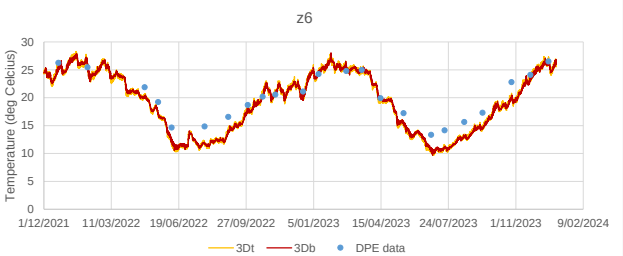

z13
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

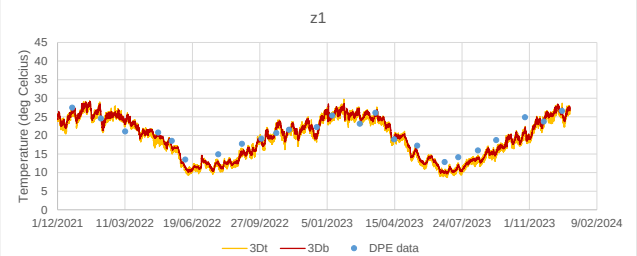

z14
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

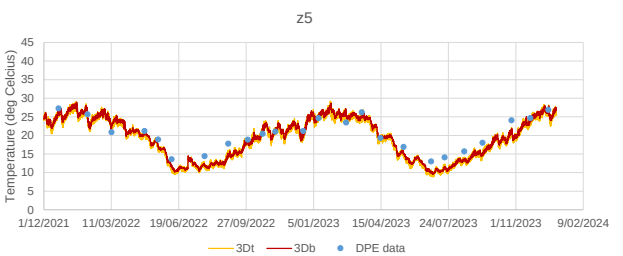

z8
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z10
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data


z7
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

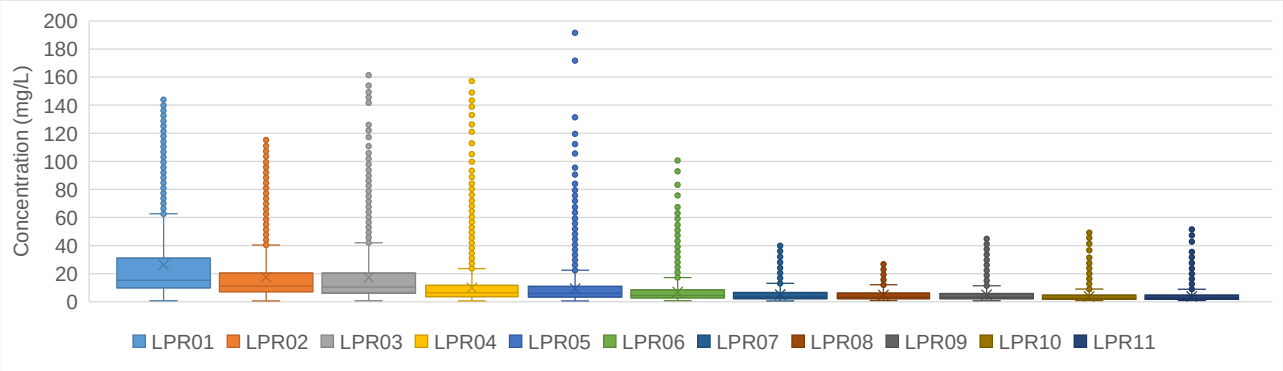

z6
Temperature (deg Celcius)
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

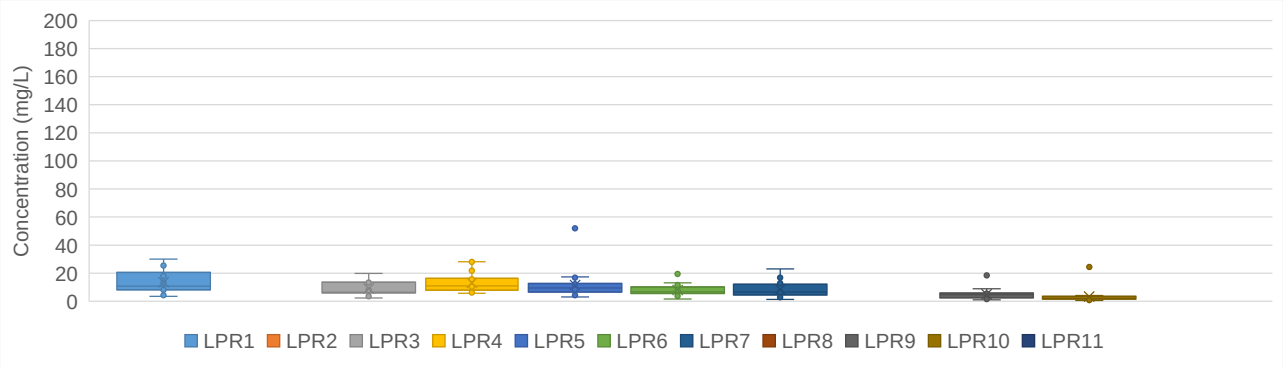

z1
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

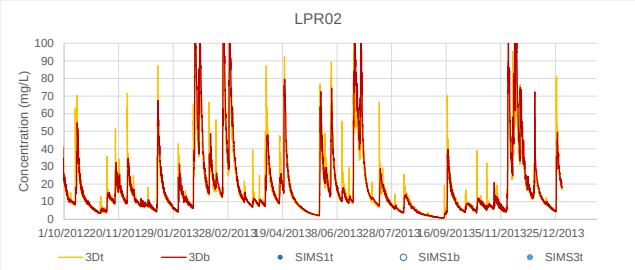

z5
Temperature (deg Celcius)
45
40
35
30
25
20
15
10
5
0
1/12/2021
11/03/2022
19/06/2022
27/09/2022
5/01/2023
15/04/2023
24/07/2023
1/11/2023
9/02/2024
3Dt
3Db
DPE data

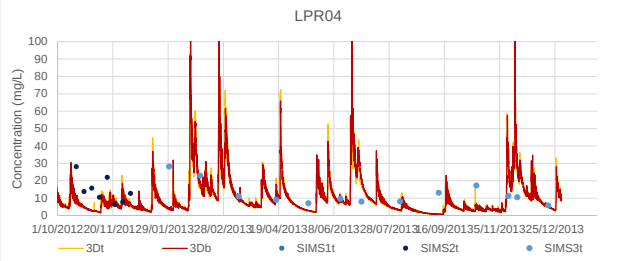
Appendix D4 Total Suspended Solids

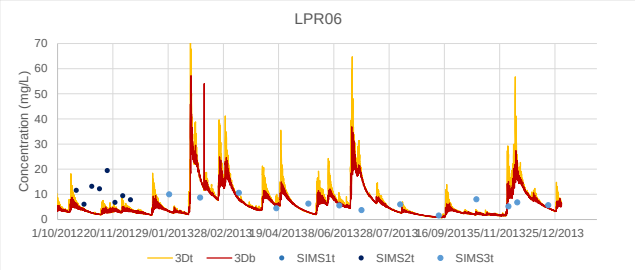
Appendix D4_1 – Total Suspended Solids calibration (SIMS data 2012-13)

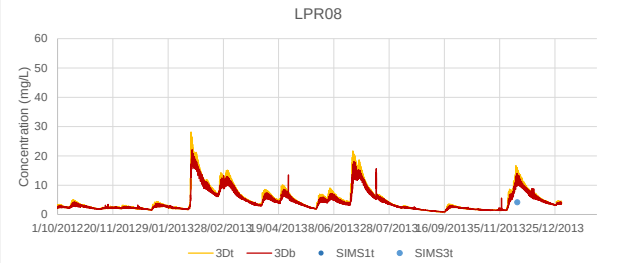


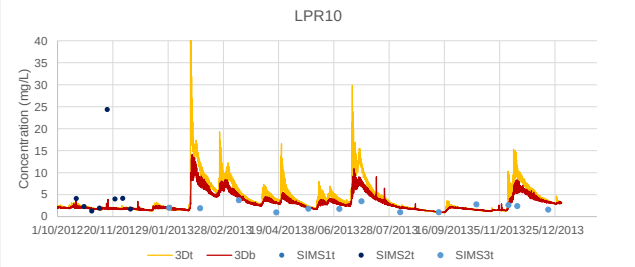


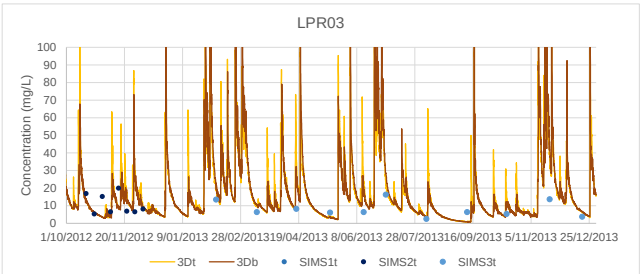

LPR02
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t

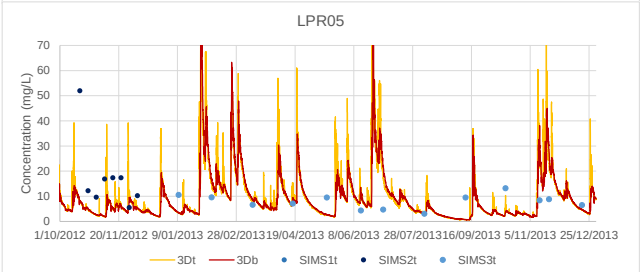

LPR04
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t

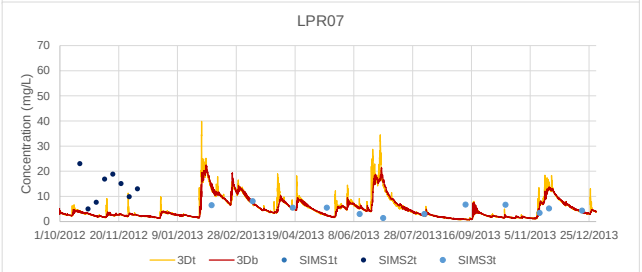

LPR06
Concentration (mg/L)
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t

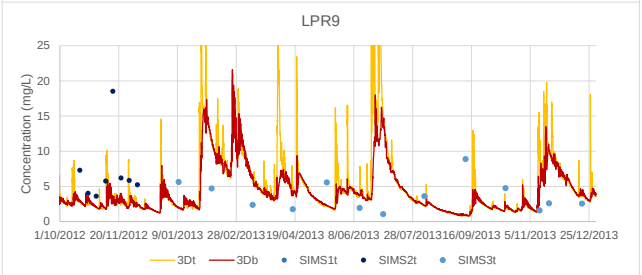

LPR08
Concentration (mg/L)
60
50
40
30
20
10
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS3t


LPR10
Concentration (mg/L)
40
35
30
25
20
15
10
5
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t


LPR03
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
9/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t

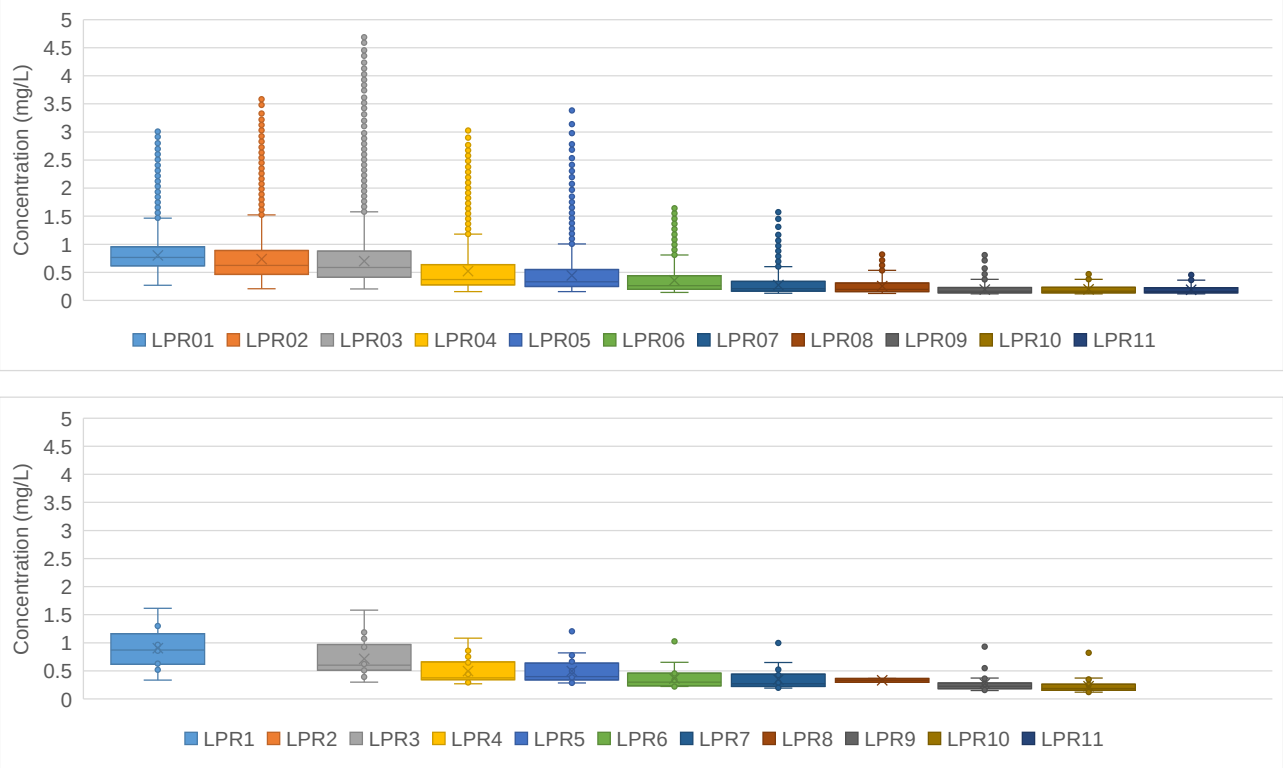

LPR05
Concentration (mg/L)
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
9/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t


LPR07
Concentration (mg/L)
70
60
50
40
30
20
10
0
1/10/2012
20/11/2012
9/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t


LPR9
Concentration (mg/L)
25
20
15
10
5
0
1/10/2012
20/11/2012
9/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
3Dt
3Db
SIMS1t
SIMS2t
SIMS3t

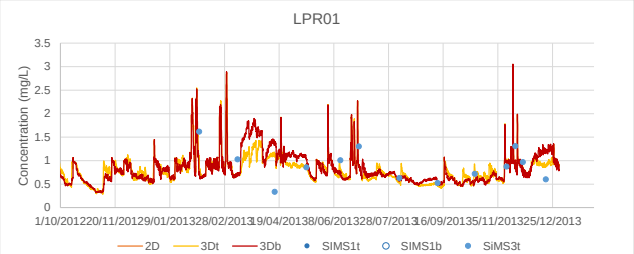
Appendix D5 Total Nitrogen

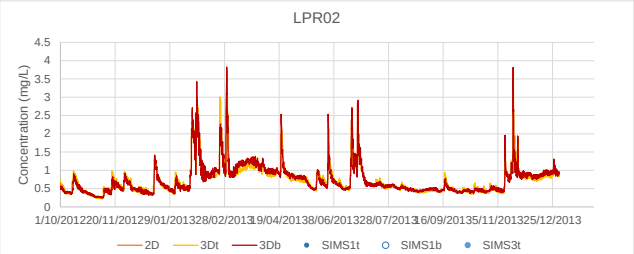
Appendix D5_1 – Total Nitrogen calibration (SIMS data 2012-13)

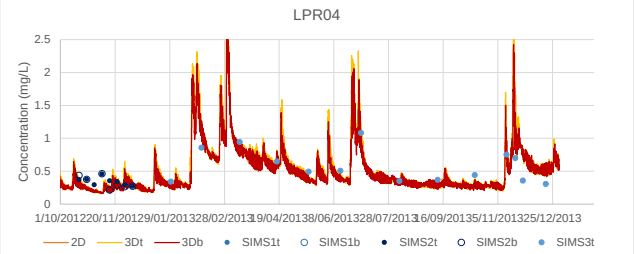


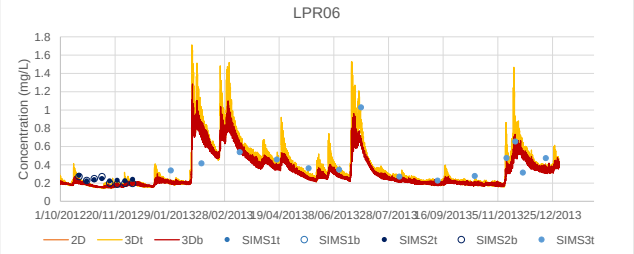
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

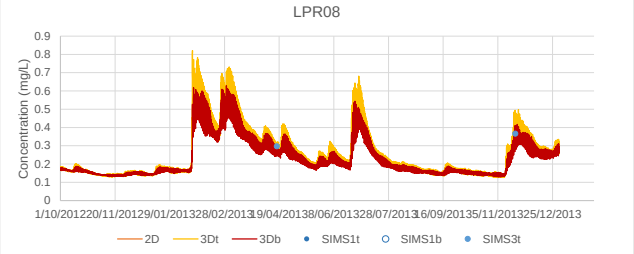
Timeseries plots presented below

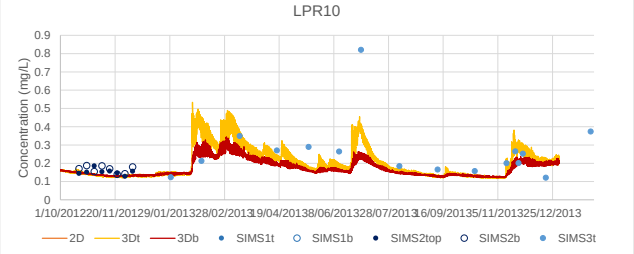

LPR01
Concentration (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SiMS3t

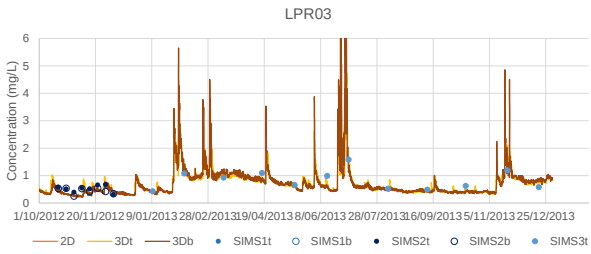

LPR02
Concentration (mg/L)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t

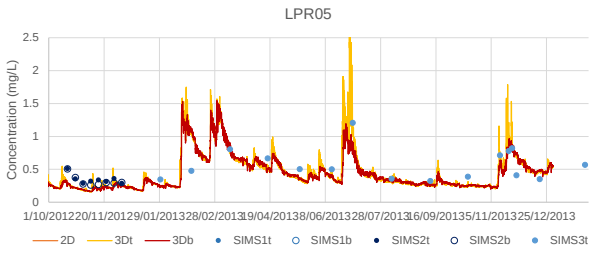

LPR04
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

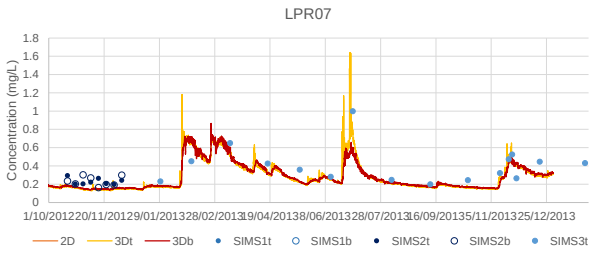

LPR06
Concentration (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

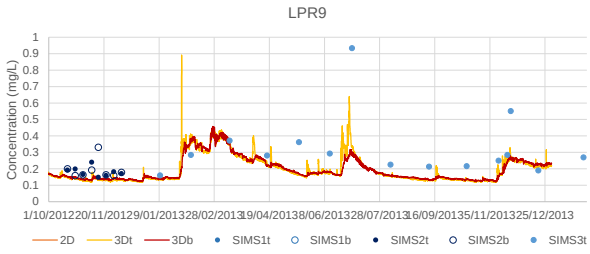

LPR08
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR10
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2top
SIMS2b
SIMS3t

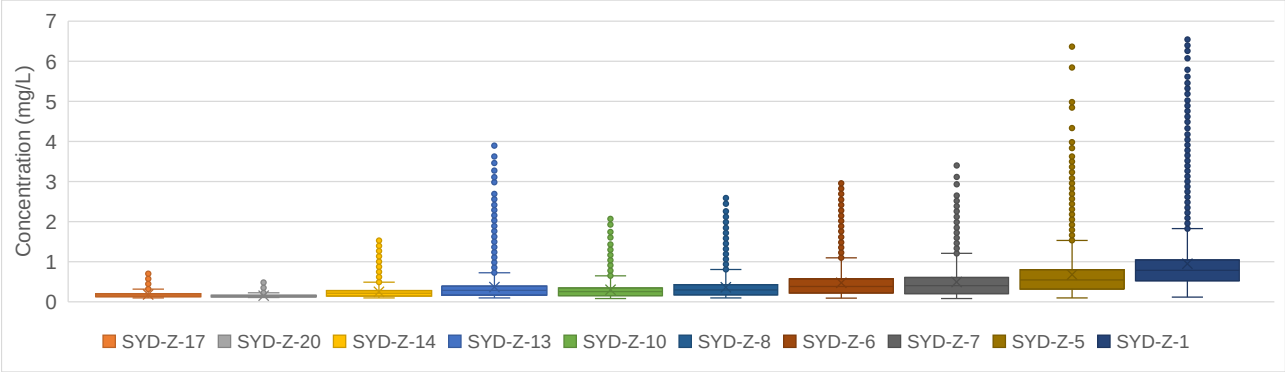

LPR03
Concentration (mg/L)
6
5
4
3
2
1
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

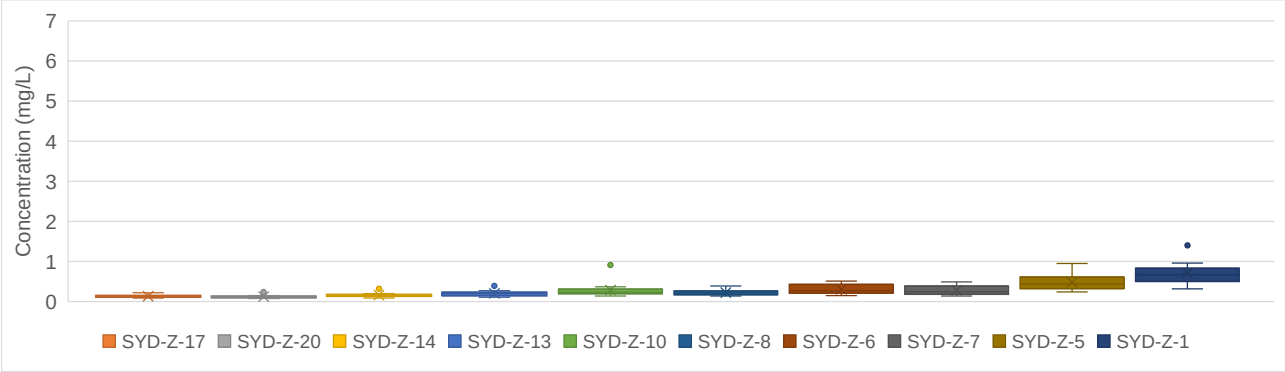

LPR05
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR07
Concentration (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR9
Concentration (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

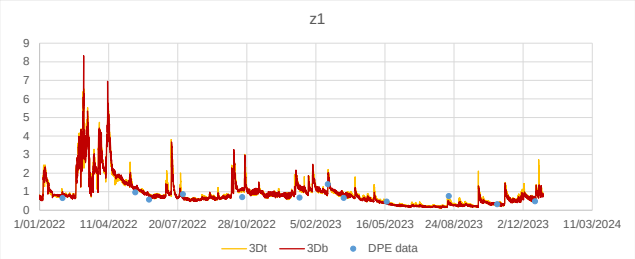
Appendix D5_2 – Total Nitrogen validation (DCCEEW data 2022-23)

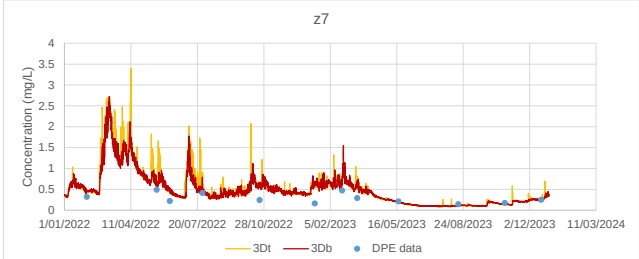


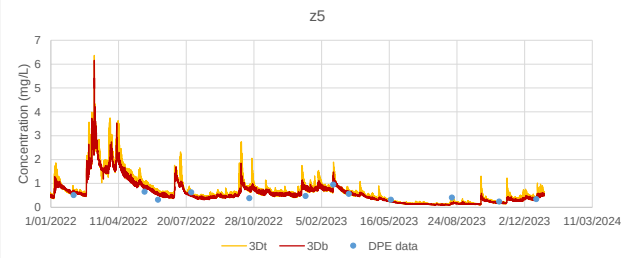


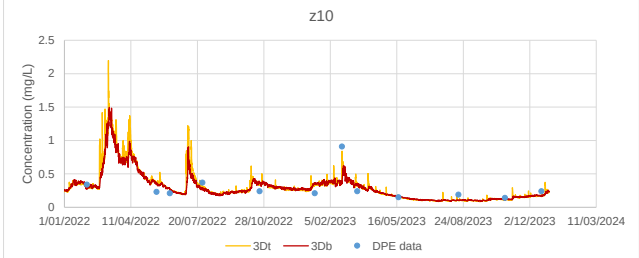
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

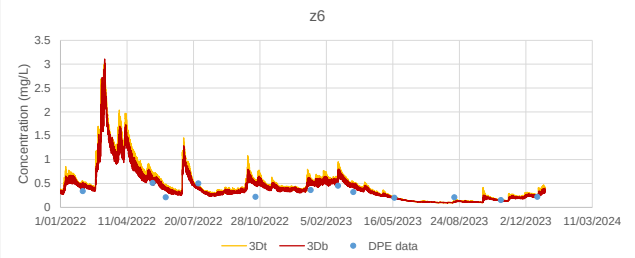
Timeseries plots presented below

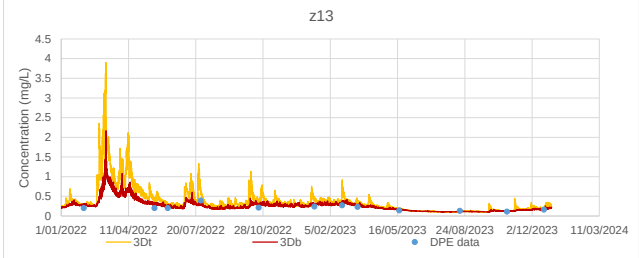

z1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

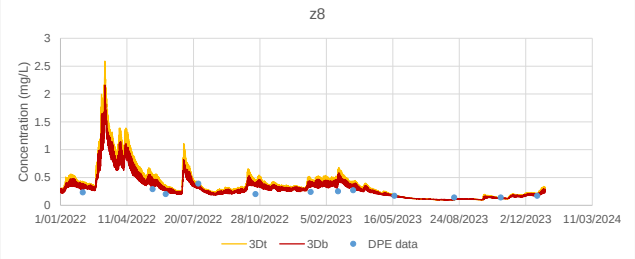

z7
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

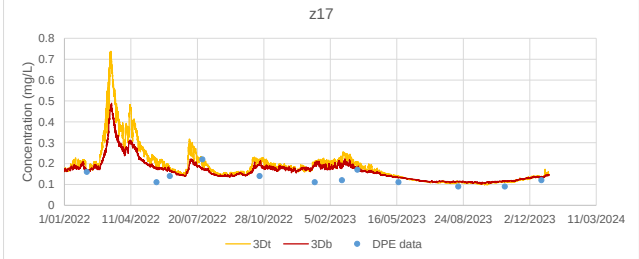

z5
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

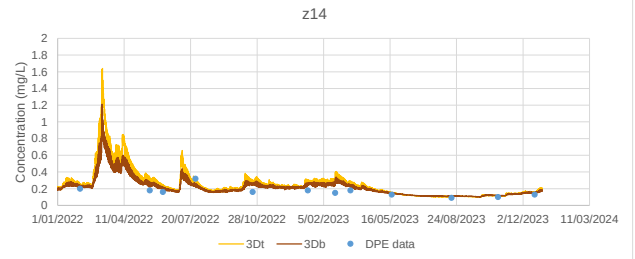

z10
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

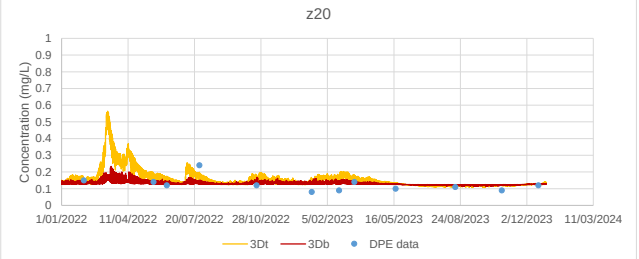

z6
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

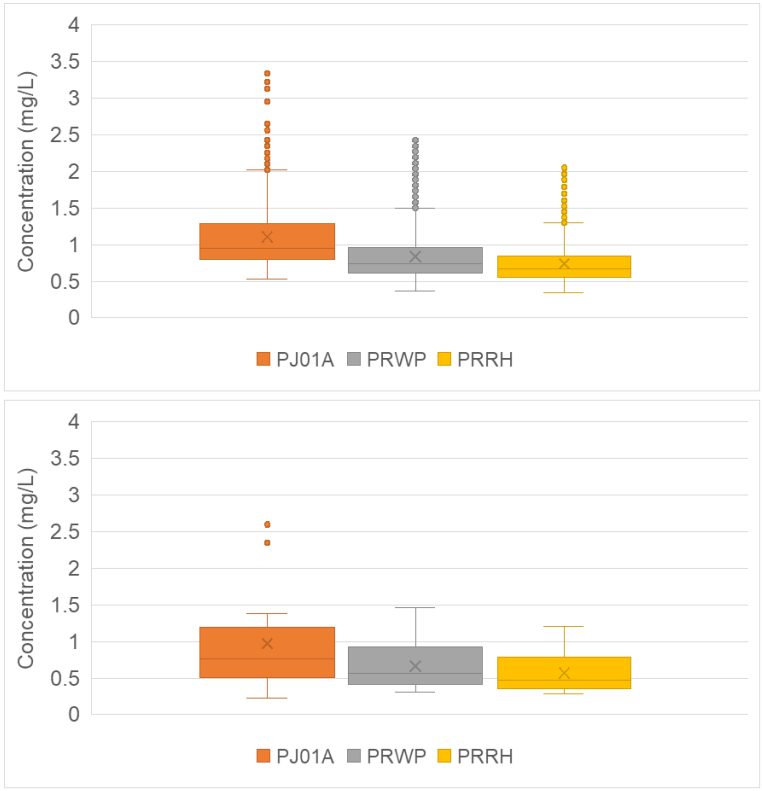

z8
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z17
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

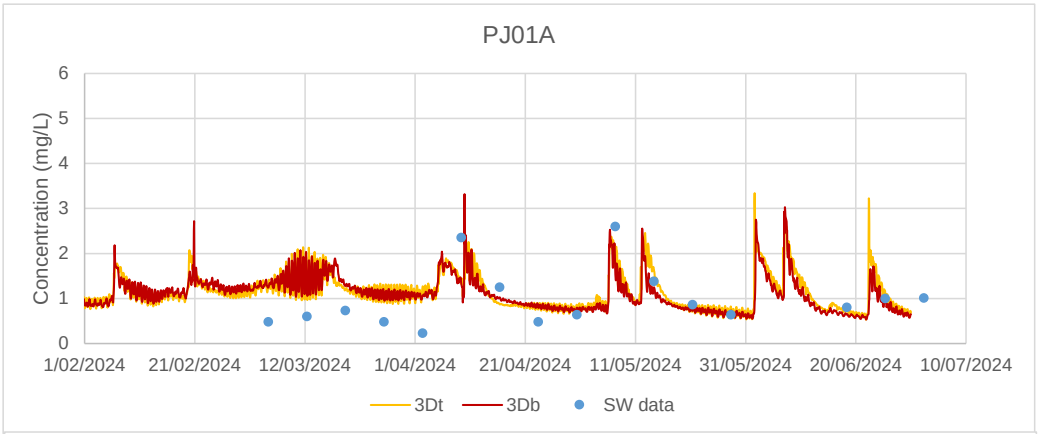

z20
Concentration (mg/L)
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

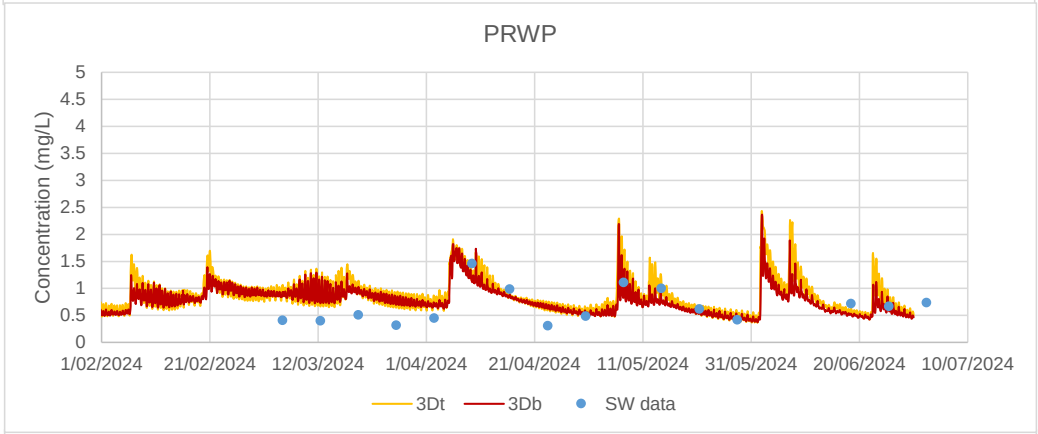
Appendix D5_3 – Total Nitrogen validation (SW data 2024)

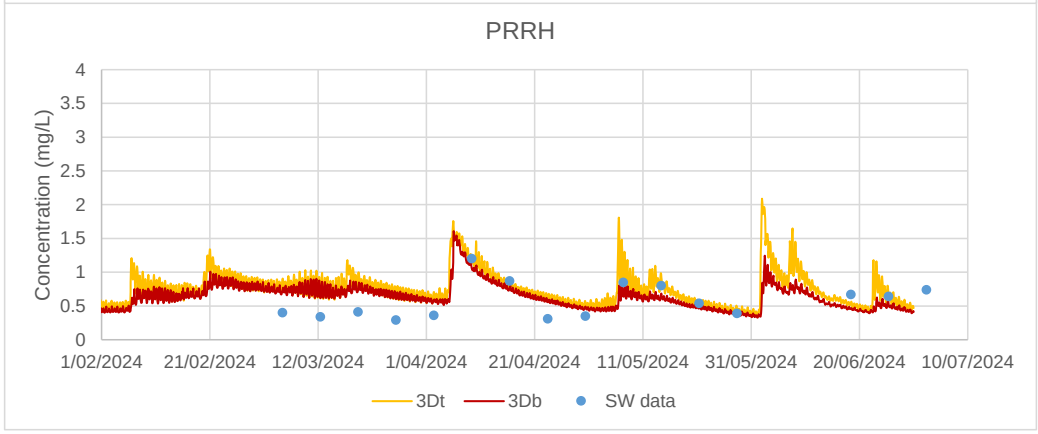


Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

Timeseries plots presented below

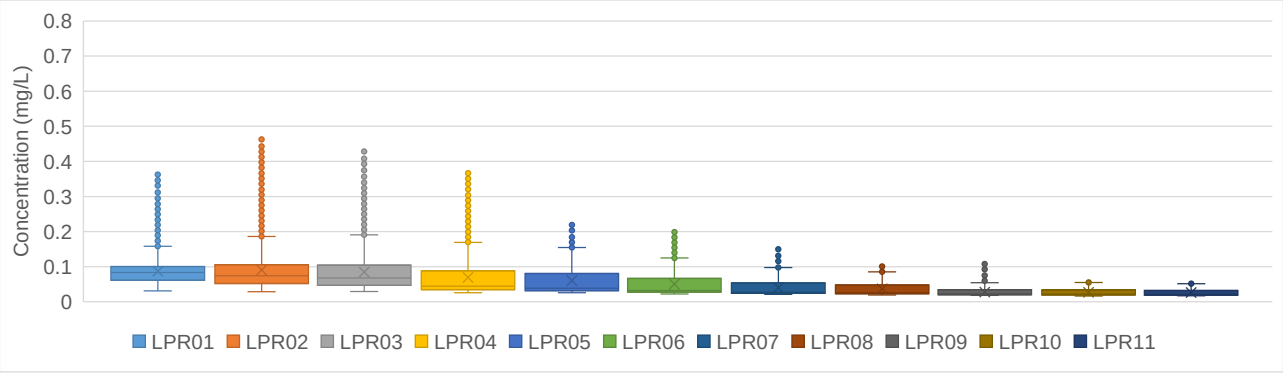

PJ01A
Concentration (mg/L)
0
1
2
3
4
5
6
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

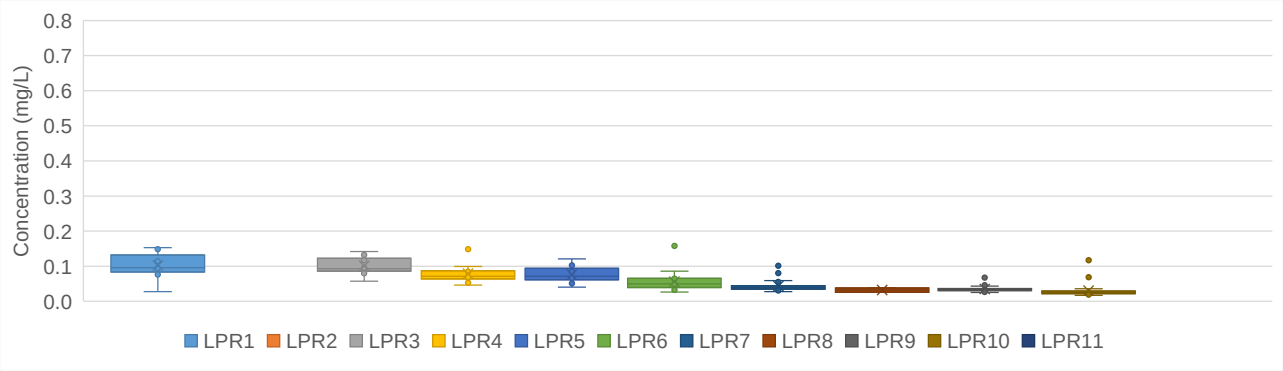

PRWP
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PRRH
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

Appendix D6 Total Phosphorus

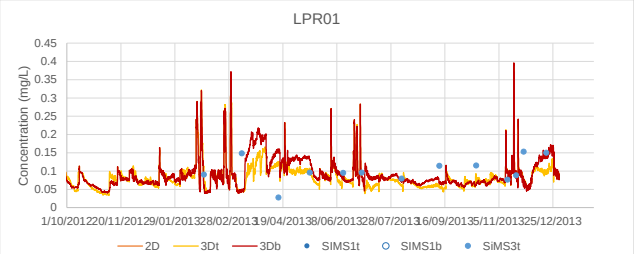
Appendix D6_1 – Total Phosphorus calibration (SIMS data 2012-13)

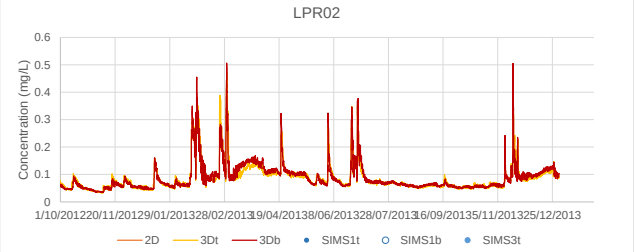


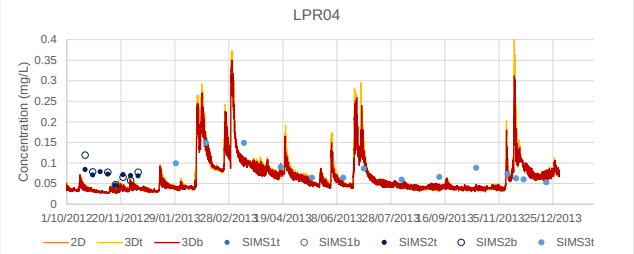


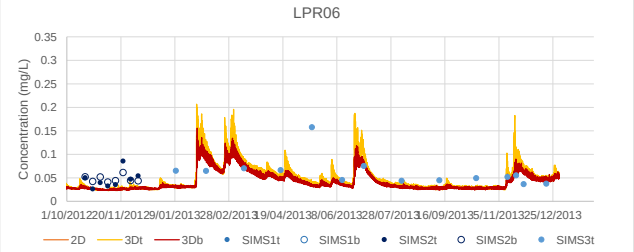
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

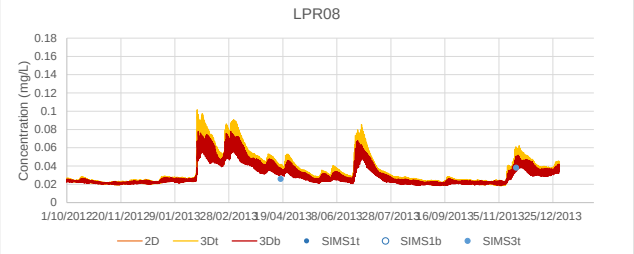
Timeseries plots presented below

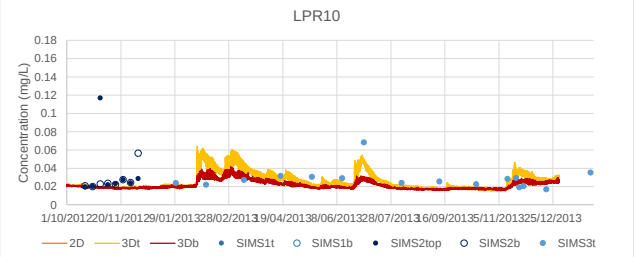

LPR01
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SiMS3t

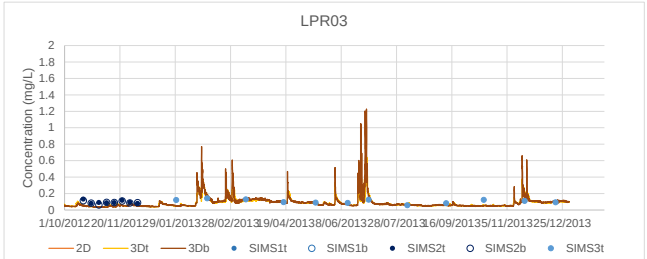

LPR02
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t

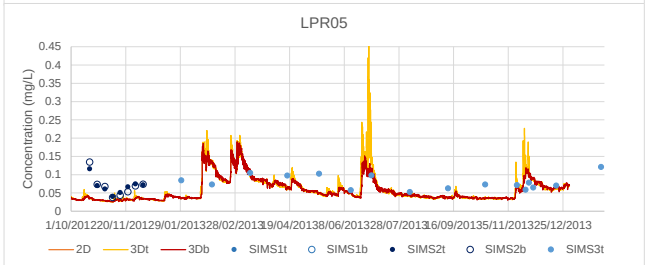

LPR04
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

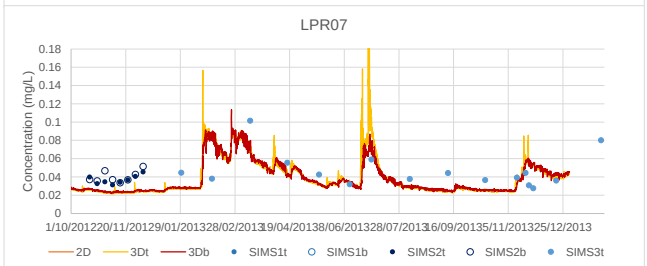

LPR06
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

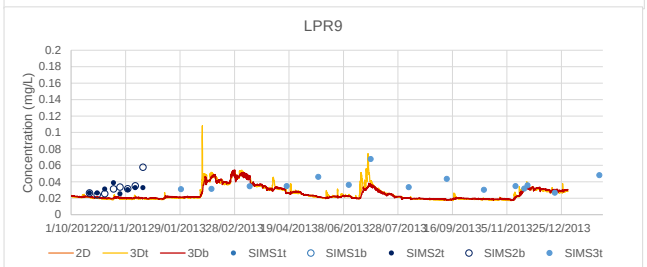

LPR08
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR10
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2top
SIMS2b
SIMS3t

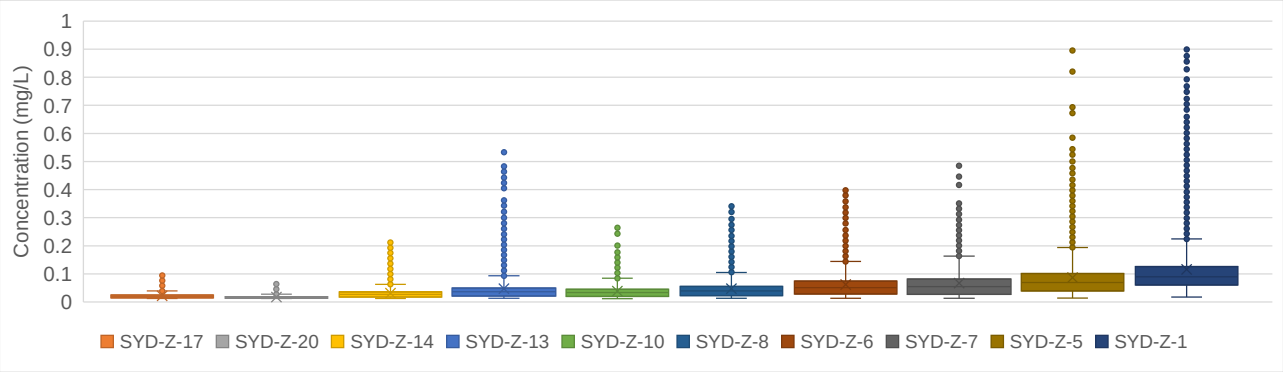

LPR03
Concentration (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

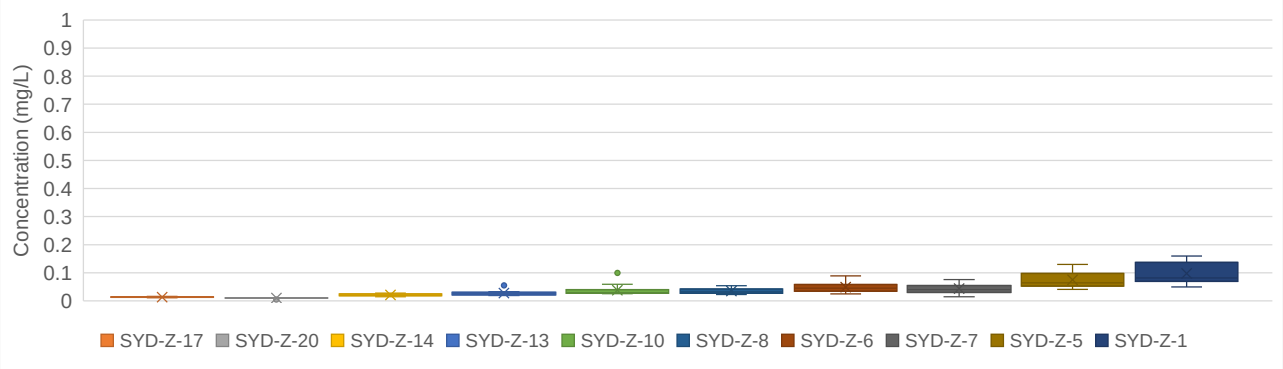

LPR05
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR07
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR9
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

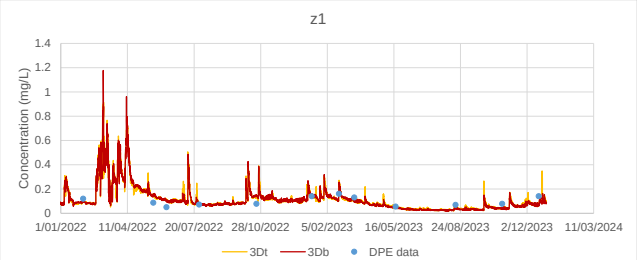
Appendix D6_2 – Total Phosphorus validation (DCCEEW data 2022-23)

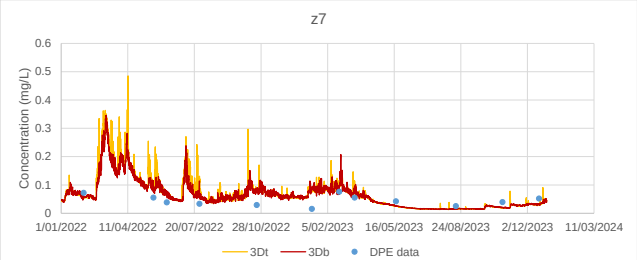


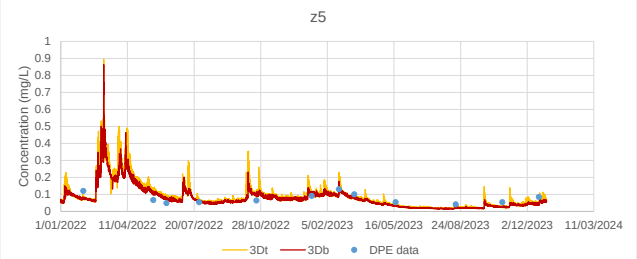


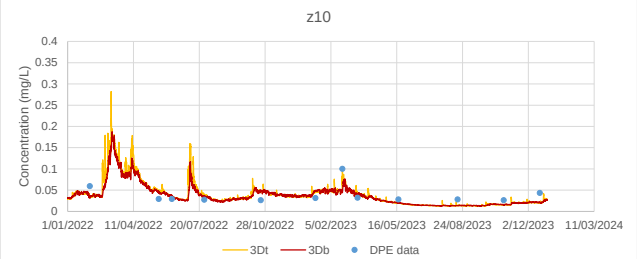
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

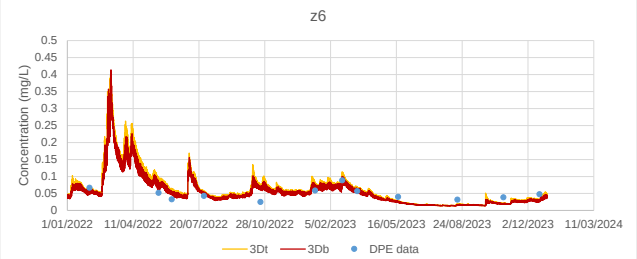
Timeseries plots presented below

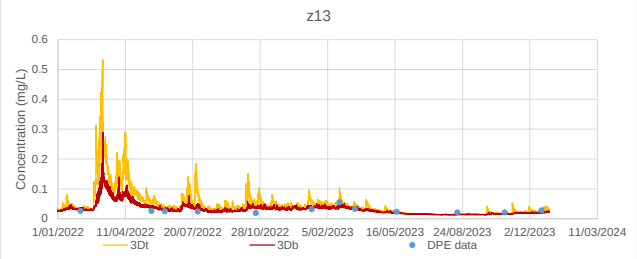

z1
Concentration (mg/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

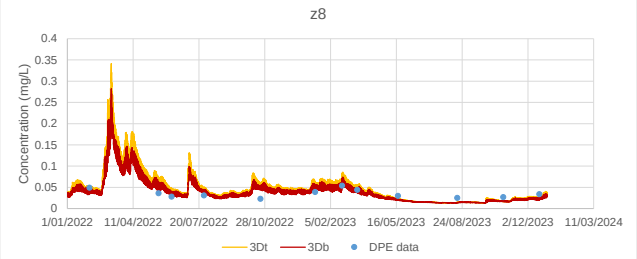

z7
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

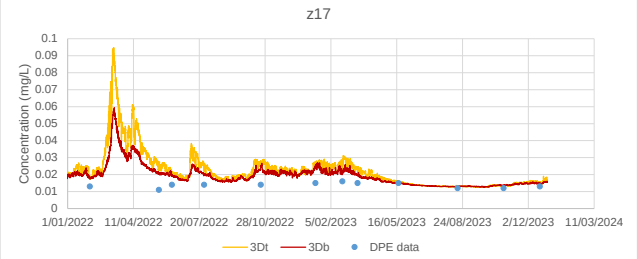

z5
Concentration (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

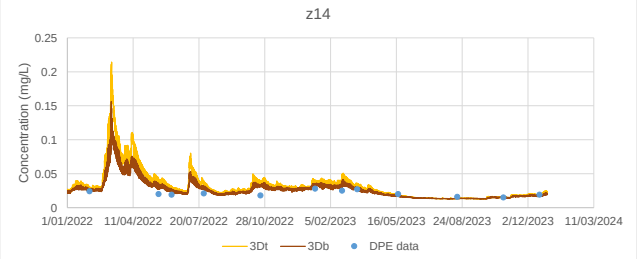

z10
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

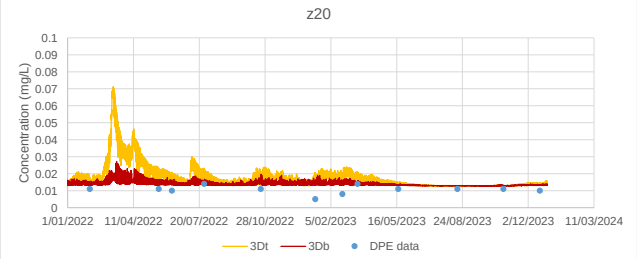

z6
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

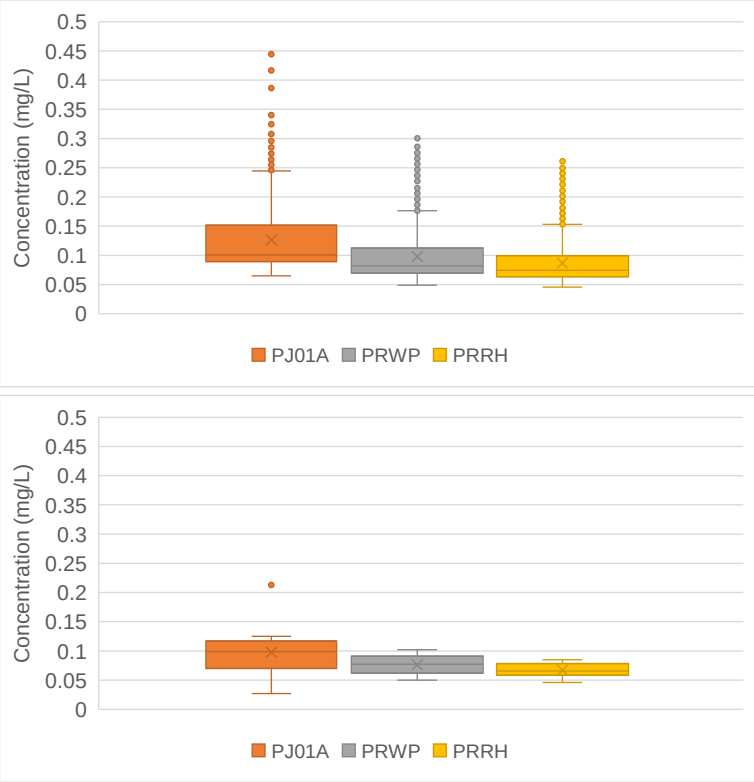

z8
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z17
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

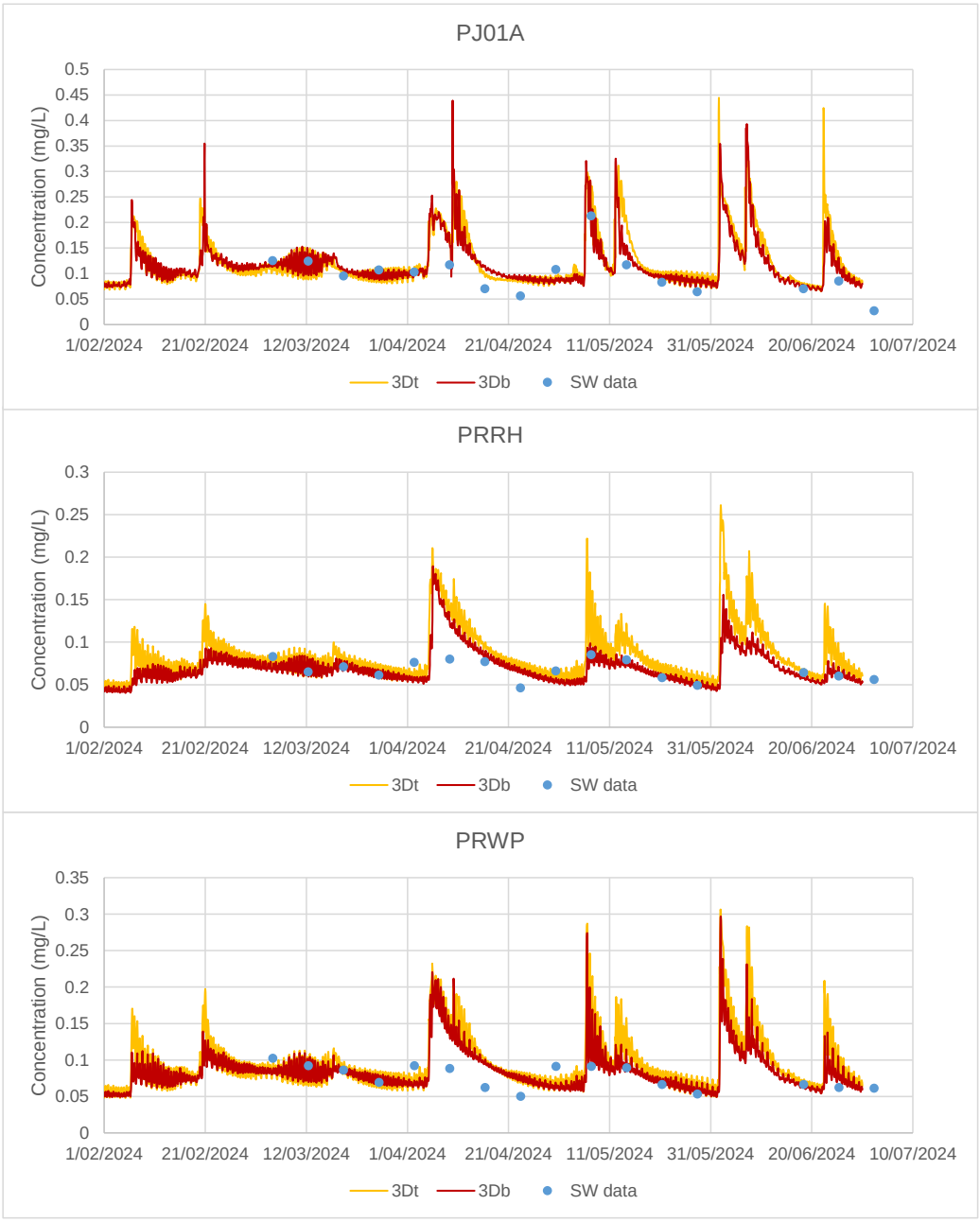

z20
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

Appendix D6_3 – Total Phosphorus validation (SW data 2024)



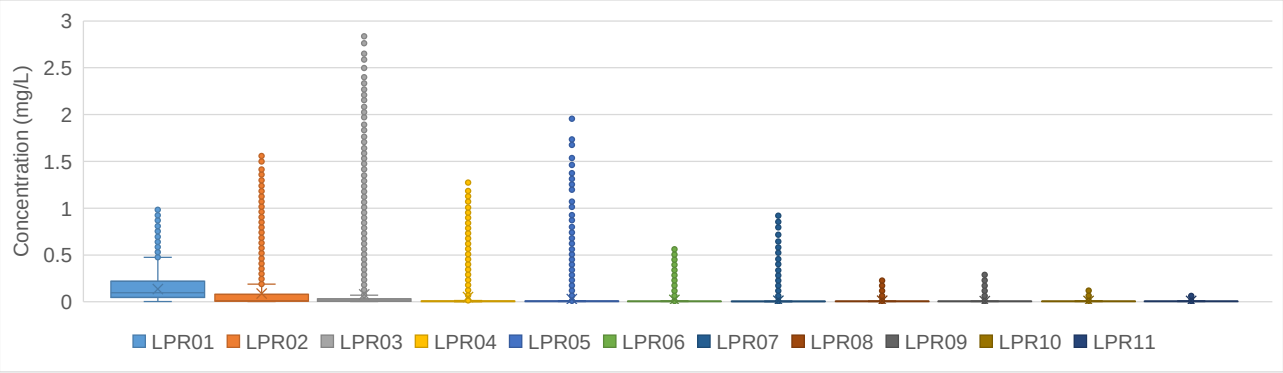
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

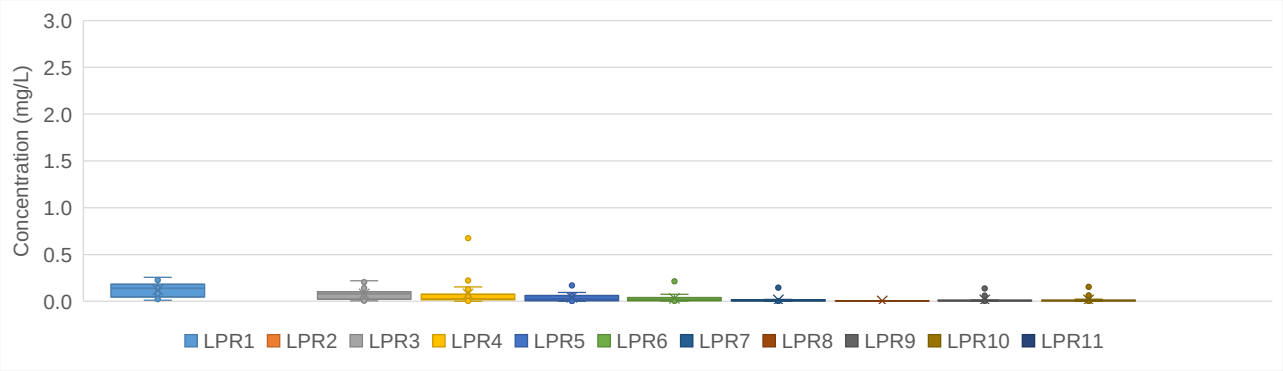
Timeseries plots presented below


PJ01A
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRRH
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRWP
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

Appendix D7 Ammonia

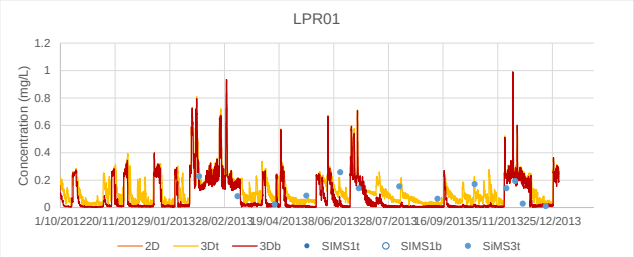
Appendix D7_1 – Ammonia calibration (SIMS data 2012-13)

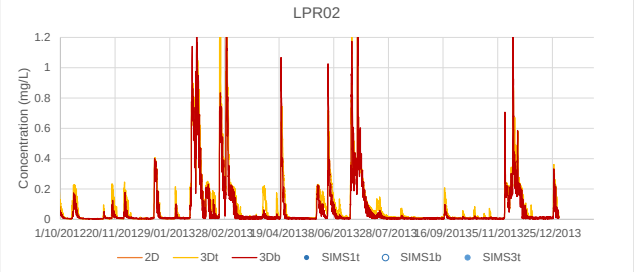


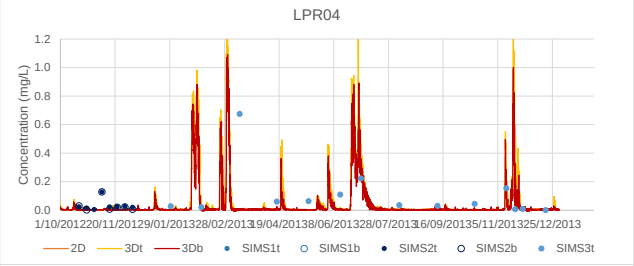


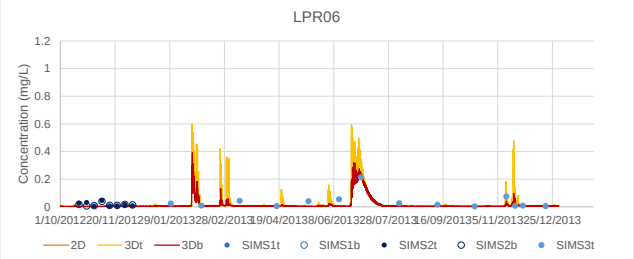
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

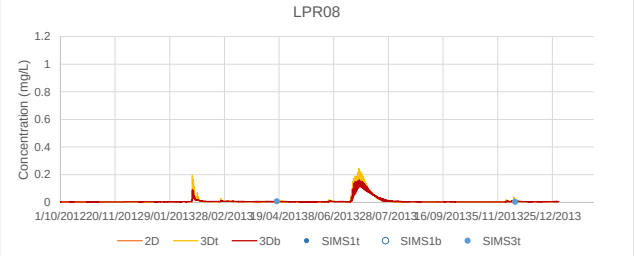
Timeseries plots presented below

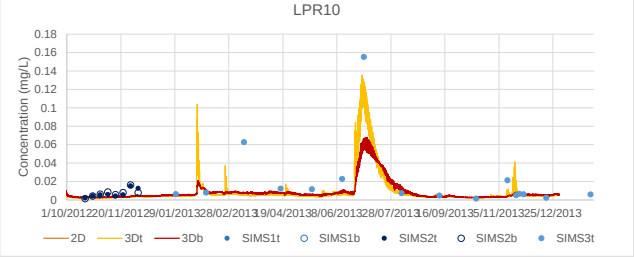

LPR01
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SiMS3t

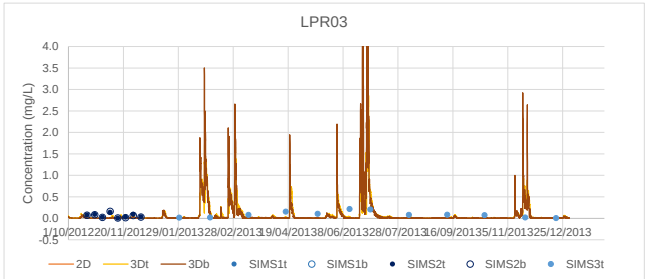

LPR02
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t

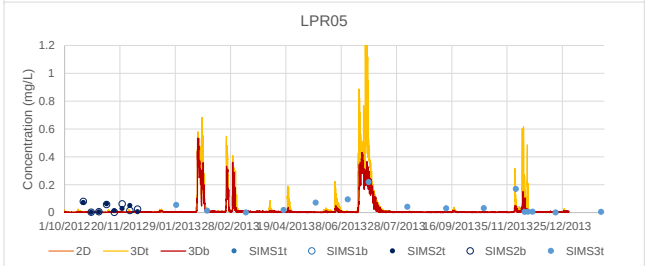

LPR04
Concentration (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

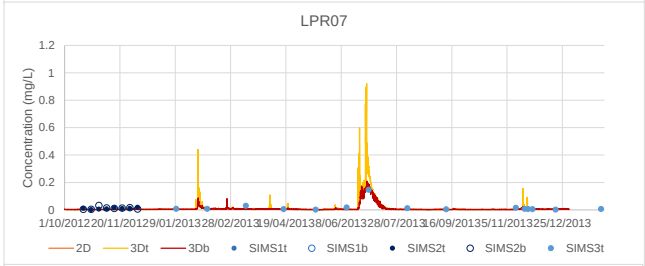

LPR06
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

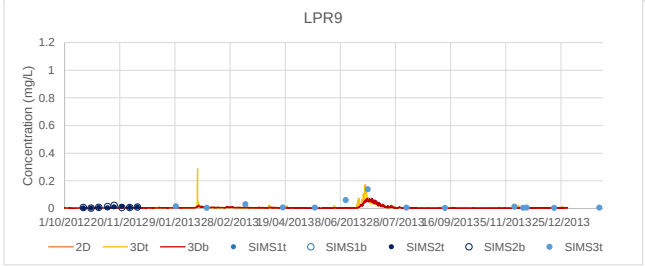

LPR08
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR10
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

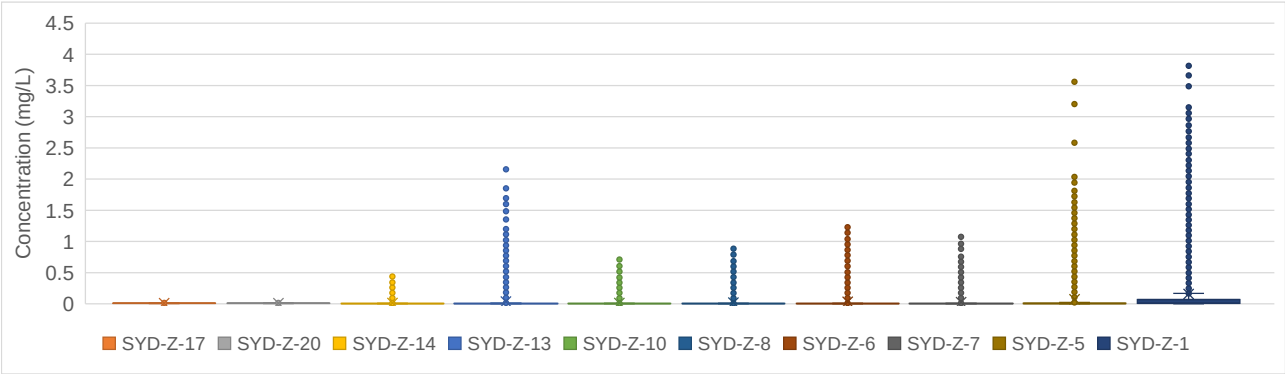

LPR03
Concentration (mg/L)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

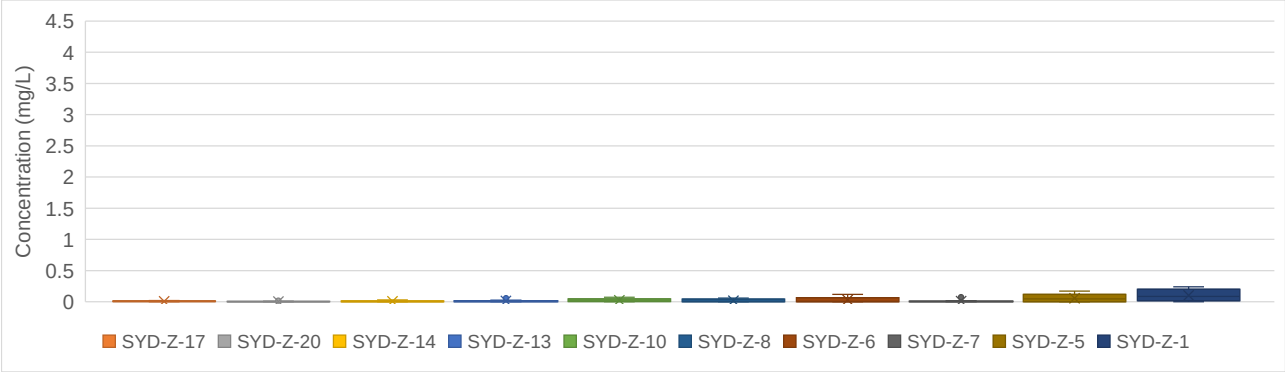

LPR05
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR07
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR9
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

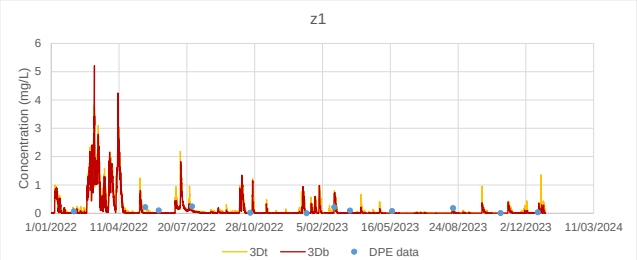
Appendix D7_2 – Ammonia validation (DCCEEW data 2022-23)

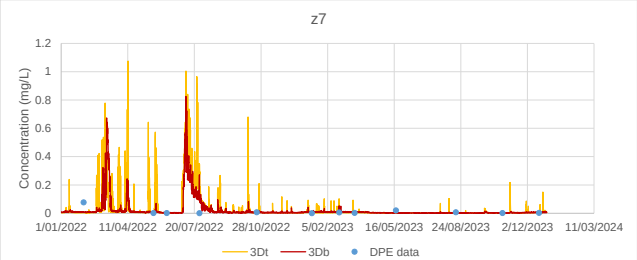


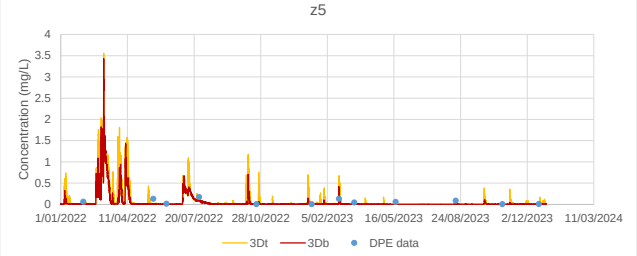


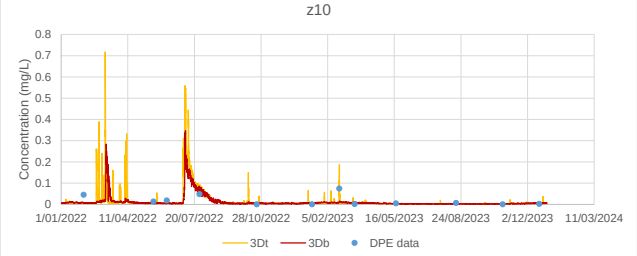
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

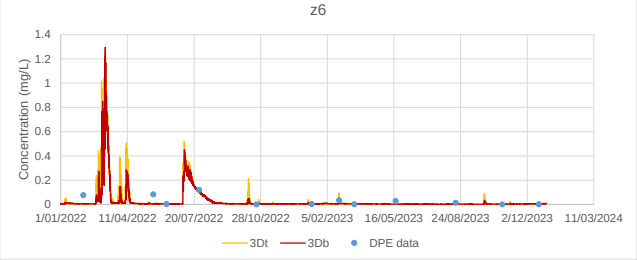
Timeseries plots presented below

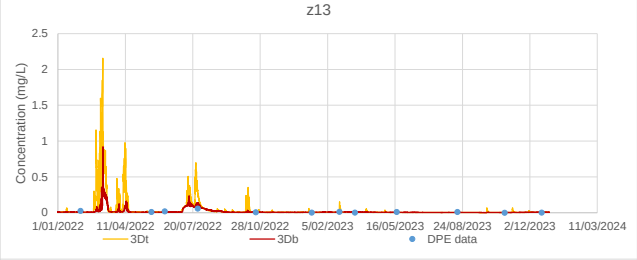

z1
Concentration (mg/L)
0
1
2
3
4
5
6
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

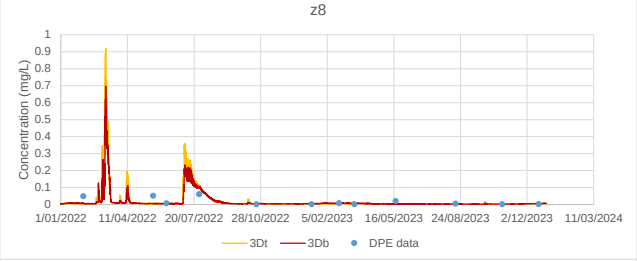

z7
Concentration (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

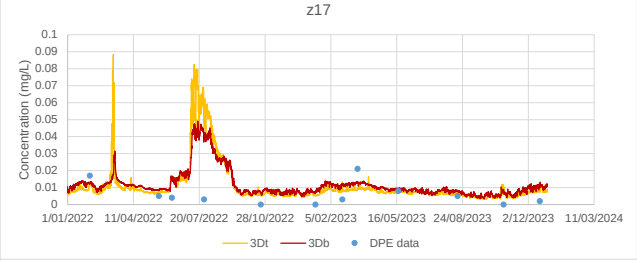

z5
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

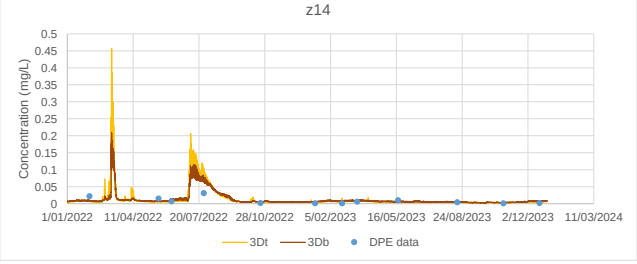

z10
Concentration (mg/L)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

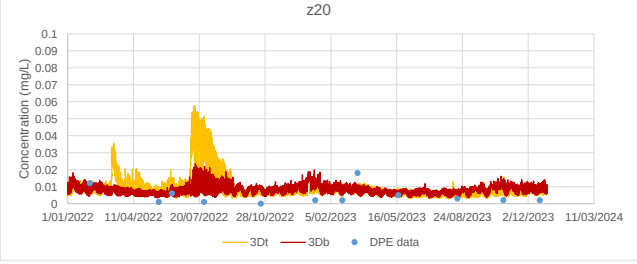

z6
Concentration (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

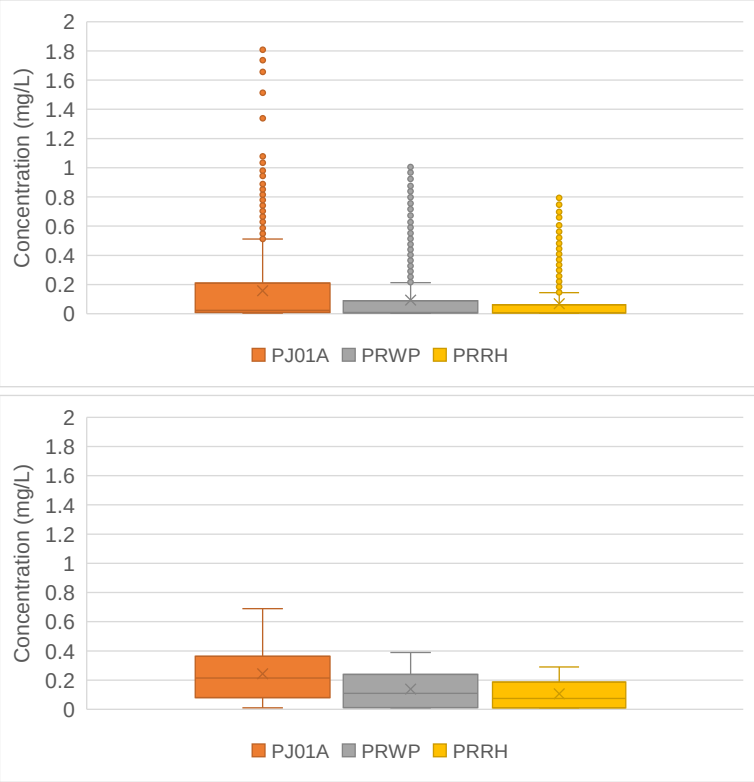

z8
Concentration (mg/L)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z17
Concentration (mg/L)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

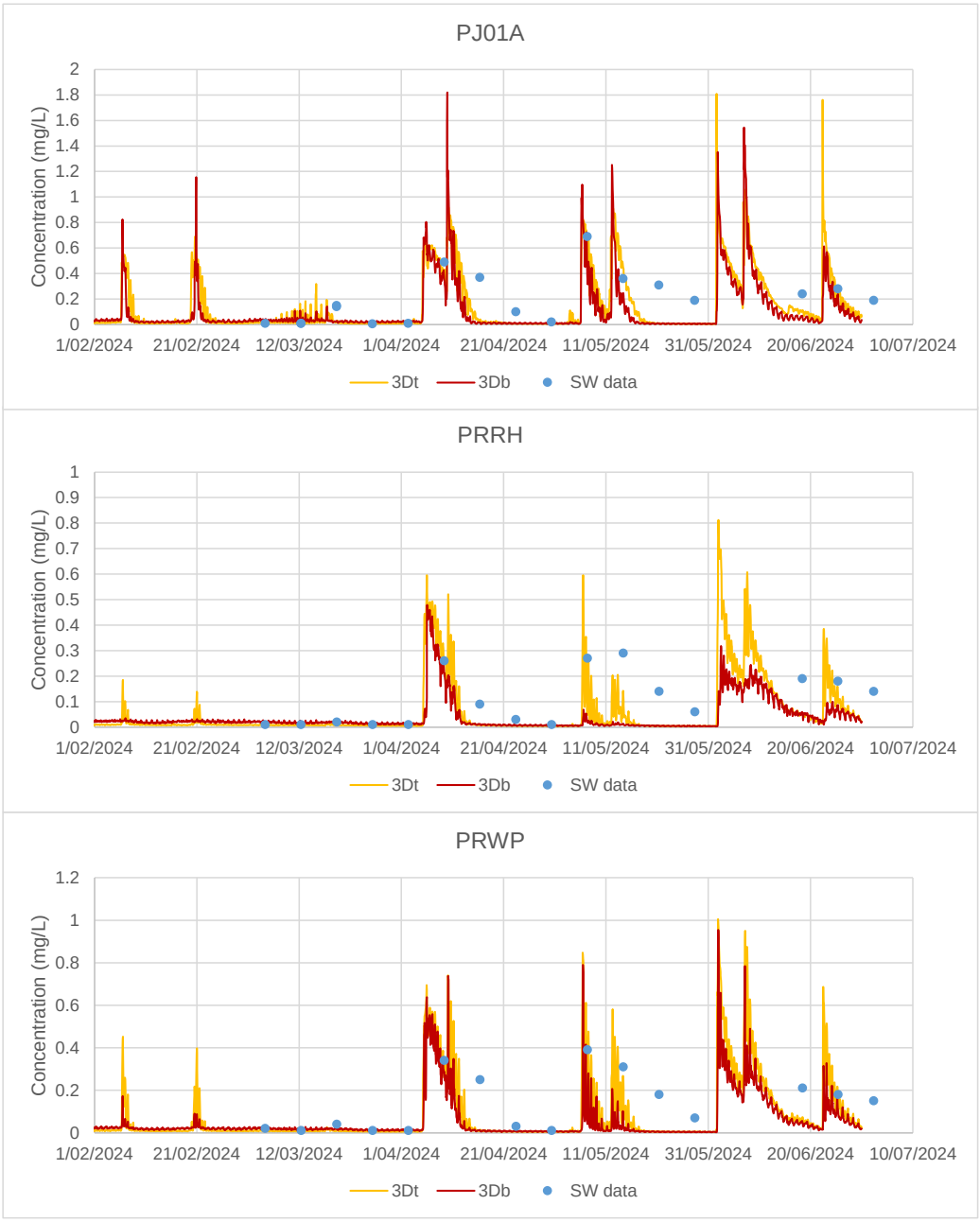

z20
Concentration (mg/L)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

Appendix D7_3 – Ammonia validation (SW data 2024)



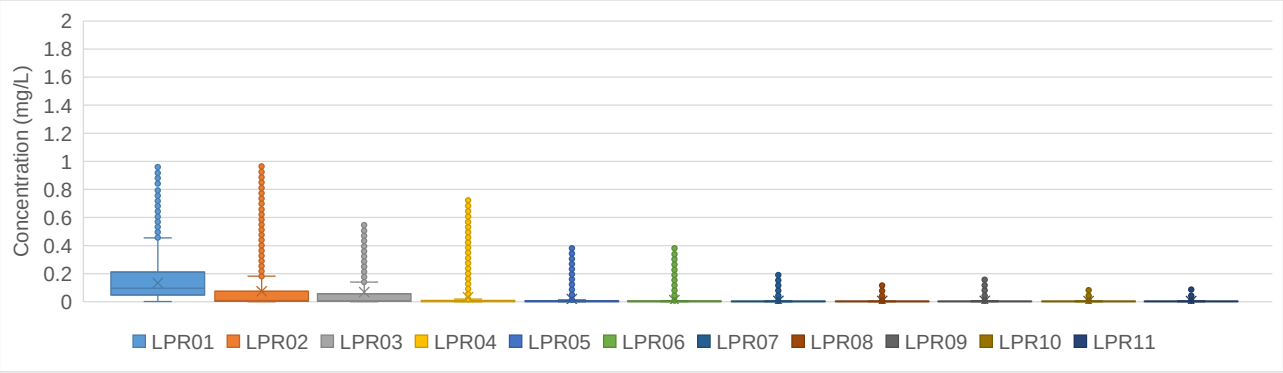
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

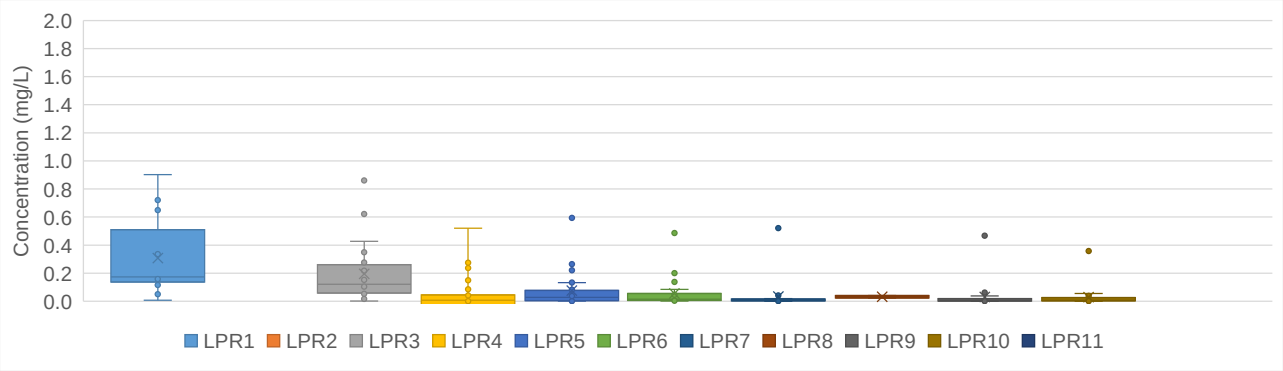
Timeseries plots presented below


PJ01A
Concentration (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRRH
Concentration (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRWP
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

Appendix D8 Oxidised Nitrogen

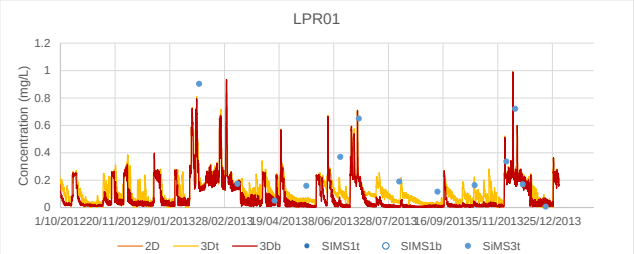
Appendix D8_1 – Oxidised Nitrogen calibration (SIMS data 2012-13)

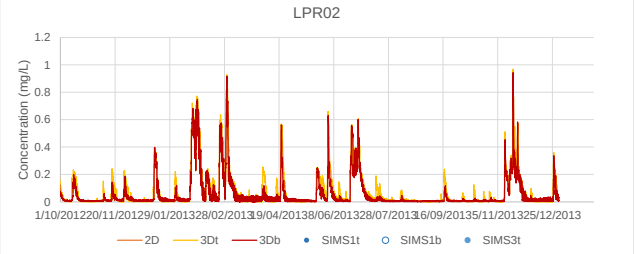


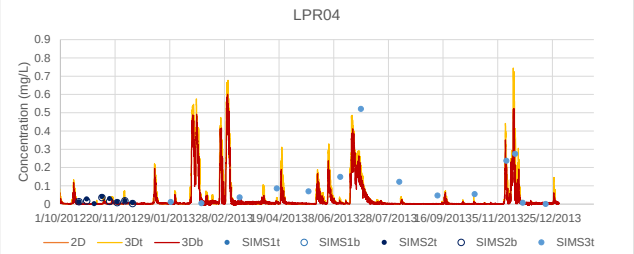


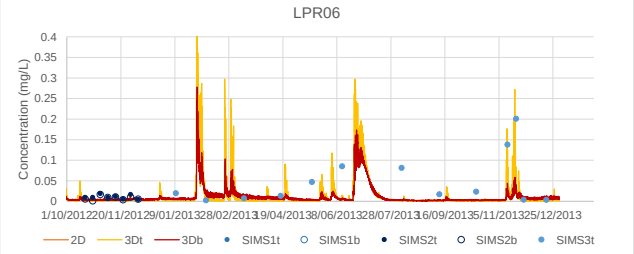
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

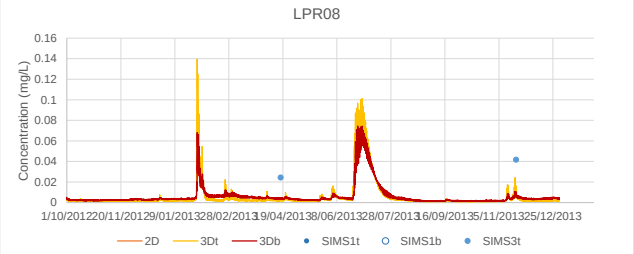
Timeseries plots presented below

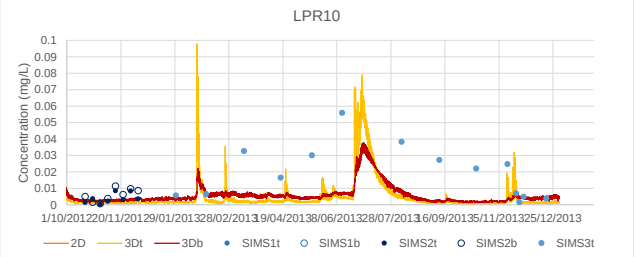

LPR01
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SiMS3t

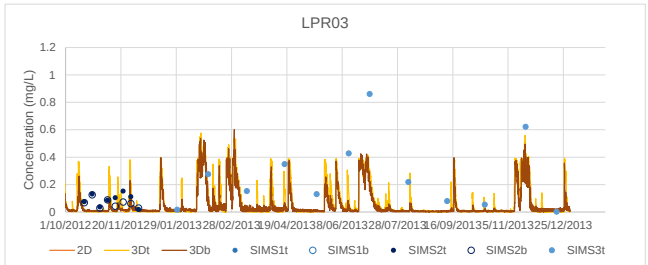

LPR02
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t

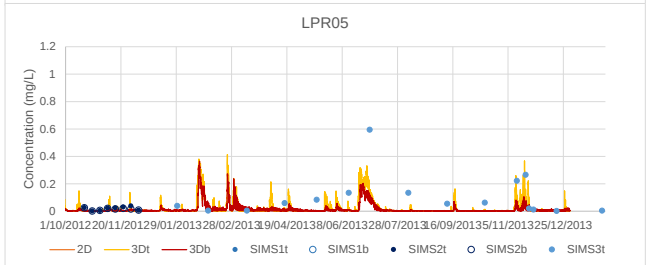

LPR04
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

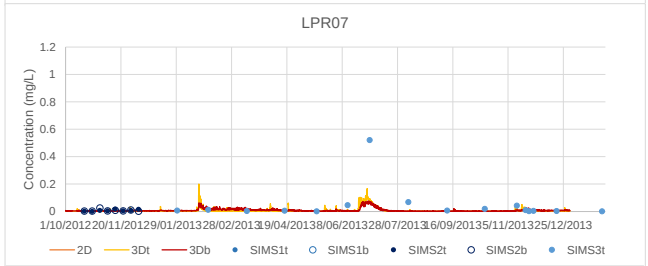

LPR06
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

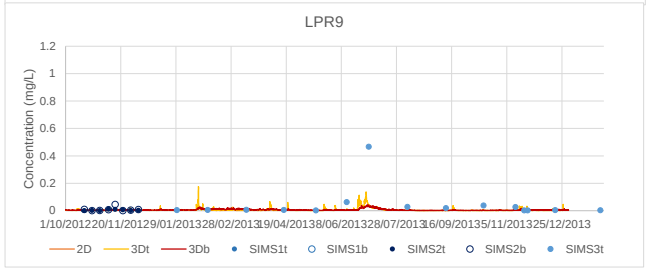

LPR08
Concentration (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR10
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

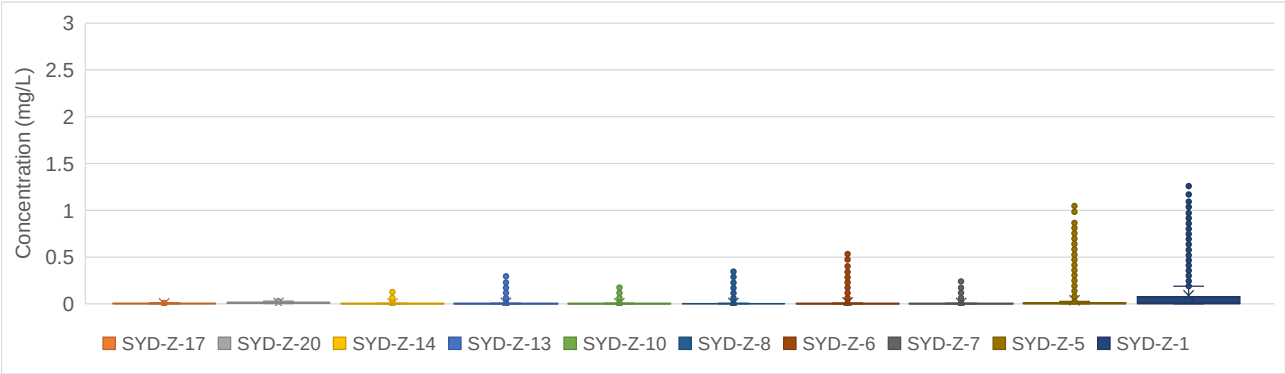

LPR03
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

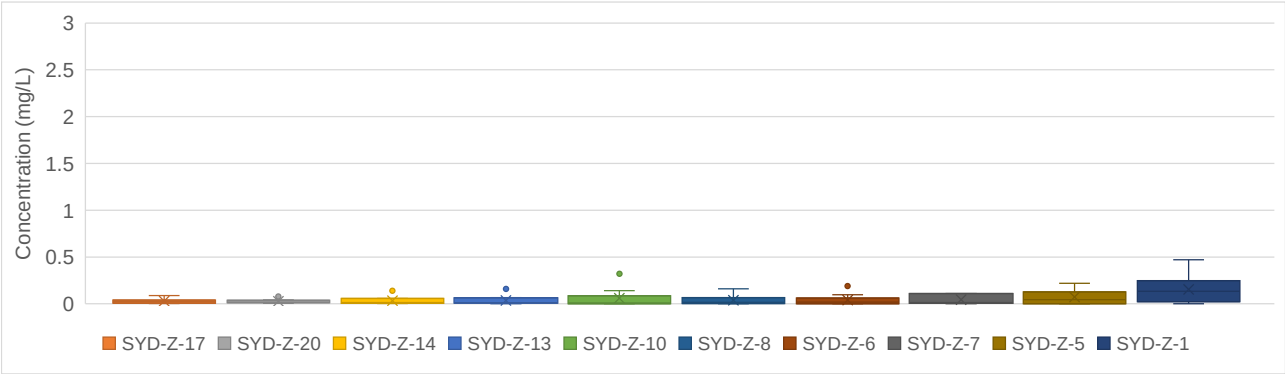

LPR05
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR07
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR9
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

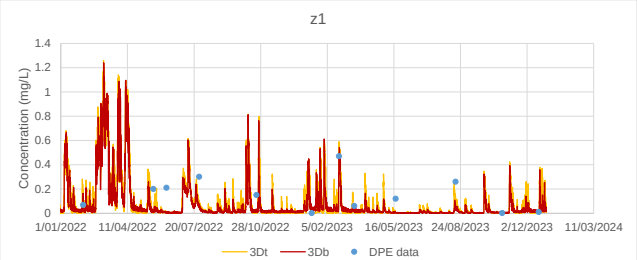
Appendix D8_2 – Oxidised Nitrogen validation (DCCEEW data 2022-23)

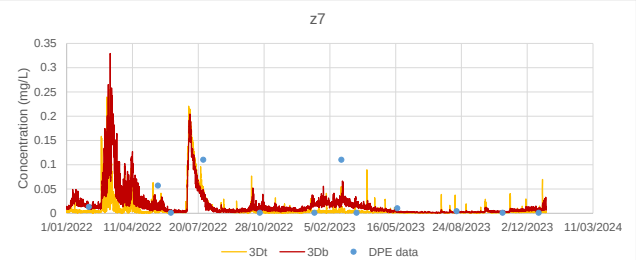


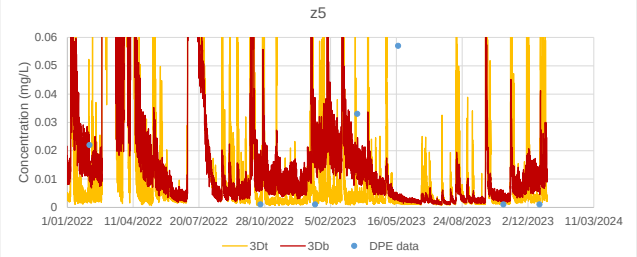


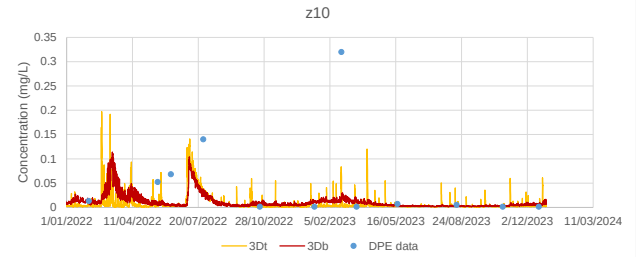
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

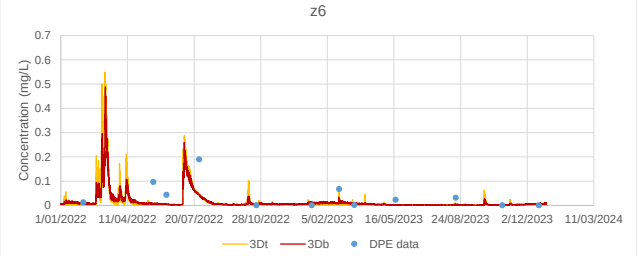
Timeseries plots presented below

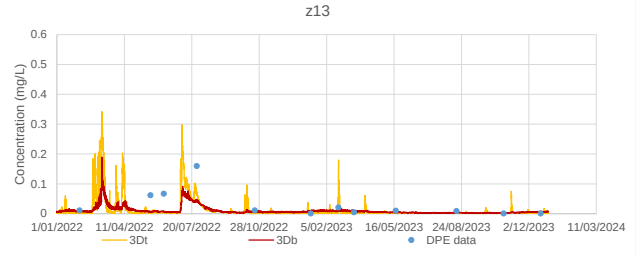

z1
Concentration (mg/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

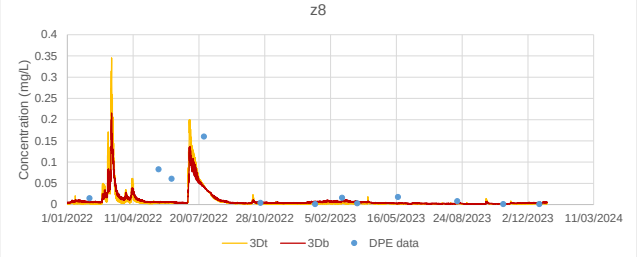

z7
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

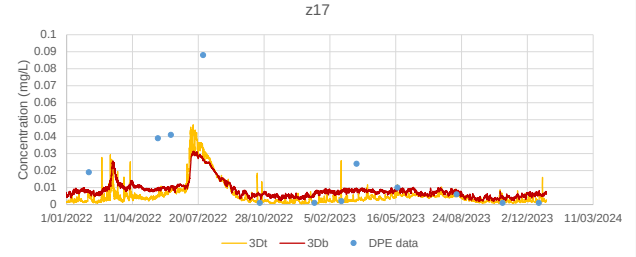

z5
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

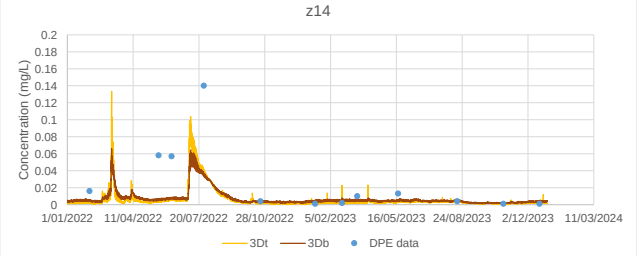

z10
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

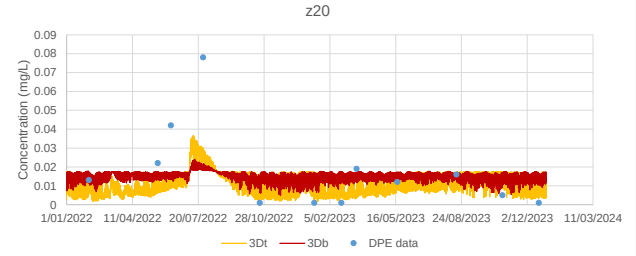

z6
Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

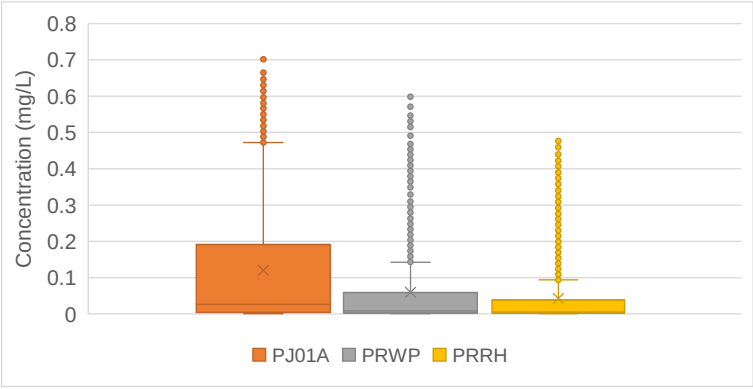

z8
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

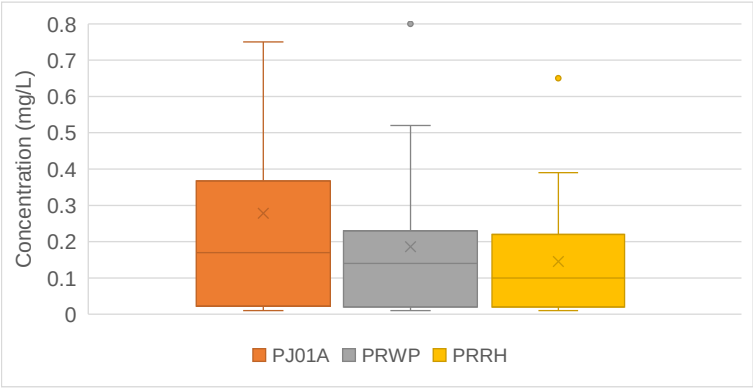

z17
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z20
Concentration (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

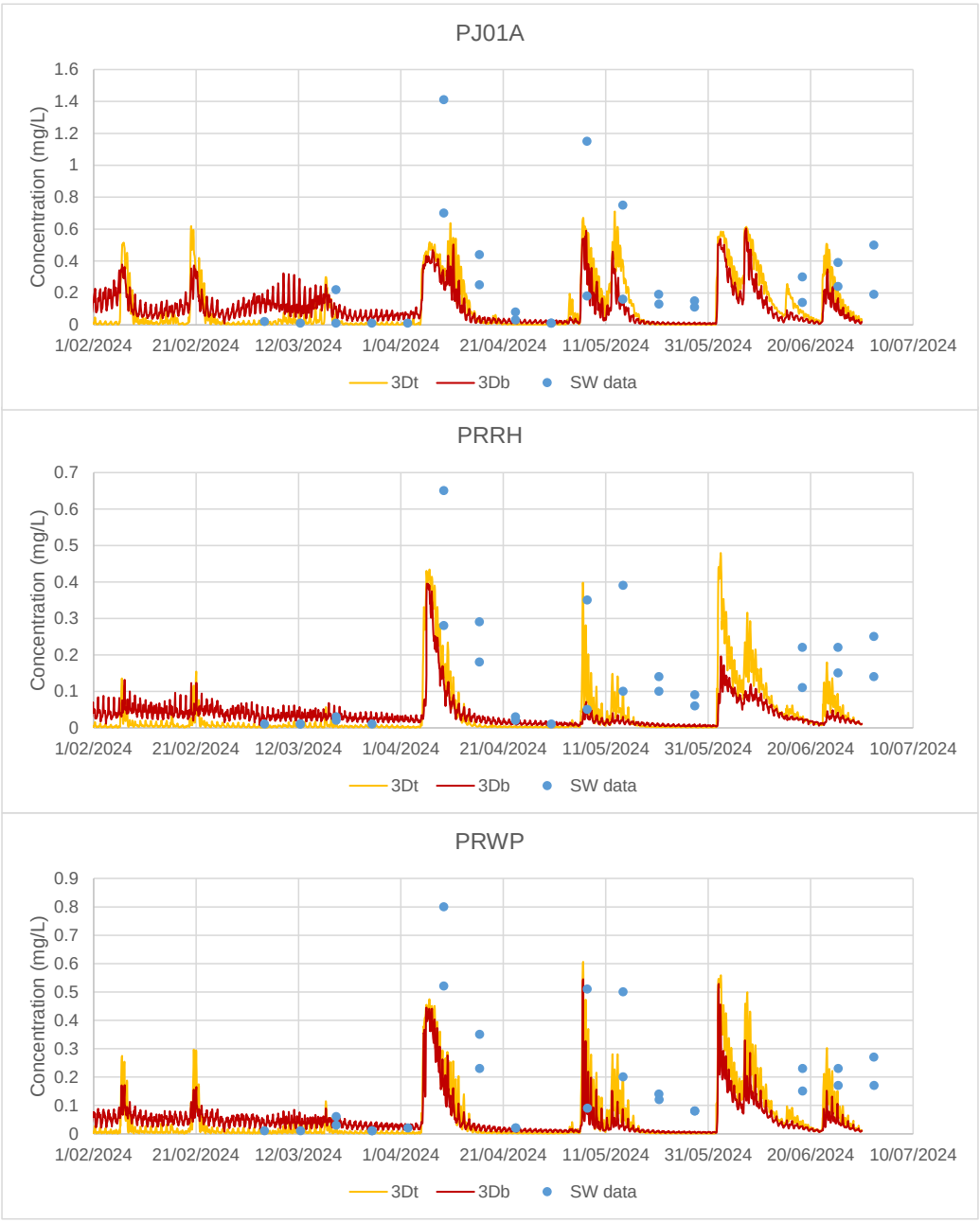
Appendix D8_3 – Oxidised Nitrogen validation (SW data 2024)





Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

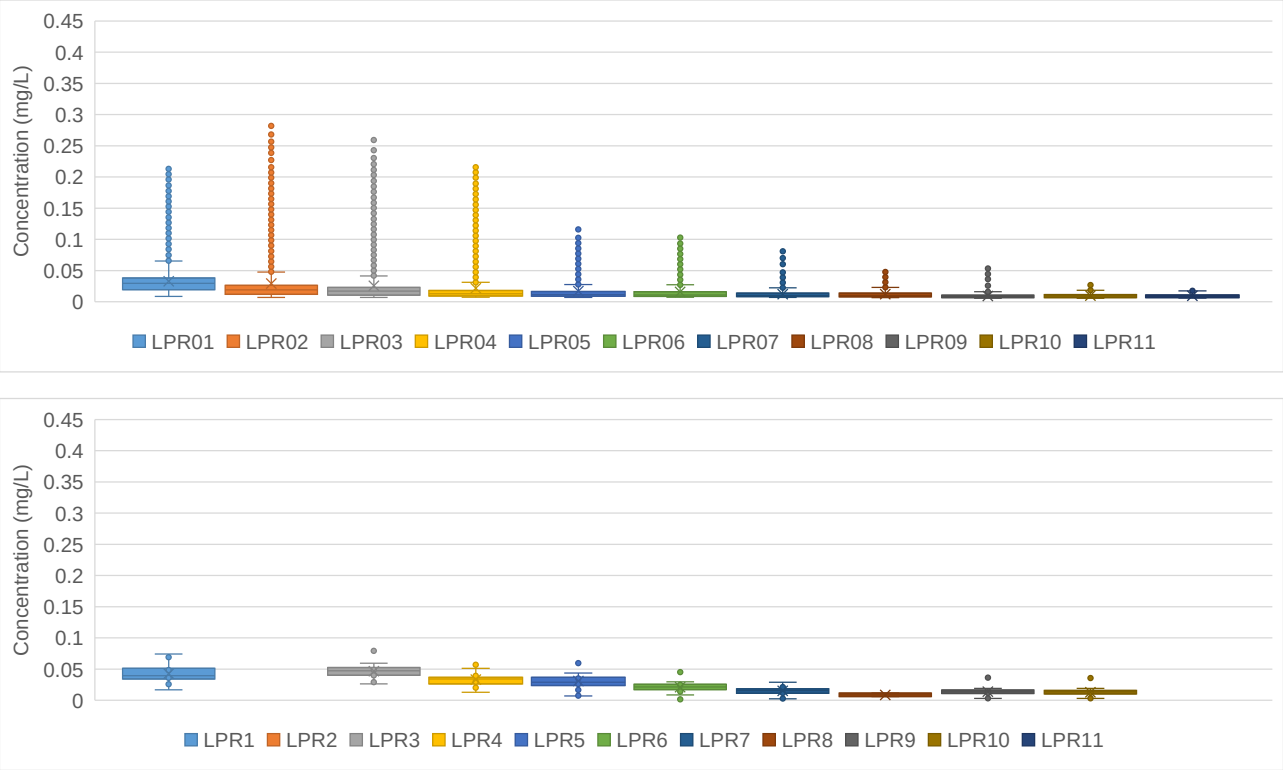
Timeseries plots presented below


PJ01A
Concentration (mg/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRRH
Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRWP
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

17 cm

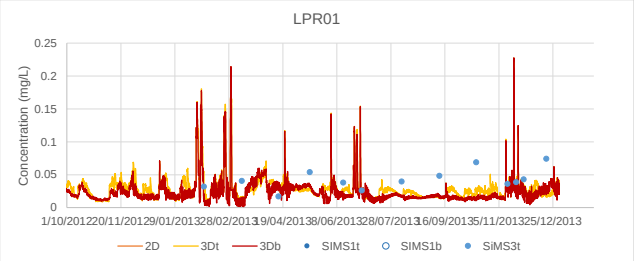
Appendix D9 Inorganic Phosphorus

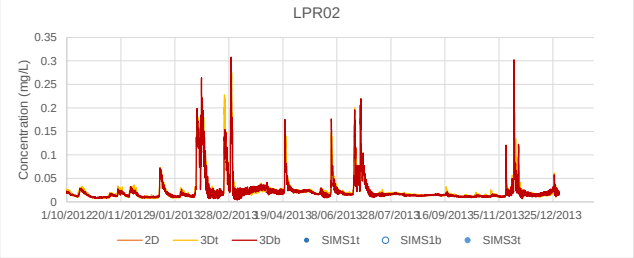
Appendix D9_1 – Inorganic Phosphorus calibration (SIMS data 2012-13)

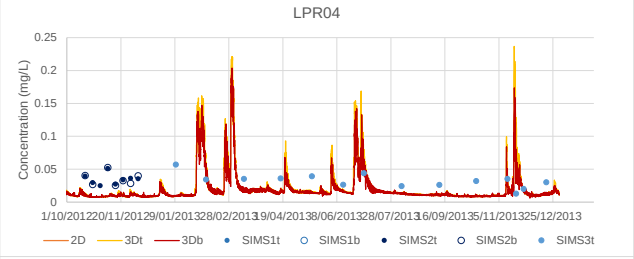


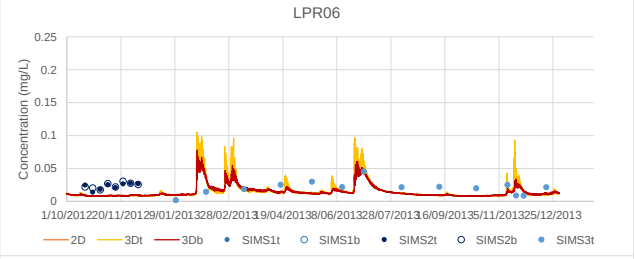
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

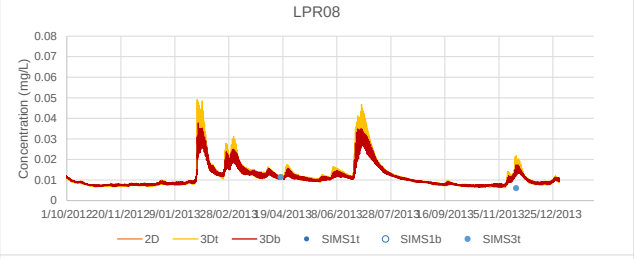
Timeseries plots presented below

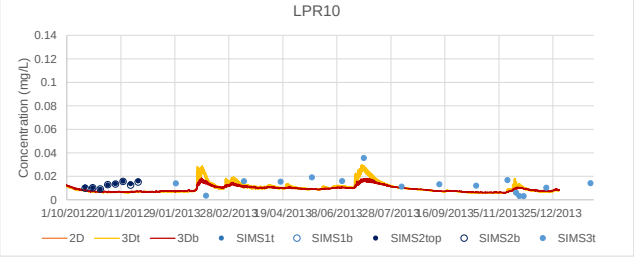

LPR01
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SiMS3t

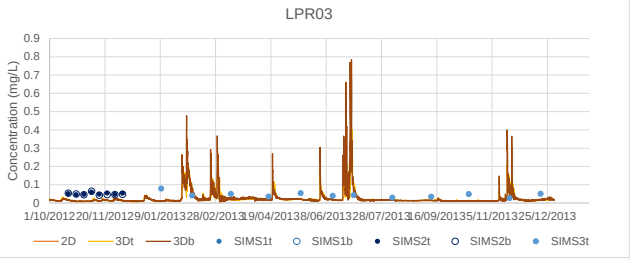

LPR02
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS3t

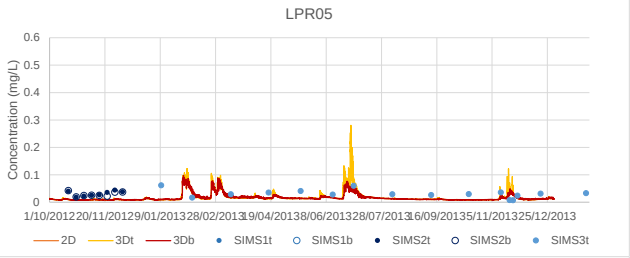

LPR04
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

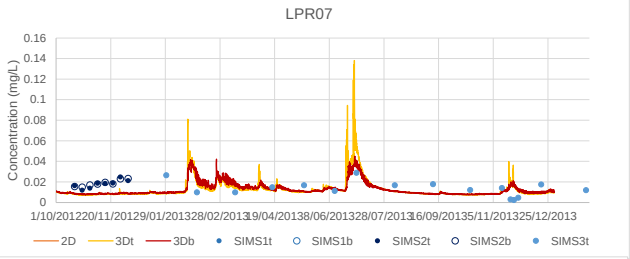

LPR06
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

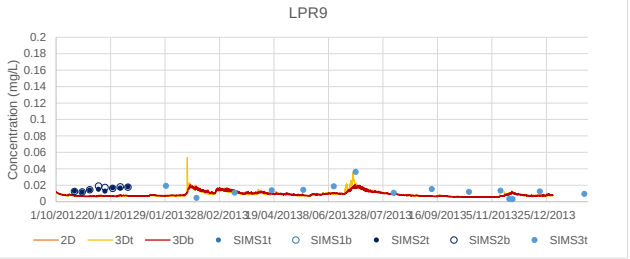

LPR08
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS3t


LPR10
Concentration (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2top SIMS2b SIMS3t

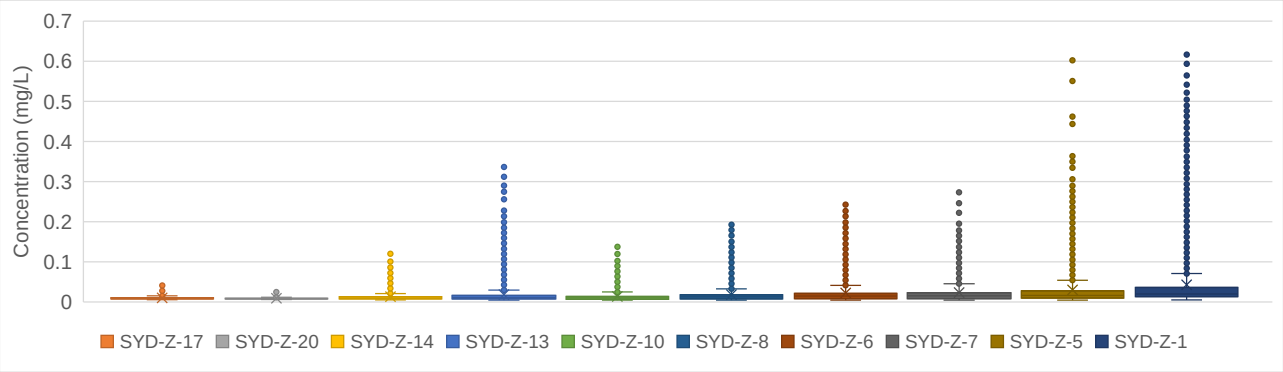

LPR03
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

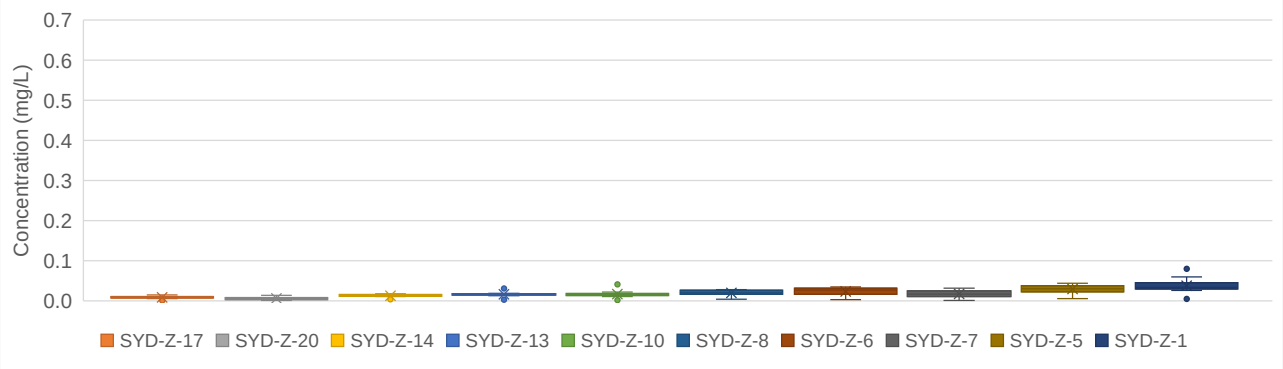

LPR05
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t


LPR07
Concentration (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t


LPR9
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/10/2012 20/11/2012 29/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

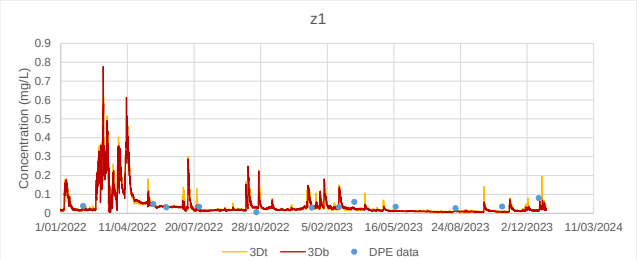
Appendix D9_2 – Inorganic Phosphorus validation (DCCEEW data 2022-23)

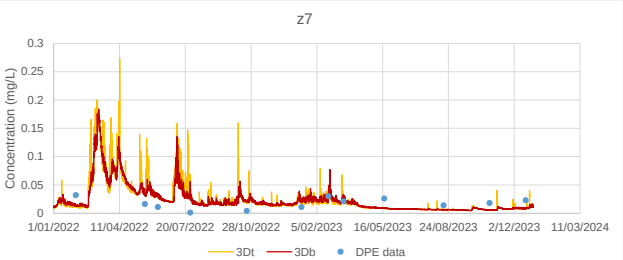


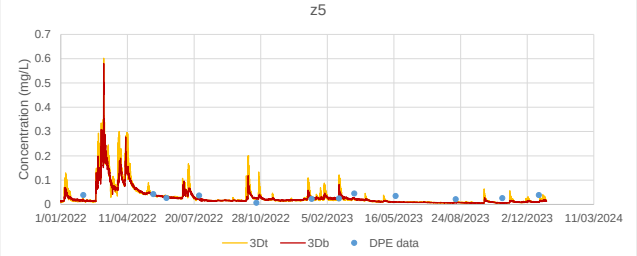


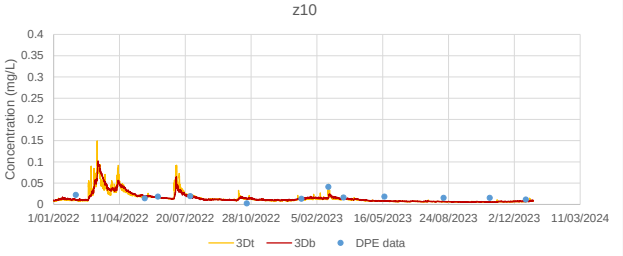
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

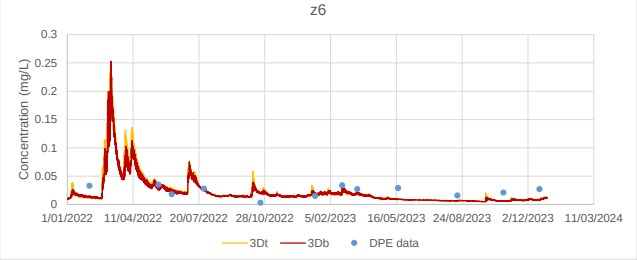
Timeseries plots presented below

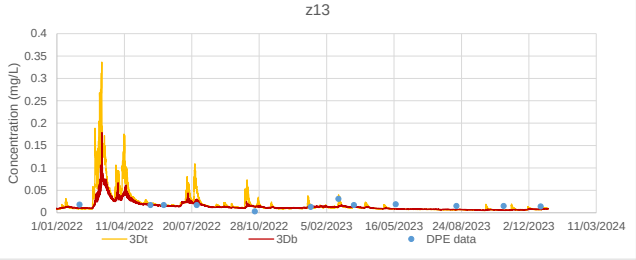

z1
Concentration (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

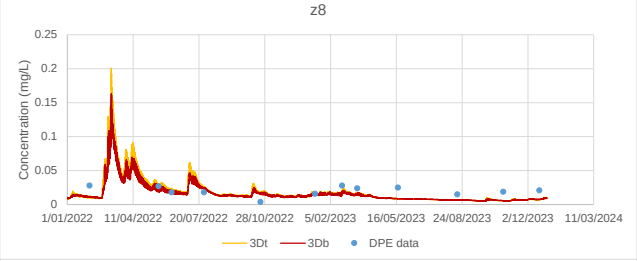

z7
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

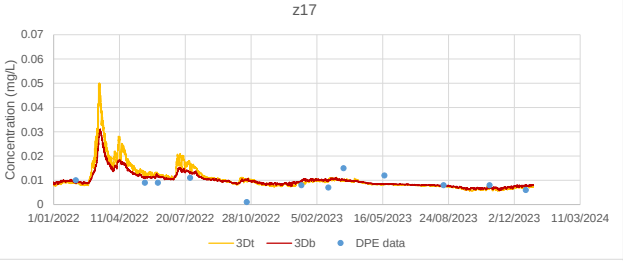

z5
Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

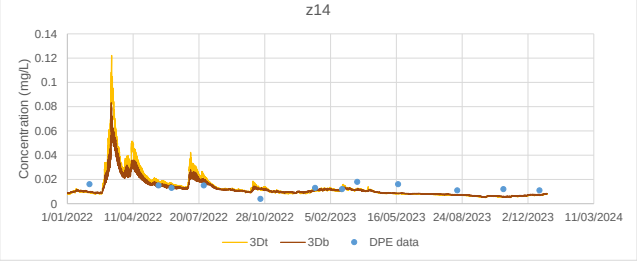

z10
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

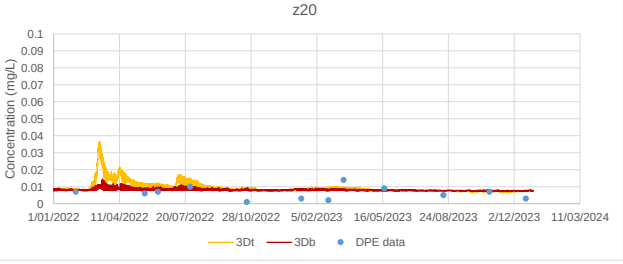

z6
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

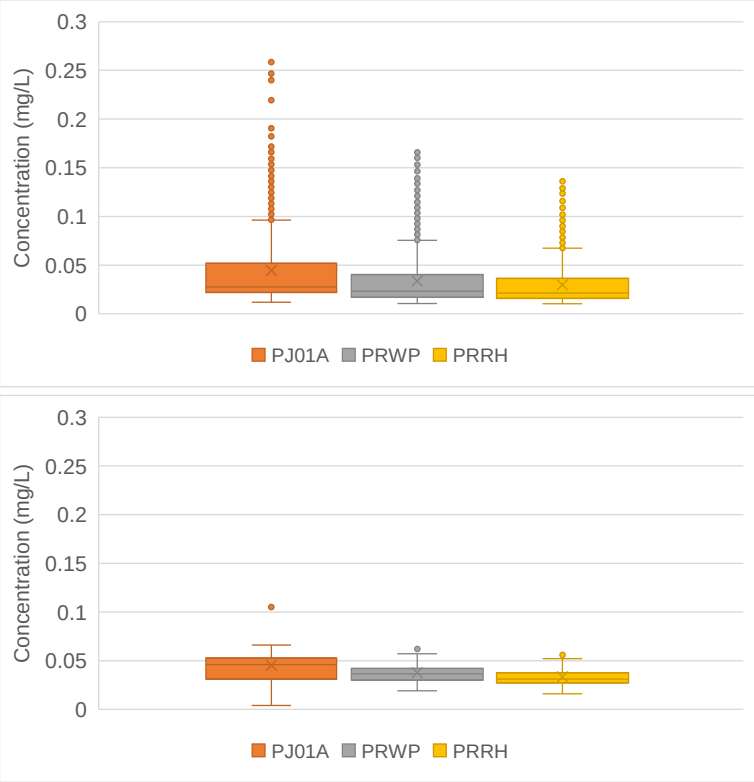

z8
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z17
Concentration (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

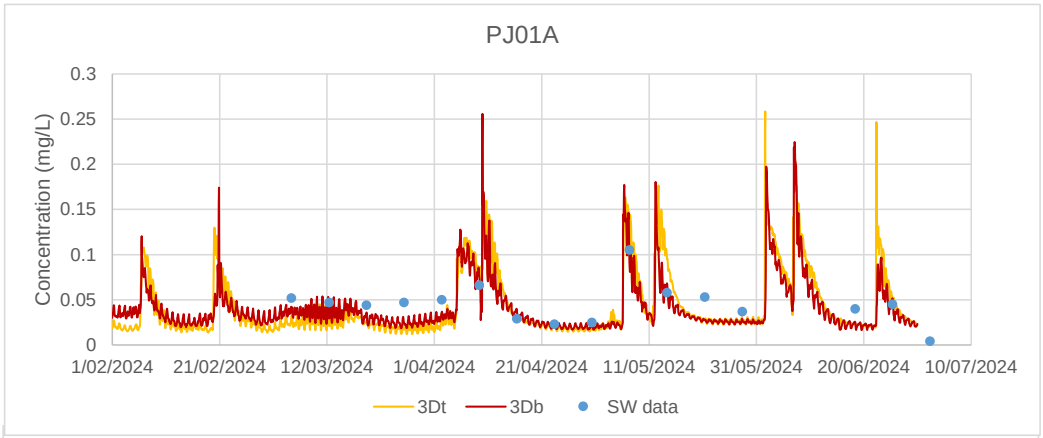

z20
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

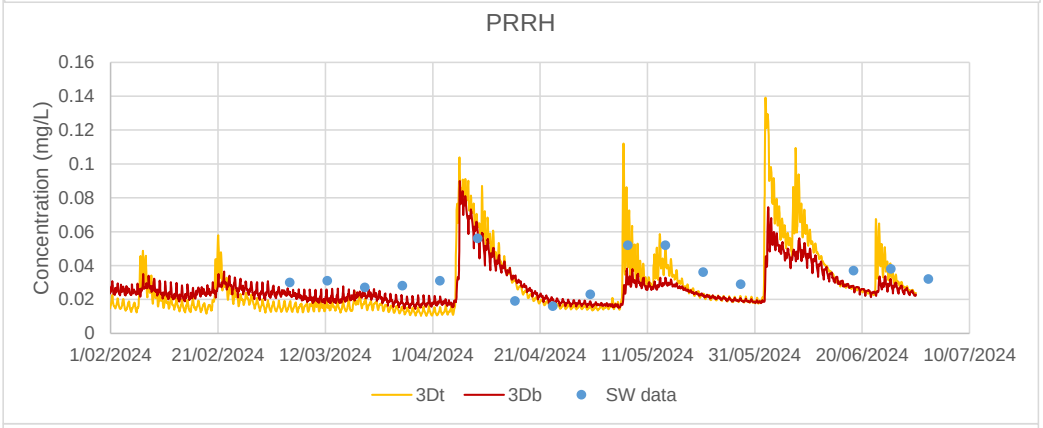
Appendix D9_3 – Inorganic Phosphorus validation (SW data 2024)

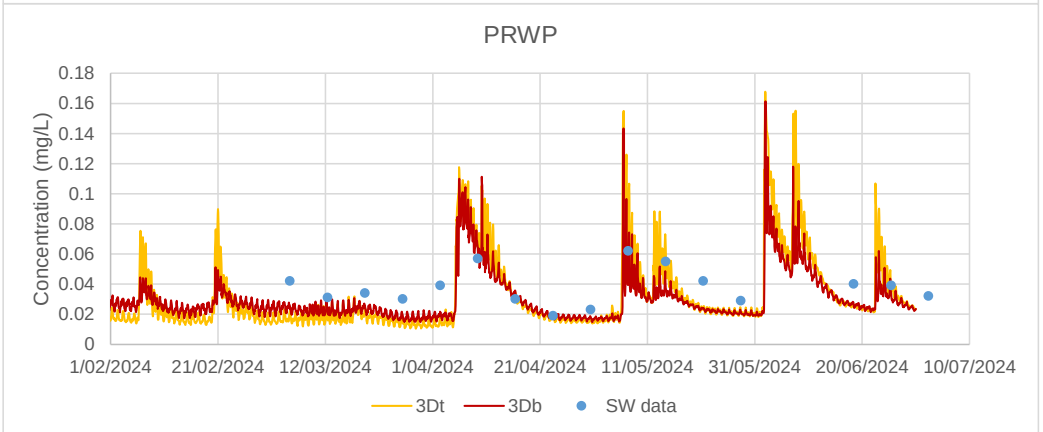


Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

Timeseries plots presented below

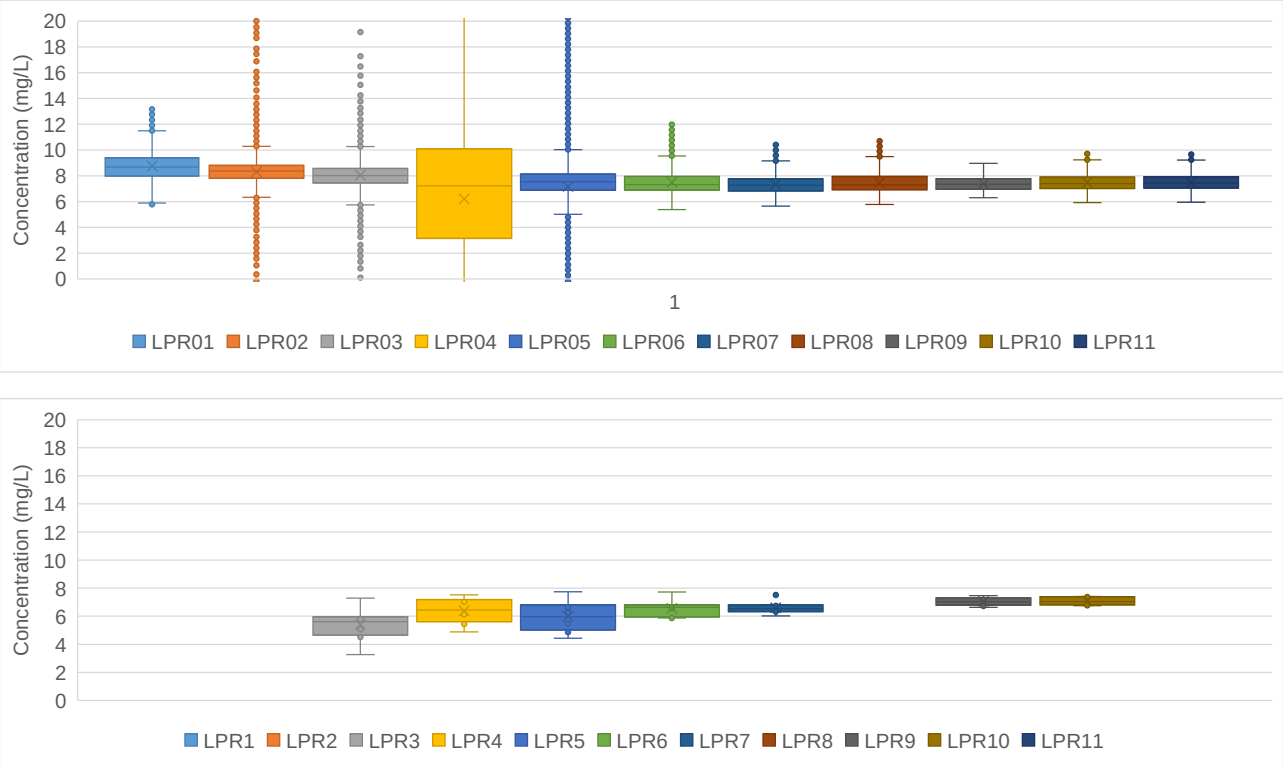

PJ01A
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PRRH
Concentration (mg/L)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PRWP
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

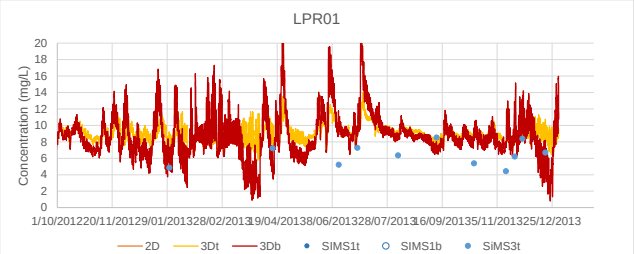
Appendix D10 Dissolved Oxygen

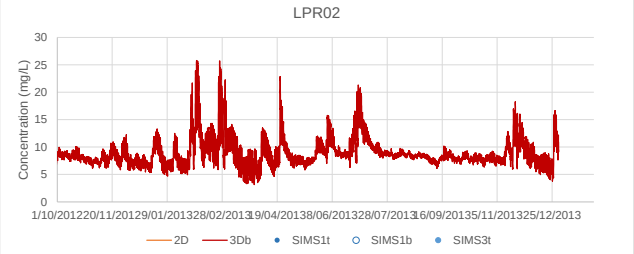
Appendix D10_1 – Dissolved Oxygen calibration (SIMS data 2012-13)

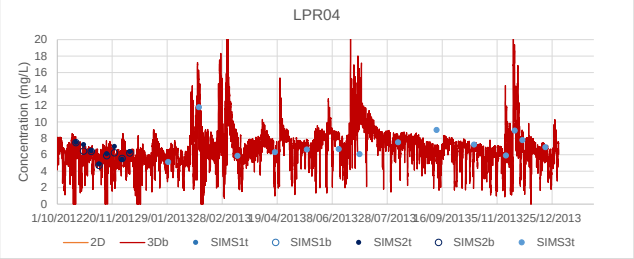


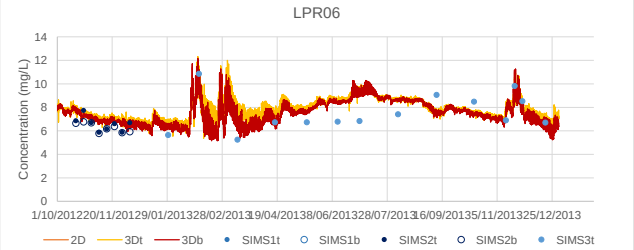
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

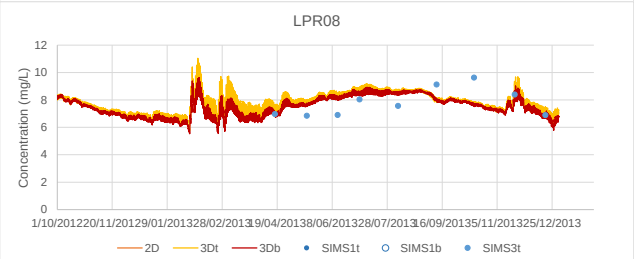
Timeseries plots presented below

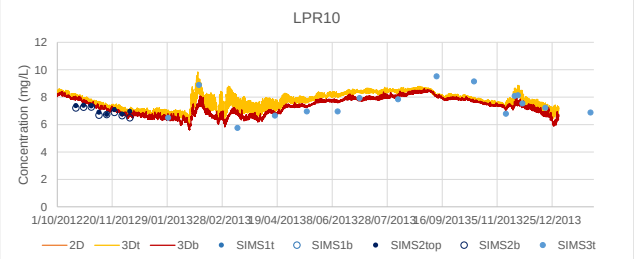

LPR01
Concentration (mg/L)
0 2 4 6 8 10 12 14 16 18 20
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SiMS3t

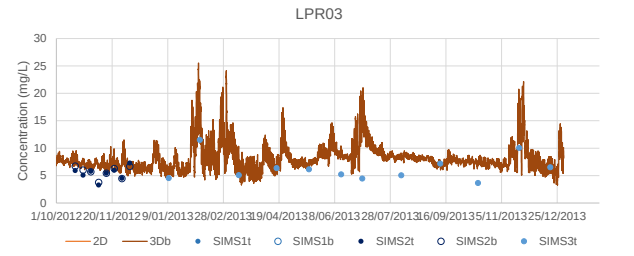

LPR02
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Db SIMS1t SIMS1b SIMS3t

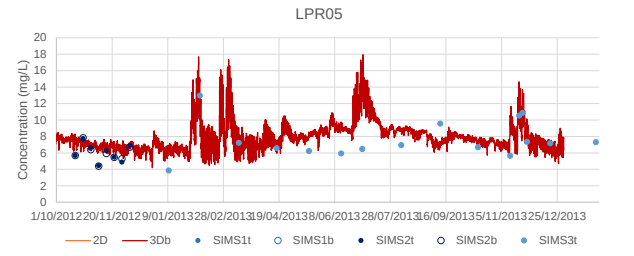

LPR04
Concentration (mg/L)
0 2 4 6 8 10 12 14 16 18 20
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

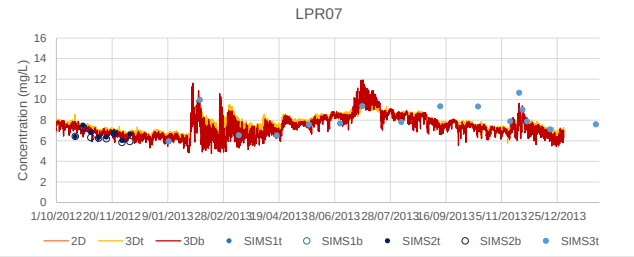

LPR06
Concentration (mg/L)
0 2 4 6 8 10 12 14
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

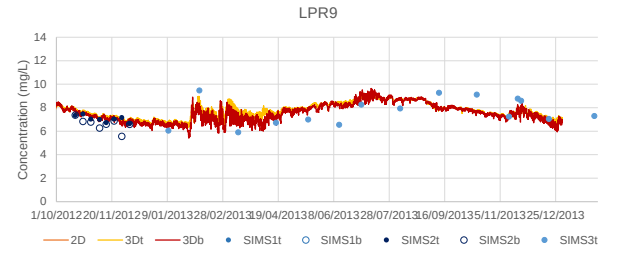

LPR08
Concentration (mg/L)
0 2 4 6 8 10 12
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS3t


LPR10
Concentration (mg/L)
0 2 4 6 8 10 12
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2top SIMS2b SIMS3t

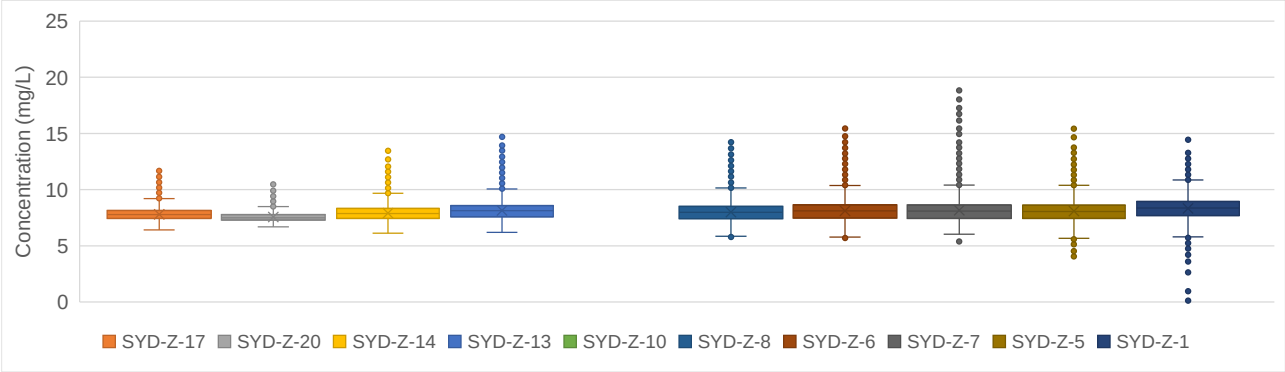

LPR03
Concentration (mg/L)
0 5 10 15 20 25 30
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

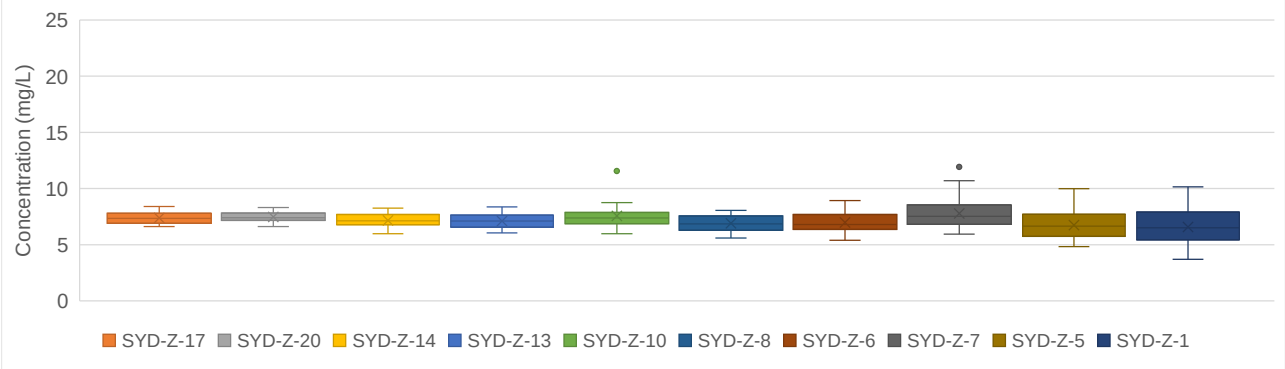

LPR05
Concentration (mg/L)
0 2 4 6 8 10 12 14 16 18 20
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t


LPR07
Concentration (mg/L)
0 2 4 6 8 10 12 14 16
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t


LPR9
Concentration (mg/L)
0 2 4 6 8 10 12 14
1/10/2012 20/11/2012 9/01/2013 28/02/2013 19/04/2013 8/06/2013 28/07/2013 16/09/2013 5/11/2013 25/12/2013
2D 3Dt 3Db SIMS1t SIMS1b SIMS2t SIMS2b SIMS3t

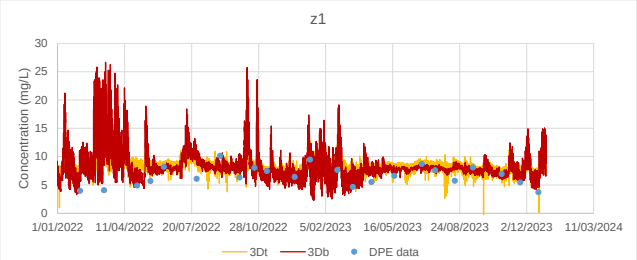
Appendix D10_2 – Dissolved Oxygen validation (DCCEEW data 2022-23)

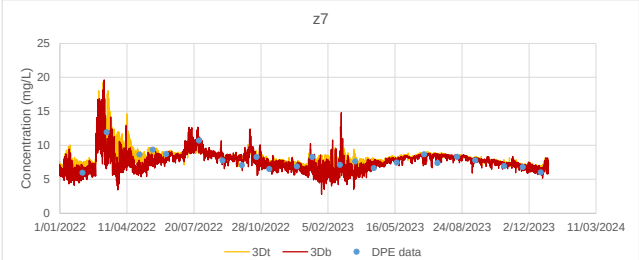


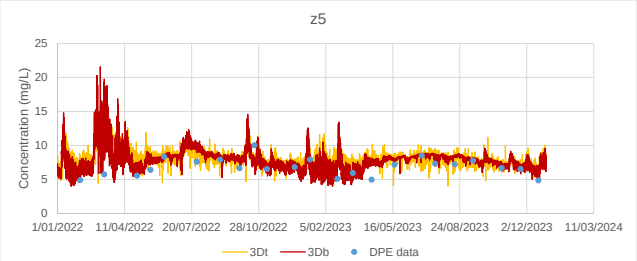


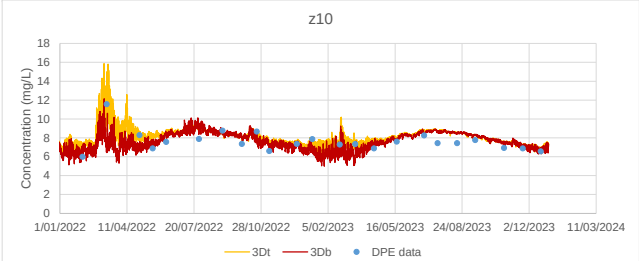
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

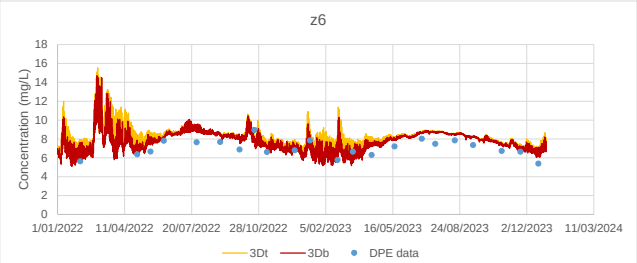
Timeseries plots presented below

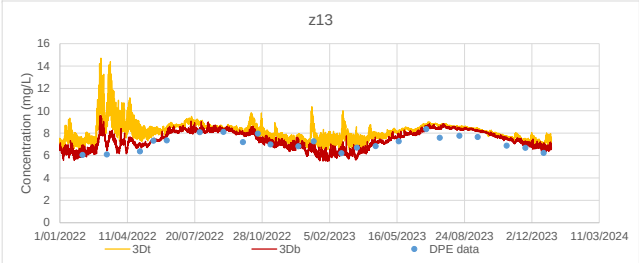

z1
Concentration (mg/L)
0
5
10
15
20
25
30
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

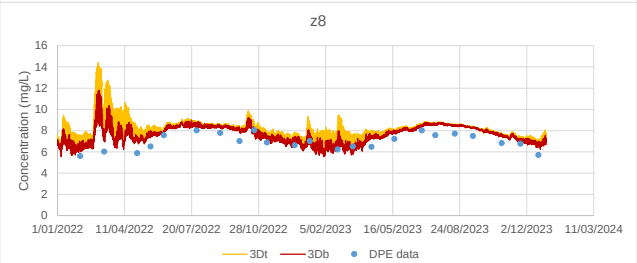

z7
Concentration (mg/L)
0
5
10
15
20
25
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

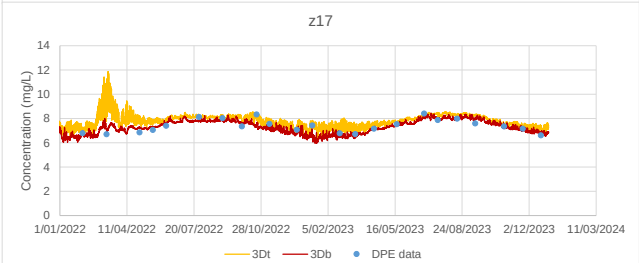

z5
Concentration (mg/L)
0
5
10
15
20
25
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

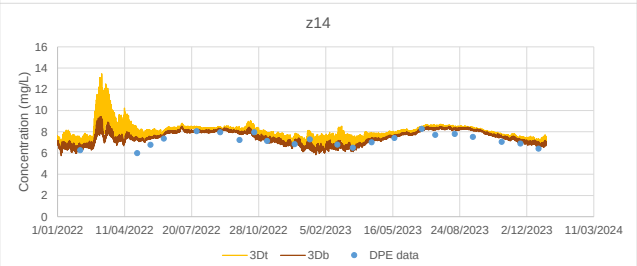

z10
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
18
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

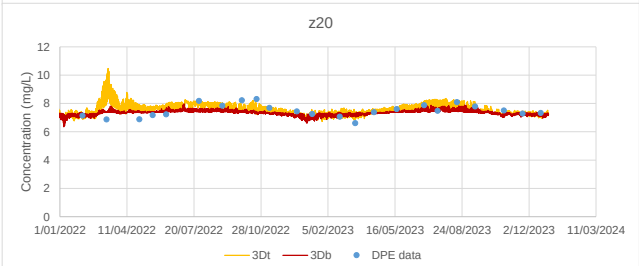

z6
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
18
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z8
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

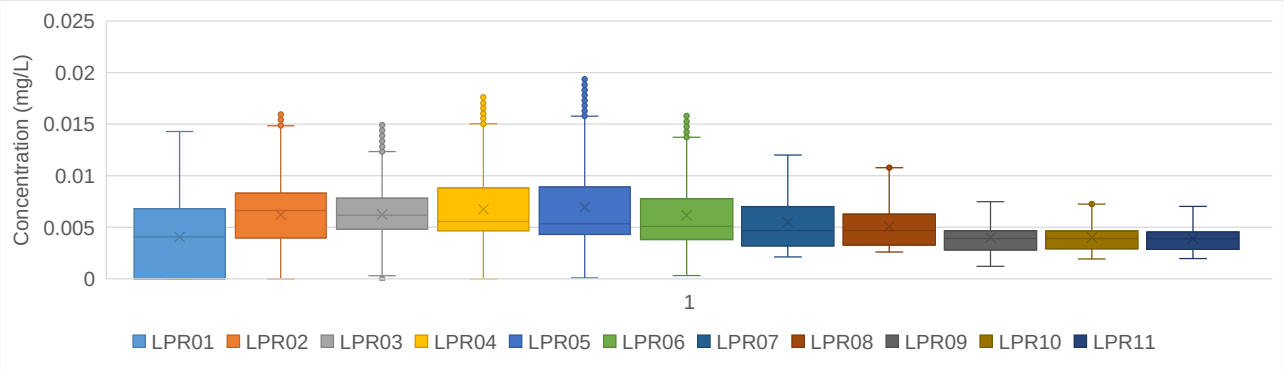

z17
Concentration (mg/L)
0
2
4
6
8
10
12
14
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

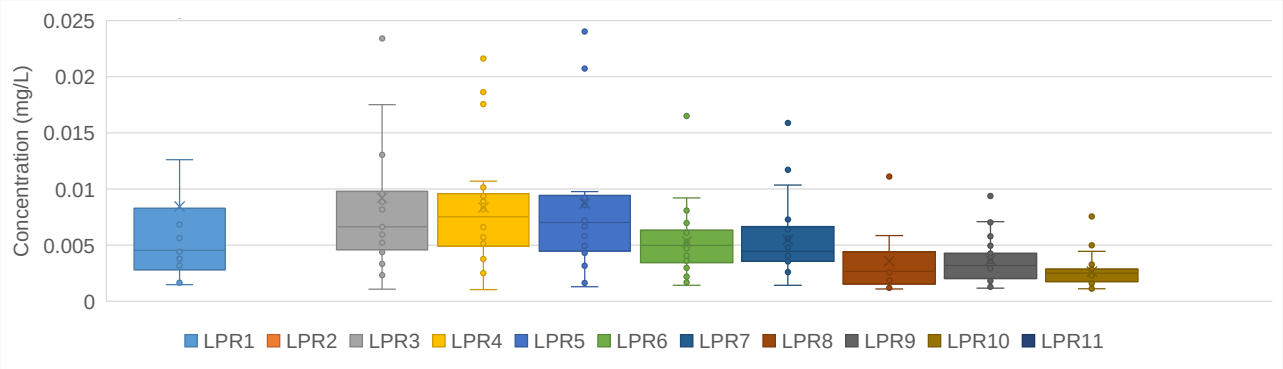

z14
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data


z20
Concentration (mg/L)
0
2
4
6
8
10
12
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
11/03/2024
3Dt
3Db
DPE data

Appendix D11 Chlorophyll *a*

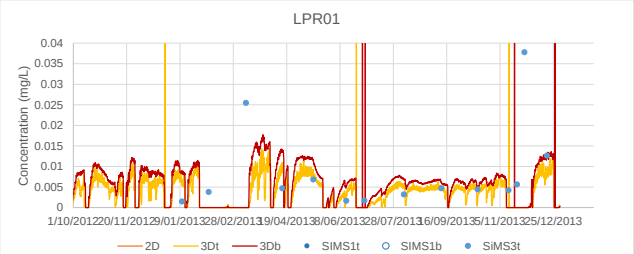
Appendix D11_1 – Chlorophyll *a* calibration (SIMS data 2012-13)

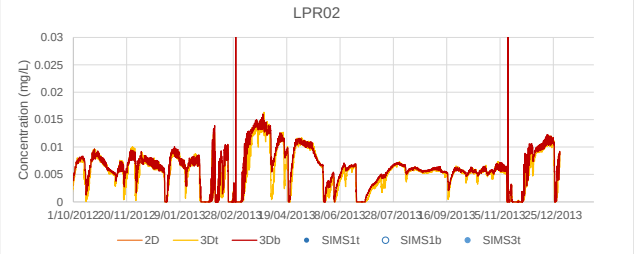


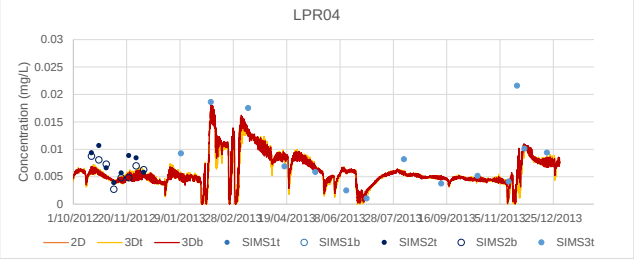


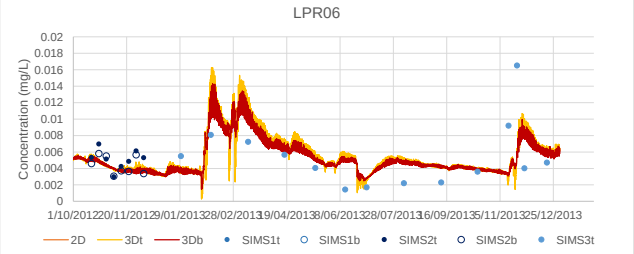
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

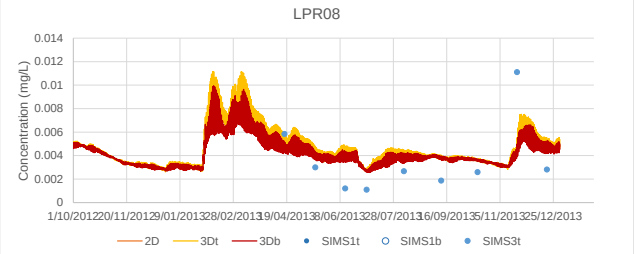
Timeseries plots presented below

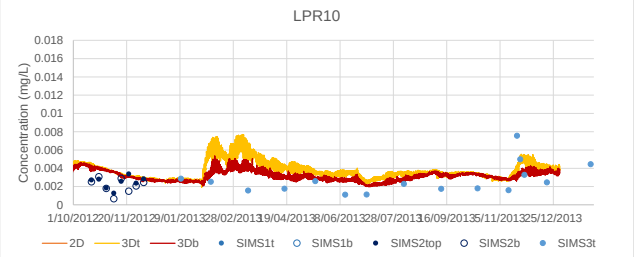

LPR01
Concentration (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SiMS3t

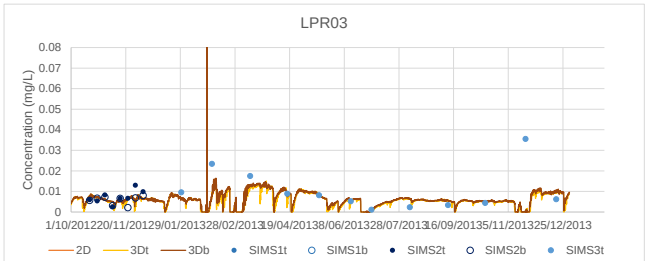

LPR02
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR04
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR06
Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t


LPR08
Concentration (mg/L)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS3t


LPR10
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2top
SIMS2b
SIMS3t

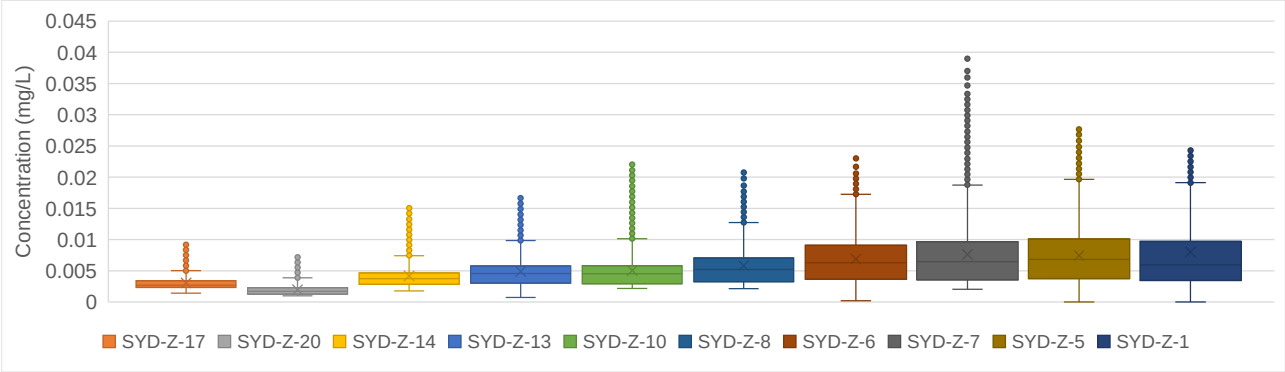

LPR03
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

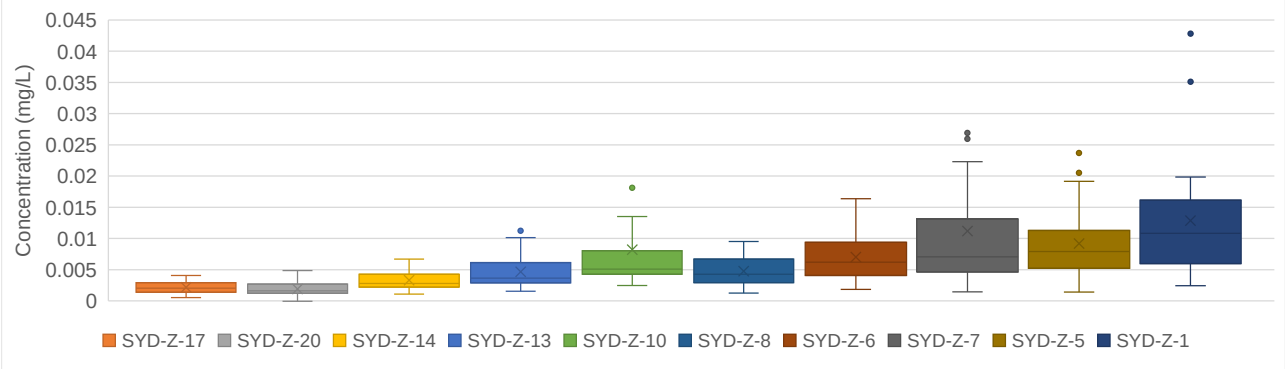
LPR05
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

LPR07
Concentration (mg/L)
0.02
0.015
0.01
0.005
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

LPR9
Concentration (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
1/10/2012
20/11/2012
29/01/2013
28/02/2013
19/04/2013
8/06/2013
28/07/2013
16/09/2013
5/11/2013
25/12/2013
2D
3Dt
3Db
SIMS1t
SIMS1b
SIMS2t
SIMS2b
SIMS3t

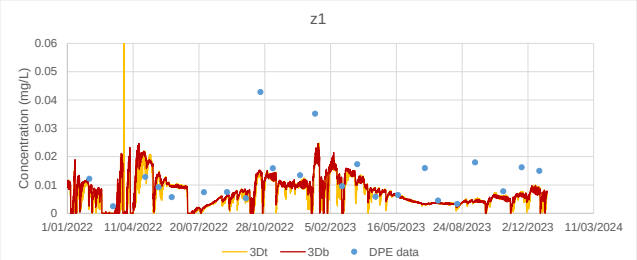
Appendix D11_2 – Chlorophyll *a* validation (DCCEEW data 2022-23)

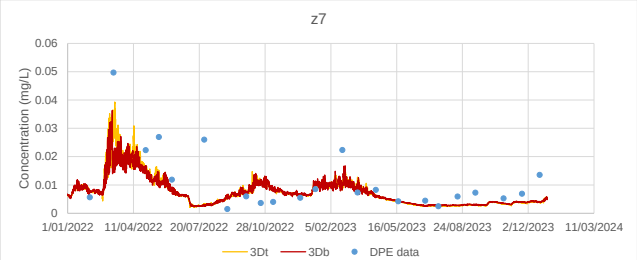


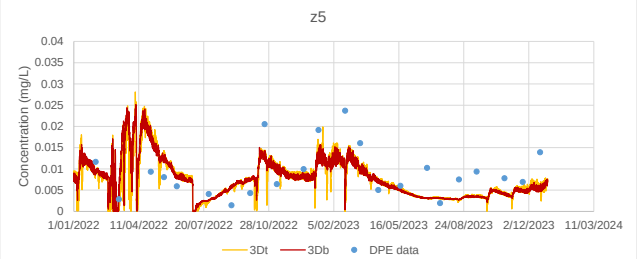


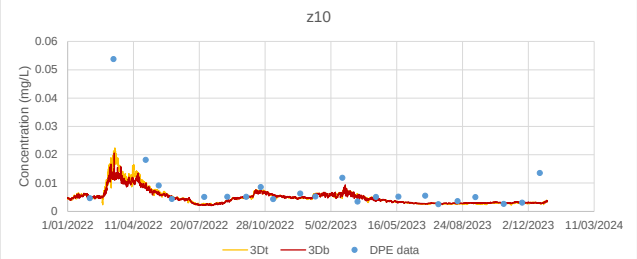
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

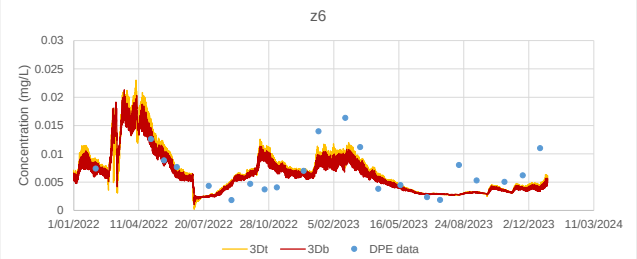
Timeseries plots presented below

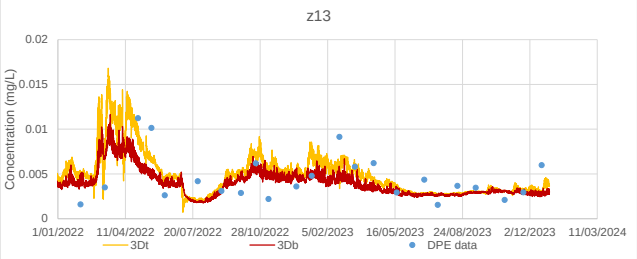

z1
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

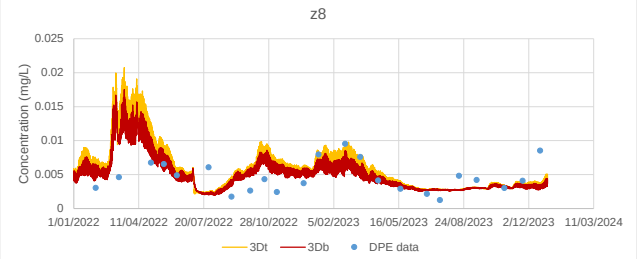

z7
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

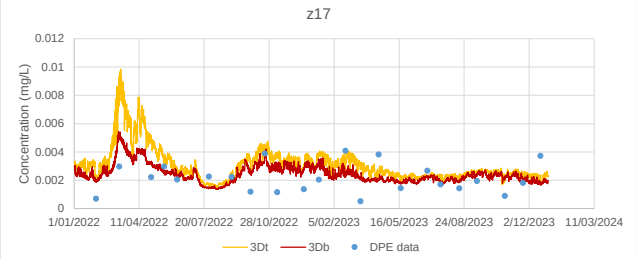

z5
Concentration (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

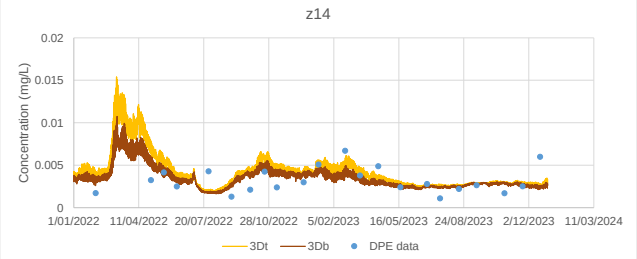

z10
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

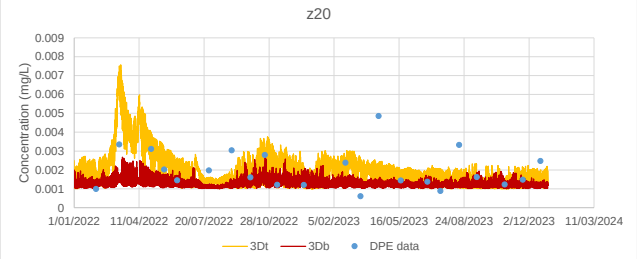

z6
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z13
Concentration (mg/L)
0.02
0.015
0.01
0.005
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

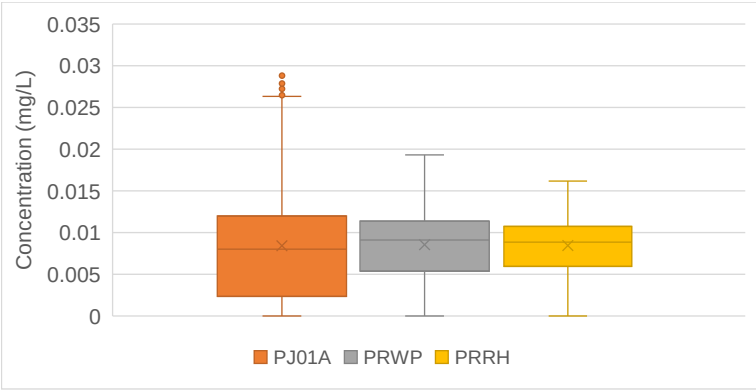

z8
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

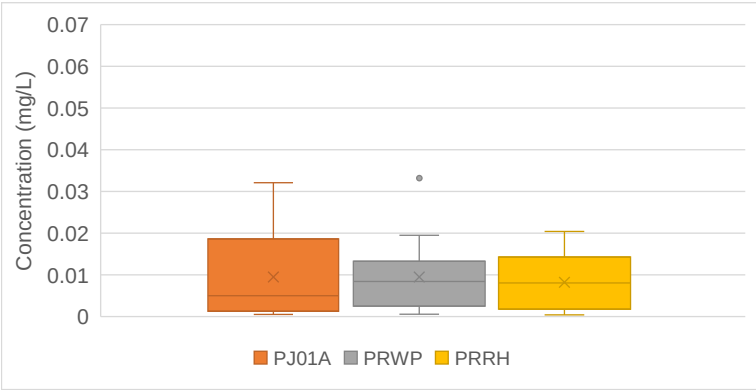

z17
Concentration (mg/L)
0.012
0.01
0.008
0.006
0.004
0.002
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z14
Concentration (mg/L)
0.02
0.015
0.01
0.005
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data


z20
Concentration (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1/01/2022 11/04/2022 20/07/2022 28/10/2022 5/02/2023 16/05/2023 24/08/2023 2/12/2023 11/03/2024
3Dt
3Db
DPE data

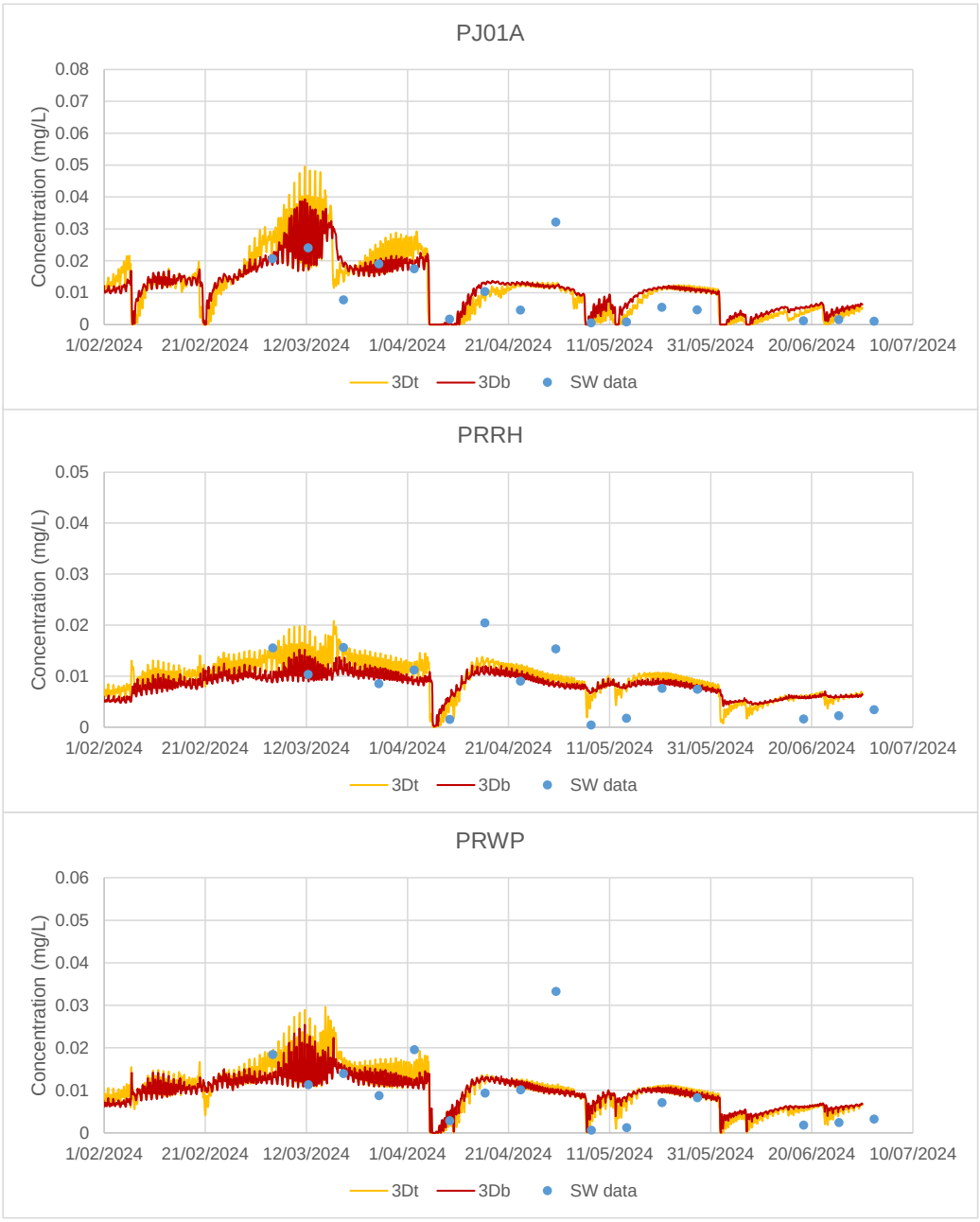
Appendix D11_3 – Chlorophyll *a* validation (SW data 2024)





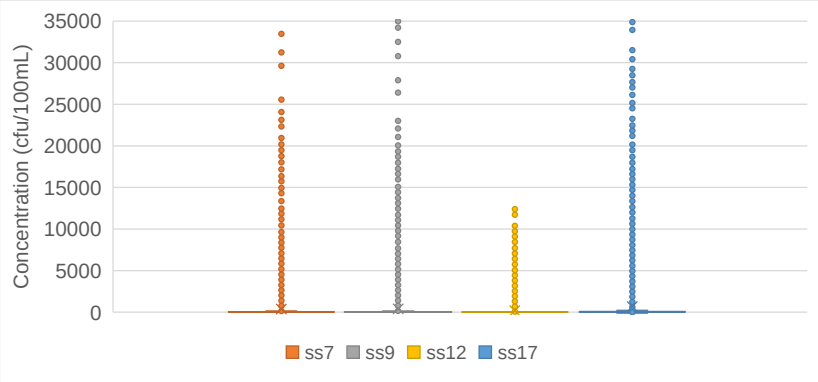
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

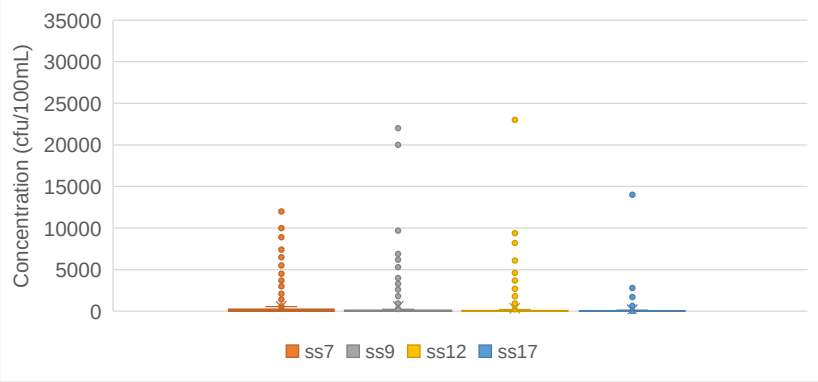
Timeseries plots presented below


PJ01A
Concentration (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRRH
Concentration (mg/L)
0.05
0.04
0.03
0.02
0.01
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data
PRWP
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data

Appendix D12 Enterococci

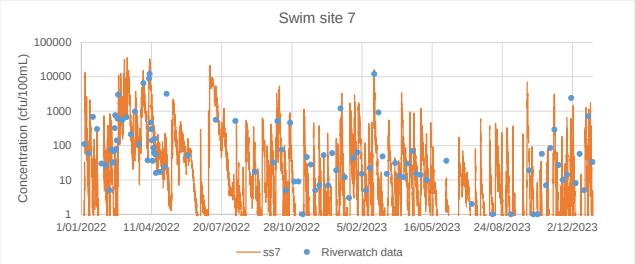
Appendix D12_1 – Enterococci calibration (SW data 2022-23)

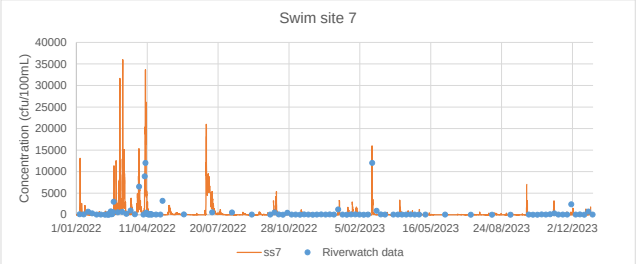


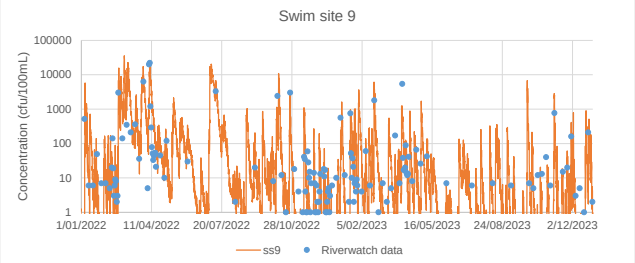


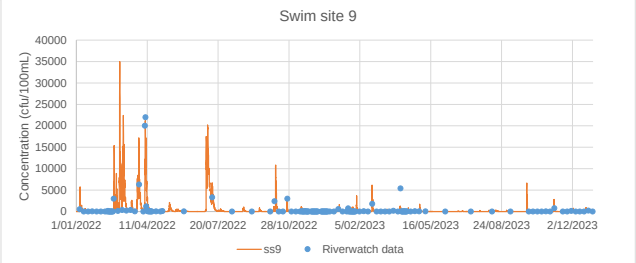
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

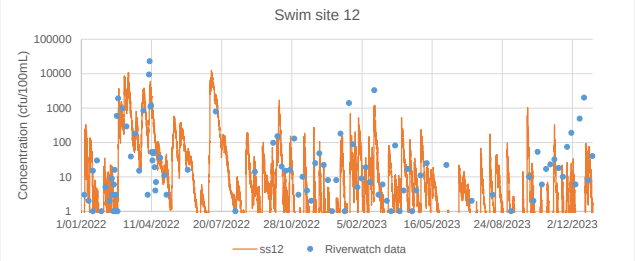
Timeseries plots below include logarithmic scale (left) and non-logarithmic scale (right)

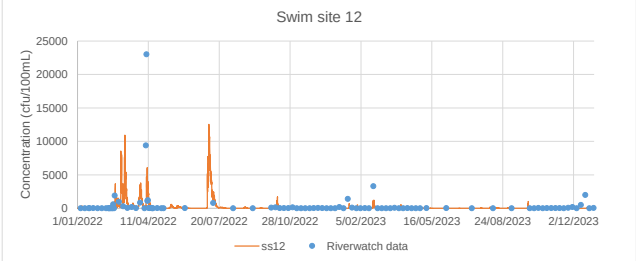

Swim site 7
Concentration (cfu/100mL)
100000
10000
1000
100
10
1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss7
Riverwatch data

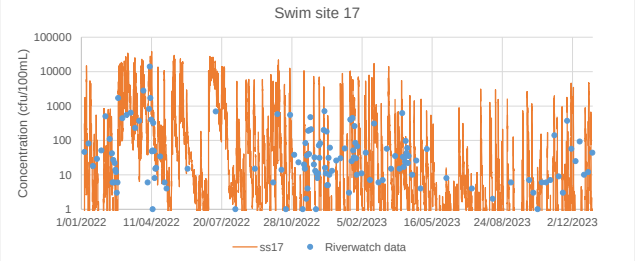

Swim site 7
Concentration (cfu/100mL)
40000
35000
30000
25000
20000
15000
10000
5000
0
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss7
Riverwatch data

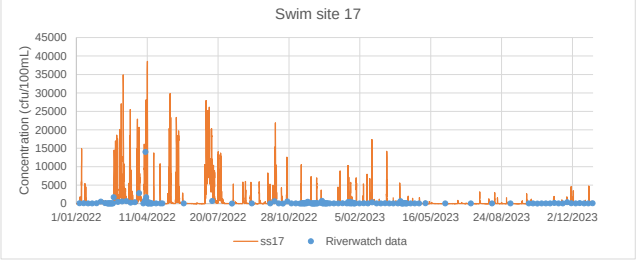

Swim site 9
Concentration (cfu/100mL)
100000
10000
1000
100
10
1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss9
Riverwatch data


Swim site 9
Concentration (cfu/100mL)
40000
35000
30000
25000
20000
15000
10000
5000
0
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss9
Riverwatch data

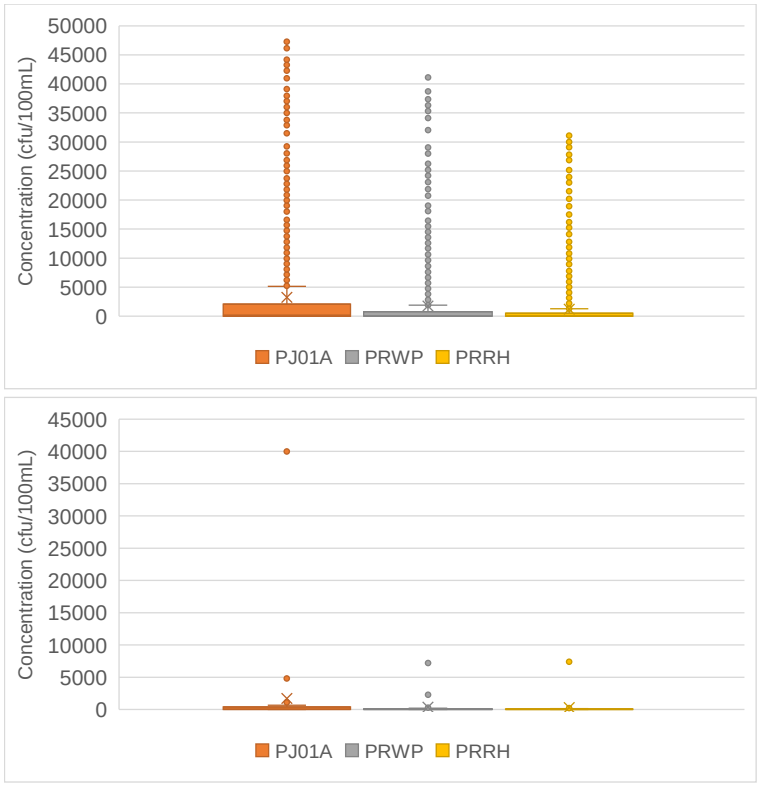

Swim site 12
Concentration (cfu/100mL)
100000
10000
1000
100
10
1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss12
Riverwatch data


Swim site 12
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss12
Riverwatch data


Swim site 17
Concentration (cfu/100mL)
100000
10000
1000
100
10
1
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss17
Riverwatch data

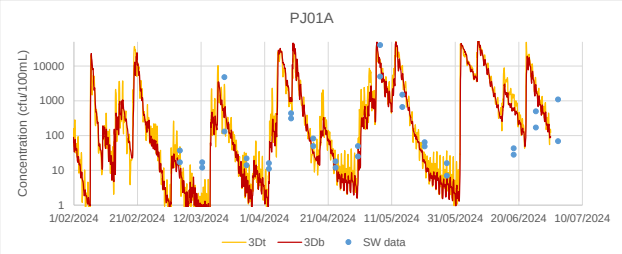

Swim site 17
Concentration (cfu/100mL)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1/01/2022
11/04/2022
20/07/2022
28/10/2022
5/02/2023
16/05/2023
24/08/2023
2/12/2023
ss17
Riverwatch data

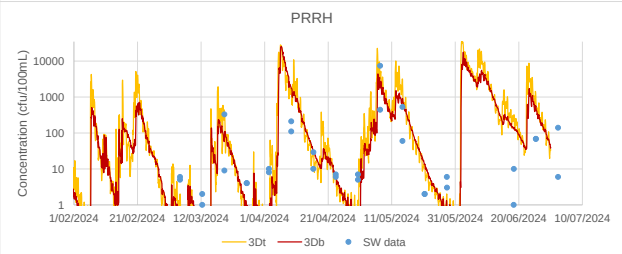
Appendix D12_2 – Enterococci validation (SW data 2024)

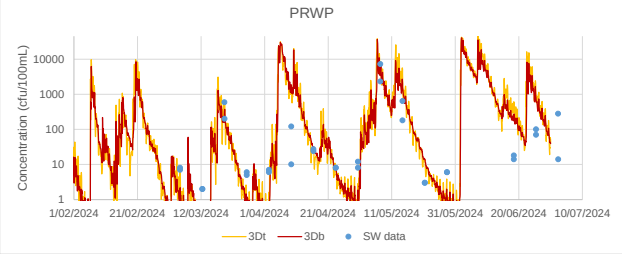


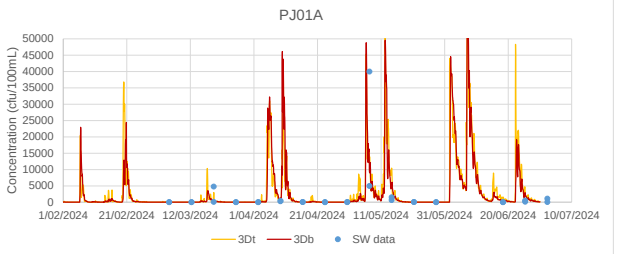
Box and Whisker distributions (Top – Model results, Bottom – Monitoring data)

Timeseries plots below include logarithmic scale (left) and non-logarithmic scale (right)


PJ01A
Concentration (cfu/100mL)
10000
1000
100
10
1
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PRRH
Concentration (cfu/100mL)
10000
1000
100
10
1
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PRWP
Concentration (cfu/100mL)
10000
1000
100
10
1
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
31/05/2024
20/06/2024
10/07/2024
3Dt
3Db
SW data


PJ01A
Concentration (cfu/100mL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1/02/2024
21/02/2024
12/03/2024
1/04/2024
21/04/2024
11/05/2024
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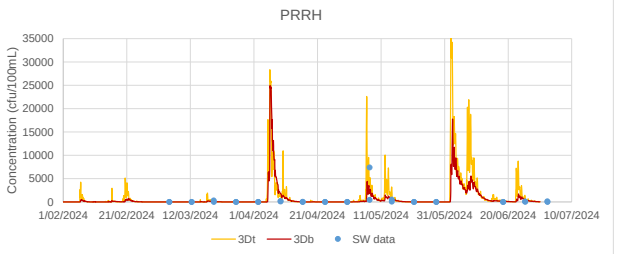
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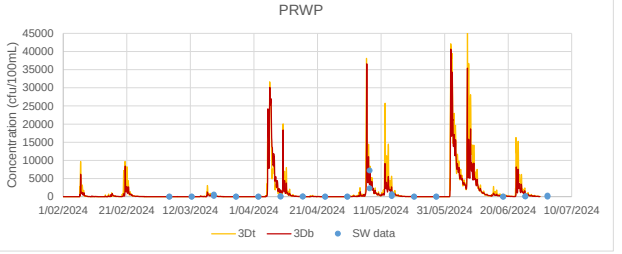
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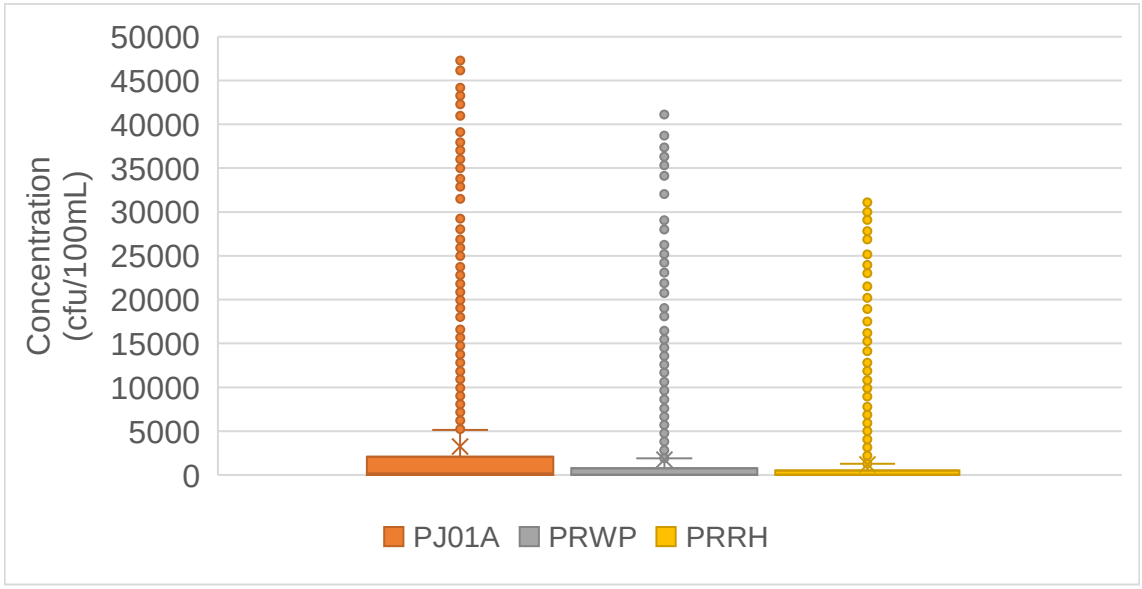
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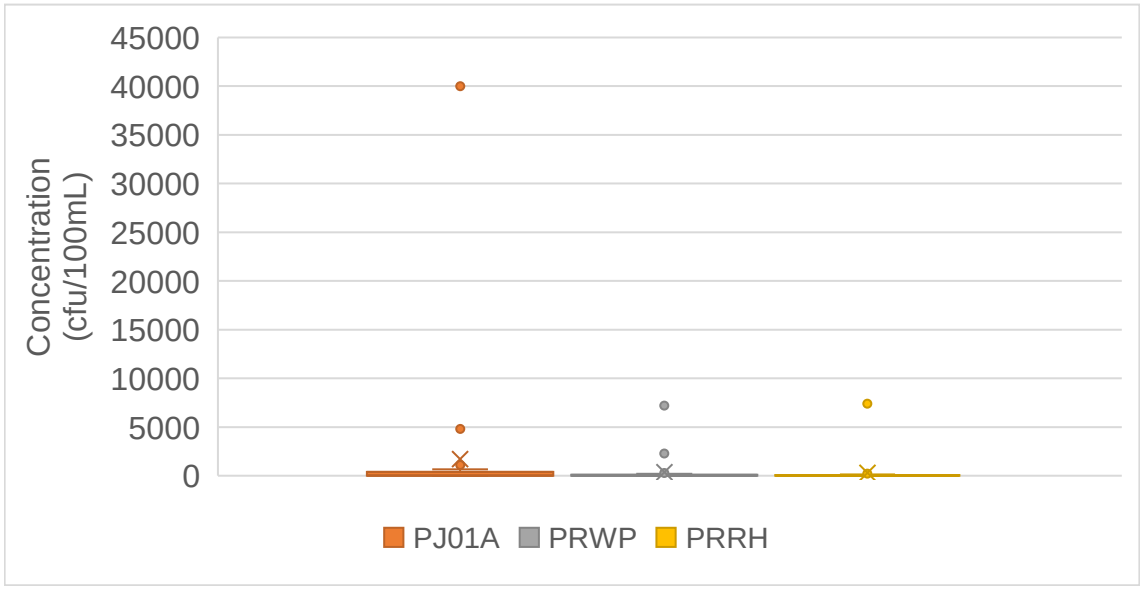
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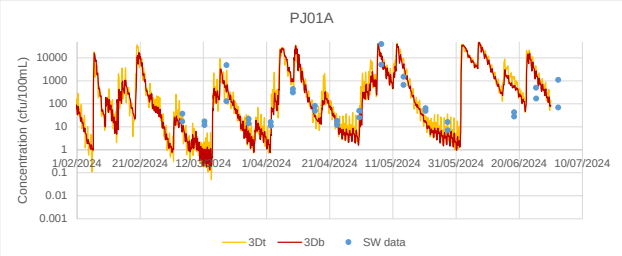
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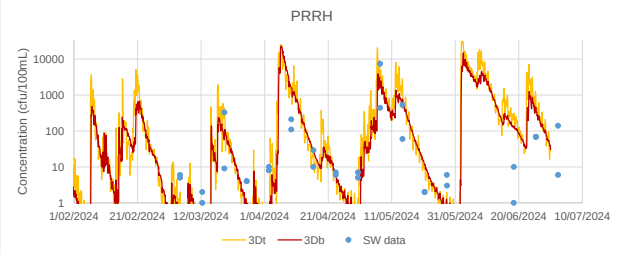
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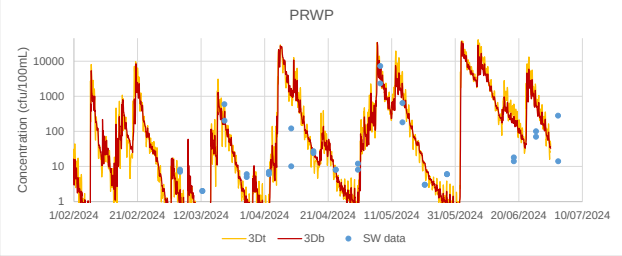
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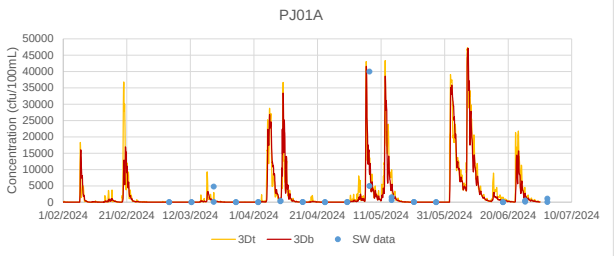
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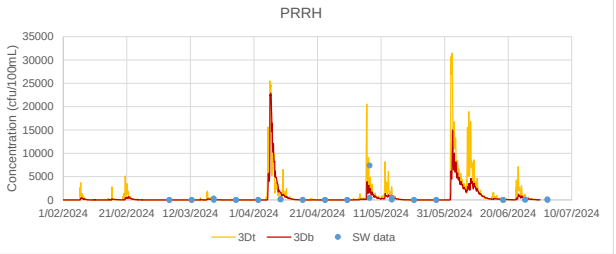
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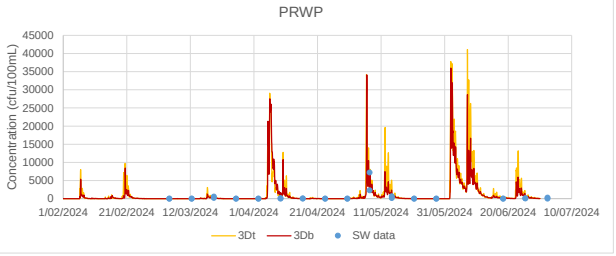
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Appendix E Parameterisation of water quality for sewer overflow releases

GPOP EIS project – Hydrodynamic and Water Quality Modelling

Parameterisation of water quality for sewer overflow releases

1 Purpose statement

As part of the GPOP EIS project, a modelling framework is being developed to allow assessment of impacts on the receiving waterways from new wastewater treatment infrastructure. The proposed infrastructure could potentially release treated water to the Parramatta River estuary and also modify existing wet weather releases from the sewer network. The framework involves the use of the following software: Source (for catchment flows/loads), MOUSE (for sewer overflow flows) and MIKE (for hydrodynamics and water quality within the receiving waters).

Previous receiving water quality modelling by Sydney Water has adopted a relatively simplistic approach for simulation of sewer overflows. This approach involves characterisation of water quality from the overflow releases by the application of a single concentration value for each of the pollutants modelled e.g. nutrients, suspended sediments, etc. Recent research and initiatives have demonstrated that such an approach may not represent the real variability in water quality that these releases present.

To improve characterisation of the water quality being released from sewer network overflow points, a new “dilution based” approach has been developed for the Georges River Flows (GRF) modelling project. The approach allows for simulation of dilution of raw sewage with stormwater and how this may change over the course of rainfall events.

This document outlines a methodology for representation of the sewer overflows within the GPOP model framework which is consistent with the approach developed for the GRF project.

2 The challenge

To parameterise the water quality release conditions from Emergency Relief Structures (ERS’s) to allow development of a water quality response model (WQRM) of the Parramatta River/Sydney Harbour for use in the GPOP EIS project, with consideration of advances in research and current initiatives relating to Wet Weather Overflow Abatement. Figure 1 presents a map of the GPOP area and Figure 2 presents the extents of the GPOP model domain including representation of sewer overflow volumes

The aspiration is to include expected variations in flows and water quality from the ERS’s within the WQRM’s so as to address the following:

- Location specific release conditions for each ERS relating to the interactions between the upstream stormwater and wastewater networks including simulation of the relative weir levels and the assumed in-pipe mixing of the stormwater and wastewater prior to release.
- The magnitude of wet weather events and how this affects the above variables and consequently the release conditions (flow and quality).
- The type of ERS e.g. symphonic, gravity, reticulation, etc. and how this may also affect the release conditions.

There currently are a number of modelling tools in development (MOUSE TRAP and ICM) that will assist in achieving these longer-term objectives. Similarly, monitoring programs are also being expanded by Sydney Water which will allow for further development and calibration of these models.

The challenge is to determine an approach that will be adopted in the GPOP EIS project that builds upon recent advances incorporated in the GRF project and moves away from the overly simplistic assignment of uniform values for each contaminant from every overflow point (ERS) within the model domain. A simplistic approach of this nature is very likely to be criticised based on findings from recent research and consultation with the NSW state government departments EPA and DPE.

The proposed approach would also preferably allow for future advances to be integrated into the WQRM’s when they are considered robust enough for use.

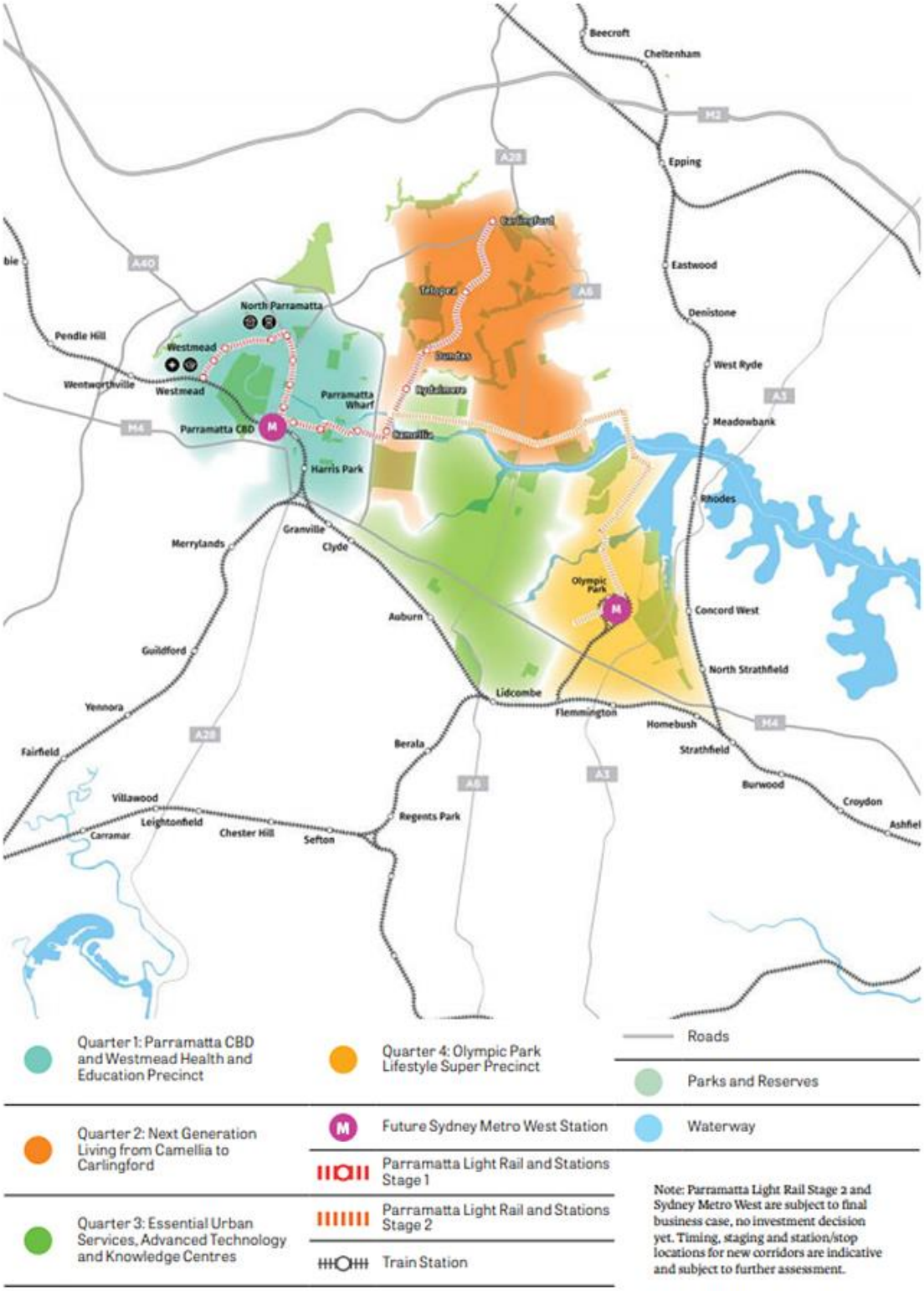
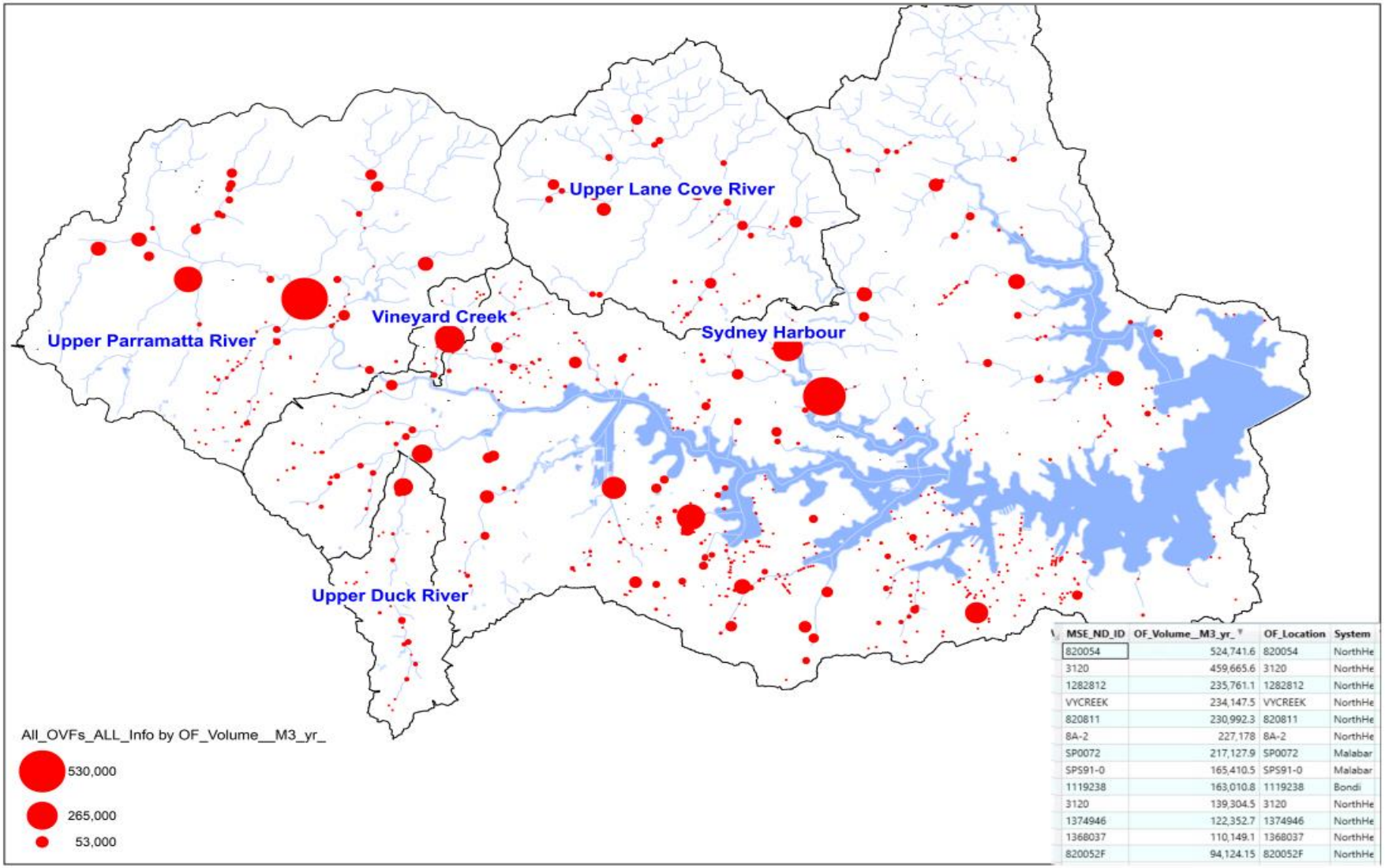


Figure 1 Map of the GPOP area (Source:NSW Government)



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VYCREEK	234,147.5	VYCREEK	NorthHe
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8A-2	227,178	8A-2	NorthHe
SP0072	217,127.9	SP0072	Malabar
SPS91-0	165,410.5	SPS91-0	Malabar
1119238	163,010.8	1119238	Bondi
3120	139,304.5	3120	NorthHe
1374946	122,352.7	1374946	NorthHe
1368037	110,149.1	1368037	NorthHe
820052F	94,124.15	820052F	NorthHe

Figure 2 Extents of the GPOP model domain including representation of sewer overflow volumes

3 Opportunities and Constraints

The following opportunities have been identified:

- Research initiatives by Sydney Water including the following:
  - The Port Hacking Integrated Catchment Model (ICM) project that aims to model three systems (stormwater, wastewater and receiving water) and has included an extensive sampling program including autosamplers located within each water type.
  - The broader ICM initiative that is currently under development and seeks to extend the application of concepts from the Port Hacking ICM to a wider spatial domain including the Georges River, Botany Bay, the Parramatta River and Sydney Harbour catchments.
  - 'The composition of gross pollutants contained in wet weather overflows for different locations, spill frequencies and discharge volumes' (Besley and Cassidy, 2022). https://doi.org/10.1016/j.jenvman.2021.114256
  - 'Tracking contaminants of concern in wet-weather sanitary sewer overflows' (Besley, Batley and Cassidy, 2023). https://doi.org/10.1007/s11356-023-29152-x
- The knowledge and processes developed will also aid a broader range of projects within Sydney Water.

The following constraints were identified:

- The budget and program of the GPOP EIS project.
- The limited availability of water quality monitoring data for ERS releases in the GPOP model domain.

4 Time periods

The simulation periods relevant to the GPOP modelling extend from 2012 through to 2024. This period includes periods required for calibration and validation as well as for scenario testing.

5 Proposed methodology

The following methodology has been developed to provide an optimal outcome for the GPOP EIS project and is consistent with the approach applied in the GRF modelling.

5.1 Release rates

For the MOUSE sewer overflow modelling, it is understood that Sydney Water's STS models will be used to develop timeseries of release volumes from the various ERS's. SCAMP models, which provide for additional resolution and inclusion of the reticulation network, are yet to be developed for the sewerage catchments within the GPOP model domain.

5.2 Water quality

The following methodology for development of water quality conditions is proposed for all the ERS's within the GPOP model domain. While there is currently no identified requirement to model individual ERS's in an alternative manner, provision is presented in Section 5.3 for simulation of "higher yield" overflows if an alternative methodology is identified as more applicable for these assets.

The proposed methodology has been developed to allow for temporal variations in water quality concentrations in ERS releases based on the magnitude of the wet weather event and also with adoption of parameterisation from previous overflow analysis including the Hawkesbury Nepean model upgrade and the Upper South Creek AWRC EIS projects.

The following stepped approach is proposed:

- Acquisition and analysis of hourly time series rainfall data for each sub-catchment in the GPOP Source model. It is noted that not every sub-catchment contains an STS overflow point and may

therefore not be applied. It is also noted that alternative time steps could be used e.g. daily, although this would affect some subsequent analysis steps and also file sizes.

- Calculation of cumulative antecedent rainfall (CAR). Provisionally the length of time adopted for the CAR was selected as 24 hours, however this could be lengthened or shortened based on further investigations and determination of a relationship between dilution factors and temporal extent of preceding rainfall.
- Calculation of a dilution factor (DF) based on the following rules (and as presented in Figure 3):
  - If CAR <5, zero DF is applied
  - If CAR >5 and <120, a linear relationship from 0 to 6 for the DF is applied
  - If CAR>120, a DF of 6 is applied

  Excel equation: DF=IF(*CARcell*>120,(6),IF(*CARcell*>5,(((*CARcell*-5)*6/(120-5))),0))
  where: *DF* represents the calculated Dilution Factor (DF)
  CARcell represents the cell for Cumulative Antecedent Rainfall
- Calculation of water quality concentrations for parameter X for each time step with application of the above dilution factor and the relevant concentrations for raw sewage and stormwater EMC (event mean concentration).
  Excel equation: C_{OF}=(1**SEWAGEcell*+*DFcell***STORMcell*)/(1+*DFcell*)
  where: C_{OF} represents the calculated concentration of the overflow
  SEWAGEcell represents the cell for assumed concentration of sewage
  STORMcell represents the cell for assumed concentration of stormwater
  DFcell represents the cell for the Dilution Factor (DF)

Table 1 presents a provisional range for concentrations of raw sewage to be applied in the analysis. Concentrations of stormwater can be provisionally determined from the EMCs as finalised in the Source and MIKE model calibration tasks.

As required, modification of the following settings can be undertaken during calibration of the receiving water quality response model:

- raw sewage concentrations
- event mean concentrations
- minimum dilution factor

Results from application of the algorithm against monitoring data collected within the Georges River and Botany Bay catchments are presented in Appendix A.

Results from application of the algorithm against monitoring data collected within the Pot Hacking catchment are presented in Appendix B.

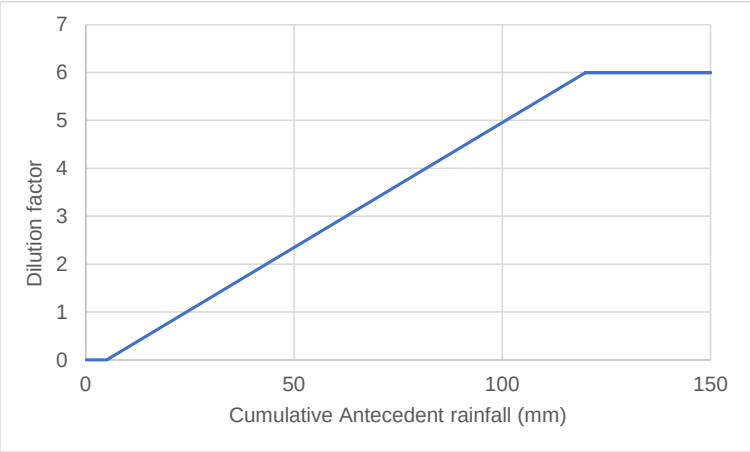


Figure 3 Proposed relationship between dilution factor and cumulative antecedent rainfall

Table 1 Initial concentrations applied in the overflow analysis

Parameter	Raw Sewage conc (mg/L)	Stormwater conc (mg/L)
TN	63-78	TBC
TP	9-13.5	TBC
TSS	320-410	TBC

Table notes

- *The ranges of raw sewage concentrations were derived from analysis of influent monitoring data (collected under dry weather conditions) from Sydney Water's Hawkesbury Nepean WWTPs, as well as from monitoring data collected from Port Hacking, Millstream and Muddy Creek ERS's.*
- *The Stormwater concentrations are to be derived from the proposed parameterisation of urbanised land use for the GPOP Source model.*

5.3 Higher yield overflows

Based on recent STS modelling, uncertainty exists in relation to which overflow assets may continue to yield higher release volumes. This uncertainty is understood to be a result of network changes as well as ongoing updates to the sewer network models.

Due to this uncertainty, all assets, regardless of their potential yield, will be modelled in line with the methodology presented in Sections 5.1 and 5.2. If modification of any release condition is required, these modifications can be implemented through adjustments in the Source model boundaries or within the sewer network model interface.

5.4 Assumptions

The following assumptions are noted in the aforementioned analysis:

- The duration of antecedent rainfall used in the calculations has nominally been set at 24 hours across all sub-catchments.
- A dilution factor profile has been developed based on the three stages defined in Section 5.2. This has been applied across all sub-catchments in the model domain.
- Concentrations of raw sewage have provisionally been derived from influent monitoring data (collected under dry weather conditions) from Sydney Water's Hawkesbury Nepean WWTPs and WRP as well as monitoring data collected at Port Hacking, Muddy Creek and Millstream ERS's. No variations to these values are proposed across any of the sub-catchments.
- Concentrations of stormwater are to be derived from the proposed parameterisation of EMCs for urbanised land use within the GPOP Source model. No variation is proposed in these values due to rainfall or runoff from the catchments. No variation is proposed across any of the sub-catchments.

6 Summary statement

As an initiative to improve the characterisation of water quality being released from sewer overflows, a dilution-based algorithm has been developed, primarily for application in Sydney Water's receiving water quality models.

The algorithm utilises available meteorological data to determine a timeseries of antecedent rainfall which is then applied to estimate a dilution factor between raw sewage and stormwater, the stormwater entering the sewerage network through inflow and infiltration processes. The resulting concentrations of the overflows are then calculated from consideration of expected nutrient concentrations in raw sewage and in stormwater.

The algorithm has been applied to overflows at Millstream and Muddy Creek within the Georges River and Botany Bay catchments. Application of the algorithm at these two overflow points presented a high correlation against monitoring data collected between 2020 and 2022 (refer Appendix A).

The algorithm has also been applied to overflows in the Port Hacking catchment. With consideration of the field data conditions (refer Appendix B), application of the algorithm at four overflow points presented a moderate to high correlation against monitoring data collected.

The algorithm and approach developed for the GPOP EIS project is consistent with the approach developed for the Georges River Flows project. Application may also be considered for use in other modelling projects within Sydney Water.

Appendix A Comparison of model results against monitoring data collected within the Millstream and Muddy Creek catchments

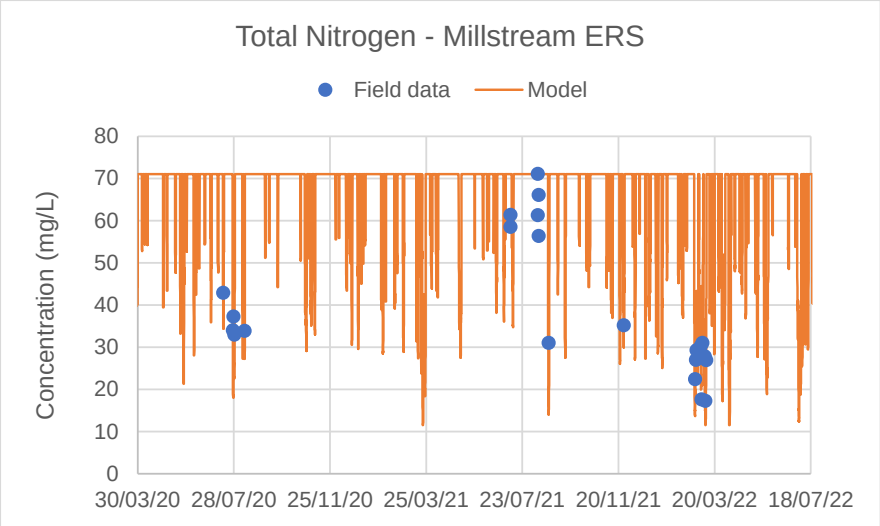


Figure A1 Predicted overflow concentrations of TN plotted against field data (Millstream ERS)

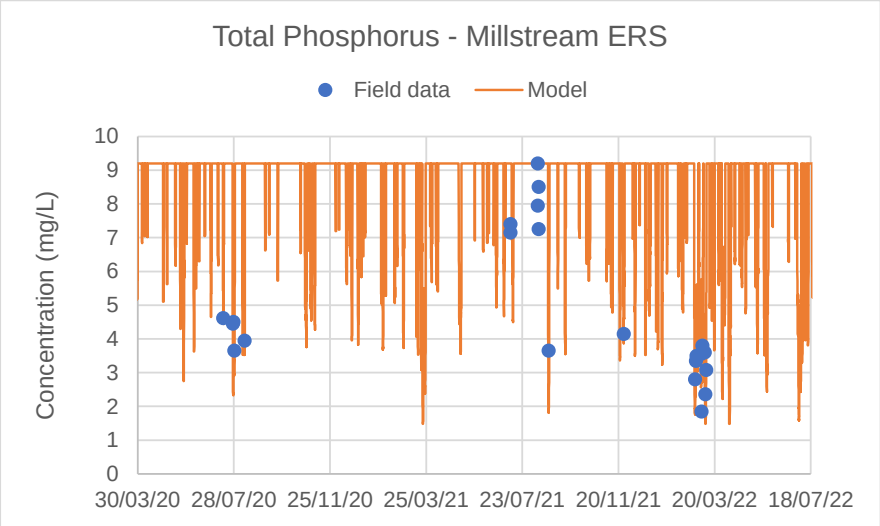


Figure A2 Predicted overflow concentrations of TP plotted against field data (Millstream ERS)

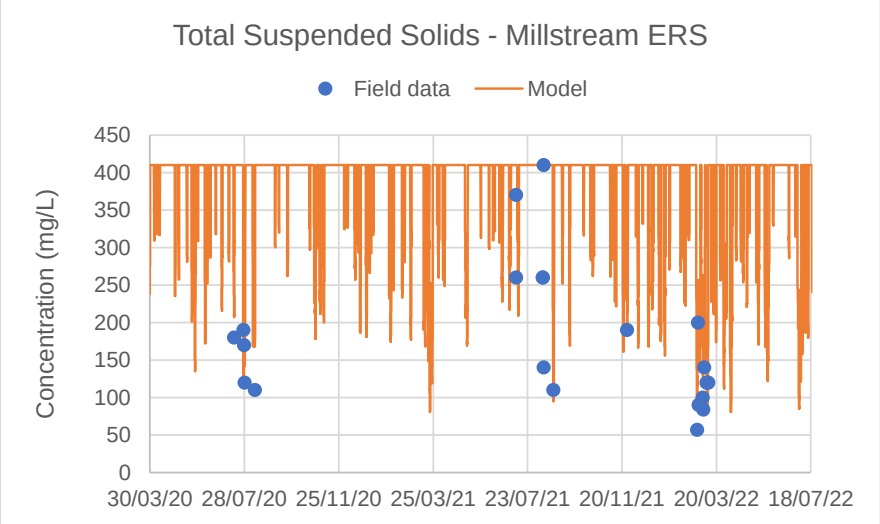


Figure A3 Predicted overflow concentrations of TSS plotted against field data (Millstream ERS)

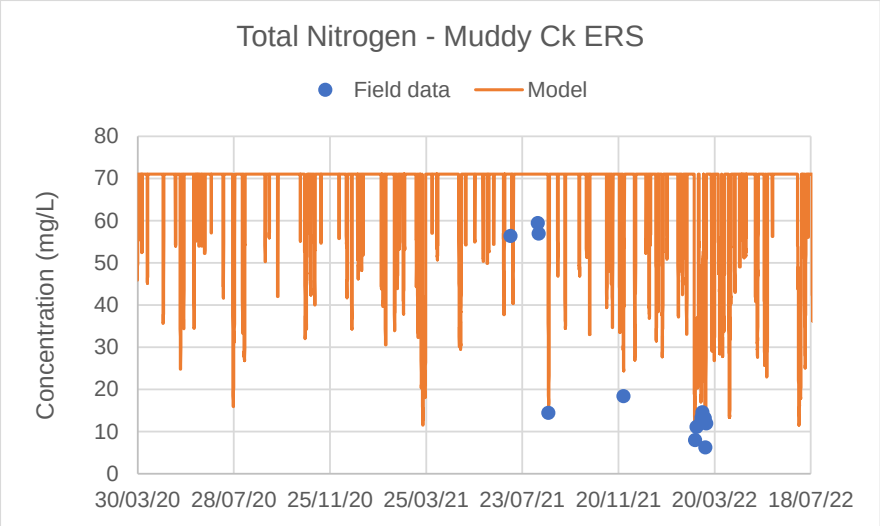


Figure A4 Predicted overflow concentrations of TN plotted against field data (Muddy Creek ERS)

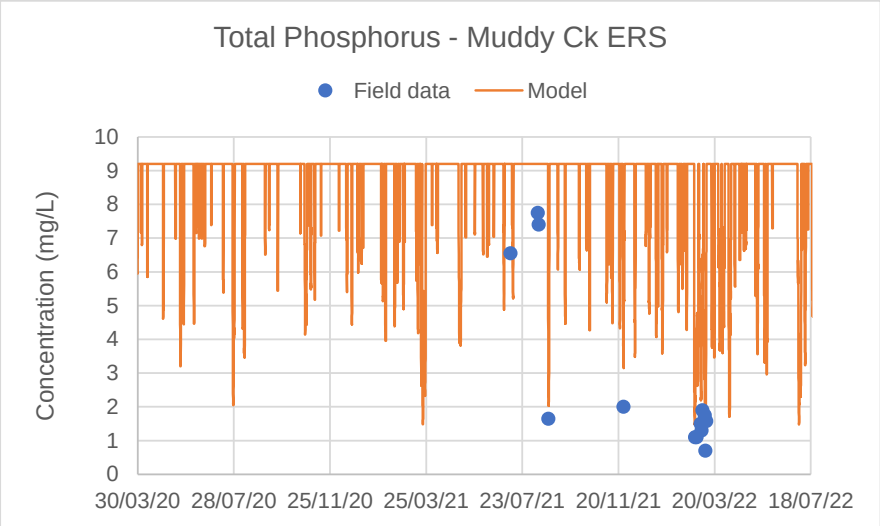


Figure A5 Predicted overflow concentrations of TP plotted against field data (Muddy Creek ERS)

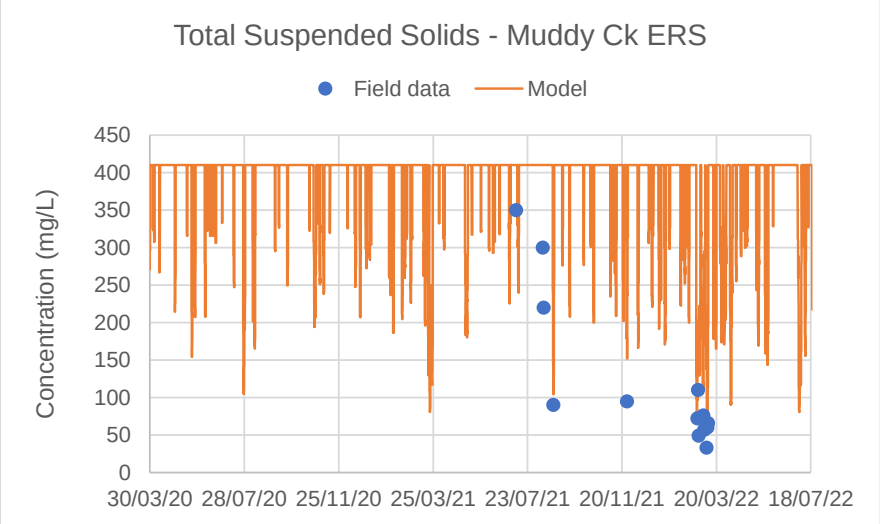


Figure A6 Predicted overflow concentrations of TSS plotted against field data (Muddy Creek ERS)

Appendix B Comparison of model results against monitoring data collected within the Port Hacking catchments

The following notes are provided in relation to the Port Hacking data:

- Samples were collected via auto-samplers
- Significant outliers were identified in relation to elevated nutrient concentrations (>90 mg/L TN and >40 mg/L TP). These data points were removed from the analysis.
- Sampling sites were generally located in networks that would be tidally influenced. The location of the sampling sites are presented below in Figure B1.
- Model 1 uses data from the nearest Sydney Water rain gauge. Model 2 uses average rainfall from the three closest Sydney Water rain rainfall gauges.

Figure B1 Location of the Port Hacking Wastewater Sampling sites

Figure B2 Predicted overflow concentrations of TN plotted against field data (Port Hacking)

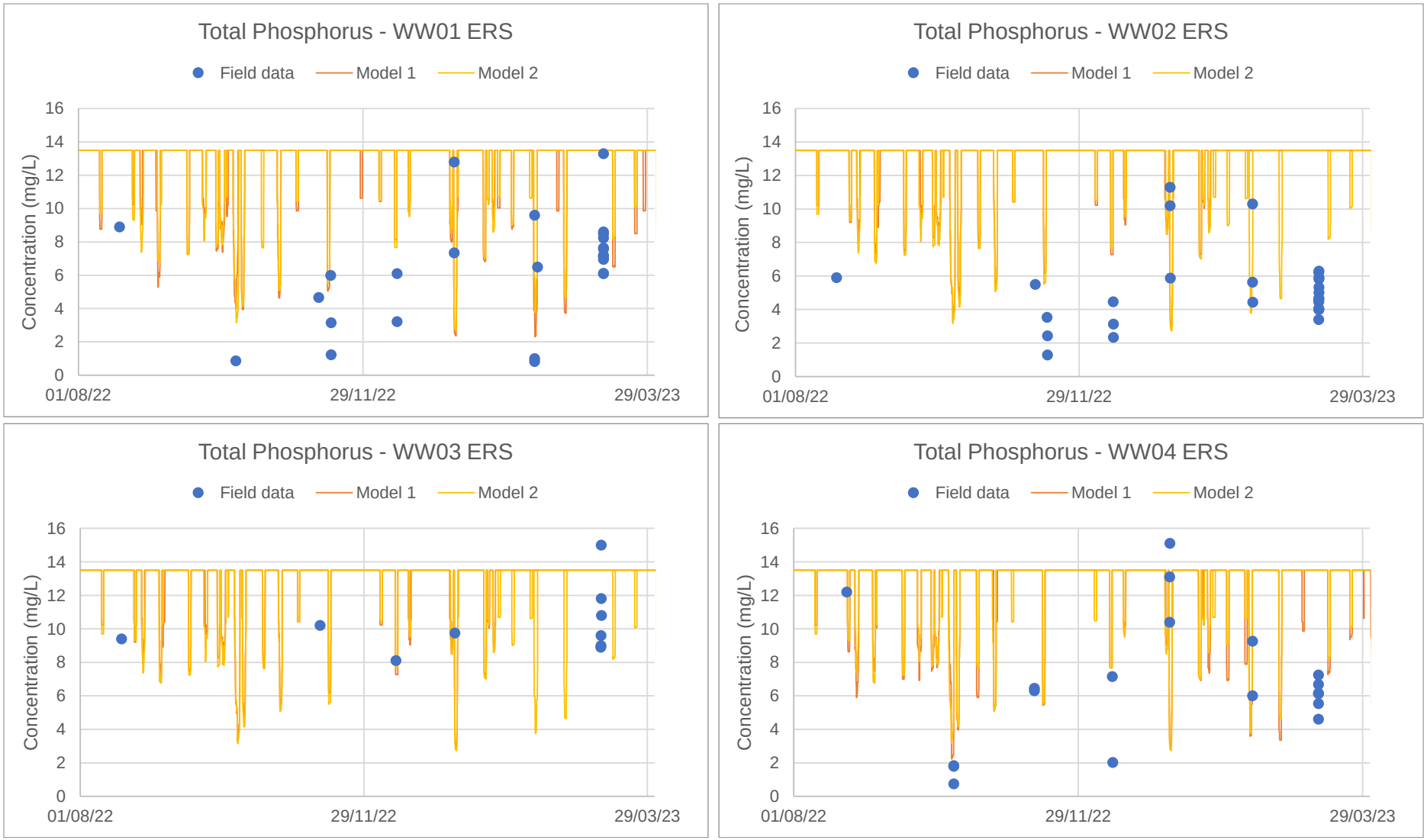


Figure B3 Predicted overflow concentrations of TP plotted against field data (Port Hacking)

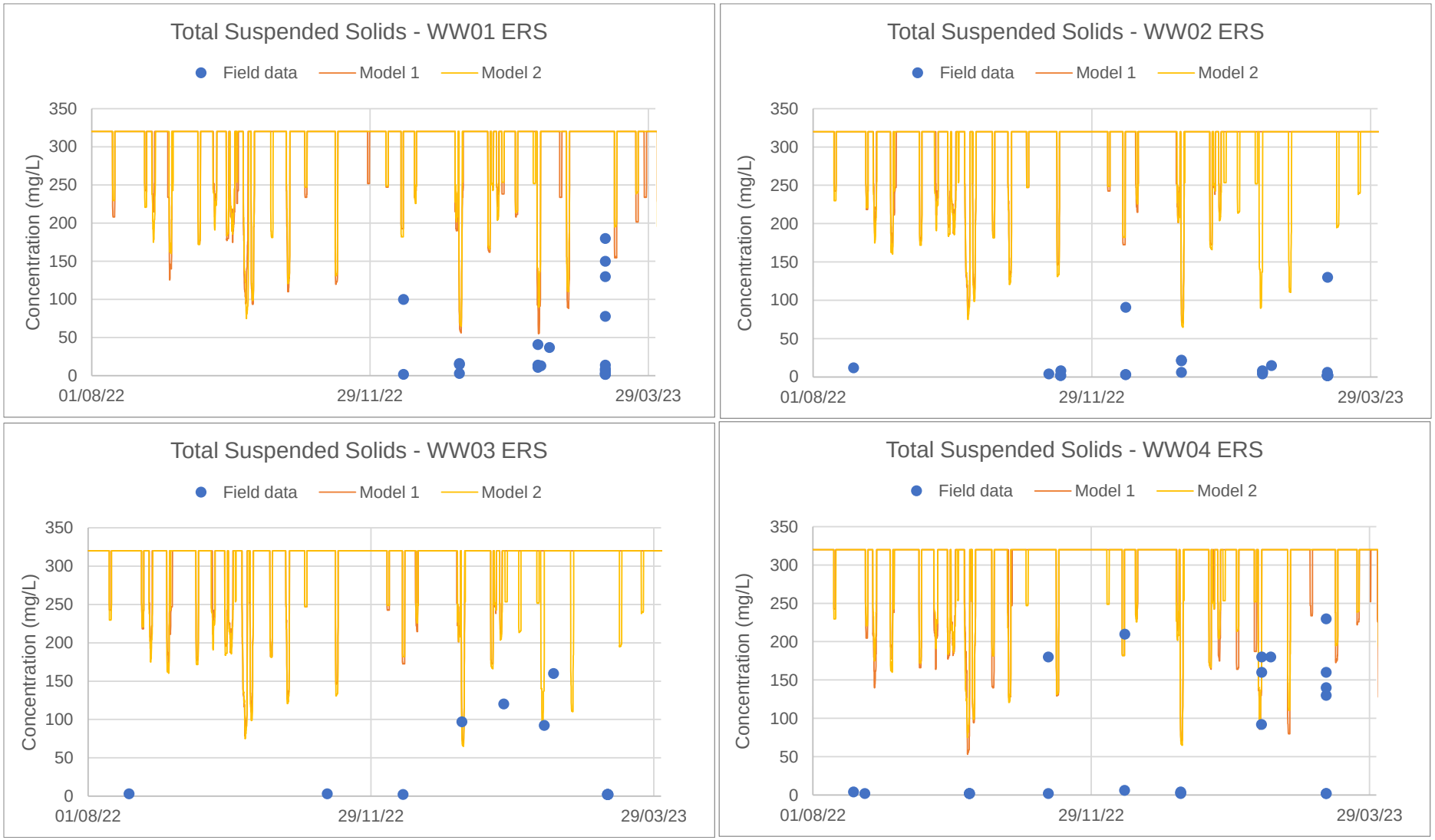


Figure B4 Predicted overflow concentrations of TSS plotted against field data (Port Hacking)

Appendix F Independent Review

10 November 2025

WRL Ref: WRL2025047 L20251110 BMM

UNSW
Water Research
Laboratory

Florence Jeong
Ed Beling
Major Projects
Sydney Water Corporation

By email: florence.jeong@sydneywater.com.au
ed.beling@sydneywater.com.au

Dear Florence and Ed,

Independent Expert Review
GPOP Water Quality Response Model Calibration Report

I (Brett Miller) undertook an independent expert review of the Sydney Water Report "*GPOP Water Quality Response Model Calibration Report*". I am considered by my peers to be expert hydrodynamic and water quality numerical modeller. I am familiar with the area of concern in Sydney Harbour and Parramatta River being part of the Greater Parramatta and Olympic Peninsula (GPOP) discharges from the Camellia Water Resource Recovery Facility (WRRF).

My initial review was of a draft version of the report dated 3rd July 2025. I asked specific questions based on the draft which were addressed and clarified in a final version dated 29th August 2025. Discussion provided in this review pertains to the final version.

Overview

The modelling suite, the model domain and modelling methods are appropriate for the investigation of expected changes in discharge quantity and quality to the upper Parramatta River. The numerical models and 3D modelling approach are commensurate with industry best practice. The overall calibration and verification are sound and the modelling suitable for assessment of hydrodynamic and water quality scenarios associated with the Greater Parramatta and Olympic Peninsula (GPOP) discharges.

Overall, this is a commendable numerical modelling calibration.

Hydrodynamics

Comparison of model discharge (for both calibration and verification) are a good match and ensure that the calibrated model is suitable for the assessment of the GPOP discharges.

Water level data was only compared against the model at a single location at Fort Denison. Given the nature of the tides throughout Sydney Harbour, this is not a major concern, however I recommend that Sydney Water continue to source additional water level data throughout Sydney Harbour for subsequent studies.

The calibration report identifies that comparison of model discharge and ADCP data is less accurate in the upper estuary than the lower estuary. There was significant change in the modelled tidal discharge timeseries between V3 and V4 (both in the upper estuary) which may be related to increased model friction. Short period fluctuations of model discharge predictions in the upper estuary may indicate model instability. The report addresses this stating "*It is recommended that for future upgrades to the model, that a review of the bed roughness parameterisation is undertaken, particularly with respect to the higher values currently attributed to the upper estuary. Reducing the existing values or undertaking a sensitivity assessment may assist in mitigating the irregularities that are seen in the results of some of the upper estuarine sites.*"

It is my opinion that the hydrodynamic model in its present form is suitable for running scenarios of GPOP changed discharges. I recommend that all scenarios include a conservation-of-mass check.

Mud Transport

The "mud" transport module relies on a cohesive sediment transport module throughout the entire estuary. Since the turbidity and subsequent light penetration predicted by this model is important for algae growth in the water quality model, I recommend that sensitivity of the sediment model be included in the assessment of any water quality scenarios. This should be undertaken in the upper estuary where background turbidity is high.

Water Quality

The calibration report presents a reasonable match of all water quality parameters to the available water quality data, which was collected at regular (but not continuous) times and several locations throughout the harbour.

In my opinion, uncertainty in the predictions made by the water quality model are dominated by uncertainty in the incoming loads boundary conditions. The report includes an uncertainty analysis of these boundary conditions which provides reassurance that the model trends are consistent regardless of the exact boundary condition. Hence, I agree that the model is acceptable for comparing the results between GPOP scenarios.

The report applies a dilution approach whereby water quality constituent concentrations are decreased in the sewer overflows discharges based on cumulative antecedent rainfall. The method is provided in Appendix E "*Parameterisation of water quality for sewer overflow releases*" (which was provided in the final report). It is important to understand and appreciate that these dilutions are theoretically based on stormwater infiltration into the sewer system and not from dilution with additional stormwater runoff in the receiving waters.

Appendix E provides some references to justify the selected cumulative rainfall bands and the dilution factors applied. Comparison of predicted sewage overflow concentrations and field data were presented for overflows at the Millstream and Muddy Creek within the Georges River and Botany Bay catchments. I recommend that the field data be clearly identified whether it was collected from discharged sewage before the receiving waters or from water quality samples within the receiving waters.

Given that the model is to be used for scenarios of sewer overflow and effluent discharge and given that uncertainty remains regarding the water quality of sewage overflows, I recommend that Sydney Water continue to collect data from within the sewers wherever possible under a range of antecedent rainfall conditions, and that model scenarios include sensitivity analysis of sewer overflow concentrations.

Should you have any queries on this review, please contact me on B.Miller@wrl.unsw.edu.au.

Yours sincerely,

Brett Miller
Principal Engineer – Hydraulics and Modelling

Appendix B. Generation of climate change rainfall data

For information

Sydney Water ref: Add file number

GPOP EIS climate change assessment – Generation of future rainfall and potential evapotranspiration data

This memo documents the approach taken for generating the future climate change precipitation and potential evapotranspiration (PET) data for the GPOP EIS. For precipitation data, an adjustment factor was calculated based on the ratio between historical and future (NARCliM 1.5) expected rainfall in the area of interest. The hourly virtual rain station data was then scaled by this factor to calculate climate adjusted future precipitation data. The future PET are estimated from future temperature change.

1. Introduction

There is a need for the simulation of the future (2056) scenario for the GPOP EIS project. Precipitation and potential evapotranspiration rate (PET) time series reflective of year 2056 climate conditions under the Representative Concentration Pathway (RCP) 4.5 are required. Both historical and future time series for a number of variables are available in the NSW an Australian Region Climate Modelling (NARCliM) data portal. There are different versions of NARCliM implementing different versions of Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR) (see Table 1).

Table 1: Key features of NARCliM data

Project features	NARCliM1.0	NARCliM1.5	NARCliM2.0
Release year	2014	2021	2024–25
Years simulated	1990–2009, 2020–2039, 2060–2079	1951–2100[1]	1951–2100
Grid cell resolution (NARCliM domain/CORDEX Australasia domain)	10km/50km	10km/50km	4km/20km
Vertical levels in the atmosphere	30	30	45
Global climate models (GCM) used in combination with regional climate models (RCM)	4 CMIP3 models: CGCM3.1, CSIRO-Mk3.0, ECHAM5, MIROC3.2	3 CMIP5 models: ACCESS1.0, ACCESS1.3, CanESM2	5 CMIP6 models: ACCESS-ESM1-5, EC-Earth3-Veg, MPI-ESM1-2-HR, NorESM2-MM, UKESM1-0-LL
Number of RCMs and WRF[2] version	3 (WRF3.3)	2 (WRF3.6.0.5)	2 (WRF4.1.2)
Emissions scenarios simulated	SRES A2[3]	RCP4.5, RCP8.5[4]	SSP1-2.6, SSP2-4.5, SSP3-7.0[5]
Number of GCM/RCM model combinations (ensemble members)	12	12	30
Reanalysis dataset used[6]	NCEP:1950–2009	ERA-Interim: 1979–2013	ERA5: 1979–2020

NARCliM2.0 implementing IPCC AR6 is the latest and most updated time series for climate change prediction. However, data set for RCP 4.5 (SSP2-4.5) is not available until around mid-2025. Thus, NARCliM1.5 data set is adopted to fit the GPOP EIS project schedule.

There is precipitation time series available in NARCliM1.5 dataset but not PET. Thus, precipitation data from NARCliM 1.5 should be able to be used directly for the future scenario modelling while PET needs to be estimated indirectly through other variables such as temperature available in the NARCliM1.5 dataset.

However, a comparison of 1967-1976 rainfall data recorded at Blacktown (67059) with historical precipitation data downloaded from NARCliM 1.5 at a same location found that, while the statistical characteristics such as mean, variance etc. are comparable, the rainfall temporal pattern are significantly different (see Figure 1) and vary significantly depends on the combinations of CGM and RCM models. This shows that the temporal pattern produced by NARCliM1.5 has high uncertainty. Thus, it is decided to adopt the temporal pattern of the original historical time series while adjusting the magnitude of the rainfall based on the change in statistical characteristics extracted from NARCliM 1.5 data set.

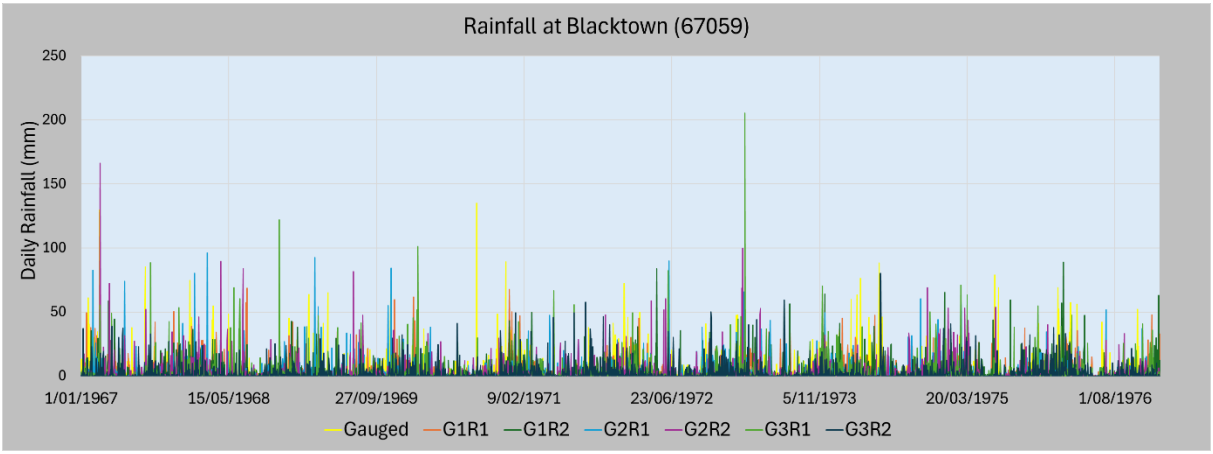


Figure 1: Comparison of recorded daily rainfall (Gauged) with six combinations of GCM (G1, G2 &G3) and RCM (r1, r2) of NARCliM1.5 data

This memo explains: (1) how statistical characteristics in NARCliM1.5 precipitation data is extracted to generate climate changed precipitation time series; (2) NARCliM1.5 temperature data is used to generate climate changed PET time series.

2. Methodology for Precipitation

In the GPOP EIS project, the hourly rainfall data from the virtual rainfall stations are key inputs for rainfall-runoff modelling in SOURCE and need to be adjusted for inputs of climate change scenario inputs. These virtual rain gauges were created at the centroid of each sub-catchment to represent the rainfall in that area. The hourly rainfall at these virtual rain gauges was calculated from the nearest five real rain stations using inverse distance weighted average techniques.

The methodology for generating the future climate change precipitation data was based on the approach by Lam et al (2024). It involves approximation by adjusting original time series based on statistical characteristics. The following six datasets from Global Climate Model (GCMs) and corresponding Regional Climate Model (RCM) combinations (Table 2) are used to extract statistical characteristics for adjustment.

Table 2 GCM and RCM combination

GCM	RCM	
	R1	R2
Driving GCM CSIRO BOM ACCESS 1.0	√	√
GCM CCCma CanESM2	√	√
GCM CSIRO BOM ACCESS1.3	√	√

The 'Bias corrected precipitation' data datasets were downloaded from the NSW Climate Data Portal in NetCDFs format for each year from 1994 – 2071. The datasets have a seasonal frequency, meaning that each data point represents the average rainfall for each season of that year. Each data point represents 10km-spaced grid points located in South-East Australia. The data process procedure was undertaken in the coding language

MATLAB. Figure 2 Workflow for precipitation below presents an overview of the workflow with further details in the following sections below.

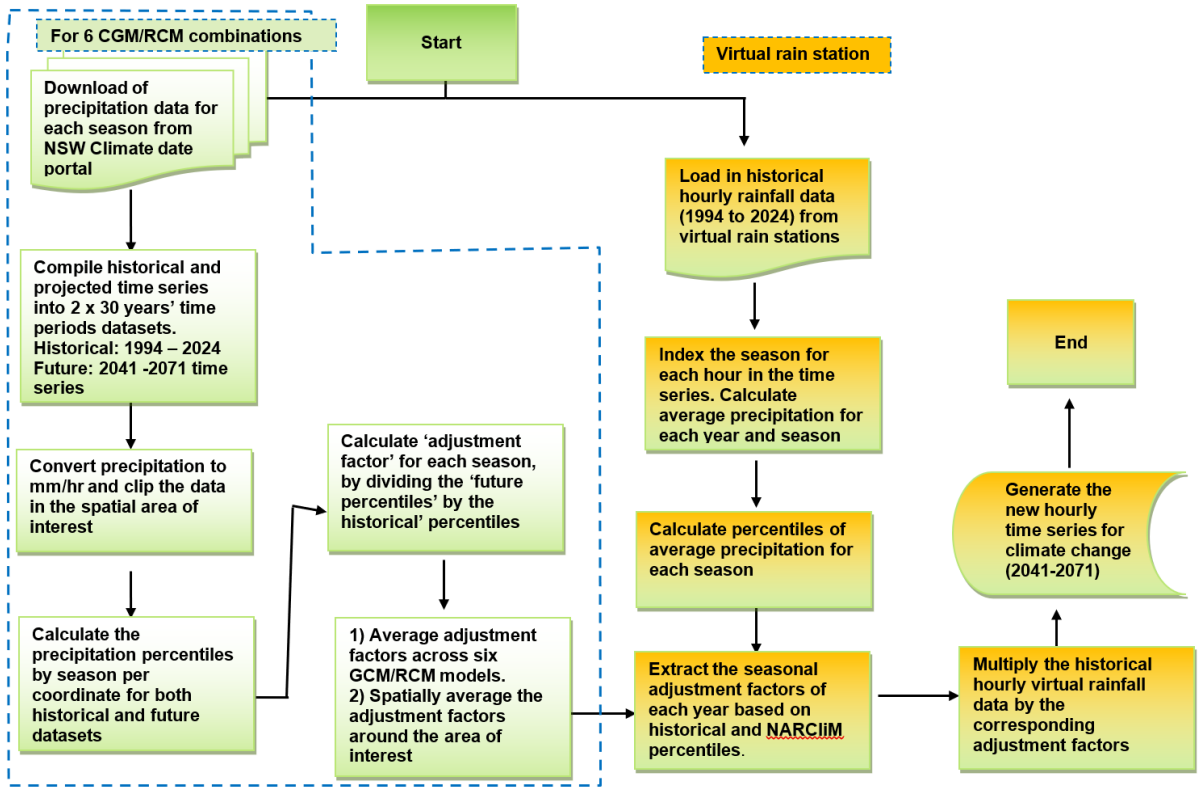


Figure 2 Workflow for precipitation

Step 1: Download precipitation data (kg/m^2/s) from NSW Climate data portal

The downloaded data contain the following four variables:

- Latitude and longitude (representing 10km-spaced data points)
- Precipitation (in units of kg/m^2/s)
- Time (in units of days since 1950-01-01 denoting the first day of a season). Seasons are defined as below:
    - Summer = December to February (DJF).
    - Autumn = March – May (MAM)
    - Winter = June – August (JJA)
    - Spring = September – November ('SON).

Step 2: Compile historical and projected data into two 30-year periods *of interest*

The continuous precipitation time series was then clipped for the two 30-year periods of interest:

- 1994 – 2024: This data period represents our 'historical' data and was chosen to match the available historical gauge monitoring data available.
- 2041 – 2071: This data period represents our 'future' data. 2056 is the time horizon for climate change, and this 30-year period was chosen such that 2056 sits in the middle of the range.

*It is noted that Autumn, Winter, and Spring precipitation data from 2006 and 2007 have been excluded from calculations as errors were noted on the timestamps of the downloaded NARCliM data.

Step 3: Convert precipitation data into appropriate units and spatially clip the data

The units of precipitation are then adjusted from kg/m^2/s to mm/hr by multiplying the existing precipitation data by 3600 (1 kg/m^2 = 1mm. 1mm/s = 3600 mm/hr). The precipitation data is then clipped to the coordinates that represent our existing historical virtual rain gauge data, using a 10 km grid (see Figure 3 below).

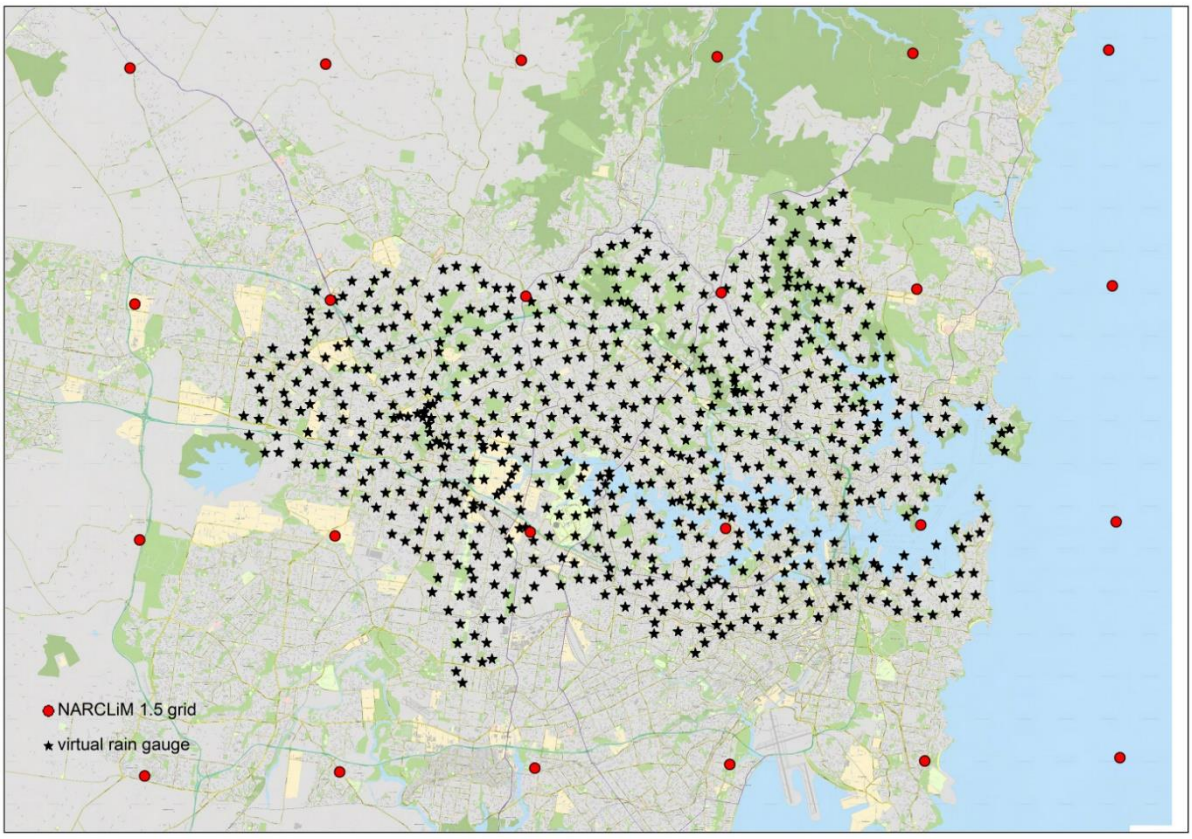


Figure 3 Area of interest

*Any 'NaN' values, indicating a grid point is located over the ocean, have been omitted from calculations.

Step 4: Calculate the percentiles of the historical and future seasonal precipitation data

For the historical and future datasets, the 0-100th percentiles were calculated for each season, for each latitude and longitude grid point of the clipped grid. Figure 4 below shows an example of the historical rainfall percentiles at Drummoyne Oval. It was generated from the seasonal time series (1994 to 2024) of six NARCliM 1.5 models, and the actual virtual

gauge seasonal time step rainfall data at that location.

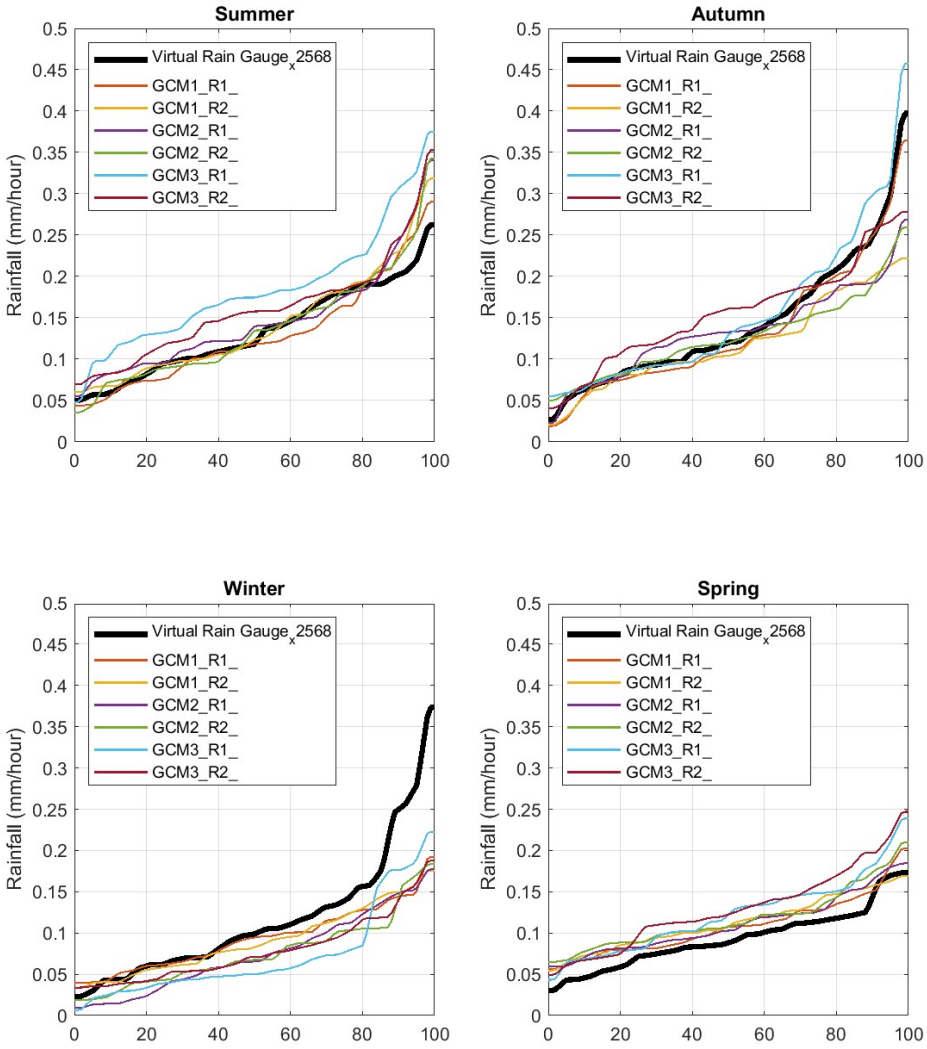


Figure 4 Percentiles of mean precipitation by season at Drummoyne Oval

Step 5: Calculate the adjustment factors for each season

An array of seasonal adjustment factors for each model and grid coordinate was then calculated, by dividing the future percentile data (2041 – 2071) by the historical percentile data (1994 – 2024) for each model and coordinate. This adjustment factor represents the ratio between the future and historical NARCliM data and represents how much bigger or smaller the future rainfall is anticipated to be at each percentile value. The adjustment factors will be applied to scale up the historical monitoring data to incorporate climate change.

Step 6: Average the seasonal adjustment factor arrays spatially and across the GCM/RCM model combinations

As a result of this step, the mean adjustment factor curves are generated for all seasons (see Figure 5). This adjustment curves will be used to adjust the historical hourly virtual rainfall data to account for projected climate change.

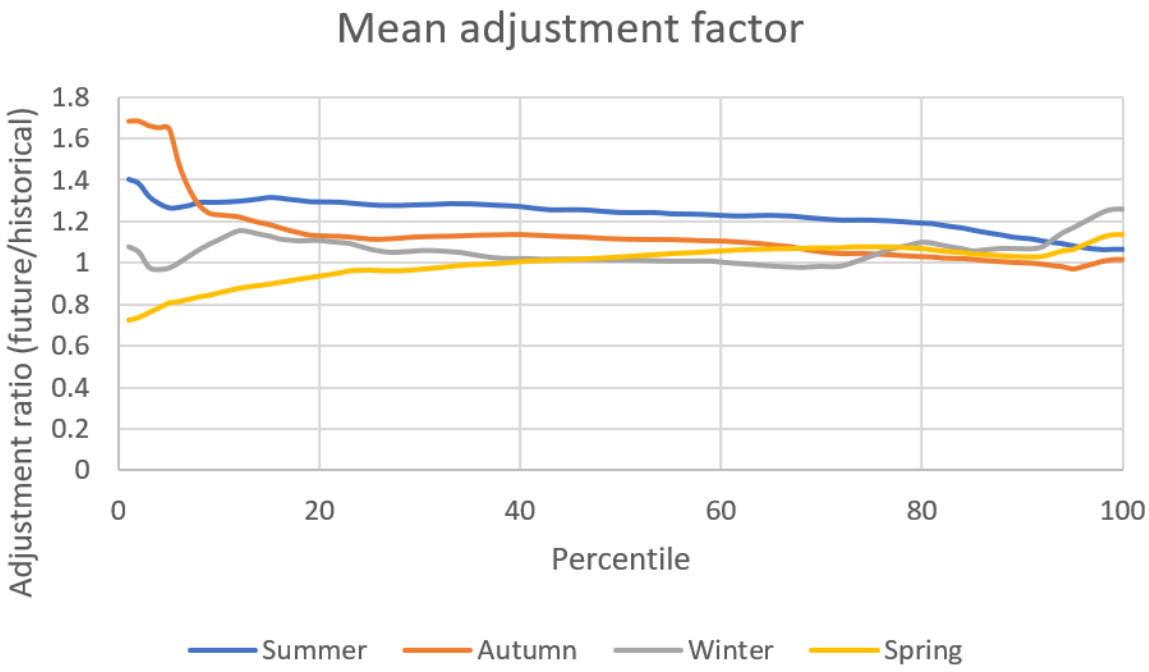


Figure 5 Mean adjustment factors

Virtual rain stations

The following steps are applied to the rainfall data from the virtual rain stations to meet the requirements for adjustments to future climate change.

Step 7: Read in historical hourly virtual rain station data

The historical hourly precipitation monitoring data (mm/hour) from 1 January 1994 to 1 July 2024 for the virtual rain stations was downloaded.

Step 8: Aggregate the hourly virtual rainfall data by season and year and calculate their average seasonal precipitations

The adjustment factor versus percentile curves in Figure 5 are created from the season (3-month) time step NARCliM data. To obtain the adjustment factor, we need to align the hourly time series of the virtual rain stations with seasonal time step.

A 'season' was indexed to each hour of the historical virtual rain station time series based on the month of the record. The hourly time step precipitations were then aggregated by season and year to obtain the average precipitation at each historical season. An example for Middle Harbour – Virtual Rain Station #1 is shown in Figure 6 below. Each data point represents the average hourly rainfall for each year in the season of autumn, spanning from 1994 to 2024.

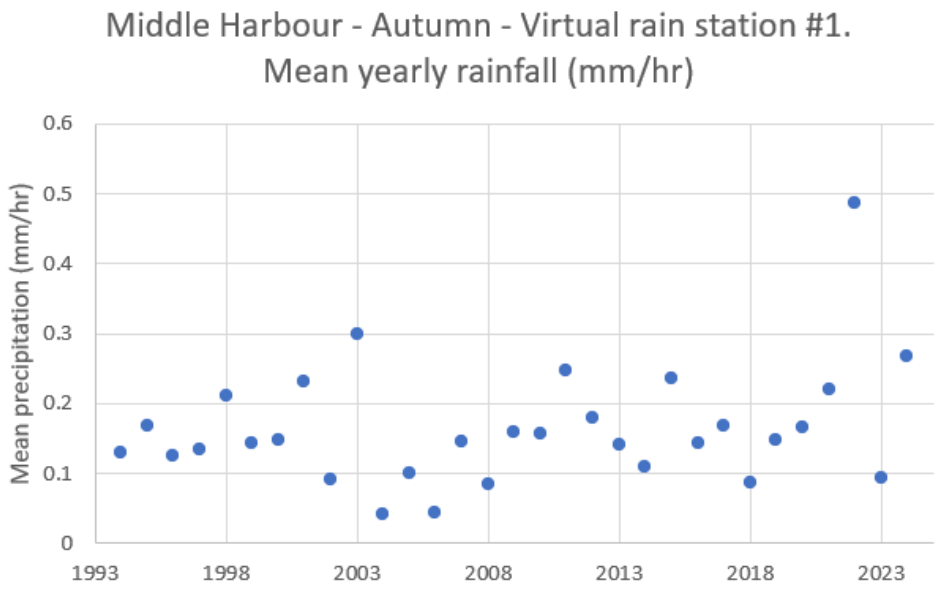


Figure 6 Hourly seasonal precipitation timeseries from Middle Harbour – Virtual Rain Station #1

Step 9: Calculate percentiles of the average seasonal precipitations

The percentiles of the average seasonal precipitations for a virtual rain station was then calculated from seasonal step precipitations from the previous step. Figure 7 displays the percentile vs precipitation curve for autumn at the Middle Harbour virtual station #1.

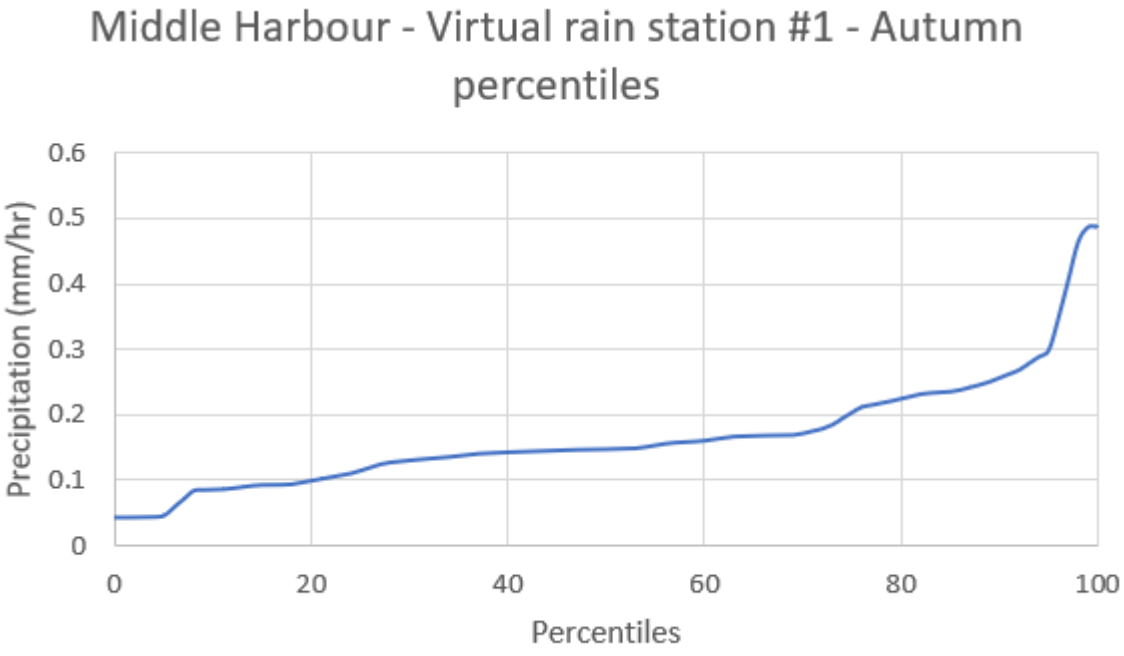


Figure 7 Percentiles of autumn for Middle Harbour – virtual rain station #1

Step 10: Extract the seasonal adjustment factors of each year

The seasonal adjustment factors of each year were then extracted from the mean adjustment factor curves (Figure 5) based on percentiles. This process is illustralised in Figure 8 and

described in the following steps. Take one virtual rainfall data point during autumn in Middle Harbour catchment as an example.

a. The time series of autumn mean historical rainfall data from virtual rain gauge #1 between 1994 to 2024 is shown in the top left of Figure 8. The average precipitation in autumn 1994 is 0.1305 mm/hr.
b. The corresponding percentile of 0.1305 mm/hr is the 31th percentile (see the bottom left of Figure 8).
c. The 31th percentile corresponds to the adjustment factor 1.1287 (see the right hand chart of Figure 8).
d. Use the adjustment factor 1.1287 to adjust the original hourly time series between March 1994 to May 1994 for future rainfall.

The above process creates an array of adjustment factors corresponding to a particular year and season for a virtual rain station. These factors will be used to scale up the hourly seasonal rainfall data for each virtual rain station as a final step to produce hourly future climate adjusted precipitation data.

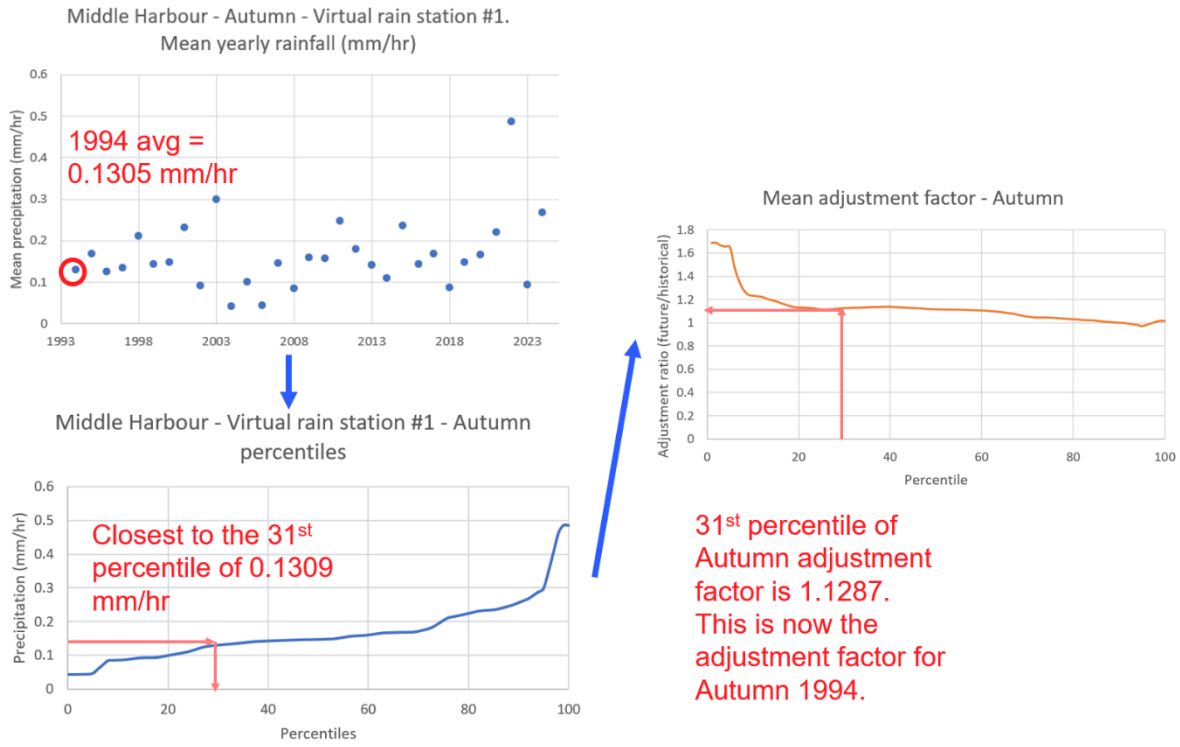


Figure 8 Finding adjustment factor

Step 12: Generate the climate adjusted hourly precipitation timeseries for future conditions

The hourly historical virtual rainfall data was then adjusted for climate change by multiplying the hourly data with the corresponding adjustment ratio for that year and season. The climate-adjusted hourly precipitation time series reflects the 2041 – 2071 conditions.

Several examples for Middle Harbour – Virtual Rain station #1 are shown below including:

- The cumulative rainfall for historical and future hourly data (Figure 9)
- Precipitation time series for historical and future hourly data (Figure 10)
- Sample 24-hour historical and future hourly precipitation data (Figure 11)

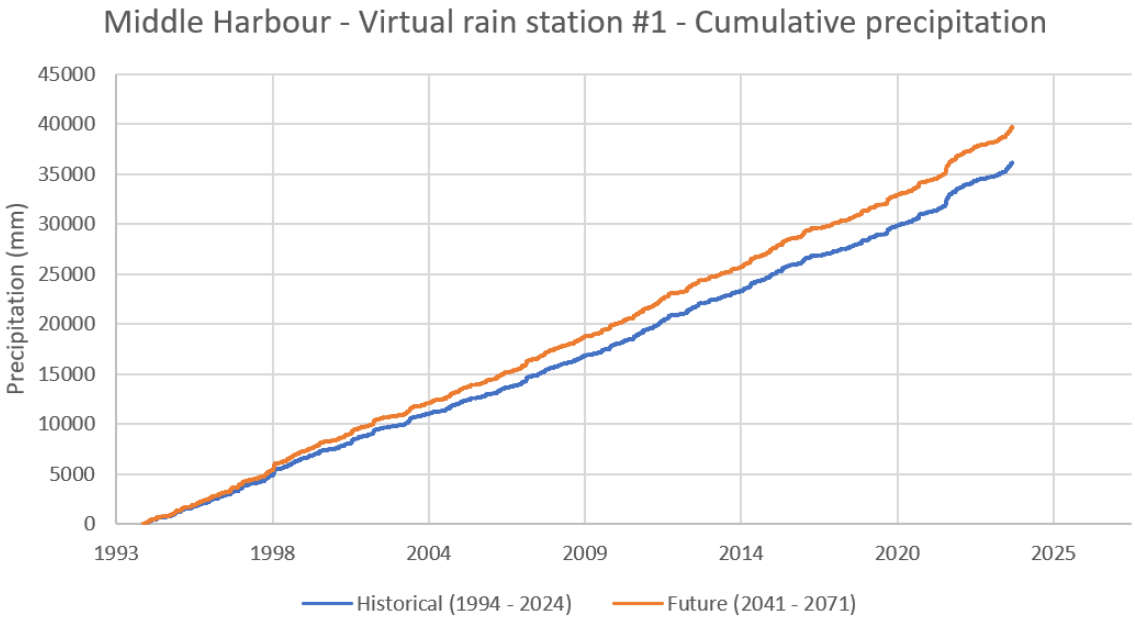


Figure 9 Cumulative rainfall at Middle Harbour - virtual rain station #1

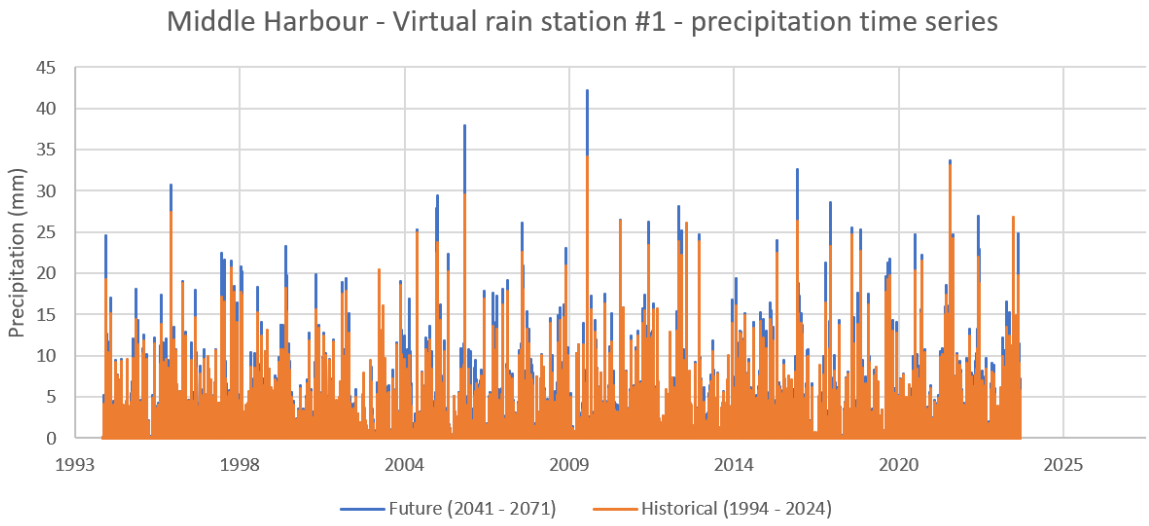


Figure 10 Precipitation at Middle Harbour -virtual rain station #1

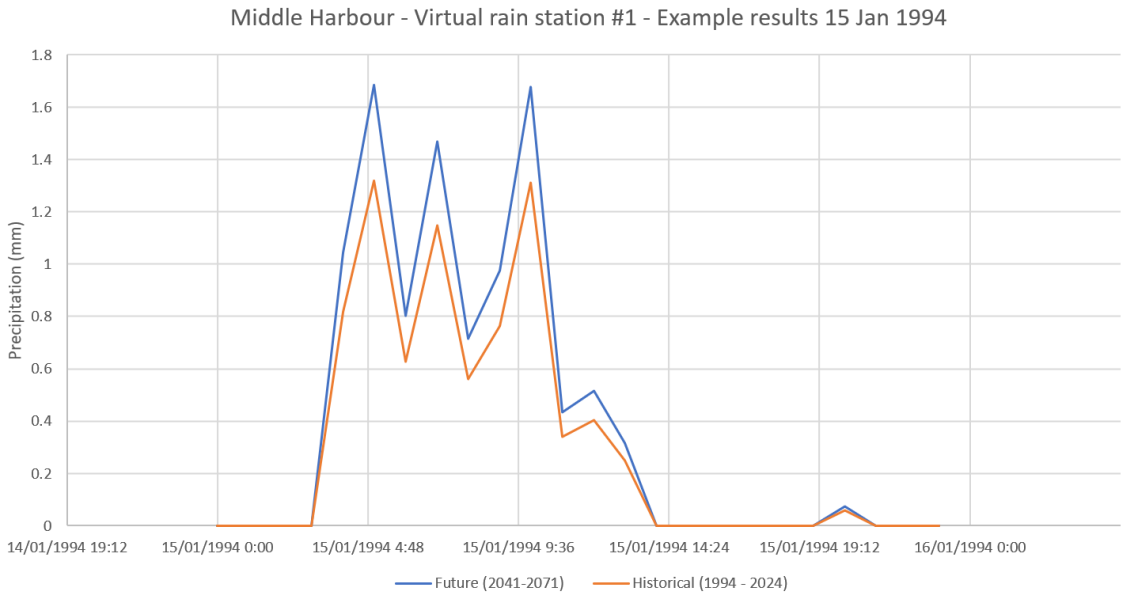


Figure 11 Precipitation at Middle Harbor virtual rain station #1 on 15 January 1994

3. Methodology for Potential Evaporation

Potential Evapotranspiration (PET) data is not available from NARCLIM1.5 dataset. PET needs to be estimated based on relevant variables available in NARCLIM 1.5. The value of PET is affected by a number of key factors, mainly temperature, wind and radiation. Temperature is the key factor, and other factors also have some co-relationship with temperature. Since the effect of PET on the performance of model is minor. Approximate relationship between PET and change in temperature due to climate change is considered adequate to account for the effect of climate change on PET.

Figure 12 below shows the relation of monthly PET and the monthly average mean daily temperature at each month in a year at Sydney Airport. The average monthly PET is obtained from BOM gridded point PET data for the period of 1961-1990. The average monthly mean daily temperature is obtained by averaging, in each month, the daily maximum temperature and daily minimum temperature recorded in Sydney Airport AMO (066037).

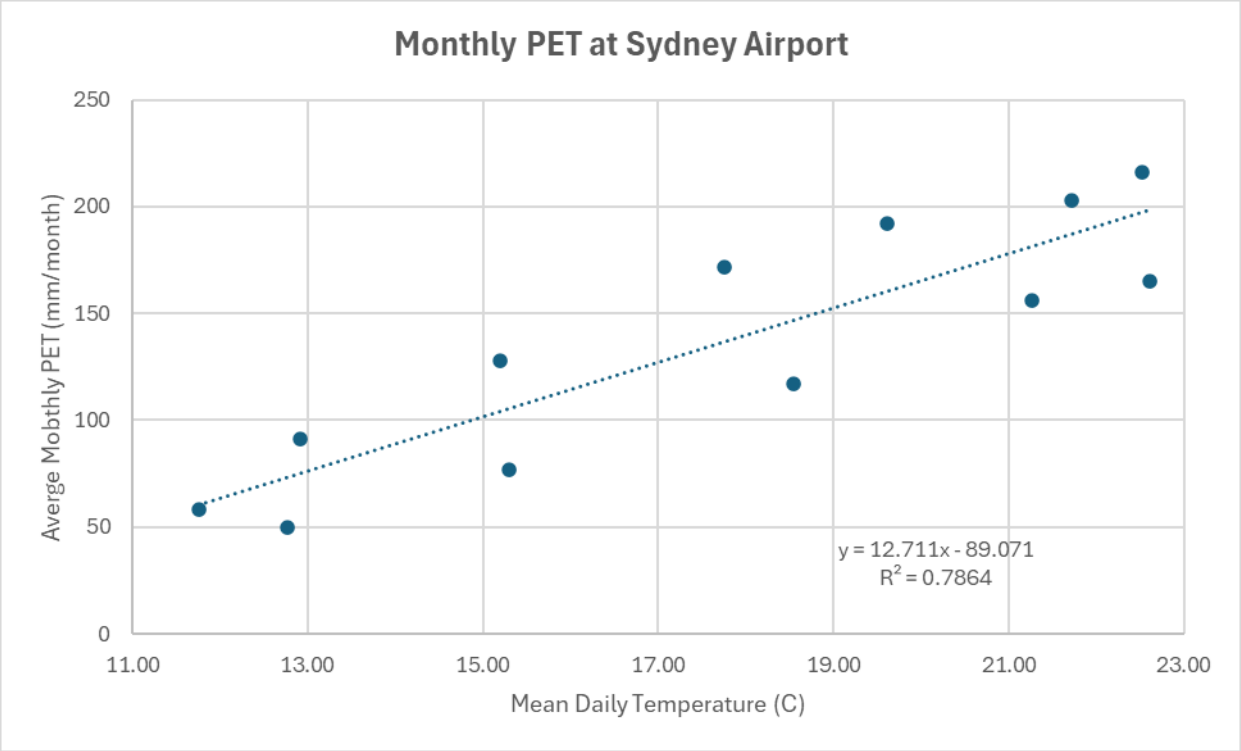


Figure 12 ***Relationship between temperature and PET***

There is reasonable correlation between the temperature and PET, especially the rate of change of PET with change in temperature. Thus, PET is estimated by the equation below:

$$PET_{future} = PET_{current} + \frac{12.711}{24 \times No.of\ dyas\ in\ a\ month} \times \Delta T\ at\ each\ time\ step \qquad \text{Equation (1)}$$

ΔT is the change in average mean daily temperature. The average mean daily temperature is estimated by the average mean daily temperature at the existing time series data period (2010-2024) and the future time series data period (2049-2063, i.e. centring at 2056).

The implementation of generating the future climate change PET data was undertaken in the coding language python in the meantime. It will be translated into MATLAB platform at later stage of the project. Figure 13 below presents an overview of the methodology undertaken in python, with further details in the following sections below.

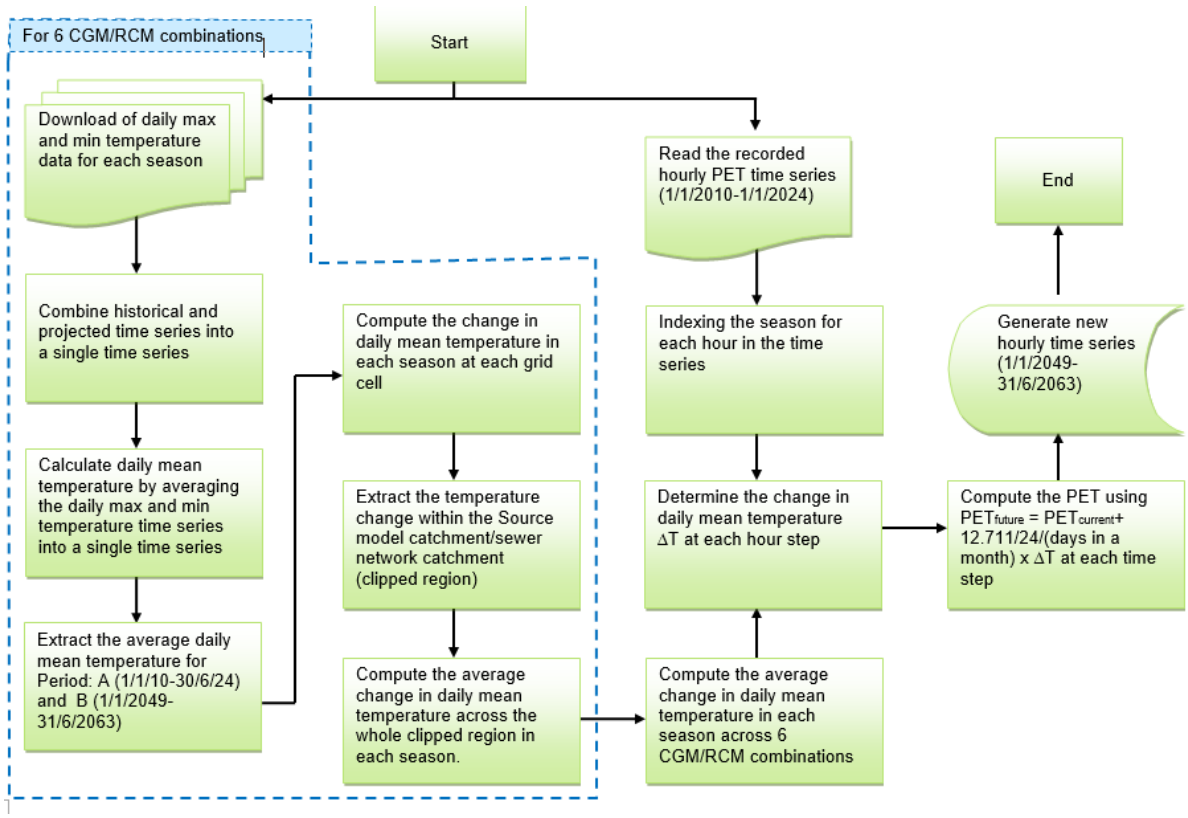


Figure 13 Workflow for PET

Step 1: Download max daily max and min temperature data (K) from NSW Climate data portal

The six datasets from the GCM and RCM combination mentioned in Table 2 are used here. The 'Bias corrected daily maximum temperature" and 'Bias corrected daily minimum temperature' data were downloaded for each year from 1994 – 2099 with a seasonal frequency, meaning that each data point represents the average rainfall for each season of that year. Each data point represents 10km-spaced grid points located in South-East Australia.

All files are in netCDF (network Common Data Form) format, and the downloaded data contained four variables:

- Latitude and longitude (representing 10km-spaced data points)
- Temperature (in units of K) – tasmax-bc and tasmin-bc
- Time (in units of days since 1950-01-01 denoting the first day of a season). Seasons are defined as below:
    - Summer = December to February (DJF).
    - Autumn = March – May (MAM)
    - Winter = June – August (JJA)
    - Spring = September – November ('SON).

Step 2: Combine historical and projected data into a single time series and extract periods of interest

A single time series spanning from 1994 – 2099 was then created by combining the downloaded historical and projected yearly seasonal precipitation data. It should be noted that Autumn, Winter, and Spring temperature data from 2006 have been excluded from calculations as errors were noted on the timestamps of the NARCliM downloaded data.

Step 3: Compute the daily mean temperature

The daily mean temperature at each gird point is computed by averaging the daily maximum and daily minimum temperature data for all time steps. A new netCDF is created to storage this new time series.

Step 4: Extraction of existing and future time series data

Time series of the following periods were extracted representing temperature time series of the recorded PET data period, and future (2056) time series:

1. Existing data period - 1/1/2010 to 30/6/2024
2. Future data period (2056) - 1/1/2049 to 30/6/2049

New records are stored in separate temporary netCDF files (see Figure 14).

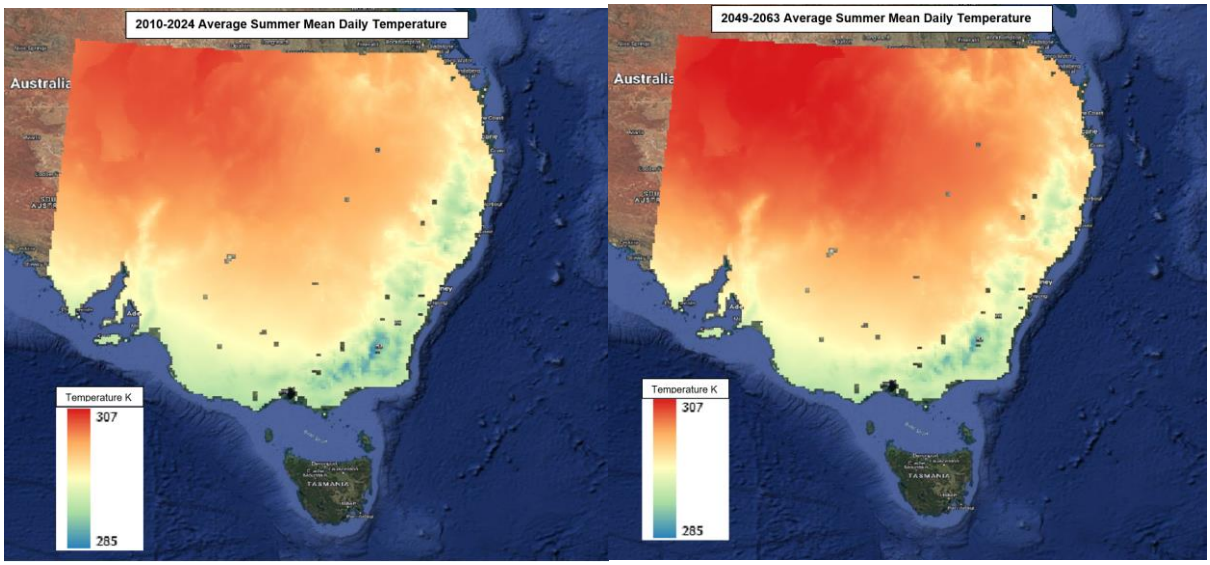


Figure 14 Average temperature in NARCliM - Example of average mean daily temperature netCDF data. Left is for 2010-2024 summer period and right is for 2049-2063 summer period.

Step 5: Calculate average change in mean daily temperature between existing and future period.

For each grid point, the temperatures within the existing data period are averaged to yield the average mean daily temperature for the existing data period for each season. Same procedure is applied to compute the average mean daily temperature for the future data period for each season. The average mean daily temperature for future data period is subtracted by the average mean daily temperature for existing data period to obtain the change in average mean daily temperature between the future and existing data periods for each season (see Figure 15).

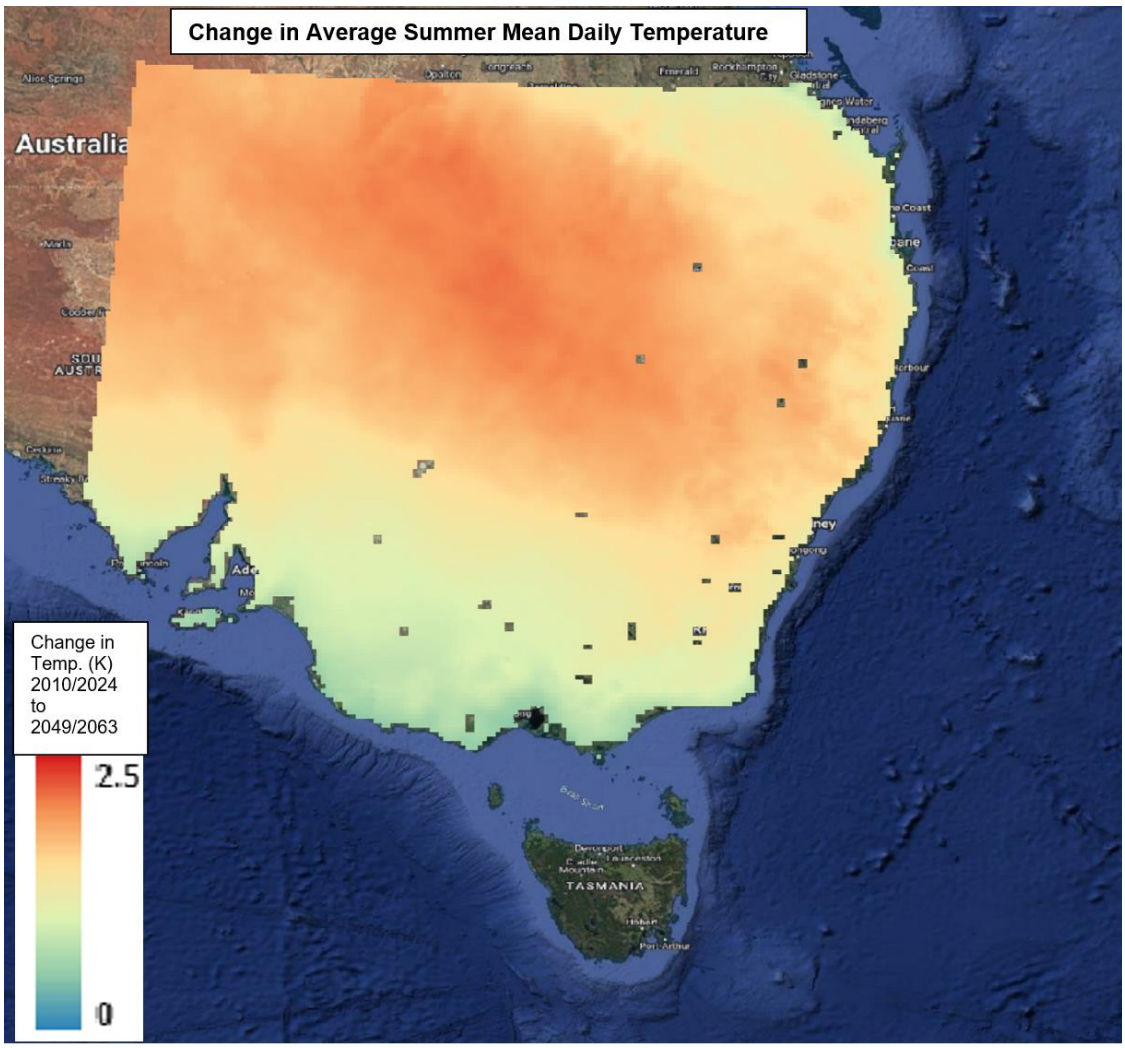


Figure 15 Change in average mean temperature - *Example of change in average mean daily temperature netCDF data. This is the change during summer season*

Step 6: Calculate average change in mean daily temperature across the region

The averages change in daily mean temperature across the extent of interest are calculated for each season. The extent of interest is defined as below:

Latitude: Max -33.65 Min -33.95
Longitude: Max 151.35 Min 150.85

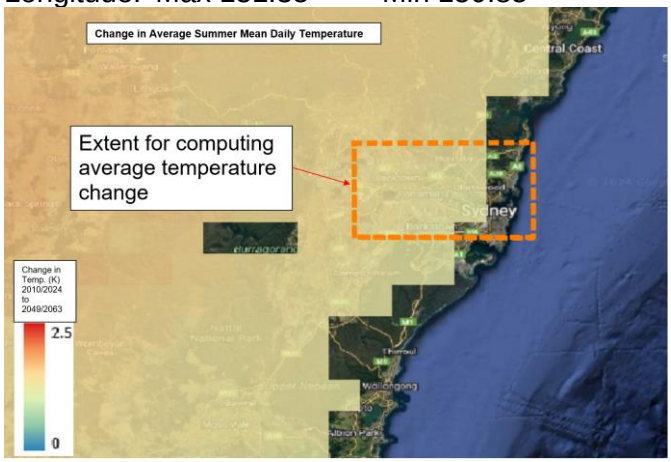


Figure 16 Extent of interest

The orange rectangle in above figure is the extent of interest. Step 1-6 is to be repeated for all (6) combinations of CGM and RPM before going into Step 7.

Step 7: Obtain average change in temperature

For each season, the average change in mean daily temperature is estimated by taking average of changes in all combination of CGM and RPM. *Table* 3 below shows the temperature change for each combination of CGM & RPM and the overall average changes.

Table 3 Average change in temperature

Season	Change in Temperature (°C)						
	G1r1	G1r2	G2r1	G2r2	G3r1	G3r2	Average
Spring (SON)	1.50	1.29	1.51	1.64	0.79	0.78	1.25
Summer (DJF)	1.31	1.28	0.77	0.78	0.93	1.11	1.03
Autumn (MAM)	0.37	0.65	0.97	0.99	0.96	0.98	0.82
Winter (JJA)	1.31	1.18	0.93	0.77	0.75	0.70	0.94

Step 7: Read and index the existing PET time series

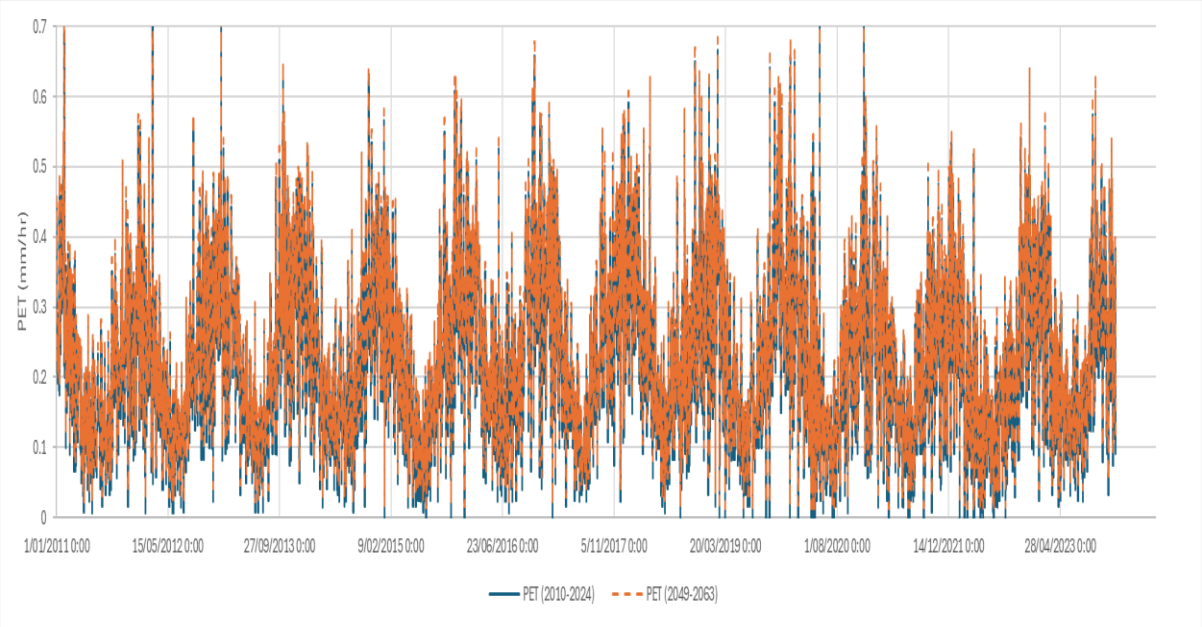
The existing recorded hourly PET time series is read and each time step in the time series is indexed with the season index this time step belongs.

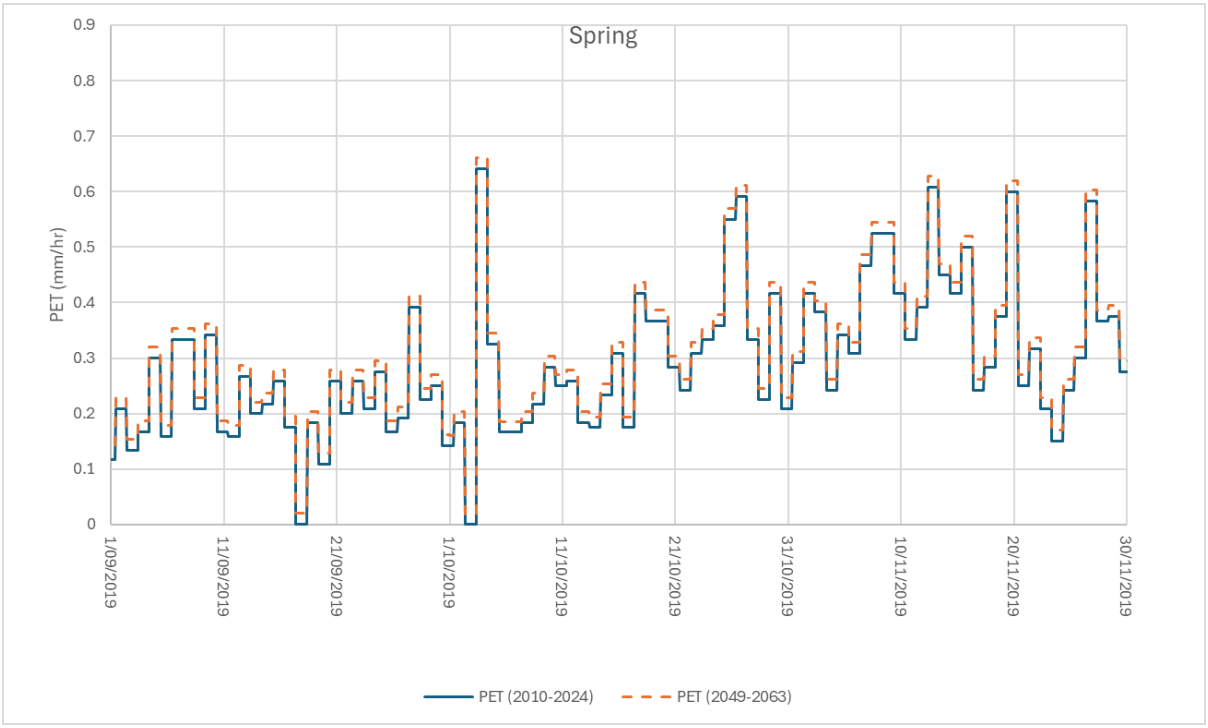
Step 8: Compute future PET at each timestep

The change in temperature at each hourly time step is estimated based on the season index and the average change in mean daily temperature estimated in Step 6. The change future PET is then computed using Equation (1).

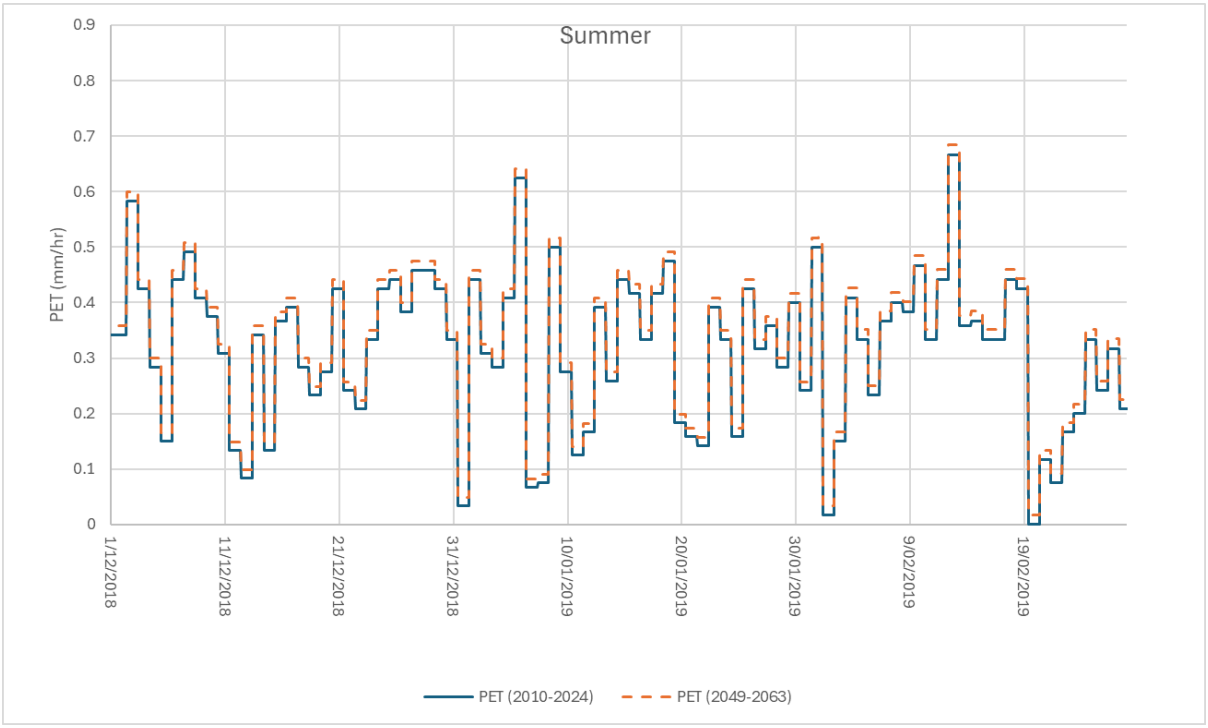
Step 9: Generation of future PET time series

The computed future PET is stored in the file PET_2056_SC.csv. Figure 17 below shows the existing and future (generated) PET time series.

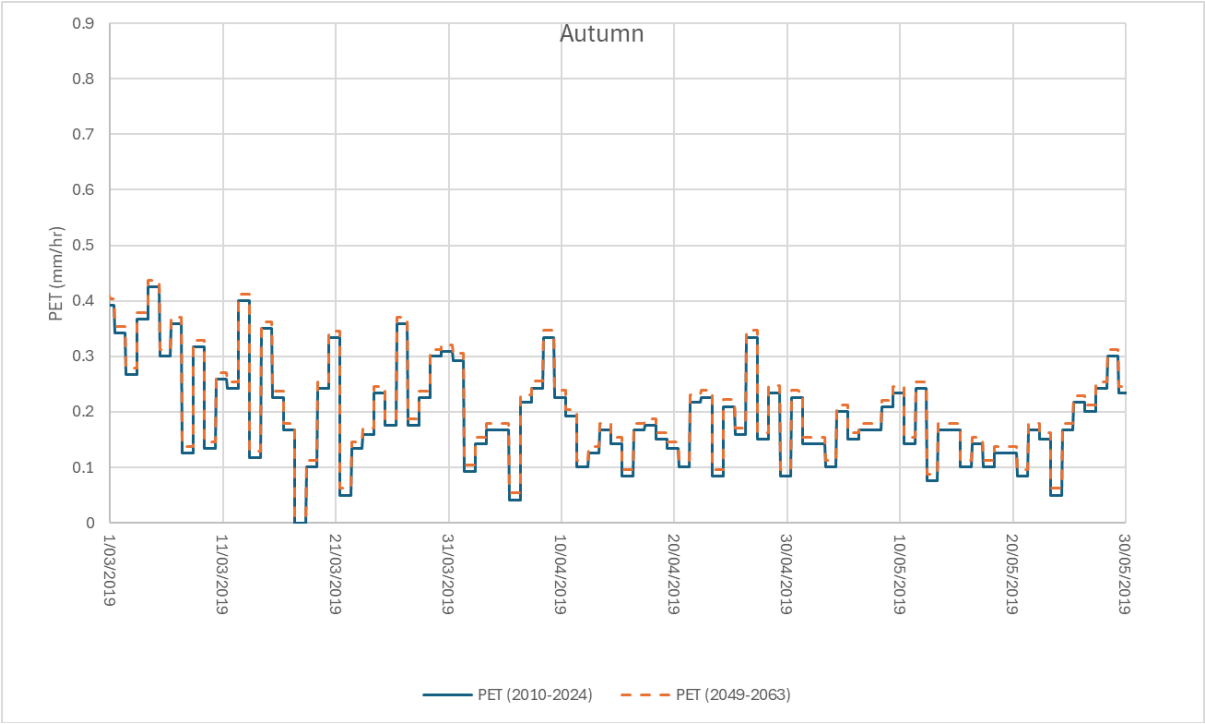




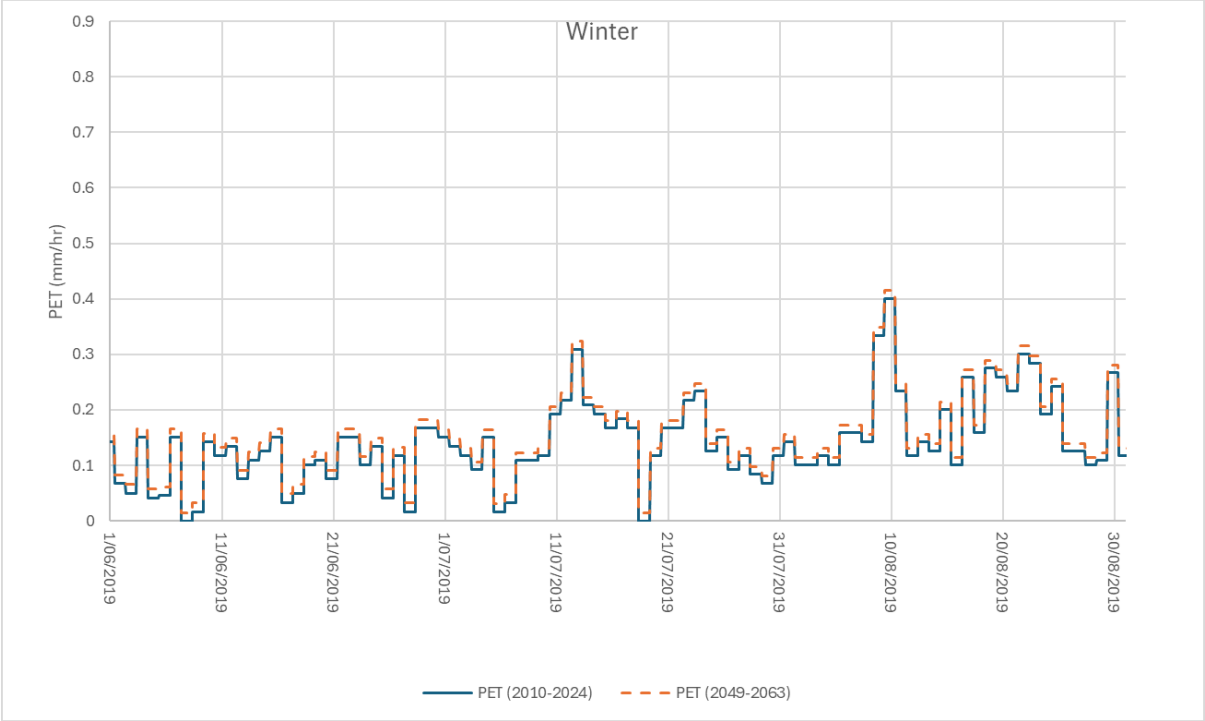
Spring 2019



Summer 2019



Autumn 2019



Winter 2019

Figure 17 Future PET

Reference

Lam, E.C and Liu, H. (2024). Use of NARCliM 1.5 data to evaluate the Climate Change Impact on WSUD treatment efficiency in Sydney Metropolitan Area. Hydrology and Water Resource Symposium HWRS 2024, 18-21 November 2024 | Melbourne.

Prepared by:

Arielle Patapanian and Pei Tillman (precipitation), Eric Lam (PET)
24/01/2025

1. Endorsed by:	2. Endorsed by:	3. Endorsed by:
Add name and title	Add name and title	Add name and title

Appendix C. Wet weather overflow volume maps for scenarios

Round Corner
Castle Hill STS
West Hornsby
Rouse Hill
West Middle Harbour
Narrabeen
Lane Cove
99 ML/y
228 ML/y
134 ML/y
2,401 ML/y
Upper NSOOS
603 ML/y
342 ML/y
257 ML/y
193 ML/y
Lower NSOOS
119 ML/y
SPS 67
103 ML/y
Vaucluse
Fairfield Smithfield
Cooks River
Bondi

Bar Chart of sewer overflow volume (ML/y)
500
Baseline
Background
Background with climate change
Impacts of Camellia-Rosehill WRRF
Impacts of Camellia-Rosehill WRRF with climate change
Modelled sewer
ERS

Round Corner
Castle Hill STS
West Hornsby
Rouse Hill
Lane Cove
West Middle Harbour
Narrabeen
Upper NSOOS
407 ML/y
Lower NSOOS
SPS 67
Fairfield Smithfield
Cooks River
Bondi
Vaucluse

Bar Chart of sewer overflow volume (ML/y)

500

Baseline
Background
Background with climate change
Impacts of Camellia-Rosehill WRRF
Impacts of Camellia-Rosehill WRRF with climate change

Modelled sewer
ERS

Round Corner
Rouse Hill
Castle Hill STS
West Hornsby
Lane Cove
West Middle Harbour
Narrabeen
Upper NSOOS
SPS 67
Lower NSOOS
Fairfield Smithfield
Cooks River
Bondi
Vaucluse

297 ML/y
5,283 ML/y
323 ML/y
945 ML/y
248 ML/y
1,540 ML/y
438 ML/y
754 ML/y
732 ML/y
492 ML/y
471 ML/y
330 ML/y
278 ML/y

Bar Chart of sewer overflow volume (ML/y)
500
Baseline
Background
Background with climate change
Impacts of Camellia-Rosehill WRRF
Impacts of Camellia-Rosehill WRRF with climate change
Modelled sewer
ERS

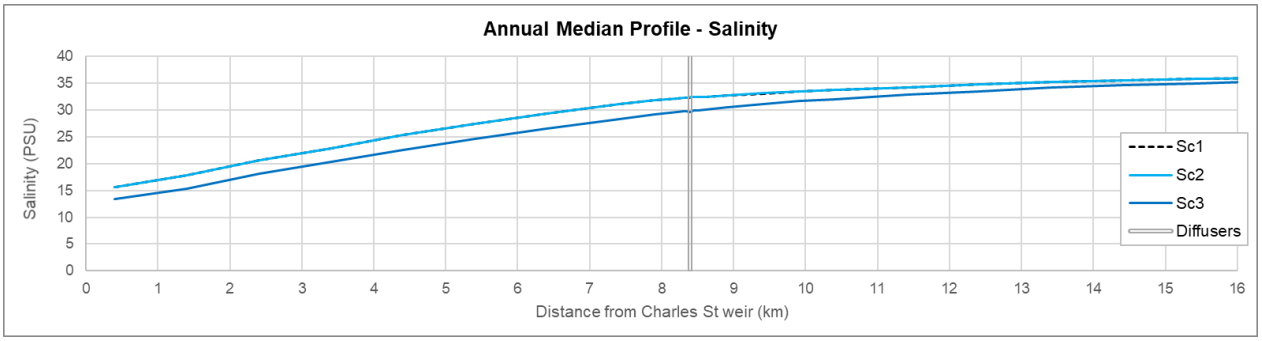
Appendix D. Scenario results

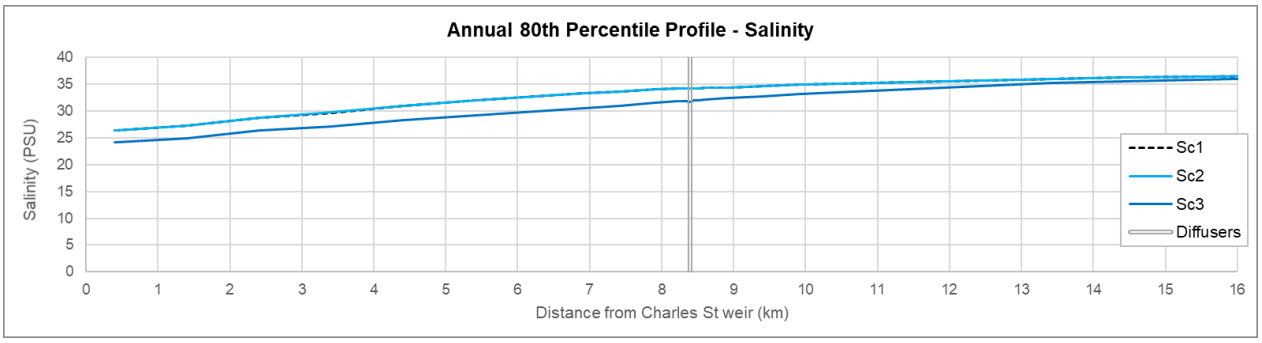
Appendices D1 River Centreline results without climate change

Appendices D1.1 Salinity

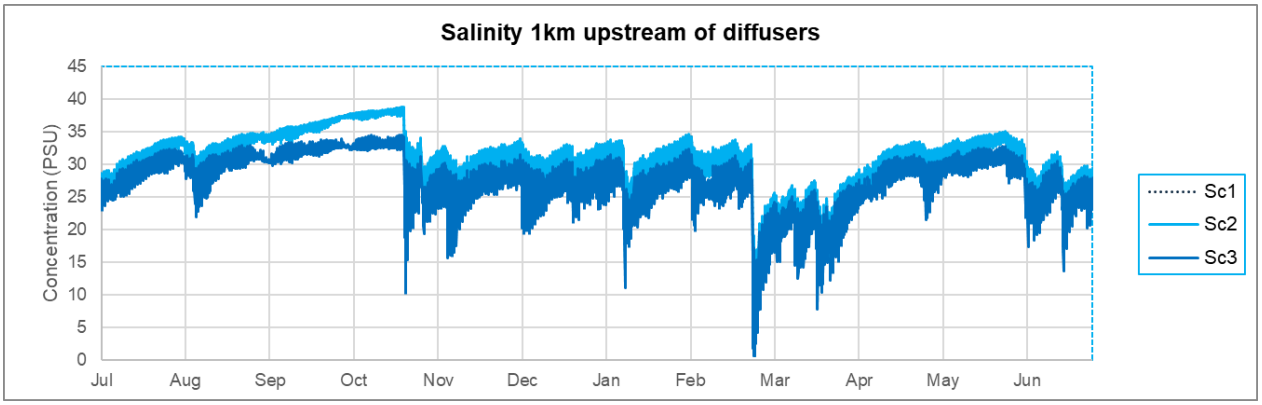
Appendices D1.1.1 Lower rainfall year scenario results (2017-2018)

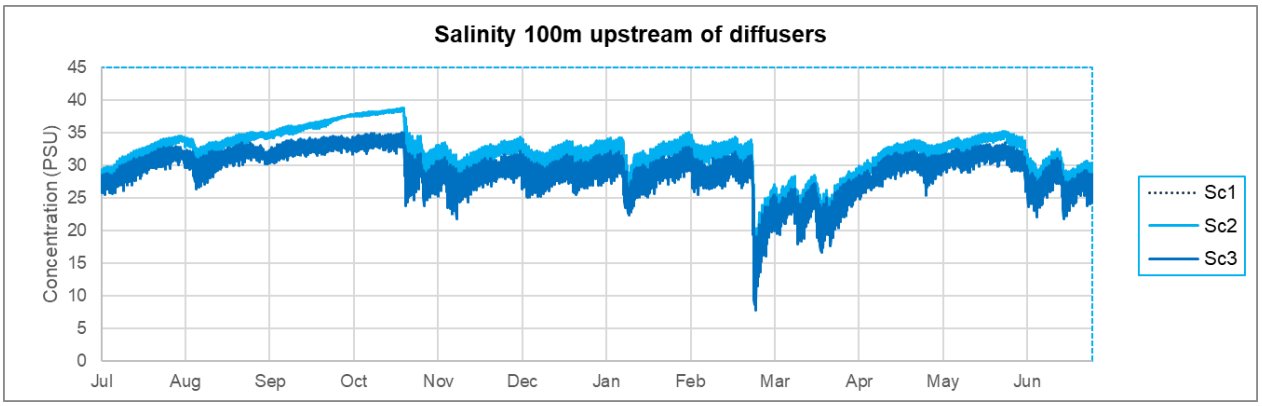
Longitudinal plots

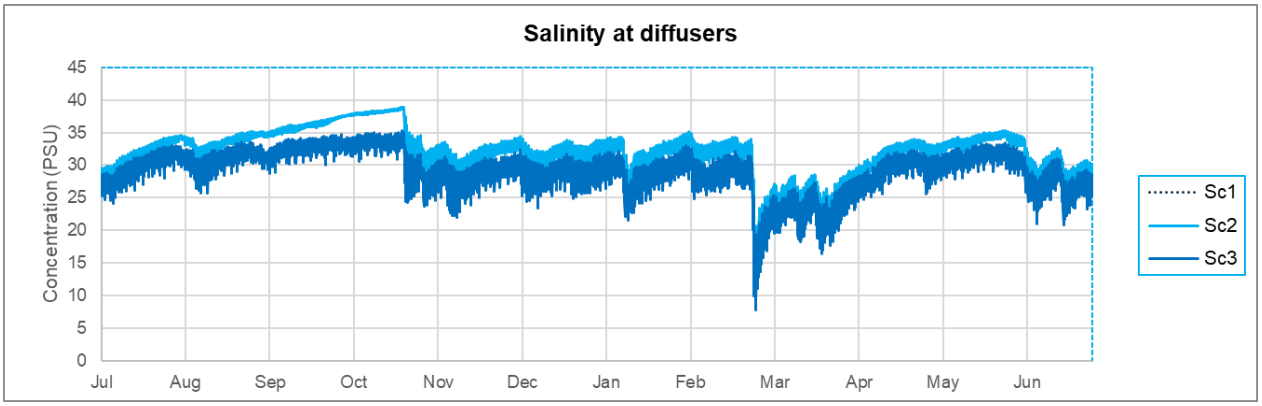


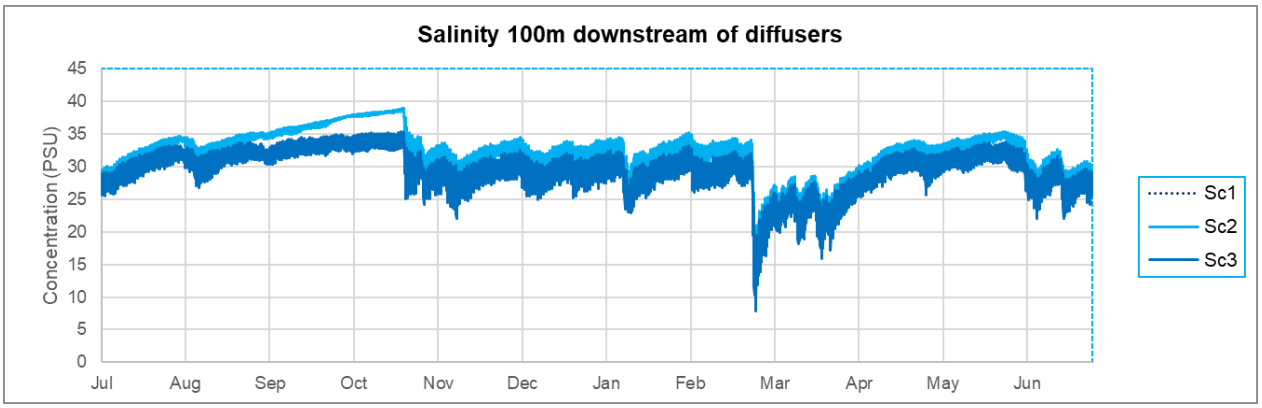


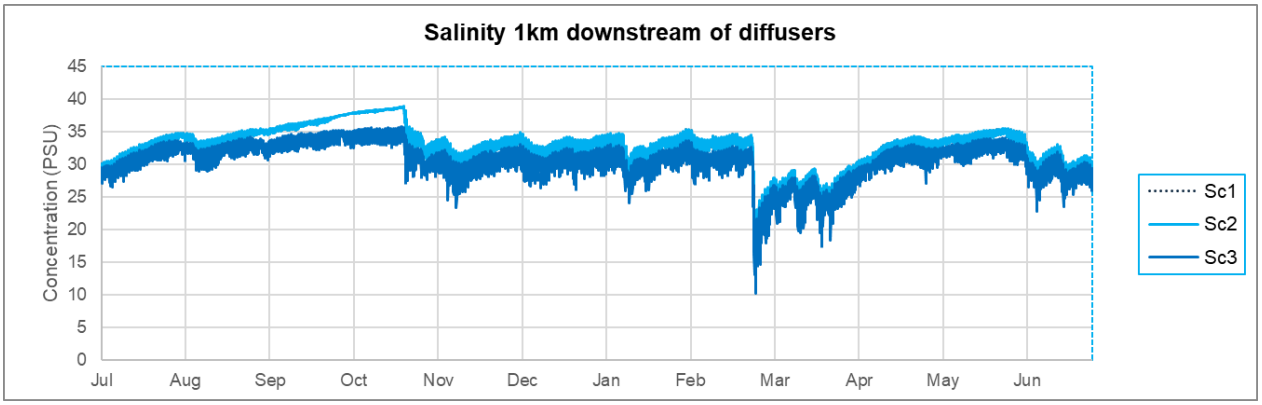
Time series plots




Salinity 100m upstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity at diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity 100m downstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity 1km downstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
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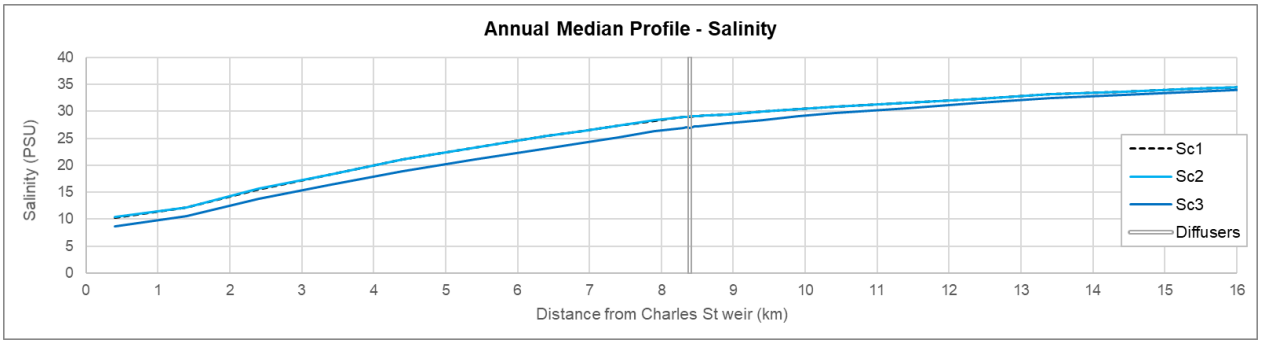
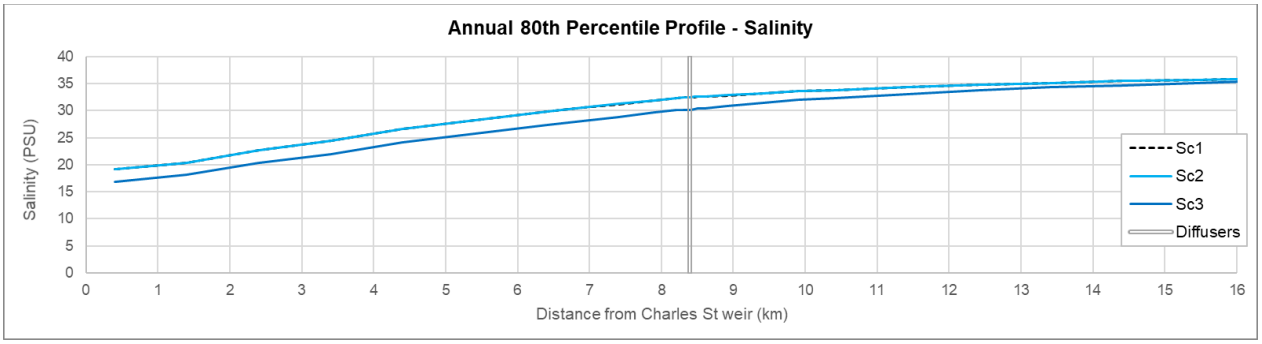
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

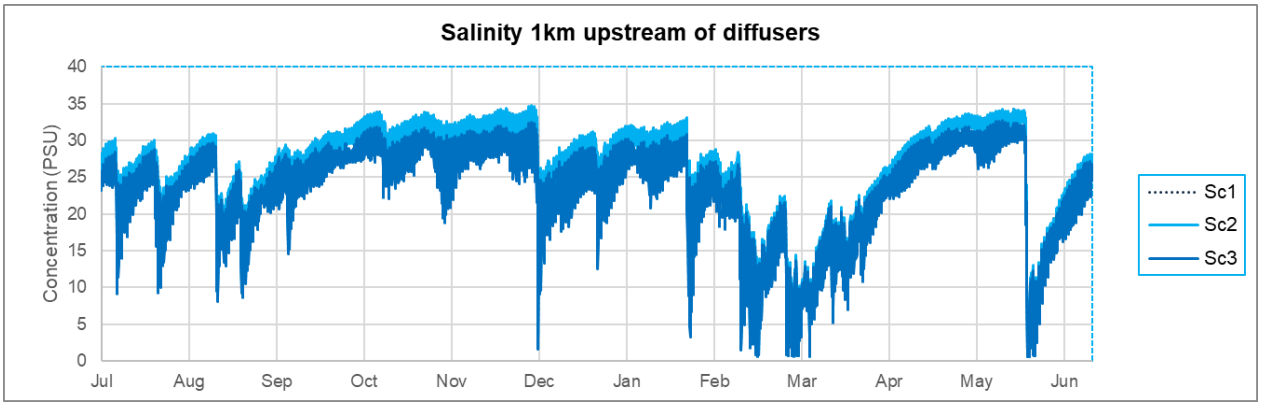
Appendices D1.1.2 Average rainfall year scenario results (2016-2017)

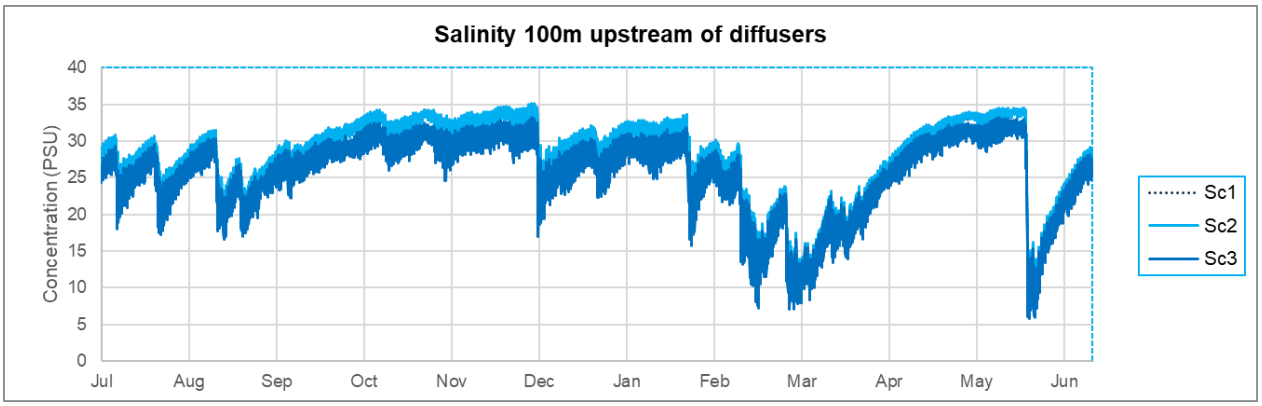
Longitudinal plots

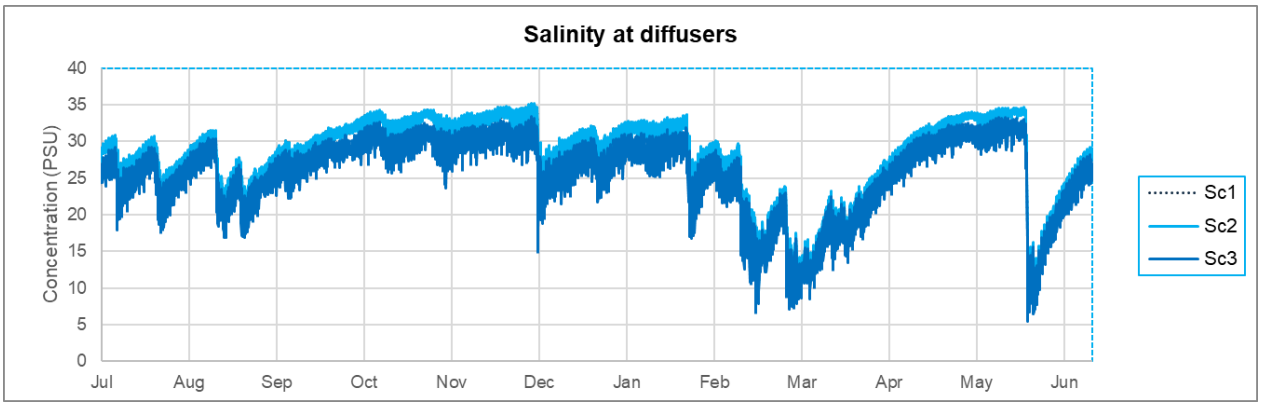


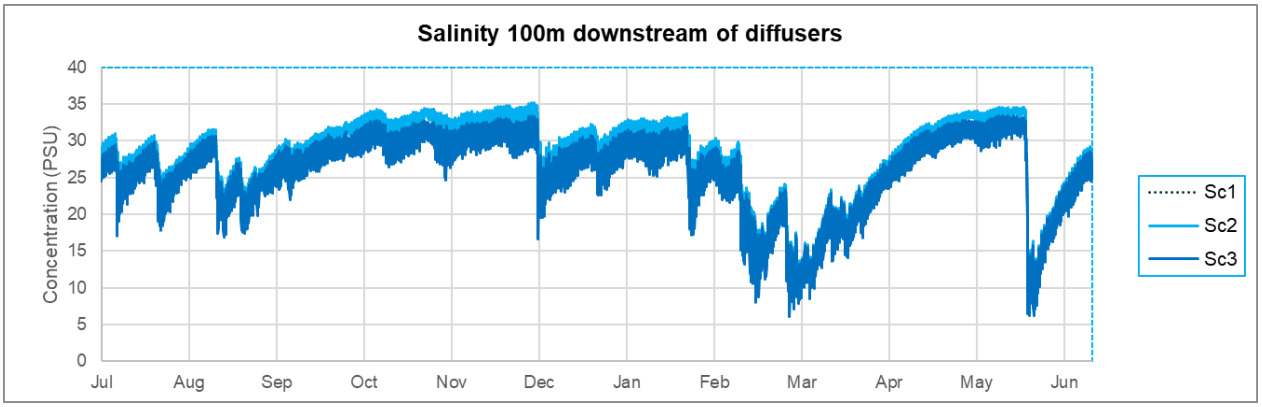


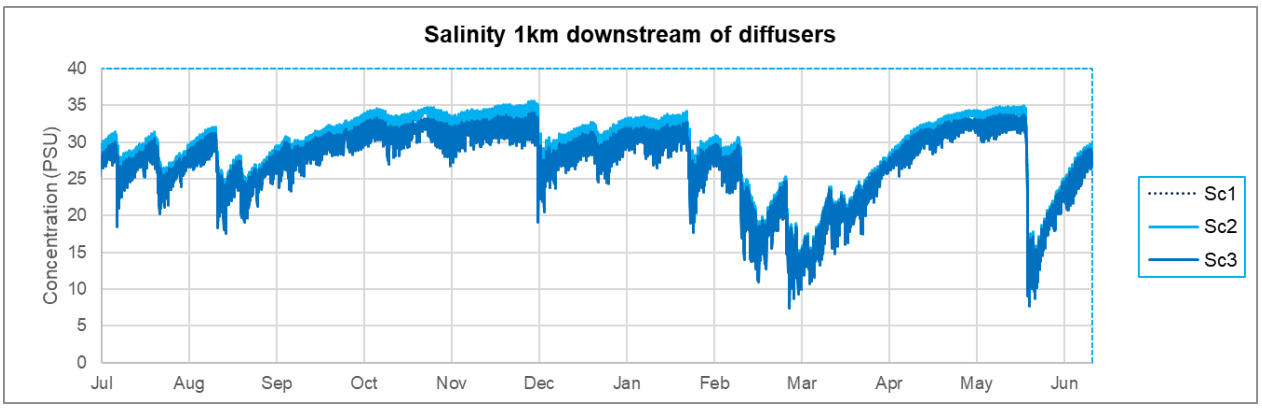
Time series plots





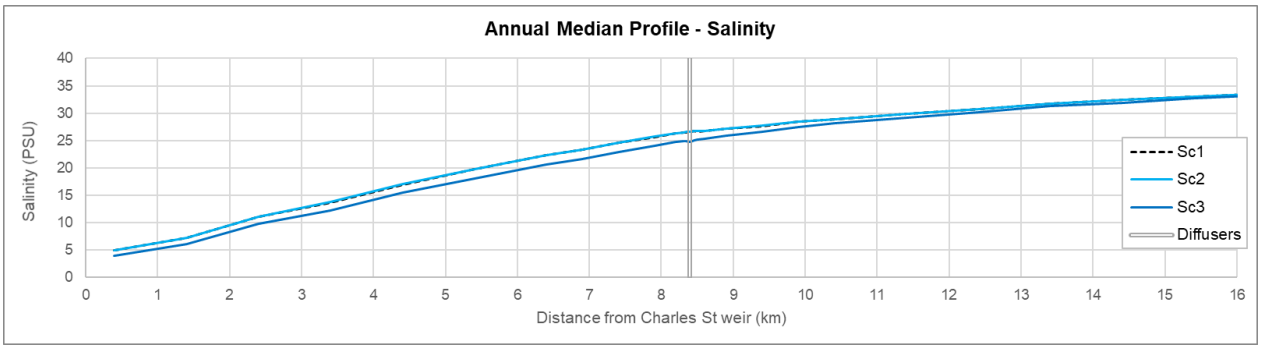


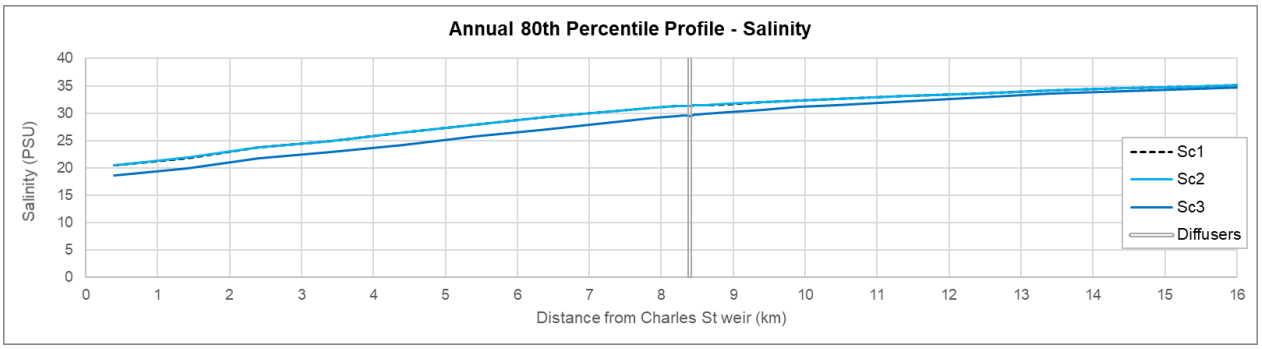




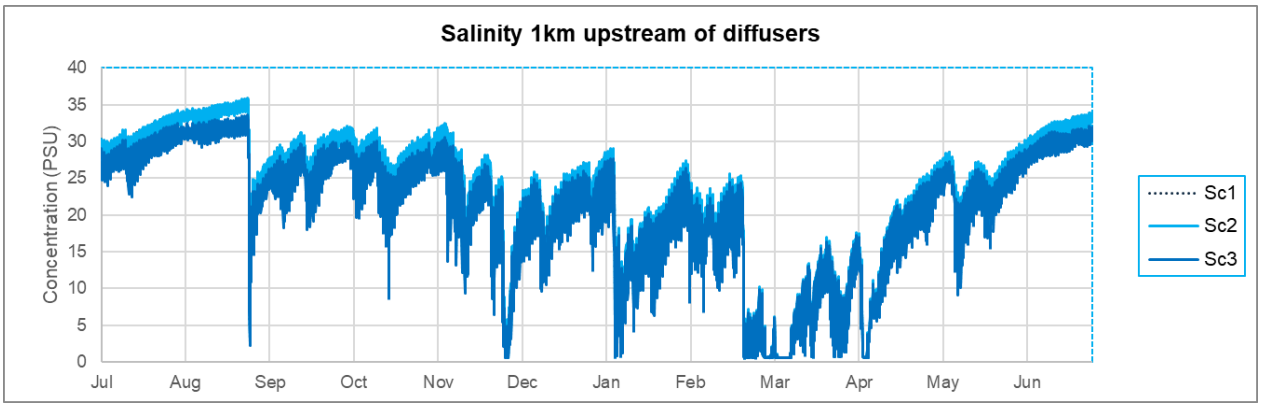
Appendices D1.1.3 Higher rainfall year scenario results (2021-2022)

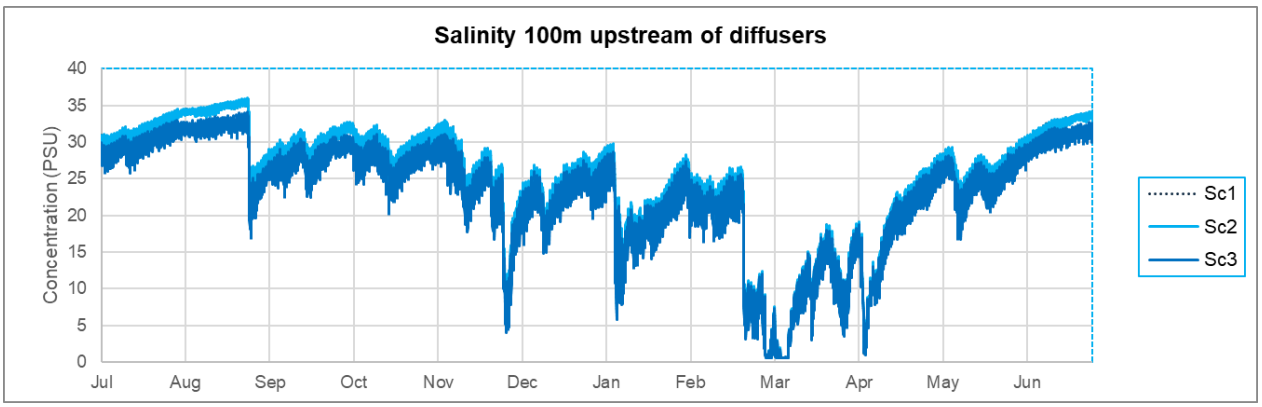
Longitudinal plots

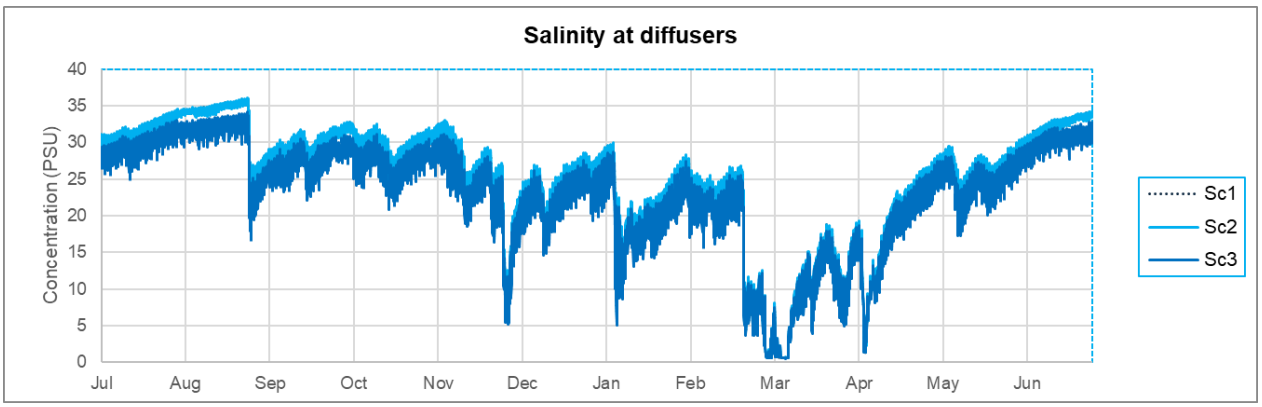


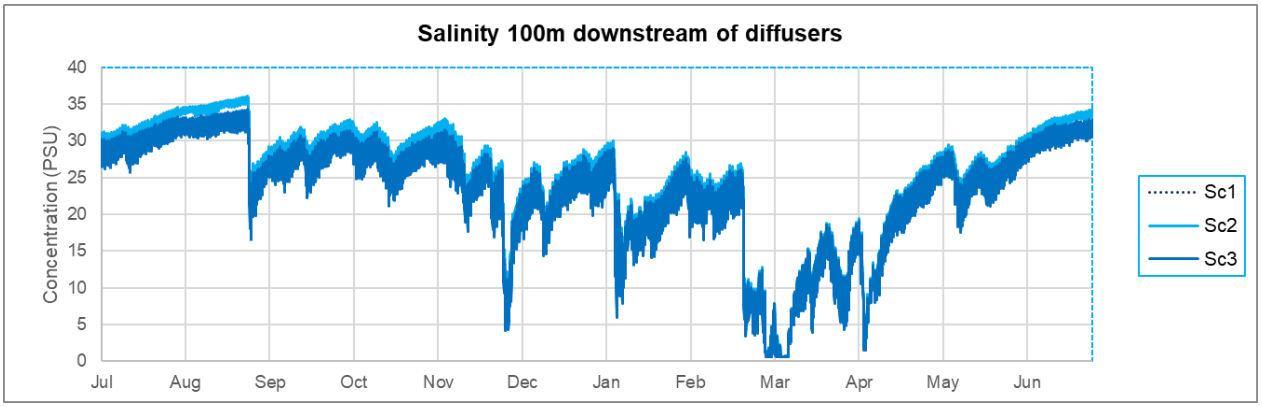


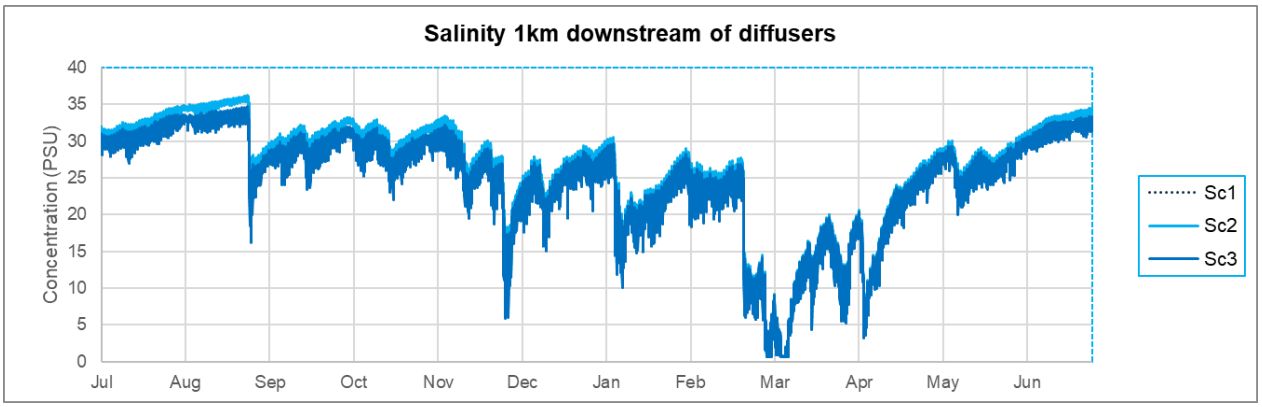
Time series plots







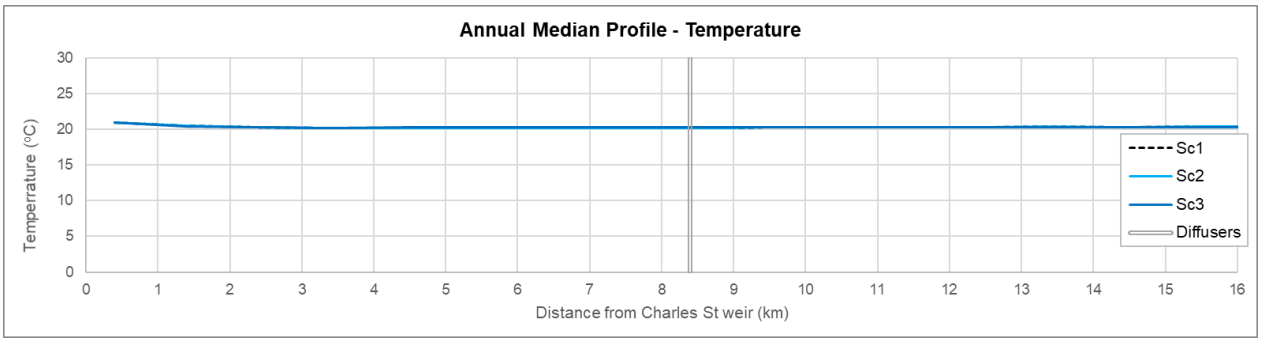


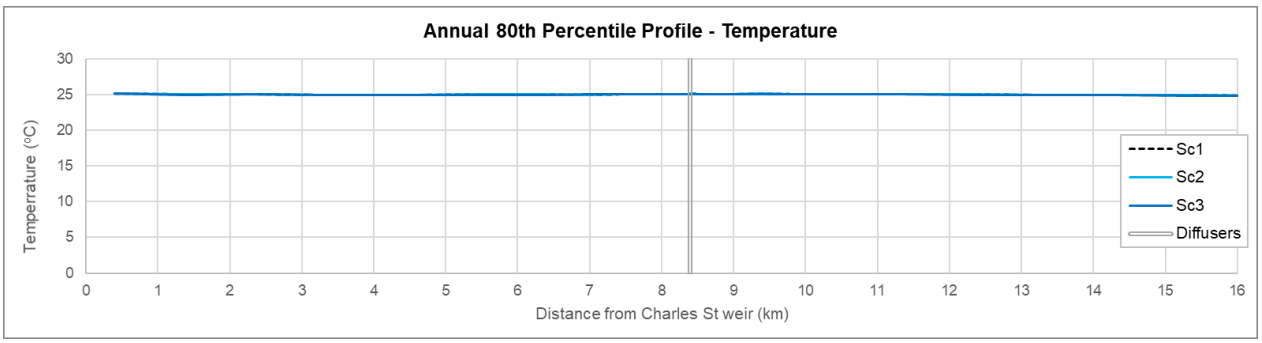


Appendices D1.2 Temperature

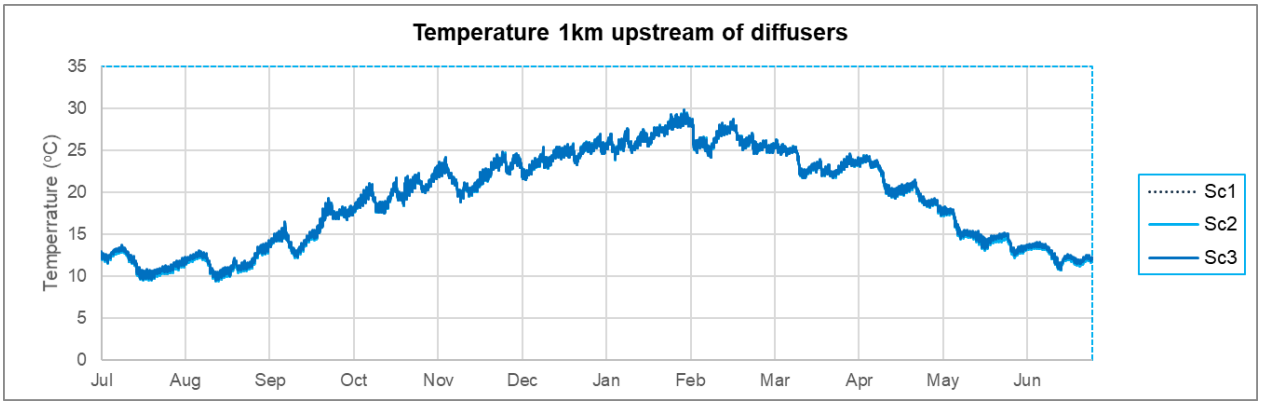
Appendices D1.2.1 Lower rainfall year scenario results (2017-2018)

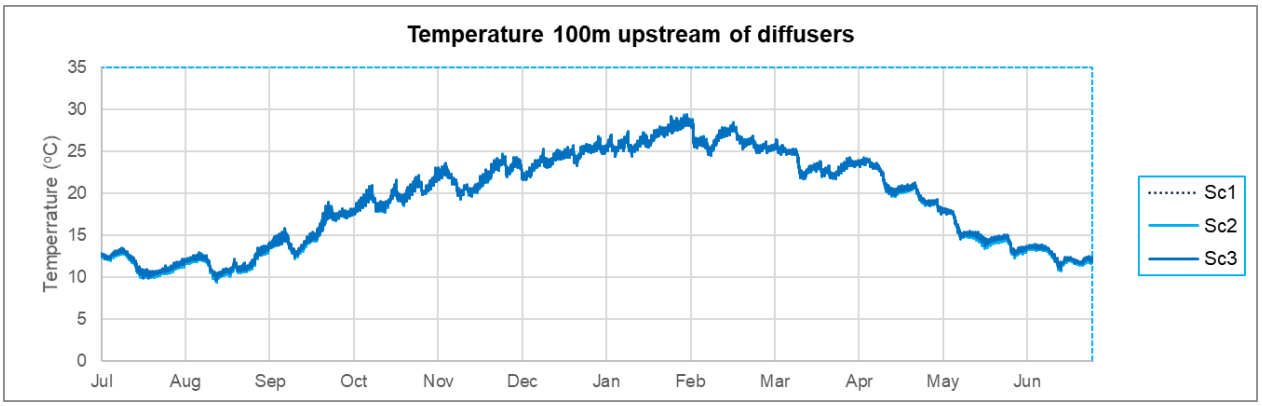
Longitudinal plots

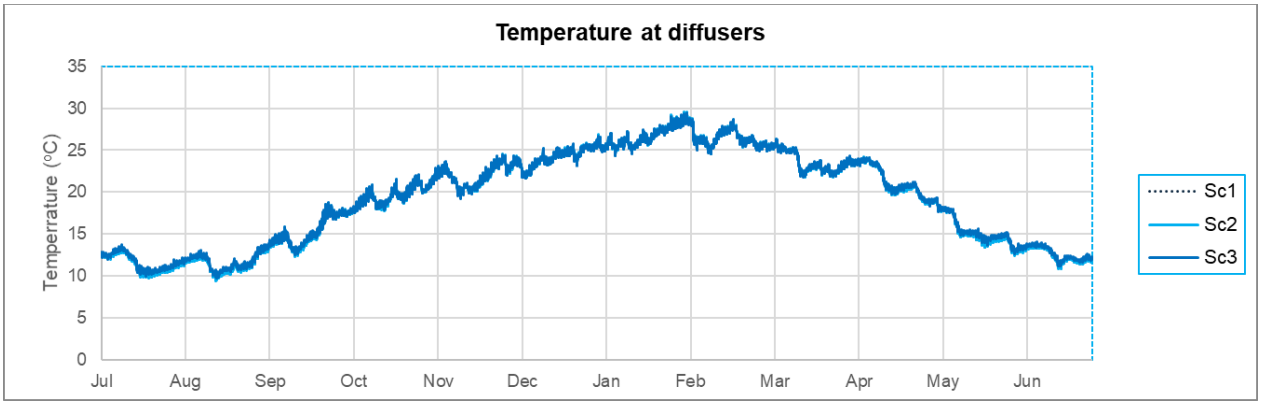


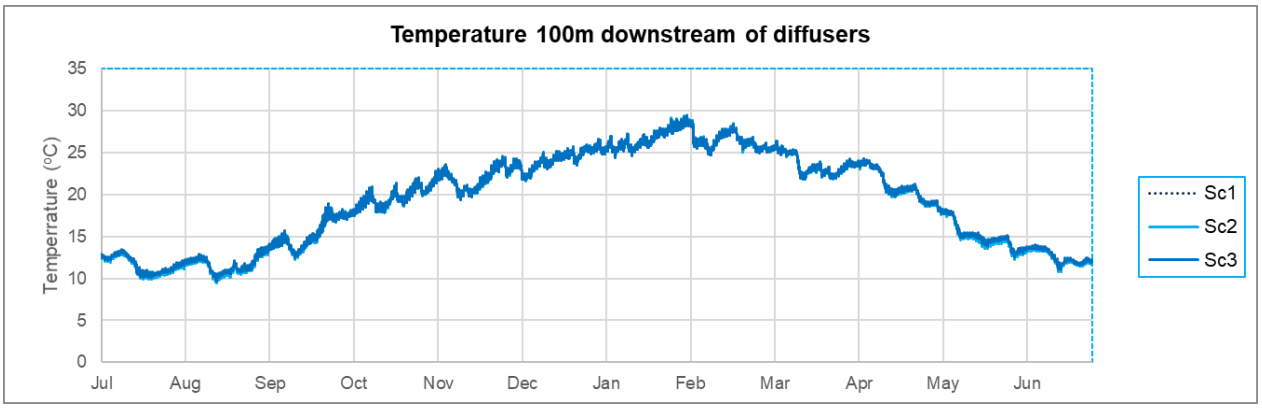


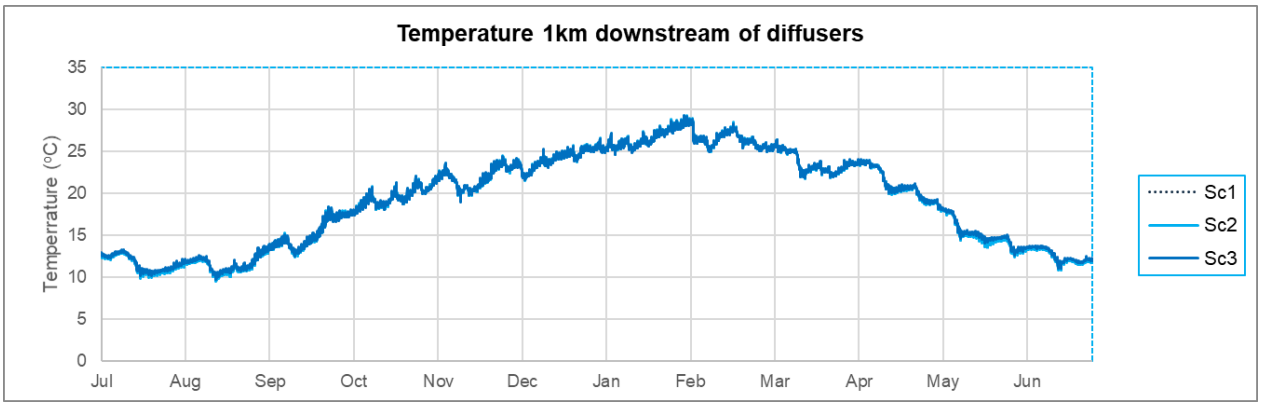
Time series plots





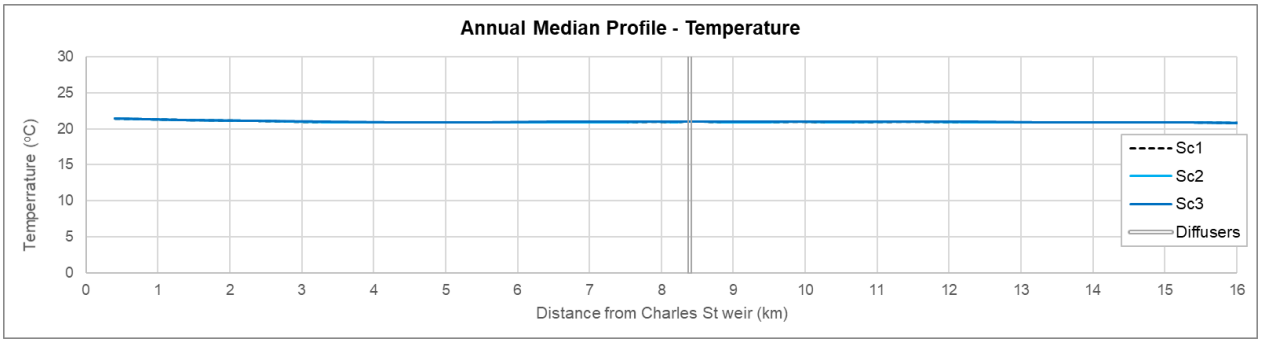


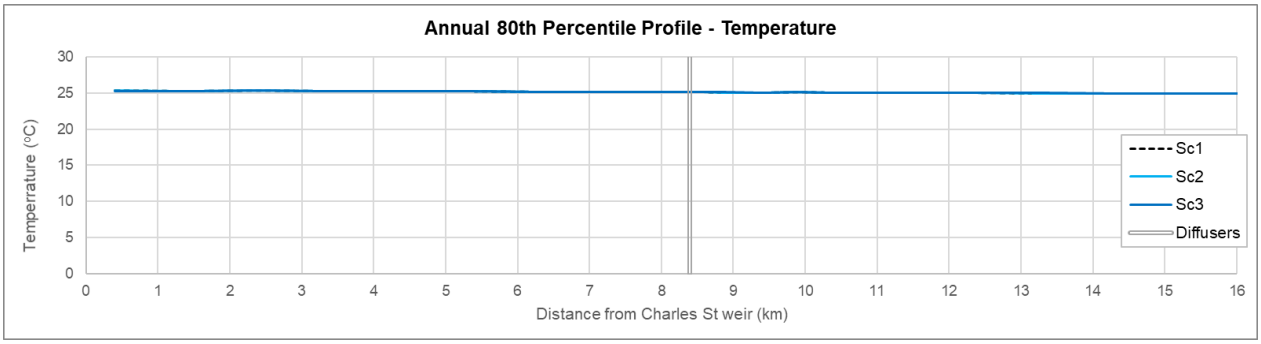




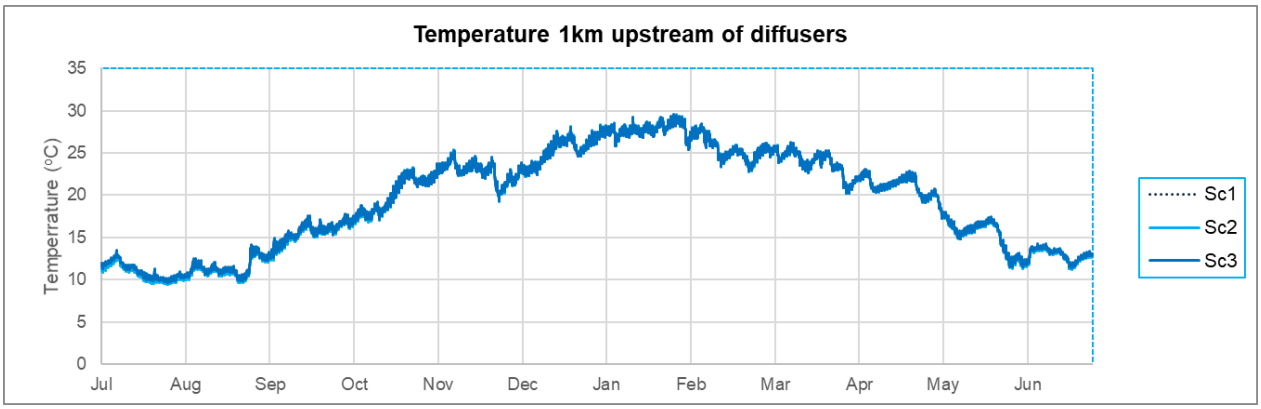
Appendices D1.2.2 Average rainfall year scenario results (2016-2017)

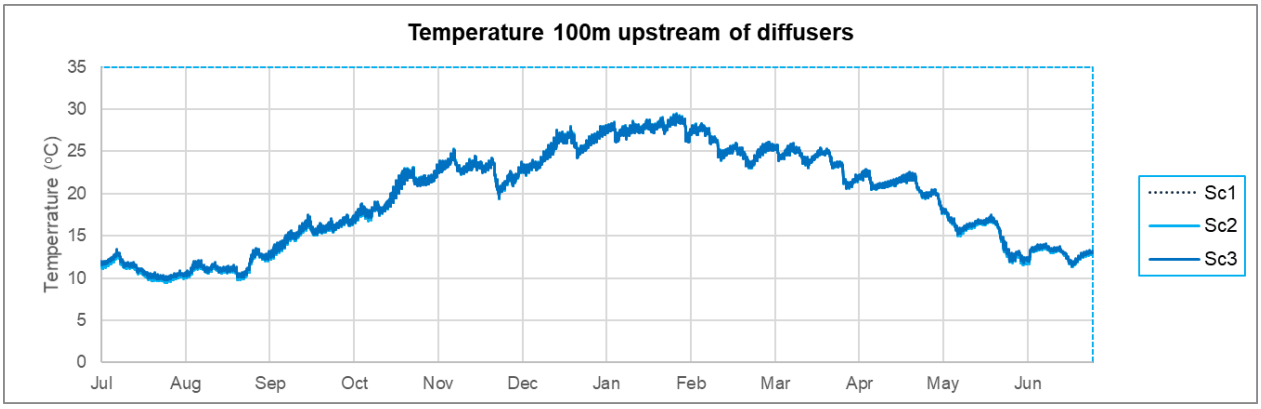
Longitudinal plots





Time series plots




Temperature 100m upstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
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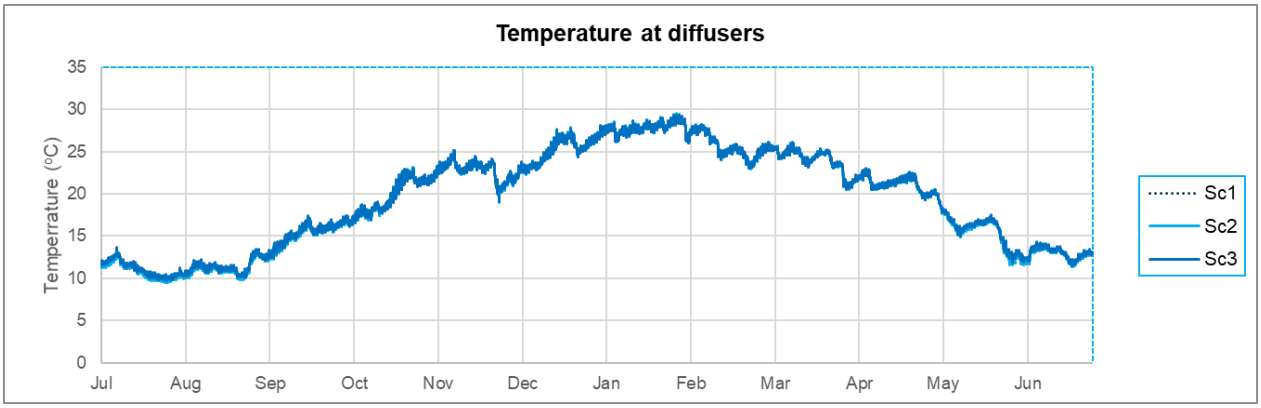
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Temperature at diffusers
Temperature (°C)
35
30
25
20
15
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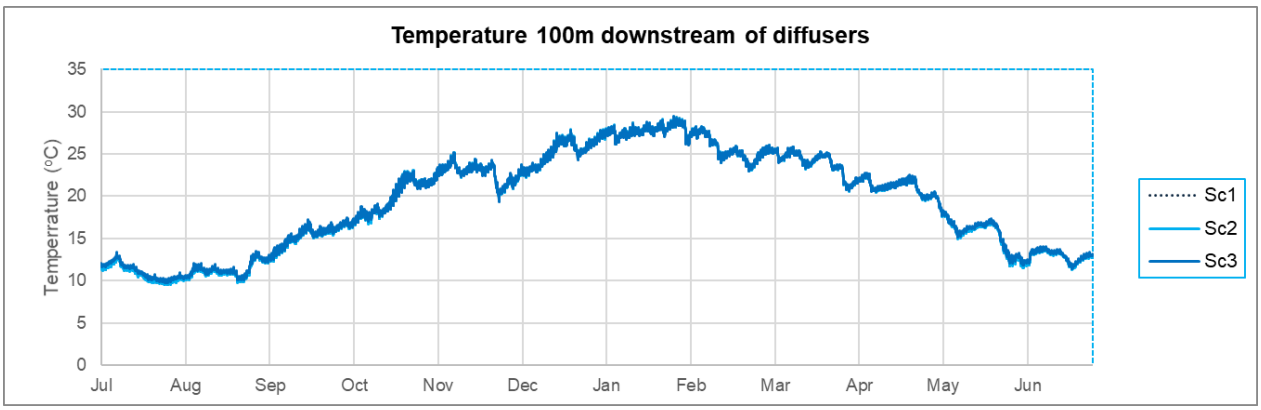
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Temperature 100m downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
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Jul
Aug
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Oct
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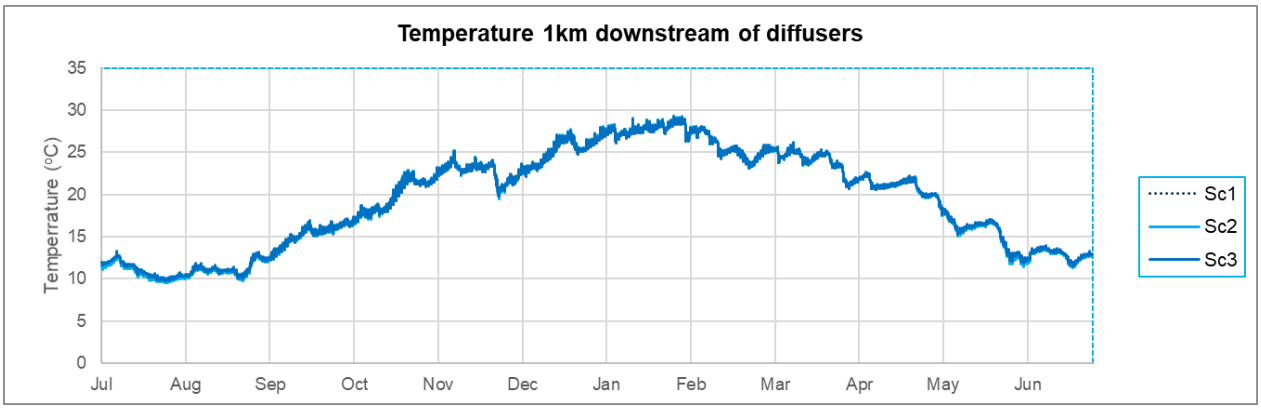
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Temperature 1km downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
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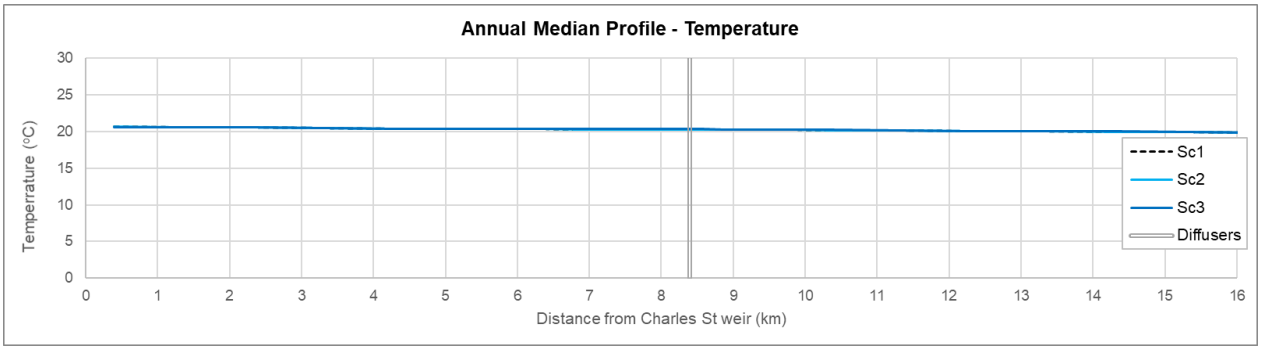
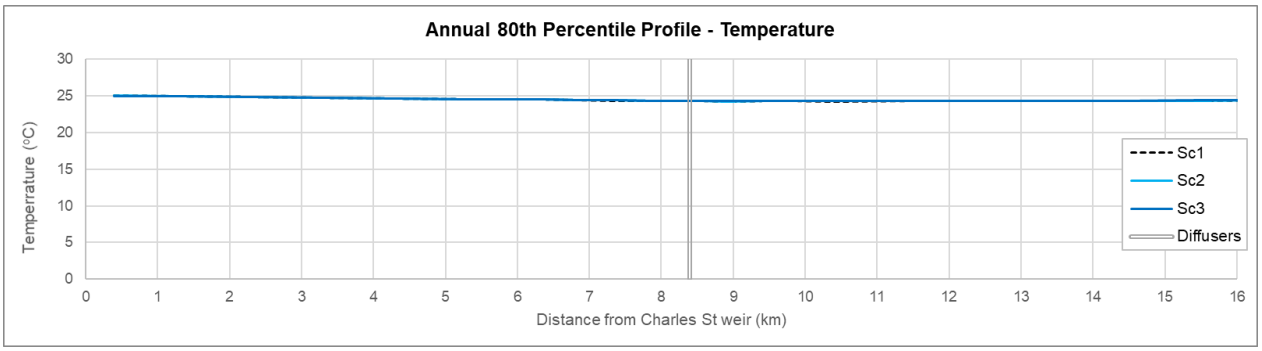
Apr
May
Jun
Sc1
Sc2
Sc3

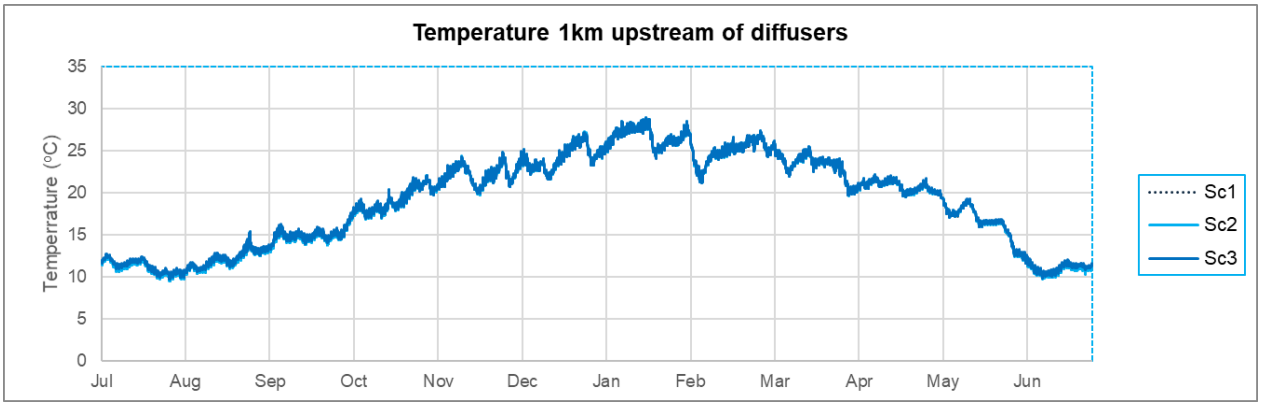
Appendices D1.2.3 Higher rainfall year scenario results (2021-2022)

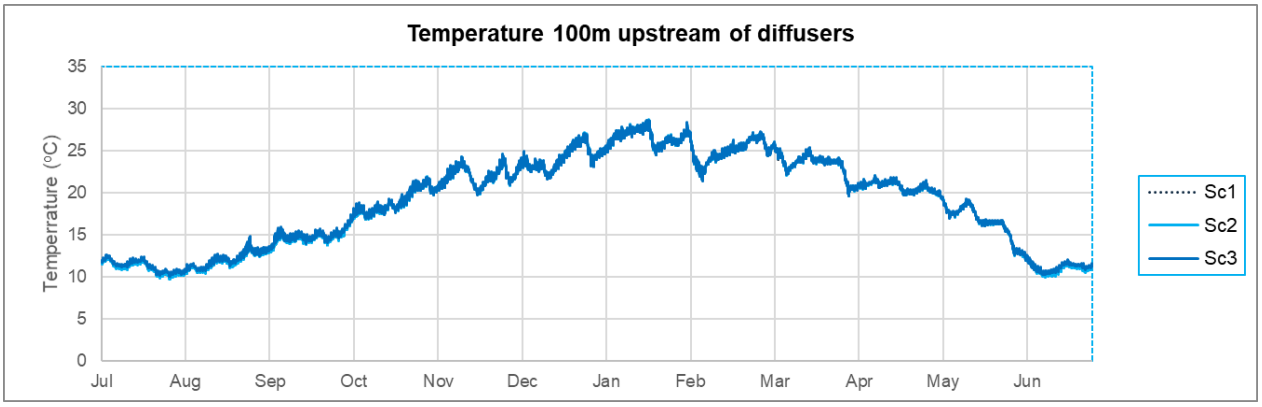
Longitudinal plots

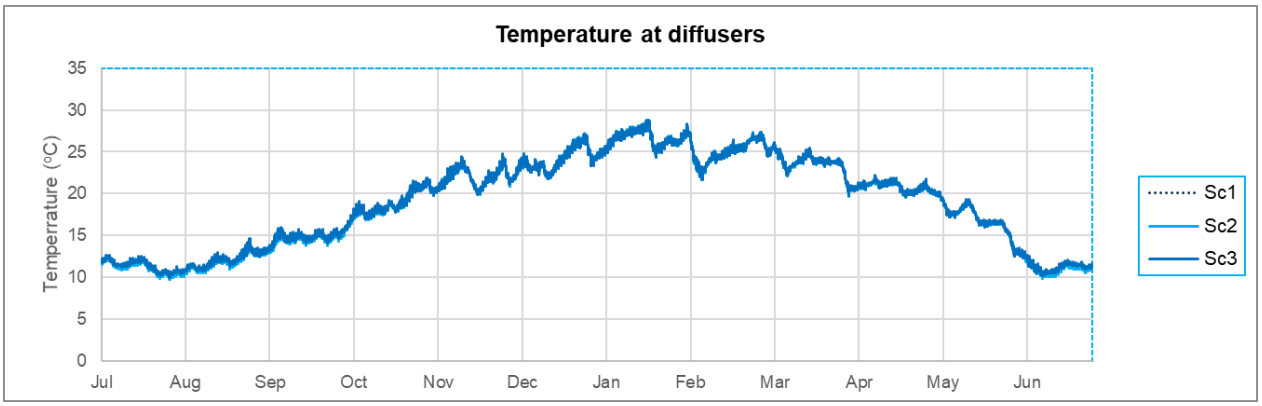




Time series plots






Temperature at diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
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Oct
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Dec
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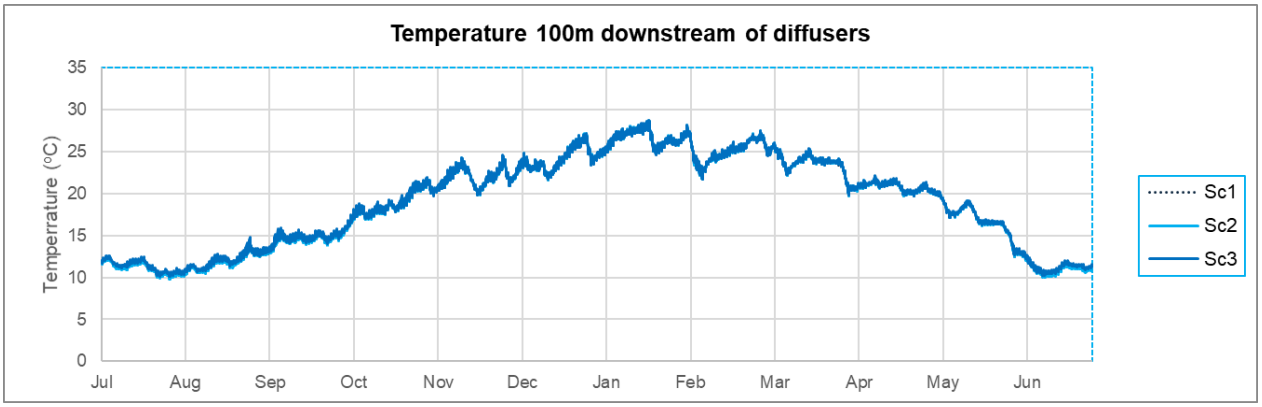
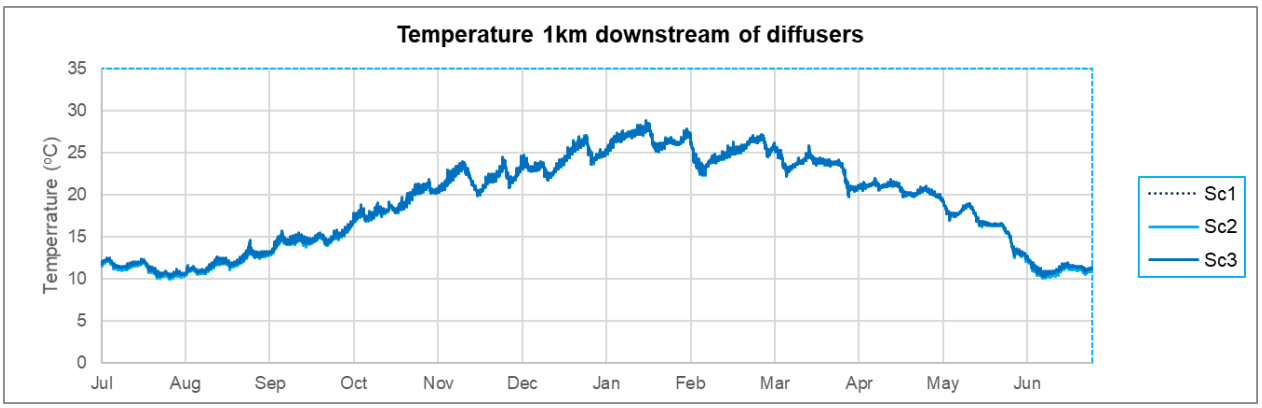
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

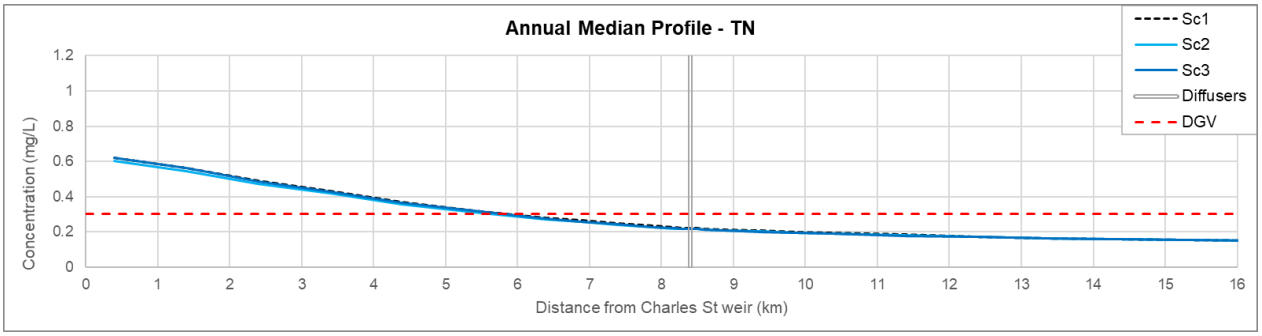

Temperature 100m downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

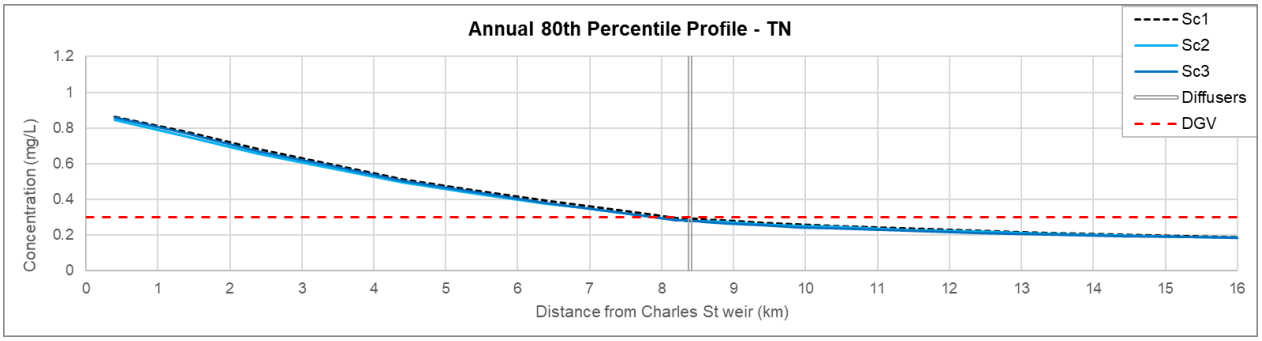

Temperature 1km downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D1.3 Total N

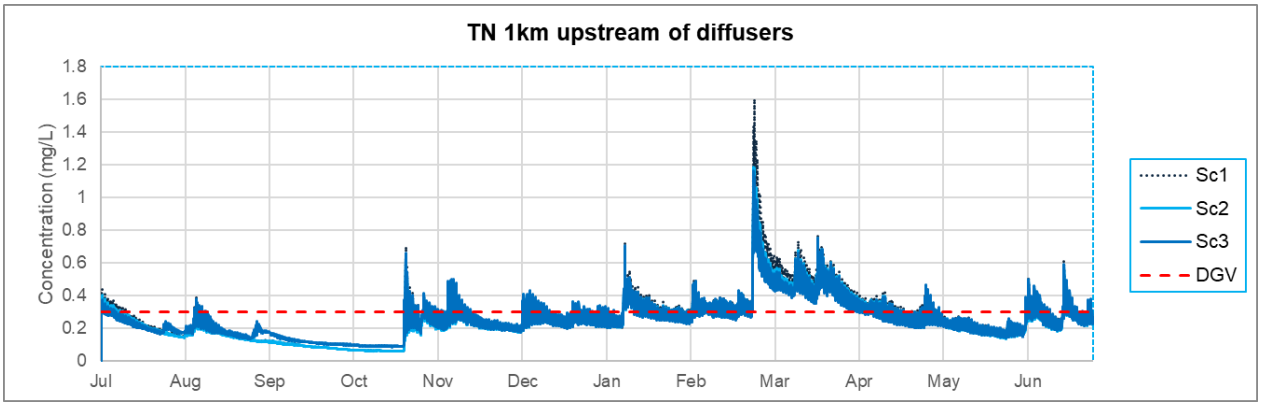
Appendices D1.3.1 Lower rainfall year scenario results (2017-2018)

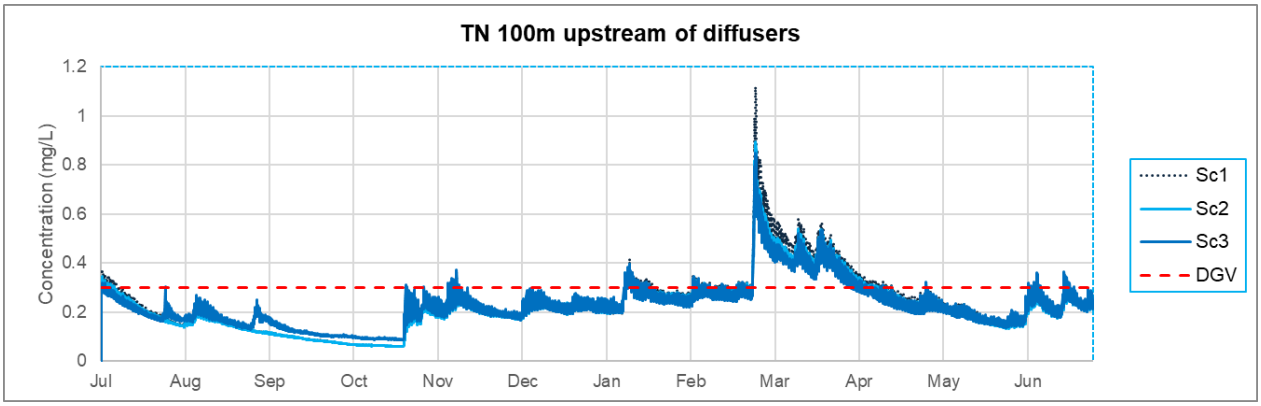
Longitudinal plots

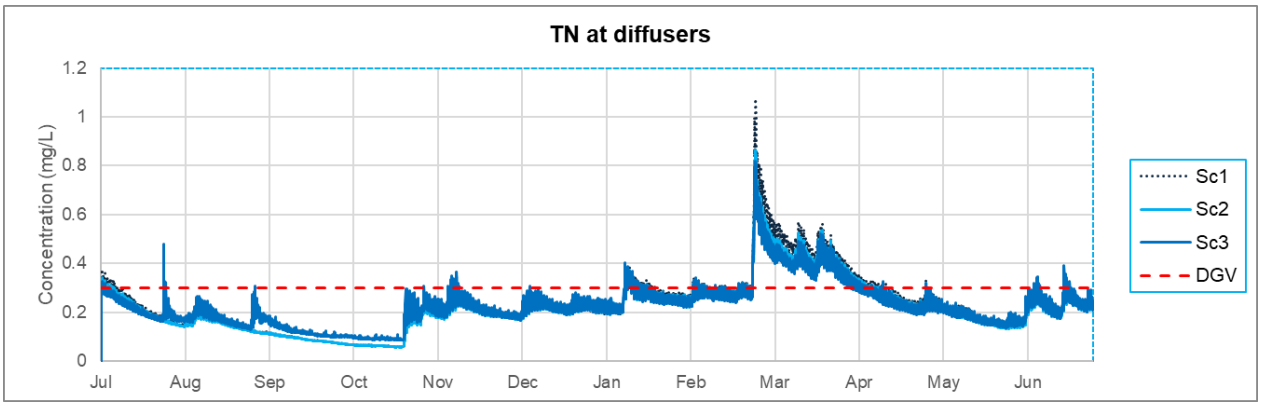


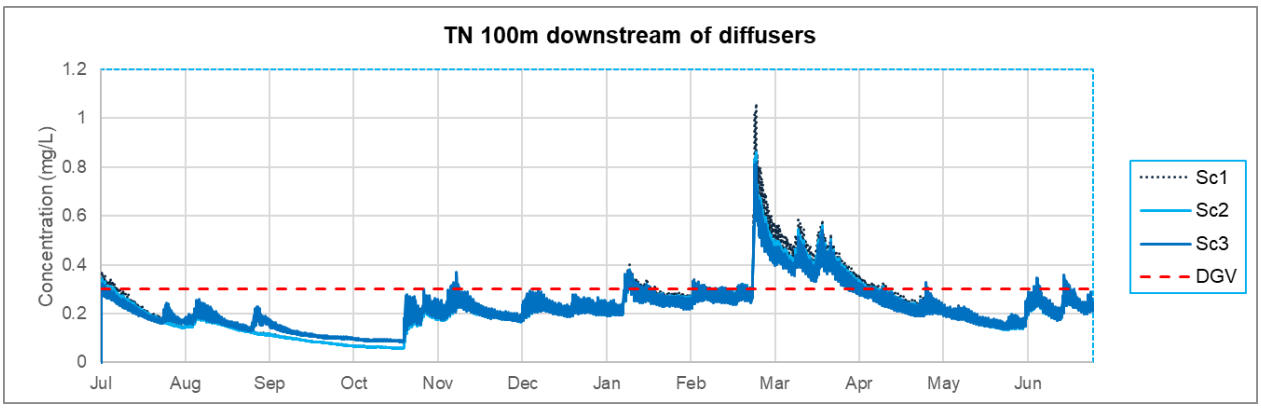


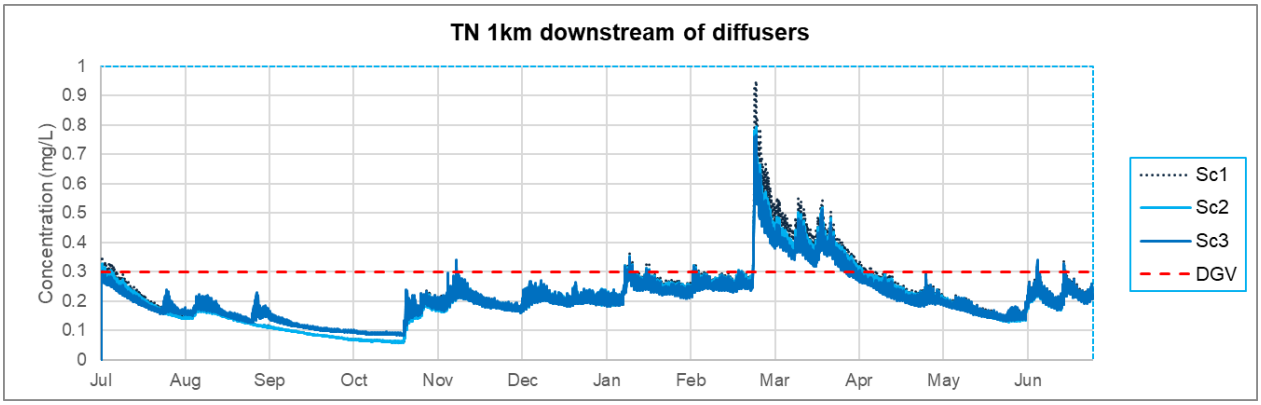
Time series plots




TN 100m upstream of diffusers
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

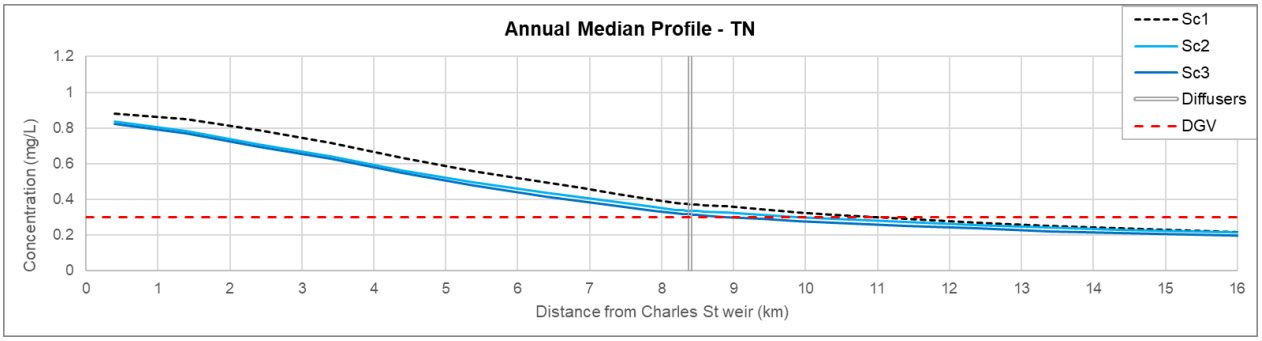

TN at diffusers
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

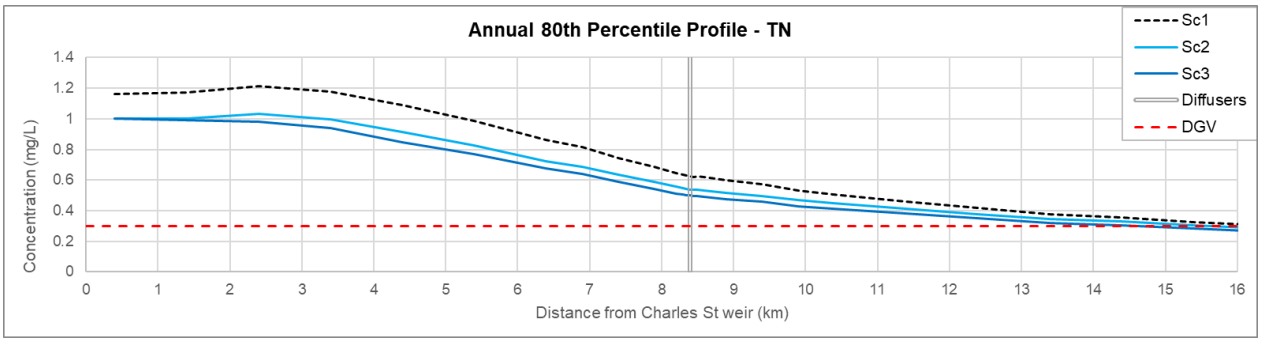

TN 100m downstream of diffusers
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


TN 1km downstream of diffusers
Concentration (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

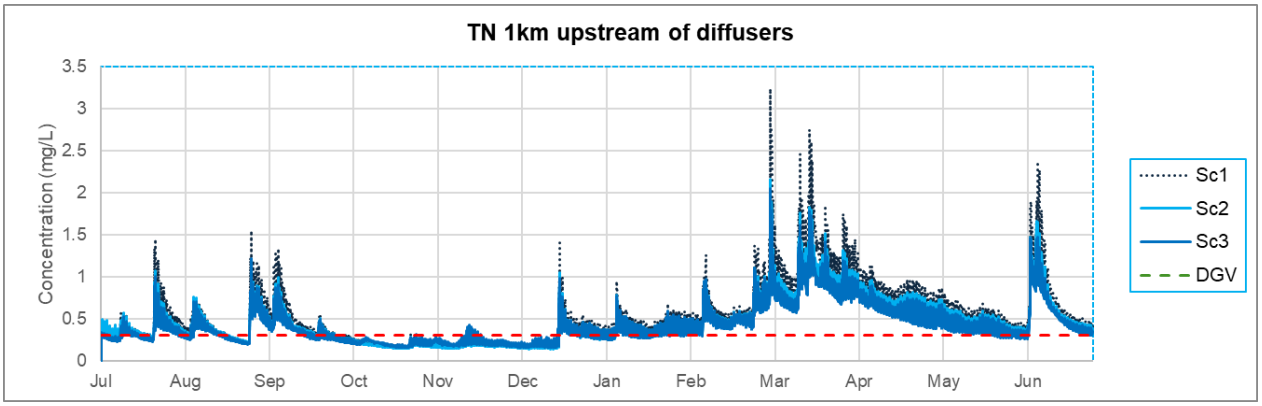
Appendices D1.3.2 Average rainfall year scenario results (2016-2017)

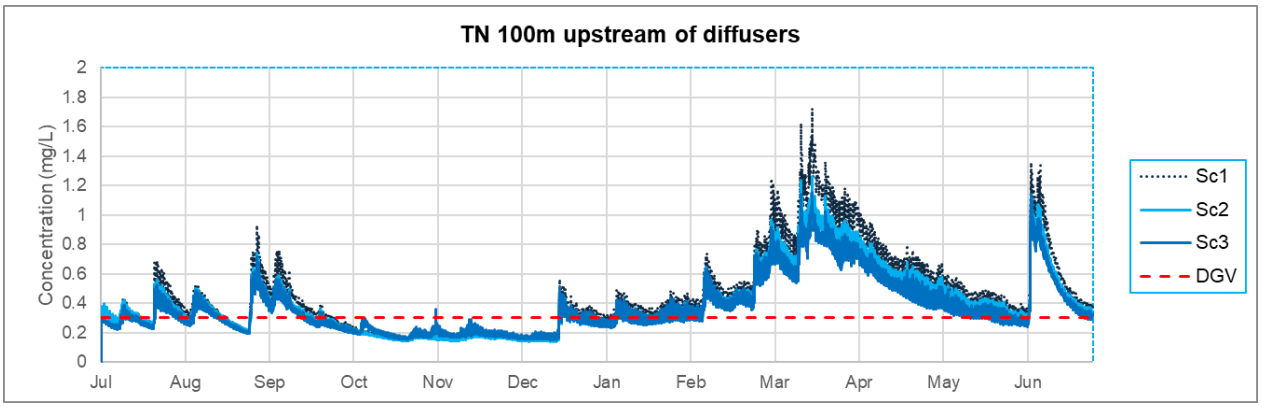
Longitudinal plots

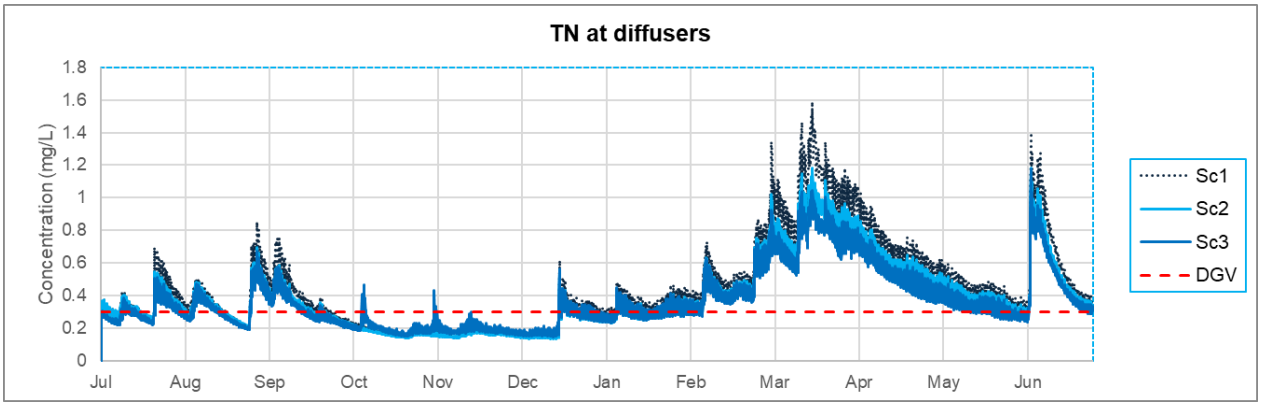


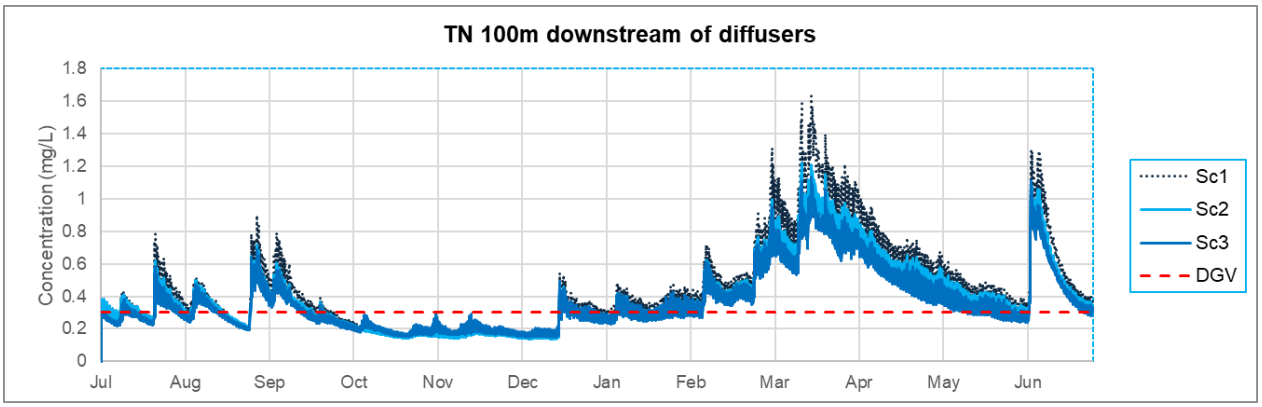


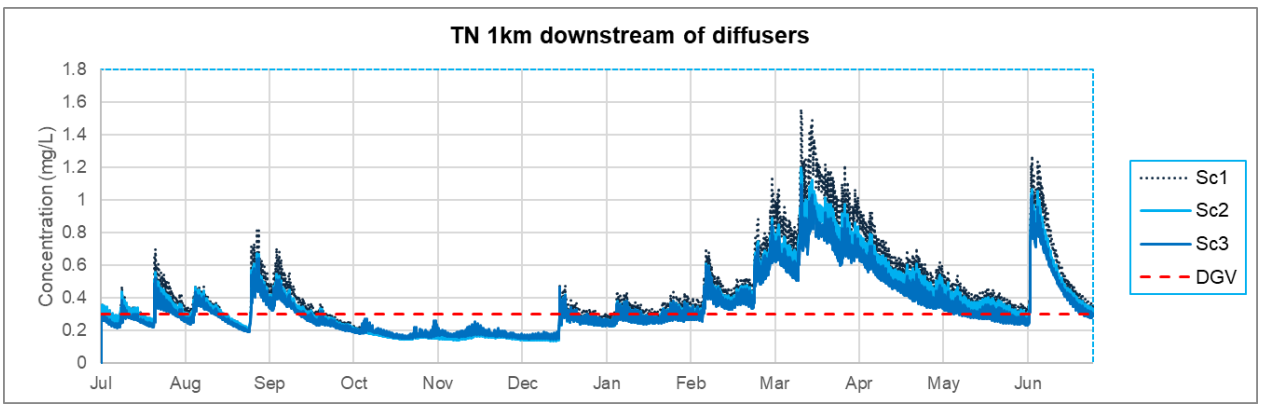
Time series plots





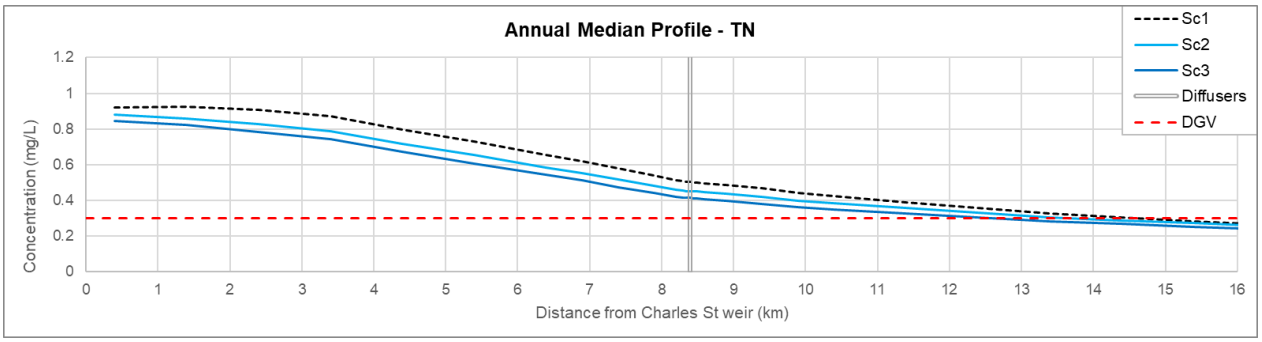


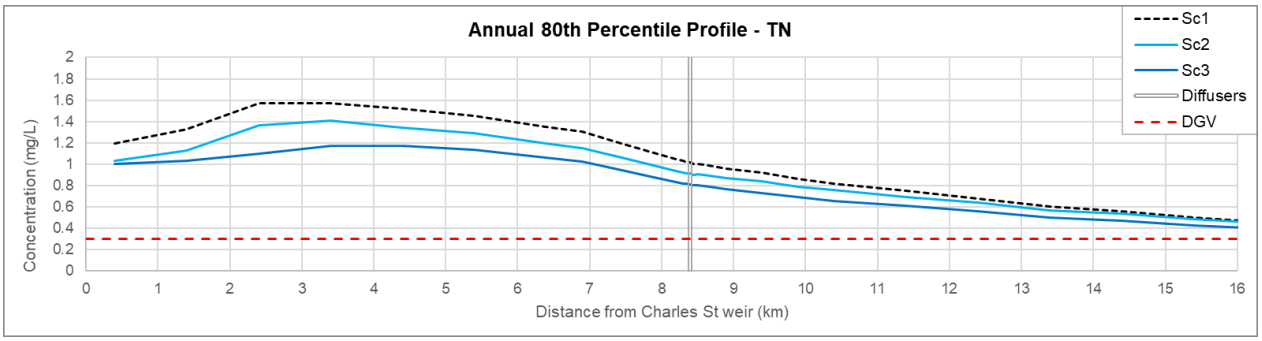




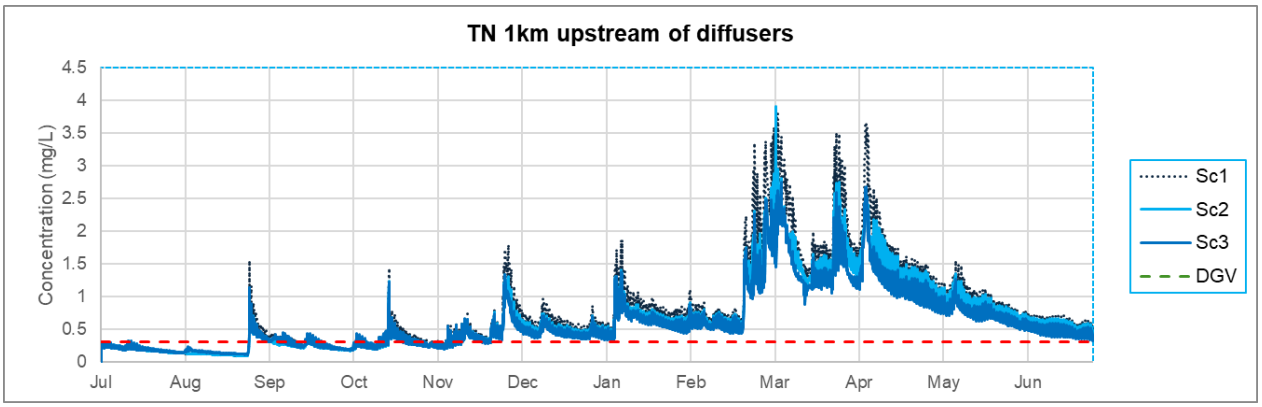
Appendices D1.3.3 Higher rainfall year scenario results (2021-2022)

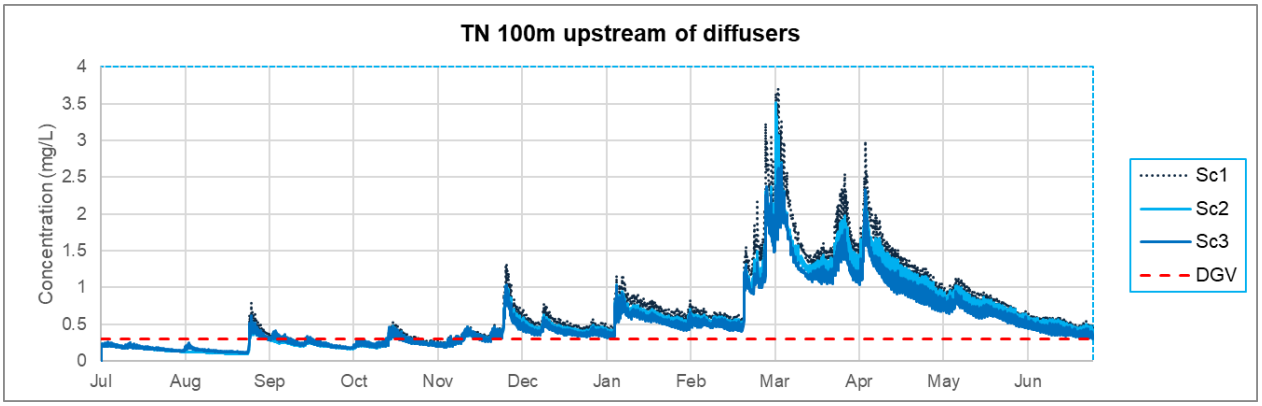
Longitudinal plots

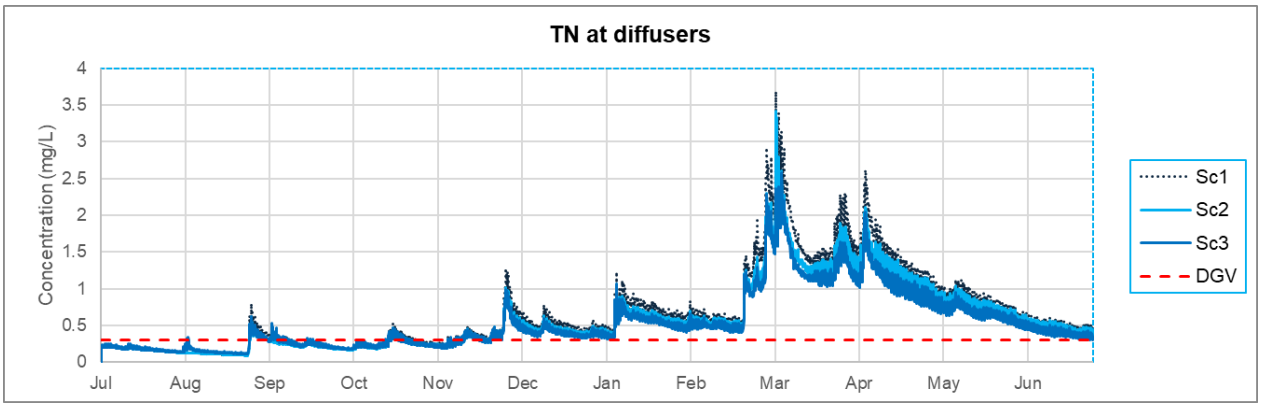


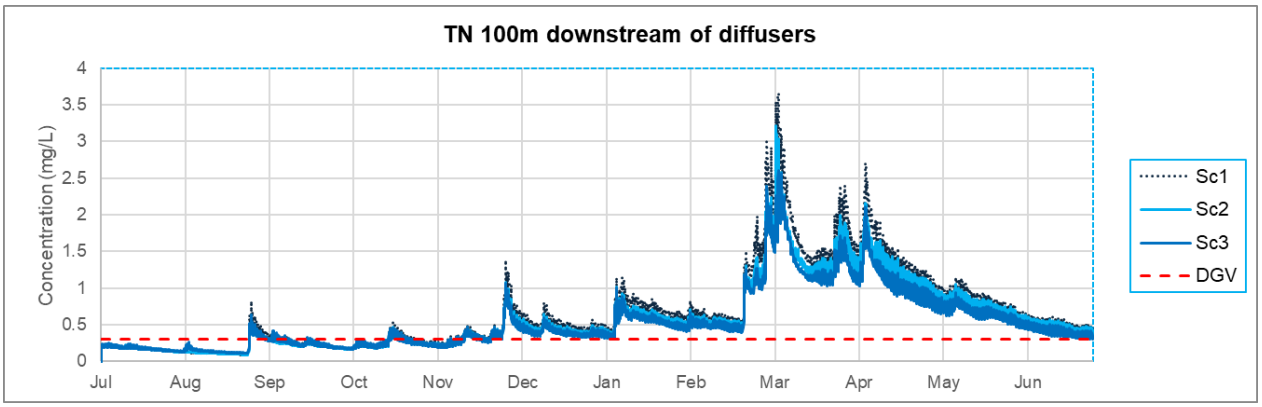


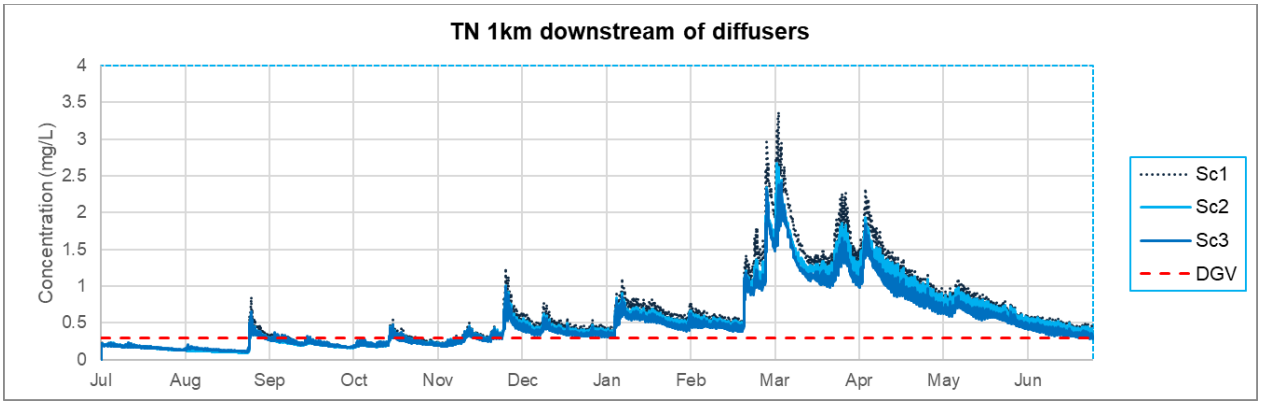
Time series plots







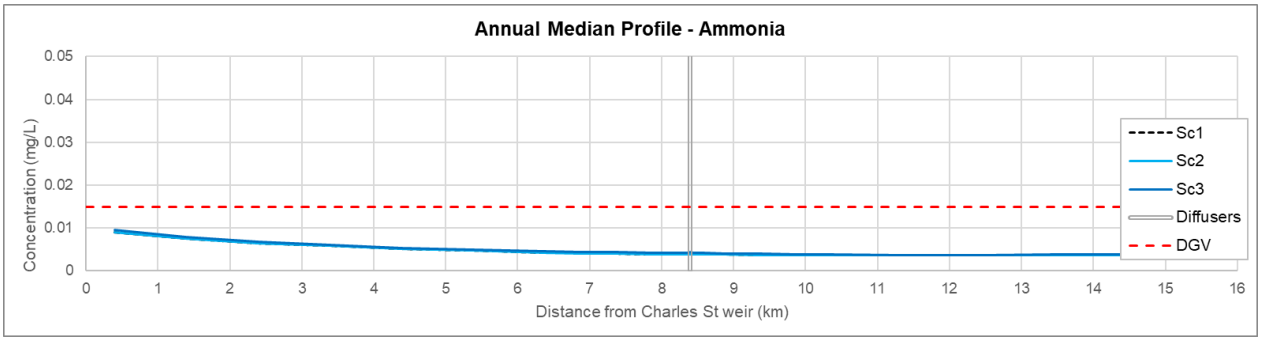


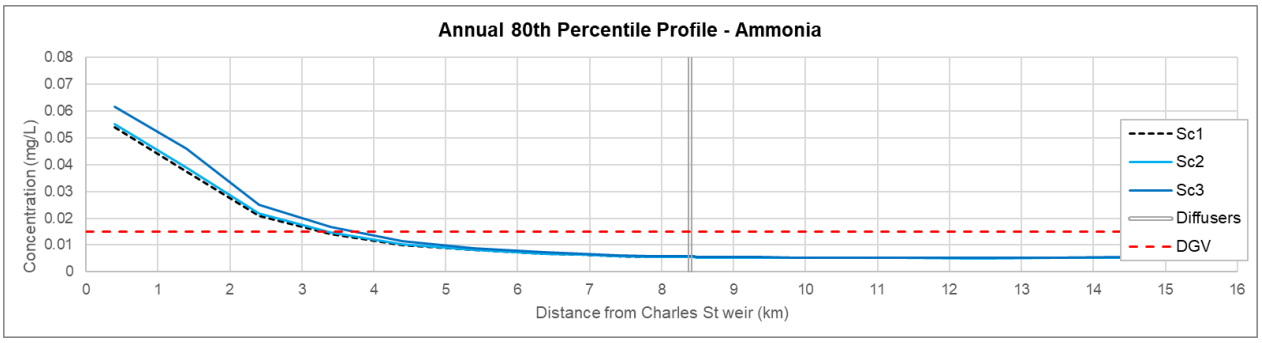


Appendices D1.4 Ammonia

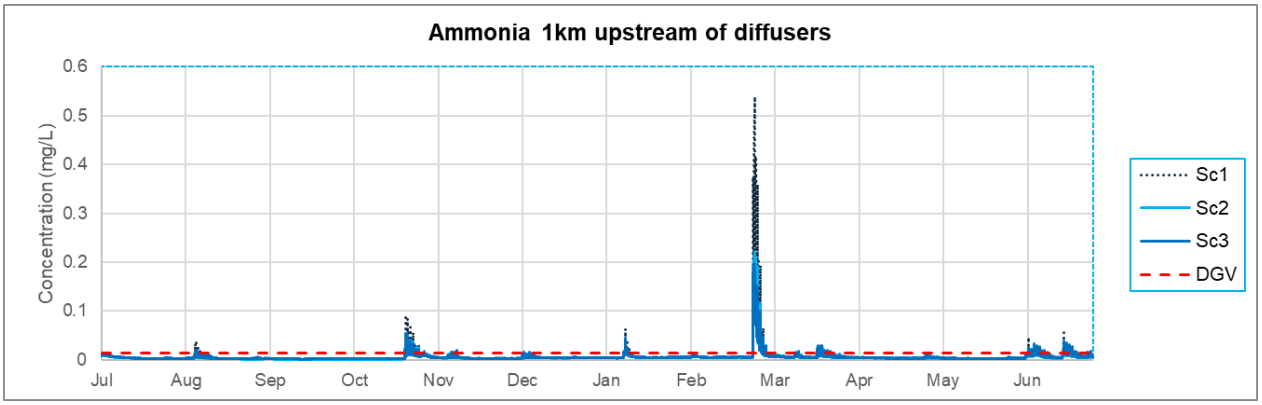
Appendices D1.4.1 Lower rainfall year scenario results (2017-2018)

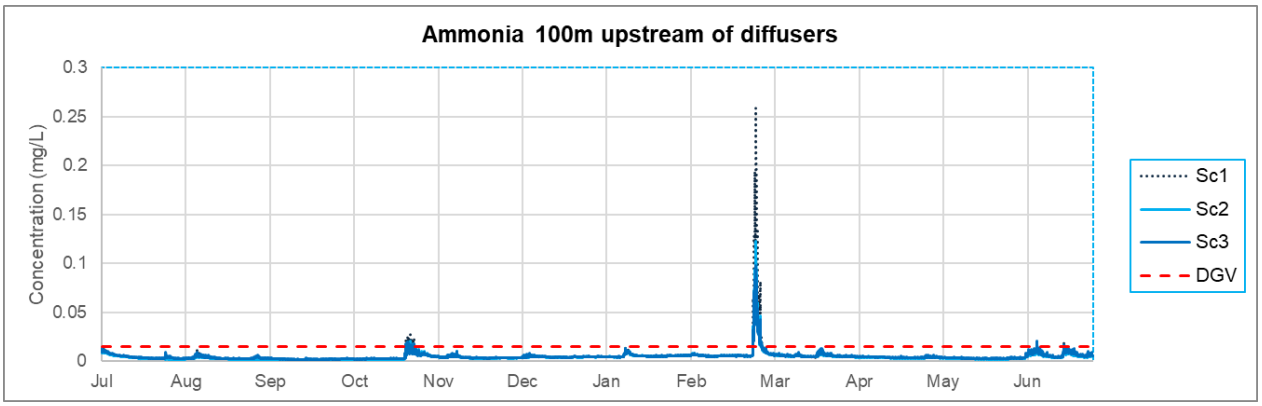
Longitudinal plots

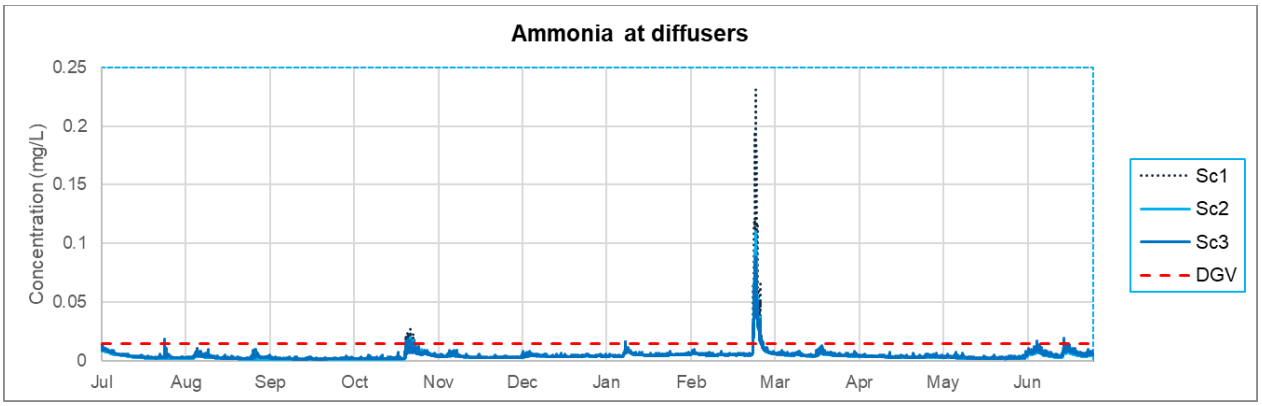


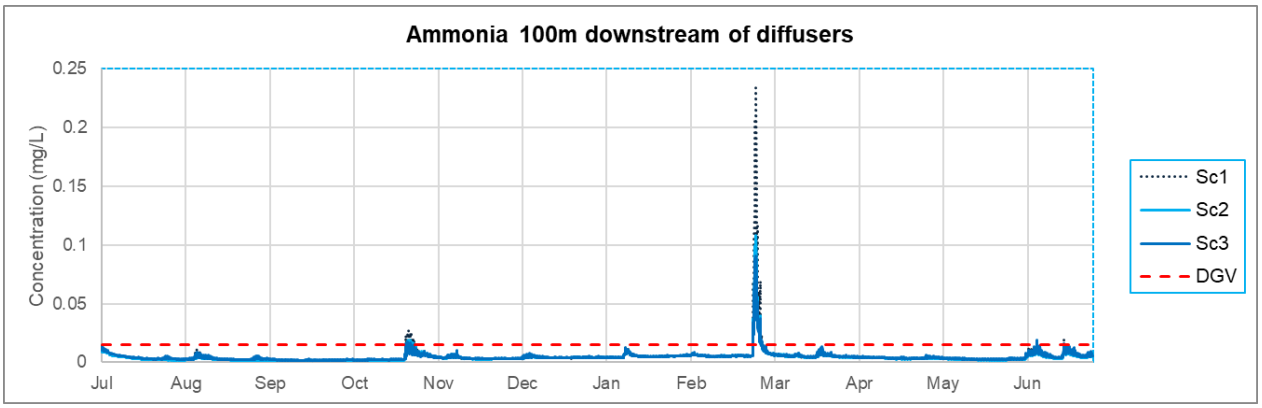


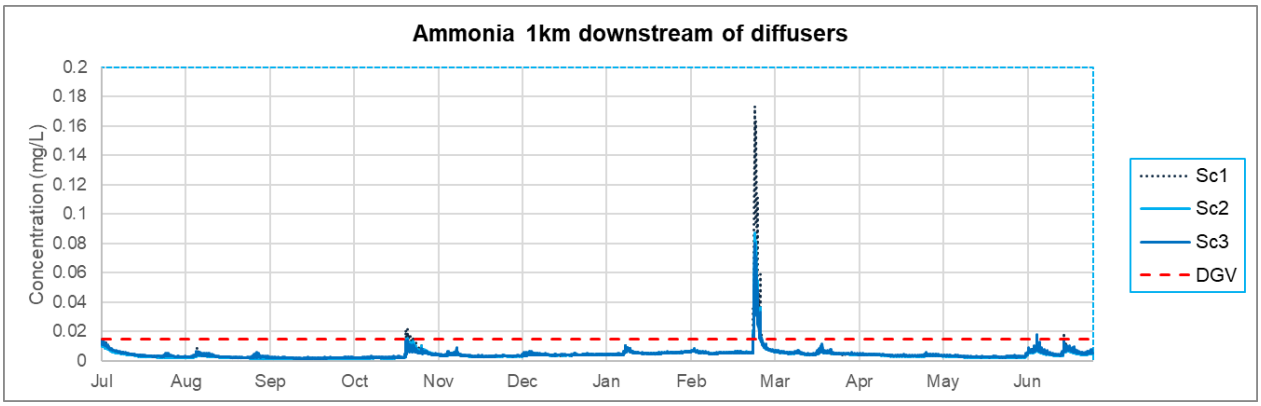
Time series plots





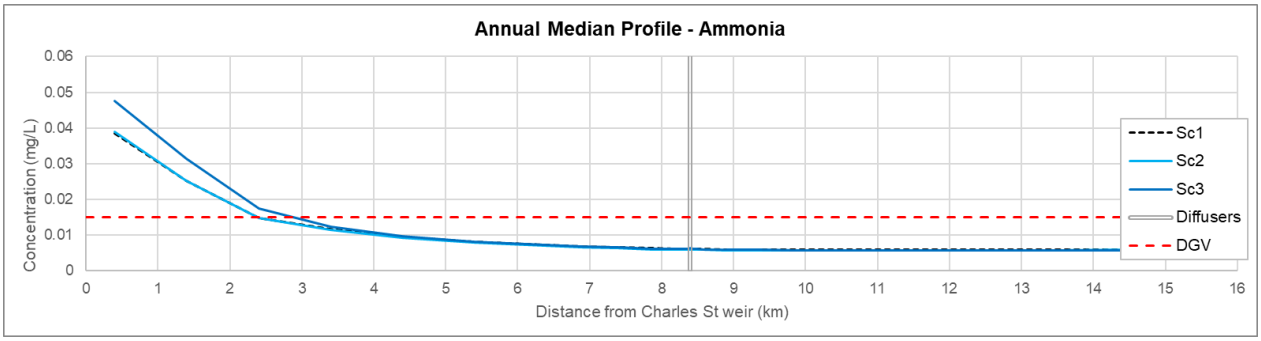


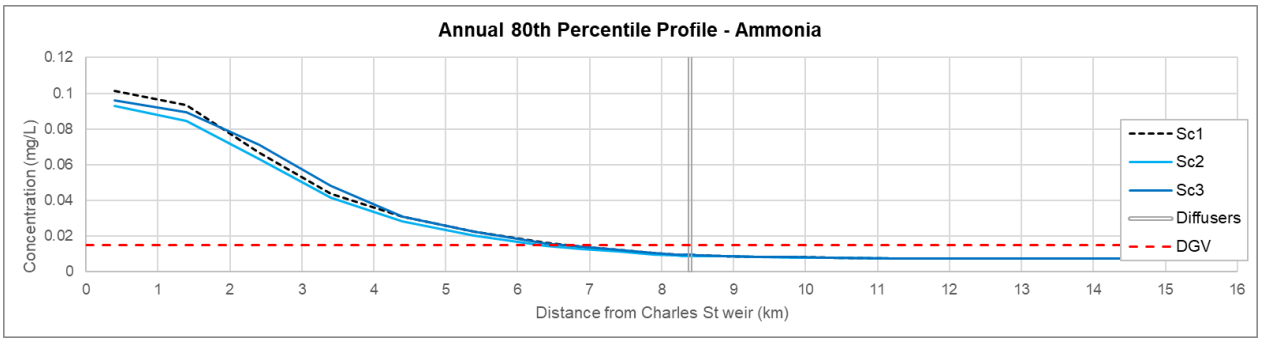




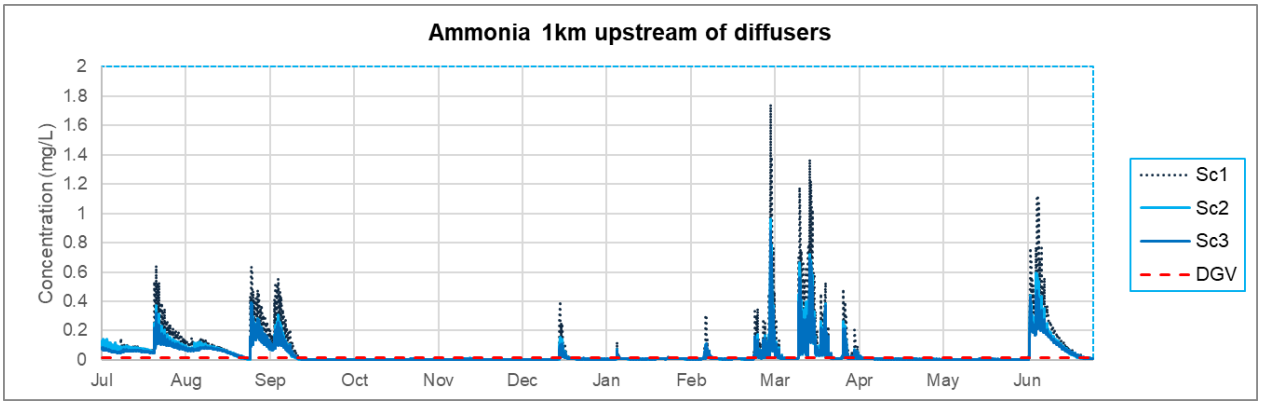
Appendices D1.4.2 Average rainfall year scenario results (2016-2017)

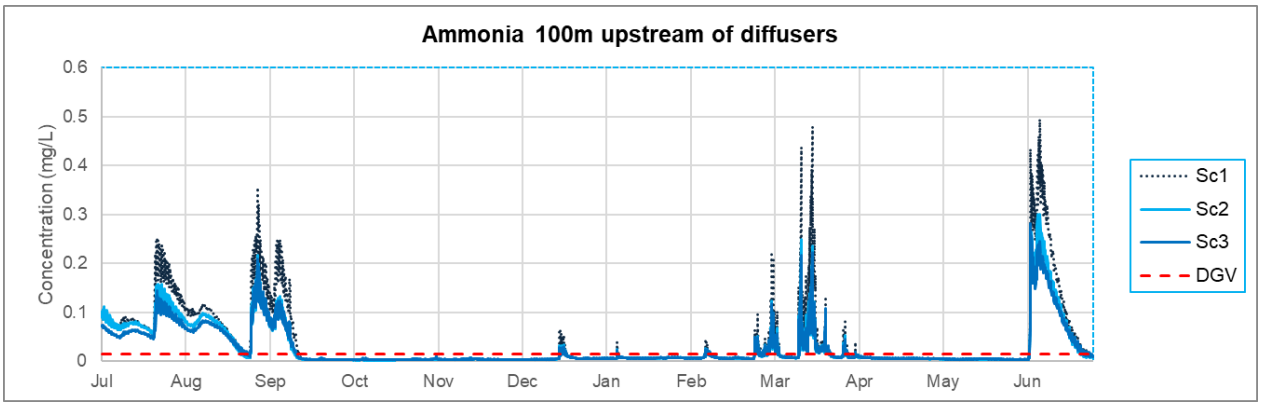
Longitudinal plots

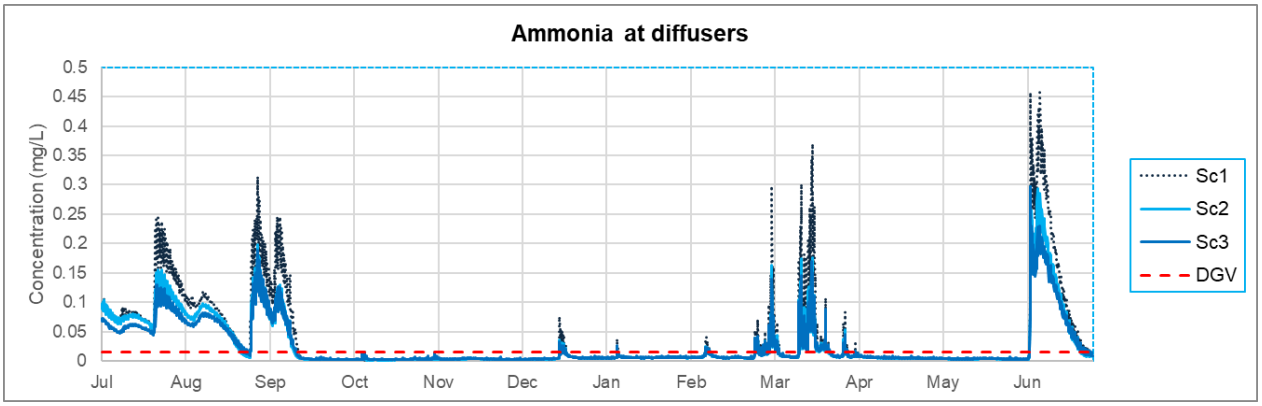


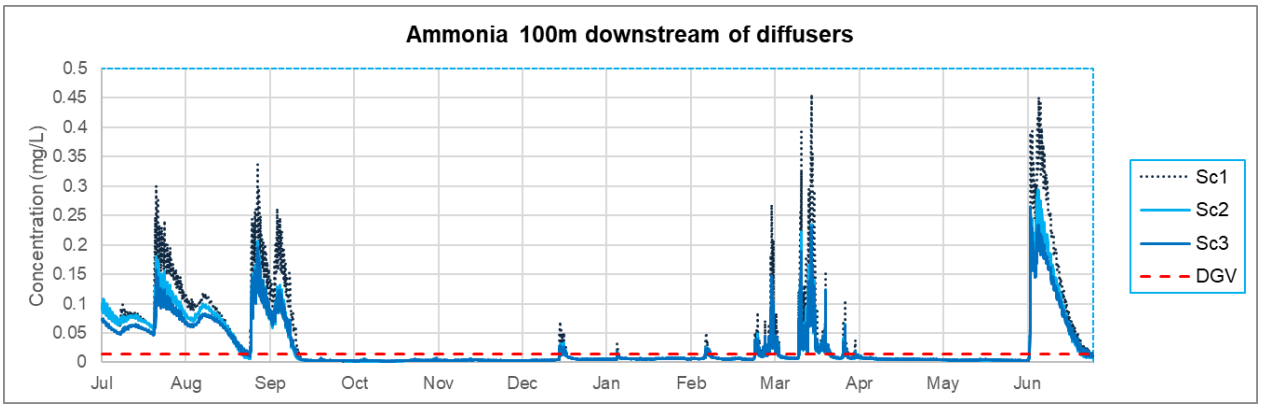


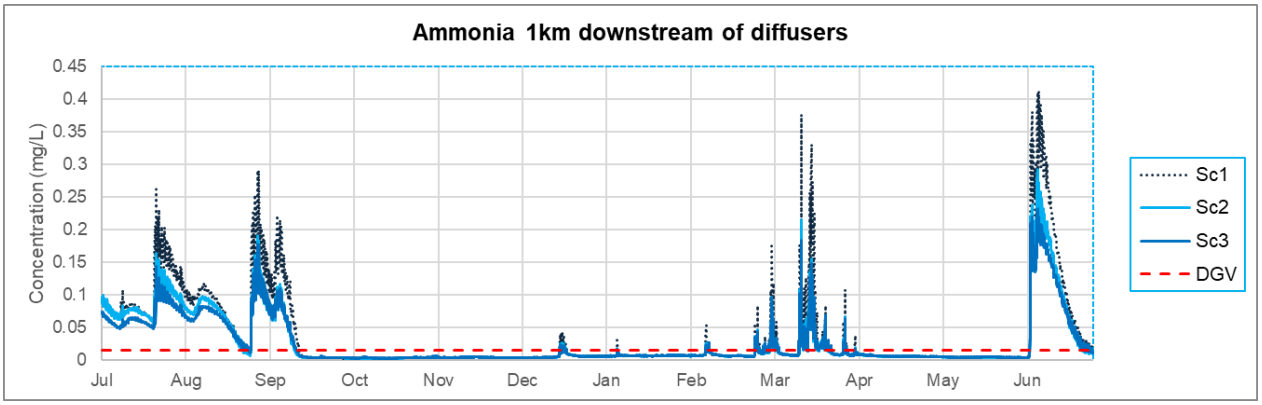
Time series plots




Ammonia 100m upstream of diffusers
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

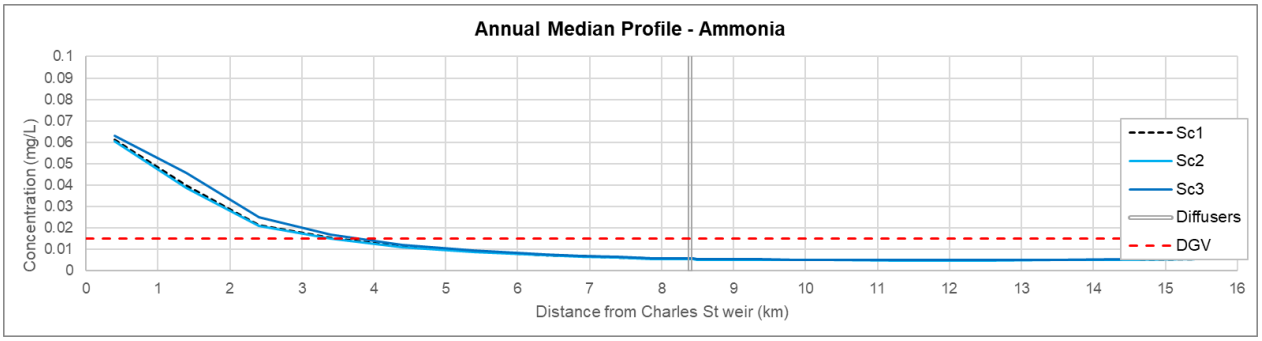

Ammonia at diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

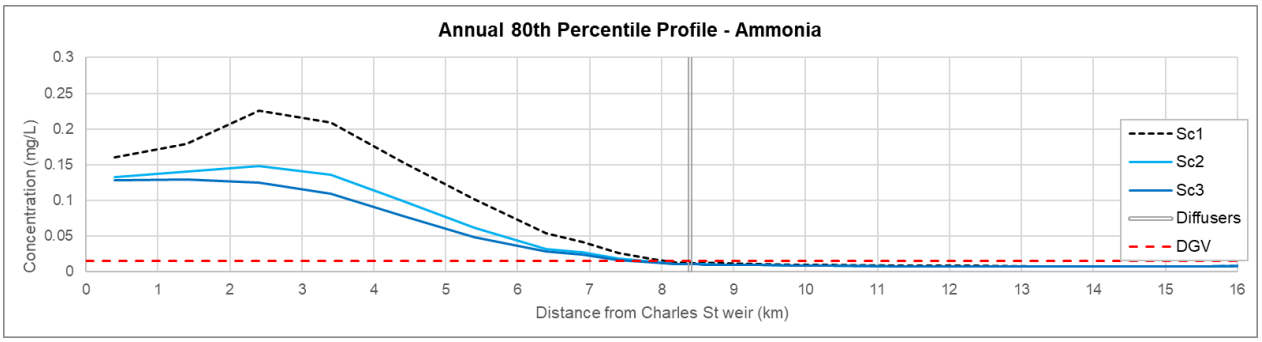

Ammonia 100m downstream of diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Ammonia 1km downstream of diffusers
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

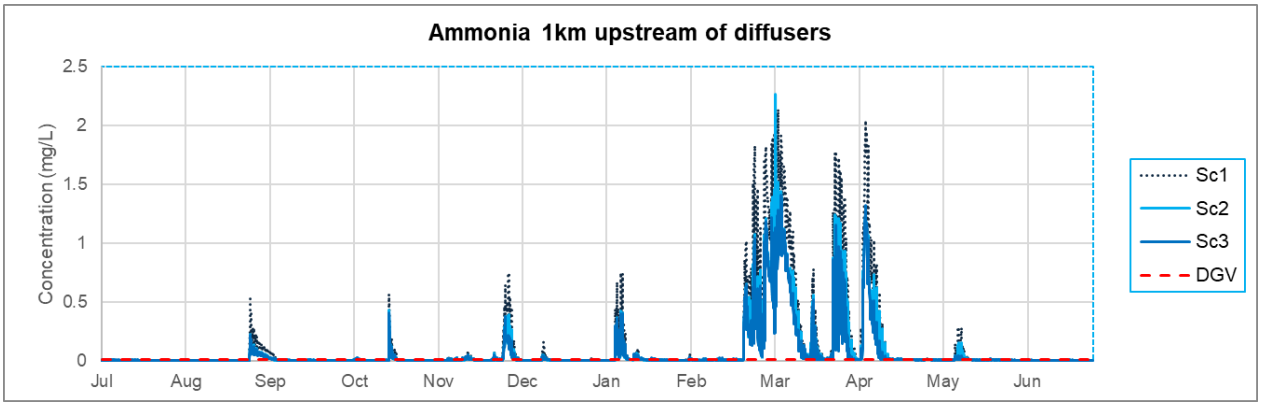
Appendices D1.4.3 Higher rainfall year scenario results (2021-2022)

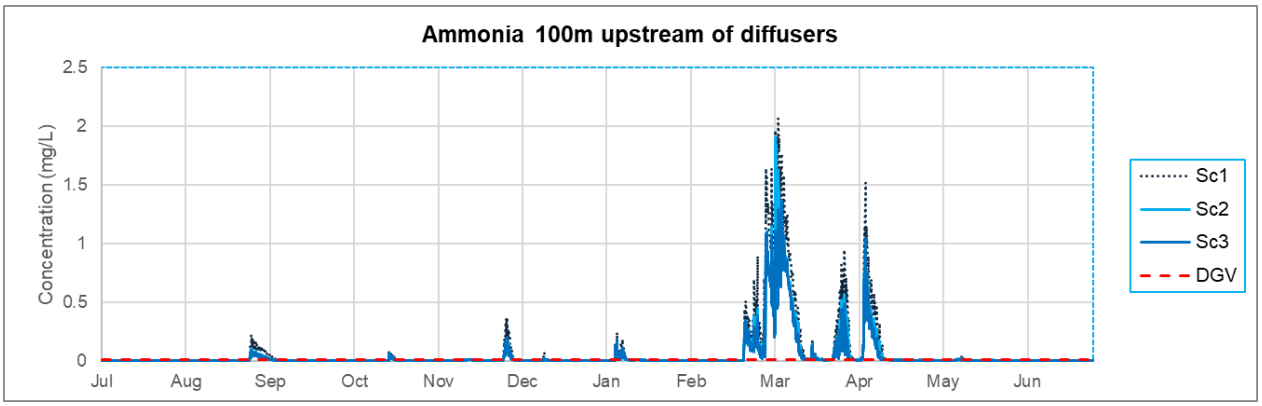
Longitudinal plots

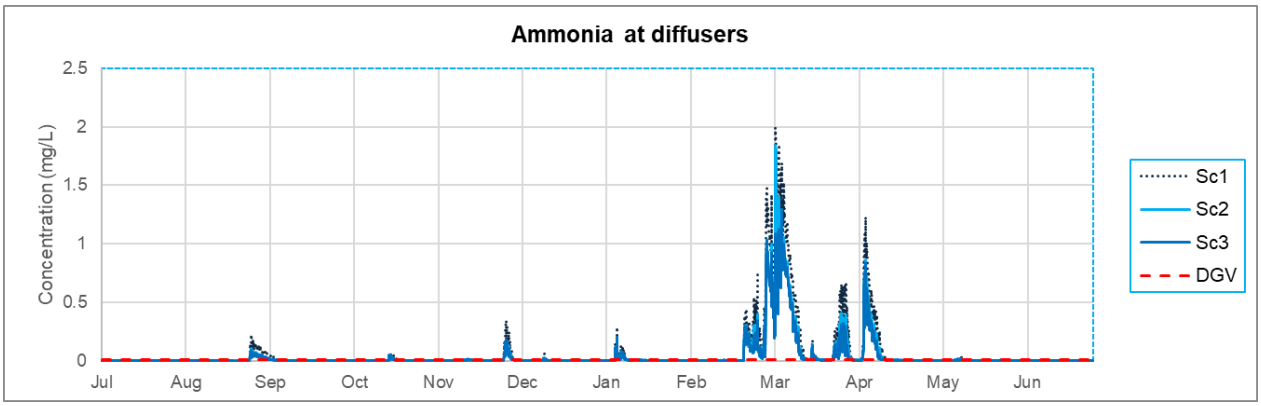


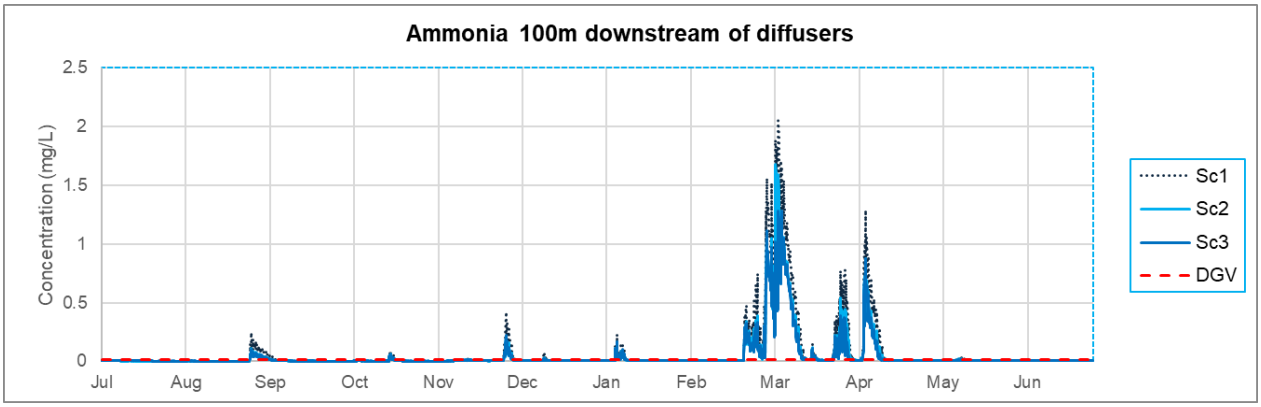


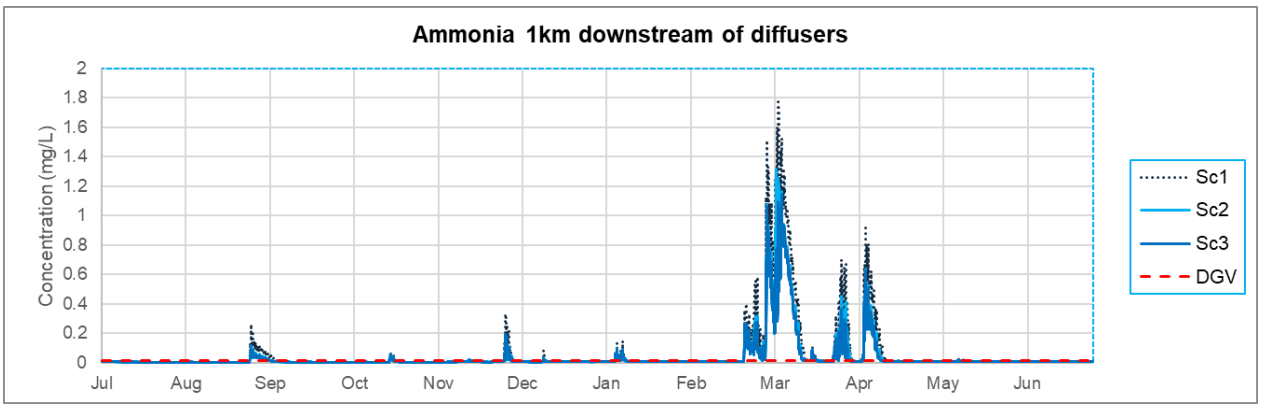
Time series plots






Ammonia at diffusers
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

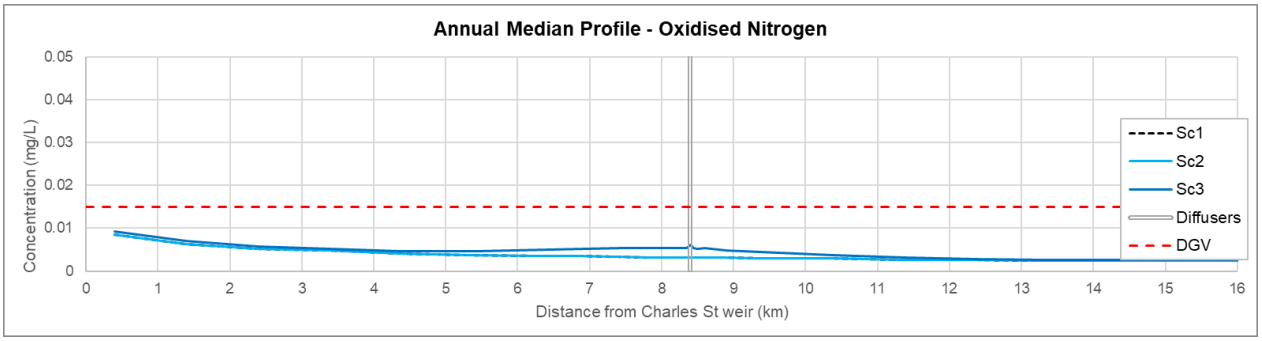

Ammonia 100m downstream of diffusers
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

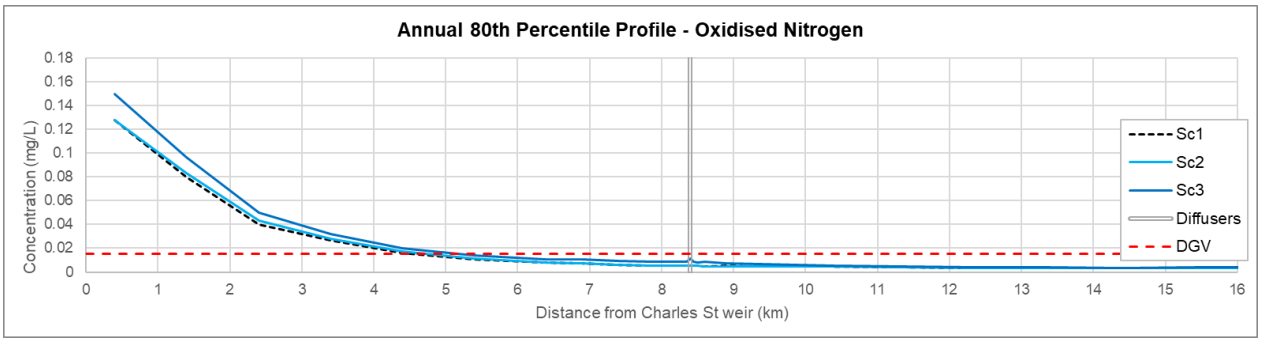

Ammonia 1km downstream of diffusers
Concentration (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

Appendices D1.5 Oxidised N

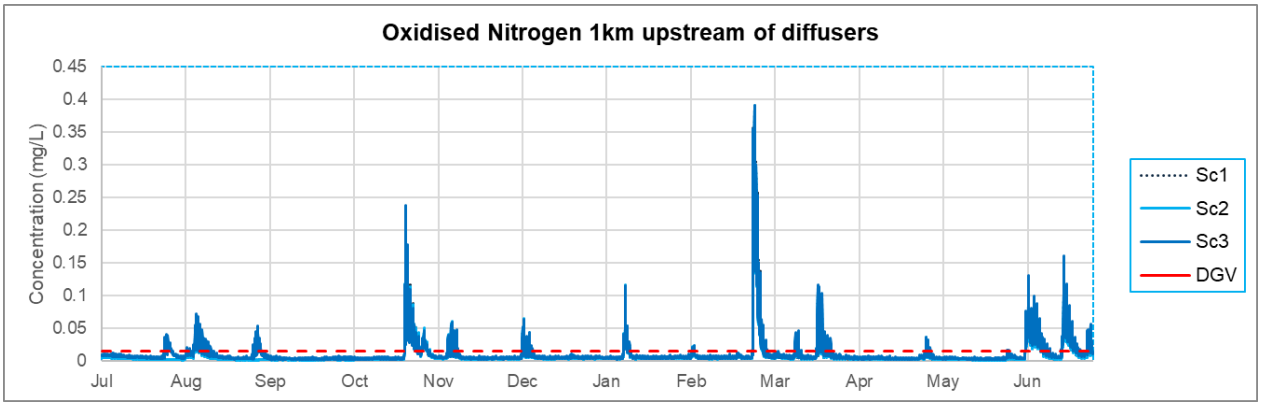
Appendices D1.5.1 Lower rainfall year scenario results (2017-2018)

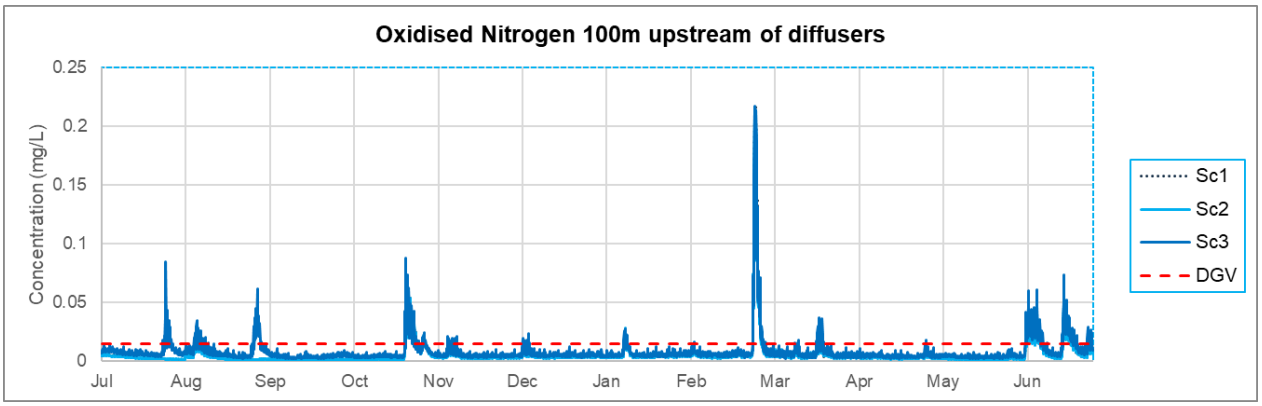
Longitudinal plots

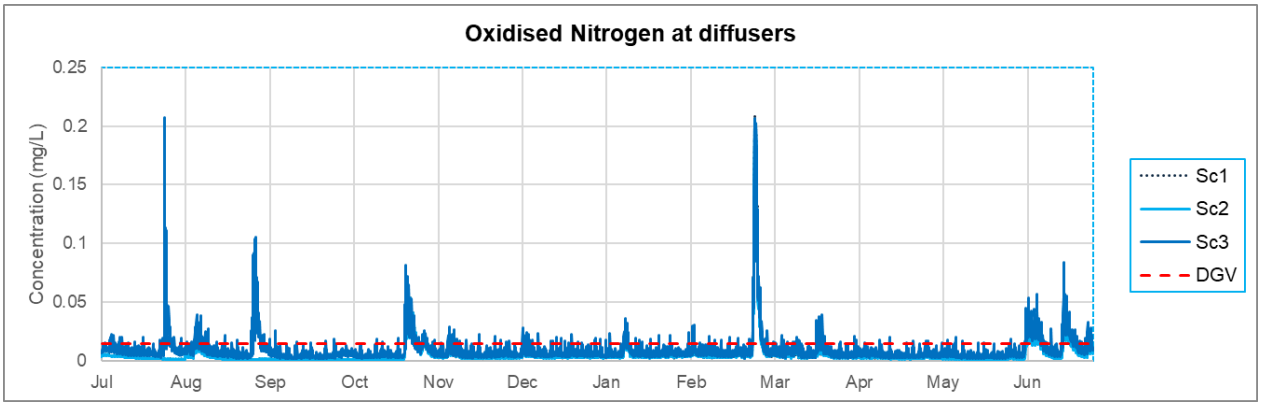


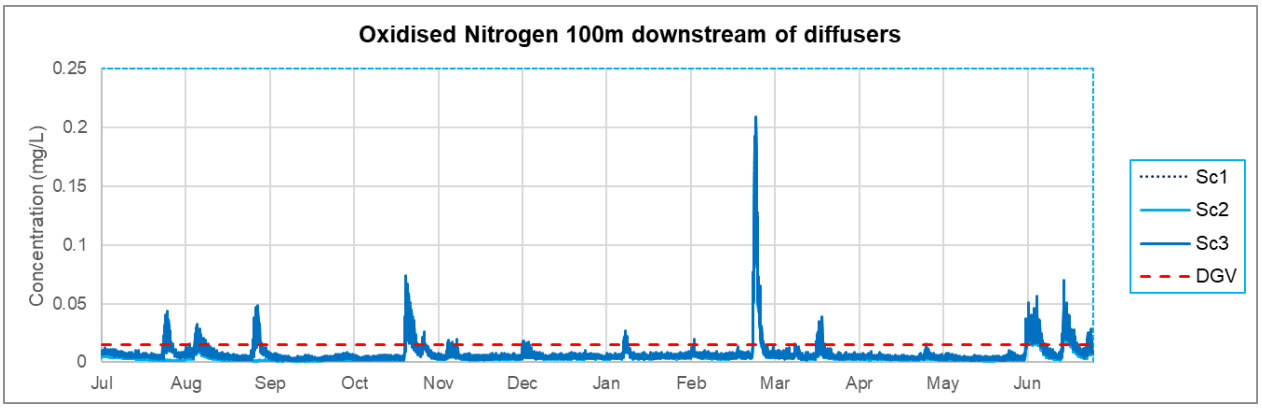


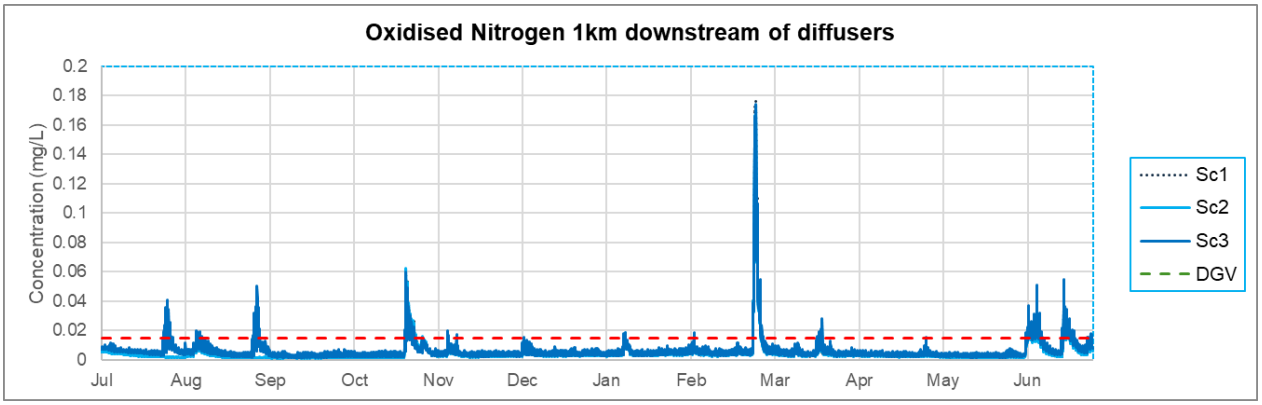
Time series plots




Oxidised Nitrogen 100m upstream of diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

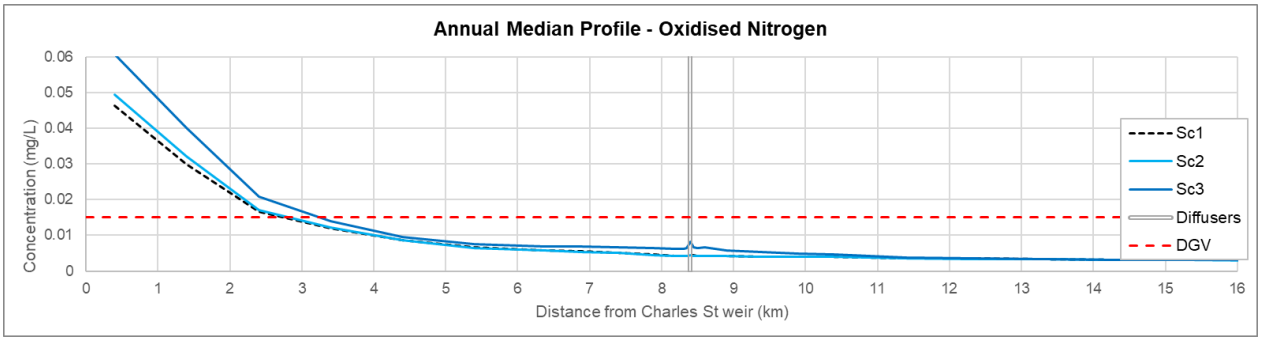

Oxidised Nitrogen at diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

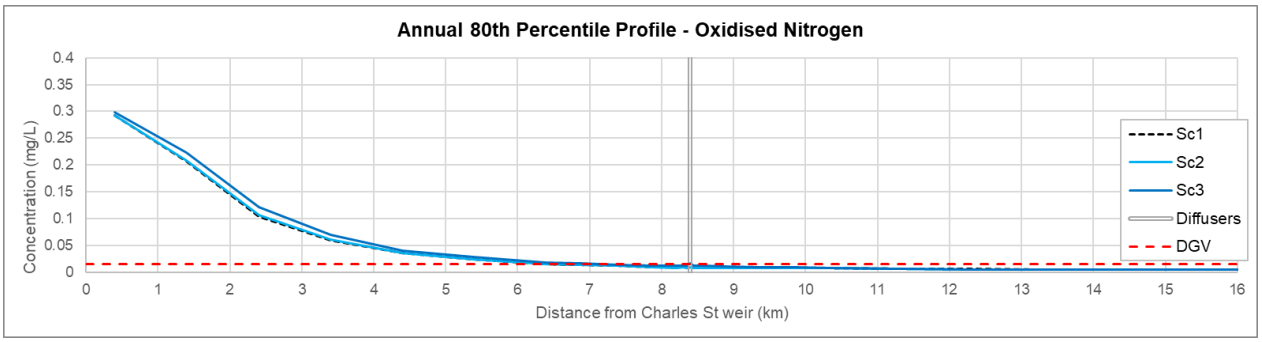

Oxidised Nitrogen 100m downstream of diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Oxidised Nitrogen 1km downstream of diffusers
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

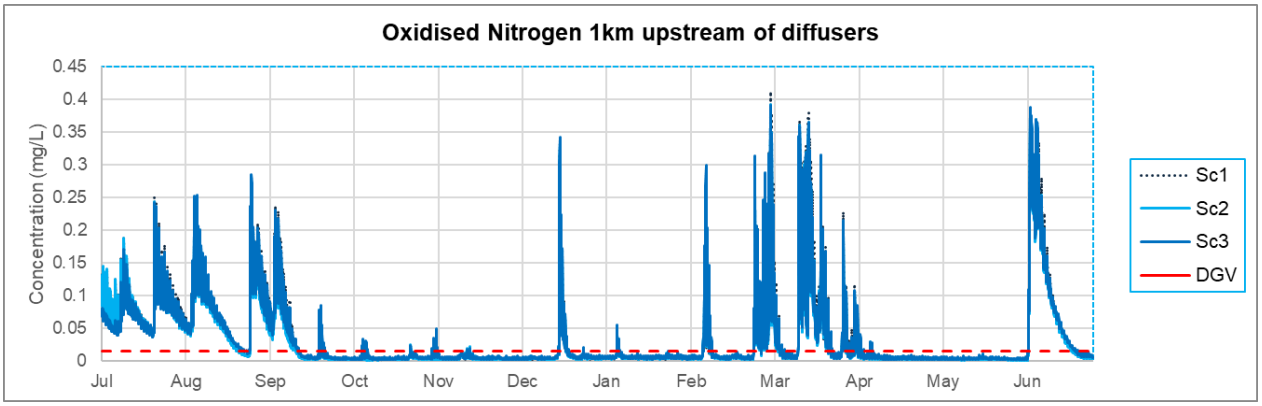
Appendices D1.5.2 Average rainfall year scenario results (2016-2017)

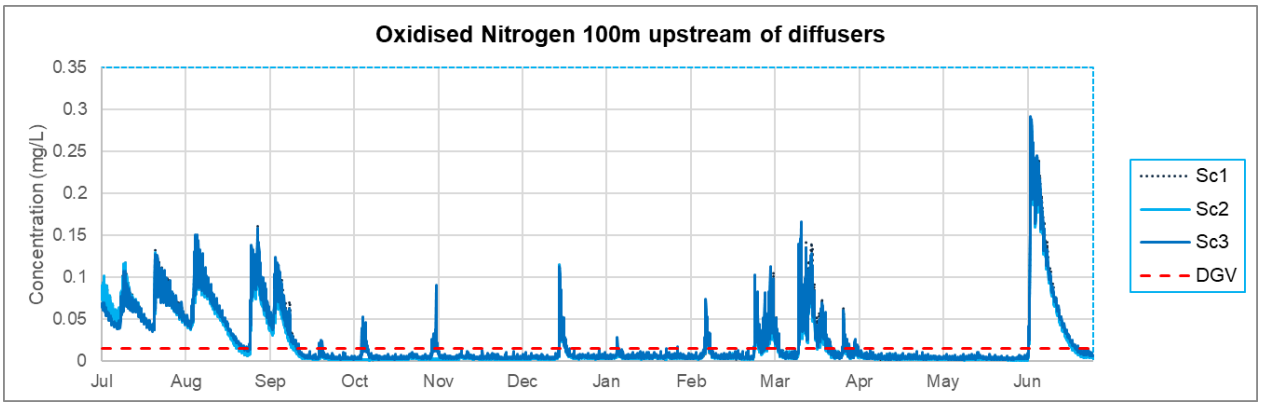
Longitudinal plots

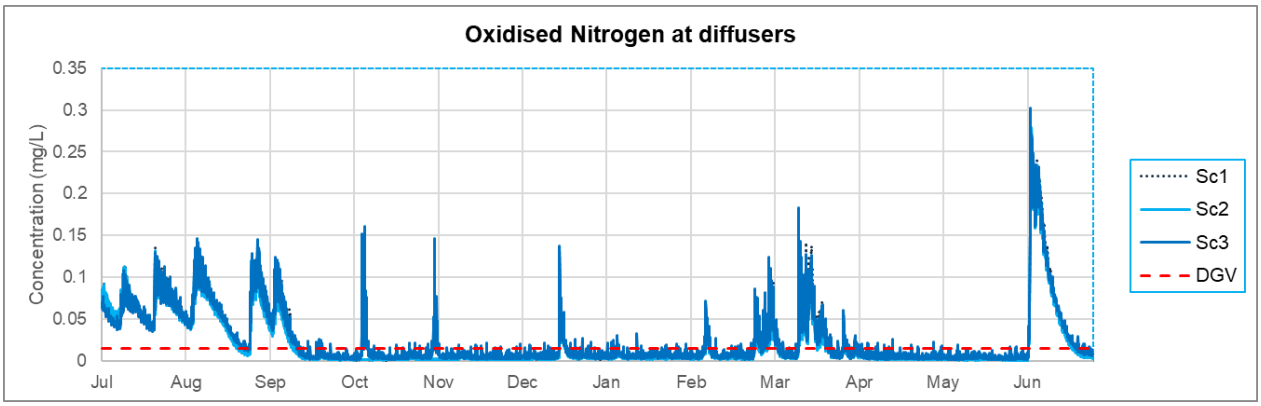


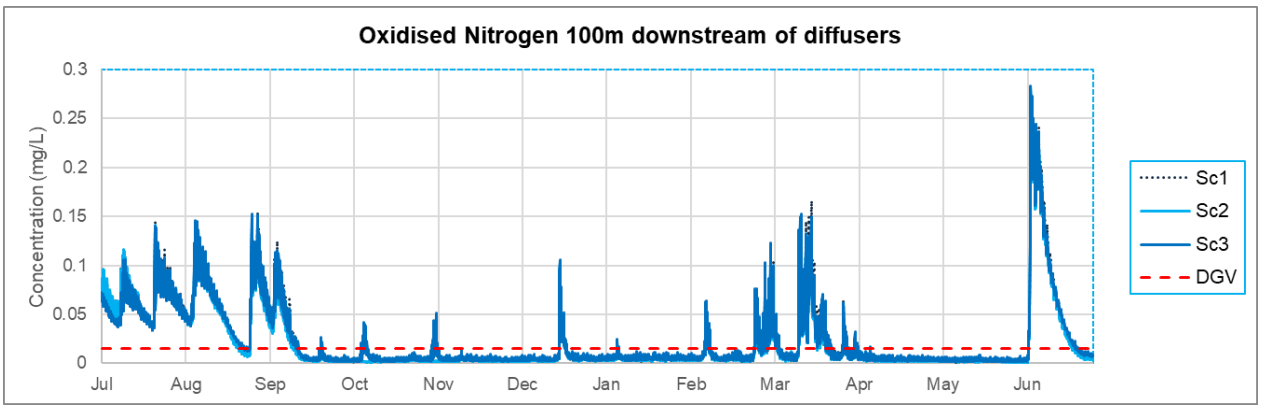


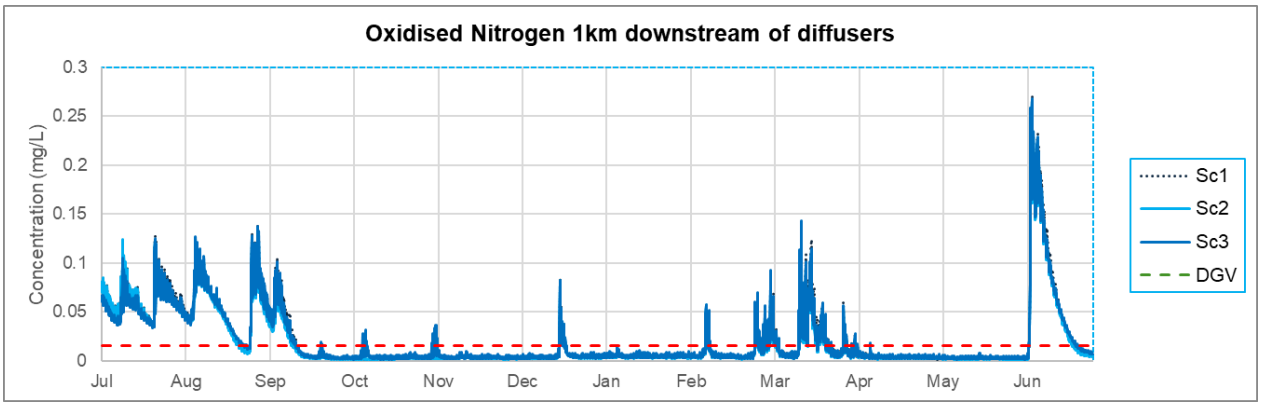
Time series plots





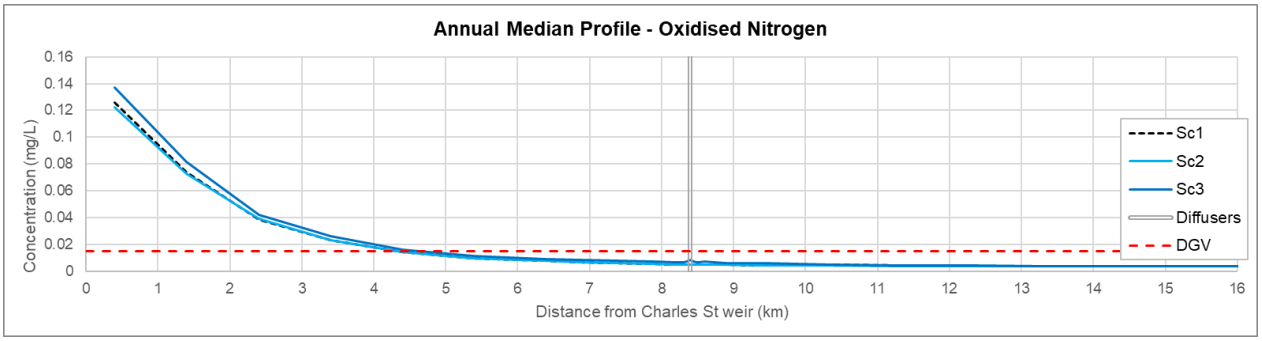

Oxidised Nitrogen at diffusers
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

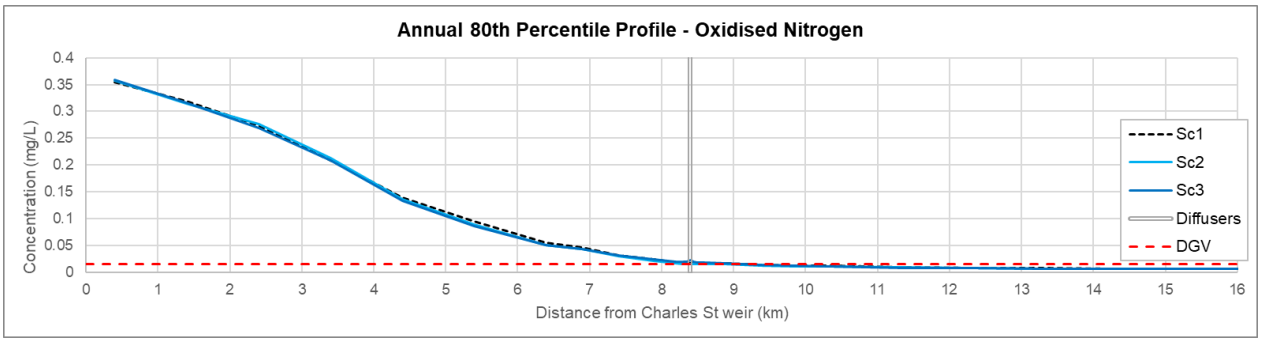

Oxidised Nitrogen 100m downstream of diffusers
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Oxidised Nitrogen 1km downstream of diffusers
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

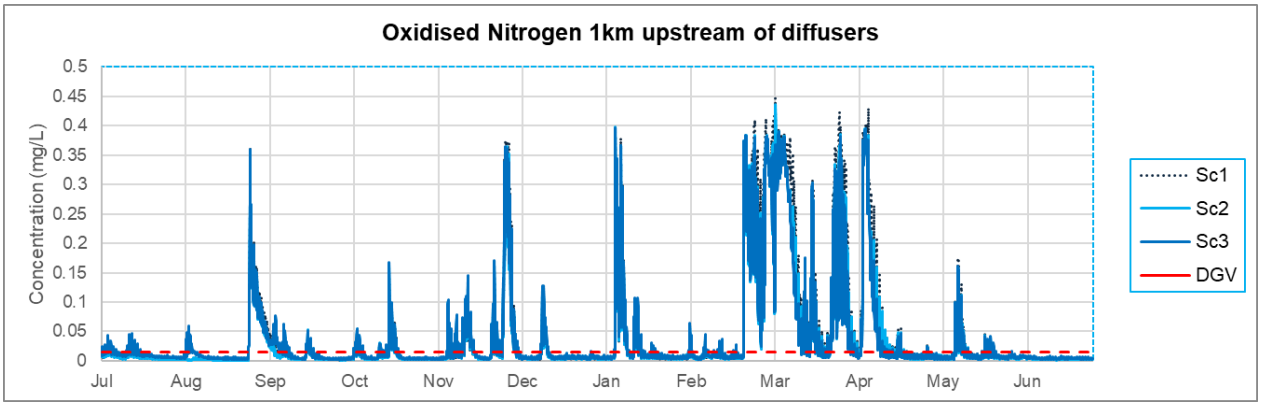
Appendices D1.5.3 Higher rainfall year scenario results (2021-2022)

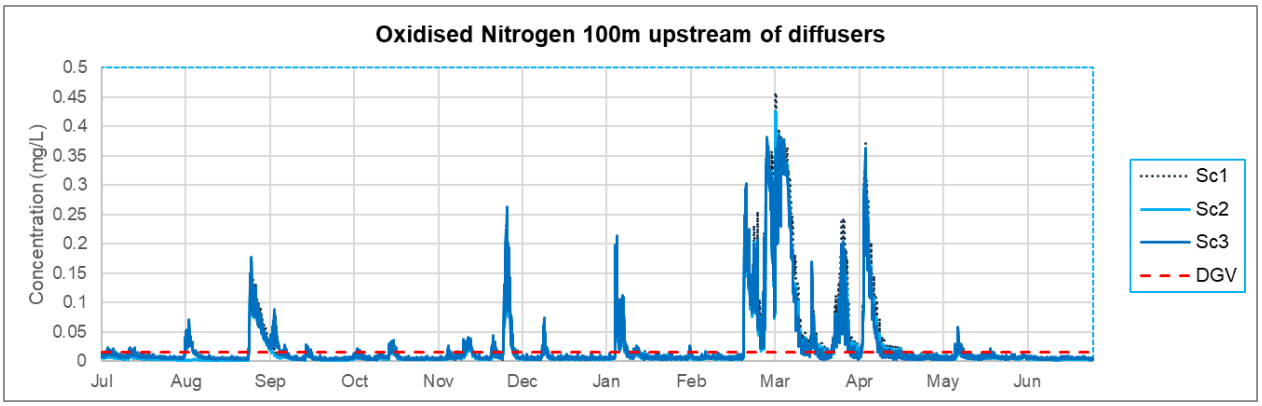
Longitudinal plots

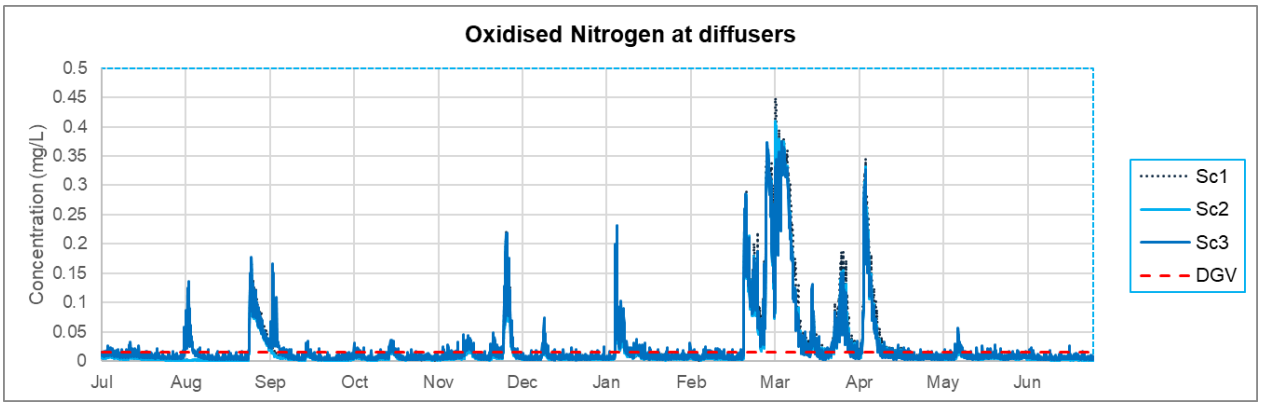


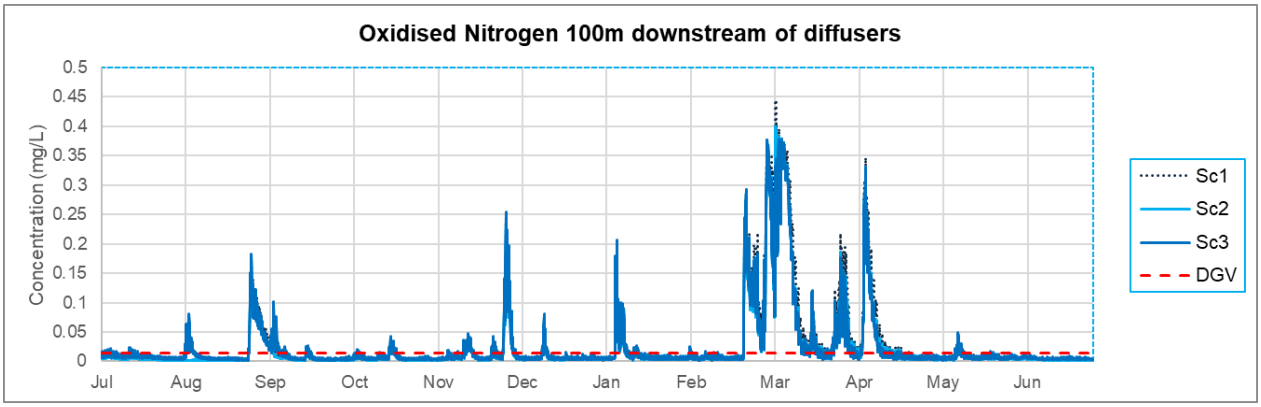


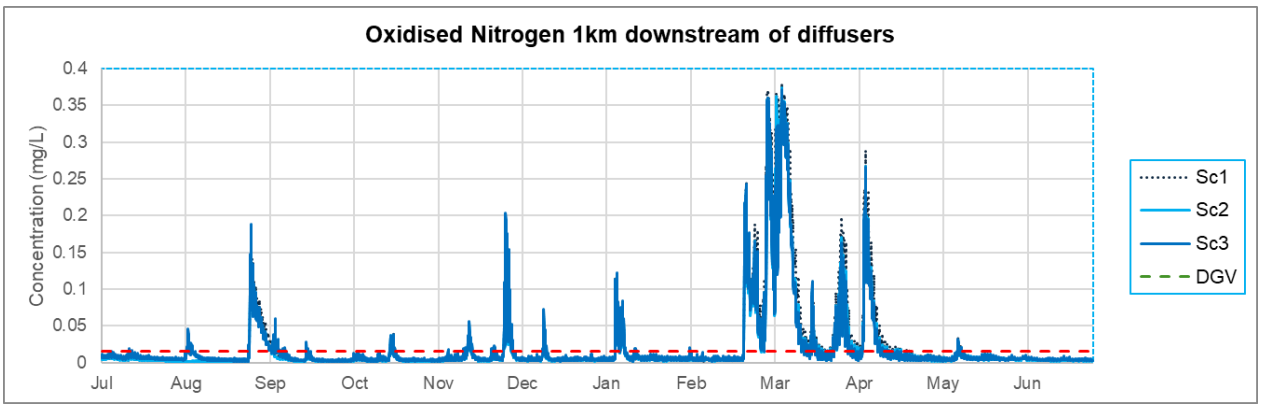
Time series plots






Oxidised Nitrogen at diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

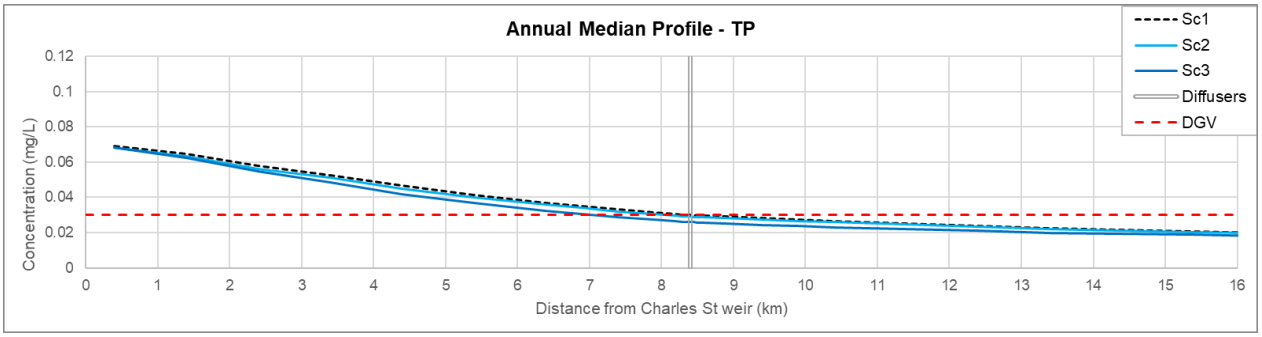

Oxidised Nitrogen 100m downstream of diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

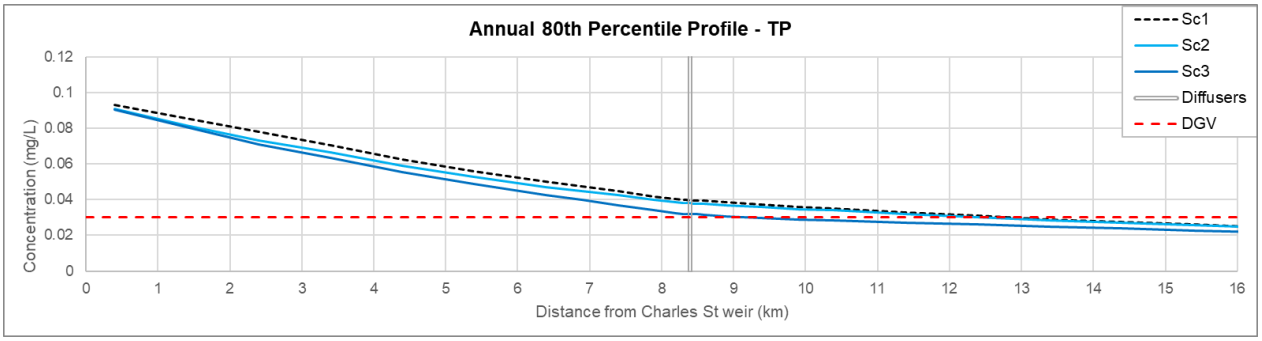

Oxidised Nitrogen 1km downstream of diffusers
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

Appendices D1.6 Total P

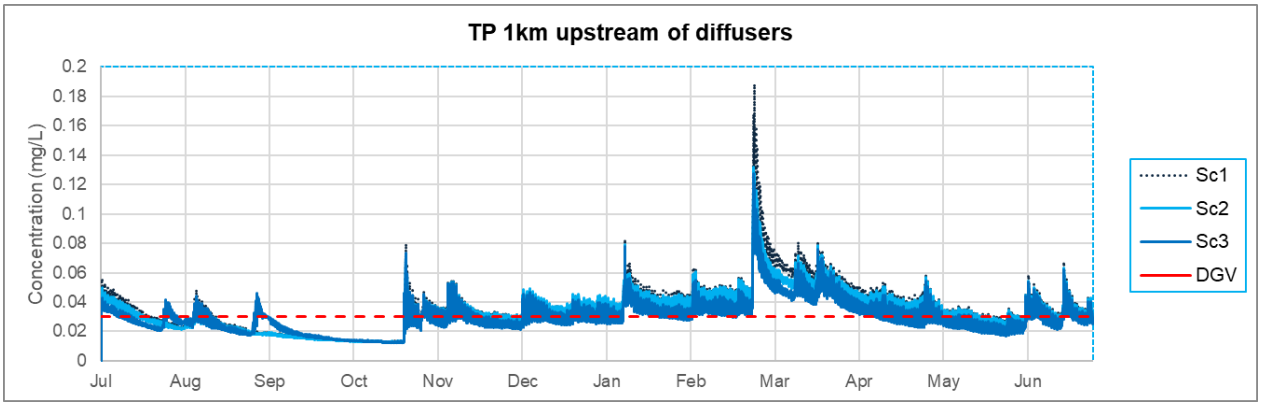
Appendices D1.6.1 Lower rainfall year scenario results (2017-2018)

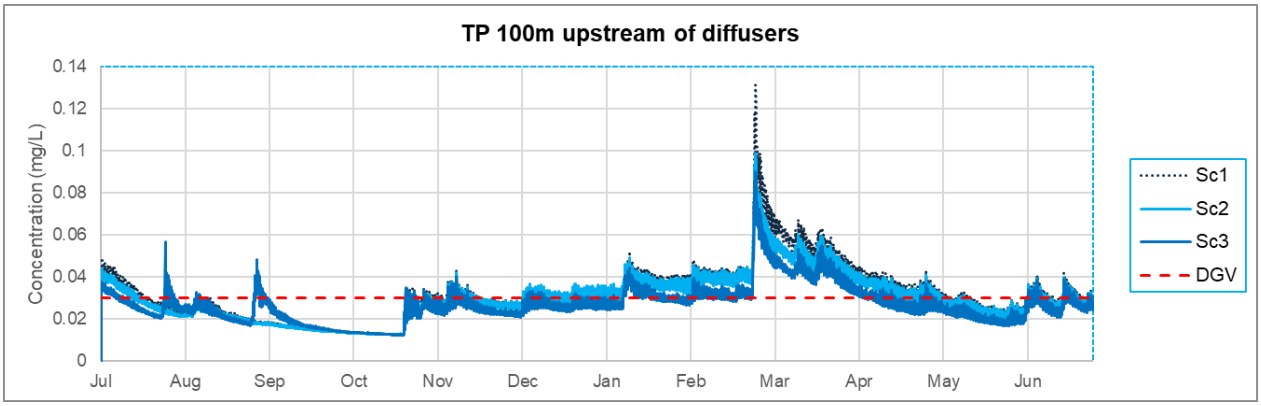
Longitudinal plots

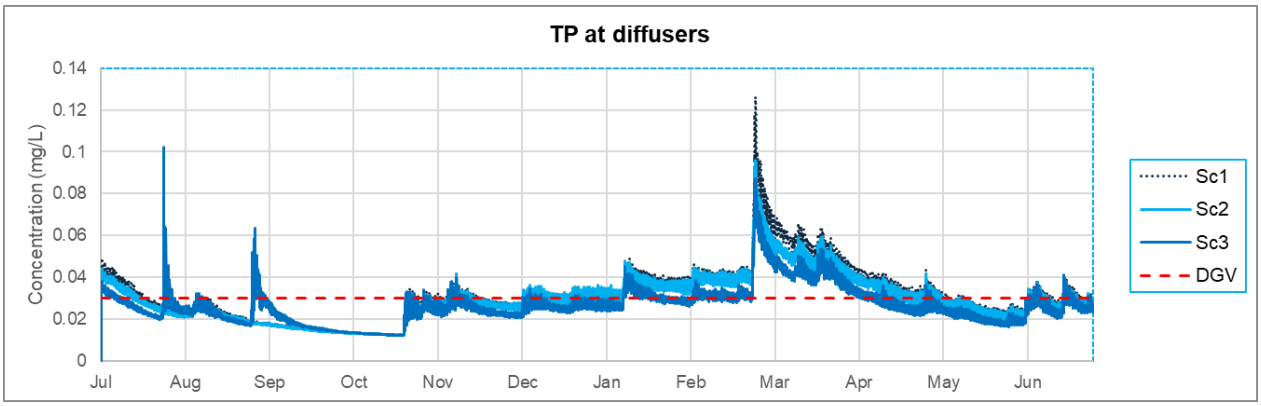


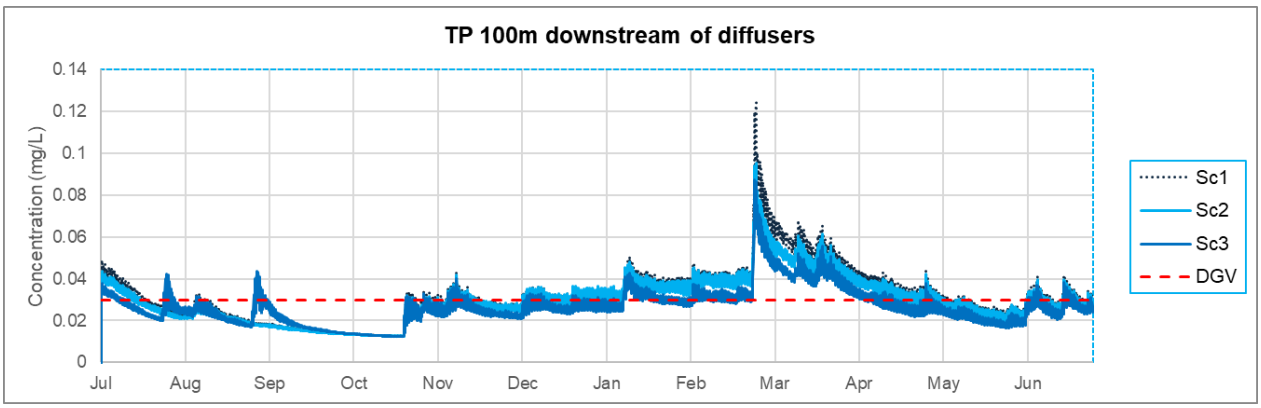


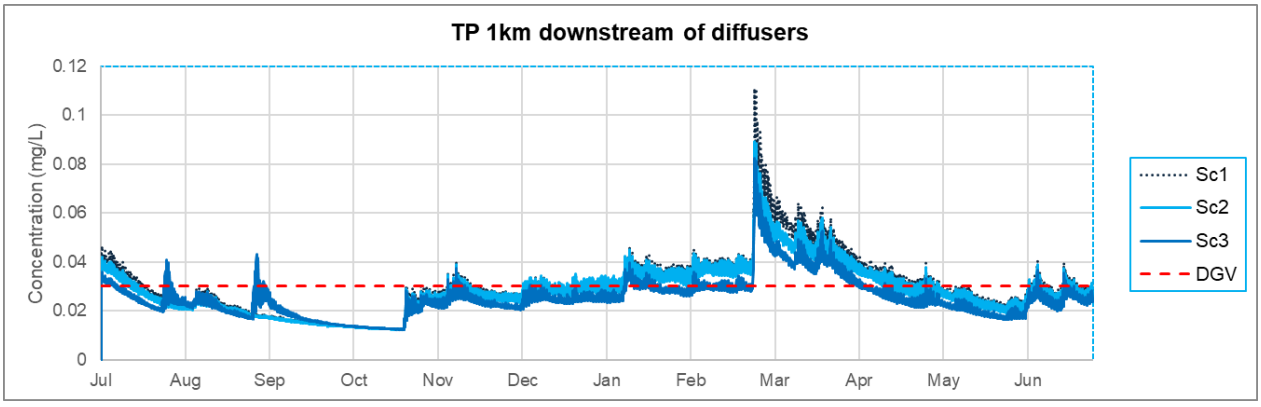
Time series plots




TP 100m upstream of diffusers
Concentration (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

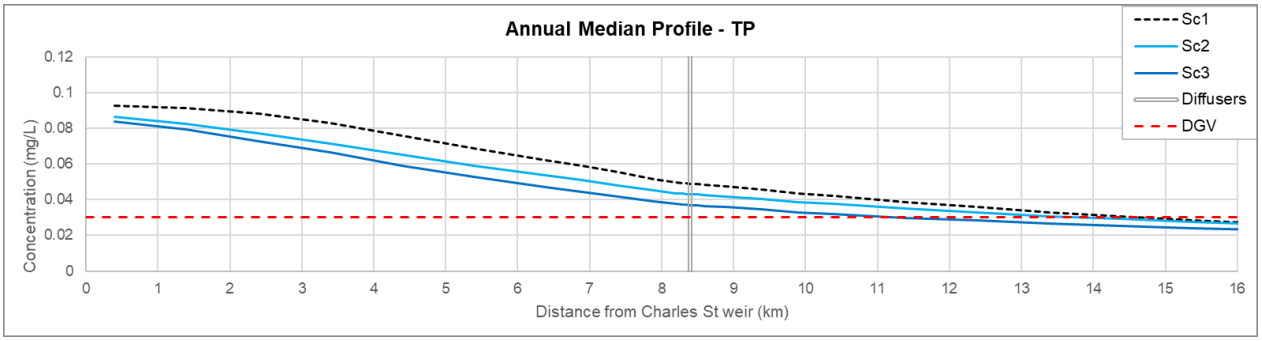

TP at diffusers
Concentration (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

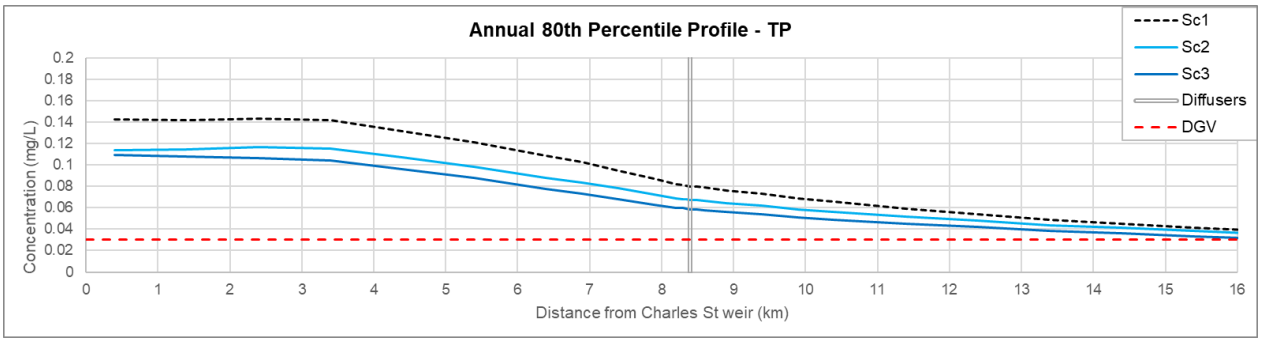

TP 100m downstream of diffusers
Concentration (mg/L)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


TP 1km downstream of diffusers
Concentration (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

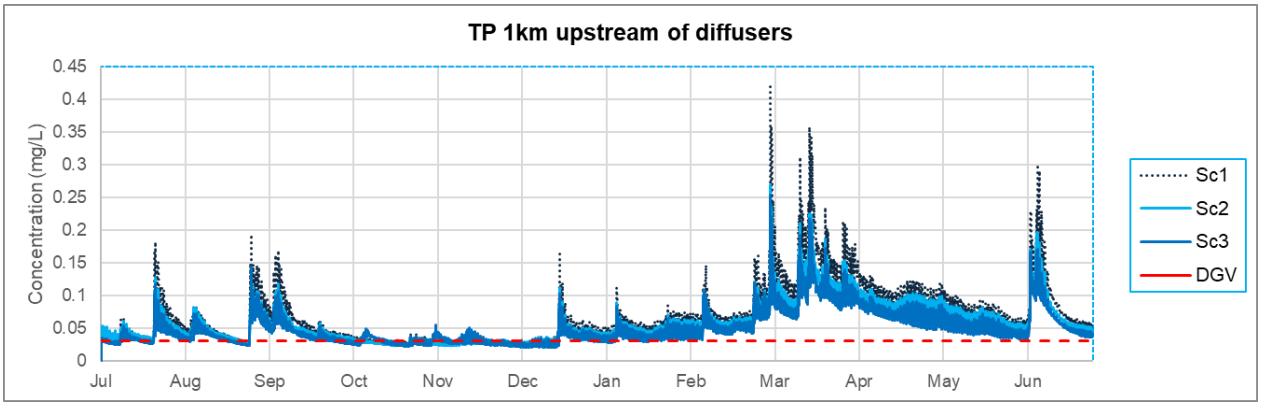
Appendices D1.6.2 Average rainfall year scenario results (2016-2017)

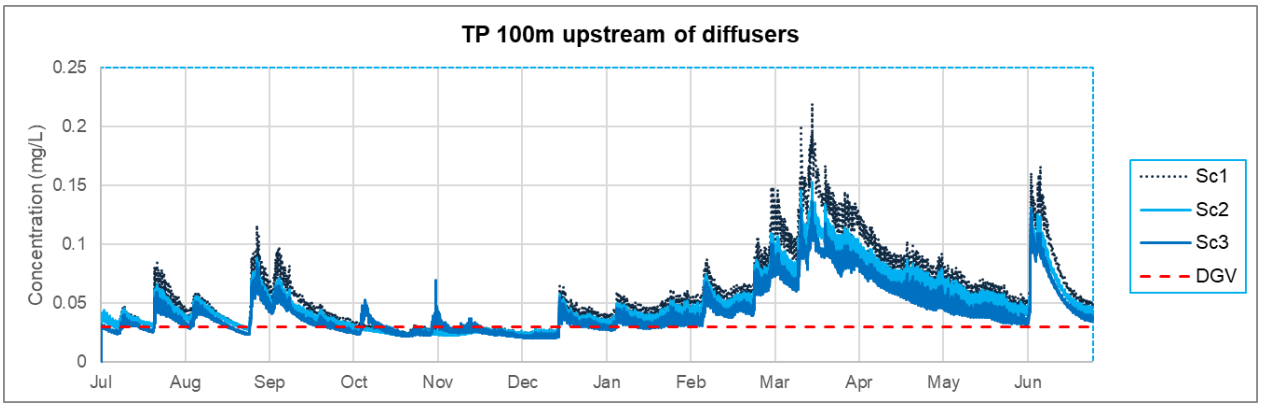
Longitudinal plots

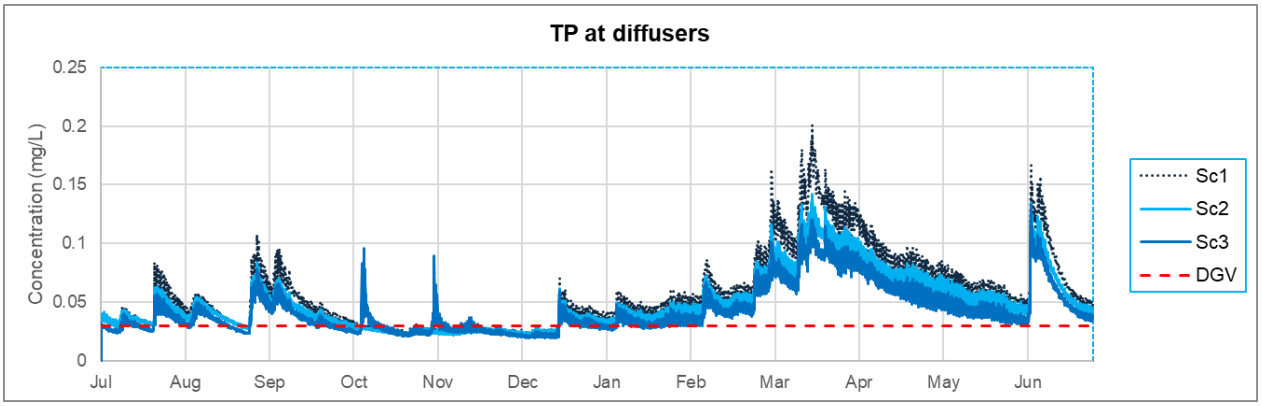


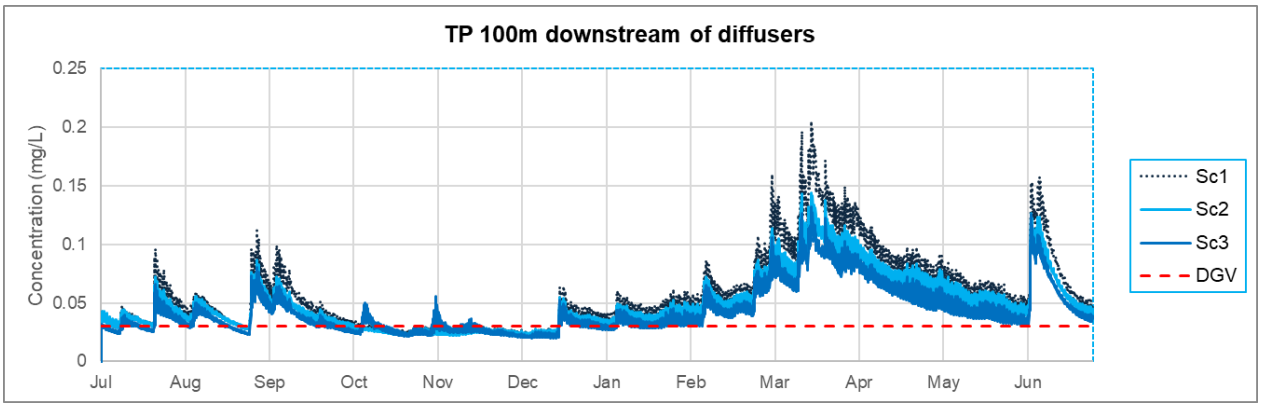


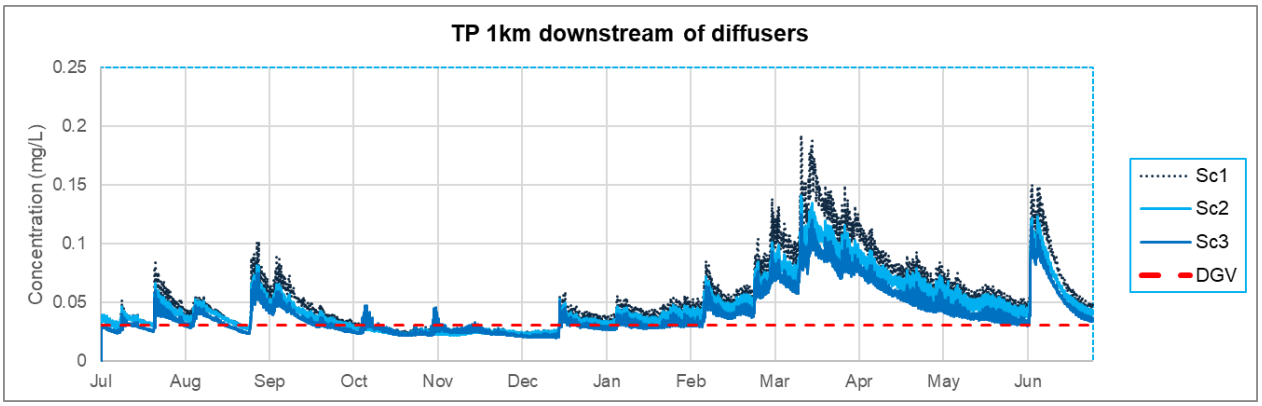
Time series plots





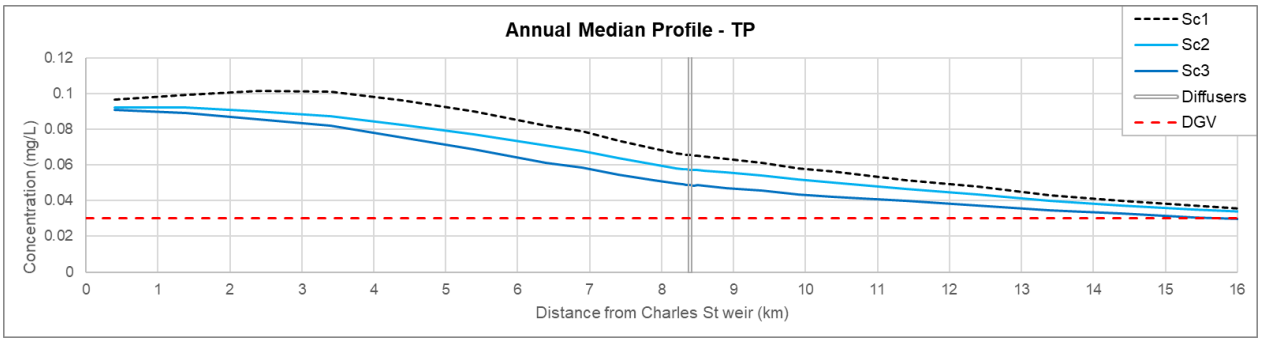


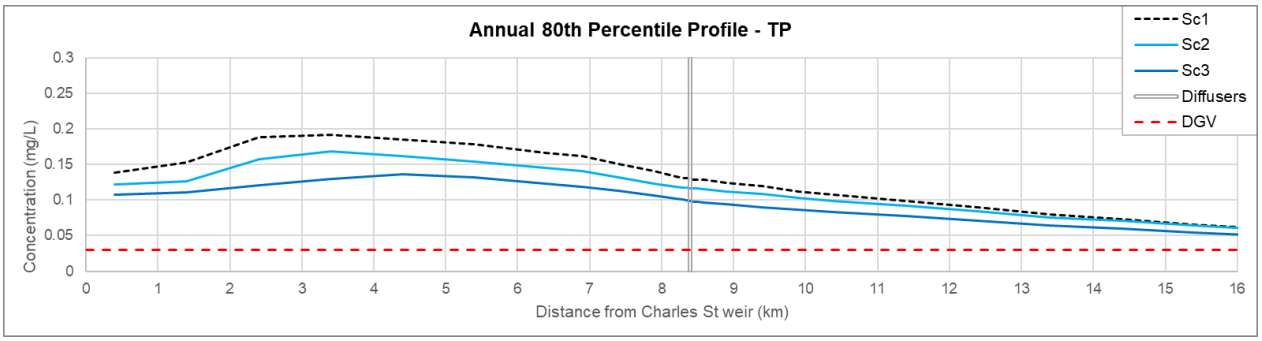




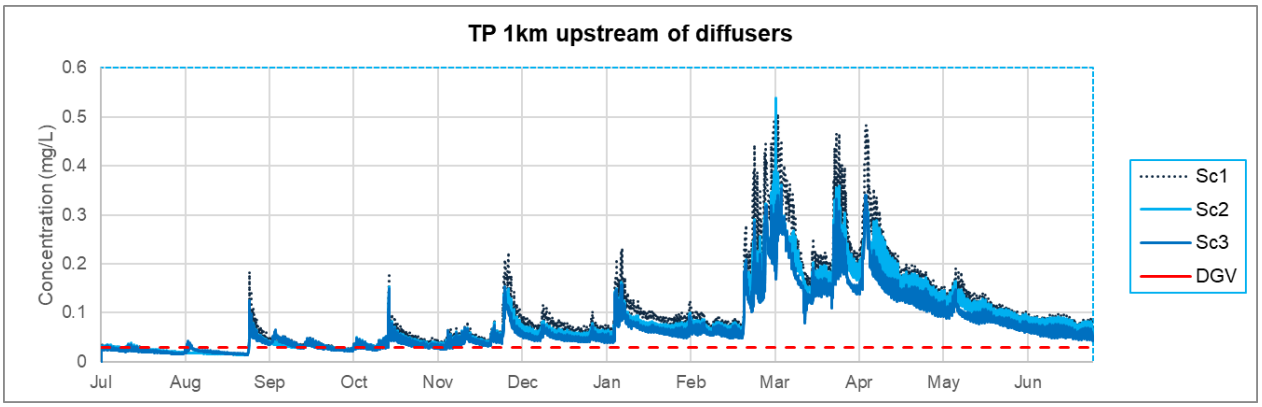
Appendices D1.6.3 Higher rainfall year scenario results (2021-2022)

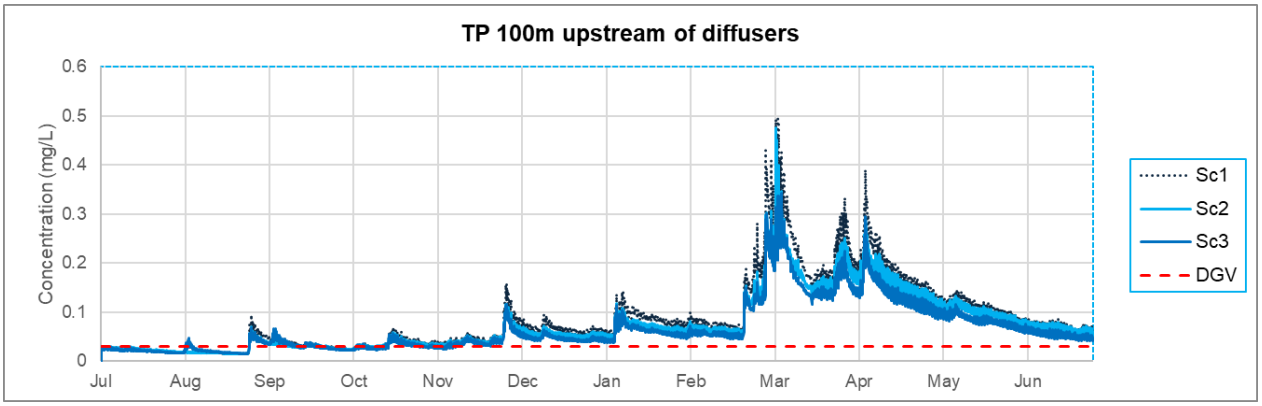
Longitudinal plots

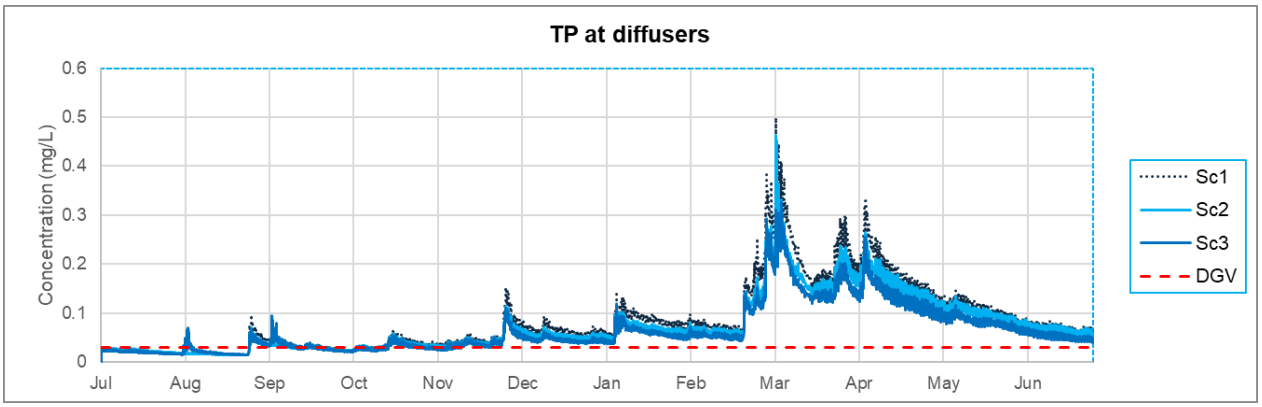


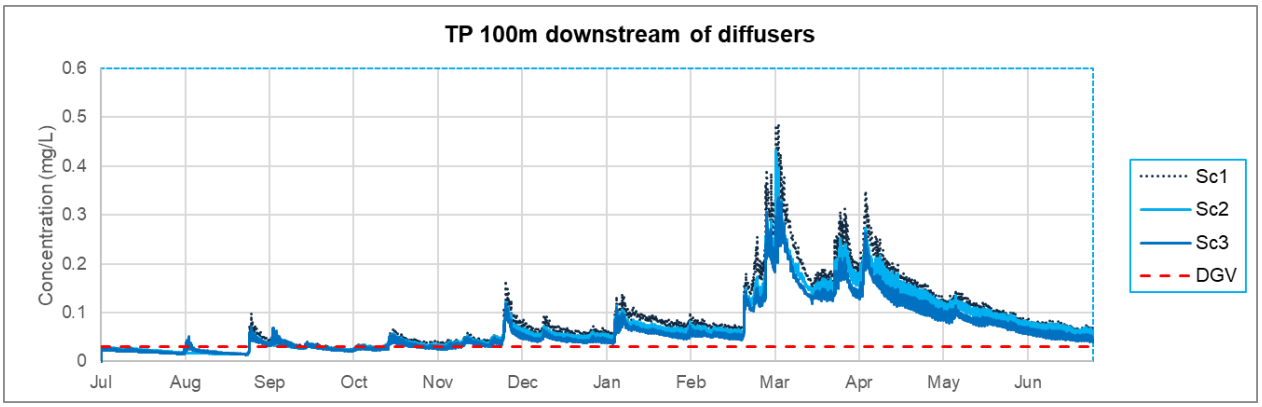


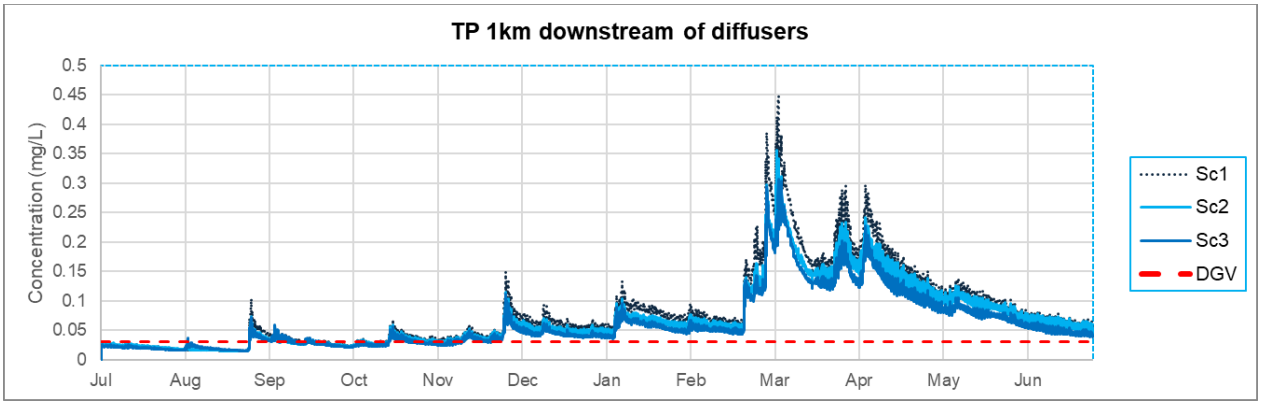
Time series plots







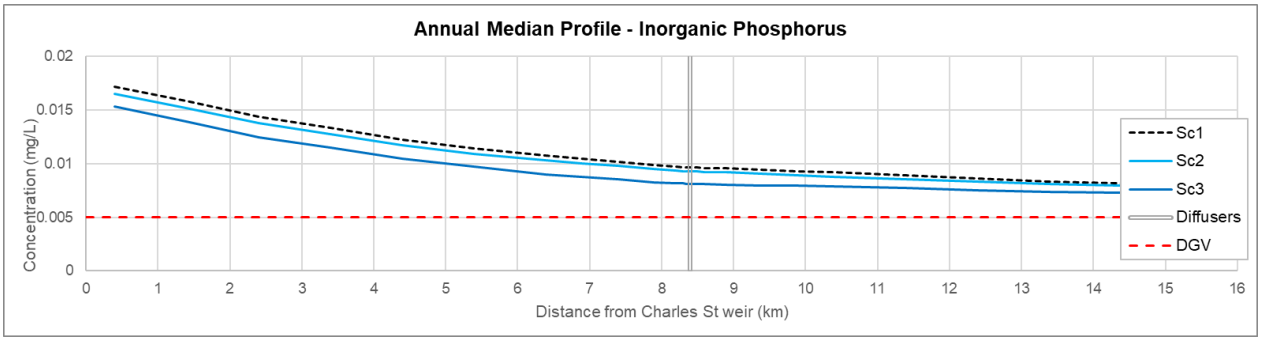


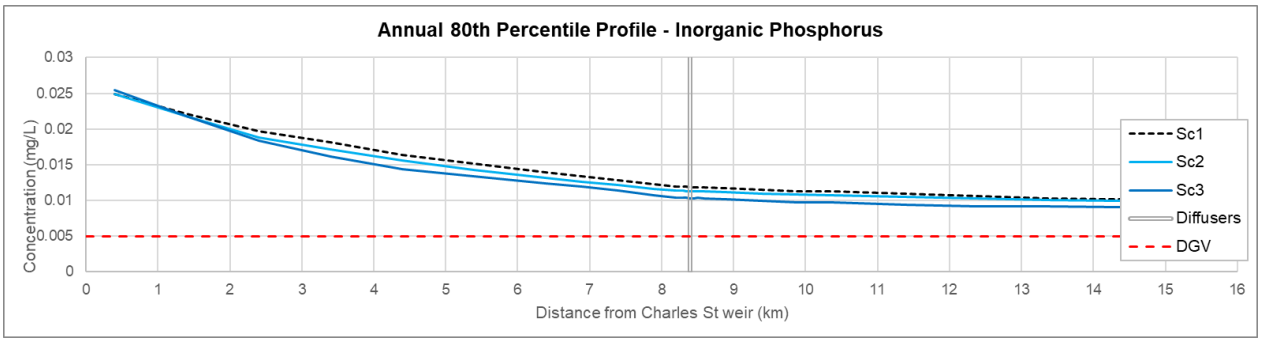


Appendices D1.7 Inorganic P

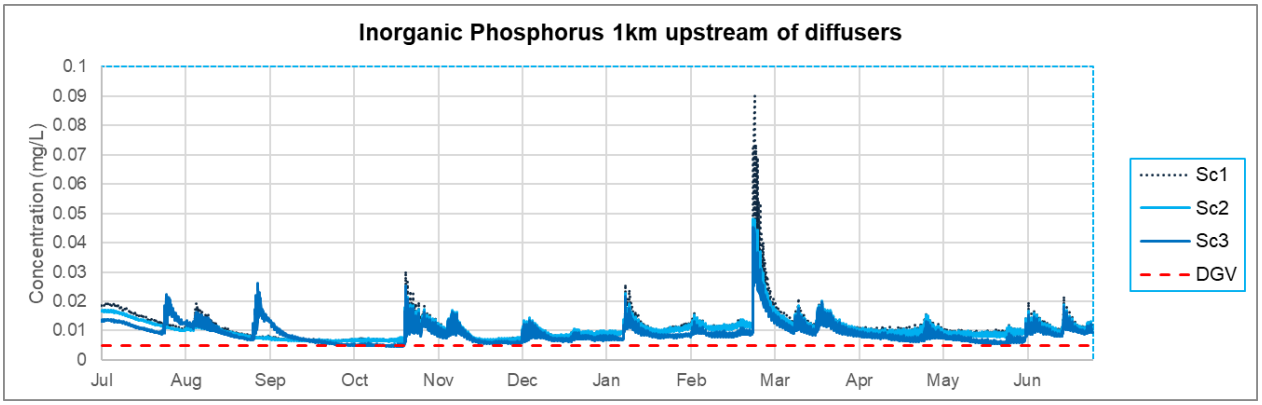
Appendices D1.7.1 Lower rainfall year scenario results (2017-2018)

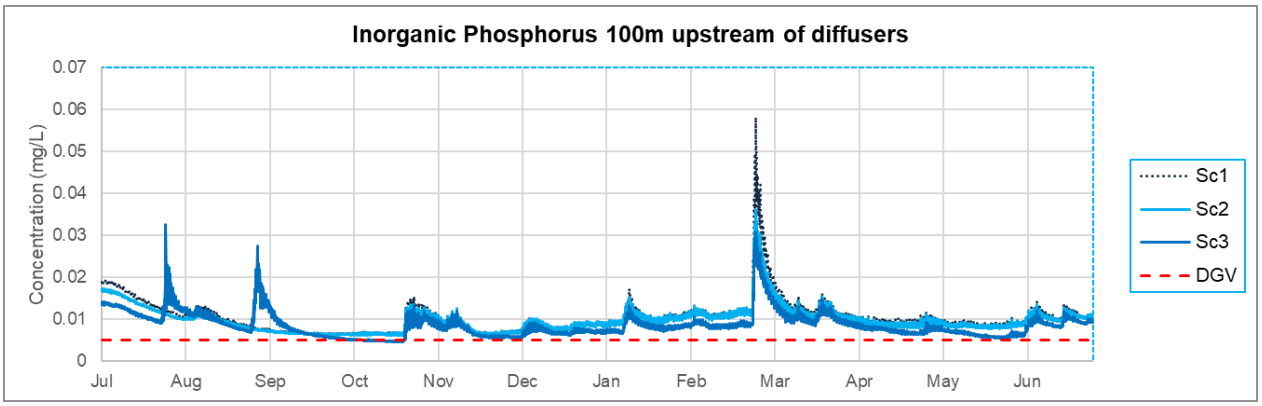
Longitudinal plots

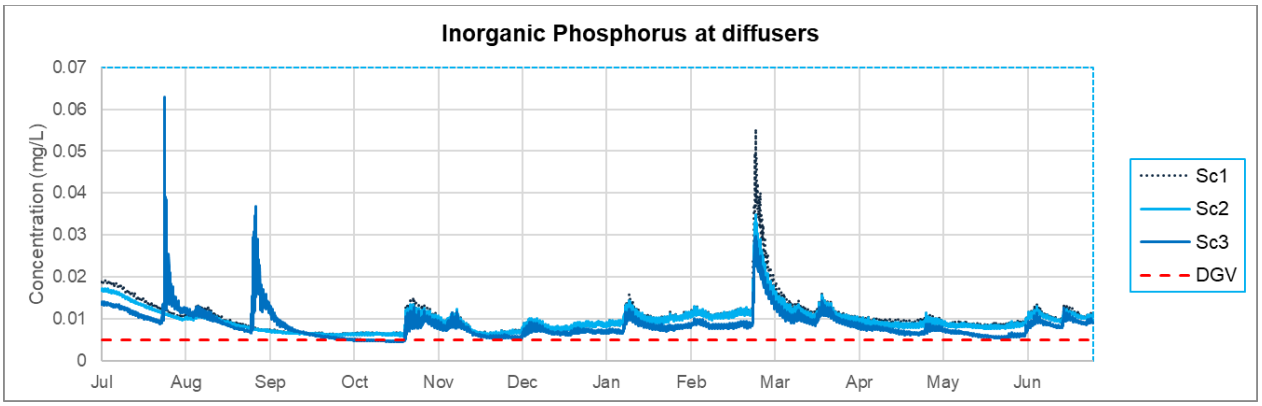


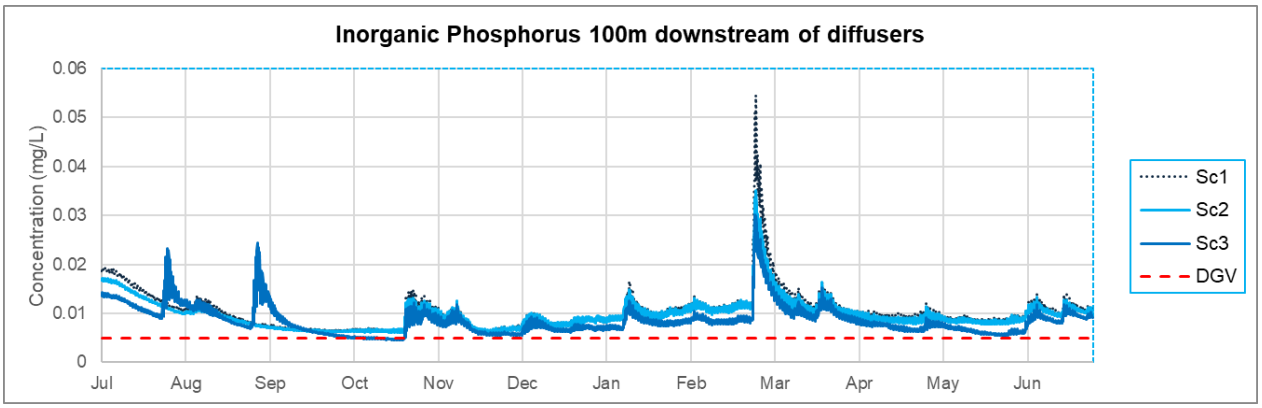


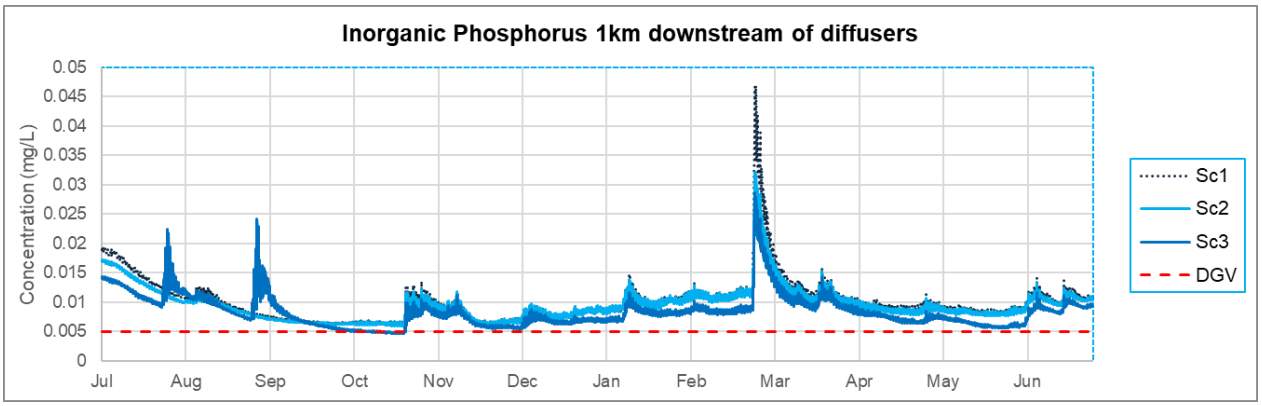
Time series plots





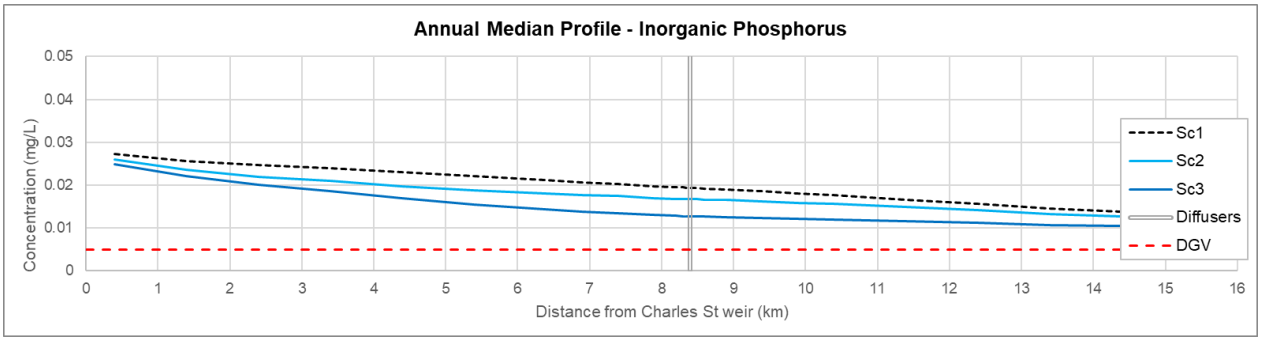


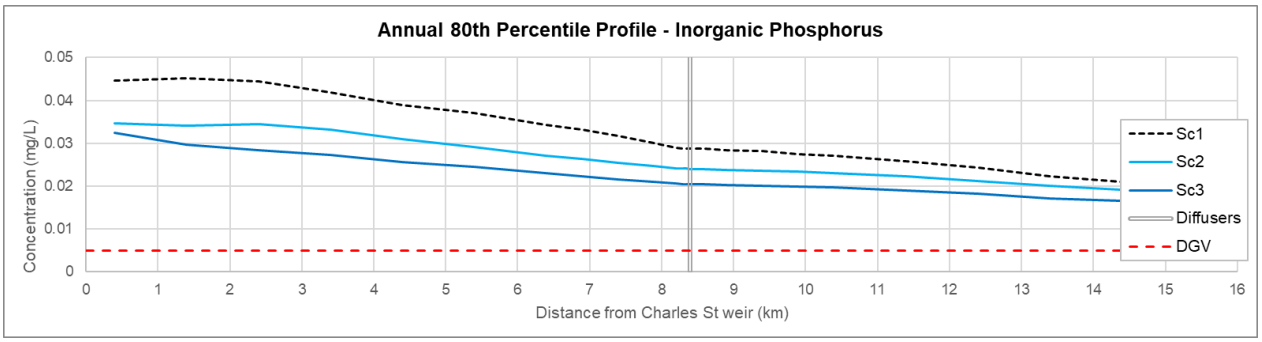




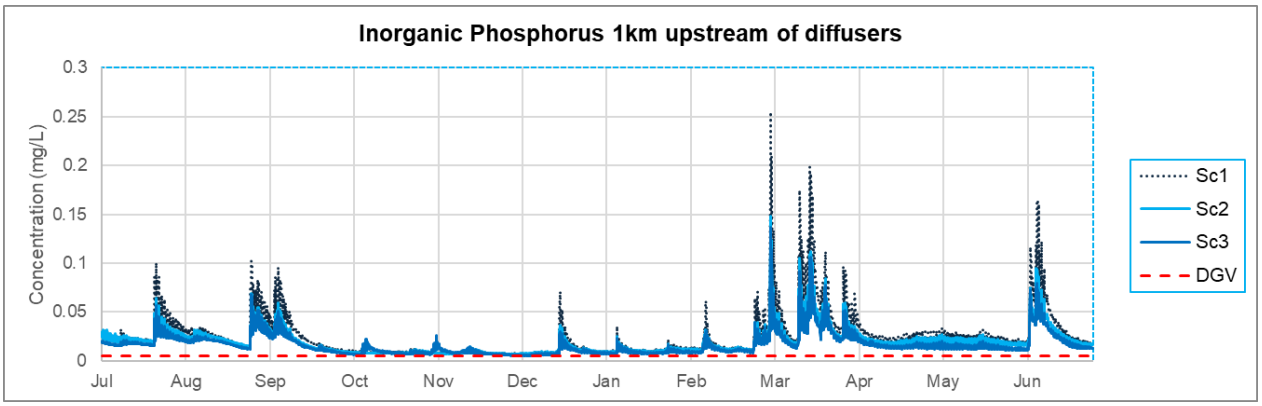
Appendices D1.7.2 Average rainfall year scenario results (2016-2017)

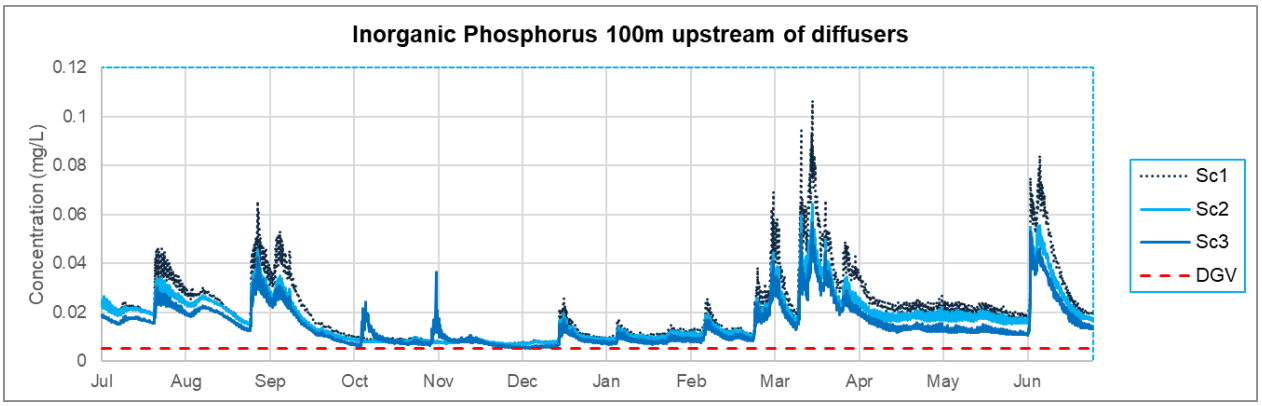
Longitudinal plots

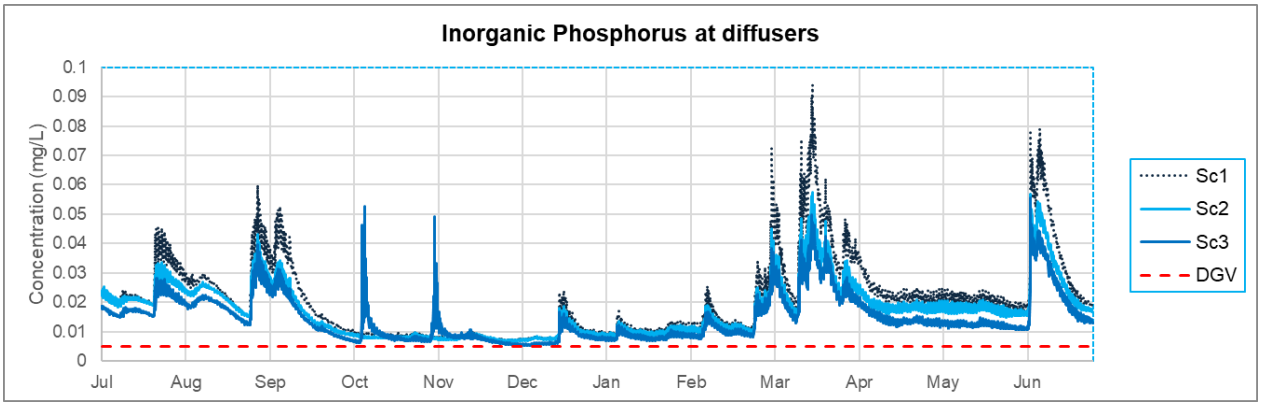


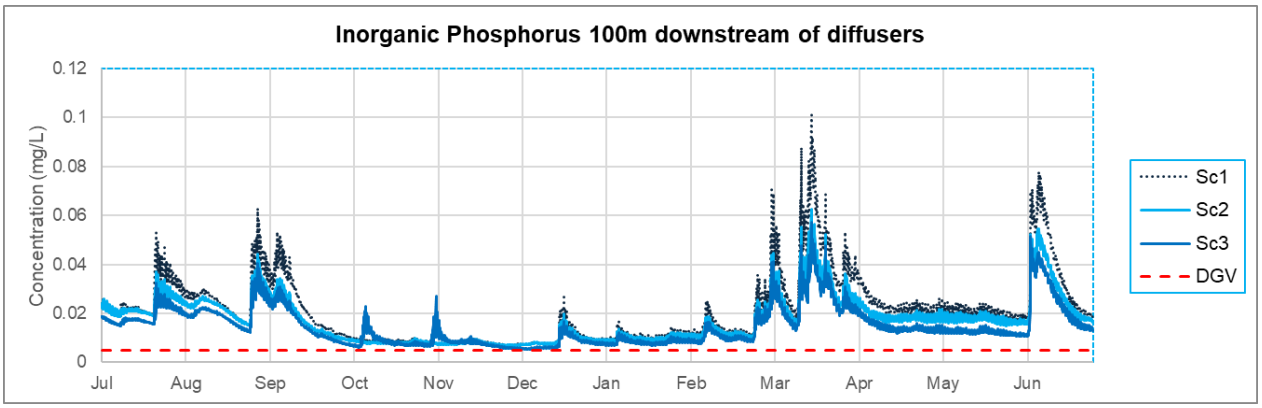


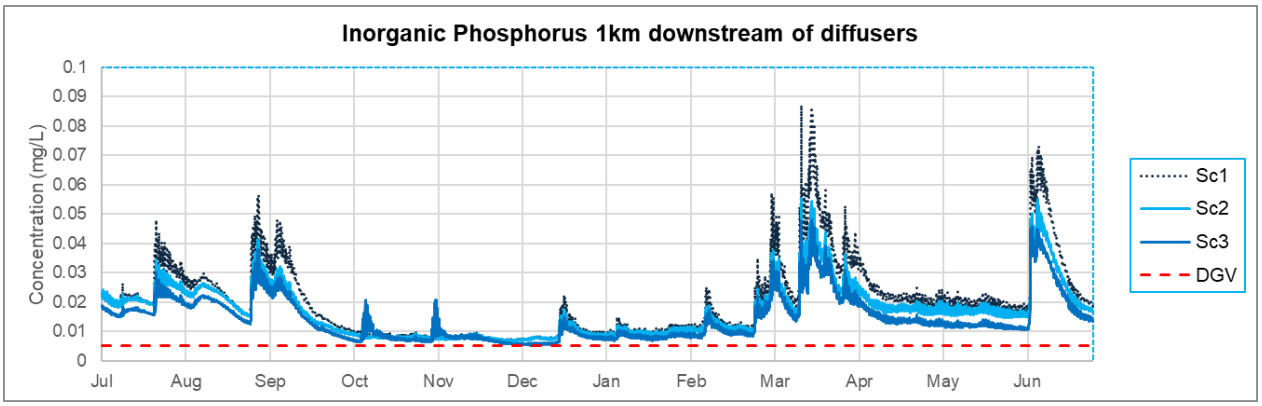
Time series plots




Inorganic Phosphorus 100m upstream of diffusers
Concentration (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

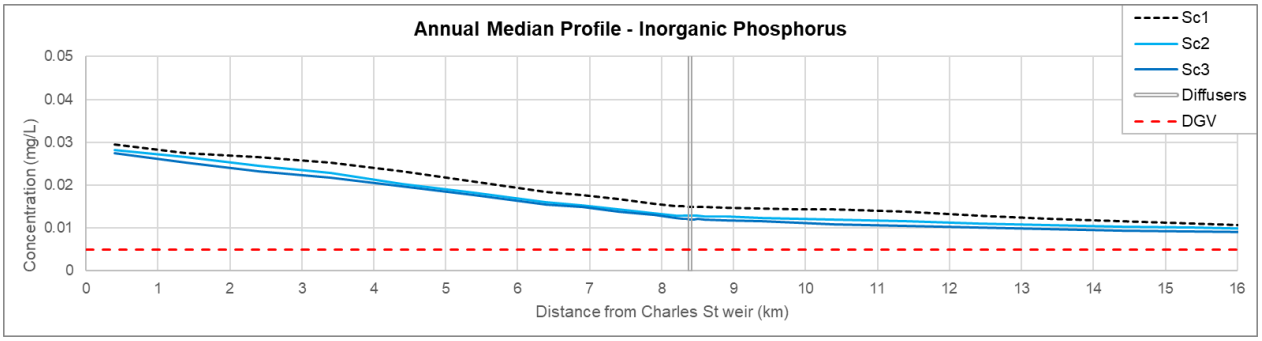

Inorganic Phosphorus at diffusers
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

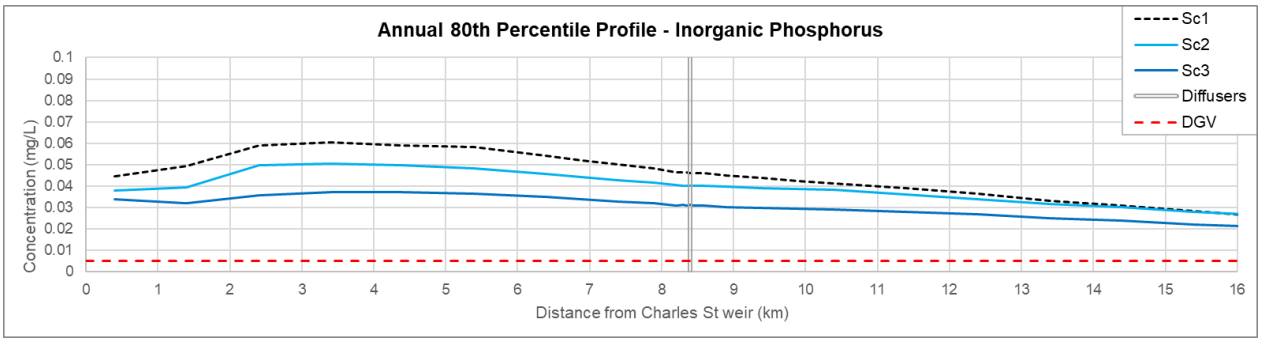

Inorganic Phosphorus 100m downstream of diffusers
Concentration (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Inorganic Phosphorus 1km downstream of diffusers
Concentration (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

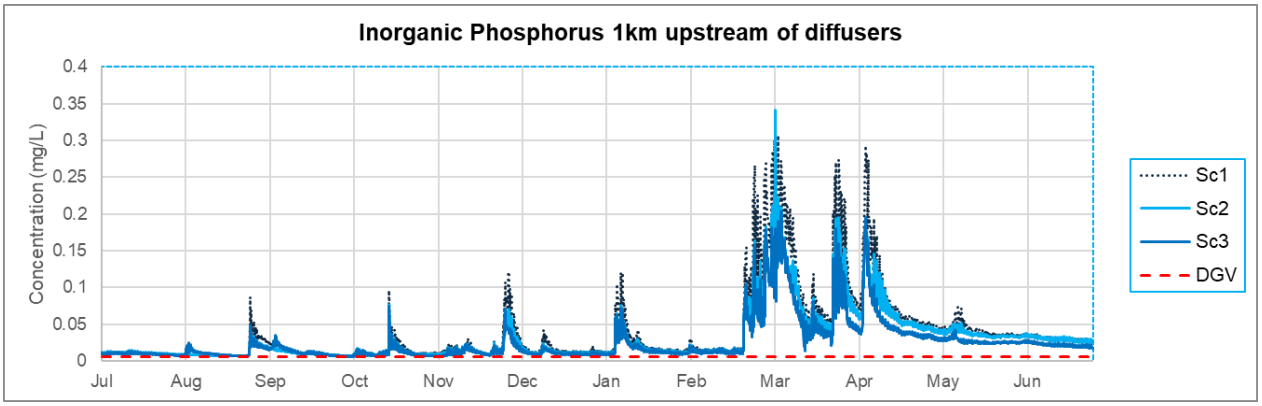
Appendices D1.7.3 Higher rainfall year scenario results (2021-2022)

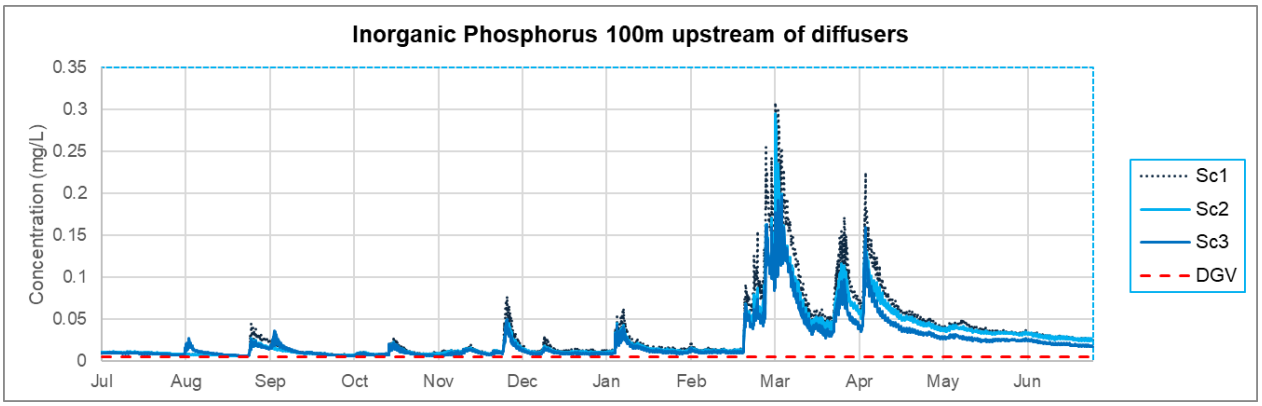
Longitudinal plots

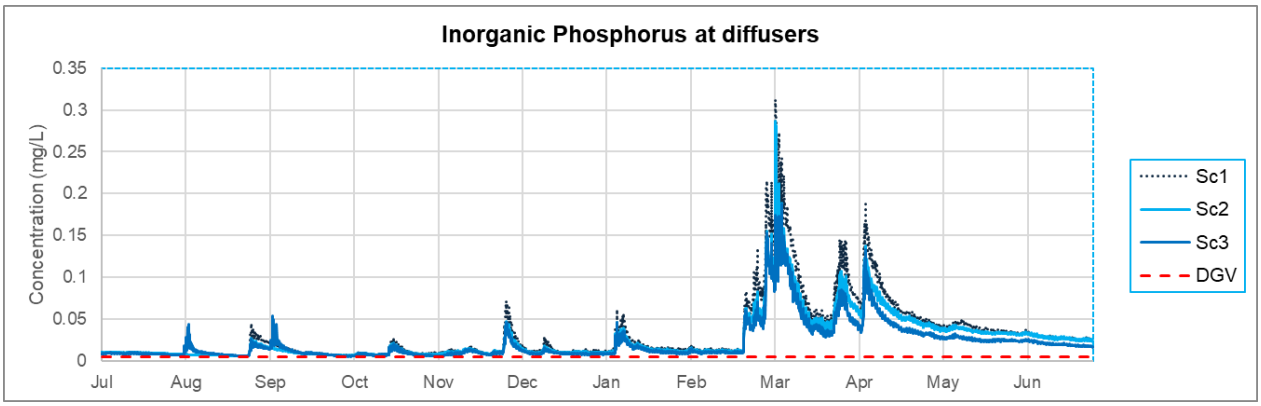


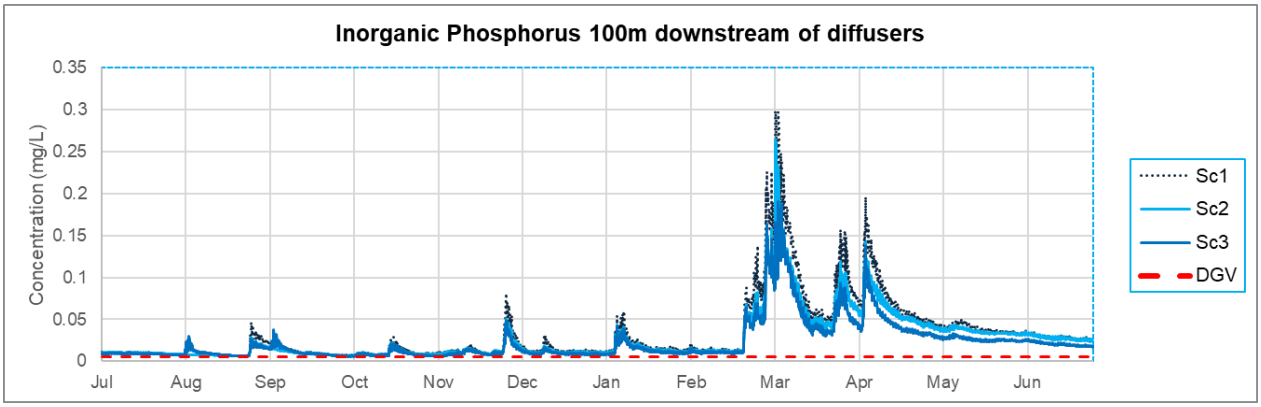


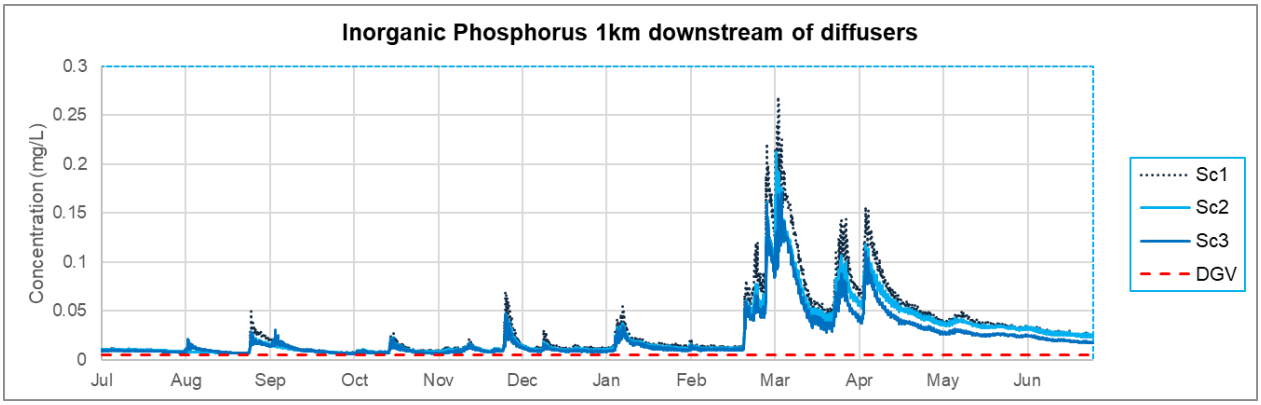
Time series plots






Inorganic Phosphorus at diffusers
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

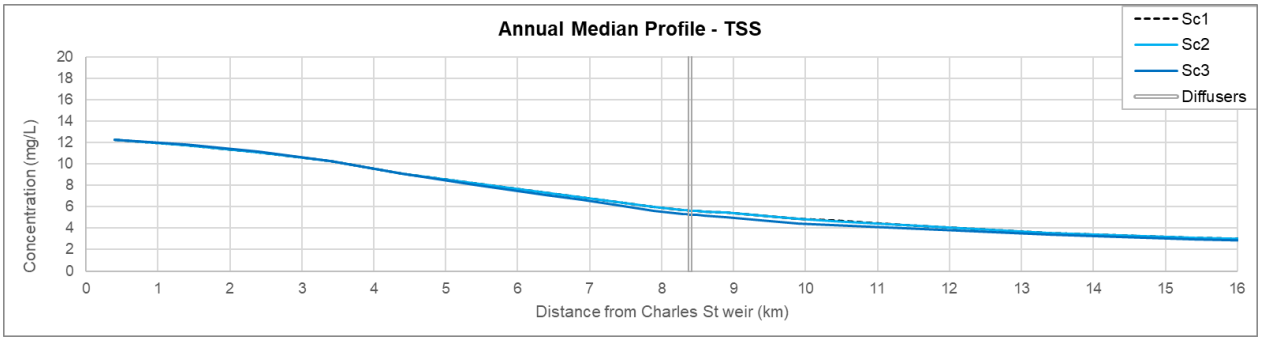

Inorganic Phosphorus 100m downstream of diffusers
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

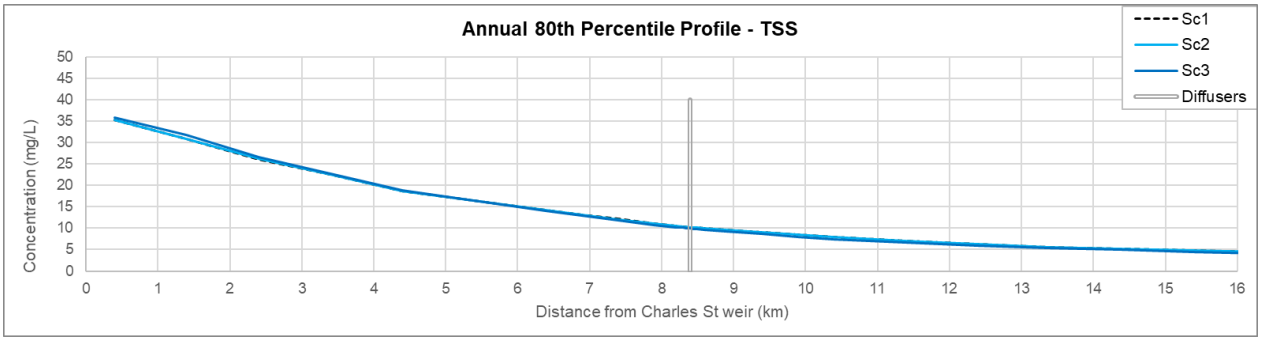

Inorganic Phosphorus 1km downstream of diffusers
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

Appendices D1.8 TSS

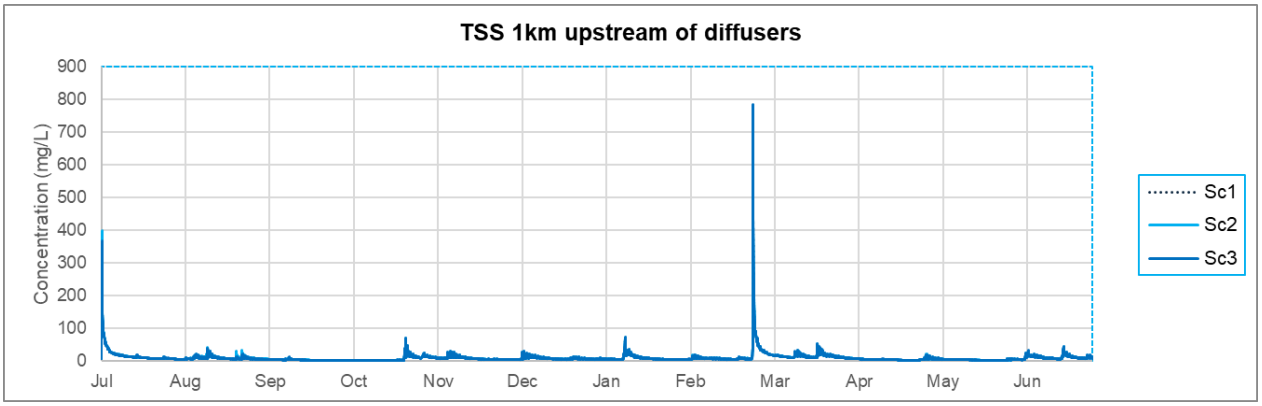
Appendices D1.8.1 Lower rainfall year scenario results (2017-2018)

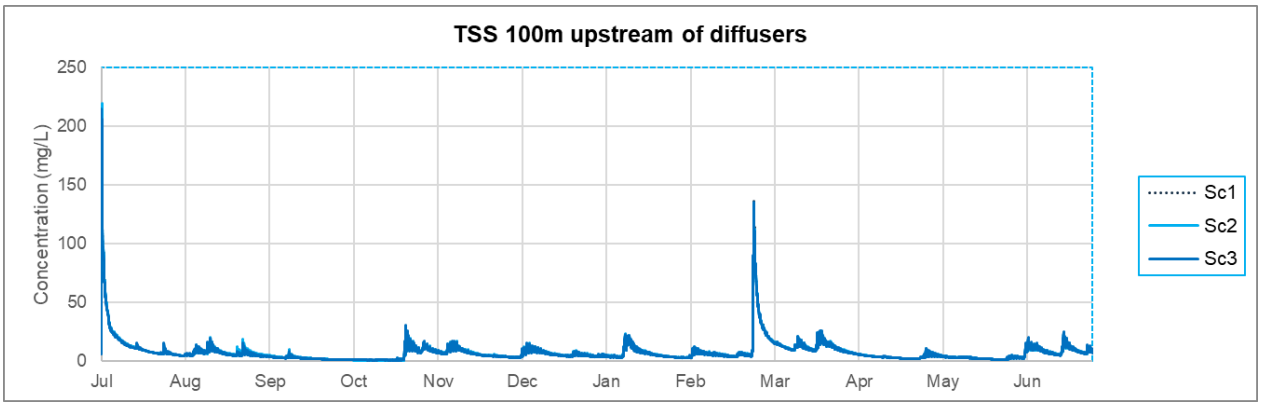
Longitudinal plots

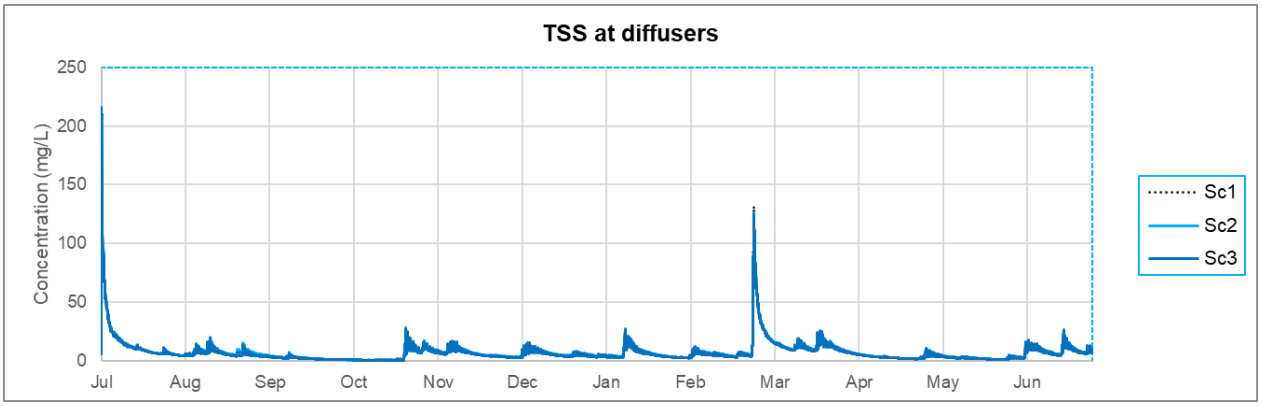


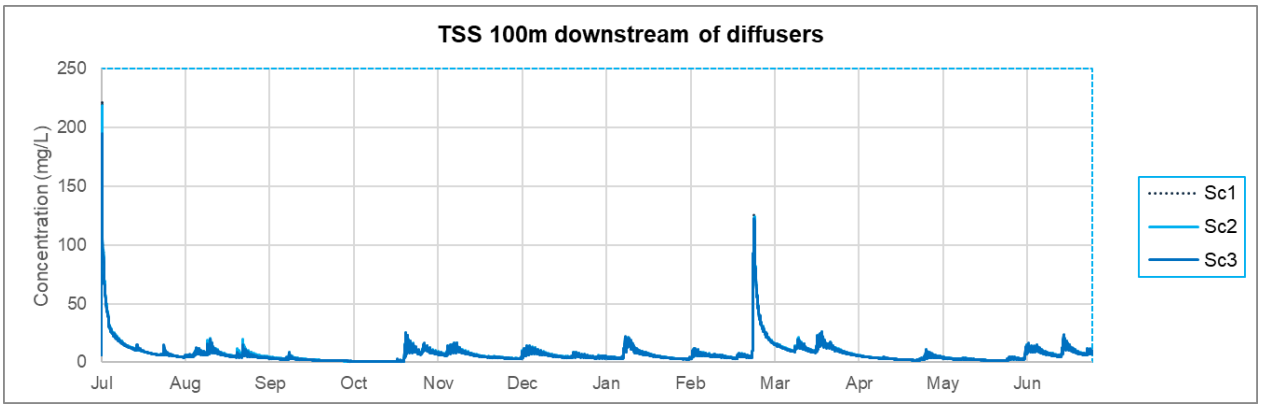


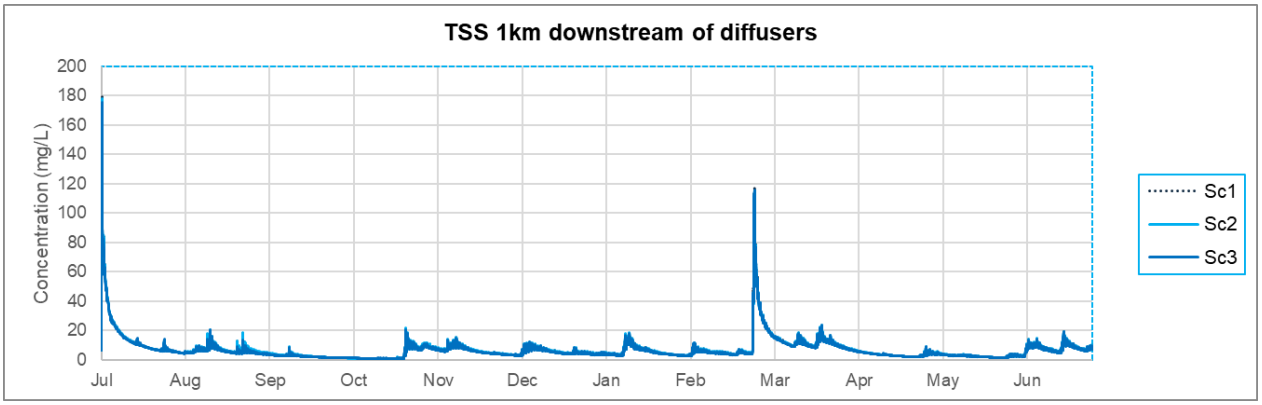
Time series plots




TSS 100m upstream of diffusers
Concentration (mg/L)
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

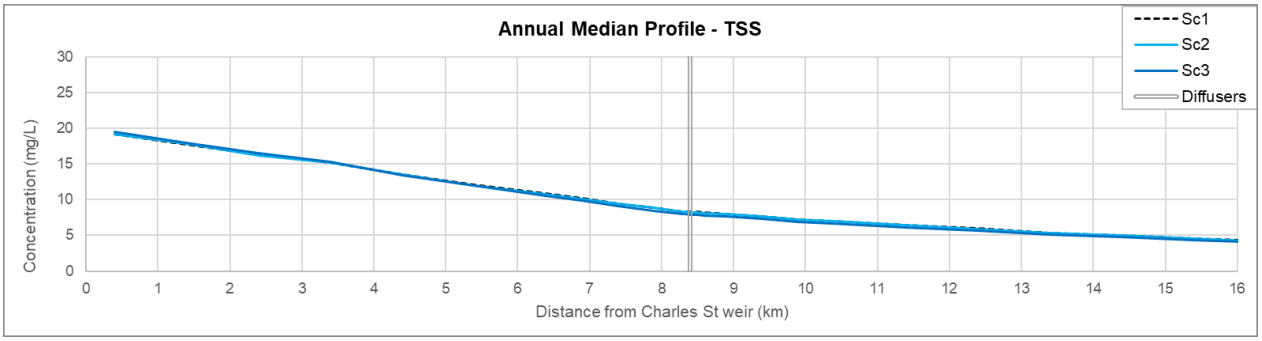

TSS at diffusers
Concentration (mg/L)
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

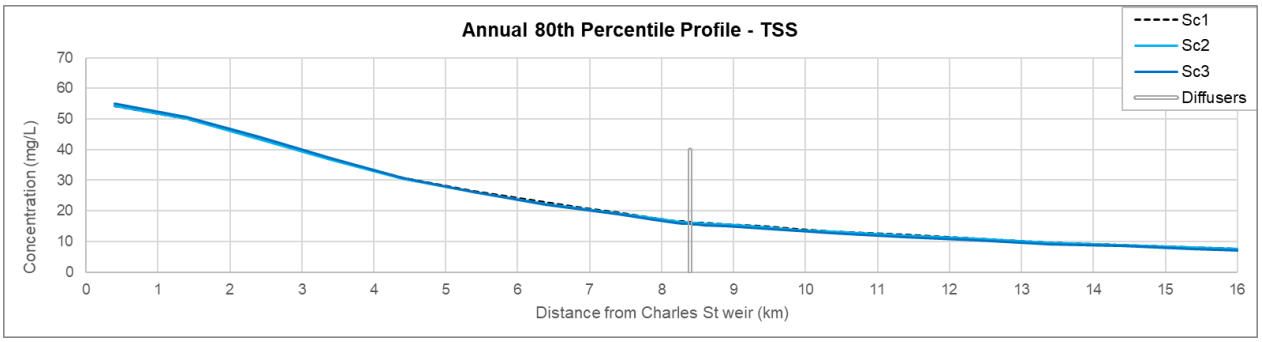

TSS 100m downstream of diffusers
Concentration (mg/L)
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TSS 1km downstream of diffusers
Concentration (mg/L)
200
180
160
140
120
100
80
60
40
20
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

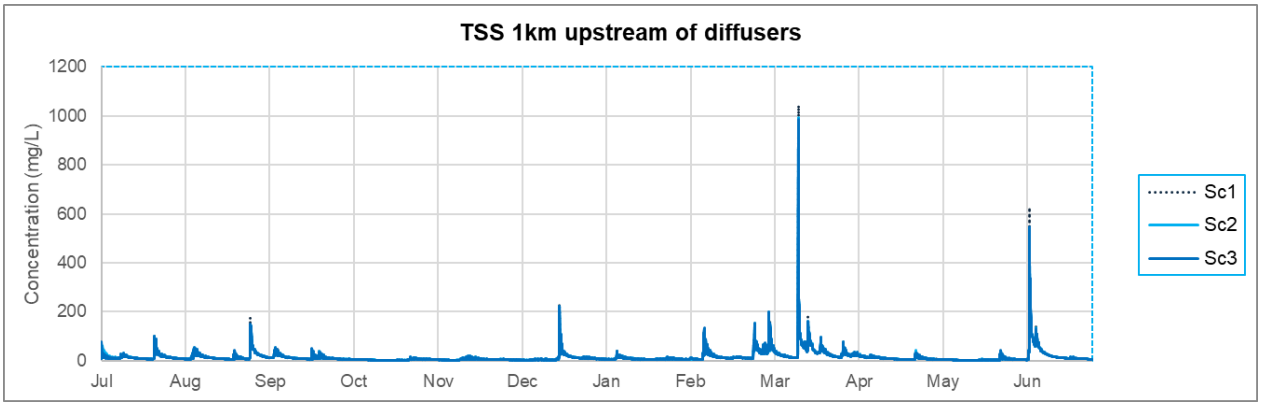
Appendices D1.8.2 Average rainfall year scenario results (2016-2017)

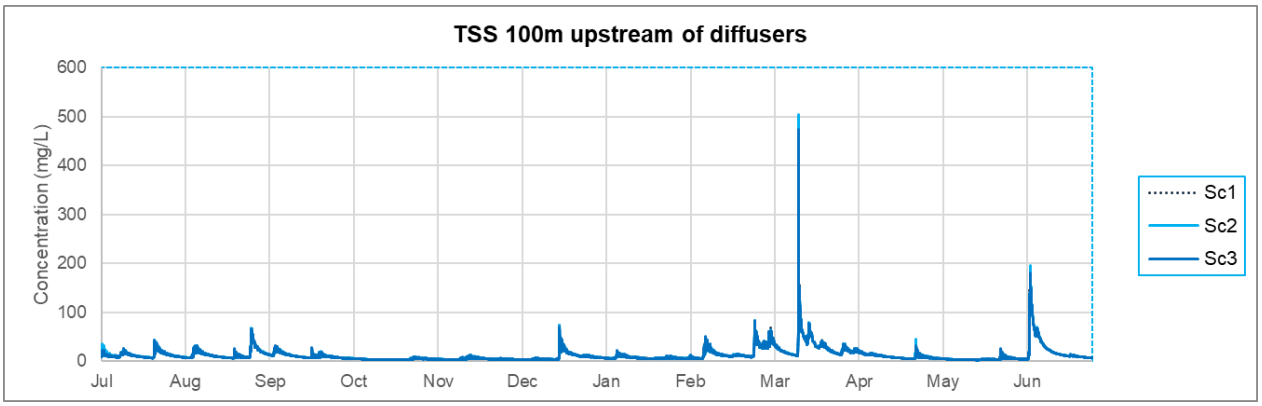
Longitudinal plots

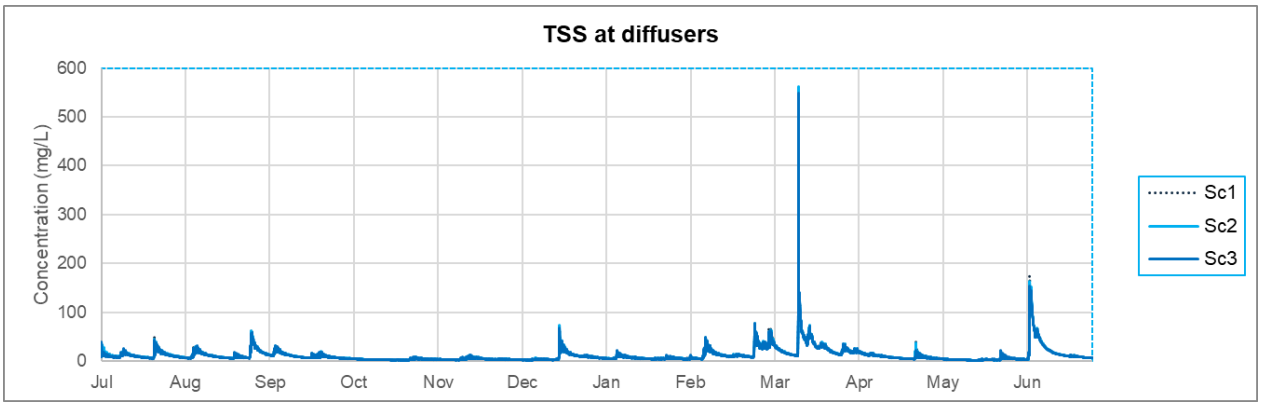


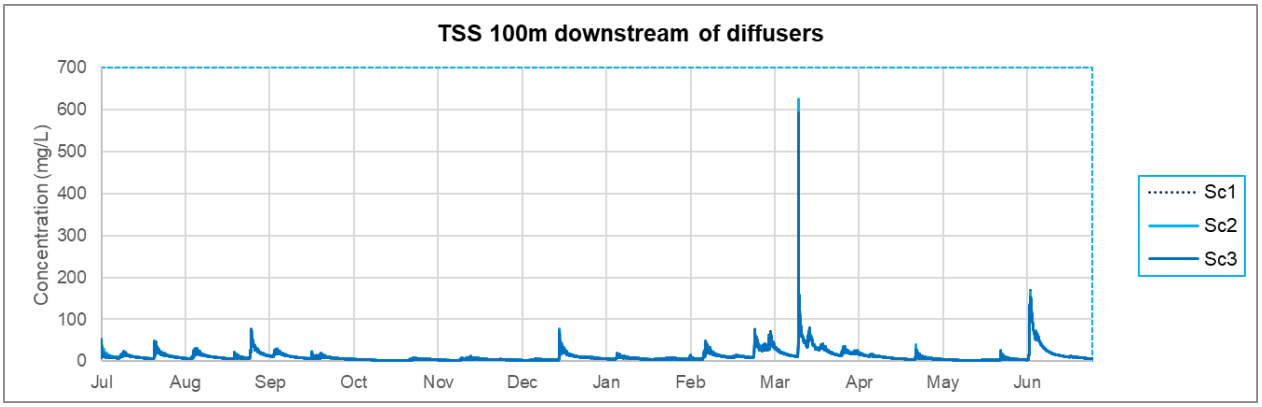


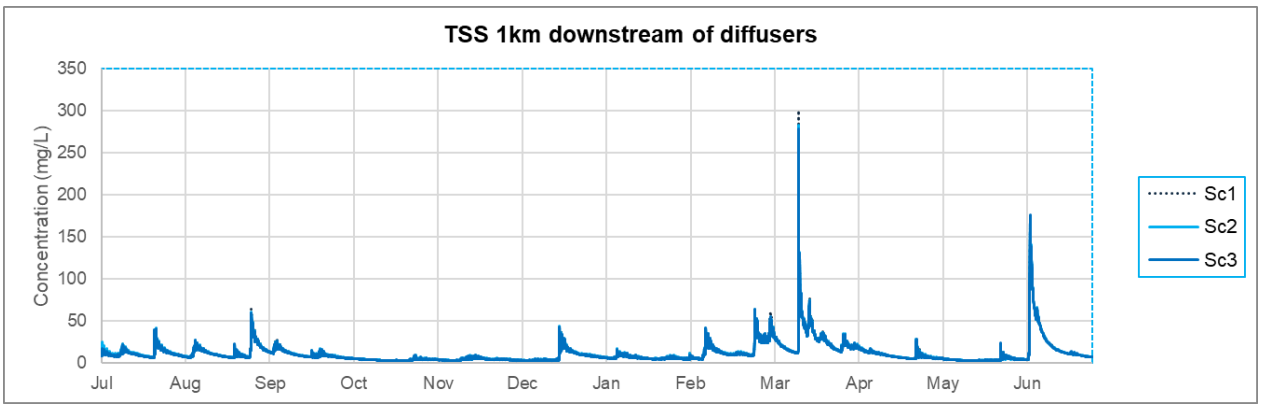
Time series plots





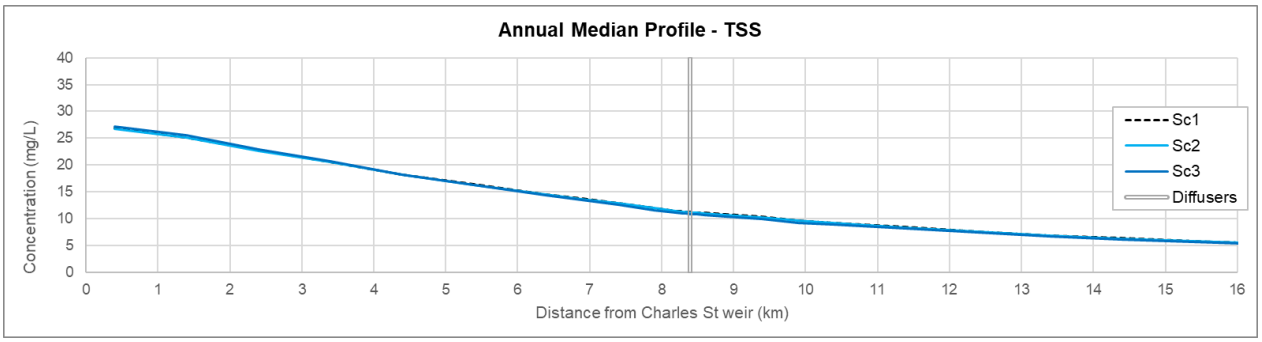


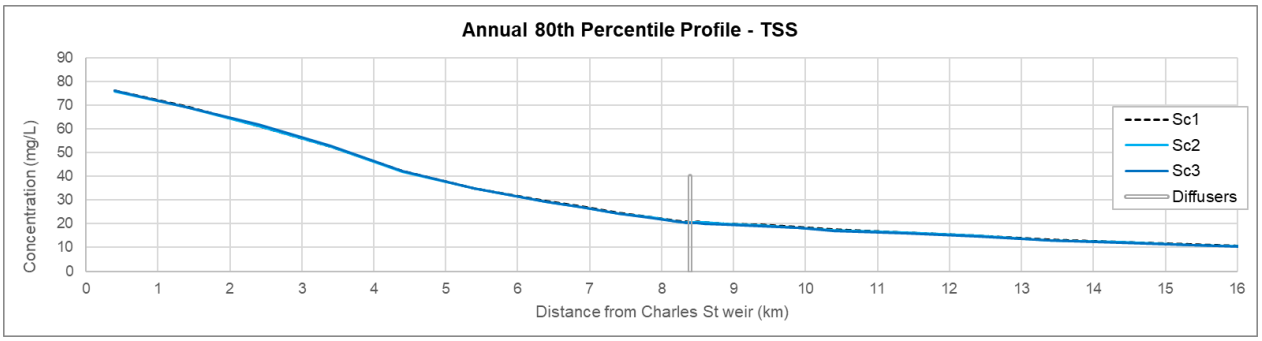




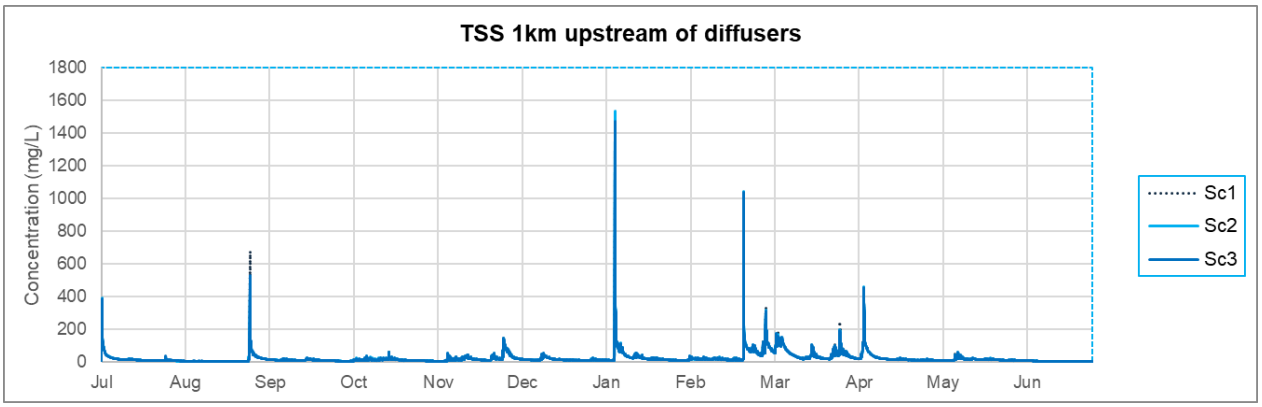
Appendices D1.8.3 Higher rainfall year scenario results (2021-2022)

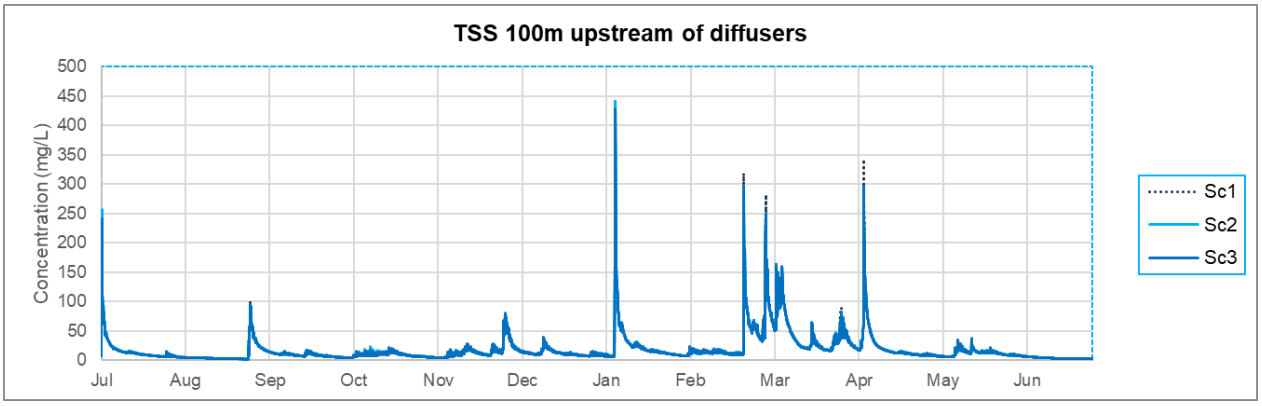
Longitudinal plots

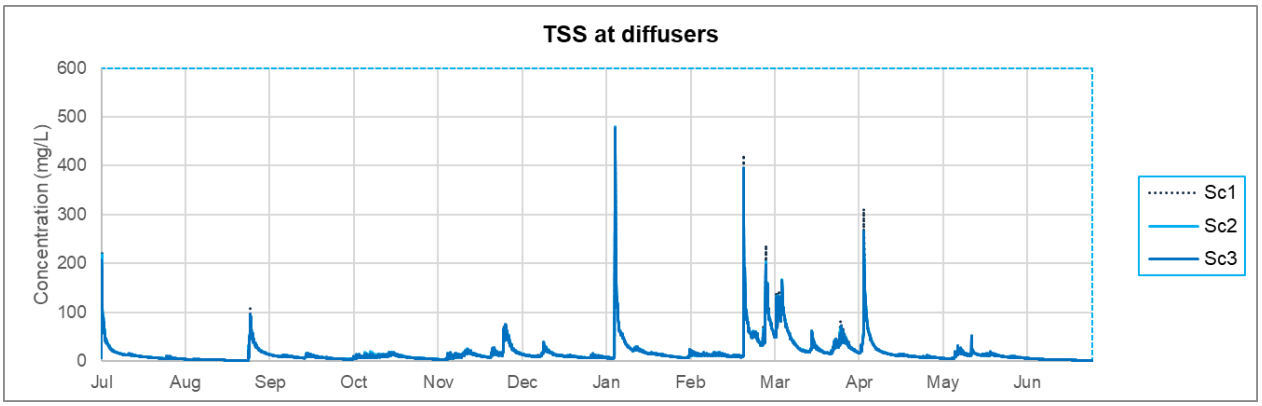


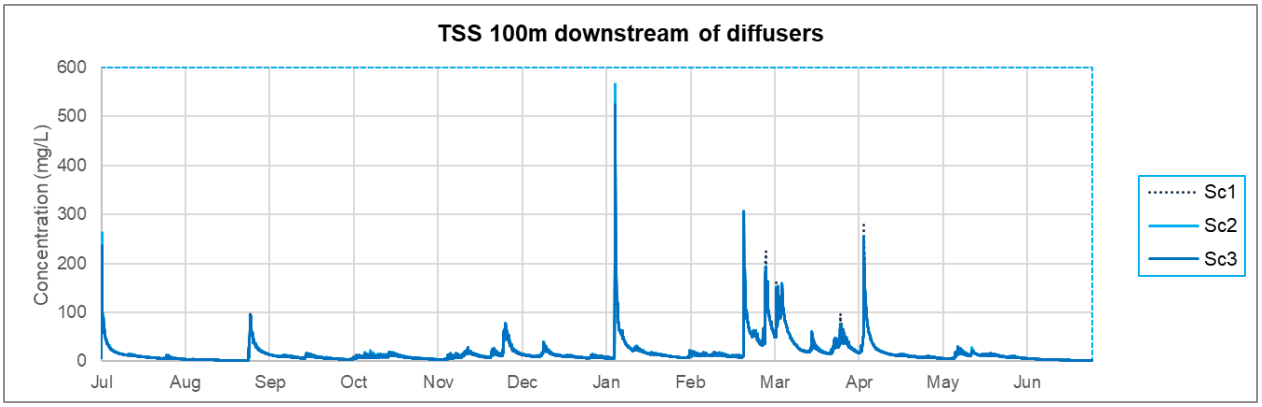


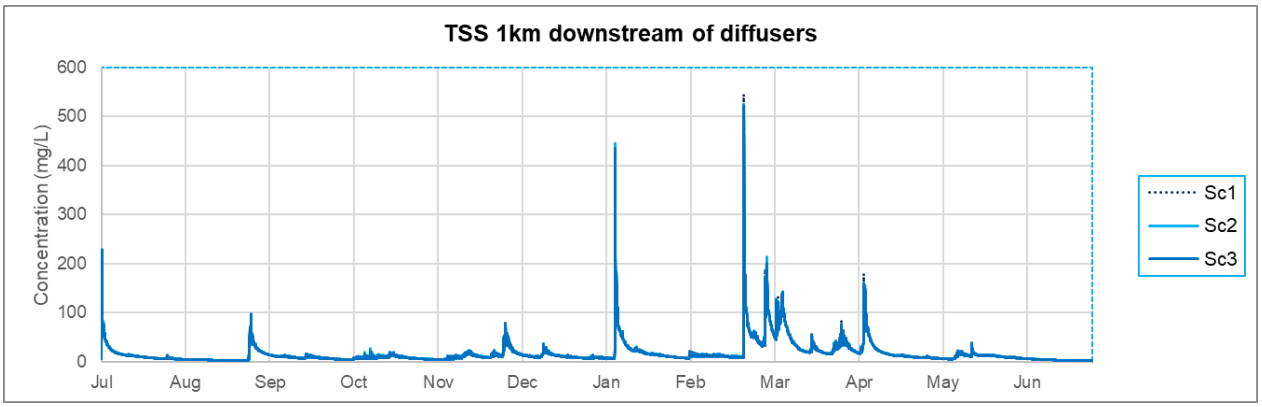
Time series plots







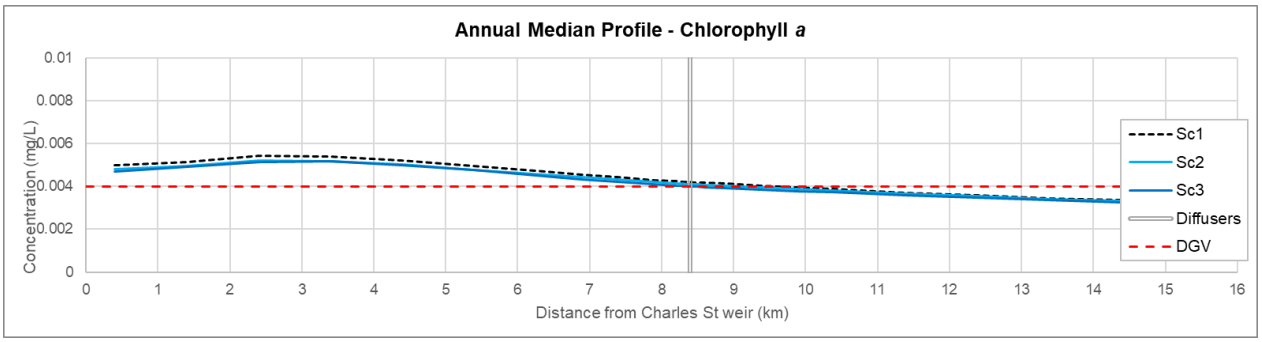


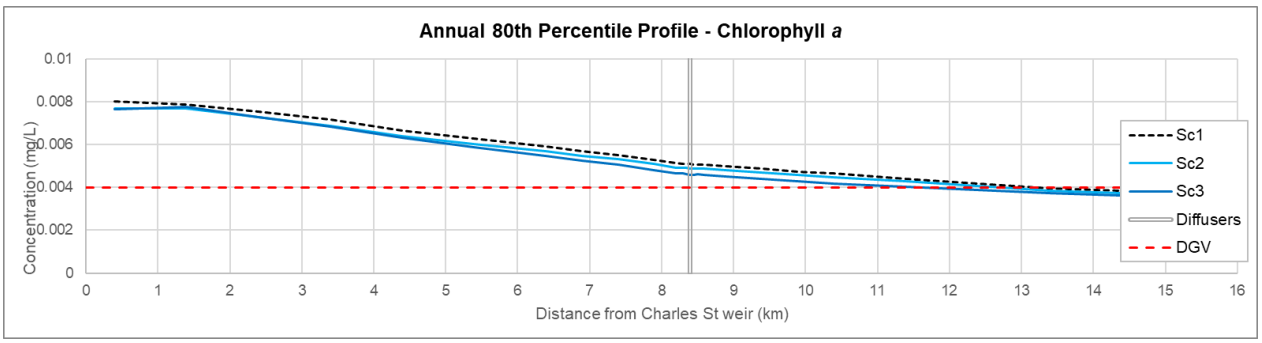


Appendices D1.9 Chlorophyll a

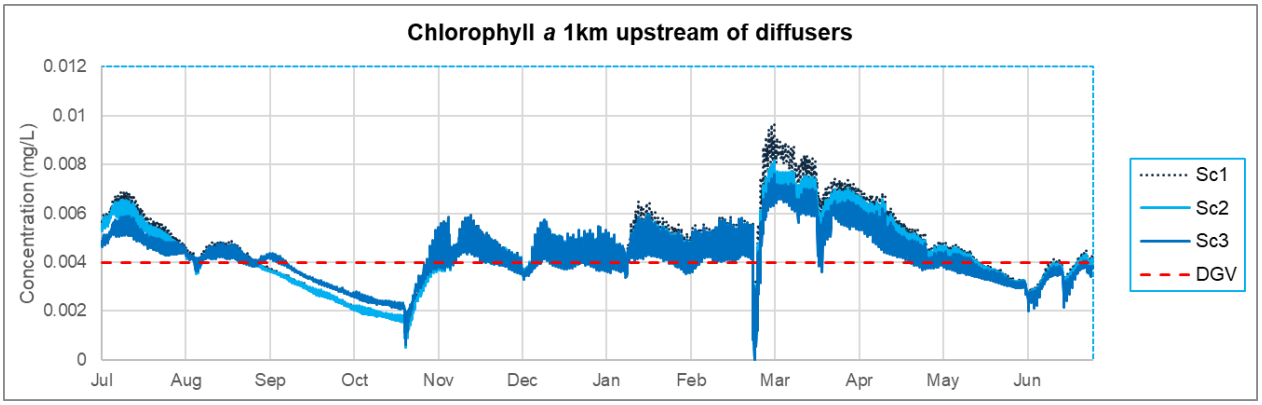
Appendices D1.9.1 Lower rainfall year scenario results (2017-2018)

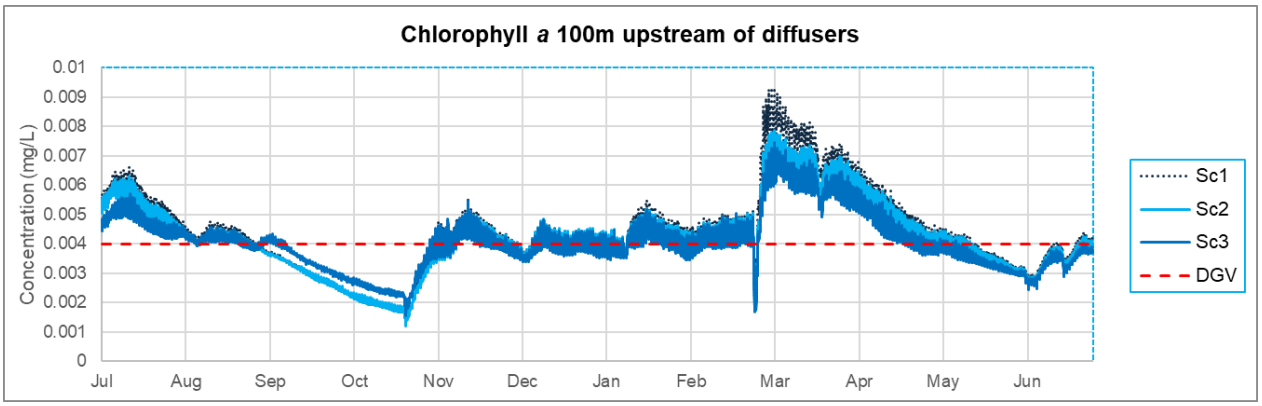
Longitudinal plots

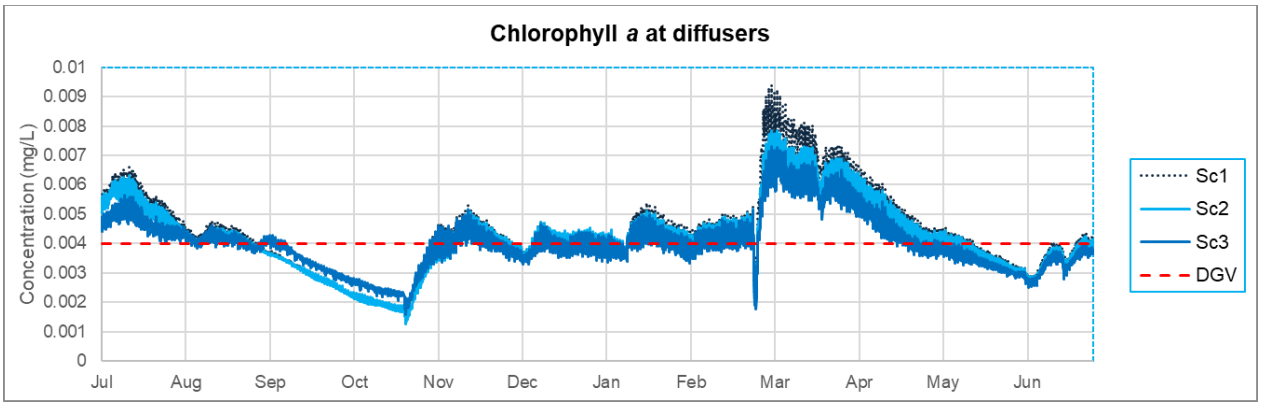


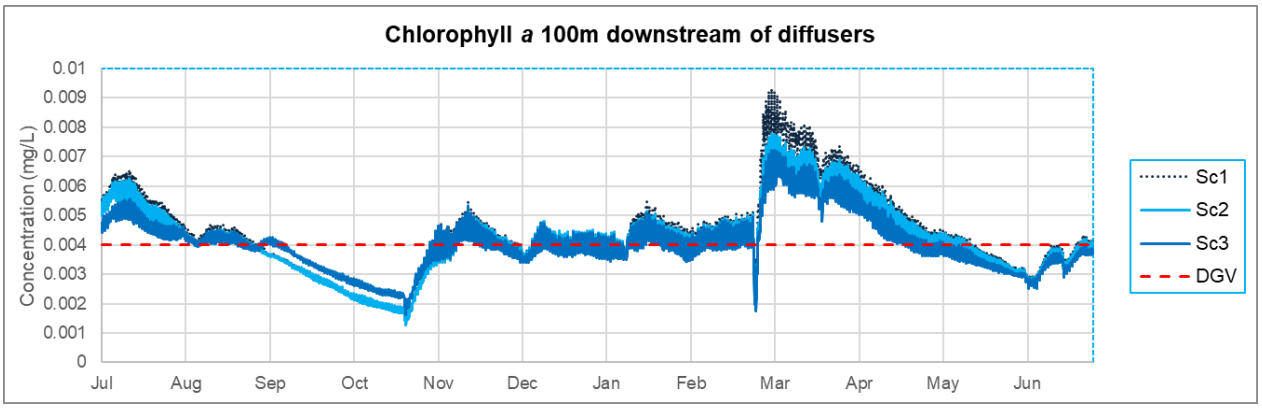


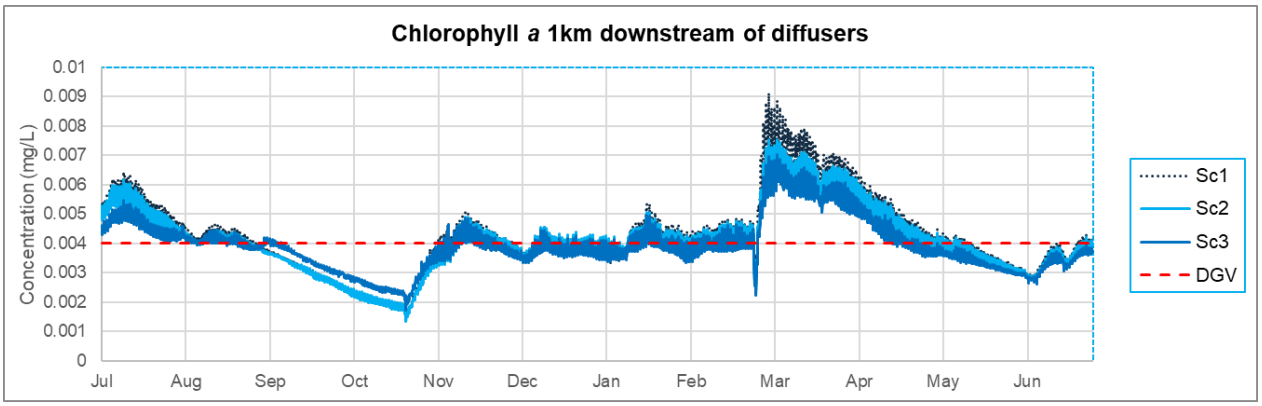
Time series plots





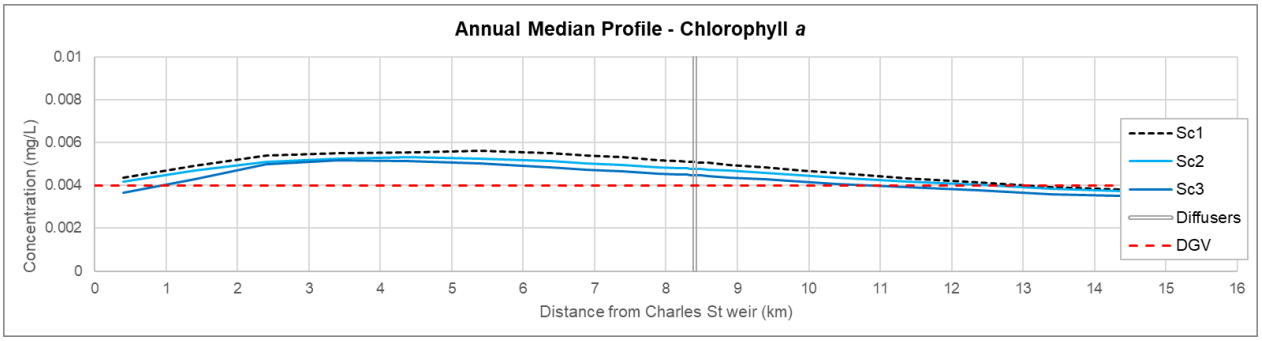


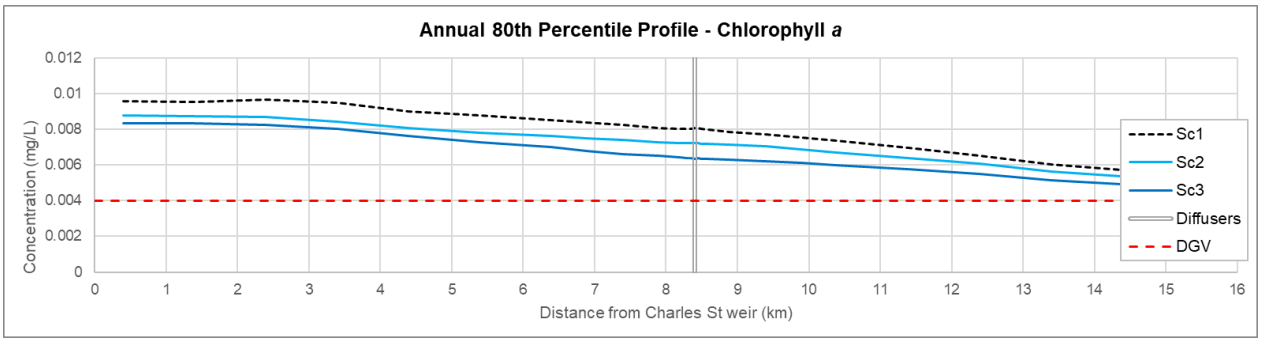




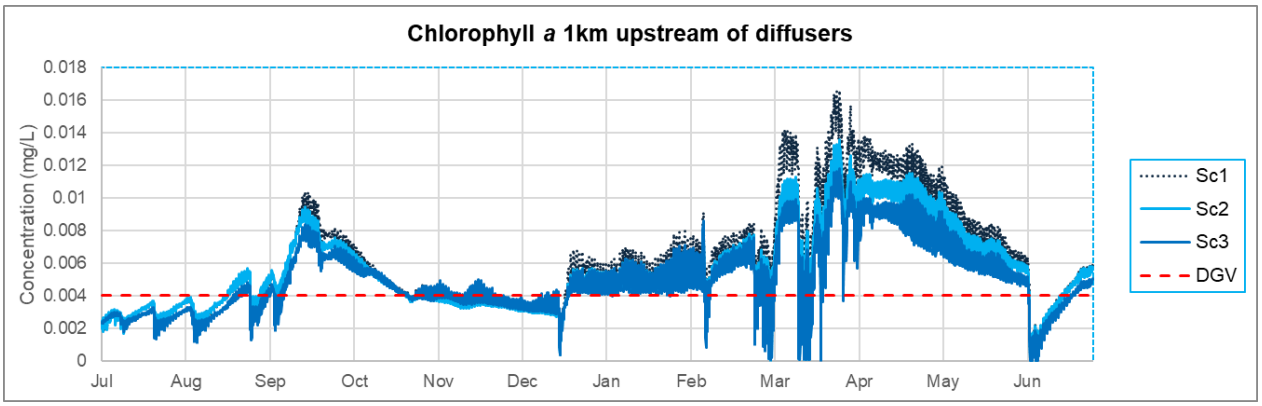
Appendices D1.9.2 Average rainfall year scenario results (2016-2017)

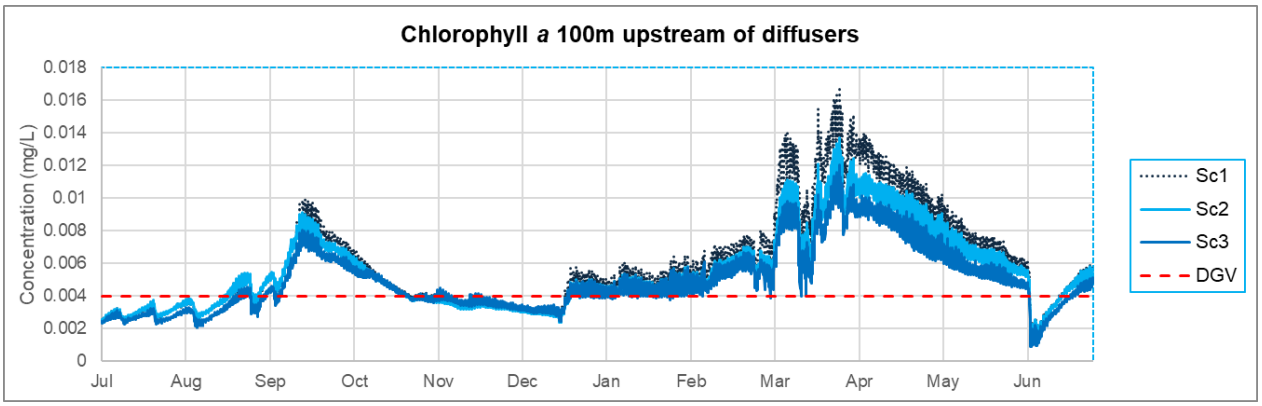
Longitudinal plots

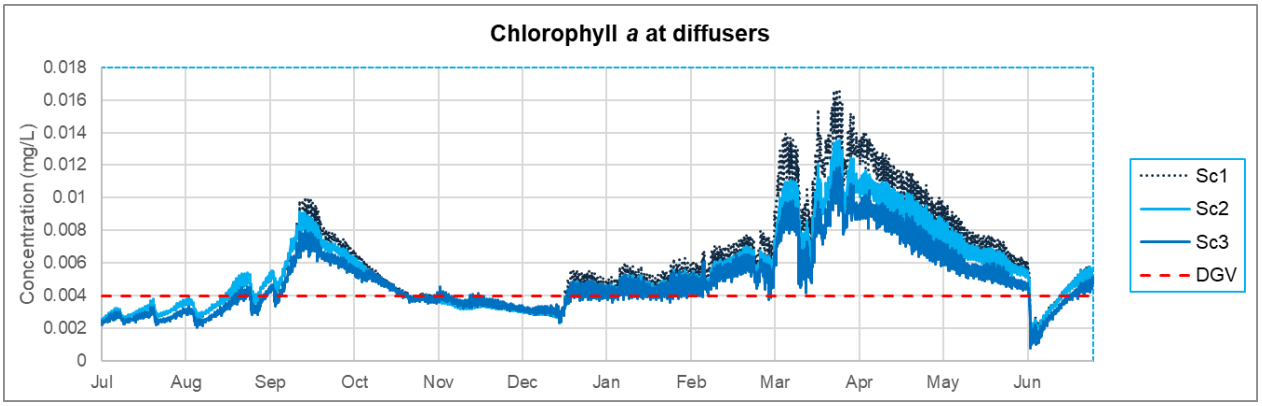


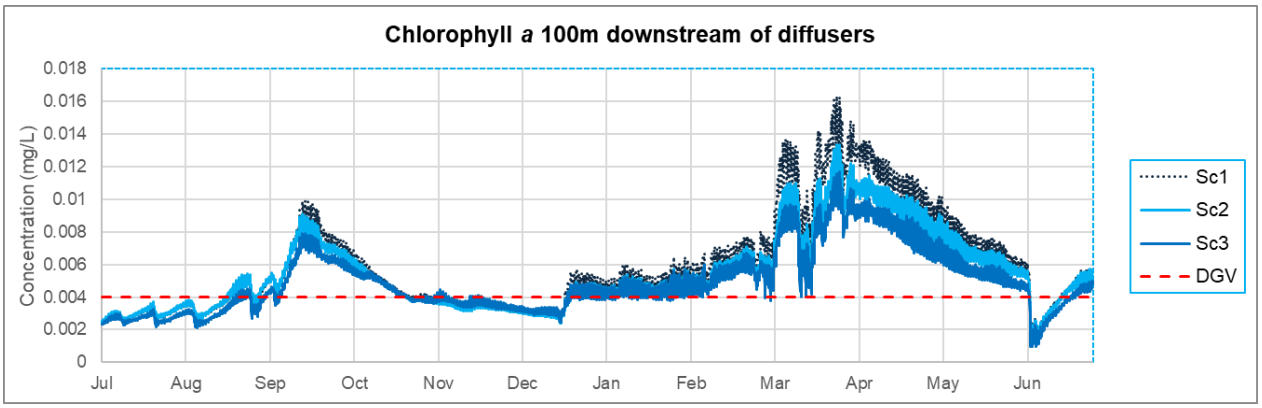


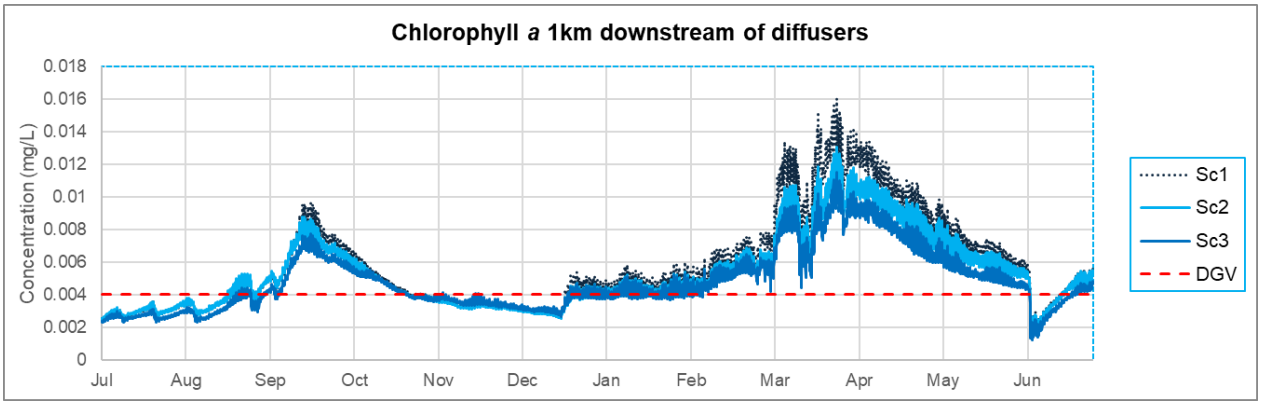
Time series plots




Chlorophyll *a* 100m upstream of diffusers
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

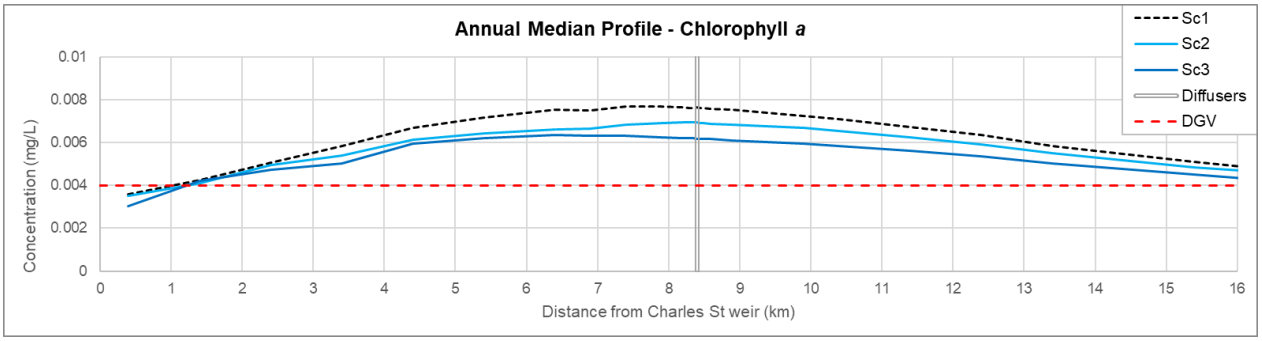

Chlorophyll *a* at diffusers
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

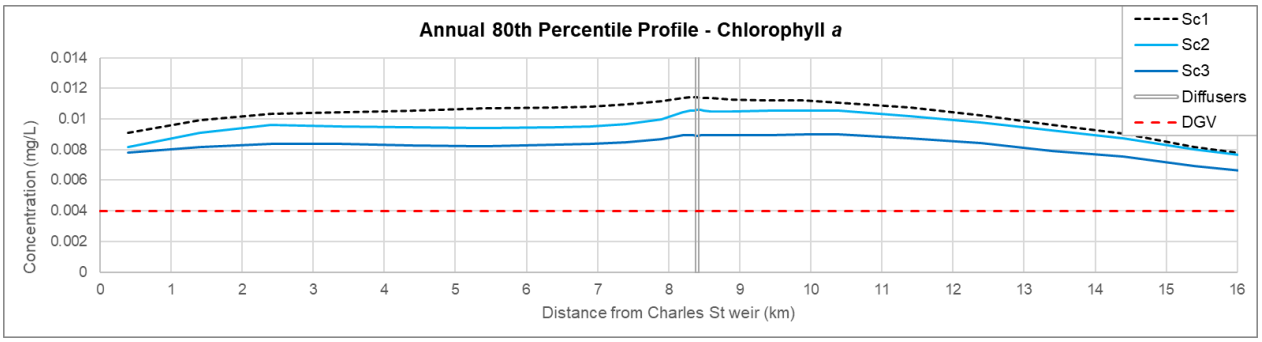

Chlorophyll *a* 100m downstream of diffusers
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Chlorophyll *a* 1km downstream of diffusers
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

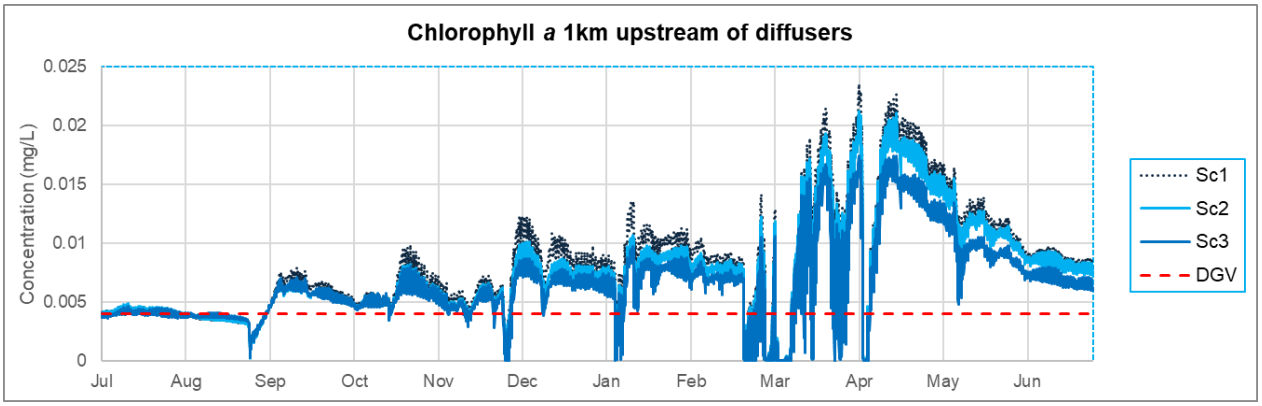
Appendices D1.9.3 Higher rainfall year scenario results (2021-2022)

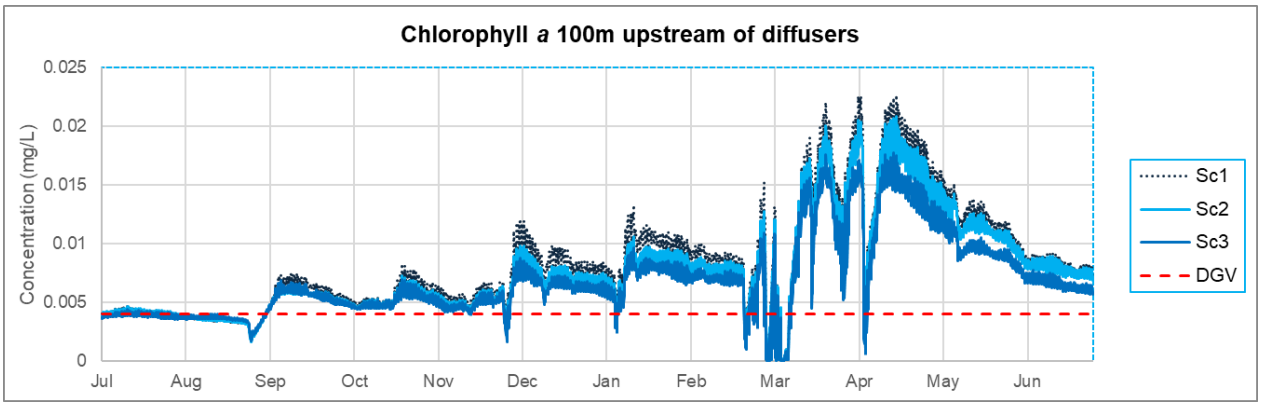
Longitudinal plots

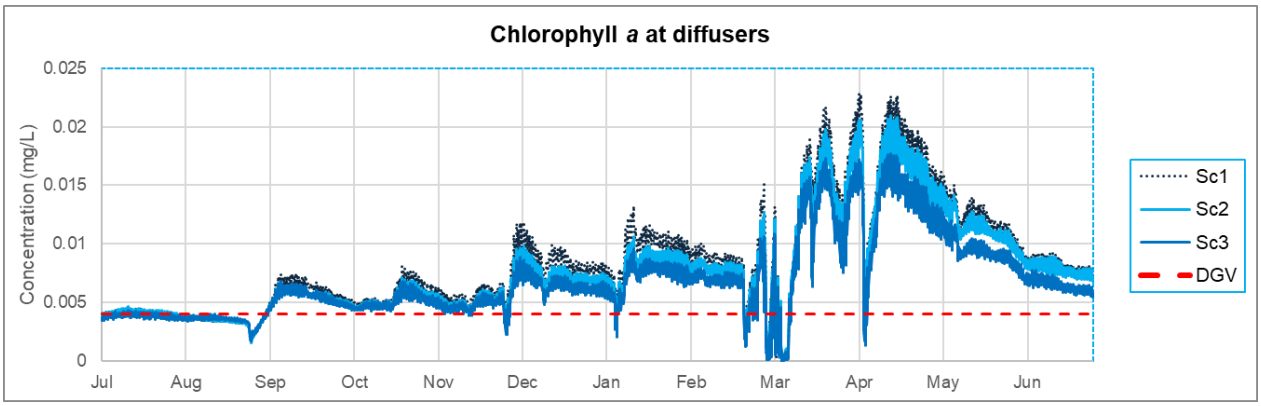


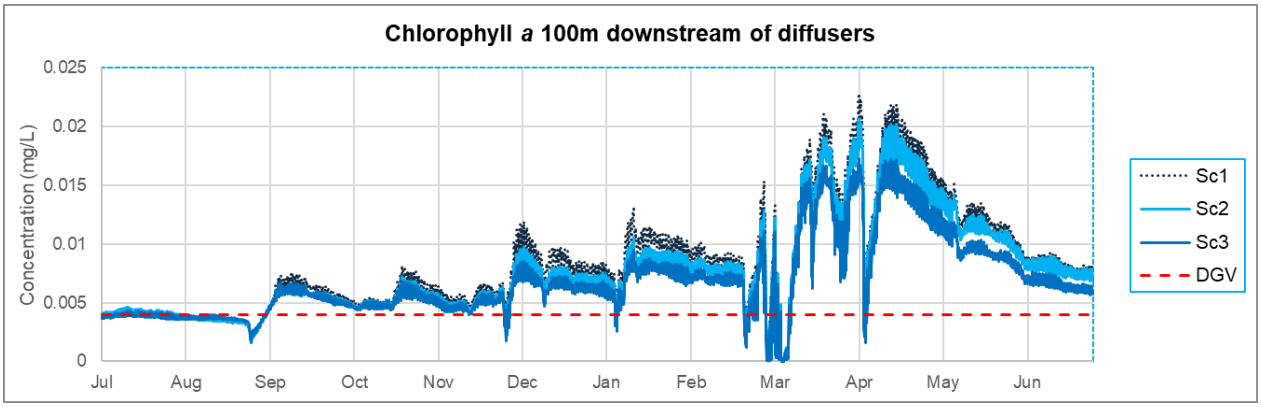


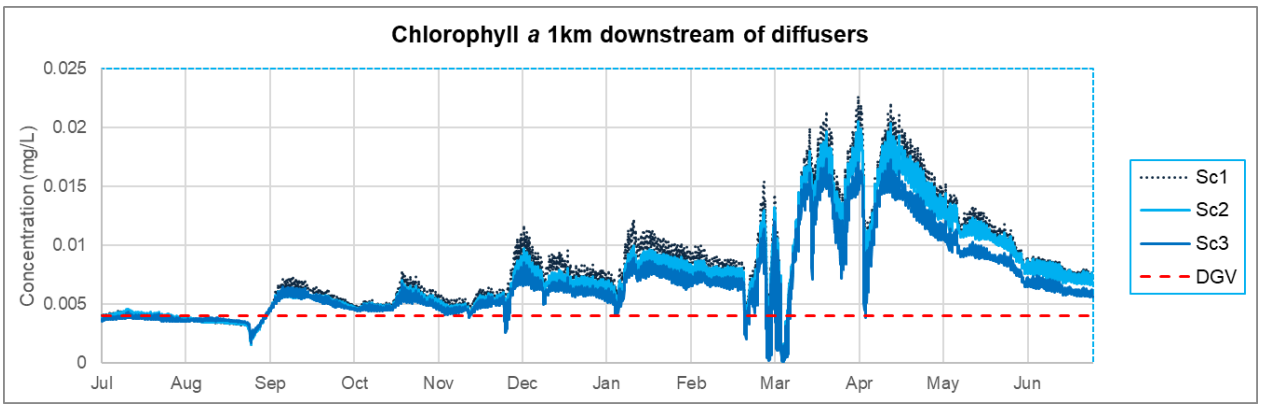
Time series plots






Chlorophyll *a* at diffusers
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

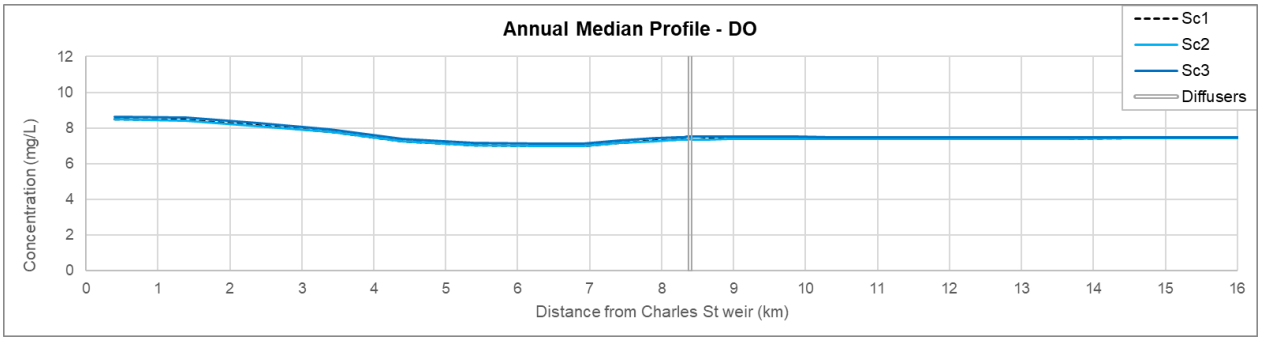

Chlorophyll *a* 100m downstream of diffusers
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

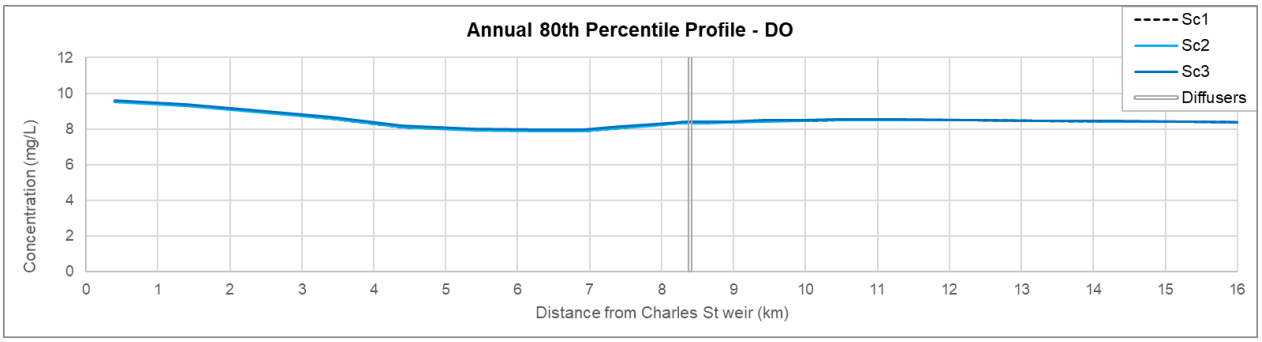

Chlorophyll *a* 1km downstream of diffusers
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

Appendices D1.10 Dissolved Oxygen

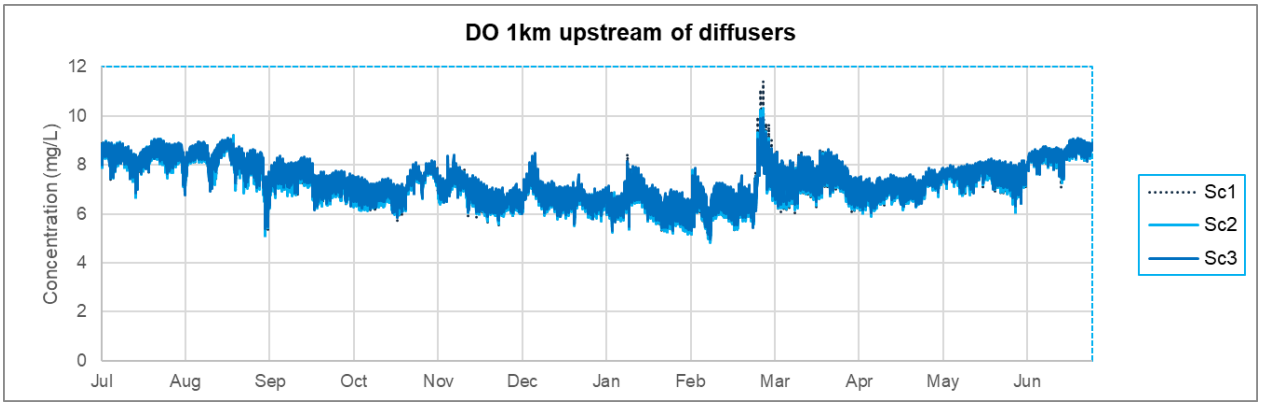
Appendices D1.10.1 Lower rainfall year scenario results (2017-2018)

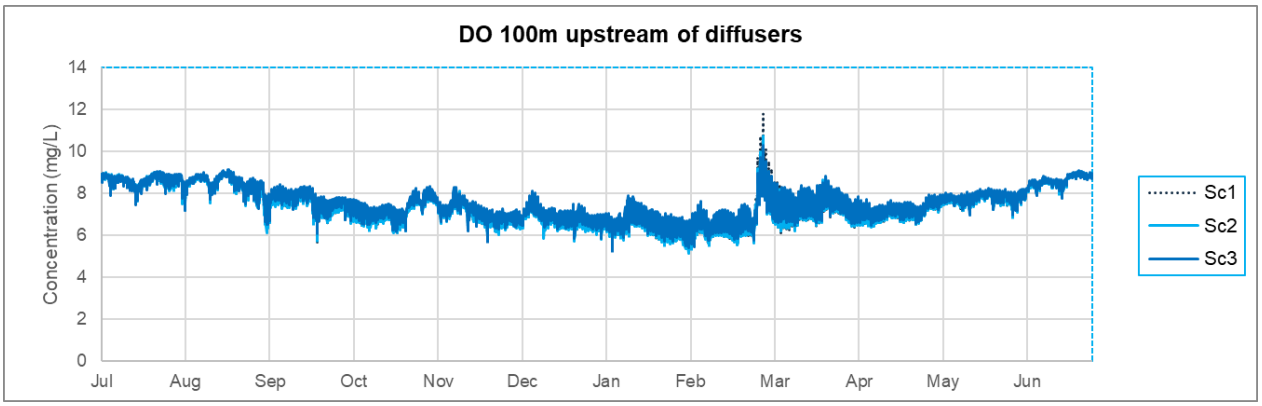
Longitudinal plots

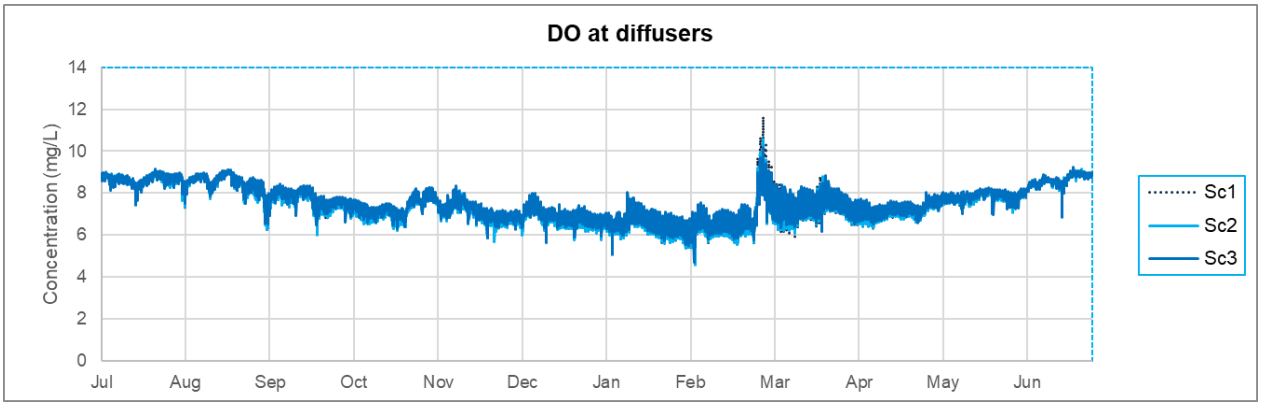


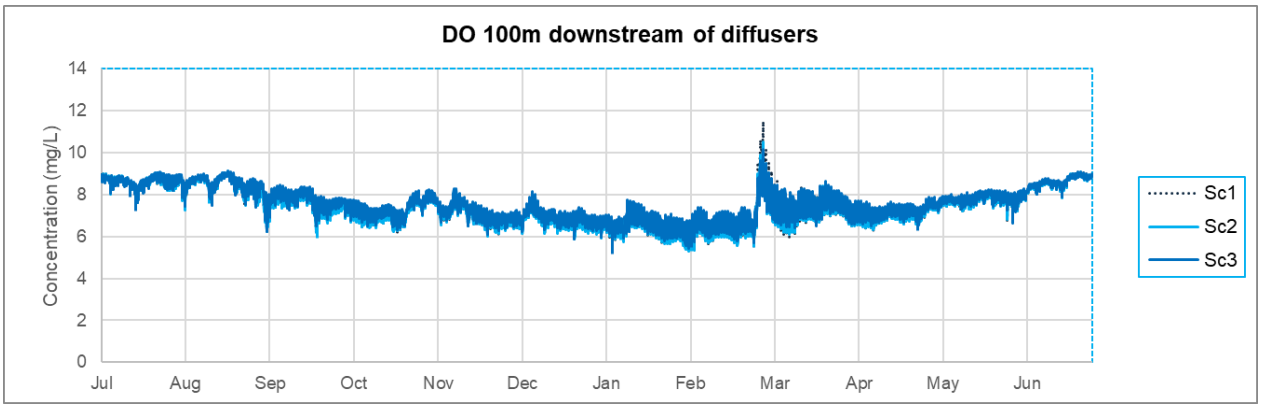


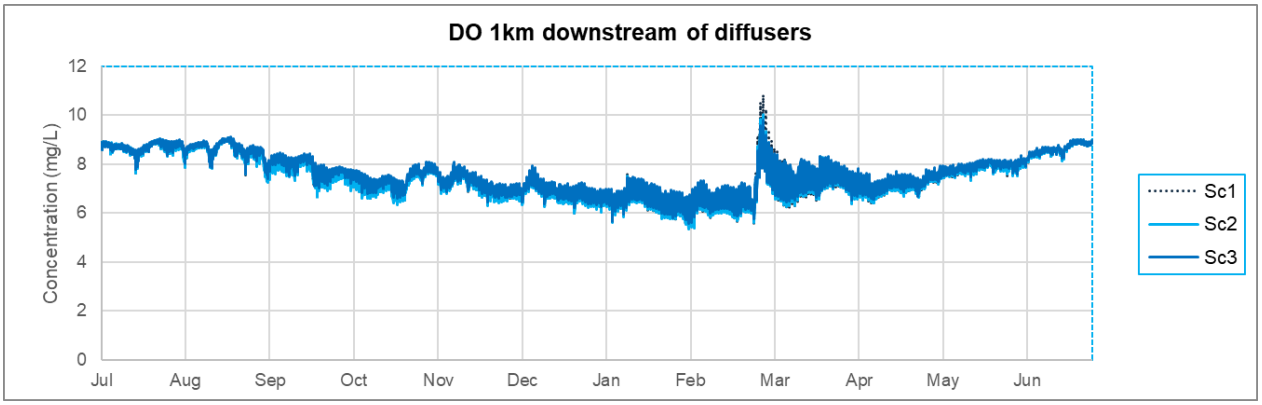
Time series plots




DO 100m upstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

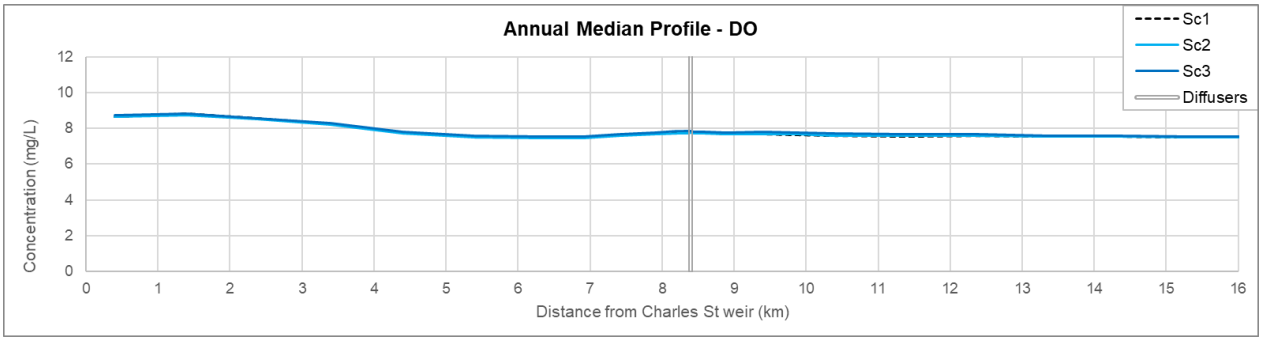

DO at diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

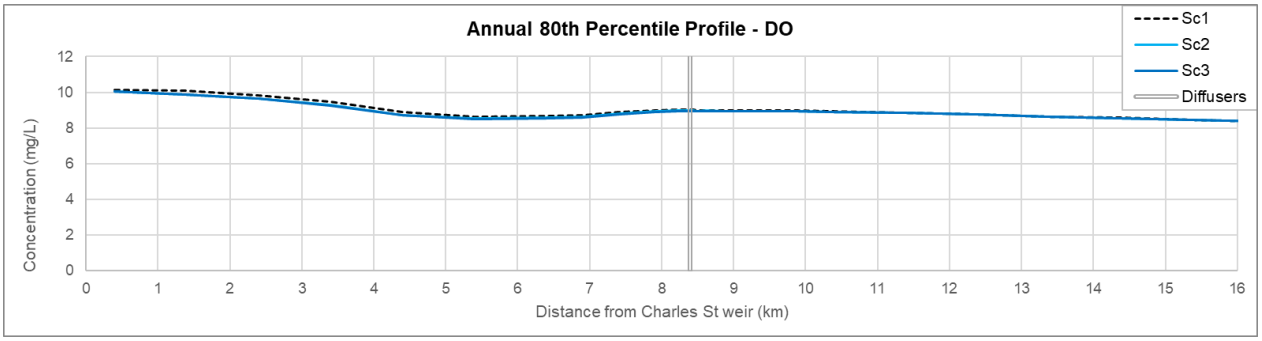

DO 100m downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


DO 1km downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

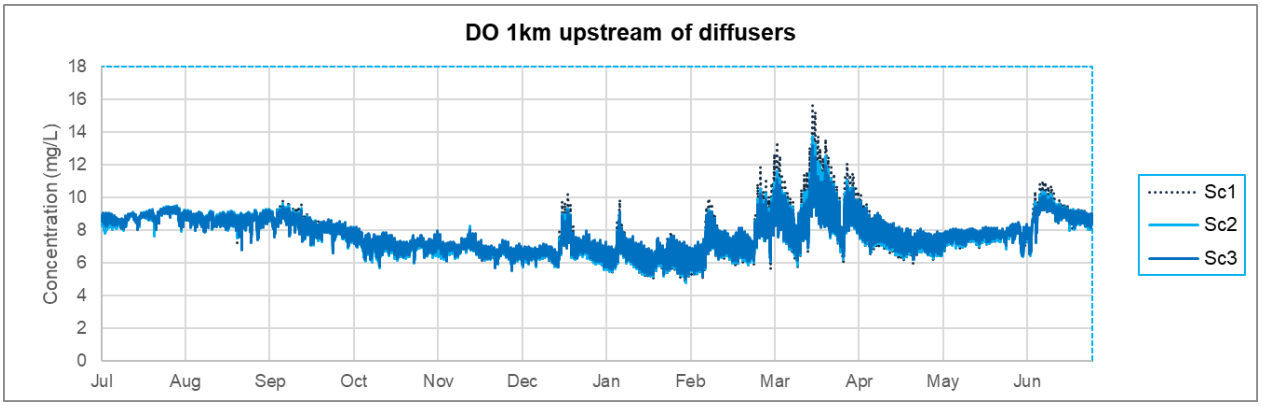
Appendices D1.10.2 Average rainfall year scenario results (2016-2017)

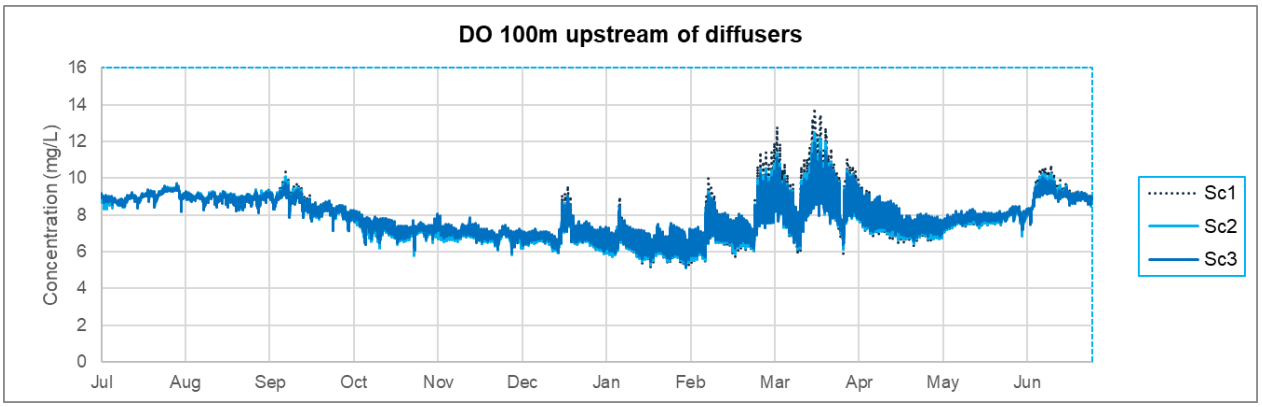
Longitudinal plots

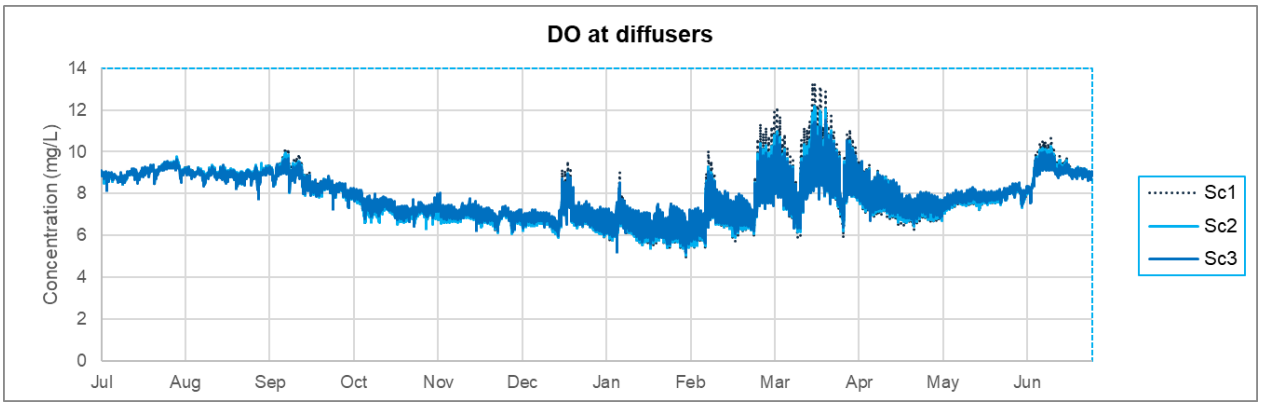


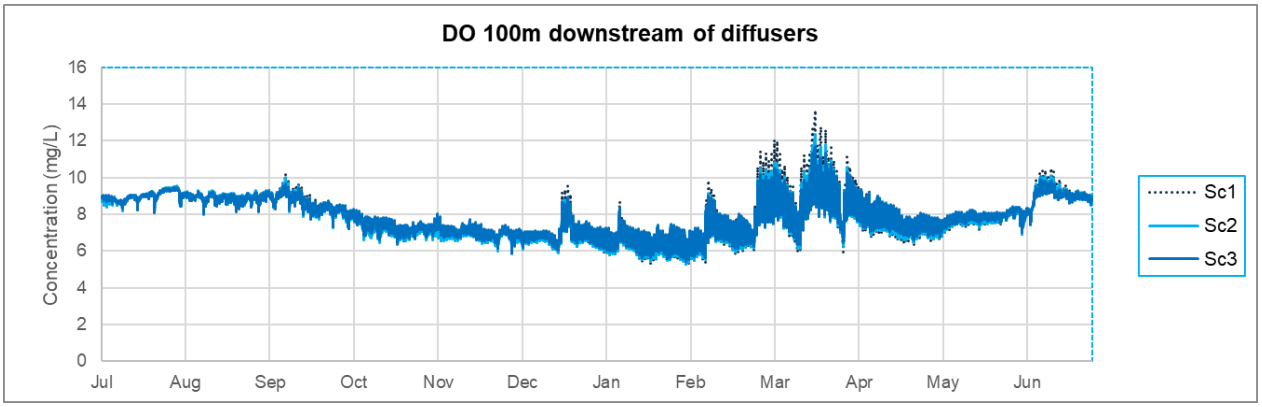


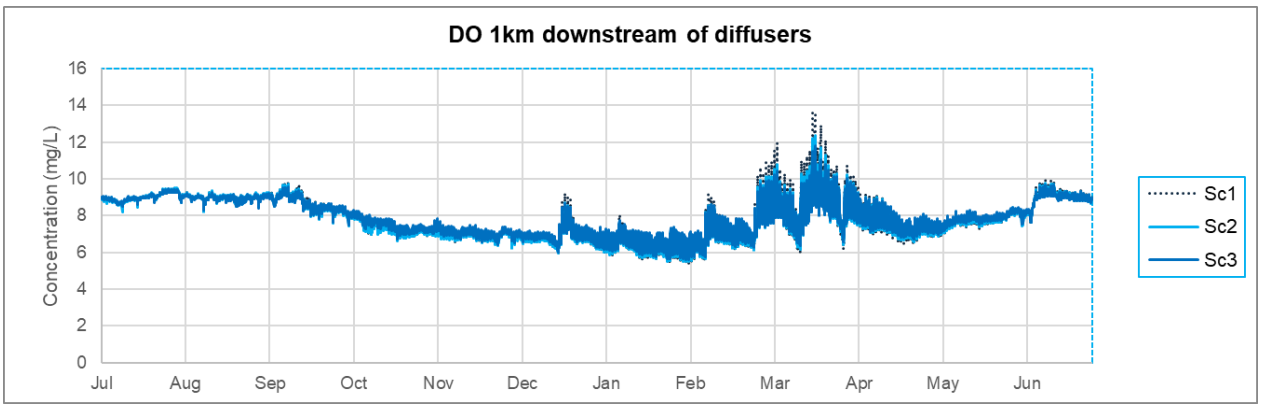
Time series plots





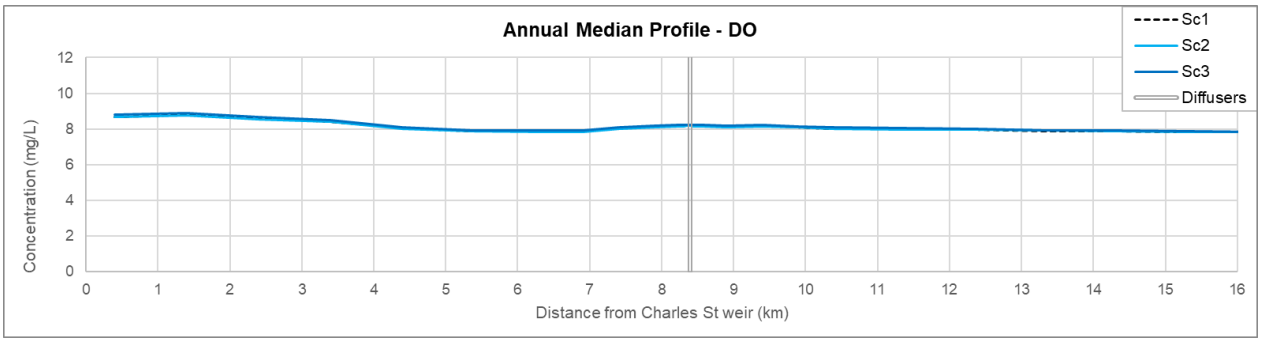


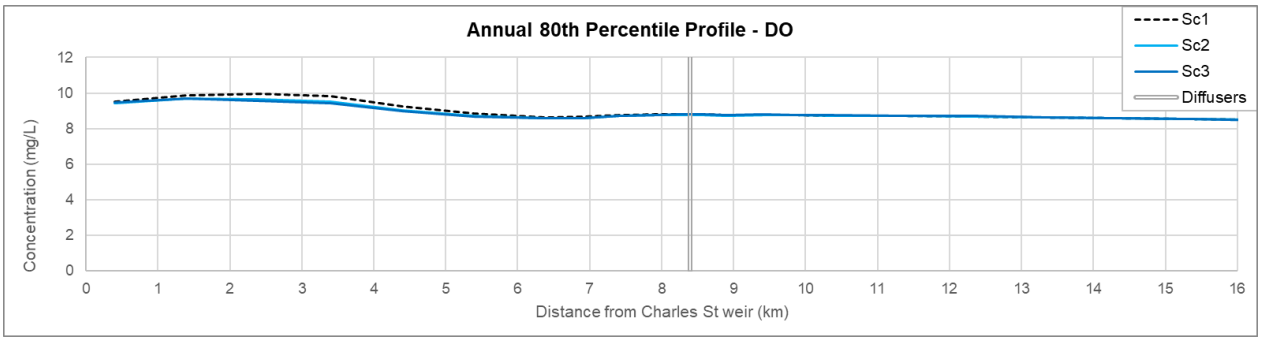




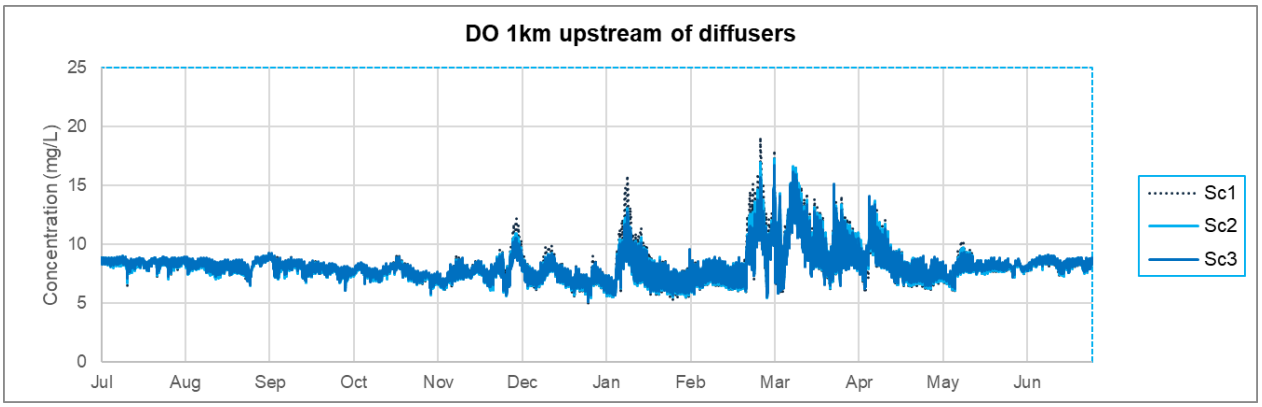
Appendices D1.10.3 Higher rainfall year scenario results (2021-2022)

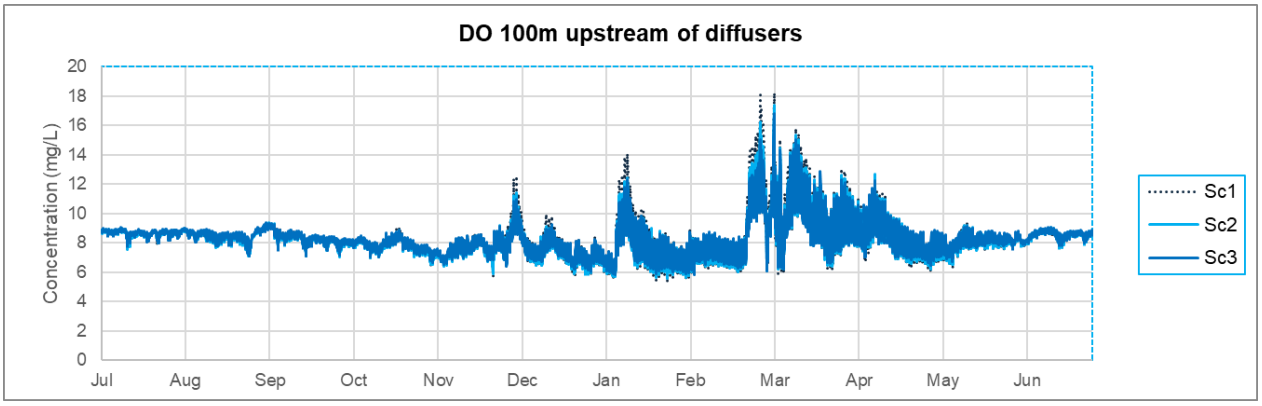
Longitudinal plots

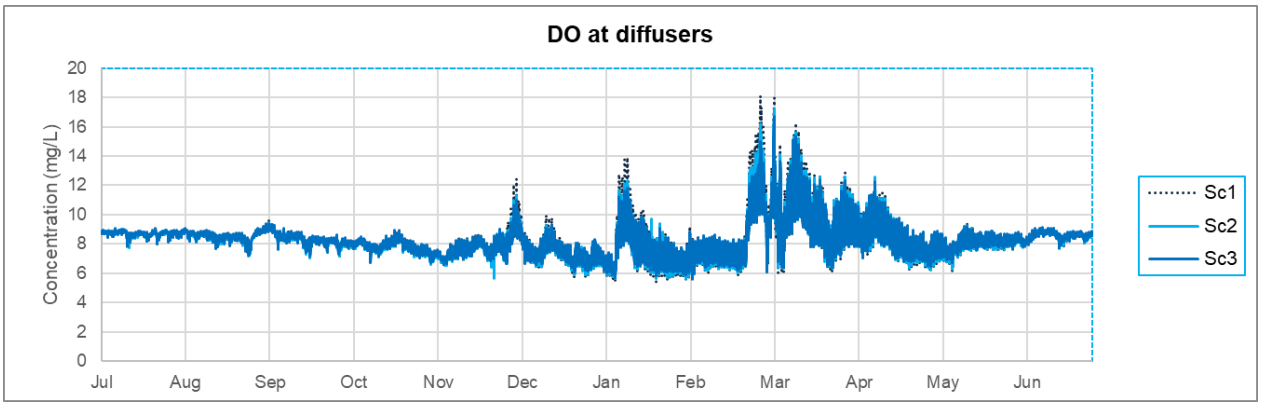


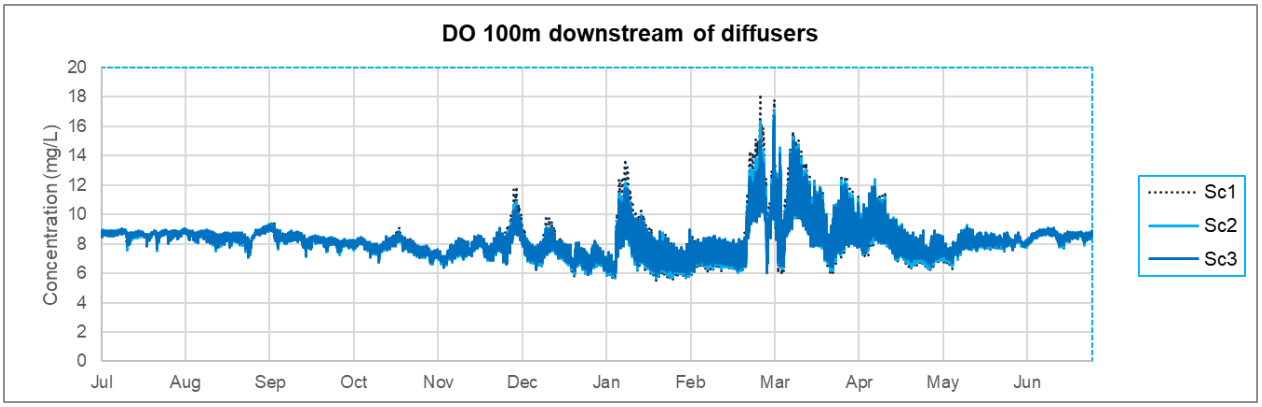


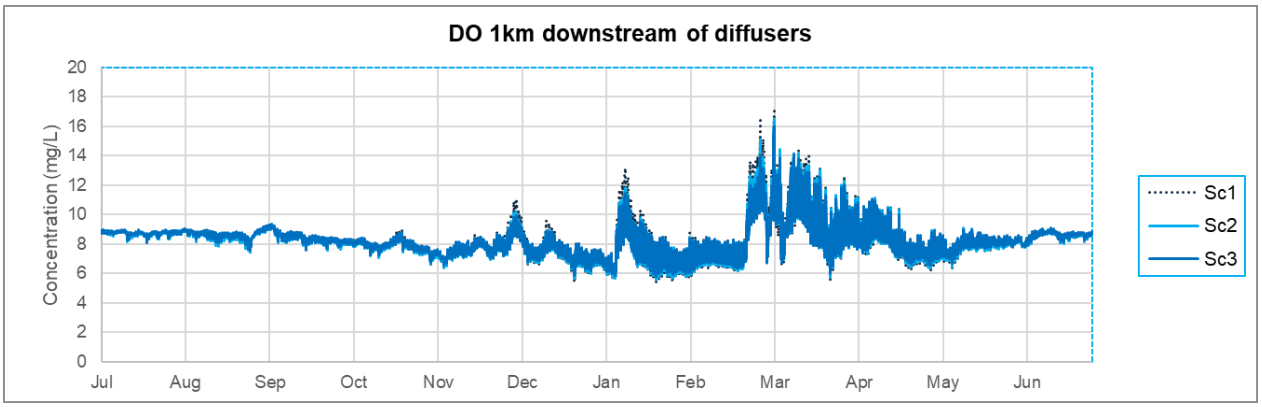
Time series plots







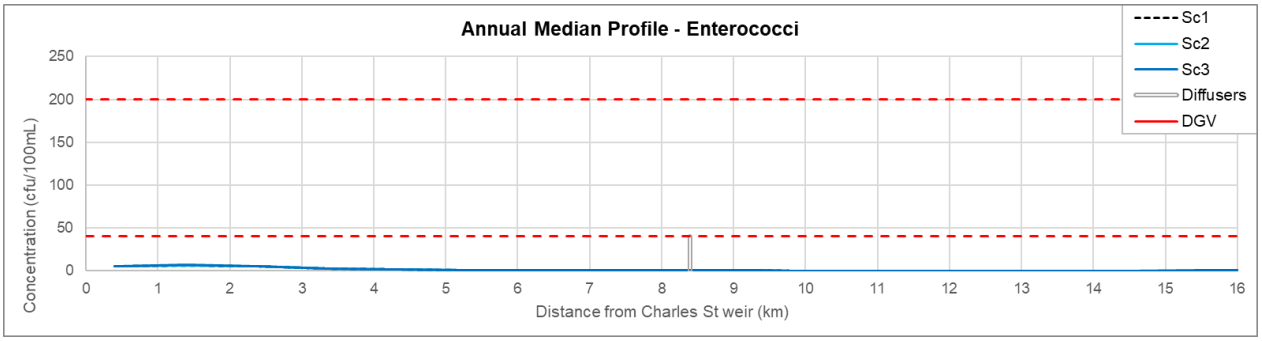


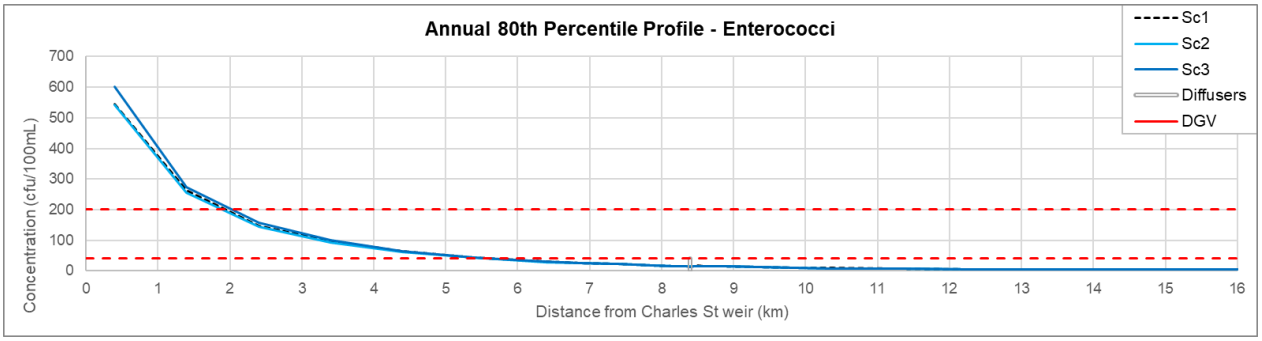


Appendices D1.11 Enterococci

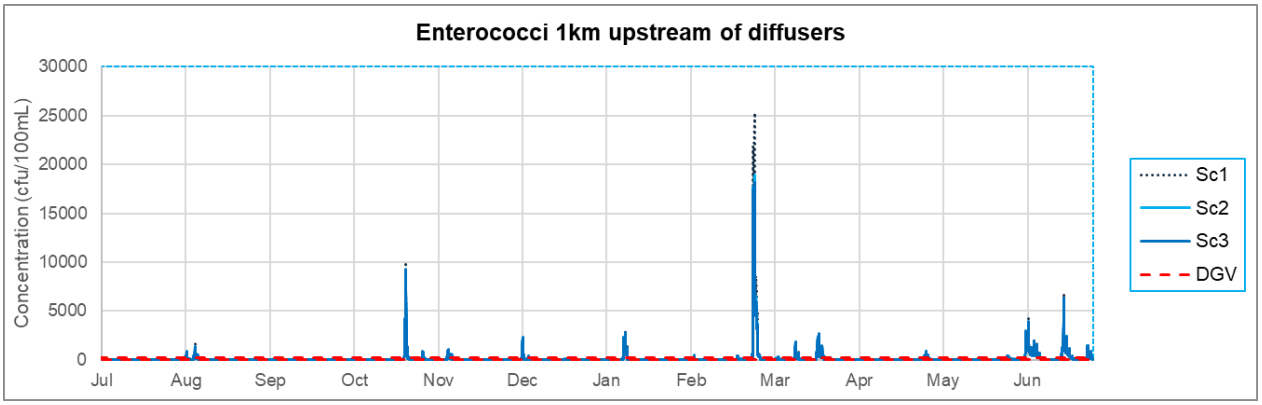
Appendices D1.11.1 Lower rainfall year scenario results (2017-2018)

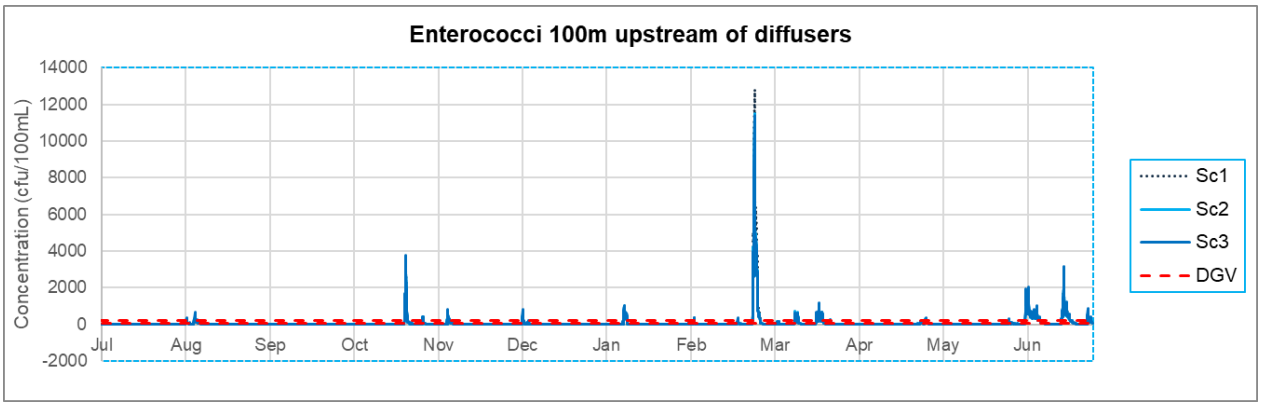
Longitudinal plots

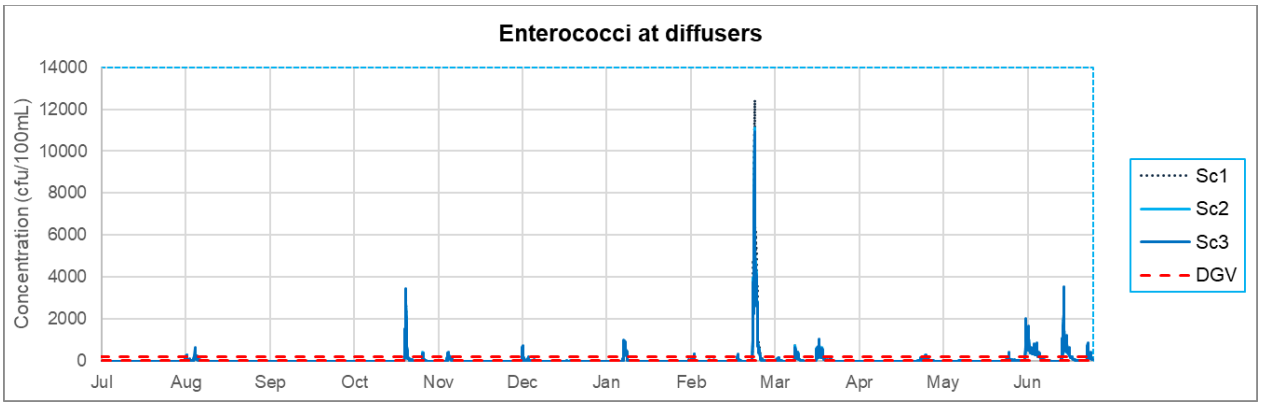


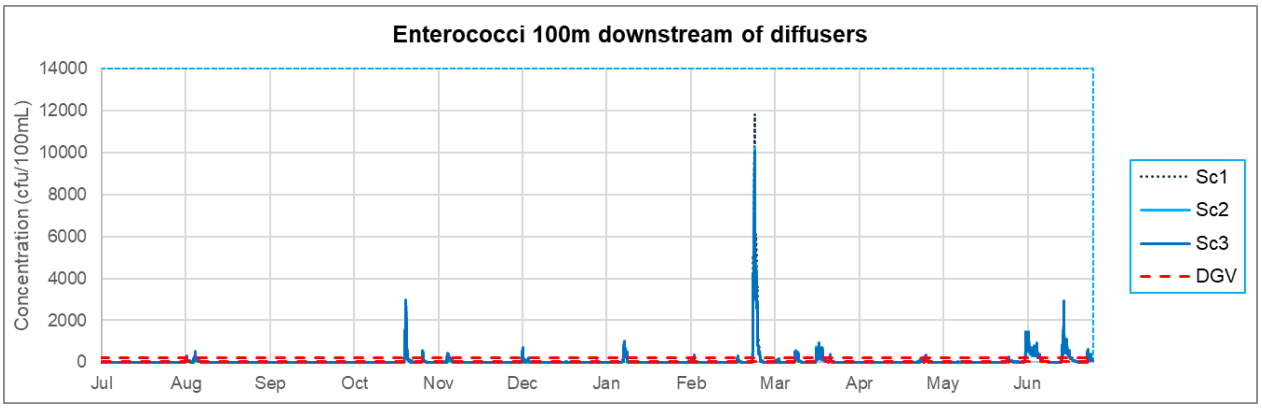


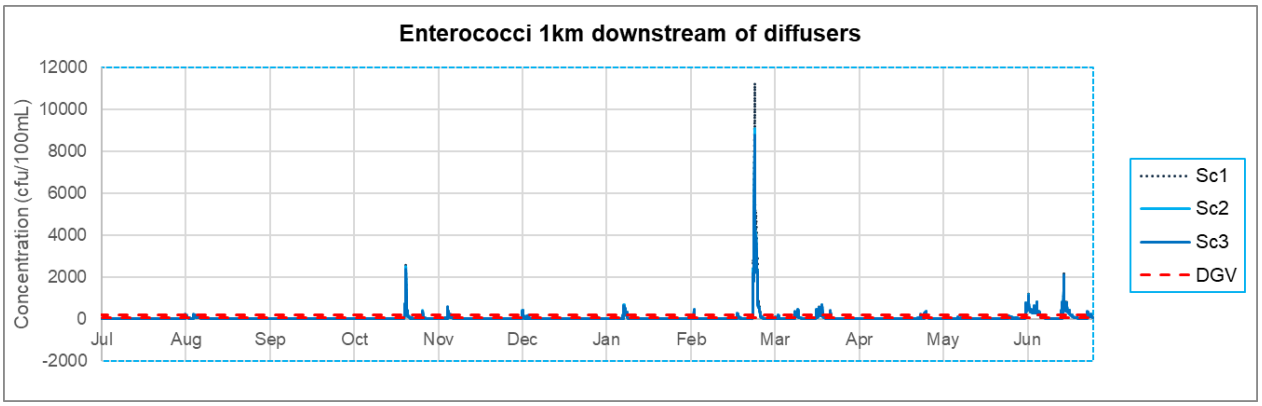
Time series plots





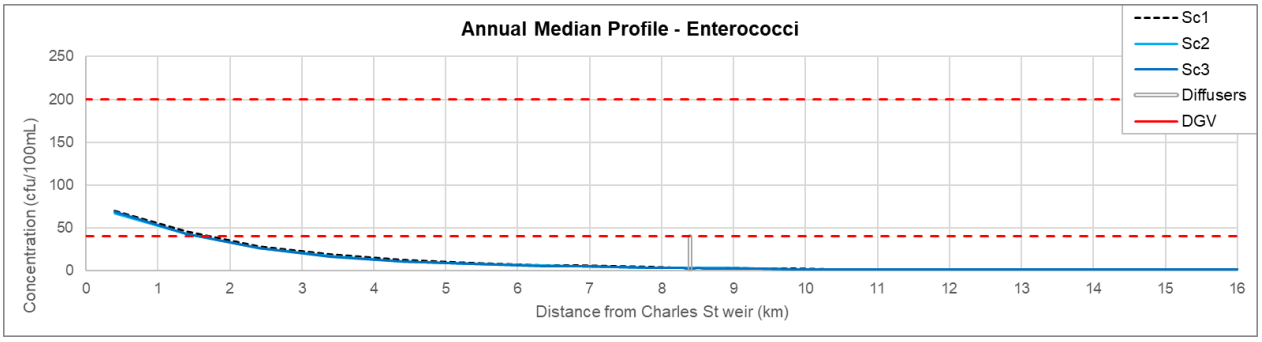


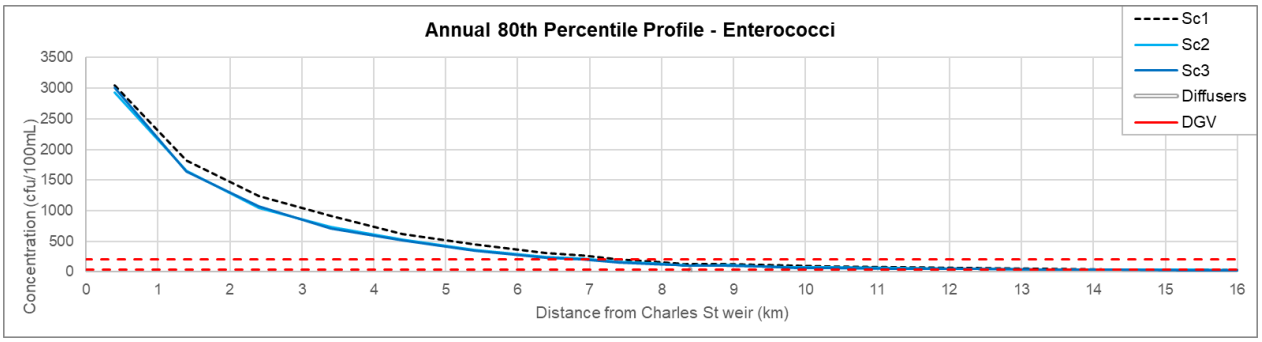




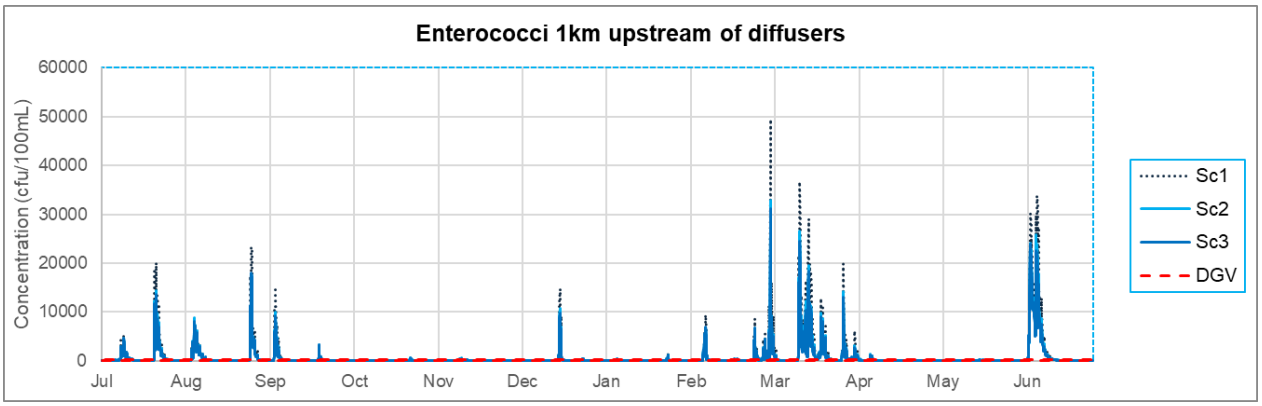
Appendices D1.11.2 Average rainfall year scenario results (2016-2017)

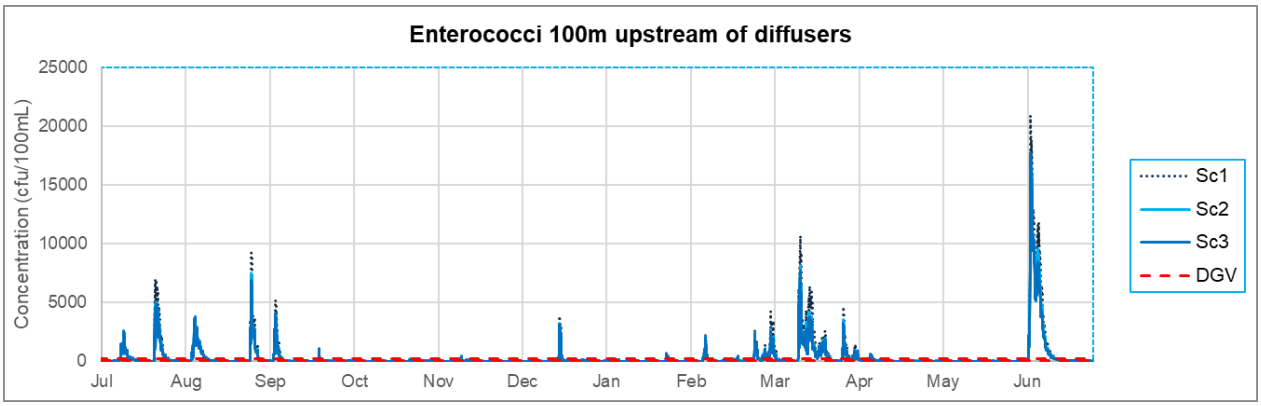
Longitudinal plots

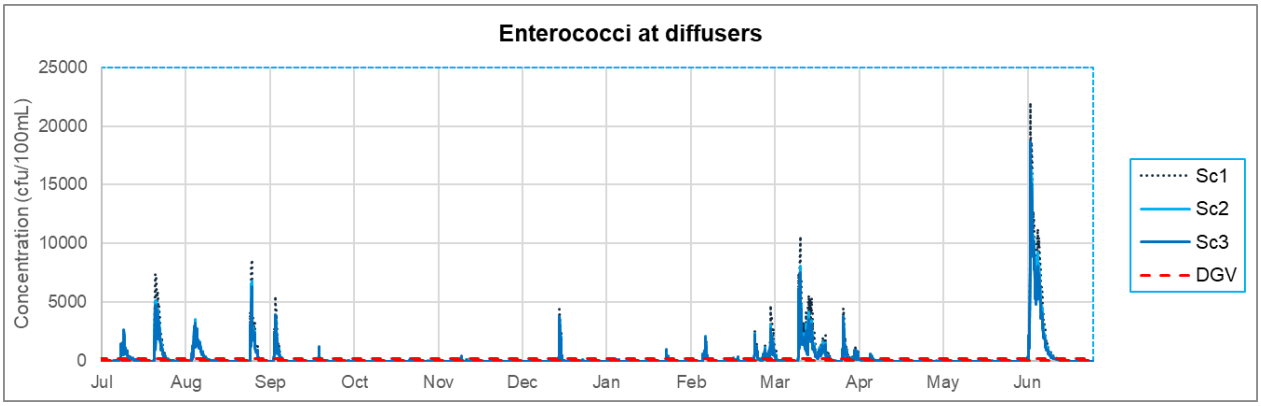


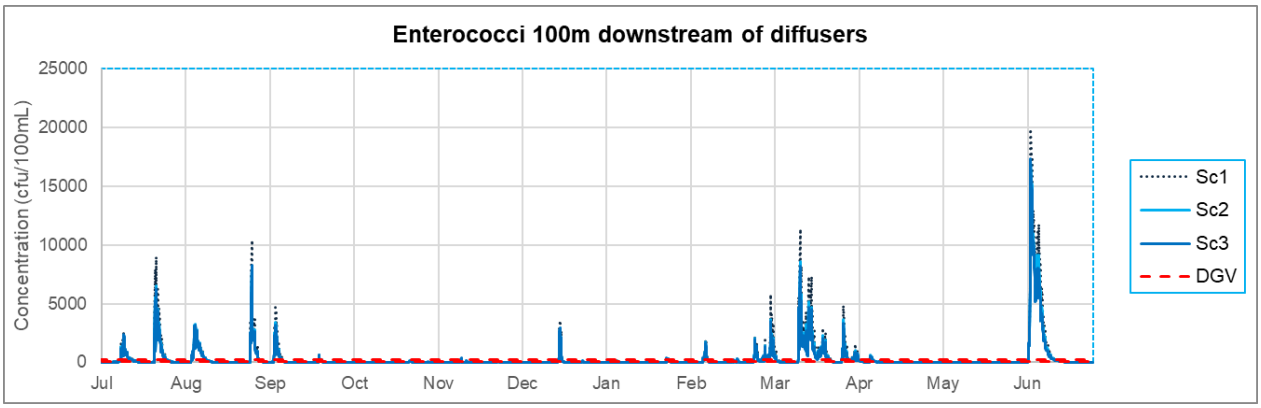


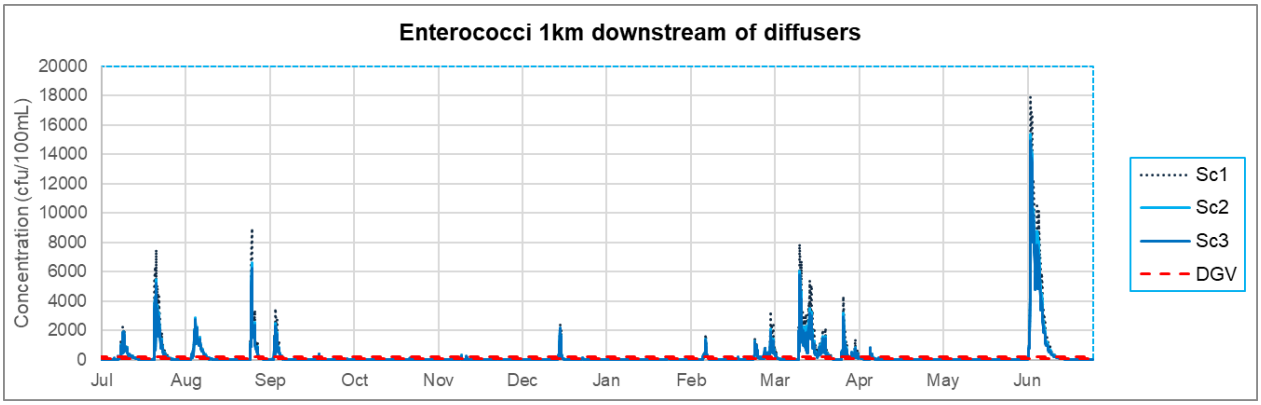
Time series plots




Enterococci 100m upstream of diffusers
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

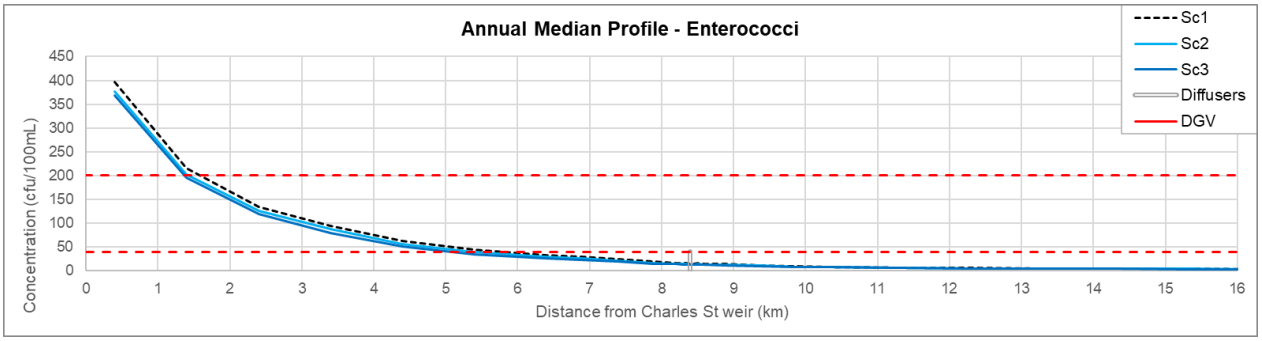

Enterococci at diffusers
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

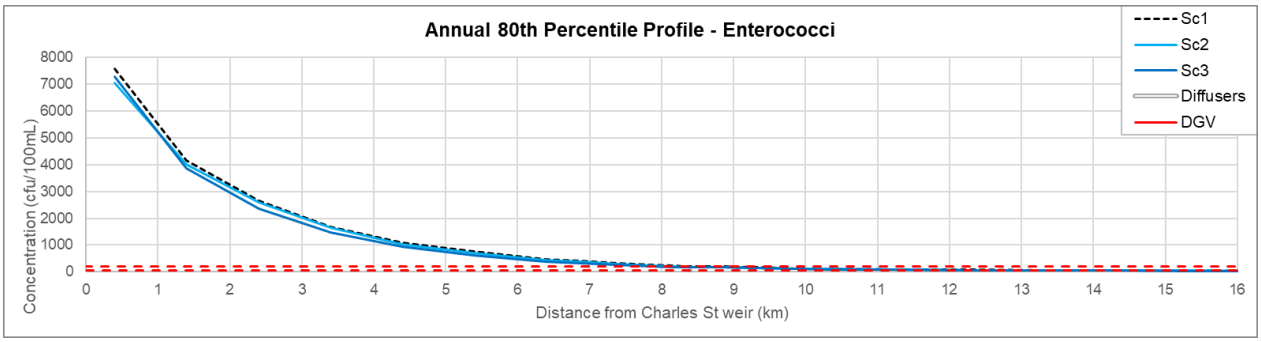

Enterococci 100m downstream of diffusers
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Enterococci 1km downstream of diffusers
Concentration (cfu/100mL)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

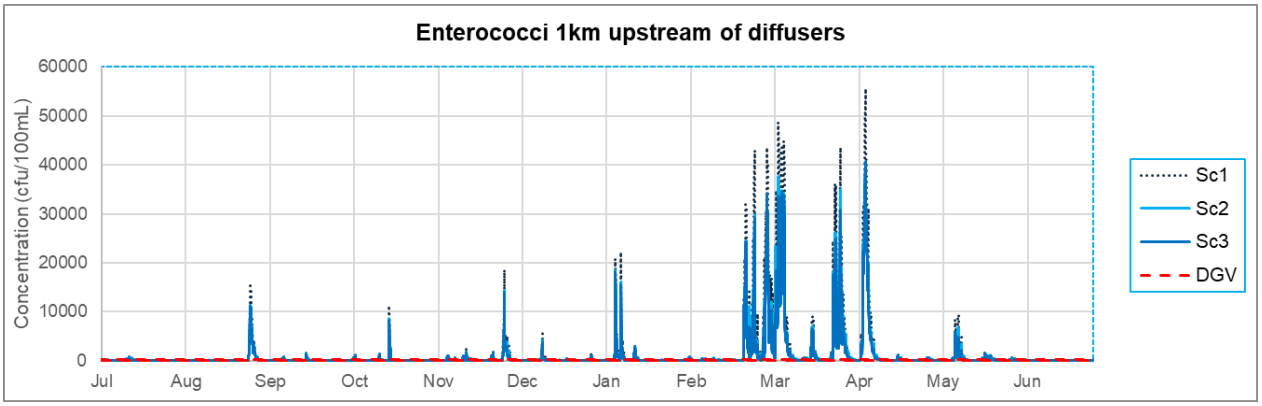
Appendices D1.11.3 Higher rainfall year scenario results (2021-2022)

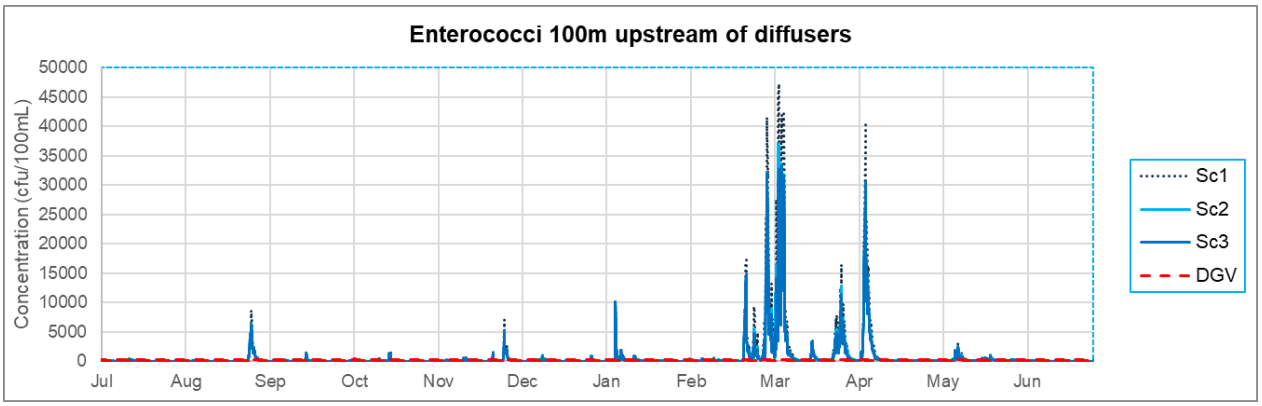
Longitudinal plots

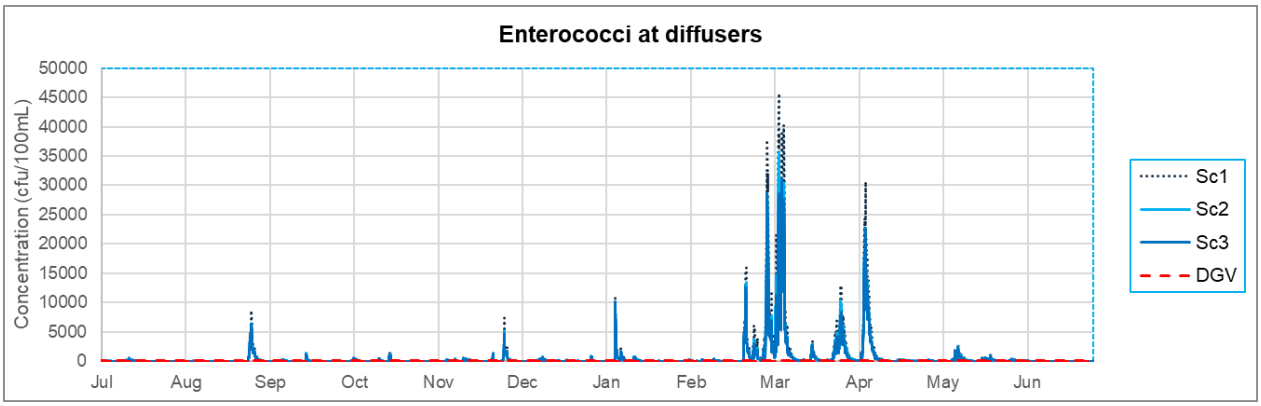


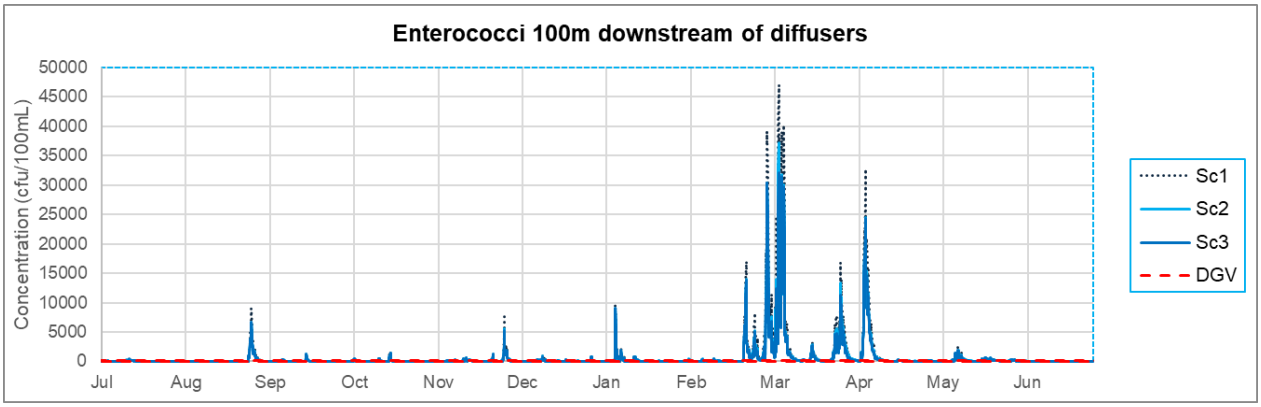


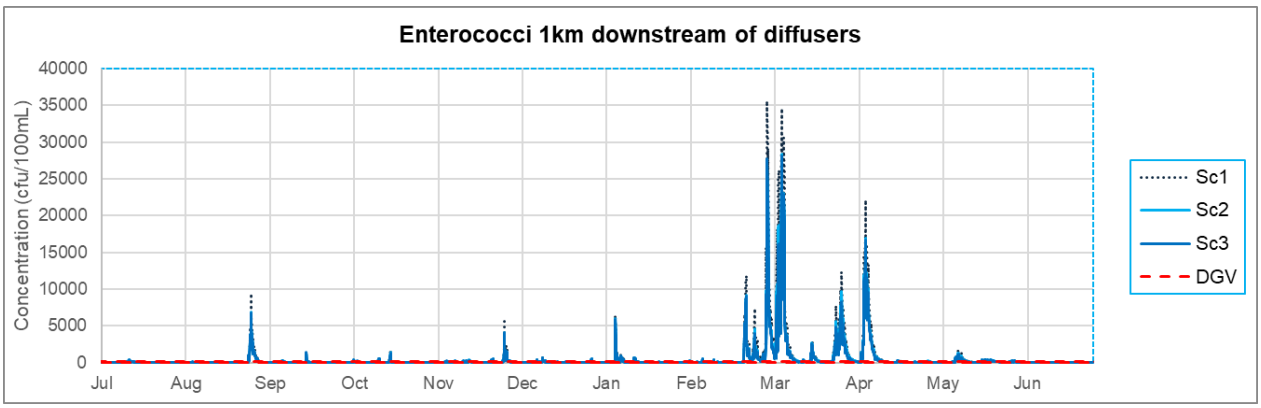
Time series plots






Enterococci at diffusers
Concentration (cfu/100mL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV


Enterococci 100m downstream of diffusers
Concentration (cfu/100mL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

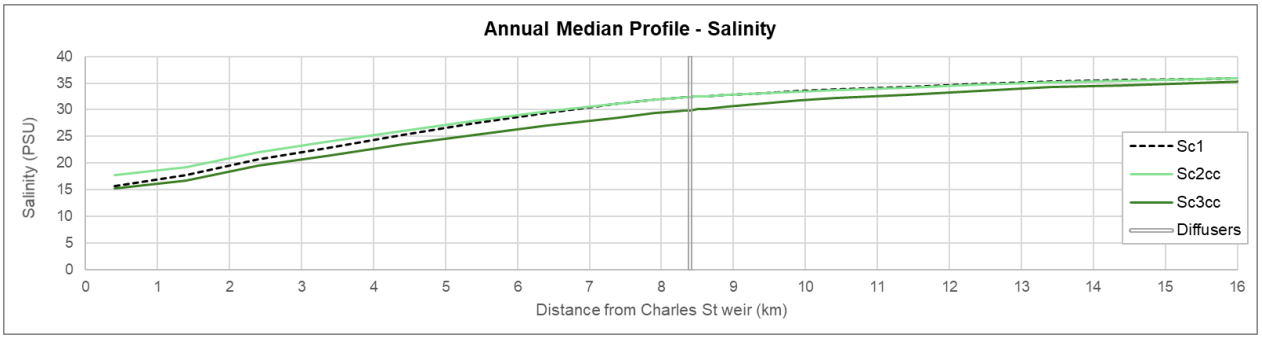

Enterococci 1km downstream of diffusers
Concentration (cfu/100mL)
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3
DGV

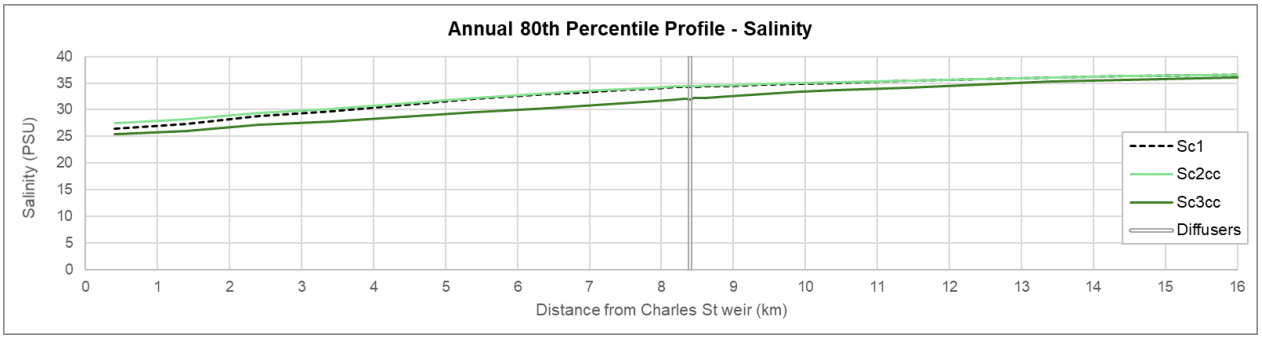
Appendices D2 River Centreline results with climate change

Appendices D2.1 Salinity

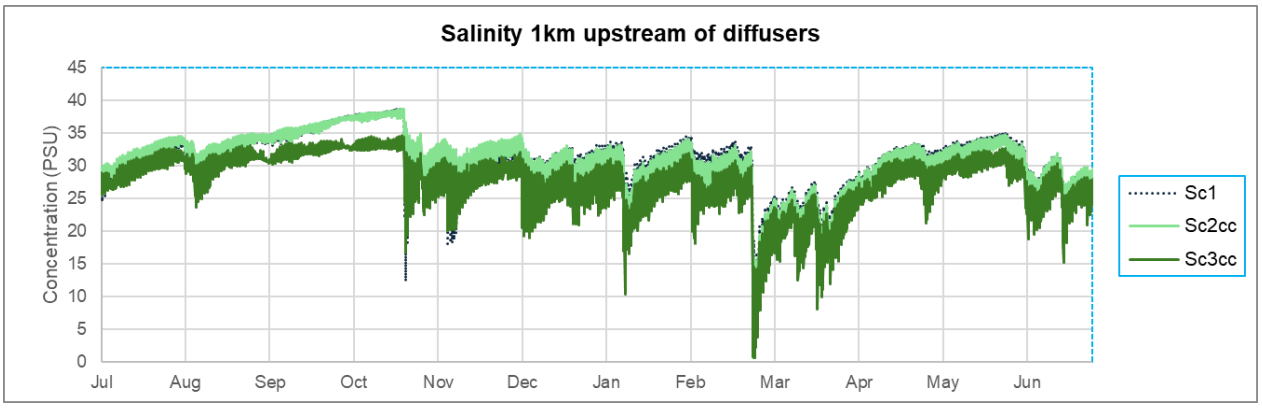
Appendices D2.1.1 Lower rainfall year scenario results (2017-2018)

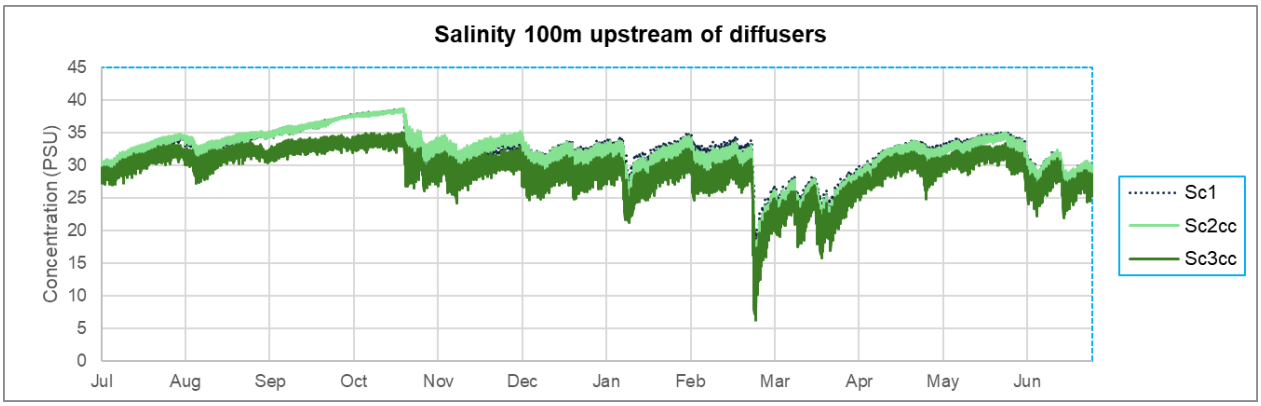
Longitudinal plots

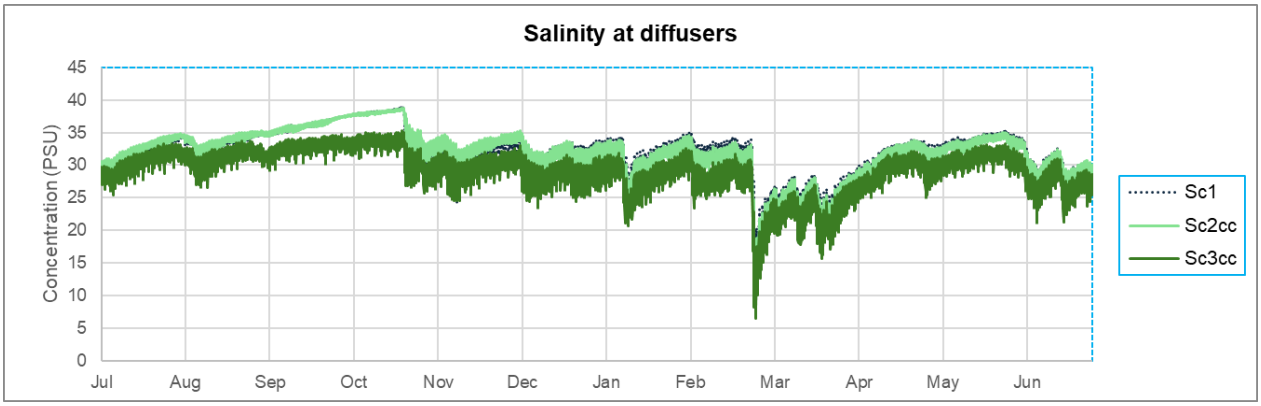


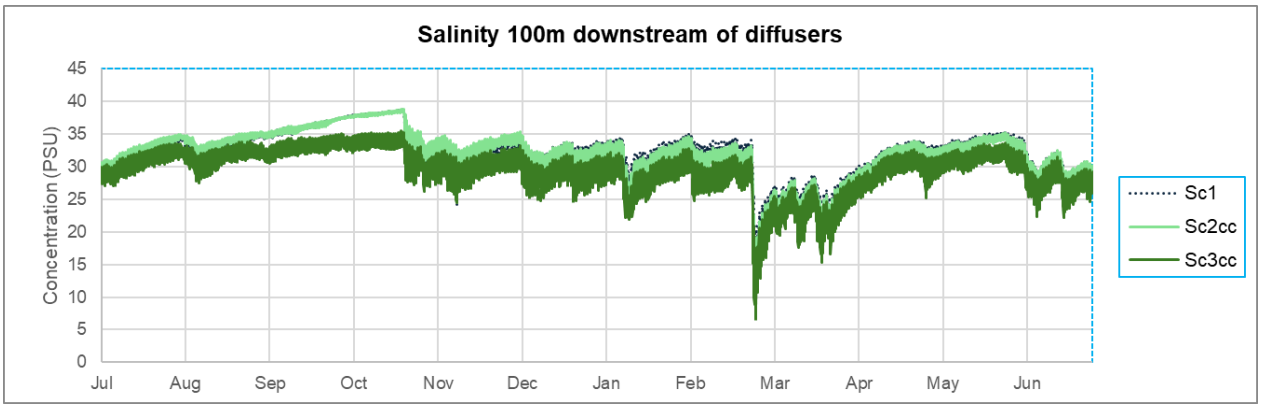


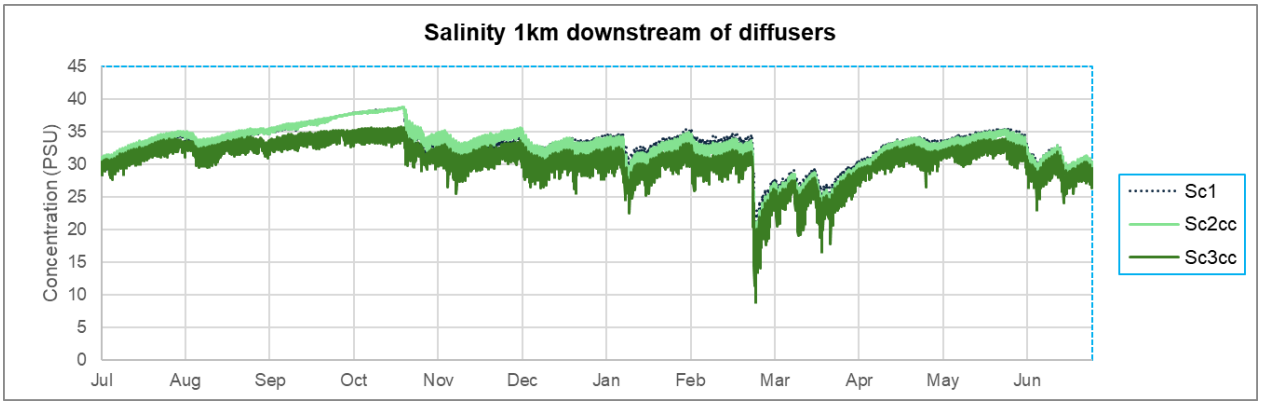
Time series plots




Salinity 100m upstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

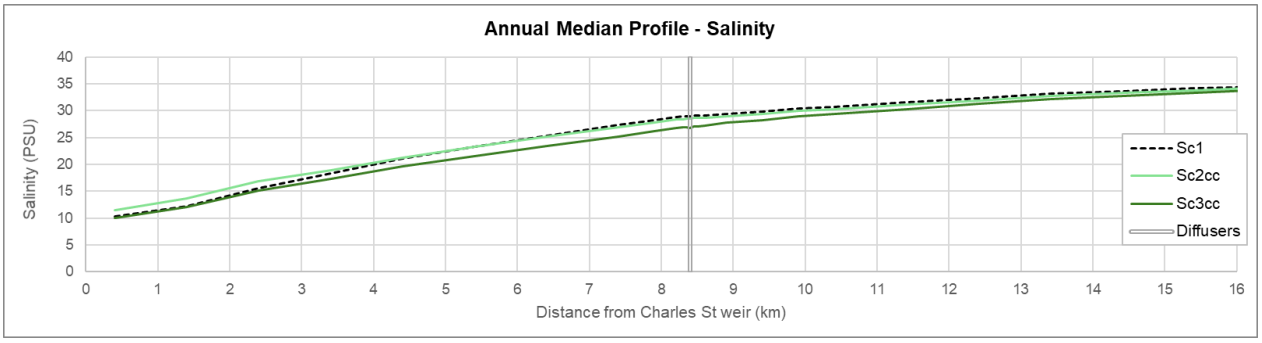

Salinity at diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

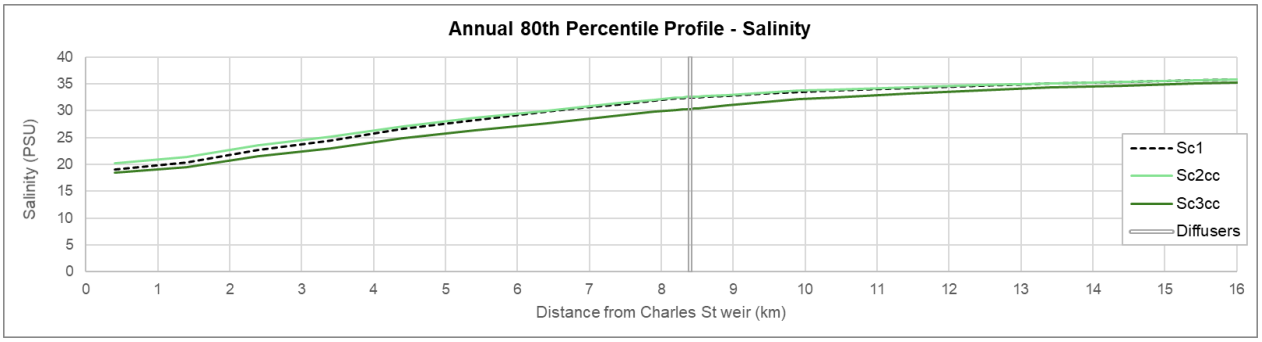

Salinity 100m downstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Salinity 1km downstream of diffusers
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

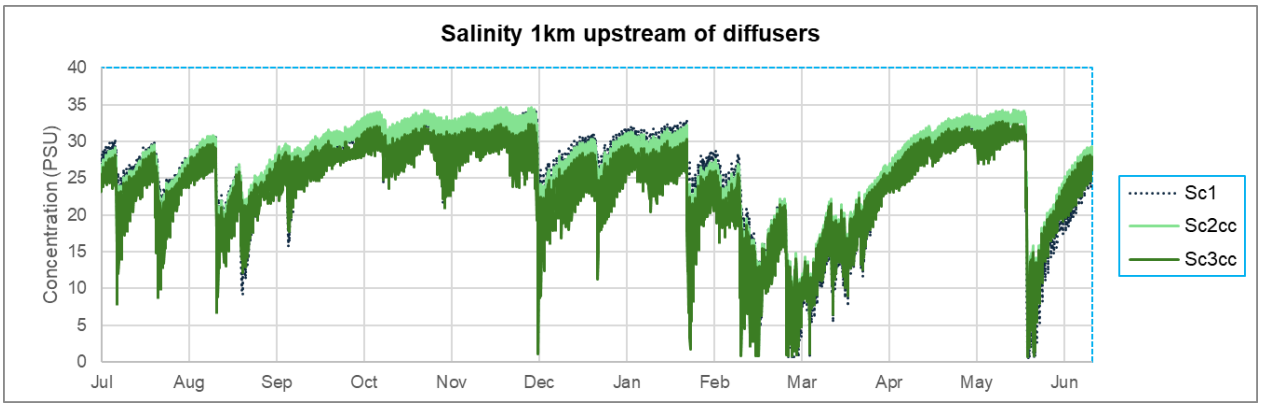
Appendices D2.1.2 Average rainfall year scenario results (2016-2017)

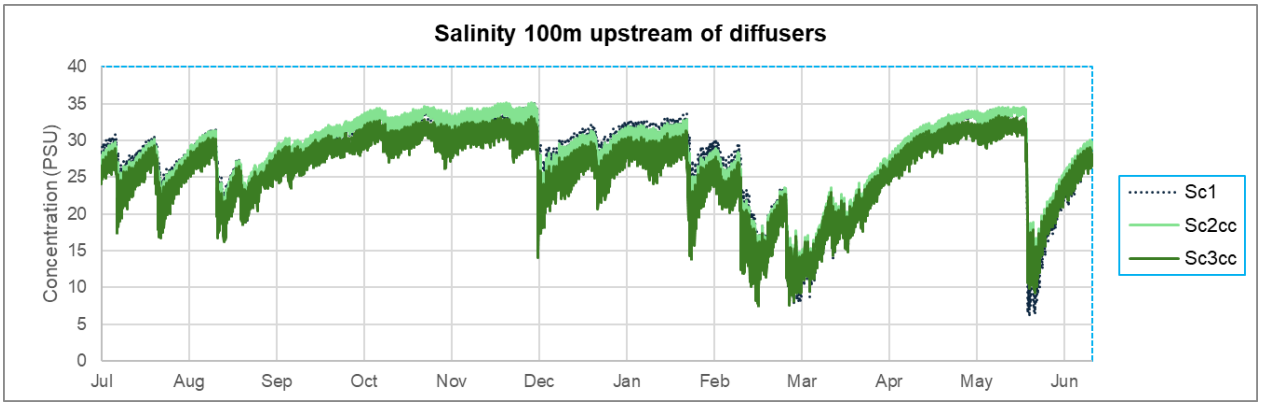
Longitudinal plots

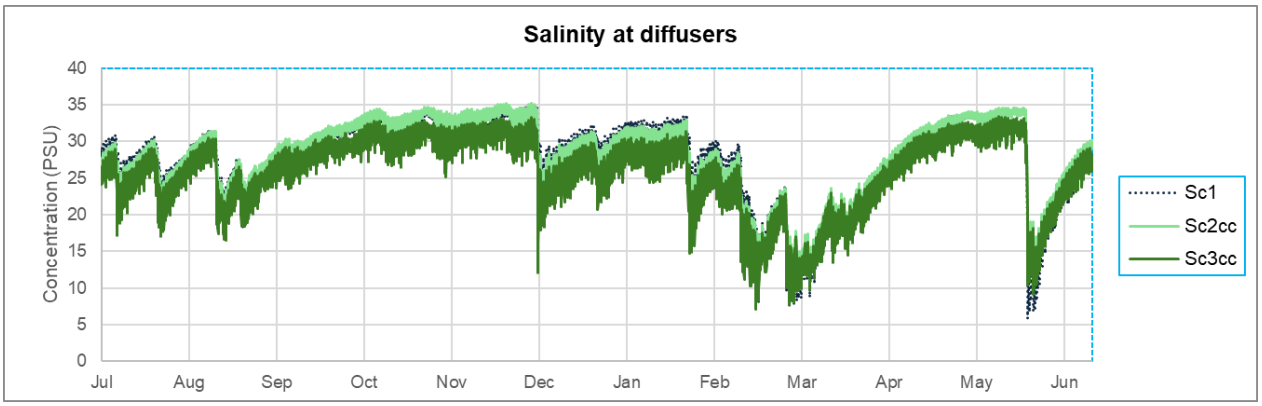


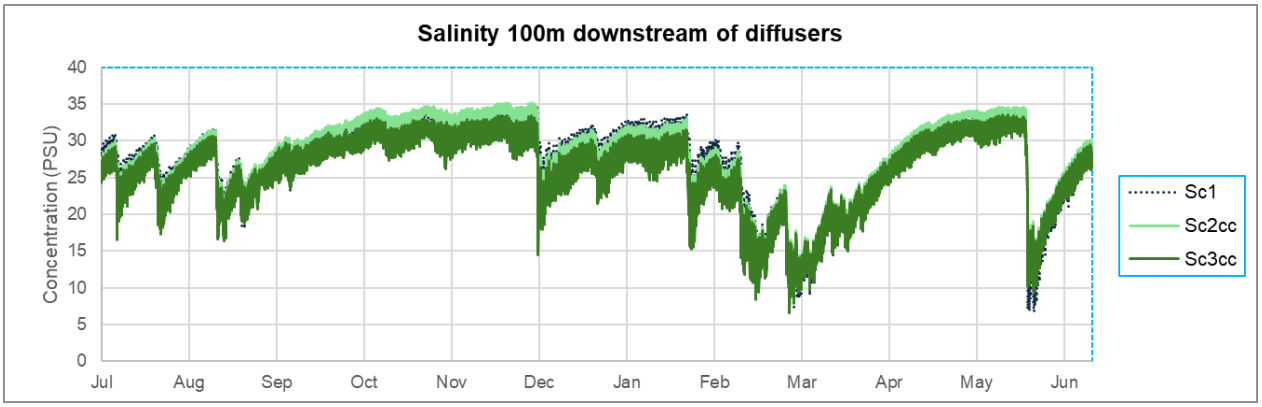


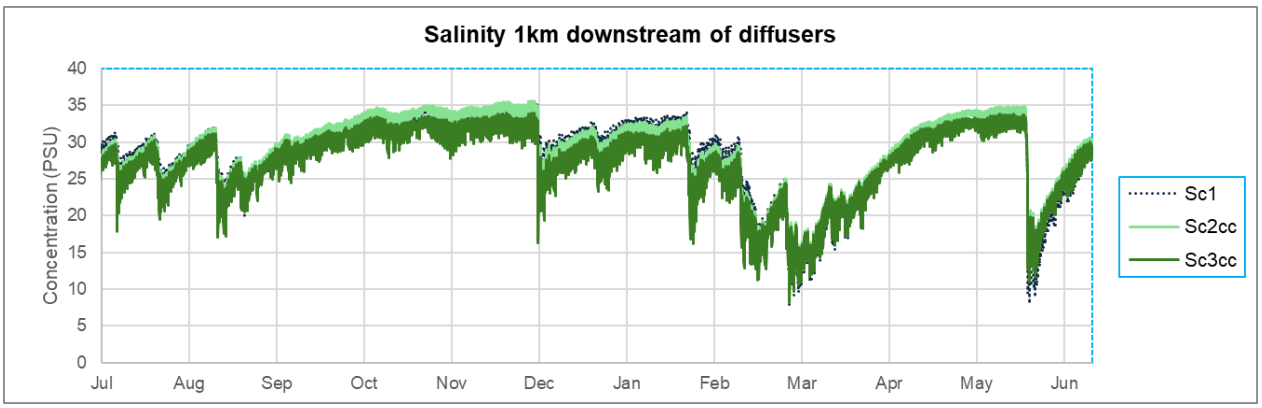
Time series plots





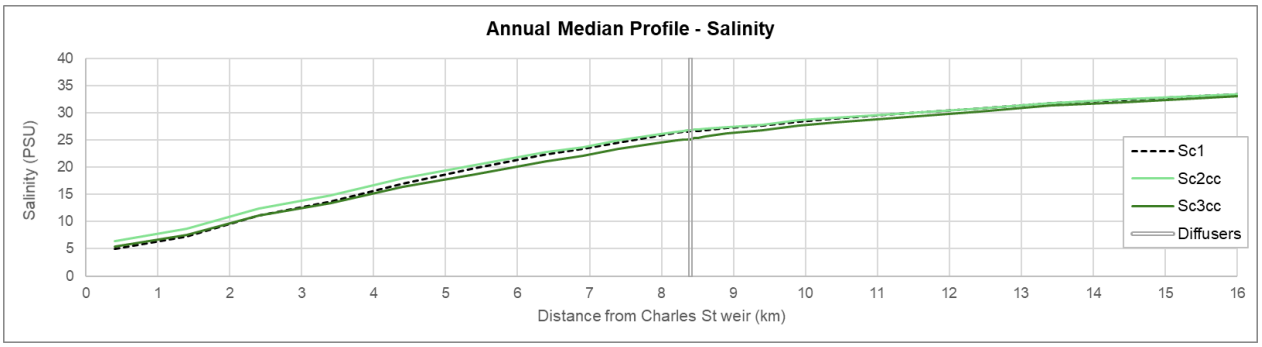


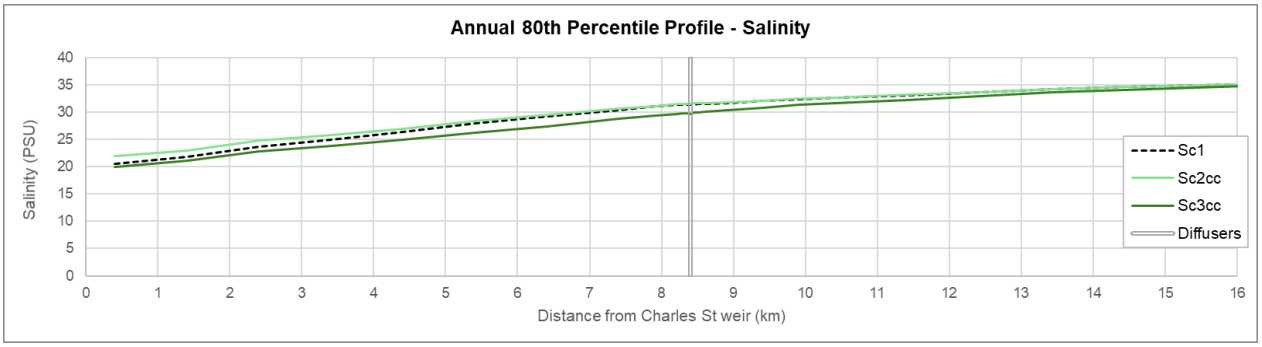




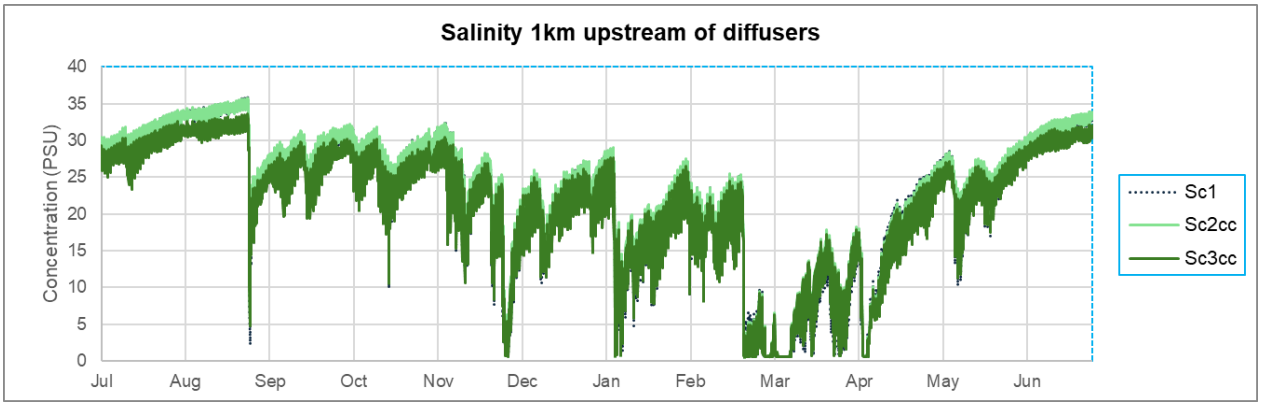
Appendices D2.1.3 Higher rainfall year scenario results (2021-2022)

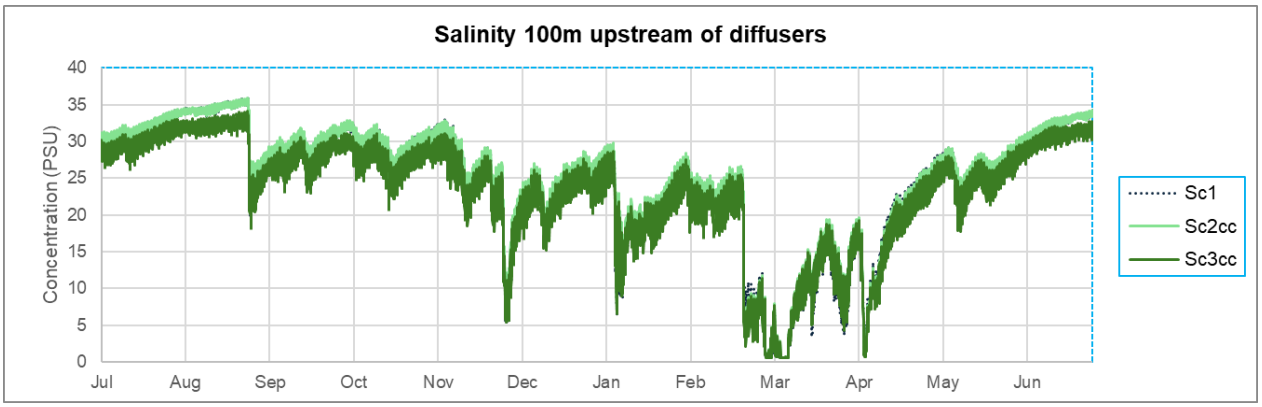
Longitudinal plots

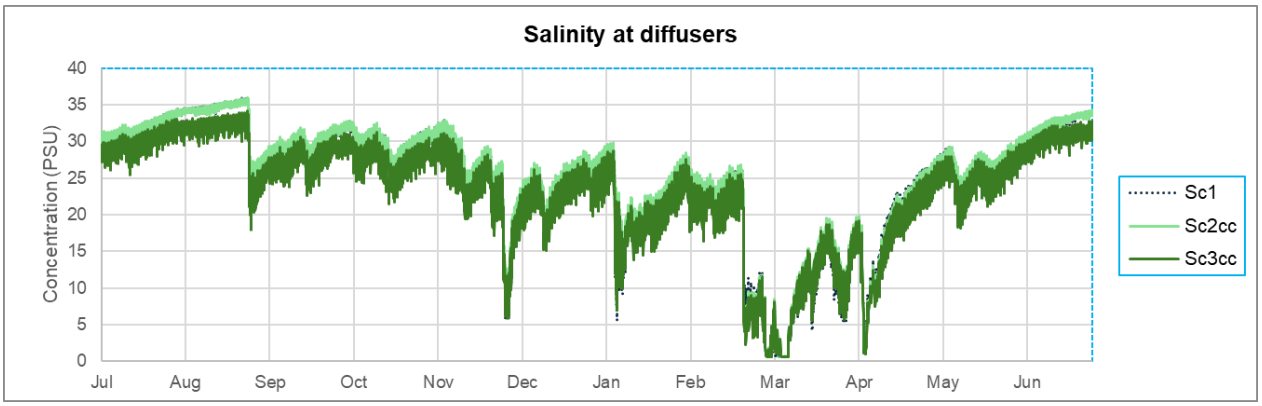


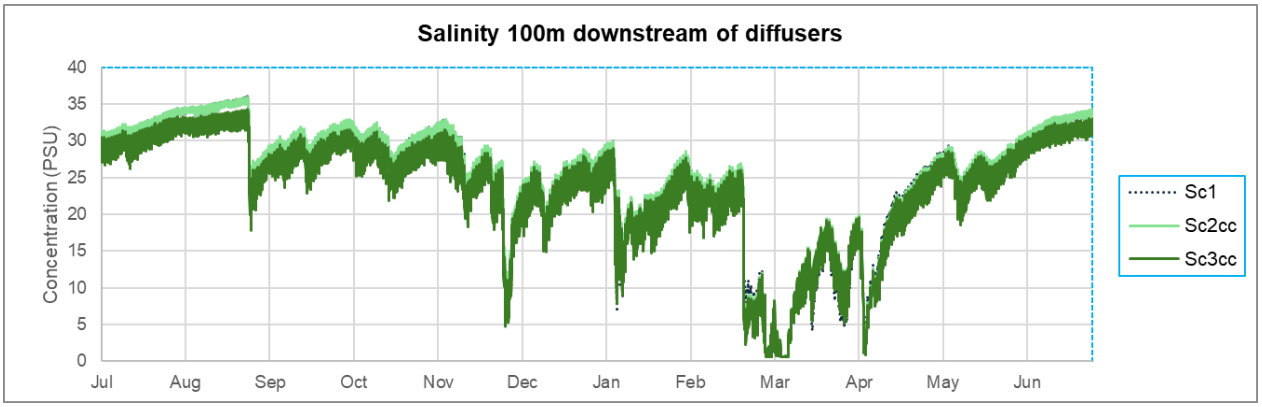


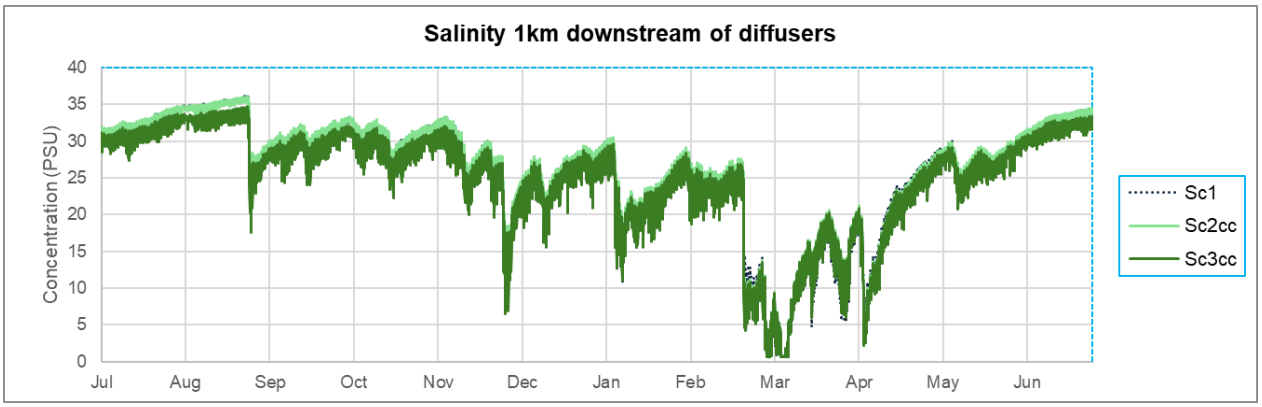
Time series plots







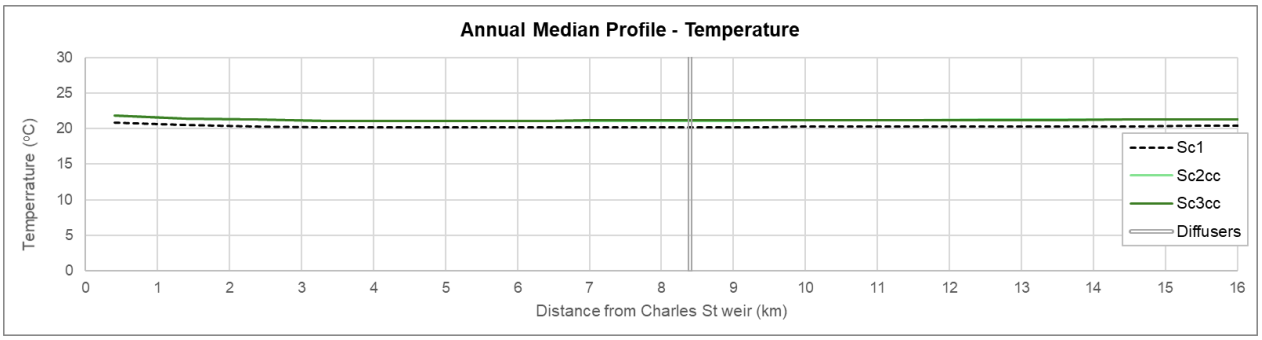


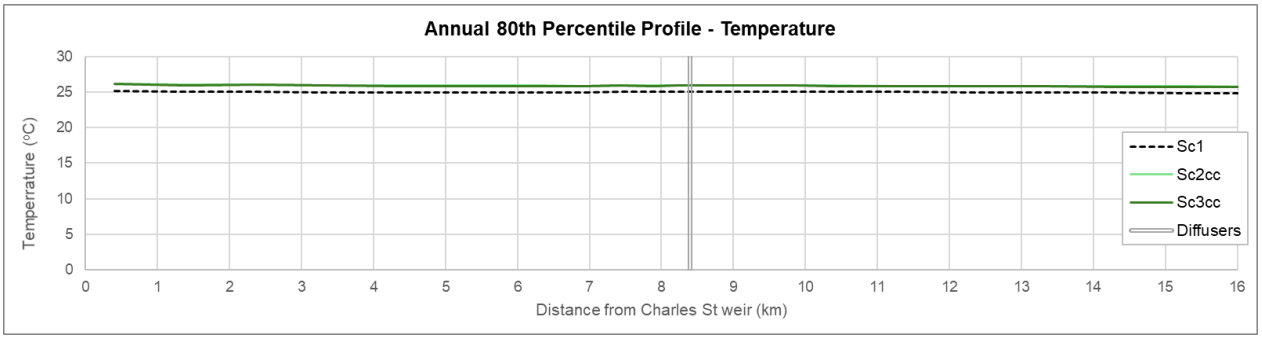


Appendices D2.2 Temperature

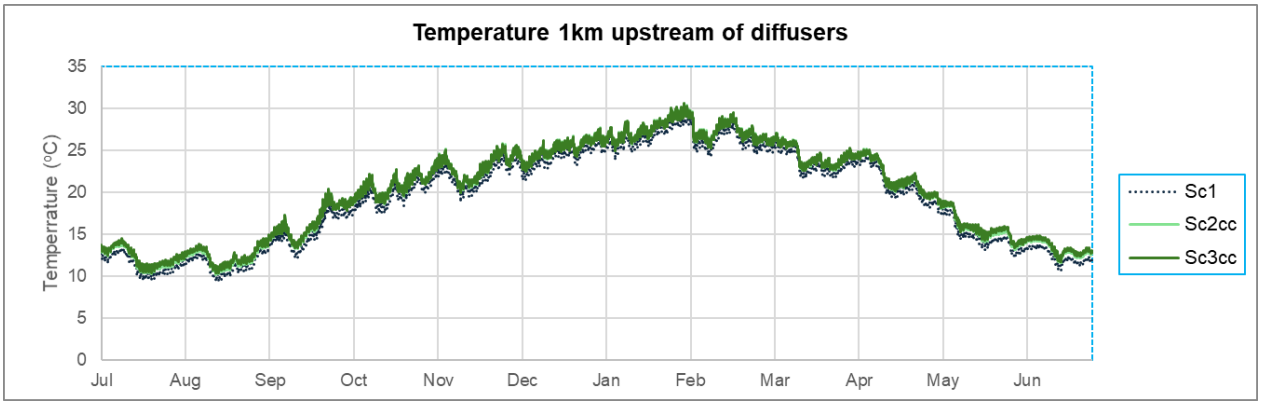
Appendices D2.2.1 Lower rainfall year scenario results (2017-2018)

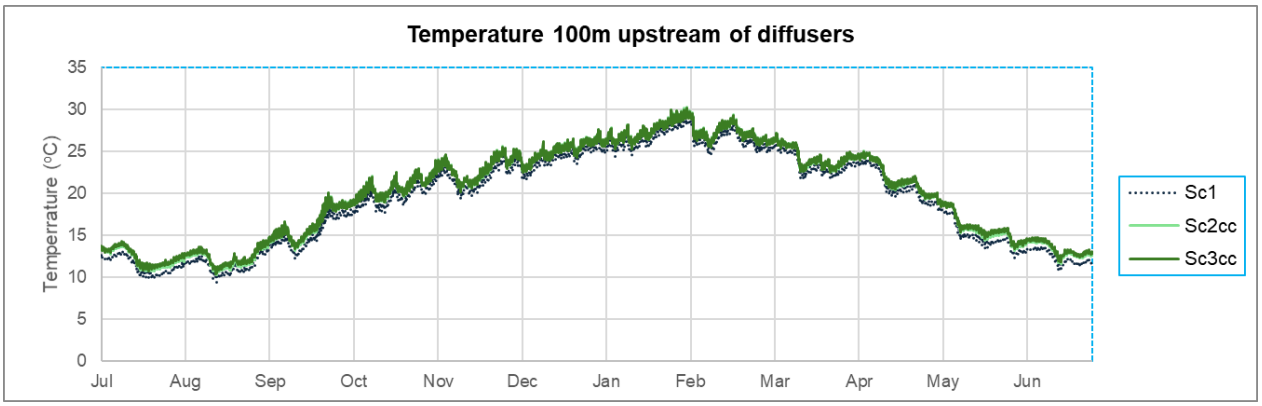
Longitudinal plots

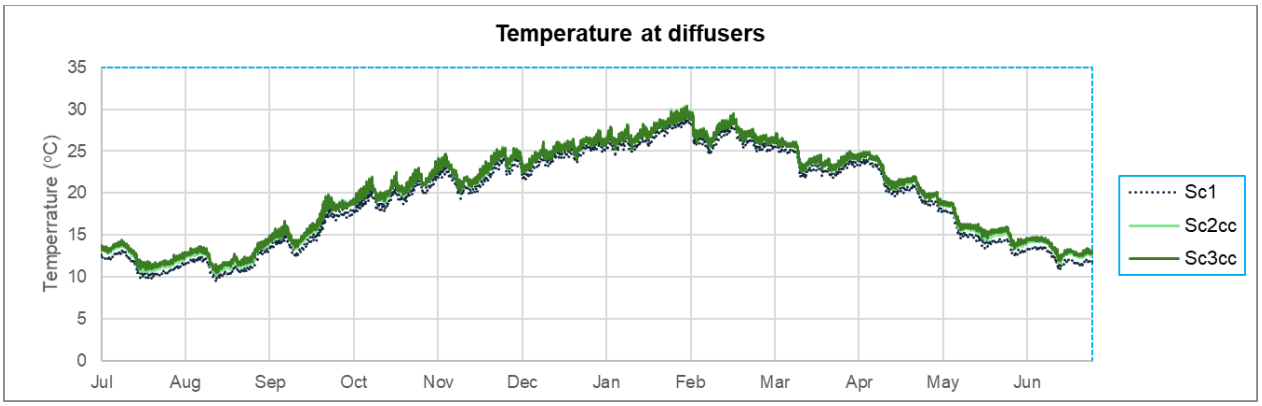


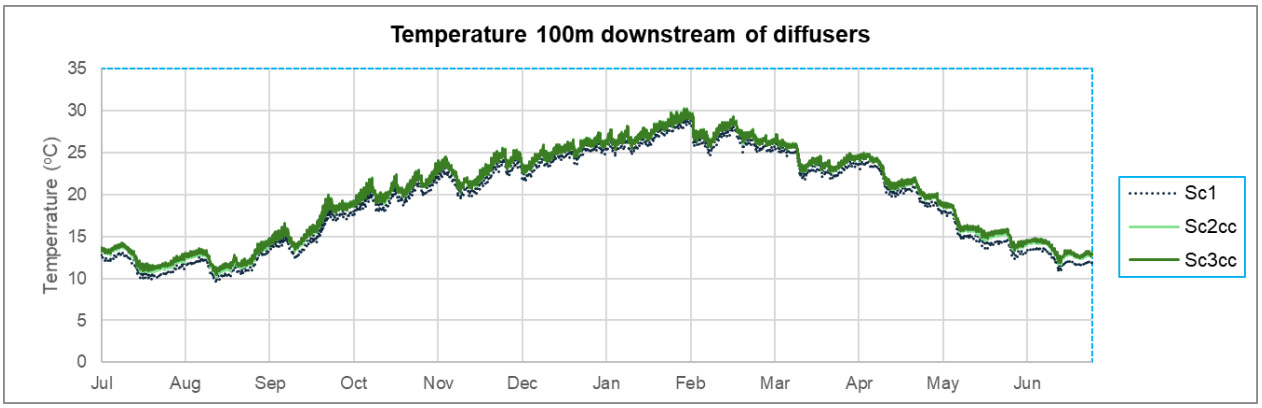


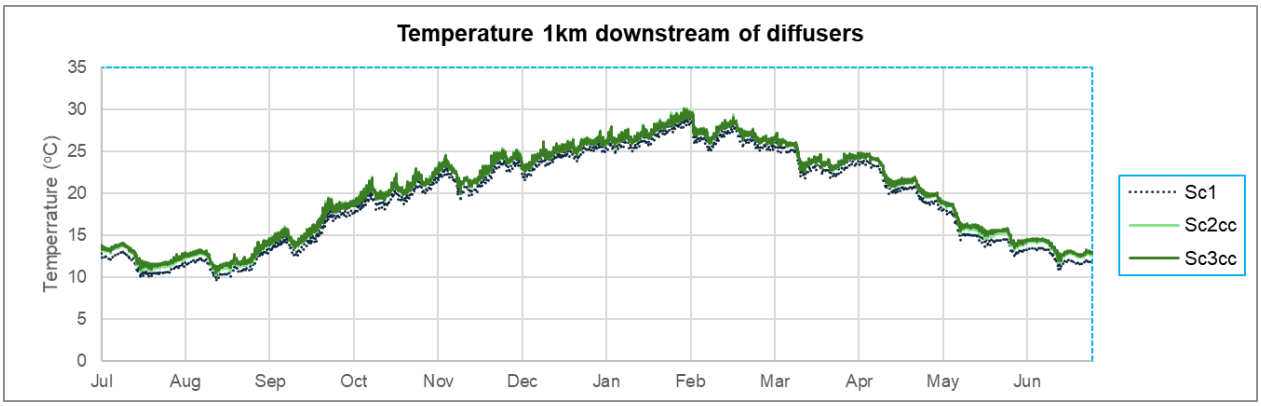
Time series plots





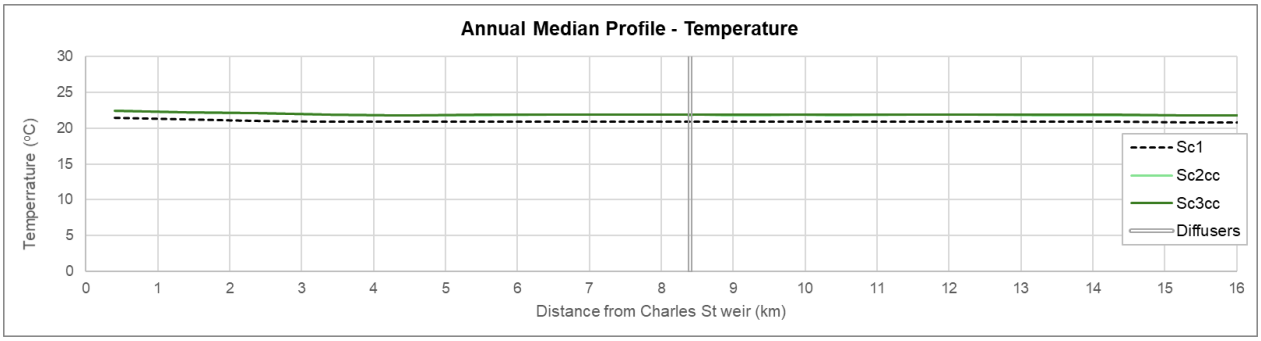


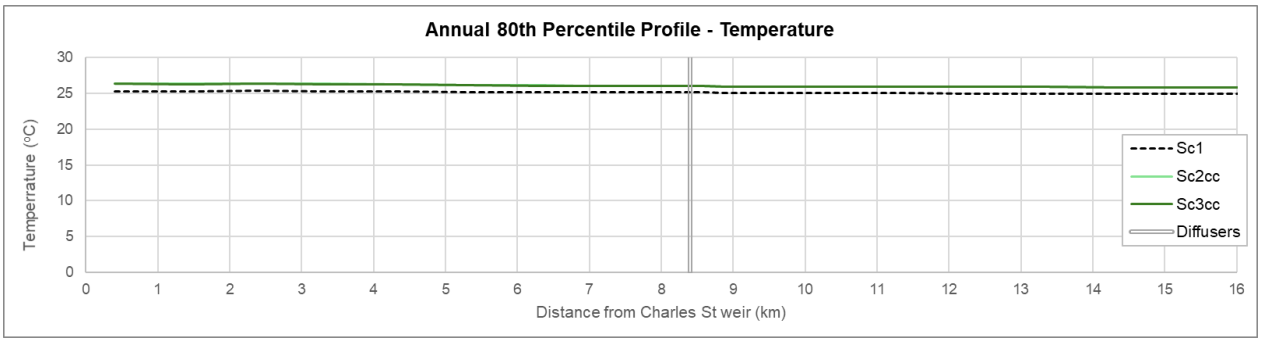




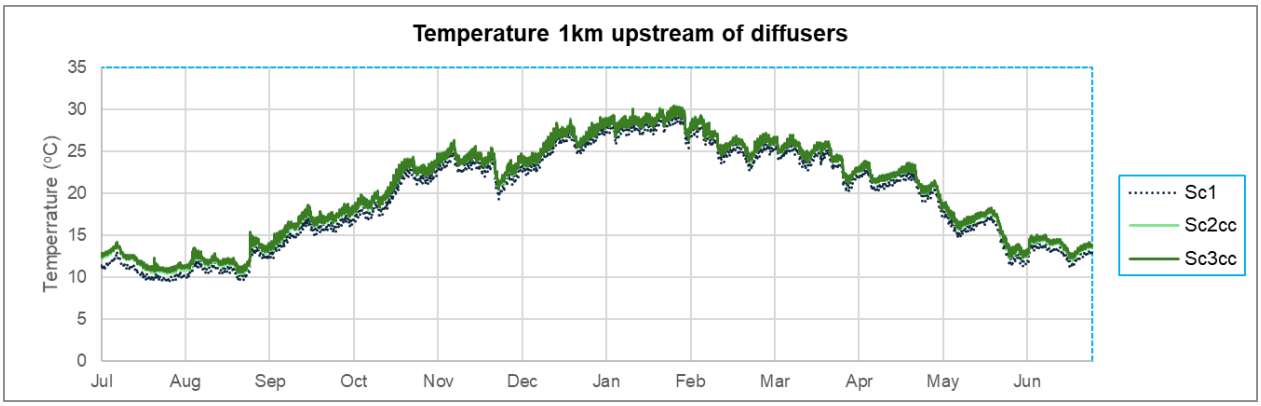
Appendices D2.2.2 Average rainfall year scenario results (2016-2017)

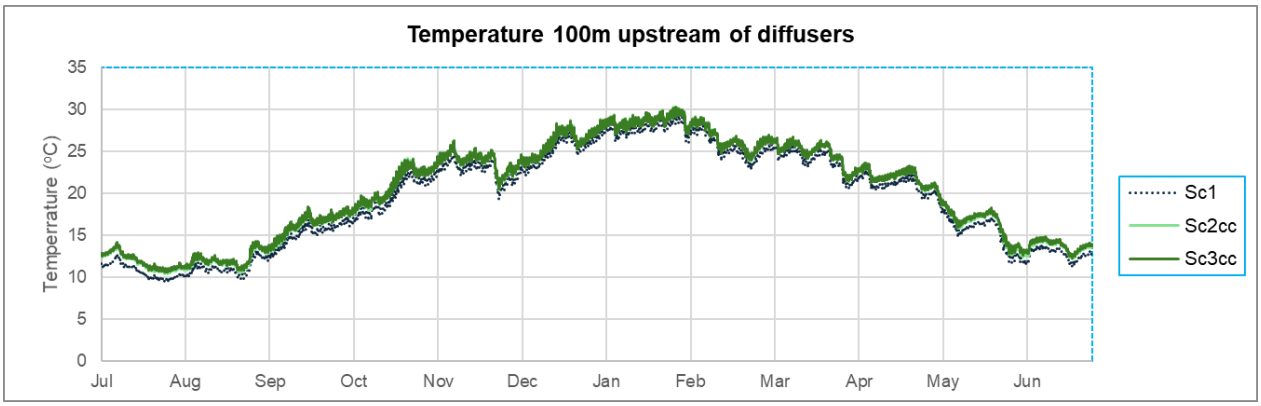
Longitudinal plots

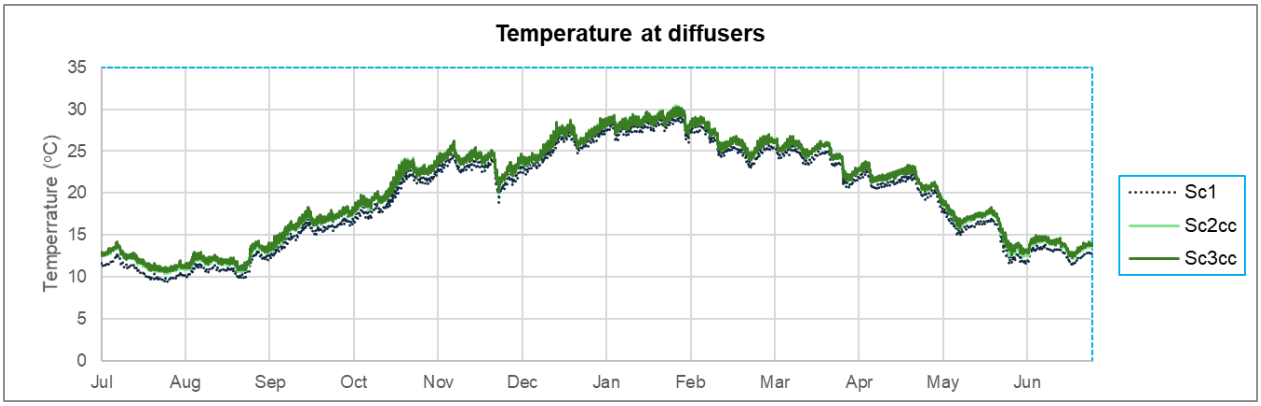


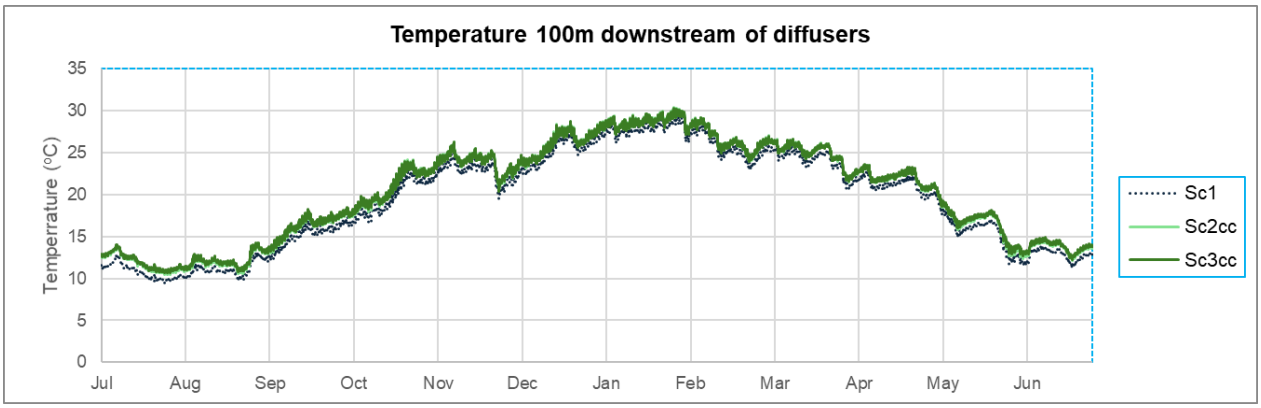


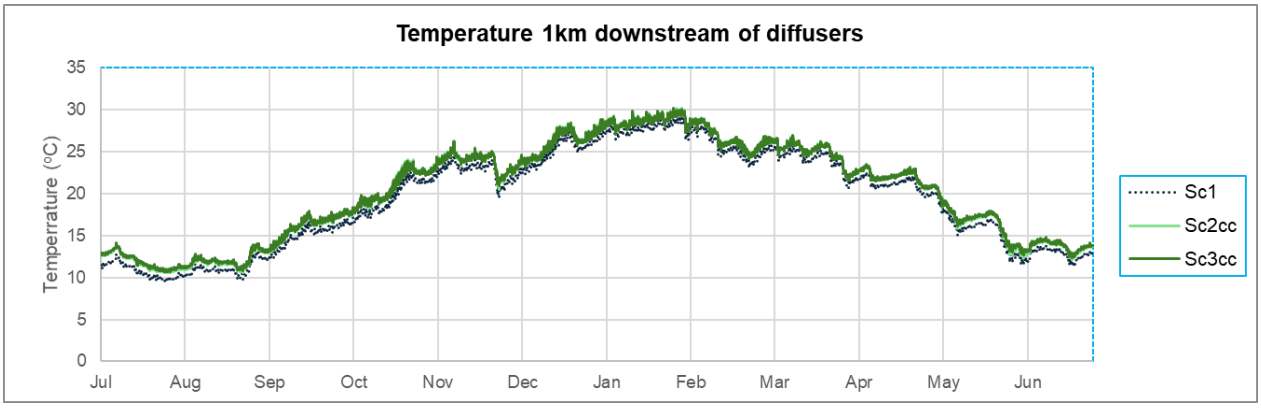
Time series plots




Temperature 100m upstream of diffusers
Temperrature (°C)
0
5
10
15
20
25
30
35
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

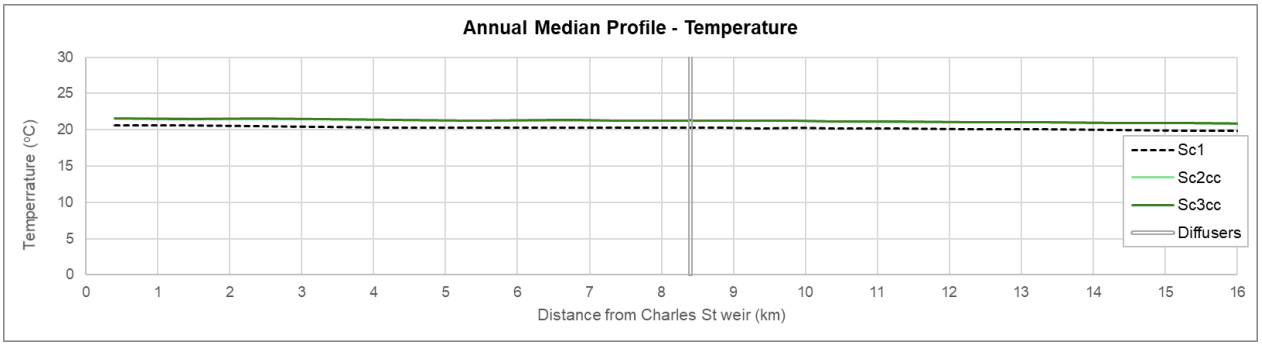

Temperature at diffusers
Temperrature (°C)
0
5
10
15
20
25
30
35
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

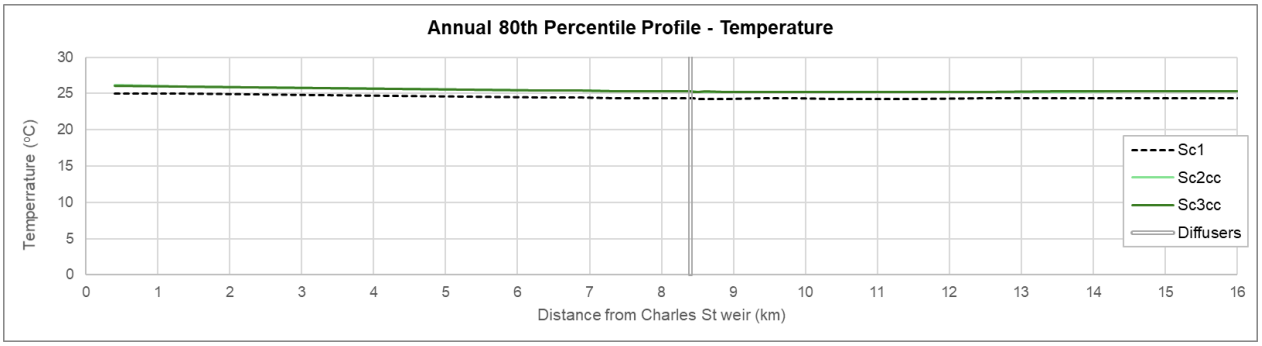

Temperature 100m downstream of diffusers
Temperrature (°C)
0
5
10
15
20
25
30
35
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Temperature 1km downstream of diffusers
Temperrature (°C)
0
5
10
15
20
25
30
35
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

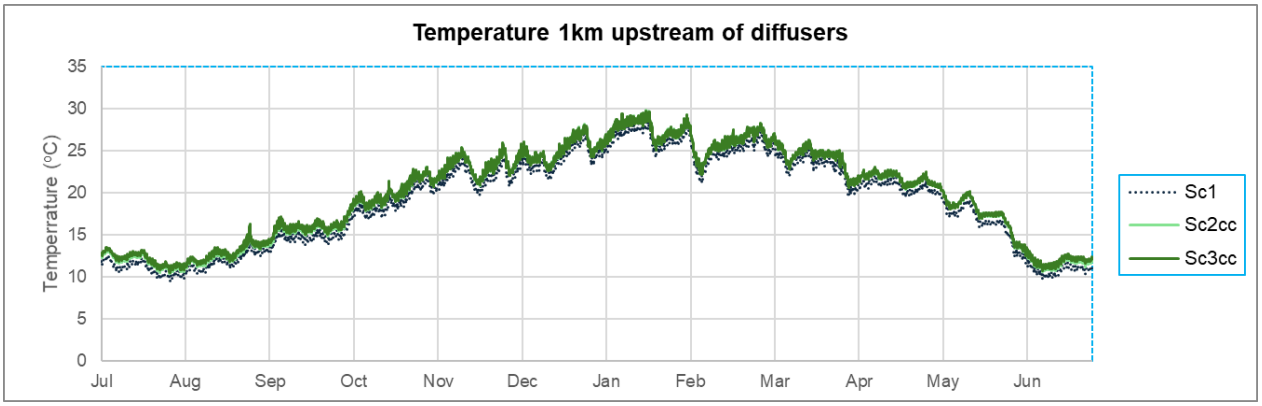
Appendices D2.2.3 Higher rainfall year scenario results (2021-2022)

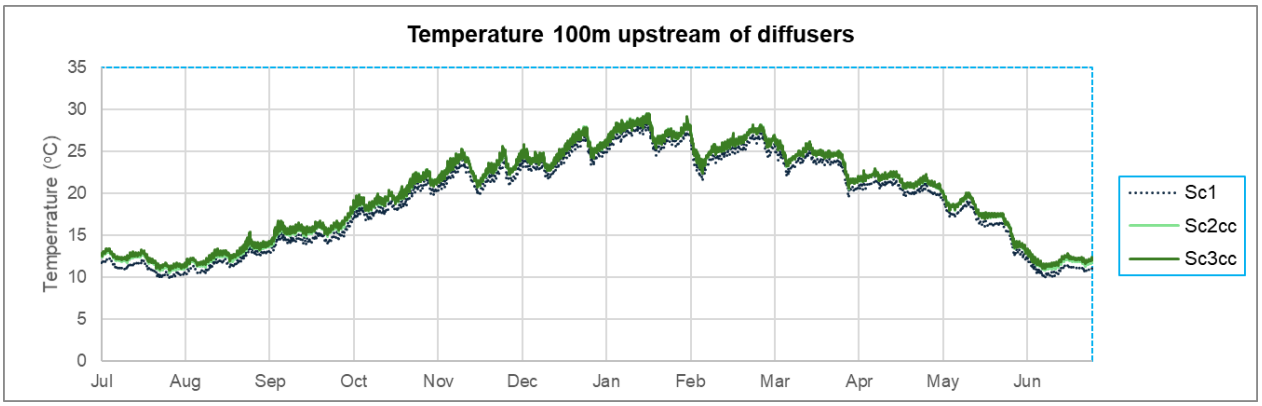
Longitudinal plots

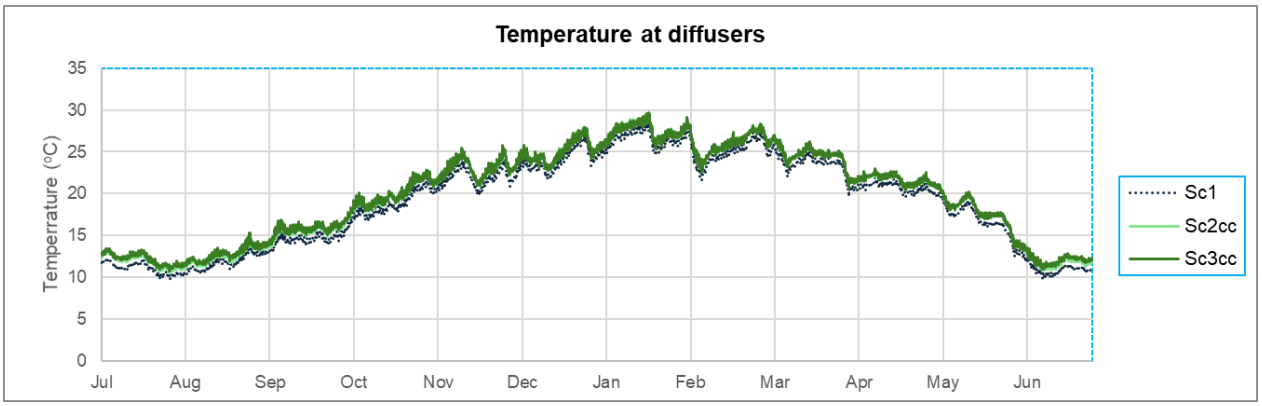


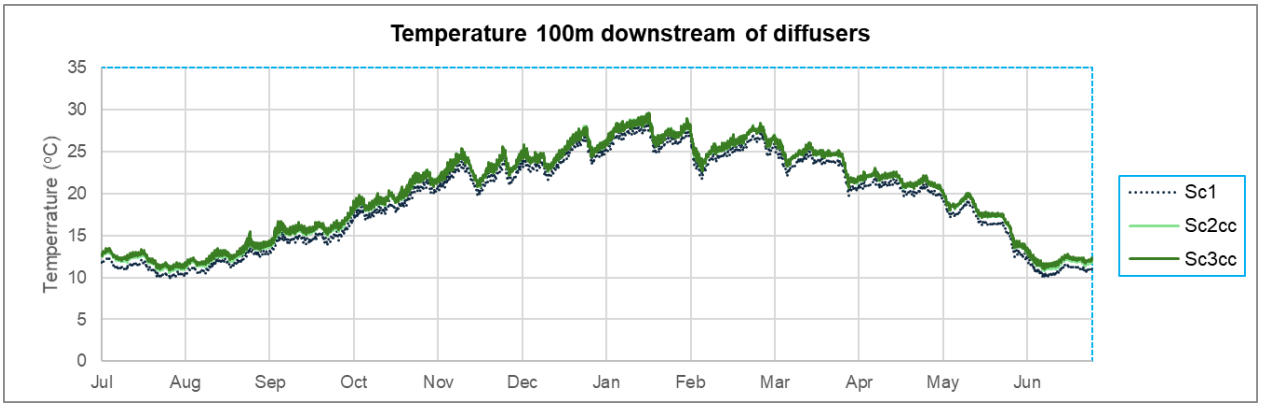


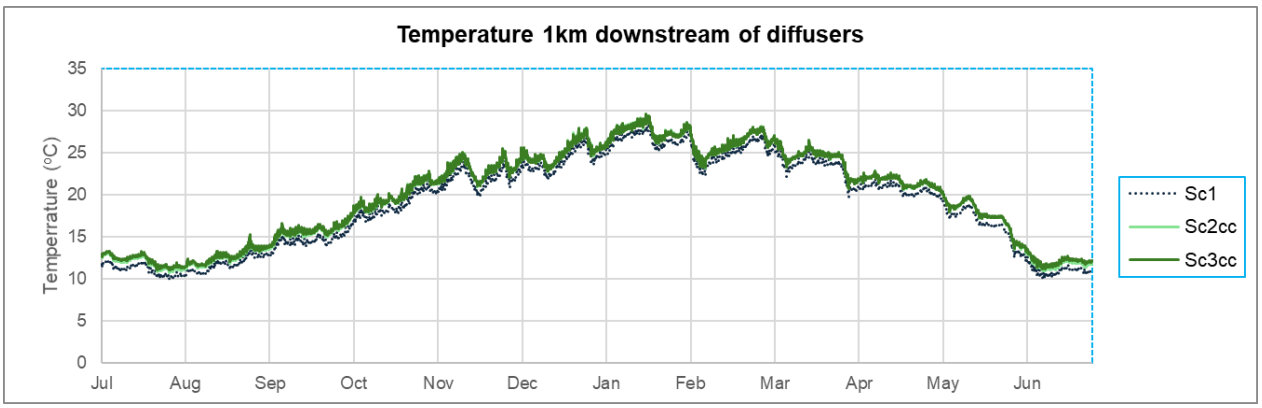
Time series plots






Temperature at diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

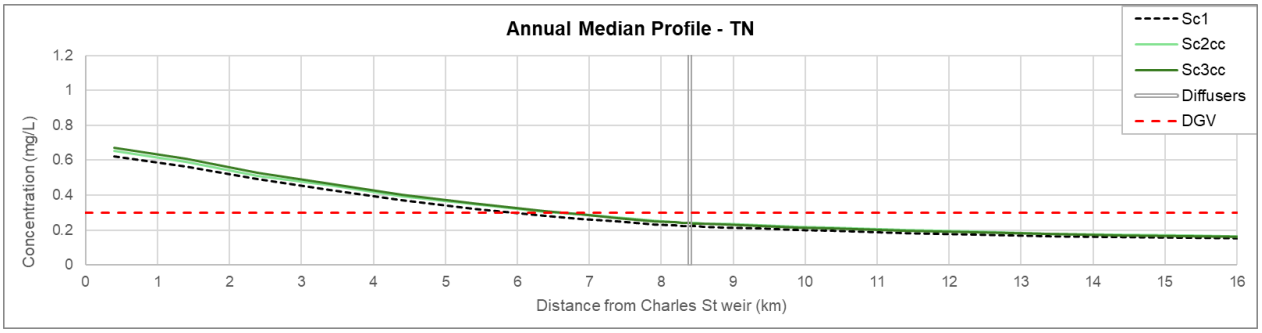

Temperature 100m downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

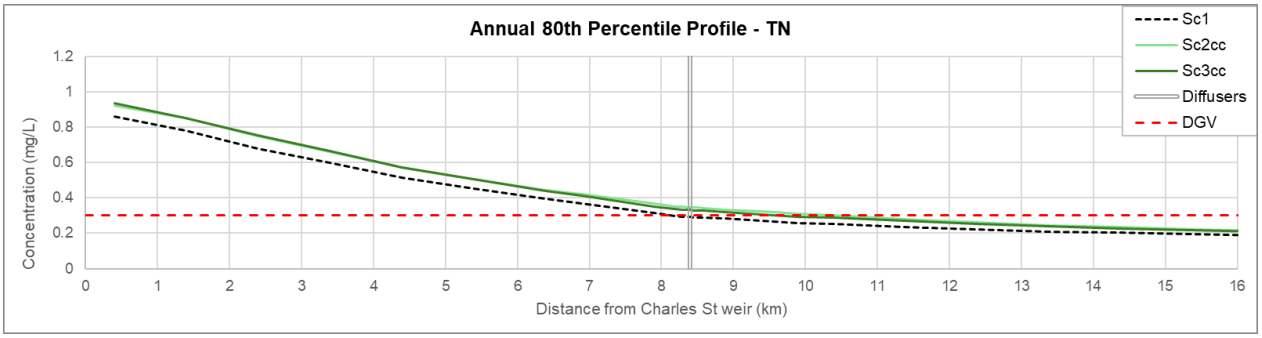

Temperature 1km downstream of diffusers
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D2.3 Total N

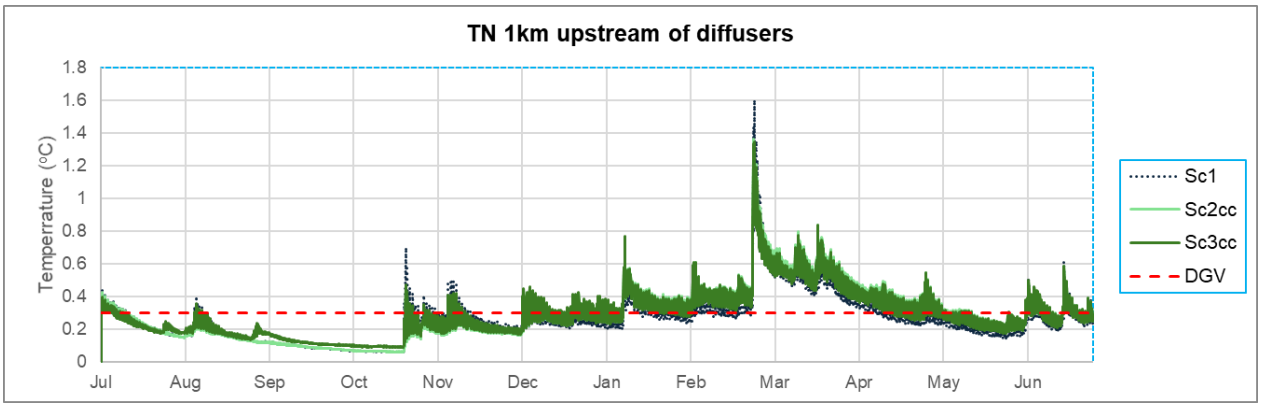
Appendices D2.3.1 Lower rainfall year scenario results (2017-2018)

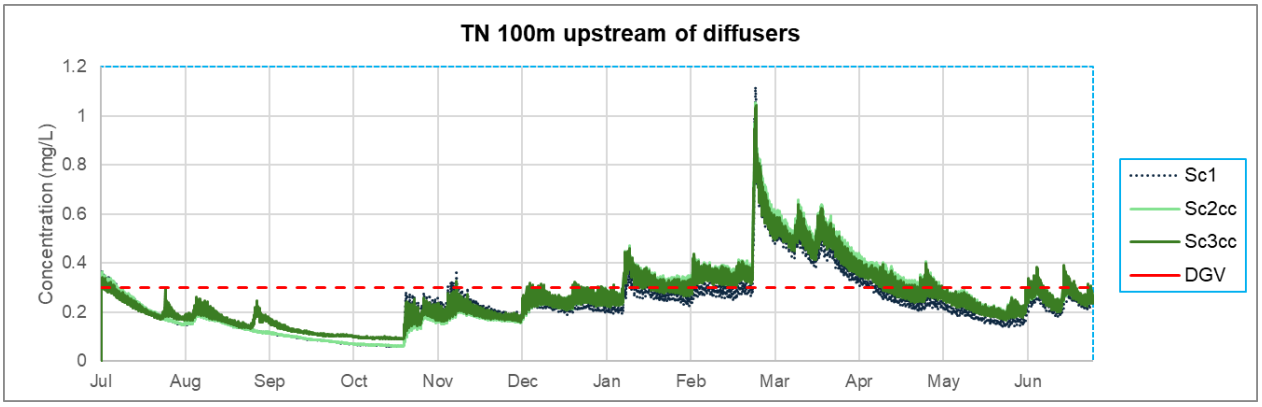
Longitudinal plots

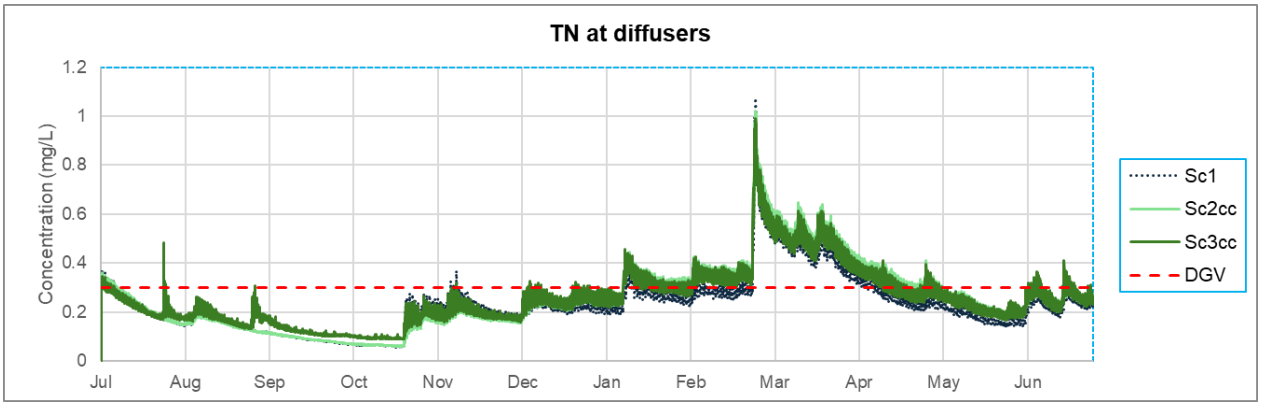


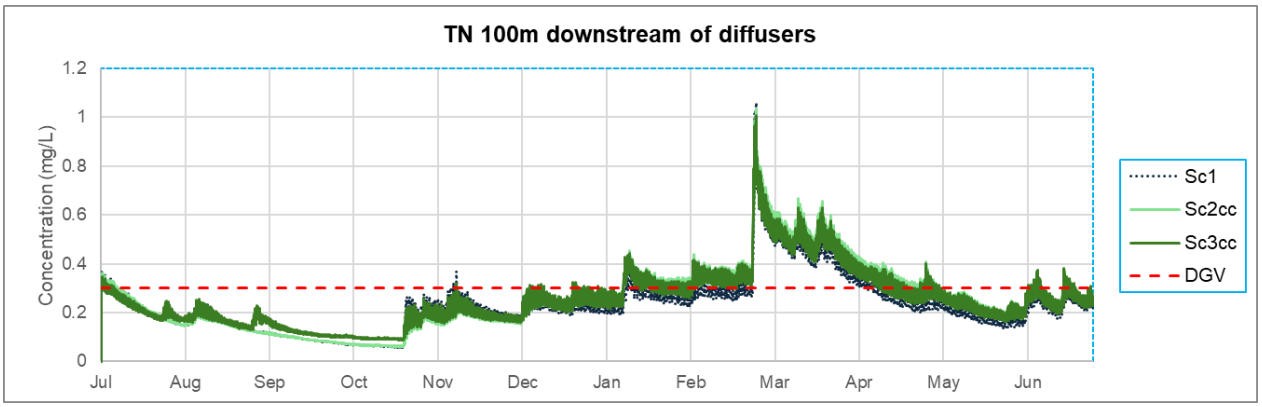


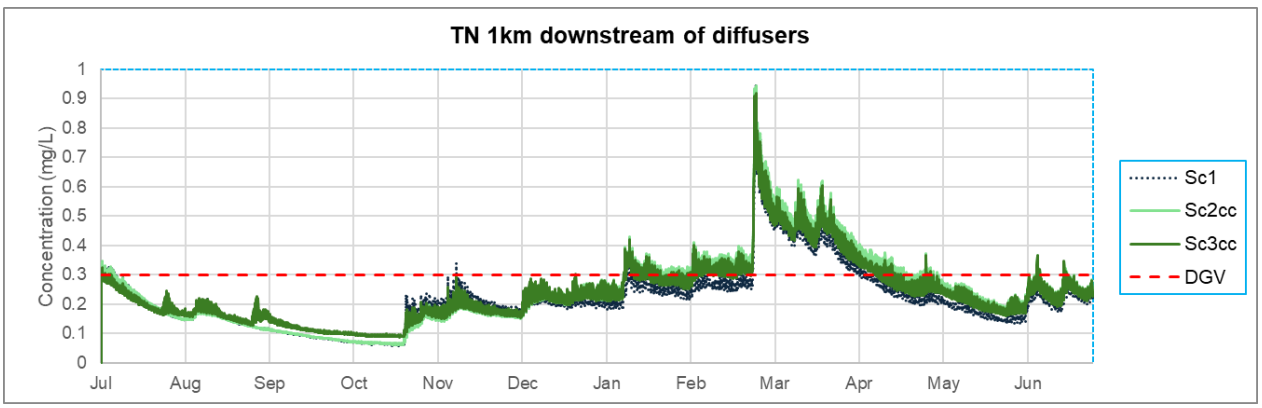
Time series plots





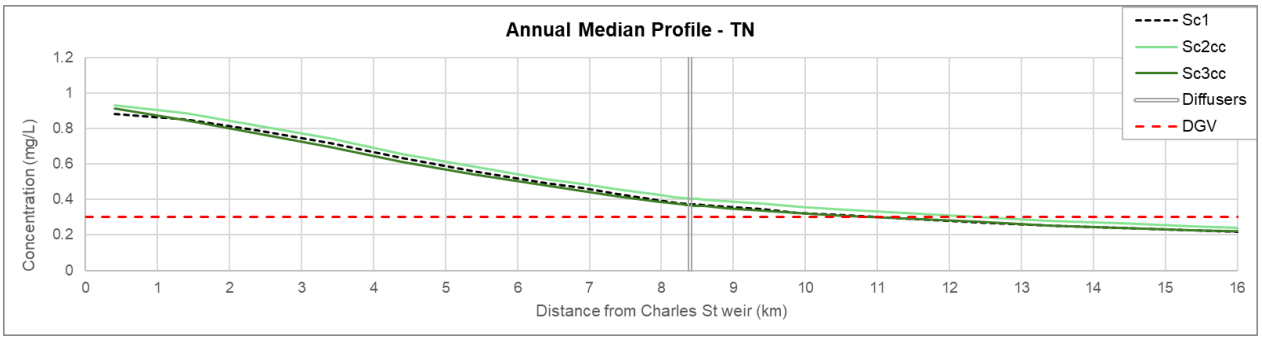


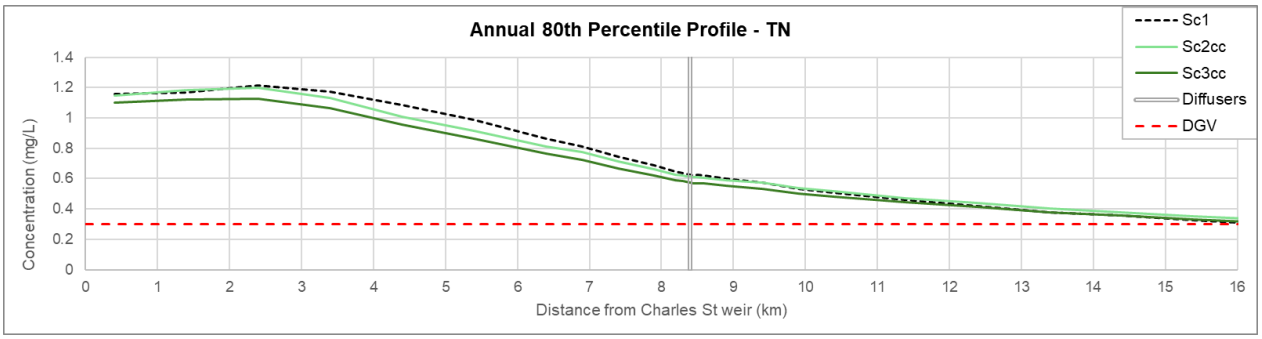




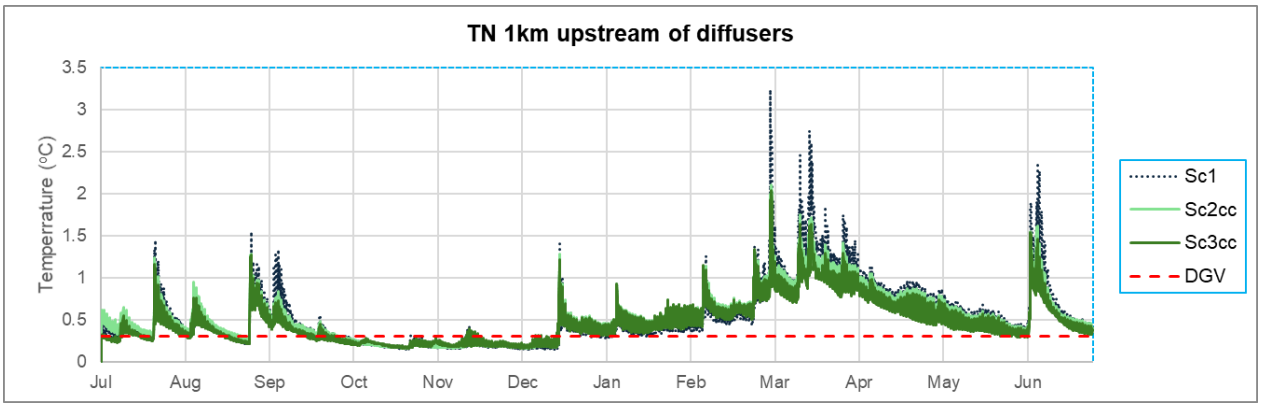
Appendices D2.3.2 Average rainfall year scenario results (2016-2017)

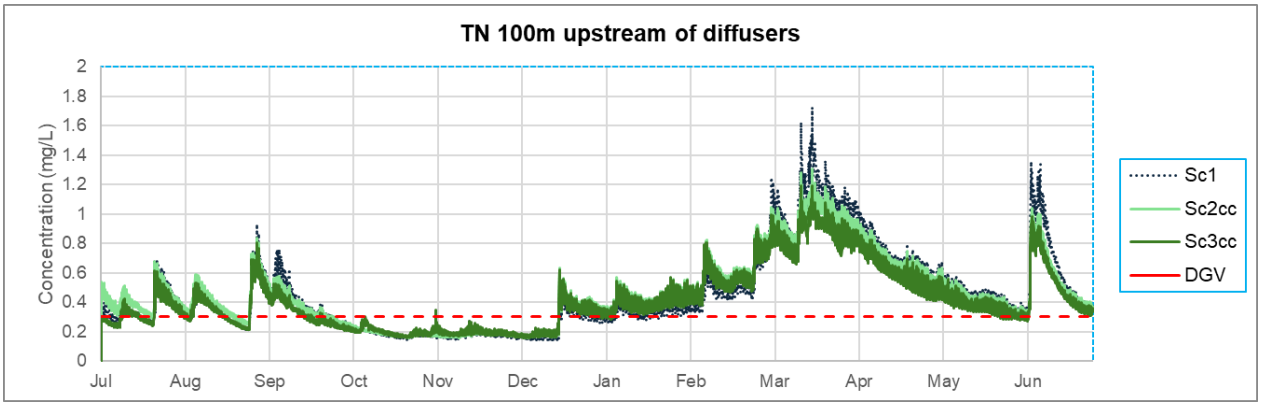
Longitudinal plots

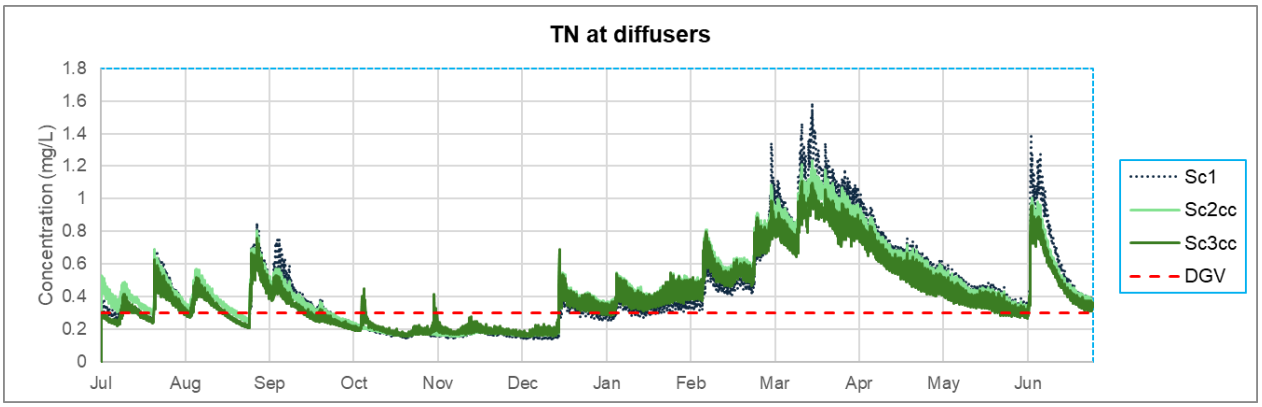


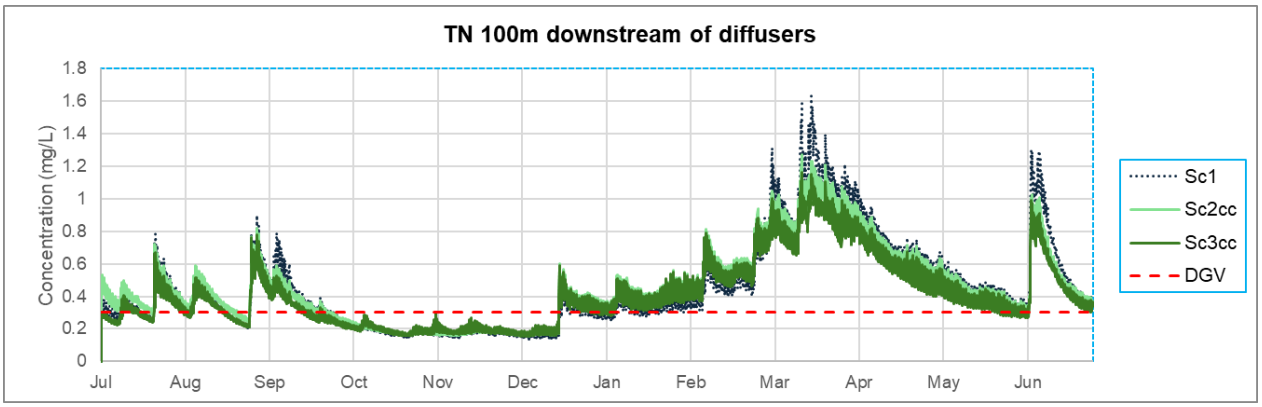


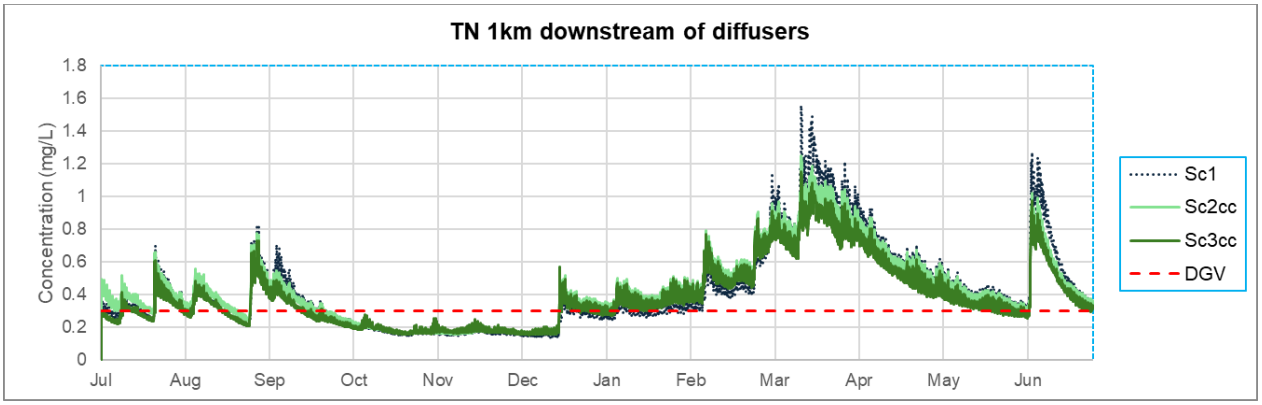
Time series plots





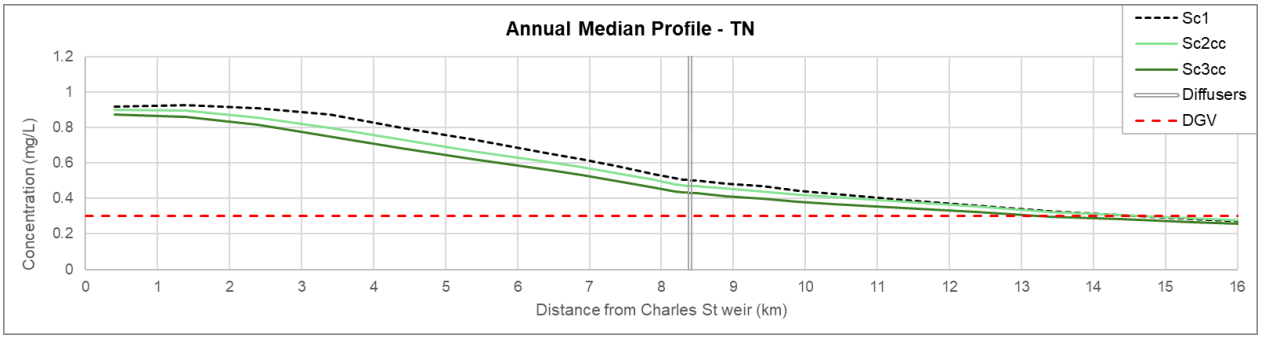


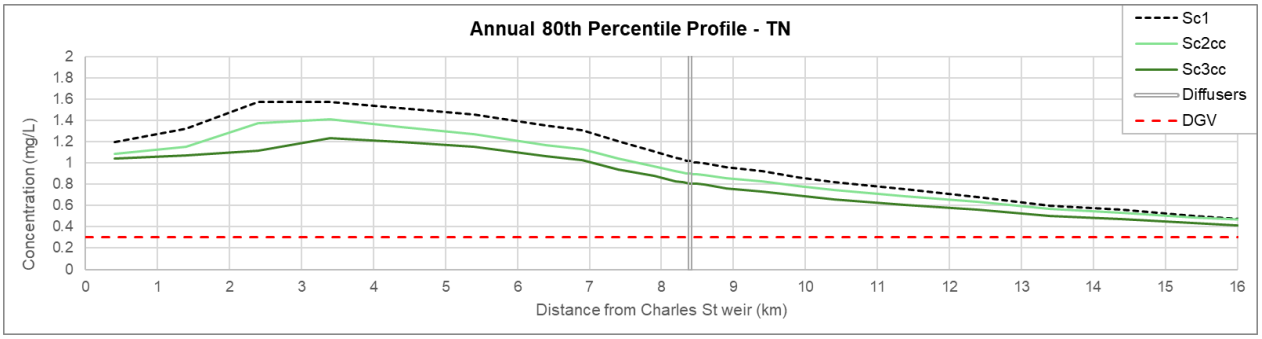




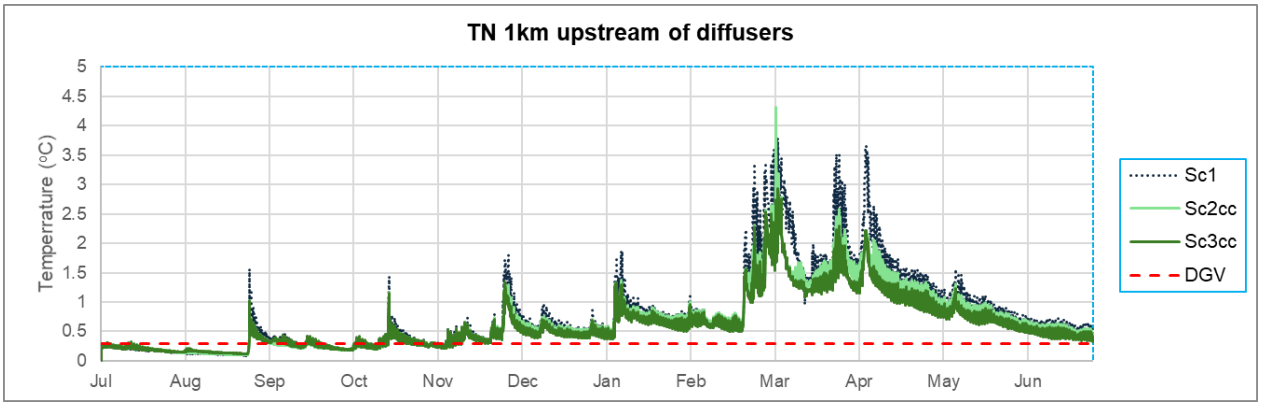
Appendices D2.3.3 Higher rainfall year scenario results (2021-2022)

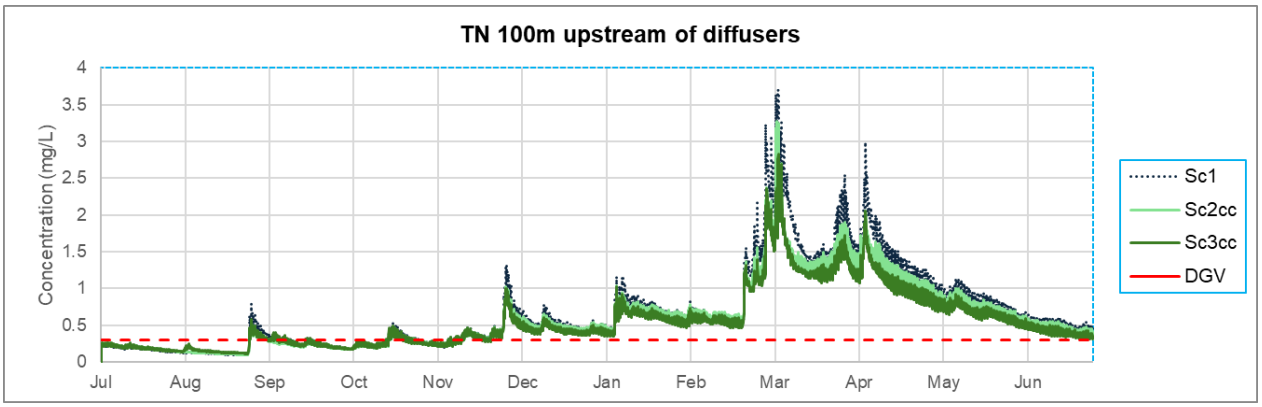
Longitudinal plots

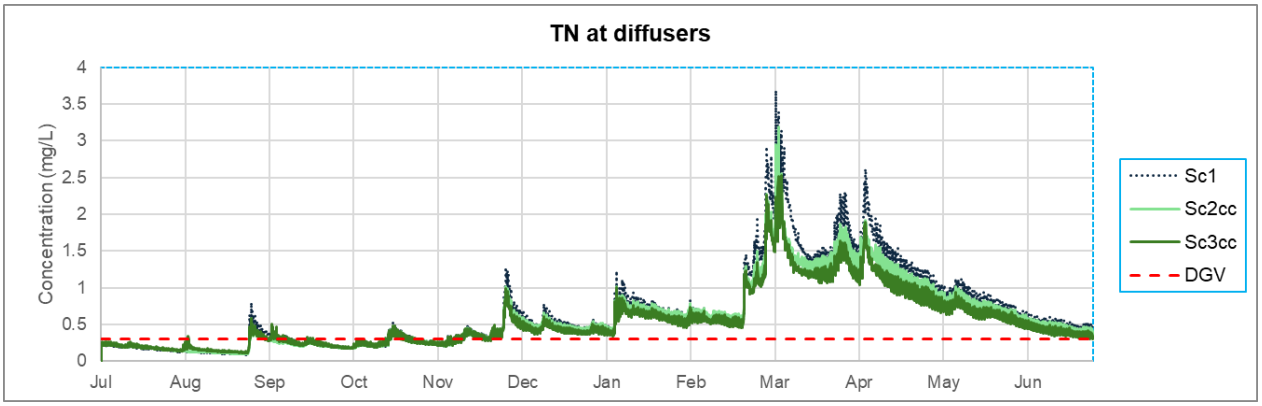


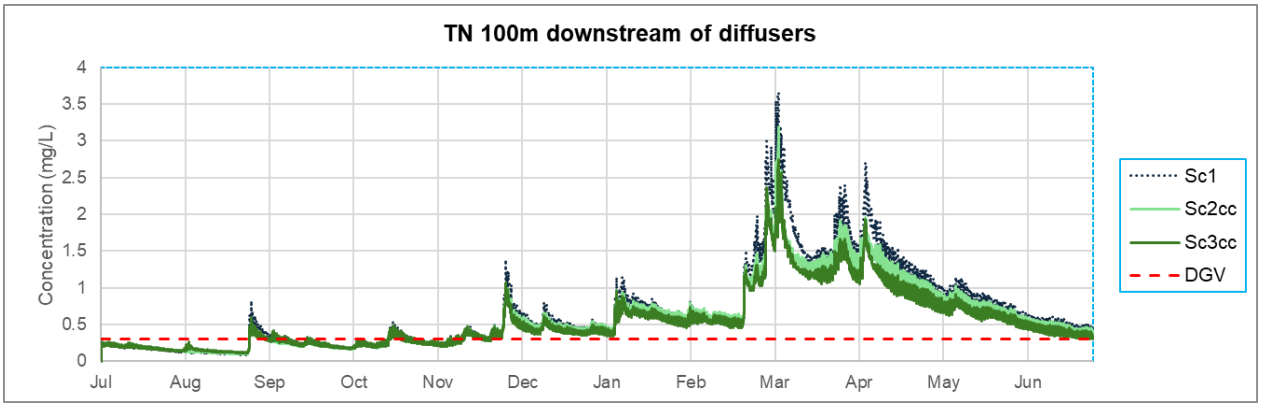


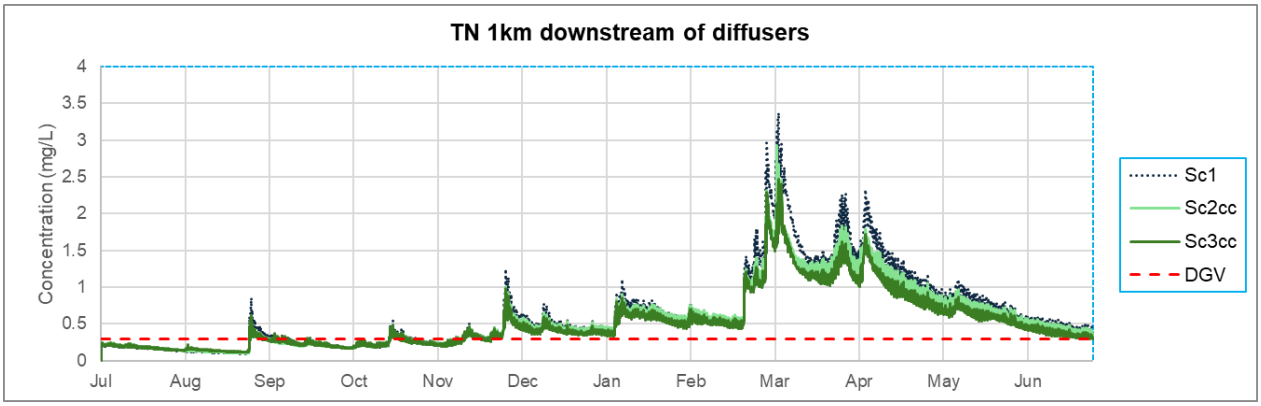
Time series plots







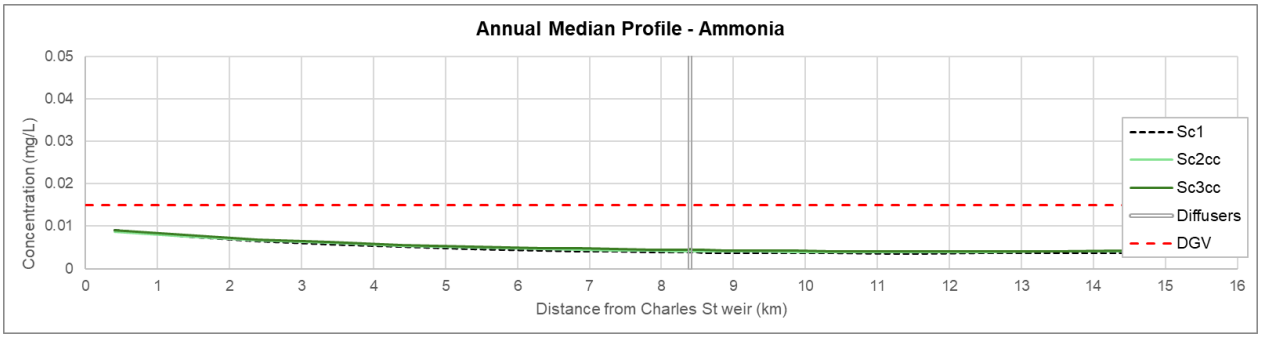


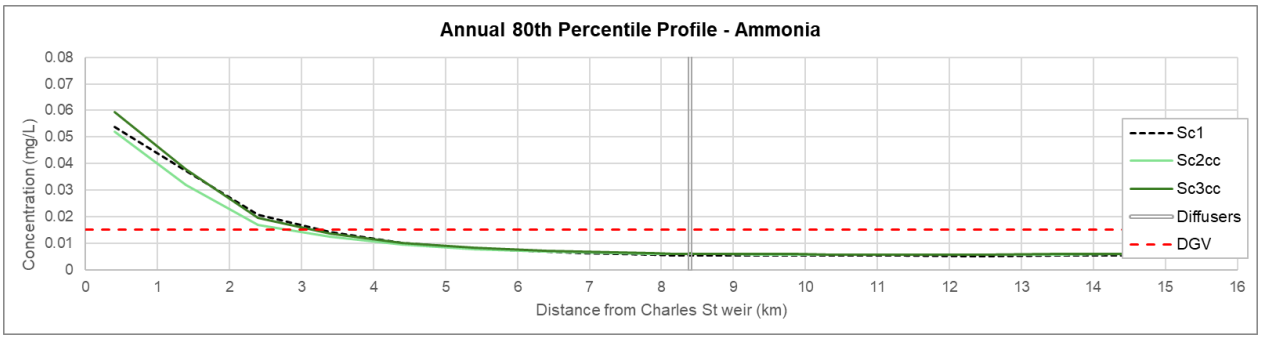


Appendices D2.4 Ammonia

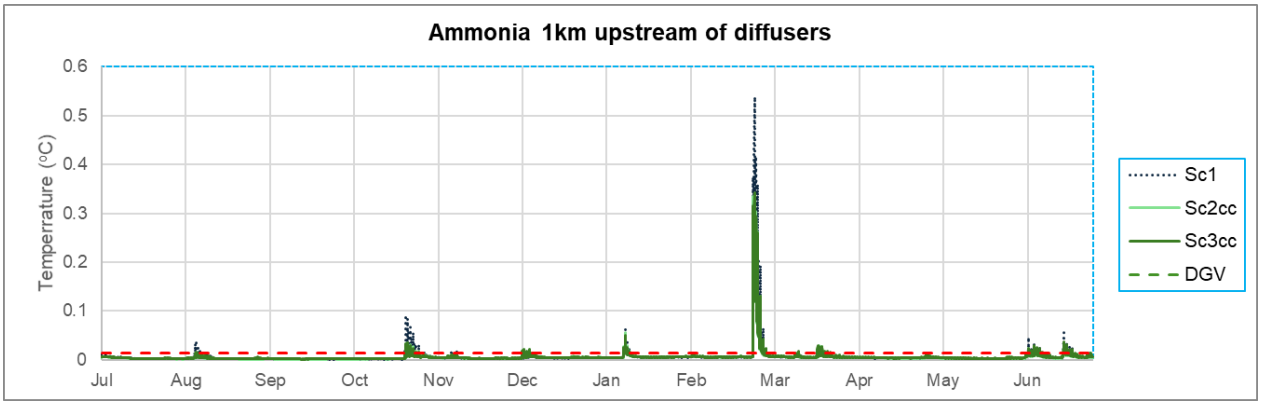
Appendices D2.4.1 Lower rainfall year scenario results (2017-2018)

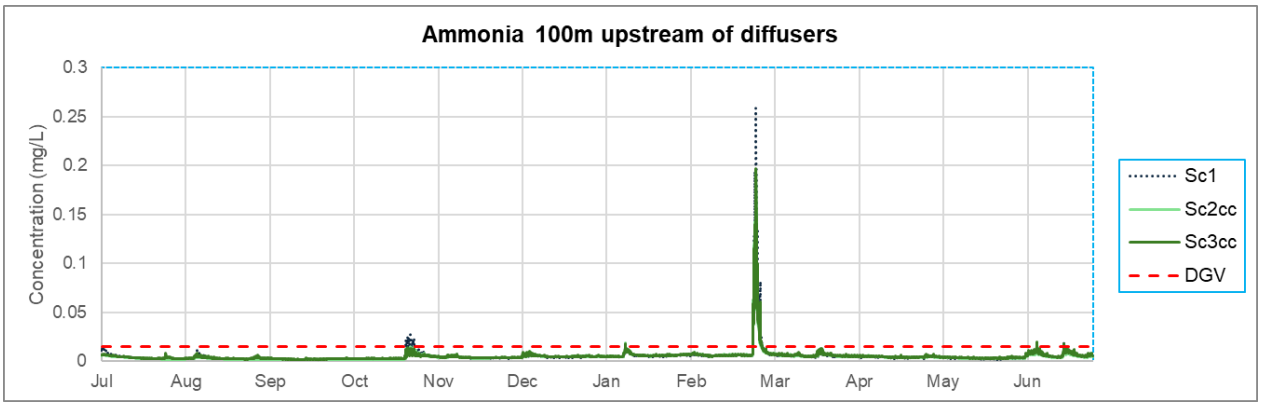
Longitudinal plots

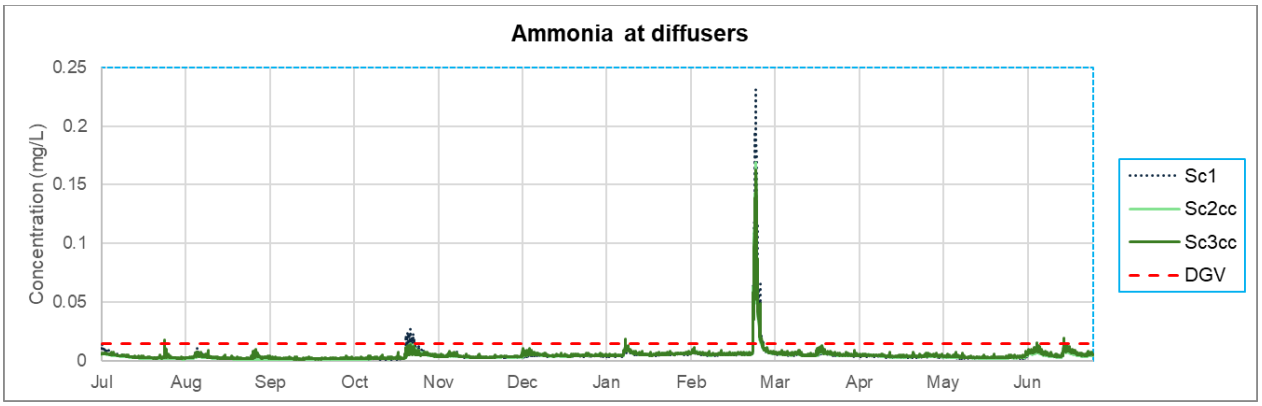


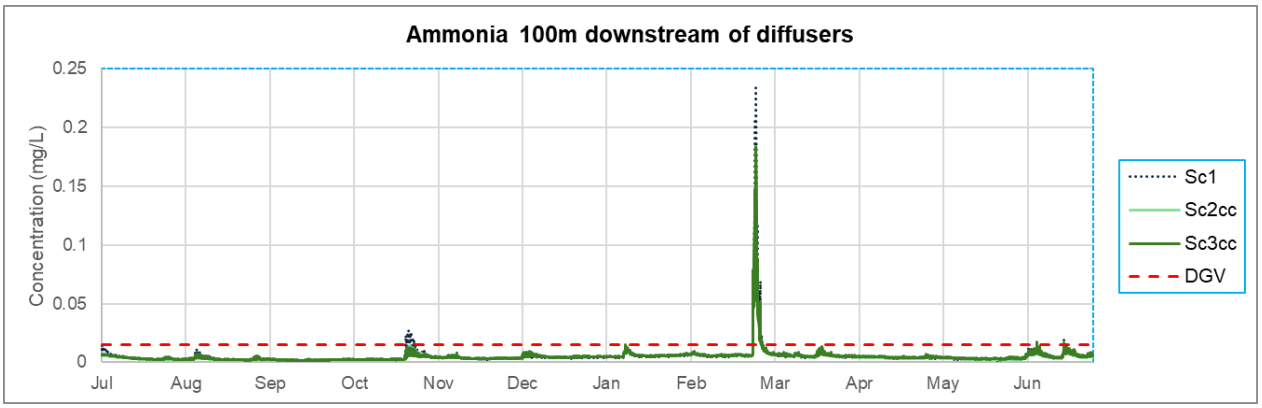


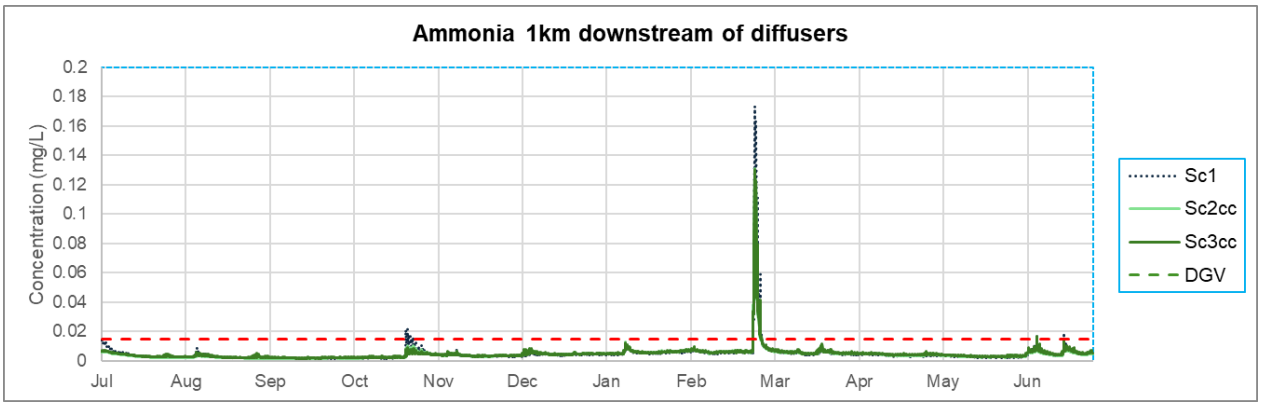
Time series plots





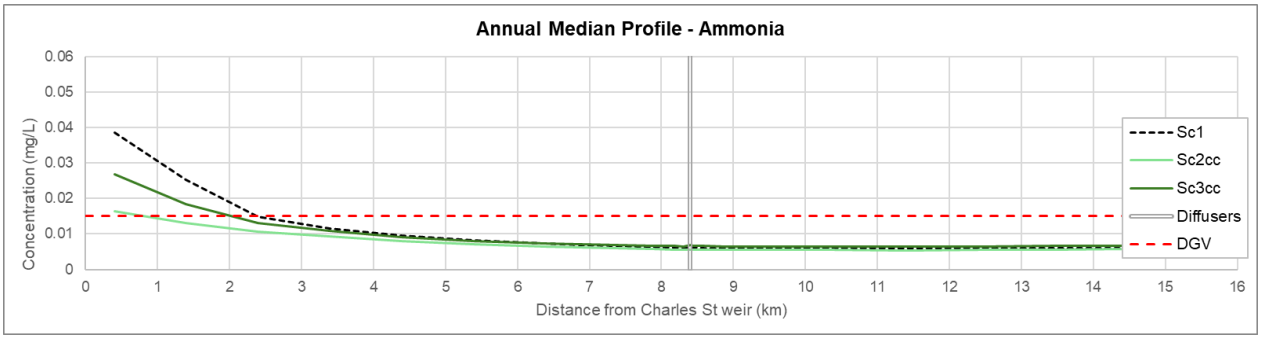


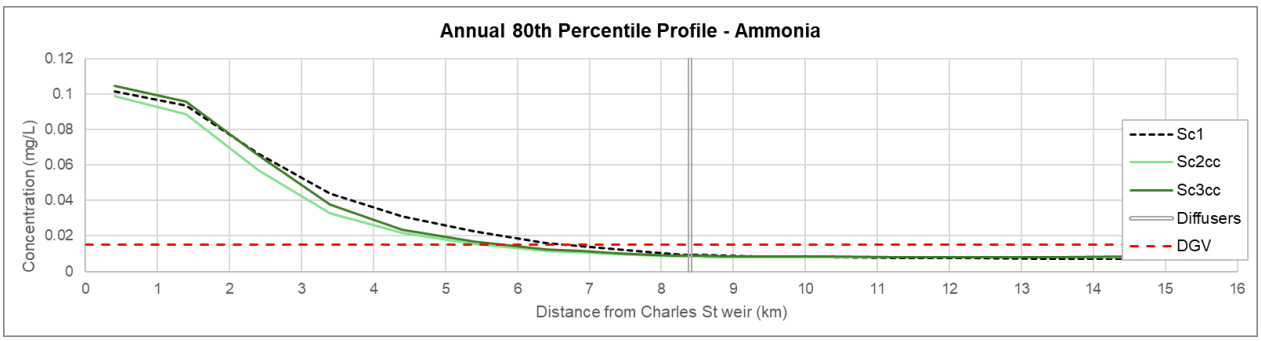




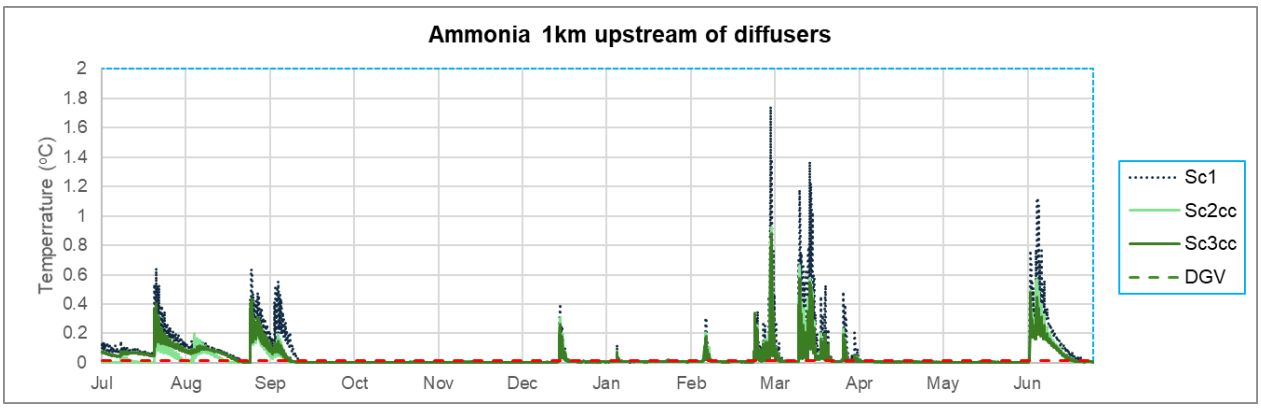
Appendices D2.4.2 Average rainfall year scenario results (2016-2017)

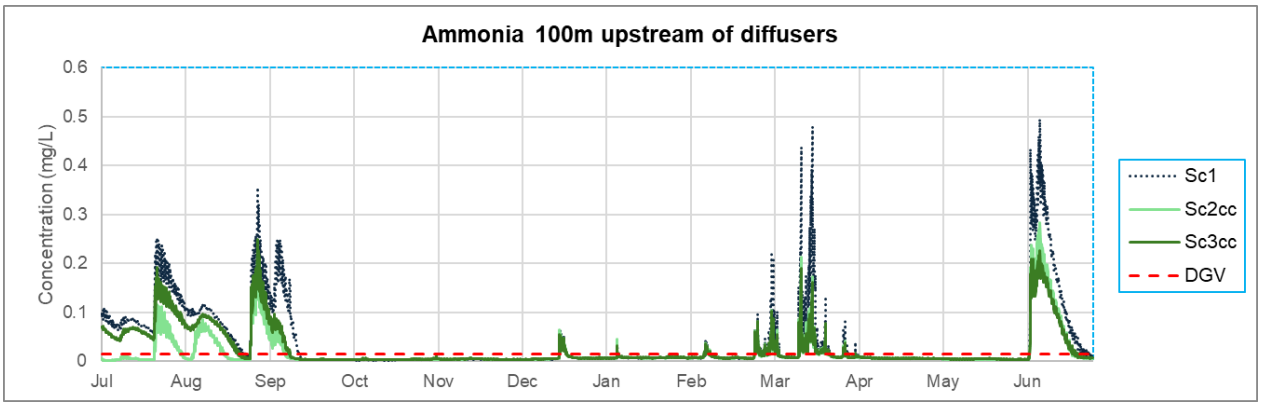
Longitudinal plots

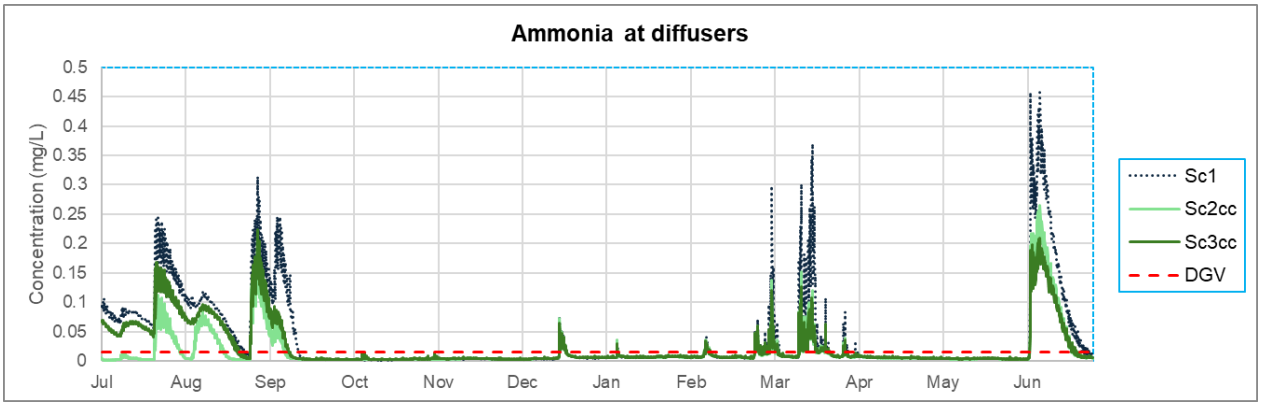


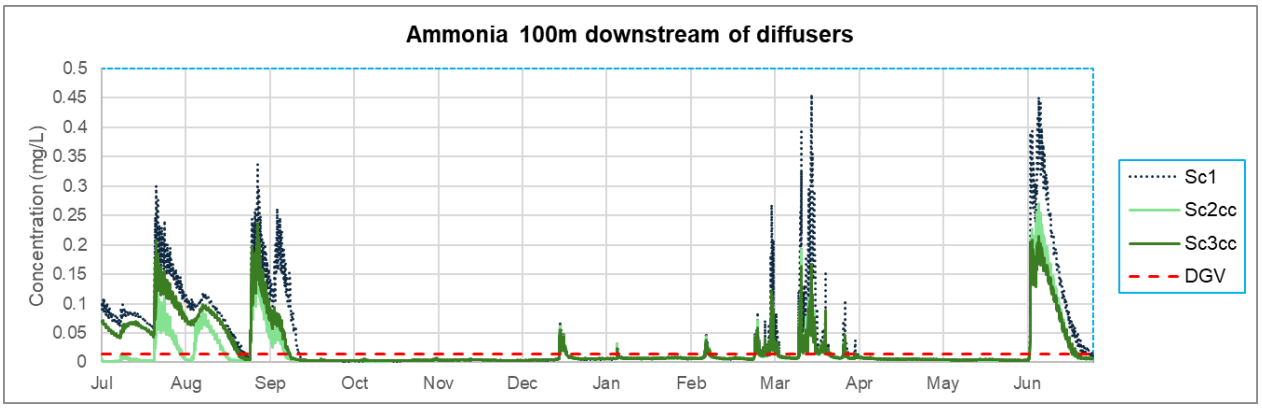


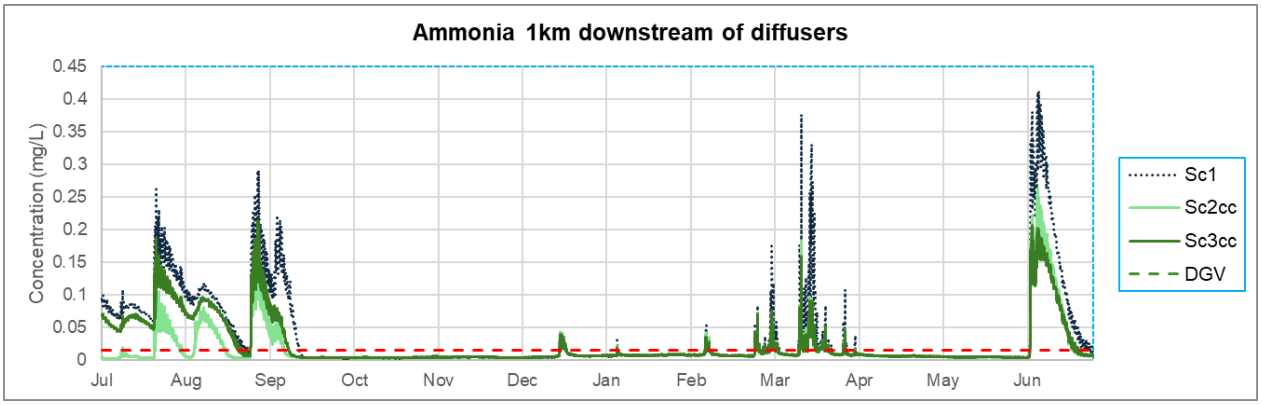
Time series plots




Ammonia 100m upstream of diffusers
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

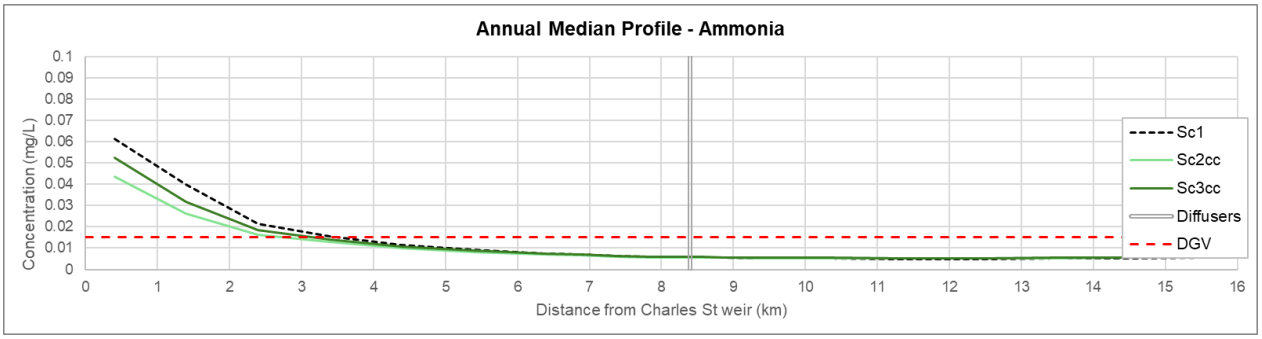

Ammonia at diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

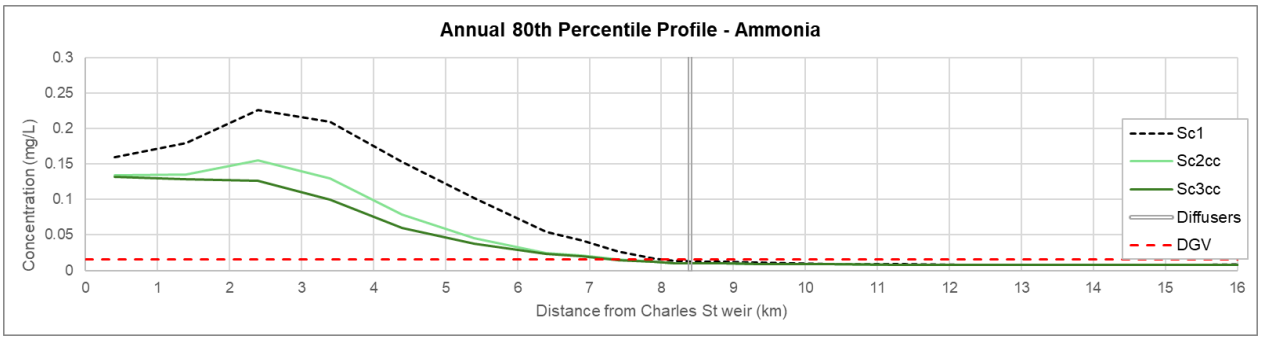

Ammonia 100m downstream of diffusers
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV


Ammonia 1km downstream of diffusers
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

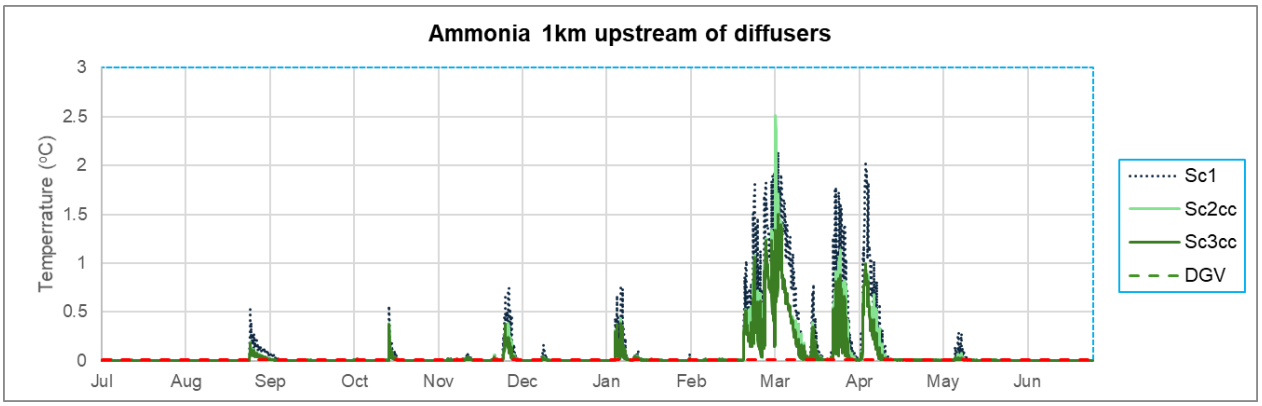
Appendices D2.4.3 Higher rainfall year scenario results (2021-2022)

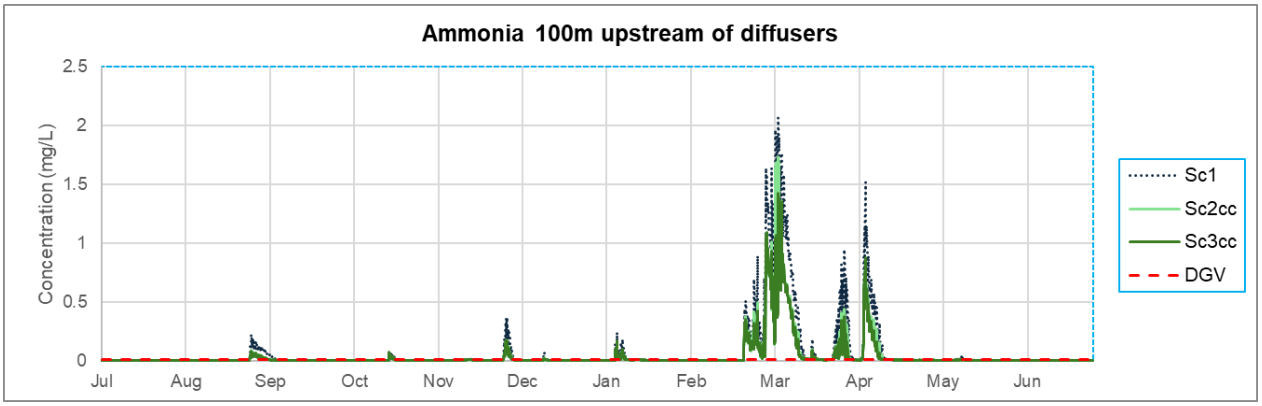
Longitudinal plots

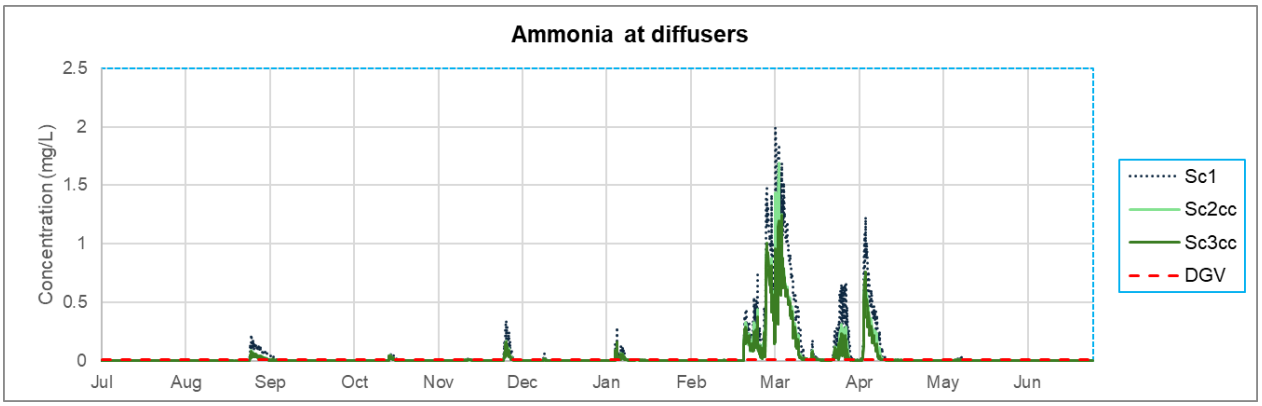


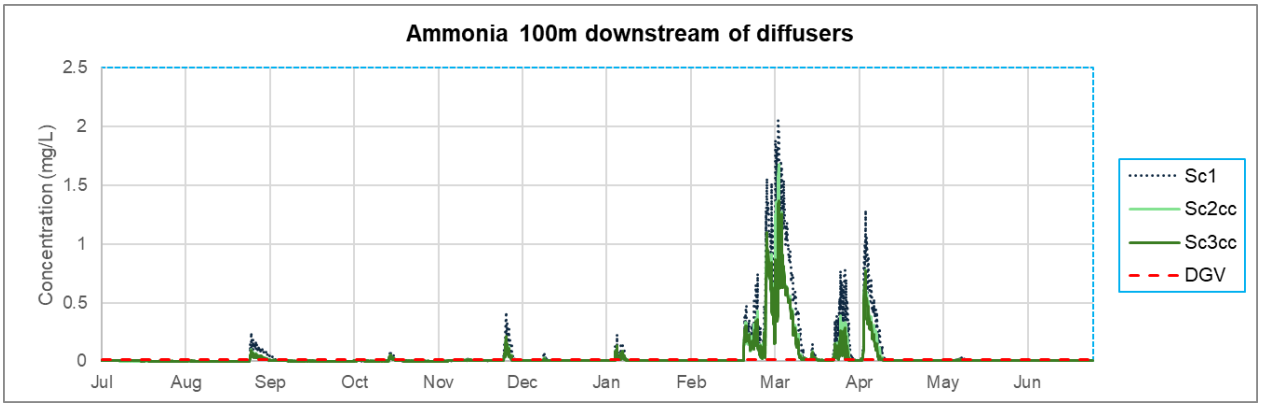


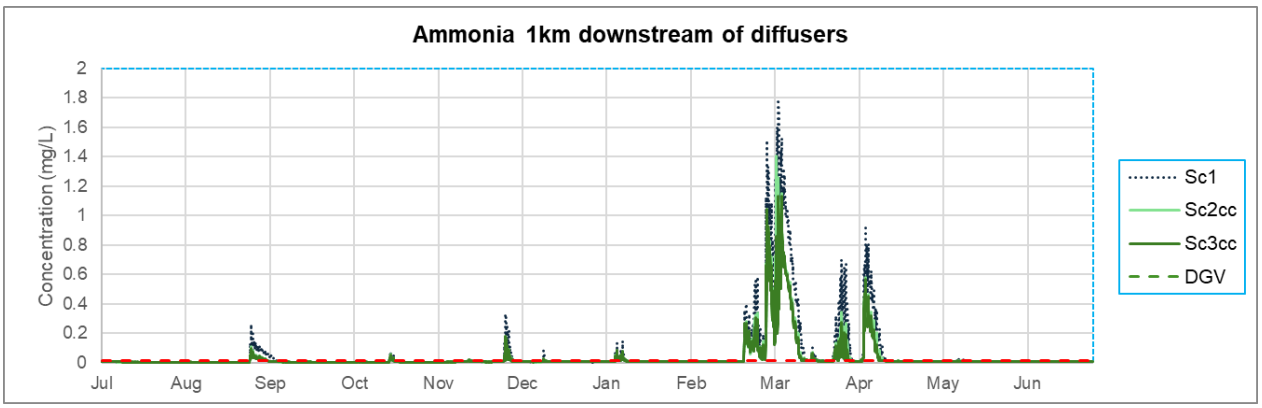
Time series plots






Ammonia at diffusers
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

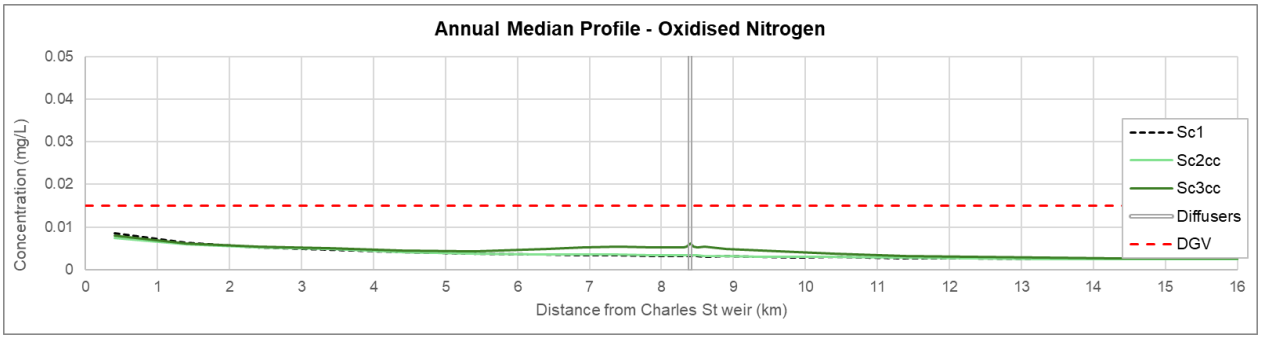

Ammonia 100m downstream of diffusers
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

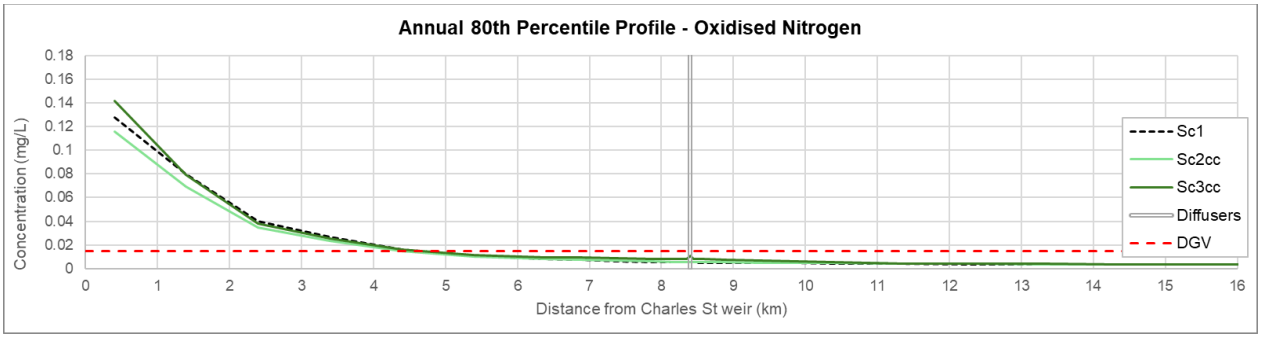

Ammonia 1km downstream of diffusers
Concentration (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

Appendices D2.5 Oxidised N

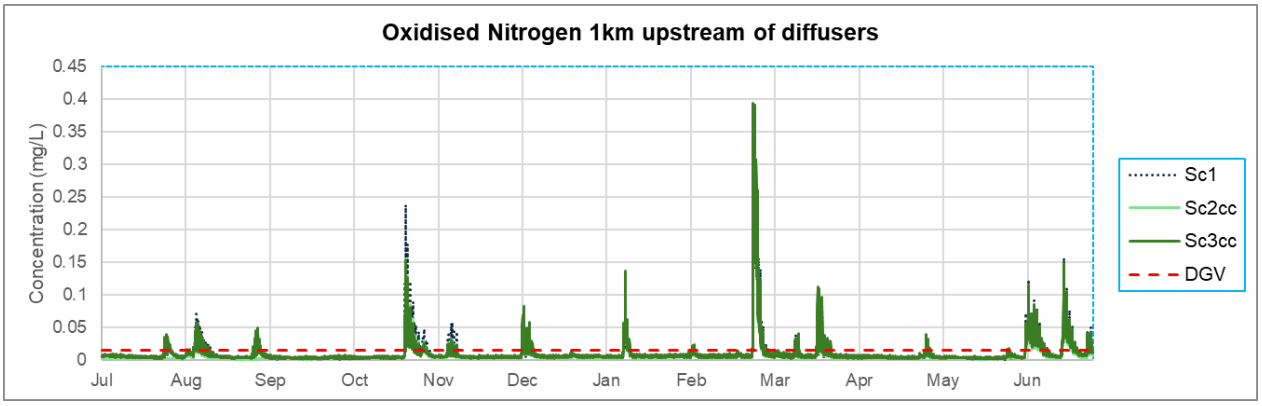
Appendices D2.5.1 Lower rainfall year scenario results (2017-2018)

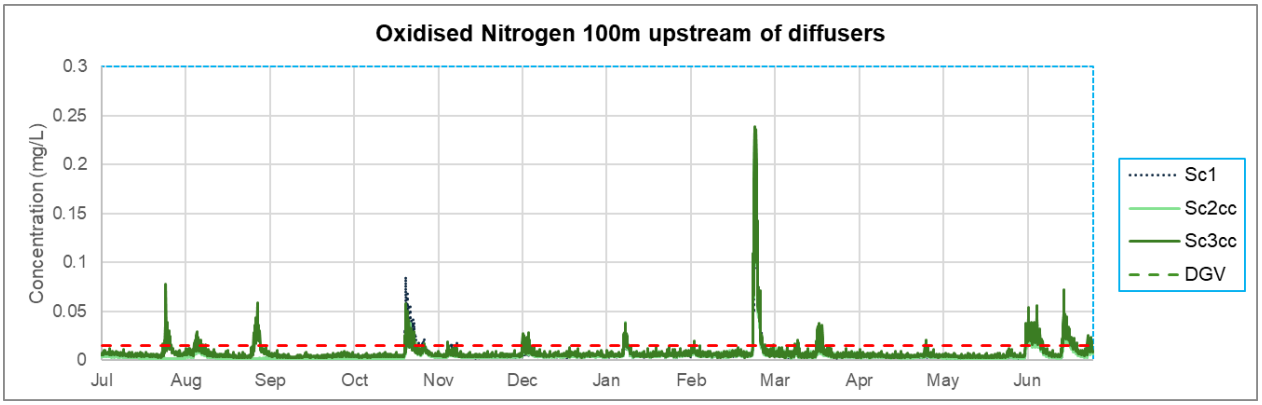
Longitudinal plots

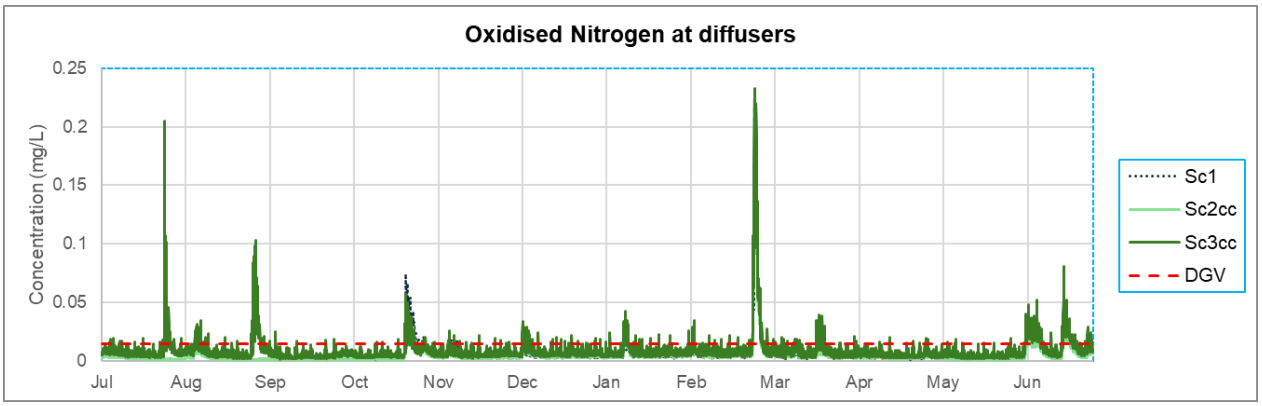


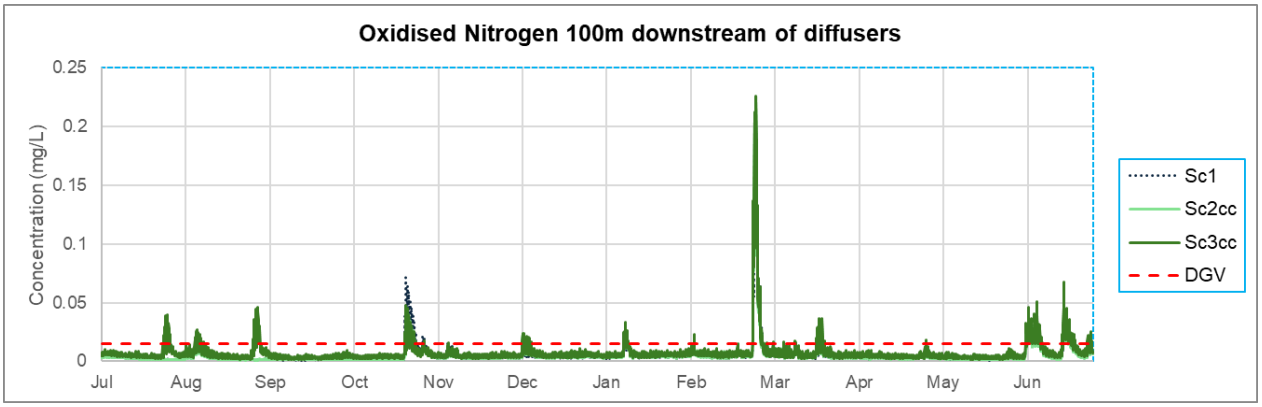


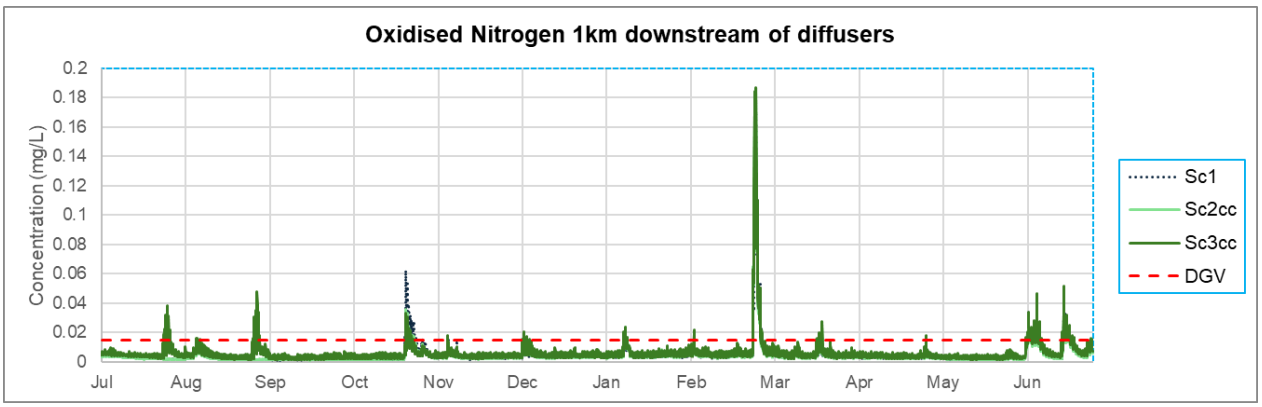
Time series plots





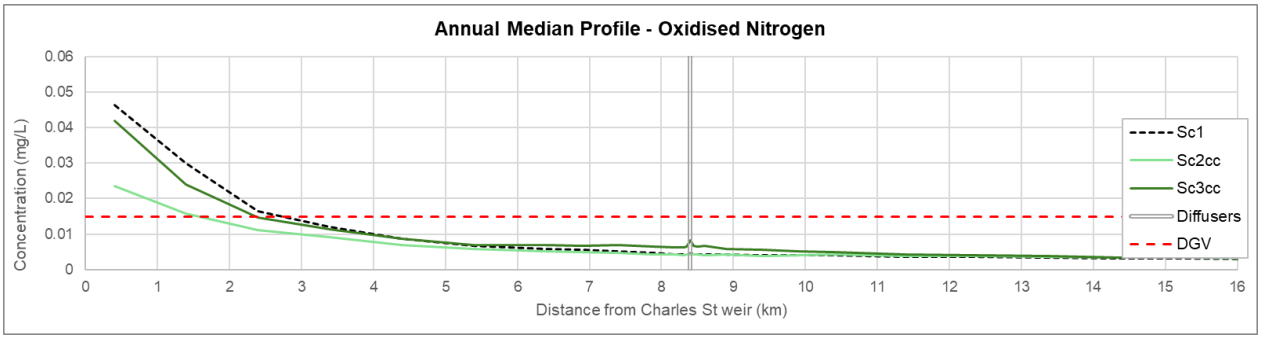


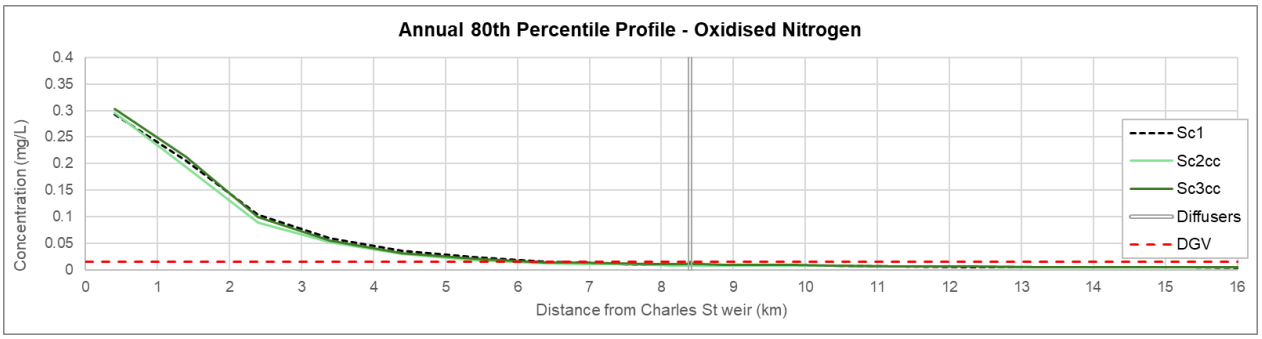




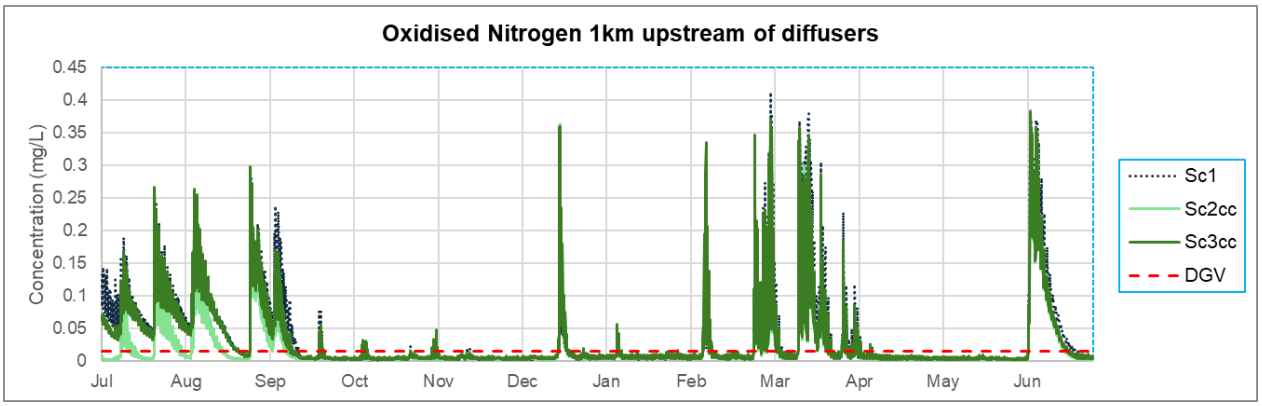
Appendices D2.5.2 Average rainfall year scenario results (2016-2017)

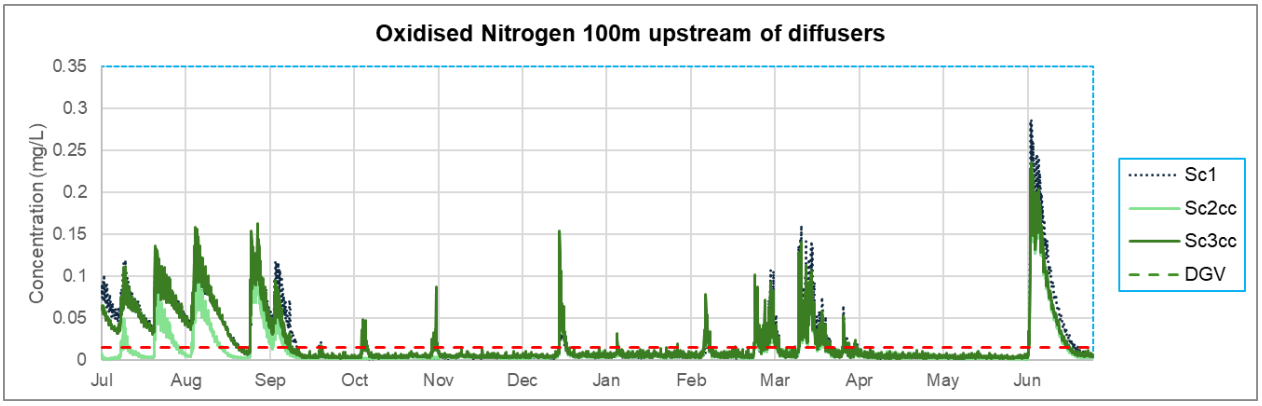
Longitudinal plots

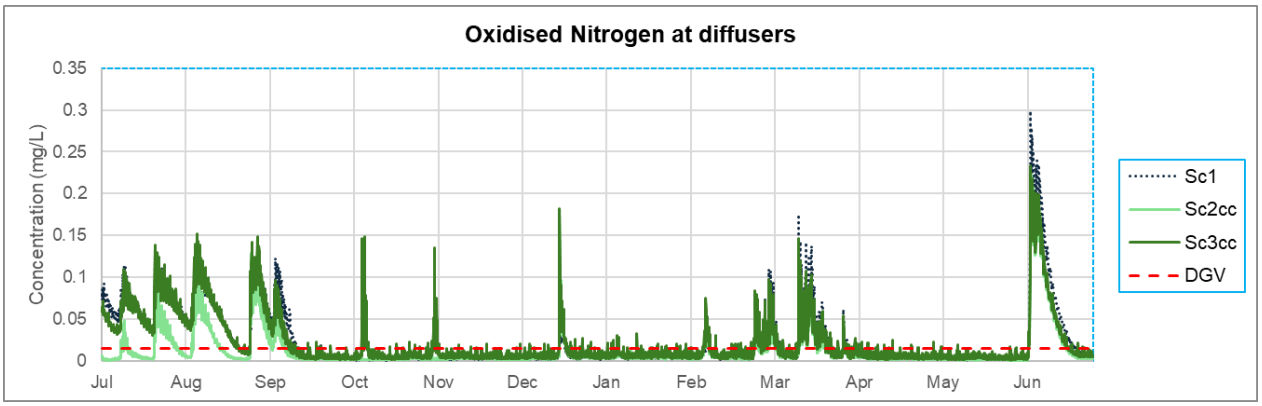


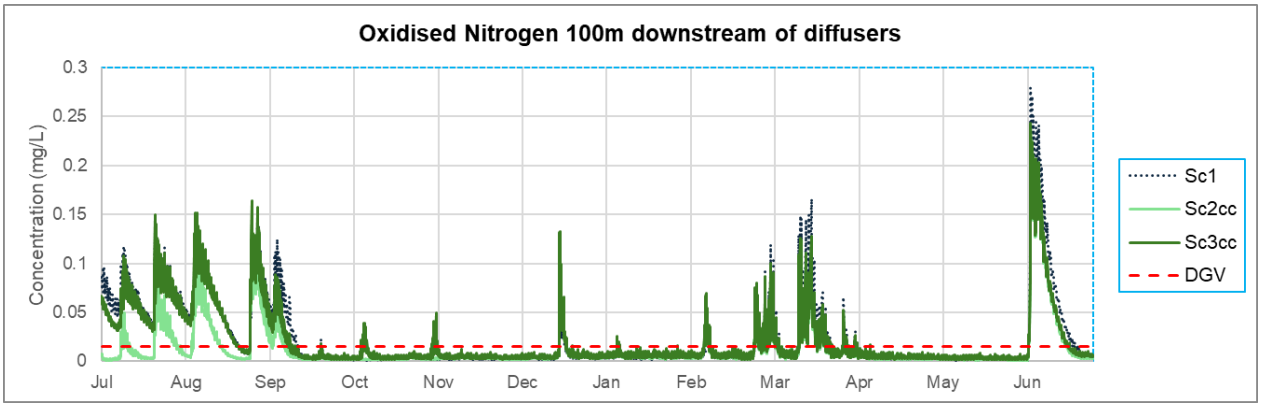


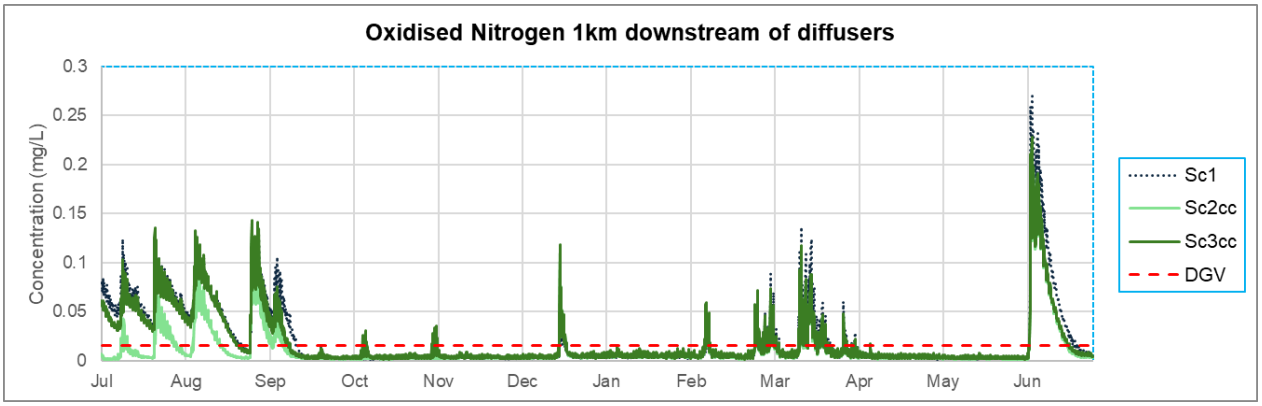
Time series plots





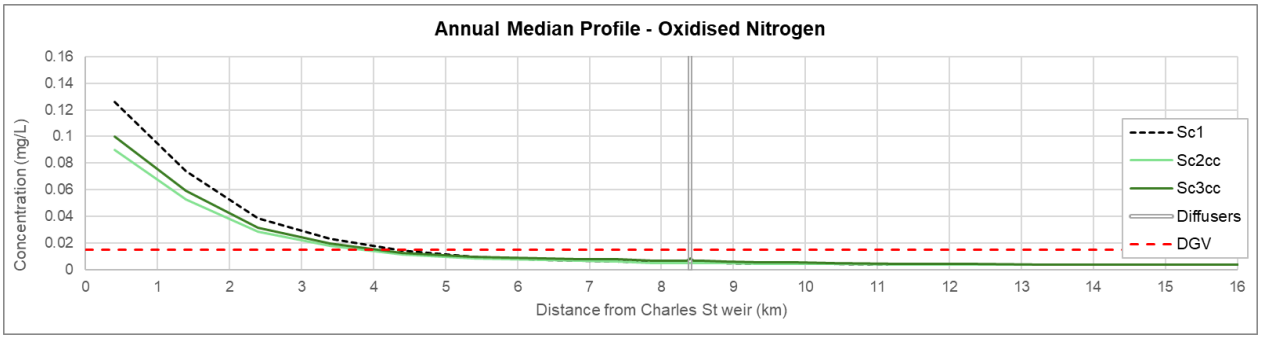


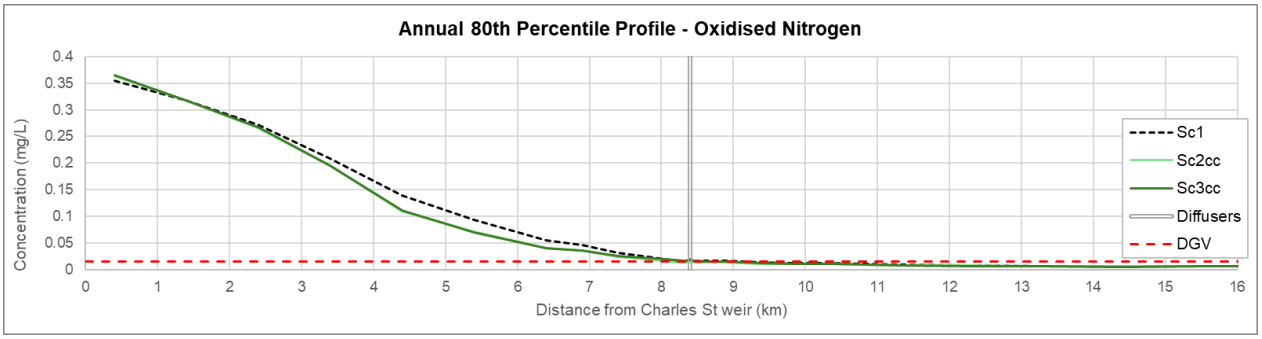




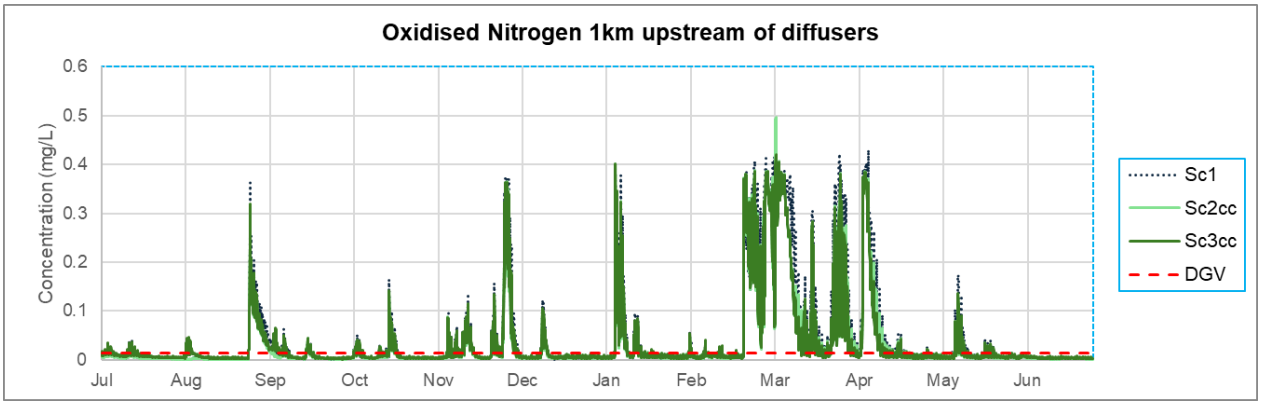
Appendices D2.5.3 Higher rainfall year scenario results (2021-2022)

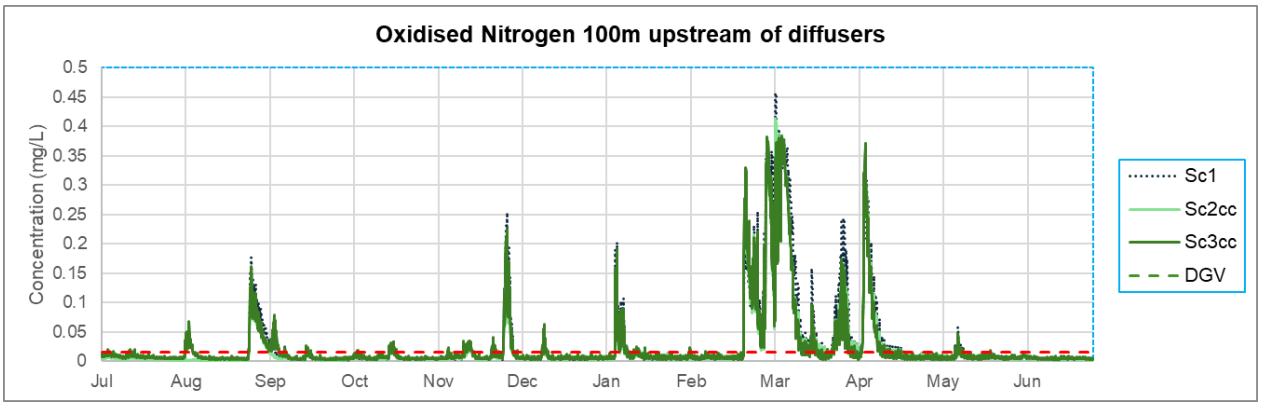
Longitudinal plots

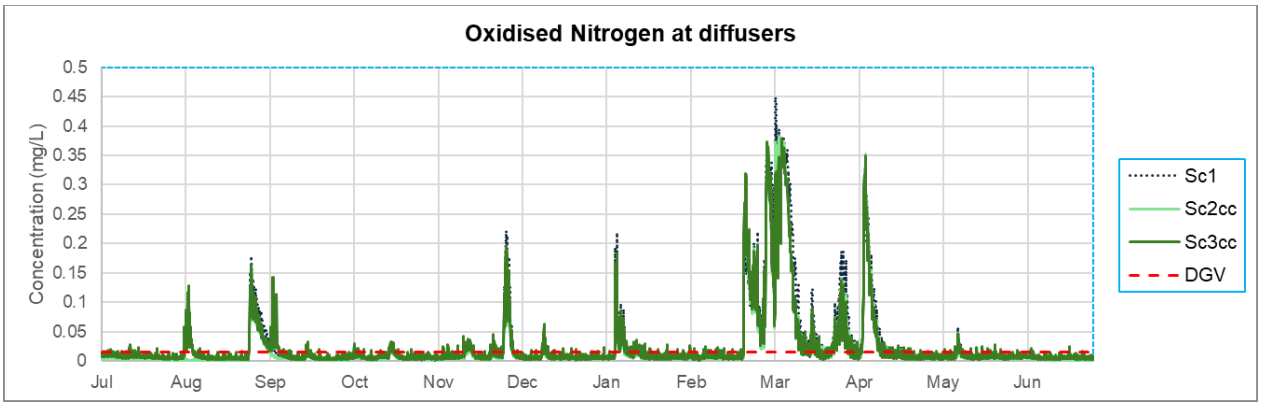


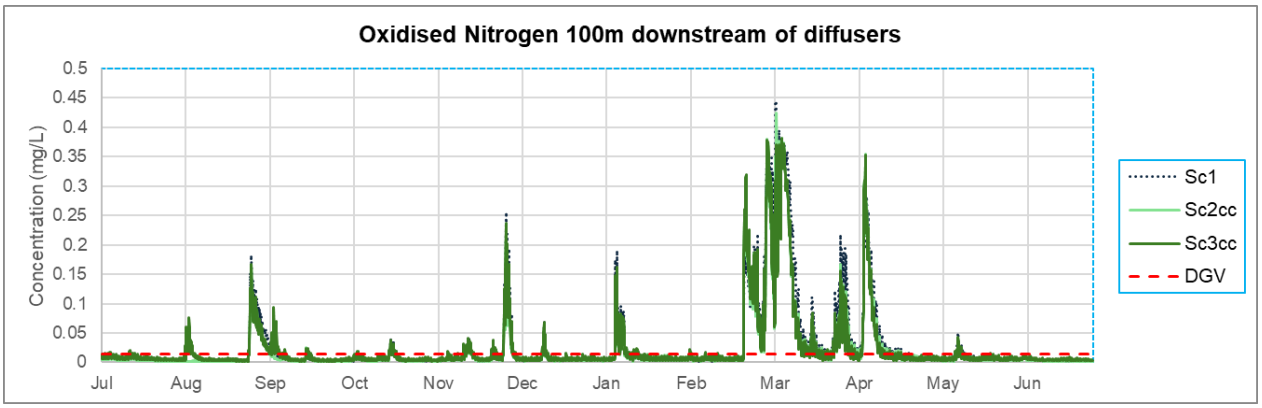


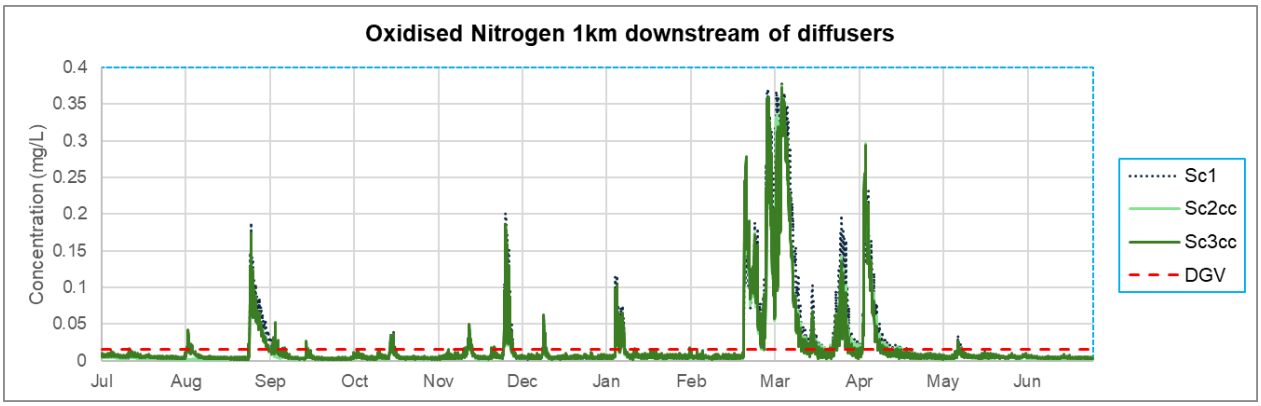
Time series plots







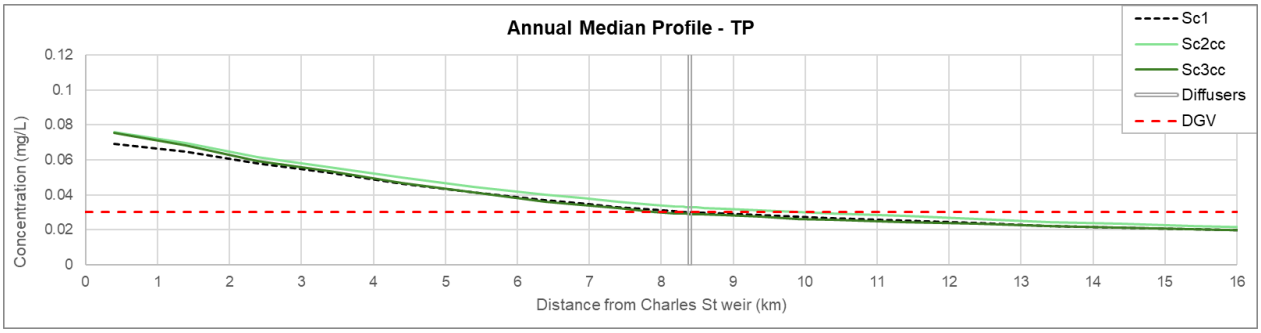


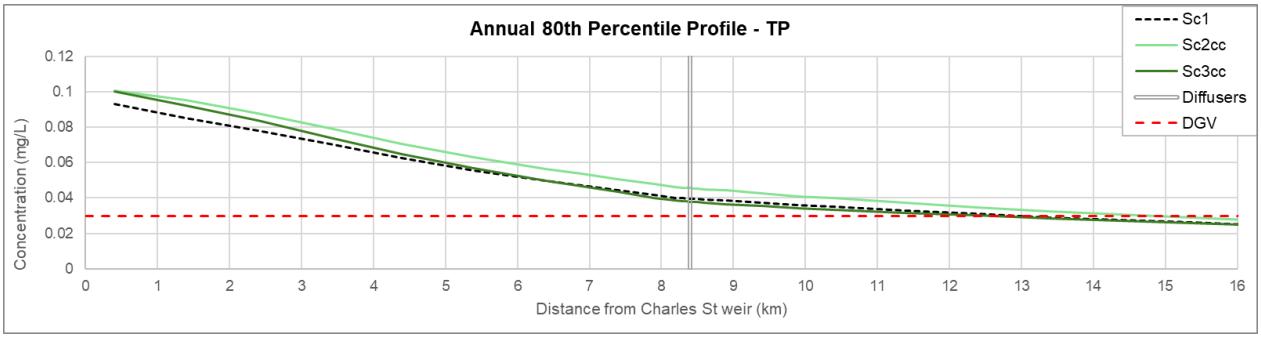


Appendices D2.6 Total P

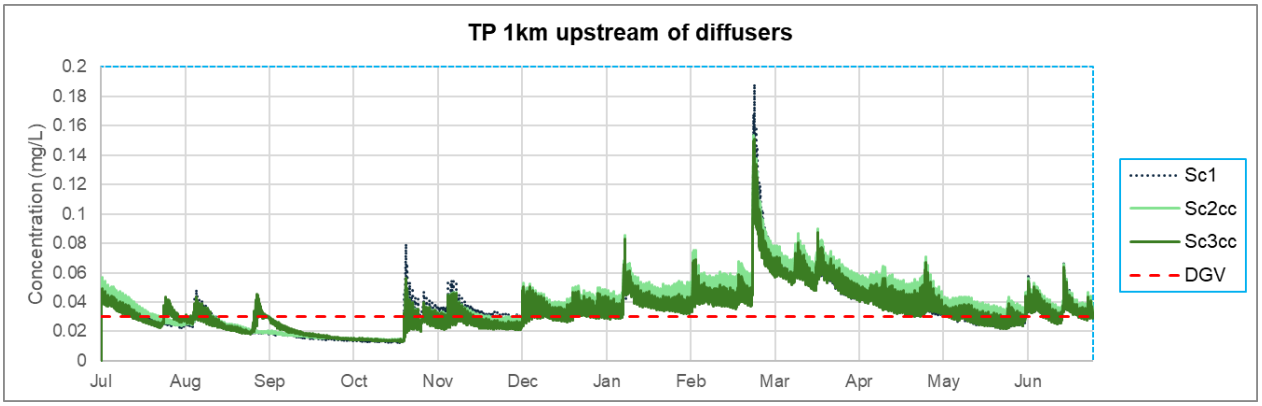
Appendices D2.6.1 Lower rainfall year scenario results (2017-2018)

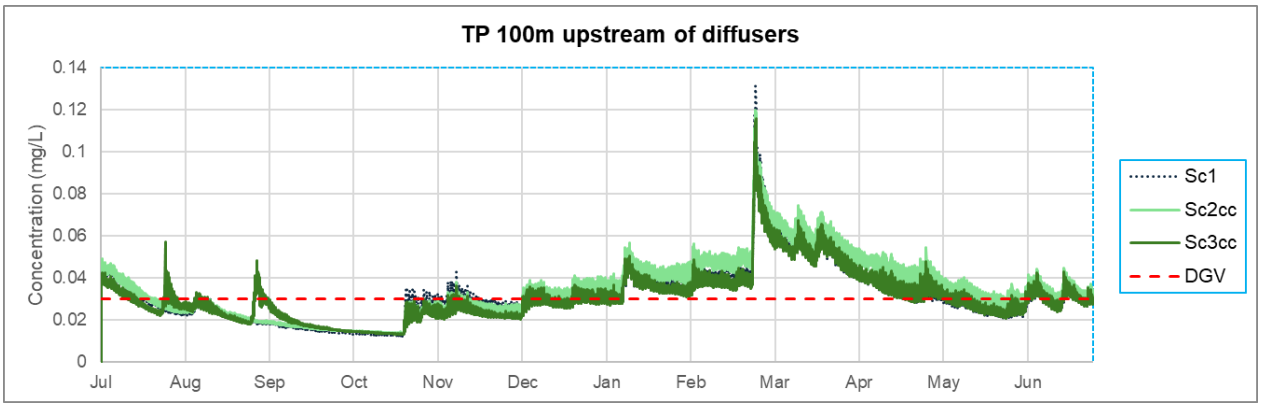
Longitudinal plots

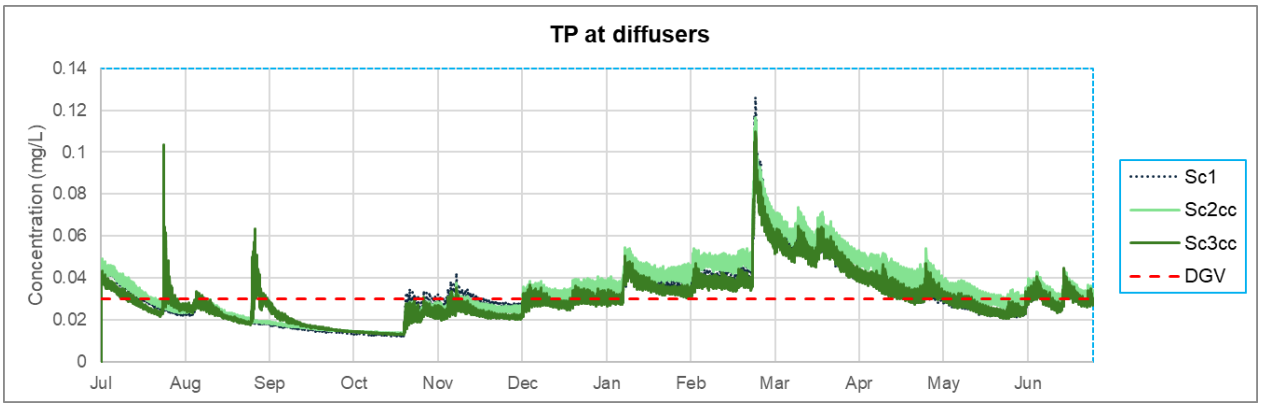


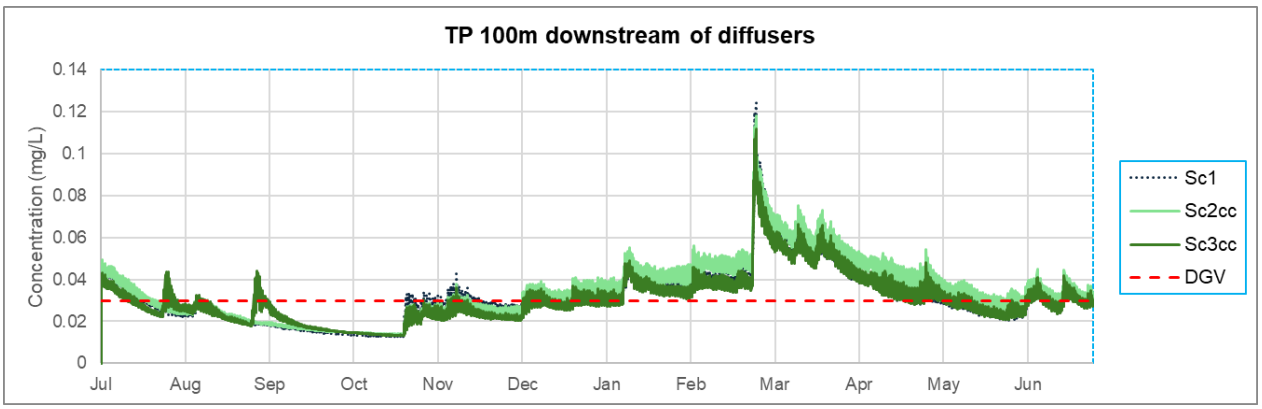


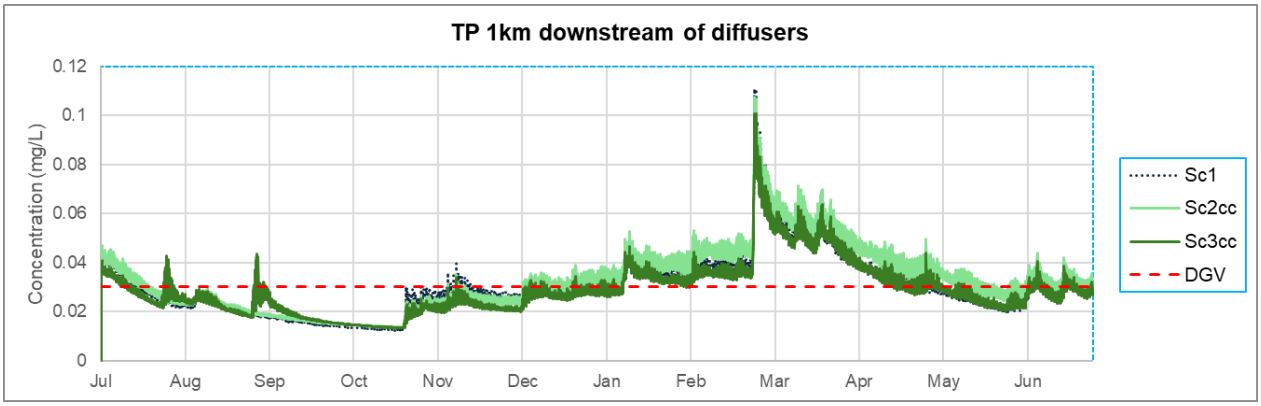
Time series plots





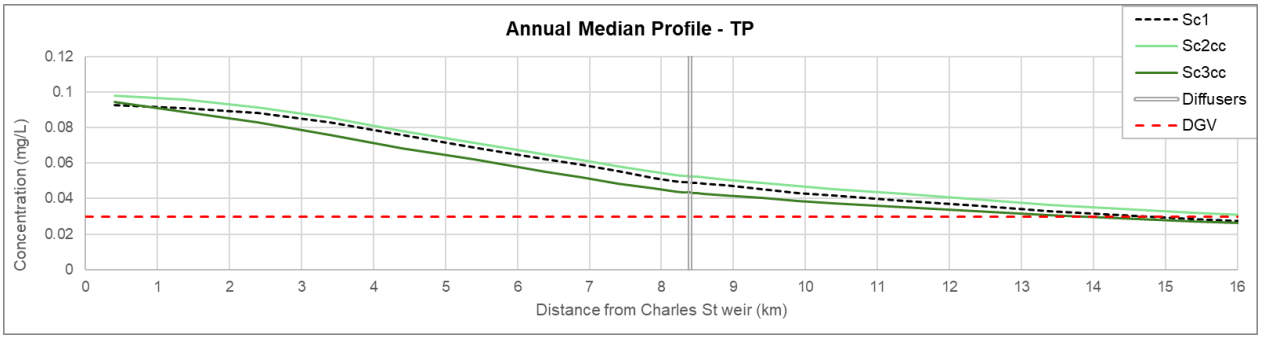


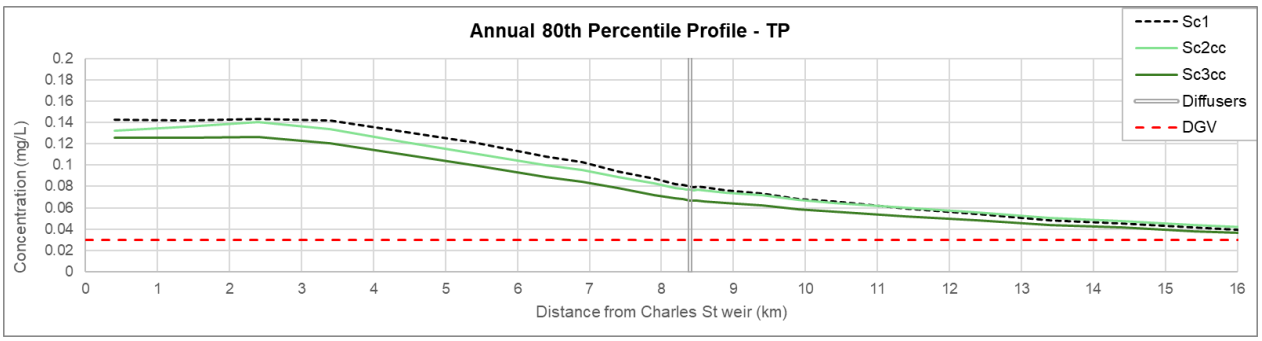




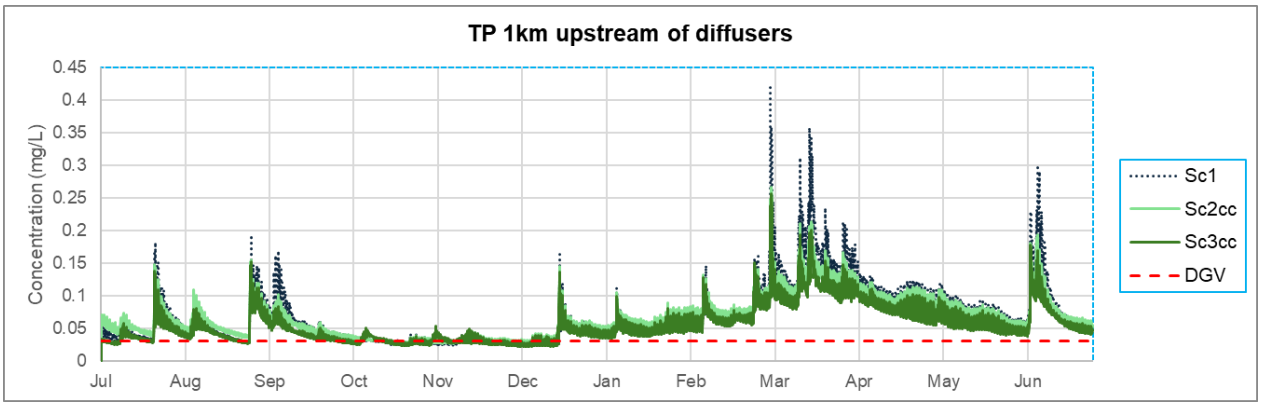
Appendices D2.6.2 Average rainfall year scenario results (2016-2017)

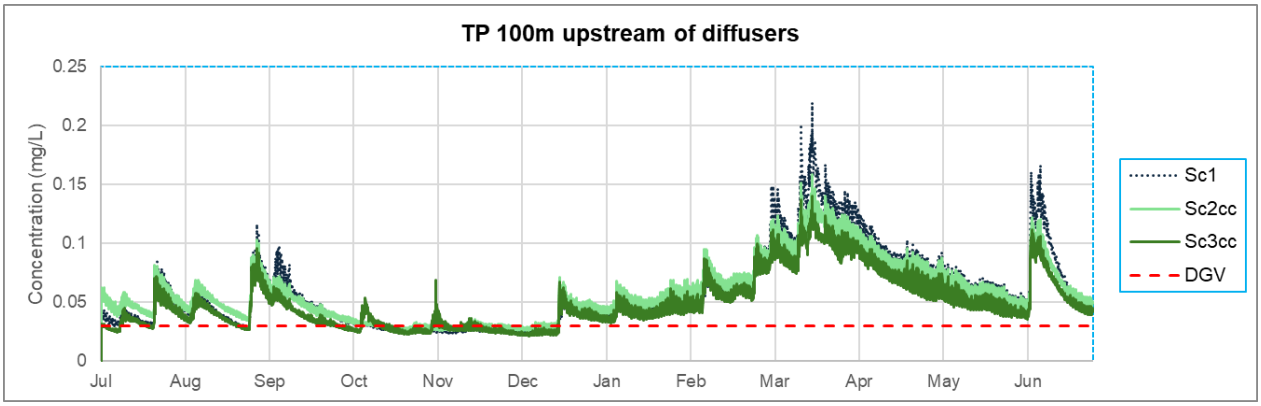
Longitudinal plots

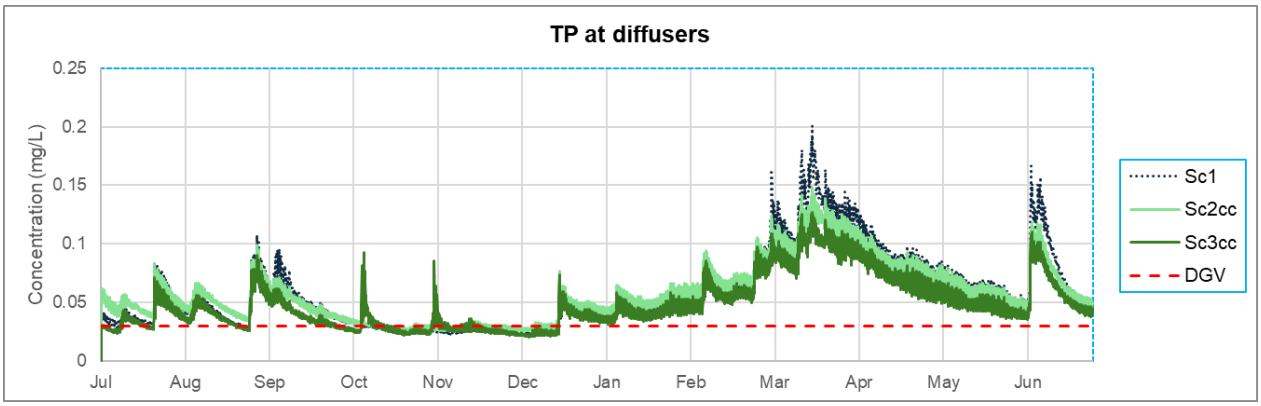


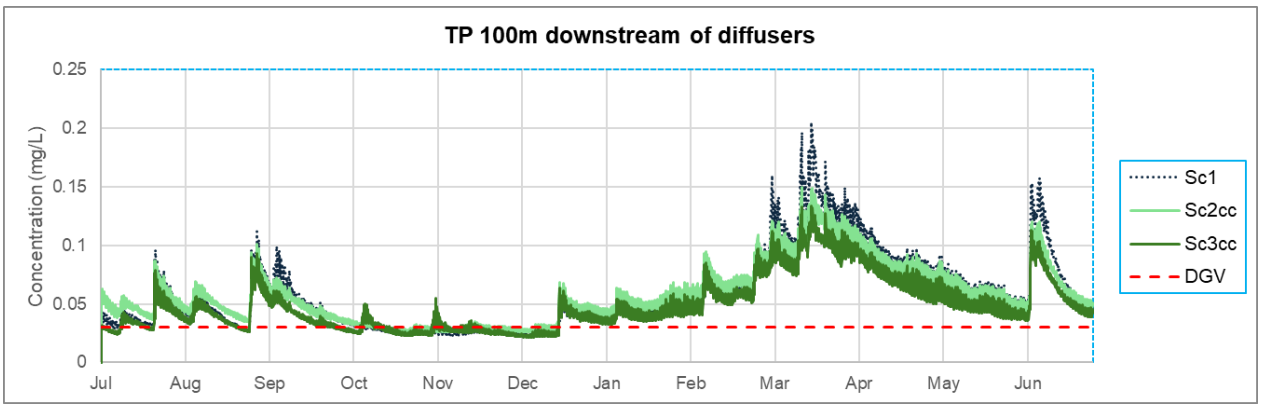


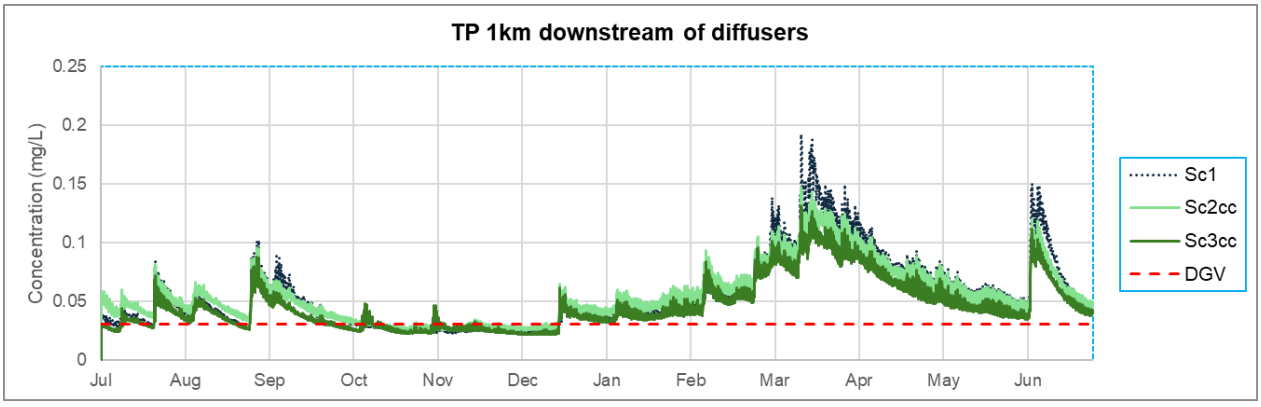
Time series plots




TP 100m upstream of diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

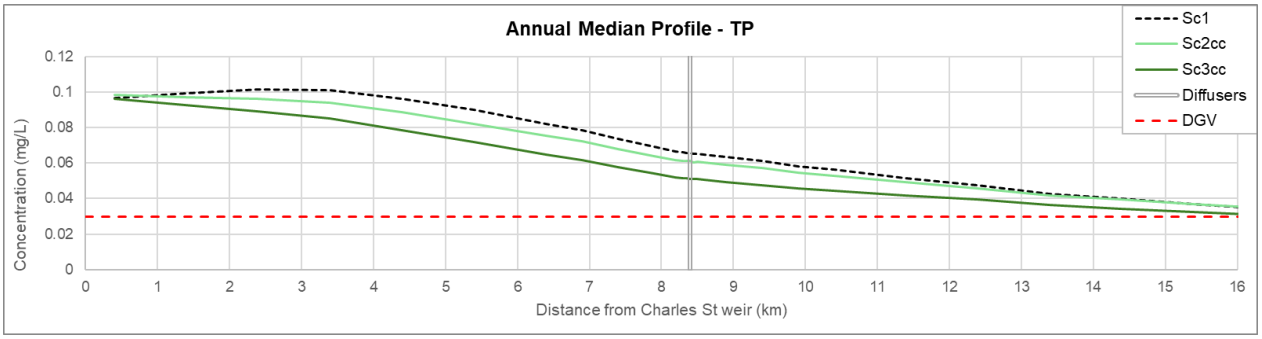

TP at diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

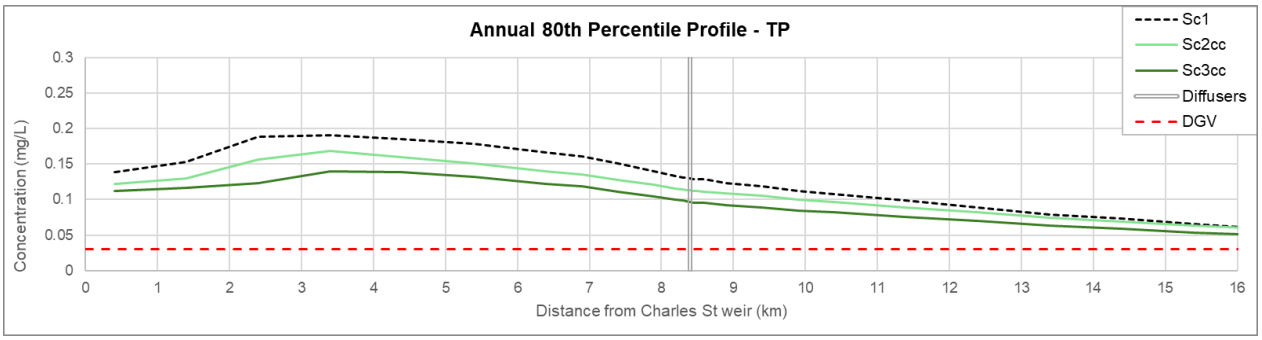

TP 100m downstream of diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV


TP 1km downstream of diffusers
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

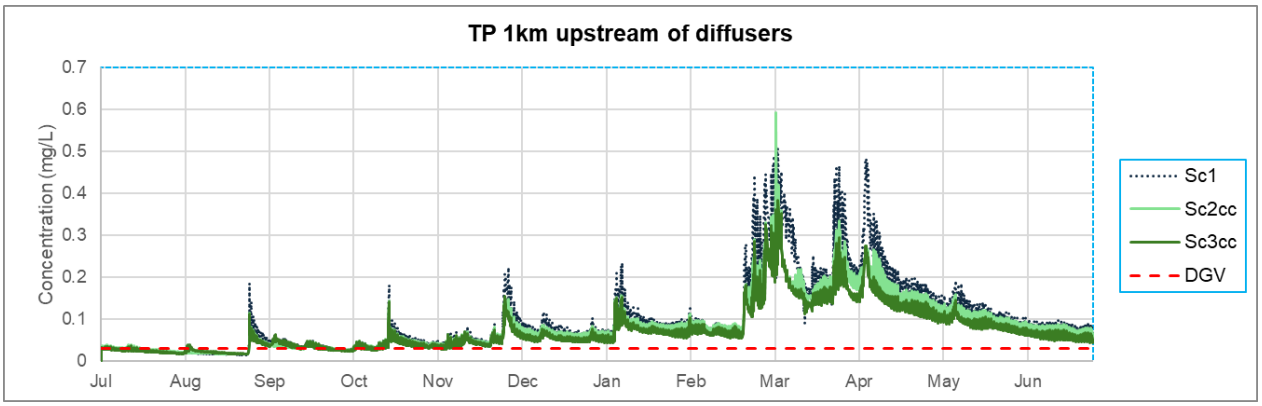
Appendices D2.6.3 Higher rainfall year scenario results (2021-2022)

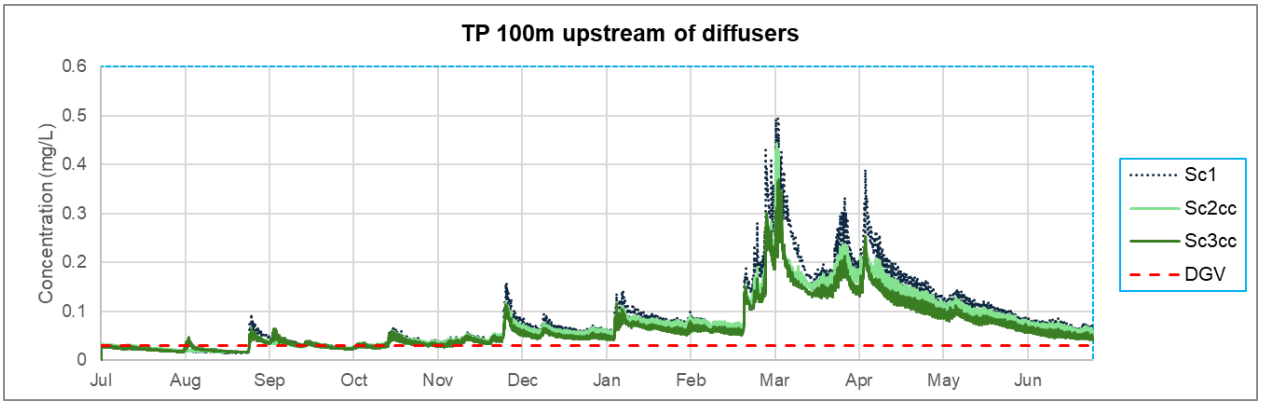
Longitudinal plots

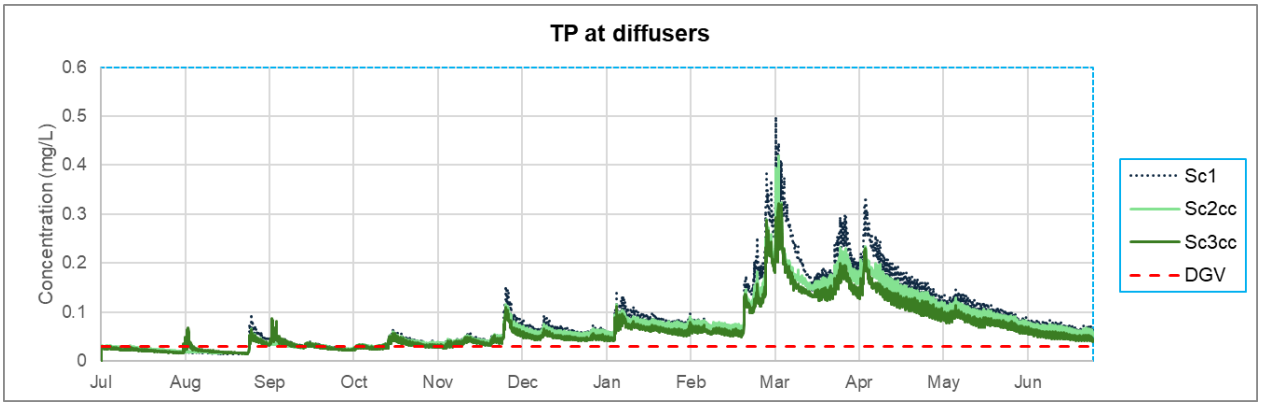




Time series plots






TP at diffusers
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
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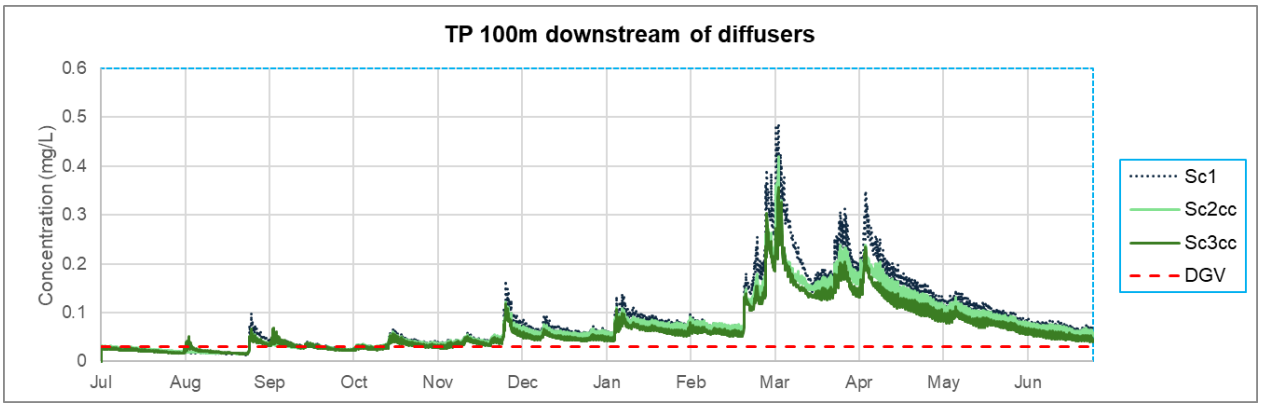
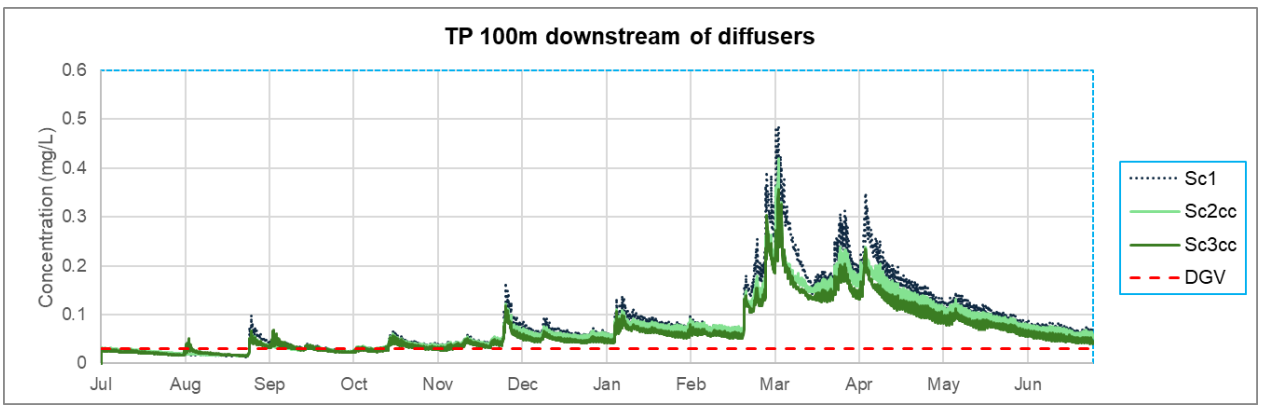
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

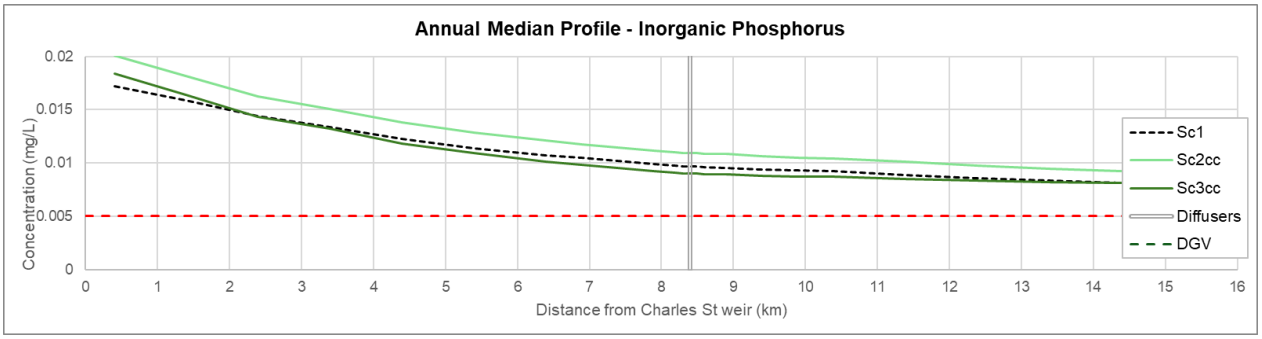

TP 100m downstream of diffusers
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

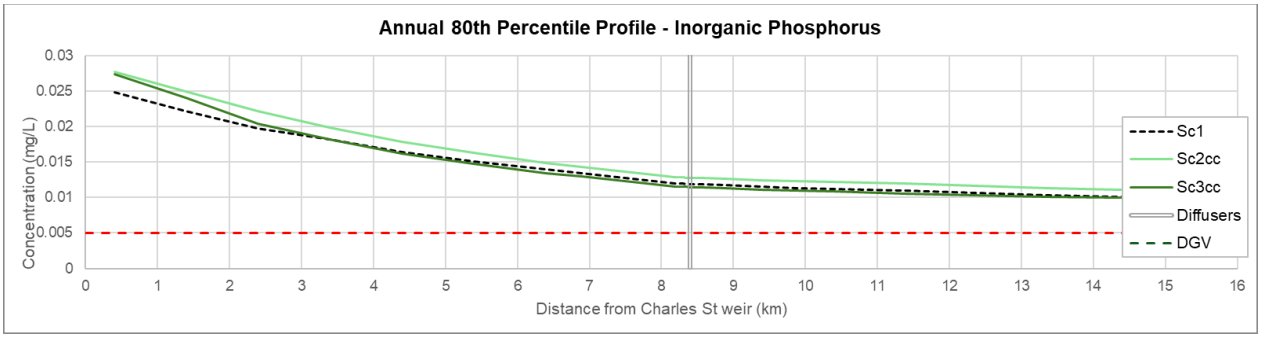

TP 100m downstream of diffusers
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

Appendices D2.7 Inorganic P

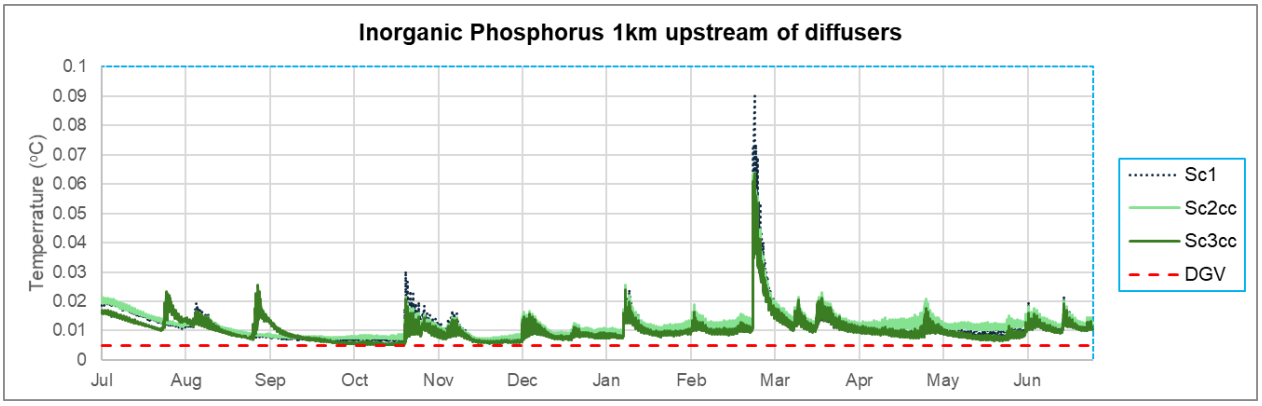
Appendices D2.7.1 Lower rainfall year scenario results (2017-2018)

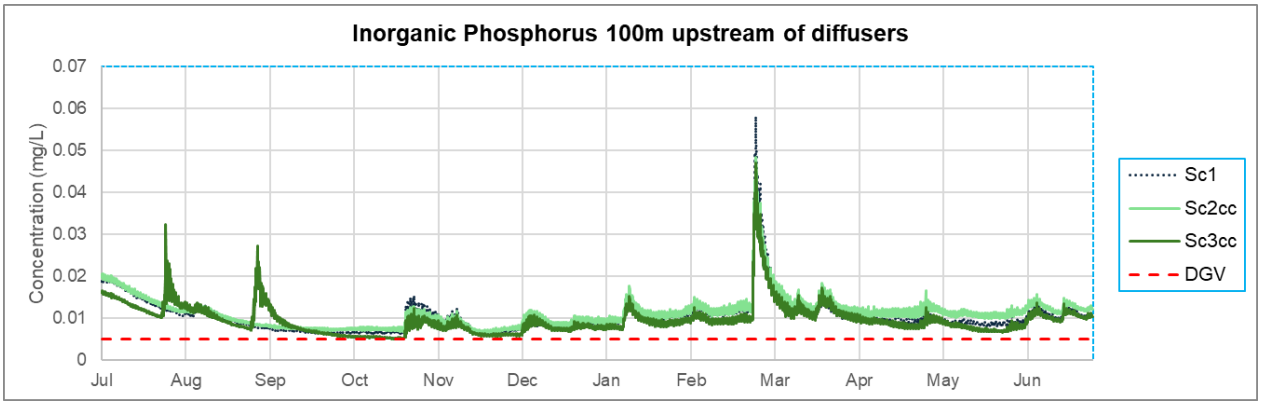
Longitudinal plots

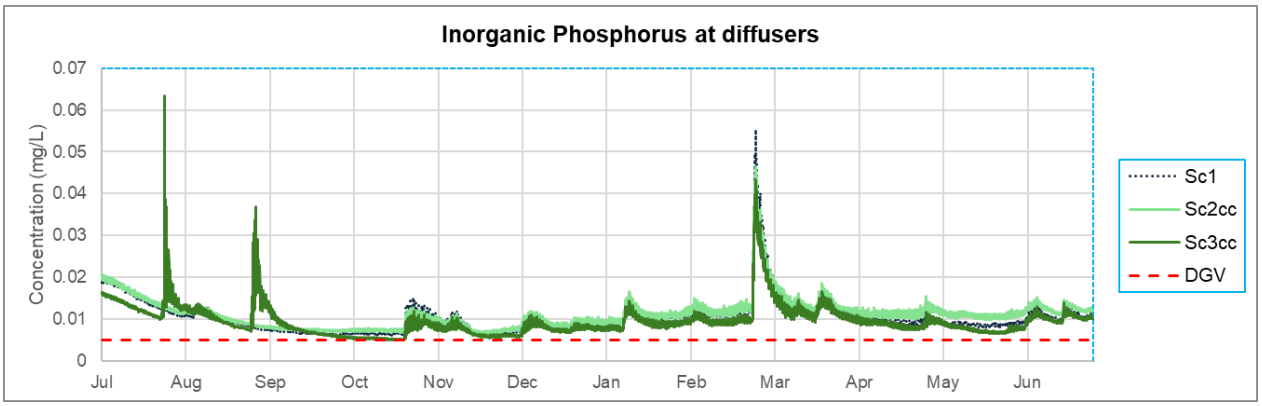


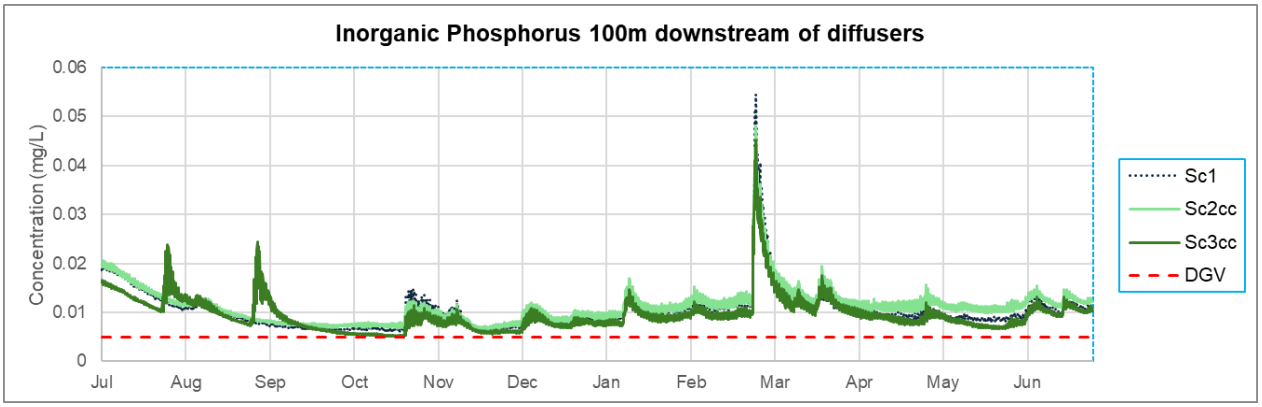


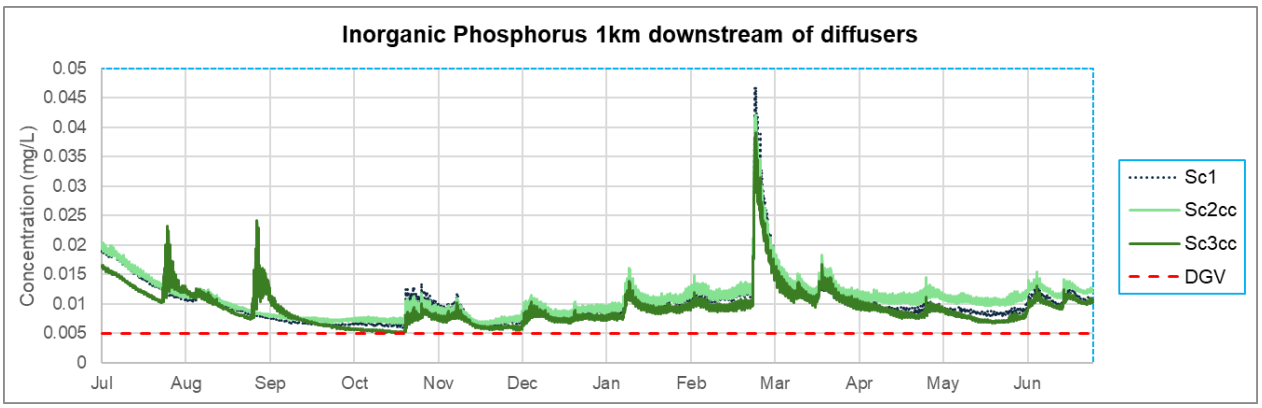
Time series plots





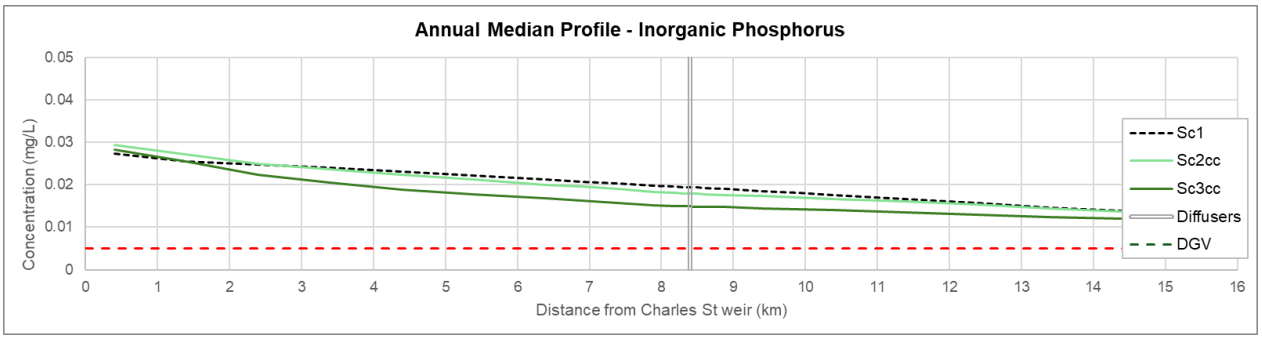


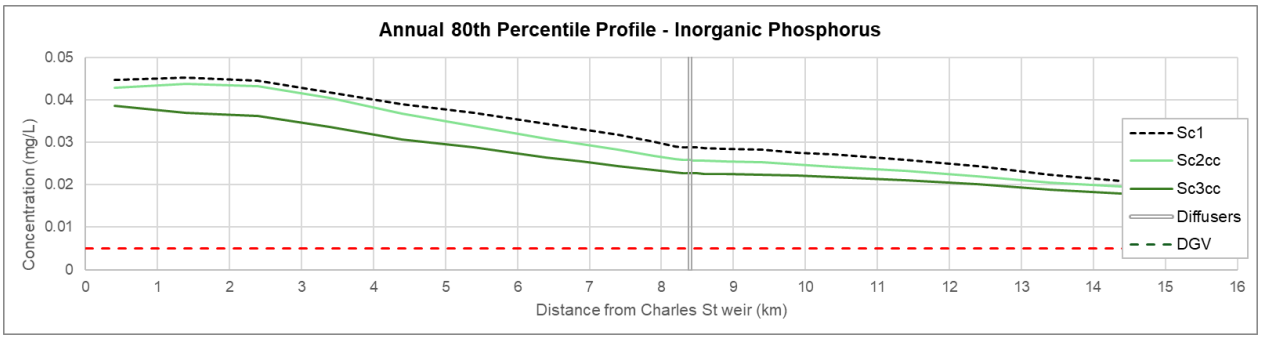




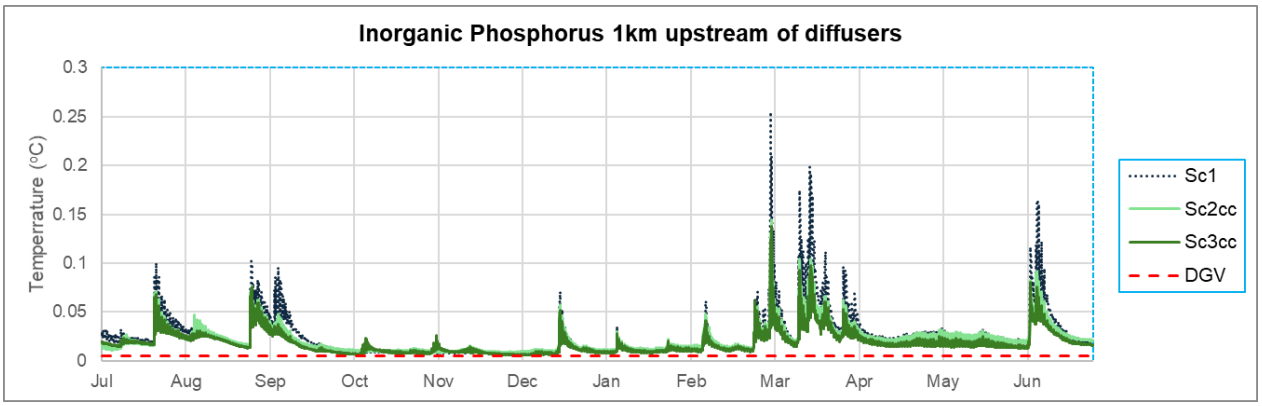
Appendices D2.7.2 Average rainfall year scenario results (2016-2017)

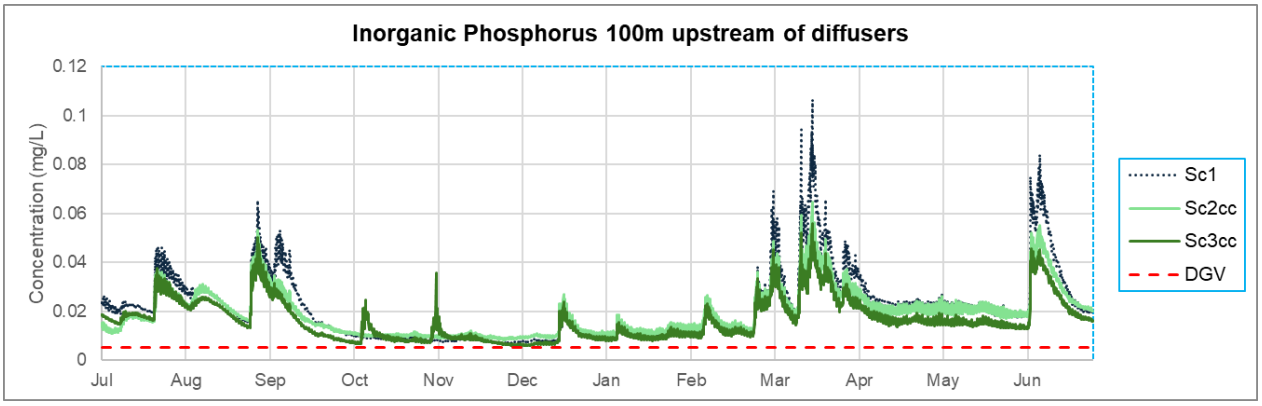
Longitudinal plots

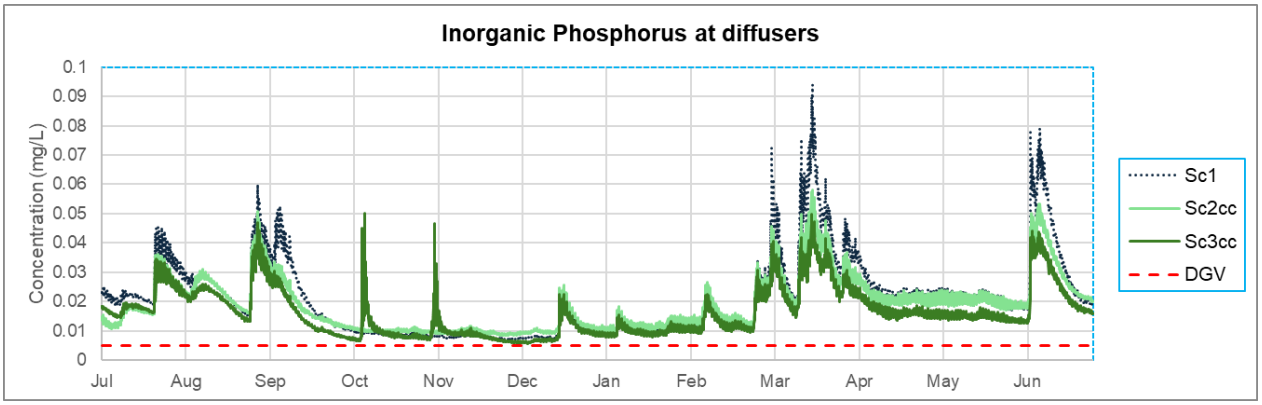


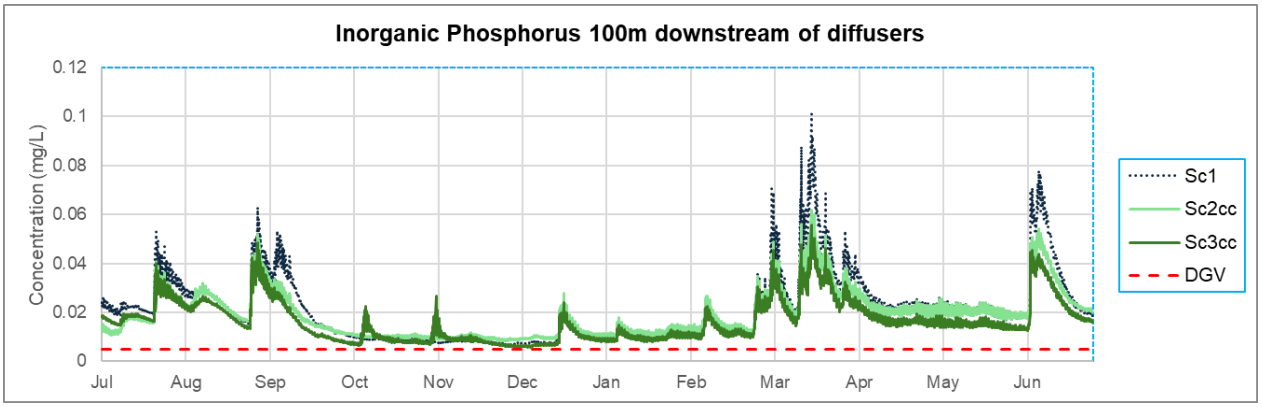


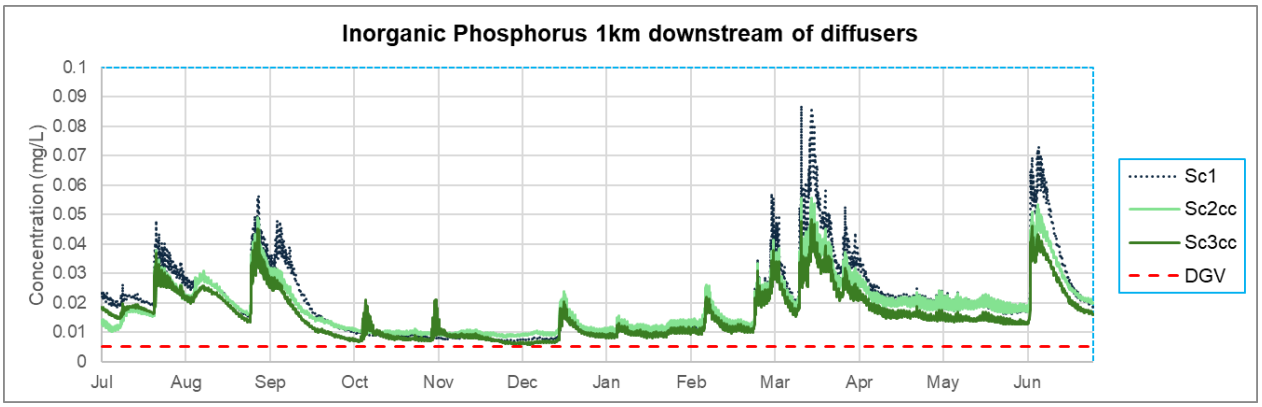
Time series plots





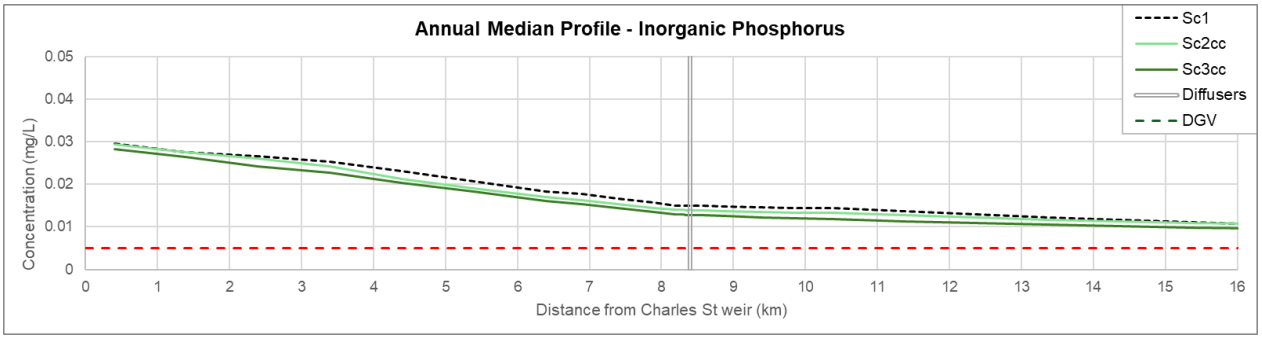


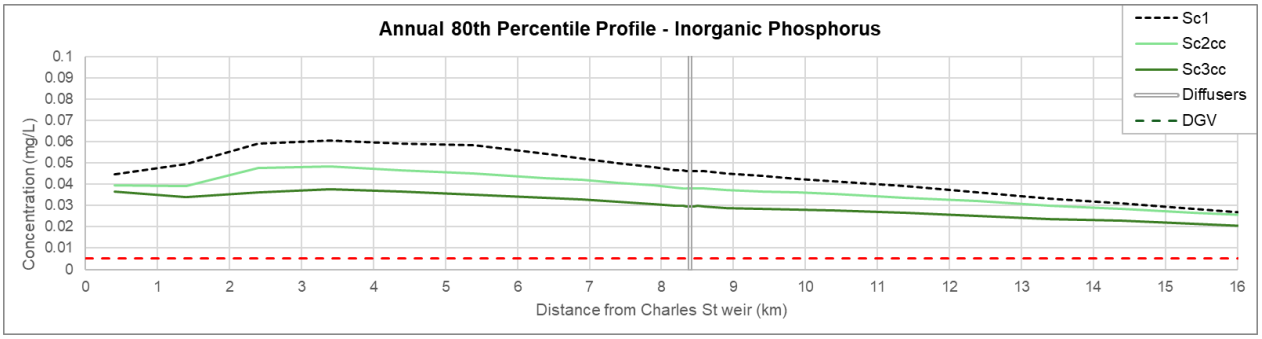




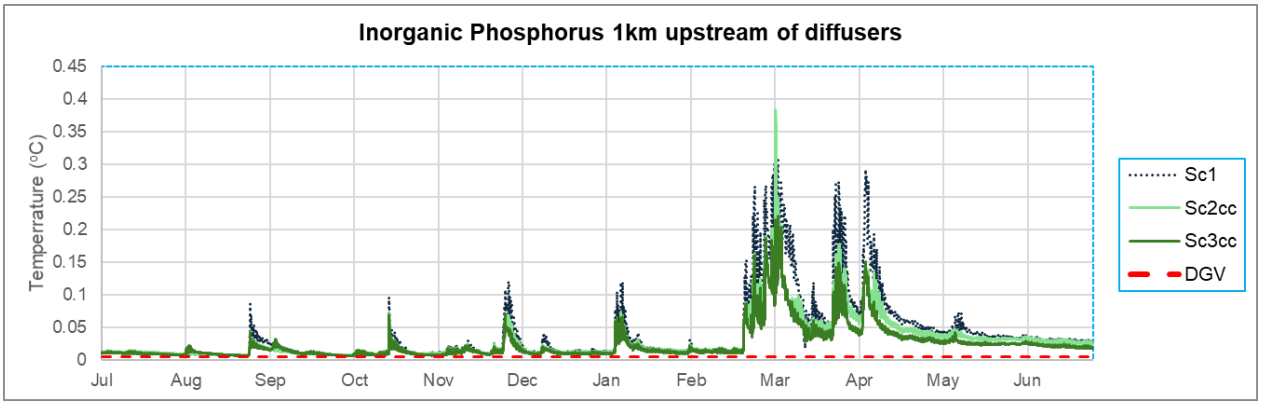
Appendices D2.7.3 Higher rainfall year scenario results (2021-2022)

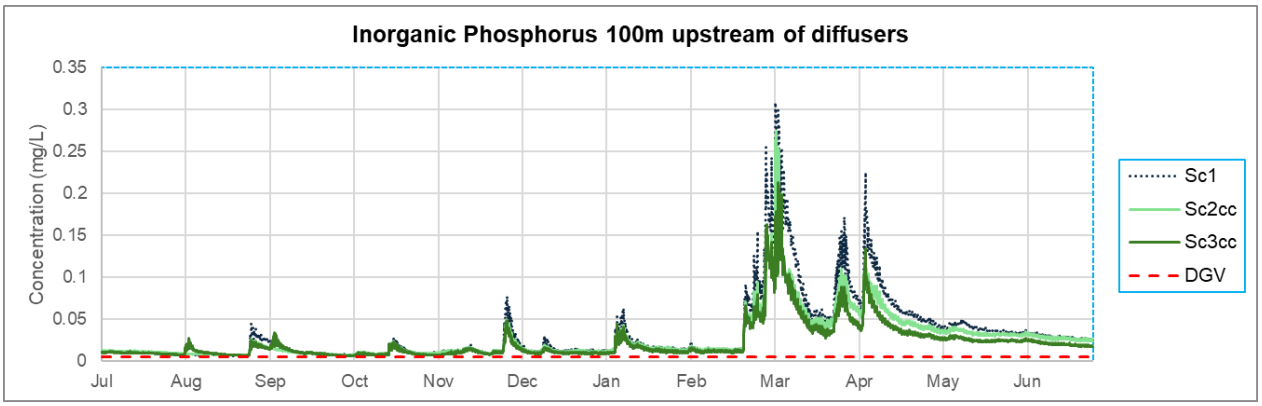
Longitudinal plots

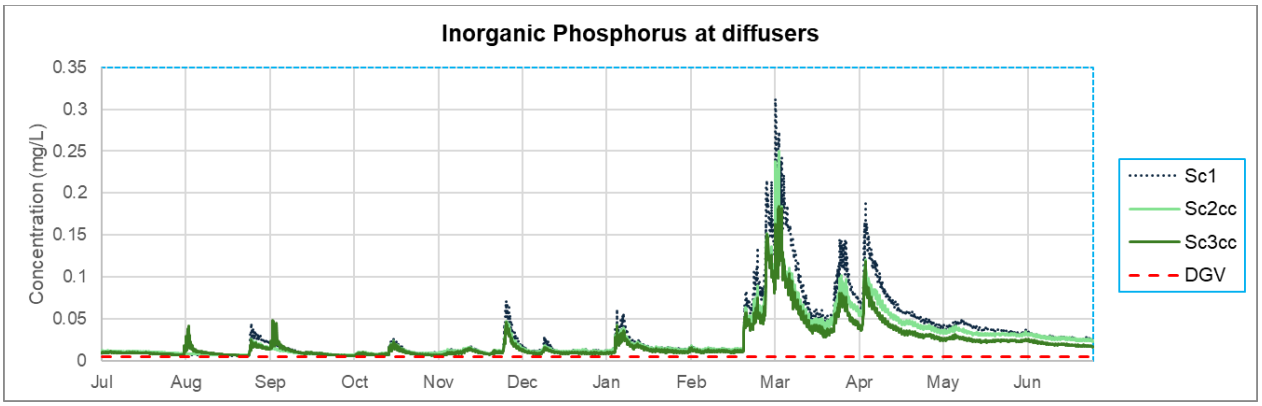


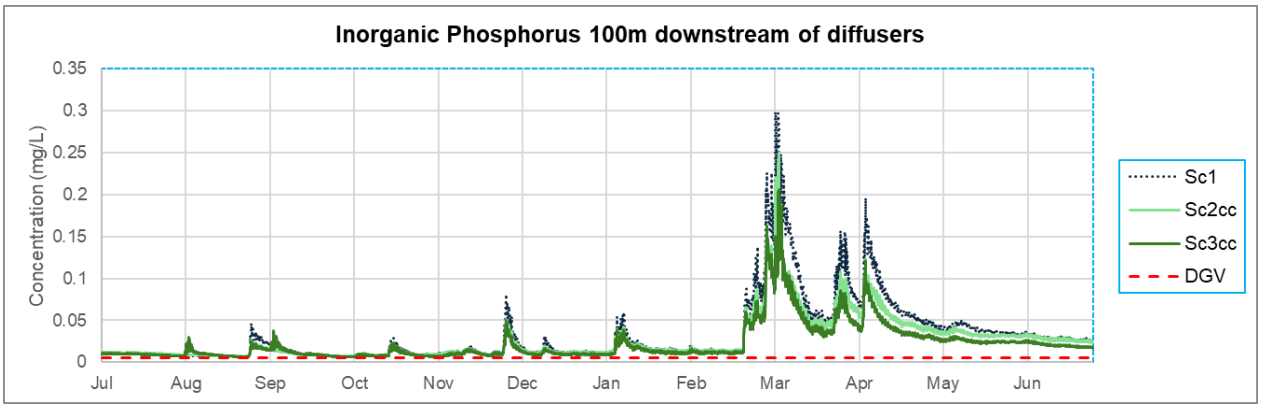


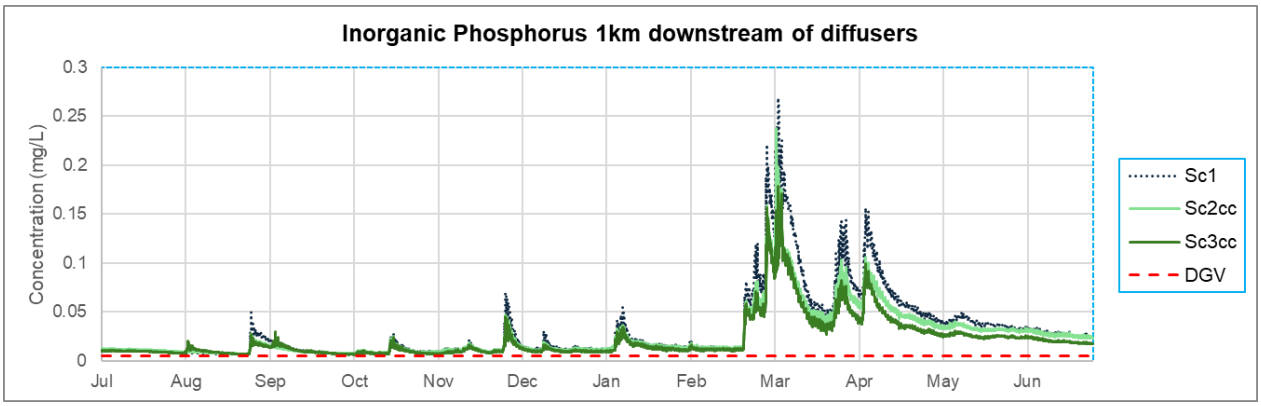
Time series plots







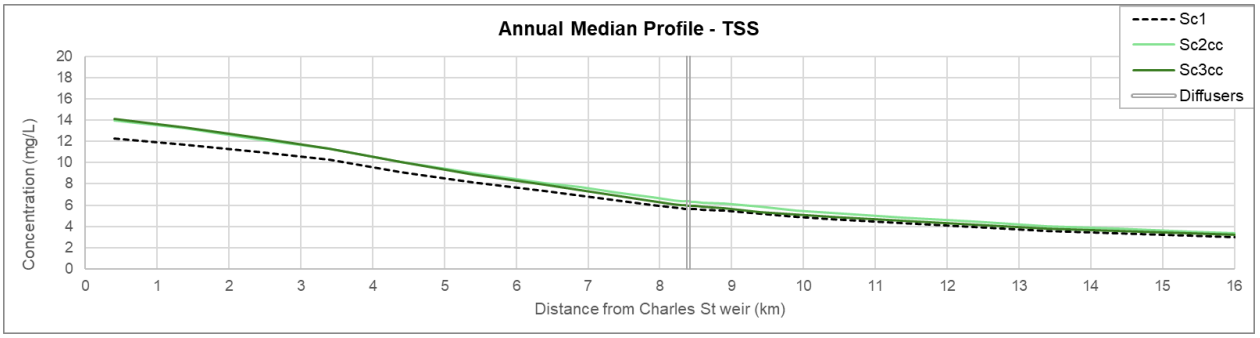


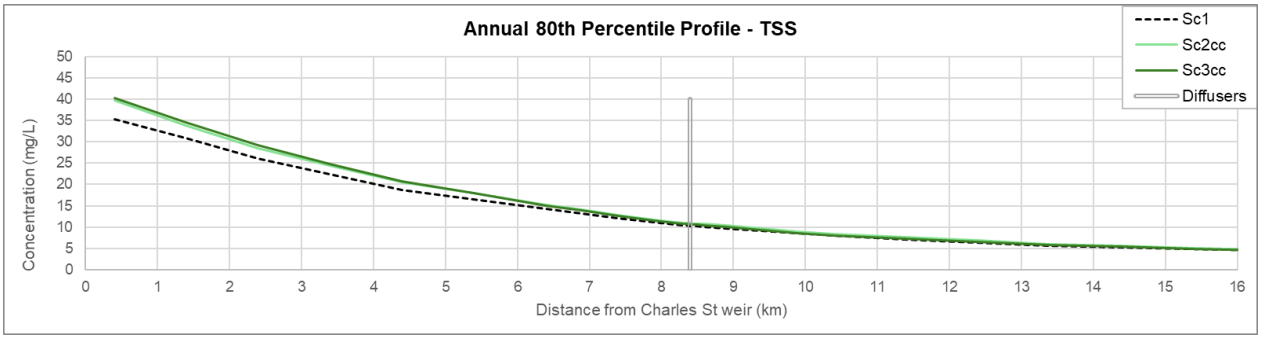


Appendices D2.8 TSS

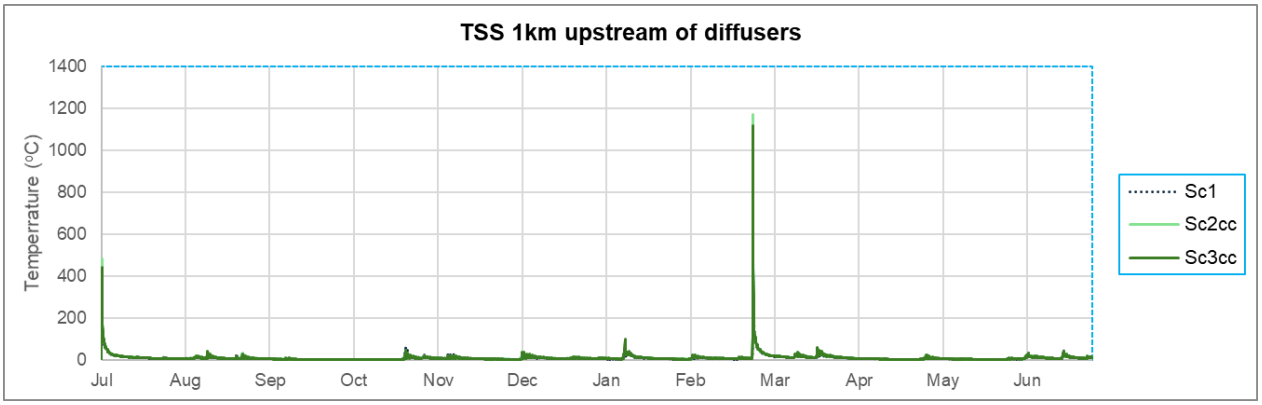
Appendices D2.8.1 Lower rainfall year scenario results (2017-2018)

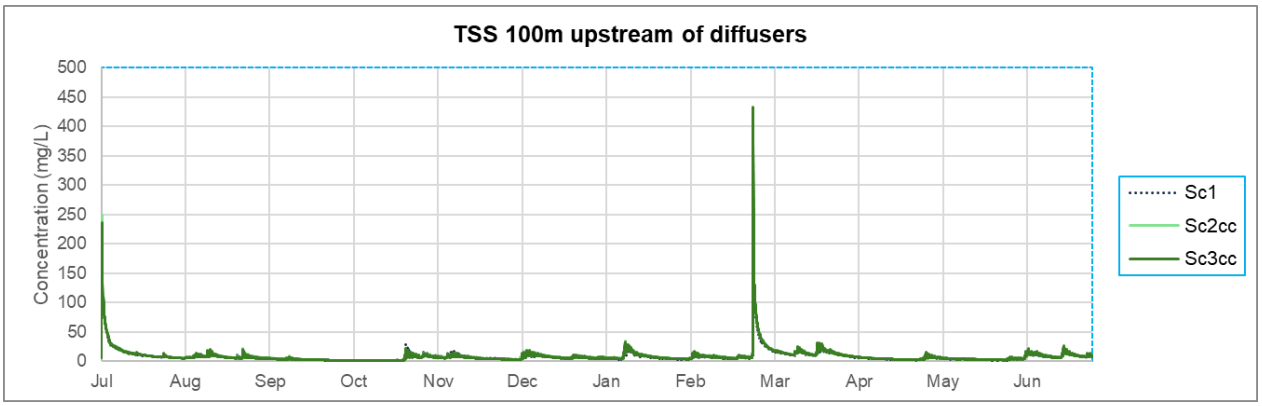
Longitudinal plots

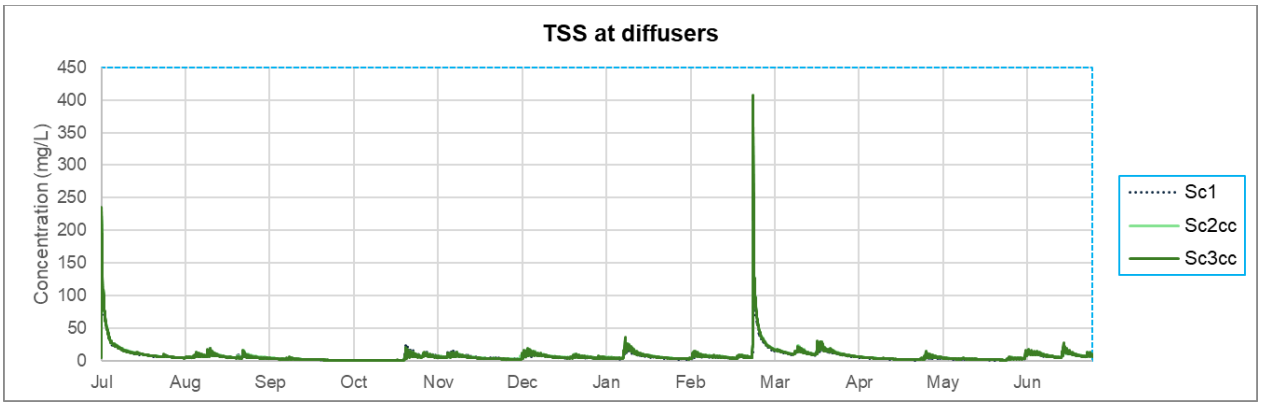


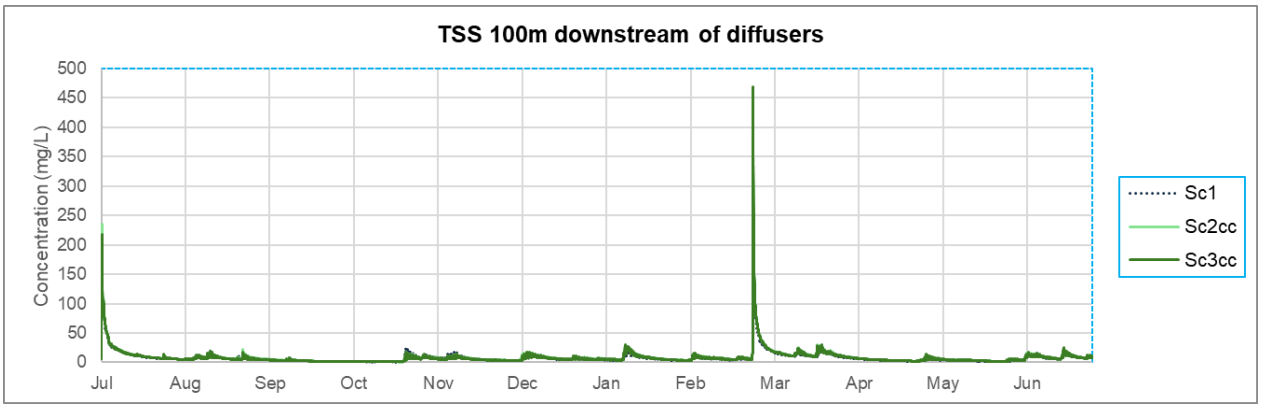


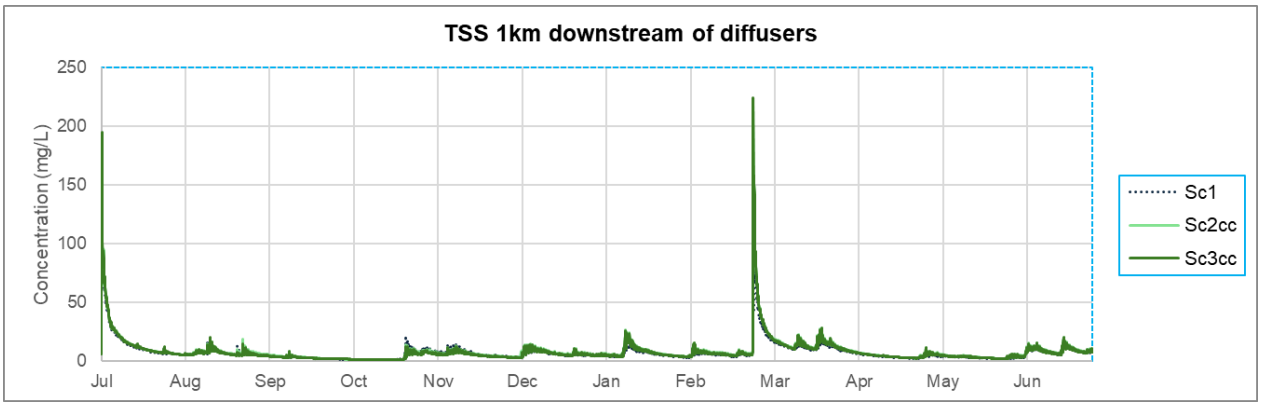
Time series plots





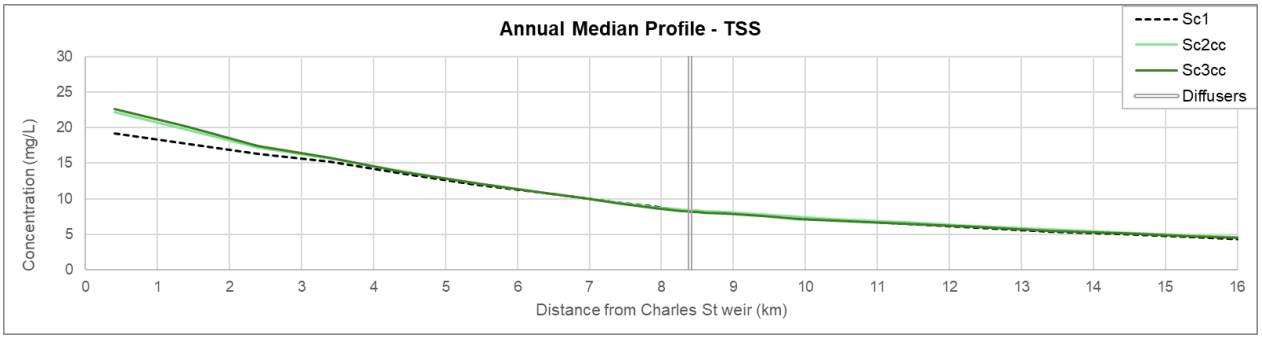


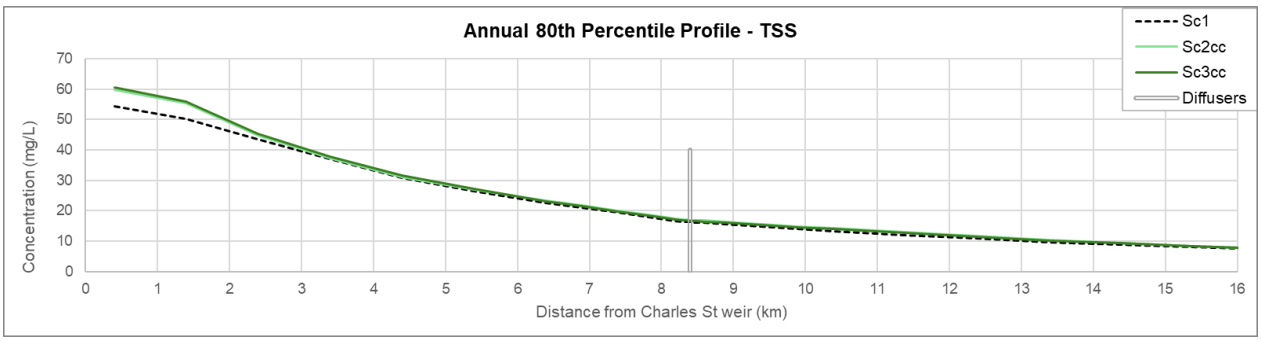




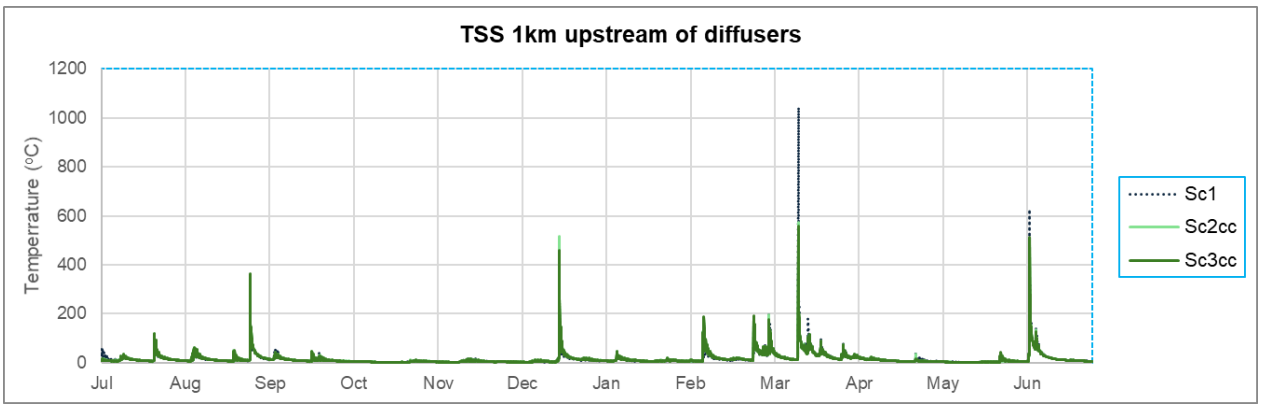
Appendices D2.8.2 Average rainfall year scenario results (2016-2017)

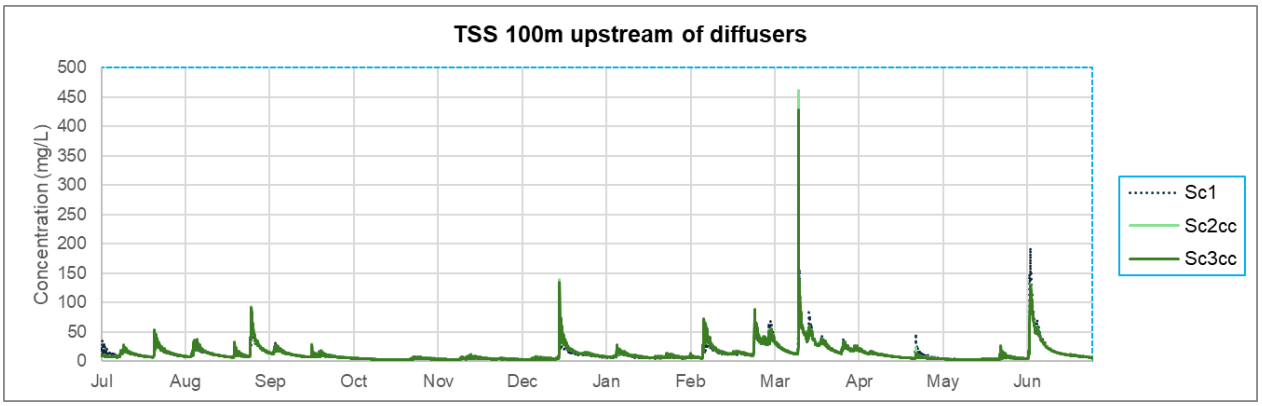
Longitudinal plots

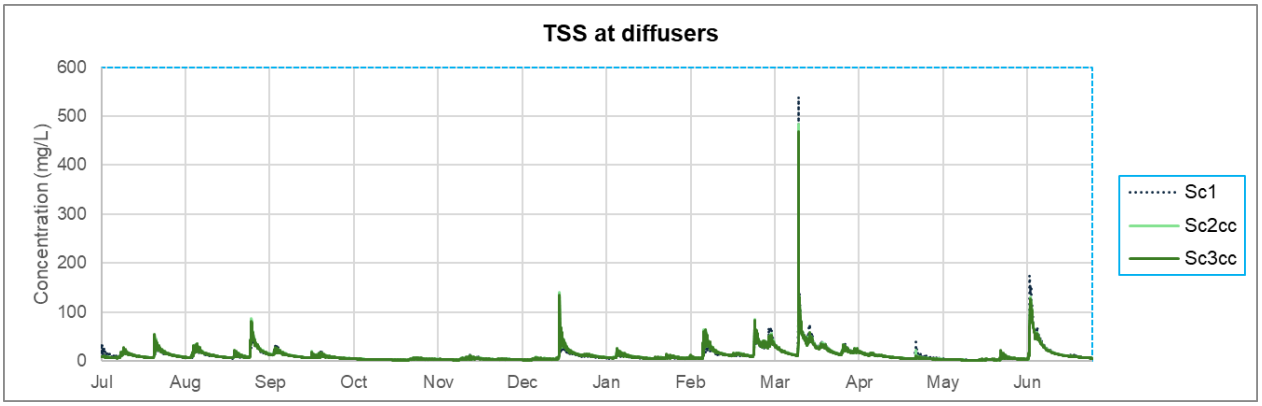


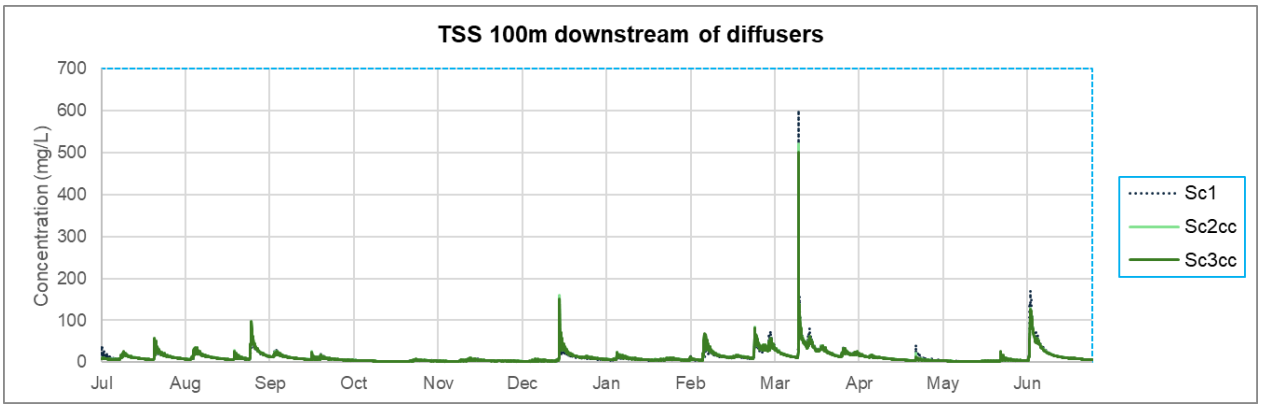


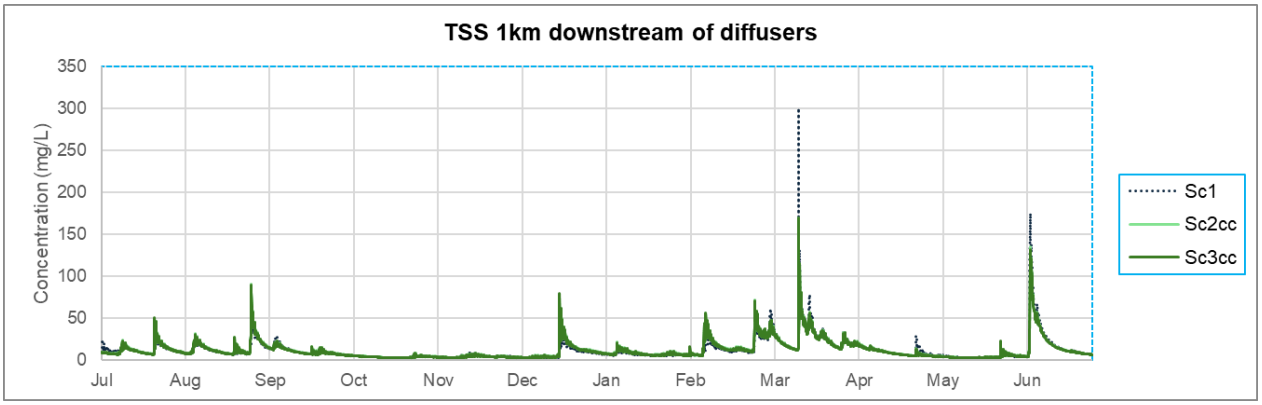
Time series plots




TSS 100m upstream of diffusers
Concentration (mg/L)
500
450
400
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

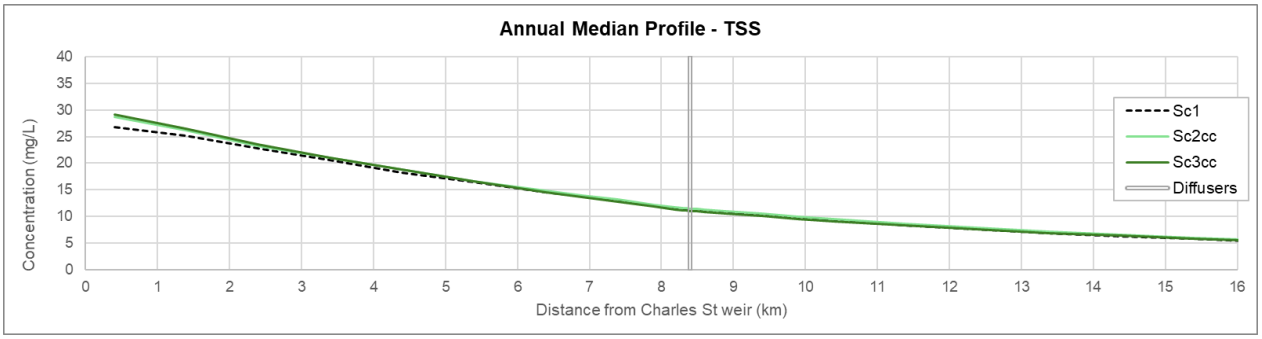

TSS at diffusers
Concentration (mg/L)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

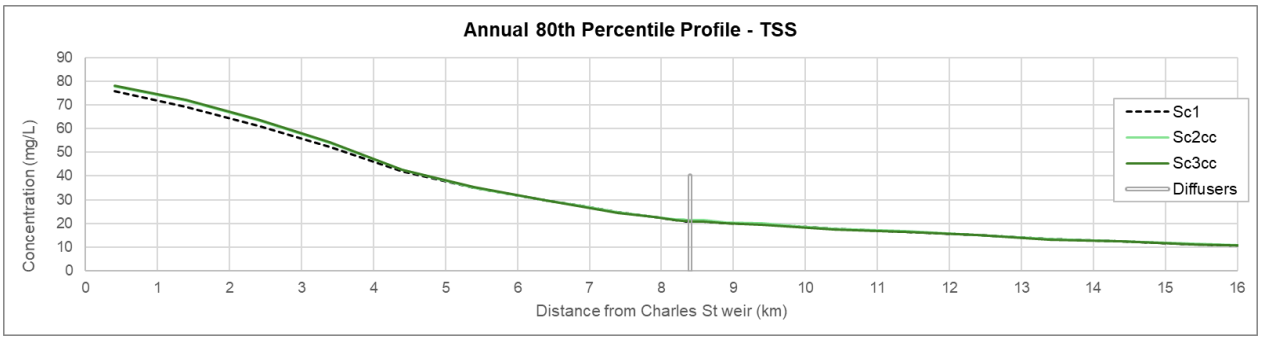

TSS 100m downstream of diffusers
Concentration (mg/L)
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


TSS 1km downstream of diffusers
Concentration (mg/L)
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

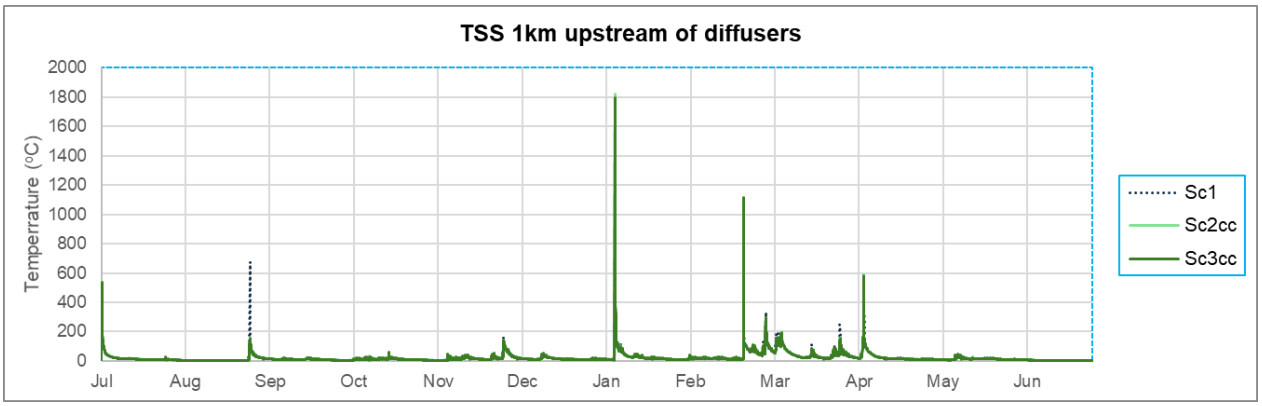
Appendices D2.8.3 Higher rainfall year scenario results (2021-2022)

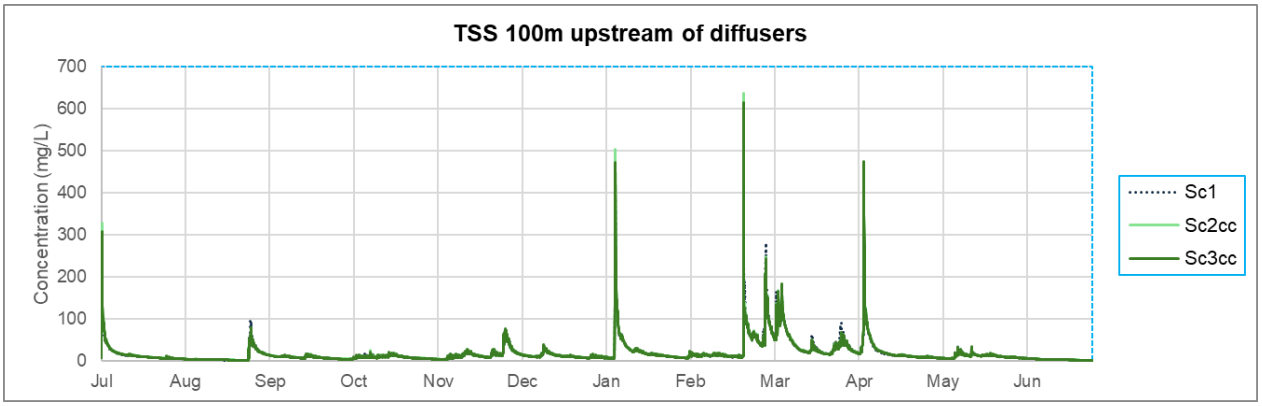
Longitudinal plots

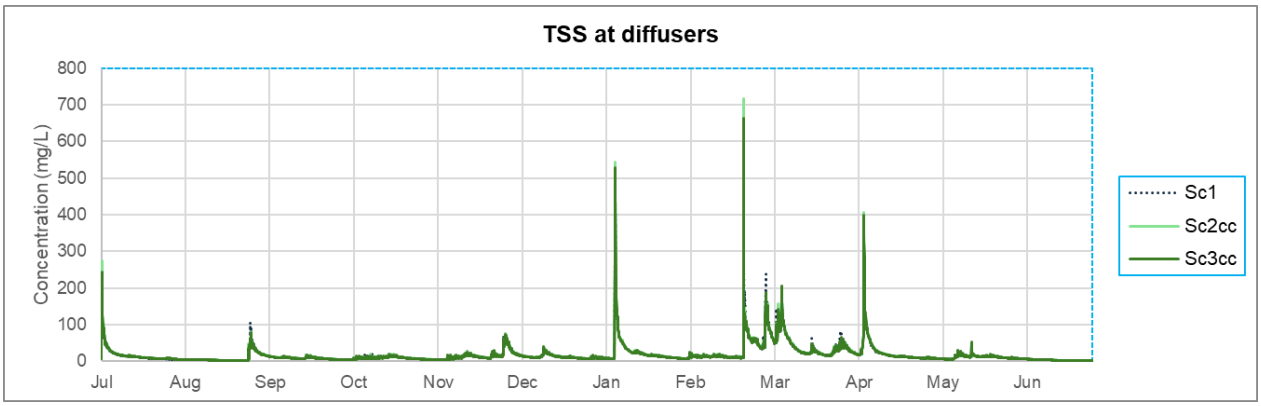


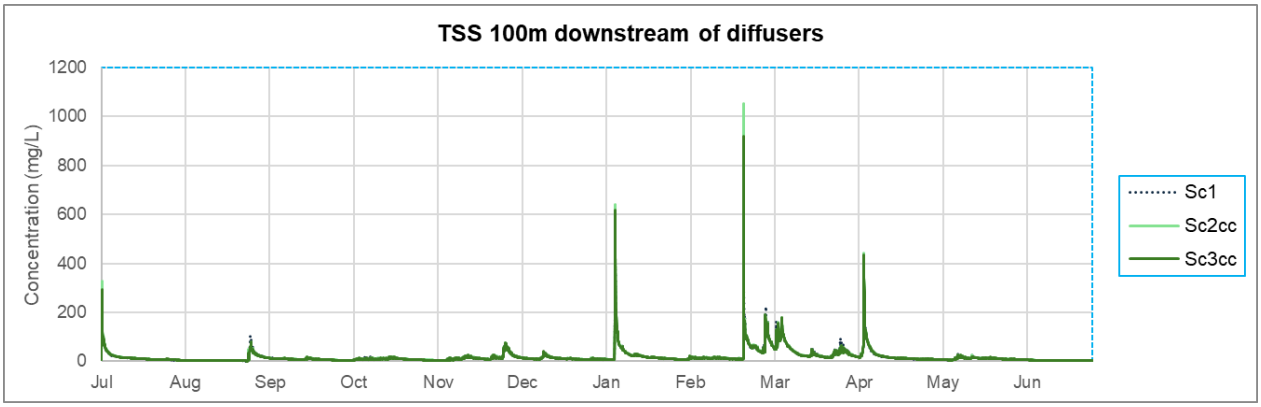


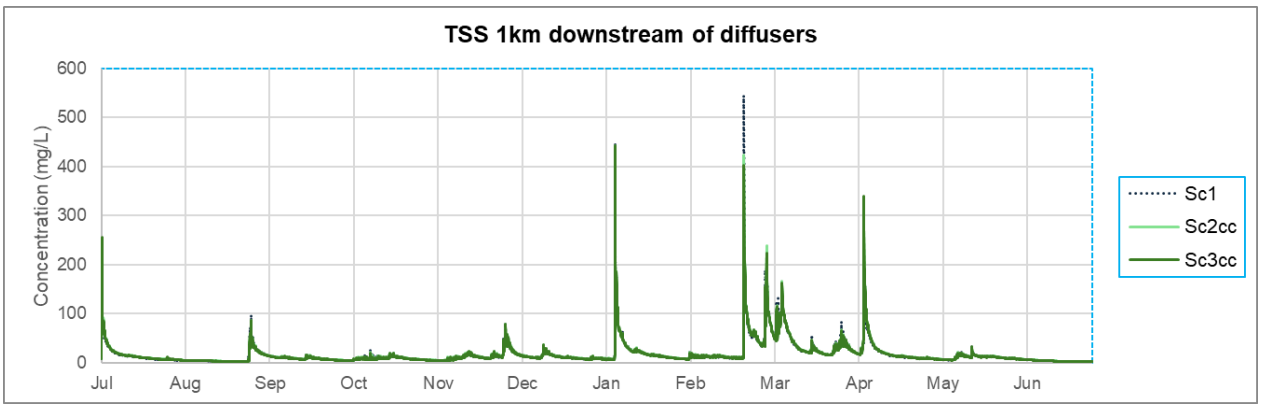
Time series plots






TSS at diffusers
Concentration (mg/L)
800
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

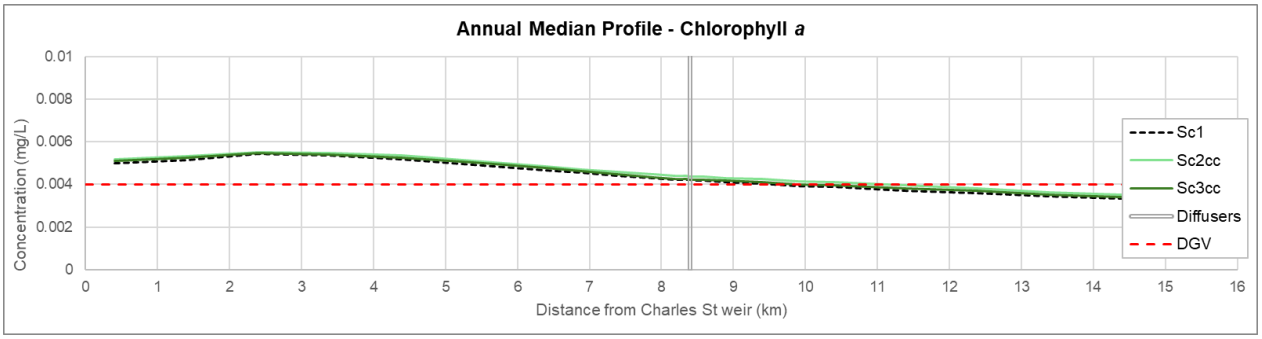

TSS 100m downstream of diffusers
Concentration (mg/L)
1200
1000
800
600
400
200
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

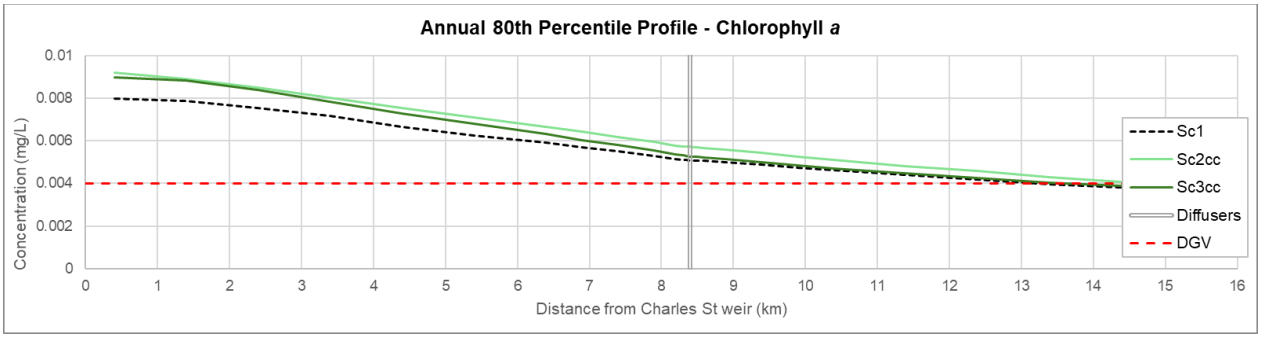

TSS 1km downstream of diffusers
Concentration (mg/L)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D2.9 Chlorophyll a

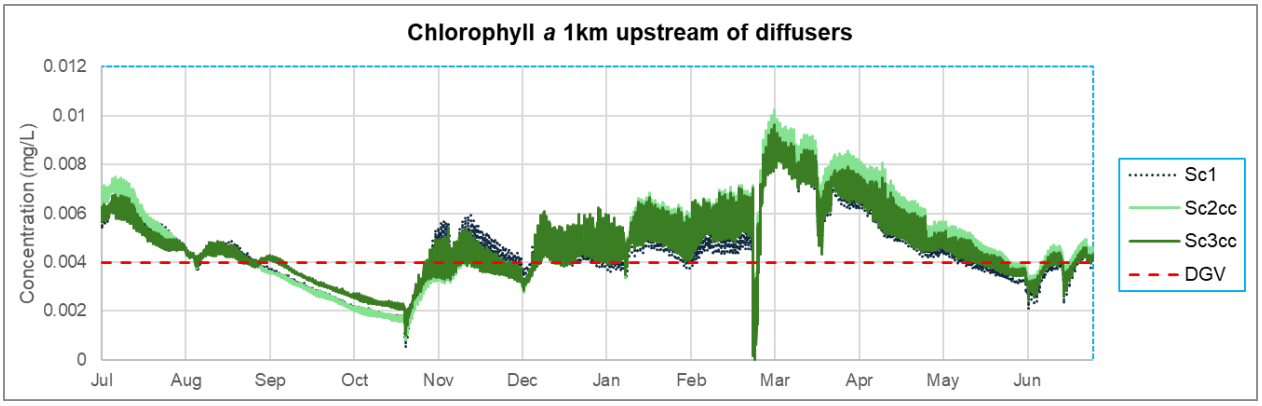
Appendices D2.9.1 Lower rainfall year scenario results (2017-2018)

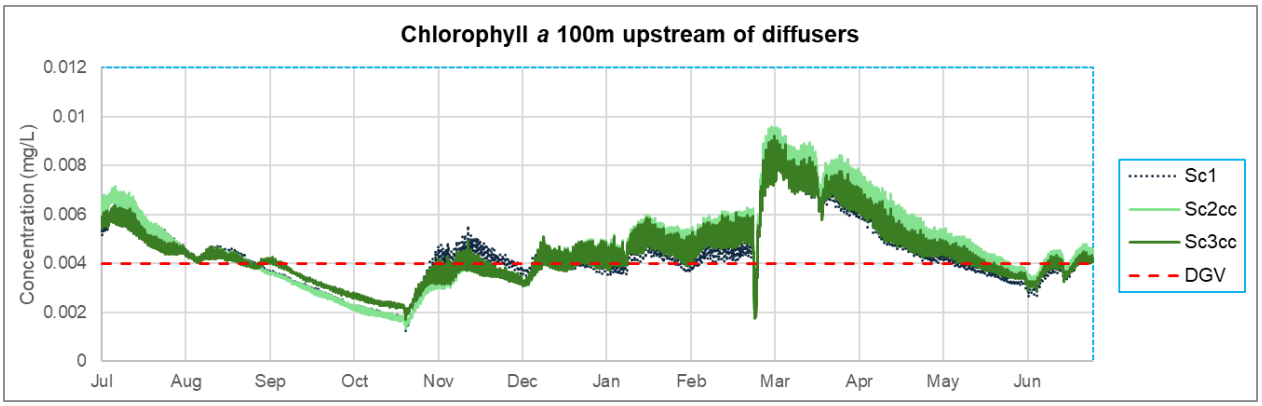
Longitudinal plots

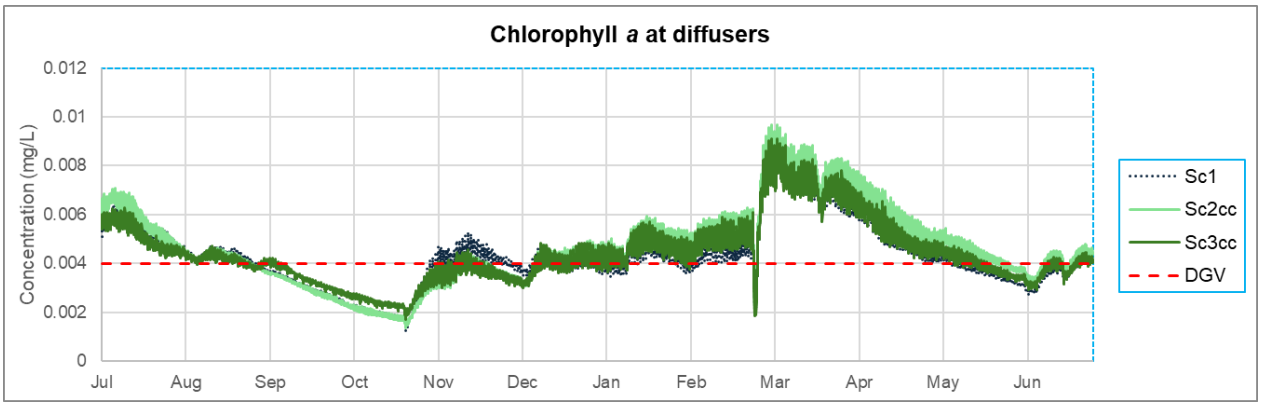


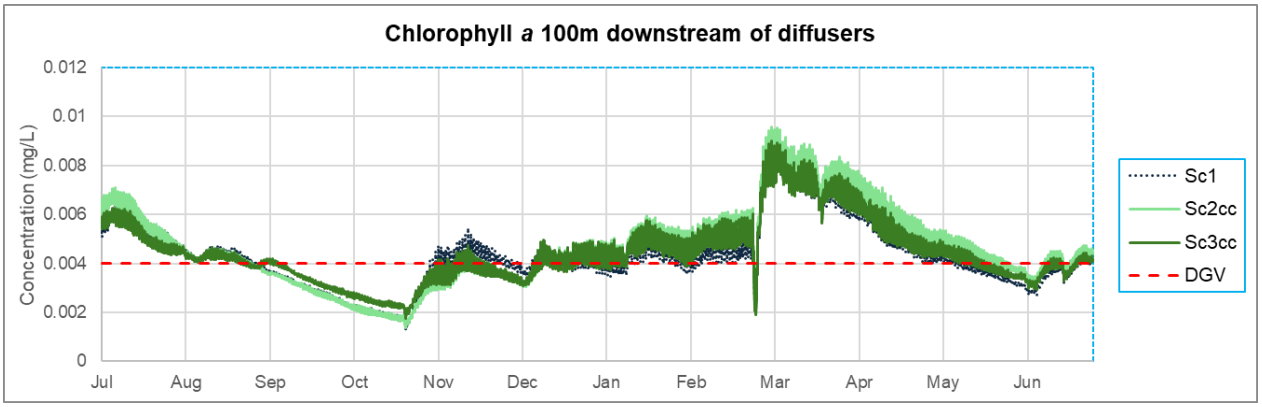


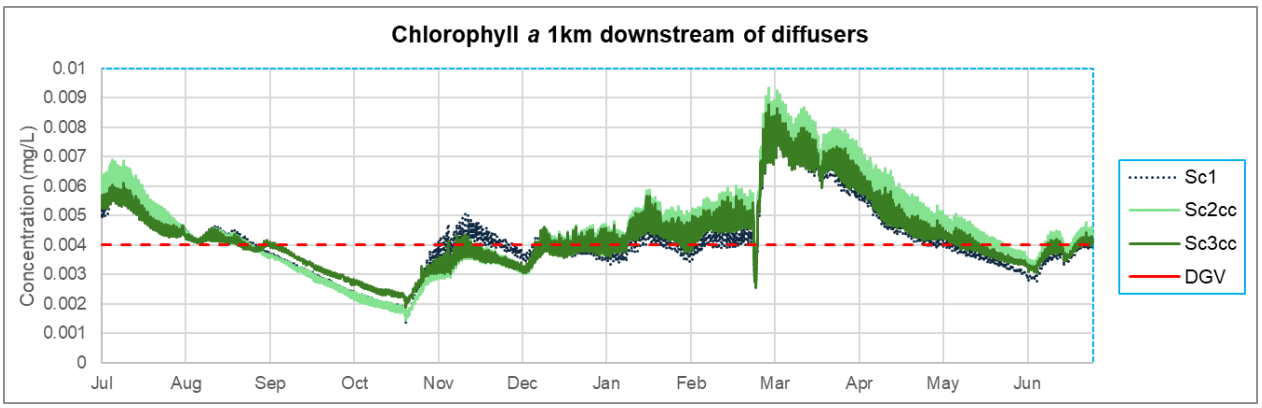
Time series plots





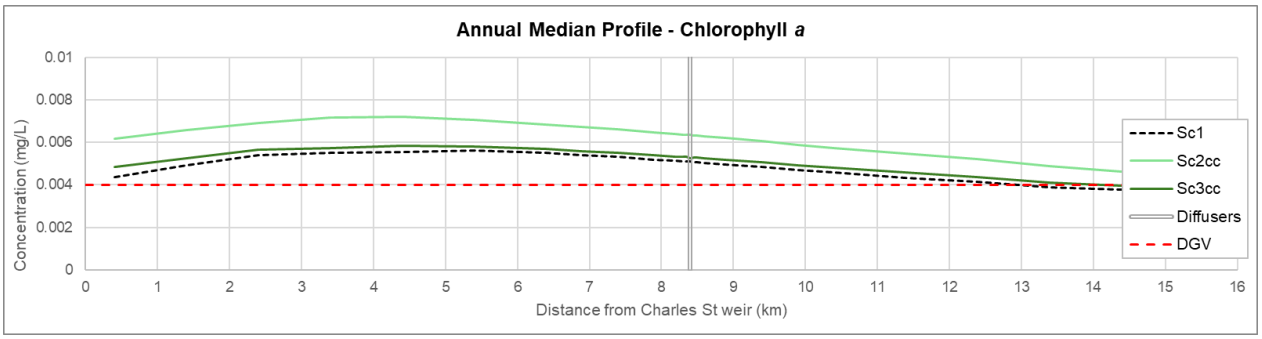


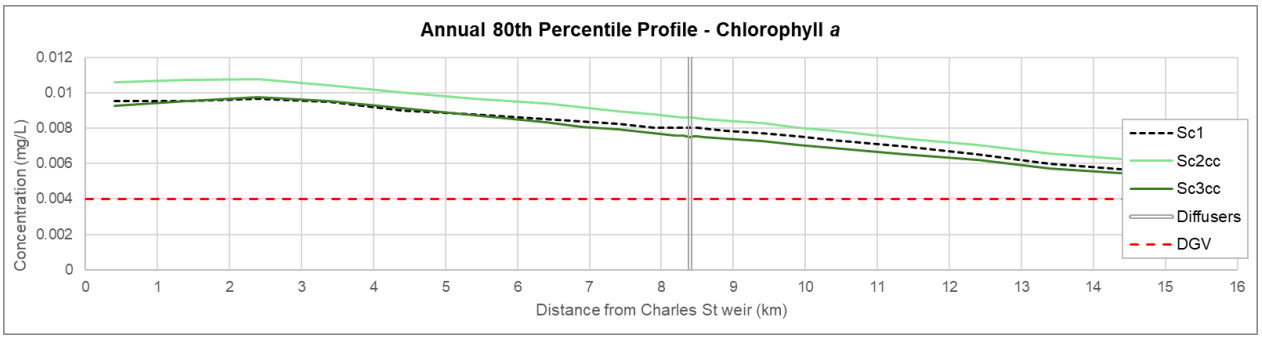




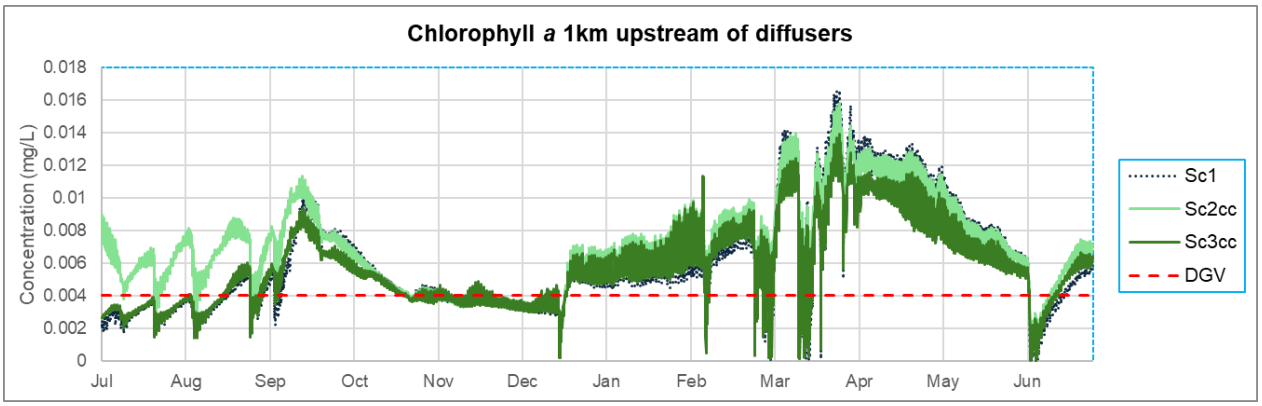
Appendices D2.9.2 Average rainfall year scenario results (2016-2017)

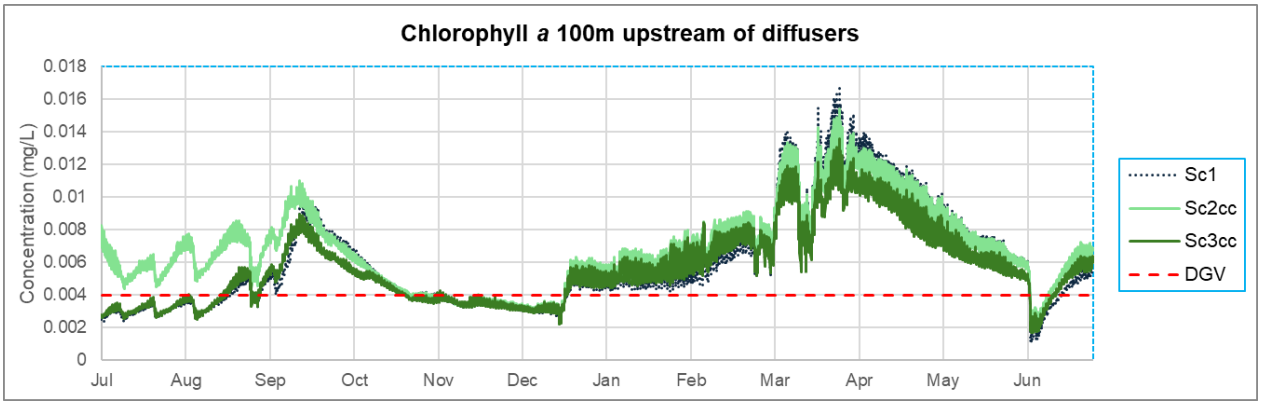
Longitudinal plots

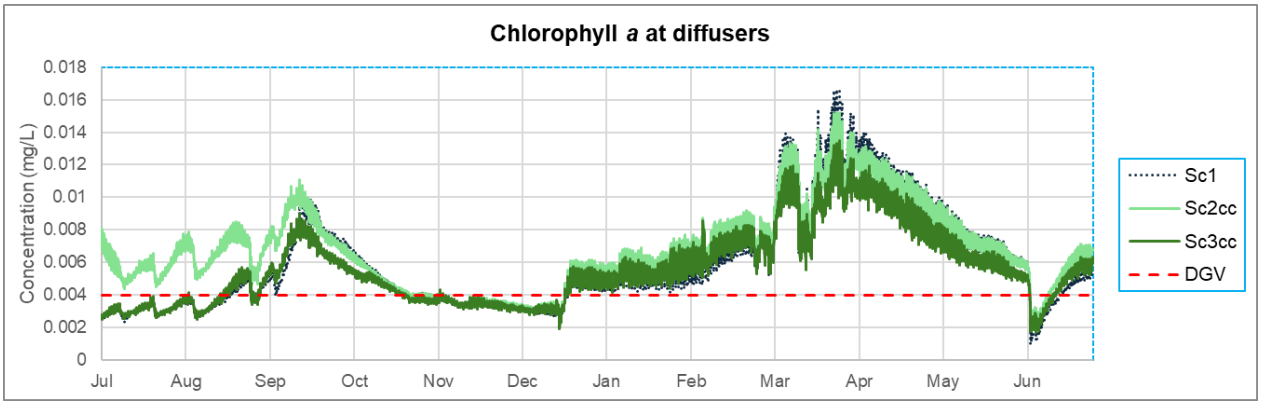


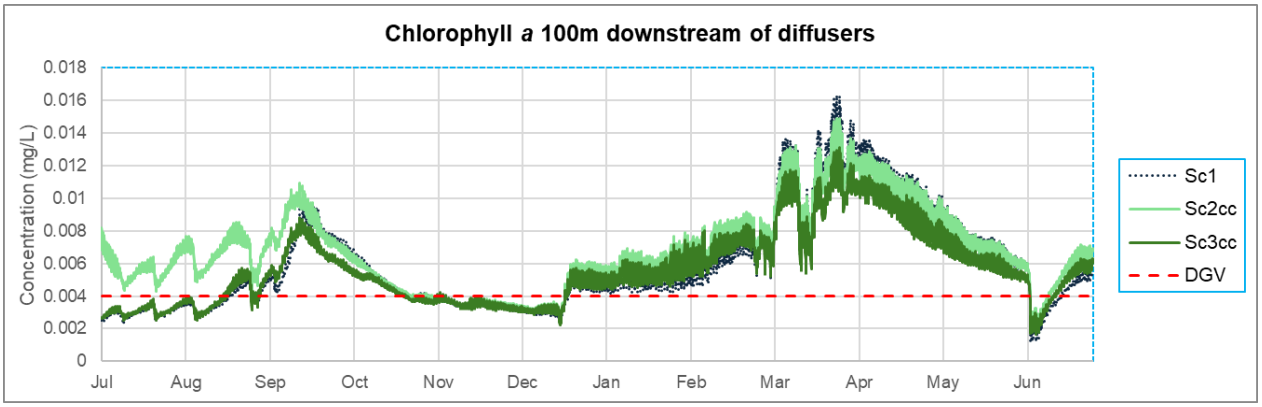


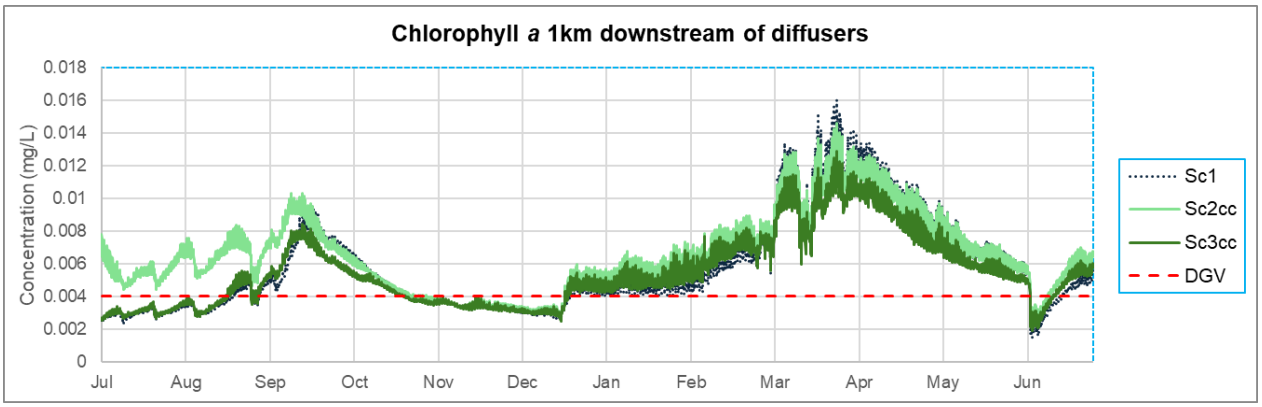
Time series plots





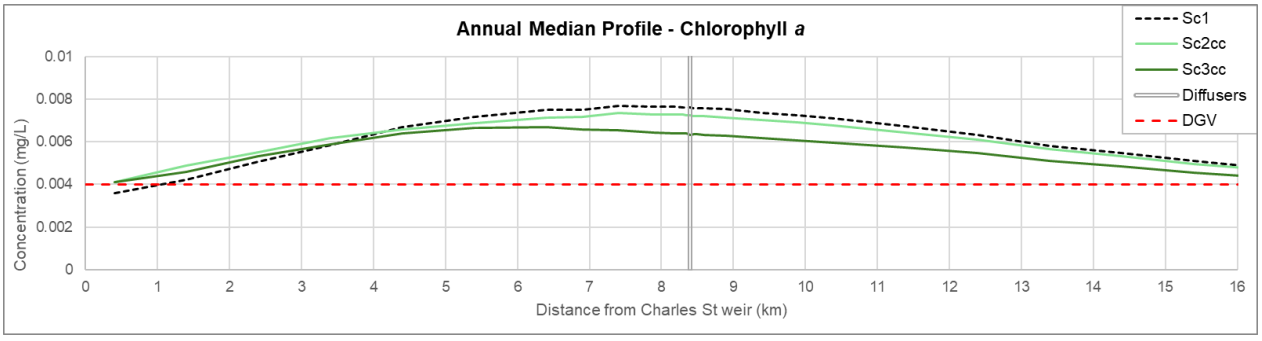


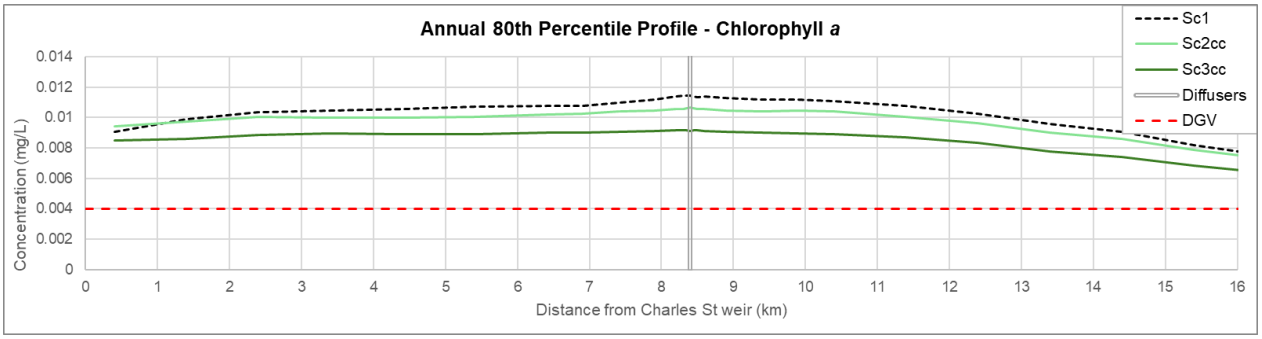




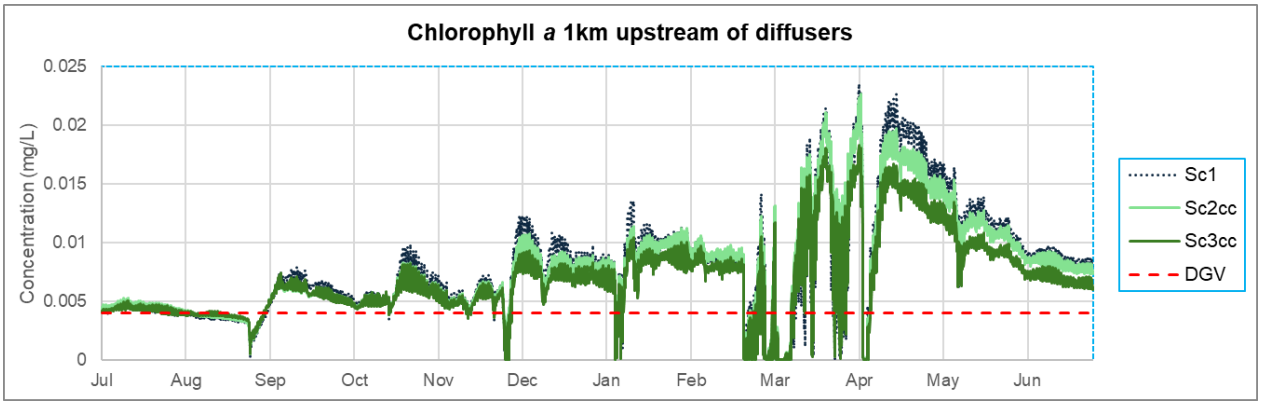
Appendices D2.9.3 Higher rainfall year scenario results (2021-2022)

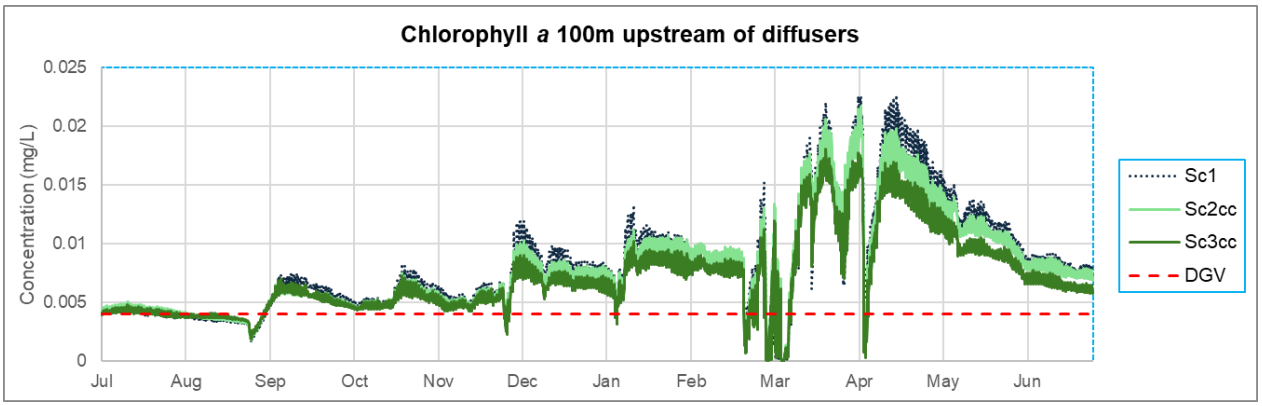
Longitudinal plots

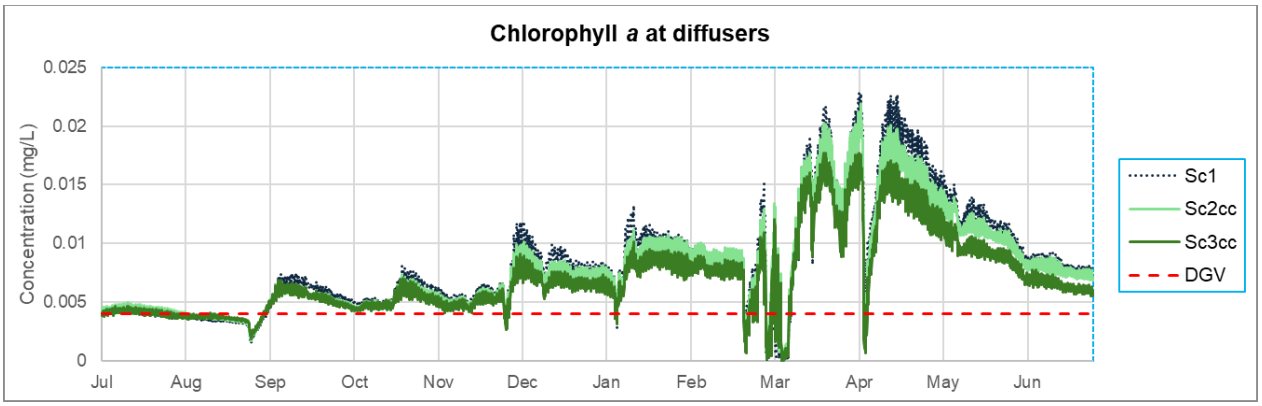


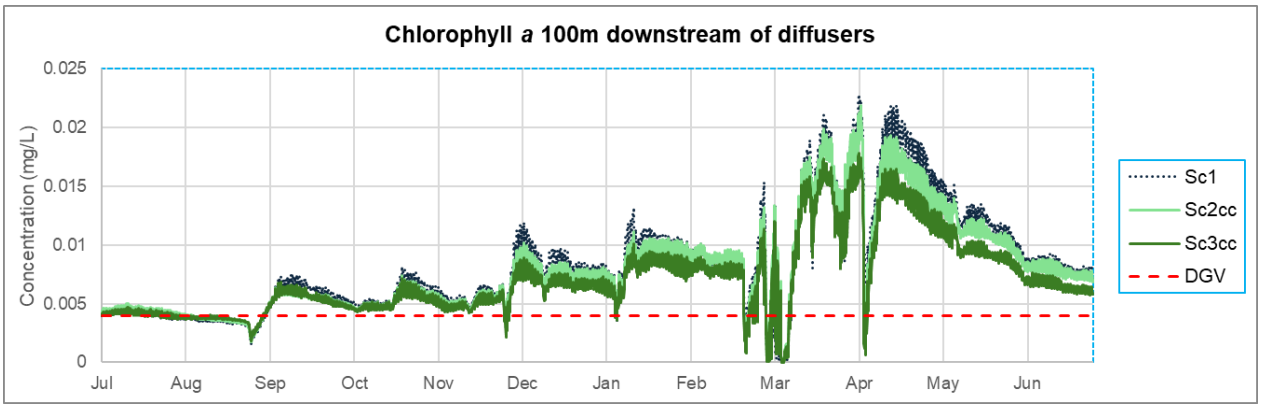


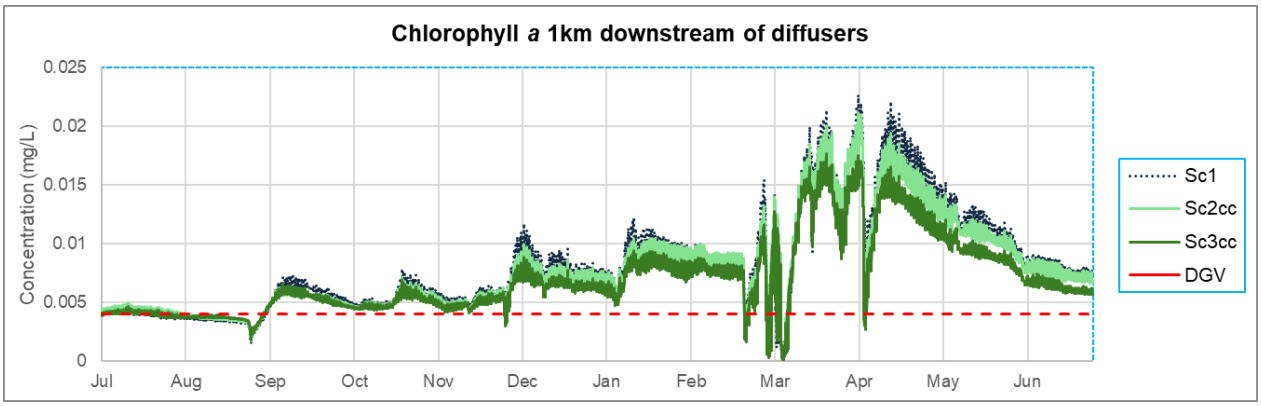
Time series plots







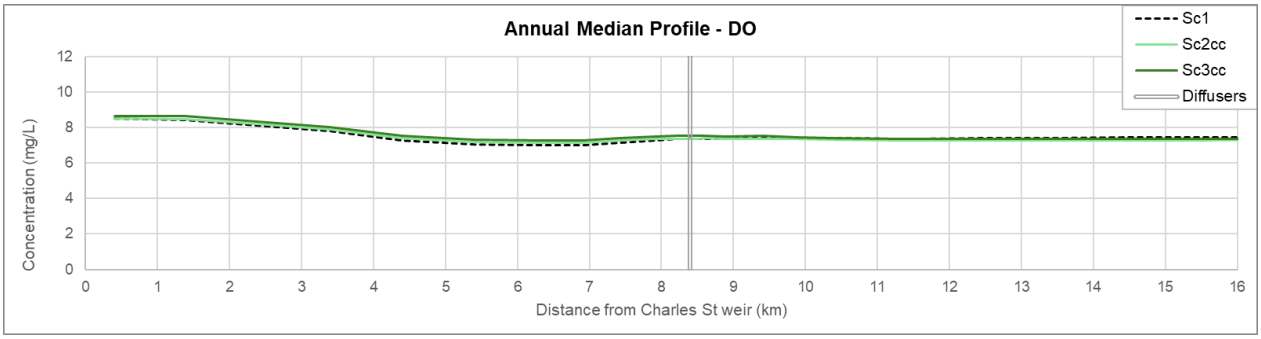


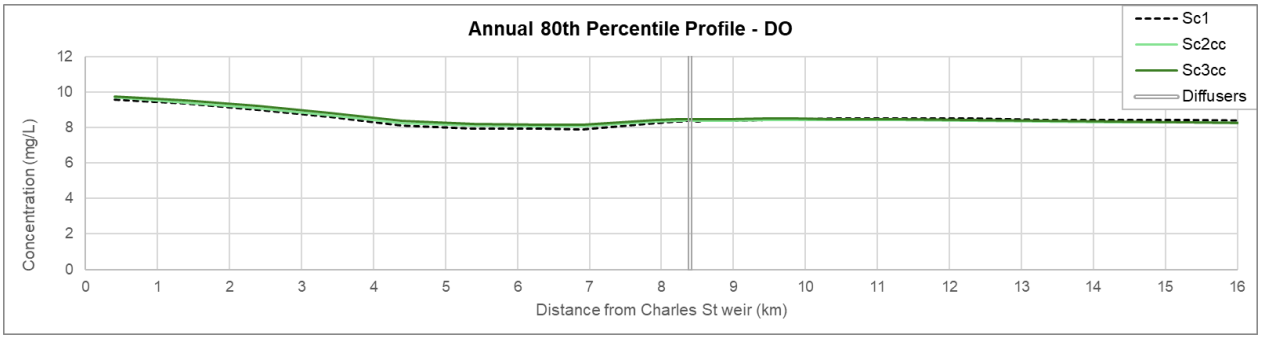


Appendices D2.10 Dissolved Oxygen

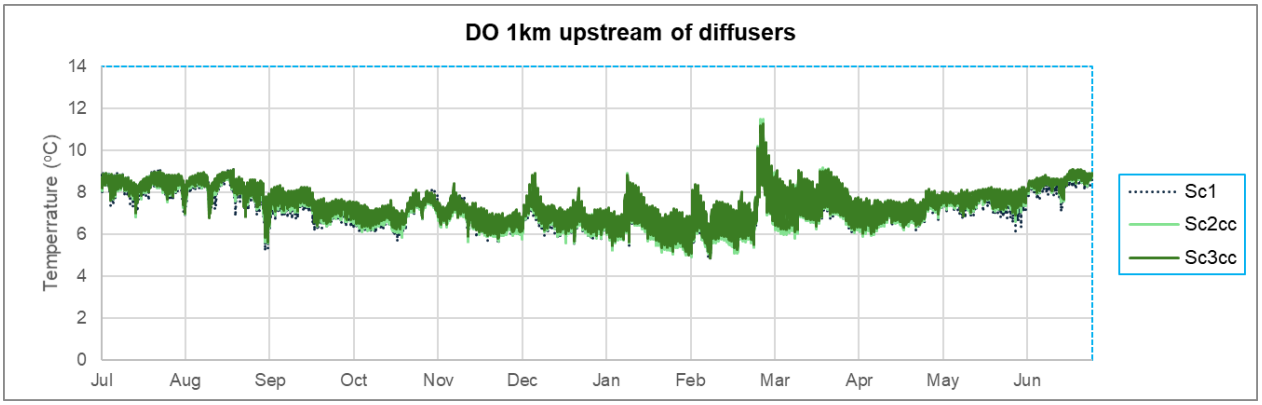
Appendices D2.10.1 Lower rainfall year scenario results (2017-2018)

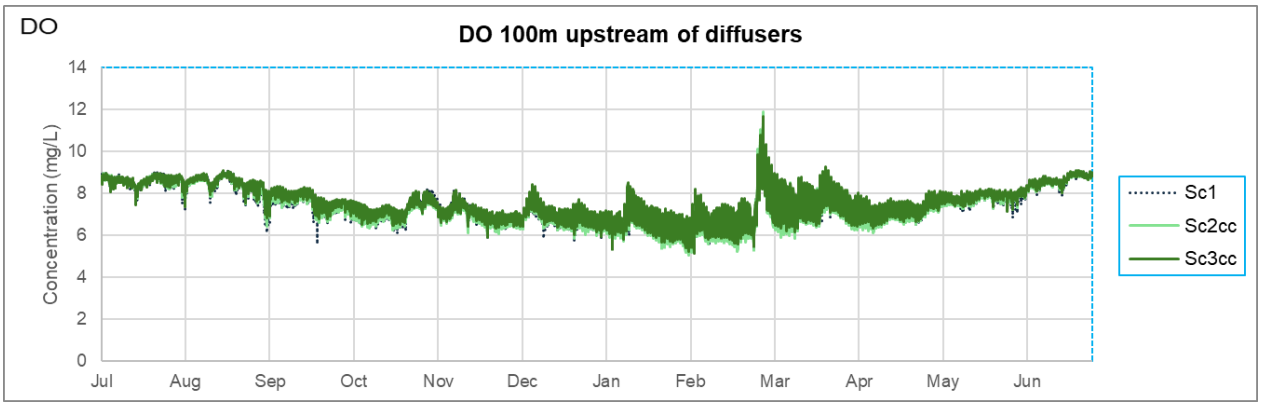
Longitudinal plots

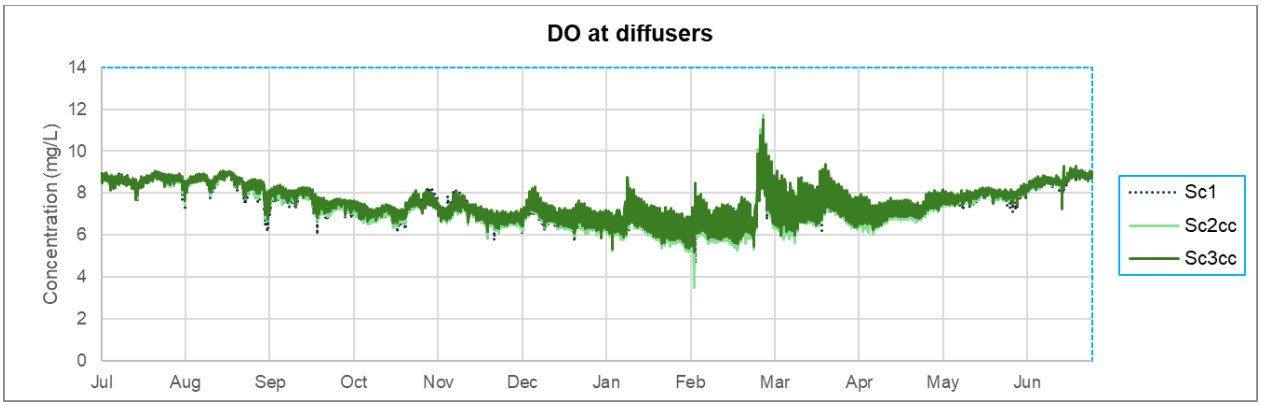


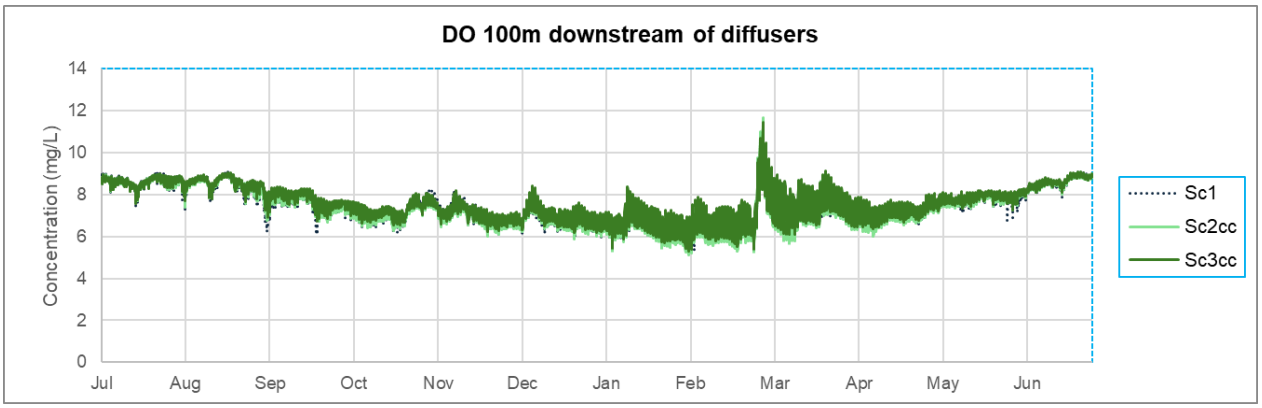


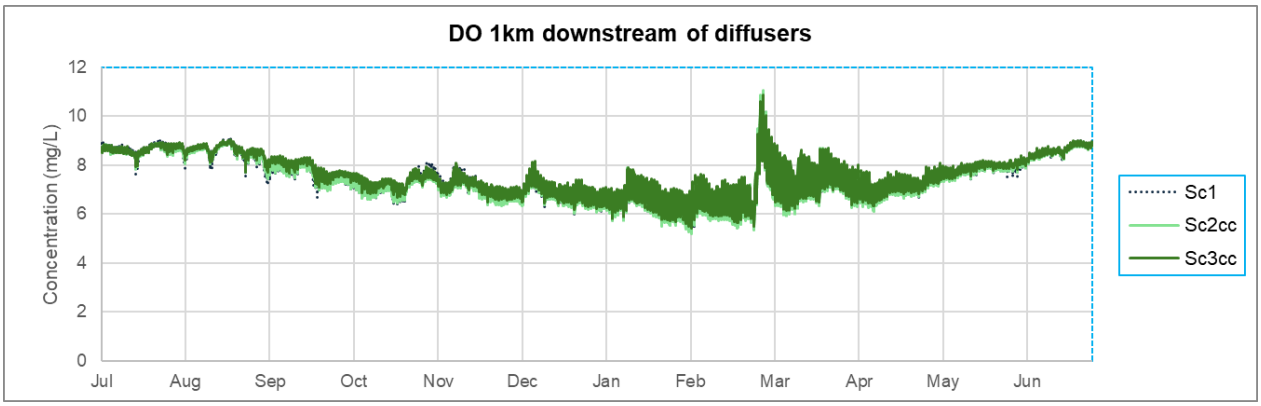
Time series plots





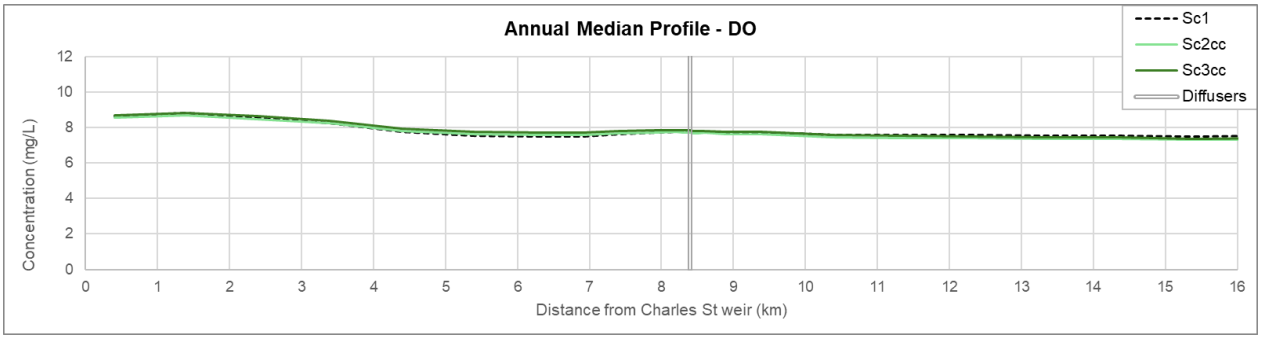


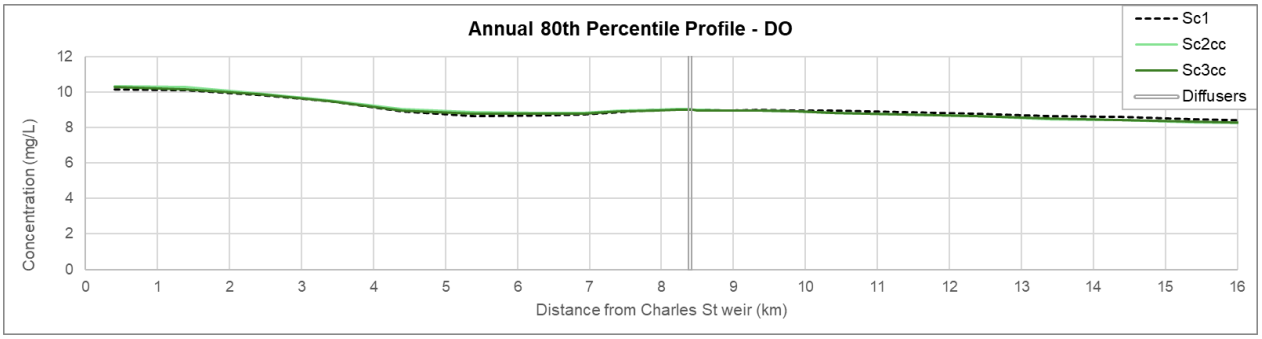




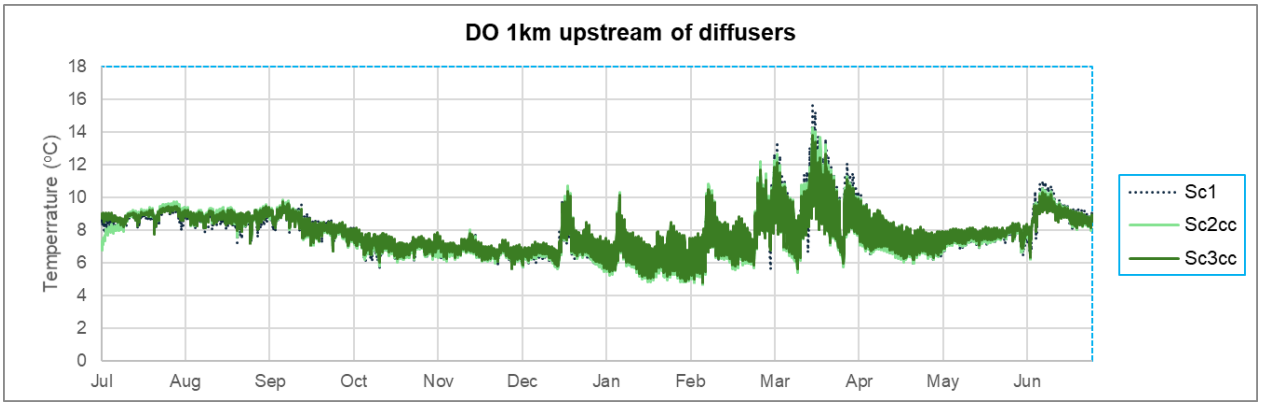
Appendices D2.10.2 Average rainfall year scenario results (2016-2017)

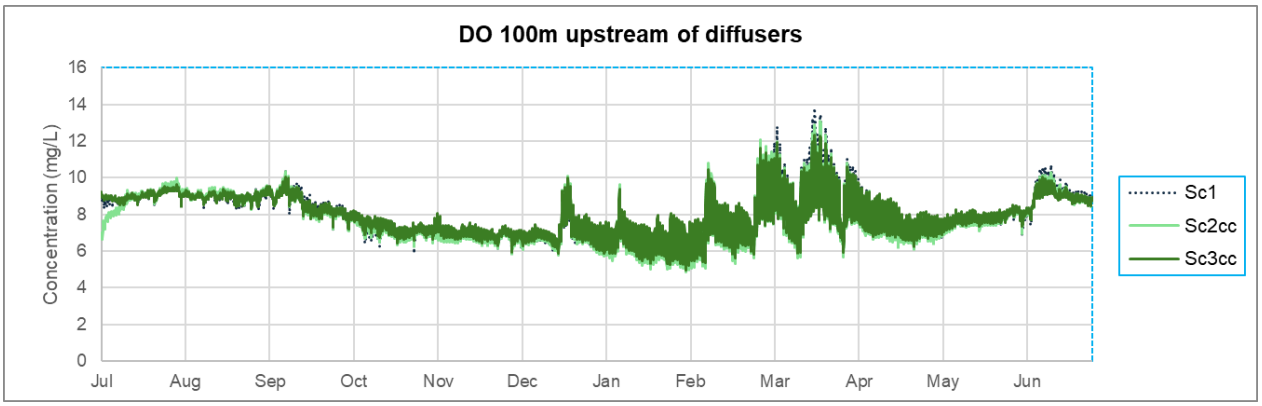
Longitudinal plots

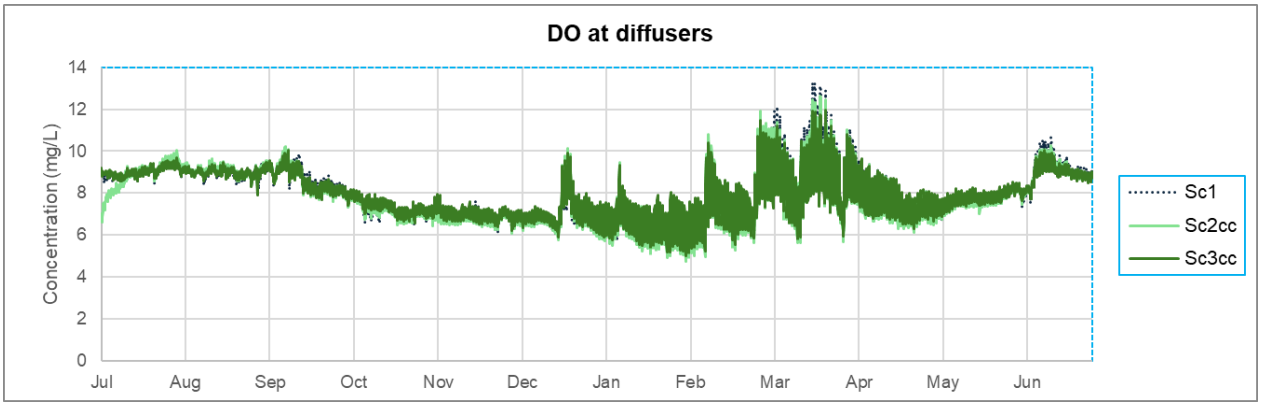


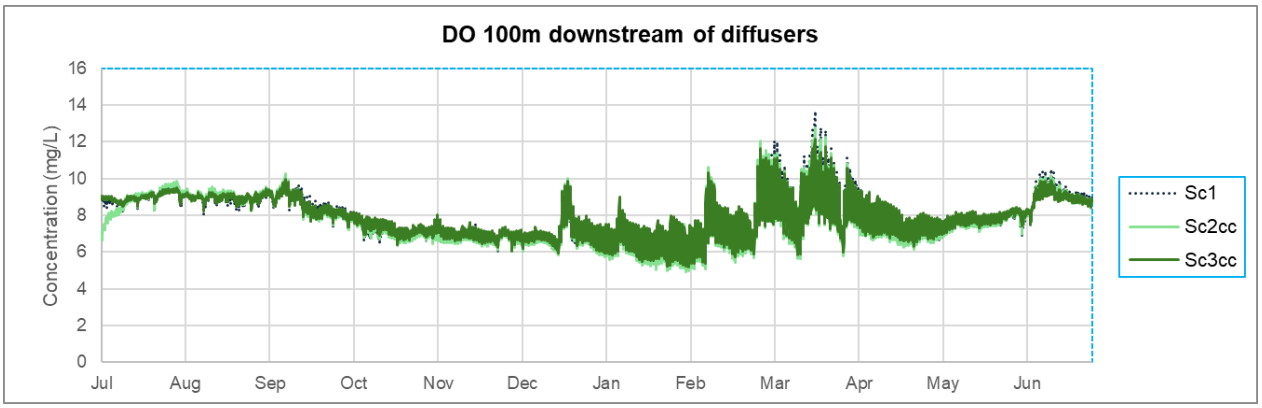


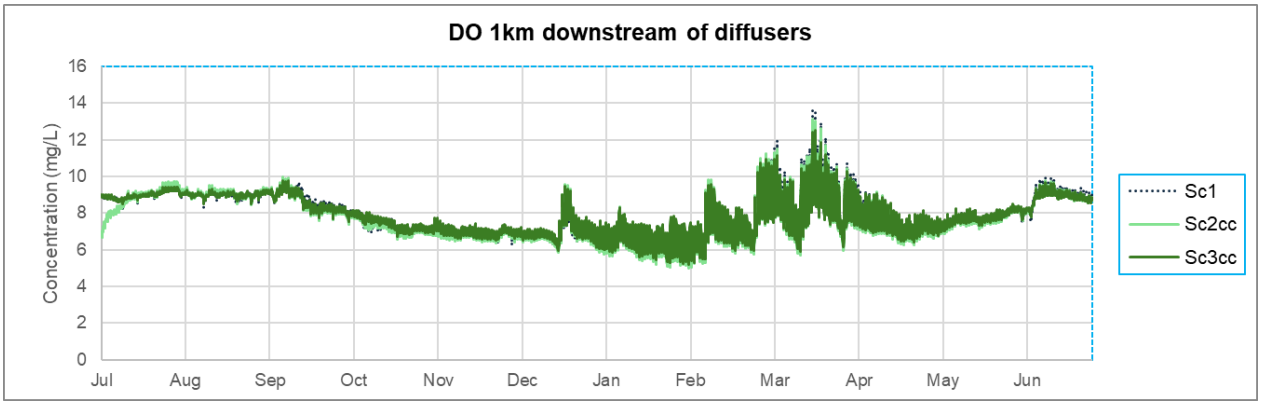
Time series plots




DO 100m upstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

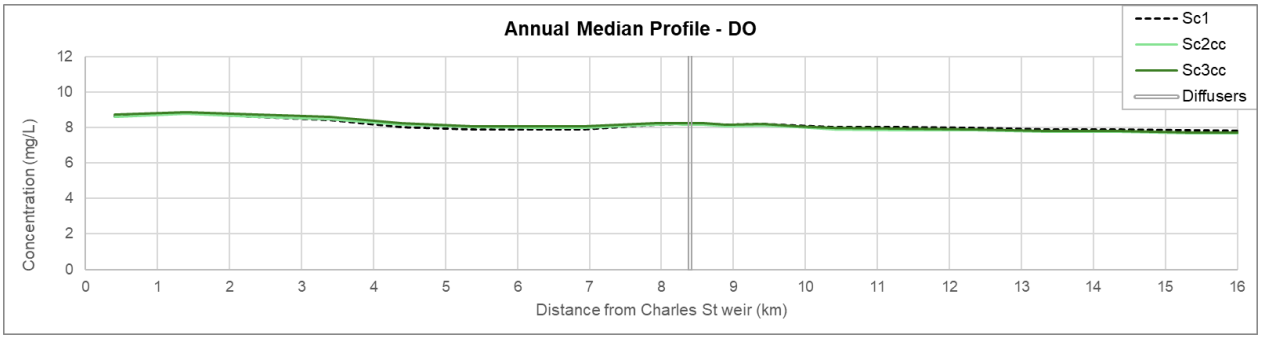

DO at diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

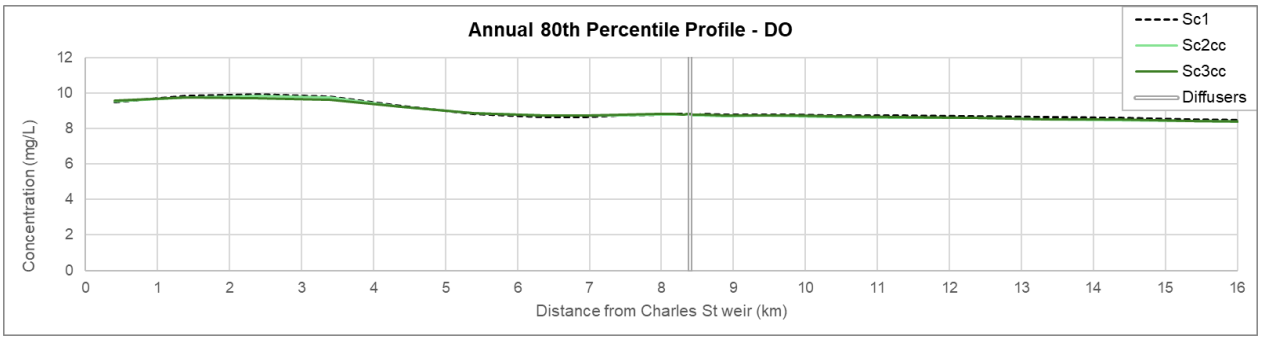

DO 100m downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


DO 1km downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

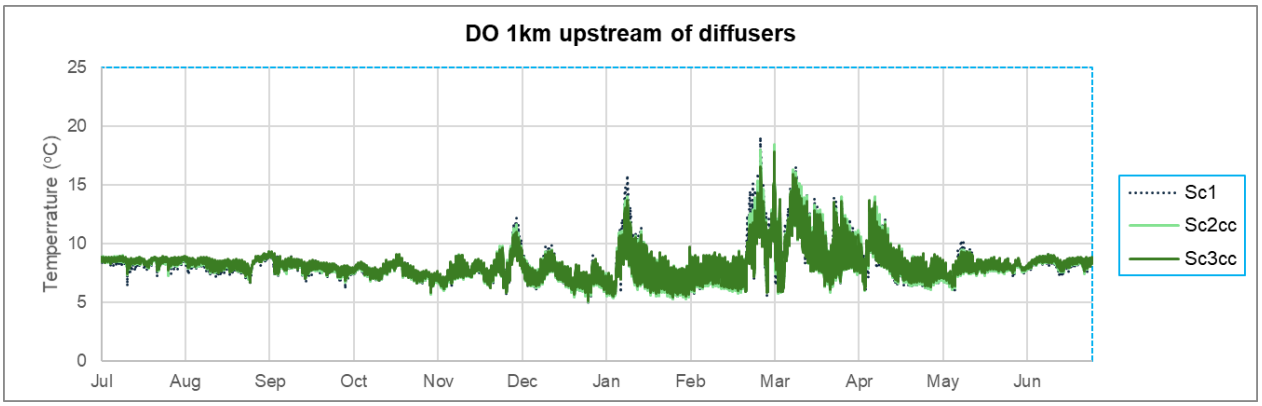
Appendices D2.10.3 Higher rainfall year scenario results (2021-2022)

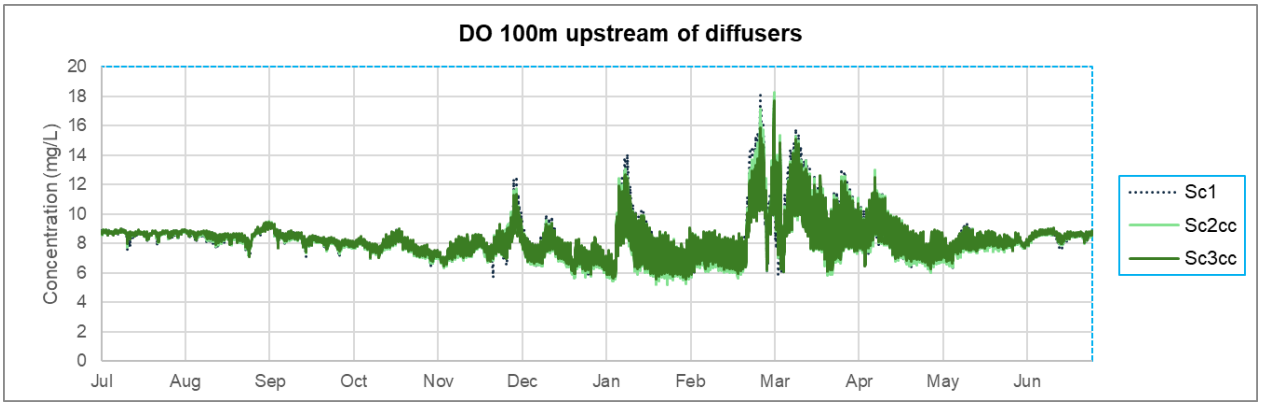
Longitudinal plots

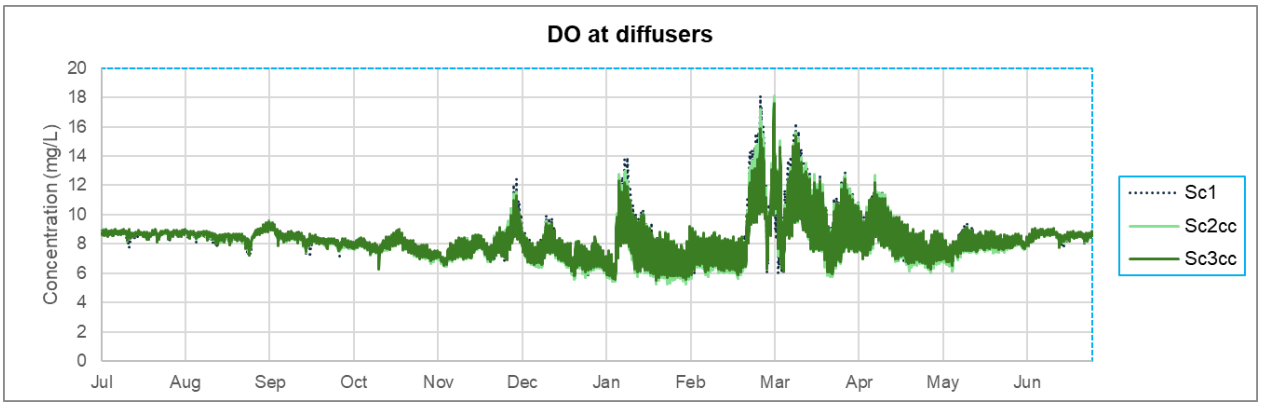


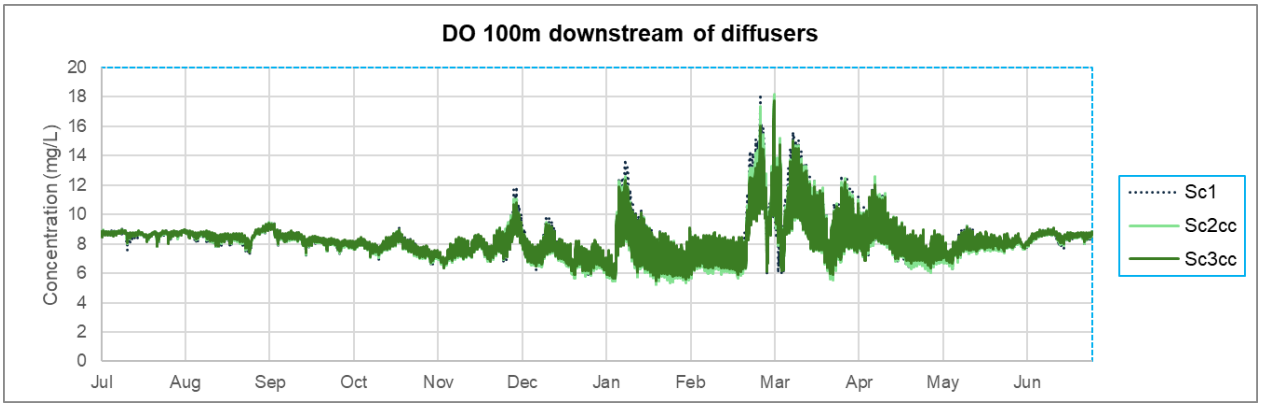


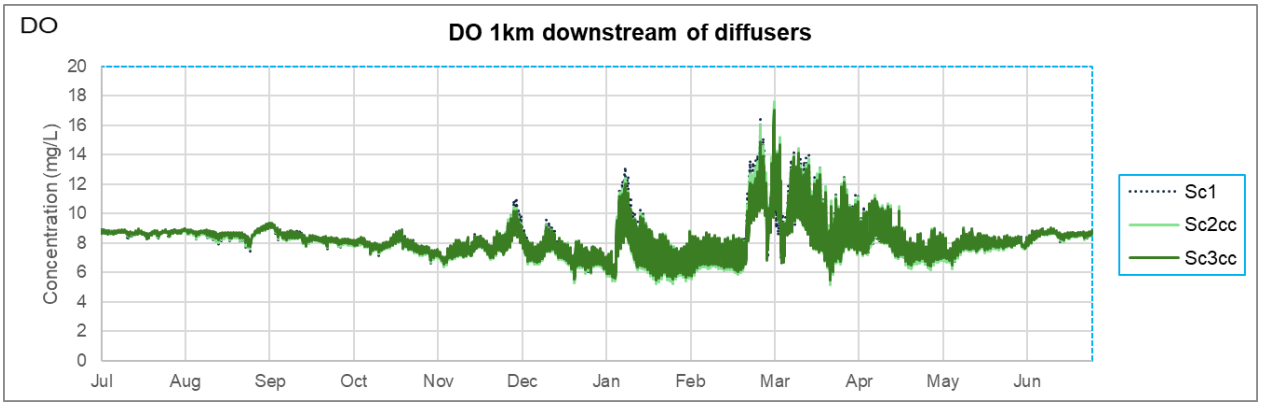
Time series plots






DO at diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
18
20
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

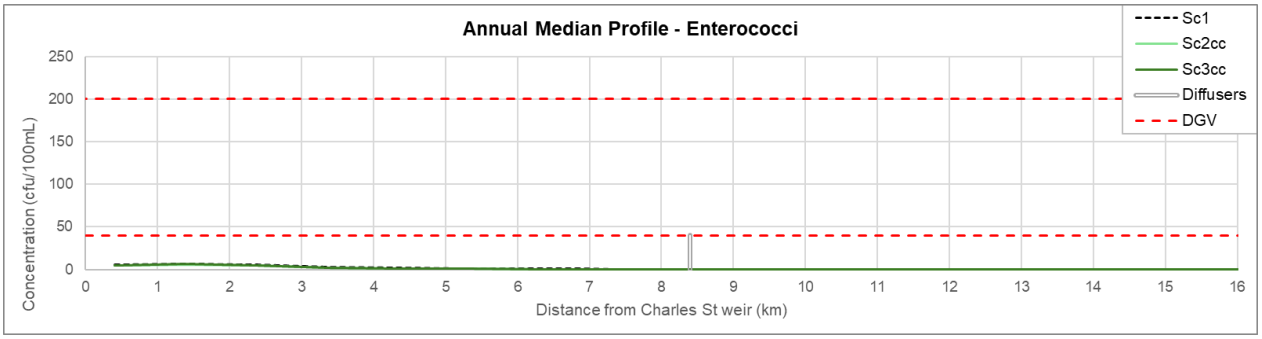

DO 100m downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
18
20
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

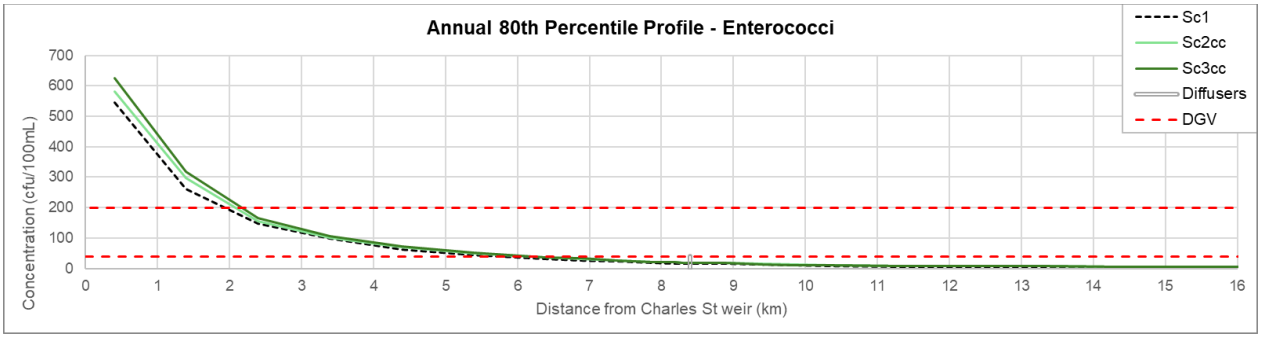

DO
DO 1km downstream of diffusers
Concentration (mg/L)
0
2
4
6
8
10
12
14
16
18
20
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D2.11 Enterococci

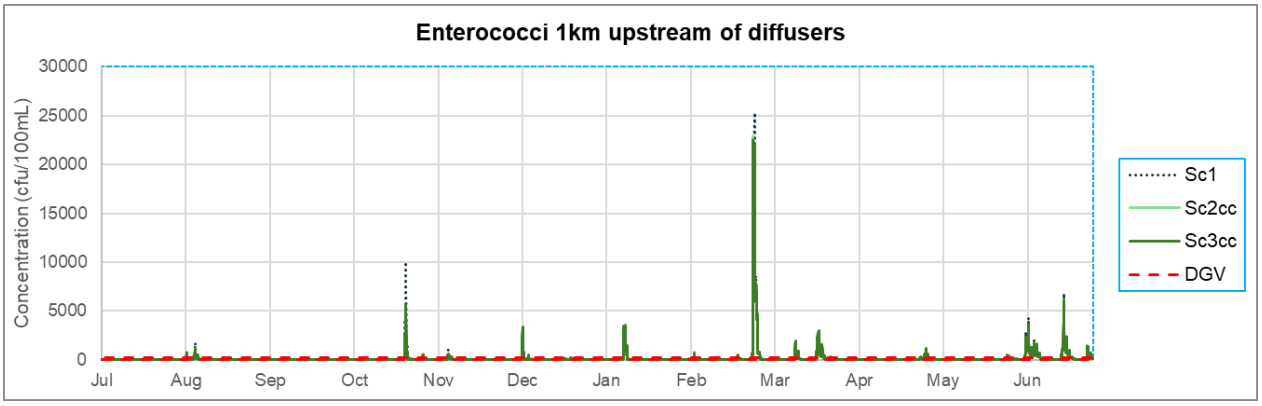
Appendices D2.11.1 Lower rainfall year scenario results (2017-2018)

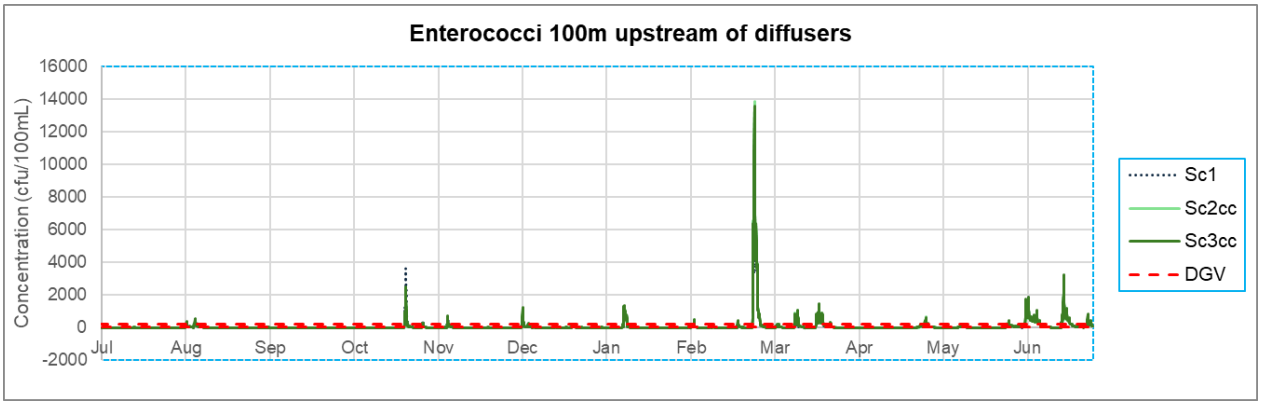
Longitudinal plots

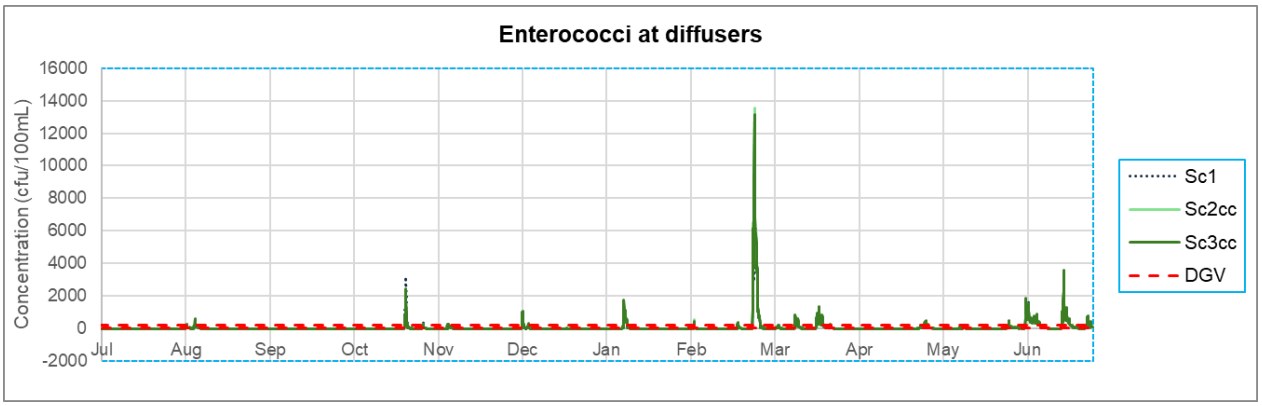


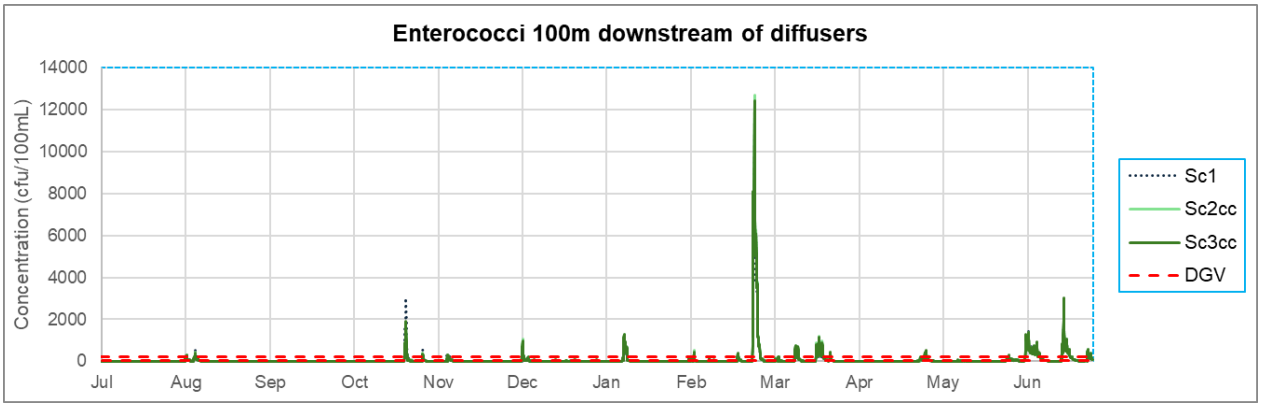


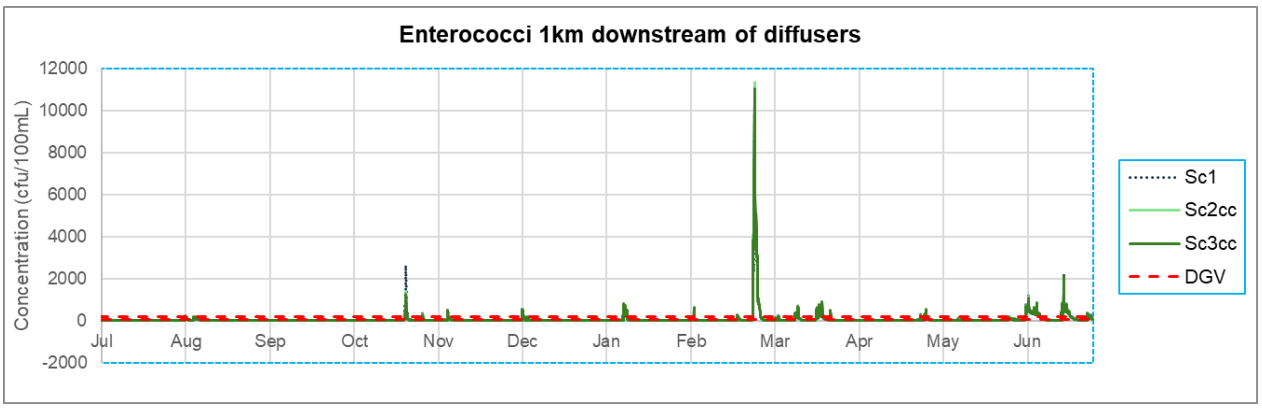
Time series plots





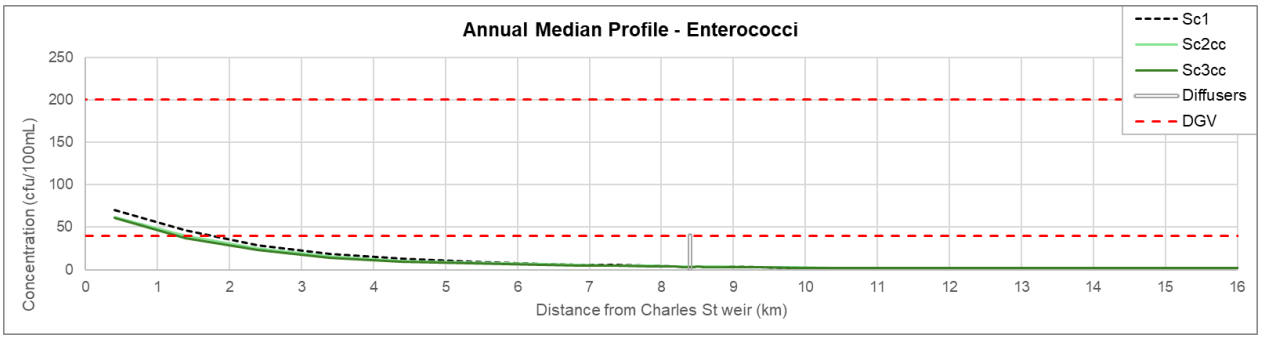


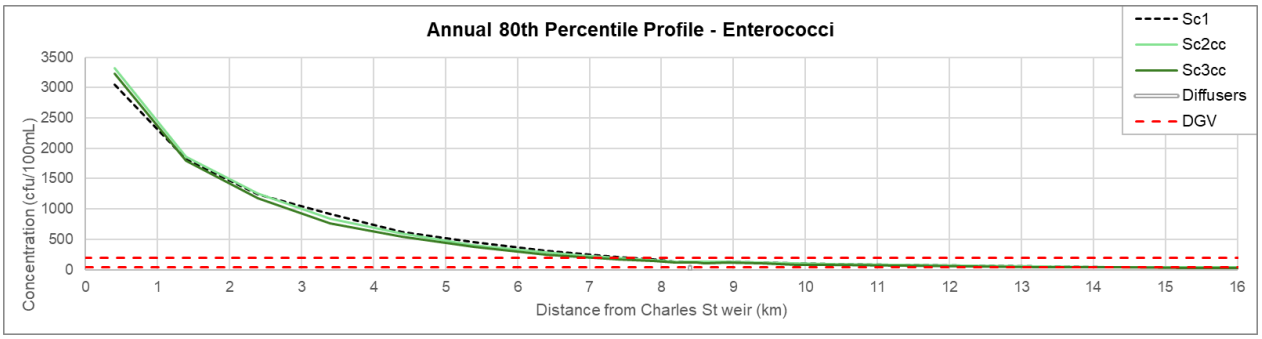




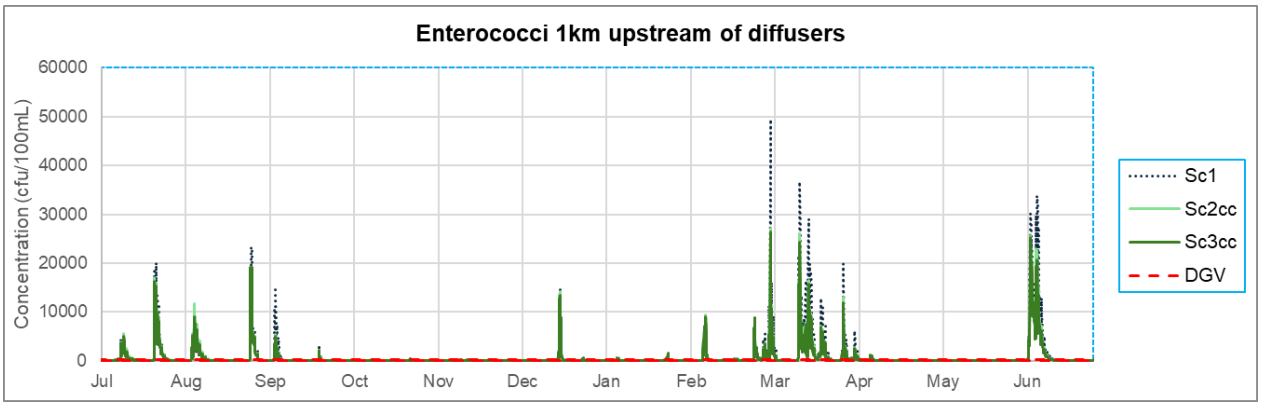
Appendices D2.11.2 Average rainfall year scenario results (2016-2017)

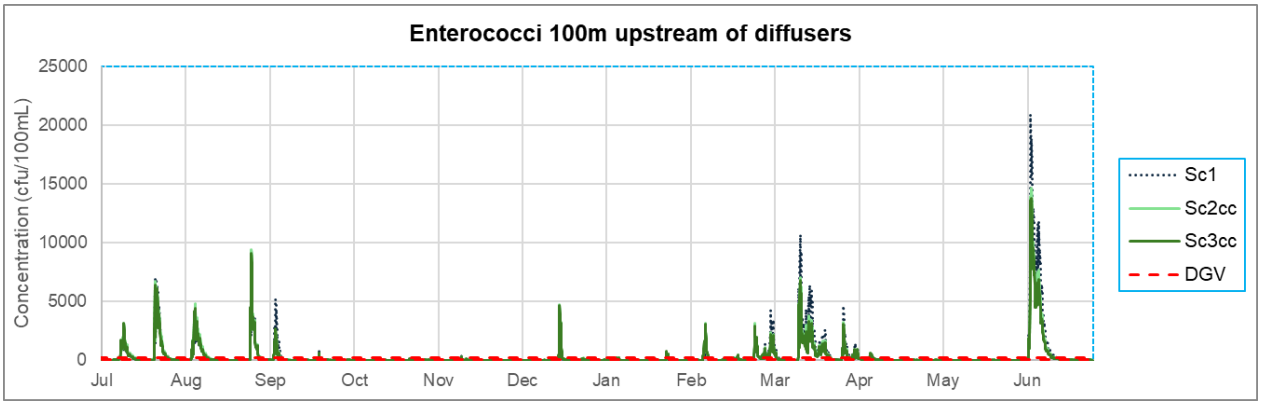
Longitudinal plots

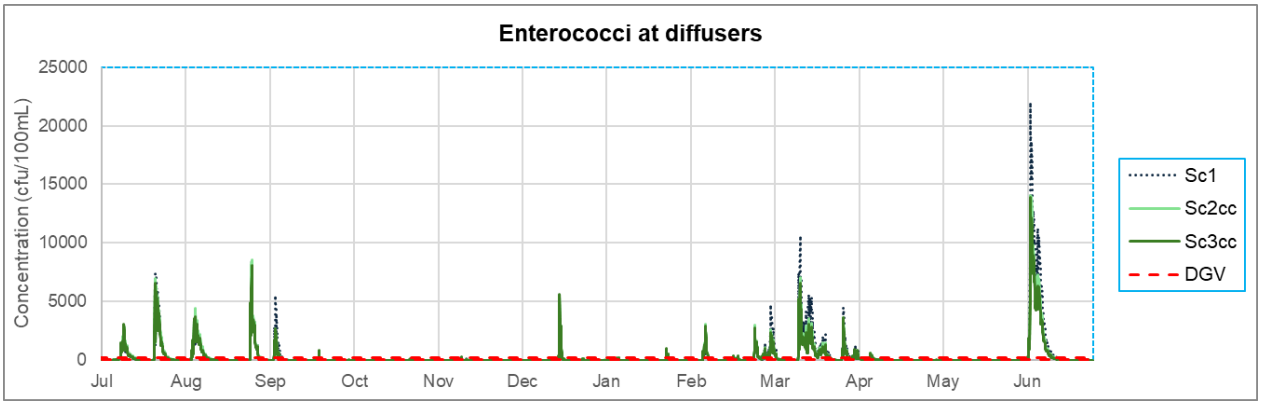


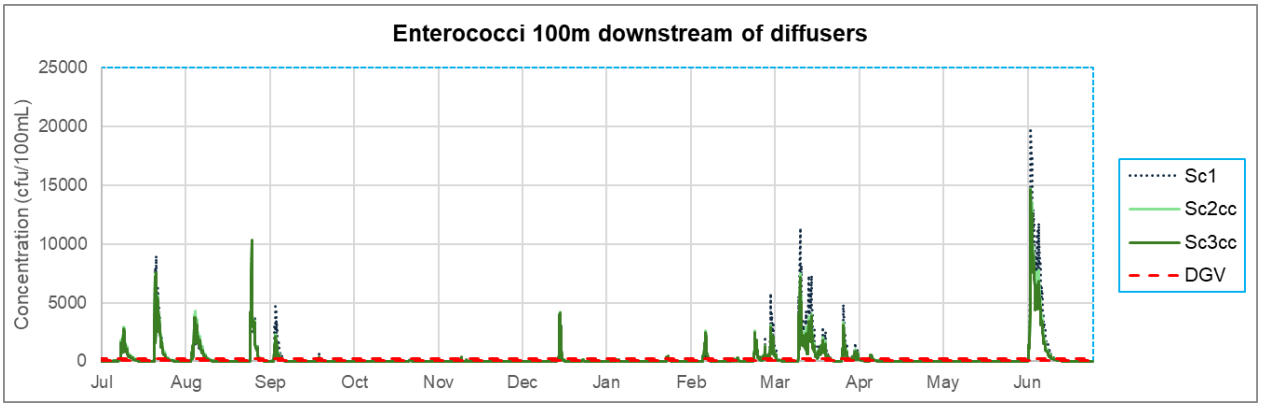


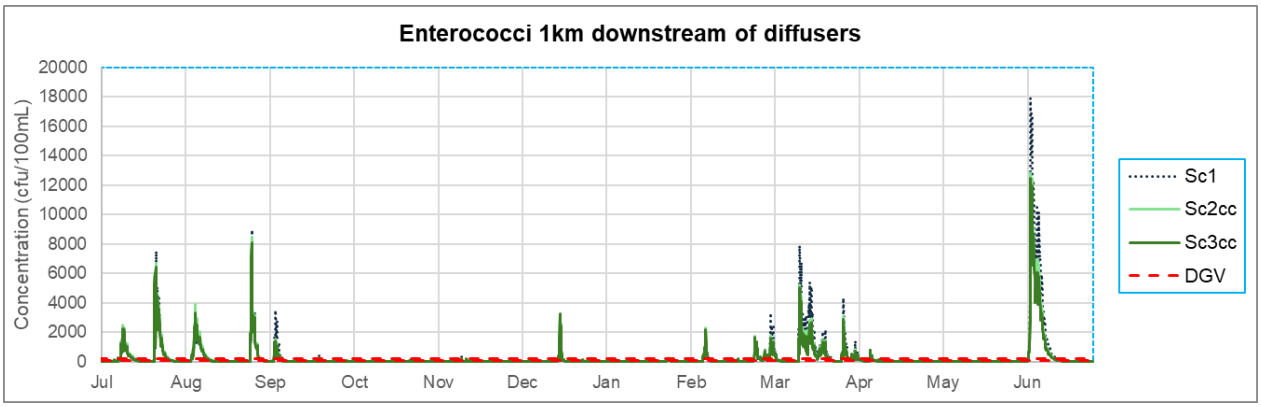
Time series plots





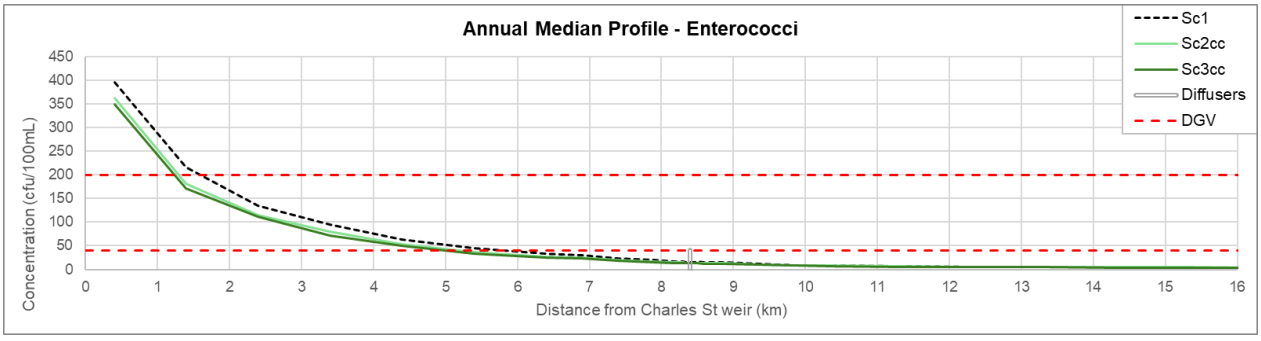


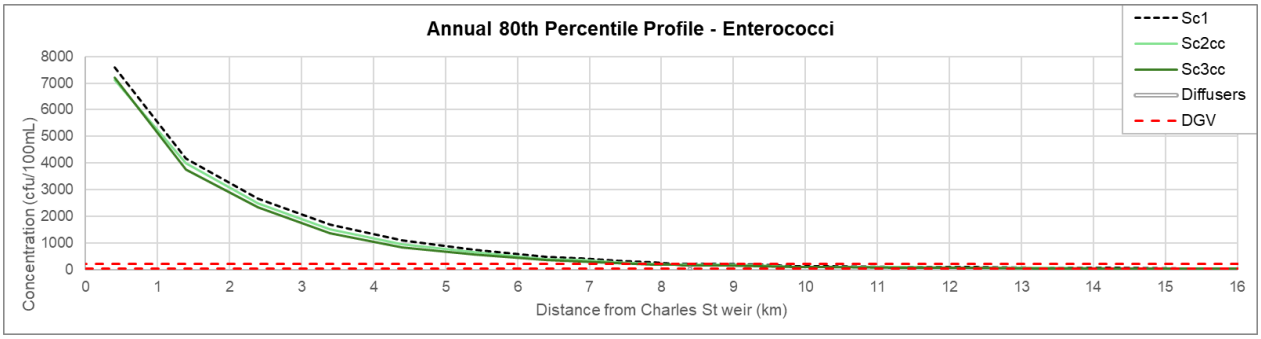




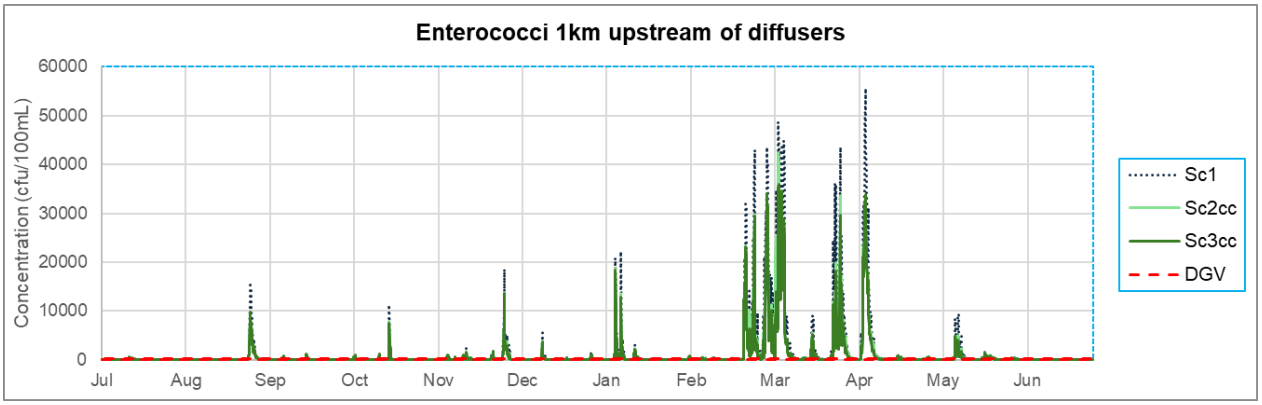
Appendices D2.11.3 Higher rainfall year scenario results (2021-2022)

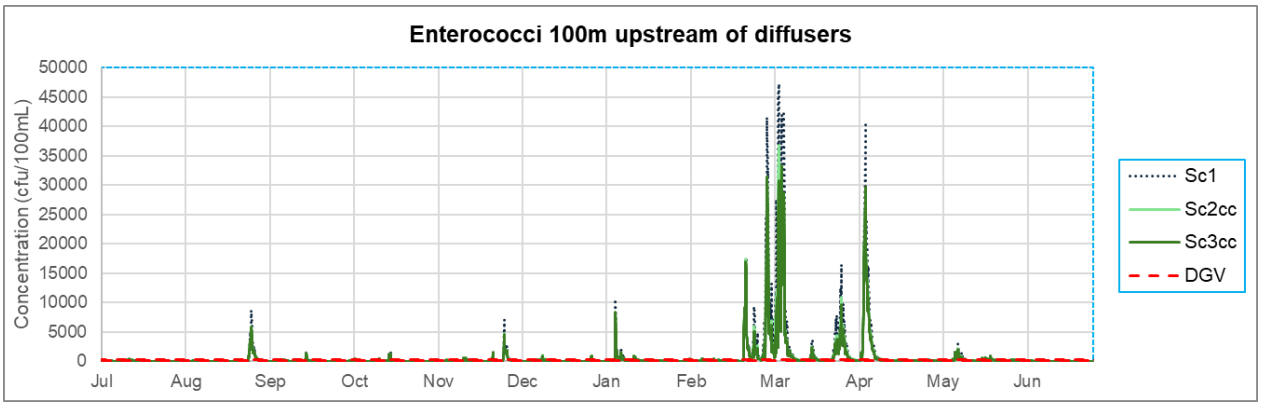
Longitudinal plots

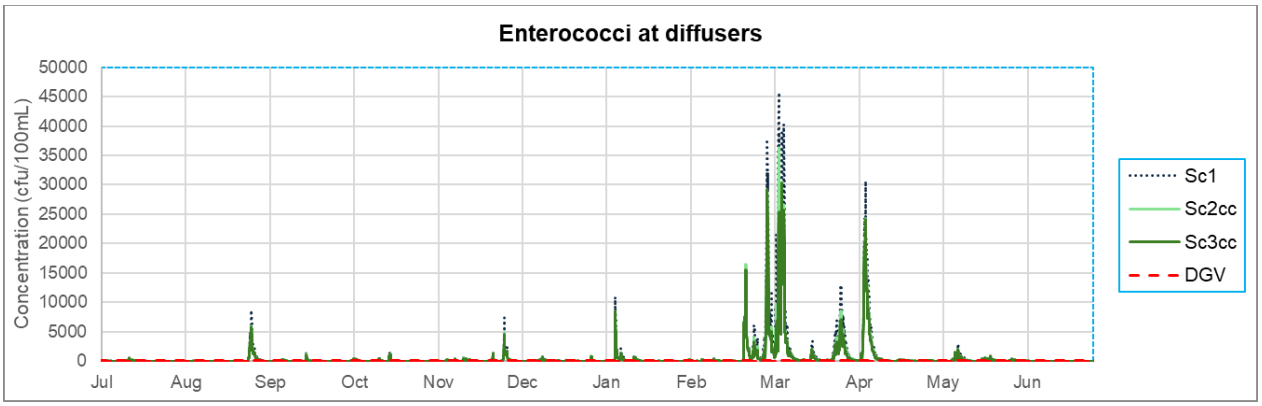


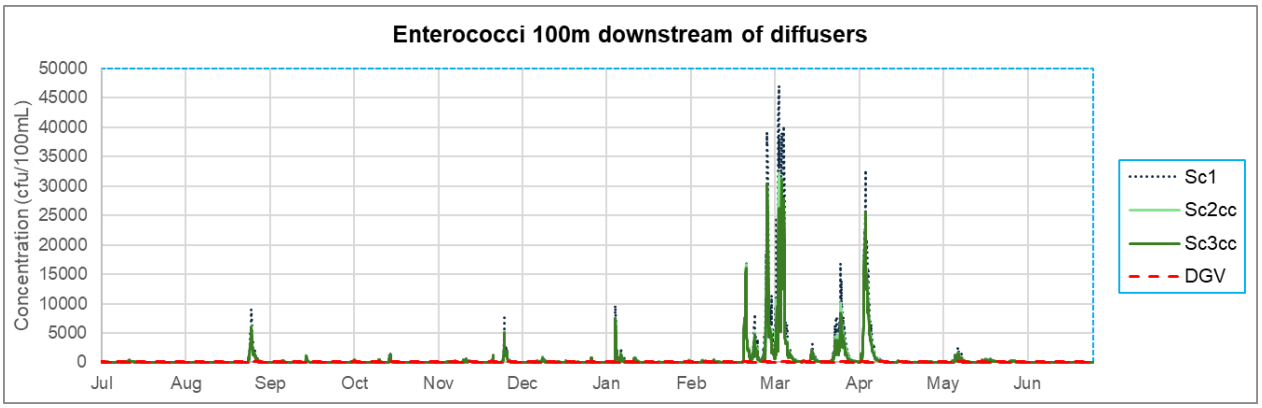


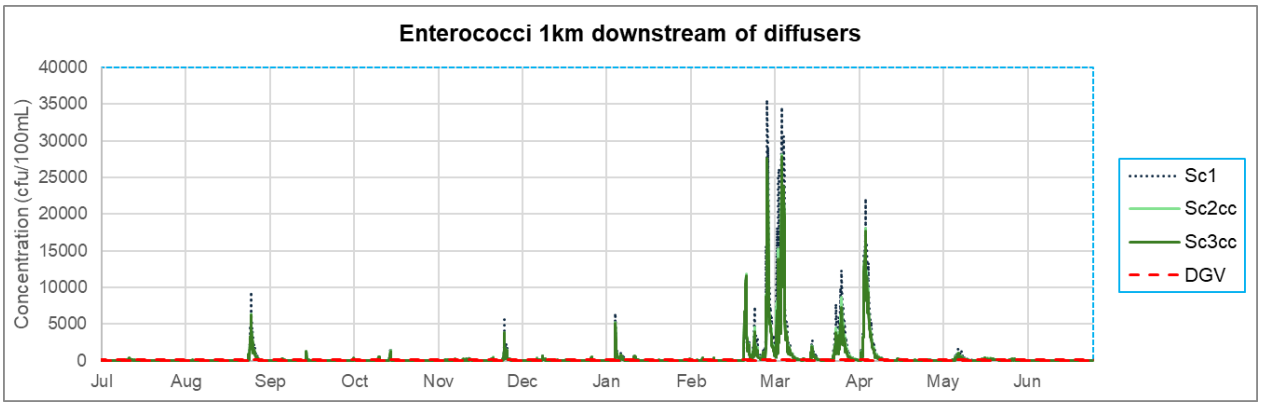
Time series plots









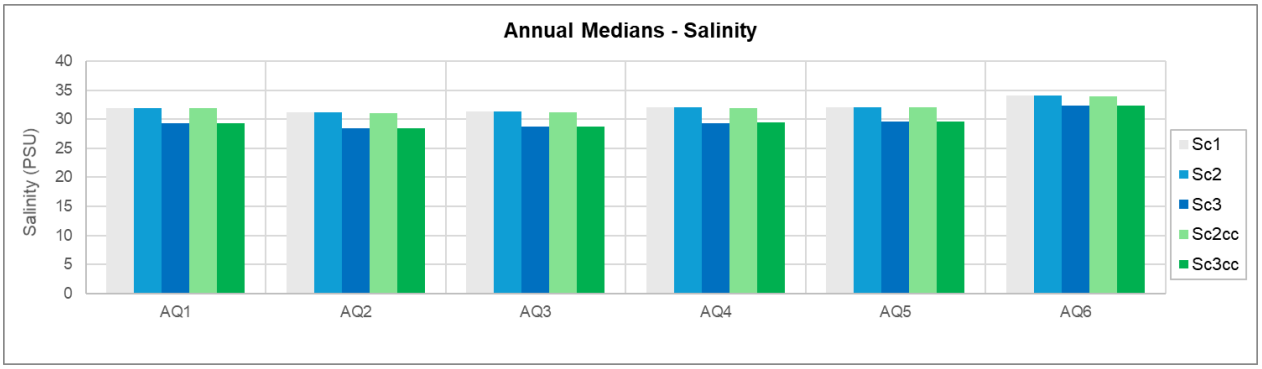

Enterococci 1km downstream of diffusers
Concentration (cfu/100mL)
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc
DGV

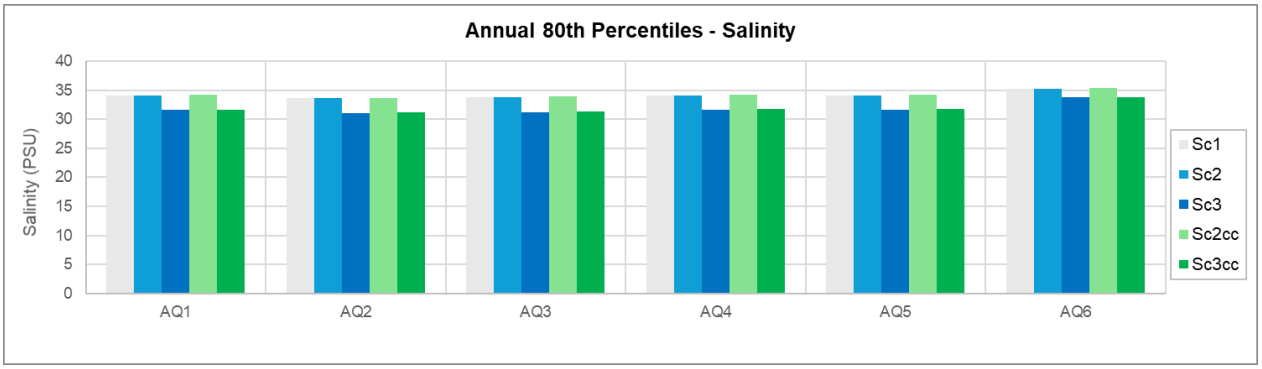
Appendices D3 Aquatic ecology sites results without climate change

Appendices D3.1 Salinity

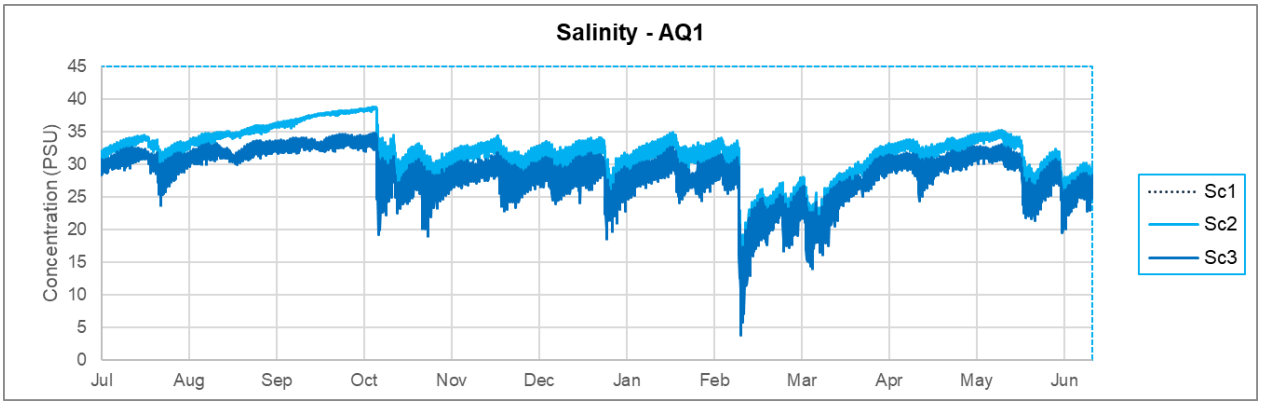
Appendices D3.1.1 Lower rainfall year scenario results (2017-2018)

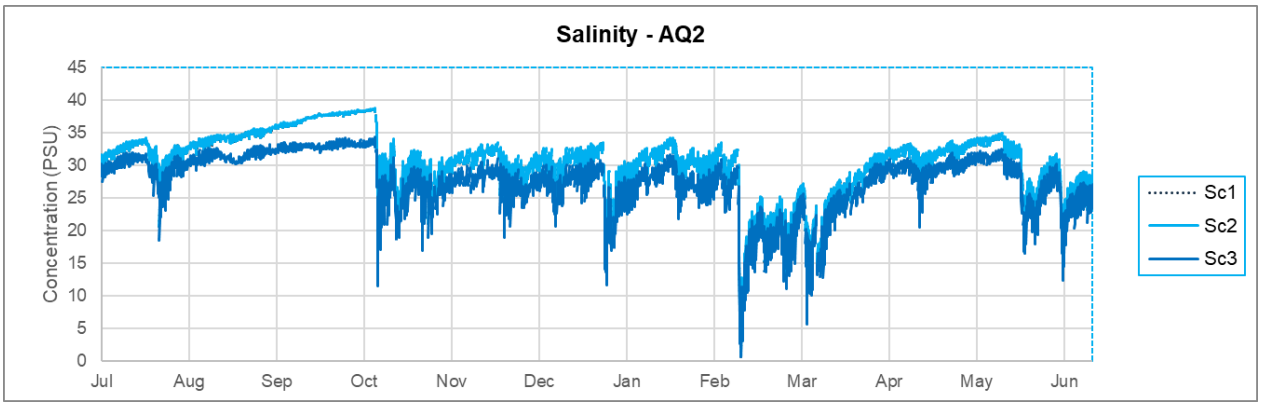
Bar charts

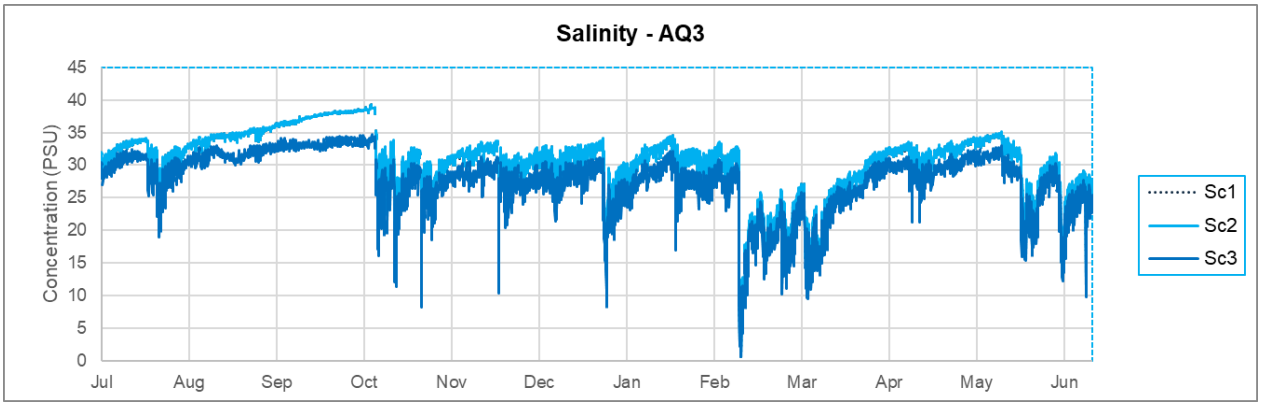


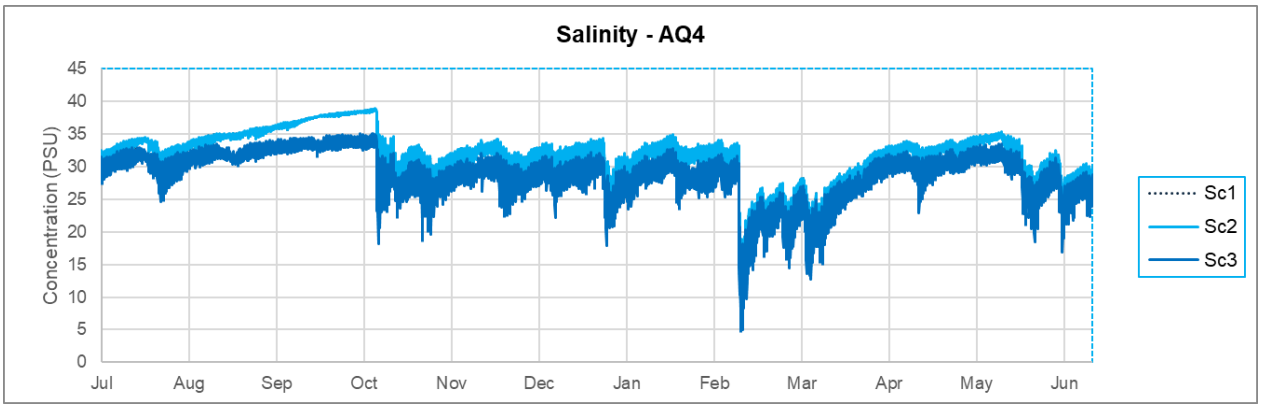


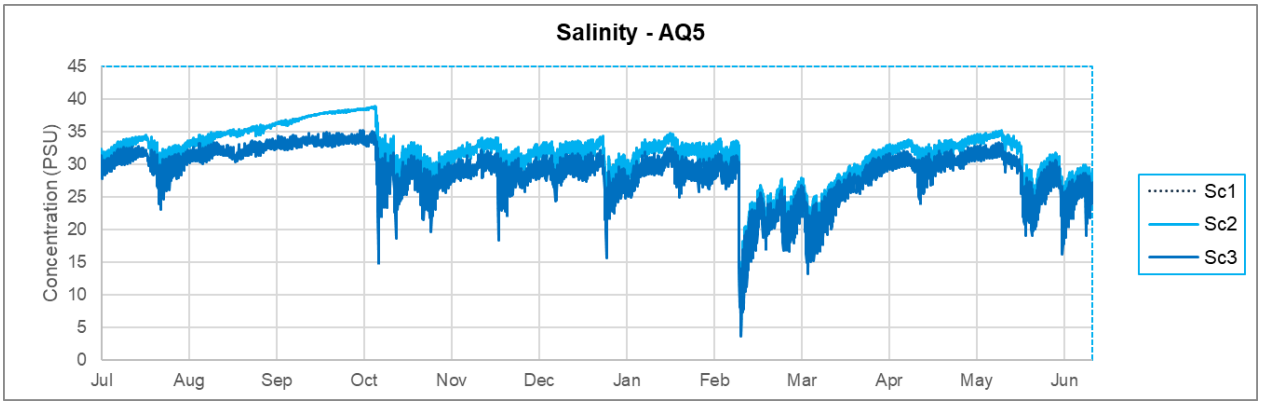
Time series plots

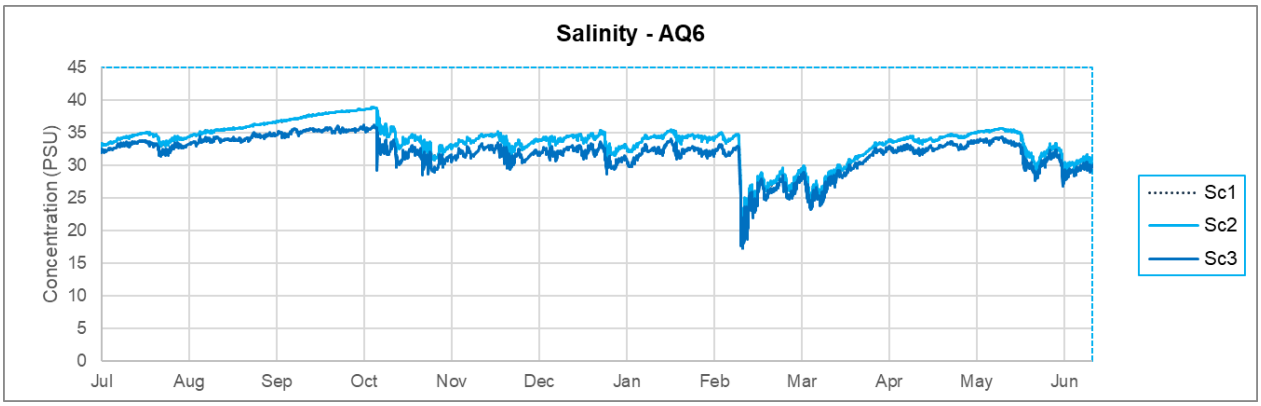



Salinity - AQ2
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - AQ3
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

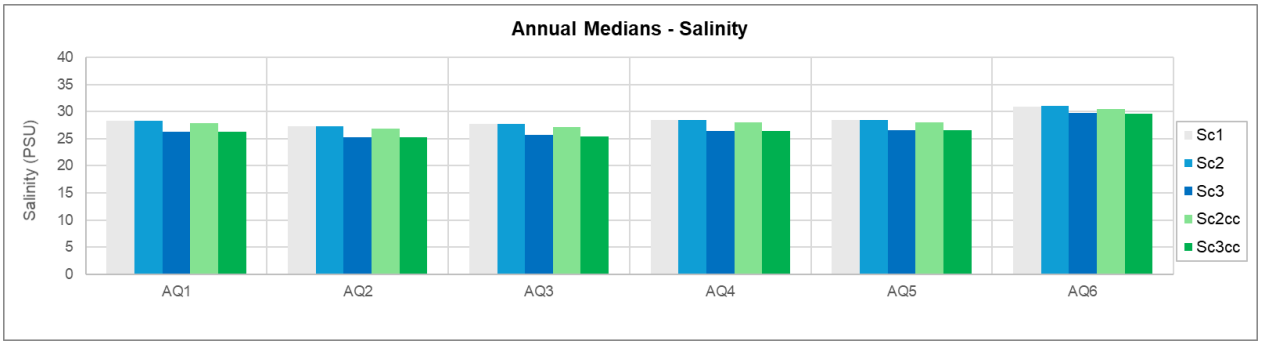

Salinity - AQ4
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

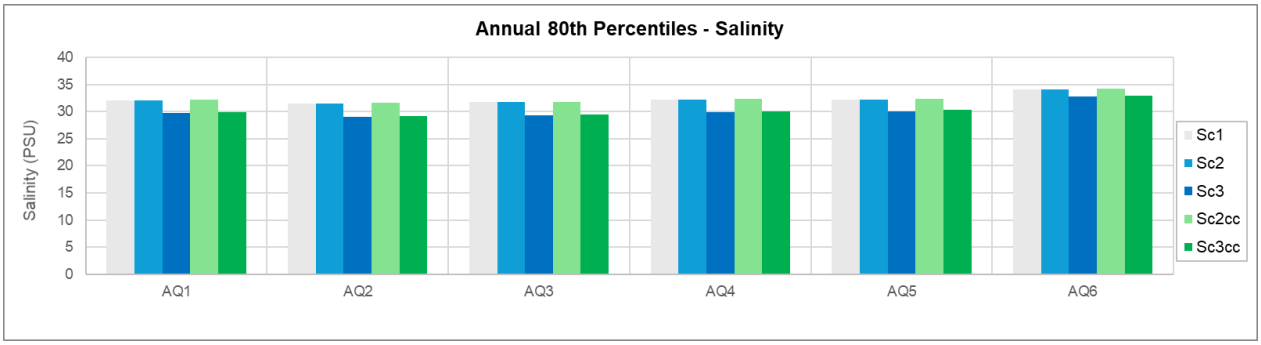

Salinity - AQ5
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3



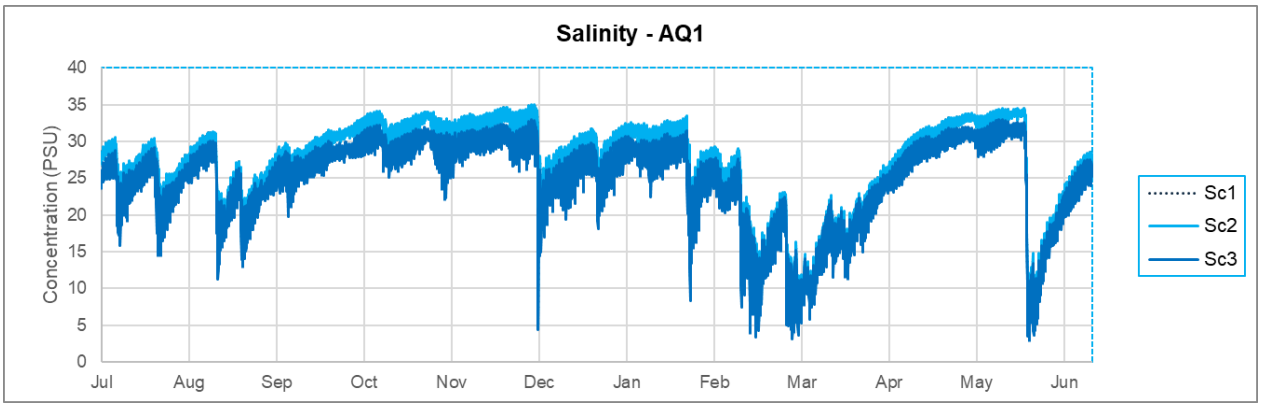
Appendices D3.1.2 Average rainfall year scenario results (2016-2017)

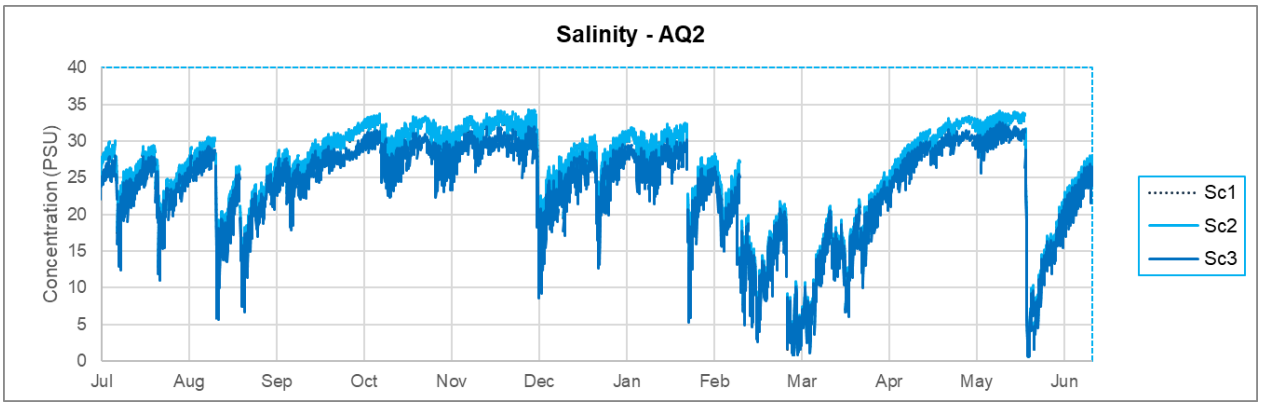
Bar charts

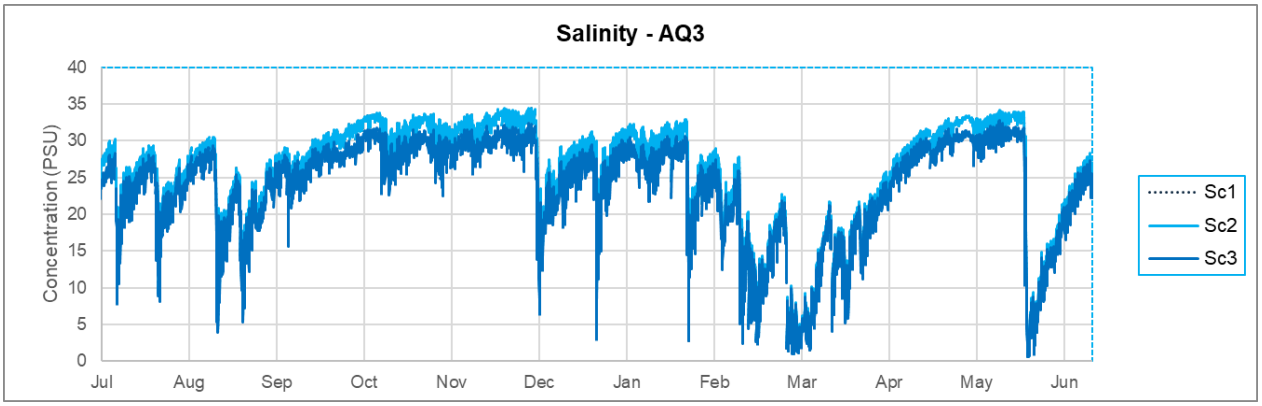


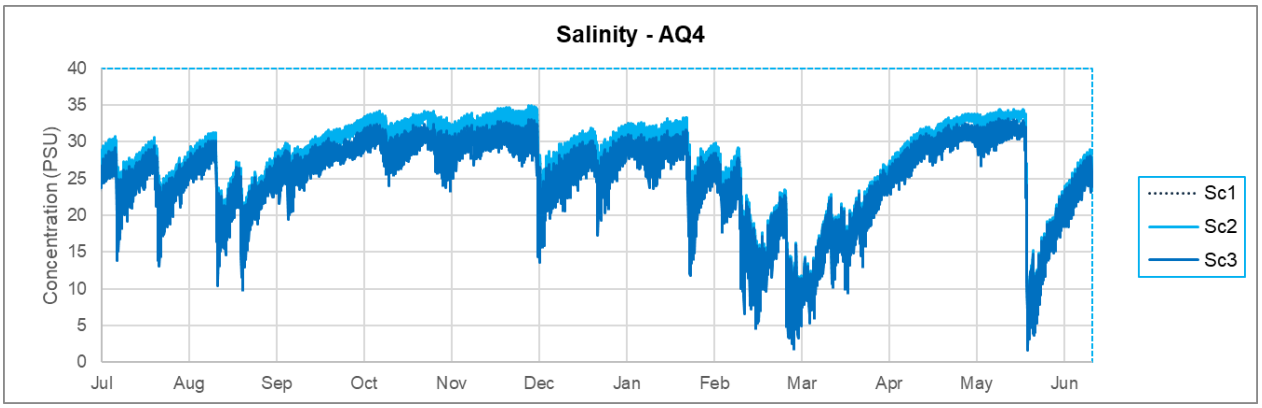


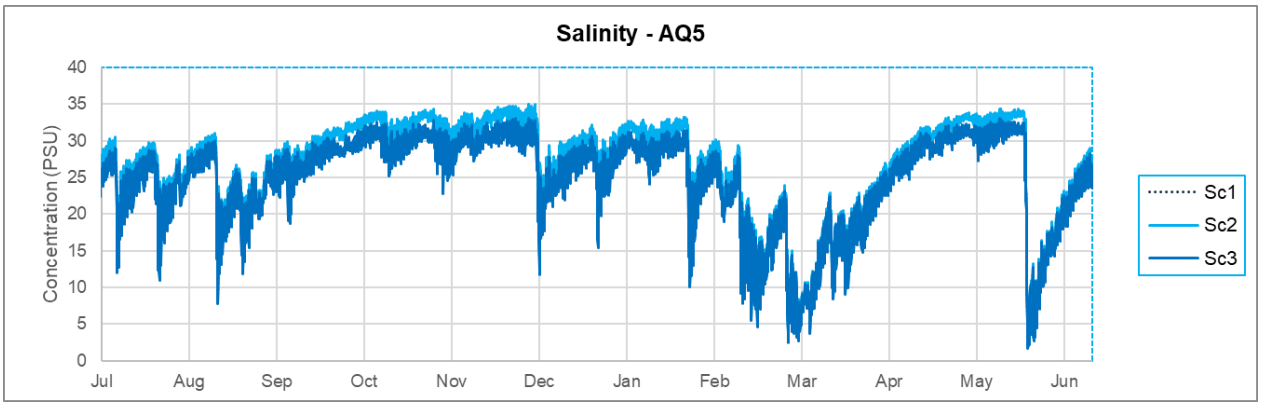
Time series plots




Salinity - AQ2
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - AQ3
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - AQ4
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - AQ5
Concentration (PSU)
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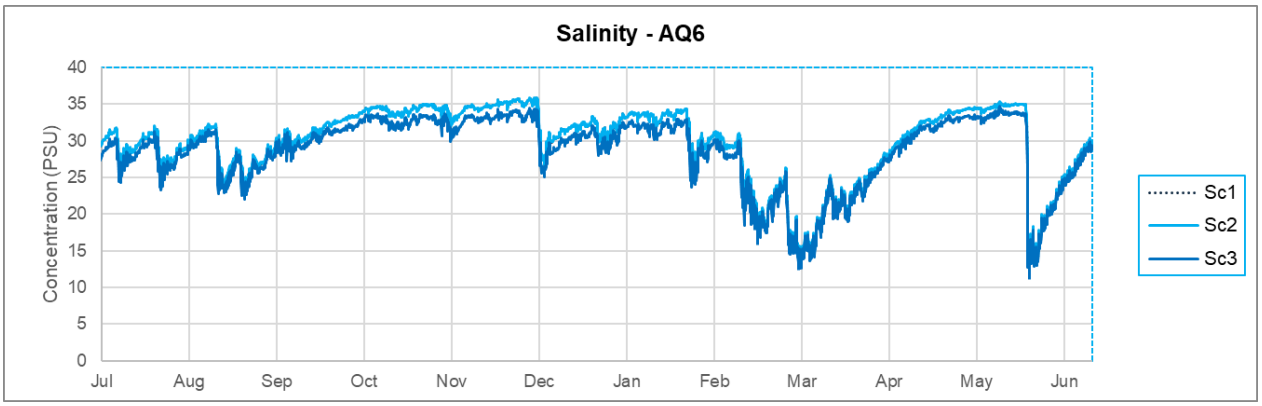
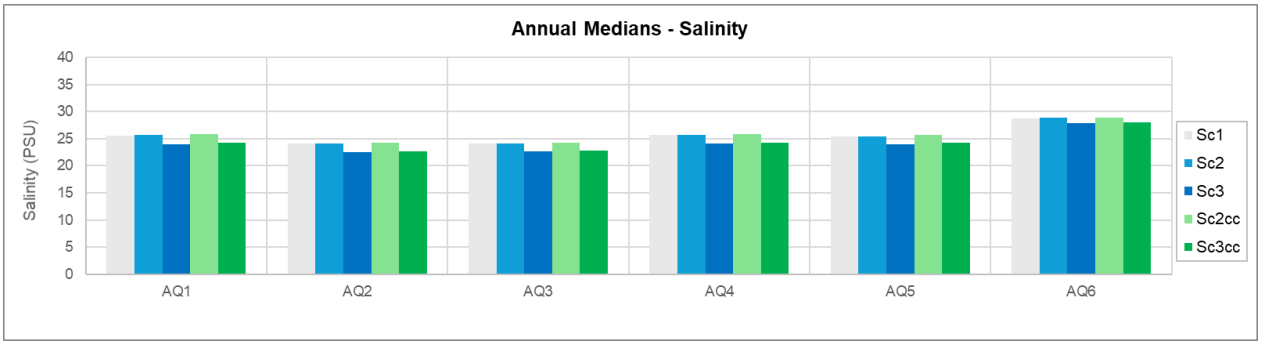
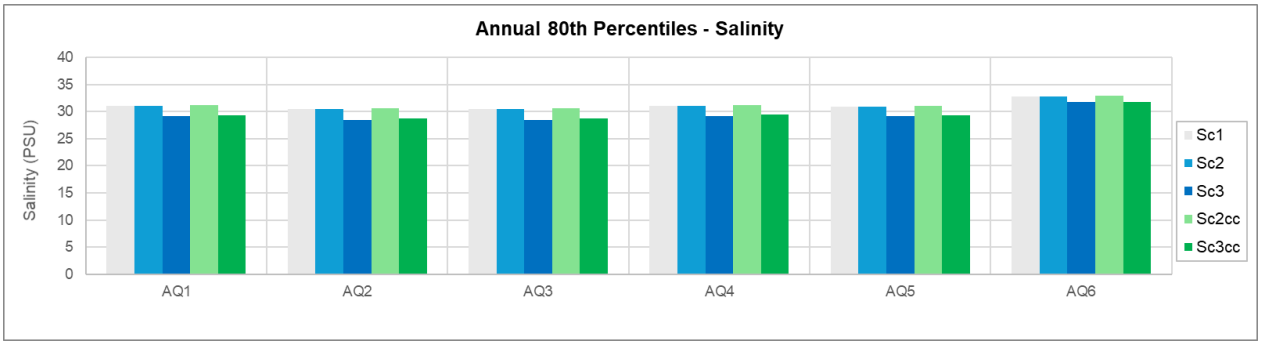
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3



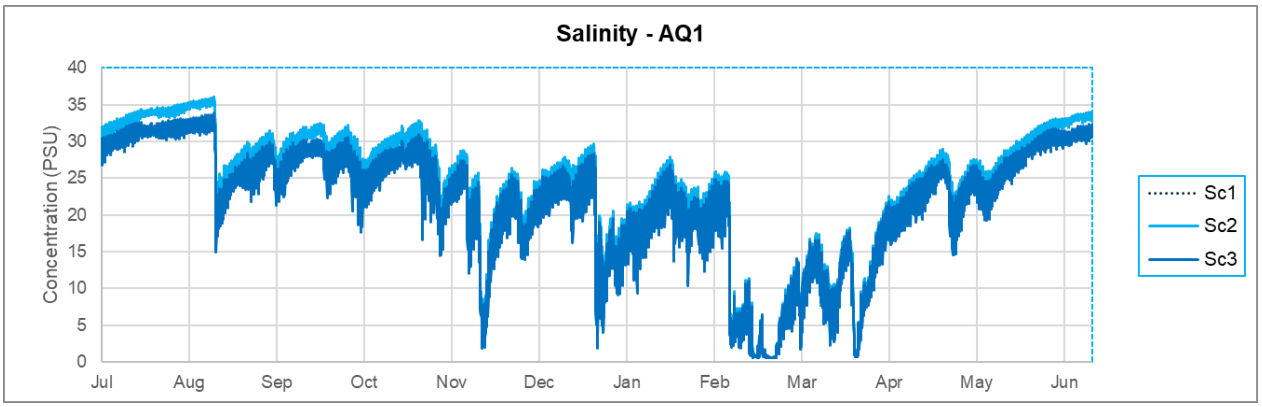
Appendices D3.1.3 Higher rainfall year scenario results (2021-2022)

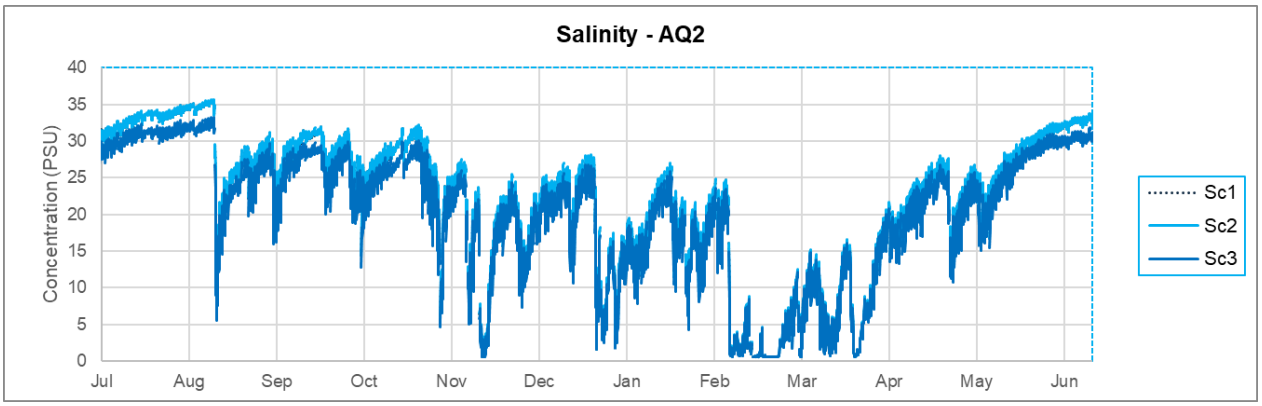
Bar charts





Time series plots




Salinity - AQ2
Concentration (PSU)
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35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
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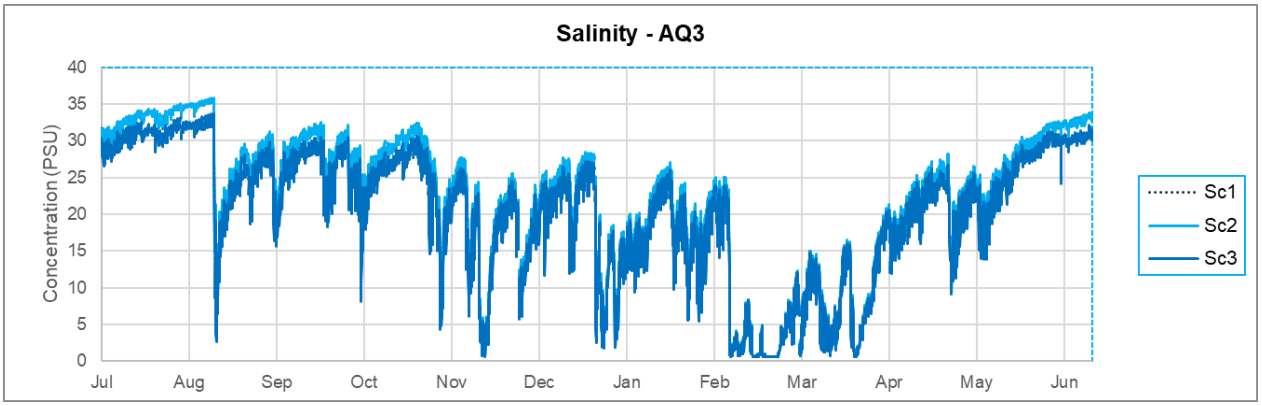
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - AQ3
Concentration (PSU)
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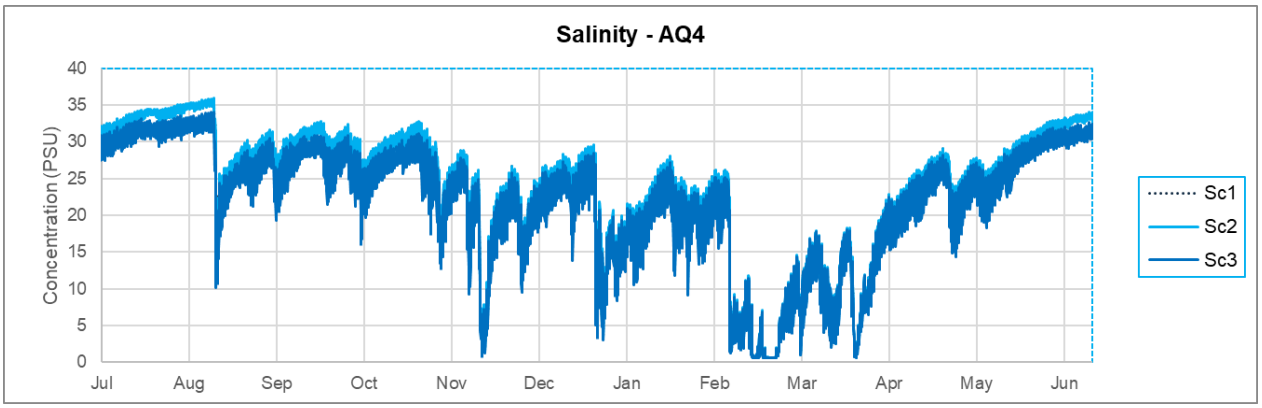
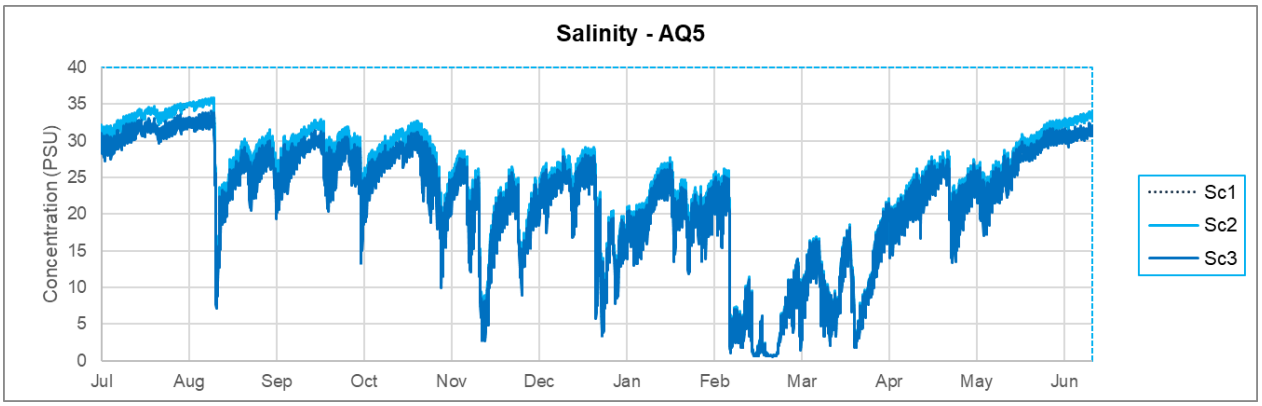
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

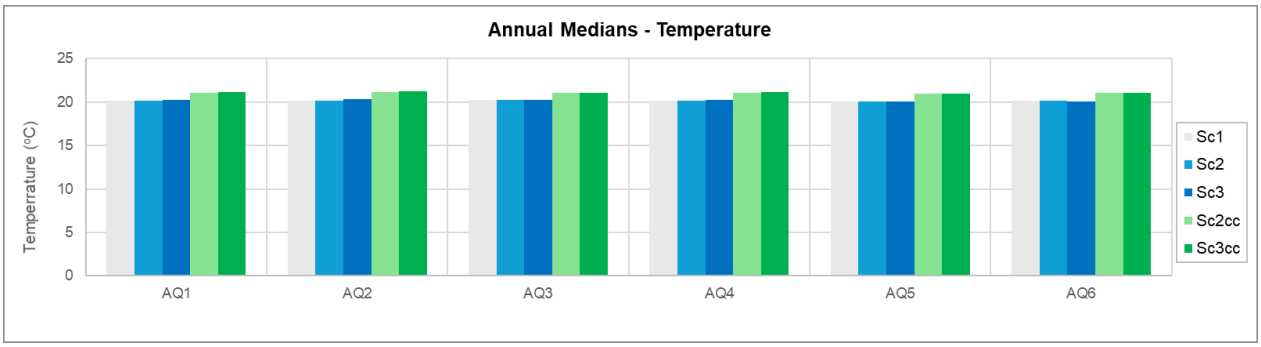

Salinity - AQ4
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

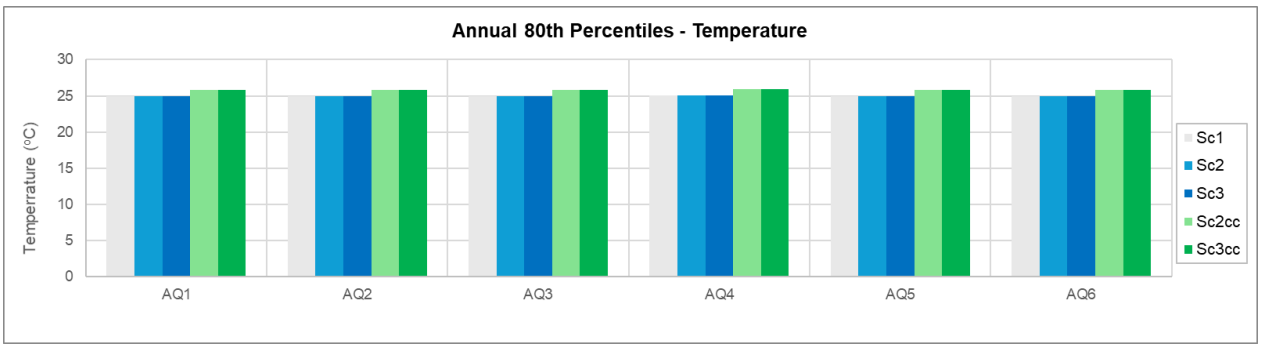

Salinity - AQ5
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D3.2 Temperature

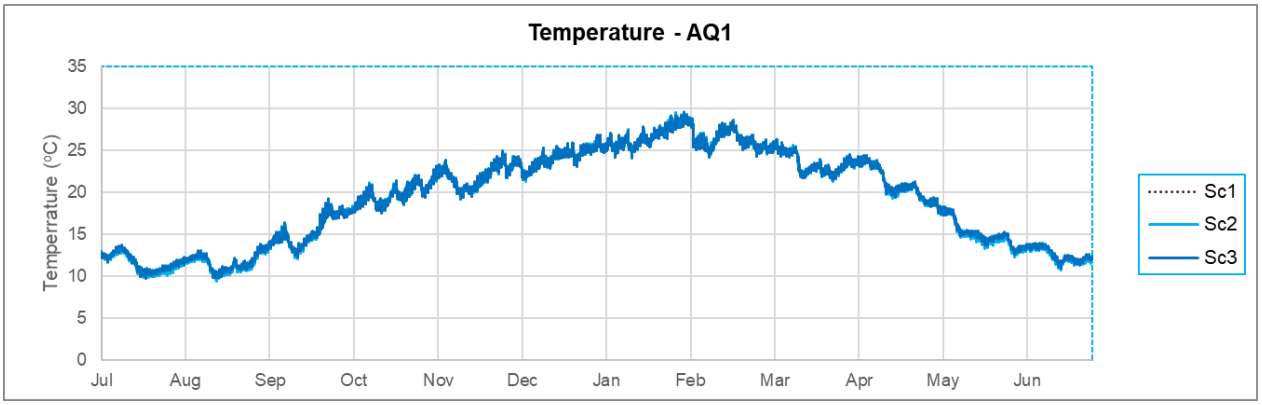
Appendices D3.2.1 Lower rainfall year scenario results (2017-2018)

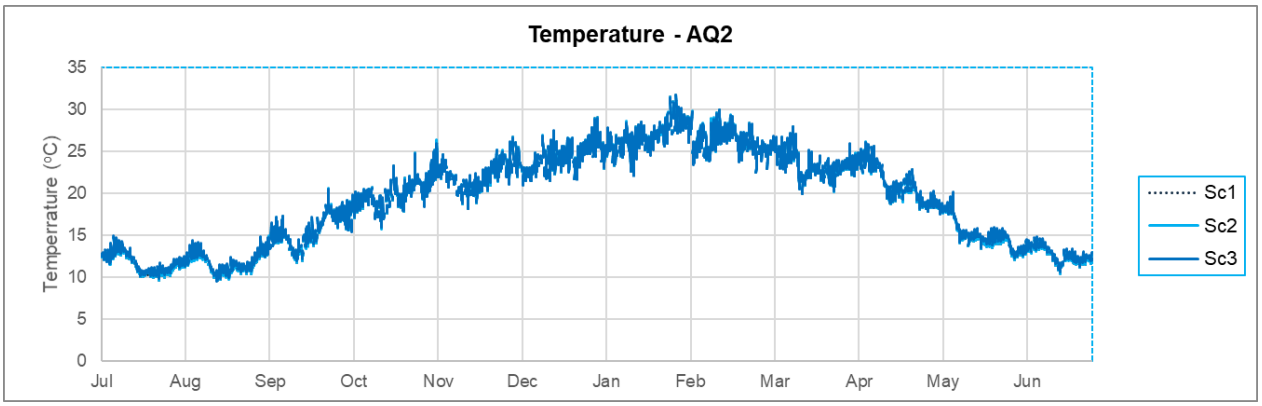
Bar charts

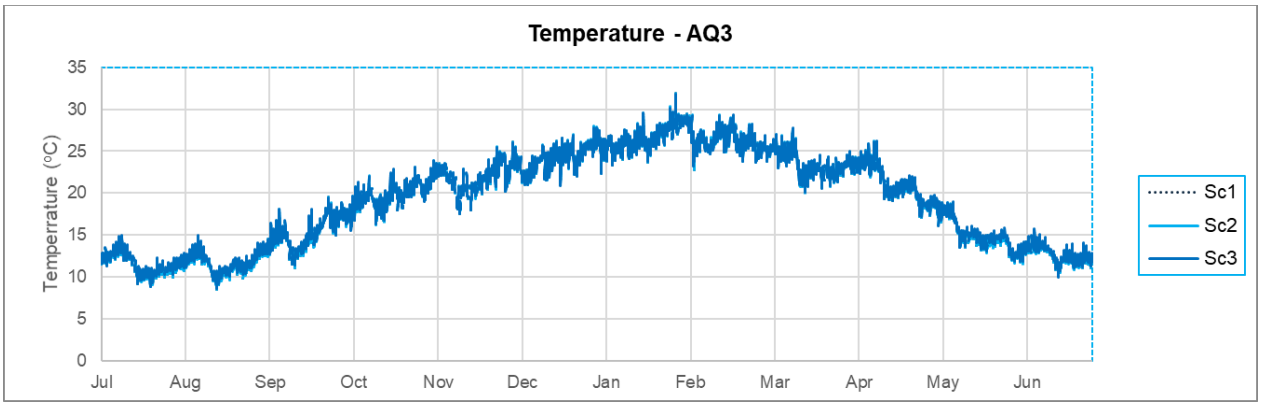


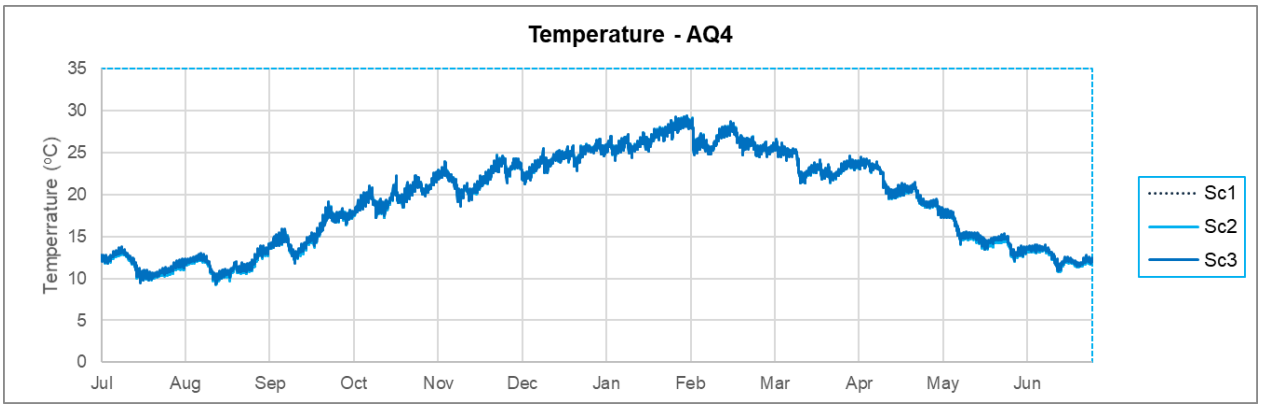


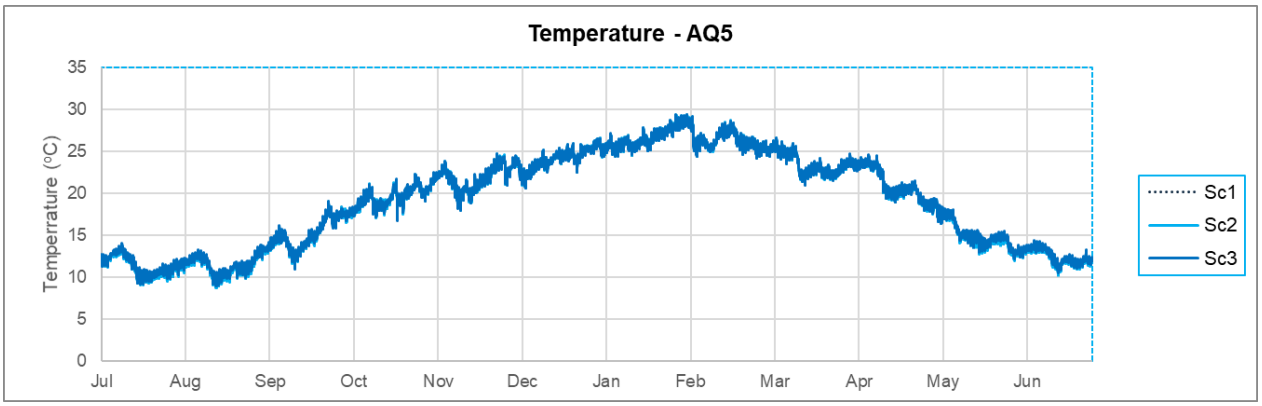
Time series plots

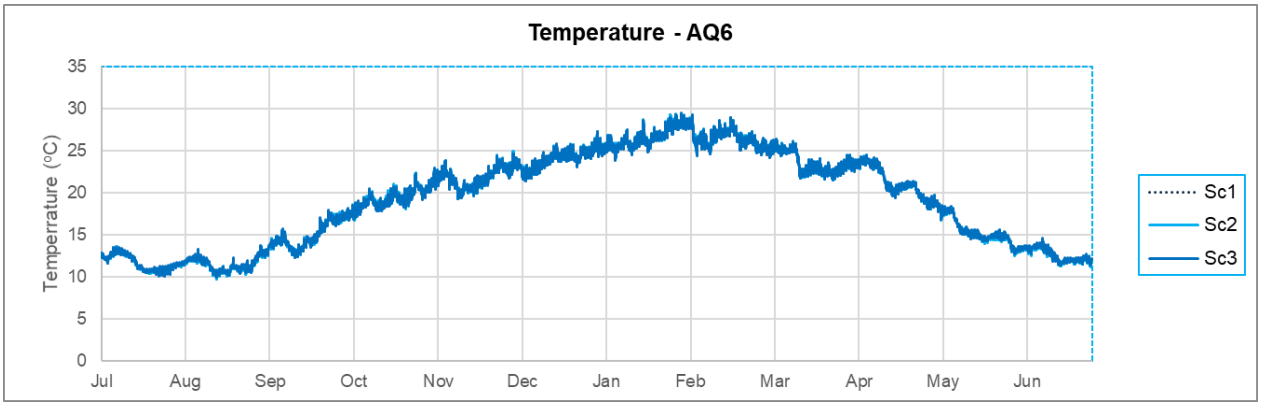






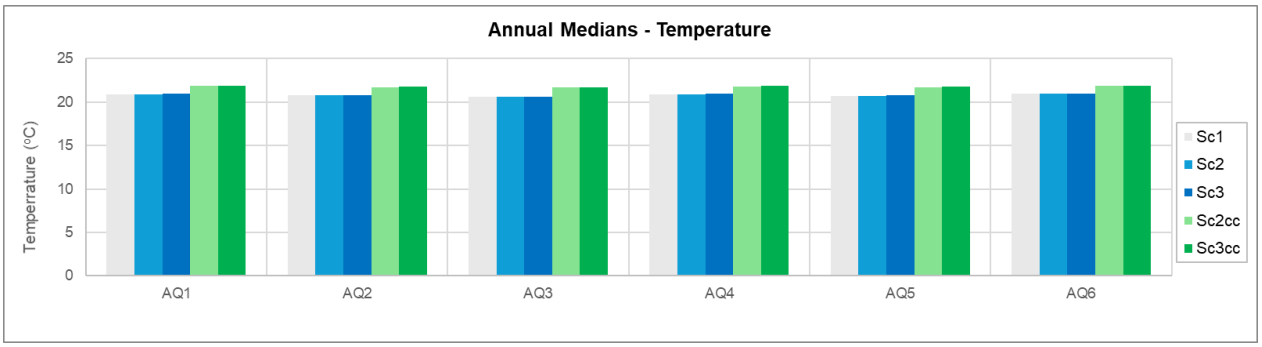


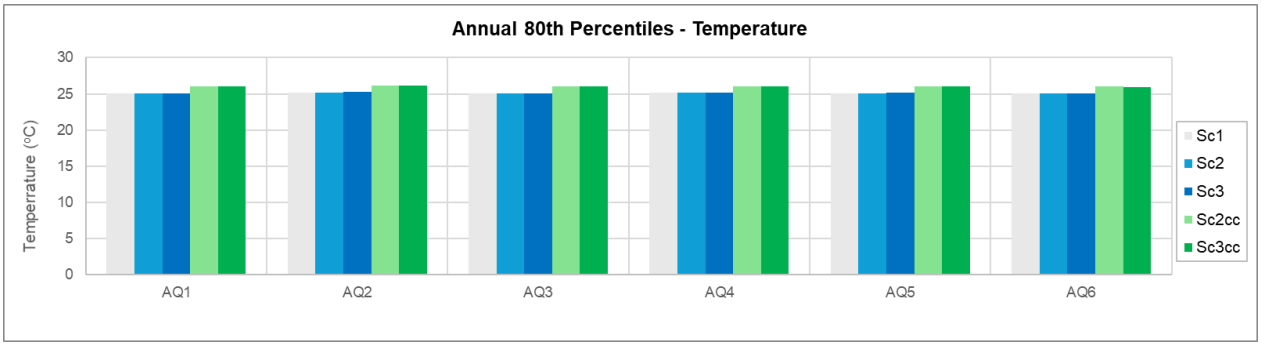




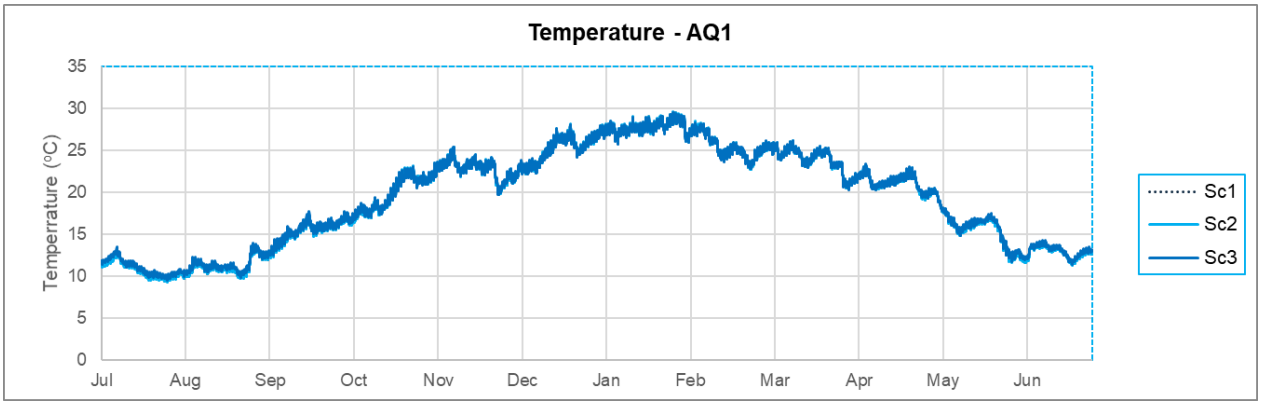
Appendices D3.2.2 Average rainfall year scenario results (2016-2017)

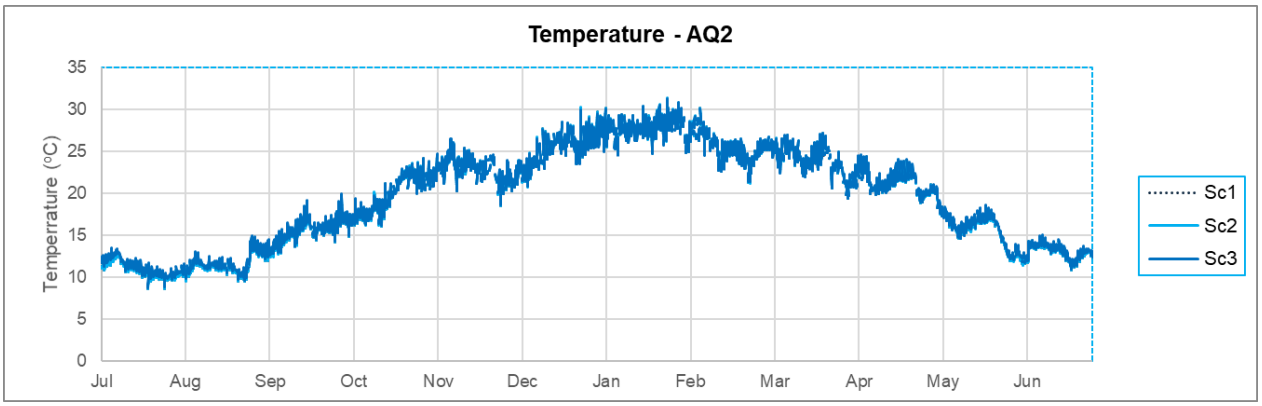
Bar charts

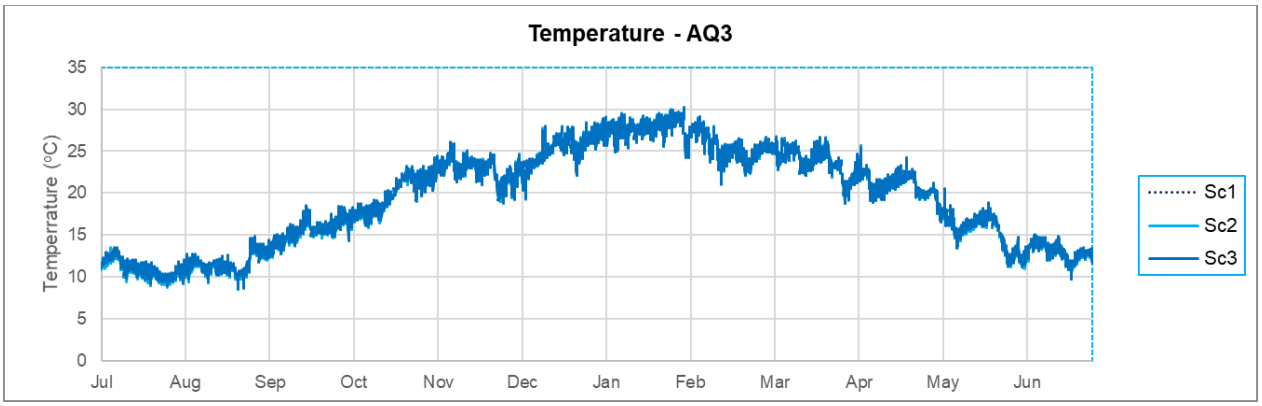


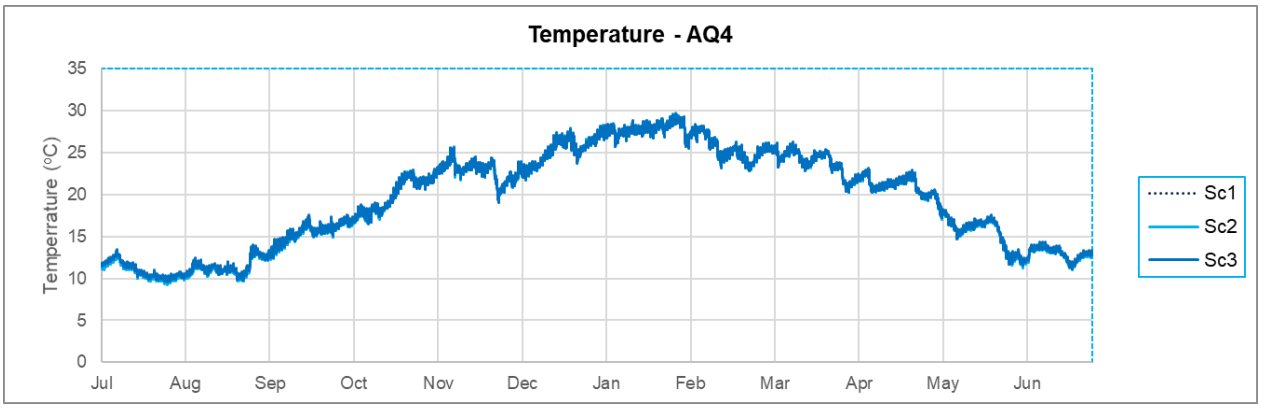


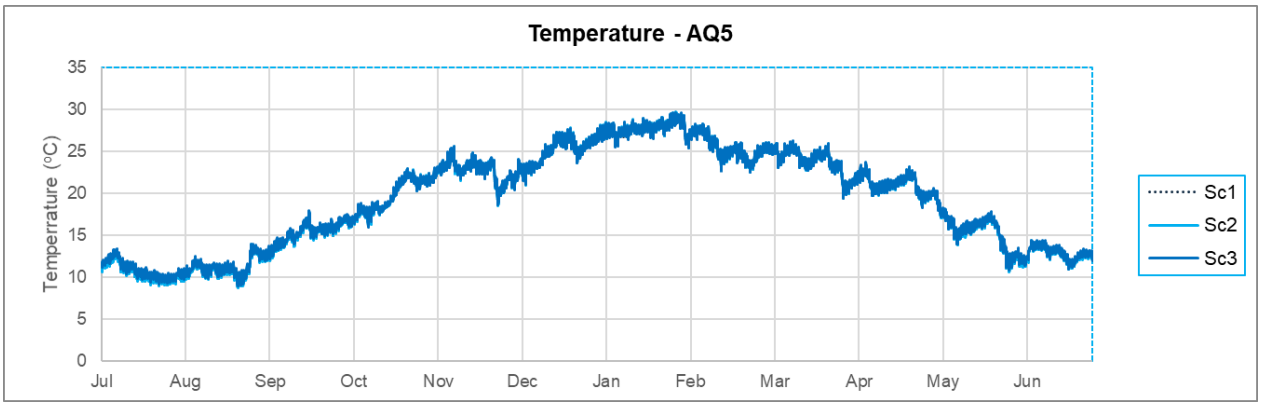
Time series plots

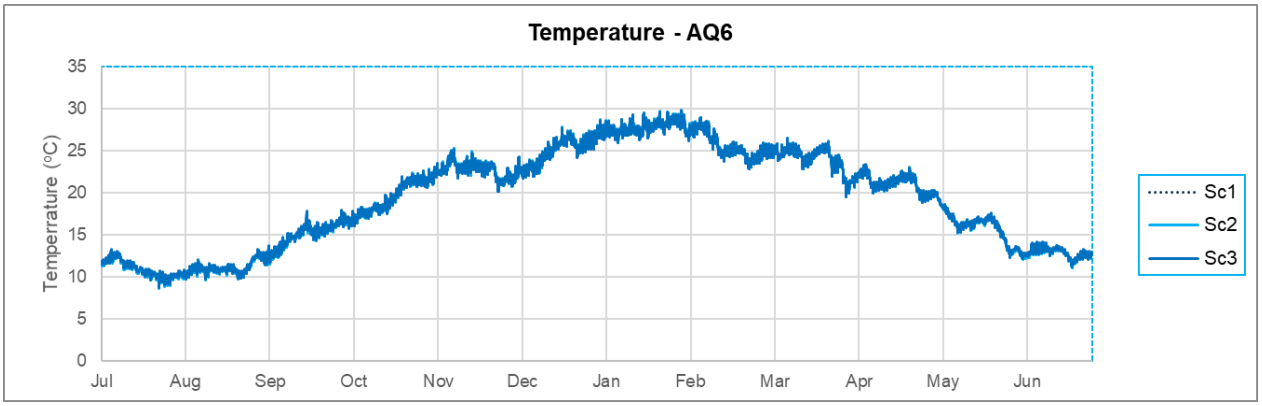






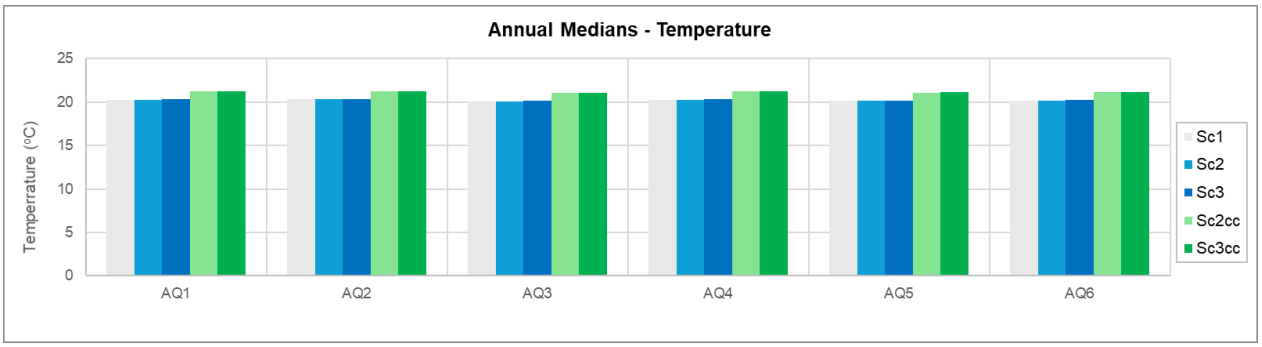


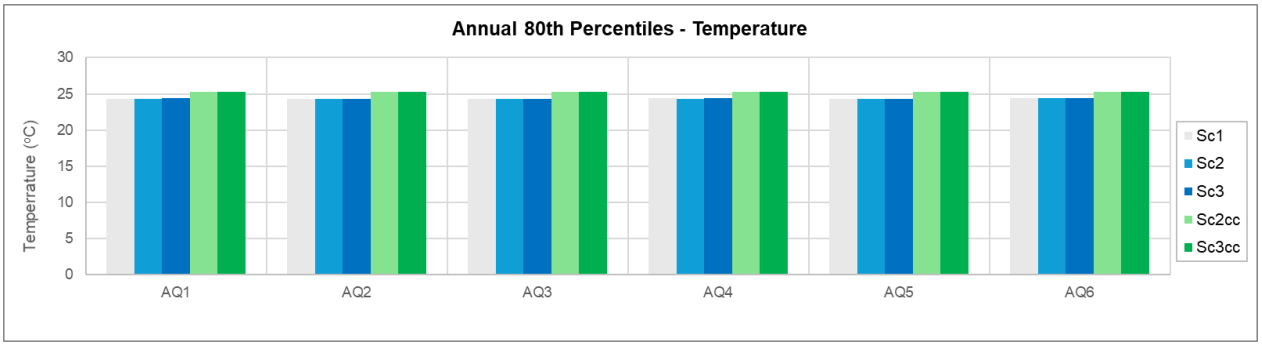




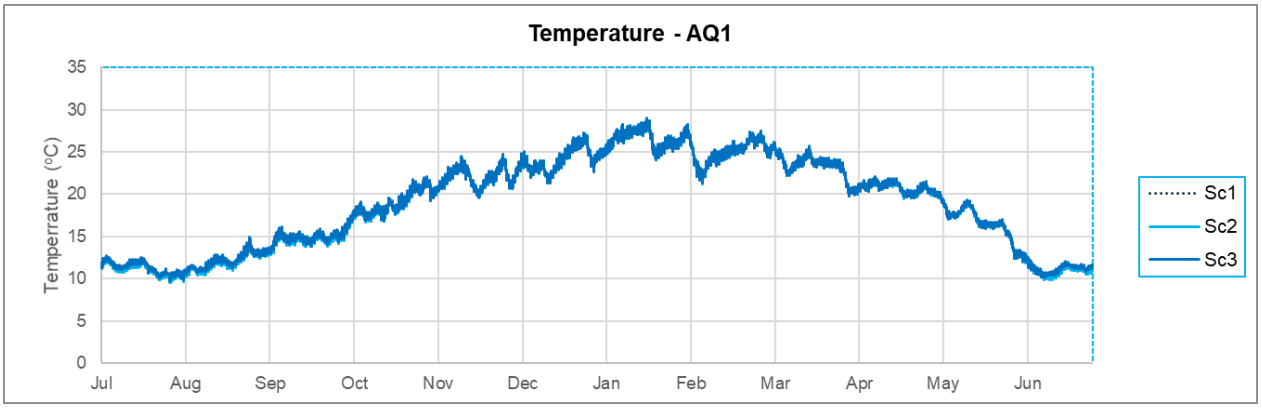
Appendices D3.2.3 Higher rainfall year scenario results (2021-2022)

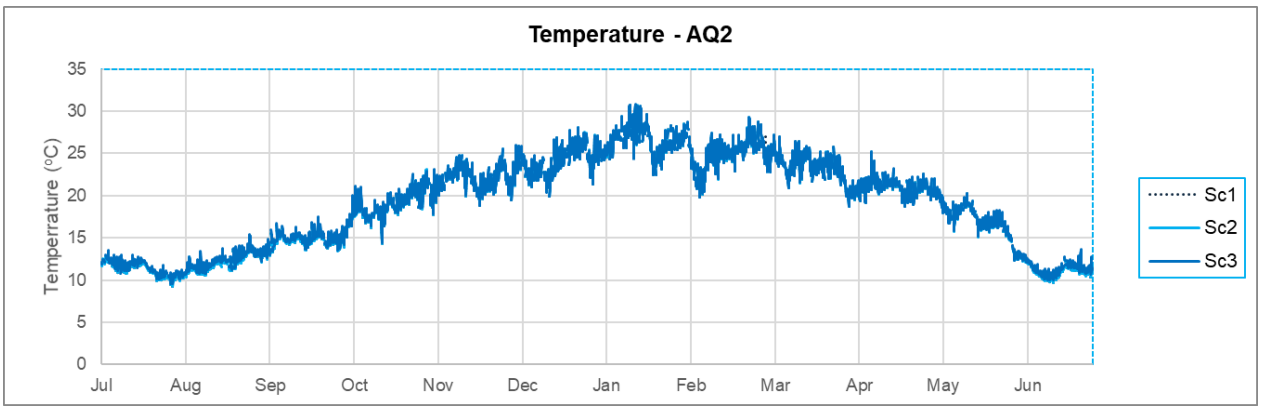
Bar charts

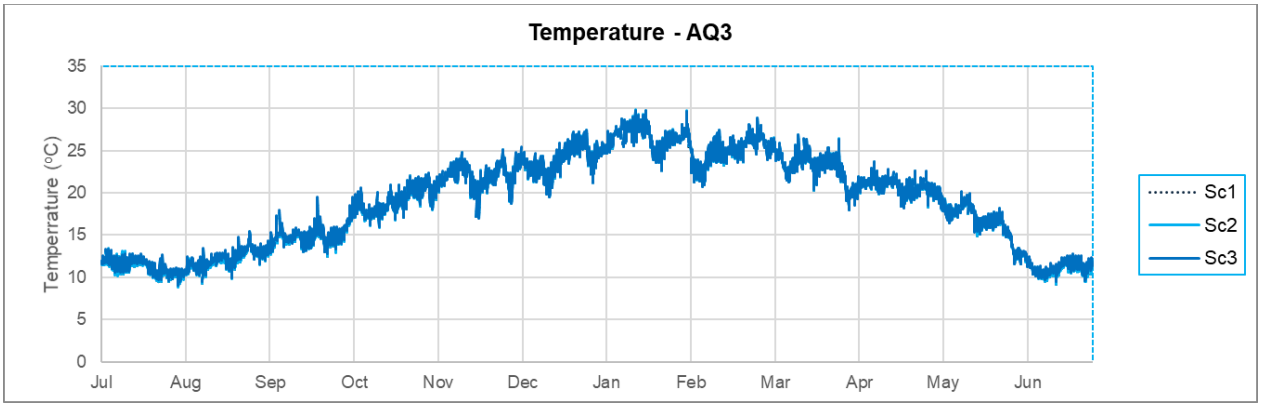


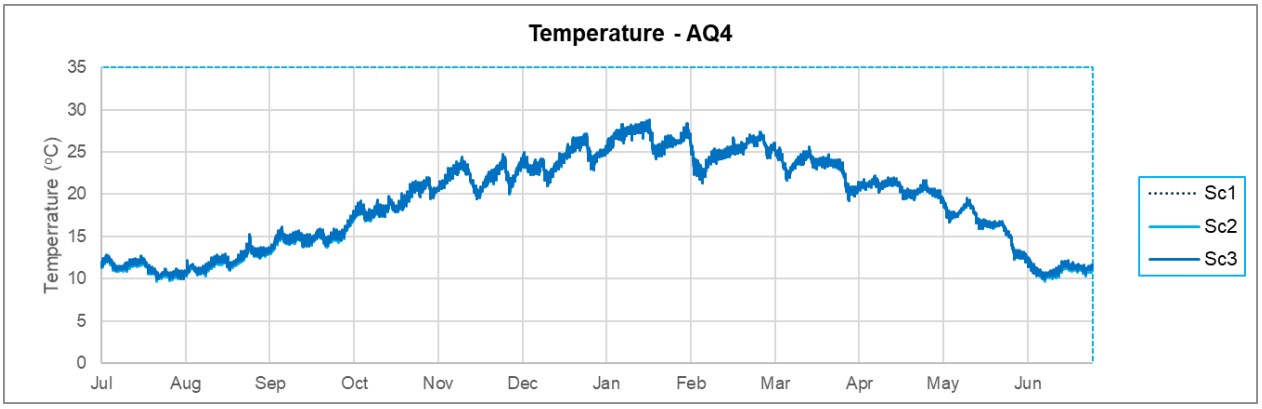


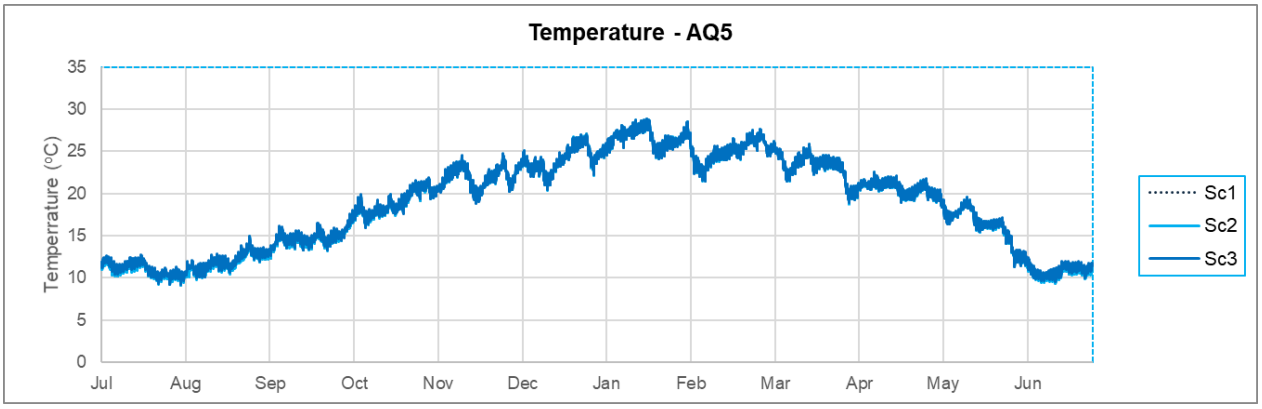
Time series plots

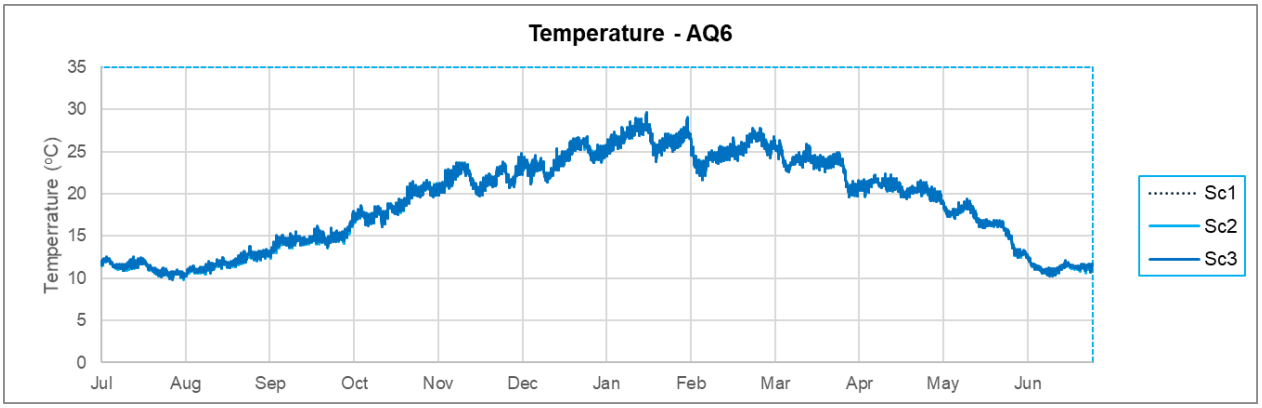








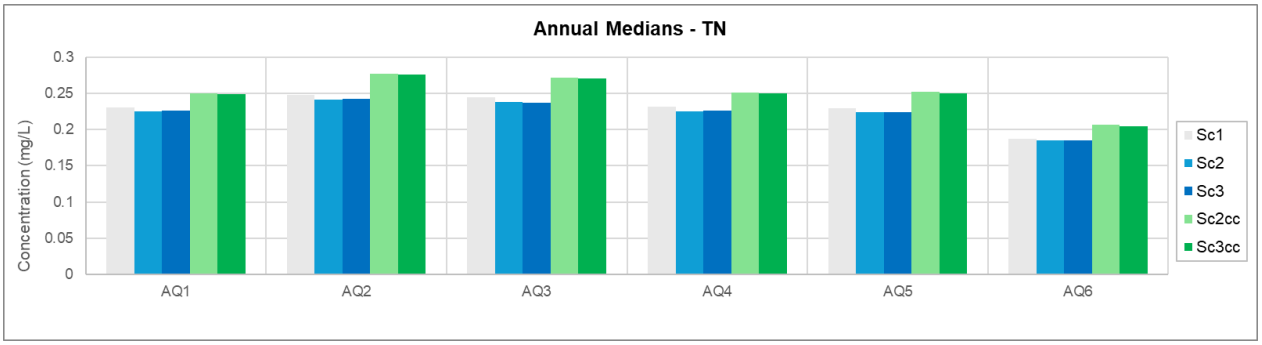


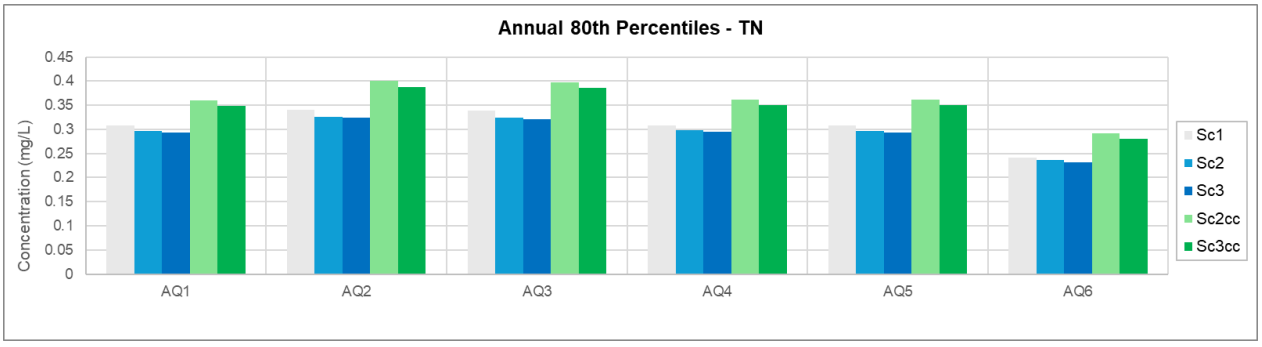


Appendices D3.3 Total N

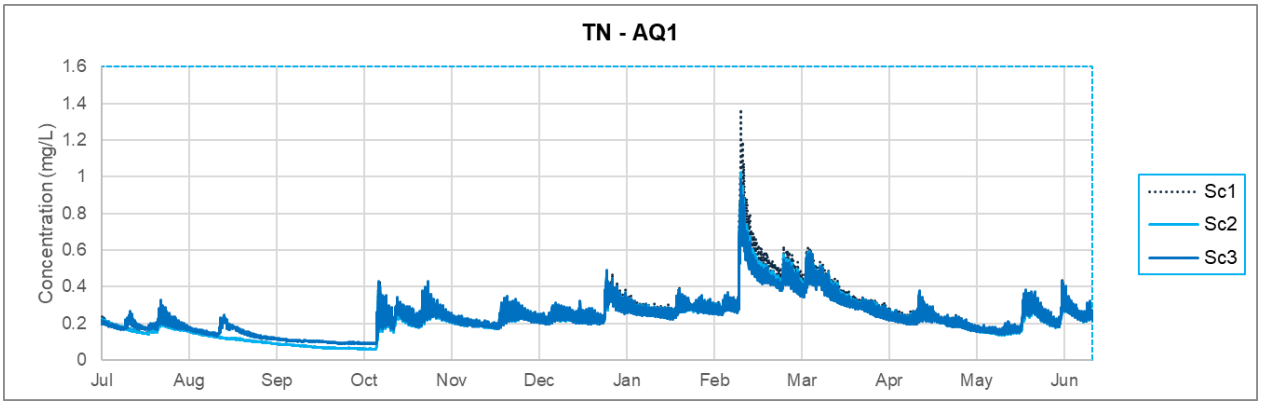
Appendices D3.3.1 Lower rainfall year scenario results (2017-2018)

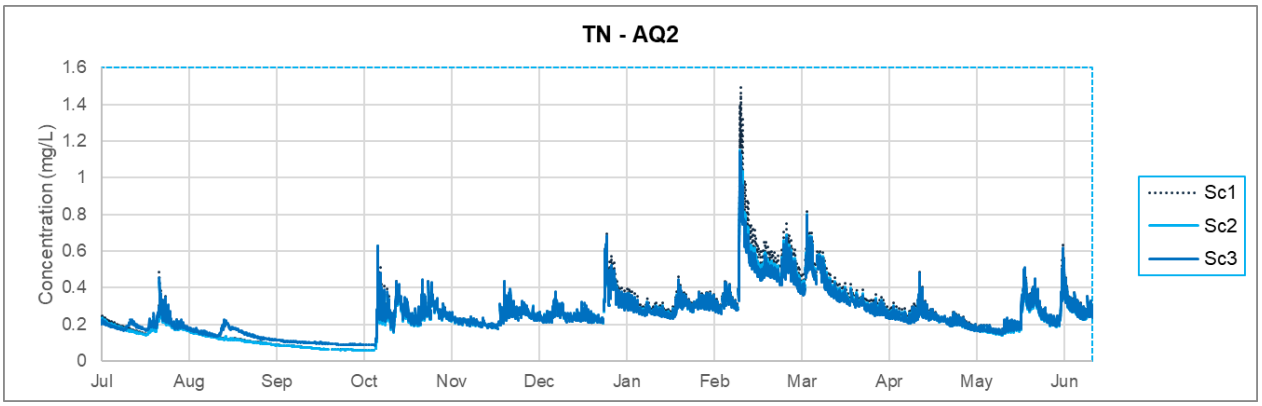
Bar charts

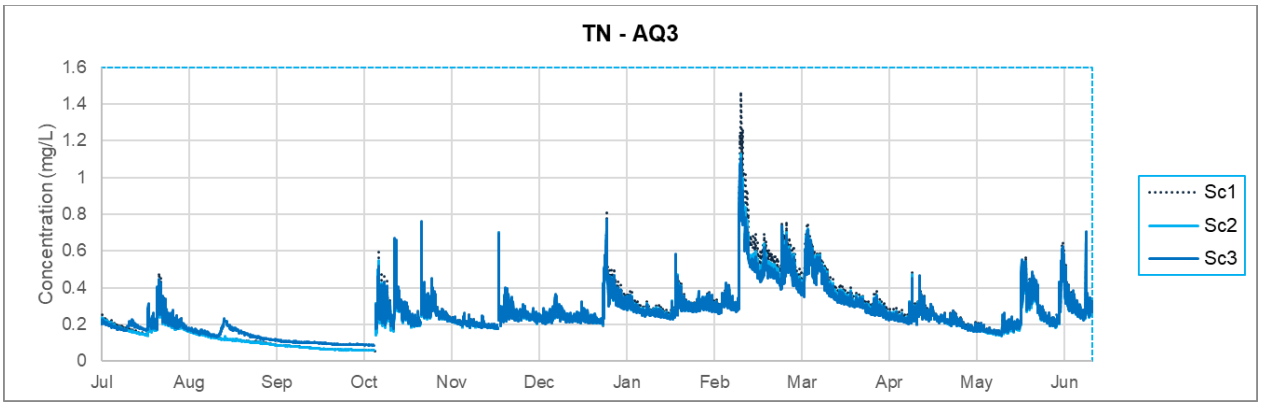


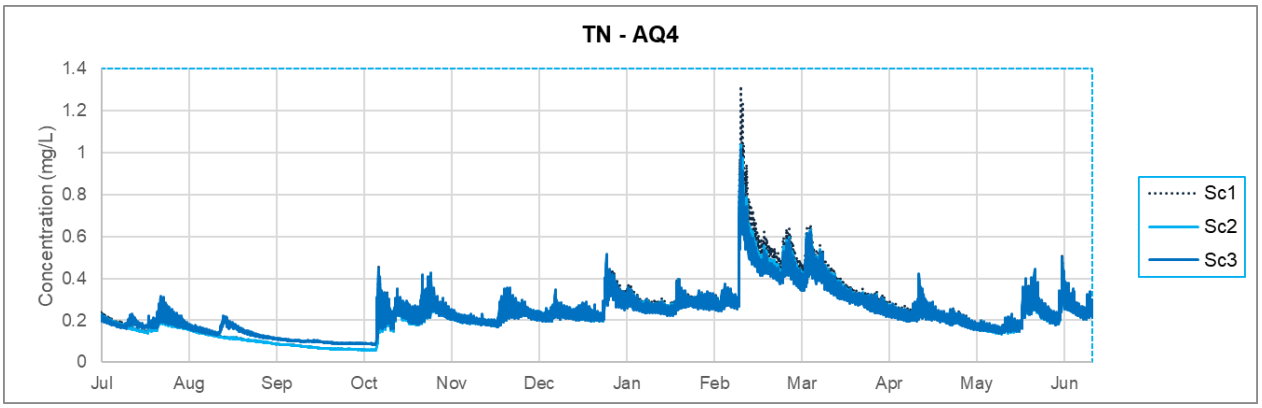


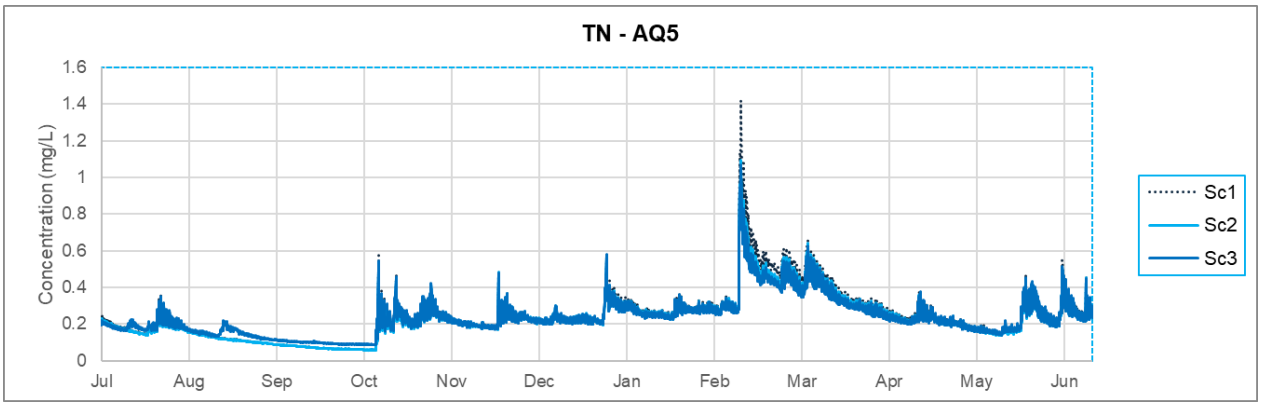
Time series plots





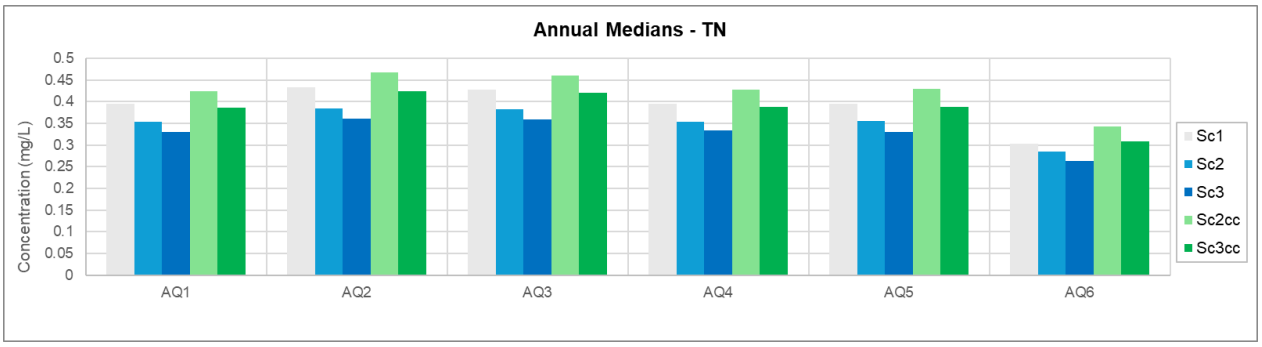


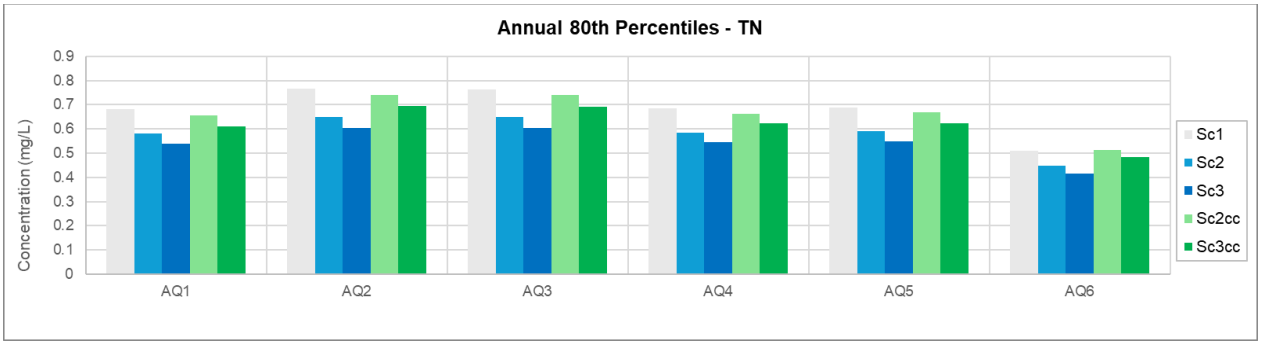




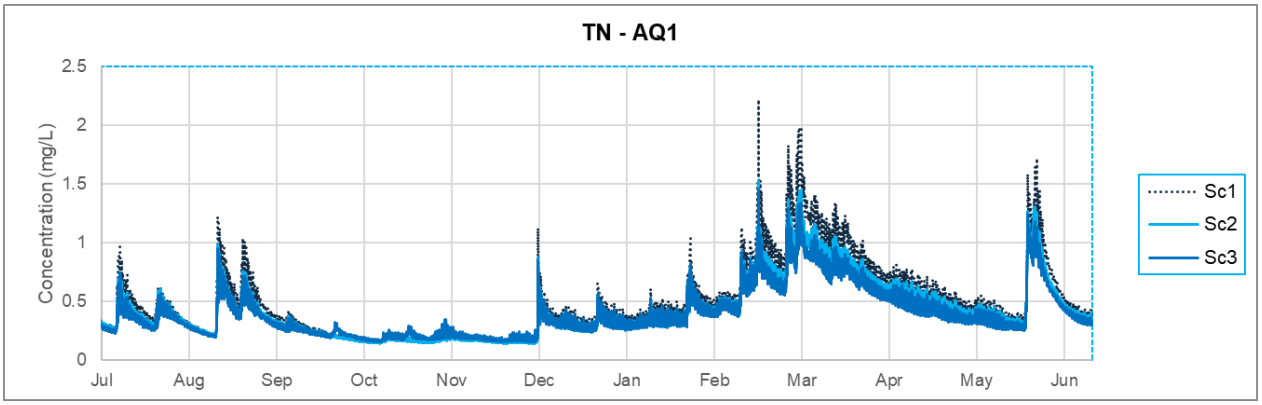
Appendices D3.3.2 Average rainfall year scenario results (2016-2017)

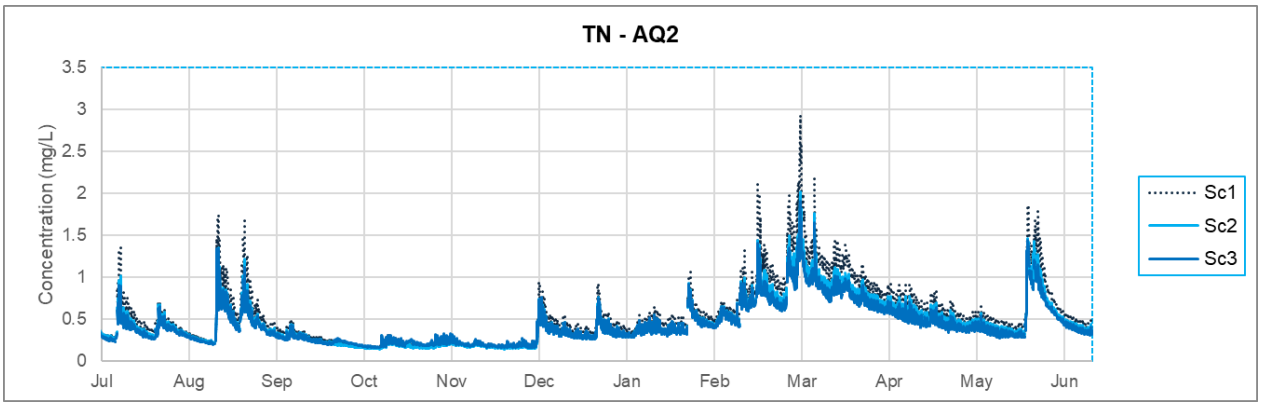
Bar charts

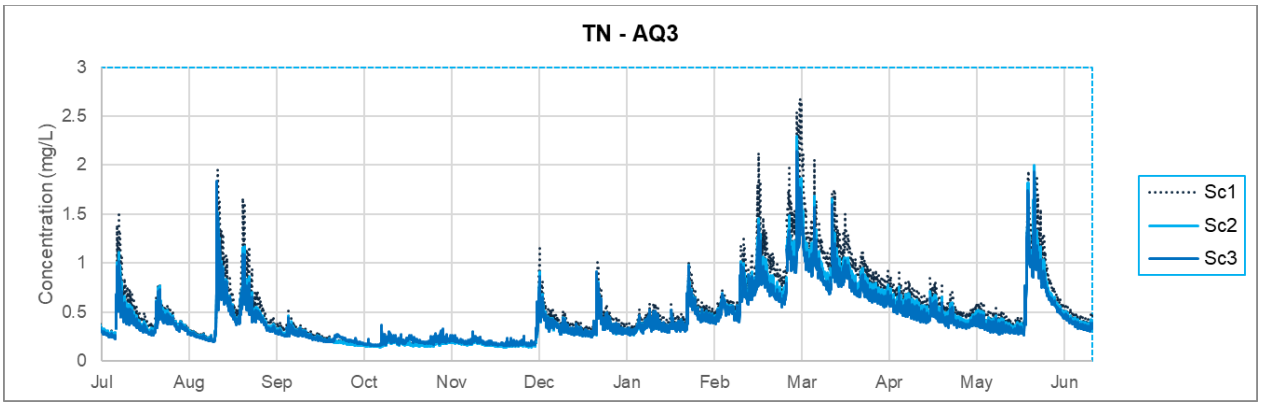


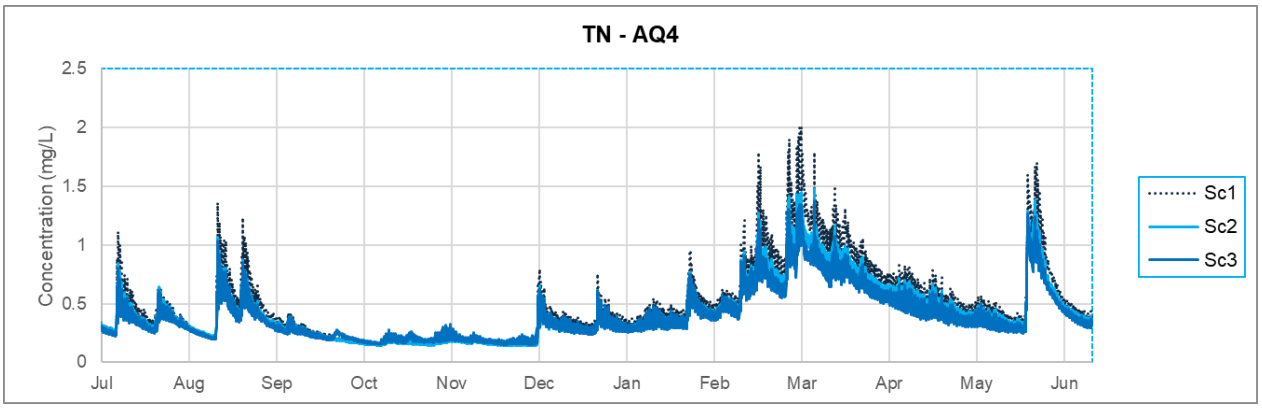


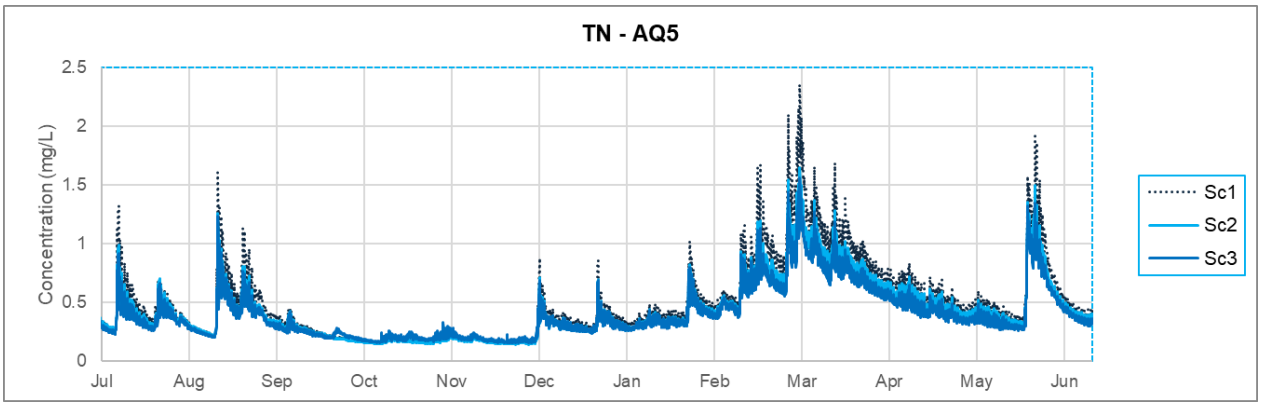
Time series plots





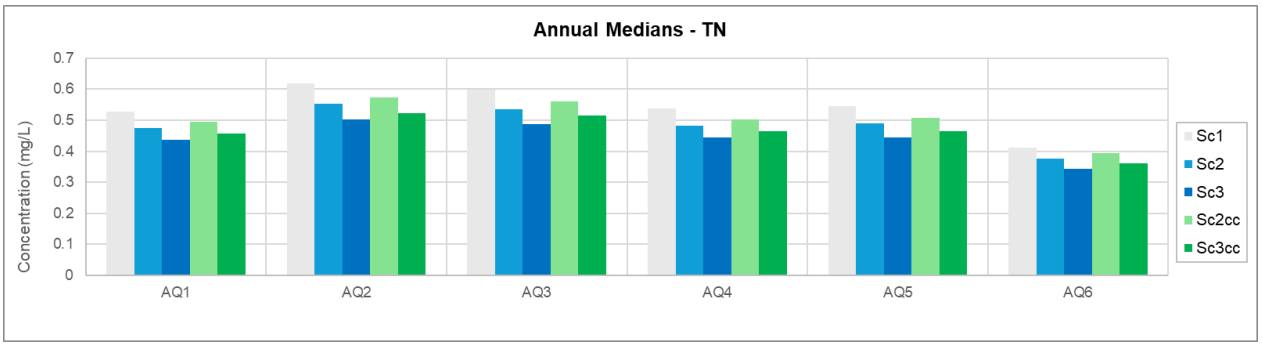


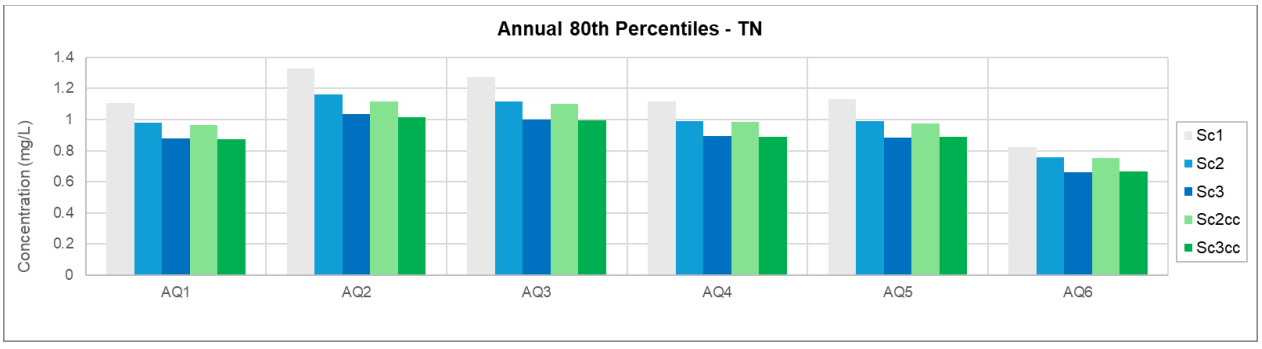




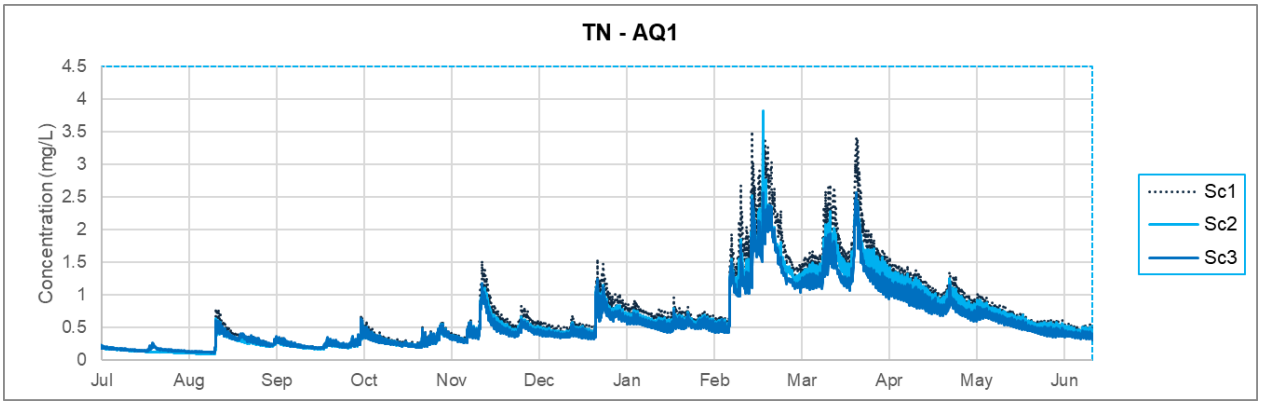
Appendices D3.3.3 Higher rainfall year scenario results (2021-2022)

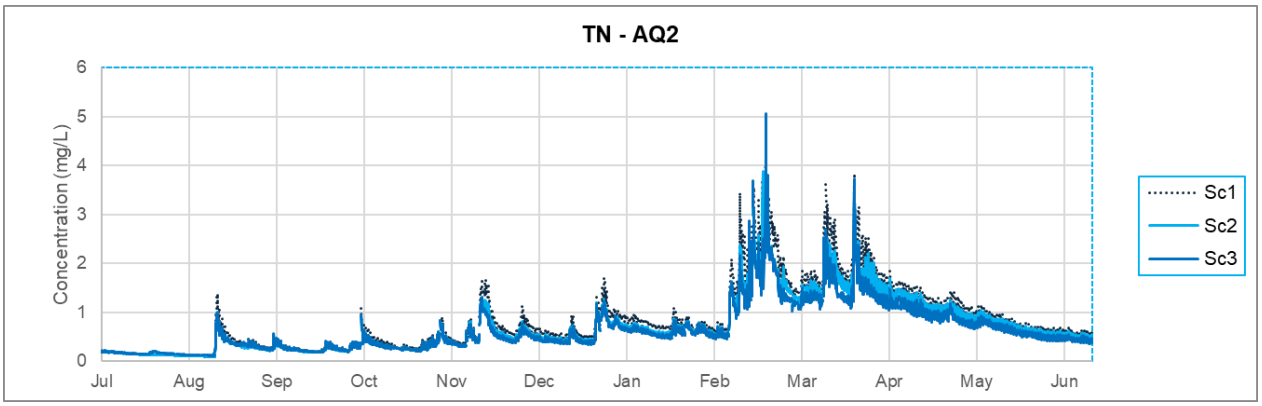
Bar charts

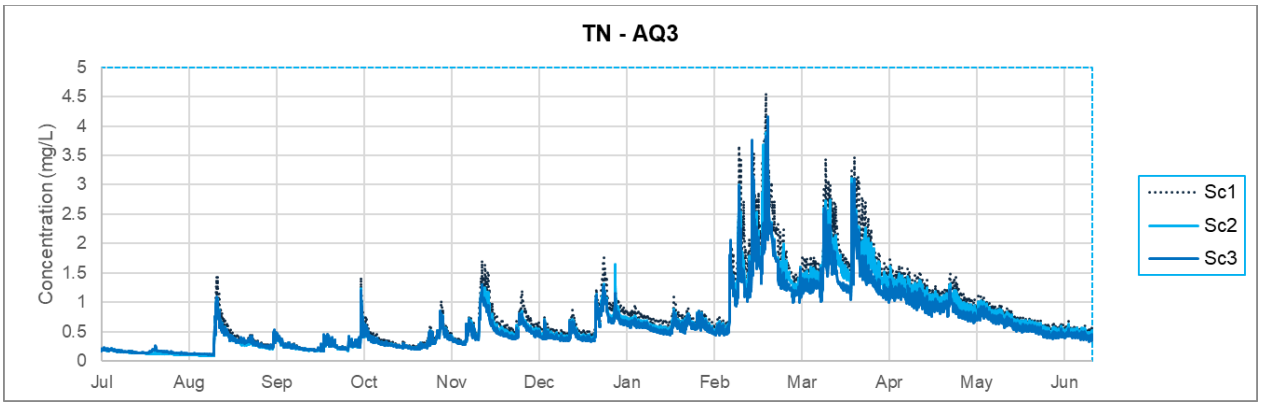


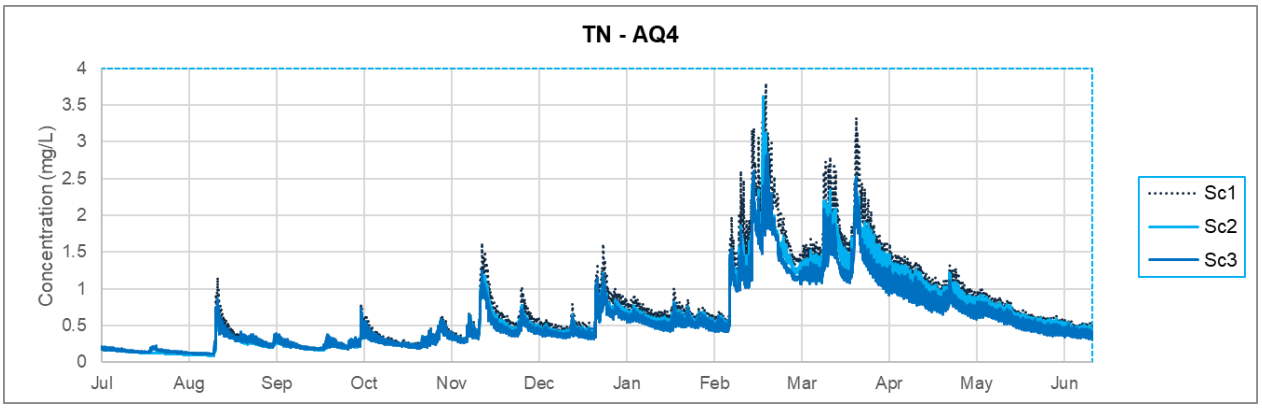


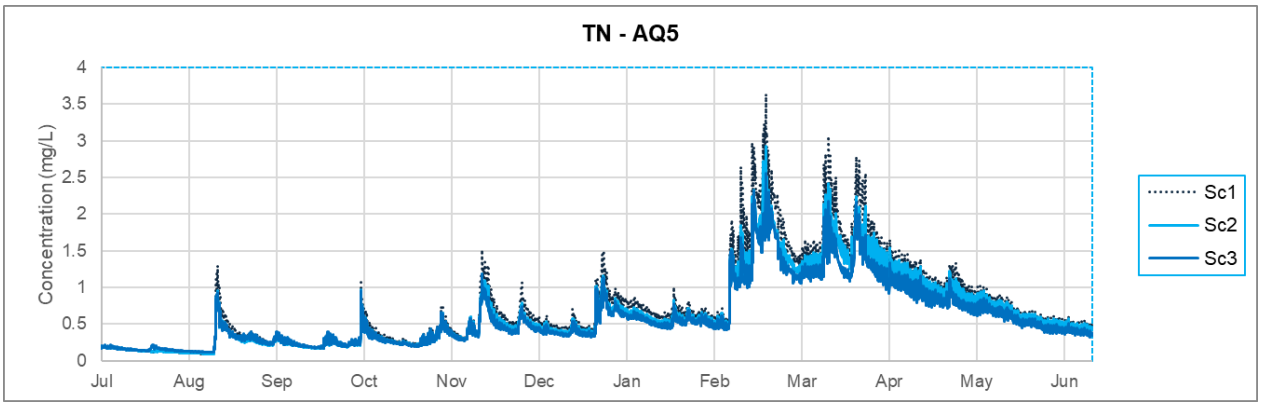
Time series plots

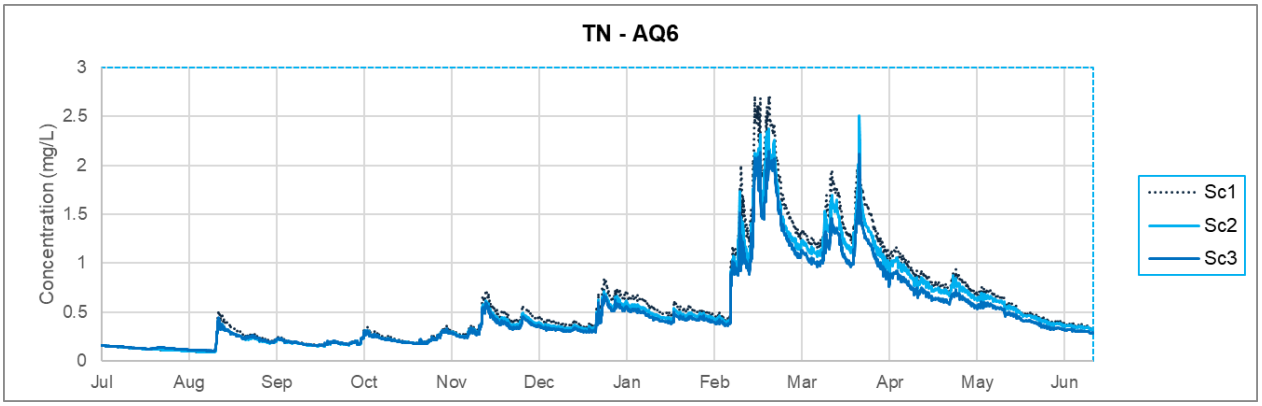








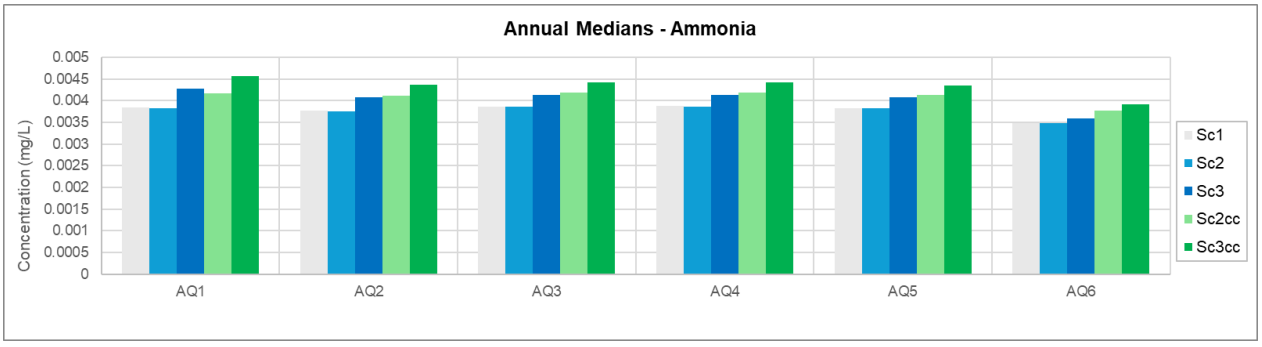


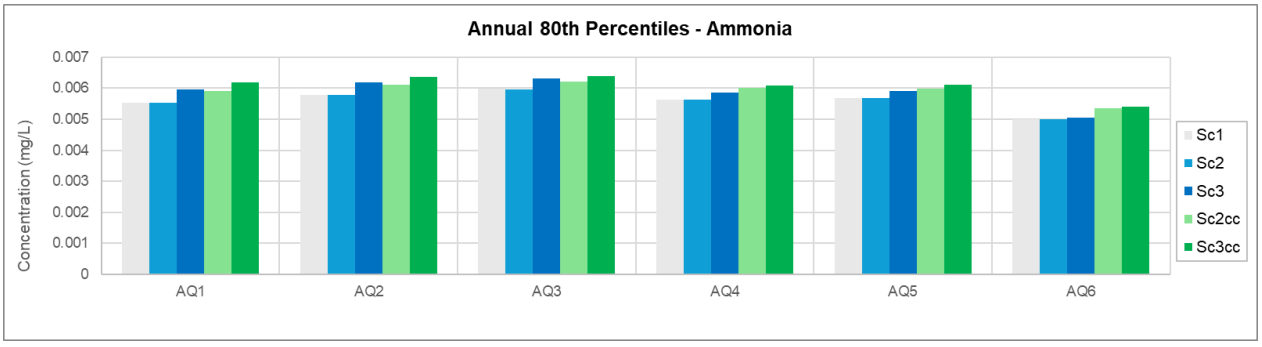


Appendices D3.4 Ammonia

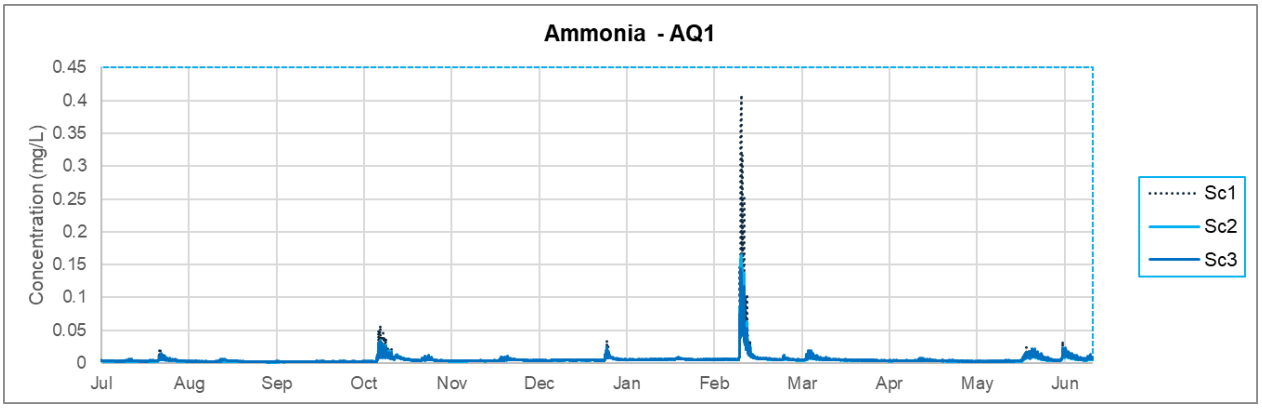
Appendices D3.4.1 Lower rainfall year scenario results (2017-2018)

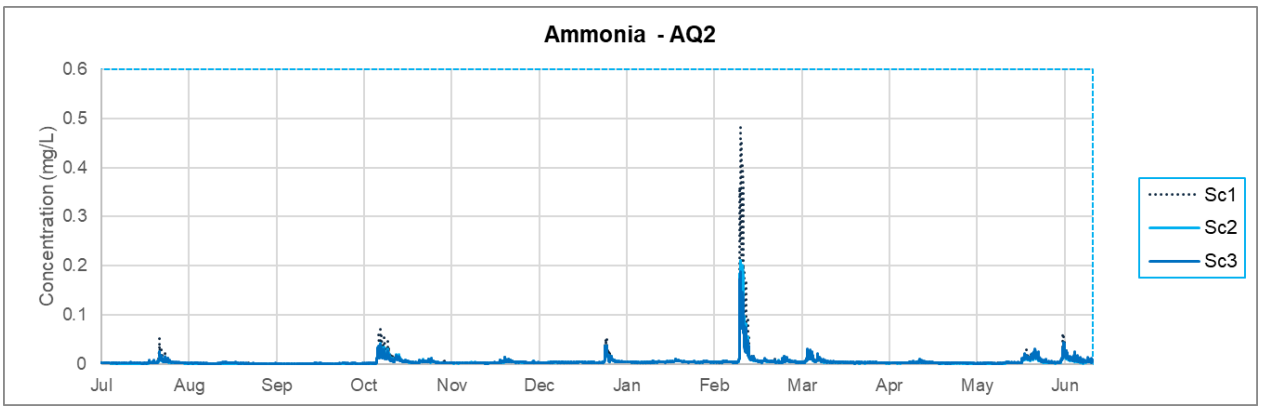
Bar charts

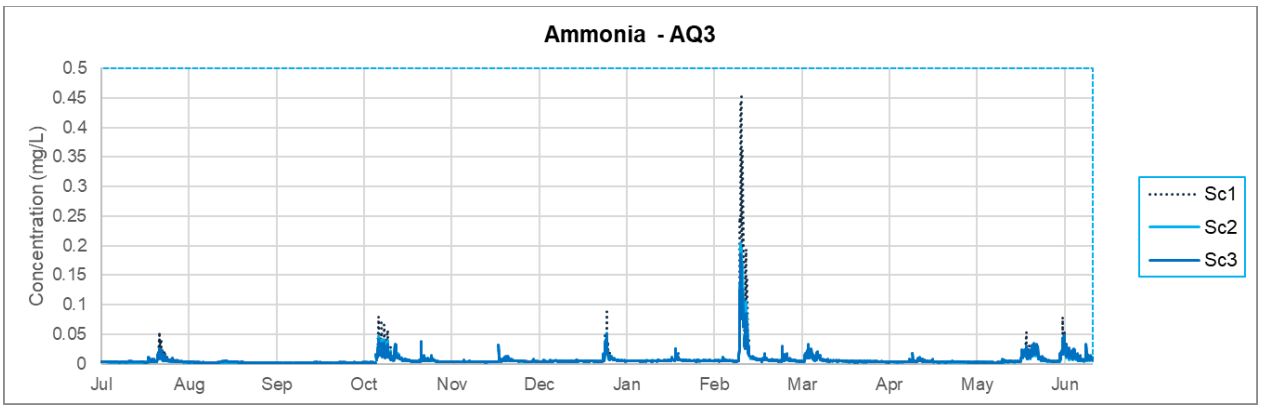


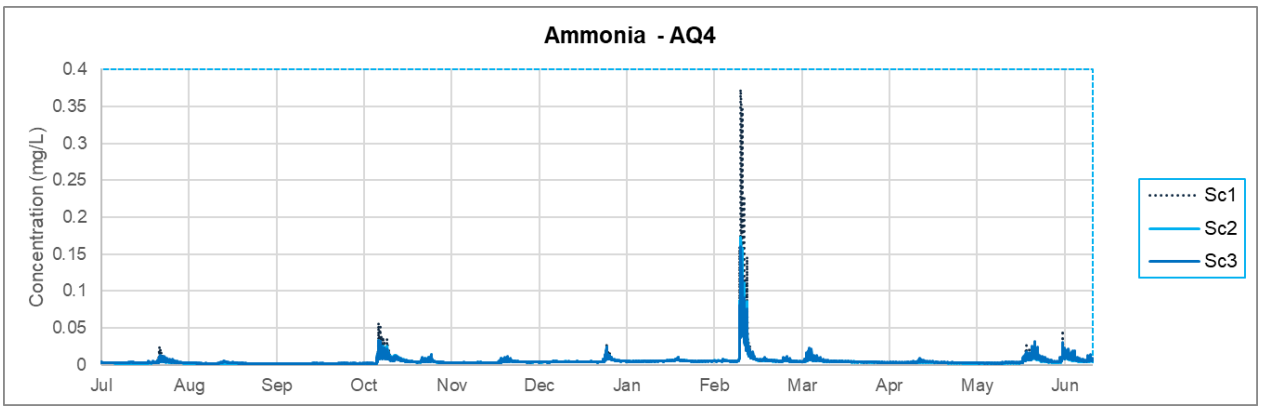


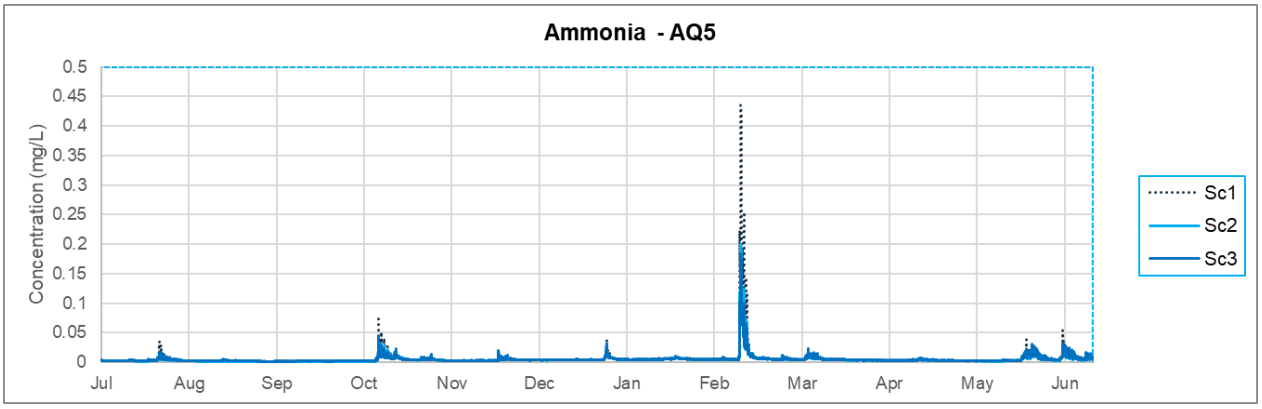
Time series plots

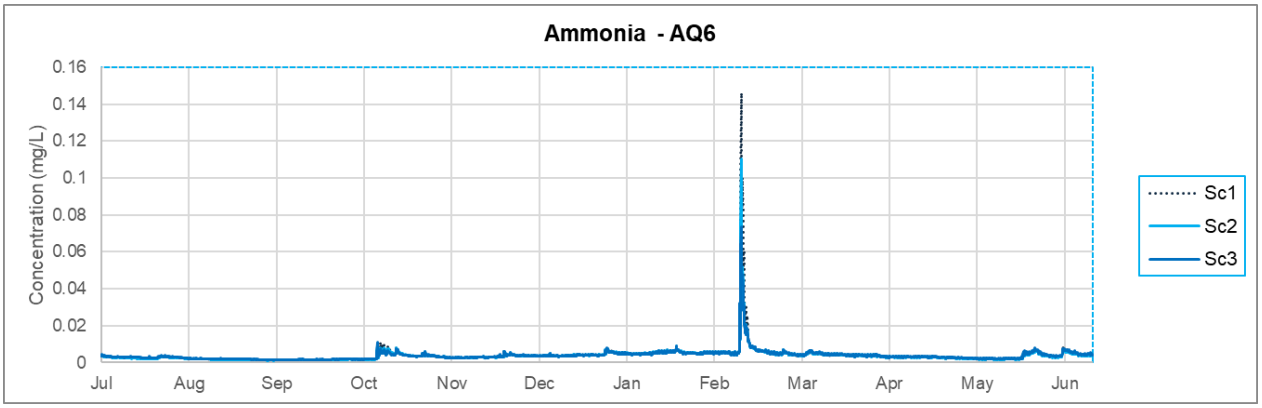






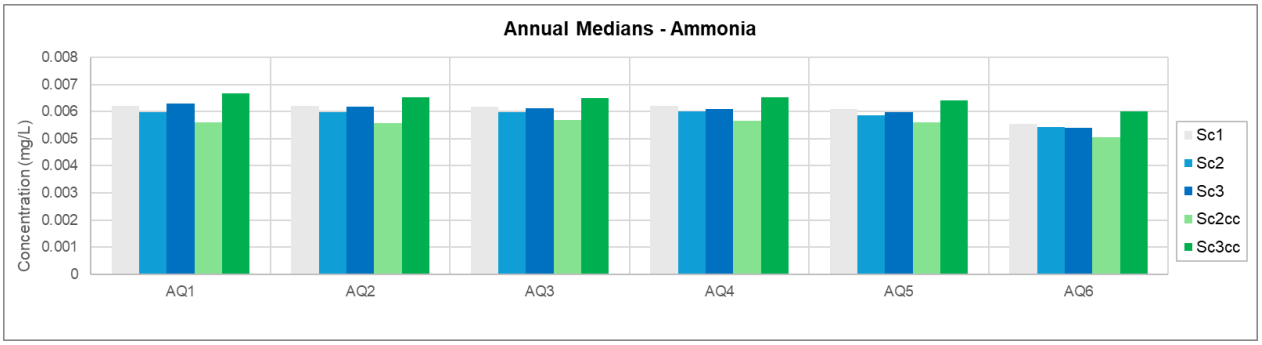


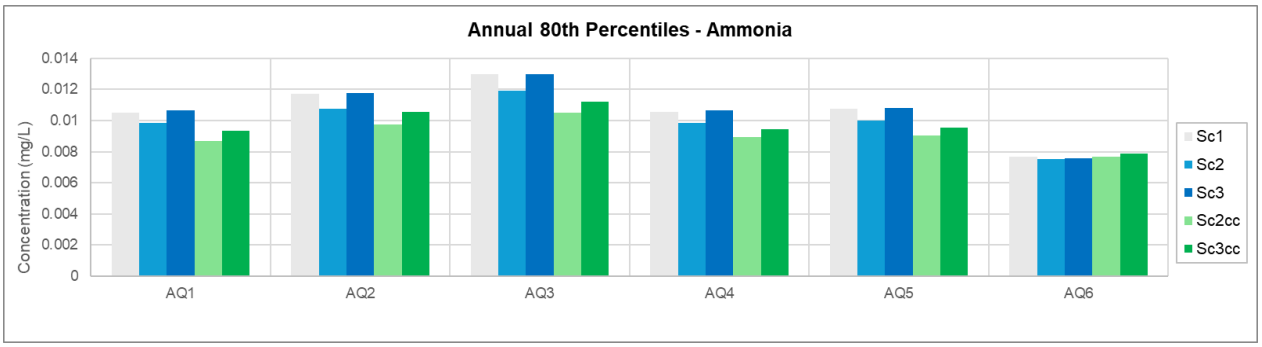




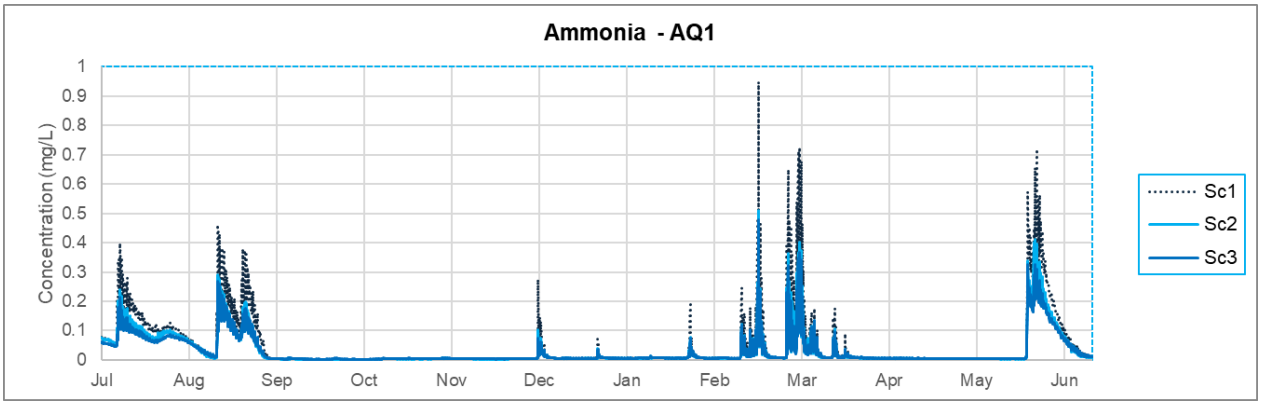
Appendices D3.4.2 Average rainfall year scenario results (2016-2017)

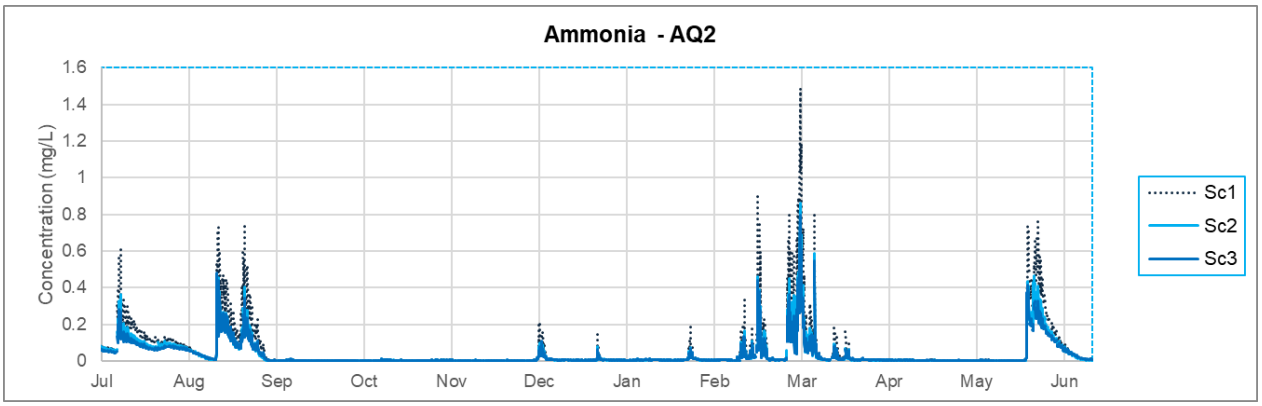
Bar charts

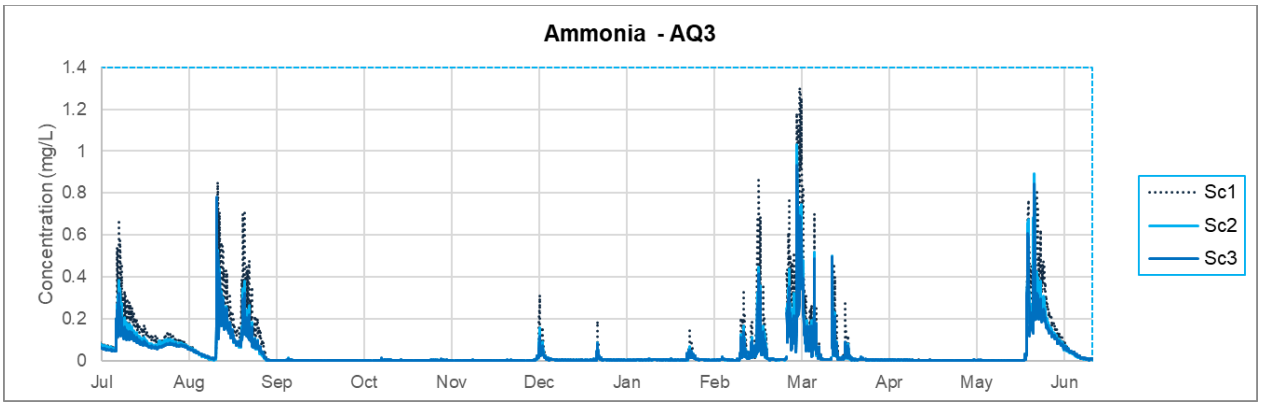


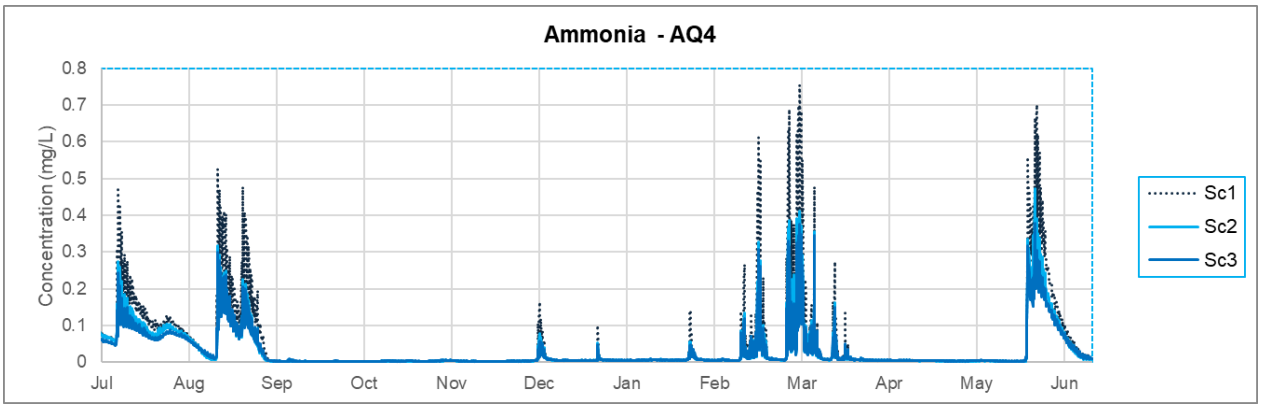


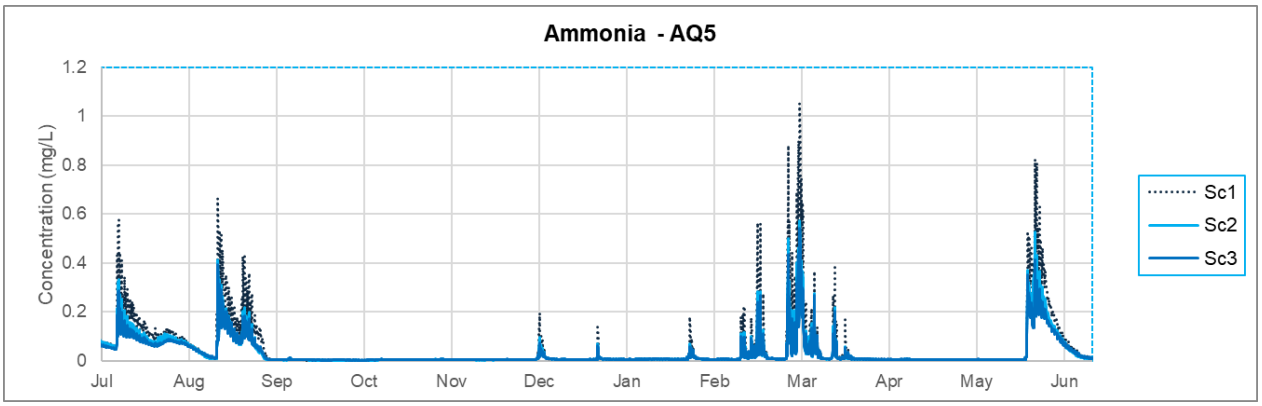
Time series plots

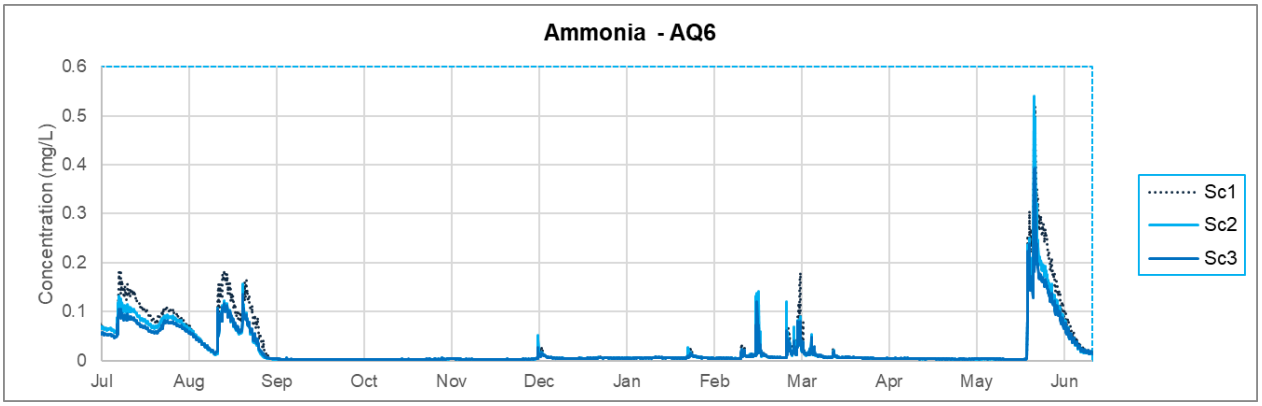






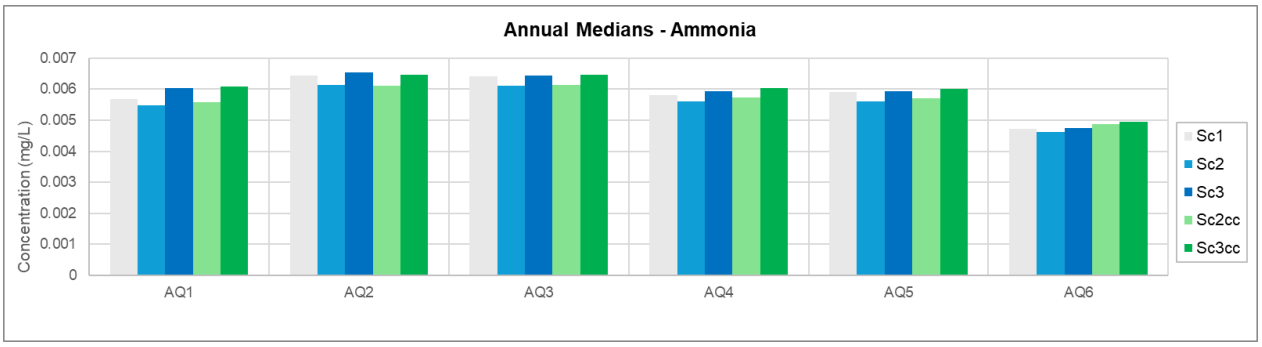


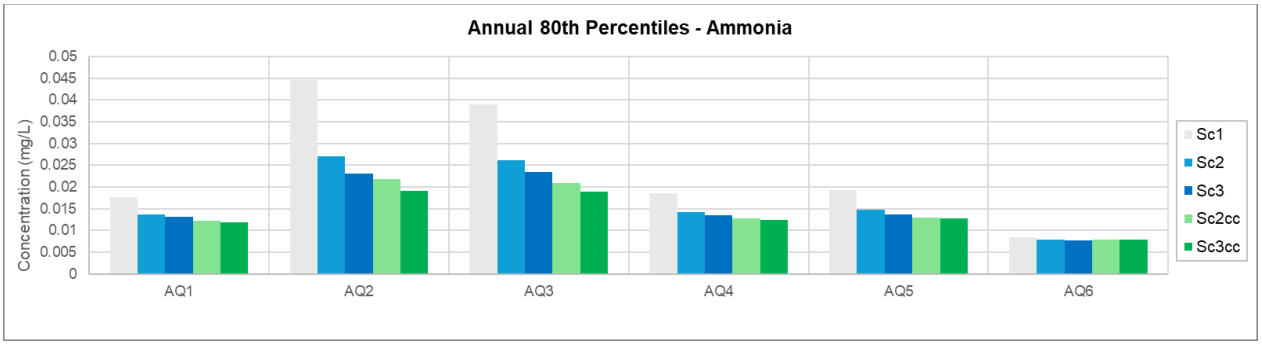




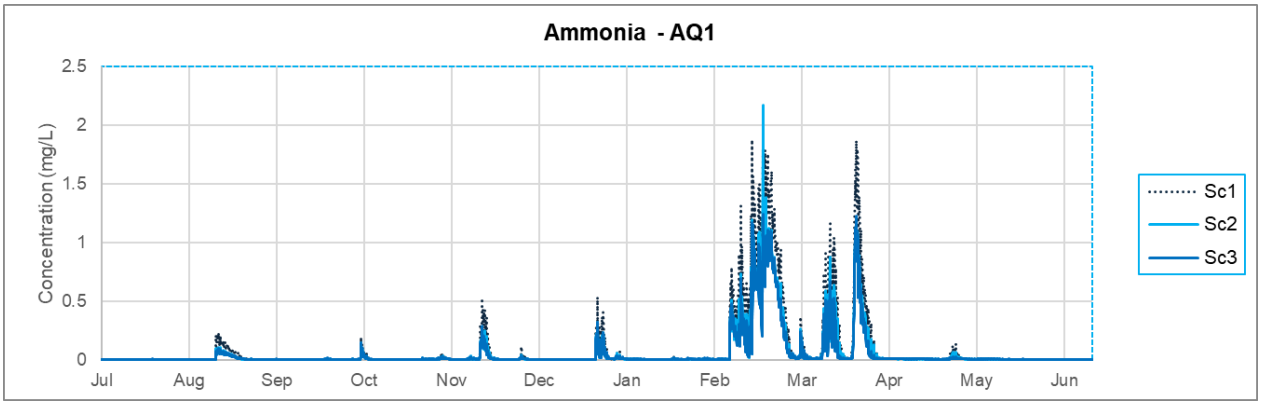
Appendices D3.4.3 Higher rainfall year scenario results (2021-2022)

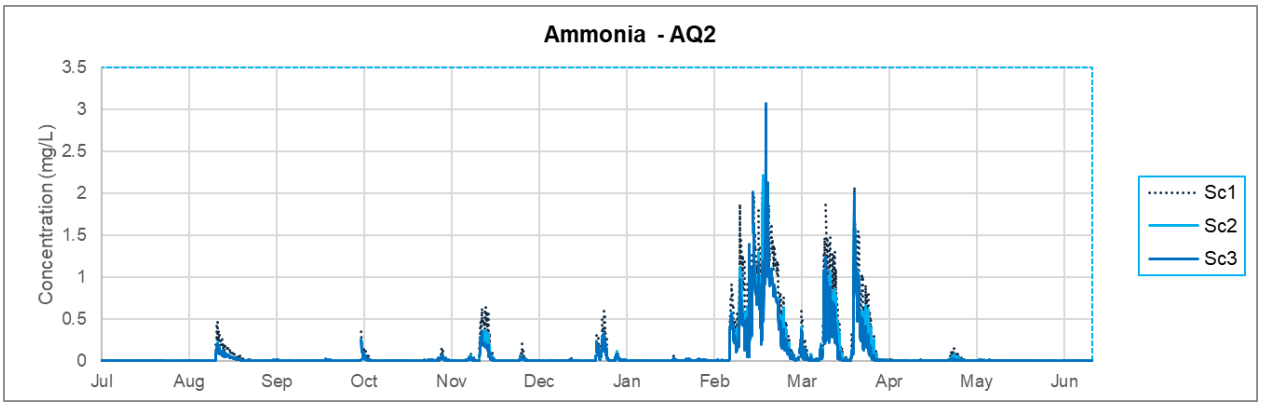
Bar charts

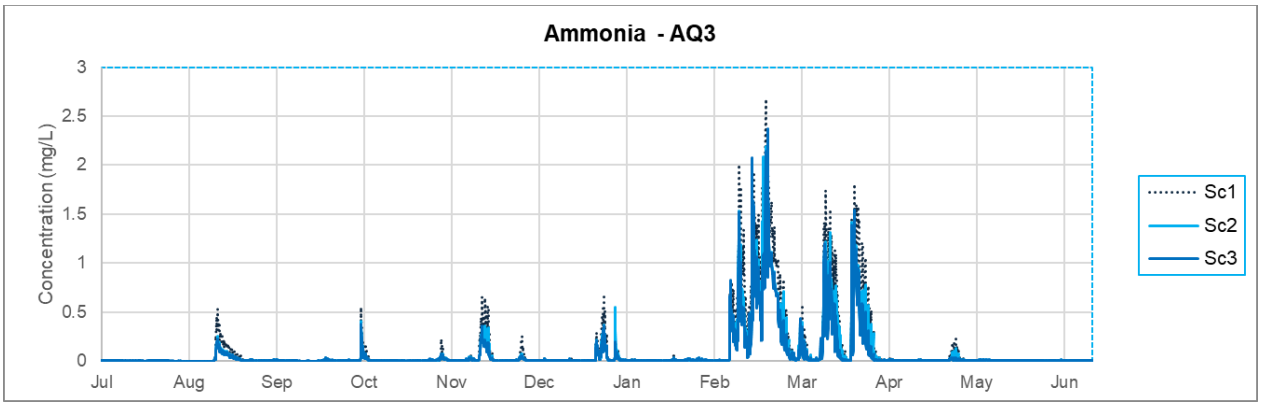


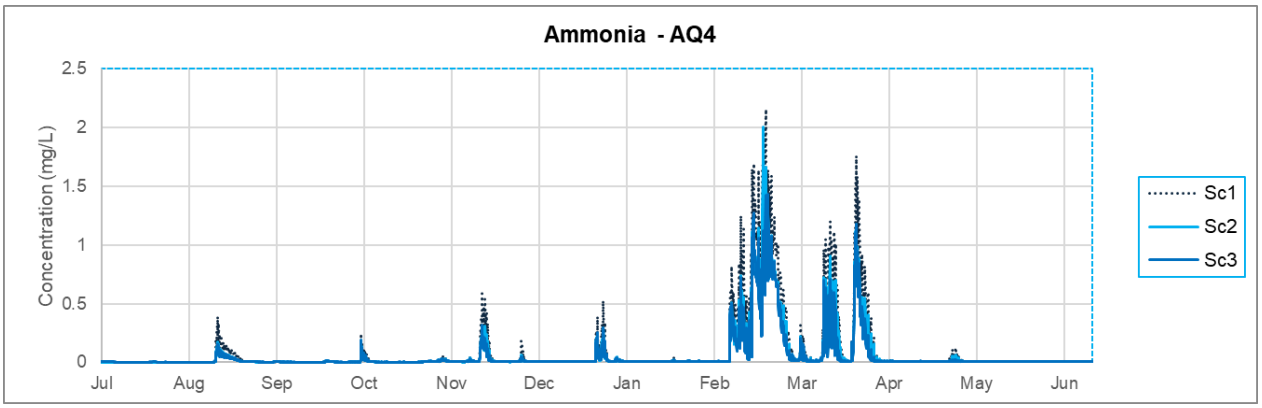


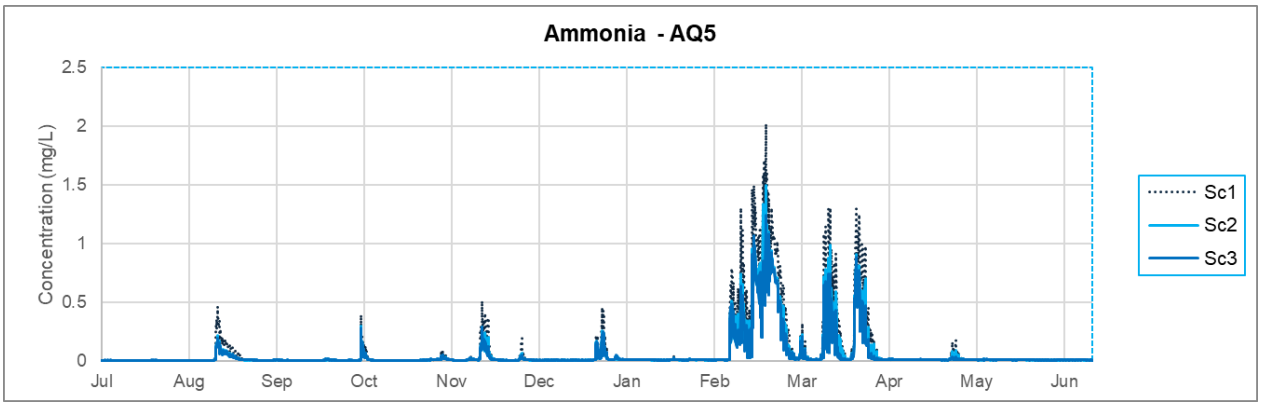
Time series plots

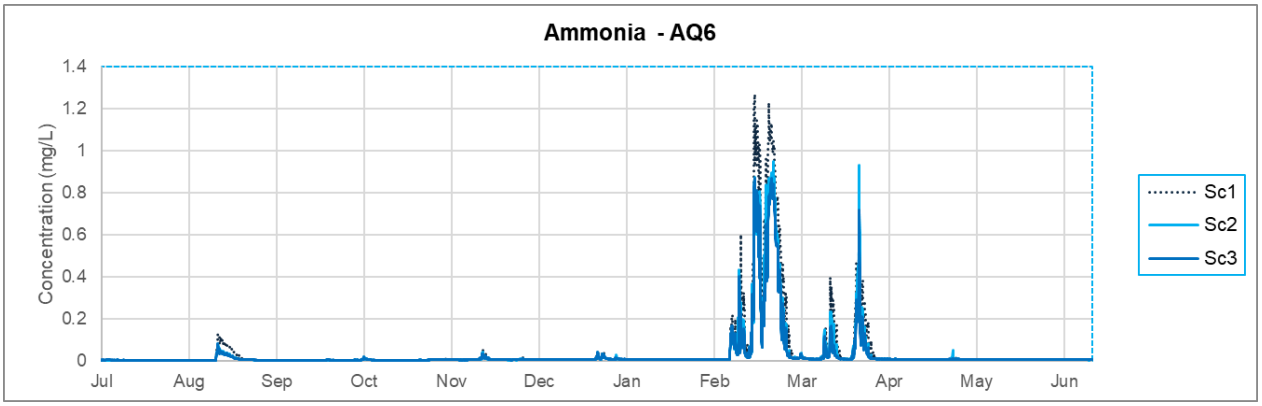








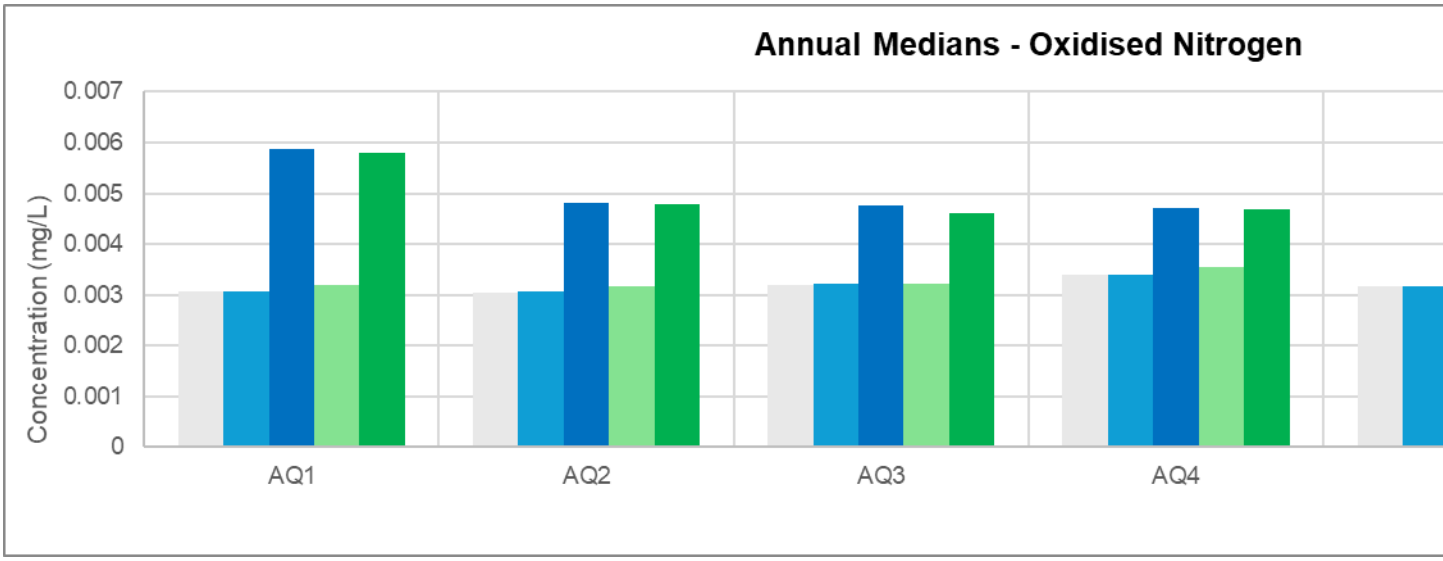


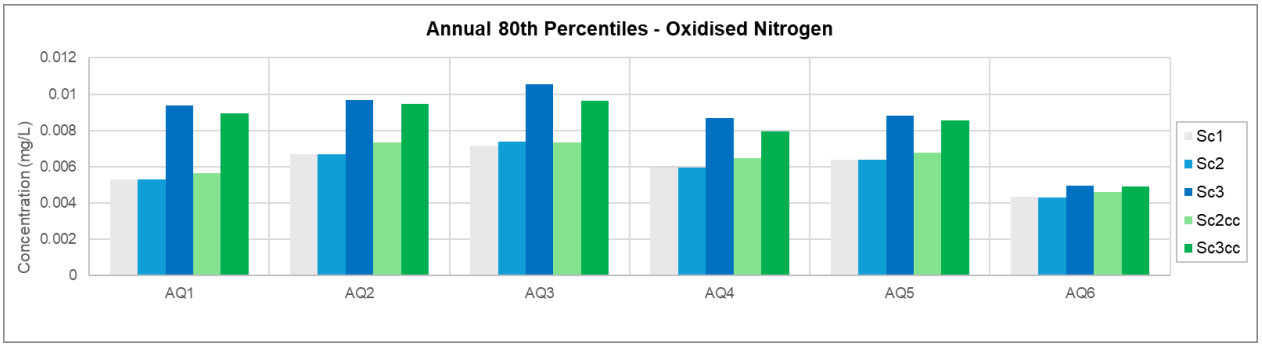


Appendices D3.5 Oxidised N

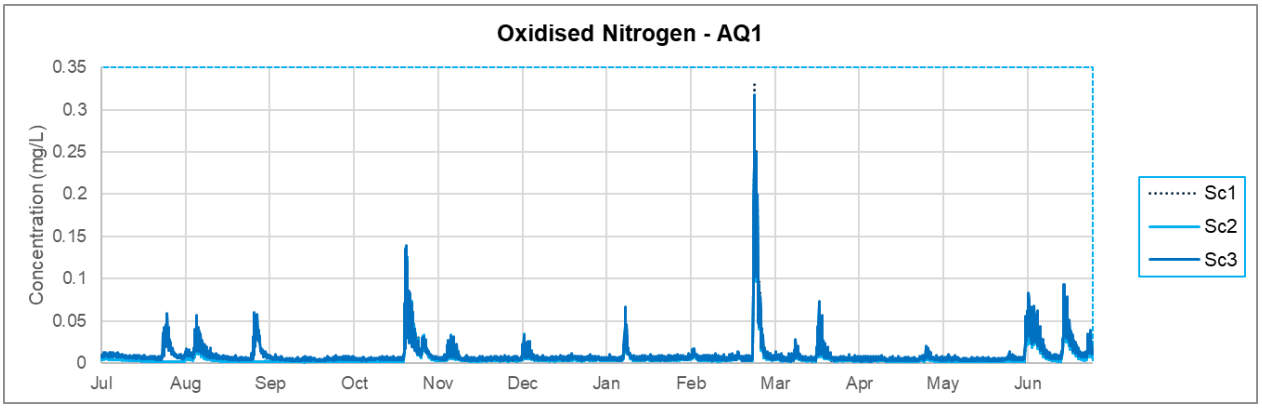
Appendices D3.5.1 Lower rainfall year scenario results (2017-2018)

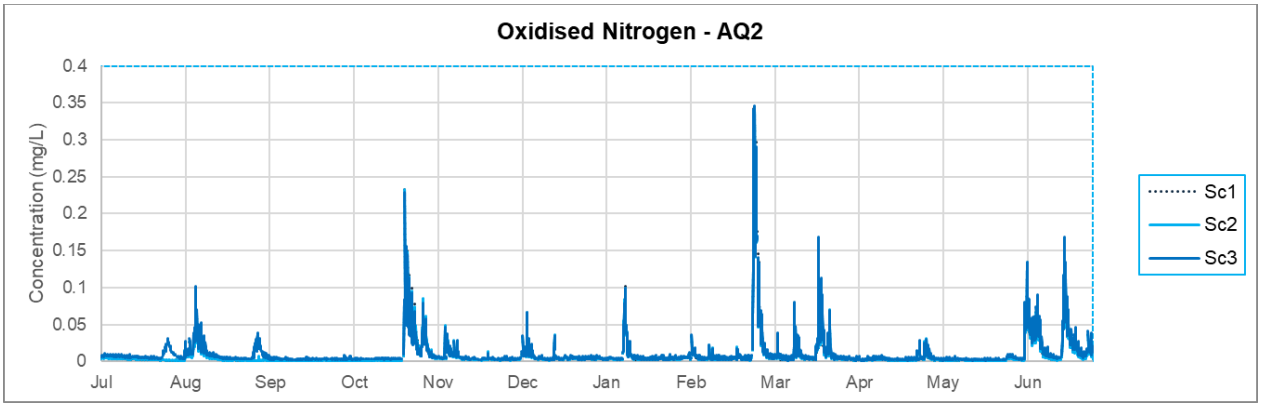
Bar charts

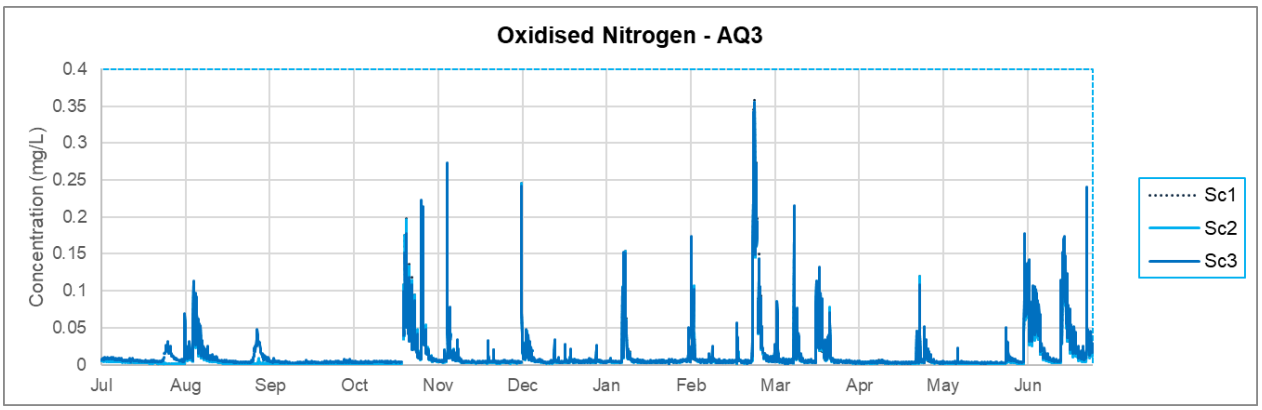


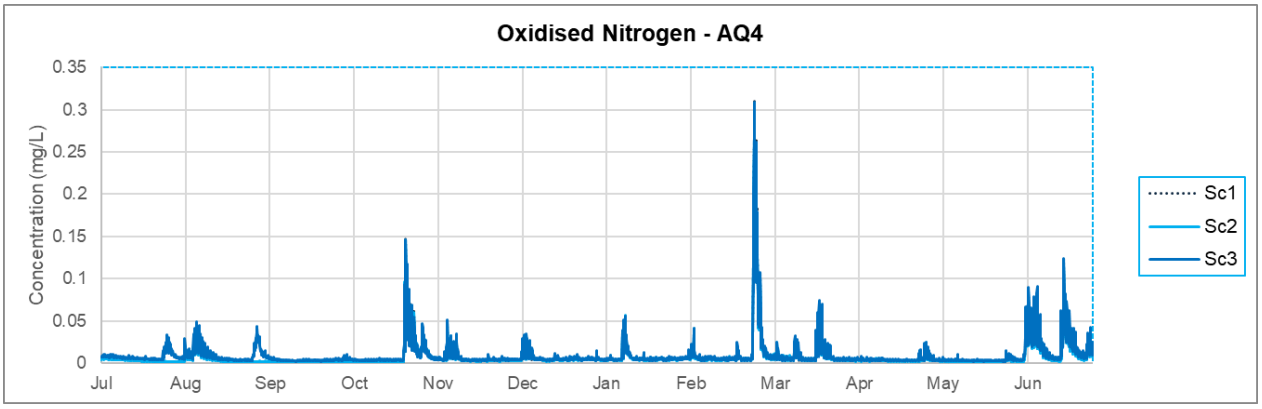


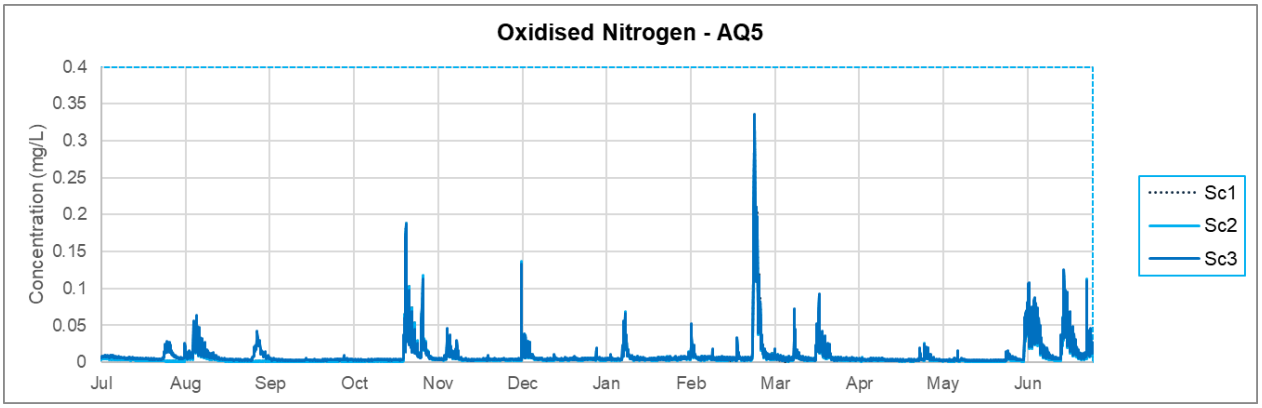
Time series plots

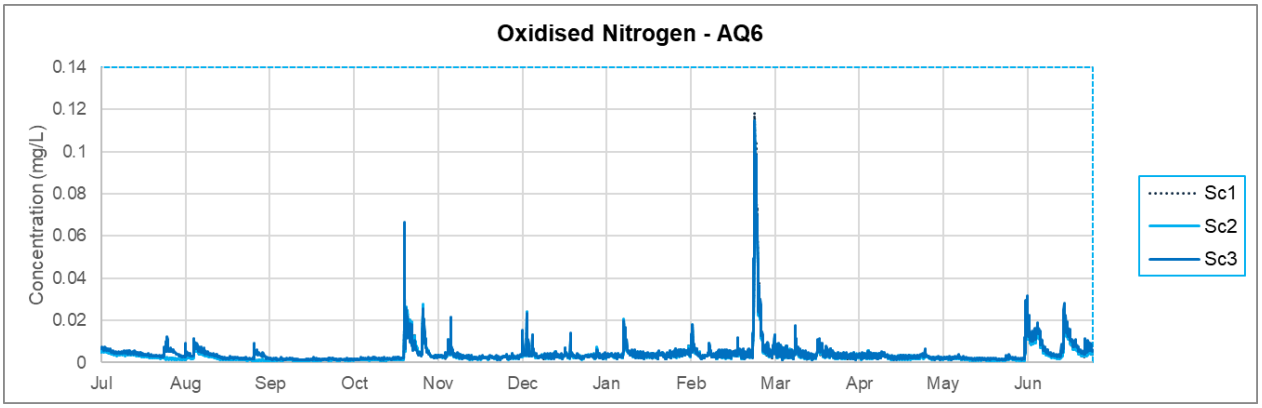






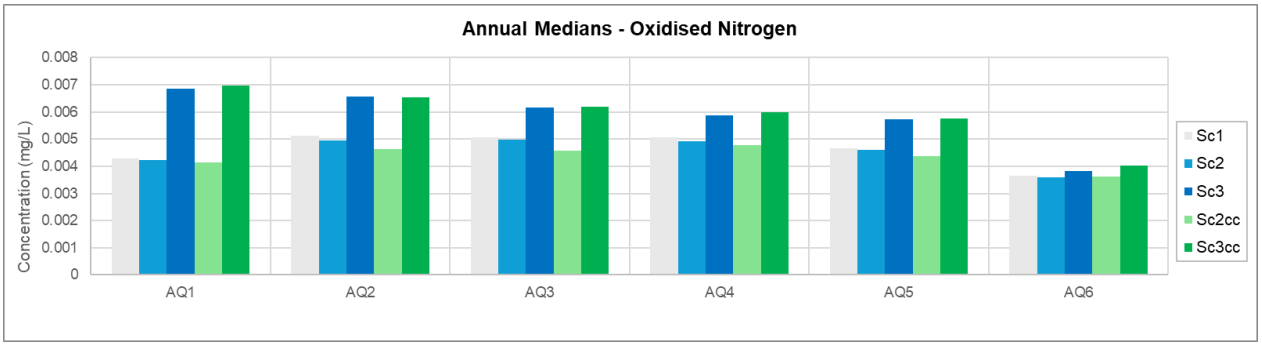


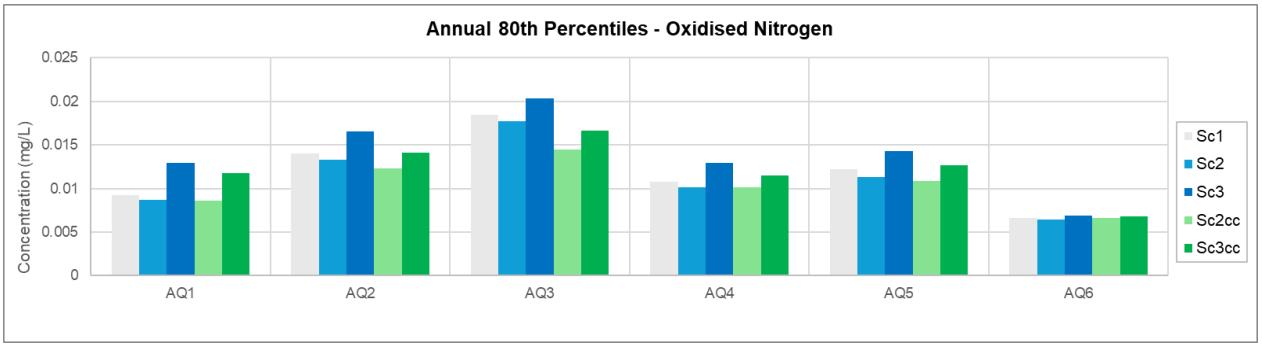




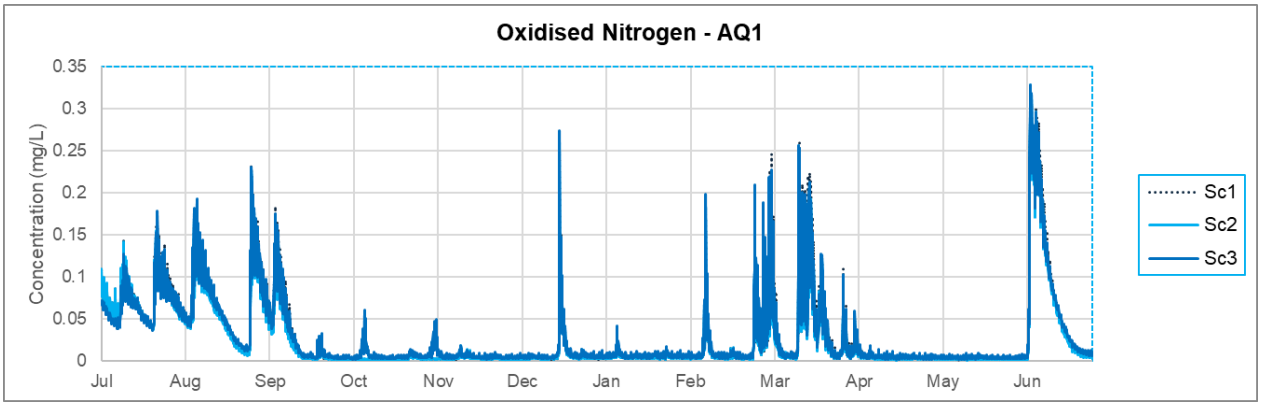
Appendices D3.5.2 Average rainfall year scenario results (2016-2017)

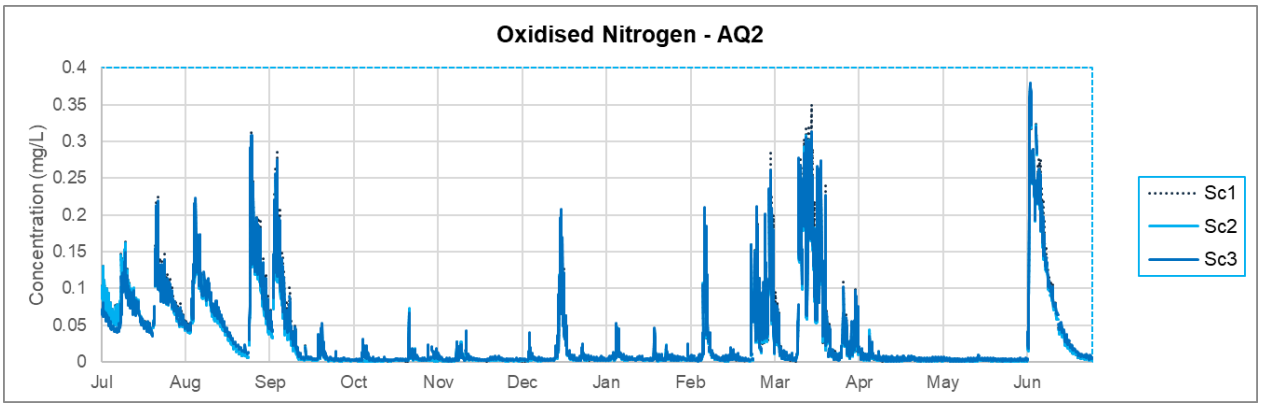
Bar charts

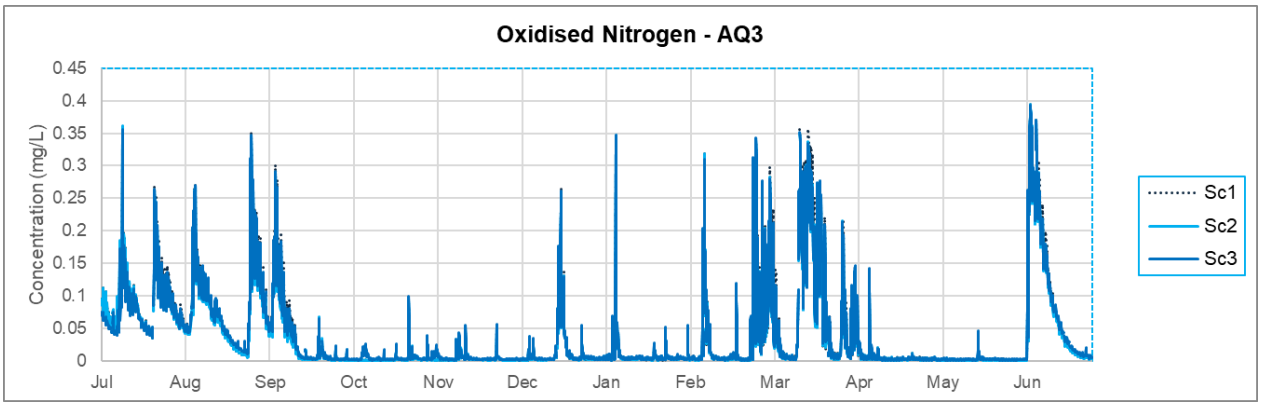


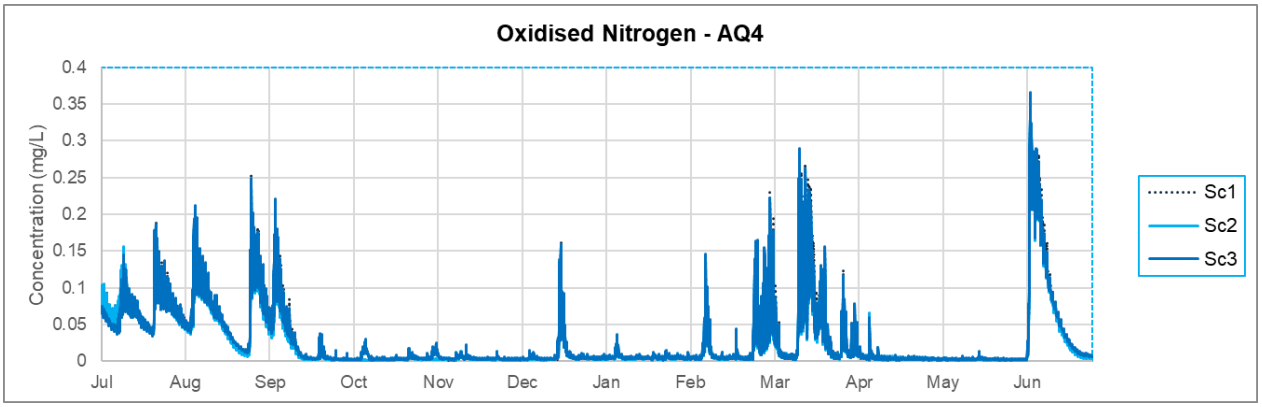


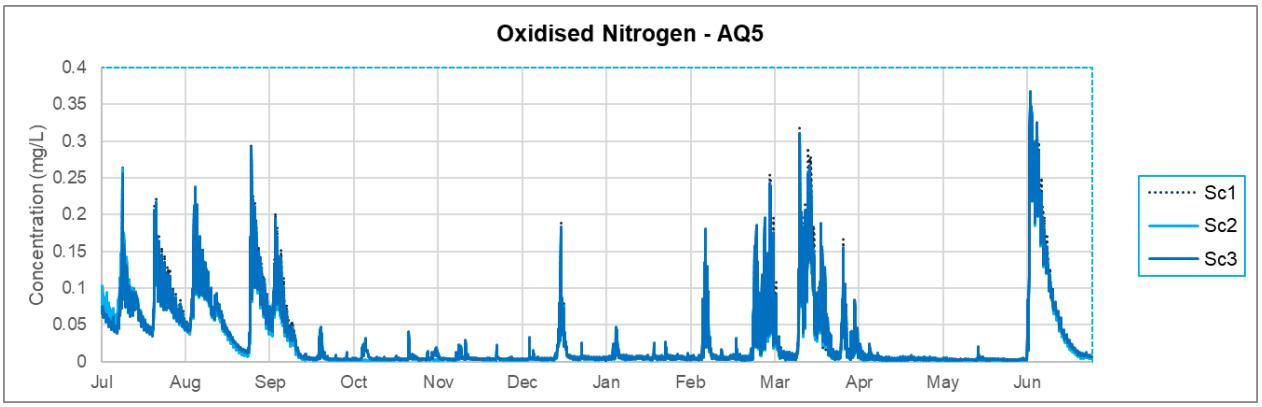
Time series plots

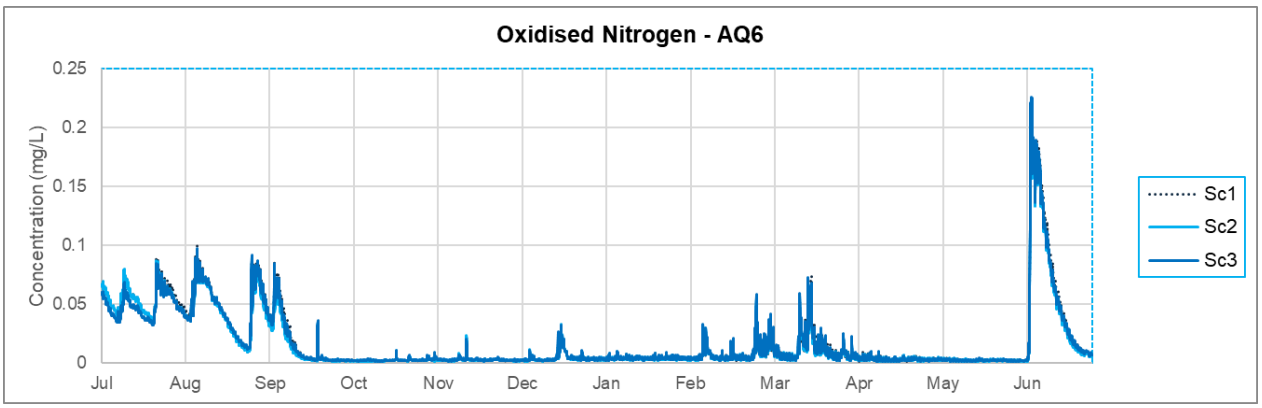






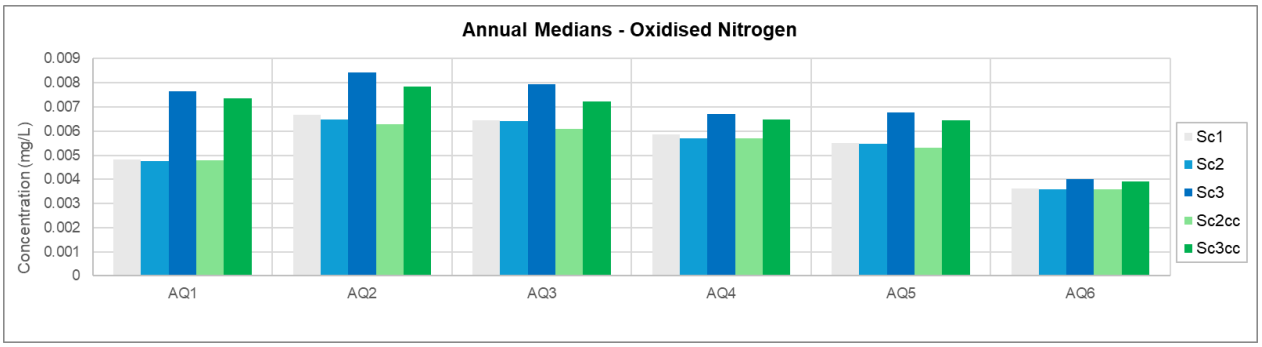


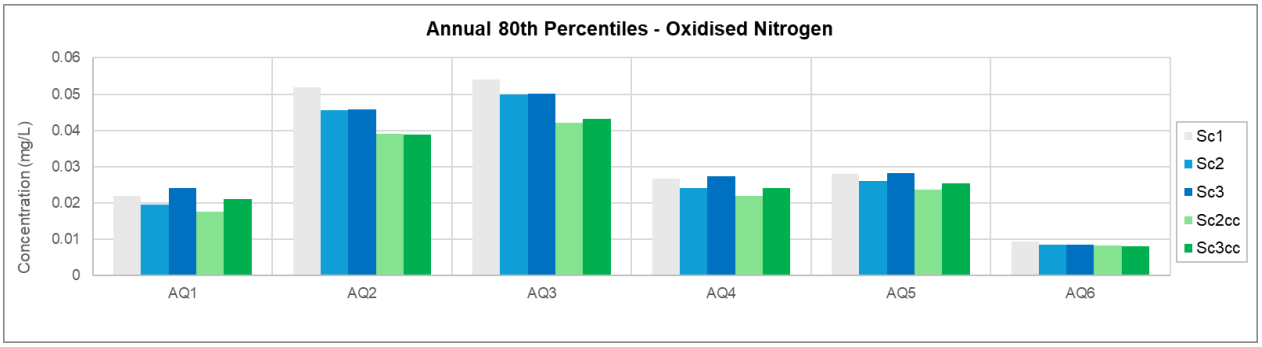




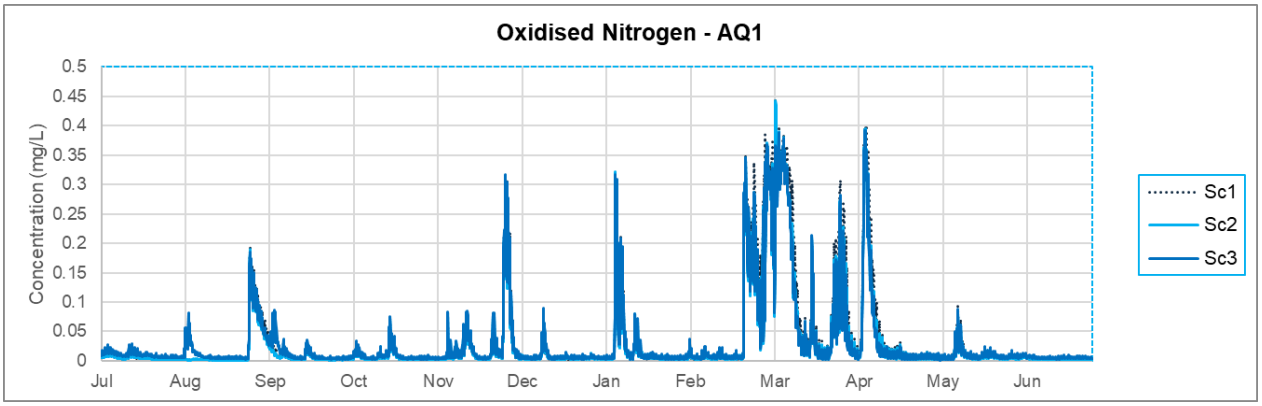
Appendices D3.5.3 Higher rainfall year scenario results (2021-2022)

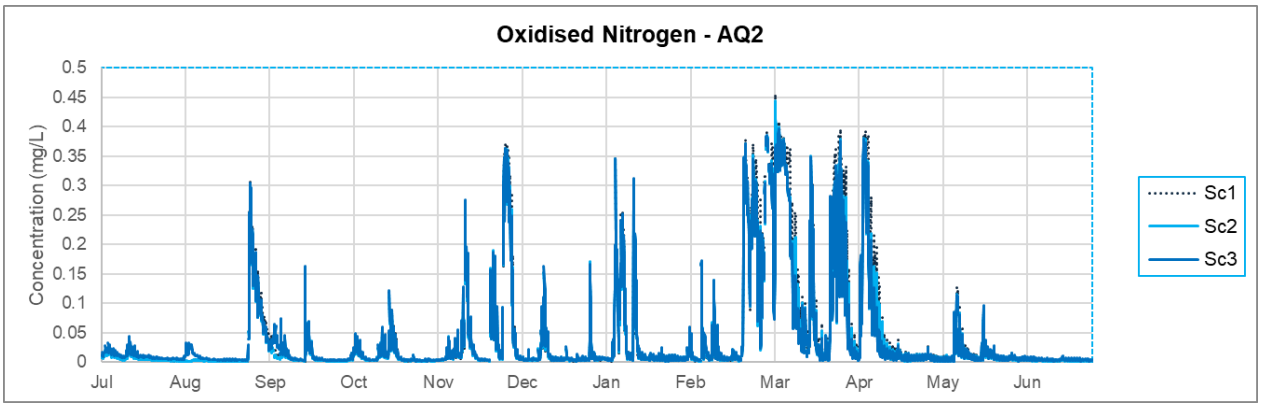
Bar charts

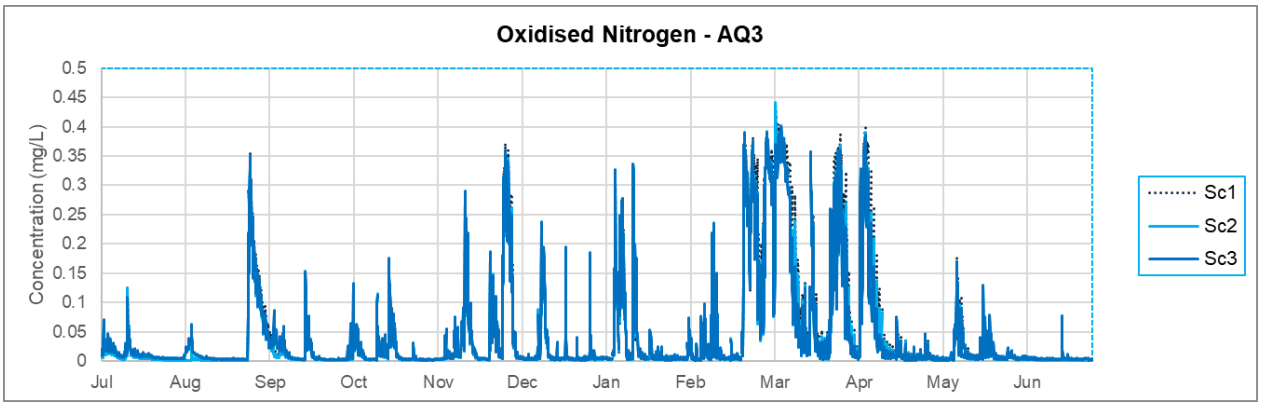


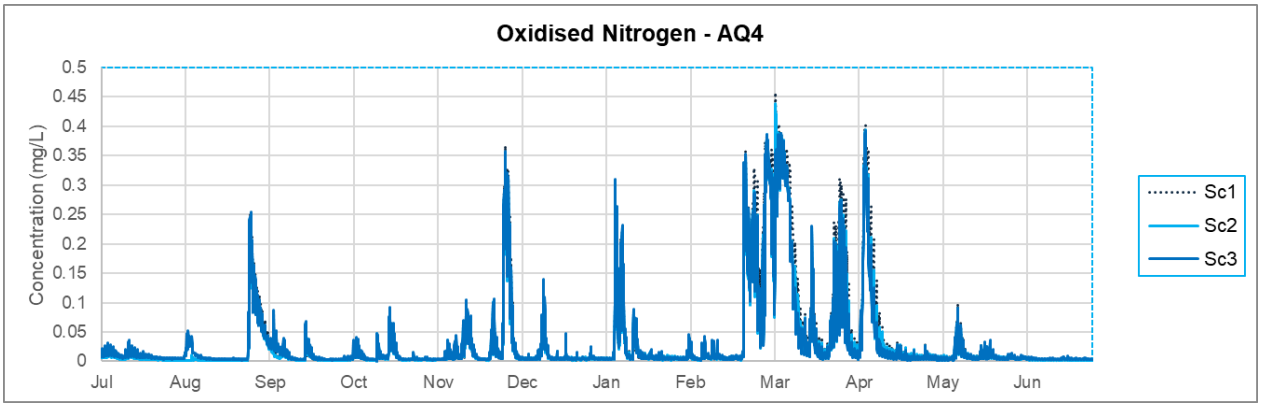


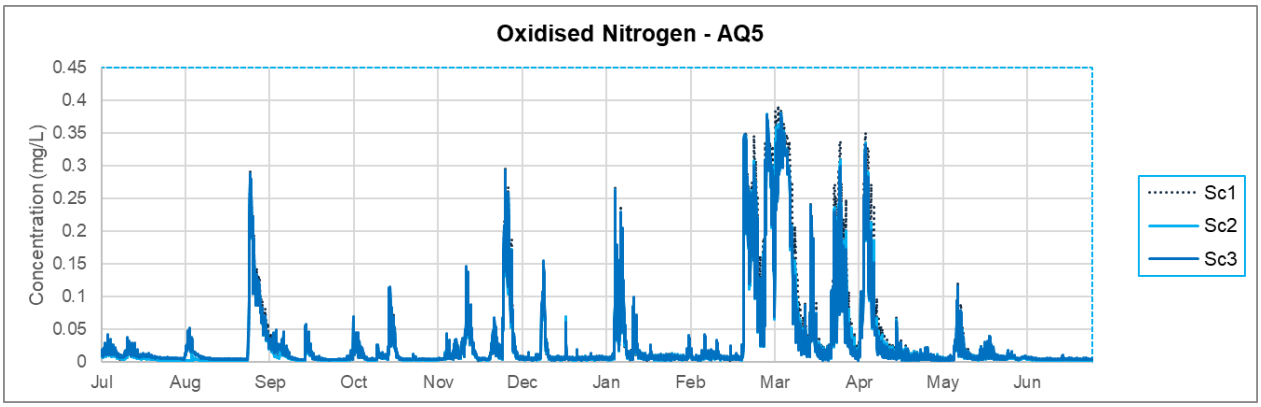
Time series plots








Oxidised Nitrogen - AQ4
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Oxidised Nitrogen - AQ5
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
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Jul
Aug
Sep
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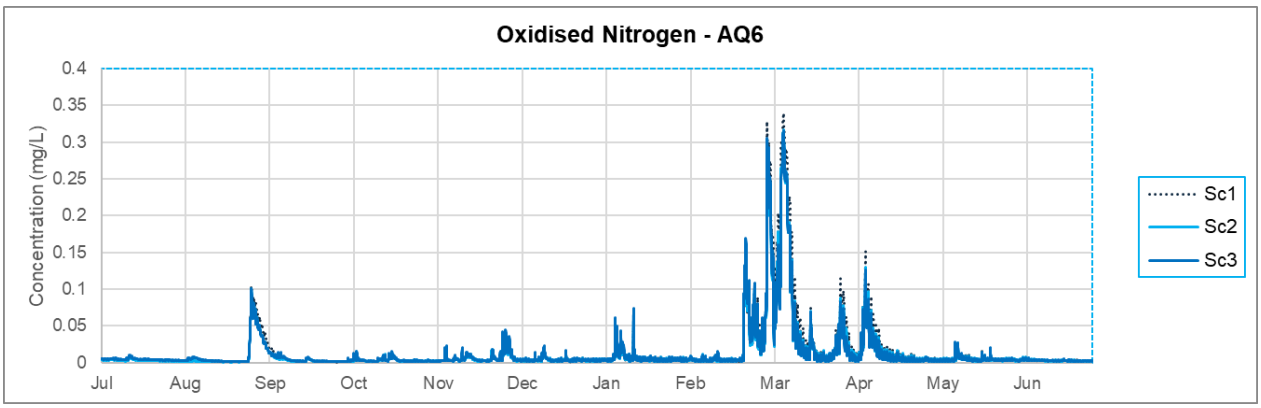
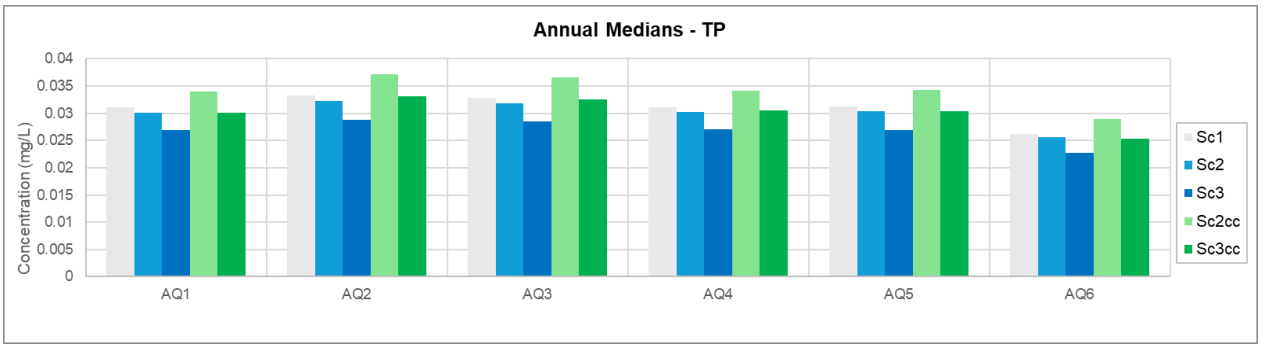
Jun
Sc1
Sc2
Sc3

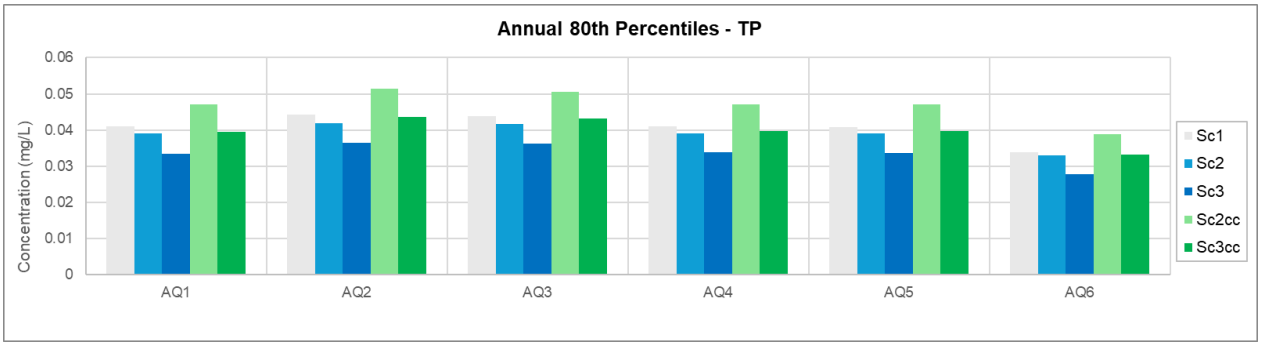

Oxidised Nitrogen - AQ6
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D3.6 Total P

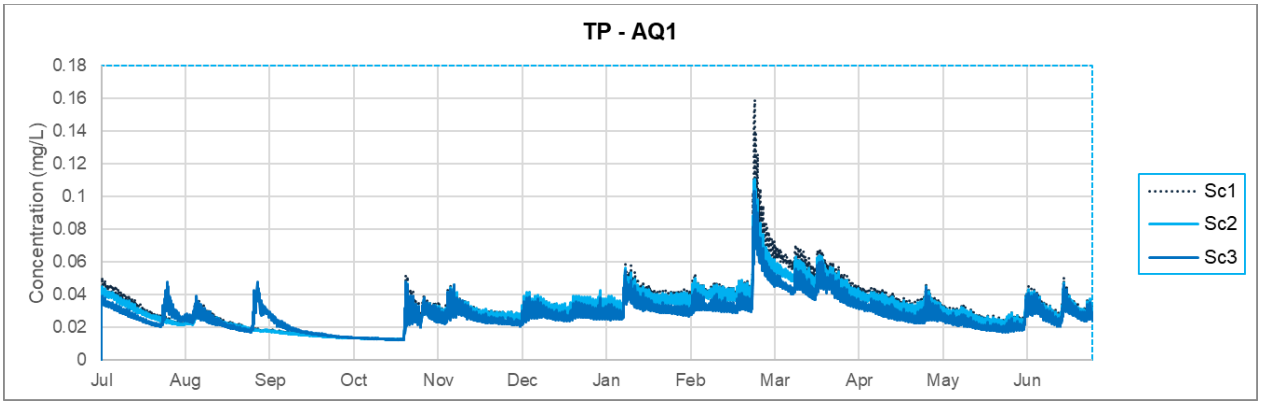
Appendices D3.6.1 Lower rainfall year scenario results (2017-2018)

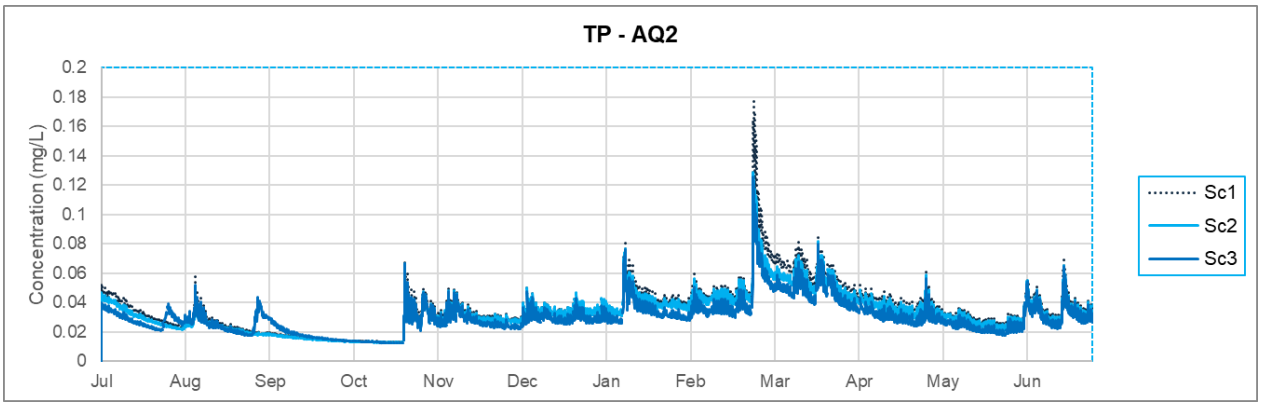
Bar charts

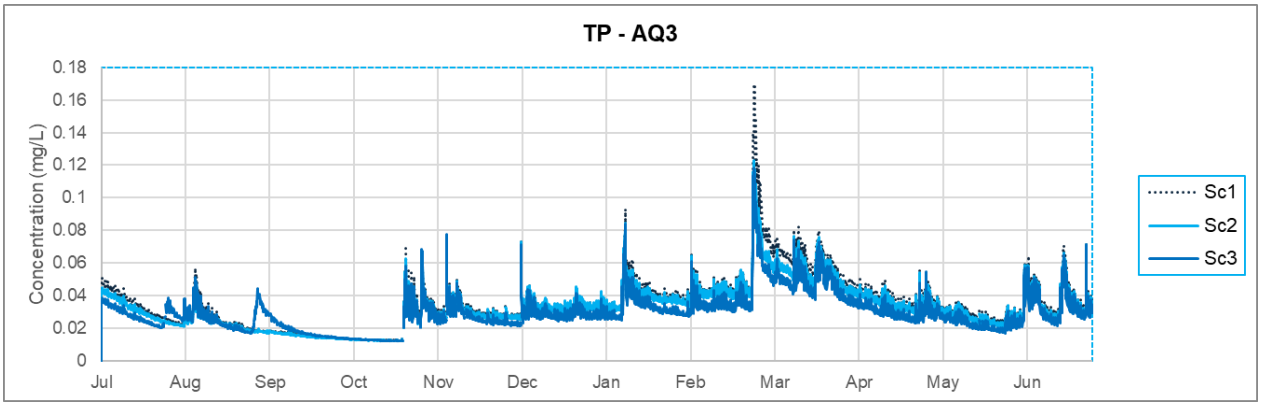


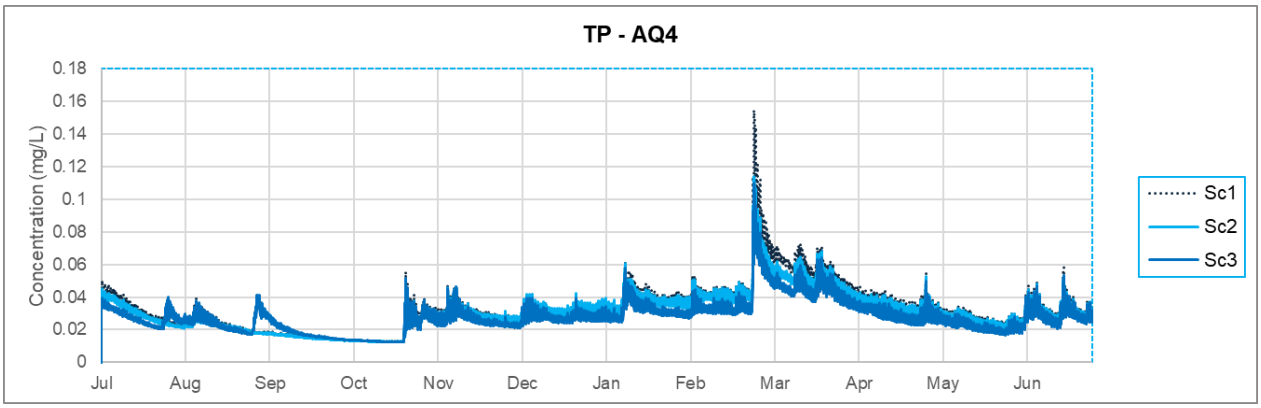


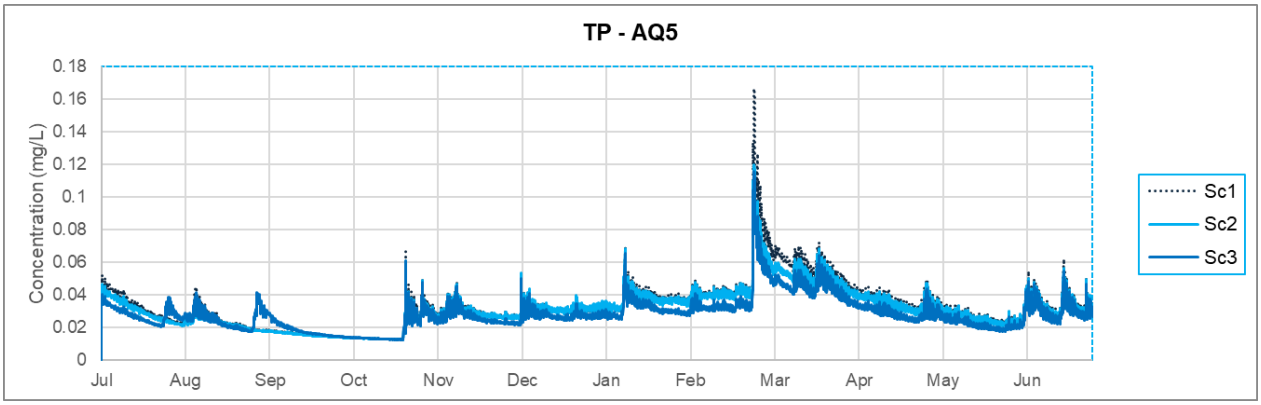
Time series plots

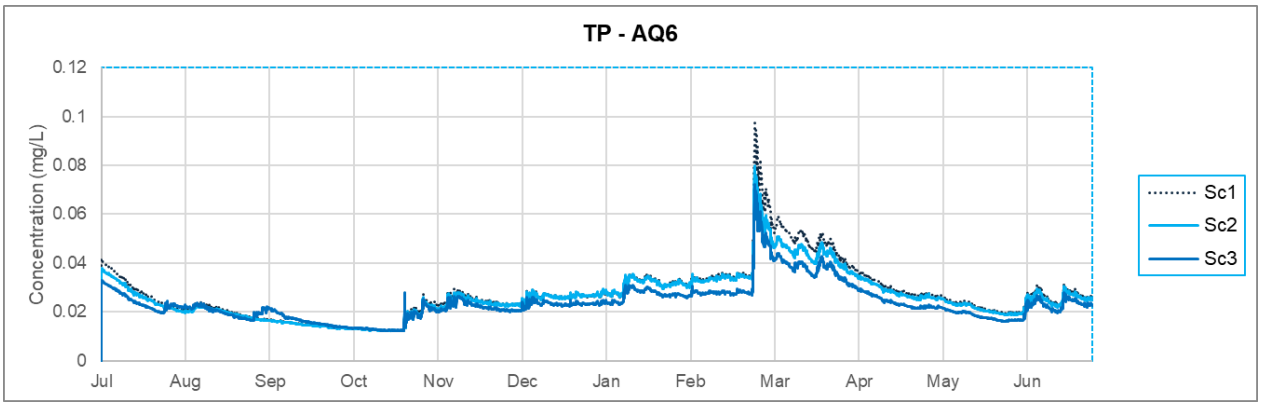



TP - AQ2
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TP - AQ3
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

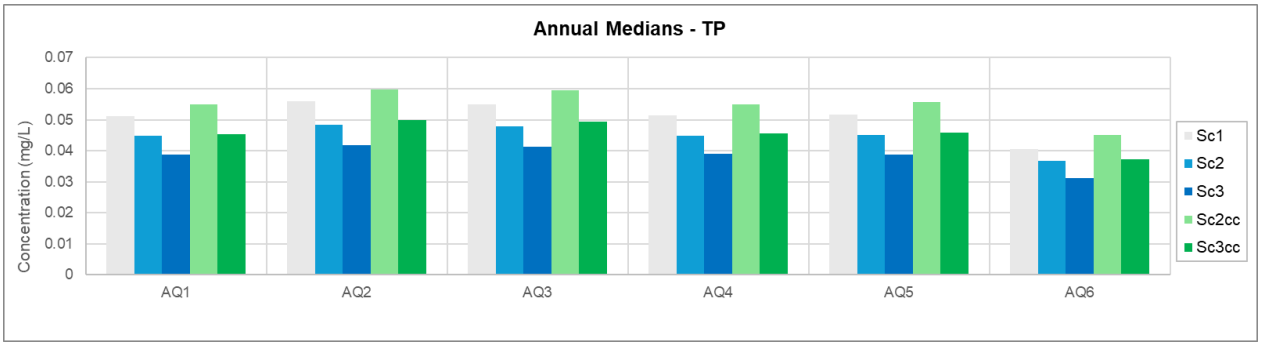

TP - AQ4
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

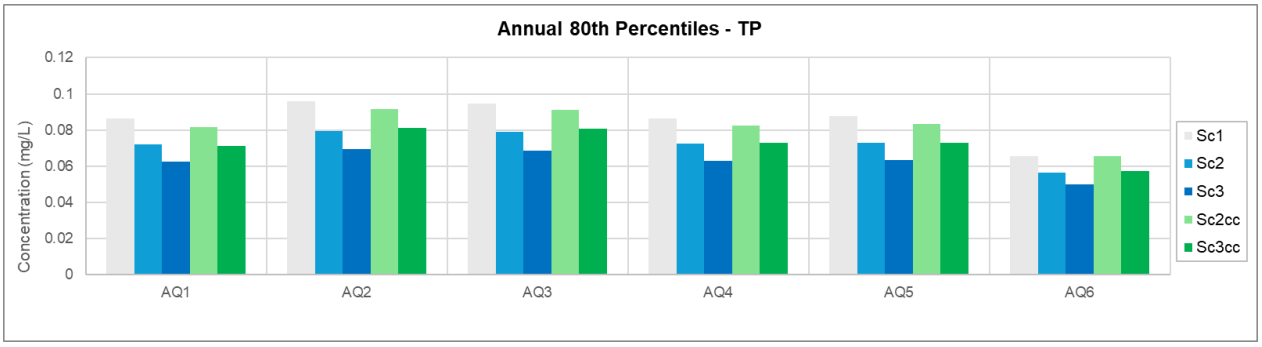

TP - AQ5
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3



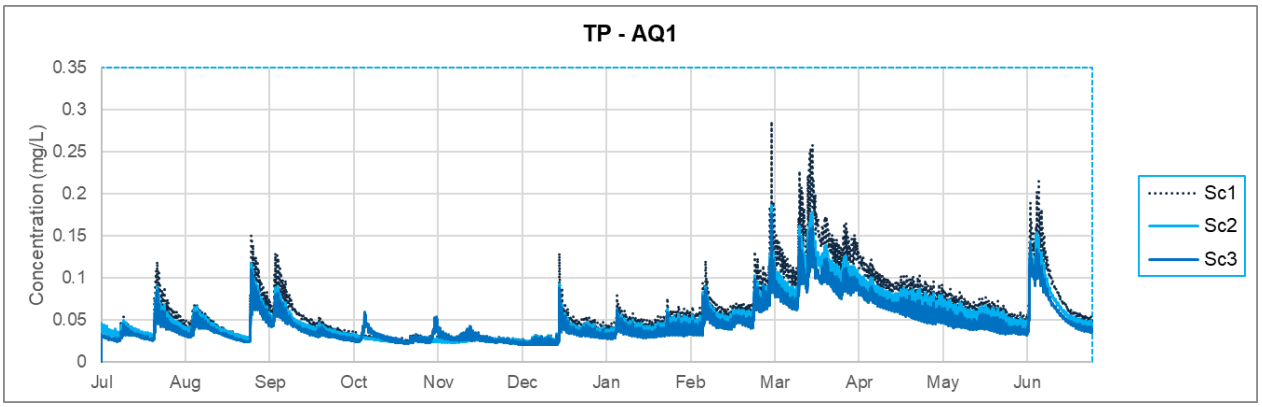
Appendices D3.6.2 Average rainfall year scenario results (2016-2017)

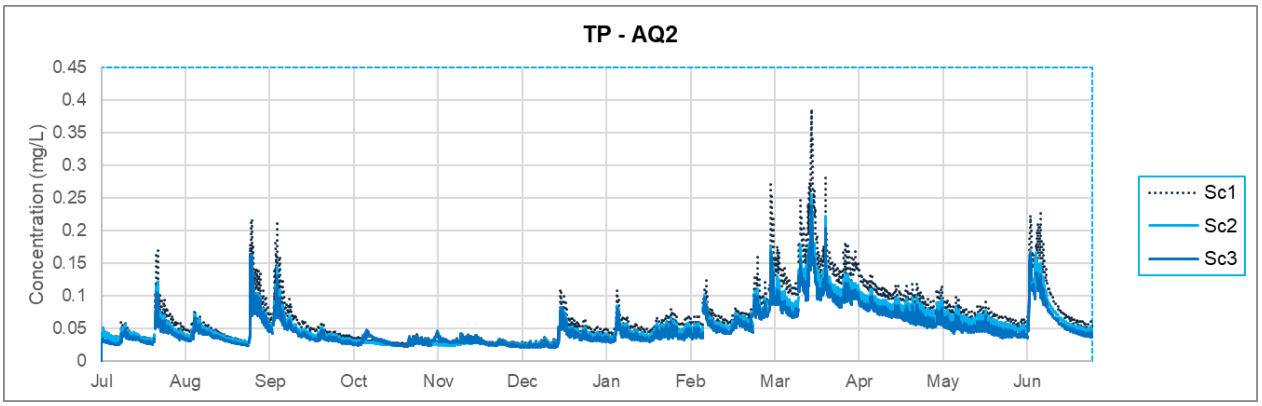
Bar charts

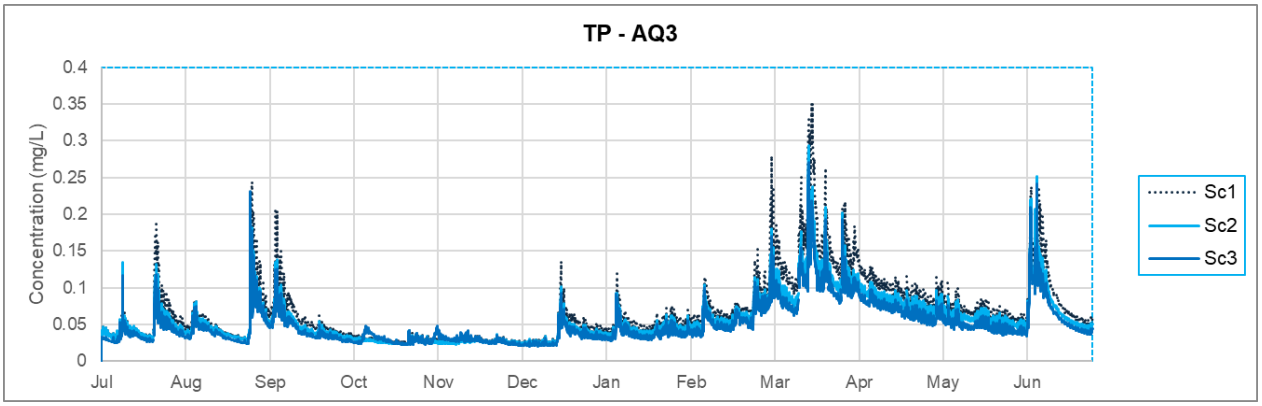


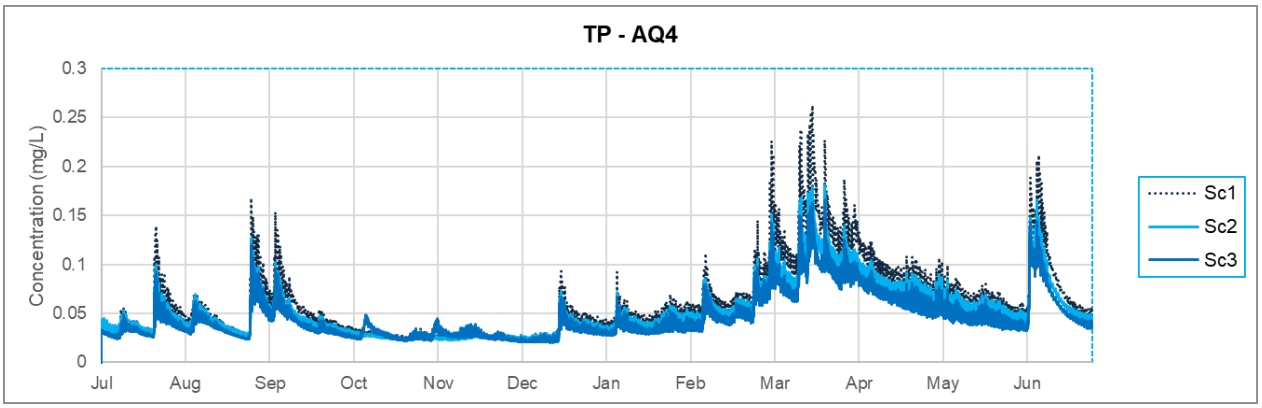


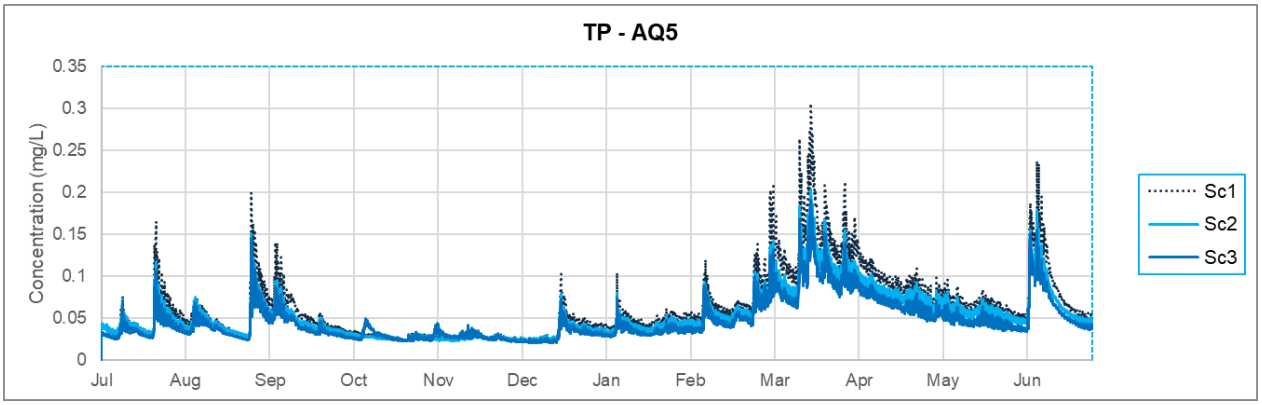
Time series plots

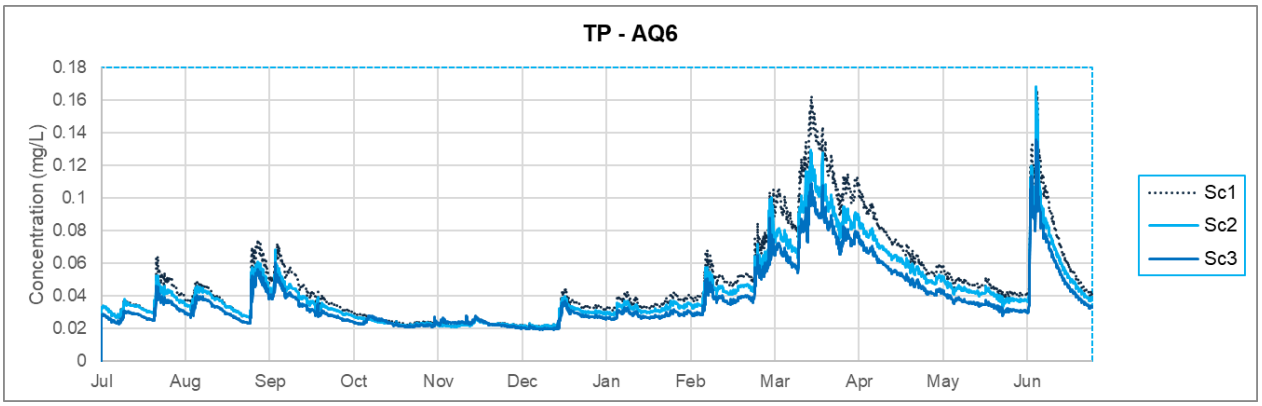



TP - AQ2
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TP - AQ3
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

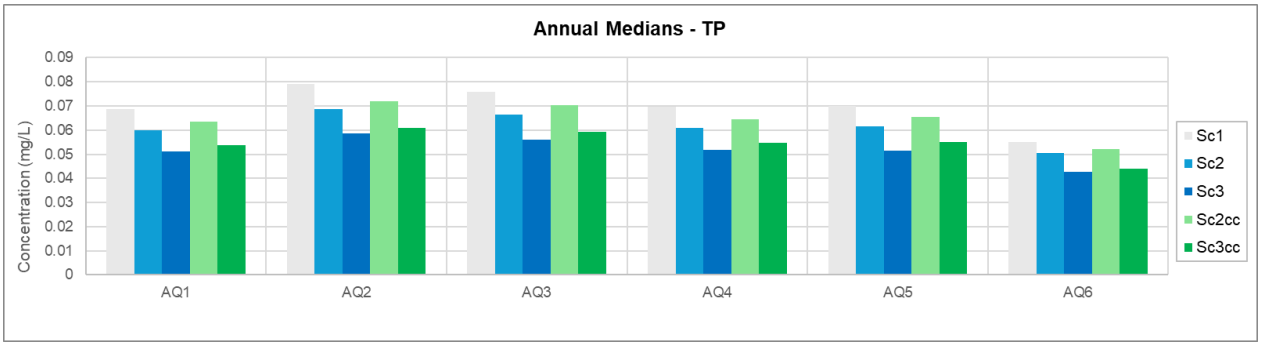

TP - AQ4
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

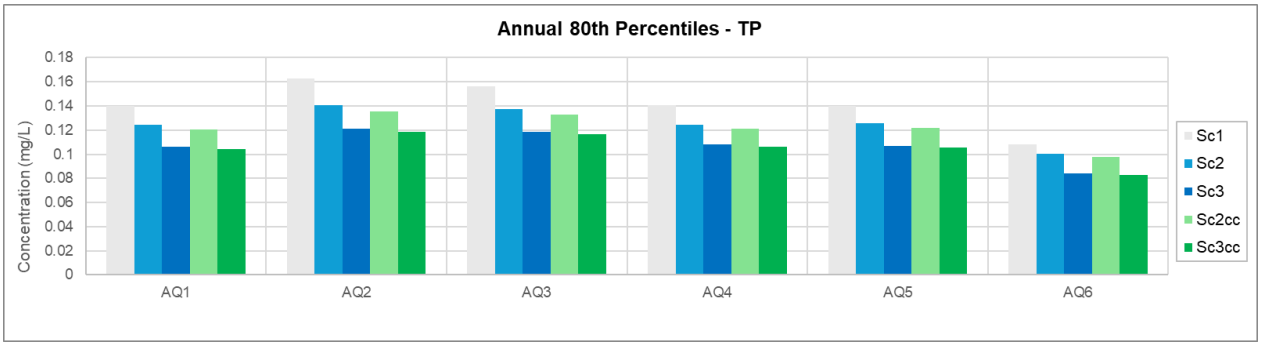

TP - AQ5
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3



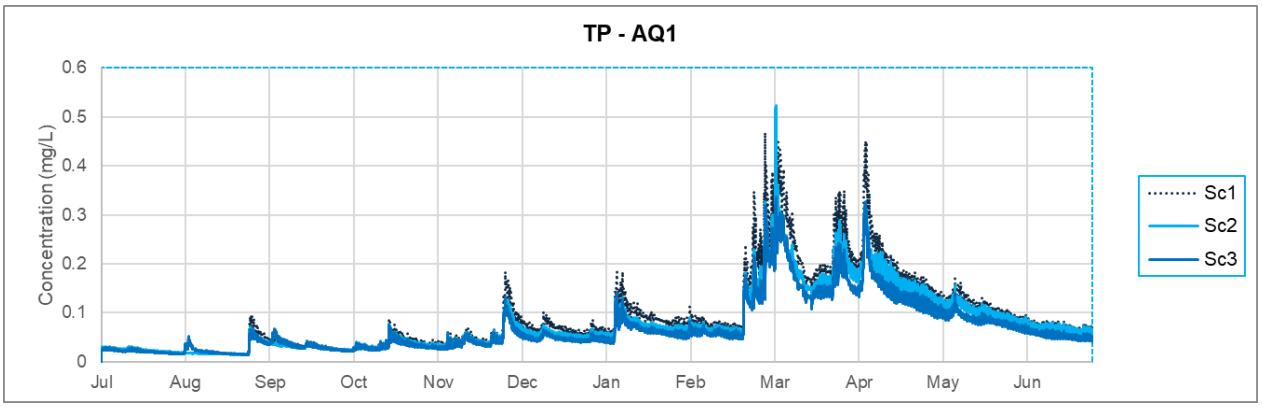
Appendices D3.6.3 Higher rainfall year scenario results (2021-2022)

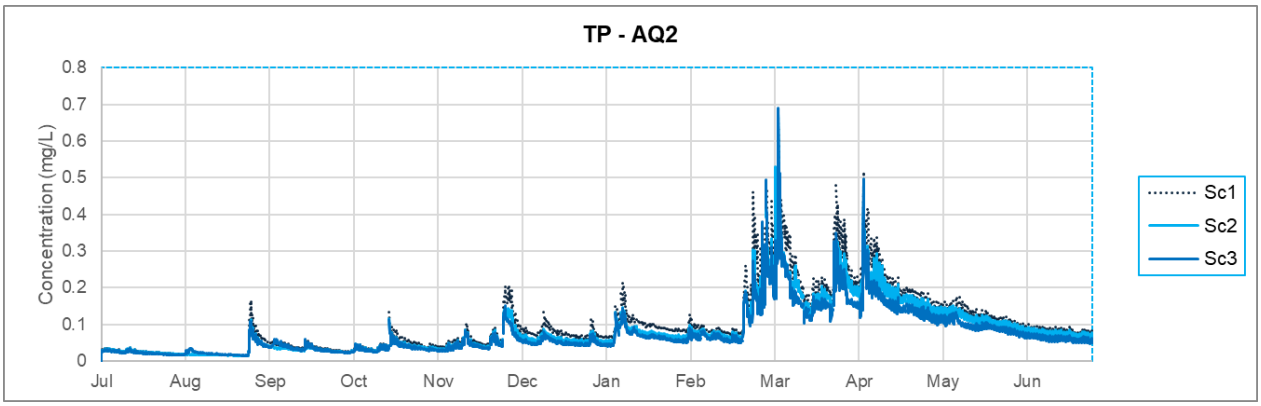
Bar charts

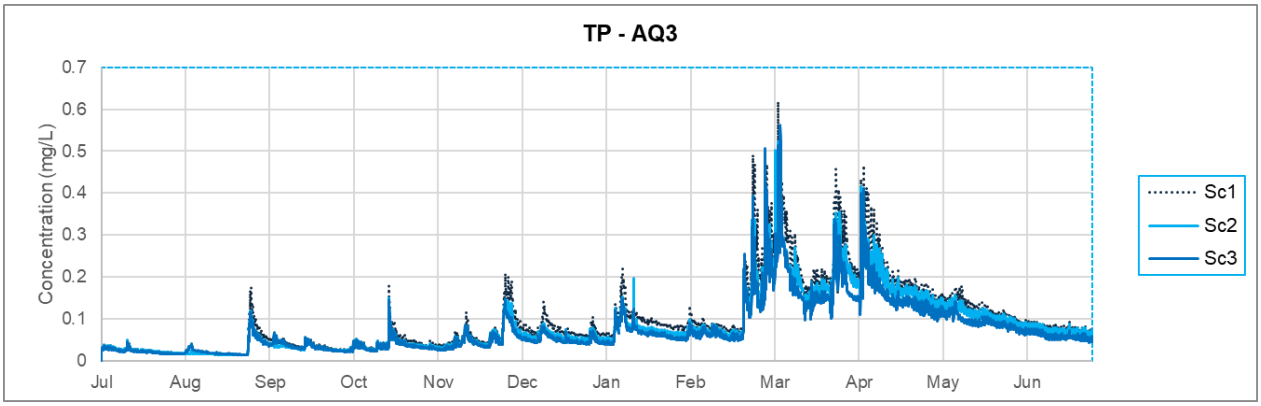


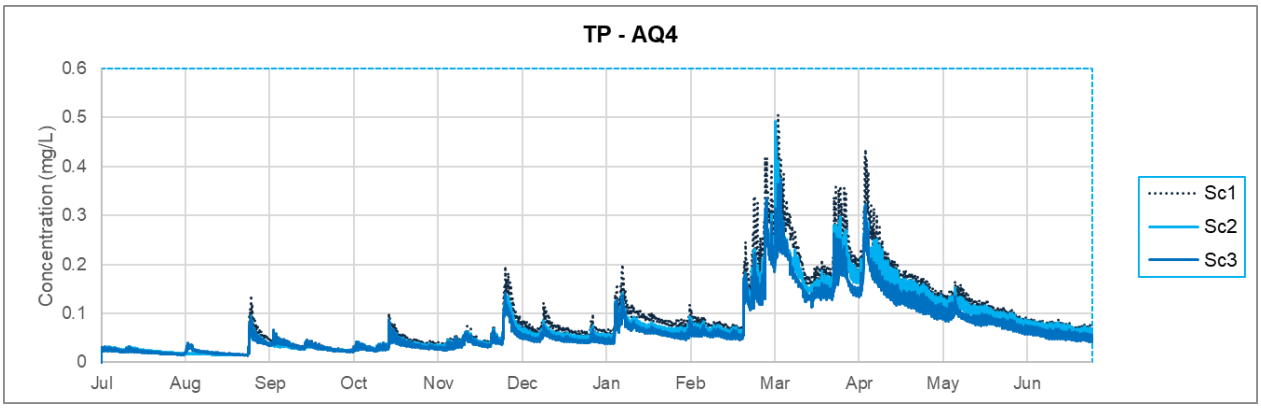


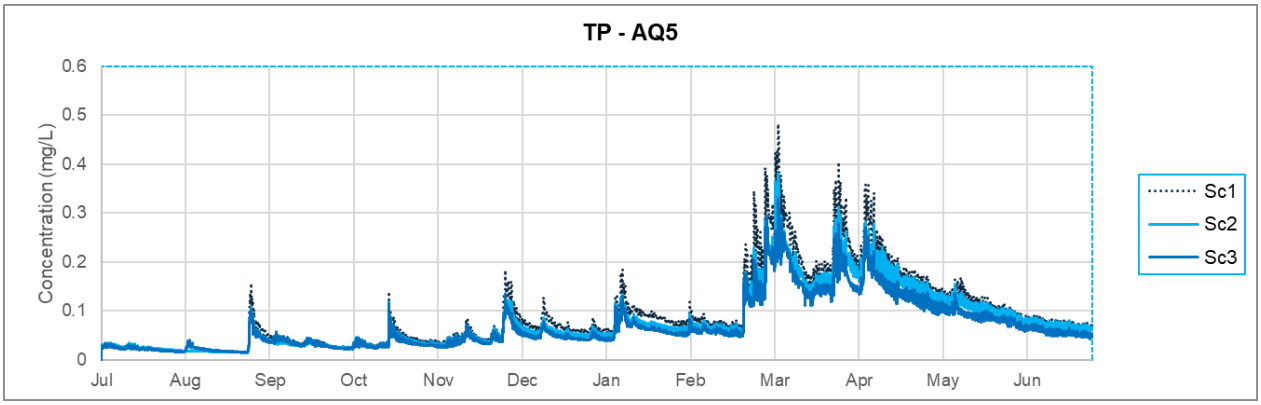
Time series plots

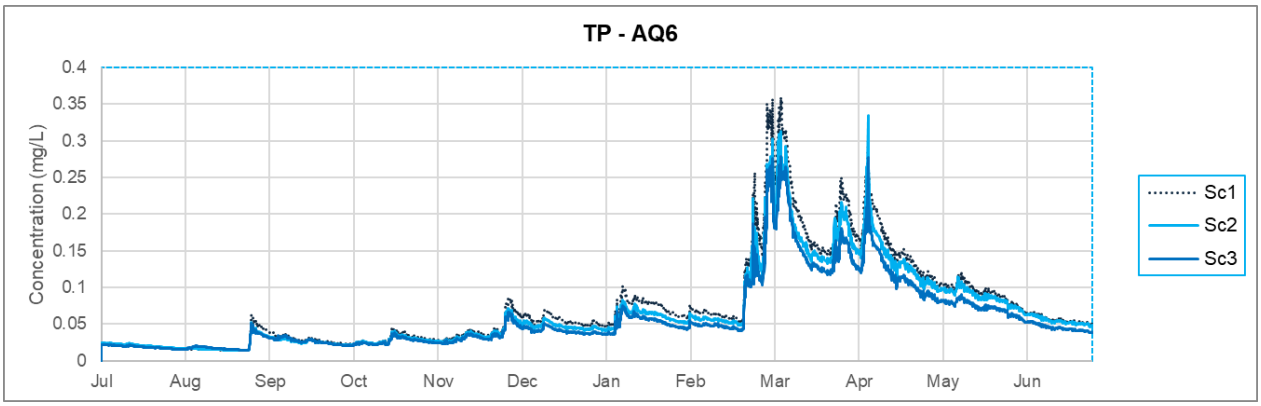



TP - AQ2
Concentration (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TP - AQ3
Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TP - AQ4
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

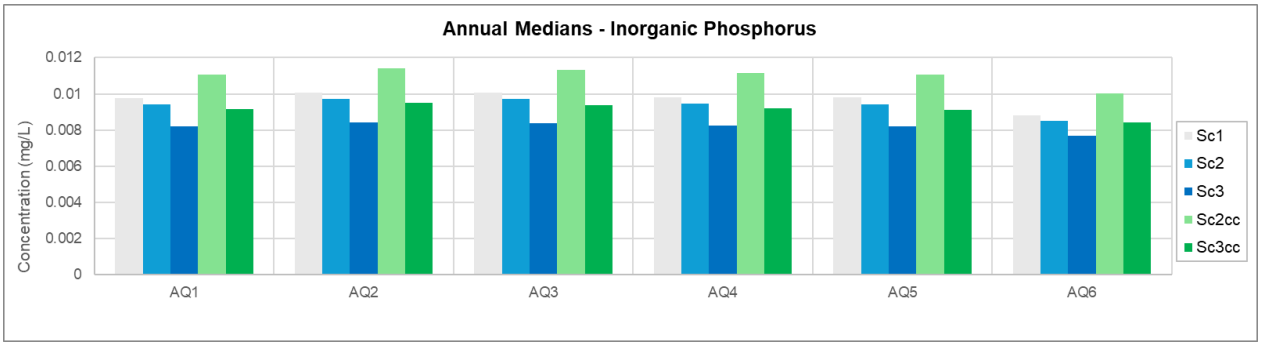

TP - AQ5
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

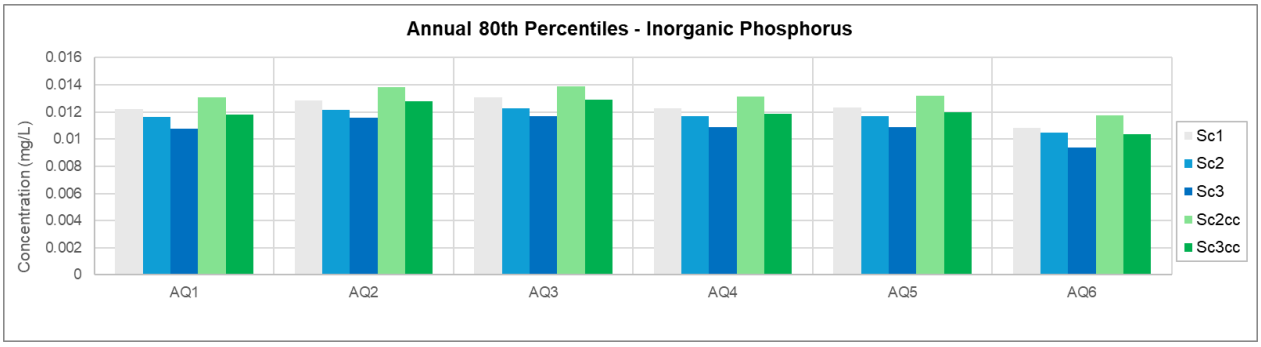


Appendices D3.7 Inorganic P

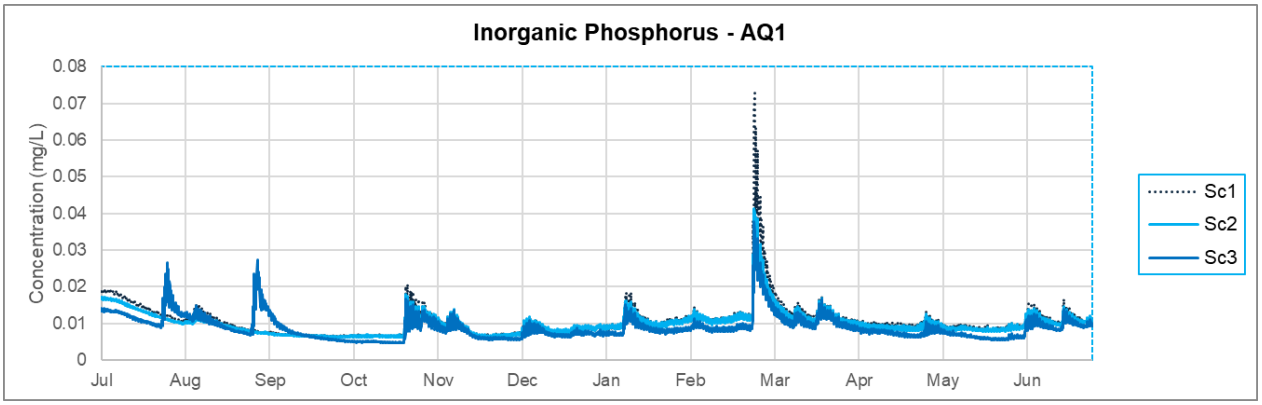
Appendices D3.7.1 Lower rainfall year scenario results (2017-2018)

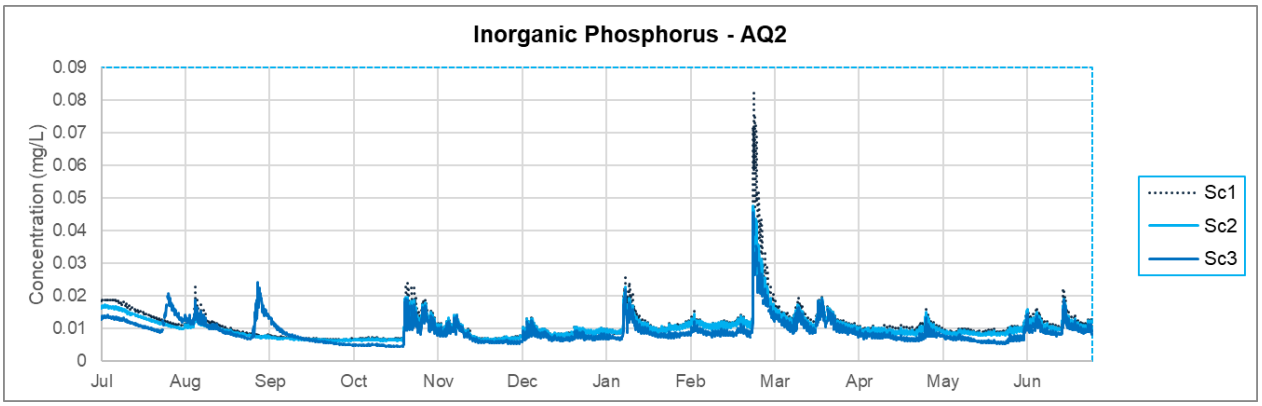
Bar charts

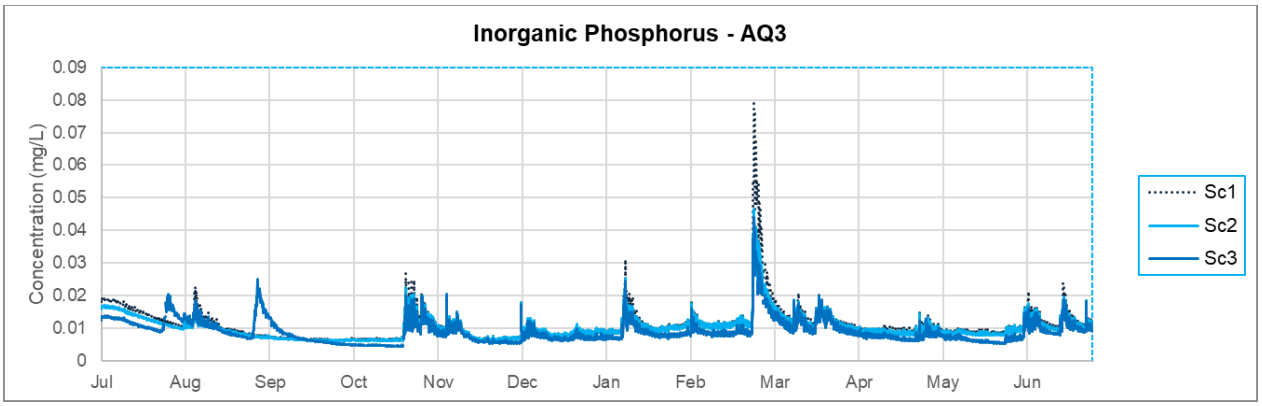


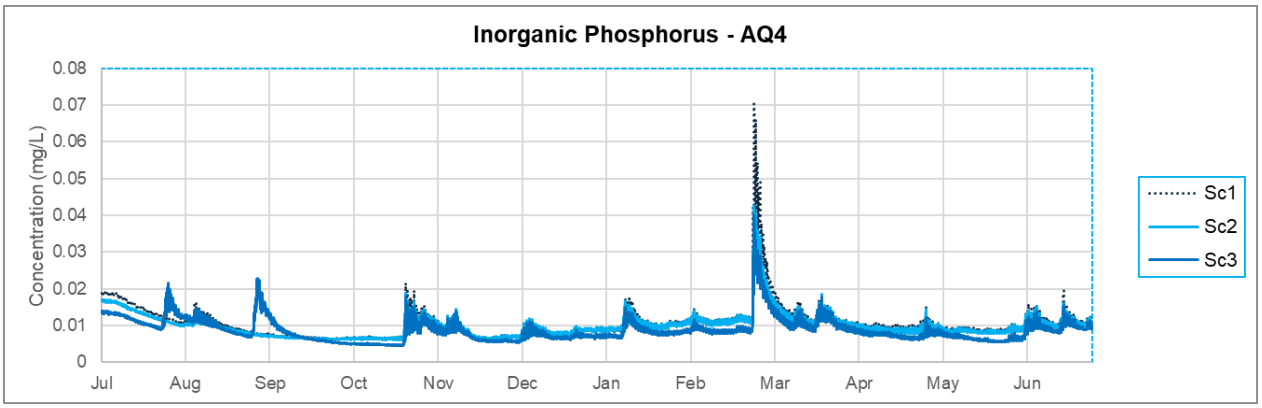


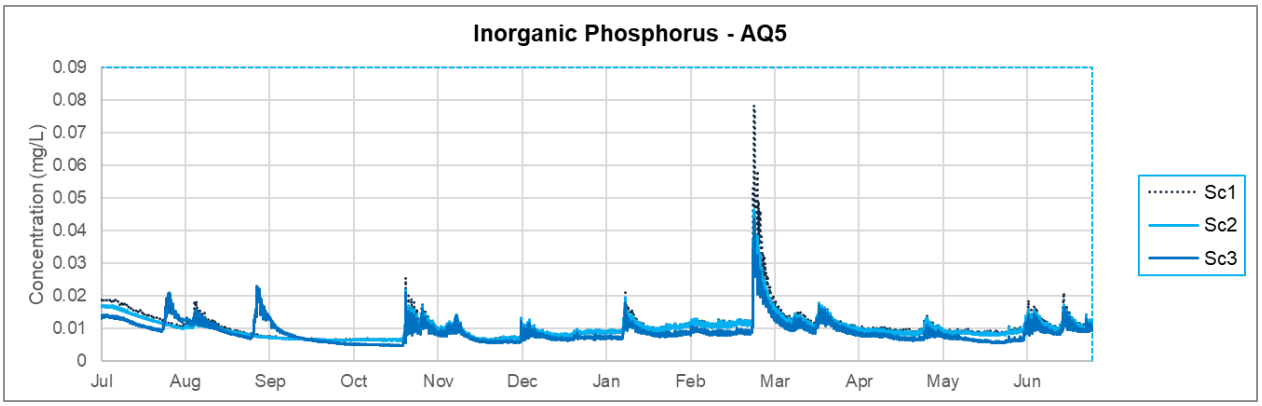
Time series plots

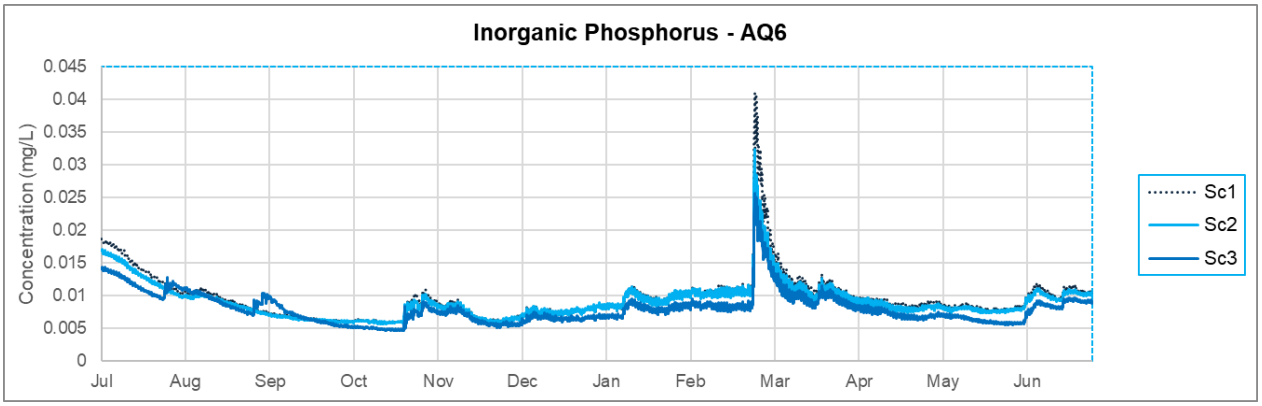






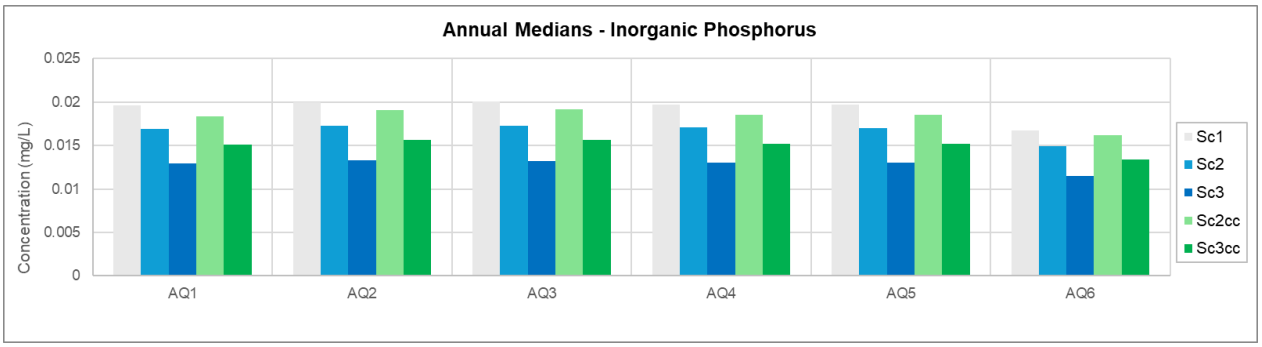


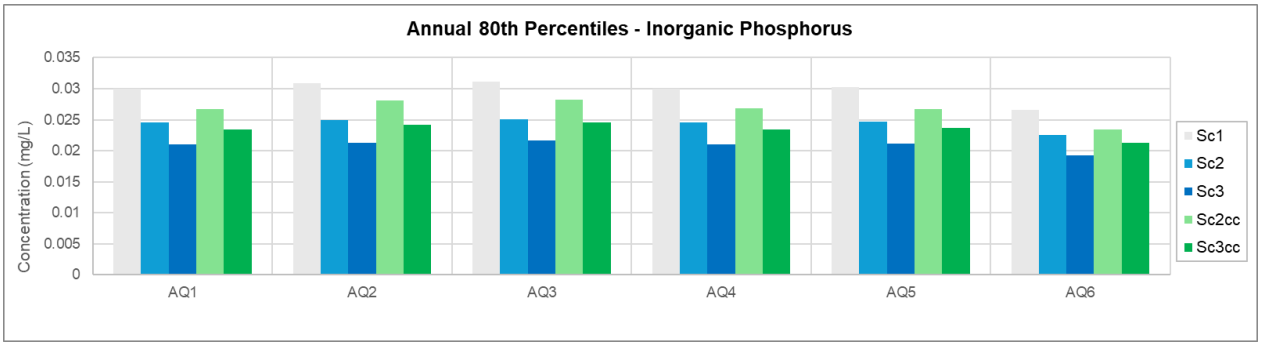




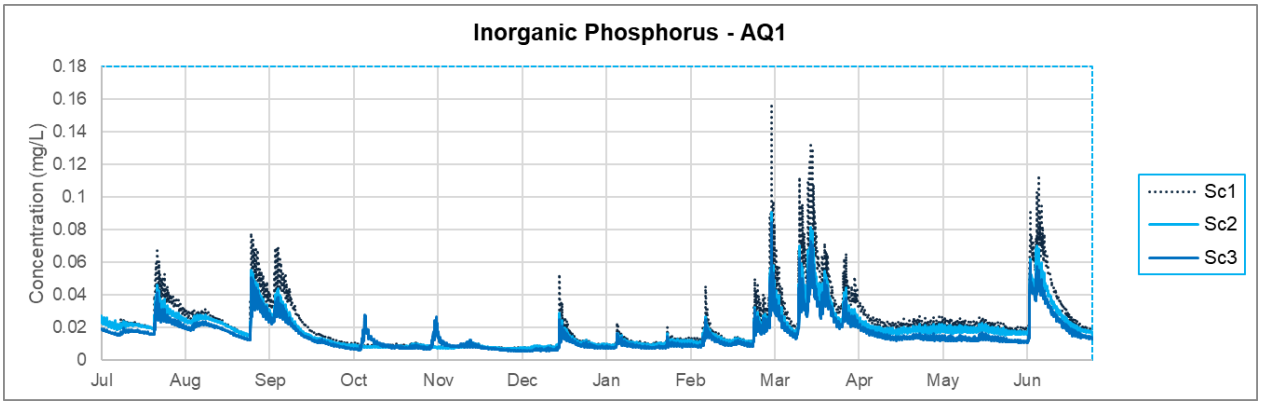
Appendices D3.7.2 Average rainfall year scenario results (2016-2017)

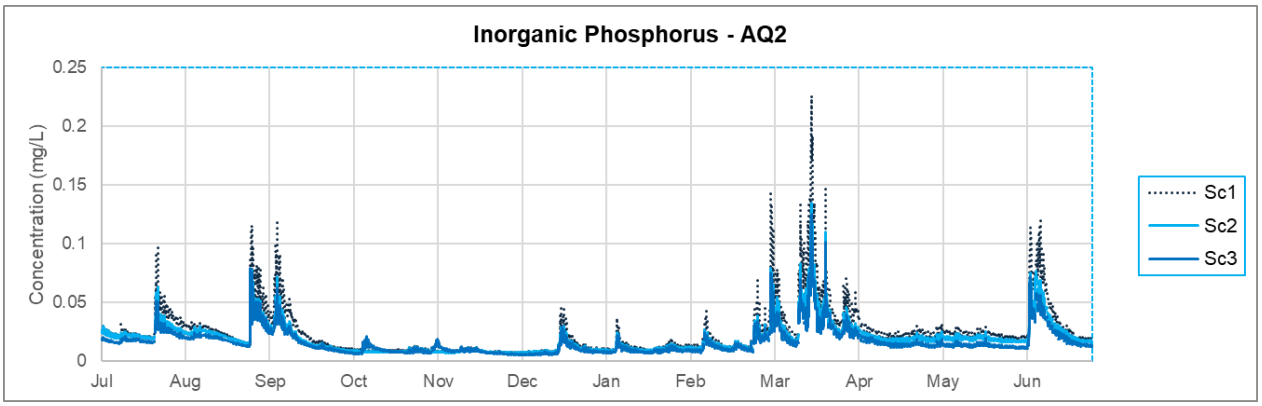
Bar charts

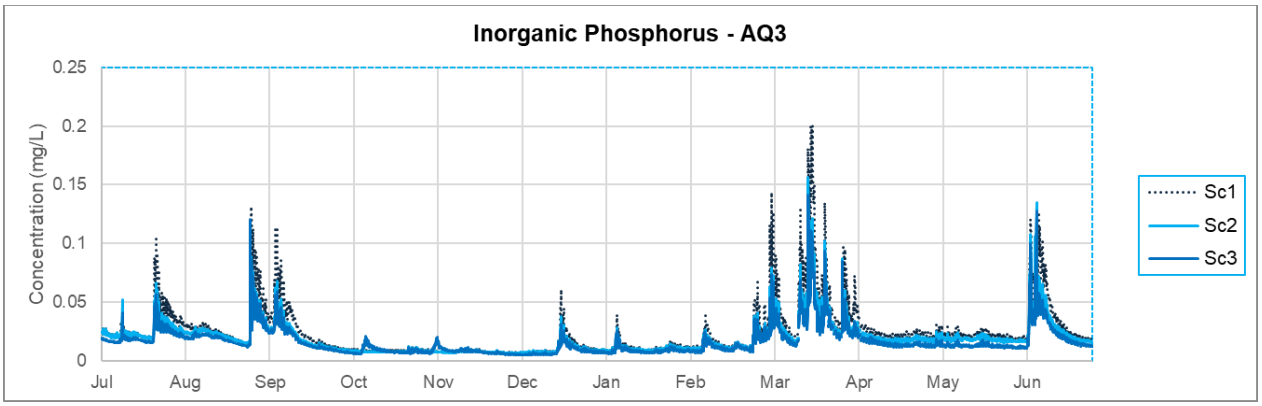


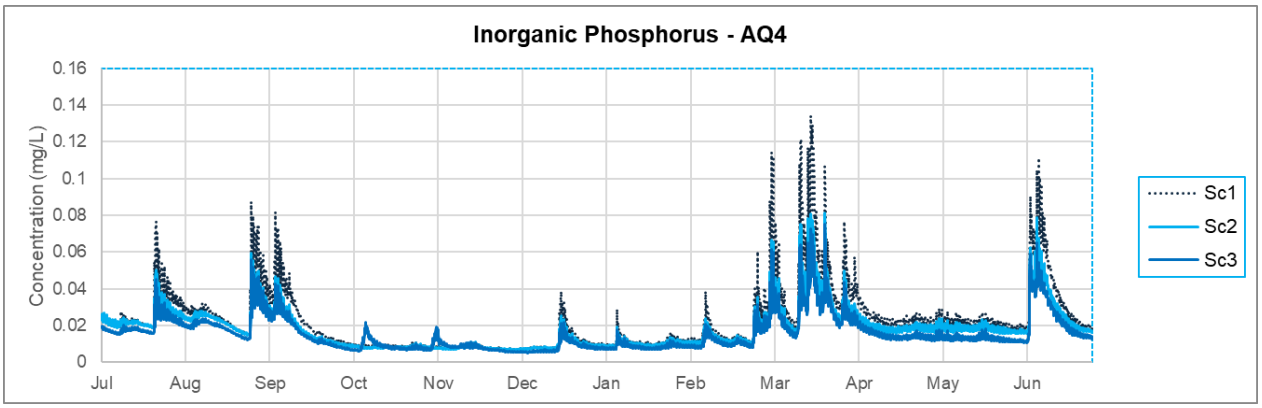


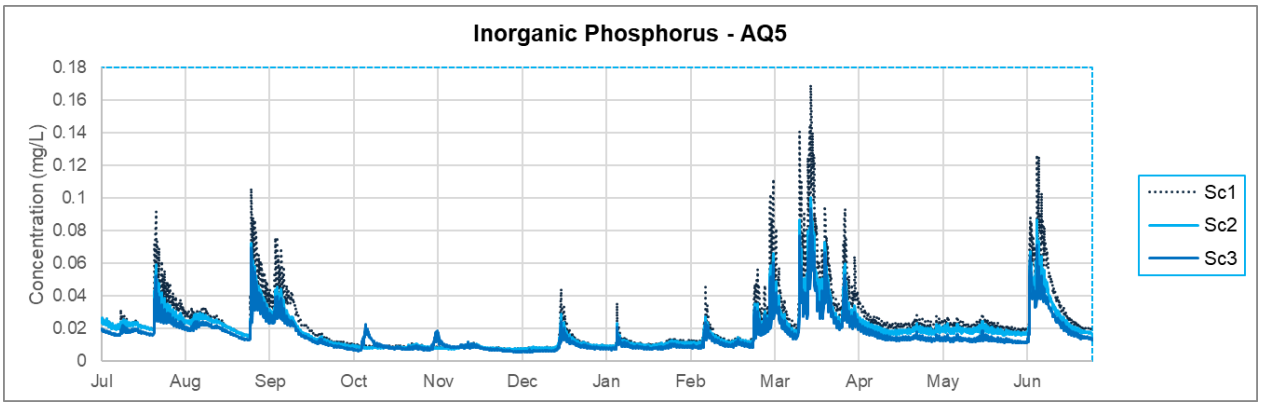
Time series plots

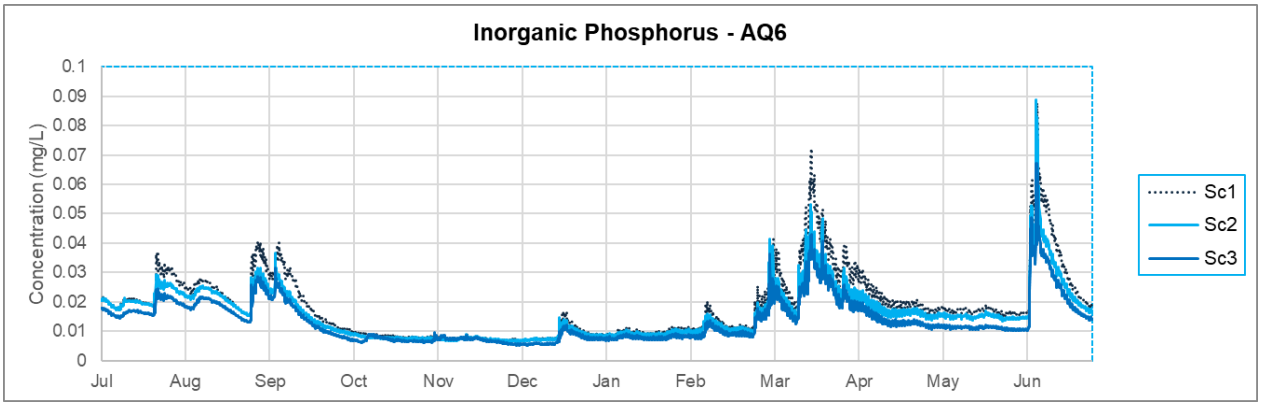






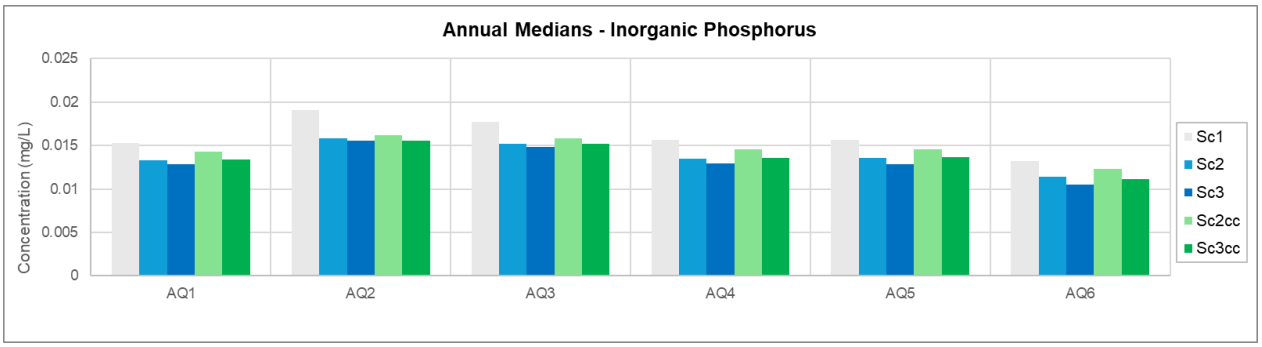


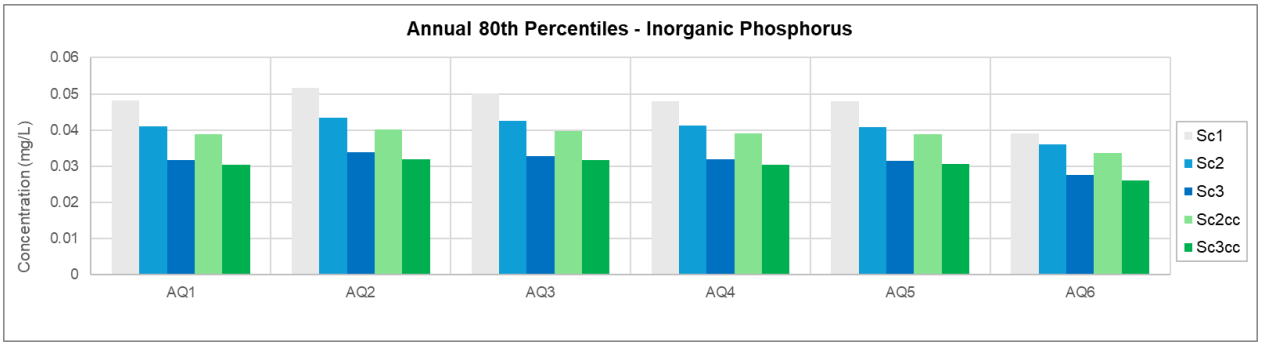




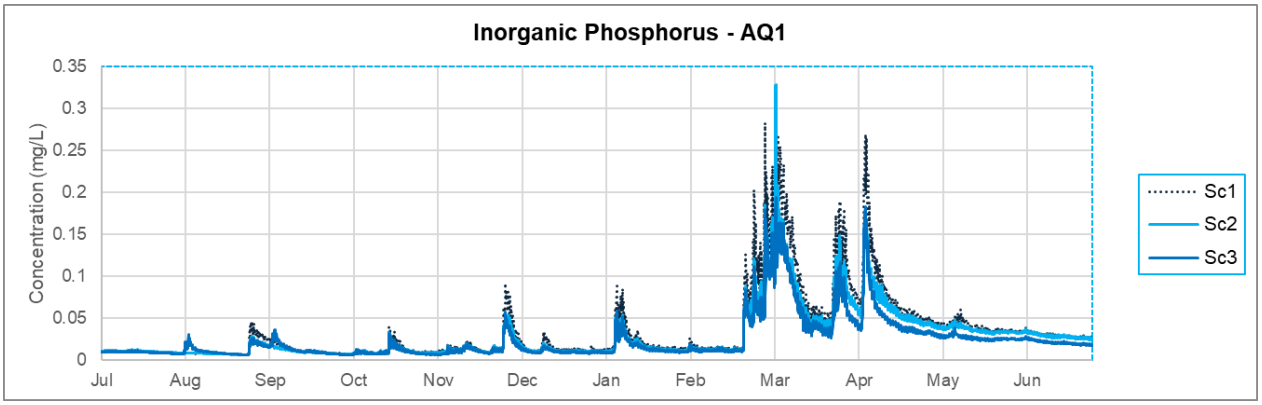
Appendices D3.7.3 Higher rainfall year scenario results (2021-2022)

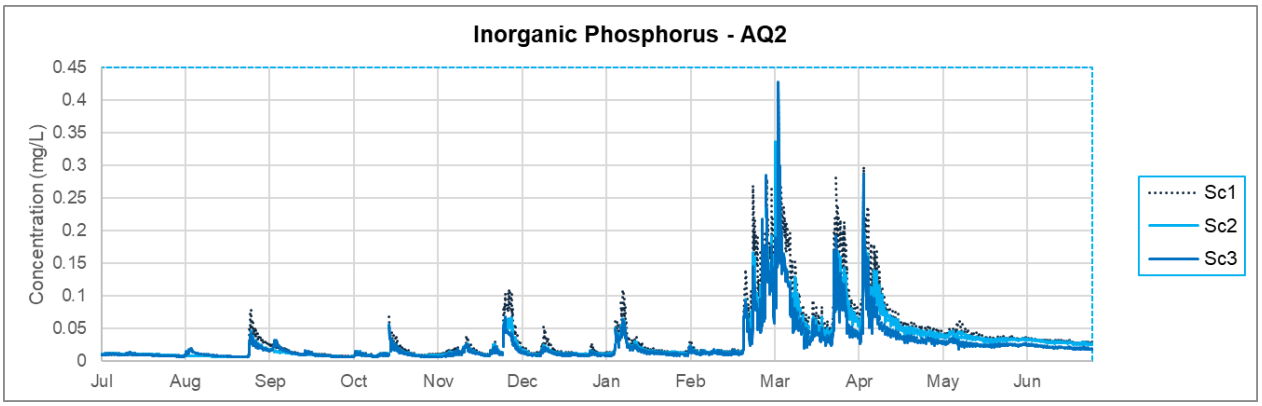
Bar charts

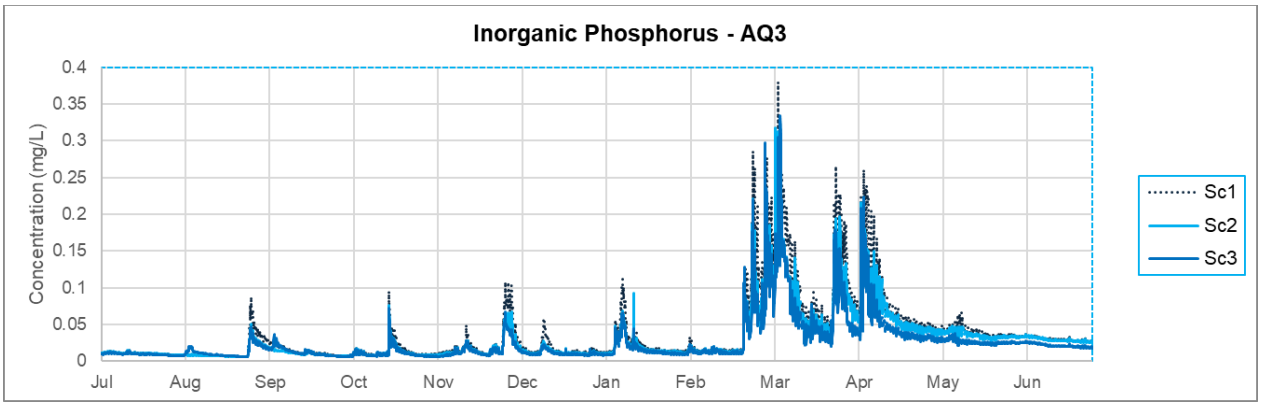


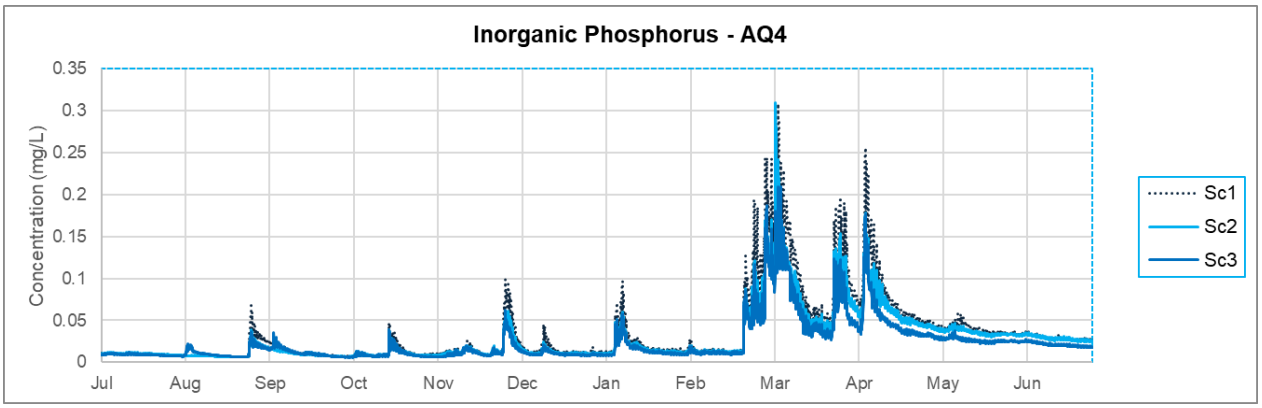


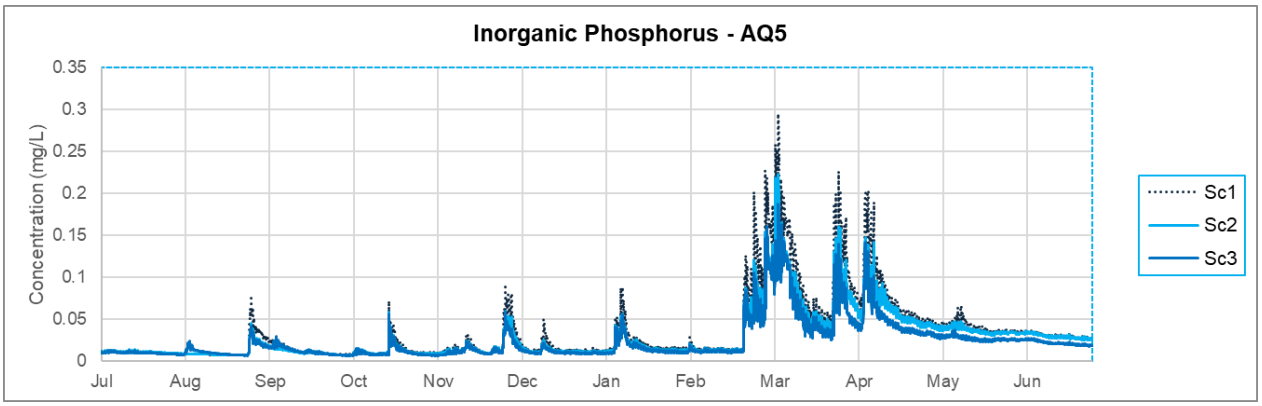
Time series plots

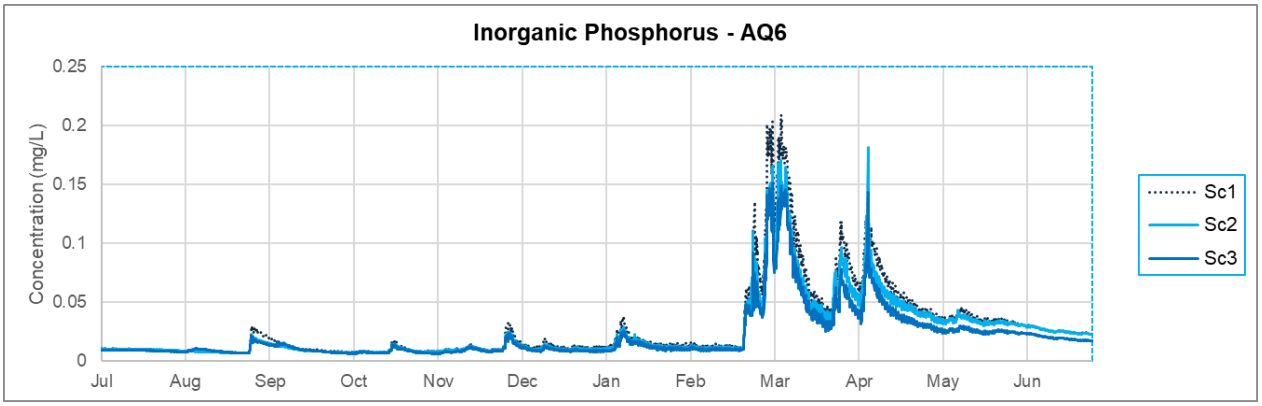










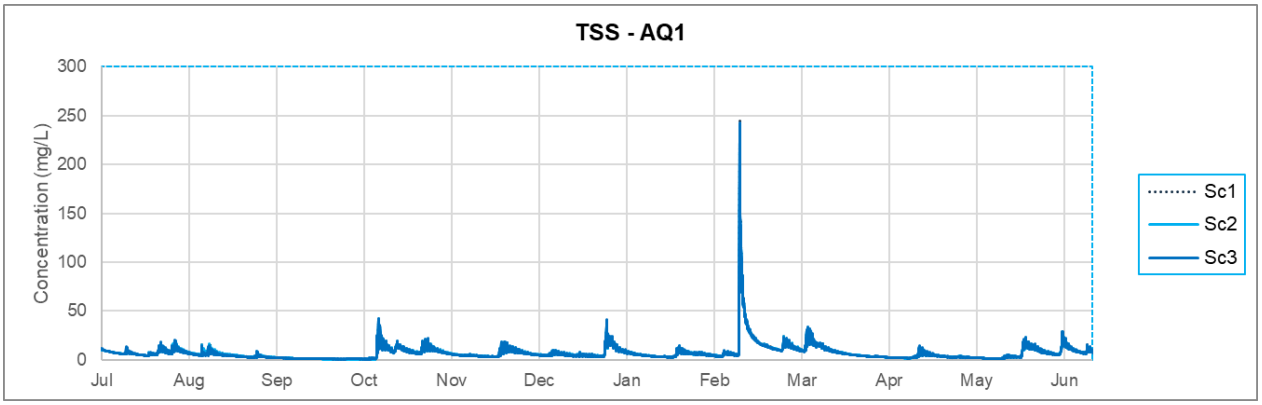


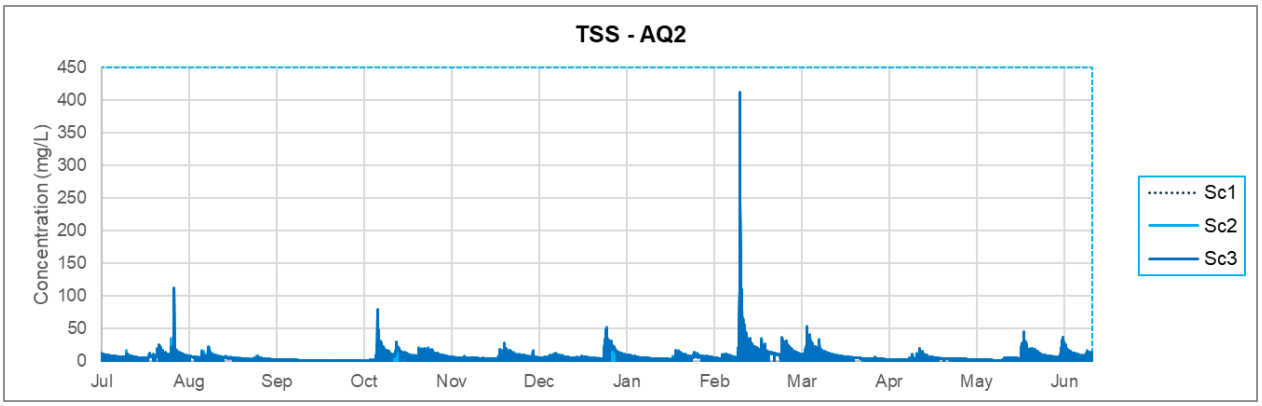
Appendices D3.8 TSS

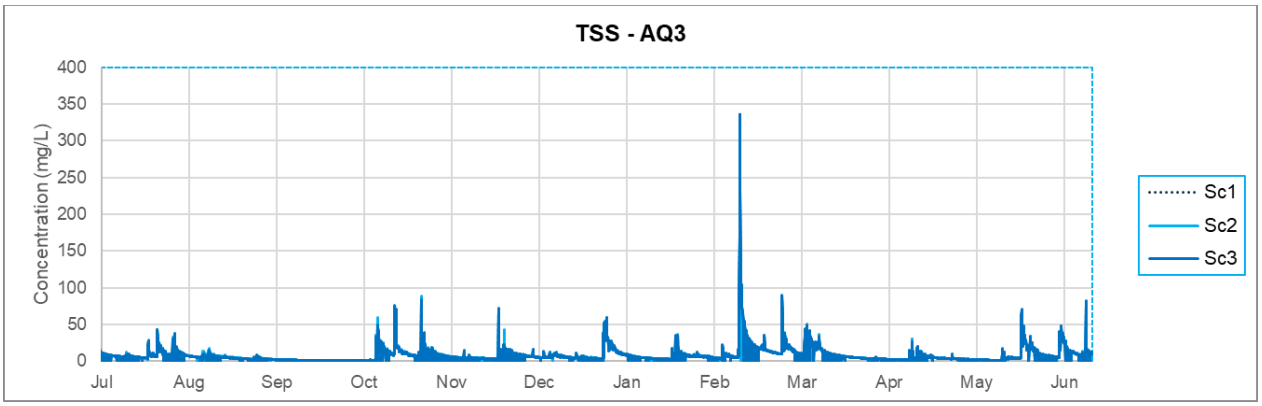
Appendices D3.8.1 Lower rainfall year scenario results (2017-2018)

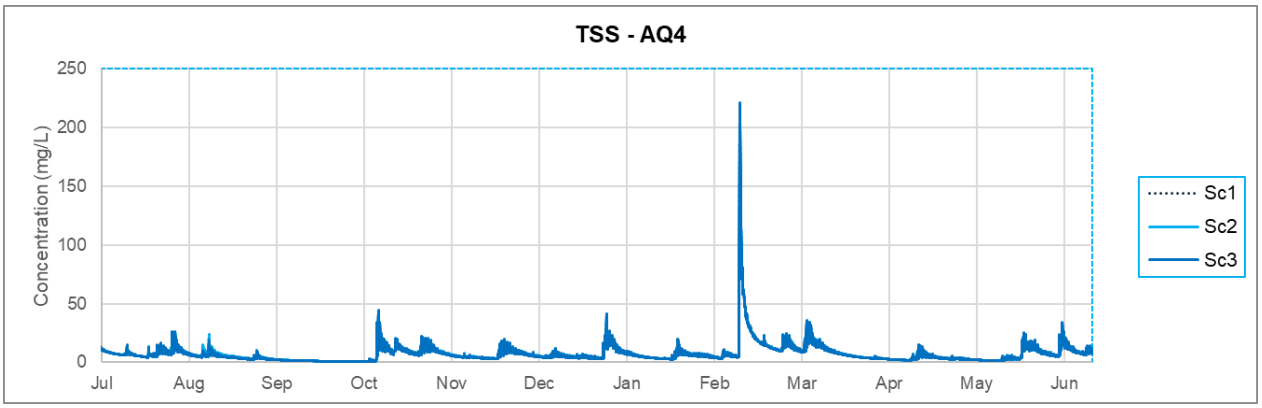
Bar charts

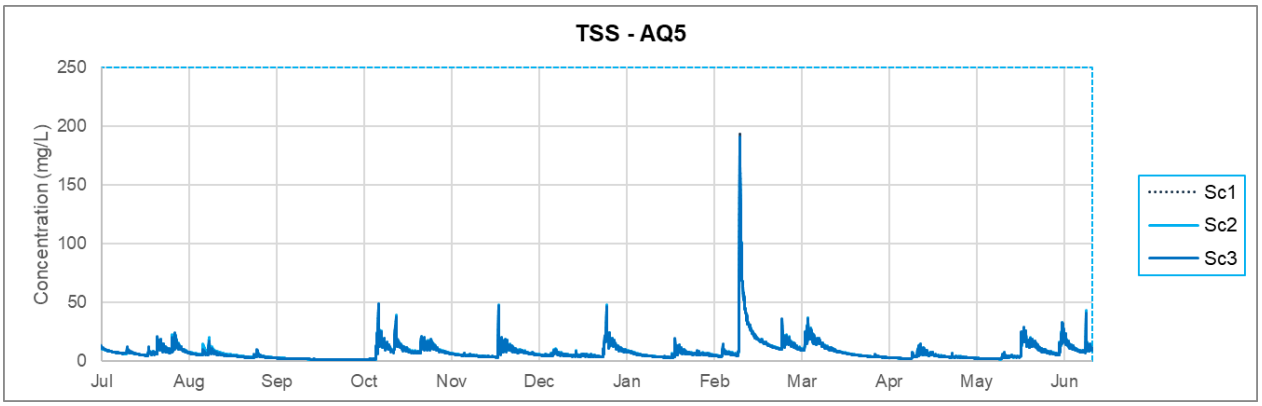
Time series plots

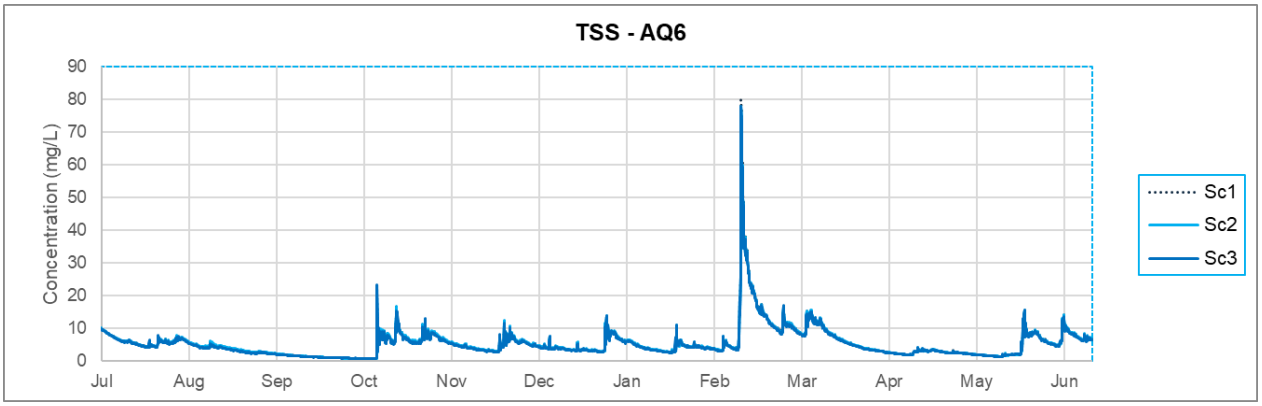








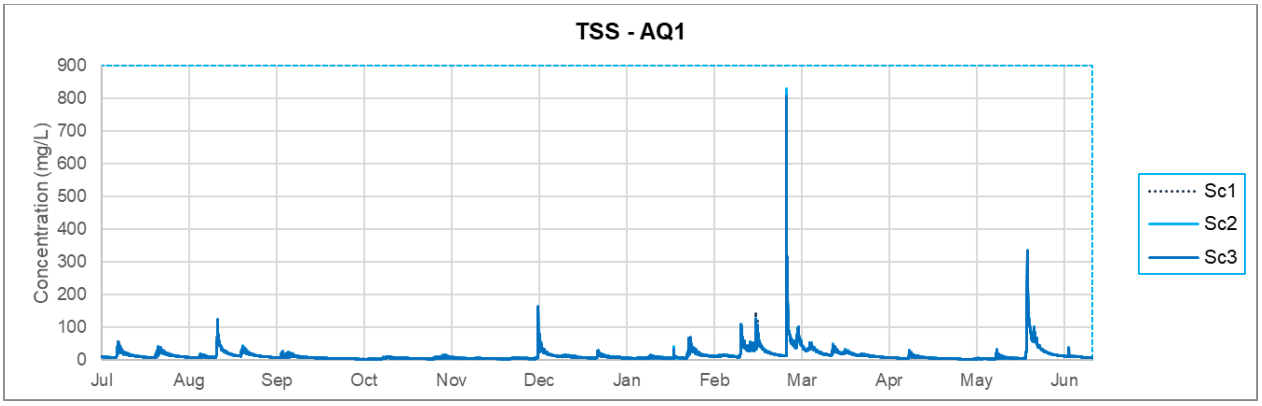


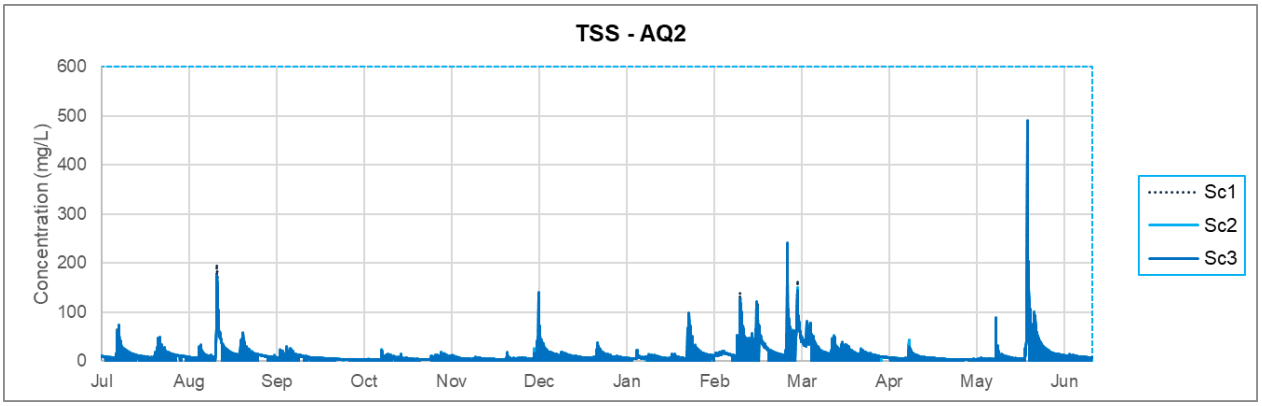


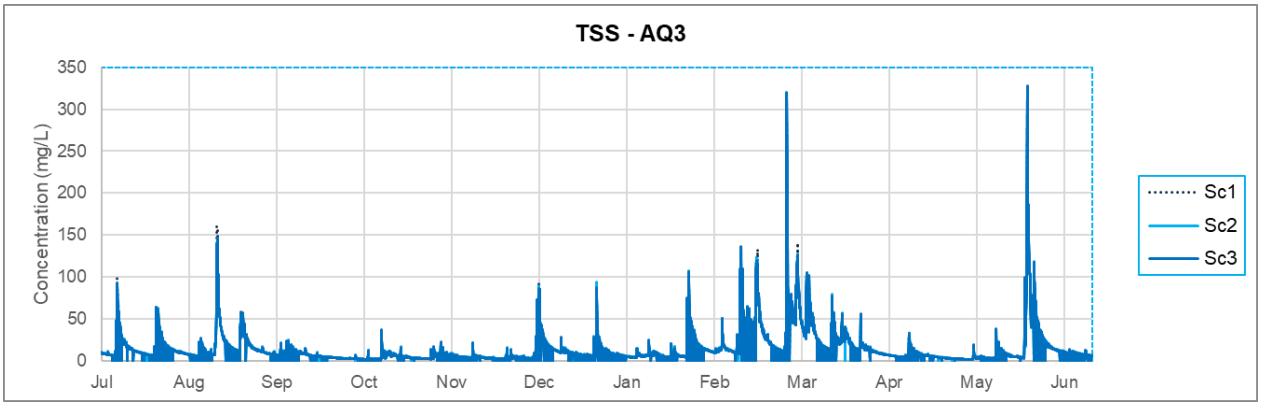
Appendices D3.8.2 Average rainfall year scenario results (2016-2017)

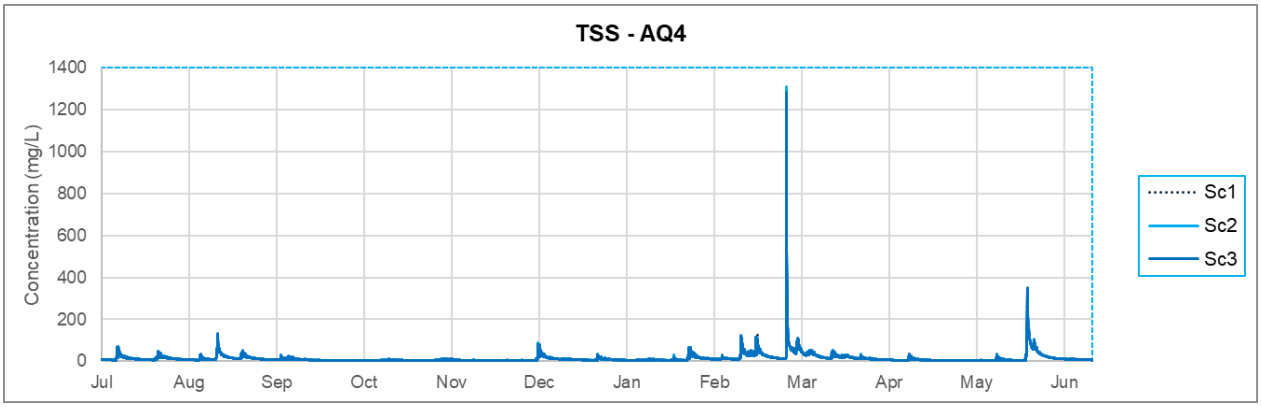
Bar charts

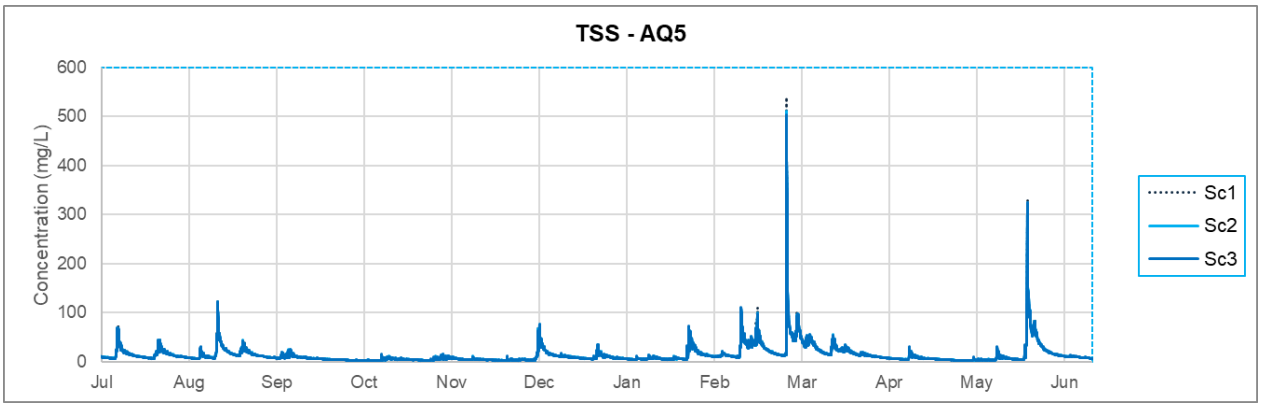
Time series plots








TSS - AQ4
Concentration (mg/L)
1400
1200
1000
800
600
400
200
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

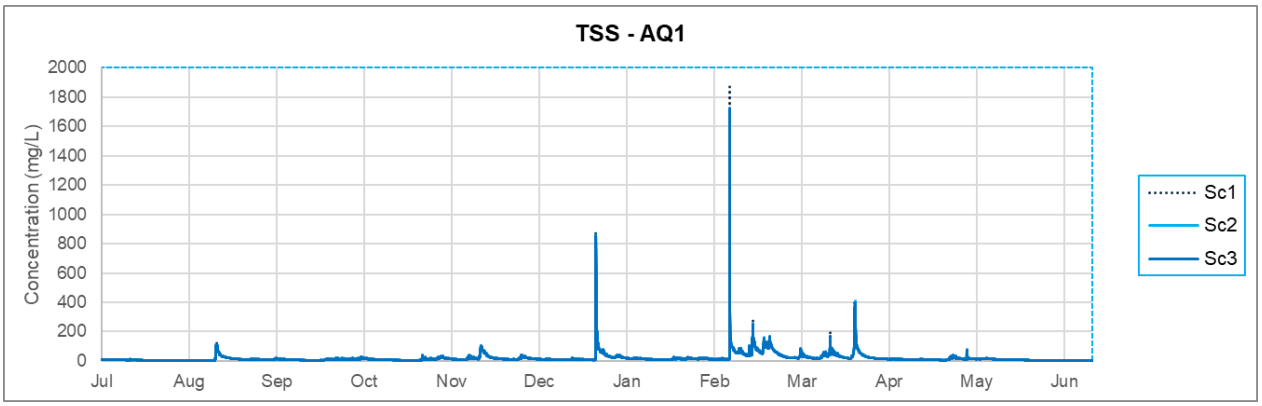

TSS - AQ5
Concentration (mg/L)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

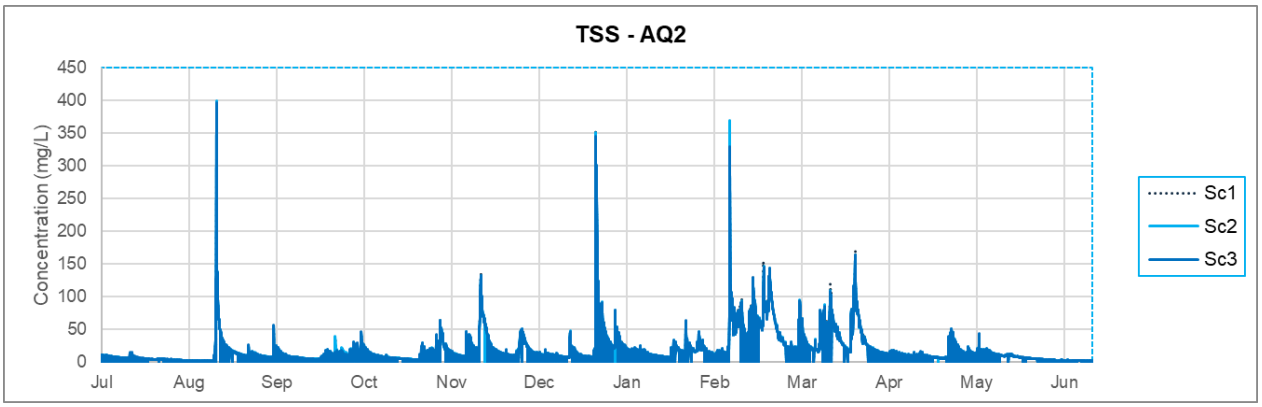
TSS - AQ6
Concentration (mg/L)
120
100
80
60
40
20
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

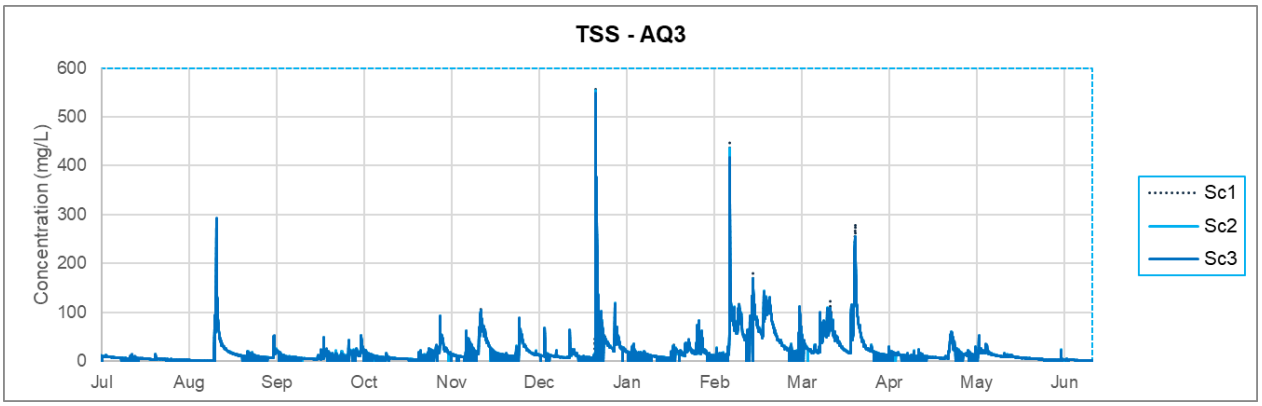
Appendices D3.8.3 Higher rainfall year scenario results (2021-2022)

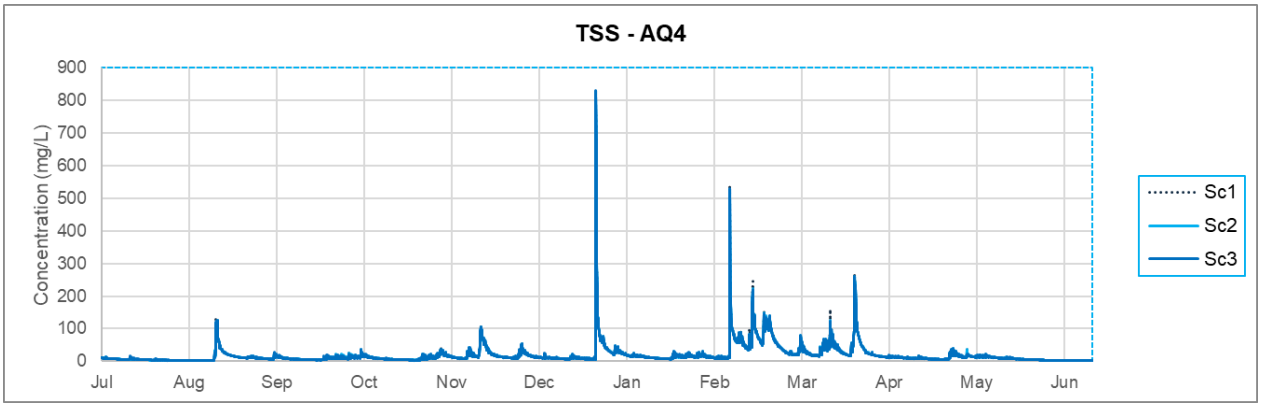
Bar charts

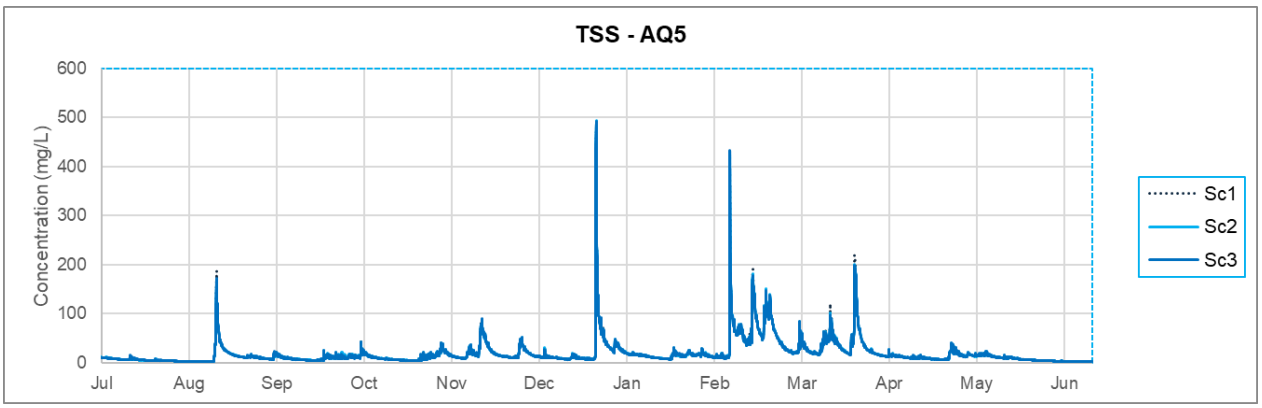
Time series plots

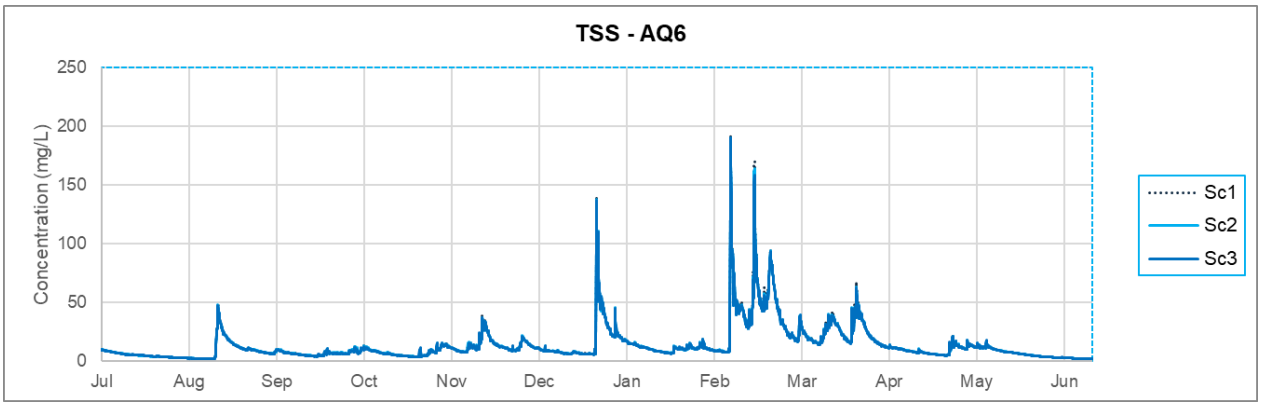





TSS - AQ3
Concentration (mg/L)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


TSS - AQ4
Concentration (mg/L)
900
800
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

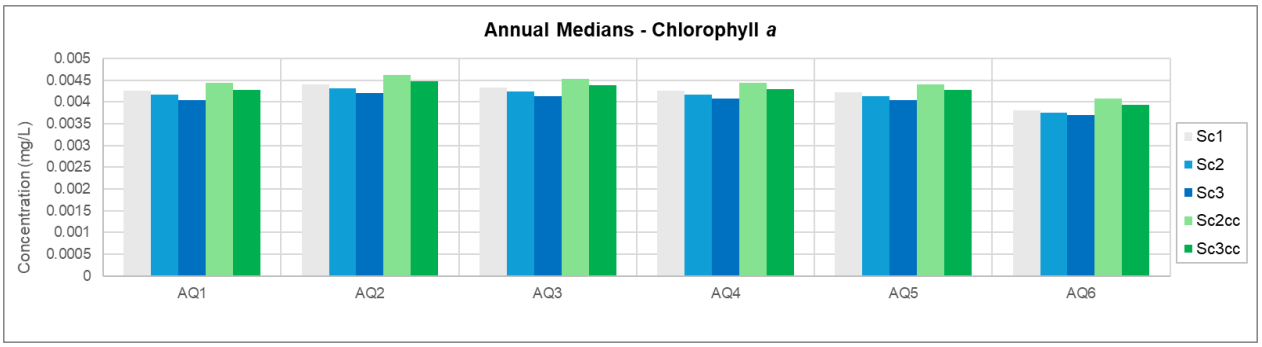

TSS - AQ5
Concentration (mg/L)
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

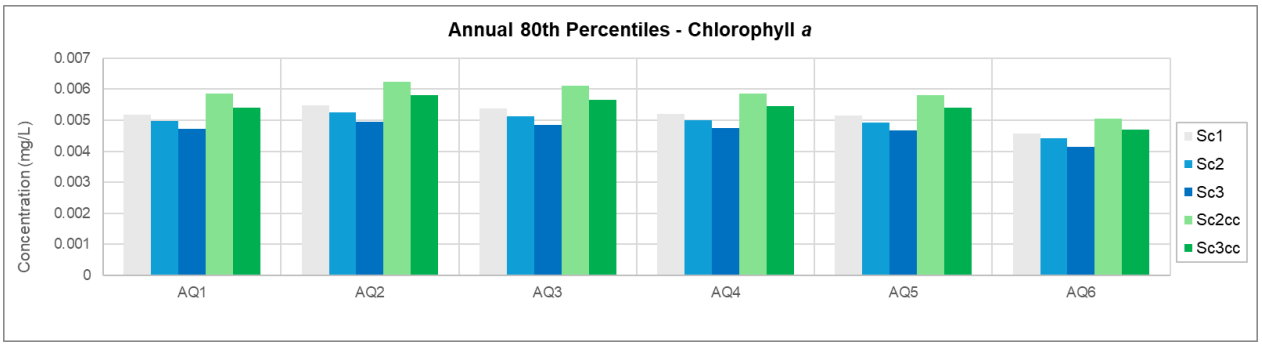

TSS - AQ6
Concentration (mg/L)
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D3.9 Chlorophyll a

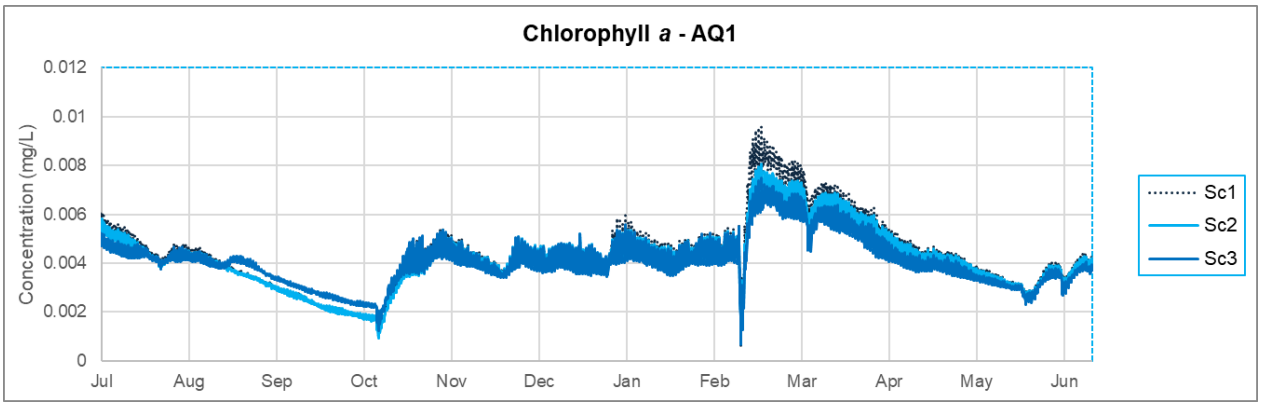
Appendices D3.9.1 Lower rainfall year scenario results (2017-2018)

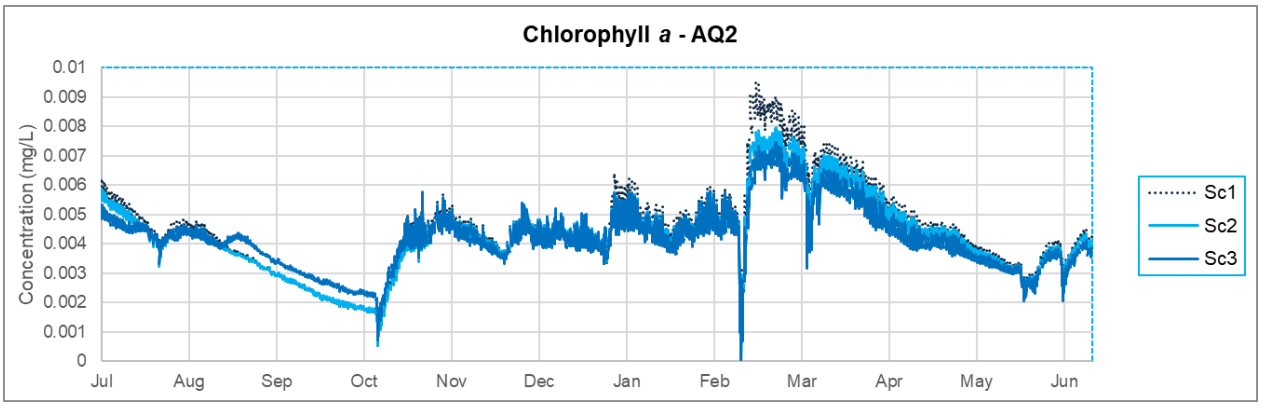
Bar charts

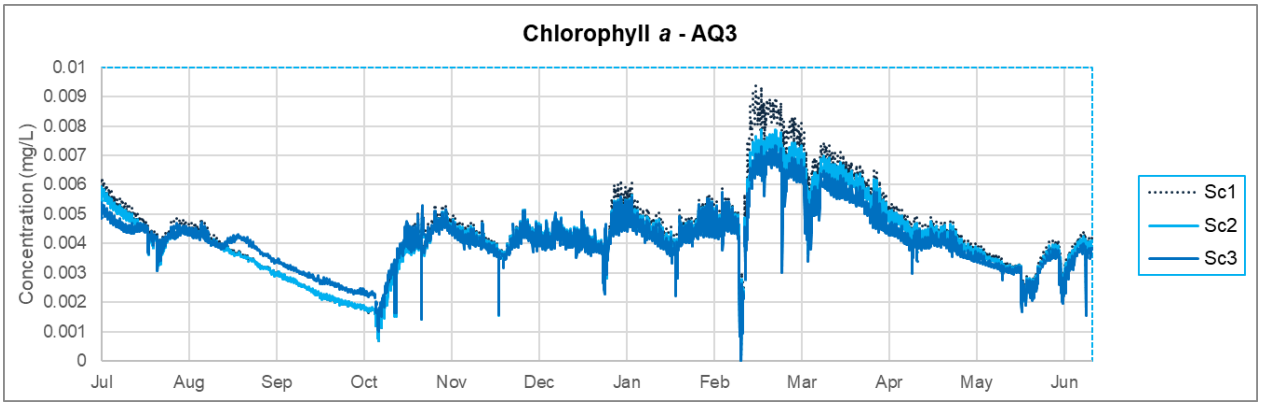


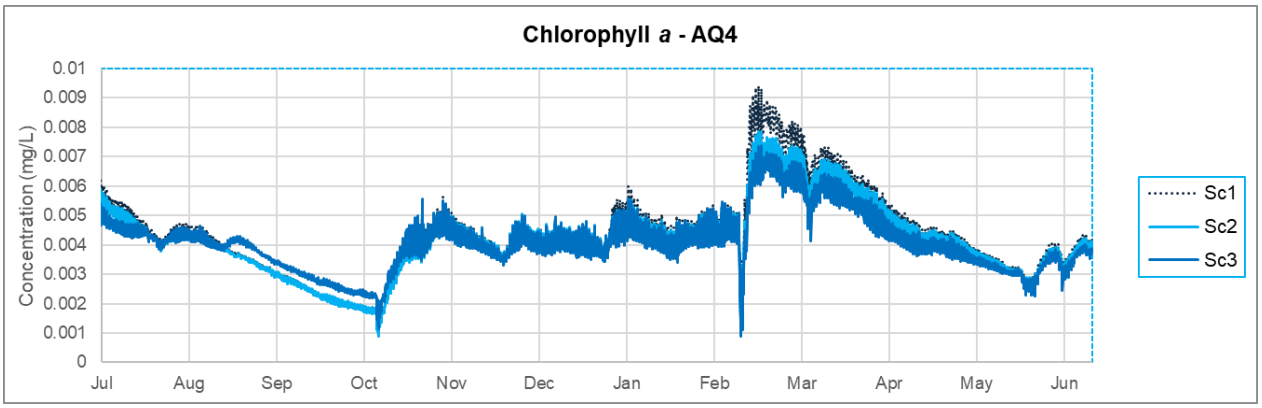


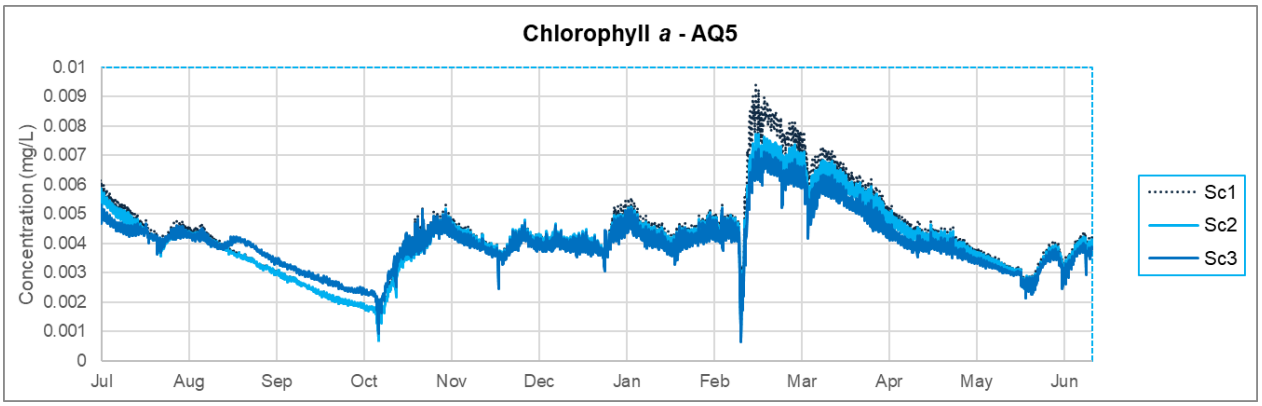
Time series plots

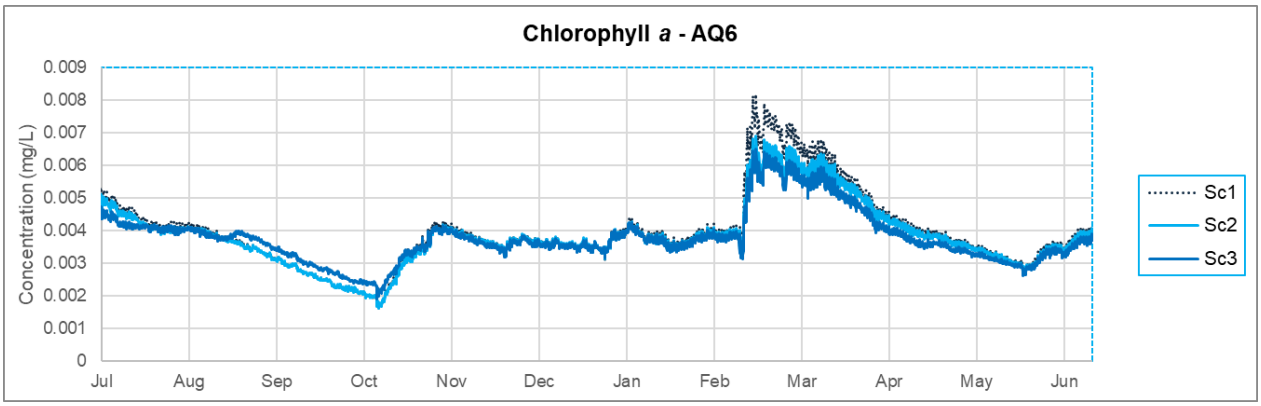



Chlorophyll *a* - AQ2
Concentration (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Chlorophyll *a* - AQ3
Concentration (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

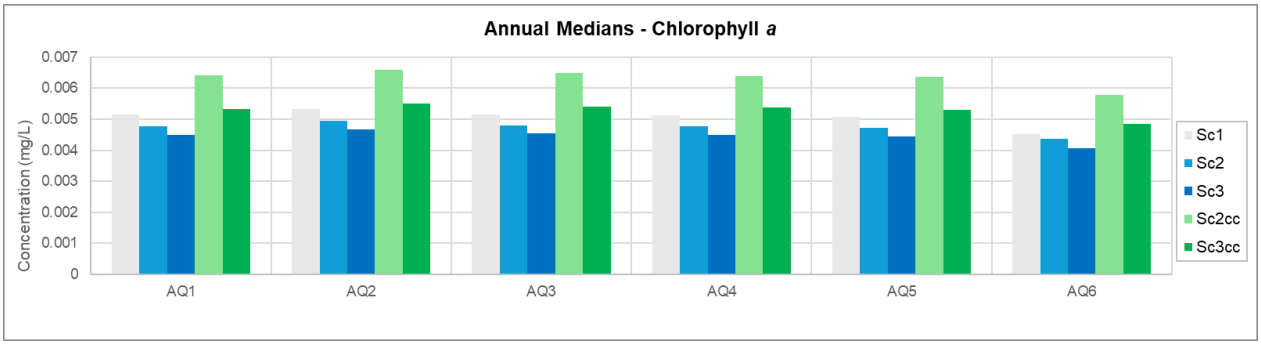

Chlorophyll *a* - AQ4
Concentration (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

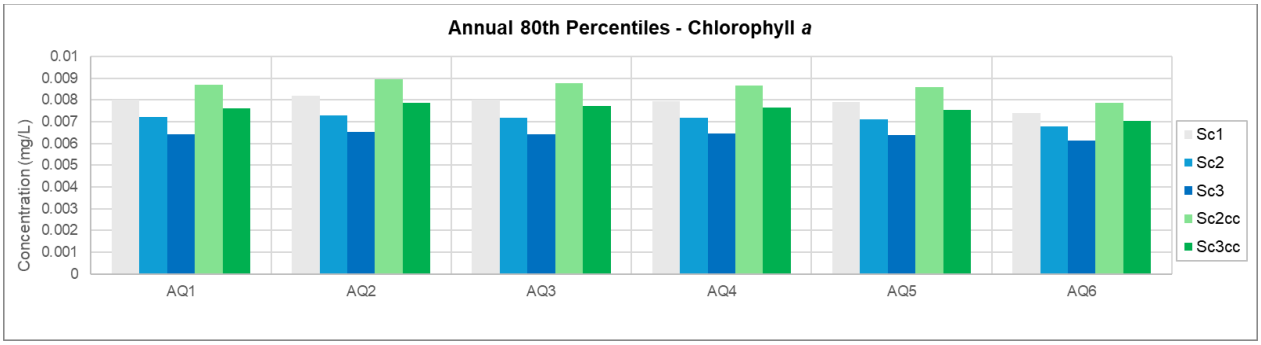

Chlorophyll *a* - AQ5
Concentration (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3



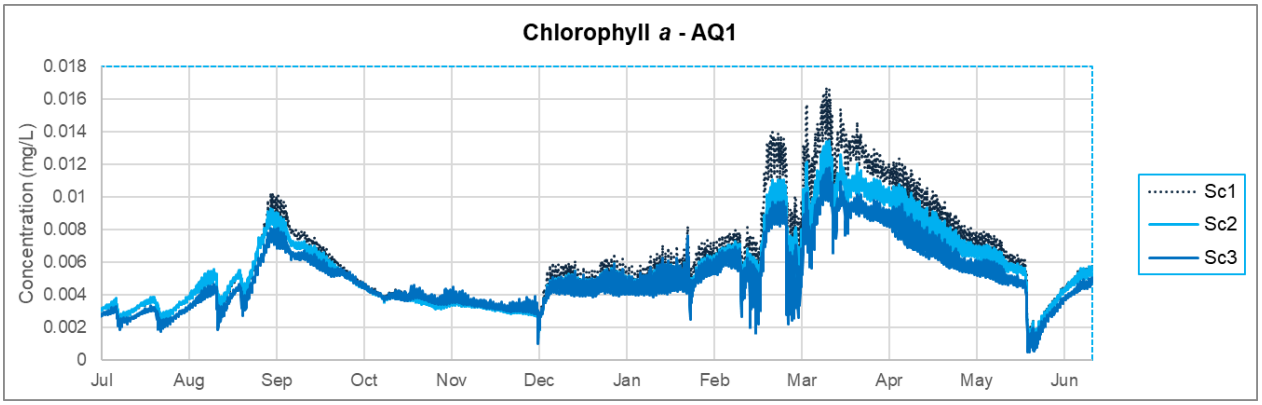
Appendices D3.9.2 Average rainfall year scenario results (2016-2017)

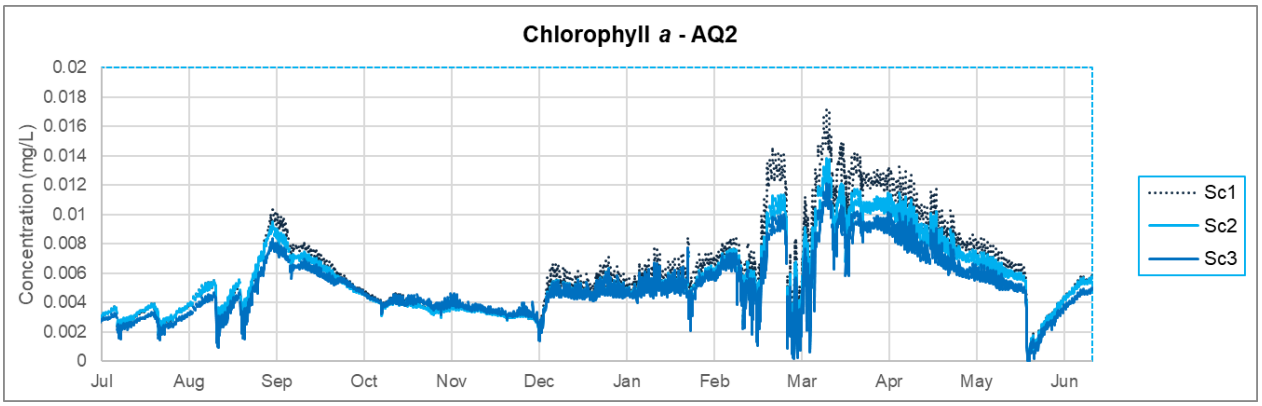
Bar charts

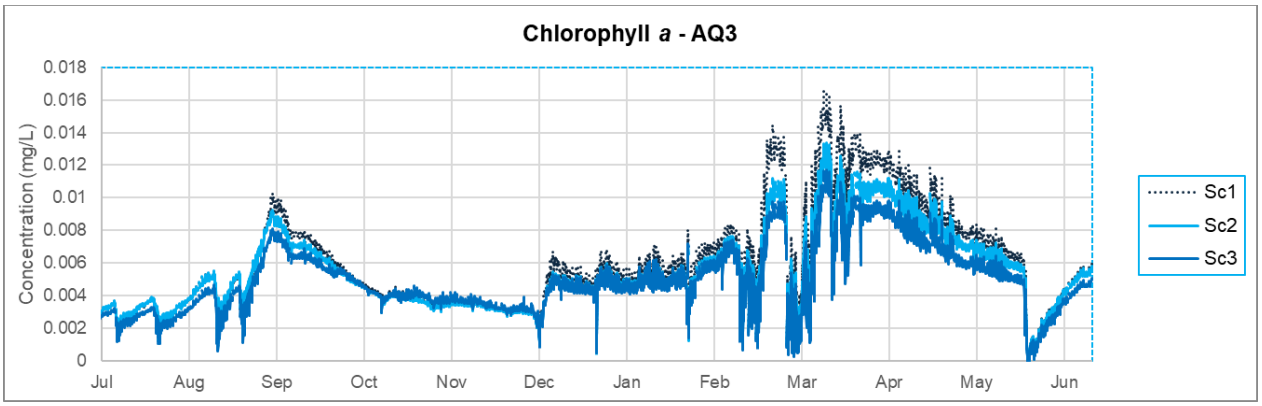


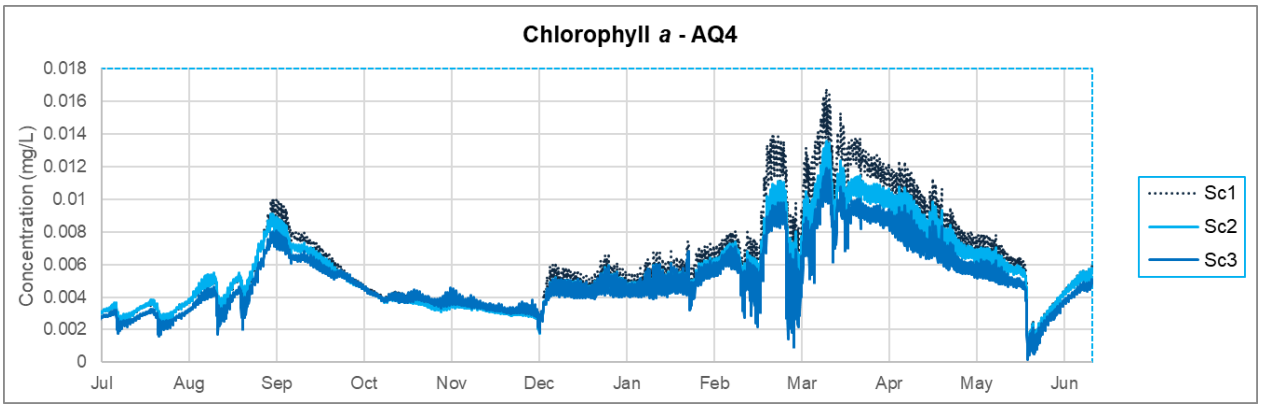


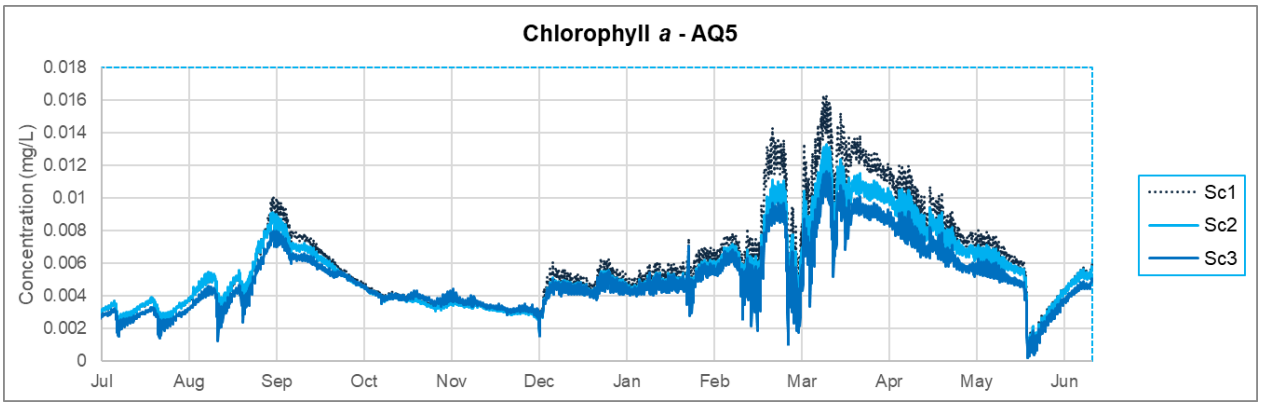
Time series plots

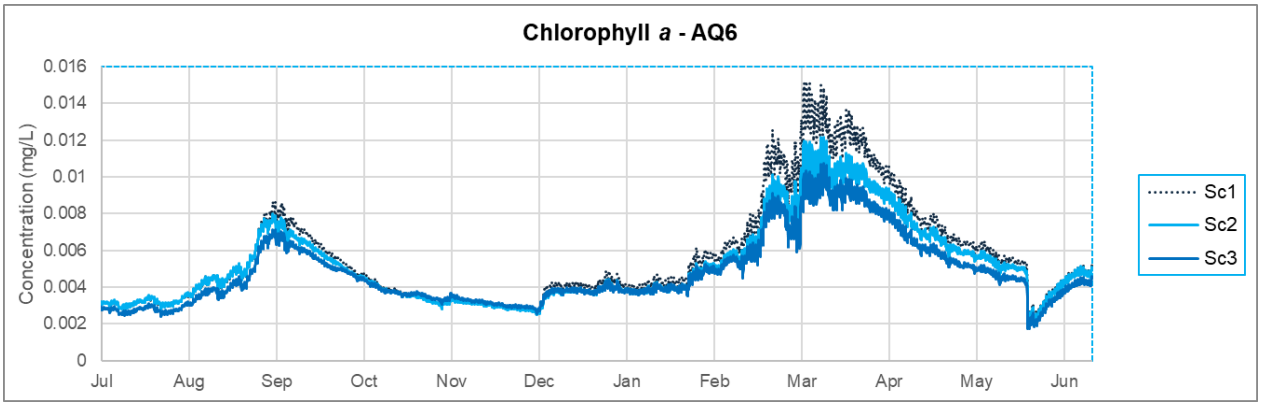






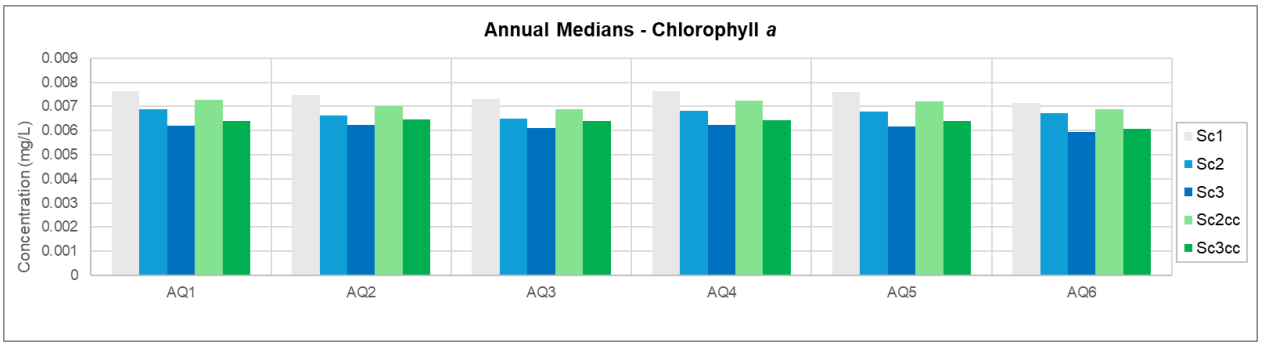


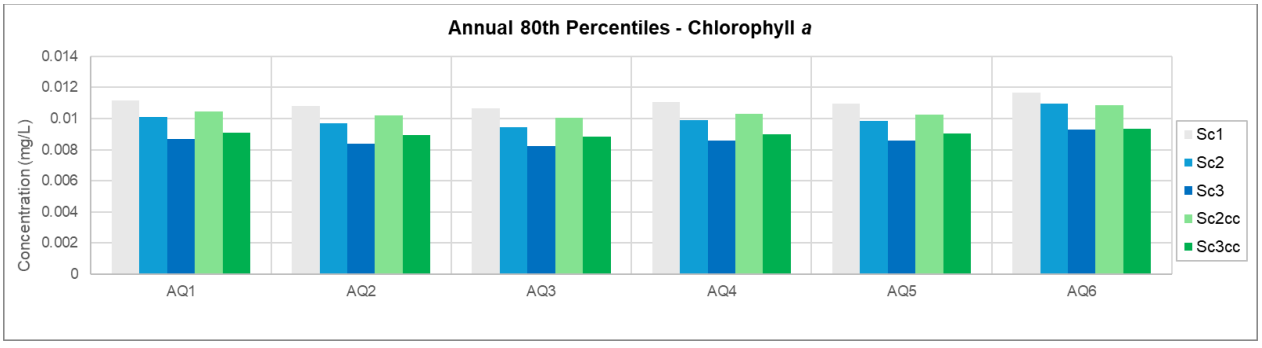




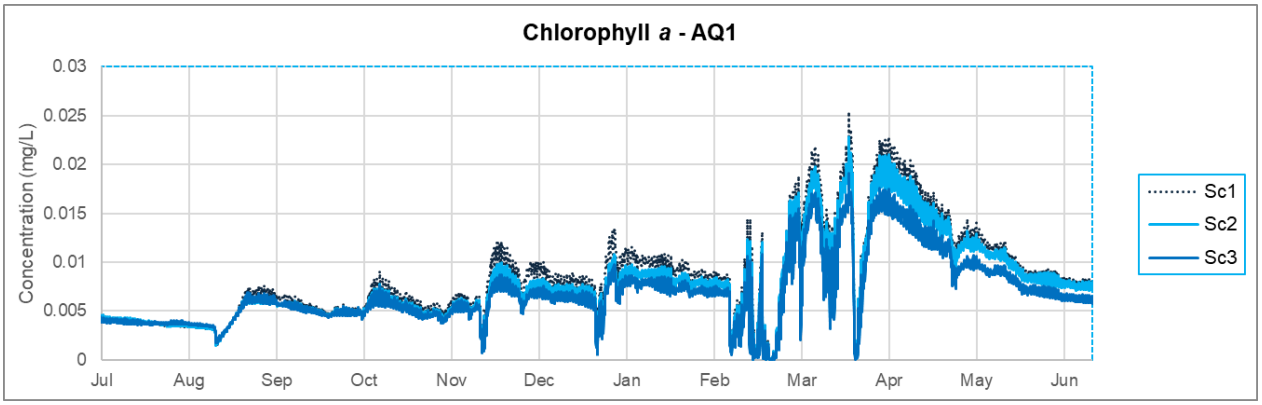
Appendices D3.9.3 Higher rainfall year scenario results (2021-2022)

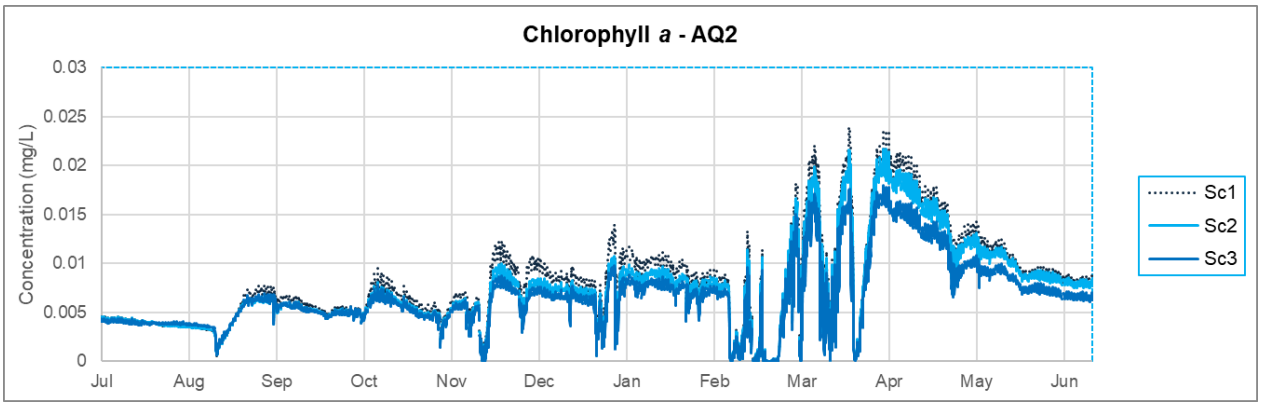
Bar charts

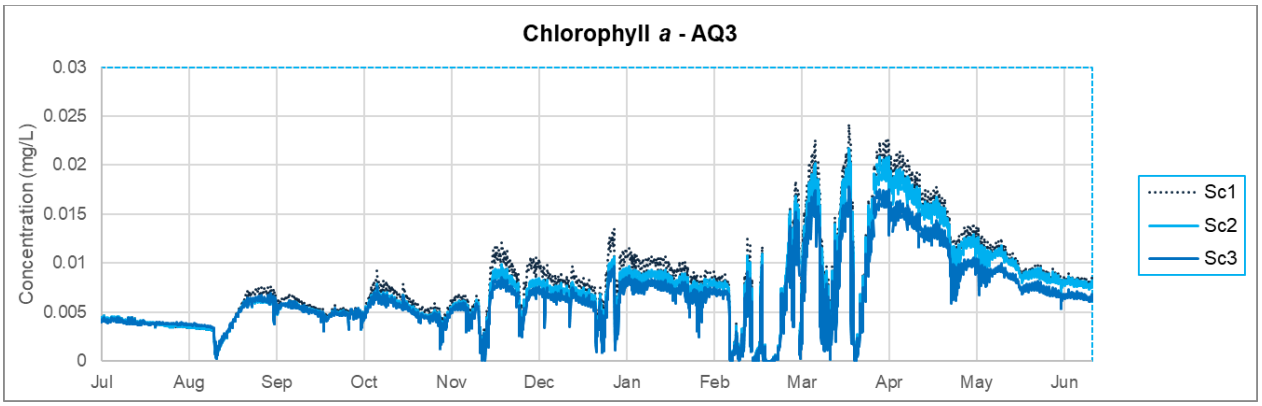


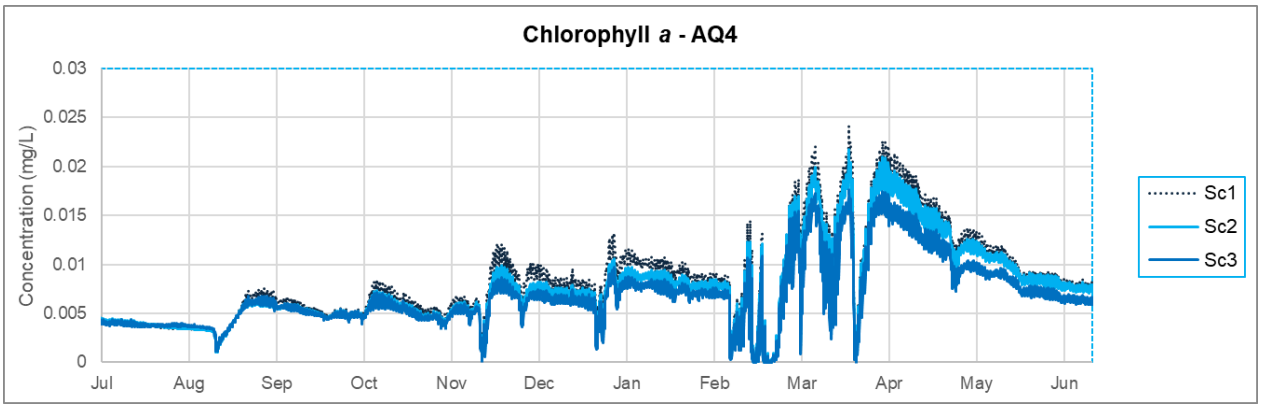


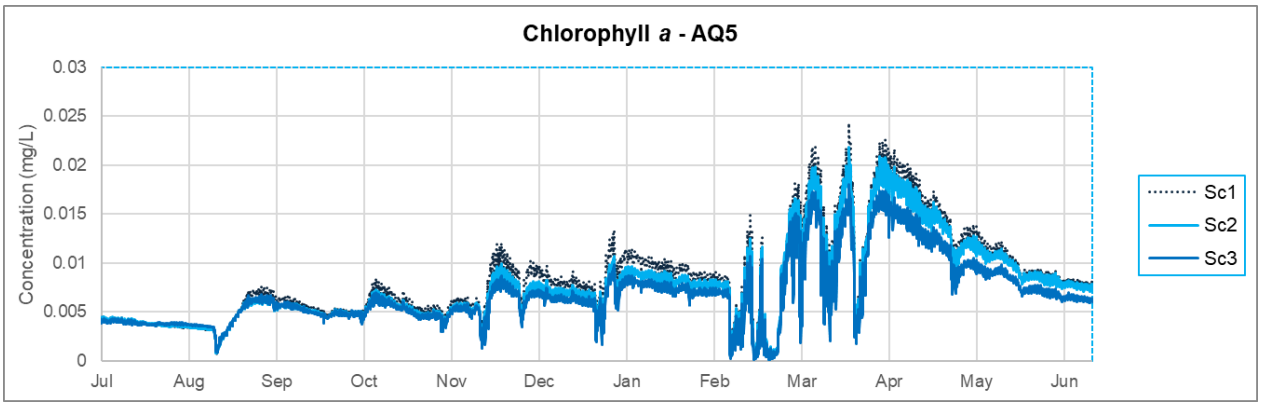
Time series plots

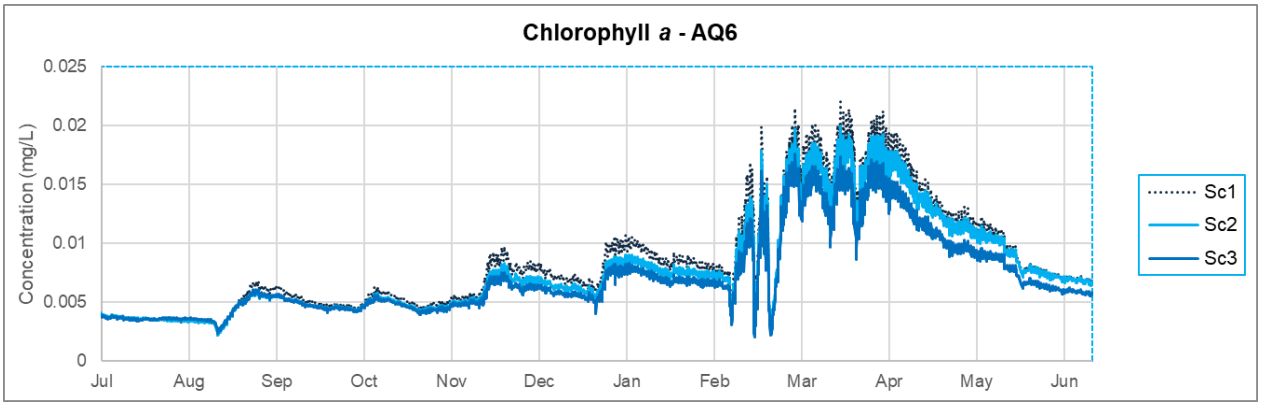








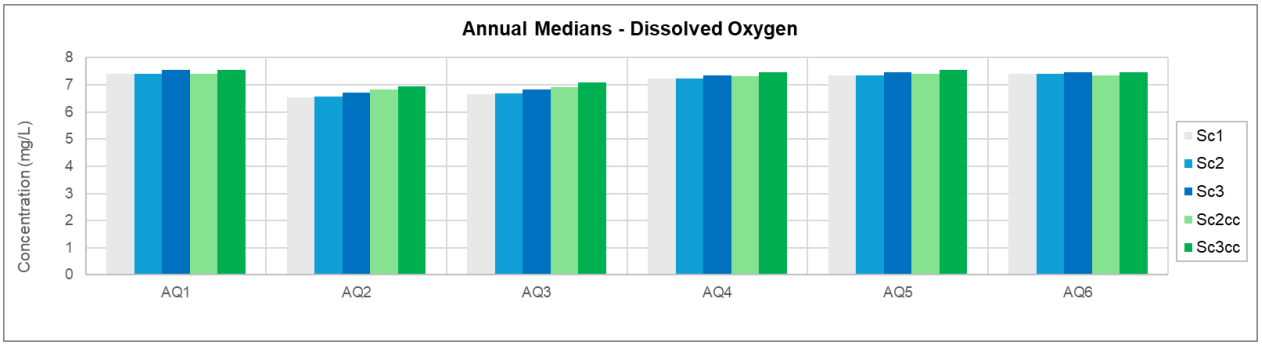


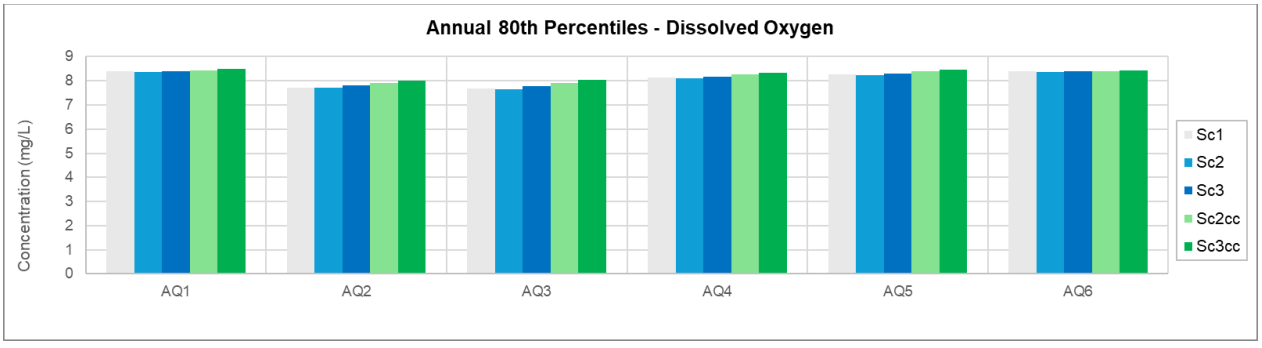


Appendices D3.10 Dissolved Oxygen

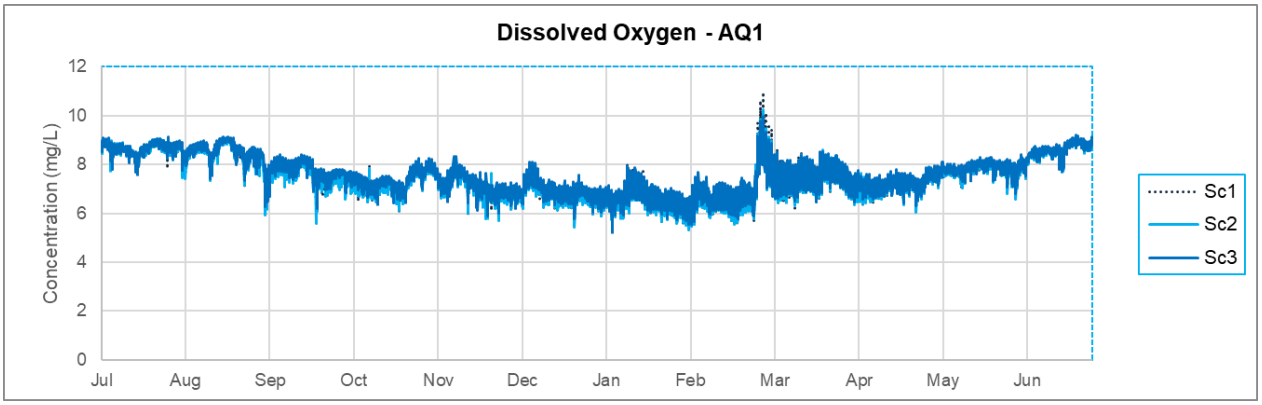
Appendices D3.10.1 Lower rainfall year scenario results (2017-2018)

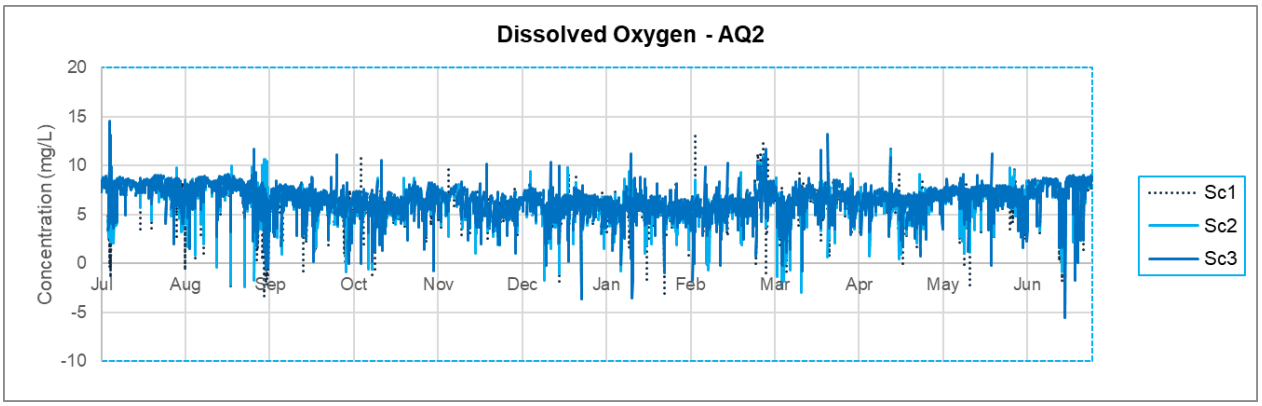
Bar charts

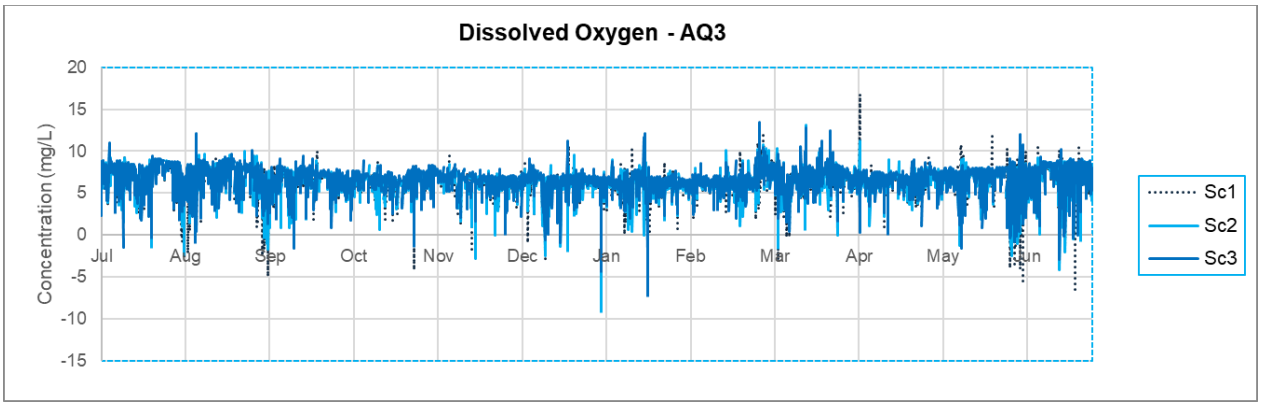


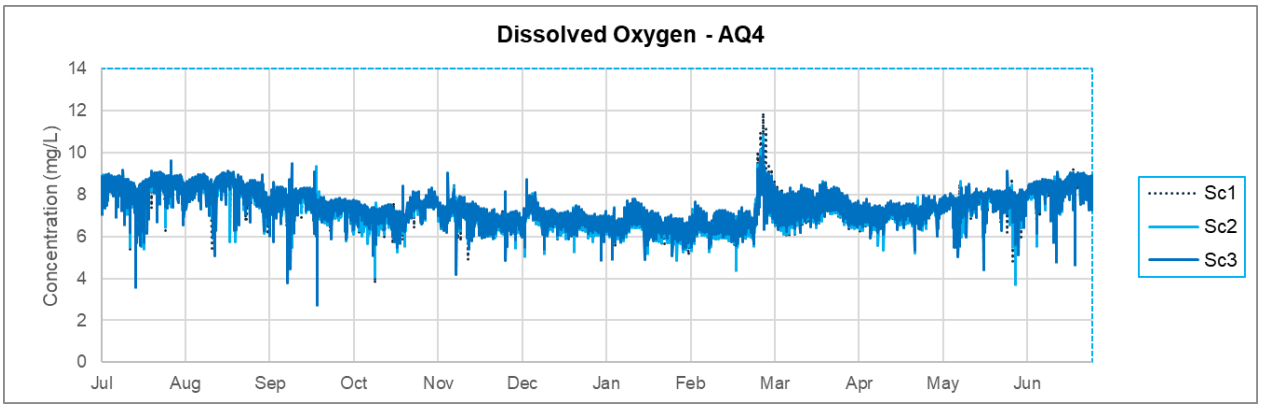


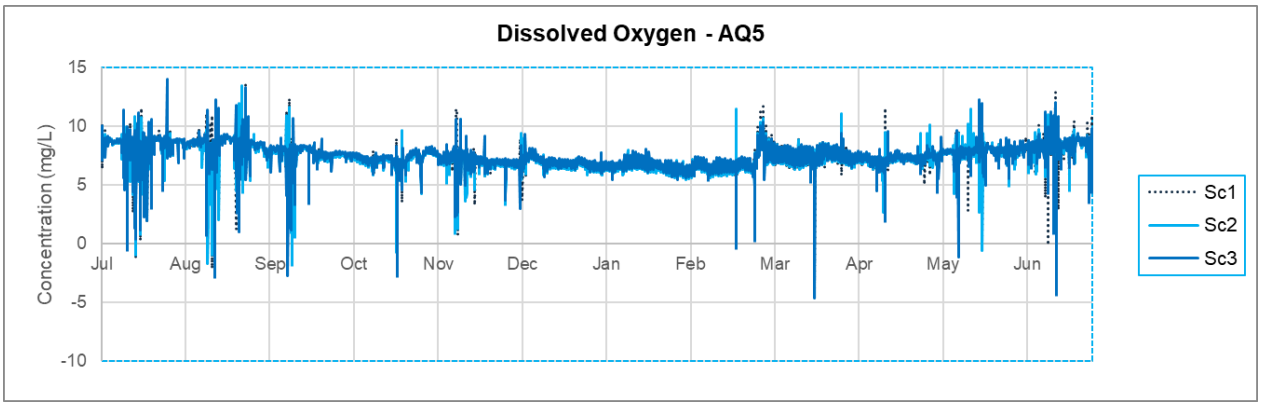
Time series plots

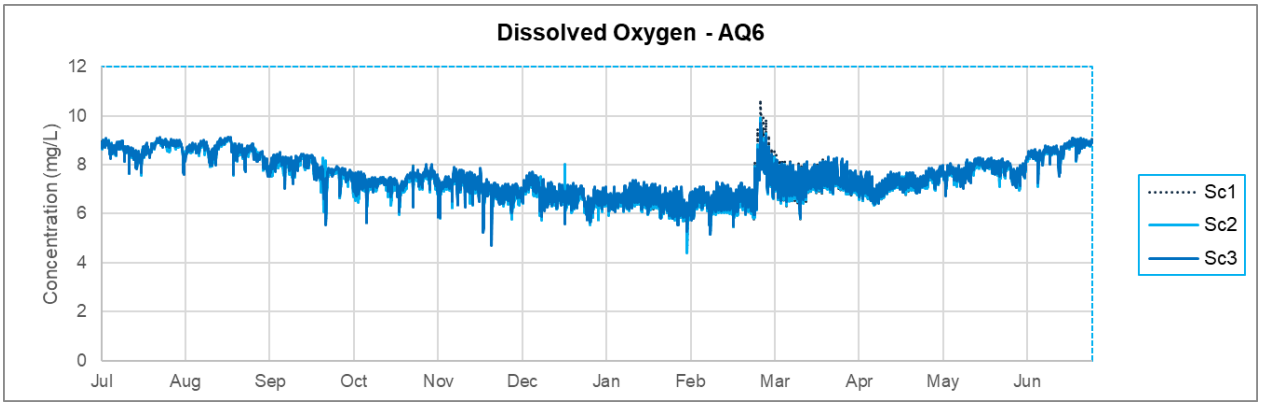






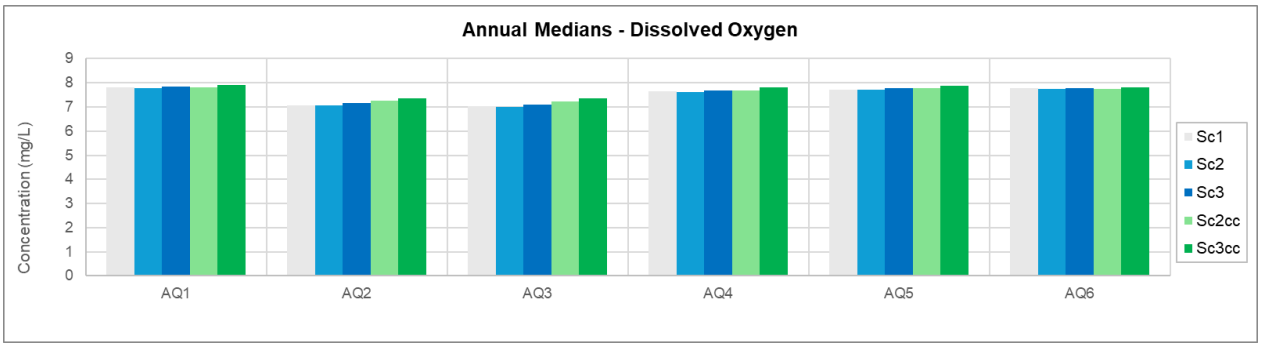


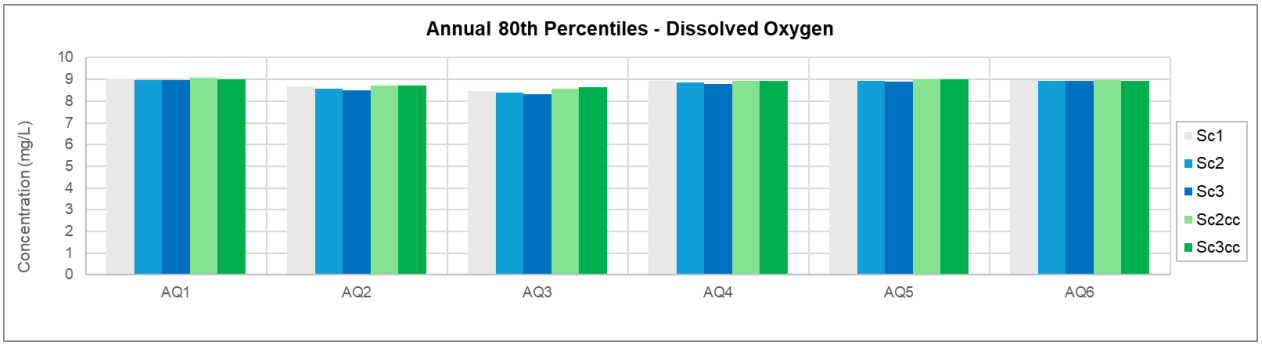




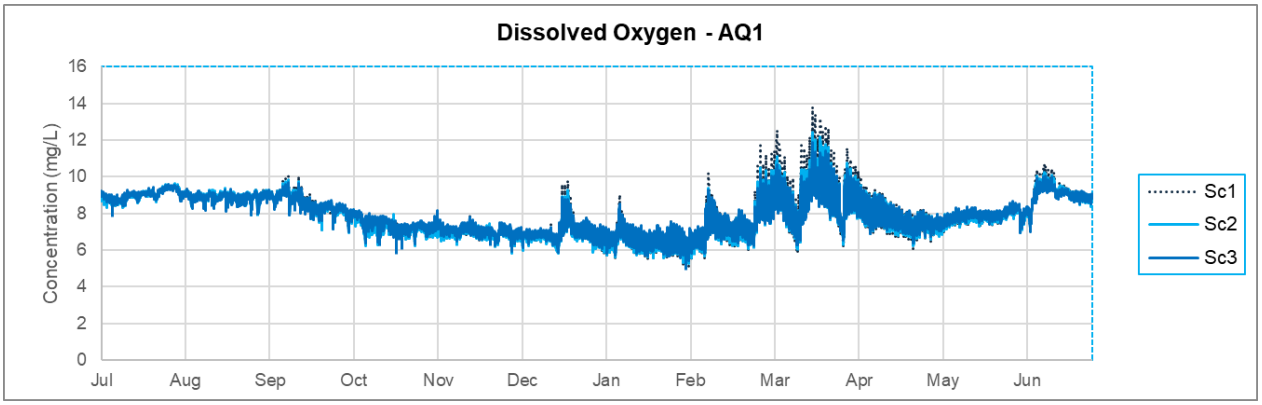
Appendices D3.10.2 Average rainfall year scenario results (2016-2017)

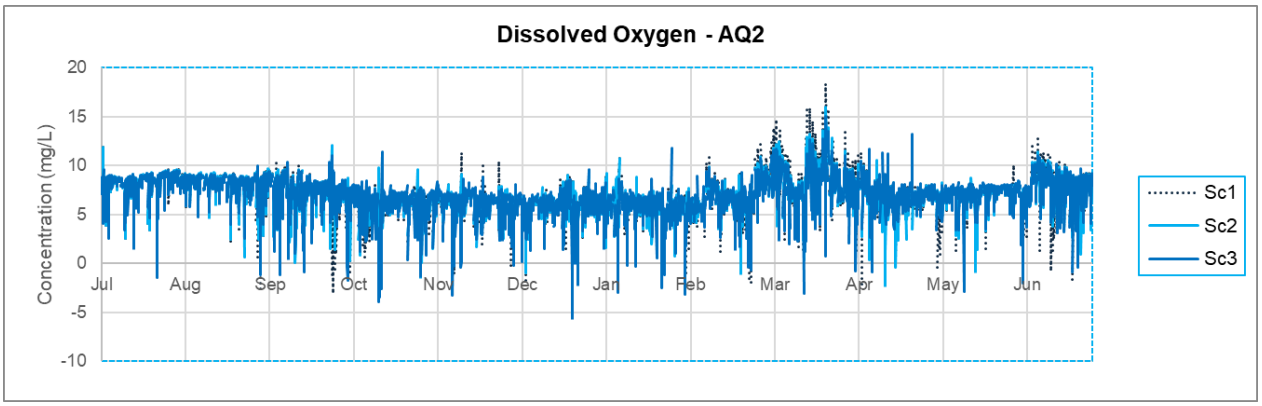
Bar charts

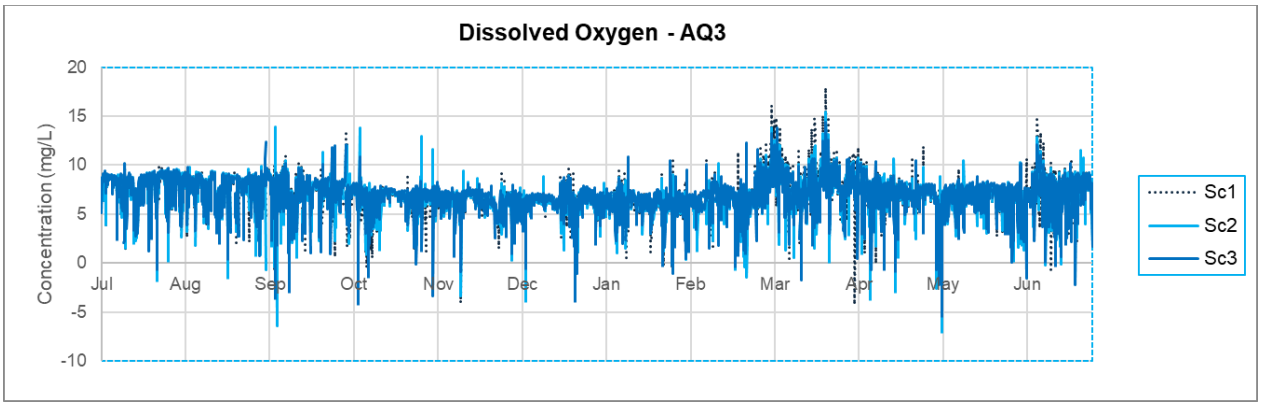


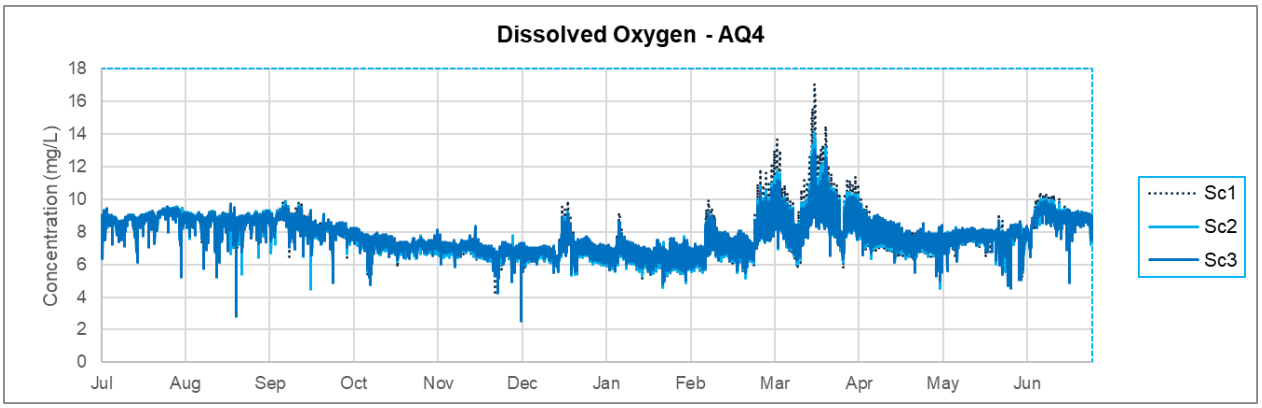


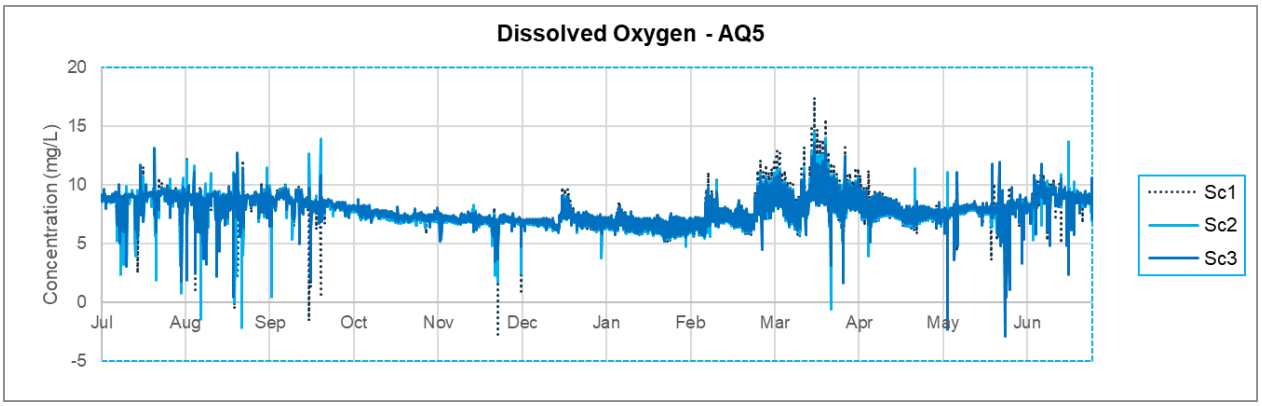
Time series plots

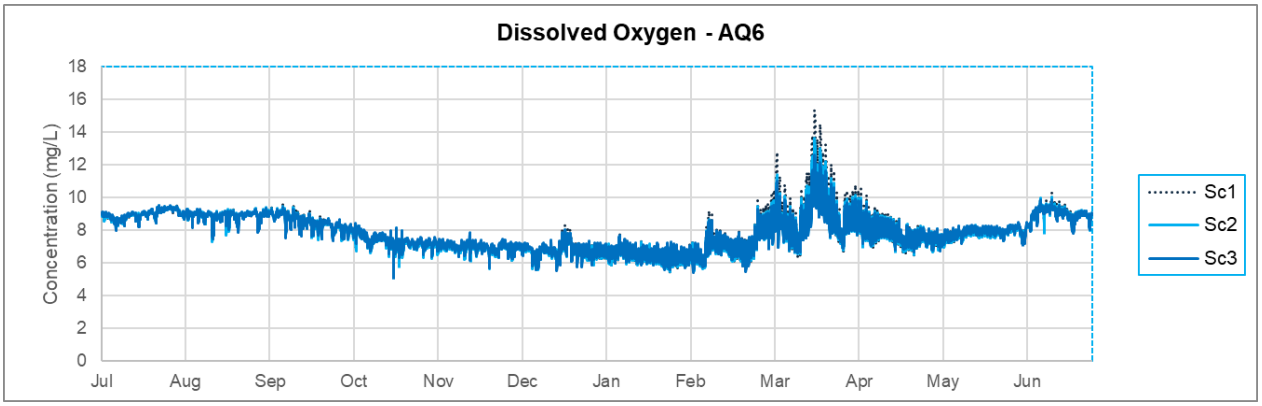






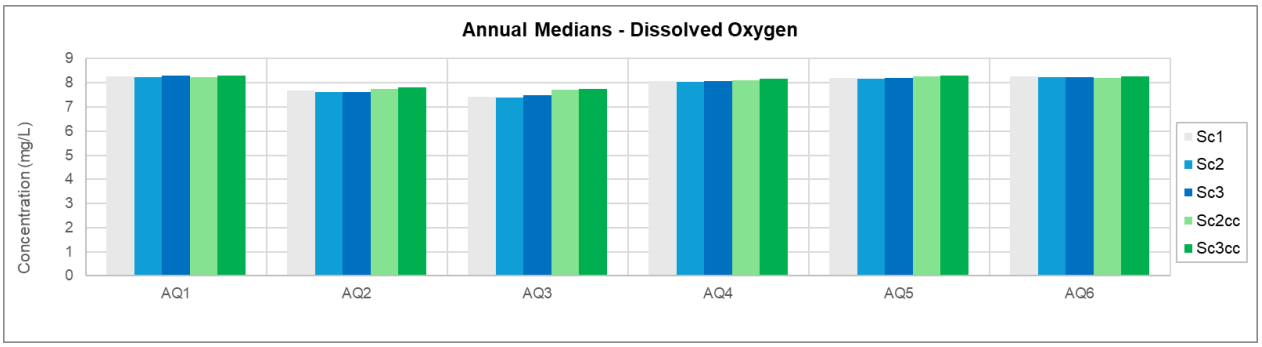


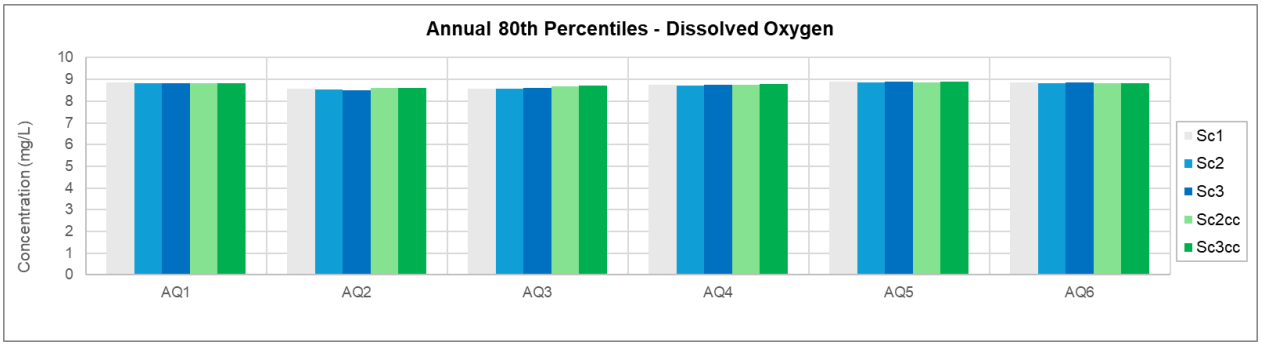




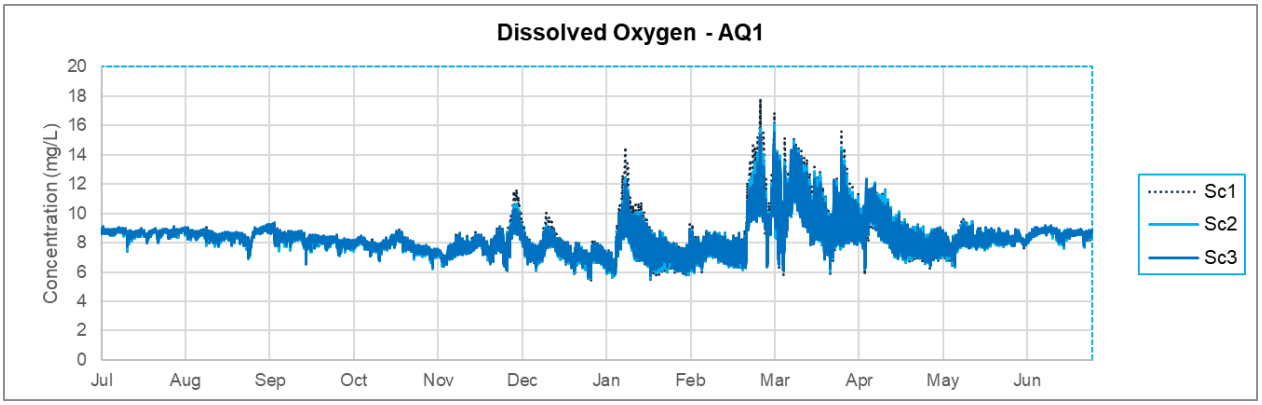
Appendices D3.10.3 Higher rainfall year scenario results (2021-2022)

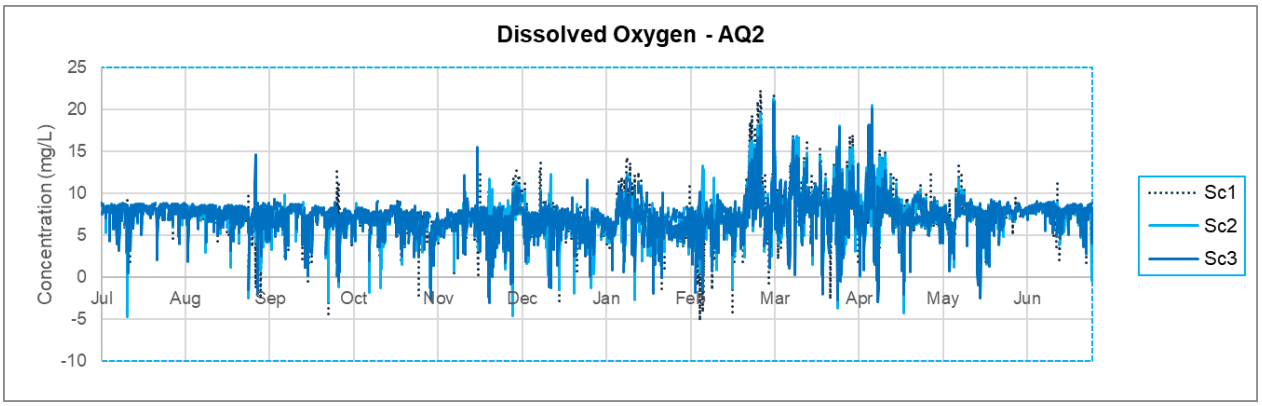
Bar charts

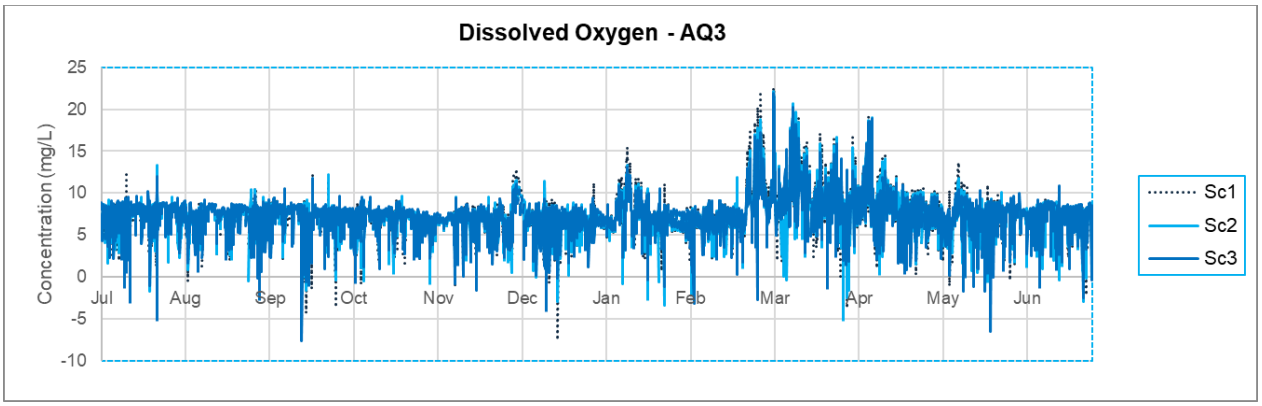


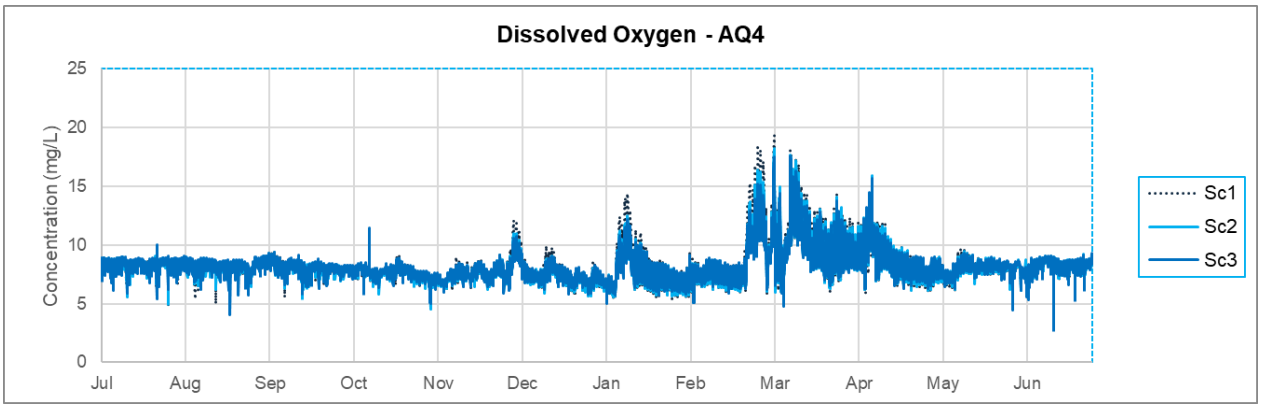


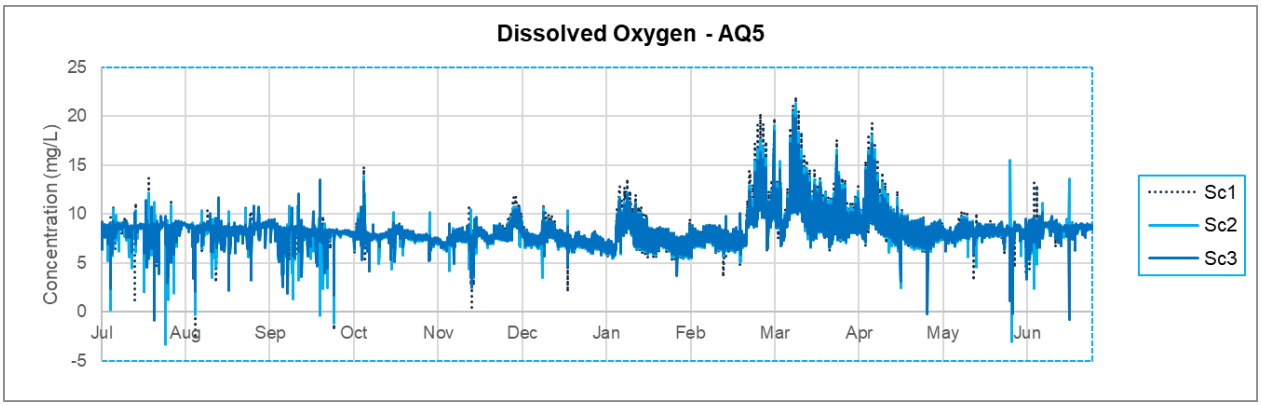
Time series plots

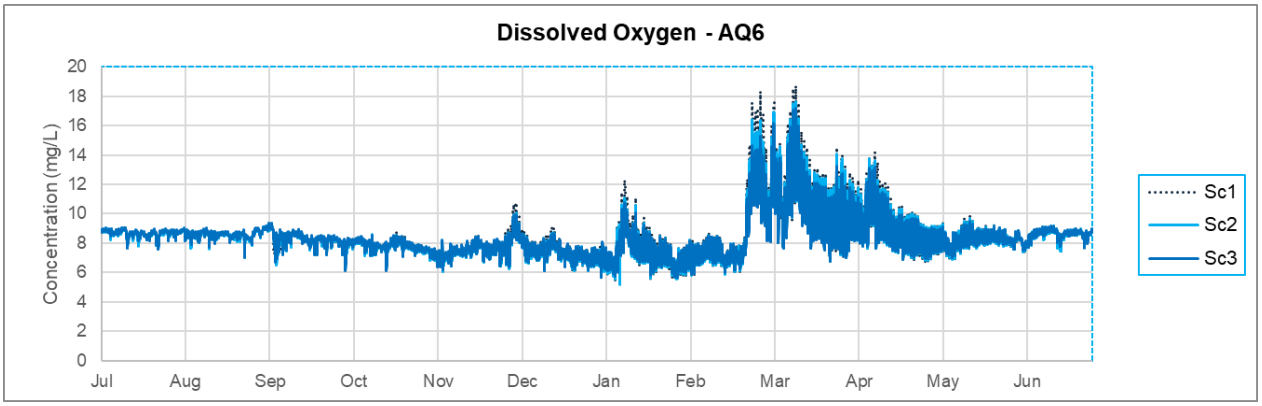








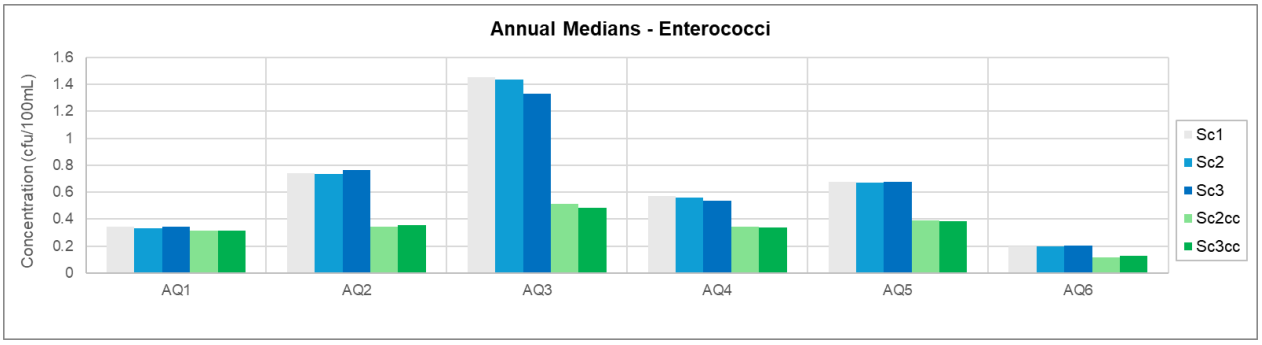


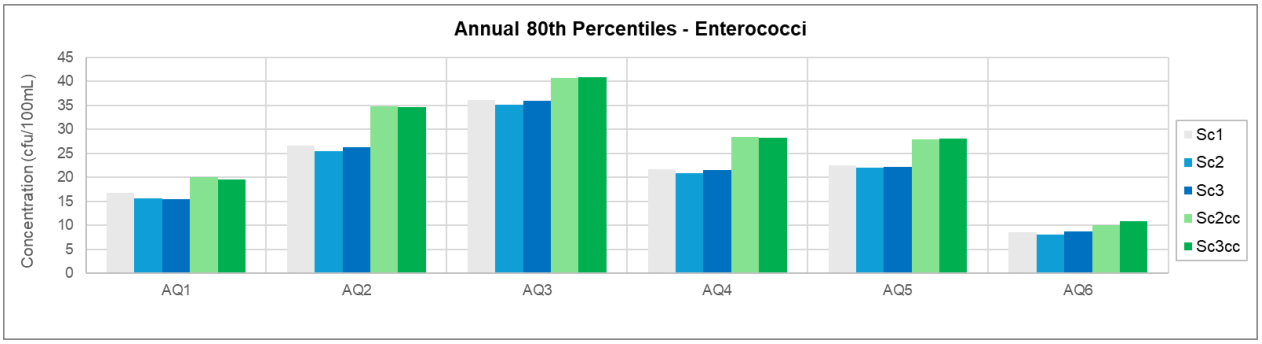


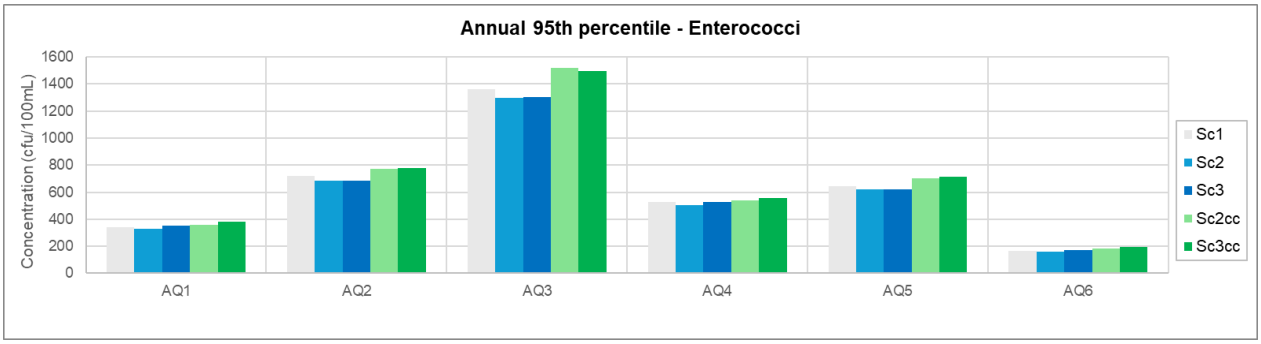
Appendices D3.11 Enterococci

Appendices D3.11.1 Lower rainfall year scenario results (2017-2018)

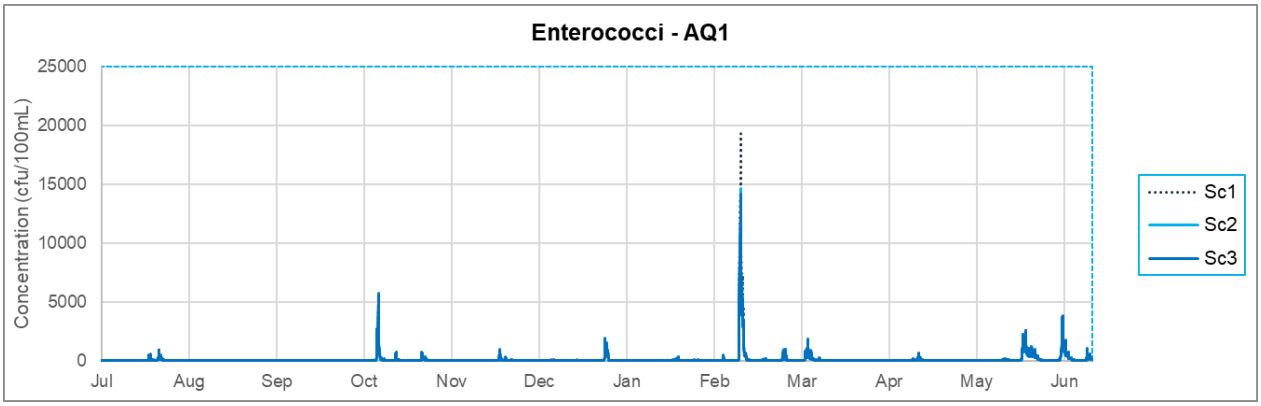
Bar charts

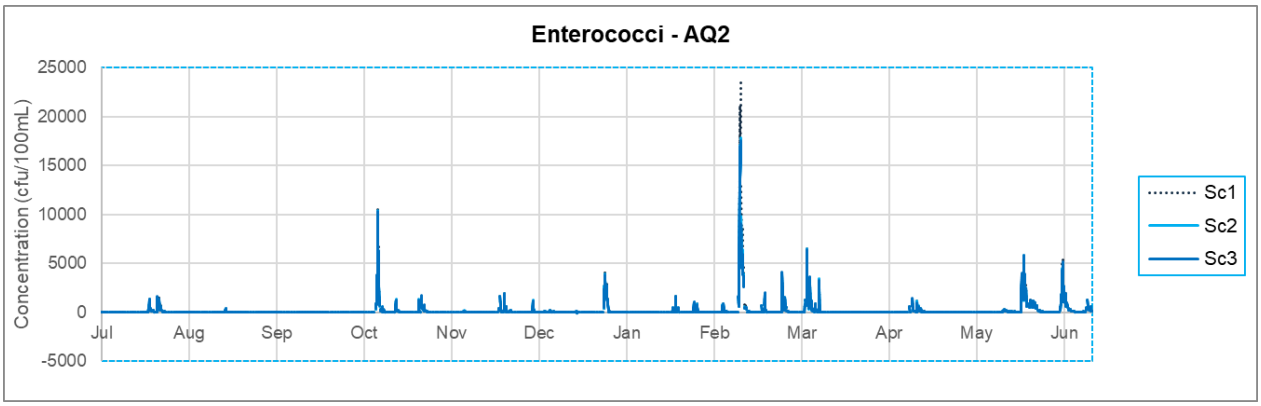


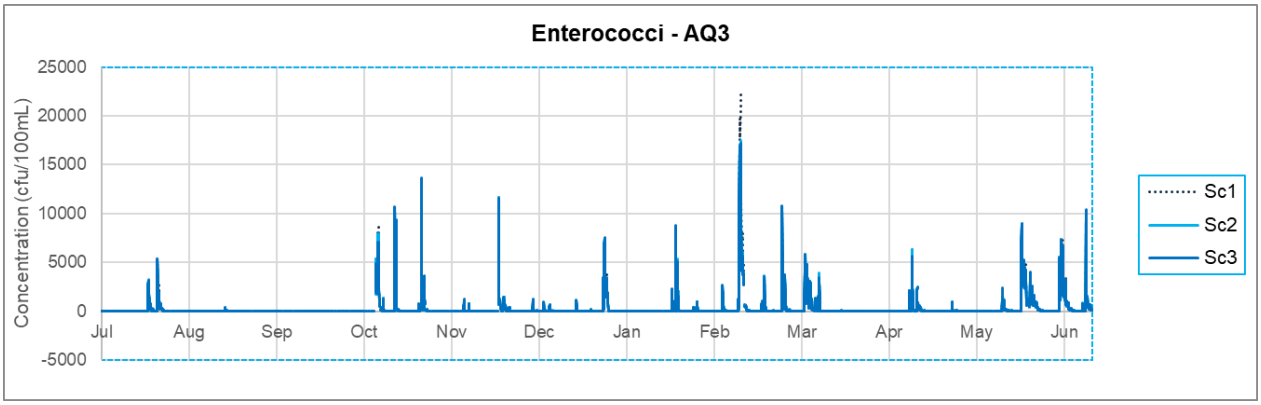


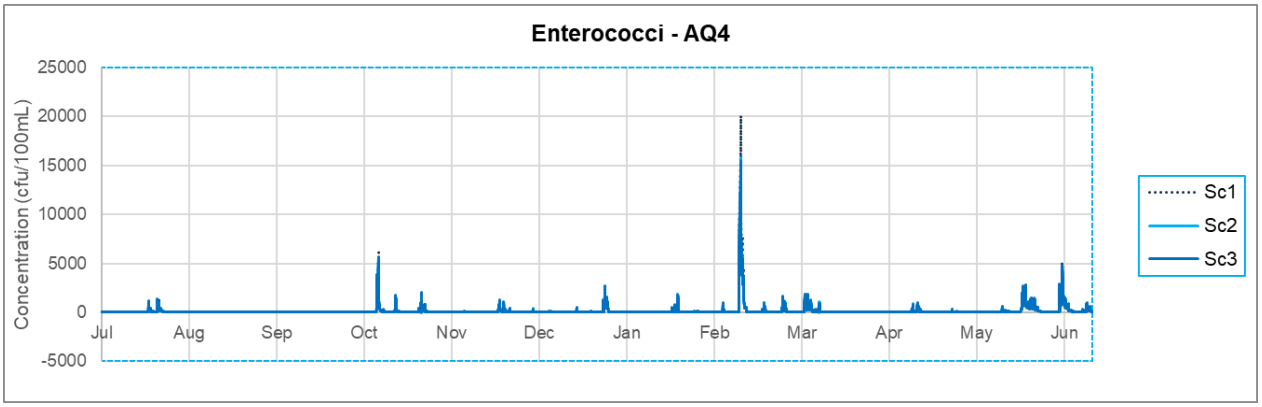


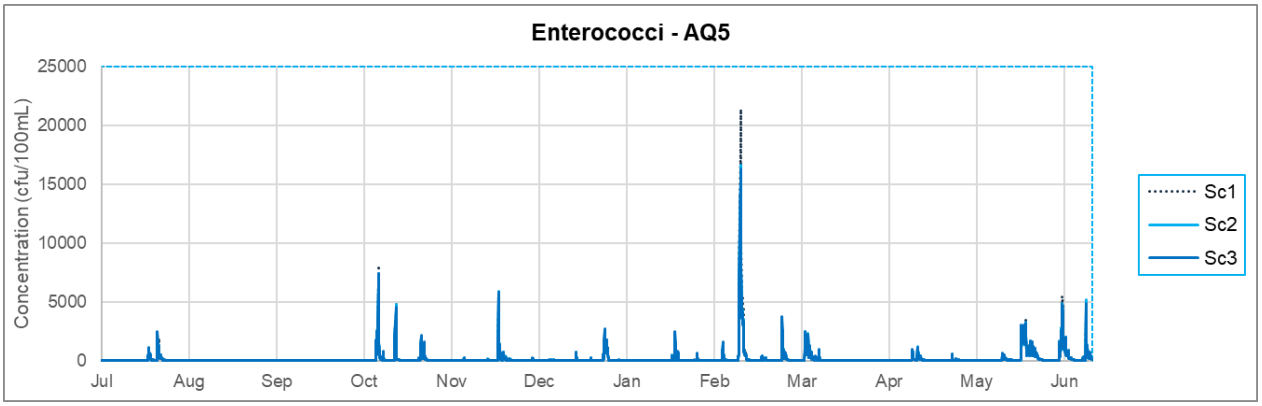
Time series plots

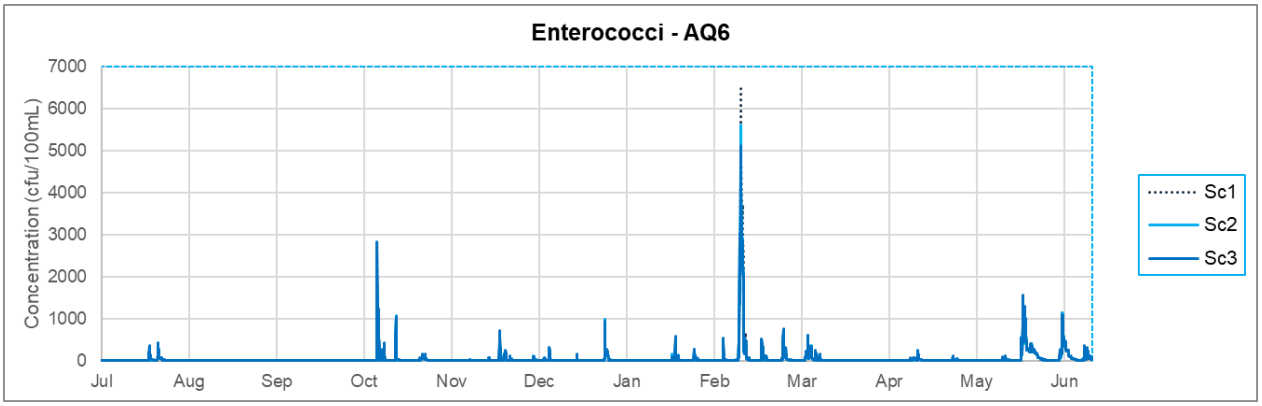






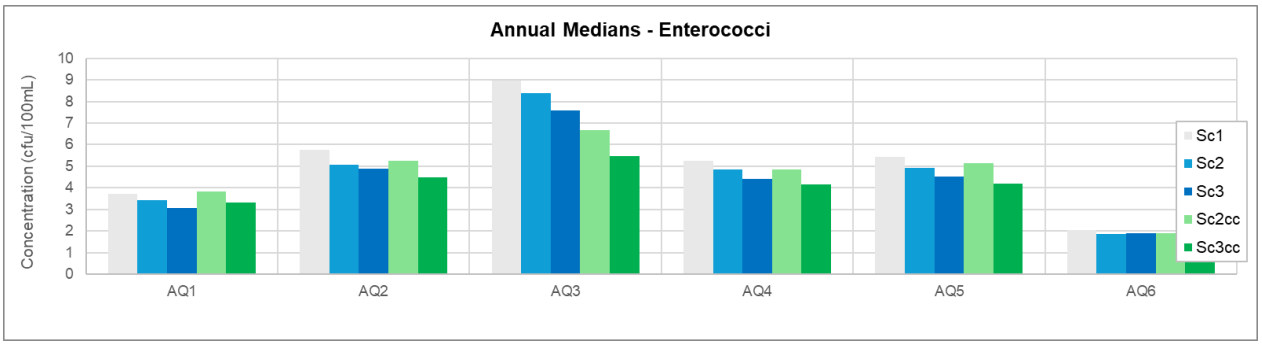


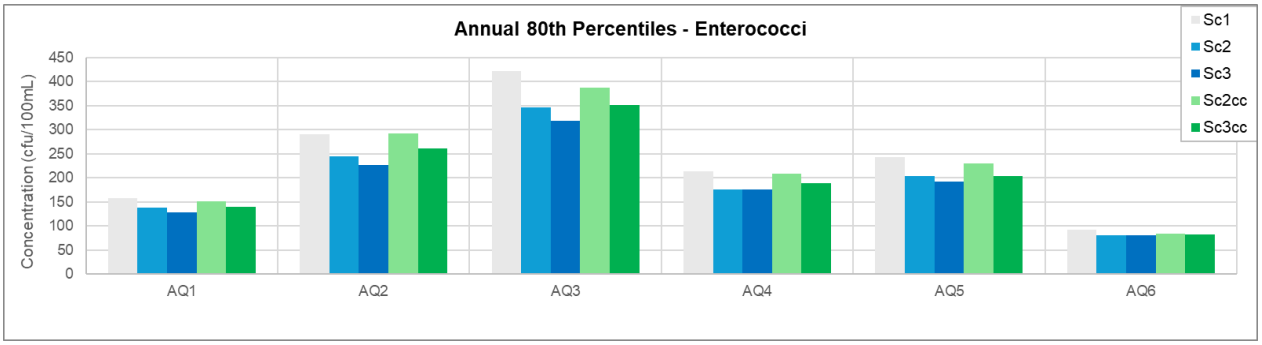


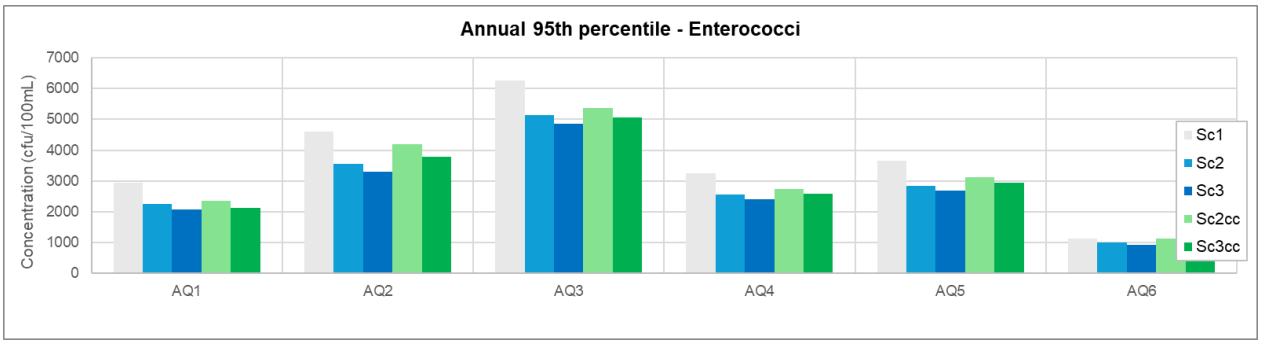


Appendices D3.11.2 Average rainfall year scenario results (2016-2017)

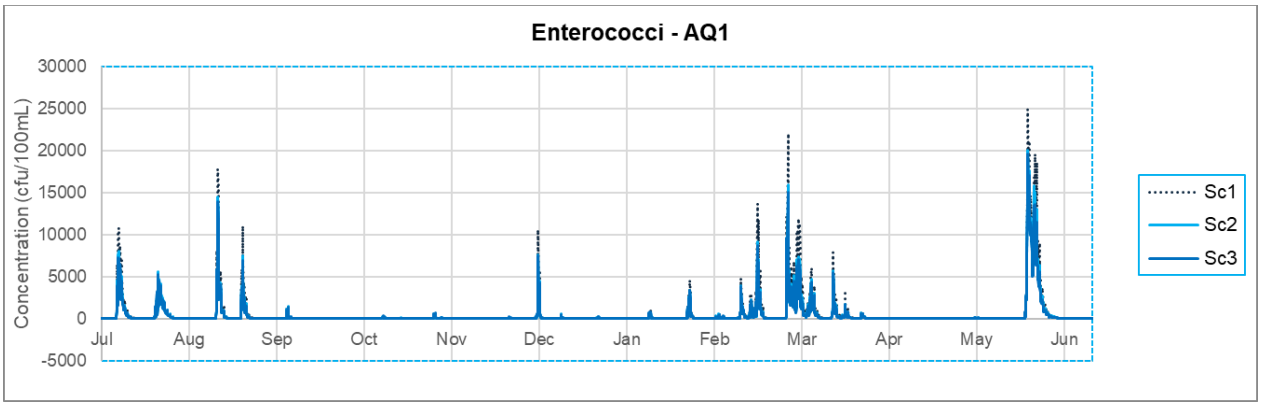
Bar charts

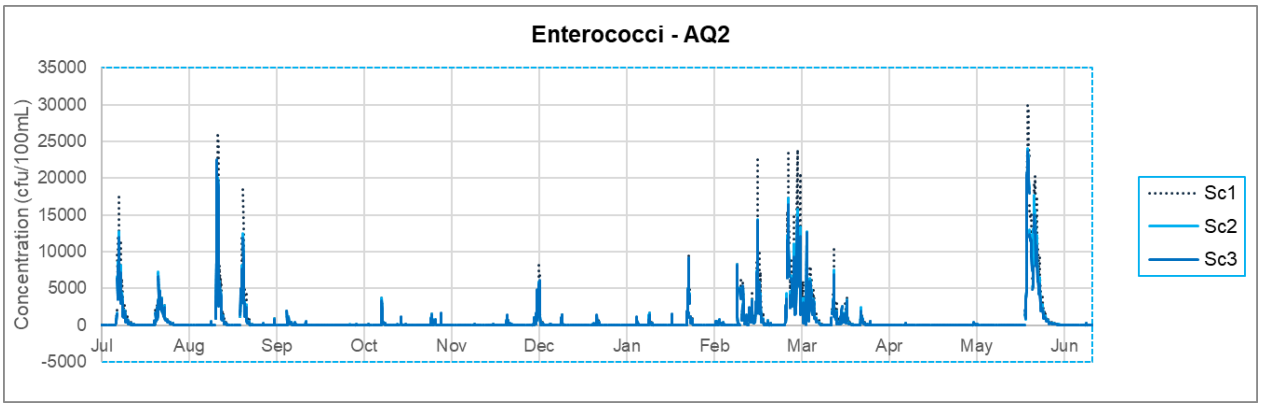


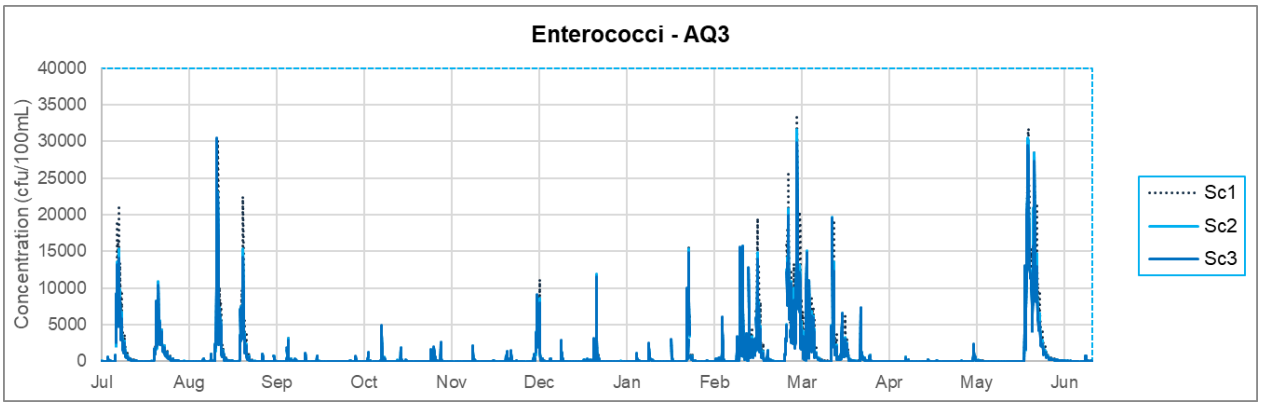


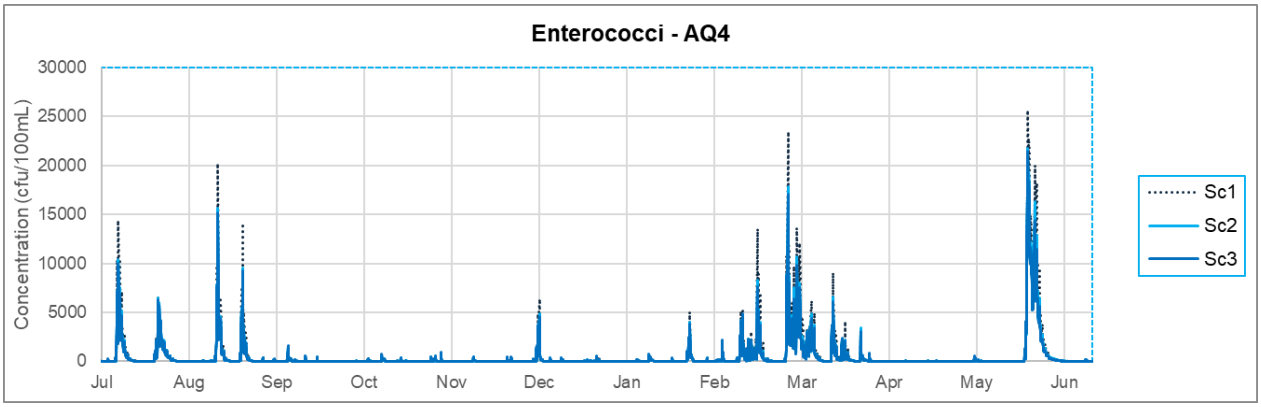


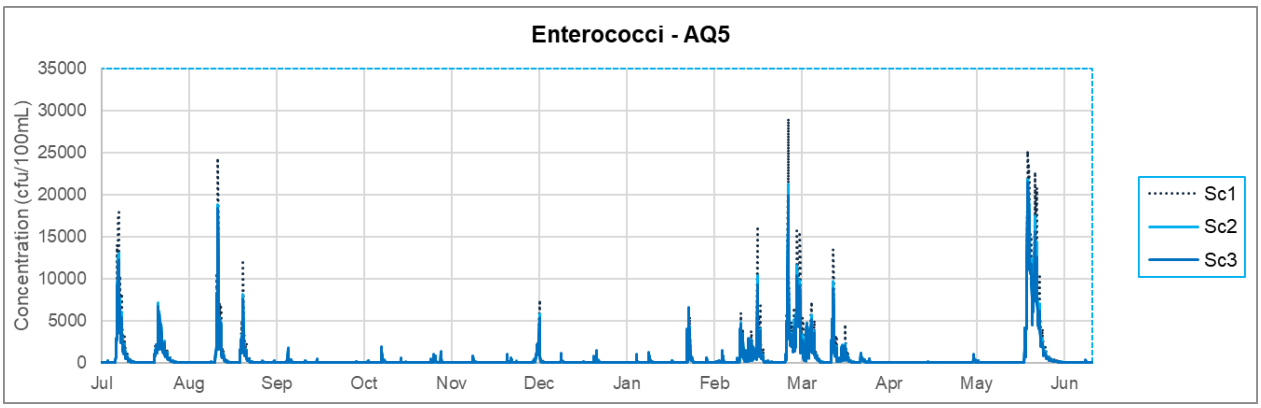
Time series plots

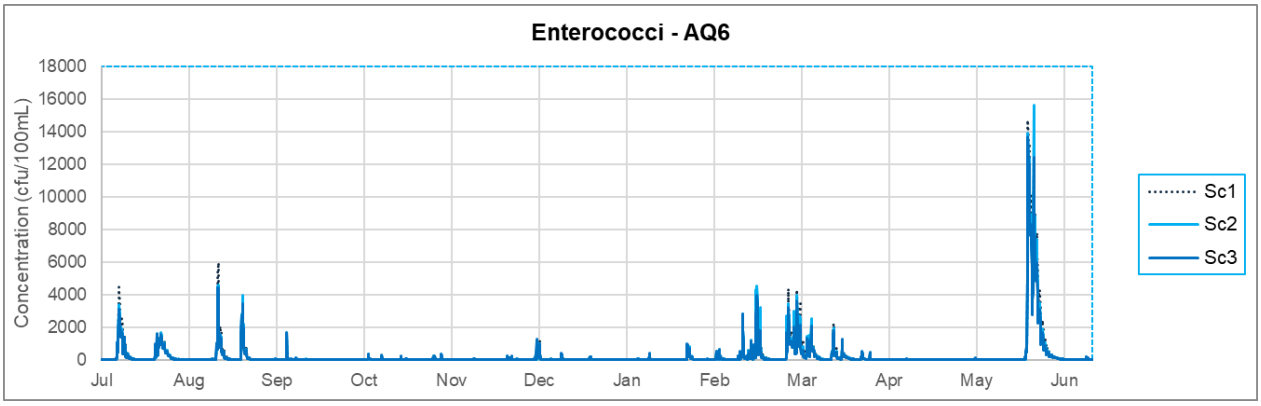





Enterococci - AQ3
Concentration (cfu/100mL)
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

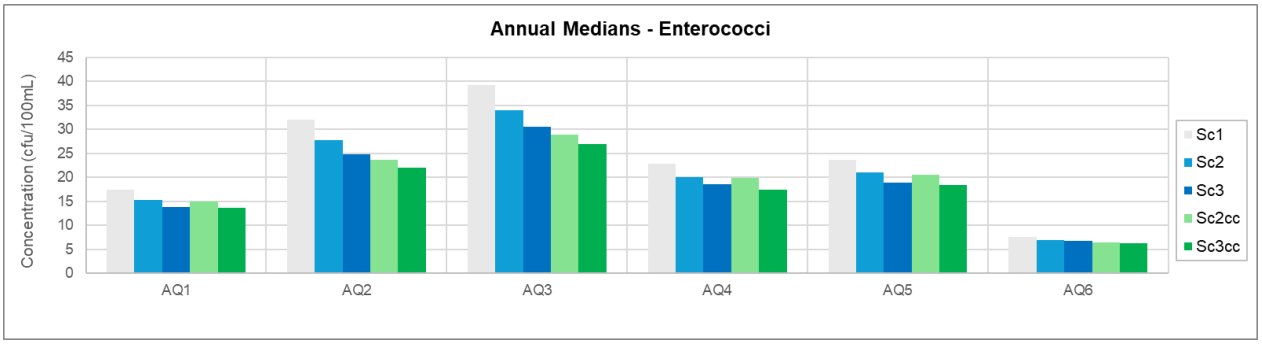

Enterococci - AQ4
Concentration (cfu/100mL)
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

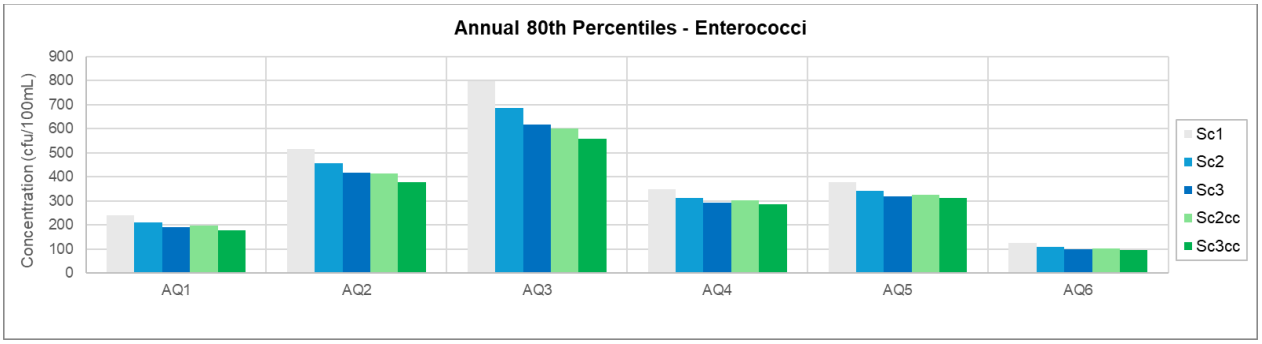

Enterococci - AQ5
Concentration (cfu/100mL)
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

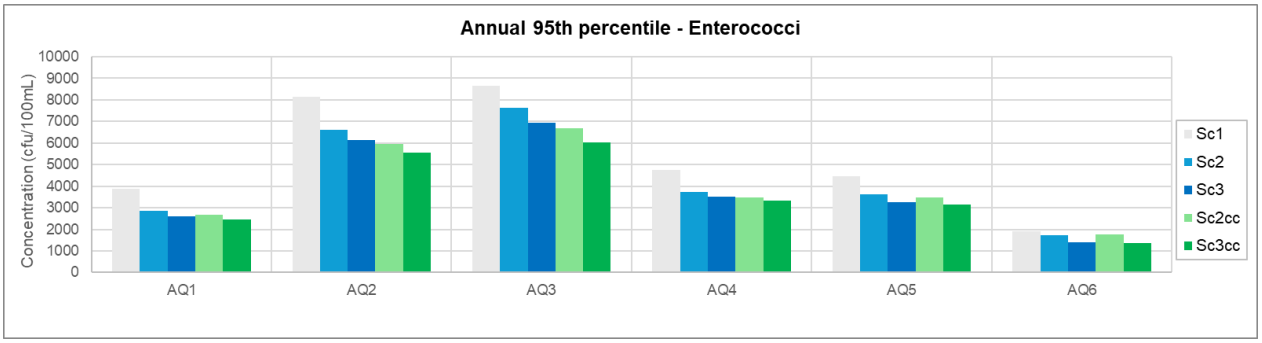

Enterococci - AQ6
Concentration (cfu/100mL)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D3.11.3 Higher rainfall year scenario results (2021-2022)

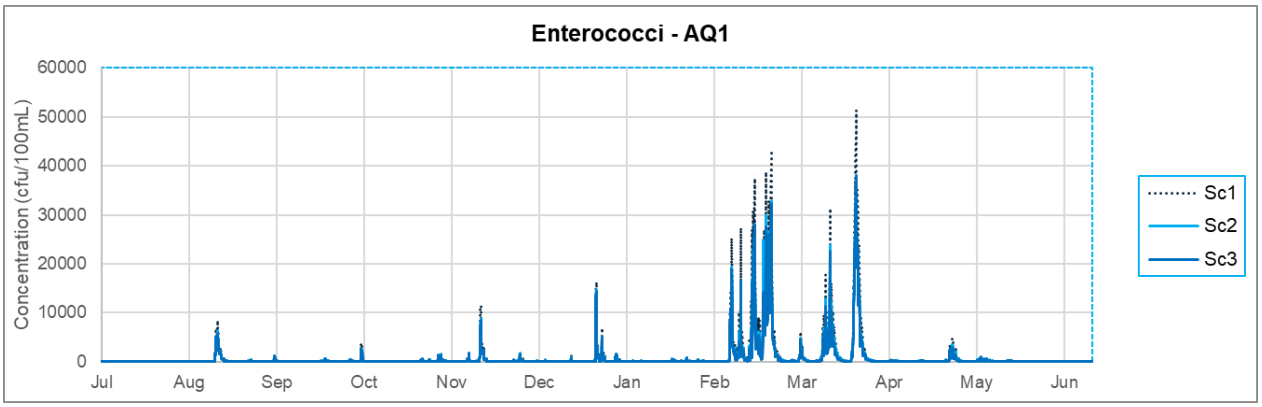
Bar charts

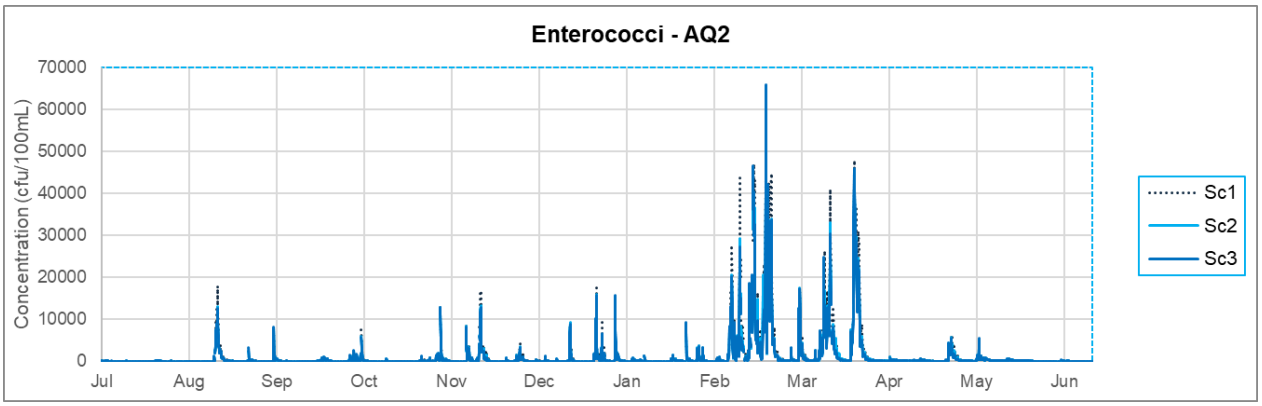


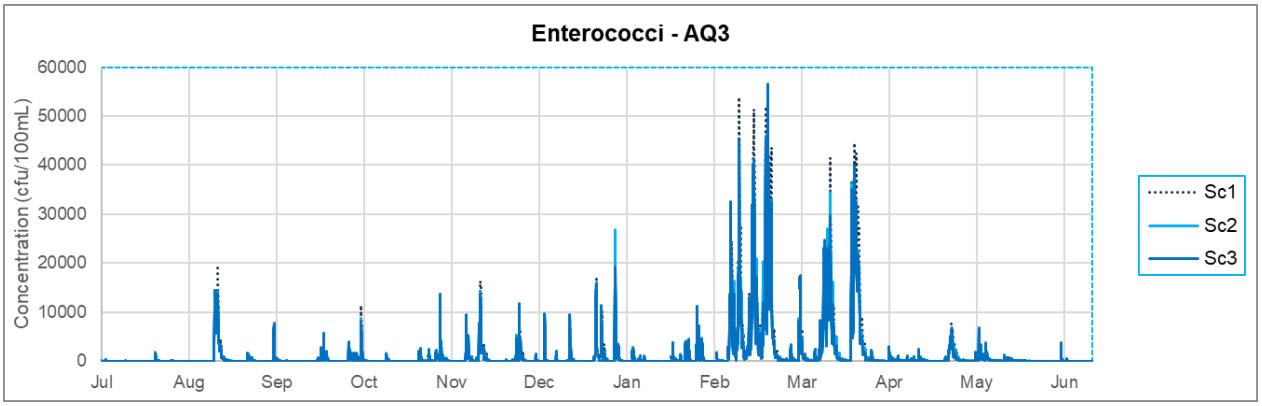


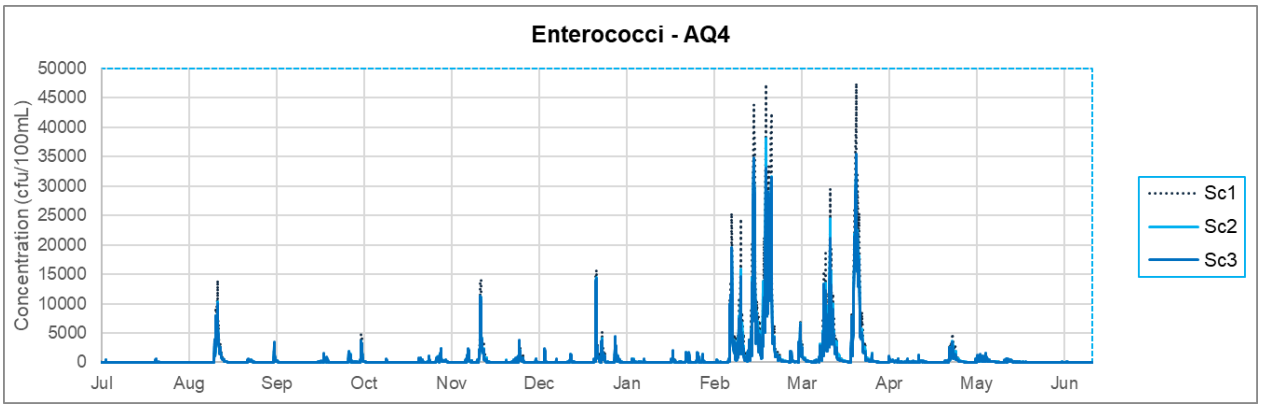


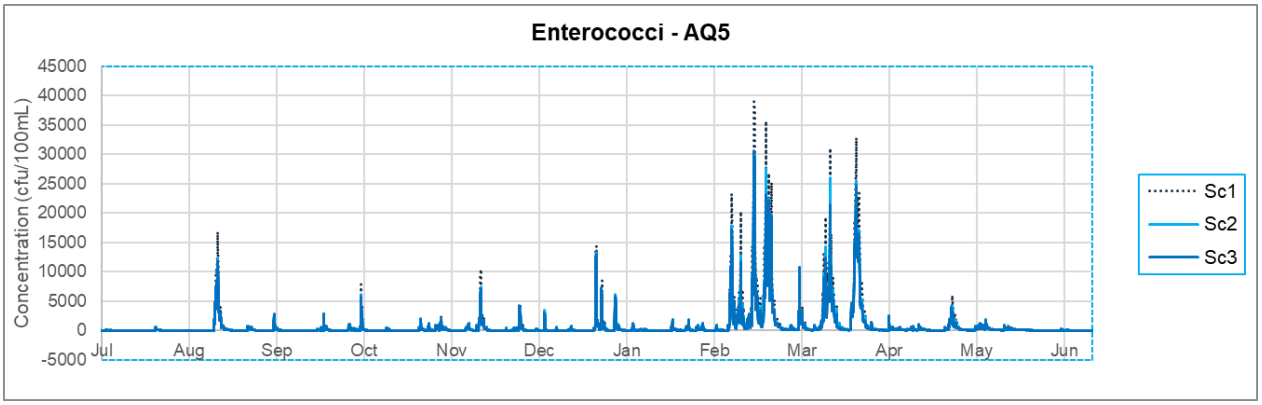
Time series plots

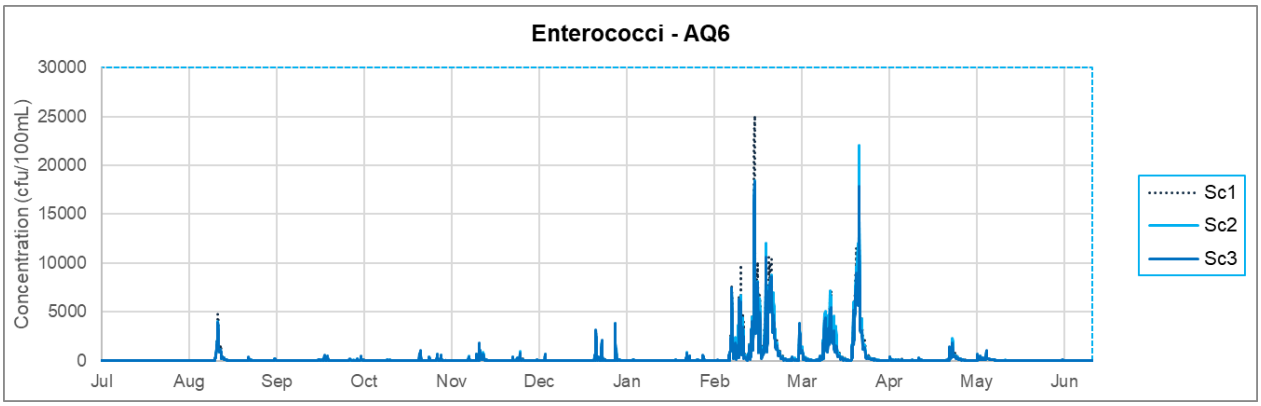



Enterococci - AQ2
Concentration (cfu/100mL)
70000
60000
50000
40000
30000
20000
10000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Enterococci - AQ3
Concentration (cfu/100mL)
60000
50000
40000
30000
20000
10000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Enterococci - AQ4
Concentration (cfu/100mL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Enterococci - AQ5
Concentration (cfu/100mL)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

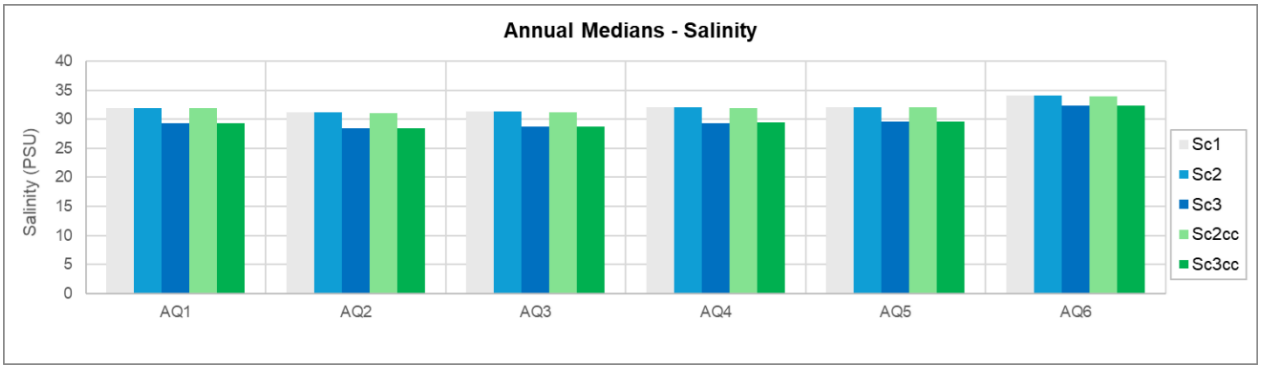

Enterococci - AQ6
Concentration (cfu/100mL)
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

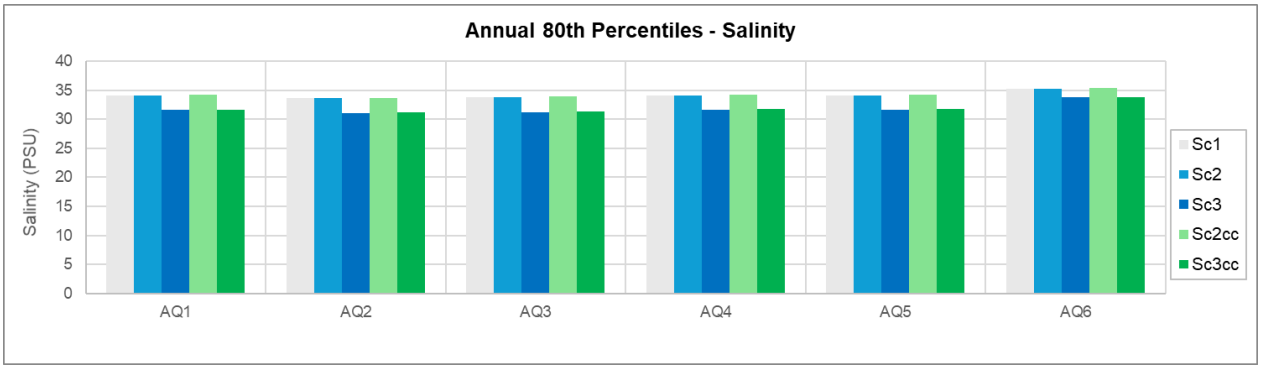
Appendices D4 Aquatic ecology sites results with climate change

Appendices D4.1 Salinity

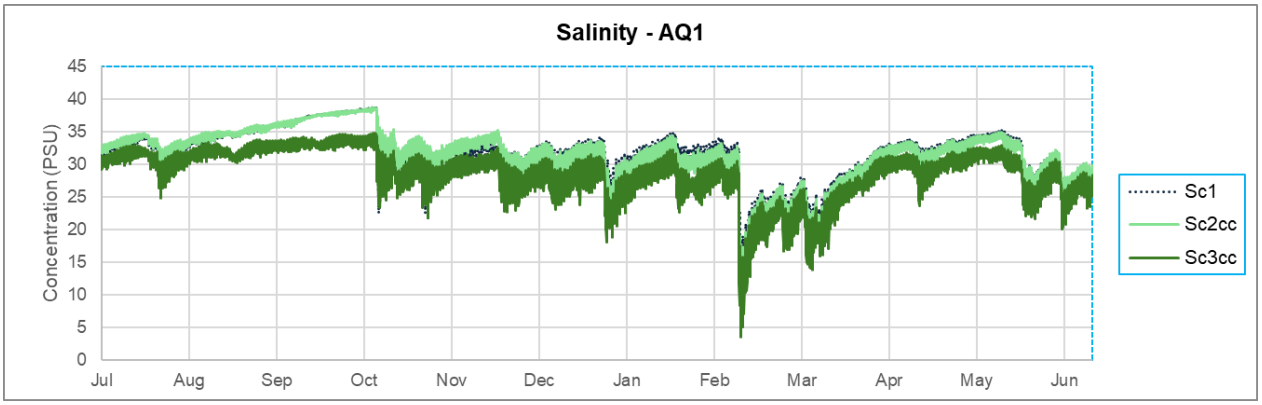
Appendices D4.1.1 Lower rainfall year scenario results (2017-2018)

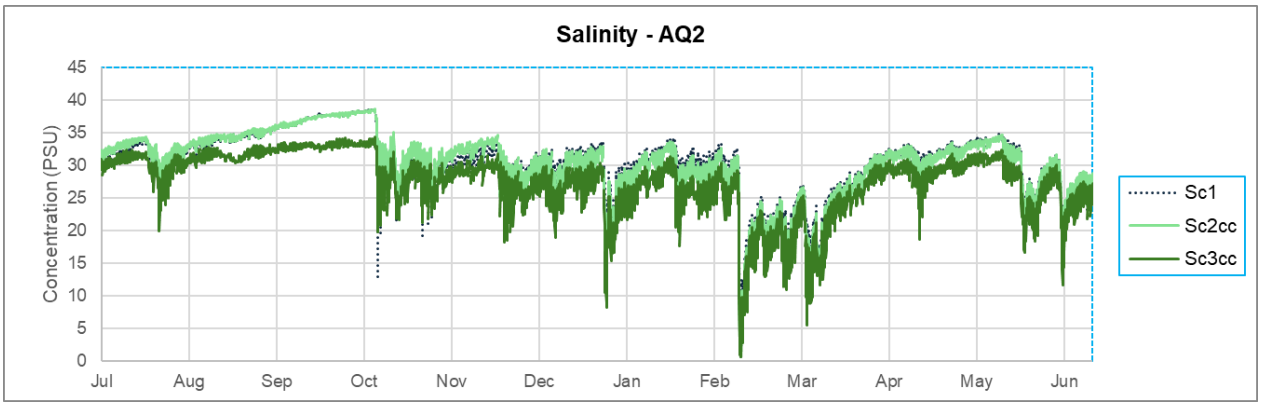
Bar charts

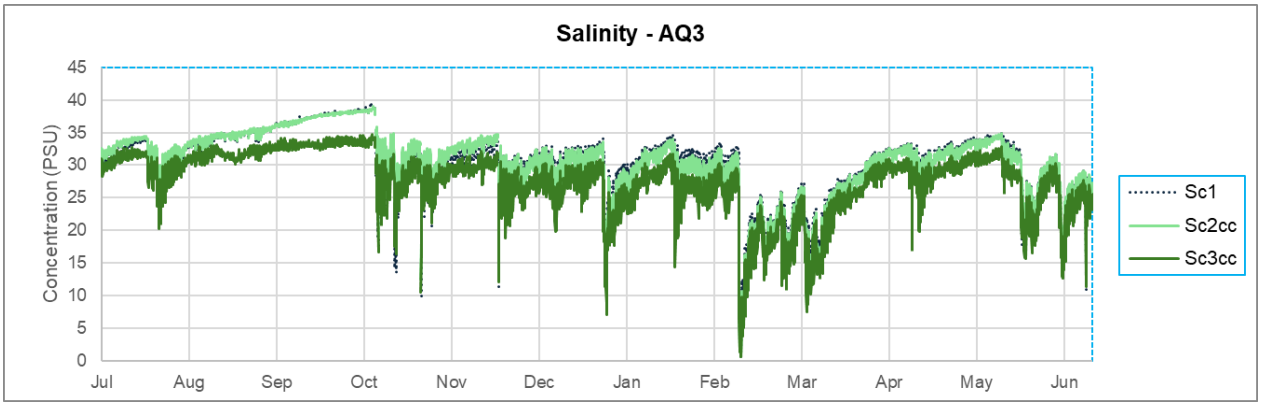


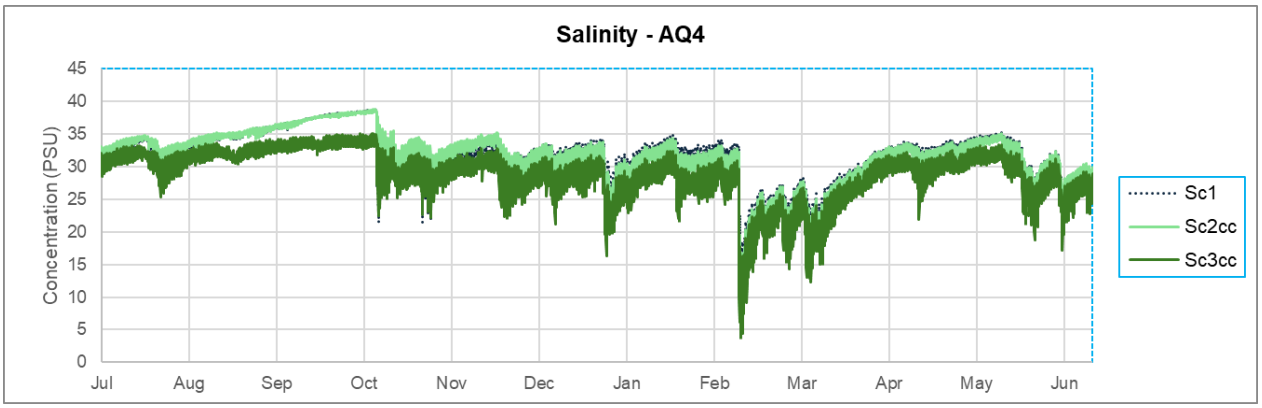


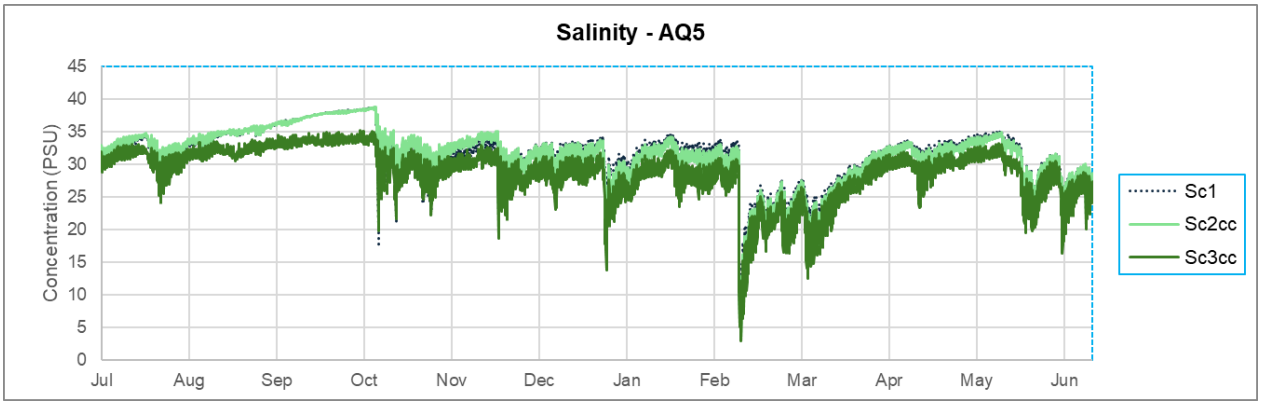
Time series plots

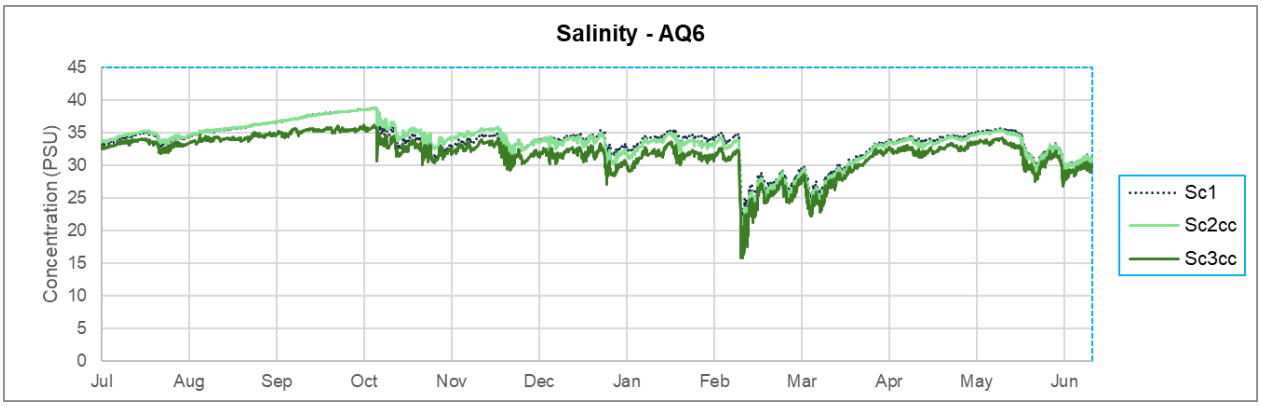



Salinity - AQ2
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Salinity - AQ3
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

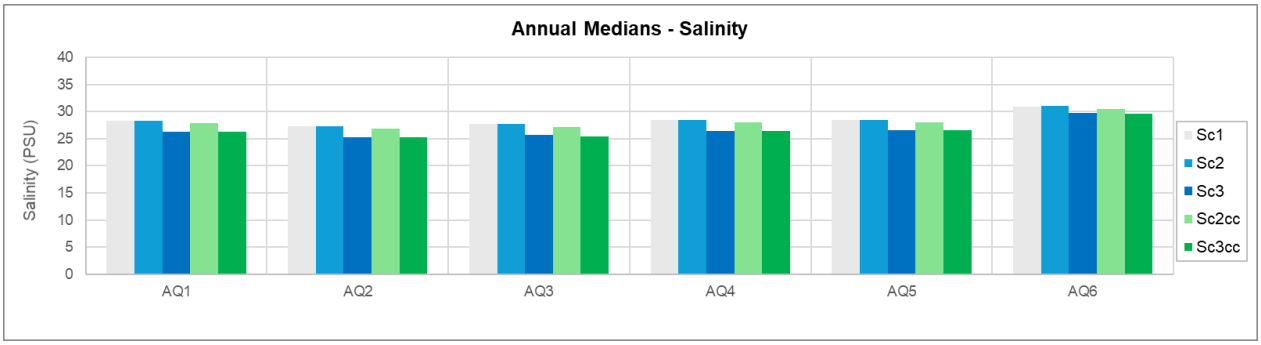

Salinity - AQ4
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

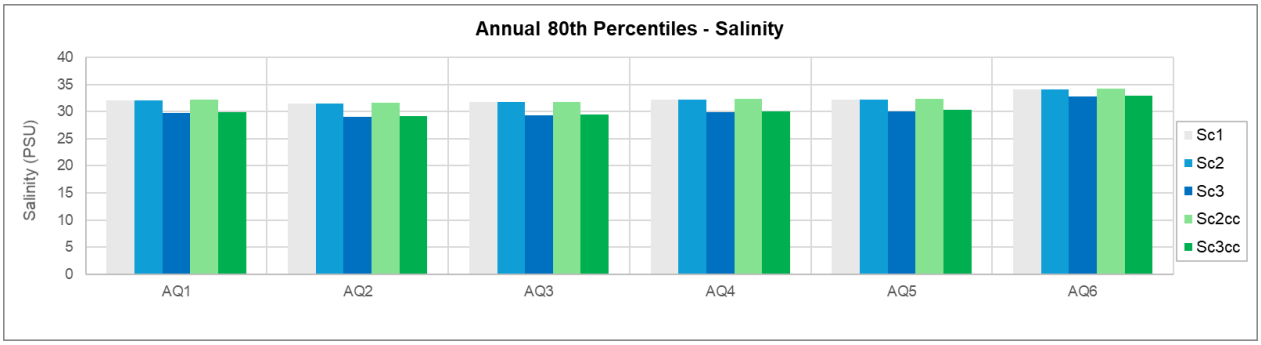

Salinity - AQ5
Concentration (PSU)
45
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



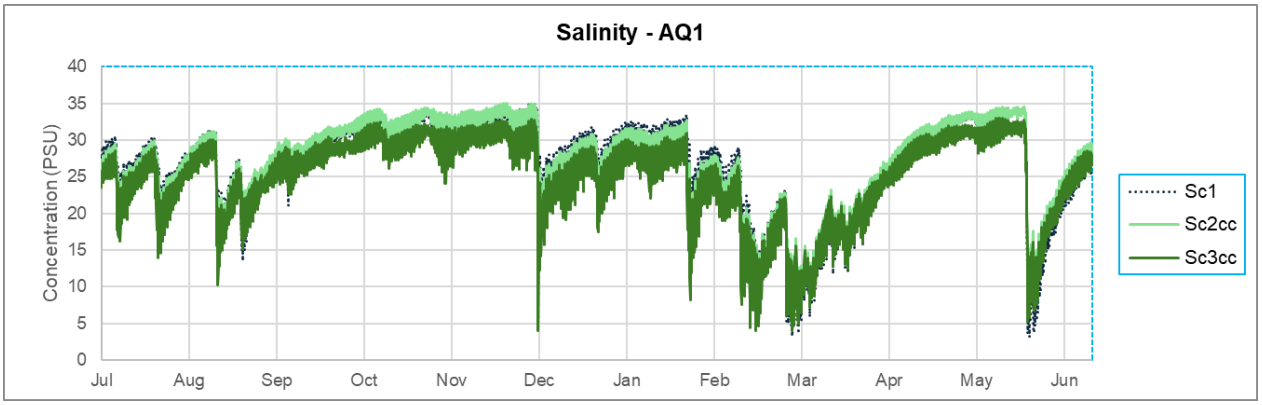
Appendices D4.1.2 Average rainfall year scenario results (2016-2017)

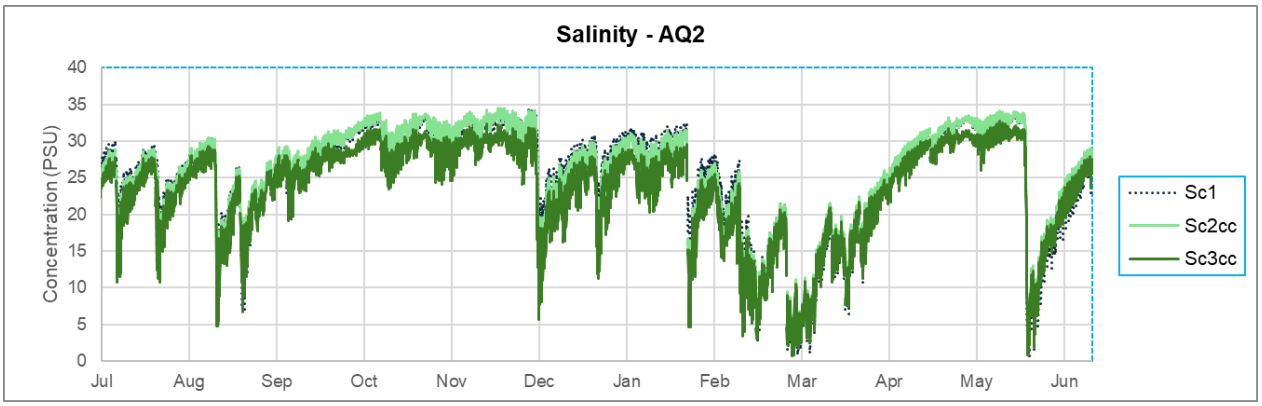
Bar charts

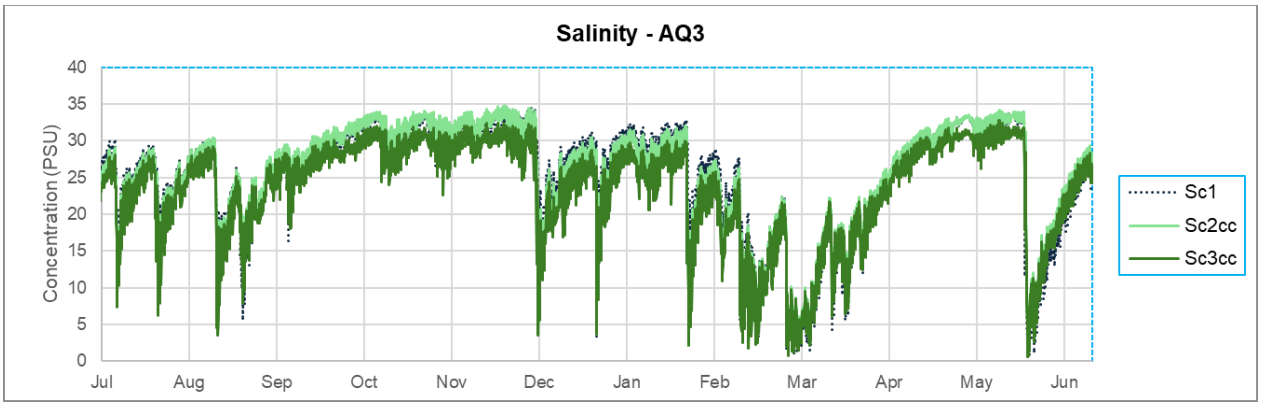


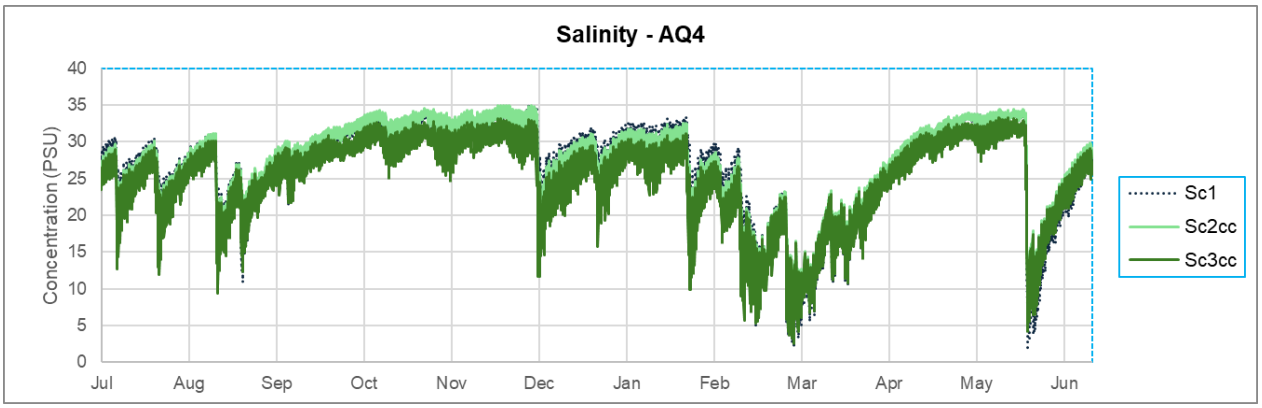


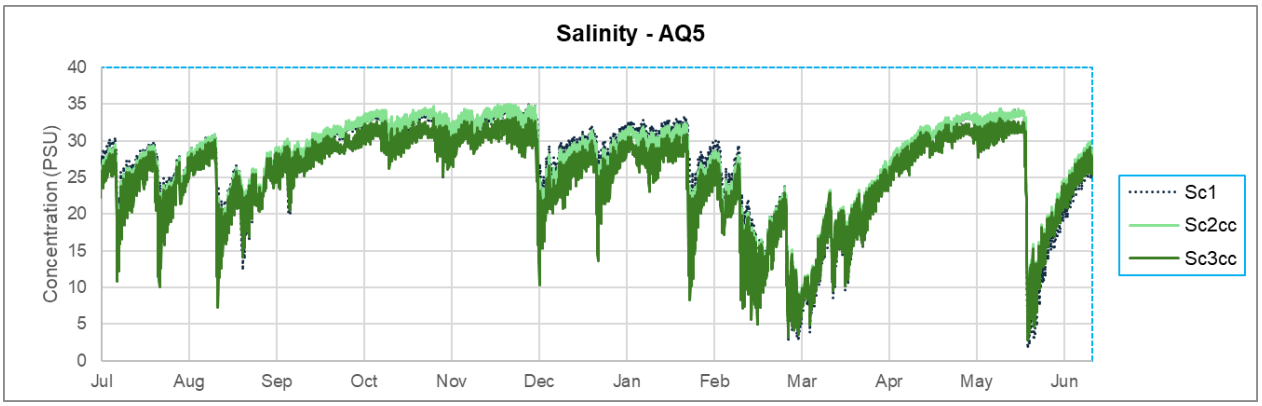
Time series plots

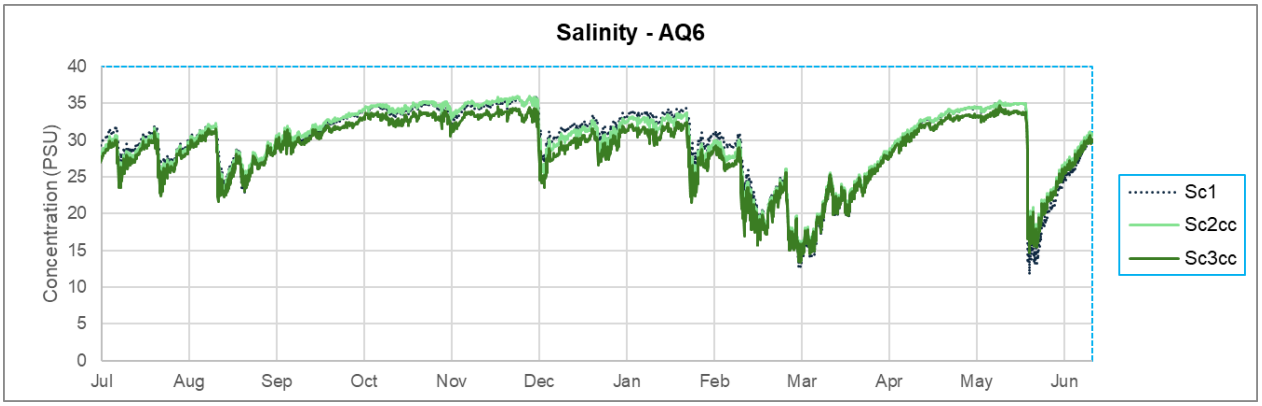






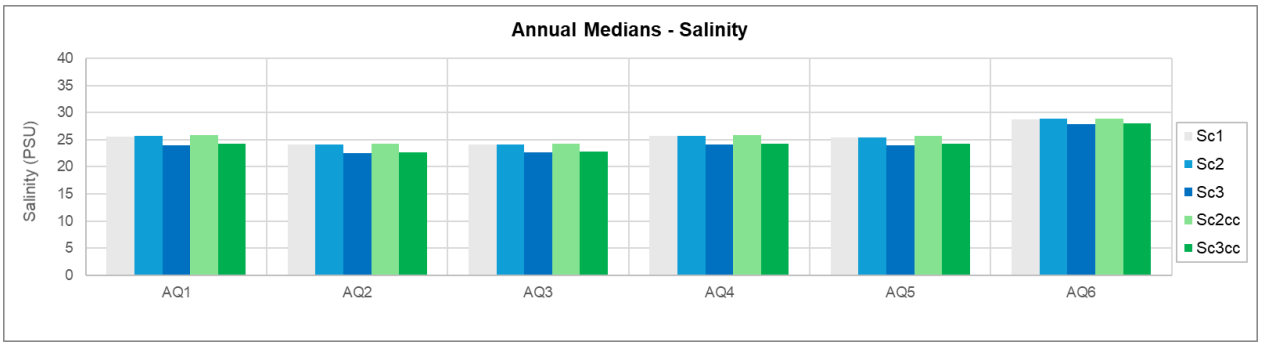


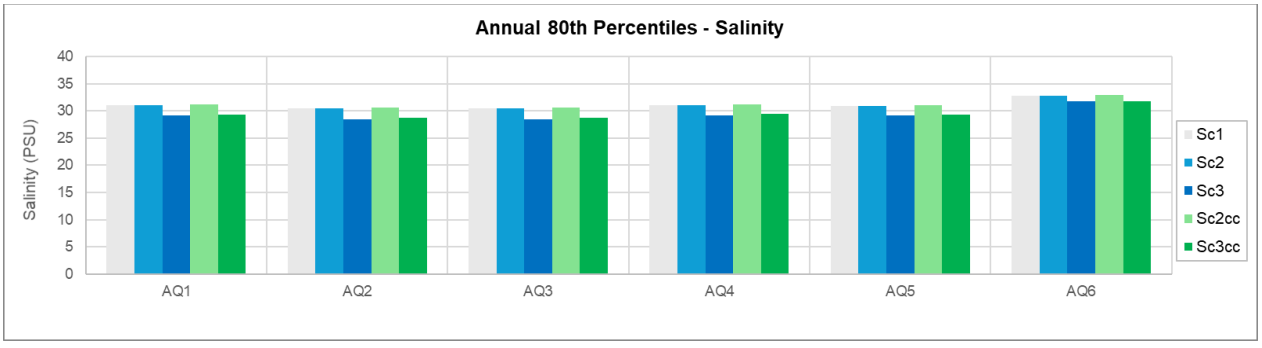




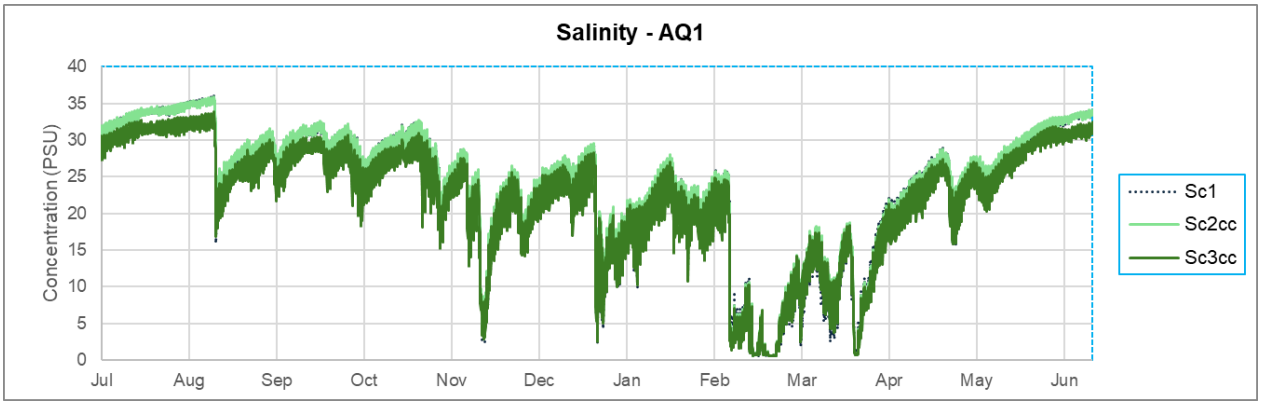
Appendices D4.1.3 Higher rainfall year scenario results (2021-2022)

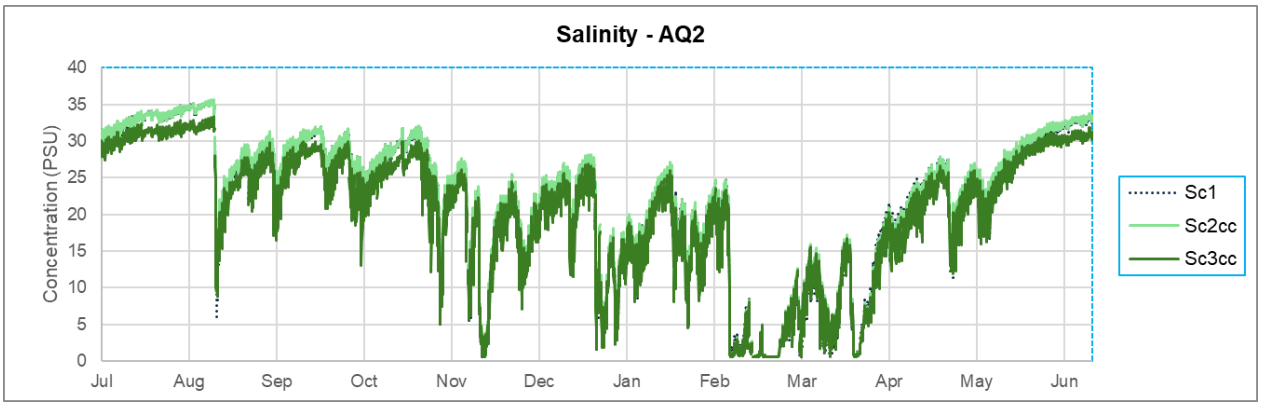
Bar charts

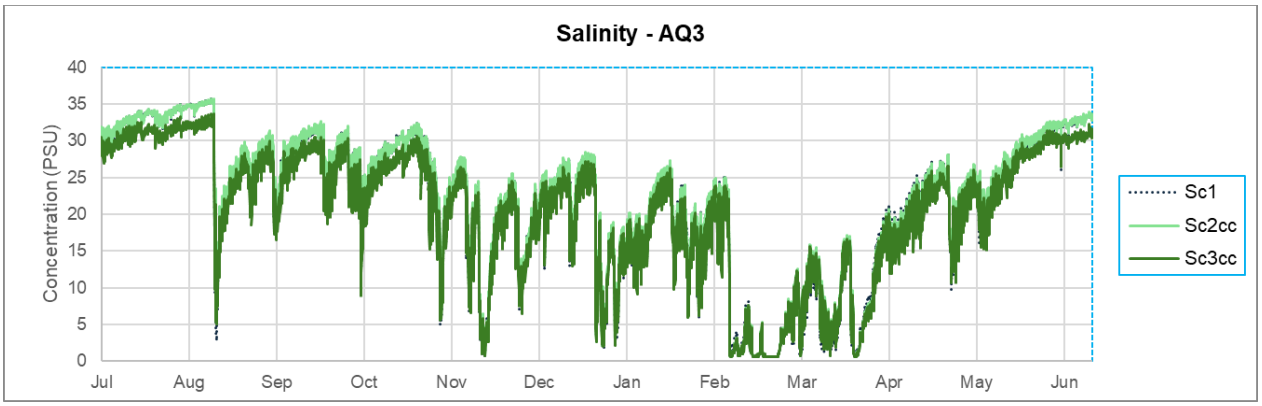


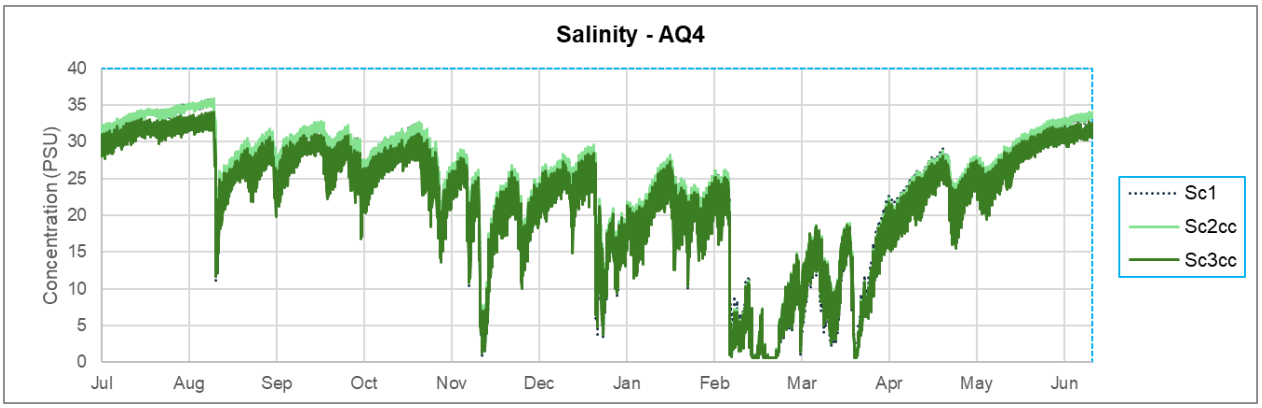


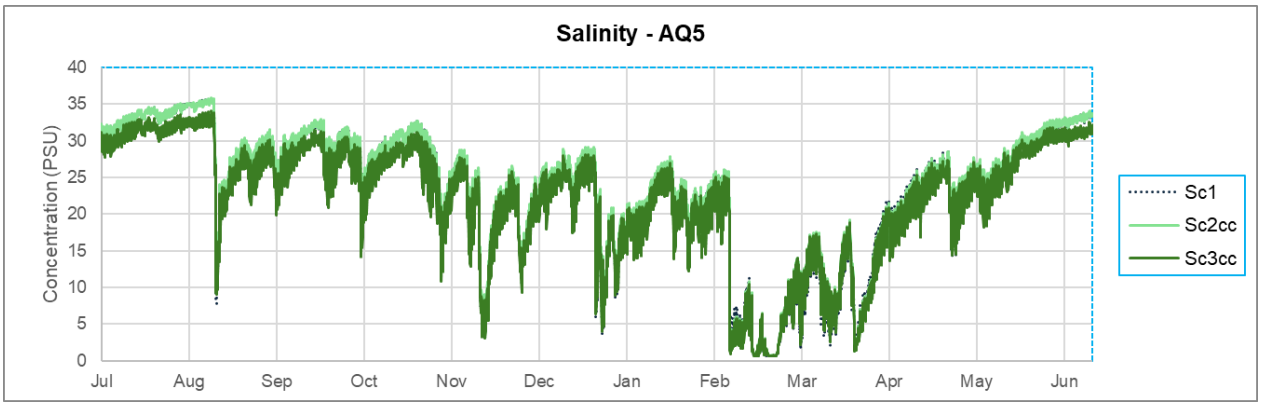
Time series plots







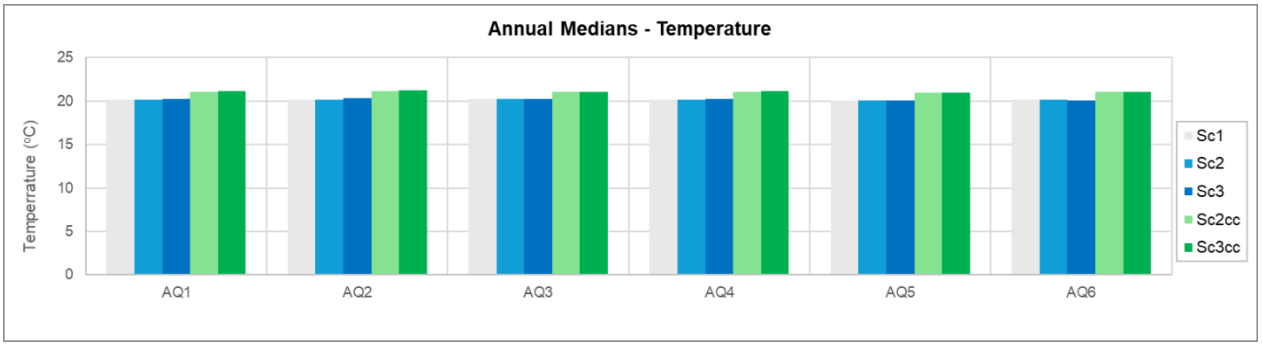


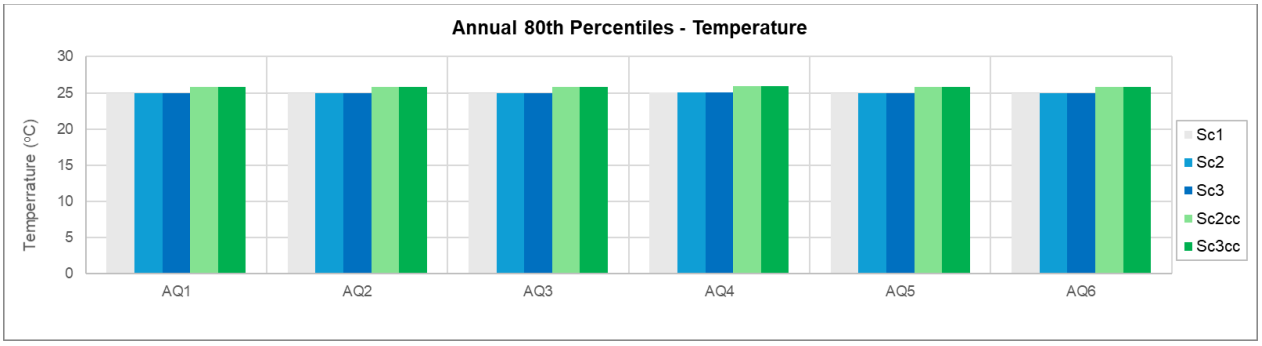


Appendices D4.2 Temperature

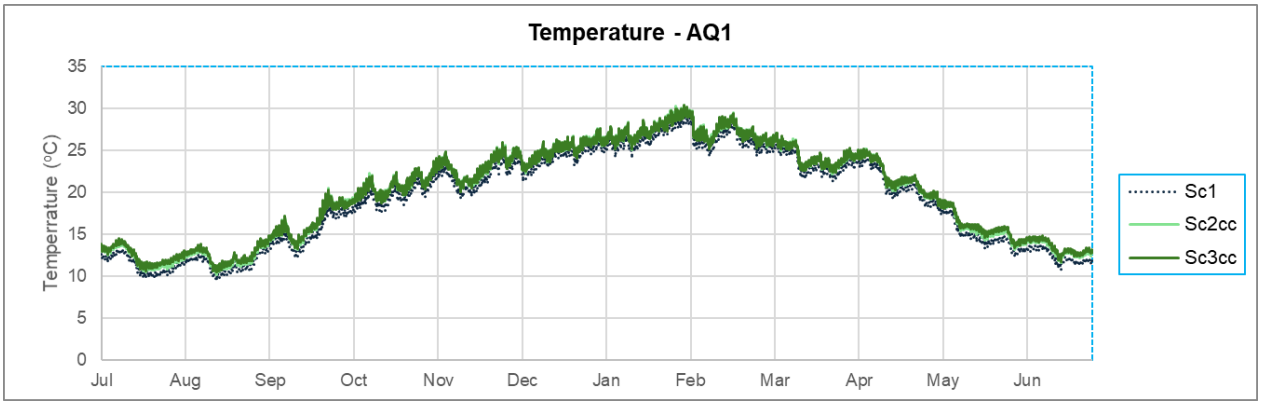
Appendices D4.2.1 Lower rainfall year scenario results (2017-2018)

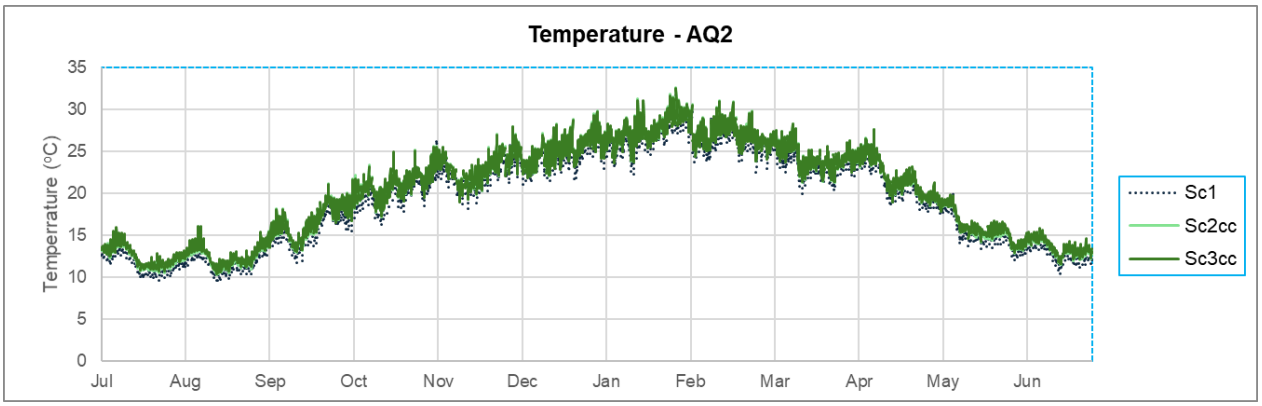
Bar charts

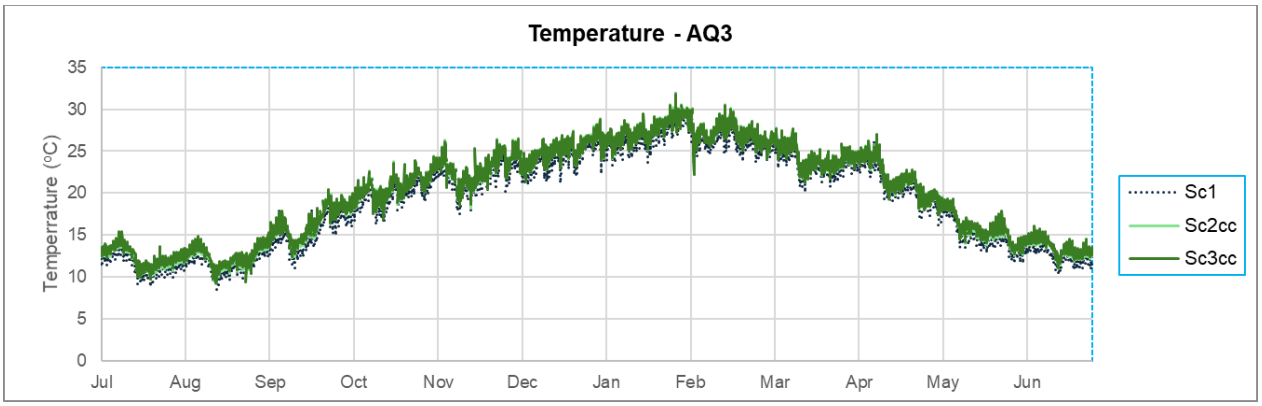


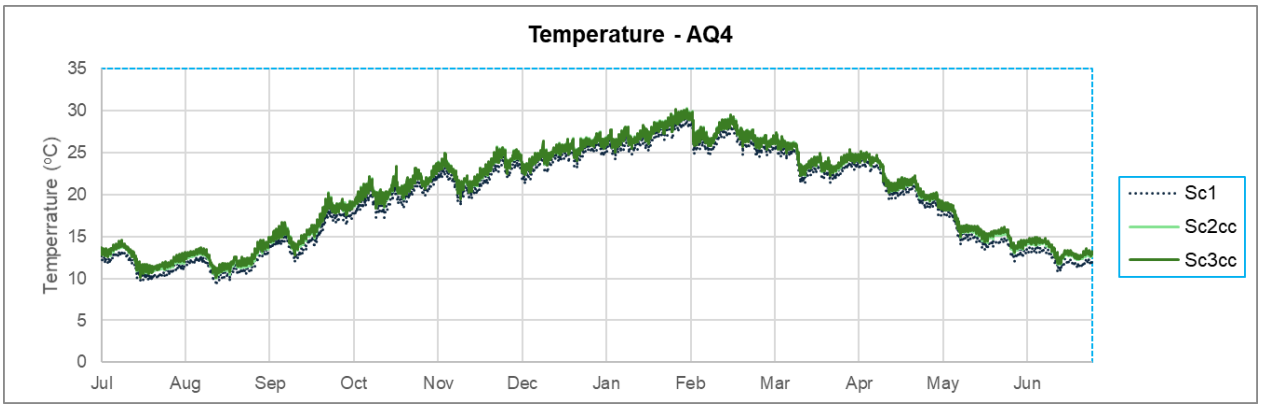


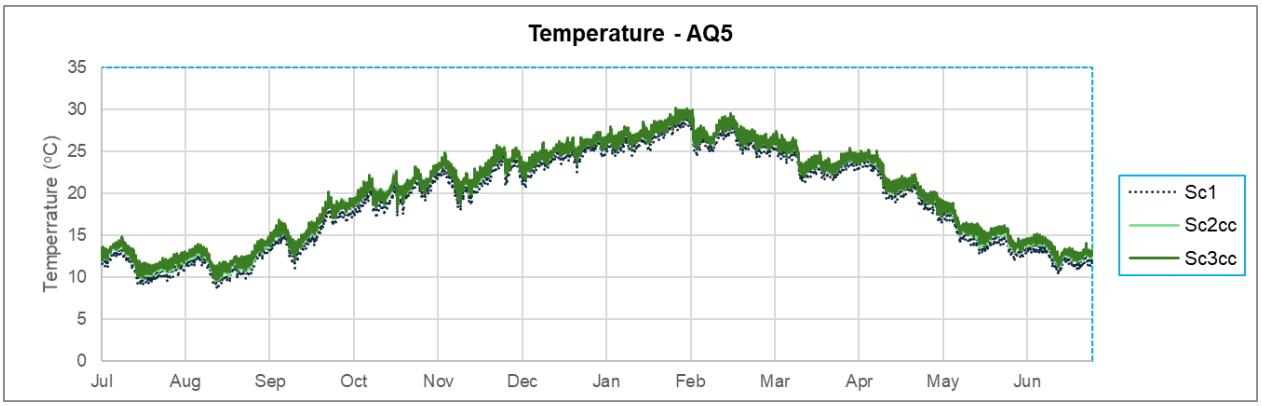
Time series plots

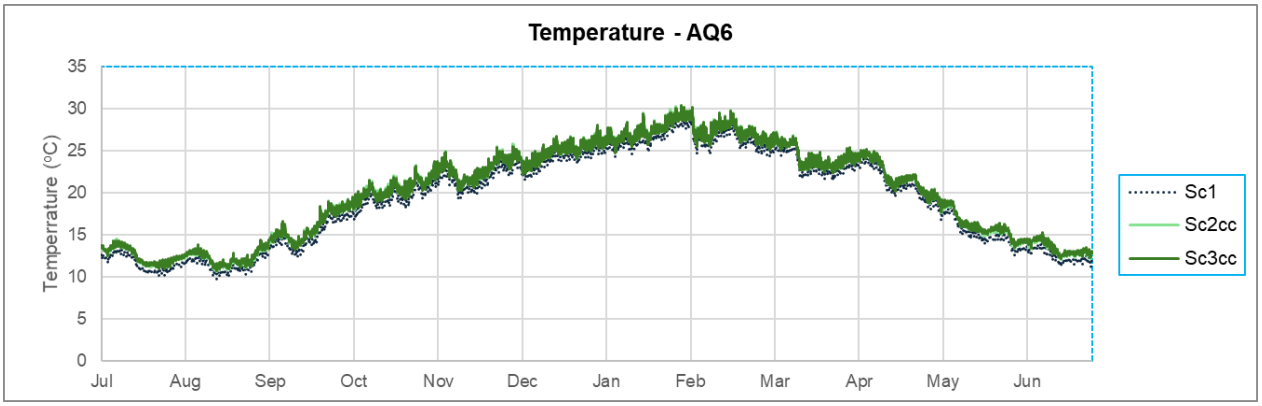






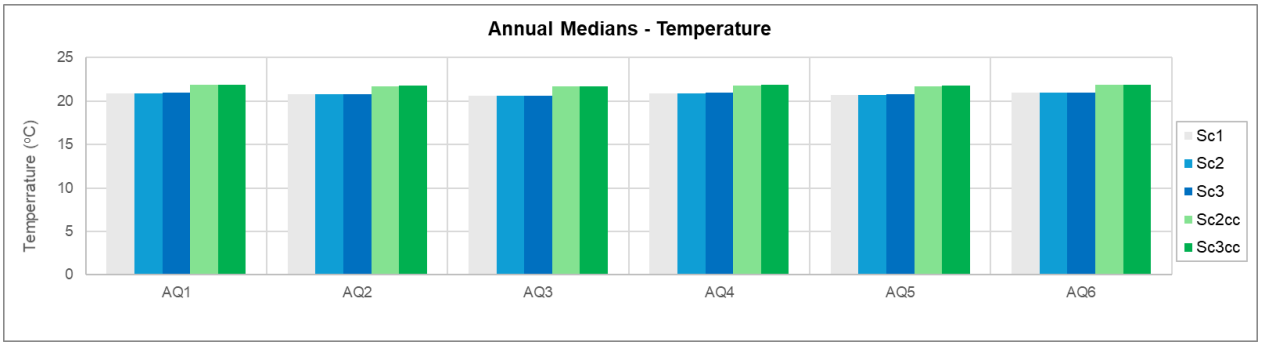


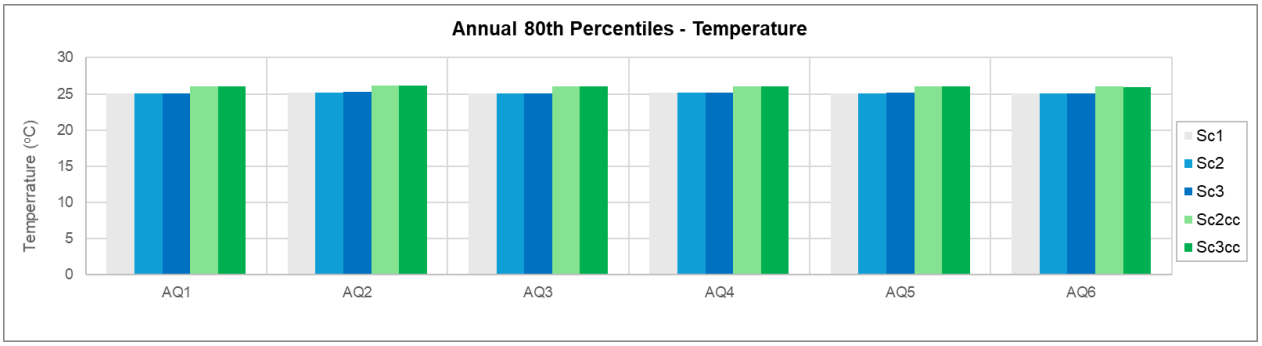




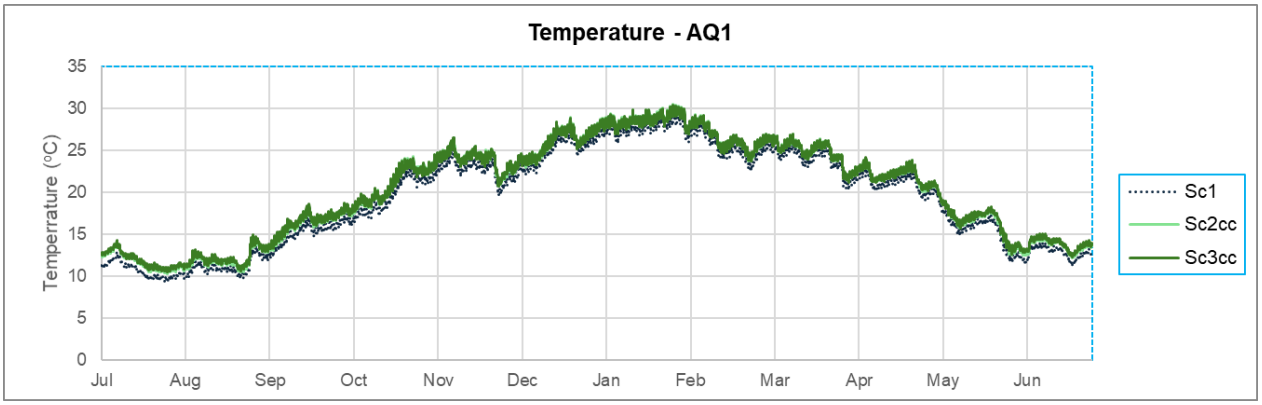
Appendices D4.2.2 Average rainfall year scenario results (2016-2017)

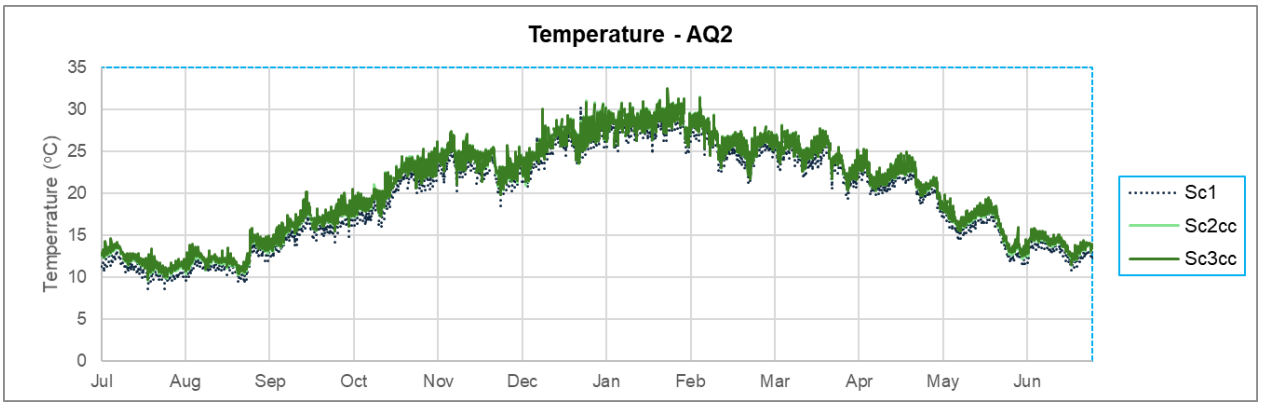
Bar charts

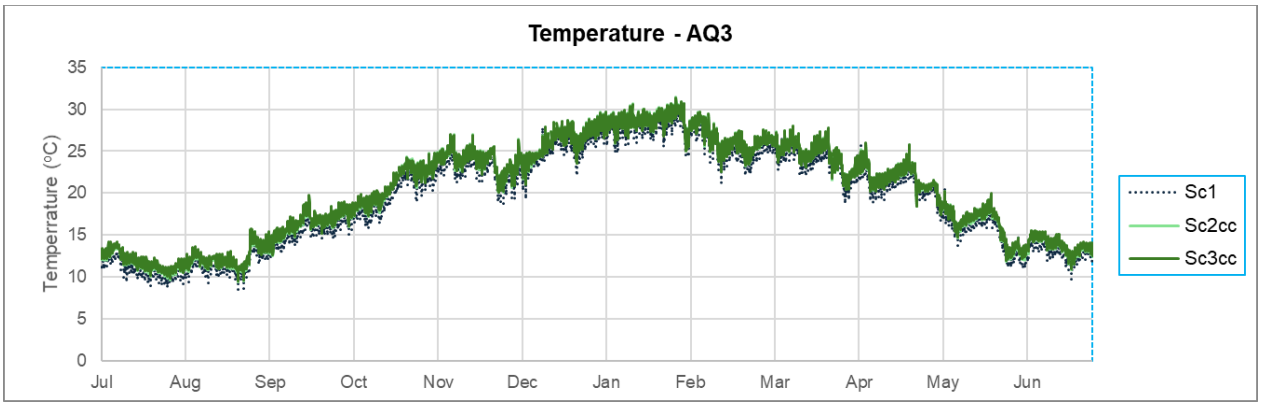


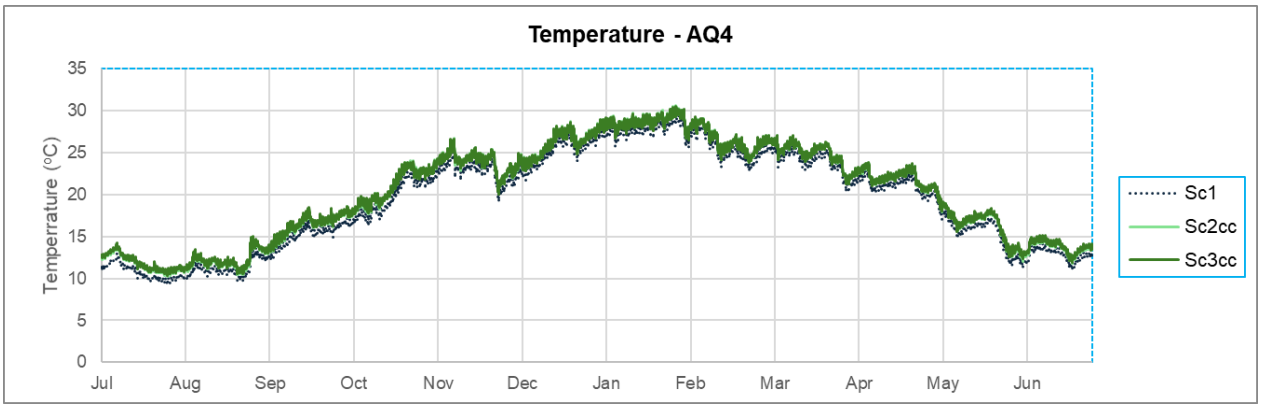


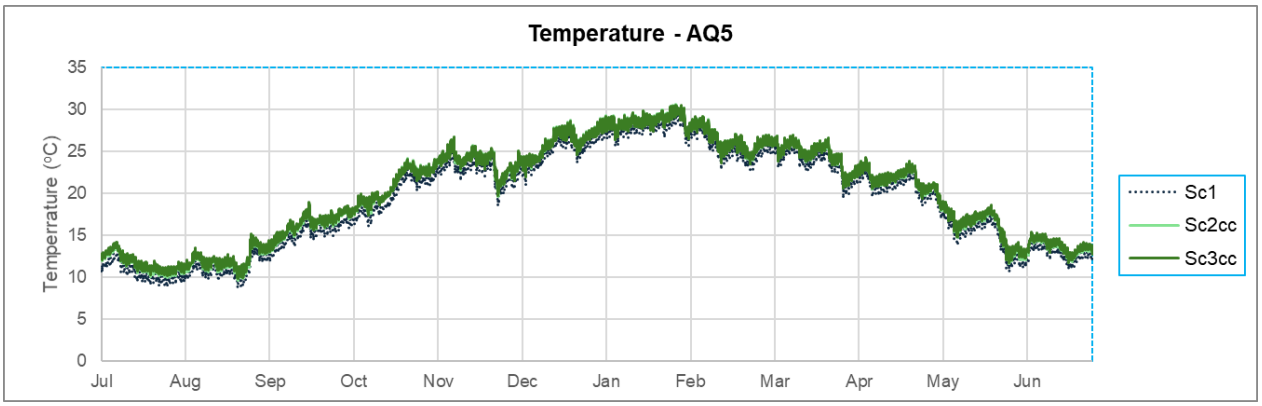
Time series plots

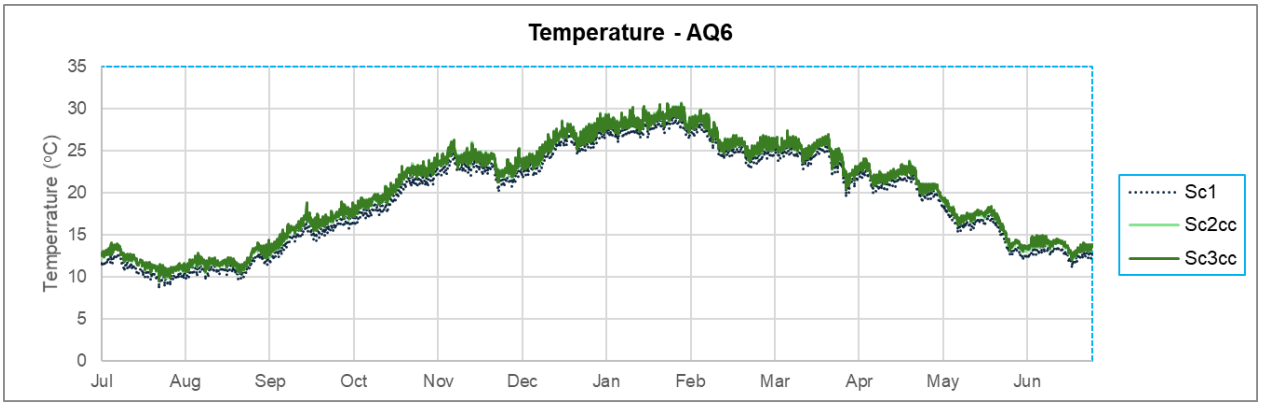






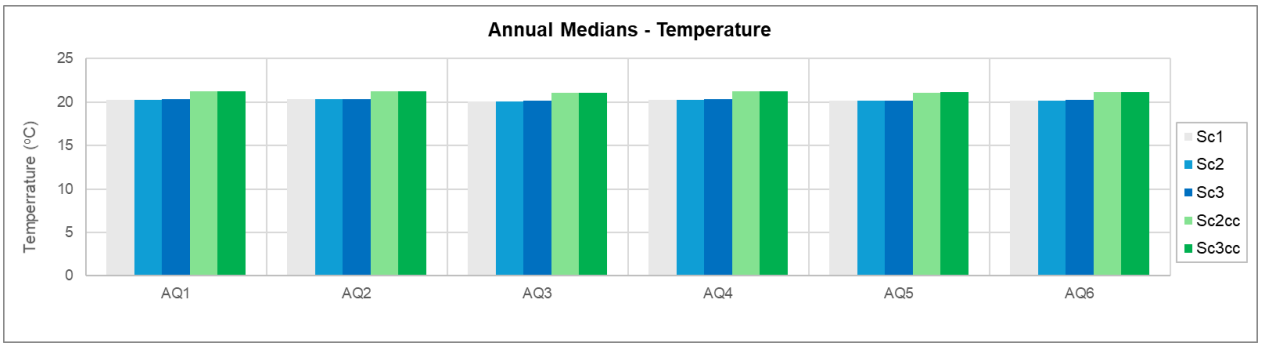


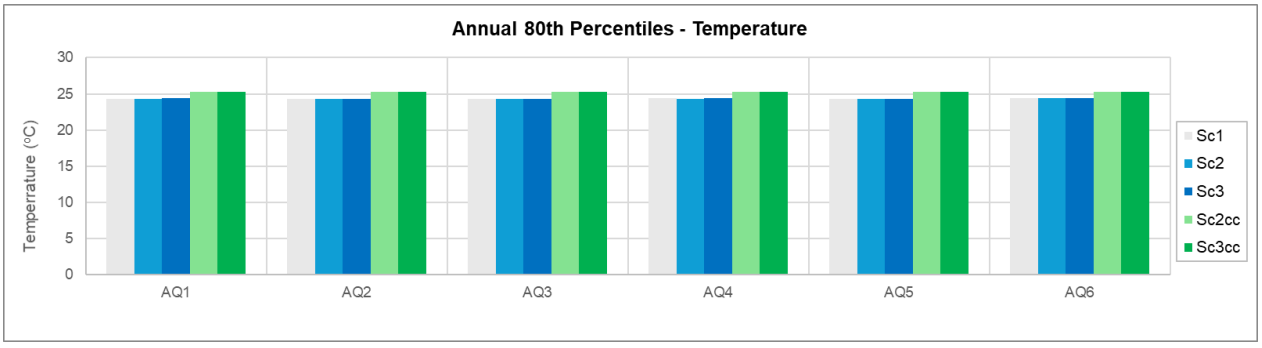




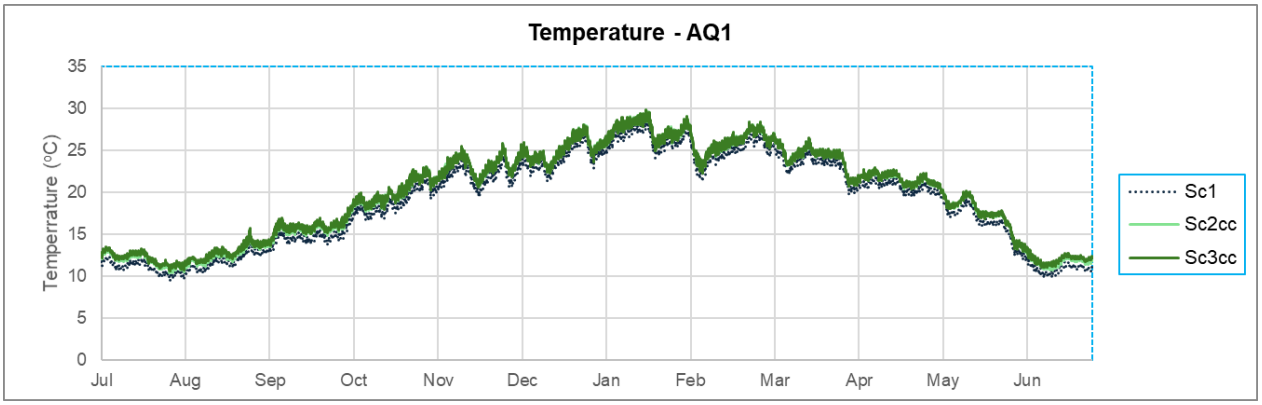
Appendices D4.2.3 Higher rainfall year scenario results (2021-2022)

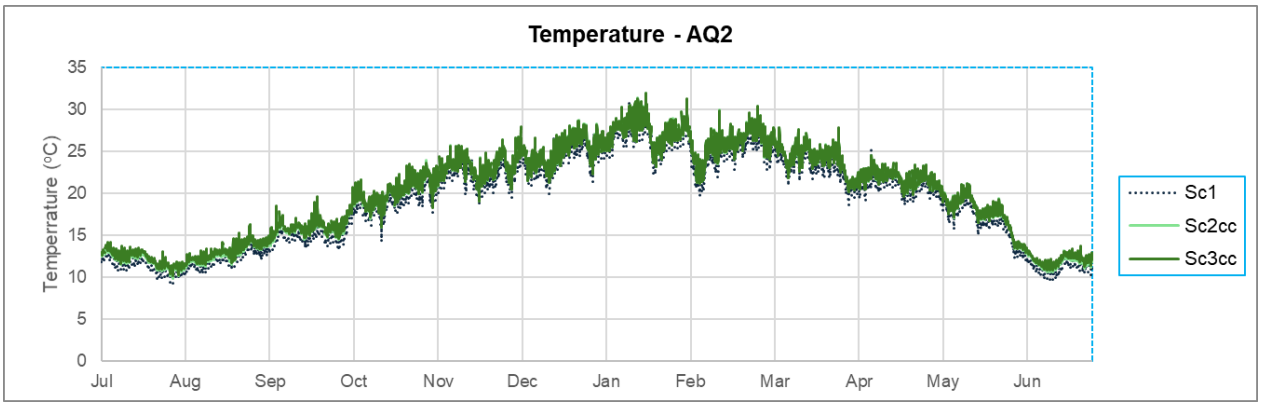
Bar charts

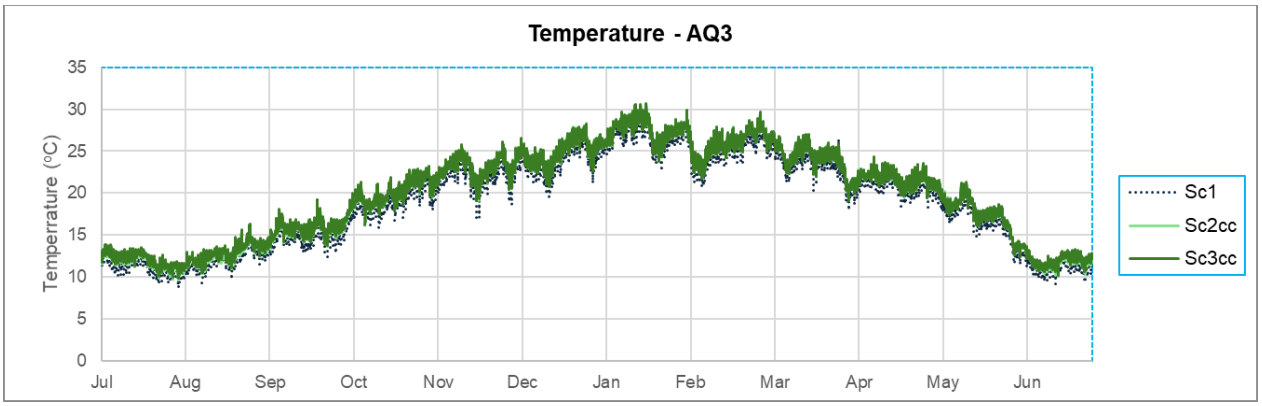


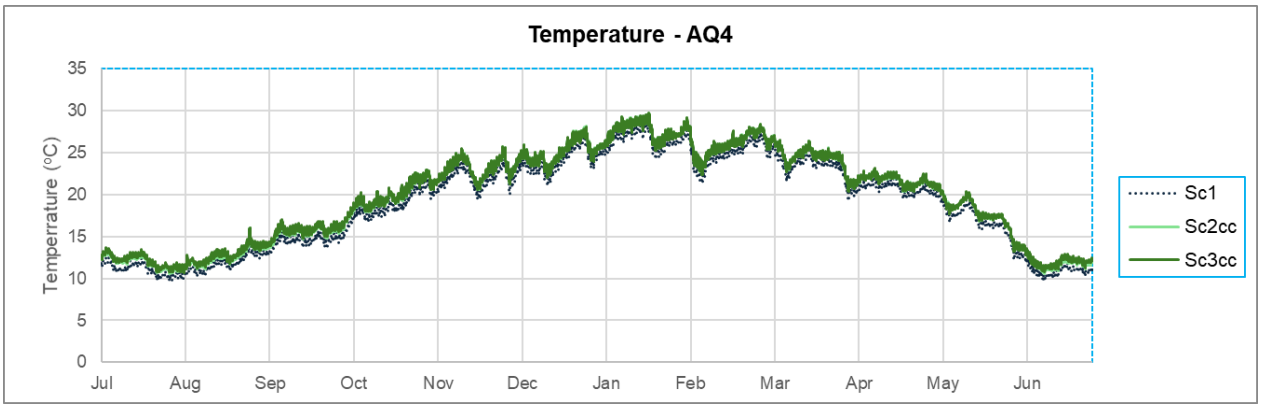


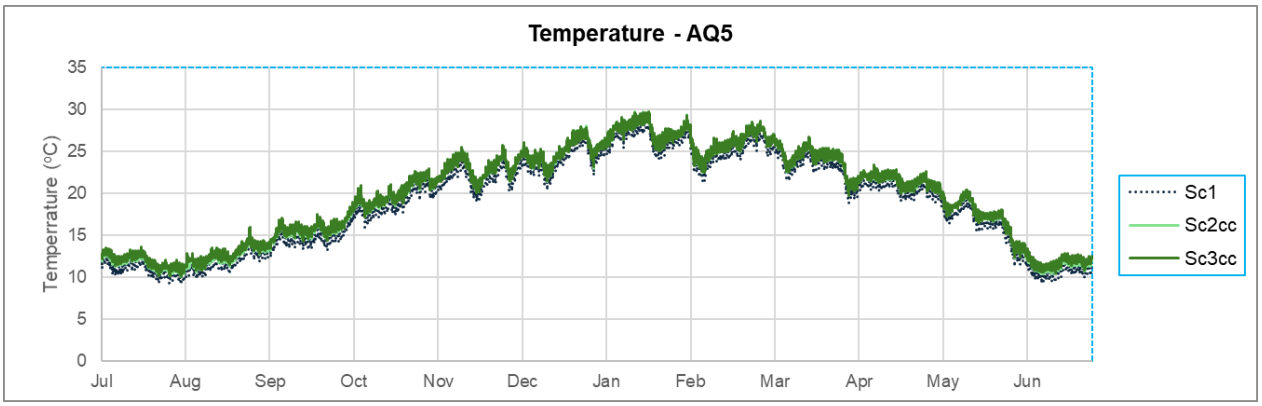
Time series plots

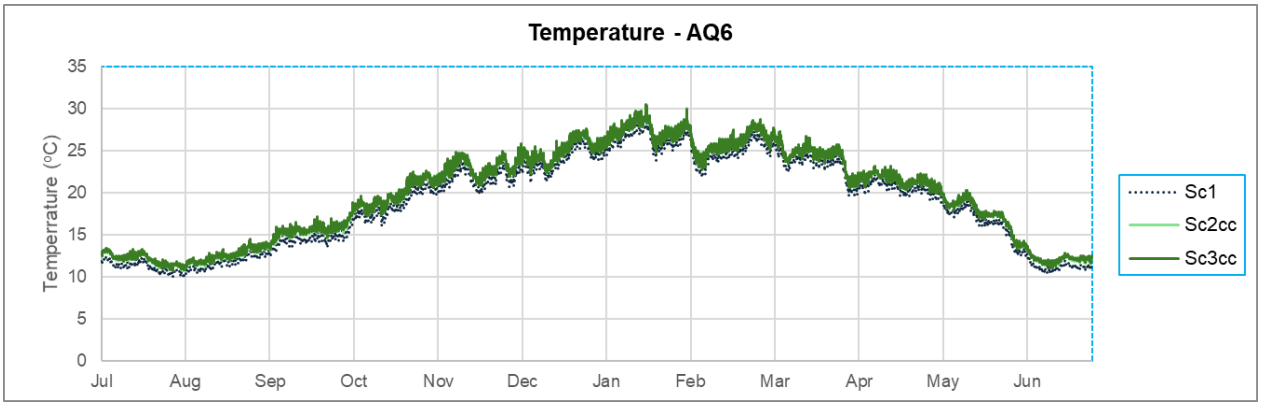








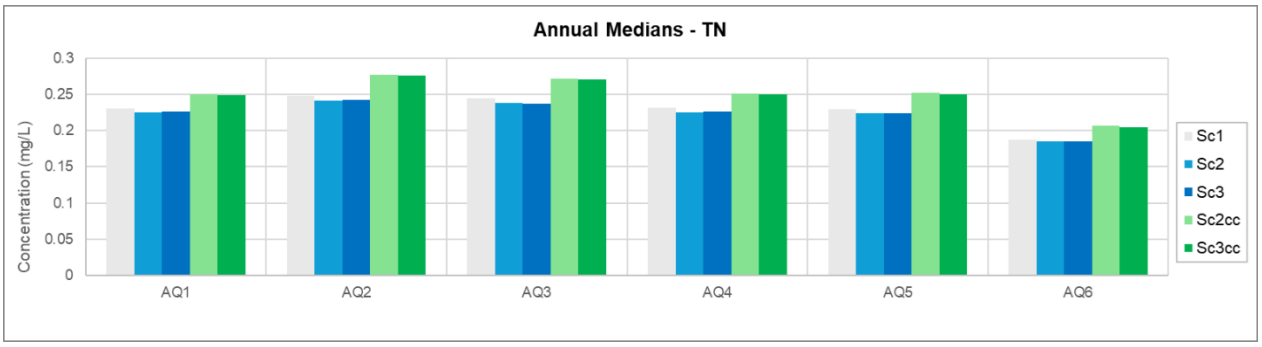


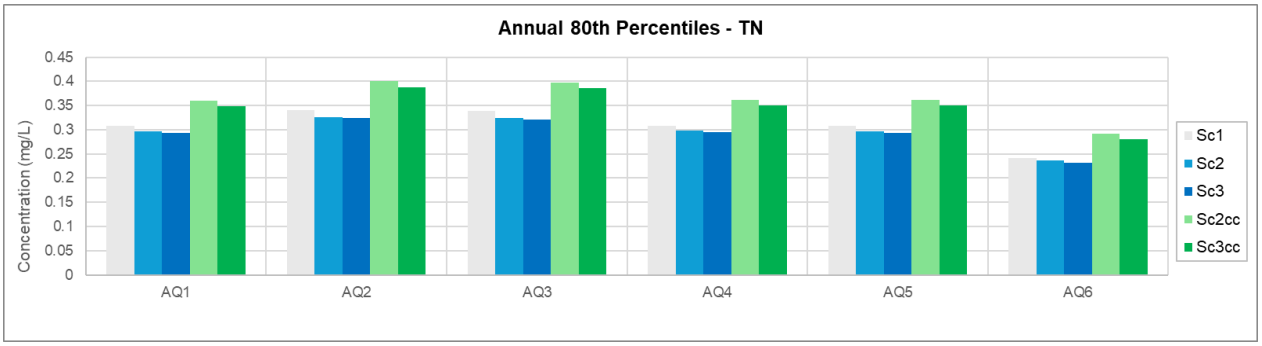


Appendices D4.3 Total N

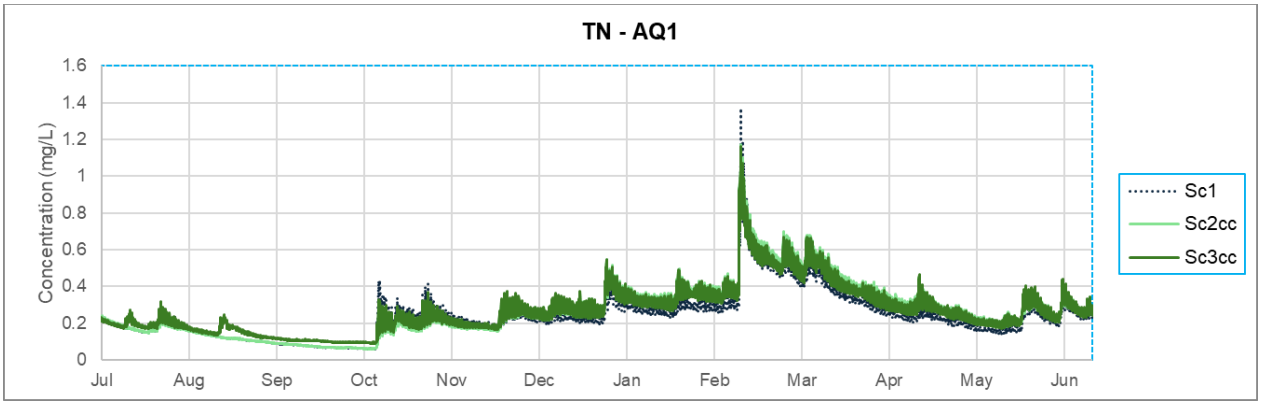
Appendices D4.3.1 Lower rainfall year scenario results (2017-2018)

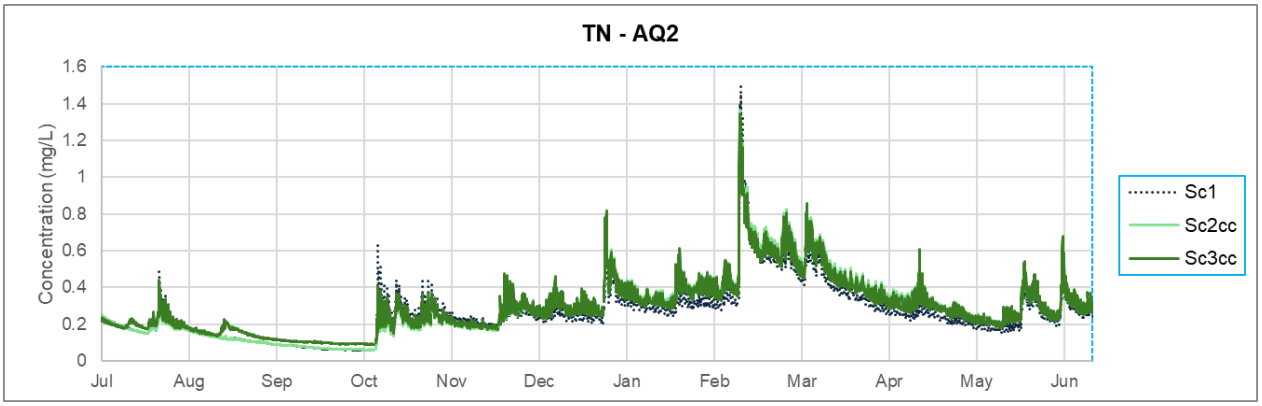
Bar charts

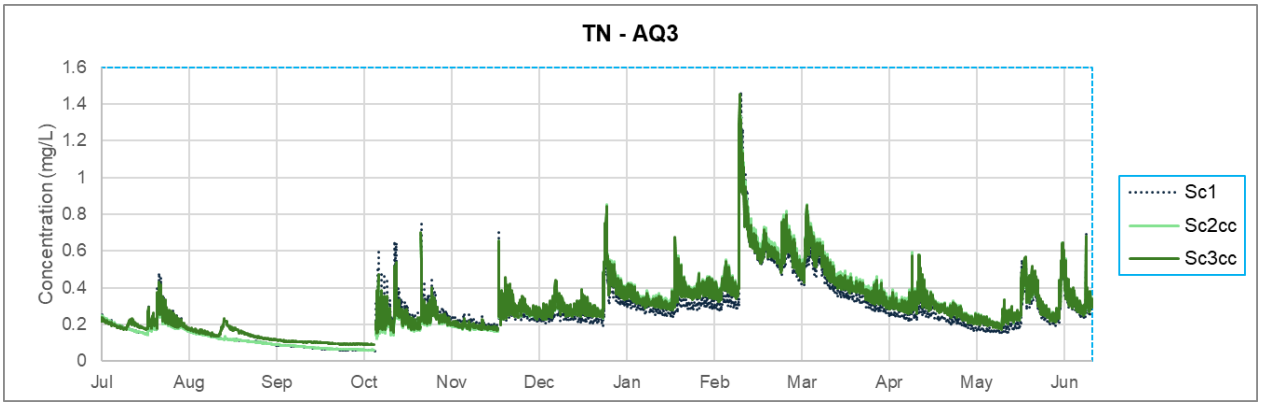


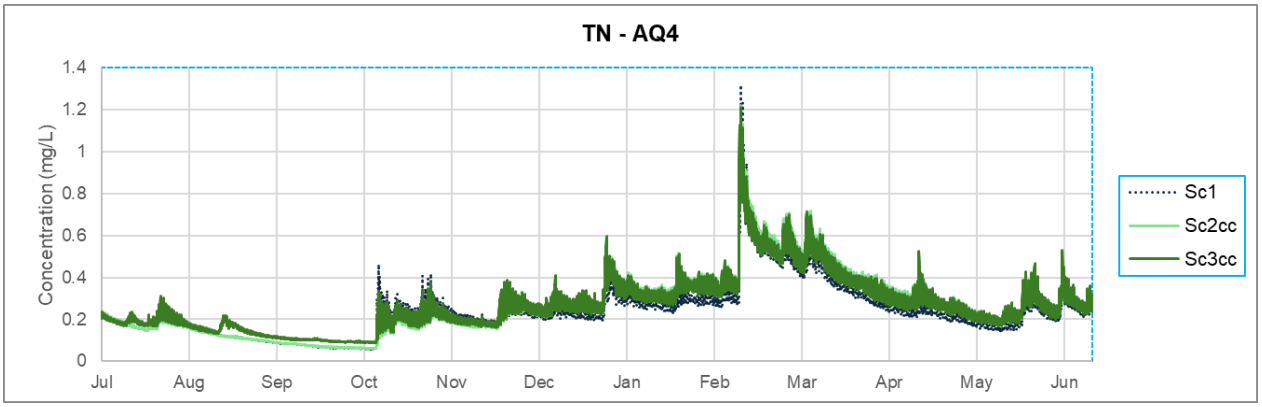


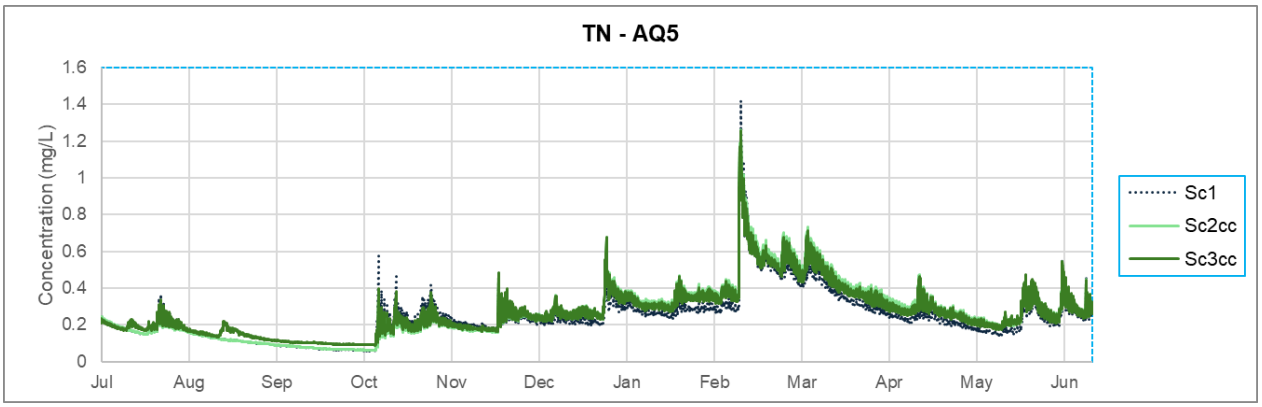
Time series plots





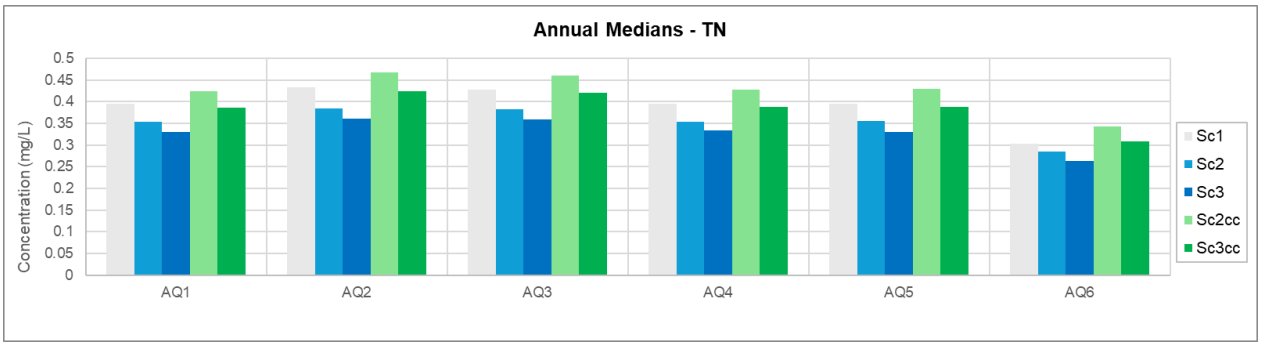


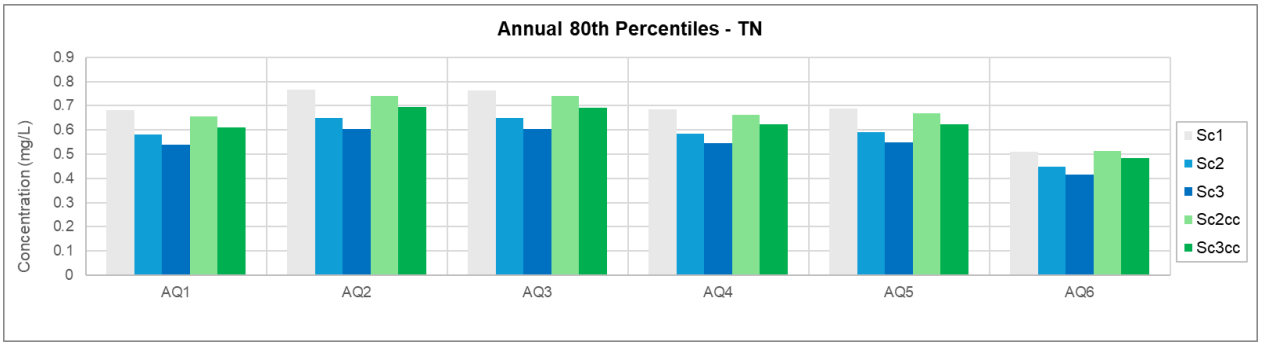




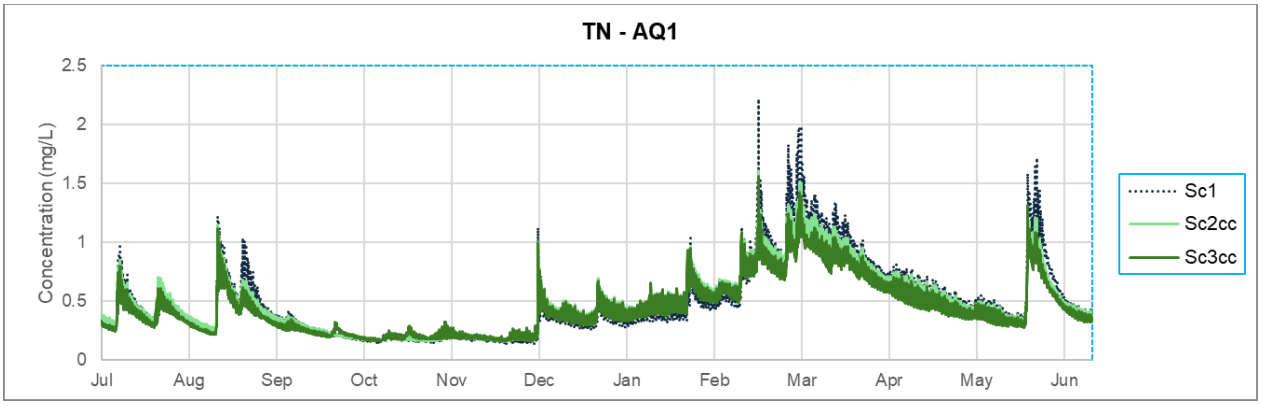
Appendices D4.3.2 Average rainfall year scenario results (2016-2017)

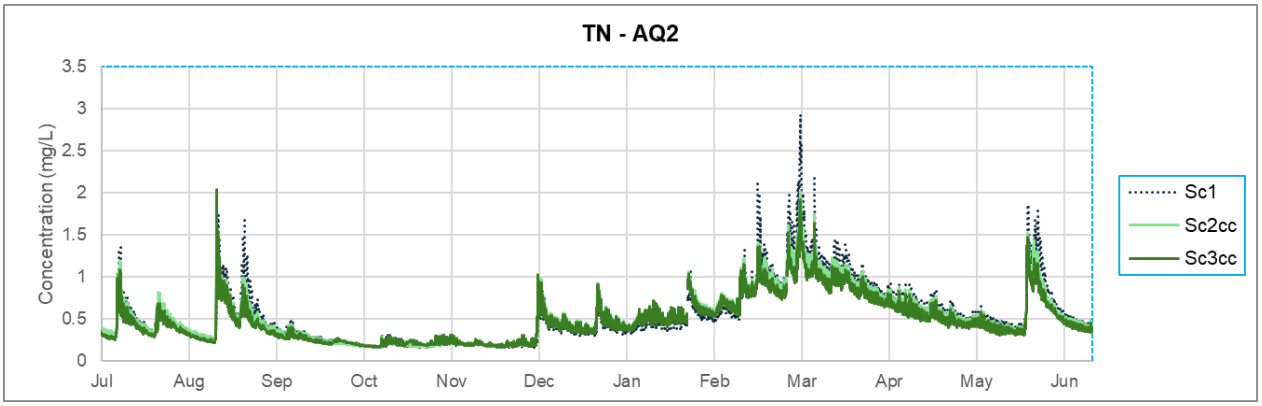
Bar charts

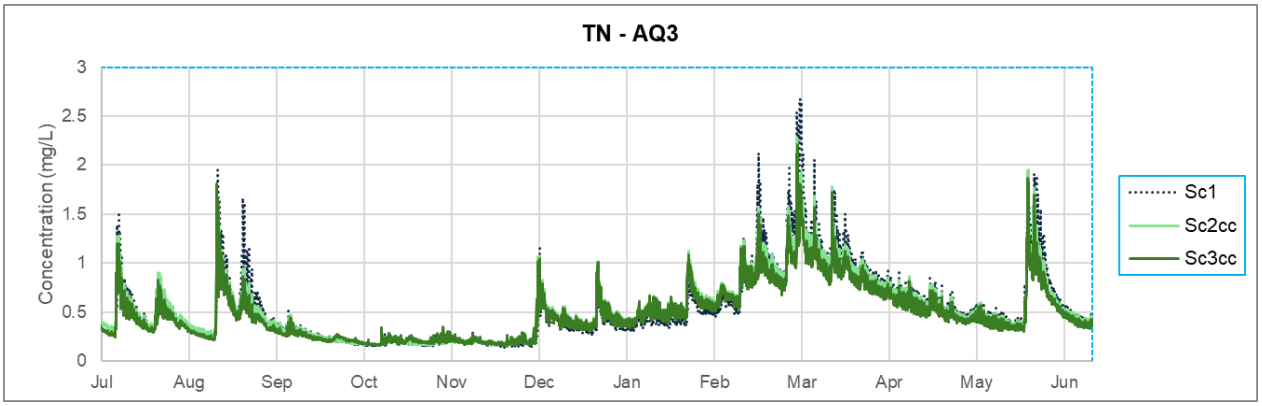


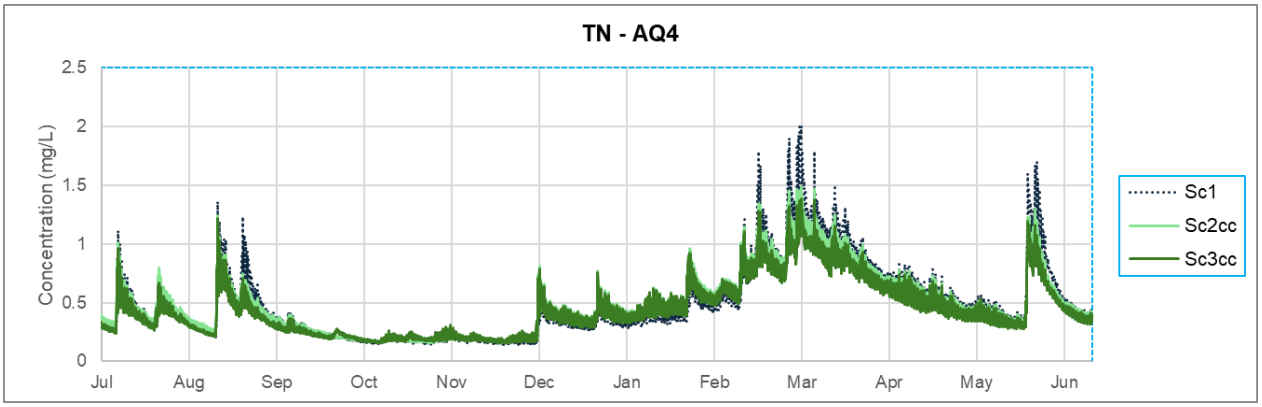


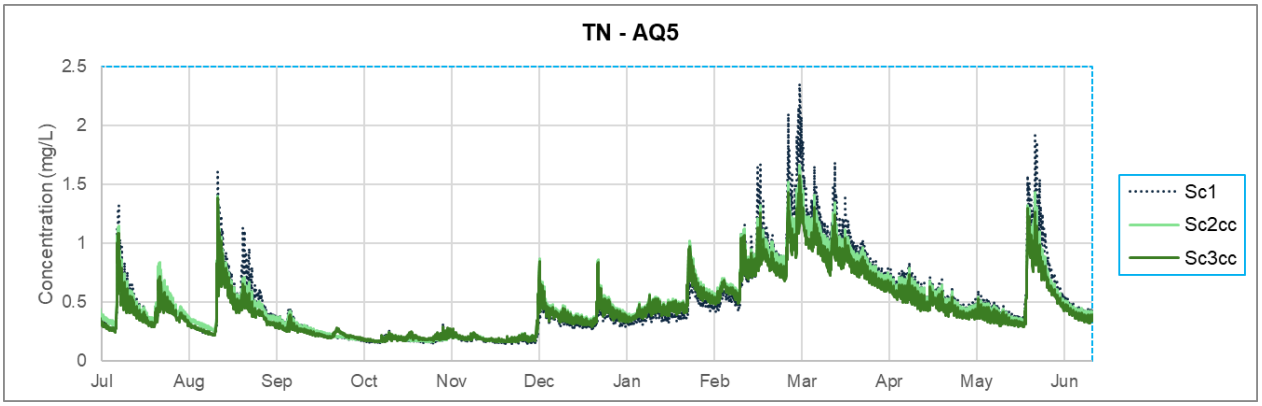
Time series plots





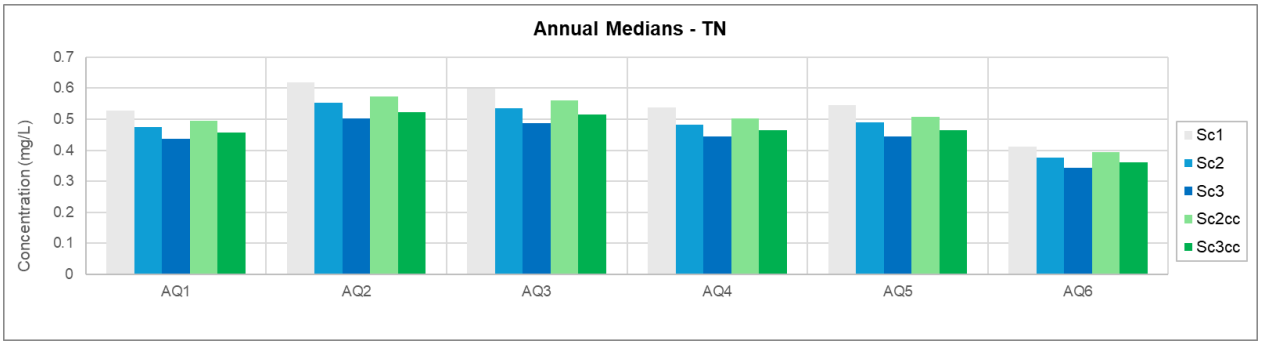


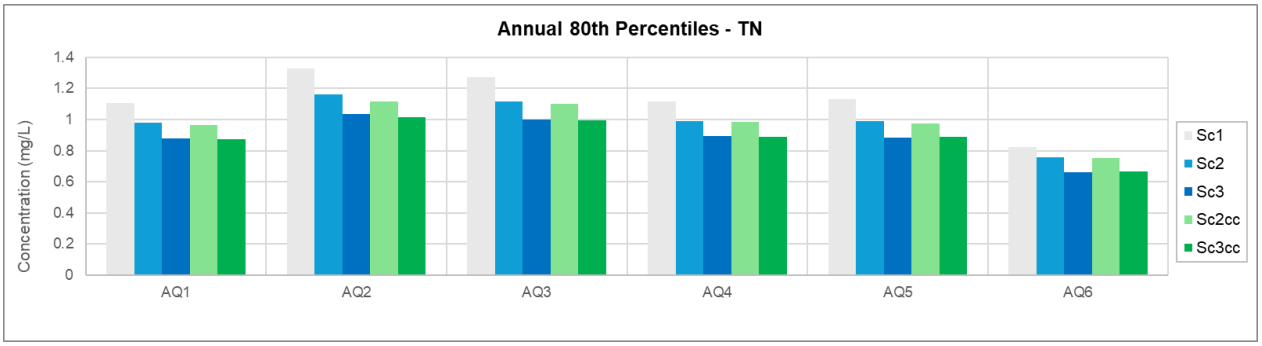




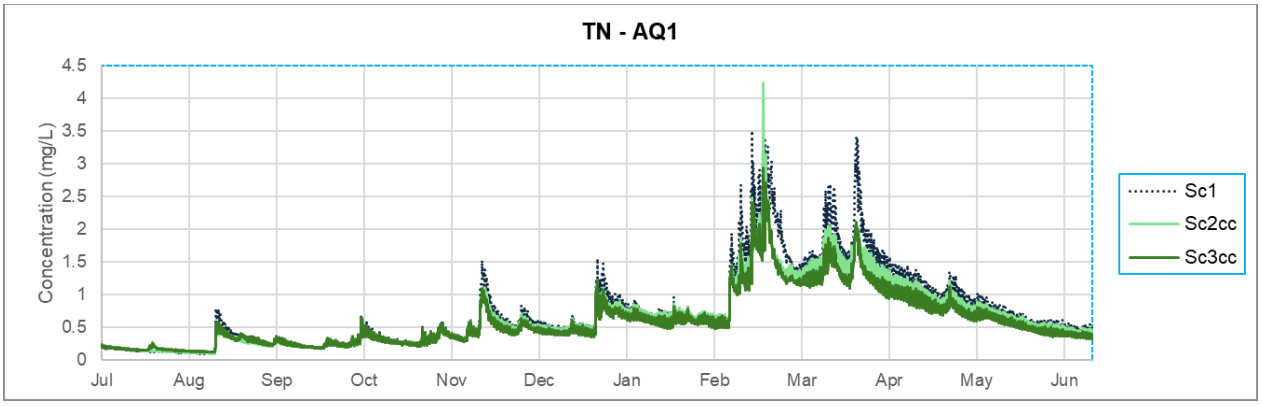
Appendices D4.3.3 Higher rainfall year scenario results (2021-2022)

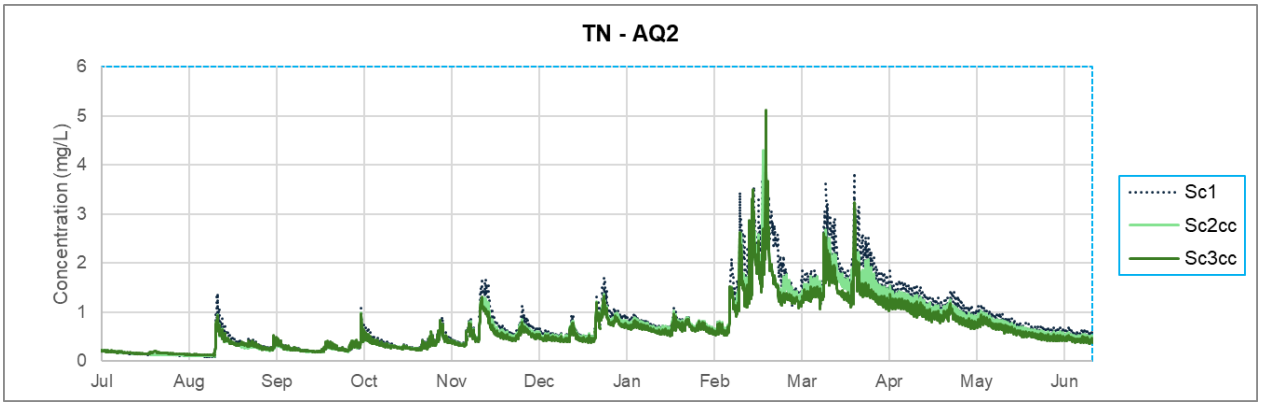
Bar charts

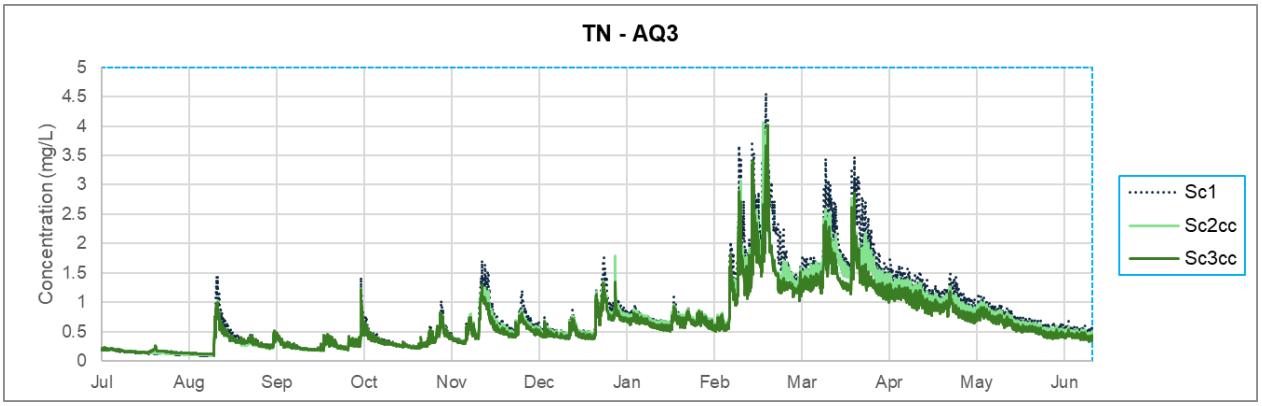


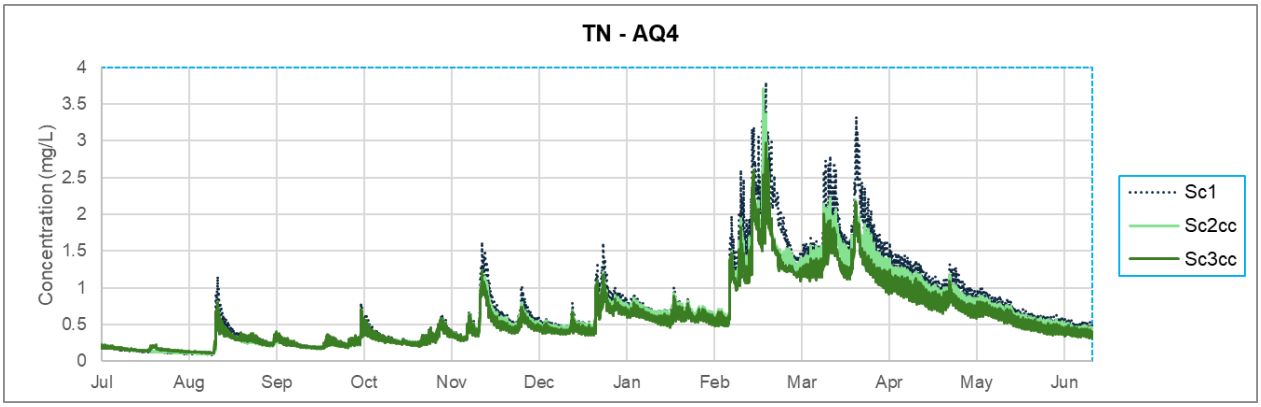


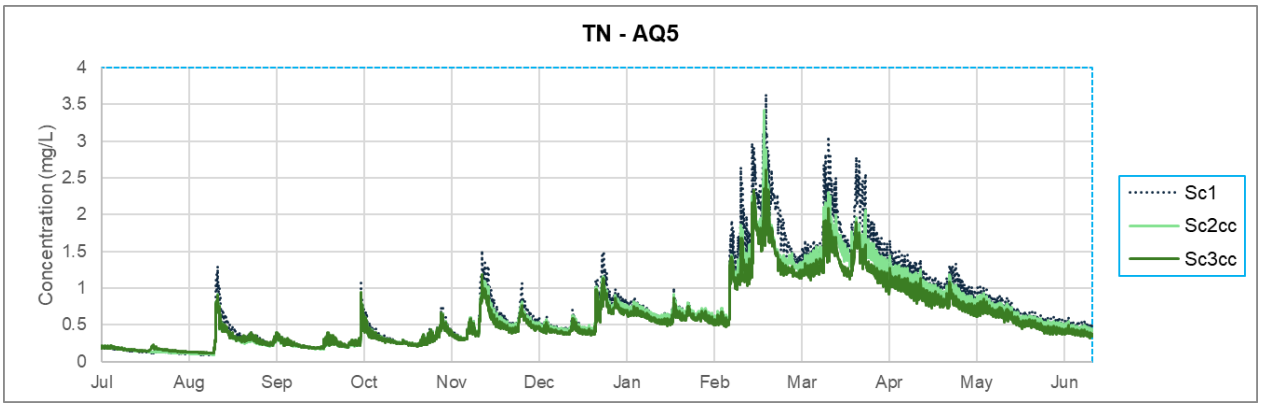
Time series plots

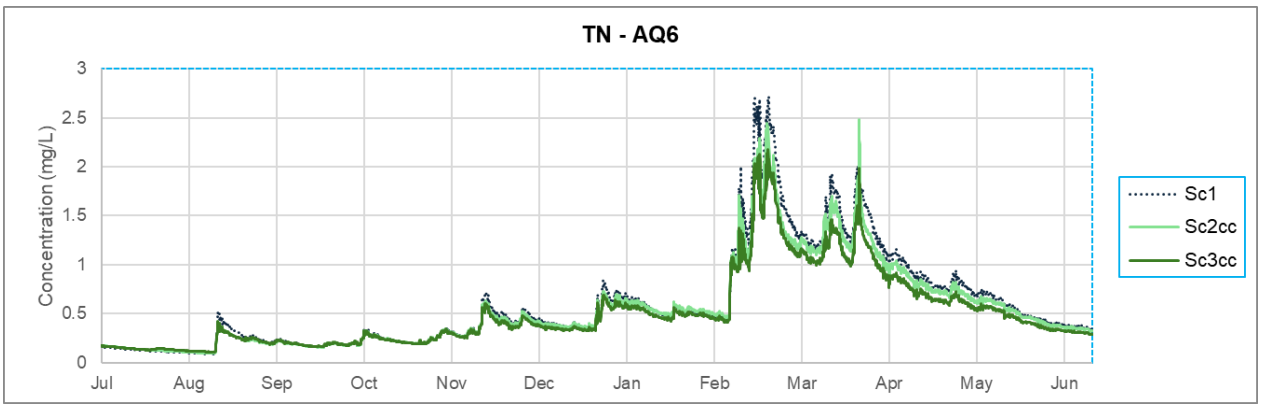







TN - AQ4
Concentration (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

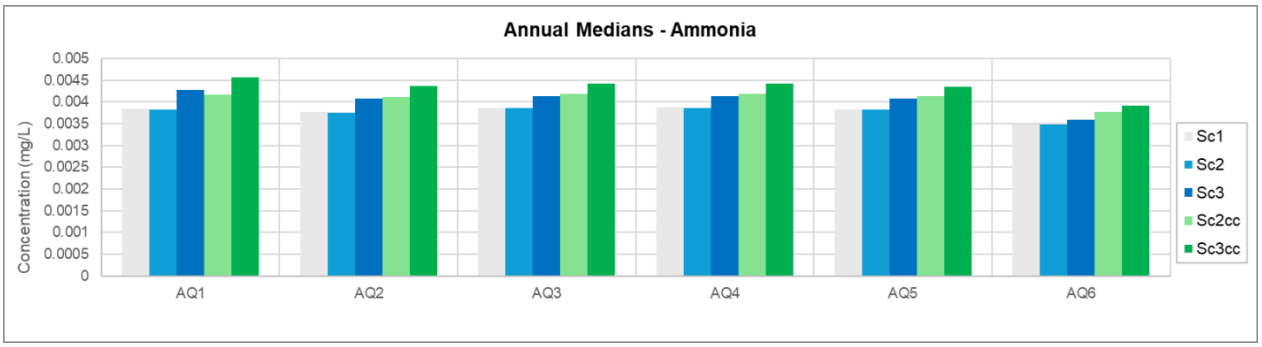

TN - AQ5
Concentration (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

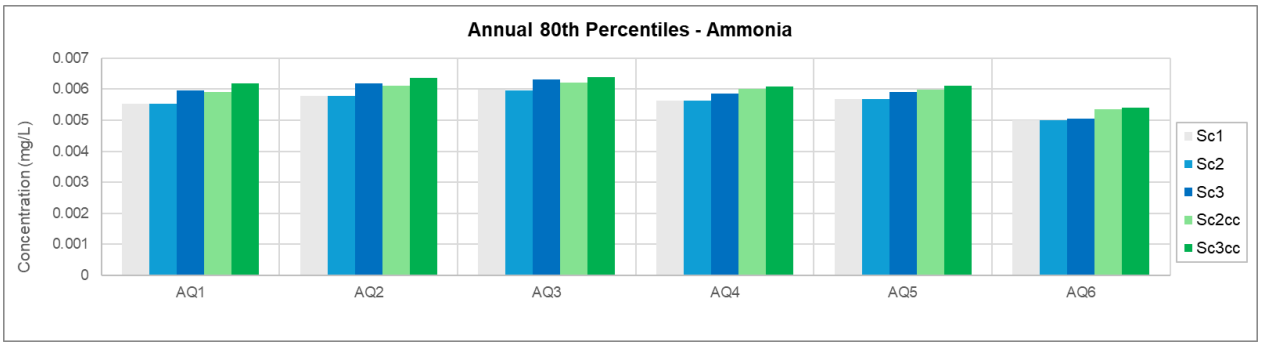

TN - AQ6
Concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D4.4 Ammonia

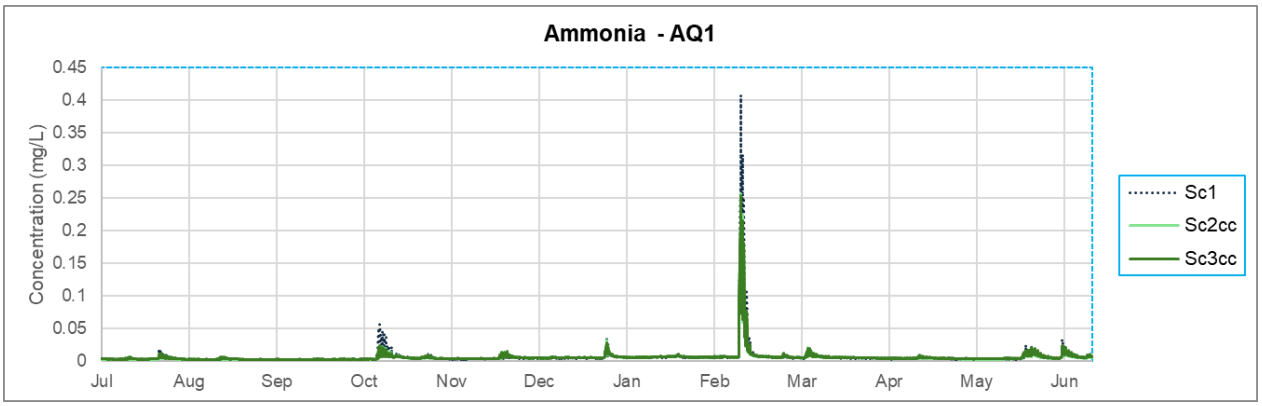
Appendices D4.4.1 Lower rainfall year scenario results (2017-2018)

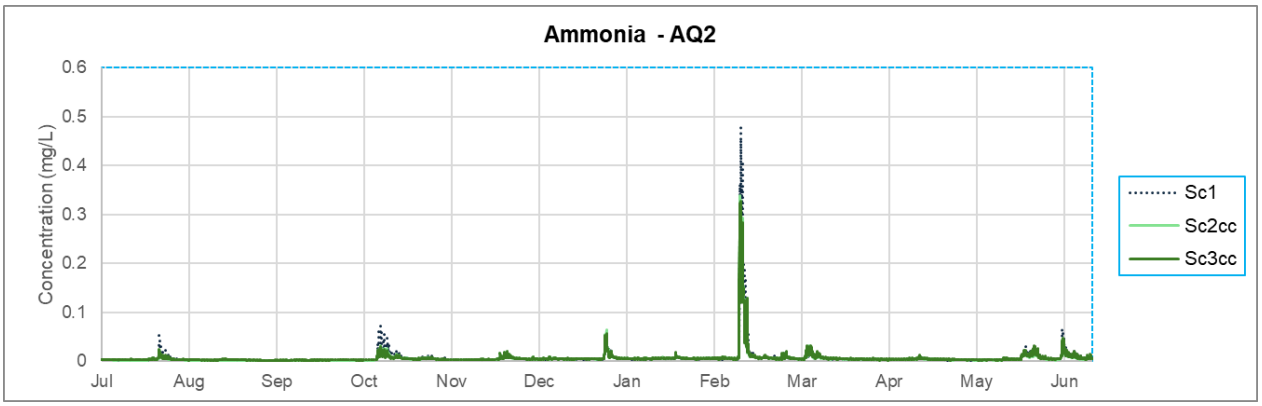
Bar charts

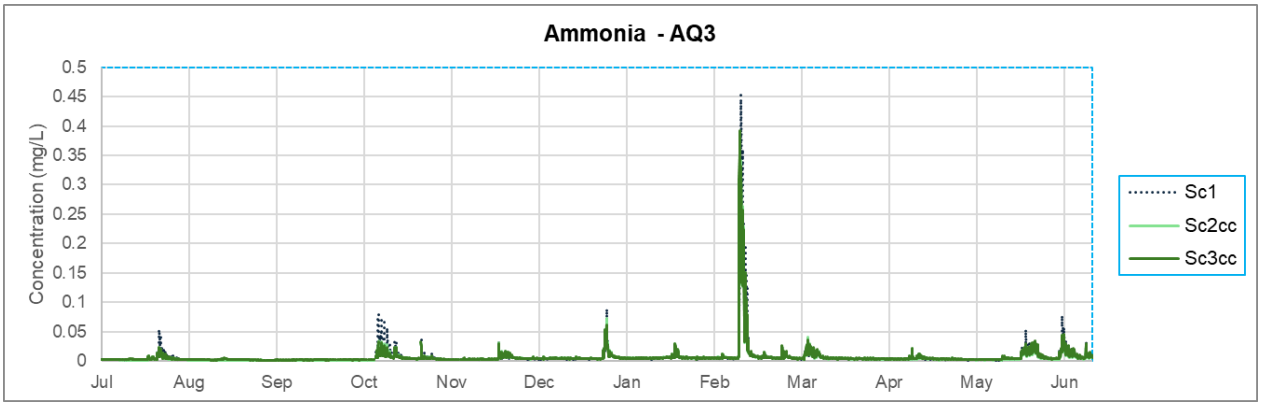


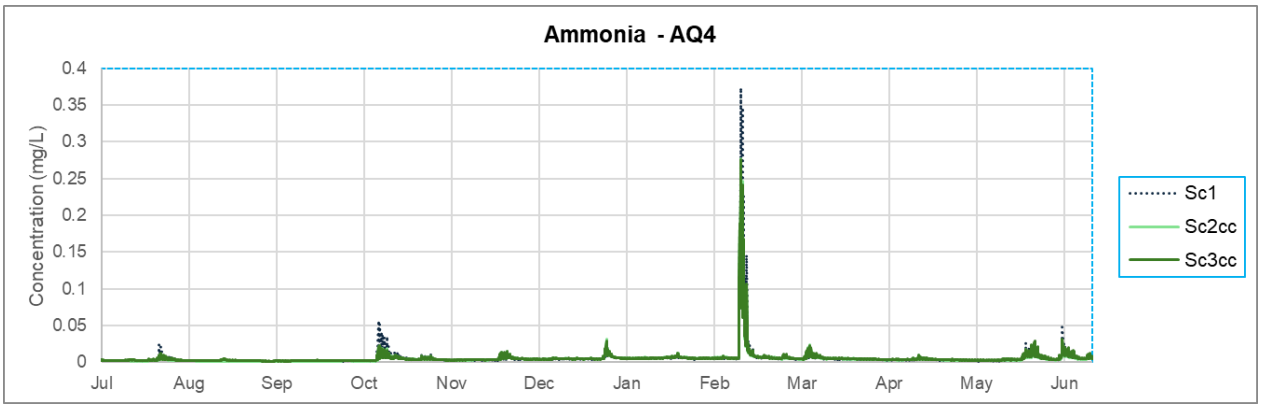


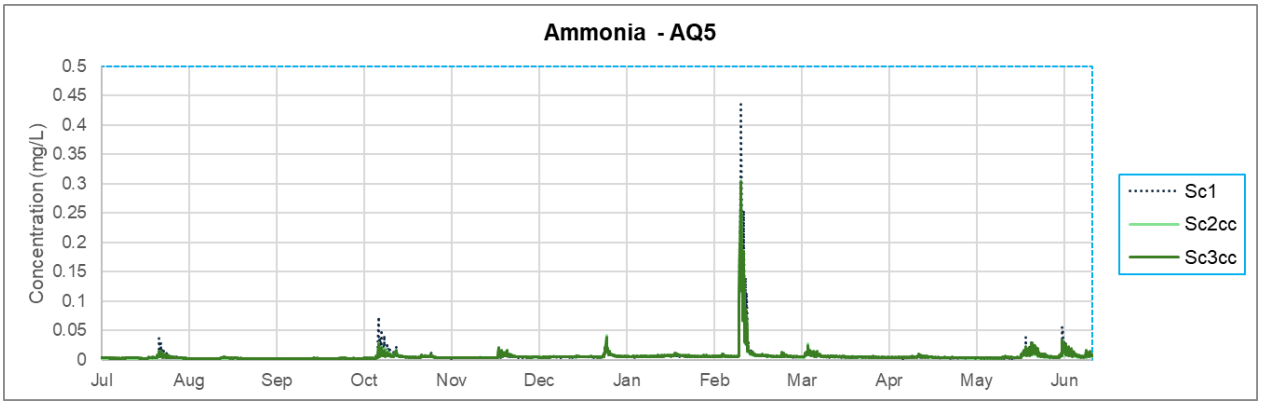
Time series plots

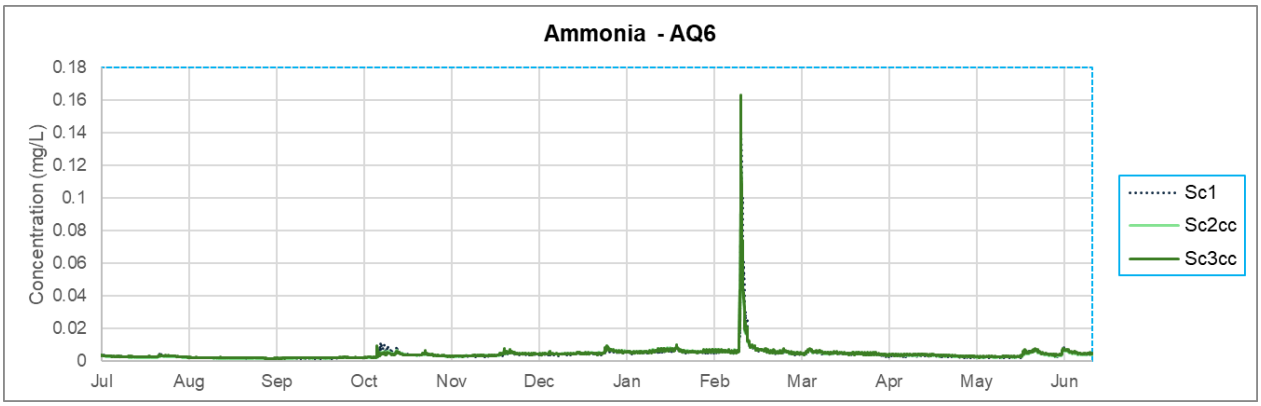



Ammonia - AQ2
Concentration (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Ammonia - AQ3
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

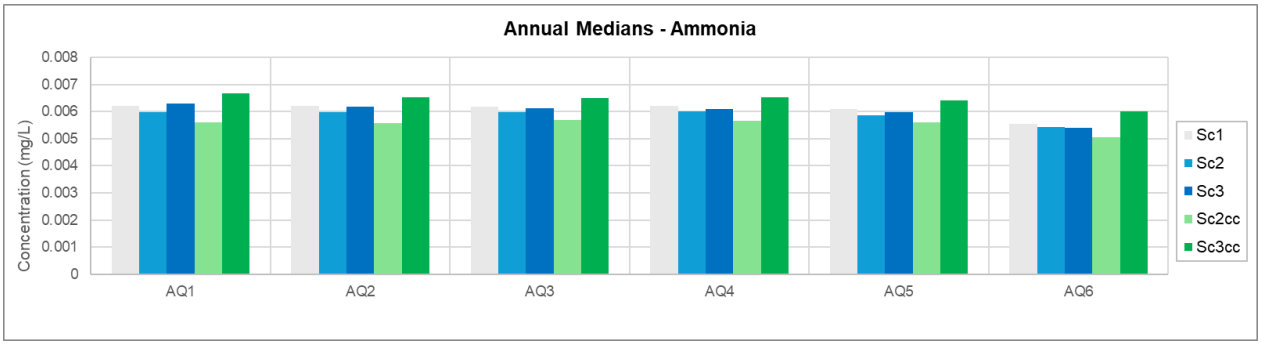

Ammonia - AQ4
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

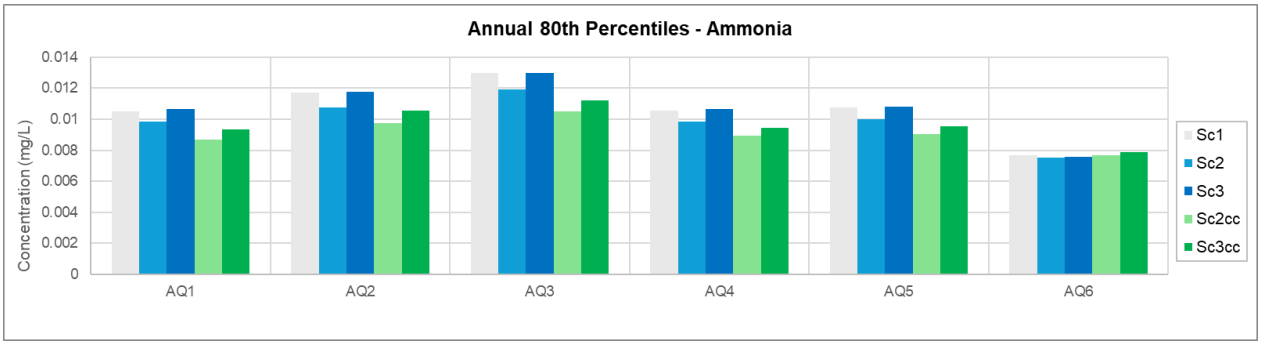

Ammonia - AQ5
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



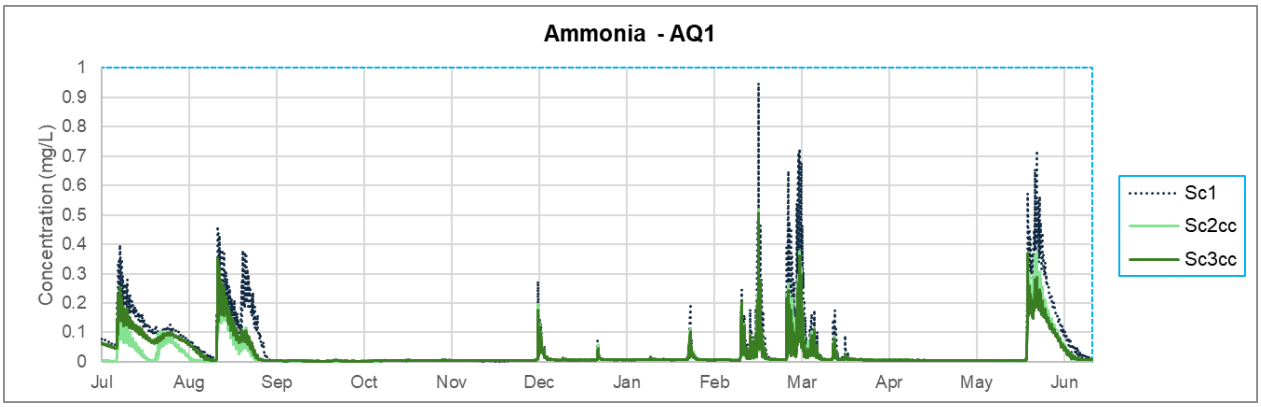
Appendices D4.4.2 Average rainfall year scenario results (2016-2017)

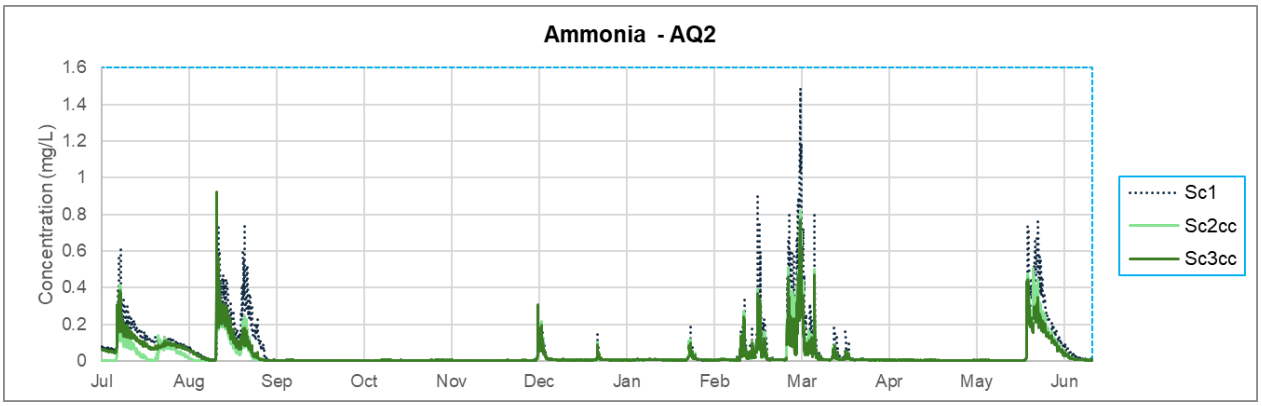
Bar charts

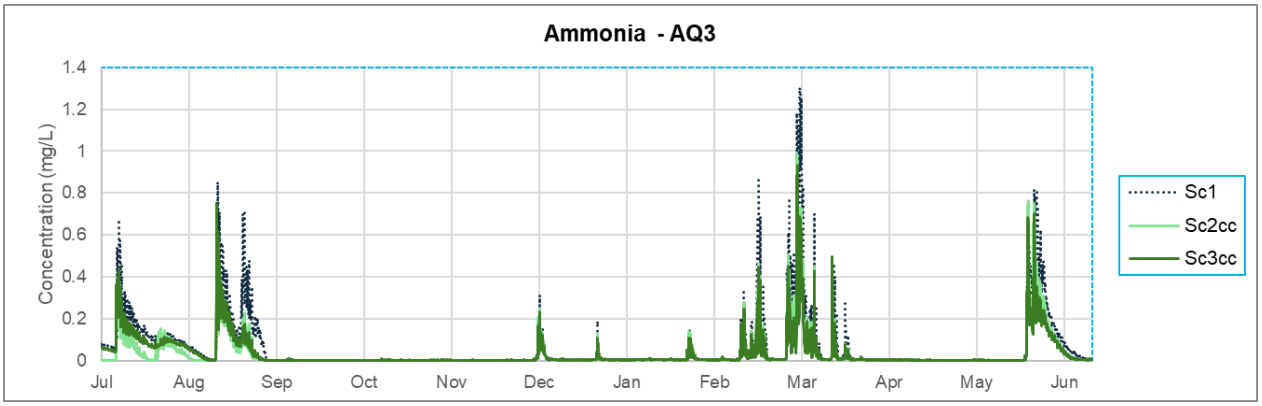


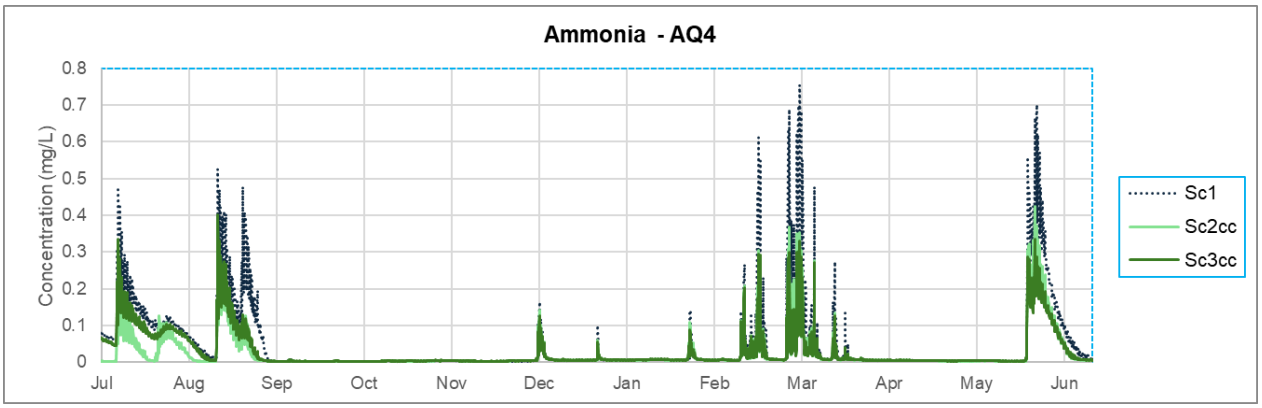


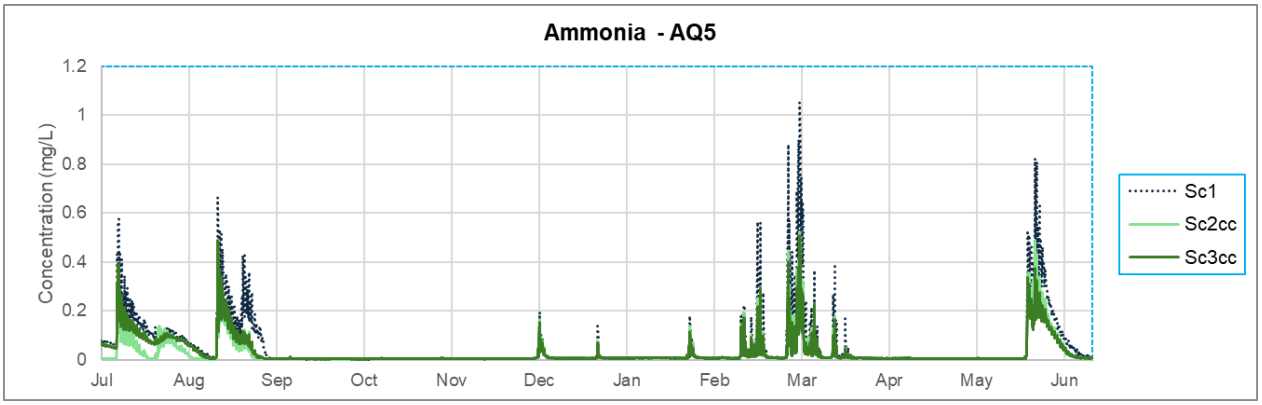
Time series plots

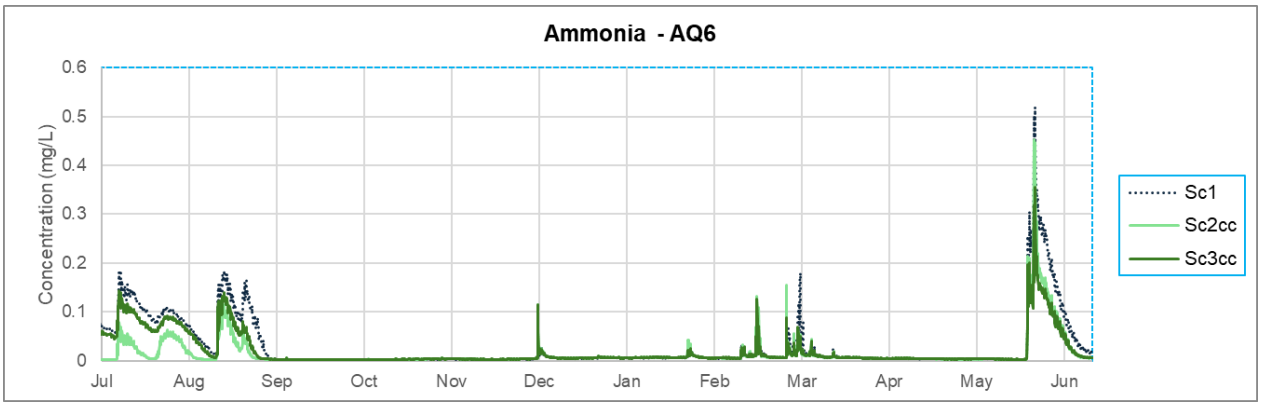



Ammonia - AQ2
Concentration (mg/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Ammonia - AQ3
Concentration (mg/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

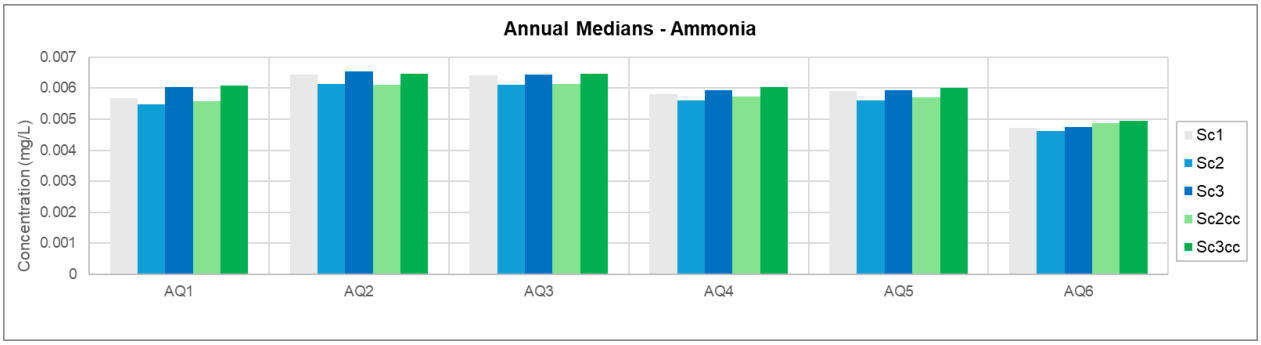

Ammonia - AQ4
Concentration (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

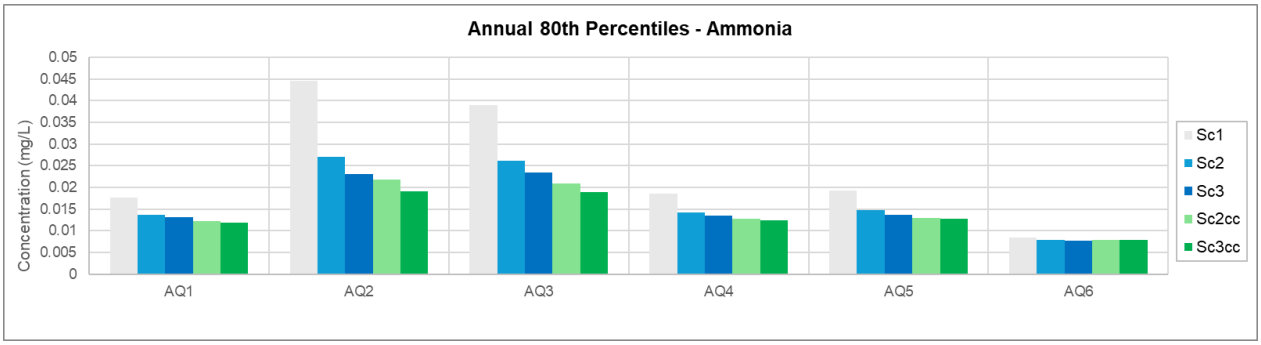

Ammonia - AQ5
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



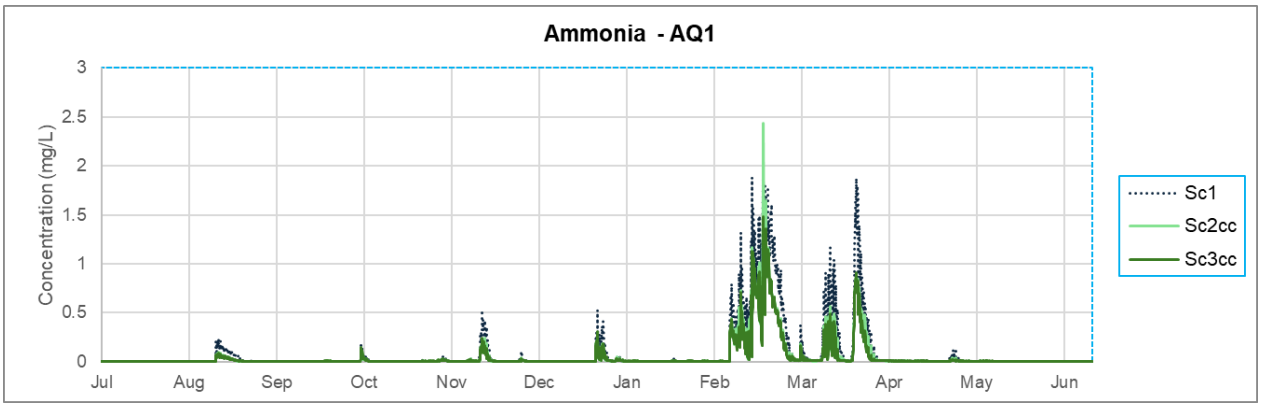
Appendices D4.4.3 Higher rainfall year scenario results (2021-2022)

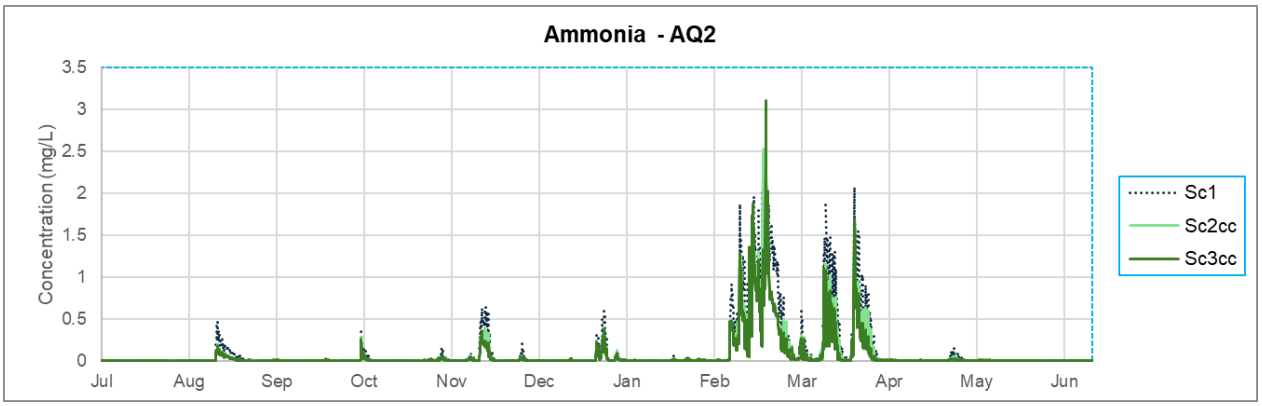
Bar charts

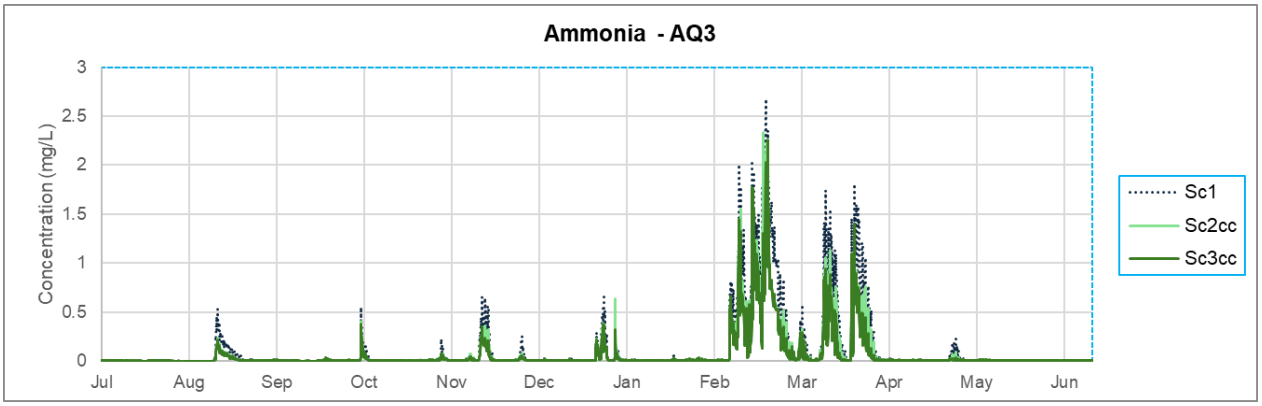


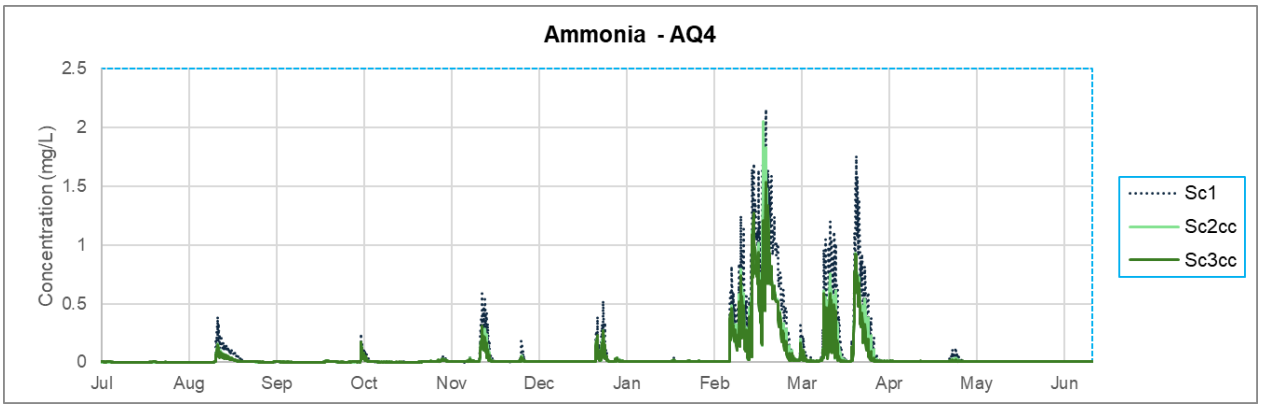


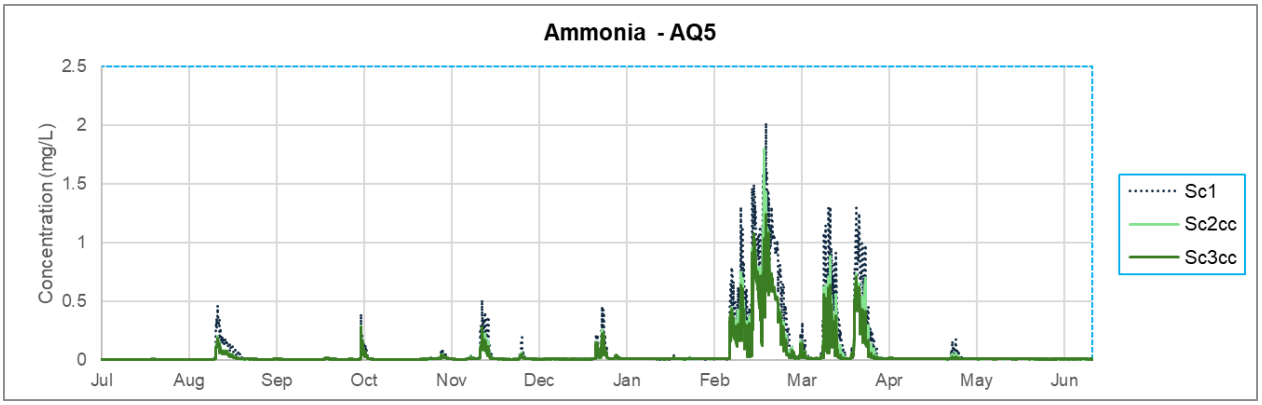
Time series plots

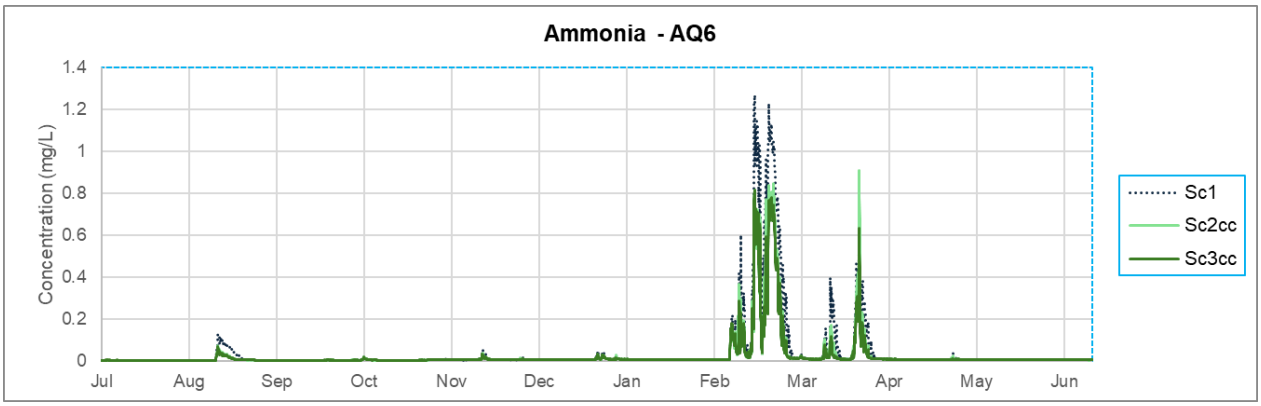



Ammonia - AQ2
Concentration (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Ammonia - AQ3
Concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Ammonia - AQ4
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

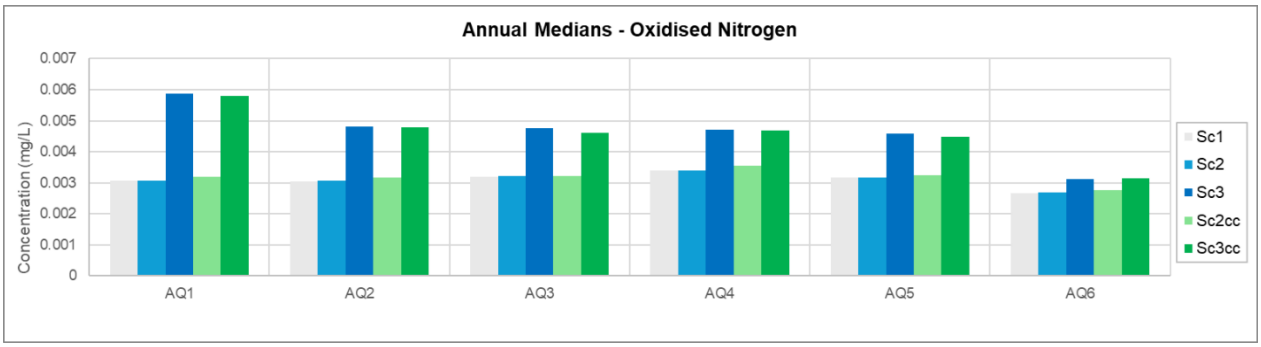

Ammonia - AQ5
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

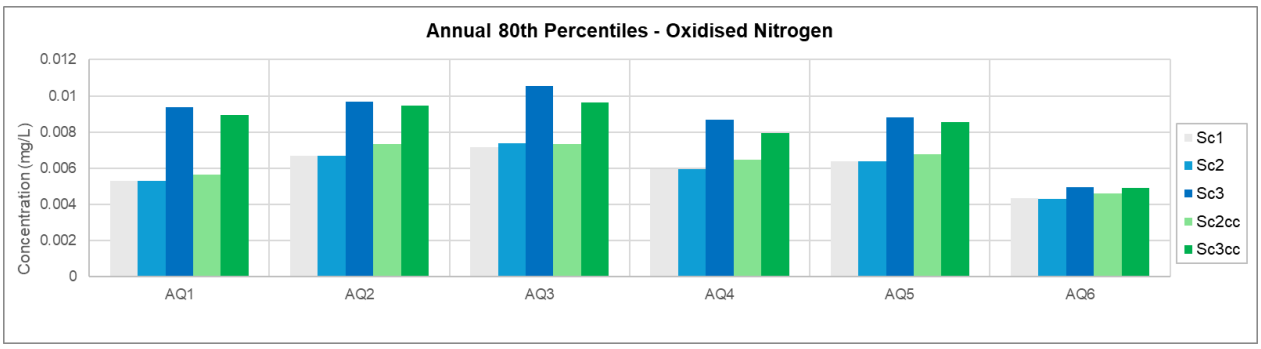


Appendices D4.5 Oxidised N

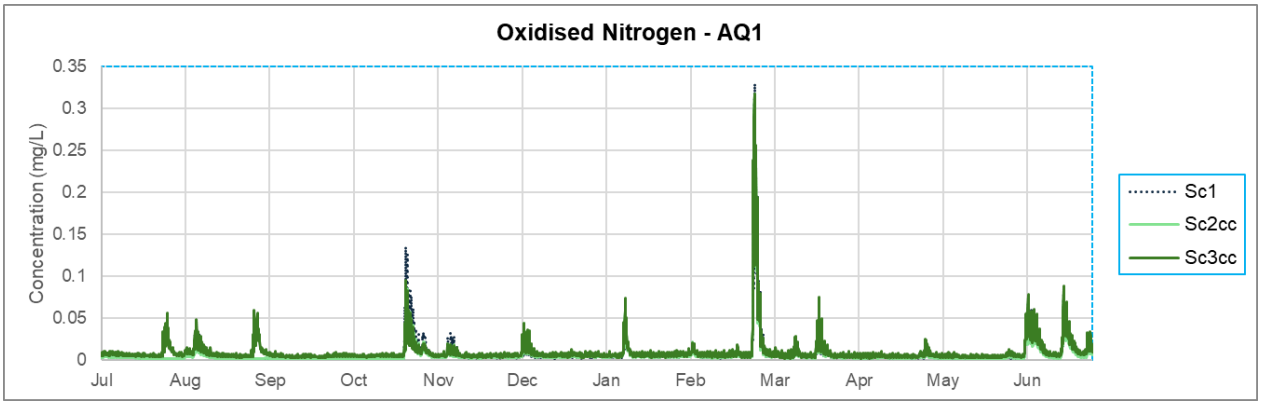
Appendices D4.5.1 Lower rainfall year scenario results (2017-2018)

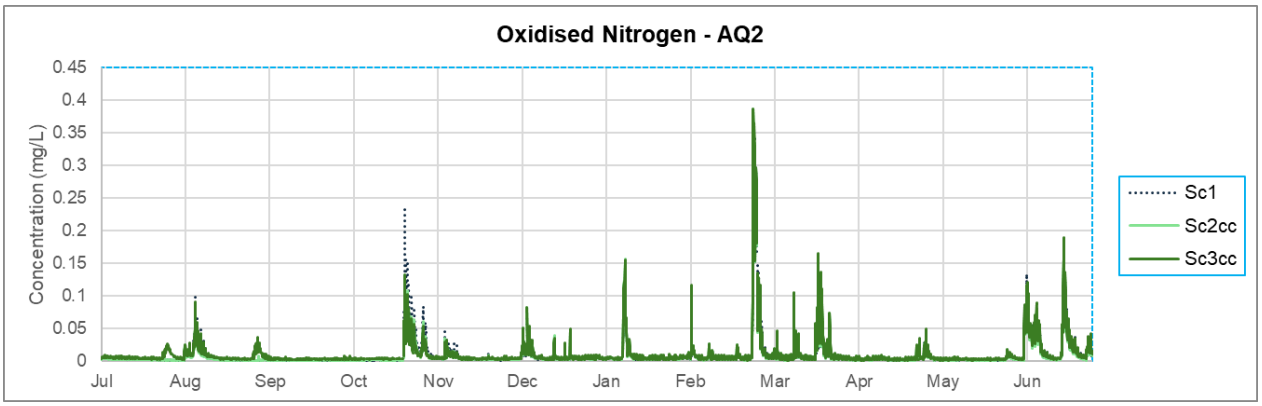
Bar charts

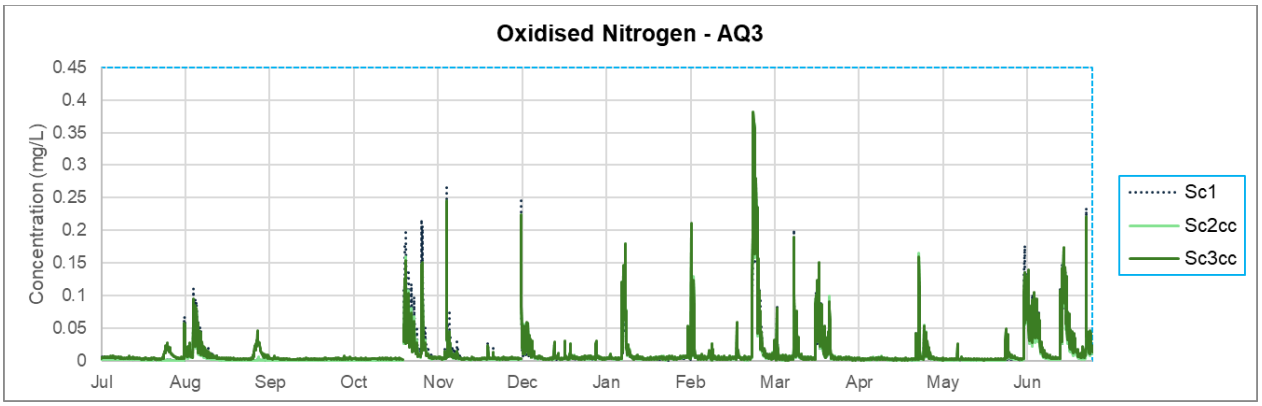


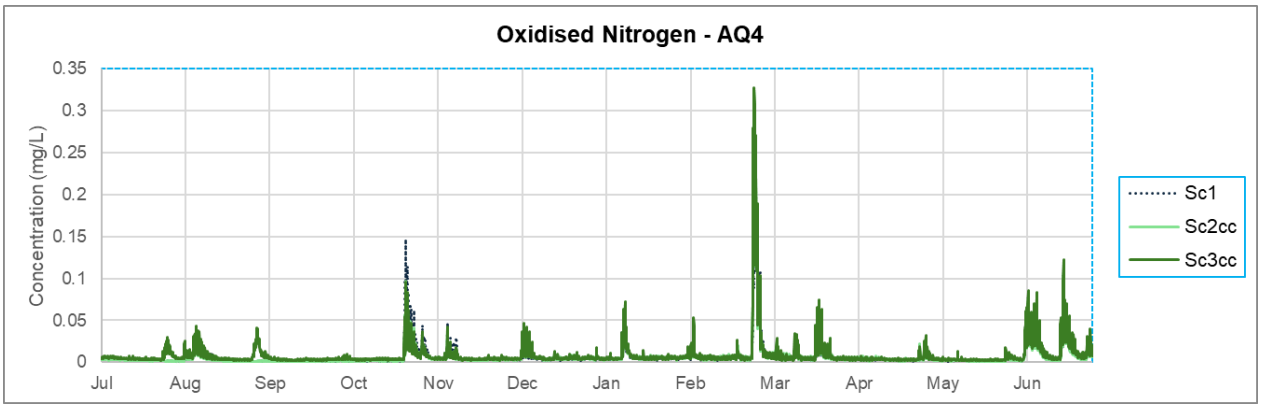


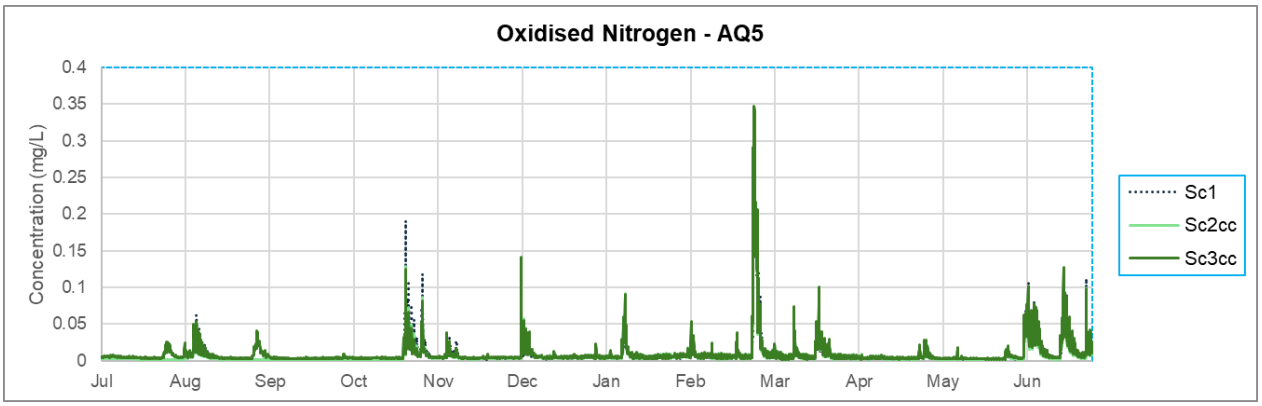
Time series plots

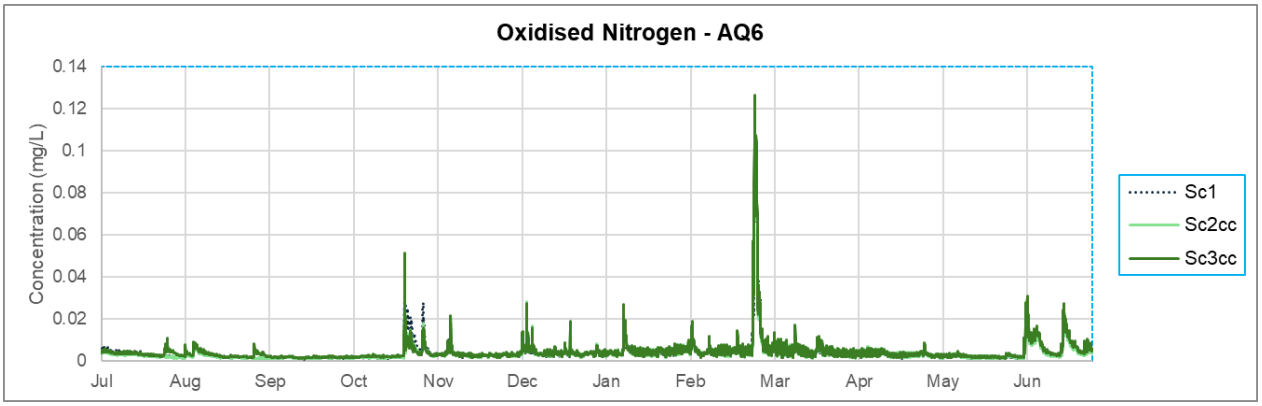






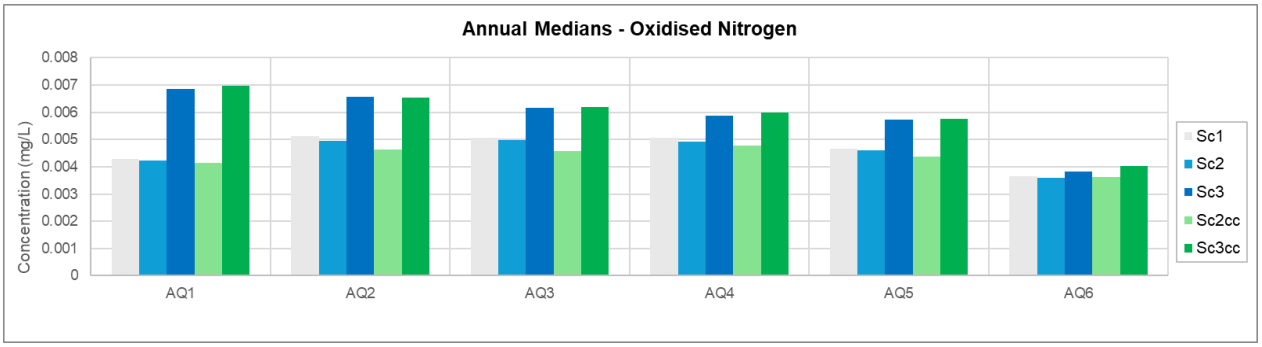


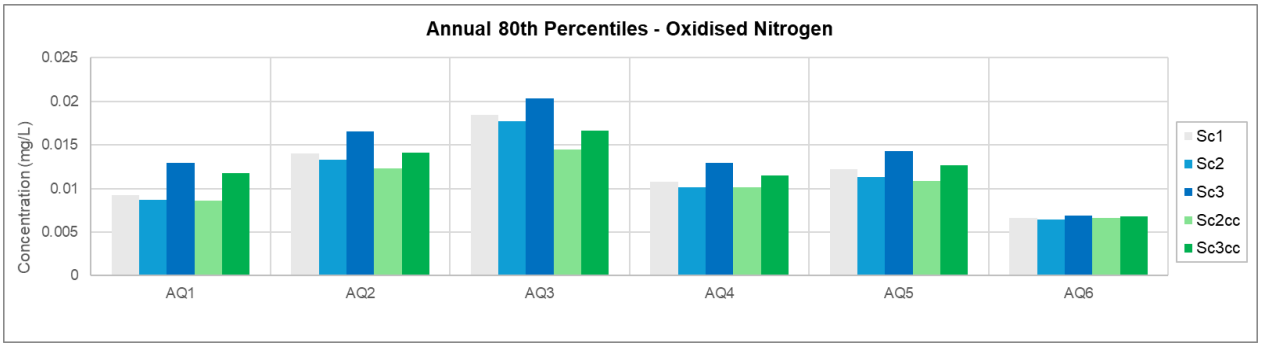




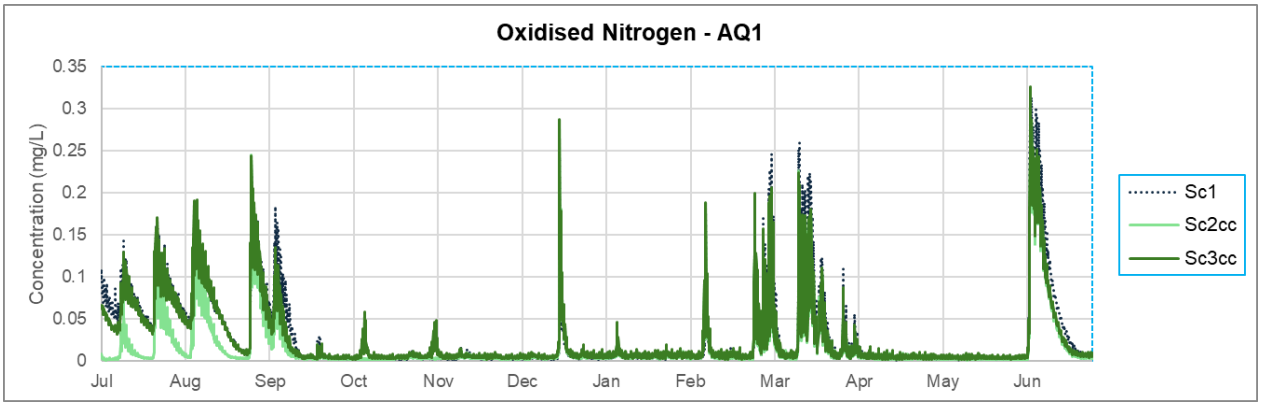
Appendices D4.5.2 Average rainfall year scenario results (2016-2017)

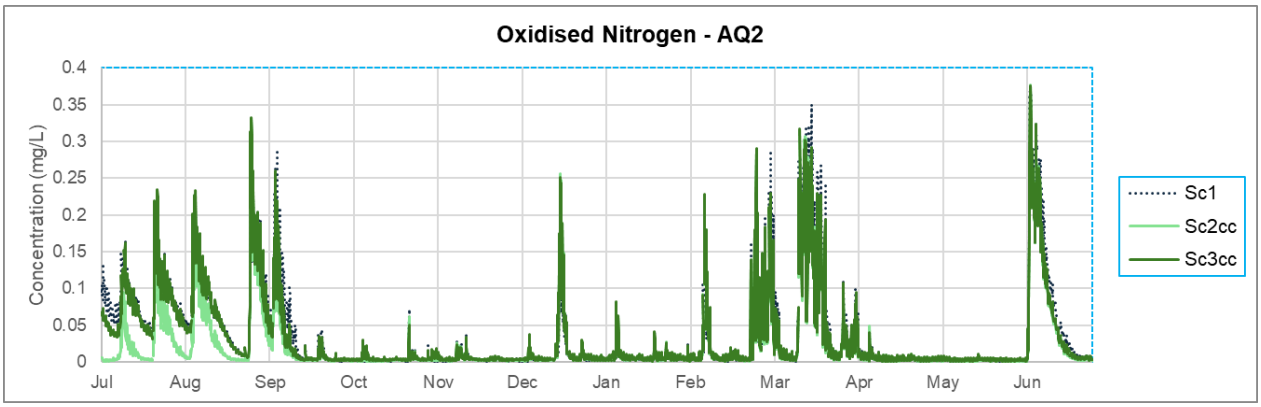
Bar charts

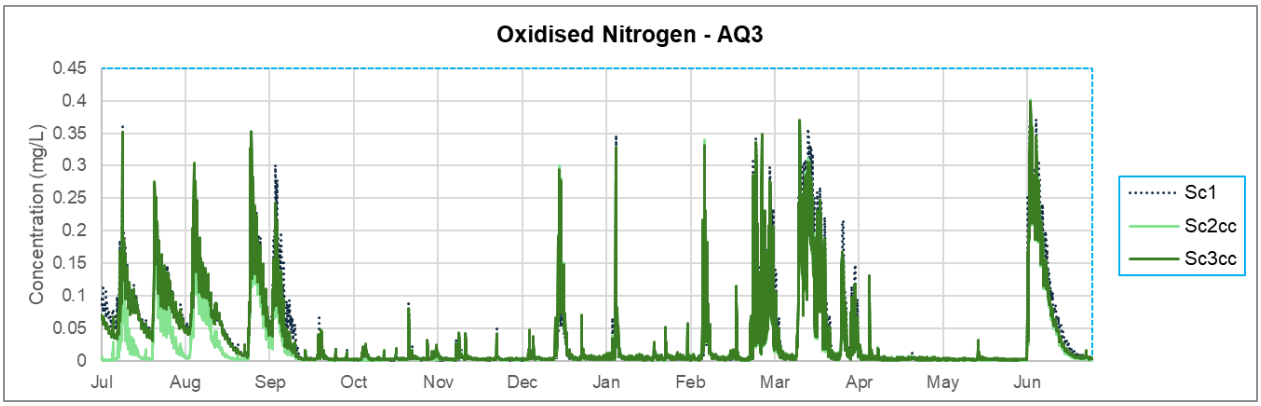


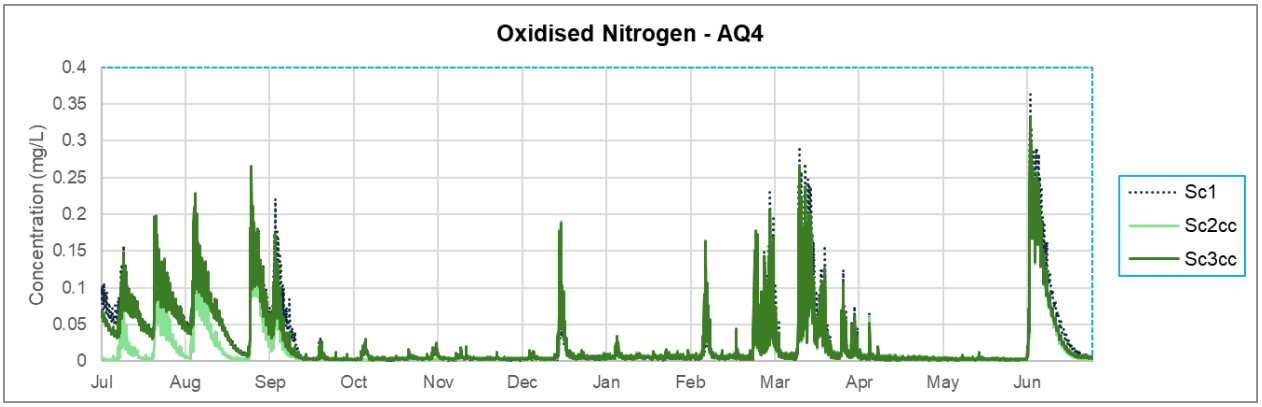


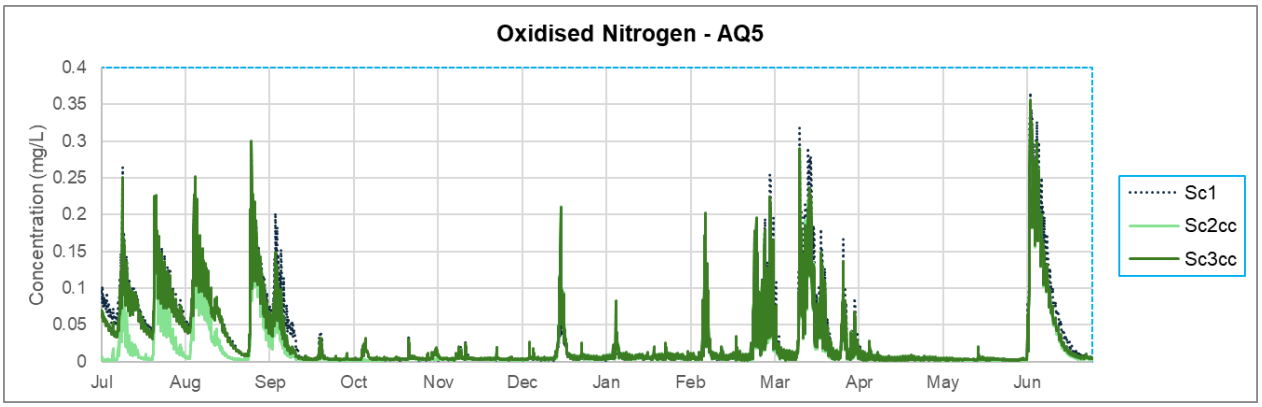
Time series plots

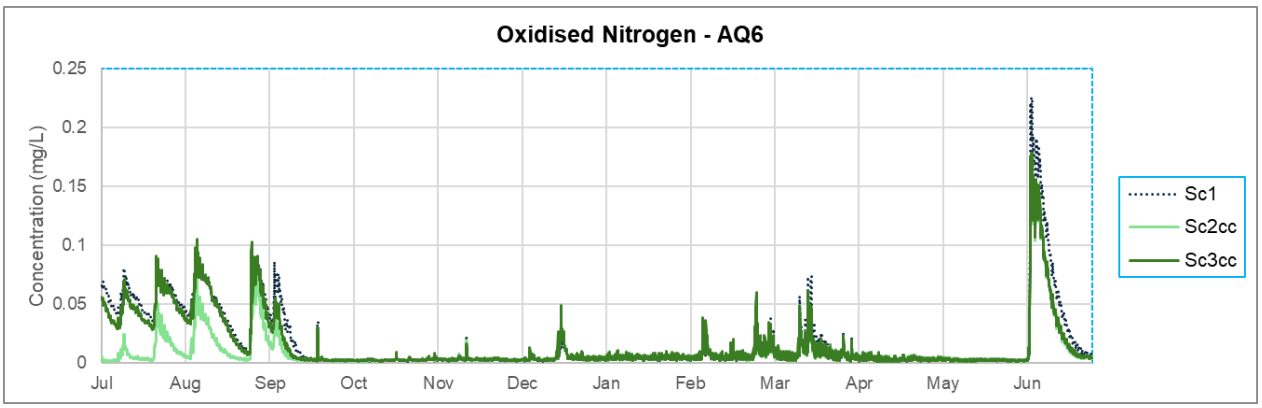






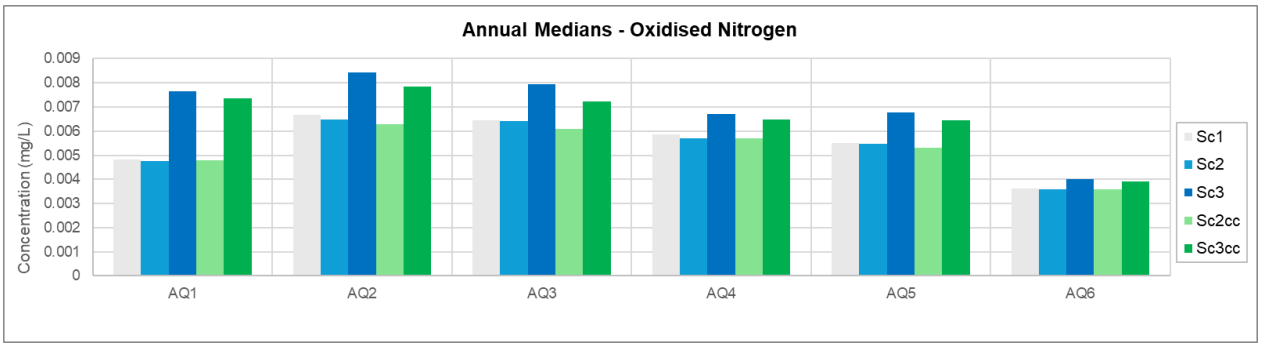


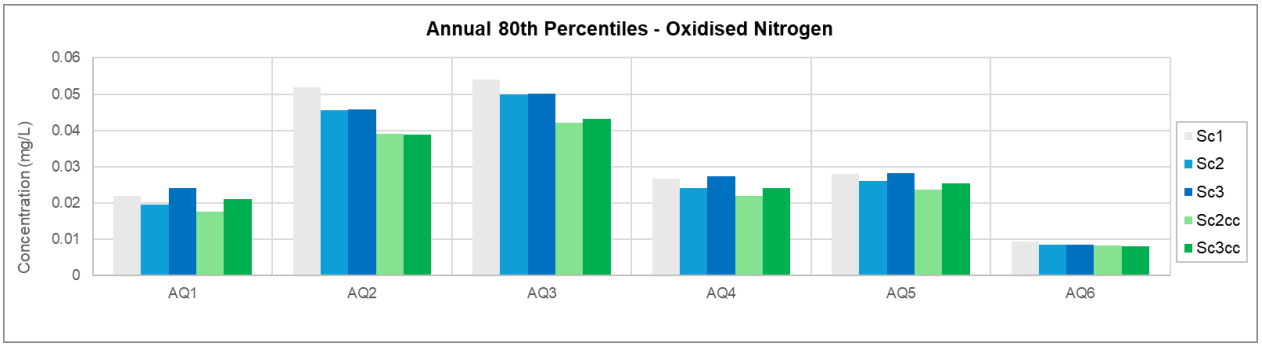




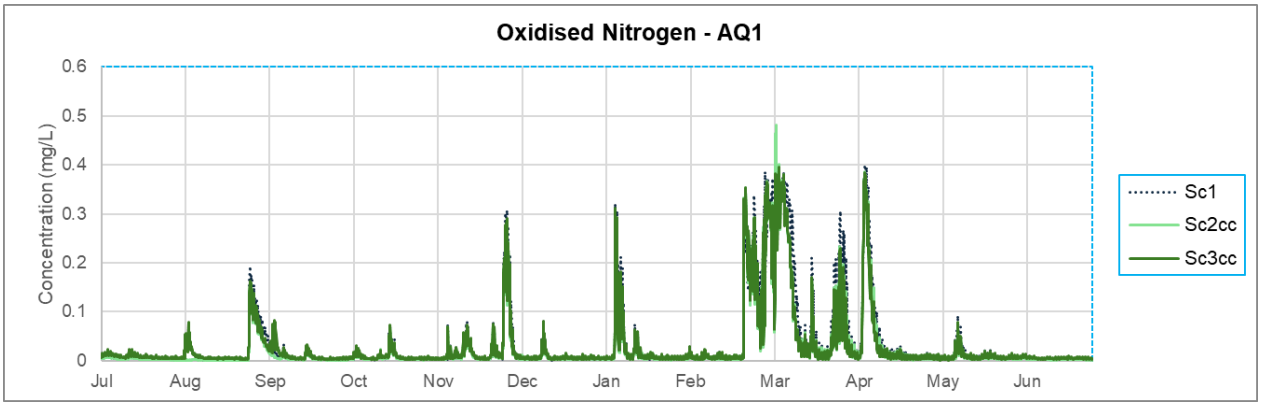
Appendices D4.5.3 Higher rainfall year scenario results (2021-2022)

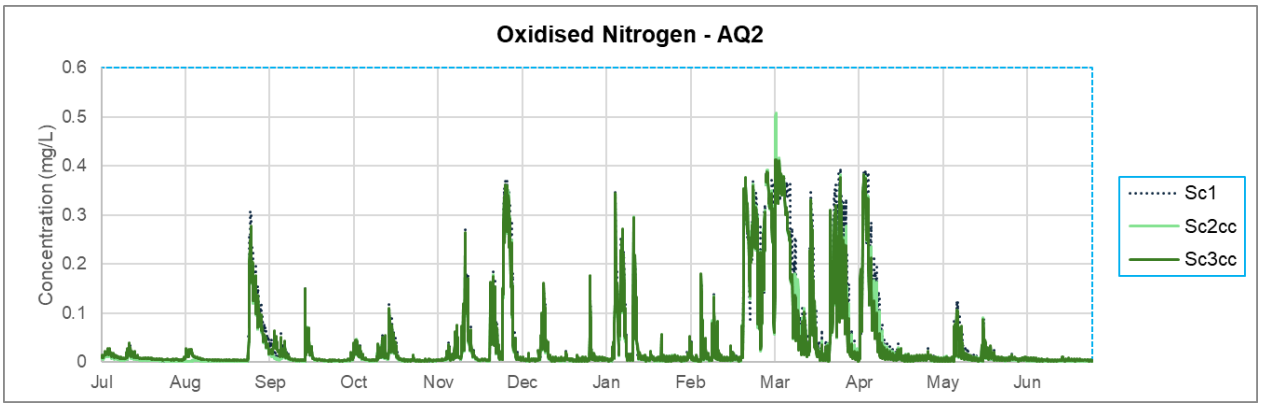
Bar charts

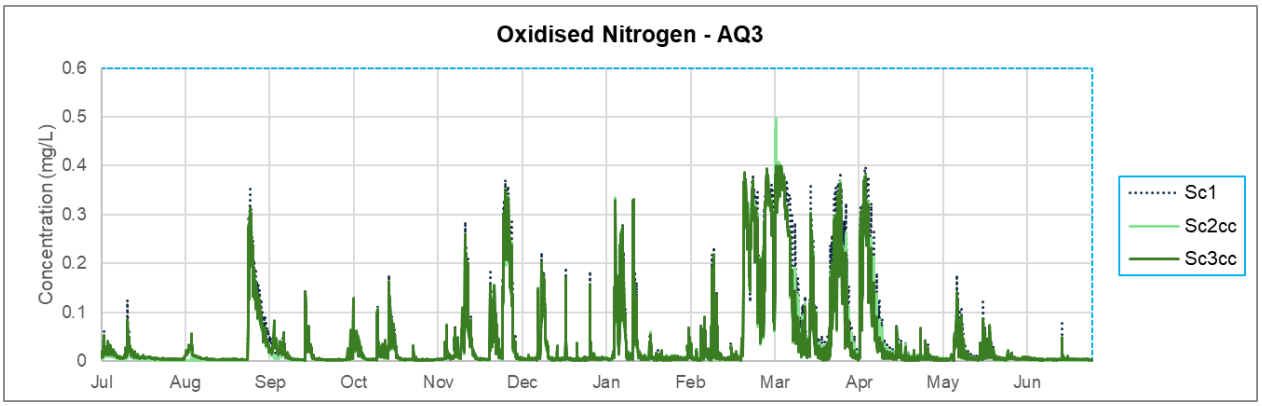


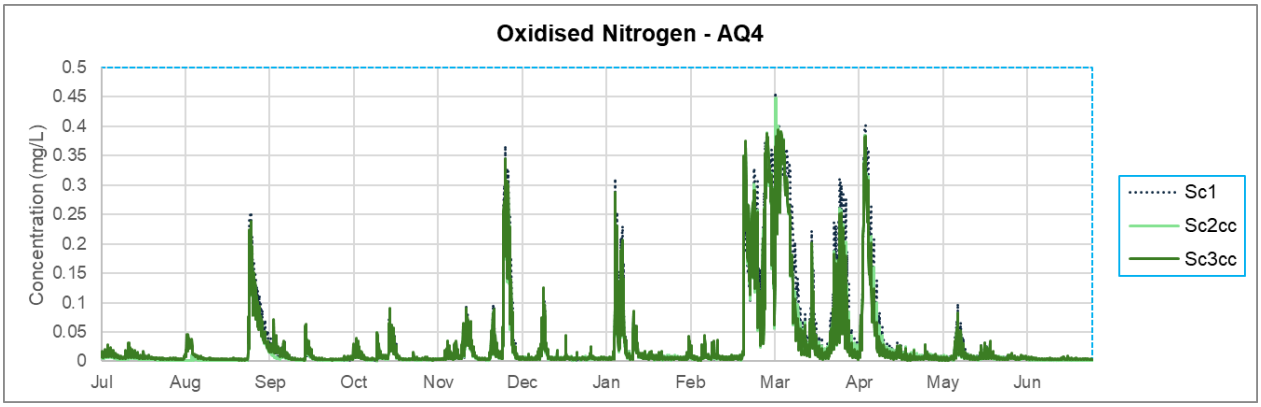


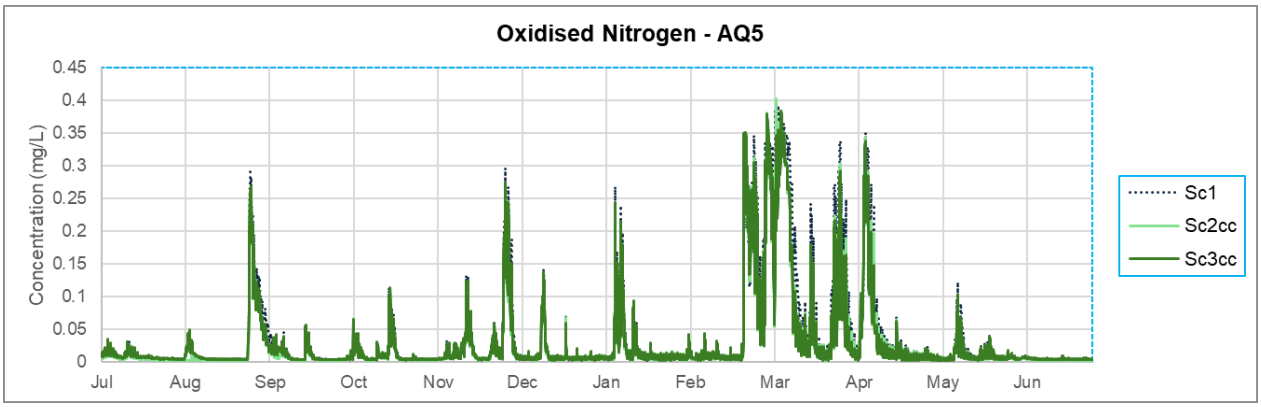
Time series plots

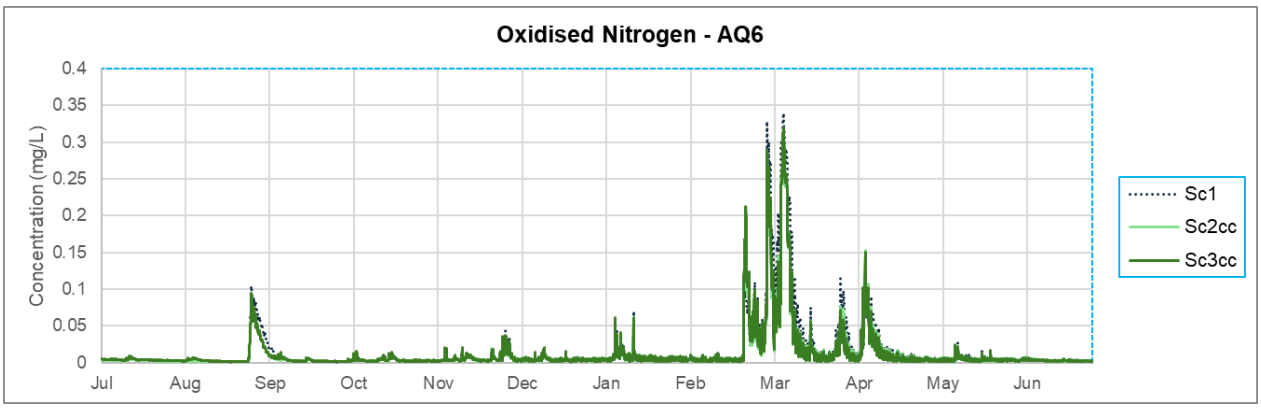







Oxidised Nitrogen - AQ4
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

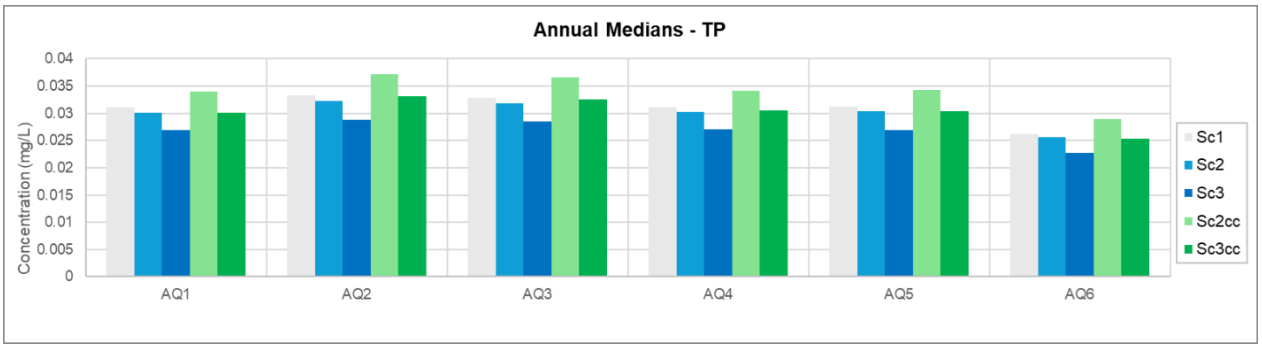

Oxidised Nitrogen - AQ5
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

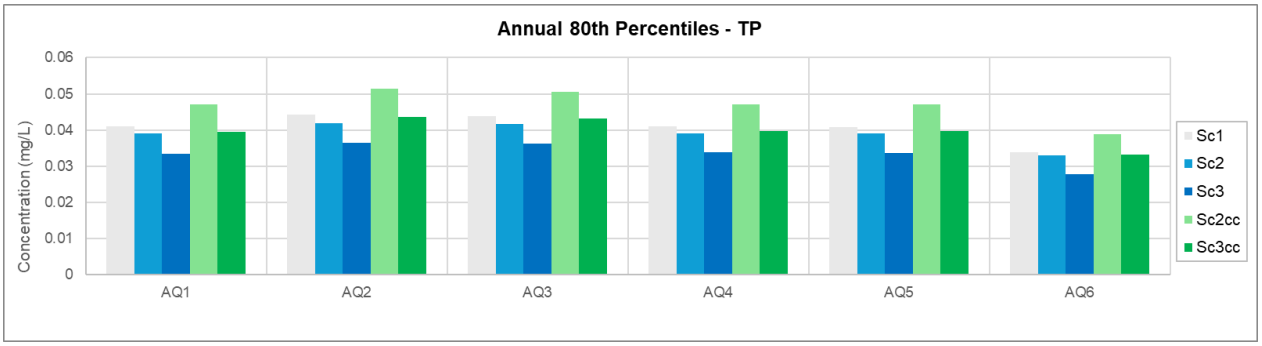

Oxidised Nitrogen - AQ6
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D4.6 Total P

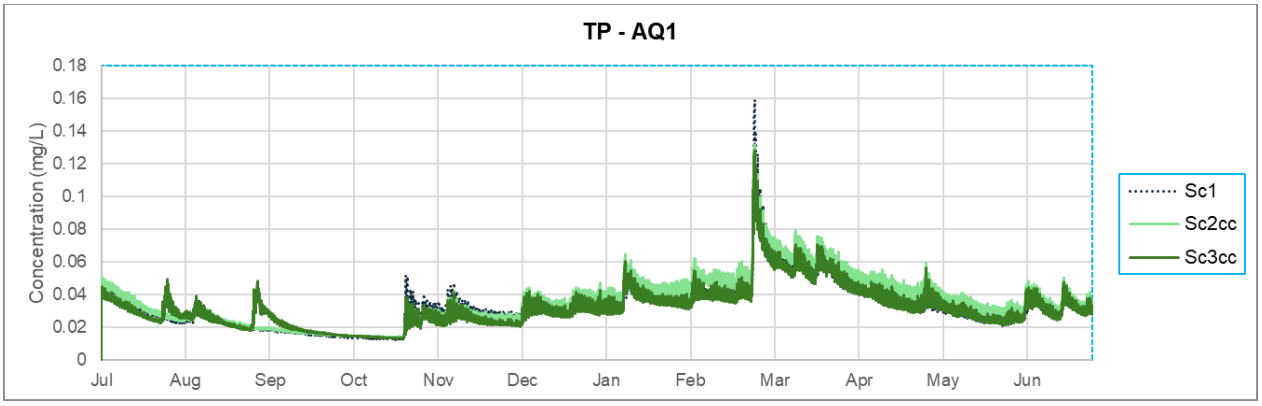
Appendices D4.6.1 Lower rainfall year scenario results (2017-2018)

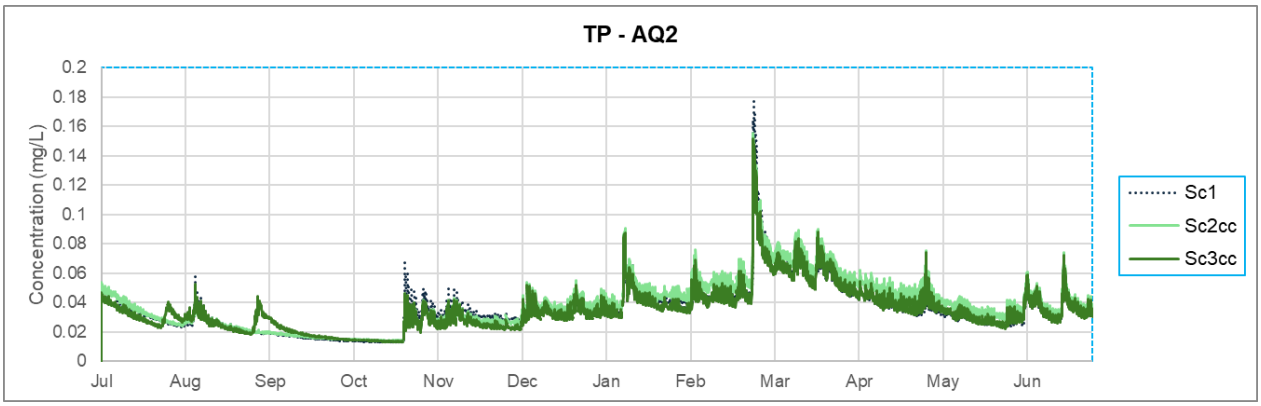
Bar charts

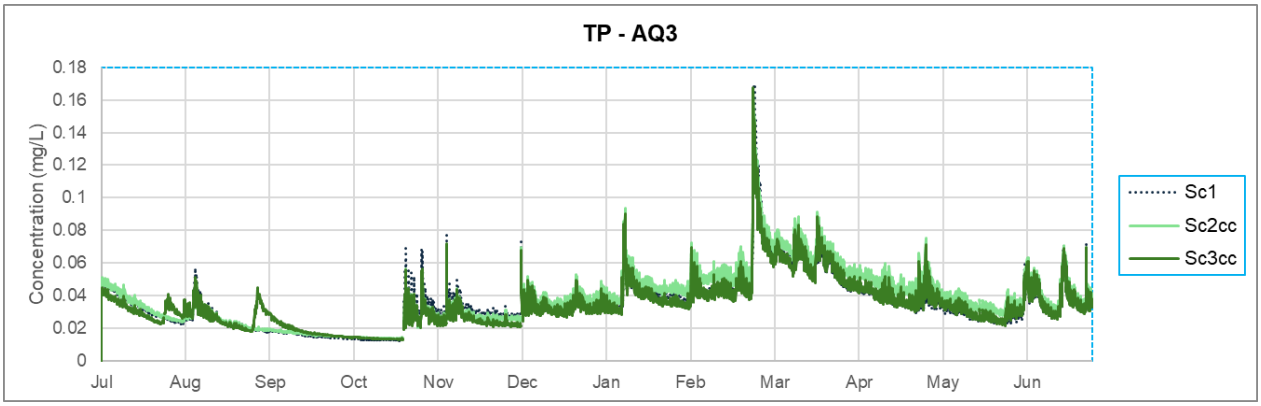


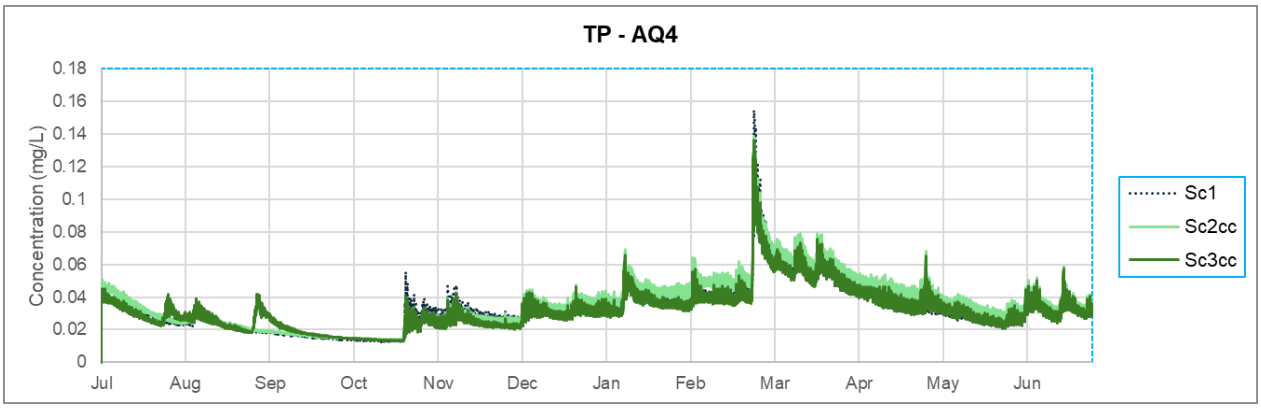


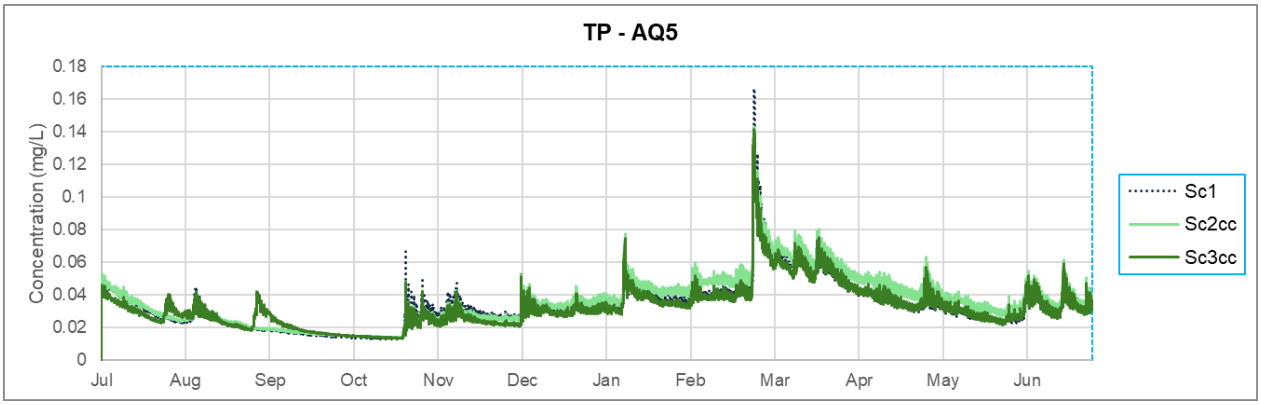
Time series plots

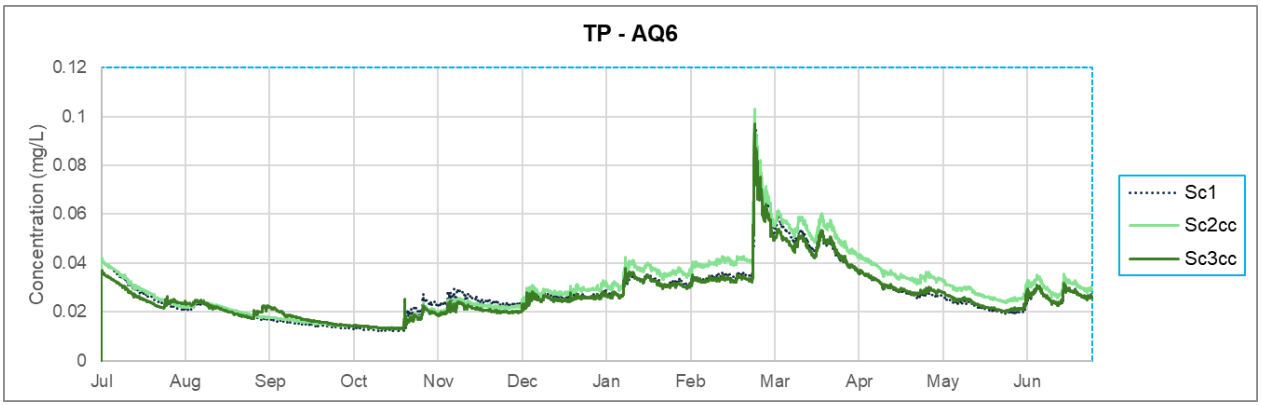



TP - AQ2
Concentration (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


TP - AQ3
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

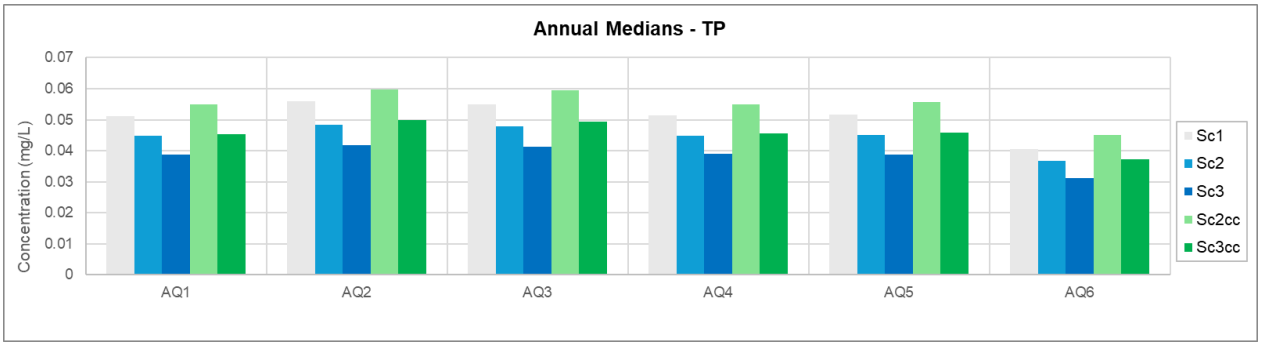

TP - AQ4
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

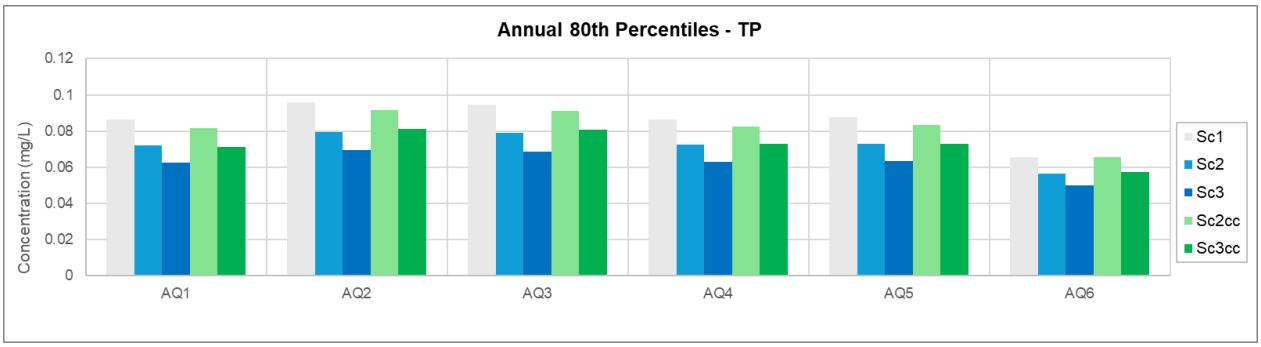

TP - AQ5
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



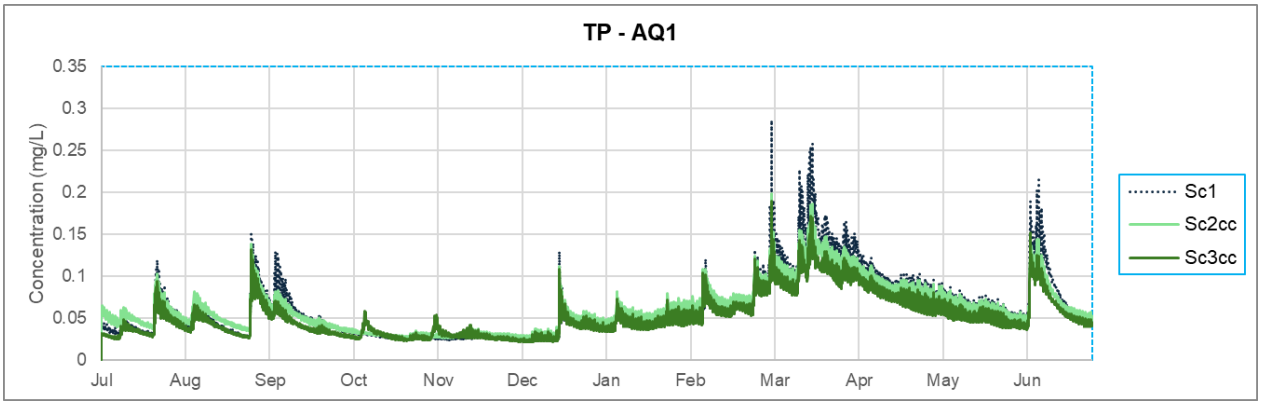
Appendices D4.6.2 Average rainfall year scenario results (2016-2017)

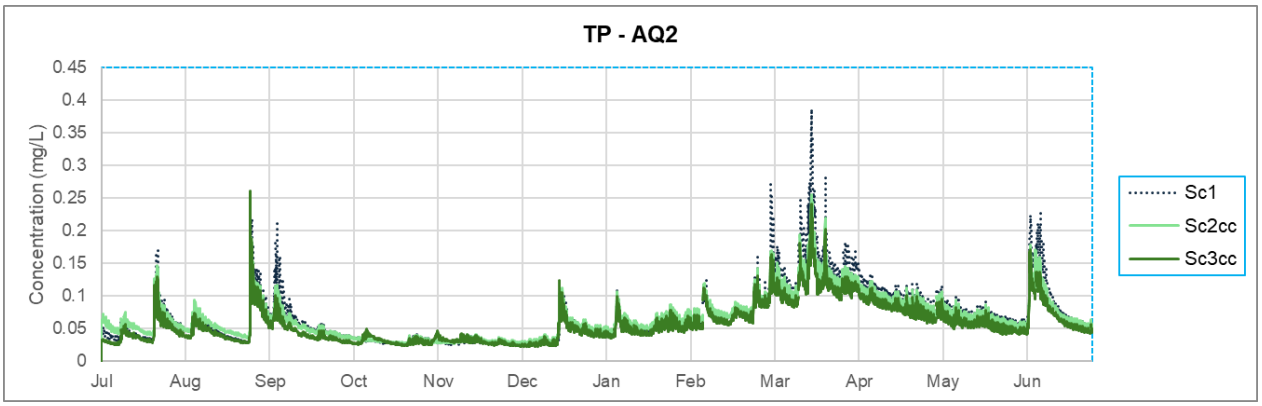
Bar charts

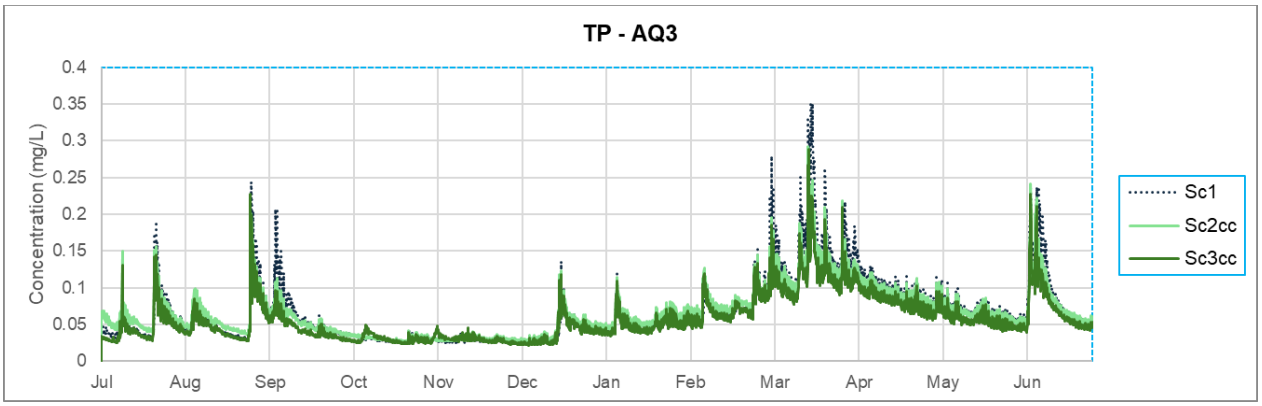


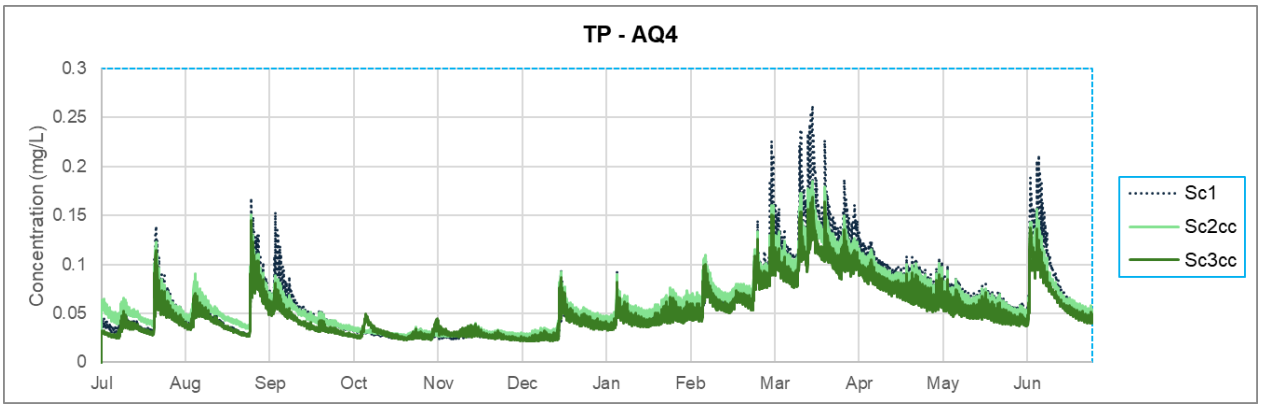


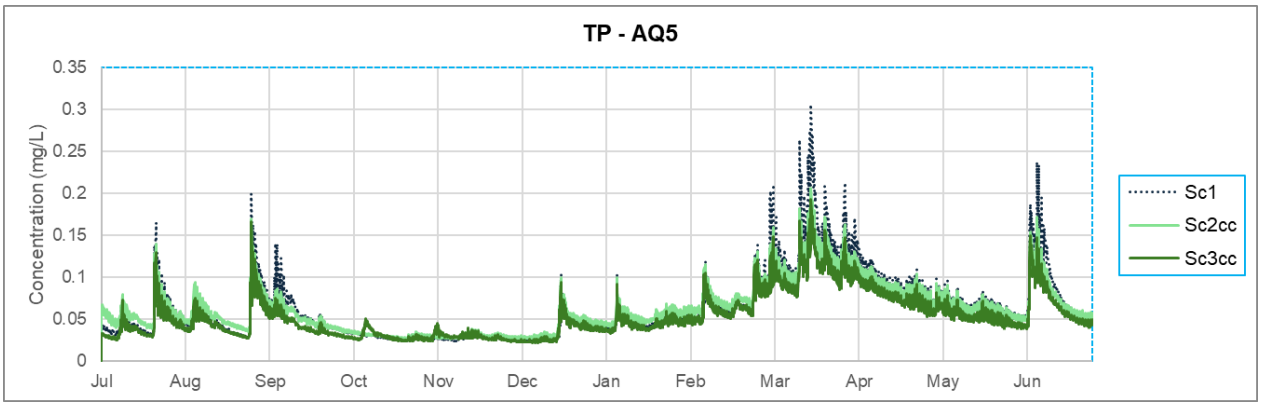
Time series plots

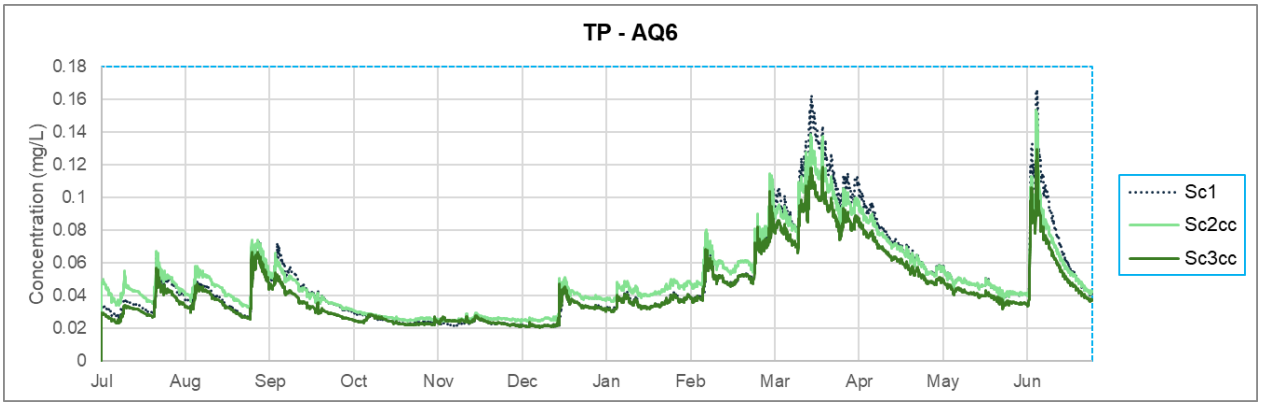






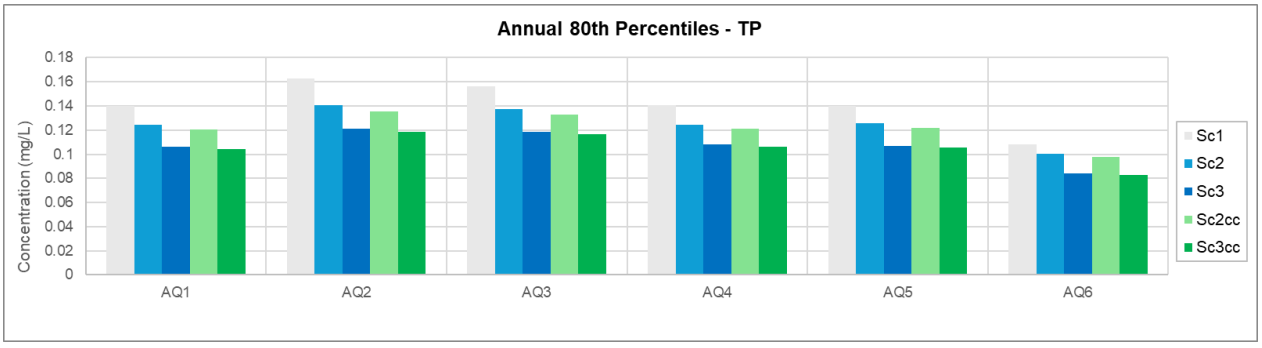




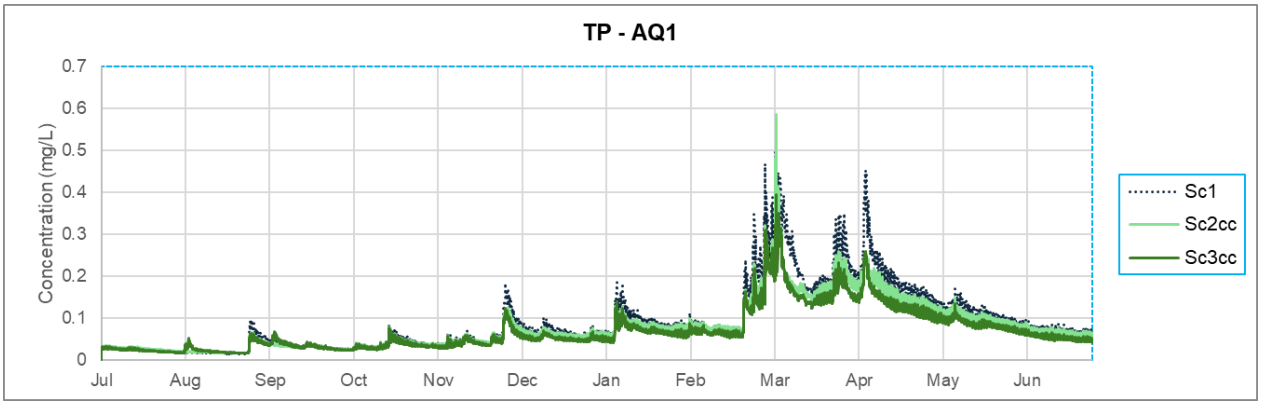


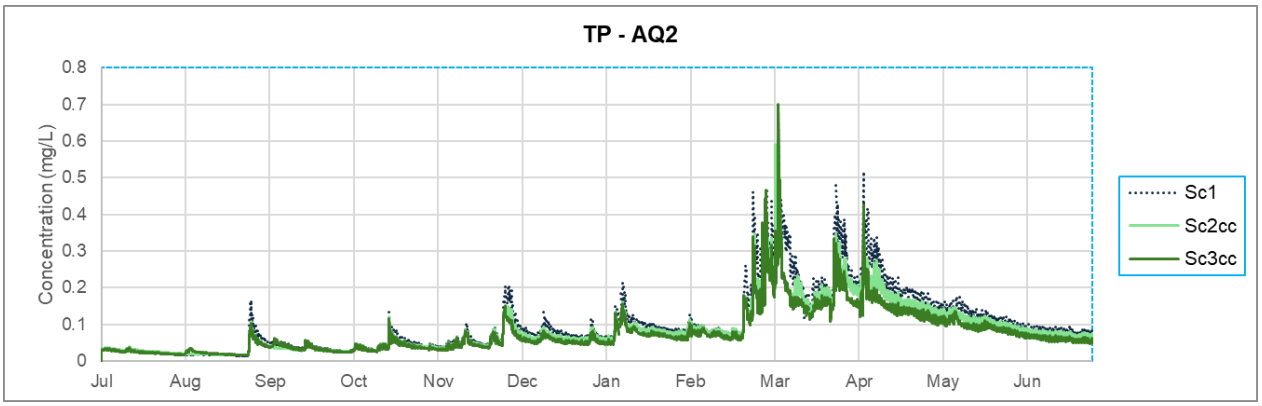
Appendices D4.6.3 Higher rainfall year scenario results (2021-2022)

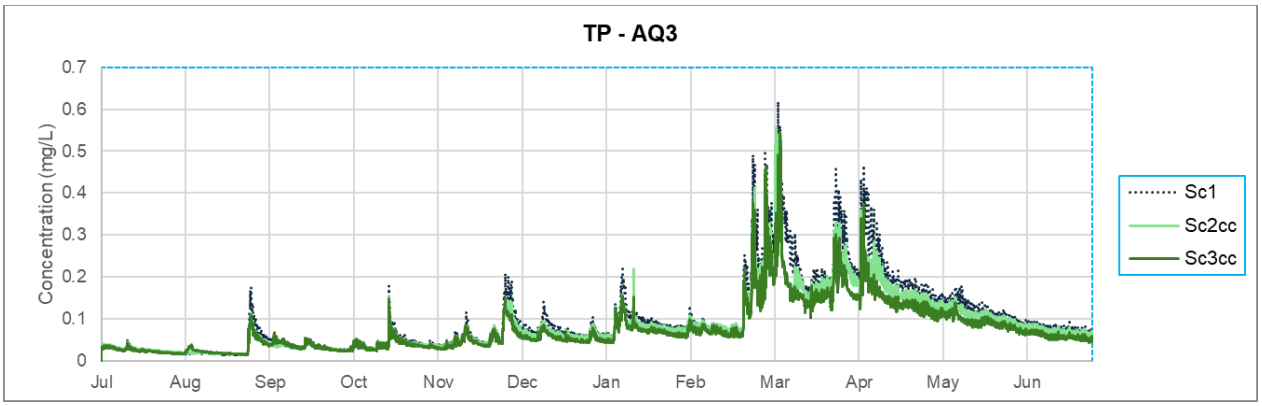
Bar charts

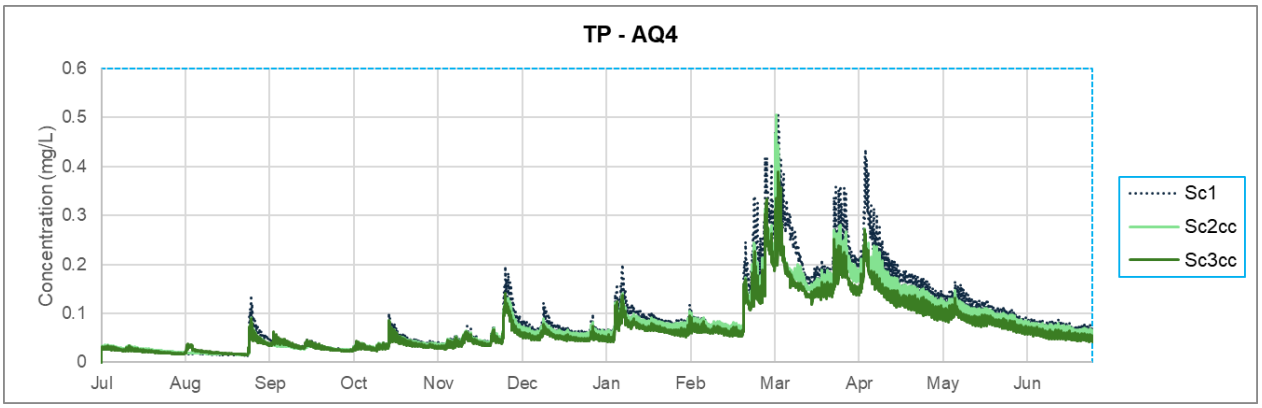


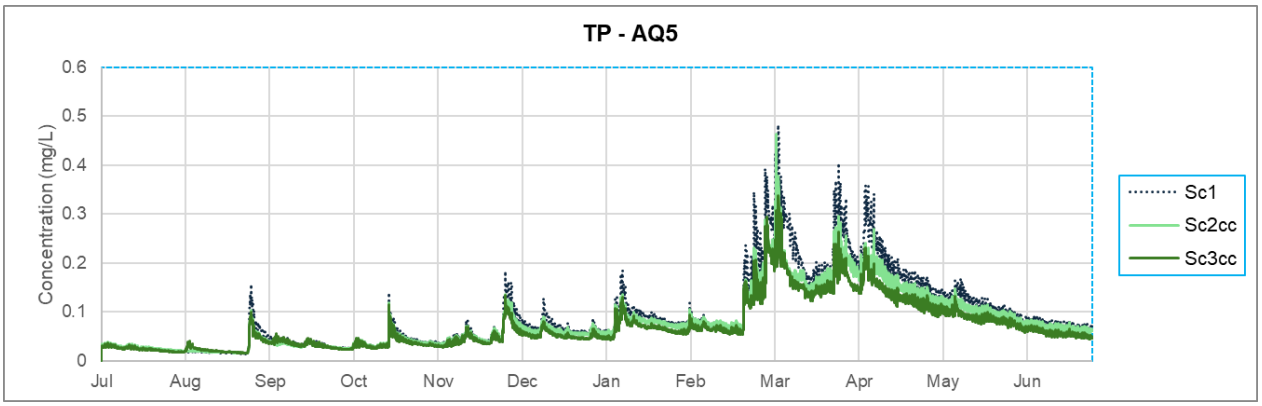
Time series plots

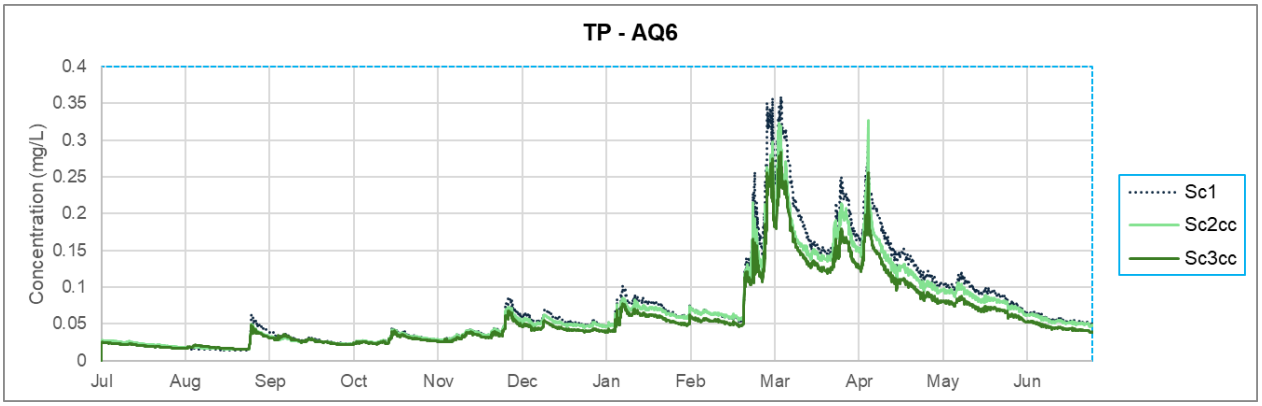








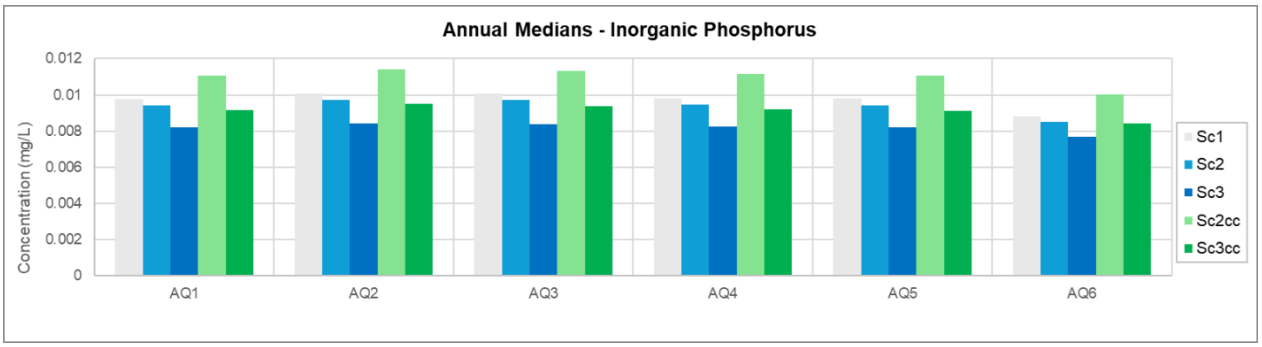


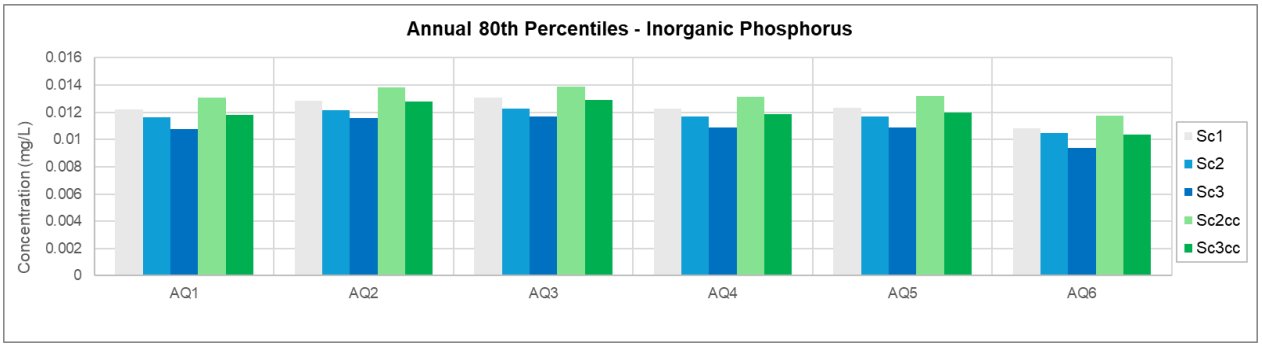


Appendices D4.7 Inorganic P

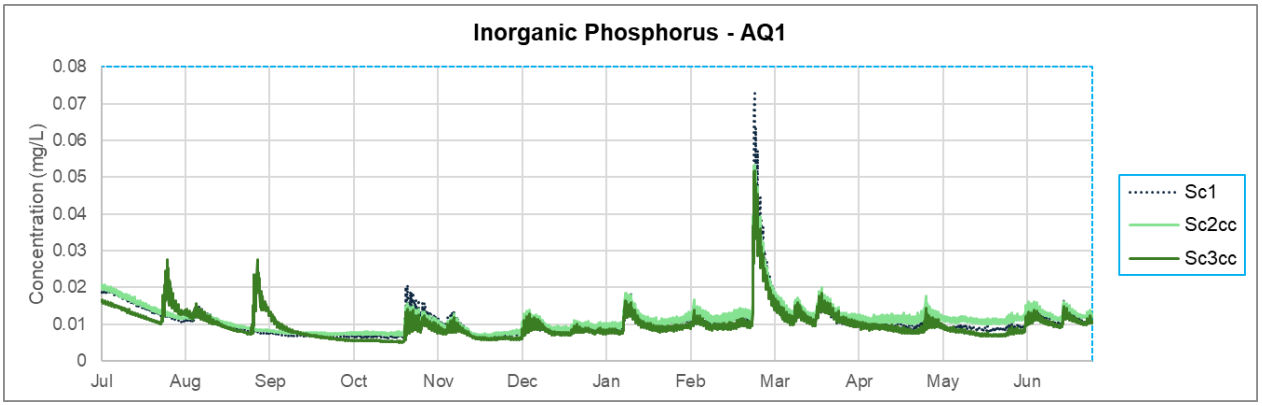
Appendices D4.7.1 Lower rainfall year scenario results (2017-2018)

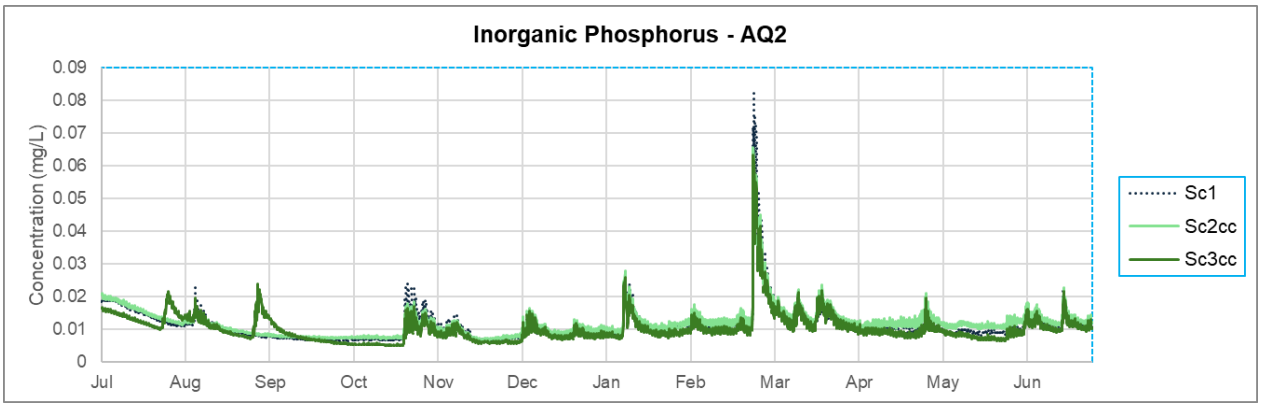
Bar charts

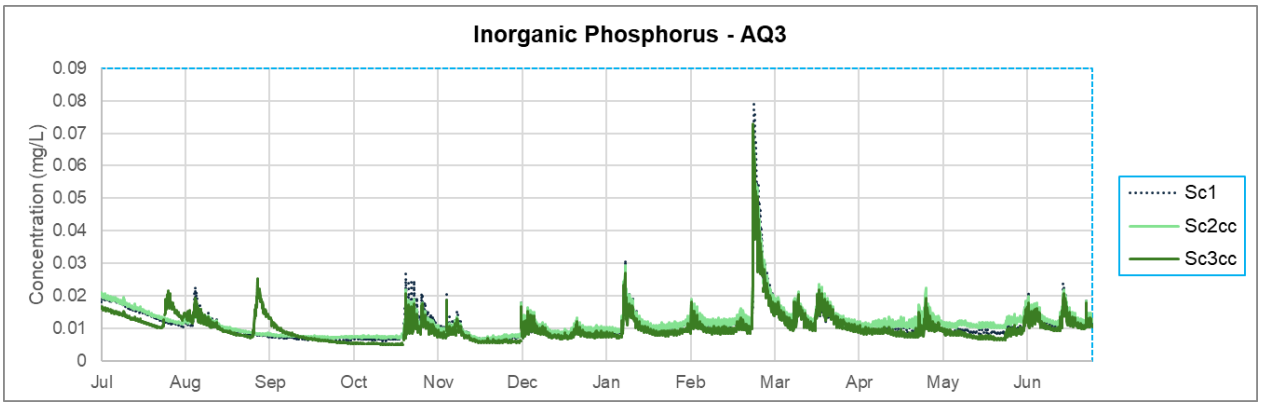


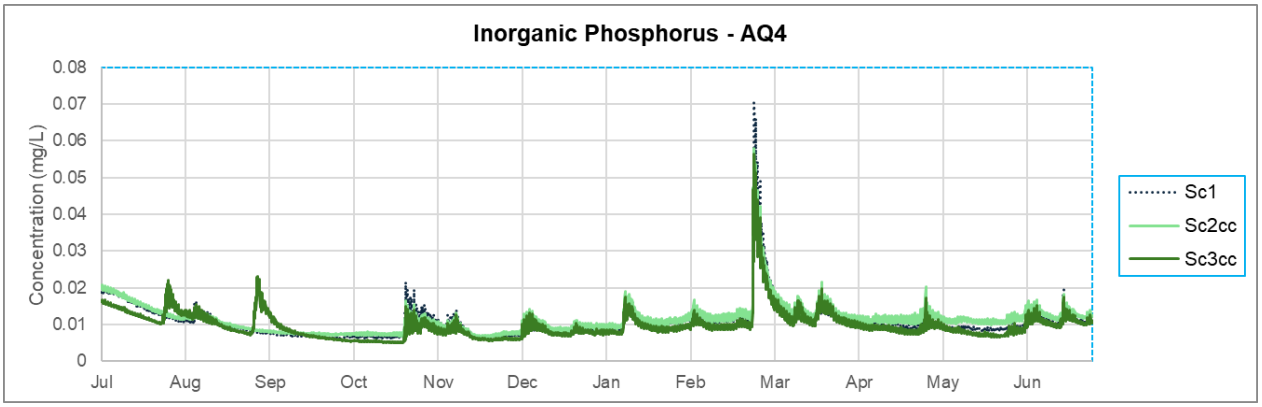


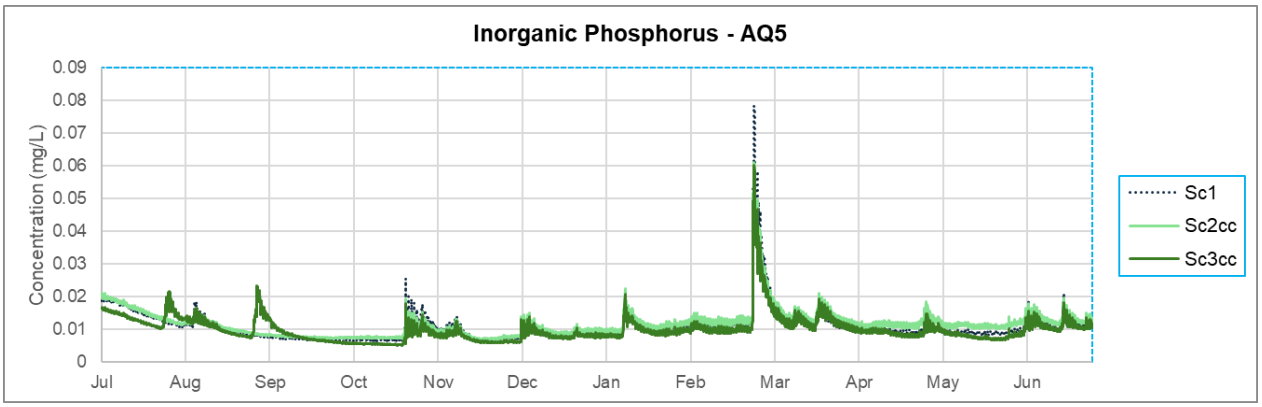
Time series plots

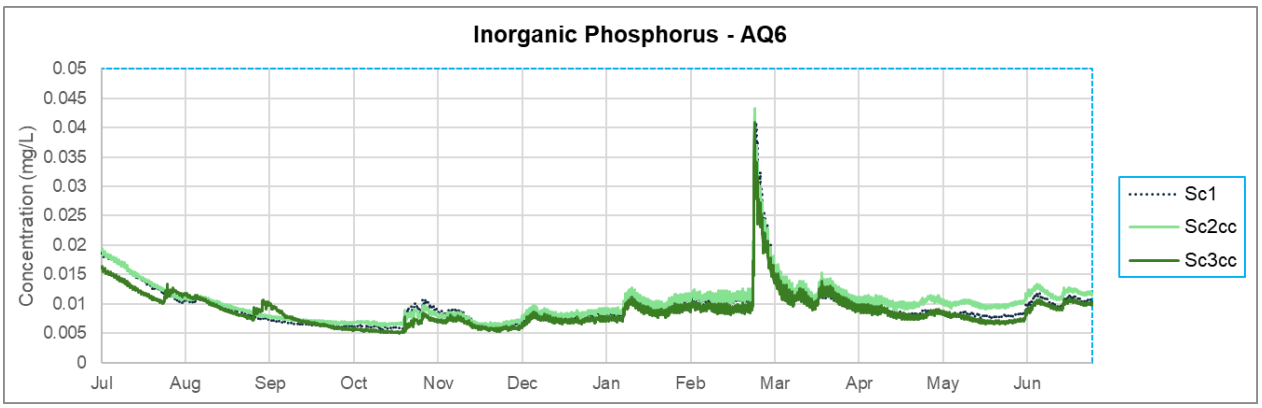






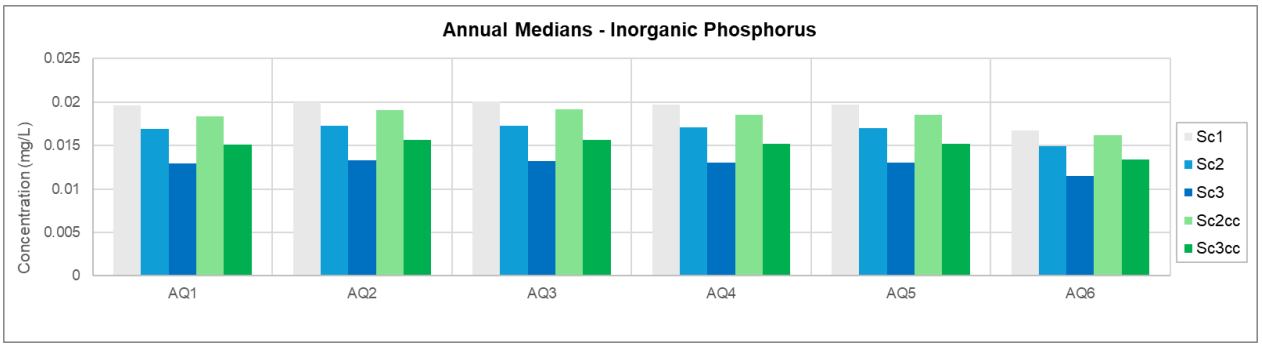


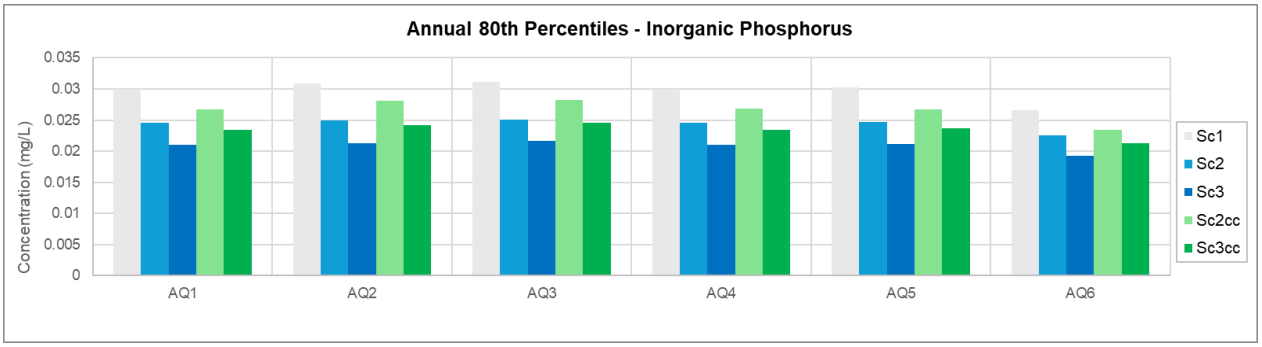




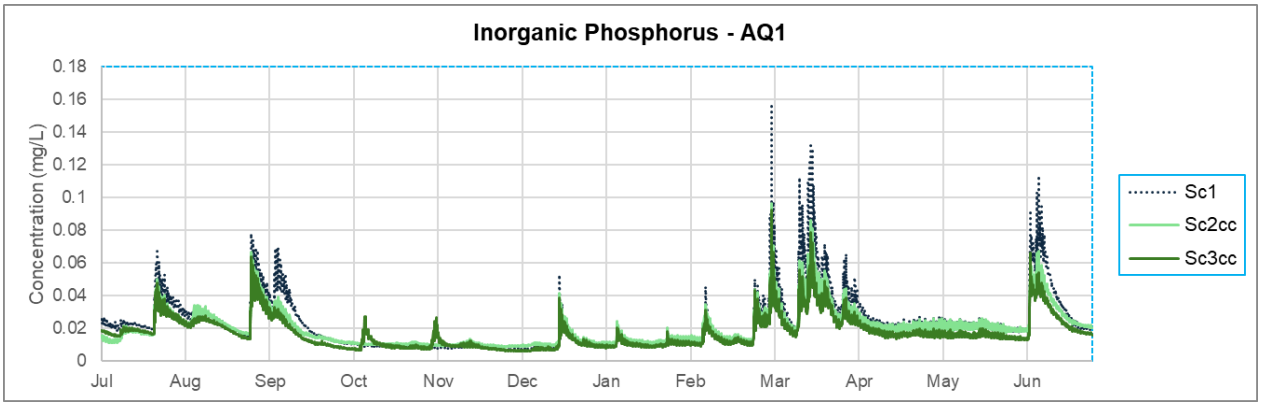
Appendices D4.7.2 Average rainfall year scenario results (2016-2017)

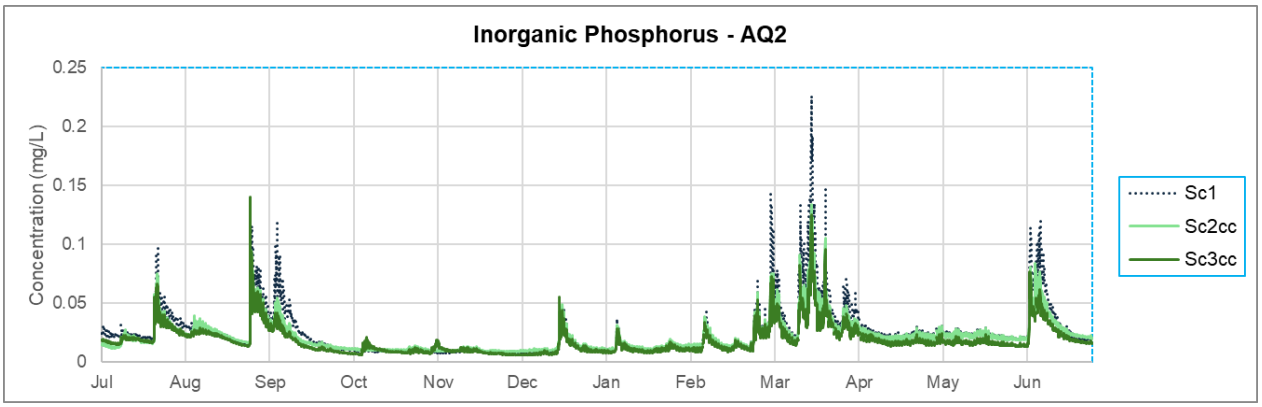
Bar charts

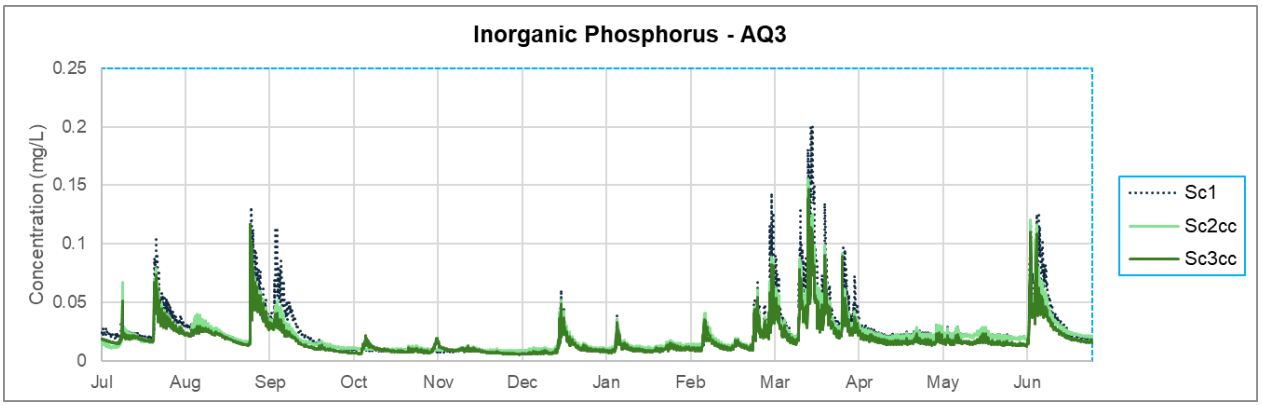


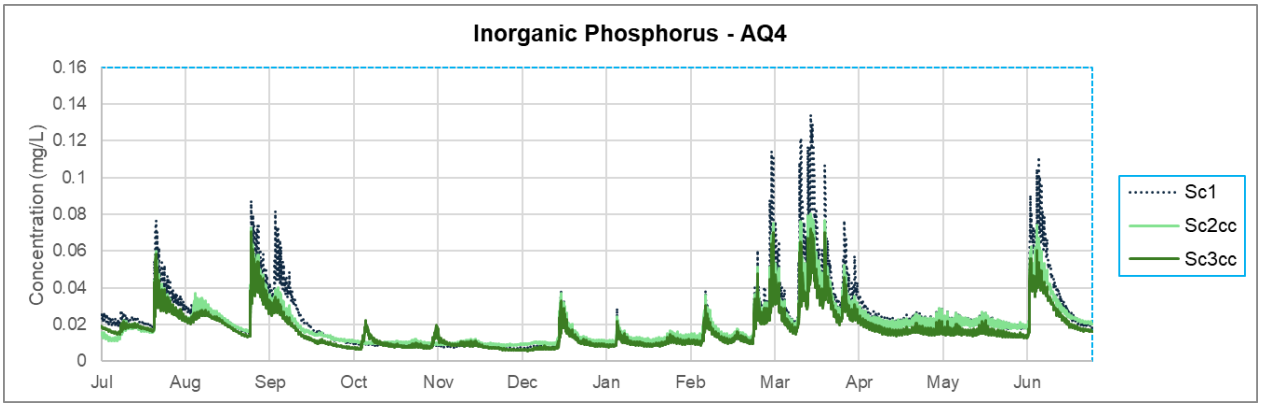


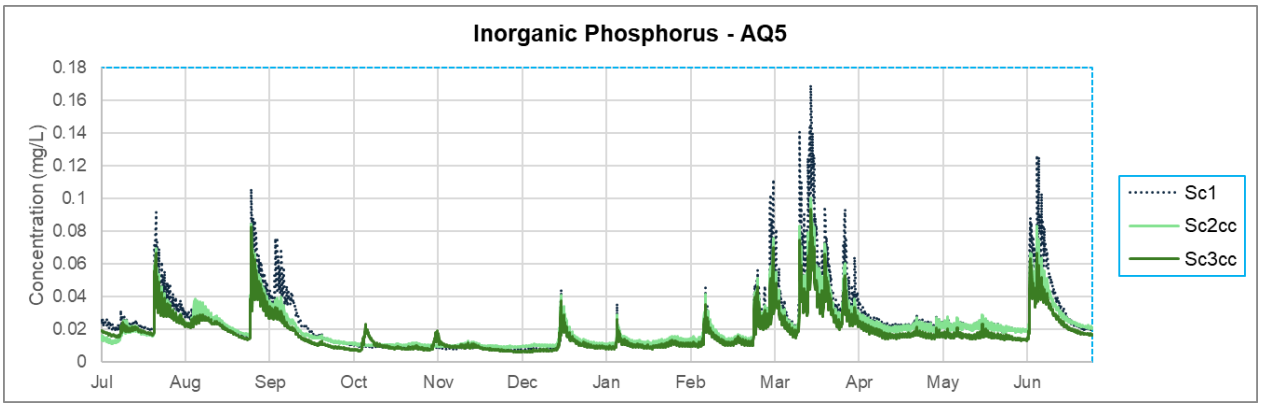
Time series plots

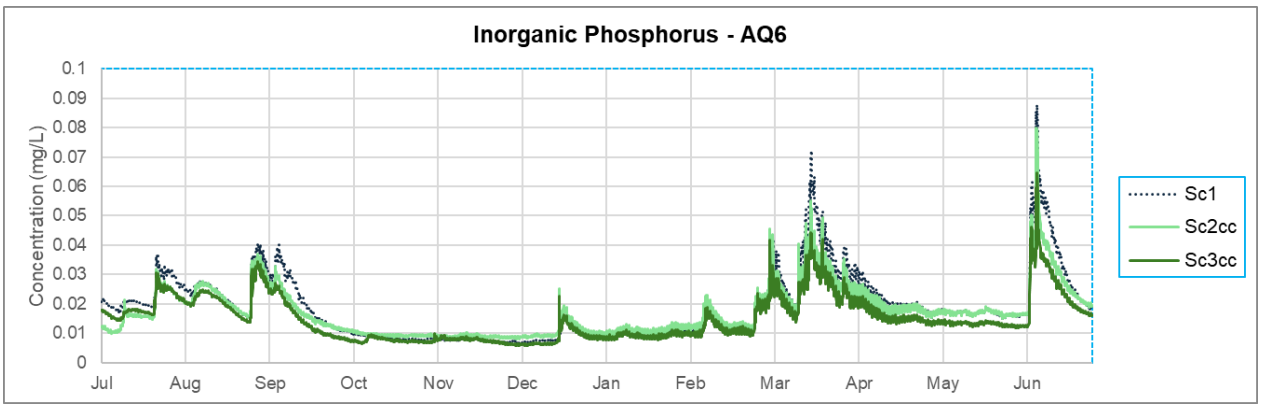






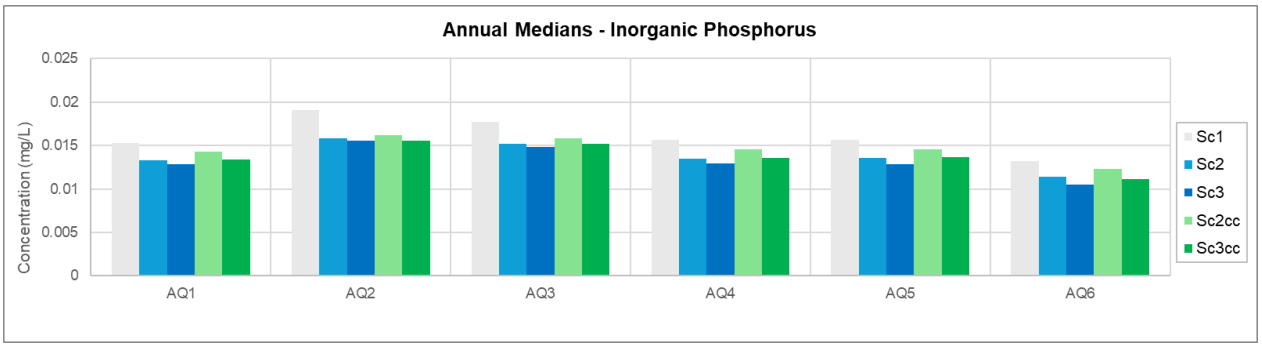


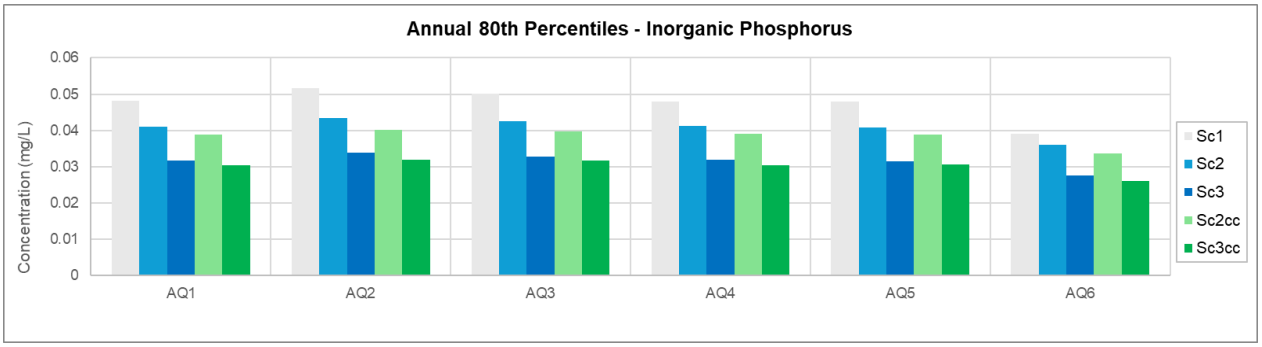




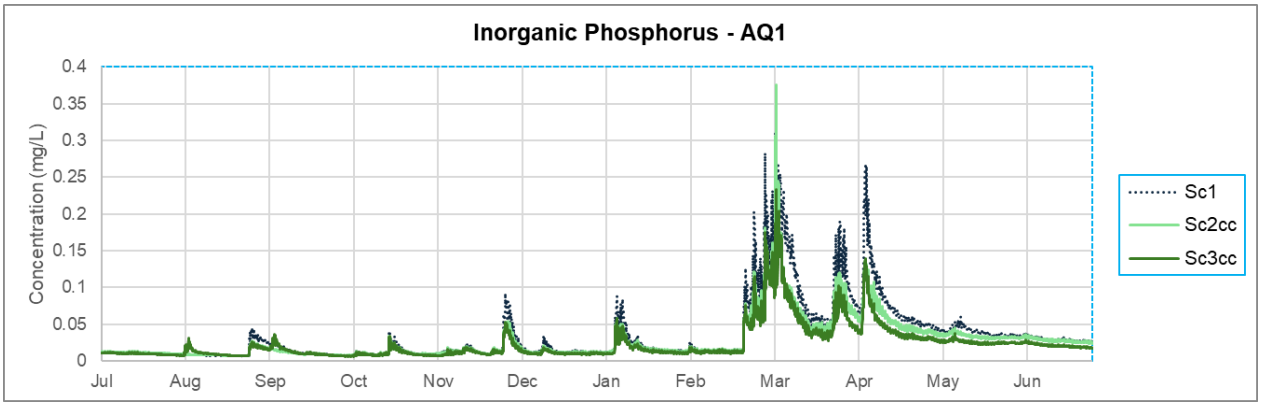
Appendices D4.7.3 Higher rainfall year scenario results (2021-2022)

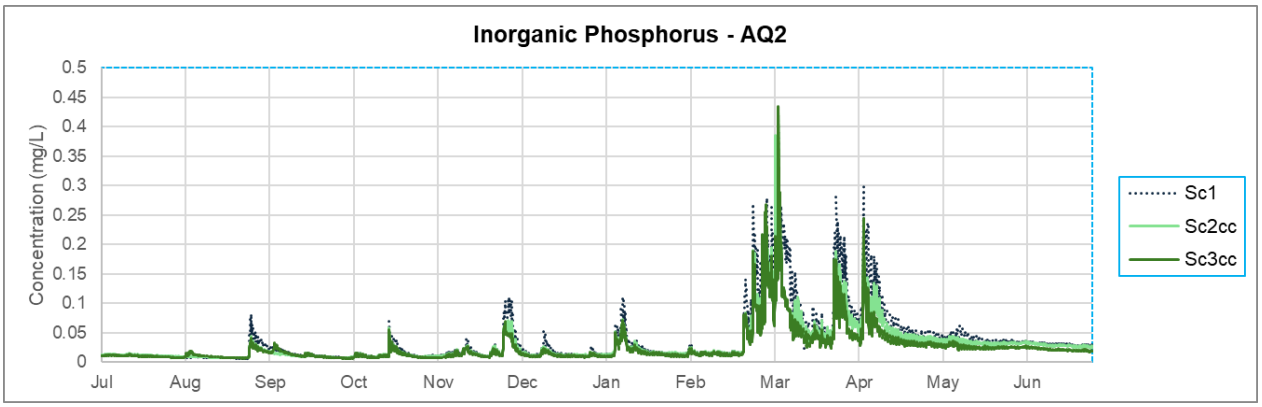
Bar charts

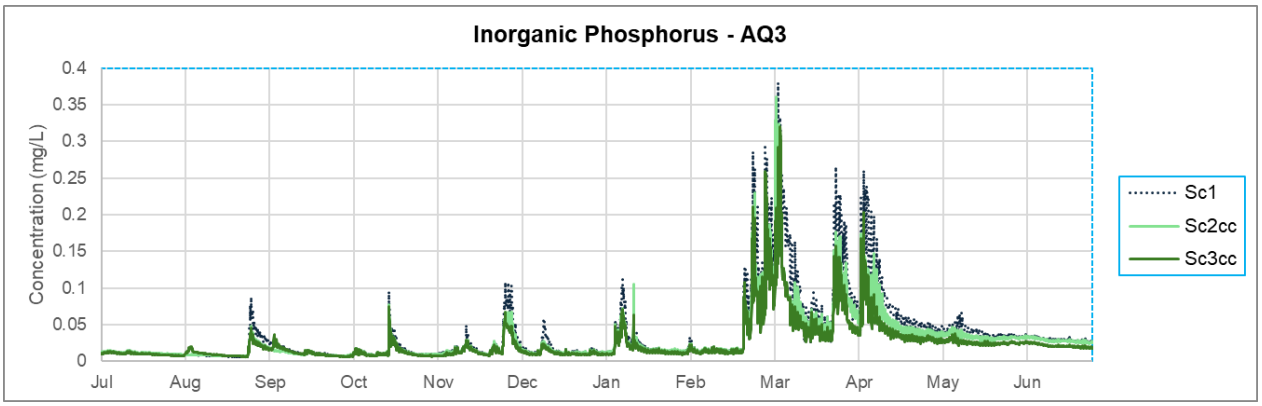


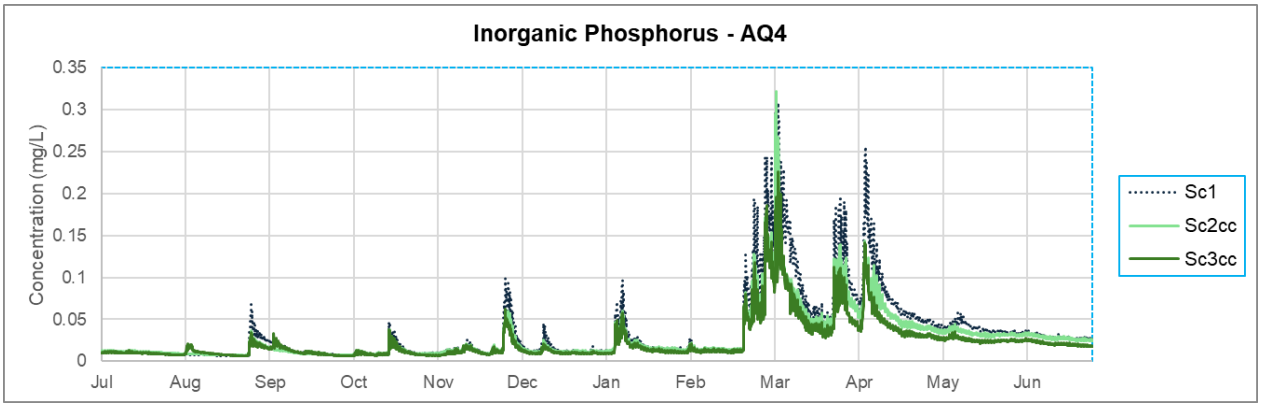


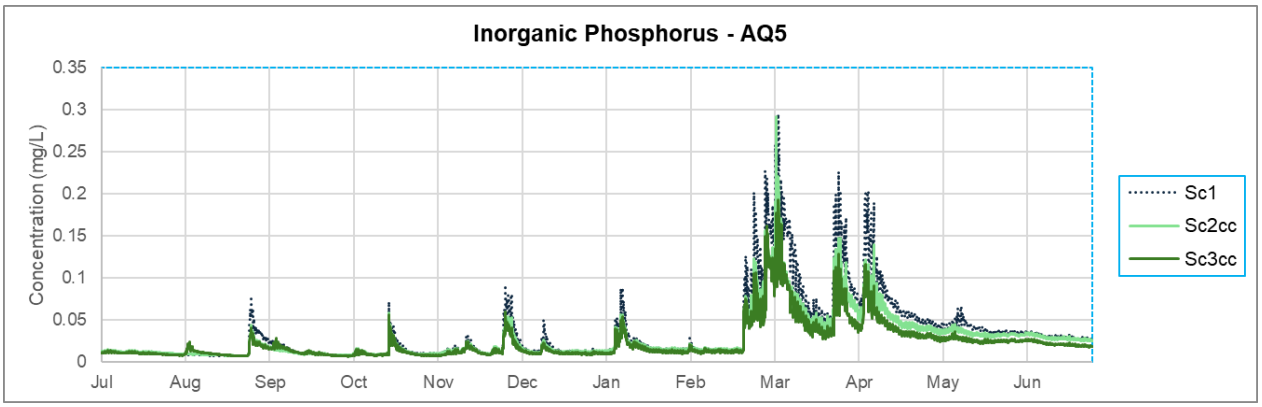
Time series plots

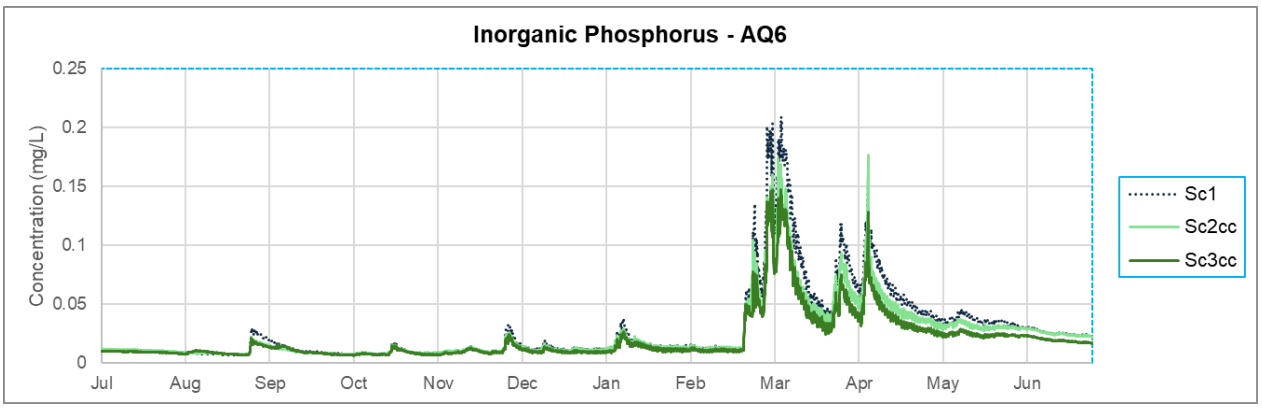







Inorganic Phosphorus - AQ4
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Inorganic Phosphorus - AQ5
Concentration (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

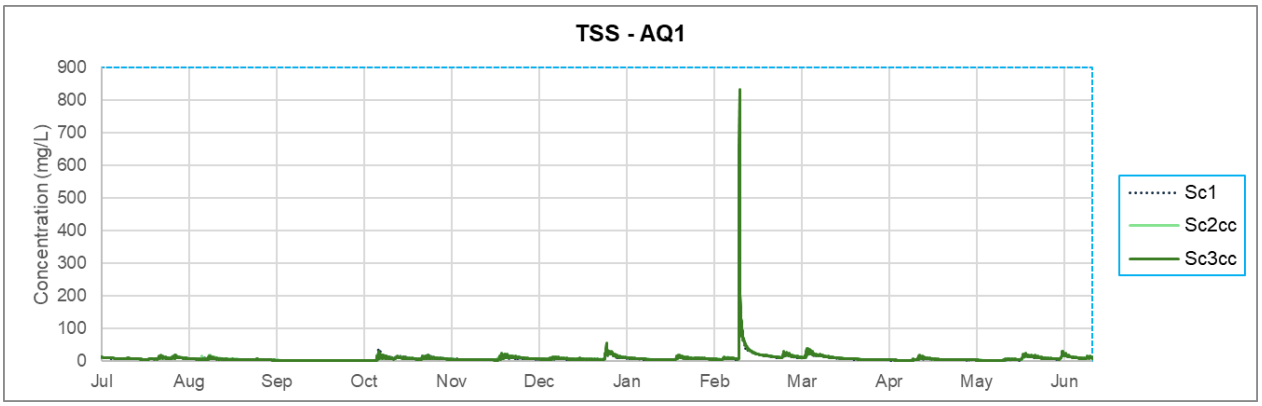

Inorganic Phosphorus - AQ6
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

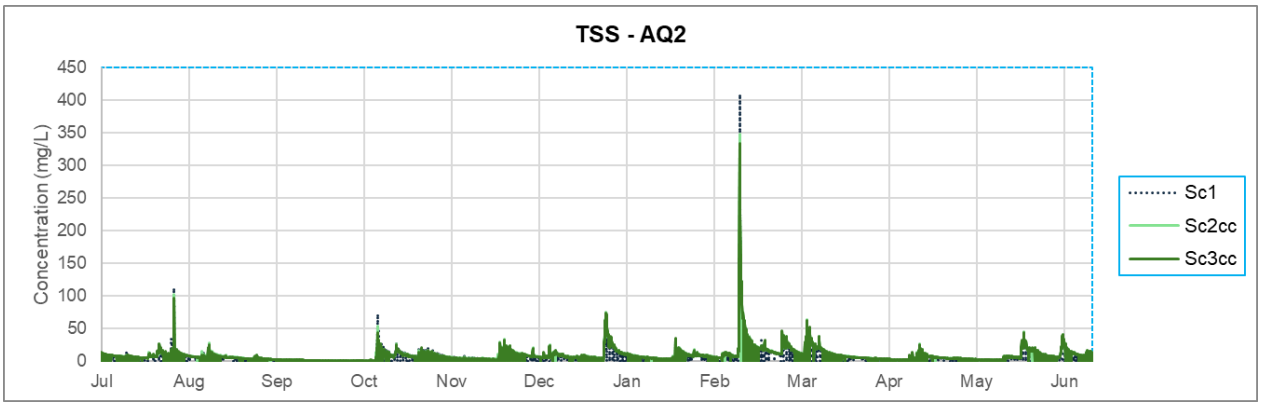
Appendices D4.8 TSS

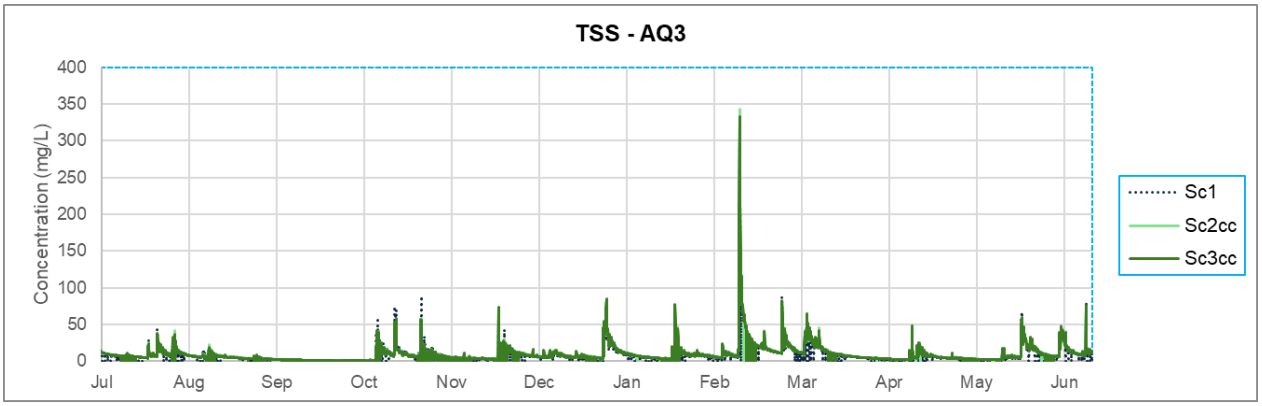
Appendices D4.8.1 Lower rainfall year scenario results (2017-2018)

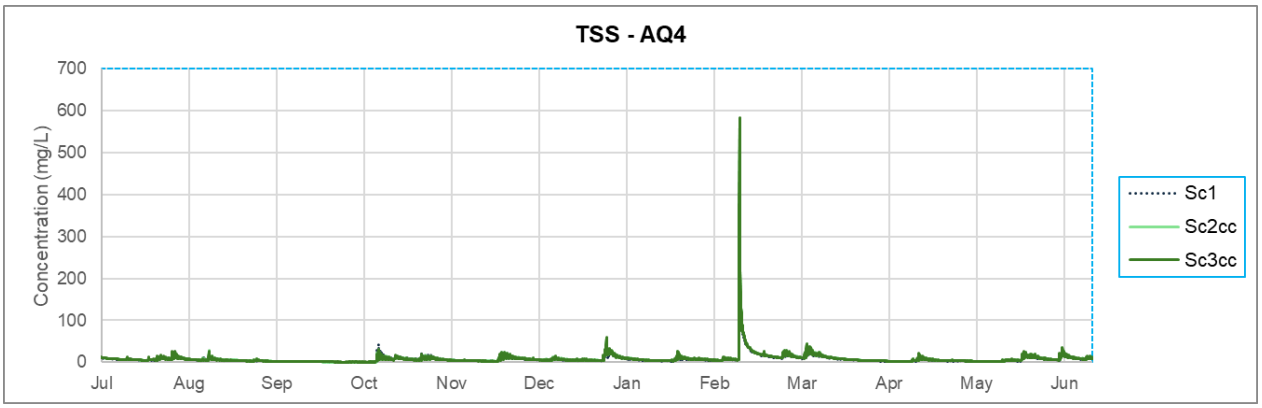
Bar charts

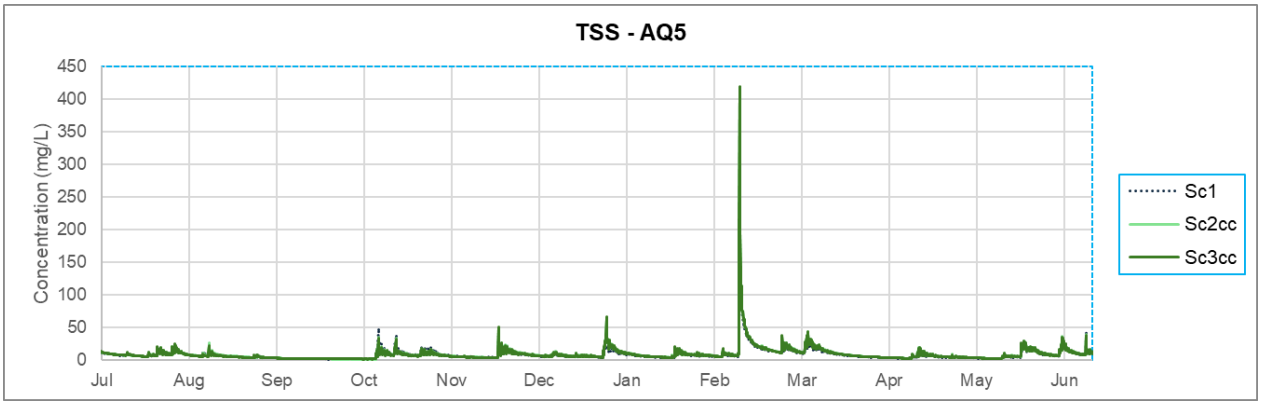
Time series plots

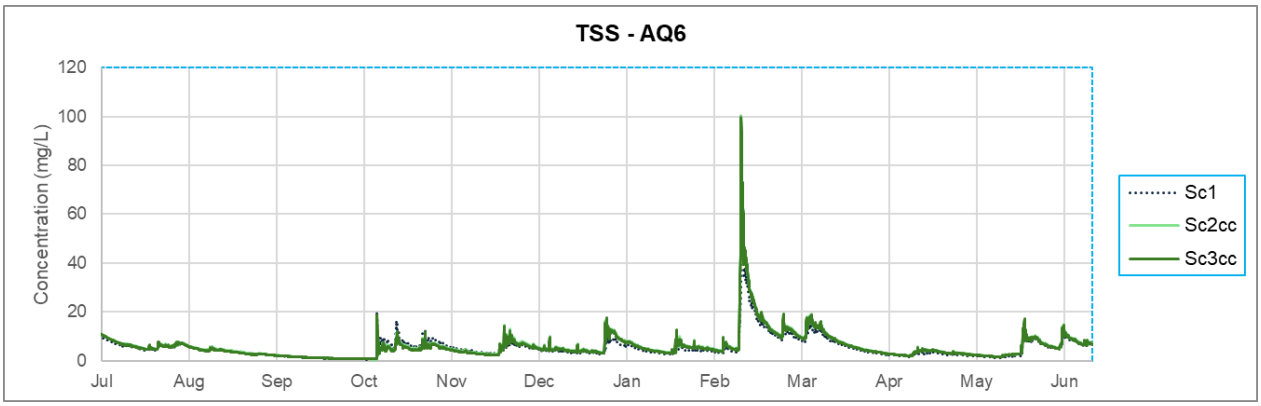



TSS - AQ2
Concentration (mg/L)
450
400
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


TSS - AQ3
Concentration (mg/L)
400
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


TSS - AQ4
Concentration (mg/L)
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

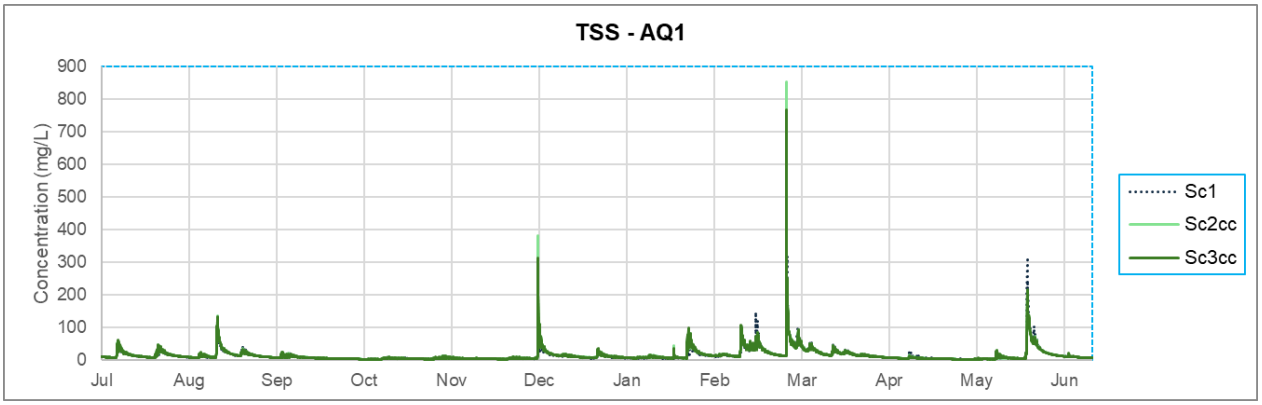

TSS - AQ5
Concentration (mg/L)
450
400
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

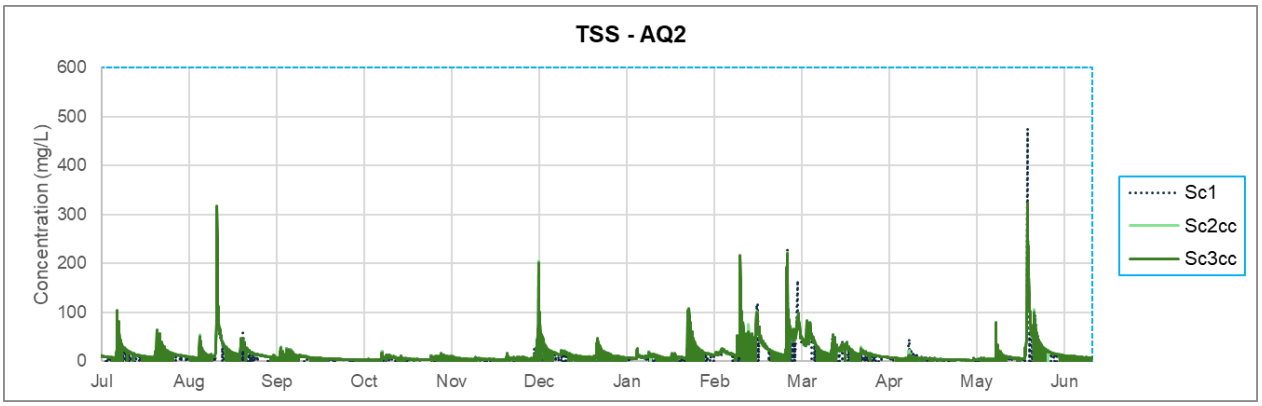


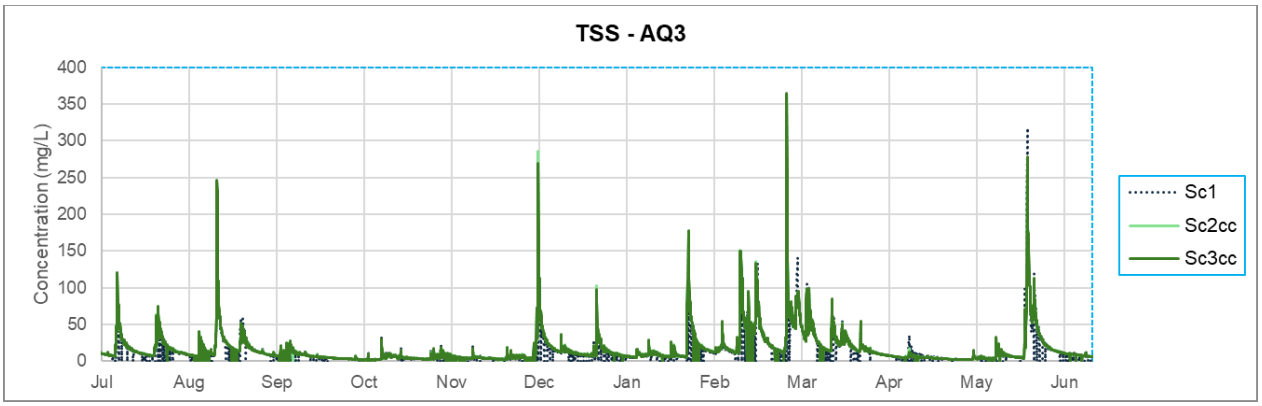
Appendices D4.8.2 Average rainfall year scenario results (2016-2017)

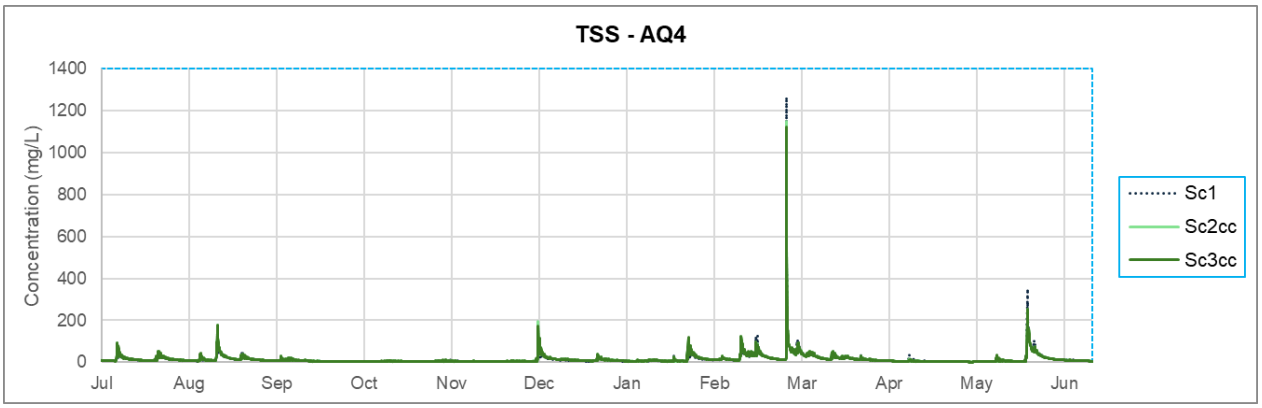
Bar charts

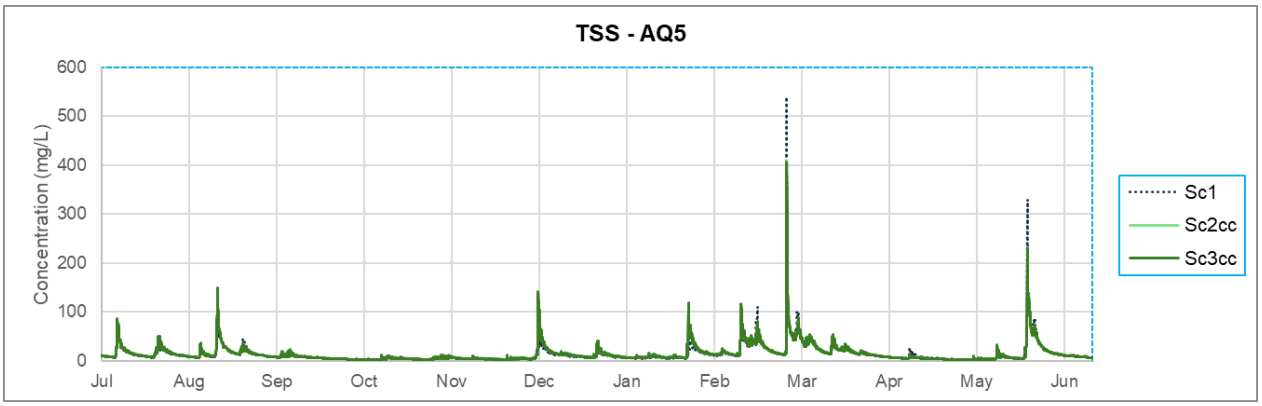
Time series plots

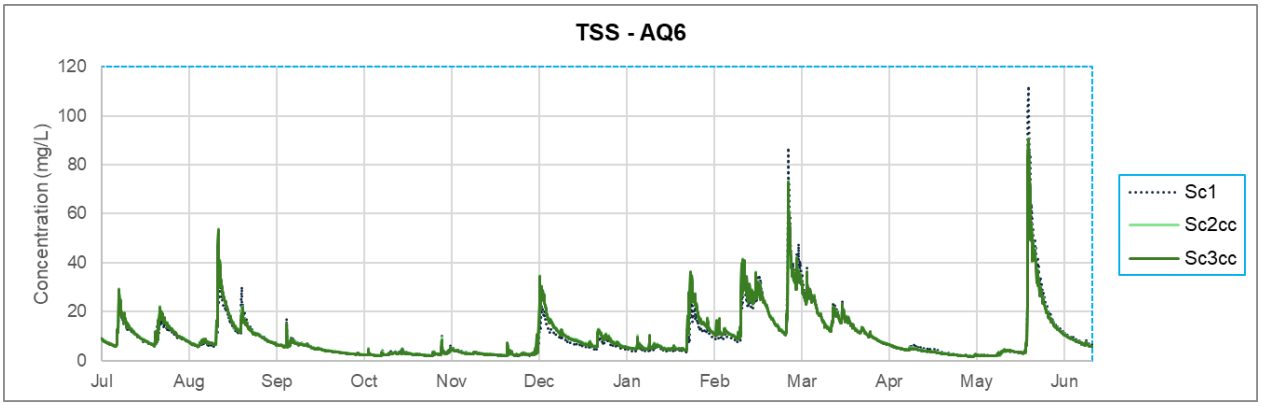








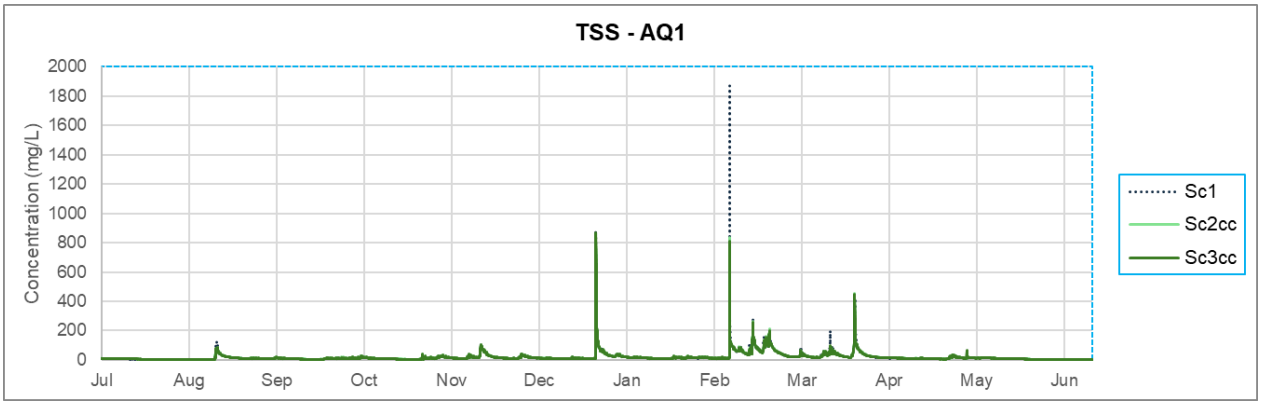


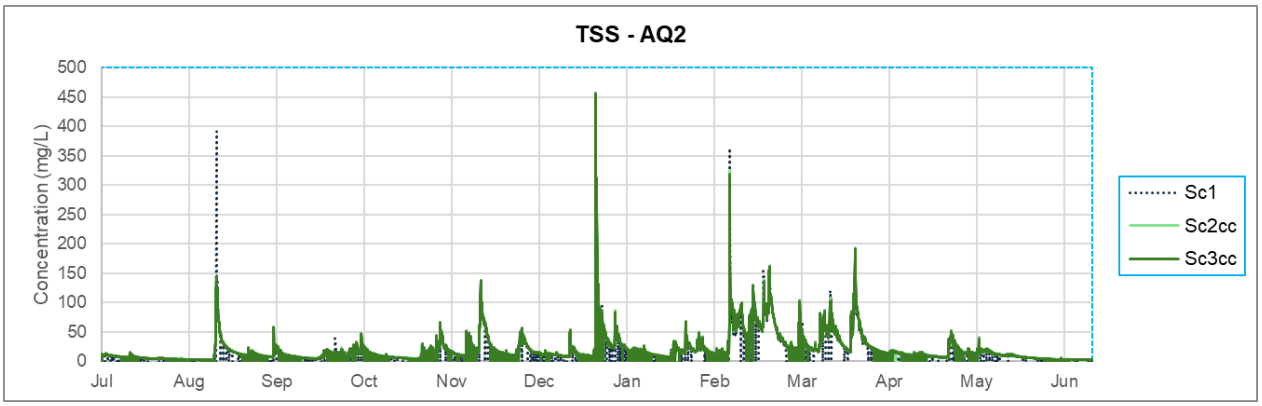


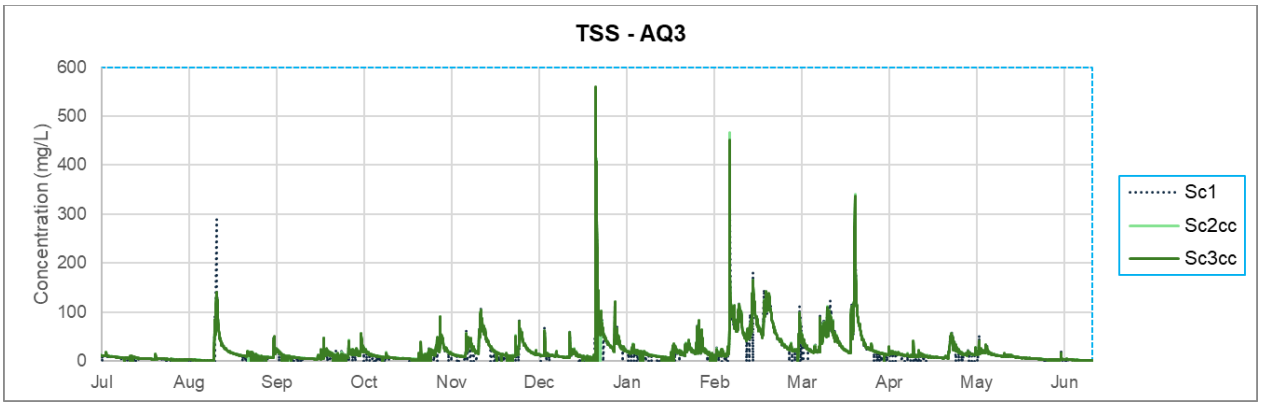
Appendices D4.8.3 Higher rainfall year scenario results (2021-2022)

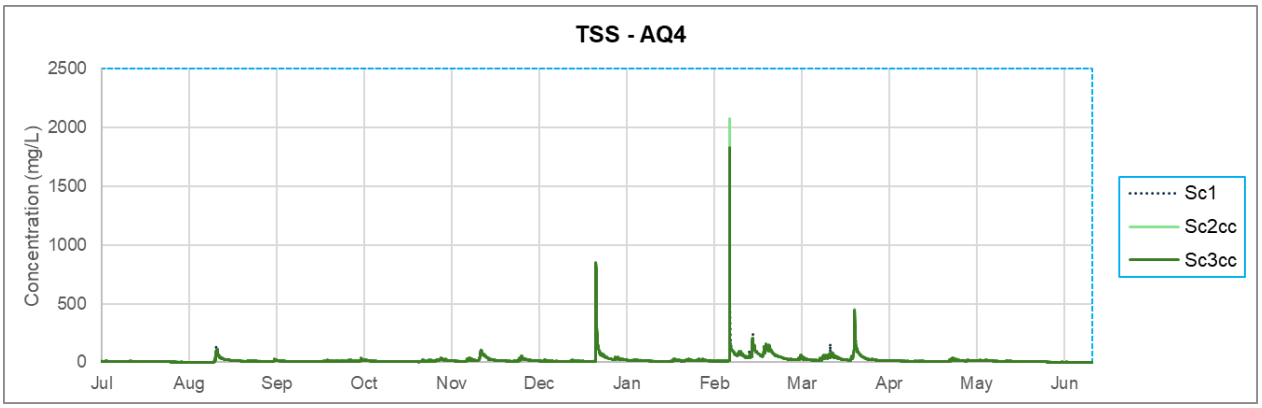
Bar charts

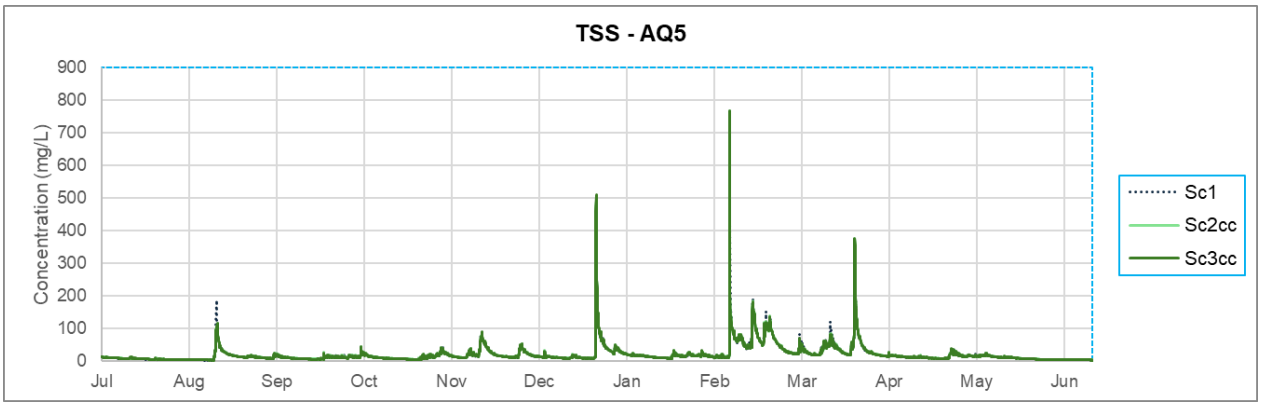
Time series plots

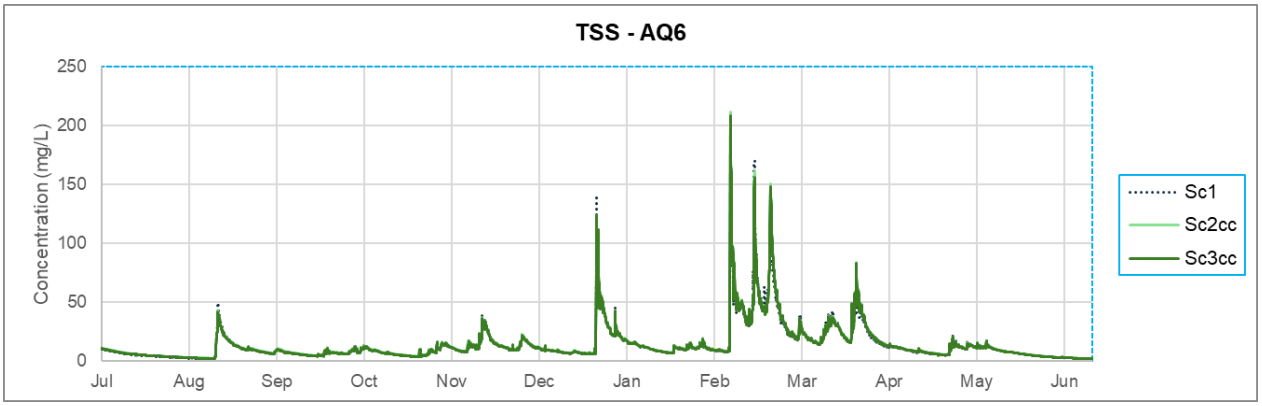








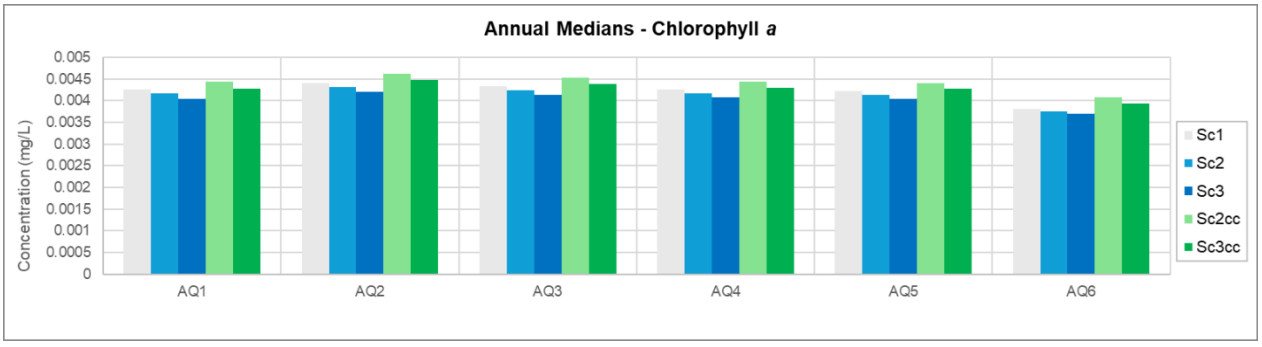


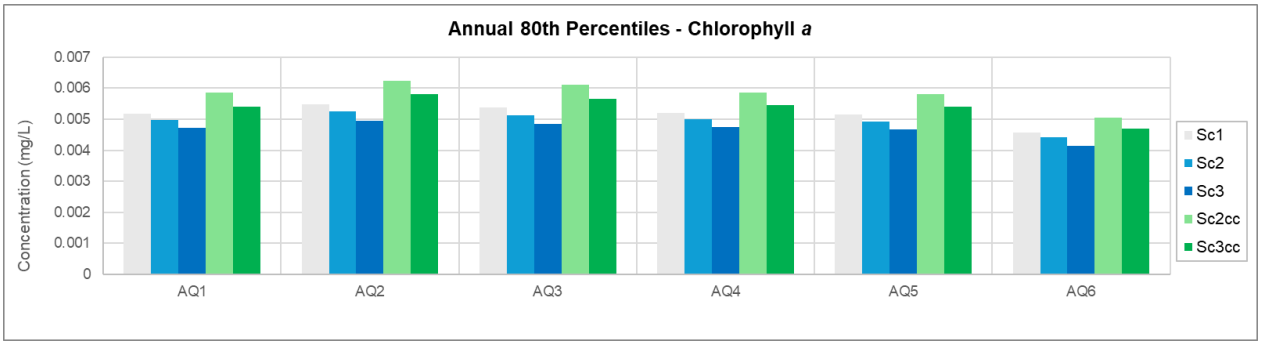


Appendices D4.9 Chlorophyll a

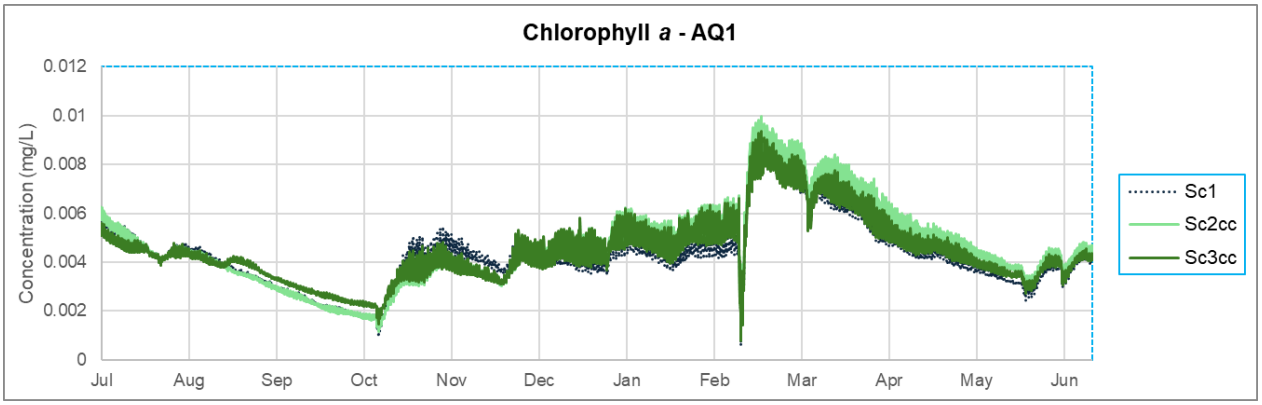
Appendices D4.9.1 Lower rainfall year scenario results (2017-2018)

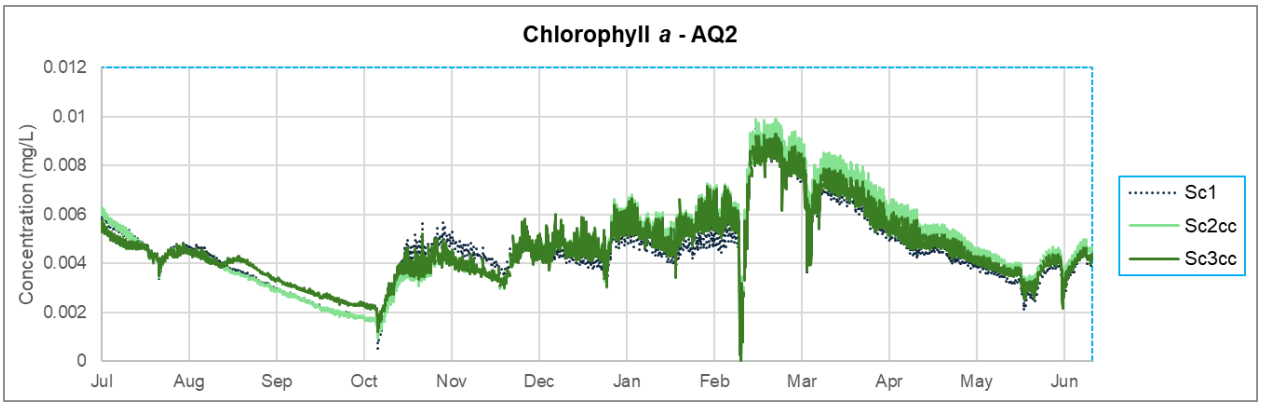
Bar charts

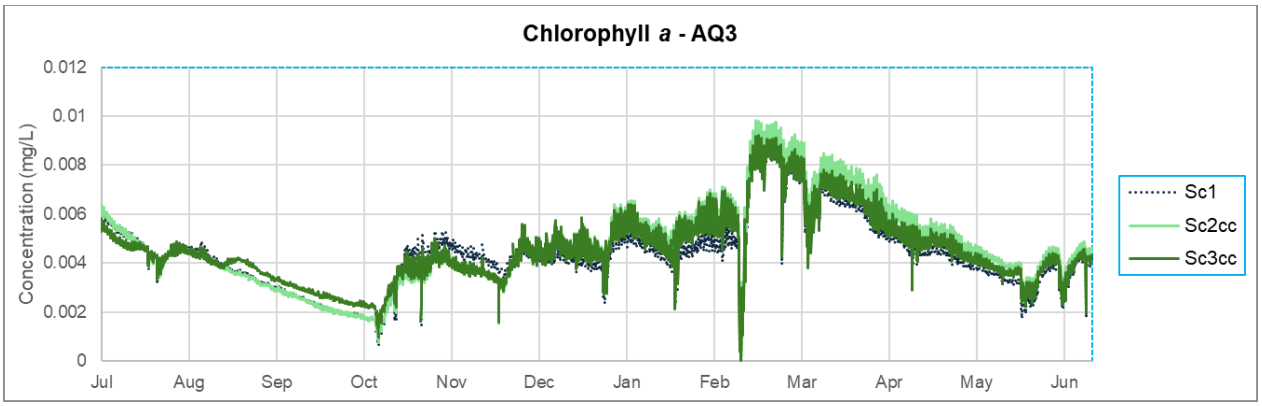


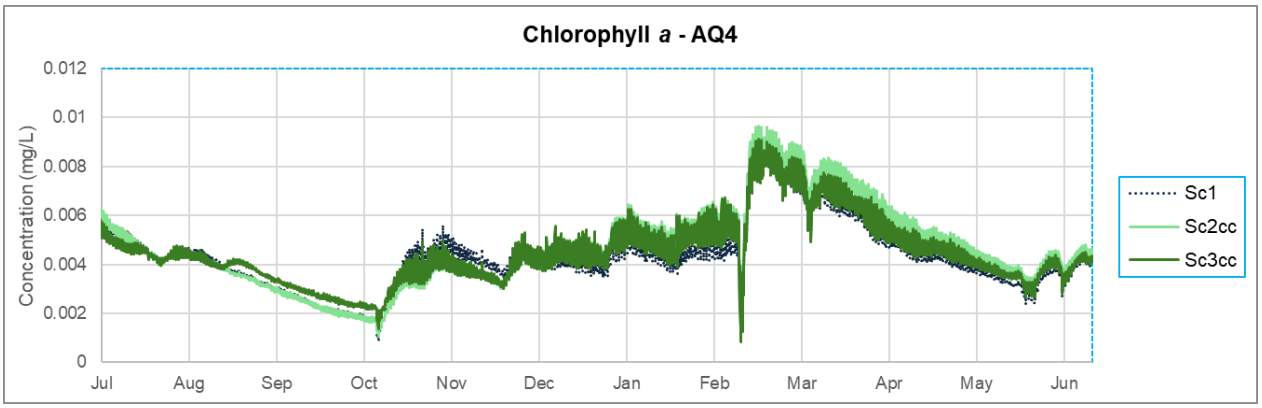


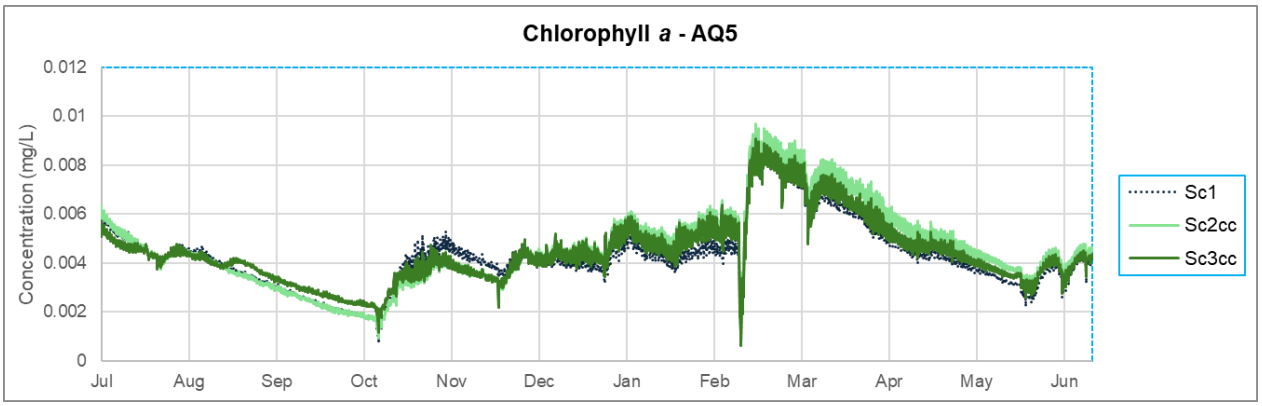
Time series plots

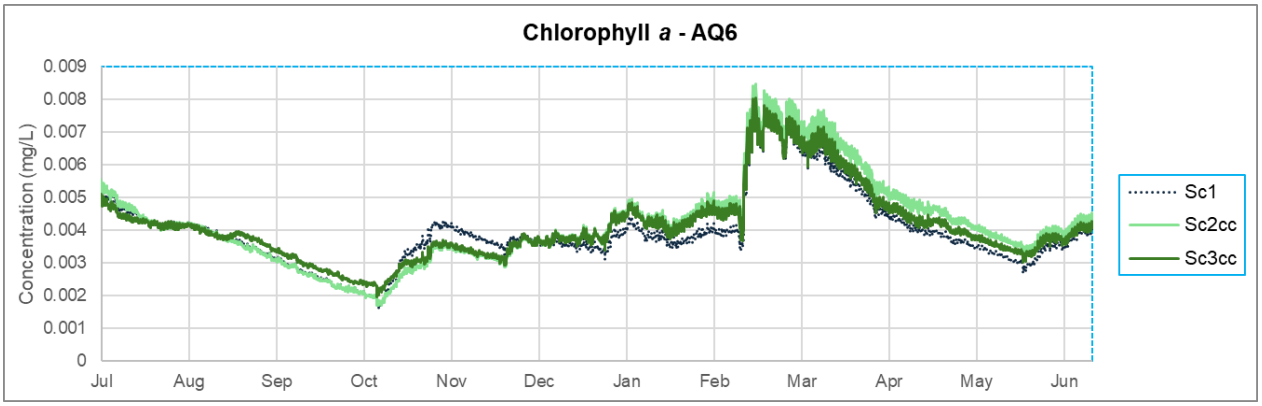






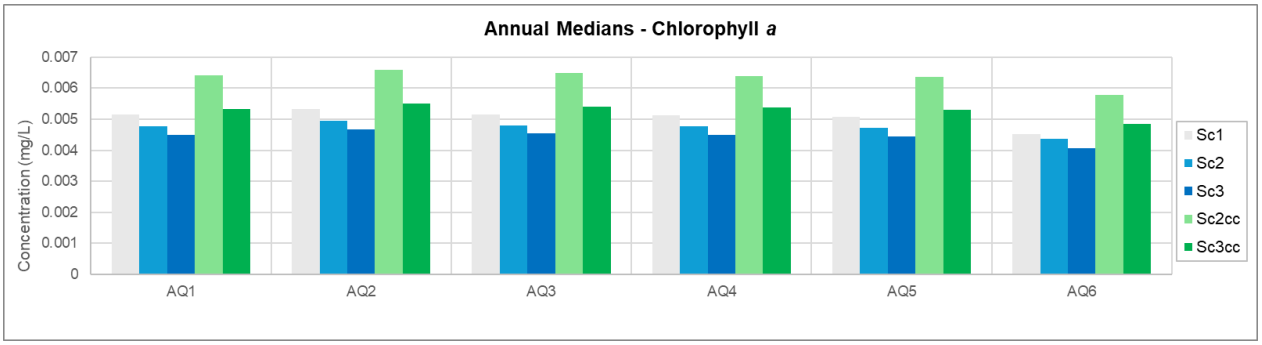


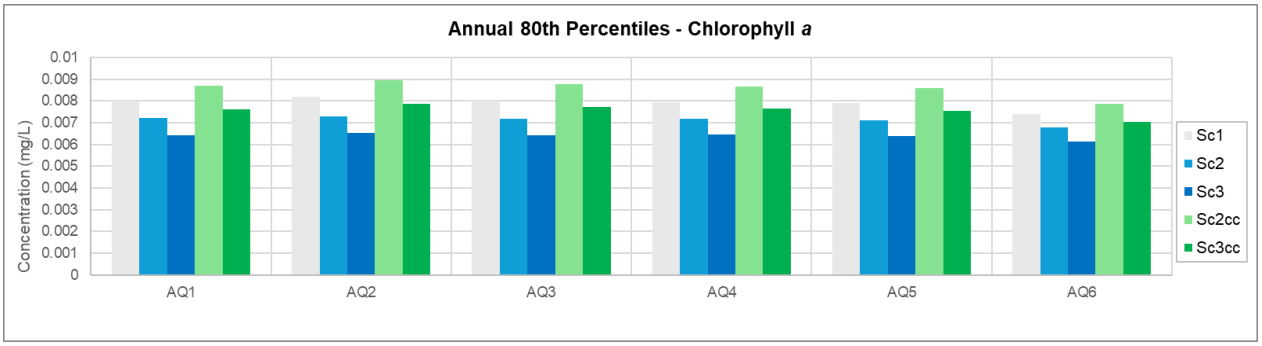




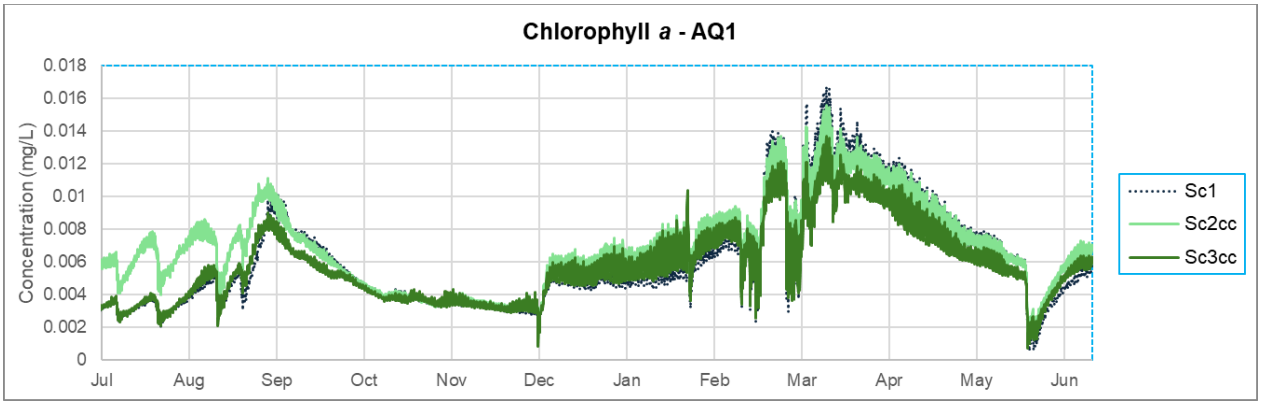
Appendices D4.9.2 Average rainfall year scenario results (2016-2017)

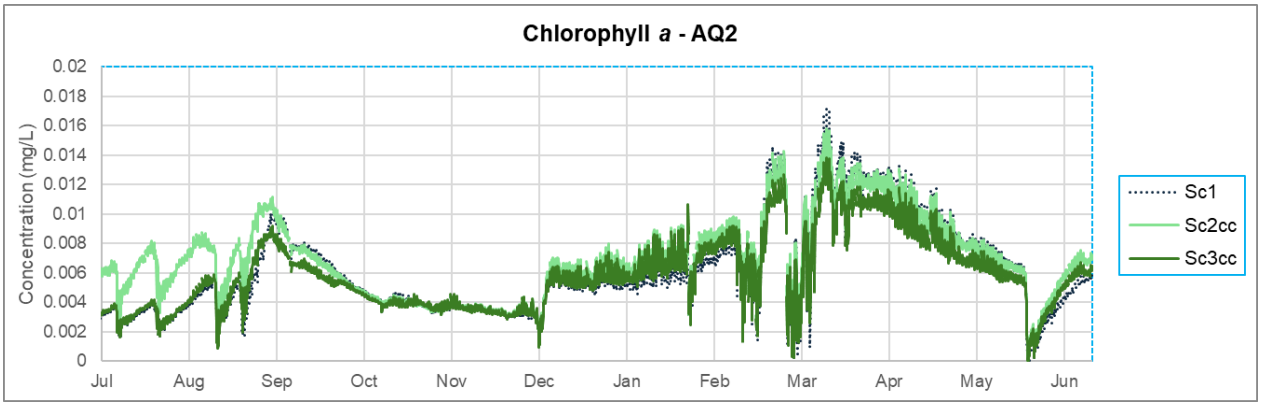
Bar charts

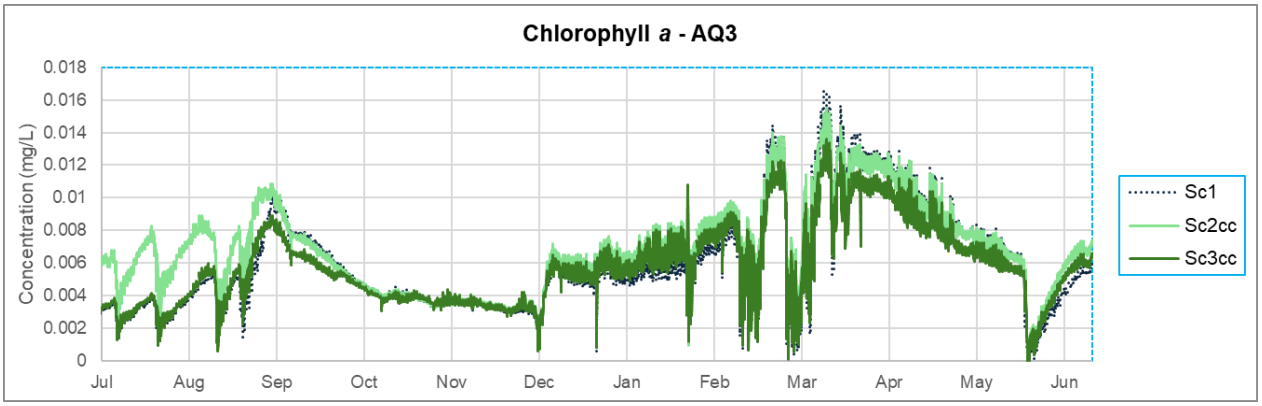


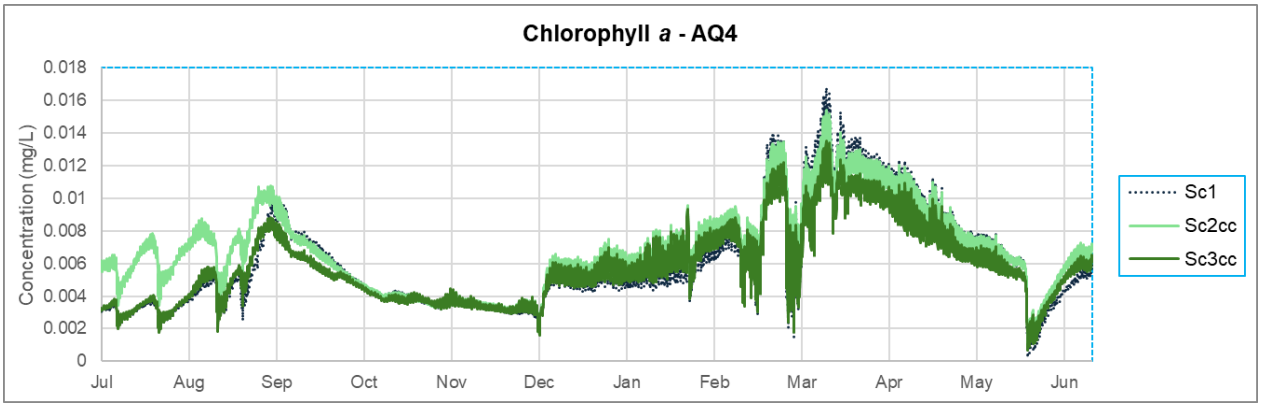


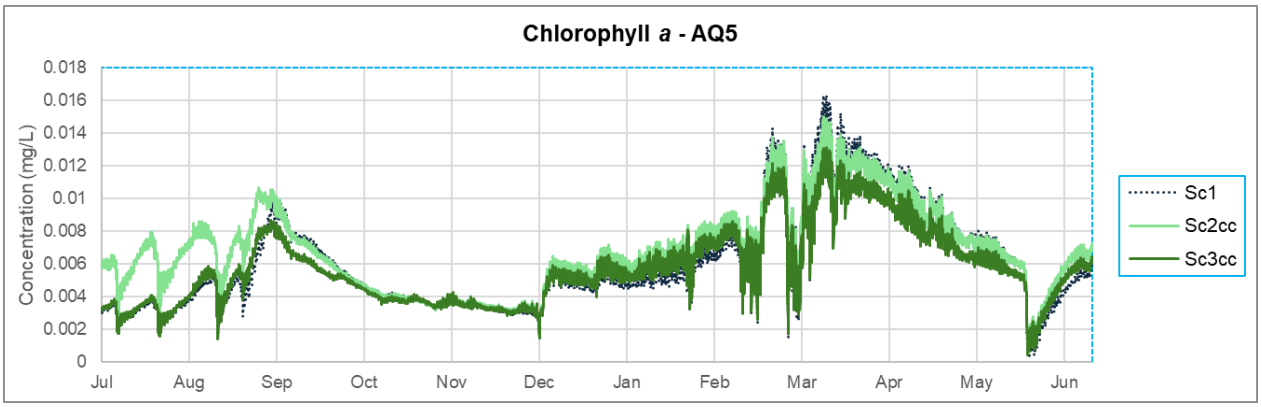
Time series plots

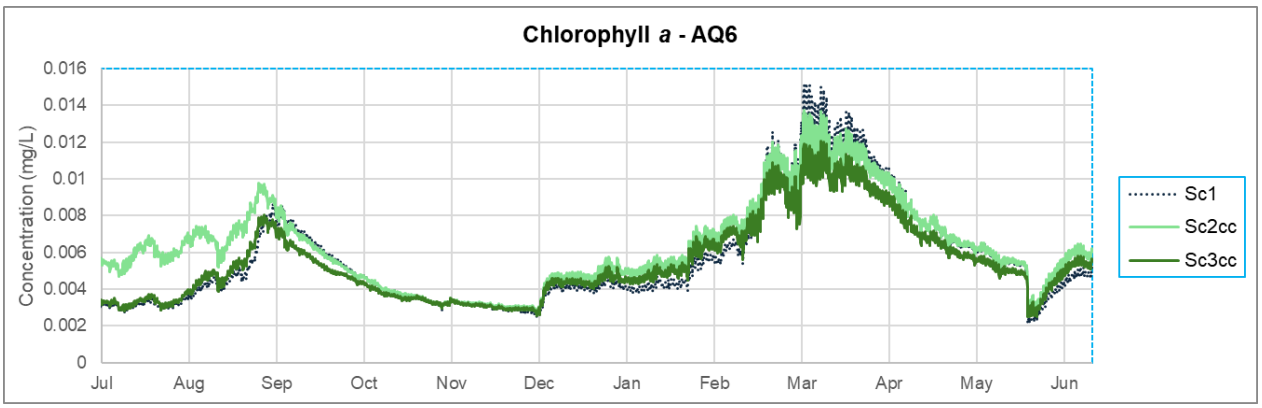






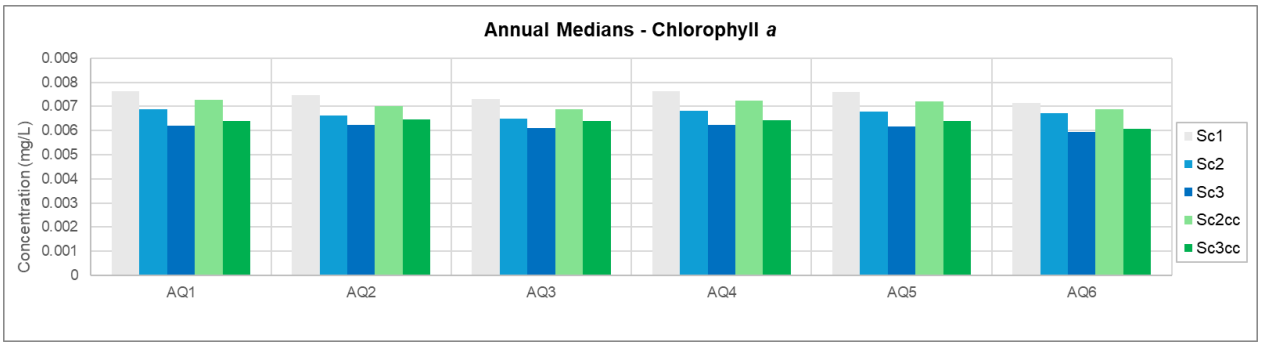


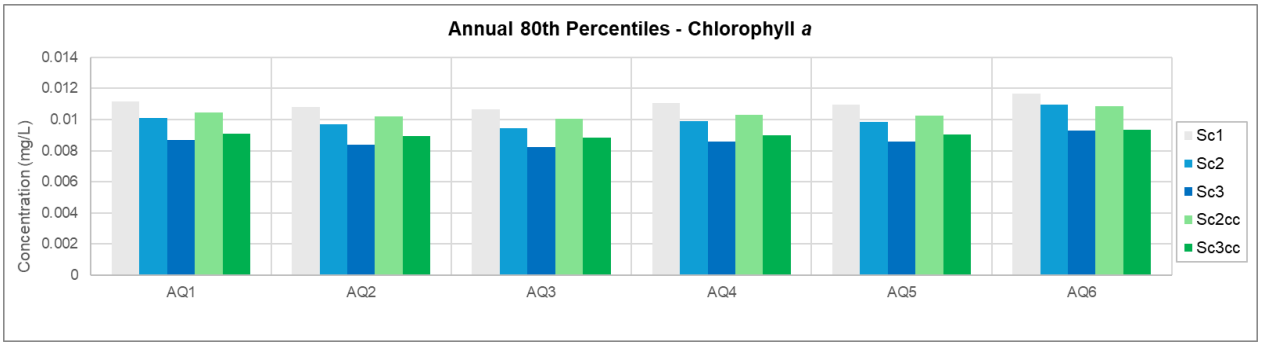




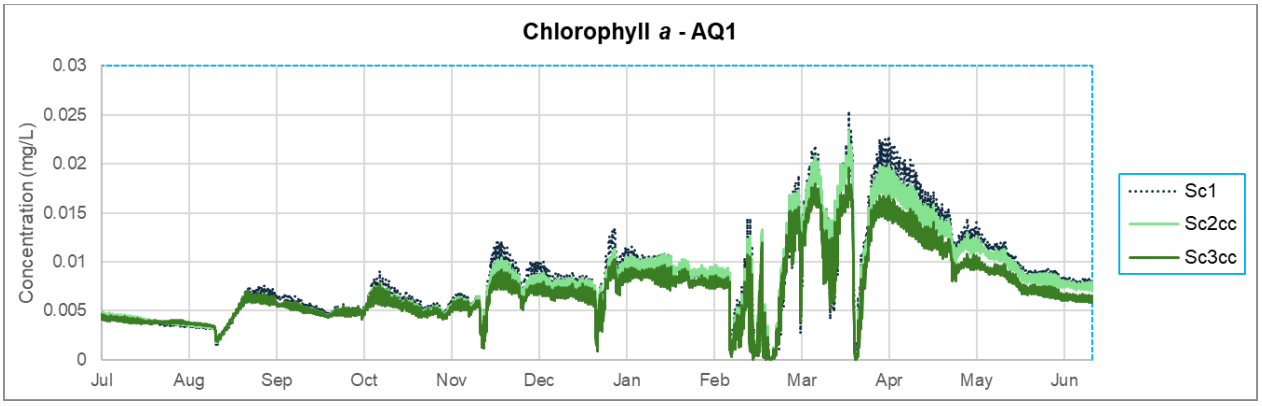
Appendices D4.9.3 Higher rainfall year scenario results (2021-2022)

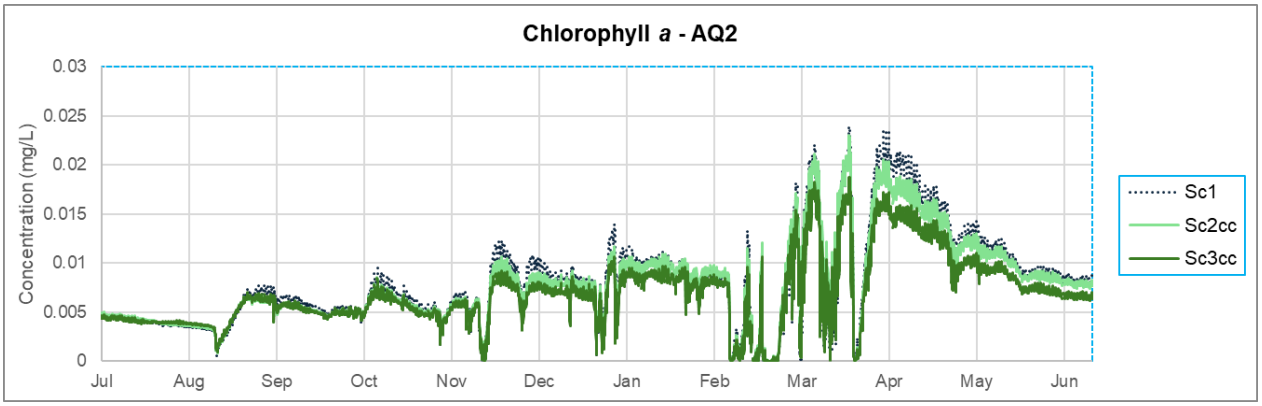
Bar charts

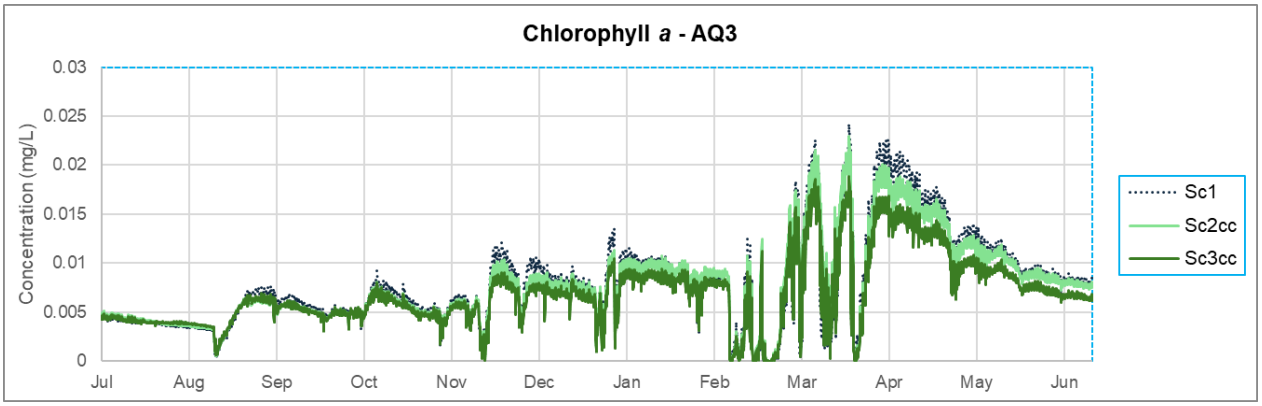


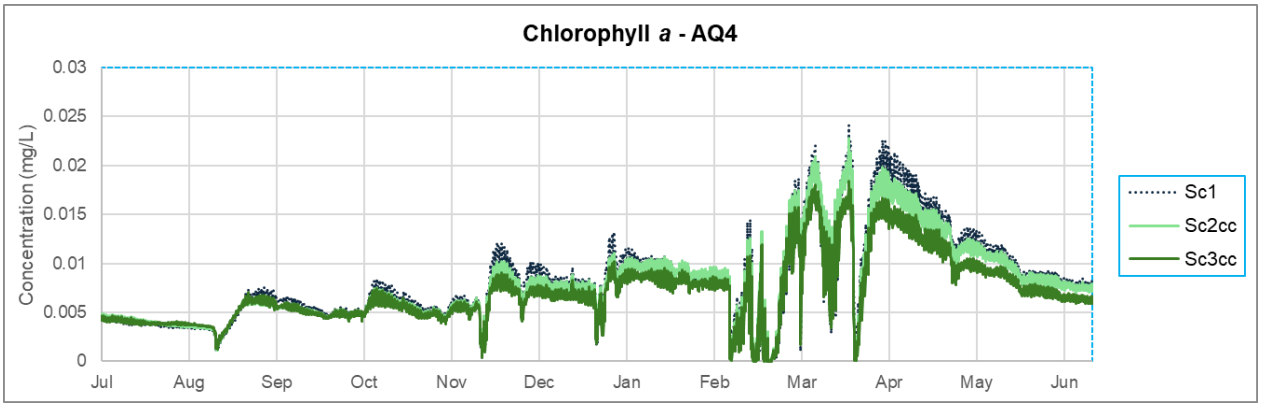


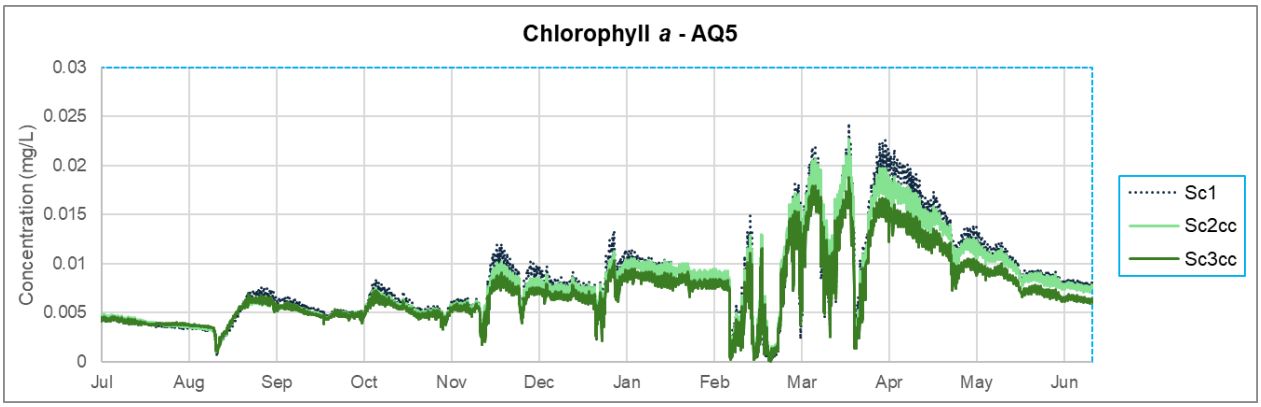
Time series plots








Chlorophyll *a* - AQ4
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Chlorophyll *a* - AQ5
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
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Jan
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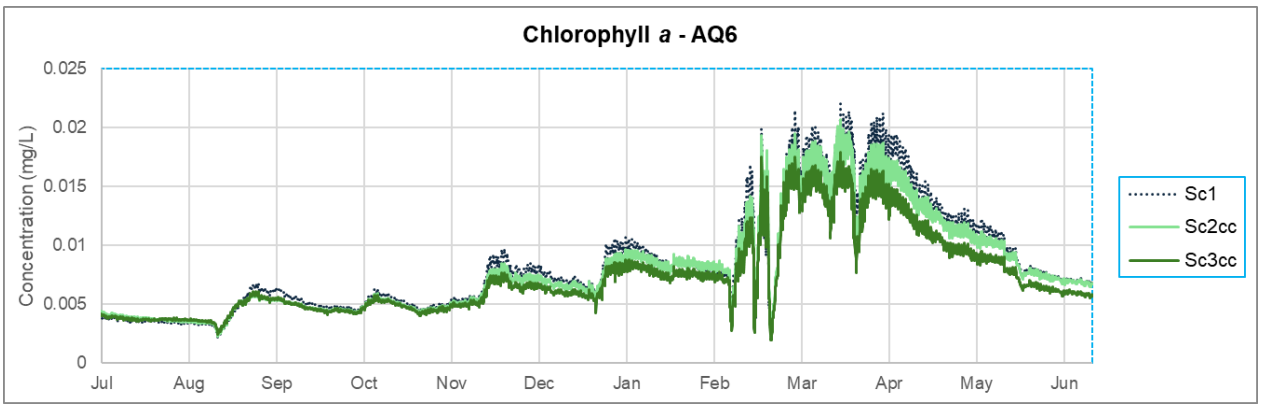
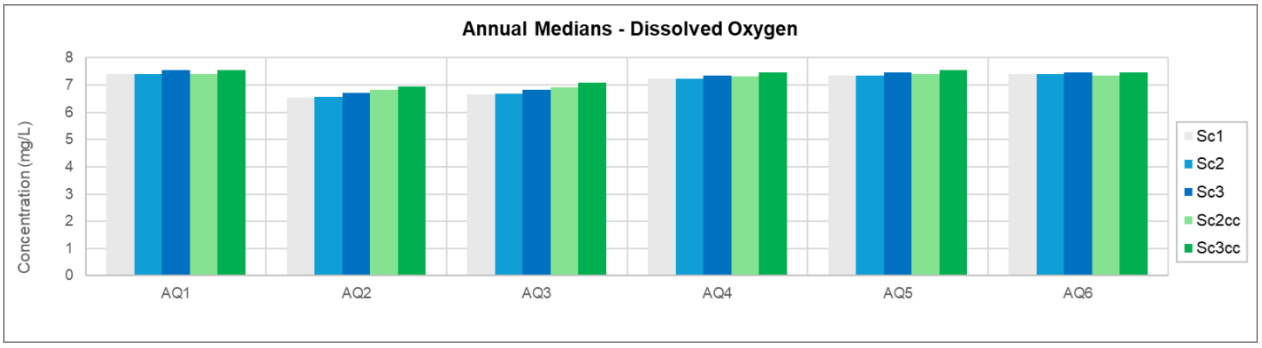
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

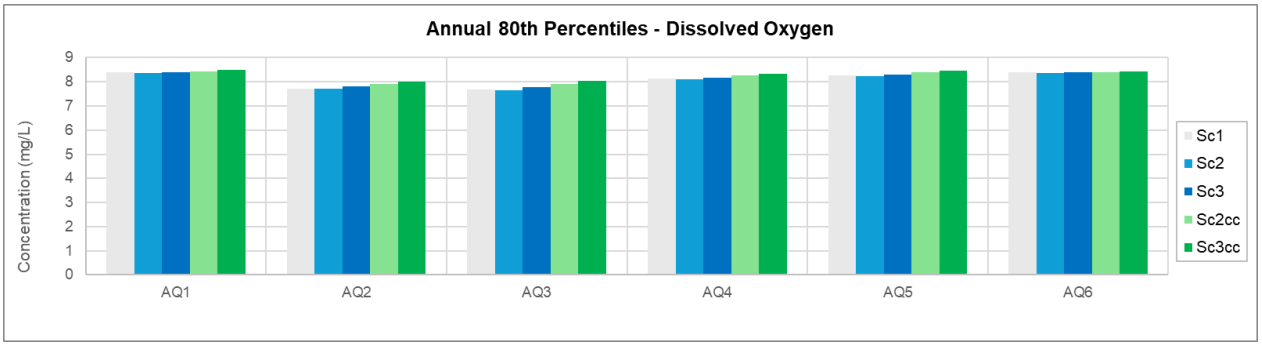

Chlorophyll *a* - AQ6
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D4.10 Dissolved Oxygen

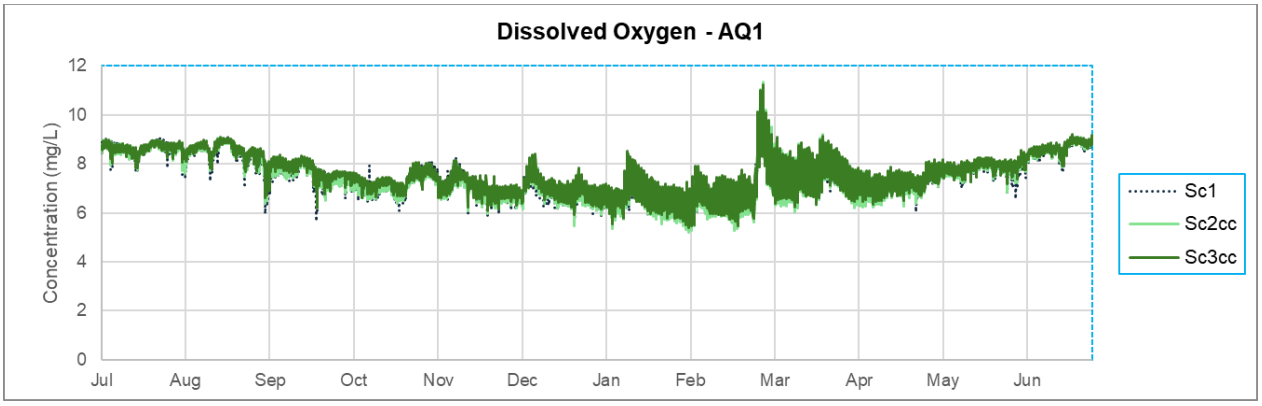
Appendices D4.10.1 Lower rainfall year scenario results (2017-2018)

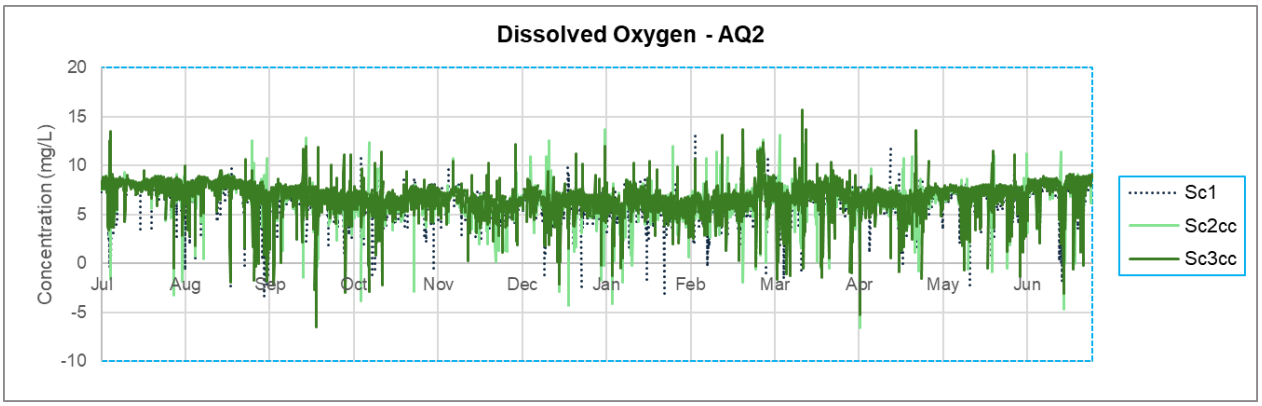
Bar charts

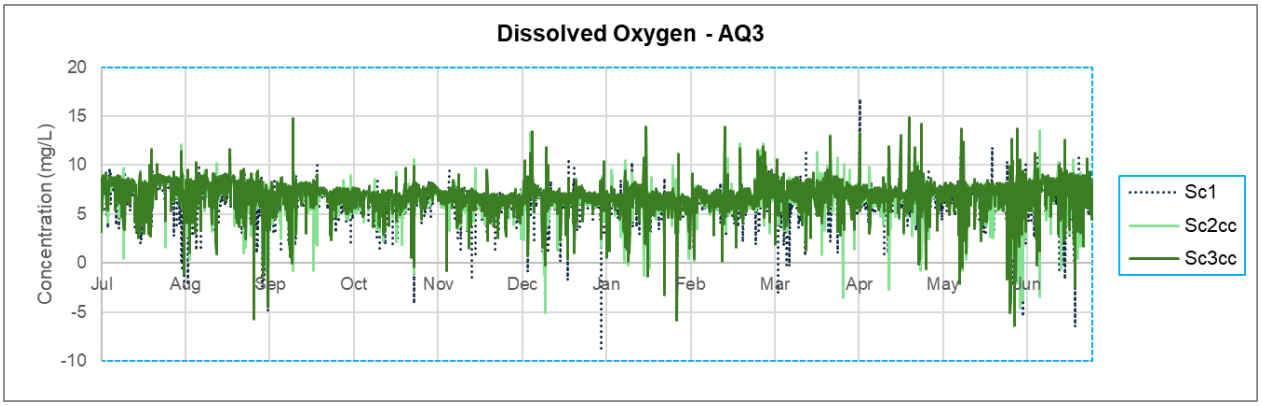


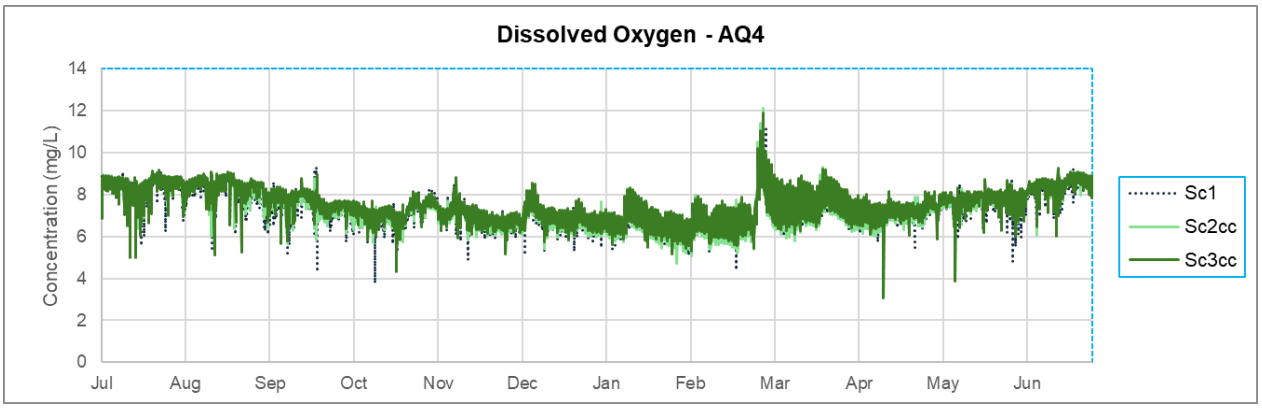


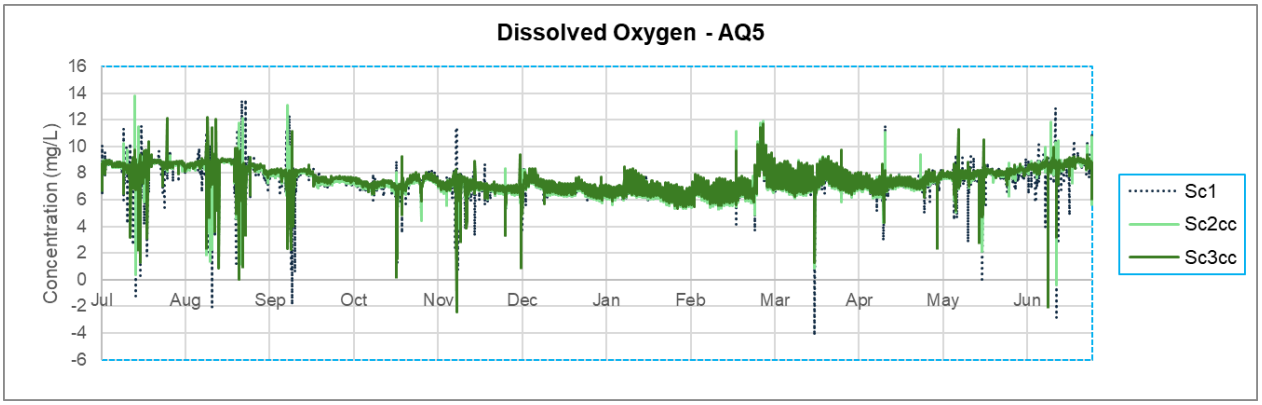
Time series plots

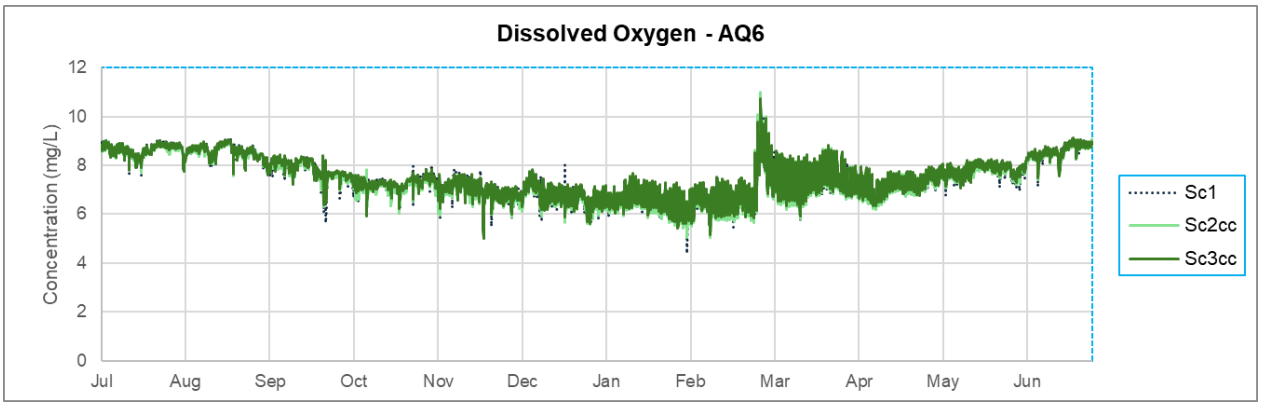



Dissolved Oxygen - AQ2
Concentration (mg/L)
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Dissolved Oxygen - AQ3
Concentration (mg/L)
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

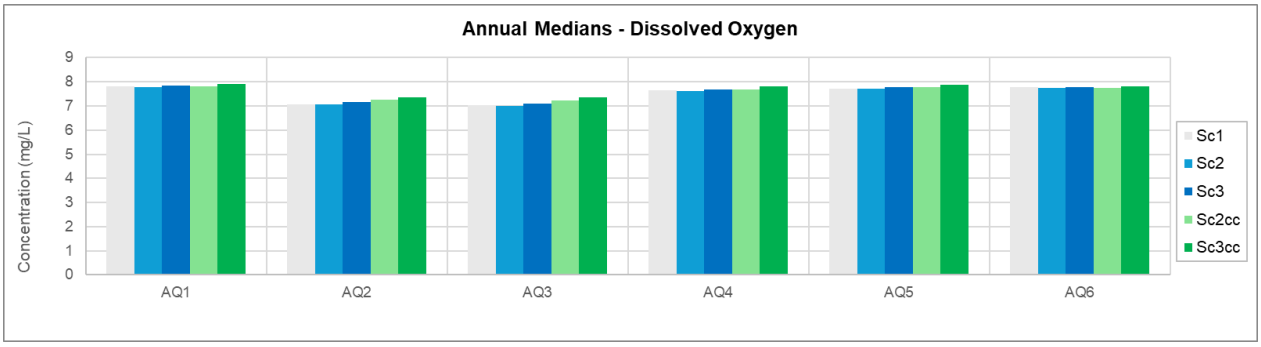

Dissolved Oxygen - AQ4
Concentration (mg/L)
14
12
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

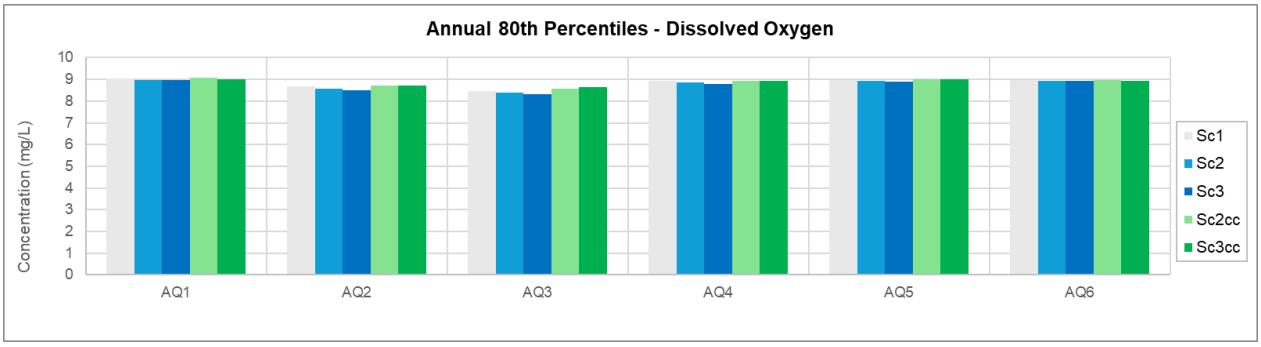

Dissolved Oxygen - AQ5
Concentration (mg/L)
16
14
12
10
8
6
4
2
0
-2
-4
-6
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



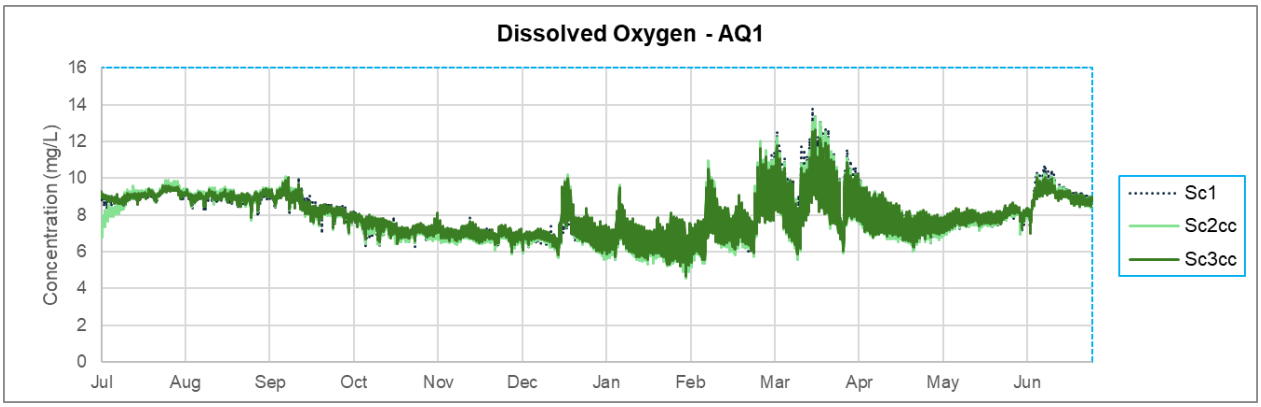
Appendices D4.10.2 Average rainfall year scenario results (2016-2017)

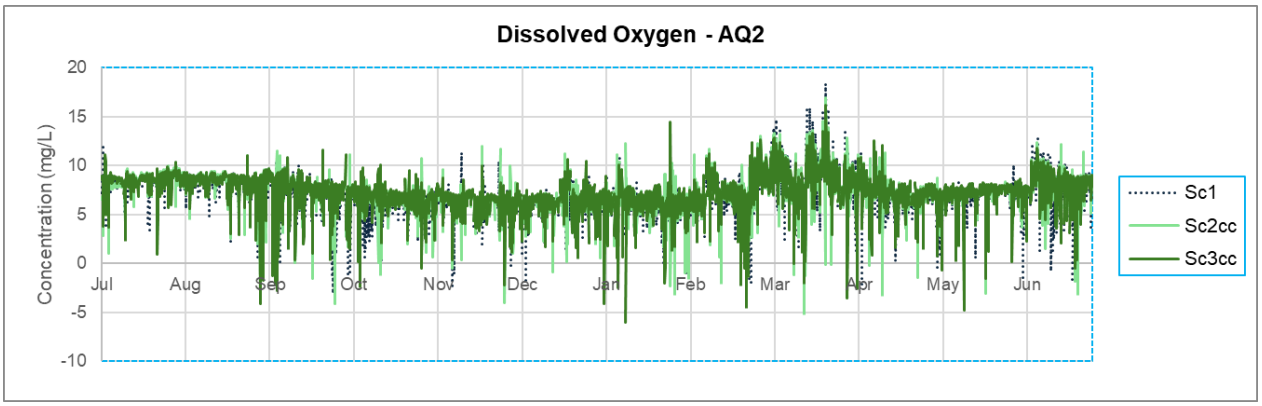
Bar charts

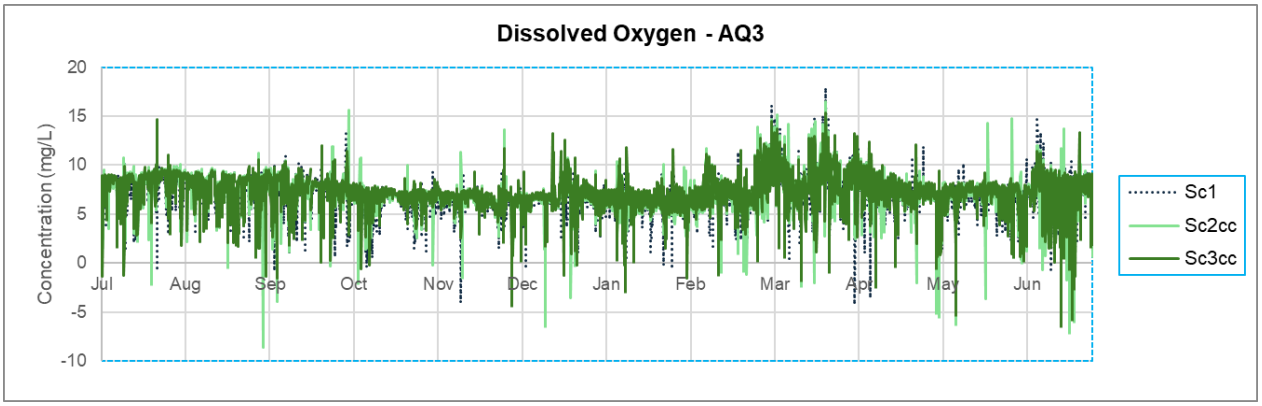


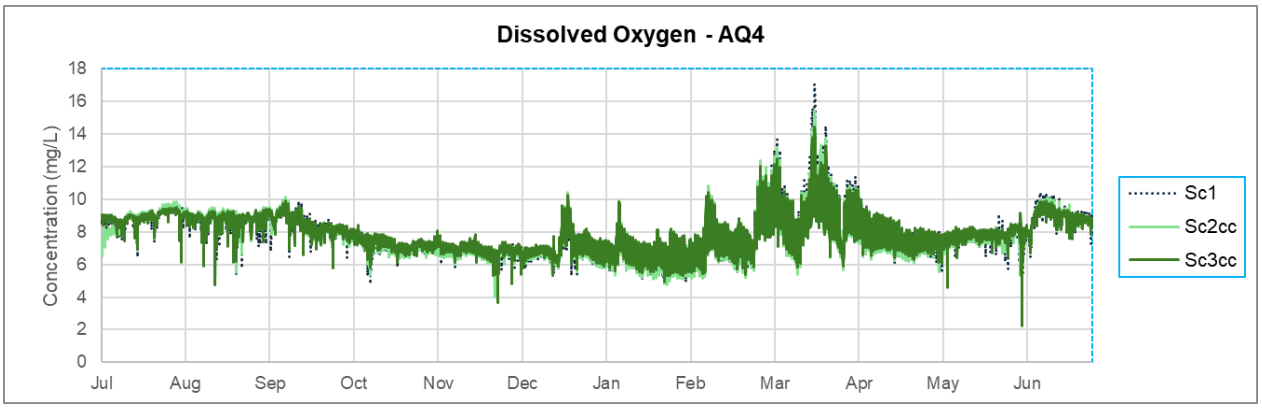


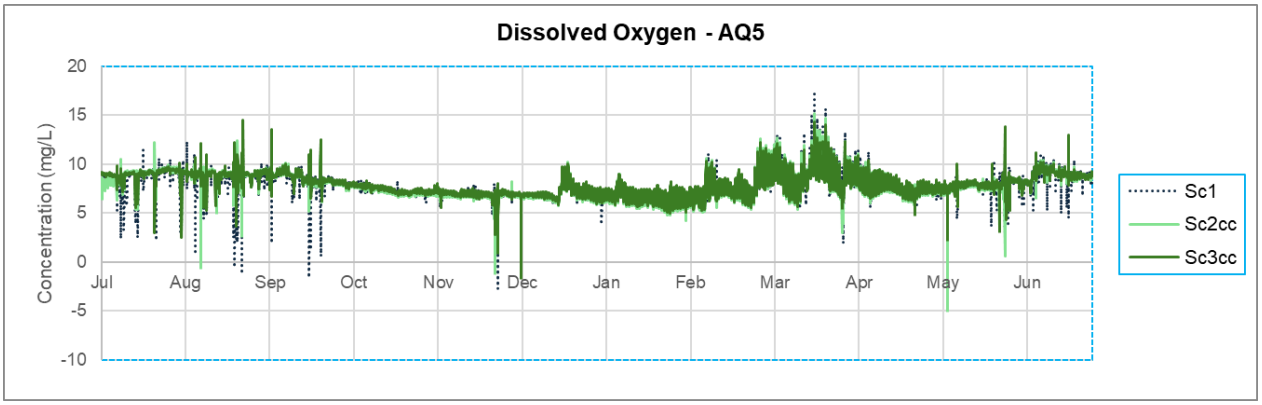
Time series plots

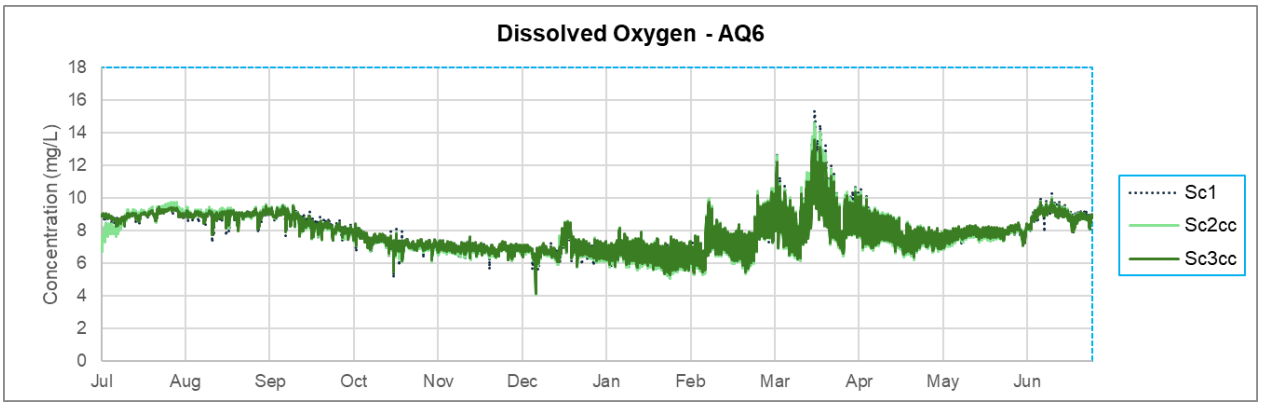



Dissolved Oxygen - AQ2
Concentration (mg/L)
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Dissolved Oxygen - AQ3
Concentration (mg/L)
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

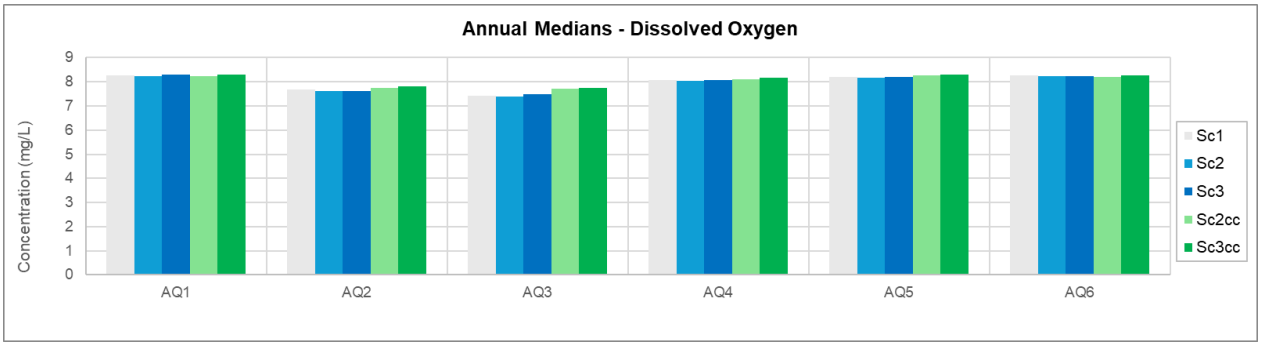

Dissolved Oxygen - AQ4
Concentration (mg/L)
18
16
14
12
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

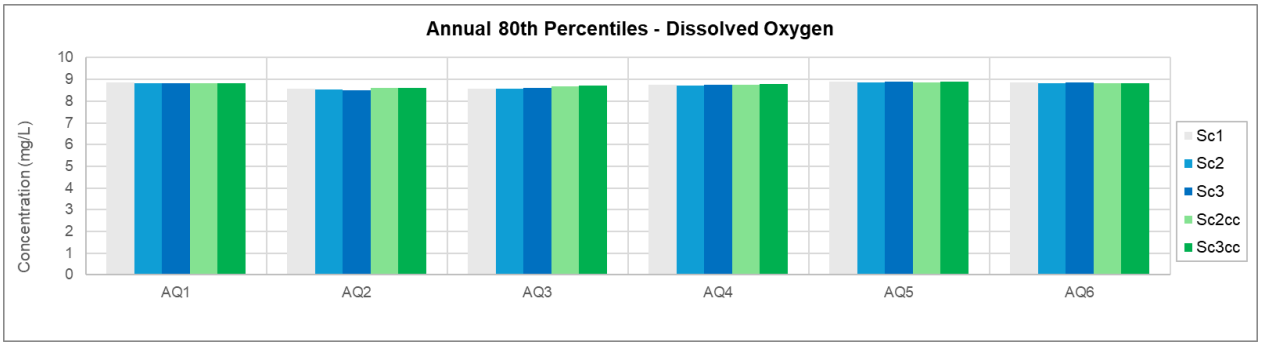

Dissolved Oxygen - AQ5
Concentration (mg/L)
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc



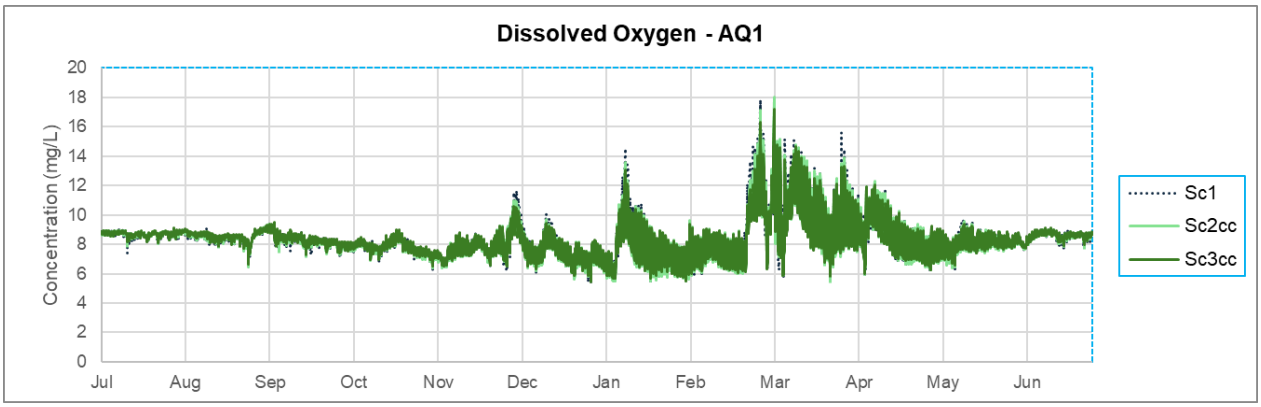
Appendices D4.10.3 Higher rainfall year scenario results (2021-2022)

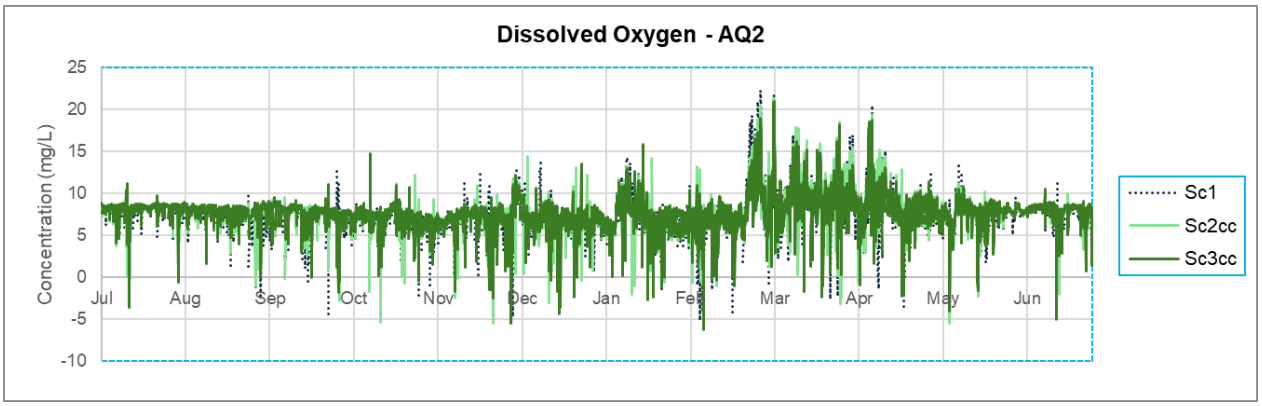
Bar charts

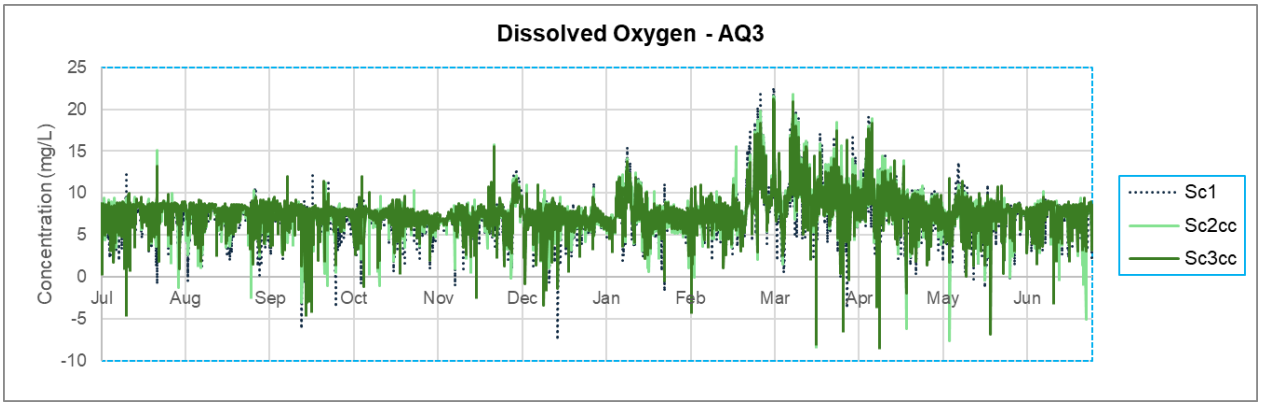


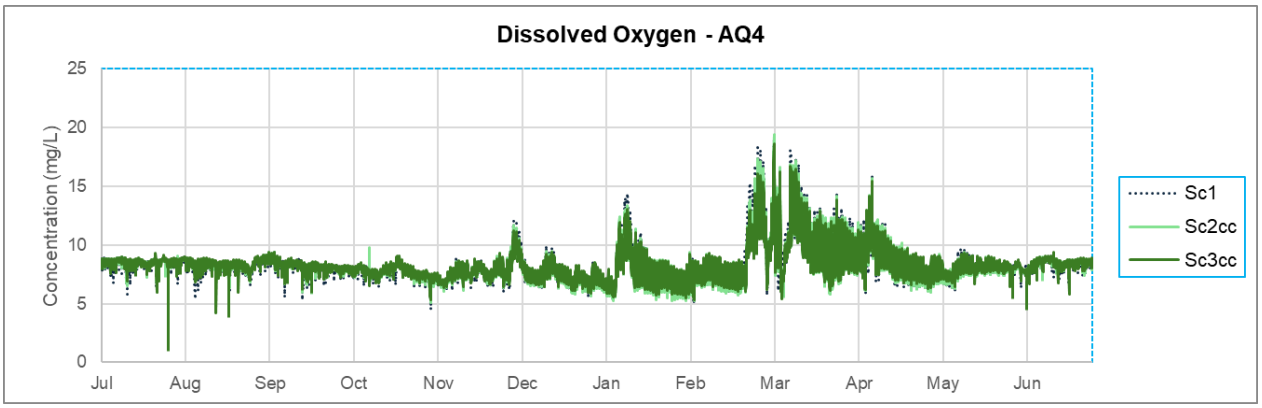


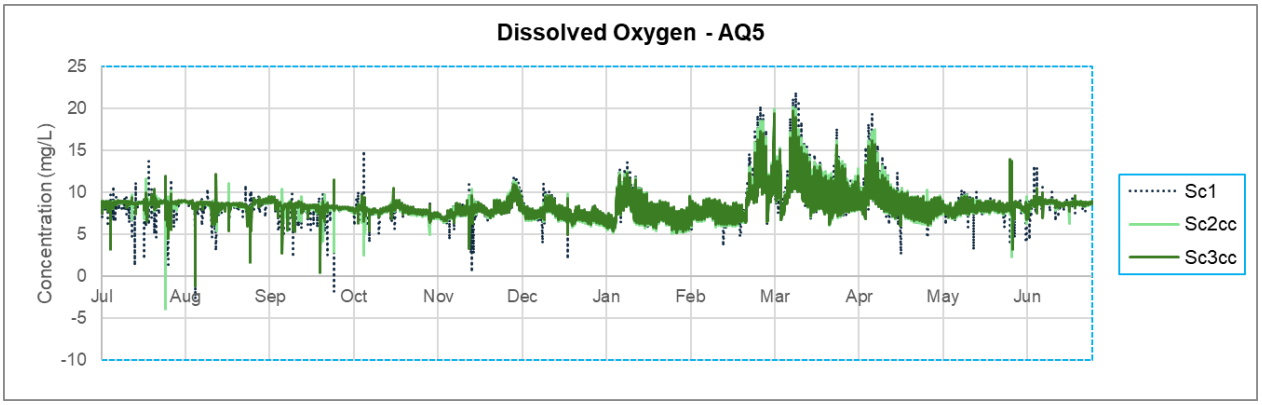
Time series plots

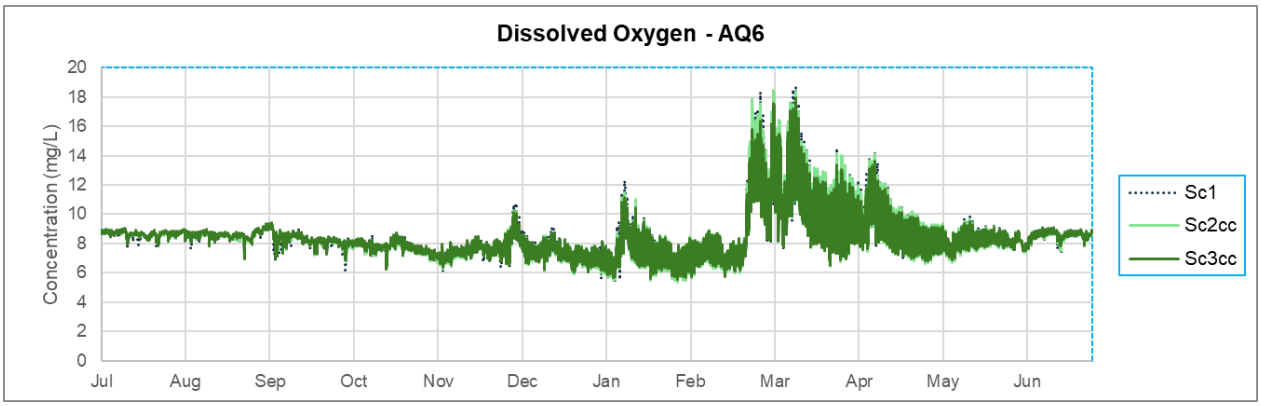



Dissolved Oxygen - AQ2
Concentration (mg/L)
25
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Dissolved Oxygen - AQ3
Concentration (mg/L)
25
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Dissolved Oxygen - AQ4
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

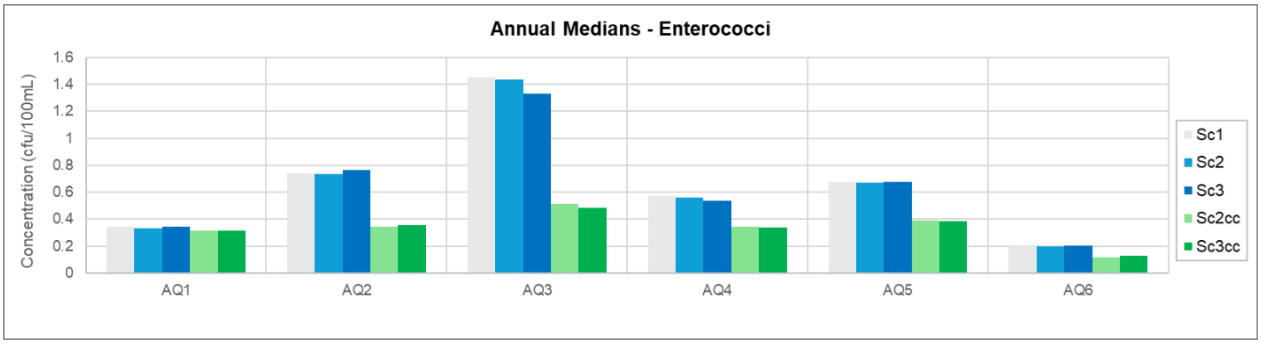

Dissolved Oxygen - AQ5
Concentration (mg/L)
25
20
15
10
5
0
-5
-10
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

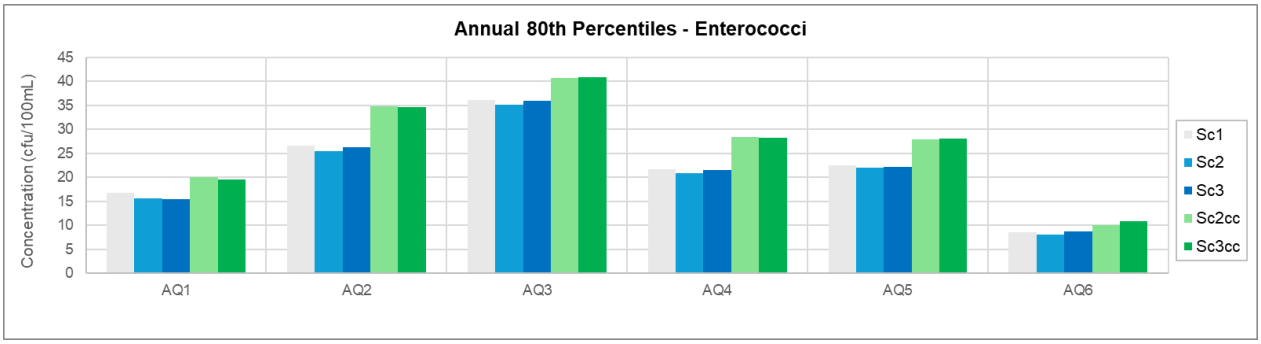


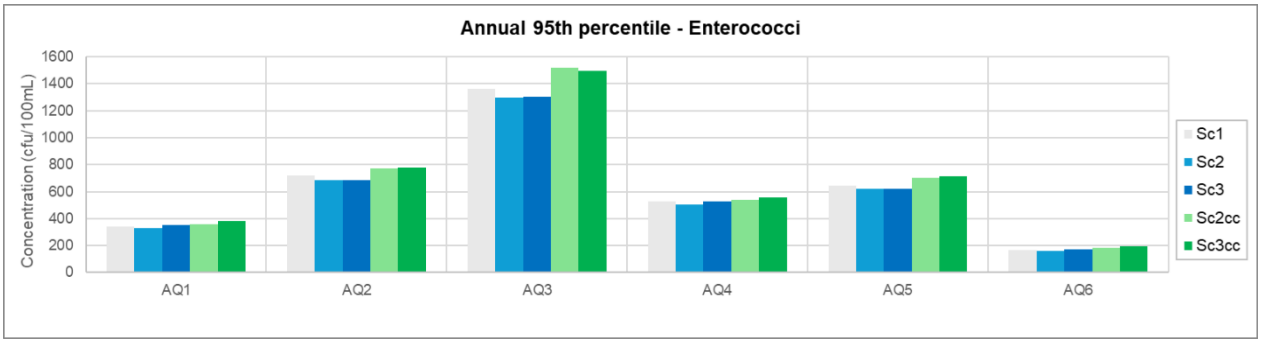
Appendices D4.11 Enterococci

Appendices D4.11.1 Lower rainfall year scenario results (2017-2018)

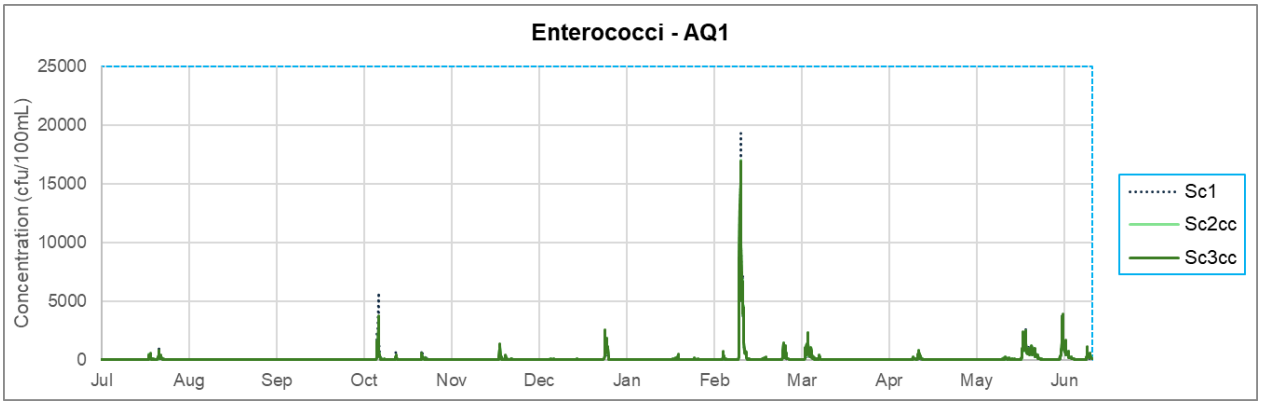
Bar charts

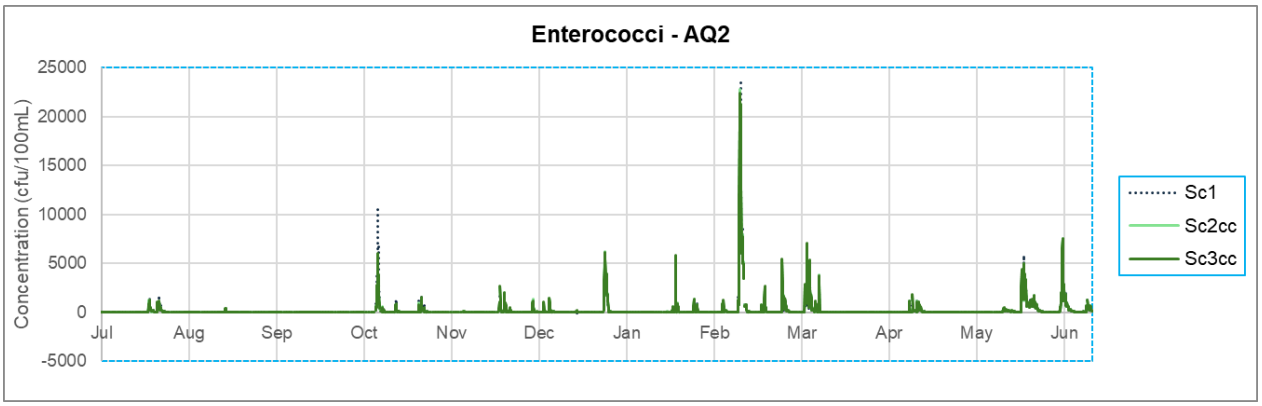


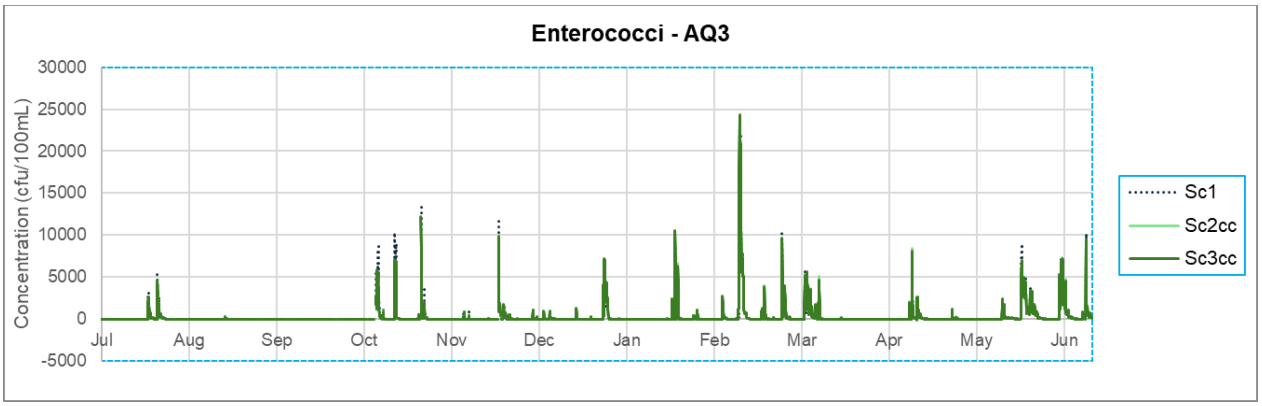


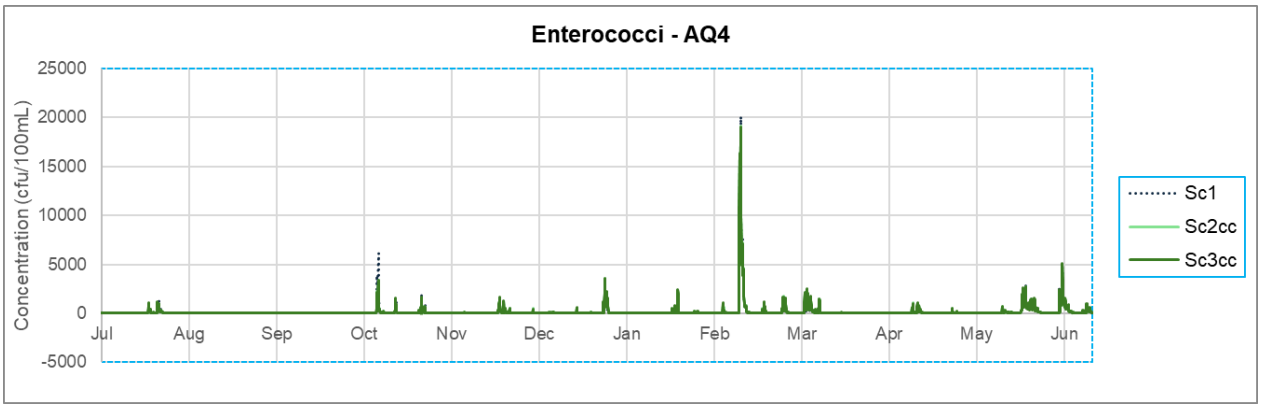


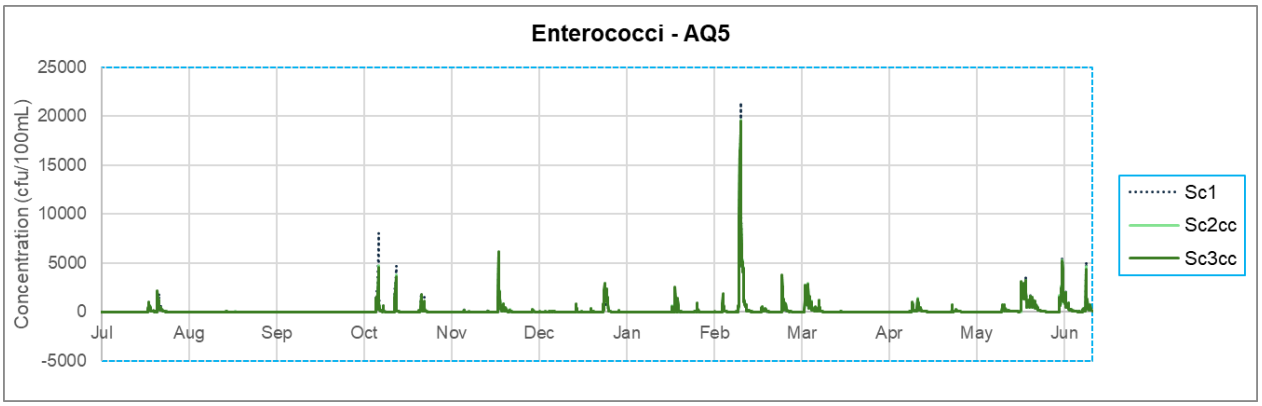
Time series plots

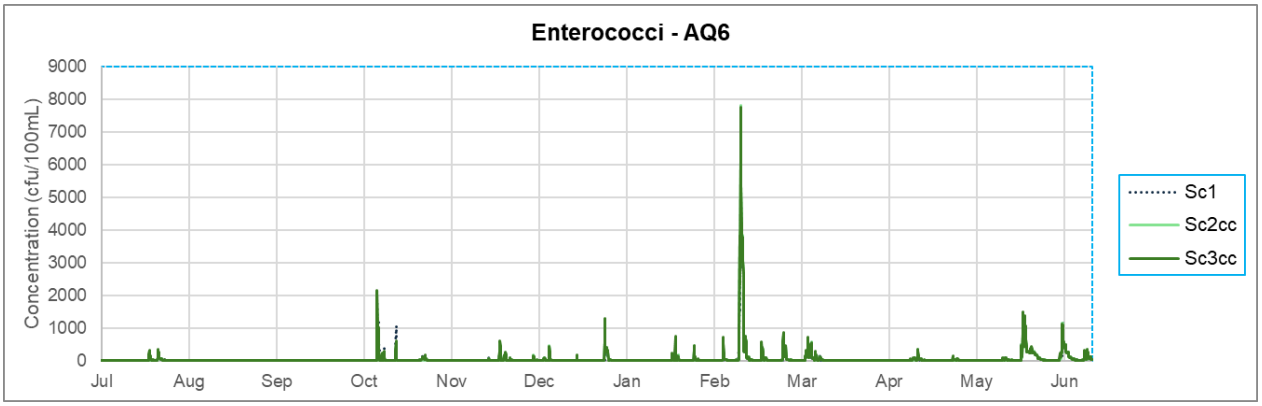






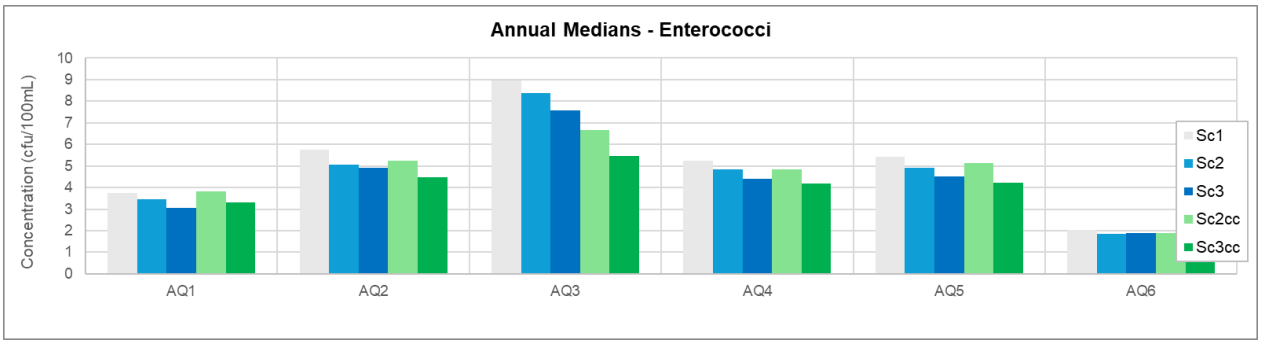


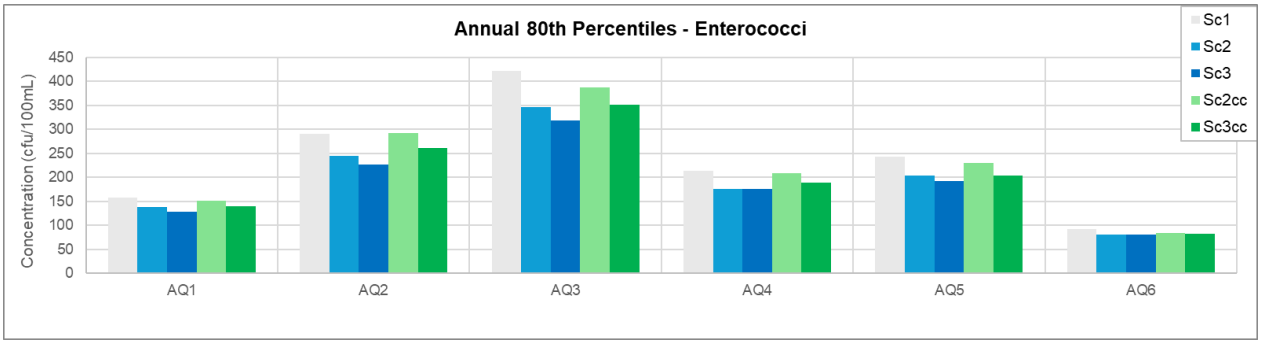


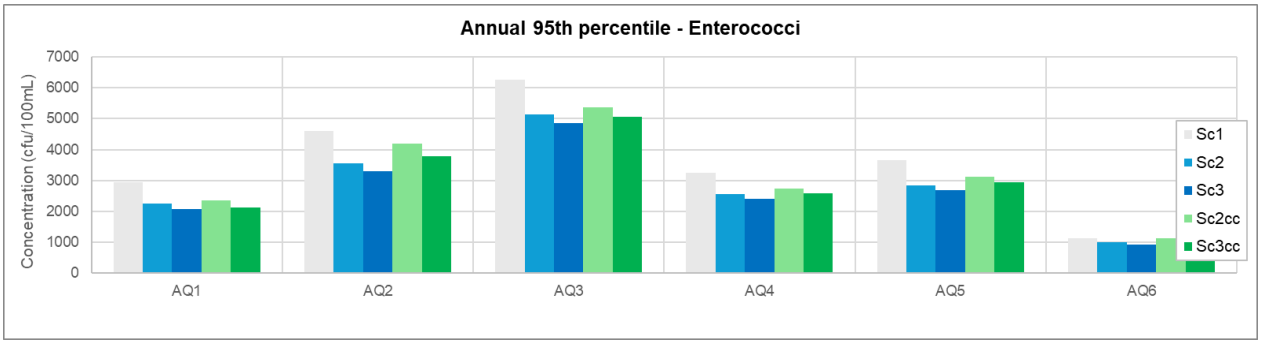


Appendices D4.11.2 Average rainfall year scenario results (2016-2017)

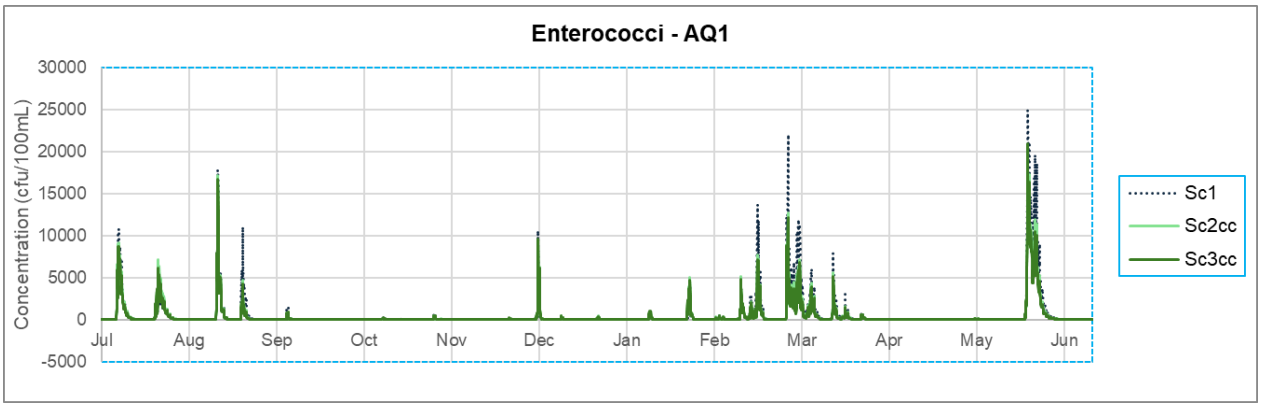
Bar charts

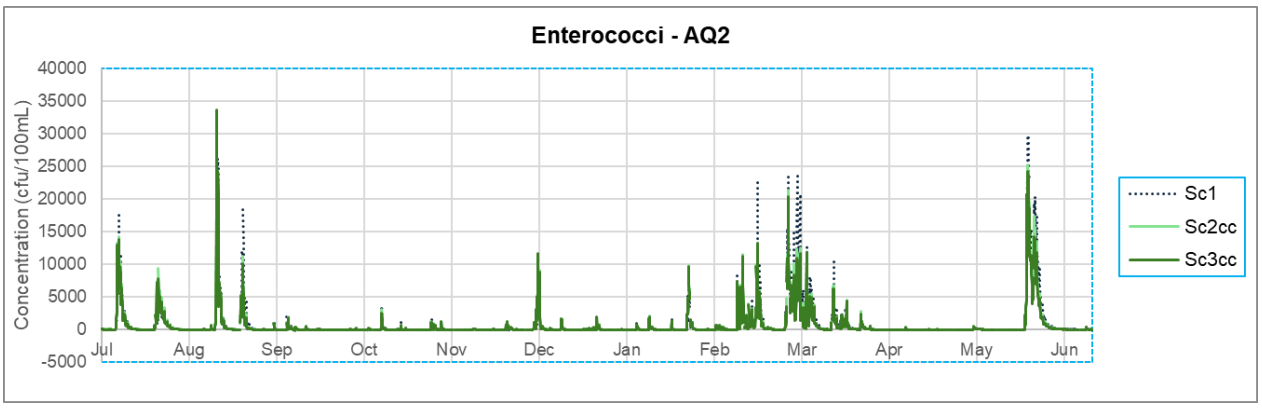


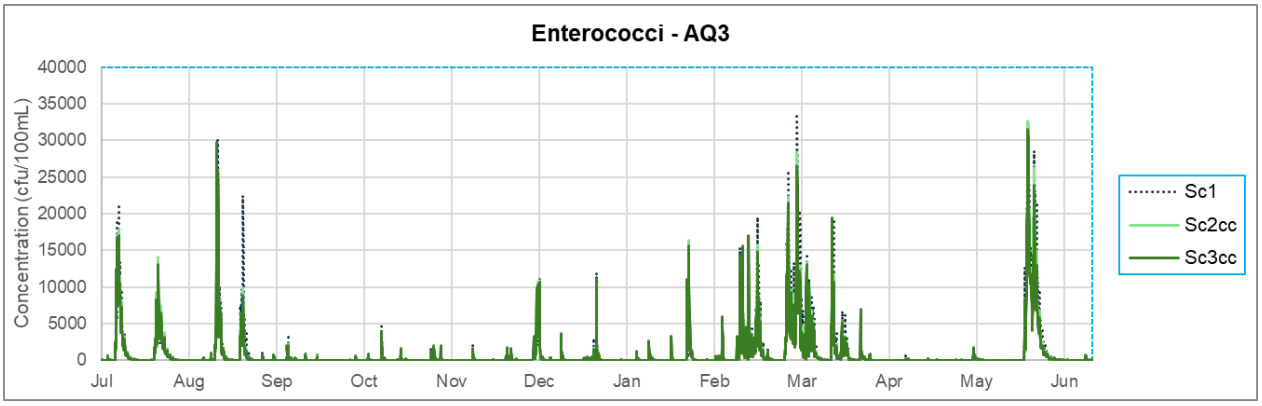


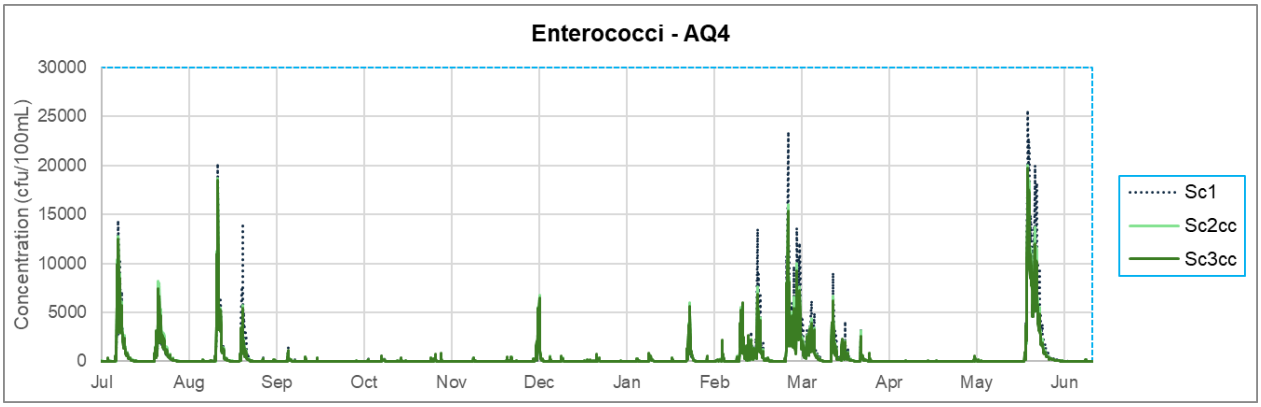


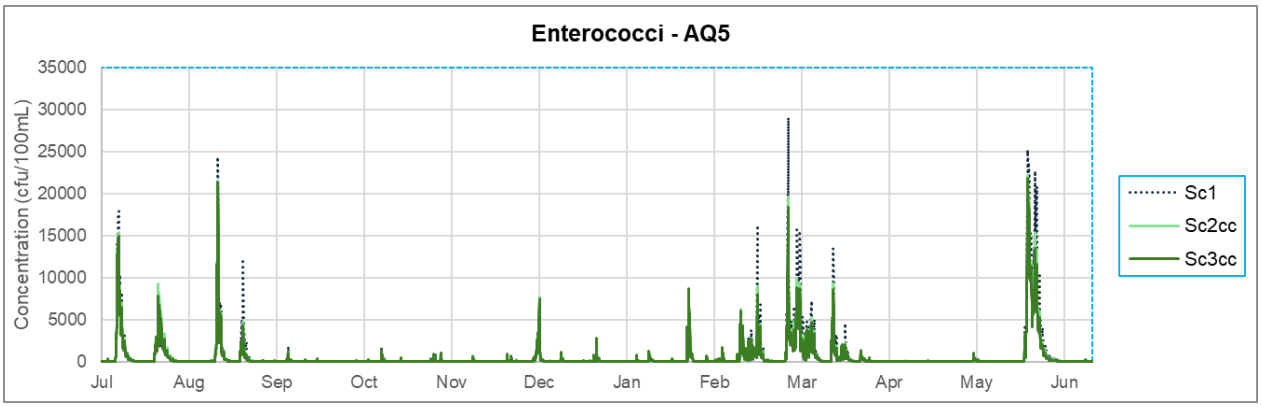
Time series plots

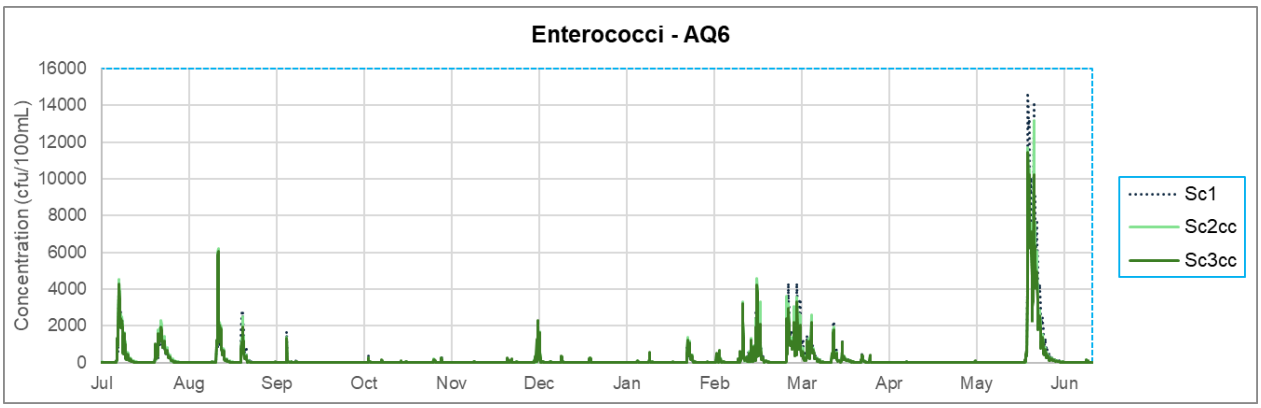






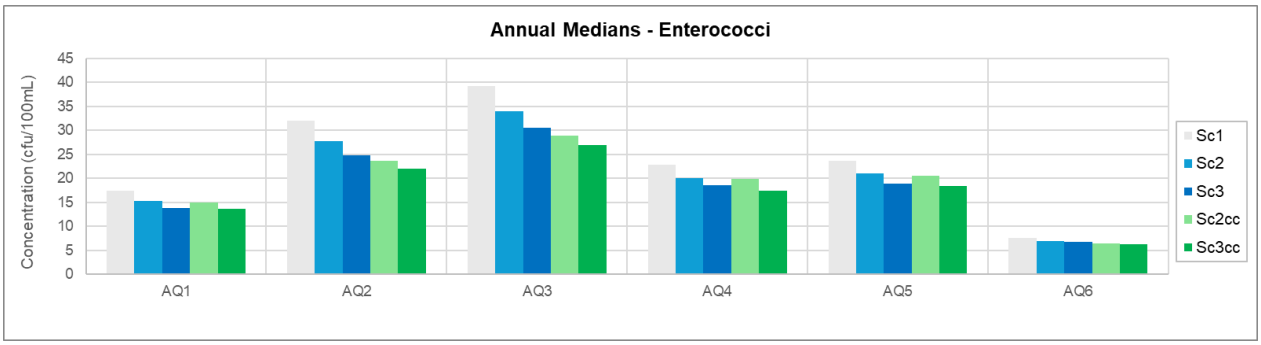


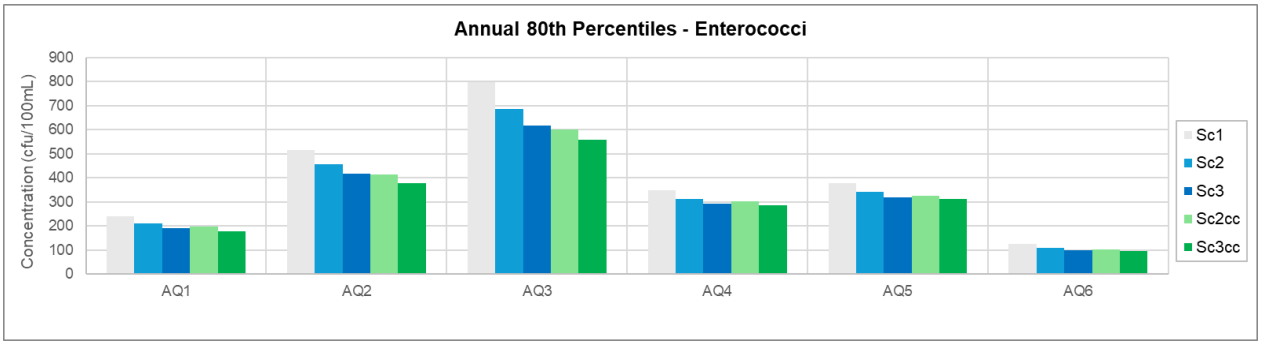


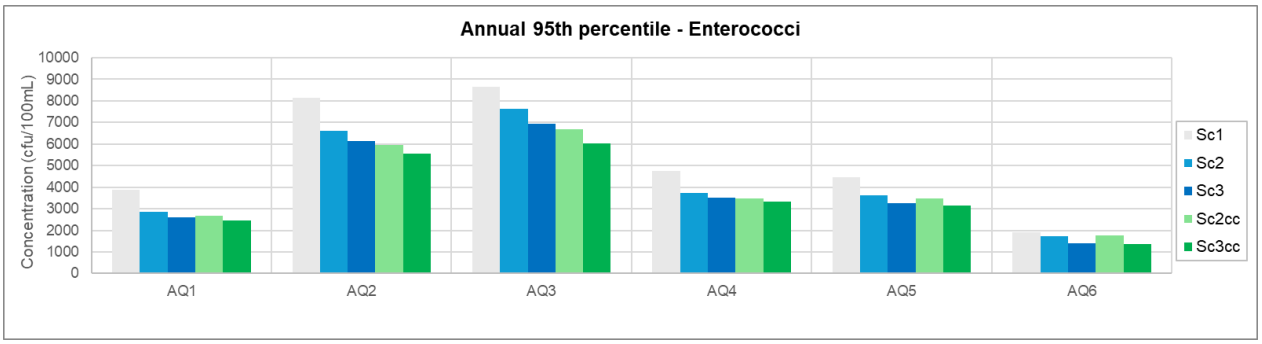


Appendices D4.11.3 Higher rainfall year scenario results (2021-2022)

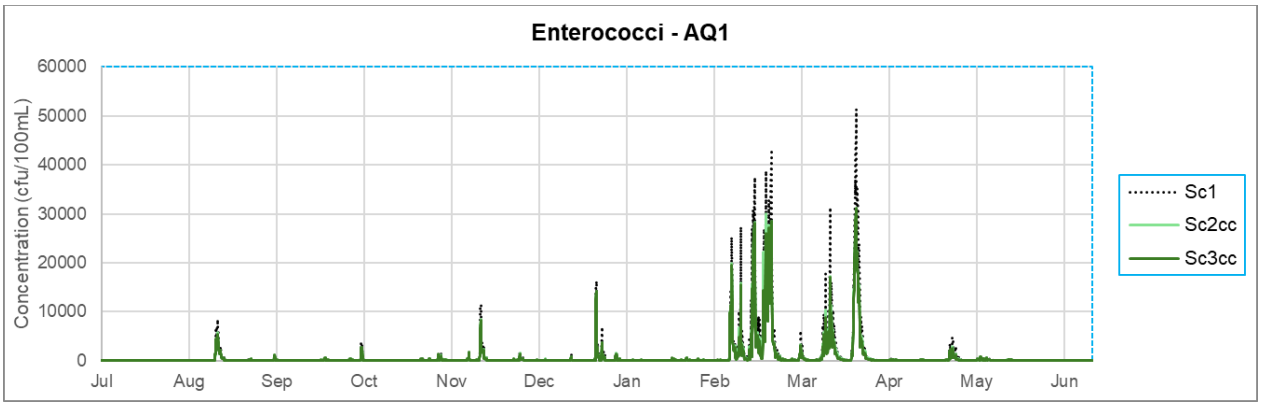
Bar charts

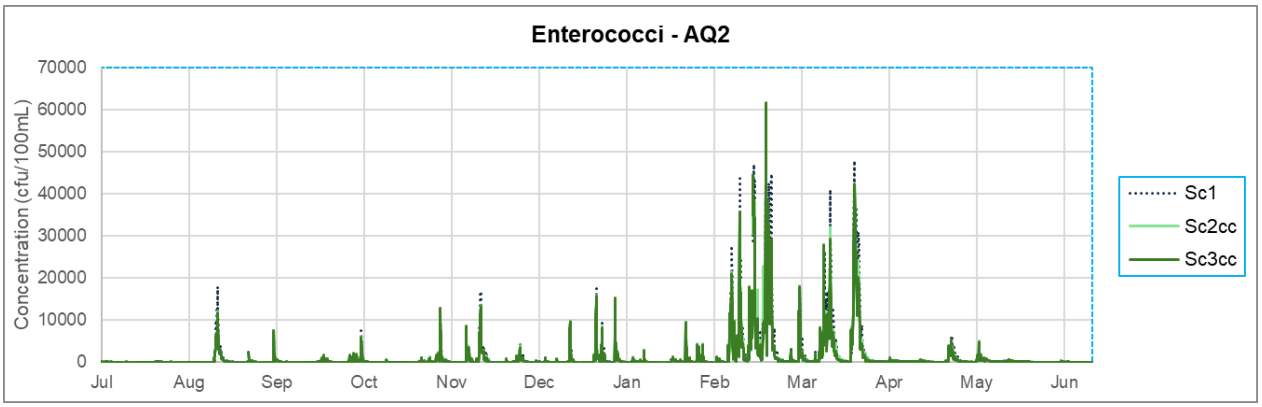


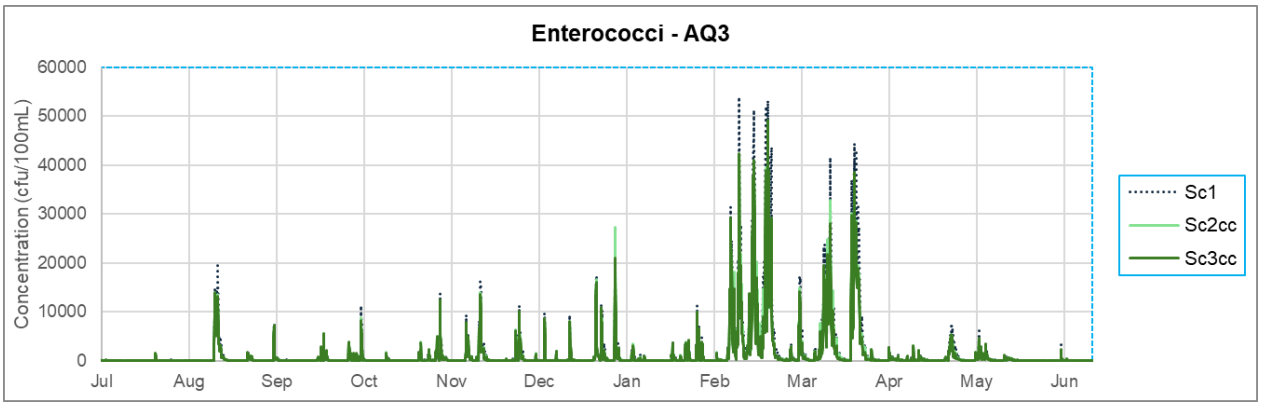


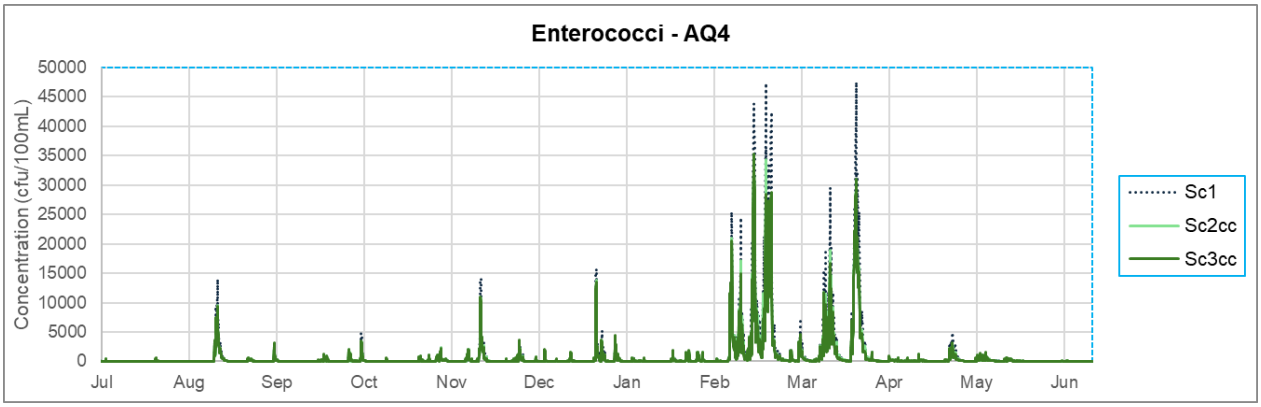


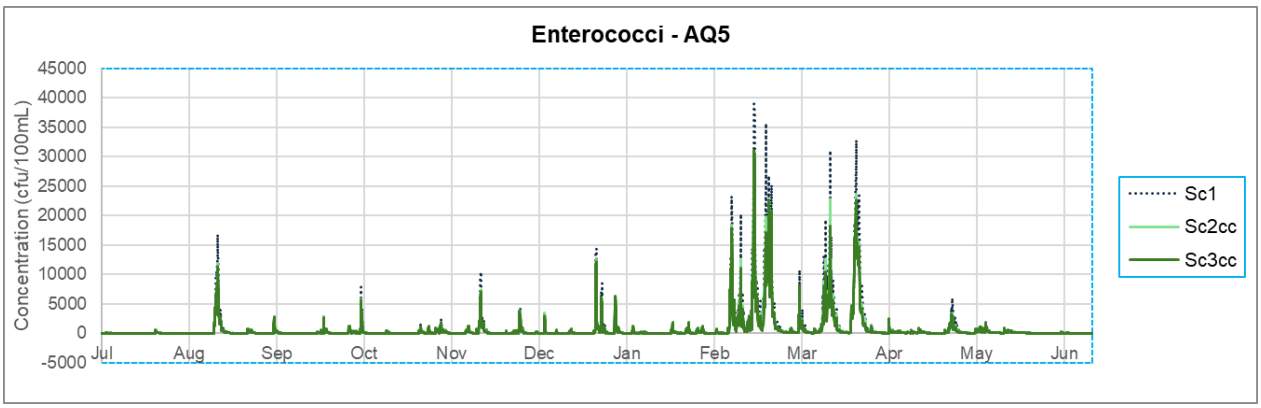
Time series plots

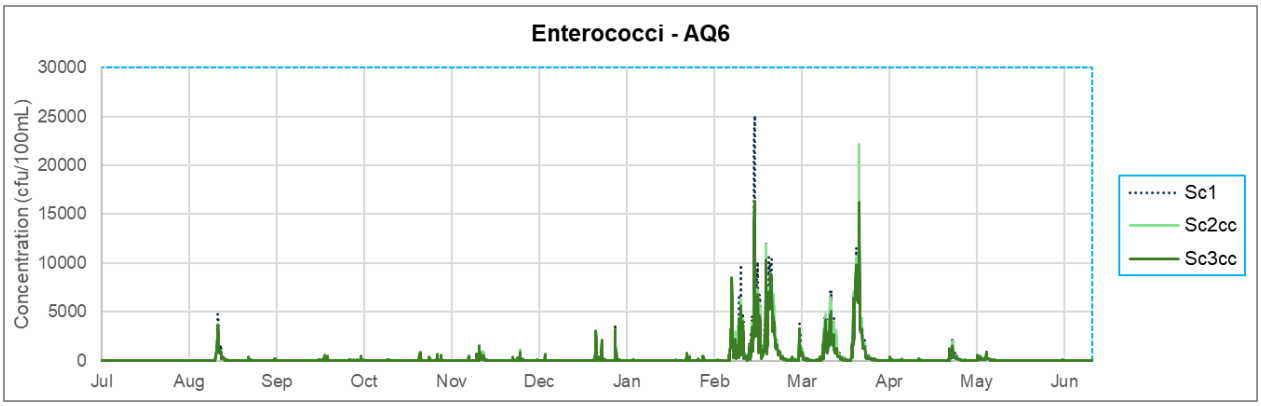





Enterococci - AQ3
Concentration (cfu/100mL)
60000
50000
40000
30000
20000
10000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Enterococci - AQ4
Concentration (cfu/100mL)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Enterococci - AQ5
Concentration (cfu/100mL)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

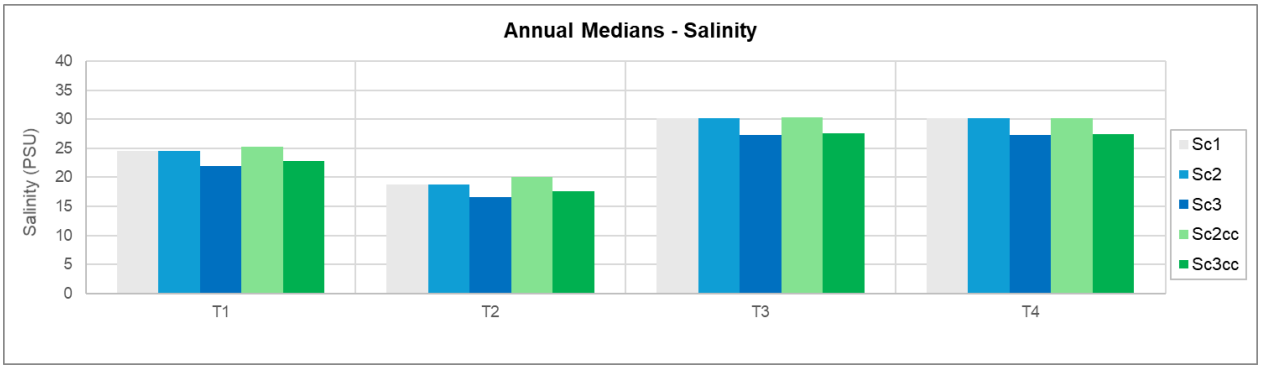

Enterococci - AQ6
Concentration (cfu/100mL)
30000
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

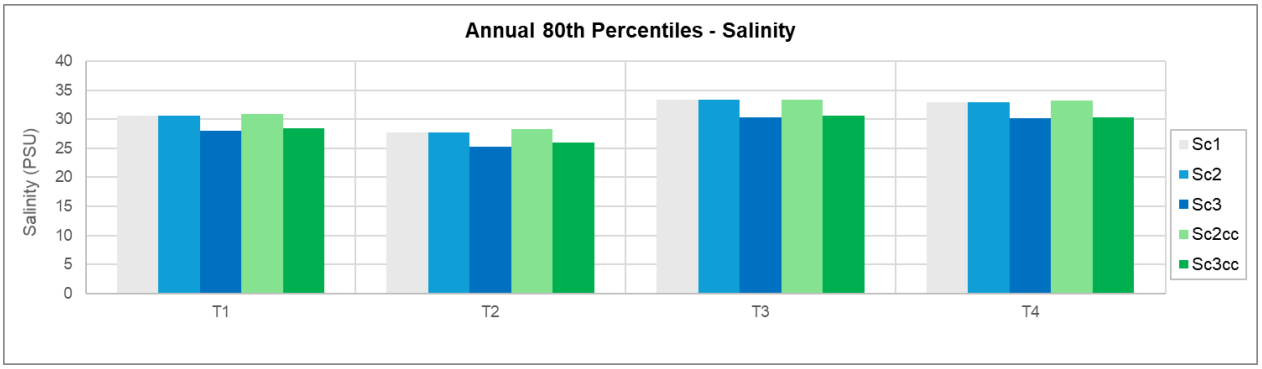
Appendices D5 SEARS reference sites results without climate change

Appendices D5.1 Salinity

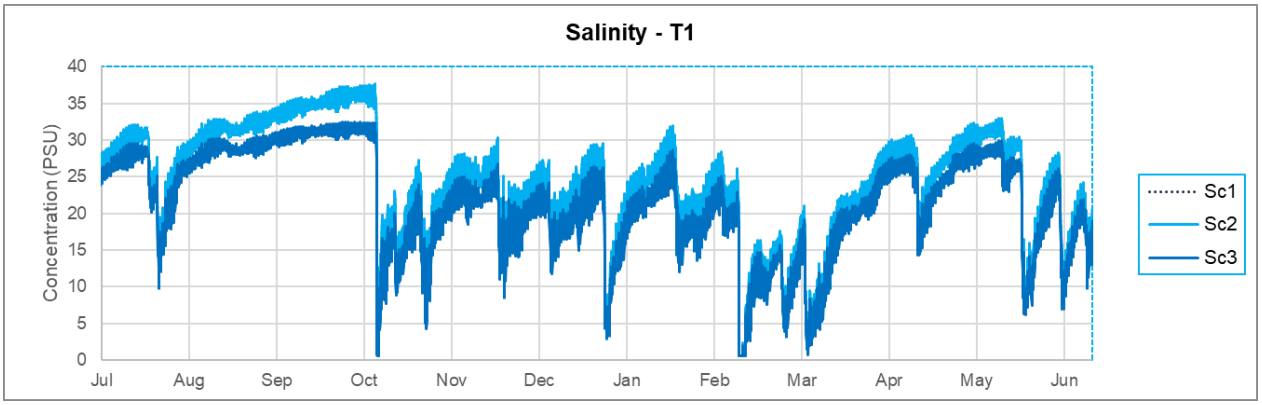
Appendices D5.1.1 Lower rainfall year scenario results (2017-2018)

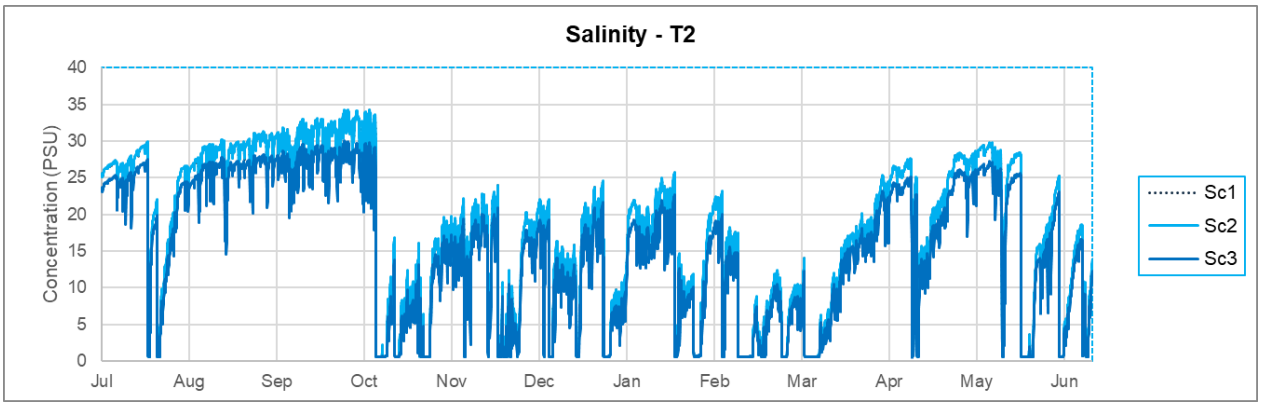
Bar charts

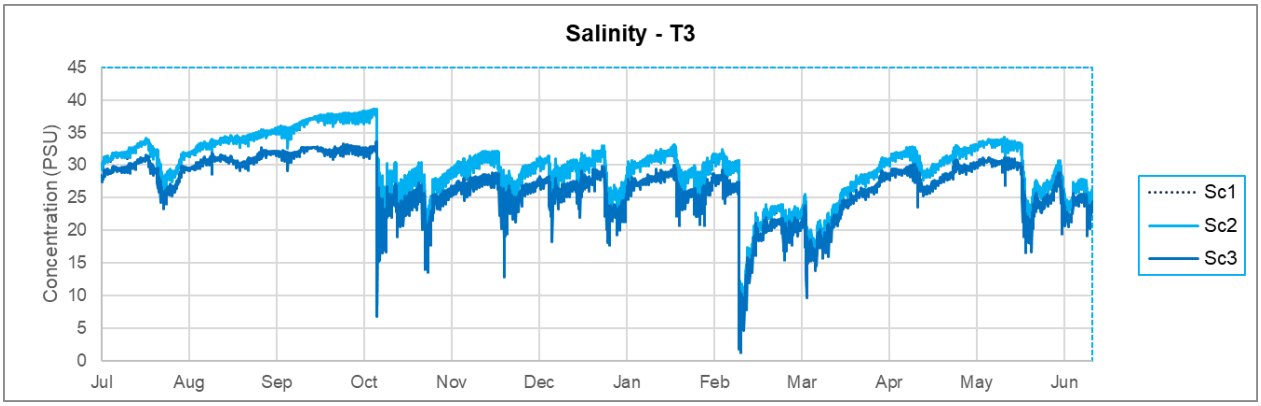


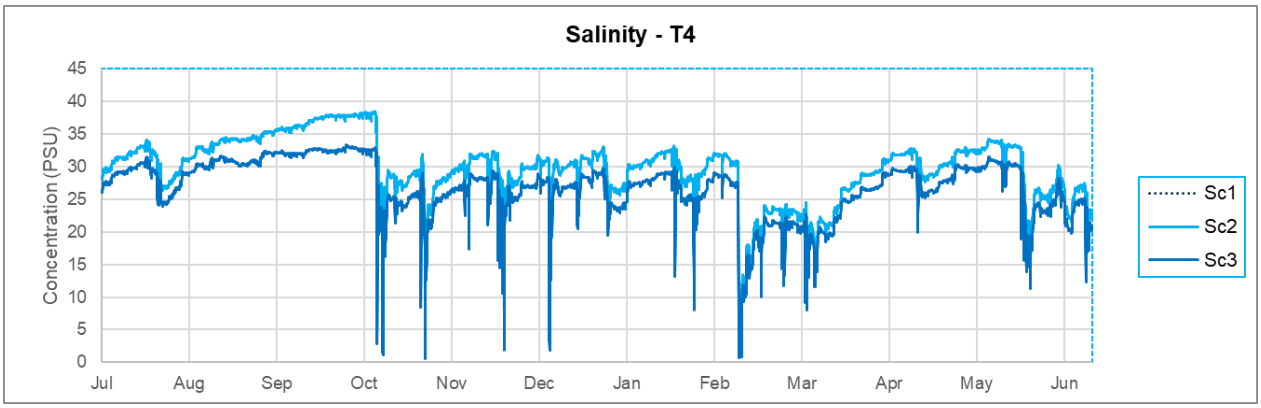


Time series plots



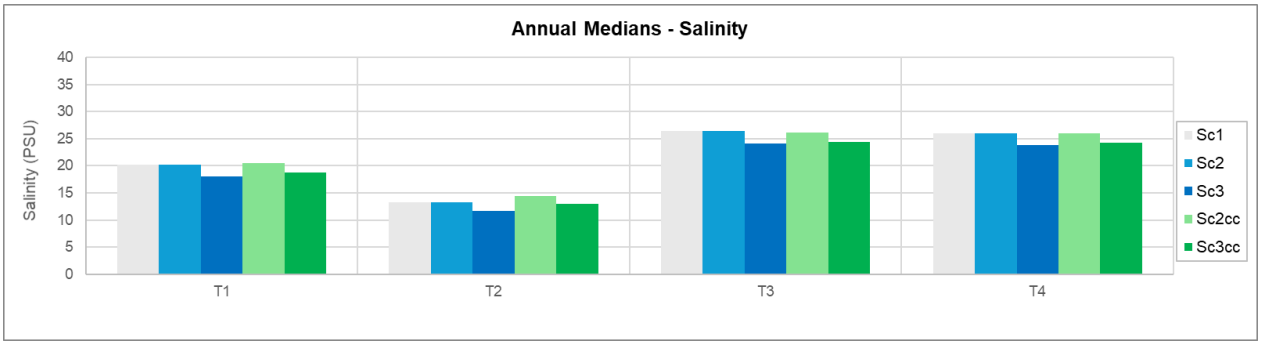

Salinity - T2
Concentration (PSU)
0
5
10
15
20
25
30
35
40
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

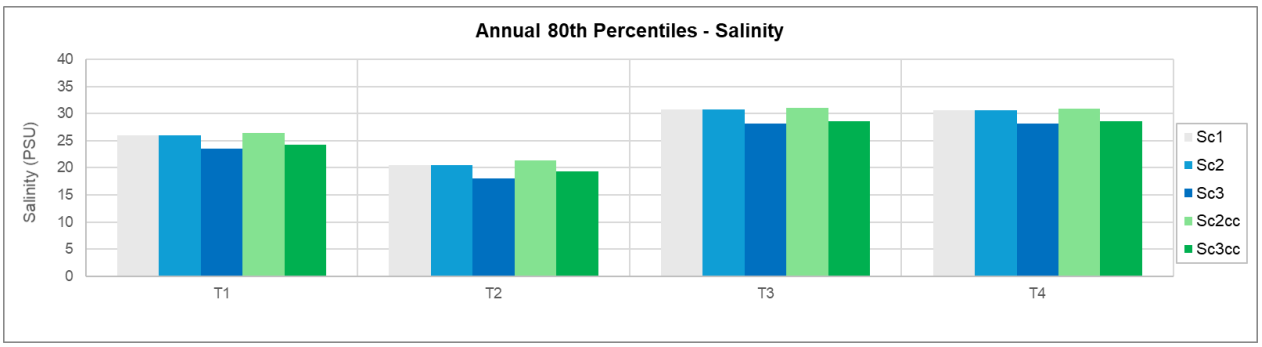

Salinity - T3
Concentration (PSU)
0
5
10
15
20
25
30
35
40
45
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Salinity - T4
Concentration (PSU)
0
5
10
15
20
25
30
35
40
45
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

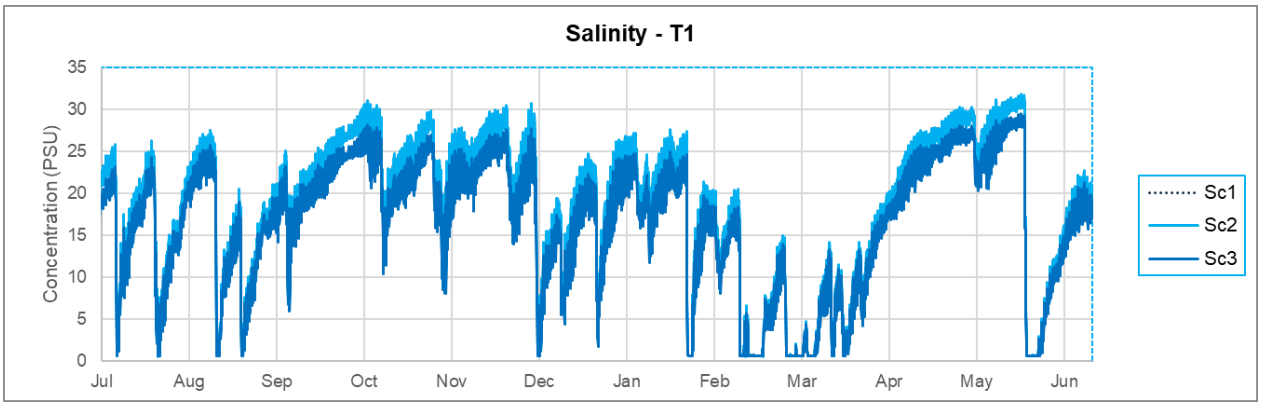
Appendices D5.1.2 Average rainfall year scenario results (2016-2017)

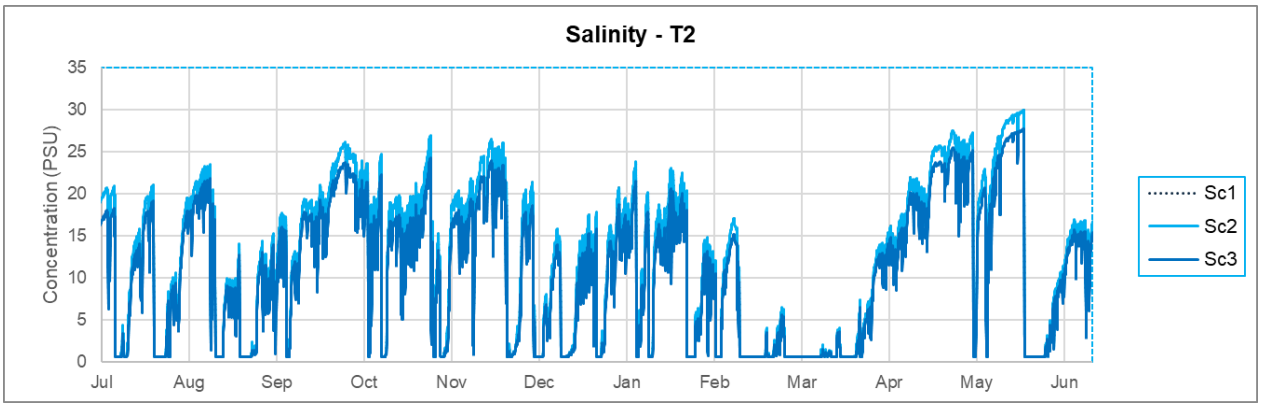
Bar charts

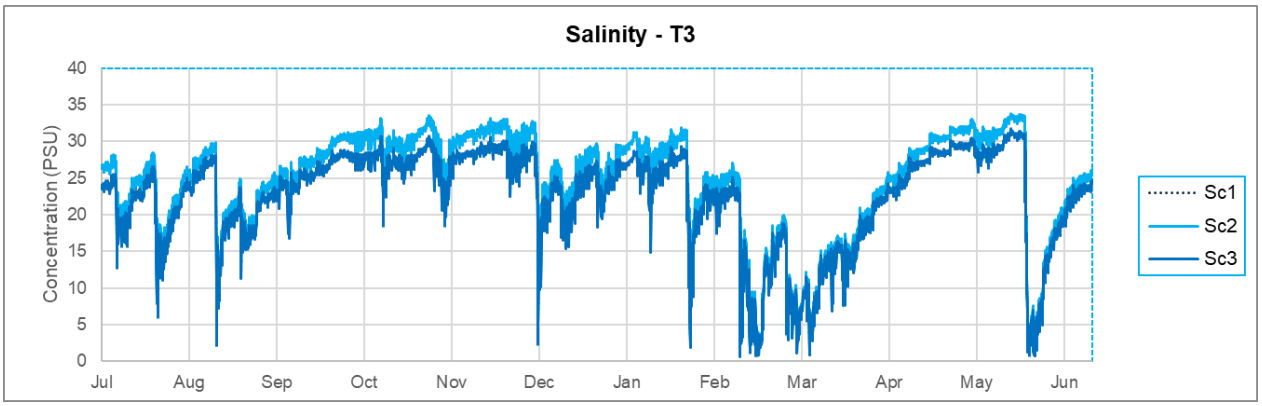


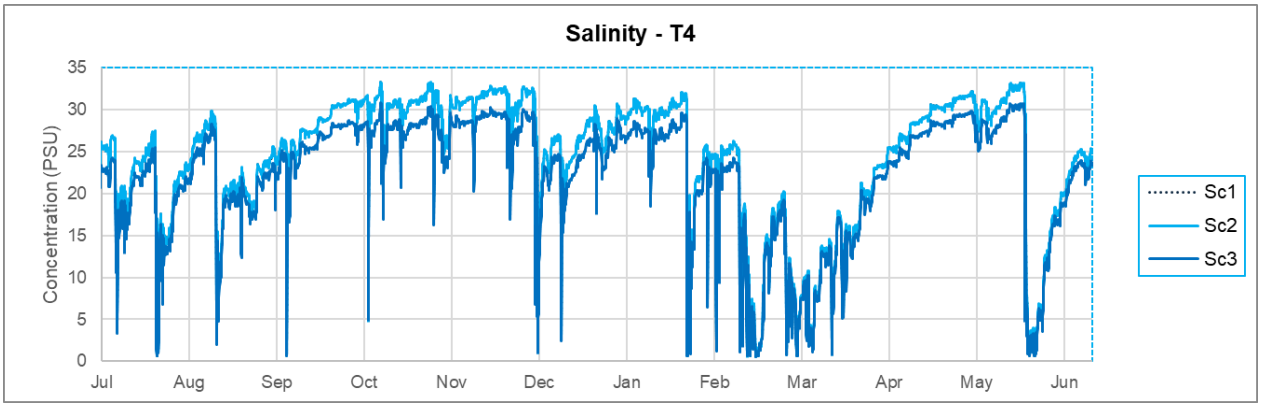


Time series plots



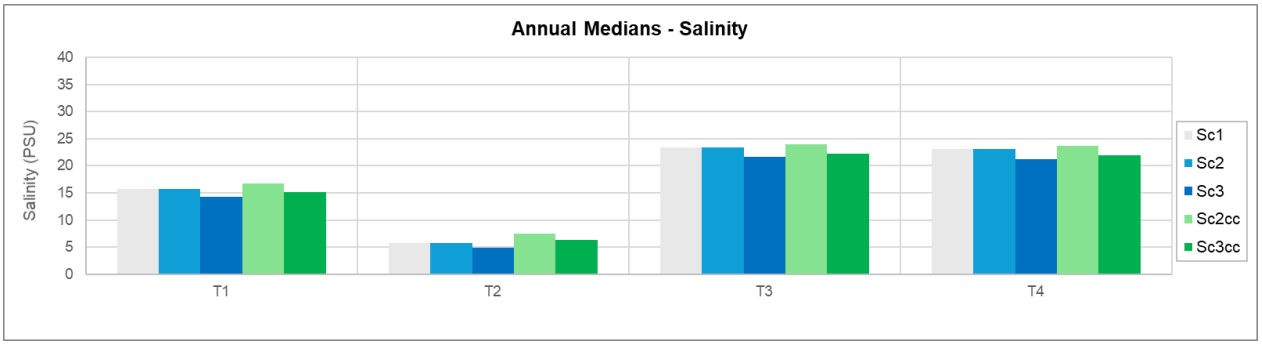


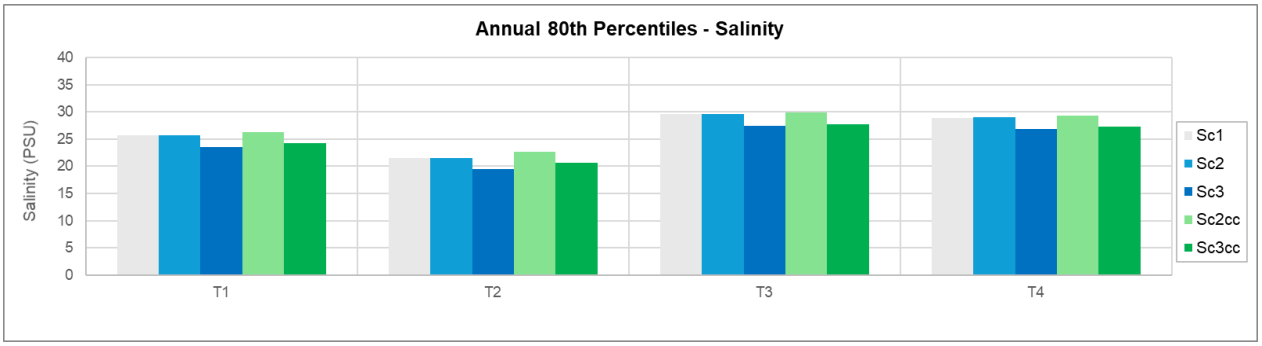




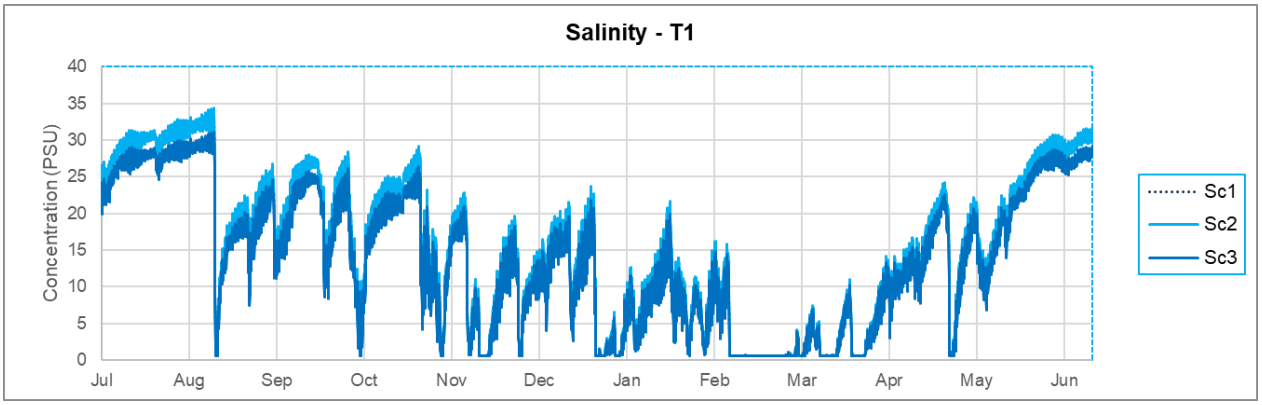
Appendices D5.1.3 Higher rainfall year scenario results (2021-2022)

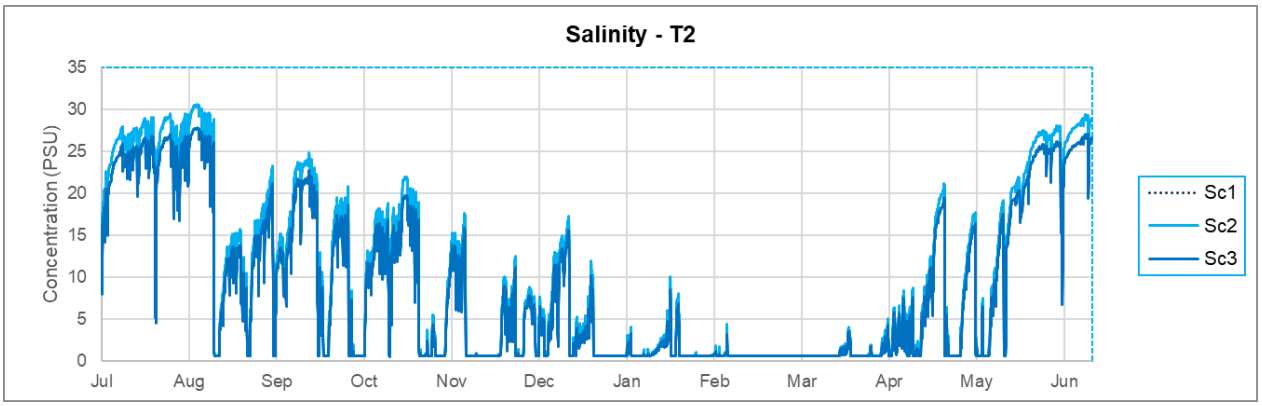
Bar charts

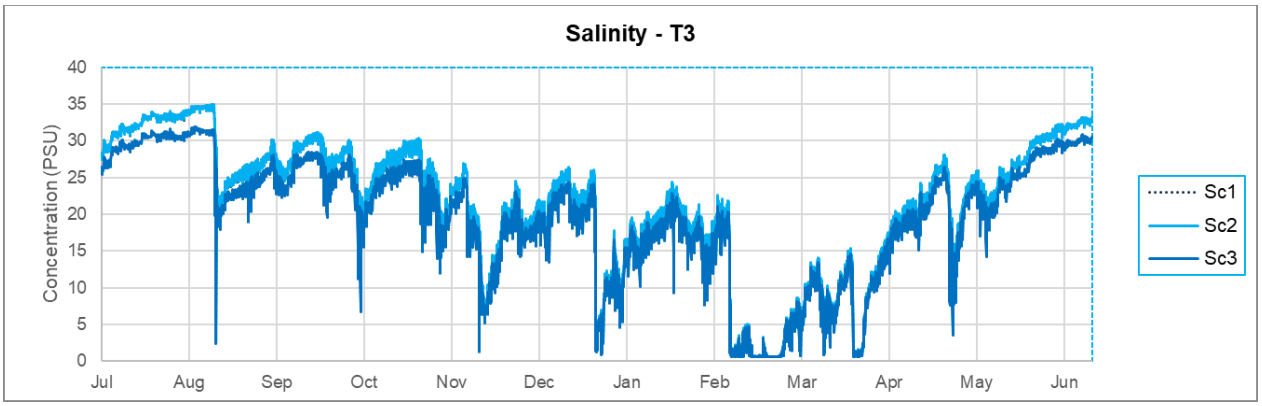


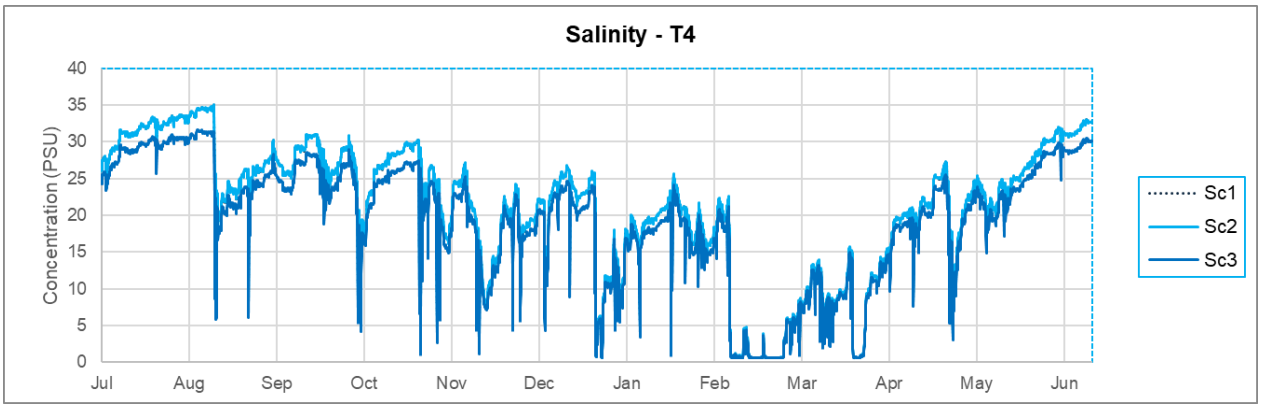


Time series plots





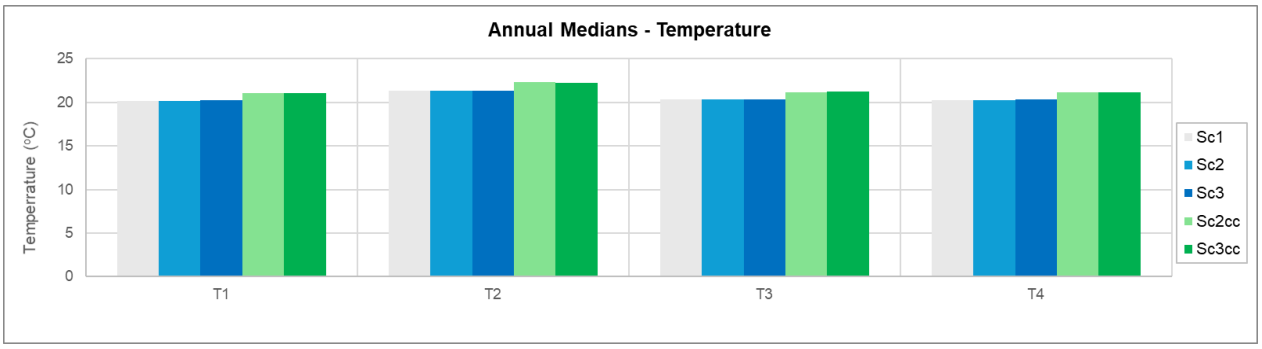


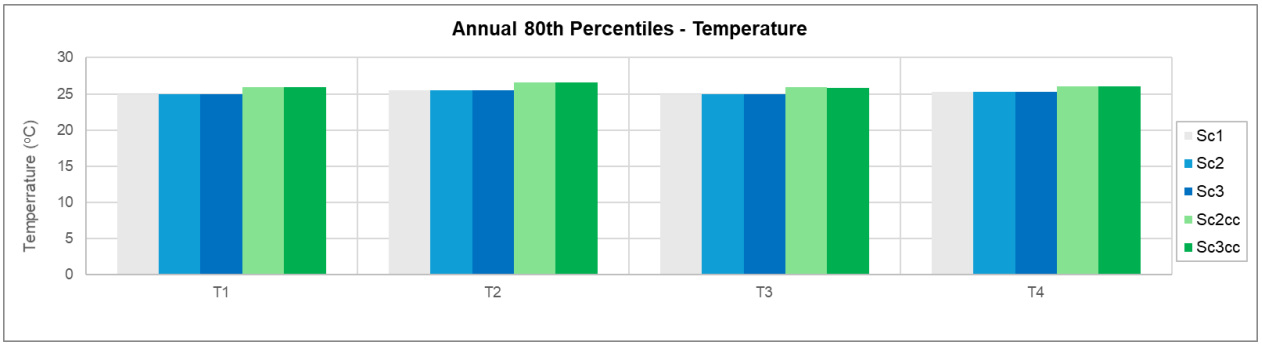


Appendices D5.2 Temperature

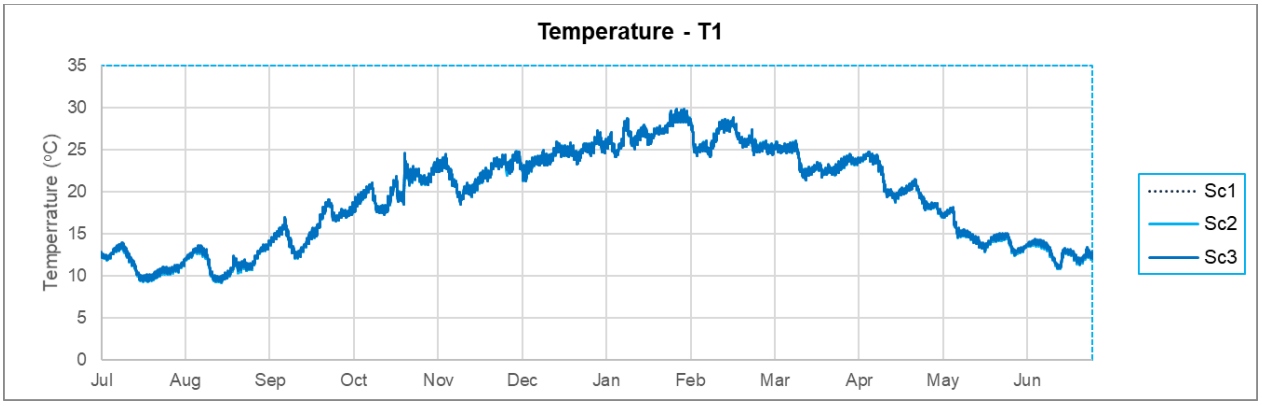
Appendices D5.2.1 Lower rainfall year scenario results (2017-2018)

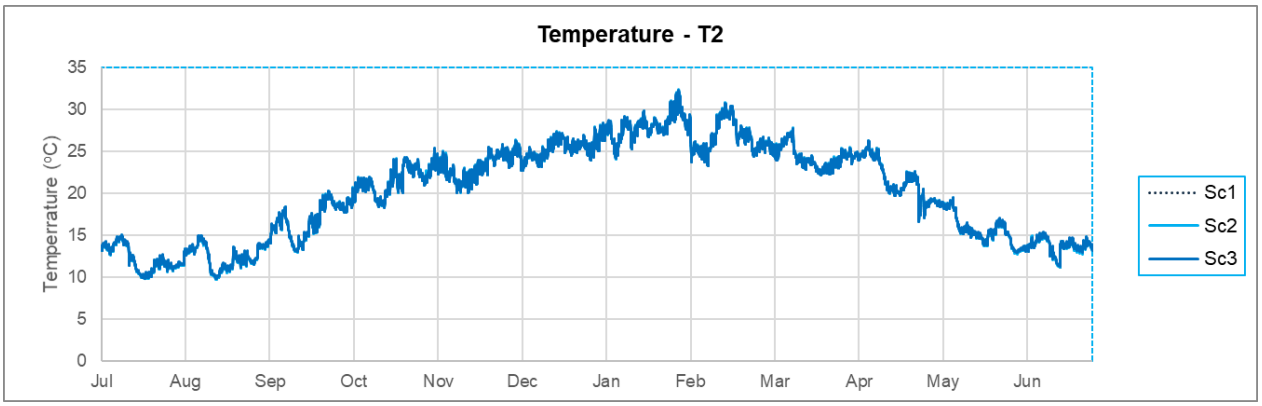
Bar charts

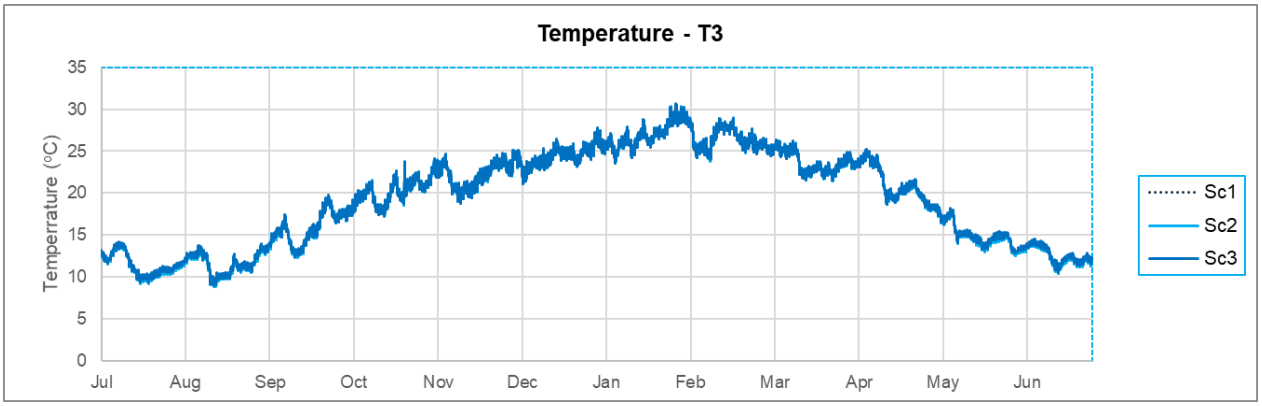


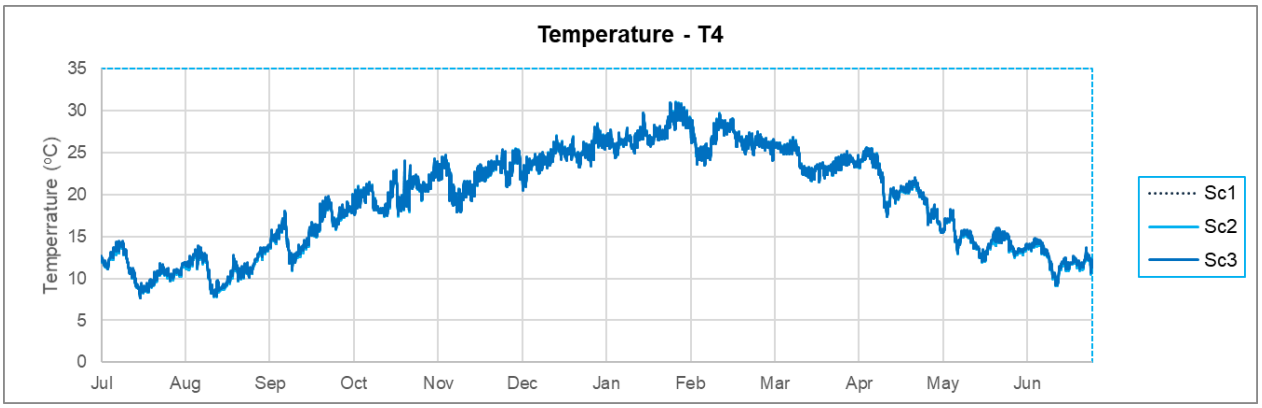


Time series plots



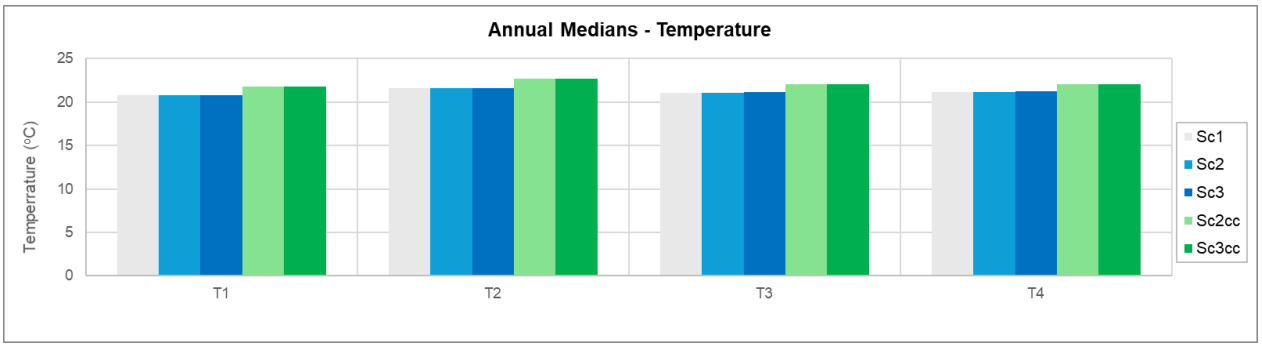


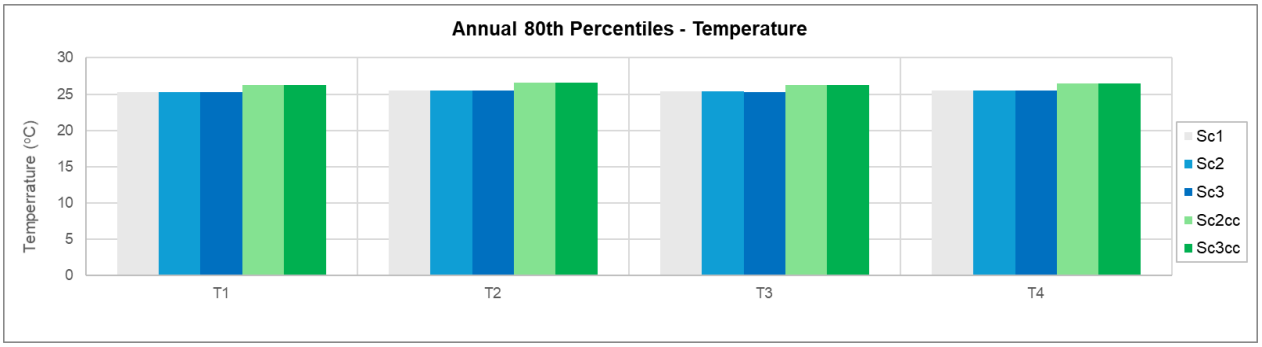




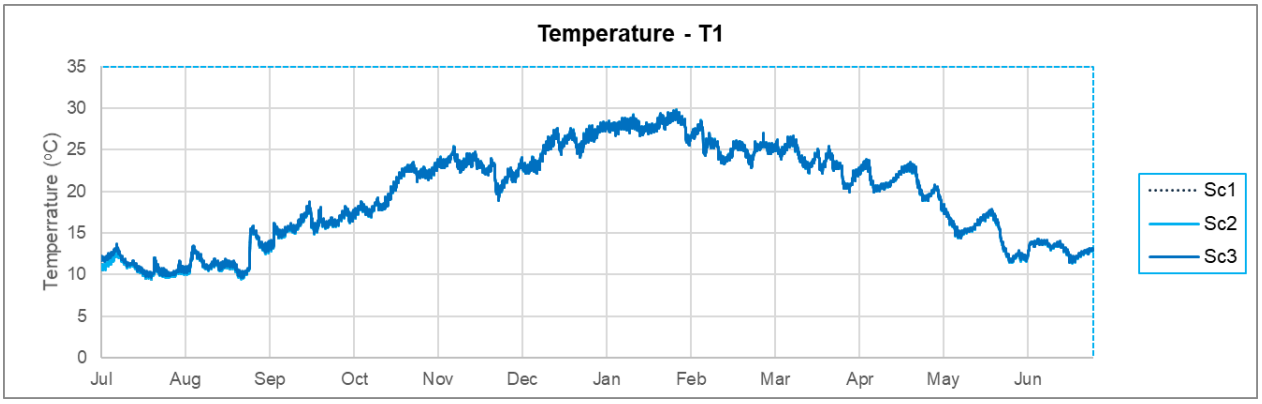
Appendices D5.2.2 Average rainfall year scenario results (2016-2017)

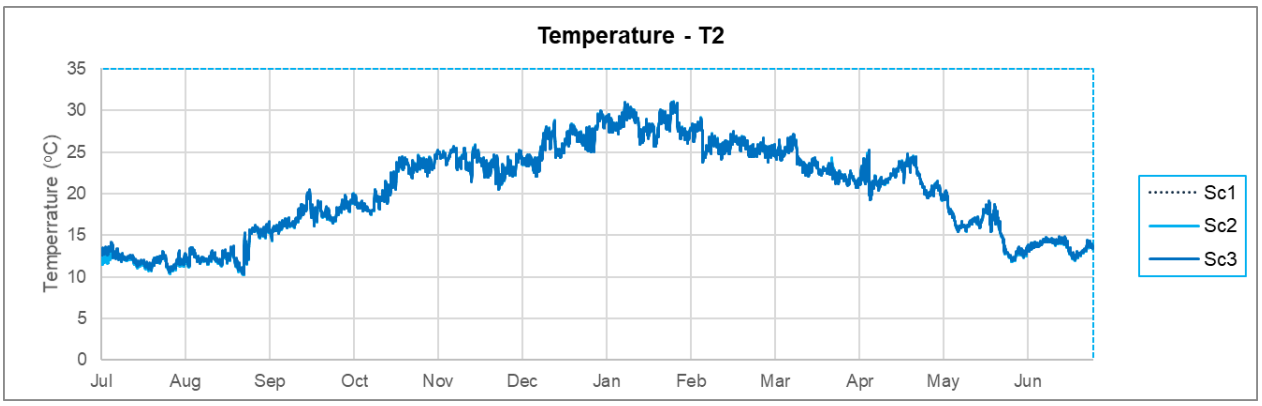
Bar charts

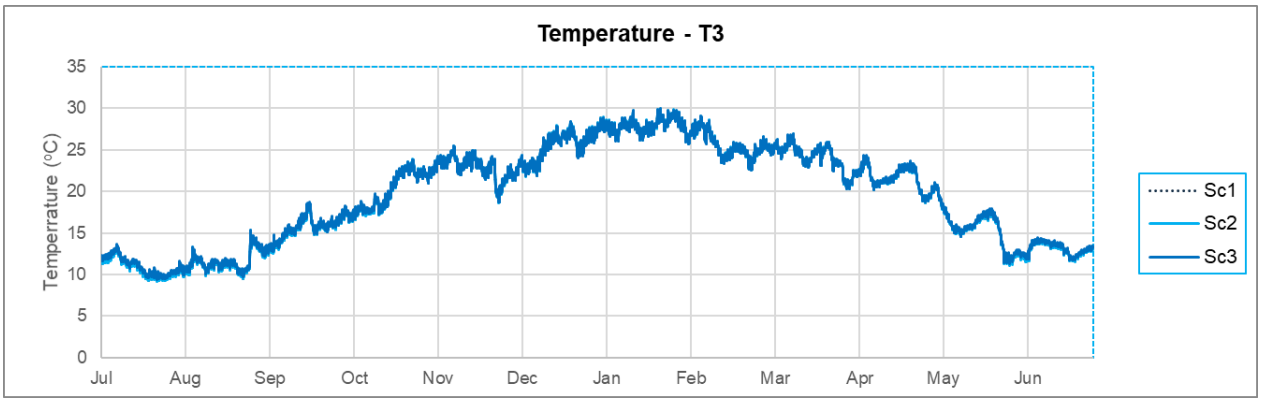


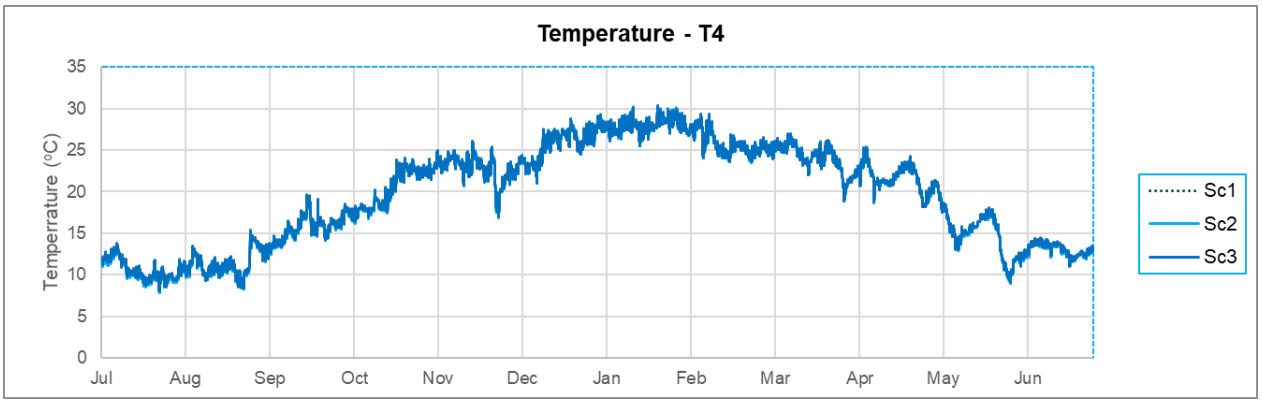


Time series plots



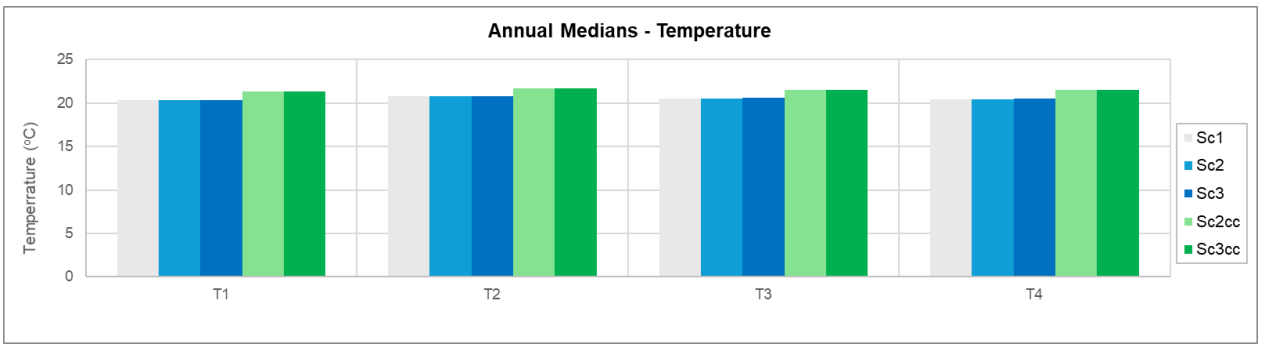


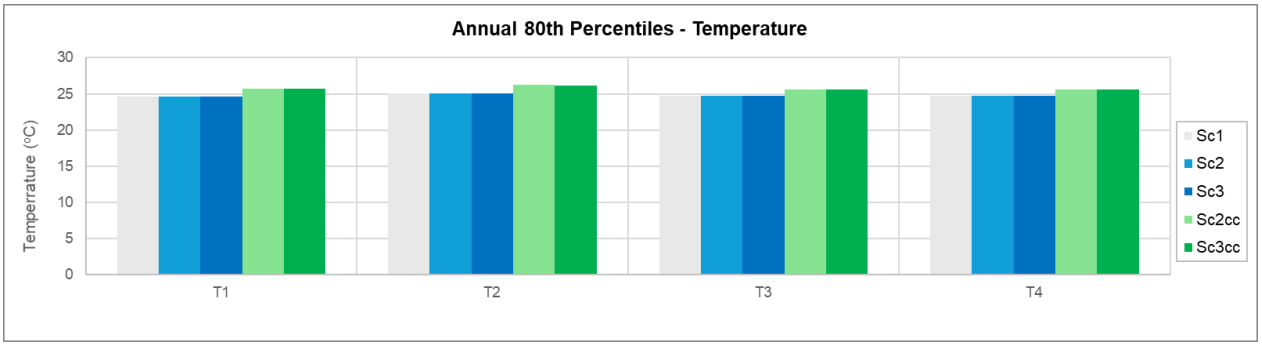




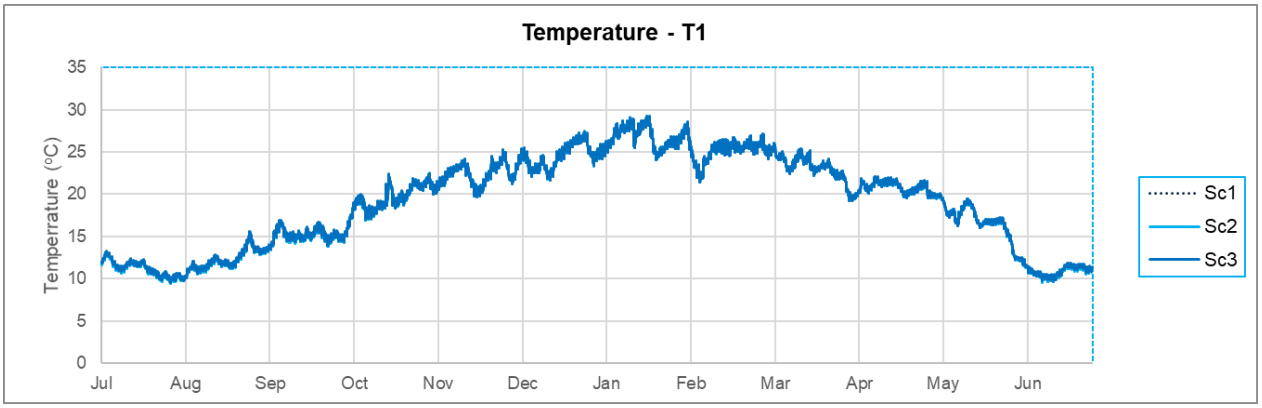
Appendices D5.2.3 Higher rainfall year scenario results (2021-2022)

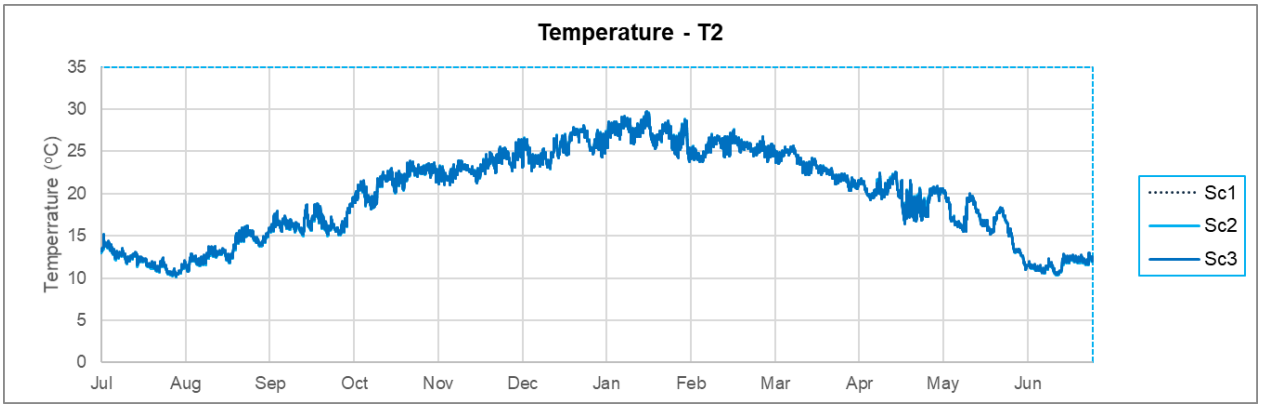
Bar charts

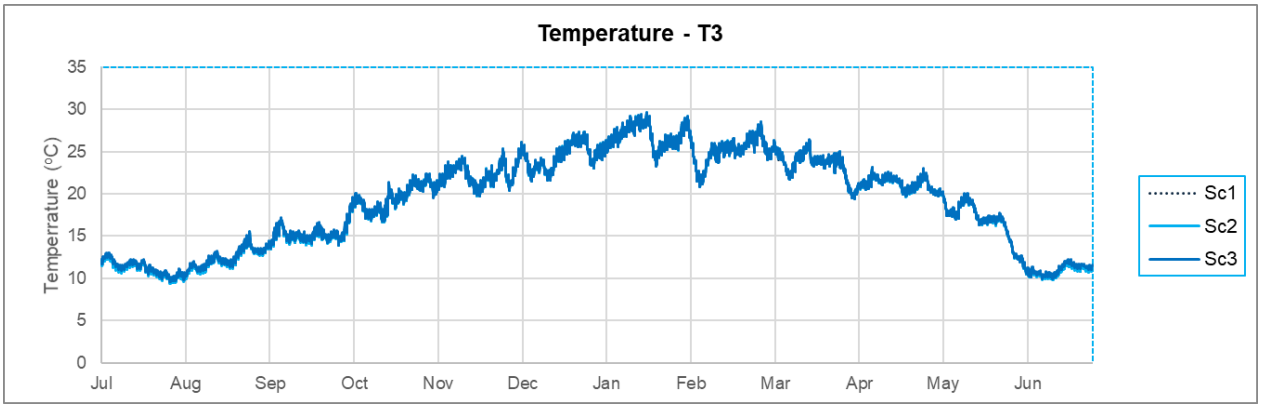


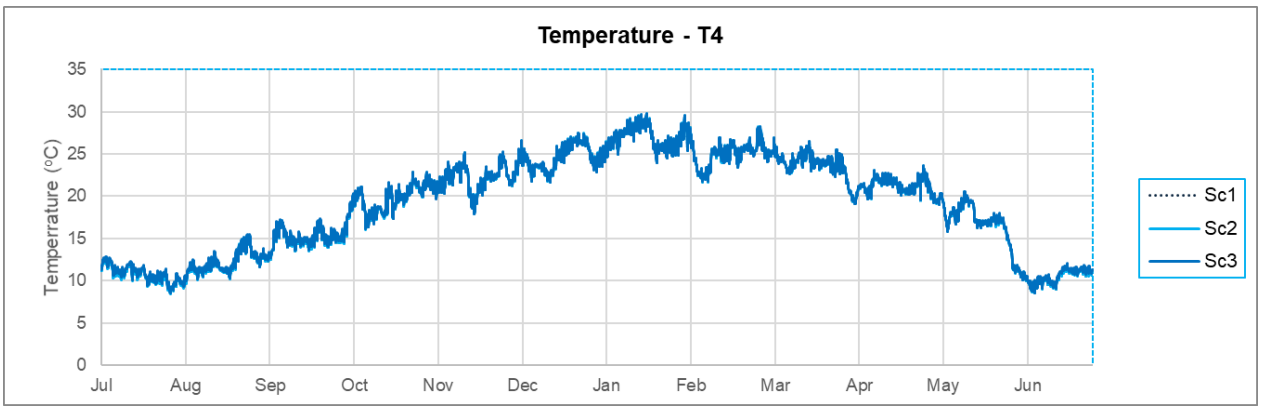


Time series plots




Temperature - T2
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

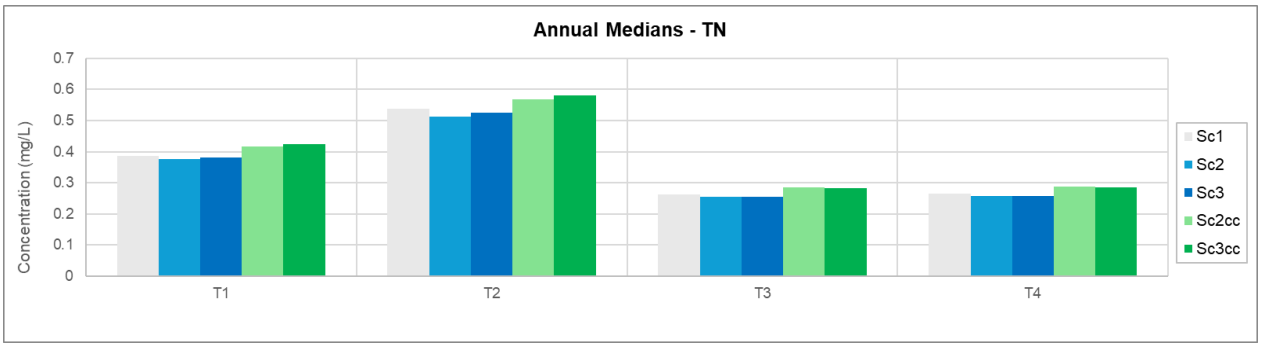

Temperature - T3
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

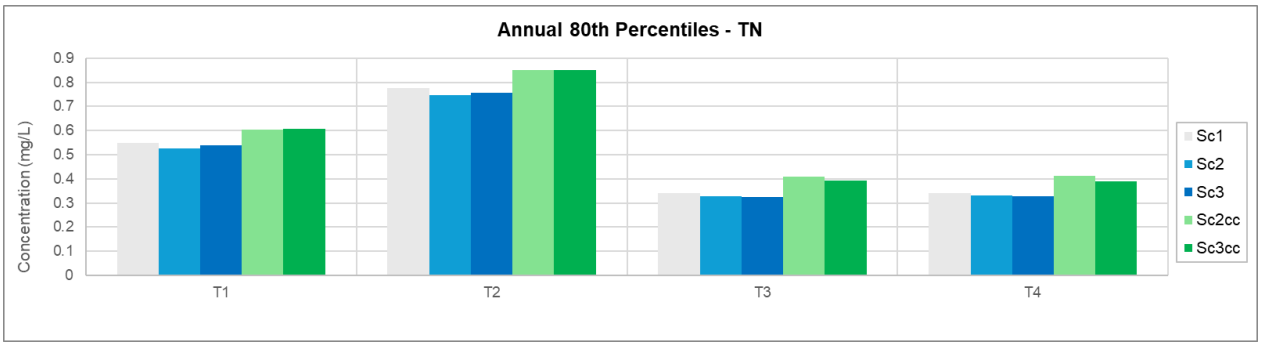

Temperature - T4
Temperature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.3 Total N

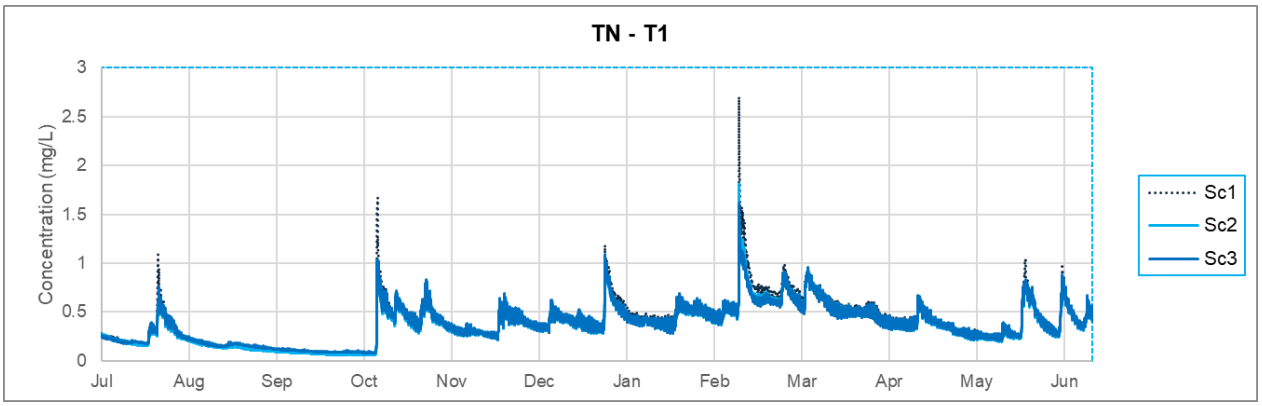
Appendices D5.3.1 Lower rainfall year scenario results (2017-2018)

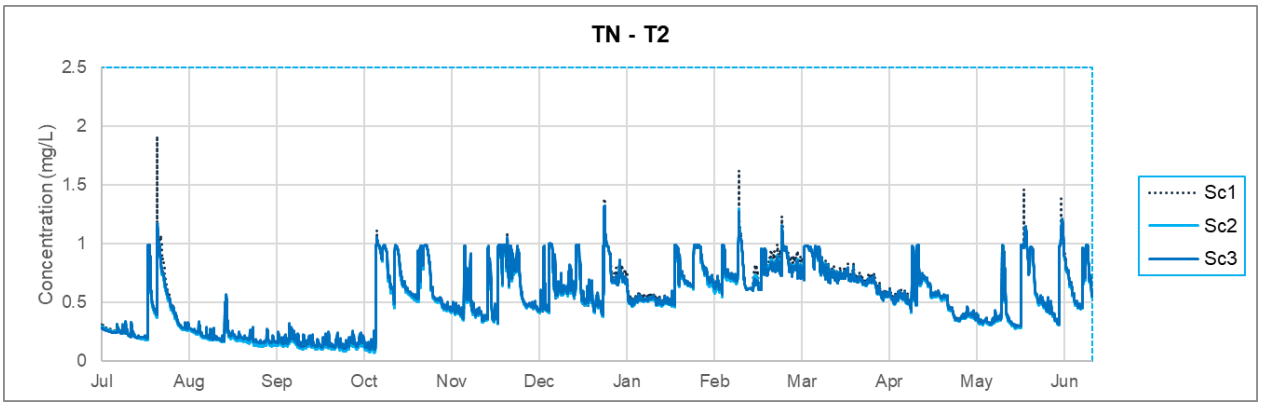
Bar charts

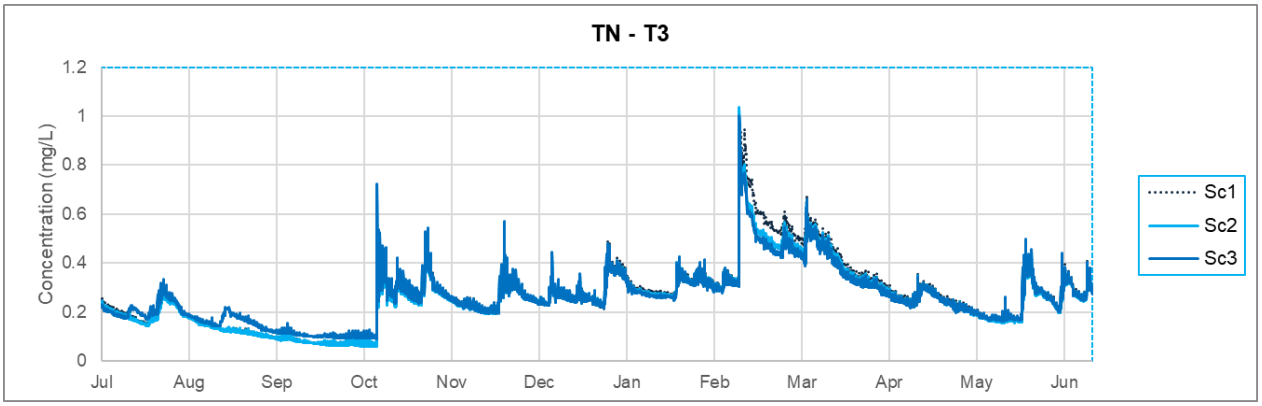


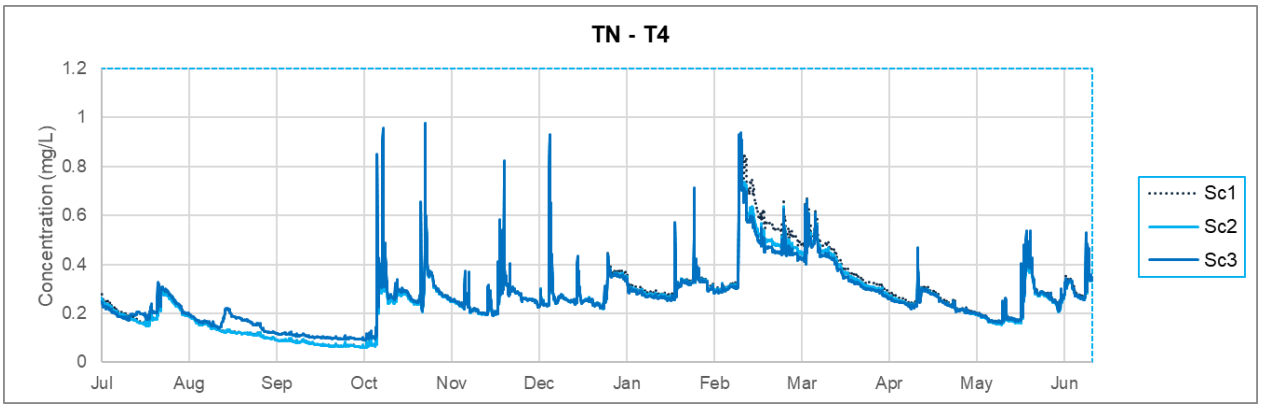


Time series plots



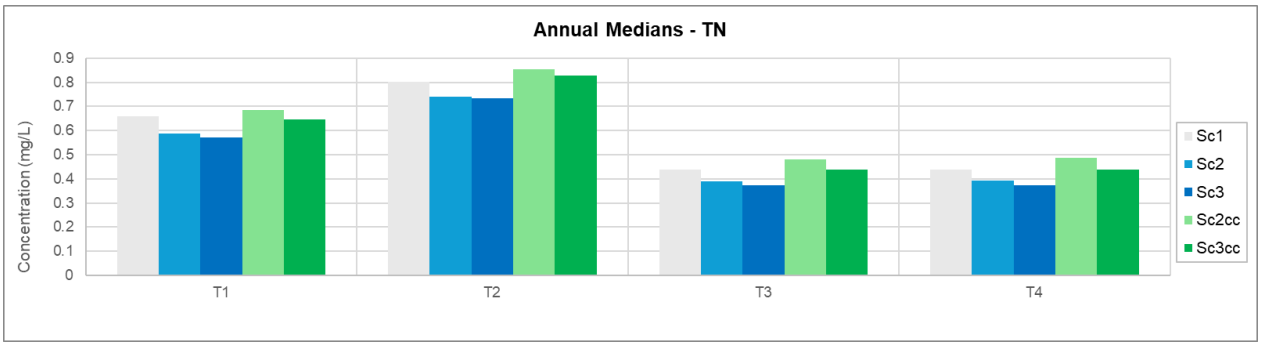


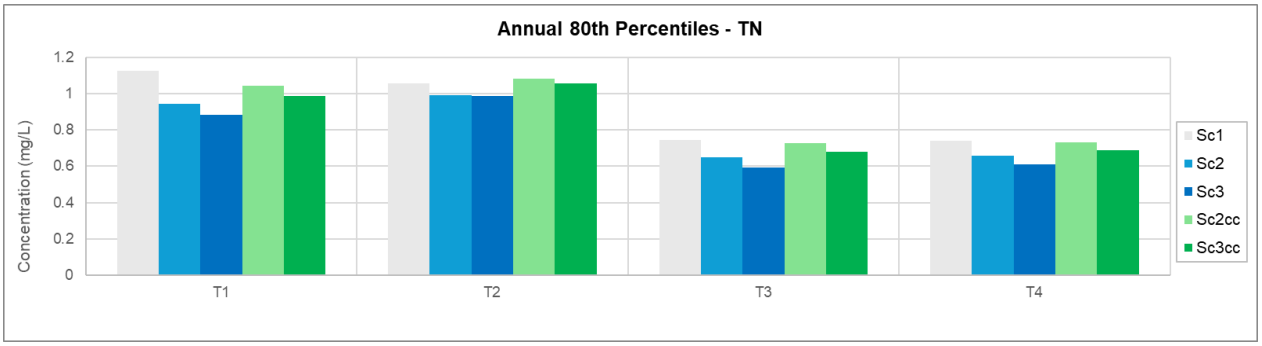




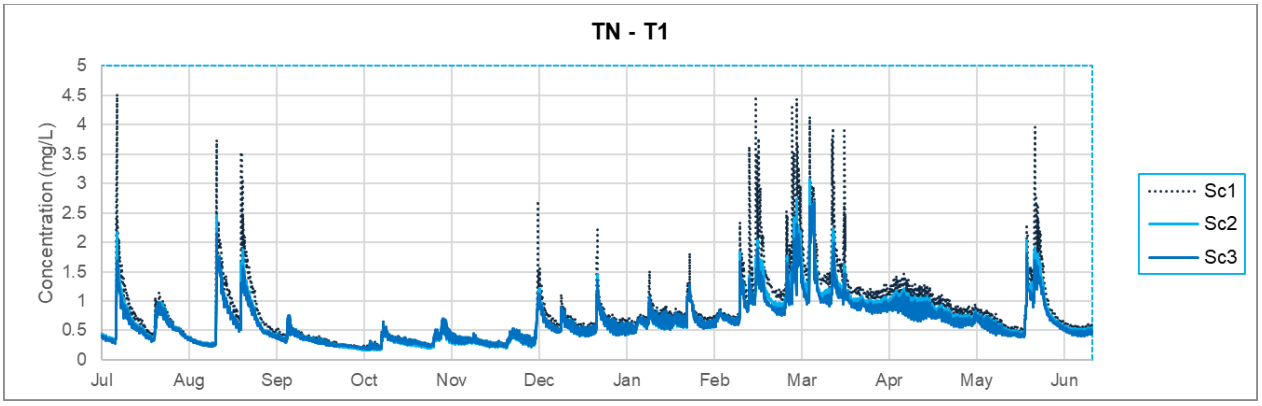
Appendices D5.3.2 Average rainfall year scenario results (2016-2017)

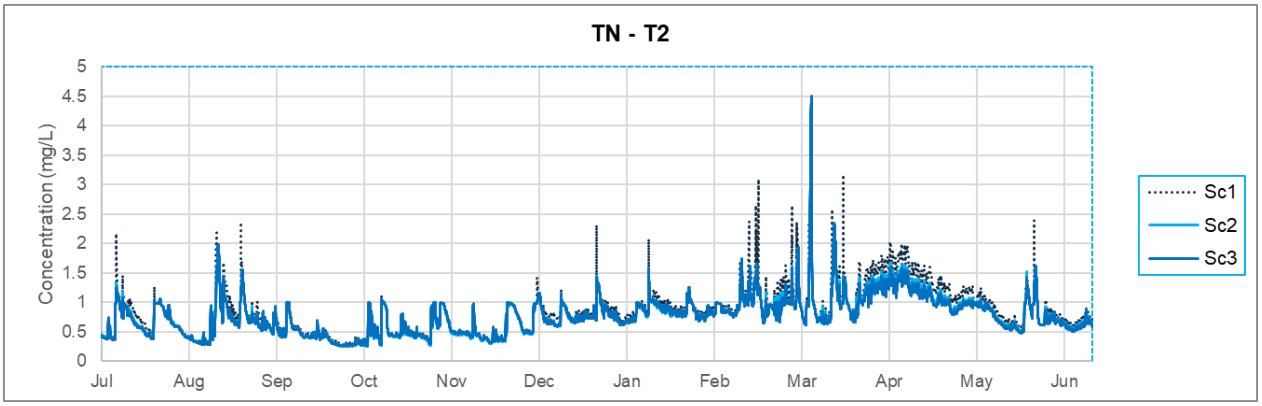
Bar charts

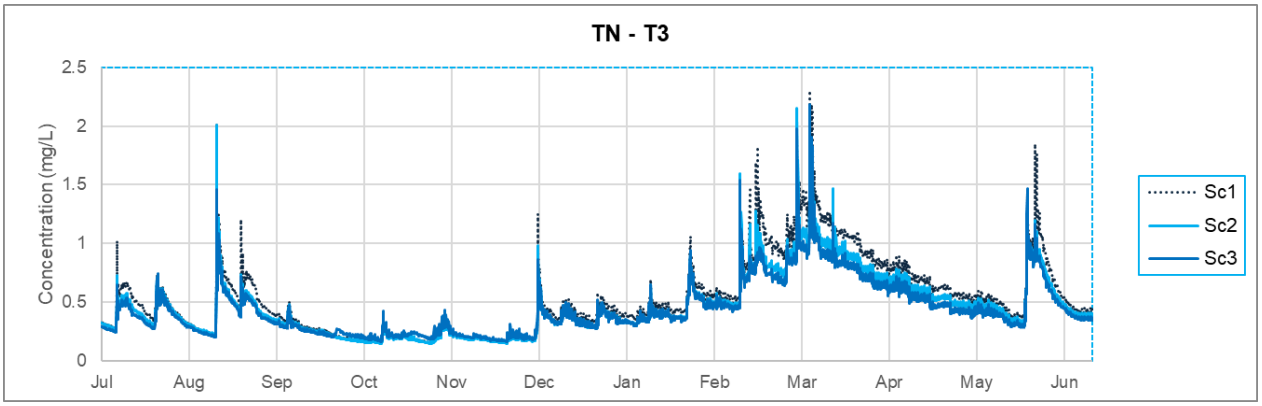


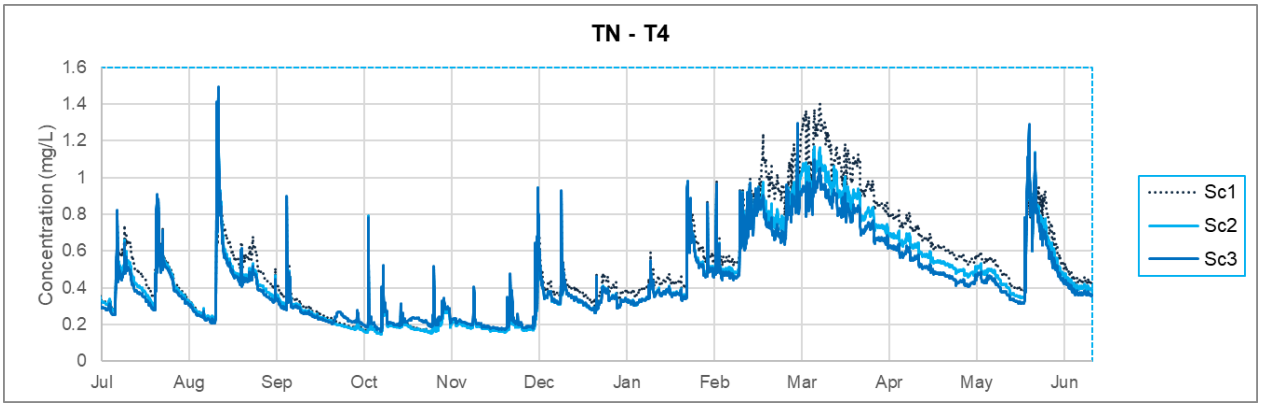


Time series plots



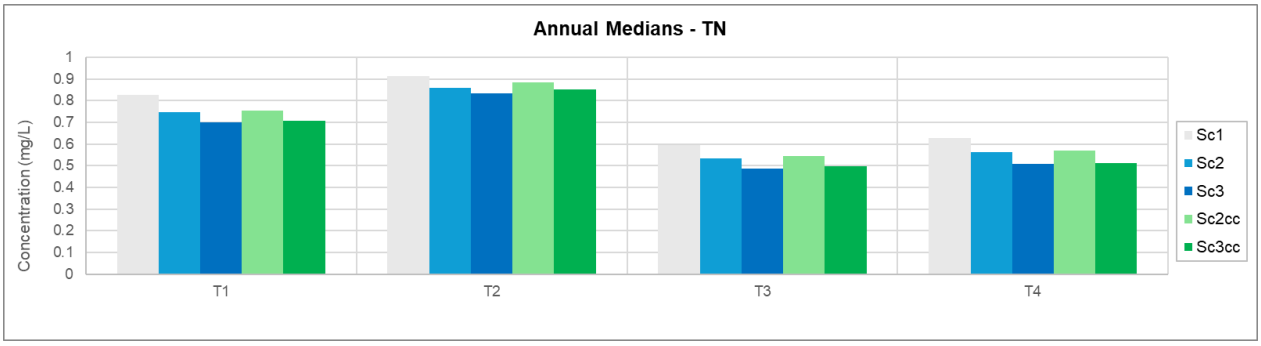


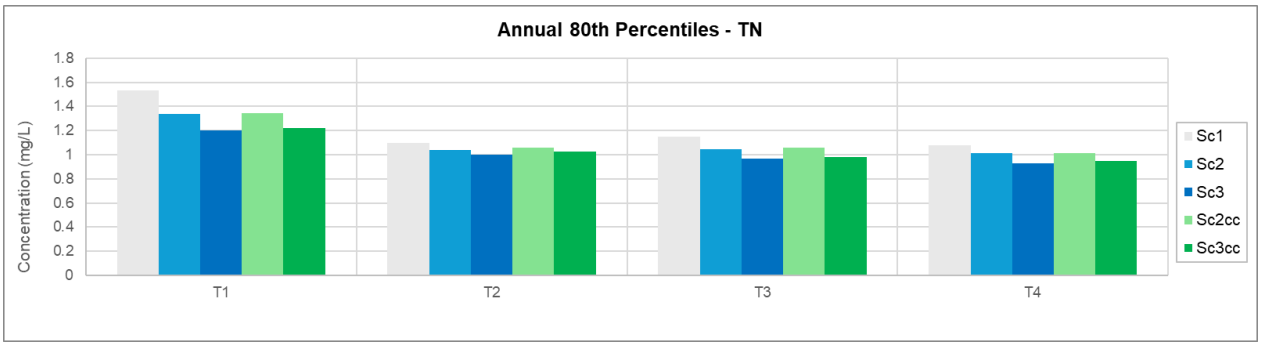




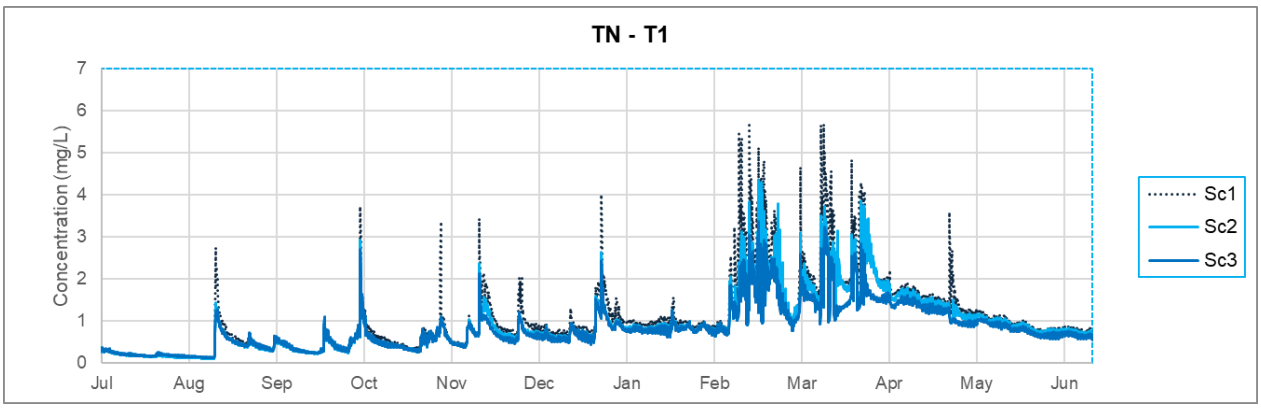
Appendices D5.3.3 Higher rainfall year scenario results (2021-2022)

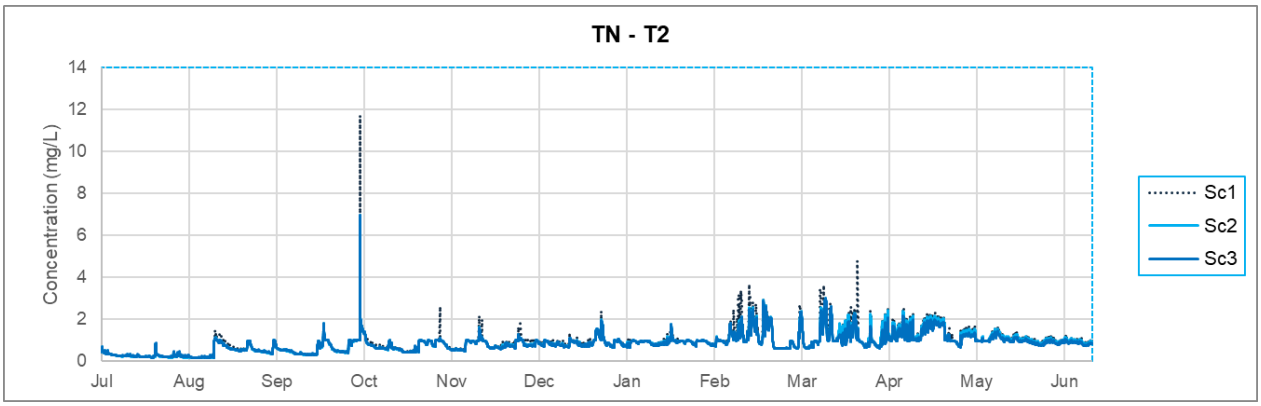
Bar charts

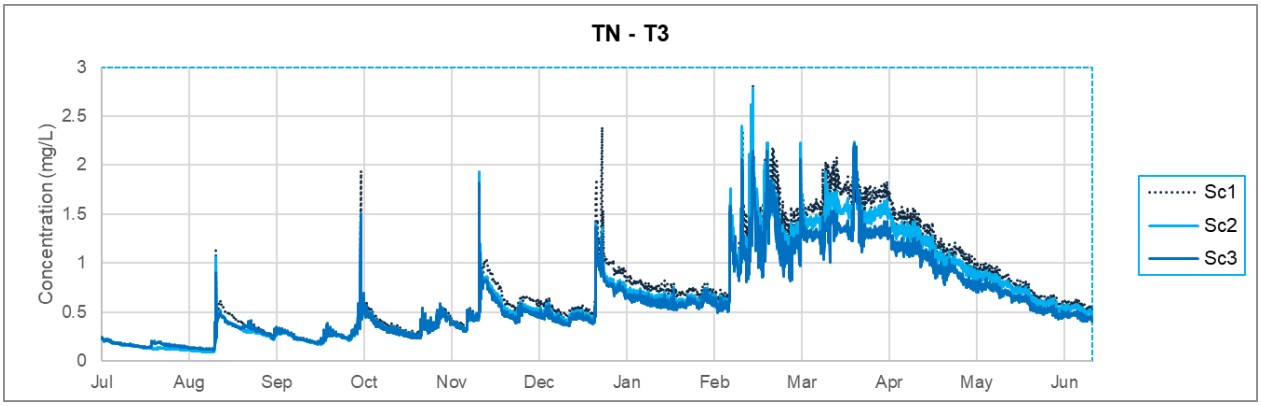


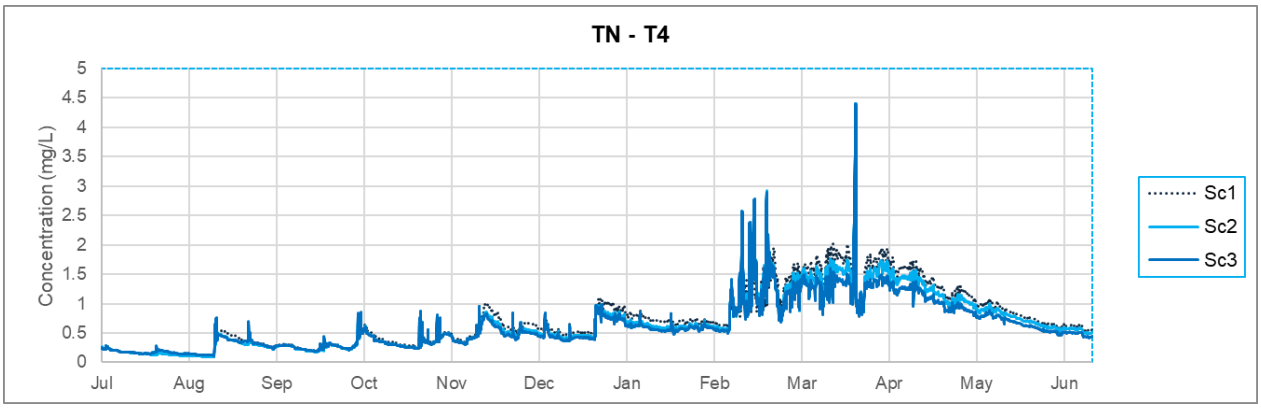


Time series plots




TN - T2
Concentration (mg/L)
14
12
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

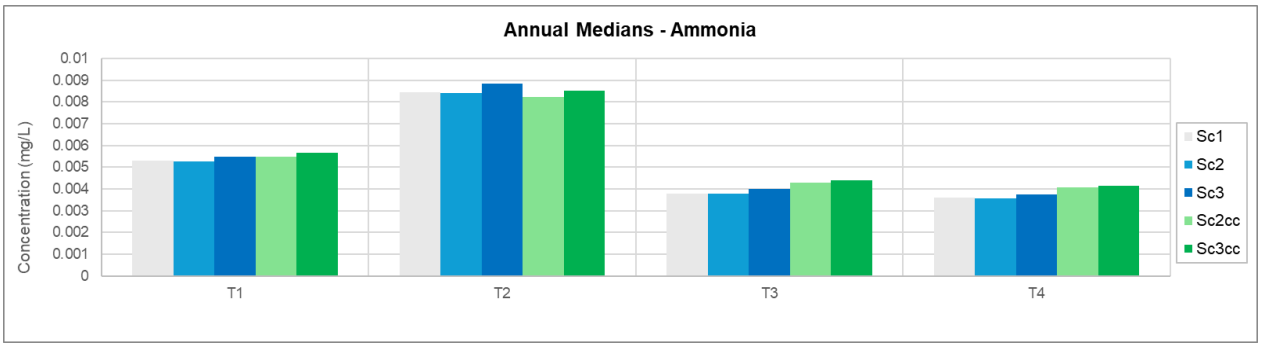

TN - T3
Concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

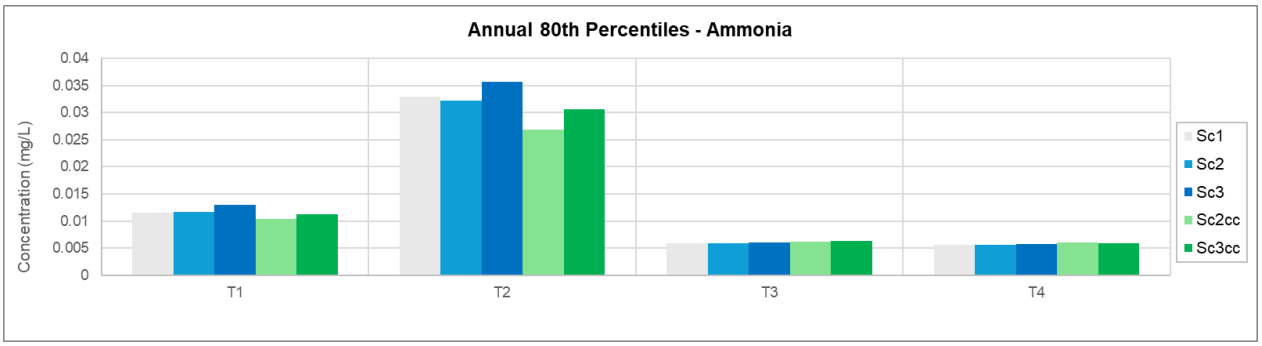

TN - T4
Concentration (mg/L)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.4 Ammonia

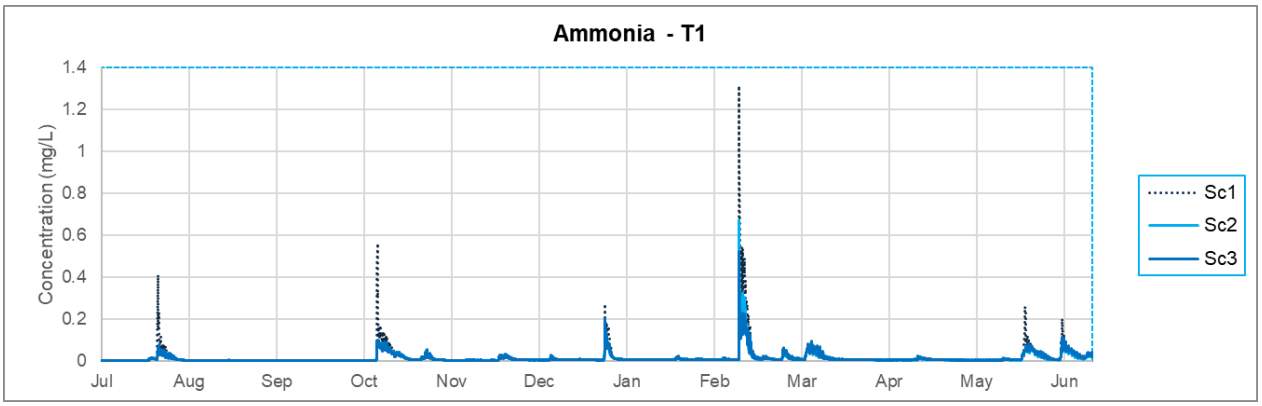
Appendices D5.4.1 Lower rainfall year scenario results (2017-2018)

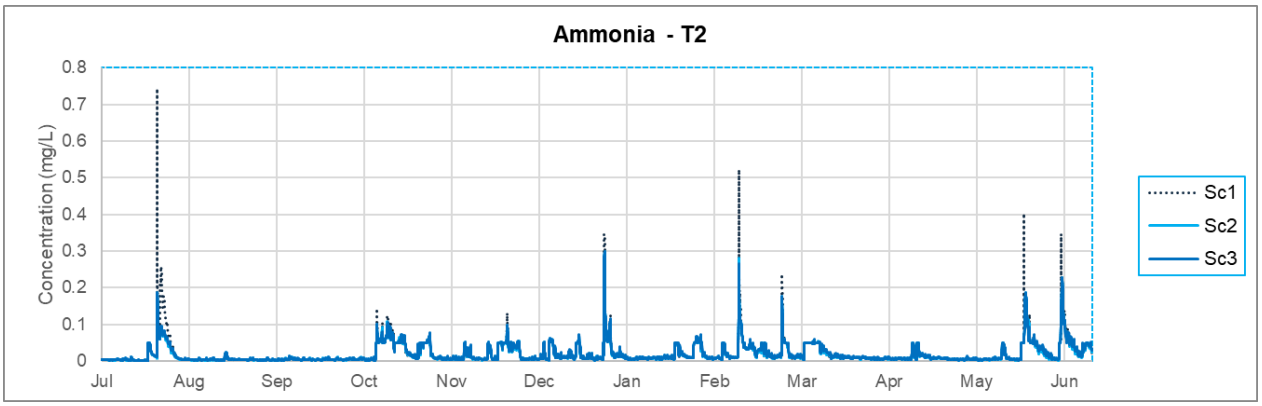
Bar charts

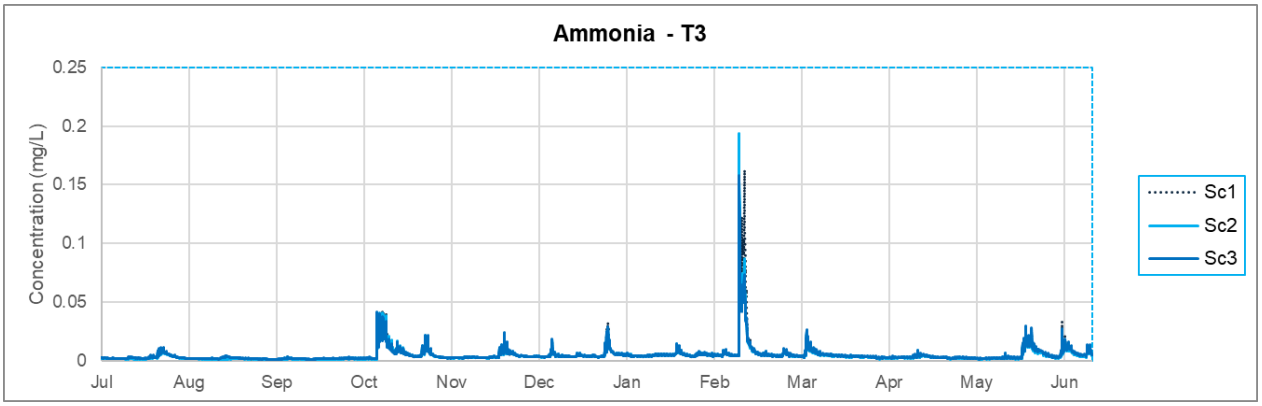


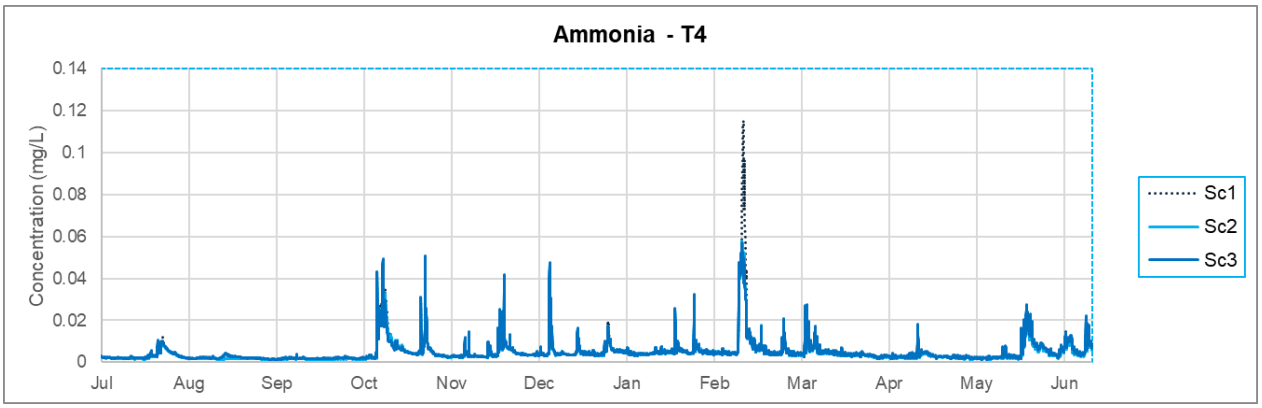


Time series plots



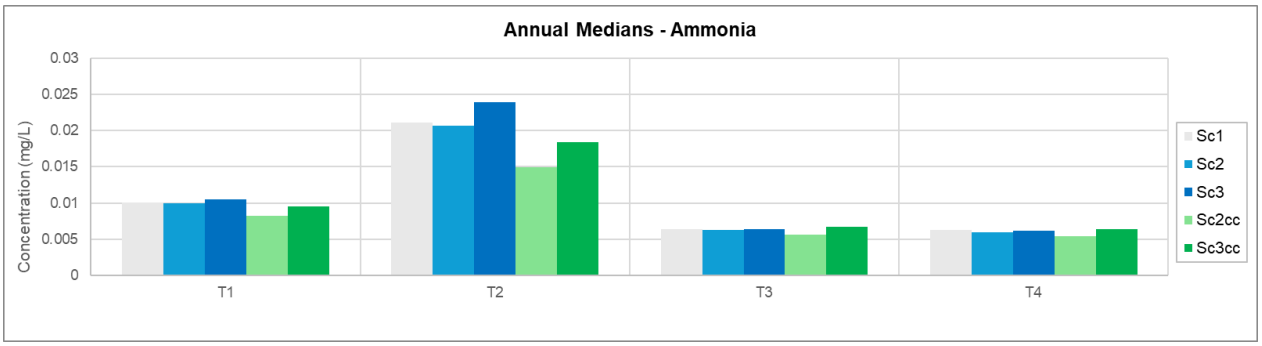


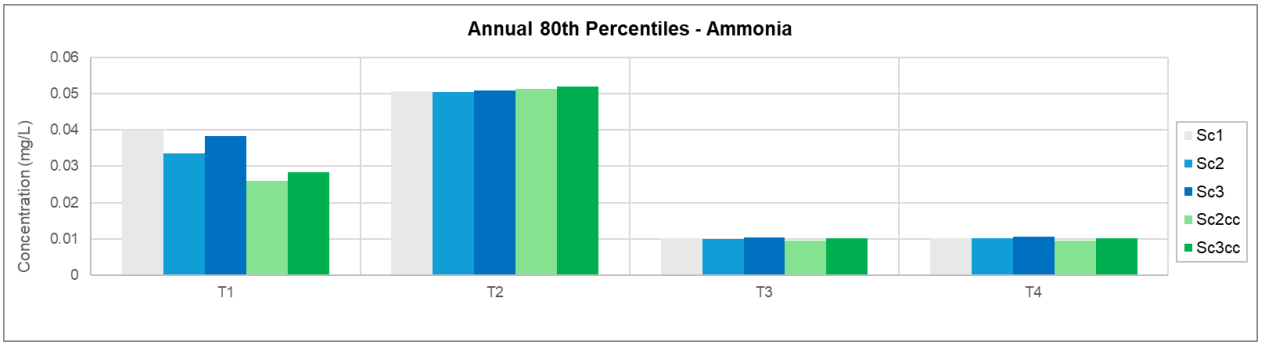




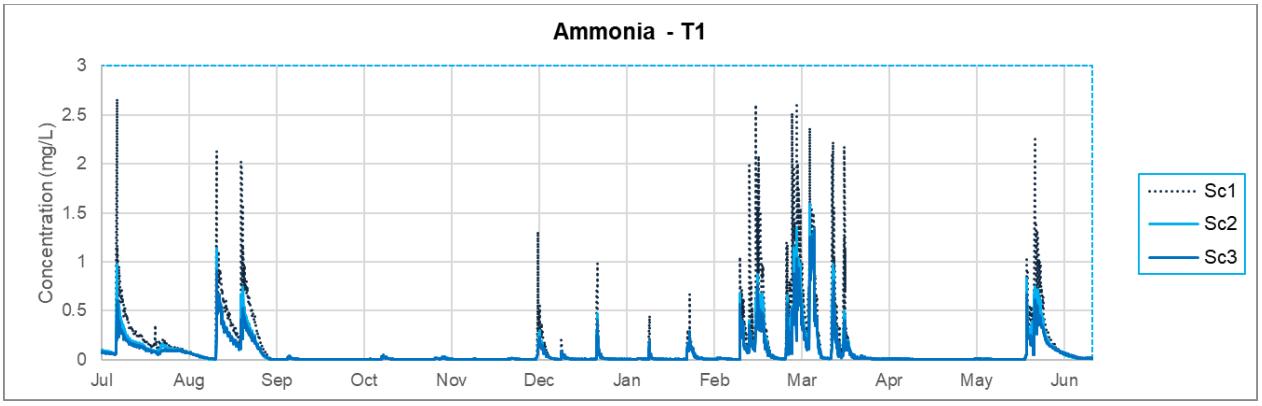
Appendices D5.4.2 Average rainfall year scenario results (2016-2017)

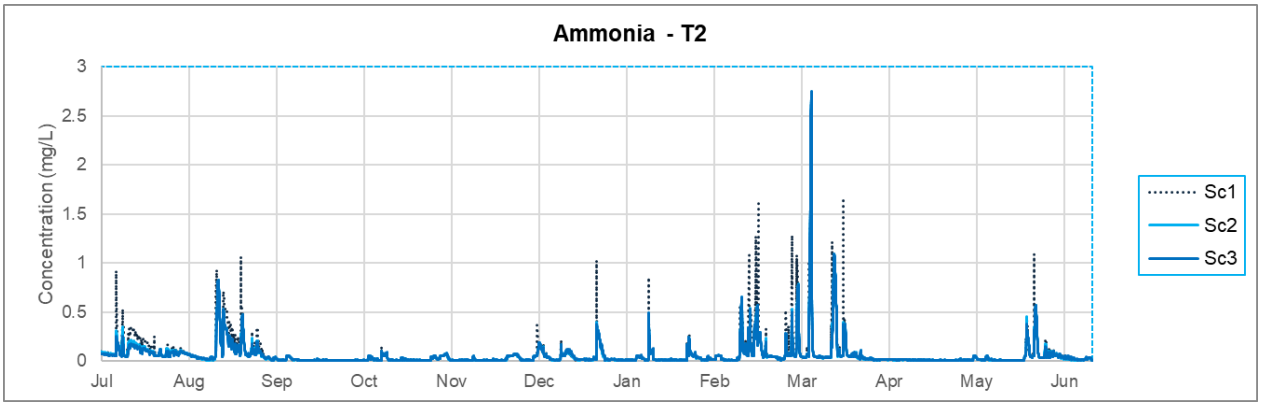
Bar charts

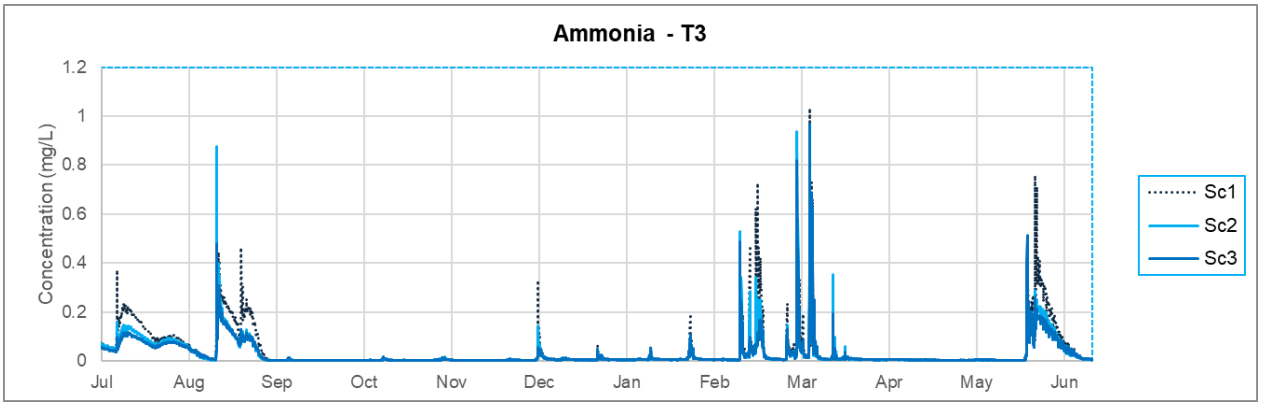


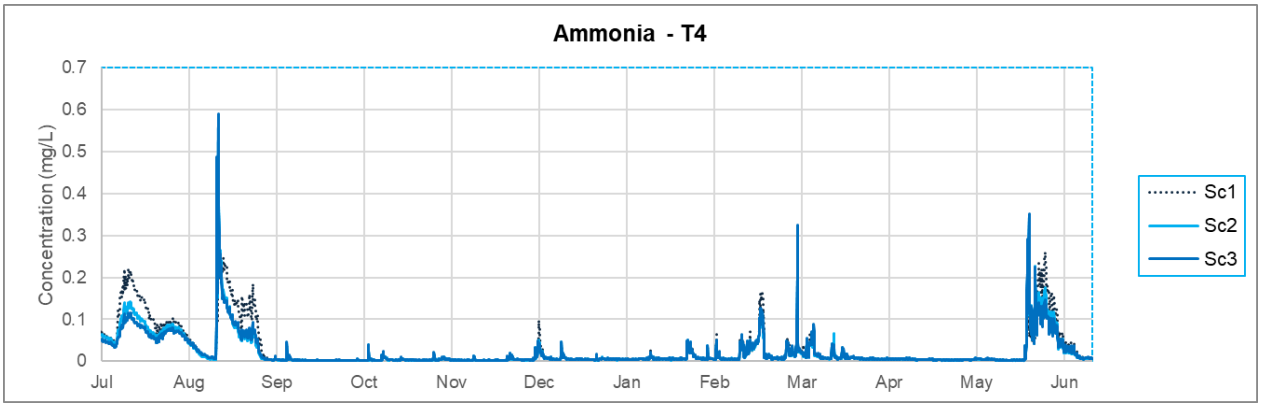


Time series plots



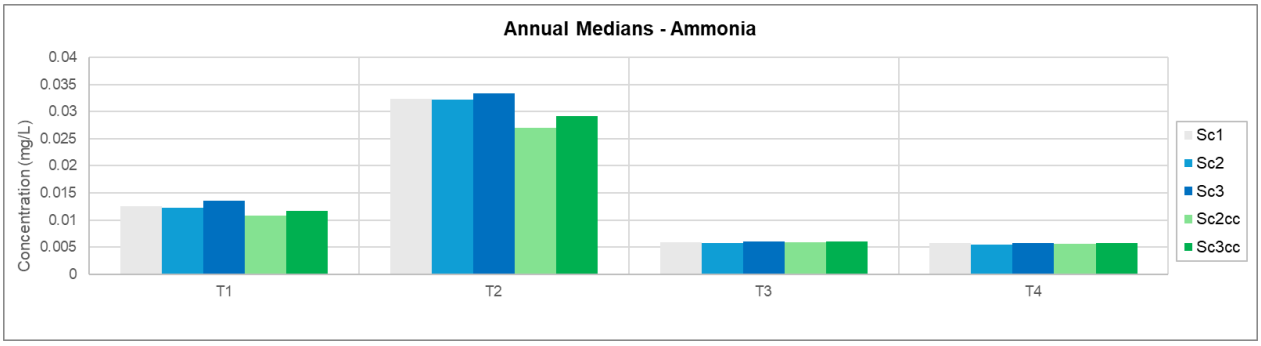


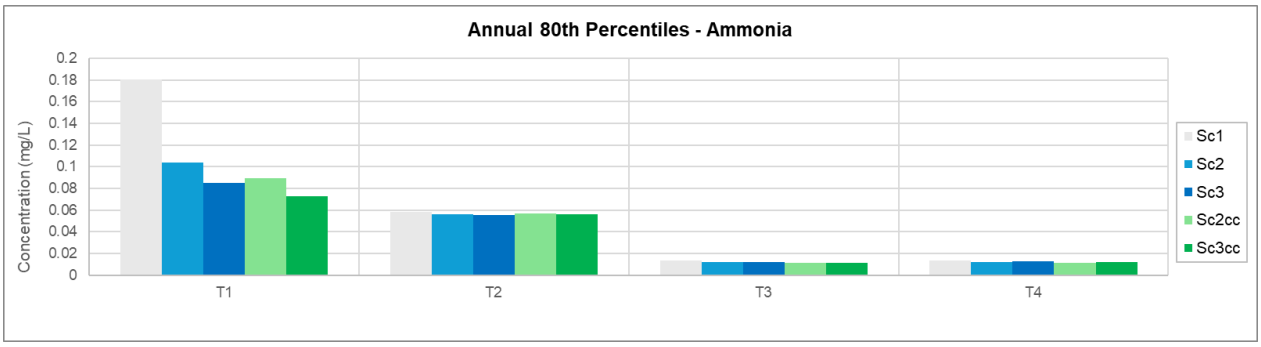




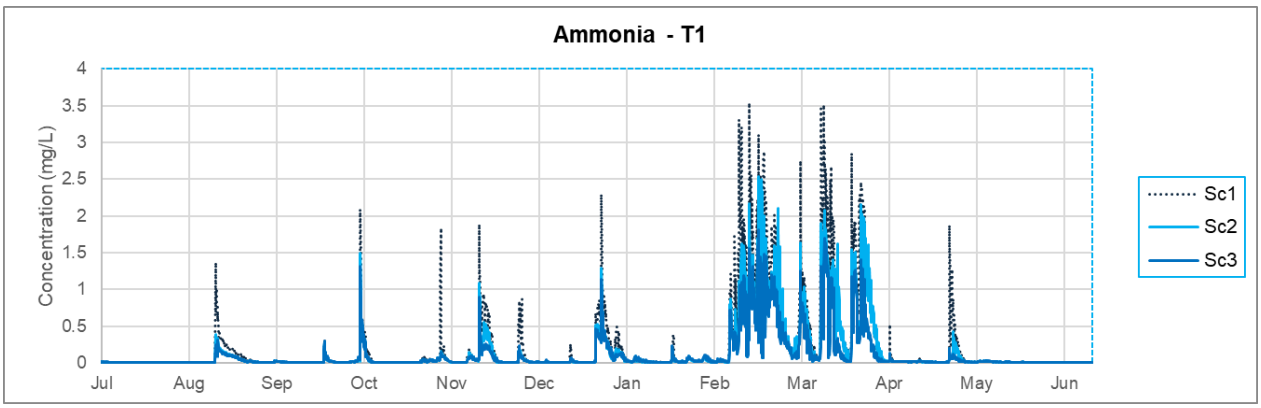
Appendices D5.4.3 Higher rainfall year scenario results (2021-2022)

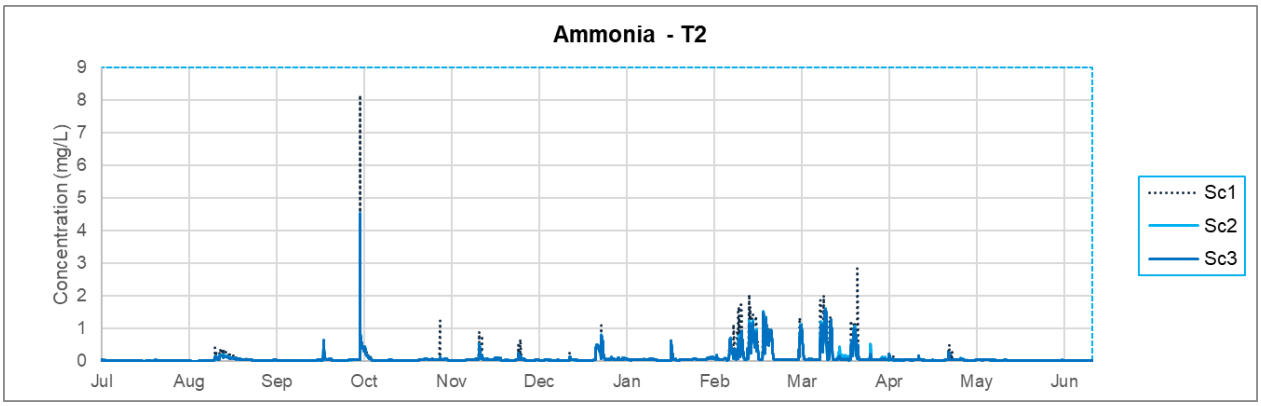
Bar charts

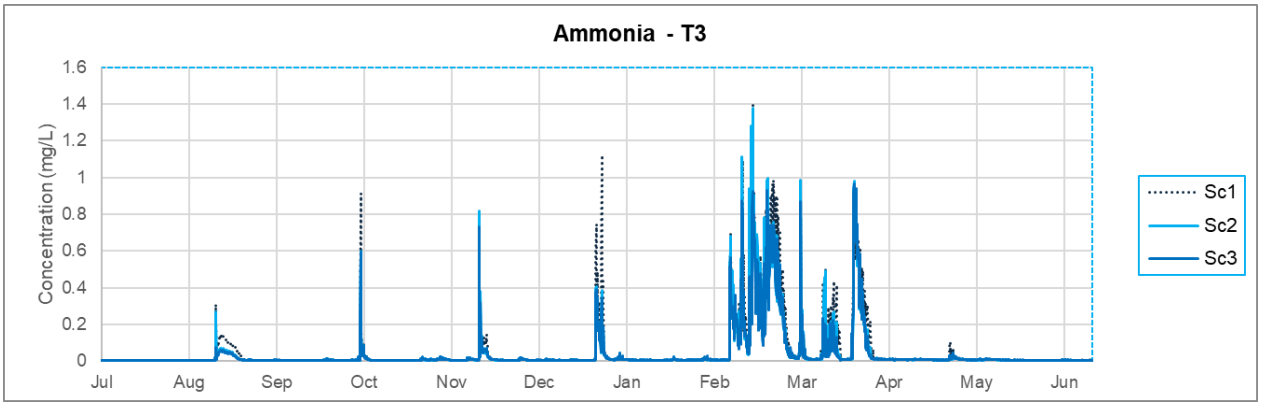


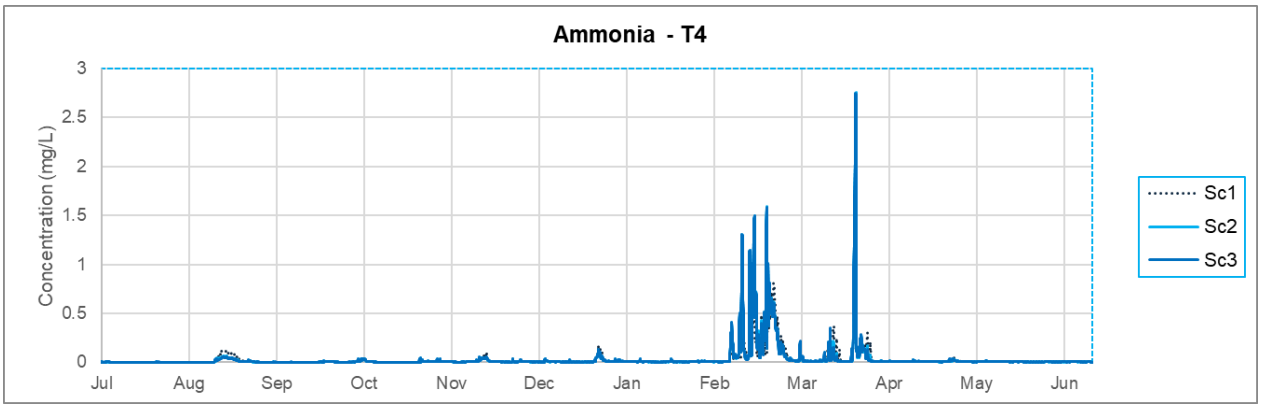


Time series plots




Ammonia - T2
Concentration (mg/L)
0
1
2
3
4
5
6
7
8
9
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

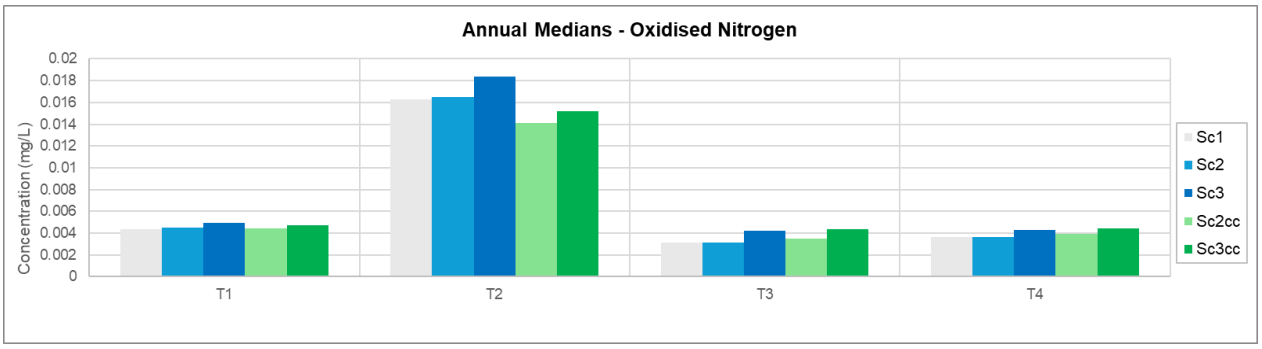

Ammonia - T3
Concentration (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

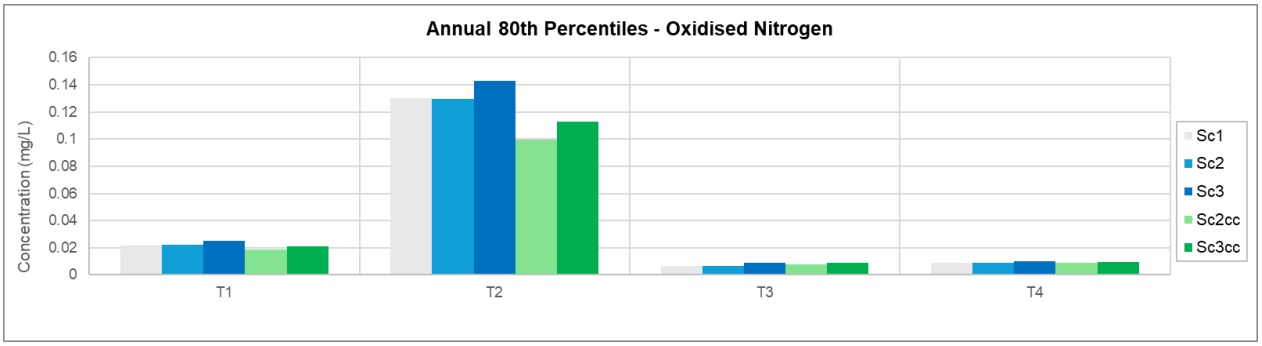

Ammonia - T4
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
3
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.5 Oxidised N

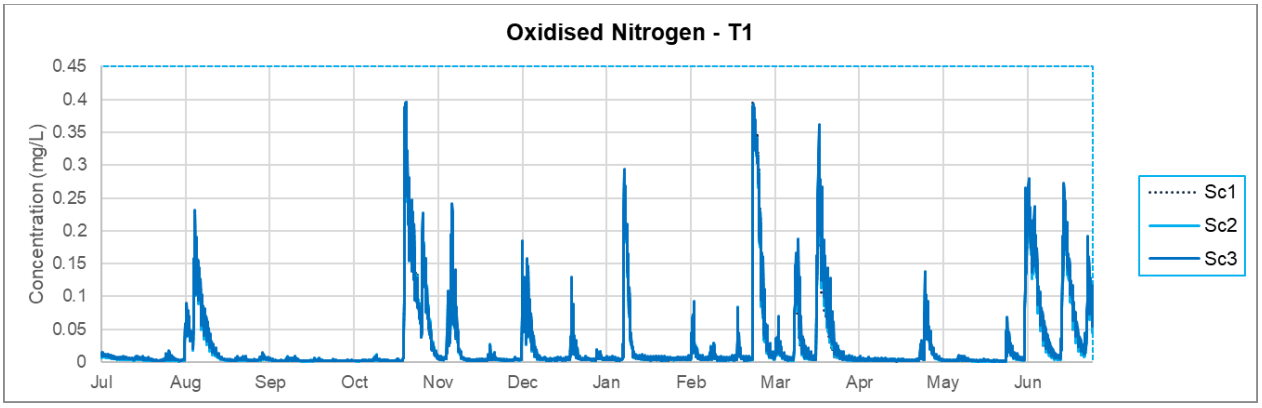
Appendices D5.5.1 Lower rainfall year scenario results (2017-2018)

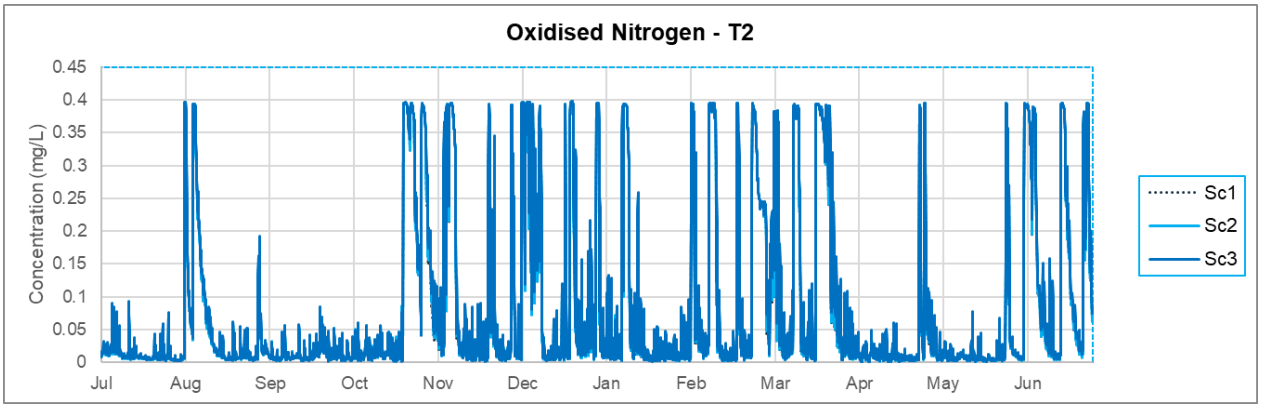
Bar charts

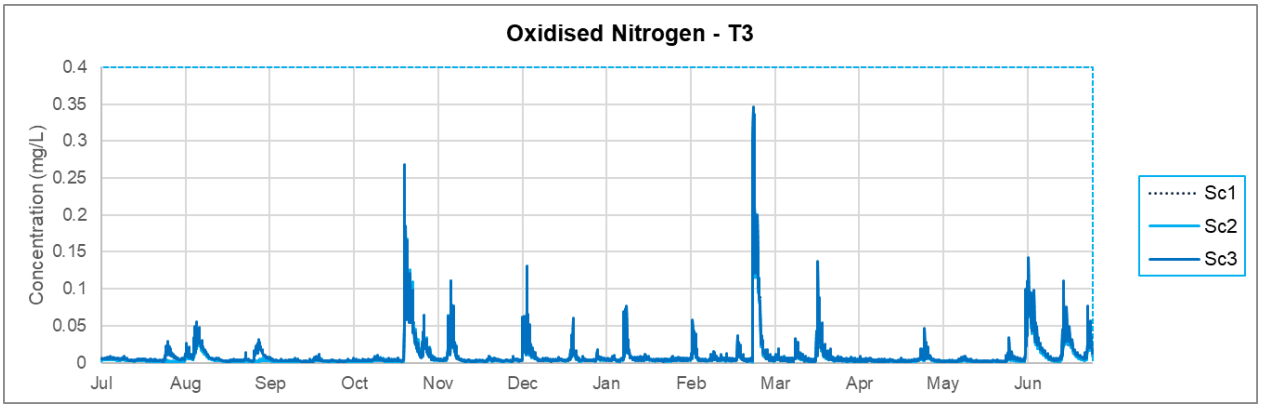


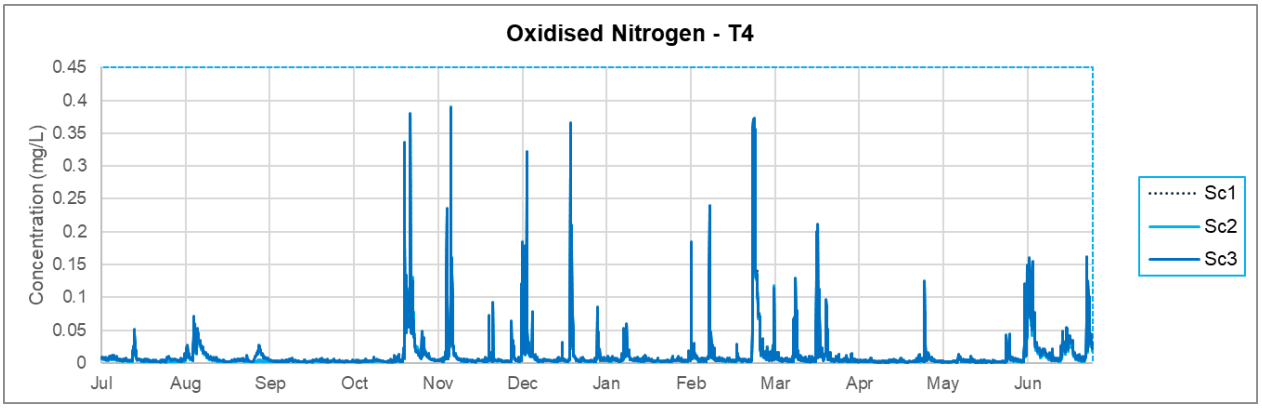


Time series plots



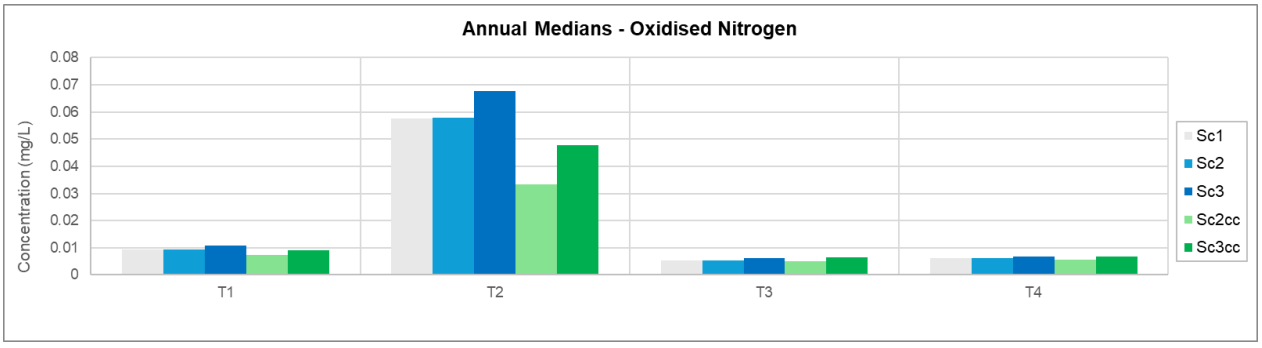


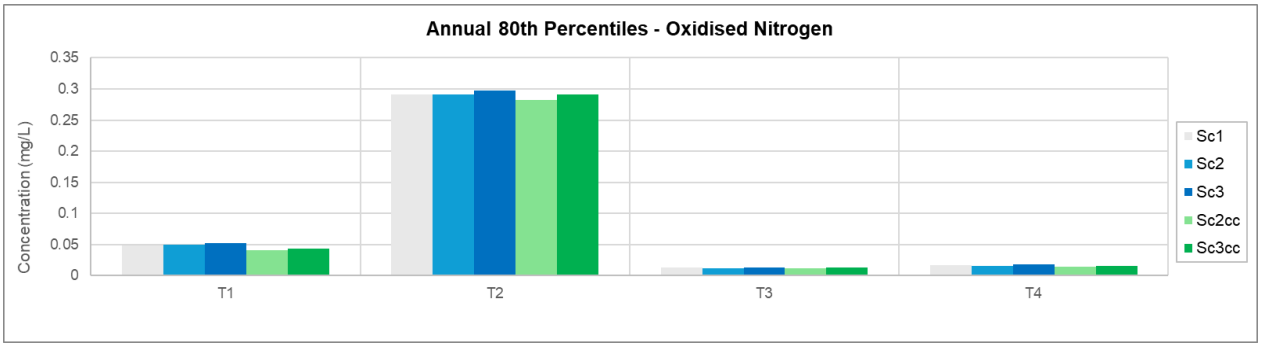




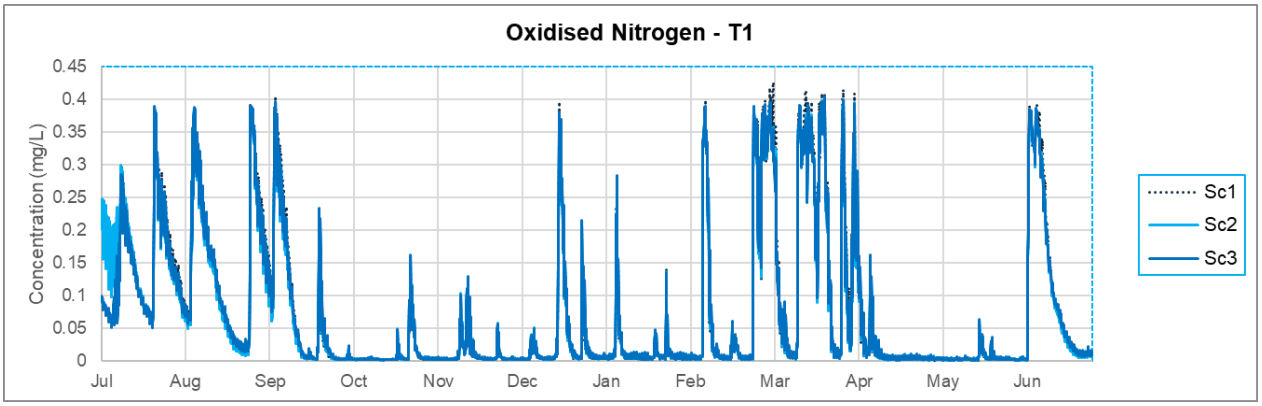
Appendices D5.5.2 Average rainfall year scenario results (2016-2017)

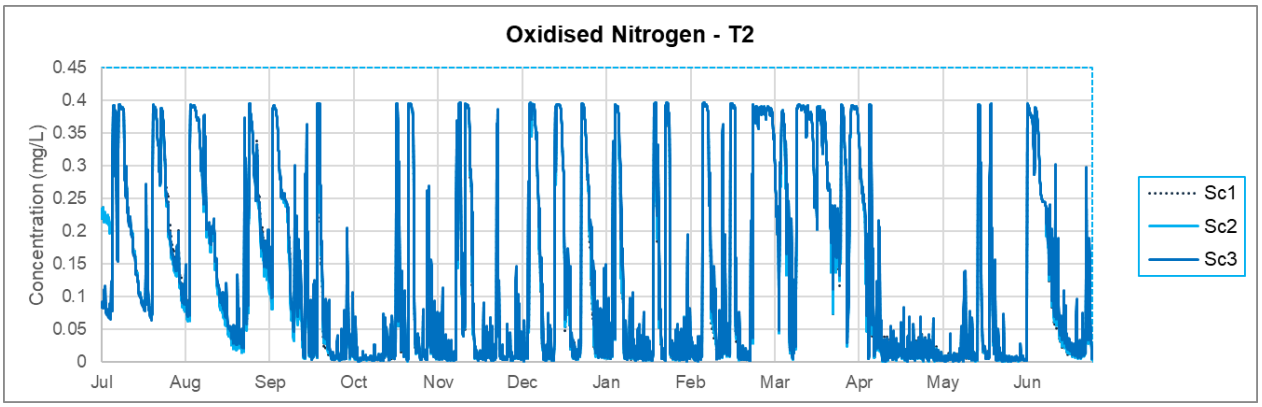
Bar charts

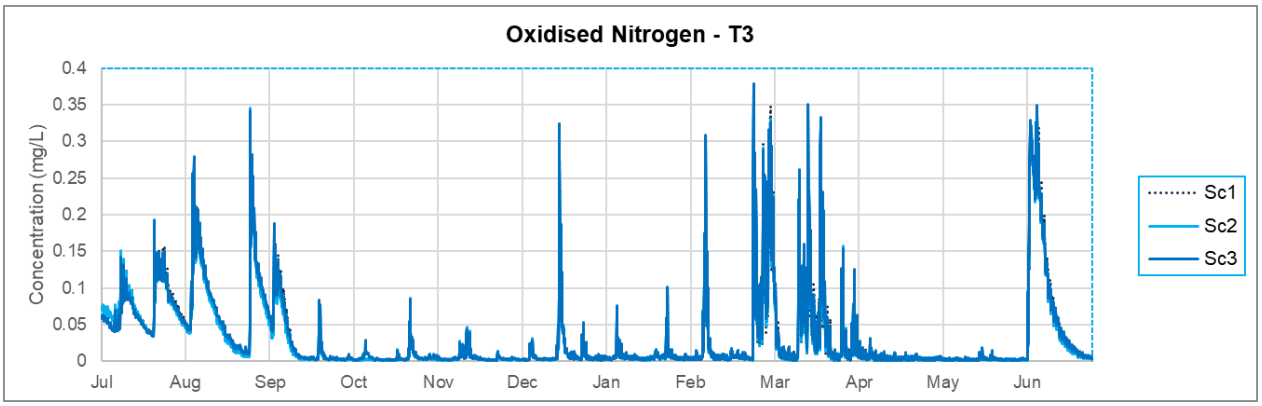


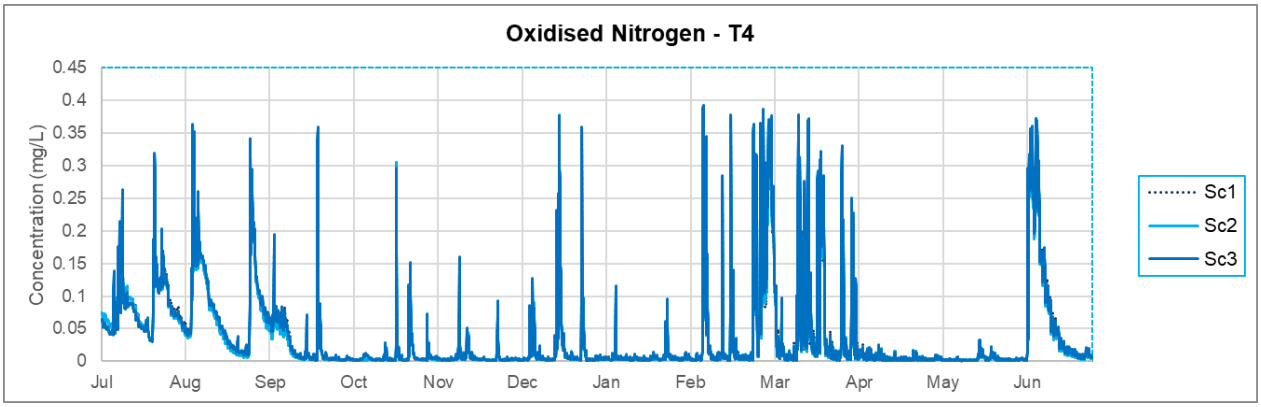


Time series plots



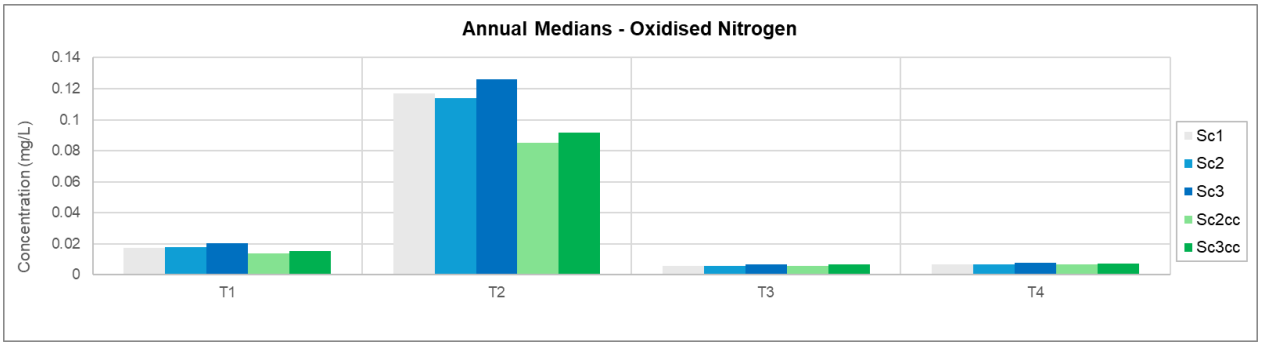


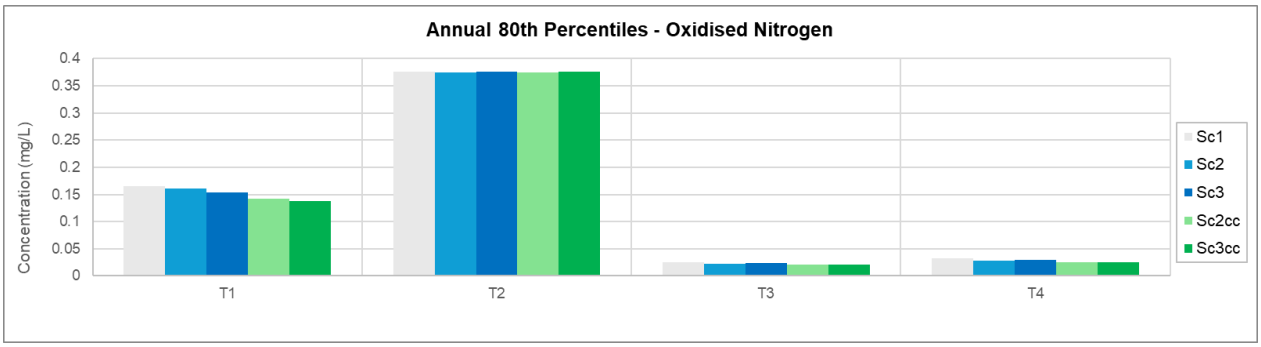




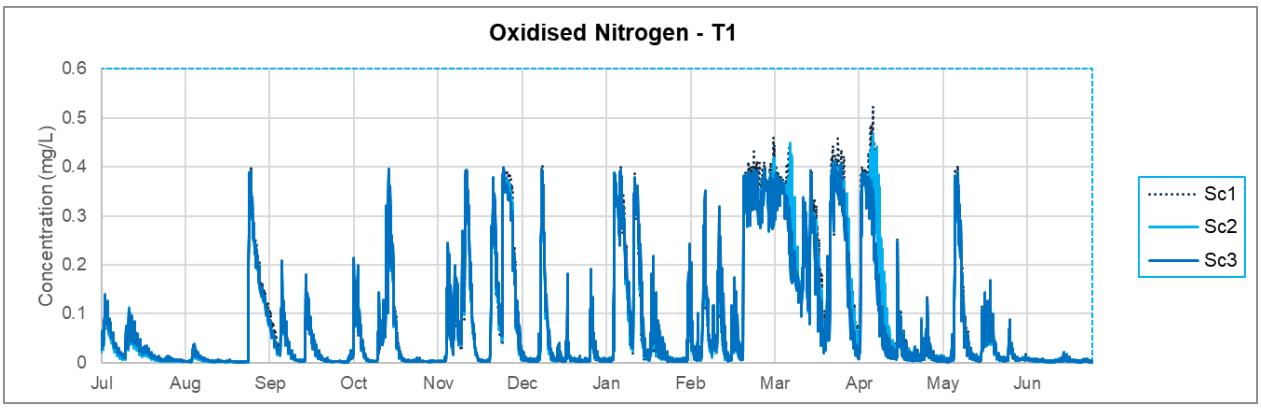
Appendices D5.5.3 Higher rainfall year scenario results (2021-2022)

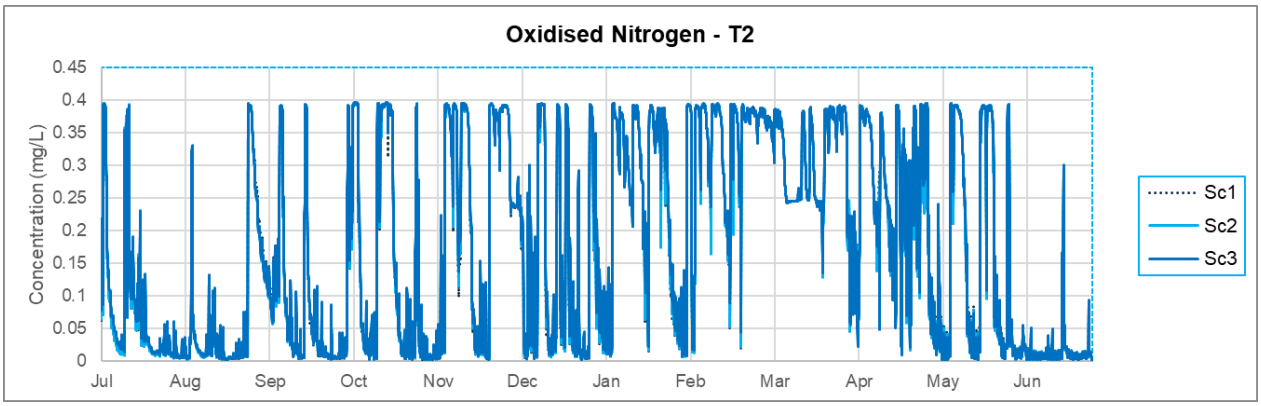
Bar charts

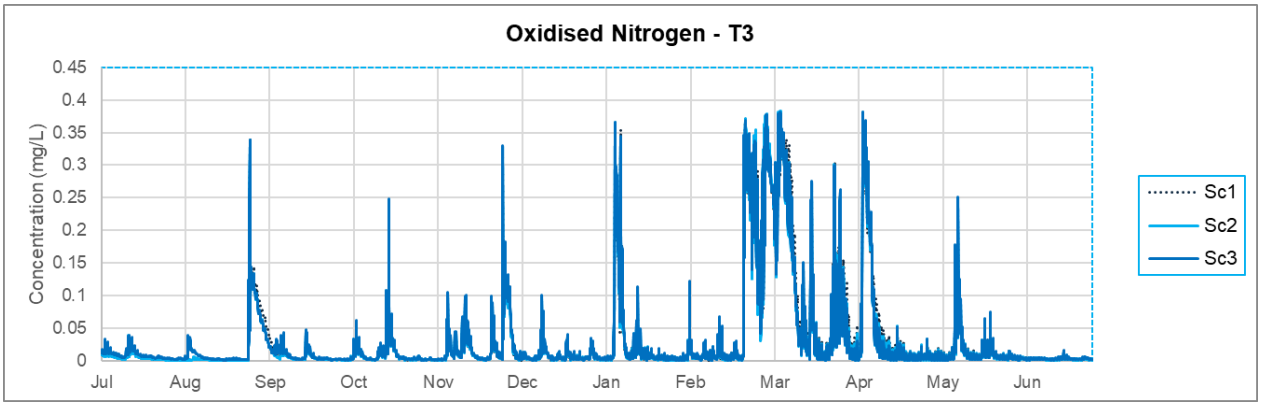


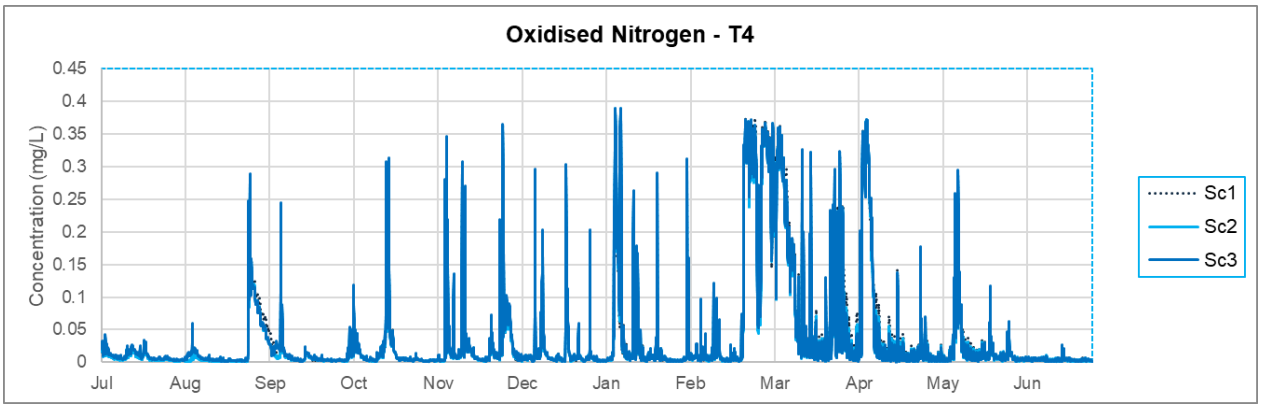


Time series plots




Oxidised Nitrogen - T2
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

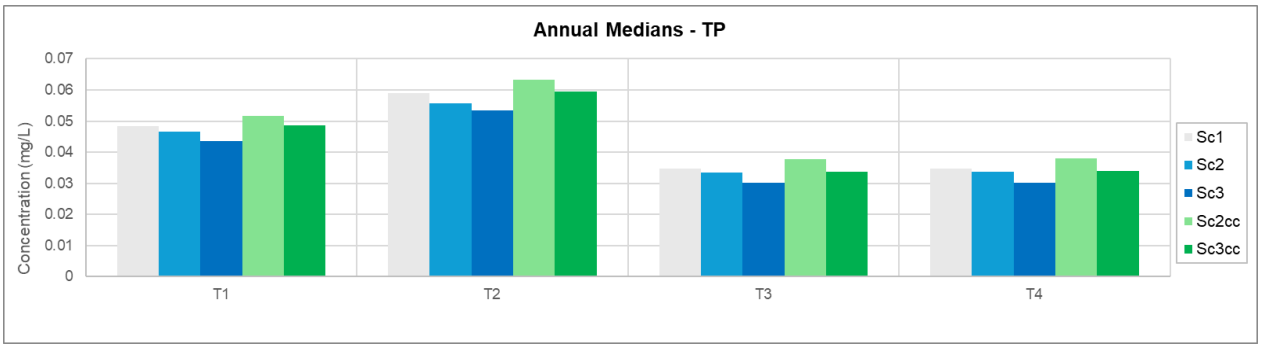

Oxidised Nitrogen - T3
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

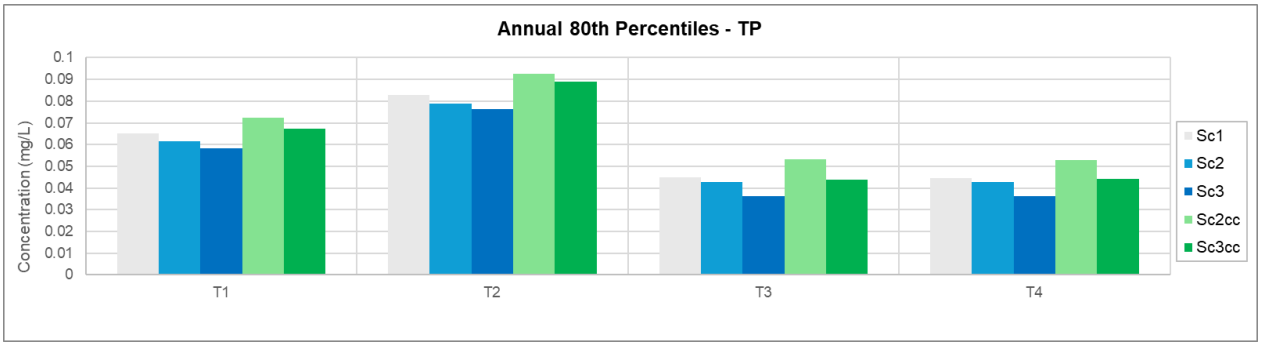

Oxidised Nitrogen - T4
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.6 Total P

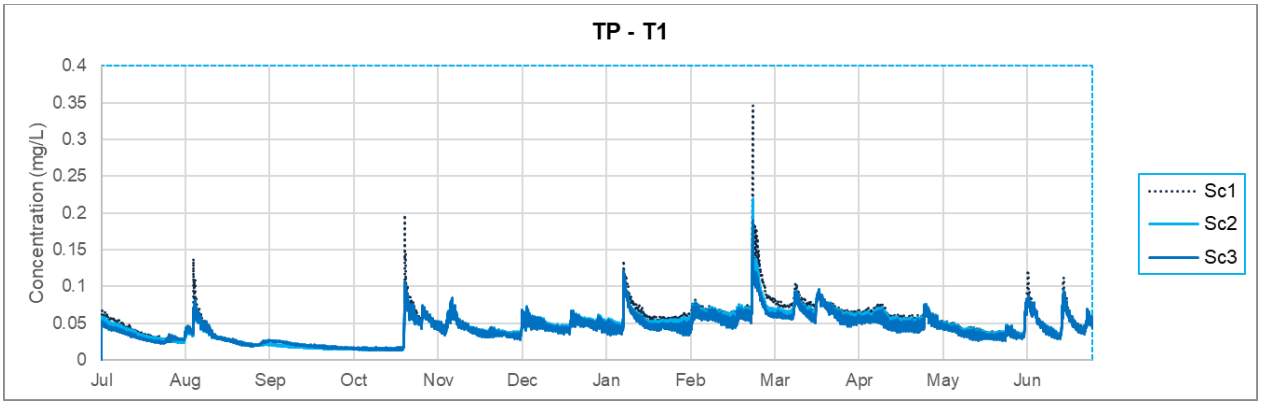
Appendices D5.6.1 Lower rainfall year scenario results (2017-2018)

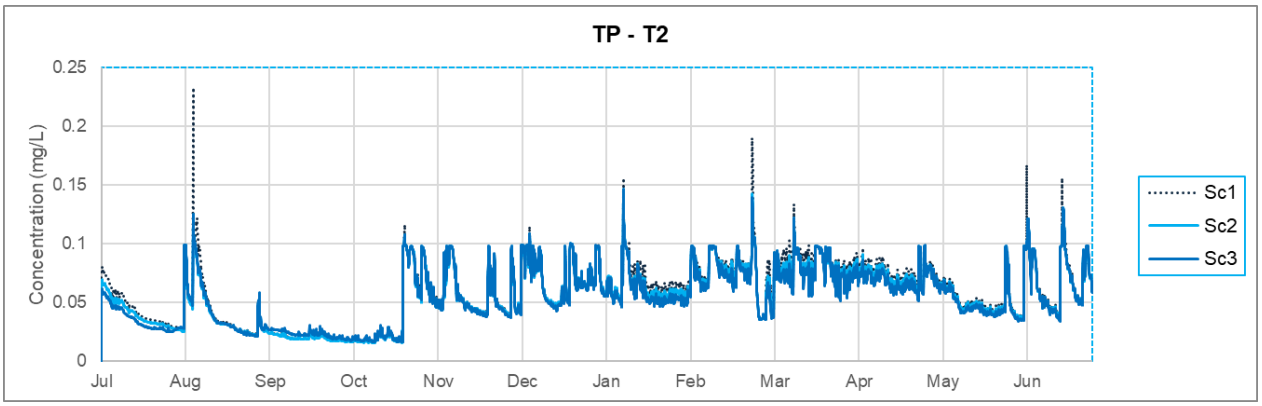
Bar charts

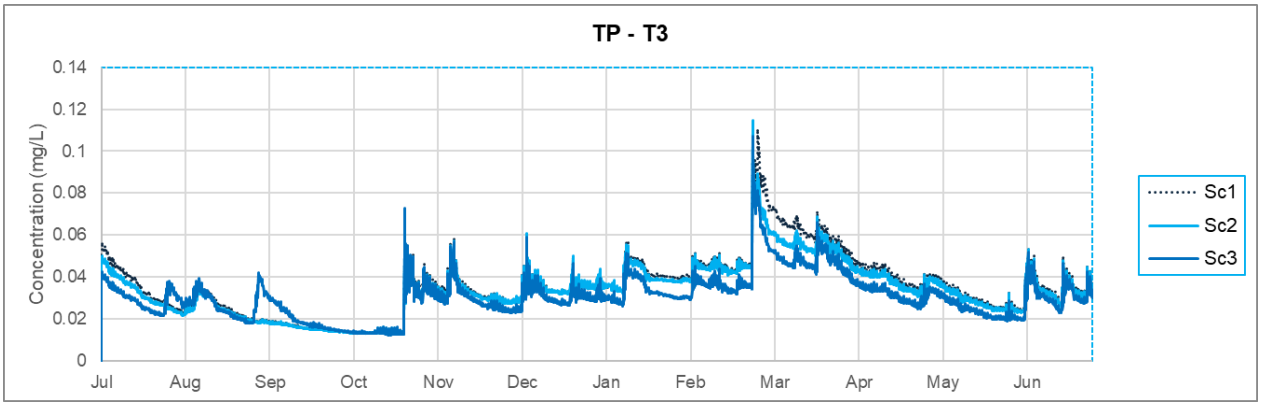


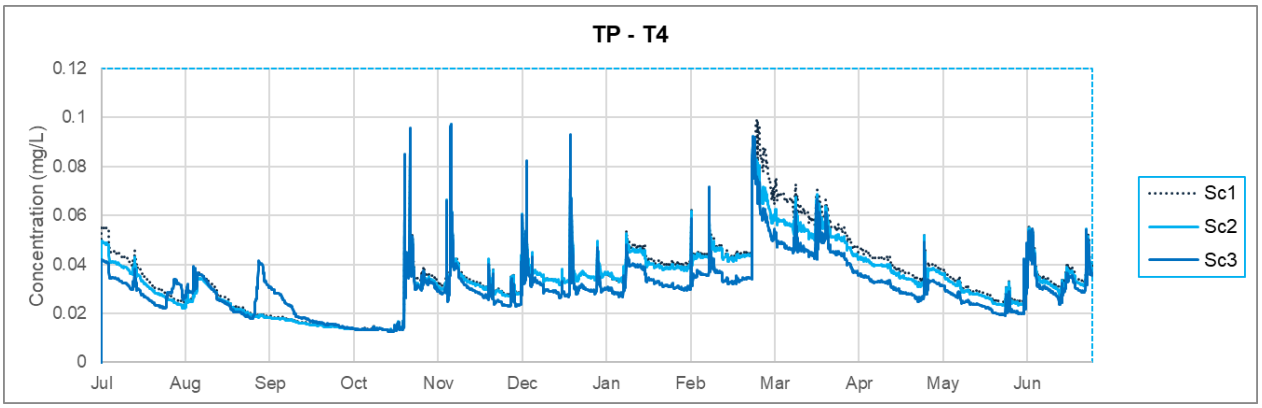


Time series plots



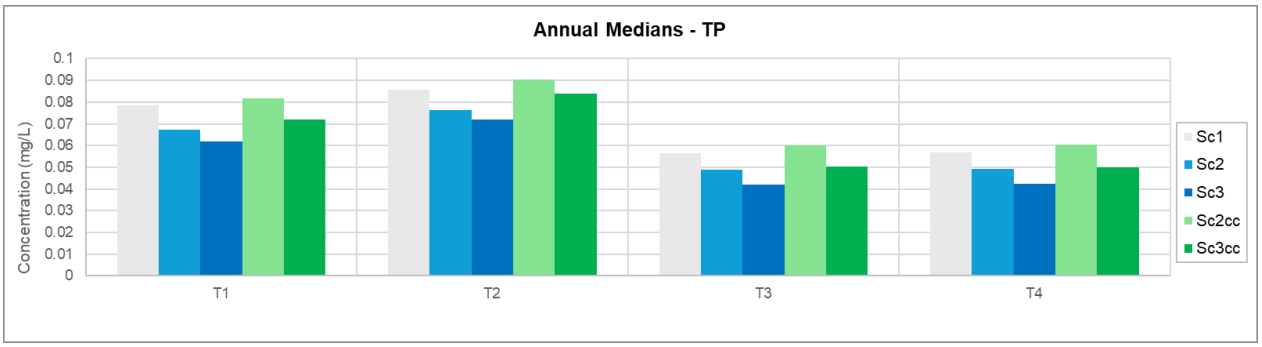


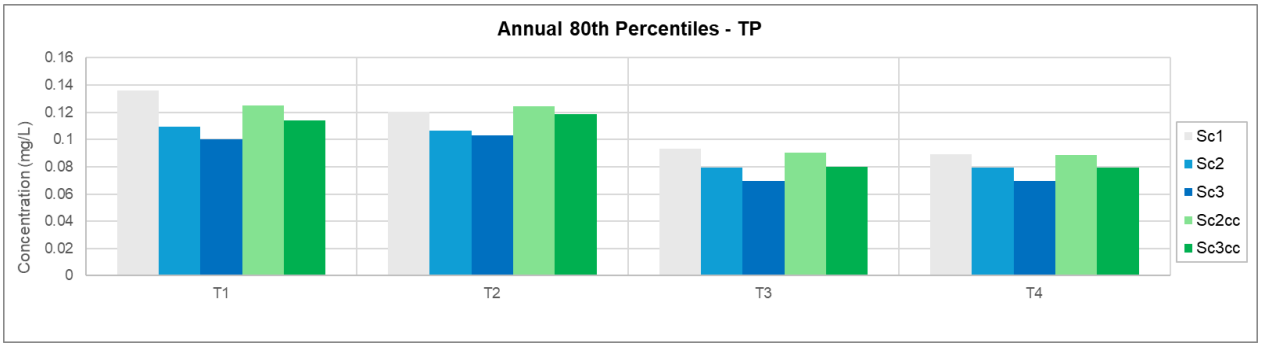




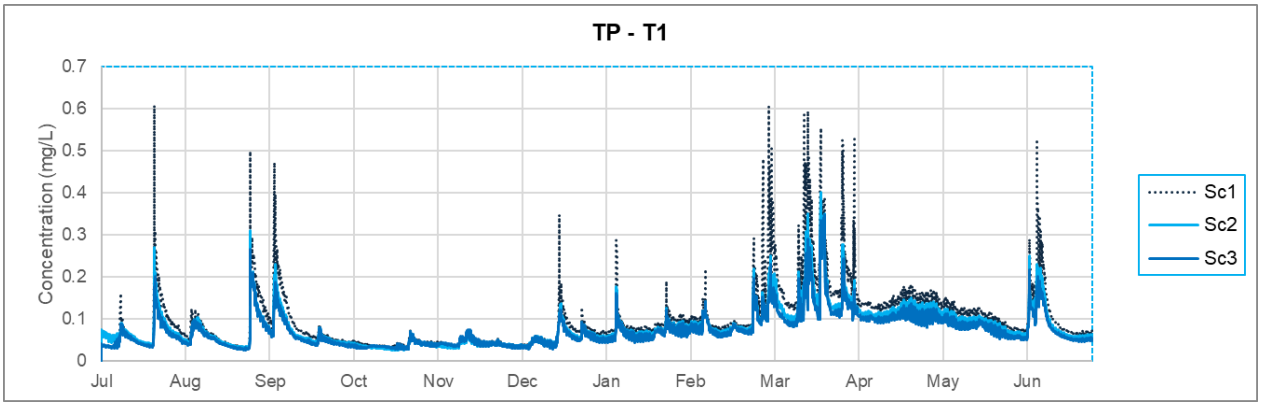
Appendices D5.6.2 Average rainfall year scenario results (2016-2017)

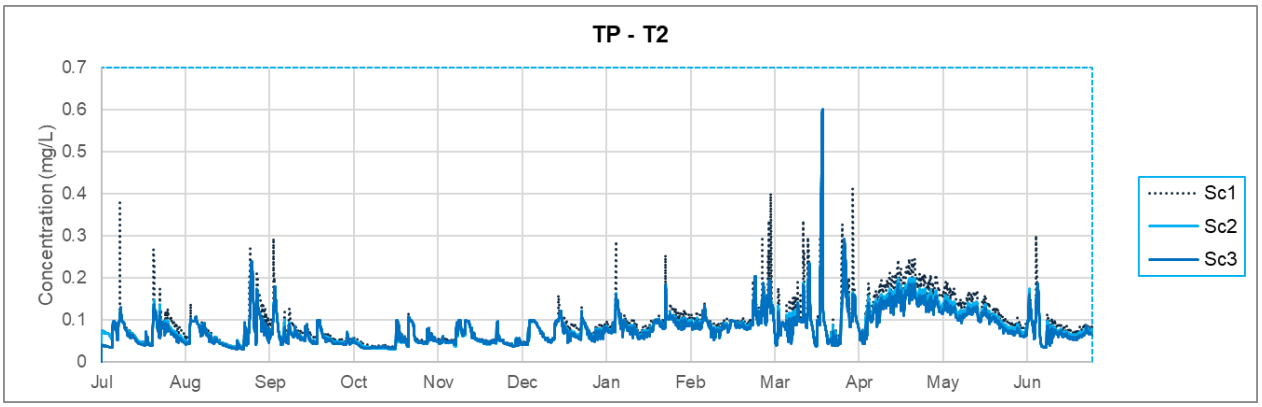
Bar charts

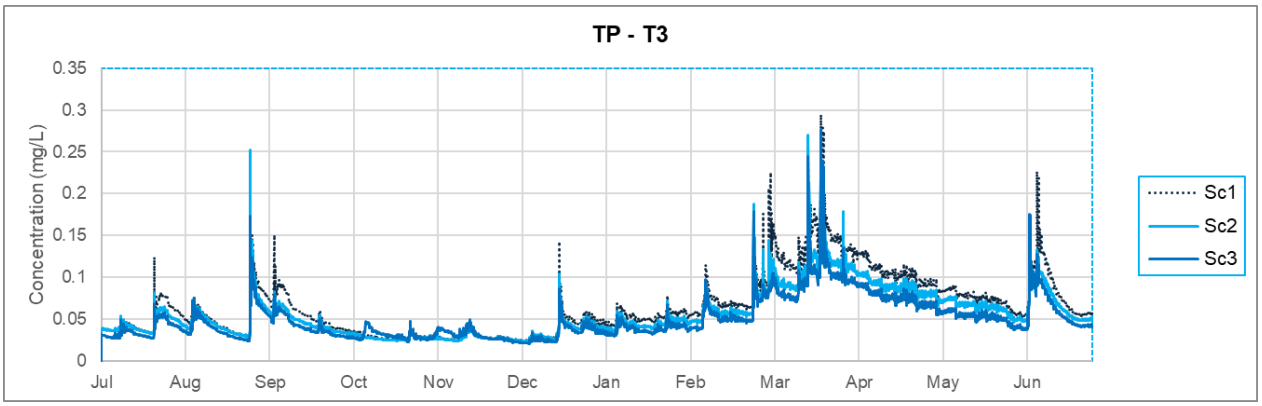


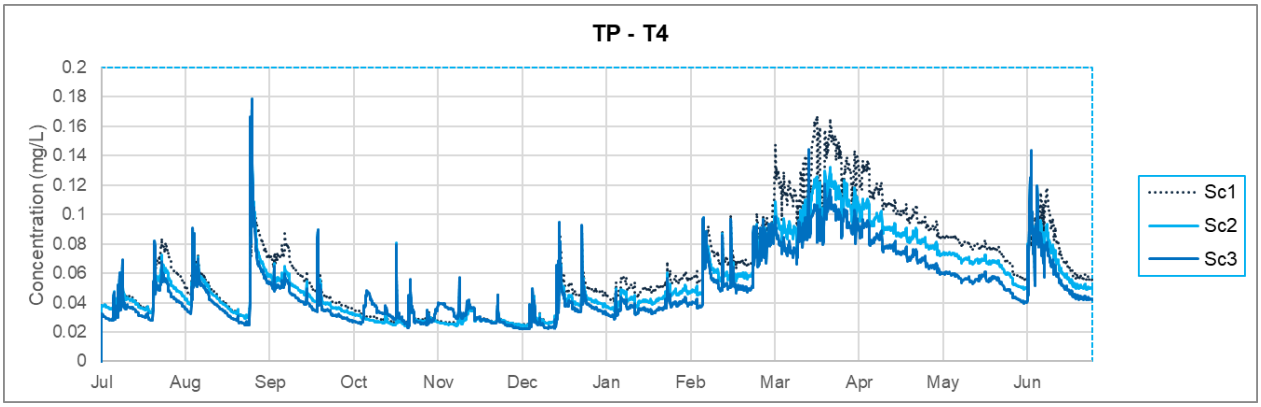


Time series plots



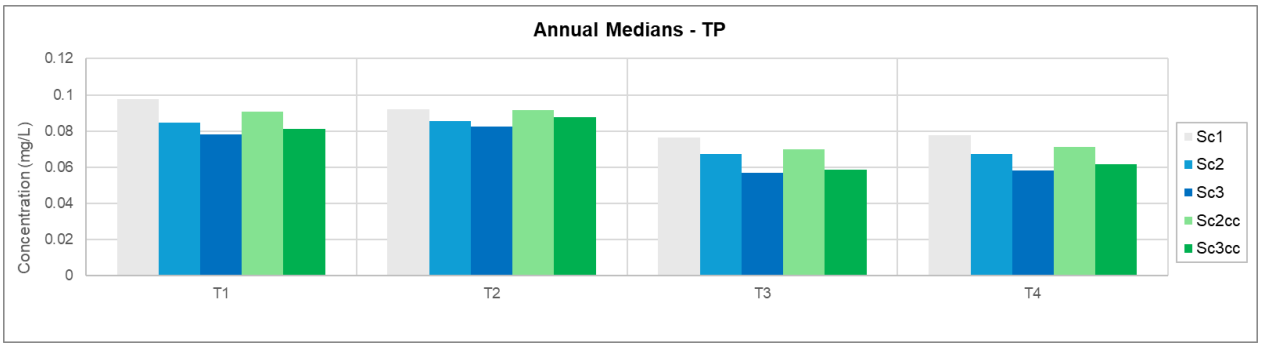


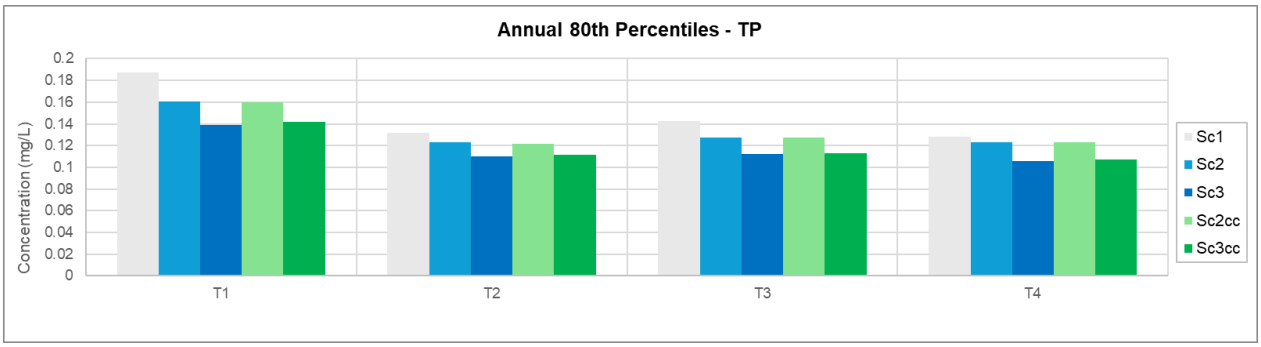




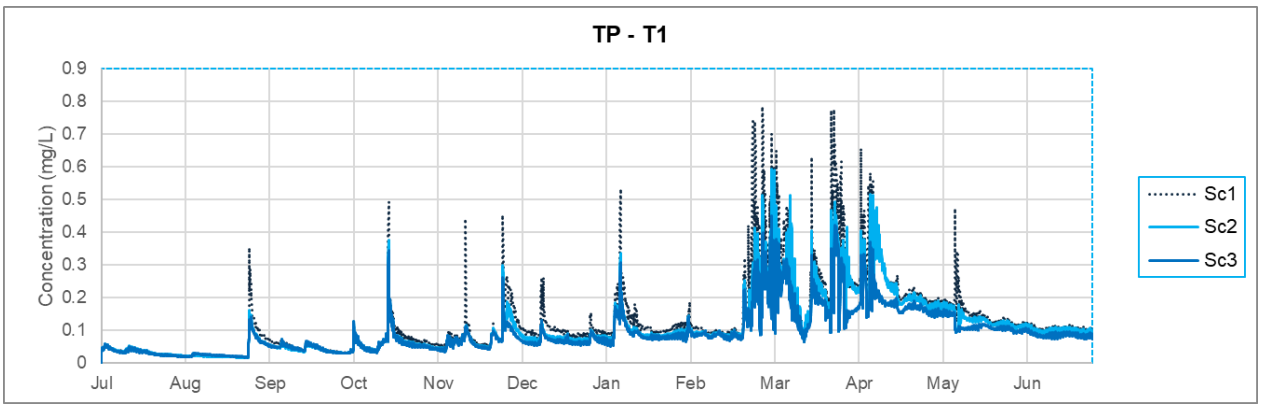
Appendices D5.6.3 Higher rainfall year scenario results (2021-2022)

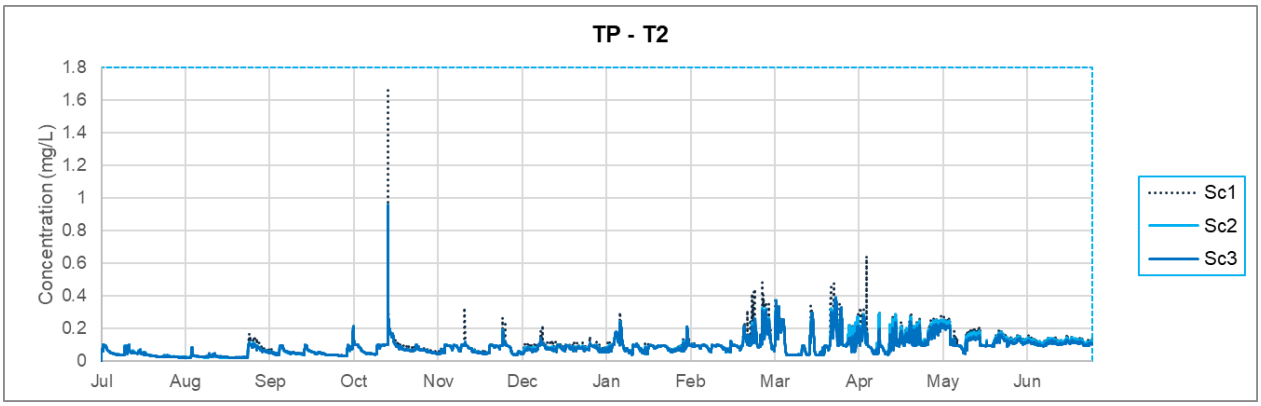
Bar charts

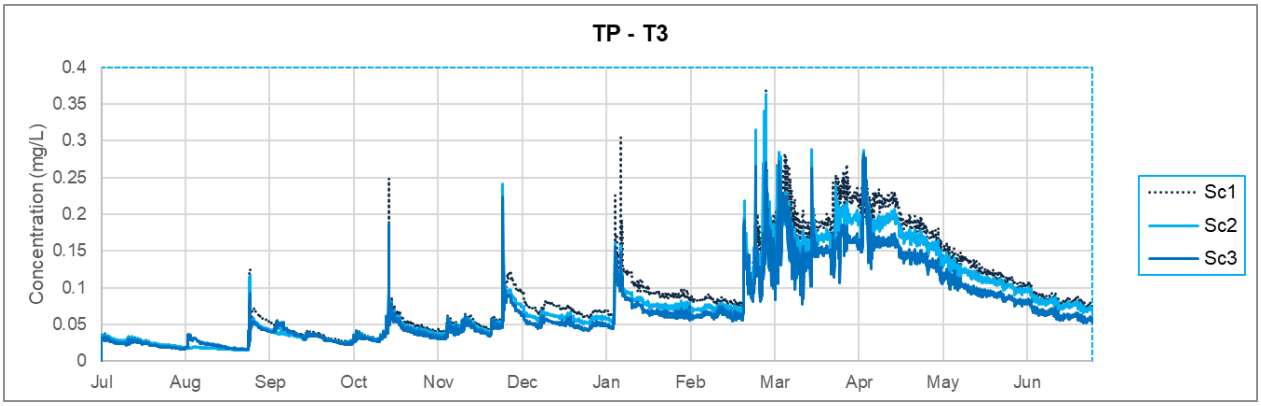


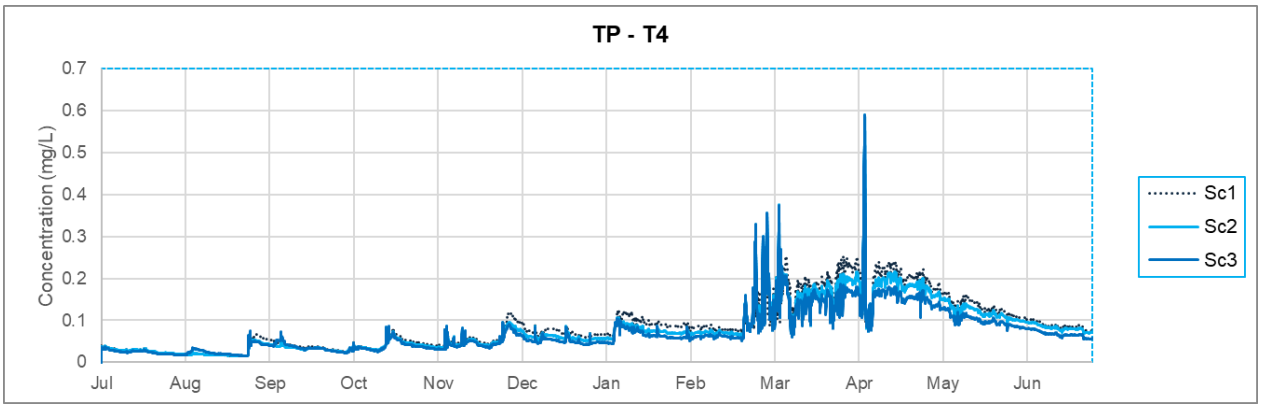


Time series plots




TP - T2
Concentration (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

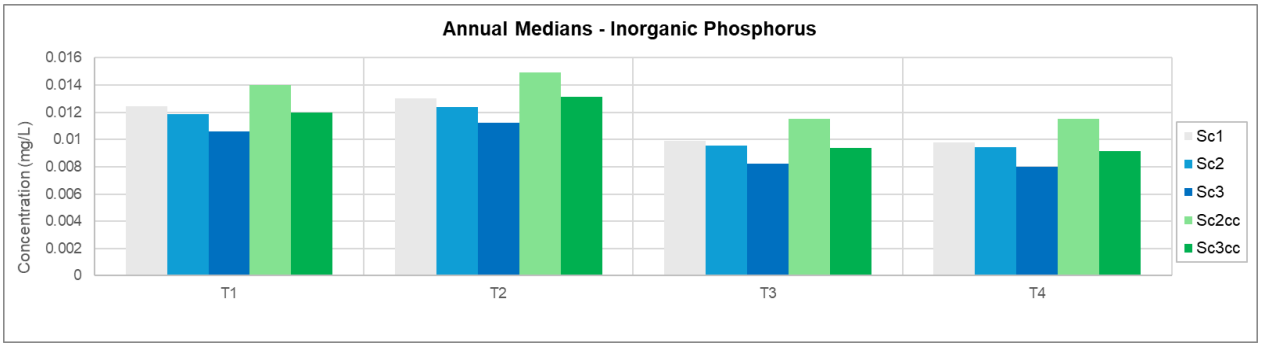

TP - T3
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

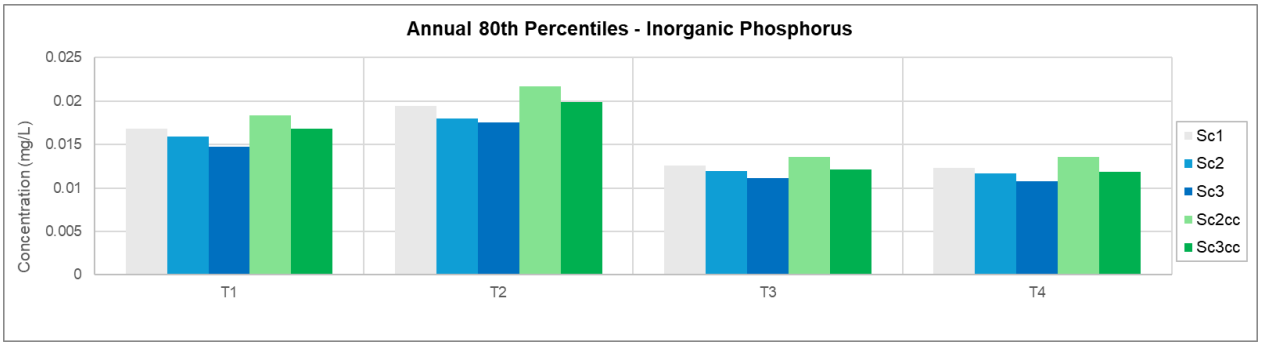

TP - T4
Concentration (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.7 Inorganic P

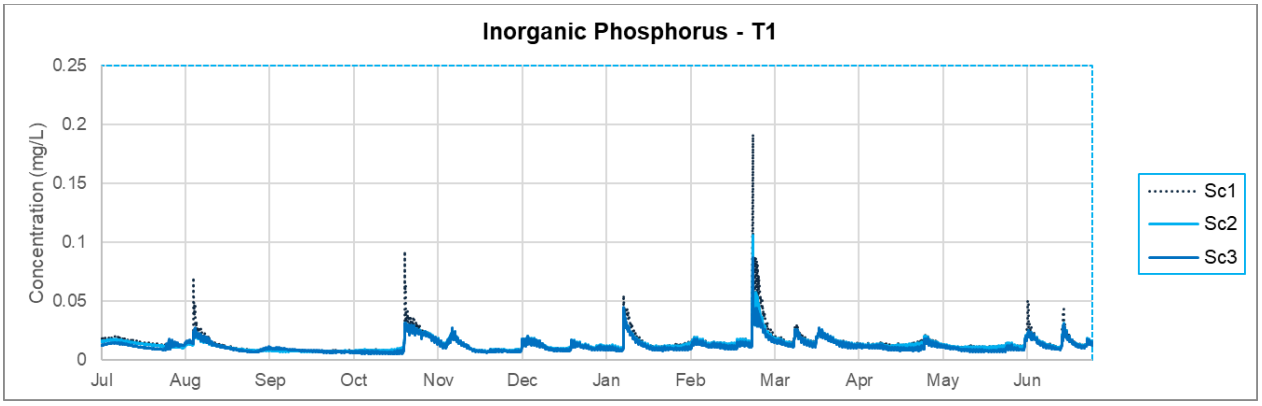
Appendices D5.7.1 Lower rainfall year scenario results (2017-2018)

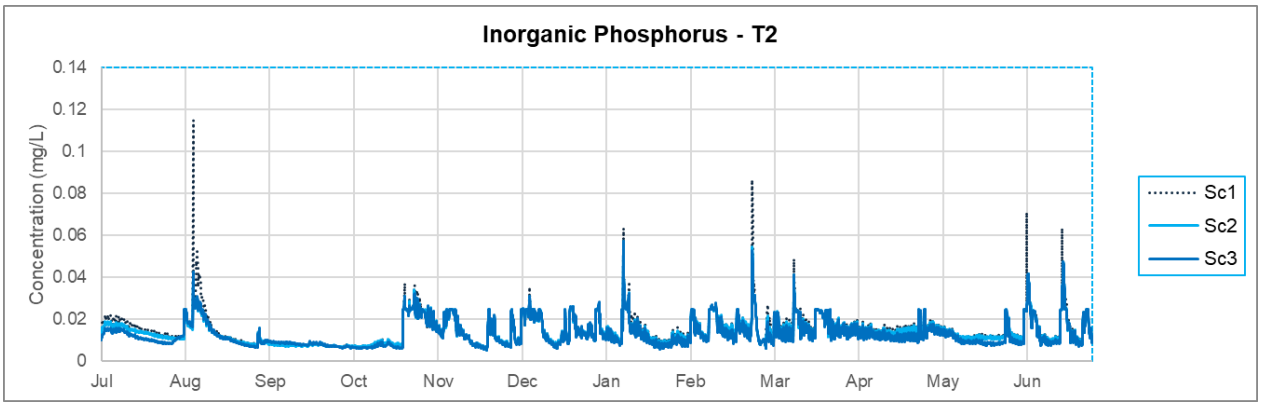
Bar charts

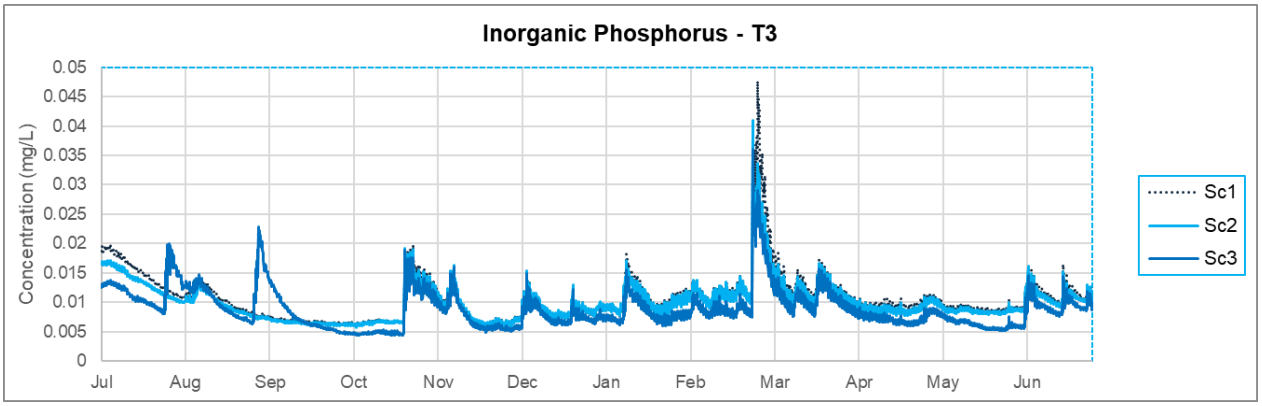


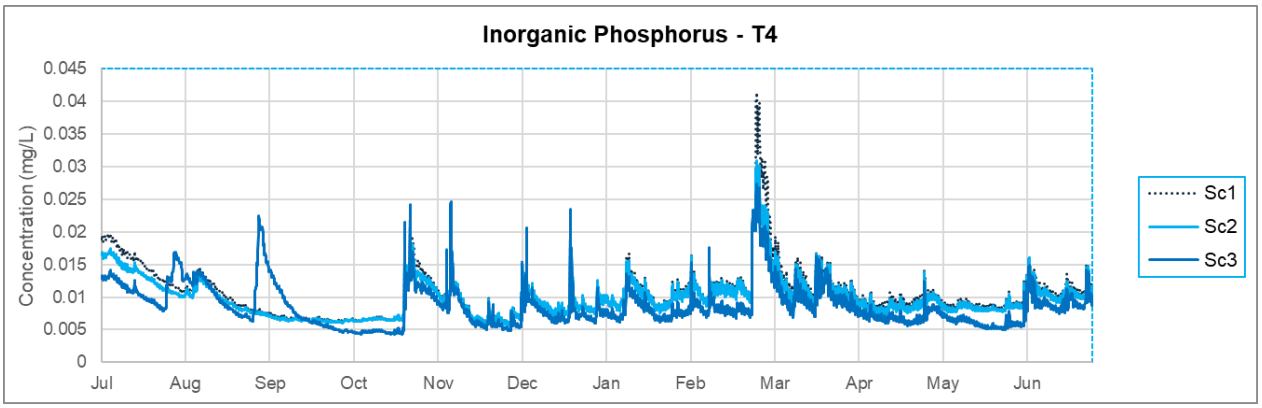


Time series plots



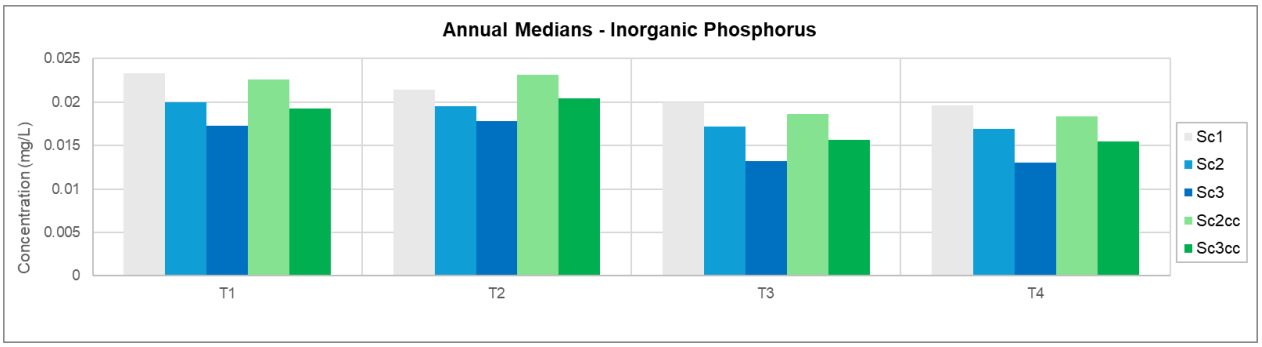


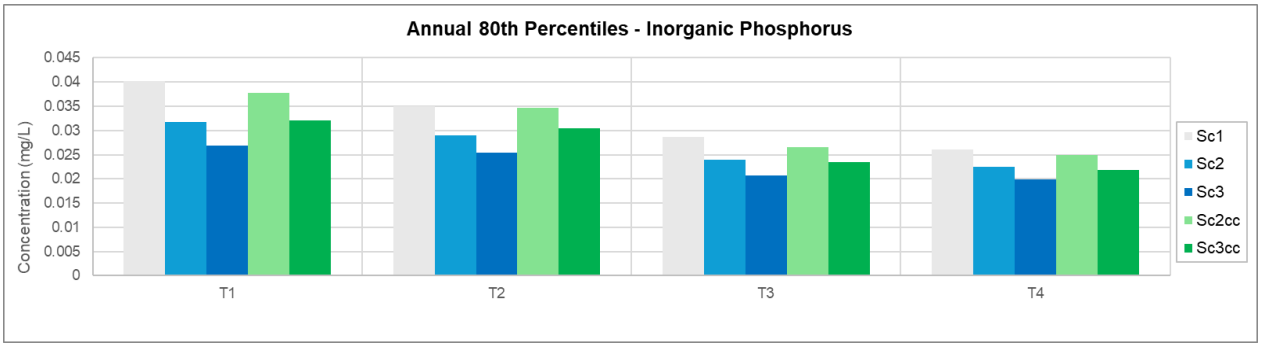




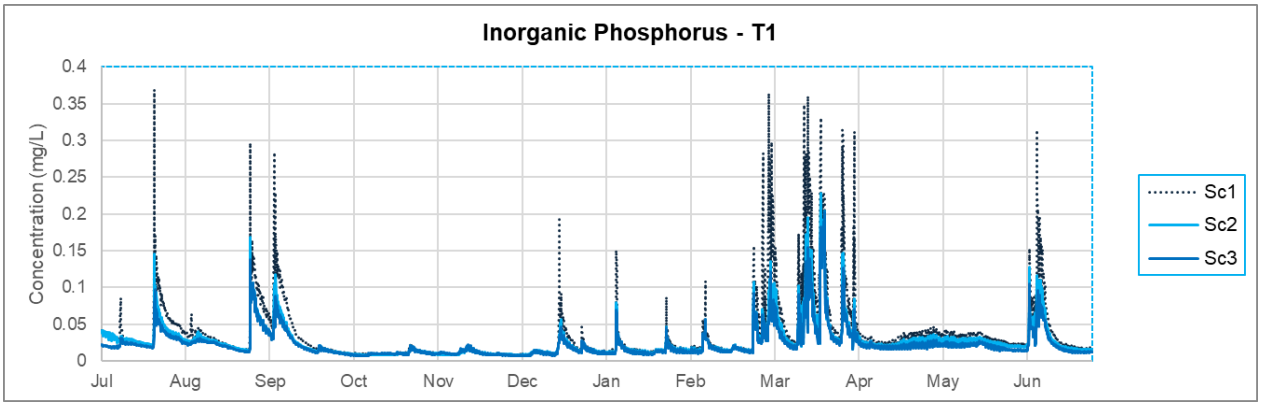
Appendices D5.7.2 Average rainfall year scenario results (2016-2017)

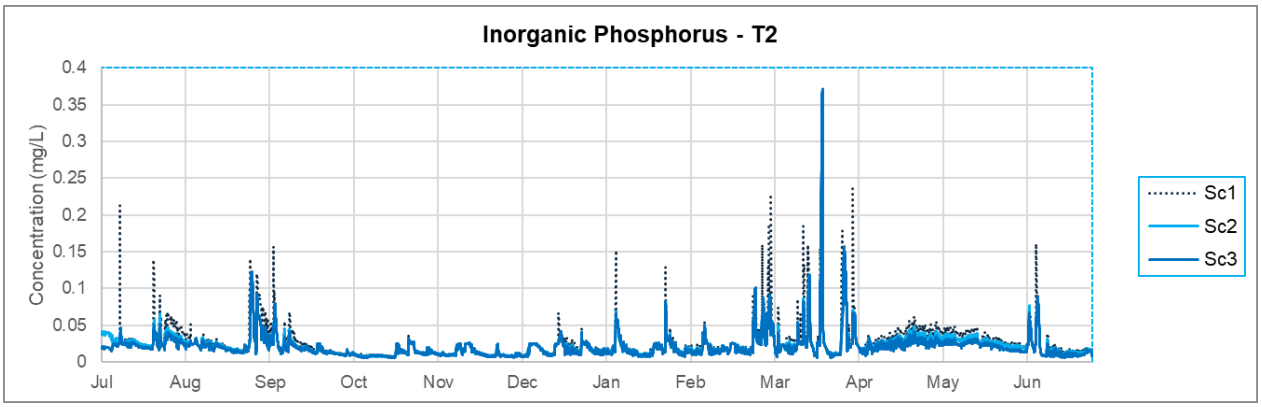
Bar charts

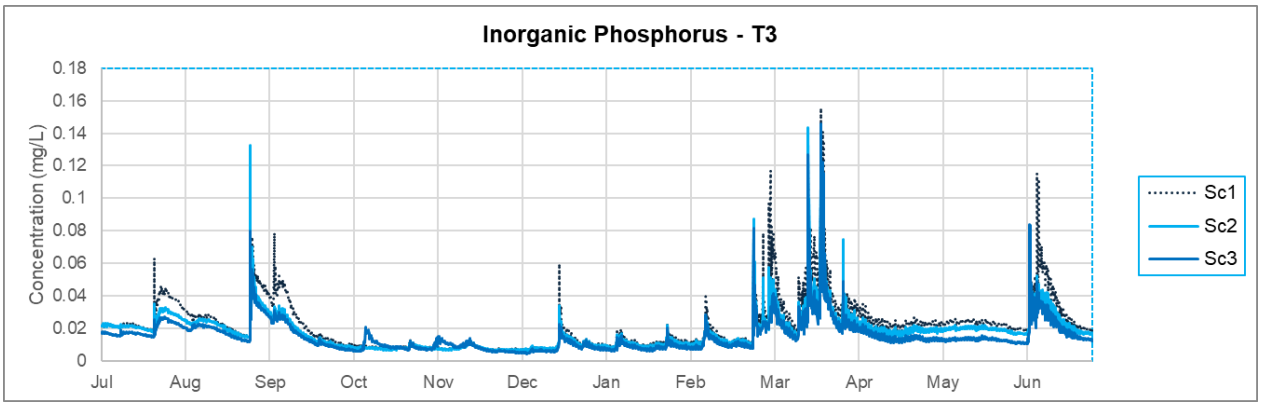


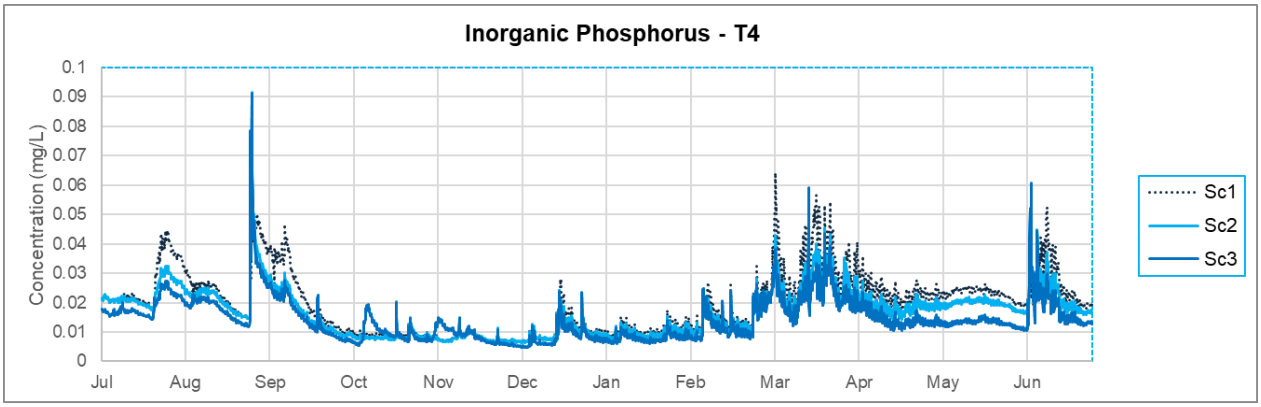


Time series plots



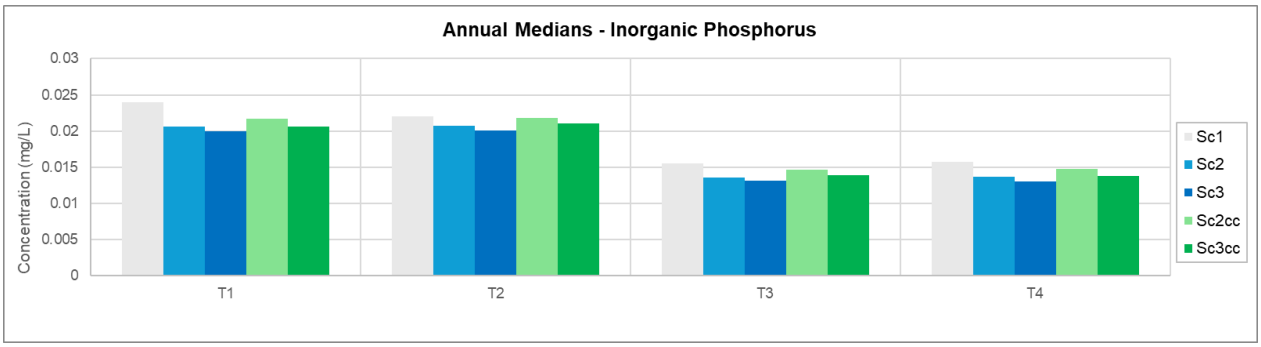


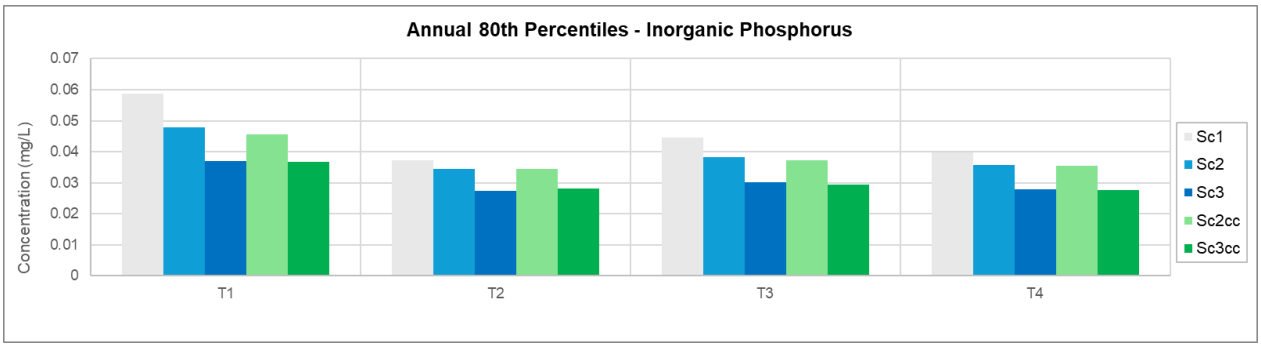




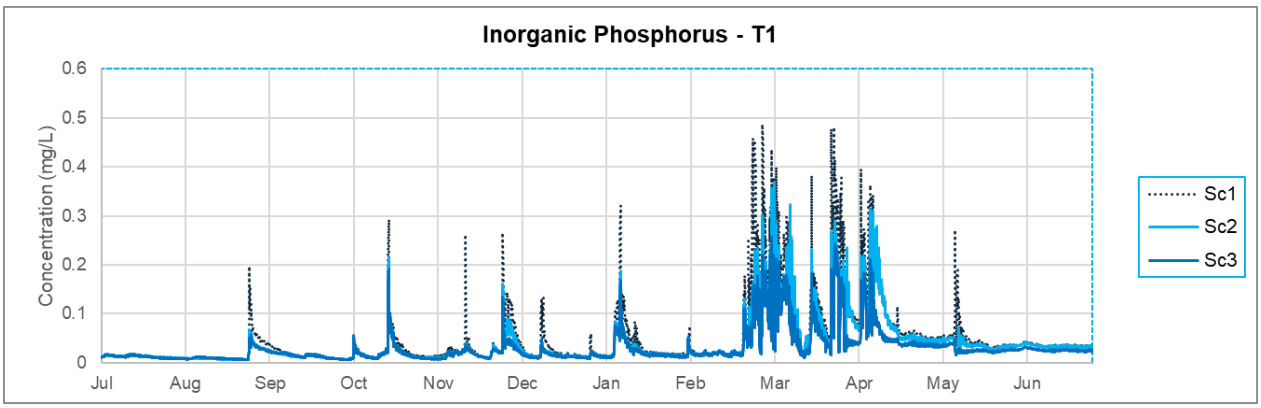
Appendices D5.7.3 Higher rainfall year scenario results (2021-2022)

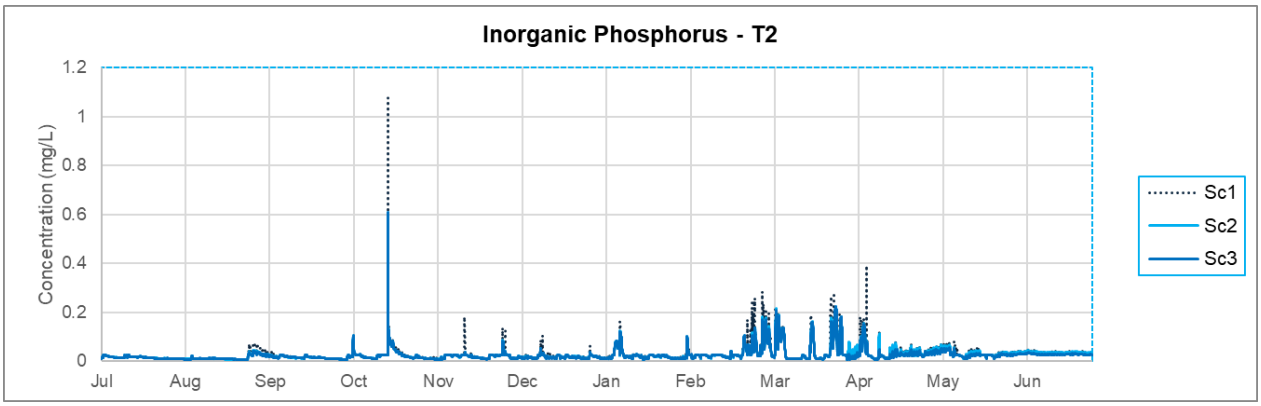
Bar charts

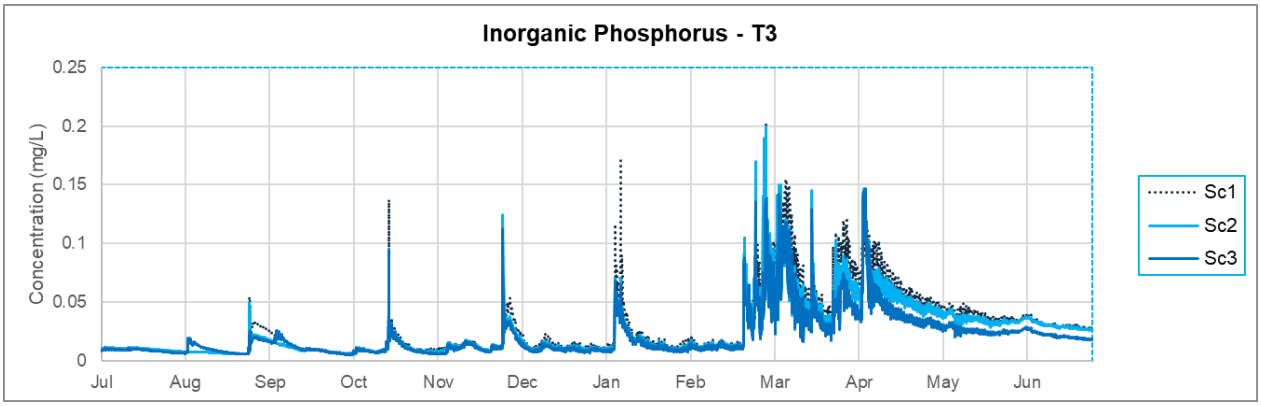


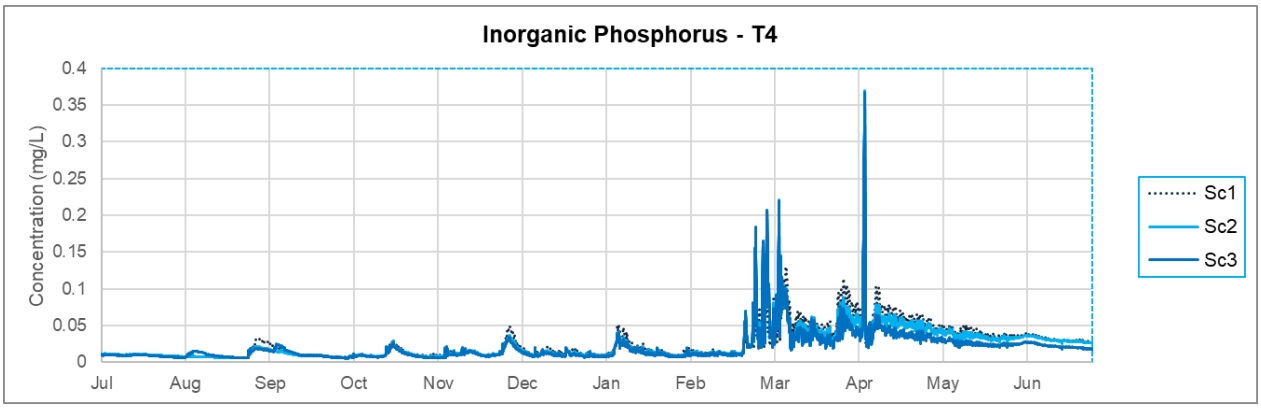


Time series plots




Inorganic Phosphorus - T2
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

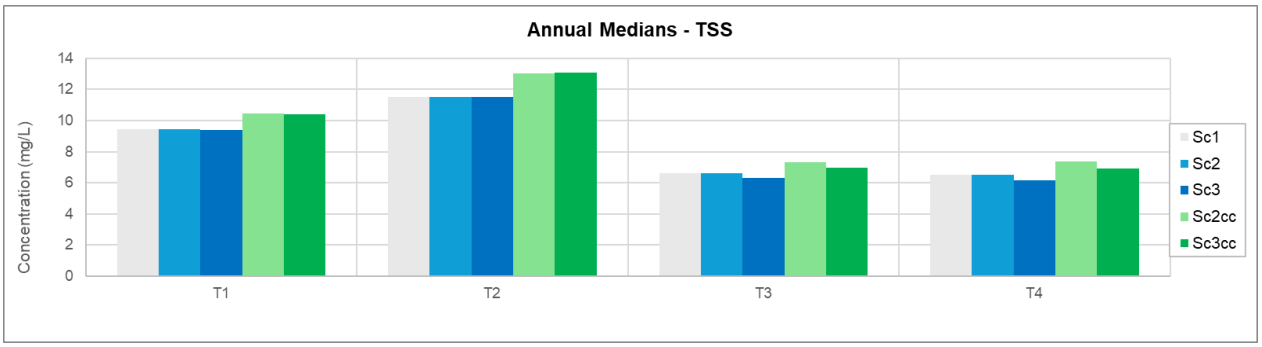

Inorganic Phosphorus - T3
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

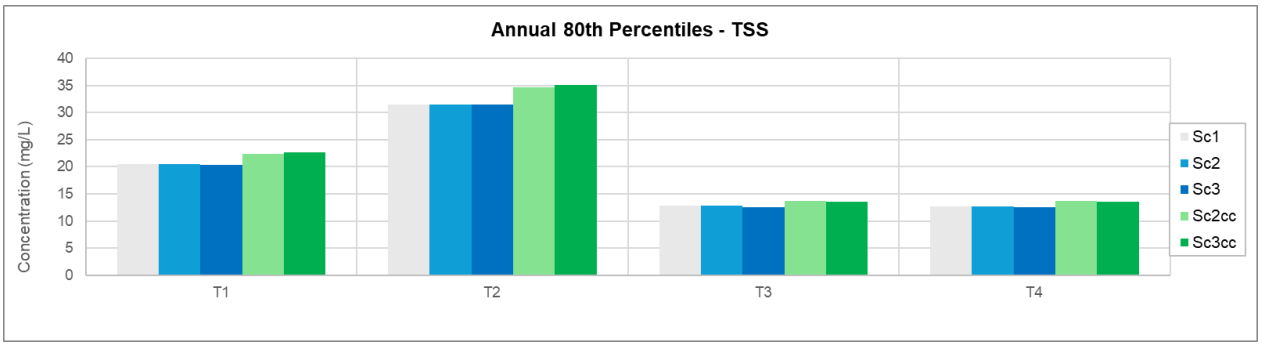

Inorganic Phosphorus - T4
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.8 TSS

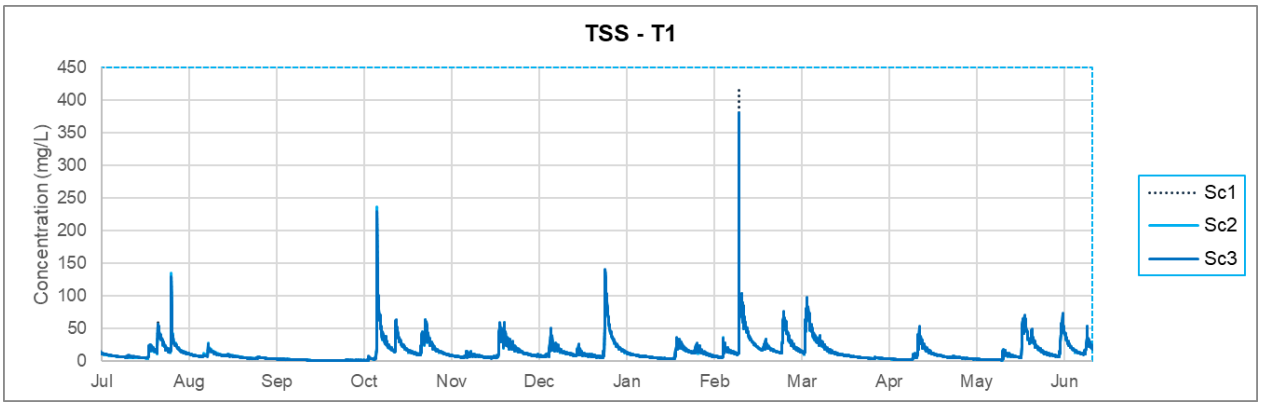
Appendices D5.8.1 Lower rainfall year scenario results (2017-2018)

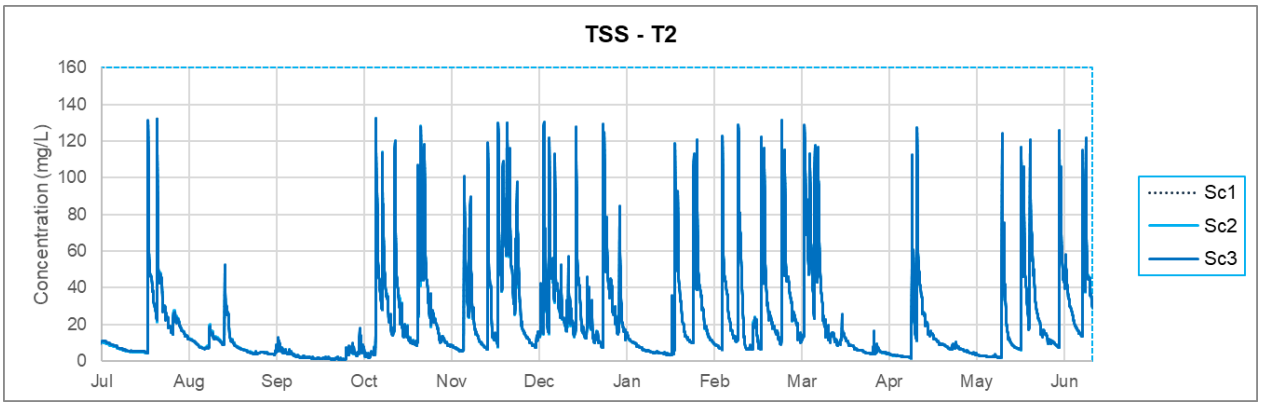
Bar charts

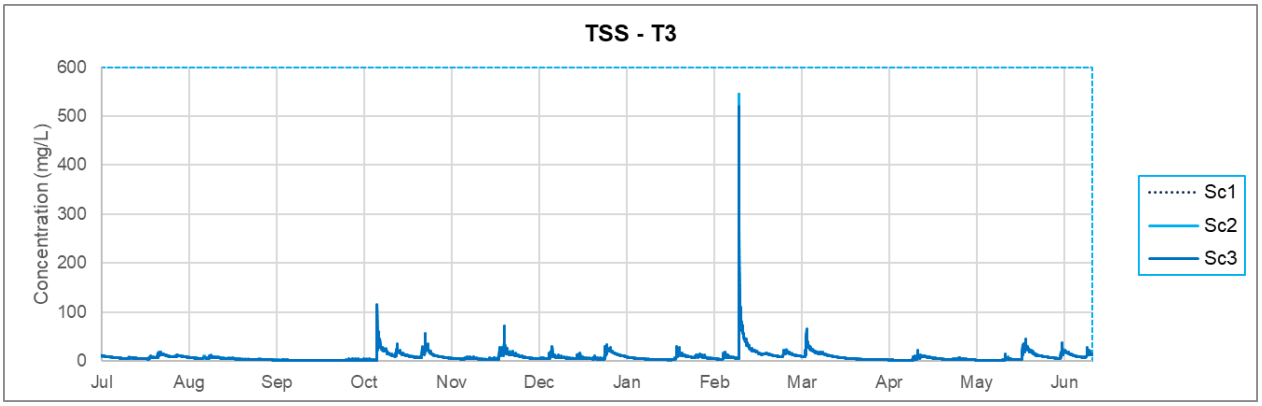


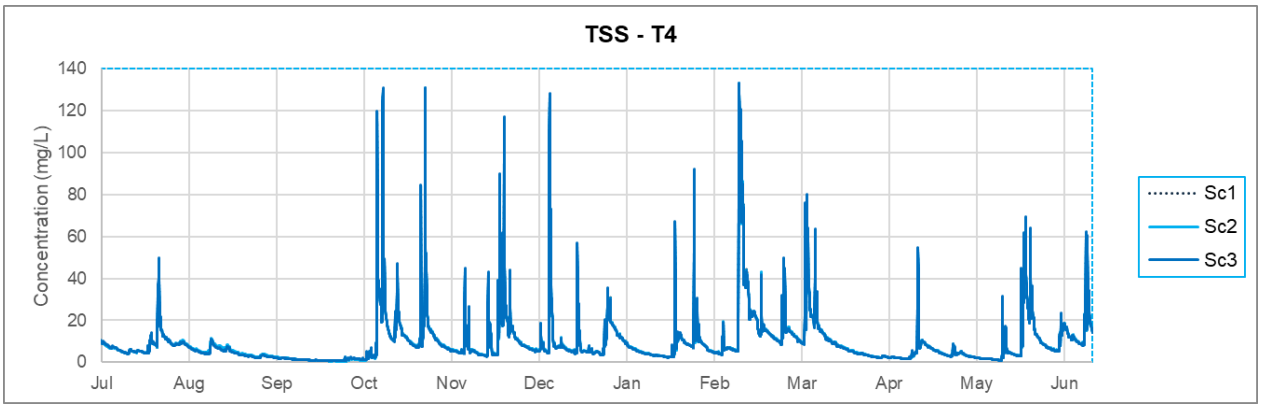


Time series plots



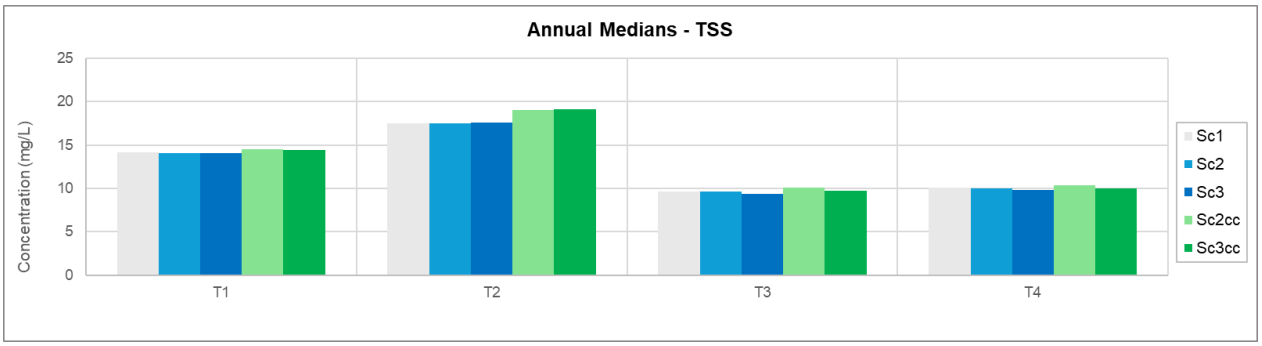




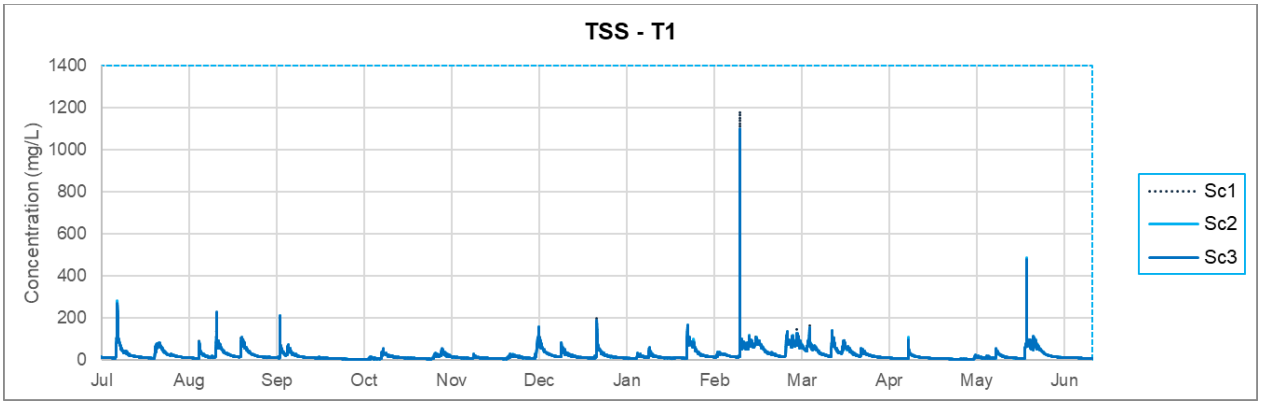


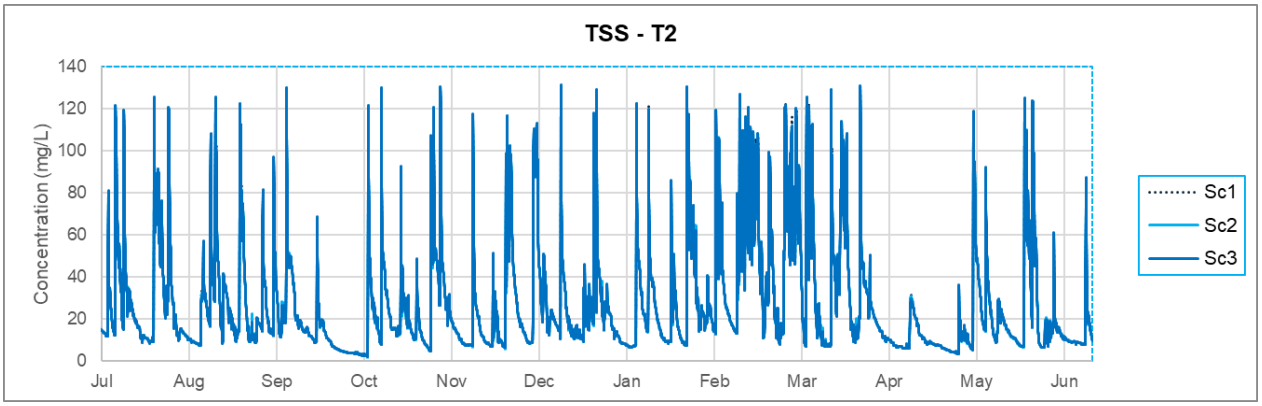
Appendices D5.8.2 Average rainfall year scenario results (2016-2017)

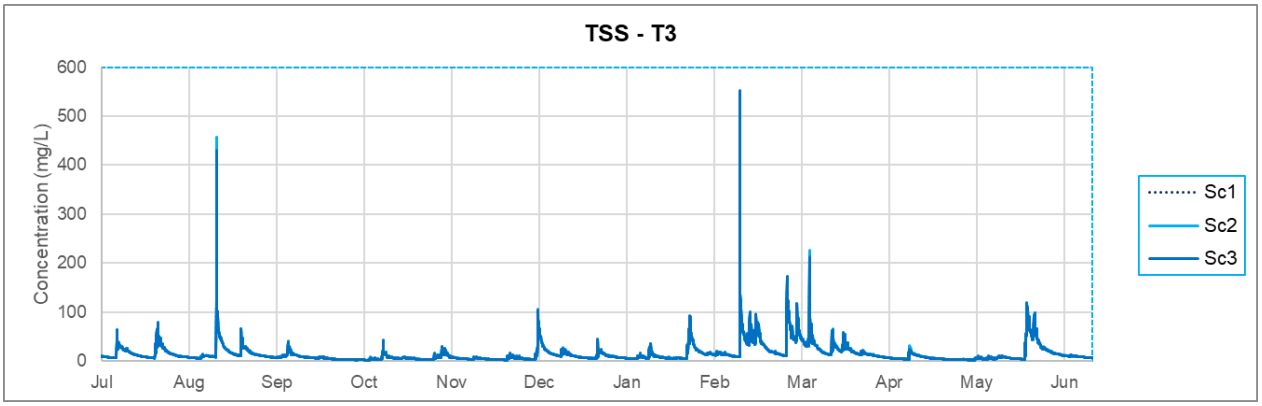
Bar charts

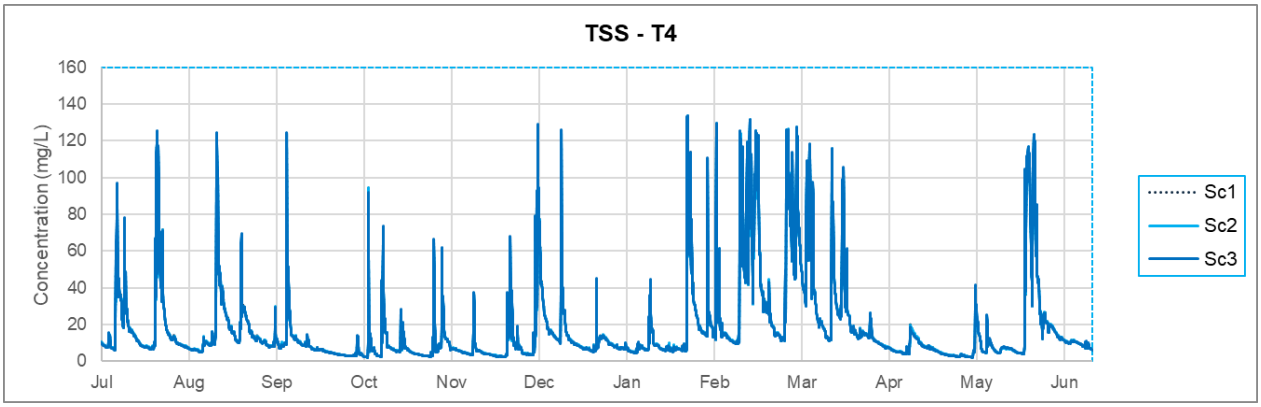


Time series plots



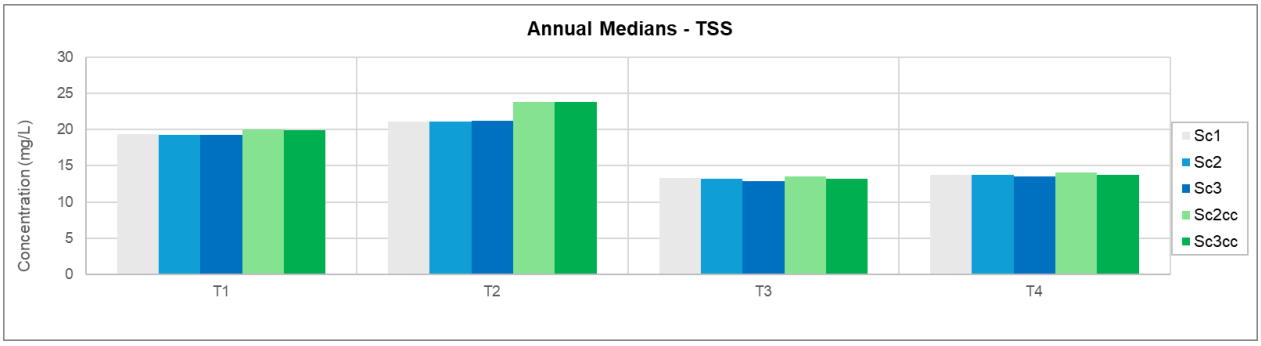


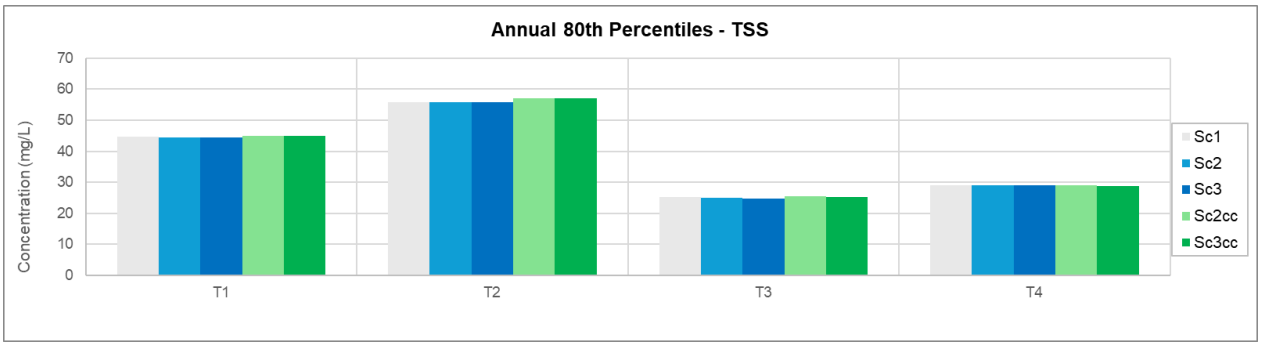




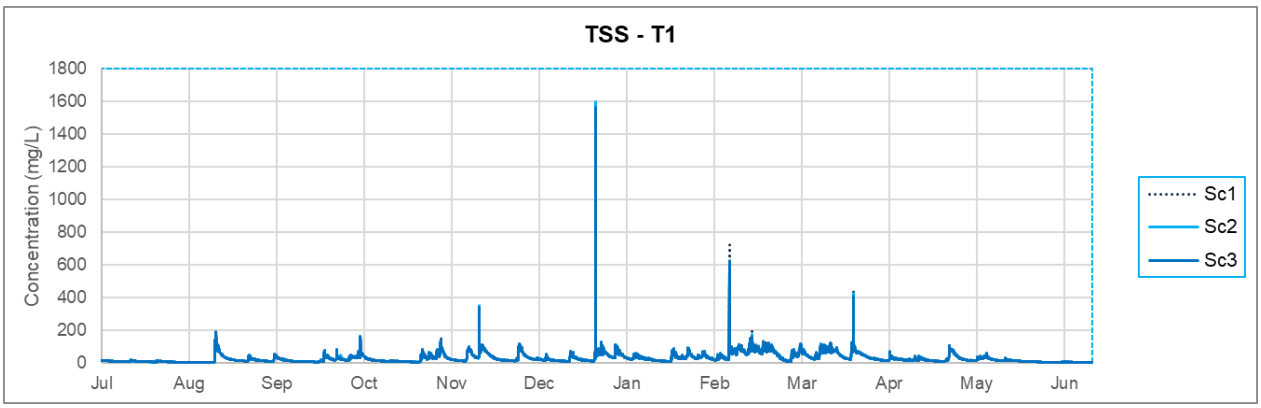
Appendices D5.8.3 Higher rainfall year scenario results (2021-2022)

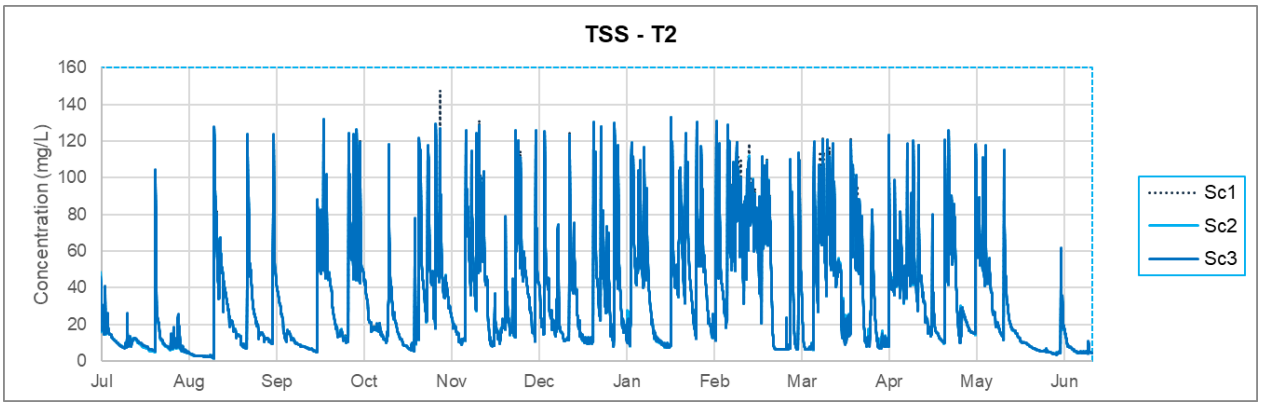
Bar charts

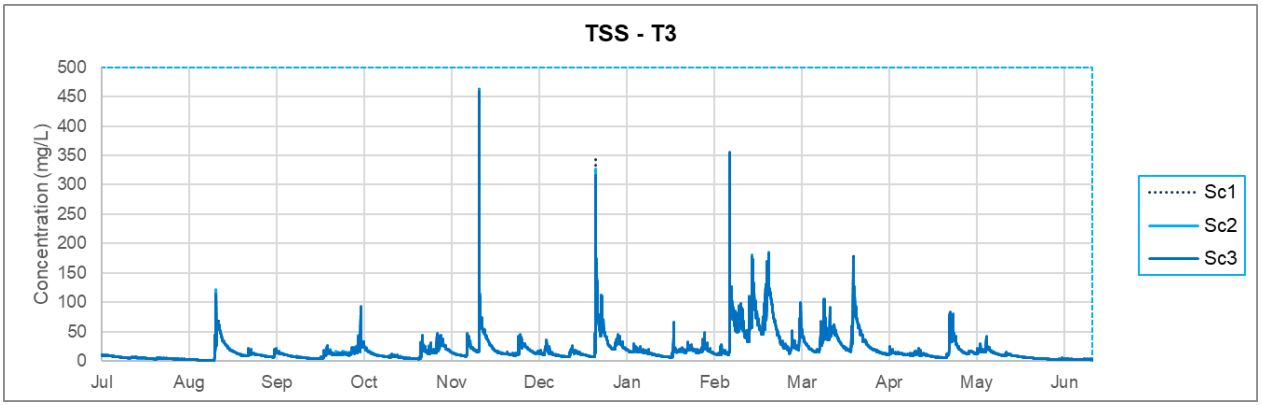


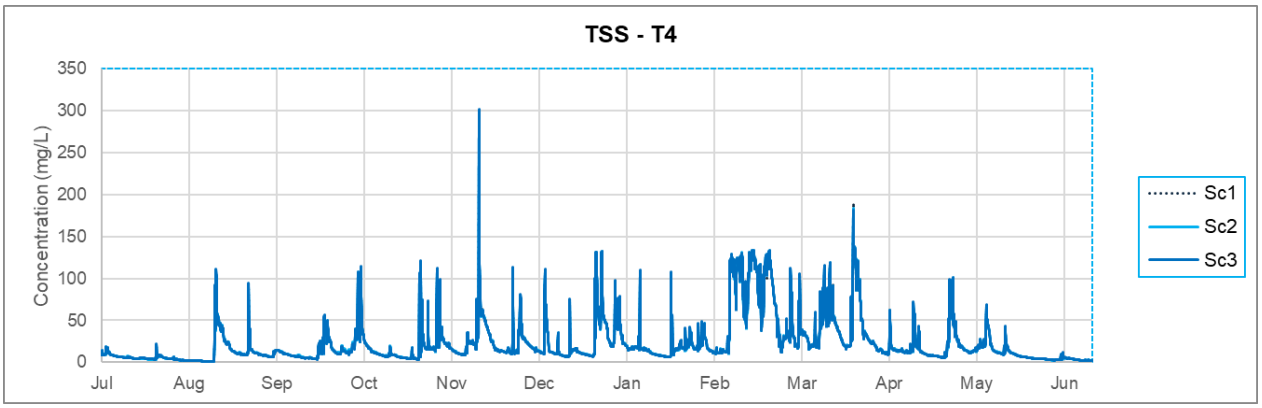


Time series plots




TSS - T2
Concentration (mg/L)
160
140
120
100
80
60
40
20
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

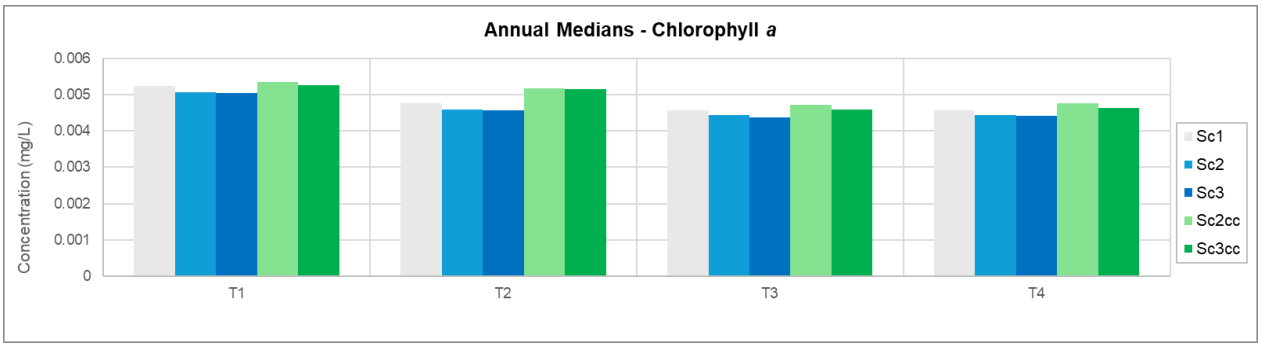

TSS - T3
Concentration (mg/L)
500
450
400
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

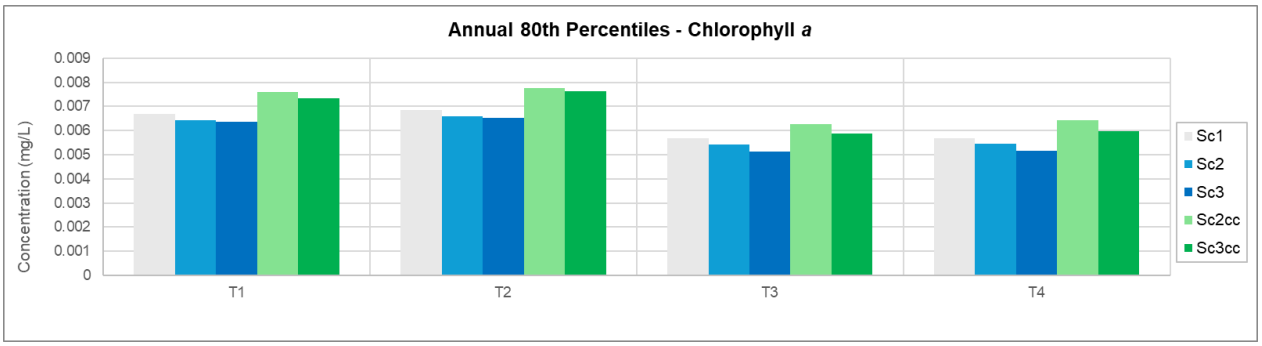

TSS - T4
Concentration (mg/L)
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.9 Chlorophyll a

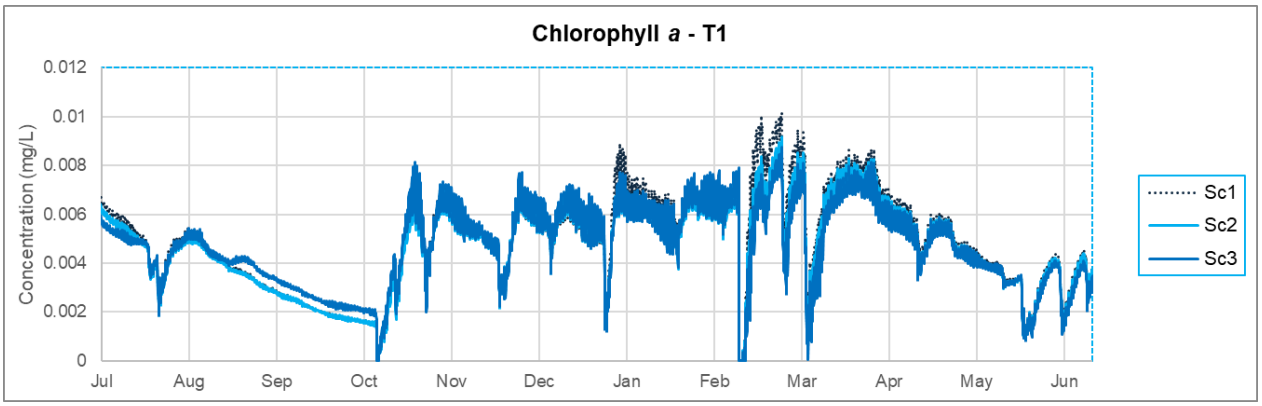
Appendices D5.9.1 Lower rainfall year scenario results (2017-2018)

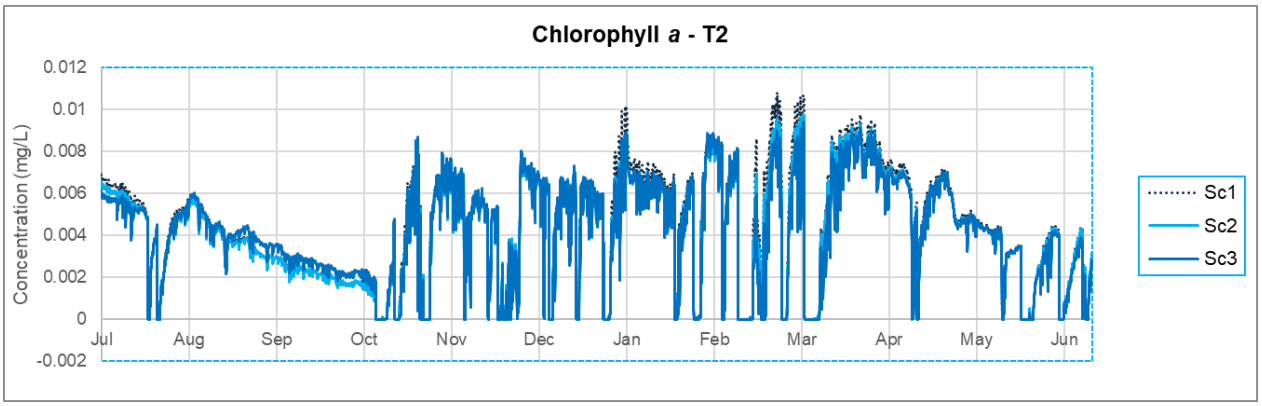
Bar charts

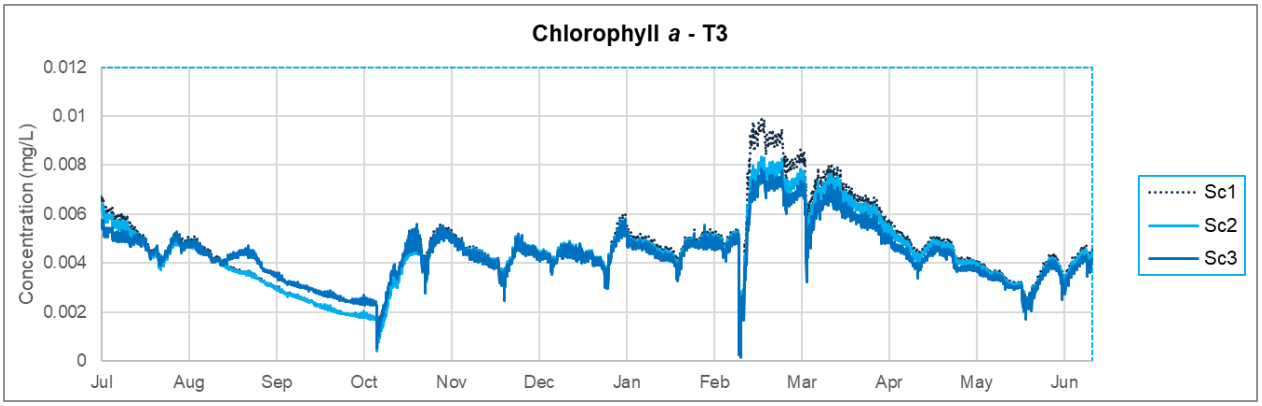


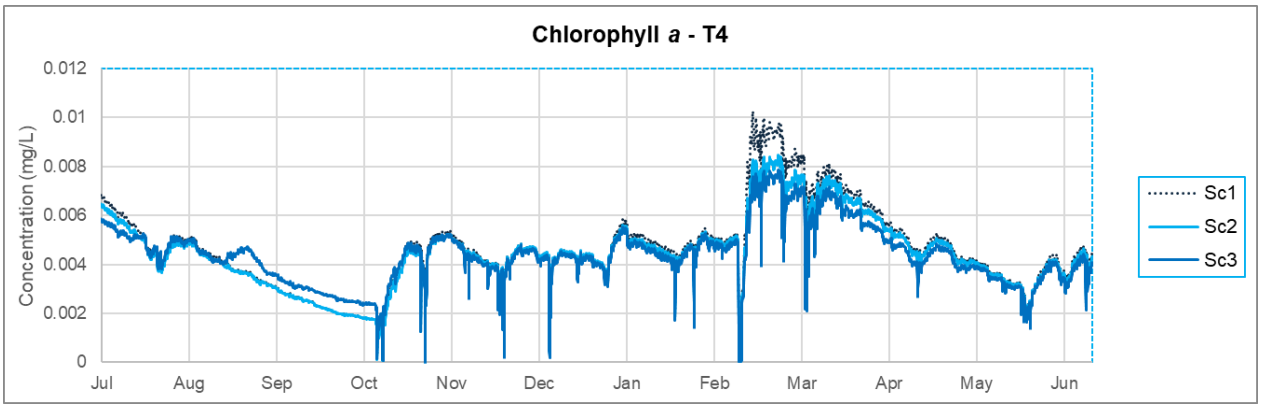


Time series plots



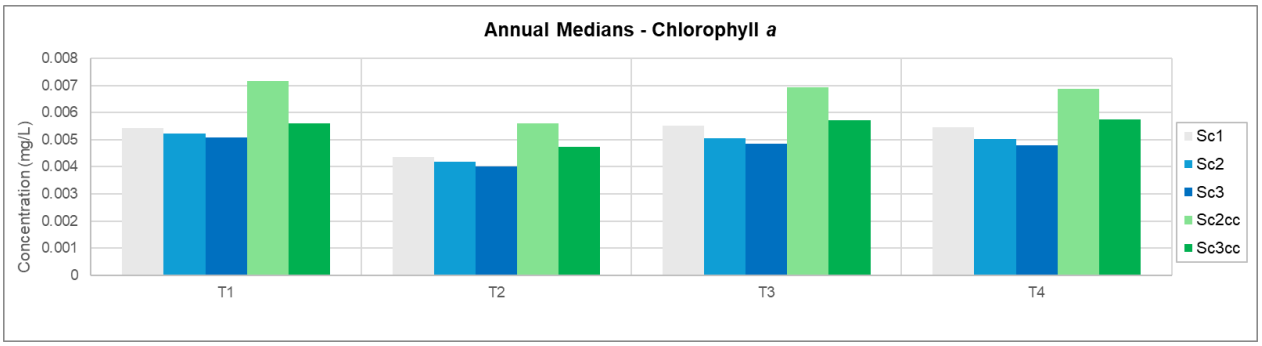


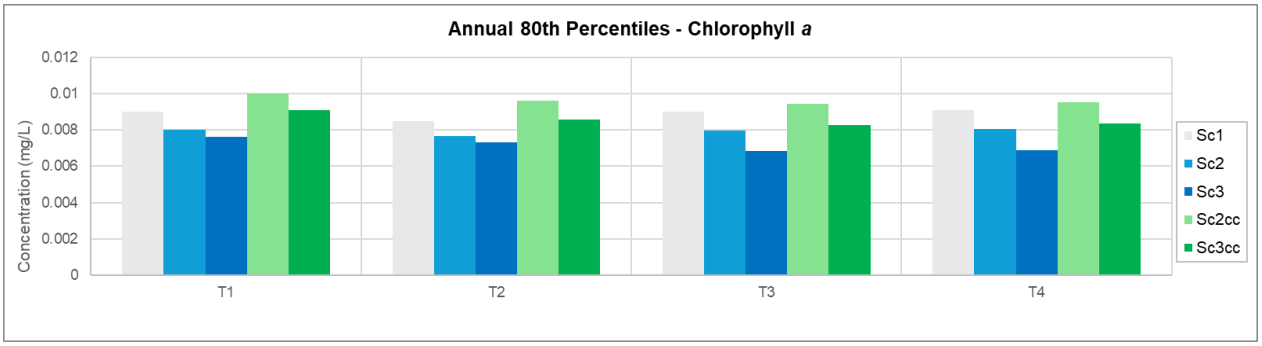




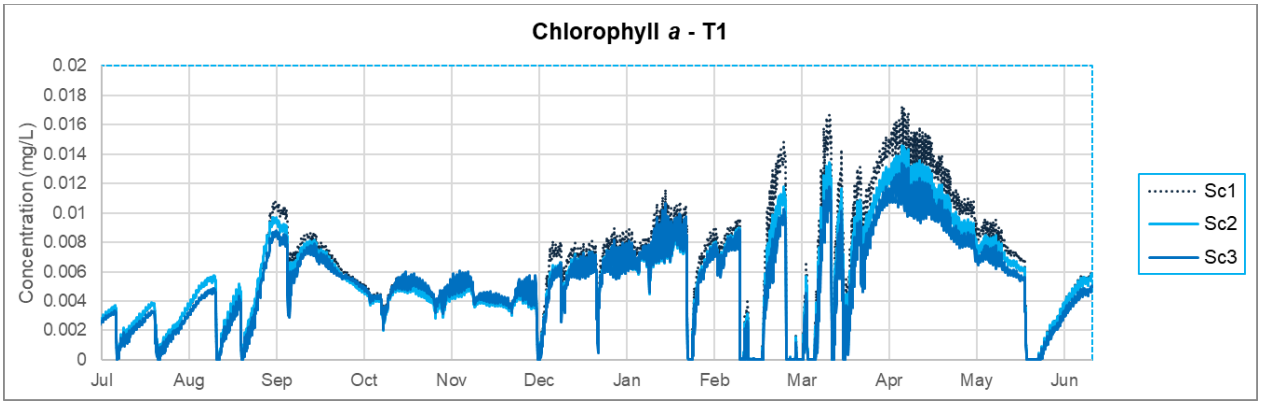
Appendices D5.9.2 Average rainfall year scenario results (2016-2017)

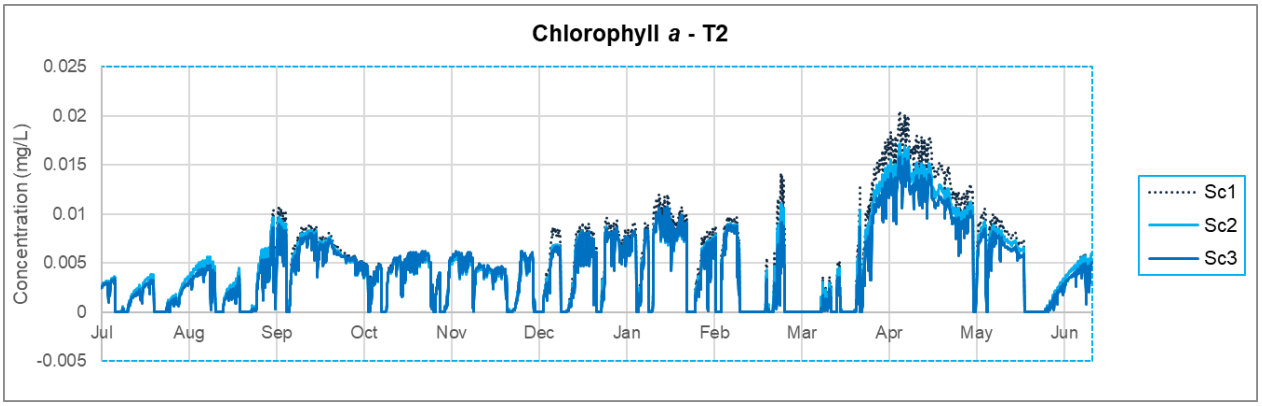
Bar charts

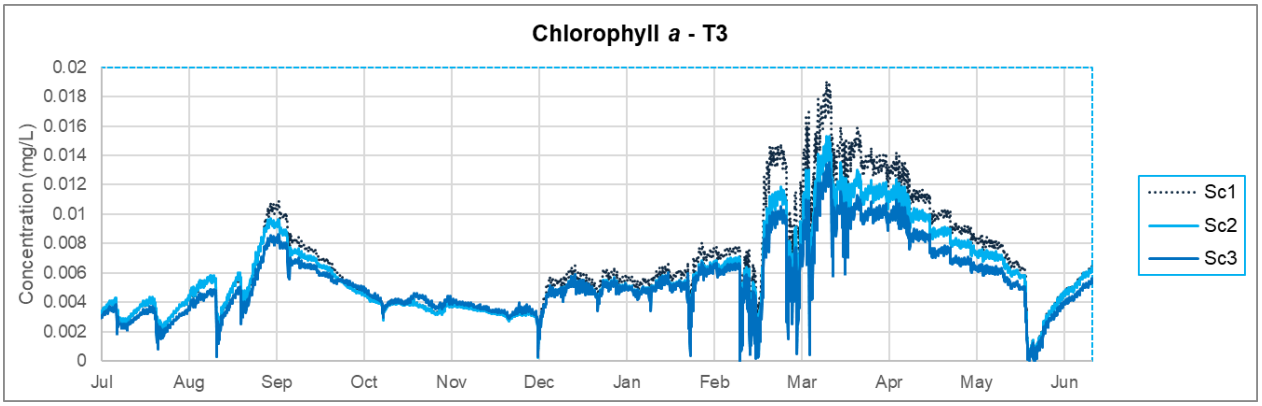


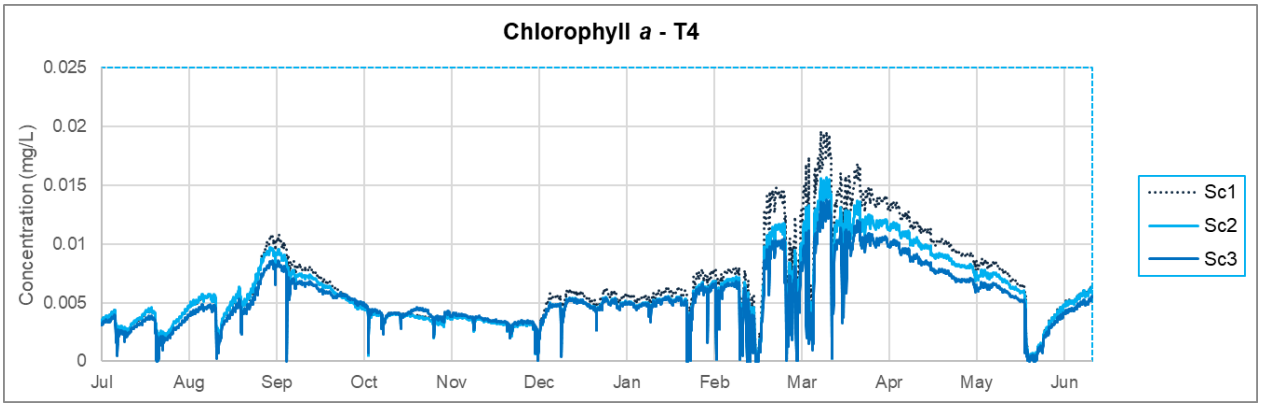


Time series plots



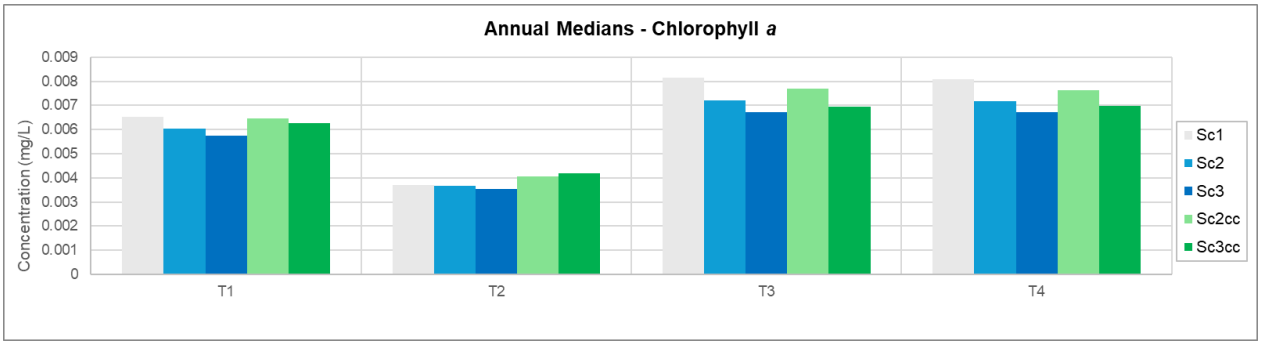


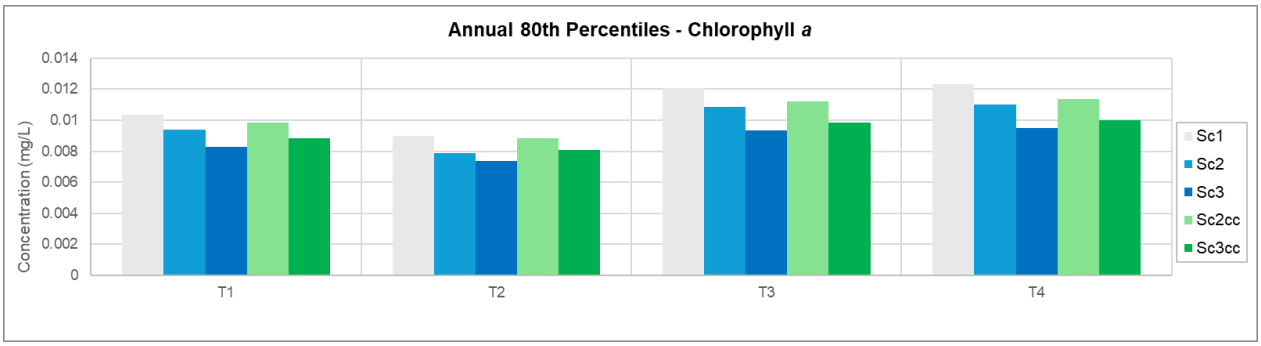




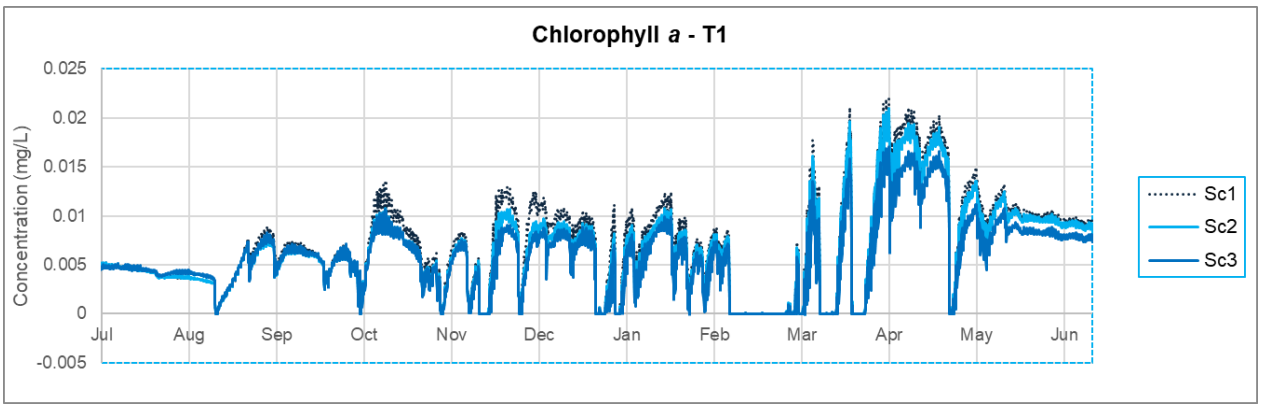
Appendices D5.9.3 Higher rainfall year scenario results (2021-2022)

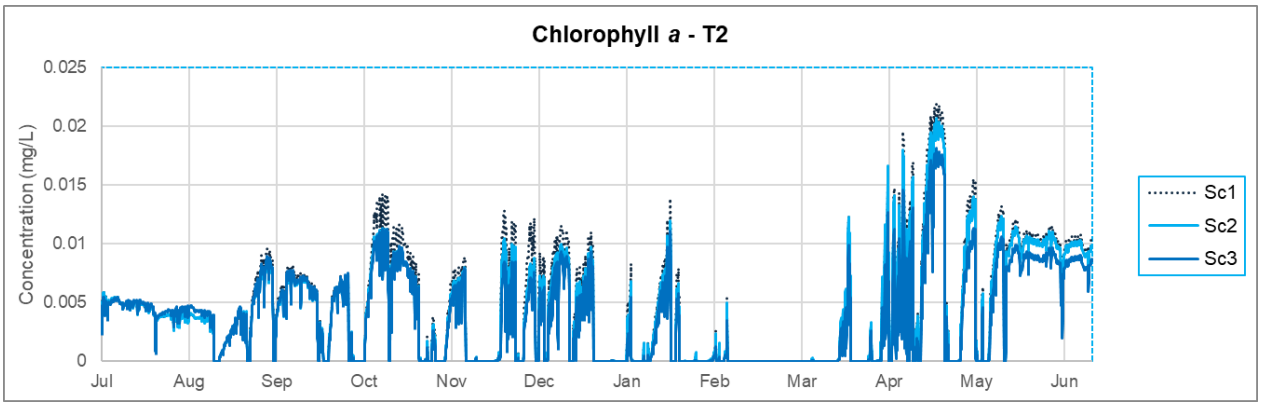
Bar charts

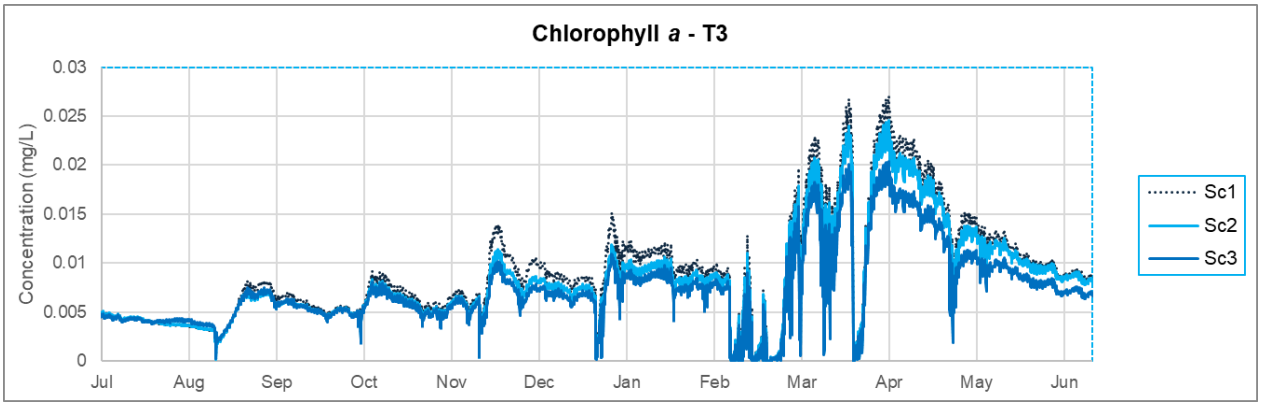


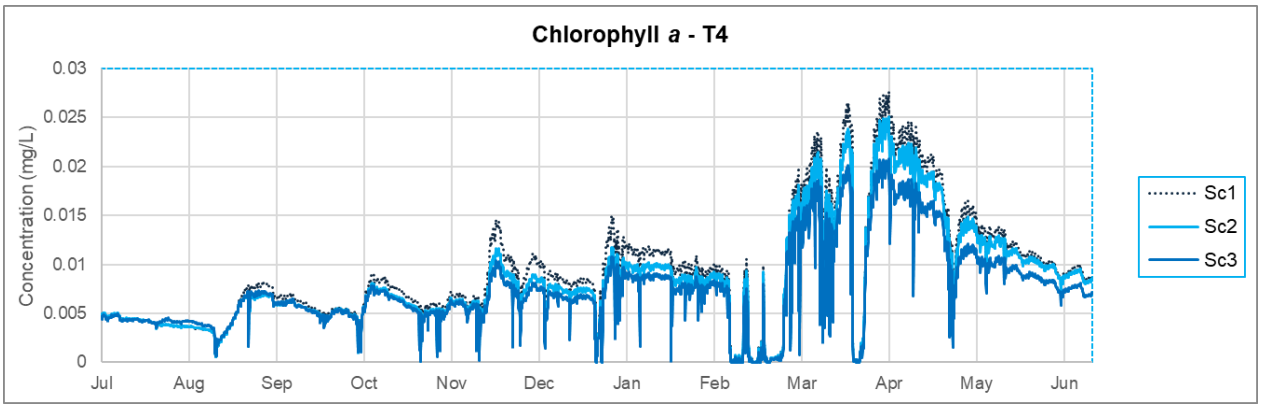


Time series plots




Chlorophyll *a* - T2
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

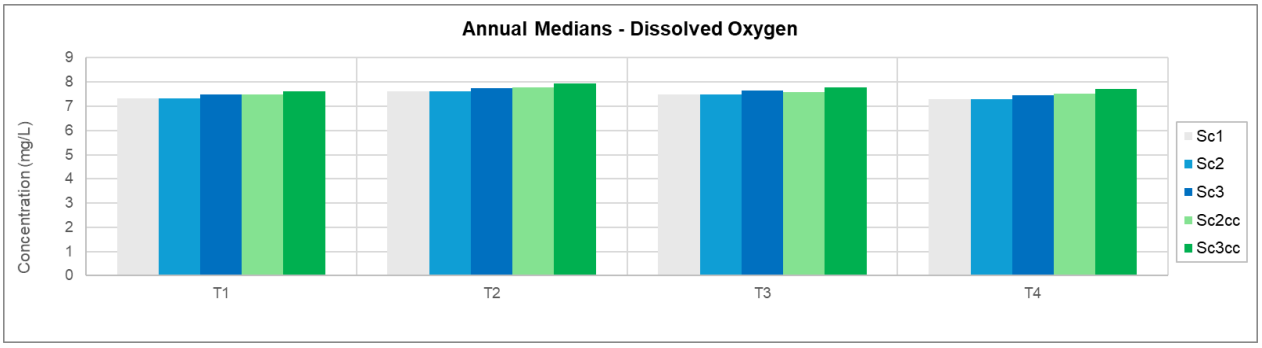

Chlorophyll *a* - T3
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

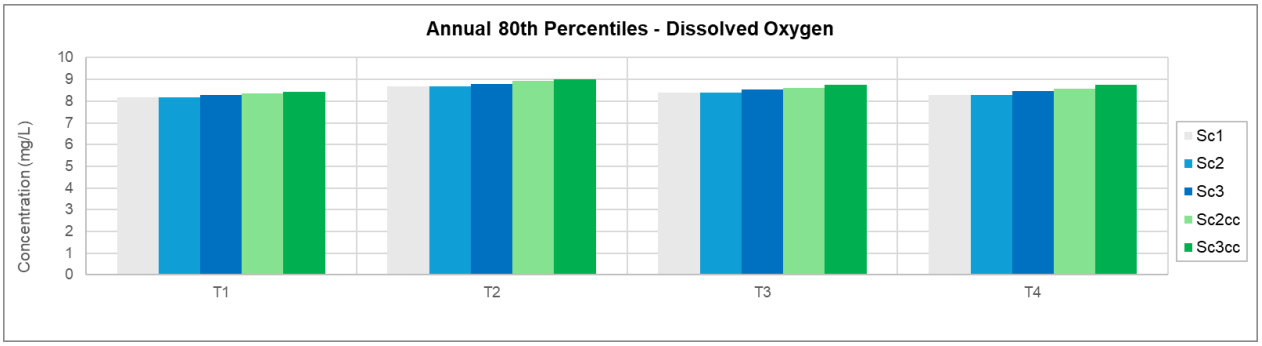

Chlorophyll *a* - T4
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

Appendices D5.10 Dissolved Oxygen

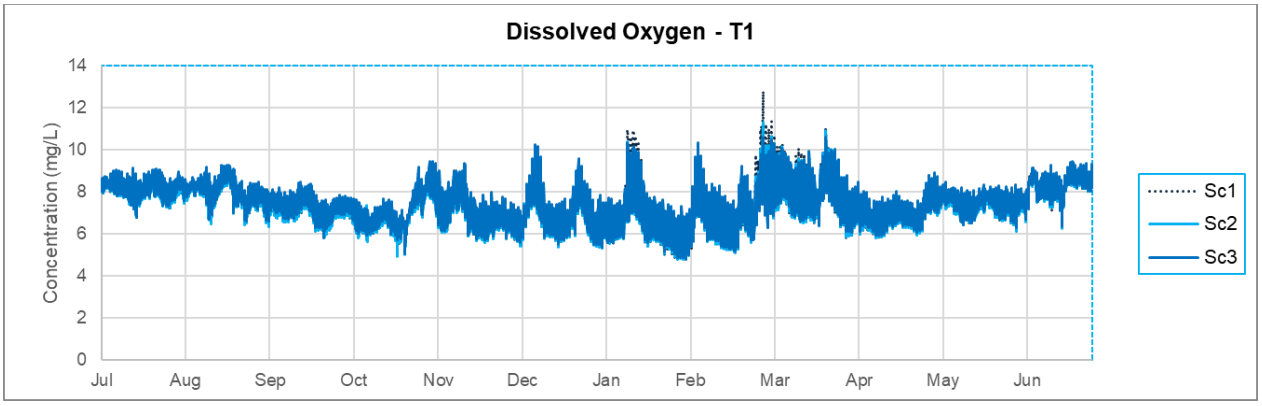
Appendices D5.10.1 Lower rainfall year scenario results (2017-2018)

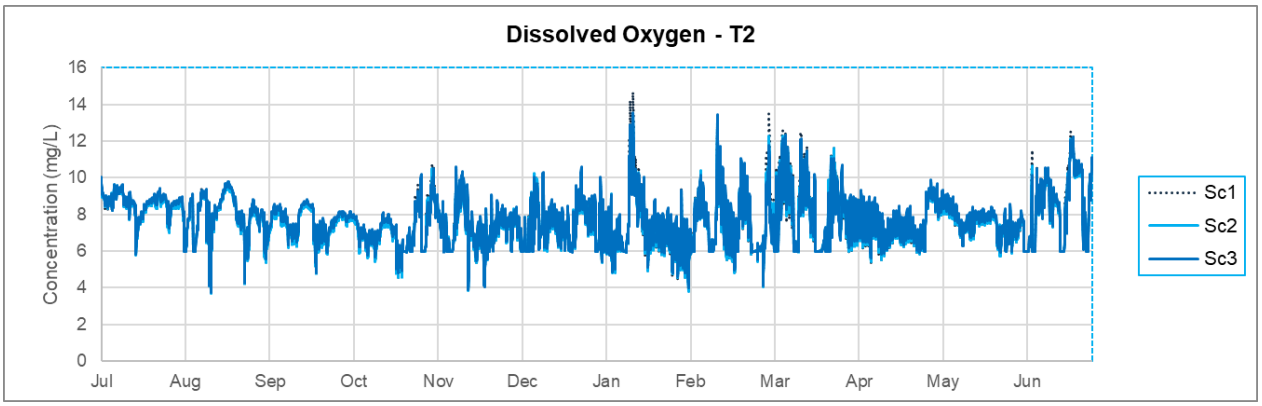
Bar charts

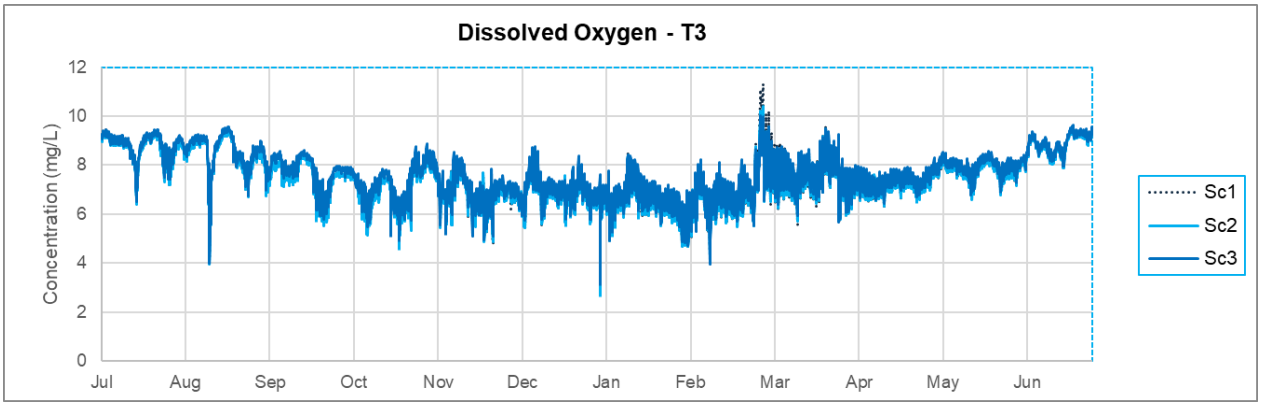


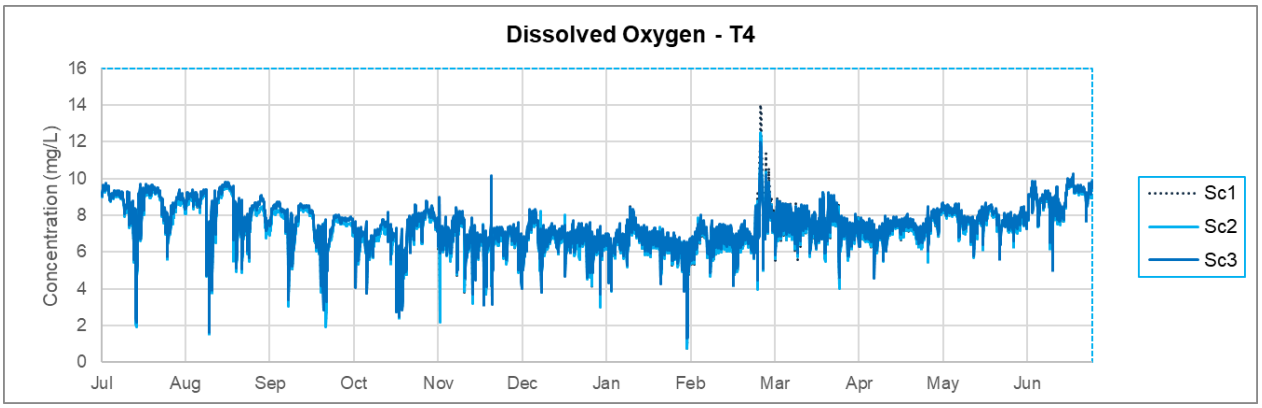


Time series plots



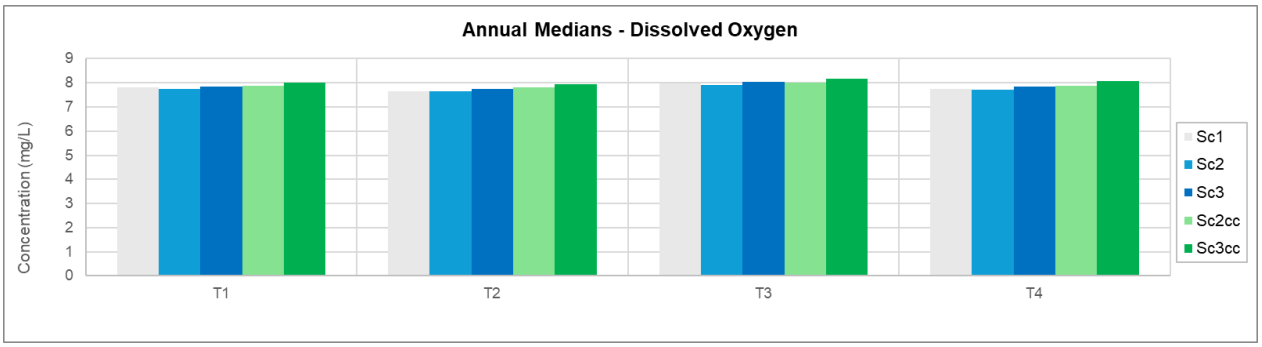


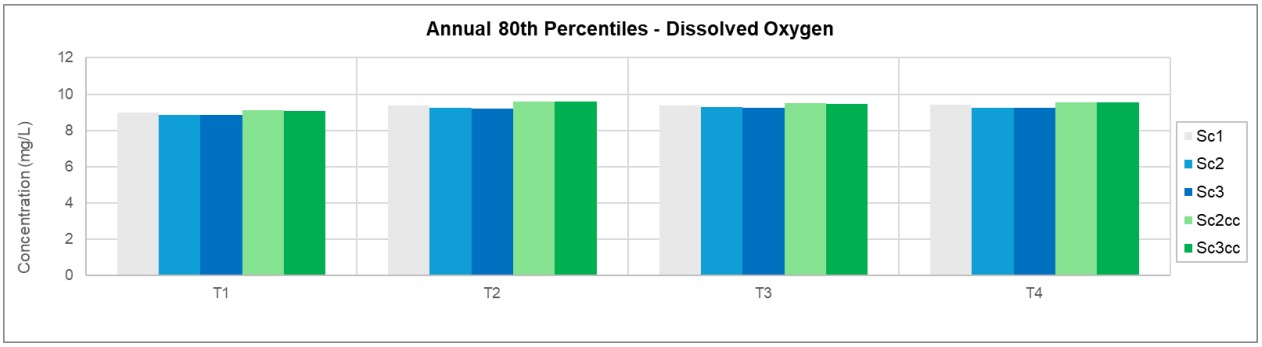




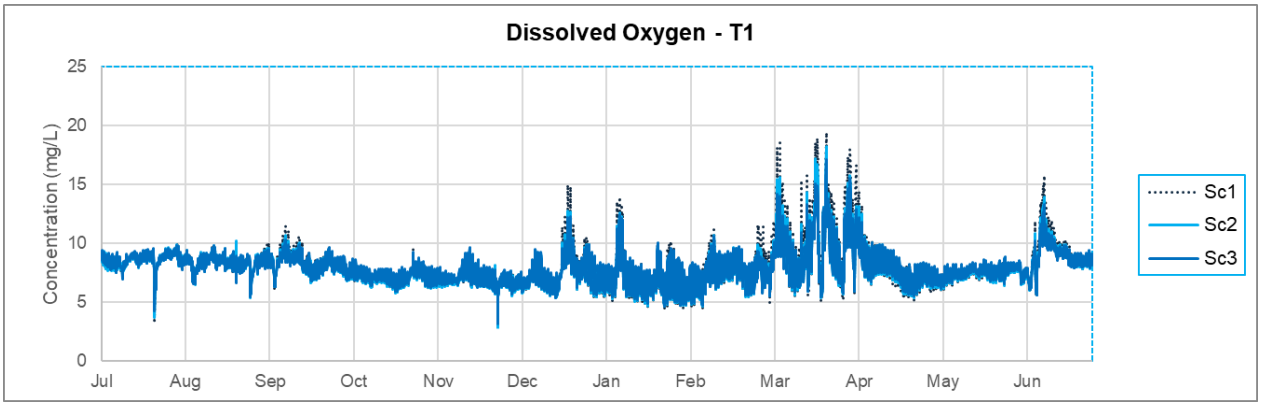
Appendices D5.10.2 Average rainfall year scenario results (2016-2017)

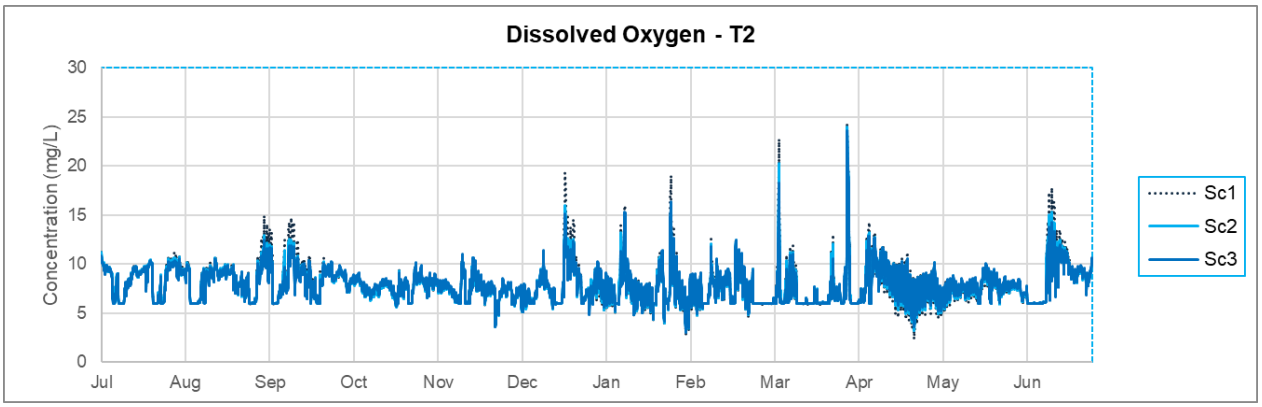
Bar charts

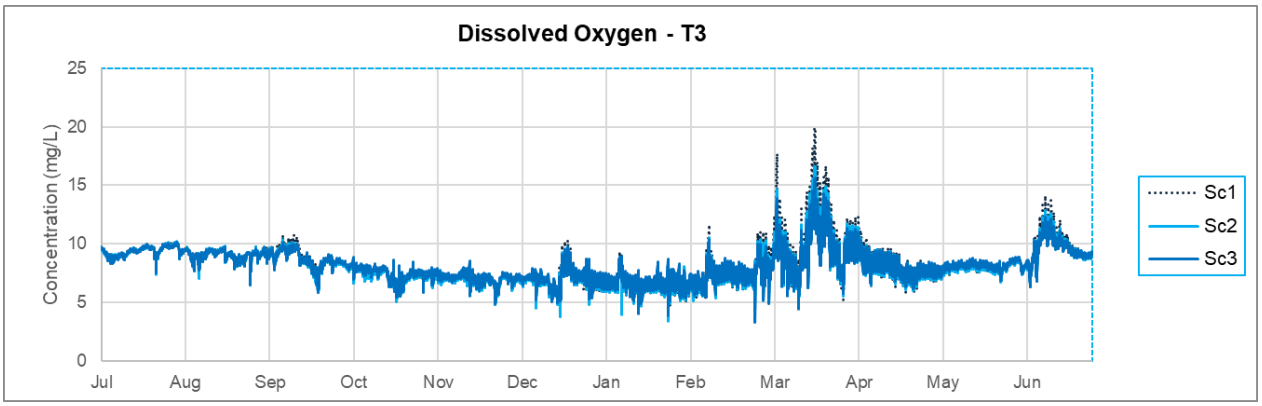


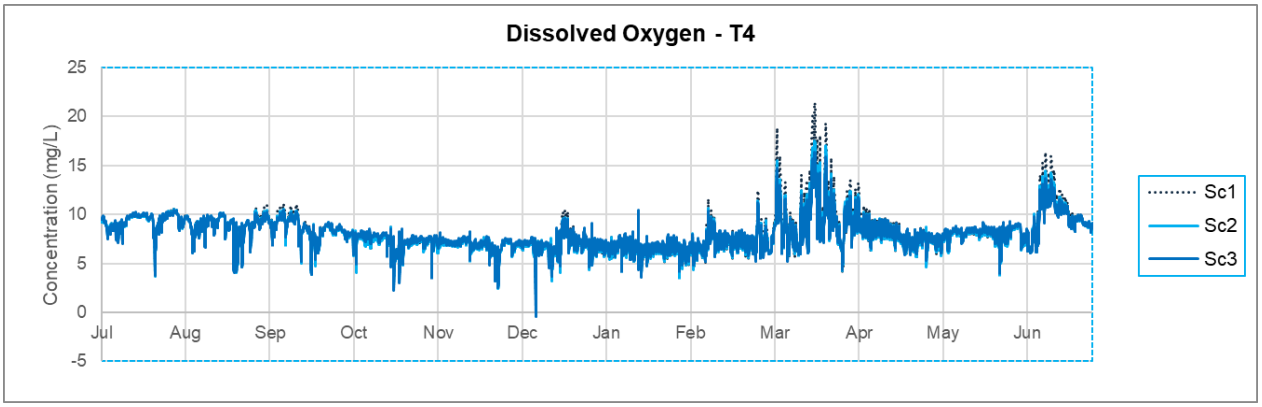


Time series plots



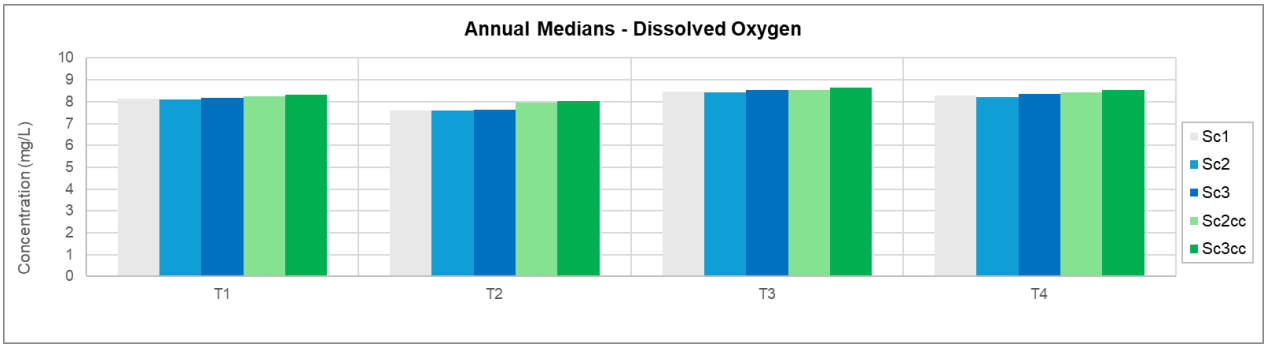


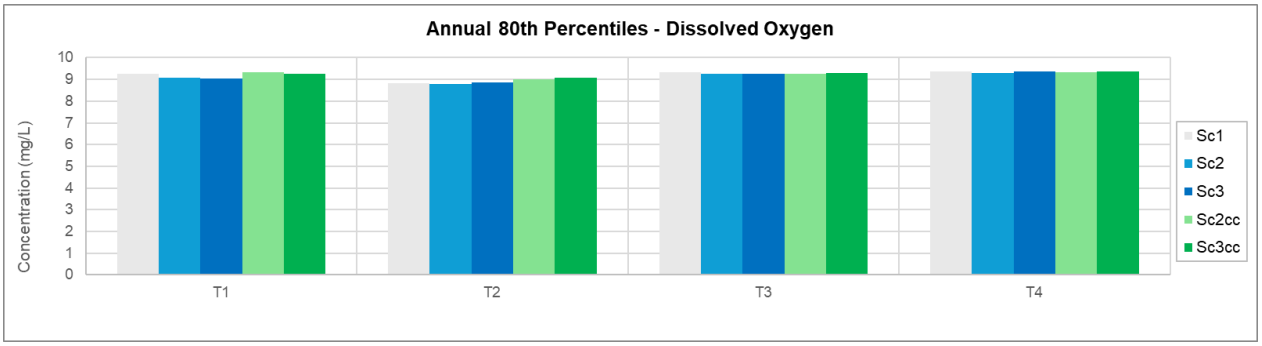




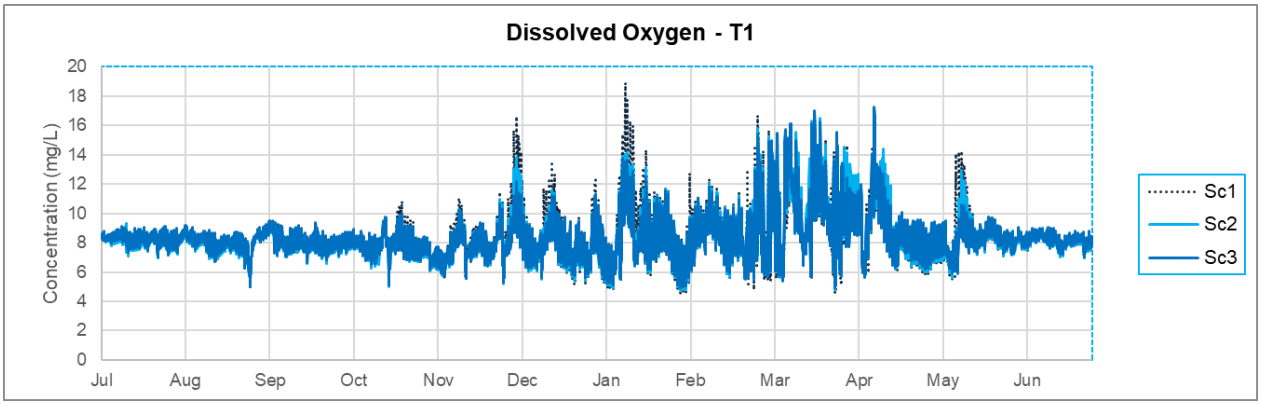
Appendices D5.10.3 Higher rainfall year scenario results (2021-2022)

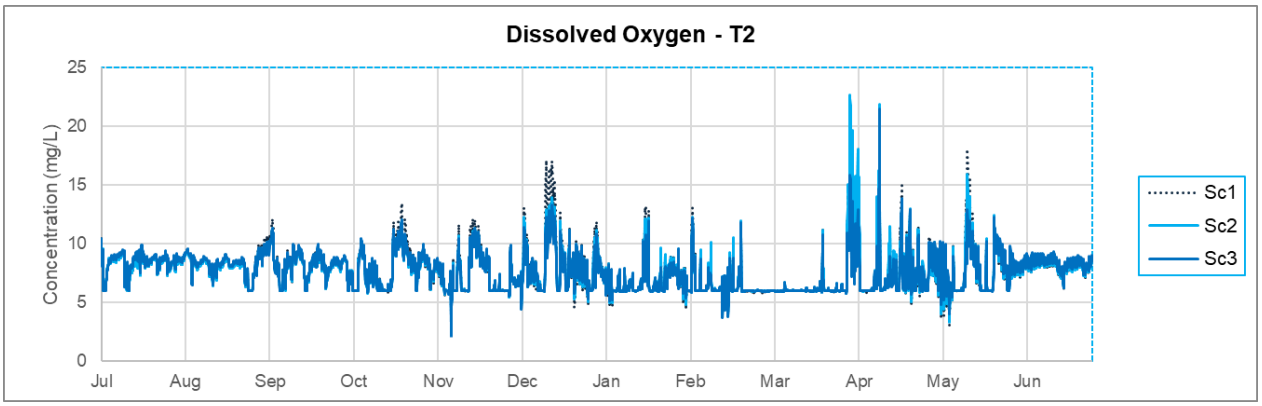
Bar charts

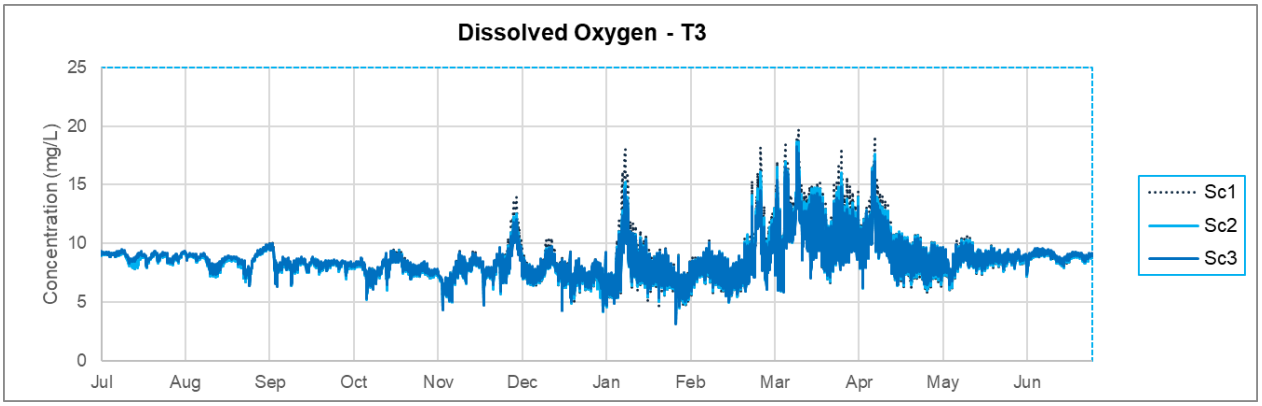


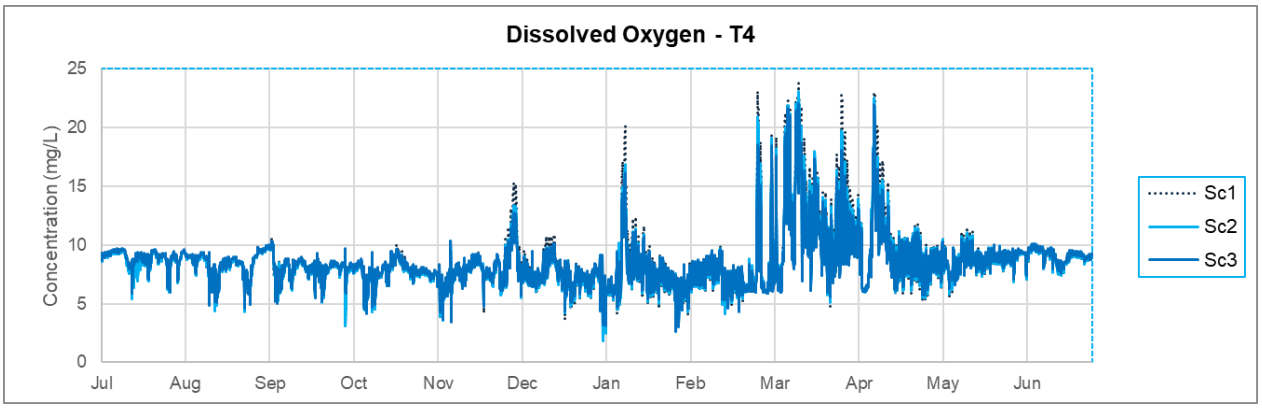


Time series plots




Dissolved Oxygen - T2
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

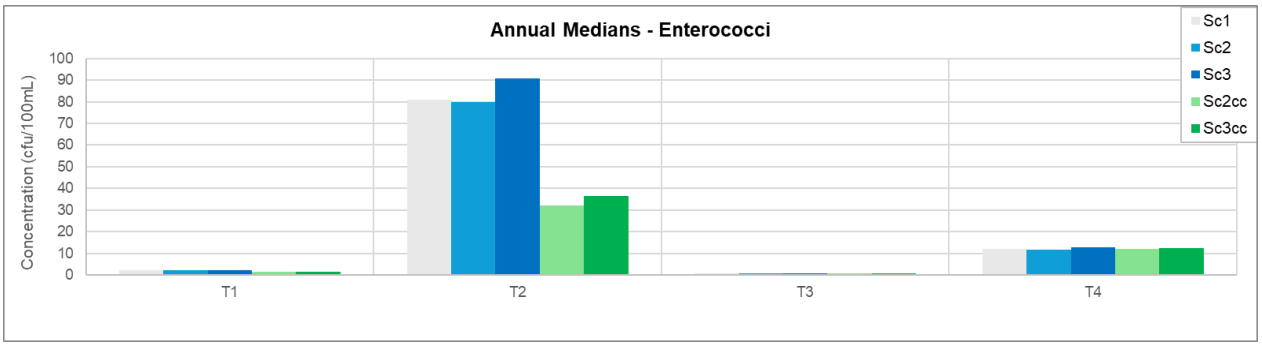

Dissolved Oxygen - T3
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

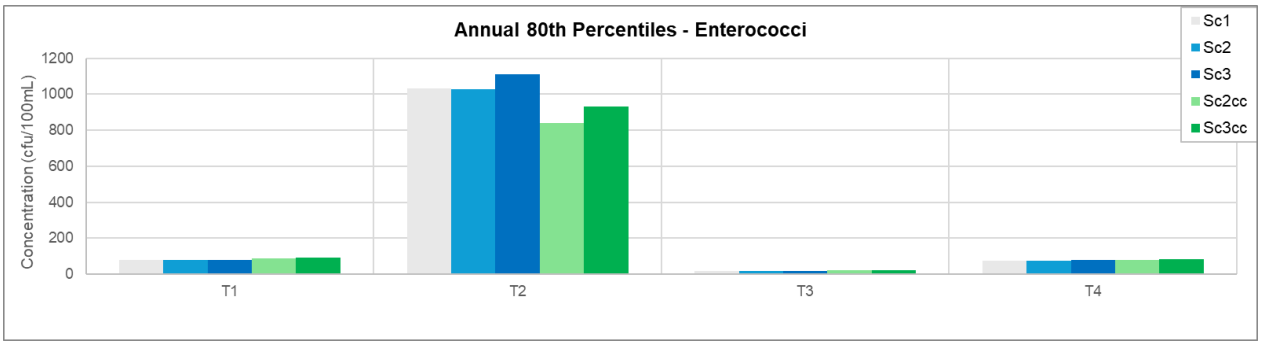

Dissolved Oxygen - T4
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

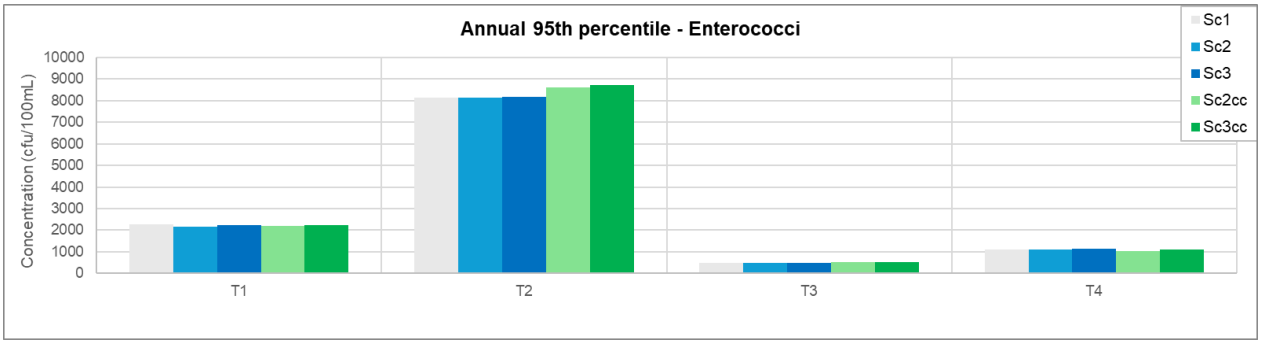
Appendices D5.11 Enterococci

Appendices D5.11.1 Lower rainfall year scenario results (2017-2018)

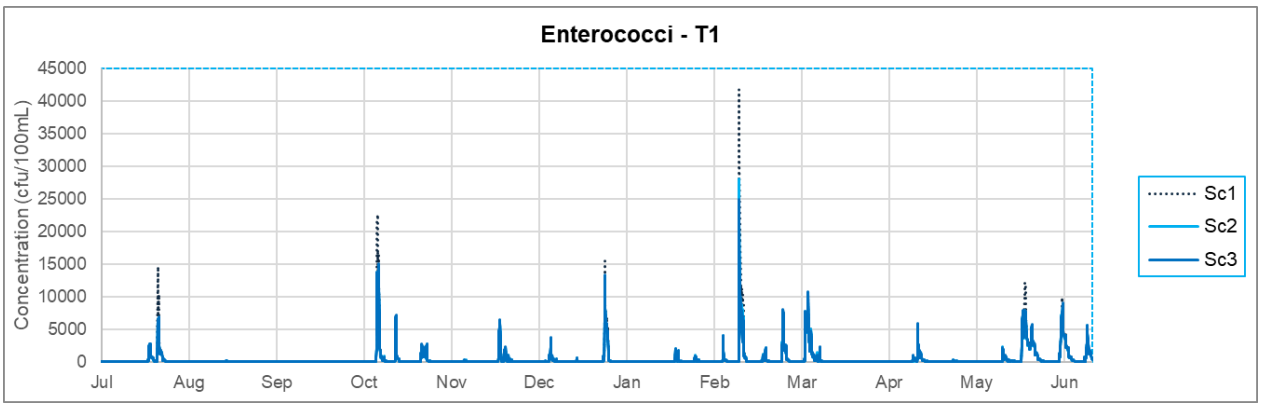
Bar charts

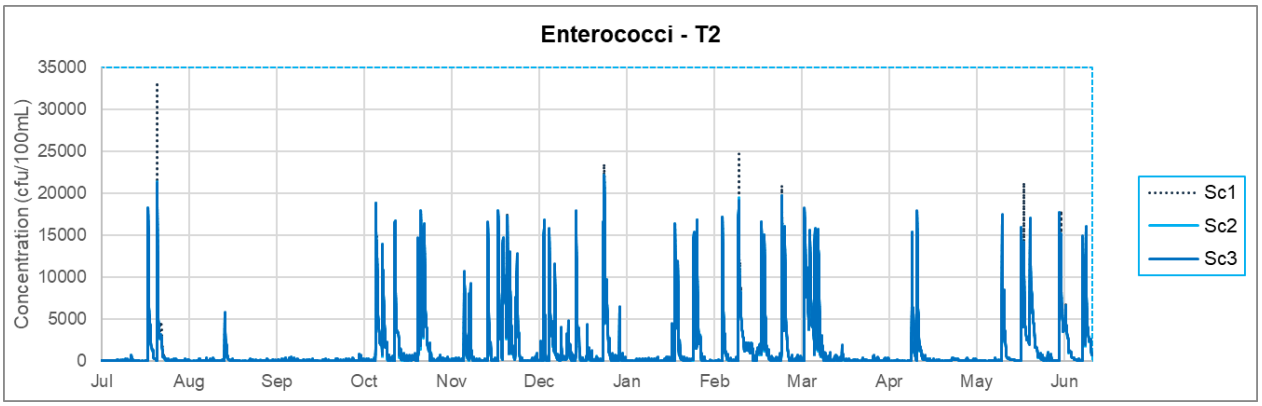


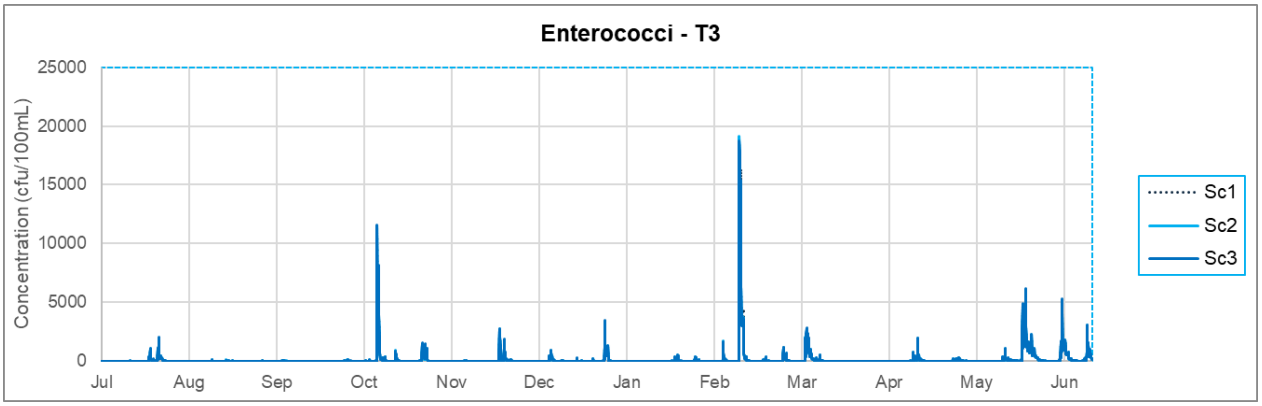


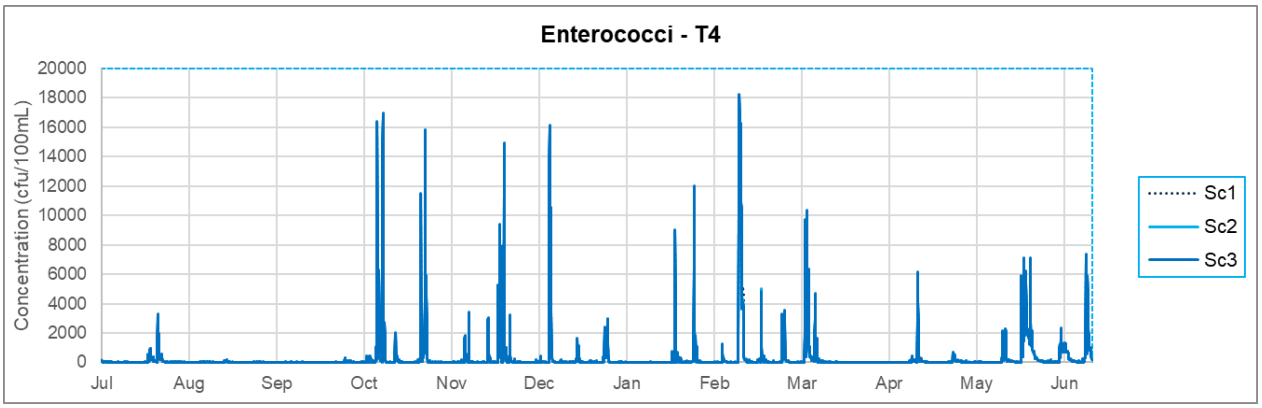


Time series plots



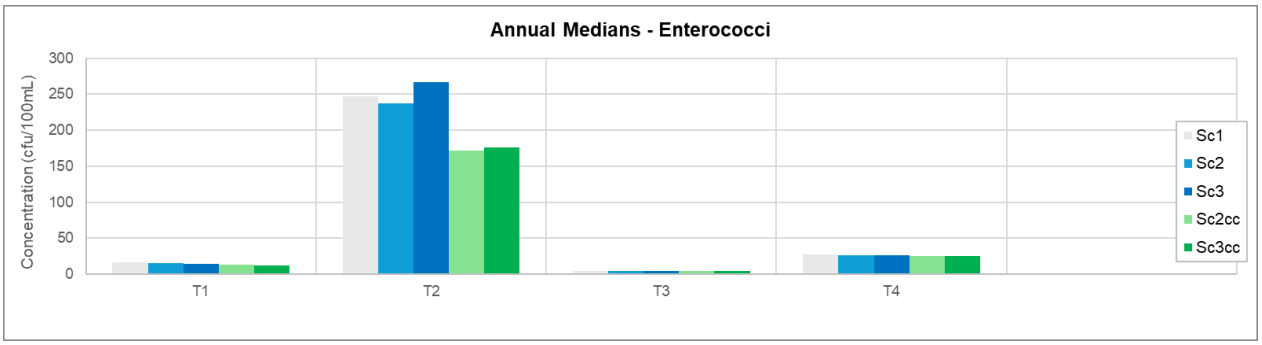


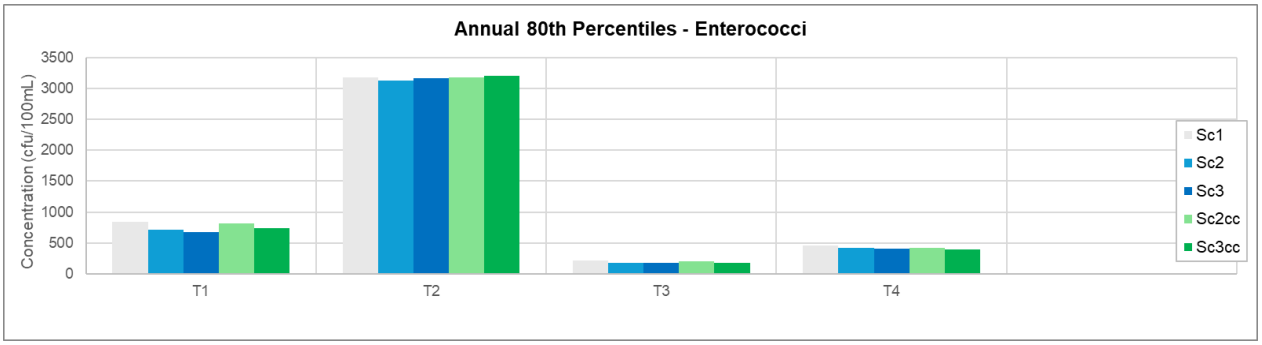


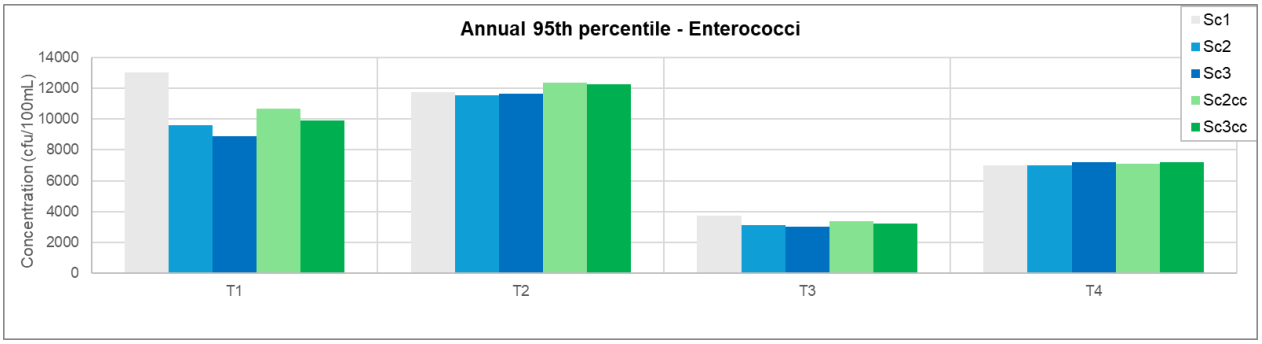


Appendices D5.11.2 Average rainfall year scenario results (2016-2017)

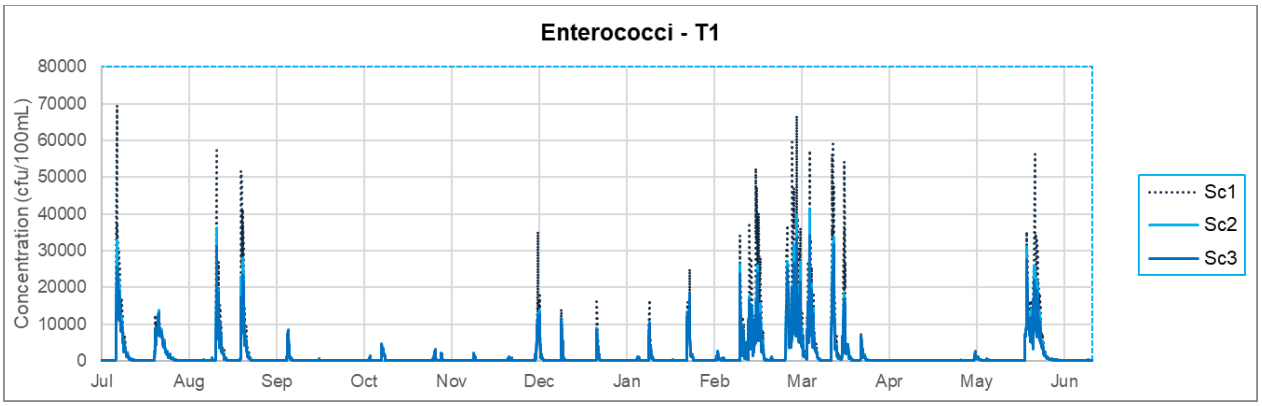
Bar charts

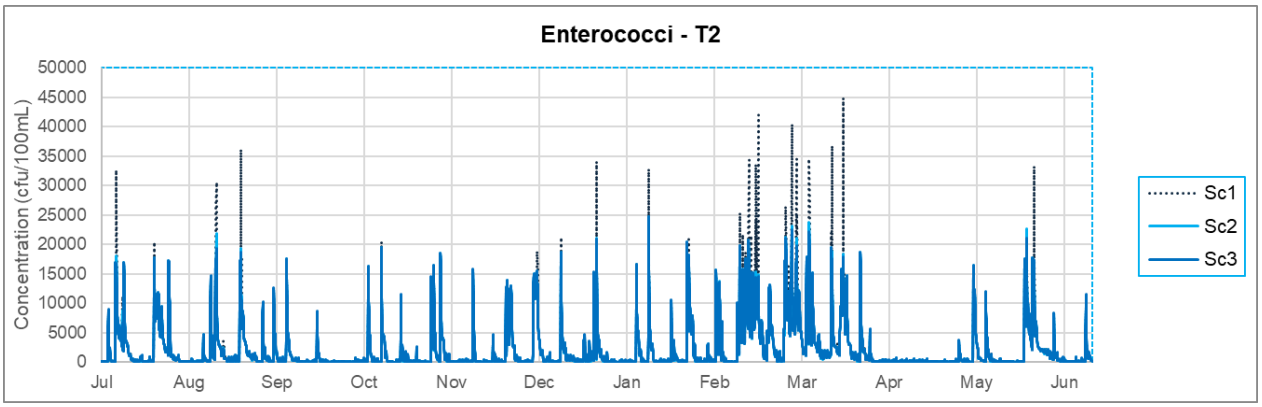


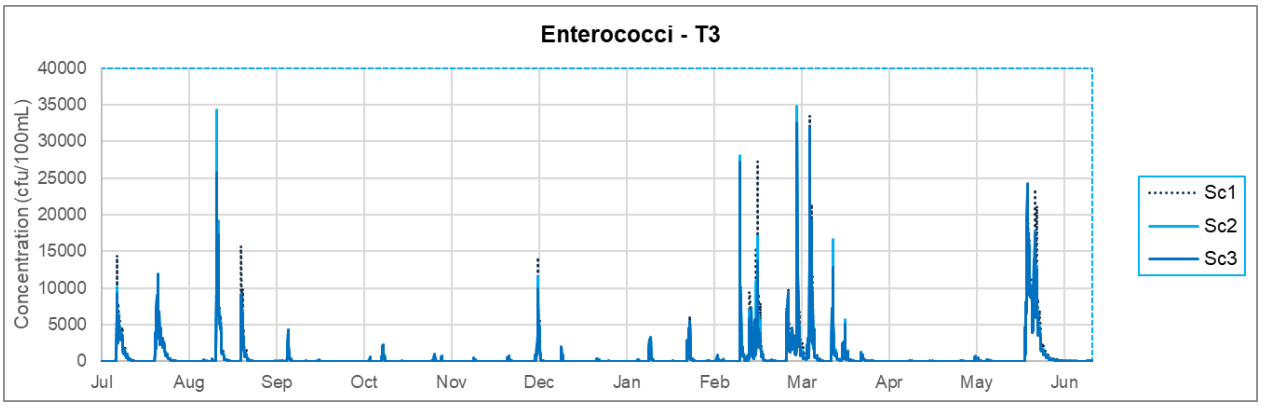


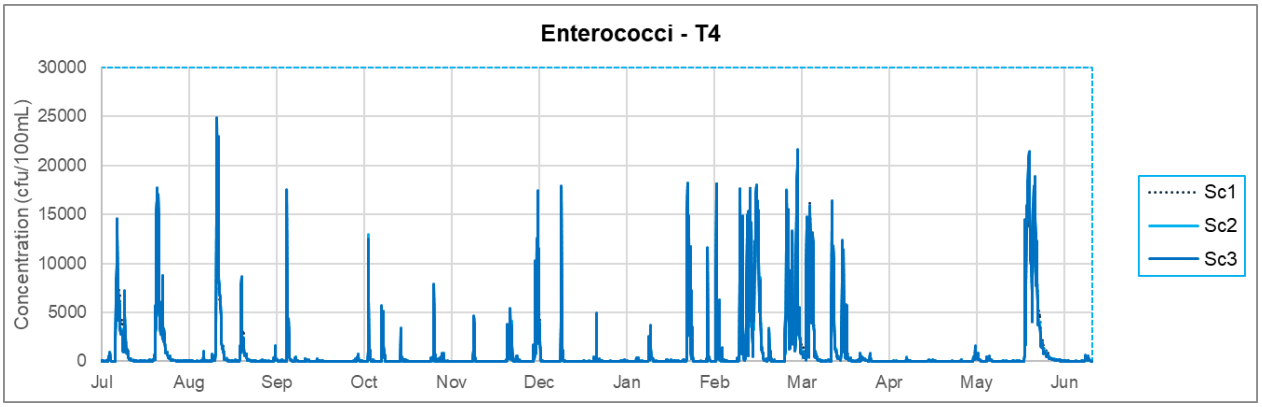


Time series plots



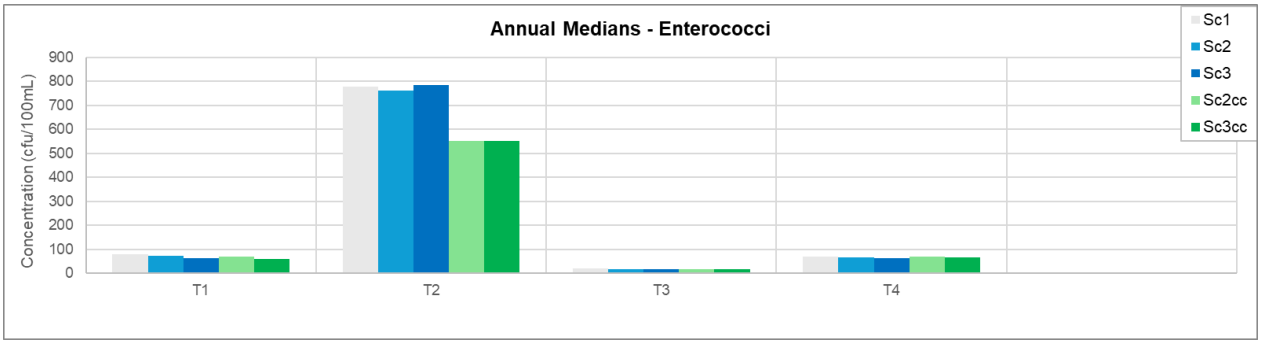


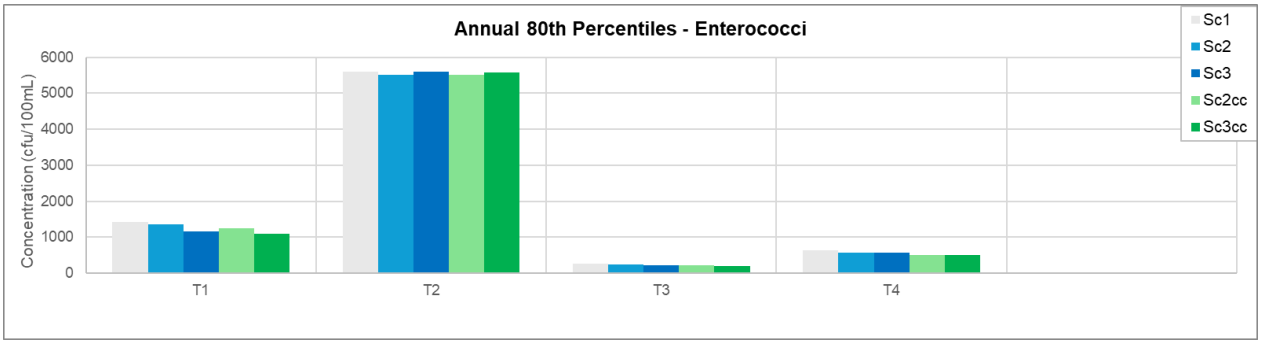


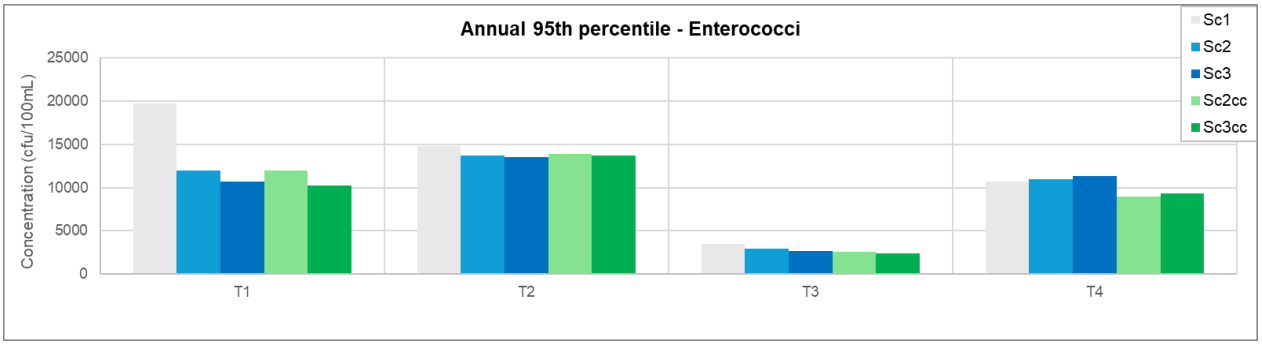


Appendices D5.11.3 Higher rainfall year scenario results (2021-2022)

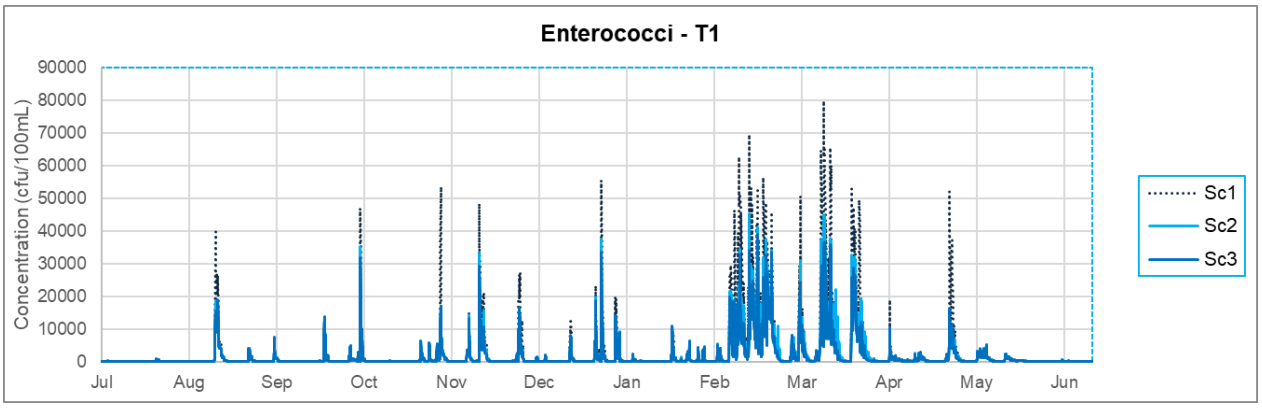
Bar charts

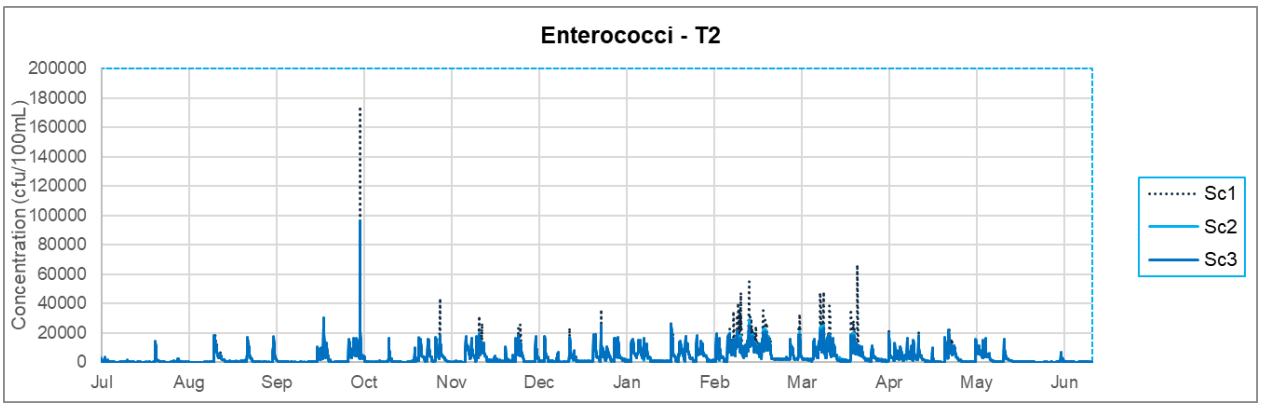


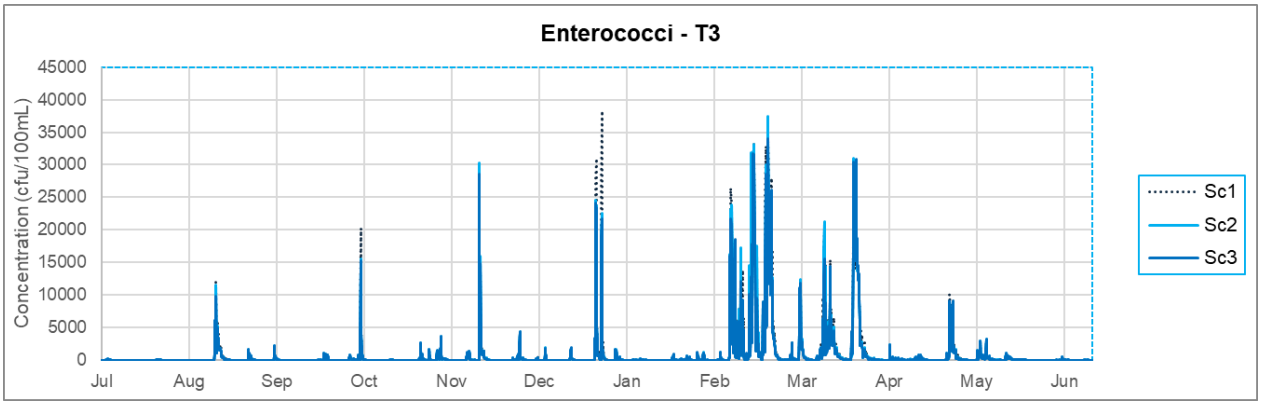


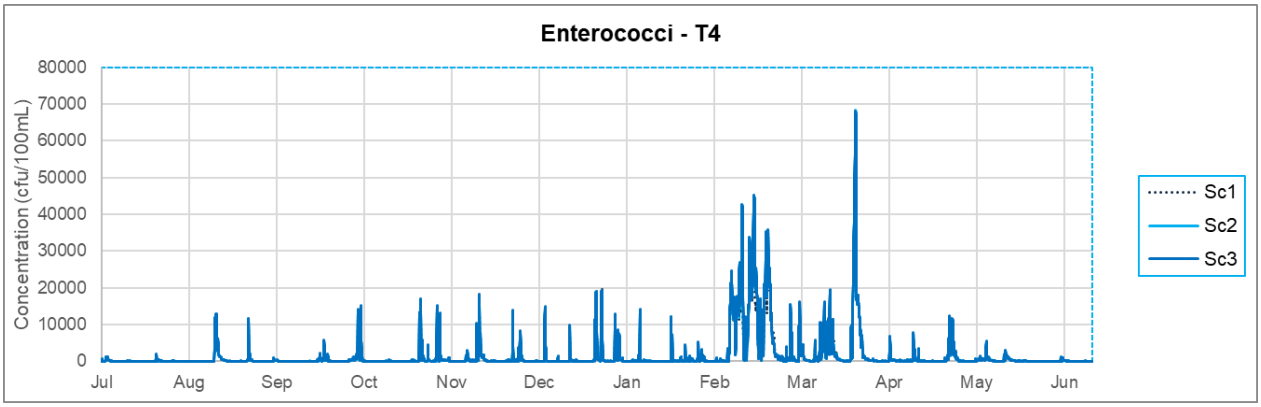


Time series plots







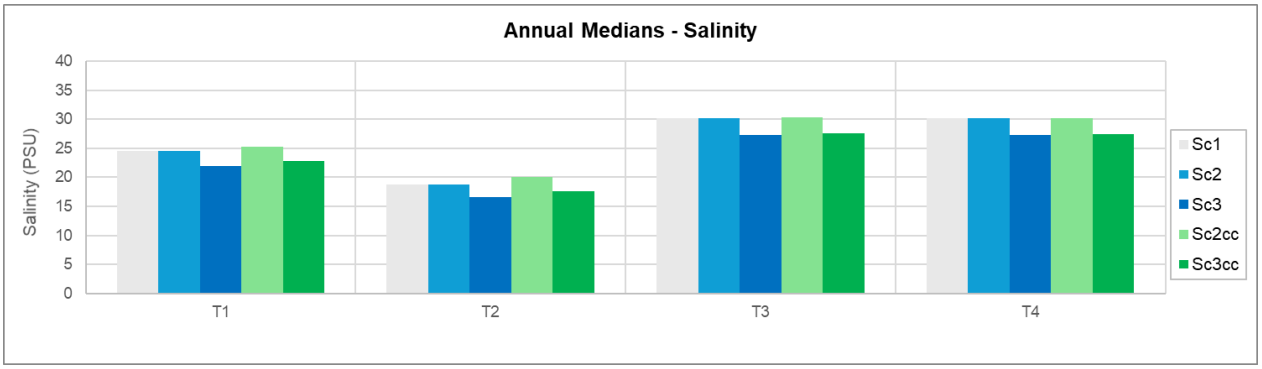

Enterococci - T4
Concentration (cfu/100mL)
80000
70000
60000
50000
40000
30000
20000
10000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

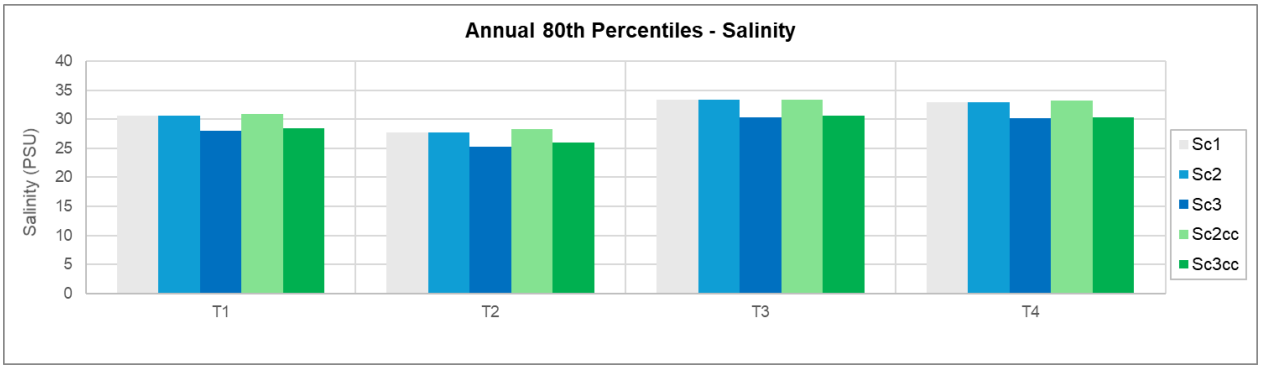
Appendices D6 SEARS reference sites results with climate change

Appendices D6.1 Salinity

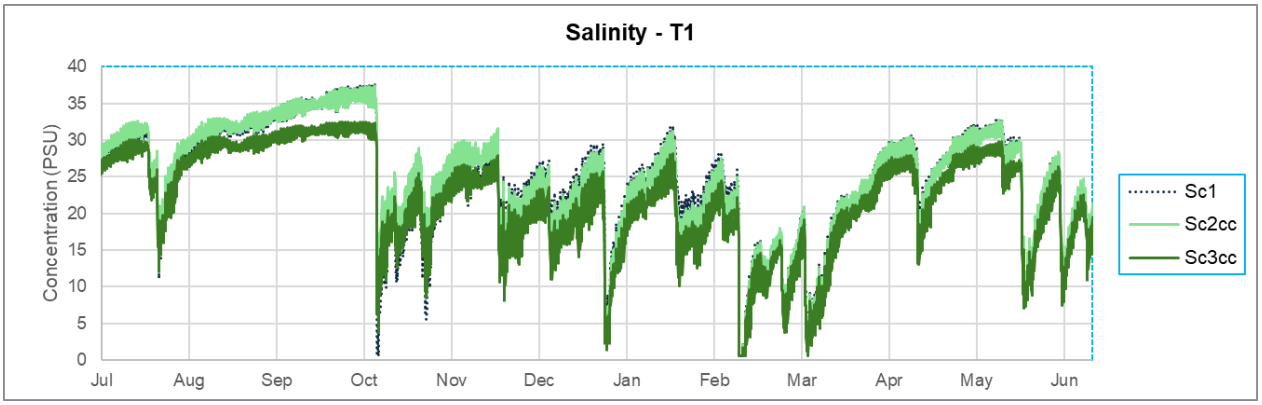
Appendices D6.1.1 Lower rainfall year scenario results (2017-2018)

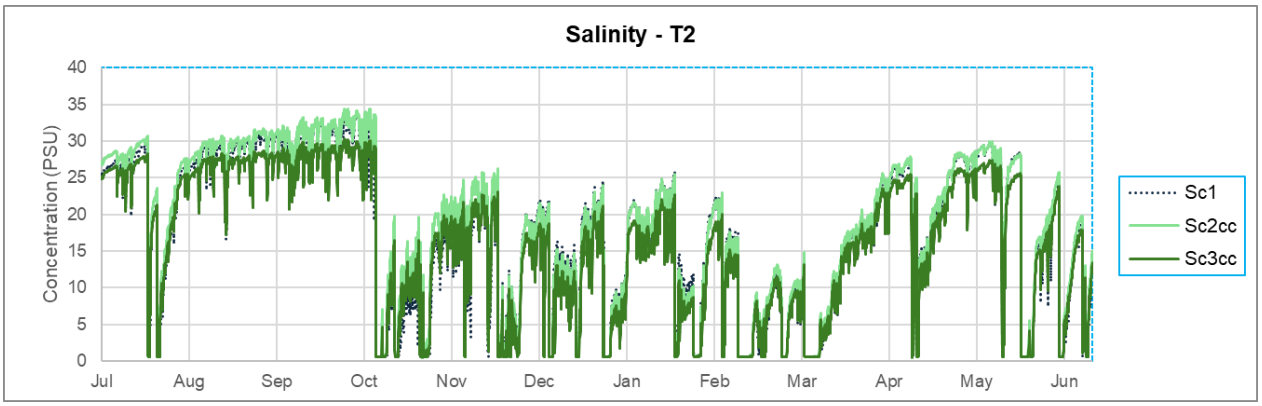
Bar charts

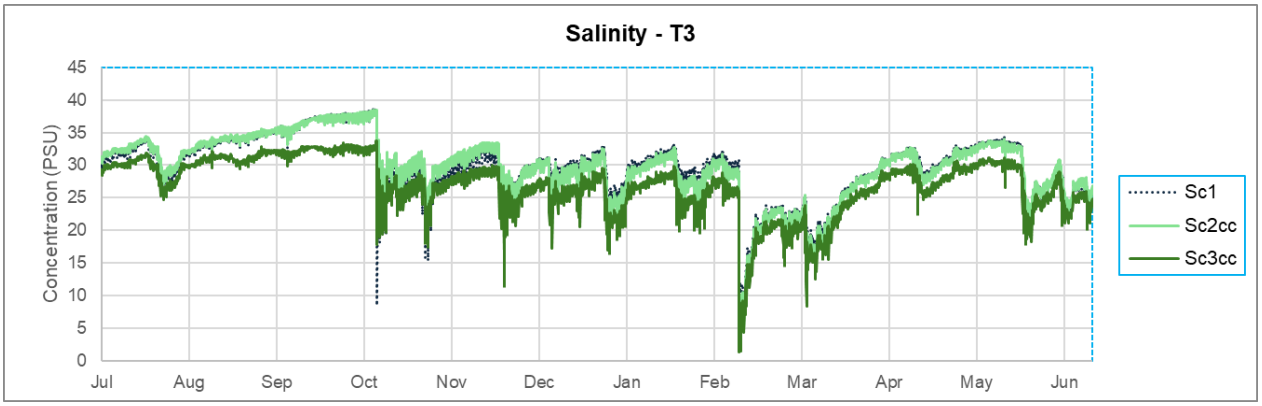


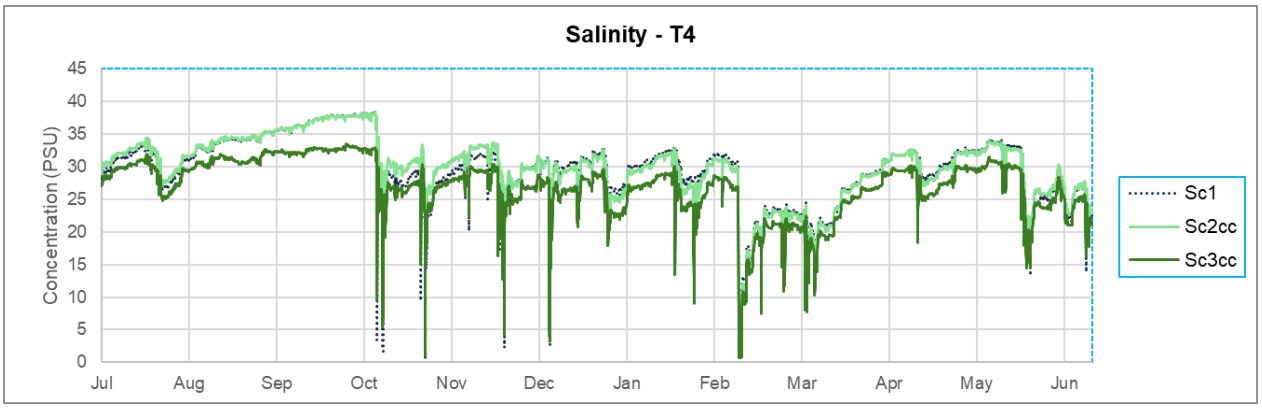


Time series plots



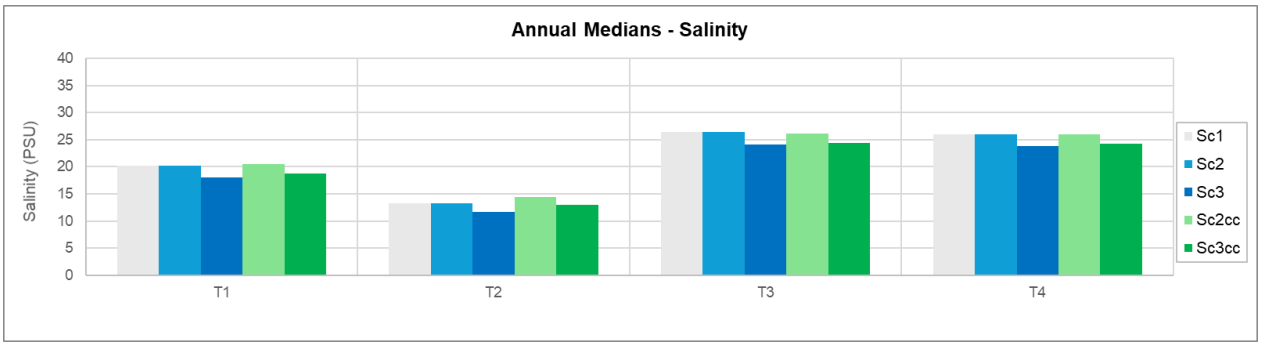


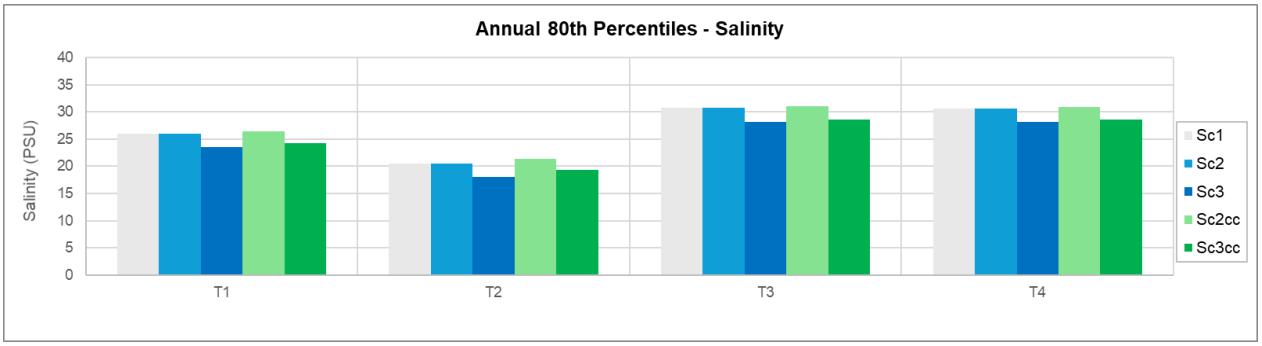




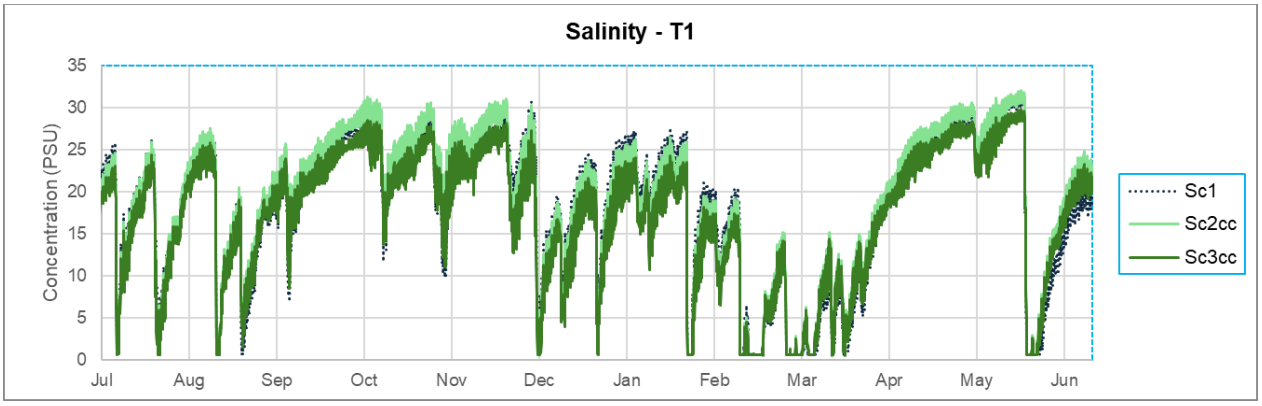
Appendices D6.1.2 Average rainfall year scenario results (2016-2017)

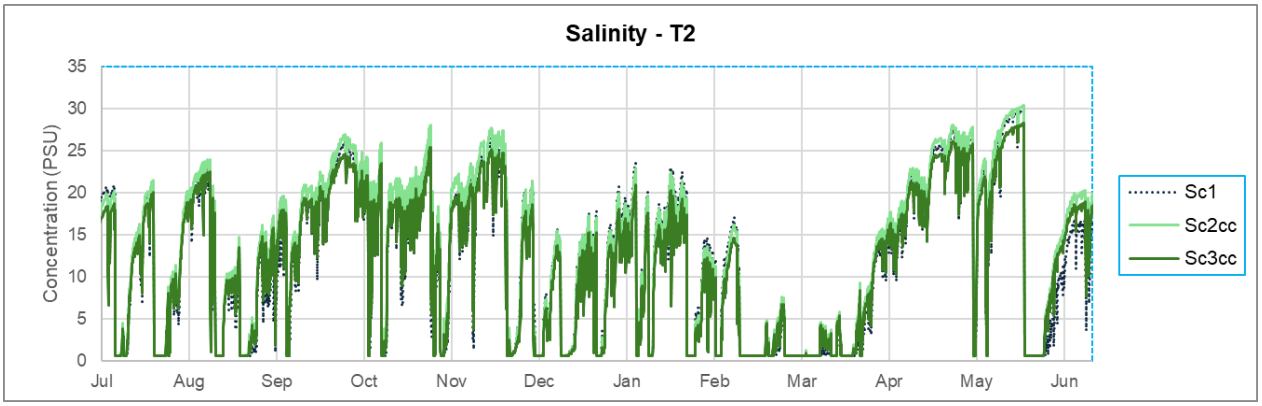
Bar charts

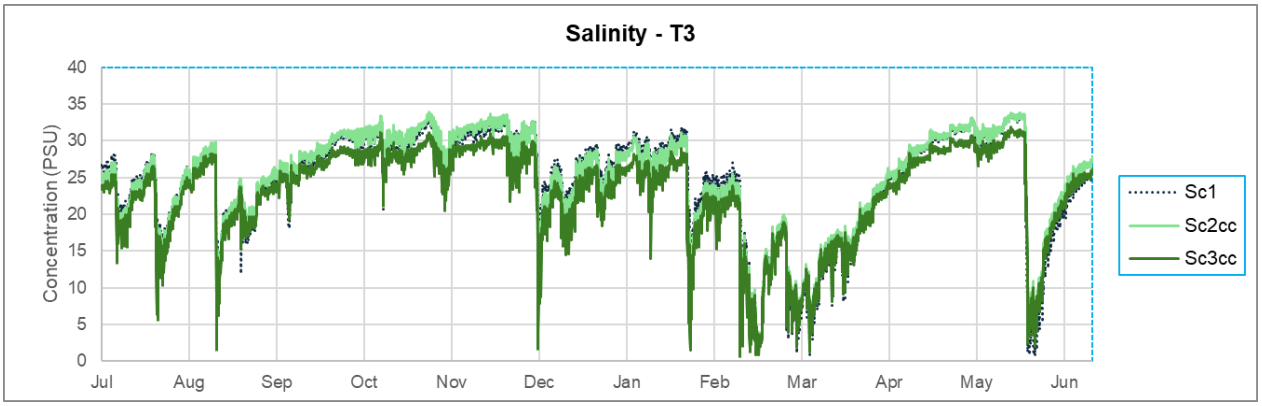


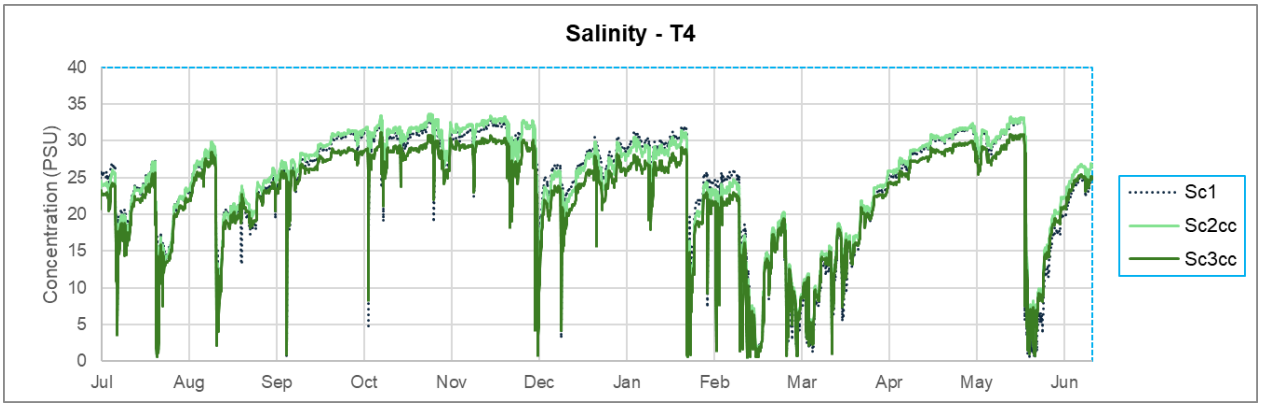


Time series plots



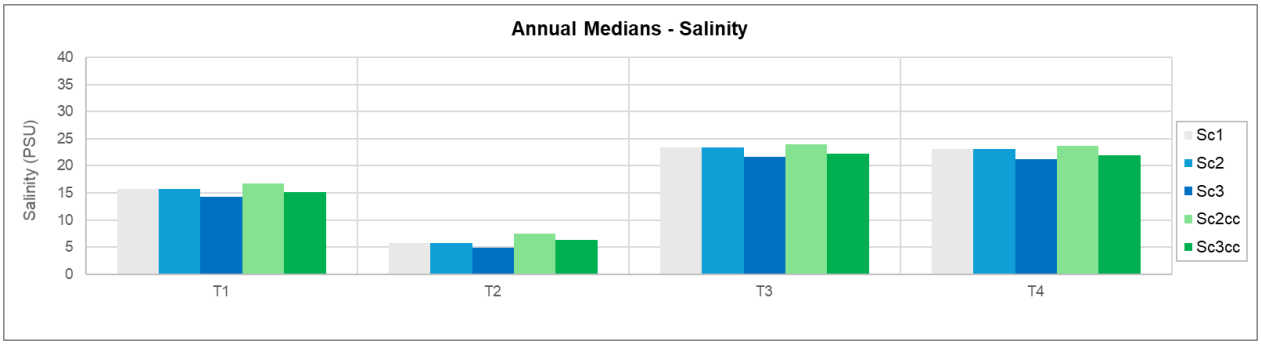


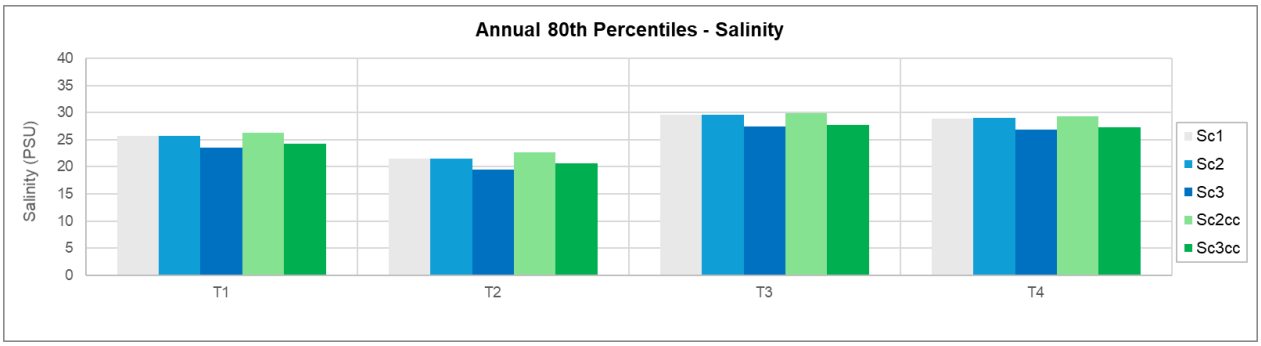




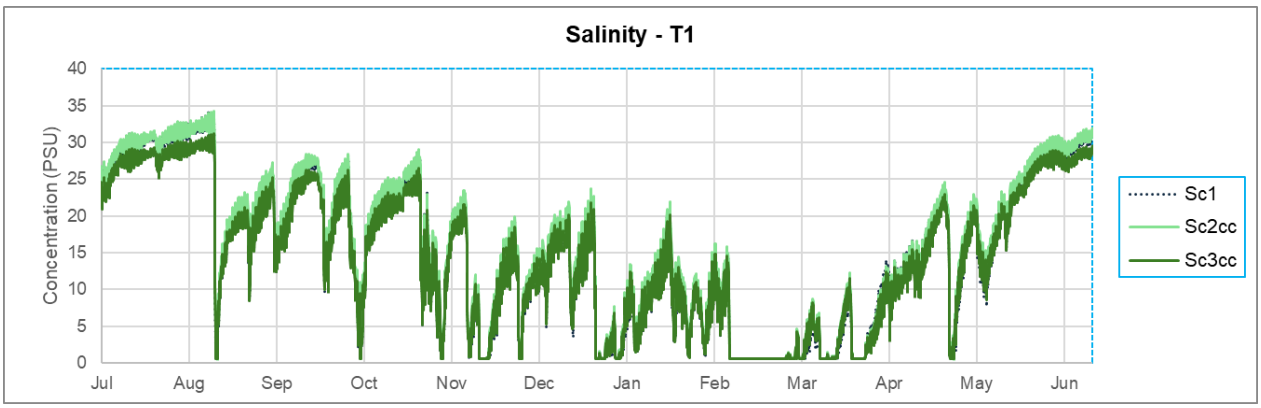
Appendices D6.1.3 Higher rainfall year scenario results (2021-2022)

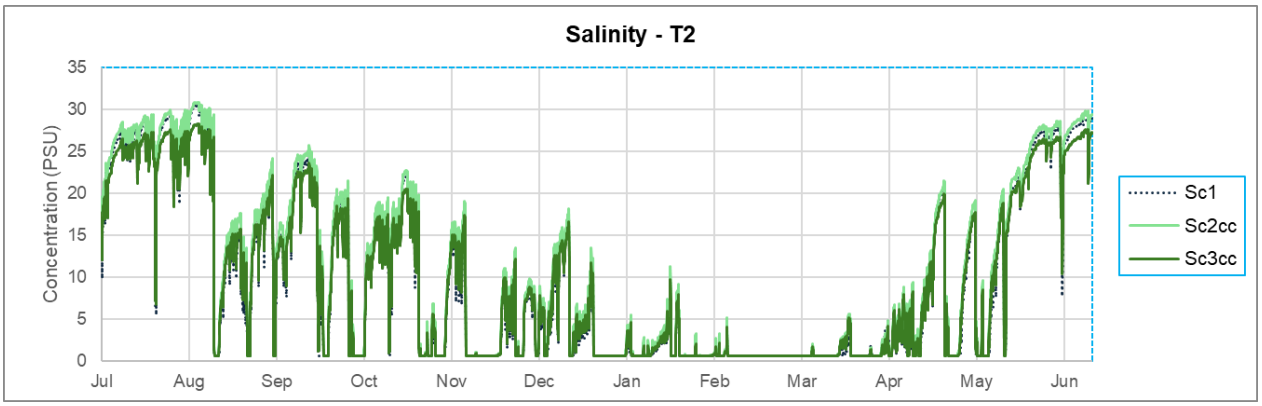
Bar charts

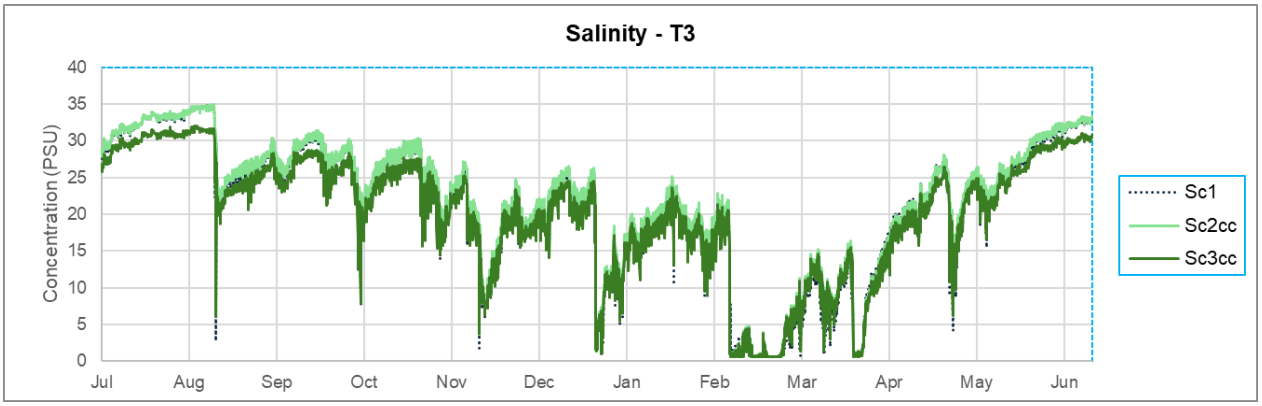


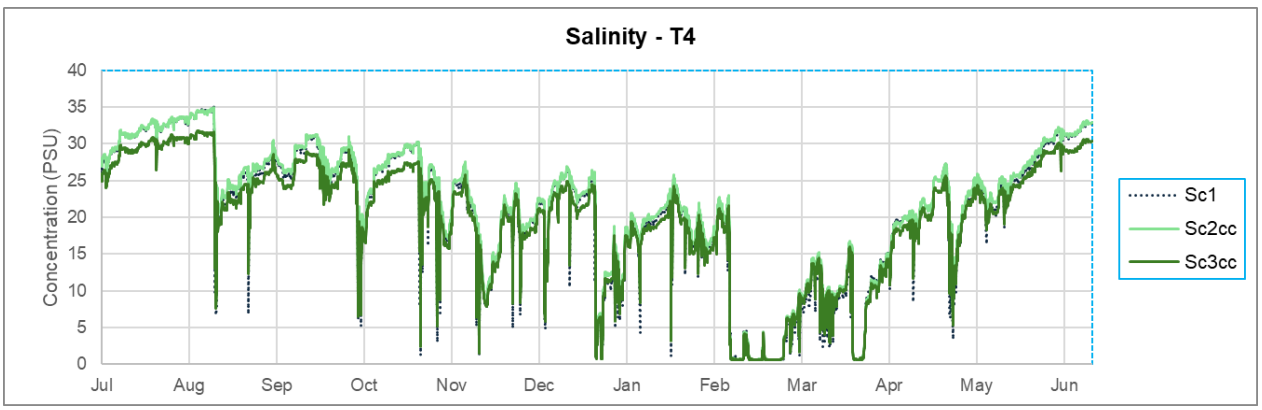


Time series plots




Salinity - T2
Concentration (PSU)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

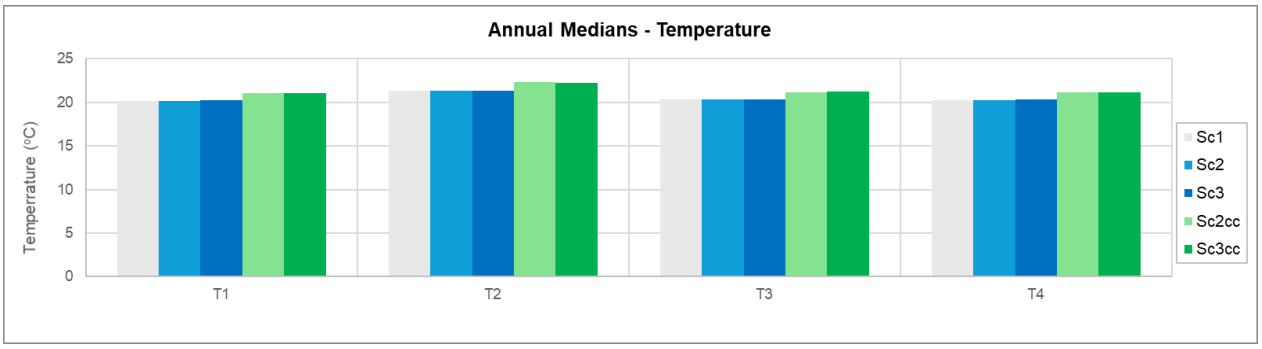

Salinity - T3
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

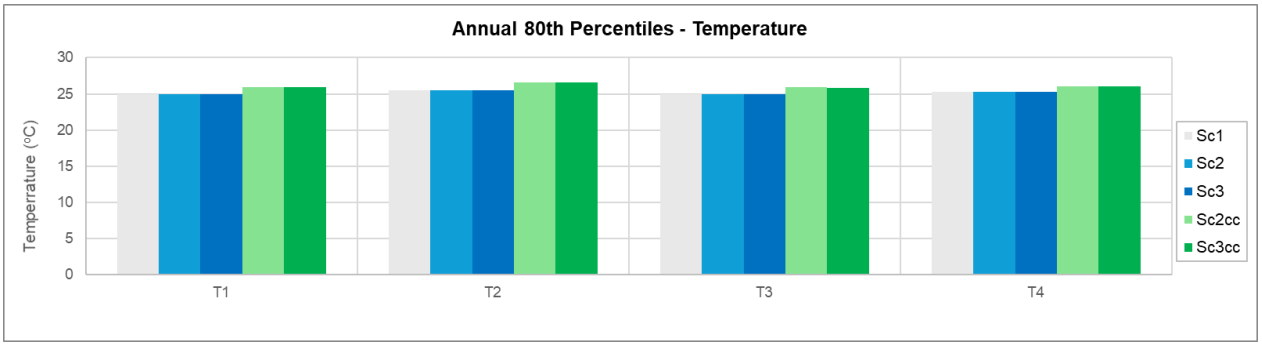

Salinity - T4
Concentration (PSU)
40
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.2 Temperature

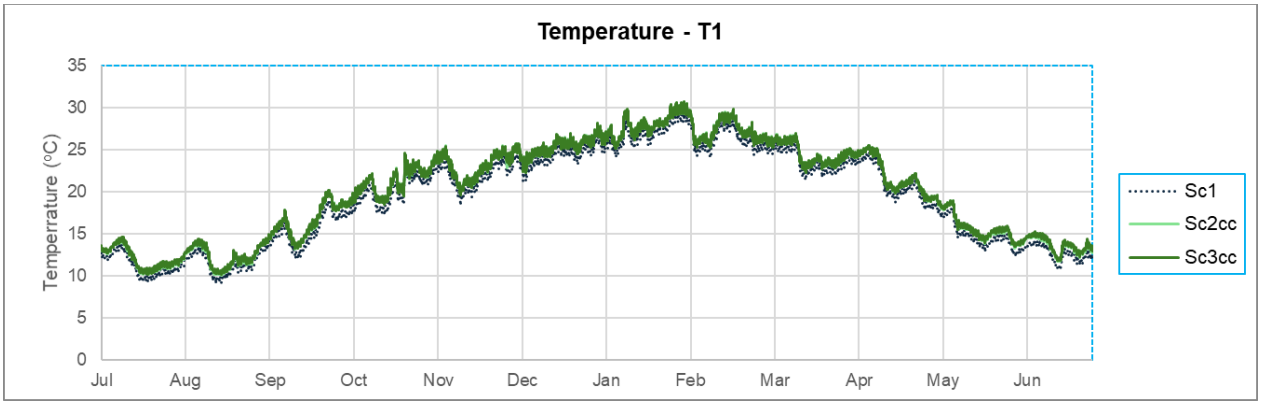
Appendices D6.2.1 Lower rainfall year scenario results (2017-2018)

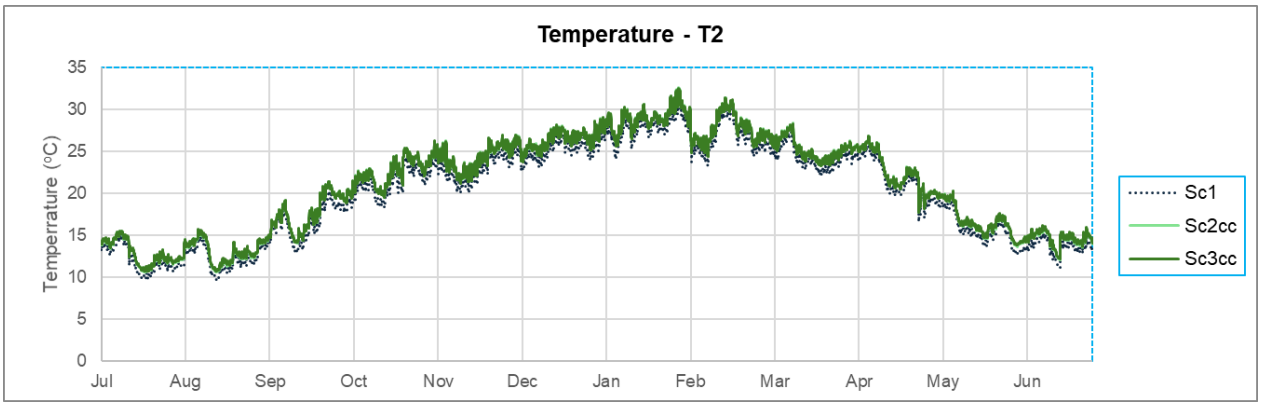
Bar charts

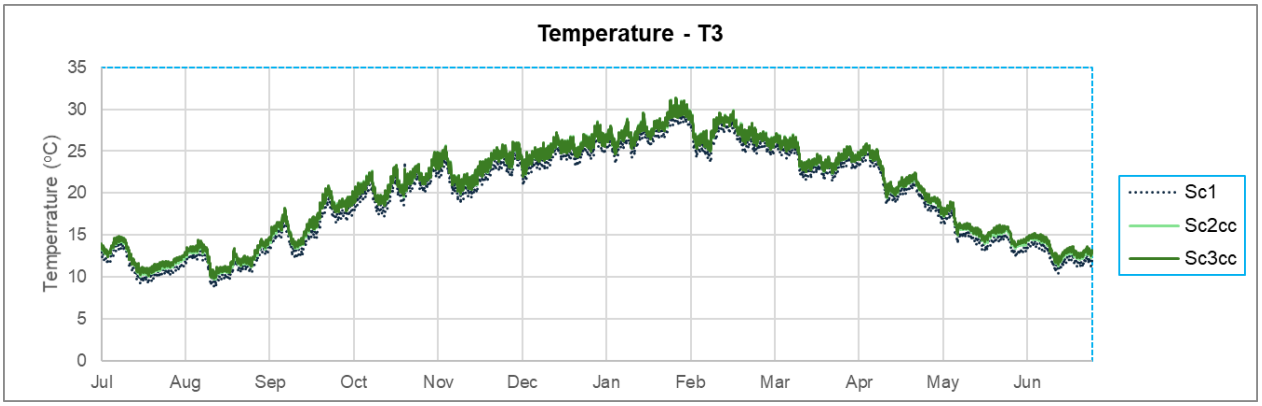


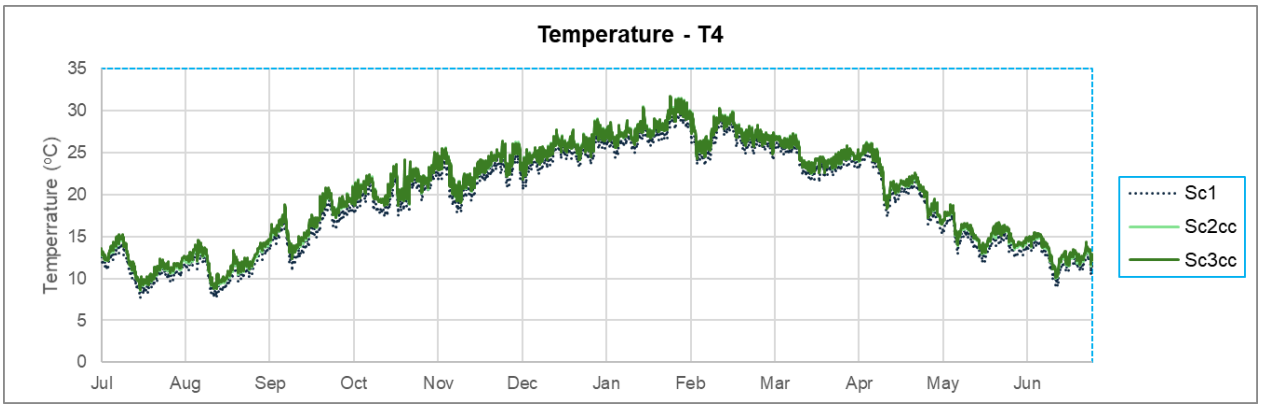


Time series plots



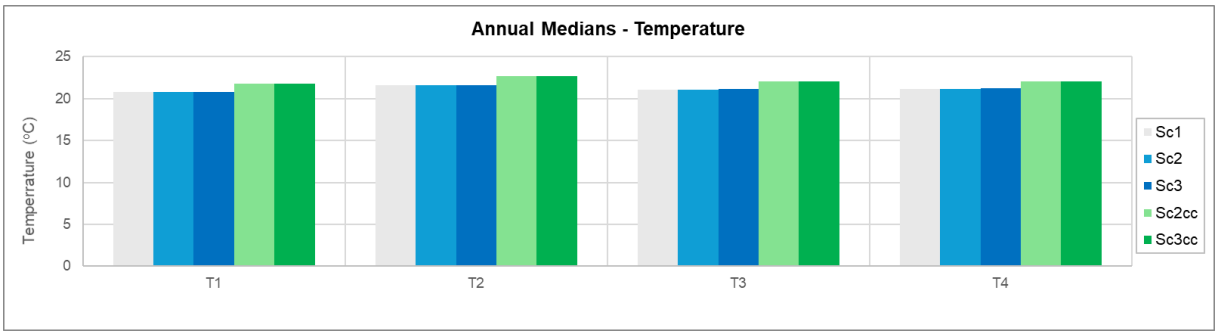


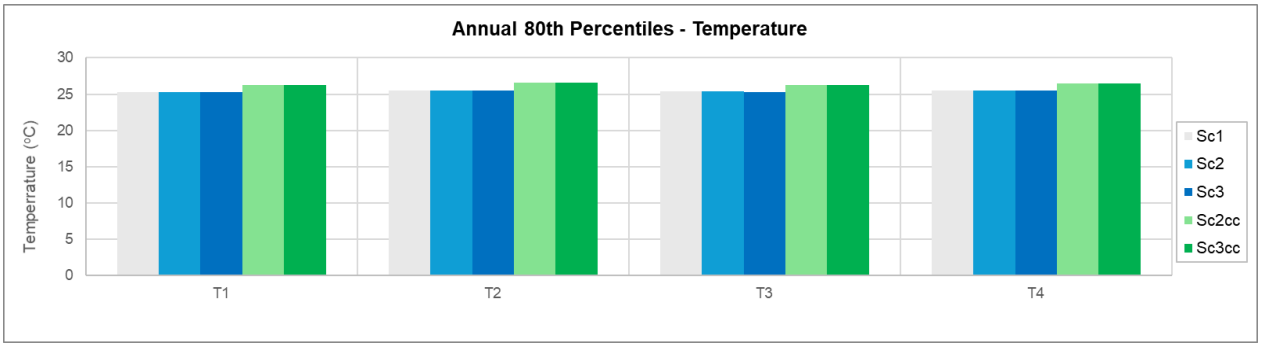




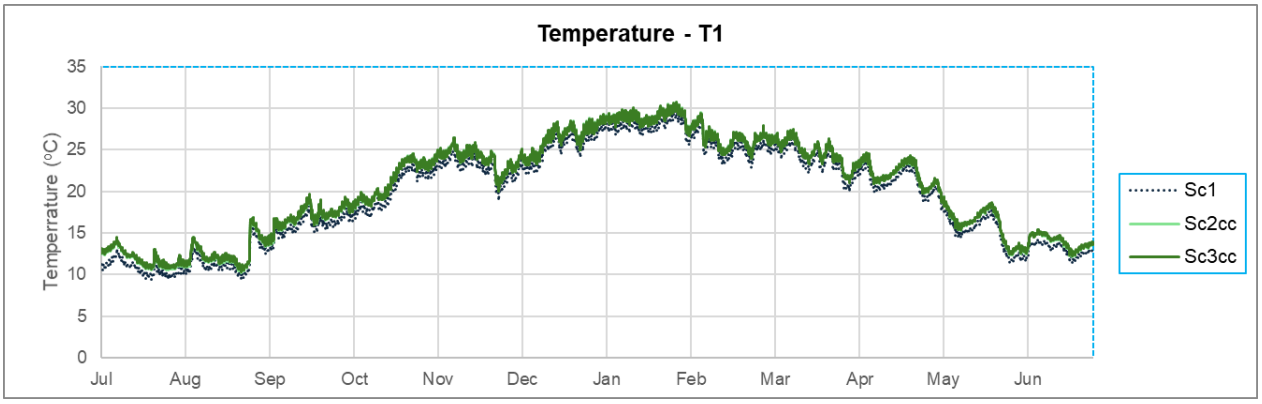
Appendices D6.2.2 Average rainfall year scenario results (2016-2017)

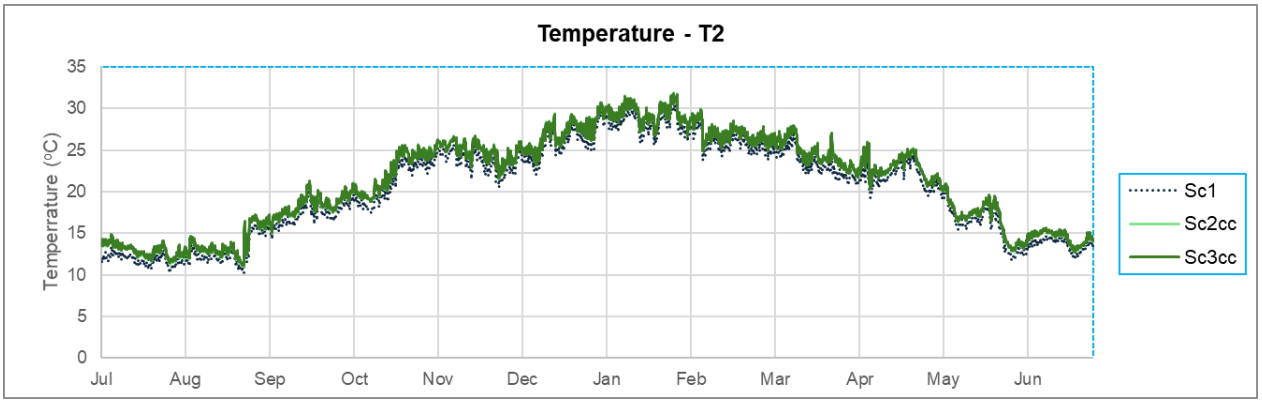
Bar charts

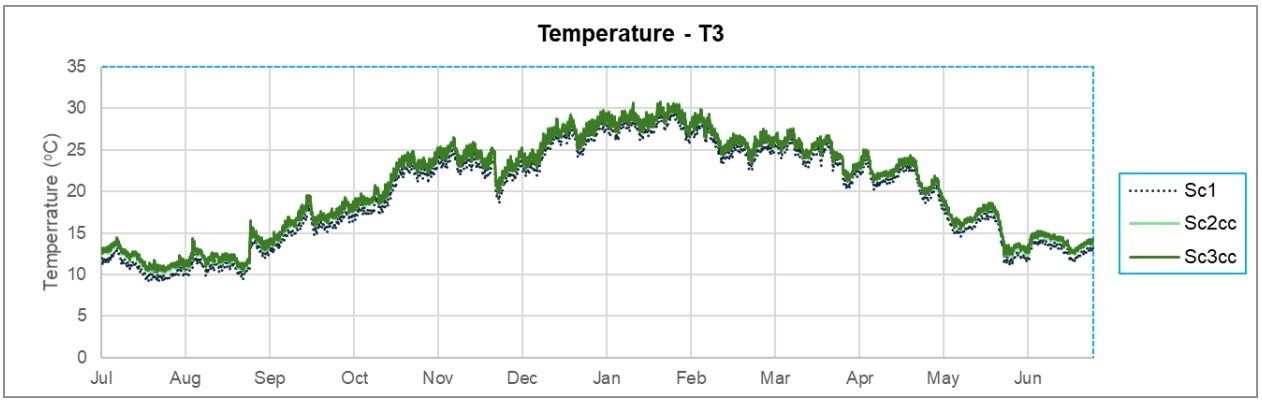


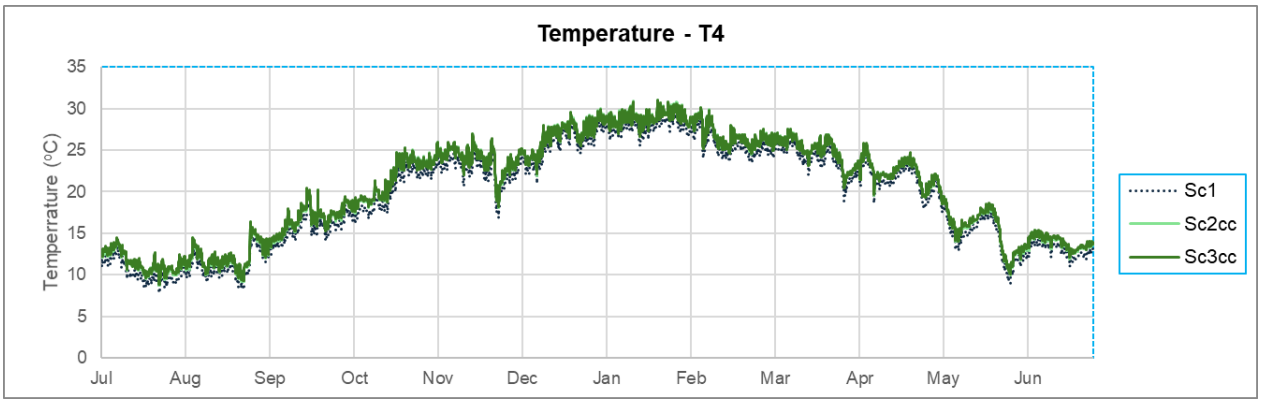


Time series plots



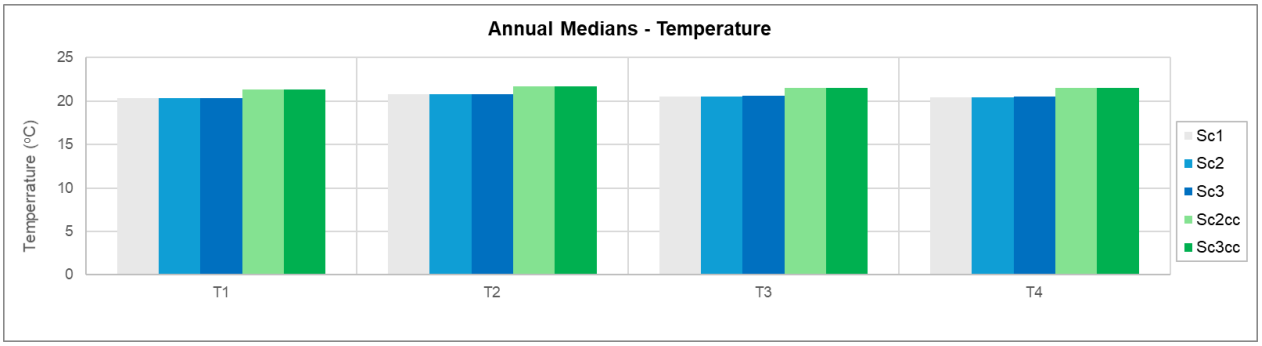


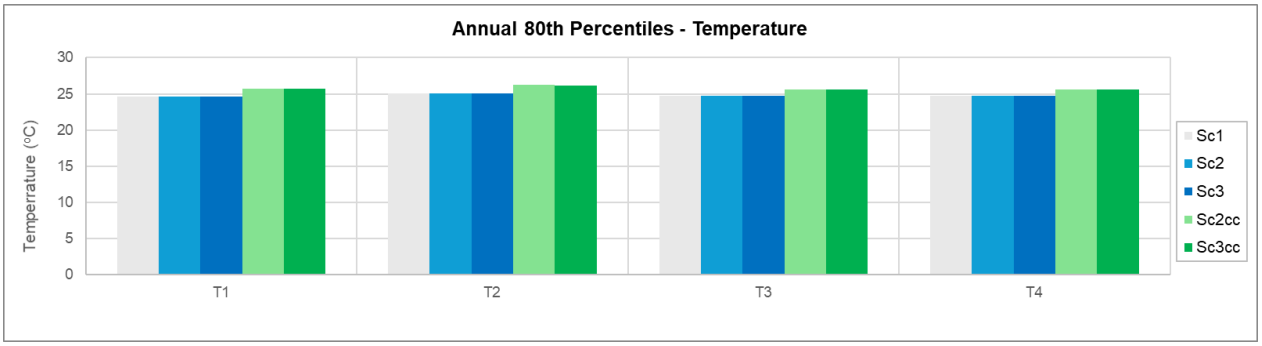




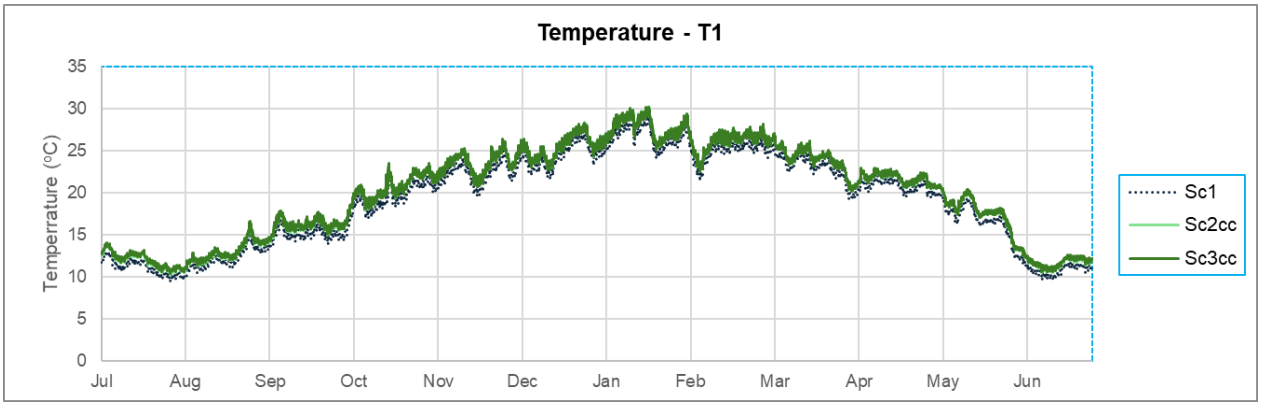
Appendices D6.2.3 Higher rainfall year scenario results (2021-2022)

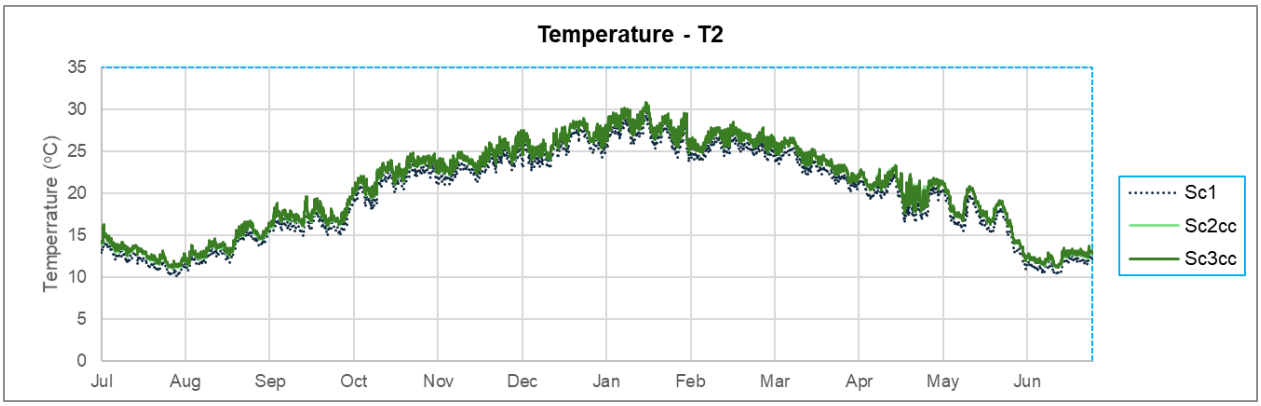
Bar charts

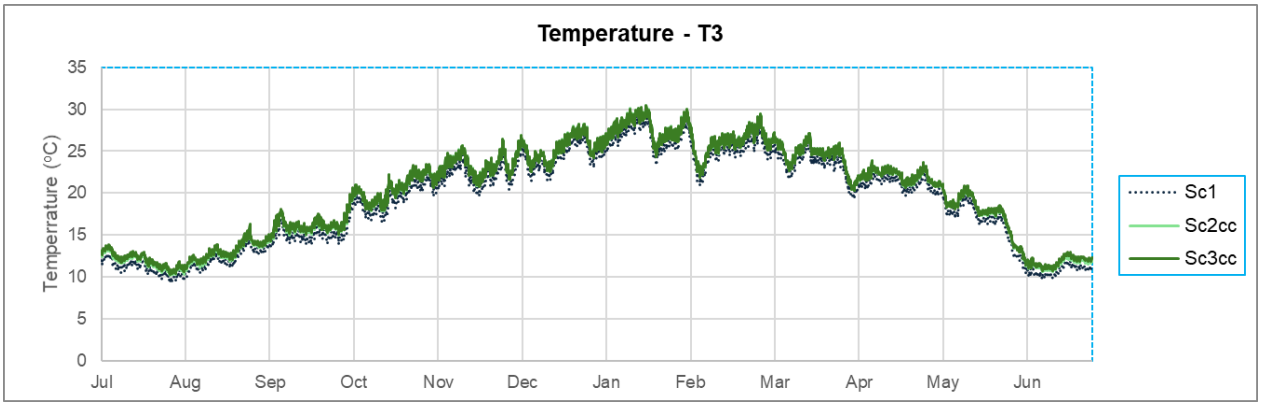


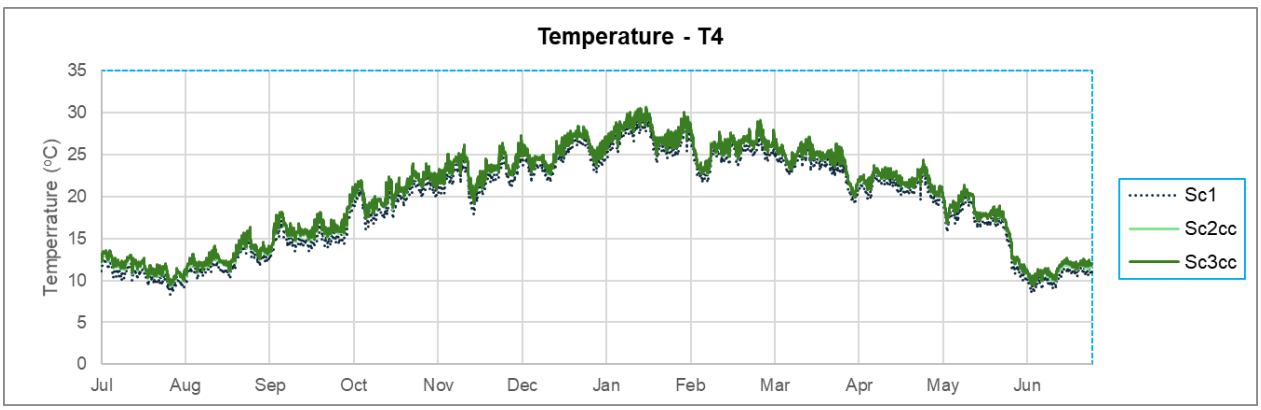


Time series plots




Temperature - T2
Temperrature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

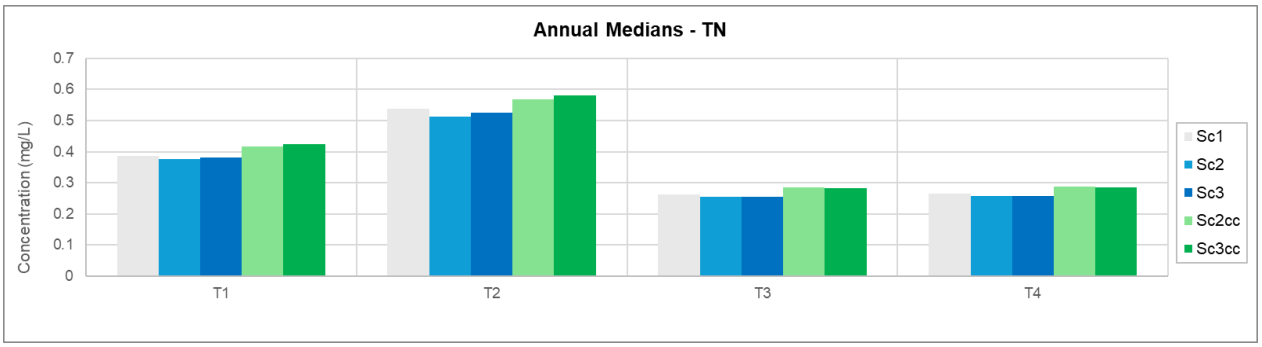

Temperature - T3
Temperrature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

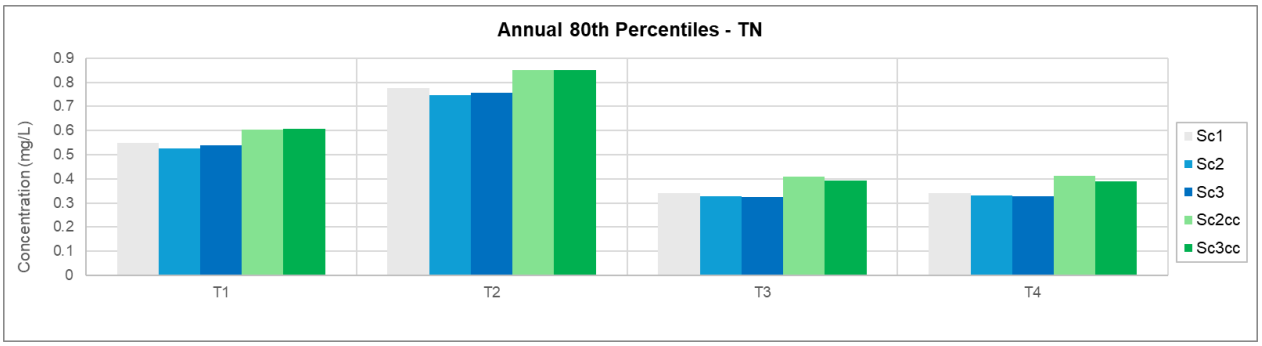

Temperature - T4
Temperrature (°C)
35
30
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.3 Total N

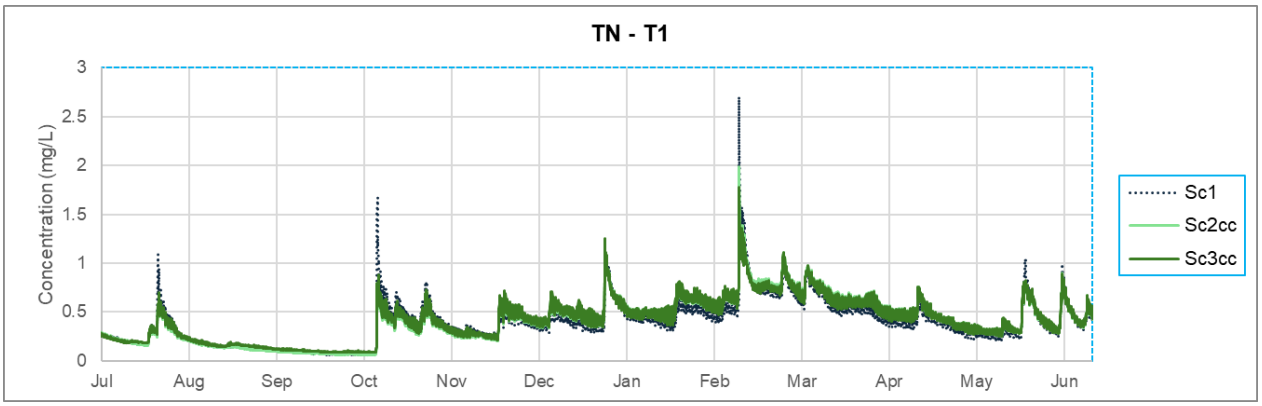
Appendices D6.3.1 Lower rainfall year scenario results (2017-2018)

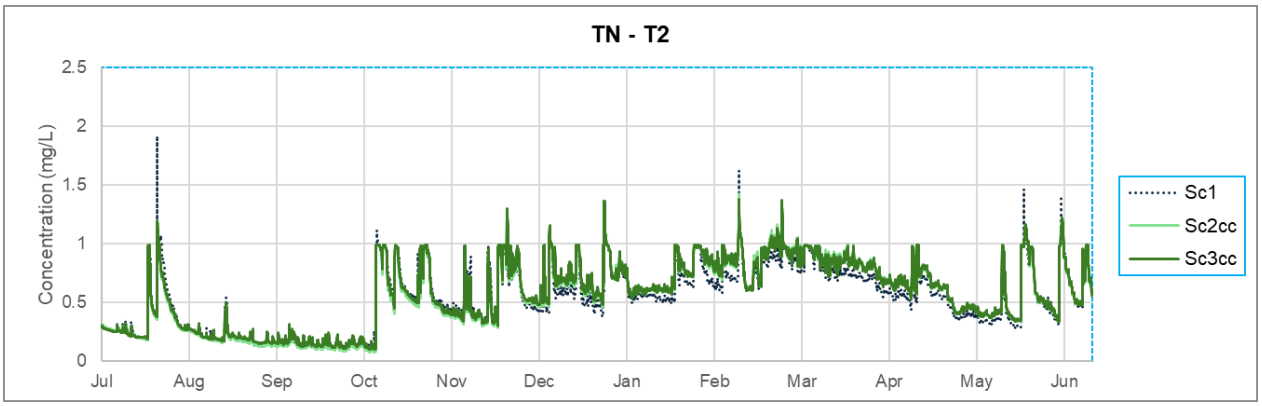
Bar charts

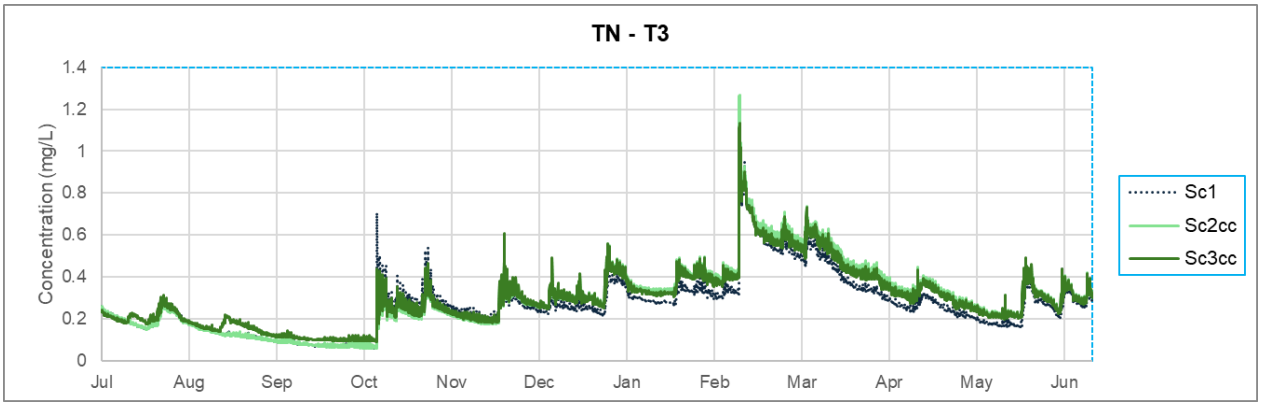


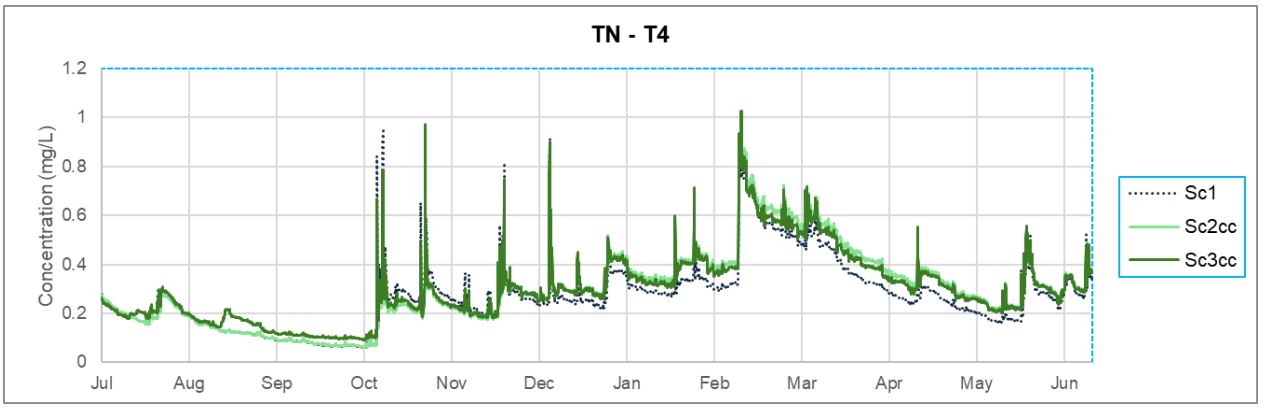


Time series plots



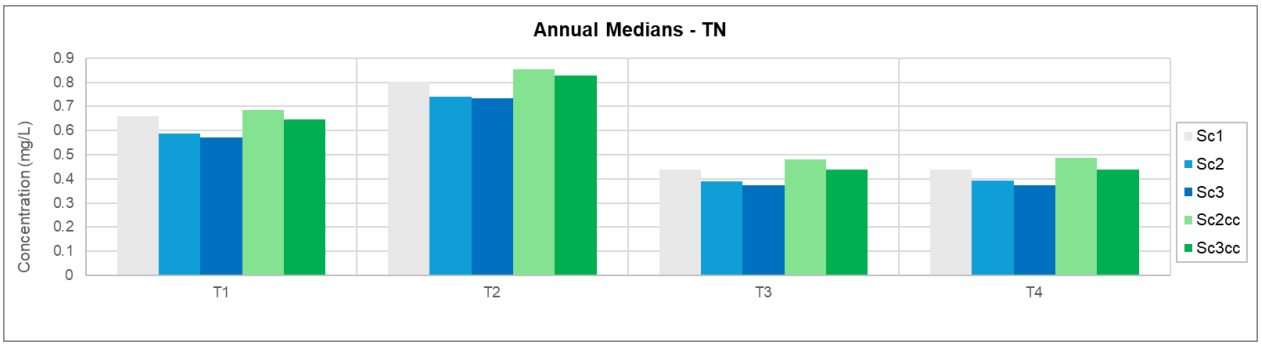


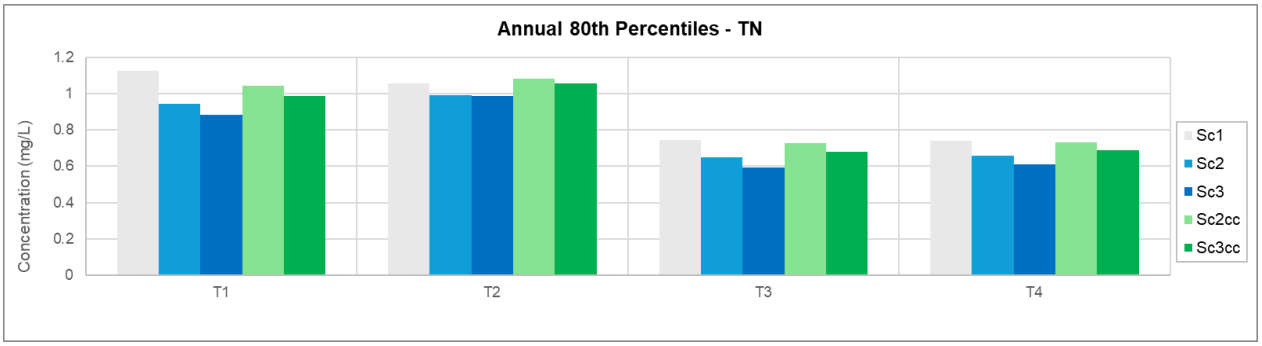




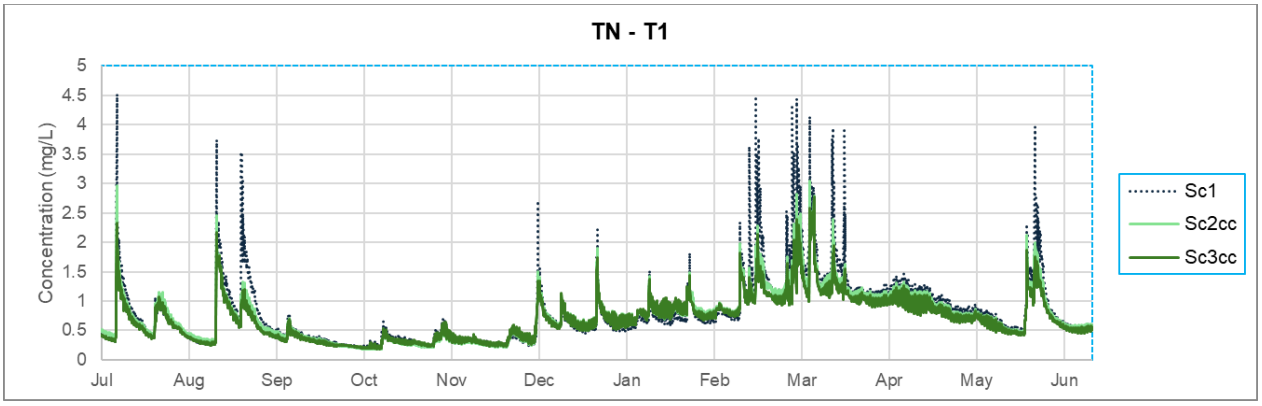
Appendices D6.3.2 Average rainfall year scenario results (2016-2017)

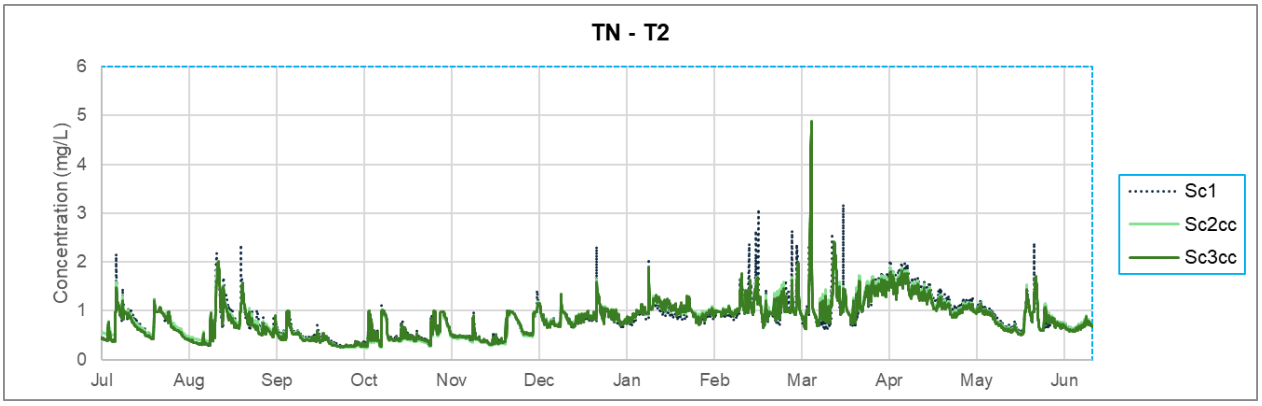
Bar charts

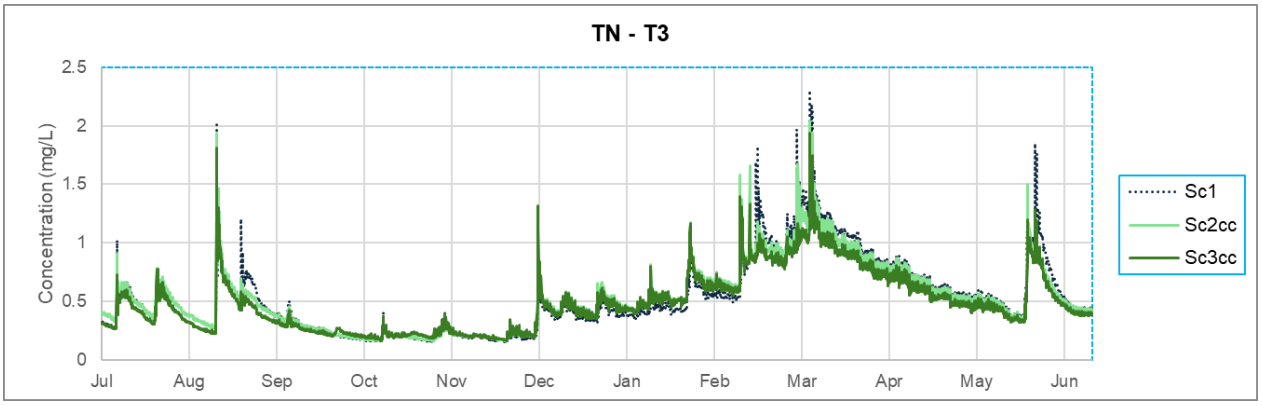


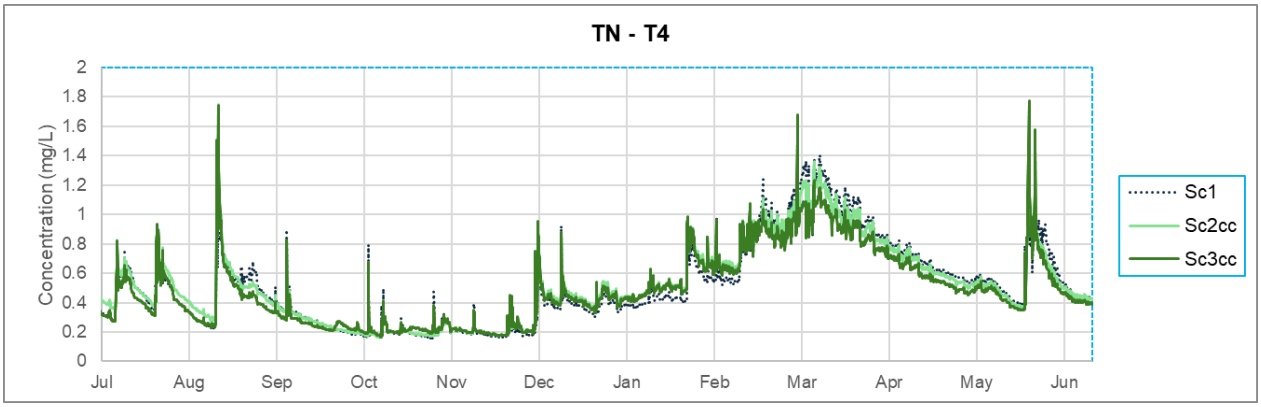


Time series plots



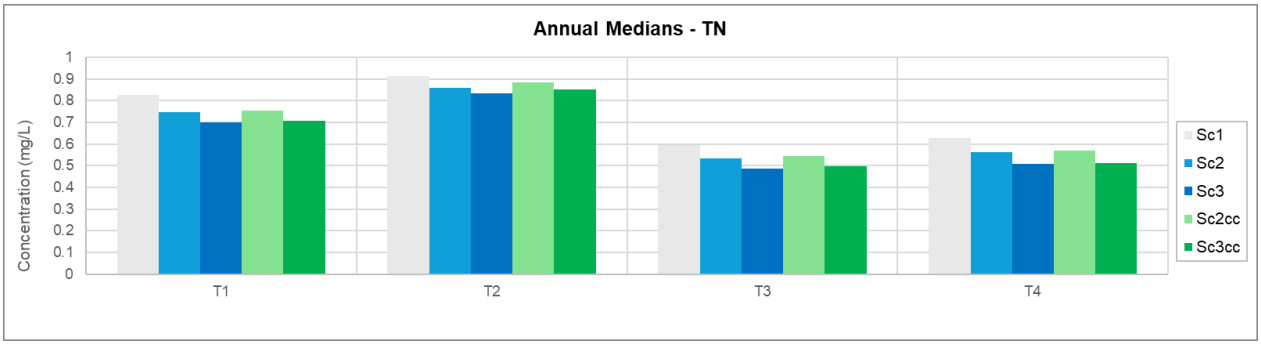


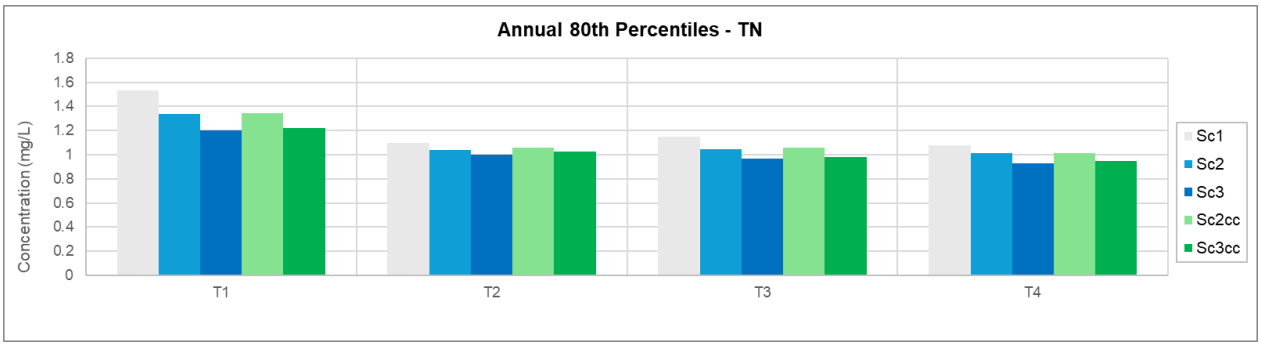




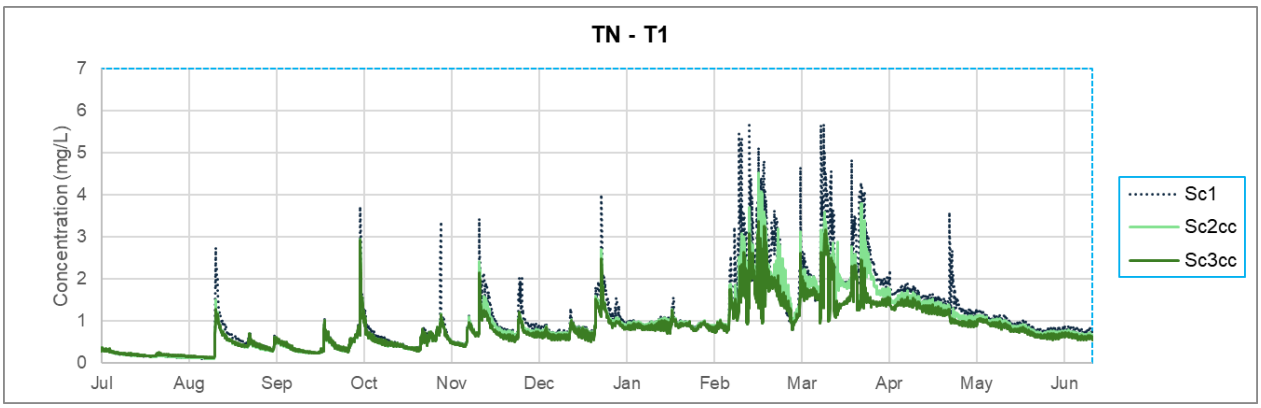
Appendices D6.3.3 Higher rainfall year scenario results (2021-2022)

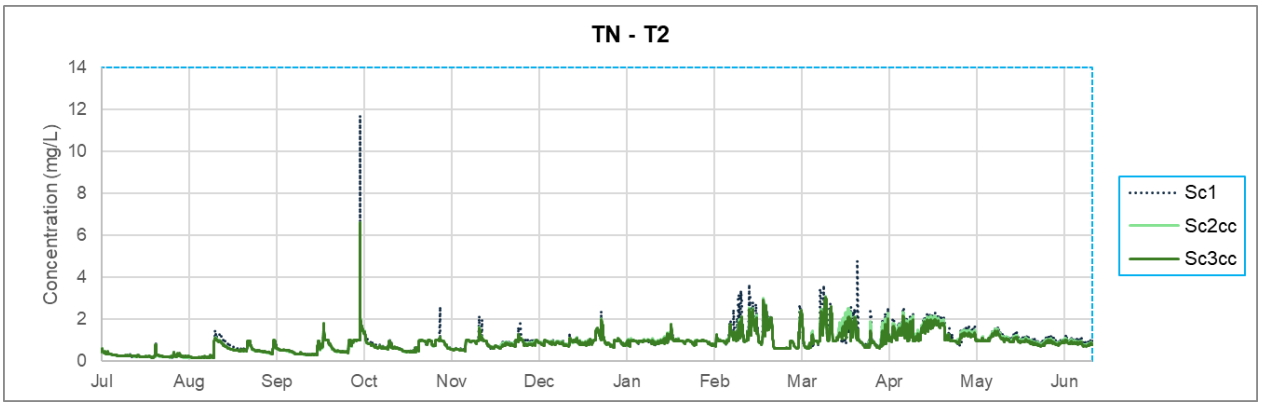
Bar charts

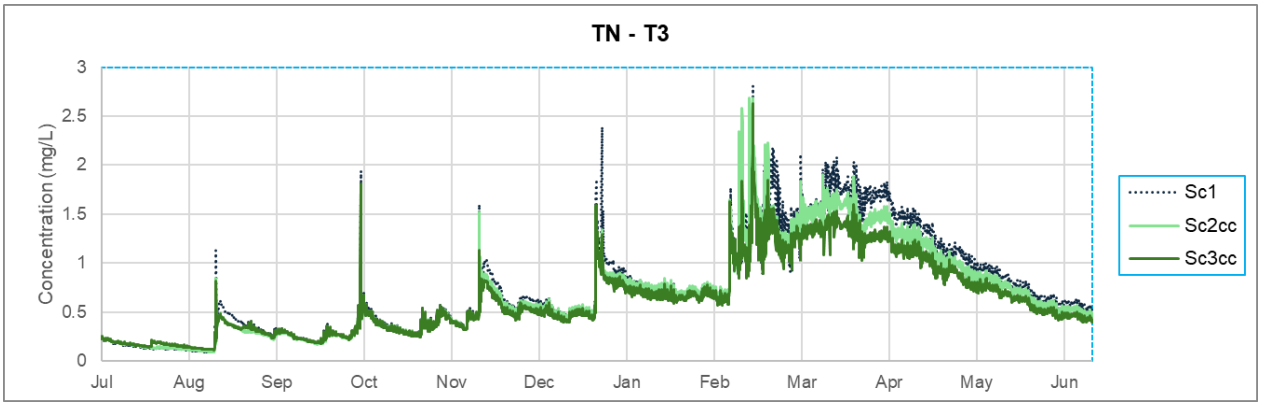


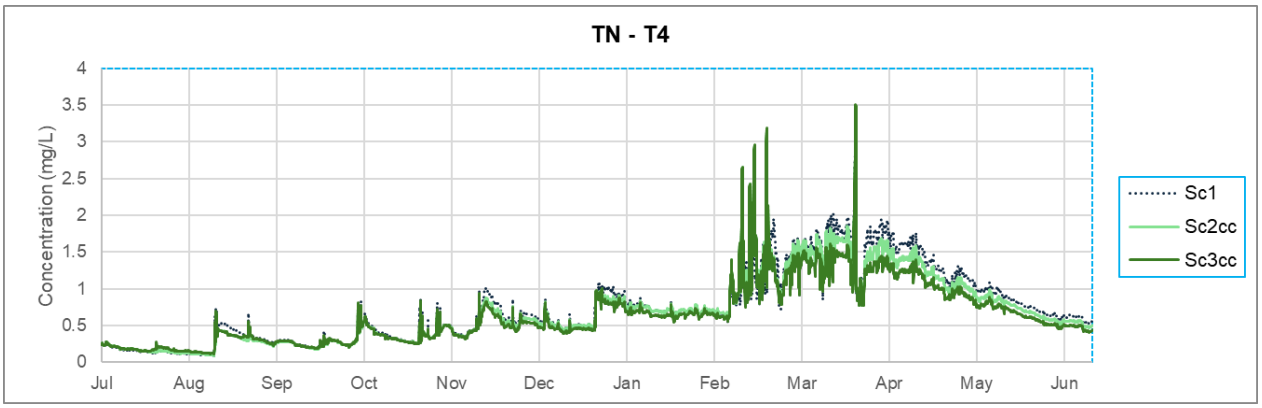


Time series plots




TN - T2
Concentration (mg/L)
14
12
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

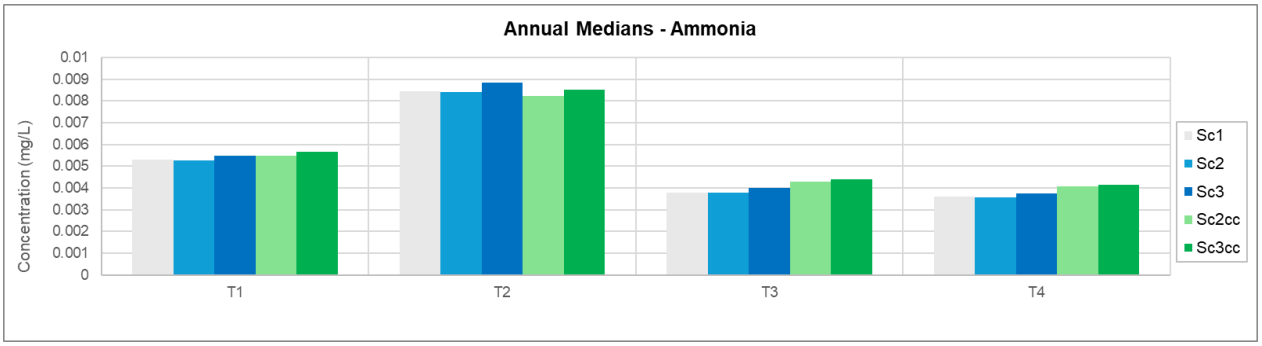

TN - T3
Concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

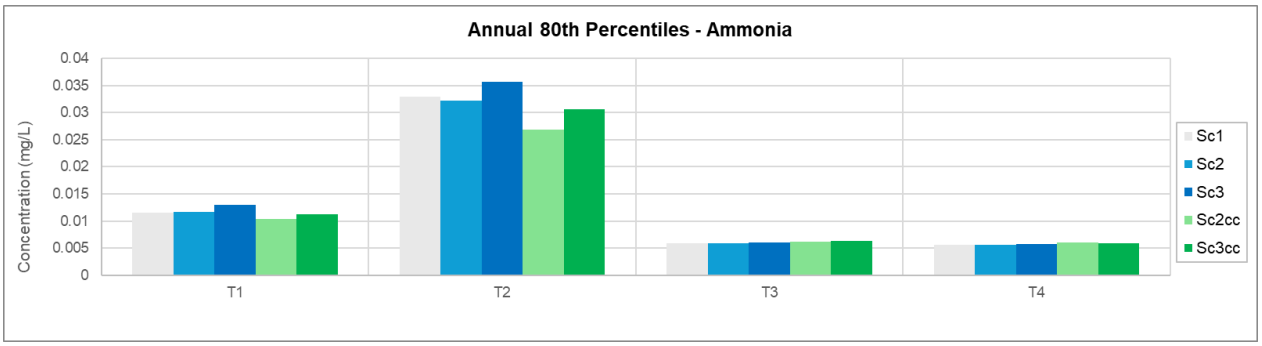

TN - T4
Concentration (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.4 Ammonia

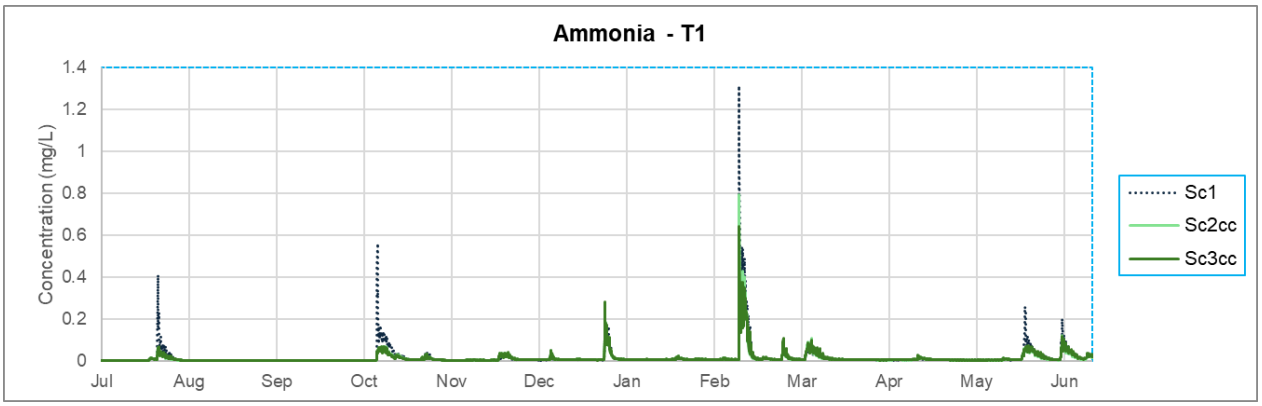
Appendices D6.4.1 Lower rainfall year scenario results (2017-2018)

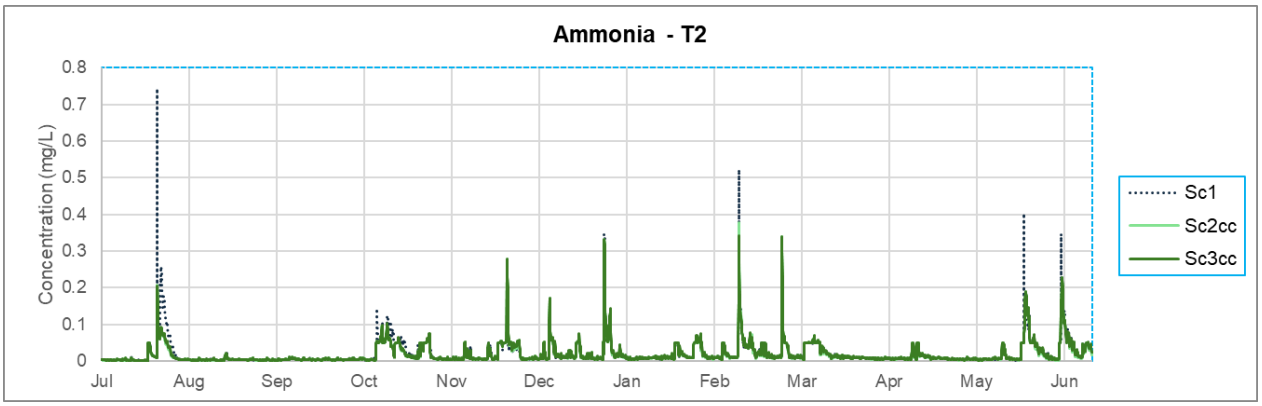
Bar charts

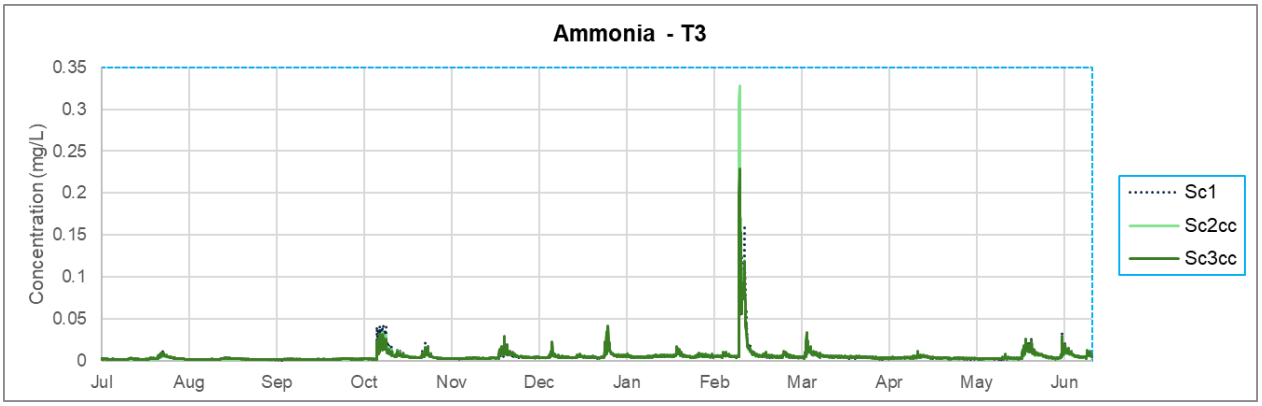


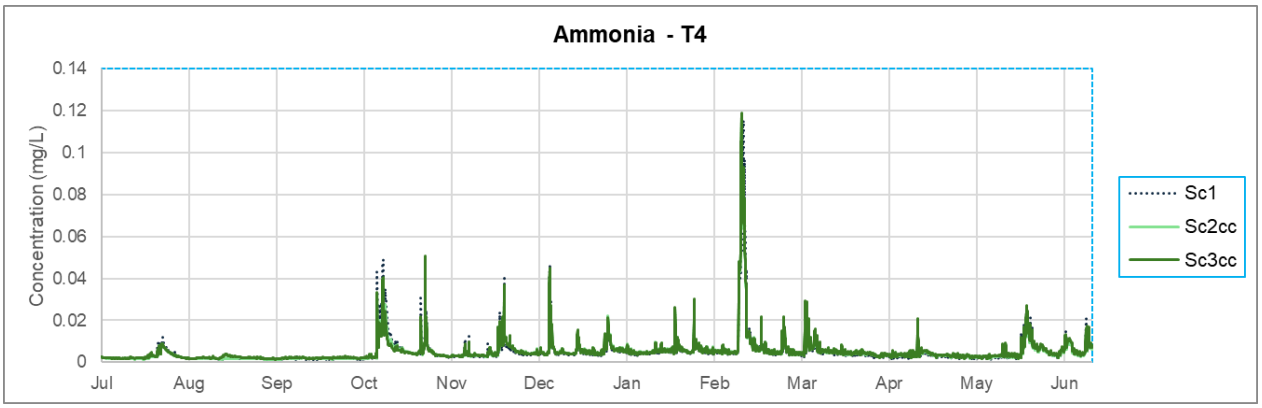


Time series plots



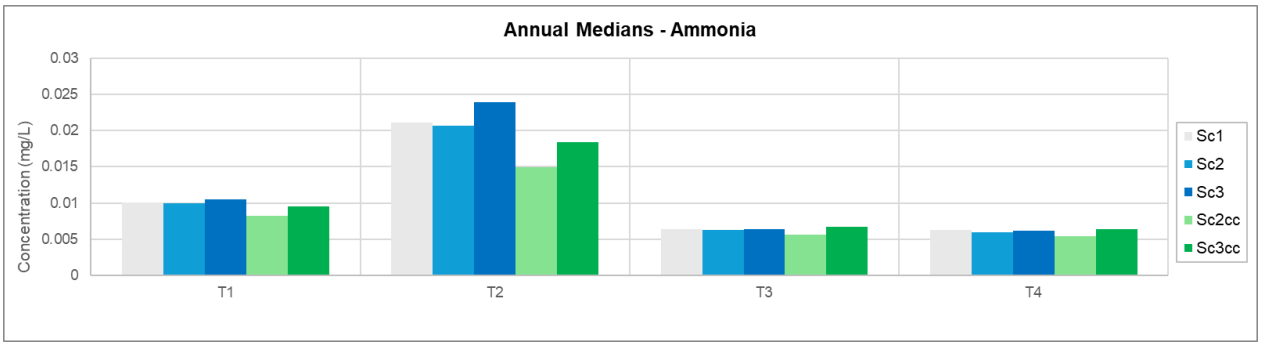


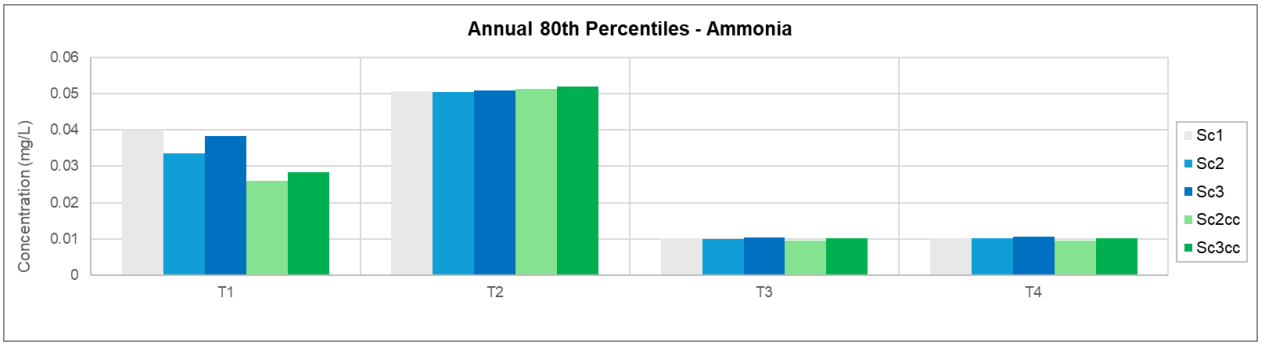




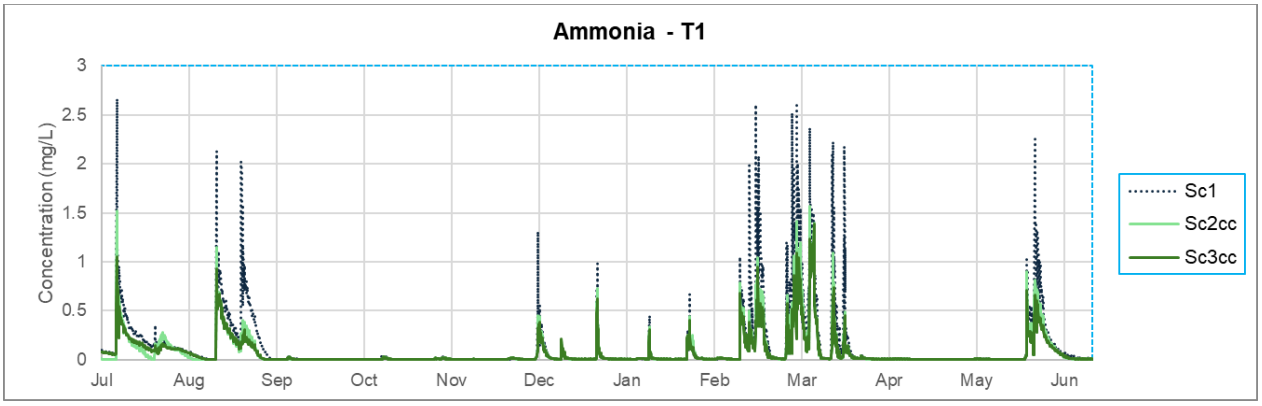
Appendices D6.4.2 Average rainfall year scenario results (2016-2017)

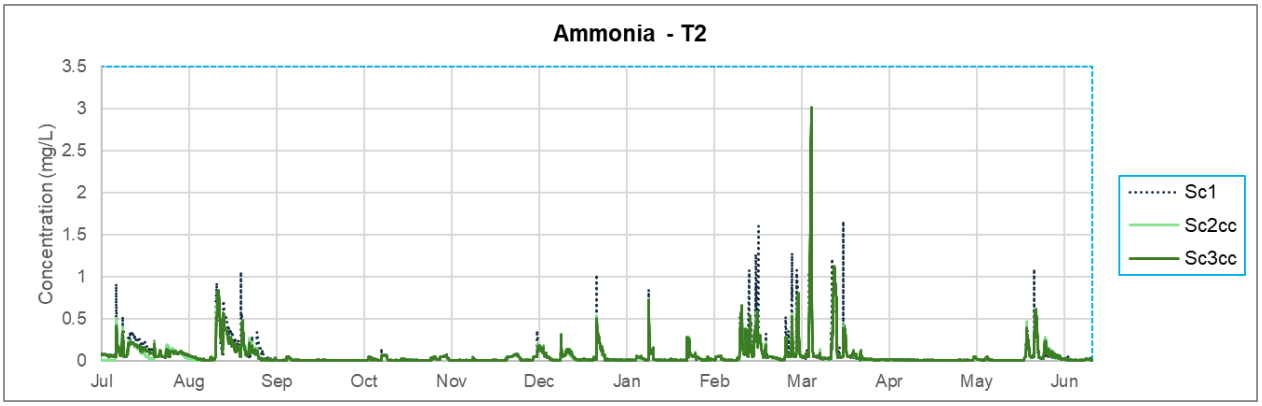
Bar charts

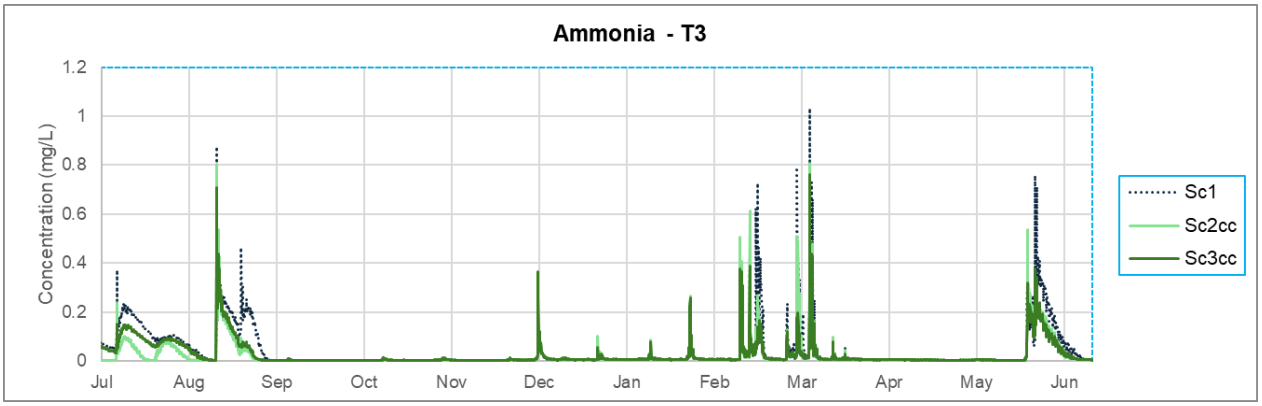


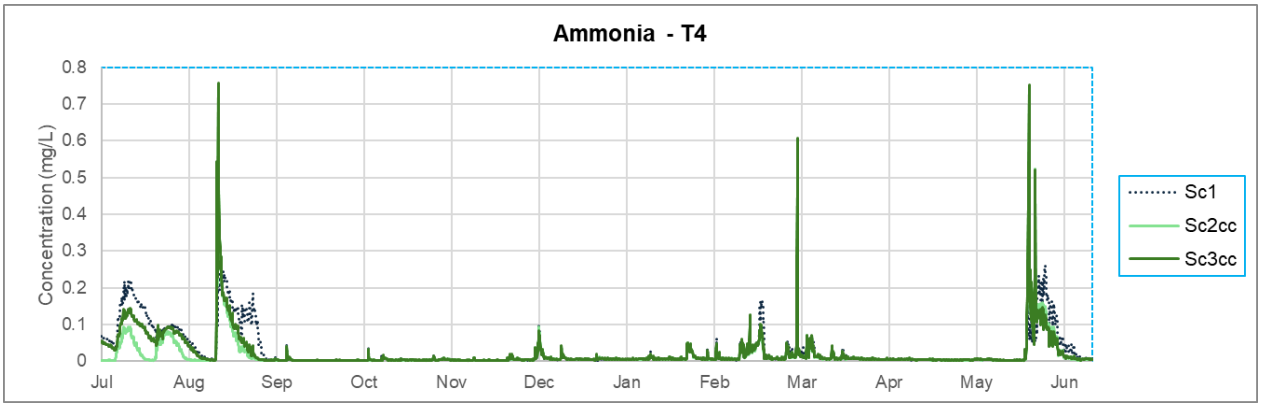


Time series plots



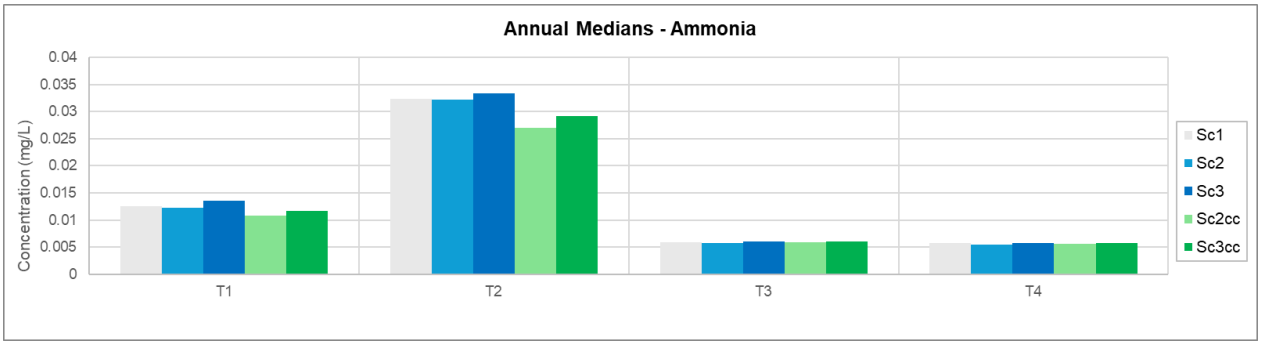


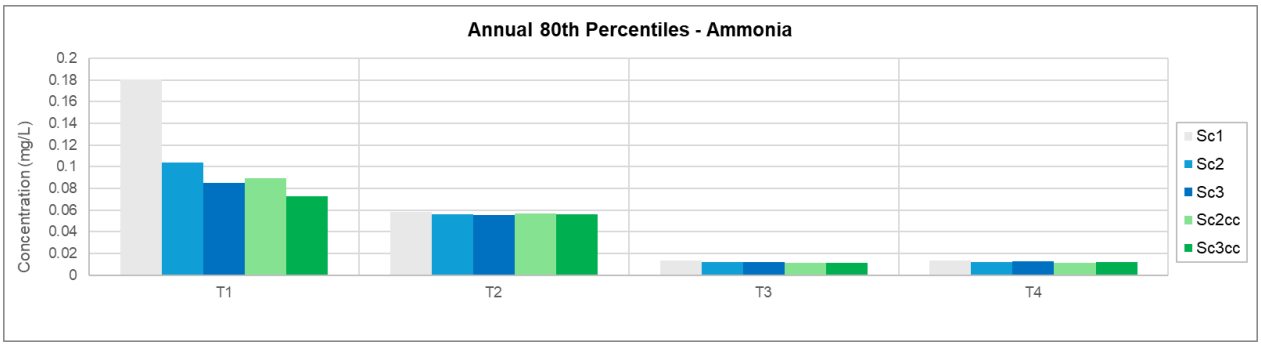




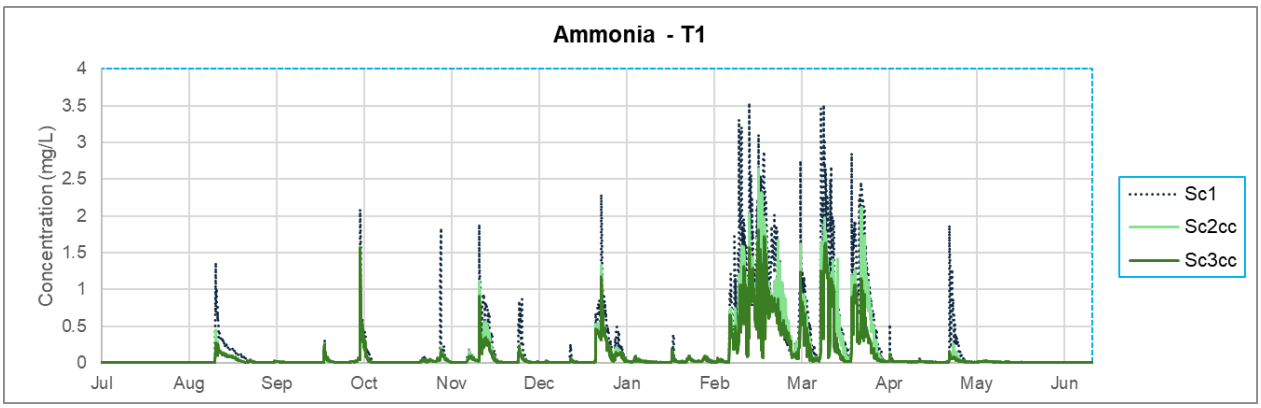
Appendices D6.4.3 Higher rainfall year scenario results (2021-2022)

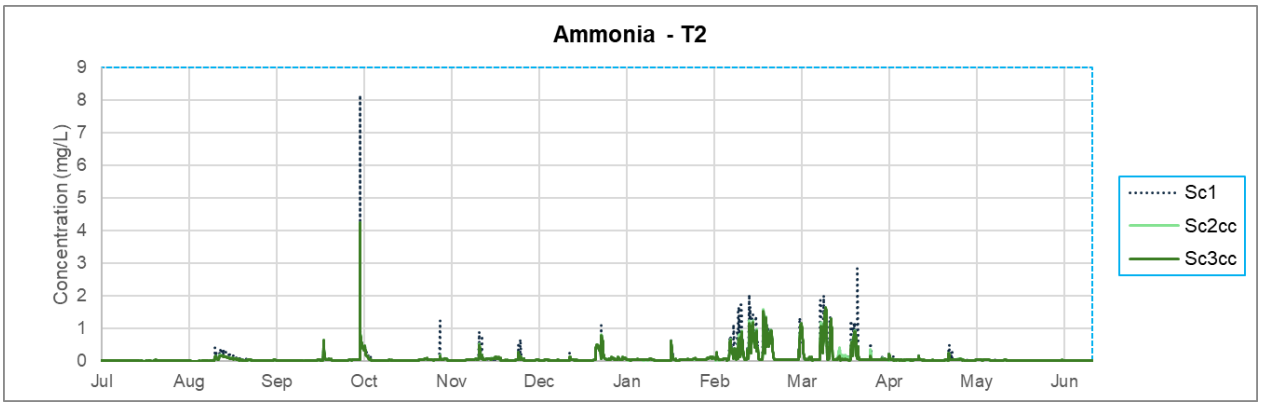
Bar charts

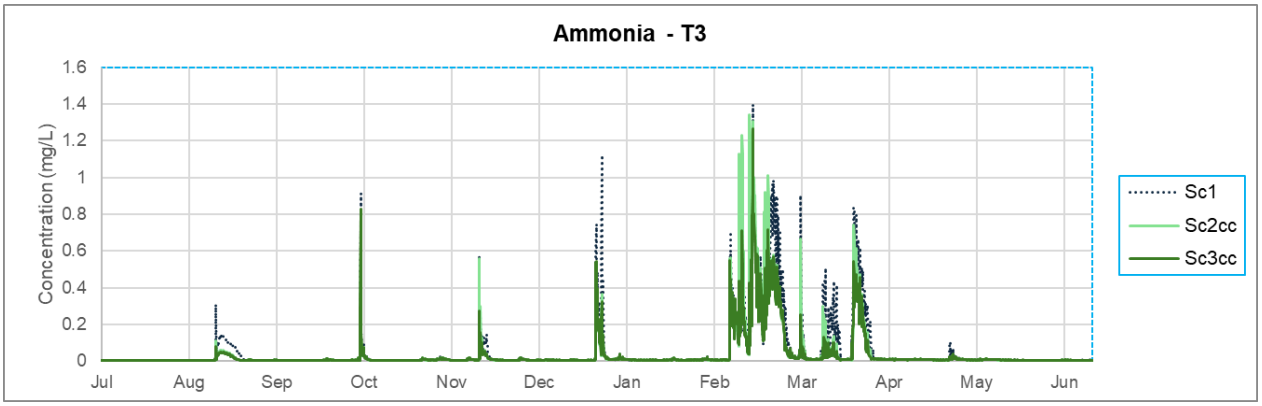


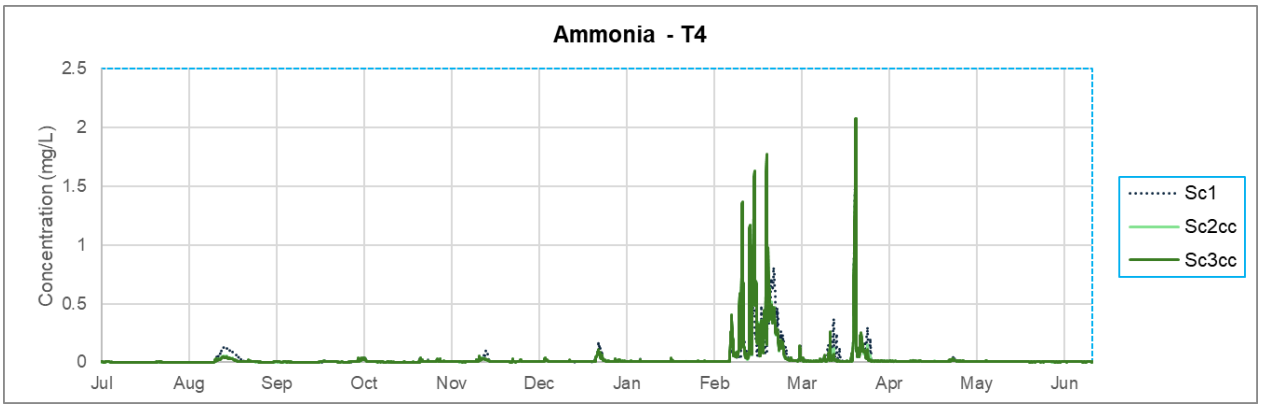


Time series plots




Ammonia - T2
Concentration (mg/L)
0
1
2
3
4
5
6
7
8
9
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

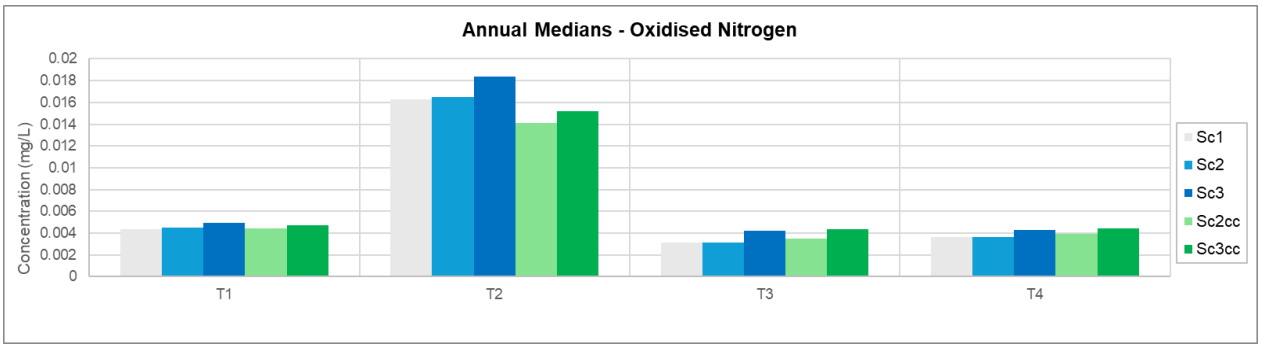

Ammonia - T3
Concentration (mg/L)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

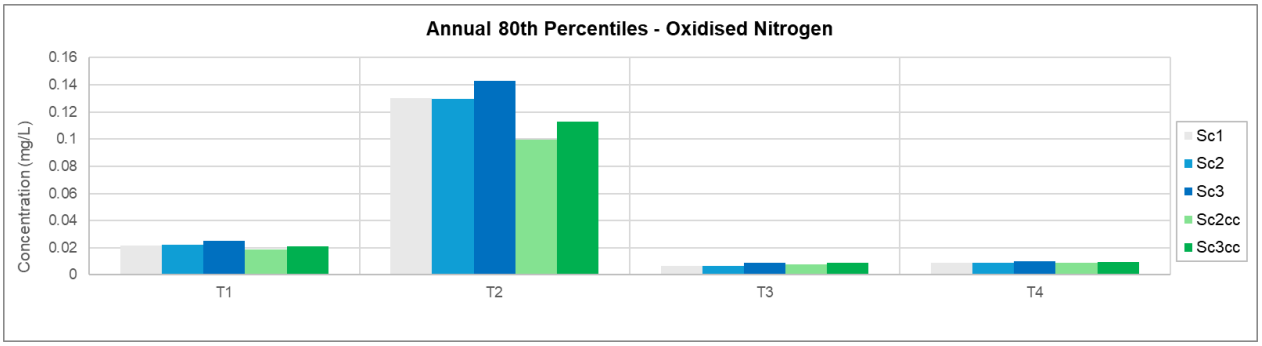

Ammonia - T4
Concentration (mg/L)
0
0.5
1
1.5
2
2.5
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.5 Oxidised N

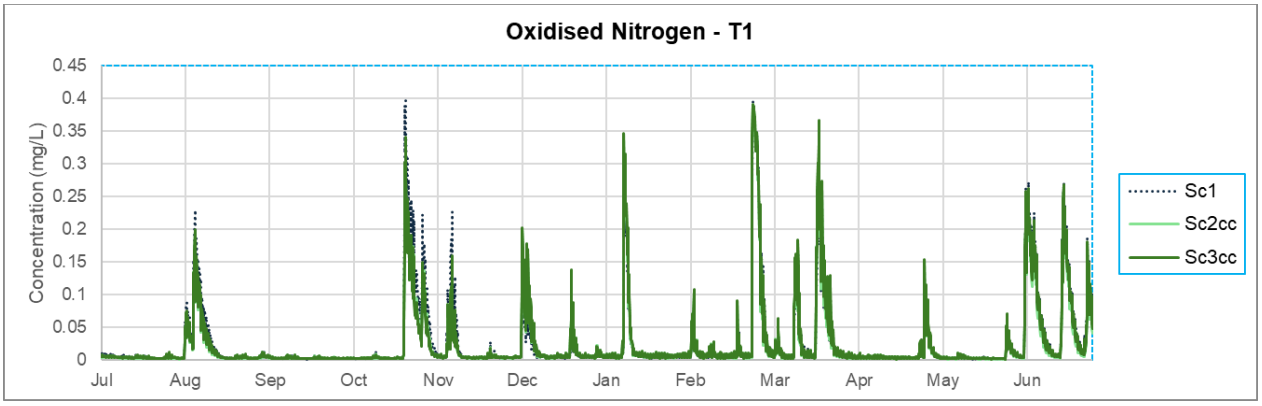
Appendices D6.5.1 Lower rainfall year scenario results (2017-2018)

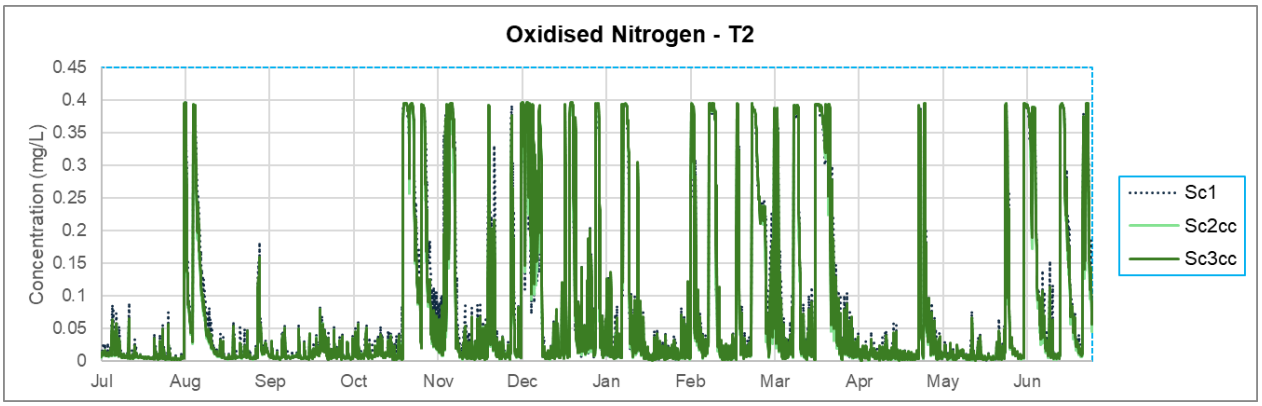
Bar charts

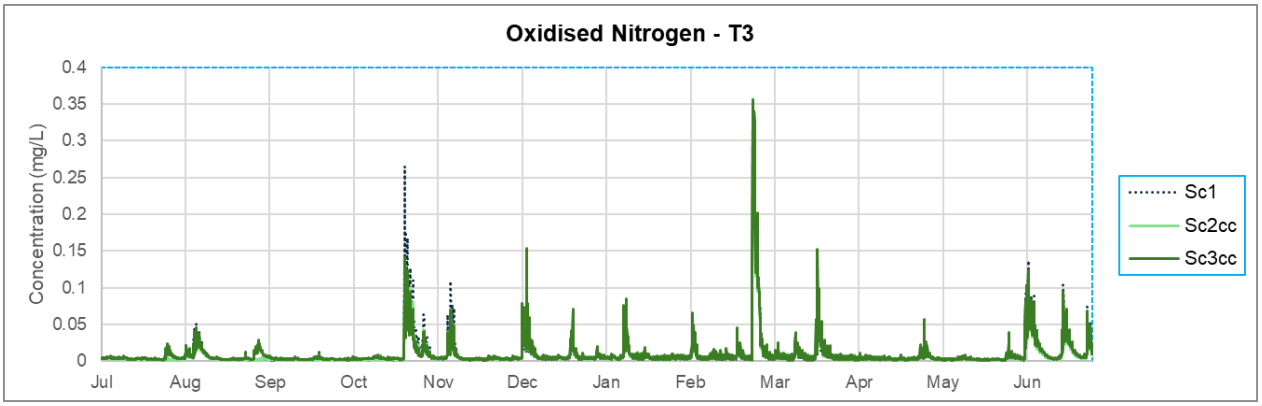


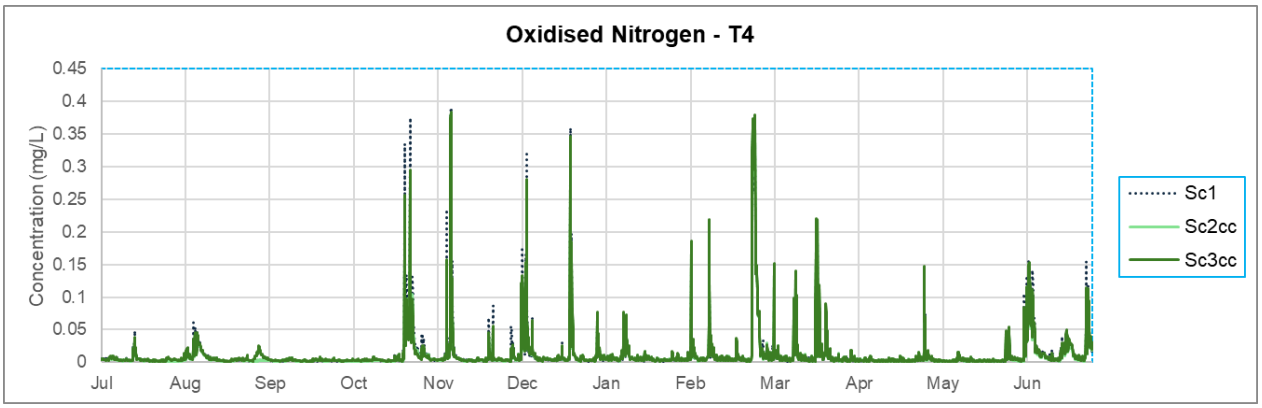


Time series plots



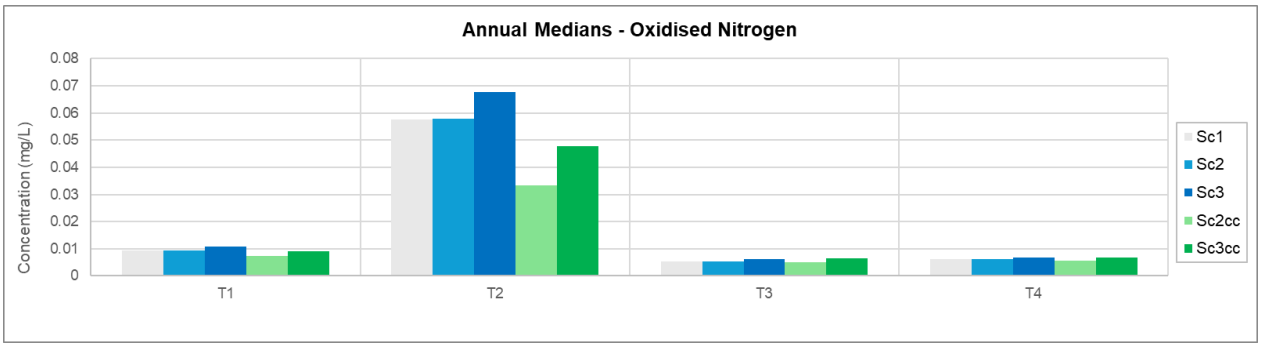


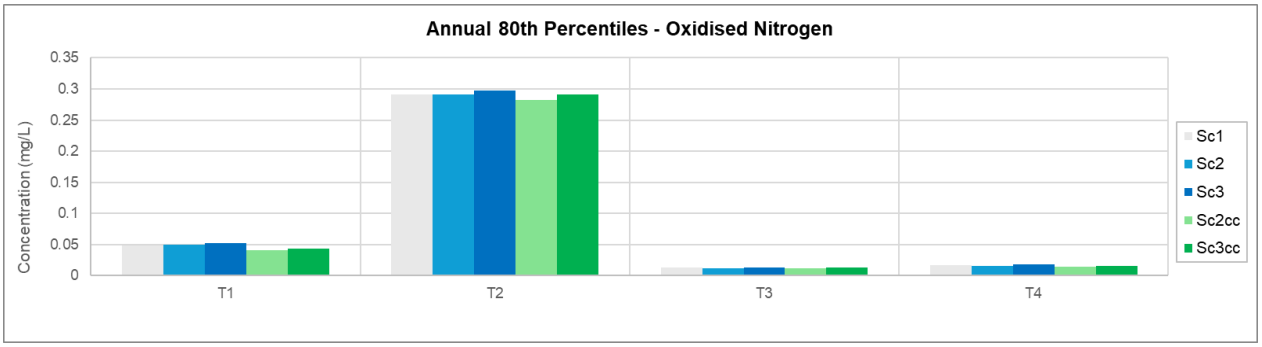




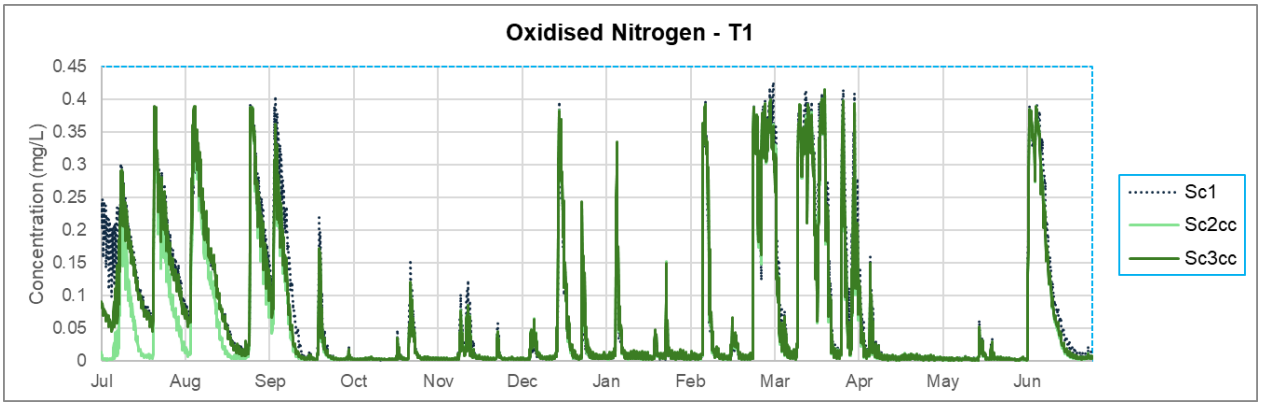
Appendices D6.5.2 Average rainfall year scenario results (2016-2017)

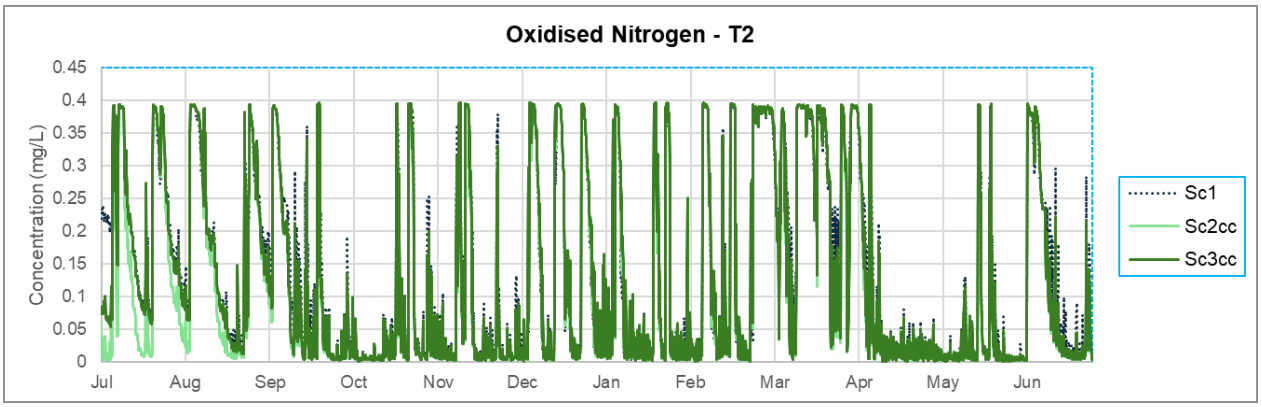
Bar charts

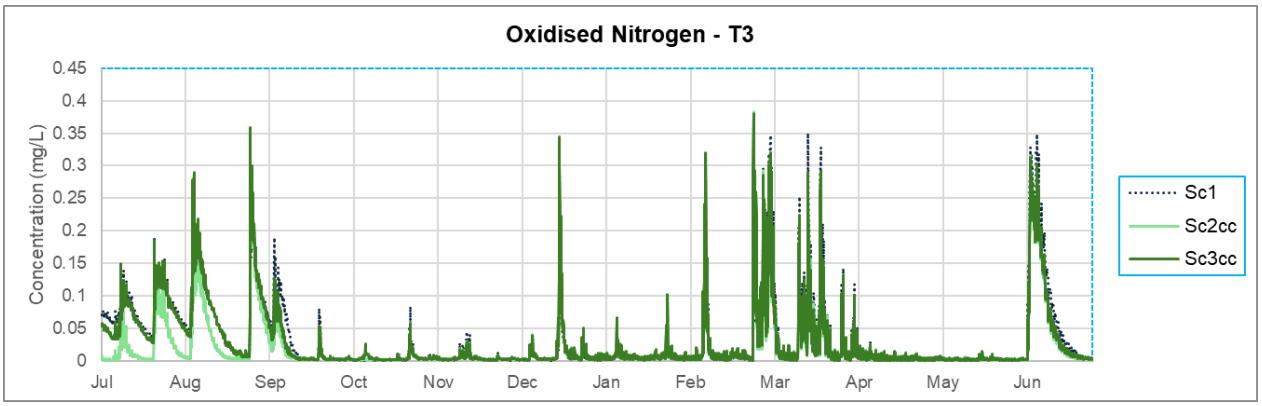


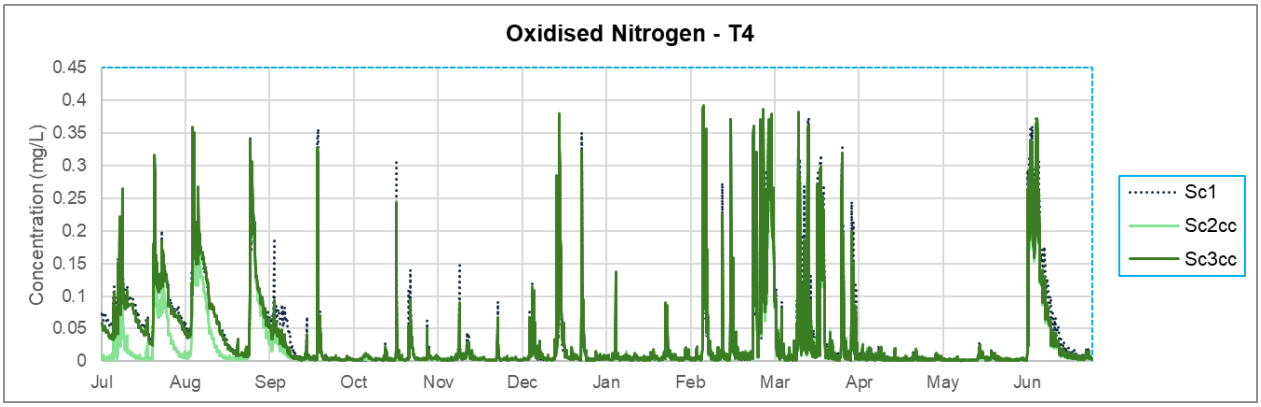


Time series plots



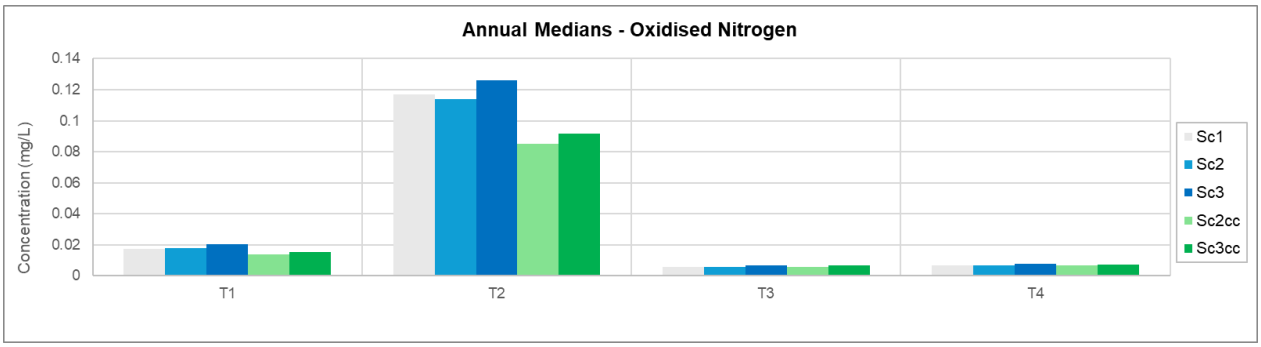


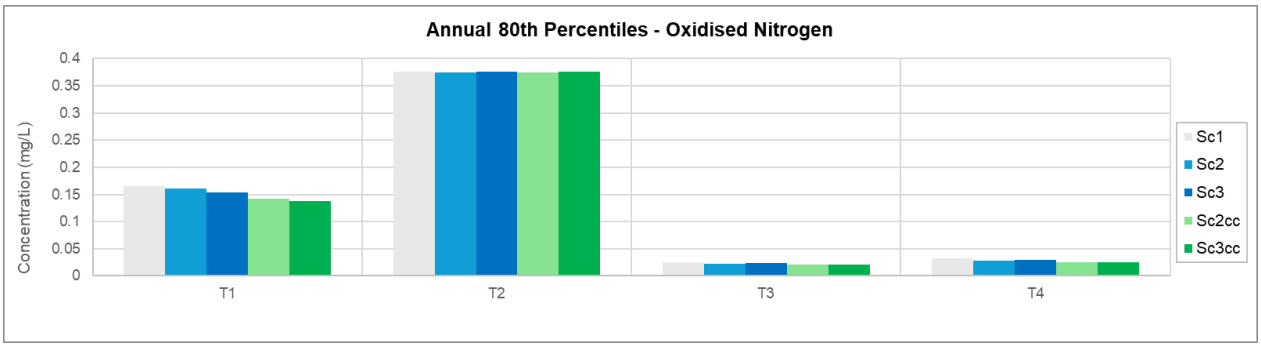




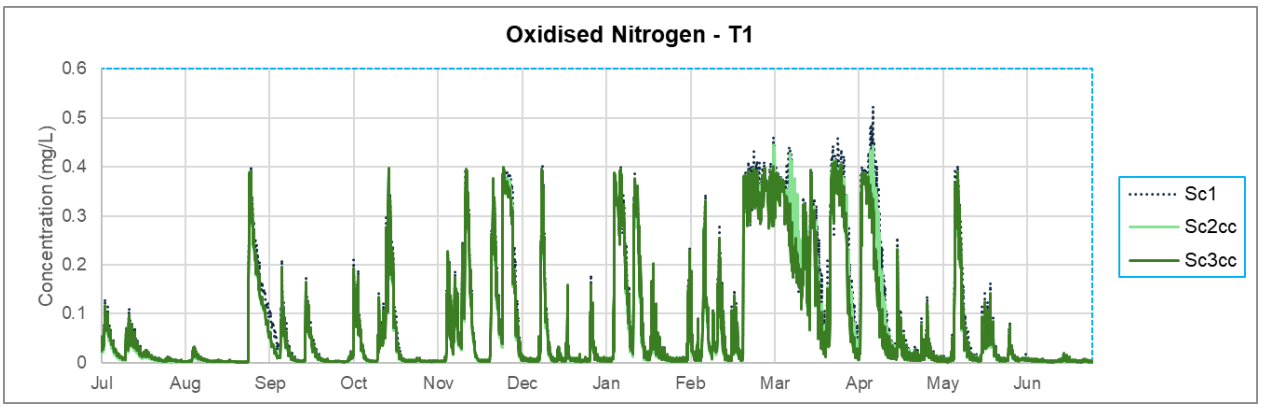
Appendices D6.5.3 Higher rainfall year scenario results (2021-2022)

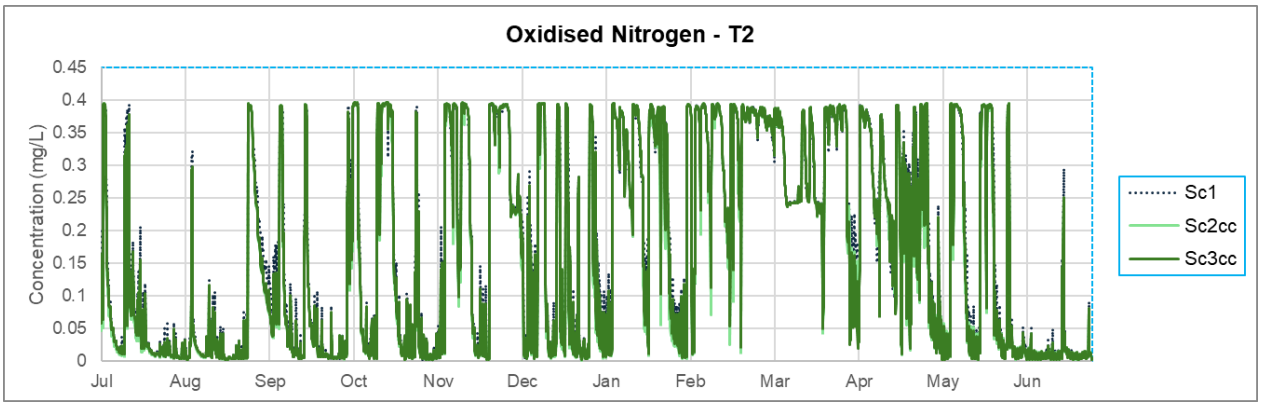
Bar charts

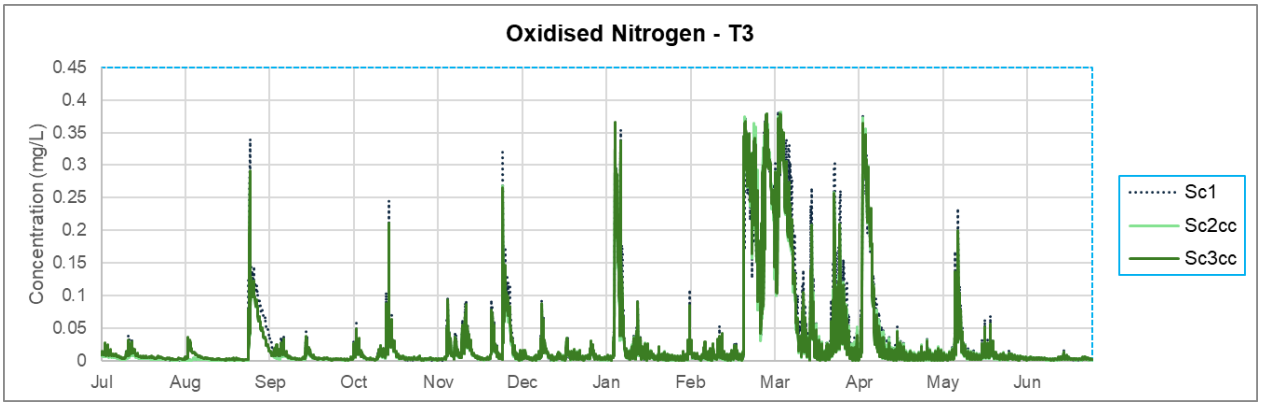


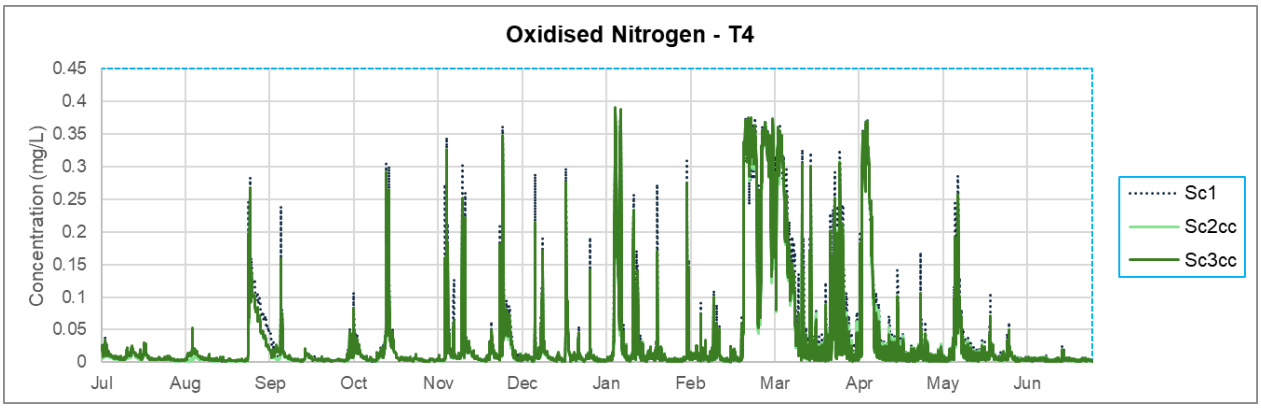


Time series plots




Oxidised Nitrogen - T2
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

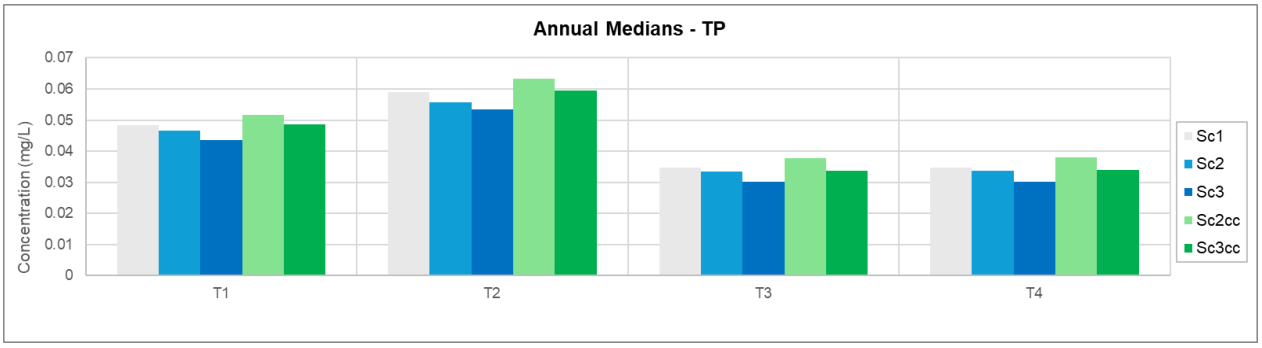

Oxidised Nitrogen - T3
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

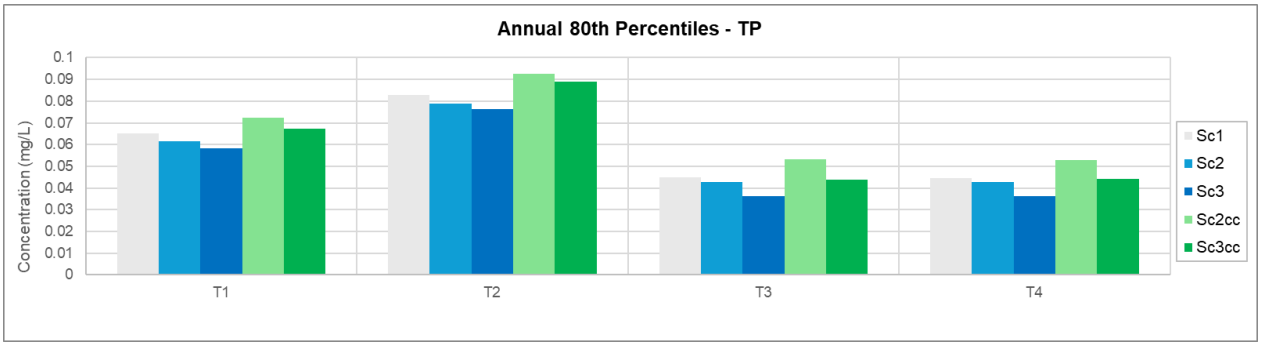

Oxidised Nitrogen - T4
Concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.6 Total P

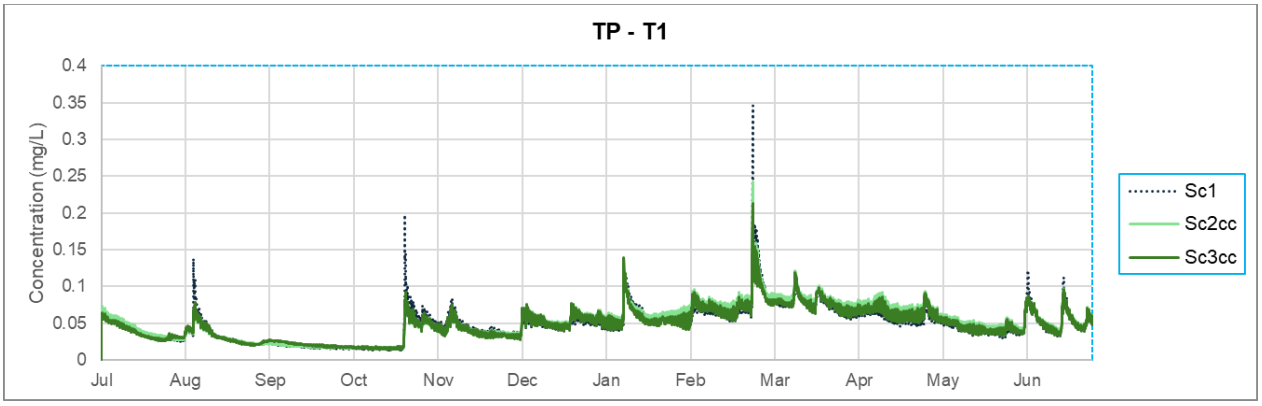
Appendices D6.6.1 Lower rainfall year scenario results (2017-2018)

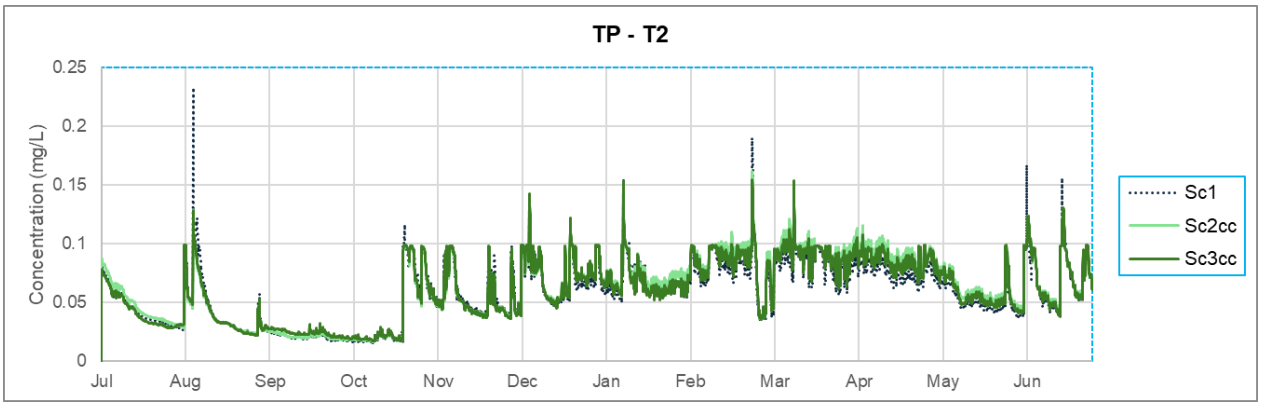
Bar charts

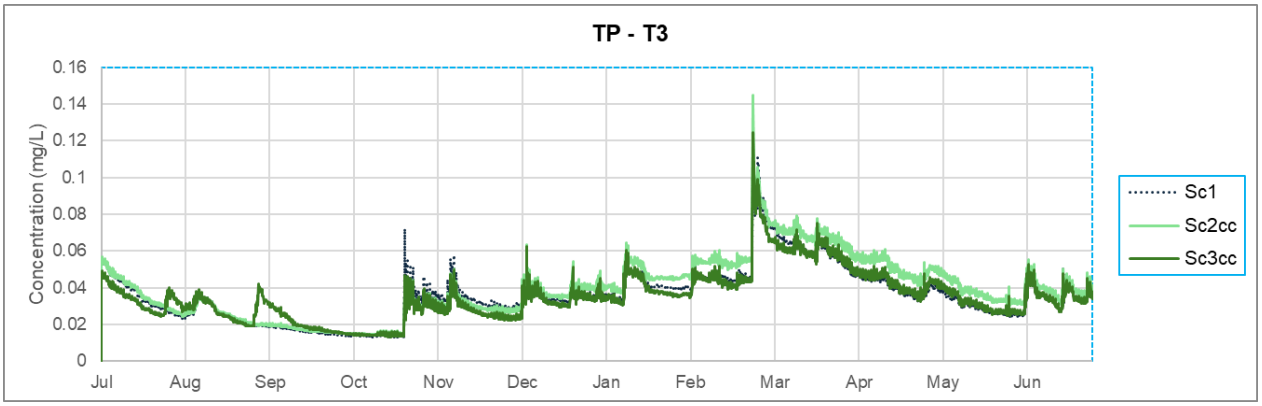


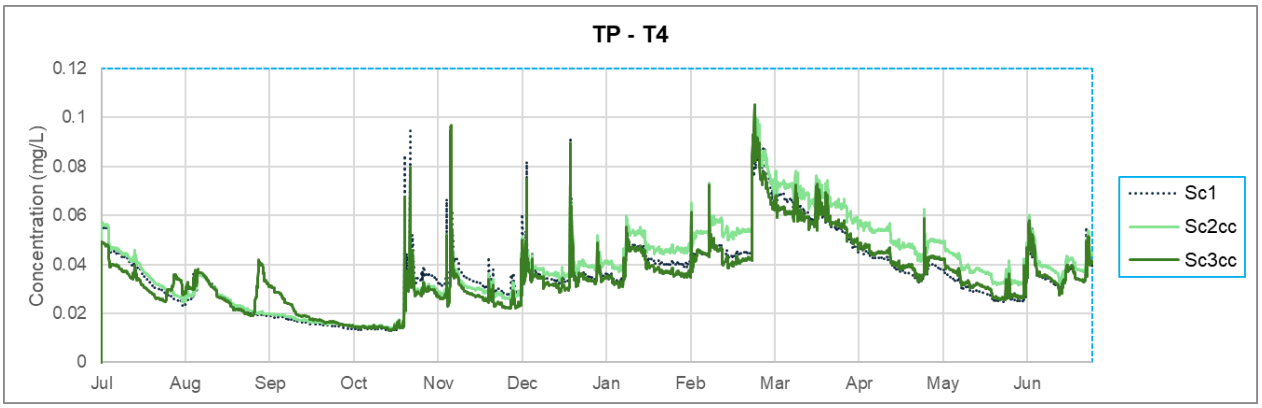


Time series plots



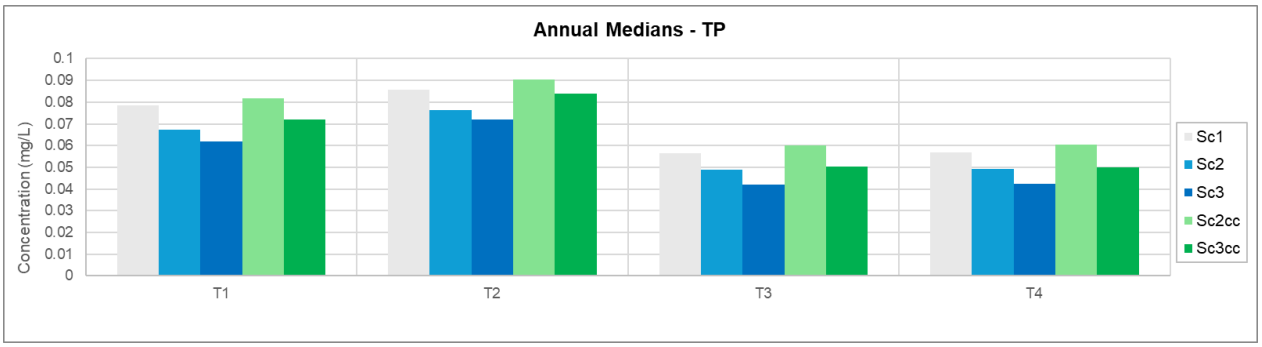


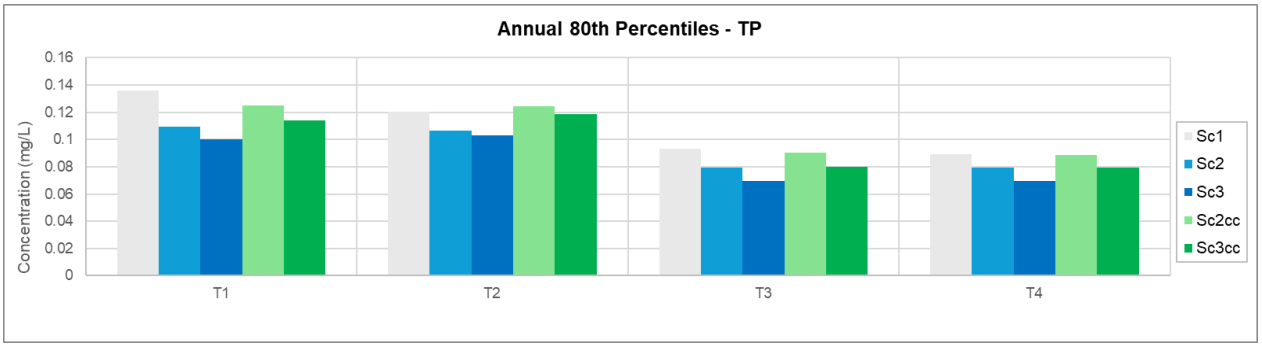




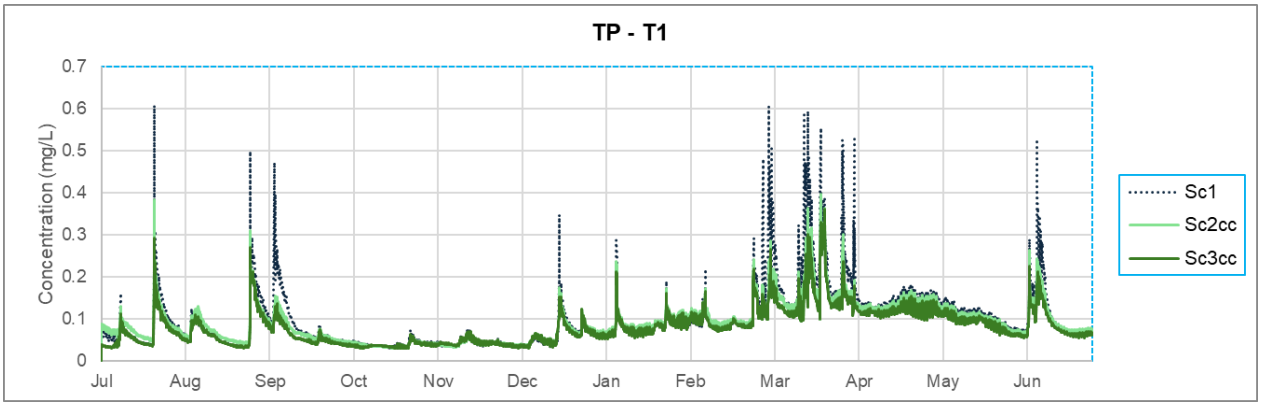
Appendices D6.6.2 Average rainfall year scenario results (2016-2017)

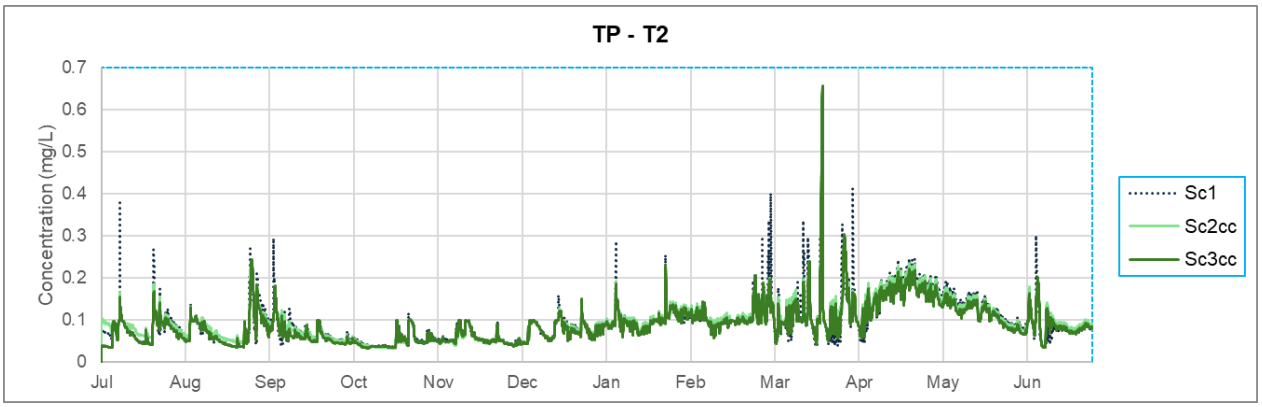
Bar charts

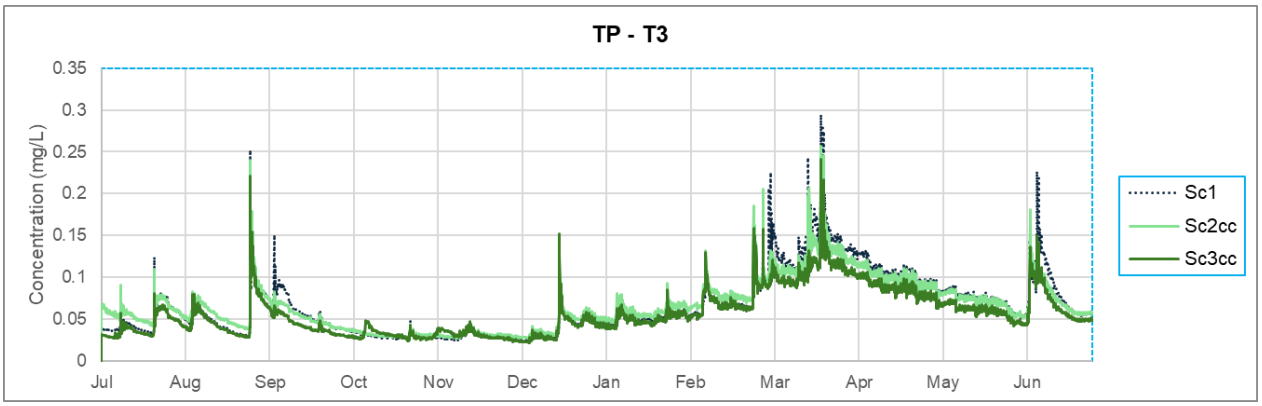


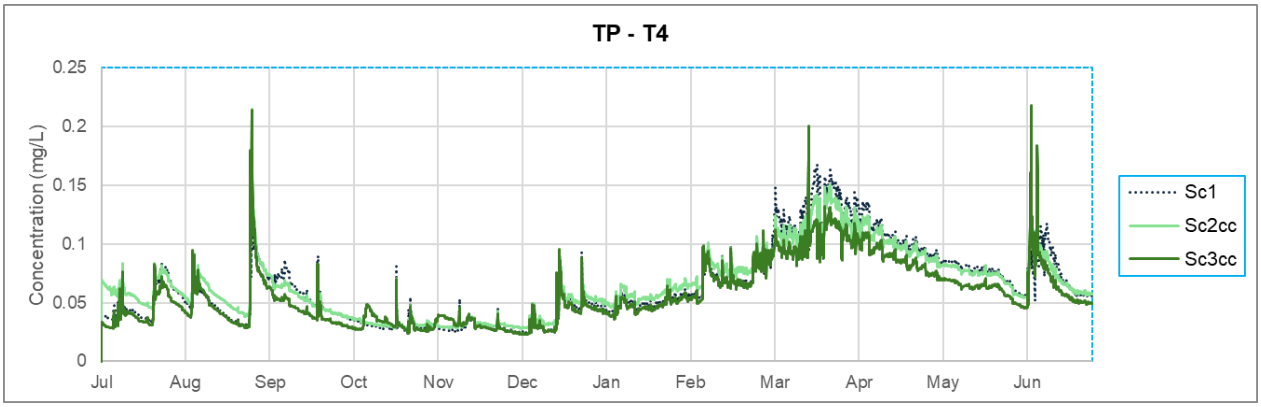


Time series plots



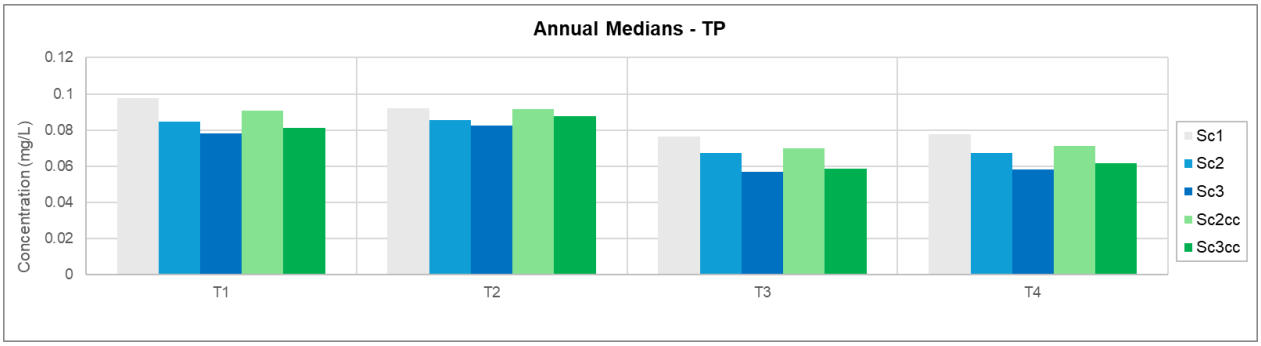


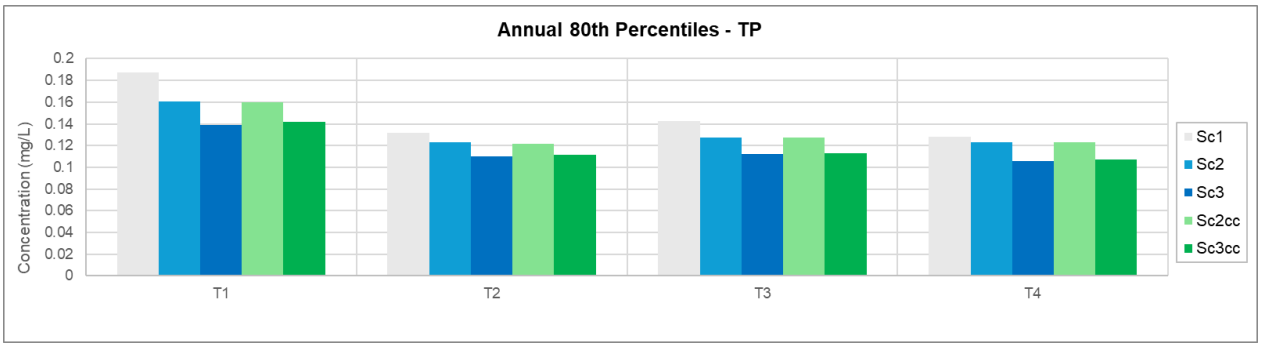




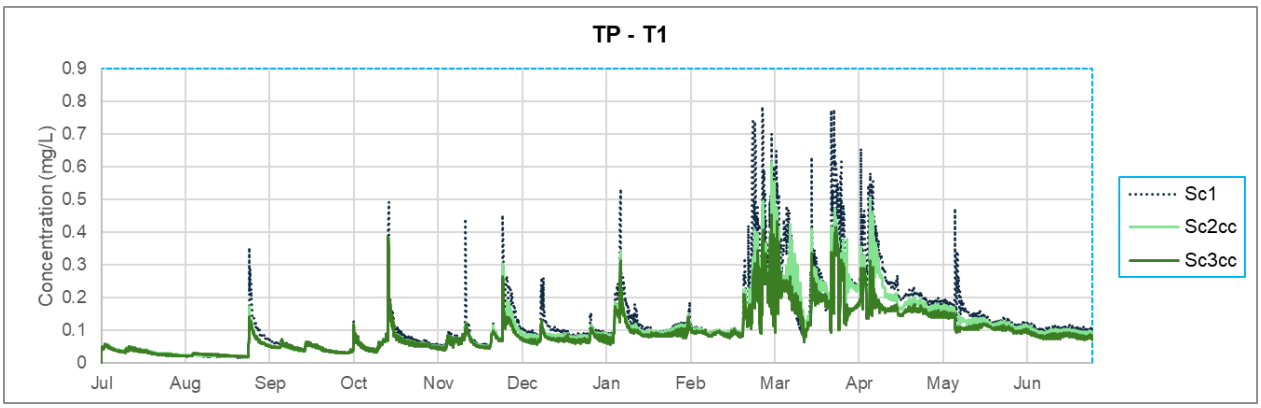
Appendices D6.6.3 Higher rainfall year scenario results (2021-2022)

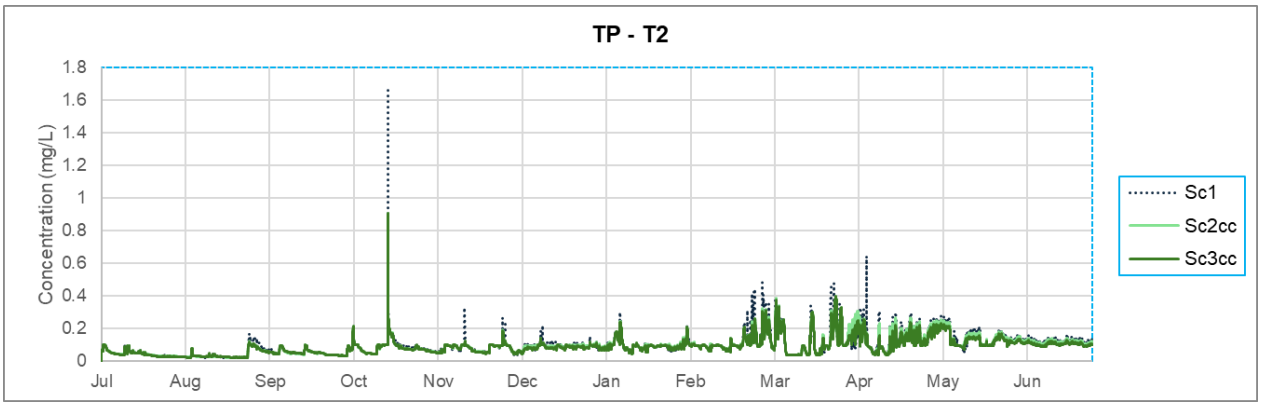
Bar charts

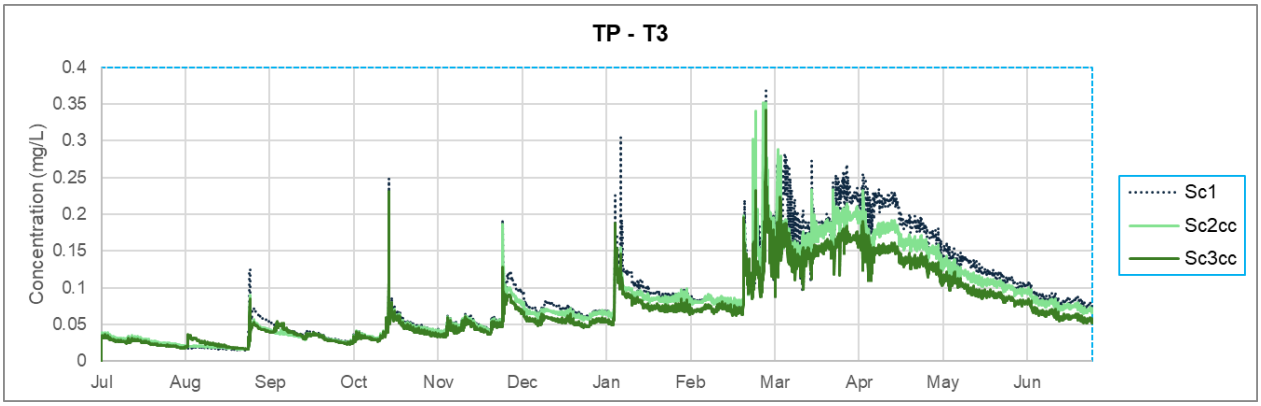


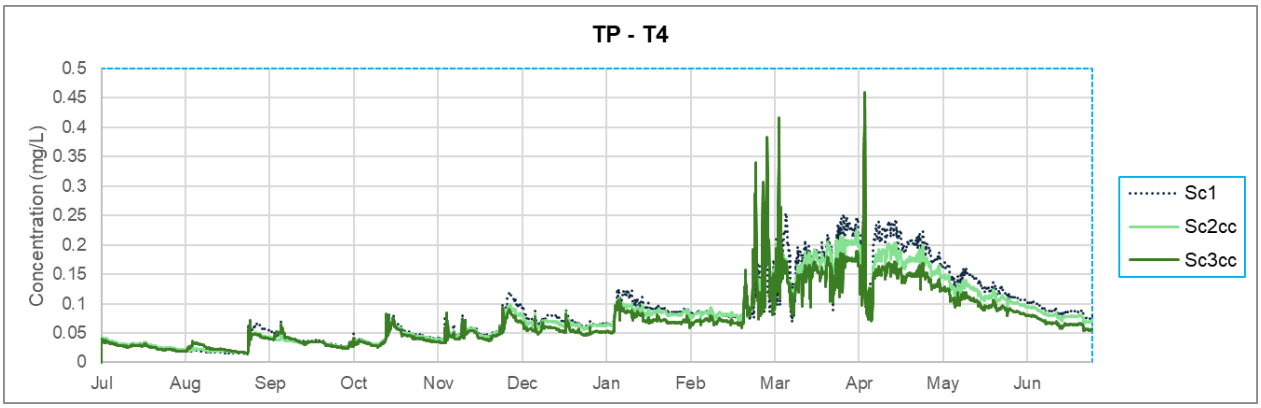


Time series plots




TP - T2
Concentration (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

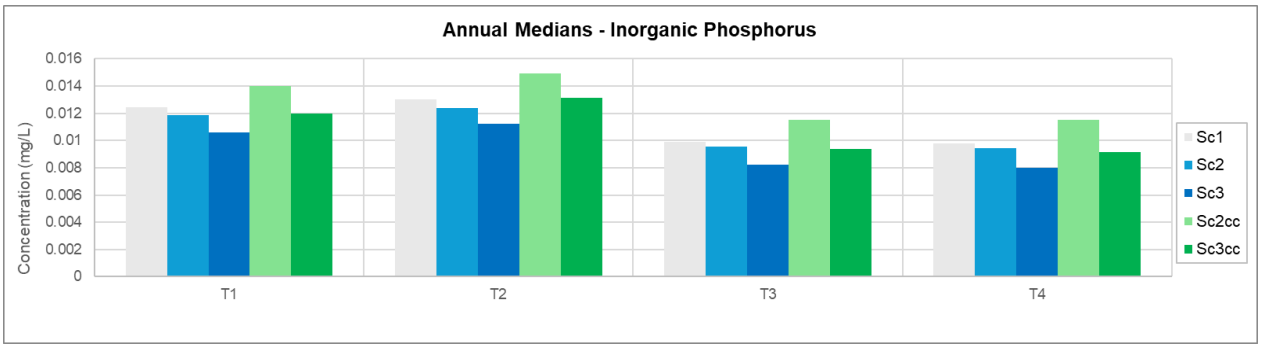

TP - T3
Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

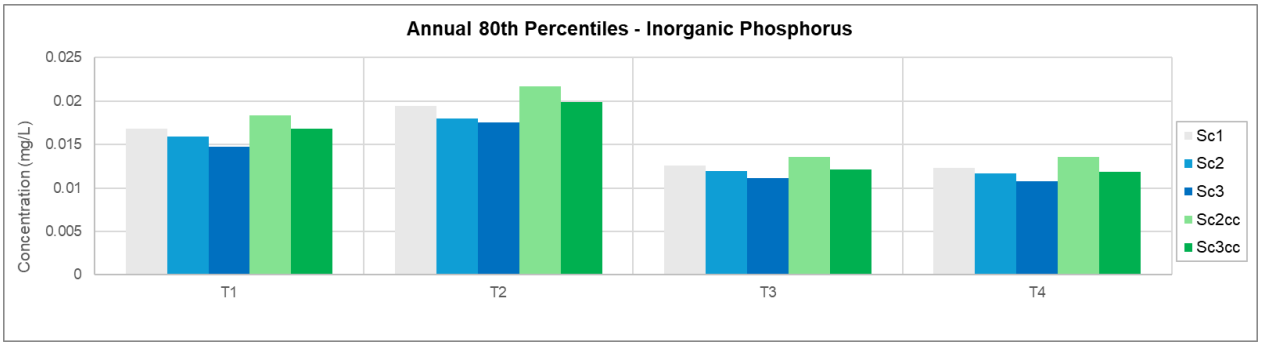

TP - T4
Concentration (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.7 Inorganic P

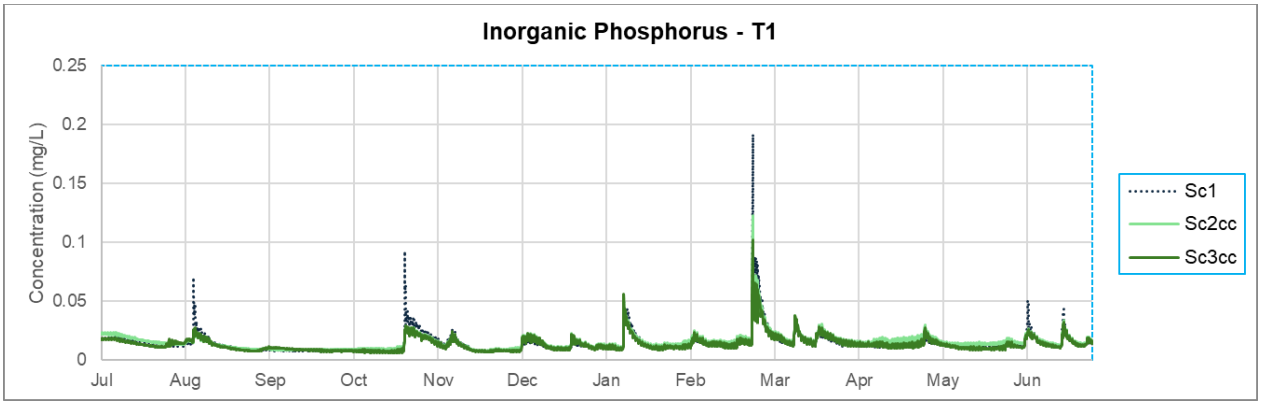
Appendices D6.7.1 Lower rainfall year scenario results (2017-2018)

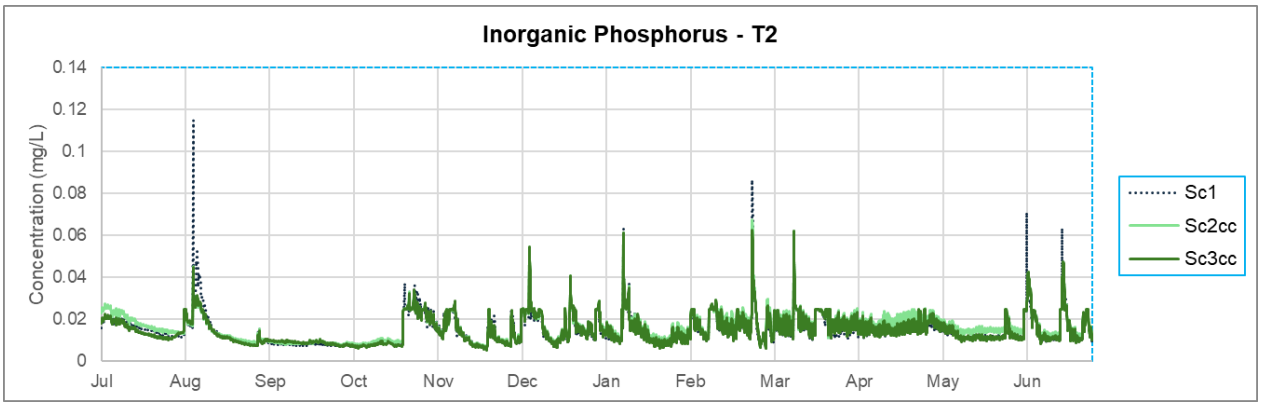
Bar charts

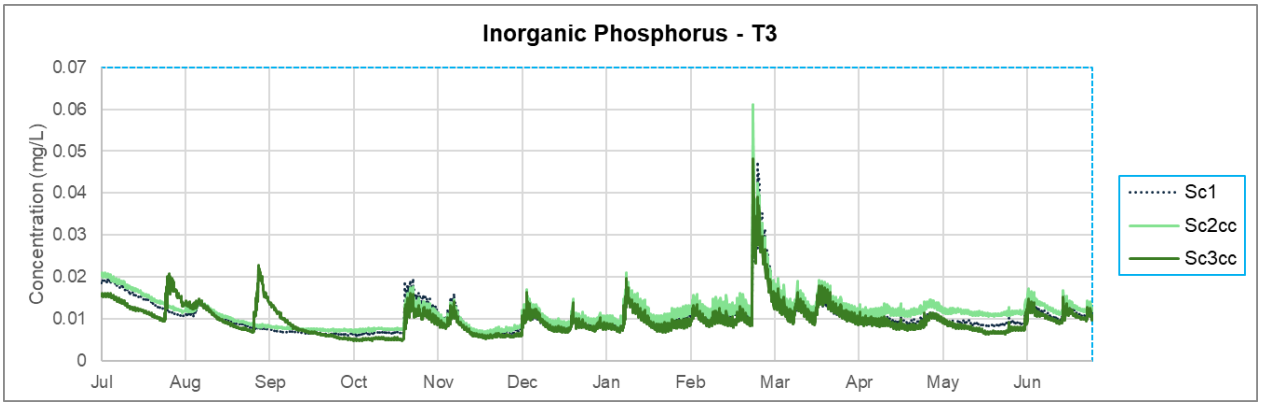


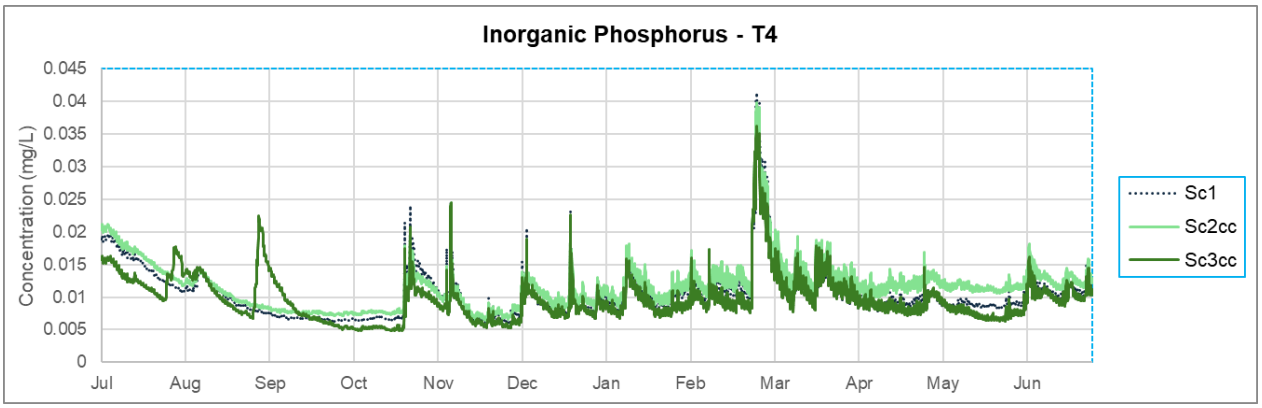


Time series plots



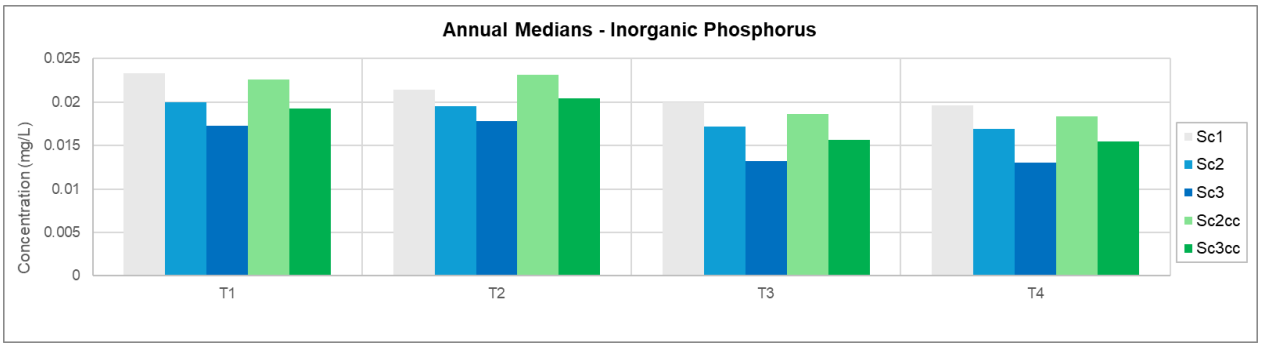


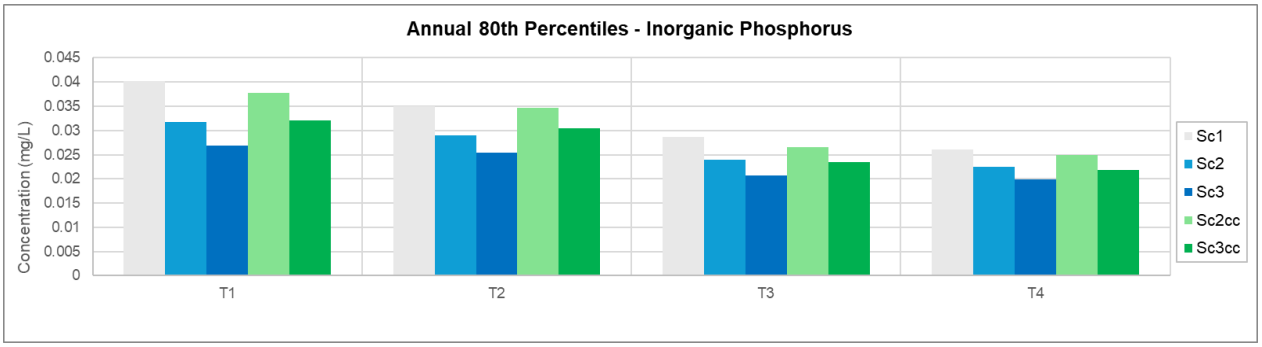




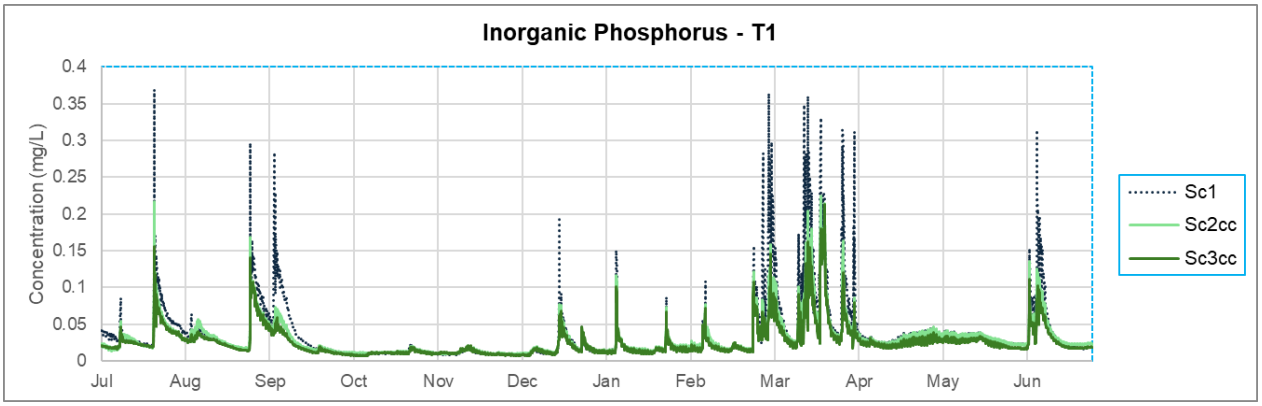
Appendices D6.7.2 Average rainfall year scenario results (2016-2017)

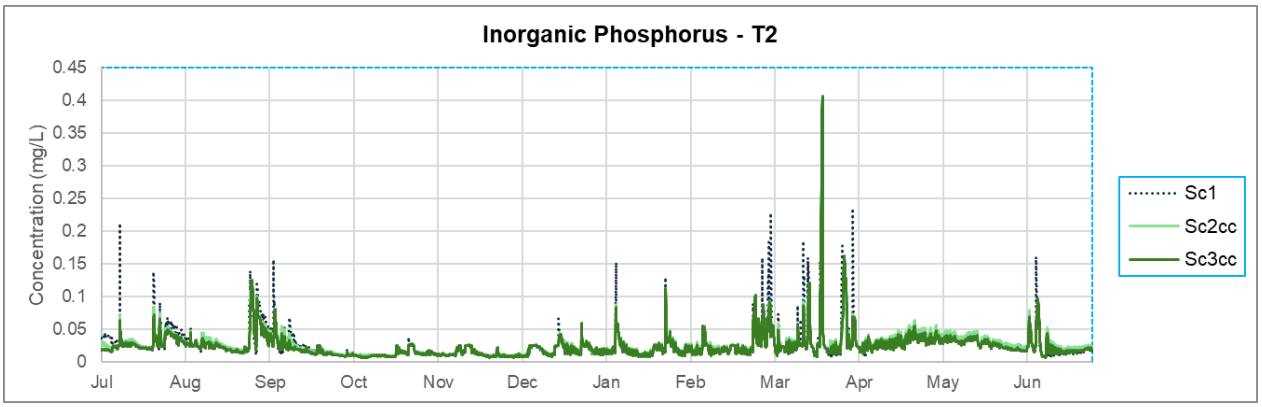
Bar charts

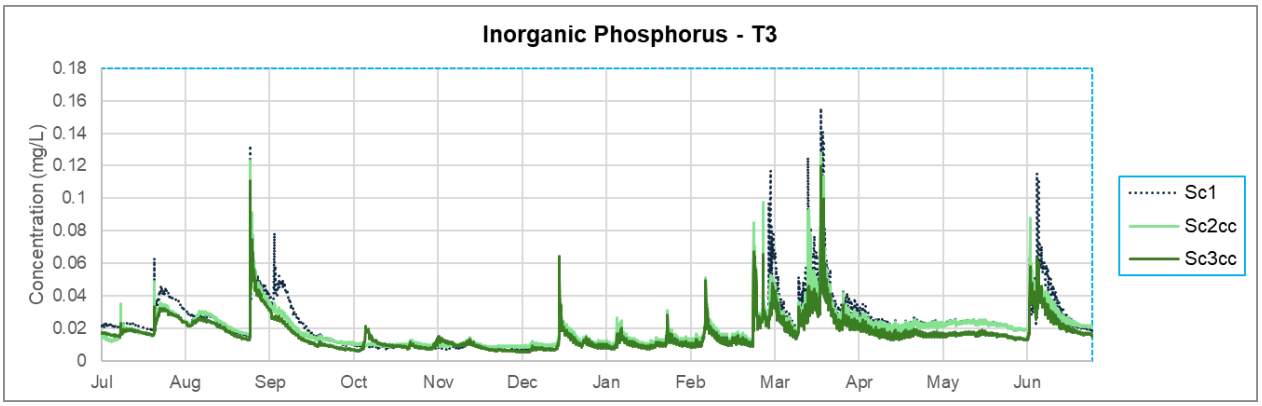


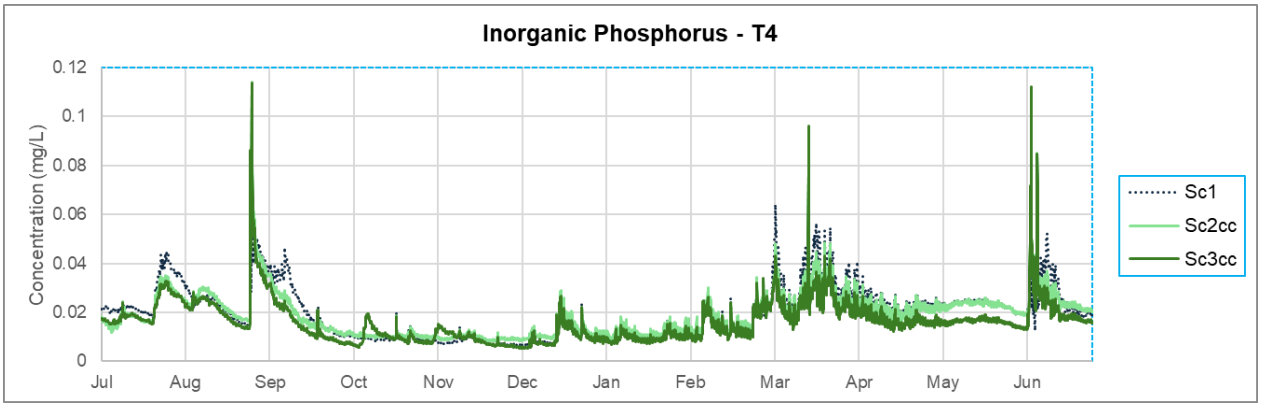


Time series plots



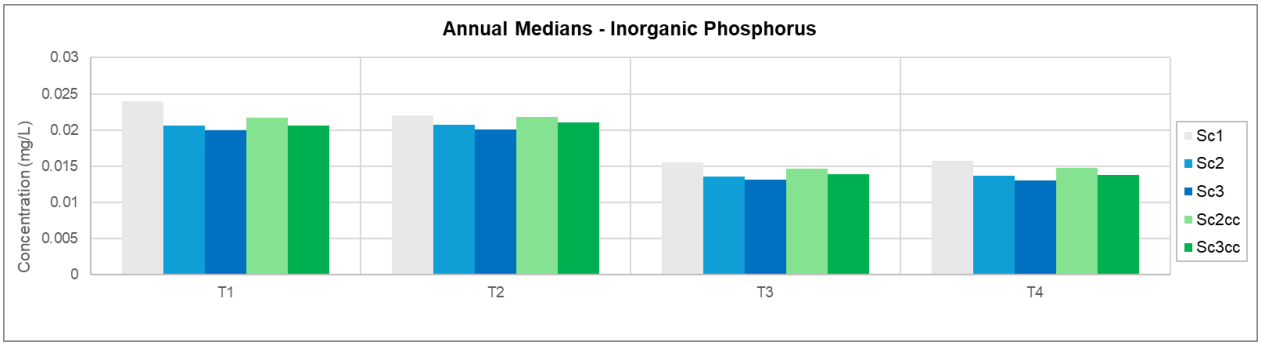


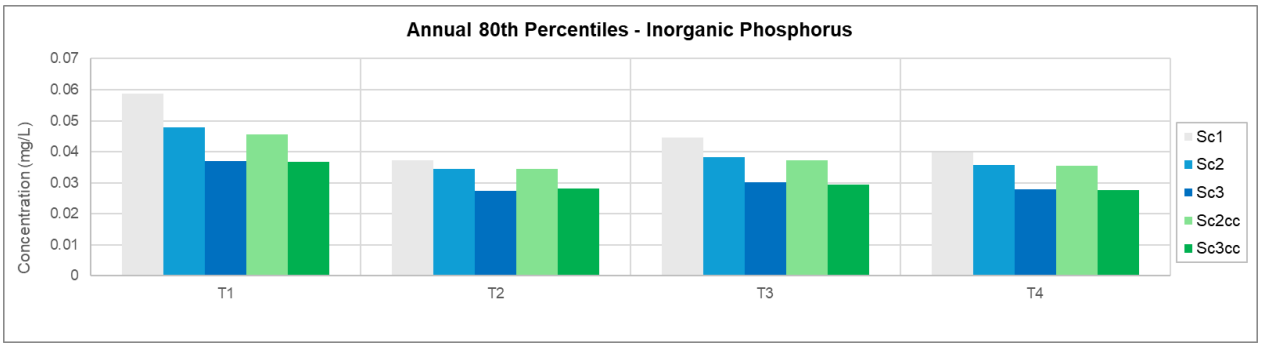




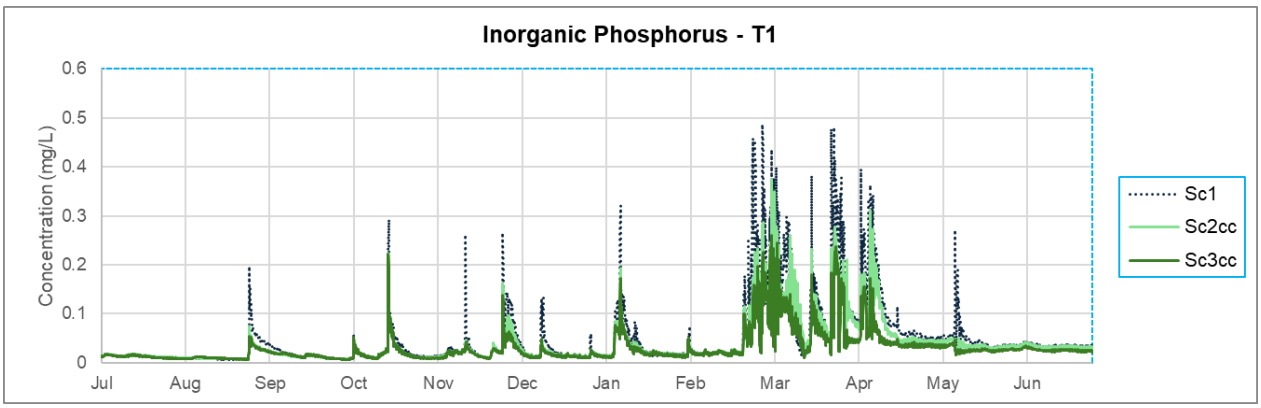
Appendices D6.7.3 Higher rainfall year scenario results (2021-2022)

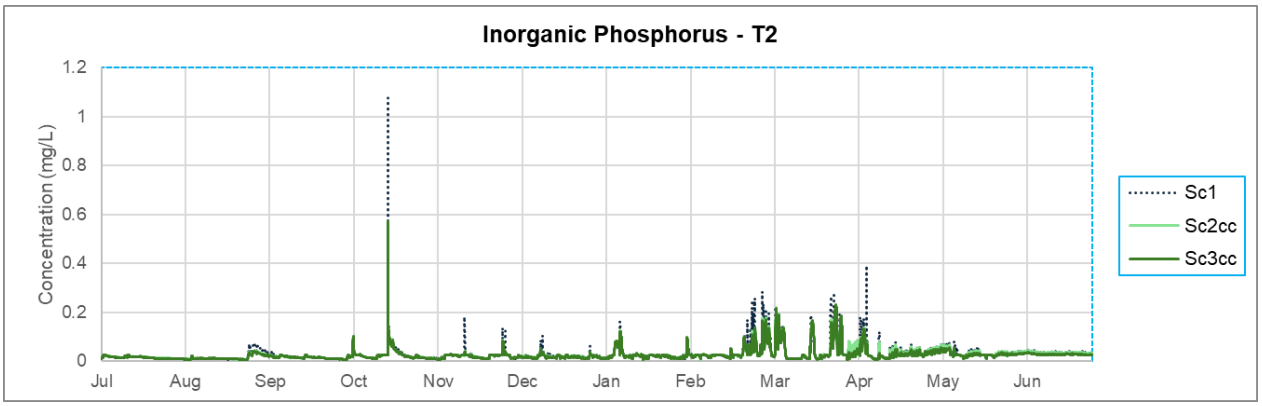
Bar charts

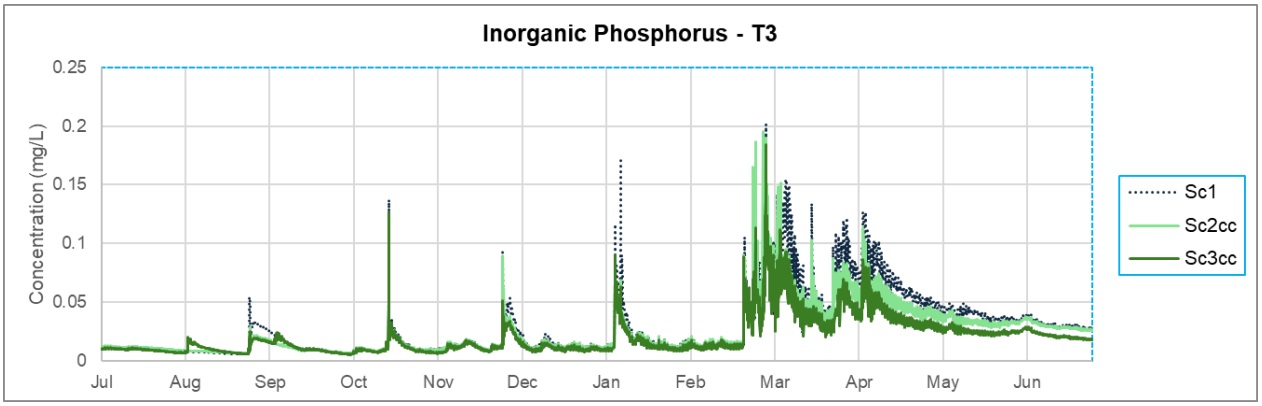


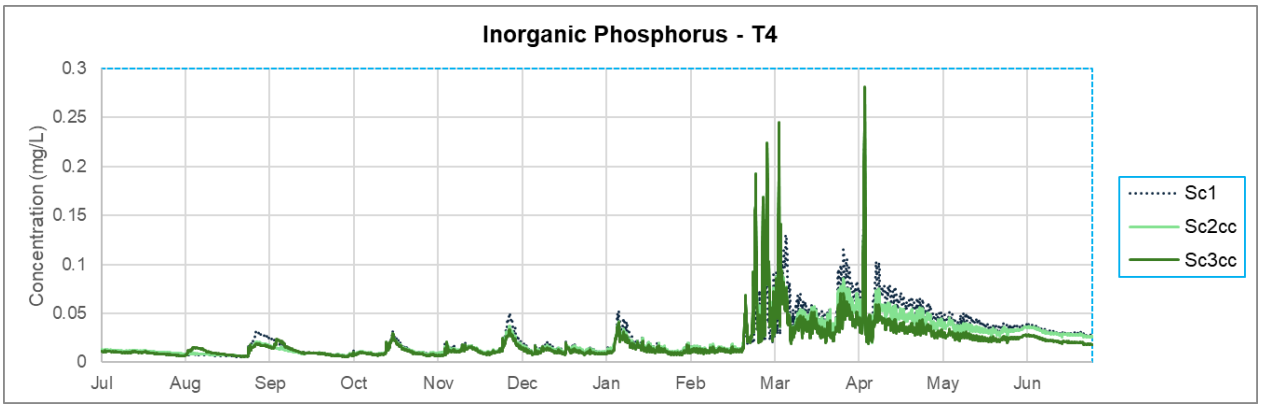


Time series plots




Inorganic Phosphorus - T2
Concentration (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

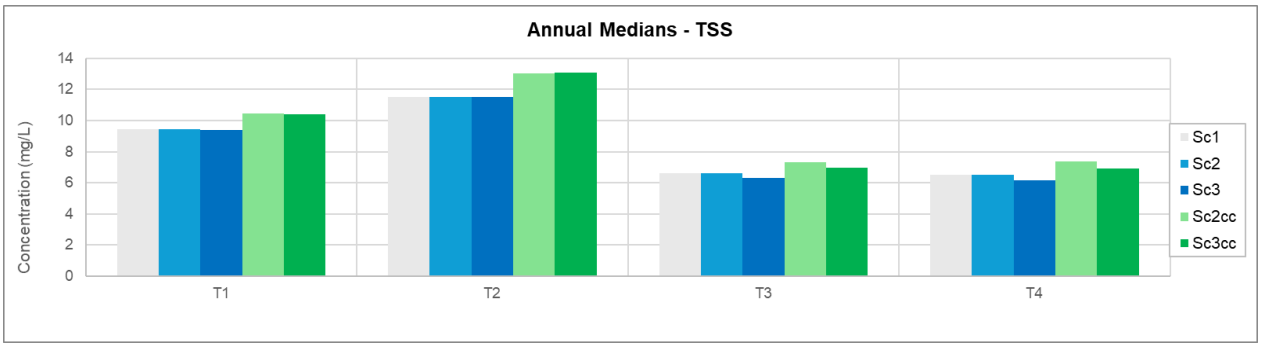

Inorganic Phosphorus - T3
Concentration (mg/L)
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

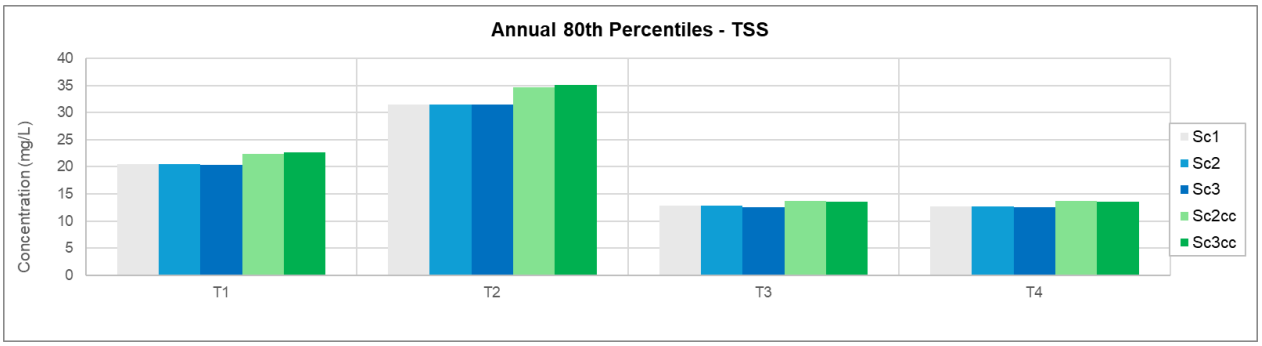

Inorganic Phosphorus - T4
Concentration (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.8 TSS

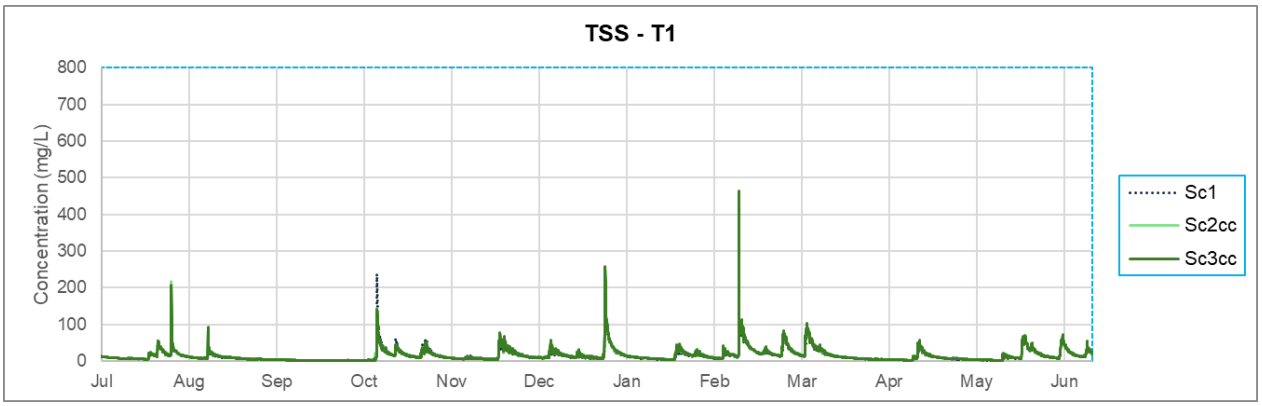
Appendices D6.8.1 Lower rainfall year scenario results (2017-2018)

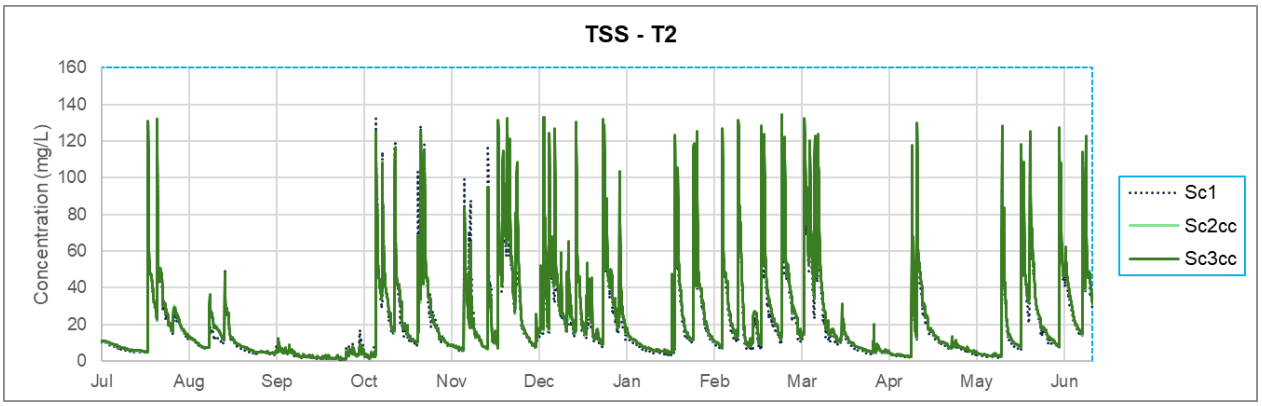
Bar charts

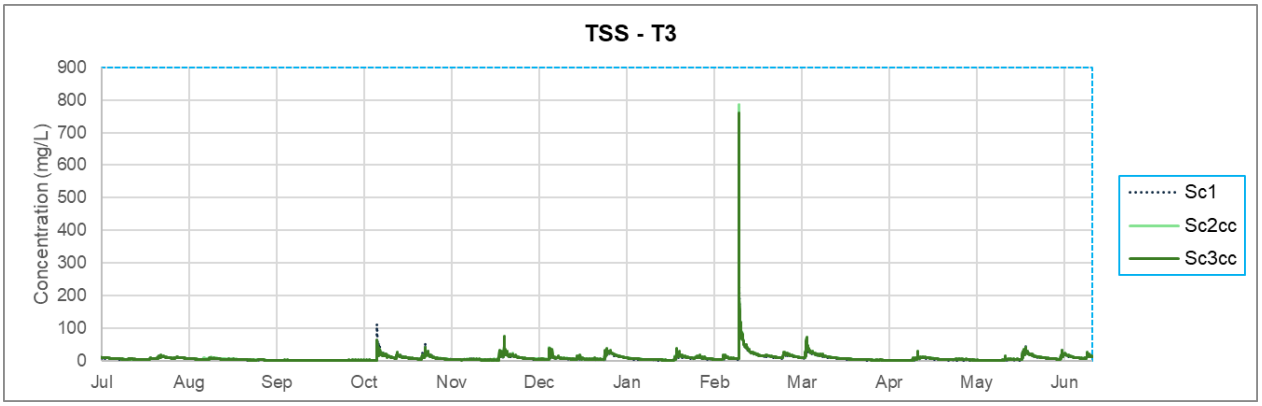


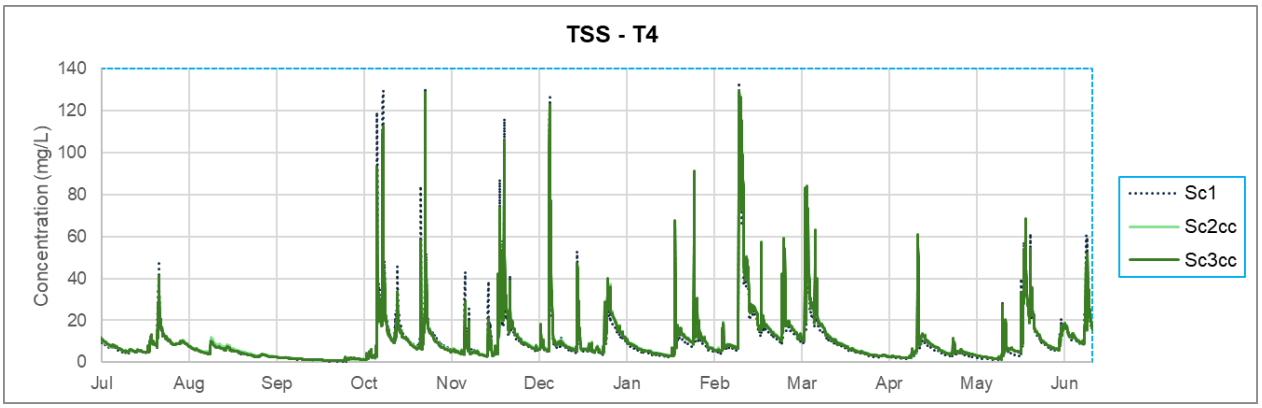


Time series plots



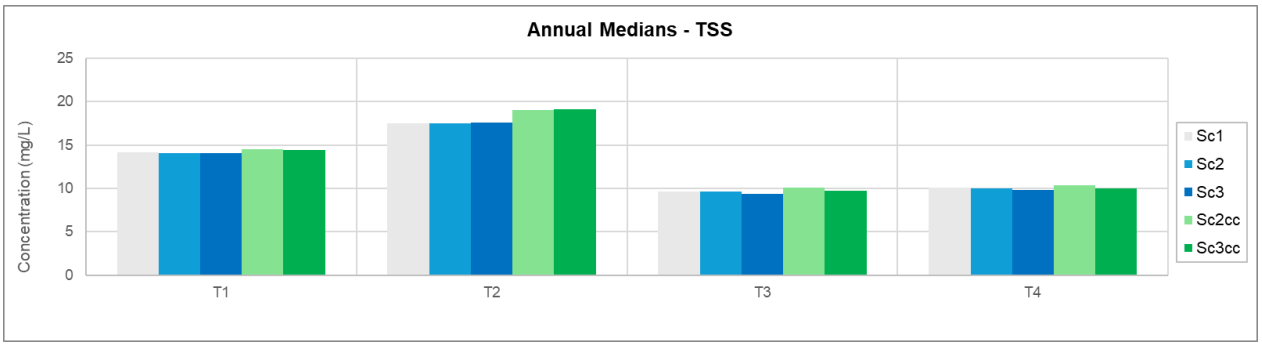




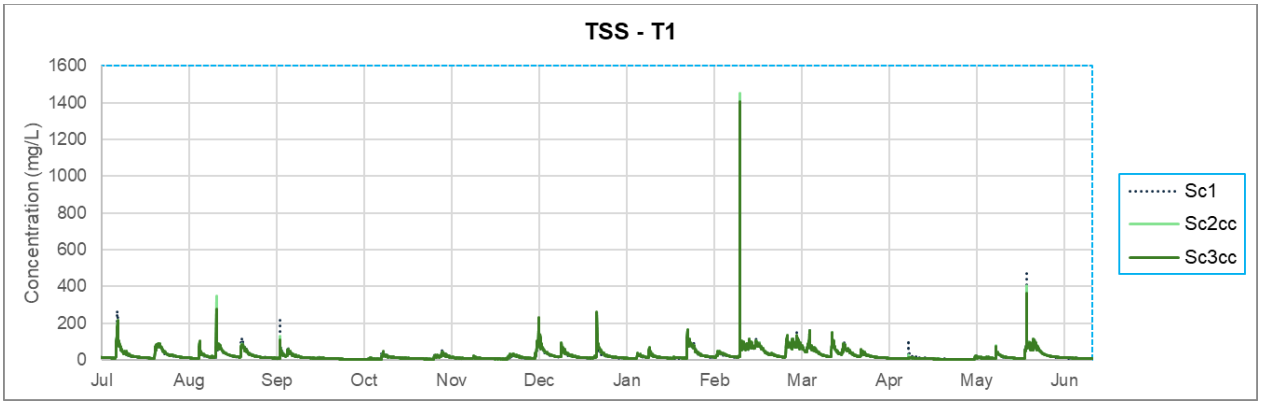


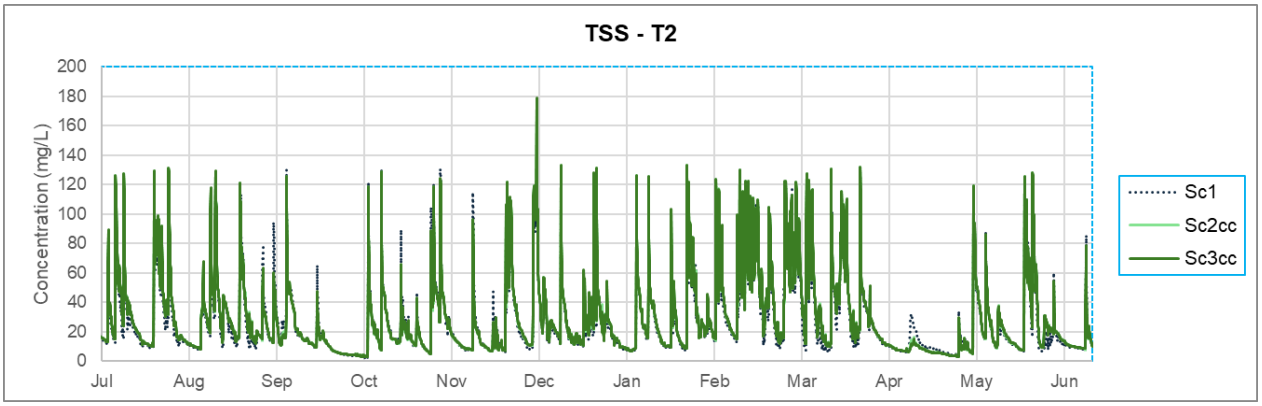
Appendices D6.8.2 Average rainfall year scenario results (2016-2017)

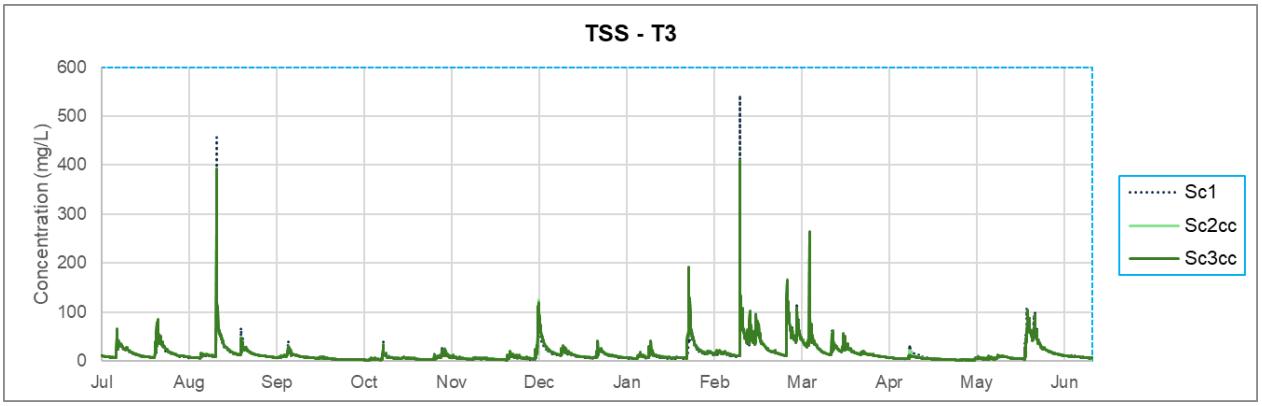
Bar charts

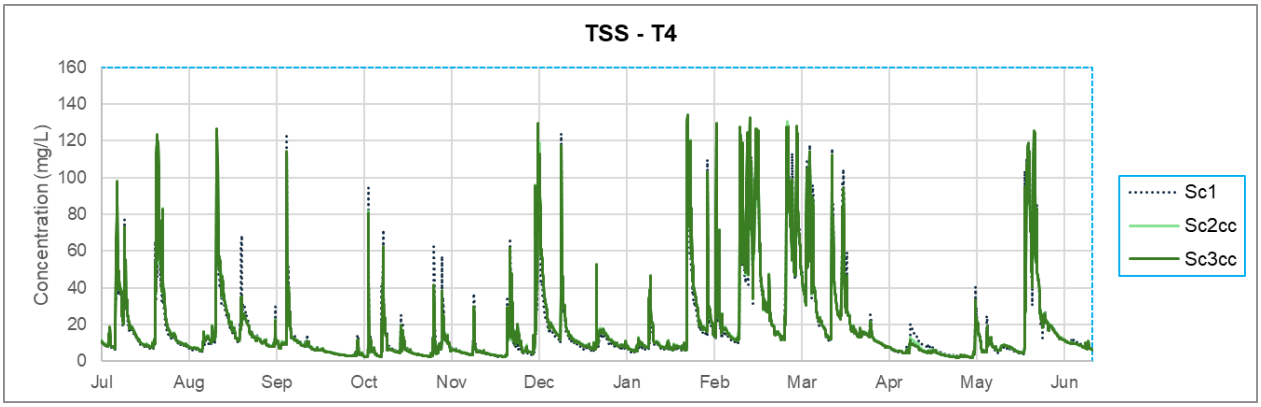


Time series plots



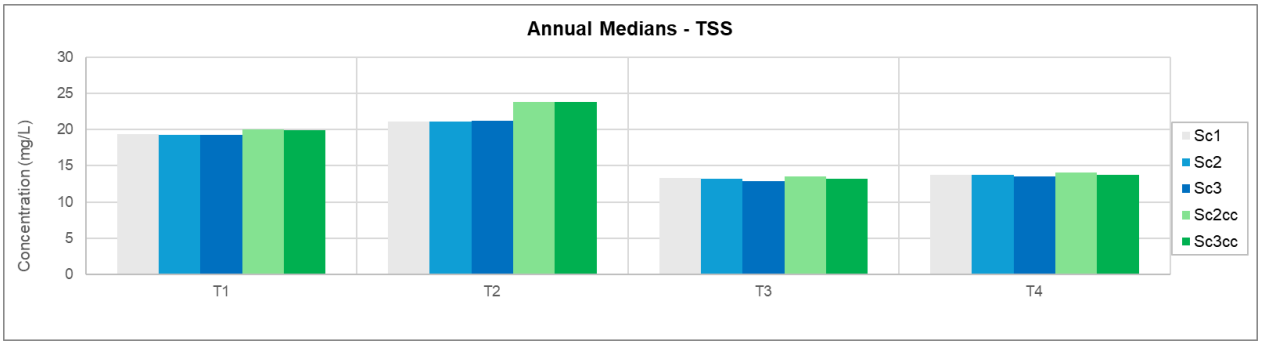


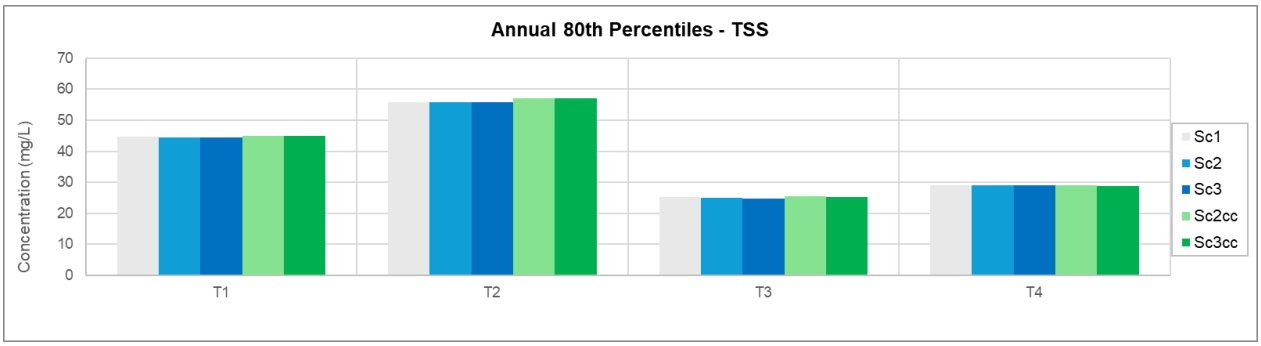




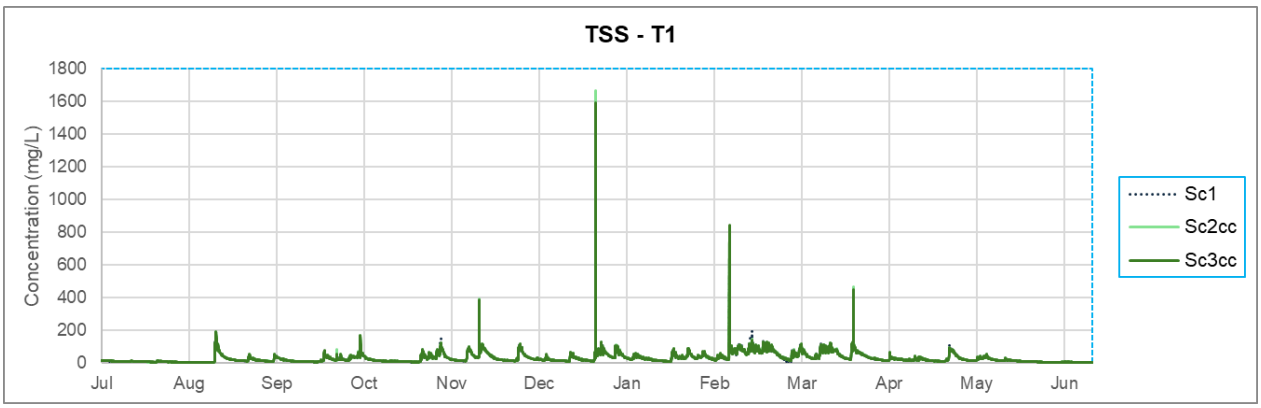
Appendices D6.8.3 Higher rainfall year scenario results (2021-2022)

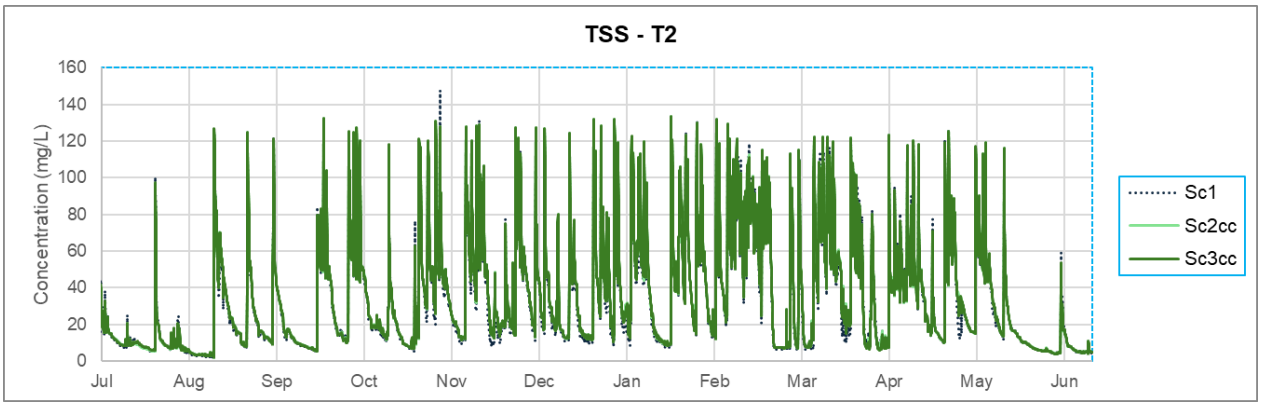
Bar charts

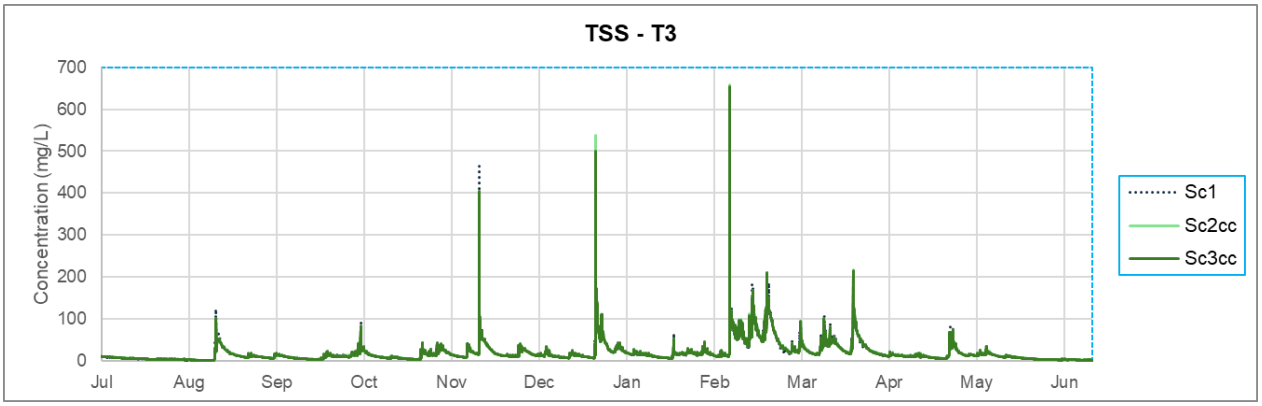


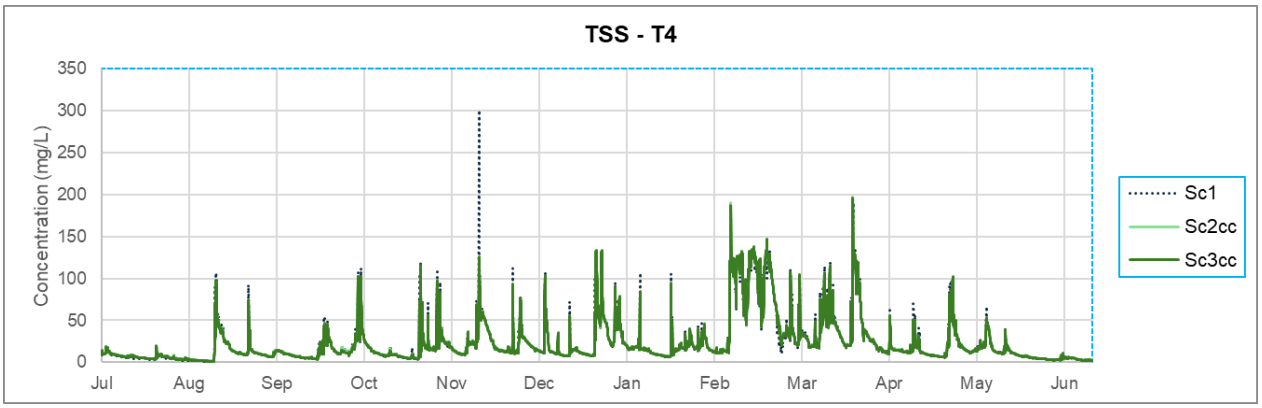


Time series plots




TSS - T2
Concentration (mg/L)
160
140
120
100
80
60
40
20
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

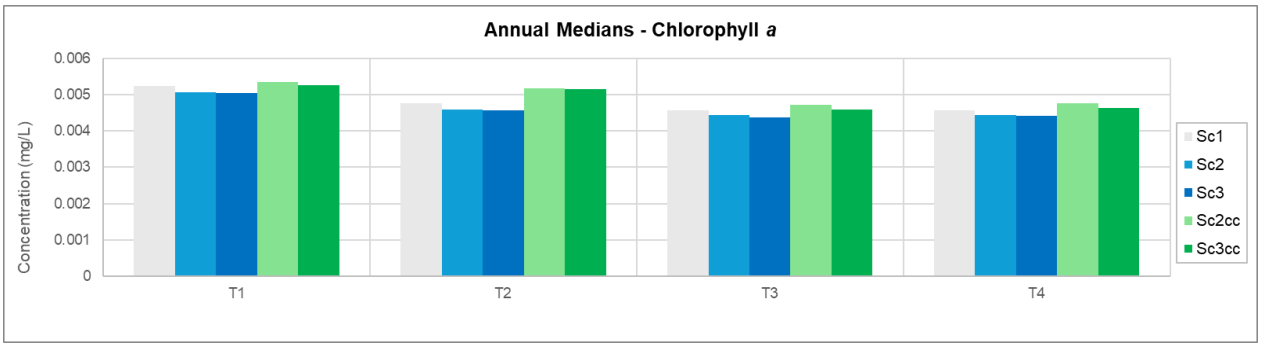

TSS - T3
Concentration (mg/L)
700
600
500
400
300
200
100
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

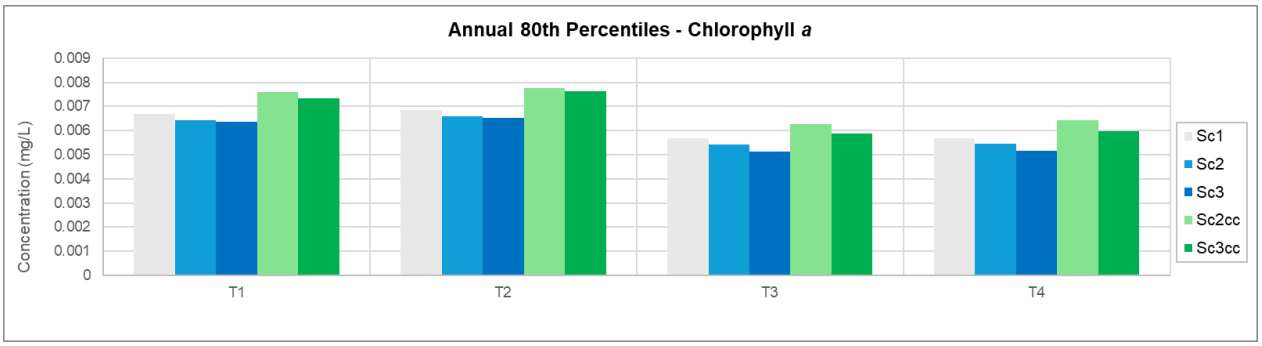

TSS - T4
Concentration (mg/L)
350
300
250
200
150
100
50
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.9 Chlorophyll a

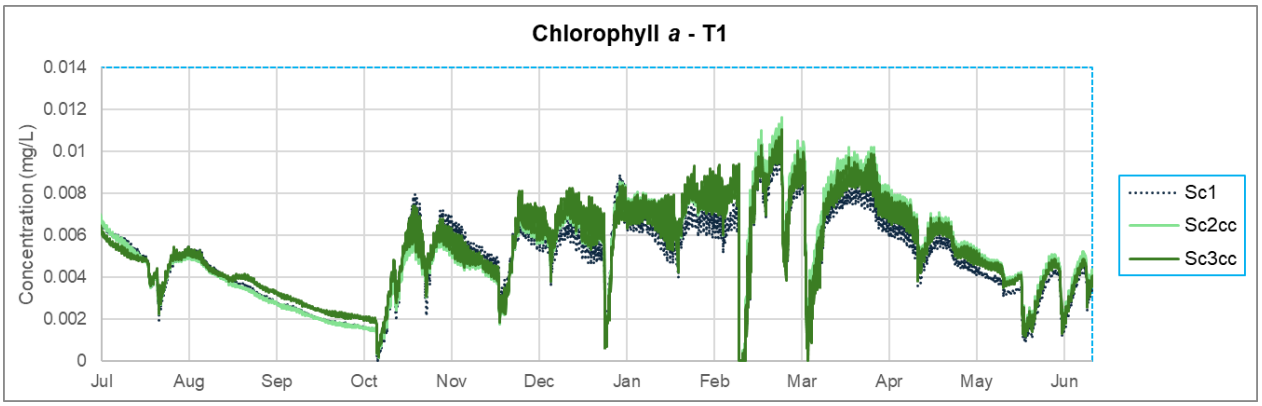
Appendices D6.9.1 Lower rainfall year scenario results (2017-2018)

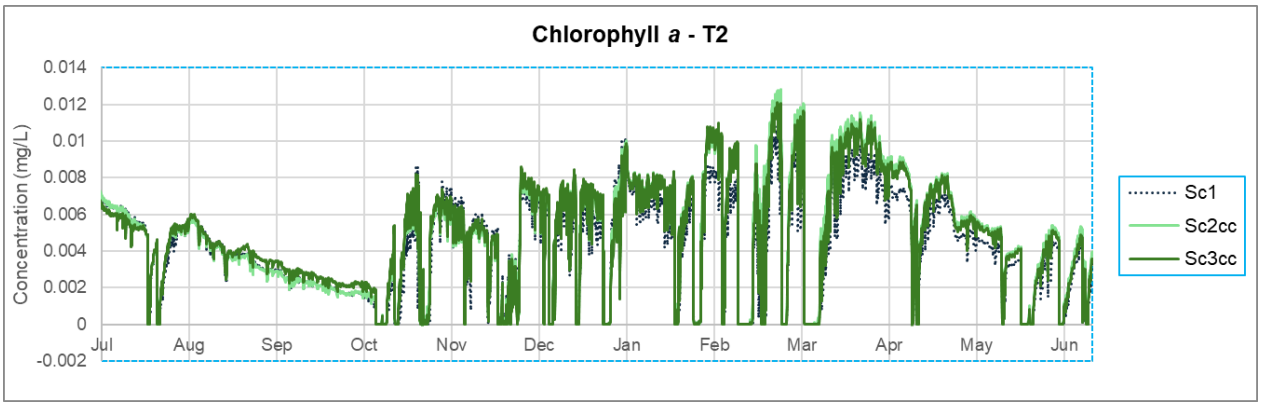
Bar charts

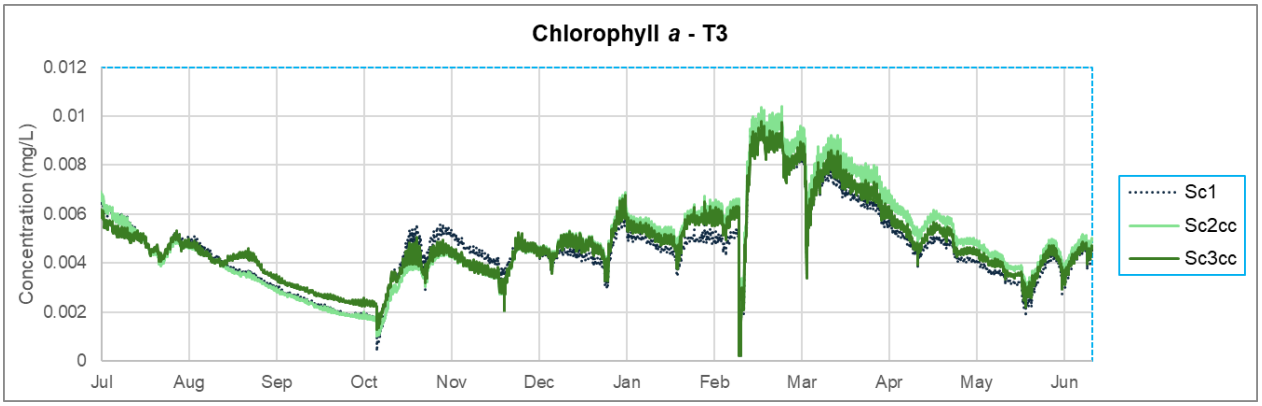


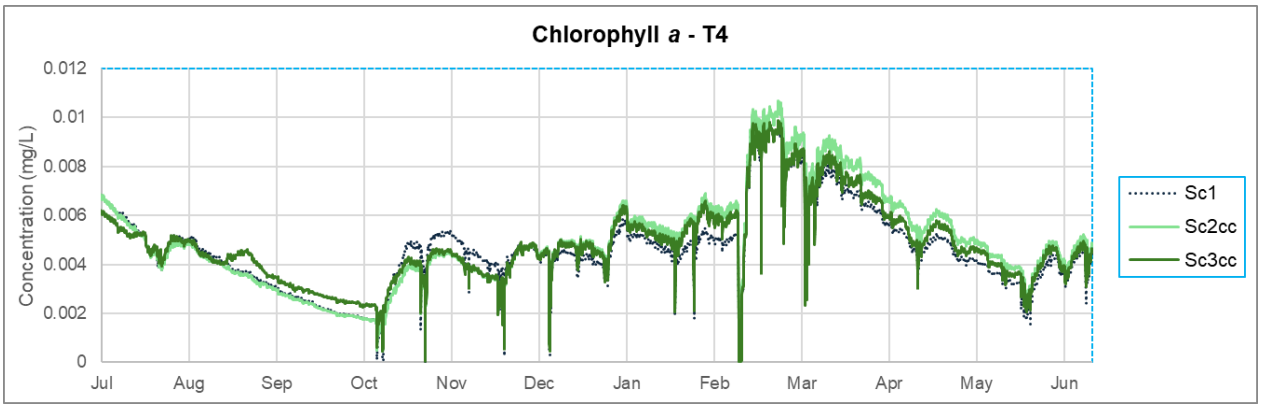


Time series plots



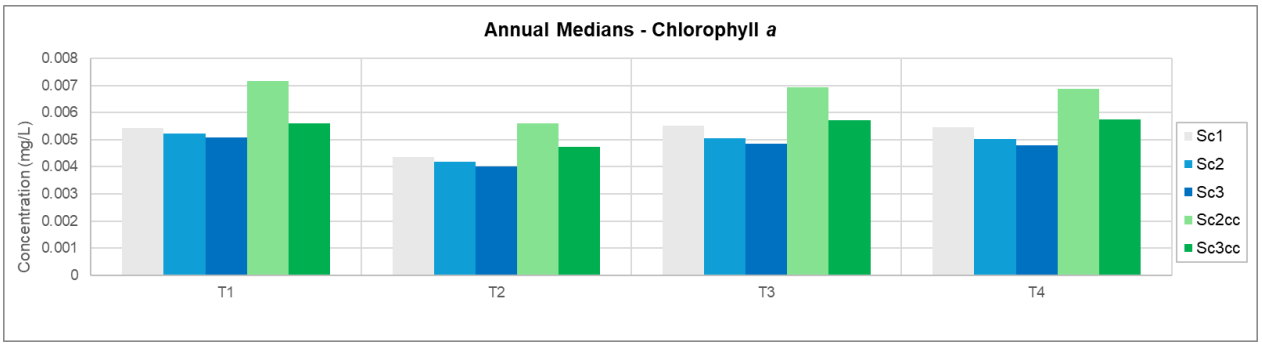


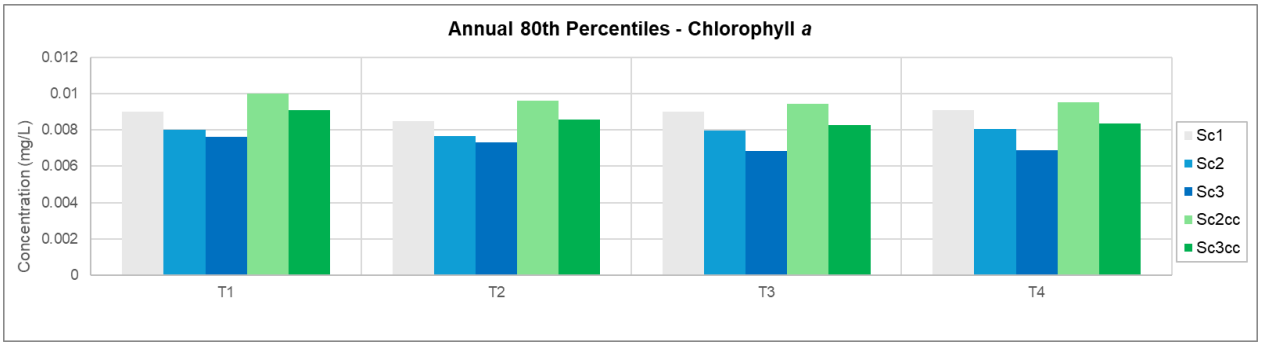




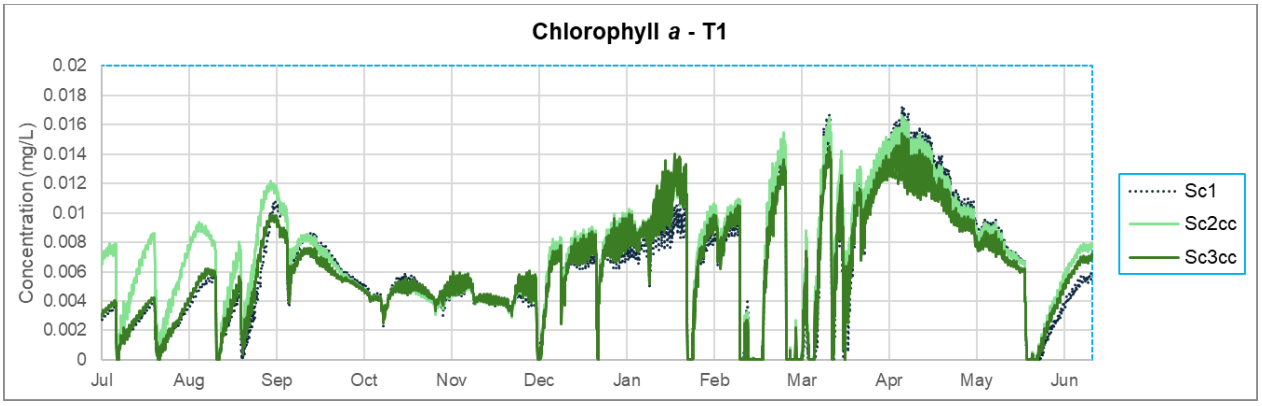
Appendices D6.9.2 Average rainfall year scenario results (2016-2017)

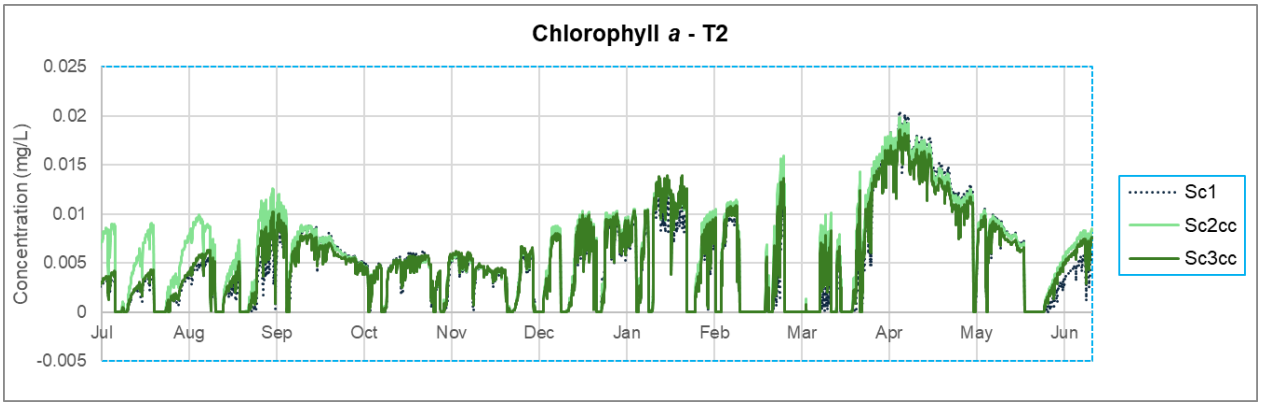
Bar charts

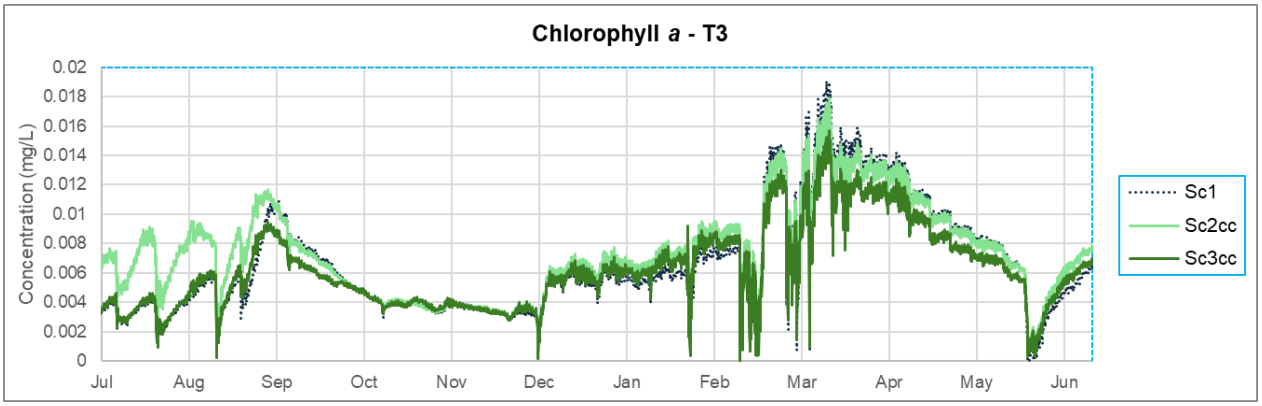


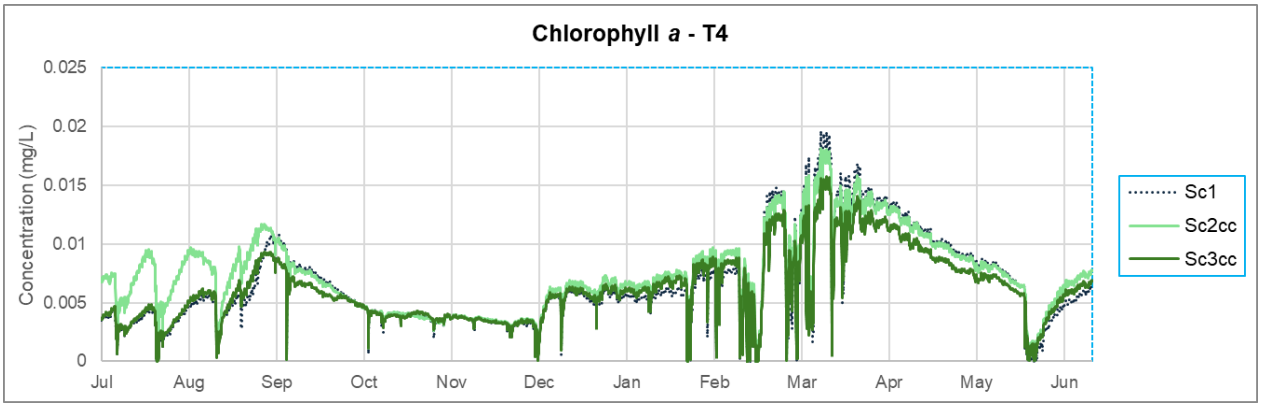


Time series plots



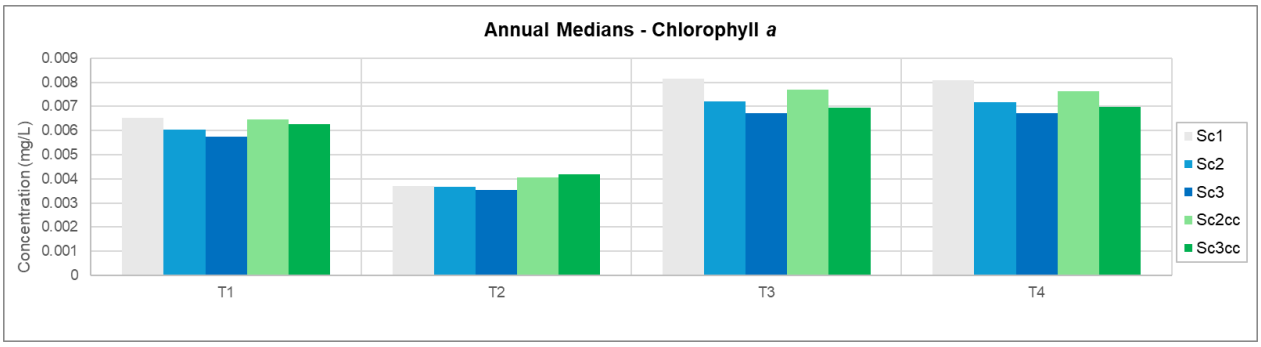


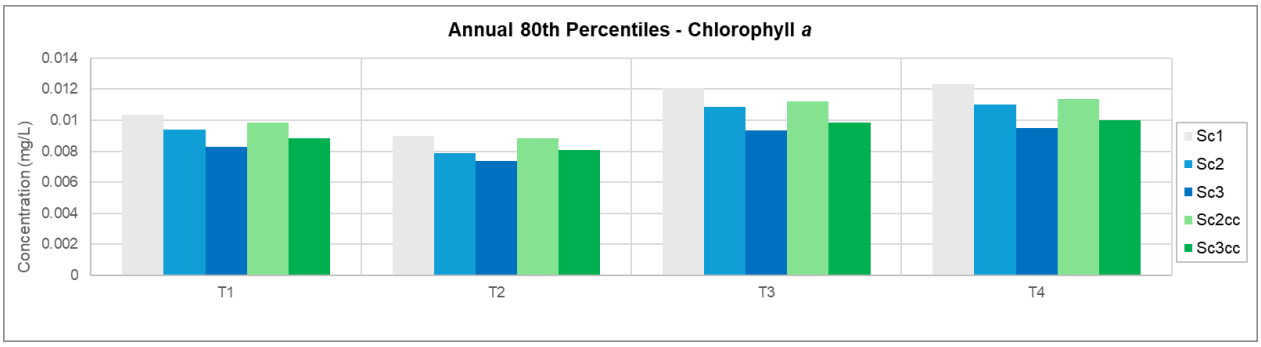




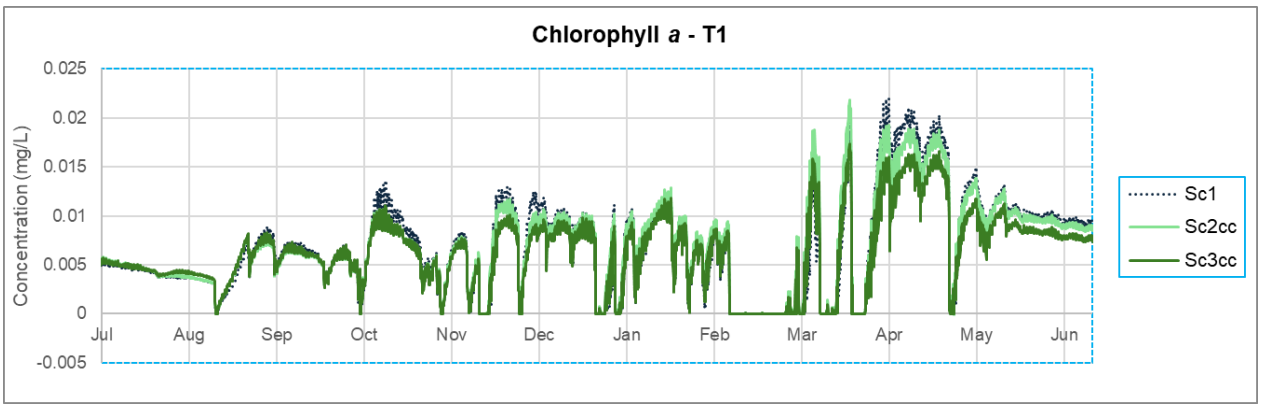
Appendices D6.9.3 Higher rainfall year scenario results (2021-2022)

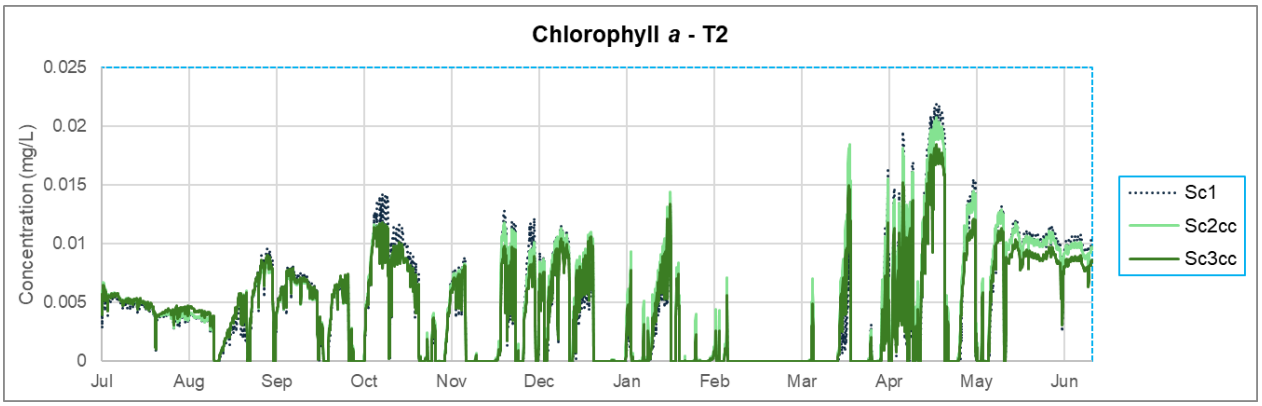
Bar charts

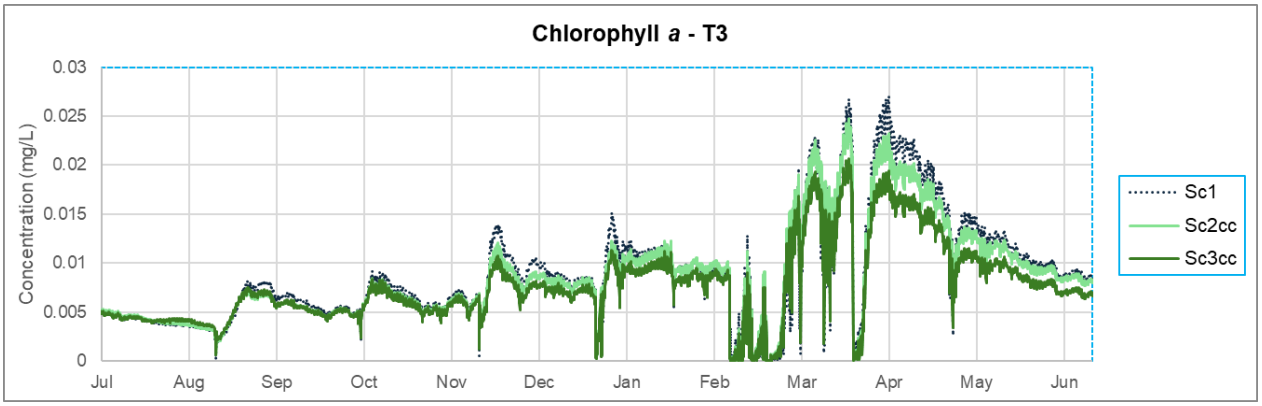


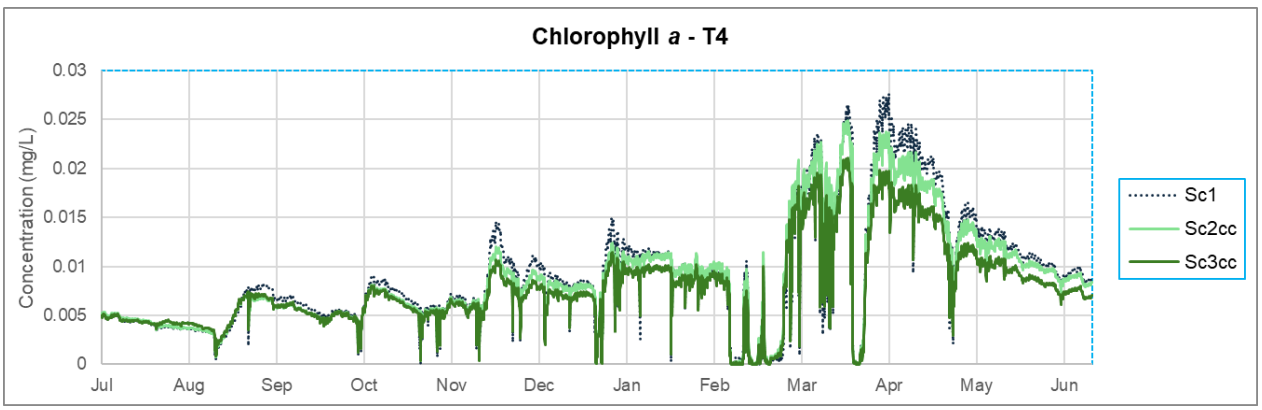


Time series plots




Chlorophyll *a* - T2
Concentration (mg/L)
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

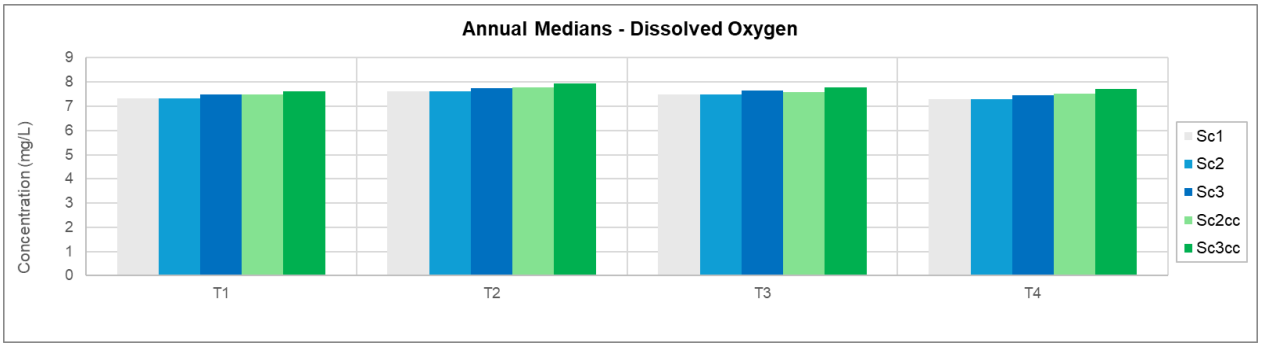

Chlorophyll *a* - T3
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

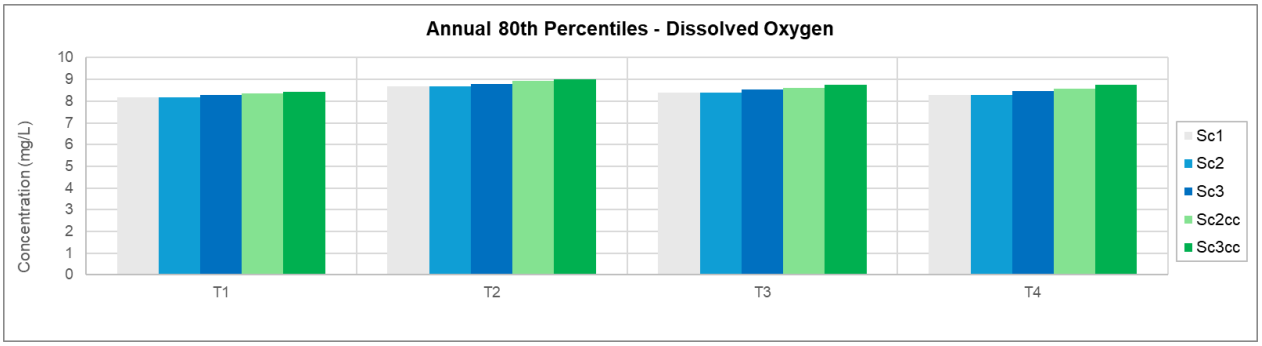

Chlorophyll *a* - T4
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

Appendices D6.10 Dissolved Oxygen

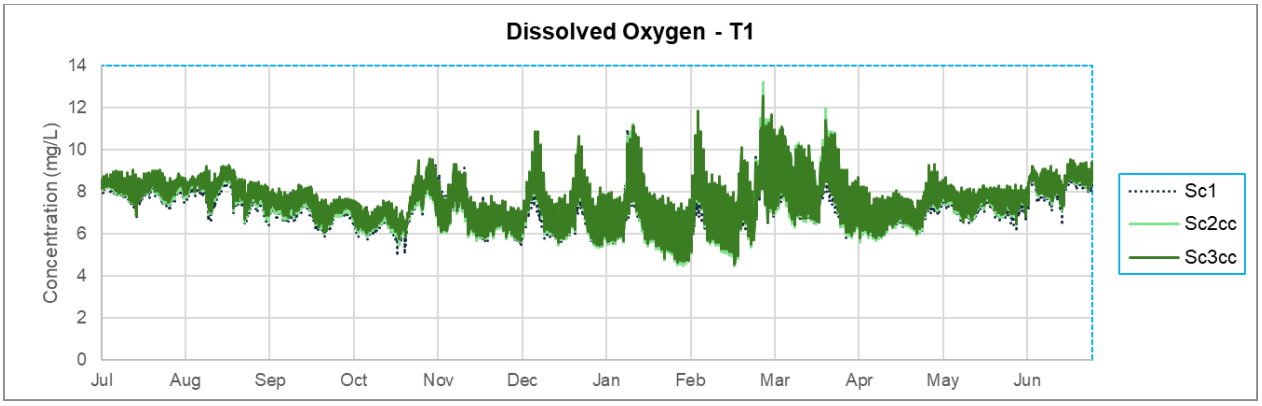
Appendices D6.10.1 Lower rainfall year scenario results (2017-2018)

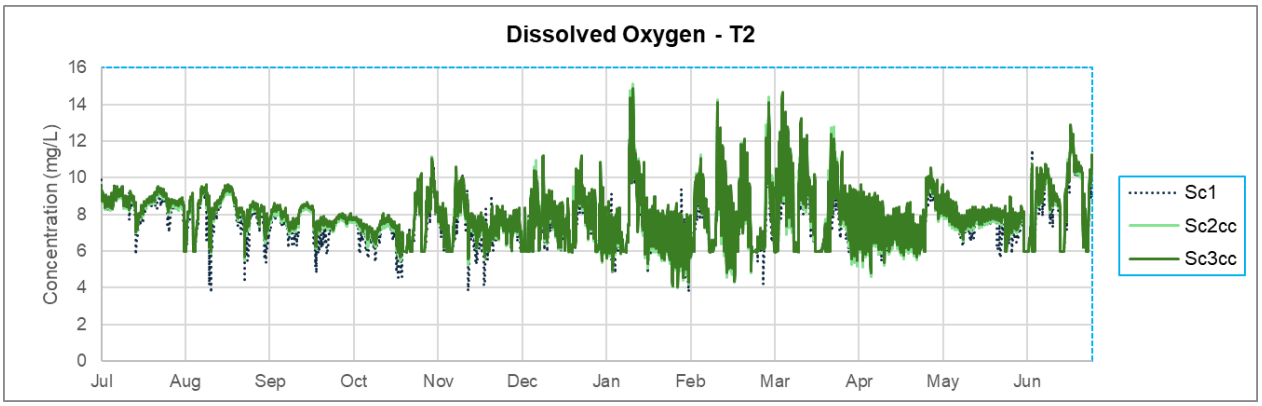
Bar charts

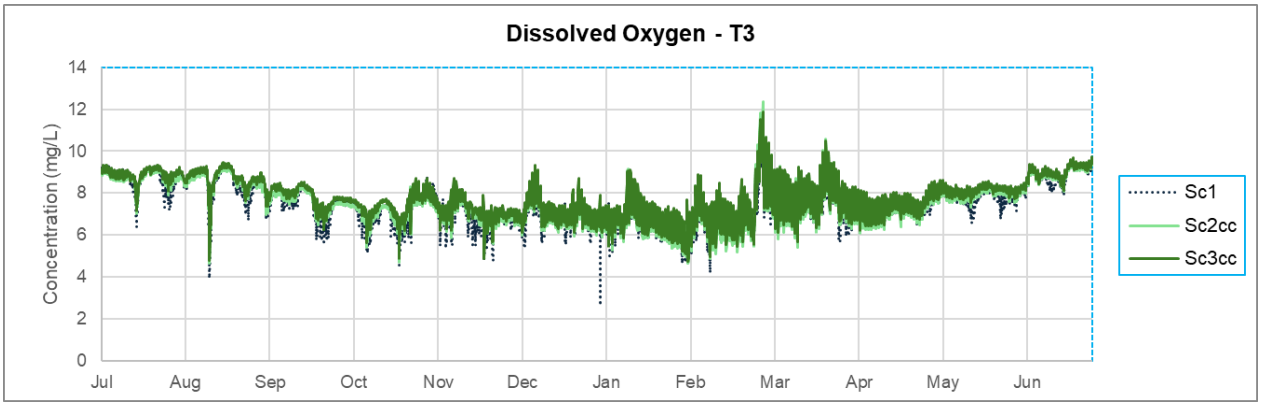


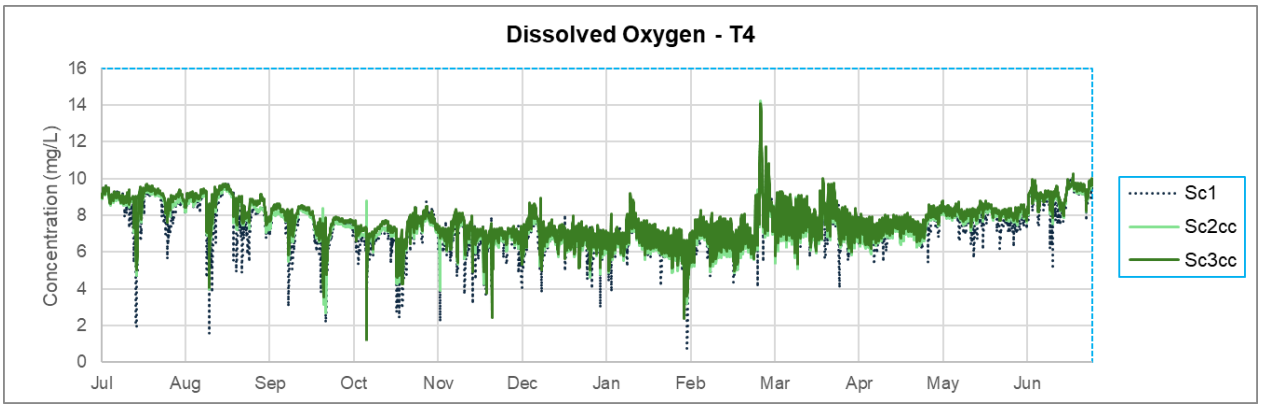


Time series plots



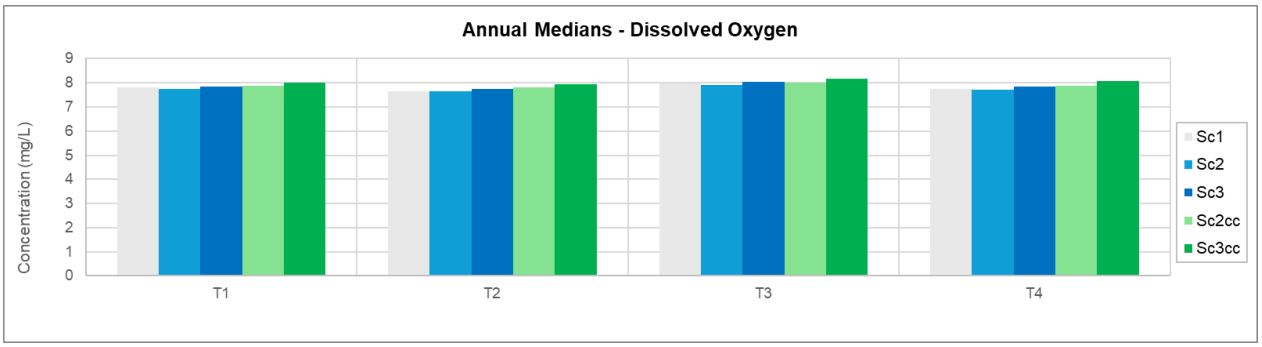


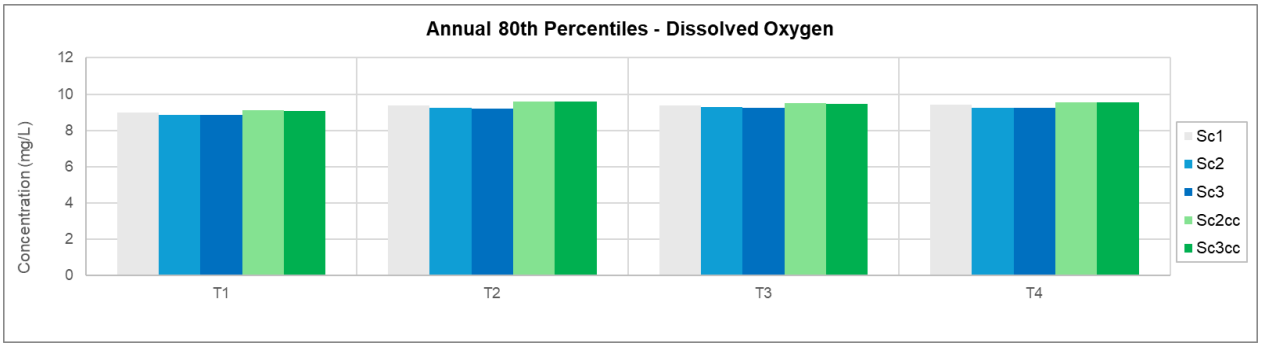




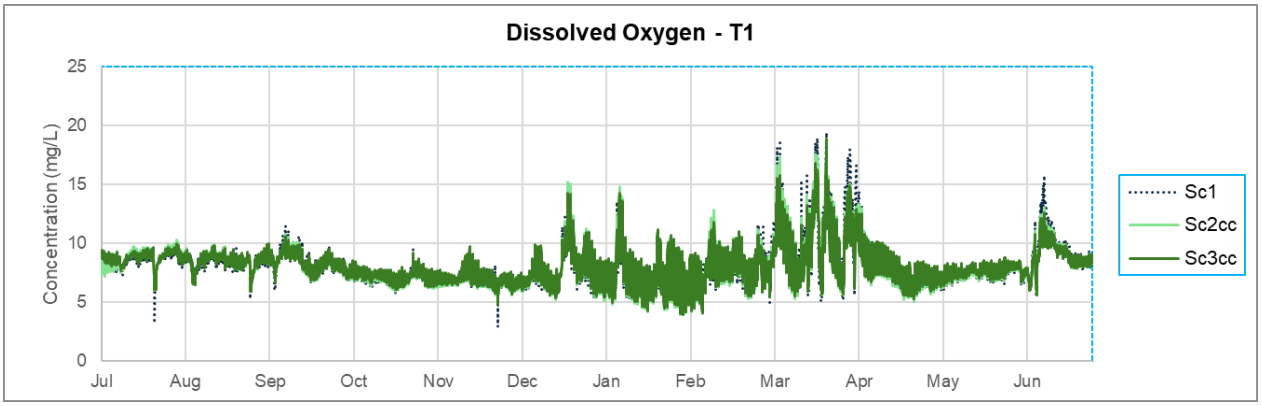
Appendices D6.10.2 Average rainfall year scenario results (2016-2017)

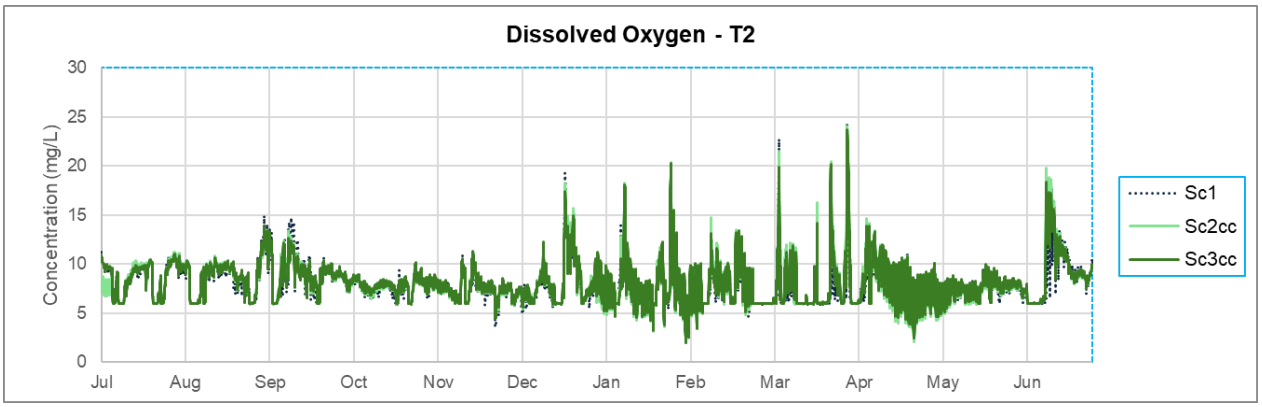
Bar charts

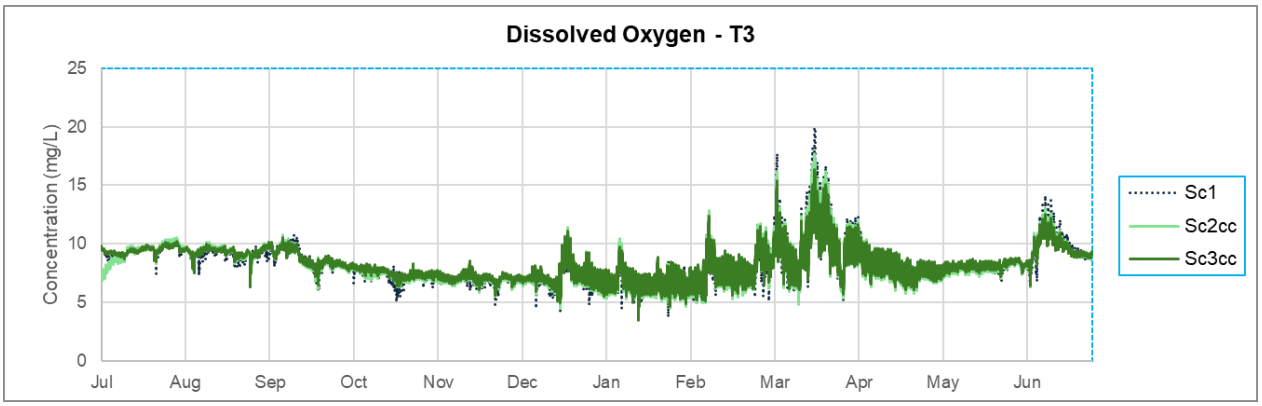


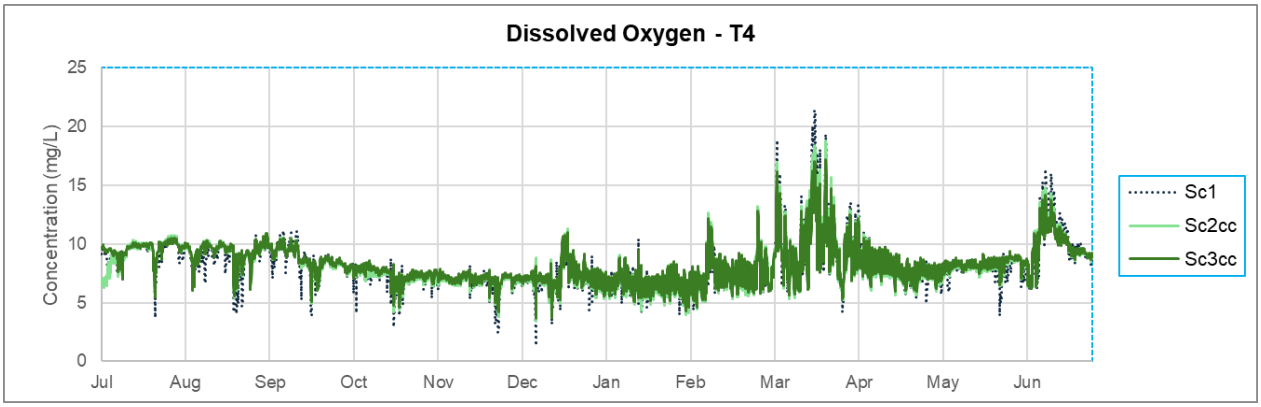


Time series plots



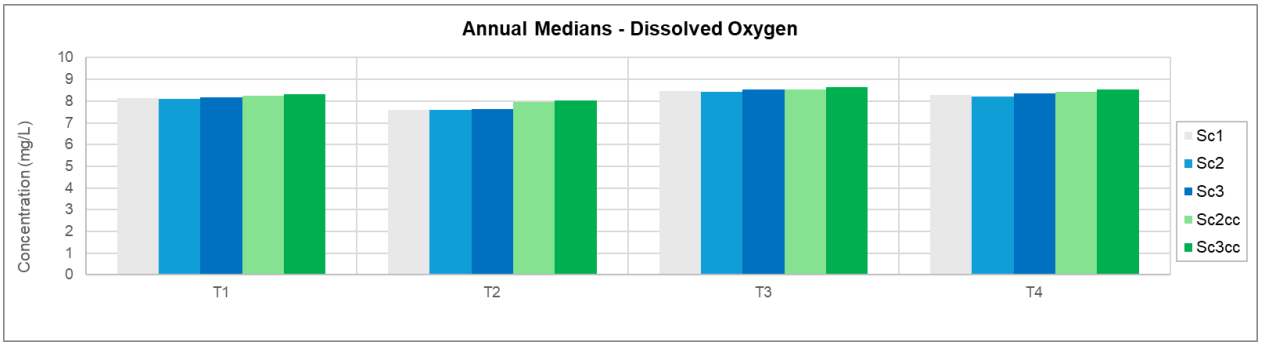


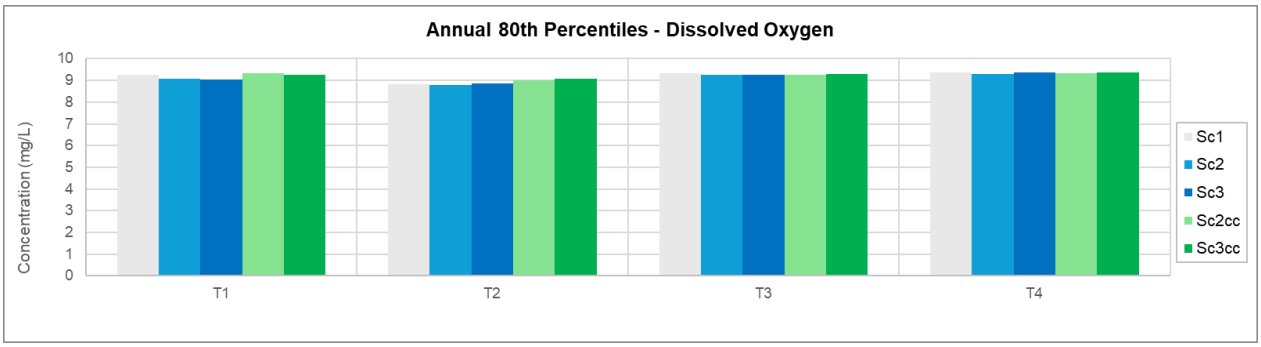




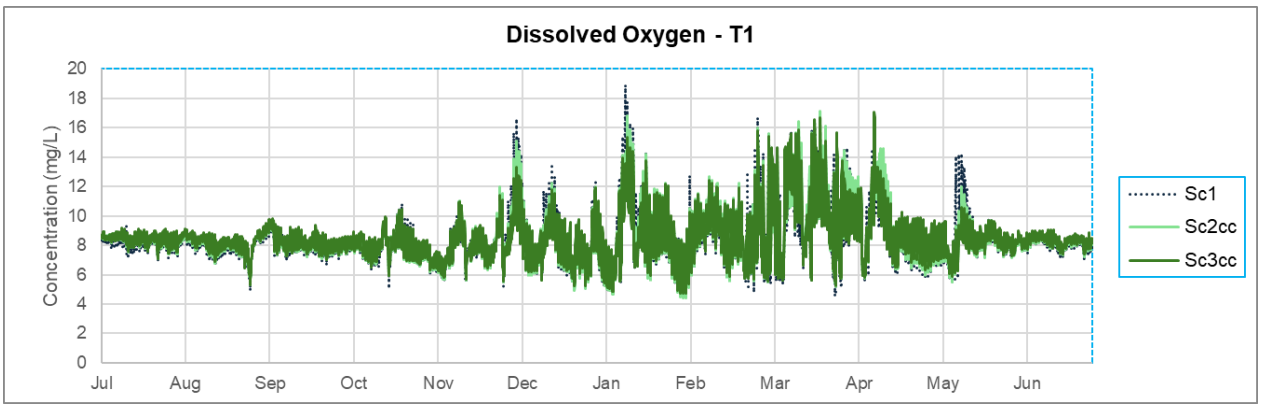
Appendices D6.10.3 Higher rainfall year scenario results (2021-2022)

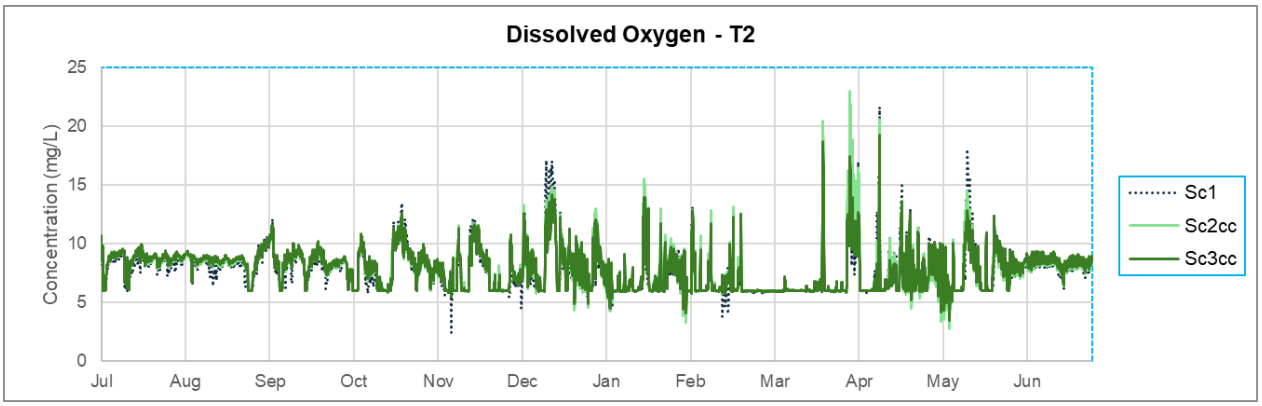
Bar charts

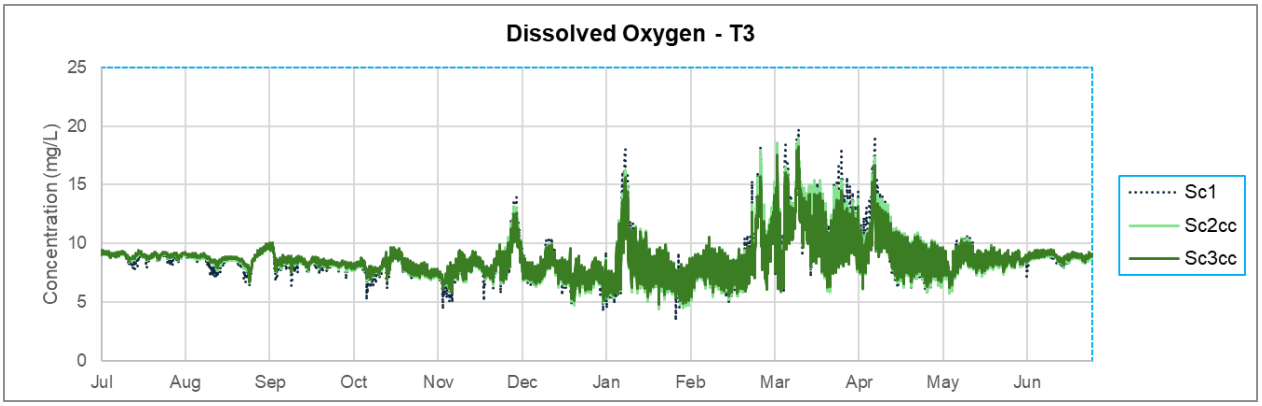


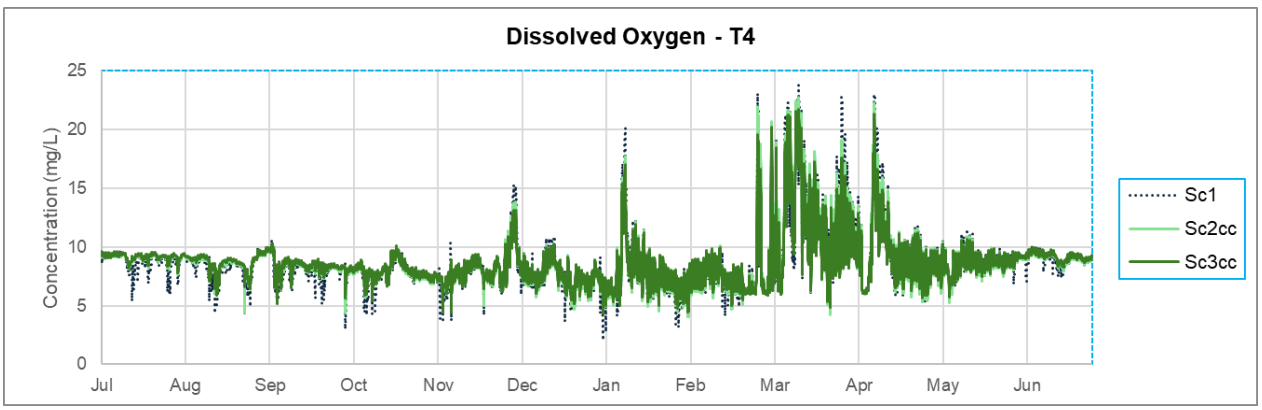


Time series plots




Dissolved Oxygen - T2
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

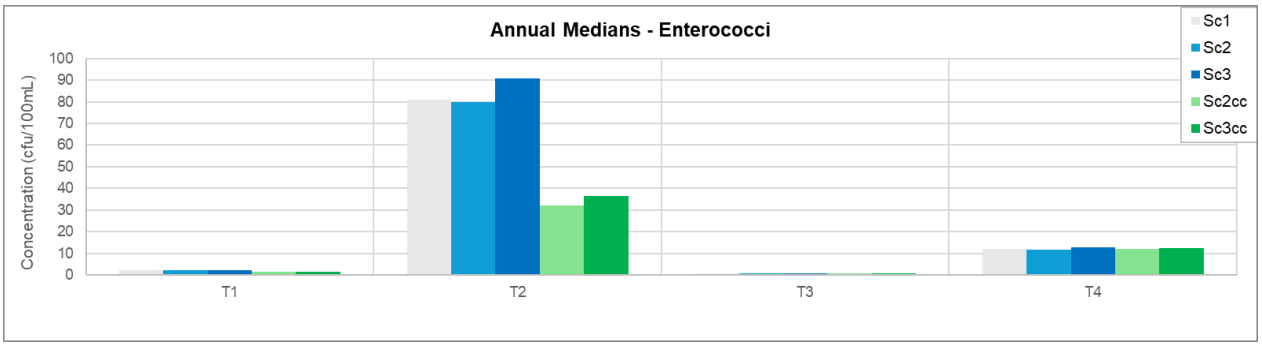

Dissolved Oxygen - T3
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

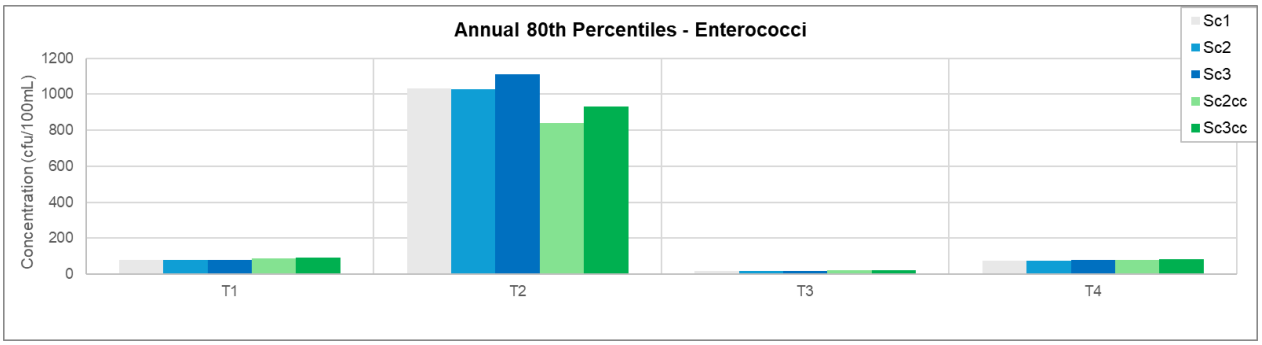

Dissolved Oxygen - T4
Concentration (mg/L)
25
20
15
10
5
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

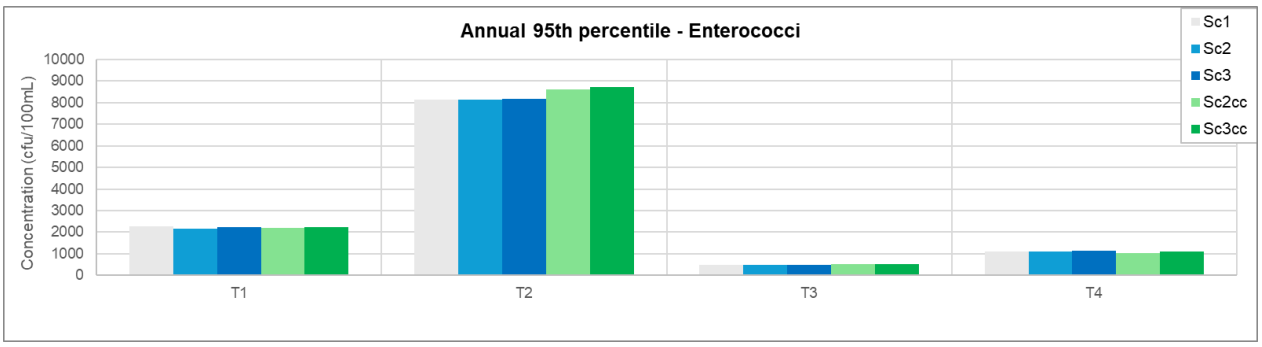
Appendices D6.11 Enterococci

Appendices D6.11.1 Lower rainfall year scenario results (2017-2018)

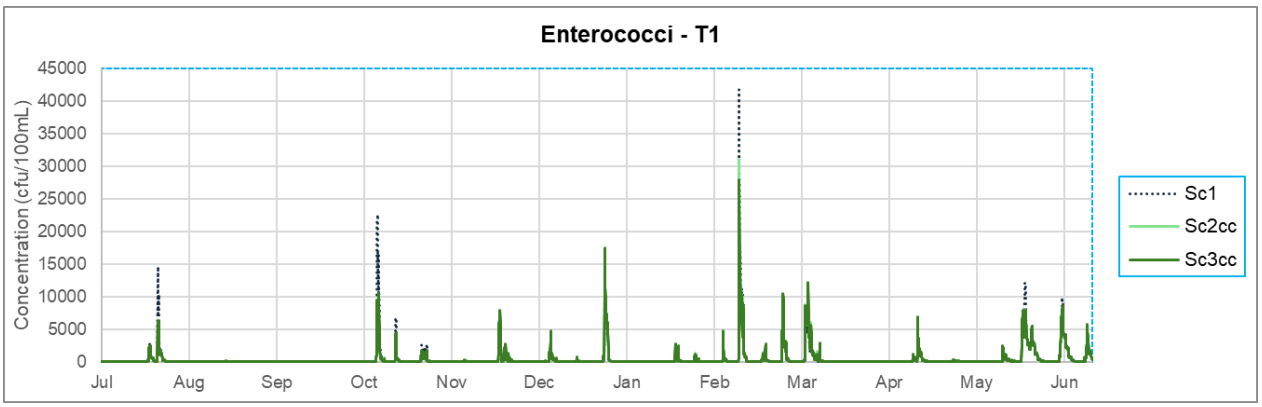
Bar charts

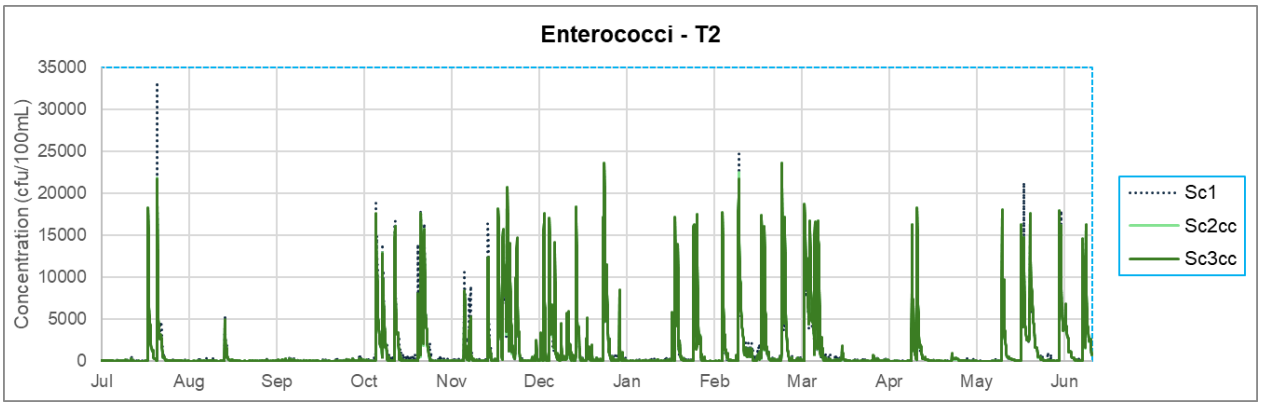


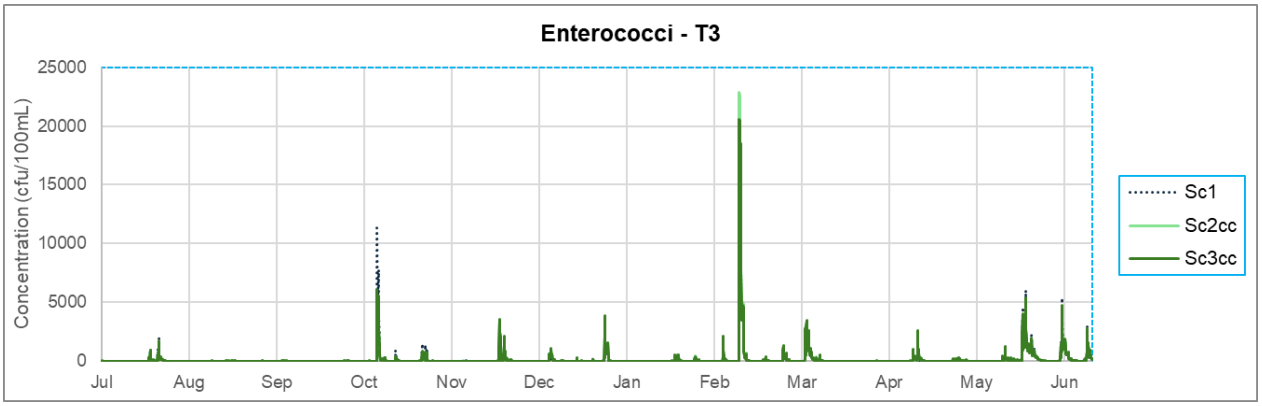


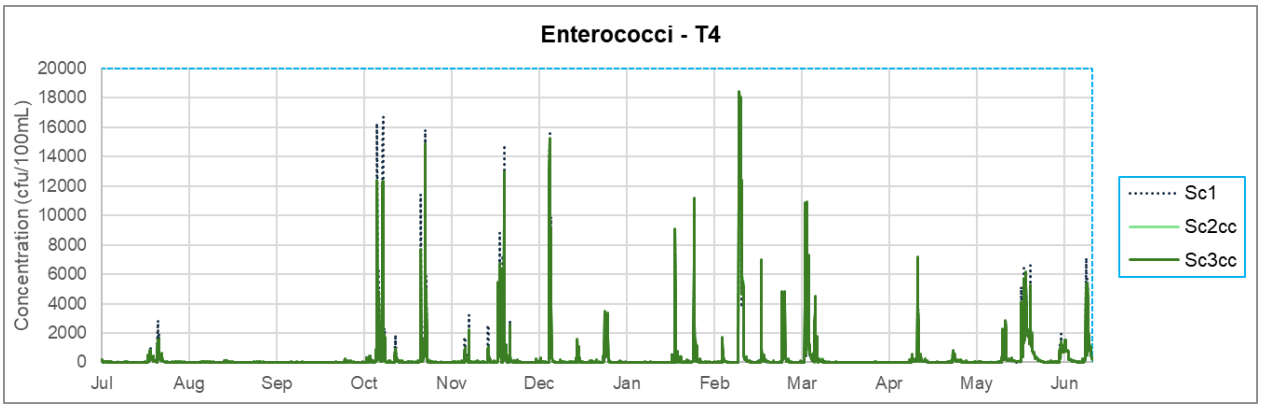


Time series plots



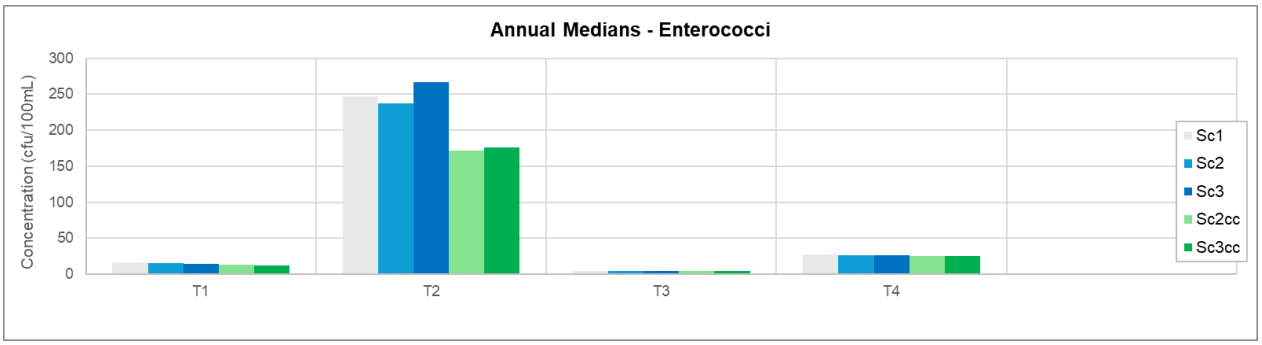


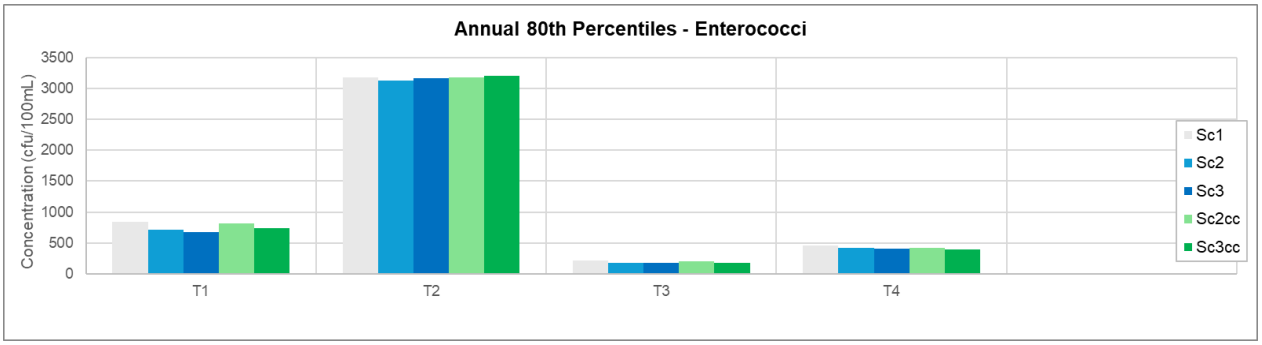


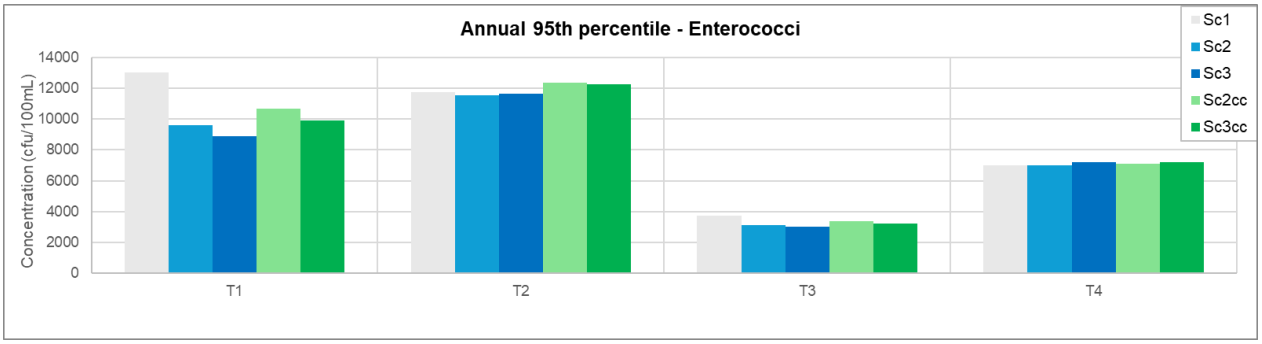


Appendices D6.11.2 Average rainfall year scenario results (2016-2017)

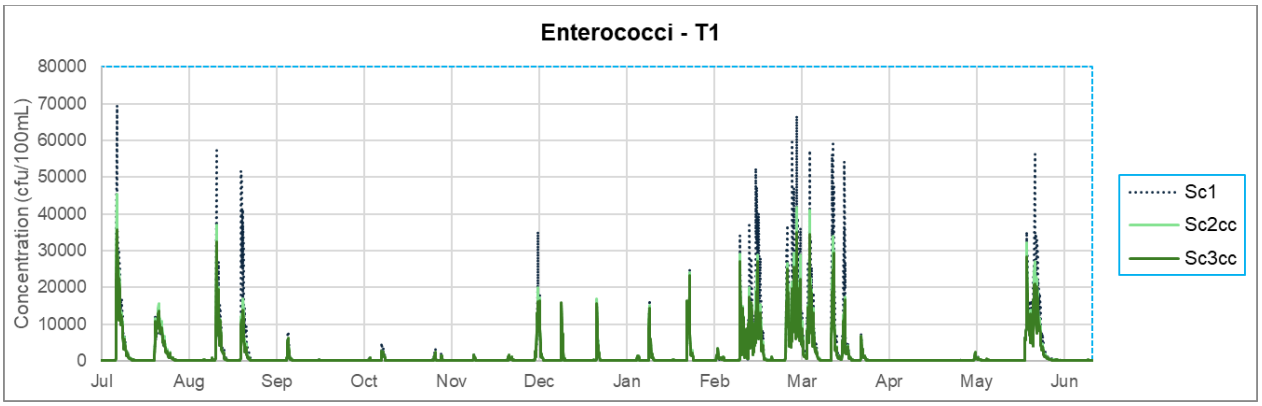
Bar charts

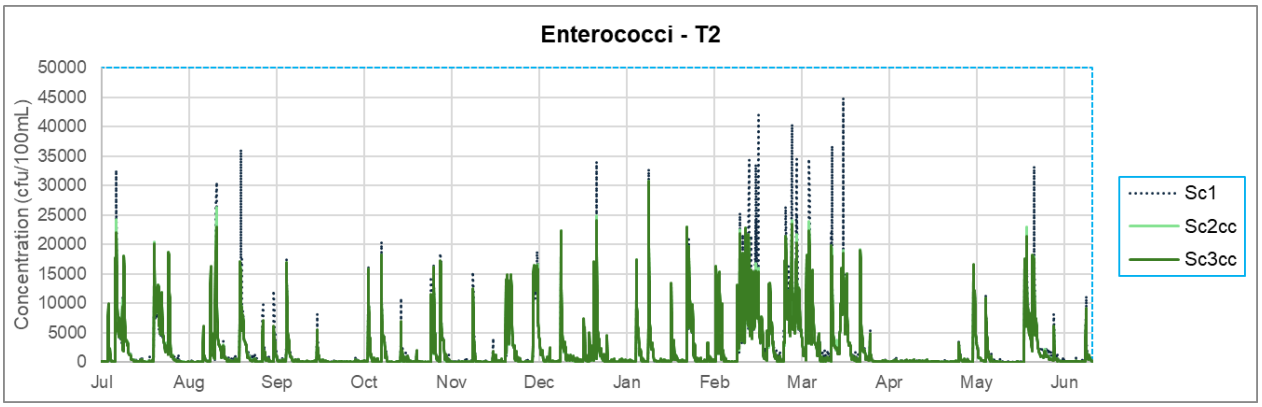


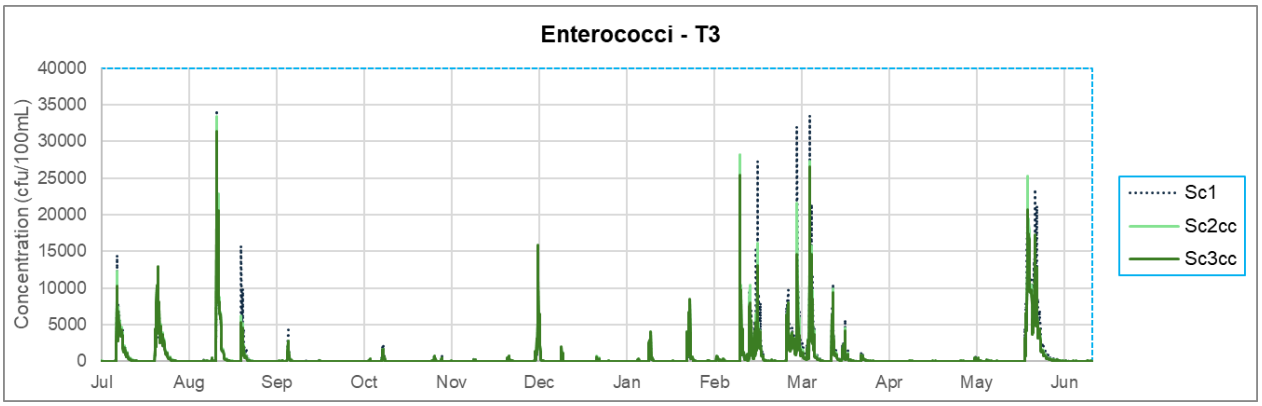


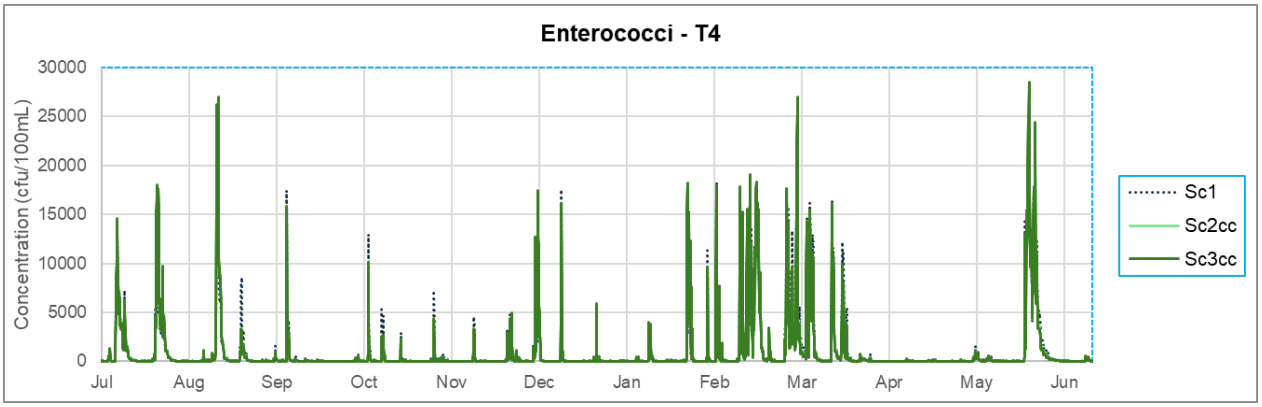


Time series plots



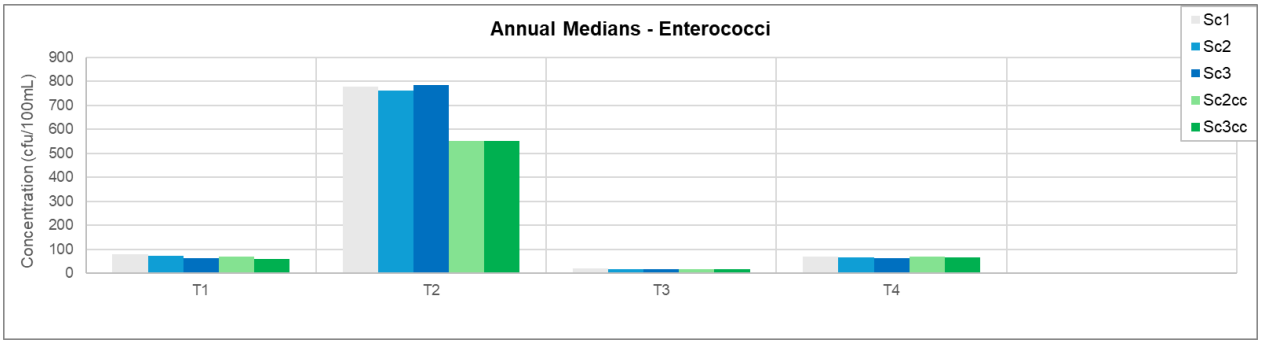


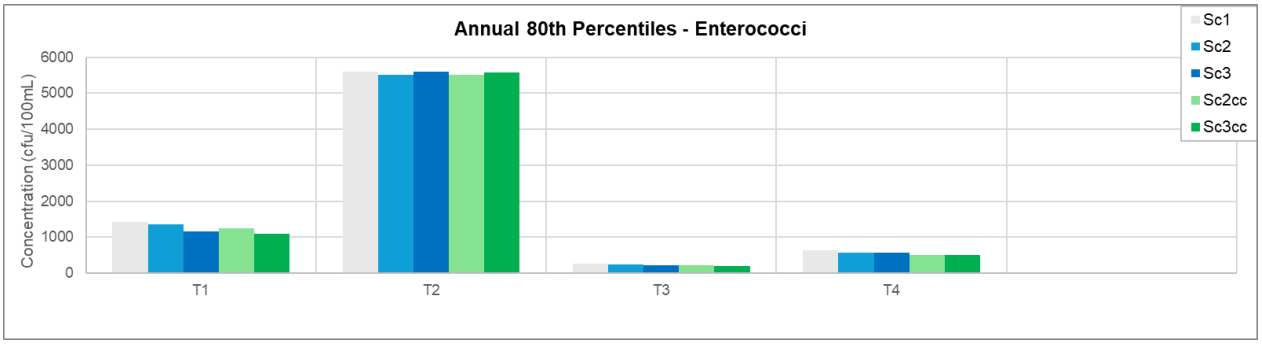


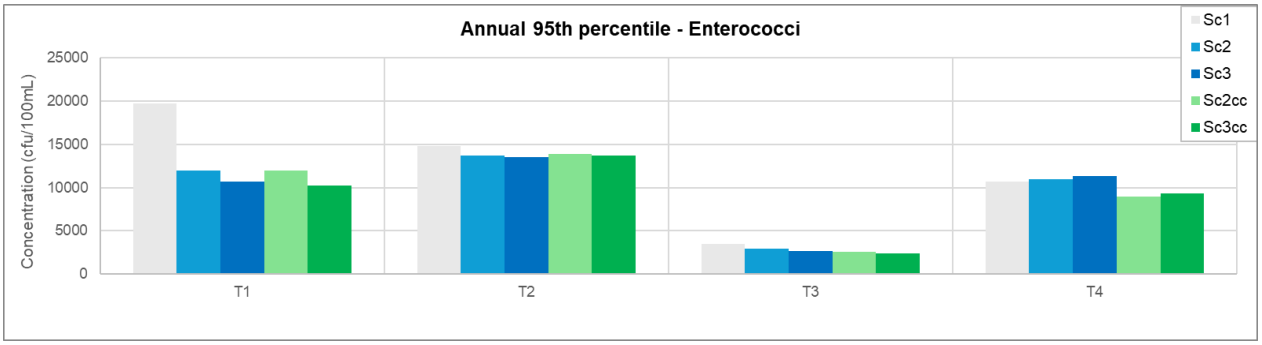


Appendices D6.11.3 Higher rainfall year scenario results (2021-2022)

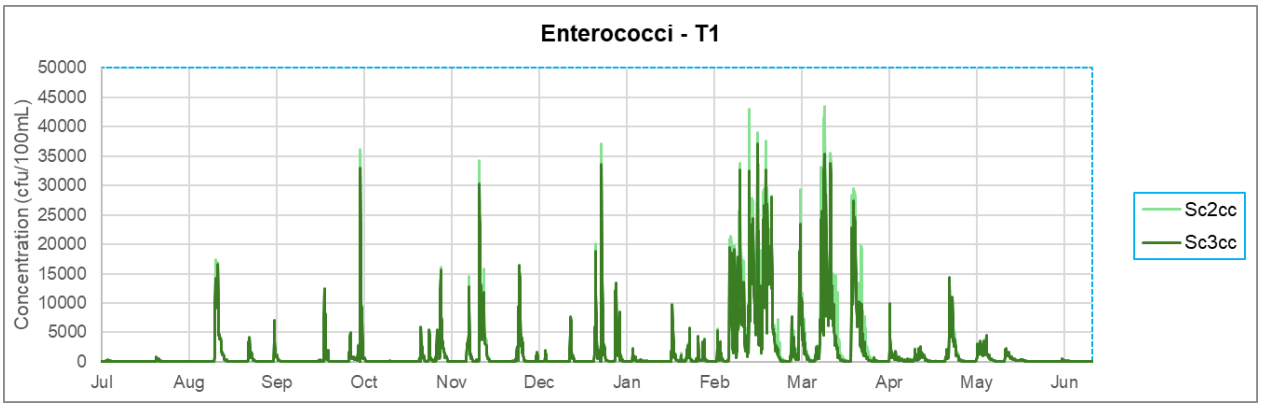
Bar charts

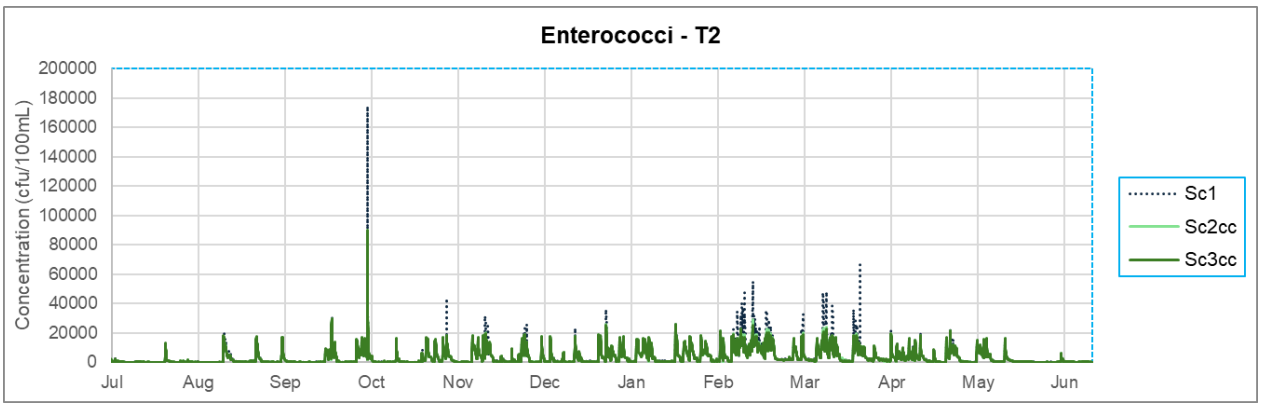


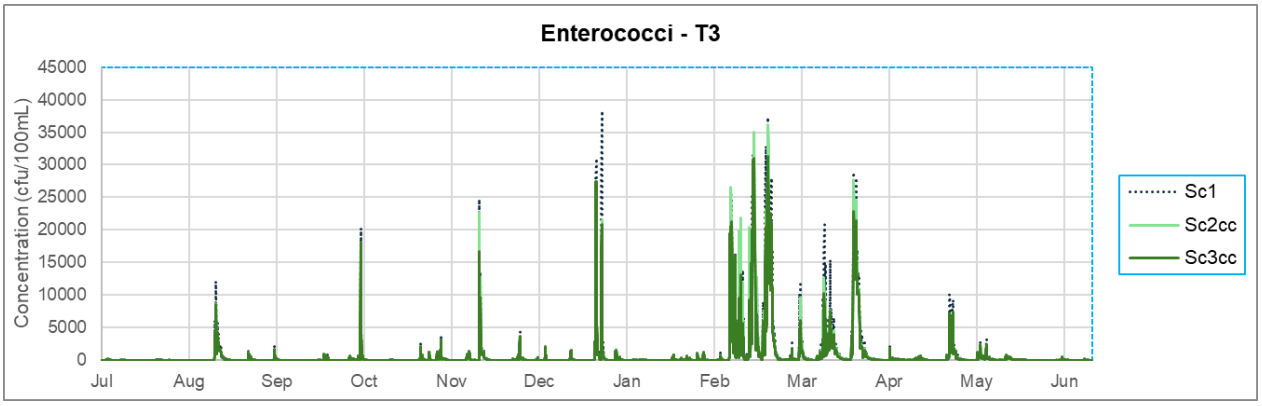


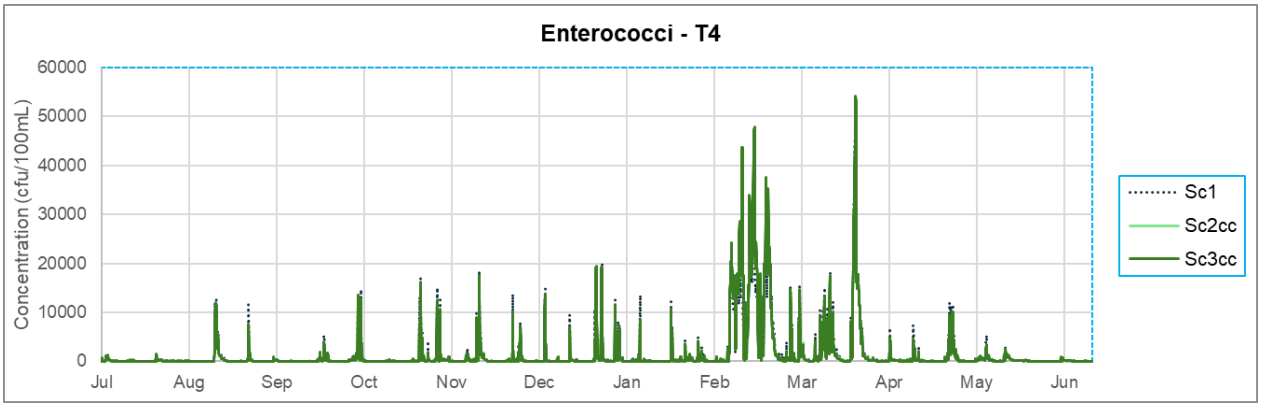


Time series plots







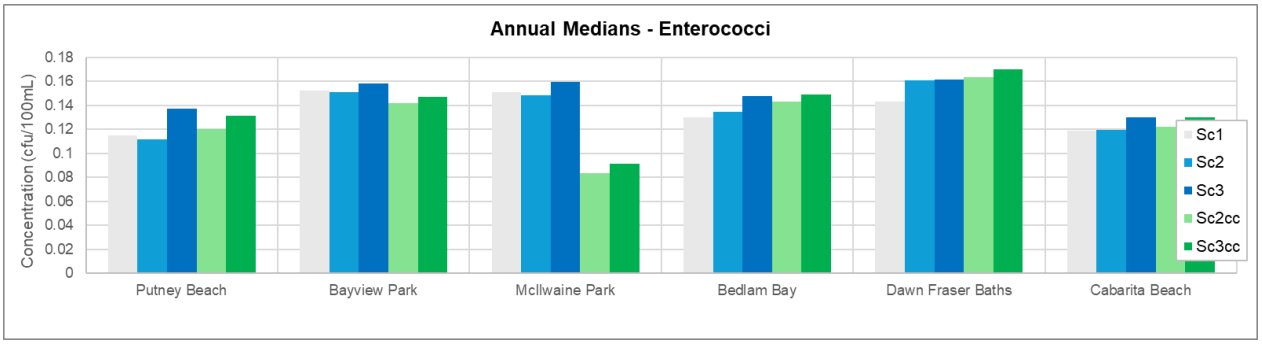

Enterococci - T4
Concentration (cfu/100mL)
60000
50000
40000
30000
20000
10000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc

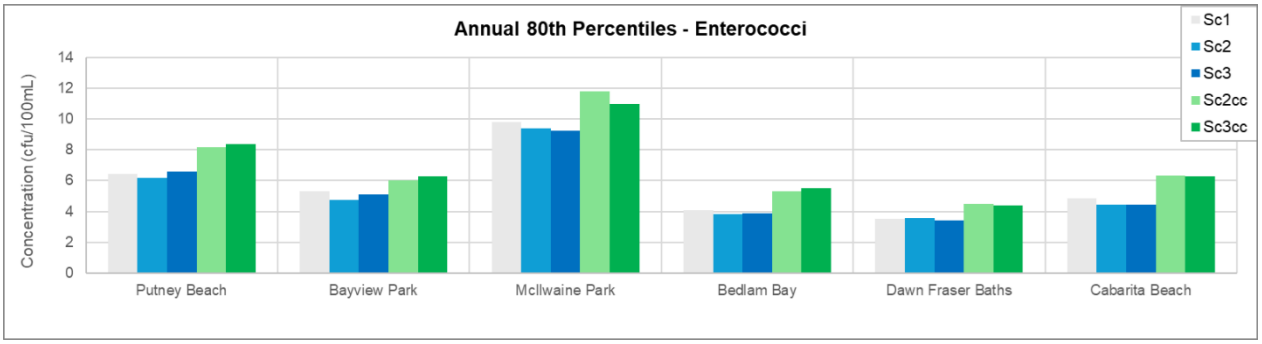
Appendices D7 Swim sites results without climate change

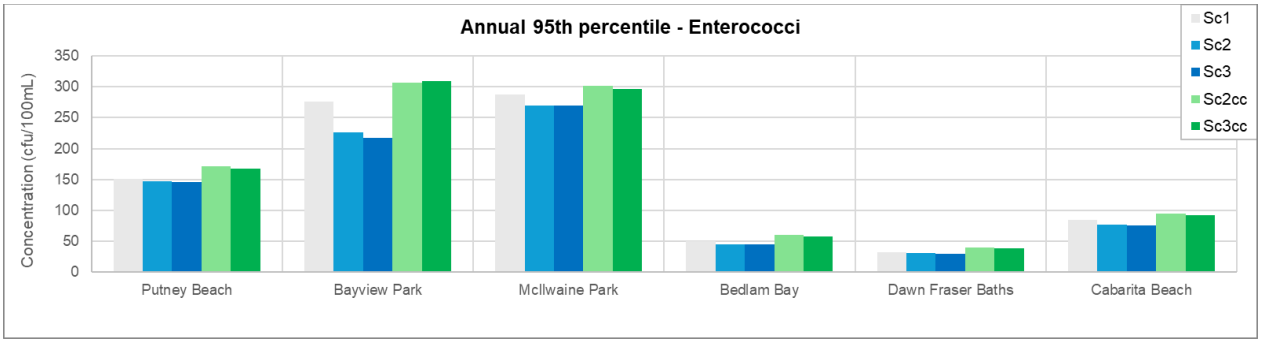
Appendices D7.1 Enterococci

Appendices D7.1.1 Lower rainfall year scenario results (2017-2018)

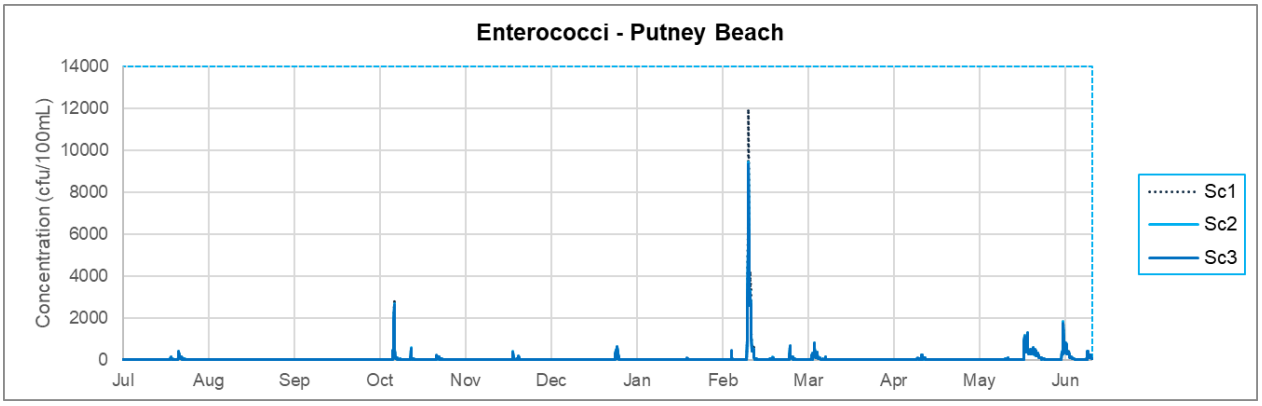
Bar charts

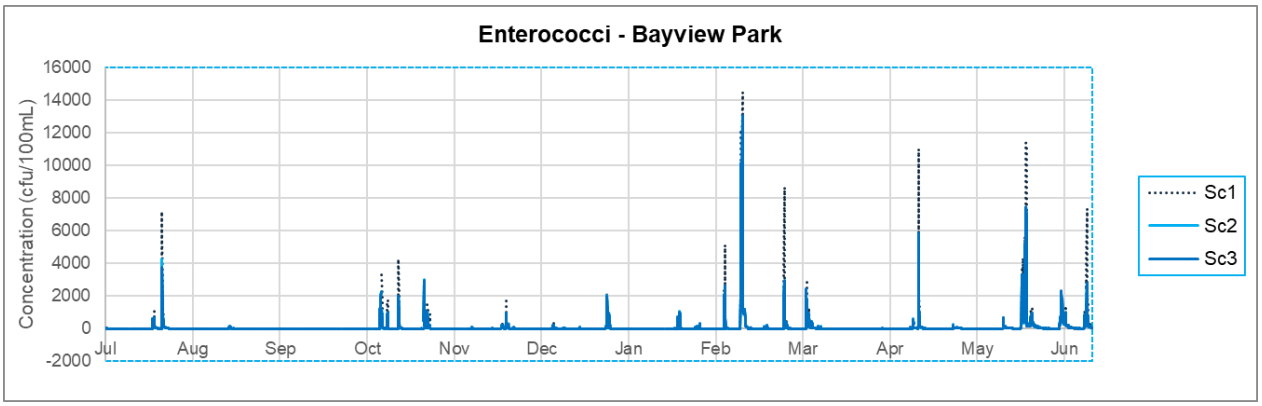


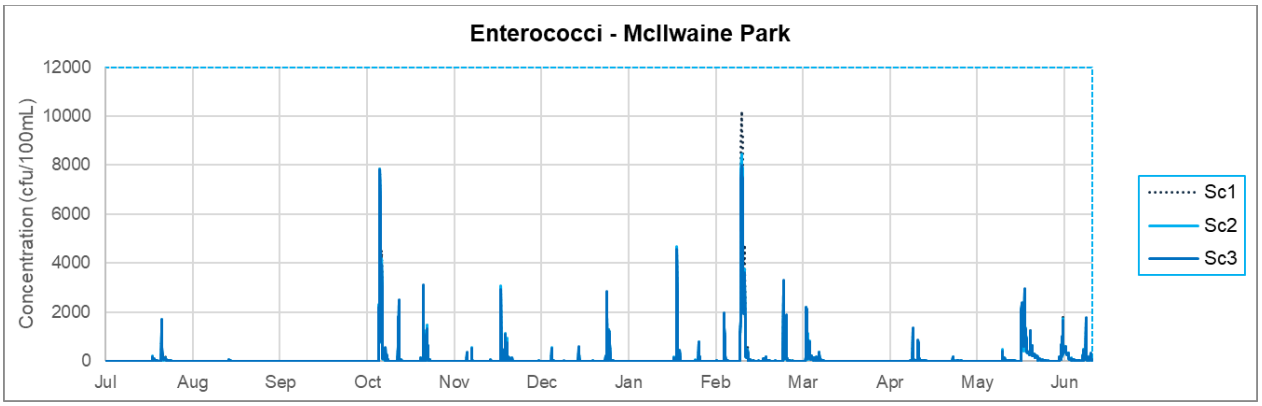


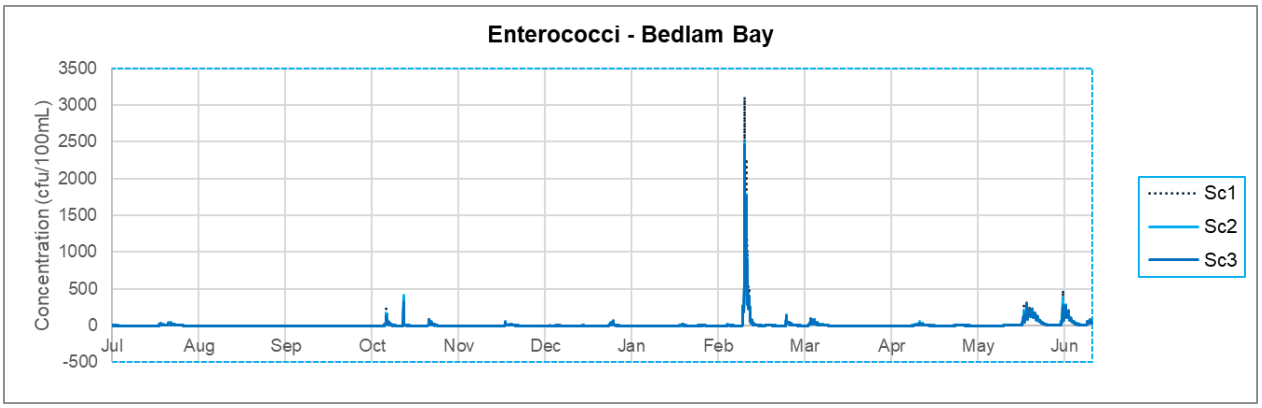


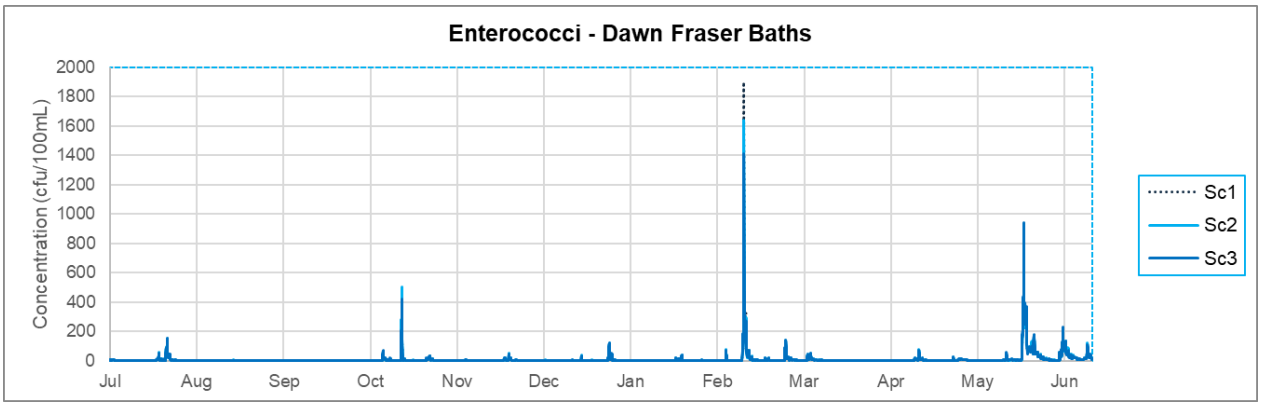
Time series plots

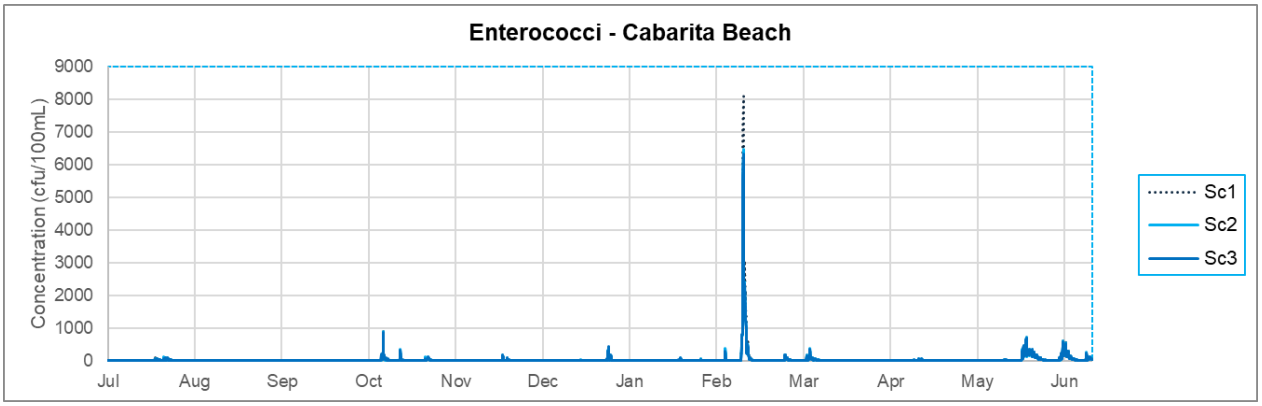






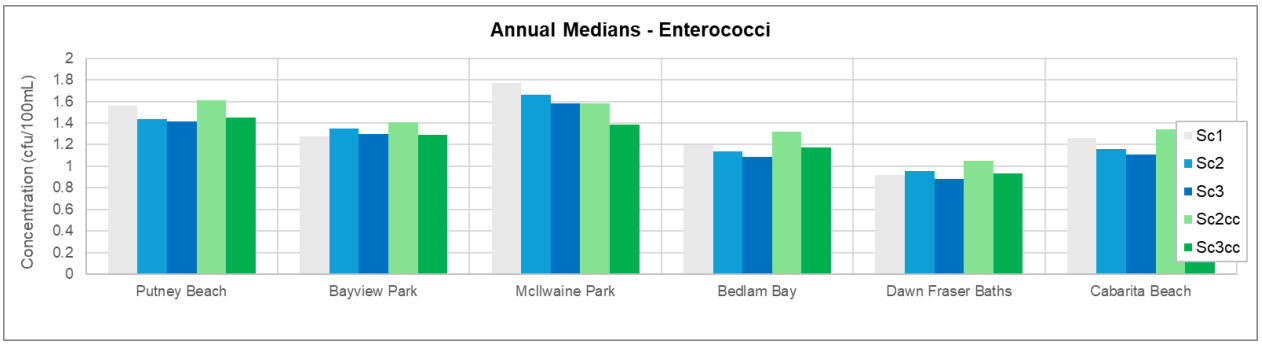


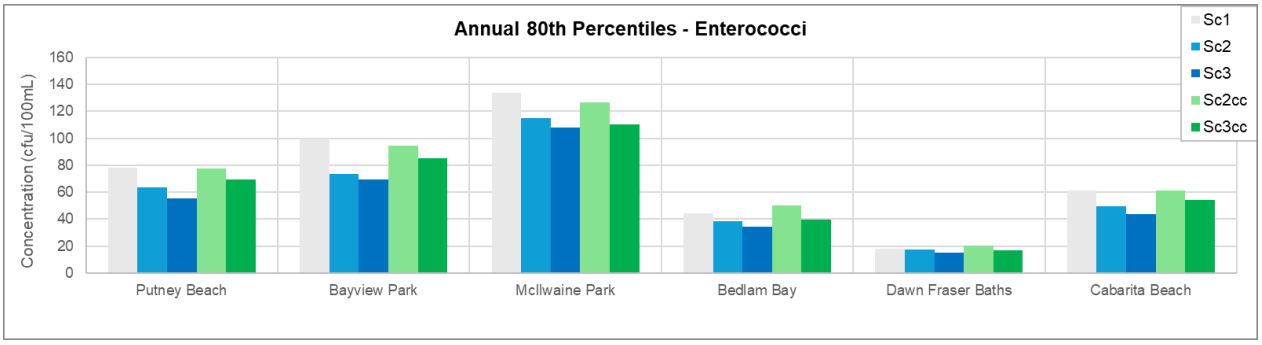


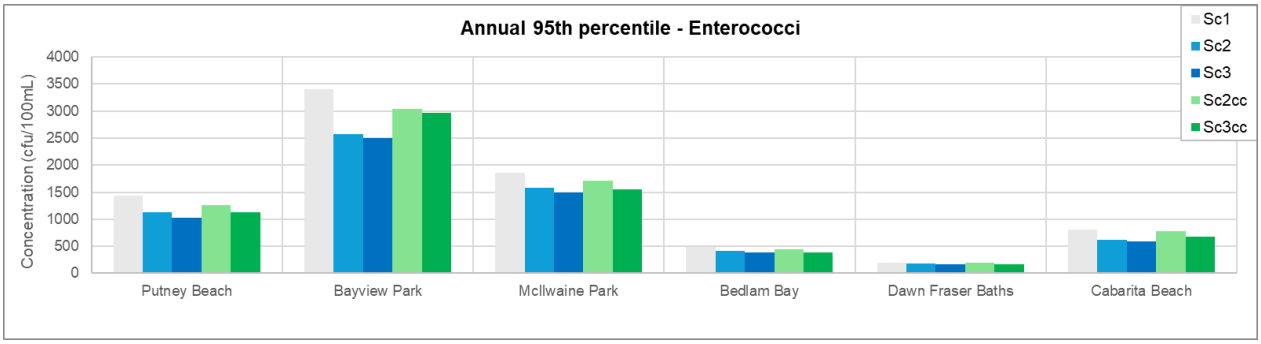


Appendices D7.1.2 Average rainfall year scenario results (2016-2017)

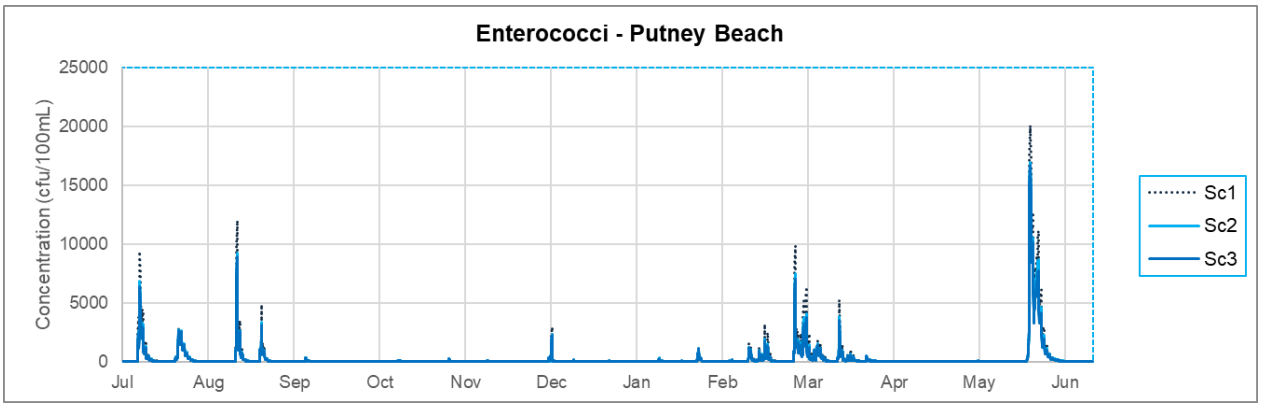
Bar charts

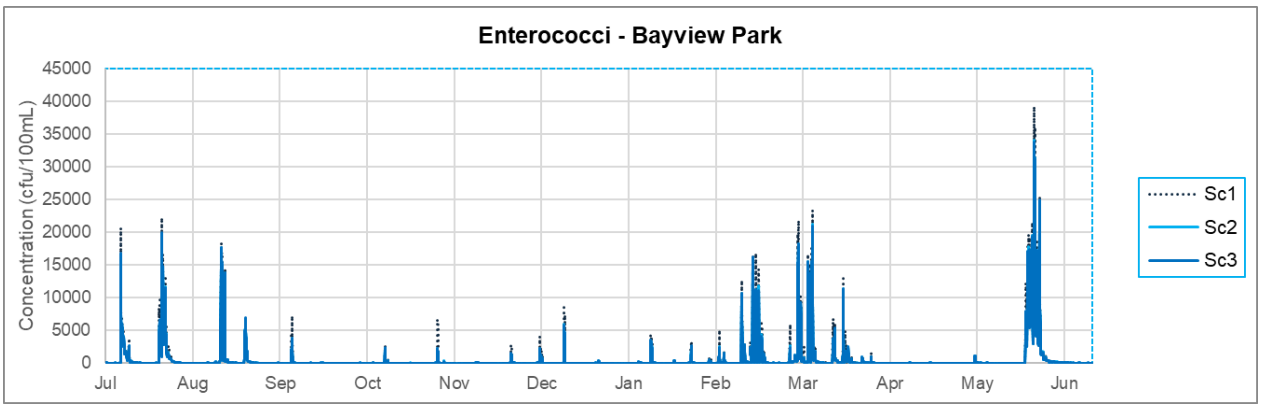


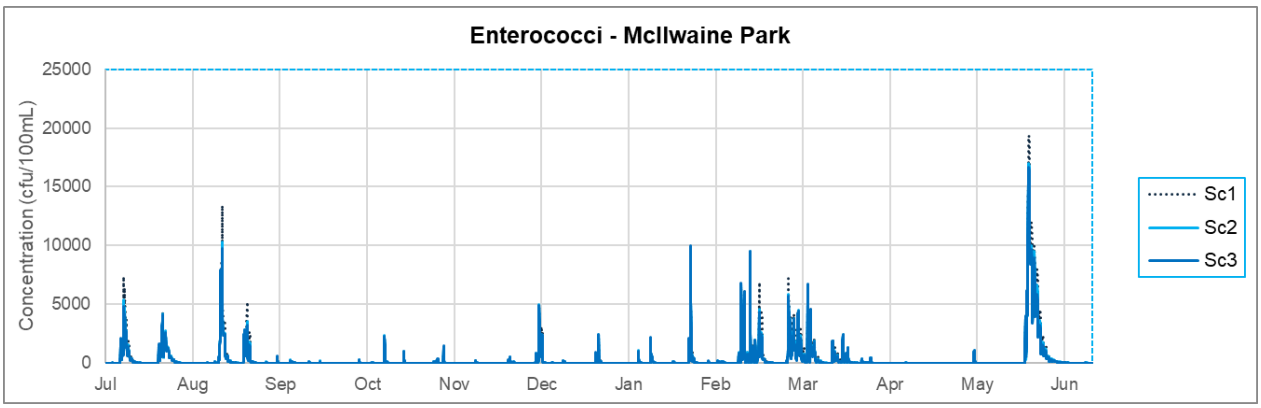


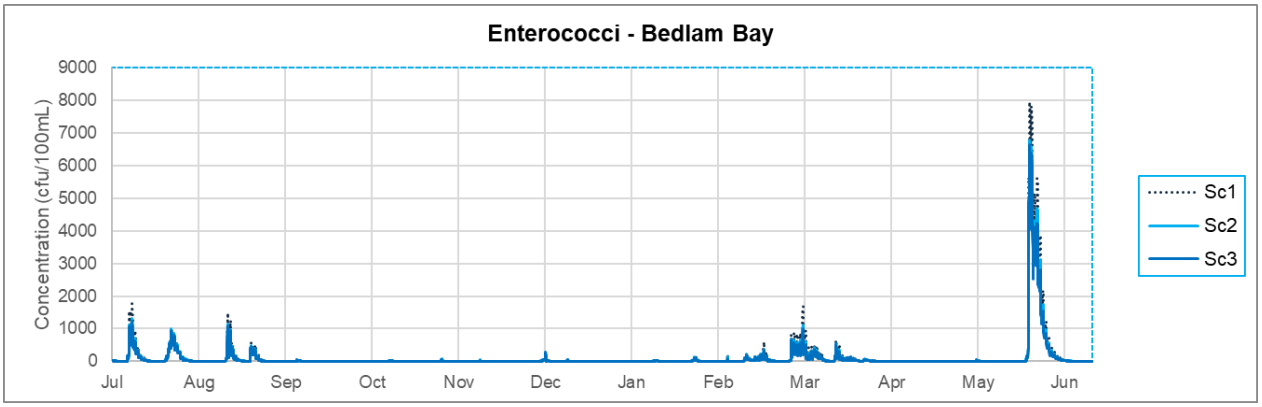


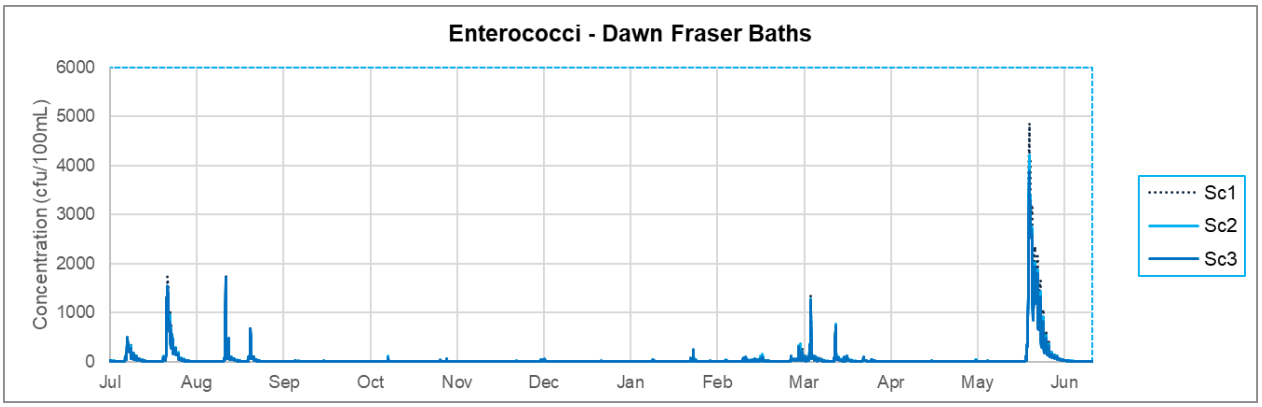
Time series plots

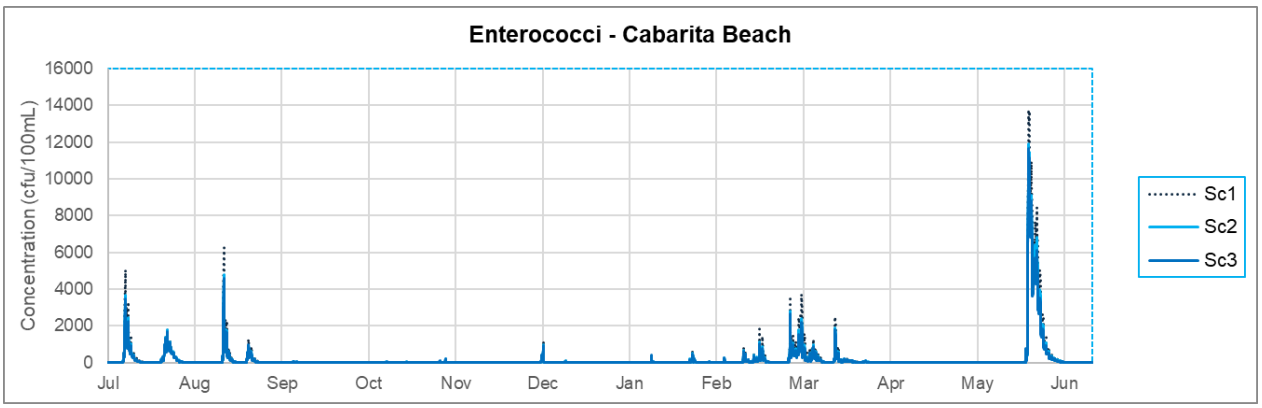






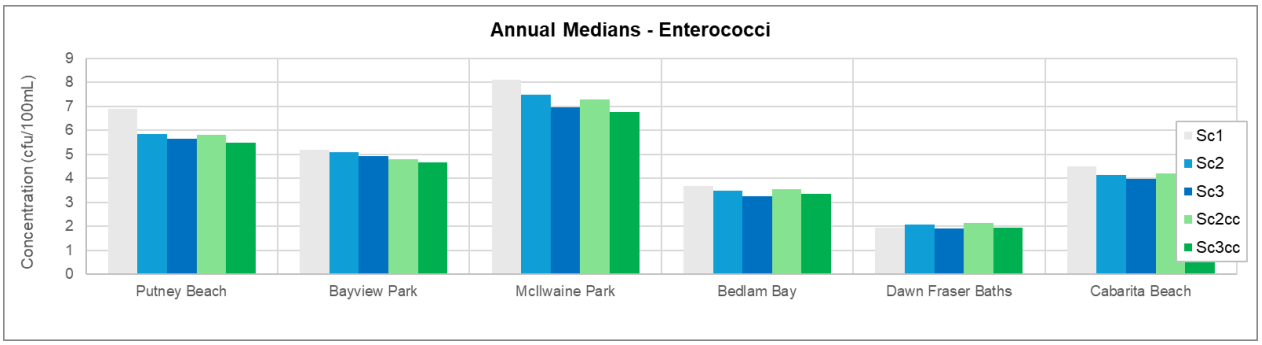


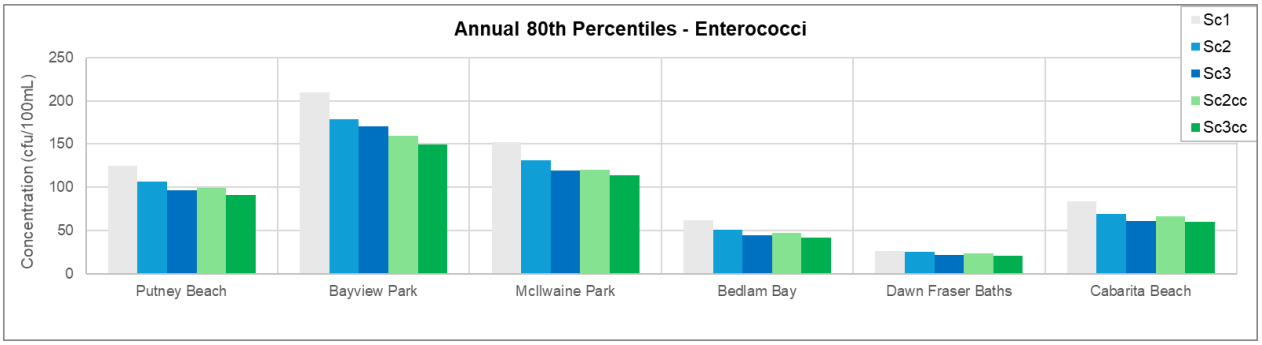


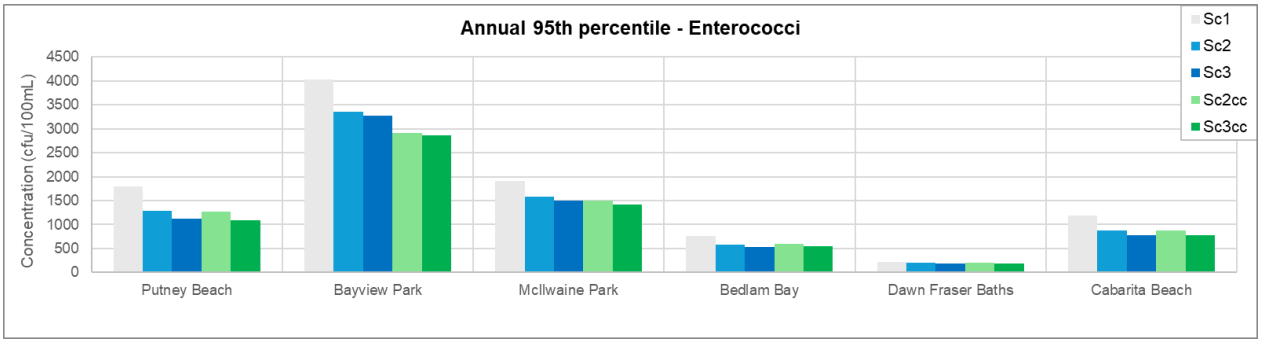


Appendices D7.1.3 Higher rainfall year scenario results (2021-2022)

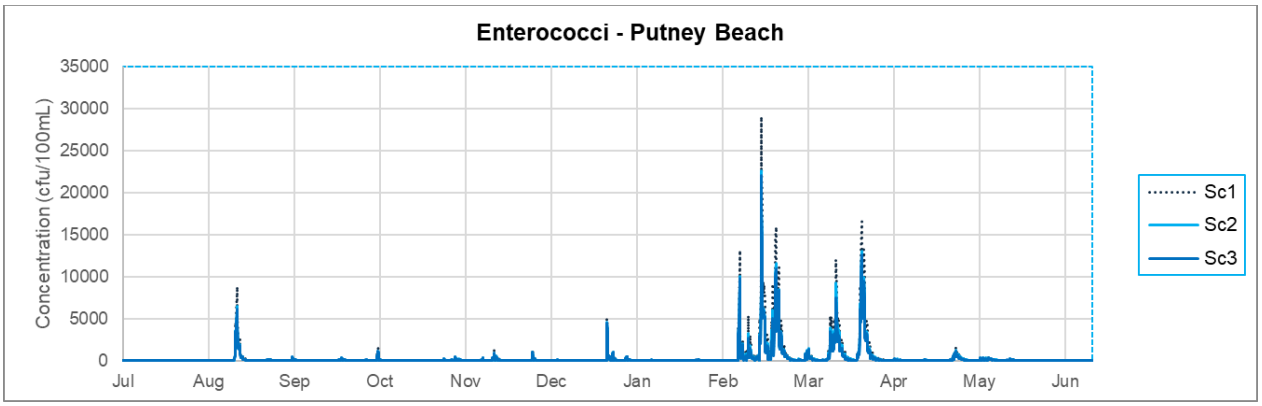
Bar charts

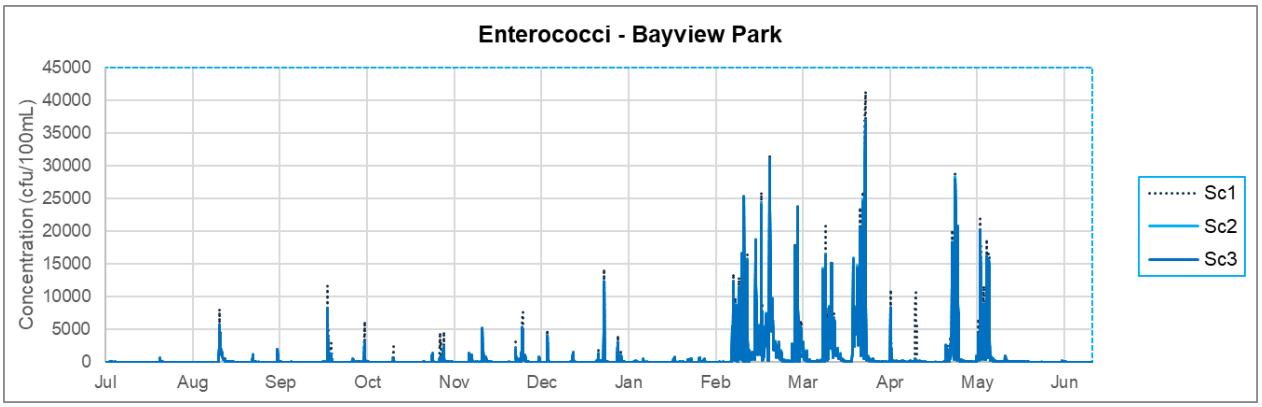


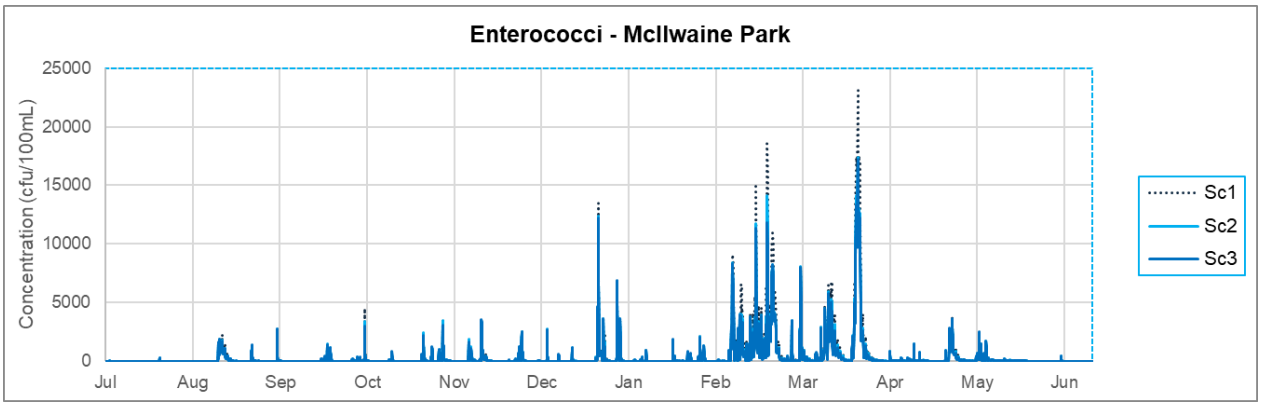


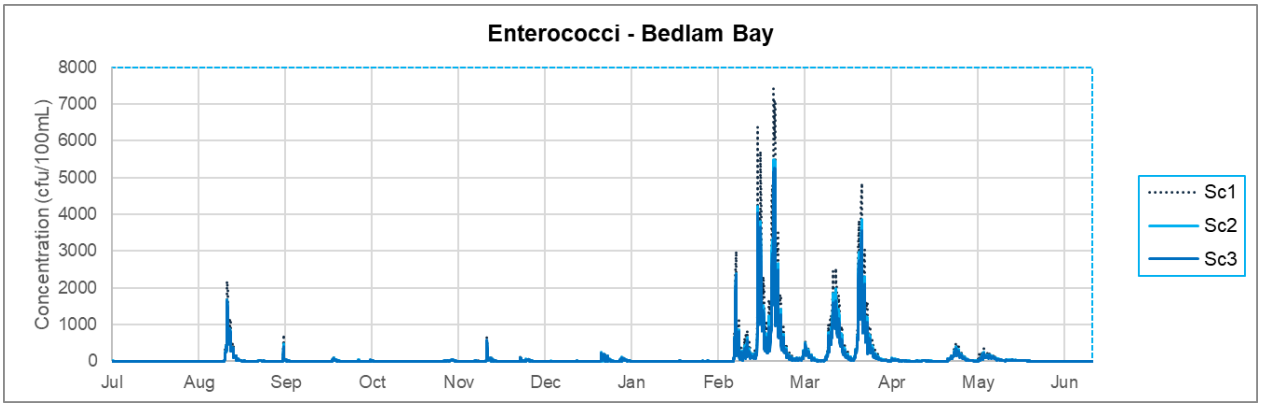


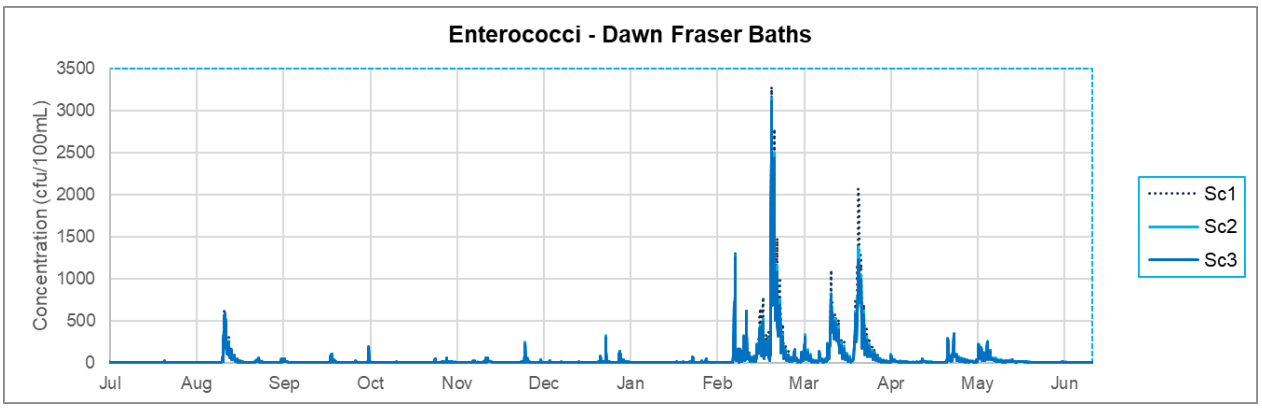
Time series plots

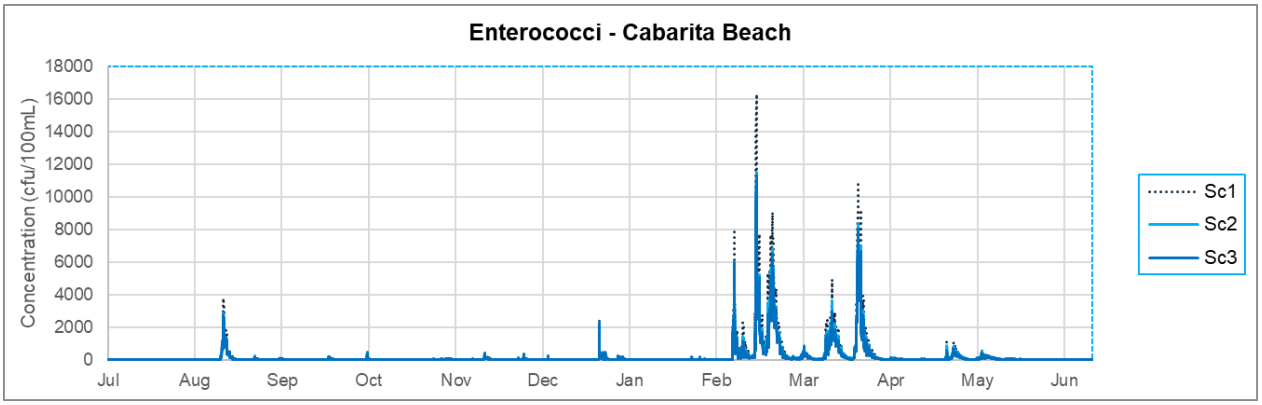





Enterococci - McIlwaine Park
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Enterococci - Bedlam Bay
Concentration (cfu/100mL)
8000
7000
6000
5000
4000
3000
2000
1000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3


Enterococci - Dawn Fraser Baths
Concentration (cfu/100mL)
3500
3000
2500
2000
1500
1000
500
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

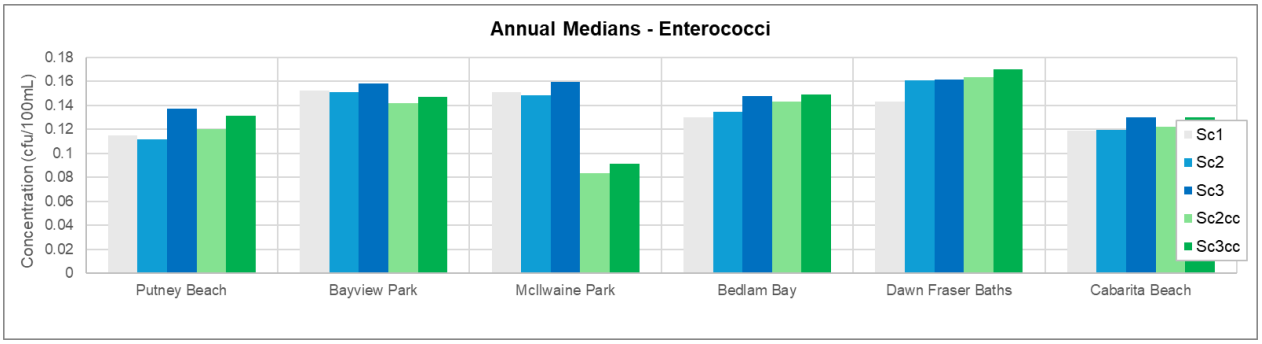

Enterococci - Cabarita Beach
Concentration (cfu/100mL)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2
Sc3

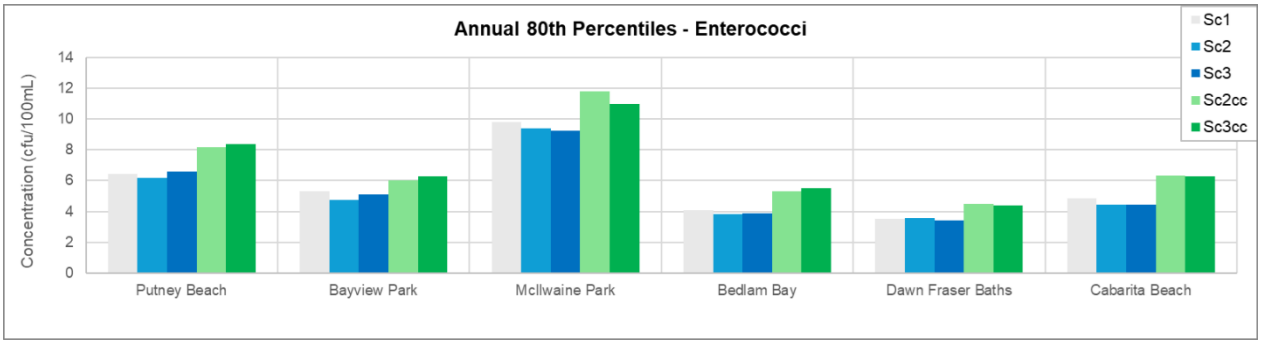
Appendices D8 Swim sites results with climate change

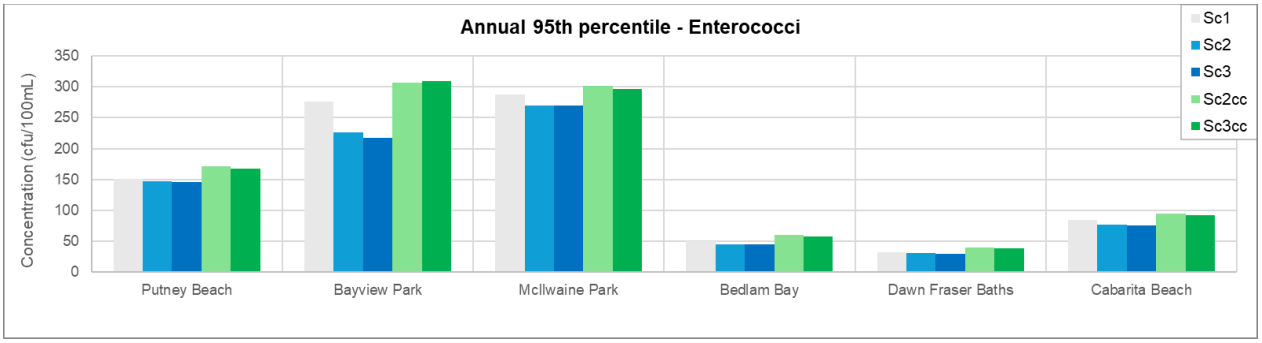
Appendices D8.1 Enterococci

Appendices D8.1.1 Lower rainfall year scenario results (2017-2018)

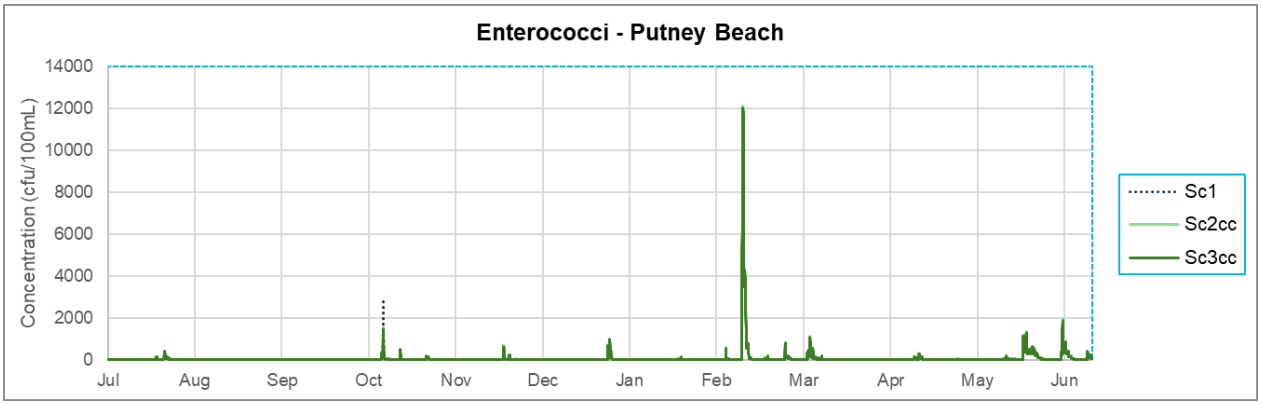
Bar charts

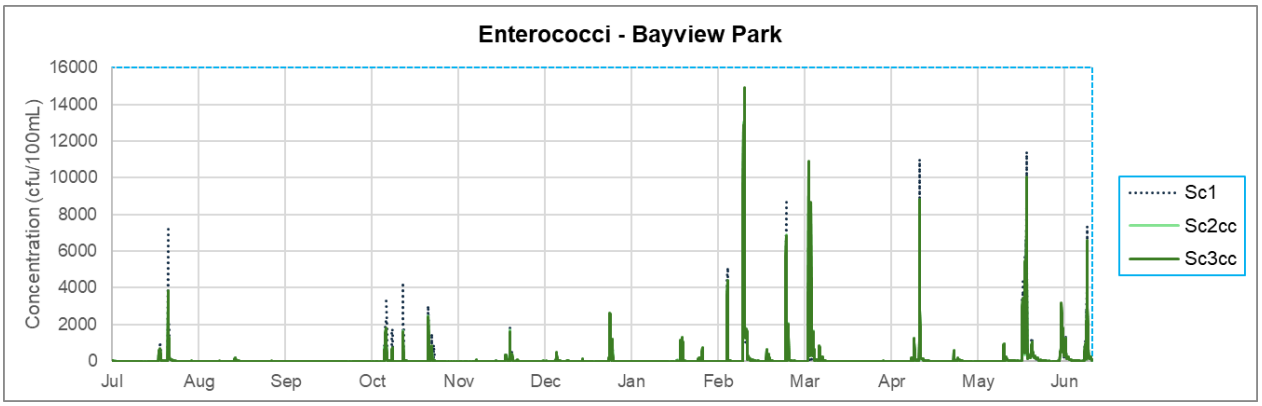


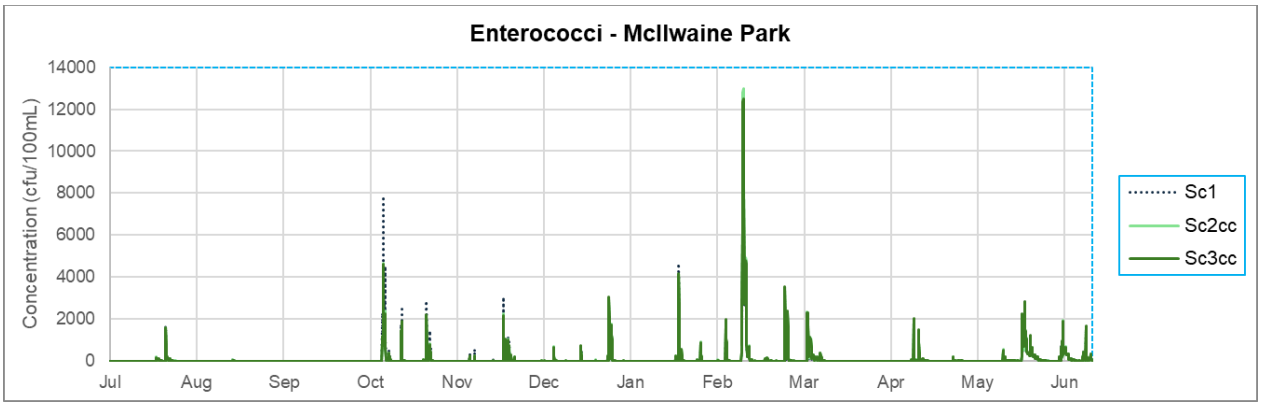


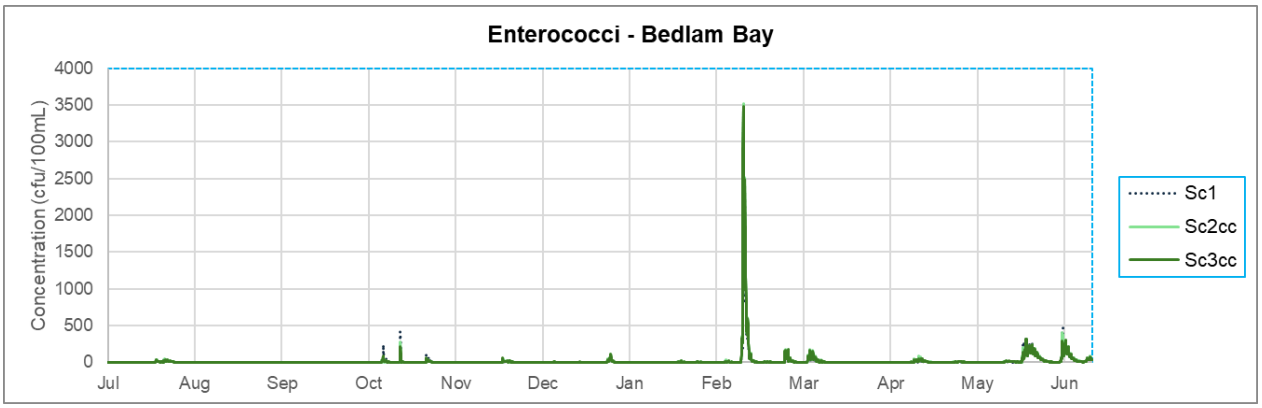


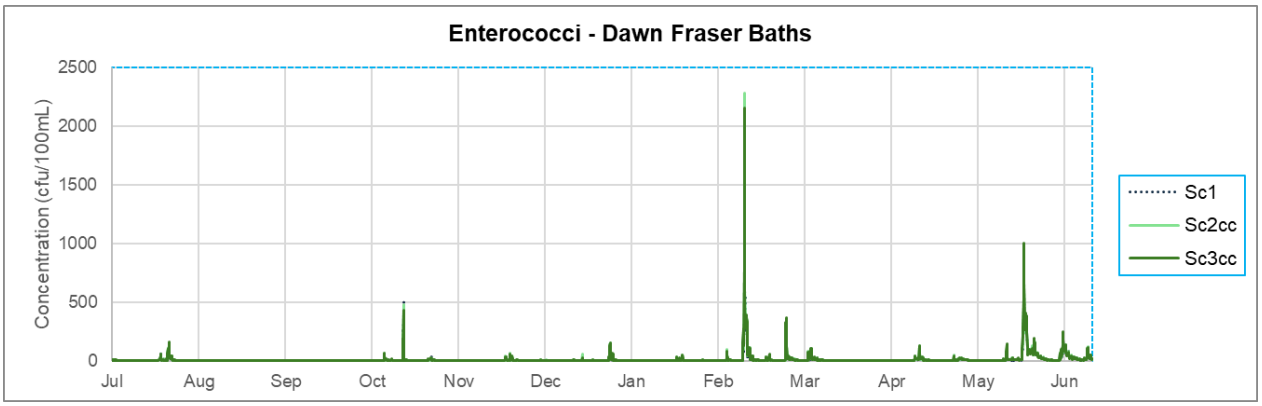
Time series plots

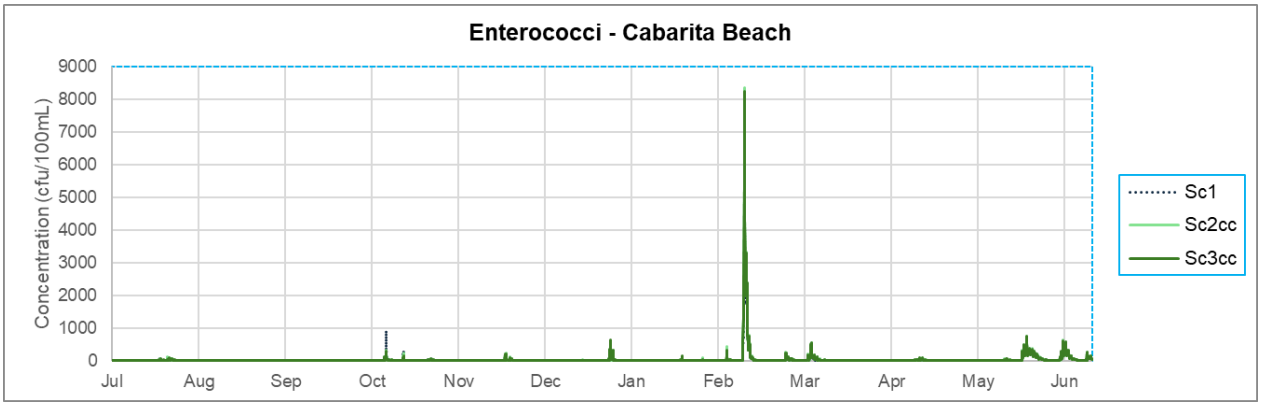






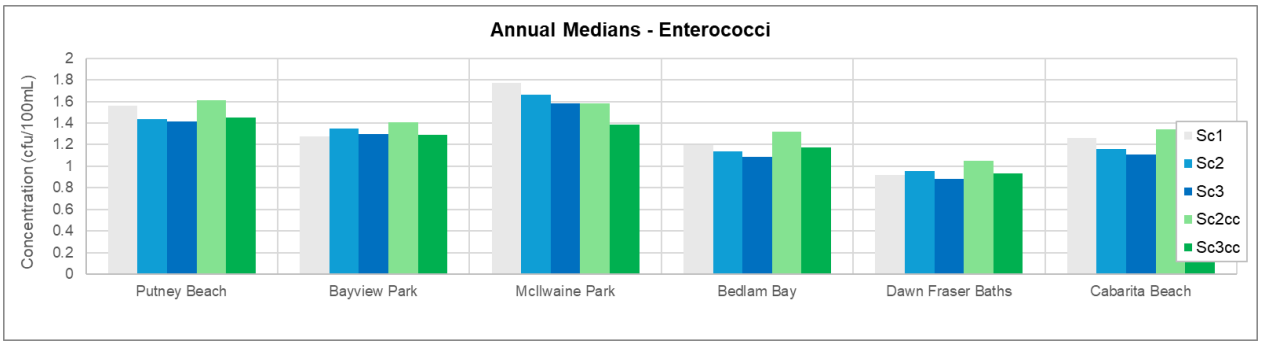


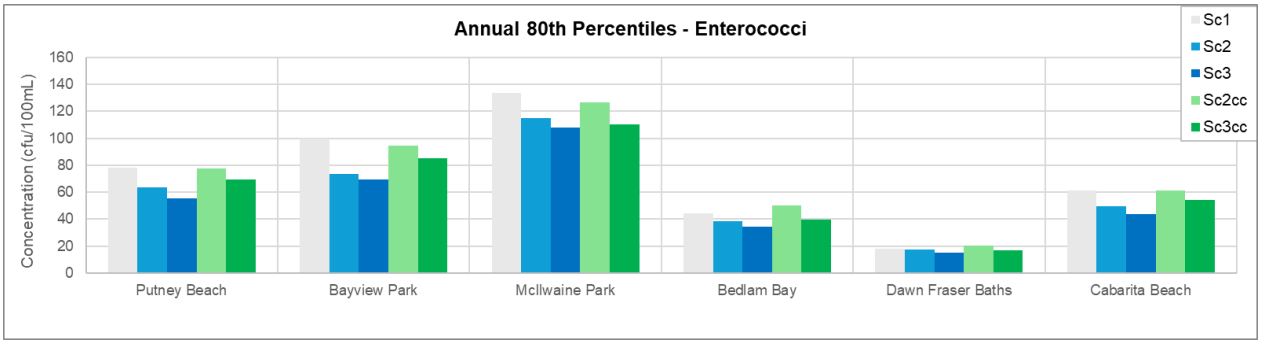


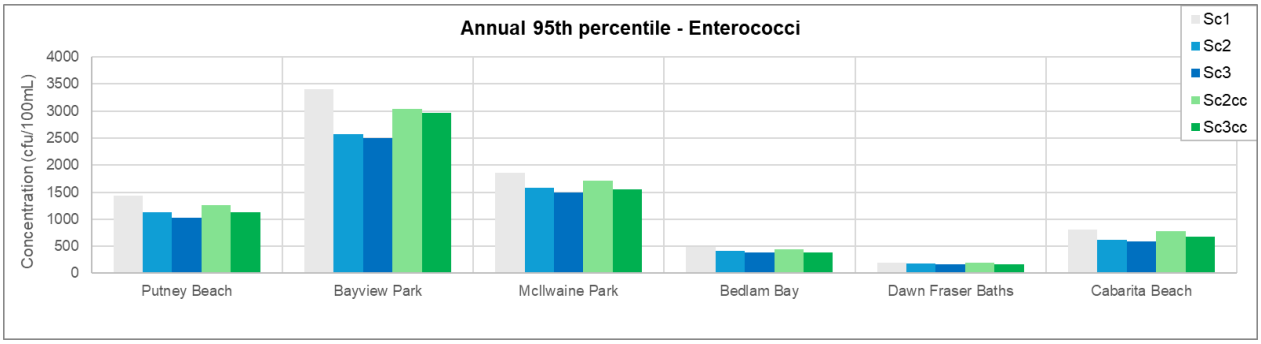


Appendices D8.1.2 Average rainfall year scenario results (2016-2017)

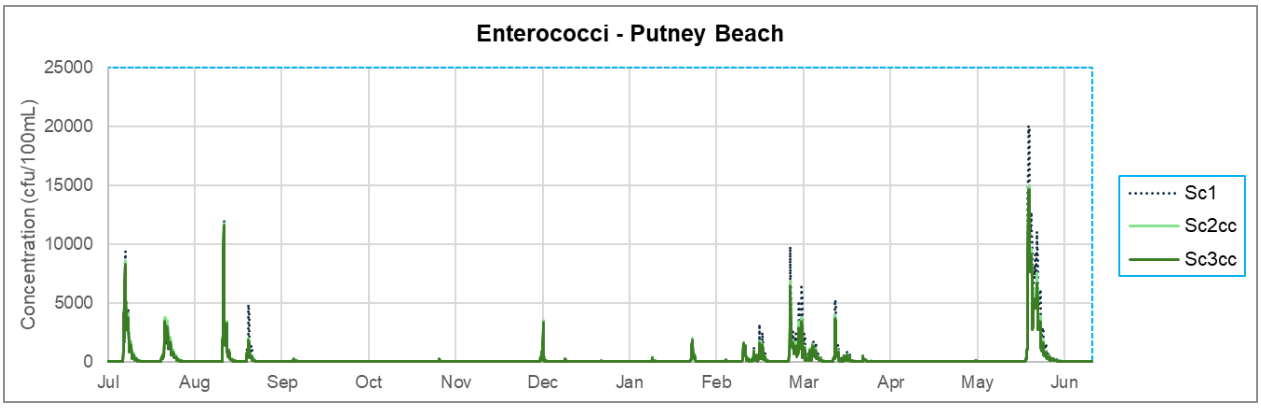
Bar charts

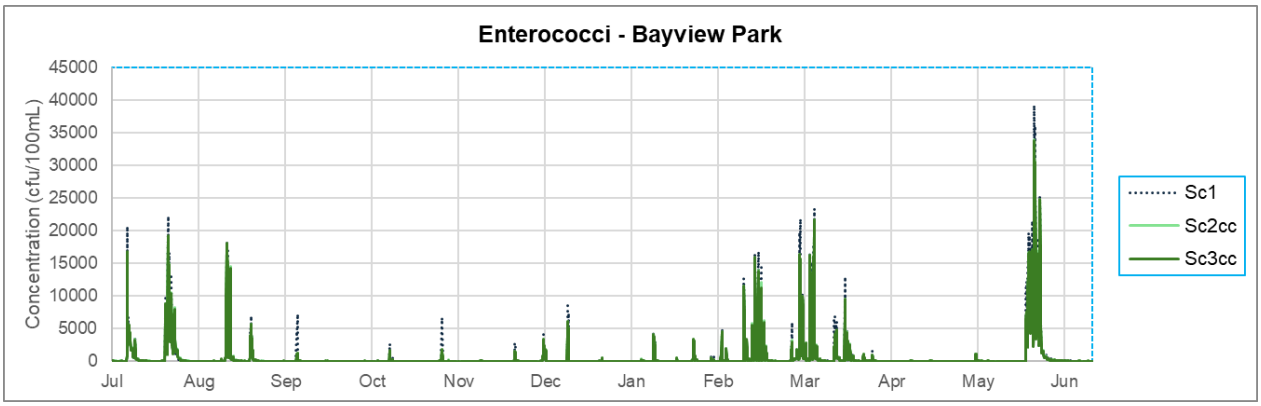


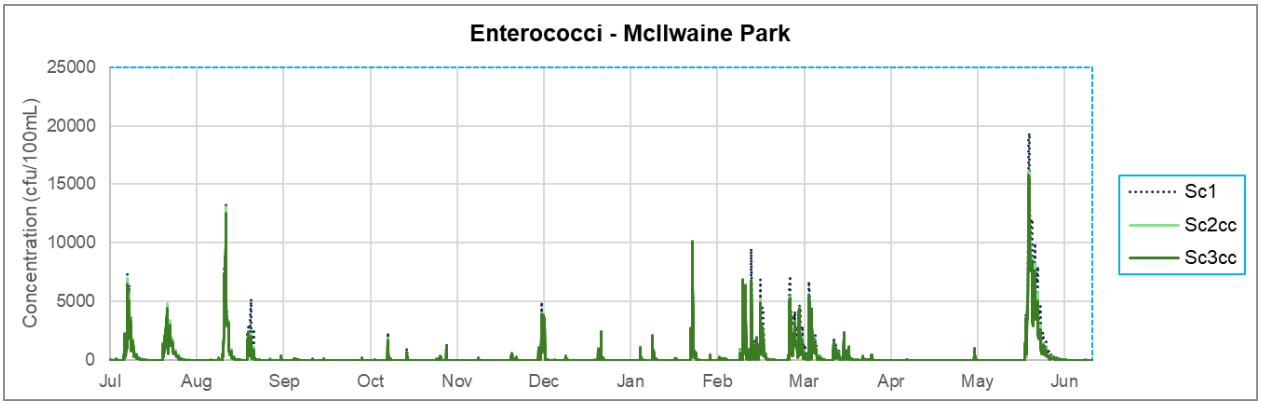


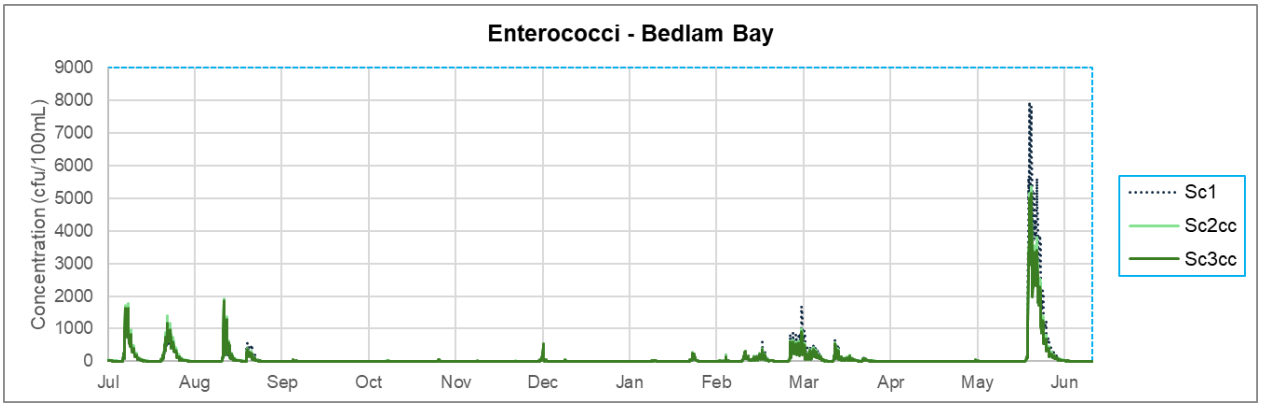


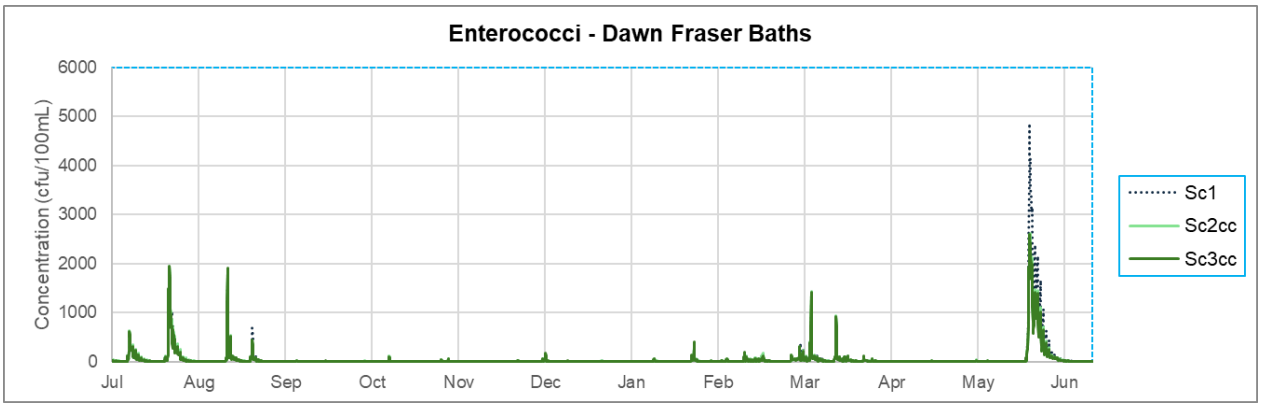
Time series plots

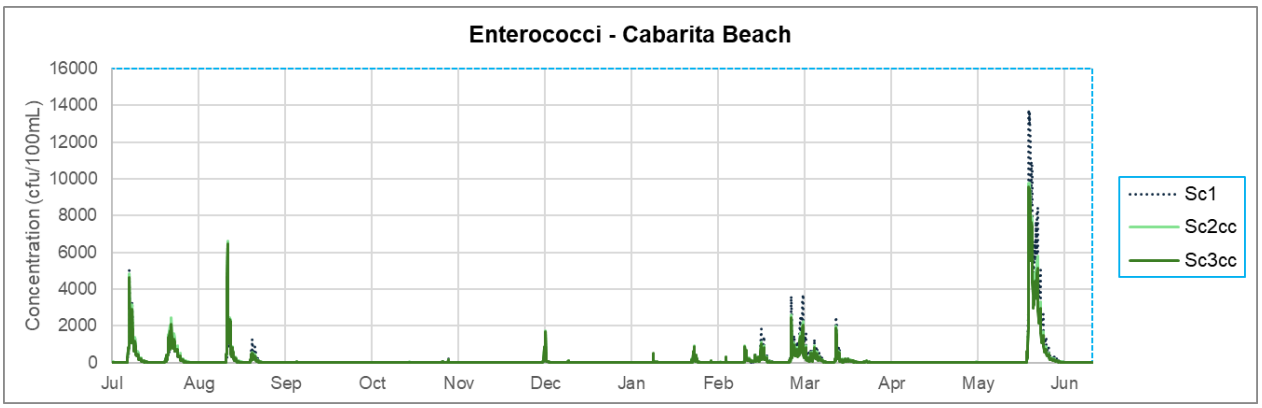






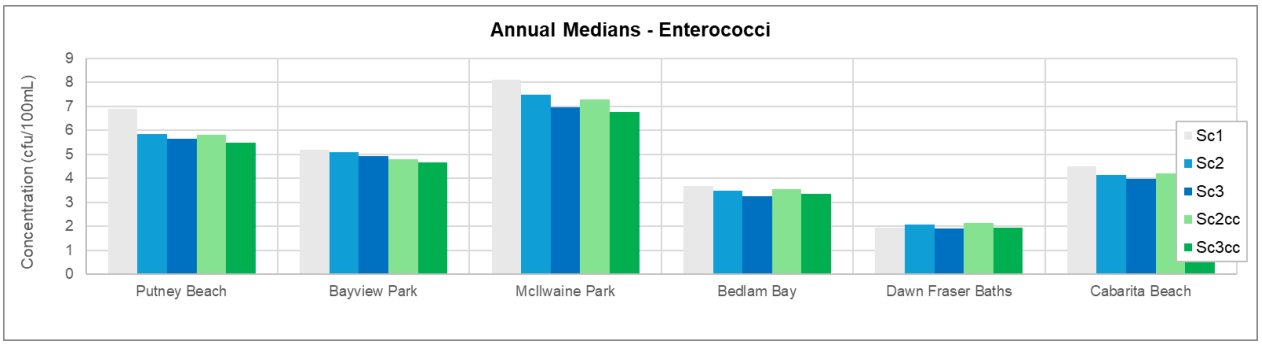


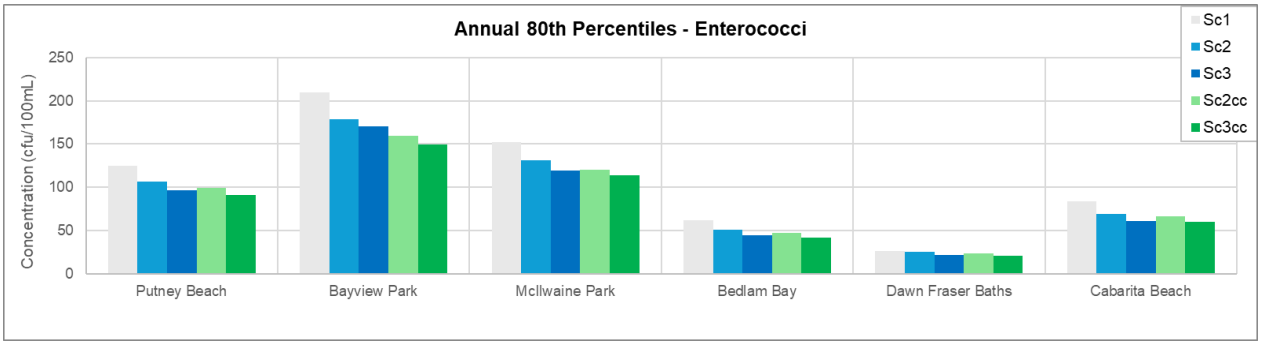


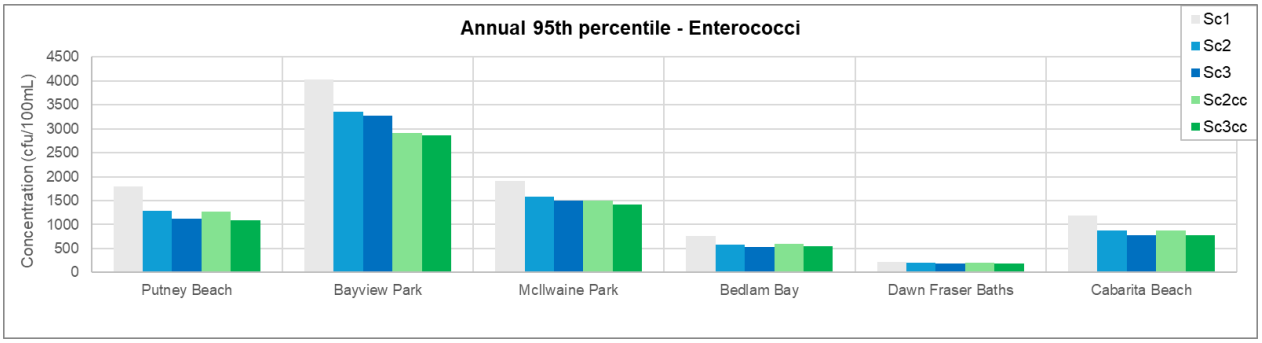


Appendices D8.1.3 Higher rainfall year scenario results (2021-2022)

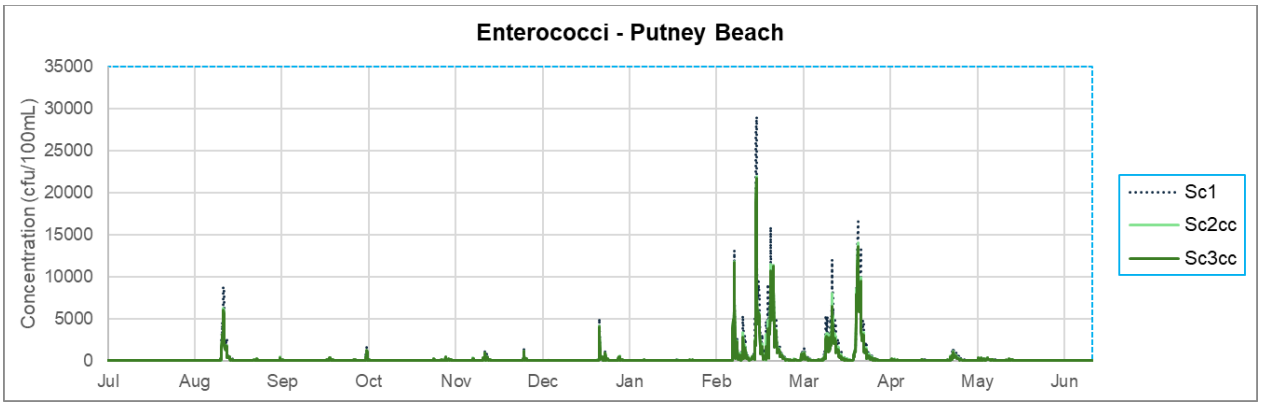
Bar charts

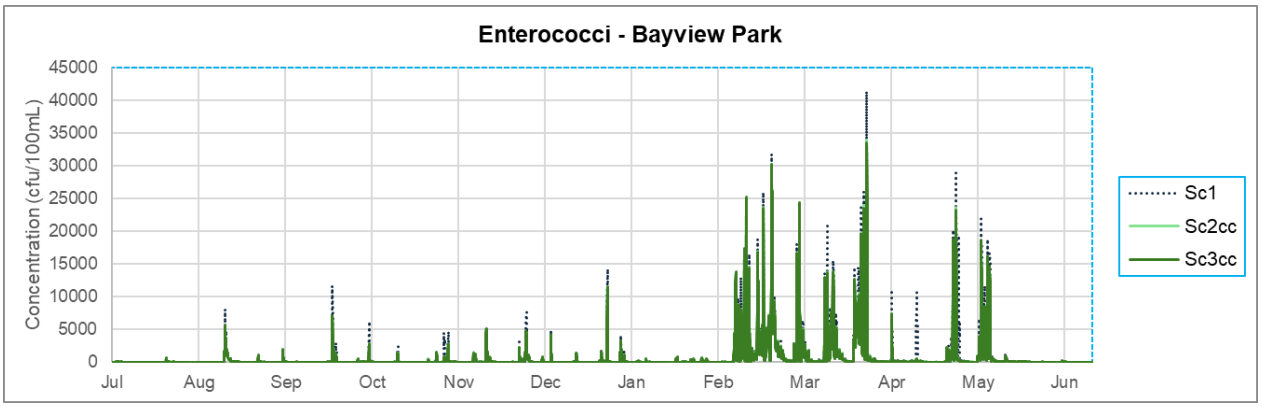


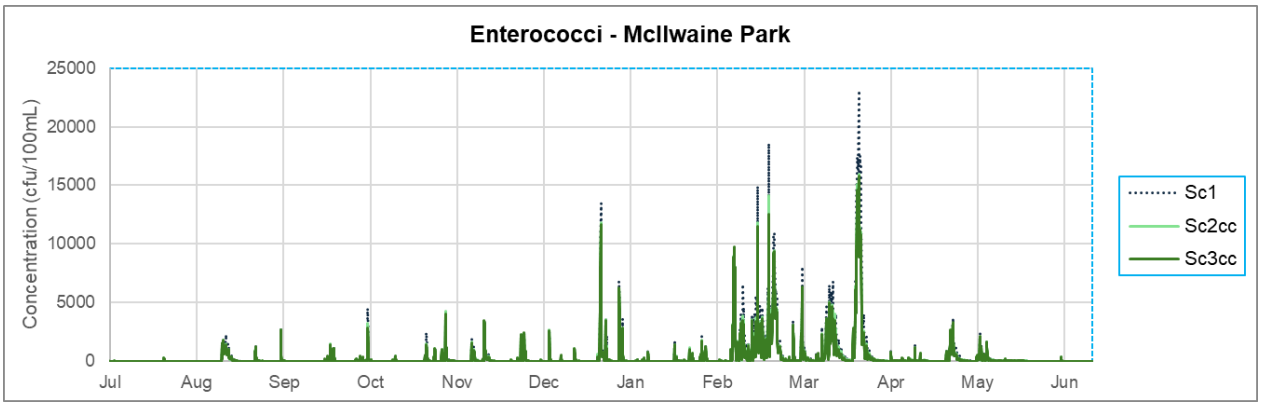


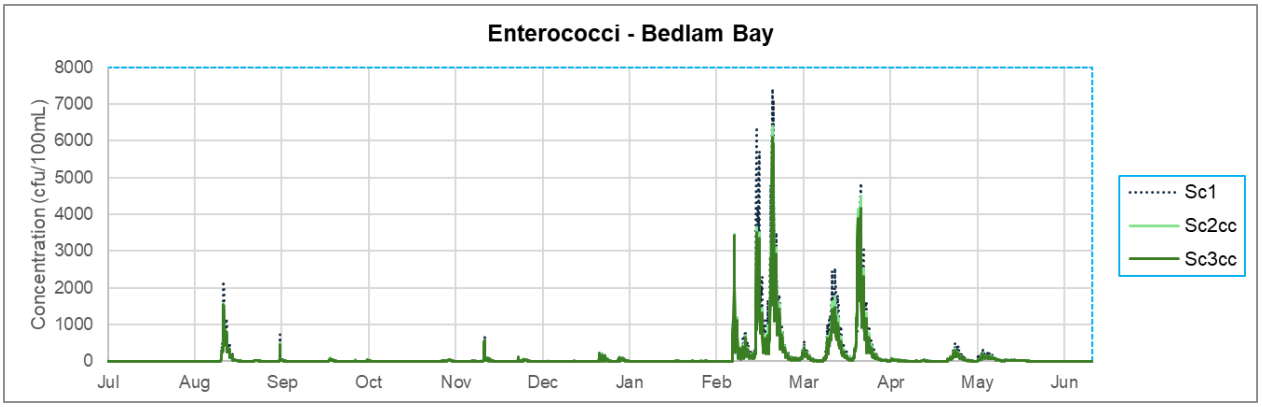


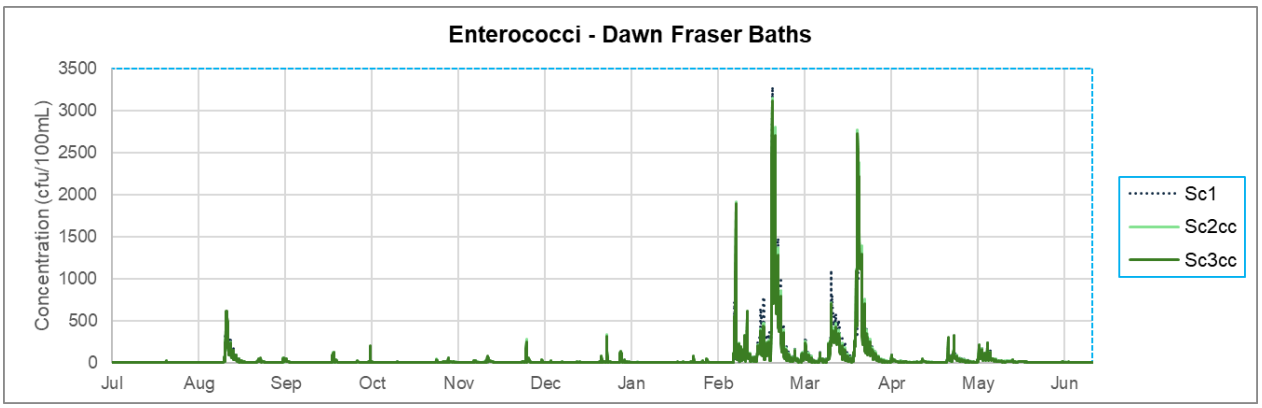
Time series plots

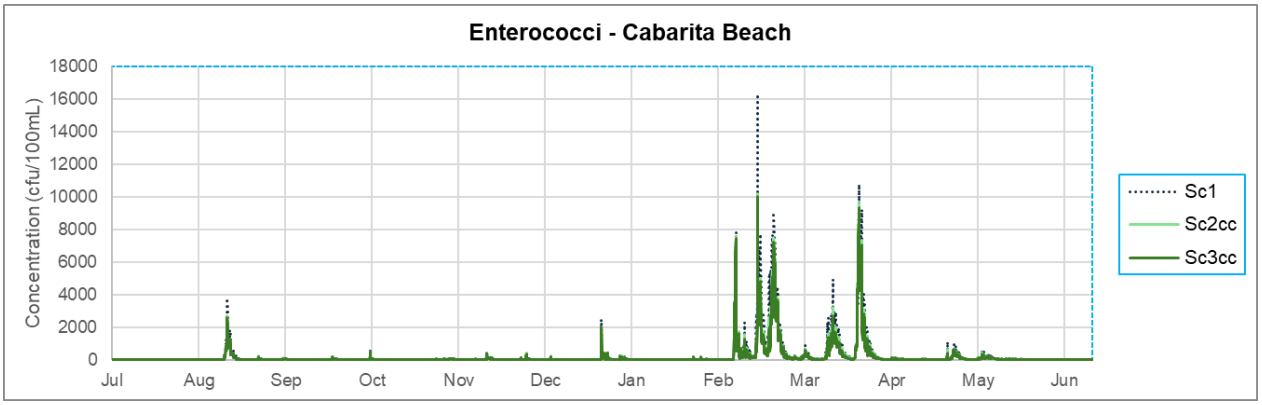





Enterococci - McIlwaine Park
Concentration (cfu/100mL)
25000
20000
15000
10000
5000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Enterococci - Bedlam Bay
Concentration (cfu/100mL)
8000
7000
6000
5000
4000
3000
2000
1000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Enterococci - Dawn Fraser Baths
Concentration (cfu/100mL)
3500
3000
2500
2000
1500
1000
500
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc


Enterococci - Cabarita Beach
Concentration (cfu/100mL)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Sc1
Sc2cc
Sc3cc