Cotter Reservoir Fish Management Plan (FMP) Version 4

Version 4.5, 17 January 2019

icon WATER

Document management

Document summary

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Version control

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4.1	John Hyam	30/07/2018	Changes incorporating feedback from FMPWG	
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4.4	John Hyam	10/12/2018	Changes incorporating feedback from DoEE review	
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Executive Summary

The delivery of this *Fish Management Plan Version 4* coincides with the completion of filling the enlarged Cotter Reservoir in July 2016. It is the fourth and final plan in the series, revised over time to inform and guide the conservation of threatened aquatic species from the construction phase, through to the present operation of the Cotter Dam.

The demand for and frequency of the operation of the Cotter Dam as a drinking water supply for the Canberra region is dependent on a range of climatic and other factors.

This plan focuses on addressing the management measures enabling the primary purpose for community drinking water supply whilst supporting conservation of threatened aquatic species within the Cotter Reservoir and Cotter River reach to Bendora Dam throughout various operational scenarios of the Cotter Dam. Specifically, the objective for this Fish Management Plan is:

"To ensure that operation of the Cotter Dam for the supply of community drinking water continues to support aquatic communities, particularly threatened native fish and crayfish species."

The Fish Management Plan is required by both Territory and Commonwealth conditions of approval for the construction of the enlarged Cotter Dam and has been underpinned by expert panels which include Government agency representatives, research organisations, ecological service providers and technical experts.

The successful management of threatened aquatic species in the Cotter Reservoir has relied heavily on information gathered through a suite of targeted research projects as outlined in previous Fish Management Plans. These projects were implemented by Icon Water (formerly ACTEW Corporation) during the planning and construction phase of the enlarged Cotter Dam in collaboration with the University of Canberra, the University of Sydney, the Australian National University and other ecological service providers. These research projects are summarised within this Fish Management Plan and inform the risks relating to the conservation of threatened fish during the construction and operation of the Cotter Dam.

Icon Water's management of identified key risks to the conservation of threatened aquatic species are outlined within this plan to:

- Guide the appropriate implementation of the mitigation measures which may include direct management actions, monitoring or further research
- Provide information to Government Regulators and other stakeholders on the potential environmental aspects and impacts affecting threatened aquatic species in the reservoir, and how these impacts may be mitigated and managed to provide environmentally acceptable outcomes during the operation of the Cotter Dam and management of the reservoir as a water source for the ACT
- Adhere to the project conditions of approval and Icon Water's Licence to Take Water issued by the ACT Government.
- Adhere to Icon Water's sustainability commitments under the *ACT Territory-owned Corporations Act 1990 (TOC Act)*, namely showing a sense of social responsibility by having regard to the interests of the community in which it operates, and effectively integrating environmental and economic considerations into decision making processes.

There are no further versions of the Fish Management Plan proposed, as the planning construction and filling phases have all been completed. However, in line with Icon Water's adaptive management principles, the plan will be reviewed at least every five years and updated following any significant changes to the operation of the dam, or associated measures/practices (e.g. environmental flow releases from Bendora Dam), or the status of threatened fish within the reservoir and the river upstream.

Threatened fish conservation within the reservoir will remain informed by a range of ongoing research and monitoring projects, namely the *Enlarged Cotter Reservoir (ECR) Fish Monitoring Program* and translocation monitoring.

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1. Introduction

1.1. Purpose of the Fish Management Plan

The purpose of this *Fish Management Plan* (FMP) *Version 4* is to support the conservation of threatened aquatic species within the Cotter Reservoir and Cotter River reach to the Bendora Dam throughout various operational scenarios of the Cotter Dam for the ongoing provision of community drinking water supply. The plan outlines the risks and the relevant controls and management measures to conserve threatened fish species within the Cotter Reservoir and the Cotter River reach to Bendora Dam.

FMP Version 4 (hereinafter referred to as the FMP) is the operational plan addressing the management of threatened fish species within the Cotter Reservoir, and follows the construction and filling phases of the Cotter Dam, referred as the Enlarged Cotter Dam (ECD) in previous documents and approvals. The threatened fish species addressed in the plan are Macquarie perch (*Macquaria australasica)* and Two-spined blackfish (*Gadopsis bispinosus*).

The FMP is required by the Commonwealth Government under the Conditions of Approval of the enlarged Cotter Dam dated the 21st of October 2009, and the ACT Government Conditions of Approval (DA 200915041) dated 16th September 2007 (Appendix A).

The plan will operate until 2027 with respect to the 20 year Enlarged Cotter Reservoir (ECR) Fish Monitoring Program required under the conditions of approval. After this time, Icon Water business procedures will be revised to incorporate relevant controls as part of business as usual within Icon Water's certified environmental management system (ISO 14001). The plan is compatible with, and complimentary to the draft Aquatic and Riparian Strategy, including the individual fish species action plans therein (ACT Government, 2018).

1.2. Responsibilities of stakeholders

The plan addresses the risks and management measures that are the responsibility of Icon Water during the ongoing operation of the dam and reservoir. It does not include an assessment of risks or the management measures relating to matters of other government authorities or land management entities such as the ACT Government or the ACT Parks and Conservation Service. However the plan highlights the shared responsibilities between Icon Water and such stakeholders in collaboratively managing threatened aquatic species within the reservoir.

1.3. Objectives

The overarching objective of the FMP is:

"To ensure that operation of the Cotter Dam for the supply of community drinking water continues to support aquatic communities, particularly threatened native fish and crayfish[1] species."

This objective was developed within the context of the *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government 2007) and will be achieved through the ongoing development and implementation of this plan, in doing so:

- Providing information to government regulators and stakeholders on the potential environmental aspects and impacts affecting threatened aquatic species in the

[1] Murray River crayfish have only confirmed from a handful of occasions in the ECR and are rarely encountered in the river below Bendora Dam. Consequently, the major focus is on the conservation of Macquarie perch and Two-spined blackfish (Broadhurst et al. 2017).

reservoir and river reach upstream to Bendora Dam, and how these impacts may be mitigated and managed to provide environmentally acceptable outcomes during the operation of the Cotter Dam as a water source for the Canberra region

- Guiding the appropriate implementation of the mitigation measures which may include direct management actions, monitoring or further research
- Adhering to the Commonwealth and ACT conditions of approval and license operating conditions of the Cotter Dam
- Adhering to Icon Water's sustainability commitments under the *ACT Territory-owned Corporations Act 1990 (TOC Act)*; namely, showing a sense of social responsibility by having regard to the interests of the community in which it operates, and effectively integrating environmental and economic considerations into decision making processes.

The FMP is:

- Designed to minimise or mitigate risks to threatened aquatic fauna and their habitats
- Scientifically based, using adaptive management
- Robust in terms of stakeholder involvement, peer review and public transparency
- Timely and updated on the basis specified in the approval conditions and if new knowledge emerges
- Developed as part of the overall requirements of the Cotter Dam
- Effective in terms of use of resources and expertise whilst at the same time ensuring the conservation of threatened species.

The delivery of this FMP coincides with the completion of the filling phase and the stabilised Full Supply Level (FSL) of the Cotter Reservoir, achieving its operational capacity. The plan is the final of four FMPs and provides specific management measures aligned with the operation of the dam and reservoir by considering a range of scenarios and their respective risks to aquatic species management. The establishment of trigger levels for management actions is ongoing and is being developed in consultation with the FMP Steering Committee, an expert panel and the ACT Government. There are also regular and timely stakeholder consultations to assess the ECR Fish Management Program and to discuss management options. When trigger levels can be established, consideration will also be given to the trigger levels specified in the new version of the ACT Government's *Environmental Flow Guidelines* (due for final publication in early 2019)

The preparation of all FMPs have been underpinned by expert panels (Fish Management Steering Committee (FMPSC) and the Fish Management Plan Working Group (FMPWG)) which include Government agency representatives, research organisations, ecological service providers and technical experts.

- Fish Management Plan Version 1 (2009) identified risks and knowledge gaps surrounding threatened aquatic species' responses to the planned construction of a new Cotter Dam; and proposed a series of nine research projects to fill these knowledge gaps.
- Fish Management Plan Version 2 (2010) provided a report on the progress of the nine research projects; and how the projects were supporting the conservation of threatened aquatic species throughout the construction phase of the new Cotter Dam. The findings of the research projects are summarised within this plan in Appendix C.
- Fish Management Plan Version 3 (2014) focussed on the ongoing management of threatened species during the filling phase of the ECR.

- This Fish Management Plan, Version 4 (2019), supports the ongoing conservation of threatened aquatic species under a range of operational scenarios of the Cotter Dam, including consideration for future conditions and management options.

There are no further versions of the plan proposed. However, in line with Icon Water's adaptive management principles, the plan will be reviewed at least every five years and updated following any significant changes to the operation of the dam, or associated measures/practices (e.g. environmental flow releases from Bendora Dam), or status of threatened fish within the reservoir and river upstream.

1.4. Structure of this report

This plan is divided into four sections:

- **Introduction**: describes the purpose of Fish Management Plan Version 4 and its context relating to previous FMPs
- **Site Description:** provides an overview of the Cotter Dam and reservoir, outlining Icon Water's strategy for operating the asset and its role in the ongoing provision of drinking water for the ACT
- **Management Actions**: highlights monitoring, management thresholds and actions relevant to the conservation of threatened aquatic species during the operation of the Cotter Dam
- **Appendices:** includes relevant reference material and sub-plans which may continue to be revised through the FMPSC/FMPWG as adaptive management documents
    - Appendix A: Conditions of Approval and Operation
    - Appendix B: Fish Management Plan Risk Assessment
    - Appendix C: Fish Management Plan Background and Projects
    - Appendix D: Water Quality Sampling Schedules
    - Appendix E: Cotter Reservoir EHN Virus Management Plan
    - Appendix F: Cotter Reservoir Destratification System Process Operating Plan
    - Appendix G: Enlarged Cotter Reservoir (ECR) Cormorant Management Plan
    - Appendix H: Enlarged Cotter Reservoir (ECR) Emergency Inspection and Translocation Plan
    - Appendix I: Cotter Reservoir Alien Fish Management Plan
    - Appendix J: Emergency Contacts.
    - Appendix L: Fish Baseline

1.5. Stakeholders

Key stakeholders involved in the development and ongoing review and assessment of the FMP are set out in Table 1.

Table 1: Key Stakeholders

Function	Role
ACT Environment Protection Authority (EPA)	• Managing operating licences and conditions for the Cotter Dam, including the *Licence to Take Water (WU67)* under the *Water Resources Act 2007 (ACT)*

ACT Chief Minister, Treasury and Economic Development Directorate (CMTEDD)	with reference to relevant plans including the *Environmental Flow Guidelines*
ACT Conservator of Flora and Fauna **ACT Environment, Planning and Sustainable Development Directorate (ESPDD)**	• Acts on issues that affect conservation matters of the Cotter Dam, embodied in the *Nature Conservation Act 2014 (ACT) and the Fisheries Act 2000.*
ACT Parks and Conservation Service (PCS) **EPSDD**	• Managing land consistent with objectives for protection of water quality, conservation and recreation and guided by the Statutory Reserve Management Plan for the Lower Cotter Catchment (LCC)
Conservation Research **ESPDD**	• Research, monitoring and management of threatened aquatic and terrestrial species in the Cotter River, Cotter Reservoir and associated lands
Catchment Management and Water Policy **EPSDD**	• Water policy, science, monitoring and modelling • Setting the guidelines for the management of environmental water through revision of the *Environmental Flow Guidelines*
Commonwealth Department of the Environment and Energy	• Approve and set the conditions for the construction and operation of the enlarged Cotter Dam under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (Appendix A).
Icon Water	• Water extraction for community drinking water supply and managing environmental flow releases from Corin, Bendora and Cotter Dam in accordance with the conditions of approval and *Licence to Take Water* (WU67) under the *Water Resources Act 2007 (ACT)* • Monitoring and operation to support maintenance of threatened fish in the Cotter Reservoir and Cotter River
Independent Technical Expertise[1]	• Provision of advice as independent specialist Fish Advisor to Icon Water • Provision of scientific and technical expertise through research and fish monitoring on behalf of Icon Water

Note 1: University of Canberra Institute of Applied Ecology (IAE) were engaged for the role of Independent Technical Experts for the development of Fish Management Plans 1-4.

Icon Water engaged Associate Professor Mark Lintermans from the University of Canberra to provide ongoing specialist expertise relating to threatened aquatic species, namely Macquarie perch and Two-spined blackfish for the planning, construction, filling and operational phases of the Cotter Dam. Associate Professor Lintermans also provided specialist input into the development of FMP Version 4. This engagement has facilitated rapid access to ecological knowledge on threatened species, and is considered as best-practice approach to collaborative threatened fish management not only in Australia, but globally (Lintermans 2012). Ongoing independent technical expertise is available as needed, and provides access to expert knowledge and enables independent specialist input to inform any operational decisions that may not be addressed already in this plan.

The implementation and success of the Fish Management Plans to date is demonstrated by the ongoing licencing of Icon Water's operations, and the cooperative and collaborative management approach with Territory and Federal stakeholders and regulators. The establishment of the FMPSC and FMPWG was to provide a forum and regular cooperative interaction to ensure that Federal and Territory Government regulators remain satisfied with how approval conditions are being met to balance community drinking water supply and conservation objectives.

The FMPSC includes representatives of the ACT Conservator of Flora and Fauna, the Commonwealth Department of the Environment and Energy and Icon Water. Under the established Terms of Reference, this steering committee is allocated the role of providing high level advice, general direction and decision making on objectives in relation to fish management.

The FMPWG includes all stakeholders (See Table 1) and its role is to identify and synthesis existing research, research needs and collaborative problem solving to make recommendations addressing the objectives of the FMP. Recommendations are directed to the FMPSC for endorsement and to consider whether a realignment of the plans objectives may be necessary based on the findings.

The FMPSC will continue to oversee the activities being undertaken to meet approval conditions and commitments for the enlargement project as well as operational conditions to meet the requirements of the *Licence to Take Water* (*WU67*). This will include providing strategic direction to inform the FMPWG, funding responsibilities and the broader project objectives.

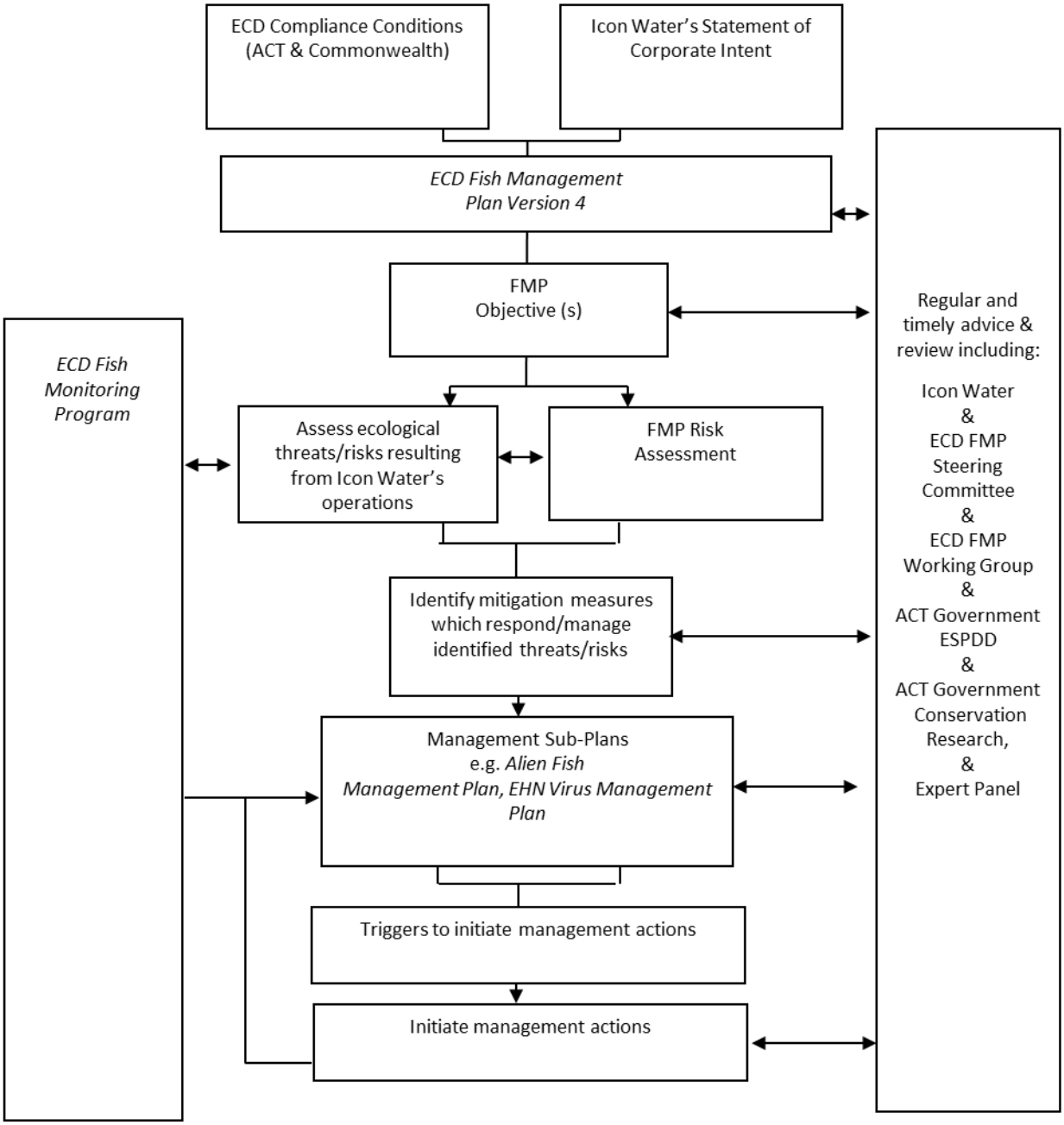

Figure 1 - Fish Management Plan Context

1.6. Review

Review of this FMP will be undertaken at least every five years to align with the ACT Government's review of the *Environmental Flow Guidelines* or if there are any significant changes to the risks and corresponding adaptive management actions to protect threatened aquatic species. The FMP review may identify the need for improved controls or the maintenance or amendment of management processes at the Cotter dam and reservoir.

A review may also be required following:

- a change in the scope of the plan and its objectives
- a change in the regulatory instruments in place
- a significant environmental incident
- a severe weather event or bushfire
- new relevant knowledge
- a requirement to improve performance in an area of environmental impact
- a significant modification of the dam infrastructure, including modifications of Bendora Dam
- amendment to the dams operating procedures, such as Icon Water's *Water Sourcing Guidelines*
- decommissioning of the dam, or
- natural disaster or force majeure affecting the dam or associated infrastructure.

The review will ensure that the FMP is meeting Icon Waters statutory requirements (Appendix A), and will consider but will not be limited to:

- compliance with the conditions of approval and regulatory and licencing conditions
- general environmental duty
- matters raised by the regulator(s)
- non-conformances, corrective actions closure
- monitoring results
- record keeping and document control
- resourcing, costs and benefits of environmental controls
- monitoring and audit findings or
- changes in standards and legislation.

Icon Water will amend the FMP to facilitate continuous improvement. Where a review identifies non-compliances, the following procedures will apply:

- non-compliance or incidents will be logged as a quality incident and investigated by an appropriate team
- agreed corrective actions will be identified by the team and reviewed by the Icon Water management
- actions will be implemented to rectify the issue and the effectiveness of the corrective actions will be assessed
- the FMPSC will be informed.

2. Site description and operation

2.1. Site description

The Cotter Dam is one of the four impoundments used by Icon Water to store raw water, and following treatment, provides potable drinking water for the community in Canberra and Queanbeyan. Construction of the enlarged Cotter Dam commenced in November 2009 and concluded in October 2013.

The dam wall was built approximately 125 metres downstream of the old Cotter Dam, approximately 18 kilometres due west of Canberra (Figure 2). The dam is located upstream of the confluence of the Cotter, Paddys and Murrumbidgee Rivers and is in the vicinity of a range of recreational areas including Cotter Avenue, Cotter Campground and Casuarina Sands.

The dam wall is approximately 80 metres high with the saddle dams approximately 12 and 16 metres in height. The enlargement of the dam has increased the storage capacity of the original reservoir from four gigalitres (GL) to approximately 78 GL, increasing the ACT's overall storage capacity by a third. The Cotter Reservoir achieved an enlarged Full Supply Level (FSL) of 550.8 metres on 7 July 2016. As a result, the reservoir has transitioned from the filling phase to an operational reservoir.

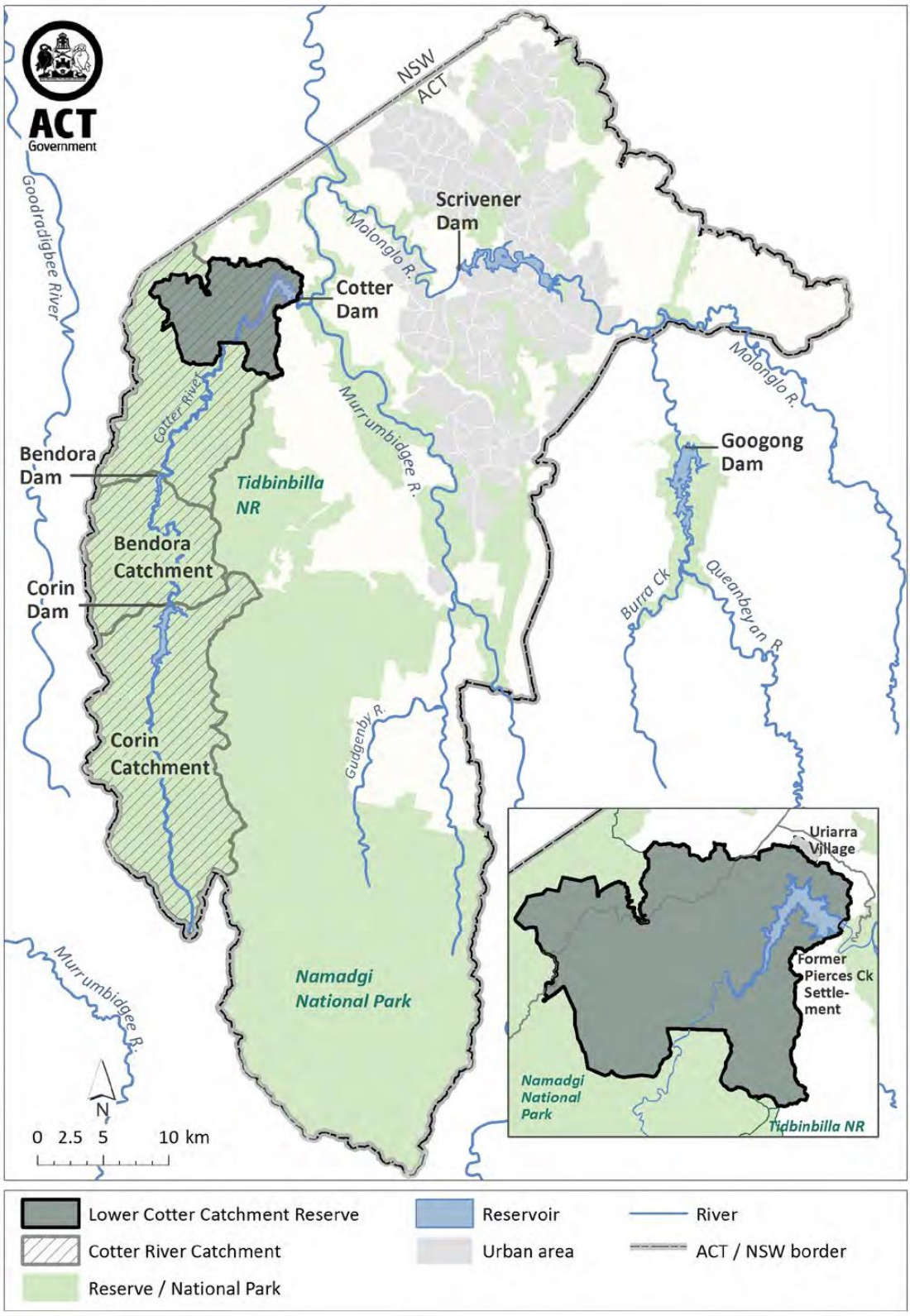

Figure 2: Location of the Cotter Dam and Reservoir. Source: ACT Government, 2017

2.2. Operation

Icon Water stores water for potable supply from the Cotter River at three locations; the Cotter, Bendora and Corin Reservoirs. Additionally, water from the Queanbeyan River is stored and extracted from Googong Reservoir, and intermittently extracted from the Upper Murrumbidgee River by pumping from Murrumbidgee Pump Station at Casuarina Sands. Bulk water can also be transferred between catchments from the Murrumbidgee River at Angle Crossing to Burra Creek at Burra via the Murrumbidgee to Googong pipeline (M2G) at Angle Crossing. Conditions for water storage and extraction is regulated by the ACT Government under Icon Water's *Licence to Take Water - WU67* under the *Water Resources Act 2007 (ACT)*.

Modelling of the proposed operation of the Cotter Dam for water supply, indicates that water level of the reservoir will remain within three metres of FSL for approximately 84 per cent of the time, within five metres of the FSL for approximately 92 per cent of the time, and within ten metres of the FSL for approximately 98 per cent of the time. The proposed levels however are dependent on climatic conditions and the overall storage status of Icon Water's reservoirs, and are therefore only indicative of the ongoing state of the reservoir. Management of drinking water storages are also dictated by broader factors such as network and asset constraints, water demand, energy pricing or changes in climatic conditions.

Icon Water storages are managed in accordance with operating guidance provided through Icon Water's *Water Sourcing Guidelines.* This operating regime has been developed using detailed water network models to maximise water supply performance, whilst meeting environmental objectives, one of which being to minimise risk to threatened aquatic species.

Minor deviations from the *Water Sourcing Guidelines* framework are unlikely to significantly impact cost, risk or performance. Therefore, the guidance presented is not intended to be applied rigidly, rather decisions should also consider other circumstances, such as:

- Weather and climate outlooks
- Source water quality
- Operational requirements, infrastructure availability and planned maintenance requirements.

2.3. Management

To maintain and achieve Icon Water's FMP objectives during operation of the Cotter Dam, a range of risks relating to the ongoing conservation of threatened aquatic species within the reservoir and Cotter River were identified and reviewed by key stakeholders (the FMPWG). These risks and corresponding mitigation measures were developed following Icon Water's risk framework and aligned with the Cotter Dam and reservoir compliance and regulatory requirements.

Conditions of approval and compliance requirements relevant to the FMP are summarised in Appendix A. Details of the research projects informing current knowledge of aquatic species within the reservoir, and the risk assessment prompting additional management measures are provided in Appendices B and C respectively. The findings of these research projects have been adapted into Icon Waters Management Plans and ongoing adaptive management of the reservoir.

The relationship between the objectives of the FMP and factors informing the operation and management of the dam and reservoir are summarised in Figure 3.

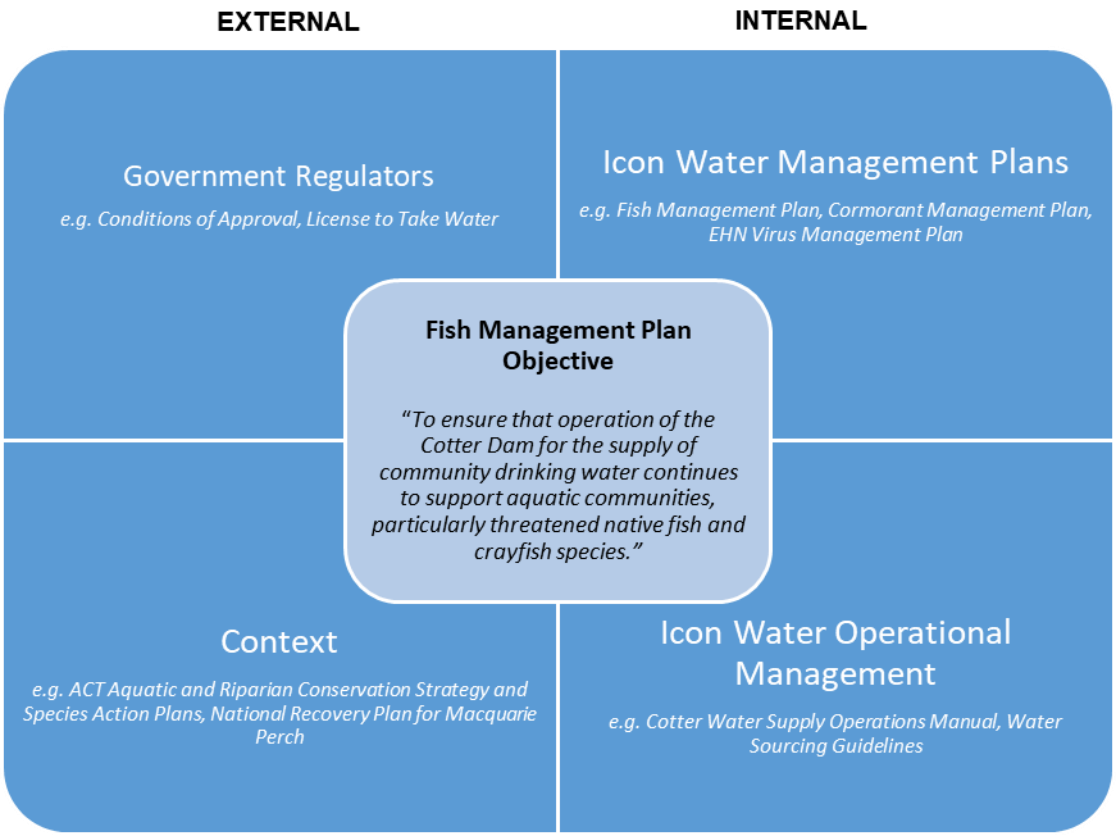

Figure 3: Summary of Fish Management Plan strategy

3. Management actions

3.1. Management Strategy

The strategy for the ongoing management of threatened aquatic species during operation of the Cotter Dam reflects that published in earlier versions of the FMP. The strategy ensures:

- Adhering to, and achieving the objectives of the FMP
- Compliance with regulatory requirements and conditions of approval of the construction of the Cotter Dam, including the preparation of the FMP with input and review from relevant stakeholders
- Consistent identification and review of the risks to threatened aquatic species arising from operation of the dam
- Availability of expert advice on fish issues and potential management approaches
- Identification of appropriate management and mitigation strategies, including plans and trigger levels to guide their implementation where practical.
- A fish monitoring program to provide data to internal and external stakeholders, including regulators to inform the ongoing management of aquatic species
- Ongoing collaboration and involvement with the FMPSC and FMPWG.

As identified in the FMPWG risk assessment workshop (Appendix B), a range of ongoing and additional activities to minimise and/or mitigate the risks to threatened aquatic species from the operation of the Cotter Dam may be feasible in ensuring the objectives of the FMP. Proposed mitigation actions will be assessed for their practicality, likelihood of success and balanced with community expectations for drinking water supply. These are presented as ongoing and additional controls and management actions in the Risk Assessment in Appendix B, and are addressed according to their current risk rating below in Section 3.3.

3.2. Operational Monitoring

Source Water Quality Monitoring

A comprehensive ongoing water quality monitoring program is undertaken upstream and within the reservoir to manage source water condition and quality for drinking water supply and license purposes. Fortnightly, monthly and quarterly water quality grab samples are taken from four sites within the Cotter River and reservoir, and are analysed to inform management decisions related to public health requirements for the water supply. Some of these parameters are also utilised as triggers for informing management measures associated with aquatic threatened species within the reservoir, and are an integral component to the ongoing conservation of Macquarie perch.

Online telemetry additionally provides instantaneous measurements of a range of physical and physiochemical parameters throughout the reservoir and Cotter River. Sites were strategically established to provide an overview of the condition of inflows into the reservoir, and data provided informs management decisions associated with the dams operation, water quality and fish management actions.

The ongoing monitoring of water quality and physicochemical parameters within the reservoir and the broader catchment supports adaptive management responses in the event of any change to conditions within the reservoir, river and broader sub catchment. Alterations that are most likely to have direct impact on threatened aquatic species that may be informed by this monitoring include changes to:

- Water quality, particularly dissolved oxygen, temperature or turbidity
- Environmental flow and reservoir level, particularly during Macquarie perch spawning season
- Biological changes within the reservoir, such as algal blooms that may indirectly impact Macquarie perch

The parameters assessed in each of the monitoring schedules that are relevant to the FMP are summarised in Appendix D.

Fish Monitoring and baseline

Potential impacts from the operation of the Cotter Reservoir are monitored through a range of research activities within the *ECR Fish Monitoring Program*. This program commenced in 2010, with baseline monitoring during the pre-filling stage of the dam completed in 2013 (Lintermans et al. 2013). A total of 5,554 fish from 13 species were captured across the three years of standardised sampling (Table 2). Macquarie perch was the most abundant species captured in reservoir environments, and Two-spined blackfish in riverine environments. Please refer to *Appendix L- Fish Baseline* for the full report.

Table 2 Total number of each species of fish captured in reservoirs and in rivers by each sampling technique from 2010-2012 (Lintermans et al, 2013, Table 5)

	Reservoirs		***Riverine***		
Species	**Gill nets**	**Fyke nets**	**E/fishing**	**Fyke nets**	**Total**
Macquarie perch	113	872	65	731	**1781**
Two-spined blackfish		74	1273	341	**1688**
Rainbow trout	323	25	1123	40	**1511**
Goldfish	1	110	64	97	**272**
Oriental weatherloach		5	31	6	**42**
Brown trout	1		43	4	**48**
Golden perch		7			**7**
Murray cod		4			**4**
Trout cod	11		4	2	**17**
Redfin perch		34	2	10	**46**
Carp			28	53	**81**
Eastern gambusia			47		**47**
Mountain galaxias			10		**10**
Total	**449**	**1131**	**2690**	**1284**	**5554**

The ongoing ecological monitoring program addresses 10 management questions which aim to assess aquatic species status and condition within the reservoir, and determine the impact of the dams operation on populations of the two focal threatened species and their potential threats within the reservoir and upstream reaches of the Cotter River to Bendora Dam. This program will operate until 2027 as required under the conditions of approval. After this time, Icon Water business procedures will be revised to incorporate relevant controls as part of business as usual within Icon Water's certified environmental management system (ISO 14001).

Details of the *ECR Fish Monitoring Program* are provided in Appendix C.

3.3. Adaptive Management

The adaptive management of threatened aquatic species within the reservoir is a structured, iterative process of decision making due to the ongoing uncertainty of climatic conditions, water demand and other external factors which influence the operation of the Cotter Dam and other upstream reservoirs. As such, management measures outlined in this section aim to provide further guidance to aid decision making associated with the operation of the dam, in doing so, minimising the risk and providing confidence in Icon Water's ongoing management and conservation of threatened aquatic species.

The ACT Water Resources Environmental Flow Guidelines 2013, Disallowable Instrument DI2013-44 made under the Water Resources Act 2007, section 12 (Environmental Flow Guidelines) sets out the environmental flow requirements needed to maintain aquatic ecosystems. Some of the ecological objectives are specific to the threatened fish species in the Cotter River, viz. Macquarie perch and Two-Spined blackfish. The objectives are as follows:

Bendora Dam to Cotter Reservoir	To maintain populations of **Macquarie Perch**	Young of the year and year 1+ age classes comprise >30% of the monitoring catch; and catch is >40 fish for standard monitoring effort.
	To maintain populations of **Two-Spined Blackfish**	Young of the year and year 1+ age classes comprise >40% of the monitoring catch; and catch is >80 fish for standard monitoring effort.

The annual ECD Fish Monitoring Program monitors these objectives by addressing the following management questions:

1. Has there been a significant change in the abundance and body condition of Macquarie perch in the enlarged Cotter Reservoir (Young-of-Year, juveniles and adults) as a result of filling and operation?
2. Has there been a significant change in the abundance, body condition and distribution of the Macquarie perch in the Cotter River above and below Vanitys Crossing as a result of the filling and operation of the ECR?
3. Have Two-spined blackfish established a reproducing population in the enlarged Cotter Reservoir and are they persisting in the newly inundated section of the Cotter River?

Note that the Environmental Flow Guidelines were reviewed in 2018 by an expert panel and stakeholders including the DoEE and a revised set of ecological objectives will be available in early 2019 to cover the next five year period.

As part of adaptive management an annual Macquarie perch spawning plan is produced in conjunction with the FMPWG prior to the spring/summer spawning season. The purpose of this plan is to document the agreed actions by Icon Water and other stakeholders to encourage

Macquarie perch spawning in the Cotter River reach immediately upstream of the Cotter Reservoir.

Management measures and controls were identified in the FMPWG risk assessment workshop in 2017, and are presented with their relevant number and risk rating according to the risk assessment. Further details of the risk assessment informing these management measures is presented in Appendix B.

Note that Icon Water's Risk Management process is consistent with ISO Standards. *ISO Guide 73:2009 Risk Management – vocabulary* defines a control as follows:

In practice, controls are actions or mechanisms that, when carried out properly and in a timely manner, minimise or reduce risk or enhance opportunities.

ISO Guide 73 notes that controls include any process, policy, device, practice, or other actions which modify risk; and that they may not always exert the intended or assumed modifying effect.

There are three main types of controls:

- preventive controls address the cause of a risk event and limit or stop the likelihood of an undesirable event happening;
- detective controls identify the occurrence of an undesirable event and function after it has happened; and
- responsive controls address the effect of the event and act to minimise the consequences.

The key risks and associated current and potential mitigation actions are presented Table 3 and outlined below, based on grouping into high, medium and low risk categories. Any changes to risk ratings will be captured in reviews carried out by Icon Water, as described in Section 1.6.

Table 3: Operational Fish Management risks

Rating	Ref	Risk
High	H1	Loss of food resources
	H2	Cold water pollution
Medium	M1	Increased abundance of alien fish
	M2	EHN virus
	M3	Increased Great cormorant predation
	M4	Drawdown of reservoir and sedimentation of river reach
	M5	Exposure of instream barriers during Macquarie perch spawning season
Low	L	Oxygen depletion Mortality of fish or pollution of fish habitat Abstraction of fish through intake and fish mortality Thermal stress for Murray cod and reduced spawning

High Risks

H1. Loss of food resources (Risk 2, Appendix B)

Current Controls
• Constructed rock reef provides substrate for food
• Inundated native hardwood and shrub habitat left in-situ provides source of nutrient loads
• Larger area of shallow fringing habitat in reservoir provides habitat for food.
Potential Additional Controls
• Trials of Reed bed establishment
• Trials of Riparian revegetation around selected areas of the reservoir.

The enlargement of the reservoir has altered reservoir food resources (loss of reed beds), particularly for Macquarie perch. As a result of research findings investigating the effect of this food resource shift, the following controls were implemented to mitigate the impact on food resources during the construction and filling of the dam:

- Constructed rock reefs to provide substrate for food.

  Rock reefs were constructed in accordance with the following design criteria:

  - Located within 5 to 28 metres below the FSL of the enlarged reservoir to provide shelter habitat for Macquarie Perch for 98 per cent of the time.
  - Positioned close to the shoreline, running along and across various contours to provide shelter across a range of reservoir depths.
  - Constructed from good quality, large rocks, ideally one metre in diameter to provide sufficient interstitial spaces and to resist fracture during transport, stockpiling and placement.
  - Rock material to contain no or minimal fines and small rocks as these waste materials may fill the interstitial spaces, reducing the usefulness of the reef as shelter habitat for fish.
  - Reefs to provide interstitial spaces (void size) between approximately 0.15 to 0.25 metres wide to allow access to adult Macquarie Perch.
  - Erosion and sediment control measures and landscape rehabilitation undertaken to minimise sediment accumulation in interstitial spaces and transfer of sediment to watercourses.

- Native hardwood and shrub habitat in the inundation zone left in-situ to provide a source of nutrients driving primary production within the system. In addition, the retention of the majority of timber and woody debris within the inundation zone provided supplementary habitat for Macquarie perch and other aquatic species, particularly during the filling phase.

Upon construction completion the provision of rock reef shelter habitat was reviewed by expert panel to determine whether the works undertaken by Icon Water were fit for purpose. The review determined that:

- The 7km of rock reef habitat provided is more than adequate to sustain the current Macquarie perch population.
- The vegetation left in the inundation zone provides significant additional habitat beyond what is required for the current population of Macquarie perch.
- Rock reefs are enhancing the ecosystem in the ECD and in combination with inundated vegetation have the potential to sustain an increased population of Macquarie perch.
- The Fish Management Program Steering Committee acknowledged that provision of rock reef habitat was completed in November 2012.

In addition to these physical additions to the reservoir, the inundation of banks adjacent to the reservoir due to the heightened filling water level resulted in additional shallow habitat suitable for aquatic vegetation (submerged or emergent). Response of vegetation to this change will not be uniform, and will depend on species characteristics, on site characteristics such as slope and exposure, and on ground water regime such as timing and duration of reservoir drawdowns (Roberts 2006). If established and dependent on the species and distribution, this vegetation may provide increased food resources through the provision of additional habitat for both terrestrial and aquatic macroinvertebrates which form a portion of the Macquarie perch diet (Norris et al. 2012; Hatton 2016).

Monitoring as a component of the *ECR Fish Monitoring Program* continues to contribute to the understanding of Macquarie perch and how the population utilises food resources and interacts within the reservoir (e.g. Broadhurst et al. 2018). The monitoring program is not an intervention monitoring program, i.e. it is not to evaluate the response to individual interventions/controls but rather a surveillance monitoring approach that evaluates the fish community and various components via multiple management questions.

Two of the management questions from this monitoring program related to food resources are as follows:

1. Has there been a significant change in the abundance and body condition of Macquarie perch (young-of-year, juveniles and adults) in the enlarged Cotter Reservoir as a result of the filling and operation of the Cotter Dam?

2. Has there been a significant change in the abundance, body condition and distribution of the Macquarie perch (young-of-year, juveniles and adults) in the Cotter River above and below Vanity's Crossing as a result of the filling and operation of the Cotter Dam?

Further details of the *ECR Fish Monitoring Program* are described in Appendix C.

Two potential additional control actions were proposed for consideration to further understand the provision of food resources for the Macquarie perch population following the FMPWG risk workshop (Appendix B).

Macrophyte Reed Beds establishment

The existing macrophyte beds in the Cotter Reservoir prior to enlargement provided important resting habitat to Macquarie perch (Roberts, 2006, Ebner and Lintermans, 2007; Lintermans 2012). Macrophyte cover was dominated by tall emergent macrophytes, mainly Cumbungi (*Typha domingensis*) and Common Reed (*Pragmites australis*) (Roberts 2006). Inlets, although much smaller, were broadly similar but typically had also Tall Spike-rush (*Eleocharis* sphacelata) so had higher overall species richness (Roberts, 2006). These beds were drowned by approximately 50 metres of water due to the filling of the enlarged reservoir, and as such a

significant portion of the beds were lost. As operation of the reservoir is presently estimated to remain within three metres of the FSL for 84% and at FSL for 57% of the time, there is potential for new macrophyte beds to establish provided that reservoir water levels do not rapidly fluctuate, however rapid fluctuation of reservoir levels is considered unlikely (Broadhurst et al. 2018).

The establishment of reed beds would increase the habitat of terrestrial macroinvertebrates and aquatic insect larvae such as mayflies, caddisflies and midges which form an important portion of the diet for Macquarie perch within the Cotter Dam (Norris et al. 2012; Hatton 2016).

Monitoring of the natural succession and formation of reed beds within the reservoir is assessed within the *ECR Fish Monitoring Program* under management question 9: "*Have macrophyte beds re-established in the enlarged cotter reservoir*?", however to date no significant beds have formed (Broadhurst et al. 2017; Broadhurst et al. 2018). Ongoing on-ground survey of the perimeter of the reservoir for signs of established macrophytes will occur monthly during spring and summer as a component of this program.

A recognised knowledge gap therefore currently exists in reference to reed bed establishment and its future likelihood and feasibility within the reservoir. As such, further research may aim to determine:

- Is the manual establishment of reed beds an effective or viable contribution to improving food resources for Macquarie perch?
- Which species and physical structure of reed beds are best suited for the conditions of the reservoir and catchment in facilitating the provision of food resources for Macquarie perch?
- What are the artificial options for reed bed establishment that provide the greatest benefit to supporting food resources for Macquarie perch?
- What the preferred management options are to establish reed beds within the reservoir?

The FMPWG will consider the benefits of this additional research with consideration to funding and responsibilities of stakeholders following the development of this plan. Any additional research contributing to the understanding of macrophyte beds in the reservoir may trigger a review and update of this FMP.

Riparian vegetation fringing the reservoir

The enlargement of the Cotter Reservoir resulted in the submersion of a significant portion of native riparian vegetation surrounding the existing reservoir, with the 2003 bushfires removing non-native vegetation of areas that are now riparian. Fluctuating water levels due to the operation of the enlarged reservoir may furthermore prevent the re-establishment of native riparian vegetation (Lintermans 2012). Loss of riparian vegetation is identified as a threat to Macquarie perch as it provides habitat to a range of terrestrial macroinvertebrates which contribute to its diet, as well as provides shading which can mitigate avian predation pressure during spawning migrations through the inundation zone at the top of the reservoir. Due to the loss of this habitat, it is expected that as the reservoir ages, terrestrial invertebrate food sources of Macquarie perch may diminish. Lack of shading or refuge from avian predation may reduce spawning success and recruitment of the population (Lintermans 2012).

Monitoring of the food resources within the reservoir is carried out as a component of the ongoing *ECR Fish Monitoring Program* under management question 10: "*Are there adequate food sources for the Macquarie perch following the filling and operation of the ECR?."* The edges of the rocky and bare shores and the woody habitat adjacent to the reservoir are sampled bi-annually in spring and autumn, which also includes sampling for instream food sources through plankton tows. This information provides a relative abundance and insight into the

composition of food resources available to Macquarie perch during the operation of the reservoir, and informs whether any additional management measures may be required over time, in consultation with the FMPWG.

Most recent findings from ongoing monitoring suggests that the minor food resource differences between baseline and the current phase are likely to fall within natural annual and sampling variation. As such, no additional management intervention is suggested at present (Broadhurst et al. 2018).

Monitoring of cormorant abundance is assessed as a component of the ongoing *ECR Fish Monitoring Program* under management question 8 "*Has there been a significant change in the abundance, distribution and species composition of piscivorous birds in the vicinity of the enlarged Cotter Reservoir as a result of the filling and operation of the Cotter Dam?"*. The most recent findings from ongoing monitoring indicate that cormorant's abundance and distribution has changed since the ECR commenced filling, but that the major cormorant threat (Great Cormorant) has not changed significantly (Broadhurst et.al. 2018). Further details on Cormorant Management are described in Risk M3. Increased Great Cormorant Predation (Risk 4, Appendix B)

Existing riparian vegetation surrounding the reservoir falls under the management responsibility of ACT Parks and Conservation Service (PCS) as the land manager. For example, in the Lower Cotter Catchment, PCS and ACT Conservation Research are trialling the planting of *Casuarina Cunninghamiana* (River Sheoak) near the FSL and will monitor survival with variation in water levels. Any additional management measures or recommendations informed by the *ECR Fish Monitoring Program* and Icon Water, such as additional research, will be assessed by the FMPWG and if deemed necessary, coordinated with ACT Parks and Conservation.

H2. Cold Water Pollution (Risk 7, Appendix B)

Current Controls
• Monitoring of water temperature upstream and in the reservoir and selective environmental releases (as practicable) from Bendora Reservoir in accordance with Icon Water's Licence to Take Water
Potential Additional Controls
• Implement targeted Bendora Reservoir thermal spill release (from Corin Reservoir)
• Explore options for use of variable offtakes and release at Bendora Reservoir

The impacts of cold water pollution, namely from deep water discharges from impoundments, on a range of organisms including fish and macroinvertebrates are well known (Astles et al. 2003; Sherman 2000). The effect on threatened species such as Macquarie perch spawning and recruitment is of particular concern as the life-cycles of such species are finely turned to natural daily and seasonal variations of temperature particularly as a spawning trigger. Cold water slows growth rates, lengthening the exposure of small or juvenile fish to predation. Large volumes of cold water, such as that derived from impoundments, can lower the overall temperature of water downstream, disturbing ecological adaptions integral to the ongoing success of fish populations (Astles et al. 2003; Starrs et al. 2009).

Release valves for downstream flows from Bendora Dam are manually controlled, requiring operators to travel to the dam to carry out any changes. This manual operation makes step-up or step-down of releases difficult in practice when required on a frequent basis, or in adverse conditions such as snow or severe wet weather.

The abstraction of water from the source waters of Bendora reservoir is primarily to supply raw water for treatment and distribution for community drinking. Abstraction at Bendora Dam is provided through a variable offtake, dependent on water quality suitable for the treatment plant. The separation of water abstraction for treatment and the water abstraction for below dam release is not possible as the same intake pipework is used for both purposes. As such, Icon Water has limited capacity to regulate the temperature of flows provided to the Cotter River when the Bendora reservoir is less than the FSL and the dam is not overtopping. However, under certain conditions, (e.g. when Corin is full and Bendora is full) there is capacity to allow Bendora surface water to overtop providing optimal thermal release conditions.

Although it would be preferable to have an independent and variable offtake to provide for environmental flows to the Cotter River, the capital cost and engineering constraints associated with retrofitting the dam wall deem this option unviable at present. As such, within the operational constraints of supplying the best quality water for treatment and distribution, Icon Water will endeavour to release water below the dam to the Cotter River that is similar temperature of the water entering the reservoir where practical. This is a requirement under clause A.2.1 of Icon Water's *Licence to Take Water* (*WU67*) and is monitored by Icon Water's ongoing water monitoring program. In circumstances where Bendora dam is near FSL, a targeted release from the dam through overtopping can be implemented to achieve this objective.

Icon Water monitors the water temperature in the Cotter River with on-line gauges immediately below the Bendora Reservoir discharge (gauge 410747) and at Vanities Crossing, upstream of the Cotter Reservoir (gauge 410725). These data informs the adaptive management of water releases particularly during the core Macquarie perch spawning season.

Cold water pollution is not specifically mentioned in the ECR monitoring program, but the impacts of cold water pollution are addressed (e.g. lack of recruitment of key species).

The proposed additional controls at present are considered unviable in improving the cold water pollution risk within and downstream of the Cotter reservoir. Existing management measures and controls abovementioned are considered as adequate in achieving the protection of threatened species.

Medium Risks

M1. Increased abundance of Alien Fish (Risks 3 / 8, Appendix B)

Current Controls
• Implement management options described in section 3.2 of the Alien Fish Management Plan (Appendix I) following approval by the FMPSC
• Report illegal fishing to PCS who as the land manager is the delegated authority for pursuing compliance matters
• Implement controls described in section 3 of the EHN Virus Management Plan related to fish vectors of EHN virus (e.g. Redfin perch)
• Implement the ECR Fish Monitoring Program to define trigger levels and inform adaptive management controls of alien fish
• Educate Icon Water contractors who are working in the catchment and inspect work sites to reduce the risk of transfer of alien fish eggs on vehicles and equipment
Potential Additional Controls

- **Monitor for trout predation on Macquarie perch larvae, and if trout are demonstrated to impact larvae, implement additional management options described in the Alien Fish Management Plan following approval by the FMPSC**

The initial review of risks to threatened fish (Lintermans 2005) and the subsequent 2010-2013 baseline *ECR Fish Monitoring Program* (Lintermans et al. 2013) identified a likely increase in alien fish numbers in the Cotter Reservoir following construction of the enlarged Cotter Dam and identified the importance of managing trout impacts on Macquarie perch and Two-spined blackfish. The FMPWG risk assessment also identified the need for an *Alien Fish Management Plan* (under the *Fish Management Plan*), which was consequently developed and includes management and mitigation measures to ensure predation risks to native fish are managed. The existing data set from the ECR monitoring program is now mature enough to interrogate to set meaningful threshold values for alien fish abundance.

The development and implementation of the adaptive *Alien Fish Management Plan* (Appendix I) ensures Icon Water meets its regulatory obligations with regard to the management of alien fish species in the Cotter Reservoir and upstream in the Cotter River. Note that the Alien Fish Management Plan is designed to be an adaptive document and triggers and management actions will be developed as more information becomes available The plan identifies the need for monitoring of alien fish numbers in the Cotter Reservoir and river. This work is undertaken annually though the *ECR Fish Monitoring Program* and is specifically related to the following management questions:

4. *Has there been a significant change in the abundance, distribution and size composition of adult trout in the enlarged Cotter Reservoir as a result of filling and operation?*

5. *Has there been a significant change in the abundance and size composition of trout in the Cotter River upstream of the enlarged Cotter Reservoir as a result of the filling and operation?*

6. *Are two-spined blackfish and Macquarie perch present in trout stomachs in the Cotter River?*

7. *Has there been a significant change in the abundance and distribution of non-native fish in the enlarged Cotter Reservoir as a result of the filling and operation?*

Most recent findings from the ongoing *ECR Fish Monitoring Program* in relation to alien fish found that in 2018 there was no difference in the abundance and size of Rainbow trout in Cotter Reservoir and Cotter River compared to any other year of monitoring (Broadhurst et al. 2018). Brown trout abundance in the Cotter Reservoir however has increased in the past two years, and could lead to changes in predation upon Macquarie perch and Two-spined blackfish. Anecdotally, Brown trout are considered more piscivorous and as such, potentially more damaging to threatened fish populations of Macquarie perch and Two-spined blackfish than Rainbow trout (NSW Fisheries, 2003). The 2018 ECR monitoring report recorded the first documented predation on Macquarie perch in the ACT, and it was by a brown trout.

Alien species besides trout continue to be detected in the reservoir, particularly Goldfish which initially increased during filling, but have decreased over the past three annual assessments, so much so that most recent monitoring reflects that of baseline years (Broadhurst et al. 2017; Broadhurst et al. 2018). This decrease in Goldfish abundance is likely a reflection of a slowing of the productivity from the newly-filled reservoir (Kimmel and Groeger 1986; Ploskey 1986; O'Brien 1990). Goldfish pose minimal direct threat to the threatened species of concern (Macquarie perch and Two-spined blackfish), however their increase in abundance immediately after filling and subsequent apparent decline to approach baseline levels may have flow on effects to the size and abundance of potential predators (both cormorants and trout) which could be of concern in relation to their respective predation on threatened species (e.g. Beukers-Stewart and Jones 2004; Baker and Sheaves 2005). The predatory Redfin perch remain undetected within the Cotter Reservoir (Broadhurst et al. 2018).

Should alien fish numbers or predation levels increase to unsustainable levels, or additional alien fish species become established (e.g. Carp, Redfin perch), options to address the issue

will be discussed further at the FMPWG and FMPSC meeting(s) in order to better understand the environmental, social and financial implications of their implementation. Several management options have already been proposed for more detailed consideration in the *Alien Fish Management Plan* (Appendix I), and include:

- Targeted harvesting of trout spawning runs for consequent removal the Cotter River directly upstream of Cotter Reservoir
- A trout trap on the Cotter River immediately upstream of Cotter Reservoir, designed to trap spawning trout for consequent removal from the Cotter system
- Targeted angling efforts during trout spawning season for consequent removal from the Cotter system
- Targeted riverine electrofishing in the Cotter River directly upstream of Cotter Reservoir
- Research to understand predation on Macquarie perch larvae from trout through stable isotope analysis or Environmental DNA methods.

Although visually detectable predation rates of post-larval native species by trout remain absent (for Macquarie perch) to low (for Two-spined blackfish), there is little confidence in the detectability of such instances, particularly for larval Macquarie predation (Ebner et al. 2007). Continued development of genetic testing methods, (detection of DNA in gut contents) would enhance confidence in whether or not trout prey on larval Macquarie perch. Options to address this recommendation, and those above will be assessed with considerations to budget and responsibility, and determined by the FMPWG.

M2. EHN Virus (Risk 9, Appendix B)

Current Controls
• Report illegal fishing to PCS who as the land manager is the delegated authority for pursuing compliance matters
• Implement controls described in section 3 of the EHN virus management plan
• Inspect Fish Monitoring Program Reports to inform potential management actions if threatened fish are exhibiting signs of infection
• Educate (Toolbox) Icon Water staff and contractors who are working in the catchment and enforce compliance with wash-down procedures
Potential Additional Controls
None identified

Epizootic Haematopoietic Necrosis (EHN) Virus is a native ranavirus of the Iridoviridae Family, and is associated with sudden high fatality rates in fish especially during spring and summer (Langdon et al., 1985). The Macquarie perch is a species known to be susceptible to EHN mortality (Langdon 1989; Whittington et al. 2011).

Once EHN Virus has entered a water body it is considered impossible to eradicate (Whittington et al., 2007). Within the reservoir, EHN virus and its major vector (Redfin perch) are not known to be present (Whittington 2008). However, during construction of the enlarged Cotter Dam there was a high risk of transporting the virus into the reservoir and catchment. Consequently, a range of defined rigorous protocols and mitigation measures were applied through the construction period and are summarised in Appendix C.

Throughout operation of the dam, it was agreed upon by the FMPWG that there is low risk of EHN virus entering the catchment by Icon Water's activities opposed to other land management practices and recreational pressures. With the aim of mitigating the residual risks, the *EHN Management and Response Plan* (Appendix E) was established to ensure that the likelihood of EHN Virus entering the Cotter Reservoir is appropriately monitored and managed within the capabilities of Icon Water.

The *EHN Management and Response Plan* requires Icon Water to monitor for visual signs of EHN Virus infection in fish in the Cotter Reservoir and upstream in the Cotter River. The ACT Government is required to be notified of any suspected EHN virus infections. This requirement is ongoing and is addressed through regular assessment in the *ECR Fish Monitoring Program*.

To date there has been no obvious visual indications of EHN infection within the reservoir, and the *ECR Fish Monitoring Program* has never detected the presence of the key vector (Redfin perch) (Broadhurst et al., 2016). Monitoring of the fish community in the Cotter River between the ECR and Bendora Dam is also conducted by ACT Government (ACT Government, 2016) and any detection of Redfin perch would trigger an emergency response. To assist in the ongoing avoidance of EHN virus within the dam, a specific work instruction for all personnel working near or in water was developed to assure the spread of the virus is avoided. This work instruction is attached to this FMP in Appendix E, however should be confirmed as to date with Icon Water's IMS system when used.

Any detection or potential detection of EHN virus throughout the operation of the Cotter Dam will be reported as per the protocols outlined in the *EHN Management and Response Plan* and work instruction (Appendix E).

Potential detection of EHN Virus could include the observation of Redfin perch or dead fish within the reservoir or the Cotter River upstream of the dam wall. Noted signs of the infection are assessed in all research involving the capture of Macquarie perch such as the *ECR Fish Monitoring Program*. Any potential detection will trigger advice to the ACT Government to conduct necessary sampling and testing to determine the presence, or absence of EHN Virus. If the EHN Virus is confirmed to be present in the reservoir, it is expected that the ACT Government will then notify the relevant agencies at State, Territory, National and International levels. The World Organisation for Animal Health (Office International des Epizooties) (OIE) would also need to be notified in accordance with Australia's international obligations.

M3. Increased Great Cormorant Predation (Risk 4, Appendix B)

Current Controls
• Constructed rock reef provides shelter/refuge habitat for Macquarie perch
• Native submerged hardwood provides shelter/refuge habitat
• Implement the monitoring and management actions specified in the Cormorant Management Plan
• Operate the destratification mixers in accordance with the Destratification operation plan to reduce the impact of low dissolved oxygen in the water column
Potential Additional Controls
None identified

Three species of cormorants are found regularly at the Cotter Reservoir being the Great cormorant (*Phalacrocorax carbo*), Little black cormorant (*Phalacrocorax sulcirostris*) and the Little pied cormorant (*Phalacrocorax melanoleucos*) (Lintermans, 2005; Broadhurst et al. 2018).

All three species of cormorants have been found to prey on Macquarie perch either from dietary analysis, or radio telemetry (Ebner and Lintermans 2007, Lintermans et al. 2011, Lintermans 2013). Although all species are known to prey on Macquarie perch, it is believed that Great cormorants pose the most significant direct predation risk on the species, particularly in the Cotter Reservoir due to their ability to prey on larger fish individuals compared to the other two species (Lintermans et al. 2011).

Prior to construction of the enlarged Cotter Dam, the interaction between cormorants and Macquarie perch within the reservoir was mediated by abundant fringing emergent macrophytes which provided diurnal refuges for adults (Ebner and Lintermans 2007; Lintermans et al. 2010; Lintermans 2012). Due to the increase in water levels associated with the inundation of the reservoir, these macrophytes have now been submerged, with limited replacement cover provided by constructed rock reefs and submerged hardwood as outlined in Appendix C.

The abundance of cormorant species in the Cotter catchment varies seasonally, with the greatest numbers occurring in spring and summer. This period is also when the greatest likelihood that stratification of the water column is to occur due to the warming of surface water layers. This would place increased predation pressure on Macquarie perch during this time as reduced oxygen in the lower reaches of the water column may force the species closer to the surface, as such making them more susceptible to avian predation.

Management of this risk to Macquarie perch is addressed through the operation of the de-stratifiers within the reservoir, and additional management measures following dissolved oxygen triggers in the *Cormorant Management Plan* (Appendix G). Operation of the de-stratifiers is determined by these triggers and the *Destratification Operation Plan* (Appendix F).

Should the dissolved oxygen trigger levels in the reservoir be reached, or cormorant abundances exceed the trigger levels specified in the *Cormorant Management Plan* (summarised in Table 4 below), the cormorant control program as per the *Cormorant Management Plan* (Appendix G) may commence. The control plan may also be implemented if nesting by Great cormorants is detected around the reservoir via ongoing monitoring programs such as the *ECR Fish Monitoring Program* management question 8 - *Has there been a significant change in the abundance, distribution and species composition of piscivorous birds in the vicinity of the enlarged Cotter Reservoir as a result of filling and operation?*

Table 4: Cormorant abundance triggers for the ECR by species and season (*Cormorant Management Plan*)

Species	Summer	Autumn	Winter	Spring
Great cormorant	50	40	27	43
Little black cormorant	37	9	18	9
Little pied cormorant	55	52	37	15

The cormorant control program was developed and subsequently refined during the filling phase of the Cotter Dam, and provides a range of methods for deterring cormorants within the catchment. Management actions are intended to reduce the number of cormorants at the reservoir through a range of on-ground actions, reporting, notification and governance.

All reporting regarding cormorant survey results, and any management actions employed or recommended will be provided by the FMPWG with reports formally tabled at FMPSC meetings.

M4. Drawdown of reservoir and sedimentation of river reach (Risk 5, Appendix B)

Current Controls
• Reservoir operating level and inflow management during spawning informed by *ECR Fish Monitoring Program* monitoring report
• Environmental flows including riffle and pool maintenance flushes.
Potential Additional Controls
None identified

The risk of drawdown and the associated impact on sedimentation of the river reach are primarily addressed through Icon Water's adaptive operational processes and the management of environmental flows throughout the Cotter Catchment.

The primary objective in operating the Cotter Dam is to retain provision of drinking water supply to the Canberra region. As such, extensive reservoir drawdown may occur in periods of drought, high water demand or low water quality to maintain drinking water provision, prior to the Macquarie perch spawning season (October – December). Drawdown below reservoir FSL due to such circumstances may inhibit both the quality of, and access to spawning habitat by Macquarie perch due to increased sedimentation in pools and riffles where they lay eggs, and the exposure of barriers preventing the upstream movement to these pools and riffles respectively.

To mitigate the potential impact of reservoir drawdown on Macquarie perch spawning, a FMPWG spawning review will be carried out in approximately July each year when the dam is either operational, or likely to become operational during or prior to that years spawning season. The timing of this review will enable detailed long-term forecasts relating to the reservoirs predicted operational level to be considered and aligned with likely barrier exposure, as well as enable adequate lead time to provide additional management actions to reduce the impact on Macquarie perch spawning.

Management actions to reduce the impact of drawdown on Macquarie perch spawning will be assessed and adaptively managed each year, but may include:

- Increasing reservoir level by reducing abstraction from the Cotter Dam
- Increasing reservoir level by increasing downstream flows from Bendora Dam
- Provision of flushing flows (such as pool and riffle maintenance flows) from Bendora Dam
- Actions must consider requirements of the EPBC Act, Environmental Flow Guidelines and other relevant legislation.

Icon Water's release of environmental flow into the Cotter Reservoir via the Cotter River from Bendora Reservoir has key linkages in ensuring riverine ecosystem health. They are also integral to the ongoing spawning success of the Macquarie perch population within reservoirs (Cadwallader and Rogan 1977; Lintermans 2007; Tonkin et al. 2010). Flow releases from Bendora Reservoir are strictly regulated by the ACT EPA under Icon Water's *Licence to Take Water* (WU67), which in turn is developed with reference to the *Environmental Flow Guidelines.*

In water supply catchments, a balance between water supply and environmental needs has to be made. Although drinking water supply for the community is the primary objective for the Lower Cotter Catchment, there is a requirement to maintain the health of the rivers, and in

particular to protect threatened aquatic species. The environmental flows that are recommended for release from Bendora Reservoir are based on extensive information about environmental flows in the Cotter River (ACT Government, 2018). Flows specified for these catchments are the minimal requirement for healthy aquatic ecosystems, while ensuring that both water supply and conservation objectives can be met. This approach is appropriate for these catchments as the intensive monitoring of the system allows adaptive management to be implemented if adverse effects are detected.

The licence, with reference to the *Environmental Flow Guidelines*, defines different levels of environmental flow protection at various levels of water restrictions being experienced by ACT. The releases from Bendora Reservoir into the Cotter River and ultimately from downstream of the Cotter Dam include base flows, riffle flows and pool flushing flows (as summarised in Appendix A), each of which perform various ecosystem functions. Special rules for drought periods have also been considered for this catchment as it is recognised that during dry times when the urban population faces water restrictions, it is appropriate that environmental flows also be reduced. Previous research has shown that drought flows in the Cotter River can still facilitate spawning of Macquarie perch, provided fish can access suitable spawning sites (M. Lintermans unpubl. data).

The purpose of environmental flows are to protect the river and the aquatic species which rely on and reside within the Cotter River and reservoir. The setting of ecological objectives within the *Environmental Flow Guidelines* enables specific ecological values to be targeted by components of the environmental flow regime and can be used to develop an adaptive management approach for these flows. For example the Guidelines specify ecological objectives for the Cotter River reach between the Bendora and Cotter Dams as: *To maintain populations of Macquarie Perch Young of year and year 1+ ages classes comprise >30% of the monitoring catch, and >40 fish captured per standard monitoring effort.*

Ecological objectives relevant for the Cotter Dam are outlined in *Environmental Flow Guidelines*, summarised in Appendix A.

M5. Exposure of instream barriers during Macquarie perch spawning season exacerbated by water level and flow (Risk 6, Appendix B)

Current Controls
• ***Reservoir operating level and inflow management during spawning informed by*** *ECR Fish Monitoring Program* ***monitoring report*** *and the* ***Annual Spawning Management Plan*** developed in conjunction with subject matter experts and endorsed by the FMPWG
• Compliance with licenced environmental flows in accordance with Icon Water's ***Licence To Take Water***
Potential Additional Controls
• Prepare guidelines that detail the target for spawning in successive years
• Management of barriers (requires annual identification of relevant barriers) including mitigation options (e.g. flows, fishways, translocation)
• Continue to gather information and conduct research to inform the adaptive management of reservoir levels and river flows in order to mitigate the impact of instream barriers. This includes: resuming the acoustic monitoring project; continuing riffle spawning habitat identification of important spawning habitats; and, installation of a pit tag station in the alien fish management structure (i.e. fish trap)

Macquarie perch require flowing water to spawn, as they lay their eggs in the runs and riffles where the flowing water keeps the eggs oxygenated and clear of sedimentation (Cadwallader & Rogan 1977; Lintermans 2007). A lack of consecutive successful spawning years since the filling of the Cotter Dam suggests that the presence of natural instream barriers may be preventing adults from accessing spawning habitats upstream of the reservoir (Broadhurst et al., 2017). Following the first two years of recruitment failure for Macquarie perch in the reservoir, a review of potential management options to address recruitment failures was prepared by the independent fish advisor to Icon Water (Lintermans 2015). These options are revisited annually as part of the development of the annual spawning plan.

In 2013, Icon Water funded a research project with the University of Canberra to investigate the location of barriers and the influence of these on Macquarie perch passage and spawning during the filling of the Cotter Dam. This project successfully characterised the location and behaviour of instream barriers to Macquarie perch passage (Broadhurst et al. 2016). Subsequently an additional research project commenced in July 2017 involving acoustic tagging of a representative sample of Macquarie perch and installation of acoustic monitoring stations along the Cotter River upstream of the FSL of the ECR (Broadhurst et al, 2018). Acoustic monitoring aimed to determine the timing and extent of Macquarie perch movements out of Cotter Reservoir, and how these movements are influenced by the discharge and presence of natural instream barriers.

The findings of the acoustic monitoring of Macquarie perch found that the majority of movements occurred during low light periods (between 5pm and 6am) with adults exiting the reservoir during the spawning window of October – December with discharges ranging from 101 – 177Ml/day (Broadhurst et al. 2018). Instream barriers to passage (known as Barriers 36 and 37 from Broadhurst et al. 2016) were passed by Macquarie perch, however no tagged individuals were detected upstream of Barrier 38. The failure of the species to surmount barrier 38 for two successive spawning years suggests that this barrier may be preventing upstream passage, even during high flow conditions (Broadhurst et al. 2018). Furthermore, Macquarie perch have not successfully spawned when the Cotter Reservoir has been below the FSL since filling commenced. As such, successful spawning has only occurred when the reservoir has been full and access to riffles upstream has been facilitated by flows.

Barriers identified within the reservoir and upstream of the FSL of the reservoir (Broadhurst et al. 2016) with their respective characteristics relevant to the passage of Macquarie perch are summarised in Figure 4 and Figure 5 and Table 5 below. The barriers identified are natural impediments to fish passage and are subject to movement and wash out under high flow scenarios.

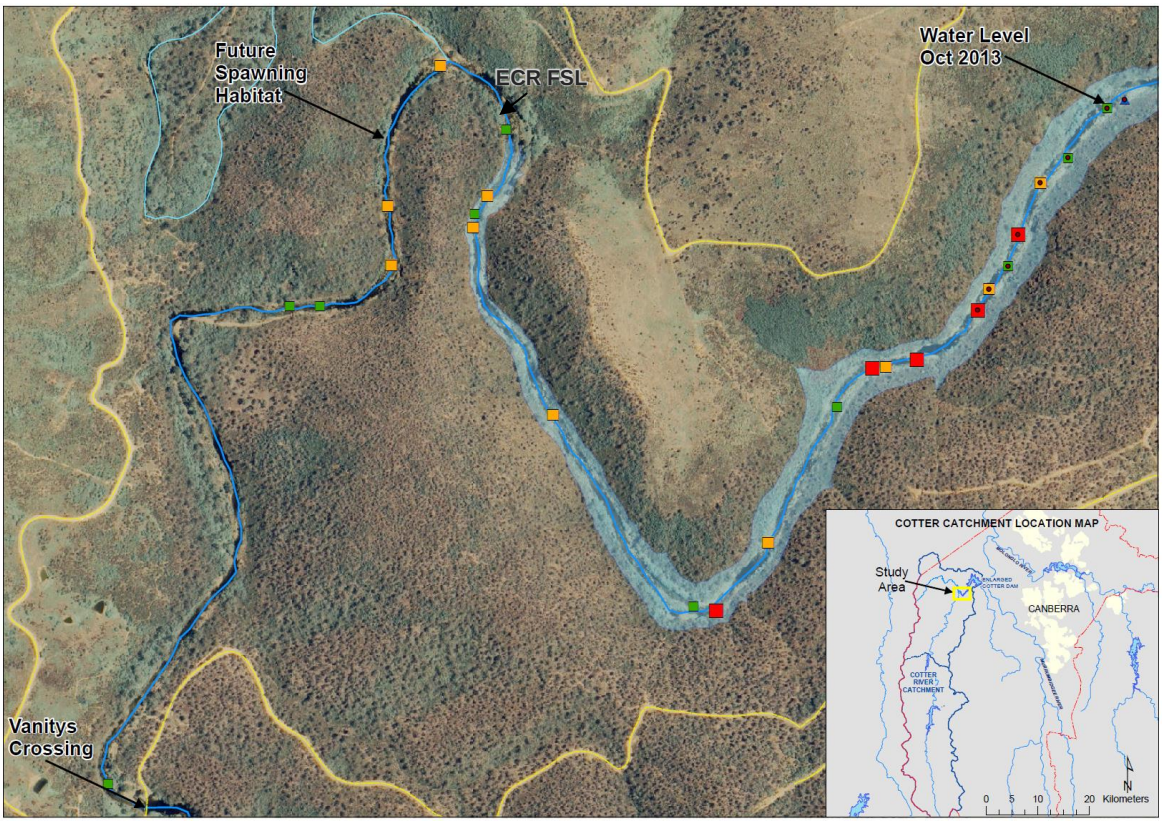

Figure 4: Location of identified barriers within the priority reach (Cotter Reservoir to Vanity's Crossing) for Macquarie perch (Broadhurst et al. 2016). Refer to Legend in Figure 5.

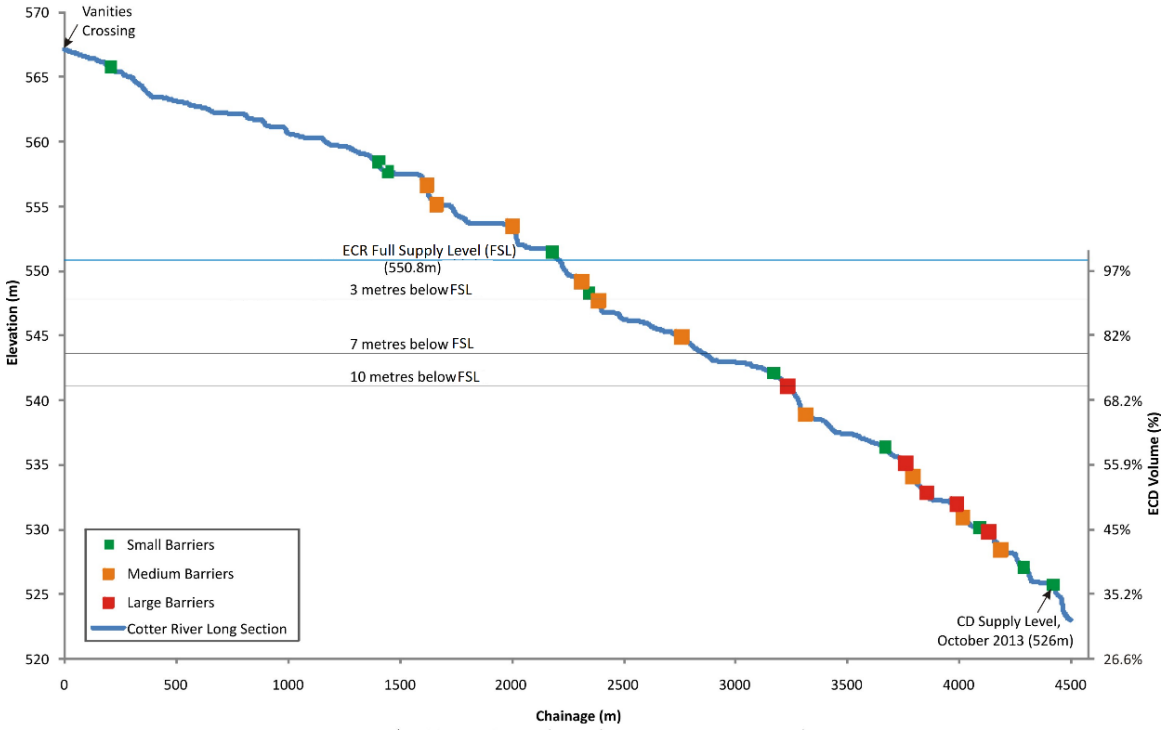

Figure 5: Cross-section and location summary of the identified barriers within the likely operating range of the ECR (Cotter Reservoir to Vanity's Crossing, Broadhurst et al., 2016) compared to the ECR FSL

Table 5: Natural instream barrier details identified within the likely operating range of the Cotter Reservoir to Vanity's Crossing for Macquarie perch within the Cotter River (Broadhurst et al. 2016).

Note that the elevation of the ECR FSL is 550.8m ASL.

Section	Barrier no.	Type	Height	Altitude (m ASL)	X coordinate	Y coordinate
Cotter Reservoir – Pierces Creek	1	Small	N/R	~503	674323	6090133
	2	Medium	N/R	~505	674107	6089951
	3	Small	N/R	~507	674058	6089655
	4	Small	N/R	~507	674023	6089561
	5	Small	N/R	~508	674007	6089476
	6	Small	N/R	~510	673872	6089259
	7	Small	N/R	~512	673787	6089139
	8	Small	N/R	~512	673753	6089085
	9	Small	0.2-0.4m	~516	673608	6088859
	10	Small	.15m	~516	673637	6088783

	11	Medium	0.2-0.4m	~516	673629	6088764
	12	Medium	0.7m over 30m	~519	673564	6088361
	13	Medium	0.3	~521	673569	6088274
Pierces Creek – Cotter Dam FSL	14	Large*	1.6m	~522	673548	6088216
	15	Small	0.1-0.15m	~522	673524	6088191
	16	Large*	1.2m	~524	673315	6088068
	17	Small	0.2-0.3m	~524	673287	6088054
	18	Small	0.2m	~525	673224	6087974
	19	Medium	0.5m	~525	673179	6087934
	20	Large*	0.8m	~527	673143	6087850
	21	Small	0.2m	~527	673127	6087799
	22	Medium	0.4m	~528	673096	6087762
	23	Large*	1.05m	~529	673078	6087728
	24	Large*	1.0m	532.852	672979	6087648
	25	Medium	0.3m	534.010	672929	6087636
	26	Large*	0.8m	535.099	672907	6087634
	27	Small*	0.35m	536.422	672851	6087572
	28	Medium	0.3-0.4	538.881	672739	6087353
	29	Large	0.7m	541.076	672655	6087243
	30	Small	0.2-0.3m	542.125	672619	6087249
	31	Medium	0.2-0.3m	544.871	672392	6087559
	32	Medium	0.4-0.7m	547.657	672263	6087862
	33	Small	0.1-0.2m	548.287	672266	6087884
	34	Medium*	0.35m	549.204	672286	6087913
Cotter Dam FSL – Vanitys Crossing	35	Small	0.1-0.15	551.445	672317	6088020
	36	Medium*	1m over 21m	553.438	672210	6088123
	37	Medium	0.3	~555	672125	6087896
	38	Medium*	0.5	~556	672131	6087801
	39	Small	0.2m	~557	672016	6087735
	40	Small	0.1-0.2m	~558	671967	6087735
	41	Small	0.2m	565.712	671674	6086963

*indicates barrier was monitored in *Broadhurst et al. 2016* to determine the effect of changes to flow on Macquarie perch passage upstream.

To deliver greater confidence in the ongoing spawning of Macquarie perch during the operation of the Cotter Dam, a range of recommendations for further assessment are provided.

- Acoustic monitoring of the headwaters of the reservoir and river upstream to determine if passage to suitable spawning habitat can be facilitated by existing environmental flow releases, or increased special purpose releases aimed at mitigating natural barriers to passage. Additional details of this project is provided in Appendix C.
- If the above recommendation is implemented and the reservoir is below FSL, an assessment of the sample size of active Macquarie perch remaining in the reservoir to provide a robust representation of spawning movements for the reservoir population.
- Characterisation of Barrier 38 (Broadhurst et al. 2016) through velocity and depth profiling to confirm its limitations to fish passage.
- Characterisation of preferred Macquarie perch spawning riffles and pools. Additional details of this project is provided in Appendix C.

These recommended research measures will be discussed and evaluated by the FMPWG with consideration to benefit, cost and resourcing, with recommendations on implementation to be approved by the FMPSC. Any additional research or changes to existing projects resulting from these recommendations will be reflected in an update to this FMP.

The installation of a pit tag station as recommended as a proposed additional control by the FMPWG is presently considered unviable for the reservoir and Cotter River reach between the Cotter and Bendora Dam. The high capital and operational investment required, lack of present electrical infrastructure to power the station and the limits of detection through this method is deemed as uneconomical considering the potential outputs.

Low Risks

Four of the twelve risk areas identified by the FMPWG in the workshop were deemed as low risk for threatened fish species within the reservoir or river. This low risk rating was determined by either their inherent rare likelihood of occurrence, or minor consequence if they were to occur according to Icon Waters Risk Assessment Framework (Appendix B). As such, this level of risk was accepted by the FMPWG, and no additional controls beyond those presently in place were considered.

Further details on low risks can be found in Appendix B.

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Appendix A: Conditions of Approval and Operation

Construction and Filling

Approval for the construction of the enlarged Cotter Dam was required under the Territory *Planning and Development Act 2007* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Territory matters were assessed by the ACT Planning and Land Authority (ACTPLA) through Icon Water's (then, ACTEW) preparation of an Environmental Impact Statement (EIS) and a Development Application (DA). Commonwealth matters were assessed by the Commonwealth Department of the Environment and Energy (DoEE), formerly the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPAC) and prior to that, the Department of the Environment, Water, Heritage and the Arts (DEWHA) through Icon Water's preparation of a Public Environment Report (PER).

The conditions of approval relevant to the FMP and the management of threatened aquatic species are presented below.

ACTPLA conditions of approval

The table below summarises the conditions of approval relevant to the management of aquatic species, as detailed in the notice of decision issued by the ACT Minister for Planning on 16 September 2009.

ACTPLA Conditions of Approval

Obligation Title	Condition	Status/ Comment
Part A: Administrative conditions		
	A3. That prior to the commencement of construction works on site, the applicant/lessee shall nominate an independent person who will be approved by ACTPLA to audit and ensure that all conditions of approval set out in the decision by ACTPLA, under the EPBC Act are fully completed in accordance with condition A4 with this decision.	**Condition met.** Vantage Environmental Management was nominated by Icon Water (then ACTEW) and endorsed by ACTPLA as the independent person.
Audit of requirements of conditions of approval	A4. That prior to the completion of work, the applicant/lessee shall submit a report prepared and endorsed by the person identified under Condition A3 of this decision to provide demonstrated evidence that the mitigation measures set out in this decision and the decision made under the EPBC Act have been fully completed to the satisfaction of ACTPLA and the Department of the Environment Water, Heritage and the Arts (DEWHA).	**Condition met.** A report was prepared by the independent person appointed in accordance with Condition A3 using inputs from the Fish Management Program team and met the conditions of A4 and A5.
	A5. That prior to the completion of work, the applicant/lessee shall submit a report prepared and endorsed by the person identified under Condition A3 of this decision to provide demonstrated evidence that the Commitments set out	

	in the Environmental Impact Statement accepted by the Minister for Planning on 18 June 2009 have been fully completed to the satisfaction of ACTPLA and to the satisfaction of DEWHA.	
Part B: Prior to construction of works on site		
Map of areas of Environmental Significance	B15. A map that identifies areas of environmental significance, including areas identified for rehabilitation, offsets and for special consideration such as artificial fish habitat and research areas and endorsed by PCL, TAMS shall be submitted to and approved by ACTPLA prior to the commencement of construction works on site.	**Condition met.** ACT Government's PCL, TAMS approved the areas of environmental significance on 22 October 2009. Endorsement that this condition was satisfied was received and documented in ACTPLA correspondence 07 June 2011.
Part C: Prior to the construction of the main dam		
Fish Management Plan, Aquatic studies and results	C2. A Fish Management Plan and other aquatic ecology studies and their results and recommendations as required shall be submitted to and endorsed by PCL, TAMS and the Department of Environment, Water, Heritage and the Arts (DEWHA) (now DoE) prior to the commencement of the main dam.	**Condition met.** FMP versions 1 and 2 and other aquatic ecology studies were submitted to relevant agencies as required via the Fish Management Program Steering Committee (FMPSC) prior to the commencement of the main dam
	C3. That the results of condition C2. Fish Management Plan, Aquatic studies and results are implemented as required to the satisfaction of PCL, TAMS and DEWHA (now DoE).	**Condition met.** The results from FMP and aquatic ecological studies have been implemented as required following consultation with the FMPSC.

Commonwealth conditions of approval

The table below summarises the conditions of approval relevant to the management of aquatic species, as detailed in the notice of decision issued by the Commonwealth Minister for the Environment, Heritage and the Arts (now Department of the Environment and Energy) on 21 October 2009.

Commonwealth conditions of approval

Obligation	Condition	Status/ Comment
Environmental Flows		
	The person taking the action must operate the Enlarged Cotter Dam in accordance with the environmental flow requirements specified in the Environmental Flow Guidelines 2006 and the Water Resources Act 2007 (ACT) except for the prescriptive flow rates that are specified under other conditions in this approval.	**Condition met.** Condition being met as per ACT EPA Licence WU67. Ongoing operations will be amended to the updated *Environmental Flow Guidelines* once finalised.
Downstream Flows		

During construction and filling of the expanded Cotter Dam the person taking the action must:	a) Release a minimum of 34 megalitres (ML) of water per day into the Cotter River below the dam wall (calculated over a 12month period);	**Condition met - ongoing.** Flows are released in accordance with this condition through a combination or Murrumbidgee To Cotter flows and releases from Cotter Reservoir.
	b) Publish monthly reports presenting the amount of water released from the Cotter Dam.	**Condition met - ongoing.** Reports on the volume of water released into the Cotter River are published monthly on the Icon Water website.
	c) Undertake monitoring of baseline indicators of ecological health in the Cotter River below the dam wall and the Murrumbidgee River below the junction with the Cotter River.	**Condition met - ongoing.** The *Murrumbidgee Ecological Monitoring Program* (MEMP), *Below Dams Monitoring Program* and Icon Water's Lower Molonglo macroinvertebrate monitoring program are in place and meet this condition.
	d) Notwithstanding the requirement under paragraph 2 a., the person taking the action must provide a plan to increase the long term flows of the Cotter River for the approval of the Minister within 4 years of the date of this approval. The plan must provide for increases in the minimum flow regime under paragraph 2 a. to improve the ecological health of the Cotter river below the dam wall, and the Murrumbidgee River below the Junction with the Cotter River.	**Condition met.** Icon Water (then ACTEW) provided a plan to the Commonwealth to meet this condition in October 2013.
	e) Provide an annual report, demonstrating how the person taking action has been releasing downstream flows in accordance with the advice of Environment Flows Technical Advisory Group established by the ACT Environment Protection Authority to determine environmental flows.	**Condition met.** Annual reports detailing environmental releases have been published on the Icon Water' website.
	The plan approved under 2 d must be implemented.	**Condition to be met** following Commonwealth Government approval of the plan.
	All plans, reports and data required under 2b, 2c 2d and 2e must be published on the Icon Water (then ACTEW) website within 1 month of finalisation.	**Condition met - ongoing.**
Fish Management Plan		
	Within 6 months of commencement of construction of the Enlarged Cotter Dam, the person taking the action must	**Condition met.** Fish Management Plan (FMP) Version 2 was submitted to the Commonwealth within agreed timeframes.

	prepare and submit to the Minister for approval, a Fish Management Plan.	
	The person taking the action must consult with the ACT Government (Territory and Municipal Services) during the preparation and any future updating the Plan.	**Condition met.** Icon Water has maintained an ongoing dialogue with ACT and Commonwealth Governments through the Fish Management Plan Steering Committee (FMPSC). The preparation of this, and potential future Fish Management Plans will be undertaken in consultation with relevant Government agencies through this committee.
The Fish Management Plan must include the following:		
Ongoing management measures	a) Baseline information on the population of Macquarie Perch in the Cotter River catchment including estimates of population size, distribution and seasonal variation;	**Condition met.** The collection of baseline data forms part of the *ECR Fish Monitoring Program.*
	b) A monitoring program with the ability to detect at a statistical power of 0.8 or greater, any environmental harm to the Macquarie Perch population in the Cotter River catchment.	**Condition met.** The ongoing *ECR Fish Monitoring Program* addresses this requirement.
	c) Identification of thresholds for management intervention in relation to all measures implemented to manage and maintain a viable Macquarie perch population in the Cotter River catchment.	**Condition met.** Thresholds for management intervention were developed as part of the *Macquarie Perch Filling Phase Plan*. Thresholds for management interventions are reviewed as part of this Fish Management Plan. Refer to Section 3.3 Adaptive Management
	d) Identification, removal and monitoring of movement barriers for the Macquarie perch between the enlarged Cotter Dam and Bendora Dam.	**Condition partly met – ongoing investigations.** A range of investigations have been undertaken to identify barriers to fish passage in the Cotter River. A report outlining a range of potential options to mitigate the impacts of the instream barriers was prepared in 2015, with options revisited annually. A risk assessment will be held at the beginning of each spawning season to identify management measures, including consideration of timed environmental flow releases, to facilitate regular successful spawning. Pipeline Road Crossing has been remediated with a fishways installed to allow fish passage. Details on this are described in *Appendix C: Fish Management Plan Background and Projects.*

	e) Collection of information to describe the swimming ability of the Macquarie perch to inform the management of water levels between Bendora Dam and Cotter Dam.	**Condition met.** Research of the swimming capacity of Macquarie perch was completed in 2010; main findings are presented in *Appendix C: Fish Management Plan Background and Projects*.
	f) Identification, construction and monitoring of artificial Macquarie perch habitat in the enlarged Cotter Dam.	**Condition met.** Rock reef habitat has been constructed and was endorsed by the FMPSC. Monitoring of the Macquarie perch population is being undertaken as part of the ongoing *ECR Fish Monitoring Program.* Details of this program are presented in *Appendix C: Fish Management Plan Background and Projects.*
	g) Identification and implementation of design features, management measures and operating controls to prevent adverse impacts on the Macquarie perch population in the enlarged Cotter Dam.	**Condition met.** The dam and associated infrastructure was designed and will be operated in a way which prevents adverse impacts on the Macquarie perch.
	h) Design, implementation and monitoring of a predator control program to protect the Macquarie perch population in the enlarged Cotter Dam.	**Condition met.** A *Cormorant Management Plan* (Appendix G) has been developed by University of Canberra and endorsed by the Fish Management Program Steering Committee. The Plan will be enacted in the event that management thresholds are triggered.
Construction Management Measures	a) Identification and implementation of measures to sterilise the area between the existing Cotter Dam wall and the enlarged Cotter Dam from all aquatic fauna or pathogens that would adversely impact the Macquarie Perch;	**Condition met.** Sterilisation of the area between the old and enlarged dams was completed during construction. Procedures were endorsed by the FMPSC in March 2011.
	b) Monitoring of the Cotter River catchment for the presence of EHN virus and the development of a response plan in the event the EHN Virus is detected;	**Condition met.** Monitoring for the likely presence of EHN virus, through the presence of the known vector Redfin perch, continues to be conducted in the Cotter River catchment as part of the ongoing *ECR Fish Monitoring Program*. A response plan for the EHN Virus was developed and remains implemented for all works within the Cotter catchment. A work instruction addressing the preventative actions of Icon Water regarding EHN Virus in the catchment is attached in Appendix E.
	c) Develop and implement measures to avoid chemical spills and sedimentation impacting on water quality of the Cotter River and	**Condition met.** The Construction Environmental Management Plan and Erosion and Sediment Control Plan protected water

	downstream during construction of the enlarged Cotter Dam	quality and the surrounding environment through the construction of the enlarged Cotter Dam.
Translocation program	a) Identification of suitable recipient sites in the ACT regions for the translocation Macquarie Perch; b) Development and implementation of suitable methods to translocate Macquarie Perch; c) A monitoring program for translocated populations lasting a minimum of 20 years which includes a review at 5 years following commencement.	**Conditions met - ongoing.** The University of Canberra translocation project identified suitable methods and recipient sites for the translocation of Macquarie perch. Annual translocation of Macquarie perch has been undertaken since 2006. The monitoring of translocated Macquarie Perch populations is ongoing and is summarised to date in *Appendix C: Fish Management Plan Background and Projects.*
Funding and Responsibilities	a) Details of funding arrangements and parties responsible for the implementation of all aspects of the Fish Management Plan.	**Condition met.** Icon Water is responsible for the funding and implementation of the *Fish Management* Plan to satisfy the mandatory Commonwealth Conditions of Approval
Performance against Fish Management plan annual report	The person taking the action must implement the plan. Every year the person taking the action must submit to the minister a report covering performance against the Fish Management Plan. The date of the first report covering performance is to be provided on 19 January 2011, with each subsequent report to be provided 12 months from the date of the previous report.	**Condition not met (timeframe only).** The Performance Report was delivered to the Commonwealth on 18 February 2014 (due 19 January 2014). The delay on the delivery arose primarily from the time required by ACTEW to appropriately consider and address comments from ACT Government representatives regarding the Macquarie Perch Barrier project, reported in FMP V3. The Commonwealth was not advised of this delay due to an administrative error. Corrective actions were established and reported to the Commonwealth and accepted.
Publication Requirements		
	Management plans, reports, systems and programs (however described) referred to in these conditions of approval must be made publicly available on the Icon Water (then ACTEW) website as determined by the Minister.	**Condition met - ongoing.** All relevant Icon Water documentation identified in these conditions of approval is available on the Icon Water website.
Record Keeping		
	The person taking the action must maintain accurate records of activities associated with or relevant to the above conditions of approval, and make them available on request by the Department. Such documents may be subjected to audits by the Department and used to verify compliance with conditions of approval.	**Condition met - ongoing.** Records have been maintained throughout construction using an accepted compliance tracking system endorsed by the Fish Management Plan Steering Committee (FMPSC).

		Icon Water continues to maintain records throughout the operation of the Enlarged Cotter Dam

Operation

During operation, the Cotter Dam and reservoir is regulated for compliance with the *Water Resources Act 2007* (ACT) under Icon Water's *Licence to Take Water (WU67)* and the *ACT Environmental Flow Guidelines*.

Licence to Take Water (WU67)

Icon Water's *Licence to Take Water* (*WU67*) under the *Water Resources Act 2007 (ACT)* prescribes the conditions by which water can be extracted from the Cotter, Queanbeyan and Murrumbidgee rivers for the purposes of urban water supply for residents of the ACT. The structure of this licence is under review by the ACT Government to facilitate the integration of an Environment Management Plan (EMP) for the activities and risks associated with the capture and extraction of water. To enable this, the licence has been extended until 30 November 2018 to support the iterative process of the format change.

A range of key current licence conditions, relevant to the FMP are summarised below.

Licence to Take Water (WU67)

Obligation Title	Condition	Status/ Comment
General conditions	A 1.5 The licence holder is to comply at all times with requirements of the *Water Resources Act 2007* including the *Environmental Flow Guidelines*.	**Condition met – ongoing**
Environmental Flows	A 2.1 Temperature and any other characteristics of released water which can be practically adjusted by the licence holder shall approximate as closely as possible the natural characteristics of water at the particular location.	**Condition met - ongoing**
	A 2.5 Environmental flows below Cotter Dam are to be provided from either the Cotter Reservoir or from the Murrumbidgee to Cotter (M2C) system. Changes between the two systems must be undertaken over a minimum 24 hour period.	**Condition met - ongoing**
	A .2.9.3 and A2.10.3 A base flow of 15ML/day below Cotter Reservoir must be maintained at all times.	**Condition met – ongoing.**
	A 2.11 An adaptive management process will be used to operate the level of Cotter Reservoir and e-flow releases from Bendora to ensure protection for fish moving in and out of the reservoir during the October – December spawning season and to maximise water supply. The level of the Cotter Reservoir will be kept in accordance with an agreed reservoir management plan. This plan will be submitted to the authority for approval by 5 September each year.	**Condition met – ongoing.** An annual spawning plan for Macquarie perch will be prepared and endorsed by the FMPSC.

Monitoring	B. 2.1 A monitoring program shall be used to determine the effectiveness of environmental flows and the effect of the licence holder's activities in each of the water supply catchments.	**Condition met – ongoing.** Biennial monitoring conducted of the Two-spined blackfish population in the Cotter river. Annual monitoring of both Two-spined blackfish and Macquarie perch populations in the Cotter River included in annual *ECR Fish Monitoring Program*. Spring and Autumn Below Dams monitoring is conducted each year for instream condition assessment.
Reporting	C 2. Macroinvertebrate, periphyton and fish survey reports and data will be provided electronically within nine months of collection.	**Condition met – ongoing.**
Riffle Maintenance	D 5. If the Cotter catchment riffle flow requirements cannot be adhered to, the licensee shall undertake sampling and assessment consistent with the document *Riffle Maintenance Flows in the Cotter River, Proposal for assessment of reduction in the frequency of riffle maintenance flows.*	**Condition met – ongoing.**

Environmental Flow Guidelines

The Environmental Flow Guidelines are a key instrument under the *Water Resources Act 2007* which set out the flow requirements to maintain aquatic ecosystems across the ACT and apply to all rivers, streams, lakes and ponds.

The original guidelines were published in 1999, and were reviewed and revised in 2006 and 2013. The guidelines will continue to be updated approximately every five years to determine if the ecological objectives specified are the most appropriate, and that the environmental flows required are relevant in achieving those objectives.

The current guidelines (2013), are under review and are in draft form for final comment as the *Environmental Flow Guidelines 2018*. The changes anticipated from this update may influence the requirements of Icon Water to monitor and manage environmental flows in the ECR. For the purposes of this FMP, the draft *Environmental Flow Guidelines 2018* were used. Once these guidelines are finalised, the FMP will be reviewed to ensure consistency with the final flow and monitoring requirements.

The draft *Environmental Flow Guidelines 2018* summarised below prescribe the environmental release requirements from Cotter Dam to downstream catchments. The ecological objectives of these guidelines are to maintain riparian vegetation values and healthy aquatic ecosystems downstream of Cotter Dam by the appropriate management of environmental flows.

Environmental Flow Guidelines (2018)

Objective	Condition	Status / Comment
Base Flows	Downstream of Cotter Dam 15% or the 80th percentile of inflows, whichever is less	**Condition met - ongoing**

Riffle Maintenance Flow	A riffle maintenance flow of 100 ML/day for one day is to occur every two months. Each time a riffle maintenance flow occurs either by spill, or by release, the next flush must occur two months +/- 1 week after the last riffle maintenance flow.	**Condition met - ongoing**
Pool Maintenance Flow	No pool maintenance flows are specified for reaches downstream of final impoundments. If further monitoring and assessment determine the need for pool maintenance flows, they can be provided as a temporary requirement.	**Condition met - ongoing**
Drought Flows – All levels of restriction	The base flow downstream of Cotter Dam will be 15 ML/day. Riffle or pool maintenance flows for these reaches are not required during drought. If further monitoring and assessment determine the need for riffle or pool maintenance flows, they can be provided as a temporary requirement.	**Condition met - ongoing**

Ecological objectives for aquatic ecosystems at Bendora to Cotter Reservoir, Cotter Reservoir and Downstream of Cotter Dam reaches - from draft Environmental Flow Guidelines (2018)[2].

Reach[1]	Objective	Indicator trigger points
Bendora Dam to Cotter Reservoir	To maintain populations of Two-Spined Blackfish	Young of the year and year 1+ age classes (<120 mm) comprise >30% of the monitoring catch; **AND** Catch is >2 fish for 80% samples (30 m section) in each reach across 2 sampling years
	To maintain populations of Macquarie Perch	Recruitment detected at 80% of monitoring sites. Minimum capture of 1 Macquarie Perch (< 150 mm) per net night per site. Annual sampling of 12 net nights per site, 5 sites between Bendora Dam and Cotter Reservoir
	To maintain healthy aquatic ecosystems	Macroinvertebrate assemblages are maintained at AUSRIVAS band A level Non-dominance (<20% cover) of filamentous algae in riffles. Temperature, turbidity and DO mimic natural inflows Instream macrophyte cover <20%. Extent and condition of riparian vegetation is maintained or improved [2]

[2] These are the objectives from the Draft Environmental Flow Guidelines (2018) which are still to be finalised.

	To prevent degradation of riverine habitat through sediment deposition	Sediment deposition is limited to <20% of total depth of pools measured at base flow. Five yearly monitoring and reporting recommended for all sediment monitoring.
Cotter Reservoir	To maintain populations of Macquarie Perch	Minimum total catch 3 Macquarie Perch per fyke net night, per year, comprised of > 50% individuals <150 mm
	and Murray River Crayfish	Murray River Crayfish detected [3]
	To maintain healthy aquatic ecosystems	Non-dominance (<20% cover) of filamentous algae.
Downstream of Cotter Dam	To maintain healthy aquatic ecosystems	Macroinvertebrate assemblages are maintained at AUSRIVAS band A level Non-dominance (<20% cover) of filamentous algae in riffles Temperature, turbidity and DO mimic natural inflows.
	To maintain riparian vegetation values	Extent and condition of riparian vegetation is maintained or improved

1. Locations of downstream of dam monitoring sites needs to be approved by the EPA.
2. Riparian vegetation method and baseline data needs to be collected before this Indicator is implemented. Rapid Appraisal of Riparian Condition (RARC, Jansen et al, 2005) or other method to be developed which is better suited to the ACT's upland zones.
3. Current monitoring techniques for Murray River Crayfish are considered unsuitable to provide a reliable method for detection.

Environmental flows established for the above reaches are designed to maintain the ecological objectives determined in the table above. Flows for each reach as outlined in the *Environmental Flow Guidelines* are summarised below.

Baseflows

In all months in all years, base flows are required to be protected. The base flow volume required by the *Environmental Flow Guidelines* between Bendora Dam and Cotter Dam was informed from experience and research within the Cotter River which indicated that varying the discharge over a two week period can mitigate some of the effects caused by low constant flows by assisting fish migration and connectivity (ACT Government, 2018). In effect, once the monthly volume has been determined, greater ecological benefits can be obtained with fortnightly variations in the rate of release of that monthly volume even though the monthly volume remains the same.

Weekly variation in base flows however will be reduced during Macquarie perch spawning season between October and December from 50% to 25%. The reduction during this period is a component of Icon Water's adaptive management of the Cotter Dam and is aimed at reducing the likelihood of egg stranding (both Two-spined blackfish and Macquarie perch) or displacement of Macquarie perch eggs from riffles, whilst aiding fish migration past low flow barriers. Furthermore, special purpose flows may be necessary to facilitate Macquarie perch spawning and will be determined prior to spawning season (October – December) by the FMPWG and approved by regulatory authorities and the ACT Government.

Baseflows downstream of Cotter Dam are specified as minimum channel wetting volumes in recognition that the reservoir is the final capture and storage for domestic supply. This wetting volume is adequate to cover a reasonable portion of riffle, allowing adequate habitat for periphyton, macroinvertebrates and fish to be wetted at all times.

Baseflows to below the Cotter Dam wall can be provided from either the Cotter Reservoir or the Murrumbidgee to Cotter (M2C) System. The M2C operates under three flow scenarios, outlined in the

table below. If the Murrumbidgee River Flow at MacDonald gauging station is less than 20ML/day then the environmental flows must be provided from the Cotter Reservoir.

Murrumbidgee to Cotter (M2C) flow regime scenarios as per *WU67: Licence to Take Water*

Operation	Scenario
Standard Operation	If the Murrumbidgee River flow at Mt MacDonald gauging station is greater than 80ML/day; then M2C discharges 40ML/day. Each month, M2C discharge flow is reduced temporarily to 20ML/day for a 36 to 48 hour period. This reduction however is not required if during the previous 28 days, any non-standard operations (as below) occurred.
Low Flow Operation	If the Murrumbidgee River flow at Mt MacDonald gauging station is less than 80ML/day but greater than 20Ml/day; then M2C discharges at a rate equal to half the gauged reading.
Drought Flow Operation	If the Murrumbidgee River flow at Mt MacDonald is less than 20ML/day, then M2C is not operational and the environmental flows are provided from Cotter Reservoir.

Riffle Maintenance Flows

Riffle flows are not designed to mimic the pattern of natural flows in water supply catchments, rather they are set to achieve specific ecological outcomes. In the case of the Bendora Reservoir and fish management within the Cotter River, riffle flows are designed to flush sediment from riffles to achieve the outcome normally provided by the irregular flushing flows that would occur naturally. Riffles are an important component of Macquarie perch spawning habitat. As such, a riffle flow of 150ML/day for three consecutive days is specified to occur every two months. The ongoing effect of riffle maintenance flows will be assessed on the identified ecological objectives and workshopped with the FMPWG where opportunities for operational improvement exist.

Riffle maintenance flows downstream of the Cotter Dam are required to be 100ML/day for one day and is to occur every two months. Following a riffle maintenance flow as the result of a dam spill or release, the next flush must occur +/- 1 week following.

Pool Maintenance Flows

Pool maintenance flows are high flows that can actively scour accumulated fine sediment from pools, protecting important pool habitats from sedimentation. Pools provide important summer refuges for native fish from high water temperatures and avian predators. A pool maintenance flow of more than 550ML/day for two consecutive days is to be provided downstream of Bendora Dam to the Cotter River between mid-July and mid-October. Three sources of water from the Bendora Reservoir may comprise a pool maintenance flow:

- Tributary inflows
- Water flowing over the dam spillway, and;
- Releases from the dam

The pool maintenance flow from Bendora Dam is measured at Vanity's Crossing gauging station (410725).

No pool flows are required downstream of the Cotter Dam.

Environmental Flow requirements applicable to Bendora to Cotter Reservoir, and Downstream of Cotter Dam reaches (ACT Government, 2018)

Reach	Flow Requirement
Standard Operating Flows	
Base Flows	
Bendora Dam to Cotter Reservoir	Maintain 75% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less.
	Weekly variation in flows reduced from 50% to 25% during Macquarie Perch breeding season (October – December inclusive).
Downstream Cotter Dam	Maintain 15% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less.[1]
Riffle Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months
Below Cotter Dam	Maintain a flow of 100 ML/Day for 1 day every 2 months
Pool Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of >550 ML/day for 2 consecutive days between mid-July and mid- October[2]
Below Cotter Dam	Not required
Groundwater Abstraction Limits	
All Reaches	Groundwater abstraction is limited to 10% of the long term recharge
Impoundment Drawdown Levels	
Cotter Reservoir	An adaptive management program will be used to guide drawdown to protect Macquarie Perch [3]
Drought Flows: Stage 1 Restrictions	
Base Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of 40 ML/day or 75% of the 80th percentile of the monthly natural inflow, or natural inflow whichever is lesser volume
Downstream of Cotter Dam	Maintain an average flow of 15 ML /day
Riffle Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of 150 ML/day for 3 consecutive days every 2 months

Downstream of Cotter Dam	Not required
Pool Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of >550 ML/day for 2 consecutive days between mid-July and mid- October
Downstream of Cotter Dam	Not required
Drought Flows: Stage 2 Restrictions	
Base Flows	
Bendora Dam to Cotter Reservoir	Maintain an average flow of 20 ML /day or inflow, whichever is lower.
Downstream of Cotter Dam	Maintain an average flow of 15 ML /day
Riffle Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of 150 ML/day for 3 consecutive days every 2 months
Downstream of Cotter Dam	Not required
Pool Maintenance Flows	
Bendora Dam to Cotter Reservoir	Maintain a flow of >550 ML/day for 2 consecutive days between mid-July and mid- October
Downstream of Cotter Dam	Not required

1. The flow requirement for downstream of Cotter Dam is equivalent to the previous requirement of 15ML/d but modified to provide variability and seasonality of flows. Note that this is still exceeded by the Commonwealth requirement of an average flow of 34ML/d.
2. Flow requirements downstream of dams can be met by releases and/or spillway flows. For Bendora, with limited release capacity, coordination with downstream tributary flows can also be used.
3. The adaptive management plan to guide drawdown leading into Macquarie perch spawning season (October-December) will be workshopped and facilitated by the FMPWG at approximately July each year, and include stakeholders from Icon Water to determine likely Cotter Dam operating scenarios for the upcoming spawning period.

These limits of operation implemented for environmental flow management within and from the Bendora and Cotter catchments are consistent with the *Environmental Flow Guidelines* and Icon Water's *Licence to Take Water* (*WU67*).

Icon Water's Ecological Monitoring Program consists of monitoring events in spring and autumn each year to determine the biological responses to and effectiveness of environmental flows from ACT aquatic ecosystems. The details of this monitoring program are described further in Appendix C, however namely consists of:

- Below Dams Monitoring
- ECR Fish Monitoring Program
- Macquarie perch Translocation Program
- Two-spined blackfish Monitoring Program (Autumn only)

Summary and annual reports associated with this program are published on the Icon Water website and when analysed alongside Icon Waters additional monitoring, inform adaptive management decisions by both Icon Water and the regulators, ensuring that the ACT aquatic resources are appropriately protected.

Tracking and Compliance

The tracking and auditing of all compliance requirements relating to the Cotter Dam conditions of approval and operation are addressed in Icon Waters Compliance Tracking Register and are described in the Compliance Tracking Plan (2014) which was approved by ACTPLA on 5 June 2014. Any amendments or change in requirements in relation to the operation of the Cotter Dam will be reflected in the Compliance Tracking Plan.

Environmental incidents and non-compliances with environmental licences or development approval conditions during the operation of the Cotter Dam are required to be recorded and tracked using Icon Water's incident response and reporting protocols. These are set out in *WI03.00.03 Environmental Incident Response and Notification* under the certified Integrated Management System (ISO 14001:2004). Effective and timely incident response and notification through this system ensures that:

- The environmental impact is minimised and remediated as soon as practicable
- All relevant parties, including regulators, are informed of the incident
- Mitigation measures are explored and implemented as appropriate to prevent recurrence.

Appendix B: Fish Management Plan Risk Assessment

Previous Risk Assessment

A detailed conceptual model was developed in 2013 to describe the key threats to the primary threatened species relating to the filling and operation of the Cotter reservoir; Macquarie perch and the Two-spined blackfish (SKM, 2013). A number of other species (Murray cod, Trout cod and Murray River crayfish) were identified as potentially threatened in previous assessments, however for the operational phase residual risks to these species were assessed as negligible.

Murray cod are located in the Murrumbidgee River downstream of the Cotter Dam. The environmental flow regime downstream of the Cotter Dam is managed within the requirements of the *Environmental Flow Guidelines, Licence to Take Water (WU67)* and the enlarged Cotter Dam conditions of approval. On this basis, any risks to Murray cod as a result of flow releases from the Cotter Dam is considered negligible.

Trout cod are located in the Bendora Reservoir and likely in the Cotter River upstream and downstream of Bendora Dam, but not in Cotter Reservoir. Although water may be released from Bendora Reservoir to help manage water quality in the Cotter Reservoir, the operating regime of Bendora is not expected to change significantly, and therefore risks to Trout cod in the reservoir are considered negligible.

Murray River crayfish are located in the Cotter River downstream of the Cotter Dam and in the Murrumbidgee River downstream of the Cotter River. Occasional records have also been made of this species in the Cotter Reservoir. Pressures to Murray River crayfish were informed by a Murray River crayfish research project, and indicated that main threats were increased predation by alien fish, sedimentation of benthic habitat and changed flow regime downstream of the Cotter Dam. All these threats to the species are considered negligible considering Icon Water's existing management measures and the operation of the Cotter Dam following the *Water Sourcing Guidelines* and the *Environmental Flow Guidelines.*

Conceptual models for Macquarie perch and Two-spined blackfish were used to inform the risk assessment in FMP Version 3 (filling phase), and as such were relevant to informing the revised risk assessment later carried out during the stakeholder workshop for this FMP. These models described the key threats to Macquarie perch and Two-spined blackfish by evaluating the main threats to each species local population. As such, the Macquarie perch conceptual models were developed for habitat and food resources, cormorant predation, spawning impacts and alien fish impacts whereas the model for the Two-spined Blackfish was developed for spawning habitat.

Risk Assessment Methodology

As the enlarged Cotter reservoir achieved its full supply level (FSL), and as such moved from the filling phase to final operational phase, an update to the FMP risk assessment was required to ensure that all risks to threatened aquatic species relating to the dams operation were addressed.

Objectives

The objectives of the revised risk assessment for the operational FMP (Version 4) were to:

- Review the scientific literature and outputs from the FMP research projects and any changes since FMP Version 3 to provide an evidence base for a review of threats and risks.
- Through a collaborative stakeholder workshop, identify the key threats which can be attributed to or indirectly associated to the Cotter Dam's operation, and revise the risk assessment and mitigation measures for inclusion in the operational FMP.

Risk Workshop

Workshop facilitation for the risk assessment was undertaken on 18 October 2017 at the Icon Water Mitchell Office. The workshop was facilitated by Dr. Fiona Dyer, a senior research fellow at the University of Canberra and included the key stakeholders, which represented functions of both the FMPWG and FMPSC.

Risk Workshop Stakeholders in attendance

Function	Stakeholder
ACT Access Canberra	Heath Chester Mitchell Downey
ACT Conservation Research	Matthew Beitzel
ACT Conservator of Flora and Fauna	Helen McKeown
ACT EPSDD, Water Science, Monitoring and Modelling	Danswell Starrs
ACT Parks and Conservation Service	James Overall
Commonwealth Department of the Environment	Tim Kaminskas
Icon Water	Zoe Dougall John Hyam Tim Purves Trond Antonsen Amanda Brown Jonathan Thirkell Kyleigh Victory
University of Canberra IAE	Fiona Dyer (facilitator) Mark Lintermans (independent Fish Advisor)

The workshop reviewed the risks from the extensive risk assessment included in FMP Version 3 for the Cotter dam and reservoir filling and operation, including consideration of the more recent findings from ongoing monitoring and technical reports.

Risks identified in FMP Version 3 were consolidated prior to the workshop for those risks relevant to the operation of the Cotter Dam and reservoir. Key threats and current risks to threatened aquatic species from this revision and recent reports were considered by the FMPWG, and are summarised in the risk assessment below with their relevant controls.

Implications of Risk Assessment on management of threatened species

Icon Water's risk management framework was utilised in the workshop by the Fish Management Plan Working Group (FMPWG) to identify and assess impacts to the environment from existing risks for the ongoing operation of the Cotter Dam and reservoir. The risk analysis process evaluated the likelihood of occurrence, and environmental consequence of threats that are currently managed using existing controls, and evaluated their respective acceptable target risk and, if necessary, considered the application of additional controls and management measures.

The target risks and proposed additional controls and/or actions determined by the FMPWG in the workshop are summarised below.

IDENTIFY (GRM - Inherent risk assessment)							ANALYSE (GRM - Current risk assessment)					EVALUATE (GRM - Target risk assessment)				TREAT (GRM - Target risk assessment)
Ref #	Risk category	Risk description	Inherent rating (no controls)			Risk owner	Current (C)ontrols and Control Descriptions (CD)	Current rating			Report risk upwards ?	Response Strategy	Target Rating			Proposed additional (C)ontrols and (A)ctions CD=Control Description / AD=Action Description
			Likelihood	Conseq.	Rating			Likelihood	Conseq.	Rating			Likelihood	Conseq.	Rating	
1	Environmental	Oxygen depletion (< 4.0mg/L in the 0-3m zone) leads to M**acquarie perch swimming closer to the surface and being predated upon by birds,** resulting in moderate impacts to threatened species.	Unlikely	Moderate	Medium		(C) Ongoing destratification system minimises effects (C) Cormorant management plan	Rare	Moderate	Low		Accept	Rare	Moderate	Low	
2	Environmental	Loss of food resources as reservoir matures leads to **insufficient food to support Macquarie perch populations,** resulting in major impacts to threatened species.	Possible	Major	High		(C) Constructed rock reef provides substrate for food. (C) Native hardwood habitat left in-situ provides source of nutrient loads. (C) Larger area of shallow habitat in reservoir provides habitat for food.	Possible	Major	High		Mitigate	Possible	Major	High	(C) Reed bed establishment (C) Riparian revegetation
3	Environmental	Increasing abundance of alien fish species in the lower Cotter River and reservoir leads to **predation on larvae, Young of Year and juvenile Macquarie perch and Blackfish,** resulting in moderate impacts to threatened species.	Possible	Moderate	Medium		(C) Alien fish management strategy	Possible	Moderate	Medium		Mitigate	Possible	Moderate	Medium	(C) Monitor for trout predation on Macquarie perch larvae (C) Revision of alien fish monitoring strategy if trout are demonstrated to impact larvae
4	Environmental	Increased Great Cormorant populations leads to **increased predation on Macquarie perch,** resulting in major impacts to threatened species.	Likely	Major	High		(C) Constructed rock reef provides protective habitat for Macquarie perch (C) Native submerged hardwood provides protective habitat (C) Cormorant management plan	Unlikely	Major	Medium		Mitigate			Low	(C) Ongoing cormorant monitoring
5	Environmental	Drawdown of reservoir and sedimentation of river reach unsuitable as spawning habitat means that M**acquarie perch are unable to breed,** resulting in moderate impacts to threatened species.	Unlikely	Moderate	Medium		(C) Reservoir operating level and inflow management during spawning informed by ECR monitoring report (C) E flow riffle and pool maintenance flushes	Unlikely	Moderate	Medium		Accept			Low	

6	Environmental	Exposure of barriers during mp spawning season (water level and flow) leads to **a reduction in fish passage by reservoir population and zero spawning in three successive years,** resulting in major impacts to threatened species	Likely	Major	High		(C) Reservoir operating level and inflow management during spawning informed by ECR monitoring report (C) Compliance with Licenced e-flows (C) Annual spawning management plan (C) Barriers identification project	Possible	Major	High		Mitigate	Unlikely	Major	Medium	(C)Guidelines detail successive spawning in successive years (C) Management of barriers (requires identification of barriers) including fish ways (C) Acoustic monitoring project (C) Riffle spawning habitat identifies important spawning habitats (C) Pit tag station
7	Environmental	Cold water releases from Bendora Reservoir during the spawning season leads to **Macquarie perch failing to spawn and/or recruit in three successive years,** resulting in major impacts to threatened species	Possible	Major	High		(C) Selective environmental releases (as practicable) rom Bendora Reservoir in accordance with Icon Water's Licence to Take Water (C)Water temperature monitoring	Possible	Major	High			Possible	Major	High	(C) Bendora Reservoir spill release (from Corin Reservoir) (C) Variable offtakes and release at Bendora Reservoir
8	Environmental	Icon Water's operations introduce additional alien fish to the Cotter Reservoir leading to **increased predation and competition or disease vector on native fish,** resulting in major impacts to threatened species	Unlikely	Major	Medium		(C) Illegal fishing reporting process to PCS (C) EHN virus management plan (C) Fish Monitoring Program Reports (C) Contractor management	Rare	Major	Medium		Accept			/Low	
9	Environmental	Icon Water's operations introduce EHN virus into Cotter Reservoir leading to **infection and death of Macquarie perch populations,** resulting in severe impacts to threatened species.	Possible	Severe	High		(C) Illegal fishing reporting process to PCS (C) EHN virus management plan (C) Fish Monitoring Program Reports (C) Contractor management	Rare	Severe	Medium		Accept			Low	
10	Environmental	Icon Water's operations contaminate aquatic environment leading to **the poisoning of fish and/or the pollution of fish habitat,** resulting in a moderate impacts to threatened species.	Unlikely	Moderate	Medium		(C) Environmental Management Procedures (C) Training and awareness for Icon Water staff and contractors (includes conditions of the Waterways Works Licence).	Rare	Moderate	Low		Accept			Low	
11	Environmental	Valve exercising leads to the **abstraction of fish through intake and death,** resulting in monor impacts to threatened species.	Rare	Minor	Low		(C) Large screens (Adults)	Rare	Minor	Low					Low	
12	Environmental	Release of cold water below Cotter reservoir leads to **thermal stress for murray cod and reduced spawning,** resulting in minor mpacts to threatened species.	Possible	Minor	Medium			Possible	Minor	Medium		Mitigate	Unlikely	Minor	Low	(C) Operating procedures for valve exercising

Appendix C: Fish Management Plan Background and Projects

Fish Management Plan

The construction and operation of the Cotter Dam raised concerns relating to the management of five threatened native aquatic species, summarised with their relevant territory and federal threatened listing the table below.

Threatened Aquatic Species

Common Name	Scientific Name	Territory Listing (ACT)	EPBC Act Listing
Macquarie perch	*Macquaria australasica*	Endangered	Endangered
Trout Cod	*Maccullochella macquariensis*	Endangered	Endangered
Murray Cod	*Maccullochella peelii*	-	Vulnerable
Two-spined Blackfish	*Gadopsis bispinosus*	Vulnerable	-
Murray River Crayfish	*Euastacus armatus*	Vulnerable	-

This FMP (Version 4) is the final in a series of four plans designed to provide information to guide the conservation of aquatic communities in the Cotter Reservoir and the Cotter River reach to Bendora Dam during operation of the Cotter Dam. Each of these four reports focused on conservation of the species during different key program milestones, as detailed below.

The FMP reports form part of the Territory and Commonwealth conditions of approval for the Cotter Dam (Appendix A), and are prepared in accordance with legislative requirements as prescribed. The FMP also presents relevant information from a range of other key information sources, including related studies focussed on threatened aquatic species and their habitats within the reservoir.

Baseline

Three years of fish monitoring were conducted between 2010 and 2012, prior to the completion of the dam construction. The results from the report (Lintermans et al, 2013) form the baseline for fish monitoring and are presented in Appendix L.

Fish Management Plan Milestones

Fish Management Plan Version	Key project stage/phase	Information sources	Fish Management Program milestones	Date
1	Planning phase, EIS Submitted.	Fish Impact study (Lintermans 2005), Current knowledge.	Identified projects to address knowledge gaps.	2009

2	Construction period.	• Progress reports for Fish Management Program. • Fish Management Program final reports. • Aquatic Flora and Fauna Management Plan. • Associated projects by other stakeholders and external sources. • Input from regulators.	• Established a Fish Management Program Steering Committee (FMPSC). • Implemented all projects identified in Fish Management Plan Version 1. • Used information from Project 1 – Constructed homes for threatened fishes to inform design for constructed shelter habitats. • Lodgement of DA for installation of constructed habitats.	2010
3	Filling and operational phase.	• Results from Fish Management Program projects. • Results from ongoing monitoring. • Results from fish Barrier studies • Input from regulators. • Documented performance against conditions of approval.	• Completed installation of rock reef habitat • Completed Phase 1 of ECR Fish Monitoring Program • Installed fishways at Pipeline Road Crossing. • Continued to implement/ finalise projects identified in FMP V1 • Revised FMP Risk Assessment for filling and operational phase • Ongoing involvement of FMP Steering Committee	2013
4	Operational phase.	• Results from ongoing monitoring. • Input from regulators.	• Continues to implement/ finalise projects • Revised FMP Risk Assessment for operational phase • Ongoing involvement of FMP Working Group and Steering Committee	2018

Fish Management Plan projects

In the initial stages of the enlarged Cotter Dam project from planning/pre-construction to filling, nine research and monitoring projects were identified for implementation as part of the Fish Management Program. These projects were to fill identified knowledge gaps required to mitigate and manage impacts on threatened aquatic species in the Cotter River system (Lintermans 2005) and to inform management and mitigation measures. The nine projects involved scientists and researchers from the University of Canberra, the Australian National University, University of Sydney and Griffith University and in kind support from Icon Water and the ACT Government.

In addition to the nine projects identified below, there have been additional student projects (PhD and Honours) and other externally-funded projects that have investigated ecological issues regarding the enlarged Cotter Reservoir or the river upstream that have informed the management strategies. This research and the resulting management measures have also been informed by ongoing independent research that is directly related to the management of fish in the Cotter reservoir.

Details of projects findings and details informing management measures are summarised according to their basis of implementation below. A listing of research literature and presentations to date associated with these projects are also provided.

Completed Fish Management Plan (FMP) projects

Project Name	Description and outcomes
Constructed homes for threatened fish in the Cotter River Catchment (Lintermans et al. 2010) **(Compliance with Commonwealth Approval Condition – Ongoing management measures (f))**	Enlargement of the Cotter Reservoir inundated fringing macrophyte beds used by threatened Macquarie perch as adult shelter habitat. This project examined the movements and habitat preferences of threatened fish to guide the provision of replacement artificial shelter habitat in the Cotter Reservoir. The findings from the constructed homes project were used to guide the provision of replacement shelter habitat in the reservoir, specifically: • Informed the design and installation of rock reef habitats to replace fringing macrophyte habitat which were inundated by the enlarged reservoir. Without the construction of this substitute rock reef habitat, the Macquarie perch would not have had adequate shelter habitat to mitigate the potential impacts of increased predation from cormorants. • The retention of the majority of timber and woody debris within the inundation zone as a form of supplementary habitat for Macquarie perch and other aquatic species, particularly during the filling phase.
Predicted passage of native and alien fish based on swimming speed and performance (Starrs et al. 2011, 2017) **(Compliance with Commonwealth Approval Condition – Ongoing management measures (e))**	Existing spawning habitat of Macquarie perch was inundated by the filling of the enlarged Cotter Reservoir. In order to reach appropriate spawning habitat in and upstream of the reservoir, the fish must be able to overcome instream barriers in the Cotter River. To facilitate the identification and remediation of potential barriers and provide an overview of fish passage in the Cotter River, an understanding of the swimming capacity of Macquarie perch and other alien fish species was required. This project identified the swimming speed of Macquarie perch and as a result, informed the remediation of Pipeline Road Crossing; and identified barriers to the upstream migration of adult Macquarie perch. This crossing had seven pipe culverts which prior to remediation, generated flow velocities above the swimming capacity of all but the largest Macquarie perch for the majority of river discharges. As a result of this project, a fishways was designed to back water up through the pipe culverts and increase depth and cross-sectional area to

	reduce water velocity enabling the fishways to meet, and in some cases exceed, the hydraulic requirements for the passage of Macquarie perch in the spawning season. This fishways also provides passage for a wide size range of fish at other times.
Murray River Crayfish Ecology (Fulton et al. 2010)	Examination of Murray River crayfish distribution, abundance and habitat selection in upland rivers aimed to identify the typical habitat preferences, densities and individual space requirements of this species. This ecological study identified habitat preferences of Murray River crayfish. The study findings have been used to inform most recent reviews of the *Environmental Flow Guidelines*, which when finalised, will consider Murray River crayfish flow preferences. The study also identified habitat preferences for this threatened species which could be used to inform broader catchment management initiatives.
Alien Fish Management Plan	Prior to the enlargement of the Cotter Reservoir, it was identified that an increase in the abundance of alien fish, particularly trout, had the potential to result in an increase in the rates of predation of, and competition of resources with native species. The development and implementation of the *Alien Fish Management Plan* (Appendix I) was determined as a crucial mitigation measure to address the potential expansion of alien fish within the Cotter Reservoir. Note that the Alien Fish Management Plan is designed to be an adaptive document and triggers and management actions will be developed as more information becomes available. The purpose of the plan outlined an adaptive framework and schedule addressing the potential impacts of alien fish to threatened fish species in the Cotter Reservoir. The Plan involves the ongoing monitoring of alien fish species and the implementation of management measures when trigger levels are reached. Ongoing monitoring is undertaken under the *ECR Fish Monitoring Program* which commenced in early 2010 and includes the monitoring of alien fish abundance and distribution. Further details of the *ECR Fish Monitoring Program* are described in the table below.
Barriers and spawning habitat identification (Broadhurst et al. 2013, 2016) **(Compliance with Commonwealth Approval Condition – Ongoing management measures (d))**	Each spring around October, Macquarie perch in the Cotter Reservoir migrate upstream into the Cotter River to spawn. The enlargement of the reservoir inundated known spawning and early recruitment habitat of the reservoir population of Macquarie perch. Knowledge of the location of current and potential spawning grounds and in-stream barriers to fish passage were paramount for the effective management of recruitment and ultimately long term survival of the Cotter population of Macquarie perch. This research project aimed to: • Identify potential barriers to fish passage in the Cotter River under three different flow range scenarios – low, medium and high. • Identify potential spawning habitat (pool/riffle sequences), given that the habitat characteristics of spawning areas were broadly known. This research identified that the manipulation of flow events and maintenance of high reservoir levels resulting from the Cotter Dam mitigates most instream barriers to upstream Macquarie perch spawning movements. Findings suggested that there were small and medium barriers just above predicted full supply level (FSL) of the reservoir. A notable finding indicated that fish passage past all but one of the small

	barriers, and some of the medium barriers can be mitigated with multiple periods of high water flow events greater than 150 ML per day during the spawning season (October – January). These high flow events can be facilitated by natural and planned releases from Bendora Reservoir under existing environmental flow legislative requirements (*Environmental Flow Guidelines*). The areas upstream of the reservoir FSL exhibited characteristics of suitable spawning habitat, although barriers that were large enough to restrict passage were present. Ongoing monitoring through the *ECR Fish Monitoring Program* includes sampling of Macquarie perch recruitment success and is described in the table below. Furthermore, additional studies to better understand Macquarie perch spawning habitat have recently been finalised and are summarised below Table. The recommendations from these recent studies have informed the active management measures for threatened aquatic species outlined in Section 3.3.
Food sources for Macquarie Perch (Norris et al. 2012)	The construction of the Cotter Dam and filling of the reservoir was expected to result in a shift in reservoir food resources, particularly for the population of Macquarie perch. In this research project, non-lethal sampling of Macquarie perch diet and food availability was conducted in the existing Cotter Reservoir, prior to expansion, and nearby established fluctuating reservoirs of Googong, Corin and Cataract to assess: • the main food of adult Macquarie perch • the habitat features that influence invertebrate production • food resources between stable (Cotter Reservoir) and established, variable water level reservoirs (Cataract, Corin and Googong reservoirs). Amongst other notable findings, the project confirmed that Macquarie perch are opportunistic feeders, however, the source of their preferred prey (freshwater prawns) would likely decline as a result of the inundation of fringing reedbeds by the enlarged Cotter Reservoir. This project highlighted the need to integrate Macquarie perch condition measurements as part of the ongoing *ECR Fish Monitoring Program*. Further details of this program are described in the *Enlarged Cotter Reservoir (ECR) Fish Monitoring Program* below.

Ongoing Fish Management Plan (FMP) projects

Project Name	Description
Enlarged Cotter Reservoir (ECR) fish monitoring program (Lintermans et al. 2013; Broadhurst et al. 2018)	The *ECR Fish Monitoring Program* is a key requirement of the Fish Management Plan. The assessment program was conducted in three broad phases; baseline (2010-2013, before the dam started to fill), filling (2013-2016 as the dam filled) and the current state of operation (2016-onwards) as the dam has filled and began operation as a water supply reservoir. Where possible, the monitoring program employs a before-after-control-impact (BACI) study design to provide a robust regime for detecting change associated within and as a result of the Cotter Dam. The study design was also field integrated with many of the field survey activities addressing multiple research questions. These monitoring questions are presented below , and include the

	integration of the other research projects such the *Alien Fish Management Plan* and the Food Sources for Macquarie perch: 1. Has there been a significant change in the abundance and body condition of Macquarie perch (young-of-year, juveniles and adults) in the enlarged Cotter Reservoir as a result of the filling and operation of the Cotter Dam? 2. Has there been a significant change in the abundance, body condition and distribution of the Macquarie perch (young-of-year, juveniles and adults) in the Cotter River above and below Vanity's Crossing as a result of the filling and operation of the Cotter Dam? 3. Have Two-spined Blackfish established a reproducing population in the enlarged Cotter Reservoir and are they persisting in the newly inundated section of the Cotter River? 4. Has there been a significant change in the abundance, distribution and size composition of adult trout in the enlarged Cotter Reservoir as a result of the filling and operation of Cotter Dam? 5. Has there been a significant change in the abundance and size composition of trout in the Cotter River upstream of the enlarged Cotter Reservoir as a result of the filling and operation of Cotter Dam? 6. Are Two-spined blackfish and Macquarie perch present in trout stomachs in the Cotter River? 7. Has there been a significant change in the abundance and distribution of non-native fish species in the enlarged Cotter Reservoir as a result of the filling and operation of the Cotter Dam? 8. Has there been a significant change in the abundance, distribution and species composition of piscivorous birds in the vicinity of the enlarged Cotter Reservoir as a result of the filling and operation of the Cotter Dam? 9. Have macrophyte beds re-established in the enlarged Cotter Reservoir? 10. Are there adequate food resources (particularly decapods) for the Macquarie perch following the filling and operation of the enlarged Cotter Reservoir? Data from this program has been, and will continue to be used to further inform and update trigger points for the ongoing management of threatened fish species. The monitoring program is already being used to inform management actions, and as situations may change throughout the operation of the Cotter Dam as detected through ongoing monitoring, may prompt revision of Icon Waters management and as a result, amendment to this FMP. Most recently, the *Enlarged Cotter Reservoir Ecological Monitoring Program: Technical Report 2017* outlined that no discernible change had been detected in the population of Macquarie perch in the Cotter Dam between the construction and filling phases, with the exception adults are in better body condition since filling began in 2013. Encouragingly, successful recruitment to juveniles was detected in 2017 for the first time since the filling, and recruitment was detected at all riverine sites. The mechanisms behind this success are not immediately clear, however it is likely that the "unregulated" flows that persisted throughout this given spawning season contributed to this success. The management of flows to assist in facilitating successful spawning within the reservoir population, is a consideration that this program will aim to address.
EHN Virus management (Whittington 2008)	Epizootic Haematopoietic Necrosis (EHN) virus is endemic to the upper Murrumbidgee catchment with the major vector being the alien Redfin perch (*Perca fluviatilis*). The virus has been shown to cause severe mortality on several native fish species, including Macquarie perch. The EHN virus was known to occur in Canberra urban lakes and Googong Reservoir, but it was unknown if it was present in the Cotter catchment upstream of Cotter Dam.

	The objective of this project was to initially determine if the EHN virus was present in samples of fish populations in, and upstream of the existing Cotter Reservoir. The project confirmed that EHN virus was not present in sampled fish from the Cotter Reservoir or tributaries upstream of the reservoir. A range of mitigation measures to ensure that the virus did not enter the reservoir as a result of the construction of the Cotter Dam were established to ensure the isolation of Cotter Reservoir from EHN. These measures included: • No connectivity between the Cotter Reservoir and the Cotter River downstream of the Cotter Dam during construction. • Regular documented audits by environment personnel onsite to ensure disinfection procedures are being implemented effectively. • Appropriate signage onsite to delineate disinfection zones where there was considered to be a high risk that the EHN virus is present. • Water used onsite was only sourced from the Cotter Reservoir through installed standpipes. No water was extracted and used from the Cotter River downstream of the existing Cotter Dam, given that Redfin perch, a primary indicator of the presence of the EHN virus, were commonly found in the Cotter River downstream of the existing Cotter Dam. • Training and awareness roll-out to site personnel regarding the potential transfer of the EHN virus through onsite activities (including illegal fishing) and potential impact on sensitive fish species. • Removal of aquatic vertebrae fauna from the stilling basin and Cotter River between the existing Cotter Dam and downstream cofferdam prior to work in the Cotter River commencing. • Removal of all water between the existing Cotter Dam and downstream cofferdam. • Chemical treatment of the area between the old and enlarged Cotter Dams. As implications of EHN virus reaching the Cotter Reservoir is considered as potentially severe to conservation efforts of Macquarie perch, a range of management measures established in the construction phase of the Cotter Dam remain ongoing throughout the operation of the dam . These include: • A work instruction outlining the required appropriate disinfection procedures and methods for all personnel, vehicles and plant prior to use in areas of the Cotter Reservoir Catchment. This work instruction is attached as Appendix E. • Monitoring for the presence of Redfin perch (vector for the EHN virus) within the *ECR Fish Monitoring Program*. • Notifying the appropriate authorities if the presence of the EHN virus in the Cotter Reservoir is confirmed. • Training of Icon Water personnel and contractors working in the Cotter Catchment.
Translocation of threatened fish species (Lintermans 2013, 2017;	To reduce the risk of adverse consequences for Macquarie perch from the construction and operation of the Enlarged Cotter Dam, the translocation of Macquarie perch to establish alternative populations was investigated. Translocation requirements for Two-spined blackfish and Trout cod were also assessed.

Todd & Lintermans 2015; Todd et al. 2017)	The project aimed to translocate Macquarie perch to existing translocation sites and monitor the success of efforts, in doing so, potentially identify additional suitable ongoing translocation sites. Translocation efforts were informed by the development of a population model for Macquarie perch. A preliminary population model was also established for Two-spined Blackfish to assess risk to the lower Cotter River population as a result of the construction of the Cotter Dam.A total of 1,057 Macquarie perch were translocated to 3 sites (Molonglo River, upper Cotter River, and Paddy's River) between 2008 and 2012. A review of monitoring at all translocation sites demonstrated survival of translocated fish, but no recruitment (breeding) (Lintermans 2013). In more recent years during the filling of the Cotter Dam, a total of only 305 Macquarie perch were captured for relocation to the upper Cotter and Molonglo sites between 2014 and 2018. This lower number was attributed to the failure of the donor population to successfully recruit during the 2013-2016 breeding seasons, as outlined in a review undertaken by Lintermans (2017). The results of translocations and the *ECR Fish Monitoring Program* will continue to inform future translocation efforts for Macquarie perch. The translocation reach upstream of Corin Reservoir represents the best chance of successful population establishment, whereas the translocation reach at Molonglo River is less likely to result in the establishment of a viable population due to less suitable habitat in the particular translocation reach. Translocations of Two-spined blackfish were assessed as feasible, but not required as there are still secure populations in the middle and upper Cotter River. Translocation of Trout cod was assessed as currently unfeasible, as there were no self-sustaining donor population capable of sustaining a harvest of individuals for translocation within the Cotter Reservoir. The translocation project is ongoing as translocation and monitoring will continue throughout the operation of the dam, dependent on availability of Macquarie perch in the donor population.

Adaptive management strategies in the Cotter Reservoir have identified additional projects with the objective of enhancing knowledge of Macquarie perch spawning behaviour. Knowledge gained from these projects, as summarised in the table below, and will be used to adapt dam and environmental flow management procedures to enhance the sustainability of the Macquarie perch population in the Cotter Reservoir throughout its operation as a drinking water resource. Refer to Section 3.3 Adaptive Management.

Further details regarding the recommendations integration into management measures of the Cotter Dam are discussed in the body of the Fish Management Plan in Section 3.1.

Additional Research and Monitoring Projects

Project Name	Description	Status
Acoustic assessment of Macquarie perch spawning movements (Broadhurst et al. 2017b, 2018c)	This two year program to determine the timing and extent of Macquarie perch spawning movements and consisted of: • Capturing approximately 20 adult Macquarie perch and surgically inserting an acoustic transmitter in each • Installing six listening stations in Cotter River pools from the headwaters of the Cotter Reservoir to upstream of Spur Hole (approximately 9km upstream from the Cotter Reservoir at Full Supply Level).	Second year of monitoring complete with recommendations for further research

	• Downloading the data weekly during spawning season (October to December) The project found that migrations into the Cotter River were restricted spatially. The duration of these entries were generally brief (<1 hour), with few instances of extended occupation (>24 hours) which were undertaken during low light periods. No tagged Macquarie perch were detected upstream of Barrier 38, however individuals were able to ascend medium-sized barriers at discharges lower than previously expected.	
Riffle characterisation and spatial distribution (Broadhurst et al. 2018b)	This project aimed to determine the location and to characterise the microhabitat features of Macquarie perch spawning habitat in the lower Cotter River upstream of the Cotter Dam. To characterise Macquarie perch spawning habitat, a suite of habitat variables were measured at each riffle such as distance, riffle length and width, water temperature, distance from shore, velocity, depth and substrate conditions. The single year of data collection suggest that there were no detectable differences between riffles containing eggs and those that did not, at either the meso or microscale. Subsequent sampling detected young of year at all reaches suggesting that spawning occurred in all three reaches (Upstream Cotter Dam, Vanity's Crossing and Spur Hole) despite the lack of eggs recorded in two of the three reaches. The reasoning for this failed detection may be attributed to spawning occurring in monitored riffles but was undetected, or spawning occurred in other riffles which were not monitored. Further investigation is recommended.	Initial year of monitoring complete with recommendations

Summary of Icon Water supported projects informing Fish Management Strategies

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Appendix D: Water Quality Sampling Schedule

Water sampling schedule at the Cotter Reservoir relevant to Fish Management

Analysis	Schedule		
	Fortnightly*	Monthly	Quarterly
Chemical			
Profile (Temperature, DO, pH, Conductivity)	X*	X	X
Turbidity	X*	X	X
Total Organic Carbon (TOC)	-	X	X
Dissolved Organic Carbon (DOC)	-	X	X
Metals			
Metals digestion	X*	X	X
Metals filtration	X*	X	X
Total Iron (Fe)	X*	X	-
Total Manganese (Mn)	X*	X	-
Dissolved Iron (Fe)	X*	X	X
Dissolved Manganese (Mn)	X*	X	X
Nutrients			
Ammonia (NH^3)	-	X	X
Nitrogen Oxides (NO_x)	-	X	X
Total Nitrogen (TN)	-	X	X
Total Kjeldahl Nitrogen (TKN)	-	X	X
Organic Phosphate (OP)	-	X	X
Total Phosphate (TP)	-	X	X
Microbiological / Biological			
Total Coliforms and E-Coli	X*	X	X
Enterococci	X*	X	X
Giardia / Cryptosporidium	-	X	-
Algal Count	X*	X	X
Blue Green Algae	X*	X	X
Chlorophyll-α	X*	X	X

*only applies in summer when the Cotter Dam is online. An additional schedule is in place when Icon Water is alerted to the potential of a Blue Green Algal bloom.

Instantaneous physical and physiochemical monitoring within the Lower Cotter Catchment relevant to Fish Management

Site	Analysis
Cotter West Buoy (410704BW) (Cotter Reservoir gauge)	Water Temperature (C) Electrical Conductivity (uS/cm) Dissolved Oxygen (% Saturation)
Cotter Central Buoy (410704BC) (Cotter Reservoir gauge)	Water Temperature (C) Electrical Conductivity (uS/cm) Dissolved Oxygen (% Saturation)
Vanity's Crossing (410725) (Cotter River gauge)	Level (m) Discharge (mL/day) Water Temperature (C)
Condor Creek at Threeways (410733) (Condor Creek gauge)	Level (m) Discharge (mL/day) Water Temperature (C) Turbidity (NTU) Electrical Conductivity (uS/cm) pH Dissolved Oxygen (% Saturation)
Cotter Below Bendora (410747) (Cotter River gauge)	Level (m) Discharge (mL/day) Water Temperature (C) Turbidity (NTU) Electrical Conductivity (uS/cm)

Appendix E: EHN Virus Management Plan

Please refer to separate stand-alone document

Appendix F: Cotter Reservoir Destratification System Process Operating Plan

Please refer to separate stand-alone document

Appendix G: Cormorant Management Plan

Please refer to separate stand-alone document

Appendix H: ECR Emergency Inspection and Translocation Plan

Please refer to separate stand-alone document

Appendix I: Alien Fish Management Plan

Please refer to separate stand-alone document

Appendix J: Emergency Contacts

Icon Water emergency contacts

Contact	Phone	Email
Operations management on-call	02 61752366	LMW_smc@iconwater.com.au
Treatment operations SMC	02 6180 6300	LMW_smc@iconwater.com.au
Environment and sustainability incident reporting	02 6180 6299	Environment.Sustainability@iconwater.com.au
Icon Water faults and emergencies	02 6248 3111	talktous@iconwater.com.au

ACT Government emergency contacts

Contact	Phone	Email
Environment Protection Authority	13 22 81	Environment.protection@act.gov.au
ACT Health Emergency Management Unit	6205 1700 0435963482	hpsops@act.gov.au
ACT Fire and Rescue	000	N/A

Appendix K: Glossary

Term	Meaning
Adaptive Management	Adaptive management is a procedure for implementing management while learning about which management actions are most effective at achieving specified objectives (usually from monitoring).
ECD – Enlarged Cotter Dam	The Enlarged Cotter Dam involved construction of a new 80m high dam approximately 100m downstream of the Cotter Dam in the ACT. The construction project was completed in February 2013.
ECR – Enlarged Cotter Reservoir	The enlarged Cotter Reservoir is impounded by the Enlarged Cotter Dam and has a capacity of 76GL.
EHN Virus	Epizootic Haematopoietic Necrosis (EHN) Virus is a native ranavirus of the Iridoviridae Family, and is associated with high fatality rates in fish
Environmental Flow Guidelines	A key instrument under the *Water Resources Act 2007* which set out the flow requirements to maintain aquatic ecosystems across the ACT and apply to all rivers, streams, lakes and ponds.
Fish Management Plan Working Group (FMPWG)	The purpose of the Fish Management Plan (FMP) Working Group (WG) is to provide expert technical advice to Icon Water on matters related to native fish populations during filling and operation of the Enlarged Cotter Dam (ECD).
Fish Management Steering Committee (FMPSC)	The purpose of the Fish Management Plan Steering Committee (FMP SC) is to ensure ongoing cooperation and coordination between Icon Water and Government Environmental Regulators on matters related to the maintenance and rehabilitation of native fish and crayfish populations during the filling and operation of the Enlarged Cotter Dam (ECD).
Full Supply Level (FSL)	The water level at which the dam managers consider the reservoir to be at full capacity. The FSL for the Cotter Reservoir is 550.779 m above sea level (ASL).
Licence to Take Water (WU67)	Under the *Water Resources Act 2007 (ACT)* the Licence prescribes the conditions by which water can be extracted from the

	Cotter, Queanbeyan and Murrumbidgee rivers for the purposes of urban water supply for residents of the ACT
Macquarie perch (*Macquaria australasica)*	The Macquarie perch is a moderate sized, large eyed, secretive freshwater fish native to the cooler middle-upper reaches of the Murray-Darling Basin. It is listed as 'endangered' under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the Australian Society of Fish Biology Threatened Fishes List, the Australian Capital Territory Nature Conservation Act 2014 (NC Act), and the New South Wales Fisheries Management Act 1994 (FM Act).
Two-spined blackfish (*Gadopsis bispinosus*).	A small to medium sized fish with a yellowish-brown to olive green back and sides, often spectacularly mottled ('giraffe' spots),and a creamy or light grey belly. It is restricted to cool, clear upland or montane streams with abundant instream cover. It is currently restricted to the Cotter River upstream of Cotter Reservoir and is listed as *Vulnerable* in the ACT.

Appendix L: Fish Baseline

Lintermans et al. Assessment of the potential impacts on threatened fish from the construction, filling and operation of the Enlarged Cotter Dam Phase 1 (2010-2012