Monitoring Large Scale Storages in an Irrigation Environment

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ABSTRACT:

Goulburn-Murray Water, Australia's largest irrigation authority, manages fifteen storages for irrigation and domestic purposes. Each of these storages is monitored for deformation twice yearly, at the beginning and end of the irrigation cycle. Theoretically this invokes maximum and minimum levels in the storages, consistent with changes in operating procedures and variances in soil mechanics.

The methods of surveillance of the storages has changed in the last ten years in accordance with improvements in surveying technology, updated calibrations of the storages and improved methods of evaluating results. The need to increase the audit of information on storages has been at the forefront of increased expenditure in this area.

The traditional method of measuring deformation or movement at various storages using a theodolite and level has in most cases been surpassed by use of GPS and electronic level or Total Station and electronic level. This is not to demean the previous methods which have produced very good results, but allows more points to be observed with greater accuracy in more remote positions. In addition, during the last ten years the storages have been at historically low levels, exposing upstream monitoring points, thus providing a true deformation model. Newer techniques have been employed to survey these points.

This paper explores some of the history of deformation surveys, the use of newer technology, the importance of information for storages and the management and evaluation of data. It incorporates the survey aspect and the dam engineering reports and evaluations. Input in this paper will come from a number of sources, experience surveyors and dam safety engineers.

Finally discussions will be presented on improvements that can be made to existing procedures in order to maximise results in the future as increased pressure is put on organisations to manage not only the water reserves but the safety of these resources.

1. INTRODUCTION

Large scale storages established fundamentally for irrigation works in Victoria, Australia, have been in existence for at least 100 years. The majority of storages for this activity are located in north eastern and central Victoria and come under the operation of Goulburn-Murray Water, the largest irrigation authority in Australia. Two of the largest storages in Australia are located in this area; Lake Eildon (capacity 3,334,158 ML) and Dartmouth Dam (3,856,232 ML).

Fig. 1

Goulburn-Murray Water

Fig 1 and Appendix 1 detail the other storages in the system and current capacities. Hume Dam which is shown in Appendix 1 is operated by New South Wales, although it is a major supplier of irrigation water to Victoria.

ANCOLD (Australian National Committee on Large Dams) defines large scale dams as **"having a crest or wall height of greater than 15 metres, or as dams with a dam wall height of greater than 10 metres but meeting other size criteria as follows:**

- **having a crest more than 500 metres in length**
- **creating a reservoir capacity of no less than 1000 megalitres**
- **the ability to deal with a flood discharge of no less than 2000 cubic metres per second**
- **Being of unusual design."**

On this basis even the smallest storage Hepburn's Lagoon (2457 ML) fits some of the criteria above, although it could not be considered a large dam in the context of Dartmouth or Eildon. The criterion of "unusual design" is usually kept for large scale buildings, where different architectural styles are the norm. Perhaps this is an impending feature, should any new storage be built in this part of the world. Watch this space!

It should be noted at this point that all the storages are earthen walls, with concrete spillways, while a number have secondary embankments/ spillways to prevent over topping during flood events. Recently in Victoria at least two of the storages experienced catastrophic flood events (Eppalock and Laanecoorie) realising significant damage to secondary embankments. Appendix 2 shows a number of photos of damaged secondary embankments.

Regardless of the size of the storage, it has been necessary and continues to be necessary to monitor the structure for movement, both vertical and horizontal. Different methodologies are used at different storages to reflect the measurements required for monitoring movements. At the end of the day, trends are developed for each storage, thus providing guidance on the stability of the storage.

The storages have been monitored since construction with the exception of some of the smaller storages. However, changes in safety legislation and standards now require that the majority of the storages be monitored for movement, twice yearly. Traditionally this occurs at the end of the irrigation season, when storages are theoretically at their lowest, and prior to the start of the irrigation season when they are again theoretically at their highest. If we were trying to predict highest and lowest over the last ten years or so, we would be considered geniuses in the meteorology industry.

This paper explores some of the history of deformation surveys, the use of newer technology, the importance of information for storages and the management and evaluation of data. It incorporates the survey aspect and the dam engineering reports and evaluations. Input in this paper will come from a number of sources, experience surveyors and dam safety engineers.

This is not to say that as surveyors with Goulburn-Murray Water we are unsurpassed in this area. It is an area, like most surveying, that is continually evolving with new technology and ideas and it may be a case of "the best is yet to come."

2. A SHORT HISTORY LESSON

The method established for monitoring storages last century was based on the offset practice and levelling the points from known marks on either side of the storage. This involved using an offset bar with a tape fastened to it, measuring the offset with a theodolite (traditionally a Wild T2) and comparing the observation with past observations of the same point. The points were then levelled from known benchmarks on one side to known marks on the other side and again compared to previous readings. In addition recovery marks were used as a check that the observation pillar had not moved, thus compromising the readings.

The processes were well thought out and with experienced operators; the whole process was completed in the shortest possible period. For example both Dartmouth and Eildon took approximately 4 days to complete, working an 8 to 10 hour day, depending on the time of year and conditions.

The advantage of this method was that it was a smooth operation and results were immediate. Offset sheets and levels were reduced prior to leaving the site, which meant that office time on return was kept to a minimum. ***More time for other jobs!***

Figure 2 shows the type of activity that took place and continues to take place at Dartmouth

Fig. 2

Dartmouth Dam – Mid Berm Offsets

This picture shows the old and the new of some of the surveillance at Dartmouth. The offset bar is set over the point and observations (2 face left and 2 face right observations) taken. The new component of the process is the walkway which was built to minimise potential injuries whilst walking across the rocks (the old way). Thus the walkway has improved the time taken to walk between points and greatly improved the safety aspect.

However, it should be remembered that experienced operators, both on the instrument and on the offset bar can cover a significant number of points in a standard day of observations. The "old method" should never be discarded for the sake of a new "fashionable" method.

It should be noted that Dartmouth is only one of a few storages that have a rock face. Eildon for example has a grassed face with easy access to the points along well formed berms, thus making the observation process safer and potentially faster.

Figure 3 below gives a very good view of the observation process, with the Wild T2 theodolite setup on an observation pillar.

Fig. 3

Dartmouth Dam – Observation pillar on lower berm.

One of the more unfortunate scenarios with these observation pillars is that they are set on ground which was filled after the completion of the dam. Over time this has resulted in some slippage of the pillars thus affecting the observations. Hence it was necessary to establish points on the far side of the storage that could be used to check movement of the pillars. These points are known as Recovery Points and are shown in Figure 4 below. Due to the nature of the rock in the area, mesh has been erected as a safety precaution to stop falling rocks impacting on cars driving past.

Fig. 4

Dartmouth Dam – Recovery Points on Right Abutment

Thus every effort has been made to ensure the integrity of the points and observations and ultimately the results transmitted to engineering staff.

Thus this basic approach has been adopted at all storages as a means of obtaining the necessary information for assessment of the state of the storages.

3. CHANGES TO EXISTING PRACTICES – FOR BETTER OR WORST!

Sometimes the need for change becomes overwhelming and the urge to do something better with new technology commences a change for better or worst. The advent of GPS, new instrumentation such as Robotic Total Stations, Digital Levels and even younger fitter staff, created a movement for change away from the original methods employed at storages. This is not to say that everything was thrown out and the new took over, but looked at how new technology could start to improve the methodology used and provide those dreaded productivity gains everyone is asked to produce from time to time.

OH&S requirements for safer environments also causes change and this can be seen in the construction of the walkways at Dartmouth. Gone are the days of clambering over rocks. Surprisingly very few injuries occurred during surveillance as staff members were ever vigilant.

New technology has allowed surveyors to implement change in such a way as to improve the way information is collected and processed for the end user. It also means that considerable thought has to be given to the way measurement is taken, using angles rather than offsets, using continuous measurements rather than offsets, GPS measurements rather than offsets and digital level information recorded onboard rather than recording everything in a level book or data manager such as a Palmtop Calculator.

Let us consider changes to practices at both Dartmouth and Eildon and determine if these new practices are enhancing the work.

3.1 Dartmouth

Dartmouth is an interesting one for implementation of change because of the surrounding topography. The embankment is located typically across a valley (North North East direction) with a heavy cluster of forested area adjacent and above the embankment. Therefore it is not overly visible to a wide part of the sky as Figure 5 below demonstrates; the hills on either side probably rise about 100 metres to put it into perspective. Note also the lines across the dam in relation to the forested areas on either side and appreciate the difficulties in the use of GPS at the end marker points.

Fig. 5

Dartmouth Dam – Overhead shot from Google

The disadvantage in the early periods of GPS was that the available configuration was not conducive to the required level of accuracy. However, with the expansion of the GPS network using GLONASS and other available systems the necessary configurations can be achieved to deliver the required accuracies necessary for dam monitoring, as least in the X – Y direction. This is based on using RTK technology with observation times on surveillance points of 3 minutes or 180 epochs.

However, it is not possible to observe the end points of the traditional observation points due to their proximity to trees. Therefore it is necessary to provide the movement relationship with other criteria such as movement upstream and downstream of imaginary lines. The results are presented in a similar way to previous results as offsets and elevations.

The results will be discussed in the next section. Suffice to say at this point is that GPS is being used over the traditional offset and level method and providing results comparable to the older established method.

The GPS method used is RTK, as VRS or GNSS (names keep changing) is not suitable as telephone contact is not available in this part of the country due to lack of demand.

3.2 Eildon

Eildon like Dartmouth was monitored using levels and offsets, again perfectly reliable for an earthen wall. However, as Eildon is in a much more open environment it was open to a variety of different methods. For example, GPS, radiations or even retaining the older system. As a way of reducing staff commitments, the use of GPS was considered a method that would provide results commensurate of previous methods

Figure 6 below shows the location of Eildon in relation to the surrounding topography. Looks similar to Dartmouth but the hills on either side are less imposing. The batters are appreciably more open to the sky than Dartmouth and lend itself more to GPS than Dartmouth does.

Fig. 6

Eildon – Overhead shot from Google

Unlike Dartmouth it is possible to use the GNSS process for the location of the monitoring points. However, it has been decided that RTK is a better option providing more reliable results. Also access to points is quicker at Eildon than Dartmouth as it is possible to drive along the berms to nominated points.

At this stage it is important to remember that Eildon has recently been reconstructed to bring it up to modern standards and enhance its earthquake capabilities. It was built in the 1950's in a time when earthquakes were not deemed to be all that important, given the stability of the Australian continent. However, standards have changed and improvements made. This approach has been adopted on all storages within Goulburn-Murray Water.

4. RESULTS – HOW DO THE VARIOUS METHODS COMPARE?

Changes in methodology are really tested when it comes to a comparison of results. In using the offset and level method of observations the comparison between the current and previous results can be compared immediately, and any significant changes in position (horizontal and vertical) can be commented on.

Not so with current GPS methods, unless you have immediate on line processing. The results are computed and evaluated the following week once the party has returned from the field. Thus the up side of the monitoring is using new equipment techniques; the current downside is not having the results immediately. The defining issue here is that we are dealing with earthen walls and not a concrete structure, for example, where a slight change could have immediate repercussions.

Below are two sets of results taken at Dartmouth using two different methods:

Figure 7 shows a section of field observations and results for levelling of Surface Settlement points. This survey was undertaken in May 2005 (Water Level = 444.48 AHD) when the storage was at its theoretical lowest after the irrigation season. The current level is approximately 467 metres AHD which presents a significant increase over the 2005 level. Surveillance will commence in the coming weeks so it is possible to make a direct comparison between the years.

The levelling information was entered directly into the electronic field book and reduced. The levelling procedure of marks has not changed with the use of GPS as it is considered the most reliable approach to measurement of vertical movement. However, electronic levels and bar coded staffs have taken over from the Automatic Level and traditional staff.

Figure 8 shows the same section of field observations and reductions for the autumn period of 2011. Figure 9 shows to the relationship between the two sets of readings for the same settlement points, and indicates the differences between the readings over that period of time. It is important to recall that over the summer period of 2010/ 2011 Victoria Australia experienced exceptional rainfall, which resulted in numerous flood events across the state. Therefore the water level against the wall rose significantly during this period, resulting in extra pressure against the wall.

The important aspect of the results are the trends established over the years and what are the parameters set before the alarm bells begin to ring. Over the last 10 years the weather pattern has changed considerably and extended periods of dry have occurred. This has resulted in the levels in the storage dropping to the lowest levels and this has an effect on

BACK	INTER	FORE	RISE / FALL	ELEV	DESCRIPTION	ADOPT
				*		
0.3653				432.4760	SR87N21	
0.8053		2.2463	-1.8810	430.5950	CP9-16	
	3.3241		-2.5188	428.0762	**TS8 RA**	**428.076**
	3.3118		0.0123	428.0885	**TS8 LA**	**428.089**
0.7609		1.1860	2.1258	430.2143	**SSP16**	**430.215**
0.7338		1.2356	-0.4747	429.7396	**SSP15**	**429.740**
1.2047		1.1375	-0.4037	429.3359	**SSP14**	**429.337**
	0.4655		0.7392	430.0751	**TS5 RA**	**430.076**
	0.4558		0.0097	430.0848	**TS5 LA**	**430.086**
1.1358		1.2547	-0.7989	429.2859	**SSP13**	**429.287**
0.9579		0.6220	0.5138	429.7997	**SSP12**	**429.801**
1.0100		0.4735	0.4844	430.2841	**SSP11**	**430.286**
0.5761		0.2797	0.7303	431.0144	**SSP10**	**431.016**
1.7330		0.4243	0.1518	431.1662	**SSP9**	**431.168**
		2.6575	-0.9245	430.2417	SR76J45	
			-2.2343	*		

Fig. 7

Dartmouth – Field Data and Results

the movement of the dam. When the level falls it moves upstream in accordance with design principles. When it fills as it is now, it will move downstream as the pressure increases against the wall. This is not rocket science but normal practice. However, if the parameters are exceeded than it may be necessary to resurvey the settlement points as a precaution.

Dartmouth Dam Surveillance

2011 June

Observation Dates= From 23/05/2011 to 27/05/2011

Date :	23/5/2011 to 27/05/2011	Terminal Structure Elevations						**RECOVERY POINT**	OFFSET mm	Adj/Offset	Previous Adj/Offset	Offset Diff
			Left Abutment	Right Abutment	Previous Surv. Date		15-19/11/10	SP N0.1-3	0.000	0.000	0.000	0.000
Res. Level:							451.66	SP N0 4-8	0.000	0.000	0.000	0.000
1	461.43	T.S.No1					451.84	SP N0.9-16	0.000	0.000	0.000	0.000
2	461.47	T.S.No2	351.608	351.603	Previous Res.Level:		451.99	SP N0.17-26	0.000	0.000	0.000	0.000
3	461.49	T.S.No3	371.248	371.209			452.11	TS No.3	0.000	0.000	0.000	0.000
4	461.50	T.S.No4	399.858	399.864		CS 1-12	0.000	TS No.5	0.000	0.000	0.000	0.000
5		T.S.No5	430.070	430.060	Pillar.adj:	SSP 1-3	0.000	**Slope Indicator Point**				
Surveyors	M. Vithanage	T.S.No6	459.945	459.983	(m)	SSP 4-8	0.000	**X**	5,004.374			
	Harold B.	T.S.No7				SSP 9-16	0.000	**Y**	10,553.995			
	Patrick D.	T.S.No8	428.082	428.061		SSP 17-26	0.000	Elevation	493.609			

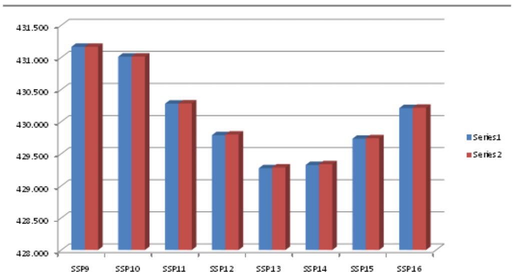
POINT No.	Res.Lev	OFFSET (metres)	Adj/Offset	Previous Adj/Offset	Offset Diff	Elevation (metres)	Previous Elevation	Elev. Diff	Running Distance	Prev/Running Distance	R.D.. Diff
SSP1	3	-1.330	-1.330	-1.329	**-0.001**	370.245	370.240	**0.005**			
SSP2	3	-1.227	-1.227	-1.223	**-0.004**	369.736	369.732	**0.004**			
SSP3	3	-1.336	-1.336	-1.339	**0.003**	369.756	369.753	**0.003**			
SSP4	3	-1.119	-1.119	-1.135	**0.016**	400.380	400.377	**0.003**			
SSP5	3	-0.442	-0.442	-0.437	**-0.005**	399.432	399.429	**0.003**			
SSP6	3	-0.494	-0.494	-0.499	**0.005**	399.349	399.346	**0.003**			
SSP7	3	-1.038	-1.038	-1.036	**-0.002**	399.744	399.742	**0.002**			
SSP8	3	-0.906	-0.906	-0.907	**0.001**	399.789	399.787	**0.002**			
SSP9	3	-4.147	-4.147	-4.142	**-0.005**	431.165	431.164	**0.001**			
SSP10	3	-3.857	-3.857	-3.863	**0.006**	431.011	431.011	**0.000**			
SSP11	3	-3.356	-3.356	-3.358	**0.002**	430.279	430.279	**0.000**			
SSP12	3	-3.438	-3.438	-3.447	**0.009**	429.787	429.788	**-0.001**			
SSP13	3	-2.459	-2.459	-2.464	**0.005**	429.272	429.273	**-0.001**			
SSP14	3	-2.561	-2.561	-2.550	**-0.011**	429.322	429.324	**-0.002**			
SSP15	3	-2.391	-2.391	-2.379	**-0.012**	429.730	429.733	**-0.003**			
SSP16	3	-2.907	-2.907	-2.908	**0.001**	430.207	430.210	**-0.003**			
SSP17	3	-1.920	-1.920	-1.922	**0.002**	459.885	459.894	**-0.009**			
SSP18	3	-1.444	-1.444	-1.449	**0.005**	459.511	459.520	**-0.009**			
SSP19	3	-1.466	-1.466	-1.473	**0.007**	459.456	459.465	**-0.009**			
SSP20	3	-1.610	-1.610	-1.617	**0.007**	458.824	458.834	**-0.010**			
SSP21	3	-1.392	-1.392	-1.385	**-0.007**	458.222	458.233	**-0.011**			
SSP22	3	-1.561	-1.561	-1.567	**0.006**	458.374	458.384	**-0.010**			

Fig. 8

Dartmouth – Field Data and Results

This was the case in the 1990's when Dartmouth experienced a minor earth tremor, whilst the actual surveillance was being undertaken and so additional surveys were requested to test for any significant movement. Fortunately no extra movement was found which was important for me as I was involved in the surveillance at the time. Nowhere to hide in Dartmouth if the wall failed!

Point	Jun-11	23-May-05	Diff
SSP9	431.164	431.164	0.000
SSP10	431.011	431.012	0.001
SSP11	430.279	430.282	0.003
SSP12	429.788	429.798	0.010
SSP13	429.273	429.285	0.012
SSP14	429.324	429.336	0.012
SSP15	429.733	429.740	0.007
SSP16	430.210	430.215	0.005



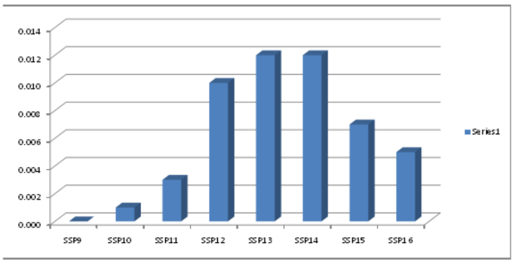


Fig. 9

Dartmouth – Comparison of results.

(Notice the bell shape curve about the centre of the wall

Which would be expected as the storage fills)

Due to time and space I have chosen only to review measurements at Dartmouth and not at Eildon, although I would expect similar results.

5. WHERE TO FROM HERE?

It is the obvious question to all involved in this type of survey. What improvements can be made to either make it simpler and/ or more efficient in order to provide the best results, but at the same time reduce the cost? Let's see if we can have our pie and eat it too.

Continuous monitoring of walls is an option for reducing the input and costs of human intervention, although some input is needed to keep the system going. This would involve establishing high accurate prisms at each surveillance point and monitor those using GPS methods or Robotic Total Station methods or a combination of both. Now in doing this there are a number of significant costs involved, namely:

Total Station

- Purchase of high accurate and stable 360° prisms.

- Purchase of Robotic Total Stations. A minimum of 2 required for cross checking, particularly elevations.

- Establishing stable measuring structures over points.

- Providing vandal proof housing for Total Station and prisms

- Establishing a computer network to the Total Station and online computing facilities for information.

- Purchase of enough computing power to service continuous monitoring.

- Invest in local staff to monitor system.

GPS

- Purchase GPS receivers for all the surveillance points. Upwards of 40 required.

- Purchase of Base Station.

- Providing vandal proof housing for Base Station and receivers.

- Establishing a computer network to the Base Station and receivers and online computing facilities for information.

Fig. 10

Dartmouth – GPS base stations and surveillance lines

The bottom downstream line suffers from a limited view of the sky and it has been mentioned that the points need to be observed a number of times in order to obtain a consistent value.

The jury is still out on whether this method is providing increased value against output, compared to previous systems. Having to visit each point twice for a period of 3 minutes to ensure the required level of accuracy means we are going over old territory, which is a taboo for surveyors priding themselves on getting the job done quickly, effectively and without revisiting the site.

- Purchase of enough computing power to service continuous monitoring.

- Invest in local staff to monitor system.

Without detailing the costs for all of this equipment, it goes without saying that this would be an expensive exercise. Is it worth it and what additional benefit would be achieved by going down this path? This question is posed in light of the storages in Dartmouth and Eildon being earthen walls and not concrete, like Hoover Dam in the United States, where continuous monitoring is required for a wide range of reasons.

The present day cost of undertaking surveillance at Dartmouth is $24,000 and takes 5 days to complete in the field and two days to reduce in the office. Eildon is $11,000 and takes 4 days to complete in the field and 1 day in the office to reduce. How many years would it take to recoup the investment costs and would there be a significant gain in investment?

In discussing this with the surveyors involved and from my own experience of undertaking such monitoring, it is highly unlikely that there would be a positive return on investment. Even the current returns on moving to GPS at Dartmouth are questionable because of the challenging aspects of GPS coverage as the following sketch shows:

As GPS technology continues to improve it may not be necessary to revisit points and the level information obtained provides the level of accuracy that is achieved through levelling with a level and staff. GPS has come a long way in a short period of time!

6. FINALLY

What I have attempted to achieve in writing this paper is to present a report on surveying methodology for two of Australia’s largest water storages, and in particular two of the largest storages used for irrigation. Dartmouth and Eildon hold a significant amount of storage capacity which supports not only irrigation in Victoria but also in New South Wales and South Australia. In addition environmental flows form a considerable contribution from these storages.

Monitoring of storages across Victoria and in particular Goulburn-Murray Water form a significant part of the workload of the Survey and Draughting team of Goulburn-Murray Water. Along with a significant workload comes a significant cost, and it is this cot which is forcing the team to evaluate and use newer methods such as GPS. Results obtained so far and highlighted in the paper suggest that the newer technologies are providing as good as accuracies as older methods. However, only time and experience will tell in the end and it is possible we will have moved from one generation of surveyors to another in that time period.

The cost involved in going to the next step of continuous monitoring seems to be a big one, one that at this stage cannot be justified for the investment involved. It is not certain that any information collected will provide any more information and given the nature of the earthen structures can it be justified.

Continuous tinkering around the edges may the correct direction to take rather than large scale forays into newer technology as it becomes available. We have been blessed by advances in technology and taken advantage of it in employing new techniques. Perhaps we are better off investing in the education and training of staff to further enhance the benefits of this new technology.

Appendix 1 – Storage Levels (26 September 2011)

- Catchments
- Water Storages
- Storage Levels
- Surface Water
- Groundwater
- Rainfall Reports

● MDBA Assets
● Managed by NSW State Water

Click a storage name for full details including tourism info and recreation facilities.

Storage	%Full	Current Volume (ML)	Current Level (mAHD)	Capacity at Full Supply Level (ML)	Full Supply Level (mAHD)	Weekly Change in Storage (ML)	Weekly Change in Storage (%)	Volume Same Time Last Year (ML)	%Full Same Time Last Year	Storage Trace
Murray Storages										
Dartmouth Dam●	71.92	2773576	467.81	3856232	486.00	10714	0.28	1756841.74	45.56	Graph...
Hume Dam●●	97.29	2923818	191.59	3005157	192.00	-19619	-0.65	2446296.80	81.40	Graph...
Yarrawonga Weir●	99.37	116762	124.88	117500	124.90	5445	4.63	110522.31	94.06	Graph...
Torrumbarry Weir●	100.02	36817	86.05	36810	86.05	0	0.00	34952.32	94.95	Graph...
Mildura Weir●										Graph...
Third Lake	97.14	2720	74.58	2800	74.60	181	6.47	2856.96	102.03	Graph...
Reedy/Middle Lakes	97.50	5850	74.87	6000	77.00	77	1.29	6084.61	101.41	Graph...
Kangaroo/Racecourse	96.77	37935	73.78	39200	73.90	1181	3.01	35590.00	90.79	Graph...
Kow Swamp	93.22	48206	83.00	51710	83.13	2593	5.02	50048.45	96.79	Graph...
Lake Boga	81.48	30148	68.68	37000	69.50	-185	-0.50	0.00	0.00	Graph...
Lake Charm	88.59	19490	73.42	22000	73.90	-150	-0.68	0.00	0.00	Graph...
Ovens Storages										
Lake Buffalo	76.19	17783	262.58	23340	264.45	2307	9.89	14468.40	61.99	Graph...
Lake William Hovell	100.42	13557	408.00	13500	408.14	-64	-0.48	13802.41	102.24	Graph...
Broken Storages										
Lake Nillahcootie	100.14	40458	264.51	40400	264.50	-82	-0.20	40566.50	100.41	Graph...
Goulburn Storages										
Lake Eildon	96.46	3216206	288.02	3334158	288.90	6196	0.19	1978200.00	59.33	Graph...
Goulburn Weir	99.43	25354	124.23	25500	124.24	1774	6.96	24267.59	95.17	Graph...
Waranga Basin	80.28	347092	119.83	432360	121.36	-17258	-3.99	410523.00	94.95	Graph...
Greens Lake	71.43	23215	101.12	32500	102.20	77	0.24	23060.02	70.95	Graph...
Campaspe Storages										
Lake Eppalock	98.47	299981	193.76	304650	193.91	-1442	-0.47	196166.25	64.39	Graph...
Loddon Storages										
Cairn Curran Reservoi	97.04	142778	208.22	147130	208.46	-274	-0.19	121316.00	82.45	Graph...
Tullaroop Reservoir	100.31	73173	222.83	72950	222.80	-37	-0.05	73434.85	100.66	Graph...
Laanecoorie Reservoir	95.44	7635	160.14	8000	160.20	-277	-3.46	6588.31	82.35	Graph...
Bullarook Creek Storages										
Newlyn Reservoir	100.11	2988	531.76	2985	531.78	-32	-1.06	3035.00	101.68	Graph...
Hepburns Lagoon	104.44	2566	516.15	2457	516.05	N/A	N/A	0.00	0.00	Graph...
Total	87.73	9979536		11375529						

mAHD = metres Australian Height Datum (metres above sea level) More information