Surface Water (and Aquatic Ecology) Monitoring Program

Googong Township Integrated Water Cycle Project

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Terms and Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BACI	Before-After-Control-Impact
BOD	Biochemical oxygen demand
CoA	Condition of Approval
DSEWPAC	Department of Sustainability, Environment, Water, Population and Communities
EPA	Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GTPL	Googong Township Proprietary Limited
IWC	Integrated water cycle
LOR	Limit of reporting/detection
MDS	Multidimensional Scalding
NATA	National Association of Testing Authorities
NO_X	Oxides of nitrogen
NOW	NSW Office of Water
NSW	New South Wales
O/E	Observed/expected
Operator	GTPL (during process commissioning and verification) or QCC (during ongoing operation)
QCC	Queanbeyan City Council
PMST	Protected Matters Search Tool
Program	Surface Water (and Aquatic Ecology) Monitoring Program
SoC	Statement of Commitments
SS	Suspended solids
SWAEMP	Surface Water (and Aquatic Ecology) Monitoring Program
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorous
WMP	Water Management Plan
WRP	Water Recycling Plant

A1 Purpose

The Surface Water (and Aquatic Ecology) Monitoring Program (SWAEMP, or the 'Program') has been prepared to satisfy Condition of Approval (CoA) D8 (a) for Stage 1 of the Googong Township Integrated Water Cycle (IWC) Project with interfaces to the other sub-plans of the Water Management Plan (WMP). This Program has been prepared to satisfy the CoAs and Statement of Commitments (SoCs) for Stage 1 of the IWC Project as identified in Table 1 and Table 2 respectively.

Table 1 Conditions of Approval

<table>
<tr><th>CoA No.</th><th>Condition requirements</th><th>Document reference</th></tr>
<tr><td>D5</td><td>The recycled water discharged to the environment shall not exceed the water quality parameters identified in Table D1 below.

Table D1: Effluent Quality Limits
<table>
<tr><th rowspan="2">Parameter</th><th colspan="2">Effluent discharge limits to environment</th></tr>
<tr><th>Units</th><th>90th Percentile</th></tr>
<tr><td>BOD</td><td>mg/L</td><td>10</td></tr>
<tr><td>Suspended Solids</td><td>mg/L</td><td>10</td></tr>
<tr><td>TN</td><td>mg/L</td><td>10</td></tr>
<tr><td>TP</td><td>mg/L</td><td>0.5</td></tr>
<tr><td>TDS</td><td>mg/L</td><td>700</td></tr>
<tr><td>Faecal Coliforms</td><td>cfu/100mL</td><td>150</td></tr>
<tr><td>pH</td><td></td><td>6.5-8.0</td></tr>
<tr><td>Free Chlorine (residual)</td><td>mg/L</td><td>0.1</td></tr>
<tr><td>Nitrogen – Ammonia</td><td>mg/L</td><td>2</td></tr>
<tr><td>Oil & Grease</td><td>mg/L</td><td>2</td></tr>
</table>
If the results of the water quality monitoring undertaken in accordance with the Water Management Plan in condition D8 indicates that the downstream ambient water quality criteria of the Queanbeyan River is exceeded as a result of the project, then the project shall be adjusted to reduce the concentration of the relevant parameters in the recycled water discharged to the environment.</td><td>This Program and WMP Appendix B

Also refer to OEMPs</td></tr>
<tr><td>D6</td><td>No recycled water shall be discharged to the environment until at least 12 months of baseline data for the receiving waterways has been obtained and the flow release protocol has been established, in accordance with the approved Water Management Plan in condition D8.</td><td>This Program, WMP Appendices B and E outline the methodology for baseline data collection.</td></tr>
<tr><td>D8</td><td>1. a Surface Water Monitoring Program, including:</td><td>This Program</td></tr>
<tr><td></td><td>A. procedures to obtain detailed baseline data on surface water flows and quality in creeks and other water bodies that could potentially be affected by the project, including relevant parameters and monitoring locations;</td><td>Section A2.1</td></tr>
<tr><td></td><td>B. surface water and stream health impact assessment criteria including trigger levels for investigating any potentially adverse surface water impacts and for the supply of compensatory water;</td><td>Section A3</td></tr>
<tr><td></td><td>C. a program to monitor and assess:
(a) surface water flows and quality;
(b) impacts on water users;
(c) stream health and habitat; and
(d) channel stability.</td><td>Section A4</td></tr>
</table>

Table 2 Statement of Commitments relevant to water management

Objective	Ref. No.	Commitment	Document reference
Ensure comprehensive monitoring of operation of the water cycle	OP1	Establishment and location details for monitoring sites will be in accordance with WQ4. Results of all monitoring programs that form part of these Statement of Commitments will be considered in terms of overall environmental impact on a regular basis, including: ▪ The trade-off between potable water savings, reduction in stormwater discharges and increased recycled water discharges. ▪ Relative impacts of excess recycled water discharges compared to impacts on soil and groundwater from recycled water uses. ▪ The timeframe for relative comparisons of impacts components of the water cycle will be determined in consultation with the relevant government agencies. ▪ The ability to feedback results for further stages of Googong township.	Section A2.1
Adaptive management	OP3	Management plans will be reviewed with consideration of the outcomes of monitoring programs: ▪ Additional management and mitigation measures will be implemented, should monitoring identify that the water cycle systems is operating outside of modelled or expected parameters.	WMP Section 7 and Section A4
Monitor impacts on waterways	WQ4	A monitoring program to assess the potential impacts of the Project on the Queanbeyan River (including water quality, flow, fish migration, macrophytes and macro invertebrate communities) will be undertaken. ▪ Details of the monitoring program will be determined in consultation with relevant government authorities/stakeholders (including the OEH, DPI and potentially Icon Water). Such consultation will ensure the sharing of available data for the Queanbeyan River for comparative and impacts assessment purposes. ▪ A new monitoring site within the Queanbeyan River is proposed to measure water quality and aquatic ecology impacts over the medium term. This site will be located near the confluence of Googong Creek and Queanbeyan River (and will be sited to enable comparison with data collected from upstream and downstream sites). ▪ Monitoring will commence approximately 12 months prior to commissioning the water recycling plant.	This Program
	WQ5	The operation environmental management plan (OEMP) will outline erosion and sediment control measures to protect buffer and riparian vegetation zones, in general in accordance with Statement Of Commitment WQ3.	Not relevant to this plan. Refer to OEMPs.

A2 Baseline Monitoring

Baseline surface water and aquatic ecology monitoring was completed by Sentinel and Hydrobiology from November 2013 to December 2014 (Hydrobiology 2015). Construction activity was occurring within the Googong Township throughout the baseline monitoring period. This activity related to both the IWC Project and residential development works.

A2.1 Monitoring methodology

A2.1.1 Program rationale

The ANZECC (Australian and New Zealand Environment and Conservation Council) and ARMCANZ (Agriculture and Resource Management Council of Australia and New Zealand) (2000) guidelines for freshwater and marine water quality provide a scientifically robust and recognised method of achieving the aims of the monitoring plan as stated in the CoA and the SoCs (Section A.1). To formulate an appropriate monitoring plan for the IWC Project, recognition of the uniqueness of the Queanbeyan River between the Googong Reservoir and the Molonglo River and its specific values has been considered. This recognition is fundamental to the establishment of a reference condition, trigger values, site selection and selection of biological indicators.

The IWC Project area is located between the Googong Reservoir and the township of Queanbeyan, and represents an upland riverine system influenced by anthropogenic modifications of the area, water regulation and occasional discharges from the existing Googong Water Treatment Plant and spill overflow from the Googong Dam. Consideration of these influences is integral, as detected change from the findings of this monitoring program need to be distinguishable from current impacts of uses of the Queanbeyan River.

A Before-After-Control-Impact (BACI) monitoring program has been implemented with the aim of assessing the present condition (before) prior to potential impacts associated with the operation of the water recycling plant (WRP). Nine sites have been assessed as part of the BACI design, which have been monitored for at least 12 months prior to the commencement of operation of the WRP.

A2.1.2 Site selection

Based on a preliminary investigation of available aerial imagery, surface hydrology and existing forms of disturbance in the Queanbeyan River, nine monitoring sites were selected for baseline assessment (refer to Figure 1 and Table 3 for further details regarding the site locations, site descriptions and rationale):

- Three sites (Sites 1, 2 and 3) upstream of the excess recycled water point of discharge into the Queanbeyan River (control). While difficult to see at the scale of the map, it is confirmed that Site 1 (refer Figure 1) is located upstream of the confluence with the Queanbeyan River and Montgomery Creek. The control sites are needed to assess the background water quality to ensure that the impact sites are assessed correctly.
- One site (Site 4) at the point of discharge into the Queanbeyan River (impact).
- One site (Site 5) at a tributary flowing to the Queanbeyan River and upstream of Wickerslack Lane. This monitoring site drains from a different catchment to the early stages of the Googong Township and so will help to provide information on the water quality of the river, not influenced by stormwater runoff (control).
- Two sites (Sites 6 and 7) downstream of the point of discharge into the Queanbeyan River (impact).

- Two sites (Site 8 and Site 9) located along Googong Creek and Montgomery Creek to assess the impact of the discharge of excess recycled water and emergency discharges respectively (impact).

Site 1 (QBN 704) is an existing water quality and macroinvertebrate monitoring sites assessed by Icon Water as part of their license requirements for the Googong Dam operation. A new site near the existing site will be sampled as part of this monitoring program.

The replication of control and impact sites allows for more accurate detection of possible impacts, as a singular control site upstream and a singular impact site downstream incorrectly assumes that both sites will always present the same results without impacts.

A2.1.3 Frequency

The nine sites were surveyed at least quarterly for 12 months prior to the operation of the WRP. A breakdown of the monitoring frequency for baseline is provided below:

- Continuous: Water monitoring stations were established close to sampling Sites 1 and 5. They have continually monitored conductivity and pH every 15 minutes from November 2013.
- Monthly: Diatoms and surface water quality (including total nitrogen, oxides of nitrogen, ammonia, total phosphorus, microbiological faecal coliforms, total algae, cyanobacteria, biochemical oxygen demand (BOD), suspended solids, total dissolved solids, free chlorine and oil and grease).
- Quarterly: Habitat (including macrophytes) and fish.

Sites eight and nine within Googong and Montgomery Creeks respectively were ephemeral during the baseline monitoring period but were monitored where stream flow made it possible throughout this period.

At each site two macroinvertebrate samples from each habitat type (edge and riffle) were collected on three occasions in Spring/Autumn during baseline.

A2.1.4 Controlled Activity Approval

Projects approved under the now repealed Part 3A of *Environmental Planning and Assessment Act 1979* are exempt from requiring controlled activity approvals under Chapter, Part 3 of the *Water Management Act 2000* for works in a waterway (i.e. installing continuous water monitoring stations).

However while the Environmental Assessment prepared for the IWC Project committed to water monitoring it provided no detail on the methodology or locations of the monitoring stations to be installed. As such, it was considered necessary to obtain approval from the NSW Office of Water (NOW) so that the appropriate environmental consideration is given to this activity as it involves some minor trenching.

Googong Township Proprietary Limited (GTPL) obtained a controlled activity approval from NOW on 24 February 2014 to install two continuous water-monitoring stations at Sites 1 and 5 (Approval no. 40 ERM2014/0097). These monitoring stations were subsequently installed following the approval.

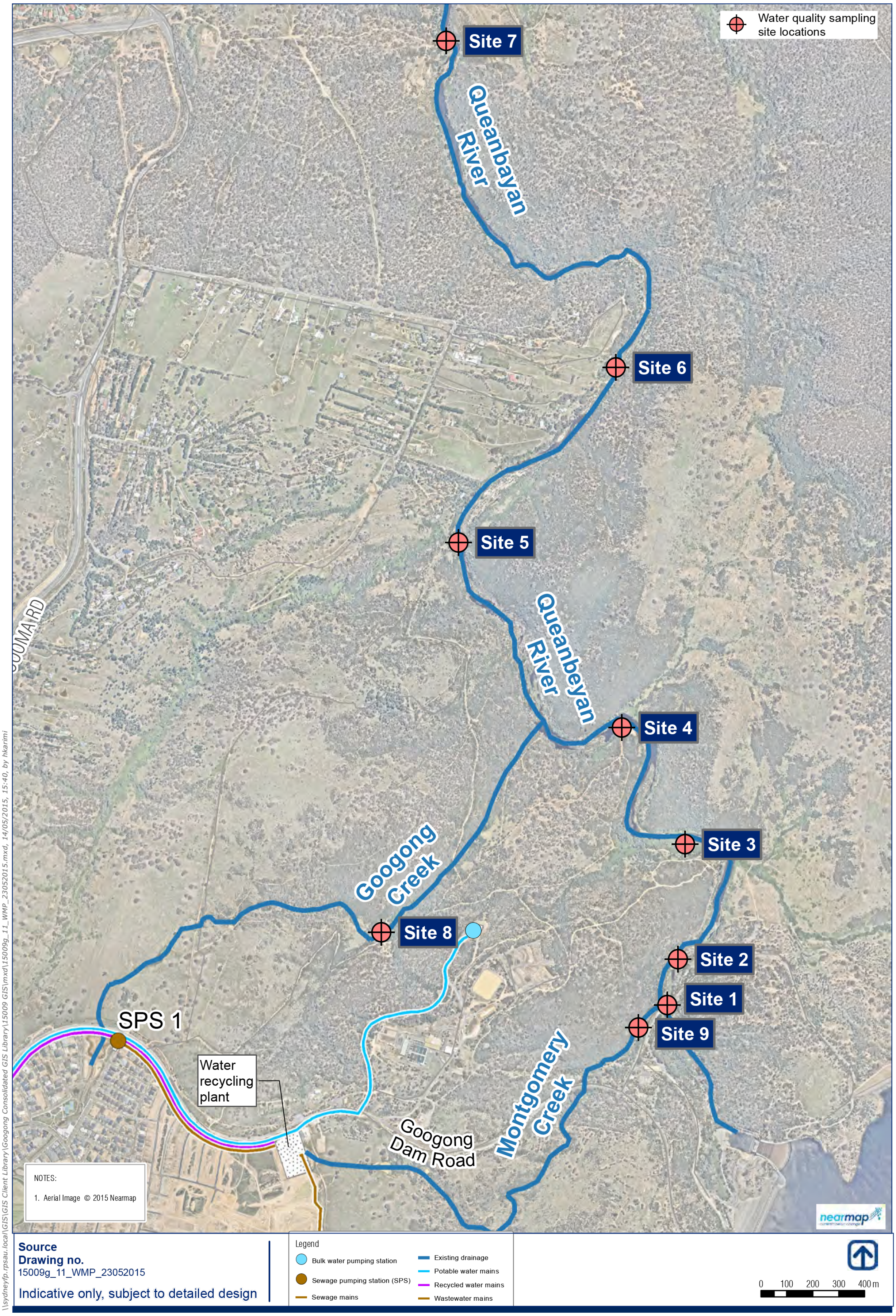

Figure 1 Water quality and aquatic ecology survey baseline monitoring site locations

Table 3 Baseline monitoring sites for water quality and aquatic ecology for the IWC Project

Site Number	Site Description	Monitoring Assessment	Rationale
1	Queanbeyan River - In the vicinity of existing site (QBN704) immediately upstream of the confluence of the Queanbeyan River and Montgomery Creek.	Habitat, water quality, diatoms, macroinvertebrate and fish. Continuous water monitoring station.	Complete assessment upstream of the Montgomery Creek and Queanbeyan River confluence, outside the future influence of the IWC Project.
2	Queanbeyan River - Immediately downstream of Googong Dam Road.	Habitat, water quality, diatoms, macroinvertebrate and fish.	Complete assessment downstream of the Montgomery Creek and Queanbeyan River confluence to provide information on upstream conditions independent of excess recycled water discharges, and may help to demonstrate changes attributable to emergency discharges into Queanbeyan River.
3	Queanbeyan River - Approximately 1 km downstream of Googong Dam Road.	Habitat, water quality, diatoms, macroinvertebrate and fish.	As above.
4	Queanbeyan River - Upstream of confluence of Googong Creek and Queanbeyan River.	Habitat, water quality, diatoms, macroinvertebrate and fish.	As above.
5	Queanbeyan River - About 300 m upstream of the existing site (QBN703) at a tributary flowing to Queanbeyan River, upstream of Wickerslack Lane residences.	Habitat, water quality, diatoms, macroinvertebrate and fish. Continuous water monitoring station.	This site receives flows draining from a different catchment to the early stages of the Googong Township and so will help to provide information on the water quality of the river, not influenced by stormwater runoff.
6	Queanbeyan River - Approximately 1 km downstream of Wickerslack Lane residences.	Habitat, water quality, diatoms, macroinvertebrate and fish.	Complete assessment of downstream parameters and conditions, and may help to demonstrate changes attributable to discharges into Queanbeyan River from both discharges (excess and recycled).
7	Queanbeyan River - Approximately 2 km downstream of Wickerslack Lane residences.	Habitat, water quality, diatoms, macroinvertebrate and fish.	As above.
8	Googong Creek upstream of the Queanbeyan River confluence.	Habitat, water quality, diatoms, macroinvertebrate and fish (where possible).	Downstream of the recycled water discharge point for the IWC Project before flows enter Queanbeyan River. This site will provide information on existing conditions, and in future may help to demonstrate changes attributable to excess recycled water discharges, independent of other catchments and flows.

Site Number	Site Description	Monitoring Assessment	Rationale
9	Montgomery Creek upstream of the Queanbeyan River confluence.	Habitat, water quality, diatoms, macroinvertebrate and fish (where possible).	Downstream of the emergency discharge point for the IWC Project before flows enter Queanbeyan River. This site will provide information on existing conditions, and in future may help to demonstrate changes attributable to emergency discharges, independent of other catchments and flows.

A2.1.5 Survey methods

The monitoring methods described in this section are in accordance with the requirements of relevant guidelines (e.g. ANZECC and ARMCANZ 2000; Scott *et al.* 2002; DSEWPaC 2011; Nichol *et al.* 2000; and EPA 2004), CoAs and SoCs for the IWC Project and seek to maintain consistency with and utilise previous data collected by Ecowise Environmental (2008).

Water quality sampling

Water quality sampling was undertaken monthly at all nine sites, where possible. Samples were taken by experienced staff and in accordance with the national water quality management guidelines (ANZECC and ARMCANZ 2000). For monthly water quality sampling the following methodology was applied:

- Selection of a representative sampling point at each location that considered a thorough mixing of water, was at a consistent depth and considered seasonal effects.
- Qualified staff manually took ‘Grab Samples’, which included taking a discrete sample by placing the required apparatus into the stream at a consistent location. Required apparatus included:
  - Wide mouth container with long length of rope
  - Sampling stick with container holder
  - Automatic sampler - Sigma or equivalent
  - Portable pH unit with calibration solutions
  - Colour comparator or chlorometre for chlorine analysis
  - Thermometer (-10 – 110°C, 1°C increments)
  - Portable Dissolved Oxygen Metre and Probe
  - Portable Conductivity Metre
  - Portable Turbidity Metre.
- Preservation of samples using appropriate bottles, preservatives and storage methods.
- Visual observations were made and digital photos were taken at the time of sampling and recorded in the Field Record Log.
- Samples were collected for laboratory-based analysis at a National Association of Testing Authorities (NATA) accredited facility.

Continuous monitoring was undertaken at site 1 and site 5, every 15 minutes from November 2013 to monitor conductivity and pH levels. Continuous samples involved setting up an autosampler (an INW Water Quality Sonde and a Campbell Scientific CR800) to take samples at a fixed period that are recorded.

All water quality measurements were made in accordance with *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (EPA 2004). Water quality parameter values have been assessed against the *National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000).

Macroinvertebrate monitoring

Macroinvertebrate monitoring and sampling was undertaken on three separate occasions during Spring and Autumn (September 2013, March 2014 and September 2014). Samples were collected generally in accordance with *Australian River Assessment System* (AusRivas) *Sampling and Processing Manual* (Nichol *et al*. 2000). The sites were sampled using 250 micron mesh dip nets. Complete samples were preserved in 70 per cent ethanol.

A single 10 metre sweep (edge) and a single 10 metre kick (riffle) sample was collected at each site, water levels permitting, per sampling event. Water levels did not permit samples to be taken at all sites for all events, therefore sites that were not sampled include:

- Spring 2013: sites 3, 4, 8 and 9 both habitats
- Autumn 2014: site 9 both habitats, and edge habitat at site 8
- Spring 2014: edge habitat at site 8.

Some variations to the methods described in the AusRivas manual (Nichol *et al*. 2000) were employed during the sampling process including:

- Water samples were not collected concurrent with sampling – water quality data was sourced from the monthly water quality sampling program.
- Sample processing involved a 'total count' of all picked taxa during the course of 30 minutes, with subsequent 10 minute blocks (up to a maximum of 60 minutes) if additional taxa were observed.

Diatoms

At each monthly monitoring event, one composite diatom sample was collected at each site. Each sample consisted of three surface (biofilm) sediment scrapes from depositional microhabitats (e.g. backwaters, downstream side of rocks where organic sediment accumulates). Each biofilm scrape was obtained using a small spoon (volume 0.5 millilitre), and then placed in an eight millilitre plastic vial with one per cent Lugol solution added as a preservative. Laboratory analysis of samples included processing and diatom identification to species level.

Habitat assessment

Habitat assessments were undertaken as part of the quarterly monitoring totalling six sampling events (September 2013, December 2013, March 2014, June 2014, September 2014 and December 2014). This included recording any observed macrophytes and general habitat characteristics within and immediately adjacent to each site. Habitat characteristics were recorded using the AusRivas field sheets for macroinvertebrates (NSW/ACT: Sloane *et al.* 2000). Any notable site characteristic and features were recorded and accompanied by photos. A brief site summary was compiled recording features including general habitat characteristics and features both within and immediately adjacent to the water, water width, riparian coverage, substrate coverage, shading and in-stream habitat features.

Fish survey

Fish surveys were conducted quarterly throughout the sampling period, totalling six sampling events (September 2013, December 2013, March 2014, June 2014, September 2014 and December 2014). The surveys were conducted by appropriately skilled and experienced personnel in accordance with the Guidelines for detecting fish listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (DSEWPaC 2011). The surveys aimed to document the fish and decapod crustacean communities occurring within the subject area and downstream. Note that survey of downstream habitats is a requirement of the *Guidelines for detecting fish listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999* (DSEWPaC 2011) and *Matters of National Environmental Significance – Significant Impact Guidelines 1.1* (DEWHA 2009). All surveys were conducted in accordance with Fisheries, FFG and Animal Ethics permits and approvals. All electrofishing adhered to the training and OH&S requirements of the *Australian Code of Electrofishing Practice* (NSW Fisheries 1997).

Fish surveys were undertaken to document the fish and decapod crustacean community assemblages of the subject area. In line with the monitoring program requirements, a number of fish sampling methods were undertaken at each site sampling event. These included:

- Electrofishing – This was carried out with a Smith-Root backpack electrofisher. It consists of a portable unit and power source, equipped with a hand held anode and a cathode, which is left trailing in the water. The operator wears the unit and uses the magnetic switch to activate the anode in order to stun the fish. The operator travels upstream, to minimise disturbance to fish prior to sampling. Sampling targets structural habitat and each site was sampled for a standard 'on time' of 400 seconds. All captured specimens are transferred into an aerated bucket of water for identification before being returned to the water.
- Fyke netting – Fyke nets are nets that act as a funnel to trap swimming fish, and are used as a non-invasive method to target medium to large fish in shallow water habitats. Two fyke nets were set overnight (dusk to dawn) at each site where suitable habitat was identified. Upon retrieval, the captured fish were transferred into a bucket of water for identification and counting before being released at the site.
- Collapsible bait traps – Four collapsible bait traps were set at each site, baited with cat biscuits and set in backwaters, snags and bank overhangs from dawn to dusk. When retrieved, captured specimens were identified, counted and returned to the water.

A2.1.6 Data analysis

The SWAEMP has been prepared according to current best practice in relevant survey guidelines and the current scientific literature. The Program aims to:

- Establish a robust data set to enable reliable conclusions to be made according to potential implications resulting from the IWC Project.
- Determine changes in the water quality, aquatic habitat and the diversity and abundance of aquatic fauna and flora using a BACI design.

The following processes/methods were considered as part of data analysis:

- Uni-variate statistics.
- Macroinvertebrate analysis with AusRivas statistical software.
- Fish cohort analysis.
- Multivariate statistics.

Water quality analysis

The baseline samples were analysed at a NATA-accredited laboratory (ALS Environmental, Fyshwick) for the following parameters:

- Total nitrogen.
- Oxides of nitrogen.
- Ammonia.
- Total phosphorus.
- Microbiological faecal coliforms.
- Total algae.
- Cyanobacteria.
- Biochemical oxygen demand (BOD).
- Suspended solids.
- Total dissolved solids.
- Free chlorine.
- Oil and grease.

Data were analysed to identify any key changes in water quality over time. Indicators were compared to the interim trigger levels, as detailed in Section A3.2.

Macroinvertebrate monitoring

Data was analysed to identify any temporal trends in macroinvertebrate communities at each site. The following approach was undertaken:

- Calculation of diversity indices (relative and total abundance, richness, Shannon diversity).
- SIGNAL 2 scores in accordance with the procedures described in Chessman (2003).
- AusRivas grading using the predictive modelling software (v3.2.0, ausrivas.ewater.com.au). Grading for autumn riffle samples were modified to adopt the Icon Water monitoring program ratings (which only apply to Autumn riffle samples).
- Multivariate analysis using Multidimensional Scaling ordinations to visualise similarity between sample communities, and permutation tests (ANOSIM2) to identify any significant difference in macroinvertebrate communities identified to Family/sub Family, and aggregated to the Order.

Diatoms

Analysis of diatom data focussed on identifying temporal and seasonal trends in diatom community compositions at each site. This was achieved by:

- Calculation of diversity indices (total abundance, richness, Shannon diversity).
- Assigning and tabulating total abundance and richness data for species known habitat preferences (habitat type, trophic level, mortality level, pH, nitrogen and oxygen tolerance) (Spaulding *et al.* 2010 and Van Dam *et al.* 1994).
- Multivariate analysis using Multidimensional Scalding (MDS) ordinations to visualise similarities between sample communities and permutation tests (ANOSIM2, Clarke & Warwick 2001) to identify any significant differences in diatom communities.

Habitat assessment

Analysis of the observed macrophytes and habitat present at each site was undertaken to document any changes to habitat due to environmental or seasonal changes. Observations were made as to why these changes may have occurred and how this might influence the environment at the site.

Fish survey

Fish data were analysed to document the fish and crustacean community assemblages and to highlight the presence of any species of key ecological importance within the study area. Focus was also placed on highlighting seasonal trends in fish populations using data standardisation to catch per unit effort.

A2.2 Results

A2.2.1 Habitat

The natural state of the Queanbeyan River has been altered by the Googong Reservoir, which has disrupted the natural flow regime, and by the surrounding agricultural land uses that have impacted water quality.

Nine surface water sampling sites were sampled as part of the ongoing monitoring program (refer to Figure 1). Seven of the sites (Sites 1-7) are located on Queanbeyan River, one is located on Googong Creek (Site 8) and one is located on Montgomery Creek (Site 9).

A summary of the habitat for the nine surface water sampling sites is provided in Table 4.

Table 4 Existing habitat at surface water sampling sites

Site	Location	Stream width	Habitat description
1	Queanbeyan River – approximately 600 m downstream of the Googong reservoir/dam wall and just upstream of Montgomery Creek confluence.	14 m	Vegetation mainly consists of macrophytes providing limited canopy cover. In-stream habitat consists largely of cobbles, pebbles, and some boulders.
2	Queanbeyan River – approximately 800 m downstream of the Googong reservoir/dam wall.	Not specified	Habitat is similar to Site 1 in that macrophytes are the main vegetation in the reach and there is limited shading.

Site	Location	Stream width	Habitat description
3	Queanbeyan River – approximately 1.5 km downstream of the Googong reservoir/dam wall. Located at an old causeway, now detached from the bank.	Varies from 3 to 12m in sections of the reach.	Vegetation consists of a smaller number of macrophytes than upstream sites. In-stream habitat consists largely of sand-clay (40%) at the outer edges of the reach and cobbles in the centre of the wetted width (55%).
4	Queanbeyan River – approximately 2.25 km downstream of the Googong reservoir/dam wall.	Not specified	The upper and lower ends of the reach are separated by a large pool. The upstream end of the reach consists of 100% sand substrate with native forest on one side of the bank. The downstream end of the reach consists of mainly boulders (80%) and cobbles (15%) with thick native forest on both sides of the bank providing approximately 40% shading.
5	Queanbeyan River – downstream of the confluence of Googong Creek.	15 m	There is native forest on one side of the bank and cleared grassland with 5% trees on the other side. In-stream habitat consists of mainly cobbles and boulders.
6	Queanbeyan River – approximately 970 m downstream of Site 5. It is located on private property.	Not specified	One side of the bank consists of cobbles with vegetation set behind this. The other consists of small shady areas/macrophytes and some overhanging native vegetation. In-stream habitat consists largely of cobbles with some boulders and pebbles.
7	Queanbeyan River – approximately 6.5 km downstream of the Googong reservoir/dam wall.	12 m	Banks are predominantly covered with grass, riparian vegetation (mainly one side of the bank) or bare. Overhanging vegetation is 10% with 20% shading. In-stream habitat consists of mainly sand with areas of large boulders and cobbles.
8	Googong Creek – upstream of the Queanbeyan River confluence.	Ephemeral system – regularly dry. When the site did have flow, the stream width is ~1 m.	Riparian vegetation mostly consists of grass and *Rubus fruticosus* (Blackberry). In-stream habitat consists of cobbles, boulders and a small amount of sediment.
9	Montgomery Creek – upstream of the Queanbeyan River confluence.	Ephemeral system – regularly dry. When the site did have flow, the stream width is ~2 m.	Riparian vegetation mostly consists of grass and *Rubus fruticosus* (Blackberry). In-stream habitat consists of large boulders and cobbles.

A physical habitat assessment of Googong Creek by Ecowise Environmental (*Wastewater Treatment and Reuse Scheme – Preliminary Assessment*, Ecowise 2008) revealed that the creek's most upstream section gently slopes to a previously constructed farm dam, which has a reasonably intact earthen bund. The landscape abutting these upstream sections of the creek continues to gently slope within the first 300 m of the creek, before the creek narrows into a series of sharply winding gullies, which head down to the river.

At the time of inspection by Ecowise Environmental (April 2008), the entire length of the creek was dry. Given the steep gradient in the creek, from the top most section at the Googong Dam Road down to the Queanbeyan River, flows in the creek during wet weather could be expected to be fast. The formation of deeply incised channel and gullies along the length supports this conclusion.

Whilst there are a small number of native trees, the majority of the vegetation in the area is degraded grassland. In the long, middle gully sections of the creek, there are stretches of varying length, which are moderately weed infested. Many areas have dense growth of various native scrub.

Human caused disturbances, such as construction of access tracks, movement of vehicles and dumping of litter and rubbish appear to be having ongoing impacts on the area. There are areas where litter and rubbish has been dumped in sections associated with the creek, as well as on the upper riparian areas.

The understorey native vegetation in the middle sections of the terrain is dominated by Burgan (*Kunzea ericoides*), which overhangs the creek bed in many stretches.

The downstream vegetation of the creek varies from relatively undisturbed native bushland and vegetation communities to well-maintained access tracks in the lower-middle section of the creek.

The topography in the area is variable, with steep gullies and evidence of erosion in some areas and gentle slopes and flat ground in others. Those areas experiencing erosion may require stabilisation and fortification by rock batter if monitoring identifies that such measures are required.

A2.2.2 Existing surface water quality

Water quality information (75th percentile concentrations) for the nine surface water sampling sites is provided in Table 5 for the initial baseline monitoring period between November 2013 and December 2014. **Bold** font indicates results that are above or outside the range of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) guideline trigger values.

Table 5 Summary of 75th percentile concentrations of water quality parameters recorded at each surface water sampling site

	Laboratory limit of reporting	ANZECC 2000*	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Total nitrogen (mg/L)		<0.25	**0.58**	**0.56**	**0.54**	**0.55**	**0.53**	**0.54**	**0.55**	**2.52**	**0.52**
Oxides of nitrogen (mg/L)	<0.05	<0.015	**0.11****	**0.1****	**0.1****	**0.09****	**0.1****	**0.09****	**0.08****	**0.6****	**0.05****
Ammonia (mg/L)	<0.1	<2.0	na***	na***	na***	na***	na***	na***	na***	na***	na***
Total phosphorus (mg/L)	<0.01	<0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	**0.035**	0.02
Microbiological faecal coliforms (cfu/100m)	<1 and <2	<150	37	38	50	61	103	57.5	76	68.25	12
Cyanobacteria (cells/mL)	<1	<15,000	914.5	474.5	803.5	1795	1485	1560	1245	40	1
Total Algae (cells/mL)		<15,000	2090	1565	2280	3805	3035	2805	2830	750.25	121
Biochemical Oxygen Demand (mg/L)	<2	<10	2	2	2	2	2	2	2	2	2
Suspended Solids (mg/L)	<2	<10	4	3	2	5	4	4	5.75	**16.5**	2.75
Total Dissolved Solids (mg/L)		<700	93.75	90	99	91	119	110.25	102	445.5	243.75
Free chlorine (mg/L)	<0.03	<0.1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Oil and grease (mg/L)	<1	<2	1	1	1	1	1	1	1	1	1

** ANZECC (2000) trigger values for Upland Rivers >150m elevation in south-eastern Australia.*

*** Laboratory limit of reporting/detection (LOR) was greater than the default trigger level.*

**** 'na' indicates that a 75th percentile was unable to be generated as parameter was rarely detected. The LOR (<0.1 mg/L) is much lower than the trigger level.*

The results of the initial baseline monitoring period are summarised as follows:

- The 75th percentile and median concentrations of total nitrogen was above the ANZECC (2000) trigger level at all sites.
- The 75th percentile of oxides of nitrogen (NOx) was above the ANZECC (2000) trigger level at all sites, however it should be noted that the laboratory limit of reporting/detection (LOR) for NOx is higher than this trigger level. This LOR will be decreased in future sampling events.
- Ammonia was only detected on four occasions (out of 108 samples), however the laboratory limit of reporting/detection (LOR) for ammonia (<0.1 mg/L) is much lower than the ANZECC (2000) trigger level (2 mg/L).
- The median concentration of total phosphorous (TP) was below the ANZECC (2000) trigger level at all sites. The 75th percentile concentrations of TP were also below this trigger level, with the exception of Site 8 (Googong Creek). Individual sample exceedances were also recorded at all sites, aside from Site 5.
- The 75th percentile for total number of microbiological faecal coliforms found in the water samples was lower than the ANZECC (2000) trigger level at all sites, with individual samples higher than this level occurring at sites 1, 2, 4, 5, 6 and 8.
- All readings of cyanobacteria, total algae and total dissolved solids (TDS) were below the ANZECC (2000) trigger level at all the sites.
- Sites 5, 6 and 7 (Queanbeyan River) had elevated levels of biochemical oxygen demand (BOD) in December 2014. All other readings of BOD and the 75th percentile concentrations were below the ANZECC (2000) trigger level.
- The median concentration of suspended solids (SS) was below the ANZECC (2000) trigger level at all sites. The 75th percentile concentrations of SS were also below this trigger level, with the exception of Site 8 (Googong Creek). Individual sample exceedances were also recorded at sites 4, 5, 6, 7 and 9.
- Free chlorine levels at sites 5, 6 and 7 (Queanbeyan River) were elevated in September and December 2013. All readings of free chlorine were below the ANZECC (2000) trigger level, with the exception of individual sample exceedances at sites 5 and 6.
- oil and grease was typically undetected (<1 mg/L), with two isolated records of 1 mg/L that fall below the ANZECC (2000) trigger level. All 75th percentile concentrations were below the ANZECC (2000) trigger level.
- There was a peak in total nitrogen, oxides of nitrogen, ammonia, TDS and total phosphorus at Site 8 (Googong Creek) in April 2014. Within two months, all of these parameters had reduced to a level comparable to all other sites.

Figure 2 displays the pH and conductivity output of the two continuous monitoring stations, located along Queanbeyan River close to sites 1 (upstream) and 5 (downstream). It shows that:

- pH levels fluctuated year-round with a slow decrease in alkalinity over time.
- Electrical conductivity at both monitoring stations remained well below the trigger value throughout sampling.

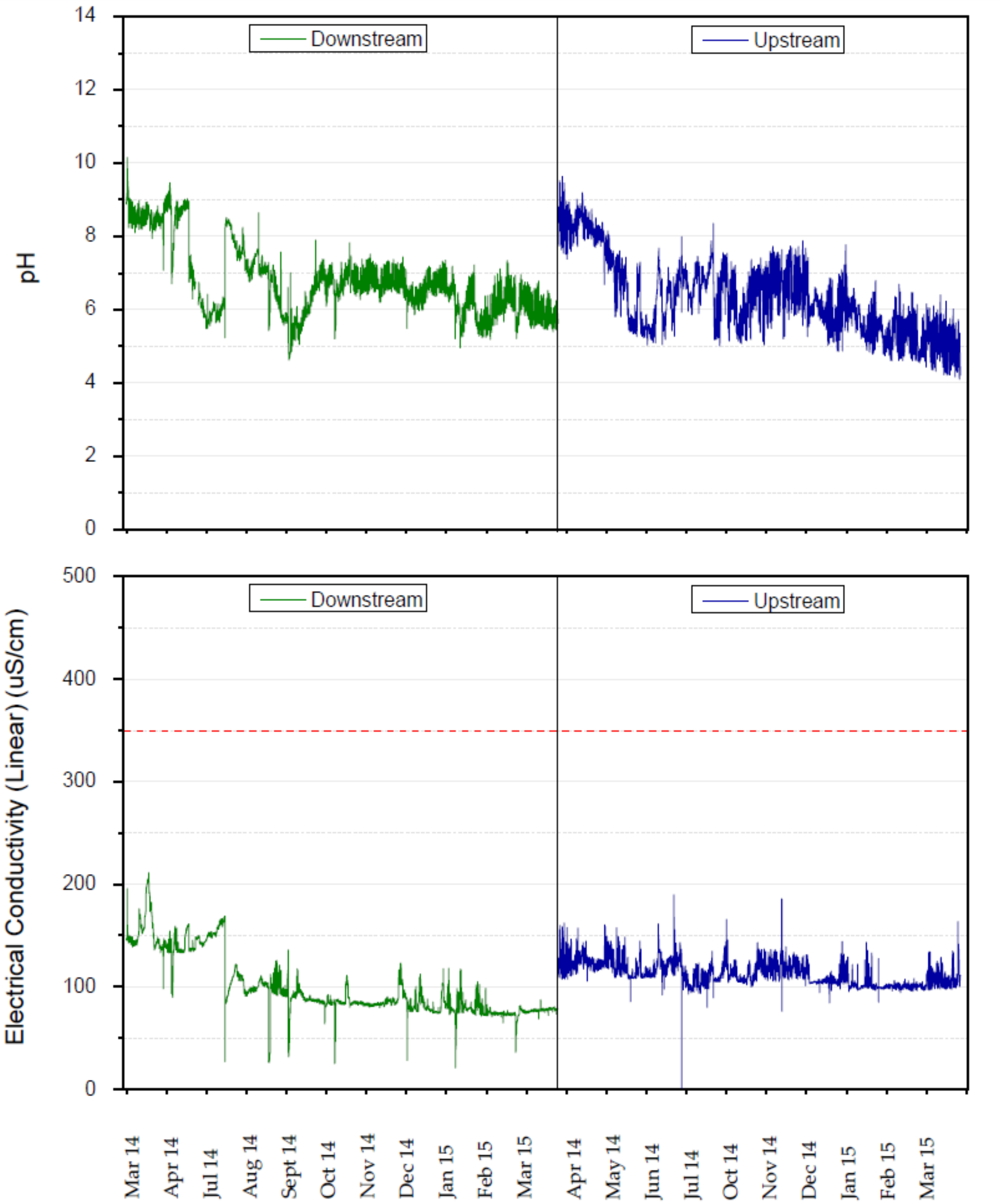

Figure 2 Conductivity and pH of the Queanbeyan River at continuous monitoring stations close to sites 1 (upstream) and 5 (downstream). Note: dashed red lines represent the ANZECC (2000) trigger values (Hydrobiology, 2015)

Flow discharge and water level were plotted at two gauge stations, the Queanbeyan River US Googong Dam, and the Queanbeyan River at Wickerslack against the sampling rounds. These are shown in Figure 3 and Figure 4 respectively.

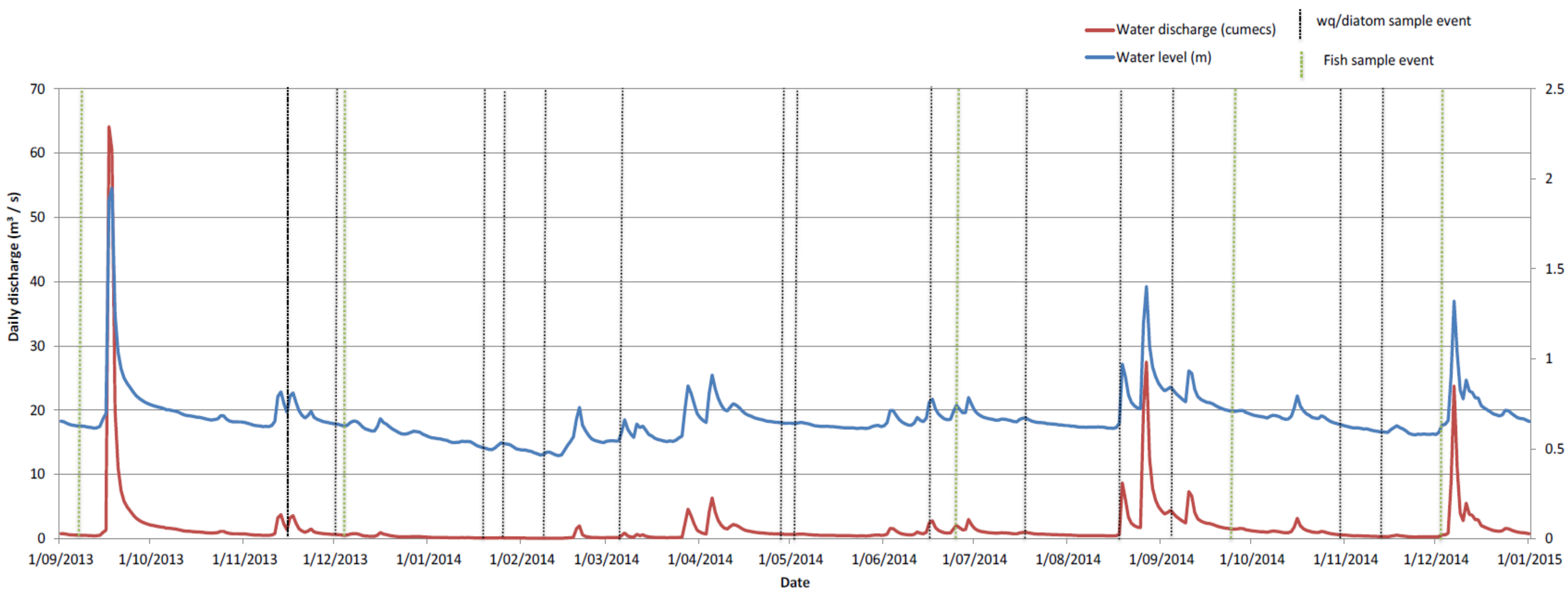

Figure 3 Flow discharge and water level at Queanbeyan River US gauge station (Hydrobiology, 2015)

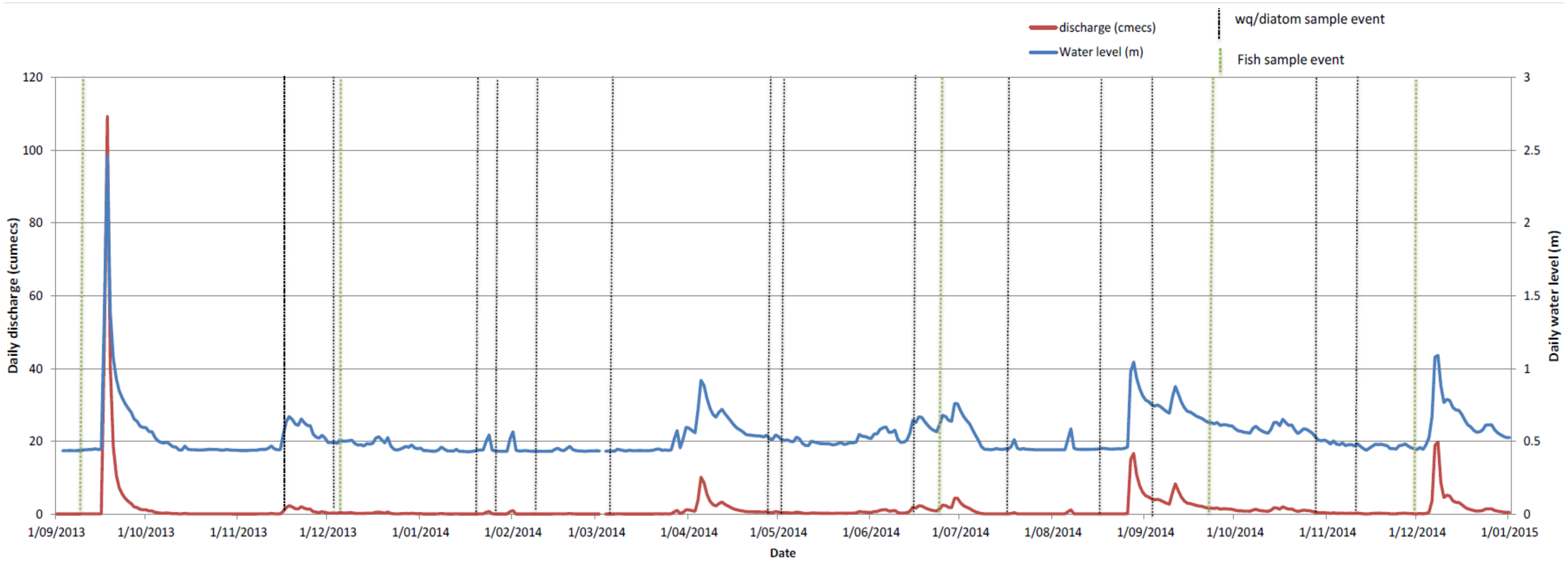

Figure 4 Flow discharge and water level at Wickerslack gauge station (Hydrobiology, 2015)

A2.2.3 Aquatic ecology

Diatoms

Diatom sampling at each of the nine surface water sampling sites was undertaken as part of the baseline monitoring for the Googong IWC Project.

Diatom total abundance and richness varied between sites over time with no clear distinction between seasons. However, a difference between sites, months and seasons occurred at a community level. A clear separation was observed between Queanbeyan River sites and its tributary sites (sites 8 and 9). This separation suggests that diatoms will provide a good early bio-indicator of impacts within the tributaries.

Total abundance and richness of each diatom species sampled revealed a range of preferences for specific functional groups. The majority of species sampled across all surveys were benthic diatoms (Table 6).

Table 6 Diatom habitat preferences from all sampling events

Habitat type	Richness	Abundance
Benthic	184	22,265
Epiphytic	11	2,109
Facultative Planktonic	16	10,061
Planktonic	7	7,024
Aerophilous	6	62
Unknown	28	553
Total	**252**	**42,074**

The trophic level of each diatom species sampled can be indicative of the level of nutrients in the water body they reside. Over the sampling period, diatoms from a range of trophic levels were sampled with the highest number of classified taxa known to occur in areas with a rich supply of nutrients.

Diatoms species with a range of motility levels were recorded over the sampling period (Table 7). This characteristic is important as a decrease in non-motile diatoms may highlight potential impacts on environmental conditions.

Table 7 Diatom motility levels from all sampling events

Motility level	Richness	Abundance
Non-motile	10	12,039
Weakly motile	4	964
Slightly motile	16	13,790
Moderately motile	48	3,232
Highly motile	4	225
Unknown	170	11,824
Total	**252**	**42,074**

The diatoms sampled had a range of pH preferences with the majority being circum-neutral and alkaliphilic. They also represented all classifications of oxygen requirements. The majority of species recorded throughout the sampling period required higher oxygen levels.

When looking at total abundance of individual species a clear numerical dominance was seen by *Achnanthidium minutissimum* which accounted for over 20% of the total abundance of diatoms (Table 8). This species is a benthic diatom associated with early biofilm development.

Table 8 Most abundant diatoms from all sampling events

Taxa	Group	Comment	Abundance in % of total
Achnanthidium minutissimum	Benthic	Broad niche, circumneutral, usually associated in early colonisation of biofilms and is a common freshwater diatom. Can also be associated with low nutrient streams.	20.4
Staurosirella pinnata	Facultative planktonic	Indicative of high nutrient status. Non-motile, alkaliphilic diatoms.	8.9
Aulacoseira subborealis	Planktonic	Alkaline more eutrophic but also occur in oligotrophic waters. In Australia (Murray Basin) this species has been associated with high turbidity and phosphorus concentrations.	8.0
Rossithidium pusilla	Benthic	Known to occur in environments with a poor supply of nutrients, circumneutral and tolerates very small concentrations of organically bound nutrients.	6.1
Staurosira construens forma venter	Facultative planktonic	Widely distributed in waters with low nutrient levels.	5.4
Cymbella affinis	Benthic	Alkaliphilic, tolerates very small concentrations of organically bound nutrients and is associated with rich nutrient environments.	5.4

Macroinvertebrates

Total abundance and species richness at each of the nine sites varied with season, with greater numbers and species richness during spring compared to autumn. Taxa from the Order Diptera (i.e. fly larvae) numerically dominated virtually all sites sampled in spring, followed by Ephemeroptera (i.e. mayfly larvae), collectively comprising 70% of the individuals collected across all samples. A distinct, albeit temporary, shift in community composition was evident in edge habitat sampled in spring versus autumn where Ephemeroptera numbers dominated in autumn.

When assessed at a community level, the macroinvertebrate assemblage varied between monitoring events, but not between sites. The sites therefore display patterns of substantial temporal heterogeneity, which is expected in a strongly seasonal system. The characteristics, and availability, of each habitat type fluctuates strongly with season, with flow usually the strongest causative agent.

AusRivas Predictive Modelling

Macroinvertebrate ecology is often considered the most appropriate indicator to measure ecological health, as it is an accepted industry standard for measuring river health.

The observed/expected (O/E) ratio of macro-invertebrate composition and abundance is how this indicator is measured. It is assessed using the Rapid Bio-assessment protocols defined in the *Australian River Assessment System (AusRivas), Sampling and Processing Manual* (Nichols *et al.* 2000).

AusRivas is a rapid, standard method for assessing the ecological health of freshwaters through biological monitoring and habitat assessment. The AusRivas model predicts the fauna (macro invertebrates) expected to occur at a test site on the basis of its environmental attributes.

When a test site is sampled, the fauna observed are compared to the model's expectations for that habitat, and the resulting O/E score is regarded as an integrated indicator of river health. AUSRIVAS compares both the expected (E) number of taxa and the expected SIGNAL[1] score against what taxa were actually observed (O) at a test site. This provides two indices, which provide a measure of biological impairment at a test site. These are:

- O/E Taxa - this is the ratio of the number of invertebrate families observed at a site to the number of families expected at that site.
- O/E SIGNAL - this is the ratio of the observed SIGNAL score for a site to the expected SIGNAL score.

The values of both indices can range from a minimum of 0 (indicating that none of the families expected at a site were actually found at that site) to a theoretical maximum of 1.0, indicating a perfect match between the families expected and those that were found.

To simplify interpretation and to aid management decisions, O/E taxa can be divided into bands representing different levels of biological condition. Table 9 provides the AusRivas banding of ecological health of assessed sites on the basis of macro-invertebrate taxa collected.

Table 9 AusRivas banding scheme

Band	Description	O/E taxa	Taxa interpretations
X	More biologically diverse than Reference	O/E greater than 90th percentile of reference sites used to create the model.	More families found than expected. Potential biodiversity 'hot-spot' or mild organic enrichment. Continuous irrigation flow in a normally intermittent stream.
A	Similar to Reference	O/E within range of central 80% of reference sites used to create the model.	Expected number of families within the range found at 80% of the reference sites
B	Significantly Impaired	O/E below 10th percentile of reference sites used to create the model. Same width as Band A.	Fewer families than expected. Potential impact either on water and/or habitat quality resulting in a loss of families.

[1] *SIGNAL – Stream Invertebrate Grade Number Average Level – a simple biotic index for macroinvertebrates that uses the pollution tolerance levels of different macroinvertebrate types to create a site score and water quality rating for the water body under investigation.*

Band	Description	O/E taxa	Taxa interpretations
C	Severely Impaired	O/E below Band B. Same width as band A.	Many fewer families than expected. Loss of families from substantial impairment of expected biota caused by water and/or habitat quality.
D	Extremely Impaired	O/E below Band C down to zero.	Few of the expected families and only the hardy, pollution tolerant families remain. Severe impairment.

A summary of the AUSRIVAS predictive modelling results is provided in Table 10. The following observations were made:

- Edge habitat generally performed better than riffle habitat, occasionally supporting invertebrate communities similar to AUSRIVAS reference sites (particularly in Spring 2014).
- Autumn reported typically worse habitat/biota conditions, with most sites considered either band B (significantly impaired) or band C (severely impaired).
- Conditions typically improve between Spring 2013 and Spring 2014 at most sites.
- Sites 1 to 7, representing a longitudinal progression downstream of Googong Dam, are not consistent in achieved AUSRIVAS band. That is, some reaches are 'better' than others despite being between two poorly performing reaches (e.g. in Spring 2014, sites 2 and 4 fell in Band C, while site 3 fell in Band B).
- Even when a site fell within a low band, the ratio of observed to expected taxa SIGNAL scores was very high, suggesting that the pollution sensitive taxa were persisting.

Table 10 Summary of AUSRIVAS band for each site (and Observed: Expected Taxa score/ Observed: Expected SIGNAL score).

Site	1	2	3	4	5	6	7	8	9
Edge									
Spring 2013	C (0.35/ 1.12)	C (0.35/ 1.29)			B (0.66/ 1.23)	C (0.55/ 1.31)	B (0.78/ 1.18)		
Autumn 2014	C (0.45/ 0.93)	B (0.57/ 0.87)	C (0.47/ 0.8)	C (0.36/ 0.57)	A (0.87/ 0.98)	C (0.25/ 0.61)	C (0.2/ 1.04)		
Spring 2014	B (0.7/ 0.9)	A (0.93/ 1.05)	A (0.93/ 1.0)	C (0.55/ 1.12)	B (0.78/ 1.06)	A (0.99/ 1.06)	A (0.89/ 1.2)		C (0.59/ 0.83)
Riffle									
Spring 2013	C (0.55/ 1.13)	D (0.23/ 1.19)			C (0.38/ 1.14)	B (0.69/ 1.13)	B (0.61/ 1.16)		
Autumn 2014	C (0.42/ 0.9)	C (0.45/ 0.79)	D (0.32/ 0.82)	D (0.34/ 0.76)	D (0.27/ 0.76)	D (0.37/ 0.92)	D (0.28/ 0.95)		
Spring 2014	C (0.55/ 0.77)	C (0.54/ 0.76)	B (0.63/ 0.79)	C (0.38/ 0.68)	C (0.38/ 0.78)	B (0.76/ 1.0)	C (0.46/ 0.8)	B (0.64/ 0.98)	C (0.55/ 0.91)

An inspection of the expected (according to AUSRIVAS modelling) but absent taxa in edge and riffle samples indicated the following:

- Diptera, or fly larvae, were often absent from site collections. It is possible this is an artefact of taxonomic identification, with several sub-families being aggregated into a single family.
- While there were some pollution sensitive taxa absent from both edge and riffle samples, the lists are largely dominated by taxa that are considered relatively tolerant to various forms of pollution (SIGNAL grades of 2 – 4). This may explain the observation that many sites fell in the severely impaired AUSRIVAS band, despite having very high O/E SIGNAL score ratios.

The macroinvertebrate analysis revealed substantial temporal heterogeneity, which is expected in a strongly seasonal system. The characteristics, and availability, of each habitat type fluctuates strongly with season, with flow usually the strongest causative agent. The most distinct shift in community composition was evident in edge habitat sampled in spring versus autumn. These temporal changes reflect the gradual succession of each macroinvertebrate family as its habitat niche changes in response to the season.

Macroinvertebrate monitoring is also understood to be used by other stakeholders in the area, most notably the operators of Googong Dam (currently Icon Water). Levings *et al.* (2012) and Harrison *et al.* (2010) both used macroinvertebrate monitoring using AUSRIVAS protocols to monitor river health in a series of rivers, including the Queanbeyan River, on behalf of Icon Water (formerly ACTEW Water). Two sites from this monitoring program (referred to as QM2 and QM3) are approximately the same as sites 1 and 5 (i.e. one and two kilometres downstream of Googong Dam respectively). These publically available reports include AUSRIVAS grading for these sites based on autumn and spring sampling of riffles, and are summarised in Table 11.

The decline in site condition detected in 2012 sampling was attributed largely to the impacts of floods in early autumn of that year. It was purported that the recovery and recruitment of macroinvertebrate families back to these sites would be delayed by the barrier effect of Googong Dam (Levings *et al.* 2012). This gradual recovery appears to have been captured in the Icon Water monitoring, as well as the baseline monitoring for the IWC Project.

Table 11 Summary of AUSRIVAS grading for sites 1 and 5 on the Queanbeyan River (and O:E taxa ratio)

Site	Site 1/QM2	Site 5/QM3
Icon Water (ACTEW) monitoring (riffle samples)		
Autumn 2008	B (0.64)	B (0.77)
Spring 2008	B (0.76)	B (0.72)
Autumn 2009	B (0.77)	B (0.67)
Spring 2009	A (0.92)	B (0.72)
Autumn 2010	A (0.97)	B (0.83)
Autumn 2011	A (0.96)	B (0.67)
Spring 2011	A (0.88)	A (0.92)
Autumn 2012	C (0.63)	B (0.70)
Spring 2012	B (0.64)	B (0.77)
Autumn 2013	B (0.77)	B (0.77)
Spring 2013	A (0.88)	A (0.92)

Site	Site 1/QM2	Site 5/QM3
Autumn 2014	B (0.70)	B (0.83)
Spring 2014	A (0.88)	B (0.84)
IWC Project baseline monitoring* (riffle/edge samples)		
Spring 2013	C (0.55/0.35)	B (0.38/0.66)
Autumn 2014	C (0.42/0.45)	A (0.27/0.87)
Spring 2014	B (0.55/0.7)	B (0.38/0.78)

** GTPL monitors both riffle and edge habitat types, Icon Water only monitors riffles. In this summary table, the site is graded according to the highest score irrespective of which habitat it occurred in.*

Fish and other aquatic fauna

Nine species of fish and two crustaceans were recorded throughout the baseline monitoring for the Googong IWC Project. Of these nine fish, only three were native to the area (*Hypseleotris klunzingeri*, *Hypseleotris* sp. and *Macquaria ambigua*). The remaining species sampled in the area have been introduced to Australia. Table 12 outlines the distribution of species sampled throughout the baseline sampling period.

Table 12 Fish and crustacean species present in the sampling area during the baseline sampling period

Site/Date		Fish									Crustaceans	
		Hypseleotris klunzingeri	*Hypseleotris* sp.	*Macquaria ambigua*	*Carassius auratus*	*Corbitidae* sp.	*Gambusia holbrooki*	*Perca fluviatilis*	*Salmo trutta*	*Trout* sp.	*Cherax destructor*	*Paratya australiensis*
		Western carp gudgeon,	Carp gudgeon, sp.	Golden perch	Goldfish	Loach sp.	Mosquitofish	Redfin perch	Brown trout	Trout sp.	Common yabby	Glass shrimp
Site 1	Sept 13	**Y**						Y	Y			**Y**
	Dec 13							Y			**Y**	**Y**
	Mar 14							Y			**Y**	**Y**
	June 14											
	Sept 14						Y	Y				**Y**
	Dec 14							Y	Y		**Y**	**Y**
Site 2	Sept 13							Y	Y		**Y**	
	Dec 13	**Y**						Y			**Y**	**Y**
	Mar 14						Y	Y			**Y**	**Y**
	June 14							Y				**Y**
	Sept 14	**Y**						Y				**Y**
	Dec 14						Y	Y	Y		**Y**	**Y**

Site/Date		Fish									Crustaceans	
		Hypseleotris klunzingeri	***Hypseleotris* sp.**	***Macquaria ambigua***	***Carassius auratus***	***Corbitidae* sp.**	***Gambusia holbrooki***	***Perca fluviatilis***	***Salmo trutta***	***Trout* sp.**	***Cherax destructor***	***Paratya australiensis***
		Western carp gudgeon,	**Carp gudgeon, sp.**	**Golden perch**	**Goldfish**	**Loach sp.**	**Mosquitofish**	**Redfin perch**	**Brown trout**	**Trout sp.**	**Common yabby**	**Glass shrimp**
Site 3	Dec 13						Y	Y			**Y**	**Y**
	Mar 14						Y	Y			**Y**	**Y**
	June 14											**Y**
	Sept 14							Y				**Y**
	Dec 14						Y	Y	Y		**Y**	**Y**
Site 4	Dec 13		**Y**					Y			**Y**	**Y**
	Mar 14						Y	Y				**Y**
	June 14	**Y**					Y	Y				**Y**
	Sept 14											**Y**
	Dec 14						Y	Y				**Y**
Site 5	Sept 13										**Y**	**Y**
	Dec 13	**Y**					Y	Y			**Y**	**Y**
	Mar 14					Y	Y	Y			**Y**	**Y**
	June 14						Y	Y			**Y**	**Y**
	Sept 14							Y			**Y**	**Y**
	Dec 14						Y	Y			**Y**	**Y**
Site 6	Sept 13	**Y**						Y			**Y**	**Y**
	Dec 13		**Y**		Y			Y		Y	**Y**	**Y**
	Mar 14						Y	Y			**Y**	**Y**
	June 14						Y	Y			**Y**	**Y**
	Sept 14						Y	Y			**Y**	**Y**
	Dec 14				Y			Y			**Y**	**Y**

Site/Date		Fish									Crustaceans	
		Hypseleotris klunzingeri	***Hypseleotris sp.***	***Macquaria ambigua***	***Carassius auratus***	***Corbitidae sp.***	***Gambusia holbrooki***	***Perca fluviatilis***	***Salmo trutta***	***Trout sp.***	***Cherax destructor***	***Paratya australiensis***
		Western carp gudgeon,	**Carp gudgeon, sp.**	**Golden perch**	**Goldfish**	**Loach sp.**	**Mosquitofish**	**Redfin perch**	**Brown trout**	**Trout sp.**	**Common yabby**	**Glass shrimp**
Site 7	Sept 13	**Y**						Y			**Y**	
	Dec 13	**Y**		**Y**	Y			Y			**Y**	**Y**
	Mar 14						Y	Y			**Y**	**Y**
	June 14							Y				**Y**
	Sept 14	**Y**					Y	Y			**Y**	**Y**
	Dec 14						Y				**Y**	**Y**
Site 8	Dec 13											
	Mar 14											
	June 14											
	Sept 14											
Site 9	Dec 13											
	Mar 14											
	June 14											
	Sept 14										**Y**	

Note: Native species are in bold.

In terms of abundance, there is a clear dominance by volume of introduced fish to native fish at all sites sampled throughout the baseline period. This highlights the damaging effects of introduced fishes as they often out-compete native fish species for limited food and territory.

There is also a seasonal variation found in the numbers of fish in the study area. Fish numbers generally peaked in summer months with the lowest catches in winter. No fish have been recorded within Googong Creek or Montgomery Creek (sites 8 and 9 respectively) to date.

A number of additional aquatic fauna were opportunistically recorded during the baseline monitoring (0). Of particular note is the consistent presence of turtles and platypus along the Queanbeyan River.

In addition to these, two terrestrial species of note were observed during the baseline surveys. In December 2013, a red-bellied black snake (*Pseudechis porphyriacus*) was spotted at sites 6 and 9. An echidna (*Tachyglossus aculeatus*) was also recorded at Site 9 in December 2014.

Table 13 Other aquatic species present in the sampling area during the baseline sampling period

Site/Date		***Amphibia* sp. (Tadpole)**	***Chelodina longicollis* (Eastern long-necked turtle)**	***Ornithocherhynchus anatinus* (Platypus)**
Site 2	Dec 14	2		
Site 3	Dec 13		2	1
	Mar 14		5	
	Dec 14	1	3	2
Site 4	Dec 13		5	
	Mar 14		1	
	Dec 14		2	
Site 5	Sept 13			
	Dec 13	1	1	
	Mar 14		2	
	Sept 14			1
	Dec 14	5	1	
Site 6	Dec 13			
	Mar 14			1
	Dec 14	3		
Site 9	Dec 13	20		

Additionally, a preliminary desktop investigation of the Queanbeyan River catchment involved a review of the Protected Matters Search Tool (PMST) of the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) for matters protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The PMST search results for a 10 km area have revealed potential habitat and/or presence of Murray Cod (*Maccullochella peelii*) and Macquarie Perch (*Macquaria australasica*) within the Queanbeyan River catchment. The Queanbeyan River downstream of Googong Dam is understood to be highly modified, particularly in terms of flow regime (Googong Dam), existing land use impacts and invasive species incursions. While there is a low likelihood of occurrence for these species within the catchment below Googong Dam, the ongoing monitoring methods would allow for detection of these species with monitoring timed for early spring immediately prior to spawning.

A3 Surface water and stream health impact assessment criteria

A3.1 Background

CoA D8 requires in part that the WMP must include ‘surface water and stream health impact assessment criteria including trigger levels for investigating any potentially adverse surface water impacts and for the supply of compensatory water’. A trigger level is a criterion which if exceeded would result in further action, in this case further investigation and assessment to determine whether ongoing monitoring indicates a deviation from the baseline characteristics, potentially as a result of irrigation or other operational practices.

A3.2 Interim trigger levels for baseline monitoring

Interim trigger levels based on existing guidelines were originally set for the IWC Project as no project-specific background information on surface water quality and aquatic ecology was available for the site.

NSW water quality guidelines are often based on the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). NSW water quality guidelines have commonly applied ANZECC objectives to defined watercourses and sub-catchments throughout NSW. The Queanbeyan River downstream of Googong Dam is defined as a 'controlled river with regulated flows' within the Murrumbidgee River and Lake George Water Quality and River Flow Objectives.

The baseline monitoring program assessed surface water quality, consistent with CoA – D8 based on primary contact objectives for recreational water users outlined in the NSW water quality guidelines. Primary contact objectives are largely consistent with those values presented in the table under CoA D5 and are detailed with the relevant aquatic ecosystem objectives in Table 14.

The water quality objectives outlined in Table 14 define specific interim trigger values or an interim trigger value range for each parameter in accordance with NSW Water Quality Objectives. The trigger values are the numeric criteria established by ANZECC guidelines (2000) that if exceeded may indicate the potential for deleterious environmental effects to occur. Existing monitoring data reviewed as part of the preliminary environmental assessment detailed water quality values in excess of these trigger values for numerous parameters.

Table 14 Aquatic ecosystem and primary contact interim water quality objectives for Queanbeyan River downstream of Googong Dam (Upland Rivers >150m elevation in south-eastern Australia) derived from ANZECC (2000) in the context of NSW water policy and CoA D5

Indicator	Units	Numerical criteria (interim trigger value)
Total nitrogen (TN)	mg/L	> 0.25
Oxides of nitrogen (NOx)	mg/L	> 0.015
Ammonia (NH4)	mg/L	> 2.0
Total phosphorus (TP)	mg/L	> 0.02
pH 6.5–7.5 (upland river)	-	> 8
Dissolved oxygen (DO)	% saturation of DO	< 90%
Conductivity	µS/cm	> 350

Indicator	Units	Numerical criteria (interim trigger value)
Microbiological faecal coliforms	cfu/100mL	> 150
Total algae	cells/mL	> 15,000
Cyanobacteria	cells/mL	> 15,000
Biochemical Oxygen Demand – BOD	mg/L	> 10
Suspended Solids	mg/L	> 10
Total Dissolved Solids – TDS	mg/L	> 700
Free Chlorine (residual)	mg/L	> 0.1
Oil and Grease	mg/L	> 2

A3.3 Revised trigger levels

A3.3.1 Development of trigger levels

The ANZECC guidelines (2000) detailed a recommended approach to deriving site-specific trigger levels. This entails, at a minimum, "*data collected after two years of monthly sampling are regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values*". Site-specific trigger values for these systems are developed using the 20th percentile (for stressors that cause problems at low levels such as dissolved oxygen) and 80th percentile (for stressors at high concentrations such as nutrients, BOD etc.) values of the baseline data.

Furthermore, the ANZECC guidelines (2000) recommends that "*Until this minimum data [monthly basis for at least two years] requirement has been established, comparison of the test site median should be made with reference to the default guidelines…*" Based on the approach outlined in ANZECC guidelines (2000), Hydrobiology (2015) did not recommend making changes to the trigger levels in the SWAEMP at this stage.

However, the interim WMP and SWAEMP outlined an approach where at least 12 months of baseline-monitoring data would be collected for surface water, aquatic ecology and groundwater. This data would assist in setting trigger levels. The SWAEMP states that if the baseline monitoring demonstrated existing exceedances, "*then the impact criteria would then be set based on ambient water quality in the 75th percentile of measurements and the IWC Project trigger level would be derived from this value*". This approach to determining site-specific trigger levels was approved by the NSW Department of Planning and Environment, in consultation with NSW EPA and NOW.

The baseline monitoring to date has allowed for the collection of up to 14 monthly data points at all sites, with the exception of Sites 8 and 9.

Calculations of the 75th percentile of each water quality parameter are summarised in Table 5. The median and 75th percentile for total nitrogen (TN) exceeds the current trigger value at all sites, therefore the trigger level for TN has been revised on a site-by-site basis.

The LOR for NOx (<0.05 mg/L) is higher than the ANZECC (2000) trigger level (0.015 mg/L), and there were some instances where the samples recorded concentrations below the LOR. However, the 75th percentile for NOx exceeded the current trigger value at all sites, with the exception of Site 9, and therefore the trigger level has been revised on a site-by-site basis.

Site 8 and 9 are located in Googong Creek and Montgomery Creek, respectively. Due to the ephemeral nature of these creeks water quality sampling was only able to be undertaken seven (Site 8) and six (Site 9) times throughout the baseline monitoring period. As the sampling dataset is limited, the ANZECC Guideline values will continue to be used as the trigger levels at these locations.

A3.3.2 Revised trigger levels

In general, the surface water quality trigger levels at all sites will remain as the numeric criteria established by ANZECC guidelines (2000), as detailed in Table 14. The exception to this are revised trigger levels for total nitrogen and NOx which are provided in Table 15.

Table 15 Revised trigger levels for total nitrogen and oxides of nitrogen

Site number	Total nitrogen (mg/L)	Oxides of nitrogen (mg/L)
1	>0.58	>0.11
2	>0.56	>0.1
3	>0.54	>0.1
4	>0.55	>0.09
5	>0.53	>0.1
6	>0.54	>0.09
7	>0.55	>0.08
8	>0.25*	>0.015*
9	>0.25*	>0.015*

** Aquatic ecosystem and primary contact interim water quality objectives for Queanbeyan River downstream of Googong Dam (Upland Rivers >150m elevation in south-eastern Australia) derived from ANZECC (2000).*

Where a trigger level is exceeded the result will be assessed against climate conditions, other users, construction related activities and irrigation loads, as outlined in the Surface Water and Groundwater Response Plan (WMP Appendix D).

These values will be reviewed and re-assessed annually, in line with review of the SWAEMP, as discussed in Section A4.

A4 Ongoing monitoring and reporting

A4.1 Ongoing surface water monitoring

A4.1.1 Water quality and aquatic ecology

Hydrobiology (2015) and QCC have made recommendations for surface water quality and aquatic ecology monitoring events during the first year of operation of the WRP. The recommendations are provided in Table 16.

Table 16 Surface water quality and aquatic ecology monitoring program recommendations during first year of operation

	Recommendation	Amendment to baseline monitoring methodology
1	Relocate Site 8 (monitoring site on Googong Creek) to immediately downstream of Beltana Pond, near Googong Road (refer to Figure 5). This will allow for safer access to the monitoring site and still enable the capture of potential impacts relating to discharges from Discharge Point 3 and Beltana pond.	Relocation of a monitoring site in Googong Creek.
2	Relocate Site 7 (monitoring site on Queanbeyan River) to Barracks Flat (refer to Figure 5). This will allow for safer access to the monitoring site.	Relocation of a monitoring site in Queanbeyan River.
3	Remove Sites 2 and 3 (monitoring sites on Queanbeyan River) (refer to Figure 5). Site 4 provides water quality information for the same stretch of the river between the Montgomery Creek and Googong Creek confluences.	Removal of two monitoring sites along Queanbeyan River.
4	Surface water quality sampling should continue to be collected on a monthly basis, extending the existing suite of analytes to include alkalinity.	Add an analyte (alkalinity) to the existing water quality suite to be sampled.
5	Extend the existing surface water quality analyte suite to include E. coli and enterococci. Undertake E.coli as a sub-set of the thermotolerant coliform test using membrane filtration. Use E. coli genotyping testing or other to characterise blooms of E.coli as the Queanbeyan River and upstream Googong Reservoir are susceptible to environmental E. coli blooms. Testing enteroccoci prevents natural bloom false positives from e. coli.	Add two analytes (E. coli and enterococci) to the existing water quality suite to be sampled.
6	Undertake algae monitoring as part of the surface water quality analyte suite during the hottest six months of the year only (October - March).	Reduce the frequency of algae monitoring to monthly from October to March only.

	Recommendation	Amendment to baseline monitoring methodology
7	Diatom sampling to continue, with sampling occurring quarterly.	Decrease diatom sampling from monthly to quarterly.
8	Macroinvertebrate monitoring: refine sampling effort to riffle habitat only, maintain spring and autumn sampling.	Discontinue edge habitat sampling.
9	Reduce fish survey frequency to yearly.	Decrease fish survey from quarterly to annually.
10	Exclude Sites 8 and 9 (on ephemeral creeks) from fish survey.	Undertake fish surveys at sites within Queanbeyan River only.
11	Ensure laboratory can achieve an LOR better than the trigger value for NO_x.	The LOR will be lowered for ongoing monitoring.
12	The continuous monitoring stations provide excellent *in situ* data, however they do not include dissolved oxygen. Strictly speaking, this *in situ* data should also be collected at each SWAEMP site concurrent with grab samples collected for the laboratory.	Add dissolved oxygen to the *in situ* field monitoring data collected concurrently with grab samples for the laboratory.
13	Undertake monitoring of channel stability at Googong Creek before, during and after process verification to assess the potential level of impact caused by discharges from the WRP, and to determine if any ongoing measures are required.	N/A

The continuation of regular monitoring of salt levels (TDS) in waterways is important, in parallel with the groundwater and soil monitoring program, to further assess whether salinisation is likely to become a significant issue at the site.

Depending on the results in the first year of WRP operation, the number of sampling sites and frequency of monitoring may change during the ongoing operational monitoring phase. In general, a consistent and comparable monitoring program would be conducted during the first year of operation as it constitutes 'after' data (post impact) consistent with the monitoring design (BACI). The potential reduction in the number of sampling points and frequency of monitoring can be more reliably assessed at the completion of the first year of operational monitoring without compromising the sensitivity of the monitoring program to detect an impact.

Future changes to the ongoing monitoring program that may be considered include the following:

- Reduce surface water quality sampling to quarterly for the second year of operation, unless the monthly sampling indicates high variability and a trend of change when compared to baseline monitoring.
- In addition to the quarterly monitoring, undertake surface water quality sampling following two wet weather discharge events during the second year of operation.
- Rationalise surface water monitoring sites along Queanbeyan River to remove Sites 7 and 5 following the first year of operation.
- Rationalise the macroinvertebrate and diatom programs to exclude one component altogether or reduce the frequency of sampling following the first two years of operation.

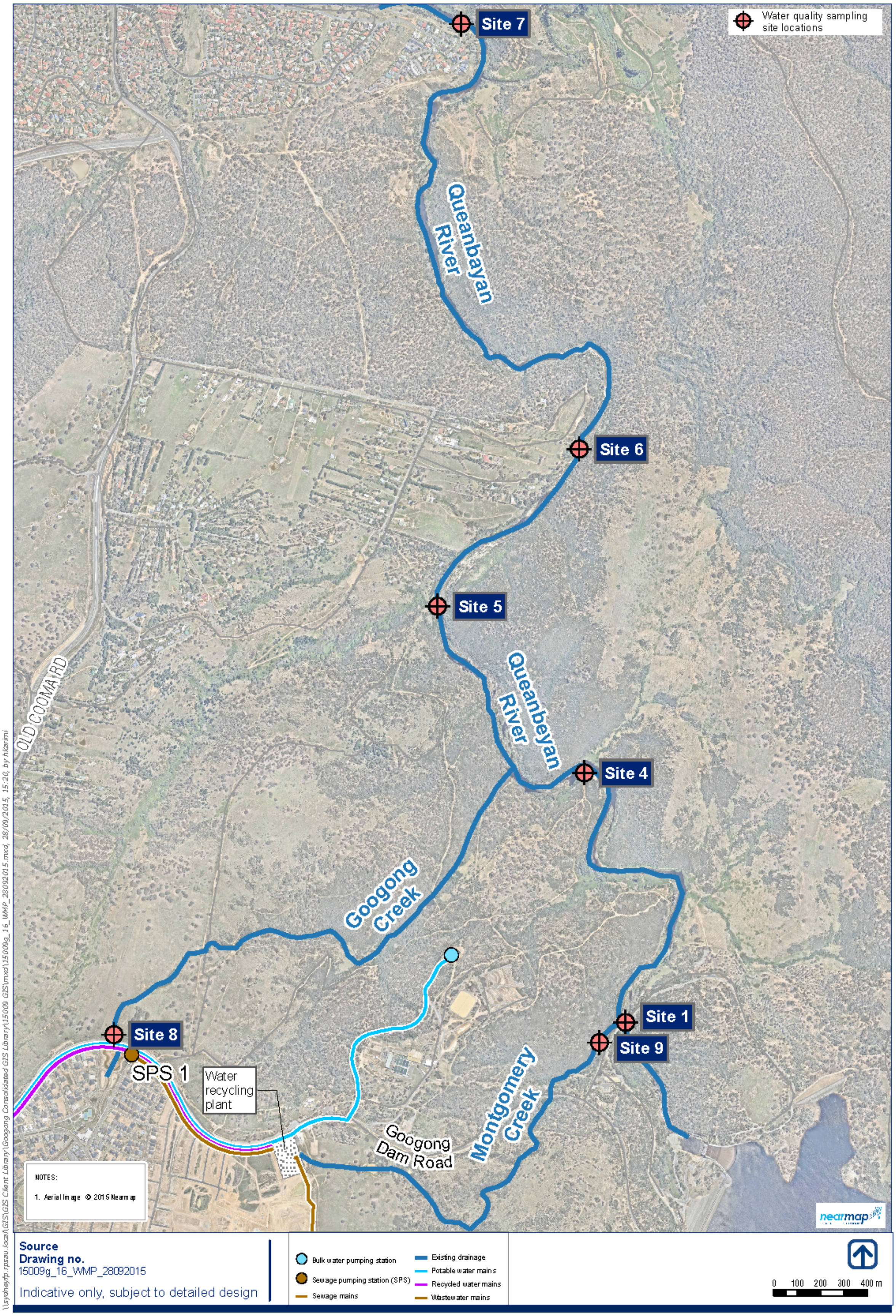

Figure 5 Water quality and aquatic ecology proposed monitoring site locations during first year of operation

A4.1.2 Flow monitoring

Flow monitoring will involve ongoing review of gauge data for flows in the Queanbeyan River at Wickerslack Lane (QBN703) and at the Googong Dam spillway (if available) in conjunction with recycled water discharge data for the IWC Project. The proposed discharge volumes will be metered, recorded and the data made available for interpretive purposes upon operational commencement of the WRP.

A4.1.3 Channel stability

Photopoint monitoring will augment habitat assessment at a defined location within each survey site, established during pre WRP-operation baseline monitoring. This will document the condition of riparian vegetation, stream health and channel stability over time.

A4.2 Reporting

To aid the adaptive management processes prescribed for the IWC Project, the need to collate information generated through regular monitoring is required to improve future management.

Section 6.5 of the WMP states that reporting (which is to include the results and analysis of the surface water and aquatic ecology monitoring), will be prepared annually. The reporting will be used to further refine measures to mitigate adverse environmental impacts that could occur as a result of the operation of the IWC Project.

A4.3 Program reviews and adaptive management

The SWAEMP will be an evolving document in response to monitoring objectives, monitoring results and periodic feedback in the form of regular reporting to inform ongoing management. It will incorporate adaptive management outcomes with regard to regular reporting inputs and in consultation with the operator, relevant stakeholders, regulatory bodies and relevant experts.

A timeline of management objectives and actions to the end of year one of operation is detailed in Table 17. Ongoing management objectives at the end of year one will be evaluated at that time to consolidate monitoring results and consultative feedback to date.

Table 17 Proposed timeline of adaptive management processes in response to water quality and aquatic ecology monitoring

Management objective	Outcome	Action	Timeline
Baseline Monitoring (COMPLETED)	Inform the operational monitoring requirements of the IWC Project.	Dependent on results of baseline monitoring an annual report would recommend measures to mitigate adverse environmental impacts through the establishment of impact criteria and refined trigger values.	Samples taken at least quarterly for at least 12 months (prior to proposed WRP operation). Report at the end of 12 months of monitoring.

Management objective	Outcome	Action	Timeline
Operational Monitoring	Collate operational monitoring on an annual (reporting) basis to document any changes in specific environmental indicators.	Identify potential impacts of the operation of the IWC Project. Recommend mitigation measures to reduce impacts if identified.	Samples taken as per Section A4.1. Report annually.
Ongoing update and review (annual review).	Update and refine monitoring program on the basis of data collected to date in consultation with the regulator.	Consider impacts and control measures instituted to date and refine the scope of the monitoring program accordingly to incorporate additional monitoring sites or environmental indicators (e.g. toxicants) as part of ongoing monitoring.	Annually.

A5 References

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