# THE BARRAGES RELEASE OF SPRING 2003

## September 2005

**A report prepared by the**

**Murray-Darling Basin Commission, Department of Water, Land and Biodiversity Conservation and the South Australian Water Corporation**

The Living Murray
One River. One Life. Our Future.

MURRAY-DARLING BASIN COMMISSION

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# 1 PURPOSE AND OBJECTIVES OF REPORT

The purpose of this report is to review the operation of the 2003 Barrages release, determine actions to improve the management of future releases and to build on opportunities for enhanced environmental outcomes.

Specifically, the objectives of the report are to:

- Document the antecedent flow and salinity conditions across the River Murray System prior to the release, including those that created this opportunity;
- Describe the objectives of the release and the process through which they were developed;
- Describe the operation of the barrages during the release, including the design of the pattern of barrage gate openings;
- Report on the hydrological and salinity responses to the release; and
- Recommend future improvements to the operation of the barrages to achieve ecological and water conservation objectives.

Included within these topics is the process through which operational decisions were made.

Monitoring of the ecological responses to the Barrages release is presented in a separate report from Mike Geddes, South Australian Research and Development Institute and the University of Adelaide. The implications of this work are considered in **Section 5 – Lessons and Recommendations**.

# 2 BACKGROUND

## 2.1 Site location and significance

The Murray Mouth, Coorong and Lower Lakes are at the junction between the River Murray and the Southern Ocean (Figure 1.1). The Coorong is a long, shallow saline to hypersaline lagoon, 140 km in length, separated from the Southern Ocean by a narrow sand dune peninsula (the Younghusband Peninsula).

**Figure 1.1.** The Murray Mouth, Coorong and Lower Lakes. The Coorong is comprised of the North Lagoon and South Lagoon shown on the figure. Note the five Barrages between the lower lakes and Coorong.


The Murray Mouth, Coorong and Lower Lakes area is of local and national importance and its classification as a Ramsar wetland, indicates it is of international significance. It has been ranked as one of the six best waterbird sites in Australia.

The wetlands surrounding the Murray Mouth are particularly important for bird breeding events and, in the summer season, have been known to support up to 122 000 summer waders compared to a national total of 403 000[1]. The site is also an important habitat for a diversity of water bird species, including egrets, pelicans, ibises, cormorants and herons.

The total area of the site, which includes the lakes and associated wetlands, is 140,500 ha.

## 2.2 River management influencing the hydrology of the Murray Mouth, Coorong and Lower Lakes

Regulation and diversions of the river system by headwater storages and diversion structures have reduced the volume of flow delivered to this site. For example, the median annual flow to the sea from the Murray Mouth is now 27% of the natural outflow[2] and flows through the Murray Mouth now cease on average once every two years, while before regulation this was experienced once every twenty years[3]. A consequence of reduced river flows is an increased risk of Mouth closure.

The Barrages have created an abrupt fresh-saline interface where once this site would have offered a range of fresh, brackish, saline and hypersaline systems. The estuary can change abruptly from saline to fresh conditions and back again in an unseasonal and unnatural pattern[3].

Operation of the Barrages has also significantly changed the hydrological regime of the Lower Lakes. Lake levels are currently managed to maintain a relatively stable full supply level (0.75 m relative to the Australian Height Datum) where possible, removing much of the natural variability.

The Barrages also act as a barrier to the movement of aquatic animals, especially diadromous fish species (reliant on both freshwater and marine environments).

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[1] ANCA 1996. *A Directory of Important Wetlands in Australia.* Second Edition. Australian Nature Conservation Agency, Canberra.

[2] Murray-Darling Basin Ministerial Council (2002). The Living Murray: *A discussion paper on restoring the health of the River Murray.* Murray-Darling Basin Commission, Canberra.

[3] Jensen, A., Good, M., Harvey, P., Tucker, P. and Long, M. 2000. *River Murray Barrages Environmental Flows*. Report to Murray-Darling Basin Commission, Canberra, ACT. Wetlands Management Program, Department of Environment and Natural Resources, Adelaide, South Australia.

For more information on the hydrology of this site and the influence of river regulation see Appendix A.

## 2.3 Decline in the ecological condition of the Murray Mouth, Coorong and Lower Lakes

The evidence of the decline of the environmental condition of the Murray Mouth, Coorong and Lower Lakes is strong.

Persistent low flows and their effects on promoting sediment build-up at the Mouth are not new. Since regulation and diversions, low flows have increased in frequency and duration[4]. The Murray Mouth itself closed in 1981, the only occasion since non-indigenous settlement, and only due to dredging the Mouth was kept open in 2003-4.

The period of low flow leading up to the Barrages release in 2003 saw the salinity level across the Coorong reach Electrical Conductivities (EC) of 141 mS/cm. A conclusion of the report prepared by Geddes (2005)[5] was that in June/July 2003, the biodiversity of the Coorong was at an historical low point.

There is also evidence of a decline in wader populations, plant communities and native fish populations, which are described in a range of reports regarding this site. Reference to this information is presented in the "Foundation Report on the significant ecological assets targeted in the First Step Decision[6]" for The Living Murray.

According to hydrological indicators developed under the original pilot Sustainable Rivers Audit framework[7], this river zone is under the greatest hydrological stress of any in the River Murray System.

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[4] Walker, D.J. (2002). *The behaviour and future of the River Murray Mouth, Centre for Applied Modelling in Water Engineering*, Department of Civil and Environmental Engineering, Adelaide University.

[5] Geddes, M.C. (2005). *Ecological outcomes for the Murray Mouth and Coorong from the managed barrage release of September-October 2003.* Report prepared for the Department of Water, Land and Biodiversity Conservation. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Aquatic Sciences Publication No. RD03/0199-2.

[6] Murray Darling Basin Commission (2005). *The Living Murray Foundation Report on the significant ecological assets targeted in the First Step Decision.* Murray Darling Basin Commission, Canberra.

[7] Norris, R.H., Liston, P., Davies, N., Coysh, J., Dyer, F., Linke, S., Prosser, I. and Young, B. (2001). *Snapshot of the Murray-Darling Basin River Condition.* A report to the Murray-Darling Basin Commission, Canberra.

The salinity regime of the Lower Lakes has perhaps faired best of all the habitats for this site, with the predominance of freshwater thought to reflect the natural character of the lakes.

## 2.4 Historical closure of the barrages

Barrage closure is not uncommon and occurs during periods of low flow. However, periods of continuous closure exceeding 150 days have only occurred on eight occasions since 1981 when this data began being recorded (Table 2.1). This compares with 630 days (approximately 21 months) of barrage closure prior to the release in September 2003– more than double the previous longest period of closure and the longest for which there is data.

**Table 2.1.** The ten longest periods of recorded barrage gate closure since 1981.

| Rank of event | Days Barrages remained closed | Date Barrages closed | Date Barrages opened |
|---|---|---|---|
| 1 | 630 | 15/15/2001 | 6/9/2003 |
| 2 | 363 | 09/07/1982 | 7/07/1983 |
| 3 | 300 | 19/08/1994 | 14/06/1995 |
| 4 | 253 | 21/11/1997 | 29/07/1998 |
| 5 | 230 | 12/12/1985 | 29/07/1986 |
| 6 | 216 | 14/10/1987 | 17/05/1988 |
| 7 | 204 | 04/12/1981 | 26/06/1982 |
| 8 | 160 | 08/01/1987 | 16/06/1987 |
| 9 | 150 | 23/11/1995 | 21/04/1996 |
| 10 | 149 | 03/12/1999 | 1/05/2000 |

## 2.5 Dredging of the Murray Mouth

Dredging of the Murray Mouth commenced in October 2002 and has continued until present. The dredging program was established to maintain connection between the Coorong, Mouth channels and the ocean. The tidal exchange resulting from the dredging is intended to keep the Coorong ecosystem in a state where recovery is possible when freshwater outflows of sufficient quantity become available. If dredging had not occurred, the Mouth would most certainly have closed (earlier in April 2004) leading a rapid decline of Coorong ecological health.

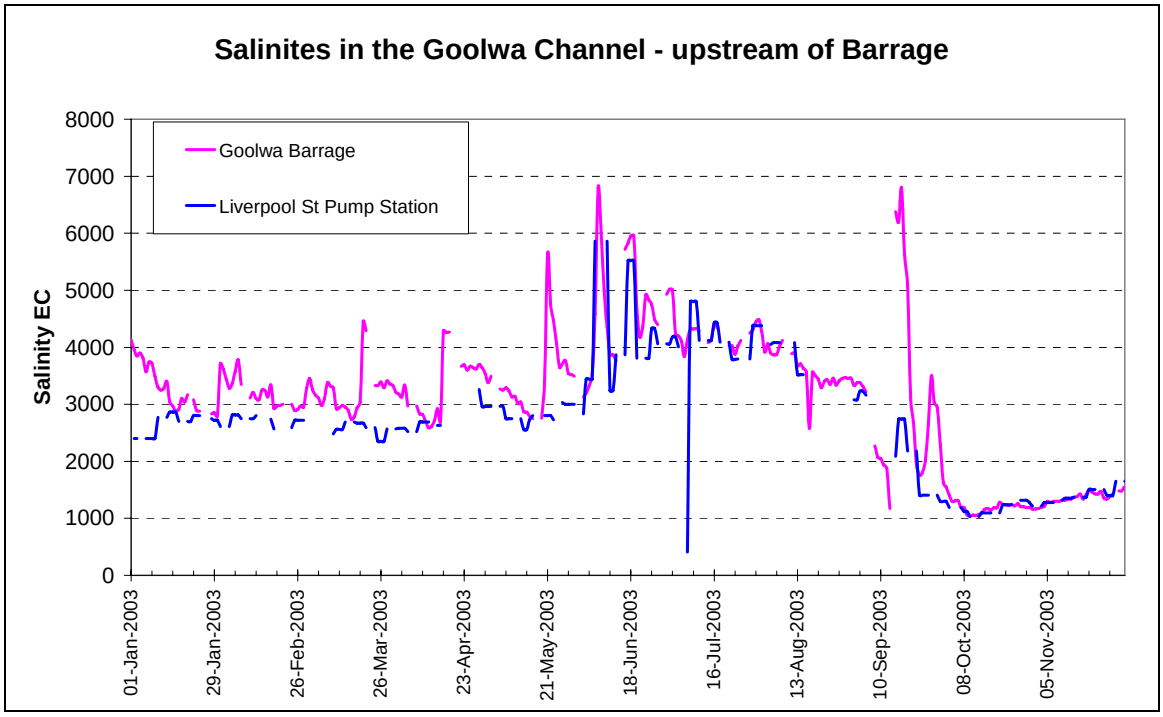
It is expected that dredging will continue until barrage releases are of sufficient quantity to enlarge and stabilize channels at the Mouth.

## 2.6 Antecedent salinity conditions

Salinity in the Goolwa channel upstream of the Barrage had increased during the period that the Barrages were closed and this was locally impacting on private water supply in the town of Goolwa and the Goolwa Barrage depot.

Figure 2.1 shows the salinity over time, including the marked reduction in salinity that occurred during the period of the Barrage opening (6 September – 18 October).

**Figure 2.1.** Salinity plot for sites in the Goolwa channel upstream of the barrage.




The very high salinity spikes during the release period and other periods were due to backflow over the barrage associated with very high downstream water levels from tidal fluctuations causing sea water to enter the lake.

## 2.7 Decision making forum

The Barrages are works under the Murray-Darling Basin Agreement and are operated and maintained by SA Water under the direction of River Murray Water. Instructions for normal operational control are not issued daily by River Murray Water. However,

instructions to implement operational decisions for the Barrages may be issued at special times.

Over the past number of years, as flow through the barrages reduced and the Mouth became constricted through sand build-up, the Murray Mouth Advisory Committee (MMAC) played a lead role in the development of flow release strategies through the barrages. These release strategies were developed to move as much sand as possible to maintain the opening of the channel and sea and to flush accumulated salt from the freshwater lakes.

During the 2003 release, operational decisions for the Barrages release were made by a group of natural resource mangers and river operators from:

- Department of Water, Land and Biodiversity Conservation (DWLBC);
- South Australian Water Corporation (SA Water);
- River Murray Water (RMW), Murray-Darling Basin Commission (MDBC); &
- River Murray Environmental Management Unit (RMEM), MDBC.

For the purpose of this document, this group will be referred to as the Barrages Release Management Group (BRMG). The Chair of the MMAC provided input to ensure that lessons learnt in previous barrage releases were included in the 2003 release. It was noted during the event that outcomes of the BRMG should be documented more formally. This task would be the duty of the Chair of the BRMG, or equivalent group, in future events (see Section 5.7 – Decision process and structure).

### 2.8 Environmental management arrangements

In March 2001, the Murray-Darling Basin Ministerial Council approved the establishment and funding of the function of River Murray Environmental Manager (RMEM) in the Commission Office.

The Barrage release of September 2003 provided an opportunity to develop and test the organisational arrangements required to operate the River Murray to achieve specific environmental outcomes with a new environmental delivery team in place. In the past, such activities had been managed on behalf of Murray-Darling Basin Commission by River Murray Water and its predecessors with policy input from DWLBC and its predecessors.

Whilst there had been a number of earlier instances of modifying river operations to achieve environmental outcomes[8], the release at the Barrages in September 2003 was the first time such an approach had been attempted at this particular ecological asset.

### 2.9 The report

The remainder of the report is divided into three sections:

1. The objective setting process;
2. A diary of the event, describing flow patterns, the process for designing releases and overall salinity responses; and

A discussion of some of the major issues arising from the intervention and recommendations for actions when a similar opportunity arises again in the future.

[8] Gippel, C.G., McLeod, A.J., Jacobs, T.A., and Harper, B.W. (2001). *Environmental Flows for the River Murray, Australia.* Presentation at Environmental Flows for River Systems Conference & Fourth Ecohydraulics Symposium, Cape Town, South Africa.

# 3 SETTING THE OBJECTIVES

## 3.1 Ecological objectives for the Murray Mouth, Coorong and Lower Lakes

### 3.1.1 General ecological objectives

A variety of objectives have been developed for different initiatives designed to guide the management of the Murray Mouth, Coorong and Lower Lakes region. These are presented in management plans such as the Ramsar Plan for the site and the Asset Environmental Management Plan for this site. Ecological objectives and expected outcomes were also agreed by the Murray-Darling Basin Ministerial Council in November 2003 for the Living Murray initiative 'First Step decision' (Table 3.1).

**Table 3.1.** Ecological objectives and expected outcomes for the Murray Mouth, Coorong and Lower Lakes under The Living Murray initiative First Step decision.

| Description of Significant Ecological Asset | Interim ecological objectives, and expected outcomes |
|---|---|
| The Murray Mouth, Coorong and Lower Lakes, covering an area of about 140,000 hectares, are nationally significant wetlands also recognised as being of international importance under the Ramsar Convention.<br><br>It is one of the ten major areas for large concentrations of waders in Australia, and one of the few south of the Tropic of Capricorn.<br><br>Thirty-three of the bird species present in the area are listed under international treaties.<br><br>With some 78 species of marine and freshwater fish inhabiting the area, it is an important nursery and feeding area for key commercial and non-commercial fish species.<br><br>The Coorong, which is 140 km in length, has been ranked within the top six waterbird sites in Australia based on the diversity and abundance of species found there.<br><br>The area represents significant intrinsic value for the broader community and has strong spiritual and cultural meaning for Indigenous peoples. | A healthier lower lakes and Coorong estuarine environment.<br><br>• Open Murray Mouth.<br>• More frequent estuarine fish spawning.<br>• Enhanced migratory wader bird habitat in the Lower Lakes. |

Objectives such as those developed for The Living Murray process are high level and require further work to provide specific objectives to guide management actions such as the Barrages release. One of the initial tasks of the BRMG was to consider the potential ecological objectives of the intervention, given the predicted available flows at this site and the conditions existing immediately prior to the event.

The major environmental opportunities in designing the release were to promote the spawning of estuarine fish and an open Murray Mouth, and address the elevated salinity levels in the Coorong.

#### 3.1.2 Estuarine fish spawning

An objective of The Living Murray initiative First Step decision (see Appendix A) is to create more frequent estuarine fish spawning events. Much of the knowledge on the spawning requirements of estuarine fish in the Coorong has been documented in the Regional Evaluation Group (REG) H report to the Murray-Darling Basin Commission as part of The Living Murray initiative. This is partly summarised in Appendix B.

### 3.2 Standard operational objectives for the Murray Mouth, Coorong and Lower Lakes

#### 3.2.1 Salinity

The decision to pass some of the available flow through the Goolwa barrage was influenced by rising salinity in the Goolwa channel, which is used by local pumpers for domestic supplies. The decision was also influenced by the possibility of increased salinity in other parts of the lake from seawater intrusion. The release of water through the Goolwa barrage is part of normal operating procedures for mitigating the salinity level in the Lower Lakes.

#### 3.2.2 Water conservation

Given the water resource conditions across the River Murray system at the time of the release, it was necessary to consider standard water conservation objectives. This required the lakes to be surcharged at the end of the event to 0.85 m AHD to compensate for evaporation and irrigation consumption during spring and summer.

REG H developed preference curves that related spawning of estuarine fish to:

- salinity levels (reported as tolerances for spawning/fingerlings and adult fish);
- rate of change in salinity;
- spawning flow timing (month of the year) (Figure 3.1a);
- flow duration (Figure 3.1b);
- rate of fall in water levels;
- flow magnitude (Figure 3.1c); and
- drop in flow over the barrages.

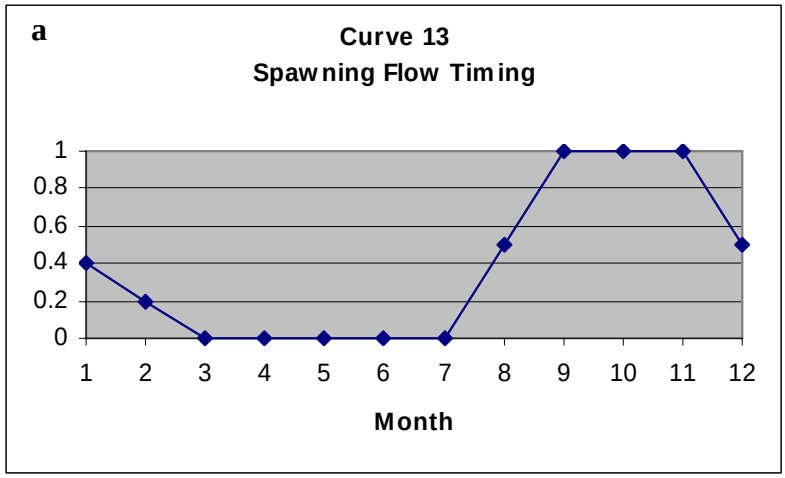
Given that the higher flow was expected to arrive in September it was noted that seasonal cues should be optimal for spawning (Figure 3.1 a). The BRMG discussed the desirable release pattern based on the preference curves linking spawning to flow magnitude and duration (Figure 3.1 b,c).

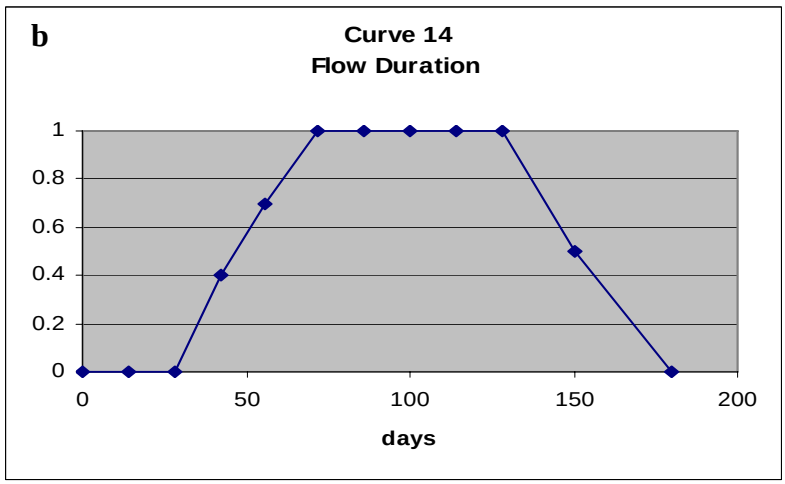
The REG H report does not specify which species of estuarine fish may respond to these flows, and hence it is taken as a general indication, but is expected to include species such as black bream.

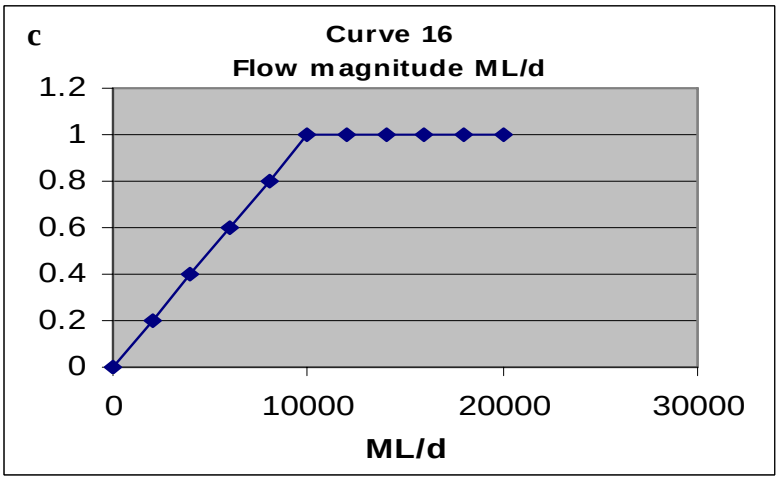
The decision of the BRMG was to aim for a release pattern primarily in order to encourage spawning of estuarine fish. The flow was to be increased at 1000 ML/day increments to a peak of 6,000 ML/day, maintained at this level for approximately 2 weeks, and then decreased by 300 ML/day. The hydrograph initially proposed is described further in Section 4 – Diary of the Release.

Although the ecological objectives for the barrages release remained unchanged during the event, changes in conditions at this site during the operation resulted in an actual flow pattern that was different to the planned flow pattern. The actual flow pattern and the process through which it was developed are detailed in Section 4 – Diary of the Release.

**Figure 3.1.** Preference curves from the Regional Evaluation Group H report (Wellington to the sea) for The Living Murray initiative describing conditions for spawning in relating to a) flow timing, b) flow duration, and c) flow magnitude. The y-axis is a dimensionless index of the suitability of conditions for a species or group of species ranging from 0 to 1, with 1 representing ideal conditions.



### 3.2.3 Murray Mouth

Although releases from the barrages were designed principally for ecological objectives, consideration was also given to the potential impact of releases on the position and openness of the Murray Mouth. Balancing flows between Goolwa and Coorong Channels also helps prevent the Mouth from moving. This is important when so much investment has been incurred to create two stable dredged channels to the Mouth.

This was addressed by aiming to split the total discharge from the barrages approximately equally between Goolwa and Tauwitchere Barrages.

Bathymetric surveys before and after the event were undertaken to inform the effect of the water release on sand removal (natural and dredging) as well as sand ingress during the event.

### 3.2.4 Elevated salinity levels in the Coorong

With prolonged low flow, siltation of the estuary and a poor exchange of water between the Murray Mouth and Coorong, the salinity of the Coorong may rise beyond the tolerance levels of many species of flora and fauna. For example, most of the invertebrate fauna in the Coorong can only tolerate salinity levels of up to 85.8 mS/cm (approx 1.5 times seawater). At higher salinity levels (for prolonged periods), the estuarine invertebrate fauna is replaced by salt lake species. This impacts upon the available food source for fauna such as wading birds and fish.

The strong salinity gradient in the Coorong also affects the distribution of fish species, each of which has different salinity tolerances. The constriction of the Mouth and channels are causing increased salinity levels across the lagoons resulting in a decline in many fish species.

The release of fresh water over the barrages is important to reduce the high salinity levels in the Coorong and thus freshen the lagoons. A study into the ecological health of the Coorong prior to the barrage release indicated that salinity levels were much higher than what would normally be found.

# 4 DIARY OF THE RELEASE

The following sections outline how the release developed over time and the management issues that arose.

## 4.1 Upper catchment flows

In late July 2003, there was heavy rainfall on the Kiewa and Ovens river catchments which resulted in high flows in the River Murray.

As the flows passed down the system it became apparent that the flows would exceed the capacity of the inlet channel to Lake Victoria and hence there would be surplus flow to South Australia (i.e., flows greater than the South Australian entitlement rate).

At this stage the level in Lake Alexandrina had risen from the near record lows (0.35m AHD) during the previous summer to 0.67 m AHD at the start of August 2003. Much of this improvement in lake levels was due to high winter rains on and surrounding the lakes.

In August 2003 there was further heavy rainfall that resulted in a second peak flow traveling down the River Murray. At this stage the Lower Lakes had risen to 0.8 m AHD. Much of the rise was due to further periods of heavy local rainfall, both on the Lakes and surrounding local catchments. With the additional flow in the Murray it became apparent that the Lakes would fill and that a release through the barrages would be necessary.

## 4.2 29 August 2003

At this stage the first forecast of flow to South Australia (SA) was made using BigMod, which is a computer based flow management model operated by the MDBC (NB. the RMW operations sheets were also used for forecasting to varying degrees throughout the event). A peak flow was forecast to SA of just under 12 000 ML/day.

The instruction was given to open the Barrages to provide a flow of 6 000 ML/d (3 September 2004). The opening occurred progressively over the next three days, increasing at 2 000 ML/day each day.

### 4.2.1 Development of the operating model

In considering the proposed operations it was noted that RMW did not have an operating model for the River Murray downstream of the SA border. A basic spreadsheet model of the Lower Lakes was set up by RMW. The model took flow at the SA border and ‘lagged’

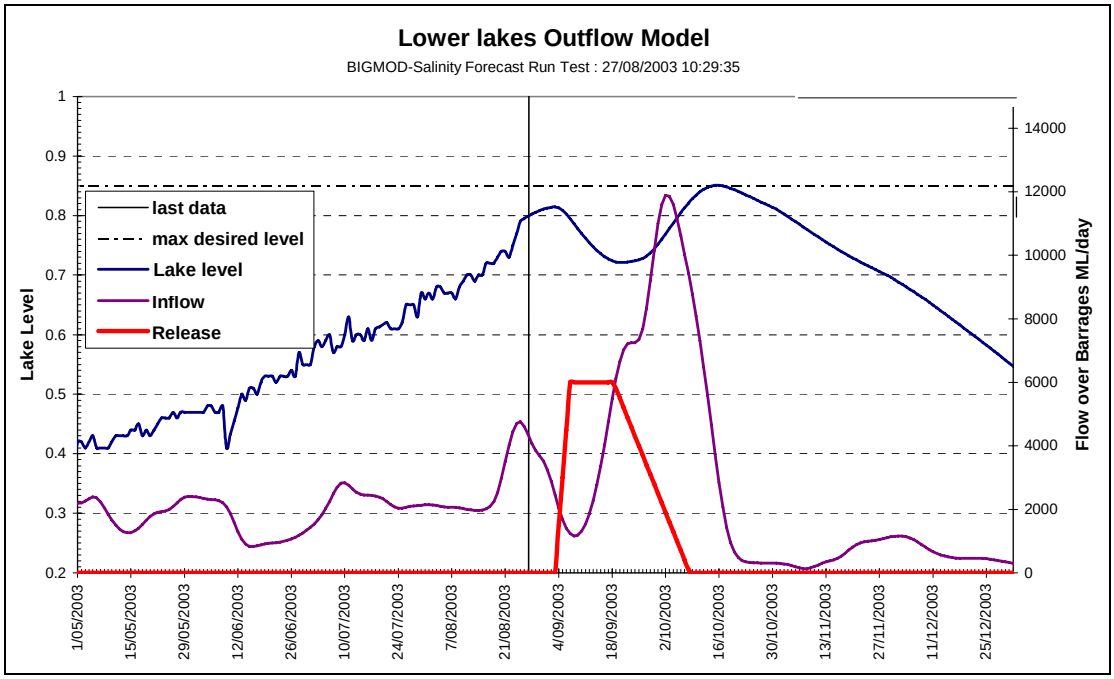
it to the Lower Lakes, with a proportional loss for consumption, evaporation and other losses.

The Lower Lakes model is a simple water balance 'bucket' model that has the capacity and surface area relationship for the Lakes as a basis. Evaporation was included and accounted for by use of the mean monthly evaporation data and a pan coefficient. Releases from the barrages is indicated as a flow rate in Figure 4.1.

### 4.2.2 Planned release

Using BigMod, a target release strategy was developed. The aim was to achieve an extended period of outflow (as shown in Figure 4.1) at a rate that would encourage fish spawning, based on the predictions of the REG H studies (see also **Section 3 – Setting the Objectives**). Given that SA was receiving less than entitlement flows at this time (end August), and for normal water conservation reasons, the operating plan required the Lower Lakes to be fully surcharged (0.85m) at the end of the release.

**Figure 4.1.** First estimate of planned outflow from the Lower Lakes 29 August 2003




## 4.3 September 2003

Based on peak inflows in the upper Murray, an improved forecast of flow to SA was made using BigMod. The forecast peak flow to SA was just under 17 000 ML/day (not shown in Figure 4.2). The predicted inflow to the Lakes was 11 000 ML/day. The reduction

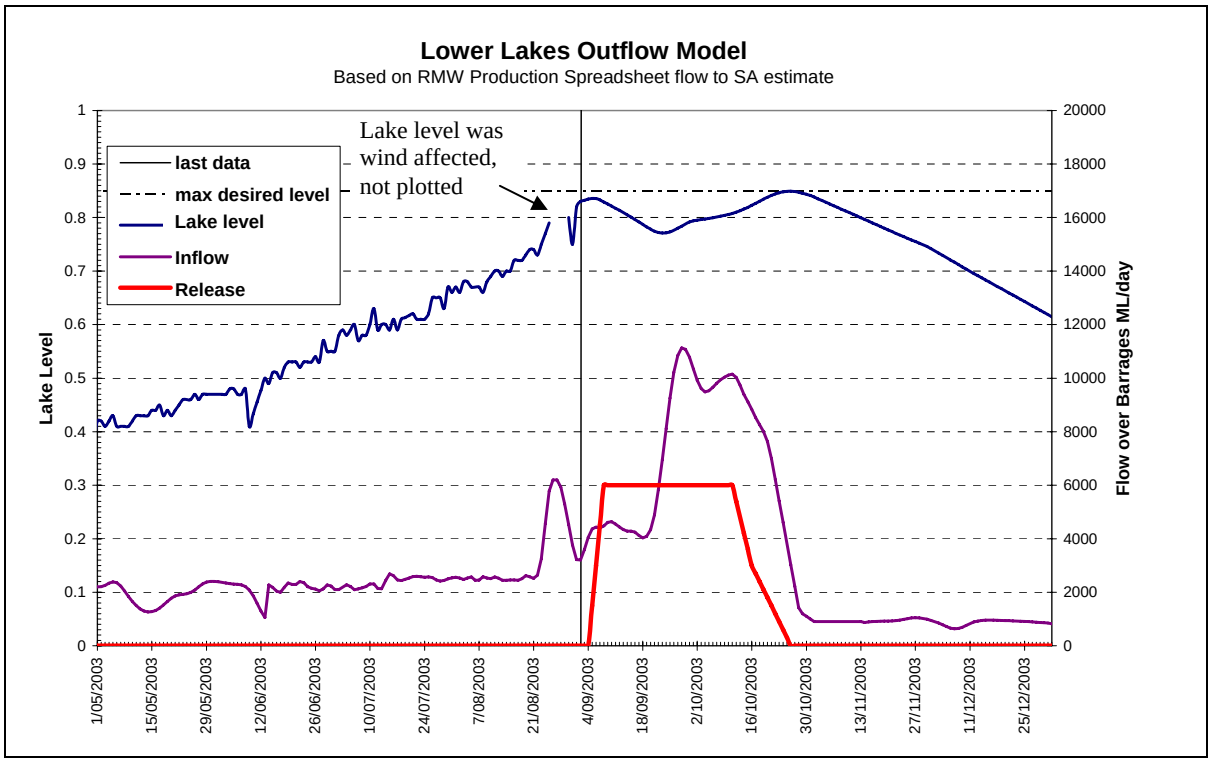
compared to that predicted at the SA border was due to allowances for transmission losses and attenuation.

Using the revised inflows, the planned release pattern was modified to a two stage closedown with a longer duration of flows at 6 000 ML/day. The intention was to provide a more gradual rate of change of salinity in the estuary. It was noted at this stage of the event by the BRMG that estimates of the release rate were likely to be inaccurate and that flow gauging at the Barrages was required.

### 4.3.1 Barrage opening

On 3 September 2003 the decision was taken to commence opening the barrages. The flow was split equally between Goolwa and Tauwitchere to flush the high salinity water from the Goolwa channel, reduce the salinity and establish estuarine conditions as well as maintain the stability of the Mouth. The intention was that these conditions would be conducive to spawning of estuarine fish.

**Figure 4.2.** Estimate of planned outflow from the Lower Lakes 3 September 2003.



## 4.4 September 2003

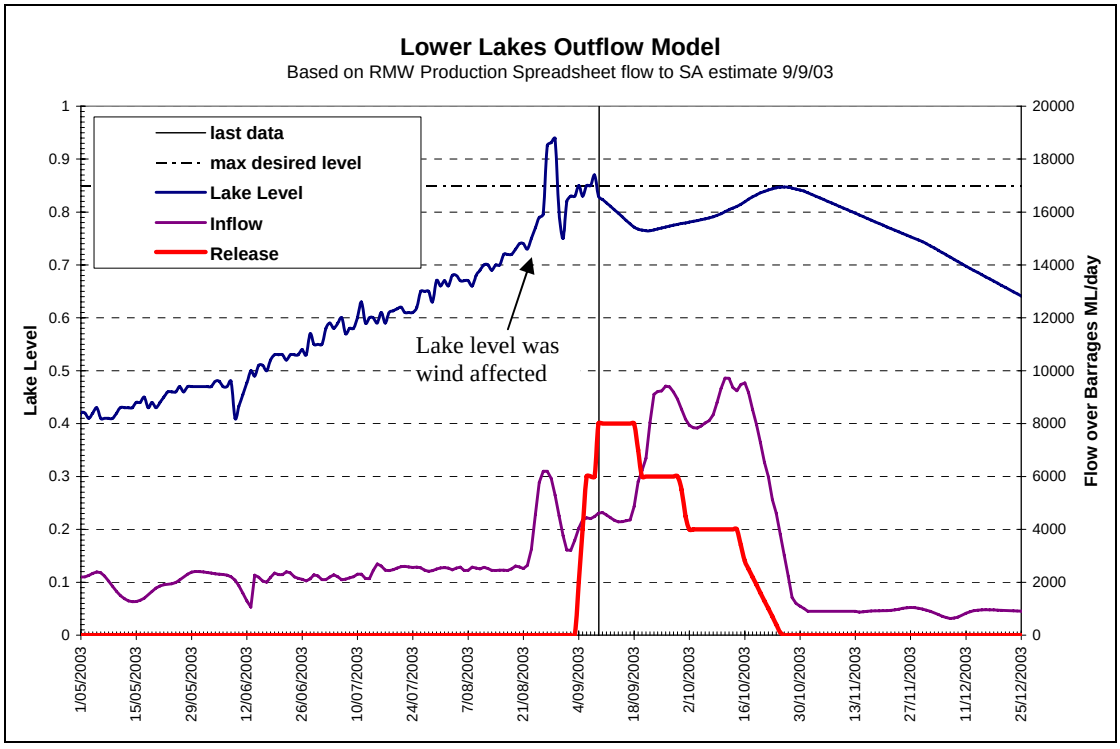
Inflows to the Lower Lakes continued to be in excess of release and the Lake level rose above the desired maximum of 0.85 m. This caused flow over the low-lying islands in between the barrages and the decision was made to increase the release to an estimated 8 000 ML/day, retaining the equal split between Goolwa and Tauwitchere.

NB. It was difficult to determine the flow through the Barrages at this time. Historically the barrages had been operated simply to achieve a lake level and there had been no requirement for the precise water balances and releases needed for this managed release. Release from the Barrages will continue to be difficult due to high sea levels influencing the rate of outflow.

### 4.4.1 Inflow forecasts

At this stage the inflow forecasts from BigMod were causing concern as they appeared to be overestimating the peak flow to SA and hence to the Lakes. Forecasts from this time onwards were based on the RMW operations spreadsheets. The peak forecast inflow to the Lakes dropped from about 11 000 ML/day to under 10 000 ML/day. The release plan was revised as per Figure 4.3.

**Figure 4.3.** Estimate of planned outflow from the Lower Lakes 8 September 2003.



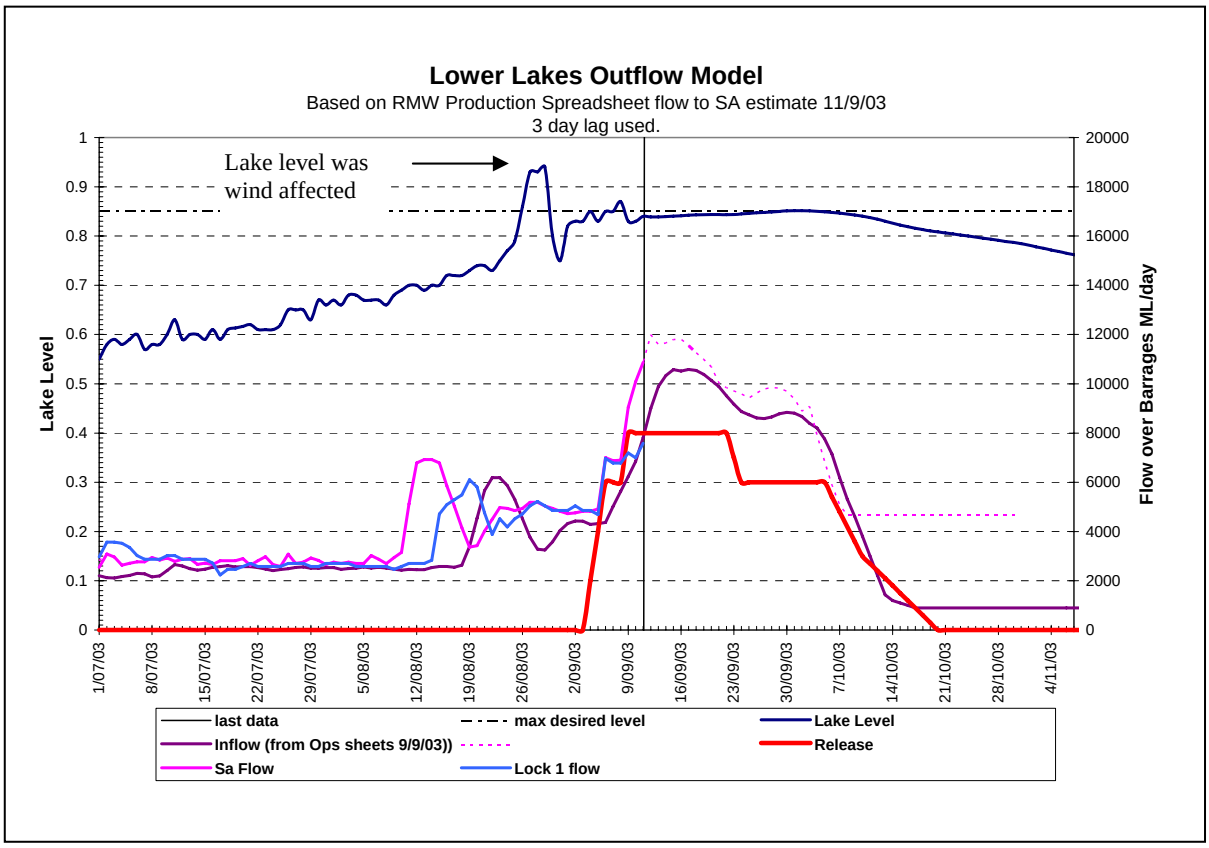
### 4.5 11 September 2003

At this stage, the first peak was not losing as much water as initially estimated however record losses were being observed across the River Murray system and this was showing in the inflow forecasts with the second peak less than forecasted in volume and peak (Figure 4.4).

The difficulty in accurately predicting the travel of the flood wave down the Murray was clearly evident at this stage. (NB. the requirement of instantaneously reflecting an increase in flow at Lock 10 at all locks downstream to, and including, Lock 1 had not been included in early planning). BigMod was overestimating the peak and was considered by the operators as too unreliable to use for this purpose. Similarly, the operational spreadsheets lacked predictive capacity, presumably on account of the travel times for flows differing from the fixed 'regulated flow scenario' values that are built into the existing sheets.

**Figure 4.4.** Estimate of planned outflow from the Lower Lakes 11 September 2003

#### 4.5.1 Barrage openings



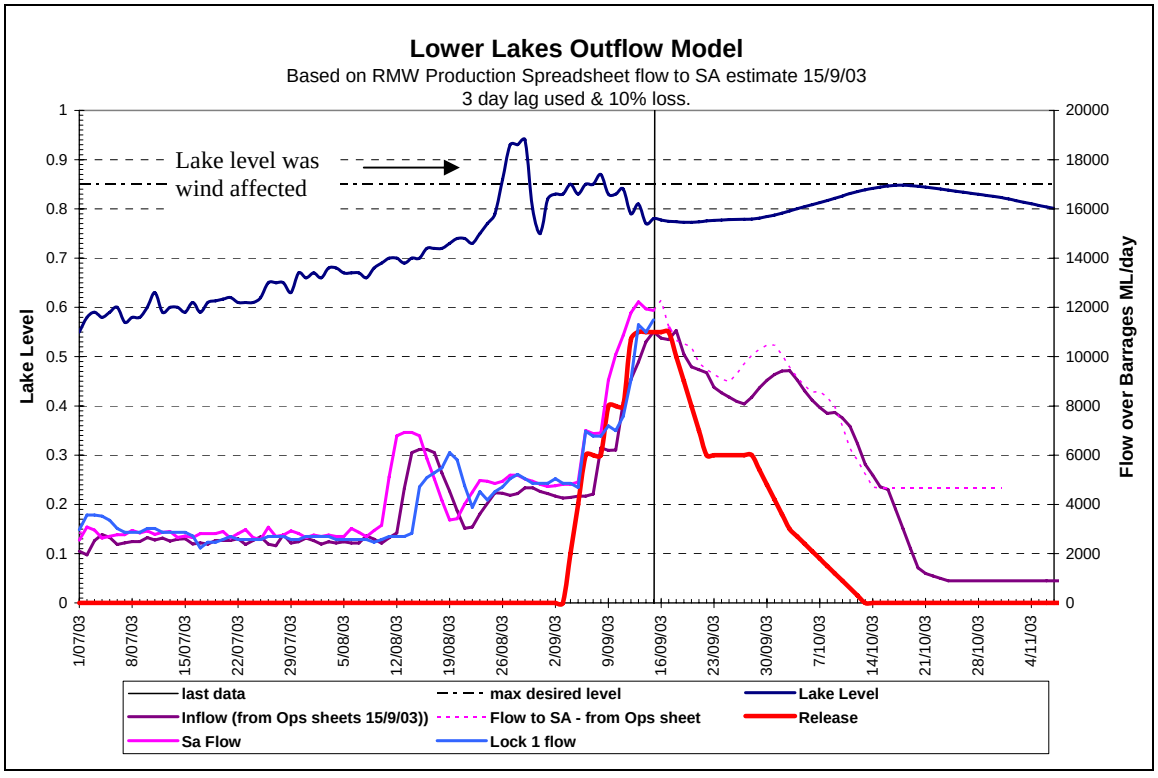
A review of lake levels indicated that the water balance could not be correct. In the discussions it was concluded that the estimates of release from the barrages were too high (i.e., actual release was presumably < 5 000 ML/day) and it was agreed to open additional barrages. A further 5 stop logs at Goolwa were removed and 5 gates at Tauwitchere opened.

The goal of the openings at Goolwa was for them to be spaced across the entire Barrage. This would draw the water evenly through the channel and minimise the opportunity for selective entrainment of fresh water from the Lower Lakes down the centre of the channel, leaving the high salinity water in the shallower areas along on the shores.

### 4.6 15 September 2003

As the high flows had arrived at the Lakes, the inflows were tracking as expected. The plan was to continue to hold the level of release, estimated at 11 000 ML/day (Figure 4.5), and review the response of the Lakes.

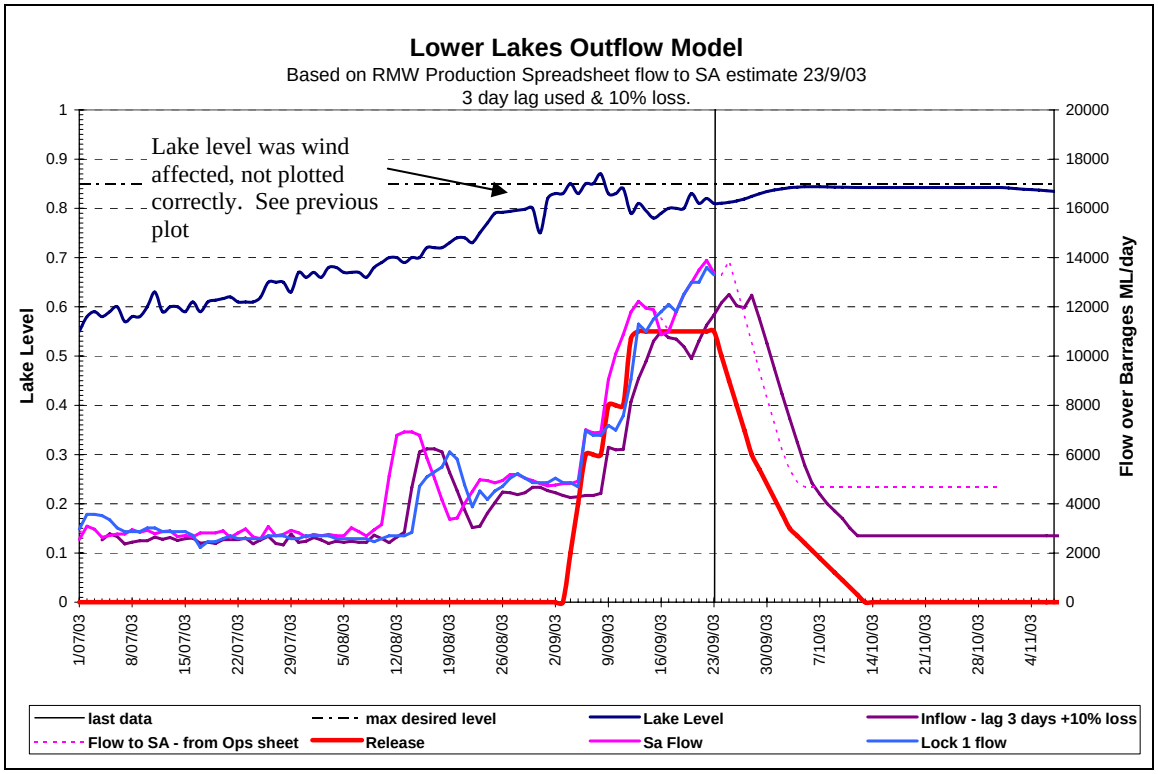
**Figure 4.5.** Estimate of planned outflow from the Lower Lakes 15 September 2003.



## 4.7 24 September 2003

The expected pattern of the inflows altered with the second peak flow arriving earlier than previously forecast and at a higher flow rate (Figure 4.6). This meant that the higher release rates had to be sustained for longer. In addition, the overall duration of the release event was likely to be reduced unless it was possible to manipulate the recession as forecast.

**Figure 4.6.** Estimate of planned outflow from the Lower Lakes 24 September 2003.




## 4.8 7 October 2003

The preceding two weeks had been dominated by periods of high tide and elevated water levels downstream of the Barrages. On one occasion, there was a period of reverse flow at Goolwa Barrage that resulted in a large volume of saline water entering the Goolwa channel upstream of the Barrage.

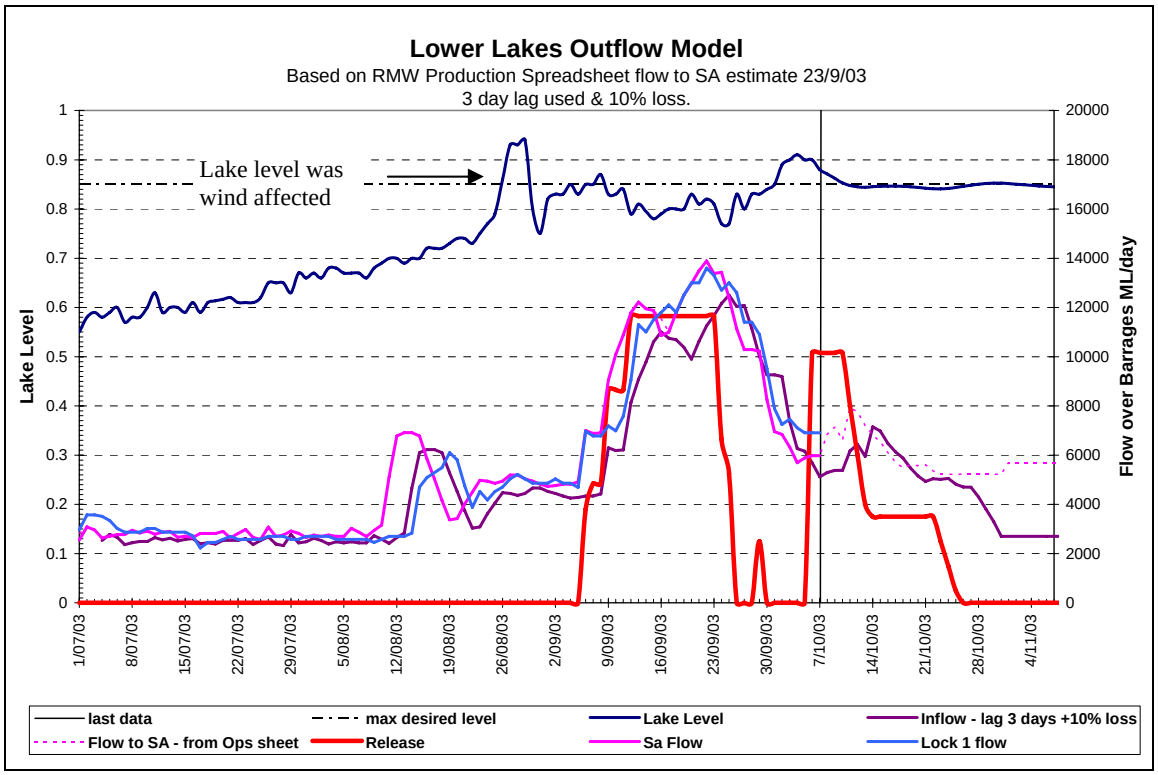
The response to this was twofold. Firstly, the barrages were closed when there was a reasonable likelihood that reverse flow could occur, either as a result of high tides or elevated water levels downstream of the Barrages, driven by wind (Figure 4.7). This necessitated closing the Barrages overnight, on most nights. While reverse flow was likely

on these occasions, the wind–tide interactions did not result in the critical situations on all occasions.

The second response was to alter the openings at Goolwa barrage to flush the salt slug out of the channel. This was achieved by removing two logs from some of the bays to draw the density-stratified water through the barrage.

As a result of the need to close the barrages overnight, the outflow was less than required for water balance and the lake rose to above the desired level of 0.85 m (Figure 4.7).

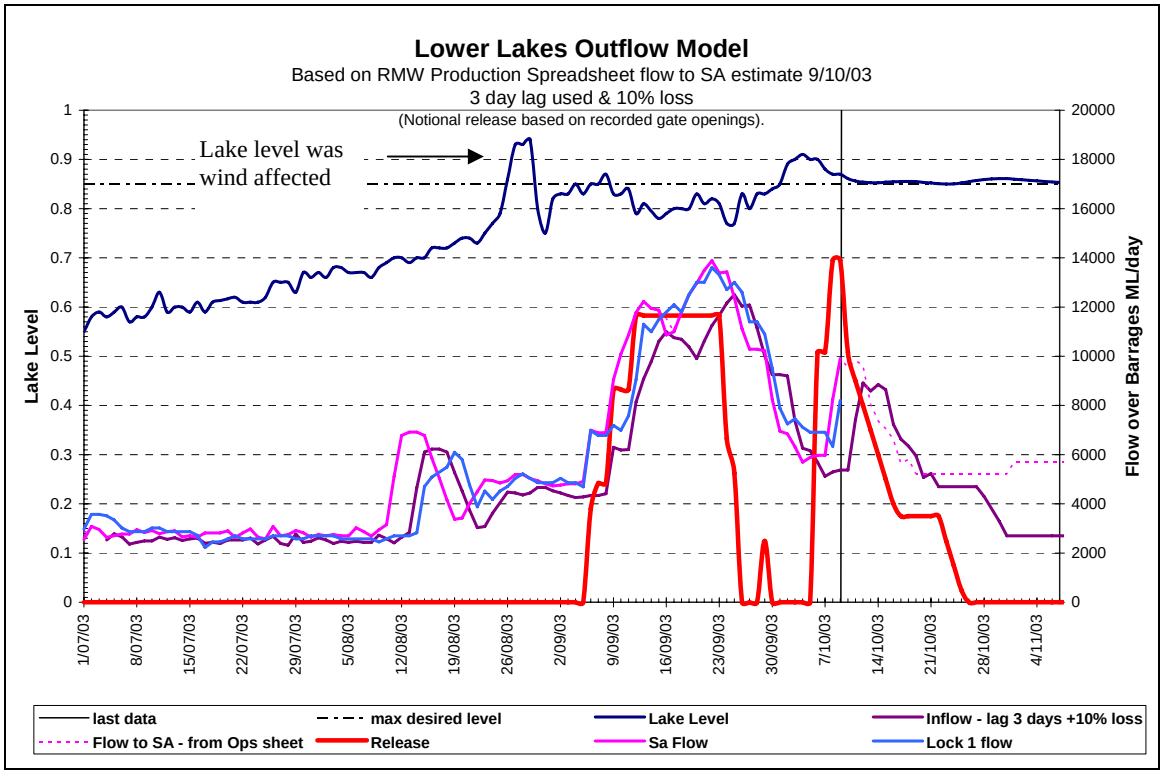
**Figure 4.7.** Estimate of planned outflow from the Lower Lakes 7 October 2003. Historical data shows zero releases for days where it was necessary to shut the barrages for some / all of the day.




## 4.9 9 October 2003

The response to the elevated Lake levels was to increase the number of openings (Figure 4.8). The analysis at this stage indicated that the shutdown required to achieve the desired gradual change in salinity would be difficult and that the actual shutdown would be dictated by inflows. This was due to the need to cease releases with the lake at 0.85 m, and the constraint of not deliberately surcharging the lake above 0.85 m.

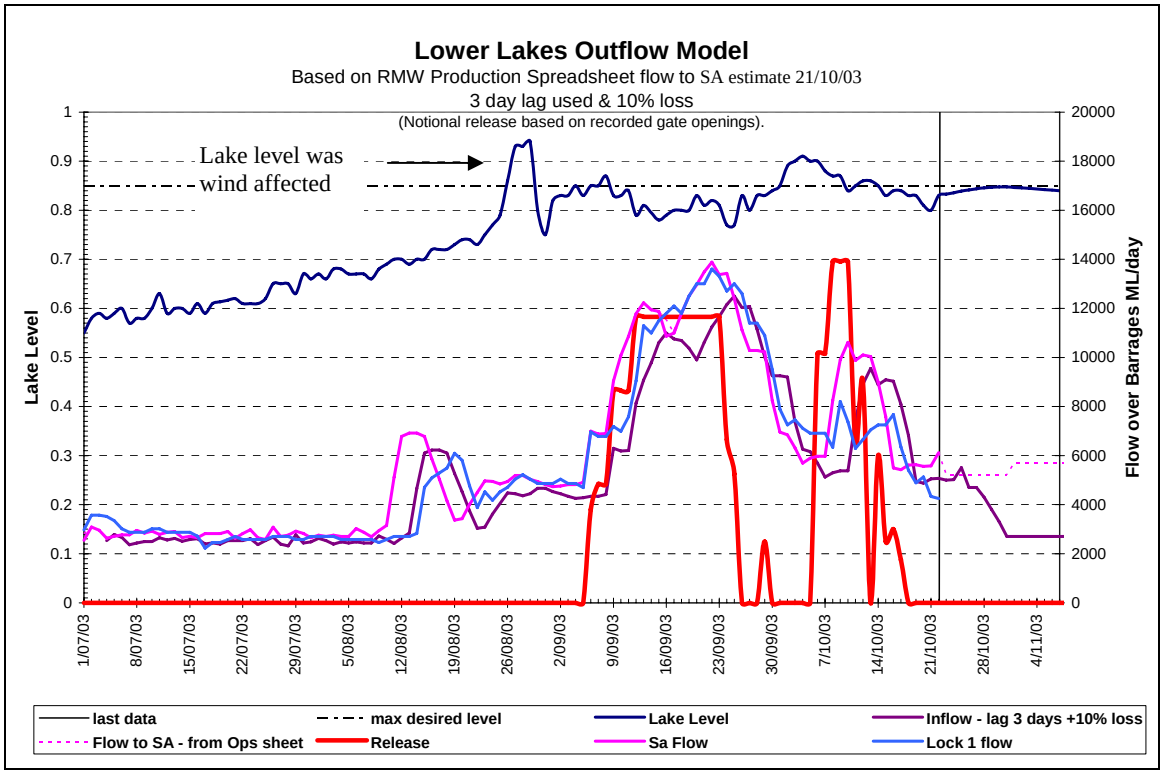
**Figure 4.8.** Estimate of planned outflow from the Lower Lakes 9 October 2003. Historical data shows zero releases for days where barrages were shut at 8:00 am due to the need to prevent reverse flow.




### 4.10 21 October 2003

The barrages were fully closed on 18 October 2003 because the lake levels were falling below 0.85 m and inflow to the lakes was receding rapidly (Figure 4.9). The estimated volume of the release was 280 GL but this has significant error bounds due to the lack of a rating for the barrages.

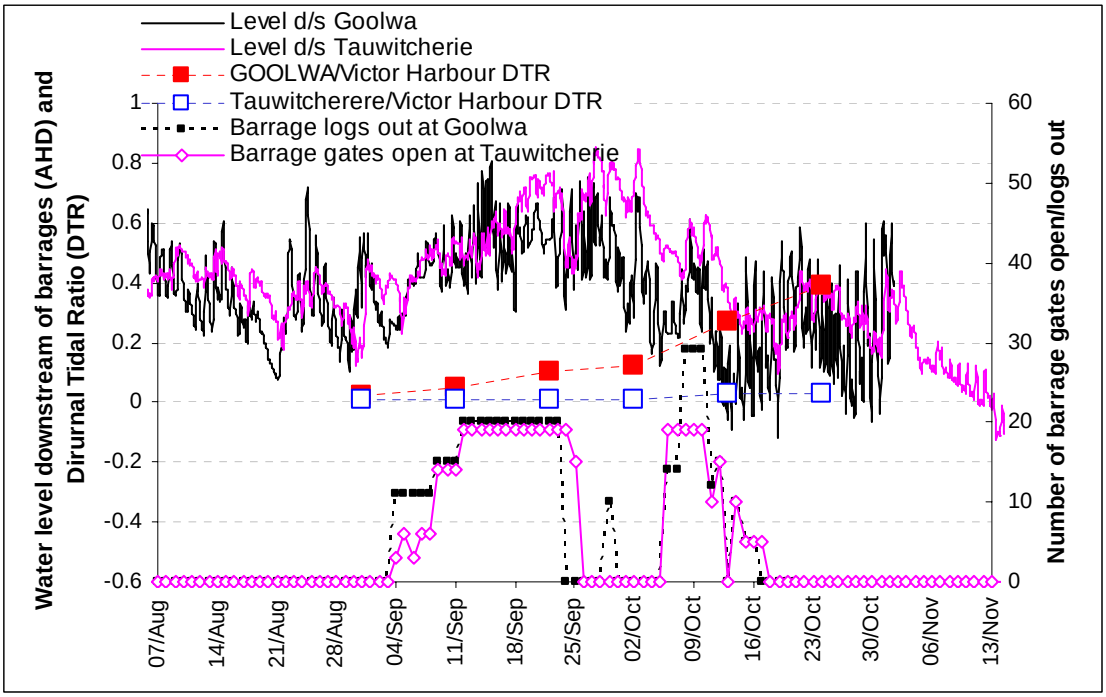
**Figure 4.9.** Estimate of planned outflow from the Lower Lakes 21 October 2003. Historical data shows zero releases for days where barrages were shut at 8:00 am due to the need to prevent reverse flow.




## 4.11 Barrage opening data

Figure 4.10 shows the number of barrage gates open at 8:00 am during the period of release. On some days the barrages were opened just after 8:00 am, but due to concerns with the possibility of reverse flow, the barrages needed to be closed later in the day. Hence on some occasions in Figure 10 indication that the barrage gates were closed does not truly reflect the operation.

**Figure 4.10.** Number of barrage gates open/logs out at Tauwitcherie and Goolwa at 8:00 am, and the water level in the Coorong downstream of the barrages during the 2003 release.




## 4.12 Elevated water levels in the Coorong

Figure 4.10 shows water levels downstream of Goolwa and Tauwitchere barrages throughout the period of the release between the 2nd of September to the 14th of October. As the release was split evenly between Goolwa and Tauwitchere, there was an increase in water levels downstream of both barrages,.

The water level of the Coorong was initially elevated as a result of the combination of the release of water through Tauwitchere barrage and the presence of sand bars closer to the mouth that prevented water exchange with both the sea and the Goolwa Channel. Eventually, the water level of the Coorong rose sufficiently to break through these sand bars and water level of the Coorong subsequently fell quite rapidly to a similar level to that of the Goolwa Channel.

## 4.13 Behaviour of the Murray Mouth

Restriction at the Murray Mouth is measured by the MMAC using Diurnal Tidal Ratio (DTR) Analysis. The tidal ratios correlate the tidal variation from both within and outside the Murray Mouth. A DTR value approaching 1 indicates a large tidal variation and

suggests that the Murray Mouth is less constricted. On the other hand, a DTR value approaching 0 indicates a low tidal variability and that the Murray Mouth is constricted.

The DTR showed a marked increase (because of wider channel) at Goolwa barrage once water started being released (Table 4.1). However, it was not until mid October when the sand bar separating the Coorong from the mouth was scoured (see section 4.12), that there was an increase of the Tauwitchere / Victor Harbour DTR, and even at this time the DTR was very low.

The 2003 release was of small volume and velocity and generally would not have held sufficient flow velocity to scour channels in its own right. In terms of the channels at the Mouth, the primary benefit of the 2003 release would have been the reduction and prevention of sand ingress during the release period. This allowed the sand pumping program to remove sand that had accumulated in the Mouth during the release period, and therefore increase the connectivity between the Coorong and the ocean. Under normal sand pumping operations when there is no water release occurring, the sand ingress is higher, which limits the ability of the dredgers to increase the channel dimensions.

**Table 4.1.** Diurnal Tidal Ratio as measured for Goolwa/Victor Harbour (outside the Coorong in Encounter Bay) and Tauwitchere/Victor Harbour. The release started on the 2nd of September and finished on the 14th of October.

| **Date / Time** | | **Goolwa / Victor Harbour** | **Tauwitchere / Victor Harbour** |
|---|---|---|---|
| 16:00 31/08/03 | Prior to release | 0.02 | 0.01 |
| 08:00 11/09/03 | During release | 0.05 | 0.01 |
| 00:00 22/09/03 | During release | 0.10 | 0.01 |
| 16:00 02/10/03 | During release | 0.12 | 0.01 |
| 08:00 13/10/03 | During release | 0.27 | 0.03 |
| 00:00 24/10/03 | Soon after release completed | 0.39 | 0.03 |

### 4.14 Effects on salinity of Coorong

Prior to opening the Barrages the salinity 1.7km downstream of the Goolwa barrage at Landing 19, was greater than 35,000 EC (Figure 4.11). The initial release of water through the Goolwa barrage resulted in a reduction of the salinity at Landing 19 to 5,700 EC. Although, there were short intervals of high salinity during the release interval due to tidal

influences, the salinity at Landing 19 remained relatively low until the barrage gates were closed for the final time.

The salinity of the Tauwitchere Channel followed a similar pattern to that observed at Landing 19 (Figure 4.12). The salinity initially reduced when the barrage gates were opened, varied during the remainder of the release and then increased when the barrages were closed.

The salinity of the Coorong at Mark Point and Robs Point (19km and 45km along Coorong from Murray Mouth respectively), initially decreased when the barrage gates were opened, but then steadily rose during the remainder of the release period (Figure 4.12). In contrast, the salinity of the Coorong at the Salt Creek gauging station (95km from Murray Mouth) remained the same during the release of water from the barrages.

**Figure 4.11.** Salinity at Landing 19 (downstream of Goolwa Barrage) during the Barrage release in 2003.

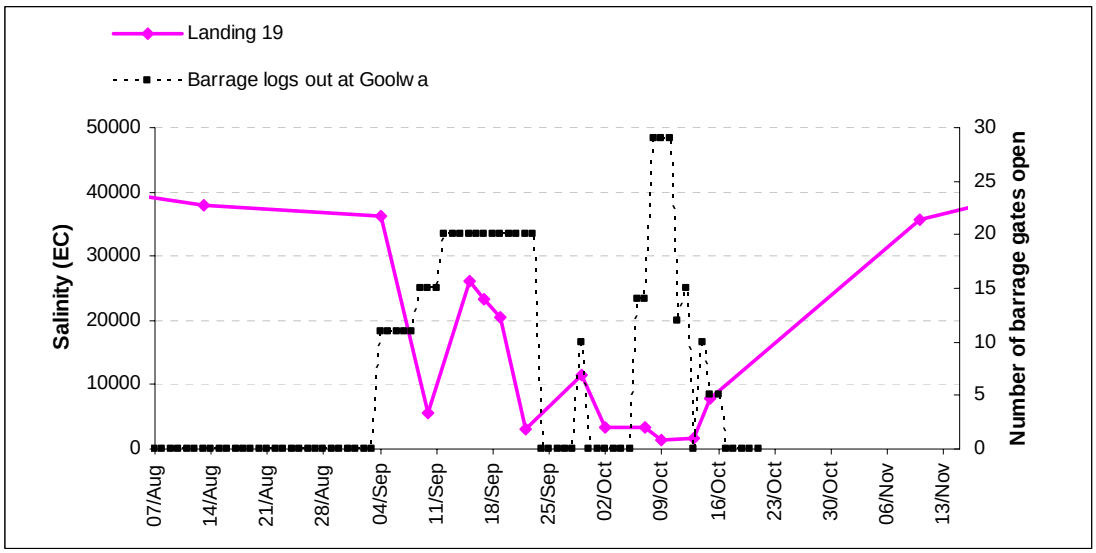
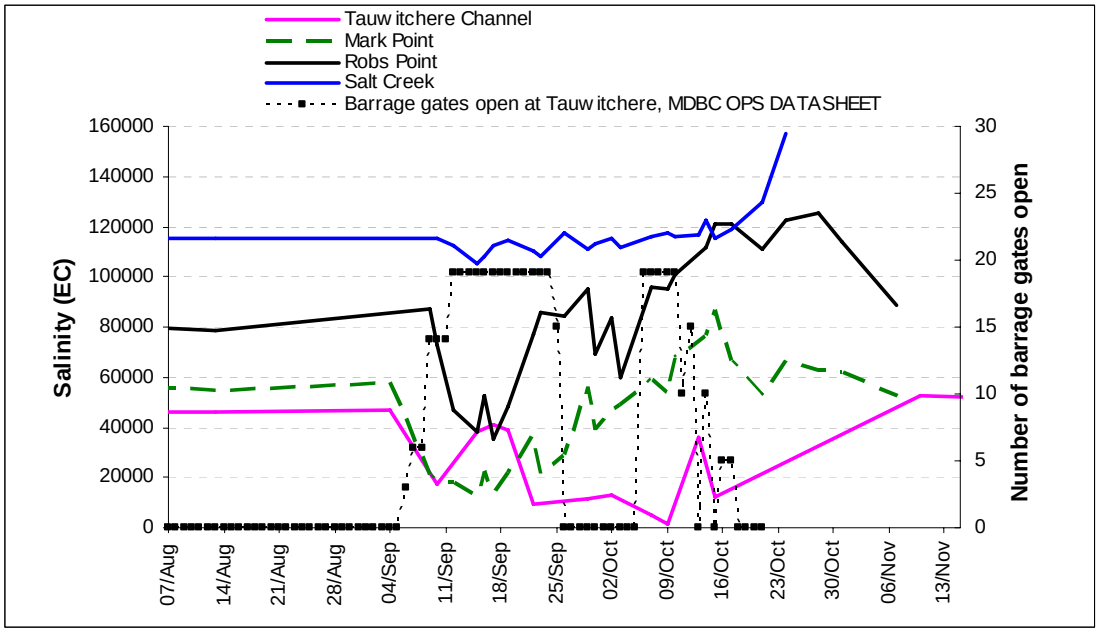


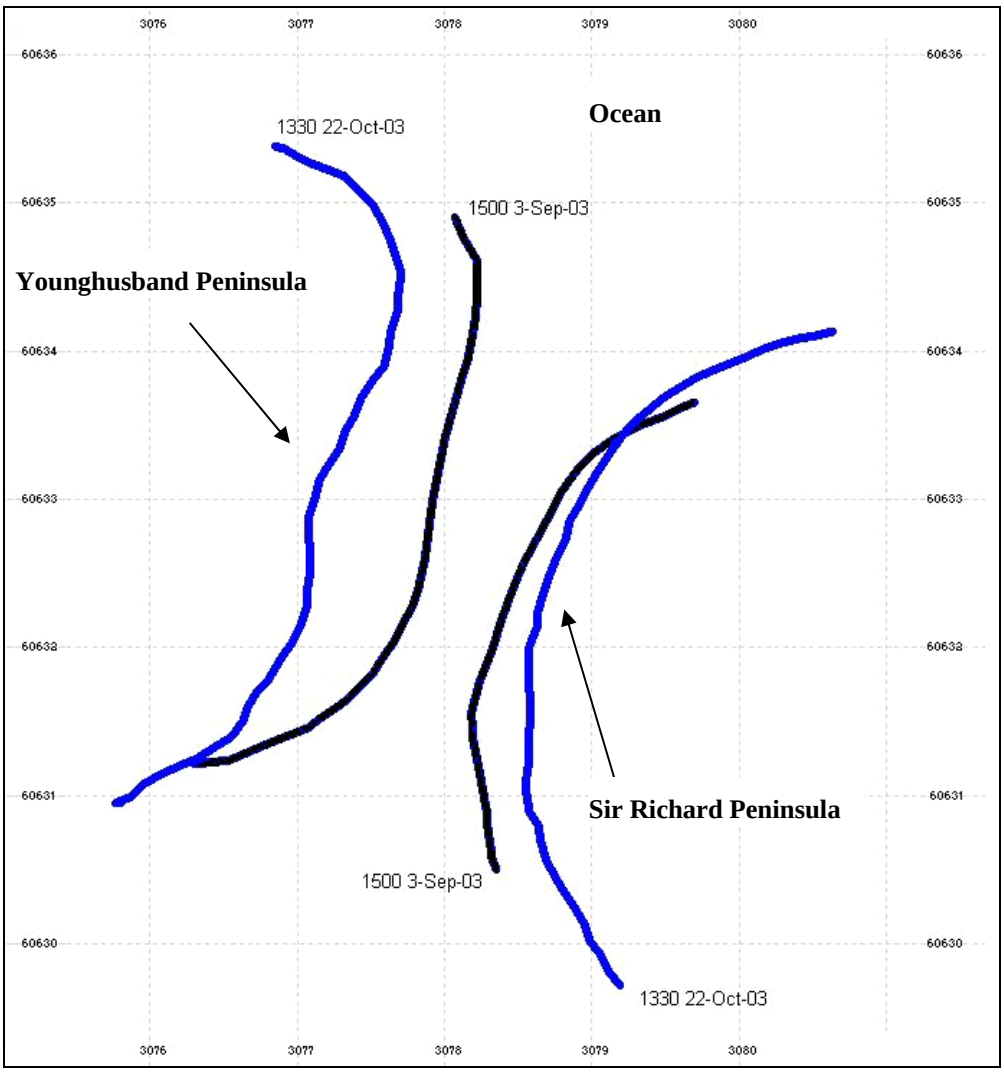
**Figure 4.12.** Salinity at Tauwitchere Channel and various locations along the Coorong during the Barrage release in 2003.




## 4.15 Position of the Murray Mouth

During the Barrages release, the sand pumping dredges were working at a reasonable distance from the Mouth and all changes in the Mouth location are considered to be due to the release. The change in the location and shape of the Mouth due to the release is shown in Figure 4.13, which indicates the waters edge at the Mouth on a 100 metre grid. Figures 4.14 and 4.15 also show the degree of mouth opening during and after the event, respectively.

**Figure 4.13.** Position of the Murray Mouth during the release (3 September 2003) and after (22 October 2003). The grid references are eastings and nothings to the WGS84 datum, in zone 54H. The lines indicate the waters edge at the Mouth on a 100 metre grid. The ocean side is on the upper portion of the grid (Source: Ross Carter, SA Water).




Prior to the release, the Mouth had contracted to approximately 60 metres at its narrowest point, with shoaling evident adjacent the tip of Younghusband Peninsula. During the release, significant scouring occurred, with the Mouth widening to 150 metres by late October 2003. The scouring was irregular over the period, with the bulk of the scouring seeming to occur in a few major events. These major scouring events appeared to be generated by the return of large water volumes from the Coorong that had been pushed into the Coorong by strong North West winds prevailing for several days.

The widening of the Mouth occurred by erosion of the tip of Sir Richard Peninsula, with little erosion evident on the tip of Younghusband Peninsula.

**Figure 4.14.** Murray Mouth 5 September 2003. (Photo: Ross Carter, SA Water)


**Figure 4.15**. Murray Mouth 23 October 2003. (Photo: Ross Carter, SA Water)


For the duration of the Barrage water releases, the water discharge existing the Mouth remained aligned in a position approximately perpendicular to the ocean beaches, indicating that there was a balance between the flows from the Goolwa Channel and the Coorong Channel.

# 5 LESSONS AND RECOMMENDATIONS

The release from the Barrages in 2003 represented the first time that a release had been actively targeted for multiple objectives, incorporating a range of management scales from local operators to system policy perspectives, to deliver ecological and water resource outcomes. Notably, there were a range of interests and objectives to consider in managing this event. As such, this operation represented a major step in the delivery of improved environmental operation of the barrages.

The operation was a major learning process for the agencies involved. The following sections outline some of the key lessons learnt and identify work that needs to be done to translate the learning's of this event into the reality of future releases.

## 5.1 Mid river forecasts

The accurate forecast of flows to SA is crucial to inform management decisions that need to be taken prior to the water arriving. The ability to forecast the high flows through the mid river was identified as a significant weakness. BigMod was initially used but was prone to overestimating the peak flow and underestimating the losses. The RMW operating spreadsheets have fixed travel times and have not been set up or calibrated to provide loss estimates under high flow scenarios. Despite the shortcomings observed in this event, BigMod has the correct structure to be developed as an accurate forecasting tool for the mid river suitable for this purpose.

The recalibration and refinement of BigMod, such as alterations to its interface to allow operators to alter assumptions regarding losses, would improve its accuracy as a high flow forecasting tool for the mid river.

## 5.2 Modeling of the lower River Murray

At present, RMW does not have an operational model for the lower River Murray (including the Lower Lakes). For the management of the lower Murray, it is necessary that such a model be developed to include the full range of river operation and management actions that are envisioned for this section of the Murray. At a minimum these would need to include:

- water abstraction and losses;
- inflows from local tributaries, including the Finnis, Angas and Bremer Rivers;
- filling of wetlands;

- local rainfall;
- barrage outflows;
- drainage from wetlands and floodplains, both controlled and managed; and
- raising of weir pools.

Further development of BigMod would enable flows to be forecast over a broad range for the lower river allowing river management activities to be simulated and operators to simply enter and alter planned management actions.

### 5.3 Reverse head

It is recognised that the water levels in the Lower Lakes and Coorong are heavily influenced by wind and tides (d/s barrages). These drivers can result in periods of reverse head across the Barrages. If the Barrages are open during a period of reverse head then this allows saline water to enter the Lakes. Thus it is necessary to close the Barrages prior to reverse head occurring.

Although there was a clear understanding of the respective roles and responsibilities between agencies and RMW when responding to rapid changes, the notification and involvement of other parties requires clarification.

To clarify involvement at the start of each release, the Standing Operating Procedure (SOP), which directs the OIC of the Barrages to operate the structures to prevent reverse flow occurring, should be referred to.

The provision for automatic closing of gates on Tauwitchere and Ewe Island barrages will allow these gates to be left open until just prior to a period of reverse head, as opposed to manual closing in anticipation of reverse head. The first ten of these gates are scheduled for commission by mid 2004, with a further twenty by the end of 2004.

### 5.4 Lake levels

With the Lower Lakes very susceptible to wind seich, it is necessary to be able to estimate the volume of water in the Lakes and to where the water has moved. To do this, it will be necessary to access time series water level data in near real time (e.g., by telephone poll and download). Analysis of the historical time series data indicates that a single reading from a telephone poll can be quite inaccurate and it will be necessary to use an average level over a given period (e.g., 15 minute average).

Water level estimations for the Lakes could be improved by incorporating a system that allows the OIC Barrages to access time series data in near real time.

### 5.5 Flow through a barrage opening

A major problem in managing the release was that it was not possible to determine how much water was being released at any point in time. This is because there is no accurate rating for the different barrages opening combinations and changing head conditions (upstream and downstream levels). This made modeling the process difficult and limits the ability to develop a range of operating strategies for future releases.

An attempt was made to address this with DWLBC arranging for the flow to be gauged on several occasions. The results of the gauging have not yet been presented in a form that is suitable for incorporation into an operating model.

Estimations on how much water is being released at any point in time through the barrage opening would improve if ratings were developed for the gates, based on the observed upstream and downstream water levels.

### 5.6 Murray Mouth Management

A morphological model of the Murray Mouth has been developed to predict morphology change at the Mouth under flow (and no flow) scenarios. This model was not complete at the time of the 2003 water release, however if water is released in the future, this tool could be used to assess the effect of a range of release strategies on the Murray Mouth. Additionally, salinity modules have been added to the model to allow the effect of water releases on Coorong salinity to be predicted. This will be an important tool in the meeting the objective of maintaining estuarine conditions in the Coorong for as long as possible.

### 5.7 Decision process and structure

The process for determining the operating strategy for the release was generally effective. The formation of the BRMG provided a forum very useful for sharing ideas, knowledge and experience. The following improvements to the administrative arrangements became apparent:

- a summary and action list should be written up for each teleconference
- all instructions to the OIC Barrages should be confirmed by written correspondence.

A summary and action list of the teleconference produced and distributed within 24 hours of the teleconference would improve the decision process.

All instructions regarding changes to barrage openings should also be fully documented in the RMW Instructions Log and be confirmed in writing to OIC Barrages.

### 5.8 Lake operating levels

Prior to the release of water from the barrages, it was decided that at the end of the event the lakes must be at maximum surcharge level of 0.85 m AHD. This was considered essential, given that at that stage South Australia was not certain of receiving entitlement in each month in early 2004.

The requirement to end an event with lake levels at 0.85 m AHD influences the nature of the recession that can be designed and implemented for a release, particularly if surcharging above this level is not desirable. The REG H report indicates the importance of managing the rate of change in salinity, the rate of fall in water levels in the Coorong and the drop in flow over the barrages to assist the spawning needs of estuarine fish and to assist the environmental requirements of a range of other biota, including vegetation. Flexibility in achieving these aims could be increased if the target lake level at the end of an event is reduced. The range of lake levels between 0.85 and the proposed lower level could be called the Lake's "environmental zone".

Based on capacity tables for Lakes Alexandrina and Albert combined, the Lower Lakes hold 2098 GL at 0.85 m AHD, and 2015 GL at 0.75 m AHD, the difference being 83 GL. Given this, a target of 0.75 m AHD for the end of an event would provide an additional 80 GL to shape the recession of flows. For example, this could be used to maintain releases at 5,000 ML/day for up to 16 days at the end of an event. The tagging of some or all of this water as environmental or otherwise would require further discussion.

Such a strategy would require developing rules to assist with setting a target lake level upon which to finish an event. Such rules would consider upstream storage levels (i.e., in all four major MDBC storages – Dartmouth Reservoir, Hume Reservoir, Menindee Lakes, Lake Victoria) and the time of year, and be similar in approach to the Menindee Lakes Harmony rules and the Lake Victoria Operating Strategy.

In order to ensure that the Lower Lakes is left at an optimal level after drawdown, a rule should be developed by the Lower Lakes Management Committee, or other group as appropriate.

### 5.9 Meeting the objectives for this site – future ecological goals

Further development of preference curves for estuarine fish spawning

The objectives for this event were informed by flow and salinity preference curves for estuarine fish spawning. This information, contained within the REG H report for the Murray Mouth, Coorong and Lower Lakes, was understood to be the best available knowledge on this relationship at that time.

As part of an adaptive management approach to interventions at this site, it is important for the results of the monitoring program being conducted by SARDI to be used to update these curves as necessary.

Monitoring of responses in the Murray Mouth, Coorong and Lower Lakes

Opportunities such as those in September 2003 are unpredictable in regard to the timing of flow. As occurred in this event and for similar opportunities in the past (e.g., Lock enhanced flood in 2000), monitoring programs are developed in the weeks or even days leading up to the event commencing.

This affects the time available to develop an experimental design and collect pre-event data and thus places stress on researchers and managers to develop an appropriate monitoring program. Given that the objectives for interventions at this site are likely to remain similar through time, it is possible to pre-define which hypotheses would be tested under a variety of management scenarios. This would enable researchers to rapidly implement a pre-designed and scientifically rigorous monitoring program.

Meeting multiple objectives

The ecological objectives of the barrages release of 2003 focused on managing the flows to trigger and sustain estuarine fish spawning. While healthy estuarine fish populations are part of the objectives for this site, other objectives also consider vegetation, water birds, freshwater fish and other biota.

The objective setting process for future releases therefore also needs to consider what the objectives are in relation to other biota. This will allow managers to ascertain whether desired management actions will result in the ability to meet multiple objectives with a single action or whether they will result in tradeoffs.

Consistent with the need to respond rapidly when such opportunities occur, pre-defined objectives for a range of flow related scenarios could be developed that flesh out the ability to meet multiple objectives, or identify tradeoffs where they occur.

# APPENDIX A

The following text is an extract from the "Foundation report on the significant ecological assets targeted in the First Step[9]" developed for The Living Murray initiative.

## FACTORS IMPACTING ON ENVIRONMENTAL VALUES

*Hydrology - degree of change to flows due to river regulation*

The source of much of the flow in the River Murray at the Mouth is winter rainfall and snowmelt on the Great Dividing Range. Not only is the source of flow distant from the Mouth, it is also highly variable. The natural average annual flow is 11,000 GL, while some wet years have natural discharges of 40,000 GL, and drought years deliver virtually no flow to the Mouth (Jensen *et al*., 2000, p. 14). Regulation of the river system by headwater storages and diversion structures has dramatically reduced the volume of flow delivered to the estuary.

Being at the downstream end of the River Murray System, the hydrology in the lower lakes and downstream is the culmination of multiple upstream changes. The degree of hydrological change relative to natural condition can be statistically summarised as follows:

- At the Barrages, the median annual outflow from the Murray system to the sea is now 27% of the natural outflow (Gippel *et al*., 2002).
- Years with annual flows <5,000 GL occurred 7% of the time under natural conditions, but now occur 66% of the time under regulated conditions (Thomson, 1992; Jacobs *et al*., 1997).
- The Murray Mouth now ceases to flow on average once every two years, while before regulation this was experienced once every twenty years (Close, 1990; Jensen *et al*., 2000, p. 78).
- There has been a threefold reduction in the frequency of medium–sized flood events (20,000 – 80,000 ML/day), and the duration of these events has also decreased (Jensen *et al*., 2000, p. 19).

[9] Murray Darling Basin Commission (2005) *The Living Murray Foundation Report on the significant ecological assets targeted in the First Step Decision*. Murray Darling Basin Commission, Canberra.

- The original indicator of hydrological stress developed in the pilot Sustainable Rivers Audit framework indicated that the flow regime in this river zone is the most modified relative to natural.

The distribution of the median of natural flows under natural and current conditions over the Barrages is shown in Figure 6.4. The area between the curves is a measure of volumetric flow change (mainly diversions and losses). There are eight months (November – June) when the median monthly flow is less than the minimum median monthly flow in any month under natural conditions (Figure 6.4). The seasonality is similar, although considerably truncated in the current case. Further detail to highlight the change in flow patterns on a monthly basis is provided on Figure 6.5, which is a summary of modelled hydrological data from 109 years of record.

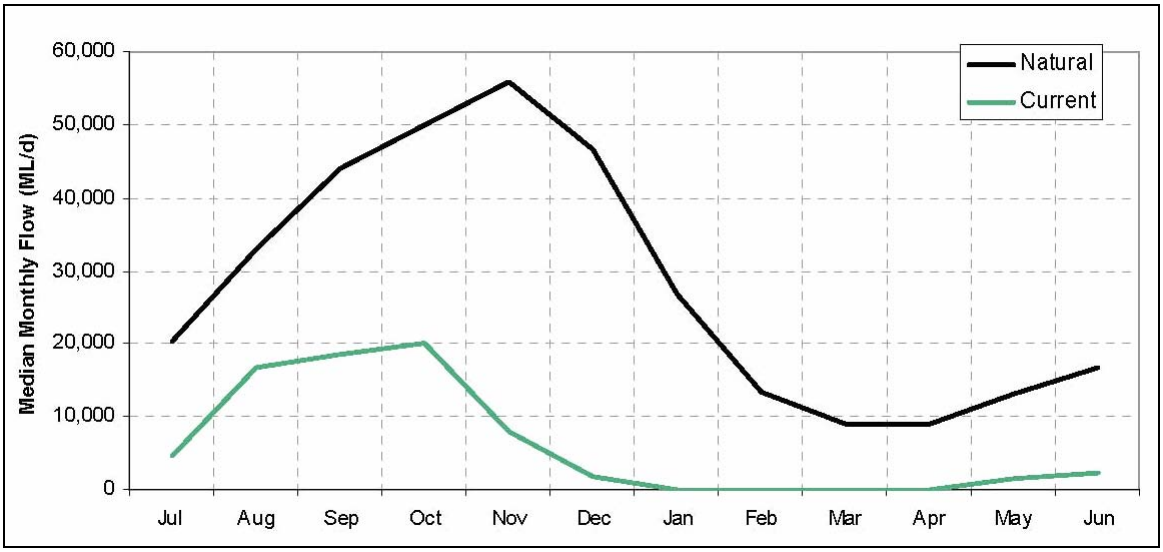



**Figure 6.4 – Median monthly flows over the Barrages under natural and current conditions.**

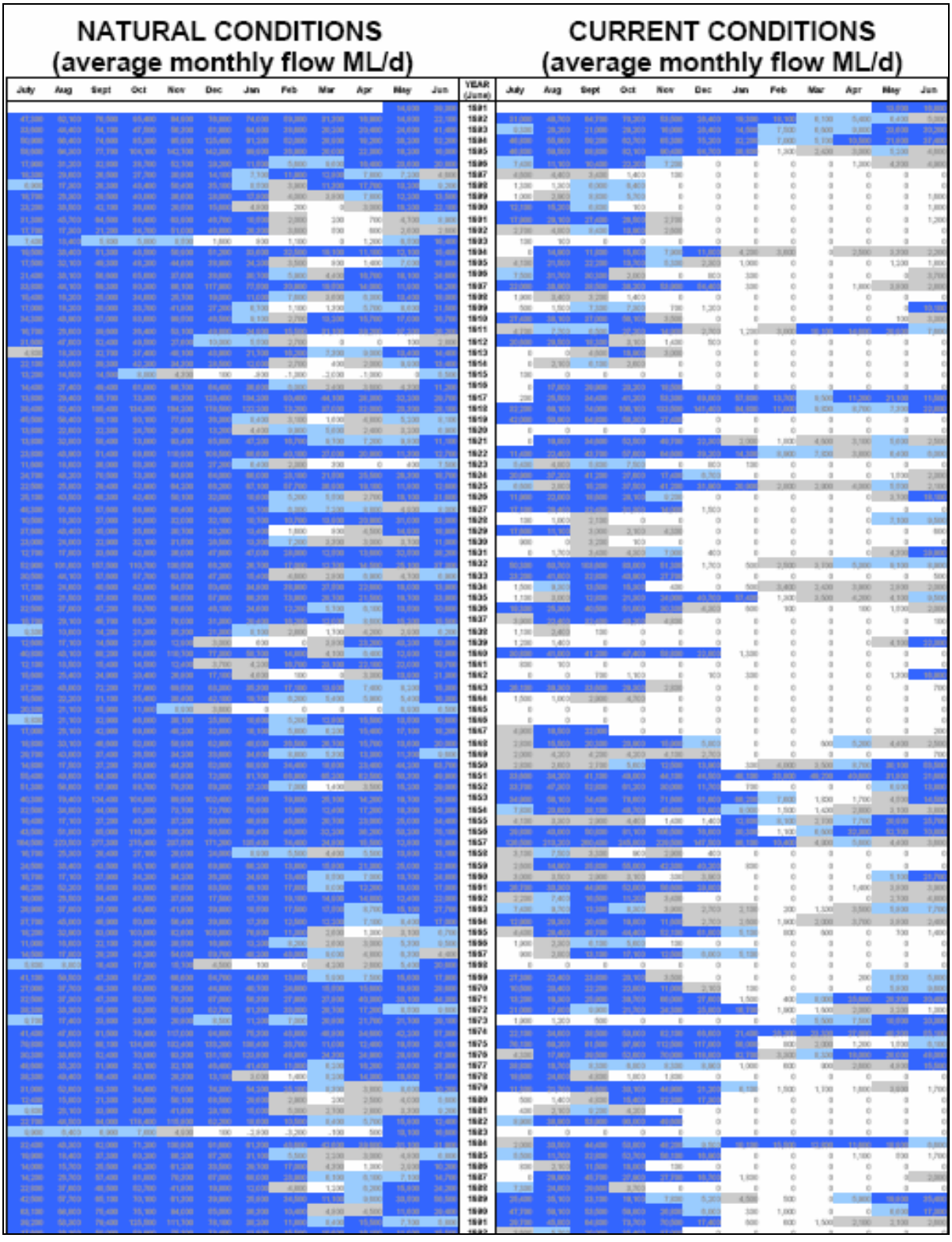



**Figure 6.5** - Comparison of monthly flows over the Barrages for Natural and Current conditions; 109 years of modelled data. The increase in white area under Current conditions compared to Natural conditions shows that flows less than 2,000 ML/d are much more frequent now.

*Hydrological impact of the Barrages*

In addition to the change in the flow regime due to regulation and diversions upstream, the operation of the Barrages has significantly changed the hydrological regime of the Lower Lakes. Lake levels are currently managed to maintain a constant water level of 0.78 m relative to the Australian Height Datum (AHD) where possible, removing much of the natural variability. Figure 6.5 illustrates the change in water level variability, with a constant level maintained for almost 60% of the time.

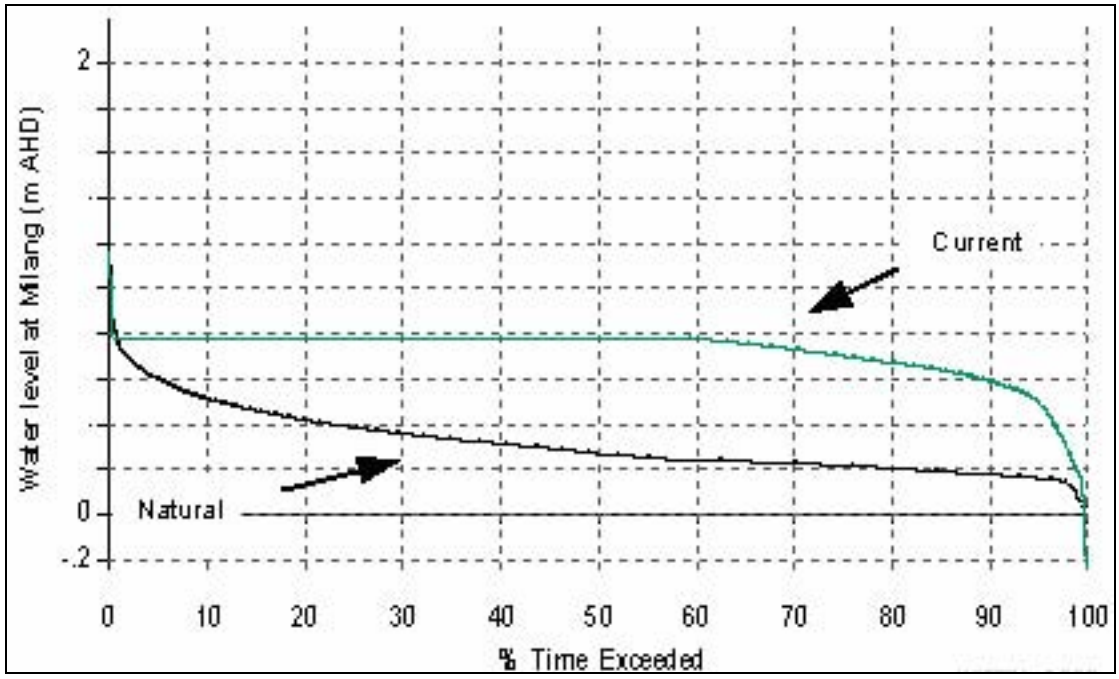



**Figure 6.6 -** Comparison of daily water levels at Milang (in Lake Alexandrina) under natural and current conditions.

# APPENDIX B

**Preferences for Estuarine fish spawning**

The following text is an extract from the report produced by Regional Evaluation Group H for The Living Murray initiative.

**Principal Authors:** Qifeng Ye and Gary Hera-Singh.

**Description:** These curves [preference curves] are based on the observation by experienced local commercial fishers, scientific studies on the key estuarine species (e.g., black bream, Harbison 1974) and in the Coorong (Geddes and Butler 1984; Geddes 1987), and scientific reports (The Murray Mouth and Coorong, Geddes and Hall 1990). Freshwater flows from the Lower Lakes through to the barrages allow mixing into the Coorong, creating estuary conditions, which are critical for the recruitment success (spawning/nursery) of the estuarine-dependent fish species. Freshwater flows into the Coorong during the spring/summer (temperature dependent) stimulate the estuarine species to spawn, but a protracted period of estuarine condition extending to late summer with a gradual tail-off of the freshwater flows to the Coorong, and a gradual change of salinity, is critical to enhance the survival of larval and juvenile fish. Barrage opening and freshwater flows are also critical for the migration needs of diadromous species (e.g., lamprey, eels) to complete life cycle.