Save the Mary River Technical Note Series

Save the Mary River - Research Team
C/- Post Office, KANDANGA Q4570
research@savethemaryriver.com
www.savethemaryriver.com

TN 1 Historical Mary River Flow Data and Implications for Downstream Flows from Traveston Crossing

D. Edward, B.Eng.(Hon), M.Eng.Sc. June 2006

Preface

This document provides a summary of statistical analyses of the recorded flow data published by the DNRM for the Dagun Pocket monitoring station (approximately 2 km downstream of the proposed Traveston Crossing Dam), and uses this analysis to evaluate flow criteria and statistics quoted in the DNRM Draft Water Resource Plan for the Mary Basin (Nov 2005).

Executive Summary

1. **Mean Annual Flow is a meaningless statistic for the Mary River.**

   The flow behaviour of the Mary River is characterised by:

   - Typically very low flow rates, with seasonal variation, and
   - Periodic "high flow" or flood events (often years apart).

   For example, over the 45 years of recorded flow at Dagun Pocket, 70% of the total water flow occurred in just 6% of the days.

   The mean (or average) annual flow rate (MAF) being used in the Mary River Basin Draft Water Resource Plan (WRP) is not a useful descriptor of the flow behaviour of the Mary River. In fact, mean annual flow rates quoted in public announcements of the downstream flow effects of the proposed Traveston Crossing Dam are worse than meaningless – they are misleading because they disguise potentially devastating effects on the patterns of downstream flows.

2. **The river ecology and downstream users will be severely impacted by the proposed dam**. The Draft Mary Basin Water Resource Plan minimum requirement of 70% of the pre-development flow at Fisherman's Pocket (35km downstream of the proposed dam wall) could be achieved by allowing the river downstream from the dam to run bone dry 94% of the time. If this proposed dam was managed to mimic the natural flow patterns downstream, it will not meet its yield targets. The State Government has said that the target mean annual flow downstream of the proposed dam will be 85% of the pre-dam flows. While this sounds reasonable, this could be achieved by letting the river downstream of the dam run dry 82% of the time (remember that most of the water in the Mary River flows during a very short period of time). Mean annual flows are a meaningless statistic in assessing impact on downstream flows. The median flow is a much more meaningful statistic (for 50% of the time, flows in the Mary River will be less than the median and for the other 50% of the time, the flow will be greater than the median). The median flow just downstream of the proposed dam is 103,000 ML per year. This is significantly less than the target yield of 140,000 ML. That is, for at least 50% of the time, more water will be extracted from the dam than

what flows in. This is without taking into account the huge evaporative losses from the dam, or any seepage losses through the deep layers of sediment under the dam. These are discussed in point 5 below.

3. **If an attempt was made to allow 85% of pre-development downstream mean annual flow on a regular basis at the dam site, the inflow will be insufficient to meet the target yield 90% of the time.** These flow levels may be achievable further downstream, but would rely on water coming in from other sub-catchments, not from water allowed to flow past the proposed dam.

4. **The dam will principally fill during periodic high flow flood events, precisely when SEQ's demand for water from the Traveston crossing Dam will be low**, because Wivenhoe's catchment area almost always floods at the same time as the Mary. In other words, the proposed dam will only fill to a level adequate to meet the target yield following a flood, when it will not be required since Wivenhoe will also have filled.

5. **Evaporation, seepage, sedimentation and climate change will all have huge additional effects on the performance of the dam and its effect on downstream flows, not accounted for in this analysis.** This analysis of historical flow data highlights significant concerns relating to the proposed dam's performance and its impact on downstream flows. Yet this analysis ignores four important factors that further decrease the yield and/or increase the downstream impact of this proposed dam:

   - **Evaporation**. Based on figures from the Bureau of Meteorology [4], the annual evaporation rate of 1440 mm/year combined with the dam surface area of 7600 Ha, predicts annual evaporation of 110,000 ML. This volume represents 1/6th of the total dam volume (of 660,000 ML), and nearly 80% of the annual target yield volume.

   - **Seepage.** The proposed dam is located in a shallow valley deeply infilled with alluvium (initial boreholes at the proposed dam site suggest a depth to bedrock of the order of 35 m). The alluvium will likely comprise layers of fine and coarse-grained sediments, corresponding to periods of low and high flow, respectively. While these will not be continuous, it would be expected that there would be preferred seepage paths through the foundation beneath the storage and beneath the dam wall, with preferential seepage parallel to the existing ground surface most likely. Seepage losses into the foundation could be in the range from 300 to 3,000 mm/year, or even higher, representing 1/30th to 1/3rd, or more, of the total dam volume, and 16 to 160%, or more, of the annual target yield [5].

   - **Sedimentation.** Sedimentation will impact in the long-term on the water storage capacity of this shallow storage. The sediment load, and sediment capture by the proposed dam, could be estimated by the SEDNET DNR modelling but this data is not included in the draft Mary Basin Water Resource Plan.

   - **Climate Change.** There is no guarantee that the historical data used in this analysis represents future conditions. In fact many experts believe that rainfall in the Mary River catchment is decreasing.

Daily Flow Data Set

The data set [1] contains daily flow measurements at the Dagun Pocket monitoring station (just downstream from the proposed dam wall site at Traveston Crossing) from 2nd February 1957 to 8th July 2002. The data set is contiguous except for a 21 day period in November 1990. It has been confirmed that this period (corresponding to 0.12% of the total data set) does not correspond to any unusual flow conditions and is therefore statistically insignificant.

Flow data are recorded in megalitres per day (ML/day).

Figure 1a below shows the daily flow data in ML/day versus time. Figure 1b shows the average (mean) and median daily flows for each month of the year.

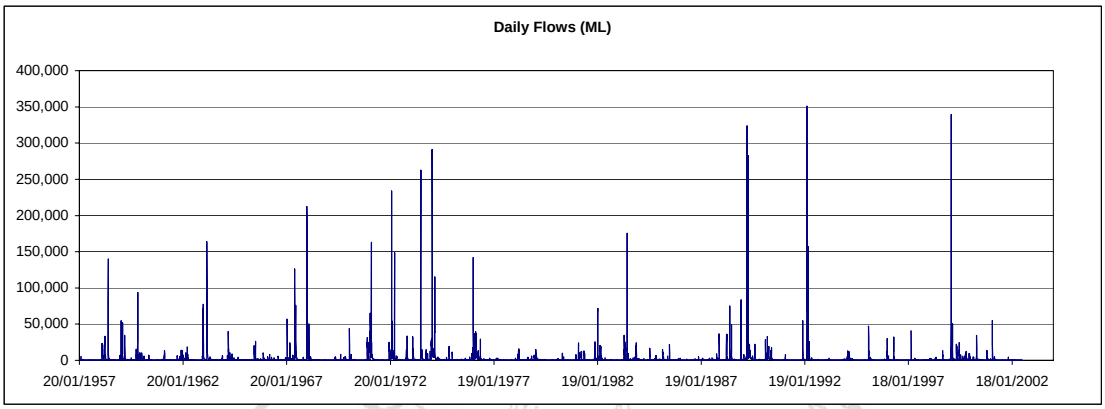


Figure 1a. Daily Flows (ML/day)

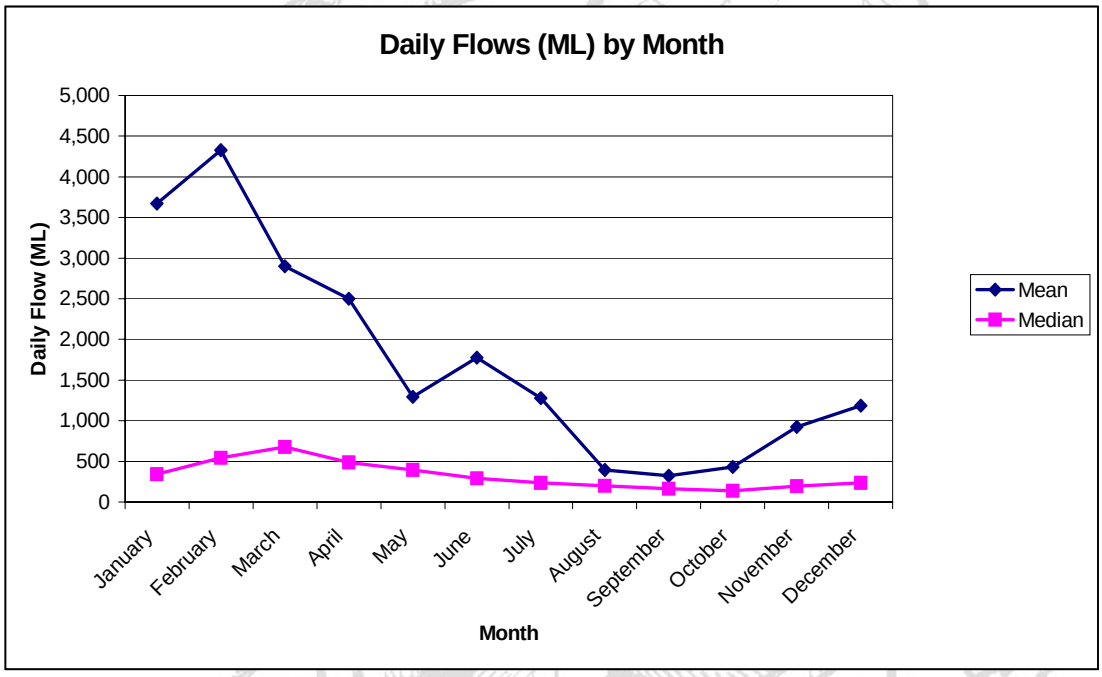


Figure 1b. Seasonal variation of daily flows

The average daily flow over the 45 year time period is 1,742 ML. This corresponds to an average annual flow of 636,000 ML.

It is immediately clear from Figures 1a and 1b that the average flow rate is not a useful or significant descriptor of the flow behaviour of the Mary River. A value of 1,742 ML/day is not discernable on the scale of Figure 1a. Rather, the flow behaviour of the Mary River is characterised by:

- Typically very low flow rates, with seasonal variation, and
- Periodic "high flow" or flood events, often years apart.

Statistical Analysis

Average flow rate is not a useful or significant descriptor of the flow behaviour of the Mary River.

A more meaningful descriptor is the median flow. Average (or mean) and median statistics are distinguished as follows:

- Mean refers to the numerical average of a data set. For instance the mean of the numbers {1,2,3,10,100} = (1+2+3+10+100)/5 = 23.2
- Median refers to the value for which 50% of the data is less than or equal to. For instance the median of the numbers {1,2,3,10,100} =3.

The median daily flow for the Mary River at Dagun Pocket is 281 ML/day, which corresponds to an average annual flow of 103,000 ML. ***This is significantly less than the target yield from the dam of 140,000 ML/year. So even when no allowance is made for factors such as evaporation, seepage and water requirements downstream of the dam, the target water yield is available less than 50% of the time.***

To examine the highly variable distribution of daily flows in more detail, a statistical tool called the *cumulative histogram* must be used. Figure 2 shows the cumulative time histogram for Dagun Pocket.

Figure 2 illustrates the interpretation of the histogram in two situations:

- 50% of the time, daily flow is less than or equal to 289 ML (median).
- 80% of the time, daily flow is less than or equal to 1060 ML.

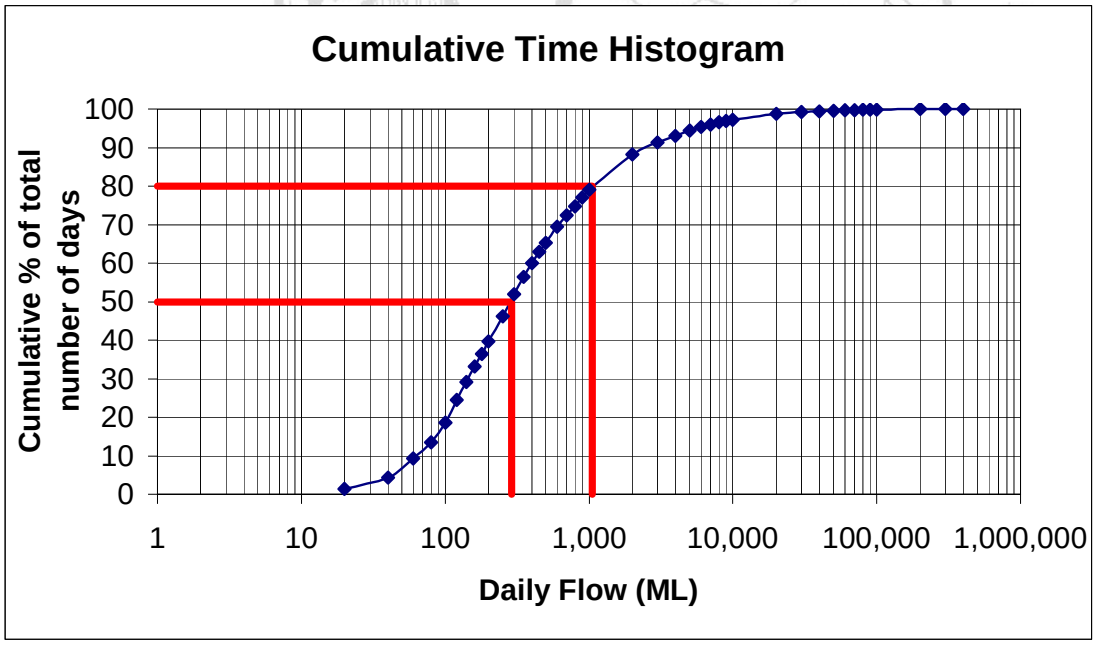


Figure 2 Cumulative Time Histogram

The target yield from the dam has been stated as 140,000 ML per year. This corresponds to a daily flow of 383 ML. Figure 2 shows that for 59% of the time, the historical flow at Dagun pocket is less than this value. ***So even when no allowance is made for factors such as evaporation, seepage and water requirements downstream of the dam, the target water yield is available only 41% of the time.***

It is also important to understand the flow behaviour in terms of total volumetric flow. This is achieved using the cumulative volume histogram, shown in Figure 3. As before, Figure 3 shows two examples illustrating the interpretation of this graph.

- Daily flows of less than or equal to 2,000 ML contribute just 20% of the total flow volume of the river.
- Daily flows of less than or equal to 9,000 ML contribute just 40% of the total flow volume of the river.

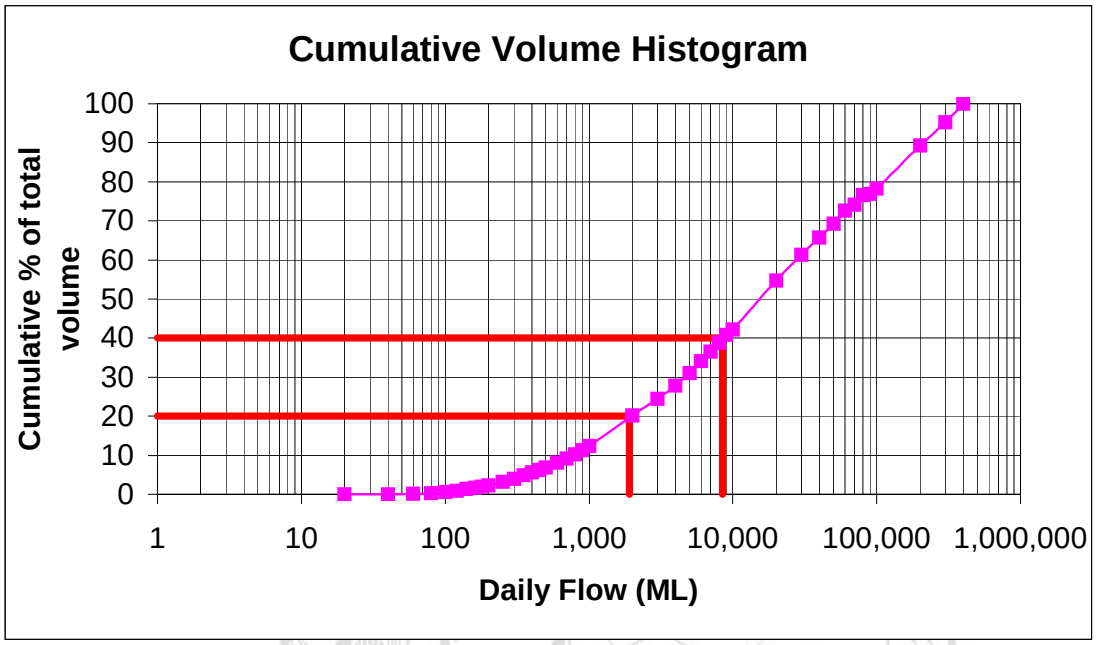


Figure 3. Cumulative Volume Histogram

Finally, the histogram calculations from Figures 2 and 3 can be combined to illustrate the relationship between cumulative flow volume and cumulative time (as shown in Figure 4).

As before, Figure 4. shows two examples illustrating the interpretation of this graph:

- The 82% lowest-flow days contribute just 15% of the total flow volume (alternatively the 18% highest-flow days contribute 85% of the total flow volume).
- The 94% lowest-flow days contribute just 30% of the total flow volume (alternatively the 6% highest-flow days contribute 70% of the total flow volume).

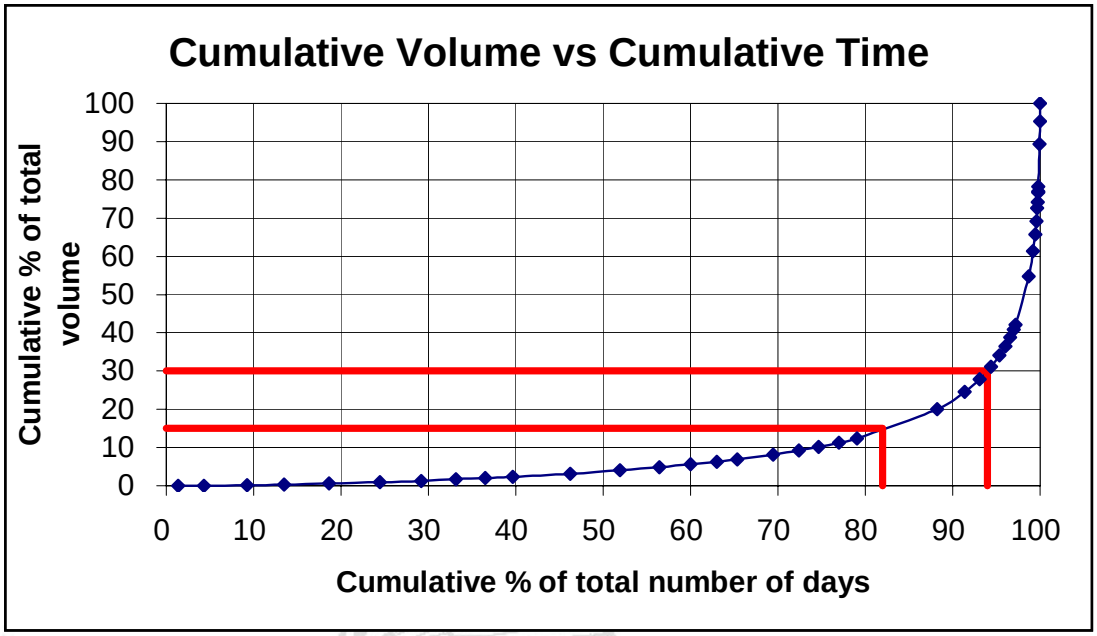


Figure 4 Cumulative Volume vs Cumulative Time

Interpretation – "So what does all this mean?"

It has been shown that the flow behaviour of the Mary River is characterised by:

- Typically very low flow rates, with seasonal variation, and
- Periodic "high flow" or flood events.

The mean (average) annual flow rate is not a useful or significant descriptor of the flow behaviour of the river. Rather, a cumulative time histogram eg Figure 2 should be used. To fully assess the performance of the proposed Mary Dam at Traveston, in terms of water yield and downstream effects, it is necessary to use a detailed time-step model of the various flows in and out of the dam. However, it is possible to draw some broad conclusions simply by examining the historical flow data at Dagun Pocket monitoring station.

1. The target yield from the dam has been stated as 140,000 ML per year. This corresponds to a daily flow of 383 ML. Examination of Figure 2 shows that for 59% of the time, the historical flow at Dagun pocket is less than this value.

   So even when no allowance is made for factors such as evaporation, seepage and water requirements downstream of the dam, the target water yield is available only 41% of the time.

2. The Mary Basin Draft Water Resource Plan [1] (Schedule 6, Table 6, p49) states that the mean annual flow (the MAF), expressed as a percentage of the MAF for the pre-development flow pattern, be at least 70% at Fisherman's pocket (nearest measurement node to the dam).

   70% sounds reasonable – only a 30% disruption to pre-development flows. But as illustrated in Figure 4, this could be achieved by letting the river downstream on the dam run bone dry 94% of the time. Mean Annual Flow is a meaningless statistic.

3. It has been stated that the *target* mean annual flow is 85% of the pre-development MAF.

Once again, 85% sounds reasonable – only a 15% disruption to pre-development flows. But as illustrated in Figure 4, this could be achieved at the dam site by letting the river downstream of the dam run bone dry 82% of the time. To re-iterate, Mean Annual Flow is a meaningless statistic.

4. If a 70% pre-development MAF is to be achieved on a yearly basis in the vicinity of the dam, then this leaves 30% of the pre-development flow available for collection in the dam. Ignoring evaporation and seepage, for this 30% to be equivalent to the target yield of 140,000 ML per year requires an average pre-development flow of 1,275 ML per day. Examination of Figure 2 shows that flows greater than or equal to 1,275 ML per day make up less than 20% of the historical data set at Dagun Pocket

   So for over 80% of the time, the dam inflow will not be sufficient to meet the target yield. Of course the dam will occasionally fill (during periodic flood events). Such events correspond precisely with times when SEQ's demand for water from the Mary Dam will be low, because Wivenhoe's catchment area almost always floods at the same time as the Mary.

5. If an 85% pre-development MAF is to be achieved on a yearly basis in the vicinity of the dam, then this leaves 15% of the pre-development flow available for collection in the dam. Ignoring evaporation, for this 15% to be equivalent to the target yield of 140,000 ML per year requires an average pre-development flow of 2,550 ML per day. Examination of Figure 2a shows that flows greater than or equal to 2,550 ML per day make up just 10% of the historical data set.

   So in this scenario, the dam inflow will be insufficient to meet the target yield 90% of the time. As stated above, the dam will occasionally fill (during periodic flood events), corresponding precisely with times when SEQ's demand for water from the Mary Dam will be low.

6. Points 1. to 5. above show two extremes of the performance and operation of the proposed Mary Dam:

   - **A dam which fills and provides useful water yields, but devastates the natural downstream flow pattern – dry most of the time in the vicinity of the dam.**
   - **A dam which allows 70% to 85% of the natural downstream flow pattern in the vicinity of the dam on a continual basis, but cannot meet the target yield except during times of periodic flooding – when the water is not needed.**

7. All of the above conclusions are based on historical flow data at Dagun Pocket and highlight significant concerns relating to the dam's performance and its impact on downstream flows. Yet this analysis ignores four important factors:

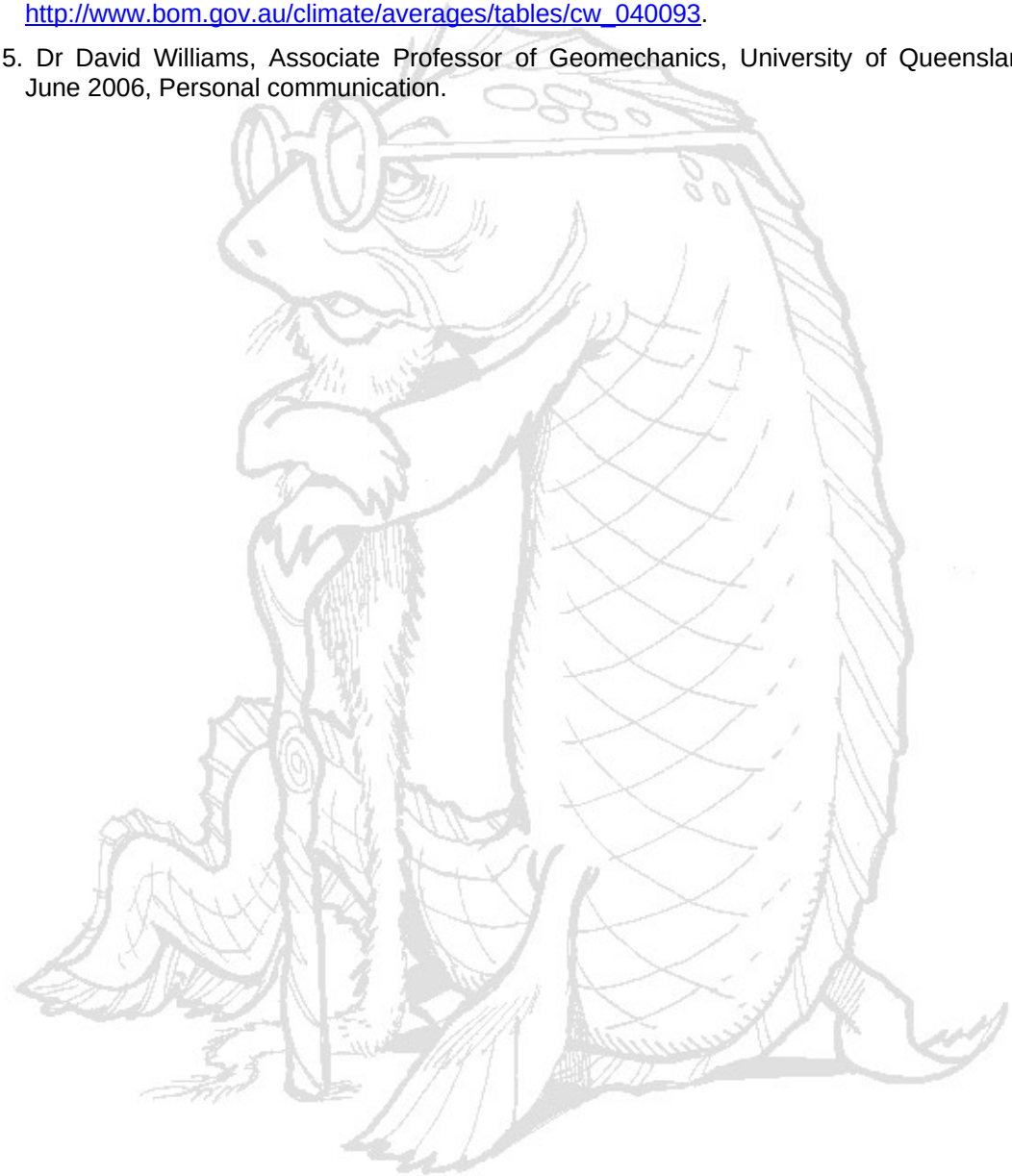
   - Evaporation. Based on figures from the Bureau of Meteorology [4], the annual evaporation rate of 1440mm/year combined with the Dam surface area of 7600 Ha, predicts annual evaporation of 110,000 ML. This volume represents 1/6th of the total dam volume, and nearly 80% of the annual target yield volume.
   - Seepage. The proposed dam is located in a shallow valley deeply infilled with alluvium (initial boreholes at the proposed dam site suggest a depth to bedrock of the order of 35 m). The alluvium will likely comprise layers of fine and coarse-grained sediments, corresponding to periods of low and high flow, respectively. While these will not be continuous, it would be expected that there would be preferred seepage paths through the foundation beneath the storage and beneath the dam wall, with preferential seepage parallel to the existing ground surface most likely. Seepage losses into the foundation could be in the range from 300 to 3,000 mm/year, or even higher, representing 1/30th to 1/3rd, or more, of the total dam volume, and 16 to 160%, or more, of the annual target yield. To prevent seepage beneath the dam wall, grouting of the alluvium beneath the dam wall will likely be required. [5. Dr David Williams, personal communication]
   - Sedimentation will impact in the long-term on the water storage capacity of this shallow storage. The sediment load, and sediment capture by the proposed dam,

could be estimated by the SEDNET DNR modelling but this data was not included in the draft Mary Basin WRP

- Climate Change. There is no guarantee that the historical data used in this analysis represents future conditions. In fact many experts believe that **rainfall in the Mary River catchment is decreasing.**

References and Data Sources

1. Department of Natural Resources and Mines, 2005, Daily Flow Data (Mary River, Dagun Pocket - 138109A) February 1957 to July 2002 – Electronic Document.
2. Department of Natural Resources and Mines, 2005, Mary Basin Draft Water Resource Plan - overview report and draft plan November 2005 – Electronic Document.
3. Department of Natural Resources and Mines, 2004, Mary Basin Draft Water Resource Plan – environmental conditions report - final report January 2004 – Electronic Document.
4. Australian Bureau of Meteorology, 2004, Climate Averages for Gympie, - web site http://www.bom.gov.au/climate/averages/tables/cw_040093.
5. Dr David Williams, Associate Professor of Geomechanics, University of Queensland, June 2006, Personal communication.



Appendix – Overall and Monthly Statistics

Table 1 shows the mean, median and histogram calculations from the Dagun Pocket site from 1957 to 2002.

Table 1: Statistical Analysis of Flow Data (ML)

	All Dates	January	February	March	April	May	June	July	August	September	October	November	December
Maximum	351,232	291,215	351,232	164,141	323,876	34,458	175,647	262,633	22,035	13,727	15,081	93,645	84,037
Minimum	0	0	21	10	0	11	19	25	16	10	3	0	1
Mean	1,742	3,671	4,328	2,900	2,502	1,292	1,779	1,279	393	325	430	925	1,185
Median	281	345	546	676	486	396	294	237	198	162	138	197	235
Percentiles													
99	25,107	70,824	54,112	39,530	27,692	17,452	42,415	15,746	3,327	2,844	5,427	12,064	17,253
95	5,631	10,657	15,131	10,912	8,068	5,092	3,888	3,266	1,181	964	1,570	3,271	5,420
90	2,471	4,806	7,306	6,138	4,099	2,405	1,854	1,804	818	648	845	1,727	2,167
85	1,494	2,689	4,499	4,228	2,415	1,601	1,245	1,035	589	504	517	1,110	1,331
80	1,057	1,528	2,749	2,792	1,690	1,269	921	703	475	411	374	845	909
75	809	1,100	1,907	2,039	1,288	1,038	794	550	386	340	310	643	697
70	614	849	1,500	1,651	1,023	854	630	444	344	295	261	471	559
65	491	648	1,149	1,295	859	688	474	353	294	255	216	372	439
60	399	523	909	1,067	653	547	405	296	253	212	183	280	343
55	335	406	701	871	558	465	352	265	220	189	159	228	282
50	281	345	546	676	486	396	294	237	198	162	138	197	235
45	237	274	435	562	411	342	262	217	181	133	122	166	193
40	202	237	362	471	348	304	234	199	159	120	111	147	167
35	169	192	315	392	299	269	205	176	142	107	101	127	147
30	144	155	262	309	220	223	176	160	121	97	93	110	126
25	122	133	219	252	154	192	148	136	104	82	77	93	110
20	105	117	166	197	113	159	130	112	89	63	64	79	91
15	86	103	129	139	94	138	113	95	72	54	51	59	78
10	63	81	95	112	75	107	97	72	51	46	35	44	65
5	43	35	58	76	52	63	71	58	39	37	21	28	45
2	25	14	45	45	31	38	47	48	33	27	11	14	15
1	14	1	42	34	4	31	23	39	27	18	9	5	6

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