Murrumbidgee to Googong Water Transfer:

Stream Flow & Water Quality Management Plan

Version 2

January 2014

Certificate of approval for issue of documents

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Document revision control

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1	Simon Webber	23 Nov 11	Version approved by regulator	23 Nov 11
2	May McDonald-Cox	28 Jan 14	Revision to reflect new ACTEW Water corporate governance arrangements & Feb 13 OEMP audit findings/recommendations	28 Jan14

Contents

Acronyms

ACT	Australian Capital Territory
AEMP	Aquatic Ecology Monitoring Plan
ANZECC	Australian and New Zealand Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARI	Average Rainfall Interval
AUSRIVAS	Australian River Assessment System
Cwlth	Commonwealth
d	day
DO	Dissolved Oxygen
DECC(W)	NSW Department of Environment, Climate Change (and Water) – now NSW Office of Environment & Heritage and NSW Office of Water
EFTAG	Environmental Flows Technical Advisory Group
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Act 1999 (Commonwealth)
ERG	Environmental Reference Group
FDEF	Flow-Dependent Ecological Features
GL	Giga Litre
hrs	hours
KPI	Key Performance Indicator
LMWQCC	Lower Molonglo Water Quality Control Centre
m	meter
min	minutes
ML	Mega Litre
M2G	Murrumbidgee to Googong Water Transfer

NSW	New South Wales
OEMP	Operation Environmental Management Plan
QA	Quality Assurance
s	second
SCADA	Supervisory Control and Data Acquisition
SEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population & Communities – now Commonwealth Department of the Environment (DotE)
SFWQMP	Stream Flow & Water Quality Management Plan
SDLP	Sustainable Diversion Limits Plan
SWIOID	Snowy Water Inquiry Outcomes Implementation Deed
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus

Register of significant changes/additions to previous version(s) or previous relevant document(s)

This document consolidates the four documents shown below. This consolidation process is occurring across all M2G operational plans. In the consolidation process, elements may have been transferred to a more relevant consolidated document; removed completely; updated; or mode more clear. Table 1.1 below identifies the key changes made in the consolidation process.

- Stream Flow & Water Quality Management Plan (NSW);
- Flow Management Plan (NSW);
- Extraction & Gauging Plan (Cwlth - EPBC 2009/5124);
- Sustainable Diversion Limit Plan (Cwlth - EPBC 2009/5124).

Table 1.1 Significant changes/additions to previous version(s) or previous relevant document(s).

Subject	Description of change/addition	Reference within this plan
Operational modes	M2G is now referred to operating in three distinct modes: suspension, standby and operating.	All M2G plans
Start-up and shutdown procedures	Start-up and shutdown pump timings have been updated to respond to new environmental information.	This plan
Water quality parameters	Reference to water quality triggers has been made clearer with the delineation of online and grab sample parameters.	This plan
Nominal pump values identified	Where appropriate, actual pump volume values (proven through the commissioning process) have been provided, in addition to the nominal values.	This plan
Release of water without delay	Reference to the release of water into Burra Creek 'without delay' has been changed to "as soon as practicable"	This plan

Subject	Description of change/addition	Reference within this plan
Ecological monitoring references	Ecological obligations have been omitted and transferred to the Aquatic Ecology Monitoring Plan	Aquatic Ecology Monitoring Plan (AEMP)
Invasive fish management	References to alien fish have been omitted and transferred to the Aquatic Ecology Monitoring Plan	Aquatic Ecology Monitoring Plan (AEMP)
Roles & Responsibilities	Detail within the Roles and Responsibilities section have been omitted from this amalgamated plan and replaced with a reference to the relevant sections in the Operation Environmental Management Plan (2012).	Operation Environmental Management Plan (OEMP)
Training	Detail within the Training section has been omitted from this amalgamated plan and replaced with a reference to the relevant sections in the Operation Environmental Management Plan (2012).	Operation Environmental Management Plan (OEMP)
Reporting	Detail within the Auditing section has been omitted from this amalgamated plan and replaced with a reference to the relevant sections in the Operation Environmental Management Plan (2012).	Operation Environmental Management Plan (OEMP)
Auditing	Detail within the Auditing section has been omitted from this amalgamated plan and replaced with a reference to the relevant sections in the Operation Environmental Management Plan (2012).	Operation Environmental Management Plan (OEMP)
General Text	Multiple editorial/grammatical changes have been made, whilst maintaining the intent of the plan. The operating mode word ‘shutdown’ replaced with ‘suspension’ to have consistent terminology with Section 10.2.7 of AS 2885.3 2012 ‘Pipelines - Gas and liquid petroleum- Operation and maintenance’.	This plan

Environmental Commitments and Conditions of Approval / Licences

Table 1.2 EIS Chapter 28 Commitments.

Commitment No.	Commitment / Condition (Chapter 28 EIS)	Reference
5	A standard operating procedure will be developed for access to the pipeline during maintenance activities, chemical/fuel storage, and for pipe flushing that meets legislative requirements.	Addressed in operating procedures.
6	ACTEW's Source Water Protection Program will continue to address water quality issues in the Murrumbidgee River.	SF&WQP Section 5
7	Installation of a grit collection hopper at the low lift pump station and discharge of captured sediments back to the Murrumbidgee River to reduce the turbidity of water transferred to Burra Creek. Use of an automatic timer on the grit collection hopper to ensure that relatively small volumes of sediments are discharged on a continuous basis to reduce impacts on the Murrumbidgee River downstream. Ongoing monitoring and appropriate adjustments to the timers or release volumes to minimise potential impacts.	Addressed in operating procedures.
8*	Operational rules will be developed to acceptance levels of turbidity in the Murrumbidgee. *amended commitment based on Consistency Review by NGH Environmental (October 13)	SF&WQP
10	Regular review of water quality monitoring results for any trends toward significant impacts in Murrumbidgee River, Burra Creek or Googong Reservoir. The monitoring and adaptive management plan will include actions required to address any identified trends in a timely manner.	AEMP & SF&WQP

Table 1.3 DoP Conditions of Approval (NSW).

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
2.1	The Proponent shall comply with section 120 of the	SF&WQP Section

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
	Protection of the Environment Operations Act 1997 which prohibits the pollution of waters.	7
2.3*	The Proponent shall design, construct, operate and maintain the project to avoid impacts on bank stability within the Burra Creek riverine corridor and Googong Reservoir outlet and does not increase local flooding risk. **Please note: pending regulator approval, ACTEW is intending to change this commitment to: "The Proponent shall design, construct, operate and maintain the project to avoid impacts on bank stability within the Burra Creek riverine corridor."*	AEMP
2.4	The Proponent shall not transfer water when Burra Creek is in flood based on a one in two year event or greater nor should the Proponent operate the pipeline where it results in water levels in Burra Creek being greater that the one in two year flood level.	SF&WQP Section 3
2.11	The Proponent shall implement the aquatic ecology management measures committed to in the documents set out in condition 1.1c) or elsewhere in these conditions of approval, including; a) monitoring and subsequent maintenance of flow transfer volumes to reasonably and feasibly mimic the natural flow regime based on the stochastic data refined in the Preferred Project Report of Burra Creek during the native fish breeding season in order to protect any spawning populations of threatened fish species; b) design measures to prevent the spread of invasive fish species; c) design measures for the protection of natural ponding habitat. If the current natural ponds along Burra Creek are lost as a result of increased flows, the Proponent is required to re-establish natural ponding habitat and d) regular review of aquatic ecology monitoring results for any trends toward significant impacts in Burra Creek or Googong Reservoir.	AEMP
2.12	Prior to the commencement of construction, the Proponent shall consult with the Department of Industry and Investment regarding the final design of the fish egg screens and proposed operating procedures of the pump stations. The pumping station shall be designed and	Addressed in operating procedures.

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
	operated in such a way that pumping cannot occur when adequate fish egg screens are not in place.	
3.1	Prior to the commencement of construction the Proponent shall prepare and implement a **Geo-Morphological Monitoring Program** to monitor the impact of the project on the present morphology of Burra Creek at the pipeline outlet location and downstream to Googong Reservoir. The Program shall be developed in consultation with the DECCW and shall include but not necessarily be limited to: a) Set out monitoring requirements in order to assess the impact of the project on the present geo-morphology of Burra Creek at the pipeline outlet location and downstream to Googong Reservoir. b) Baseline monitoring prior to the introduction of flows through Burra Creek in order to establish any geo-morphological changes resulting from the project. c) Provisions for monitoring during construction, operational and non-operational phases; d) Mechanisms for immediately investigating any anomalous monitoring results; e) Mechanisms for the management and mitigation of any impacts on the waterways including cessation of flows where necessary; and f) Details of how the monitoring results will be reported to the Director-General and the DECCW. The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by written evidence that the DECCW has been consulted and that the DECCW is satisfied with the Program. Construction shall not commence until written approval has been received from the Director-General.	AEMP
3.2	Prior to the commencement of construction, the Proponent shall prepare and implement a **Surface Water Monitoring Program** to monitor and manage the impact of the project on the waterways into which any extracted Murrumbidgee River water is discharged. The Program shall be prepared in accordance with sections 8.2.3.3 and 8.2.3.4 of *Australian and New Zealand Guidelines for*	SF&WQP AEMP

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
	Fresh and Marine Water Quality – Volume 2: Aquatic Ecosystems (ANZECC & ARMCANZ, 2000). The Program shall be developed in consultation with the DECCW and shall include but not necessarily be limited to: a) the monitoring framework detailed in the documents referred to in condition 1.1; b) a baseline monitoring program; c) an evaluation of the discharges in terms of temporal and spatial scales; d) a comparison of discharge data with baseline data; e) sampling and data collection at representative sites, both impact (downstream of the discharge point) and control (upstream of the discharge point) sites; f) sampling and data collection for the discharges and immediate receiving environment to quantify the changes in ecosystem health and water quality with specific reference to phytoplankton, aquatic vegetation, macroinvertebrates, fish, temperature, salinity, dissolved oxygen, iron and manganese; g) provisions for the review of the Program within six months of commencement of the first full operational flow into Burra Creek; h) identification of key water parameters including but not limited to flow rate, temperature, ph, salinity, total dissolved solids and nutrient parameters for the operation of the project; i) management actions for the parameters identified in h) should they be breached; and j) details of how the monitoring results will be reported to the Director-General and DECCW. The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by evidence that the DECCW has been consulted regarding the Program. Construction shall not commence until written approval has been received from the Director-General.	
3.3	Prior to the commencement of construction, the Proponent shall prepare and implement an **Ecological Monitoring Program** to monitor the impact of the project on the ecology that may be impacted by the proposal. The	Terrestrial Plan AEMP

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
	program shall be developed in consultation with the DECCW and Department of Industry and Investment NSW and shall include but not necessarily be limited to: a) set out monitoring requirements as detailed in the documents referred to in condition 1.1 c), in order to assess the impact of the project on Ecology present along the easement and at Burra Creek at the pipeline outlet location and downstream including the Googong Reservoir; b) baseline monitoring prior to the introduction of flows through Burra Creek in order to establish any ecological changes resulting from the project. c) provisions for monitoring trench areas for any native fauna impacts likely to result from this work. Any native fauna found in the open trench shall be recorded and managed in consultation with DECCW; d) provisions for monitoring during construction, operational and non-operational phases; e) mechanisms for immediately investigating any anomalous monitoring results; f) mechanisms for the management and mitigation of any impacts on the waterways including cessation of flows where necessary; and g) details of how the monitoring results will be reported to the Director-General and the DECCW and the Department Industry and Investment NSW. The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by evidence that the DECCW has been consulted regarding the Program. Construction shall not commence until written approval has been received from the Director-General. The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by written evidence that the DECCW has been consulted and that the DECCW is satisfied with the Program. Construction shall not commence until written approval has been received from the Director-General.	

Commitment No.	Commitment / Condition (DoP Conditions of Approval NSW)	Reference
6.2	As part of the Operation Environmental Management Plan required under condition 6.4, the Proponent shall prepare and implement a Flow Management Plan that identifies the quantity, timing, duration and velocity of water transfer flows to Burra Creek. The Plan shall be developed in consultation with the DECCW.	SF&WQP

Table 1.4 DA Conditions of Approval (ACT).

Commitment No.	Commitment / Condition (DA Conditions of Approval ACT)	Reference
E9	Sourcing water – long term Under the Water Resources Act 2007, the proponent is required to hold an appropriate Water Access Entitlement and Licence To Take Water prior to extraction of any water from Murrumbidgee River for delivery to Googong Reservoir.	WU67 – Licence To Take Water
E20	The licence to extract water will be in keeping with environmental flow guidelines. This commitment was made by the proponent during the preparation of the EIS. The condition must take into account the effects of extraction on, and by, downstream users. It should also consider any new information which may be forthcoming as a result of ecological investigations that may be used to maintain or enhance the ecological values of the Murrumbidgee River in an adaptive management forum.	WU67 – Licence To Take Water AEMP SF&WQP

1. Introduction

1.1 Purpose

The Murrumbidgee to Googong (M2G) Stream Flow & Water Quality Management Plan (SFWQMP) is a consolidation of the following operational plans, which formed part of the M2G approval process:

- Stream Flow & Water Quality Management Plan (NSW)
- Flow Management Plan (NSW)
- Extraction & Gauging Plan (Cwlth - EPBC 2009/5124)
- Sustainable Diversion Limit Plan (Cwlth - EPBC 2009/5124).

The purpose of the SFWQMP is to describe in detail how ACTEW will:

- Manage, gauge, measure, monitor and report on stream flow, abstraction and discharge in the Murrumbidgee River and Burra Creek during M2G operation and maintenance.
- Manage, gauge, measure, monitor and report on water quality in the Murrumbidgee River and Burra Creek during M2G operation and maintenance.

The SFWQMP identifies how these issues are to be managed (and the commitments underpinning them).

2. Regulatory Framework

Outlined below is the legislation, guidelines and conditions of approval (for the M2G project) that are relevant to the SFWQMP.

2.1 Relevant Legislation

Table 2.1 Legislation relating to the extraction of water at Angle Crossing (Murrumbidgee River).

Legislative Jurisdiction	Relevant Act
Territory (ACT)	*Environmental Protection Act 1997* *Environment Protection Regulation 2005* *Water Resources Act 2007*
Commonwealth (Cwlth)	*Environment Protection and Biodiversity Conservation Act 1999* *Australian Capital Territory (Planning and Land Management) Act 1998* *Water Act 2007* *Canberra Water Supply (Googong Dam) Act 1974*
New South Wales (NSW)	*Protection of the Environment Operations Act 1997* *Environment Planning and Assessment Act (1979)*

2.2 Guidelines and Standards

ANZECC Water Quality Guidelines

ANZECC and ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

These guidelines form the central technical reference of the National Water Quality Management Strategy, which the federal, state and territory governments have adopted for managing water quality.

2.3 The National Water Plan

On 23 May 2008 the Murray-Darling Basin Ministerial Council approved the ACT Water Cap, the total amount of water the Territory is allowed to use or divert from the Murray Darling Basin. The ACT Water Cap is:

- 40 GL net (42 GL minus a 2 GL saving allocated to the Living Murray Initiative);
- Climate-adjusted as recommended by the Independent Audit Group; and
- Reviewed and increased by 0.75 % of the current per capita consumption of water for population growth of Canberra and Queanbeyan.

The ACT Water Cap allows the ACT, mostly through ACTEW's network, to take a net 40 GL of water per year from rivers in the basin within the ACT, that is, total water extracted less water returned to the river system from sewerage treatment facilities in the ACT and Queanbeyan.

The 40 GL/year ACT Water Cap is enough water for the ACT to use sustainably. For example, in 2007-08, the ACT and Queanbeyan net use was approximately 21 GL, made up of 44 GL through ACTEW's network, plus about 4 GL used by others, less 27 GL returned to the river.

Environmental flow rules

The *2006 Environmental Flow Guidelines* under the *Water Resources Act 2007* have been used to guide the protection of environmental flows at Angle Crossing. The *Environmental Flow Guidelines* define the Murrumbidgee River as a 'modified ecosystem'.

2.4 Commonwealth Conditions of Approval

The SFWQMP responds primarily to two Commonwealth Conditions of Approval outlined below. It is important to note that the required plans were submitted and approved by the Minister; however the new SFWQMP consolidates these plans, and is the living document for the ongoing adaptive management of the M2G.

1. *The person taking the action must submit an Extraction and Gauging Plan (now SFWQMP) that describes in detail how river flow and water extraction will be gauged, measured and reported in the Murrumbidgee River, to the Minister for approval. The plan must address the following requirements:*

   a) *How river flow will be measured at Lobbs Hole gauging station and other relevant locations;*

   b) *How base flow in the Murrumbidgee River will be maintained to abide by the conditions of this approval;*

   c) *Reporting of water extraction data; and*

   d) *Reporting of any breaches of this approval.*

   The project may not operate until an Extraction and Gauging Plan is approved by the Minister. The approved plan must be implemented.

2. *The person taking the action must submit a Sustainable Diversion Limit Plan (now SFWQMP) to the Minister for approval to ensure the long-term protection and recovery of listed threatened fish species in the Murrumbidgee River, including the Murray Cod (Maccullochella peelii), the Trout Cod (Maccullochella macquariensis) and Macquarie Perch (Macquaria australasica).*

   The SDL Plan must be developed in consultation with expert(s) approved by the Department, and in accordance with Terms of Reference submitted for the Department's approval within four weeks of the date of this approval decision. The Terms of Reference must address the matters outlined in Attachment B for this decision.

   The project may not operate without an approved SDL Plan. The approved SDL Plan must be implemented.

2.5 New South Wales Conditions of Approval

Part 3a Planning Approval Conditions (NSW) relating to M2G stream flow water quality flow management are shown below:

1. The Proponent shall comply with section 120 of the Protection of the Environment Operations Act 1997 which prohibits the pollution of waters.
2. As part of the Operation Environmental Management Plan required under condition 6.4, the Proponent shall prepare and implement a Flow Management Plan that identifies the quantity, timing, duration and velocity of water transfer flows to Burra Creek. The Plan shall be developed in consultation with the DECCW.
3. The Proponent shall design, construct, operate and maintain the project to avoid impacts on bank stability within the Burra Creek riverine corridor and Googong Reservoir outlet and does not increase local flooding risk.
4. The Proponent shall not transfer water when Burra Creek is in flood based on a one in two year event or greater nor should the Proponent operate the pipeline where it results in water levels in Burra Creek being greater that the one in two year flood level.
5. The Proponent shall implement the aquatic ecology management measures committed to in the documents set out in condition 1.1c) or elsewhere in these conditions of approval, including;

   a) monitoring and subsequent maintenance of flow transfer volumes to reasonably and feasibly mimic the natural flow regime based on the stochastic data refined in the Preferred Project Report of Burra Creek during the native fish breeding season in order to protect any spawning populations of threatened fish species;

   b) design measures to prevent the spread of invasive fish species;

c) design measures for the protection of natural ponding habitat. If the current natural ponds along Burra Creek are lost as a result of increased flows, the Proponent is required to re-establish natural ponding habitat and

d) regular review of aquatic ecology monitoring results for any trends toward significant impacts in Burra Creek or Googong Reservoir.

6. Prior to the commencement of construction, the Proponent shall consult with the Department of Industry and Investment regarding the final design of the fish egg screens and proposed operating procedures of the pump stations. The pumping station shall be designed and operated in such a way that pumping cannot occur when adequate fish egg screens are not in place.

7. Prior to the commencement of construction, the Proponent shall prepare and implement an Ecological Monitoring Program to monitor the impact of the project on the ecology that may be impacted by the proposal. The program shall be developed in consultation with the DECCW and Department of Industry and Investment NSW and shall include but not necessarily be limited to:

   a) set out monitoring requirements as detailed in the documents referred to in condition 1.1 c), in order to assess the impact of the project on Ecology present along the easement and at Burra Creek at the pipeline outlet location and downstream including the Googong Reservoir;

   b) baseline monitoring prior to the introduction of flows through Burra Creek in order to establish any ecological changes resulting from the project.

   c) provisions for monitoring trench areas for any native fauna impacts likely to result from this work. Any native fauna found in the open trench shall be recorded and managed in consultation with DECCW;

   d) provisions for monitoring during construction, operational and non-operational phases;

   e) mechanisms for immediately investigating any anomalous monitoring results;

   f) mechanisms for the management and mitigation of any impacts on the waterways including cessation of flows where necessary; and

   g) details of how the monitoring results will be reported to the Director-General and the DECCW and the Department Industry and Investment NSW.

   The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by evidence that the DECCW has been consulted regarding the Program. Construction shall not commence until written approval has been received from the Director-General.

8. Prior to the commencement of construction, the Proponent shall prepare and implement a Surface Water Monitoring Program to monitor and manage the impact of the project on the waterways into which any extracted Murrumbidgee River water is discharged. The

Program shall be prepared in accordance with sections 8.2.3.3 and 8.2.3.4 of Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Volume 2: Aquatic Ecosystems (ANZECC & ARMCANZ, 2000). The Program shall be developed in consultation with the DECCW and shall include but not necessarily be limited to:

a) the monitoring framework detailed in the documents referred to in condition 1.1;

b) a baseline monitoring program;

c) an evaluation of the discharges in terms of temporal and spatial scales;

d) a comparison of discharge data with baseline data;

e) sampling and data collection at representative sites, both impact (downstream of the discharge point) and control (upstream of the discharge point) sites;

f) sampling and data collection for the discharges and immediate receiving environment to quantify the changes in ecosystem health and water quality with specific reference to phytoplankton, aquatic vegetation, macro invertebrates, fish, temperature, salinity, dissolved oxygen, iron and manganese;

g) provisions for the review of the Program within six months of commencement of the first full operational flow into Burra Creek;

h) identification of key water parameters including but not limited to flow rate, temperature, ph, salinity, total dissolved solids and nutrient parameters for the operation of the project;

i) management actions for the parameters identified in h) should they be breached; and

j) details of how the monitoring results will be reported to the Director-General and DECCW.

The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by evidence that the DECCW has been consulted regarding the Program. Construction shall not commence until written approval has been received from the Director-General.

9. Prior to the commencement of construction the Proponent shall prepare and implement a Geo-Morphological Monitoring Program to monitor the impact of the project on the present morphology of Burra Creek at the pipeline outlet location and downstream to Googong Reservoir. The Program shall be developed in consultation with the DECCW and shall include but not necessarily be limited to:

   a) Set out monitoring requirements in order to assess the impact of the project on the present geo-morphology of Burra Creek at the pipeline outlet location and downstream to Googong Reservoir.

   b) Baseline monitoring prior to the introduction of flows through Burra Creek in order to establish any geo-morphological changes resulting from the project.

c) Provisions for monitoring during construction, operational and non-operational phases;

d) Mechanisms for immediately investigating any anomalous monitoring results;

e) Mechanisms for the management and mitigation of any impacts on the waterways including cessation of flows where necessary; and

f) Details of how the monitoring results will be reported to the Director-General and the DECCW.

The Program shall be submitted for the approval of the Director-General no later than one month prior to the commencement of construction, or within such period otherwise agreed by the Director-General, accompanied by written evidence that the DECCW has been consulted and that the DECCW is satisfied with the Program. Construction shall not commence until written approval has been received from the Director-General.

10. As part of the Operation Environmental Management Plan required under condition 6.4, the Proponent shall prepare and implement a Flow Management Plan that identifies the quantity, timing, duration and velocity of water transfer flows to Burra Creek. The Plan shall be developed in consultation with the DECCW.

2.6 Australian Capital Territory Conditions of Approval

The ACT conditions of approval relating to stream flow and water quality were captured through the Development Application Process, and are shown below

1. Sourcing water – long term: Under the Water Resources Act 2007, the proponent is required to hold an appropriate Water Access Entitlement and Licence To Take Water prior to extraction of any water from Murrumbidgee River for delivery to Googong Reservoir.

2. The Licence To Take Water will be in keeping with environmental flow guidelines. This commitment was made by the proponent during the preparation of the EIS. The condition must take into account the effects of extraction on, and by, downstream users. It should also consider any new information which may be forthcoming as a result of ecological investigations that may be used to maintain or enhance the ecological values of the Murrumbidgee River in an adaptive management forum.

2.7 M2G Environmental Impact Assessment

The M2G Environmental Impact Assessment (EIS) detailed the following commitments relevant to the SFWQMP:

1. ACTEW's Source Water Protection Program will continue to address water quality issues in the Murrumbidgee River.

2. A standard operating procedure will be developed for access to the pipeline during maintenance activities, chemical/fuel storage, and for pipe flushing that meets legislative requirements.

3. Installation of a grit collection hopper at the low lift pump station and discharge of captured sediments back to the Murrumbidgee River to reduce the turbidity of water transferred to Burra Creek. Use of an automatic timer on the grit collection hopper to ensure that relatively small volumes of sediments are discharged on a continuous basis to reduce impacts on the Murrumbidgee River downstream. Ongoing monitoring and appropriate adjustments to the timers or release volumes to minimise potential impacts.

4. Water abstracted from the Murrumbidgee River will be released into Burra Creek as soon as practicable to minimise deoxygenisation and temperature changes. Operational rules will be developed to acceptable levels of turbidity in the Murrumbidgee.

5. Regular review of water quality monitoring results for any trends toward significant impacts in Murrumbidgee River, Burra Creek or Googong Reservoir. The monitoring and adaptive management plan will include actions required to address any identified trends in a timely manner.

3. M2G Operational controls

3.1 Existing Water Abstraction

All existing ACTEW water abstractions are taken from the Murrumbidgee River and its tributaries with approximately 25 GL/year returned to the Molonglo River near its confluence with the Murrumbidgee River (from the Lower Molonglo Water Quality Control Centre). Consequently, all water consumption in Canberra and Queanbeyan impacts on the Murrumbidgee River. All current water extraction is within the negotiated National Water Plan Cap for the ACT of 40 GL.
It is important to note that M2G is a transfer not an extraction. Hence the water transferred from the Murrumbidgee will be counted in the Cap as it passes through Googong Reservoir.
ACTEW is currently licensed by the ACT EPA to take water from:

- Bendora Reservoir on the Cotter River
- Cotter Reservoir on the Cotter River
- Googong Reservoir on the Queanbeyan River
- Directly from the Murrumbidgee River downstream of the Cotter River confluence.

In addition to these sources, ACTEW stores water in Corin Reservoir, upstream of the Bendora and Cotter Reservoirs on the Cotter River. ACTEW can also transfer water taken from the Cotter River or Murrumbidgee River into Googong Dam.
The amount of water taken (and protected for environmental flows) from the Murrumbidgee catchment and tributaries is dictated by urban water demand, and the environmental flow regulations prescribed and licenced by the ACT Environment Protection Authority (ACT EPA).
ACTEW operating rules are used to determine which of the sources are used to supply water. The general operating guidelines for these sources are outlined below. Note that the operating guidelines are updated yearly to work with new infrastructure, updated environmental flow requirements, and forecast demand and supply ratios.

- If demand is high it may be necessary to supply water simultaneously from Stromlo treatment plant (Bendora/Cotter/Murrumbidgee) and Googong treatment plant. However, if demand is low a preferred source will normally be selected. In low demand periods it may also be desirable to transfer water into Googong Dam via the Stromlo treatment plant.
- As the first priority, use Bendora water as required to minimise the likelihood of Bendora overflowing. An operational level of 5 m below spillway should be targeted.
- If Bendora Dam is at target and Corin Dam and Googong Dam are both below 90% full, use Cotter Dam and Murrumbidgee water whenever possible to improve the overall storage situation.
- If possible, transfer water to Googong Dam in the following situations:
    - Transfer Bendora water to Googong to bring Bendora to target if Googong is less than 90% full.

- Transfer Corin water to Googong if Corin's percentage storage is well above Googong's storage and Googong is less than 90% full.
- Transfer Cotter and Murrumbidgee water to Googong if supply exceeds demand and Googong is less than 80% full.

- Maintain a balance between the storage in Corin Dam and Googong Dam.
- The M2G Transfer will supply water into Googong Reservoir whenever it is below 80% of capacity, in accordance with the M2G extraction regime.

3.2 Relationship to Tantangara Reservoir

Tantangara Reservoir is located at the headwaters of the Murrumbidgee River in NSW and is managed and operated by Snowy Hydro Ltd under the Snowy Water Licence. Under this licence, Snowy Hydro Ltd is required to release water from Tantangara Reservoir for environmental purposes. The volumes and release regimes are determined based on advice from the Water Administration Ministerial Corporation (who in turn is advised by the Snowy Scientific Committee). If no advice is received, then a default pattern of environmental water releases is applied, as set out in the Snowy Water Inquiry Outcomes Implementation Deed (SWIOID 2002). Currently ACTEW Corporation has no ability to influence the release of water from Tantangara Reservoir, nor is ACTEW informed when releases have, or are going to occur.

The ACTEW Tantangara Transfer is an additional water security project being pursued by ACTEW. The proposed project is based on transferring water from the regulated Murrumbidgee River to the ACT via the Snowy Mountains Scheme. This would involve:

- Buying NSW water entitlements from Murrumbidgee River irrigators downstream of the ACT;
- Agreeing on commercial arrangements with Snowy Hydro Ltd for the storage and release of water from Tantangara Reservoir;
- Putting in place arrangements between the NSW and ACT Governments to allow for transfer of water from NSW to the ACT; and
- Delivery of water to the ACT via the Upper Murrumbidgee River.

The Tantangara Transfer project involves a high level of legal and political assurance to provide the confidence to rely on this option. At this point, ACTEW is still working through many legal, technical and political issues associated this project.

The Tantangara Transfer project is discrete from the M2G Transfer project and is currently several steps away from being implemented. If the Tantangara Transfer becomes a viable project, it will have implications for the volumes of water available for extraction in the Murrumbidgee River. Throughout this SFWQMP, all 'flow' references refer to those flows occurring naturally in the Murrumbidgee River (including Tantangara environmental flow releases). This SFWQMP does not apply to water purchased by ACTEW.

3.3 Predicted quantity, timing, duration and velocity of water flows

The design of the M2G pumping system enables water to be pumped through the pipeline in five discrete steps; nominal quantities of 20, 45, 60, 90 and 100 ML/day (see also Table 3.1). When the scheme is in operation, water transfers may occur up to 24 hours a day.

The predicted average volume of water transferred from Angle Crossing to Googong via Burra Creek for the first ten years of operation was modelled in the Environmental Impact Statement to be 8 to 10 GL/year. However, the rate of transfer will change significantly from year to year due to the high variability in climate conditions, to the point where the project could operate virtually all year round, or not at all.

Figure 3-1 shows the potential, modelled rate of transfer against historical flows in the Murrumbidgee River and the current environmental flow requirements during a characteristic low, medium and high flow year. This figure shows that the proposed transfer regime will protect key ecosystem processes as identified in the *ACT Environmental Flow Guidelines* (2006). The figure also shows that that the scheme will typically operate during the wetter (spring) months in each year, however it is possible that the duration of transfers could be all year round.

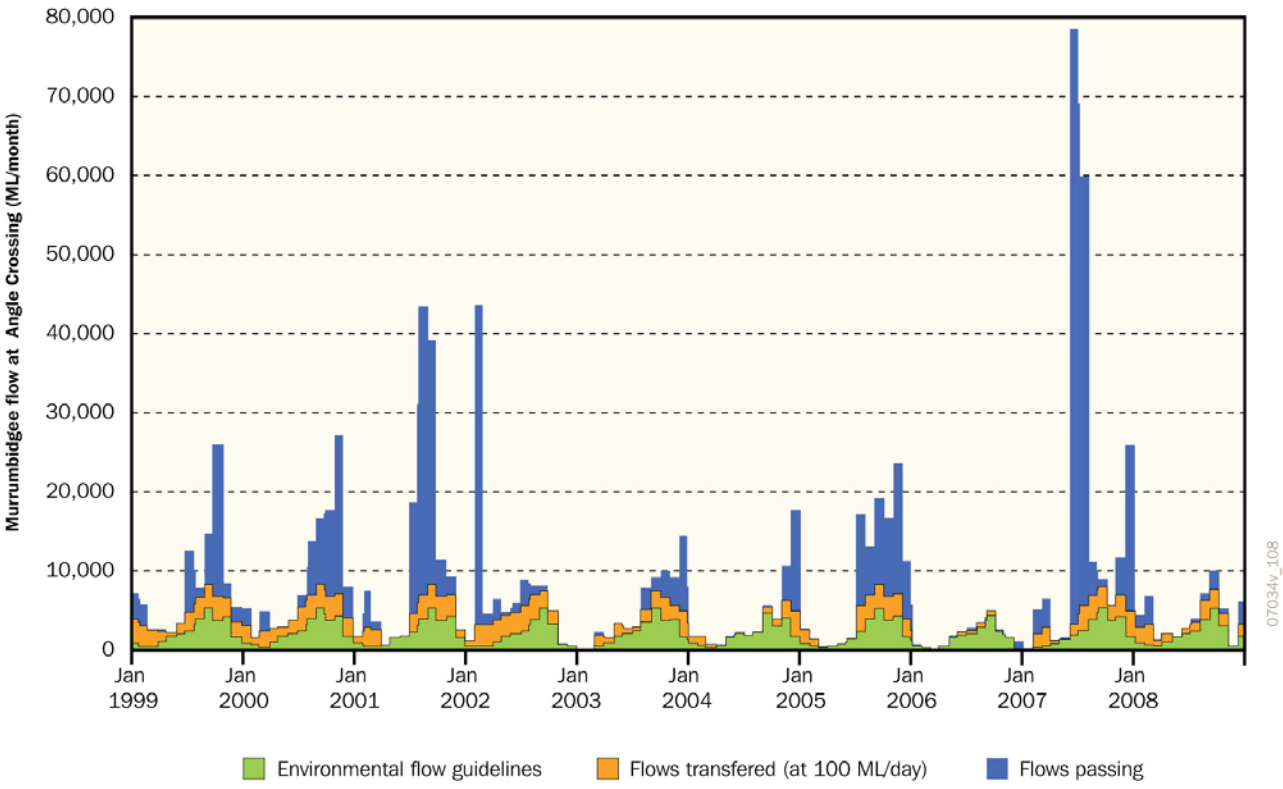


Figure 3.1 Murrumbidgee River flows showing proposed transfer volumes and environmental flows using historical data.

Where there are prolonged periods where M2G is not required to be transferring bulk to the Googong Reservoir ('operation' mode), the M2G will be in either 'suspension' or 'standby' mode:

- Suspension: parts of the system may be decommissioned requiring lead time before start up. No water can be transferred.
- Standby: ready to run, all components in place and being operated routinely for maintenance purposes, which includes the transfer of smaller quantities of water (around 50ML/d) for shorter periods of time (generally around 48 hours).

3.4 River Gauging and Flow Measurement

The three key measurement devices for gauging river flow and water extraction from the Murrumbidgee River are:

- **Upstream Angle Crossing Gauging Station (MURW2) (#41000270):** This is a stream flow gauging station located approximately 1km upstream of the extraction point in the Murrumbidgee River. The data from this station (MURW2) will be used on a day to day basis to manage the extraction regime. The station, which is owned by ACTEW Corporation, is a typical station with a rating curve that translates a depth of flow to a flow rate; and also monitors a range of water quality parameters. Data is currently polled via satellite telephony (by a hydrographic services provider) once every six hours. MURW2 is a critical measuring device for the operation of the scheme.
- **Pipeline Flow Meter:** The pipeline installation includes an electromagnetic flow meter which will very accurately measure and record the amount of water being transferred through the pipeline. The Pipeline Flow Meter is a critical measuring device for the operation of the scheme.
- **Lobb's Hole Gauging Station (#410761):** This is a stream flow gauging station located approximately 2km downstream of the extraction point in the Murrumbidgee River. The station, which is owned by the ACT Government, is a typical river weir with rating curve that translates a depth of flow to a flow rate. Data is currently polled via satellite telephony (by a hydrographic services provider) once every six hours. Lobb's Hole is not a critical gauging station for the operation of the scheme.

M2G uses all three measurement devices to provide reliable data to inform management ad operational decisions. River flow data from the Pipeline Flow Meter and MURW2 will be telemetered via a microwave communications link to the SCADA System. The SCADA System is the primary operational control system for gauging and measuring river flow and water extraction for the Murrumbidgee to Googong Water Transfer, and indeed most of ACTEW's operations. Data within the SCADA System is remotely backed up to enable systems recovery in the event of system failure.

Data from the stream flow gauging stations is also kept remotely by a hydrographic services provider (currently ALS Global).

3.5 SCADA System

The SCADA (Supervisory Control and Data Acquisition) System records all necessary data and logs all events associated with the Water Transfer. This system will be the primary system to support this Stream Flow and Water Quality Management Plan. The System will be set up to include alarms and/or automatic shut off if the Water Transfer is not being operated in accordance with the environmental flow rules or any other requirement.

3.6 Base flow Protection

Base flow in the Murrumbidgee River will be protected by ensuring that the amount of water extracted from the Murrumbidgee River (as measured by the Pipeline Flow Meter) will not reduce the flow to below the protected flows for each month. Whenever M2G is operating, a review will be undertaken at least daily to ensure that extraction from the Murrumbidgee River can continue for the following 24 to 48 hours.

This check is made through the following calculation:

River Flow = MURW2 – Pipeline Flow Meter Flow

In the event that the daily review of the extraction regime fails to pick up any potential non-compliance in relation to protected flows, the automated alarms and logs within the SCADA System will make a record, for subsequent review and reporting.

The information obtained through the above calculation of river flow will also be compared to the hydrographic records for Lobbs Hole Gauging Station. If a significant discrepancy exists between the river flow calculation and the Lobbs Hole Gauging Station data, ACTEW will arrange for a site inspection to check the gauging stations to clear any debris or to remove any other noticeable cause. It should be noted that all gauging station are regular inspected and calibrated to ensure data is within the acceptable error margins.

3.7 M2G Start Up Check (STANDBY OR OPERATION)

The following outlines the rules that must be met prior to M2G pump start-up for standby or operation.

- Googong Reservoir shall be below 80% capacity (for full operation only), as measured at the dam wall
- ACTEW, having assessed other conditions relevant to the water storage system, including total system capacity and predicted weather conditions, wish to proceed with commencement of pumping
- Environmental flow protection conditions can be met for the period until flows next reviewed

- Online water quality monitoring measured at MURW2 (or using the in-system sensors) in the Murrumbidgee River must be within the acceptable levels for water transfer to commence. Allowance is to be made for the likely validity of the data output, expected trend over the next 24 hours (or until data is downloaded again) based on predicted rainfall events and predicted flows. The online trigger levels are identified in this plan.
- The flow in Burra Creek must be below the level associated with a 1 in 2 year flood (currently 1830ML/d). The water transfer must not cause Burra creek flow to exceed the 1 in 2 (currently 1830ML/d) year flood level
- Fish egg filtration screens must be in place and fully functional at the abstraction point
- Management actions required to be taken to address ecological and/or geomorphological impact since the last flow episode must have been completed.
- If water quality monitoring measured at MURW2 (the M2G in-system sensors or Lobbs Hole may be used as surrogates or supports or MURW2) is above trigger levels then additional aquatic ecology and water quality monitoring in Burra Creek is to be initiated.

If the above criteria are met then the water transfer or maintenance run can take place via the pump start up procedure(s) outlined further below.

3.8 Maintain, regulate or unplanned stoppage of water transfer (OPERATION)

Once bulk water transfer has commenced (operation) decisions will be made about maintaining, regulating or ceasing flow. Water transfer will be managed under the following circumstances:

- Fish egg filtration screens must remain in place at the abstraction point and be fully functional.
- The flow in Burra Creek must be below the level associated with a 1 in 2 year flood flow. Levels are to be checked in a timely manner or an alarm level set up at the gauging site (410774). The water transfer must not cause Burra creek flow to exceed the 1 in 2 year flood level.
- Flow in the Murrumbidgee River for the day (to the standard 8am data download) must protect environmental flow requirements.
- Googong Reservoir is to remain below 80% full, although some operational flexibility is required, as measured at the dam wall.
- If online water quality monitoring is above levels which trigger additional aquatic ecological monitoring in Burra Creek then that monitoring must be initiated. Allowance is to be made for the likely validity of the data output. The water quality trigger levels are identified in this SFWQMP.

- If the above criteria are met then the water transfer can continue to take place at a rate which:
  - Does not reduce flows downstream of Angle Crossing below those required to be protected under all environmental protection flow rules
  - Does not cause flows in Burra Creek to exceed the 1 in 2 year ARI (currently 1830ML/d)
  - Does not exceed 100Ml/d (nominal).
- Where possible introduce flow level changes that mimic natural flow variability. A constant flow shall not be maintained for a long period of time such that it would negatively impact establishing a healthy ecological system.
- If flow cannot continue and needs to be stopped abruptly then monitoring of fish in Burra Creek should take place to identify any episodes of native fish stranding. If native fish stranding is observed then rescue procedures must be initiated. (Note: no native fish are currently known to exist in Burra Creek).
- If turbidity at Angle Crossing (or surrogate sensors) is between the HiHi value and the HiLo value (see this SFWQMP), then pumping is to continue until the turbidity is below the HiLo value to ensure suspended material is transported to Googong Reservoir.

3.9 Pump Start Up/shutdown procedure (OPERATON & STANDBY)

The following outlines the start up and shutdown procedures for the water transfer scheme. The step-up and step-down times were updated in 2012 in response to additional environmental analyses. The updated step times more closely mimic natural events occurring within Burra Creek.

- On all start up processes (i.e. pump start ups), ensure environmental flow requirements in the Murrumbidgee will remain protected, and Burra Creek flows will not exceed the 1 in 2 year flood flow;
- Follows step-up and step-down times as shown below in Table 3.1:

Table 3.1 step-up and step-down times for peak pumping rates from 21 to 109 ML/d.

Peak Pumping Rate	High Lift Pumps required for peak rate	Minimum Step-up time	Minimum Step-down time
21 ML/d	1 small pump	0 hrs	2 hrs
49 ML/d	1 large pump	0.5 hrs	4 hrs
68 ML/d*	1 small pump and 1 large pump	1 hr	6 hrs
94 ML/d*	2 large pumps	2 hrs	8hrs
109 ML/d*	1 small pump initially then add 2 Large pumps incrementally	2hrs	8hrs

** Utilising more than the capacity of one large pump is not required for a maintenance standby run as the large pumps can be run consecutively. Flow rates above 49ML/d are expected during operational mode water transfer only.*

In the Table above the step-up time is the time taken to reach the desired peak pumping rate. Therefore for 49 ML/d, it is recommended the small 21 ML/d pump be switched on for approximately 30 minutes prior to switching on a large 49 ML/d pump.
If the 109 ML/d pump rate is required to be tested during a maintenance run, a scenario would be to have the small pump run for half an hour before the first large pump is switched on, and then incrementally step up the pump rate over the next hour and a half to achieve the minimum 2hr step-up time to 109 ML/d.

The timing of flow increases should provide as smooth a transition as possible to the peak pumping rate, with the switching down of pumps tapering off more gradually.

For the minimum step-down time, this is the recommended time for the flow to reduce from the peak pump rate to no pumps operating. Reducing from the 49 ML/d pumping rate would require the small pump to run for 4 hours after the large pump is turned off. From higher pump rates the pumps would be incrementally stepped down with a preference to running the small pump at the end for about half the total step-down time, to simulate the slow tapering off in the tail end of a natural hydrograph.

If the maintenance run is to be undertaken over two consecutive days to run one large 49 ML/d pump on each day, then the minimum 4 hour step-down time only applies to the large pump run on the second day. This is because any fish (noting currently no native fish are

present in Burra Creek) potentially trapped on the first day from a quicker shutdown would be able to remobilise during the flow and step-down time on the second day. The minimum step-up time still applies on each day.

There are minimum time intervals between a pump stopping and re-starting (approximately 15 min) and also minimum times between stepping up and stepping down the flows due to transient surges in the pipeline (approximately 30 min). Within these limits the stepping up and stepping down can be sequenced to best accommodate the environmental considerations. As with all aspects of the water transfer scheme, the start up and close down procedures are subject to review as part of the adaptive management process.

Using remote telemetry and SCADA, specific attention will be provided to the predicted Murrumbidgee River flow rates to ensure extraction does not reduce flow in river below the protected environmental flow volumes.

4. M2G Stream Flow & Water Quality Management

4.1 Protection of Environmental Flows

The protection of environmental flows at Angle Crossing is a key governing factor around the operation of the M2G. M2G environmental flow protection is linked to ecological objectives and key performance indicators, as shown below.

4.1.1 Sustainable Diversion Limit Plan (SDLP)

The Sustainable Diversion Limit Plan (SDLP) was the key Commonwealth document (in the approvals process) to define what flows are to be protected from extraction. The overall aim of the SDLP (and now this SFWQMP) is to ensure the long-term protection and recovery potential of listed threatened fish species in the Murrumbidgee River, including Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*) and Macquarie Perch (*Macquaria australasica*). These species are discussed in more detail, including their relevance to M2G at Appendix A.
The SDLP terms of reference for the original SDLP are outlined below:

1. Identify the Flow-Dependent Ecological Features (FDEF) critical to the threatened fish, including:
    a) What is currently known of the threatened fish species populations, their distribution and status and their habitats downstream of the proposed extraction point (to the Molonglo River confluence), and considering the priority knowledge gaps ('status gaps');
    b) Which of the listed threatened fish species are the priority species for the SDLP and how further investigation / monitoring / adaptive management actions will be balanced across these species;
    c) Critical / priority flow dependent ecological features potentially affecting the fish species (recognising that for some, FDEF gaps may need to be filled before this is possible);
    d) Potential impacts of reduced flow on priority flow dependent ecological features and priority knowledge gaps in respect to these processes ('FDEF gaps');
    e) Regional context for the project including interactions with other water utilisation projects i.e. potential for cumulative impacts;
    f) Any other relevant requirements and factors contained in Attachment B to the EPBC Act Approval Notice, which need to be considered in identifying the ecological flow requirements.

2. Identify critical knowledge gaps and research needs for priority species and flow-dependent ecological features. This will include an evaluation of the consequences of the knowledge gaps for setting water extraction volumes such as the viability of follow-up monitoring and adaptive management. If necessary, identify and undertake FDEF investigations to identify the flow requirements for threatened fish. In light of this evaluation, the best method for obtaining and utilising the required information will be determined, taking account of critical project timeframes.
3. Determine extraction rules taking into account:
    g) Flow requirements for priority threatened species and flow-dependent ecological features;
    h) Knowledge gaps and research needs; and
    i) Water supply requirements.
4. Determine:
    j) Monitoring focused on the priority threatened fish species and/or flow-dependent ecological features, which provides the necessary feedback into an adaptive management system;
    k) Details of the adaptive management system including triggers and management responses; and
    l) Any operational changes or offsets related to the project that may be required should the monitoring regime indicate that the project has resulted in impacts to threatened fish.
5. Provide a glossary of key terms.

These terms of reference and the original SDLP were developed in consultation with SEWPaC (now Commonwealth Department of the Environment; DotE) and a panel of independent experts with expertise in environmental flows, fish ecology, river health, geomorphology and the ACT reaches of the Murrumbidgee River.

4.1.2 Environmental flow objectives for M2G at Angle Crossing

The key environmental objectives for the setting of environmental flows at Angle Crossing for M2G were developed by the Commonwealth Expert Panel and are described below:

Objective 1 (SDLP)

Provide suitable habitat and habitat diversity for fish species by maintaining and/or improving:

a) Depth and extent of deep pools;
b) Water retention times in pools;
c) Structural complexity including woody habitat, overhanging vegetation and instream boulders; and
d) A range of instream depth profiles and flow velocities.

Rationale: these measures will improve habitat quality for threatened fish currently within the river and provide habitat for new recruits to establish. Hard surfaces are required for egg laying by Murray Cod.

Objective 2 (SDLP)
Provide opportunities for fish movement, as required, by ensuring:

a) Longitudinal connectivity of the channel during spring and early summer; and
b) Suitable water depth.

Rationale: movement of fish during key times of year, i.e. for spawning, is facilitated. Vagrant fish and new recruits can move freely throughout the system and can arrive at areas of suitable habitat.

Objective 3 (SDLP)
Maintain clean and productive riffle habitats.
Rationale: riffle zones are key areas of productivity within the river and reflect general river health. If a breeding population of Macquarie Perch establishes, clean riffles are available as spawning habitat.

Objective 4 (SDLP)
Maintain and improve water quality in the river downstream of the extraction point, especially dissolved oxygen in pools.
Rationale: suitable water quality conditions are necessary for adults and larval development. Spring water temperature increases are important cues for spawning.

Objective 5 (SDLP)
Ensure that M2G does not create extended periods where flow is no higher than base flow level i.e. drought-like conditions.
Rationale: if flow is maintained at low levels for an extended time, then there is little opportunity for recovery and potentially prolonged duration of 'poor' conditions. Such extended base flow conditions are likely to occur at times of natural low flow and high temperatures i.e. "hot, dry years", when risks to native fish are the highest.

There are also additional objectives outlined in the *2006 Environmental Flow Guidelines which relate to the support of* a range of functions including recreation, conservation and irrigation in the Murrumbidgee River; and the maintenance of healthy aquatic ecosystems in terms of biota; and prevent degradation of riverine habitat through sediment deposition.

4.1.3 Environmental flow rules for M2G at Angle Crossing

The environmental flow protection rules governing M2G were guided by the ACT Government's Environmental Flow Guidelines (2006), and developed using expert scientific input and take account of a number of environmental issues including native fish requirements. They represent the currently best informed guidance for developing an extraction regime for the M2G Transfer.
It was recognised by the expert panel that there is insufficient scientific knowledge to develop the environmental flow protection rules with full certainty regarding threatened fish species

flow requirements. However, the research, monitoring and adaptive management program will be used to confirm, validate and update rules and ecological outcomes, as required. It is expected that over time, as the knowledge of native fish ecology and flow requirements increases, ACTEW will respond to either a) propose adaptations to the rules or b) design fish offset / recovery actions, in association with relevant government agencies.

The rules are designed to meet the following goals:

- To ensure the M2G Transfer meets the stated ecological objectives (above)
- To satisfy social, environmental and economic sustainability principles
- To assist the long term protection and/or recovery of the fish species by improving scientific knowledge
- Respond to concerns identified by the expert panel during the development of the SDLP.

The environmental flow protection rules for M2G focus on the protection of three flow types (as per the Environmental Flow Guidelines 2006), hence identifying base flow, riffle maintenance flow; and pool and channel maintenance flow requirements.

- Environmental base flows at Angle Crossing (minimum flow protected) has been set at the 80th percentile flow between November and May and the 90th percentile flow between June and October (using post-Tantangara reservoir river flow data from approximately 35 years of record November 1974 – January 2010 at Lobbs Hole gauging station no. 410761). The base flows are strengthened during drought conditions in order to ensure M2G does not prolong natural low flow conditions in the Murrumbidgee River.
- No riffle flows are required in the current Environmental Flow Guidelines for the Murrumbidgee. However, ACTEW is proposing to operate the Murrumbidgee to Googong Water Transfer in a manner that protects riffle flows every thirty days, for at least a 24 hour period, should they occur naturally (“Riffle maintenance flow rule”); and
- Pool and channel maintenance flows have been identified as important in the Environmental Flow Guidelines. However, the volumes of water required to provide these ecosystem services is of such magnitude (<12,000ML/d for channel maintenance for the Murrumbidgee River) that the extraction of 100Ml/d has been identified as not impacting these events. Hence, specific pool and channel maintenance flows are not required.

The adaptive management approach applied to the abstraction rules will allow for adjustment in the environmental flow requirement to ensure ecological objectives are maintained over time.

Base flow protection rule (normal conditions)

Protect natural flows at the following volumes presented below (ML/d):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
32.5	22.4	15.7	35.0	54.8	64.8	78.9	98.6	169.1	127.6	130.3	53.4

Base flow protection rule (drought conditions)

Protect natural flows (ML/d) shown below when the following 'drought rule' is triggered – where average flow in at least 15 of the 18 (~80%) past dry season months (Nov-April inclusive) is below the flows shown above.

Jan	Feb	Mar	Apr	May	Jun
115.7	93.4	95.2	75.9	355.3	190.9

Riffle maintenance flow rule

Protect a minimum of 195ML/d natural flow, for a period of 24 hours, once every thirty days, measured at Lobbs Hole (stream flow station 410761). Extraction during this period cannot reduce flows to below 250ML/d. Note that the 30 day count will reset to zero whenever flow downstream of the pump station exceeds 195ML/d continuously for 24 hours.

The base flow protection (normal conditions) and riffle flow rules are programmed into the M2G operating system and automatically administered via SCADA. The base flow protection rule (drought conditions) is considerably more complex (being time based over three years) and is administered manually.

4.1.4 How the environmental flow rules meet ecological objectives

Table 4.1 demonstrates the relationship between flow rule and ecological objectives set for M2G. Details of the method used to determine volumes are also shown below.

Table 4.1: Flow components that are required to fulfil each ecological objective.

ECOLOGICAL OBJECTIVE	FLOW COMPONENT(S) REQUIRED TO ACHIEVE OBJECTIVE	EXTRACTION REGIME REQUIRED TO ACHIEVE OBJECTIVE, SUBJECT TO ADAPTIVE MANAGEMENT
Objective 1: provide suitable habitat and habitat diversity for fish species	Base flow: maintains minimum pool volume, regulates maximum water retention time in pools, maintains habitat, maintains riparian vegetation Moderate flow: improves habitat condition and diversity through flushing, water for riparian vegetation High flow: channel and pool maintenance flows, delivers woody debris and organic matter from riparian zone, transports riparian propagules laterally and longitudinally for recruitment opportunities, may trigger recruitment for some riparian species (e.g. seed drop, germination).	Base flow Moderate flow: 195 – 250 ML/d High flow: >1,100 ML/d
Objective 2: provide opportunities for fish movement, as required	Base flow: allows movement between instream barriers Moderate flow: drown out instream barriers, allows downstream movement of larvae and juveniles High flow: drown out large instream barriers allowing connectivity for adults, allows vagrant fish to enter system	Base flow Moderate flow: 195 – 250 ML/d High flow: >1,100 ML/d
Objective 3: maintain clean and productive riffle habitats	Moderate flow: scour sediment and algae from riffles	Moderate flow: 195 – 250 ML/d
Objective 4: maintain and improve water quality and temperature in the river downstream of the extraction point	Base flow: allows mixing to prevent anoxic conditions at depth, regulates maximum water retention time in pools Moderate flow: flushing flows to remove accumulated organic matter	Base flow Moderate flow: 195 – 250 ML/d
Objective 5: ensure that M2G does not create extended periods where flow is no higher than base flow level	Base flow: protects a larger base flow during times of prolonged low flow (i.e. drought) in order to allow more water to pass down the river to environmental purposes (if water is available)	Base flow

4.1.5 Flow volume rationale

Objective 1: Provide suitable habitat and habitat diversity for fish species

Base flow rationale – Suitable habitat for Murray Cod includes deep pools. These pools are largely independent of ecological base flow functions indicating the extraction regime is unlikely to have negative impacts. it is important to note that Murray Cod have persisted in the upper Murrumbidgee River (below Gigerline Gorge) during very low flow (i.e. drought) conditions over the past 10 – 15 years that have seen the flow in the river drop regularly below the base flow rates indicated above.

Moderate flow rationale – flows required to perform a riffle maintenance flow function would require a velocity approaching 0.5 m/s. Assuming a minimum depth of 0.15m this indicates a minimum flow requirement of 195ML/d. It is proposed to conservatively include a riffle maintenance protection flow at 25% above this value at 250 ML/d, to account for the significant variability in riffle structure.

High flow volume rationale – a pool maintenance flow requires a significant rainfall event to occur in the upper Murrumbidgee catchment resulting in a significant increase in river flow volume. For example, the cross sectional area in the pool immediately upstream of Angle Crossing varies, but assuming a 30m^2 area from a recent survey, and mean velocity of 0.4m/s to mobilise fine silt during an event, a minimum flow of 1100ML/d is required. Some pools may require larger velocities to mobilise silt, which means a flow in excess of 1100ML/d would be required.

Objective 2: Provide opportunities for fish movement, as required

Base flow rationale – Adult Murray Cod are thought to remain in deep pools during low flows. Minimum flows are to be allowed to pass M2G pumping station to facilitate continuous water delivery (if naturally available) to pools.

Moderate flow rationale – Adult Murray Cod are thought to remain in deep pools during moderate flows. Juvenile Murray Cod may utilise moderate flows to undertake short-range movements between pools. Minimum flows are to allow to pass M2G pumping station to facilitate continuous water delivery (if naturally available) to pools.

High flow rationale – Adult Murray Cod are thought to utilise large flow events to move. High flow events will not be impacted by M2G Transfer extraction of up to 100 ML/day.

Objective 3: Maintain clean and productive riffle habitats

Moderate flow rationale – as for objective 1.

Objective 4: Maintain and improve water quality downstream of the extraction point

Base flow rationale – The impact of extraction on water quality (primarily dissolved oxygen, DO) and temperature will be highest when the flow in the river is very low, i.e. the lower the mass of water the lower the amount of energy required to change its temperature and associated percent DO saturation. As the low flows in the Murrumbidgee River will be protected from extraction, an ecologically detrimental change in temperature and DO due to water extraction is not expected to occur. Any potential changes in water temperature resulting from M2G operations (albeit small changes) would result in a warming effect. Current understanding identifies decreasing (not increasing) temperatures as having possible detrimental effects on Murray Cod spawning and growth rates.

Moderate flow rationale – Flushing flows as described for objective 1, which are designed to scour riffles of sediment and algae will also provide water quality maintenance function.

Objective 5: Ensure that M2G does not create extended periods where flow is no higher than base flow level

Base flow rationale – a concern of the expert panel was the M2G Transfer has the potential to extend the period during which flows are at low levels e.g. no higher than the base flows identified on page 29. In order to address this concern, protected base flow levels have been increased for "drought conditions". Based on discussions with expert panel members and extensive modelling of the existing record (1974 – 2011), "drought conditions" have been defined as – months where average flow in at least 15 of the 18 previous dry season months (Nov – April inclusive) is below the flow volumes shown in Table 4.1 above. This situation was observed in summers of 2004-05, 2005-06 and 2006-07, giving confidence that this definition is a realistic representation of "drought conditions".

4.1.6 Interaction with other water extractions

There are no likely additional or cumulative impacts on threatened fish from M2G water extraction regime, for the following reasons:

- Environmental flows released from ACT impoundments on the Cotter River exist under an established adaptive management framework.
- Cotter River environmental flows (below Cotter Dam) were approved by the Commonwealth in 2010 as part of the Enlarged Cotter Dam referral process.
- Extraction of water from the Murrumbidgee River at the Cotter Pumping station is also subject to existing environmental flow rules determined by the ACT Government. These rules have been established on the same environmental flow basis as the M2G flow rules.
- Moderate riffle protection flows passing the M2G pumping station would not be extracted at the Cotter Pumping Station.
- High flows will not be impacted by the M2G Transfer.
- Substantial inflows into the Murrumbidgee occur downstream of Angle Crossing, both naturally (e.g. tributary inflows from Gudgenby River, Paddy's River, Molonglo River, Tuggeranong Creek etc) and as managed releases from the Lower Molonglo Water Quality Control Centre (LMWQCC).

4.1.7 Key performance indicators

Key performance indicators (KPIs) are required to determine if the environmental flows provided for by this SFWQMP are meeting the stated ecological objectives. Measurement of the following KPIs will be an integral part of the monitoring and adaptive management framework. If KPIs are not being met, management actions will be triggered as outlined in the adaptive management framework. Note that some knowledge gaps may need to be filled before analysis of KPIs is possible. Note that KPIs relate specifically to the effects produced by the operation of M2G i.e. not naturally occur scenarios.

Table 4.2: Key performance indicators to determine if the environmental flows provided for by this plan are meeting the stated ecological objectives.

ECOLOGICAL OBJECTIVE	KEY PERFORMANCE INDICATOR
Objective 1: provide suitable habitat and habitat diversity for fish species	Minimum depth and extent of key habitat pools are maintained in low flow conditions. Structural complexity of key reaches is maintained or improved, as measured by on-going presence of woody debris, riparian vegetation, instream boulders. A range of instream depth and flow velocities are provided.
Objective 2: provide opportunities for fish movement, as required	In-stream barriers are drowned out at key times of key, on moderate to high flows. Minimum depth is maintained in key shallow reaches.
Objective 3: maintain clean and productive riffle habitats	Riffle cleaning flows effectively scour riffles of sediment and algal films.
Objective 4: maintain and improve water quality and temperature in the river downstream of the extraction point	Water retention time in large pools does not result in hostile water quality conditions, particularly at depth.
Objective 5: ensure that M2G does not create extended periods where flow is no higher than base flow level	M2G does not extract water above drought condition base flows (when triggered)

The SFWQMP and associated flow rules have been developed based on the best currently available information about native fish in the Murrumbidgee River and the environmental flow requirements of rivers in the ACT i.e. *ACT Environmental Flow Guidelines*. It is acknowledged that there is residual uncertainty about several elements pertaining particularly to Murray Cod ecological requirements.

These knowledge gaps are being addressed in the research, monitoring and management framework. This approach will enable knowledge of fish needs and flow requirements (incl. volumes) to increase over time and management responses will be employed as required e.g. adapt rules and/or design fish offset / recovery actions.

Given this approach, the residual risk of negative impacts to threatened fish and/or their recovery potential is deemed to be low.

4.1.8 Addressing the precautionary principle

The precautionary principle states:
If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

There is residual uncertainty about both the ecology of threatened fish species and the specific flow volumes / regime required to protect critical flow dependent ecological features for these species. As such, the precautionary principle has been applied throughout the development of this SFWQMP.

As discussed above, even with the remaining uncertainty, consensus opinion is that there is low to moderate residual risk of negative impacts from M2G to threatened fish species and/or their recovery potential. Therefore, it is not considered that there is a threat of serious or irreversible environmental damage. Furthermore, this SFWQMP, including the way it was developed, employs many measures to prevent environmental damage. These include:

- Having flow rules based on the volume of water required to maintain critical flow dependent ecological features for threatened fish, rather than setting arbitrary %ile limits;
- Considering all fish species in the SFWQMP, even though only the best available information suggested that Murray Cod is the only species with a viable reproducing population;
- Developing and implementing a research, monitoring and adaptive management framework, that identifies if impacts have or are likely to occur, and presents management and/or offsetting strategies to address such impacts;
- Ensuring ongoing liaison with the ACT Environmental Flows Technical Advisory Group (EFTAG) to provide expert advice and guidance about the research, monitoring and adaptive management regime and associated results; and
- Ensuring the SFWQMP will be regularly reviewed and updated as required.

5. Stream Flow and Water Quality Monitoring Program - Murrumbidgee River

ACTEW has a critical relationship with the flow and water quality in the Murrumbidgee River. ACTEW is regulated to protect environmental flows, and is operationally limited by water quality in the river.

ACTEW has in place a Source Water Protection Program to improve protection of the sources of the ACT's drinking water supply. This program will impact on the Murrumbidgee to Googong water transfer because its aim is to improve water quality in the Murrumbidgee and therefore potentially enable more frequent operation of the water transfer.

ACTEW has adopted the risk management approach recommended in the Australian Drinking Water Guidelines 2004 to manage all aspects of drinking water from its source to final delivery to the consumer.

These guidelines state 'source water protection provides the first barrier for the protection of water quality'. The basis of the risk management approach is to improve our understanding of the risks of contamination in our catchments and to ensure that all stakeholders work together to protect the source water.

The fundamental tenets of the Australian Drinking Water Guidelines are:

- Multiple barriers are required to protect drinking water quality;
- The most efficient barrier is protection of source waters rather than reliance on treatment;
- Source waters should be protected to the maximum degree practicable;
- Water quality should be maintained at the highest practicable quality; and
- Water quality should not be degraded even if it is currently of better quality than the minimum required.

A number of examples of actions that are undertaken as part of the ACT Regional Source Water Protection Program and with a focus on source water protection are:

- Formalise partnerships with key stakeholders;
- Conduct catchment condition assessments;
- Develop inter-agency emergency management plans;
- Encourage off-stream stock watering points;
- Develop targeted programs on sewage and stormwater;
- Develop, support or enhance educational programs;
- Identification and management of erosion hot spots;

- Ensure there is signage at all recreational areas; and
- Develop an incentive program to support best land management practices.

The primary monitoring focus of the SFWQMP in the Murrumbidgee River will be the local abstraction reach at Angle Crossing. There are also ACTEW online stream flow and water quality monitoring sites further upstream and downstream which will be linked to the local Angle Crossing results where appropriate.

The key elements of the SFWQMP are listed below:

- Stream flow gauging upstream and downstream of the M2G abstraction point on the Murrumbidgee River (MURW2 and Lobbs Hole) to continuously measure water flows and fluctuations that could occur due to climatic conditions and water abstractions; and
- Online water quality monitoring, at upstream and downstream locations (MURW2 and Lobbs Hole), including regular in-situ grab samples at Angle Crossing only (MUR213) recording physicochemical data not possible to monitor via online devices.

5.1 Stream flow and water quality measurement aims

Measuring changes in river flow and quality at various locations along the Murrumbidgee River provides the necessary information for linking the various environmental monitoring components together.

Aims

- To provide river flow and water quality data and information enabling decisions for commencing , regulating, or ceasing M2G operations
- To provide river flow data and information, for evaluating potential impacts of water abstraction at Angle Crossing
- To provide water quality data and information to assist in determining whether water abstraction is contributing to any water quality deterioration at Angle Crossing and Burra Creek
- To assist in determining compliance with environmental flow provisions with regard to the Murrumbidgee River.

Rationale

Stream flow and water quality affects the quality of life in waterways, and biota respond to parameters such as flow rate, temperature and turbidity, which also affects light penetration, dissolved oxygen and nutrients.

In Australia, water quality has been assessed nationally using biological indicators since the mid-1990s. Measuring physico-chemical water quality is now conducted as an essential component of river condition assessments, but largely to provide a basis for explaining the response of biological components in the riverine ecosystems.

Measuring the flows upstream and downstream of Angle Crossing is essential to confirm that abstraction of water at Angle Crossing is not affecting the maintenance of healthy aquatic ecosystems in the Murrumbidgee River, in terms of biological communities.

In the absence of human impacts, water quality of a river may be regarded as generally reflecting upstream catchment conditions and results of natural disturbances, such as forest fires. However, in a river like the Murrumbidgee, water quality is significantly affected by a variety of human activities. These include on stream and off stream water storage, various land-uses (irrigated agriculture and livestock farming), industrial uses of the river (sand-mining) and recreational uses. As an impounded river (from Tantangara Dam), the impacts of human influences are particularly felt in downstream reaches, where natural flow volumes and regimes have been significantly altered.

5.2 Stream flow gauging and water quality methodology

Stream gauging and data collection will be undertaken by a qualified field hydrology group familiar with the ACT stream gauging network and ACTEW reporting requirements. The field hydrology group would be required to have an accredited QA system, to AS/NSS ISO 9002:1994.

Consistent with other sites in the ACT, the water quality probes shall log data at 15 minute intervals. Data shall be downloaded daily via telemetry and made available for viewing by web page, though unvalidated at that stage. Data will be validated and archived monthly into the existing HYDSTRA data management system. Site visits shall be carried out monthly to check and calibrate the sensor units. Data will be updated and provided to ACTEW in conjunction with current data management agreements. The Water Operations Engineer will receive monitoring results in a timely manner to enable flow initiation and regulation management actions to be taken as necessary.

Routine inspection procedures for maintaining the gauging stations, calibration, instrument testing, data recording, downloading and data management are well established in the ACT and will be used in this monitoring program. The techniques are current best practice, accredited, and follow certified Quality Assurance and Control procedures.

5.2.1 Online Sites

ACTEW's online Murrumbidgee River flow and quality monitoring is currently conducted at six gauging sites. Table 5.1 provides the gauging station locations and the parameters to be measured at each location. Site 7 will be the key site for the Murrumbidgee to Googong abstraction point and Site 3 is the key downstream location at Lobbs Hole.

Table 5.1 Murrumbidgee River flow monitoring locations and parameters.

Site	Site Code	Location	Parameters*	Latitude	Longitude
1	410777	M'bidgee River @ Hall's Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.13277	E 148.94250
2	410738	M'bidgee River @ Mt. McDonald	WL, Q	S 35.29166	E 148.95528
3	410761	M'bidgee River @ Lobbs Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.53980	E 149.10015
4	410756	Molonglo River @ Coppins Crossing (U/S of STP)	WL, Q, Rainfall	S 35.27360	E 149.00861
5	410741	Molonglo River @ Sturt Island (D/S of STP)	WL, Q, Rainfall	S 35.25000	E 148.95833
6	410731	Gudgenby River @ Tennent	WL, Q, EC, Temp, Rainfall	S 35.57472	E 149.06834
7	MUR W2	U/S Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.35327	E 149.07054
8	NUM W1	Numeralla River @ Chakola Road	WL, Q*, pH, EC, DO, Temp, Turb, Rainfall	S 36.10051	E 149.18869
9	MUR W1	M'bidgee River @ Pilot Creek Road	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 36.16458	E 149.09428

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (0.2 mm increments);

5.1.2 Data analysis and reporting

The stream flow and continuous water quality data collected shall be QA certified and stored on the HYDSTRA data management system. The results are reported with the aquatic ecological monitoring program reporting framework.

5.1.3 Quality assurance and quality control

All monitoring work will be undertaken in accordance with the relevant Australian quality assurance /quality control standards.

Data collected for this program will be analysed using the most appropriate statistical techniques.

5.2 M2G Murrumbidgee River key water quality monitoring elements

The key water quality monitoring sites covered by the SFWQMP are:

- Upstream of Angle Crossing, approximately 500m upstream of the causeway;
- Downstream of Angle Crossing, at Lobbs Hole (existing gauging station 410761); and
- In-system sensors within the M2G pipe infrastructure.

Key water quality parameters and indicators which are monitored upstream and downstream of the abstraction point, and within the transfer system, are shown below:

- Temperature (online);
- pH (online);
- Turbidity (online);
- Electrical conductivity (for salinity) (online);
- Dissolved oxygen (online);
- Total dissolved solids (grab sample only);
- Iron and manganese, (dissolved and total) (grab sample only);
- Nutrients (TKN, TN, TP) (grab sample only);
- Pathogens (*E.coli*) (grab sample only); and
- Pesticides (grab sample only).

The program monitors stream flow and water quality during periods of abstraction but also at times of no operation.

Grab samples are taken approximately every two-three months. The processing of these samples is a lengthy process; and no suitable/appropriate technology currently exists to measure these parameters online.

6. Stream Flow and Water Quality Monitoring Program - Burra Creek

The primary monitoring focus of the Burra Creek monitoring program will be downstream of the discharge point. The framework for this program is similar to the Angle Crossing abstraction assessment but shall include additional initial event monitoring to establish improved base flow information.

6.1 Key monitoring elements

The key monitoring objectives of the program will enable the collection of quantitative and semi-quantitative data that will assist the program to identify changes occurring in Burra Creek with regard to:

- how the discharge into Burra Creek from the Murrumbidgee River affects the maintenance of healthy aquatic ecosystems in terms of biological communities; and
- whether or not the discharge into Burra Creek creates flow variations that impact on erosion, sediment deposition and movement.

The potential zone of monitoring covered by this program is proposed as:

- Upstream of the discharge point on Burra Creek as a control, being just upstream of the Cassidy Creek confluence; and
- Downstream of the discharge point to approximately 1km downstream of the Burra Creek confluence with the Queanbeyan River, where Googong Reservoir levels permit.

The key elements of the monitoring program proposed are listed below:

- Stream flow gauging will occur at one site upstream of the Googong Reservoir on the Queanbeyan River (410781) and on Burra Creek (410774) approximately 3km downstream of the proposed discharge point; and
- Water quality monitoring through the use of online water quality probes at one location downstream of the discharge point on Burra Creek as well as one location on Queanbeyan River upstream of the confluence with Burra Creek (as a control). Additional grab samples are collected at various locations as part of the ACTEW's grab sample regime and the ecological monitoring program undertaken in Burra Creek. Further, water quality monitoring is undertaken within the M2G transfer system.

6.2 Stream flow and water quality measurement aims

Measuring changes in river flow and water quality at the two gauging locations on the Queanbeyan River and Burra Creek will provide necessary information for linking the various environmental monitoring components together.

6.2.1 Aims

- To provide Burra Creek flow and water quality data and information enabling decisions for commencing, regulating, or ceasing water transfer operations;
- To provide river flow data and information (flow levels and volumes, distribution pattern, variability), for evaluating potential impacts of water discharges into Burra Creek;
- To provide water quality data and information to assist in determining whether water discharges into Burra Creek lead to changes in water quality and ecosystem health; and
- To assist in compliance reporting of approval conditions with regard to Burra Creek.

6.2.2 Rationale

Measuring the water quality and flows before and after the proposed discharges is essential to determine whether or not, and to what extent, abstraction of water at Angle Crossing and its release into Burra Creek affects the health of aquatic ecosystems in Burra Creek and the downstream section of the Queanbeyan River, (below the Burra Creek confluence) in terms of biological communities.

6.3 Stream flow gauging and water quality methodology

Stream gauging and data collection will be undertaken by a qualified Field Hydrology Group who are familiar with ACT stream gauging and ACTEW reporting requirements. The Field Hydrology Group shall have an accredited QA system, to AS/NSS ISO 9002:1994.

The in-situ water quality data shall be logged at 15 minute intervals at the current flow gauging sites on Burra Creek (410774) and the Queanbeyan River Upstream Googong site (410781). Data shall be downloaded daily via telemetry and made available for viewing by web page, though unchecked at that stage. Data will be certified and archived monthly into the existing HYDSTRA data management system. Site visits shall be carried out monthly to check and calibrate the sensor units. Data will be updated and provided to ACTEW in conjunction with current data management agreements.

Routine inspection procedures for maintaining the gauging stations, calibration, instrument testing, data recording, downloading and data management are well established within ACTEW's current monitoring programs, and will be used in this program. The techniques are

current best practice, accredited, and follow certified Quality Assurance and Control procedures.

6.3.1 Online Sites

Water quality, level and flow monitoring will be conducted at two existing gauging sites and a new site at London Bridge (water level only). The flow gauging sites shall also have multi-parameter water quality probes. Table 6.1 provides the site locations and the parameters measured at each location.

Table 6.1 Water level, stream flow, and water quality monitoring locations.

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	410774	Burra Creek	WL, Q, pH, EC, DO, Temp, Turb	S 35.5425	E 149.2279
2	410781	Queanbeyan River US of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb	S 35.5222	E 149.3005
3	BURLB	Burra Ck at London Bridge	WL	S 35.5155	E 149.2624

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity

M2G also has in-system sensors that measure the quality of the water being transferred to Burra Creek.

6.3.2 Grab samples

In addition to the Table 6.1 locations grab samples shall be collected from the MEMP sites and tested for key WQ parameters as well as the key parameters for ecosystem health, for baseline monitoring and impact assessment. It is anticipated that water quality data shall include some storm event based samples in addition to base flow samples. Burra Creek only flows intermittently and therefore a detailed water quality profile may not be possible for all locations.

Current locations for obtaining base flow and impact assessment information are indicated in Table 6.2.

Table 6.2 Current water quality grab sample locations.

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	BUR 1	Burra Creek U/S Cassidy's Ck - reference site	pH, EC, DO, Temp, Turb, TSS, Fe-Mn nutrients	S 35.5982	E 149.2284
2	BUR 2	Burra Creek just U/S of discharge point	pH, EC, DO, Temp, Turb, TSS, Fe-Mn nutrients	S 35.5559	E 149.2215
3	BUR 2a	Burra Ck within 200m D/S discharge point	pH, EC, DO, Temp, Turb, TSS, Fe-Mn nutrients + PHYTO	S 35.5551	E 149.2234
4	BUR 3	Burra Creek at Drawdown Crossing	pH, EC, DO, Temp, Turb, TSS, Fe-Mn nutrients	S 35.5093	E 149.2650
5	QBY 2	Queanbeyan River D/S Burra Ck confluence	pH, EC, DO, Temp, Turb, TSS, Fe-Mn nutrients	S 35.4987	E 149.2660

* EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity, Fe-Mn = Iron and Manganese; TSS = Total Suspended Solids; Phyto - Phytoplankton

Key water quality parameters to be tested include:

- Temperature (online);
- pH (online);
- Turbidity (online);
- Electrical conductivity (for salinity) (online);
- Dissolved oxygen (online);
- Total dissolved solids (grab sample only);
- Iron and manganese, (dissolved and total) (grab sample only);
- Nutrients (TKN, TN, TP) (grab sample only); and

- Phytoplankton (grab sample only).

6.3.3 Data analysis and reporting

The stream flow and continuous water quality data collected shall be QA certified and stored on the HYDSTRA data management system. The results are reported with the aquatic ecological monitoring program reporting framework.

6.3.4 Quality assurance and quality control

All monitoring work will be undertaken in accordance with the relevant Australian quality assurance /quality control standards.

Data collected for this program will be analysed using the most appropriate statistical techniques.

7. Triggers and Management Actions

7.1 ANZECC Guidelines (2000)

Trigger values are fundamental to the use of the ANZECC Guidelines. The trigger values for different indicators of water quality are set as a threshold or as a range of desirable values. The trigger values in Table 7.1 are default values which can be used in the absence of other information. Trigger values are not a pass / fail compliance criteria, but are used to trigger actions to monitor potential environmental impacts and undertake mitigation actions if required.

Table 7.1 Key water quality parameters and default trigger values identified by ANZECC for ecosystem protection and NHMRC for drinking water.

Parameter	Default Trigger values (from ANZECC (2000) and NHMRC (2004))		Median value at Angle Crossing (Murrumbidgee) (2005-2010)	Mean value at Angle Crossing (Murrumbidgee) (2005-2010)	Mean or range value in Burra Creek* (2008-2010)
	Ecosystem Protection Upland Streams	Drinking Water			
Turbidity (NTU)	2-25	5**	17	56	<5 39 (after events)
Total Nitrogen (mg/L)	0.25 mg/L	50 mg/L NO3	0.43	0.75	0.45
Total Phosphorus (mg/L)	0.02 mg/L	NA	0.04	0.09	0.015
Dissolved Oxygen (%sat) (mg/L)	90 - 110	NA	- 9.6	- 9.64	93-105
pH	6.5 - 7.5	6.5 – 8.5**	7.5	7.43	6.5 - 7.8

*Burra Creek is an ephemeral stream and therefore sample data has been intermittent; ** Guideline values are determined for aesthetic implications, as currently there is insufficient data to set a guideline value based on health considerations.

Local conditions vary between waterways and it is preferential to modify trigger levels to local conditions. Based on recently gathered information it is proposed to adjust the trigger values to encompass the range of local conditions expected.

The modified triggers can be applied to assess compliance with the *Protection of the Environment Operations Act* (1997), or as conditions of any Environment Protection Licence issued under that Act. The guidelines provide a process for refining trigger levels and ACTEW intends to adopt that process over a period of time.

7.2 Murrumbidgee River Water Quality

Turbidity values in the Murrumbidgee rise quickly during rainfall events due to the ready mobilisation of fine sediments upstream. Field trips have found that a significant source of sediment loads is the Numeralla River, due to ongoing impacts of soil erosion from land clearing and agriculture activities.

It is proposed to use trigger levels based on the local water quality conditions measured in recent times. Proposed trigger levels have been set to encompass existing water quality parameter values measured during routine sampling at Angle Crossing. Murrumbidgee River near Angle Crossing typically has a river health AUSRIVAS score of Band B. Ongoing analysis of low flow and event based water samples including the results of the ecological monitoring program shall be used to fine tune the trigger levels in the future.

Proposed initial water quality trigger levels are given in Table 7.2.

Table 7.2 Murrumbidgee River proposed water quality parameters and default trigger values.

Parameter	Mean value in Murrumbidgee River (2008-2010)*	Proposed trigger Levels of inflow water to M2G	
		Autumn / Winter	Spring / Summer
Turbidity (NTU) (online) (increase monitoring)	75 (median 24)	>80	>100
Turbidity Hi-Hi value (online) (cease to pump)		800	800
Turbidity Hi-Lo value (online) (flushing flow value)		150	150
Total Nitrogen (mg/L)*	0.35(autumn) 0.8(spring)	>0.5	>0.8

Parameter	Mean value in Murrumbidgee River (2008-2010)*	Proposed trigger Levels of inflow water to M2G	
Total Phosphorus (mg/L)*	0.07	>0.10	>0.10
Dissolved Oxygen (%sat) (online)	93-103	<80 or >110	<80 or >110
pH (online)	7.3	<6.5 or > 8.0	<6.5 or > 8.0
EC (µs/cm) (online)	95	> 600	> 400
Temperature 0C (online)	21 (autumn)	< 5	> 24
Total Iron (mg/L)*	2.02	>2.0	>2.0
Total Manganese (mg/L)*	0.11	>0.15	>0.15
TDS*	30(spring) 83(autumn)	>100	>50

Turbidity Trigger value: level above which increased monitoring of impacts is required;

Turbidity Hi-Hi value: level above which abstraction from the Murrumbidgee River shall cease until the turbidity value returns to below the Hi-Lo value. Water abstraction between the Hi-Lo and Hi-Hi level would require a flushing flow at below the Hi-Lo value to ensure sediment is transported down Burra Ck into Googong Reservoir.

Turbidity Hi-Lo value: level which turbidity value must fall below to allow transfer of previously abstracted higher turbidity water from the discharge point down to Googong Reservoir**.**

*Note that those parameters that are grab sampled only (identified by the asterisk) are long term triggers and do not correlate to immediate correlations to M2G operations. These parameters will analysed over time (through the Aquatic Ecology Monitoring Plan) to determine if there are long term trends occurring, and any potential ecological impacts arising.

7.3 Burra Creek Water Quality

Burra Creek is a tributary of the Queanbeyan River and during the low rainfall years from 2000 has only flowed intermittently. Some water samples have been taken since 2008 when flows have been evident. The water quality values from these low flows have generally been similar to those in the Murrumbidgee River with the exception that the electrical conductivity can be higher, and the turbidity has been lower. The higher EC is believed to be a result of the Karst limestone within the catchment.

Low turbidity is most likely due to the groundwater contribution and the fact that there have not been significant rainfall runoff events during the monitoring period. Burra catchment land use includes significant agricultural land with cleared and grazed areas similar to the

Murrumbidgee catchment. This Burra agricultural land is expected to yield turbid water during significant rainfall runoff events and has recently been measured at over 800 NTU. Burra Creek river health AUSRIVAS scores vary from Band A to Band C and depend heavily on the degree of flow permanence before sampling.

A set of proposed trigger levels for Burra is given in Table 7.3.

Table 7.3 Burra Creek proposed water quality parameters and default trigger values.

Parameter	Mean value in Burra Ck (2008-2010)*	Proposed Trigger Levels downstream of the Burra Creek discharge point during abstraction	
		Autumn / Winter	Spring / Summer
Turbidity (NTU) (online)	<5	>80	>100
Turbidity HiLo Value (online)		150	150
Turbidity Hi Hi value (online)		800	800
Total Nitrogen (mg/L)*	0.45	>0.5	>0.8
Total Phosphorus(mg/L)*	0.015	0.10	0.10
Dissolved Oxygen (%sat) (online)	94.5	<80 or >110	<80 or >110
pH (online)	7.4	<6.5 or > 8.0	<6.5 or > 8.0
EC (online)	260	> 600	> 400
Temperature ^{0}C (online)	21(autumn)	< 5	> 24
Total Iron (mg/L)*		>2.0	>2.0
Total Manganese (mg/L)*		>0.15	>0.15
TDS*	230	>150	>150

*Note that those parameters that are grab sampled only (identified by the asterisk) are long term triggers and do not correlate to immediate correlations to M2G operations. These parameters will analysed over time (through the Aquatic Ecology Monitoring Plan) to determine if there are long term trends occurring, and any potential ecological impacts arising.

Coarse sediments are filtered out by a 0.5 mm screen at the abstraction point with the majority of fine sediments to be transported down Burra Creek by the abstraction flow into the reservoir. Some sedimentation shall occur in the emergent macrophyte beds due to the slow velocities created in those regions.

7.4 Googong Reservoir Water Quality

As a result of the increased flow rate and turbidity possible through Burra Creek, there is expected to be an associated increase in sediment and nutrient load entering Googong Reservoir.

Although nutrient levels from Murrumbidgee are similar to Burra Creek in value, the increased flow volume significantly increases the nutrient loads into Googong Reservoir and may trigger increased algal blooms given the right combination of slow moving water, temperature and bio-available nutrients. This was identified and assessed in the EIS.

Monitoring of nutrients and turbidity in the upper reservoir shall be undertaken separately by ACTEW as part of its ongoing operation and maintenance for the water supply reservoir.

7.5 Management Actions

Should any of the online trigger levels stated above be exceeded then the following actions are to be undertaken:

- If it is found that the exceedance parameter is due to the water abstraction/discharge and is causing an unacceptable ecological health risk or unacceptable Googong Reservoir water quality impact, then pumping of water from the Murrumbidgee River shall cease until such time as the problem can be rectified or mitigation options put in place.
- If the turbidity values from Angle Crossing or Lobbs Hole on the Murrumbidgee River exceeds the Hi-Hi value then pumping is to cease until the turbidity drops to below the Hi-Lo value.
- If the cause of the breach is not evident from the data or site information then additional sampling runs are required to determine the cause of the exceedance.
- The monitoring program shall also be stepped up once pumping is recommenced to confirm that the action taken is successful in eliminating or reducing the parameters back into an acceptable range.

Trend lines for water quality shall be established from the monitoring results to provide information on increased variability due to flow level or season. These will allow the fine tuning of trigger levels and may provide an early warning of potential impacts if results are outside established trends.

Water quality guidelines and triggers are to be reviewed within six months of water abstraction commencing and then as required. The purpose is to use water quality and related data as it becomes available to modify the flow management rules to minimise the risk to ecological health in the Murrumbidgee River, Burra Creek, and Googong Reservoir.

Should any of the grab sample data exceed trigger values, then these will be analysed specifically in conjunction with the Aquatic Ecology Monitoring Plan. The adaptive management of that Plan will incorporate changes to trigger levels to grab sample parameters where appropriate. Note that regardless of whether or not grab sampled data exceeds trigger values, there will be analyses incorporated into the ecological monitoring results.

8. Research, Monitoring and Adaptive Management of Environmental Flows

ACTEW will institute an adaptive management framework with regard to M2G environmental flow, based on the current and successful Cotter River catchment adaptive management model. The framework relies upon:

- The collection of ecological monitoring data in response to environmental flows (see Aquatic Ecological Monitoring Plan);
- Analysis of this data by relevant experts; and
- The updating of environmental flow protection rules in response to the findings and analysis of the ecological data.

While the identification of initial flow protection rules are required to initiate a base-case operation, these rules are not considered static for the remainder M2G operation. As has been shown in the Cotter system (and in the wider environmental management community), riverine ecosystems have different requirements and responses depending on the weather and condition of the host river and environment.

Consequently, it is proposed that the M2G extraction regime for the protection of environmental flows is governed by an adaptive management framework allowing for refinement and updates of the rules over time. Given the overlapping regulatory nature of the M2G project, any refinements of the operating rules must consider both ACT and Commonwealth threatened species legislation, particularly the protection of the Murray Cod.

The NSW Department of Planning has approved the monitoring regime which would inform the adaptive management framework. The ACT Government's Environmental Flow Guidelines confirm the establishment of this framework with respect to its jurisdiction.

8.1 Governance

The ACT Environmental Flow Guidelines are reviewed by the ACT Environment Protection Authority (EPA) every five years. The ACT EPA uses an Environmental Flows Technical Advisory Group (EFTAG) to provide advice on the flow guidelines and the licensing of all water users in the ACT when required. When requested by the EPA, this group will oversee the research, monitoring and adaptive management programs for the M2G Transfer.

The general terms of reference for this group as relates to this SFWQMP will be to:

- Technical review of all research and monitoring results;
- Highlight any issues of concern from review of results;
- Work with ACTEW to develop management strategies to address issues of concern. This may include undertaking additional studies or implementing management actions;
- Review extraction rules in light of additional information gathered during research and monitoring programs; and

- Make recommendations on amendments or changes to the SFWQMP.

8.2 Filling knowledge gaps

A research program to fill the key knowledge gaps around the Murray Cod flow has been implemented by ACTEW. The program is based around four sub-programs:

- Flow in impacted reaches of Murrumbidgee River;
- Dissolved oxygen and retention times in pools in impacted reaches of the Murrumbidgee River;
- Characterisation of the Murrumbidgee river along impacted reaches; and
- Spawning and larval ecology of upland Murray Cod.

Details of each sub-program and how these relate to the knowledge are provided in Appendix B.

As information is gathered against each sub-program a further analysis will be undertaken to determine if the knowledge gained can assist in identifying priority and cost effective management measures or conservation works (offsets). This information will then be used as part of the adaptive management framework to guide and identify any activities seen as necessary to offset unforeseen or unexpected impacts.

9. Plan Review

9.1 SFWQMP Review

The SFWQMP will be reviewed in the following instances:

- after key research, monitoring and adaptive management program triggers and/or milestones
- on advice from EFTAG and the M2G ERG
- when extreme water shortage is occurring or predicted to in the ACT (defined as level 3 – 4 water restrictions)
- in times of critical human needs.

Any proposed changes to the protected flows or trigger levels for dissolved oxygen, nitrogen, phosphorous and temperature must be approved by the Commonwealth Minster for the Environment (or delegate) prior to implementation.
ACTEW will manage the review process with the assistance and overview of the ACT EPA, EFTAG, the M2G ERG and other relevant regulators.

10. Roles and Responsibilities

The OEMP outlines M2G roles and responsibilities that will underpin the sound environmental performance of the water transfer.

11. Training

The OEMP outlines the training procedures and likely training topics that will underpin the sound environmental performance of the water transfer.

All the training matters canvassed in the OEMP will apply to personnel involved in the implementation of the flow management plan.

12. Compliance Tracking Program – Operations

The OEMP outlines the compliance tracking procedures that will underpin the sound environmental performance of the water transfer.

Appendix A: Threatened Fish Species

Appendix A is an extract from the Sustainable Diversion Limit Plan.

Species of concern

The threatened native fish species of concern regarding the M2G are Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*) and Macquarie Perch (*Macquaria australasica*). Under the EPBC Act, the Murray Cod is listed as vulnerable and Trout Cod and Macquarie Perch are listed as endangered. Murray Cod are not listed as threatened in the ACT, with both Trout Cod and Macquarie Perch listed as endangered under the ACT *Nature Conservation Act 1980*.

Populations within the Upper Murrumbidgee

The following table summarises the known records in the Murrumbidgee River of the three species of concern downstream of the Murrumbidgee River extraction point at Angle Crossing. Further details for each species are provided below.

Table 1: Presence of fish species downstream of the extraction point

SPECIES	ANGLE CROSSING TO GIGERLINE GORGE	DOWNSTREAM OF GIGERLINE GORGE
Murray Cod (*Maccullochella peelii*)	No	Yes
Trout Cod (*Maccullochella macquariensis*)	Stocked	Stocked
Macquarie Perch (*Macquaria australasica*)	Vagrants from upstream	Vagrants from Murrumbidgee upstream and/or Cotter Reservoir population

Murray Cod

Murray Cod is endemic to the Murray-Darling River system of south-eastern Australia, including streams in the ACT. The species was formerly widespread and abundant in the Murrumbidgee, Molonglo and lower Queanbeyan Rivers. Natural populations of Murray Cod in the ACT are now largely confined to the Murrumbidgee River where they have been recorded as far upstream as Tharwa Sandwash (Lintermans, 2002, 2007). Adult, juvenile and young-of-year Murray cod are regularly encountered in the Murrumbidgee River in the ACT in the biennial fish monitoring program conducted by ACT Government. Gigerline Gorge represents the upper extent of normal distribution for a range of native fish including Murray Cod (Lintermans 2005) and thus the species is not considered to occur upstream of this natural barrier. Stocked populations of Murray Cod are maintained in several of Canberra's urban lakes and Googong Reservoir. Stocking of rivers for recreational purposes is not conducted in the ACT.

Trout Cod

There are only two documented currently self-sustaining populations of Trout Cod and these are located in NSW (Murray River between Yarrawonga and Tocumwal) and Victoria (Sevens Creek) (Trout Cod Recovery Team 2008). In the ACT, Trout Cod were stocked in the Bendora Reservoir in 1989 and 1990 as part of a national recovery plan (Lintermans, 1995; ACT Government, 2007) and this population is the only known reproducing population of the species in the ACT (Lintermans, 2007).

There has been extensive stocking of Trout Cod close to the extraction site at Angle Crossing during 1996 – 2005 (~100,000 individuals, ACT Government 2007). However, there has been no recruitment detected and no adults captured at this site since stocking began, despite repeated survey and monitoring effort. A single adult was captured in 2006 at Tharwa Sandwash. Since 2006 (when stocking ceased), no Trout Cod have been captured in fish monitoring programs at Angle Crossing. Trout Cod

have also been stocked at Kambah Pool in the mid 2000s, with no recruitment detected in subsequent monitoring programs. Trout cod have also been stocked further upstream in the upper Murrumbidgee catchment in the early 1990s with releases around Cooma and below Adaminaby failing to establish (Mark Lintermans unpublished data). The lack of recruitment of stocked Trout Cod in the upper Murrumbidgee may be a result of ongoing environmental stressors, but is more likely the result of limitations of the stocking program, with too few fish released to establish a viable population with potential Allee effects limiting individuals' ability to find each other and breed (Mark Lintermans pers comm. 2010). This lack of detectable adults and impaired recruitment is a common finding of the stocking program for this species, and only where significant numbers have been stocked for a number of years has recruitment been recently detected e.g. in the Ovens River, Victoria (Arthur Rylah Institute unpublished data).

Macquarie Perch

It is widely accepted that the only viable population of Macquarie Perch in the ACT is located in Cotter Reservoir (Lintermans 2006; ACT Government 2007; Lintermans et al. 2010). There is also a known population that occurs significantly further upstream of the extraction point in the Murrumbidgee River in NSW i.e. within a reach immediately downstream of Tantangara Dam to Murrell's Crossing (Snowy Scientific Committee 2010) and isolated concentrations of fish below this e.g. around Michelago (Mark Lintermans unpubl. data).

The detection of Macquarie Perch in the Murrumbidgee River between the Angle Crossing extraction point and the confluence of the Cotter River is relatively rare and sporadic. There have been occasional records of individuals at the extraction site with a total of five individuals captured between 2000 and 2006 (ACTEW Corporation 2010) and another two between 1994 and 1998 (Mark Lintermans unpubl. data). None of these individuals were young-of-year, indicating the species was not recruiting in this region during this period. A further single individual has been recorded at the extraction site post-2006 (ACT Government unpublished data), and again no young of year were recorded. This makes a total of only 6 individuals in monitoring spanning a 16 year period. It seems most likely that all records from the vicinity of Angle Crossing represent vagrant fish from upstream reaches, as migration from downstream reaches is not possible as a result of the barrier formed by Gigerline Gorge. Macquarie Perch have been shown to be able to move 4 km in a single night in Cotter Reservoir, so downstream dispersal from upstream populations is entirely feasible.

Species focus of the SDLP

The Murray Cod, and its specific flow requirements, have been given primary attention in the SDLP. This is based on the best available information, gathered over the last 16 years, which indicates that:

- The Murrumbidgee River and its reaches in the ACT have a viable self-sustaining population of Murray Cod.
- Trout Cod appear to be a stocked non-reproducing population, and as soon as stocking ceases the species will gradually disappear from local rivers, and
- Macquarie Perch in the ACT reaches of the Murrumbidgee River are vagrants from upstream.

Whilst given a lower priority for the SDLP, the Trout Cod and Macquarie Perch present in the ACT reaches of the Murrumbidgee River will also benefit from the implementation of this plan. The range of flow dependant ecological features of all three species, as impacted by the M2G Transfer, are similar enough that a focus on Murray Cod is likely to allow adults of the other species to continue their current patterns of utilization of the river. Furthermore, as the extraction regime has been designed to maintain critical processes within the river, any potential recovery of these species is unlikely to be impeded.

Ecological requirements of priority threatened fish species

Murray Cod

Habitat

Murray Cod are found in habitats ranging from small, clear, rocky headwater streams to turbid, slow-flowing rivers, creeks and lakes of the Western Plains. This species is generally found in or near relatively deep water, and shows a distinct preference for habitats containing cover such as rocks, large woody snags, smaller woody debris, undercut banks and overhanging vegetation (Rowland 2005). Koehn (2009) found that adult and age 0-year fish selected similar microhabitats regardless of site or hydrologic conditions, and selection was primarily influenced by the presence of higher loadings of structural woody habitat, higher coefficient of variation in depth, more overhanging vegetation, shallower comparative depths and lower water velocities closer to the bank. Age 0-year Murray Cod appeared to select shallower habitats with greater amounts of structural woody habitat, closer to the river bank than adult fish. In the Murrumbidgee River, Murray Cod are found downstream of Gigerline Gorge.

Movement

The species is sedentary from late summer through to winter with individuals remaining within a relatively small 'territory' often associated with a specific snag or hole in the river (Kearney & Kildea 2001). During spring and early summer Murray Cod have been recorded to migrate upstream for spawning. The migration appears to require water temperatures from 16 – 21 ºC (Koehn 1996), and may take the fish 40 – 50 km or more upstream. Following migration, the fish return downstream to the same territory previously occupied. It is unknown what proportion of the adult population migrates. Murray cod will breed successfully in still-water environments where migration is not possible (e.g. farm dams and hatchery ponds.

Post-spawning, downstream dispersal of larvae occurs via drifting, which may last up to 14 days (Humphries 2005, Koehn and Harrington 2005). This is likely to be an active rather than passive process, as Murray Cod embryos are active and strong swimmers and likely to be able to determine their location in the water column (Humphries 2005).

Breeding

Murray Cod spawn on an annual basis in Oct – Nov and reproductive development (i.e. from formation of gametes to spawning) occurs according to a distinct seasonal cycle (Rowland 2005, Humphries 2005). It appears that Murray Cod prefer protected spawning sites, and typically spawn large (3.0-3.5mm diameter) adhesive eggs onto firm substrates such as hollow logs, rocks, pipes and clay banks.

Feeding

Murray Cod are top order predators (Ebner 2006) and feed on a variety of prey. The most common components of adult cod's diet include crustaceans such as yabbies, shrimp and crayfish; alien fishes such as Carp, Goldfish and Redfin Perch; and the native fishes Bony Herring, Freshwater Catfish, Golden Perch, Western Carp Gudgeon and other cod. They have been recorded to eat water birds, reptiles, frogs, snakes and mice (Kearney and Kildea 2001).

Fish habitat in the ACT reaches of the Murrumbidgee River

The nominal "study area" for the SDLP is the reach of the Murrumbidgee River between the M2G pumping station at Angle Crossing and downstream of the Molonglo River confluence. There will be no impact on flows above the pumping station. Once at the northern ACT border, flow in the Murrumbidgee is made up of the combined influence of the Upper Murrumbidgee, Molonglo and Cotter Rivers and their tributaries. Many of the rivers within the study region are highly regulated.

The following information is from the ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007).

Angle Crossing to Gigerline Gorge Reach

Description	For approximately 5 km immediately to the north of Angle Crossing (ACT/NSW border), the Murrumbidgee River is a series of relatively shallow pools with prominent rock bars, rapids and riffles. Some sandy beaches are present with previous small-scale sand extraction activities occurring in the reach. The river then narrows, turning north-west to flow through the steep, rugged Gigerline Gorge with extensive rocky terraces composed of boulders, bedrock and large stones.
Aquatic Fauna	The fish community is largely defined by the barrier presented by Gigerline Gorge and so represents a more 'upland' fish fauna. Lowland species such as Murray Cod, Golden Perch and the alien Redfin Perch are absent or extremely rare.
Threatened Species (EPBC Act)	Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, reduced flows (Tantangara and rural extraction), alien species.

Gigerline Gorge to Tharwa Reach

Description	Upon exiting the Gigerline Gorge, the river abruptly changes, widening to become a depositional stream with a sandy bed, long pools and occasional beaches. Previous sand extraction activities at the old Tharwa Sandwash have resulted in a long, flat sandy terrace. The Gudgenby River enters at this point, although fish access to this river is restricted by the large quantities of sand in the Gudgenby channel.
Aquatic Fauna	The fish fauna of this reach contains more of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch. The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.
Threatened Species (EPBC Act)	Murray Cod, Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, lack of riparian trees, alien species.

Tharwa to Point Hut Crossing Reach

Description	North of Tharwa the river passes through broad river flats in an undulating, pastoral landscape. In this deposition zone, the channel is shallow and contains significant quantities of sand that has filled pools and smothered the previously stony substrate for several kilometres. The riverbanks have been largely cleared of the former stands of Ribbon Gum (*Eucalyptus viminalis*), leaving some isolated remnant individual trees as evidence of the earlier vegetation type. Stock access to the river has been limited in recent years by fencing off the river corridor.
Aquatic Fauna	The fish fauna of this reach contains more of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch. The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.
Threatened Species (EPBC Act)	Murray Cod, Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, lack of riparian trees, alien species, barrier to fish movement (Point Hut Crossing).

Point Hut Crossing to Kambah Pool Reach

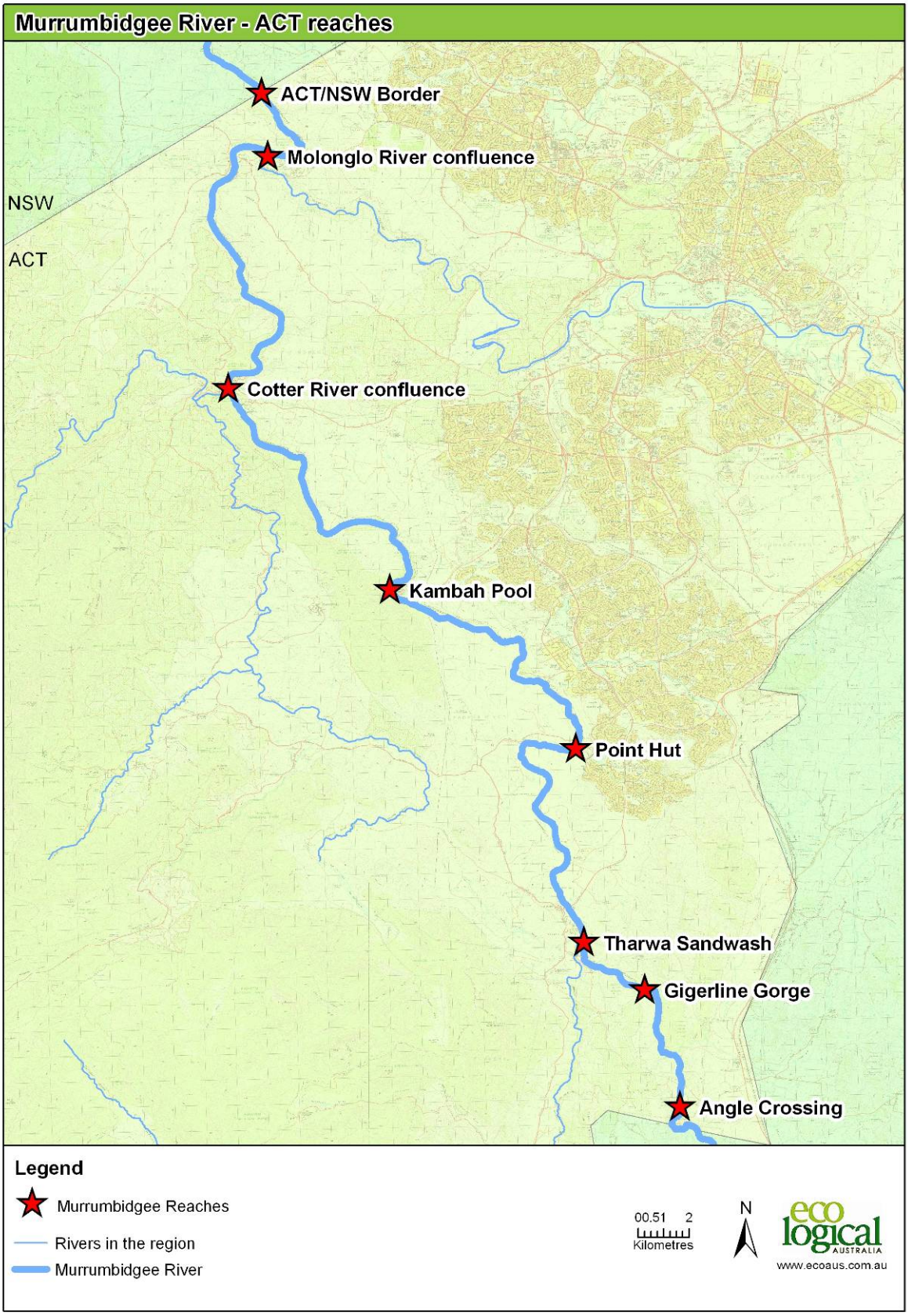
Description	Downstream from Point Hut Crossing the open valley environments give way to steeper slopes with elevated terraces of sandy or rocky banks, with shrub vegetation and scattered trees. The recreation area at Pine Island Reserve takes advantage of the river's broad channel, deep pools, occasional beaches and rocky substrate. Downstream of the Reserve is Red Rocks Gorge, a relatively less accessible area of high cliffs and rugged rock formations. Red Rocks Gorge meets the Bullen Range Nature Reserve near Kambah Pool recreation area. This part of the Murrumbidgee River has high ecological, scenic and conservation value, with some elements such as the Peregrine Falcon nesting sites requiring special attention in order to ensure they are protected from human disturbance.
Aquatic Fauna	The fish fauna of this reach contains more of the lowland elements including Murray Cod, Golden Perch and the alien Redfin Perch. The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.
Threatened Species (EPBC Act)	Murray Cod, Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, lack of riparian trees, alien species, urban impacts.

Kambah Pool to Cotter River Confluence/Casuarina Sands Reach

Description	The Bullen Range is a controlling influence on the course of the river downstream of Kambah Pool. The Bulgar, New Station and McQuoids Creeks drain the undulating pastoral land between the river and Weston Creek urban area. The river is deeply entrenched below surrounding terrain. The streambed is rocky with pools, rapids, rock bars, islands and sandy margins. Riverine vegetation is well developed with River Oaks along almost the entire stretch. This section was severely burnt in the bushfires of January 2003.
Aquatic Fauna	Full complement of lowland fish present. Silver Perch historically common but now rare. The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.
Threatened Species (EPBC Act)	Murray Cod, Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, alien species, willows.

Cotter River Confluence/Casuarina Sands to ACT/NSW Border Reach

Description	Between the Cotter/Casuarina Sands area and the point at which the Murrumbidgee River leaves the ACT, the river passes through deeply dissected slopes cut through the surrounding undulating terrain. Stony Creek Nature Reserve protects much of the river's course as far as Uriarra Crossing where a small recreation area has been developed in association with a road crossing. North of Uriarra Crossing, and a few kilometres south of the ACT/NSW border, the Molonglo River joins the Murrumbidgee River. High up on the eastern edge of the confluence is the Lower Molonglo Water Quality Control Centre.
Aquatic Fauna	Full complement of lowland fish are present. Silver Perch historically common but now rare. The full complement of alien species is present including Carp, Goldfish, Redfin Perch, Brown Trout, Rainbow Trout, Oriental Weatherloach and Eastern Gambusia.
Threatened Species (EPBC Act)	Murray Cod, Trout Cod, Macquarie Perch.
Threats	Illegal fishing, sedimentation, alien species, willows.


Murrumbidgee River - ACT reaches
ACT/NSW Border
Molonglo River confluence
NSW
ACT
Cotter River confluence
Kambah Pool
Point Hut
Tharwa Sandwash
Gigerline Gorge
Angle Crossing
Legend
Murrumbidgee Reaches
Rivers in the region
Murrumbidgee River
0 0.5 1 2
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www.ecoaus.com.au

Figure 1: Murrumbidgee River reaches downstream of pumping station at Angle Crossing

Flow Dependent Ecological Features for Threatened Fish Species

The aim of the SDLP is to ensure the long-term protection and recovery potential of listed threatened fish species in the Murrumbidgee River. In order to achieve this aim, the overarching ecological objective is to minimise any significant additional stress from the M2G operation on the fish species. In the context of the M2G Transfer, this must be done by allowing appropriate flows to remain in the river.

The majority of important ecological requirements of the three threatened fish species are dependent on water flow to some degree. These flow dependent ecological features are often complex and are not currently fully understood for the priority species (Murray Cod) or the upper Murrumbidgee River more generally. Also, not all flow dependent ecological features will likely be impacted by the M2G Transfer project.

The purpose of this section is to identify the flow dependent ecological features that may be impacted by the M2G Transfer and of these, which present the highest potential risk to threatened fish in the Murrumbidgee River in the ACT. These are the processes around which extraction / flow rules have been developed in order to identify and protect key flows from being impacted by the M2G Transfer. The information provided below was developed primarily by the expert panel.

Flow dependent ecological features

Flow-dependent ecological and geomorphological features that may be impacted by M2G water extractions were identified by the expert panel based on the currently best available information. The primary focus was on Murray Cod, however, key issues relating to Macquarie Perch were also noted. The features were identified for each life stage: eggs, larvae, juveniles and adults. The months in which potential impacts from reduced flows would be most pronounced were also highlighted.

Threats to flow dependent ecological features of Murray Cod (from M2G)

LIFE STAGE	FLOW-DEPENDENT ECOLOGICAL & GEOMORPHOLOGICAL FEATURE	TIMING OF POTENTIAL IMPACTS
Eggs[1]	E1: Spawning sites free of excess sediment E2: Suitable water velocity over spawning sites E3: Dissolved oxygen (DO) above critical levels in spawning pools E4: No sand deposition at spawning sites from abrupt reduction in water velocity	November Note: egg stage lasts ~ 5 – 13 days
Larvae[2]	L1: Suitable water velocity available to suspend and disperse larvae L2: Dissolved oxygen (DO) above critical levels in larval pools L3: No negative consequences of extended retention times in pools e.g. increased parasite / disease risk, algal blooms, reduced water quality as algal blooms decay	Nov – Dec
Juveniles[3]	J1: Dissolved oxygen (DO) above critical levels in pools during naturally	Dec – March

	low flow – high temperature months J2: No negative consequences of extended retention times in pools during naturally low flow – high temperature months	
	J3: Suitable extent of riffle zones	All year
Adults[4]	A1: Suitable longitudinal connectivity for spawning movement	Sept – Nov
	A2: Suitable longitudinal connectivity for non-spawning movement	All year
	A3: Dissolved oxygen (DO) above critical levels in pools during naturally low flow – high temperature months A4: No negative consequences of extended retention times in pools during naturally low flow – high temperature months	Dec – March

1 – Macquarie Perch spawn earlier than cod (in Oct) and require clean riffles for egg laying, their egg stage lasts ~10 days

2 – Due to earlier spawning, Macquarie Perch larvae are likely to be present in the water column earlier than cod larvae

3 – Information is applicable to both Murray Cod and Macquarie Perch at juvenile stage

4 – Adult Macquarie Perch will be impacted by the same processes as cod, however, connectivity to spawning sites is vital during spawning months

Risk assessment

A risk assessment was undertaken by the expert panel to determine the life stages and times of year when M2G presents a potential risk to threatened fish species. The risks assessment is based on the currently best available information (as presented in Section 0 above) and the currently proposed extraction rules (see Section **Error! Reference source not found.** below). The level of uncertainty surrounding the risk assignment is also presented.

There were several common risks for all life stages, which were not assigned a specific risk level. These are:

- Potential for M2G to create extended periods where flow is no higher than base flow level
- Cumulative impacts of water extraction threats and other existing pressures
- Lack of knowledge

Total risk levels by life cycle threat and month

Life cycle threat	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Uncertainty level
E1								L – M					Low – moderate
E2								L					Low
E3								L					Low – moderate
E4								L					Low
L1								L	L				Low
L2								L	L – M				Low – moderate
L3								L	L – M				Moderate
J1									L – M	L – M	L – M	L – M	Moderate – high
J2									L – M	L – M	L – M	L – M	Moderate – high
J3	L – M	L – M	L – M	L – M	L – M	L – M	L – M	L – M	M	M	M	M	Moderate – high
A1						L – M	L – M	L – M					Moderate – high
A2	L – M	L – M	L – M	L – M	L – M	L – M	L – M	L – M	M	M	M	M	High
A3									L – M	M	M	L – M	Moderate – high
A4									L – M	M	M	M	Moderate – high

Risk colour coding:

NO RISK	LOW	LOW – MOD	MODERATE	MOD – HIGH	HIGH

Key outcomes of the risk assessment are:

- Risks to eggs were the lowest of all life stages. Juvenile and adult life stages were identified as the most “at risk”
- For the majority of months, risks were not identified as arising from the proposed M2G extraction rules as set out in the current draft SDLP
- The highest number of individual risks was identified in November. However, it should be noted that this is the only month in which all life stages are potentially present, and where eggs are predominantly present. The significant knowledge gaps around upland Murray cod breeding ecology also highlight the risks in this month. Given that this is the month with the greatest number of life stages, risks and knowledge gaps, it is a key period to understand the flow–habitat– ecological response relationships.
- December to March is a time of low-moderate to moderate risk for juveniles and adults, but there is high uncertainty associated with this risk assessment
- Results reinforce the need to fill knowledge gaps, particularly for processes occurring in Dec – March in years where low flows have occurred in previous winter and spring months, and with a focus on adult and juvenile life stages. There is a need to be confident that the protected flows in the SDLP will provide the ecological services required for these months

Risks can be reduced by:

1. Filling information gaps to clarify whether perceived risk is an actual risk. If additional information highlights that risks are not likely to eventuate, then no further action is required

If additional information highlights that risks have the potential to eventuate, actions can include management and mitigation measures, revising extraction rules and/or offsetting impacts (which arise when risks are realised).

APPENDIX B – Murray Cod research Program

The Murray Cod Research Program implemented by ACTEW includes four sub-programs, of which the results will feed into the adaptive management framework of the SF&WQP.

KEY QUESTIONS TO ANSWER	METHOD	BENEFITS OF RESEARCH
SUB-PROGRAM 1: FLOW IN IMPACTED REACHES OF MURRUMBIDGEE RIVER		
What is the input of tributary flow, groundwater and surface runoff to the river downstream of the extraction point?	Modelling of flow at a series of nodes downstream of the extraction point to identify flow recovery using hydrological models. This will identify how far downstream the influence of the extraction persists	Determine how far downstream potential impacts of M2G may persist Fills knowledge gaps 1a
SUB-PROGRAM 2: DISSOLVED OXYGEN AND RETENTION TIMES IN POOLS IN IMPACTED REACHES OF THE MURRUMBIDGEE RIVER		
Do pools stratify for DO and if so which pools stratify; when; how long does stratification persist what is the depth at which the pools stratify and how low does DO get? Under what flow conditions is DO stratification observed and what flow is required to remove the stratification or reduce the extent? What is the flow – water retention time relationship for key pools? What retention times / conditions are necessary for "hostile'" conditions in pools to develop e.g. algal blooms, increase in disease/parasite load?	Loggers to record water quality conditions in pools (key parameters are DO and temperature) – relate back to flow recorded at gauges to derive relationships Particular focus on Dec – March period or other times of observed low flow Using the dimensions of the pools, the retention time can be modelled (assuming various stratification options) for differing flow conditions Potential to develop predictive/probabilistic model based on literature rather than relying on 'hostile conditions' occurring during any monitoring period. Important to define what hostile conditions are and the appropriate management response should hostile conditions occur	Understand if DO and retention time potential issues are real risks to Murray Cod from M2G Flow relationship – understand potential impacts of M2G on water quality and retention times Fills knowledge gaps 2a – e
SUB-PROGRAM 3: CHARACTERISATION OF THE MURRUMBIDGEE RIVER ALONG IMPACTED REACHES		
What is the distribution of habitats and their characteristics along the impacted reaches? Where are potential barriers to fish movement between habitats? What is the impact of flow on the characteristics of habitats e.g. changes	Initial mapping of habitats and basic characteristics by desktop review of aerial photographs/Google Earth/hydrographic LiDAR and local knowledge – use this geomorphic assessment to focus on potential key habitat areas Field assessment to refine desktop mapping for key habitat areas e.g. record substrate, depth, width, length, drop, flow type, other habitat features. Define flow – habitat relationships using targeted field survey to record how	Flow-habitat relationship – understand potential impacts of M2G on habitats Fills knowledge gaps 3a – d, 4a, 6c, 7d – e Whole program will increase knowledge of upland Murray Cod populations that can be used in other recovery projects

in depth, drown out of barriers, contraction of riffles / wetted area?	characteristics of key habitat areas change under various flow regimes e.g. high flows that might drown out barriers, low flows that may create barriers etc Field work to be supplemented by modelling works – define key points of interest along the reach following the geomorphic mapping. At each of these key points of interest, develop a set of rating curves that gives information about the relationship between water depth and flow (and possibly flow and extent of habitat). This requires surveys of the site and measurements of water depth at different flows	
SUB-PROGRAM 4: SPAWNING AND LARVAL ECOLOGY OF UPLAND MURRAY COD		
Do upland populations spawn in November? Where are the spawning sites? Where do larvae occur in the river and in the water column?	Larval sampling – weekly between mid-Oct and mid-Dec Back-date larvae collected to determine spawning date Sample at appropriate locations (~ 5) along the river between Angle Crossing and Casuarina sands, including between Gigerline Gorge and the Gudgenby River confluence Address knowledge gap of where larvae occur in the water column by setting larval traps at different depths	Determine whether flow rules in Dec need review (i.e. if spawning occurs in Dec, then might need to increase protected flow in this month) Understanding spatial patterns will tell us if there are critical spawning areas and where these are. If they are close to the extraction point, will need to ensure that protected flow during spawning months is adequate Fills knowledge gaps 4a – b, 5a – b Whole program will increase knowledge of upland Murray Cod populations that can be used in other recovery projects