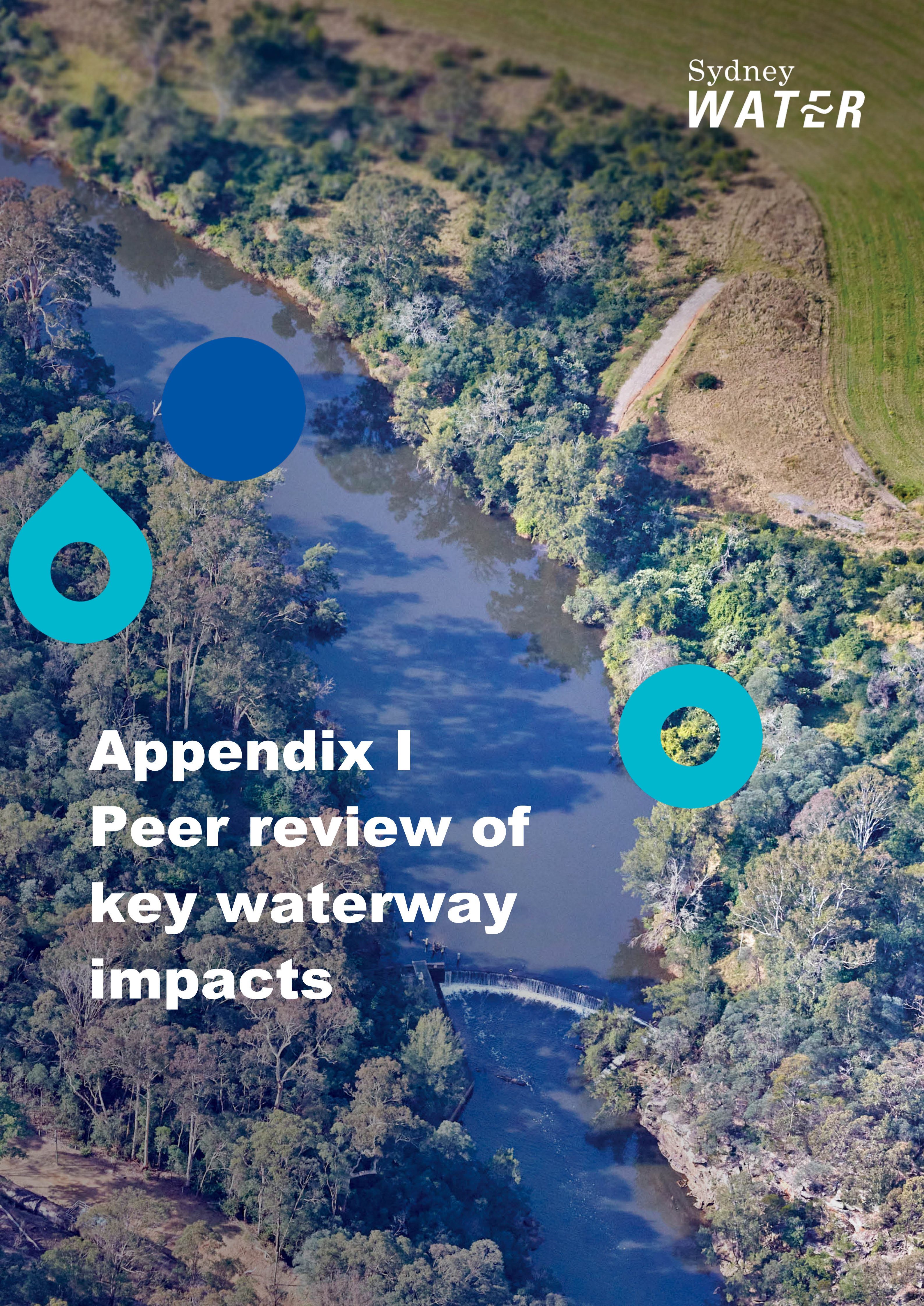

Sydney WATER

Appendix I
Peer review of key waterway impacts

Upper South Creek Advanced Water Recycling Centre Environmental Impact Statement – *Environmental impacts of treated water releases*

Peer review report

Dr Chris Gippel[a] and Dr Rick van Dam[b]

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September 2021

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Acknowledgments

The peer review panel would like to acknowledge Cathy O'Rourke and Elissa Howie from Sydney Water, and Tony Church from Tony Church & Associates, for their assistance and advice throughout the peer review process. Also, the specialist consultants, Ed Beling from Intrawater and Paul Dunne from Aurecon Arup (Hydrodynamic and water quality impact assessment), Geoff Vietz, Christine Arrowsmith and Steve Clark from Streamology (Ecohydrology and geomorphology impact assessment), and Carl Tippler and Ben Green from CT Environmental (Aquatic ecology impact assessment) are thanked for their cooperation, assistance and patience throughout the peer review process.

Executive summary

The following waterway studies for the Environmental Impact Statement (EIS) for Sydney Water's proposed Upper South Creek Advanced Water Recycling Centre (AWRC) were peer reviewed:

- Hydrodynamic and water quality impact assessment;
- Ecohydrology and geomorphology impact assessment; and
- Aquatic ecology impact assessment.

The peer review panel comprised two independent reviewers, Dr Chris Gippel (Fluvial Systems) and Dr Rick van Dam (WQadvice), both of whom have over 30 years' experience in applied aquatic science. The peer review process involved a site visit, numerous on-line workshops and meetings, and peer review of the above impact assessments and several associated documents. The material reviewed by the review panel was progressively refined by the specialist consultants who authored the reports following iterative engagement facilitated by Sydney Water. As a result, the review panel concluded that the final reports were acceptable and fit for purpose for the EIS. The main conclusions for the key components of the review are summarised below.

Overall assessment approach

- the overall assessment approach was considered to be consistent with the expected standard approach to conducting an EIS.

Waterway objectives

- the waterway objectives for assessing impact were appropriate and developed in accordance with the relevant state and national guidelines. In addition to these objectives, other important physical and ecological metrics were used to assess impact.

Hydrodynamic and water quality impact assessment

- The Hydrodynamic and water quality impact assessment adequately described the existing conditions of the receiving waters of South Creek and the Warragamba and Nepean rivers based on the available data.
- The modelling approach that was adopted for the impact assessment, comparing baseline, background and impact scenarios for a representative dry and wet year was appropriate for assessing potential hydrological and water quality impacts of AWRC releases.
- The toxicants review and near field dilution modelling were appropriate for assessing potential impacts of contaminants not included in the water quality modelling.
- Some aspects of the draft impact assessment that were highlighted by the review panel, but were adequately resolved, included:
  - An error in the hydrological modelling for the Nepean River that resulted in an under-prediction of baseflow, which was identified during the project by other specialist consultants relying on the model outputs;
  - Insufficient details on some aspects of the scenarios and justification for the selected dry and wet years;
  - Insufficient descriptions of water quality for some variables, including lack of discussion on spatial and temporal variability for key variables (e.g. nutrients) and lack of data and discussion for salinity, turbidity and toxicants; and
  - Lack of clarity around terminology to describe impact ("significant", "not significant").
- The review panel agreed with the overall conclusions that the likely impacts of the AWRC releases on the hydrology and water quality of South Creek, and the Nepean and Warragamba rivers will largely be negligible with some localised minor impacts.

Ecohydrology and geomorphology impact assessment

- The Ecohydrology and geomorphology impact assessment adequately described the existing ecohydraulic (instream physical water conditions that relate to habitat availability) and geomorphologic (physical forms and processes) conditions of the receiving waters of South Creek and the Warragamba and Nepean rivers.
- The impact assessment relied on ecohydraulic modelling to assess water surface elevation, wetted perimeter, velocity and bed shear stress, and the Urban Streamflow Impact Assessment (USIA) method to assess zero flow, freshes and bed erosion threshold, with a risk assessment framework used to integrate the results. The impact assessment also addressed impacts of the river release infrastructure. The approach was considered appropriate for assessing potential ecohydraulic and geomorphologic impacts of AWRC releases.
- Some aspects of the draft impact assessment that were highlighted by the review panel, but were adequately resolved, included:
  - Some deficiencies and a lack of detail and transparency in the risk assessment process and associated decision making, and limitations/uncertainties associated with the assignment of the classifications for the ecohydraulic stressors for each of the river reaches;
  - No explicit assessment of uncertainty that could arise from models or supplied or measured data;
  - Absence of background information on the theory applied in the assessment; and
  - Lack of consideration of impacts under low flow conditions, which will be relatively greater;
- The review panel agreed with the overall conclusions that (i) geomorphological impacts associated with pipeline construction can be appropriately mitigated, and (ii) the predicted geomorphological impacts of the AWRC releases to South Creek and the Warragamba and Nepean rivers would be minor and of low risk, during both the construction and operational phases.

Aquatic ecology impact assessment

- The Aquatic ecology impact assessment adequately described the existing riparian and aquatic ecological conditions of the receiving waters of South Creek, the Warragamba and Nepean rivers and other relevant waterways.
- The assessment approach of drawing on the results of the hydrodynamic, water quality, ecohydrological and geomorphological impact assessments, and a desktop- and field-based assessment of the aquatic ecology of the relevant waterways, was appropriate for assessing potential aquatic ecological impacts of AWRC releases.
- Some aspects of the draft impact assessment that were highlighted by the review panel, but were adequately resolved, included:
  - Insufficient detail on how the impact assessment was undertaken;
  - Limitations of the Rapid Riparian Appraisal (RRA) method for characterising relative condition of riparian vegetation and waterway channels;
  - Insufficient attention paid to predicted increases in chlorophyll a in the Warragamba River downstream of the proposed treated water (e-flows) release location; and
  - Insufficient justification for conclusions about impacts of ecohydraulic responses to riparian vegetation and aquatic ecology.
- The review panel acknowledged the challenges of definitively inferring ecological impact given the coarseness of, and uncertainties in, the ecohydraulic modelling results, and considers that the Aquatic ecology project team did as much as could be done with the available data.
- The review panel agreed with the overall conclusions that (i) risks of construction activities to riparian vegetation and aquatic ecology can be appropriately mitigated or managed, and (ii) the impacts of AWRC releases on the riparian vegetation and aquatic ecology of South Creek and the Nepean and Warragamba rivers will largely be negligible with some localised minor impacts.

1. Introduction

1.1 Background

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

Advanced Water Recycling Centre

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

Treated water pipelines

- a pipeline about 17 km long from the AWRC to the Nepean River at Wallacia Weir, for the release of treated water
- infrastructure from the AWRC to South Creek to release excess treated water and wet weather flows
- a pipeline about 5 km long from the main treated water pipeline at Wallacia to a location between the Warragamba Dam and Warragamba Weir, to release high-quality treated water to the Warragamba River as environmental flows.

Brine pipeline

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

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

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

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

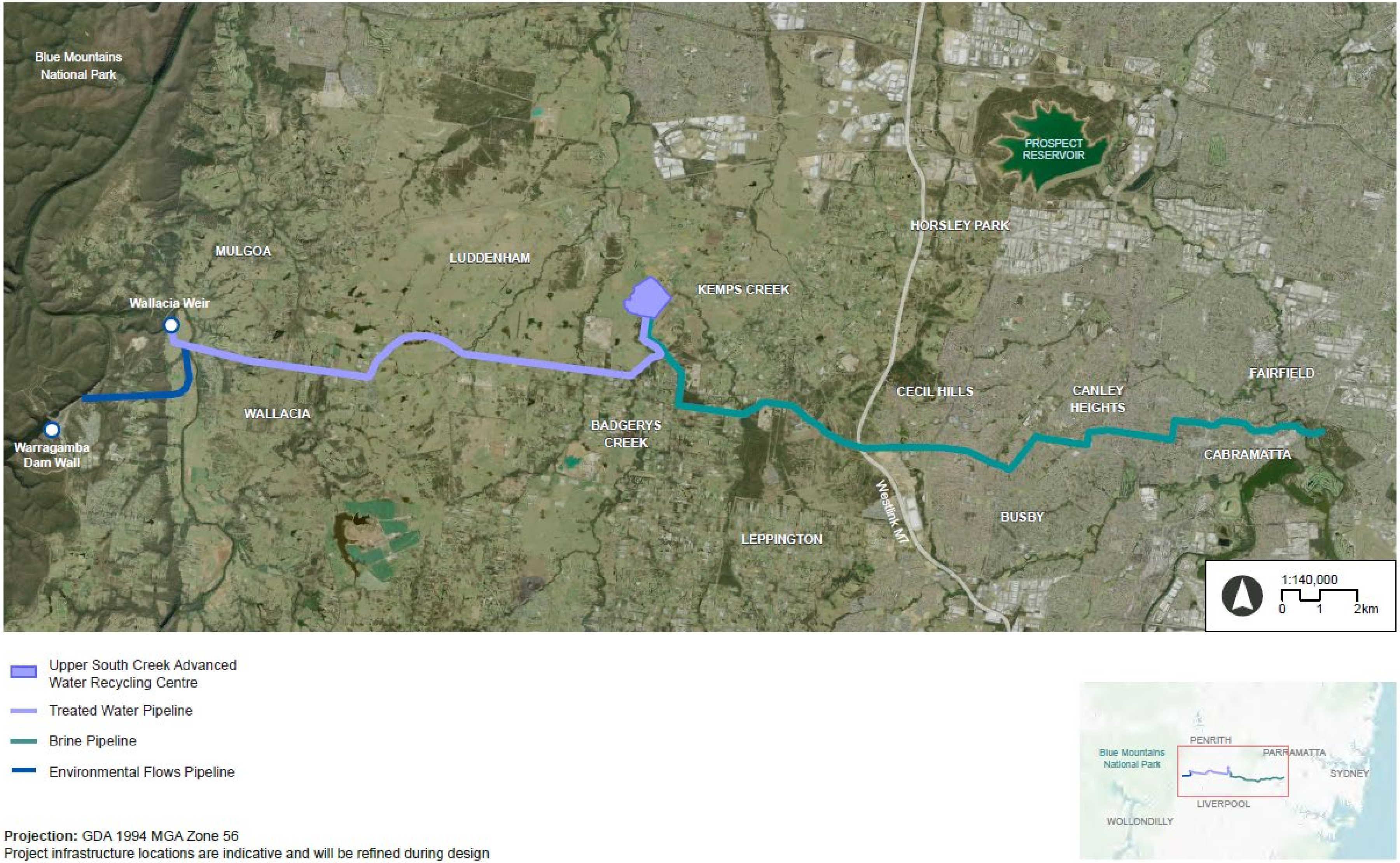

Figure 1-1 South Creek AWRC project overview

1.2 Environmental Impact Statement

Sydney Water considers that the project has the potential to have significant impact on the environment, primarily as a result of the scale of the AWRC and its releases to waterways. It is therefore considered State Significant Infrastructure (SSI) and requires an Environmental Impact Statement (EIS) and approval from the Minister for Planning, under Division 5.2 of the *Environmental Planning and Assessment Act* (EP&A Act). The EIS must be undertaken in accordance with the Secretary's Environmental Assessment Requirements (SEARs) as well as other relevant legislation and guidelines.

Sydney Water is seeking a staged approval for the project, with detailed approval for the AWRC to treat an average dry weather discharge of 50 ML/d and concept approval for 100 ML/d.

1.3 Peer review of the EIS

Sydney Water has chosen to have the key waterway studies peer reviewed by independent specialists. The purpose of the peer review is to provide independent and specialist advice and feedback on relevant aspects of the EIS. This report constitutes the peer review of the project EIS. The focus of this peer review was environmental impacts of the release of treated water from the project to South Creek and the Nepean and Warragamba rivers. The scope and process of the peer review is further detailed below and in Section 2.

1.3.1 Terms of reference

The terms of reference of the peer review were to provide independent and specialist peer review on assessments of the environmental impacts of the release of treated water to South Creek and the Nepean and Warragamba rivers.

Within the above context, the peer review was to focus on:

- review of the proposed assessment approach;
- participation in stakeholder workshops;
- review of specialist reports;
  - Hydrodynamic and water quality impact assessment;
  - Ecohydrology and geomorphology impact assessment;
  - Aquatic ecology impact assessment;
- review of relevant EIS chapters; and
- submission of a single peer review report.

The peer review panel, comprising two independent reviewers, coordinated to provide joint responses to each identified issue. In practice, with the exception of the final peer review report, the reviewers initially generated their written responses independently, then subsequently discussed issues if and where their review comments were divergent. The final peer review report was prepared in accordance with DPE (2019).

It should be noted that the expected process for the peer review was affected by general and travel restrictions associated with the COVID-19 pandemic. For example, in-person, multi-stakeholder workshops were not held.

1.3.2 Peer reviewer credentials

Dr Chris Gippel

Dr Gippel has been continuously involved in applied science related to hydrology, environmental hydraulics and fluvial geomorphology for 38 years. He has a First Class Honours Degree in Geography (1983) and a PhD in Hydrology and Geomorphology (1989). At present, he is an independent consultant undertaking projects within his range of expertise for government and the private sector in Australia and other countries, and is also an Adjunct Senior Research Fellow with the Australian Rivers Institute, Griffith University. His research and applied work covers a range of fields, including: river and lake health assessment; assessment of environmental flow requirements; prediction of river geomorphology; numerical modelling of dam operations and downstream impacts; stream design and rehabilitation; lake and wetland water balance; hydrological prediction and hydraulic modelling for ecological and geomorphological objectives; assessment of hydraulic, hydrological and geomorphological impacts of developments such as mining, industrial and urban development, dam construction and operation, and pipeline construction and operation; and, terrain and remote sensing analysis for landform, vegetation and watercourse definition. He developed the hydrology software Flow Health (http://watercentre.org/portfolio/rhef/project-resources/flow-health-hydrology-assessment-tool), and was a co-author of the international text book *Stream Hydrology: An Introduction for Ecologists* (Wiley & Sons, Chichester). Chris regularly undertakes peer review for journals, and acts as an Expert Witness to the Courts. A copy of Dr Gippel's Curriculum Vitae is provided in Appendix A.

Dr Gippel has no pecuniary interest in the AWRC project, nor has he worked directly for Sydney Water or collaborated with Sydney Water's specialists in the past two years. He has not undertaken any work on the assessment of the impacts of a project that may result in material cumulative impacts with the AWRC project.

Dr Rick van Dam

Dr van Dam has been continuously involved in applied science related to water quality and aquatic ecosystem protection since 1990. He has an Honours Degree in Marine Ecology (1990) and a PhD in Aquatic Toxicology (1996). At present, he is an independent consultant that undertakes water quality related projects for government and the private sector, and also participates in strategic research and development projects. He has extensive experience in a number of key areas, including: metals bioavailability and toxicity; impacts of industrial waste waters, including saline waters; development of toxicity test methods; derivation of water quality guideline values; and ecological risk assessment. Dr van Dam has been significantly involved in the development of the ANZECC/ARMCANZ (2000) and subsequent ANZG (2018) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, and is currently the technical advisor to the Australian government for the ongoing updating of the ANZG (2018) Guidelines. Dr van Dam has co-produced and published national and international guidance on water quality related issues, including approximately 100 peer-reviewed publications. A copy of Dr van Dam's Curriculum Vitae is provided in Appendix A.

Dr van Dam has no pecuniary interest in the AWRC project and nor has he worked for Sydney Water or collaborated with Sydney Water's specialists in the past two years. He has not undertaken any work on the assessment of the impacts of a project that may result in material cumulative impacts with the AWRC project.

1.3.3 Out of scope issues

The peer review did not formally extend to review of the following water-related impact assessments completed for the EIS:

- groundwater impact assessment
- surface water (stormwater) impact assessment
- flooding impact assessment

Nevertheless, the opportunity was provided for the review panel to read and provide comments on the EIS chapters summarising these reports.

Also, the Hawkesbury-Nepean and South Creek Source Model Calibration Report and the Hawkesbury Nepean and South Creek TUFLOW FV and AED2 Model Calibration Report were out of scope of this peer review. These reports were separately peer reviewed and deemed fit for purpose.

Also, the peer review panel was not asked to review aspects around Malabar Environment Protection Licence (EPL) compliance nor the regulation of nutrients from sewage treatment plants in the Lower Hawkesbury Nepean River catchment (EPA 2019).

2. Peer review process

2.1 Site visit

A site visit was conducted on 15 December 2020. The field trip was attended by the peer reviewers and several Sydney Water personnel and associated technical advisors, and visited the following locations:

- Proposed AWRC site on South Creek (**Figure 2-2**);
- Proposed treated water release location on Nepean River near Wallacia Weir; and
- Core Park Road, near Warragamba Dam (near proposed release location on the Warragamba River)

Figure 2-2 Peer review panel site visit, South Creek at proposed AWRC site, 15 December 2020

2.2 Review of material

Table 2-3. Reviews of documents leading up to the delivery of the specialist reports were often accompanied by videoconferences with Sydney Water and specialists to discuss details. However, no videoconferences were necessary during the review of the specialist reports and EIS chapter.

A briefing paper provided by Sydney Water at the commencement of the project included information on the proposed assessment approach for each of the three specialist studies.

The peer reviewers were centrally involved in providing input to and review of the waterway values (subsequently renamed to waterway objectives to conform to OEH (2017) requirements).

The micropollutants/toxicants report was reviewed only by Dr van Dam, while the flooding, surface water (stormwater) and groundwater reports were reviewed only by Dr Gippel. The reviews of the flooding, surface water (stormwater) and groundwater reports were not as extensive as reviews of 'in-scope' documents.

The 'in scope' specialist reports were each reviewed at least four times. An initial full review was followed up by subsequent reviews that focused on how the peer review comments had been addressed. Detailed review comments were provided and responded to via Excel spreadsheet comments registers. A number of additional documents were provided or accessed for context and information towards the peer review. These are listed in Appendix B.

Table 2-3 Materials formally reviewed as part of the peer review process

File	File type	Number of reviews [a,b]	Comments
Upper South Creek Water Factory Draft Briefing Paper for assessment of waterway releases	Briefing paper	1	Paper was for familiarisation purposes and to aid in initial discussions with Sydney Water and specialists.
Draft waterway values for South Creek, Hawkesbury-Nepean River	Spreadsheet	2	'Waterway values' later renamed the 'waterway objectives'.
South Creek Increased WWTP Treated Effluent Discharge Analysis - Memo 1	Memo	1	Preliminary modelling of impacts of treated water discharge scenarios on South Creek using the Urban Streamflow Impact Assessment (USIA) method.
Dunheved Creek Analogue Site Preliminary Assessment for Hydrology and Geomorphology	Memo	1	Document became redundant after dry weather releases to South Creek were removed from the EIS.
Assessment of suitability to apply Dunheved Creek as an appropriate analogue site to understand potential impacts of dry weather discharge on aquatic and riparian ecology of South Creek	Memo	1	Document became redundant after dry weather releases to South Creek were removed from the EIS.
Draft review of micropollutant concentrations in other wastewater treatment plants	Draft report for EIS	3[c]	Later renamed 'Review of potential toxicants in release streams'.
Hydrodynamic and water quality impact assessment	Draft report for EIS	4	Specialist waterway report included as Appendix in EIS; included review of toxicants in release streams.
Ecohydrology and geomorphology impact assessment	Draft report for EIS	5	Specialist waterway report included as Appendix in EIS.
Aquatic ecology report	Draft report for EIS	4	Specialist waterway report included as Appendix in EIS.
Flooding impact assessment	Draft EIS chapter	1[d]	EIS chapter summarising findings of a specialist report.
Surface water impact assessment	Draft EIS chapter	1[d]	EIS chapter summarising findings of a specialist report.
Groundwater impact assessment	Draft EIS chapter	1[d]	EIS chapter summarising findings of a specialist report.
Chapter 8 – Key waterway impacts	Draft EIS chapter	3	EIS chapter summarising findings of the three waterway reports.

[a] Subsequent reviews after the first review did not represent full reviews but, rather, focused on how authors had addressed peer review comments.

[b] Reviewed by both peer reviewers unless otherwise indicated.

[c] Reviewed only by Dr van Dam.

[d] Reviewed only by Dr Gippel.

2.3 Meetings with specialist consultants

Twelve formal meetings with Sydney Water and/or specialist consultants were held between 1 May 2020 and 16 June 2021, as summarised in Table 2-2. Additional details of the meeting content and attendees are provided in Appendix C.

Table 2-2 Summary of meetings with specialist consultants

Date	Topic	Organisations in attendance
1 May 2020	Project overview and draft waterway values for the Nepean and Warragamba Rivers	Sydney Water Tony Church & Associates
13 May 2020	Draft waterway values, indicators and criteria for aquatic ecology	Sydney Water Tony Church & Associates
17 July 2020	Draft South Creek waterway values	Sydney Water Tony Church & Associates
21 August 2020	Proposed approach to assessing dry weather releases to South Creek	Sydney Water Tony Church & Associates
14 October 2020	Project update and draft waterway objectives	Sydney Water Tony Church & Associates
15 December 2020	Site discussions during site visit	Sydney Water GHD Tony Church & Associates
16 December 2020	Waterways workshop – proposed assessment approaches for: ○ Hydrodynamic and Water Quality ○ Ecohydraulic and Geomorphology ○ Aquatic Ecology and Riparian Ecosystems	Sydney Water Tony Church & Associates Intrawater Streamology CT Environmental
19 April 2021	Micropollutants review	Sydney Water Tony Church & Associates
31 May 2021	Water quality and hydrodynamics – presentation of results	Sydney Water Tony Church & Associates Intrawater University of Western Australia
31 May 2021	Ecohydraulic and geomorphology impact assessment – presentation of results	Sydney Water Tony Church & Associates Streamology
3 June 2021	Aquatic ecology and riparian impact assessment – presentation of results	Sydney Water Tony Church & Associates CT Environmental
12 July 2021	Flow discrepancies at Wallacia Weir	Sydney Water Tony Church & Associates Intrawater Streamology
29 September 2021	Comment #60 on Aquatic ecology report from van Dam – justification for conclusions on impact	Sydney Water CT Environmental

2.4 Other requests from Sydney Water

As part of micropollutants/toxicants review, and on request from Sydney Water, Dr van Dam provided Sydney Water with a short memo (15 May 2020) that defined and listed types of micropollutants. This was used to inform the basis of the micropollutants/toxicants review.

As noted in Section 2.2, both peer reviewers provided considerable input to the development of the waterway objectives. This input would typically be considered additional to the peer review process.

2.5 Preparation of peer review report

The peer review report was prepared in accordance with DPE (2019), and generally follows the structure and includes the details described therein. The final draft peer review report was reviewed by Sydney Water. Only minor edits and comments were received from Sydney Water, all of which were addressed.

3. Peer review findings

3.1 Assessment approach

The assessment approach was detailed in the Sydney Water (2020a) briefing paper. This paper was discussed with Sydney Water via videoconference on 1 May 2020. The main components of the assessment approach were consistent with the expected standard approach to conducting an EIS, i.e. describe the project; understand and document waterway values/objectives; then for each key discipline, use baseline data to describe the existing environment as it relates to these values and the SEARs; model or assess risks to the environment associated with the project, particularly with respect to relevant legislation and guidelines, waterway values and the SEARs; and, recommend appropriate mitigation and monitoring. The assessment approaches for the three key impact assessments under review (i.e. *Hydrodynamics and water quality*, *Ecohydrology and geomorphology* and *Aquatic ecology*) as well as the process of developing the waterway values/objectives were also scrutinized by the panel throughout the peer review process as documents were submitted for review and discussions were held between the peer reviewers, Sydney Water and the specialist consultants. These are discussed in the following sections.

At the outset, Sydney Water planned to undertake the following tasks to allow a thorough assessment of potential impacts:

- A baseline monitoring program to collect data on the aquatic environment of South Creek, Warragamba River and the Nepean River;
- Development of waterway values and objectives for South Creek, Warragamba River and Nepean River;
- Hydrodynamic and water quality modelling of the waterways and impact assessment;
- Ecohydrology and geomorphology assessment;
- Aquatic ecology assessment; and
- Stakeholder engagement and consultation.

Sydney Water confirmed that the baseline monitoring program had already commenced in March 2020 (Sydney Water 2020b). The review panel noted that, where possible, the baseline data should inform the EIS.

The panel considered the above overall approach suitable for the assessment of potential environmental impacts of treated water releases from the AWRC. However, the panel also agreed that the details of methodologies employed by, and linkages between, the specialist studies would be critical to successful implementation of the assessment approach (see Sections 3.3, 3.4 and 3.5).

3.2 Waterway values / objectives

One of the first key tasks for the waterways assessment was the development of waterway values. These were later renamed waterway objectives to conform to the terminology of OEH (2017) and, hence, are referred to herein as such.

The review panel provided significant initial advice on the waterway objectives, via three meetings (Table 2-2) and in writing. A summary of the key review comments is provided below:

- To the extent possible, align terminology with that used for the ANZG (2018) national water quality management framework (WQMF).
- Establish definitions of the terms used in the final document that sets out the values.
- Include pressures and stressors in the hierarchy of information for the waterway objectives.

- There may be a need to identify linkages/interaction between values.
- For the *Water quality* component, turbidity and conductivity need to be formally included. Also, will viruses, metals and pharmaceuticals be considered? Even if deemed to be a low risk, this low risk needs to be justified.
- Stressors and indicators for which there are currently no appropriate guideline values should still be listed, as this will help point to information gaps.
- Need to be clear about which guideline values/water quality objectives (e.g. national or state-based) take precedence, and be sure about what they represent and what type of values (e.g. medians, 95th percentiles) they need to be compared with
- Aquatic flora and Aquatic fauna could possibly be merged under a "Biodiversity" heading.
- Environmental flows and geomorphology do not readily fall into what one would define as values, and may be better included as attributes within the aquatic ecosystems value.
- For cultural and spiritual values, recommend engagement as early as possible with local Indigenous communities.
- Need to cite ANZECC/ARMCAMZ (2000) Guidelines for livestock drinking water and aquaculture.
- Is there scope to embed the NSW e-flows waterways values within the primary contact and secondary contact components/attributes, as they are clearly recreational-based values?

By and large, the peer review comments were adopted and, where not, decisions were appropriately justified by Sydney Water. Subsequent to most of the peer review comments, Sydney Water revised the waterway objectives to be consistent with the requirements in the SEARs and the 'Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions' (OEH 2017). Key changes from previous versions included:

- Waterway objectives for South Creek, Warragamba River, Nepean River and Hawkesbury River consolidated into one version; and
- Structuring the waterway objectives so as to be consistent with OEH (2017), which includes a primary focus on only those indicators that have a direct relationship to the risk posed by the project. Effectively, these indicators are typically water quality indicators. Thus, indicators of aquatic biodiversity (response to water quality) and geomorphic form and process (driver of aquatic biodiversity and response to hydrology) are not specifically included in the waterway objectives, but would still form critical indicators that would be assessed as part of the EIS.

The above changes were considered acceptable by the review panel. Overall, the review panel found that the process of identifying waterway objectives and associated indicators was thorough and appropriate.

Although not included in the waterway objectives, preliminary flow and water quality objectives for South Creek, developed and published in draft form by the Environment, Energy and Science (EES) section of the Department of Planning, Industry and Environment (DPIE 2020), were also taken into account in the impact assessments. The review panel has some concerns over these draft water quality objectives for South Creek, as discussed in Section 3.6.1.

3.3 Hydrodynamic and water quality impact assessment

The Hydrodynamic and water quality impact assessment report included details of existing hydrodynamic and water quality conditions, and hydrodynamic, water quality and near field dilution modelling to assess potential impacts of AWRC releases. The review panel provided over 100 written comments on the draft Hydrodynamic and water quality impact assessment report in addition to comments/queries provided at three meetings/workshops attended by the specialist consultants (Intrawater) (Table 2-2). All comments were addressed to the satisfaction of the review panel. A summary of the key issues raised by the review panel is provided below.

3.3.1 Hydrodynamic and water quality modelling

The Water Quality Response Models (WQRMs) that were applied in the Hydrodynamic and water quality impact assessment have been built upon established models already used for water quality modelling of the Hawkesbury Nepean River system. Moreover, a new WQRM of South Creek was developed to allow simulation of the finer scale details of the sub-catchments within the South West and Western Sydney Aerotropolis growth areas. As noted in Section 1.3.3, the development and calibration of the WQRMs was largely outside the scope of the current peer review.

In June 2021, the Ecohydrology and geomorphology project team identified a non-trivial prediction error in the hydrological modelling (from the Hydrodynamic and water quality impact assessment). The calibration procedure resulted in a good fit between modelled and observed flow for event hydrographs, but under-prediction of baseflows in the Nepean River. Whilst technically this problem could be corrected by recalibration of the model, there was insufficient time available to recalibrate the model and rerun the scenarios and then undertake another iteration of the impact assessments that relied on the hydrological model outputs. Sensitivity analysis undertaken to establish the influence of this issue with respect to the water quality impacts revealed there was a minor improvement in the predicted water quality (e.g. nitrogen, phosphorus) as a result of additional dilution and dispersion arising from higher volumes of flow in the receiving waters. The Hydrodynamic and water quality impact assessment report described the nature of the hydrological error and its flow-on effects in Section 6.1.2.6. Given how late in the EIS development process the error was discovered, and that the modelling results had already been provided to the Ecohydrology and geomorphology and Aquatic ecology project teams to inform their impact assessments, it was apparent that there was insufficient time available to rewrite the assessments using recalibrated model results. Therefore, the impact assessments relied on the original modelling results, aware that modelled baseflows were likely lower than reality, and modelled baseflow water quality impacts would likely be over-predicted relative to reality, i.e. the results for the impact scenarios could be considered conservative. The panel appreciates the transparency applied by all parties in seeking the most practical and appropriate resolution of this problem. As a result, we do not believe that the error significantly compromised: (i) our ability to review the rest of the report and the other reports that relied on the modelling data, and (ii) our confidence in the overall results.

Sensitivity analysis relating to the boundary conditions and other model parameterization was undertaken as part of the calibration process, and the report provided discussion regarding the levels of uncertainty and model limitations. Plotting tools were used to compare model predictions against observed data. The WQRMs were reported to perform well across the range of calibration and validation periods and also across the range of parameters that were assessed. The WQRMs were independently reviewed by the University of New South Wales (UNSW) Water Research Laboratory and considered fit for purpose. The panel considered this process adequate to establish the validity of the models. However, accepting the existence of uncertainty, the review panel commented on how this could be captured in the Hydrodynamic and water quality report. In addition to model uncertainty, the predictions exhibit considerable temporal variability, as would be expected. Thus, while comparison of measures of central tendency (median) are an important indicator of magnitude of impact, the panel considered that measures of dispersion (variability) were also important. To this end, the time series data was also presented in the report as box and whisker plots to allow evaluation of the impacts and variability of the results.

For the hydrodynamic and water quality impact assessment, a scenario testing approach was adopted whereby baseline (current catchment conditions) and a range of background (future catchment conditions minus the AWRC release) and impact (future conditions plus the AWRC release) scenarios were modelled.

This way, changes in hydrodynamics and water quality could be considered in the context of both the AWRC releases as well as other non-AWRC related catchment factors. In addition, scenarios were run over a representative dry year (2013-14) and wet year (2014-15). Information on some aspects of the scenarios was missing from the draft report (e.g. details on the three land use time horizons, the two stormwater management options); however, sufficient details were subsequently added. In general, the review panel supported the scenario testing approach and believed that it was an appropriate way to assess and interpret impacts.

The review panel queried the basis of the representative dry and wet years. Additional details were added to the draft report to demonstrate that the dry and wet years corresponded to the approximate 10th and 95th percentile annual rainfalls, respectively, across the 25-year continuous period from 1994 to 2019. The review panel considered these to be appropriate as representative dry and wet years for the purpose of the impact assessment.

At various times in meetings and workshops the issue of uncertainty was raised, particularly with respect to predicting future runoff conditions, as well as the unavoidable uncertainty with quantifying current conditions, and error in modelling impact to changed runoff conditions. Despite the numerous potential sources of uncertainty, the panel formed the view that the errors were no greater than typically found in comparable modelling exercises, and the differences between scenarios provided a reliable guide to the relative impact of the project compared to current and realistic future conditions.

There were several deficiencies with the reporting of existing water quality data for South Creek and Nepean River presented in the draft report, most notably, (i) there was no presentation or discussion of temporal/seasonal variability, and (ii) no data or discussion was included for some water quality variables such as salinity, turbidity and toxicants. These omissions were generally due to a scarcity of data; however, the final report included brief discussions and figures where possible and acknowledged the limited available data. Overall, the characterisation of the existing hydrology and water quality of the waterways was appropriate.

Given the number of background and impact scenarios assessed (i.e. four background and five impact for South Creek, four background and nine impact for the Hawkesbury Nepean River), there were many potential comparisons and it was at times confusing to know which scenarios were being compared. However, the Hydrodynamic and water quality project team made improvements to the draft report to minimise any such confusion.

Some predicted changes in water quality from AWRC releases (i.e. impact scenarios), particularly in the Warragamba River between the proposed e-flows release point and the confluence with Nepean River, were insufficiently described in the draft report. In particular, this included the temporal dynamics of FRP and total P, and changes from baseline and background conditions for chlorophyll a. Additional explanation was added to the final report.

The review panel made several suggestions, which were adopted in the final report, about the assessment of some of the water quality modelling data, in particular, adjusting some guideline values (e.g. ammonia) to account for relevant environmental conditions (e.g. pH) and comparing concentration spikes for nitrate and ammonia with toxicity-based guideline values.

The draft report referred to environmental impacts being not significant but gave little detail about what this meant. The review panel noted that the conclusion of any EIS needs to clearly align with the results and be unambiguous. To avoid confusion with statistical significance, the review panel recommended replacement of the term not significant with negligible, and inclusion of definitions of the terms negligible and minor when used to describe environmental impact. The review panel agreed with the overall conclusions of the Hydrodynamic and water quality impact assessment that the risks of AWRC releases to the water quality of South Creek and the Nepean and Warragamba rivers are low and that impacts will largely be negligible with some localised minor impacts.

The review panel made some comments about the proposed water quality monitoring program, which were appropriately addressed. However, it is acknowledged that finer details of monitoring programs would be addressed post-approval.

The Hydrodynamic and water quality impact assessment report suggested that the primary form of mitigation and management of environmental impacts on the receiving waterways is through the implementation of the AWRC treatment and release strategy. Under dry weather operating conditions only advanced treated water will be released, while during wetter conditions, the treated water releases in the Nepean River consist of a combination of advanced treated water and tertiary treated water being released from the AWRC. In more severe and infrequent wet weather events, the releases to the Nepean River will represent tertiary treated water. For South Creek, releases will only occur under moderate to severe wet weather conditions. If releases from the AWRC were to be implemented in the Warragamba River, these releases would only consist of advanced treated water. The Hydrodynamic and water quality impact assessment report recommended that opportunities to improve mixing and dilution of releases be considered during the detailed design phase. It was noted that for South Creek, the daily time-step of the hydrological model could have failed to characterise conditions when there was a possibility of treated water releases being made to South Creek when creek flows were low and/or rising in response to rainfall (i.e. not at the event peak). The Hydrodynamic and water quality impact assessment report recommended that this issue be investigated by undertaking additional sub-daily modelling. The review panel considers these recommendations for mitigation to be appropriate.

3.3.2 Near field and toxicity assessment

Sydney Water undertook a review of toxicants present in treated water from other sewage treatment plants with similar levels of treatment to those that would be in operation at the AWRC. The aim of this review was to identify toxicants (in addition to those modelled via the WQRMs) that are detected in treated water and whether their concentrations exceed appropriate national water quality guideline values. For those (soluble, non-bioaccumulatory) toxicants that were detected above relevant guideline values (and hence, deemed to be a hazard), dilution modelling was undertaken using CORMIX to predict near field dilution rates and concentrations in the receiving waters beyond the AWRC release points. The review panel believed this was an appropriate way to assess toxicants that could not be modelled using the WQRMs.

As noted in Section 2.4, Dr van Dam provided advice at the request of Sydney Water on relevant types of toxicants (initially termed micropollutants). Subsequently, Dr van Dam provided numerous review comments on the draft toxicants review. The final toxicants review (reported in Appendix B of the Hydrodynamic and water quality impact assessment report) is considered to be appropriate for the purpose.

The draft Hydrodynamic and water quality impact assessment report did not properly integrate the toxicants review with the near field dilution modelling. Also, insufficient information was provided on the data used to determine the ambient conditions for the near field dilution modelling. However, both issues were addressed in the final report. Also, the review panel provided advice on relevant guideline values for key toxicants, how to compare measured concentrations with guideline values, and additional supporting information required when presenting the information, all of which was adopted.

Workshop discussions between the project team and the review panel focused on the need to put CORMIX modelling results into the appropriate environmental context and the associated conservativeness of the assessment. The review panel believes that this was appropriately done and agreed with the conclusion that the risk of toxicity arising from release events is low.

3.4 Ecohydrology and geomorphology impact assessment

The Ecohydrology and geomorphology impact assessment report included details of ecohydraulics (instream physical water conditions that relate to habitat availability) and geomorphology (physical forms and processes) to assess potential impacts of AWRC releases on in the receiving waters of South Creek and the Hawkesbury Nepean River system. The assessment also considered potential geomorphic impacts of construction of waterway crossings for pipelines and release structure outlet infrastructure. The review panel provided over 100 written comments on the draft Ecohydrology and geomorphology impact assessment report in addition to comments/queries provided at three meetings/workshops attended by the specialist consultants (Streamology) (Table 2-2). All comments were addressed to the satisfaction of the review panel. A summary of the key issues raised by the review panel is provided below.

The original scope of work for ecohydraulic and geomorphic assessment of the project had a focus on the Nepean River, which led to development of hydraulic models for the river that could be used to predict changes in water surface elevation, and depth-averaged velocity and bed shear stress at the river reach scale. Together with knowledge of the materials forming the bed and banks, plus the extent of vegetation coverage, these hydraulic variables could then be used to predict ecohydraulic and geomorphic responses. Later in the EIS preparation process, wet weather releases to South Creek were included in the assessment. As no dry weather releases are proposed for South Creek, it was decided that hydraulic modelling at the habitat scale was not necessary in order to reliably assess geomorphic impacts of the project. Note that hydraulic impacts on South Creek were assessed within the flood impact assessment report (not reviewed here). The alternative to an ecohydraulic approach was to base the assessment of geomorphic impacts at South Creek on hydrological time series data. Hydrologic metrics relevant to biota were used to demonstrate changes in the hydrologic regime for different scenarios. The assessment used an approach developed for the Western Sydney region, the Urban Stream Flow Impact Assessment (USIA) method, whereby specific flow-related metrics relate biotic condition and response to the character of the flow regime. The hydrologic metrics were assessed in terms of the relative difference between baseline, background, and impact scenarios. Due to the previously mentioned baseflow under-prediction error in the hydrologic modelling for the Nepean River (from the Hydrodynamic and water quality impact assessment), the Ecohydrology and geomorphology impact assessment focused on relative rather than absolute differences between the Nepean River scenarios. The review panel considered this an appropriate response to this circumstance.

The geomorphic assessment made use of existing River Styles data obtained from the NSW River Styles database (available online). This a standard method of characterising existing geomorphic state and assessing potential impact. As well as Style, River Styles includes the mapped variables Condition, Fragility, and Recovery Potential. These can be used to assist the assessment. Initially the assessment reported only Style (i.e. the river geomorphic type) but did not utilize other River Style variables (e.g. Fragility and Condition) in the assessment. At the suggestion of the review panel, more use was made of River Styles data.

The review panel identified that the absence of any literature review was a weakness of the report. Such a review would cover the theory assumed to apply in the assessment. For example, using sediment mobilisation thresholds. Subsequently, further information was included to explain the assumptions used in application of this method. The review panel also suggested that a literature review could also cover similar situations, where releases from wastewater treatment plants have or have not impacted waterway geomorphology, especially in the Sydney Water area. In response to this comment, it was explained that the hydraulic conditions in the sites and reaches being assessed are very site specific, and influence of the hydraulic controls (Wallacia Weir and Penrith Weir) mean that extrapolation of results from other systems to this one would be of limited value.

The geomorphic risk assessment approach (i.e. qualitative risk matrices based on combinations of likelihood and consequence classifications) was relatively consistent with the risk assessment framework detailed by ISO (2018). However, the review panel found that there were some deficiencies and a lack of detail and transparency in the risk assessment process and associated decision making, as follows:

- Poorly constructed likelihood and consequence classifications and lack of detail on how they were developed; and
- Insufficient justification and lack of independent verification of assignment of likelihood and consequence classifications, and therefore risk characterisation, for the ecohydraulic stressors (i.e. water surface elevation, wetted perimeter, velocity, shear stress) for each of the river reaches.

Following peer review comments, issues with the likelihood and consequence classifications were addressed and limitations/uncertainties associated with the assignment of the classifications for the ecohydraulic stressors for each of the river reaches were acknowledged. An attempt was made to provide justifications for the assignment of the classifications for the ecohydraulic stressors for each of the river reaches. This was minimal but deemed to be adequate. The final risk outcomes were considered to be appropriate.

The Ecohydrology and geomorphology impact assessment report did not explicitly include an assessment of uncertainty that could arise from models or supplied or measured data. However, commentary concerning data accuracy was provided in the report under the heading Assumptions and Limitations. For example, it was assumed that the hydrologic scenario data provided by Aurecon Arup for the purposes of the hydrologic modelling was true and correct, yet it later transpired that the model was poorly calibrated to baseflows. The gauged hydrological data were assumed to be correct, when it is known that depending on the type of gauge, such data could be in error up to ±20%. The hydraulic model was considered fit for purpose for flows close to the median flow, but the report suggested that it would likely be less accurate under higher or flood flow conditions due to the increased engagement of floodplain areas and the lack of schematisation of floodplain storage in the model. The accuracy of hydraulic modelling was dependent on bathymetric and topographic data supplied by Sydney Water. The report assumed these data properly characterised the channel topography, although this was not evaluated. Review of modelling results by the review panel revealed that in fact there did appear to be (expected) gaps in data and sparse data in some areas of the river channel. The method used to predict sediment mobilisation relies on knowledge of the particle size of sediments on the bed of the channels. Adequate bed sediment data was not available for the Nepean River, so size estimates were based on visual inspection from a boat. For South Creek, bed sediment particle size distributions were based on measurements of bed sediments in the field. The review panel considered that the uncertainties arising from these assumptions, although not quantified, would have been material, although likely not greater than the uncertainties associated with typical similar assessments undertaken elsewhere.

The Ecohydrology and geomorphology impact assessment report characterised the current hydrological and geomorphological conditions within the waterways potentially impacted by the project, namely the Nepean River (upstream of Wallacia weir), receiving releases of treated water, South Creek (upstream of Kemps Creek), receiving wet weather releases, and the Warragamba River (downstream of the dam wall), potentially receiving advanced treated water releases. The hydrological characterization included text to describe river operations and land use impacts on hydrology, plus flow duration curves. The review panel considered this approach consistent with standard hydrological characterization.

Detailed geomorphic description of the Nepean and Warragamba rivers was previously reported by NSW Department of Primary Industries, Office of Water (2014). The Ecohydrology and geomorphology impact assessment rightly considered that this information effectively represented current conditions, so utilised it, along with River Styles data, in the report. For South Creek, the assessment was based on River Styles data and surveys of South Creek using the Urban Stream Flow Impact Assessment (USIA). Overall, the review panel considered the characterization of existing geomorphic conditions to be comprehensive and appropriate for the purpose.

The draft Ecohydrology and geomorphology impact assessment report had a predominant focus on comparisons between baseline (i.e. current catchment conditions) and the various impact scenarios (i.e. future catchment conditions including the AWRC releases), with less consideration of the corresponding background scenarios (i.e. future catchment conditions minus the AWRC releases). The final report provided appropriate justification for the greater emphasis on baseline versus impact comparisons (i.e. for the Nepean River in particular, negligible differences between results for the background and baseline scenarios negated the need for extensive consideration of the background scenario), but also paid more attention to the background scenarios. The review panel was satisfied with the final balance.

The impact assessment documented the impact of 50 ML/d increase on hydraulic variables in Nepean River. The change in hydraulic variables were correctly assessed as small relative to the existing magnitudes, but this was only considered for the median flow condition. This is a reasonable index to choose, as it represents common flow conditions. For high flow conditions the relative hydrologic impact is smaller, but for low flow conditions the relative hydrologic impact is greater. The review panel suggested that the report should assess the geomorphic impact (risk) for a low flow index as well, as the purpose of the assessment is to reveal the most significant risks to the environment. Subsequently, consideration of low flows determined that the geomorphic risk was also very low (as relative change is greater, but magnitude is low). For South Creek, the wet weather releases have a relatively small impact on the magnitude of high flows, which is a reasonable assessment of low geomorphic risk. Even though the project will theoretically not have a geomorphic impact for the low flow situation, the review panel suggested that this should be explicitly stated. The final version included assessment of ecohydraulic changes at 10th and 90th percentile flow conditions, which provided an understanding of the variability and confirmed the minor nature of the changes to the ecohydraulic metrics under the scenario with AWRC operational.

The impact assessment of river release infrastructure considered construction and operational impacts. The main identified construction impacts were, as expected, related to turbidity generation and bank stability. Operational impacts of releases to Nepean and Warragamba rivers were considered to be small because of either the relatively low flows released to the river or the stable nature of the river channel. For South Creek, the potential for geomorphic impact was higher, so the report appropriately recommended that the detailed design carefully consider riparian planting and natural bank stabilisation measures. The report also noted that future urban development will likely increase stormwater runoff to South Creek, which would likely result in a geomorphic response that involved bank and bed erosion. The review panel agreed with the recommendation made in the report that the detailed design of the release structure consider the future channel geomorphic conditions.

The report suggested that the main concern about pipeline waterway crossings impacting creek geomorphic character would manifest during the construction phase. In addition to disturbance during construction, it was suggested that trenching can result in localised erosion in the post-construction phase. The report adequately considered the risk of hydrological changes brought about by the project on the geomorphic environment. However, there is also a risk of the existing geomorphic processes impacting the project infrastructure. The pipeline watercourse crossings are an example of this. The work of burying the pipeline disturbs the geomorphic forms during construction, and requires a period of recovery, but the dynamic nature of the watercourses could pose a threat to the buried pipeline, e.g., if the watercourse avulsed or if a headcut worked its way upstream to the crossing. The other thing to consider is the possibility of the pipeline crossing altering the rate of the existing geomorphic processes, either increasing or decreasing the risk of natural processes impacting the pipeline infrastructure. The final version of the assessment report included a recommendation to undertake local on-ground site assessments by a qualified geomorphologist, including upstream and downstream implications, prior to the final approval for a works plan.

The impact assessment report recommended standard mitigation approaches be implemented during construction and operation of the pipelines, particularly where the pipeline crosses waterways with high geomorphic sensitivity (South Creek and Mulgoa Creek). The mitigation measures include standard advice concerning planning, timing, equipment operation and erosion and sediment control. Additional measures specific to the project were also included.

Mitigation measures for release structures included setbacks from the waterway, measures to dissipate energy, and scour protection along adjacent banks which mitigate potential operational impacts. The report suggested that any residual risks associated with operation of release structures would be addressed through an on-going field monitoring program. It was recommended to undertake regular (6 monthly) inspections at each structure.

Additional measures were not recommended to mitigate impacts of releases to the Nepean River during the operational phase due to the predicted negligible impact of the releases of treated water at Wallacia Weir. It was recommended to implement a program of pre-works and on-going monitoring of bank stability and change upstream of Wallacia Weir. Implementation of bank stabilisation measures should be considered on the basis of monitoring data. The assessment found that the impacts of wet weather flow releases to South Creek were small enough that no additional mitigation measures were proposed. The review panel considered the mitigation and monitoring recommendations made in the Ecohydrology and geomorphology impact assessment report appropriate.

3.5 Aquatic ecology impact assessment

The Aquatic ecology impact assessment report drew on the results of the previous two reports on hydrodynamic, water quality, ecohydrological and geomorphological impacts, and a desktop review and field assessment of the aquatic ecology of South Creek and the Nepean River, to assess potential impacts of AWRC releases to riparian vegetation and aquatic ecosystems. The review panel provided over 110 written comments on the draft Aquatic ecology impact assessment report in addition to comments/queries provided at two workshops attended by the specialist consultants (CT Environmental) (Table 2-2). Most comments were addressed to the satisfaction of the review panel. A summary of the key issues raised by the review panel is provided below.

The review panel provided advice and review in mid 2020 in relation to proposed approaches for assessing potential impacts of dry weather releases to South Creek. However, the option of dry weather releases to South Creek was removed from the treated water release strategy for the AWRC and, hence, no further review of this option was required.

The review panel found that the draft report had a number of structural issues, some of which were addressed in the final report, while others were not. Some examples are provided, below. A lack of sub-section numbering made it very difficult to navigate the document, but this was added in subsequent drafts. Also, the draft report incorporated discussion of the existing environment and potential impacts into one section (Section 6), rather than splitting these into two sections. This structure was different to the other two specialist reports and also the EIS. In addition, some methodological text on Hydrology and hydraulics, wetted perimeter analysis and flow velocity analysis was included in the impact assessment section. Although the above two, and some other, structural issues were not changed for the final report, this did not impact on the technical veracity of the report's conclusions on environmental impact.

The Assessment method section of the draft report listed the information that was used to assess current condition and impacts for the construction and operational phases, but did not sufficiently describe how this information was used (e.g. how impact was assessed). For example, there was no detail on how the results from the Hydrodynamic and water quality impact assessment or the Ecohydrology and geomorphology impact assessment were used to assess impacts to aquatic ecology. Nor was there any detail on how the macroinvertebrate and fish data were analysed. The final report contained adequate details on how the information was used.

The Aquatic ecology impact assessment relied on a different water quality dataset to characterise the current water quality conditions to that used for the same purpose in the Hydrodynamic and water quality impact assessment. The review panel believes that maximum consistency between such datasets is important and that there should have been greater coordination/integration of this aspect between the two impact assessment project teams. The key risk of not standardising the datasets is that different water quality statistics are reported for comparison with relevant water quality objectives, which could yield different compliance outcomes. This has the potential to undermine confidence in the water quality component of both assessments. Sydney Water indicated that the Hydrodynamic and water quality project team needed to use a longer time series for its modelling purposes and that a smaller, more contemporary dataset was used for the Aquatic ecology report and main body of the EIS. Nevertheless, both impact assessments compared their water quality data to relevant waterway objectives when describing the existing environment, resulting in slightly different 'compliance' outcomes. A statement recognising this potential difference in outcomes was added to the Aquatic ecology report. However, the review panel acknowledges that these different compliance outcomes were minor and did not result in inconsistent outcomes between the two impact assessments.

The characterisation of the existing environment relied upon a desktop review and field assessment and, overall, was thoroughly undertaken. The review panel found that the characterisation of the riparian vegetation and aquatic ecology was appropriate, although the characterisation of water quality was not as comprehensive as that of the Hydrodynamic and water quality impact assessment. However, this was not of concern as characterisation of water quality was not the main focus of the Aquatic ecology impact assessment. Moreover, the baseline monitoring program will continue to characterise the water quality and aquatic ecology prior to commencement of AWRC construction. Some details associated with the baseline data (e.g. period of record, details of data analysis) were missing, but were included in the final report.

To assess the relative condition of riparian vegetation and waterway channels across the study area, the Rapid Riparian Appraisal (RRA) method was used in the Aquatic ecology impact assessment. This method combines qualitative and quantitative assessment of urban stream condition and riparian habitat (on both the left and right bank), incorporating land use, riparian vegetation and weed density, channel features, key fish habitat, and depositional and erosional features. The RRA method includes visual assessment of geomorphic form and process, specifically erosion and deposition. Deposition was assessed as presence or absence, in terms of benches, islands and channel bars. Erosion was assessed as presence or absence, in terms of underlying bed exposure, knick points and bank erosion, as well as relative area of bank undercutting and slumps. One of the likely problems with this type of visual assessment is its low repeatability, i.e. high variability between observers and high variability of individual observers between observations. Another problem is that all the features being observed occur naturally in streams and rivers, so it is difficult to determine if the observations indicate a degraded state or not. Finally, the observations are of geomorphic forms at an instant in time, but are used to infer whether geomorphic processes are accelerated or not, e.g., the presence of steep bare banks could infer accelerated bank erosion, when in fact high silt and clay content might support stable steep bank angles, vegetation might not be expected on vertical banks, and the banks might have formed in a single flood event decades earlier and remained stable since. The review panel requested removal of all suggestions that RRA erosion and deposition scores could be interpreted to mean that a geomorphic process was negative or positive. This was edited to indicate only that erosion or deposition was observed, i.e. the value judgement was removed.

It was not always clear in the draft report which scenarios were being compared (i.e. baseline versus impact or background versus impact) when assessing potential impacts. To address this, additional information was included in the final report, including background details for the scenarios, clarification of which scenarios were being compared, and details of the limitations of the scenario comparisons. The report authors noted that they focused on comparisons between baseline (current conditions) and impact scenarios (future conditions with the AWRC releases) on the assumption that there is negligible difference between current and future ecological conditions. While this assumption may be valid for the Nepean and Warragamba rivers, for which the hydrodynamic and water quality modelling predicted little difference between baseline (current conditions) and background (future conditions without the AWRC releases) scenarios, it may not be valid for South Creek, where there were often marked differences between baseline and background hydrology and water quality due to significant projected urban development in the South Creek catchment over the coming decades. The risk of this is that impacts to the South Creek environment caused by external catchment factors could be falsely attributed to the AWRC releases. However, the final impact assessment adequately dealt with this. The summaries of predicted hydrology and water quality that were provided in the report, and upon which the assessment of ecological impacts were based, clearly described the differences between the predicted background and impact scenario outcomes. Thus, the focus was on AWRC related impacts.

One of the largest responses predicted from the hydrodynamic and water quality modelling was a series of sustained increases of one month or more in chlorophyll a concentration in the Warragamba River downstream of the AWRC (e-flows) release location. These increases were well above baseline and background scenarios, and also in excess of the relevant regional guideline value of 3 µg chlorophyll a / L (ANZG 2018). The draft report acknowledged this predicted response but concluded there was a low risk of eutrophication. The review panel believed that insufficient attention was paid to this issue, and that the conclusion of low risk was not accompanied by sufficient supporting evidence. Initial attempts by the authors to elaborate on the risk suggested that the impact on chlorophyll a concentration was short-lived; however, the modelling suggested otherwise. The review panel suggested several other factors that the authors may wish to draw upon to further support the conclusion of low risk, namely: (i) in contrast to the chlorophyll a results, the cyanobacterial modelling reported in the hydrodynamic and water quality impact assessment found no significant increase in cyanobacterial risk; (ii) exceedance of guideline values/objectives that are based on the reference site approach (e.g. comparison of 80th %ile from reference site with median from 'exposed' site) does not necessarily infer ecological impact, as emphasised in ANZECC/ARMCANZ (2000, Vol 2, Appendix 7, section 6) and ANZG (2018); and (iii) the chlorophyll a spikes were spatially localised and annual median concentrations at these sites remained below the ANZG (2018) default guideline value for chlorophyll a for both the dry and wet year (for the 2036 scenario). The final report included factors (i) and (iii) to further support the conclusion of low risk associated with the chlorophyll a response.

The potential impacts of increases in stream flows on macroinvertebrates was supported by empirical data of macroinvertebrate mobilisation velocity thresholds from both the literature and an experiment performed by CT Environmental in April 2021. The review panel strongly supports the use of such empirical data for determining impacts. However, the review panel suggested that, in addition to the use of the collated data for the impact assessment, that a description of the available literature and current state of knowledge on flow-related impacts to macroinvertebrates was included in the report. Such a summary was added to the final report, and included data from several additional studies that had not been included in the draft report.

The Aquatic ecology impact assessment correctly identified that increased sedimentation has the potential to impact aquatic biodiversity, particularity benthic macroinvertebrate fauna which are vulnerable to smothering. The assessment initially referred to clay being responsible for this damaging sedimentation. The review panel suggested that in reality clay particles, once mobilized in the water column, are generally held in suspension until deposited within estuarine reaches or ponded areas of floodplains. The material that settles on coarse stream beds is generally silt-sized, although it can contain aggregated clays. The final version of the assessment report removed reference to the settled material being clays.

The Aquatic ecology impact assessment measured changed in wetted perimeter of rivers at selected cross-sections. Wetted perimeter is commonly used as an indicator of habitat availability, especially for macroinvertebrates, and changes to wetted perimeter could indicate a response by riparian vegetation to changed wetness and flow regime. The data used to predict the water level appeared to be relatively coarse, which would be a function of the resolution of the original bathymetric data and the resolution of the hydraulic model. This resulted in what appeared to be anomalous results for changes in wetted perimeter at certain locations that might not have been well characterised by the hydraulic model. The assessment report suggested that accurate quantification of the potential magnitude of impacts associated with wetted perimeter increase on riparian and aquatic ecosystems was not possible using these data. The review panel agreed with this conclusion and formed the opinion that the somewhat unexpected results at some cross-sections were most likely an artefact of the method.

The review panel generally supported the conclusions of the Aquatic ecology impact assessment. However, the review panel queried the decision process for determining the level of impact based on specified percentages of effect on the various ecohydraulic metrics. For example, for assessment zone 2, a 7% change in inundation extent was considered to cause an impact, whereas a change of <5% for assessment zone 3 was not considered to cause an impact. The basis for such conclusions was unclear, especially given the uncertainties in the hydraulic modelling results that were being relied upon (as noted in the previous paragraph). Following correspondence with the Aquatic ecology project team, the review panel acknowledged the challenges of definitively inferring ecological impact given the coarseness of, and uncertainties in, the modelling results. Nevertheless, the technical bases for any conclusions on impacts to riparian vegetation and aquatic ecology still need to be provided; otherwise, such conclusions can lack defensibility even if they are likely to be correct. To address this, the final report included additional discussion on the coarseness of the modelling and the artefacts discussed in the previous paragraph, and qualified the conclusions on impact accordingly. Additionally, available evidence was added to support the conclusions of likely low or negligible impact of increases in wetted perimeter and depth on riparian vegetation and aquatic ecology. In the absence of empirical data on responses of various ecological communities to changes in these ecohydraulic metrics, this evidence focused on the relatively small changes in the metrics and associated areal extent affected, and other relevant aspects where possible (e.g. morphology of the gorge section between Wallacia Weir and the confluence of Warragamba River). Given the uncertainties associated with this assessment, the review panel considered this approach to be appropriate.

Appropriate justification for the low likelihood of unacceptable toxicity due to toxicants in the treated release waters was also missing from the draft report. Such justification had been provided in the near field toxicity assessment in the Hydrodynamic and water quality impact assessment. The Aquatic ecology impact assessment drew upon this information for the final report.

Notwithstanding the limitations of the aquatic ecology impact assessment, the review panel agreed with the overall conclusions that: (i) risks of construction activities to riparian vegetation and aquatic ecology exist but can be appropriately mitigated or managed; and (ii) the risks of AWRC releases to the riparian vegetation and aquatic ecology of South Creek and the Nepean and Warragamba rivers are low and that impacts will largely be negligible with some localised minor impacts.

One of the monitoring recommendations in the Aquatic ecology impact assessment was to establish a diatom monitoring program. Sydney Water specifically asked for review panel comments (from Dr van Dam) on this recommendation. In recommending such a program, the Aquatic ecology impact assessment suggests that benthic diatoms are less susceptible to hydrological change compared to macroinvertebrates and chlorophyll a. However, no supporting evidence was provided to justify this statement. Moreover, although mentioned in the recommendations, diatoms were not discussed at all in the main report. Standard monitoring indices have been developed for diatoms in south-east Australia, for example, the Diatom Index for Australian Rivers (DIAR) (Chessman et al. 1999) and Diatom Species Index for Australian Rivers (DSIAR) (Chessman et al. 2007). As the review panel does not have first-hand experience with the use of these indices, it cannot comment from direct experience. Based on published work, diatom indices appear to correlate reasonably well with key water quality variables, including major ions and nutrients (Chessman et al. 2007, Chessman & Townsend 2010, Nhiwatiwa et al. 2017, Oeding & Taffs 2017). However, a key question is whether they are better predictors of water quality, or are predictive of more relevant types of water quality perturbations, than macroinvertebrates. Several studies have found that diatoms were generally more associated with water quality gradients than macroinvertebrates (e.g. Newall et al. 2006), but this wasn't always the case for all water quality variables (e.g. TP), so it is difficult to generalise. If ANZG (2018) principles are followed, then an additional biological line of evidence will benefit a water quality/aquatic ecosystem monitoring program, as long as (i) it has been demonstrated to be relevant and relatively sensitive to the major pressures and stressors (i.e. treated sewage water and its constituents), and (ii) it does not duplicate the type of response already provided by existing indicators (i.e. macroinvertebrates and chlorophyll a). There would be considerable effort in adding an additional indicator, so one would want to be confident of the case to do so, and it may require some pilot work. It is worth noting that the diatom monitoring recommendation is not just relevant to the AWRC, but to Sydney Water's overall environmental monitoring program, and it may be best considered at this level. The views of relevant freshwater monitoring experts would be valuable to inform this issue.

The Aquatic ecology impact assessment included recommendations to mitigate impacts of the project. The recommendations included mitigating impact of construction of the brine and treated water pipelines. Underboring presents a risk of frac-outs, which would be managed by undertaking a risk assessment and modifying the design of works and undertake operational measures as necessary. Mitigation of potential and actual impacts associated with open trenching would be managed by application of a comprehensive set of management measures to control the severity of impacts, developed by Sydney Water. These same measures would be applied to all project areas where construction activities would be undertaken. The review panel agreed that these mitigation measures will minimize potential sediment and erosion and water quality driven impacts to the aquatic ecosystem during the construction phase. The Aquatic ecology impact assessment report recommended establishment of an appropriately revegetated and managed vegetated riparian zones (VRZs) to improve on the current condition of the riparian corridor of South Creek and the wetland/anabranch of South Creek. The review panel agreed that establishment of VRZs in South Creek and application of Vegetation Management Plans (VMPs) for impacted Warragamba and Nepean River sites and reaches should result in long term benefits to both aquatic and terrestrial biodiversity.

3.6 Other issues

3.6.1 Draft DPIE/ESS flow and water quality objectives

The Hydrodynamic and water quality and Aquatic ecology impact assessments refer to draft DPIE/ESS flow and water quality objectives for South Creek. On request from NSW DPIE, these objectives were applied to South Creek when assessing flow and water quality related impacts, rather than ANZG (2018) (or ANZECC/ARMCANZ 2000) guideline values. The review panel had some concerns about this for both the flow and water quality objectives, as discussed below. The review panel understands that this is not an issue that should be addressed as part of the AWRC EIS, but feels that it warrants some technical commentary, nonetheless.

Currently, there appears to be no published document that details the rationale, data and methods for the derivation of these objectives. The only relevant document that Sydney Water was able to locate and provide to the review panel was a copy of a presentation by DPIE in October 2020 (DPIE 2020), which provides some, albeit insufficient, details. The review panel has concerns about the application of flow and water quality objectives that appear to be erroneous and/or cannot be technically verified. Specific commentary on the flow objectives and water quality objectives is provided below.

Flow objectives

To inform the planning of the Western Parkland City, the NSW Department of Planning, Industry and Environment (DPIE) drafted numerical objectives to preserve the hydrologic condition of Wianamatta-South Creek and its tributaries. Flows objectives were developed by applying the Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (OEH 2017), as cited in the Western Sydney Aerotropolis Interim Report (Sydney Water 2020c).

The review panel noted that the Wianamatta-South Creek waterway health generic flow objectives for freshes assumed that event duration is shorter for 3rd order streams than 1st and 2nd order streams, which appears counter to what would be expected. The objectives recommend 4 freshes per year in a 1st order stream and 24.6 in in 3rd order and larger streams, which again the review panel considered counter to what would be expected. Average duration could be interpreted as either average event duration or average total annual duration, but neither make hydrological sense. A total of 38 days per year exceeding the freshes threshold was considered by the review panel to be reasonable for 1st order streams, but over 4 events per year the average duration would be 9.6 days per fresh event, which is much too long. In reality, the event duration would be 1 or 2 hours maximum. The recommendations for 3rd order and larger streams suggest an average event duration of 2.4 hours, which the review panel considered might be reasonable, but the frequency of 24.6 events per year seemed unrealistic.

The Ecohydrology and geomorphology impact assessment report noted that the published NSW government Wianamatta-South Creek waterway health flow objectives currently lack availability of detailed information concerning the principles and calculation methods used to derive them. Thus, at the current time it was not possible to critique the applicability of these generic flow objectives to protection of waterways as part of the Ecohydrology and geomorphology impact assessment. The objectives for freshes, which were the most ambiguous of the objectives, were not used as a reference in the impact assessment report. The review panel agreed that it was impractical to use the flow objectives for freshes in particular, and supported the alternative approach taken in the impact assessment. The impact assessment report relied on flow metrics used by the Urban Streamflow Impact Assessment (USIA) method. For freshes (events exceeding 3 x Median Flow), the metrics were Number of Fresh Events Per Year, Percent of Time Exceeding Fresh Event, and Average Fresh Duration (days). These metrics were specific to the hydrology of the stream reaches being assessed for impact by the project.

Water quality objectives

The information in DPIE (2020) indicates that the water quality objectives (expressed as numerical criteria) were determined using the methods of ANZG (2018) and that data from South Creek site(s) were used. This implies that a reference site approach was used; however, one could question whether South Creek can be considered to have any appropriate reference sites. According to the Sydney Water (2020c) Aerotropolis water management report, "...the Wianamatta-South Creek catchment is the most degraded catchment in the Hawkesbury-Nepean River system due to historical vegetation clearing and urbanisation.". Thus, the DPIE (2020) water quality objectives will reflect the current degraded/impacted state of the South Creek system. This is not necessarily consistent with ANZG (2018), which would recommend that objectives be set that allow for improvement of water quality in highly degraded systems, not just to maintain such systems. The objectives as they are currently reported might serve as meaningful short-term targets to at least prevent further degradation, ahead of revised objectives that seek to drive improvements to water quality. It is acknowledged that the objectives are still draft and may change.

Moreover, few if any details are available for the water quality objectives – for example: the nature of the dataset used to derive them; what statistical estimate they are based on (i.e. which percentile of the data) or what statistical estimate of water quality they should be compared with. Without such details, it is very difficult to know whether the objectives are being appropriately applied and, therefore, whether any associated conclusions about water quality are correct.

4. Conclusions and recommendations

The material reviewed by the panel was progressively refined based on the iterative engagement between the peer reviewers, Sydney Water and the specialist consultants who authored the reports. As a result, the review panel concludes that the final reports are acceptable and fit for purpose for the EIS. The following specific concluding statements are provided.

Overall assessment approach

- the overall assessment approach was considered to be consistent with the expected standard approach to conducting an EIS.

Waterway objectives

- the waterway objectives were appropriate and developed in accordance with the relevant state and national guidelines.
- The review panel noted some concerns with the draft DPIE (2020) flow and water quality objectives for South Creek, although it is not within the scope of the EIS to address these concerns.

Hydrodynamic and water quality impact assessment

- The Hydrodynamic and water quality impact assessment adequately described the existing conditions of the receiving waters of South Creek and the Warragamba and Nepean rivers based on the available data.
- Baseline water quality data were limited for some variables but will continue to be built upon through the baseline water quality monitoring program.
- The modelling approach that was adopted for the impact assessment, comparing baseline, background and impact scenarios for a representative dry and wet year was appropriate for assessing potential hydrological and water quality impacts of AWRC releases.
- An error in the hydrological modelling was identified during the project by other specialist consultants relying on the model outputs. Although it was too late in the impact assessment process to fully correct the error, a practical and appropriate resolution was identified, and the error did not compromise the results of any of the impact assessments that relied on the modelling outputs.
- The toxicants review and near field dilution modelling were appropriate for assessing potential impacts of contaminants not included in the water quality modelling.
- The review panel agreed with the overall conclusions that the likely impacts of the AWRC releases on the hydrology and water quality of South Creek, and the Nepean and Warragamba rivers will largely be negligible with some localised minor impacts.

Ecohydrology and geomorphology impact assessment

- The Ecohydrology and geomorphology impact assessment adequately described the existing ecohydraulic (instream physical water conditions that relate to habitat availability) and geomorphologic (physical forms and processes) conditions of the receiving waters of South Creek and the Hawkesbury Nepean River system, via a mix of desktop and field-based assessment. The hydrological characterization included text to describe river operations and land use impacts on hydrology, plus flow duration curves. The report utilised a comprehensive assessment of geomorphic condition undertaken in 2014, as well as River Styles data, plus field survey of South

Creek. Overall, the review panel considered the characterization of existing hydrologic and geomorphic conditions to be comprehensive and appropriate for the purpose.

- The geomorphic risk assessment approach (i.e. qualitative risk matrices based on combinations of likelihood and consequence classifications) was relatively consistent with the risk assessment framework detailed by ISO (2018). Some deficiencies and a lack of detail and transparency in the risk assessment process and associated decision making that were identified by the review panel were subsequently addressed, and limitations/uncertainties associated with the assignment of the classifications for the ecohydraulic stressors for each of the river reaches were acknowledged.
- The report did not explicitly include an assessment of uncertainty that could arise from models or supplied or measured data. However, commentary concerning data accuracy was provided in the report. The review panel considered that the uncertainties arising from the assumptions made, although not quantified, would have been material, although likely not greater than the uncertainties associated with typical similar assessments undertaken elsewhere.
- The impact assessment report had a predominant focus on comparisons between baseline (i.e. current catchment conditions) and the various impact scenarios (i.e. future catchment conditions including the AWRC releases), with less consideration of the corresponding background scenarios (i.e. future catchment conditions minus the AWRC releases). This was considered appropriate.
- The impact assessment of river release infrastructure considered construction and operational impacts. The main identified construction impacts were, as expected, related to turbidity generation and bank stability. Operational impacts of releases to Nepean and Warragamba rivers were considered to be small because of either the relatively low flows released to the river or the stable nature of the river channel. For South Creek, the potential for geomorphic impact was higher, so the report appropriately recommended that the detailed design carefully consider riparian planting and natural bank stabilisation measures.
- The report suggested that the main concern about pipeline waterway crossings impacting creek geomorphic character would manifest during the construction phase. In addition to disturbance during construction. Standard mitigation approaches were recommended for construction and operational phases of the pipelines, particularly where the pipeline crosses waterways with high geomorphic sensitivity. The report recommended to undertake local on-ground site assessments by a qualified geomorphologist, including upstream and downstream implications, prior to the final approval for a works plan.
- Additional measures were not recommended to mitigate impacts of releases to the Nepean River during the operational phase due to the predicted negligible impact of the releases of treated water at Wallacia Weir. The assessment found that the impacts of wet weather flow releases to South Creek were small enough that no additional mitigation measures were proposed.
- The review panel considered the mitigation and monitoring recommendations made in the Ecohydrology and geomorphology impact assessment report appropriate.

Aquatic ecology impact assessment

- The Aquatic ecology impact assessment adequately described the existing riparian and aquatic ecological conditions of the receiving waters of South Creek, the Warragamba and Nepean rivers and other relevant waterways, via a mix of desktop and field-based assessment. The use of a different water quality dataset to that used for the Hydrodynamic and water quality impact assessment was not ideal, but did not impact on the results of the impact assessment.
- The assessment approach of drawing on the results of the hydrodynamic, water quality, ecohydrological and geomorphological impact assessments, and a desktop- and field-based assessment of the aquatic ecology of South Creek and the Nepean and Warragamba rivers, to assess potential impacts of AWRC releases on riparian vegetation and aquatic ecology was considered appropriate.

- The review panel acknowledges the challenges of definitively inferring ecological impact from the available modelling results, and considers that the Aquatic ecology project team did as much as could be done given the uncertainties.
- The review panel agreed with the overall conclusions that: (i) risks of construction activities to riparian vegetation and aquatic ecology exist but can be appropriately mitigated or managed; and (ii) the risks of AWRC releases to the riparian vegetation and aquatic ecology of South Creek and the Nepean and Warragamba rivers are low and that impacts will largely be negligible with some localised minor impacts.

The review panel has no further specific recommendations. As a result of the iterative nature of the peer review process, all recommendations to improve the impact assessments were made throughout the process and, for the most part, have been satisfactorily addressed. Any recommendations that were not satisfactorily addressed concerned aspects that had no material effect on the conclusions of the impact assessments and, hence, are not critical to the EIS.

5. References

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ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia. https://www.waterquality.gov.au/anz-guidelines.

Chessman B, Bate N, Gell PA & Newall P 2007. A diatom species index for bioassessment of Australian rivers. *Marine and Freshwater Research* 58, 542–557.

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DPE 2019. Preparing a peer review report. Department of Planning and Environment, NSW Government, Sydney, NSW.

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NSW Department of Primary Industries, Office of Water 2014. Warragamba Environmental Flow Options Assessment: Geomorphology. Report 3 in a series of 12 baseline reports, December.

Oeding S & Taffs KH 2017. Differing effects of catchment land use on water chemistry explain contrasting behaviour of a diatom index in tropical northern and temperate southern Australia. *Ecological Indicators* 80, 135–146.

OEH 2017. Risk-based framework for considering waterway outcomes in strategic land-use planning decisions. State of NSW and Office of Environment and Heritage

Sydney Water 2020a. Upper South Creek Water Factory – Draft briefing paper for assessment of waterway releases. Unpublished report to peer review panel. Sydney Water, April 2020.

Sydney Water 2020b. Upper South Creek Water Factory baseline monitoring programs 2020-23. Unpublished report. Sydney Water, August 2020.

Sydney Water 2020c. Western Sydney Aerotropolis (Initial Precincts) Stormwater and Water Cycle Management Study Interim Report – October 2020. Sydney Water.

Appendices

Appendix A Credentials of peer reviewers

Curriculum Vitae for Dr Chris Gippel

Christopher James GIPPEL (PhD)

Employment

Current:

- Company Director of Fluvial Systems Pty Ltd (since 1999), providing specialist consulting services to the land and water resources management industry
- Fellow in the Department of Resource Management and Geography, Melbourne School of Land and Environment, The University of Melbourne (since 1999)
- Adjunct Senior Research Fellow, Australian Rivers Institute, Griffith University (since 2012)

Former:

- Changjiang Water Resources Protection Institute, Ministry of Water Resources (China), High-end Foreign Recruitment Programme Visiting Fellow (Sep – Oct 2013)
- College of Water Resources and Hydropower Engineering, Wuhan University (China), High-end Foreign Recruitment Programme Visiting Fellow (Nov – Dec 2013, May – Jul 2014, June – July 2015)
- The University of Melbourne (Senior Research Fellow 1990 – 1999); The University of NSW (Teaching Fellow 1985 – 1989); Adelaide University (Tutor 1983 – 1984)
- Visiting Fellow, Loughborough University (U.K.) and Exeter University (U.K.) (1992 – 1993) – Australian Bicentennial Fellowship and British Council Academic Links and Interchange Scheme Grant

Expertise

- Specialist expertise in applied fluvial geomorphology, environmental hydraulics and hydrology, especially as applied to environmental flows, river health assessment and environmental impact of developments, and stream design and rehabilitation
- Multi-disciplinary environmental research, especially linking hydrology, hydraulics and geomorphology with ecology
- Numerical modeling approach where appropriate, supported by field data collection
- Expert in terrain analysis in GIS, and evaluation of vegetation and water bodies using multi-spectral remote sensing data
- Expertise in freshwater rivers, estuaries and wetlands
- Working across all scales, from local site issues, to landscape scale analysis, to national policy level
- Overseas experience, including Asia and South America
- Flexible consulting arrangements, working as an individual, leading a consortium, member of consortium, or engaged as a sub-consultant
- Experienced in science communication
- Widely published, including books and scientific journals
- Peer review, including, international journals, national and international development projects, and appointed a member of an international expert panel for large-scale peer-review process for research grant financing that applies across the Republic of Kazakhstan.
- Co-author of international text book *Stream Hydrology: An Introduction for Ecologists* (Wiley & Sons, Chichester).
- Hydrological software development: FlowHealth (http://watercentre.org/portfolio/rhef/project-resources/flow-health-hydrology-assessment-tool)

Personal details

Date of birth:

- 21st May 1957, Newcastle, New South Wales, Australia

Academic qualifications:

- PhD 1989, Department of Geography and Oceanography, University College, University of NSW, Australia
- BSc (Hons. Class I) 1982, Department of Geography, University of Newcastle, NSW, Australia

Languages:

- English – native language
- German – tourist level
- Chinese – tourist level

Referees

- Assoc Prof Brian Finlayson (https://au.linkedin.com/in/brian-finlayson-a8751710), The University of Melbourne, email: brianlf@unimelb.edu.au; ph +61 (0)3 8344 9169
- Damein Bell, CEO, Gunditj Mirring Traditional Owners Aboriginal Corporation, Heywood Victoria; ph: +61 (0)3 5527 1427; email: Damein@gunditjmirring.com; www.gunditjmirring.com

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- fluvialsystems@fastmail.net
- LinkedIn: https://au.linkedin.com/in/chris-gippel-156a8015

Publications (since 2009)

Jiang, C., Li, S., Du T., Gippel, C.J. and Zhang, Q. 2020. A modified Fu (1981) equation with a time-varying parameter that improves estimates of inter-annual variability in catchment water balance. (under review).

Gippel, C., Zhang, Y., Qu, X.D., Bond, N., Kong, W.J., Leigh, C., Catford, J., Speed, R. and Meng, W. 2017. Design of a National River Health Assessment Program for China. Chapter 18 in Hart, B. and Doolan, J. (Eds) *Decision Making in Water Resources Policy and Management*, Elsevier, pp. 321-339.

Zou, L., Zhan, C.S., Xia, J., Wang, T.J. and Gippel, C.J. 2017. Implementation of evapotranspiration data assimilation with catchment scale distributed hydrological model via an ensemble Kalman filter. *Journal of Hydrology* **549**: 85-702.

Shi, W., Xia, J., Gippel, C.J., Chen, J.X. and Hong, Si. 2017. Influence of disaster risk, exposure and water quality on vulnerability of surface water resources under a changing climate in the Haihe River basin. *Water International*, March. DOI: 10.1080/02508060.2017.1301143.

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Chen X.C., Zhang, L.P., Gippel, C.J., Shan, L.J., Chen, S.D.and Yang, W. 2016. Uncertainty of flood forecasting based on radar-rainfall data assimilation. *Advances in Meteorology*. DOI: 10.1155/2016/2710457.

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Gippel, C.J. and Bond, N. 2016. Hydropower simulation model to predict the impact of environmental flow rules on power production potential. In *Proceedings, 11th ISE 2016*, International Symposium on Ecohydraulics, 7 – 12 February, Melbourne.

Xia, J., Shi, W., Luo, X.P., Hong, S., Ning, L. and Gippel, C.J. 2015. Revisions on water resources vulnerability and adaption measures under climate change. *Advances in Water Science* **26**(2): 279-286, doi:10.14042/j.cnki.32.1309.2015.02.019 (in Chinese with English abstract).

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Wu, S.F, Zhang, X., Shao, Q.X. and Gippel, C.J. 2015. Impact of river flow on water quality combination events under different scenarios: a case of Bengbu Sluice in Huai River Basin. *Journal of Basic Science and Engineering* **23**(4): 669-679, doi:10.16058/j.issn.1005-09030.2015.04.000.

Li, L.C., Zhang, L.P., Xia, J., Gippel, C.J., Wang, R.C., Zeng, S.D. 2015. Implications of modelled climate and land cover changes on runoff in the Middle Route of the South to North Water Transfer Project in China. *Water Resources Management* **8**: 2563-2579.

Catford, J.A., Morris, W.K., Vesk, P.A., Gippel, C.J. and Downes, B.J. 2014. Species and environmental characteristics point to flow regulation and drought as drivers of riparian plant invasion. *Diversity and Distributions* **20**(9): 1084-1096.

Ma, Z., Wang, J., Xia, T, Gippel, C.J. and Speed, R. 2014. Hydrograph-based hydrologic alteration assessment and its application to the Yellow River. *Journal of Environmental Informatics* **23**(1): 1-13.

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Gippel, C.J., Bond, N.R., James, C. and Wang, X. 2009. An asset-based, holistic, environmental flows assessment approach. *Water Resources Development* **25**(2): 305-333.

Curriculum Vitae for Dr Rick van Dam

September 2021

Dr Rick van Dam

Independent aquatic ecosystem and water quality specialist

PROFILE

Rick has been continuously involved in applied science related to water quality and aquatic ecosystem protection since 1990. For much of this time he has worked at the interface of science and regulation.

Prior to working as an independent consultant, Rick was the Director of the Environmental Research Institute of the Supervising Scientist (ERISS), leading a multidisciplinary research program of over 25 staff with an annual operating budget of approximately $4 million.

Rick has an extensive background in applied research on the impacts and risks of contaminants to aquatic environments. He also has extensive knowledge and experience on inter/national guidance for the management and assessment of water quality (including the Aust/NZ Water Quality Guidelines)

Rick has an extensive network across multiple sectors, including the mining industry, government, and other scientists. He also brings 20 years of management and leadership experience.

CONTACT

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ABN

19 281 600 310

QUALIFICATIONS

Doctor of Philosophy (Aquatic Toxicology), 1992-1996
Royal Melbourne Institute of Technology (RMIT) University

BSc (Hons) (H1; Marine Ecology), 1986-1990
The University of Adelaide

RECENT CAREER

Independent environmental consultant (Sole Trader)
Sept 2018–present
Provision of independent advice, guidance, assessment, analysis and mediation on water quality management issues

ERISS, Department of the Environment & Energy (Darwin) - Director and Senior Principal Research Scientist
Nov 2012–May 2019
Lead the development and delivery of the ERISS research and biological monitoring program (including necessary stakeholder liaison);
Provide technical and scientific advice to the Department / Minister

Adjunct appointments
Adjunct Associate Professor of RMIT University
Honorary Fellow of Charles Darwin University

KEY EXPERTISE

- Ecotoxicology
- National water quality management framework
- Metals bioavailability and toxicity
- Development of toxicity test methods
- Issue conceptualisation
- Ecological risk assessment
- Derivation of water quality guideline values
- Risks/impacts of wastewater discharges (incl. saline waters)
- Evidence-based water quality regulation
- Multidisciplinary research

KEY PROJECTS (LED OR OVERSEEN)

Review panel Chair for technical review of the Port Curtis Integrated Monitoring Program (PCIMP)

Technical manager for the derivation of default water quality guideline values for toxicants for Australia and New Zealand

Development of water quality monitoring program for Snowy 2.0 Joint Venture construction team – construction phase

Guidance for selecting and evaluating approaches for deriving local water quality guideline values

Co-technical coordination for the 2018 revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Development of the Supervising Scientist's Key Knowledge Needs for the rehabilitation of Ranger uranium mine

Development of the Supervising Scientist's rehabilitation standards for the Ranger uranium mine

Assessment of assets and threats to Australia's tropical rivers (TRIAP)

KEY PEER-REVIEWED PUBLICATIONS

(>100 peer-reviewed publications and >100 conference presentations)

Fox DR, **van Dam RA**, Fisher R, Batley GE, Tillmans AR, Thorley J, Schwarz CJ, Spry DJ & McTavish K 2021. SSD modelling: recent developments and future directions. *Environmental Toxicology & Chemistry* 40(2), 293-308.

van Dam RA, Hogan AC, Harford AJ & Humphrey CL 2019. How specific is site-specific? A review and guidance for selecting and evaluating approaches for deriving local water quality benchmarks. *Integrated Environmental Assessment & Management* 15(5), 683-702.

Warne MStJ, Batley GE, **van Dam RA**, Chapman JC, Fox DR, Hickey CW & Stauber JL 2018. Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments. 48 pp.

Van Dam JW, Trenfield MA, Streten C, Harford AJ, Parry D & **van Dam RA** 2018. Water quality guideline values for aluminium, gallium and molybdenum in marine environments. *Environmental Science and Pollution Research* 25(26), 26592- 26602.

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van Dam RA, Humphrey CL, Harford AJ, Sinclair A, Jones DR, Davies S, Storey AW 2014. Site-specific water quality guidelines: 1. Derivation approaches based on physico-chemical, ecotoxicological and ecological data. *Environmental Science and Pollution Research* 21, 118-130.

van Dam RA, Harford AJ & Warne MStJ 2012. Time to get off the fence: The need for definitive international guidance on statistical analysis of ecotoxicity data. *Integrated Environmental Assessment and Management* 8(2), 242-245.

van Dam RA, Hogan AC, McCullough C, Houston M, Humphrey CL & Harford AJ 2010. Aquatic toxicity of magnesium sulfate, and the influence of calcium, in very low ionic concentration water. *Environmental Toxicology & Chemistry* 29(2), 410-421.

van Dam RA, Harford AJ, Houston MA, Hogan AC & Negri A 2008. Tropical marine toxicity testing in Australia: A review and recommendations *Australasian Journal of Ecotoxicology* 14(2/3), 55-88.

van Dam RA & Chapman JC 2001. Direct toxicity assessment (DTA) for water quality guidelines in Australia and New Zealand. *Australasian Journal of Ecotoxicology* 7(2), 175-198.

Appendix B Additional materials provided or accessed as part of the peer review

The following reports were provided by Sydney Water or accessed by the review panel to aid in completing the peer review.

ANZECC/ARMCANZ 2000. Australian and New Zealand guidelines for Fresh and Marine Water Quality. Paper No. 4 -National Water Quality Management Strategy. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia.

Birtles P, Hoban A, Tippler C, Shoo B, Davies P & Wright I 2015. Liveability and an urban creek: Perspectives and dreams of residents who are not yet. In *9th international water sensitive urban design (WSUD 2015)* (pp. 24-36). Engineers Australia.

Chessman B, Bate N, Gell PA & Newall P 2007. A diatom species index for bioassessment of Australian rivers. *Marine and Freshwater Research* 58, 542–557.

Chessman B, Growns I, Currey J & Plunkett-Cole 1999. Predicting diatom communities at the genus level for the rapid biological assessment of rivers. *Freshwater Biology* 41, 317–331.

Chessman BC & Townsend SA 2010. Differing effects of catchment land use on water chemistry explain contrasting behaviour of a diatom index in tropical northern and temperate southern Australia. *Ecological Indicators* 10, 620–626.

DPE 2019. Preparing a peer review report. Department of Planning and Environment, NSW Government, Sydney.

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Appendix C Engagement with other specialists

Table B1 Details of meetings with specialist consultants

Meeting date	Purpose of meeting / issues discussed	Attendees
1 May 2020	Project overview and draft waterway values for the Nepean and Warragamba Rivers: Project overview - Proposed waterway releases, including locations, quality and volumes - Overview of the proposed assessment approach - Need for and definition of waterway values - Draft values - Discussion - Next steps	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Hannah Lockie – Sydney Water Cathy O'Rourke – Sydney Water
13 May 2020	Discussion about draft waterway values, indicators and criteria for aquatic ecology	Rick van Dam Tony Church – Tony Church & Associates Cathy O'Rourke – Sydney Water
17 July 2020	Draft South Creek waterway values: - Proposed waterway releases to South Creek - Condition of South Creek - Sources of information - Presentation of draft values and discussion	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Hannah Lockie – Sydney Water Cathy O'Rourke – Sydney Water
21 August 2020	Proposed approach to assessing dry weather releases to South Creek: - Current condition of South Creek - Quality of dry weather releases and nutrient loads to waterways - Context for a dry weather release, including USIA work - USIA work undertaken to assess stormwater scenarios and findings - Proposed approach to assessment of dry weather release	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Hannah Lockie – Sydney Water Cathy O'Rourke – Sydney Water Alex Paton – Sydney Water

14 October 2020	Project update and draft waterway objectives:
	- Updated draft waterway objectives
	  o Summary of key changes and explanation of approach
	  o General discussion/feedback
	  o Next steps
	- Project update
	  o Hawkesbury Nepean model and scenario analysis
	  o Dry weather assessment
		Chris Gippel
		Rick van Dam
		Tony Church – Tony Church & Associates
		Elissa Howie – Sydney Water
		Cathy O'Rourke – Sydney Water

Meeting date	Purpose of meeting / issues discussed	Attendees
	○ Program	
15 December 2020	Site visit, including: - AWRC and South Creek - Nepean River near release location - Warragamba River near release location	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Dane Collins – GHD Simon Murphy – Sydney Water Cathy O'Rourke – Sydney Water
16 December	Waterways workshop with specialist consultants, including: - General project update - Specialist presentations, including assessment approach and results to date for: ○ Hydrodynamic and Water Quality ○ Ecohydraulic and Geomorphology ○ Aquatic Ecology and Riparian Ecosystems	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water Paul Dunne – Aurecon Arup Ed Beling – Intrawater Steve Clarke - Streamology Carl Tippler – CT Environmental
19 April 2021	Results of the micropollutant review: - Purpose of the review - Approach - Results for advanced and tertiary treated water - Discussion and feedback	Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water
31 May 2021	Water quality and hydrodynamics – presentation of results - Impact assessment results for South Creek and Nepean River - Preliminary CORMIX results	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water Paul Dunne – Aurecon Arup Steph Kermode – Sydney Water Ed Beling – Intrawater Matt Hipsey – University of Western Australia
31 May 2021	Ecohydraulic and geomorphology impact assessment – presentation of results: - Assessment overview and approach - Assessment results - Scenario modelling results - Summary of findings	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water Christine Arrowsmith - Streamology Geoff Vietz - Streamology
3 June 2021	Aquatic ecology and riparian impact assessment – presentation of results:	Chris Gippel Rick van Dam

Meeting date	Purpose of meeting / issues discussed	Attendees
	- Study overview - Key findings - Constraints and impact assessment - Early recommendations and mitigation	Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water Carl Tippler – CT Environmental Ben Green – CT Environmental Brad Cameron – CT Environmental
12 July 2021	Flow discrepancies at Wallacia Weir: - Explanation of the issue - Results from the sensitivity analysis - Implications to water quality and geomorphology studies - Proposed next steps	Chris Gippel Rick van Dam Tony Church – Tony Church & Associates Elissa Howie – Sydney Water Cathy O'Rourke – Sydney Water Paul Dunne – Aurecon Arup Ed Beling - Intrawater Christine Arrowsmith - Streamology Geoff Vietz - Streamology
29 September 2021	Discussion on comment #60 on Aquatic ecology report from van Dam – justification for conclusions on ecological impact	Rick van Dam Elissa Howie – Sydney Water Carl Tippler – CT Environmental