

RIVER, LAKES & COORONG ACTION GROUP Inc.

Keep our waters alive!



**The Secretary
Senate Standing Committee on Rural and Regional Affairs and Transport
Parliament House
Canberra ACT 2600**

Inquiry into Water Management in the Coorong and Lower Lakes

Public Submissions

River, Lakes and Coorong Action Group Inc. (RLCAG) is a community-based environmental organisation with membership based primarily along the western shore of Lake Alexandrina, South Australia. The Group's focus is upon the waterway between Lock 1 and the Murray Mouth.

RLCAG welcomes your committee's invitation to comment on your Inquiry.

1. Water management in the Coorong and Lower Lakes, report by 30 September 2008

a. Water audit

RLCAG supports your requirement for an *independent* audit of water currently available in the Murray-Darling Basin. Independence from past policies and practices is essential.

b. Nett Water balance in the Lower Lakes

RLCAG accepts the thesis presented by Brooks and South ("Applying a localised Water Balance approach to estimate losses from Lake Alexandrina and Lake Albert for the years 1970 to 2006". 2008. pdf copy attached) that "Lake Alexandrina and Lake Albert collectively lose close to a median value of 400GL of water per annum". Much greater loss amounts are used in various publications and it is important that your Inquiry settles on a responsible figure.

c. Transmission 'losses'

The term 'transmission losses' in your terms of reference is misleading and betrays our past failures to appreciate the valuable (and, often, crucial) environmental contribution of water that fills billabongs and floodplains, and

*River, Lakes and Coorong Action Group Inc.
ABN 23 590 559 324*

*Secretary: J.H. Yelland PO Box 73 Milang SA 5256
secretary@riverlakescoorong.com.au*

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replenishes groundwater reserves. These have been described as the nurseries of life along the river system and their value should not be forgotten even as we focus upon the current emergency in the Coorong and Lower Lakes.

d. **Lease of water from willing lessors**

Downstream water lessors—particularly those with 100% carryover from last year—should be immediate buyback targets. Otherwise, their entitlements will in many cases be sold upstream and lost to the environment.

Many irrigators would appreciate the Government leasing water for the environment.

e. **Inappropriate taxation incentives**

RLCAG requests the immediate removal of tax incentives which encourage planting of permanent plantings which, as shown by this ongoing drought, are unsustainable.

f. **Caps on water licences**

RLCAG requests the removal of water trading caps—especially that of 6% within Victoria—to limit trading of water licences beyond districts. Such caps contradict the argument for allowing market forces to produce rational distribution of water.

2. Long-term sustainable management of the Murray Darling Basin system, report by 4 December 2008

a. Adequacy of the Intergovernmental Agreement.

The Agreement is completely inadequate.

- The timelines are too long. Unless we have a succession of very wet years, significant areas of the Basin will have suffered irretrievable ecological damage before the new system has been phased in. It is not responsible to simply pray for rain.
- The new system retains the worst facet of its predecessor: Authority recommendations must run a full gamut of approval from State and Federal Ministers. The result will be a repetition of piecemeal and partisan policies that caused so much damage through the twentieth century.
- The new system excises Goulburn and Murrumbidgee rivers, two of the most significant tributary systems and crucial component of the natural river system. An essential foundation for integrated management is to align governance and natural systems.
- The new system does not integrate surface water and ground water. One cannot properly manage the former without careful attention to the latter.

- b. Adequacy of current arrangements
Current arrangements are completely inadequate. They have not prepared us for droughts because they do not include provision for maintenance water: flow sufficient to keep the ecosystem alive. RLCAG draws your attention to the latest Drought Update from Murray-Darling Basin Commission (Number 15, September 2008), which states “Recovery of the system is likely to take several years of above average rainfall.” We need governance that does more than pray for rain.
- c. Long-term prospects for the management of Ramsar wetlands
Under the Ramsar agreement, Australia promised to retain the ecological condition of the Coorong and Lower Lakes at least at the same level as prevailed in 1985. This commitment followed a crisis in 1981 when the Murray Mouth closed for the first time in 8,000 years¹. RLCAG judges that the Ramsar wetlands can be managed within the terms of the treaty only if a concept of maintenance flow is incorporated into management. Refer to the work of Professor Mike Young for an exposition of how this may be achieved.
- d. Risks to the basin posed by unregulated water interception activities and water theft
Anecdotal evidence indicates that water theft is rife throughout the system. RLCAG judges that current policing resources are inadequate.
- e. Ability of the Commonwealth to bind state and territory governments to meet their obligations under the National Water Initiative
No such ability exists under current arrangements. Even in this current drought crisis we have maintained paralysis by consensus. Contrast our inaction in the Murray-Darling Basin over the last two years with that generated by Equine Influenza, and consider the relative stakes involved.
- f. Adequacy of existing state and territory water and natural resource management legislation and enforcement arrangements
RLCAG judges that all state and territory jurisdictions should be immediately ceded to the Federal government. Management of the Murray Darling Basin since Federation has been the greatest failure in governance in Australia’s history.
- g. Impacts of climate change on the likely future availability of water
RLCAG accepts Prof Mike Young’s calculation (ibid, page 30), based on experience in Western Australian, that a 10% drop in mean rainfall may mean a 67% decrease in water available to irrigators. RLCAG also notes inflow implications of afforestation and the proliferation of small lifestyle blocks (each with its own dam) in high-rainfall catchments. The Basin currently supports approximately 15,000 irrigation enterprises; it is difficult to believe that more than two-thirds can survive.

¹ A Fresh History of the Lakes: Wellington to the Murray Mouth, 1800s to 1935. Terry Sim and Kerri Muller. © River Murray Catchment Water Management Board, 2004. Page 4.

h. Other matters. Office locations.

An Australian river, with its dramatic cycles between floods and droughts, can only be properly managed with an estuary mindset. We have tried and failed to manage the Murray Darling Basin with attitudes formed in our East coast population centres. RLCAG recommends:

- New Murray Darling Authority should be headquartered in Goolwa, the population centre closest to the Murray Mouth. That positioning will encourage an estuary culture among employed staff, policy makers and water harvesters.
- Subsidiary Authority offices should be correspondingly located at key estuary points of major tributary rivers.

i. Other matters. Salinity.

RLCAG directs your attention to 1999 Salinity Audit undertaken for Murray Darling Basin Commission and its projection of a doubling of salinity loads in the Basin during this century. In drought, the spectre of salinity recedes. In future years of average or heavy rainfall it will return, perhaps at levels that we have not previously experienced. RLCAG asks that the Salinity Audit is considered in your deliberations about long-term Basin governance.

j. Other matters. Prioritisation.

We have forgotten the parable of the golden goose. 'Economic reality' is given as an argument for putting consumptive use—critical human needs and irrigation—ahead of environmental preservation but that argument holds for at most one more human generation. Thereafter, we shall pay an inordinate economic and social cost because we will have destroyed the river system.

We trust that the Committee will give these points serious consideration.

The future of the River and the Lakes depends on it.

Yours faithfully

John Yelland

Secretary

Applying a localised Water Balance approach to estimate losses from Lake Alexandrina and Lake Albert for the years 1970 to 2006

Discussion Paper 19 August 2008

Authors:

Bruce Brooks B Sc (Hons). Dip Met.

Retired: Manager Climate Services

South Australian Regional Office

Bureau of Meteorology

Contact details:

RSD 3 Finnis SA 5255

E-mail: jbrooks@bigpond.com

Telephone: 0417891909

Mike South B Ag Sc, Grad Dip Bus Admin,

Retired: AFAIM, CMC

Formerly Business Development Manager & Deputy to the Director

Cooperative Research Centre for Soil and Land Management

Contact details:

Point Sturt SA 5256

E-mail: mlhsouth@activ8.net.au

Telephone: 08 85370332

Executive Summary

- **This Discussion Paper ('Paper') argues that total evaporation from Lake Alexandrina and Lake Albert does not equate to total losses from these lakes. There are many integrated processes occurring on the Lower Lakes, such as rainfall and local stream inflows, and these cannot be ignored when considering the losses from Lake Alexandrina and Lake Albert.**
- **When considered as water storage lakes, Lake Alexandrina and Lake Albert collectively lose close to a median value of 400GL of water per annum.**
- **This estimate is considerably lower than other estimates of losses, which consider evaporation alone.**
- **Data for the Lower Lakes indicates that, in a median year, Lake Alexandrina and Lake Albert together receive some 330GL from rain falling on the surface of the lakes. They also receive an estimated 114.5GL of water from the eastern Mt Lofty streams which flow into Lake Alexandrina.**
- **It is submitted in this Paper that the evaporation from a large lake area such as the Lake Alexandrina and Lake Albert is not as great as for a Class A evaporation pan. Class A pans receive radiant heat through the sides of the vessel, whereas this is not the case in a large lake area. Thus, taken in isolation, the Class A pan reading will result in an over estimate of the evaporation from a large lake area.**
- **This Paper stresses the importance of a holistic appreciation of the integrated environmental processes, and as such argues the benefits of the Water Balance approach.**

Purpose of the Paper

The purpose of this Paper is to argue that the total evaporation from the Lower Lakes does not equate to total losses from the Lower Lakes. Processes such as rainfall and local stream inflows cannot be ignored when considering water losses from Lake Alexandrina and Lake Albert. This Paper will use data from a 37 year period, from 1970 to 2006.

Expert advice has been sought and received on the methodology contained within this Paper. The expert advice confirms that the methodology contained within the Paper appears to be in order. However, the results obtained from the methodology contained within this Paper differ from the results obtained by the users of BIGMOD. BIGMOD is a computer simulation model used by the Murray Darling Basin Commission and has been used to estimate evaporation from the Lakes. Hence, the opinion of others is currently being sought, including those who developed and use BIGMOD, in order to receive any further evaluation or criticism of the methodology. If the methodology is confirmed as appropriate, an attempt to reconcile any discrepancies with BIGMOD will be made.

Once these attempts to reconcile any discrepancies have been made, the information contained within this Paper will be included in an Information Sheet on the Lower Murray. This Information Sheet is currently under development, and the draft of relevant sections is attached as Appendix 2.

Background

Since late 2006, a number of residents, including families that have lived in the Lower Lakes region for a number of generations, have expressed concern regarding predictions provided by Government Departments on water loss from the lakes. These predictions are apparently based on BIGMOD, and may not be true representation of the situation.

Specific concerns include:

- That anecdotal and historic rises in lake levels resulting from localised rainfall events both on the lakes and the surrounding catchments do not appear to be reflected under the BIGMOD model;
- That variations in localised inflows from the wettest to driest years are of great ecological significance, and that the use of median, average or worst case scenarios ignore this variation and consequent environmental value;
- That evaporation as reported in the Media ranging from 1000GL to 1400GL are likely to be over estimations, and that in some cases these estimations are being confirmed publicly by a number of people in positions of authority and as such these estimations are gaining credibility in the general populace;
- That the Department for Water Land, and Biodiversity Conservation's ('DWLBC') estimations of annual losses in the order of 750GL to 850GL appear to be at variance to that reported in the Media, however there has been no clarification or correction offered by DWLBC; and
- That important decisions regarding the future of the Lower Lakes could be based on incomplete, or possibly flawed, information.

Initial investigations conducted by community groups were unable to determine the reasons for this discrepancy in evaporation losses. Moreover, community groups were unable to obtain any information or details on what data BIGMOD estimations were being modelled on, or how these models were being developed. However, the efforts of community groups did unveil some interesting issues which require further consideration and investigation, including the following:

- In a 2004 report, the CSIRO reported that "the lack of data for calibrating and running BIGMOD means that modeled data for flow at Lock 1 and evaporation rates are almost 500ML/d too high." (Lamontagne et al, 2004) Thus, Australia's preeminent scientific body has questioned the results produced by BIGMOD, and has indeed challenged the very basis of its use to estimate evaporation;
- The DWLBC stated that river losses from the South Australian border to the Locks at Goolwa were apportioned based on area of water, above and below Lock 1, with no allowance for differing evaporation rates (and Pan Coefficients), local catchment inflows or incident rainfall;
- The only recent piece of research carried out on the Water Balance of Lake Alexandrina, where actual data was collected and analysed, was that of Vincent Kotwicki over the period 1990 to 1992 (Kotwicki, 1993).

With this in mind, the members of the Lower Murray Drought Reference Group: Recovery subcommittee decided to consider other methods for deriving estimates of evaporation from Lake Alexandrina and Lake Albert and also to estimate the net loss after evaporation of the Lower Lakes as a water catchment. The research conducted by Vincent Kotwicki is instructive on this point, and will now be discussed.

In his PhD thesis, "Evaporation from Lake Alexandrina", Vincent Kotwicki lists 35 different methods to estimate evaporation. He remarks that some methods require complex instrumentation while others can be considerably simpler. He argues that it "should be realised that the cost and complexity of the apparatus involved is in no way a guide to the reality of the measurement it produces" (Kotwicki, 1993, p23).

It is considered that one of the best methods to estimate the evaporation from the lake surface would be to position fully instrumented automatic weather stations over the lake surface. Such an approach makes use of micrometeorology and turbulence theory to estimate the water loss from the surfaces of the Lower Lakes. There are many other methods, however, this requires recorded data from the area to have been collected for a number of years, and this would need to be an ongoing process. Unfortunately this has not been the case.

For many years evaporation from a Class A pan was measured at Milang. Unfortunately at the start of arguably the most interesting period in the Lower Lakes' history, during the late 1990s, most evaporation measurements were discontinued. Evaporation data available to the Bureau of Meteorology includes data collected from Milang (1968 to 1998), Wellington (1969 to 1998), Pelican Point (1968 to 1987) and Mundoo Island (2003 to 2007). However, it must be noted that much of the data from Mundoo Island is incomplete. The importance of complete data collection cannot be stressed highly enough.

Due to the lack of continuous data available from the Bureau of Meteorology, this Paper has utilised SILO data available for the relevant period. SILO is a database maintained by the Queensland Department of Natural Resources and Water, from where an historical climate series, including rainfall and evaporation, is able to be generated. SILO data for the 37 year study period of 1970 to 2006 was selected as this was the period for which most data existed. Fortunately it also included the extremely wet year of 1992 and the extremely dry year of 2006.

Water Balance

This Paper argues that the most effective way to measure water losses is to use the Water Balance approach. The Water Balance approach is used to determine water losses in restricted water bodies, such as Lake Alexandrina and Lake Albert, usually over a longer averaging period. While it is true that few Water Balance experiments have been undertaken, this Paper argues that it will provide good guidance in this case.

The Water Balance approach represents the change in storage as:

$$\Delta S = P + I + U - O - E$$

Where ΔS is the change in storage volume, P is the amount of precipitation, I is the surface inflow, U is the groundwater throughflow, O is outflow and E is the evaporation of a particular body of water.

The precipitation (P), can be estimated data collected from reporting stations around the Lakes. The area is relatively flat and the variation in the rainfall pattern due to orography should be slight. Therefore, it was assumed that the rain gauges provide reasonable indication as to the actual rainfall.

The surface inflow to the lake (I), includes runoff only from the streams in the Eastern Mount Lofty Ranges ('EMLR'), excluding the contribution of the River Murray. Very little stream gauging is undertaken in the EMLR, with readings from Yundi on the Finnis River spanning the longest period. Estimates of stream flow provided indicate that the median annual contribution from the EMLR is approximately 114.5GL. This is the DWLBC median modelled estimate for the period 1970 to 2006.

The groundwater throughflow (U) is unknown and long term records of this flow do not exist. Barnett is quoted as suggesting groundwater inflow to be of the order of 250 m³ per day, which is insignificant in the overall Water Balance.

Surface outflow (O), can be estimated by the volume of flow over barrages, and for the purposes of this investigation, it is assumed that the surface outflow is zero.

The evaporation (E) is the volume of water lost to evaporation.

Thus the simplified Water Balance equation now becomes:

$$\Delta S = P + I - E$$

Data Sources and Manipulation

Rainfall

The Bureau of Meteorology has rainfall stations situated at many locations around the Lakes. A significant number of these stations have been reporting for many years, many approaching 100 years of records. The Bureau of Meteorology uses a 30 year average as its standard period for rainfall.

There are no rainfall gauging stations located inside the lake perimeter. The surrounding terrain is generally flat and it is unlikely there would be any terrain induced rainfall variation in the area.

In an attempt to make use of as long a record as possible, a SILO data set for a location near Milang was used. This gave a median value of 402mm. For the period 1970 to 1998 the median rainfall for Milang #24558 was 363mm, and for Milang #24519 was 416mm.

The average of all rainfall sites around the lake gives a median value of 406mm.

Evaporation

Evaporation is estimated using a Class A evaporation pan. Put simply the evaporation is measured as the water loss from a 1.2 metre diameter galvanised water trough, approximately 300mm deep, as illustrated in Figure 1. Class A pans have been used for much of the past 40 years. A problem experienced with Class A pans is that in very arid areas, birds and animals would drink from this trough. To overcome this, a guard

consisting of a cover of approximately 12mm mesh was installed. This has been estimated to lead to a reduction of the measured evaporation of about 7% when compared to readings taken from a pan without a guard.



Figure 1 Class A Evaporation Pan

SILO data for Milang, consisting of rainfall and evaporation data for the period 1970 to 2007, has been used in an attempt to extend the length of the data set. While actual rainfall data is available from the Bureau of Meteorology for the period 1970 to 2008, evaporation data is not always available over the same period. This is due to Milang, Wellington and Pelican Point evaporation sites all ceasing operation.

The median annual evaporation from the SILO dataset for a point near Milang was 1544mm. Median annual Class A pan evaporation values were 1489mm at Milang, 1475mm at Wellington and 1655mm at Pelican Point. An estimate of the Class A pan evaporation for the Lower Lakes would simply be the average of these median evaporation estimates, or 1543mm.

Local Catchment Inflow

In the estimation of the local catchment inflow (I), rainfall run-off data captured by the DWLBC from a site on the Finniss River near Yundi has been used. This is not a measure of actual flows into the Lower Lakes, but records flows considerably upstream from them. In order to provide an estimate of inflow into the Lakes it has been assumed that this catchment is relatively representative of the other catchments. Using the median inflow of 114.5GL (modelled by DLWBC for the period 1970-1998) into the Lower Lakes over all catchments, estimates of inflow into the Lakes were produced for the study period 1970 to 2006. The estimation procedure is attached as Appendix 1.

It is noted that the Marne Rodwell Rivers do not discharge directly into the Lower Lakes but into the Murray River below Lock 1. These account for about 10 per cent of the total.

For comparison, using a different methodology, also presented in Appendix 1, the derived catchment inflows are confirmed to be of around the same order.

Table 1 Comparison of methodologies

Year	Estimates of catchment inflow		Difference
	Method used	Check method	
1997	50	58	-8
1998	53	67	-14
1999	48	64	-16
2000	169	155	+14
2001	118	137	-19
2002	27	36	-9
2003	106	104	+2
2004	96	81	+15
2005	95	96	-1
2006	31	36	-5

There is some discussion as to whether the geology and hydrology of all catchments are sufficiently similar to allow for this premise, however this has been used failing any other available data.

As the median inflow of 114.5GL was modelled over the period 1970 to 1998, there may be some discussion as to whether it is appropriate to extrapolate to the 1999 to 2006 period of this study. However, any differences are thought to be marginal and would not detract from the main tenets of this study. Any difference in magnitude would be in the order of tens of gigalitres or less.

Pan Coefficient

To better estimate evaporation from the Lake Alexandrina and Lake Albert, the following equation was used:

$$E_{\text{lake}} = K_p * E_{\text{pan}}$$

Where E_{lake} is the evaporation from Lake Alexandrina and Lake Albert

E_{pan} is the evaporation pan reading

K_p is the Pan Coefficient

Linacre argues that the pan coefficient is on average about 0.75, which implies there is 30% more evaporation from the small area of a pan than from a lake due to the extra heat absorbed through the pan wall. Linacre claims that the pan coefficient is not constant but varies. The rate of evaporation may well be around 0.75 at 5mm a day and may decrease to around 0.58 when the pan evaporation increases to around 12 mm a day. Linacre also contends that evaporation from a salty lake is reduced by the salt

concentration, because the saturation vapour pressure over salt water is less than over fresh.

Kotwicki investigated evaporation on Lake Alexandrina and Lake Albert and found that for the years 1990 to 1992 the pan coefficient averaged 0.67. Kotwicki found that the microclimate across the lake changes with the area towards the centre of the lake having a higher relative humidity than that nearer the edge. His airborne measurements showed that relatively more evaporation occurs from the edges of the lake than from the centre. Therefore a K_p value of 0.67 was chosen.

Other studies claim that the coefficient is a function of temperature with values around 0.9 when the temperature was near 10°C and values near 0.6 when the temperature was closer to 40°C.

This study will present annual figures, from January to December, over the period 1970 to 2006. The average rainfall in column 2 of the following table, Table 2, is an average for the Lakes. This depth of rain is multiplied by the surface area of the Lake at a pool level of 0.75AHD, in Column 3. In a similar manner the evaporation for the Lake is estimated and then multiplied by the evaporating surface, again at a surface area consistent with a pool level of 0.75AHD. Catchment inflows are derived from the DWLBC modelling as described above, and the final column is the Lakes' storage loss for the year.

Table 2 Results: Water Balance for Lake Alexandrina and Lake Albert

	Rain (mm)	Rain (GL)	Evap (mm)	Evap (GL)	Catchment Loss (GL)	Loss (GL)
1970	463.8	380.4	1615.8	-887.9	112.0	-395.5
1971	466.1	382.3	1600.4	-879.4	261.5	-235.6
1972	388.1	318.3	1721.8	-946.1	51.4	-576.5
1973	404.1	331.4	1674.8	-920.3	140.5	-448.4
1974	596.8	489.5	1544.4	-848.6	174.8	-184.4
1975	385.0	315.8	1620.8	-890.6	122.7	-452.2
1976	370.4	303.8	1655.0	-909.4	50.7	-554.9
1977	356.3	292.2	1710.2	-939.8	56.5	-591.1
1978	468.5	384.2	1573.2	-864.5	131.0	-349.2
1979	500.8	410.7	1539.8	-846.1	155.0	-280.4
1980	385.8	316.4	1751.2	-962.3	38.0	-607.9
1981	401.4	329.2	1706.0	-937.4	206.5	-401.8
1982	248.8	204.1	1695.4	-931.6	20.1	-707.5
1983	531.9	436.2	1534.4	-843.2	104.8	-302.1
1984	384.2	315.1	1533.6	-842.7	114.5	-413.1
1985	475.4	389.9	1481.0	-813.8	88.7	-335.2
1986	402.2	329.9	1550.2	-851.8	216.6	-305.4
1987	418.9	343.6	1557.0	-855.6	184.8	-327.2
1988	333.7	273.7	1550.6	-852.1	129.9	-448.5
1989	443.4	363.7	1537.4	-844.8	146.7	-334.4
1990	425.6	349.1	1553.6	-853.7	156.1	-348.5
1991	371.8	304.9	1513.4	-831.6	128.3	-398.4
1992	695.5	570.4	1295.4	-711.8	248.7	107.3
1993	409.4	335.8	1478.2	-812.3	83.6	-392.9
1994	345.2	283.1	1514.4	-832.2	25.8	-523.3
1995	337.7	277.0	1472.8	-809.3	144.8	-387.5
1996	380.8	312.3	1539.8	-846.1	163.5	-370.3
1997	376.1	308.5	1474.6	-810.3	49.6	-452.3
1998	431.9	354.2	1513.2	-831.5	53.0	-424.2
1999	359.0	294.4	1575.0	-865.5	47.8	-523.2
2000	504.7	413.9	1597.6	-877.9	168.9	-295.0
2001	404.3	331.6	1512.8	-831.3	118.4	-381.3
2002	289.8	237.7	1572.0	-863.8	26.7	-599.5
2003	481.0	394.5	1498.6	-823.5	106.2	-322.7
2004	378.7	310.6	1543.8	-848.3	95.8	-441.9
2005	515.8	423.0	1466.2	-805.7	94.5	-288.1
2006	288.8	236.9	1558.6	-856.5	31.1	-588.5

The median loss from the Lower Lakes pool for this period has been calculated as 396GL. Given the errors in measurement, this estimate should be approximated as 400GL of net water loss for the Lakes.

The usefulness of the SILO data for this monitoring purpose and trying to estimate the net water loss from the Lower Lakes was investigated. From the data below, it can be seen there is a strong correlation when there is data at Milang. Net water loss from the lakes using local rainfall and evaporation data is 384GL. For the period since 1999 it is impossible to determine how good the correlation actually is.

Lake levels during early August 2008 were approximately -0.3AHD, which is 1.05m below the normal pool level of 0.75AHD at which the surface area of the lakes is 820.15 sq km. The estimated surface area at -0.3AHD is 709.71 sq km. At this reduced lake level the surface area over which evaporation can take place has therefore been reduced by 13.5% and therefore the evaporation from the lake surface will be reduced by an equivalent amount.

Table 3 Evaporation Comparison

	Net Loss using SILO data (GL)	Net loss using Actual Rainfall and Evaporation data(GL)
1970	-395.5	-411
1971	-235.6	-215
1972	-576.5	-531
1973	-448.4	-396
1974	-184.4	-178
1975	-452.2	-413
1976	-554.9	-545
1977	-591.1	-565
1978	-349.2	-355
1979	-280.4	-276
1980	-607.9	-557
1981	-401.8	-337
1982	-707.5	-657
1983	-302.1	-282
1984	-413.1	-363
1985	-335.2	-328
1986	-305.4	-284
1987	-327.2	-336
1988	-448.5	-450
1989	-334.4	-326
1990	-348.5	-381
1991	-398.4	-409
1992	107.3	67
1993	-392.9	-421
1994	-523.3	-565
1995	-387.5	-384
1996	-370.3	-365
1997	-452.3	-416

1998	-424.2	-472
1999	-523.2	N/A
2000	-295.0	N/A
2001	-381.3	N/A
2002	-599.5	N/A
2003	-322.7	N/A
2004	-441.9	N/A
2005	-288.1	N/A
2006	-608.6	N/A

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Appendix 1: Estimation of Catchment inflows.

DWLBC	Surface	Water	Archive	HYANN	V59	Output	18/02/2008
Site	A4260504	FINNISS RIVER @ 4Km East Of Yundi					
Variable	151	Stream Discharge Volume in Megalitres,					
Year	Annual	Days	Rank	Estimated end flow all catchment from Finniss Ranked Sheet			
	Total (Megalitres)	Missing					4.6356
						ML	GL
1969	10210	65	33	47330	Disregard too many days missing		
1970	24160		20	111996.8			112
1971	56420		1	261542.1			262
1972	11080	6	29	51362.8			51
1973	30300		13	140459.5			140
1974	37710	27	6	174809.5			175
1975	26460		17	122658.7			123
1976	10940		30	50713.8			51
1977	12180		27	56461.9			56
1978	28260		14	131002.8			131
1979	33440		10	155015.4			155
1980	8193		34	37979.7			38
1981	44540		4	206470.9			206
1982	4337		38	20104.7			20
1983	22610		22	104811.5			105
1984	24700		19	114500.0			115
1985	19130		25	88679.6			89
1986	46720		3	216576.5			217
1987	39860		5	184776.1			185
1988	28020		15	129890.3			130
1989	31650		11	146717.6			147
1990	33680		9	156127.9			156
1991	27670		16	128267.8			128
1992	53660		2	248747.8			249
1993	18040		26	83626.7			84
1994	5561		37	25778.7			26
1995	31240		12	144817.0			145
1996	35280		8	163544.9			164
1997	10690		31	49554.9			50
1998	11440		28	53031.6			53
1999	10320		32	47839.7			48
2000	36440		7	168922.3			169
2001	25550		18	118440.3			118
2002	5755		36	26678.0			27
2003	22920		21	106248.6			106
2004	20670		23	95818.4			96
2005	20390		24	94520.4			95
2006	6710		35	31105.1			31
2007	2775	196	39	12863.9	Disregard too many days missing		
Total	29700	294					
Minimum	2775						
Maximum	56420						
Mean	23840						
Median	24160						

Appendix 1: Catchment Inflows

Finniss flow close to Yundi									
Year	Annual Flow	Days Missing	Ranking						
1971	56420		1						
1992	53660		2						
1986	46720		3						
1981	44540		4				Top 10% say		
1987	39860		5				Using factor highest 10 % is	184.78	
1974	37710	27	6						
2000	36440		7						
1996	35280		8						
1990	33680		9						
1979	33440		10						
1989	31650		11						
1995	31240		12						
1973	30300		13						
1978	28260		14						
1988	28020		15						
1991	27670		16						
1975	26460		17						
2001	25550		18						
1984	24700		19				Say median is 1984 (18th of 36)		
1970	24160		20				If 114.5gl is median on whole catchment flow		
2003	22920		21				Then factor is $114.5/24.7 =$	4.6356	
1983	22610		22						
2004	20670		23						
2005	20390		24						
1985	19130		25						
1993	18040		26						
1977	12180		27						
1998	11440		28						
1972	11080	6	29						
1976	10940		30						
1997	10690		31						
1999	10320		32						
1969	10210	65	33						
1980	8193		34						
2006	6710		35				Bottom 10% say		
2002	5755		36				Using factor lowest 10% is	31.06	
1994	5561		37						
1982	4337		38						
2007	2775	196	39						

Appendix 1: Catchment Inflows

Lower Murray River						
Estimate of Eastern Flowing Streams of the Mt Lofty Ranges connecting to the Murray River.						
All flows are Annual						
	Current Flow					
System	Mean (ML)	Median (ML)				
Burra	-	-				
Marne	3,528	2,616	}	}	10%	Marne & Eastern Hills
Eastern Hills	12,420	9,210				
Bremer	25,807	22,317	}	49,807	Total inflow % from these 4 rivers	44%
Angas	18,113	15,664				
Finniss	44,452	45,704	}	64,216	The Finniss alone contributes	40%
Tookayarta	11,647	11,410				
Currency	7,249	7,102				
Total of Eastern Flowing Streams	123,217	114,023		114,023		

APPENDIX 2: Excerpt of related topics from draft Information Sheet

What is the Natural Water Balance of the lakes system?

A water balance measures the difference between input and output flows from the system.

The components of the Natural Water Balance for the Lower Lakes, include: rainfall and inflows from the local catchments (Finniss River, Currency Creek, Tookayerta, Bremer River, Angas River and Marne-Rodwell River) and local lake shore groundwater and surface flows (which are hard to quantify and therefore not included in figures below) and losses due to evaporation.

An estimate of the Natural Water Balance (before considering River flow into the lakes or from the lakes over the barrages or consumptive use) carried out for the period 1970 to 2006 by investigators independent of government , but using government supplied data, has arrived at the figures below for the Water Balance of the Lower Lakes:

All quantities in GL	Median Year	Best Year (1992)	Worst Year (1982)
Rainfall	Na	570	204
+ Catchment Inflow	Na	249	20
+ Lake shore surface run-off	Na	Unknown	Unknown
+ net groundwater inflows	Na	Unknown	Unknown
- Evaporation	Na	711	932
Water Balance	-396 GL	+107	-707

Essentially this means that River Murray flow into the lower lakes (before any extractions and without any flow out of the lakes over the Barrages) needs, in a median year, to be in the order of 396 GL in order to maintain the Pool Level of the lakes

Analysis of the same period indicates the following median values: Rainfall inflows-330GL (range 204 to 570GL), Local Catchment Inflows-114GL (range, 20 to 262), Evaporative Losses-852GL (range 962 to 711).

Note that:

- these figures are based at a Lake level of 0.75 AHD and that at lower lake levels the water balance is more responsive to catchment and rainfall inflows. At current low lake levels (with a reduced lake surface area): evaporation from the lakes is less while rainfall and catchment inflow remain about the same, meaning that the Natural Water Balance (to maintain existing level) of the lakes improve. This means we can expect lake levels to rise by than normal if we have normal winter inflows. Using the same climate data as in the table above but starting at a lake

- AHD of -0.5M, where the surface area is 677.87 sq km we get the following results: Natural Water Balance median -247 GL(ranging from +231 to -546)
- catchment inflows have been modelled from median inflows of 114GL. It has been suggested that median inflow could be as little as 40GL per annum which would reduce catchment inflow for 1992 to 88GL and 2006 to 11GL. If this is the case then Water Balance for 1992 and 2006 would be -53GL and -609GL respectively. Anecdotal evidence tends to confirm that 1992 catchment flows were of a very high magnitude.
 - Net groundwater inflow or outflow from the lakes has not been determined, some researchers say that it is likely to be insignificant and others possibly not, due to high water tables about the lake.
 - Lake shore run off has also not been quantified but again some researchers indicate it could be significant.

To get an operating water balance (Complete Water Balance) for the lakes, River flows in and out of the lakes as well as extractions (consumptive uses such as irrigation, stock and domestic use, etc) from the lakes would need to be considered.

Is this Natural Water Balance Data and approach agreed by all?

No, DWLBC using BIGMOD (the only independently audited and accredited daily flow and salinity routing model: developed for the MDBC) prefer to use the term System Losses or Evaporation and Losses. On this basis DWLBC say that Lakes average loss is 750GL (compared with the 396GL median loss calculated by the Natural Water Balance as discussed above) and the river from Lock 1 to Wellington is about a 100GL loss.

System Losses are calculated from:

Flow into SA – flow over Barrages –consumptive uses = System Loss

System Loss is then apportioned between above and below lock1 based on surface area of water.

What is the difference between Water Balance and Evaporation?

Evaporation is just one of the components of the Water Balance. It is misleading to quote evaporation losses alone without considering all other components of the Natural Water Balance which in most years considerably reduce the net quantity of water lost from the lakes.

What is E_{pan} ?

The standard way to daily measure of the amount of evaporations is measure the depth/height of water lost from an internationally recognised 'A Class evaporation pan'; a metal pan 1.2metres in diameter and 0.3 metre deep and adjust the reading for any precipitation that may have occurred since the last reading.

Why is E_{pan} reduced by a coefficient to work out actual evaporation and why does it vary?

While the evaporation pan is a standard way to make the measurement, it doesn't directly measure the amount of water evaporating from the surface of say Lake Alexandrina or say a green lawn. A raft of factors have been determined to adjust raw

E pan measurement to provide a better estimation of the evaporation that is actually occurring off that particular surface. These factors are called Pan Coefficients . The Pan Coefficient for a lake is generally reported in the Literature to be in the order of 0.7 Vincent Kotwicki in 1992 found that the Pan Coefficient for Lake Alexandrina over the years 1990 to 1992 was 0.67.

Epan measurement x Pan Coefficient = Estimated Evaporation

How much water evaporates from the Lower Murray and Lakes?

At pool level (0.75 AHD) and over the period 1968 to 2006 estimated evaporation varied between 711GL and 962 GL per annum with a median of 852GL from the lakes and about 125 GL per year from the river channel below Lock 1. To demonstrate the importance of Lake level (and therefore lake area) at the current level of approximately 0.5AHD evaporation over the same period of time, would range between 588 and 795GL with a median value of 704GL. A considerable reduction in evaporation than occurs at Pool Level.

DRAFT