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

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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 form 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 Finniss 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 m^3 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, 1475m 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 b 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:

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

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 Kp 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 10ºC and values near 0.6 when the temperature was closer to 40ºC.

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 the 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	Missing				4.6356
		(Megalitres)					
						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					
	Mean	**Median**				
System	**(ML)**	**(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**		The Finniss alone contributes		40%
			64,216	Total inflow % from these 3 rivers		56%
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 lock1based 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)l 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.