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Environmental Water Provisions from SA Water Reservoirs in the Mount Lofty Ranges

Ed Pikusa

Michelle Bald

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation
Level 11, 25 Grenfell Street, Adelaide SA 5000
GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) (08) 8463 6984
	International	+61 8 (08) 8463 6984
Fax	National	(08) (08) 8463 6999
	International	+61 8 (08) 8463 6999
Website	www.dwlbc.sa.gov.au	

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EXECUTIVE SUMMARY

Summary EWP Program

Environmental Water Provisions (EWPs) have been recommended for river reaches at four locations across three catchments within the Western Mount Lofty Ranges. The ecological integrity of these sites was considered to be high, except for the lack of flows. Therefore it is considered that these sections of river are the most likely to display short-term benefit from an EWP and that this benefit would occur in isolation of other restoration activities. The

Releases from four SA Water reservoirs/controlling structures are required to deliver to the EWPs:

- Barossa Diversion Weir on the South Para River (2.24 GL/a),
- Gumeracha Weir on the Torrens River (4.11 GL/a[1]),
- Gorge Weir on the Torrens River, (0.89 GL/a) and
- Clarendon Weir on the Onkaparinga River (9.43 GL/a – 17.05 GL/a).
  There are 4 options for EWPs at Clarendon Weir, as determined at a workshop of DWLBC, catchment water management board and CRCFE freshwater ecologists on 6 June 2005:
    - EWP Option A: 17 050 ML/a
    - EWP Option B: 15 650 ML/a
    - EWP option C: 10 495 ML/a
    - EWP option D: 9 428 ML/a

  The details of these options are detailed in the section 'The Onkaparinga River'.

Implementing a regional EWP program would require a combined reservoir release of 12.56 GL/a – 20.18 GL/a. This represents 10% - 17% of the 121 GL/a that enters the reservoirs in an average year (Water Proofing Adelaide 2004 p11).

The recommended EWP Program has been designed specifically for each river reach, based on hydrological modelling and ecological objectives particular to that reach.

The extent and depth of background information (both hydrological and ecological) varies between the three catchment areas. Consequently the ecological objectives and predicted ecological responses are more highly developed for the EWP in the Onkaparinga, where more detailed information exists, compared to the South Para or the Torrens Rivers.

As EWPs are designed to address issues specific to each location and the history of hydrological and ecological stresses vary between locations, it is unlikely that lessons learnt from an EWP trial in one location will be directly applicable to another location.

[1] Considered a 4.11 GL EWP but a 'zero' reservoir release as the flows are recovered in Kangaroo Creek Reservoir

Monitoring Ecological Response of EWPs

EWP monitoring must focus on demonstrating a causal link between the flow provision and the observed ecological response. A framework for monitoring the ecological response has been determined, based on the CRC for Freshwater Ecology 'Environmental Flows Monitoring and Assessment Framework' (EFMAF) (Cottingham et al 2005). A series of parameters are to be monitored before, during and after EWPs are implemented:

- Flow,
- Sediment particle size and organic content,
- Physio-chemical water quality,
- Biofilms,
- Vegetation, both riparian and aquatic,
- Macroinvertebrates, and
- Fish.

Implementation of the EWP program

This report makes the following recommendations regarding the EWP program

- EWPs need to be trialed and monitored in all four locations concurrently (via the Planning Framework for EWPs and the EFMAF). The trial should commence as soon as possible and continue for no fewer than 3 years.
- The EWP program needs to be reviewed by DWLBC prior to implementation to determine:
  - The potential impact upon the security of Adelaide's water supply
  - The potential 'Triple Bottom Line' cost of providing extra water from alternative sources (e.g. the River Murray, demand management, leakage / evaporation reduction etc) to supplement Adelaide's water supply while still providing the EWP Program to be implemented.
- The initial EWPs Program needs to be reviewed by DWLBC, with appropriate peer review, after the initial 3 years to determine whether it is delivering the desired ecological outcomes.
- The EWP program needs to be included as a condition of the SA Water management provision under the prescription of the Western Mount Lofty Ranges, if the area becomes prescribed.
- In the long term, the EWP allocation needs to be monitored and reviewed by DWLBC every 5 years under the water allocation planning framework, if the Western Mount Lofty Ranges become prescribed.

INTRODUCTION

On October 14 2004, the Minister for Environment and Conservation placed a Notice of Intent to Prescribe and a Notice of Prohibition on the surface water, watercourses and underground water of the area defined as the Western Mount Lofty Ranges. The area is shown in Figure 1, and includes the catchments of the reservoirs for Adelaide's water supply.

If prescription does occur, it will trigger a water allocation planning process for the water resources of this area. The full requirements of what issues a Water Allocation Plan (WAP) must address[2] are detailed in Appendix A, but they include:

- an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at, or the periods during, which those ecosystems will need that water
- provide for the allocation (including the quantity of water that is to be available for allocation) and use of water so that—
    i. an equitable balance is achieved between social, economic and environmental needs for the water; and
    ii. the rate of use of the water is sustainable

This report provides background technical information and management recommendations on the following:

- the technical assessments relating to the hydrological and ecological impacts of SA Water reservoirs and operations on the 5 watershed catchments of the western Mount Lofty Ranges
- an assessment of the Environmental Water Requirements[3] (EWRs) that have been determined for each catchment
- a program of Environmental Water Provisions[4] (EWPs) or 'releases' from SA Water reservoirs based on EWRs. It is recommended that this EWPs program be trialled and incorporated into future management of the water resources of the western Mount Lofty Ranges
- a monitoring program to determine the ecological responses of the EWPs program, so they can be modified as part of future WAP revisions

2 Water Resources Act 1997 section 101(4) and Natural Resources Management Act 2004 section 76(4)
3 See Glossary
4 See Glossary

Figure 1: SA Water Reservoirs in the Western Mount Lofty Ranges

ADELAIDE'S WATER SUPPLY

Adelaide's reservoirs are one of two components used to supply Adelaide's water. The other is a set of three pipelines that transfer water from the River Murray.

These two water sources are used in conjunction to provide Adelaide's water supply. In general, Adelaide's reservoirs are allowed to fill over winter and spring, and water is pumped from the River Murray to maintain supply levels over summer and autumn.

There are a total of 10 storages across 5 catchments in the Western Mount Lofty Ranges. The total storage of these reservoirs is approximately 200 GL. Storages and their volumes are detailed in Appendix B.

HYDROLOGICAL IMPACT OF FARM DAMS AND RESERVOIRS

It has been recognised for some time that the reservoirs and pipelines of the Mount Lofty Ranges have a hydrological impact on the water resources of these catchments.

- The State Water Plan (Government of South Australia 2000) assessment of the water resources of the Mt Lofty Ranges watershed (volume 2 p39) indicates that surface water use is 120 GL, the bulk of which is extracted for metropolitan Adelaide Water supply. This level of use far exceeds the 'Use Limit[5]' of 44 GL for surface water in the area.
- The National Land and Water Resources Audit assessment of the Gulf Drainage Division (Commonwealth of Australia 2000 pp 97-98) indicates that the catchments of the Gawler River, Little Para, Myponga River, Onkaparinga River and Torrens River have diversions that place them in category D ('over developed') where >100% of the sustainable flow regime is diverted.
- The Draft State Natural Resources Management Plan (The Natural Resources Management Council 2005 pg 23) states that 'the use of surface water is currently above the estimated sustainable limit in the Mount Lofty Ranges'

Since 2001, the Department of Water, land and Biodiversity Conservation (DWLBC) commissioned a Mount Lofty Ranges Water Resources Assessment Program, which has among its activities determined the effects of farm dams and reservoirs on the surface water resources of the catchments in the region. Work has been completed for the Onkaparinga (Teoh 2003), Torrens (Heneker 2003) and South Para (Teoh 2003) catchments. Myponga and Little Para studies are underway, and are due for completion in 2005.

The outputs of these studies show the relative impacts of farm dams and reservoirs on the water resources of these catchments. While farm dams do have some impact, reservoirs have by far the greatest single impact. A summary of the results available to date is shown in Table 1.

[5] Use Limit is the general term describing the total maximum annual volume of water that can be used for human activities without serious impact to ecological values (State Water Plan 2000 volume 2 p xv). Method of calculation is described in the Glossary

Table 1. Summary results of surface water assessments of reservoir catchments.

Catchment	*Site where Yield and Impact are measured*	*Median Annual Adjusted Catchment Yield*[6]	*Current Storage Volume in catchment (50% is considered the indicative sustainable limit)*	*% Impact to Median Annual Adjusted Catchment Yield*
South Para River	AW505503 SE Gawler	32 200 ML	57 600 ML Total **(179% of Yield)** 3 000 ML farm dams 54 080 ML reservoirs	90% Total 7% farm dams 83% reservoirs
Torrens River	AW504501 Gorge Weir	40 493 ML	40 974 ML Total **(101% of Yield)** 5 750 ML farm dams 38 480 ML reservoirs	~97+% Total 7% farm dams ~90+% reservoirs[7]
Onkaparinga River	AW503500 Clarendon Weir	72 100 ML	67 170 ML Total **(93% of Yield)** 8 500 ML farm dams 57 740 ML reservoirs	~95+% Total 5% farm dams ~90+% reservoirs
Myponga River	Myponga Reservoir	15 300 ML[8]	27 949 Total **(183% of Yield)** 1 109 ML farm dams 26 800 ML reservoir	Currently being assessed, likely to be high

[6] The long term (>100 year) annual yield (volume of water) that would be discharged in a median year at a defined point in the catchment under current land use conditions, but in the absence of all water diversions (farm dams and reservoirs).

[7] Estimates based on assumptions regarding SA Water operations and storage volumes of reservoirs

[8] Estimated from measured flow volumes, extrapolated to a neighbouring catchment. Modelling in 2005 will update and publish findings.

ECOLOGICAL IMPACTS OF FARM DAMS AND RESERVOIRS

The natural flow pattern observed in rivers and streams consists of five basic hydrological components (Poff et al 1997):

- Magnitude (of flow)
- Frequency (of particular events)
- Duration (of specific events)
- Timing (seasonality of specific events)
- Rate of change of hydrological condition

The combination of these five components forms the flow regime[9] of a given catchment. Flow is considered to be the ‘master variable’ of river systems and therefore it largely determines the distribution of flora and fauna, and the ecological integrity of rivers and streams (Poff et al 1997).

It is well established in international ecological literature that flow modification, such as that caused by river regulation, alters the ecology of rivers and streams. The Cooperative Research Centre for Freshwater Ecology (CRCFE) has provided unequivocal evidence for ecological consequences following alterations to flow regime (Lloyd et al 2003). However, the nature of the ecological response is not necessarily predictable or proportional to the size of the hydrological change. The response will depend on which of the five components of the flow regime has been most severely altered (Poff et al 1997). Even small changes in flow were capable of producing large ecological responses (Lloyd et al 2003).

Bunn and Arthington (2002) defined four guiding principals linking flow regime to aquatic biodiversity, and the consequences of a modified flow regime on these principles:

- *Principle 1*: Flow is a major determinant of physical habitat in streams.
- *Principle 2*: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regime.
- *Principle 3*: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.
- *Principle 4*: The invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regime.

The CRCFE review by Lloyd et al (2003) provided supporting evidence for these four principles, particularly principles 1 and 4.

The ecological stress imposed through hydrological modification has consequences not only to the inherent conservation value of the ecosystem but also to the ecosystem services that the rivers provide. Cullen and Lake (1995) stated,

> *“We have degraded our rivers and wetlands in ways that prevent them from sustaining natural aquatic ecosystems and their high levels of endemicity, and are replacing them with simplified systems of lower diversity and many exotic species that will be much less useful to humans in the future."*

[9] See Glossary

The nature and the severity of hydrological change within the Mount Lofty Ranges varies throughout the catchment, depending on the land and water management practices of specific regions. For example, the Onkaparinga River downstream of the Hahndorf dissipater has undergone a seasonal reversal of flow (i.e. flowing in the summer months, and drier in the winter months), whereas the Onkaparinga River below Clarendon Weir has suffered from a dramatic reduction in flow magnitude and volume throughout the year. It is therefore reasonable to expect that the specific ecological impacts will vary from catchment to catchment, and reach to reach across the Mount Lofty Ranges.

Water for the Environment

The State Water Plan (2000 vol 1) recognises the need to allocate water specifically to the environment.

> *'to protect and where necessary, restore the health of water resources and water dependant ecosystems…providing water for the environment through appropriate flow regimes and legally recognising these environmental water entitlements is an essential component of any water allocation system…'*
> (State Water Plan 2000 vol 1 p5).

The goal of providing water to the environment, which is based on ARMCANZ & ANZECC National Principles for the Provision of Water for Ecosystems, is 'to sustain and, where necessary, restore ecological processes, habitats and biodiversity of water-dependant ecosystems' (State Water Plan 2000 vol 1 p40).

Flow restoration aims to identify and restore flow components that will move a flow stressed river in the direction of its natural condition, or the best representation of this that can be identified. Rehabilitation, on the other hand, aims to improve the condition of an area, but not necessarily in the direction of the pre-existing state (Arthington and Pusey 2003). Water provisions for the environment need to aim for flow restoration rather than rehabilitation.

The State Water Plan (2000 vol 1 p39-40) defines two types of environmental water: Environmental water requirements (EWRs) and environmental water provisions (EWPs). The EWRs are defined as 'the water regimes needed to sustain ecological values of aquatic ecosystems, including their processes and biological diversity at a low level of risk'. EWPs, however, recognises that social and economic constraints may (at least initially) limit the delivery of the EWRs. The EWPs are therefore defined as 'that part of the environmental water requirements that can be met'.

The process of deriving and implementing EWPs has been outlined in the Planning Framework for EWPs in the State Water Plan (2000 vol 1 p41). This framework stipulates that EWPs need to be set to meet ecological objectives with targets and performance measures in place. Therefore, flows need to be linked directly to expected ecological outcomes. To achieve this, EWRs and EWPs need to be described in terms of all components of the flow regime, i.e. the magnitude, frequency, duration, timing and rate of change, not just described as minimum flow volume. This allows for the development of specific hypotheses for particular flow scenarios or flow bands and therefore will provide a clear link between a particular EWP and specific ecological outcomes.

EWPs need to identify and incorporate the key components of the flow regime that are considered essential to achieving those objectives. This assumes that firstly the essential components can be identified and secondly that restoring these components will arrest any further effects of the original flow modification.

Ecological objectives may relate to the needs of a particular species or to ecosystem scale processes, however they need to be determined specifically on a reach-by-reach basis. Examples of ecological objectives include the creation of new habitat through large scouring floods, facilitating productivity and nutrient cycling, maintaining refuge for biota in times of low flow and drought in permanent pools, providing longitudinal connection between pools for the movement of biota particularly for migration of native fish, providing lateral connection between the river and associated wetlands and floodplains.

It should be recognised that flow restoration, as opposed to rehabilitation, may require the re-introduction of combinations or suites of flows rather than isolated flow events. For example, pulse flows may achieve the objectives associated with scouring and habitat diversity, but without ‘follow-up’ flows that provide longitudinal connectivity, organisms may not be able to exploit the newly created habitat.

EWPs need to be evaluated and adapted based on monitoring and the advent of new knowledge (Refer to the section on monitoring the ecological responses of environmental water provisions).

It should also be noted that it might be necessary to combine EWPs with a variety of non-flow related management actions in order to achieve maximum environmental benefit. In the Mount Lofty Ranges, such activities include water quality improvements, watercourse habitat restoration, and water use demand management by various government agencies.

THE SOUTH PARA RIVER

Background

The South Para River is a tributary of the Gawler River. The catchment is controlled by four SA Water storages totalling 54.3 GL:

- The Warren Reservoir (4,770 ML);
- The South Para Reservoir (45,000 ML);
- The Barossa Diversion Weir (volume unknown but small); and
- The Barossa Reservoir (4,510 ML)

The potential release point is the Barossa Diversion Weir, which diverts releases from the South Para Reservoir via a tunnel to the Barossa Reservoir. Spill from Barossa Diversion Weir flows down the South Para River towards Gawler.

The Barossa Reservoir is the primary water treatment and supply point for the northern suburbs of Adelaide. Mt Lofty Ranges runoff is supplemented with flow from the Mannum-Adelaide Pipeline.

In addition to functioning as an integral part of the public water supply system, the Warren Reservoir has recently changed purpose to a holding storage for River Murray transfers supplying the Barossa Infrastructure Limited (BIL) irrigation scheme.

The capacity of the Mannum Adelaide Pipeline is understood to be approaching its maximum pumping capacity, and upgrade options are being considered.

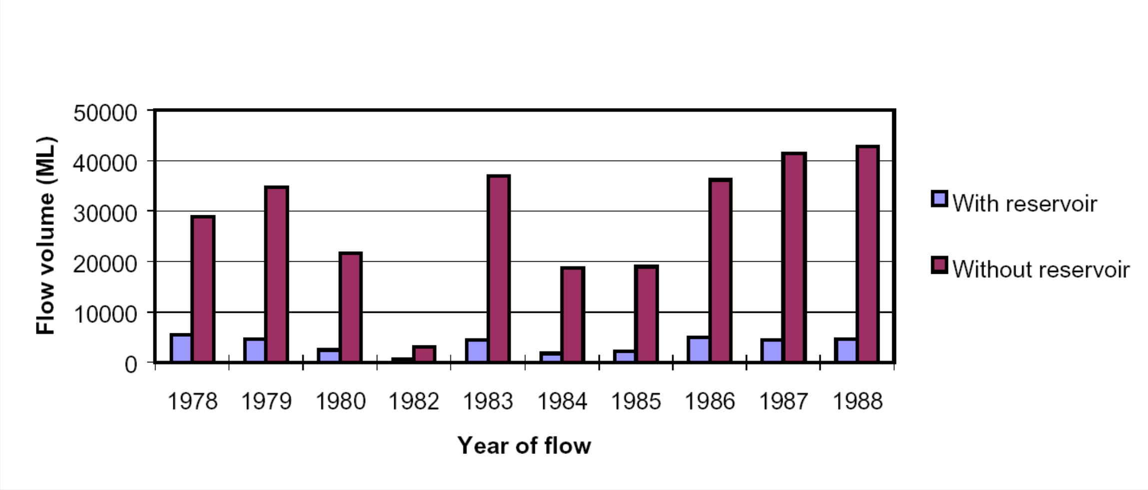
Environmental Water Requirements

Environmental water requirements of the Gawler River catchment were originally assessed in 1999 by the then Environment Protection Agency (Philpott et al pp 39 - 41). The South Para downstream of the reservoirs and upstream of Gawler was geomorphically classified as a 'Constrained Zone'.

This section of channel is a high-energy flow zone, characterised by steep bed slopes and in-channel complexity. There has been very little geomorphological change to the structure of this reach since settlement. This is due to the stable rock nature of the reach, the steep gorge topography, and the existence of a Recreation park to preserve a significant amount of riparian vegetation.

The main EWRs identified for this reach is the lack of flow. Philpott et al pp 63-65 illustrates the effects of the South Para reservoir diversions on flows. This is reproduced in Figure 2.

Figure 2. Effect of the South Para Reservoir on flows 1978-1988



(Source: Philpott et al 1999 p 65)

There is a great deal of stable physical and structural aquatic habitat in this reach, but no flows mean that this is almost always dry.

In summary, this reach is considered to environmentally intact but for lack of flow. There is a high likelihood that restoration of flows would lead to an increase in ecological processes and values in the reach.

Environmental Water Provisions

There have been two studies relating to the quantification of potential Environmental Water Provisions from the South Para Reservoir.

NORTHERN ADELAIDE AND BAROSSA CATCHMENT WATER MANAGEMENT BOARD 2002 STUDY

A feasibility study on EWPs from South Para Reservoir was commissioned by the Northern Adelaide and Barossa Catchment Water Management Board (Sinclair Knight Merz 2002). It concluded that

- Regulation by the reservoir system had reduced flows in the lower South Para by 90%, with no flows at all between January and July.
- All low-medium flows have been 100% impacted, and that any flows down the river are only during extreme events when the reservoir has spilled. This level of impact was described as ‘extreme’ (Sinclair Knight Merz 2002 p7).
- Spell analysis[10] of flow events indicated that events of median daily flow or higher have been reduced by 85%, and duration of low flow spells have increased nine-fold as a result of reservoir regulation.
- A water balance was determined assuming that
  - natural flow patterns are to be replicated (June-December flows)

[10] See Glossary

  - o no further pumping from the River Murray was available due to the BIL scheme
  - o flows out of the bottom of the reservoir were fixed based on reservoir level.

  The outlet at Barossa Diversion Weir has recently been upgraded, and the BIL Scheme has been operating for a few years, so these assumptions need to be re-examined.
- A total provision available based on the above constraints was calculated to be 1.9 GL, although more water was seen as desirable. More available data on the operation of BIL, and recent changes in the headworks at South Para Reservoir indicate that this figures may need to be re-assessed.
- A monitoring program based on fish and macroinvertebrate sampling was recommended, which has been implemented jointly by the Northern Adelaide and Barossa Catchment Water Management Board and DWLBC.
- A minimum 3 year continuous release program was recommended to allow an opportunity for a measurable ecological response.

2004 FLOW RELEASE FOR HEADWORKS UPGRADE

In July 2004, SA Water was undertaking maintenance work upon the reservoir structure. This required that the Barossa Diversion Weir and offtake tower be emptied. The 120 ML (0.12 GL) of water was released down the South Para River over 3 days, where DWLBC had installed water level and salinity detectors along the watercourse.

It was possible to track the release event to gain a better understanding of the hydraulic properties of the river channel. The data from this release was evaluated by Walter (2005) to find that:

- The transmission losses of the channel (during winter) are considered to be quite low, with 85% of flows reaching the gauging station (AW505503) 22km downstream.
- A culvert at Bassnet Road crossing has a flow capacity of 1.6 $m^3.s^{-1}$, or 138 $ML.day^{-1}$. If flows are to exceed this rate, some upgrade of this culvert capacity may need to be considered.
- With a flow release of 1.6 $m^3.s^{-1}$, water level rise varied from 250 mm (downstream site) to 600 mm (upstream site). Instream pools filled and overflowed, causing increases in aquatic habitat.
- A flow rate of 0.1 $m^3.s^{-1}$ (8.6 $ML.day^{-1}$) was estimated to be the minimum flow to achieve pool connection.

A flow regime consisting of 0.1 $m^3.s^{-1}$ (8.64 $ML.day^{-1}$) baseflow with a 1 $m^3.s^{-1}$ (86.4 $ML.day^{-1}$) flushing flow was recommended. The specifics of the release program through winter were not specified.

ECOLOGICAL OBJECTIVES OF EWPS:

- Connect in-stream pools to increase aquatic habitat diversity and improve water quality.
- Restore components of natural seasonality including high flow flushing events

Proposed EWP Strategy for the South Para River

- Pool connection flows were quantified at 0.1 $m^3.s^{-1}$, and small flow events of 1 $m^3.s^{-1}$ were also quantified (Walter 2005).
- Mimicking natural seasonality is desirable (Sinclair Knight Merz 2002 p9)
- The months of June to December have median flows above zero (Sinclair Knight Merz 2002 p10)

A proposed release program consists of:

- A 0.1 $m^3.s^{-1}$ low flow from 1 Jun to 31 Dec (214 continuous days at 8.64 ML/day) or **1.85 GL/a**
- Periodic 1 $m^3.s^{-1}$ flushes (5 events of 1 day each at 86.4 ML/day) or **0.39 GL/a**

The total required flows equal **2.24 GL/a**

2.24 GL represents approximately 7% of the 32.2 GL median annual adjusted flow at Barossa Diversion Weir (Teoh 2003a p 65)

THE TORRENS RIVER

Background

The Torrens River is controlled by numerous reservoirs, weirs and pipeline discharges (scours) from the River Murray. The 39 GL of reservoir storages in the catchment are as follows:

- Gumeracha Weir (200 ML)
- Millbrook Reservoir (16,500 ML)
- Kangaroo Creek Reservoir (19,030 ML)
- Gorge Weir (24 ML)
- Hope Valley Reservoir (3,470 ML)

The Torrens Catchment Water Management Board has undertaken the assessments of environmental water requirements and provisions in the Torrens catchment (Schultz 2004).

Environmental Water Requirements

In relation to releases of water from SA Water infrastructure, two reaches have been identified as requiring restoration of some flows:

- The Torrens between Gumeracha Weir and Millbrook Creek (9.3 km) (Schultz 2004 pp 11 – 16)
- The Torrens between Gorge Weir and Torrens Lake (20.0 km) (Schultz 2004 pp 18-23)

GUMERACHA WEIR TO KANGAROO CREEK RESERVOIR

The operating practice of SA Water is to divert as much water as possible from Gumeracha Weir to Millbrook reservoir via a tunnel. As such, the Torrens River below Gumeracha Weir is almost completely dry (wet for a total of only 121 days for the 8 year period 1996-2003), except in large floods.

Structural habitat within the streambed remains intact. However, large pools which would have previously provided a permanent refuge for aquatic flora and fauna are now completely dry over summer.

The major ecological asset of this reach is the Cudlee Creek Conservation Park, 1.5 km downstream of Gumeracha Weir. This section of the reach has excellent riparian vegetation, and the Torrens CWMB has been involved in riparian habitat improvement works, reducing the extent of exotic trees and woody weeds in this area.

GORGE WEIR TO TORRENS LAKE

This reach contains the start of the Torrens Linear Park, which has a significant public amenity value.

Downstream of Gorge Weir there are significant reduction in flow. As a result, this reach of the Torrens is most affected in terms of channel form and losses in biodiversity. Lack of flow and sedimentation has caused narrowing of the channel, allowed reed beds to develop and reduced the depth of in-stream pools, all reducing habitat. This has and continues to cause reductions in habitat diversity.

The lower portions of this reach are fed by urban stormwater and groundwater expression, and there are minimal base flow reduction issues.

There are many water quality implications of groundwater and stormwater inflows, and flushing flows from the upper catchment may play a part in alleviating such impacts. These issues have not been quantified in this assessment.

Environmental Water Provisions

GUMERACHA WEIR TO KANGAROO CREEK RESERVOIR

The advantage of Environmental Water Provisions in this reach is that the flows are not lost to the storage network. Any water released in this area will be captured in Kangaroo Creek Reservoir, and available for water supply via the Hope Valley Reservoir system. Therefore, any ‘release’ over Gumeracha Weir, while quantified, is considered a zero release across the region as the water is still available for water supply.

Ecological Objectives of EWPs:

Ecological objectives for EWPs in this reach have been determined by the Torrens Catchment Water Management Board.

Anticipated ecological benefits from low flows EWP:

- Increase permanent pools habitat for macroinvertebrates, frogs and fish
    - Decrease temperature fluctuations
    - Reduce salinity
    - Increase dissolved oxygen
- Increase fish movement
- Increase area and diversity of submerged macrophytes.

Anticipated ecological benefits from medium to high flushing flows EWP:

- Arrest current stream contraction and infilling
- Control encroachment by emergent macrophytes (reeds and rushes)
- Sediment transport
- Creation of deeper pool habitat
- Provide appropriate breeding cues for native fish
- Improve health of riparian vegetation
- Restore connection between river and floodplain.

GORGE WEIR TO TORRENS LAKE

The proposed base flow provisions are concerned with the flows immediately (1.5 km) downstream of Gorge Weir. However the medium to high flows should provide geomorphic benefits throughout the 20km reach.

Ecological Objectives of EWPs:

Ecological objectives for EWPs in this reach have been determined by the Torrens Catchment Water Management Board.

- Maintain and further improve water quality, visual amenity, and macroinvertebrate and fish habitat with low flows
- Scour sediment build up and control encroaching vegetation with winter pulse flows

Proposed EWP Strategy for the Torrens River

The Torrens CWMB and SA Water have been working towards implementation of environmental water provisions, and some minor changes have recently been made. The following flow quantities are a reflection of these recent negotiations (Peter Schultz pers comm 6 May 2005)

GUMERACHA WEIR TO KANGAROO CREEK RESERVOIR

The flows for this reach are recommended to be:

- 2.5 ML/day (0.028 $m^3.s^{-1}$) low flows to be delivered all year (**0.91 GL/a**) and
- 2 large events of 800 ML/day (8.96 $m^3.s^{-1}$) for 2 days each in winter (**3.2 GL/a**)

The total release proposed for this reach equals **4.11 GL/a**, although this EWP does not form part of the regional release as Kangaroo Creek Reservoir subsequently captures these flows.

GORGE WEIR TO TORRENS LAKE

The flows for this reach are recommended to be:

- 0.25 ML/day (0.0028 $m^3.s^{-1}$) year round (**0.091 GL/a**) and
- 2 large events of 200 ML/day for 2 days each (2.3 $m^3.s^{-1}$) pulses in winter (**0.80 GL/a**)

The total release proposed for this reach equals **0.89 GL/a**

0.89 GL represents approximately 2% of the 40.5 GL median annual adjusted flow at Gorge Weir (Heneker 2003 p iv)

THE ONKAPARINGA RIVER

Background

Two reservoirs and one weir control the Onkaparinga River, with a total storage of 58.9 GL.

- Mount Bold Reservoir (45,900 ML)
- Clarendon Weir (320 ML)
- Happy Valley Reservoir (12 700 ML)

The Murray Bridge to Onkaparinga Pipeline provides a supplementary water supply from the River Murray.

The Onkaparinga River has experienced some degree of flow restriction for approximately 110 years, with the construction of Clarendon Weir in 1896. However, the most significant alteration to flow regime has occurred over the past 70 years since the construction of Mt Bold Reservoir in 1938. While the Clarendon Weir does spill occasionally during large flow events, the river below Clarendon Weir has experienced significantly reduced flows during this period.

This catchment has had the most rigorous EWRs assessment of all the catchments in the Mount Lofty Ranges. Sinclair Knight Merz completed this assessment in 2003 on behalf of the Onkaparinga Catchment Water Management Board. EWRs were defined in terms of the individual components of flow regime, and each flow band has also been linked to specific ecological outcomes.

Environmental Water Requirements

The Onkaparinga River catchment was divided into seven distinct reaches, and 11 sites across these reaches were examined in detail.

Each of the 11 sites have had a series of desired flow conditions quantified using a set of six ecologically desirable flow components. These were based on ecological and geomorphic objectives for the reach, and the hydraulics of the river channel at each site. Six categories of flow requirements were defined for each of the 11 sites across the catchment, cease to flow, low flows and fresh flows during low flow period (Jan-May) and low flows, minor freshes and major freshes during high flow period (Jul-Nov).

The level to which these EWRs are currently being achieved varies across the catchment.

Environmental Water Provisions

The environmental flows needs for the 11 sites were given a priority ranking both within reaches and across the entire river. A set of eight priority EWPs were determined (Sinclair Knight Merz 2003 p 22) using the following criteria:

- Current environmental condition
- Potential for further degradation at current development levels
- Potential for improvement of ecological condition based on environmental water provisions alone; and
- Timeframe for the improvement of ecological condition

The top two priorities identified for the entire Onkaparinga River were low flows and major freshes in the Onkaparinga Gorge, downstream of Clarendon Weir. This priority is based upon the following characteristics of this reach:

- Current *Average environmental condition*
- *A High risk of further degradation*
- *A High potential for restoration* by environmental water provisions alone
- *A Short term timeframe for improvement* from environmental water provisions alone

The other reaches of the Onkaparinga Catchment did not have this combination of issues, i.e. other reaches were either currently in poor condition, had a low potential for recovery by EWPs alone, and/or it was considered that recovery would occur over a long time frame.

Therefore, this study concluded that the greatest environmental response from EWPs in the Onkaparinga Catchment would occur in the Onkaparinga Gorge, downstream of Clarendon Weir, and it was therefore recommended that EWPs would be best targeted at this reach.

The reach below Clarendon Weir incorporates study sites 9, 10 and 11 (Sinclair Knight Merz 2001). Site 9 is the closest to Clarendon Weir and therefore this site is used to quantify releases from Clarendon Weir. The recommended EWRs are described in Table 2 (reproduced from Sinclair Knight Merz 2002 p67):

Table 2. EWRs determined for site 9, on the Onkaparinga River downstream of Clarendon Weir

EWR	Timing	Magnitude	Frequency	Duration	Priority	Total Annual Volume
9.1	Low flow (Jan-may*)	≥ 10 ML/day	Low flow period	Entire period	1	**1 830 ML**
9.2		≥ 20 ML/day	2 annually	10 days	4	**200 ML****
9.3	High flow (Jul-Nov[1])	≥ 40 ML/day	High flow period	Entire period	2	**7 320 ML**
9.4		≥ 100 ML/day	4 annually	5 days	5	**1 200 ML*****
9.5		≥ 650 ML/day	5 annually	2 days	3	**6 500 ML**
TOTAL						**17 050 ML**

* Includes half a month between high and low flow periods for ramping up and ramping down of flows.
** Calculated assuming that low flow 9.1 (10 ML/day) is simultaneously being delivered
*** Calculated assuming that low flow 9.3 (40 ML/day) is simultaneously being delivered

ECOLOGICAL OBJECTIVES OF EWRS:

These EWRs were designed to address a number of key ecological objectives:

- Provide longitudinal connection for fish and macroinvertebrate migration
- Maintain and improve water quality
- Maintain self sustaining fish populations
- Maintain and restore habitat diversity for macroinvertebrates
- Control terrestrial vegetation encroachment of the river channel
- Reset aquatic habitat

A series of specific hypotheses are also associated with each of the flow bands:

- *9.1 Summer low flows:* Maintain shallow water habitat for macroinvertebrates and improve water quality in pools.
- *9.2 Summer freshes:* Flush pools to improve water quality and increase habitat value.
- *9.3 Winter low flows:* Create surface water flow sufficient to fill low flow channels and therefore provide migration opportunities for fish and macroinvertebrates. These flows will not significantly impact the depth of pools.
- *9.4 Winter freshes:* Will provide longitudinal connection between pools and allow migration for fish and macroinvertebrates. Will not be sufficient to scour biofilms or sediment.
- *9.5 Large winter pulses:* Reset habitat and ecosystem processes by scouring sediments and biofilms. Will also aid in controlling the vegetation encroachment.

DETERMINING A FLOW RELEASE TRIAL FOR THE ONKAPARINGA RIVER

It has been recognised that the provision of just over 17GL from Mount Bold Reservoir down the Onkaparinga River may be difficult to secure in full.

Therefore, a workshop of ecologists, including the principal ecologist from the original EWR study, was conducted on 6 June 2005 (Appendix C lists the workshop participants). The purposes of the workshop were:

- to assess each assumption and flow component, and
- to design a flow release trial that would require less flows, but still test the underlying hypotheses and assumptions of the study.

The workshop participants considered the flow bands in isolation and in various combinations and determined which ecological objectives would and would not be met (see appendix C).

The group agreed that it was imperative that the combination of EWRs 9.1, 9.3 and 9.5 (ie the top three priorities from Table 2) be maintained in an EWPs trial. Flows less than these would pose an unacceptably high environmental risk.

However, it was agreed that the duration of low flows (9.1 & 9.3), the magnitude of winter low flows (9.3) and/or the frequency of winter pulses (9.5) could be reduced in order to achieve water savings, while still being able to assess the associated ecological responses.

The workshop participants developed four EWPs scenarios and these are detailed below.

Proposed EWP Strategy for the Onkaparinga River

EWP OPTION A:

It was agreed that the most desirable EWP combination was that described by the EWR study (Table 2), totalling 17.05 GL/a. This option has the greatest potential of achieving all the ecological objectives and also provides the greatest opportunity to link flow regime to specific ecological responses.

It was acknowledged that this EWP option represents a significant volume of water relative to the reservoir storage in the catchment, and therefore alternative scenarios were developed.

17 GL represents approximately 24% of the 72 GL median annual adjusted flow at Clarendon Weir (Teoh 2003b p 12)

EWP OPTION B:

This option consists of a combination of the low flow periods (both summer and winter) and the large winter pulses. Participants agreed these need to be maintained in order to achieve the desired ecological objectives.

This was considered particularly important for the terrestrial vegetation encroachment of the Onkaparinga River channel, where workshop participants agreed that providing periods of low flow in the absence of large winter pulses was likely to encourage future terrestrial vegetation encroachment, and accelerate the reduction in available aquatic habitat.

EWP B (Table 3) is a modification of EWP A where the summer and winter freshes have been removed. Appendix C contains the predicted ecological benefits and consequences of this combination of flows.

Table 3. EWP B, consisting of periods of low flow plus winter pulses.

EWR	Timing	Magnitude	Frequency	Duration	Total Volume
9.1	Low flow (Jan-may)	≥ 10 ML/day	Low flow period	Entire period	**1 830 ML**
9.3	High flow (Jul-Nov)	≥ 40 ML/day	High flow period	Entire period	**7 320 ML**
9.5		≥ 650 ML/day	5 annually	2 days	**6 500 ML**
					15 650 ML

15.6 GL represents approximately 22% of the 72 GL median annual adjusted flow at Clarendon Weir (Teoh 2003b p 12)

EWP OPTION C:

The workshop participants discussed the potential to further alter frequency and duration of flows while still achieving ecological objectives. It was agreed that for the purposes of testing the hypotheses,

- the number of winter pulses and winter freshes could be reduced (with magnitude and duration remaining the same),
- the duration of summer low flows could be reduced (by omitting the half month ramping up and ramping down periods) and
- the duration of winter low flows could be reduced (by omitting two months and the ramping up period).

By maintaining all EWR flow bands (in a reduced form) it is possible to assess the full range of hypotheses and predicted ecological responses.

Table 4. EWP Option C with reduced frequency of winter pulses and winter freshes and reduced duration of low flow periods.

EWR	Timing	Magnitude	Frequency	Duration	Total Volume
9.1	Low flow (Jan-may)	≥ 10 ML/day	Low flow period	Entire period	**1 525 ML**
9.2		≥ 20 ML/day	2 annually	10 days	**200 ML****
9.3	High flow (Jul-Nov*)	≥ 40 ML/day	High flow period	Jul-Nov	**4 270 ML**
9.4		≥ 100 ML/day	2 annually	5 days	**600 ML****
9.5		≥ 650 ML/day	3 annually	2 days	**3 900 ML**
					10 495 ML

*Includes half a month ramping down from winter low flows.

**Calculated assuming that low flows are still being delivered.

10.5 GL represents approximately 15% of the 72 GL median annual adjusted flow at Clarendon Weir (Teoh 2003b p 12)

EWP OPTION D:

As with EWP Option C, this option sees a reduction in the frequency (but not magnitude or duration) of winter pulses and freshes, as well as a reduction in the duration of summer and winter low flows (Table 5).

A tributary of the Onkaparinga River (Bakers Gully, or Peters Creek) joins the Onkaparinga River between sites 9 and 10. The hydrological modelling suggested that this creek could provide 10 ML/day of the winter low flow requirements for the

Onkaparinga River below the confluence with Peter's Creek. Therefore winter low flows could be reduced to 30 ML. The risk of this option is that the ecological objectives associated with winter low flows will not be achieved at site 9.

Table 5. EWP Option D with a reduction in frequency of winter pulses and freshes, reduction in duration of low flow periods, reduction in magnitude of winter low flows.

EWR	Timing	Magnitude	Frequency	Duration	Total Volume
9.1	Low flow (Jan-may)	≥ 10 ML/day	Low flow period	Entire period	**1 525 ML****
9.2		≥ 20 ML/day	2 annually	10 days	**200 ML**
9.3	High flow (Jul-Nov)	≥ 30 ML/day	High flow period	Jul-Nov	**3 203 ML****
9.4		≥ 100 ML/day	2 annually	5 days	**600 ML**
9.5		≥ 650 ML/day	3 annually	2 days	**3 900 ML**
					9 428 ML

*Includes half a month ramping down from winter low flows.

**Calculated assuming that low flows are still being delivered

9.4 GL represents approximately 13% of the 72 GL median annual adjusted flow at Clarendon Weir (Teoh 2003b p 12)

FURTHER EWP OPTIONS

The workshop participants discussed the ecological merit of a further reduced EWP. Lower volumes could only be achieved by omitting the summer low flows from the EWP, and thus transforming the river from what was naturally a perennial system to an ephemeral system. This was considered to be an ecologically undesirable long-term outcome, as an ephemeral system would not provide suitable habitat for recruitment and long-term population viability for many on the Onkapraringa's fish and macroinvertebrate communities.

The consensus opinion of the workshop participants was that summer low flows, winter low flows and winter freshes formed the core of the EWP and that these flow bands must be maintained as a inseparable suite that could not be traded-off if the EWP was to achieve any ecological improvement to the Onkaparinga River.

The expert position of the workshop participants was that an EWP scenario with a flow volume less than that of EWP Option D (9.4 GL/a) would not achieve a sustainable ecological outcome and would therefore be considered to be ecologically unacceptable.

MONITORING THE ECOLOGICAL RESPONSE OF ENVIRONMENTAL WATER PROVISIONS

As discussed previously[11], current ecological knowledge provides strong evidence that flow modification induces an ecological response (Poff et al 1997, Bunn and Arthington 2002, Lloyd et al 2003). However, these responses are often difficult to predict as the specific effect of flow regime on aquatic flora and fauna is not easily quantified (Bunn and Arthington 2002). Consequently, the ecological response to restoring components of natural flow regimes after periods of flow modification may also be unpredictable.

This uncertainty of response reinforces the need for monitoring programs to be carefully planned and rigorously executed.

Adaptive management is a widely accepted principle that allows for the management of natural systems despite the inherent uncertainly and unpredictability. At its most basic, adaptive management provides a feedback framework within which management programs can be assessed, designed, implemented, monitored, evaluated, and adjusted (Allan and Curtis 2003).

The Planning Framework for EWPs in the State Water Plan (2000 vol 1 p41) follows an adaptive management approach, where EWPs are determined, implemented, monitored, evaluated and adapted accordingly. This framework suggests that EWPs be reviewed in at least five yearly cycles, which is consistent with water allocation and regional NRM plans[12].

The aim of EWP monitoring programs is to demonstrate a link between the flow provision and observed ecological responses. Therefore the program needs to determine how the river or stream may respond to the new flow regime and predict the components of the ecosystem we might see a measurable response. The spatial distances and time frames over which these responses are predicted to occur are also very important for monitoring program design (King et al 2003).

The CRC for Freshwater Ecology's 'Environmental Flows Monitoring and Assessment Framework' (EFMAF) (Cottingham et al 2005) is a management tool that aims to measure the effectiveness of EWPs and establish a causal link between EWPs and observed ecological responses in specific river systems. It is focused particularly on the monitoring and evaluation steps of adaptive management process. The EFMAF is consistent with the State Water Plan / State NRM plan Planning Framework for EWPs and is currently being adopted by other environmental flows projects, including icon sites for the Living Murray Program.

The basic steps of EFMAF are:

- Define the scope of the project and its objectives
- Define the conceptual understanding of the flow-ecology relationships and the questions (hypotheses) to be tested.
- Select variables to be measured
- Determine the study design, accounting for the specific activities and location

[11] refer to section 'Ecological Impacts of Farm Dams and Reservoirs'
[12] Natural Resources Management Act 2004 section 81(4) and Draft State NRM Plan p 69

- Optimise study design and identify how data are to be analysed
- Implement the study design
- Assess whether the environmental flow has met specific objectives and review conceptual understanding and hypotheses.

EFMAF emphasises the importance of engaging all the relevant stakeholders, upholding standards of quality control/quality assurance as well as encouraging the development of risk assessment and contingency planning. This framework is consistent with other literature on monitoring ecological responses to management interventions such as King et al (2003) and Downes et al (2002). Additional benefits of this framework are the scientifically rigorous approach, the emphasis on using conceptual models to generate hypotheses of ecological response, the focus on design with a mind to statistical analysis and the aim to establish a causal link between the EWP and observed ecological responses.

For these reasons the monitoring of EWPs within the Mount Lofty Ranges will be based on EFMAF.

Expected outcomes of such a monitoring program include:

- Establish links between flow regime and the aquatic ecology of the Mount Lofty Ranges.
- Rigorous and defensible recommendations for reviewing water allocation plans and determining future EWPs and reviewing WAPs.
- Improved conceptual understanding of the ecological assets of the Mount Lofty Ranges.

Monitoring Program Design

There are a number of basic designs that can be applied to monitoring EWPs. The choice of design will determine how you observe the response to the EWPs and will also form the basis upon which the success of the EWPs will be assessed. Therefore, care needs to be taken to ensure the most appropriate design is chosen. The Before-After-Control-Impact (BACI) design incorporates data from both before and after an intervention, such as an EWP (see Downes et al 2002 p120). These designs provide the greatest power for establishing causality between a management action and an ecological response, and are therefore most desirable for monitoring EWPs (Downes et al 2002, King et al 2003, Cottingham et al 2005).

The decision support flow chart of the EFMAF helps to identify the most appropriate type of BACI design for individual EWP projects (Cottingham et al 2005). The selection is based on the availability of control sites[13] and reference sites[14] and the existence of baseline data[15].

Monitoring of EWPs can be ‘event based’, i.e. conducted at the time of the flow release, or conducted on a seasonal basis. Seasonal monitoring uses baseline data and control/reference sites to track changes in ecological condition after an EWP has been

[13] See Glossary
[14] See Glossary
[15] See Glossary

implemented. As seasonal monitoring only captures a snapshot in time, it may take several sampling events before measurable differences in ecological condition are detected. Event-based monitoring allows for testing of specific hypotheses of the physical processes that may occur as a result of the EWP and how the biota respond to these changes. Event based monitoring is useful for assessing whether the system responds to the EWP in a predictable way and allows for short-term assessment of ecological responses. This is particularly important for validating the conceptual models of the system that are created in the EFMAF. Both monitoring methods can establish the causal link between the EWP and ecological response, and both methods also inform the adaptive management process. The ideal monitoring program would include both long-term seasonal trends and appropriate event-based sampling.

INDICATORS OF ECOLOGICAL RESPONSE

There are many indicators that can be used to monitor ecological responses to interventions such as EWPs (see Reid and Brooks 1998, Downes et al 2002, King et al 2003 p12). Indicators can be classed as either structural components of the ecosystem (eg species abundance, biomass) or as functional processes of the ecosystem (eg productivity, nutrient cycling) (Reid and Brooks 1998). Most monitoring programs tend to focus on structural indicators alone and therefore run the risk of ignoring aspects of ecosystem integrity or sustainability. Monitoring programs will ideally measure both structural and functional attributes, as this will greatly increase the chance of detecting ecological response (Reid and Brooks 1998).

Selection of indicators should be based on our current understanding of the ecosystem and how the ecosystem is expected to respond to the proposed intervention. However, other factors such as time, resources and cost will also strongly influence the final decision. The indicators recommended for monitoring EWPs in the Mt Lofty Ranges are as follows:

Flow

Monitoring flow volumes and velocities and the extent to which particular flow releases reach within the landscape is crucial if you are to assess whether the EWPs are being met. Flow monitoring will also allow the hydrological models used to determine EWPs to be evaluated and modified accordingly. There are some gauging stations within the Mount Lofty Ranges that will supply the necessary information, however, there is a need for additional stations in order to assess whether EWPs are meeting their hydrological objectives.

Sediment

Sampling of sediment within river channels can give insight into the physical responses to flow. Very fine sized sediment will be transported by fast flowing water and will be deposited where flows are slow. This movement of sediment within the river channel is important for creating habitat for biota such as macroinvertebrates. The objective of many EWPs is to induce a physical response primarily for habitat creation and therefore sediment sampling should be included in the monitoring program. Measuring sediment particle size is relatively simple, using specialised laboratory equipment, and the results can be used to infer physical responses to flow.

The organic content of sediment can be established using 'ash free dry weight' techniques. This can be useful for inferring the relative rates of productivity at particular sites.

More detailed analysis of sediments, such as nutrient concentrations, is generally expensive and unless it relates to specific objectives of an EWP, it is probably not worthy of inclusion in EWP monitoring programs.

Water Quality

A variety of physio-chemical parameters can be monitored to assess the impact of flow releases on water quality. Some water quality parameters can be measured easily and cheaply using field probes. However other parameters require collection (and specialised storage) of samples for laboratory testing. These analyses can be expensive, particularly for long-term monitoring programs.

A basic water quality monitoring program could include:

Field analysis:

- Salinity
- pH
- Dissolved oxygen
- Temperature
- Turbidity

Laboratory analysis:

- Nutrients[16]; filterable reactive phosphorus, total phosphorus, oxides of nitrogen, ammonia, total nitrogen.

Biofilms

Biofilms are an assemblage of algae, fungi and bacteria that colonise submerged surfaces in rivers and streams. Biofilms, including the diatom assemblages within the biofilm, are useful biological indicators (see Reid et al 1995 and Burns and Ryder 2001), particularly in monitoring environmental flow releases (see Sutherland et al 2002). The main advantages of using biofilms for monitoring ecological responses are their rapid response times (due to short generation times), their sessile nature and their responsiveness to environmental conditions (Burns and Ryder 2002). In addition to the structural information on species composition and abundance, biofilms can also be used to quantify functional aspects of the ecosystem, such as productivity, respiration and the structure of food webs (see Burns and Ryder 2001).

Biofilm sampling can be time consuming and expensive, therefore the final sampling regime will depend on cost and the specific ecological responses expected from a particular flow release.

Do these biofilms include diatoms, if so they should be highlighted. For example

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[16] depending on available funds

Diatoms are microscopic phytoplankton that occupy a wide variety of habitat niches. They are abundant in almost all aquatic environments and the majority of diatom species are attached; living on rock surfaces, larger plants, mud, slit and sand; whilst there are also less common planktonic species (Reid et al 1995). Diatoms are used as indicators of water quality as they have distinct ecological requirements and are very sensitive to changes in water chemistry (Reid et al 1995 and references therein). Changes in diatom communities are rapid in response to environmental changes and the response time of diatoms provides a useful intermediate between physico-chemical sampling and the response of higher organisms (Reid et al 1995).

Vegetation

Vegetation, both riparian and aquatic, plays an important role in aquatic ecosystems. They provide a source of carbon, influence water chemistry and provide habitat for aquatic animals and epiphytic algae. Relationships between hydrological regime and macrophyte community structure in wetland systems are relatively well understood. Therefore, monitoring changes in vegetation structure can be a useful measure of ecosystem response (see Reid and Brooks 1998). Vegetation surveys are non-destructive and can be conducted in the field or via desktop studies using visual imagery.

Macroinvertebrates

Macroinvertebrates have been used extensively for biomonitoring throughout Australia. Macroinvertebrate communities are often abundant, diverse, and widespread and occur in most rivers and streams (Downes et al 2002). Relationships between water quality and the diversity and abundance of macroinvertebrate have been well established through models such as AusRivAS. The advantage of this model is that it uses standardised collection and identification protocols so data can be compared across monitoring programs. The model was developed to assess the overall health of the river or stream, so does not directly address ecosystem changes due to flow modification. Therefore, even though aspects of the AusRivAS model will be useful to the monitoring of EWPs, it should not form the sole basis of the monitoring program.

Recently, attentions have shifted from health assessments towards establishing habitat preferences for particular types of macroinvertebrates and therefore draw links between alterations in flow regime and changes in macroinvertebrate communities (King et al 2003, SKM 2001). Event based responses (ie linked to a flow release) and linking macroinvertebrate diversity and abundance to habitat preferences should form the foundation of EWP monitoring programs. This type of monitoring requires highly trained staff to identify and analyse samples and to interpret the changes observed in the macroinvertebrate communities.

Fish

Fish are generally widespread throughout flowing waters and therefore can be useful indicators. Species at the top of the food chain are particularly useful as they integrate signals of change from species at the lower trophic levels (Downes et al 2002). However, the highly mobile nature of fish and their patchy distribution may make it difficult to establish a causal link between alterations to flow and changes in community structure. These changes in community structure (ie species composition and age classes etc) may take several years before a measurable response is detected. Some species may show an immediate response to flow, such as movement or spawning, and therefore event based sampling should also be used.

Sampling fish often requires licences and ethics approval and specialised equipment and expertise. Investigations on adult stages can largely be done in the field, and fish can be released unharmed. However, investigations into larval and juvenile fish will require some destructive sampling where fish are collected from the field and identified in a laboratory.

CONCLUSIONS & RECOMMENDATIONS

Summary EWP Program

EWPs relating to SA Water reservoirs have been defined at four locations across three catchments within the Western Mount Lofty Ranges

- below the Barossa Diversion Weir on the South Para River (2.24 GL/a),
- below the Gumeracha Weir on the Torrens River (4.11 GL/a[17]),
- below the Gorge Weir on the Torrens River, (0.89 GL/a) and
- below Clarendon Weir on the Onkaparinga River (9.43 GL/a – 17.05 GL/a, depending on which EWP Option is selected).

The total EWP program ranges from 16.67 GL/a – 24.29 GL/a, with 4.11 GL/a still available for water supply.

Reservoir Release Requirement for the EWP Program

Implementing this program would require a reservoir release of 12.56 GL/a – 20.18 GL/a. This represents approximately 10% - 17% of the 121 GL/a that enters the reservoirs in an average year (Water Proofing Adelaide 2004 p11)

Specific Nature of the EWP Program

The EWPs are designed to address issues specific to each location and the history of hydrological and ecological stresses vary between the locations. Therefore, it is highly unlikely that lessons learnt from an EWP trial in one location will be directly applicable to another location.

Implementation and Monitoring of the EWP program

It is recommended that EWPs need to be trailed and monitored (via the Planning Framework for EWPs and the EFMAF) in all four locations concurrently for a period of no less than 3 years.

It is recommended that the EWP program monitoring be assessed and the ecological responses compared with the hypotheses of the supporting studies.

It is recommended that the initial EWPs Program be reviewed after the 3 years.

Legal Recognition of EWP Program

It is recommended that the EWP program determined in this study be included as a condition of the SA Water allocation and license under the prescription of the Western Mount Lofty Ranges, if the area becomes prescribed.

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[17] Considered a 4.11 GL EWP but a 'zero' reservoir release as the flows are recovered in Kangaroo Creek Reservoir

It is recommended that in the long term, the EWP allocation be monitored and reviewed by DWLBC every 5 years under the water allocation planning framework, if the Western Mount Lofty Ranges become prescribed.

Triple Bottom Line Assessment of EWP Program

This report has focussed largely on the hydrological and ecological aspects of EWPs in the Western Mount Lofty Ranges. EWP trials need to incorporate the predicted social and economic impacts associated with the flow release.

It is recommended that the EWP program be reviewed by DWLBC to determine:

- The potential impact upon the security of Adelaide's water supply
- The potential economic cost of providing extra water from alternative sources (e.g. the River Murray, demand management, leakage / evaporation reduction etc) to supplement Adelaide's water supply while still providing the EWP Program to be implemented.

GLOSSARY

Baseline Data

Data collected prior to a management intervention, eg data collected prior to the release of an environmental water provision.

Control Site

A site that is ecologically similar to the intervention site, except there is no management intervention, eg no environmental water provision.

Environmental Water Provisions (EWPs)

Those parts of environmental water requirements that can be met, at any given time. This is what can be provided at that time with consideration of existing users' rights, social and economic impacts.
(State Water Plan 2000 volume 1 p84)

Environmental Water Requirements (EWRs)

The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.
(State Water Plan 2000 volume 1 p84)

Flow Regime

The characteristic pattern of a river's flow quantity, timing and variability. Consists of five critical components; magnitude, frequency, duration, timing and rate of change of hydrological condition.

Reference Site

A site that is, as nearly as possible, in the condition of an environment undisturbed by human activity.

Spell

The period of time that flows in a watercourse are above or below an ecologically important threshold value. Spells can be used to define ecologically significant events such as inundation of floodplains, timing and seasonality of breeding events for aquatic organisms, or periods of natural drying. Statistics on the timing, frequency and duration of spells is considered to be relevant to ecological processes.

Use Limit

Use Limit is the general term described in the *State Water Plan 2000* to describe the total maximum annual volume of water that can be taken for use by human activities (e.g. irrigation, industry, agriculture, domestic supply) without serious impacts to ecological values.

Surface Resources: A use limit for surface resources (outside of prescribed areas) of 25% of the median annual natural streamflow for the catchment, prior to development of farm dams and other storages (natural flow), has been developed as an interim estimate while stream ecosystem water requirements are being determined.

The 25% factor is based on the current catchment allowance for farm dams being 50% of the median annual natural flow. The remaining 50% is available to the environment. Of the 50% allowance for farm dams, only half is considered to be able to be diverted for use, with the other half being lost to evaporation, seepage and dam overflow, or not available during periods of drought. The use limit is estimated to be 50% of 50% of the median natural flow.
(*State Water Plan 2000 volume 2 p xv)*

SI Units Commonly Used Within Text

Table 6. SI Units Commonly Used Within Text

Name of unit	Symbol	Definition in terms of other metric units	
Millimetre	mm	10^{-3} m	length
Metre	m		length
Kilometre	km	10^{3} m	length
Litre	L	10^{-3} m^3	volume
Megalitre	ML	10^{3} m^3	volume
Gigalitres	GL	10^{6} m^3	volume
Microgram	µg	10^{-6} g	Mass
Milligram	mg	10^{-3} g	Mass
Gram	g		Mass
Kilogram	kg	10^{3} g	Mass
Cubic Metres Per Second	$m^3.s^{-1}$	86.4 ML/day	Flow
Megalitres per day	ML/day	0.012 $m^3.s^{-1}$ or 0.365 GL/a	Flow
Gigalitres per annum	GL/a	2.74 ML/day or 0.032 $m^3.s^{-1}$	Flow

Abbreviations Commonly Used Within Text

Table 7. Abbreviations Commonly Used Within Text

Abbreviation	Name
EWP	Environmental Water Provision
EWR	Environmental Water Requirements
MLR	Mount Lofty Ranges
WAP	Water Allocation Plan
EFMAF	Environmental Flows Monitoring and Assessment Framework

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Personal Communications

6 May 2005	Peter Schultz, Scientific Officer, Torrens and Patawalonga Catchment Water Management Boards.
July 2005	Alan Collett; Planning Engineer Network Planning, SA Water.

APPENDIX A
WATER ALLOCATION PLAN REQUIREMENTS

Under the *Water Resources Act 1997*, the following issues need to be addressed by a Water Allocation Plan[18]:

'(4) a water allocation plan must -

a) include an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at, or the periods during, which those ecosystems will need that water; and

b) include an assessment as to whether the taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other water resource; and

c) provide for the allocation (including the quantity of water that is to be available for allocation) and use of water so that—

    i. an equitable balance is achieved between social, economic and environmental needs for the water; and

    ii. the rate of use of the water is sustainable; and

d) in providing for the allocation of water take into account the present and future needs of the occupiers of land in relation to the existing requirements and future capacity of the land and the likely effect of those provisions on the value of the land; and

e) assess the capacity of the resource to meet the demands for water on a continuing basis and provide for regular monitoring of the capacity of the resource to meet those demands; and

f) provide for the transfer of and other dealings with water allocations; and

g) specify the applications for the transfer of a licence or the water allocation of a licence (if any) in relation to which section 40 will apply; and

h) identify the changes (if any) that are necessary or desirable to a Development Plan under the *Development Act 1993* or to any Act or subordinate legislation; and

i) include such other information or material as is contemplated by this Act or is required by regulation.'

[18] Water Resources Act 1997section 101(4)

The *Natural Resources Management Act 2004* carries through these requirements of water allocation plan almost identically[19]

(4) A water allocation plan must—

(a) include—

(i) an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water; and

(ii) an assessment as to whether the taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other water resource; and

(b) provide for the allocation (including the quantity of water that is to be available for allocation) and use of water so that—

(i) an equitable balance is achieved between environmental, social and economic needs for the water; and

(ii) the rate of use of the water is sustainable; and

(c) in providing for the allocation of water take into account the present and future needs of the occupiers of land in relation to the existing requirements and future capacity of the land and the likely effect of those provisions on the value of the land; and

(d) assess the capacity of the resource to meet the demands for water on a continuing basis and provide for regular monitoring of the capacity of the resource to meet those demands; and

(e) identify and assess methods for the conservation, use and management of water in an efficient and sustainable manner; and

(f) provide for the transfer of, and other dealings with, water allocations; and

(g) specify the applications for the transfer of a licence or the water allocation of a licence (if any) in relation to which section 159 will apply; and

(h) to the extent that the regional NRM plan does not so provide—

(i) set out the matters that the board will consider when exercising its powers to grant or refuse permits under Chapter 7 Part 2; and

(ii) identify the changes (if any) considered by the board to be necessary or desirable to—

(A) a Development Plan under the Development Act 1993; or

(B) any other statutory instrument, plan or policy (including subordinate legislation); and

(i) include such other information or material contemplated by this Act or required by the regulations.

[19] *Natural Resources Management Act 2004* section 76(4)

APPENDIX B
SA WATER STORAGES IN THE MOUNT LOFTY RANGES

Catchment	Storage	Volume	Total Volume	Supplementary Pipeline(s)
South Para	Warren Reservoir	4 770 ML	54 080 ML	Swan Reach Stockwell Pipeline and the Mannum Adelaide Pipeline
	South Para Reservoir	44 800 ML		
	Barossa Diversion Weir	0* ML		
	Barossa Reservoir	4 510 ML		
Little Para	Little Para Reservoir	20 800 ML	20 800 ML	Mannum Adelaide Pipeline
Torrens	Millbrook Reservoir	16 500 ML	38 480 ML	Mannum Adelaide Pipeline
	Kangaroo Creek Reservoir	19 030 ML		
	Gumeracha Weir	200 ML		
	Gorge Weir	24 ML		
	Hope Valley Reservoir	2 760 ML		
Onkaparinga	Mount Bold Reservoir	45 900 ML	57 740 ML	Murray Bridge Onkaparinga Pipeline
	Clarendon Weir	320 ML		
	Happy Valley Reservoir	11 600 ML		
Myponga	Myponga Reservoir	26 800 ML	26 800 ML	None
	TOTAL STORAGE	**197 900 ML**		

* Not known, but a small volume

Source: Alan Collett pers comm

APPENDIX C
ONKAPARINGA EWPS WORKSHOP 6TH JUNE 2005

Participants at the EWPs workshop held on the 6th June 2005 at the department of Water Land and Biodiversity Conservation were:

- Michelle Bald (Project Ecologist, DWLBC)
- Ed Pikusa (Program Manager, MLR Assessments, DWLBC)
- Jason Vanlaarhoven (Senior Ecologist, DWLBC)
- Nick Souter (Senior Ecologist, DWLBC)
- Kate McNicol (Ecological Assessment Officer, DWLBC)
- Michael Shirley (Principal Ecologist SKM),
  from the original Onkaparinga EWR/EWP Project Team
- Steven Gatti (Project Manager, OCWMB)
- Mardi van der Wielen (Project Ecologist, RMCWMB)
- Amy George (Knowledge Broker, CRCFE)

Table 8. Ecological objective predicted to addressed and not be addressed via particular flow bands (in isolation and in various combinations).

Scenario	Flow bands	Hypotheses and objectives that will be addressed	Disadvantages and objectives that will not be addressed
1	Summer low flow 10 ML/day Jan-May	• Maintain water quality • Maintain shallow water habitat on edges of pools • Very limited riffle habitat created	• Does not stop vegetation encroachment – in absence of scouring flows, may actually promote vegetation • Does not provide connection between pools • Does not provide optimum riffle habitat

Scenario	Flow bands	Hypotheses and objectives that will be addressed	Disadvantages and objectives that will not be addressed
2	Winter low flow 40 ML/day July-Nov	• Longitudinal connection between pools and allow for migration between pools • Increase habitat diversity – eg riffles	• If no summer flows, will turn the system to an ephemeral system • Does not stop vegetation encroachment • May allow migration of exotic species (eg fish) • Will only promote minimal fish recruitment
3	Winter pulses (650 ML/day)	• Will start to control vegetation encroachment • Will scour sediments • Will reset biofilms/diatoms • Cue for fish breeding • May flush some exotics	• Does not improve summer habitat diversity or water quality issues • Only provides very short term connection between pools • Without follow-up flows, may get accumulation of organic matter in pools which could become anoxic – potential impact on estuary • Without follow-up flows, may not get recruitment of native fish

Scenario	Flow bands	Hypotheses and objectives that will be addressed	Disadvantages and objectives that will not be addressed
4	Summer low flow + winter low flow + winter pulses	• All of objectives I-3, plus additional benefits • Promoting some fish recruitment • Moving from maintenance of the system to recovery	• Sub-optimum conditions for fish recruitment – need winter freshes as well
5	Summer low flow + winter low flow + winter pulses + summer freshes	• All of objectives 1-3, plus additional benefits • Improved summer habitat for fish, macroinvertebrates etc and improved water quality • Begin to reinstate natural processes	• Sub-optimum conditions for fish recruitment – need winter freshes as well
6	Summer low flow + winter low flow + winter pulses + summer freshes + winter freshes	• All of objectives 1-5, plus additional benefits • Reinstate full suite of natural processes not just reintroducing components • Provide optimum conditions for fish recruitment	