Where's the water going to come from? Environmental flows for the Onkaparinga River and estuary

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Abstract
The Onkaparinga River catchment is one of the principal water supply sources for metropolitan Adelaide. It also hosts 47 different types of land uses including irrigated horticulture, grazing, and rural and urban living. The river is also a vital component of the environment of the Mt Lofty Ranges, providing water and habitats for a variety of instream and riparian flora and fauna.

The river suffers from significantly reduced flows, which has resulted in degraded riverine and estuarine environments. The Onkaparinga Catchment Water Management Board is seeking to return environmental flows to the Onkaparinga River through a variety of measures. Two of these measures involve low flow bypasses on selected farm dams and formulating planning policy that would assist with the achievement of environmental flows in the long term.

Keywords
Environmental flows; environmental water requirements; Onkaparinga River; low flow bypass

INTRODUCTION

The need to reform the water resource industry and provide water for the environment has been recognised by both Federal and State Governments in the Council of Australian Governments (COAG) Water Reform Agenda (ARMCANZ, 1995). Under the 1994 COAG agreement, the environment is recognised as a legitimate water user and therefore has a right to its own water allocation.

South Australia is a signatory to both the COAG Water Reform Agenda and the National Principles for the Provision of Water for Ecosystems (ARMCANZ and ANZECC, 1996). These national policies are reflected in the Onkaparinga Catchment Water Management Plan (Onkaparinga Catchment Water Management Board, 2000).

In 2003, the Onkaparinga Catchment Water Management Board (the Board) completed a two and a half year investigation into the environmental water requirements of the Onkaparinga River catchment (Sinclair Knight Merz, 2003). In 2004, the Board investigated policy and planning options which, over time, could assist with the delivery of those environmental water requirements. The results of these investigations are discussed in this paper.

THE ONKAPARINGA RIVER CATCHMENT

The Onkaparinga River flows for 95km through the Mt Lofty Ranges, onto the Adelaide plains and into Gulf St Vincent through the estuary at Port Noarlunga (refer to Figure 1). The river is a vital component of the environment of the Mt Lofty Ranges, providing water and habitats for a variety of instream and riparian flora and fauna. The Onkaparinga River estuary at Port Noarlunga and the coastal environment it empties into is an important spawning ground for native fish as well as one of Adelaide's premier summer recreational destinations.

The river and its 1,500km system of tributaries receive runoff from 560km^2 of land that comprises a wide variety of land uses. Land use mapping undertaken in 2003 by the Department of Water, Land and Biodiversity Conservation indicates that grazing of modified pastures occupies the largest area, followed by grazing and rural residential living. Irrigated land comprises around 10% of the Onkaparinga River catchment. The catchment also includes urban centres, ranging from small rural townships with populations of several hundred to the sprawling southern suburbs of Adelaide concentrated around the estuary.

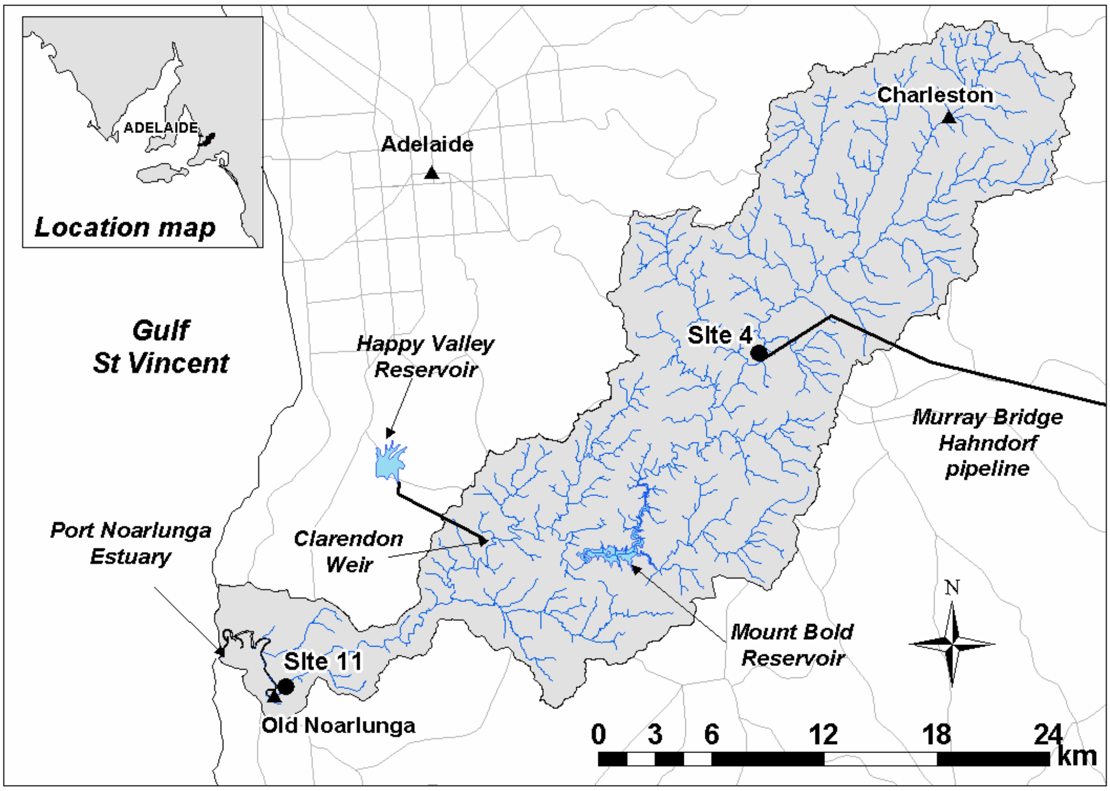

Figure 1. The Onkaparinga River catchment.

The Onkaparinga River catchment is one of the principal water supply sources for metropolitan Adelaide. Located on the Onkaparinga River, the Mt Bold Reservoir and Clarendon Weir water supply system diverts water to meet around 30% of Adelaide's demand in an average year. On its own, runoff from the Onkaparinga River catchment is insufficient to fully supply the water demand of Adelaide and so River Murray water is discharged into the river at Hahndorf.

The annual volume of River Murray water discharged into the Onkaparinga River varied from 4,000ML/yr to 72,000ML/yr during the 22 year period from 1976 to 1998, compared to a median catchment inflow into Mt Bold of 42,000ML/yr over the same period. Over this period the proportion of River Murray water discharged into the Onkaparinga River varied from 6% to 86% of the total annual inflow into Mt Bold.

There are more than 2,700 farm dams throughout the Onkaparinga River catchment, with the greatest density occurring above Mt Bold Reservoir. Here, there are more than 2,200 dams with an estimated aggregated volume of 10,900 ML (Sinclair Knight Merz, 2004a).

HOW MUCH WATER DOES A RIVER NEED?

The approach adopted for determining the environmental water requirements was based on the FLOWS method (Department of Natural Resources and Environment, 2002) which recognises the conceptual link between key flow components and ecological processes. This approach involved the collaboration of a multidisciplinary team across the fields of geomorphology, hydrology, and macroinvertebrate and fish ecology, identifying the critical parts of the flow regime as well as the ecological and geomorphological roles of these flow components (Shirley et al., 2002).

Environmental water requirements were identified for 11 key sites chosen for their overall representativeness of the remainder of the Onkaparinga River catchment. An example of the environmental water requirements determined for two key locations is presented in Table 1. This table also provides an indication of the degree to which these requirements are being achieved under the current hydrological and natural flow regime.

Table 1. Environmental water requirements and their achievement at two key sites in the Onkaparinga River catchment.

Site	Season	Magnitude	Frequency	Duration	Frequency (events/year)		% Time Duration Satisfied	
		(ML/day)		(days)	Natural*	Current	Natural*	Current
4 Upstream of Mt Bold Reservoir	Low flow (Jan – May)	10 (min)	Annually	**	-	-	78%	53%
		>20	2 annually	10	2.2	5.1	50%	13%
	High flow (Jul – Nov)	40 (min)	All of period	**	-	-	80%	73%
		>100	4 annually	5	4.4	5.1	70%	63%
		>650	5 annually	2	3.8	3.8	50%	50%
11 Onka. River estuary	Low flow (Jan – May)	7.5 (min)	Annually	**	-	-	80%	7%
		19.5	2 annually	15	1.8	0.1	48%	0%
	High flow (Jul – Nov)	35 (min)	All of period	**	-	-	80%	32%
		>100	5 annually	5	4.6	0.5	50%	40%
		>90	5 annually	2	5.5	0.3	50%	55%

* The natural flow regime is defined as the flows that would exist if no diversions or storage of water occurred, accepting that there have been changes in flow associated with land use alterations.
** Duration of streamflow is for the remainder of that season.

Site 4 is located in the upper Onkaparinga River catchment, outside of the influence of major water supply infrastructure (Mt Bold Reservoir and the entry of River Murray water). During the low flow period there are currently more frequent freshes over shorter durations than natural. For example, there are currently on average 5.1 freshes per year (13% of which are above 10 days duration) compared to an average 2.2 freshes per year under natural conditions (50% of these being above 10 days duration).

Site 11 is located at the upstream end of the Onkaparinga River estuary. Both the frequency of flow events and the duration of those events have been severely impaired under current flow conditions for most flow components. This is particularly the case for the critical ecologically important low flow period where the minimum flow recommended duration is achieved only 7% of the time, and summer freshes occur around 5% of the time they used to under natural conditions but never last the recommended 15 days.

It is likely that the reduction of flows in the Onkaparinga River and through the estuary exacts a heavy cost on the aquatic environment. As there is little scientifically verifiable data on the pre-development condition of the Onkaparinga River, its tributaries and the estuary, this cost cannot be accurately known. It is known that these reductions in environmental flows has given rise to loss of instream habitat, narrowing of riparian corridors, terrestrial vegetation encroachment into river channels and smothering of river substrate. Further, as the river flows into the coastal plain, the reduced flow and sediment discharges, combined with the urbanisation of the adjacent catchment area, have changed the nature of the estuarine reach from sand-dominated to mixed sand-mud sediments. Reduced flows through the estuary have also resulted in narrowing of the river mouth, presenting a barrier to fish passage between estuarine and marine environments.

The need to provide water for environmental flows in the Onkaparinga River catchment is evident. Given the competing land uses within rural areas of the catchment, the function of the river and catchment as a source of water for metropolitan Adelaide, and a long history of unregulated use of surface water, the challenge to provide environmental flows for the Onkaparinga River is significant.

The Board is taking on this challenge by focussing on two distinct areas. These areas are divided on the basis of hydrology and are discussed below.

PROVIDING FLOWS DOWNSTREAM OF CLARENDON WEIR

Environmental flows downstream of Clarendon Weir are dominantly controlled by the operation of the metropolitan Adelaide water supply system. The operation of this system is in turn driven by the demand for water from Adelaide and on the operational requirements of SA Water.

There are a number of options that could be employed to provide environmental flows for the Onkaparinga River. Some of these options, such as implementing water conservation measures in metropolitan Adelaide and reducing reliance on catchment water by reusing stormwater and recycled water sourced within metropolitan Adelaide, have long turn around times and face testing social challenges.

Other options are able to be implemented more immediately, but face similarly testing challenges. These options include retrofitting a flow bypass to Clarendon Weir and modifying water releases from Mt Bold Reservoir.

Clarendon Weir flow bypass

The construction of a low flow bypass of Clarendon Weir is likely to lead to large environmental benefits downstream at relatively low cost. It is likely that this option will be able to meet the minimum environmental water requirements during both the low flow and high flow periods and contribute to meeting the major fresh during the high flow period.

A relatively simple structure is required to modify Clarendon Weir to allow the passage of low flows. Additional releases from Mt Bold may be required to ensure that water is available to enable the bypass structure to be effective. This in turn may require additional (replacement) water inflows to Mt Bold Reservoir so that SA Water’s obligations to supply Adelaide’s water demand are not compromised (this is further discussed in the section on providing flows upstream of Mt Bold Reservoir).

Modifying releases from Mt Bold Reservoir

Mt Bold Reservoir regulates all flows downstream in the Onkaparinga River. The two valves at the base of Mt Bold Reservoir have sufficient capacity to provide both the low flows downstream of Clarendon Weir as well as the major fresh during the high flow period. The modification of releases would involve a change in both the timing and volume of releases to enable more water to be provided downstream of Clarendon Weir. As above, this may require additional water inflows to Mt Bold Reservoir to ensure Adelaide's water supply is not compromised.

The modification of releases from Mt Bold Reservoir will require the support of SA Water. To date SA Water has been a keen participant in all of the Board's environmental flows investigations.

Additional water to support environmental flow releases from Mt Bold Reservoir
The provision of environmental flows downstream of Clarendon Weir ultimately represents another demand on water stored in the Mt Bold Reservoir. Additional water may need to be supplied to Mt Bold Reservoir in order that it can meet this demand.

Without significant water savings through water conservation measures or a reduction on the reliance of Onkaparinga River catchment water in metropolitan Adelaide, additional water would need to be sourced from the River Murray. This is a suboptimal solution, as River Murray water is generally lower quality than water sourced from the upper Onkaparinga River catchment, being higher in turbidity and total dissolved solids. Ultimately, it also puts added pressure on the River Murray.

Nonetheless, in the face of the continued degradation of the Onkaparinga River environment downstream of the Clarendon Weir, and the likely long turn around time in reducing reliance on the Onkaparinga River for metropolitan water supply, the pumping of additional River Murray water appears to be the only practical short term solution available.

However, this should only ever be considered a short term solution. In the longer term, additional water to support environmental flows below Clarendon Weir should come from reducing (Onkaparinga River) water usage in Adelaide and changes in water management above Mt Bold Reservoir. These changes in water management require a better understanding of the impact of land use in the upper Onkaparinga River catchment on stream flows so that future land use change can be managed to assist with the achievement of environmental water requirements.

The Board has recently investigated policy and planning options that could support local planning authorities in managing land use change that could assist with the achievement of environmental water requirements. These options provide the best potential for the long term recovery of environmental flows in the Onkaparinga River. The results of this investigation are reported later in this paper.

The next step
The Board is currently in discussions with SA Water regarding an environmental flows release trial for the Onkaparinga River downstream of Clarendon Weir. The trial is divided into three stages and would extend over three years.

The trial would initially focus on delivering low flows downstream of Clarendon Weir and through the Onkaparinga River estuary. In the second year the flow regime is proposed to be extended to include minimum high flows. This flow regime would be continued into the third year of the trial. A monitoring and evaluation program would operate in parallel.

While the magnitude, frequency and duration of the required flows is known, what is actually provided during the trial still needs to be negotiated. The mechanism by which environmental flows are released downstream of Clarendon Weir also need to be determined in consultation with SA Water.

PROVIDING FLOWS UPSTREAM OF MT BOLD RESERVOIR

Land use planning

Land use is a key driver in the hydrology of the Upper Onkaparinga River catchment. Changes in land use have the potential to alter the surface water (and groundwater) hydrology of the catchment in ways that may either be to the advantage or detriment of aquatic ecosystems and river health.

In recognition of this, the Board conducted investigations in 2004 to help develop planning provisions that would assist with the delivery of environmental flows in the Onkaparinga River Catchment upstream of Mt Bold Reservoir (Sinclair Knight Merz, 2004b). The investigations relied on land use mapping data sets from 1993, 1999 and 2003, Agricultural Census data from the Australian Bureau of Statistics and farm dam data from 1987, 1995 and 1999.

Land use mapping in 2003 indicates that there are 47 different types of land use in the Onkaparinga River catchment above Mt Bold Reservoir. Since the purpose of the investigation is to consider the implications of land use change on catchment hydrology, land uses were regrouped according to their hydrologic characteristics (such as depth of rooting, growing season length, perenniality, water use characteristics, rainfall-runoff relationship, use of irrigation). The nine hydrologic groups and their occurrence in the catchment are summarised in Figure 2.

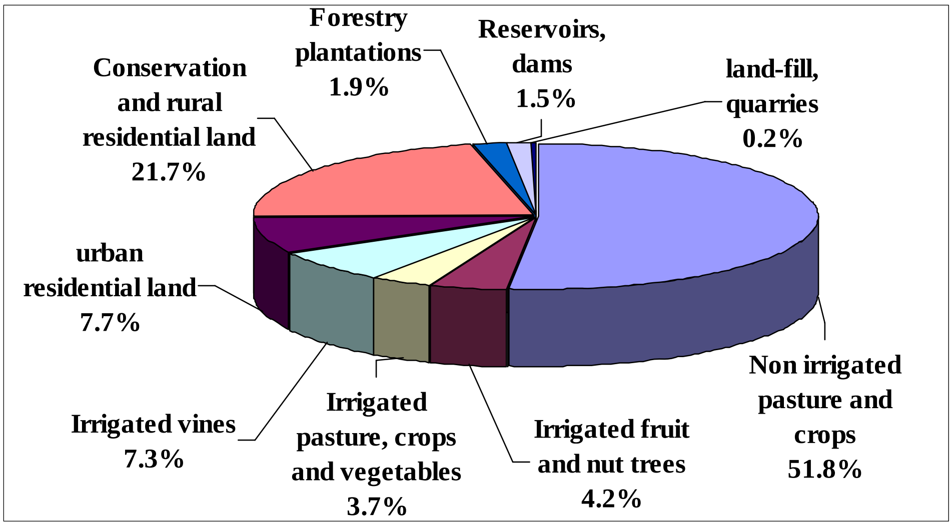

Figure 2. Major hydrological land use groups of the upper Onkaparinga River catchment.

Six land use change scenarios were developed based on the analysis of land use data sets and industry consultation as follows.

- Historical trend– sees a continuation of recent historical trends in land use change.
- Base case– based on likely status of industry and lifestyle drivers and planning constraints over the coming 10-20 years - provides the best estimate of future land use change.
- High growth – viticulture scenario – anticipates double the base case expansion in the viticulture industry.

- High growth – native vegetation scenario – proposes a more rapid expansion in native vegetation cover.
- High growth – fruit trees scenario – envisages a four times more rapid expansion in new orchard development than under current industry expectations.
- High growth – urban scenario – foresees a more rapid infilling of defined urban areas than predicted under the base case scenario.

The hydrologic impact of the various land use change scenarios was modeled using a spatially explicit annual water balance model (the changes in each subcatchment above the Mt Bold Reservoir are modelled separately). The model predicts the impact on annual average streamflow of each land use change scenario for each sub-catchment and hence the change in catchment streamflow from current conditions.

The impact of each land use change scenario is summarised in Figure 3. This figure shows the change in mean annual streamflow in 2010 and 2020 from current (2003) levels, where a negative value indicates a decrease in streamflow and the dashed line shows the natural (pre-farm dams) scenario. Annual changes can be up to 5,000ML, although this represents a change of less than 8% from the 2003 mean annual streamflow of approximately 66,000ML/yr. The predicted change in streamflow under the base case scenario (the most likely scenario) is a modest increase in streamflow from 2003 levels until the year 2010 followed by a decrease until the year 2020 (but still remaining above current streamflow).

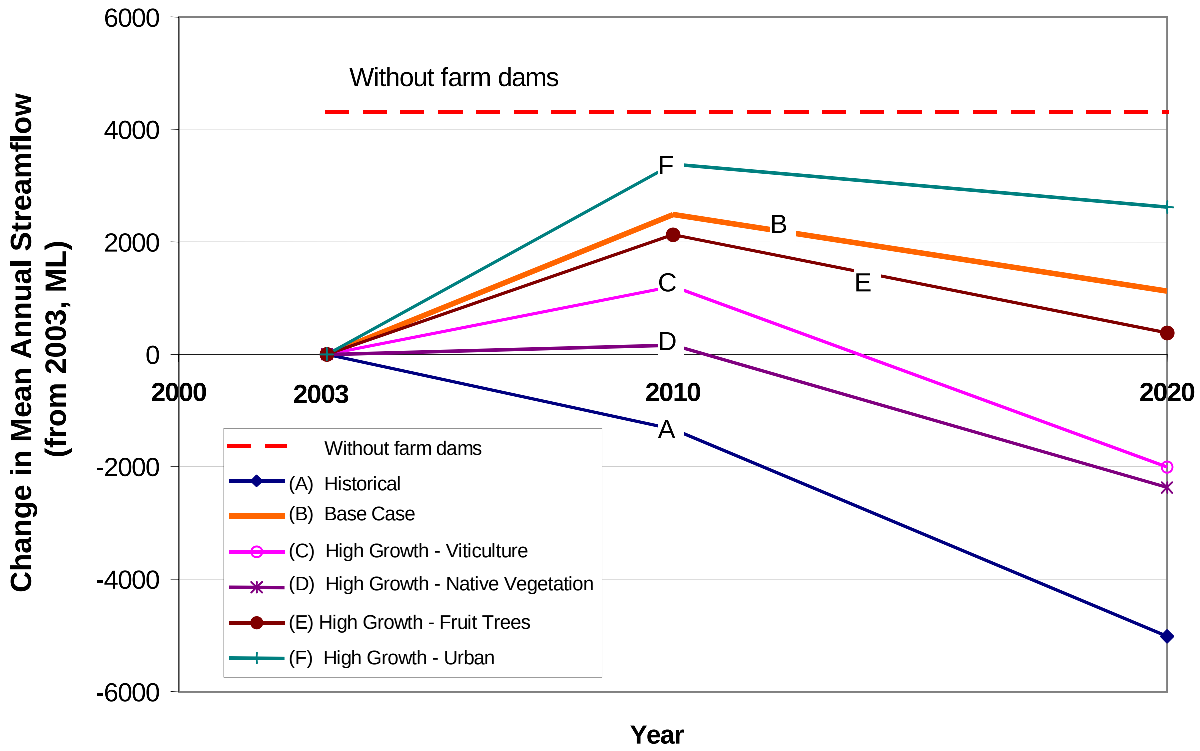

Figure 3. Change in mean annual streamflow (from 2003 levels).

The predicted impact of changes in land use on annual streamflow was used to guide development of the Board's policy response. This policy has been developed in a manner that hopefully will assist local government in making land use change decisions that favour the provision of environmental flows over the long term. This is further discussed later in this paper.

Farm dam low flow bypasses

Farm dam modelling. Modelling undertaken by Teoh (2002) and Sinclair Knight Merz (2004a) indicates that farm dam development in the Onkaparinga River catchment has significantly reduced stream flows during the low flow period. As a result, the achievement of low flow period environmental water requirements in the Onkaparinga River catchment above Mt Bold Reservoir is everywhere found to be poor. Streamflows during the high flow period remain relatively unaffected, with a good level of achievement experienced throughout the catchment.

In view of this, the Board investigated the ability of low flow bypasses on farm dams to increase low flows during low flow periods. Additionally, the investigation identified the characteristics of farm dams that have a large impact on catchment stream flow and hence those that should be targeted for installation of bypass mechanisms as a priority. These investigations were undertaken using the modelling software Tool for Estimating Dam Impacts (TEDI) (Neal, 2002) and Complete Hydrological Evaluation of the Assumptions of TEDI (CHEAT) (Sinclair Knight Merz, 2004c).

TEDI is a computer based model that was initially developed with the specific intention of modeling the hydrologic effect of catchment farm dams on downstream flows. It uses information on the dam sizes, aggregated volume, demands, climate data, low flow bypass criteria and potential future levels of dam development to determine the impact of farm dams on the seasonal stream flow.

The CHEAT model is a spatially explicit and much more complex version of TEDI. It models each individual farm dam in the catchment and the complex flow paths between dams and their interaction with the stream network. CHEAT was applied to one subcatchment in the upper Onkaparinga River catchment (Lenswood Creek), and the results used to inform the TEDI modelling undertaken in the remaining subcatchments.

CHEAT modelling results for the Lenswood Creek subcatchment. Bypass flow rates between 0.2L/sec/km^2 and 12.73L/sec/km^2 were trialled to determine an appropriate flow rate that would result in a significant reduction in the impact of farm dams on low flows.

The reduction in impact of farm dams on low flows (monthly flow exceeded 95% of the time) given varying proportions of farm dams with low flow bypasses (rated at 0.2L/sec/km^2) installed is shown in Figure 4. A 100% reduction represents pre-dam flows and a 0% reduction in impact represents the current impact due to existing farm dams.

The two curves represent the selection of farm dams either by their volume or upstream catchment area. The results for farm dams with volume thresholds of 30ML, 15ML, 10ML, 5ML and 0ML (or all farm dams) are shown, as well as the results for farm dams with upstream catchment area thresholds of 150ha, 100ha, 50ha, 20ha, 10ha and 0ha (or all farm dams).

Figure 4 shows that upstream dam catchment area has a greater influence on the impact of farm dams than dam volume. For example, by installing low flow bypass mechanisms on the 25 farm dams (about 10% of farm dams in the catchment) with upstream area greater than 50ha, there will be a reduction in the impact of farm dams on stream flow by about 60% from current levels. In comparison, by installing low flow bypasses on the 30 farm dams greater than 5ML in volume, there will only be a reduction in the impact of farm dams on stream flow by about 36% from current levels.

At the same time that low flow bypasses are predicted to significantly increase low flows, the modelling indicates that the impact on farm dam reliability (measured as the number of years that a dam does not empty) in the Lenswood Creek subcatchment is negligible (refer Figure 5). For a different subcatchment in the Board's area (Inverbrackie), this impact is only a few percent for dams up to around 50ML in size. While dams 100ML in size in the Inverbrackie subcatchment empty 1 year in 10 without low flow bypasses, this could increase to about 2 years in 10 with a bypass.

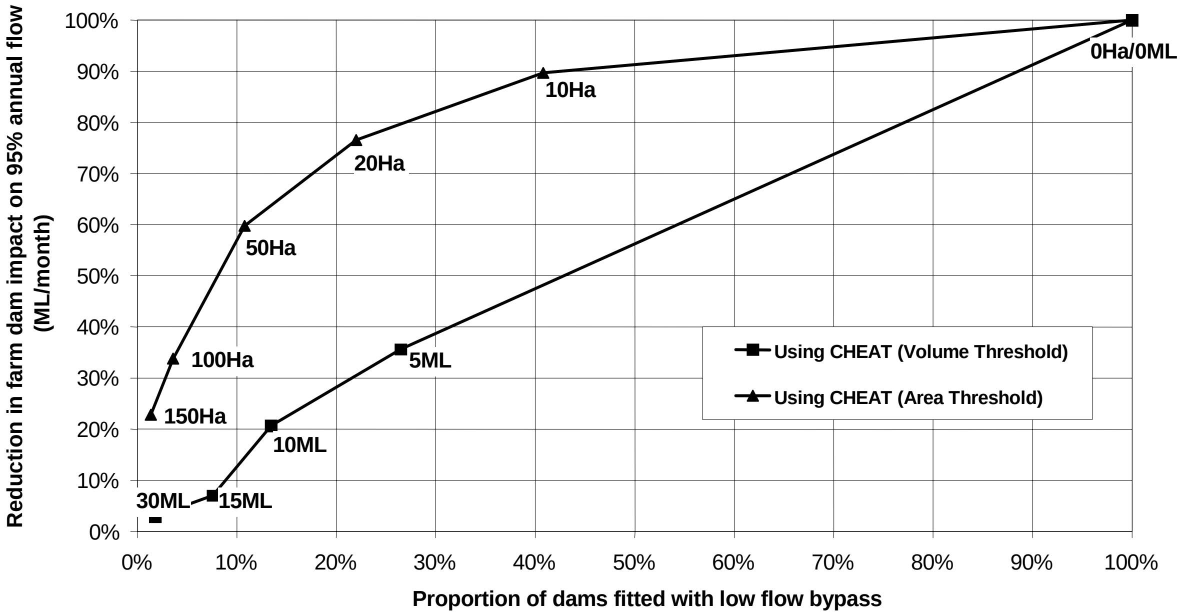

Figure 4. Reduction in impact on low flows for farm dams with low flow bypasses installed, using volume or area thresholds for selection.

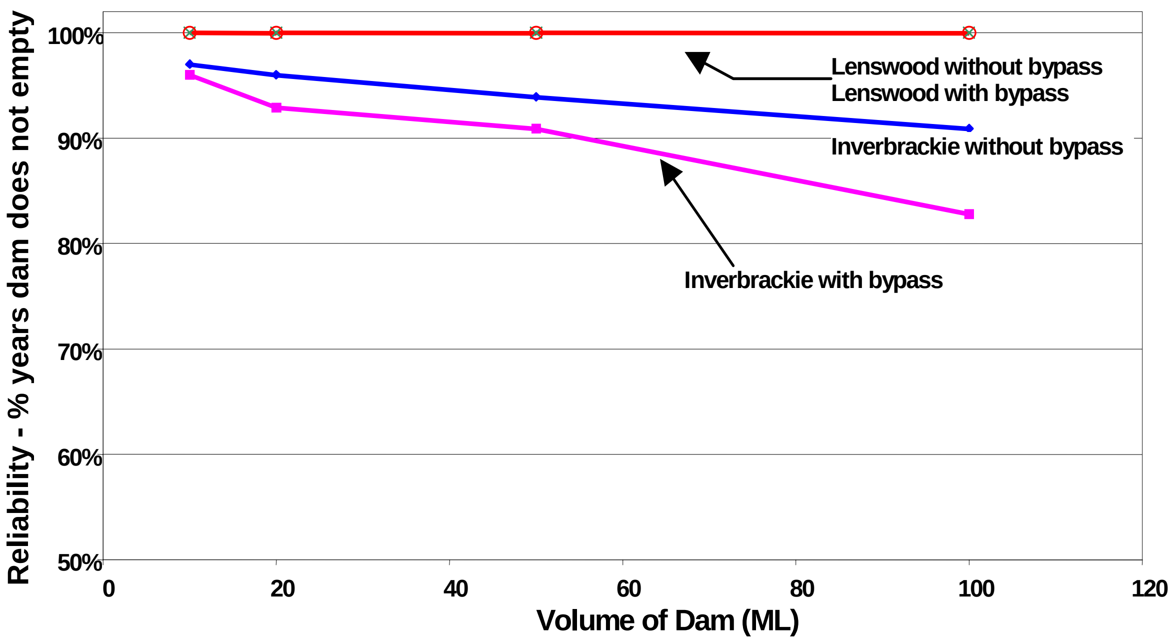

Figure 5. Effect of low flow bypasses on reliability of farm dams.

The next step
The installation of mechanisms to bypass low flows from some or all farm dams in the catchment has the potential to reduce the impact of farm dams without requiring the removal of any dams. This way farm dams can continue to supply virtually the same amount of water for agricultural purposes across the catchment, while having a significantly reduced impact on low flows. Examples of low flow bypass mechanisms include:

- **contour channel** around the edge of the dam, such that only water above the channel capacity can flow into the dam;
- **upstream weir** with pipe off-take, such that only when the capacity of the bypass pipe is exceeded, can water overtop the weir and flow into the dam; and
- **floating arm pipe** that discharges through the dam wall, such that whenever the dam level is rising, flow can be bypassed through the pipe.

The typical cost of installing low flow bypass mechanisms is between $5,000 and $15,000, depending on the size and type of mechanism selected. This equates to about 10-20% of the cost of constructing a new farm dam.

Armed with the information it now has from its investigations, the Board is considering how it can provide incentives to motivate farm dam owners to retrofit low flow bypass mechanisms. As a priority, the Board will consider incentives for landholders with high priority farm dams (identified from the outcomes of its CHEAT and TEDI modelling) located in high priority areas (identified from the outcomes of its environmental water requirements investigations). The Board is striving to be in a position to provide incentives for farm dam owners in early 2005.

From a planning and policy perspective, the outcomes of the land use planning study will provide benefits at both a broad level and more practical level. At the broad level the outcomes of the study will enable the Board to:

1. provide both input and direction into the Inner Region Planning Strategy currently being prepared by the State Government. The Inner Region Strategy is one of three volumes of the Planning Strategy for South Australia, which present the State Government's policy direction for the physical development of the state. The Inner Region Planning Strategy provides this broad framework by guiding land-use through Local Government Development Plans.
2. identify changes necessary to the Board's Catchment Water Management Plan or assist in providing advice and direction to the soon to be established Natural Resource Management Boards which will replace Catchment Water Management Boards in 2005. The possible amendments relate particularly to Water Affecting Activities identified under the Water Resources Act.

At the more practical level the results of the investigations undertaken during the study will enable the Board to make recommendations to local councils in the region to amend their Development Plans to include policies to achieve environmental flows. The Board can achieve this outcome in two ways by either:

1. working with local councils to prepare Plan Amendment Reports that will introduce policy relating to environmental flows; or
2. through the Section 30 Plan Review process, which enables the Board to make submissions to Council when it undertakes a review of its Development Plan as required under Section 30 of the Development Act.

The delivery of environmental flows in the long term is likely to be more successful where the Board works with the local councils to achieve changes to land-use policy. To this end, being able to influence councils in their development planning process is an important part of the Board's environmental flows program.

CONCLUSIONS

The health of the Onkaparinga River and estuary has decreased markedly as a result of whole of landscape changes in land use, the impoundment of water in farm dams and reservoirs, and flow diversion for irrigation and urban supply. In spite of this, the river still contains ecological values that are key to river health recovery. The main driver in this recovery is the restoration of a flow regime that supports vital ecological and riverine processes.

The Onkaparinga Catchment Water Management Board believes that it has developed a regime of environmental flows that if provided, would markedly improve river and estuary health. Recent work completed by the Board indicates that river health recovery need not come at the expense of sustainable rural economic development or threaten farm water availability. However, some adjustment to the way we manage on farm and urban source water is essential.

Barriers to the restoration of environmental flows in the Onkaparinga River are not technical, or the result of a lack of understanding about how to proceed. There are, however, challenging economic and social barriers to overcome in order that sufficient flows can be returned to the Onkaparinga River in a manner that would produce meaningful ecological improvements.

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